SEDAR
Southeast Data, Assessment, and Review

SEDAR 81
Stock Assessment Report

Gulf of Mexico Spanish Mackerel

July 2023

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

Table of Contents

SEDAR

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SEDAR 81

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SECTION I: Introduction

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Overview

SEDAR 81 addressed the stock assessment for Gulf of Mexico Spanish mackerel. The assessment process was completed inhouse by the SEFSC.

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 Spanish mackerel was disseminated to the public in July 2023. 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 July 2023 meeting, followed by the Council receiving that information at its August 2023 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 Fishery Management Plan for Coastal Migratory Pelagic Resources of the Gulf of Mexico and South Atlantic (FMP) and Environmental Assessment (EA), approved in 1982 andimplemented by regulations effective in February of 1983, treated king and Spanish mackerel each as one U.S. stock. Allocations were established for recreational and commercial fisheries,and the commercial allocation was divided between net and hook-and-line fishermen.

GMFMC FMP Amendments affecting Spanish mackerel:

Description of Action	FMP/Amendment	Effective Date
Recognized two migratory groups for Gulf Spanish mackerel	CMP FMP Amendment 2	1987
Reallocated catch equally between recreational and commercial fishermen	CMP FMP Amendment 4	1989
Revised fishing year for Gulf group Spanish mackerel to April - March, made GMFMC responsible for pre-season changes to TAC and bag limits	CMP FMP Amendment 5	1990
Increased income requirement for Gulf Spanish mackerel permit to 25% of earned income or $10,000 from commercial sale	CMP FMP Amendment 8	1998
Marine reserve establishment at Tortugas North and Tortugas South off Key West, FL	CMP FMP Amendment 13	2002
Removed sector allocation, specified catch limits	CMP FMP Amendment 18	2012

GMFMC Regulatory Amendments:

May 1987:
TAC for Gulf group Spanish mackerel was set at 2.5 MP with a commercial quota of 1.4 MP andrecreational allocation for 1.1 MP. The bag limit for Spanish mackerel was set at 3 fish.

May 1988:
The TAC for Gulf group Spanish mackerel was increased to 5.0 MP allocated 43% to recreational sector and 57% to commercial sector. The Spanish mackerel bag limit was set at 4fish off Florida and 10 fish off AL-TX.

May 1989:
The TAC for Gulf group Spanish mackerel was increased to 5.25 MP. The allocation ratio between commercial (57%) and recreational (43%) remained unchanged as did the bag limit.

May 1990:
The TAC (5.25 MP) for Gulf group Spanish mackerel was unchanged. The bag limits for Spanish mackerel were changed to 4 fish off FL, 3 fish off TX, and 10 Fish off AL-LA at therequest of the states.

May 1991:
The TAC for Gulf group Spanish mackerel was increased to 8.6 MP and the bag limit modifiedto 3 fish off TX, 5 fish off FL, and 10 fish off AL-LA. The amendment also set the overfishingthresholds at 30% SPR (SSBR).

May 1992:
The TAC for Gulf group Spanish mackerel remained at 8.6 MP. The bag limits were increasedto 7 fish off TX, and 10 fish off FL-LA.

May 1996:
TAC for Gulf group Spanish mackerel was reduced to 7.0 MP and bag limits were maintained.

July 1999:

The TAC for Gulf group Spanish was changed from 7.0 million pounds to 9.1 million pounds,and the bag limit for Gulf group Spanish was increased from 10 to 15 fish per person per day.

May 2003:

The 2003 regulatory amendment, implemented on May 14, 2003, establishes definitions of maximum sustainable yield (MSY), optimum yield (OY), the overfishing threshold, and theoverfished condition for Cobia and Gulf group king and Spanish mackerel.

2014: Framework Amendment 1 – ACL/ACT Modifications

This rule modifies the annual catch limits (ACL) for Atlantic and Gulf migratory groups of Spanish mackerel and modifies the recreational annual catch target (ACT) for Atlantic migratory group Spanish mackerel, based on the results of the most recent stock assessments for these stocks. Framework Amendment 1 also specifies the optimum yield and acceptable biological catch (ABC) estimates for Atlantic and Gulf migratory groups of Spanish mackerel. The purpose of this rule is to update ACLs based on the best scientific information available and to ensure overfishing does not occur for Spanish mackerel. This final rule is effective December 22, 2014.

2017: Framework Amendment 5 – King and Spanish Mackerel Permit Restrictions

This Framework removes the restriction on fishing for, or retaining the recreational bag and possession limits of king and Spanish mackerel on a vessel with a Federal commercial permit for king or Spanish mackerel when commercial harvest of king or Spanish mackerel in a zone or region is closed. This final rule is effective August 31, 2017.

2.1. Management Program Specifications

Table 2.1.1. General Management Information

Species	Spanish mackerel
Management Unit	Southeastern US
Management Unit Definition	All waters Dade/Monroe county to Texas within Gulf of Mexico Fishery Management Council Boundaries
Management Entity	Gulf of Mexico Fishery Management Council
Management Contacts SERO / Council	Ryan Rindone Peter Hood
Current stock exploitation status	Not undergoing overfishing/not overfished
Current stock biomass status	18,998 metric tons (SEDAR 28 2013)

Table 2.1.2. Specific Management Criteria

Criteria	Gulf of Mexico - Current (SEDAR 28 2013)		Gulf of Mexico - Proposed	
	Definition	Value	Definition	Value
MSST	$(1\text{-}M)*SSB_{MSY}$	6,410 mt	$(1\text{-}M)*SSB_{MSY}$	SEDAR 81
MFMT	F_{MSY}	0.36	F_{MSY}	SEDAR 81
MSY	Yield at F_{MSY}	0.36	Yield at F_{MSY}	SEDAR 81
F_{MSY}	$F_{30\%SPR}$	0.36	F_{MSY}	SEDAR 81
OY	Equil. Yield @ 75% of $F_{30\%SPR}$ (2022)	3,410 mt	Equil. Yield @ 75% of $F_{30\%SPR}$	SEDAR 81
F_{OY}	75% of $F_{30\%SPR}$	0.27	F_{OY} = 65%,75%, 85% F_{MSY}	SEDAR 81
M	n/a	0.38	M	SEDAR 81

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 landingsparameters are 'landings' or 'catch' (Landings + Discard). If 'landings', please indicate how discards are addressed.

Table 2.1.3. Stock projection information.

Requested Information	Value
First Year of Management	2024
Projection Criteria during interim years should be based on (e.g., exploitation or harvest)	Fixed Exploitation
Projection criteria values for interim years should be determined from (e.g., terminal year, avg of X years)	Preliminary landings data, or average of previous 3 years

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

Projections:
Project future stock conditions and develop rebuilding schedules if warranted, includingestimated generation time. Develop stock projections in accordance with the following:

A) If stock is overfished:
$F=0$, $F_{Current}$, F_{MSY}, F_{OY} (F_{OY}=65%, 75%, 85% F_{MSY})
$F=F_{Rebuild}$ (max that permits rebuild in allowed time)

B) If stock is undergoing overfishing:
$F= F_{Current}$, F_{MSY}, F_{OY}

C) If stock is neither overfished nor undergoing overfishing: $F= F_{Current}$, F_{MSY}, F_{OY}

D) If data limitations preclude classic projections (i.e. A, B, C above), explore alternatemodels to provide management advice

Table 2.1.4. Quota Calculation Details

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

Current Quota Value	11.3 mp lw
Next Scheduled Quota Change	None
Annual or averaged quota ?	Annual
If averaged, number of years to average	n/a
Does the quota include bycatch/discard ?	No

2.2 Federal Management and Regulatory Timelines for Spanish Mackerel

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

First Yr In Effect	Effective Date	End Date	Fishery	Bag Limit Per Person/Day	Bag Limit Per Boat/Day	Region Affected	FR Reference	Amendment Number or Rule Type
1983	2/4/83	6/29/87	Rec	none	NA	Gulf of Mexico EEZ	48 FR 5270	Original CMP FMP
1983	2/4/83	Present	Comm	N/A	none	Gulf of Mexico EEZ	48 FR 5270	Original CMP FMP
1983	2/4/83	6/1/96	For-hire	2 capt/crew	N/A	Gulf of Mexico EEZ	49 FR 5270	Original CMP FMP
1987	6/30/87	6/30/88	Rec	3	N/A	Gulf of Mexico EEZ	52 FR 25012	May 1987 Reg Amendment
1988	7/1/88	9/3/91	Rec	4	N/A	FL	53 FR 25611	May 1988 Reg Amendment
1988	7/1/88	7/31/90	Rec	10	N/A	AL, MS, LA, TX	53 FR 25611	May 1988 Reg Amendment
1990	8/1/90	9/17/92	Rec	3	N/A	TX	55 FR 31188	May 1990 Reg Amendment
1990	8/1/90	12/31/99	Rec	10	N/A	AL, MS, LA	55 FR 31188	May 1990 Reg Amendment
1991	9/4/91	9/17/92	Rec	5	N/A	FL	56 FR 45898	May 1991 Reg Amendment
1992	9/18/92	12/31/99	Rec	7	N/A	TX	57 FR 43153	May 1992 Reg Amendment
1992	9/18/92	12/31/99	Rec	10	N/A	FL	57 FR 43153	May 1992 Reg Amendment
1996	6/2/97	Present	For-hire	0 capt/crew	N/A	Gulf of Mexico EEZ	62 FR 23671	May 1996 Reg Amendment
2000	1/1/00	Present	Rec	15	N/A	Gulf of Mexico EEZ	64 FR 45457	July 1999 Reg Amendment

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

First Yr In Effect	Effective Date	End Date	Fishery	Size Limit	Length Type	Region Affected	FR Reference	Amendment Number or Rule Type
1983	2/4/83	Present	Both	12 inches	FL	Gulf of Mexico EEZ	48 FR 5270	Original CMP FMP

Quota History:

First Yr In Effect	Effective Date	End Date	TAC/ACL	Comm Quota	Rec Quota	Region Affected	FR Reference	Amendment Number or Rule Type
1983	2/4/83	6/29/87	300,000 lbs lw	-		Gulf of Mexico EEZ	48 FR 5270	Original CMP FMP (purse seine allocation only)
1987	6/30/87	Present	0	-		Gulf of Mexico EEZ	52 FR 25012	May 1987 Reg Amendment (Purse seines prohibited)
1983	2/4/83	6/30/88	2.5 mp lw	1.4 mp lw	1.1 mp lw	Gulf of Mexico EEZ	52 FR 25012	May 1987 Reg Amendment
1988	7/1/88	6/30/89	5.0 mp lw	2.85 mp lw	2.15 mp lw	Gulf of Mexico EEZ	52 FR 23838	May 1988 Reg Amendment
1989	7/1/89	9/3/91	5.25 mp lw	2.99 mp lw	2.26 mp lw	Gulf of Mexico EEZ	54 FR 30554	May 1989 Reg Amendment
1991	9/4/91	6/1/97	8.6 mp lw	4.90 mp lw	3.70 mp lw	Gulf of Mexico EEZ	56 FR 45898	May 1991 Reg Amendment
1997	6/2/97	9/19/99	7.0 mp lw	3.99 mp lw	3.01 mp lw	Gulf of Mexico EEZ	62 FR 23671	May 1996 Reg Amendment
1999	9/20/99	1/29/12	9.1 mp lw	5.19 mp lw	3.91 mp lw	Gulf of Mexico EEZ	64 FR 45457	July 1999 Reg Amendment
2012	1/30/12	12/21/14	5.15 mp lw	-	-	Gulf of Mexico EEZ	76 FR 82057	CMP Amendment 18 (Removed sector allocation)
2014	12/22/14	3/31/15	12.7 mp lw	-	-	Gulf of Mexico EEZ	79 FR 69058	CMP FA 1
2015	4/1/15	3/31/16	11.8 mp lw	-	-	Gulf of Mexico EEZ	79 FR 69058	CMP FA 1
2016	4/1/16	Present	11.3 mp lw	-	-	Gulf of Mexico EEZ	79 FR 69058	CMP FA 1

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
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
	1984	11/8/84	Ongoing	Both	Year round		Prohibited pots and traps for Reef FMP	49 FR 39548	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
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
EEZ, inside 20 fathoms east of Cape San Blas, FL	1990	2/21/90	4/17/09	Both	Year round		Prohibited longline and buoy gear for Reef FMP	55 FR 2078	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
EEZ, inside 35 fathoms east of Cape San Blas, FL	2009	10/16/09	4/25/10	Both	Year round		Prohibited bottom longline for Reef FMP	74 FR 53889	Sea Turtle ESA Rule
	2010	4/26/10	Ongoing	Rec	Year round		Prohibited bottom longline for Reef FMP	75 FR 21512	Reef Fish Amendment 31
	2010	4/26/10	Ongoing	Com	1-Jun	31-Aug	Prohibited bottom longline for Reef FMP	75 FR 21512	Reef Fish Amendment 31
Madison-Swanson	2000	4/19/00	6/2/04	Both	Year round		Fishing prohibited except HMS[1]	65 FR 31827	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
	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
	2021	8/20/21	Ongoing	Both	Year round		Fishing prohibited	86 FR 38416	RF Framework Action
Steamboat Lumps	2000	4/19/00	6/2/04	Both	Year round		Fishing prohibited except HMS[1]	65 FR 31827	Reef Fish Regulatory Amendment
	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
	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
	2021	8/20/21	Ongoing	Both	Year round		Fishing prohibited	86 FR 38416	RF Framework Action
The Edges	2010	7/24/09	Ongoing	Both	1-Jan	30-Apr	Fishing prohibited	74 FR 30001	Reef Fish Amendment 30B Supplement
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
Flower Garden	1992	1/17/92	Ongoing	Both	Year round		Fishing with bottom gears prohibited[3]	56 FR 63634	Sanctuary Designation
Riley's Hump	1994	2/7/94	8/18/02	Both	1-May	30-Jun	Fishing prohibited	59 FR 966	Reef Fish Amendment 5
Tortugas Reserves	2002	8/19/02	Ongoing	Both	Year round		Fishing prohibited	67 FR 47467	Tortugas Amendment
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

[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 restrictions

Gear Type	First Yr In Effect	Effective Date	End Date	Gear/Harvesting Restrictions	Region Affected	FR Reference	Amendment Number or Rule Type
Poison	1984	11/8/84	Ongoing	Prohibited for Reef FMP	Gulf of Mexico EEZ	49 FR 39548	Original Reef Fish FMP
Explosives	1984	11/8/84	Ongoing	Prohibited for Reef FMP	Gulf of Mexico EEZ	49 FR 39548	Original Reef Fish FMP
Pots and Traps	1984	11/23/84	2/3/94	Established fish trap permit	Gulf of Mexico EEZ	50 FR 39548	Original Reef Fish FMP
	1984	11/23/84	2/20/90	Set max number of traps fish by a vessel at 200	Gulf of Mexico EEZ	50 FR 39548	Original Reef Fish FMP
	1990	2/21/90	2/3/94	Set max number of traps fish by a vessel at 100	Gulf of Mexico EEZ	55 FR 2078	Reef Fish Amendment 1
	1994	2/4/94	2/7/97	Moratorium on additional commercial trap permits	Gulf of Mexico EEZ	59 FR 966	Reef Fish Amendment 5
	1997	3/25/97	2/6/07	Phase out of fish traps begins	Gulf of Mexico EEZ	62 FR 13983	Reef Fish Amendment 14
	1997	12/30/97	2/6/07	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	Reef Fish Amendment 15
	2007	2/7/07	Ongoing	Traps prohibited	Gulf of Mexico EEZ	62 FR 13983	Reef Fish Amendment 14
All	1992	4/8/92	12/31/95	Moratorium on commercial permits for Reef FMP	Gulf of Mexico EEZ	68 FR 11914 59 FR 39301	Reef Fish Amendment 4 Reef Fish Amendment 9
	1994	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 39301	Reef Fish Amendment 9
	1996	6/1/96	12/31/05	Moratorium on commercial permits for Gulf reef fish.	Gulf of Mexico EEZ	61 FR 34930 65 FR 41016	Interim Rule Reef Fish Amendment 17
	2006	9/8/06	Ongoing	Use of Gulf reef fish as bait prohibited.[1]	Gulf of Mexico EEZ	71 FR 45428	Reef Fish Amendment 18A
Vertical Line	2008	6/1/08	Ongoing	Requires non-stainless steel circle hooks and dehooking devices	Gulf of Mexico EEZ	74 FR 5117	Reef Fish Amendment 27
	2008	6/1/08	9/3/13	Requires venting tools	Gulf of Mexico EEZ	74 FR 5117 78 FR 46820	Reef Fish Amendment 27 Framework Action

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

2.3 Closures in the Gulf of Mexico Due to Meeting Commercial Quota or Commercial/Recreational ACL

None

3 ASSESSMENT HISTORY AND REVIEW

Beginning in 1985, the Mackerel Stock Assessment Panel (MSAP) started meeting regularly to oversee and review the status of mackerel and other coastal pelagic stocks within the jurisdiction of the Gulf of Mexico and South Atlantic Fishery Management Councils (GMFMC and SAFMC). Full stock assessments of the Gulf of Mexico Spanish mackerel were conducted by Powers et al. (1996), Legault et al. (1998), the Sustainable Fisheries Division (2003) and SEDAR (2013).

The 2003 assessment, which included data through 2001/2002 (Sustainable Fisheries Division 2003) was conducted using an age based Virtual Population Analysis (VPA) procedure (Ortiz et al. 2002) calibrated to standardized fishery specific abundance indices. Uncertainty was incorporated into model estimates using a mixed Monte Carlo Bootstrap approach that accounted for variability in natural mortality, abundance indices, and estimated catch at age inputs. Based on MSAP recommendations, the Councils adopted $F_{30\%SPR}$ as the maximum fishing mortality threshold (MFMT). The proxy for maximum sustainable yield (MSY) was computed as the long-term yield at $F_{30\%SPR}$ when the stock is at equilibrium. Following the Technical Guidelines, the MSA recommended adopting (1.0-M)*B_{MSY} as the minimum stock size threshold (MSST), with M being the natural mortality rate. Results from this assessment indicated that the median estimate of F/F_{MSY} for Gulf Spanish mackerel was 0.53 in fishing year 2002/03 and the percentage of estimated $F_{2002/03}/F_{MSY}$ greater than 1.0 was 9% (n = 44 of 500 bootstraps). Based on the acceptable risk level chosen by the GMFMC, that there should be no greater than a 50% probability that current F exceeds MFMT, the MSAP's estimation is that overfishing was not occurring in 2002/03 for Gulf Spanish mackerel. The median estimate of B_{2003}/B_{MSY} for Gulf Spanish mackerel was 1.34 and the estimated percentage of B_{2003} less than MSST was 3% (n = 16 of 500 bootstraps). Based on the acceptable risk level chosen by the GMFMC, that there should be no greater than a 50% probability that current B is less than MSST, the MSAP's estimation is that Gulf Spanish mackerel were not overfished in 2002/03. Estimated spawning stock size continued to increase in 2002/2003.

The most recent stock assessment conducted on Gulf of Mexico Spanish Mackerel was completed in 2012 (SEDAR 28) through the Southeast Data, Assessment, and Review (SEDAR) process (SEDAR, 2013). SEDAR 28 was conducted using an integrated statistical catch-at-age model, Stock Synthesis (SS; Methot 2010) version 3.24h (beta), with data through 2011. Data inputs included commercial landings in pounds whole weight from 1886-2011, recreational landings in numbers of fish from 1955-2011, discard estimates in numbers of fish for the commercial, recreational and shrimp bycatch components (1946-2011), relative indices of abundance (recreational number caught per angler hour, pounds per trip from the FWC vertical line fish tickets, and SEAMAP trawl survey in number caught per trawl hour), length composition data from the commercial, recreational and SEAMAP catches, and conditional age-at-length data from the commercial and recreational components. Sensitivity runs were conducted with two alternative levels of natural mortality (0.27, 0.49, base run=0.38), three levels of fixed steepness (0.7, 0.9, base run=0.8), an assumed 20% increase in discard mortality, data component weighting (within SS), and index inclusion. Additional sensitivity runs were conducted in response to Center for Independent Experts (CIE) reviewer suggestions. The SSC carried out an initial review of the assessment during its March 2013 meeting. At its August 2013 meeting, the SSC accepted the SEDAR 28 Spanish mackerel Benchmark Assessment as the best available science and deemed it suitable for management advice. Given uncertainty surrounding the steepness parameter, the SSC recommended using an MSY proxy of 30%SPR. The minimum stock size threshold (MSST) was defined as (1-M)*SSB_{MSY} with M being the point estimate of M resulting from the Hoenig maximum age natural mortality estimator (maximum age = 11) recommended by the SEDAR 28 Data Workshop (i.e., M = 0.38y^{-1}). The maximum fishing mortality threshold (MFMT) was defined as F30%SPR. Based on the 30%SPR proxy, current (2011) spawning stock biomass level was estimated to be above the minimum stock size threshold (SSB_{2011}/MSST = 2.96), therefore the stock was not considered to be overfished. Current (2011) level of fishing mortality (geometric mean of the 2009-11 levels) was estimated to be below the maximum fishing mortality threshold (Fcurrent/MFMT = 0.40), therefore the stock was not considered to be experiencing overfishing.

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4 REGIONAL MAPS

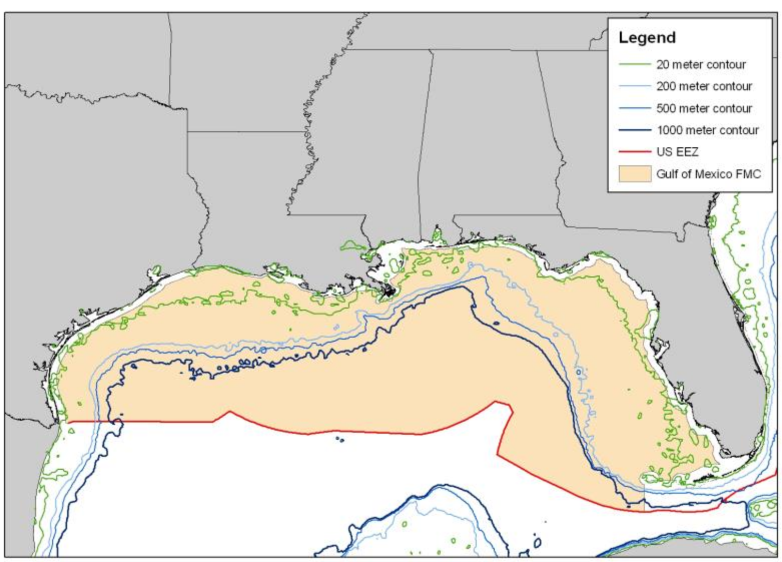

Figure 4.1 Gulf of Mexico Region including Council and EEZ Boundaries.

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	stock biomass level
BAM	Beaufort Assessment Model
B_{msy}	value of 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 of effort
EEZ	exclusive economic zone
F	fishing mortality (instantaneous)
FES	Fishing Effort Survey
FIN	Fisheries Information Network
F_{MSY}	fishing mortality to produce MSY under equilibrium conditions
F_{OY}	fishing mortality rate to produce Optimum Yield under equilibrium
$F_{XX\%\ SPR}$	fishing mortality rate that will result in retaining XX% of the maximum spawning production under equilibrium conditions

F_{max}	fishing mortality that maximizes the average weight yield per fish recruited to the fishery
F_o	a fishing mortality 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, a value of F above which overfishing is deemed to be occurring
MRFSS	Marine Recreational Fisheries Statistics Survey; combines a telephone survey of households to estimate number of trips with creel surveys to estimate catch and effort per trip
MRIP	Marine Recreational Information Program
MSA	Magnuson Stevens Act
MSST	minimum stock size threshold, a value of B below which the stock is deemed to be overfished
MSY	maximum sustainable yield

NC DMF	North Carolina Division of Marine Fisheries
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
OST NOAA	Fisheries Office of Science and Technology
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	Fisheries Southeast Fisheries Science Center, National Marine Fisheries Service
SERFS	Southeast Reef Fish Survey
SERO	Fisheries Southeast Regional Office, National Marine Fisheries Service
SRFS	State Reef Fish Survey (Florida)
SRHS	Southeast Region Headboat Survey
SPR	spawning potential ratio, stock biomass relative to an unfished state of the stock
SSB	Spawning Stock Biomass
SS	Stock Synthesis
SSC	Science and Statistics Committee
TIP	Trip Incident Program; biological data collection program of the SEFSC and Southeast States.
TPWD	Texas Parks and Wildlife Department
Z	total mortality, the sum of M and F

SEDAR

Southeast Data, Assessment, and Review

SEDAR 81

Gulf of Mexico Spanish Mackerel

SECTION II: Assessment Process Report

SEDAR
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SEDAR 81 Gulf of Mexico Spanish Mackerel Operational Assessment Report

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

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Table of Contents

1. Introduction

This document summarizes the SEDAR 81 Gulf of Mexico Spanish Mackerel Operational stock assessment as implemented in the Stock Synthesis 3 (V3.30.21.00) modeling framework (Methot and Wetzel 2013). The last assessment for Gulf of Mexico Spanish Mackerel was the SEDAR 28 Benchmark assessment (SEDAR 2013).

Where practicable, the SEDAR 81 base model used the same data sets as the SEDAR 28 assessment model with time series updated through 2021. However, notable changes include:

- changing the start year of the model from 1886 to 1986 to coincide with the time period where commercial and recreational landings are most reliable
- updating the time series of landings and discards from the Coastal Household Telephone Survey (CHTS)-based estimates to the Fishing Effort Survey (FES)-based estimates
- splitting up recreational landings and discards from a single fleet (SEDAR 28) to three distinct fleets (SEDAR 81) - shore, private, headboat/charterboat - with each their separate selectivity curves
- modeling recreational discards annually with assigned CVs instead of using the super period approach
- including recreational discard length data to inform the retention curve for recreational fleets
- modeling the commercial handline fleet as total catch (landings + dead discards) instead of using landings and discards as separate time series
- dropping the Marine Recreational Fisheries Statistical Survey (MRFSS) index (not deemed defensible as an index of relative abundance for Gulf of Mexico Spanish Mackerel)
- separating the SEAMAP trawl survey index into an early (pre 2008) and late (2009+) time series with separate catchability and selectivity parameters due to the 2008/2009 change in survey design
- applying the Lorenzen scaling to the natural mortality estimate internally within SS to keep the scaling consistent with the internally estimated growth curve
- correcting the slope of the maturity function input (*error detected in SEDAR 28*)
- applying a Dirichlet Multinomial internal re-weighting approach to age and length compositions

These changes reflect improvements in data inputs and parameterization compared with SEDAR 28. A more comprehensive descriptions 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 81 Gulf of Mexico Spanish Mackerel assessment was conducted by the Southeast Fisheries Science Center (SEFSC). No Topical Working Groups were convened by SEDAR.

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 28 Gulf of Mexico Spanish mackerel base model with data through 2021.

2. Document any changes or corrections made to model and input datasets and provide updated input data tables.

    a. Document changes in MRIP data, both pre- and post-recalibration, in terms of the magnitude of changes to catch and effort.
        i. Generate a catch equivalency table to describe the catch recommendations which would have resulted had MRIP-FES data been used in SEDAR 28
    b. Include available length frequency for the commercial fleet(s).
    c. Update life history data (e.g., growth, reproduction, mortality) if warranted.
        i. Consider age-dependent versus constant natural mortality estimates
    d. Characterize any differences in annual commercial and recreational landings data from the SEDAR 28 stock assessment greater than 5% in any year, respecting appropriate data currencies.
3. To the extent possible, the following should be considered for inclusion in the model.

    a. Consider whether steepness can be estimated, with or without a prior. If steepness is fixed, evaluate the sensitivity of that assumption.
4. 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 proxy = yield at F_{MSY} or $F_{Rebuild}$ (if overfished)
        ii. MSST = (1-M)*B_{MSY}
        iii. MFMT = F_{MSY} and $F_{Rebuild}$ (if overfished)
        iv. OY = ACL as defined by the Gulf and South Atlantic Councils in CMP and Amendment 18 (GMFMC and SAFMC 2011)
    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. Describe changes in catch advice as they relate to the use of FES-adjusted MRIP recreational catch and effort data, versus changes related to stock abundance

d. 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 five years
   iii. For the equilibrium yield at F_{MSY}, when estimable
5. Develop a stock assessment report to address these TORS and fully document the input data and results of the stock assessment.

1.3. List of Participants

No Topical Working Groups were convened by SEDAR.

1.4. List of Working Papers and Reference Documents

Document #	Title	Authors	Date Submitted
Documents Prepared for the Operational Assessment			
SEDAR81-WP-01	Summary of Management Actions for Spanish Mackerel (Scomberomorus maculatus) from the Gulf of Mexico as Documented within the Management History Database	K. Godwin, G. Malone, S. Atkinson, A. Rios	29-Sep-22
SEDAR81-WP-02	General Recreational Survey Data for Spanish Mackerel in the Gulf of Mexico	Matthew A. Nuttall	7-Nov-22
SEDAR81-WP-03	A review of Gulf of Mexico Spanish mackerel (Scomberomorus maculatus) age data, 1987 -2021, from various age-data sources	Chris Palmer and Beverly Barnett	18-Nov-22
SEDAR81-WP-04	Commercial Landings of Gulf of Mexico Spanish Mackerel (Scomberomorus maculatus) 1887-2021	M. Refik Orhun, Sarina F. Atkinson, Michaela E. Pawluk	21-Dec-22
SEDAR81-WP-05	Calculated discards of Spanish Mackerel from the commercial fishing vessels in the Gulf of Mexico	Sarina Atkinson and Kevin McCarthy	21-Dec-22
SEDAR81-WP-06	Gulf of Mexico Spanish Mackerel (Scomberomorus maculatus) Recreational Landings Length and Age Compositions	Molly H. Stevens	21-Dec-22

Document #	Title	Authors	Date Submitted
SEDAR81-WP-07	Gulf of Mexico Spanish Mackerel (Scomberomorus maculatus) Commercial Landings Length and Age Compositions	Molly H. Stevens	21-Dec-22
SEDAR81-WP-08	Annual indices of abundance of Gulf of Mexico Spanish Mackerel from Florida commercial trip tickets, 1986-2021	Joe OHop and Steve Brown	18-Jan-23
SEDAR81-WP-09	Spanish Mackerel Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of Mexico	Adam G. Pollack and David S. Hanisko	18-Jan-23
Final Stock Assessment Reports			
SEDAR81-SAR1	Gulf of Mexico Spanish Mackerel		
Reference Documents			
SEDAR81-RD01	S82_WP_06: Evaluation and Limitations of MRIP Intercept Data for Developing a Gray Triggerfish Abundance Index		

2. Data Review and Update

A variety of data sources were used in the SEDAR 81 Operational Assessment. Where practicable, the SEDAR 81 base model used the same data sets as the SEDAR 28 Benchmark assessment model with updated time series through 2021. However, a couple of corrections were made to the SEDAR 28 assessment model (maturity function and minimum size limit selectivity time block) and new or revised data sets were provided for consideration in the SEDAR 81 stock evaluation. These data sets included the National Marine Fisheries Service's (NMFS) MRIP-FES catch and discard time series, improved Southeast Region Headboat Survey (SRHS) discard proxy estimates, and length composition of recreational discards provided by the Florida Fish and Wildlife Commission (FWC) Fish and Wildlife Research Institute (FWRI) At-Sea Observer Program. These new data series were considered because they had not previously been available for the SEDAR 28 assessment or represented improved data inputs for use in the assessment. The data utilized in the SEDAR 81 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.

1. Life history

   a. Meristics
   b. Age and growth
   c. Natural mortality
   d. Maturity
   e. Discard mortality
2. Landings
   a. Commercial Gillnet + Other: 1986-2021 (metric tons whole weight)
   b. Commercial Handline + Other: 1986-2021 (metric tons whole weight; modeled as total catch, i.e. landings + dead discards)
   c. Recreational Headboat + Charterboat: 1986-2021 (thousands of fish)
   d. Recreational Private: 1986-2021 (thousands of fish)
   e. Recreational Shore: 1986-2021 (thousands of fish)
3. Discards
   a. Commercial Handline + Other: 1993-2021 (converted to dead discards and added to Commercial Handline + Other "landings" modelled as total catch)
   b. Recreational Headboat + Charterboat: 1986-2021 (thousands of fish)
   c. Recreational Private: 1986-2021 (thousands of fish)
   d. Recreational Shore: 1986-2021 (thousands of fish)
   e. Shrimp Bycatch: 1986-2011 (thousands of fish)
4. Age composition of landings
   a. Commercial Gillnet + Other: 1988-2015
   b. Commercial Handline + Other: 1988-2021
   c. Recreational Headboat + Charterboat: 1987-2021
   d. Recreational Private: 1990-2021
   e. Recreational Shore: 2011-2021
5. Length composition of landings
   a. Commercial Gillnet + Other: 1986-2021
   b. Commercial Handline + Other: 1991-2021
   c. Recreational Headboat + Charterboat: 1986-2021
   d. Recreational Private: 1986-2021
   e. Recreational Shore: 1986-2021
6. Length composition of discards
   a. Recreational Headboat + Charterboat: 2005-2021
7. Abundance indices
   a. Fishery-independent:
      i. SEAMAP Trawl Survey Early: 1987-2008
      ii. SEAMAP Trawl Survey Late: 2009-2020
   b. Fishery-dependent:
      i. Shrimp Bycatch: 1986-2021 (effort as a "survey" of F to scale annual discards for the Shrimp Bycatch fleet)
      ii. VL CPUE: 1986-2021
8. Length composition of surveys

a. SEAMAP Trawl Survey Early: 1987-2008
b. SEAMAP Trawl Survey Late: 2009-2020

2.1. Stock Structure and Management Unit

Spanish mackerel are found throughout the Gulf of Mexico and US Atlantic Coast (Collette and Russo 1979, 1984). As in SEDAR 28, fish landed north of US Highway 1 in Monroe County Florida are assigned to the Gulf of Mexico stock and managed by the GMFMC, and fish landed south of US Highway 1 are assigned to the South Atlantic stock and managed by the South Atlantic Fishery Management Council (SAFMC).

2.2. Life History Parameters

Life history parameters used in the assessment include the length-weight relationship, growth, natural mortality and maturity. Some of the life history parameters were input to the assessment model as fixed values, while others were estimated. Sex ratio at birth was assumed to be 1:1 as recommended by the SEDAR 28 Data Workshop (DW).

2.2.1. Morphometric and Conversion Factors

The weight-length relationship ($W = aFL^b$) developed during the SEDAR 28 Benchmark DW was used as a fixed model input (**Table 1**, **Figure 2**). The relationship was derived by pooling data from both sexes (male + female) and regions (GOM + SATL) (SEDAR 2013).

2.2.2. Age and Growth

Growth was estimated internally using a von Bertalanffy growth function, sexes combined (**Figure 2**) based on age data collected by federal and state sampling programs between 1987 and 2021 and aged by the Panama City Laboratory of the SEFSC (PC Lab), FWRI and The Gulf States Marine Fisheries Commission (GulfFin). See Palmer and Barnett (2022) for a thorough review of age data.

Though age data were provided from the commercial sector, recreational sector and fishery independent monitoring programs, only the commercial and recreational data were input into SS. In SS, all composition data need to be affiliated with a fleet and selectivity curve. Given the Operational nature of this assessment, there was no time to investigate modeling pathways for these data given that they did not pertain to any existing fleet in the modeling. However, we recommend this issue be revisited during a future assessment (**Section 8**).

An ageing error matrix (Punt et al. 2008) was developed based on blind double reads from a single reader (no reference set available) of 200 otoliths ranging ages 1-8 (**Figure 3**). Given that the two reads came from a single reader, no bias was assumed. A curvilinear standard deviation (SD) function was used to estimate SD by age group. The extrapolation method used by Punt et al. (2008) to derive SDs for ages falling beyond the data range (i.e. age 0 and ages 9+) yielded unrealistically large estimates of SD for ages 9+. To avoid modeling issues caused by the large CVs and based on the knowledge that the difficulty in ageing Spanish Mackerel otoliths with 8 to 11 rings is relatively equivalent (PC Lab personal communication), the CV estimated for age 8 was applied to ages 9+ for input in SS. The resulting ageing error matrix is shown in (**Figure 4**).

The expert reader whose precision is being represented by this ageing error matrix was the age reader responsible for conducting all Gulf of Mexico Spanish Mackerel otolith reads since 2011 and therefore assumed to be a good proxy for age reading precision for all ages input into SS.

2.2.3. Natural Mortality

As in SEDAR 28, natural mortality 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), scaled to the Hoenig (1983) point estimate of M (0.38 per year based on a maximum age of 11) over the range of fully recruited ages (2-11) (**Table 2**, **Figure 2**).

Back when the SEDAR 28 assessment was conducted, the SS platform did not have the flexibility of defining a spawning and settlement season for age 0 fish so the M vector was manually adjusted before input in SS. This is no longer necessary with the new SS version when a settlement season is defined. As such, all scaling was done internally to SS with a settlement season specified as May 1st (peak spawning month for Gulf of Mexico Spanish Mackerel (Palmer and Barnett 2022)). This allowed for consistency between the life history parameters as the M vector gets automatically updated when growth parameter estimates change.

2.2.4. Maturity

During SEDAR 28, the recommendation from the DW was to use maturity data collected in the Atlantic (**Figure 5**) as a proxy for the Gulf of Mexico due to data quality issues in Gulf of Mexico data (i.e., few samples available and macroscopic staging performed vs. larger sample sizes and histological readings available for SATL samples). However, the parameters input into SS for SEDAR 28 contained an error (**Figure 6**). As such, the maturity function was re-estimated during SEDAR 81 by fitting a logistic regression to Atlantic data found in Table 2.3 of the SEDAR 28 Stock Assessment Report (SEDAR 2013) (**Figure 5**). The slope was estimated at -0.44 and the length at 50% maturity predicted around 31.41 cm FL. The first mature age was changed from 1 (SEDAR 28) to 0 (SEDAR 81) based on the fact that the youngest mature female observed in the Gulf of Mexico and South Atlantic were age 0 (SEDAR 2013). The maturity at age function used in SS (derived from the maturity at length input and estimated growth curve) is shown in **Figure 6** with the erroneous SEDAR 28 curve plotted for comparison.

2.2.5. Fecundity

The fecundity schedule was assumed directly proportional to the weight of females (i.e., $eggs = aW^b$, where $a = 1$ and $b = 1$) as in SEDAR 28. Female-only spawning stock biomass (SSB) was used as the measure of reproductive potential.

2.3. Fishery-Dependent Data

Different start years were explored during the initial model development phase (see **Section 4.10.**): 1886 (as in SEDAR 28; presumed virgin conditions), 1950 (after a period of minimal fishing following World War II), 1986 (low confidence in landings data prior to 1986). Due to model stability issues with the 1886 and 1950 start years, a 1986 start year was selected for SEDAR 81, which coincides with the time period where commercial and recreational landings are most reliable.

2.3.1. Commercial Landings

Commercial landings data (1986-2021) used in the assessment are presented in **Table 3**, **Figure 7** (comparison with SEDAR 28) and **Figure 8** (extended time series).

The commercial landings are partitioned into two fleets: Commercial Gillnet + Other and Commercial Handline + Other. Gillnet and Handline represent the two main commercial harvesting gears capturing Gulf of Mexico Spanish Mackerel. Commercial landings were reported in pounds whole weight and converted to metric tons for input to the assessment model. As in SEDAR 28, the miscellaneous ("Other") gears (i.e., traps, trawls, seines, long lines, cast nets, spears) were proportioned into Gillnet and Handline fleets based on the annual proportions of landings by those respective gears.

The majority of commercial landings over time have been from the Commercial Gillnet + Other fleet (**Figure 7**). Commercial Gillnet + Other landings declined sharply in 1995 following the FL gillnet ban (**Figure 9**). Prior to July 1, 1995, gill nets could be used in state as well as in federal waters. After Florida's net limitations (Article X of the Florida Constitution) went into effect on July 1, 1995, usage of entangling nets was limited to federal waters only, and other nets (seines, trawls, cast nets) usable in state waters were limited to 500 square feet or smaller in mesh area.

The commercial landings time-series used for this operational assessment differed only slightly from what was used during SEDAR 28 (**Figure 7**). A detailed explanation of the observed differences is presented in Orhun et al. 2022. **Table 4** shows any difference in annual commercial landings data from the SEDAR 28 stock assessment greater than 5% in any year, both by gear and aggregated over all gears.

Uncertainty estimates were not provided for commercial landings from the Gulf of Mexico. A CV of 0.01 was assumed, as was done in SEDAR 28.

2.3.2. Recreational Landings

Recreational landings data (1986-2021) used in the assessment are presented in **Table 5**, **Figure 7** (comparison with SEDAR 28) and **Figure 8** (extended time series).

Final recreational landings were computed using fully calibrated estimates from the MRIP using FES, the SRHS, Louisiana Creel, and the Texas Parks and Wildlife Department (TPWD) data (see Nuttall 2022). Recreational landings are reported by mode and include Charter, Headboat, Private, Shore and Private/Shore (LA Creel). In SEDAR 28, all modes were aggregated into a single fleet (**Figure 7**). For the SEDAR 81 assessment, recreational landings from the Charter and Headboat modes were aggregated given similarities in length composition through space and time and to allow for proper post stratification of the length composition data (see Stevens 2022b), and Private and Shore mode were modeled separately. Landings categorized as Private/Shore from the LA Creel survey were lumped in with Shore, the dominant mode in the total recreational landings by numbers over the majority of the time series. Recreational landings were reported in numbers of fish and input into the assessment model as 1000s of fish.

Differences between the fully calibrated estimates (i.e., redesigned APAIS in 2013, FES in 2018) and the time series of recreational landings used in SEDAR 28 (i.e., based on CHTS) are shown in **Figure 10**.

Uncertainty estimates were provided for each recreational fleet and presented in **Table 6**. Recreational Private and Recreational Shore CVs were obtained from MRIP FES. For Recreational Headboat + Charterboat, Charterboat CVs (from MRIP FES) and Headboat CVs (proxy CV from SRHS) were weighted by landings and combined to produce annual CVs for the fleet. Proxy CVs from SRHS were calculated using the following equation:

$$ProxyCV_i = 1 - \sum_{j=1}^{n}\left[\left(\frac{n_{ij}}{N_{ij}}\right) * \left(\frac{L_{ij}}{L_i}\right)\right] + 0.05$$

where n is the number of reported trips, N is the number of estimated trips, L is the landings, i the year and j the state or region. Specifying annual CVs is a departure from SEDAR 28 where all CVs were fixed to 0.01, but believed to be a better reflection of uncertainty about catch estimates.

Following guidance from MRIP, any yearly landings value with CV≥0.5 was replaced by the average of the two neighboring years (**Figure 11**). This included a single year/fleet combination for the SEDAR 81 time series of landings: the Recreational Headboat + Charterboat fleet in 1990 where the point estimate of 423 thousand fish was replaced with an estimated 215 thousand fish.

2.3.3. Commercial Discards

An updated analysis of the commercial discard data available for Gulf of Mexico Spanish Mackerel was conducted by Atkinson and McCarthy (2022). While reef fish observer data is the preferred method for estimating discards in the Gulf of Mexico, there were insufficient data available for Spanish Mackerel (Smith et al. 2018). As such, the approach used to calculate discards of Gulf of Mexico Spanish Mackerel followed the methods recommended in SEDAR 32 (McCarthy, 2013). This method has become the standard approach for commercial fishery discard calculation in cases where observer reported data are insufficient for discard calculation. Discard rates are computed directly from the discard logbook data and applied to gear specific total effort from the coastal logbook program to calculate total discards of Spanish Mackerel. The available discard logbook data include all trips from vessels that reported in the Gulf of Mexico from 2002-2021, while the coastal logbook program began collecting data from all fishers in 1993. Therefore, the mean discard rate for the years 2002-2021 was used to calculate discards for the years 1993-2001 when only effort data were available.

Results showed that Gillnet discard rates were negligible (so no discards were modeled for the Commercial Gillnet + Other fleet in SEDAR 81, similarly to what had been done in SEDAR 28) and that discards for the Handline fleet (Handline and Trolling gear) were estimable but yielded lower estimates than what had been previously estimated during SEDAR 28 (Atkinson and McCarthy 2022). Discard estimates ranged from 4,063 to 11,996 fish per year with a median of 9,703 fish per year (**Table 7**). Discards in numbers were converted to weight by multiplying estimated numbers discarded by the mean weight of fish at the size limit (0.26kg). This corresponded to an average discard rate of 9% of total Handline catches (landings + discards) in weight across the data time period (range:3-22% annually), with the lowest discard rates observed over the last 20 years of the time series (**Figure 12**). With the 10% discard rate applied (as recommended during SEDAR 28 for commercial discards), dead discards represent just 1% of total handline catches. Length data for discarded fish collected by the RFOP were too few to characterize the length composition of discards accurately (32 fish between 2006 and 2020) but did indicate fish being discarded both above and below the size limit.

Given the high level of uncertainty in the discard estimates and the difficulty in estimating a retention curve to characterize the length composition of discarded fish, the Commercial Handline + Other fleet was modeled as total dead catch (landings + dead discards) by converting total discards in numbers to dead discards in weight using the approach detailed above (discards in numbers * weight at minimum size limit * 10% discard mortality).

2.3.4. Recreational Discards

Recreational discards from the Recreational Headboat + Charterboat, Recreational Private and Recreational Shore fleets (1986-2021) used in the assessment are presented in **Table 8** and **Figure 13** (comparison with SEDAR 28) and **Figure 14** (extended time series).

Final recreational discards were computed using fully calibrated estimates from MRIP using FES and the redesigned APAIS (Nuttall 2022) for Recreational Private (1986-2021) and Recreational Shore modes. For the Recreational Headboat + Charterboat modes, discards estimates from Charterboat (MRIP FES estimates) and Headboat (SRHS estimates) were combined. The SRHS estimates were composed of SRHS discard estimates for 2004-2021, and the SEDAR Best Practices super ratio approach for 1986-2003 (MRIP Charter discard ratio applied to SRHS landings and scaled by the mean ratio of SRHS:MRIP charter discard rate in recent (04-21) years).

Recreational discards were reported in numbers of fish and input into the assessment as 1000s of fish with corresponding log-scale standard errors (SE, **Table 8**). For the Recreational Headboat + Charterboat fleet, MRIP FES Charterboat CVs were used for 1986-2003. For 2004-2021, Charterboat CVs (from MRIP FES) and Headboat CVs (from SRHS) were weighted by landings and combined to produce annual CVs for the fleet. Headboat landings CVs were used as a proxy for headboat discard CVs for 2004-2021. Specifying annual CVs for the recreational fleets is a departure from SEDAR 28 where all CVs were fixed at 0.01, but believed to be a better reflection of uncertainty about discard estimates.

Following guidance from MRIP, any yearly landings value with $CV \geq 0.5$ was replaced by the average of the two neighboring years (**Figure 11**). This included seven years in the earlier part of the Recreational Headboat + Charterboat fleet time series (with some estimates revised upward and others downward) and a single year (1991) in the Recreational Shore fleet time series.

A discard mortality rate of 20%, as recommended by the SEDAR 28 DW, was applied to all recreational fleets.

Differences between the fully calibrated estimates (i.e., redesigned APAIS in 2013, FES in 2018) and the time series of recreational discards used in SEDAR 28 (i.e., based on CHTS) are shown in **Figure 10**.

2.3.5. Shrimp Discards

Estimates of Spanish Mackerel caught by Gulf of Mexico shrimp trawlers from 1972 to 2011 were made available during SEDAR 28 (**Figure 15**; Linton, 2012). No updated time series was made available for SEDAR 81. Because of the large uncertainty (**Figure 14**) in the annual estimates of shrimp bycatch, the bycatch discards were input as a single super period (i.e. median value from 1986-2011 of 5854 thousands of fish) which was then scaled annually by a time series of shrimp effort (available for 1986-2021; **Figure 16**). Shrimp effort data using the same methodology as was used in SEDAR 28 (Linton, 2012; Nance, 2004) were only available up to 2020, as such, the shrimp effort value for 2021 was filled in using the new shrimp effort estimation method that is currently under development (Anon., 2023).

The log SE for the mean discard numbers was set to 0.01. The shrimp effort time series was scaled to a mean of 1 for input in SS (**Table 9**).

2.3.6. Commercial Size Composition

Gillnet length compositions of landed (retained) fish (1986-2021) are presented in **Figure 17**. Handline length compositions of landed (retained) fish (1991-2021) are presented in **Figure 18**. Length compositions were combined into 2-cm fork length interval bins (10:82).

While SEDAR 28 used nominal length compositions, the Center for Independent Experts (CIE) review team recommended considering post-stratification prior to combining data for compositions (Cordue 2013). Therefore, gear-specific commercial length compositions weighted annually with spatially stratified landings data were used. A detailed description of the revised methodology, data filtering, results and data limitations are discussed in Stevens 2022a.

In SEDAR 28, length composition sample sizes were input in numbers of fish capped at a maximum effective sample size of 100 fish to prevent the length composition data from driving the model fitting process. In SEDAR 81, the new Dirichlet Multinomial re-weighting procedure was used to adjust input sample sizes, as such capping the sample size was no longer necessary and the input sample size associated with each year/fleet was set as the number of trips sampled. Year-fleet combinations with less than 10 trips sampled were removed from the assessment model.

There was insufficient data available from the Reef Fish Observer Program (RFOP) to accurately characterize commercial discards length compositions (32 fish between 2006 and 2020). However, the few samples available for Commercial Handline + Other showed fish being discarded both above and below the minimum size limit. This justifies combining dead discards and landings into a single with selectivity characterized by the length composition of retained fish.

2.3.7. Recreational Size Composition

Recreational Headboat + Charterboat length compositions of landed (1986-2021) and discarded (2005-2021) fish are presented in **Figure 19** and **Figure 20**, respectively. Recreational Private length compositions of landed fish (1986-2021) are presented in **Figure 21**. Recreational Shore length compositions of landed fish (1986-2021) are presented in **Figure 22**.

While SEDAR 28 used nominal length compositions (all modes aggregated) to characterize the length composition of the recreational fleet landings, the Center for Independent Experts (CIE) Review recommended considering post-stratification prior to combining data for compositions (Cordue 2013). Therefore, mode-specific recreational length compositions weighted annually with spatially stratified landings data were used. A detailed description of the revised methodology, data filtering, results and data limitations are discussed in Stevens 2022b. Length compositions were combined into 2-cm fork length interval bins (10:82).

In SEDAR 28, length composition sample sizes were input in numbers of fish capped at a maximum effective sample size of 100 fish to prevent the length composition data from driving the model fitting process. In SEDAR 81, the new Dirichlet Multinomial re-weighting procedure was used to adjust input sample sizes, as such capping the sample size was no longer necessary and the input sample size associated with each year/fleet was set as the number of trips sampled. Year-fleet combinations with less than 10 trips sampled were removed from the assessment model.

Data from the Florida Fish and Wildlife Commission (FWC) Fish and Wildlife Research Institute (FWRI) At-Sea Observer Program (2005-2021) were used to characterize the length compositions of recreational discards. A total of 282 samples were available (95% from Headboat, 5% from Charterboat). The annual length compositions were combined into 2-cm fork length interval bins (10:82). Given, the sparse nature of the data, no weighting procedure was applied. Nominal length compositions were used with number of trips sampled used as the input sample size for each year. Given the few samples available to characterize the size of discarded fish, no minimum yearly sample size threshold was applied. The length composition of discards in the Recreational Headboat + Charterboat fleet include fish both below and above the size limit and were used to inform the parameter estimates of the retention curve for all recreational fleets.

2.3.8. Commercial Age Composition

Commercial age compositions of landed fish used in the assessment are presented in **Figure 23** and **Figure 24**. Historically, age samples for Spanish mackerel have followed a two-stage sampling protocol (SEDAR 2013). Therefore, age observations were assumed to be conditional on length and input as conditional-age-at-length data with sample sizes specified as number of fish (Stevens 2022a; as was done in SEDAR 28). This linkage allows more detailed information on the size-age relationship to be incorporated into the growth model fitting process and improves estimates of variance of size-at-age (Methot 2011). Ages were input in calendar age (i.e. fish reach age 1 when they first reach January 1st regardless of time of birth; see Palmer and Barnett (2022) for a detailed explanation of the age adjustment protocol applied).

An overview of the data available for the commercial sector is shown in **Figure 25**. A number of strong cohorts are apparent in the data, including 1991, 1995, 2001, 2010, 2013, 2015 and 2019.

2.3.9. Recreational Age Composition

Recreational age compositions of landed fish used in the assessment are presented in **Figures 26 -28**. Historically, age samples for Spanish mackerel have followed a two-stage sampling protocol (SEDAR 2013). Therefore, age observations were assumed to be conditional on length and input as conditional-age-at-length data with sample sizes specified as number of fish (Stevens 2022b; as was done in SEDAR 28).

An overview of the data available for the recreational sector is shown in **Figure 29**. A number of strong cohorts are apparent in the data, including 1990, 1998, 2004, 2010, 2013, 2015, and 2019.

2.3.10. Commercial Catch Per Unit of Effort Index of Abundance

The standardized CPUE index (scaled to mean) for commercial handline used in the assessment (O'Hop and Brown 2023) is summarized in **Table 9** and **Figure 30**. This index was developed from Florida Gulf Coast Commercial Trip Ticket data using the same methodology that was used in SEDAR 28 (see O'Hop and Brown (2023)). Different distributions were tested and the lognormal model was the best performing model (as opposed to the gamma distribution used in SEDAR 28) with natural log-transformed (loge) pounds of Spanish Mackerel being the response variable, and year, month, inshore benthic species presence, reef fish species presence and FL regulatory area code as the set of predictors (see O'Hop and Brown (2023) for a detailed description of the methodology, diagnostics and selection process).

2.3.11. Recreational Catch Per Unit of Effort Index of Abundance

SEDAR 28 had a single recreational CPUE index of abundance: the MRFSS/MRIP catch per angler hour abundance index. CIE reviewers at the time raised the concern that the time series used to develop the index had very low proportion of successful trips (<5%) and questioned the ability of the data to track abundance of Gulf of Mexico Spanish Mackerel (SEDAR 2013). They also raised the concern that changes in fishing regulations through time (numerous changes in bag limits over the period covered by the MRFSS CPUE index) made it unlikely that the proportionality between stock abundance and CPUE remained constant through time. An analysis by Fitzpatrick and Williams (2022) conducted on Gray Triggerfish came to the same conclusion: "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. For all the reasons listed, the MRFSS index was dropped from the SEDAR 81 assessment.

2.4. Fishery-Independent Data

2.4.1. SEAMAP Trawl Survey

The recommendation from SEDAR 28 was for one abundance index for Spanish mackerel from the SEAMAP Summer and Fall Groundfish Surveys. However, following current best practices the time series was split when the survey design was changed in 2008 and two indices were produced for Spanish mackerel (Pollack and Hanisko 2023). The first index covers the time period from 1987 – 2008 covering the northwestern and central GOM and the second from 2008 – 2021 covering the entire northern GOM. Although the second index goes through 2021, it should be noted that zero Spanish mackerel were captured in 2021. That data point was therefore excluded from the index. A detailed description of the data, limitations, methodology and results can be found in Pollack and Hanisko (2023).

The standardized indices for the early and late time period are summarized in **Table 9**, and **Figures 31** and **32**. CVs were converted to log-scale SEs for input into SS (**Table 10**).

Length composition for the survey comprised a total of 2008 individuals measured during the early period of the index and 496 during the late period. Length compositions were input as nominal lengths with sample sizes specified as the number of stations from which successful measurements were obtained (**Figures 33 and 34**).

3. Stock Assessment Model Configuration and Methods

3.1. Stock Synthesis Model Configuration

The assessment model used was Stock Synthesis (hereafter referred to as SS), version 3.30.21.00. Descriptions of SS algorithms and options are available in the SS User's Manual (Methot et al. 2020), the NOAA Fisheries Toolbox website (*http://nft.nefsc.noaa.gov/*), and Methot and Wetzel (2013). SS is a widely used integrated statistical catch-at-age model (SCAA) that has been tested for stock assessments in the United States (US), particularly on the West Coast and in the Southeast, and also throughout the world (see Dichmont et al. 2016 for review). SCAA models consist of three closely linked modules: the population dynamics module, an observation module, and a likelihood function. Input biological parameters (e.g., **Section 2.2**) are used to propagate abundance and biomass forward from initial conditions (population dynamics model) and SS develops expected data sets based on estimates of fishing mortality, 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 SS 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 SS 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 Spanish Mackerel: metric tons), and harvest rate (units for Spanish Mackerel: total biomass killed / total biomass age 1+). 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.

3.1.1. Initial Conditions

Exploratory runs testing different start years (1886, 1950, 1986) for the SEDAR 81 stock assessment model showed high levels of model instability when starting in 1886 and 1950. As such, the start year was set to 1986, which coincides with the time period where commercial and recreational landings are most reliable.

The SEDAR 81 Gulf of Mexico Spanish Mackerel assessment begins in 1986 and has a terminal year of 2021. Since removals of Spanish Mackerel 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 conditions in 1986 and initial conditions had to be estimated.

In order 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 is estimated) had to be specified. Typically, initial equilibrium catches are set equal to the average landings from the first 5 years. However, in the case of Gulf of Mexico Spanish Mackerel, some fleets actually had historically higher catches than the assessment time period (**Figure 8**). Therefore, a search for optimal initial equilibrium catches was done by taking the following steps:

1. Each fleet's initial equilibrium catches were set to the mean landings over the first five years of the time series and initial equilibrium F for the Shrimp Bycatch fleet was set to 0.05. A value of 0.05 was chosen for the Shrimp Bycatch fleet to reflect a fishing mortality that was similar in magnitude to the mid 2000s when effort was of a similar magnitude as the 1960s (**Figure 16**). This was thought to provide a reasonable lower limit from which to scale up to find the optimal equilibrium F.

2. Each initial catch (+ the shrimp effort initial F) was multiplied by a series of scalars ranging from 0.5 to 5 in 0.3 increments (i.e. where .5 would cut the equilibrium catches by half and 2 would double them) and the model was re-run;

3. A likelihood profile of each model run was plotted to determine the most likely scalar (i.e. lowest negative log likelihood) given the information present in the model;

4. The model with the lowest total negative log likelihood was used for the base model run, and once all initial catches were adjusted by the chosen scalar, the initial F for the shrimp bycatch was freed up for estimation to allow some freedom over initial conditions when exploring sensitivity runs.

This allowed us to determine the level of equilibrium catch needed for the model to start at a level of depletion that was in agreement with the rest of the data sets while preserving the relative contribution of catches by fleet.

3.1.2. Temporal Structure

The Spanish Mackerel population was modeled from age-0 through age-11 (the maximum age), with data bins spanning age-0 through age-11+, with the last age representing a plus group. Settlement was specified as May 1st to coincide with Gulf of Mexico Spanish Mackerel peak spawning (Finucane and Collins, 1986). 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. 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 Fork Length, FL) to body weight (kg whole weight; **Table 1, Figure 2**). Stock Synthesis moves fish along 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 1st for Spanish Mackerel in the Gulf of Mexico (Finucane and Collins, 1986), settlement was specified as May 1st, which allowed SS to internally convert between input calendar ages and real age when estimating growth and natural mortality-at-age (both in terms of real age).

Growth within SS was modeled with a three parameter von Bertalanffy equation: (1) L_{Amin} (cm FL), the mean size at age-0.33 Spanish Mackerel; (2) L_{Amax} (cm FL), the mean size at maximum aged Spanish Mackerel; 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 4 cm FL). Fish then grow linearly until they reach a real age equal to the input value of A_{min} (growth age for L_{Amin}) and have a size equal to L_{Amin}. As they age further, they grow according to the von Bertalanffy growth equation (**Figure 2**). L_{Amax} was specified as equivalent to L_{inf}. 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 0.33) and A_{max} (age 11). For intermediate ages, a linear interpolation of the CV on mean size-at-age is used.

The von Bertalanffy growth model parameters L_{Amin}, L_{Amax} and K and the variance parameters CV_{Amin} and CV_{Amax} were re-estimated internally to SS using updated length and age compositions (**Table 11**).

Target M was set to the Hoenig (1983) point estimate of 0.38 per year (based on a maximum age of 11) and scaled internally using the Lorenzen function over the range of fully recruited ages (2-11) to derive an age-specific vector of M (**Table 2, Figure 2**).

The assessment model was set-up with both sexes combined. Immature females transitioned to mature females based on a fixed logistic function of length (**Figure 6**). Reproductive potential was defined in terms of females only.

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 spawner-recruit levels) requires three parameters: (1) steepness (h) 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) represents the asymptote or virgin recruitment levels; and (3) the variance or recruitment variability term (*sigmaR*) which is the SD of the log of recruitment (it both penalizes deviations from the spawner-recruit curve and defines the offset between the arithmetic mean spawner-recruit curve and the expected geometric mean from which the deviations are calculated). Similar to SEDAR 28, h and *sigmaR* were fixed at 0.8 and 0.7, respectively, in the SEDAR 81 Base Model, while virgin recruitment (lnR_0) was freely estimated.

Annual deviations from the stock-recruit function were estimated in SS as a vector of deviations forced to sum to zero and assuming a lognormal error structure. A lognormal bias adjustment factor was applied to recruitment estimates as recommended by Methot et al. (2020).

For the SEDAR 81 Base Model, main period (i.e. data rich, when representative length or age composition data are available) recruitment deviations spanned 1990-2020, while early period (i.e. data poor) recruitment deviations spanned 1975-1989. The start year of the model is 1986 but recruitment deviations are estimated starting in 1975 to inform the age structure used in the start year. Full bias adjustment was used from 1984 to 2020. Bias adjustment was phased in linearly, from no bias adjustment prior to 1982 to full bias adjustment in 1984. Bias adjustment was phased out in 2020, decreasing from full bias adjustment to no bias adjustment in that year, because the age composition data contains less information on recruitment in more recent years.

The years selected for full bias adjustment were estimated following the methods of Methot and Taylor (2011).

3.1.6. Fleet Structure and Surveys

Six fishing fleets were modeled. The SS fleet codes were: Commercial Gillnet + Other (Com_GN_1), Commercial Handline + Other (Com_HL_2), Recreational Headboat + Charterboat (Rec_CB_HB_3), Recreational Private (Rec_PRIV_4), Recreational Shore (Rec_SH_5) and Shrimp Bycatch (Byc_SHRIMP_6). Fleet structure was characterized by the availability of length and age composition data, comparisons of length distributions between gears (commercial) or modes (recreational), and resulting sample sizes. Fishing was assumed to be continuous and homogeneous across the entire year.

One fishery-dependent CPUE index was included in the SEDAR 81 Base Model: VL CPUE (CPUE units: biomass kept per trip). Selectivity of the index was assumed identical to the selectivity of the Commercial Handline + Other fleet.

Two fishery-independent surveys were included in the SEDAR 81 Base Model: the SEAMAP Trawl Survey Early (pre 2008) and the SEAMAP Trawl Survey Late (post 2008). The SEAMAP Trawl Survey Early and SEAMAP Trawl Survey Late indices had length observations available which were fit to directly based on estimated length-based selectivity functions.

The Shrimp Bycatch fleet was modeled as a bycatch-only fishery with the catch driven by an effort time series and fitted to the median estimate of Spanish mackerel bycatch from 1986-2011 (5854 fish with a CV of 0.01) using the “super-period” feature in SS. No age/length data was available for that fleet so selectivity was mirrored to that of the SEAMAP Trawl Survey Early fleet due to similarities in gear and area fished. Discards from the Shrimp Bycatch fleet were included in the search for MSY.

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). SS 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.

For SEDAR 81, like SEDAR 28, only length-based selectivity was estimated.

Selectivity patterns were assumed to be constant over time except for the Commercial Gillnet + Other fleet. For the Commercial Gillnet + Other fleet, a time block was created in 1995 to reflect changes in selectivity/availability engendered by the 1995 FL gillnet ban, which impacted not only the type of gear used to target Spanish Mackerel but also the spatial coverage of the fleet (with catches shifting from being Florida centric to Alabama centric, **Figure 9**).

3.1.7.1. Length-based Selectivity

Length-based selectivity patterns were specified for each fleet and survey and were characterized as one of two functional forms: (1) a two-parameter logistic function (SS pattern 1), (2) a six-parameter double normal function (SS pattern 24). 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.

The double normal has the feature that it allows for domed or asymptotic 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 or use priors to improve model stability as long as fixing the parameter/specifying a prior 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 81 Base Model, separate selectivity patterns were defined for each fleet/survey: 1) Commercial Gillnet + Other (double normal with a 1995-2021 time block), 2) Commercial Handline + Other (logistic), 3) Recreational Headboat + Charterboat (logistic), 4) Recreational Private (logistic), 5) Recreational Shore (double normal), 6) SEAMAP Trawl Survey Early (double normal), and 7) SEAMAP Trawl Survey Late (double normal). Selectivity for the VL CPUE was mirrored to the Commercial Handline + Other fleet and selectivity for the Shrimp Bycatch was mirrored to the SEAMAP Trawl Survey Early fleet given similarity in gear and geographical coverage.

The more flexible double normal selectivity pattern was explored for all fleets in earlier iterations of the model. For parsimony, the 6 parameter double normal pattern was replaced with the 2-parameter logistic pattern if the estimated parameters resulted in a logistic shape. The largest fish were apparent in data from all fleets except for the SEAMAP surveys (**Figure 35**).

The Commercial Gillnet + Other selectivity was the most problematic one to estimate. The data exhibited strong, conflicting patterns (e.g., 1996-2006, 2016+; **Figure 36**) and no single selectivity function could properly describe the data observed across the entire time series. Different time block configurations were explored in sensitivity runs (see **Section 3.5.**) but ultimately a single time block was used, which coincided with the 1995 FL GN ban. There was not enough evidence regarding changes in regulation or fishery behavior to justify the use of additional time blocks. For both time blocks (1986-1994; 1995-2021), the estimation ignored the first and last size bins and allowed SS to decay the small and large fish selectivity according to parameters of ascending width and descending width, respectively, to reduce the number of parameters being estimated and improve model stability. Since certain parameters were highly correlated with one another, diffuse beta priors were used to help steer estimates towards a central value and avoid them crashing into the bounds. For the 1995-2021 block, the top logit parameter had a correlation near zero. It was therefore fixed at the value estimated to avoid model convergence issues. The model was not sensitive to that parameter over a range of values.

For the Commercial Handline + Other, Recreational Headboat + Charterboat, Recreational Private fleets, both parameters of the logistic function were estimated freely with no priors.

For Recreational Shore, where selectivity was specified as a double normal, the parameter specifying the peak of the plateau was estimated with high uncertainty due to the plateau-ing in selectivity. That parameter was therefore fixed at the value estimated. The shape of the double normal was not sensitive to changes in the peak parameter over a range of parameter values.

Double normal selectivity was used for the SEAMAP surveys (and Shrimp Bycatch fleet through mirroring to the SEAMAP Trawl Survey Early survey selectivity) because dome-shaped selectivity was considered highly likely due to areas fished (e.g., closer to shore, shallower) and fish behavior in response to the gear (e.g. larger/faster swimming fish species like Spanish Mackerel are able to escape the trawl).

3.1.7.2. Age-based Selectivity

Age-based selectivity was not specified for any of the fleets (unchanged from SEDAR 28).

3.1.8. Retention

A common retention function was estimated for the recreational fleets using discard length data obtained largely from the Charterboat fishery (i.e. a retention function was estimated for the Recreational Headboat + Charterboat fleet and mirrored across the Recreational Private and Recreational Shore fleets).

Time-varying retention functions are commonly used in Gulf stock assessments to allow for varying discards at size due to the impacts of management regulations (see Godwin et al. 2022 for a list of federal management regulations affecting Gulf of Mexico Spanish Mackerel). For Spanish Mackerel, the most influential management regulation thought to affect retention was the minimum size limit in 1983. Because this regulation was enacted before the start year of the model, no time blocks were necessary and the retention function reflected retention post-size limit. In SEDAR 28, the start year of the model was 1886. As such, a time block was put in place to reflect the 12-inch minimum size limit. However, the time block was erroneously set to 1993 instead of 1983.

Another management regulation likely to affect the shape of the retention function is the presence of bag limits (causing legal sized fish to be returned to sea). For Spanish Mackerel, bag limits have been in place since 1987 (Godwin et al. 2022) and varied through time. However, given the limited data available to characterize discard length composition for the recreational fleets, a single retention function was used to characterize retention across the time series.

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). The inflection point, slope and asymptote parameters were all estimated freely inside SS. This is a departure from SEDAR 28 where the asymptote was fixed at 1 (i.e. all fish above the size limit retained) but believed to be a better reflection of fishing behavior given the presence of bag limits in the fishery and the fact that discard size composition data from the Charterboat and Headboat modes showed fish both above and below the legal size-limit.

3.1.9. Landings and Associated Length and Age Compositions

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

The commercial landings were assumed the most representative and reliable data source in the model, because this information was collected in the form of a census as opposed to being collected as part of a survey. A CV of 0.01 was assumed for the landings from the Commercial Gillnet + Other and Commercial Handline + Other fleets. The recreational landings were assumed to be less precise than the commercial landings. Larger CVs were assumed for all three recreational fleets (see **Section 2.3.2** and **Table 6**), allowing SS more freedom to deviate from the observed data. All CVs were converted to a log-scale SE (see **Section 3.2.**).

A new feature available for fitting composition data in SS is the Dirichlet Multinomial (DM) which differs from the standard multinomial in that it includes an estimable parameter (theta) which scales the input sample size (Thorson et al. 2017; Methot et al. 2020). The DM is self-weighting, which avoids the potential subjectivity involved in applying the Francis re-weighting procedure (Francis 2011). The DM approach also allows for observed zeros in the data, and the effective sample sizes calculated to be directly interpretable. The DM uses the input sample sizes directly (each year within a fleet has a relative weight set by the input sample size), 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 DM is considered an improved practice and recommended for use by the SS model developers, and was first used in a Gulf stock assessment during SEDAR 70 in 2020 for Gulf of Mexico Greater Amberjack. A normal prior was used on the DM parameters of 0 (SD = 1.813), which is recommended to counteract the effect of the logistic transformation between the DM parameter and the data weighting (Methot et al. 2020).

For SEDAR 81, the age and length composition data for each fleet/survey were assumed to follow a Dirichlet multinomial error structure where input sample sizes were number of trips for commercial and recreational length composition data, number of fish for conditional age at length data and number of stations for fishery independent surveys. Number of trips/stations were used instead of number of fish for length compositions because it was thought to better reflect relative effective sample size in each year, as samples are rarely truly random or independent (Hulson et al. 2012).

3.1.10. Discards and Associated Length Compositions

Discard data for the Recreational Headboat + Charterboat fleet were directly fit in the SS model using size-based retention functions, and a log-normal error structure. The model estimates total discards based on the selectivity and retention functions, then calculates dead discards based on the discard mortality rate of 20% assumed for the recreational sector (**Section 2.3.4**). Length compositions of discards for the Recreational Headboat + Charterboat fleet were input specifying annual sample sizes as number of trips and using the Dirichlet Multinomial approach for weighting.

3.1.11. Indices

The indices are assumed to have a lognormal error structure. For the SEAMAP Trawl Survey Early and SEAMAP Trawl Survey Late surveys, input CVs were those obtained through index standardization. For the VL CPUE index, annual CVs were scaled upward ($newCV = \frac{oldCV}{mean(oldCV)} * minCV_{SEAMAP}$) such that the average CV matched the minimum CV of the SEAMAP fishery independent indices ($minCV_{SEAMAP} = 0.22$). This was done to reflect the fact that the standardization of fishery dependent indices is thought to under-represent the true uncertainty compared to that of indices developed from fishery independent surveys. All CVs were converted to log-scale SEs for input into SS (**Table 10**).

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 predicted 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 impact 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 using the approximation: $log_e(SE) = \sqrt{\left(log_e(1 + CV^2)\right)}$ provided in Methot et al. (2020).

Weak penalty functions were used to keep parameter estimates from hitting their bounds (Methot et al. 2020). 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 all, 347 parameters were included in the analysis for the SEDAR 81 Base Model, of which 305 were active parameters (**Table 12**). These parameters include: year specific (1986-2021) fishing mortality for each fleet, the stock-recruit deviations for the data-poor time period (1986-1989) the stock-recruit deviations for the data-rich time period (1990-2020), three von Bertalanffy growth parameters (L_{Amin}, L_{Amax}, K) and associated CVs (*CV_Amin*,*CV_Amax*), one stock-recruit relationship parameter ($ln(R_0)$), recruitment deviations, initial fishing mortality rates for each fleet at the start of the model (1986), initial age structure at the start of the model, size selectivity parameters for each fleet and survey, logistic retention parameters for the Recreational

Headboat + Charterboat fleet, catchability parameters for each index and 4 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, discards). Any temporal trends in model residuals (or trends with age or length for compositions data) can be indicative of model mis-specification 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). 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. Profile Likelihoods

Profile likelihoods are used to examine the change in log-likelihood for each data source in order 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 are in agreement. 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 need to be reconsidered.

For this assessment, a profile on the log of virgin recruitment ($ln(R_0)$) was carried out.

3.4.4. Jitter Analysis

Jitter analysis is a relatively simple method that can be used to assess model stability and to determine whether a global as opposed to local minima has been found by the search algorithm. The premise is that all of 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 ever 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 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

A retrospective analysis is a useful approach for addressing the consistency of terminal year model estimates. The analysis sequentially removes a year of data at a time and reruns the model. If the resulting estimates of derived quantities such as SSB or recruitment differ significantly, particularly if there is serial over- or underestimation 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 compositional 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 for the SEDAR 81 base model.

3.4.6. Jack-knife Analysis on Indices of Abundance

Another type of data exclusion analysis is the jack-knife approach where individual datasets are removed and the model is rerun with the remaining data. The goal of this analysis 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 dataset leads to dramatically different results, it suggests that the dataset 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).

For the SEDAR 81 base model, each index was removed (VL index, and both SEAMAP indices at once) and the model rerun. Other datasets (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.

3.4.7. Additional Diagnostics

Additional diagnostics using the R package 'SS3Diags' are presented following the recommendations of Carvahlo 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; Carvahlo 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 (Carvahlo 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 (Carvahlo et al. 2021).

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 MASE scales the mean absolute error (MAE) of forecasts (i.e., prediction residuals) to the MAE of a naïve in-sample prediction (Carvahlo et al. 2021). A skilled model would improve the model forecast compared to the baseline (i.e., random walk), with a MASE 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 (Carvahlo et al. 2021; Kell et al. 2021).

3.5. Sensitivity Runs

Sensitivity runs were conducted with the SEDAR 81 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).

Time blocks for the GN fleet - Four time blocks were used to model time varying selectivity in the Commercial Gillnet + Other fleet (1986-1995, 1996-2005, 2006-2015, 2016-2021) to match the time trends observed in the residual analysis of composition data for the base model run (**Figure 37**).

Natural Mortality (***M***) - An alternative target M of 0.49 was tested to evaluate the influence of M on the results. This alternative M was derived using the M estimator developed by Hamel and Cope (2022): $M = \frac{5.4}{t_{max}}$, using a t_{max} of 11. This estimator evaluates Then et al.'s (2015) updated dataset of M and t_{max} using a more appropriate transformation than was used by Then et al. (2015) (see Hamel and Cope 2022 for more detail on the approach).

Steepness (***h***) - Three alternative steepness scenarios were evaluated:
1. Estimating steepness (no prior)
2. Fixing steepness at 0.7
3. Fixing steepness at 0.9

Shrimp Bycatch - Bycatch in the shrimp fishery is difficult to determine given the low encounter rate between shrimp trawls and Spanish Mackerel, and irregular observer coverage. A sensitivity run was therefore conducted which removed the shrimp bycatch from the assessment model altogether to evaluate the influence of this fleet on model results. This sensitivity run was more involved than the other sensitivity runs as it required a re-evaluation of initial equilibrium catches.

Recreational discard mortality rate - Post release mortality for Gulf of Mexico Spanish Mackerel is highly uncertain. As such, two alternative values of discard mortality (40% and 60% instead of the 20% base model run value) were evaluated to determine the impact on model results.

4. Stock Assessment Model - Results

4.1. Initial Conditions

The total negative log likelihood for each model run in the search for initial conditions was plotted to determine the most likely scalar on initial equilibrium catches given the information present in the model (**Figures 38**). The best model run had a scalar of 3.5 (though scalars ranging 3.2-4.1 fell within 2 log likelihood units indicating they did not yield significantly different results). Differences in resulting SSB and fraction unfished (SSB/SSB0) time series between each model run are shown in **Figure 39**. Expected initial catches in mt are shown as 1985 catches in **Figure 40**. SSB was estimated to be at 11% of SSB0 at the start of the model (1986).

4.2. Estimated Parameters and Derived Quantities

Table 12 contains a summary of model parameters for the SEDAR 81 Base Model: estimated parameter values and their associated CVs from SS, initial parameter values, minimum and maximum bounds on parameters, and the prior densities assigned to each parameter (if a prior was used). Most parameter estimates and variances were reasonably well estimated (i.e., CV < 1). Of the 305 active parameters, 10 exhibited CVs above 1 and were poorly estimated, including 3 recruitment deviations, and 7 Early_InitAge parameters (for ages 5-11) which are used to set up an equilibrium age structure for 1986.

Figure 41 shows parameter distribution plots along with starting values, bounds, and priors.

Most of the Dirichlet-Multinomial (D-M) parameters were estimated >5 (i.e. a weight of >99% through inverse logit transformation), indicating no need for down-weighting the input sample size, so these were fixed in the final model run. Four of the D-M parameters were estimated below 5: Com HL length compositions: 85% ; Rec Private length compositions: 94%; Com GN age compositions: 99%; Rec shore age compositions: 99%.

4.3. Fishing Mortality

The exploitation rate (total biomass killed / total biomass age 1+) for the entire stock are provided in **Table 13** and **Figure 42**. Since 1986, the exploitation rate for the stock has averaged around 0.441, and ranged between 0.252 in 2021 to 0.731 in 1986. Overall, the exploitation rate decreases over the time frame of the assessment. Exploitation rates decreased from 1990 to 1998, then increased from 1998 to 2004. They experienced a drop in 2005 but then increased again peaking in 2013, and decreased over the remainder of the time series, with high annual variability in the last 5 years of the assessment period. The terminal year (2021) exploitation rate for the entire stock was 0.252, which is below the time series mean.

Table 14 and **Figure 43** provide estimates of exploitation rate by fleet and year. The exploitation rate for the stock was driven largely by the Recreational Shore fleet throughout the entire time series, and particularly in recent years. The next largest exploitation rates were that of Recreational Private. The Shrimp Bycatch fleet had relatively higher exploitation rates earlier in the time series (1980s-1990s) but has been relatively low since 2005. Commercial Handline + Other and Recreational Headboat + Charterboat exploitation rates were significantly lower than the other fleets' exploitation rates and relatively stable across the time series. The Commercial Gillnet + Other fleet had higher exploitation rates prior to the 1995 FL Gillnet Ban. In the most recent years (2012+), Recreational Shore exploitation rates have been variable, ranging from a low of 0.12 to a high of 0.48. The terminal year (2021) fishing mortality rates for the Commercial Gillnet + Other, Commercial Handline + Other, Recreational Headboat + Charterboat, Recreational Private, Recreational Shore and Shrimp Bycatch fleets were 0.01, 0.001, 0.01, 0.09, 0.12 and 0.02, respectively (**Table 14**).

The SEDAR 28 time series of estimated exploitation rates is shown for comparison (**Figure 43**).

4.4. Selectivity

Length-based selectivity curves estimated in SS for SEDAR 81 are shown in **Figure 44**. **Figures 45-49** provide fleet specific terminal year selectivity, retention, discard mortality and fraction of fish kept, dead and discarded for the 9 directed fleets A detailed comparison of the estimated length-based selectivity functions between the SEDAR 81 and SEDAR 28 models is shown in **Figure 50**.

The Commercial Gillnet + Other selectivity function was allowed to assume either a dome shape or an asymptotic selectivity shape in SEDAR 81 but converged to an asymptotic shape (as opposed to the dome shape estimated in SEDAR 28). There was considerable uncertainty and year to year variation in the length composition of that fleet so the selectivity curve was poorly estimated. Residual plots (**Figure 36**) of the fits to length composition data show noticeable temporal patterns. Selectivity for the earlier part of the time series (prior to the 1995 FL GN ban) was estimated to be dome shaped (**Figure 51**).

The Commercial Handline + Other selectivity function estimated in SEDAR 81 was shifted slightly towards larger fish with the addition of new data.

A single selectivity curve was used for the recreational fleets in SEDAR 28 vs. three separate selectivity curves in SEDAR 81. Breaking up the data into multiple fleets revealed noticeable differences between modes with Shore selecting smaller fish than Headboat, Charter and Private modes, and not fully selecting the largest/oldest fish (asymptote near 0.6; **Figure 44**).

The estimated length-based selectivity functions for the SEAMAP Trawl Survey Early (and, through mirroring, the Shrimp Bycatch fleet – **Figure 52**) and SEAMAP Trawl Survey Late were very similar (**Figure 44**). Comparison with SEDAR 28 is shown in **Figure 53**. The estimated selectivity of the SEAMAP survey from SEDAR 81 is shifted towards younger ages and more narrowly distributed compared with that of SEDAR 28 with the additional years of length data.

The derived age-based selectivity functions are shown in **Figure 54** and **Figure 55**. The Commercial Gillnet + Other fleet reached 50% selectivity at around age 2, while the Commercial Handline + Other fleet reached 50% selectivity at age 4. The Recreational Headboat + Charterboat and Recreational Private fleets reached 50% selectivity around age 2. The Recreational Shore fleet attained maximum selection at age 2. Age at maximum selection was 1 for both SEAMAP surveys (**Figure 54**). That was also the case in SEDAR 28 but in SEDAR 81 selectivity was more restricted, with most of the selection occurring between the ages of 0 and 3.

All selectivity parameter estimates and associated uncertainty are listed in **Table 12** with the Label prefix “Size_”.

4.5. Retention

The retention function for the recreational fleets is shown in **Figure 56**. All retention parameter estimates and associated uncertainty are listed in **Table 12** and shown in **Figure 41** with the Label prefix “Retain_”. All retention parameters appeared well estimated. The inflection point was estimated close to the minimum size limit of 12in/30.5cm FL at 31.3cm FL. The asymptote was estimated to be slightly below 1 (0.96), indicating some (yet minimal) discarding of legal sized fish (as opposed to SEDAR 28 where the asymptote was fixed at 1; **Figures 47 -49)**.

4.6. Recruitment

As noted in the description of the SS model configuration, two of three of the S/R parameters were fixed at values agreed upon during SEDAR 28: steepness (0.8) and *sigmaR* the recruit variance parameter (0.7). The corresponding Beverton-Holt stock recruit relationship is show in **Figure 57**. Estimated annual recruitment of age-0 fish (1000s), recruitment deviations and variance are shown in **Table 15** and **Figures 58-59**. Virgin recruitment in log-space (Ln(R_0)) was estimated at 11.56 (**Table 12**), which equates to 104 million age-0 Spanish Mackerel. The estimated (and applied) recruitment bias adjustment ramp is shown in **Figure 60**.

During the main recruitment period (1990-2020, see **Section 3.1.5.**), estimated recruitment averaged 65.31 million Spanish Mackerel and was lowest in 1994 at 23.8 million Spanish Mackerel and highest in 2010 at 107.95 million Spanish Mackerel (**Figure 58**). Recruitment deviations were fairly randomly distributed with a few noticeable trends (1989-1991, 2003-2006, 2016-2019). Strongly positive deviations coincided with the strong cohorts apparent in the age composition data (e.g., 1998, 2010, 2013, 2015, 2019) (**Figures 29 and 25**).

CVs for recruitment deviations during the main recruitment period averaged 0.08 between 2019 and 2018, and ranged from 0.061 in 2010 to 0.12 in 2019 (**Figure 59**). Main recruitment deviations were estimated up to 2020 (**Figure 61**) since there was little data in the model to inform 2021 recruitment as age-0 fish had not yet fully recruited to the fisheries. Estimated recruitment for the last 10 years fell both above and below the overall average.

4.7. Biomass and Abundance Trajectories

The estimated annual total biomass (metric tons), exploitable biomass (ages 1+, metric tons), SSB (metric tons), SSB ratio (SSB/virgin SSB) and exploitable abundance (1,000s of fish) from 1986 to 2021 are provided in **Table 15**. Total biomass averaged 12,996 metric tons, and ranged from 7,994 metric tons in 1995 to 16,314 metric tons in 2021 (**Figure 62**). Exploitable biomass and numbers, which were comprised of Spanish Mackerel age-1 or older, averaged 11,731 metric tons and 42,619,947 Spanish Mackerel, respectively. Exploitable biomass was lowest in 1995 at 6,908 metric tons and peaked in 2006 at 15,260 metric tons, whereas exploitable numbers ranged from 20,657,200 Spanish Mackerel in 1995 to 58,141,900 Spanish Mackerel in 2020 (**Table 15**). SSB averaged 8,797 metric tons, and ranged from 5,465 metric tons in 1995 to 11,931 metric tons in 2006 (**Figure 63**). Both total biomass and SSB show an overall increase between 1986 and 2021.

The SSB ratio averaged 0.16, and ranged from 0.1 in 1995 to 0.21 in 2006 (**Table 15**, **Figure 64**). Spawning stock biomass in the most recent year (2021) is predicted to be at 21% of the corresponding unfished spawning stock biomass (**Table 15**).

The predicted numbers-at-age and biomass-at-age Spanish Mackerel at virgin conditions are shown in **Figure 65** with biomass highest for age 3. Predicted numbers at age and mean age over the entire time series for both SEDAR 28 and SEDAR 81 is shown in **Figure 66**.

4.8. Model Fit and Residual Analysis

4.8.1. Landings

Landings for the Commercial Gillnet + Other and Commercial Handline + Other fleets were fit almost exactly given their small SEs (**Table 16-17**, **Figures 67 and 68**). Given the large SEs assigned to the recreational fleet landings, predicted landings had more freedom to deviate from input values (**Table 18-20**, **Figures 69-71**). For Recreational Headboat + Charterboat, observed and predicted values matched fairly well after 1991. Prior to 1991, expected values fall below observed to better fit the discards (**Section 4.8.2.**). For Recreational Private, observed and predicted values also matched fairly well, though there was a period from 2004 to 2015 where the model consistently overestimated landings. For Recreational Shore, landings also tended to be overestimated between 2005 and 2011 and there were noticeable departures at some of the peaks and troughs (2016-2017) where the model expected more variability than was observed. These differences coincided with the model fitting more closely to the discard data in 2015-18 (**Section 4.8.2.**). In general, there was a closer fit to the landings data in SEDAR 28 compared with SEDAR 81 due to increased CVs used in SEDAR 81 (**Figure 72**).

4.8.2. Discards

The time series of discards for the recreational fleets begins in 1986 (**Tables 21-23**, **Figures 73-75**). 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 76-78**), all three recreational fleets showed an overall slight increase in discard rates throughout the model time frame. However, the predicted discard rates for these fleets exhibited a flatter trend and less variability than the underlying data given the use of fixed selectivity and retention curves.

4.8.3. Indices

Observed and predicted CPUE are provided in **Tables 24 and 25** and **Figure 79**.

The model fit best to the VL CPUE index (root mean squared error [RMSE] = 0.23 and worst to the SEAMAP Trawl Survey Late index (root mean squared error [RMSE] = 1.32. Both SEAMAP index fits showed relatively flat trends through time with high inter-annual variability in the underlying data, while the SEAMAP Trawl Survey Early index showed an overall increasing trend from 1986-2011. After 2009, the VL CPUE and SEAMAP Trawl Survey Late show somewhat opposing trends with the VL CPUE index indicating an increase in biomass and the SEAMAP Trawl Survey Late indicating a decrease in biomass. The decline in the SEAMAP Trawl Survey Late index is steeper than that of the fitted values (**Figure 79**).

In SEDAR 28, the VL CPUE index fit showed a sharp increase over the last 10 years of that assessment (2001-2011), consistently predicting higher index values than observed over the last 5 years of the time series. In contrast, in SEDAR 81, that pattern flattens out with additional years of data.

Of the two SEAMAP indices, the model fit better to the SEAMAP Trawl Survey Early (RMSE= 0.51) than to the SEAMAP Trawl Survey Late (RMSE= 1.32). The fits to the SEAMAP index were comparable between SEDAR 28 and SEDAR 81 (**Figure 79**).

4.8.4. Length Compositions

Aggregate model fits to the retained and discarded length composition data are presented in **Figures 37**. Annual fits are presented in **Figures 80-87** with residuals shown in **Figure 36** (all fleets) and **Figures 88-95** (by fleet).

Fits to retained length compositions for the Commercial Gillnet + Other fleet exhibited trends in the residuals (**Figures 36 and 88**), particularly between 1995-2006 (larger fish predicted than observed) and 2016-2021 (smaller fish predicted than observed).

Annual fits to retained length compositions for the Commercial Handline + Other fleet were poor due to the large inter-annual variability in the underlying length composition data with many years suffering from low sample sizes (**Figures 81 and 89**). However, the overall aggregated fit was adequate (**Figure 37**).

Annual fits to retained length compositions for the recreational fleets were generally good (**Figures 37 and 82-85**), particularly for the Recreational Private and Recreational Shore fleets. Residuals were relatively small and there were no persistent trends apparent (**Figures 90-93**).

The length composition of discards for the Recreational Headboat + Charterboat fleet showed large annual peaks coinciding with age 0 fish. Though most fish being discarded are below the size limit, some legal sized fish also appear in the data (**Figure 83**). Fits to the recreational discard lengths were relatively poor, which is to be expected given the small sample sizes available (**Figures 83 and 91**).

The aggregate fit to the length composition data in SEDAR 28 vs. SEDAR 81 is shown in **Figure 36** and **Figure 37**. The fit to the recreational fleets' length compositions was improved by splitting the fleet into its components in SEDAR 81.

Fits to length compositions of indices were generally good despite the small sample sizes (**Figures 37 and 86-87**). Residuals were relatively small and there were no persistent trends apparent (**Figures 94 and 95**). At least two modes are apparent in the underlying data, appearing to correspond with age 0 and 1 fish (**Figures 37**).

4.8.5. Age Compositions

Model fits to the age composition data are provided in **Figures 96-100**. The goodness of fit varied from year to year with certain years predicting a younger age at length than the underlying data (e.g. 1995 and 2003 in the Recreational Private fleet and 2019 in the Recreational Headboat + Charterboat fleet) and other years predicting older ages at length than the underlying data (e.g. 2007, 2010, 2011 in the Recreational Headboat + Charterboat fleet). Generally, the fits to the age composition were similar between SEDAR 28 and SEDAR 81.

Mean age estimated from conditional data (aggregated across length bins) for each fleet is shown in **Figures 101-105**. Mean age in the Commercial Handline + Other fleet increased from 1988 (1.5) to 2000 (3.5), then stabilizing around age 3.5. Mean ages for the Commercial Gillnet + Other fleet (3) and the recreational fleets (2-3) were relatively stable across time.

4.8.6. Shrimp Bycatch

Predicted discards from the Shrimp Bycatch fishery compared with landings and discards from other fleets is shown in **Figure 106** and **Table 26**. Given the tight CV placed on the shrimp bycatch super period value, the 1986-2011 mean bycatch value (5807 thousand fish) was estimated very close to the input value of 5854 thousand fish.

The Shrimp Bycatch fishery is the primary source of discard mortality from 1986 to the early 2000s (50-85% of total dead discards). From 2004-2009, dead discards from the shrimp fishery and shore mode are near equal, each making up ~40% of total dead discards. From 2010 on, shore mode is the primary source of dead discards (50-75% compared with 20-30% for the shrimp bycatch fishery). In terms of total catch (landings + dead discards), the shrimp bycatch fishery represents ~15-30% of removals between 1986 and the mid-2000s. That number drops to ~5-10% after 2005, with little year to year variability.

4.9. Model Diagnostics

4.9.1. Correlation Analysis

A summary of correlations for the base model parameters considered as outliers is contained in **Table 27**. Given the highly parameterized nature of this model, some parameters were mildly correlated (correlation coefficient > 70%) and 3 combinations of selectivity parameters displayed a strong correlation (> 95%; **Table 27**). Correlation among many of these parameters is not surprising, especially for the selectivity parameters, because the parameters of selectivity functions are inherently correlated (i.e., as the value of one parameter changes the other value will compensate). The same can be said for the von Bertalanffy growth parameters, which are by their very nature correlated. Moderate correlations occurred between the parameters defining the initial conditions (initial Fs and initial age structure).

4.9.2. Profile Likelihoods

The total likelihood component from the lnR_0 likelihood profile indicates that the global solution for this parameter is at 11.56 (CV = 0.003) (**Figure 107**). The data sources were generally in close agreement though the age and length components favored a lower (~11.2) and higher (~12.2) lnR_0, respectively.

4.9.3. Jitter Analysis

A jitter analysis was conducted using a jitter value of 0.1. With this procedure, the starting model parameter values are randomly adjusted by 10% from the SEDAR 81 best fit over 100 runs. The model converged to the same likelihood of the SEDAR 81 Base Model in 55% of runs, with no runs demonstrating a lower negative log-likelihood solution (**Figure 108**). For the 45 remaining runs, given that the total negative log-likelihood values were much higher than that of the base run, 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 base model is relatively stable and reached the global solution.

4.9.4. 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 109-111**).

Mohn's rho, which measures the severity of retrospective patterns, was equal to 0.05, -0.07,-0.03 for the SSB, recruitment and *F* time series, respectively, which is within the acceptable range (-0.15 to +0.20; see Hurtado-Ferro et al. (2015))

4.9.5. Jack-knife Analysis on Indices of Abundance

The SEAMAP indices and the VL CPUE index were each removed from the base run. Differences between the base run and jack-knife runs are shown in **Figure 112**. Though the impacts were not statistically significant, removing the SEAMAP indices increased SSB0, R0, recent SSB and recent recruitment, causing 2021 depletion estimates to decrease from 0.21 (base model) to 0.25. The opposite effect was observed when removing the VL index with SSB0, R0, recent SSB and recent recruitment all decreasing, causing 2021 depletion estimates to increase from 0.21 (base model) to 0.18.

4.9.6. Additional Diagnostics

All three index fits passed the runs test indicating no evidence ($p \geq 0.05$) to reject the hypothesis of a randomly distributed time-series of residuals (**Figures 113**). The runs test performed on the length compositions highlighted issues in the Gillnet length composition time series which showed strong evidence (p=0.025) to reject the hypothesis of a randomly distributed time-series of residuals (**Figure 114**). That series also showed two outlier years. All other length composition time series passed the runs test but a single outlier year was observed in the Recreational Headboat + Charterboat and Recreational Shore time series.

Results from the hindcasting were poor for both indices (**Figure 115**). The VL CPUE index had a MASE score of 2.26, which suggests that the model's prediction skill for the CPUE index was very low. Only 3 of the 5 data points fell within the hindcasting horizon of the terminal 5 years. The SEAMAP Trawl Survey Late index had a MASE score of 1.28, which suggests that the model's prediction skill for the survey was low. Only 1 of the 4 data points fell within the hindcasting horizon of the terminal 4 years (no 2021 index value).

4.10. Bridging analysis

The general flow of model building runs that led to the final SEDAR 81 base model is shown in **Table 28**. Changes in estimated quantities are shown in **Table 29** and **Figures 116-119**.

Model building occurred in phases, starting with converting the original SEDAR 28 model (Step 1) from SS version 3.24 to 3.30 (Step 2). Step 3 was replacing CHTS-based recreational landings and discard estimates with FES-based estimates without altering the rest of the model structure (including landings and discard CVs). This increased the estimate of virgin SSB and recruitment and caused the persistent increase in SSB over the last 5 years of the SSB time series to disappear, dropping end year depletion estimates from 0.47 to 0.33 (**Figure 116**, **Table 29**). Step 4 and 5 involved correcting errors in SEDAR 28. Correcting the slope of the maturity function affected the population scale but did not have a large impact on recent depletion levels. Correcting the time block brought estimates of virgin recruitment and SSB up slightly. Step 6 involved updating all data streams up to 2021 while starting the model in 1950. This required changing the fleet structure (separating the recreational fleets) and adding all new catches, discards, indices, length and age compositions. This further increased estimates of SSB0 and depletion but had some model instability in the late 70s/early 80's. Step 7 let the Recreational Shore fleet have its selectivity curve estimated separately from the other two recreational fleets which brought current depletion estimates higher from 0.24 to 0.13 in 2021 (**Table 29**). Step 6 and 7 were very unstable. The decision was therefore made to further truncate the dataset to start in 1986 (Step 8). Trends SSB, recruitment and F over the 1986-2021 time period were similar between Step 7 and 8 but model stability was much improved by truncating the datasets to the more data rich period. The remaining steps did not have as drastic an impact on the results as the previous steps. Step 9 involved updating the M vector to use the internal Lorenzen scaling approach and adjusting the spawning season. This change increased the virgin recruitment estimate but also led to lower estimates of terminal year depletion (0.17 compared with the previous 0.14). The remainder of the steps 10 (modeling recreational discard length compositions as separate years instead of a single super period and estimating all parameters of the retention function), 11 (estimating HL selectivity, rescaling the VL index CVs), 12 (splitting SEAMAP into two separate indices) had very little impact on the overall population trends and statistics. Step 13 involved adjusting selectivity parameters and adding priors where needed to improve model stability. Step 14 was a tuning step to add the Dirichlet Multinomial parameters to the model for weighting age and length compositions. Step 15 modified the initial equilibrium catch inputs to match the optimal scalar obtained from search on initial conditions and turned off estimation of Dirichlet parameters near bounds (i.e. indicating no downweighing was necessary). Step 16 was the final tuning step where the recruitment deviations bias adjustment ramp was applied.

4.11. Sensitivity Model Runs

Results for the sensitivity runs summarized in **Section 3.5** are discussed below.

Time blocks for the GN fleet -

Figures 120 and **121** show the impact of additional time blocks on model derived quantities of interest. Adding more time blocks did improve fits to the Commercial Gillnet + Other length compositions (60 likelihood units) but it did not have a measurable impact on the results (terminal year depletion was 0.20 in the sensitivity run compared to 0.21 in the base model run). Since there was no good justification for the presence of these blocks (other than poor residual patterns), the base model was left unchanged (single block in 1995).

Natural Mortality (*M*) -

Figures 122 and **123** show the impact of a higher M (0.49, Hamel and Cope 2022) on model derived quantities of interest. Changing M had a significant impact on the results. It scaled virgin SSB and F down while scaling up estimated recruitment and the SSB time series (1986-2021). This had the net effect of decreasing depletion across the time series with terminal year depletion going from 0.21 (base model) to 0.40.

Steepness (***h***) -

Three alternative steepness scenarios were evaluated:
1. Estimating steepness (no prior)
2. Fixing steepness at .7
3. Fixing steepness at .9

Figures 124 and **125** show the impact of different steepness values on model derived quantities of interest. Changing h had a significant impact on the results. Increasing steepness to .9 had the net effect of decreasing depletion across the time series, and shifting terminal year depletion from 0.21 (base model) to 0.24. Decreasing steepness to .7 had the net effect of increasing depletion across the time series, and shifting terminal year depletion from 0.21 (base model) to 0.15.

When h was estimated freely, the model converged on a value of 0.85 (**Figures 124** and **125**). However, looking at the likelihood profile (**Figure 126**) for steepness over a range of plausible values (0.6-1) reveals a flat profile (with a few instances of non-optimal solutions caused by a trade-off between fitting to the age data and fitting to the length data). This flat profile indicates that the data provides no information as to the likely value of steepness. The decision was therefore to maintain steepness fixed at .8 for the SEDAR 81 base model run.

Shrimp Bycatch -

Figures 127 and **128** show the impact of removing the shrimp bycatch fleet on model derived quantities of interest. Removing the shrimp bycatch fleet had a significant impact on the results. It scaled the population down (SSB and recruits) as well as F, which had the net effect of scaling down depletion across the time series, with terminal depletion going from 0.21 (base) to 0.25.

Recreational discard mortality rate -

Figures 129 and **130** show the impact of different recreational discard mortality rates on model derived quantities of interest. Changing the recreational discard rate had no perceivable impact on the results.

5. Discussion

The SEDAR 81 Gulf of Mexico Spanish Mackerel assessment included several important changes to data inputs and model parameterization that affected the assessment results. Correcting errors detected in SEDAR 28 (maturity and time block), adding 10 more years of data, splitting up the recreational fleet into multiple components, post-stratifying the length composition data, and using recreational discard length data to inform retention curves for the recreational fleets all improved the accuracy of the model and had a considerable impact on the overall assessment results and estimated parameters.

Improvements in model fits and model stability was demonstrated though fewer parameters having to be fixed, an improved characterization of uncertainty about recreational catches, an improved characterization of selectivity for the different recreational modes with improved fits to the length composition data, and better fits to the VL CPUE index (particularly in the terminal years of the assessment). In SEDAR 28, the fit to the VL index was poor for the last 4 years of the time series, showing estimated values falling consistently above the observed index. In SEDAR 81, the fit to this index is much improved (**Figure 79**). Additionally, converting the previous SEDAR 33 SS 3.24s model to the upgraded SS 3.30 version had virtually no impact on model results but was seen as an overall improvement in the assessment as the updated SS version (3.30.21) allows even greater flexibility in handling a number of processes including the age at settlement, mortality scaling, data weighting and projections.

The SEDAR 81 model fit most of the data sources well. As with SEDAR 28, the dominant data inputs were the length and age compositions as these produced the greatest impact on the model fit (as measured in the contribution to the total likelihood). There were a few parameters with high correlations, but they did not appear to be the source of any major model stability issues as shown by the diagnostics. The jitter analyses did not indicate instability as most runs converged to the same (and lowest) solution space. No substantial retrospective patterns are present in the model fits, indicating internal consistency within the model. Likelihood profiles on *R0* showed general agreement between data sources.

That being said, a few issues remain. There was somewhat of a trade-off observed between fitting lengths and fitting ages. Lee et al. (2021) warn modelers that using unrepresentative CAAL can cause bias in dynamics and management quantities. Given all the apparent disagreement between age and length data, these datasets will need more scrutiny in future iterations of the assessment to ensure that the basic assumption of the CAAL model are not being violated. It is also possible that growth in Spanish Mackerel is time varying, which may explain some of the residual patterns observed. That hypothesis should be tested.

Another apparent issue was in the fits to the length compositions of the retained catch for the commercial fleets. Misfits to the Commercial Handline + Other length compositions can largely be attributed to the low sample sizes available. But misfits to the Commercial Gillnet + Other length compositions have more of a pathological pattern (as confirmed by the runs test) and seem to indicate either changes in selectivity through time or changes in sampling. The SEDAR 28 stock assessment report does mention the following:

"Follow up research by the lead analyst to federal and state port samplers confirmed that around 2006, sampling intensity increased significantly in Alabama and in particular observations of fish less than 30 cm fork length, occurred in the time series after that time. Fish less than 30 cm fork length were not previously recorded observed in the gillnet samples."

For SEDAR 28, a 2006-2011 time block was imposed on the Gillnet fleet to improve fits. However, if the above statement is correct, it would suggest that the data prior to 2006 for AL are biased and that the selectivity estimated from the more recent data (2006+) should be used as a proxy for informing selectivity for the fleet prior to 2006 when there were gaps in sampling. However, there was no clear documentation to support that claim that could be used to inform the parameterization of the SEDAR 81 model and there was the added issue that additional patterns in the residuals appeared in SEDAR 81 with the presence of additional years of data (e.g. 2016-2021). This issue will therefore need to be revisited in future assessments to determine if the changes observed are true changes in selectivity or changes in sampling (in which case it will be important to accurately characterize the selectivity of the fleet despite the gaps in sampling). In the meantime, a sensitivity run was performed and showed that adding additional time blocks, though beneficial for improving fits to the length composition data, did not significantly alter the results.

It is important to note that uncertainties remain in multiple components of the Spanish Mackerel assessment model. The landings data are dominated by the recreational fishery, and recreational landings are more uncertain than commercial data. Additionally, data pertaining to the size composition of discarded fish in the recreational fleet were largely obtained from the Charterboat fishery which is not the dominant mode for Gulf of Mexico Spanish Mackerel. The level of bycatch from the shrimp fishery is also highly uncertain and a sensitivity run testing the removal of that fleet did show a significant impact on the results. Values for steepness and natural mortality are also highly uncertain and, unsurprisingly, have a significant impact on model results and depletion levels in the final year of the assessment, as shown through the sensitivity runs.

Some of the issues pointed out by the CIE review team during SEDAR 28 were able to be addressed in SEDAR 81. Particularly, the need for composition data to be appropriately post-stratified and scaled (Stevens 2022a,b). However, one important issue that remains is the availability of defensible abundance indices. The SEAMAP index catches very few Spanish mackerel each year (no Spanish Mackerel caught in 2021) which puts into question its ability to track abundance. The commercial index has not been standardized for actual time fished or number of crew (a field available on the Trip Ticket since 2000) so the increasing trend could simply be the result of longer trips over time or of a change in the fleet with vessels that used to make short trips and/or not catch many fish, dropping out of the fishery over time (Cordue 2013). The hindcast results showed that neither index had good prediction skills. And the information each index provided with regards to population trend was conflicting as shown by the jack-knife analysis. More research is needed to develop useful indices of abundance for Gulf of Mexico Spanish Mackerel, if possible.

A number of research questions were raised during the SEDAR 28 assessment process. While attempts were made to address these questions through sensitivity runs and preliminary data exploration, the Operational nature of this assessment did not leave enough time to thoroughly evaluate each and every one of these questions. The SEFSC strongly recommends that these topics (listed in **Section 8**) be more thoroughly examined during a future assessment.

Overall, the SEDAR 81 base model is improved since the SEDAR 28 Benchmark assessment, and it incorporates the best available data and addressed modeling issues evident in the previous assessment.

6. Projections

6.1. Introduction

The SEDAR 81 projections were run for the $F_{30\%SPR}$ (F_{MSY} proxy used in SEDAR 28) key fishing mortality scenarios: F_{OFL} and F_{OY}. As the stock is not overfished, F_0 and rebuilding projections were not conducted.

6.2. Projection methods

The simulated dynamics used for projections assumed nearly identical parameter values and population dynamics as the SS base model. **Table 30** provides a summary of projection settings. Projections were run assuming that selectivity, discarding and retention were the same as the most recent years. Forecast recruitment values were derived from the Beverton-Holt stock-recruitment relationship with fixed steepness. No catch allocation among fleets was used, instead, relative Fs among fleets over the last 3 years of the assessment (2019-2021) was used for forecasting.

The terminal year of the SEDAR 81 assessment was 2021 and the first year of management advice was set to 2025. Retained catch for the interim years (2022-2024) used landings statistics when available, and the average of the last 3 years of retained catches, when not. Finalized landings statistics for 2022 were available for all fleets. For the other two interim years (2023 and 2024), the average of the last 3 years of available landings, by fleet, were used as interim catch (i.e. 2020-2022), see **Table 30**. For the Shrimp Bycatch fishery, a fixed value of F (average F over 2015-2019) was input for each year in the projection (0.06; **Figure 131**).

$F_{30\%SPR}$ was determined using a long-term 100-year projection assuming that equilibrium was obtained over the last 10 years (2111-2121). For the OFL projection, the $F_{30\%SPR}$ was applied to the stock starting in 2025 while maintaining the relative Fs among fleets the same as the average over the last 3 years of the assessment (2019-2021; **Table 30**)

The minimum stock size threshold (MSST) used to determine overfished status was calculated by multiplying the reference spawning stock biomass, $SSB_{F30\%SPR}$, by (1-M) (per the SEDAR 81 TORS), where M is the mortality rate estimated using the Hoenig (1983) regression and a maximum age of 11 (0.38) (**Table 31**). The maximum fishing mortality threshold (MFMT) was set equivalent to the harvest rate ($F_{30\%SPR}$) that achieved $SSB_{F30\%SPR}$, and was used to assess whether overfishing was occurring in a given year (**Table 31**).

Once the proxy values were calculated, 2021 stock status was used to determine whether a rebuilding plan was required (i.e., if SSB < MSST then Gulf of Mexico Spanish Mackerel would be considered overfished and a rebuilding plan would be required).

6.3. Projection results

Following the Terms of Reference, benchmarks and reference points were calculated assuming an SSB defined in terms of females only.

6.3.1. Biological Reference Points

The following status determination criteria (SDCs) were adopted for Gulf of Mexico Spanish Mackerel:

- MSY proxy = yield at $F_{30\%SPR}$,
- MSST = (1-M)*$SSB_{F30\%SPR}$,
- MFMT = $F_{30\%SPR}$ or $F_{rebuild}$ if overfished.
- OY = ACL as defined by the Gulf and South Atlantic Councils in CMP Amendment 18 (GMFMC and SAFMC 2011).

The harvest rate that results in $SSB_{F30\%SPR}$ over the long-term (100 years) was 0.384 (**Table 31**). The resulting $SSB_{F30\%SPR}$ was 14169 metric tons. The minimum stock size threshold (MSST) was 8785 metric tons (**Figure 132**).

6.3.2. Stock Status

Benchmarks and reference points are shown in **Table 31**. Detailed time series of fishing mortality and SSB relative to associated biological reference points are presented in **Table 32**. According to the reference points, the Gulf of Mexico Spanish Mackerel stock is not undergoing overfishing ($F_{current} < MFMT$) and not overfished ($SSB_{2021} > MSST$) based on the definition of MSST ($(1 - M) * SSB_{F30\%SPR}$), $F_{current}$ (geometric mean of the harvest rate over 2019-2021) and MFMT ($F_{30\%SPR}$) for the final SEDAR 81 base model (**Table 31**). In 2021, SSB was 83% of the biomass level needed to support MSY. From 2019 to 2021 the estimated stock harvest rate, using the geometric mean, was 0.36, which was equivalent to 93% of $F_{30\%SPR}$ (**Table 31**, **Figure 132**).

The Kobe plot for the female-only SSB scenario (**Figure 133**) indicates that over the time horizon of the assessment (i.e., 1986 - 2021), the stock has experienced overfishing for 23 of the 36 and has experienced overfishing as recently as 2019.

Using the MSST definition for Gulf of Mexico Spanish Mackerel, the stock was overfished in recent years (**Table 32**) dipping to 10% of SSB_0 in 1995.

6.3.3. Overfishing Limits and ABC projections

OFL projection results are provided in **Tables 33** and **Figure 134**. Forecasts begin in 2025 because management based on this stock assessment is not expected to begin until 2025.

ABC projections using F = $75\% F_{30\%SPR}$ are shown in **Table 34**.

6.3.4. Constant Catch

OFL yields (F = $F_{30\%SPR}$) under a three- and five-year "constant catch" scenario are provided below:
- three-year (2025-2027): 13.876 mp whole weight.
- five-year (2025-2029): 13.239 mp whole weight.

Optimum yields (F = $75\%F_{30\%SPR}$) under a three- and five-year "constant catch" scenario are provided below:
- three-year (2025-2027): 11.102 mp whole weight.
- five-year (2025-2029): 11.145 mp whole weight.

6.4. SEDAR 28 FES Projections

The SEDAR 28 base model run was modified to include MRIP-FES-based estimates of recreational landings and discards in place of the CHTS-based estimates, and a new set of deterministic projections were run to compare the catch recommendations which would have resulted had MRIP-FES data been used in SEDAR 28 (**Table 35**). During SEDAR 28, both deterministic and stochastic (i.e., including recruitment variability) projections were presented. Results from the stochastic projections were used as the basis for management advice; differences in OFL between the two sets of projections amounted to an approximately 5% difference in each year (**Table 35**). For this exercise, and for simplicity, deterministic projections were carried out to compare OFLs resulting from the use of CHTS vs. FES based estimates of recreational landings and discards. Substituting CHTS-based estimates for FES-based estimates resulted in a 20-39% annual increase in OFL (**Table 35**).

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.

Composition data

- Further investigate seasonal migration patterns alongside the commercial fishing year (April-March) to ensure there are no errors in the data (see Stevens 2022a).
- Link the age data sets with the length only data sets to determine paired samples and better inform the appropriateness of utilizing CAAL.
- Implement systematic age sampling for the general recreational and commercial sectors. Sample sizes were limited, particularly for the shore sector, which account for the majority of the recent landings.

Develop defensible indices of relative abundance of Gulf of Mexico Spanish Mackerel

- Investigate whether the VL index could include "time fish" in the standardization process.
- Because this species is migratory, oceanic temperatures and circulation to which Spanish Mackerel respond vary spatially and temporally may impact availability to fishery participants. As such, it may be worth exploring an index which can account for spatiotemporal correlations.

Fishery Independent Age Data

- Age data from fishery independent (FI) sources are available but not incorporated in the model to date as they would need to be assigned to a new fleet whose selectivity would need to be specified. These are valuable data. Efforts should be made to figure out how to best incorporate FI age data into the assessment model.

Stock-recruit parameters

- Investigating the use of fixed vs. estimated parameters for steepness (h) and recruitment variability (sigmaR).

Shrimp Bycatch

- Estimates of shrimp bycatch are highly uncertain and need further investigation.

Gillnet fleet selectivity

- Investigating changes in catchability/selectivity for the Gillnet fleet.

Length composition of discards

- A better understanding of the size composition and mortality of discarded fish is needed, particularly for the recreational sector.

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10. Tables

Table 1. Length-weight relationship used to convert fork length (FL) in centimeters to whole weight (WW) in kilograms for Gulf of Mexico Spanish Mackerel, sexes combined.

Model	N	Range	R^2
$WW=1.5x10^{-05}FL^{2.8617}$	88,067	FL (cm): 11-90	0.92

Table 2. Age-specific natural mortality (per year) for Gulf of Mexico Spanish Mackerel used in SEDAR 81 (“Base M”) and SEDAR 28. Note: M at age 0 values are not comparable between models given differing definitions for fish settlement timing.

Age	Base M	SEDAR 28 M
0	1.26	0.40
1	0.64	0.56
2	0.50	0.47
3	0.43	0.41
4	0.40	0.38
5	0.38	0.36
6	0.37	0.35
7	0.36	0.34
8	0.35	0.33
9	0.35	0.32
10	0.35	0.32
11	0.35	0.32

Table 3. Gulf of Mexico Spanish Mackerel commercial landings in pounds whole weight. Landings by “Other” gears were apportioned to Commercial Gillnet + Other and Commercial Handline + Other fleets based on the annual proportions of landings by the gillnet and handline gears. Commercial landings were assigned a CV of 0.01.

Year	Gillnet	Handline	Other
1986	2,176,265	95,738	340,183
1987	2,292,950	220,319	42,948
1988	1,950,308	22,870	124,947
1989	2,507,767	53,527	205,429
1990	2,258,655	16,132	221,940
1991	2,970,872	124,495	310,314
1992	2,971,087	24,597	265,269
1993	2,238,722	15,154	321,022
1994	2,407,421	29,926	239,628
1995	1,356,724	26,963	110,791
1996	405,947	36,878	18,935
1997	486,496	39,732	13,988
1998	344,134	44,958	71,499
1999	750,054	55,675	66,626
2000	817,321	39,915	53,720
2001	1,006,204	72,671	104,044
2002	857,613	39,116	63,550
2003	1,390,227	42,351	40,724
2004	1,058,416	40,104	37,319
2005	1,540,021	34,221	14,053
2006	1,209,365	52,648	198,707
2007	942,583	29,412	7,714

Table 3 Continued. Gulf of Mexico Spanish Mackerel commercial landings in pounds whole weight. Landings by “Other” gears were apportioned to Commercial Gillnet + Other and Commercial Handline + Other fleets based on the annual proportions of landings by the gillnet and handline gears. Commercial landings were assigned a CV of 0.01.

Year	Gillnet	Handline	Other
2008	1,197,191	84,191	18,131
2009	1,717,067	76,192	22,469
2010	1,067,599	140,661	43,395
2011	1,112,305	113,583	94,018
2012	1,531,291	76,703	44,253
2013	1,145,710	67,656	119,853
2014	683,710	103,051	54,294
2015	928,013	110,118	32,585
2016	1,068,781	130,377	33,531
2017	493,164	95,388	40,626
2018	958,177	56,713	136,000
2019	774,569	76,066	44,856
2020	400,347	70,509	52,384
2021	321,098	37,754	60,835

Table 4. Percent difference (%Diff) in commercial landings (mt ww) between SEDAR 81 and SEDAR 28 for the Gillnet + Other fleet (_GN), Handline + Other fleet (_HL) and overall (_COM).

Yr	GN_S81	GN_S28	%Diff_GN	HL_S81	HL_S28	%Diff_HL	%Diff_COM
1986	1,134.94	1,225.10	-7.40	49.93	14.15	252.80	-4.4
1987	1,057.84	1,190.63	-11.20	101.64	101.82	-0.20	-10.3
1988	940.66	1,038.64	-9.40	11.03	11.63	-5.20	-9.4
1989	1,228.74	1,388.06	-11.50	26.23	26.08	0.60	-11.3
1990	1,124.46	1,161.13	-3.20	8.03	8.14	-1.30	-3.1
1991	1,482.66	1,488.33	-0.40	62.13	72.76	-14.60	-1.0
1992	1,467.00	1,682.05	-12.80	12.14	17.26	-29.60	-13.0
1993	1,160.10	1,167.93	-0.70	7.85	13.03	-39.70	-1.1
1994	1,199.35	1,249.59	-4.00	14.91	10.32	44.40	-3.6
1995	664.67	674.73	-1.50	13.21	9.76	35.30	-1.0
1996	192.01	171.67	11.80	17.44	12.92	35.00	13.5
1997	226.54	226.47	0.00	18.50	18.46	0.20	0.0
1998	184.78	185.55	-0.40	24.14	23.86	1.20	-0.2
1999	368.35	368.41	-0.00	27.34	27.16	0.70	0.0
2000	393.96	394.25	-0.10	19.24	18.94	1.60	0.0
2001	500.42	500.44	-0.00	36.14	36.11	0.10	0.0
2002	416.57	412.71	0.90	19.00	17.42	9.10	1.3
2003	648.52	627.98	3.30	19.76	19.78	-0.10	3.2
2004	496.40	469.40	5.80	18.81	18.92	-0.60	5.5
2005	704.78	662.48	6.40	15.66	15.70	-0.20	6.2
2006	634.93	614.04	3.40	27.64	28.29	-2.30	3.2
2007	430.94	413.79	4.10	13.45	13.25	1.50	4.1
2008	550.72	521.23	5.70	38.73	38.70	0.10	5.3
2009	788.61	789.10	-0.10	34.99	34.61	1.10	0.0
2010	501.65	501.34	0.10	66.09	65.52	0.90	0.2
2011	543.23	560.77	-3.10	55.47	42.97	29.10	-0.8

Table 5. Gulf of Mexico Spanish Mackerel recreational landings in numbers. Landings from Charter and Headboat were aggregated in a single fleet. Landings from Private/Shore (from LA Creel) were lumped into the Recreational Shore fleet for input into the stock assessment.

Year	Charter	Headboat	Private	Shore	Private/Shore
1986	251,285	391	2,454,548	3,398,924	
1987	194,426	1,330	1,277,829	1,128,106	
1988	154,981	327	1,497,123	523,476	
1989	273,263	562	1,235,297	1,112,463	
1990	421,979	877	1,588,933	2,506,091	
1991	154,337	1,719	1,967,344	1,767,890	
1992	198,913	1,342	1,985,528	3,199,788	
1993	93,657	569	688,627	3,215,174	
1994	107,260	1,603	931,592	3,101,334	
1995	198,677	880	511,720	1,120,469	
1996	127,024	641	820,835	1,133,175	
1997	95,921	540	1,167,146	1,013,930	
1998	98,165	336	851,134	1,476,203	
1999	108,232	474	1,835,692	3,076,051	
2000	182,297	517	1,708,558	2,431,085	
2001	161,764	211	1,515,194	4,319,611	
2002	115,679	265	1,464,624	3,473,557	
2003	166,124	271	1,208,487	2,549,327	
2004	150,685	261	1,975,251	3,538,440	
2005	70,342	282	1,830,249	1,236,486	
2006	260,793	392	1,414,945	1,614,977	

Table 5 Continued. Gulf of Mexico Spanish Mackerel recreational landings in numbers. Landings from Charter and Headboat were aggregated in a single fleet. Landings from Private/Shore (from LA Creel) were lumped into the Recreational Shore fleet for input into the stock assessment.

Year	Charter	Headboat	Private	Shore	Private/Shore
2007	172,766	534	1,384,728	1,969,820	
2008	234,758	634	2,819,397	1,710,050	
2009	220,046	693	1,895,900	1,478,822	
2010	129,535	1,597	1,867,464	2,475,197	
2011	274,081	5,261	1,764,689	2,842,884	
2012	278,438	3,367	1,490,783	3,712,868	
2013	103,821	2,828	1,712,936	7,183,603	
2014	81,687	2,336	1,136,088	3,262,724	10,214
2015	235,462	3,306	839,073	4,416,443	10,074
2016	223,354	2,854	1,638,001	3,725,854	14,402
2017	209,552	2,063	756,215	5,405,204	6,807
2018	326,994	1,683	1,102,901	3,320,113	8,497
2019	254,083	2,285	1,475,324	6,591,836	17,726
2020	186,933	1,981	1,295,841	2,585,361	10,352
2021	235,775	1,212	2,187,815	1,875,738	4,842

Table 6. Log scale standard error associated with each recreational fleet for Gulf of Mexico Spanish Mackerel.

Year	Rec Headboat Charter	Rec Private	Rec Shore
1986	0.255	0.188	0.412
1987	0.206	0.129	0.275
1988	0.411	0.208	0.246
1989	0.330	0.159	0.312
1990	0.561	0.159	0.237
1991	0.308	0.178	0.340
1992	0.292	0.100	0.159
1993	0.452	0.149	0.179
1994	0.362	0.207	0.358
1995	0.436	0.252	0.358
1996	0.329	0.148	0.294
1997	0.319	0.168	0.217
1998	0.226	0.138	0.237
1999	0.148	0.129	0.237
2000	0.207	0.246	0.198
2001	0.178	0.149	0.284
2002	0.234	0.129	0.188
2003	0.236	0.119	0.198
2004	0.330	0.129	0.198
2005	0.254	0.274	0.367
2006	0.366	0.158	0.312
2007	0.235	0.129	0.217
2008	0.330	0.367	0.349

Table 6 Continued. Log scale standard error associated with each recreational fleet for Gulf of Mexico Spanish Mackerel.

Year	Rec Headboat Charter	Rec Private	Rec Shore
2009	0.462	0.274	0.246
2010	0.195	0.216	0.246
2011	0.165	0.217	0.246
2012	0.186	0.129	0.246
2013	0.212	0.139	0.217
2014	0.133	0.167	0.246
2015	0.205	0.128	0.227
2016	0.174	0.206	0.303
2017	0.194	0.156	0.312
2018	0.234	0.157	0.208
2019	0.167	0.281	0.303
2020	0.195	0.206	0.227
2021	0.346	0.236	0.256

Table 7. Gulf of Mexico Spanish Mackerel commercial discards in numbers. Discards refer to the total number of fish discarded before applying the discard mortality rate. In SEDAR 81, Commercial Handline + Other catches were modelled as total catch, by summing the landings with the dead discards. Commercial Gillnet + Other discards were assumed negligible.

Year	Handline
1993	7,629
1994	9,064
1995	8,969
1996	9,712
1997	10,819
1998	10,031
1999	11,058
2000	10,611
2001	10,692
2002	11,211
2003	11,996
2004	10,680
2005	9,717
2006	10,005
2007	9,704
2008	8,585
2009	10,499
2010	8,019
2011	9,833
2012	11,305
2013	8,909
2014	9,235
2015	8,145

Table 7 Continued. Gulf of Mexico Spanish Mackerel commercial discards in numbers. Discards refer to the total number of fish discarded before applying the discard mortality rate. In SEDAR 81, Commercial Handline + Other catches were modelled as total catch, by summing the landings with the dead discards. Commercial Gillnet + Other discards were assumed negligible.

Year	Handline
2016	8,265
2017	7,660
2018	6,070
2019	6,063
2020	5,029
2021	4,063

Table 8. Gulf of Mexico Spanish Mackerel recreational discards in numbers with associated log-scale standard errors (SE) input into the assessment model. Discards refer to the total number of fish discarded before applying the discard mortality rate.

Year	Heaboat/Charter	Heaboat/ Charter SE*	Private	Private SE	Shore	Shore SE
1986	47,707	0.42	1,360,621	0.21	164,058	0.52
1987	6,217	0.41	293,853	0.22	250,027	0.43
1988	8,716	0.61	987,140	0.24	289,493	0.44
1989	8,716	0.48	481,166	0.26	329,286	0.45
1990	8,716	0.51	1,143,999	0.31	9,552,269	0.42
1991	11,215	0.29	767,777	0.22	6,214,211	0.49
1992	135,761	0.46	994,654	0.13	2,876,152	0.22
1993	72,051	0.74	352,271	0.22	2,440,052	0.27
1994	72,051	0.70	445,960	0.18	1,401,950	0.38
1995	72,051	0.49	410,052	0.41	743,620	0.31
1996	8,341	0.42	546,277	0.22	650,470	0.28
1997	15,119	0.53	550,753	0.22	1,094,078	0.28
1998	21,897	0.28	526,628	0.17	1,102,147	0.27
1999	16,251	0.25	1,350,916	0.15	2,948,934	0.17
2000	34,644	0.28	1,286,747	0.34	1,967,851	0.20
2001	42,208	0.47	1,557,112	0.21	3,484,845	0.27
2002	33,250	0.36	1,122,106	0.14	3,880,245	0.26
2003	40,983	0.20	1,578,473	0.19	4,076,266	0.22
2004	56,999	0.24	2,982,019	0.19	2,908,330	0.16
2005	22,601	0.22	2,271,538	0.34	1,540,321	0.27
2006	49,625	0.33	2,243,313	0.16	3,612,227	0.34

*Headboat CVs provided for 04-21 (SRHS). MRIP Charter CV values used as proxy for 86-03. Heaboat and Charter CVs weighted by landings to compute overall CV for the combined fleet.

Table 8 Continued. Gulf of Mexico Spanish Mackerel recreational discards in numbers with associated log-scale standard errors (SE) input into the assessment model. Discards refer to the total number of fish discarded before applying the discard mortality rate.

Year	Heaboat/Charter	Heaboat/ Charter SE*	Private	Private SE	Shore	Shore SE
2007	55,465	0.27	1,617,295	0.15	3,493,253	0.27
2008	29,313	0.29	1,424,390	0.17	3,428,088	0.27
2009	94,318	0.42	1,806,382	0.15	1,842,066	0.18
2010	127,812	0.38	2,107,330	0.16	4,233,675	0.22
2011	94,390	0.27	2,578,519	0.19	3,707,456	0.32
2012	77,284	0.19	1,562,546	0.15	2,980,616	0.15
2013	78,227	0.46	2,155,217	0.16	9,623,715	0.22
2014	35,030	0.34	1,290,306	0.17	4,845,797	0.37
2015	72,813	0.24	1,138,145	0.25	3,039,502	0.23
2016	77,214	0.23	987,355	0.23	1,708,269	0.23
2017	48,846	0.22	1,085,287	0.19	6,816,381	0.37
2018	121,764	0.33	1,072,267	0.19	4,975,632	0.31
2019	85,942	0.30	1,769,147	0.24	8,057,682	0.27
2020	82,493	0.37	1,392,890	0.23	4,333,584	0.28
2021	64,643	0.31	783,036	0.17	2,057,230	0.24

*Headboat CVs provided for 04-21 (SRHS). MRIP Charter CV values used as proxy for 86-03. Heaboat and Charter CVs weighted by landings to compute overall CV for the combined fleet.

Table 9. Standardized indices of relative abundance for Gulf of Mexico Spanish Mackerel and Shrimp Bycatch effort time series used in the assessment.

Year	Shrimp Effort	VL CPUE	CPUE SEAMAP early	CPUE SEAMAP late
1986	1.729	0.592		
1987	2.009	0.475	0.264	
1988	1.518	0.595	1.234	
1989	1.814	1.088	1.405	
1990	1.766	0.789	1.402	
1991	1.689	0.887	0.781	
1992	1.467	0.764	0.702	
1993	1.373	0.534	1.756	
1994	1.503	0.619	0.586	
1995	1.291	0.768	1.248	
1996	1.384	0.639	0.854	
1997	1.414	0.756	0.403	
1998	1.536	1.077	0.700	
1999	1.600	1.060	0.798	
2000	1.431	0.764	0.842	
2001	1.389	1.190	1.075	
2002	1.231	0.965	0.381	
2003	1.003	1.395	1.385	
2004	0.773	1.654	0.665	
2005	0.465	1.119	2.020	
2006	0.618	1.373	0.854	
2007	0.605	1.044	1.975	
2008	0.519	0.949	0.670	

Table 9 Continued. Standardized indices of relative abundance for Gulf of Mexico Spanish Mackerel and Shrimp Bycatch time series used in the assessment.

Year	Shrimp Effort	VL CPUE	CPUE SEAMAP early	CPUE SEAMAP late
2009	0.609	1.056		1.704
2010	0.432	1.229		1.890
2011	0.412	1.222		0.439
2012	0.567	1.119		0.375
2013	0.420	0.857		4.364
2014	0.551	1.007		0.145
2015	0.424	1.428		1.398
2016	0.481	1.294		0.252
2017	0.479	1.043		0.656
2018	0.488	1.078		0.312
2019	0.409	1.346		0.084
2020	0.314	1.302		0.380
2021	0.288	0.923		

Table 10. Log scale standard error associated with each standardized relative abundance index for Gulf of Mexico Spanish Mackerel.

Year	SE Shrimp	SE VL CPUE	SE SEAMAP early	SE SEAMAP late
1986	0.125	0.146		
1987	0.125	0.127	0.413	
1988	0.125	0.173	0.273	
1989	0.125	0.194	0.284	
1990	0.125	0.170	0.255	
1991	0.125	0.174	0.289	
1992	0.125	0.212	0.300	
1993	0.125	0.231	0.247	
1994	0.125	0.220	0.323	
1995	0.125	0.278	0.274	
1996	0.125	0.252	0.310	
1997	0.125	0.262	0.342	
1998	0.125	0.277	0.306	
1999	0.125	0.270	0.311	
2000	0.125	0.261	0.278	
2001	0.125	0.246	0.330	
2002	0.125	0.266	0.428	
2003	0.125	0.235	0.279	
2004	0.125	0.283	0.306	
2005	0.125	0.311	0.227	
2006	0.125	0.272	0.269	
2007	0.125	0.261	0.249	
2008	0.125	0.286	0.315	

Table 10 Continued. Log scale standard error associated with each standardized relative abundance index for Gulf of Mexico Spanish Mackerel.

Year	SE Shrimp	SE VL CPUE	SE SEAMAP early	SE SEAMAP late
2009	0.125	0.224		0.236
2010	0.125	0.219		0.290
2011	0.125	0.256		0.400
2012	0.125	0.213		0.403
2013	0.125	0.184		0.317
2014	0.125	0.210		0.604
2015	0.125	0.188		0.295
2016	0.125	0.193		0.606
2017	0.125	0.178		0.346
2018	0.125	0.224		0.466
2019	0.125	0.195		0.776
2020	0.125	0.221		0.566
2021	0.125	0.243		

Table 11. Growth parameters for Gulf of Mexico Spanish Mackerel. Amin and Amax were fixed, all other parameters were estimated internally to SS.

Parameter	Value
A_{min}	0.3
A_{max}	11
L_{Amin}	13
L_{Amax}	59
K ($year^{-1}$)	0.40
CV_{Amin}	8.72
CV_{Amax}	6.65

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

Label	Value	Range	SE	CV	Prior	Phase
NatM_Lorenzen_averageFem_GP_1	0.382					Fixed
L_at_Amin_Fem_GP_1	13.09	(2,30)	0.866	0.066		3
L_at_Amax_Fem_GP_1	58.66	(40,90)	0.665	0.011		6
VonBert_K_Fem_GP_1	0.403	(0.1,1.2)	0.022	0.054		6
SD_young_Fem_GP_1	8.72	(0.001,20	0.207	0.024		7
SD_old_Fem_GP_1	6.65	(0.001,45	0.117	0.018		7
Wtlen_1_Fem_GP_1	1.50e-05					Fixed
Wtlen_2_Fem_GP_1	2.86					Fixed
Mat50%_Fem_GP_1	31.41					Fixed
Mat_slope_Fem_GP_1	-0.438					Fixed
Eggs/kg_inter_Fem_GP_1	1					Fixed
Eggs/kg_slope_wt_Fem_GP_1	0.00e+00					Fixed
CohortGrowDev	1					Fixed
FracFemale_GP_1	0.5					Fixed
SR_LN(R0)	11.56	(1,20)	0.035	0.003		1
SR_BH_steep	0.8					Fixed
SR_sigmaR	0.7					Fixed
SR_regime	0.00e+00					Fixed
SR_autocorr	0.00e+00					Fixed
Early_InitAge_11	2.22e-05	(-5,5)	0.7	31,54		3
Early_InitAge_10	1.11e-04	(-5,5)	0.7	6,332		3
Early_InitAge_9	6.36e-04	(-5,5)	0.7	1,100		3
Early_InitAge_8	0.004	(-5,5)	0.701	197.1		3
Early_InitAge_7	0.018	(-5,5)	0.706	39.91		3
Early_InitAge_6	0.065	(-5,5)	0.72	11.02		3
Early_InitAge_5	0.099	(-5,5)	0.711	7.190		3
Early_InitAge_4	-0.138	(-5,5)	0.689	-		3
Early_InitAge_3	-0.281	(-5,5)	0.476	-		3
Early_InitAge_2	-0.347	(-5,5)	0.238	-		3

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

Label	Value	Range	SE	CV	Prior	Phase
Early_InitAge_1	0.305	(-5,5)	0.079	0.259		3
Early_RecrDev_1986	-0.347	(-5,5)	0.095	-		3
Early_RecrDev_1987	-0.34	(-5,5)	0.079	-		3
Early_RecrDev_1988	-0.024	(-5,5)	0.073	-		3
Early_RecrDev_1989	0.508	(-5,5)	0.066	0.131		3
Main_RecrDev_1990	0.396	(-5,5)	0.067	0.169		3
Main_RecrDev_1991	0.136	(-5,5)	0.063	0.464		3
Main_RecrDev_1992	-0.661	(-5,5)	0.086	-		3
Main_RecrDev_1993	-0.031	(-5,5)	0.07	-		3
Main_RecrDev_1994	-0.82	(-5,5)	0.107	-		3
Main_RecrDev_1995	0.071	(-5,5)	0.073	1.020		3
Main_RecrDev_1996	-0.01	(-5,5)	0.075	-		3
Main_RecrDev_1997	-0.157	(-5,5)	0.078	-		3
Main_RecrDev_1998	0.578	(-5,5)	0.056	0.097		3
Main_RecrDev_1999	-0.084	(-5,5)	0.077	-		3
Main_RecrDev_2000	0.158	(-5,5)	0.065	0.414		3
Main_RecrDev_2001	-0.136	(-5,5)	0.066	-		3
Main_RecrDev_2002	-0.112	(-5,5)	0.07	-		3
Main_RecrDev_2003	0.42	(-5,5)	0.065	0.154		3
Main_RecrDev_2004	0.221	(-5,5)	0.073	0.330		3
Main_RecrDev_2005	-0.031	(-5,5)	0.073	-		3
Main_RecrDev_2006	-0.416	(-5,5)	0.079	-		3
Main_RecrDev_2007	0.238	(-5,5)	0.056	0.238		3
Main_RecrDev_2008	-0.245	(-5,5)	0.069	-		3
Main_RecrDev_2009	-0.448	(-5,5)	0.076	-		3
Main_RecrDev_2010	0.54	(-5,5)	0.053	0.098		3
Main_RecrDev_2011	-0.131	(-5,5)	0.068	-		3

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

Label	Value	Range	SE	CV	Prior	Phase
Main_RecrDev_2012	-0.183	(-5,5)	0.071	-		3
Main_RecrDev_2013	0.476	(-5,5)	0.057	0.119		3
Main_RecrDev_2014	-0.576	(-5,5)	0.084	-		3
Main_RecrDev_2015	0.448	(-5,5)	0.068	0.151		3
Main_RecrDev_2016	0.002	(-5,5)	0.08	33.73		3
Main_RecrDev_2017	0.065	(-5,5)	0.073	1.120		3
Main_RecrDev_2018	0.297	(-5,5)	0.076	0.256		3
Main_RecrDev_2019	0.441	(-5,5)	0.098	0.221		3
Main_RecrDev_2020	-0.446	(-5,5)	0.156	-		3
Late_RecrDev_2021	0.00e+00					Fixed
InitF_seas_1_flt_1Com_GN_1	1.07	(0,2)	0.361	0.339		1
InitF_seas_1_flt_2Com_HL_2	0.058	(0,1)	0.02	0.352		1
InitF_seas_1_flt_3Rec_CB_HB_3	0.083	(0,1)	0.018	0.212		1
InitF_seas_1_flt_4Rec_PRIV_4	0.334	(0,2)	0.051	0.153		1
InitF_seas_1_flt_5Rec_SH_5	0.19	(0,1)	0.023	0.122		1
InitF_seas_1_flt_6Byc_SHRIMP_6	0.224	(0,2)	0.078	0.349		1
F_fleet_1_YR_1986_s_1	0.414	(0,2.9)	0.062	0.150		1
F_fleet_1_YR_1987_s_1	0.315	(0,2.9)	0.045	0.143		1
F_fleet_1_YR_1988_s_1	0.241	(0,2.9)	0.032	0.131		1
F_fleet_1_YR_1989_s_1	0.303	(0,2.9)	0.039	0.129		1
F_fleet_1_YR_1990_s_1	0.275	(0,2.9)	0.037	0.133		1
F_fleet_1_YR_1991_s_1	0.363	(0,2.9)	0.05	0.136		1
F_fleet_1_YR_1992_s_1	0.364	(0,2.9)	0.05	0.137		1
F_fleet_1_YR_1993_s_1	0.317	(0,2.9)	0.044	0.139		1
F_fleet_1_YR_1994_s_1	0.38	(0,2.9)	0.054	0.143		1
F_fleet_1_YR_1995_s_1	0.124	(0,2.9)	0.01	0.082		1
F_fleet_1_YR_1996_s_1	0.032	(0,2.9)	0.003	0.078		1

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

Label	Value	Range	SE	CV	Prior	Phase
F_fleet_1_YR_1997_s_1	0.031	(0,2.9)	0.002	0.074		1
F_fleet_1_YR_1998_s_1	0.022	(0,2.9)	0.002	0.071		1
F_fleet_1_YR_1999_s_1	0.038	(0,2.9)	0.003	0.069		1
F_fleet_1_YR_2000_s_1	0.038	(0,2.9)	0.003	0.069		1
F_fleet_1_YR_2001_s_1	0.048	(0,2.9)	0.003	0.068		1
F_fleet_1_YR_2002_s_1	0.044	(0,2.9)	0.003	0.068		1
F_fleet_1_YR_2003_s_1	0.076	(0,2.9)	0.005	0.071		1
F_fleet_1_YR_2004_s_1	0.055	(0,2.9)	0.004	0.072		1
F_fleet_1_YR_2005_s_1	0.066	(0,2.9)	0.005	0.069		1
F_fleet_1_YR_2006_s_1	0.055	(0,2.9)	0.004	0.066		1
F_fleet_1_YR_2007_s_1	0.04	(0,2.9)	0.003	0.067		1
F_fleet_1_YR_2008_s_1	0.053	(0,2.9)	0.003	0.066		1
F_fleet_1_YR_2009_s_1	0.079	(0,2.9)	0.005	0.067		1
F_fleet_1_YR_2010_s_1	0.059	(0,2.9)	0.004	0.068		1
F_fleet_1_YR_2011_s_1	0.063	(0,2.9)	0.004	0.067		1
F_fleet_1_YR_2012_s_1	0.076	(0,2.9)	0.005	0.072		1
F_fleet_1_YR_2013_s_1	0.074	(0,2.9)	0.005	0.073		1
F_fleet_1_YR_2014_s_1	0.046	(0,2.9)	0.004	0.076		1
F_fleet_1_YR_2015_s_1	0.054	(0,2.9)	0.004	0.082		1
F_fleet_1_YR_2016_s_1	0.055	(0,2.9)	0.005	0.091		1
F_fleet_1_YR_2017_s_1	0.024	(0,2.9)	0.002	0.085		1
F_fleet_1_YR_2018_s_1	0.055	(0,2.9)	0.005	0.092		1
F_fleet_1_YR_2019_s_1	0.04	(0,2.9)	0.004	0.102		1
F_fleet_1_YR_2020_s_1	0.019	(0,2.9)	0.002	0.126		1
F_fleet_1_YR_2021_s_1	0.014	(0,2.9)	0.002	0.152		1
F_fleet_2_YR_1986_s_1	0.027	(0,2.9)	0.004	0.142		1
F_fleet_2_YR_1987_s_1	0.044	(0,2.9)	0.006	0.135		1

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

Label	Value	Range	SE	CV	Prior	Phase
F_fleet_2_YR_1988_s_1	0.004	(0,2.9)	4.99e	0.126		1
F_fleet_2_YR_1989_s_1	0.009	(0,2.9)	0.001	0.122		1
F_fleet_2_YR_1990_s_1	0.003	(0,2.9)	3.34e	0.123		1
F_fleet_2_YR_1991_s_1	0.021	(0,2.9)	0.003	0.126		1
F_fleet_2_YR_1992_s_1	0.004	(0,2.9)	5.49e	0.129		1
F_fleet_2_YR_1993_s_1	0.003	(0,2.9)	4.06e	0.133		1
F_fleet_2_YR_1994_s_1	0.007	(0,2.9)	8.94e	0.137		1
F_fleet_2_YR_1995_s_1	0.006	(0,2.9)	8.51e	0.142		1
F_fleet_2_YR_1996_s_1	0.007	(0,2.9)	9.76e	0.138		1
F_fleet_2_YR_1997_s_1	0.006	(0,2.9)	8.57e	0.134		1
F_fleet_2_YR_1998_s_1	0.007	(0,2.9)	9.17e	0.131		1
F_fleet_2_YR_1999_s_1	0.007	(0,2.9)	9.04e	0.128		1
F_fleet_2_YR_2000_s_1	0.005	(0,2.9)	5.95e	0.130		1
F_fleet_2_YR_2001_s_1	0.008	(0,2.9)	0.001	0.128		1
F_fleet_2_YR_2002_s_1	0.005	(0,2.9)	5.84e	0.127		1
F_fleet_2_YR_2003_s_1	0.005	(0,2.9)	6.71e	0.128		1
F_fleet_2_YR_2004_s_1	0.005	(0,2.9)	6.83e	0.130		1
F_fleet_2_YR_2005_s_1	0.004	(0,2.9)	5.16e	0.132		1
F_fleet_2_YR_2006_s_1	0.006	(0,2.9)	7.59e	0.129		1
F_fleet_2_YR_2007_s_1	0.003	(0,2.9)	3.53e	0.125		1
F_fleet_2_YR_2008_s_1	0.008	(0,2.9)	0.001	0.121		1
F_fleet_2_YR_2009_s_1	0.008	(0,2.9)	0.001	0.125		1
F_fleet_2_YR_2010_s_1	0.017	(0,2.9)	0.002	0.126		1
F_fleet_2_YR_2011_s_1	0.016	(0,2.9)	0.002	0.125		1
F_fleet_2_YR_2012_s_1	0.01	(0,2.9)	0.001	0.133		1
F_fleet_2_YR_2013_s_1	0.011	(0,2.9)	0.001	0.134		1
F_fleet_2_YR_2014_s_1	0.019	(0,2.9)	0.003	0.139		1

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

Label	Value	Range	SE	CV	Prior	Phase
F_fleet_2_YR_2015_s_1	0.017	(0,2.9)	0.002	0.145		1
F_fleet_2_YR_2016_s_1	0.017	(0,2.9)	0.002	0.146		1
F_fleet_2_YR_2017_s_1	0.012	(0,2.9)	0.002	0.144		1
F_fleet_2_YR_2018_s_1	0.008	(0,2.9)	0.001	0.148		1
F_fleet_2_YR_2019_s_1	0.01	(0,2.9)	0.002	0.156		1
F_fleet_2_YR_2020_s_1	0.009	(0,2.9)	0.002	0.173		1
F_fleet_2_YR_2021_s_1	0.004	(0,2.9)	7.85e	0.191		1
F_fleet_3_YR_1986_s_1	0.038	(0,2.9)	0.004	0.094		1
F_fleet_3_YR_1987_s_1	0.016	(0,2.9)	0.004	0.234		1
F_fleet_3_YR_1988_s_1	0.012	(0,2.9)	0.005	0.405		1
F_fleet_3_YR_1989_s_1	0.012	(0,2.9)	0.004	0.356		1
F_fleet_3_YR_1990_s_1	0.005	(0,2.9)	0.002	0.498		1
F_fleet_3_YR_1991_s_1	0.006	(0,2.9)	0.002	0.261		1
F_fleet_3_YR_1992_s_1	0.034	(0,2.9)	0.009	0.274		1
F_fleet_3_YR_1993_s_1	0.02	(0,2.9)	0.008	0.416		1
F_fleet_3_YR_1994_s_1	0.024	(0,2.9)	0.009	0.358		1
F_fleet_3_YR_1995_s_1	0.039	(0,2.9)	0.014	0.356		1
F_fleet_3_YR_1996_s_1	0.009	(0,2.9)	0.003	0.320		1
F_fleet_3_YR_1997_s_1	0.011	(0,2.9)	0.003	0.316		1
F_fleet_3_YR_1998_s_1	0.01	(0,2.9)	0.002	0.211		1
F_fleet_3_YR_1999_s_1	0.009	(0,2.9)	0.001	0.170		1
F_fleet_3_YR_2000_s_1	0.015	(0,2.9)	0.003	0.204		1
F_fleet_3_YR_2001_s_1	0.016	(0,2.9)	0.003	0.204		1
F_fleet_3_YR_2002_s_1	0.013	(0,2.9)	0.003	0.229		1
F_fleet_3_YR_2003_s_1	0.015	(0,2.9)	0.003	0.184		1
F_fleet_3_YR_2004_s_1	0.016	(0,2.9)	0.003	0.218		1
F_fleet_3_YR_2005_s_1	0.006	(0,2.9)	0.001	0.195		1

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

Label	Value	Range	SE	CV	Prior	Phase
F_fleet_3_YR_2006_s_1	0.019	(0,2.9)	0.005	0.273		1
F_fleet_3_YR_2007_s_1	0.018	(0,2.9)	0.004	0.206		1
F_fleet_3_YR_2008_s_1	0.013	(0,2.9)	0.003	0.256		1
F_fleet_3_YR_2009_s_1	0.031	(0,2.9)	0.01	0.334		1
F_fleet_3_YR_2010_s_1	0.021	(0,2.9)	0.004	0.203		1
F_fleet_3_YR_2011_s_1	0.03	(0,2.9)	0.005	0.176		1
F_fleet_3_YR_2012_s_1	0.029	(0,2.9)	0.005	0.170		1
F_fleet_3_YR_2013_s_1	0.017	(0,2.9)	0.004	0.227		1
F_fleet_3_YR_2014_s_1	0.012	(0,2.9)	0.002	0.171		1
F_fleet_3_YR_2015_s_1	0.028	(0,2.9)	0.005	0.194		1
F_fleet_3_YR_2016_s_1	0.024	(0,2.9)	0.004	0.187		1
F_fleet_3_YR_2017_s_1	0.019	(0,2.9)	0.004	0.189		1
F_fleet_3_YR_2018_s_1	0.039	(0,2.9)	0.009	0.233		1
F_fleet_3_YR_2019_s_1	0.027	(0,2.9)	0.005	0.199		1
F_fleet_3_YR_2020_s_1	0.019	(0,2.9)	0.005	0.235		1
F_fleet_3_YR_2021_s_1	0.02	(0,2.9)	0.006	0.283		1
F_fleet_4_YR_1986_s_1	0.381	(0,2.9)	0.039	0.102		1
F_fleet_4_YR_1987_s_1	0.147	(0,2.9)	0.023	0.157		1
F_fleet_4_YR_1988_s_1	0.223	(0,2.9)	0.041	0.183		1
F_fleet_4_YR_1989_s_1	0.126	(0,2.9)	0.022	0.171		1
F_fleet_4_YR_1990_s_1	0.18	(0,2.9)	0.031	0.172		1
F_fleet_4_YR_1991_s_1	0.172	(0,2.9)	0.03	0.173		1
F_fleet_4_YR_1992_s_1	0.255	(0,2.9)	0.034	0.132		1
F_fleet_4_YR_1993_s_1	0.106	(0,2.9)	0.018	0.168		1
F_fleet_4_YR_1994_s_1	0.155	(0,2.9)	0.028	0.182		1
F_fleet_4_YR_1995_s_1	0.106	(0,2.9)	0.027	0.252		1
F_fleet_4_YR_1996_s_1	0.135	(0,2.9)	0.023	0.168		1

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

Label	Value	Range	SE	CV	Prior	Phase
F_fleet_4_YR_1997_s_1	0.151	(0,2.9)	0.027	0.177		1
F_fleet_4_YR_1998_s_1	0.094	(0,2.9)	0.014	0.153		1
F_fleet_4_YR_1999_s_1	0.199	(0,2.9)	0.029	0.145		1
F_fleet_4_YR_2000_s_1	0.185	(0,2.9)	0.042	0.227		1
F_fleet_4_YR_2001_s_1	0.19	(0,2.9)	0.03	0.159		1
F_fleet_4_YR_2002_s_1	0.191	(0,2.9)	0.027	0.139		1
F_fleet_4_YR_2003_s_1	0.177	(0,2.9)	0.025	0.144		1
F_fleet_4_YR_2004_s_1	0.276	(0,2.9)	0.04	0.146		1
F_fleet_4_YR_2005_s_1	0.235	(0,2.9)	0.054	0.231		1
F_fleet_4_YR_2006_s_1	0.246	(0,2.9)	0.036	0.148		1
F_fleet_4_YR_2007_s_1	0.194	(0,2.9)	0.027	0.137		1
F_fleet_4_YR_2008_s_1	0.258	(0,2.9)	0.048	0.186		1
F_fleet_4_YR_2009_s_1	0.351	(0,2.9)	0.057	0.163		1
F_fleet_4_YR_2010_s_1	0.287	(0,2.9)	0.045	0.157		1
F_fleet_4_YR_2011_s_1	0.305	(0,2.9)	0.051	0.169		1
F_fleet_4_YR_2012_s_1	0.227	(0,2.9)	0.033	0.146		1
F_fleet_4_YR_2013_s_1	0.297	(0,2.9)	0.045	0.150		1
F_fleet_4_YR_2014_s_1	0.218	(0,2.9)	0.037	0.172		1
F_fleet_4_YR_2015_s_1	0.129	(0,2.9)	0.022	0.170		1
F_fleet_4_YR_2016_s_1	0.179	(0,2.9)	0.037	0.208		1
F_fleet_4_YR_2017_s_1	0.121	(0,2.9)	0.021	0.172		1
F_fleet_4_YR_2018_s_1	0.149	(0,2.9)	0.026	0.177		1
F_fleet_4_YR_2019_s_1	0.198	(0,2.9)	0.044	0.221		1
F_fleet_4_YR_2020_s_1	0.165	(0,2.9)	0.036	0.218		1
F_fleet_4_YR_2021_s_1	0.136	(0,2.9)	0.028	0.202		1
F_fleet_5_YR_1986_s_1	0.309	(0,2.9)	0.016	0.053		1
F_fleet_5_YR_1987_s_1	0.071	(0,2.9)	0.018	0.261		1

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

Label	Value	Range	SE	CV	Prior	Phase
F_fleet_5_YR_1988_s_1	0.048	(0,2.9)	0.011	0.234		1
F_fleet_5_YR_1989_s_1	0.058	(0,2.9)	0.017	0.285		1
F_fleet_5_YR_1990_s_1	0.316	(0,2.9)	0.066	0.209		1
F_fleet_5_YR_1991_s_1	0.277	(0,2.9)	0.078	0.280		1
F_fleet_5_YR_1992_s_1	0.291	(0,2.9)	0.04	0.136		1
F_fleet_5_YR_1993_s_1	0.351	(0,2.9)	0.054	0.153		1
F_fleet_5_YR_1994_s_1	0.244	(0,2.9)	0.063	0.259		1
F_fleet_5_YR_1995_s_1	0.118	(0,2.9)	0.029	0.245		1
F_fleet_5_YR_1996_s_1	0.092	(0,2.9)	0.021	0.227		1
F_fleet_5_YR_1997_s_1	0.108	(0,2.9)	0.02	0.189		1
F_fleet_5_YR_1998_s_1	0.108	(0,2.9)	0.021	0.195		1
F_fleet_5_YR_1999_s_1	0.188	(0,2.9)	0.027	0.146		1
F_fleet_5_YR_2000_s_1	0.154	(0,2.9)	0.023	0.150		1
F_fleet_5_YR_2001_s_1	0.235	(0,2.9)	0.043	0.182		1
F_fleet_5_YR_2002_s_1	0.298	(0,2.9)	0.045	0.152		1
F_fleet_5_YR_2003_s_1	0.252	(0,2.9)	0.038	0.150		1
F_fleet_5_YR_2004_s_1	0.203	(0,2.9)	0.028	0.139		1
F_fleet_5_YR_2005_s_1	0.093	(0,2.9)	0.021	0.222		1
F_fleet_5_YR_2006_s_1	0.175	(0,2.9)	0.04	0.226		1
F_fleet_5_YR_2007_s_1	0.21	(0,2.9)	0.037	0.175		1
F_fleet_5_YR_2008_s_1	0.186	(0,2.9)	0.039	0.209		1
F_fleet_5_YR_2009_s_1	0.149	(0,2.9)	0.023	0.152		1
F_fleet_5_YR_2010_s_1	0.302	(0,2.9)	0.05	0.166		1
F_fleet_5_YR_2011_s_1	0.241	(0,2.9)	0.049	0.204		1
F_fleet_5_YR_2012_s_1	0.268	(0,2.9)	0.038	0.142		1
F_fleet_5_YR_2013_s_1	0.679	(0,2.9)	0.09	0.132		1
F_fleet_5_YR_2014_s_1	0.3	(0,2.9)	0.06	0.198		1

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

Label	Value	Range	SE	CV	Prior	Phase
F_fleet_5_YR_2015_s_1	0.28	(0,2.9)	0.045	0.162		1
F_fleet_5_YR_2016_s_1	0.146	(0,2.9)	0.031	0.210		1
F_fleet_5_YR_2017_s_1	0.557	(0,2.9)	0.113	0.202		1
F_fleet_5_YR_2018_s_1	0.303	(0,2.9)	0.055	0.183		1
F_fleet_5_YR_2019_s_1	0.429	(0,2.9)	0.084	0.196		1
F_fleet_5_YR_2020_s_1	0.207	(0,2.9)	0.046	0.220		1
F_fleet_5_YR_2021_s_1	0.144	(0,2.9)	0.033	0.229		1
F_fleet_6_YR_1986_s_1	0.24	(0,2.9)	0.031	0.127		1
F_fleet_6_YR_1987_s_1	0.266	(0,2.9)	0.034	0.127		1
F_fleet_6_YR_1988_s_1	0.2	(0,2.9)	0.026	0.129		1
F_fleet_6_YR_1989_s_1	0.271	(0,2.9)	0.036	0.133		1
F_fleet_6_YR_1990_s_1	0.283	(0,2.9)	0.038	0.134		1
F_fleet_6_YR_1991_s_1	0.251	(0,2.9)	0.033	0.131		1
F_fleet_6_YR_1992_s_1	0.2	(0,2.9)	0.026	0.130		1
F_fleet_6_YR_1993_s_1	0.186	(0,2.9)	0.024	0.131		1
F_fleet_6_YR_1994_s_1	0.202	(0,2.9)	0.026	0.131		1
F_fleet_6_YR_1995_s_1	0.178	(0,2.9)	0.024	0.133		1
F_fleet_6_YR_1996_s_1	0.203	(0,2.9)	0.028	0.136		1
F_fleet_6_YR_1997_s_1	0.195	(0,2.9)	0.025	0.131		1
F_fleet_6_YR_1998_s_1	0.205	(0,2.9)	0.026	0.127		1
F_fleet_6_YR_1999_s_1	0.22	(0,2.9)	0.028	0.128		1
F_fleet_6_YR_2000_s_1	0.188	(0,2.9)	0.024	0.127		1
F_fleet_6_YR_2001_s_1	0.189	(0,2.9)	0.025	0.130		1
F_fleet_6_YR_2002_s_1	0.169	(0,2.9)	0.022	0.131		1
F_fleet_6_YR_2003_s_1	0.136	(0,2.9)	0.018	0.131		1
F_fleet_6_YR_2004_s_1	0.108	(0,2.9)	0.014	0.133		1
F_fleet_6_YR_2005_s_1	0.064	(0,2.9)	0.009	0.134		1

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

Label	Value	Range	SE	CV	Prior	Phase
F_fleet_6_YR_2006_s_1	0.086	(0,2.9)	0.012	0.135		1
F_fleet_6_YR_2007_s_1	0.083	(0,2.9)	0.011	0.134		1
F_fleet_6_YR_2008_s_1	0.071	(0,2.9)	0.01	0.134		1
F_fleet_6_YR_2009_s_1	0.084	(0,2.9)	0.011	0.134		1
F_fleet_6_YR_2010_s_1	0.06	(0,2.9)	0.008	0.135		1
F_fleet_6_YR_2011_s_1	0.058	(0,2.9)	0.008	0.136		1
F_fleet_6_YR_2012_s_1	0.077	(0,2.9)	0.01	0.135		1
F_fleet_6_YR_2013_s_1	0.057	(0,2.9)	0.008	0.135		1
F_fleet_6_YR_2014_s_1	0.074	(0,2.9)	0.01	0.134		1
F_fleet_6_YR_2015_s_1	0.057	(0,2.9)	0.008	0.135		1
F_fleet_6_YR_2016_s_1	0.067	(0,2.9)	0.009	0.137		1
F_fleet_6_YR_2017_s_1	0.066	(0,2.9)	0.009	0.136		1
F_fleet_6_YR_2018_s_1	0.066	(0,2.9)	0.009	0.135		1
F_fleet_6_YR_2019_s_1	0.056	(0,2.9)	0.008	0.136		1
F_fleet_6_YR_2020_s_1	0.044	(0,2.9)	0.006	0.137		1
F_fleet_6_YR_2021_s_1	0.04	(0,2.9)	0.005	0.136		1
LnQ_base_Byc_SHRIMP_6(6)	1.98	(-25,25)				Float
LnQ_base_Srv_VL_7(7)	-8.13	(-25,25)				Float
LnQ_base_Srv_SEAMAPearly_8(8)	-10.38	(-25,25)				Float
LnQ_base_Srv_SEAMAPlate_9(9)	-10.43	(-25,25)				Float
Size_DblN_peak_Com_GN_1(1)	55.68	(20,70)	2.3	0.041		2
Size_DblN_top_logit_Com_GN_1(1)	-3	(-20,20)	7.93	-	Sym_Beta(0.2)	3
Size_DblN_ascend_se_Com_GN_1(1)	5.14	(-20,15)	0.188	0.037	Sym_Beta(0.2)	4
Size_DblN_descend_se_Com_GN_1(1)	5.27	(-2,15)	3.34	0.633	Sym_Beta(0.2)	5
Size_DblN_start_logit_Com_GN_1(1)	-999					Fixed
Size_DblN_end_logit_Com_GN_1(1)	-999					Fixed
Size_inflection_Com_HL_2(2)	48.75	(30,80)	1.1	0.022		2

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

Label	Value	Range	SE	CV	Prior	Phase
Size_95%width_Com_HL_2(2)	12.43	(0,50)	0.704	0.057		3
Size_inflection_Rec_CB_HB_3(3)	36.57	(30,80)	1.17	0.032		2
Size_95%width_Rec_CB_HB_3(3)	16.41	(0,50)	1.12	0.069		3
Retain_L_infl_Rec_CB_HB_3(3)	31.31	(7,55)	0.121	0.004		3
Retain_L_width_Rec_CB_HB_3(3)	1.78	(0.005,30	0.06	0.034		3
Retain_L_asymptote_logit_Rec_CB_HB_3(3	3.13	(-10,10)	0.305	0.097		3
DiscMort_L_infl_Rec_CB_HB_3(3)	-4					Fixed
DiscMort_L_width_Rec_CB_HB_3(3)	1					Fixed
DiscMort_L_level_old_Rec_CB_HB_3(3)	0.2					Fixed
Size_inflection_Rec_PRIV_4(4)	36.68	(30,80)	1.79	0.049		2
Size_95%width_Rec_PRIV_4(4)	24.64	(0,50)	1.57	0.064		3
Size_DblN_peak_Rec_SH_5(5)	21.38					Fixed
Size_DblN_top_logit_Rec_SH_5(5)	-1.13	(-20,20)	0.159	-	Sym_Beta(0.2)	3
Size_DblN_ascend_se_Rec_SH_5(5)	-2.47	(-20,15)	0.842	-	Sym_Beta(0.2)	4
Size_DblN_descend_se_Rec_SH_5(5)	4.01	(-2,15)	0.657	0.164	Sym_Beta(0.2)	5
Size_DblN_start_logit_Rec_SH_5(5)	-999					Fixed
Size_DblN_end_logit_Rec_SH_5(5)	0.272	(-20,20)	0.267	0.981		4
Size_DblN_peak_Byc_SHRIMP_6(6)	16.59	(10,70)	0.917	0.055		2
Size_DblN_top_logit_Byc_SHRIMP_6(6)	-1.52	(-15,3)	0.212	-	Sym_Beta(0.2)	3
Size_DblN_ascend_se_Byc_SHRIMP_6(6)	2.8	(0,10)	0.36	0.129	Sym_Beta(0.2)	4
Size_DblN_descend_se_Byc_SHRIMP_6(6)	4.31	(0,10)	0.375	0.087	Sym_Beta(0.2)	3
Size_DblN_start_logit_Byc_SHRIMP_6(6)	-999					Fixed
Size_DblN_end_logit_Byc_SHRIMP_6(6)	-999					Fixed
Size_DblN_peak_Srv_SEAMAPlate_9(9)	16.06	(10,70)	1.14	0.071		2
Size_DblN_top_logit_Srv_SEAMAPlate_9(9	-1.25	(-15,3)	0.263	-	Sym_Beta(0.2)	3
Size_DblN_ascend_se_Srv_SEAMAPlate_9(	2.22	(0,10)	0.526	0.237	Sym_Beta(0.2)	4
Size_DblN_descend_se_Srv_SEAMAPlate_9	3.63	(0,10)	0.788	0.217	Sym_Beta(0.2)	3

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

Label	Value	Range	SE	CV	Prior	Phase
Size_DblN_start_logit_Srv_SEAMAPlate_9(	-999					Fixed
Size_DblN_end_logit_Srv_SEAMAPlate_9(9	-999					Fixed
ln(DM_theta)_Len_P1	5					Fixed
ln(DM_theta)_Len_P2	1.74	(-5,5)	0.264	0.152	Normal(0,1.81	3
ln(DM_theta)_Len_P3	5					Fixed
ln(DM_theta)_Len_P4	2.74	(-5,5)	0.454	0.166	Normal(0,1.81	3
ln(DM_theta)_Len_P5	5					Fixed
ln(DM_theta)_Len_P6	5					Fixed
ln(DM_theta)_Age_P7	4.57	(-5,5)	0.667	0.146	Normal(0,1.81	3
ln(DM_theta)_Age_P8	5					Fixed
ln(DM_theta)_Age_P9	5					Fixed
ln(DM_theta)_Age_P10	5					Fixed
ln(DM_theta)_Age_P11	4.49	(-5,5)	0.676	0.150	Normal(0,1.81	3
Size_DblN_peak_Com_GN_1(1)_BLK1repl_	39.18	(20,70)	0.821	0.021		2
Size_DblN_top_logit_Com_GN_1(1)_BLK1r	-5.05					Fixed
Size_DblN_ascend_se_Com_GN_1(1)_BLK1	3.69	(-20,15)	0.177	0.048	Sym_Beta(0.2)	4
Size_DblN_descend_se_Com_GN_1(1)_BLK	12.37					Fixed
Size_DblN_end_logit_Com_GN_1(1)_BLK1	-999					Fixed

Table 13. Estimates of annual exploitation rate (total biomass killed / total biomass age 1+) combined across all fleets for Gulf of Mexico Spanish Mackerel, which was used as the proxy for annual fishing mortality rate. Estimates are provided for the SEDAR 81 Operational Assessment and SEDAR 28.

Year	SEDAR81	SEDAR28
1986	0.731	0.502
1987	0.406	0.385
1988	0.378	0.330
1989	0.414	0.408
1990	0.614	0.417
1991	0.584	0.434
1992	0.586	0.403
1993	0.532	0.355
1994	0.518	0.365
1995	0.365	0.325
1996	0.305	0.314
1997	0.311	0.296
1998	0.291	0.324
1999	0.417	0.329
2000	0.360	0.312
2001	0.416	0.349
2002	0.439	0.296
2003	0.438	0.260
2004	0.445	0.240
2005	0.316	0.151
2006	0.373	0.177
2007	0.357	0.152
2008	0.383	0.160
2009	0.429	0.156
2010	0.492	0.138
2011	0.478	0.118
2012	0.453	
2013	0.720	
2014	0.469	

Table 13 Continued. Estimates of annual exploitation rate (total biomass killed / total biomass age 1+) combined across all fleets for Gulf of Mexico Spanish Mackerel, which was used as the proxy for annual fishing mortality rate. Estimates are provided for the SEDAR 81 Operational Assessment and SEDAR 28.

Year	SEDAR81	SEDAR28
2015	0.407	
2016	0.336	
2017	0.545	
2018	0.436	
2019	0.540	
2020	0.332	
2021	0.252	

Table 14. Estimates of annual exploitation rate (total biomass killed / total biomass age 1+) by fleet for Gulf of Mexico Spanish Mackerel.

Year	Com GN	Com HL	Rec Hbt Cbt	Rec Pri	Rec Sh	Shrimp	Total
1986	0.114	0.005	0.018	0.197	0.262	0.135	0.731
1987	0.119	0.011	0.009	0.089	0.060	0.117	0.406
1988	0.106	0.001	0.007	0.141	0.039	0.083	0.378
1989	0.130	0.003	0.007	0.081	0.050	0.143	0.414
1990	0.097	0.001	0.002	0.103	0.261	0.151	0.614
1991	0.125	0.005	0.003	0.097	0.227	0.125	0.584
1992	0.128	0.001	0.018	0.140	0.220	0.079	0.586
1993	0.128	0.001	0.011	0.062	0.259	0.070	0.532
1994	0.147	0.002	0.013	0.089	0.185	0.081	0.518
1995	0.096	0.002	0.024	0.068	0.096	0.078	0.365
1996	0.025	0.002	0.006	0.088	0.080	0.104	0.305
1997	0.024	0.002	0.007	0.097	0.092	0.089	0.311
1998	0.018	0.002	0.006	0.064	0.095	0.106	0.291
1999	0.028	0.002	0.005	0.121	0.157	0.105	0.417
2000	0.029	0.001	0.009	0.117	0.125	0.079	0.360
2001	0.036	0.003	0.009	0.116	0.180	0.073	0.416
2002	0.032	0.001	0.007	0.116	0.221	0.061	0.439
2003	0.056	0.002	0.009	0.111	0.200	0.061	0.438
2004	0.039	0.002	0.009	0.168	0.172	0.055	0.445
2005	0.051	0.001	0.004	0.149	0.080	0.030	0.316
2006	0.042	0.002	0.011	0.151	0.135	0.031	0.373
2007	0.031	0.001	0.011	0.124	0.159	0.030	0.357
2008	0.039	0.003	0.008	0.160	0.145	0.029	0.383
2009	0.058	0.003	0.018	0.211	0.111	0.029	0.429
2010	0.043	0.006	0.012	0.177	0.229	0.026	0.492
2011	0.044	0.004	0.016	0.180	0.204	0.030	0.478
2012	0.056	0.003	0.016	0.135	0.212	0.032	0.453
2013	0.048	0.003	0.008	0.160	0.477	0.024	0.720
2014	0.032	0.005	0.006	0.127	0.260	0.039	0.469

Table 14 Continued. Estimates of annual exploitation rate (total biomass killed / total biomass age 1+) by fleet for Gulf of Mexico Spanish Mackerel.

Year	Com GN	Com HL	Rec Hbt Cbt	Rec Pri	Rec Sh	Shrimp	Total
2015	0.041	0.005	0.017	0.082	0.235	0.027	0.407
2016	0.041	0.005	0.014	0.113	0.129	0.034	0.336
2017	0.017	0.003	0.010	0.069	0.419	0.026	0.545
2018	0.040	0.002	0.022	0.092	0.248	0.031	0.436
2019	0.028	0.003	0.015	0.117	0.350	0.028	0.540
2020	0.015	0.003	0.011	0.102	0.181	0.021	0.332
2021	0.012	0.001	0.013	0.091	0.119	0.016	0.252

Table 15. Expected biomass (metric tons) for all Spanish Mackerel and exploited (1+ years) Spanish Mackerel, spawning stock biomass (SSB, metric tons), exploited numbers (1,000s of fish), age-0 recruits (1,000s of fish), and SSB ratio (SSB/SSB_0) where SSB_0 = 55,927 metric tons for Gulf of Mexico Spanish Mackerel.

Year	Biomass (all)	Biomass (exploited)	SSB	Abundance (exploited)	Recruits	SSB ratio
1986	10,682	9,935	6,125	54,366	38,401	0.11
1987	9,624	8,854	6,516	31,284	39,564	0.12
1988	9,961	8,875	7,043	28,099	55,798	0.13
1989	11,285	9,425	7,147	34,076	95,509	0.13
1990	13,331	11,604	8,035	51,117	88,730	0.14
1991	13,195	11,852	8,247	50,400	68,958	0.15
1992	12,055	11,447	8,362	43,697	31,207	0.15
1993	10,139	9,050	7,222	26,824	55,891	0.13
1994	8,599	8,135	6,046	31,418	23,804	0.11
1995	7,994	6,908	5,465	20,657	55,783	0.10
1996	8,792	7,773	5,695	31,079	52,316	0.10
1997	10,258	9,312	6,927	34,076	48,581	0.12
1998	12,288	10,224	7,929	33,860	105,989	0.14
1999	14,494	13,371	9,469	57,115	57,665	0.17
2000	15,068	13,598	10,464	44,326	75,480	0.19
2001	15,179	14,073	10,879	48,200	56,824	0.20
2002	14,124	13,008	10,267	40,815	57,306	0.18
2003	13,455	11,617	9,110	37,858	94,359	0.16
2004	14,090	12,590	8,970	52,566	77,036	0.16
2005	14,967	13,763	10,071	51,808	61,853	0.18
2006	16,116	15,260	11,931	48,830	43,946	0.21
2007	15,578	13,948	11,484	38,285	83,700	0.20
2008	15,084	14,095	10,784	50,443	50,836	0.19
2009	14,446	13,638	10,759	41,704	41,481	0.19
2010	13,860	11,757	9,577	33,591	107,951	0.17
2011	13,499	12,458	8,581	56,689	53,445	0.15
2012	13,871	12,848	9,644	43,882	52,511	0.17
2013	13,898	11,936	9,395	38,344	100,758	0.17
2014	11,027	10,407	6,868	50,859	31,837	0.12

Table 15 Continued. Expected biomass (metric tons) for all Spanish Mackerel and exploited (1+ years) Spanish Mackerel, spawning stock biomass (SSB, metric tons), exploited numbers (1,000s of fish), age-0 recruits (1,000s of fish), and SSB ratio (SSB/SSB_0) where SSB_0 = 55,927 metric tons for Gulf of Mexico Spanish Mackerel.

Year	Biomass (all)	Biomass (exploited)	SSB	Abundance (exploited)	Recruits	SSB ratio
2015	12,341	10,515	8,132	32,395	93,780	0.14
2016	13,353	12,160	8,671	51,942	61,272	0.16
2017	15,398	14,053	10,638	47,945	69,067	0.19
2018	13,820	12,188	9,226	43,930	83,805	0.16
2019	15,046	13,143	9,563	51,640	97,750	0.17
2020	14,608	13,813	9,713	58,142	40,809	0.17
2021	16,313	14,668	11,734	42,058	84,516	0.21

Table 16. Input (with log-scale standard errors, SE) and expected (Exp) landings for the Commercial Gillnet + Other fleet in weight (B, million pounds whole weight) and number (1,000s of fish) for Gulf of Mexico Spanish Mackerel. The mean body weight (MW, whole pounds per fish) was determined by dividing the expected landings in weights by the expected landings in numbers.

Year	Input B SE	Input B	Exp B	Exp N	MW
1986	0.01	2.50	2.50	1,338	1.9
1987	0.01	2.33	2.33	1,168	2.0
1988	0.01	2.07	2.07	950	2.2
1989	0.01	2.71	2.71	1,219	2.2
1990	0.01	2.48	2.48	1,168	2.1
1991	0.01	3.27	3.27	1,590	2.1
1992	0.01	3.23	3.23	1,553	2.1
1993	0.01	2.56	2.56	1,169	2.2
1994	0.01	2.64	2.64	1,197	2.2
1995	0.01	1.47	1.47	885	1.7
1996	0.01	0.42	0.42	261	1.6
1997	0.01	0.50	0.50	310	1.6
1998	0.01	0.41	0.41	246	1.7
1999	0.01	0.81	0.81	513	1.6
2000	0.01	0.87	0.87	533	1.6
2001	0.01	1.10	1.10	659	1.7
2002	0.01	0.92	0.92	538	1.7
2003	0.01	1.43	1.43	842	1.7
2004	0.01	1.09	1.09	695	1.6
2005	0.01	1.55	1.55	997	1.6
2006	0.01	1.40	1.40	851	1.6
2007	0.01	0.95	0.95	544	1.7
2008	0.01	1.21	1.21	719	1.7
2009	0.01	1.74	1.74	1,036	1.7
2010	0.01	1.11	1.11	643	1.7
2011	0.01	1.20	1.20	776	1.5
2012	0.01	1.57	1.57	1,004	1.6
2013	0.01	1.26	1.26	766	1.6
2014	0.01	0.73	0.73	490	1.5

Table 16 Continued. Input (with log-scale standard errors, SE) and expected (Exp) landings for the Commercial Gillnet + Other fleet in weight (B, million pounds whole weight) and number (1,000s of fish) for Gulf of Mexico Spanish Mackerel. The mean body weight (MW, whole pounds per fish) was determined by dividing the expected landings in weights by the expected landings in numbers.

Year	Input B SE	Input B	Exp B	Exp N	MW
2015	0.01	0.96	0.96	607	1.6
2016	0.01	1.10	1.10	703	1.6
2017	0.01	0.53	0.53	330	1.6
2018	0.01	1.09	1.09	670	1.6
2019	0.01	0.81	0.81	519	1.6
2020	0.01	0.44	0.44	290	1.5
2021	0.01	0.38	0.38	227	1.7

Table 17. Input (with log-scale standard errors, SE) and expected (Exp) landings for the Commercial Handline + Other fleet in weight (B, million pounds whole weight) and number (1,000s of fish) for Gulf of Mexico Spanish Mackerel. The mean body weight (MW, whole pounds per fish) was determined by dividing the expected landings in weights by the expected landings in numbers.

Year	Input B SE	Input B	Exp B	Exp N	MW
1985	0.01	0.30	0.30	149	2.0
1986	0.01	0.11	0.11	54	2.0
1987	0.01	0.22	0.22	103	2.2
1988	0.01	0.02	0.02	10	2.4
1989	0.01	0.06	0.06	24	2.4
1990	0.01	0.02	0.02	8	2.4
1991	0.01	0.14	0.14	60	2.3
1992	0.01	0.03	0.03	12	2.3
1993	0.01	0.02	0.02	7	2.4
1994	0.01	0.03	0.03	14	2.4
1995	0.01	0.03	0.03	12	2.5
1996	0.01	0.04	0.04	16	2.5
1997	0.01	0.04	0.04	17	2.4
1998	0.01	0.05	0.05	22	2.5
1999	0.01	0.06	0.06	25	2.4
2000	0.01	0.04	0.04	18	2.4
2001	0.01	0.08	0.08	32	2.5
2002	0.01	0.04	0.04	17	2.5
2003	0.01	0.04	0.04	17	2.5
2004	0.01	0.04	0.04	17	2.4
2005	0.01	0.04	0.04	15	2.4
2006	0.01	0.06	0.06	25	2.4
2007	0.01	0.03	0.03	12	2.5
2008	0.01	0.09	0.09	34	2.6
2009	0.01	0.08	0.08	31	2.5
2010	0.01	0.15	0.15	58	2.5
2011	0.01	0.12	0.12	51	2.4
2012	0.01	0.08	0.08	34	2.4
2013	0.01	0.07	0.07	31	2.4

Table 17 Continued. Input (with log-scale standard errors, SE) and expected (Exp) landings for the Commercial Handline + Other fleet in weight (B, million pounds whole weight) and number (1,000s of fish) for Gulf of Mexico Spanish Mackerel. The mean body weight (MW, whole pounds per fish) was determined by dividing the expected landings in weights by the expected landings in numbers.

Year	Input B SE	Input B	Exp B	Exp N	MW
2014	0.01	0.11	0.11	48	2.3
2015	0.01	0.11	0.11	49	2.3
2016	0.01	0.14	0.14	57	2.4
2017	0.01	0.10	0.10	43	2.4
2018	0.01	0.06	0.06	27	2.4
2019	0.01	0.08	0.08	34	2.4
2020	0.01	0.08	0.08	34	2.3
2021	0.01	0.04	0.04	18	2.4

Table 18. Input (with log-scale standard errors, SE) and expected (Exp) landings for the Recreational Headboat + Charterboat fleet in numbers (N, 1,000s of fish) and weight (B, million pounds whole weight) for Gulf of Mexico Spanish Mackerel. The mean body weight (MW, whole pounds per fish) was determined by dividing the expected landings in weights by the expected landings in numbers.

Year	Input N SE	Input N	Exp N	Exp B	MW
1986	0.01	252	252	0.37	1.5
1987	0.21	196	111	0.18	1.6
1988	0.41	155	78	0.14	1.8
1989	0.33	274	84	0.15	1.8
1990	0.56	215	37	0.06	1.7
1991	0.31	156	50	0.08	1.6
1992	0.29	200	258	0.43	1.7
1993	0.45	94	125	0.22	1.8
1994	0.36	109	131	0.23	1.8
1995	0.44	200	200	0.36	1.8
1996	0.33	128	53	0.10	1.8
1997	0.32	96	75	0.13	1.8
1998	0.23	99	74	0.14	1.8
1999	0.15	109	81	0.14	1.7
2000	0.21	183	147	0.26	1.8
2001	0.18	162	156	0.29	1.8
2002	0.23	116	112	0.21	1.9
2003	0.24	166	121	0.23	1.9
2004	0.33	151	136	0.24	1.7
2005	0.25	71	67	0.11	1.7
2006	0.37	261	208	0.37	1.8
2007	0.24	173	177	0.34	1.9
2008	0.33	235	126	0.23	1.9
2009	0.46	221	287	0.53	1.8
2010	0.20	131	161	0.30	1.9
2011	0.17	279	258	0.44	1.7
2012	0.19	282	264	0.45	1.7
2013	0.21	107	121	0.22	1.8
2014	0.13	84	84	0.14	1.6

Table 18 Continued. Input (with log-scale standard errors, SE) and expected (Exp) landings for the Recreational Headboat + Charterboat fleet in numbers (N, 1,000s of fish) and weight (B, million pounds whole weight) for Gulf of Mexico Spanish Mackerel. The mean body weight (MW, whole pounds per fish) was determined by dividing the expected landings in weights by the expected landings in numbers.

Year	Input N SE	Input N	Exp N	Exp B	MW
2015	0.20	239	220	0.38	1.7
2016	0.17	226	213	0.36	1.7
2017	0.19	212	177	0.31	1.7
2018	0.23	329	330	0.59	1.8
2019	0.17	256	238	0.41	1.7
2020	0.19	189	198	0.33	1.7
2021	0.35	237	225	0.40	1.8

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

Year	Input N SE	Input N	Exp N	Exp B	MW
1986	0.01	2,455	2,452	3.50	1.4
1987	0.13	1,278	959	1.52	1.6
1988	0.21	1,497	1,381	2.43	1.8
1989	0.16	1,235	821	1.43	1.7
1990	0.16	1,589	1,347	2.19	1.6
1991	0.18	1,967	1,350	2.14	1.6
1992	0.10	1,986	1,877	3.07	1.6
1993	0.15	689	618	1.09	1.8
1994	0.21	932	797	1.38	1.7
1995	0.25	512	514	0.91	1.8
1996	0.15	821	742	1.29	1.7
1997	0.17	1,167	1,000	1.73	1.7
1998	0.14	851	700	1.24	1.8
1999	0.13	1,836	1,795	3.04	1.7
2000	0.25	1,709	1,762	3.07	1.7
2001	0.15	1,515	1,760	3.16	1.8
2002	0.13	1,465	1,597	2.93	1.8
2003	0.12	1,208	1,347	2.46	1.8
2004	0.13	1,975	2,342	3.94	1.7
2005	0.27	1,830	2,351	3.91	1.7
2006	0.16	1,415	2,571	4.52	1.8
2007	0.13	1,385	1,816	3.40	1.9
2008	0.37	2,819	2,385	4.33	1.8
2009	0.27	1,896	3,125	5.63	1.8
2010	0.22	1,867	2,160	3.98	1.8
2011	0.22	1,765	2,519	4.15	1.6
2012	0.13	1,491	1,994	3.33	1.7
2013	0.14	1,713	2,064	3.62	1.8
2014	0.17	1,136	1,538	2.44	1.6

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

Year	Input N SE	Input N	Exp N	Exp B	MW
2015	0.13	839	973	1.64	1.7
2016	0.21	1,638	1,545	2.57	1.7
2017	0.16	756	1,095	1.87	1.7
2018	0.16	1,103	1,227	2.13	1.7
2019	0.28	1,475	1,707	2.86	1.7
2020	0.21	1,296	1,635	2.67	1.6
2021	0.24	2,188	1,474	2.60	1.8

Table 20. Input (with log-scale standard errors, SE) and expected (Exp) landings for the Recreational Shore fleet in numbers (N, 1,000s of fish) and weight (B, million pounds whole weight) for Gulf of Mexico Spanish Mackerel. The mean body weight (MW, whole pounds per fish) was determined by dividing the expected landings in weights by the expected landings in numbers.

Year	Input N SE	Input N	Exp N	Exp B	MW
1986	0.01	3,399	3,394	3.80	1.1
1987	0.27	1,128	701	0.88	1.3
1988	0.25	523	423	0.57	1.4
1989	0.31	1,112	555	0.73	1.3
1990	0.24	2,506	3,716	4.54	1.2
1991	0.34	1,768	3,422	4.17	1.2
1992	0.16	3,200	3,249	4.11	1.3
1993	0.18	3,215	2,902	3.94	1.4
1994	0.36	3,101	1,856	2.42	1.3
1995	0.36	1,120	812	1.10	1.4
1996	0.29	1,133	750	0.97	1.3
1997	0.22	1,014	1,062	1.39	1.3
1998	0.24	1,476	1,155	1.55	1.3
1999	0.24	3,076	2,578	3.27	1.3
2000	0.20	2,431	2,124	2.83	1.3
2001	0.28	4,320	3,092	4.20	1.4
2002	0.19	3,474	3,485	4.83	1.4
2003	0.20	2,549	2,730	3.72	1.4
2004	0.20	3,538	2,645	3.32	1.3
2005	0.37	1,236	1,404	1.79	1.3
2006	0.31	1,615	2,601	3.52	1.4
2007	0.22	1,970	2,645	3.79	1.4
2008	0.35	1,710	2,463	3.33	1.4
2009	0.25	1,479	1,881	2.58	1.4
2010	0.25	2,475	3,149	4.39	1.4
2011	0.25	2,843	3,137	3.85	1.2
2012	0.25	3,713	3,518	4.54	1.3
2013	0.22	7,184	6,801	9.08	1.3
2014	0.25	3,273	3,418	4.09	1.2

Table 20 Continued. Input (with log-scale standard errors, SE) and expected (Exp) landings for the Recreational Shore fleet in numbers (N, 1,000s of fish) and weight (B, million pounds whole weight) for Gulf of Mexico Spanish Mackerel. The mean body weight (MW, whole pounds per fish) was determined by dividing the expected landings in weights by the expected landings in numbers.

Year	Input N SE	Input N	Exp N	Exp B	MW
2015	0.23	4,427	3,110	4.05	1.3
2016	0.30	3,740	1,933	2.43	1.3
2017	0.31	5,412	7,402	9.69	1.3
2018	0.21	3,329	3,665	4.80	1.3
2019	0.30	6,610	5,628	7.12	1.3
2020	0.23	2,596	3,188	3.97	1.2
2021	0.26	1,881	2,191	3.00	1.4

Table 21. Input (with log-scale standard errors, SE) and expected (Exp) discards for the Recreational Headboat + Charterboat fleet in number (N, 1,000s of fish) and biomass (B, thousand pounds whole weight) for Gulf of Mexico Spanish Mackerel. Dead discards in numbers (discard mortality rate = 0.2), dead discards in biomass, and mean weight (MW, whole 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	MW
1986	0.42	47.71	119.05	23.81	61.35	12.27	0.50
1987	0.41	6.22	34.20	6.84	19.99	4.00	0.60
1988	0.61	8.72	25.97	5.20	14.39	2.88	0.60
1989	0.48	8.72	38.31	7.66	18.38	3.67	0.50
1990	0.51	8.72	17.57	3.51	8.59	1.72	0.50
1991	0.29	11.21	21.13	4.23	10.99	2.20	0.50
1992	0.46	135.76	83.10	16.62	49.70	9.94	0.60
1993	0.74	72.05	40.76	8.15	22.62	4.52	0.60
1994	0.69	72.05	44.92	8.98	26.48	5.29	0.60
1995	0.49	72.05	72.17	14.44	38.10	7.62	0.50
1996	0.42	8.34	21.92	4.38	11.48	2.30	0.50
1997	0.52	15.12	26.52	5.30	14.94	2.99	0.60
1998	0.28	21.90	31.33	6.27	15.35	3.07	0.50
1999	0.25	16.25	31.85	6.37	17.59	3.52	0.60
2000	0.28	34.64	48.34	9.67	27.58	5.52	0.60
2001	0.47	42.21	50.09	10.02	29.71	5.94	0.60
2002	0.36	33.25	34.90	6.98	20.86	4.17	0.60
2003	0.20	40.98	49.10	9.82	25.11	5.02	0.50
2004	0.24	57.00	59.02	11.80	30.66	6.13	0.50
2005	0.22	22.60	23.32	4.66	13.29	2.66	0.60
2006	0.33	49.62	57.02	11.40	36.59	7.32	0.60
2007	0.27	55.47	54.64	10.93	31.59	6.32	0.60
2008	0.29	29.31	42.70	8.54	25.25	5.05	0.60
2009	0.42	94.32	80.18	16.04	51.36	10.27	0.60
2010	0.38	127.81	64.61	12.92	32.14	6.43	0.50
2011	0.27	94.39	111.69	22.34	59.79	11.96	0.50
2012	0.19	77.28	83.03	16.61	49.06	9.81	0.60
2013	0.46	78.23	51.25	10.25	24.89	4.98	0.50
2014	0.34	35.03	35.48	7.09	19.50	3.90	0.50

Table 21 Continued. Input (with log-scale standard errors, SE) and expected (Exp) discards for the Recreational Headboat + Charterboat fleet in number (N, 1,000s of fish) and biomass (B, thousand pounds whole weight) for Gulf of Mexico Spanish Mackerel. Dead discards in numbers (discard mortality rate = 0.2), dead discards in biomass, and mean weight (MW, whole 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	MW
2015	0.24	72.81	82.89	16.58	42.12	8.42	0.50
2016	0.23	77.21	86.23	17.25	46.34	9.27	0.50
2017	0.22	48.85	59.92	11.98	33.87	6.78	0.60
2018	0.33	121.76	130.80	26.16	68.31	13.66	0.50
2019	0.30	85.94	104.67	20.93	52.42	10.48	0.50
2020	0.38	82.49	69.92	13.98	40.75	8.15	0.60
2021	0.31	64.64	66.71	13.34	39.23	7.85	0.60

Table 22. Input (with log-scale standard errors, SE) and expected (Exp) discards for the Recreational Private fleet in number (N, 1,000s of fish) and biomass (B, thousand pounds whole weight) for Gulf of Mexico Spanish Mackerel. Dead discards in numbers (discard mortality rate = 0.2), dead discards in biomass, and mean weight (MW, whole 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	MW
1986	0.21	1,361	2,126	2,126	809	809	0.4
1987	0.22	294	572	572	226	226	0.4
1988	0.24	987	979	979	341	341	0.3
1989	0.26	481	843	843	251	251	0.3
1990	0.31	1,144	1,344	1,344	436	436	0.3
1991	0.22	768	1,129	1,129	398	398	0.4
1992	0.13	995	1,100	1,100	469	469	0.4
1993	0.22	352	435	435	149	149	0.3
1994	0.18	446	507	507	211	211	0.4
1995	0.41	410	411	411	132	132	0.3
1996	0.21	546	631	631	218	218	0.3
1997	0.22	551	703	703	264	264	0.4
1998	0.17	527	672	672	200	200	0.3
1999	0.15	1,351	1,350	1,350	520	520	0.4
2000	0.34	1,287	1,186	1,186	436	436	0.4
2001	0.21	1,557	1,107	1,107	438	438	0.4
2002	0.14	1,122	997	997	387	387	0.4
2003	0.19	1,578	1,205	1,205	380	380	0.3
2004	0.19	2,982	2,044	2,044	715	715	0.3
2005	0.34	2,272	1,577	1,577	614	614	0.4
2006	0.16	2,243	1,307	1,307	576	576	0.4
2007	0.15	1,617	1,212	1,212	427	427	0.4
2008	0.17	1,424	1,549	1,549	627	627	0.4
2009	0.15	1,806	1,641	1,641	713	713	0.4
2010	0.16	2,107	2,008	2,008	592	592	0.3
2011	0.19	2,579	2,065	2,065	784	784	0.4
2012	0.15	1,563	1,209	1,209	481	481	0.4
2013	0.16	2,155	2,000	2,000	590	590	0.3
2014	0.17	1,290	1,166	1,166	473	473	0.4

Table 22 Continued. Input (with log-scale standard errors, SE) and expected (Exp) discards for the Recreational Private fleet in number (N, 1,000s of fish) and biomass (B, thousand pounds whole weight) for Gulf of Mexico Spanish Mackerel. Dead discards in numbers (discard mortality rate = 0.2), dead discards in biomass, and mean weight (MW, whole 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	MW
2015	0.25	1,138	822	822	254	254	0.3
2016	0.22	987	1,221	1,221	453	453	0.4
2017	0.19	1,085	747	747	276	276	0.4
2018	0.19	1,072	1,027	1,027	344	344	0.3
2019	0.23	1,769	1,589	1,589	516	516	0.3
2020	0.23	1,393	1,043	1,043	441	441	0.4
2021	0.17	783	911	911	334	334	0.4

Table 23. Input (with log-scale standard errors, SE) and expected (Exp) discards for the Recreational Shore fleet in number (N, 1,000s of fish) and biomass (B, thousand pounds whole weight) for Gulf of Mexico Spanish Mackerel. Dead discards in numbers (discard mortality rate = 0.2), dead discards in biomass, and mean weight (MW, whole 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	MW
1986	0.52	164	4,457	4,457	1,945	1,945	0.4
1987	0.43	250	608	608	283	283	0.5
1988	0.44	289	420	420	187	187	0.4
1989	0.45	329	725	725	306	306	0.4
1990	0.42	9,552	4,980	4,980	2,128	2,128	0.4
1991	0.49	6,214	4,036	4,036	1,770	1,770	0.4
1992	0.22	2,876	3,127	3,127	1,438	1,438	0.5
1993	0.28	2,440	2,738	2,738	1,229	1,229	0.4
1994	0.38	1,402	1,995	1,995	898	898	0.5
1995	0.31	744	830	830	366	366	0.4
1996	0.28	650	922	922	400	400	0.4
1997	0.28	1,094	1,111	1,111	498	498	0.4
1998	0.28	1,102	1,384	1,384	591	591	0.4
1999	0.17	2,949	3,055	3,055	1,349	1,349	0.4
2000	0.20	1,968	2,031	2,031	921	921	0.5
2001	0.26	3,485	3,076	3,076	1,392	1,392	0.5
2002	0.26	3,880	3,312	3,312	1,509	1,509	0.5
2003	0.22	4,076	3,234	3,234	1,393	1,393	0.4
2004	0.16	2,908	3,329	3,329	1,445	1,445	0.4
2005	0.26	1,540	1,429	1,429	646	646	0.5
2006	0.34	3,612	2,185	2,185	1,029	1,029	0.5
2007	0.26	3,493	2,461	2,461	1,109	1,109	0.5
2008	0.28	3,428	2,641	2,641	1,186	1,186	0.4
2009	0.18	1,842	1,605	1,605	755	755	0.5
2010	0.22	4,234	3,632	3,632	1,552	1,552	0.4
2011	0.32	3,707	4,017	4,017	1,755	1,755	0.4
2012	0.15	2,981	3,189	3,189	1,474	1,474	0.5
2013	0.22	9,624	8,194	8,194	3,486	3,486	0.4
2014	0.37	4,846	4,256	4,256	1,879	1,879	0.4

Table 23 Continued. Input (with log-scale standard errors, SE) and expected (Exp) discards for the Recreational Shore fleet in number (N, 1,000s of fish) and biomass (B, thousand pounds whole weight) for Gulf of Mexico Spanish Mackerel. Dead discards in numbers (discard mortality rate = 0.2), dead discards in biomass, and mean weight (MW, whole 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	MW
2015	0.23	3,040	3,170	3,170	1,395	1,395	0.4
2016	0.23	1,708	2,342	2,342	1,025	1,025	0.4
2017	0.37	6,816	7,260	7,260	3,282	3,282	0.5
2018	0.31	4,976	4,245	4,245	1,849	1,849	0.4
2019	0.28	8,058	7,035	7,035	3,030	3,030	0.4
2020	0.28	4,334	3,378	3,378	1,530	1,530	0.5
2021	0.24	2,057	1,866	1,866	860	860	0.5

Table 24. Observed (Obs) versus predicted (Exp) standardized fishery-dependent catch-per-unit-effort (CPUE) indices for Gulf of Mexico Spanish Mackerel. Values are normalized to the mean. CVs estimated by the standardization process were scaled to have a mean equal to the minimum CV from the SEAMAP index and converted to log-scale SEs.

Yr	VL (Obs)	VL (Exp)	VL (SE)
1986	0.59	0.51	0.15
1987	0.48	0.65	0.13
1988	0.59	0.80	0.17
1989	1.09	0.85	0.19
1990	0.79	0.83	0.17
1991	0.89	0.81	0.17
1992	0.76	0.80	0.21
1993	0.53	0.74	0.23
1994	0.62	0.65	0.22
1995	0.77	0.64	0.28
1996	0.64	0.72	0.25
1997	0.76	0.85	0.26
1998	1.08	1.00	0.28
1999	1.06	1.12	0.27
2000	0.76	1.22	0.26
2001	1.19	1.27	0.25
2002	0.96	1.20	0.27
2003	1.40	1.09	0.24
2004	1.65	1.04	0.28
2005	1.12	1.17	0.31
2006	1.37	1.35	0.27
2007	1.04	1.39	0.26
2008	0.95	1.32	0.29

Table 24 Continued. Observed (Obs) versus predicted (Exp) standardized fishery-dependent catch-per-unit-effort (CPUE) indices for Gulf of Mexico Spanish Mackerel. Values are normalized to the mean. CVs estimated by the standardization process were scaled to have a mean equal to the minimum CV from the SEAMAP index and converted to log-scale SEs.

Yr	VL (Obs)	VL (Exp)	VL (SE)
2009	1.06	1.22	0.22
2010	1.23	1.08	0.22
2011	1.22	0.97	0.26
2012	1.12	1.01	0.21
2013	0.86	0.88	0.18
2014	1.01	0.76	0.21
2015	1.43	0.88	0.19
2016	1.29	1.03	0.19
2017	1.04	1.09	0.18
2018	1.08	1.05	0.22
2019	1.35	1.03	0.20
2020	1.30	1.12	0.22
2021	0.92	1.41	0.24

Table 25. Observed (Obs) versus predicted (Exp) standardized fishery-independent indices and associated lognormal standard error (as estimated by the standardization process) for Gulf of Mexico Spanish Mackerel. Values are normalized to the mean. CVs as estimated by the standardization process were converted to log-scale SEs.

Year	SEAMAP early (Obs)	SEAMAP early (Exp)	SEAMAP early (SE)	SEAMAP late (Obs)	SEAMAP late (Exp)	SEAMAP late (SE)
1987	0.26	0.70	0.41			
1988	1.23	0.79	0.27			
1989	1.41	1.20	0.28			
1990	1.40	1.34	0.26			
1991	0.78	1.18	0.29			
1992	0.70	0.77	0.30			
1993	1.76	0.73	0.25			
1994	0.59	0.59	0.32			
1995	1.25	0.70	0.27			
1996	0.85	0.85	0.31			
1997	0.40	0.84	0.34			
1998	0.70	1.28	0.31			
1999	0.80	1.22	0.31			
2000	0.84	1.15	0.28			
2001	1.08	1.04	0.33			
2002	0.38	0.93	0.43			
2003	1.38	1.22	0.28			
2004	0.67	1.34	0.31			
2005	2.02	1.22	0.23			
2006	0.85	0.96	0.27			
2007	1.98	1.12	0.25			
2008	0.67	1.08	0.32			
2009				1.70	0.78	0.24

Table 25 Continued. Observed (Obs) versus predicted (Exp) standardized fishery-independent indices and associated lognormal standard error (as estimated by the standardization process) for Gulf of Mexico Spanish Mackerel. Values are normalized to the mean. CVs as estimated by the standardization process were converted to log-scale SEs.

Year	SEAMAP early (Obs)	SEAMAP early (Exp)	SEAMAP early (SE)	SEAMAP late (Obs)	SEAMAP late (Exp)	SEAMAP late (SE)
2010				1.89	1.12	0.29
2011				0.44	1.14	0.40
2012				0.38	0.89	0.40
2013				4.36	1.08	0.32
2014				0.15	0.91	0.60
2015				1.40	1.03	0.29
2016				0.25	1.15	0.61
2017				0.66	1.01	0.35
2018				0.31	1.13	0.47
2019				0.08	1.31	0.78
2020				0.38	1.08	0.57

Table 26. Expected (Exp) discards for the Shrimp Bycatch fleet in number (N, 1,000s of fish) and biomass (B, thousand pounds whole weight) for Gulf of Mexico Spanish Mackerel. All discards are dead discards. Mean weight (MW, whole pounds per fish) was determined by dividing the expected discards in weights by the expected discards in numbers.

Year	Exp N	Exp B	MW
1986	8,304	2,960	0.36
1987	6,372	2,285	0.36
1988	5,385	1,618	0.30
1989	11,165	2,975	0.27
1990	13,025	3,856	0.30
1991	10,167	3,278	0.32
1992	5,294	2,004	0.38
1993	4,697	1,399	0.30
1994	4,046	1,454	0.36
1995	4,226	1,191	0.28
1996	5,870	1,782	0.30
1997	5,575	1,832	0.33
1998	9,020	2,386	0.26
1999	9,166	3,108	0.34
2000	7,367	2,362	0.32
2001	6,709	2,253	0.34
2002	5,388	1,757	0.33
2003	5,693	1,562	0.27
2004	4,914	1,536	0.31
2005	2,641	915	0.35
2006	2,795	1,044	0.37
2007	3,182	933	0.29
2008	2,605	891	0.34
2009	2,378	869	0.37
2010	2,586	663	0.26
2011	2,410	817	0.34
2012	2,537	896	0.35
2013	2,369	623	0.26
2014	2,436	890	0.37

Table 26 Continued. Expected (Exp) discards for the Shrimp Bycatch fleet in number (N, 1,000s of fish) and biomass (B, thousand pounds whole weight) for Gulf of Mexico Spanish Mackerel. All discards are dead discards. Mean weight (MW, whole pounds per fish) was determined by dividing the expected discards in weights by the expected discards in numbers.

Year	Exp N	Exp B	MW
2015	2,244	629	0.28
2016	2,802	922	0.33
2017	2,485	809	0.33
2018	2,812	832	0.30
2019	2,790	817	0.29
2020	1,697	638	0.38
2021	1,634	517	0.32

Table 27. Summary of correlated parameters with correlation coefficients > 0.7 for Gulf of Mexico Spanish Mackerel from the SEDAR 81 base model.

Parameter 1	Parameter 2	Correlation
VonBert_K_Fem_GP_1	L_at_Amax_Fem_GP_1	-0.918
SD_young_Fem_GP_1	L_at_Amin_Fem_GP_1	-0.910
VonBert_K_Fem_GP_1	L_at_Amin_Fem_GP_1	-0.876
Size_DblN_descend_se_Srv_SEAMAPlate_9(9)	Size_DblN_top_logit_Srv_SEAMAPlate_9(9)	-0.867
Size_DblN_descend_se_Rec_SH_5(5)	Size_DblN_top_logit_Rec_SH_5(5)	-0.830
Size_DblN_descend_se_Byc_SHRIMP_6(6)	Size_DblN_top_logit_Byc_SHRIMP_6(6)	-0.825
Size_inflection_Rec_CB_HB_3(3)	VonBert_K_Fem_GP_1	-0.784
Size_inflection_Rec_PRIV_4(4)	VonBert_K_Fem_GP_1	-0.756
Size_inflection_Rec_PRIV_4(4)	Size_95%width_Rec_CB_HB_3(3)	0.732
InitF_seas_1_flt_1Com_GN_1	Early_InitAge_3	0.733
InitF_seas_1_flt_6Byc_SHRIMP_6	InitF_seas_1_flt_4Rec_PRIV_4	0.735
InitF_seas_1_flt_5Rec_SH_5	Early_InitAge_3	0.745
InitF_seas_1_flt_3Rec_CB_HB_3	Early_InitAge_3	0.746
InitF_seas_1_flt_2Com_HL_2	Early_InitAge_3	0.751
Size_inflection_Rec_PRIV_4(4)	L_at_Amin_Fem_GP_1	0.758
SD_young_Fem_GP_1	VonBert_K_Fem_GP_1	0.763
Size_inflection_Rec_CB_HB_3(3)	L_at_Amin_Fem_GP_1	0.763
InitF_seas_1_flt_6Byc_SHRIMP_6	Early_InitAge_3	0.768
Size_95%width_Com_HL_2(2)	Size_inflection_Com_HL_2(2)	0.770
InitF_seas_1_flt_5Rec_SH_5	InitF_seas_1_flt_3Rec_CB_HB_3	0.823
InitF_seas_1_flt_5Rec_SH_5	InitF_seas_1_flt_1Com_GN_1	0.832
InitF_seas_1_flt_5Rec_SH_5	InitF_seas_1_flt_2Com_HL_2	0.841
InitF_seas_1_flt_4Rec_PRIV_4	InitF_seas_1_flt_1Com_GN_1	0.843

Table 27 Continued. Summary of correlated parameters with correlation coefficients > 0.7 for Gulf of Mexico Spanish Mackerel from the SEDAR 81 base model.

Parameter 1	Parameter 2	Correlation
Size_95%width_Rec_PRIV_4(4)	Size_inflection_Rec_PRIV_4(4)	0.854
Size_inflection_Rec_PRIV_4(4)	Size_inflection_Rec_CB_HB_3(3)	0.862
InitF_seas_1_flt_6Byc_SHRIMP_6	InitF_seas_1_flt_3Rec_CB_HB_3	0.865
InitF_seas_1_flt_6Byc_SHRIMP_6	InitF_seas_1_flt_1Com_GN_1	0.870
InitF_seas_1_flt_6Byc_SHRIMP_6	InitF_seas_1_flt_5Rec_SH_5	0.876
InitF_seas_1_flt_6Byc_SHRIMP_6	InitF_seas_1_flt_2Com_HL_2	0.878
InitF_seas_1_flt_4Rec_PRIV_4	InitF_seas_1_flt_2Com_HL_2	0.886
Size_95%width_Rec_CB_HB_3(3)	Size_inflection_Rec_CB_HB_3(3)	0.893
InitF_seas_1_flt_2Com_HL_2	InitF_seas_1_flt_1Com_GN_1	0.901
InitF_seas_1_flt_3Rec_CB_HB_3	InitF_seas_1_flt_1Com_GN_1	0.914
Size_DblN_ascend_se_Com_GN_1(1)	Size_DblN_peak_Com_GN_1(1)	0.941
InitF_seas_1_flt_4Rec_PRIV_4	InitF_seas_1_flt_3Rec_CB_HB_3	0.943
InitF_seas_1_flt_3Rec_CB_HB_3	InitF_seas_1_flt_2Com_HL_2	0.948
Size_DblN_ascend_se_Com_GN_1(1)_BLK1repl_1995	Size_DblN_peak_Com_GN_1(1)_BLK1repl_1995	0.952
Size_DblN_ascend_se_Srv_SEAMAPlate_9(9)	Size_DblN_peak_Srv_SEAMAPlate_9(9)	0.955
Size_DblN_ascend_se_Byc_SHRIMP_6(6)	Size_DblN_peak_Byc_SHRIMP_6(6)	0.966

Table 28. Summary of key model building steps towards the SEDAR 81 Base Model for Gulf of Mexico Spanish Mackerel and associated convergence diagnostics. Note that steps within each model progression are not shown due to the vast number of intermediate runs conducted.

Model Name	Description	NLL	Gradient	Bounded Parms
2_S28converted	Step 1 + converted to v 3 30 21	5,028	3.34e+01	0
3_2+FES	Step 2 + replace REC catches and discards with FES no change to CVs, end year	5,085	3e-04	0
4_3+CorrectMat	Step 3 + Correct maturity error in S28	5,120	2e-04	1
5_4+CorrectBlock	Step 4 + Correct size limit time block from 93 to 83 error in S28	4,939	2e-04	0
6_5+Fleet structure	Step 5 + 1950 start year, end year 2021, fleet structure changes, all new data added catches, discards, indices, length comps, age comps CAAL	8,058	2.9e-03	1
7_6+ShoreSel	Step 6 + separate shore selectivity, adjust recruitment deviation settings	7,498	1.1e-03	0
8_7+1986Start	Step 7 + 1986 start year	7,216	5.22e-02	1
9_8+M	Step 8 + Internal Lorenzen M and May 1 spawning settlement	7,334	1.5e-03	0
10_9+NoSuperLen	Step 9 + No super period of REC discard lengths, estimate width asymptote inflection for retention function, max population length 84, HL logistic	7,375	2.2e-03	1
11_10+Finit	Step 10 + fix shrimp initial F to .05, use rescaled CVs for VL index, estimate HL selectivity	7,326	1e-03	2
12_11+SEAMAPsplit	Step 11 + split the two SEAMAP series	7,329	3.7e-03	1
13_12+Selex	Step 12 + selectivity adjustments	7,263	5e-04	2
14_13+Dirichlet	Step 13 + Dirichlet	16,174	1.36e-02	9
15_14+InitCat	Step 14 + adjust initial catch based on results from likelihood profile and turn off estimation of Dirichlet parameters on bounds	16,113	1.31e-02	0
16_15+RecDev	Step 15 + Recruitment deviation adjustment	16,115	2.38e-02	0

Table 29. Summary of key model building steps towards the SEDAR 81 Base Model for Gulf of Mexico Spanish Mackerel and associated key estimates and derived quantities (note that steepness and sigmaR were fixed at 0.8 and 0.7, respectively, across all runs). Steps within each model progression are not shown due to the vast number of intermediate runs conducted.

Model Name	Ln(R0)	Target M	Virgin SSB (mt)	Virgin Recr (1000s)	Depletion Start Yr	Depletion End Yr
2_S28converted	10.78	0.38	41,806	47,985	1.00	0.47
3_2+FES	10.89	0.38	46,453	53,740	1.00	0.33
4_3+CorrectMat	10.83	0.38	54,099	50,449	1.00	0.30
5_4+CorrectBlock	10.84	0.38	55,925	51,093	1.00	0.35
6_5+Fleet structure	11.12	0.38	68,486	67,418	0.91	0.23
7_6+ShoreSel	11.18	0.38	68,132	71,405	0.92	0.13
8_7+1986Start	11.13	0.38	64,551	68,131	0.10	0.14
9_8+M	11.55	0.38	55,018	103,745	0.11	0.17
10_9+NoSuperLen	11.48	0.38	53,689	97,148	0.12	0.18
11_10+Finit	11.47	0.38	52,345	95,675	0.14	0.18
12_11+SEAMAPsplit	11.50	0.38	53,169	98,468	0.14	0.19
13_12+Selex	11.52	0.38	54,544	101,204	0.13	0.20
14_13+Dirichlet	11.53	0.38	54,655	101,231	0.13	0.20
15_14+InitCat	11.56	0.38	55,975	104,498	0.11	0.21
16_15+RecDev	11.56	0.38	55,928	104,409	0.11	0.21

Table 30. Settings used for Gulf of Mexico Spanish Mackerel projections.

Parameter	Value	Comment
Relative F	Average from 2019 - 2021	Average relative fishing mortality (apical F) over terminal three years of model
Selectivity	Average from 2019 - 2021	Fleet specific selectivity estimated in the terminal year of the model
Retention	Average from 2019 - 2021	Fleet specific retention estimated in the terminal year of the model
Recruitment	Beverton-Holt stock-recruitment relationship	Derived from the Beverton-Holt stock-recruitment relationship
Interim Landings (2022-2024)	148.51/173.55/173.55 mt (Comm. GN) 14.12/23.23/23.23 mt (Comm. HL) 175.77/200.56/200.56 thousands of fish (HB/CB) 1245.29/1576.32/1576.32 thousands of fish (PR) 3025.09/2500.46/2500.46 thousands of fish (SH)	Final landings estimates provided for 2022; For 2023-2024, used 3-year average of landings (2020-2022)
Shrimp bycatch F	0.06	Average F over 2015-2019
Allocation Ratio	None	

Table 31. Summary of Magnuson-Stevens Reauthorization Act benchmarks and reference points for the SEDAR 81 Gulf of Mexico Spanish Mackerel assessment. Spawning Stock Biomass (SSB) is in metric tons, whereas F is a harvest rate (total biomass killed / total biomass age 1+).

Criteria	Definition	Value
Base M	Target M for fully selected ages in the Lorenzen (2005) scaling	0.38
Steepness	Steepness of the Beverton-Holt stock-recruit relationship (fixed)	0.80
R0	Virgin Recruitment (1000s)	104,409
Generation Time	Fecundity-weighted mean age	5
SSB0	Virgin spawning stock biomass (mt)	55,928
	Mortality Rate Criteria	
$F_{MSYproxy}$	$F_{30\%SPR}$	0.38
MFMT	$F_{MSYproxy}$	0.38
$F_{current}$	Geometric mean of the last 3 years of the assessment ($F_{2019-2021}$), including shrimp bycatch fleet	0.36
$F_{current}$/MFMT	Current stock status based on MFMT	0.93
	Biomass Criteria	
$SSB_{MSYproxy}$	Equilibrium SSB at $F_{30\%SPR}$	14,168
MSST	(1-M)* $SSB_{MSYproxy}$	8,754
$SSB_{current}$	SSB_{2021}	11,734
$SSB_{current}/SSB_{FMSY}$	Current stock status based on $SSB_{F30\%SPR}$	0.83
$SSB_{current}$/MSST	Current stock status based on MSST	1.34
$SSB_{current}$/SSB0	SSB ratio in 2021	0.21

Table 32. Time series of fishing mortality and SSB relative to associated biological reference points. SSB is in metric tons, whereas F is a harvest rate (total biomass killed / total biomass age 1+). Reference points include $F_{30\%SPR}$ = 0.384, $SSB_{F30\%SPR}$ = 14,168 metric tons, and MSST = 8,753 metric tons which was calculated as (1-M)*$SSB_{F30\%SPR}$. SSB ratio was calculated as annual SSB divided by SSB_0 where SSB_0 = 55,927 metric tons. Red indicates overfishing and/or overfished states.

Year	F	F/FMSY	SSB	SSB/ SSBFMSY	SSB/MSST	SSB/SSB0
1986	0.731	1.905	6,125	0.432	0.700	0.110
1987	0.406	1.058	6,516	0.460	0.744	0.117
1988	0.378	0.985	7,043	0.497	0.805	0.126
1989	0.414	1.079	7,147	0.504	0.817	0.128
1990	0.614	1.600	8,035	0.567	0.918	0.144
1991	0.584	1.522	8,247	0.582	0.942	0.147
1992	0.586	1.527	8,362	0.590	0.955	0.150
1993	0.532	1.386	7,222	0.510	0.825	0.129
1994	0.518	1.350	6,046	0.427	0.691	0.108
1995	0.365	0.951	5,465	0.386	0.624	0.098
1996	0.305	0.795	5,695	0.402	0.651	0.102
1997	0.311	0.810	6,927	0.489	0.791	0.124
1998	0.291	0.758	7,929	0.560	0.906	0.142
1999	0.417	1.087	9,469	0.668	1.082	0.169
2000	0.360	0.938	10,464	0.739	1.195	0.187
2001	0.416	1.084	10,879	0.768	1.243	0.195
2002	0.439	1.144	10,267	0.725	1.173	0.184
2003	0.438	1.141	9,110	0.643	1.041	0.163
2004	0.445	1.160	8,970	0.633	1.025	0.160
2005	0.316	0.824	10,071	0.711	1.151	0.180
2006	0.373	0.972	11,931	0.842	1.363	0.213
2007	0.357	0.930	11,484	0.811	1.312	0.205
2008	0.383	0.998	10,784	0.761	1.232	0.193
2009	0.429	1.118	10,759	0.759	1.229	0.192
2010	0.492	1.282	9,577	0.676	1.094	0.171
2011	0.478	1.246	8,581	0.606	0.980	0.153
2012	0.453	1.181	9,644	0.681	1.102	0.172

Table 32 Continued. Time series of fishing mortality and SSB relative to associated biological reference points. SSB is in metric tons, whereas F is a harvest rate (total biomass killed / total biomass age 1+). Reference points include $F_{30\%SPR}$ = 0.384, $SSB_{F30\%SPR}$ = 14,168 metric tons, and MSST = 8,753 metric tons which was calculated as (1-M)*$SSB_{F30\%SPR}$. SSB ratio was calculated as annual SSB divided by SSB_0 where SSB_0 = 55,927 metric tons. Red indicates overfishing and/or overfished states.

Year	F	F/FMSY	SSB	SSB/ SSBFMSY	SSB/MSST	SSB/SSB0
2013	0.720	1.876	9,395	0.663	1.073	0.168
2014	0.469	1.222	6,868	0.485	0.785	0.123
2015	0.407	1.061	8,132	0.574	0.929	0.145
2016	0.336	0.876	8,671	0.612	0.991	0.155
2017	0.545	1.420	10,638	0.751	1.215	0.190
2018	0.436	1.136	9,226	0.651	1.054	0.165
2019	0.540	1.407	9,563	0.675	1.092	0.171
2020	0.332	0.865	9,713	0.686	1.110	0.174
2021	0.252	0.657	11,734	0.828	1.341	0.210

Table 33. OFL projection results ($F=F_{30\%SPR}$) for Gulf of Mexico Spanish Mackerel. Recruitment (R) is in 1000s of age-0 fish, SSB is in metric tons (mt), F is a harvest rate (total biomass killed / total biomass age 1+), and OFL is the overfishing limit in millions of pounds whole weight. Reference points include $F_{30\%SPR}$ = 0.384, $SSB_{F30\%SPR}$ = 14,168 mt, and MSST = 8,753 mt which was calculated as $(1-M)*SSB_{F30\%SPR}$. SSB ratio was calculated as annual SSB divided by SSB0. 1st year of management shown in bold.

Year	R	F	F/FMSY	SSB	SSB/ SSBFMSY	SSB/ MSST	SSB/SSB0	OFL
2022	86,494	0.271	0.71	12,964	0.915	1.481	0.232	7.131
2023	88,258	0.240	0.62	14,238	1.005	1.626	0.255	7.069
2024	90,542	0.216	0.56	16,208	1.144	1.852	0.290	7.157
2025	92,472	0.384	1.00	18,244	1.288	2.084	0.326	14.980
2026	91,102	0.384	1.00	16,759	1.183	1.914	0.300	13.732
2027	90,031	0.384	1.00	15,731	1.110	1.797	0.281	12.915
2028	89,339	0.384	1.00	15,120	1.067	1.727	0.270	12.429
2029	88,905	0.384	1.00	14,756	1.041	1.686	0.264	12.137

Table 34. ABC projection results (F=75%$F_{30\%SPR}$) for Gulf of Mexico Spanish Mackerel. Recruitment (R) is in 1000s of age-0 fish, SSB is in metric tons (mt), F is a harvest rate (total biomass killed / total biomass age 1+), and retained optimum yield (OY) in millions of pounds whole weight. Reference points include $F_{30\%SPR}$ = 0.384, $SSB_{F30\%SPR}$ = 14,168 mt, and MSST = 8,753 mt which was calculated as (1-M)*$SSB_{F30\%SPR}$. SSB ratio was calculated as annual SSB divided by SSB0. 1st year of management shown in bold.

Year	R	F	F/FMSY	SSB	SSB/ SSBFMSY	SSB/ MSST	SSB/SSB0	OY
2022	86,494	0.271	0.71	12,964	0.915	1.481	0.232	7.131
2023	88,257	0.240	0.62	14,238	1.005	1.627	0.255	7.069
2024	90,541	0.216	0.56	16,208	1.144	1.852	0.290	7.157
2025	92,471	0.288	0.75	18,244	1.288	2.084	0.326	11.004
2026	91,101	0.288	0.75	18,483	1.305	2.111	0.330	11.128
2027	90,031	0.288	0.75	18,561	1.310	2.120	0.332	11.175
2028	89,338	0.288	0.75	18,603	1.313	2.125	0.333	11.201
2029	88,905	0.288	0.75	18,629	1.315	2.128	0.333	11.217

Table 35. Catch equivalency table describing the OFL recommendations which would have resulted had MRIP-FES data been used in SEDAR 28. Though stochastic projections were used as the basis for management advice (column 2), deterministic projections (column 3 and 4) are used for this exercise. The percent differences in annual OFL between the CHTS-based projections and FES-based projections are shown in column 5.

Year	SEDAR 28 CHTS OFL (stochastic)	SEDAR 28 CHTS OFL (deterministic)	SEDAR 28 FES OFL (deterministic)	% Difference OFL CHTS vs. FES (deterministic)
2013	14,396,226	13,340,707	15,980,894	20
2014	12,897,078	12,086,476	14,772,100	22
2015	12,059,320	11,311,376	14,433,537	28
2016	11,530,209	10,831,056	14,313,782	32
2017	11,133,375	10,522,276	14,240,611	35
2018	10,824,727	10,319,782	14,188,582	37
2019	10,670,403	10,183,294	14,151,632	39

11. Figures

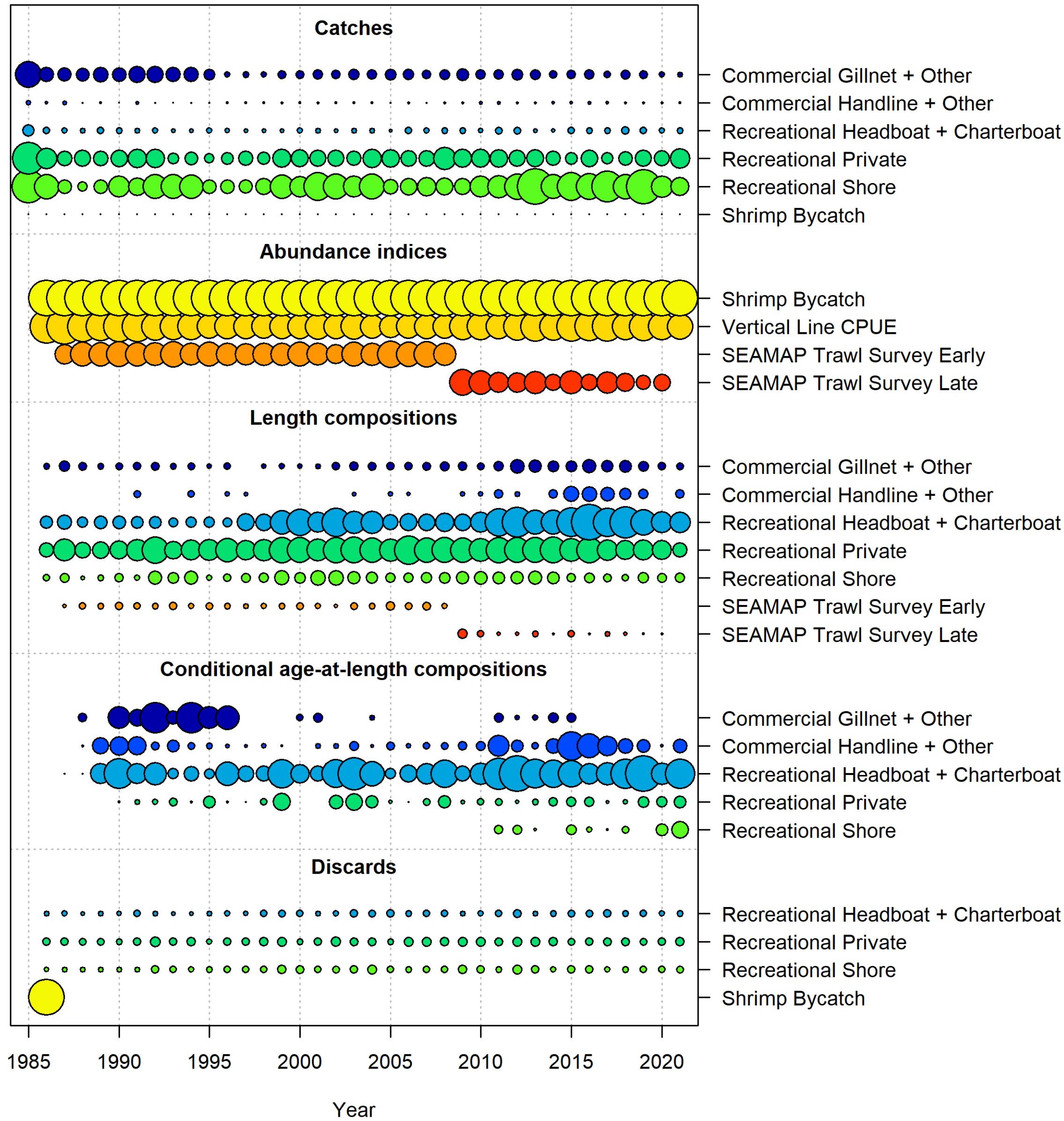


Figure 1. Data sources used in the Gulf of Mexico Spanish Mackerel Stock Synthesis assessment model. Circle area is relative within a data type. Circles are proportional to total catch for catches; to precision for indices, discards, and mean body weight observations; and to total sample size for compositions and mean weight- or 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.

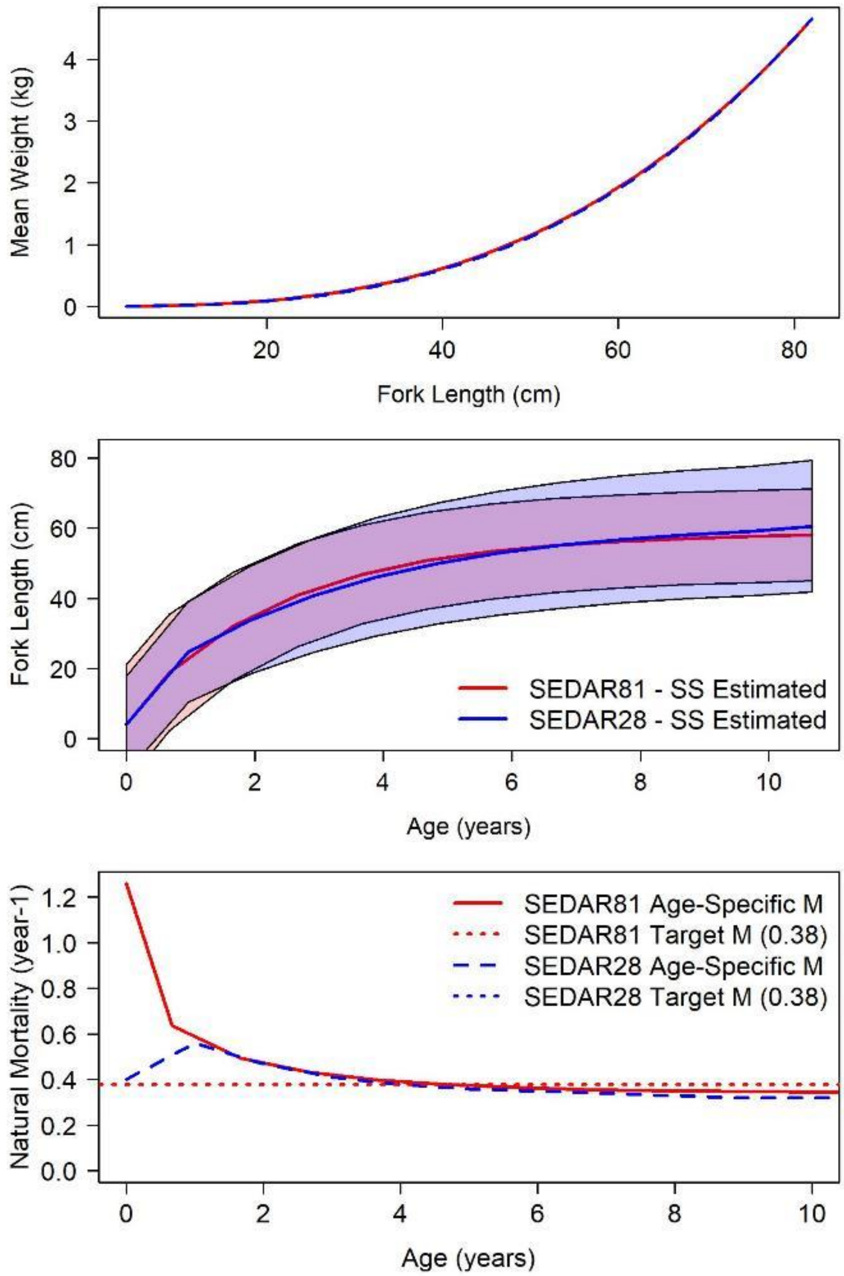


Figure 2. Mean weight-at-length (top panel), growth curves (with 95% confidence intervals; middle panel), and natural mortality (bottom panel) used in the assessment model for Gulf of Mexico Spanish Mackerel. SEDAR 28 and SEDAR 81 inputs are presented for comparison. Note: M at age 0 values are not comparable between models given differing definitions for fish settlement timing.

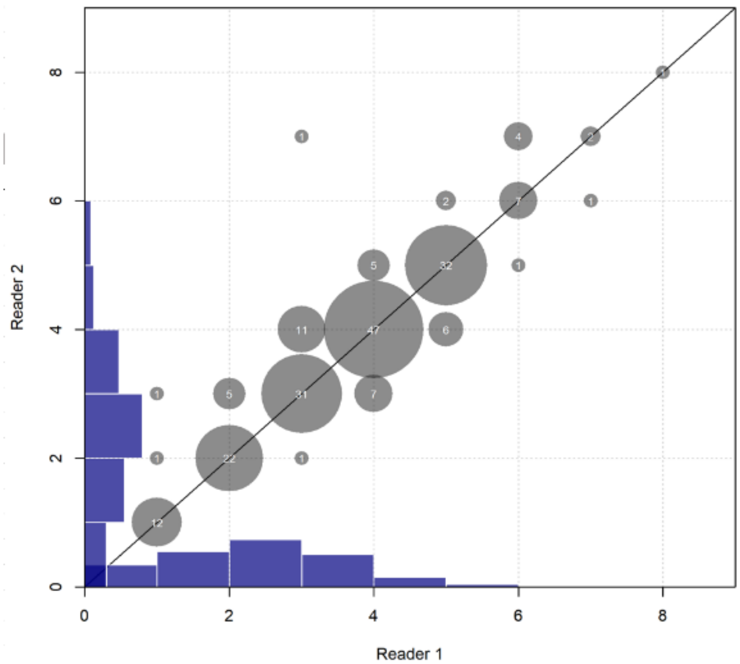


Figure 3. Results from the double-blind reads of the 200 otoliths used to develop the ageing error matrix. Reader 1 and Reader 2 are the same reader performing the blind readings at two separate times. Numbers inside bubbles show otolith sample sizes with the histograms showing the distribution of estimated ages. Bubbles along the 1:1 line indicate identical readings.

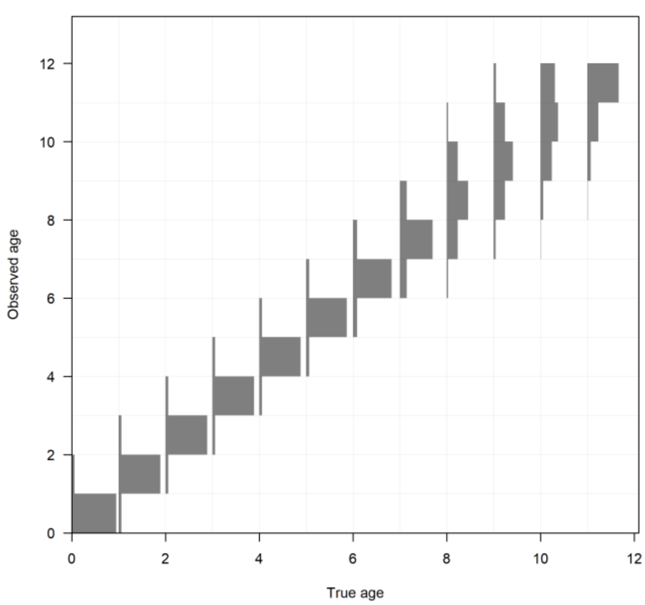


Figure 4. Distribution of observed age at true age for the ageing error matrix used for all ages input in SEDAR 81.

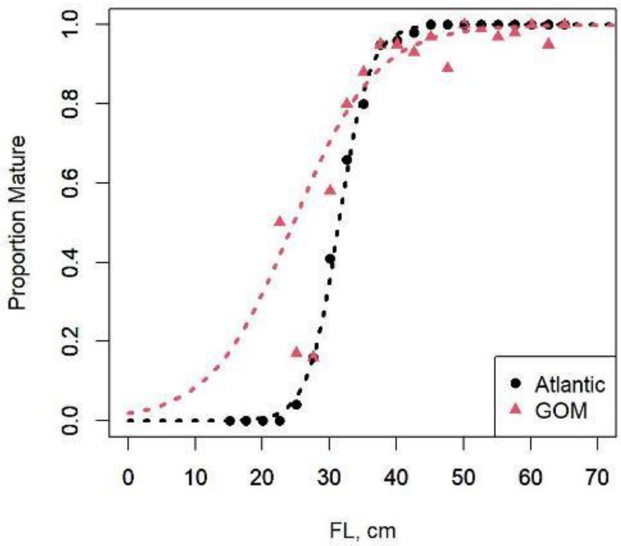


Figure 5. Fitted logistic regressions for proportion of female Spanish Mackerel mature by fork length for each region. The Atlantic curve was used in SEDAR 81 as recommended by the SEDAR 28 data workshop.

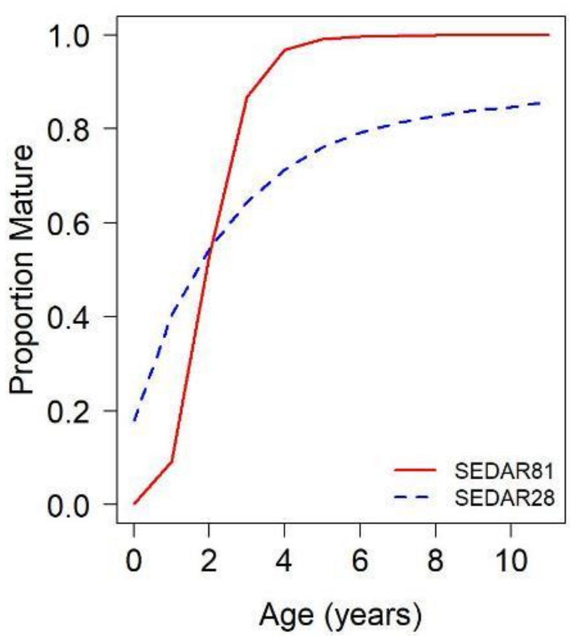


Figure 6. Maturity functions used in SEDAR 81 and SEDAR 28 for Gulf of Mexico Spanish Mackerel. Note: the maturity function input for SEDAR 28 contained an error which was corrected during SEDAR 81.

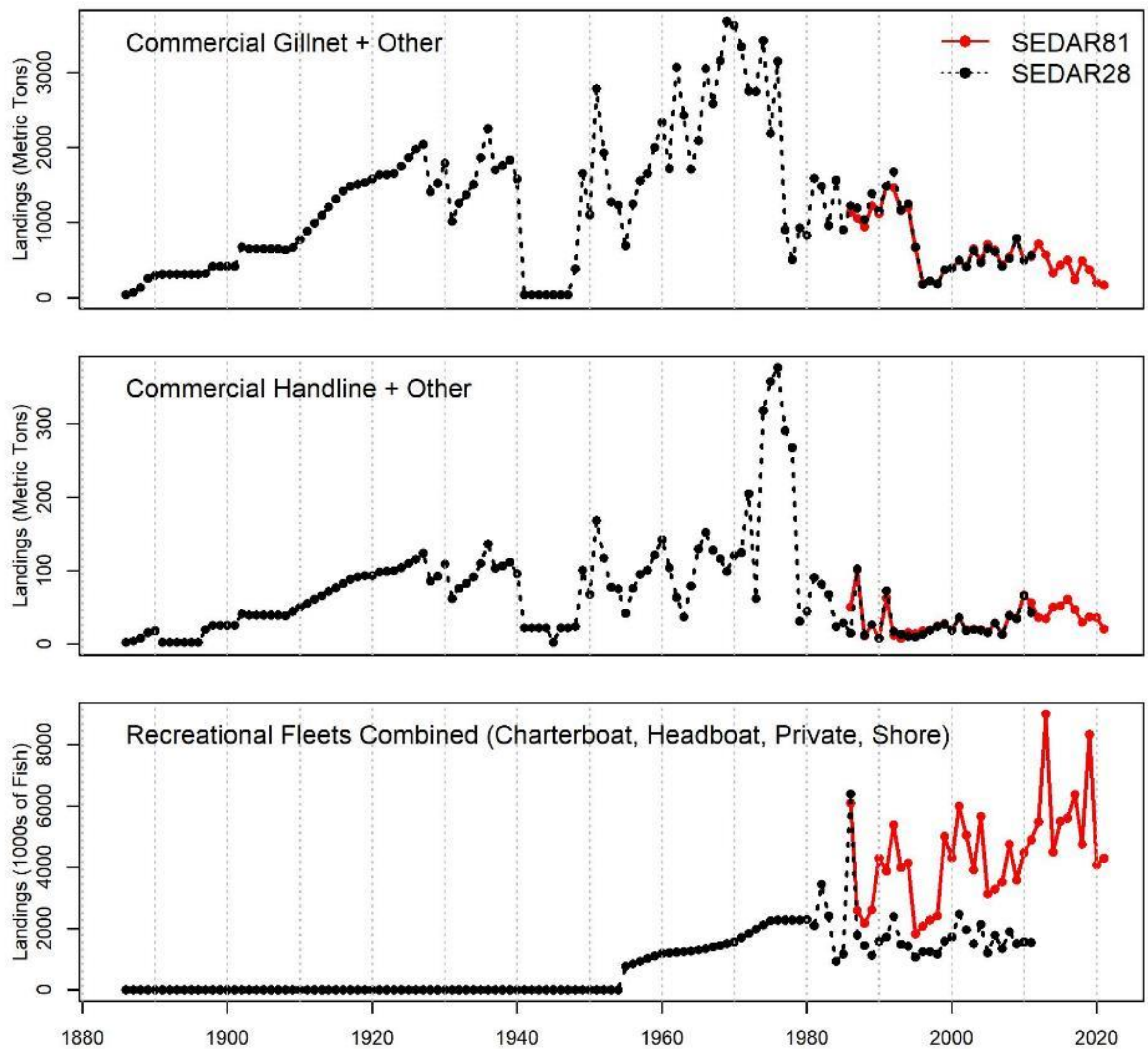


Figure 7. Gulf of Mexico Spanish Mackerel observed landings by fleet for SEDAR 81 and SEDAR 28. Commercial and recreational landings are in metric tons and numbers of fish, respectively. Note: 1. In SEDAR 81, the Commercial Handline + Other fleet landings was modelled (and is plotted here) in terms of total catch, i.e. landings + dead discards. 2. In SEDAR 81, recreational fleets were modelled as 3 separate fleets but are plotted here as an aggregate fleet for comparison with SEDAR 28. 3. The scale of the recreational landings is not directly comparable given the different currencies (SEDAR 28: CHTS; SEDAR 81: FES).

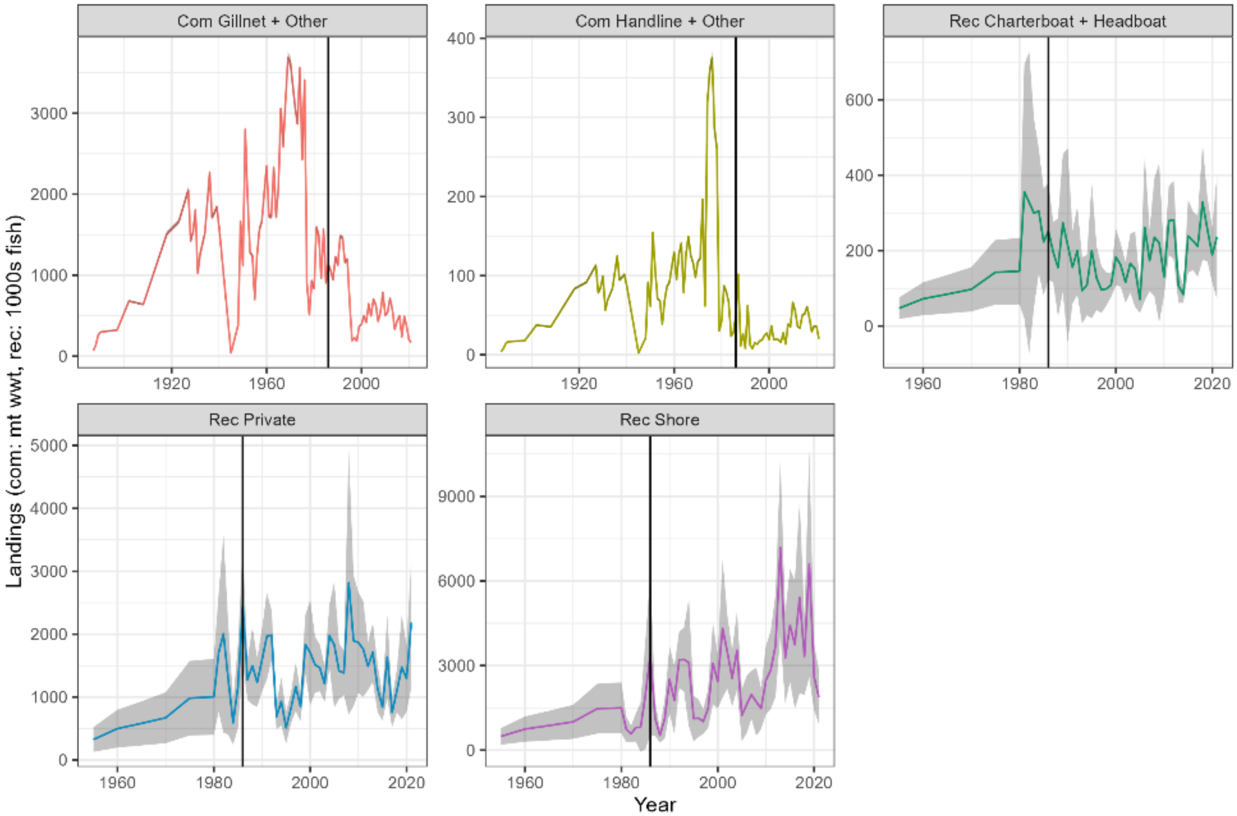


Figure 8. Full time series of landings data available with 95% CI (shaded area) for each fleet. Data to the right of the black vertical line (1986) reflect data used in the SEDAR 81 assessment model.

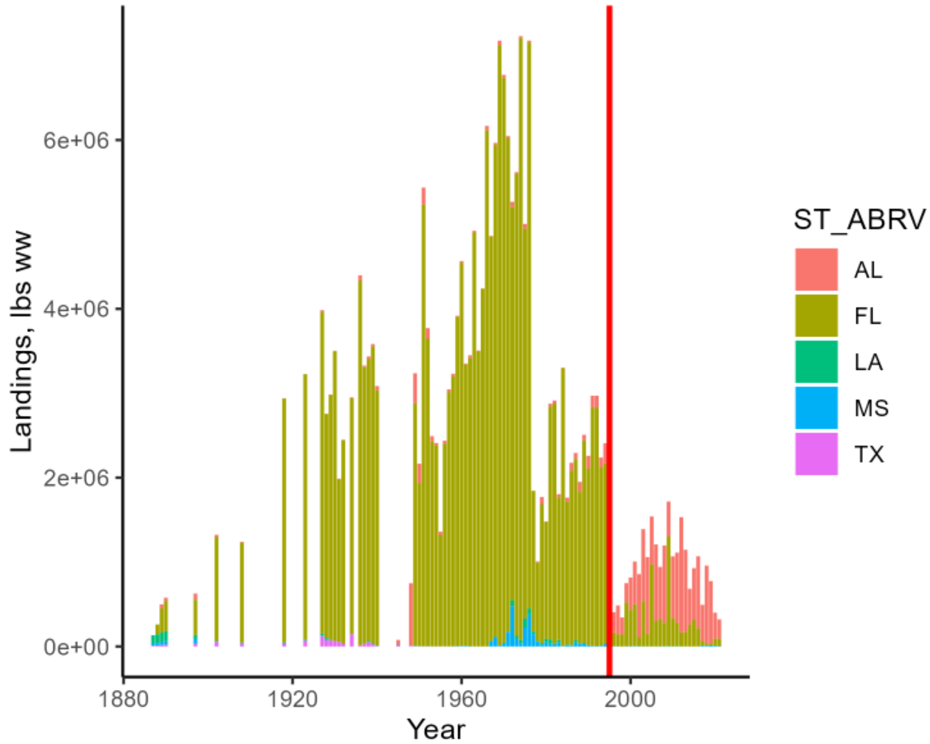


Figure 9. Annual gillnet landings by state. The shift in catches from FL to AL after the 1995 FL GN ban (red line) is evident.

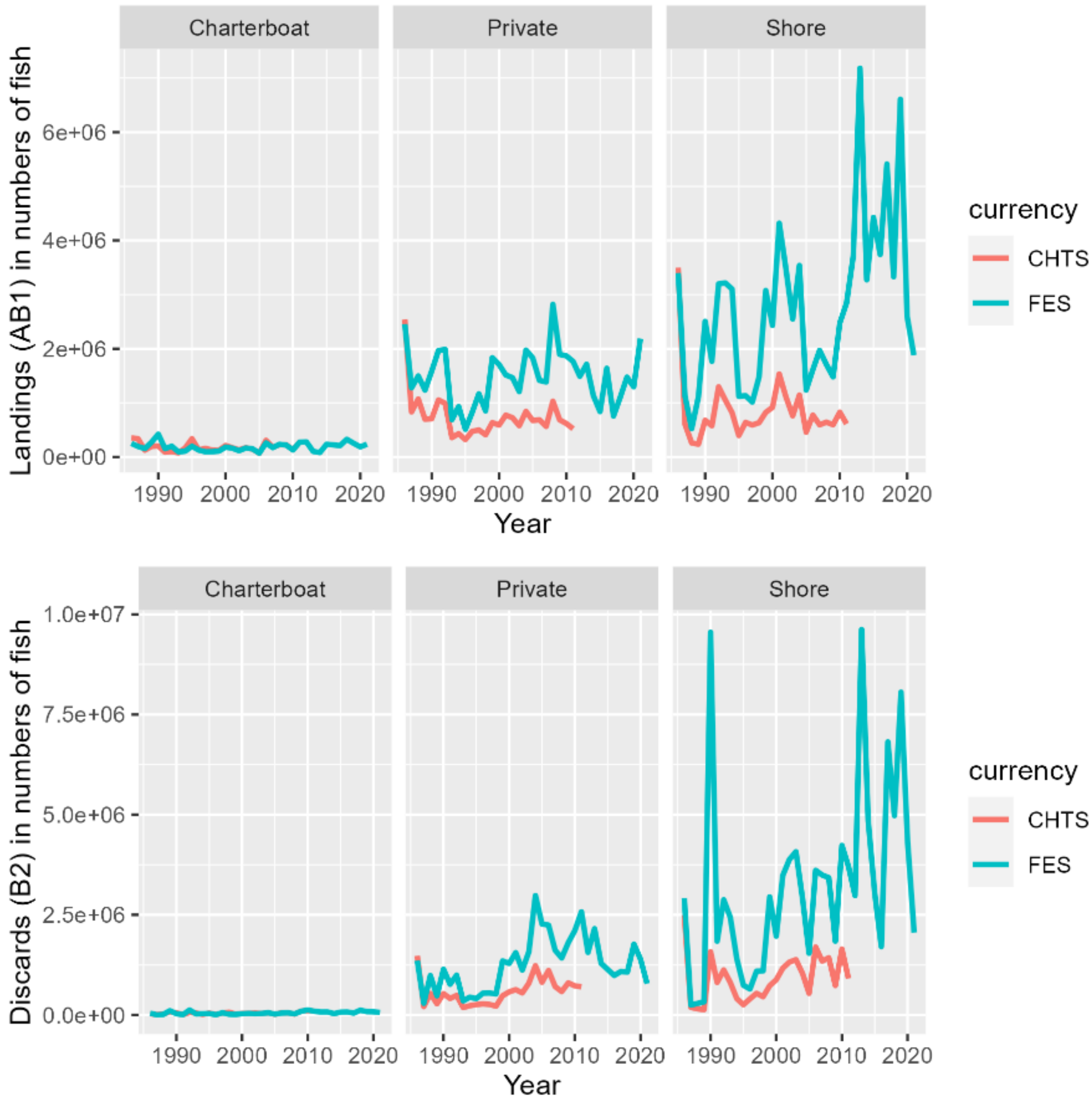


Figure 10. Differences in recreational landings and discards between CHTS (used in SEDAR 28) and FES (used in SEDAR 81) based estimates.

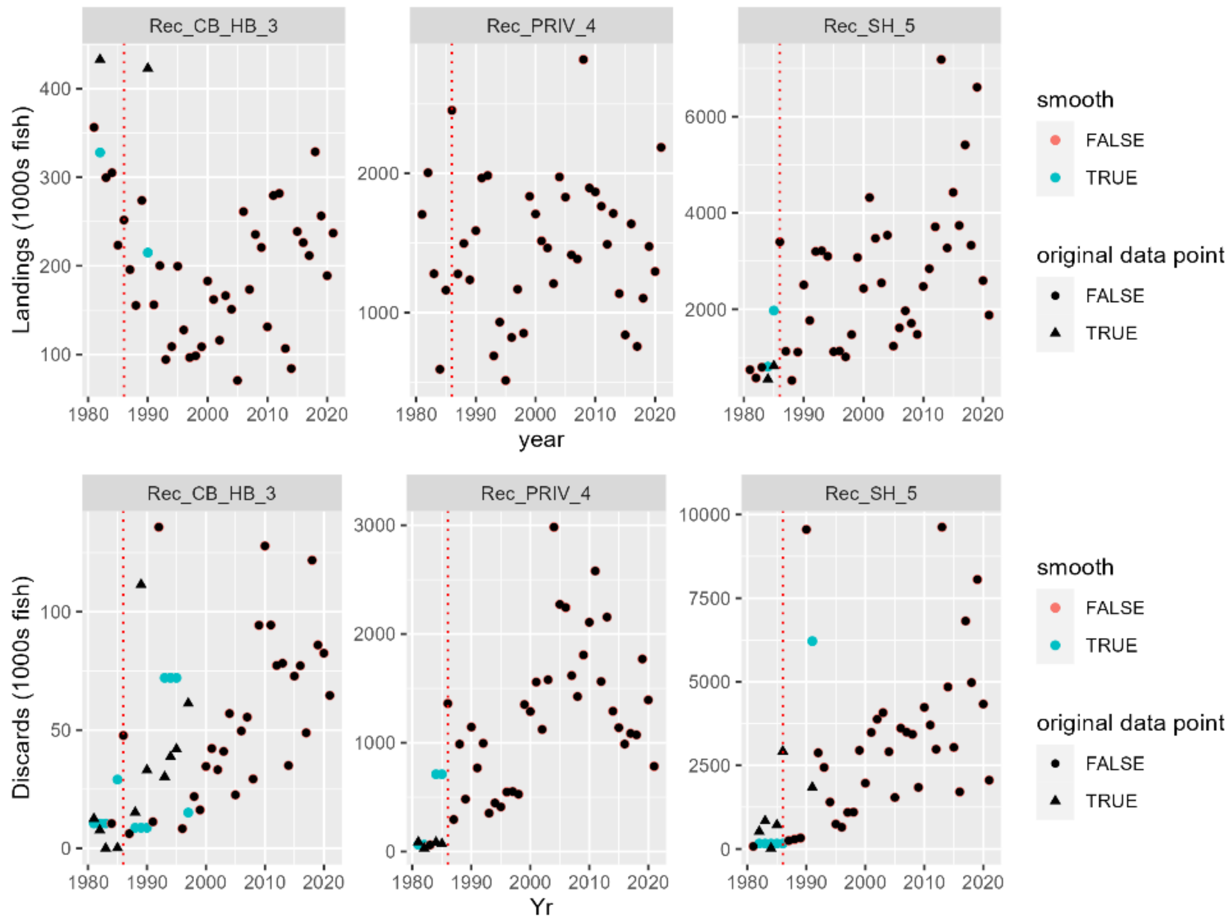


Figure 11. Smoothing process for the recreational landings (top) and discards (bottom) used in the assessment. Any annual value with CV≥0.5 was replaced by the average of the two closest years' values. For smoothed out years, original values are shown as black triangles and new values used in their place are shown in teal circles. The start year of the assessment 1986 is shown as a red dotted line.

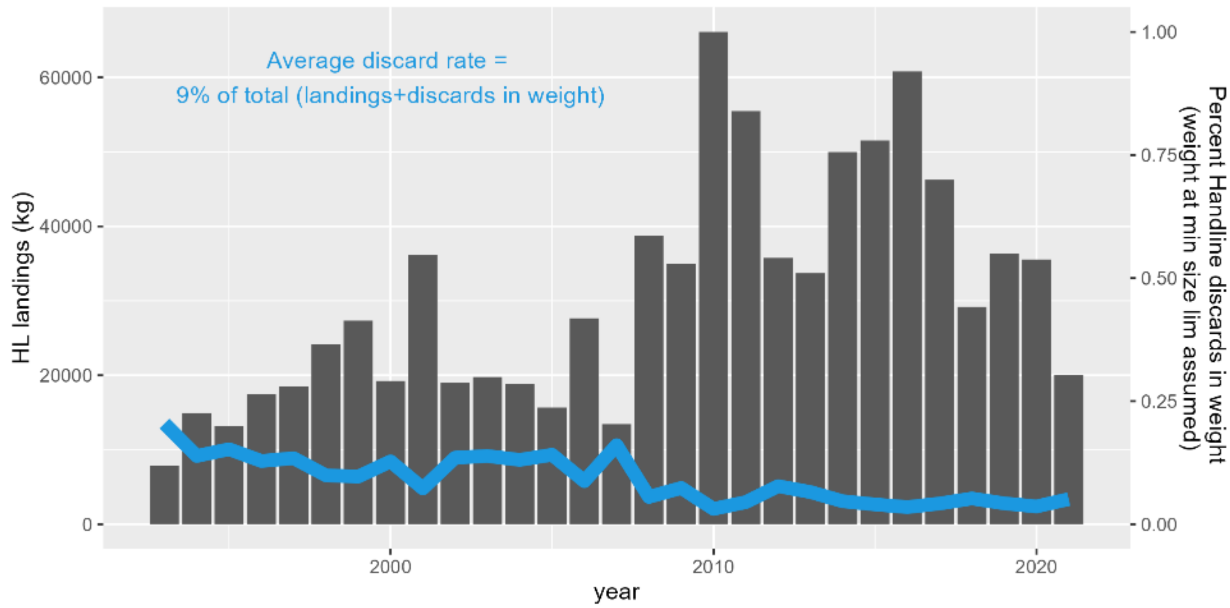


Figure 12. Annual proportions of handline discards in weight (blue line) as a function of total catches (landings + discards). The average discard rate (in weight) is 9% across the entire time series.

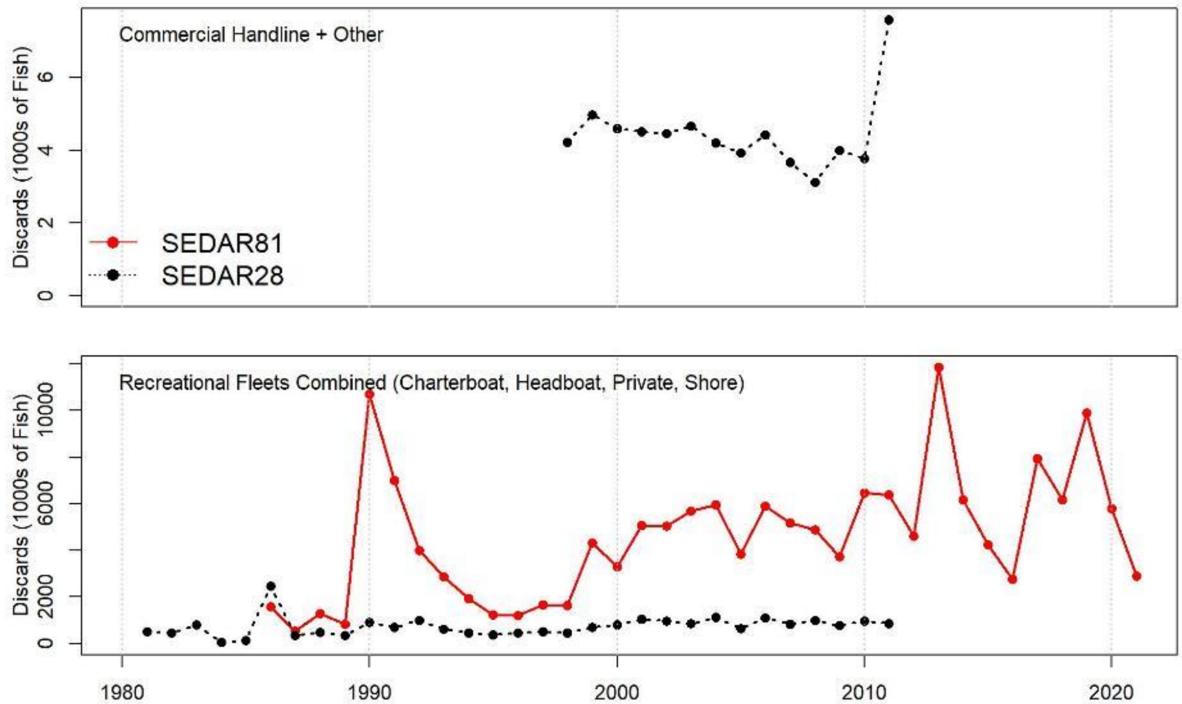


Figure 13. Gulf of Mexico Spanish Mackerel observed discards by fleet for SEDAR 81 and SEDAR 28. Commercial and recreational discards are both in numbers of fish. Note: 1. In SEDAR 81, the Commercial Handline + Other fleet discards were added to the landings and are not plotted here. 2. In SEDAR 81, recreational fleets were modelled as 3 separate fleets but are plotted here as an aggregate fleet for comparison with SEDAR 28. 3. The scale of the recreational discards is not directly comparable given the different currencies (SEDAR 28: CHTS; SEDAR 81: FES).

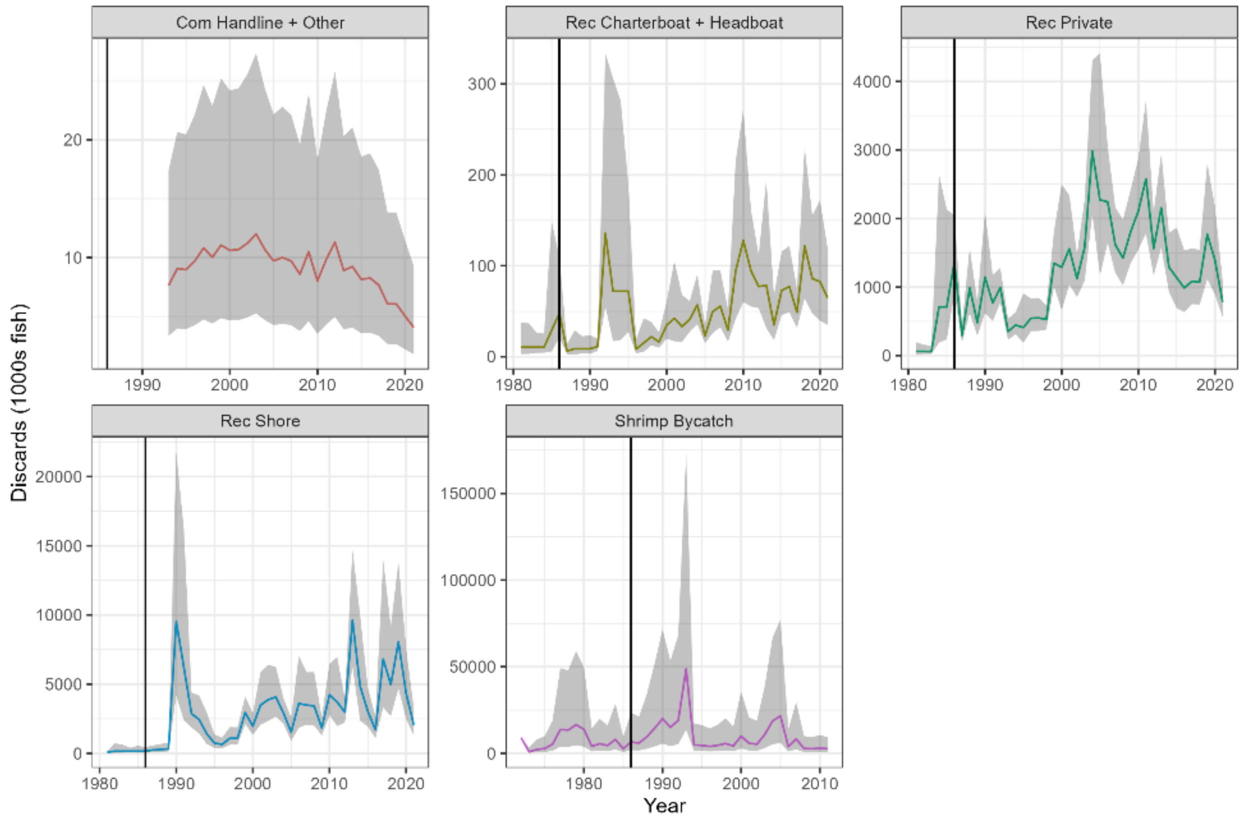


Figure 14. Full time series of discard data available with 95% CI (shaded area) for each fleet. Data to the right of the black vertical line (1986) reflect data used in the SEDAR 81 assessment model.

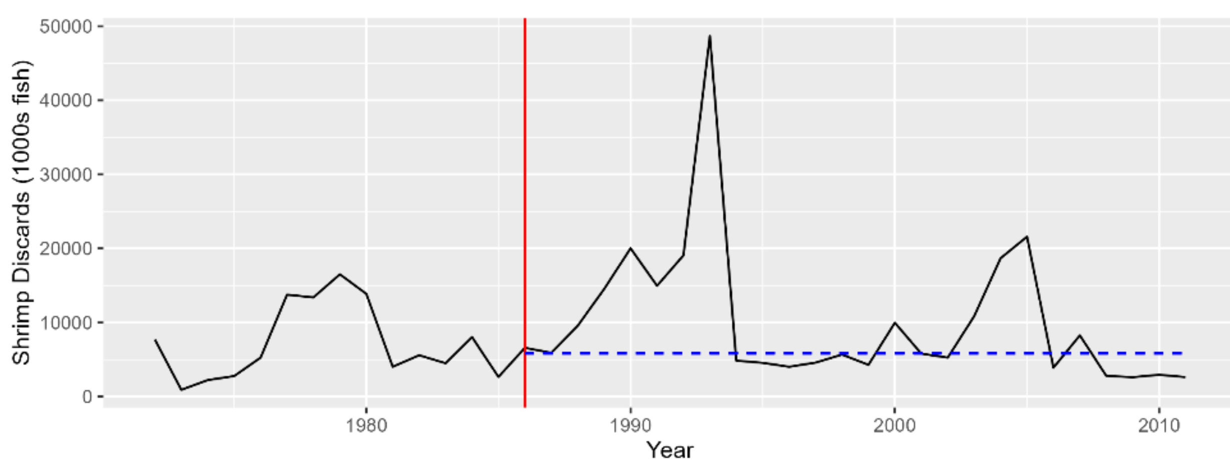


Figure 15. Time series of available Gulf of Mexico Spanish Mackerel discard estimates from the shrimp bycatch fleet. The truncated time series from 1986 (red solid line) to 2011 was used for SEDAR 81 with its median value (dashed blue line; 5854 thousand fish) input into SS as a super period.

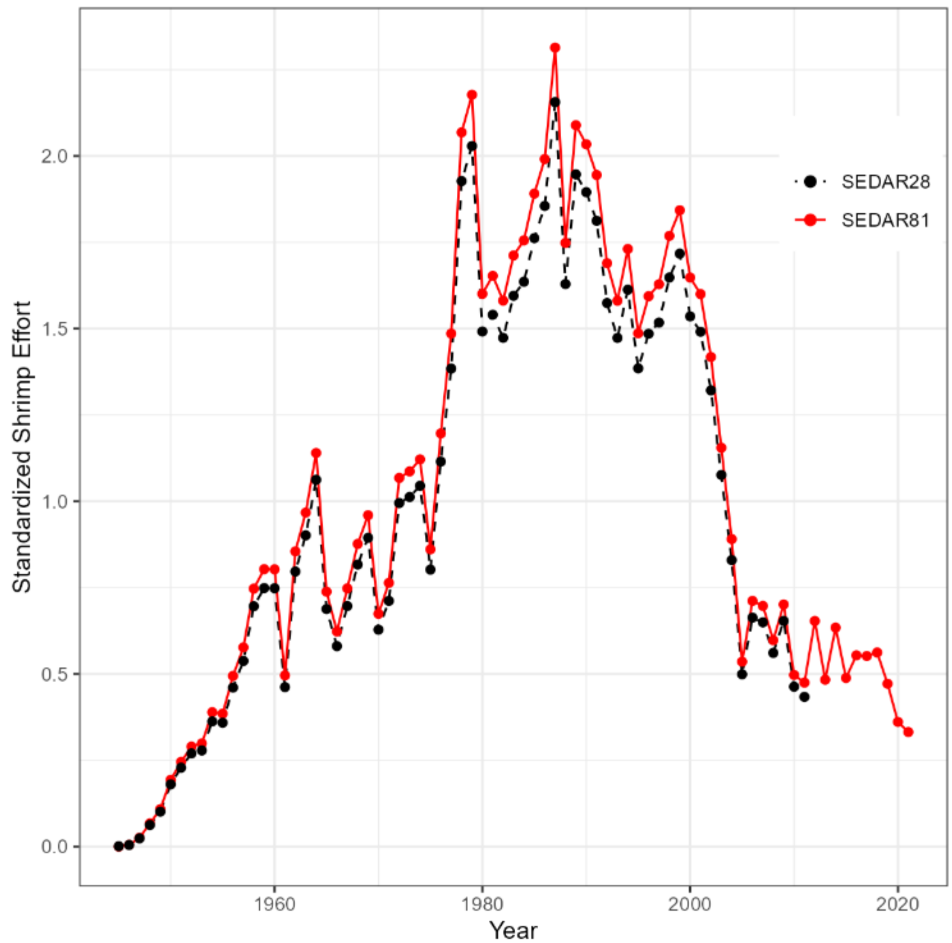


Figure 16. Comparison of the shrimp effort time series made available for Gulf of Mexico Spanish Mackerel in SEDAR 81 and SEDAR 28. Both time series have been scaled to a mean of 1. The truncated time series from 1986 to 2021 was scaled to a mean of 1 and input in the SEDAR 81 assessment model.

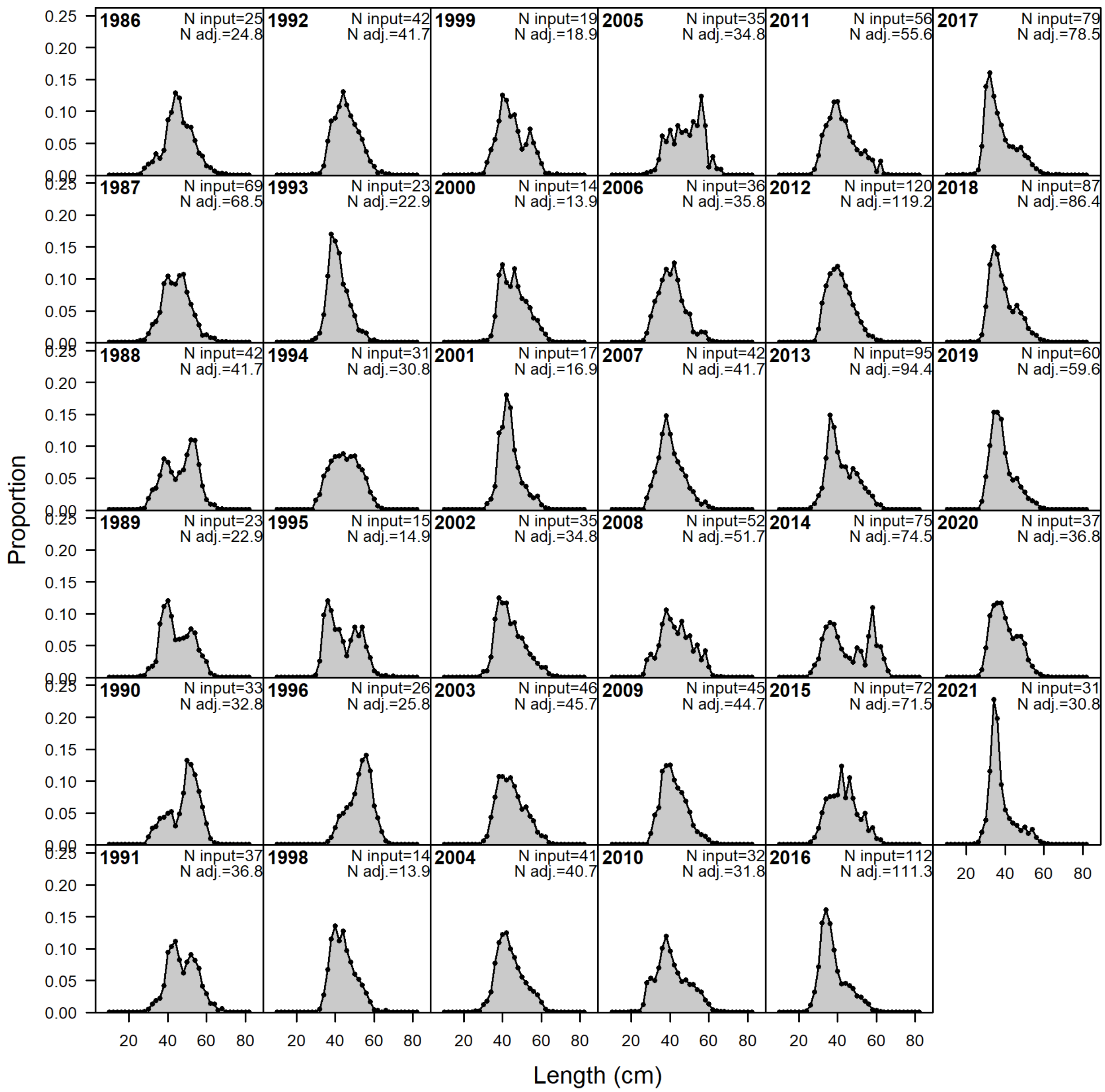


Figure 17. Observed length composition data (retained) of Gulf of Mexico Spanish Mackerel in the Commercial Gillnet + Other fleet.

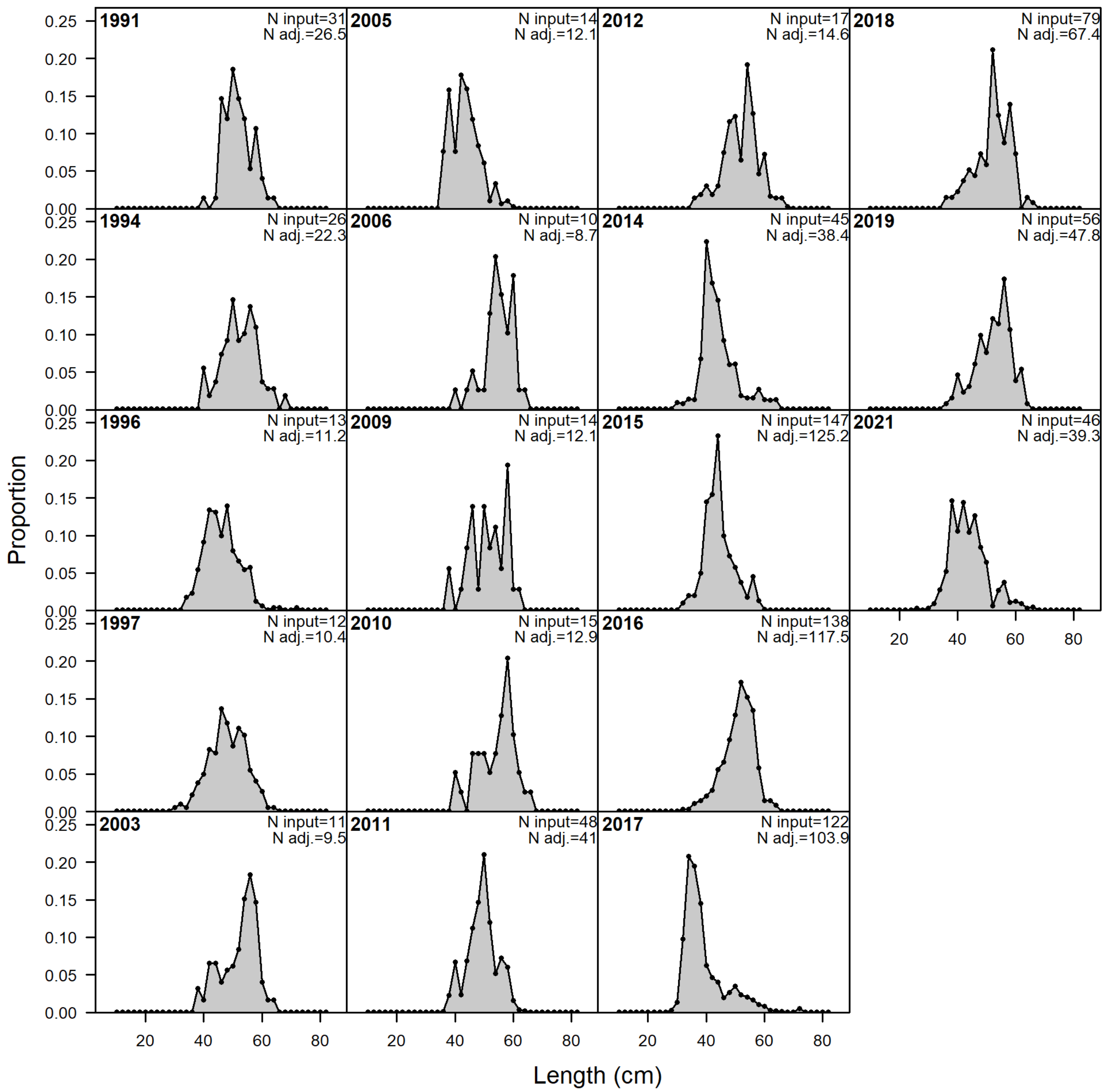


Figure 18. Observed length composition data (retained) of Gulf of Mexico Spanish Mackerel in the Commercial Handline + Other fleet.

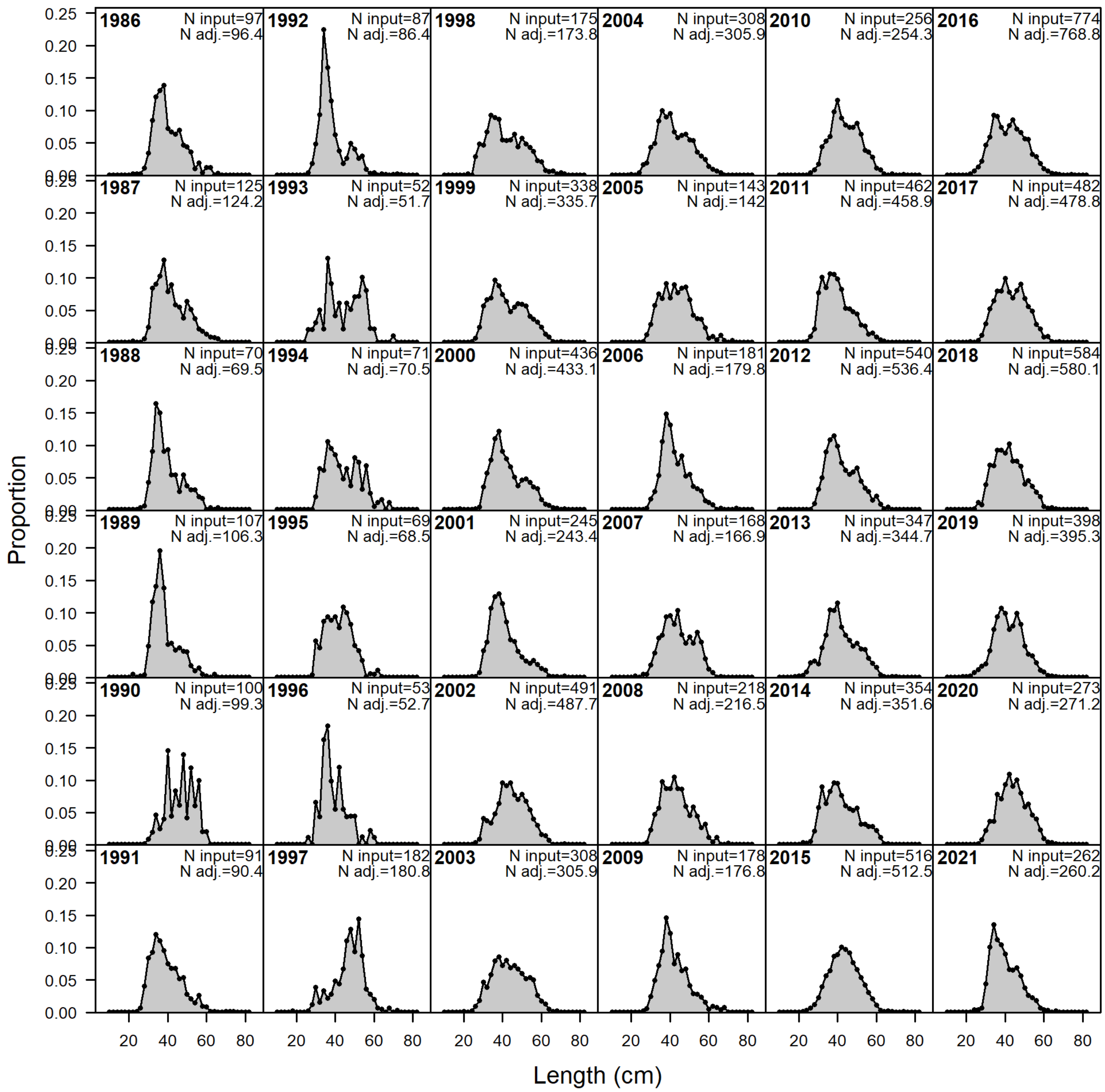


Figure 19. Observed length composition data (retained) of Gulf of Mexico Spanish Mackerel in the Recreational Headboat + Charterboat fleet.

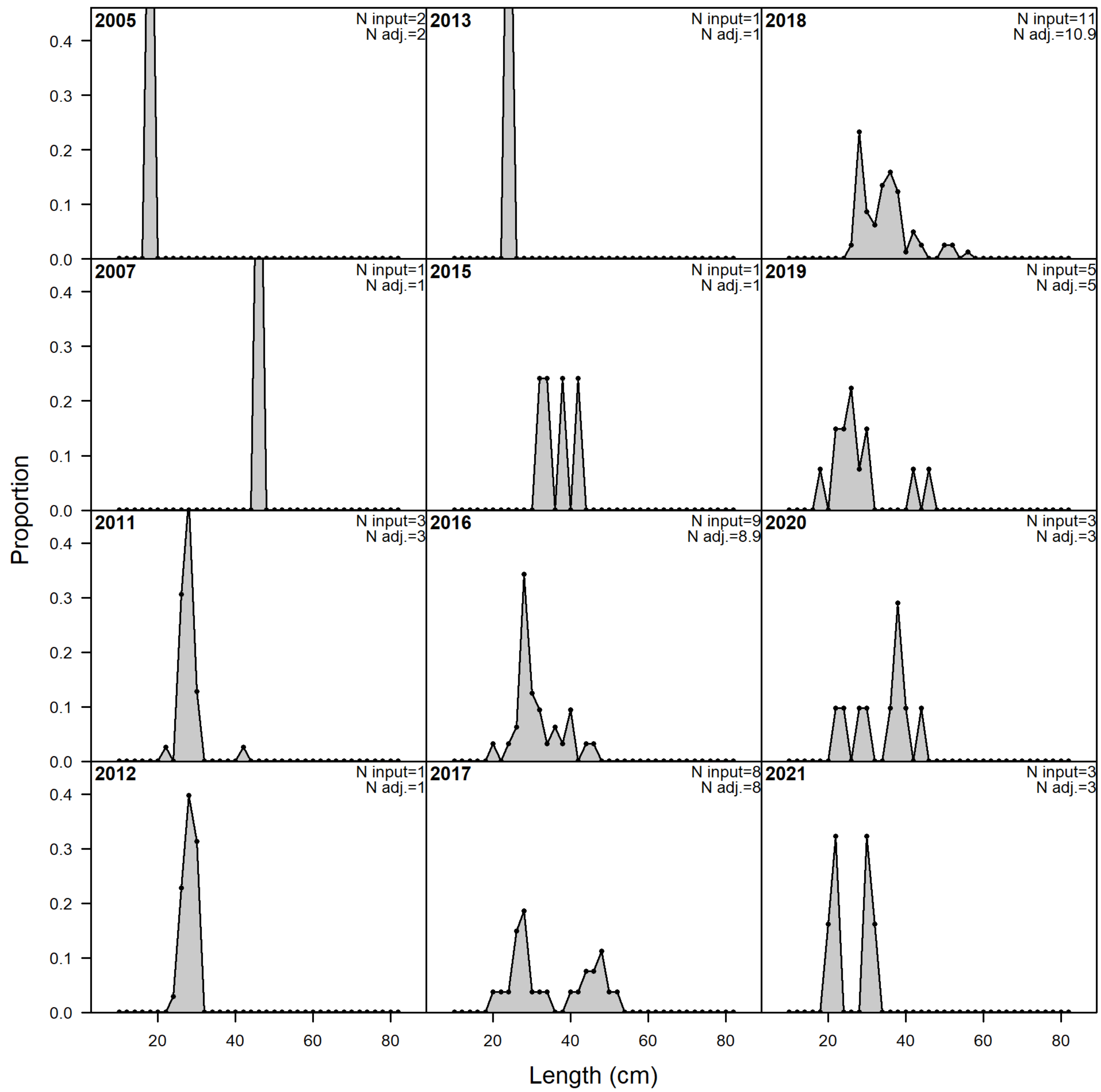


Figure 20. Observed length composition data (discarded) for Gulf of Mexico Spanish Mackerel from the FWRI At-Sea Observer Program for the Recreational Headboat + Charterboat fleet.

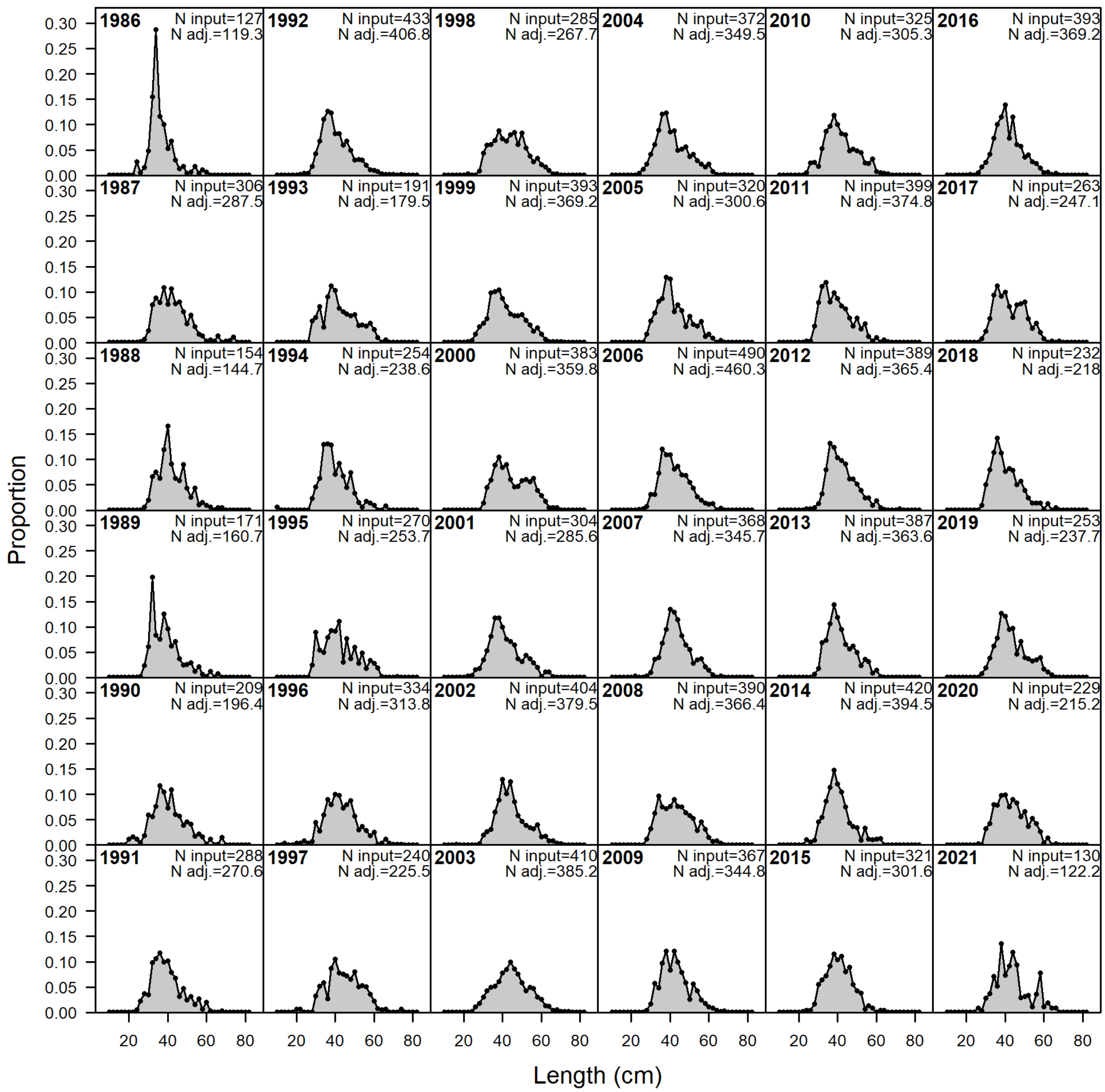


Figure 21. Observed length composition data (retained) of Gulf of Mexico Spanish Mackerel in the Recreational Private fleet.

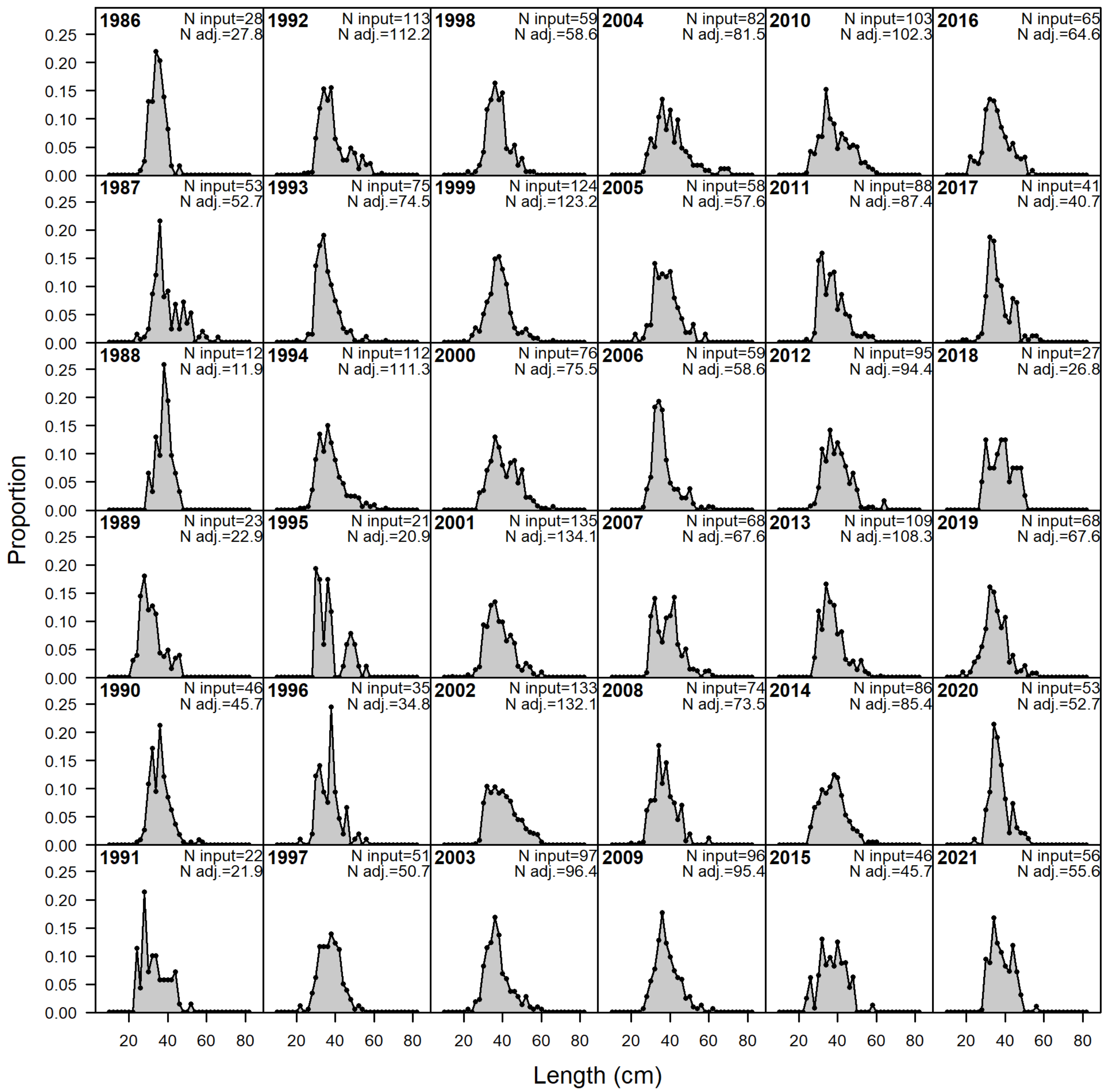


Figure 22. Observed length composition data (retained) of Gulf of Mexico Spanish Mackerel in the Recreational Shore fleet.

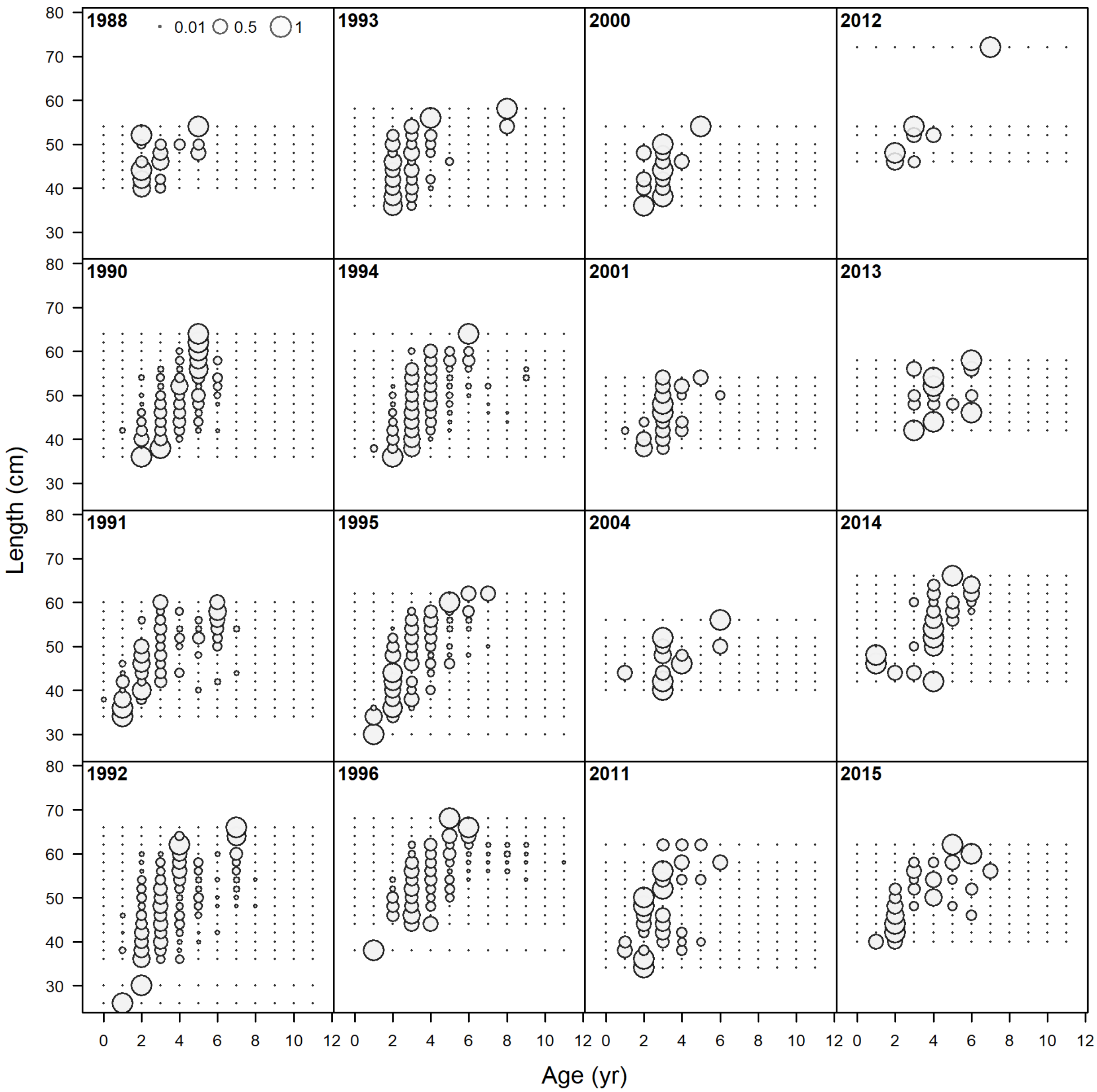


Figure 23. Observed conditional age at length composition data (retained) of Gulf of Mexico Spanish Mackerel in the Commercial Gillnet + Other fleet.

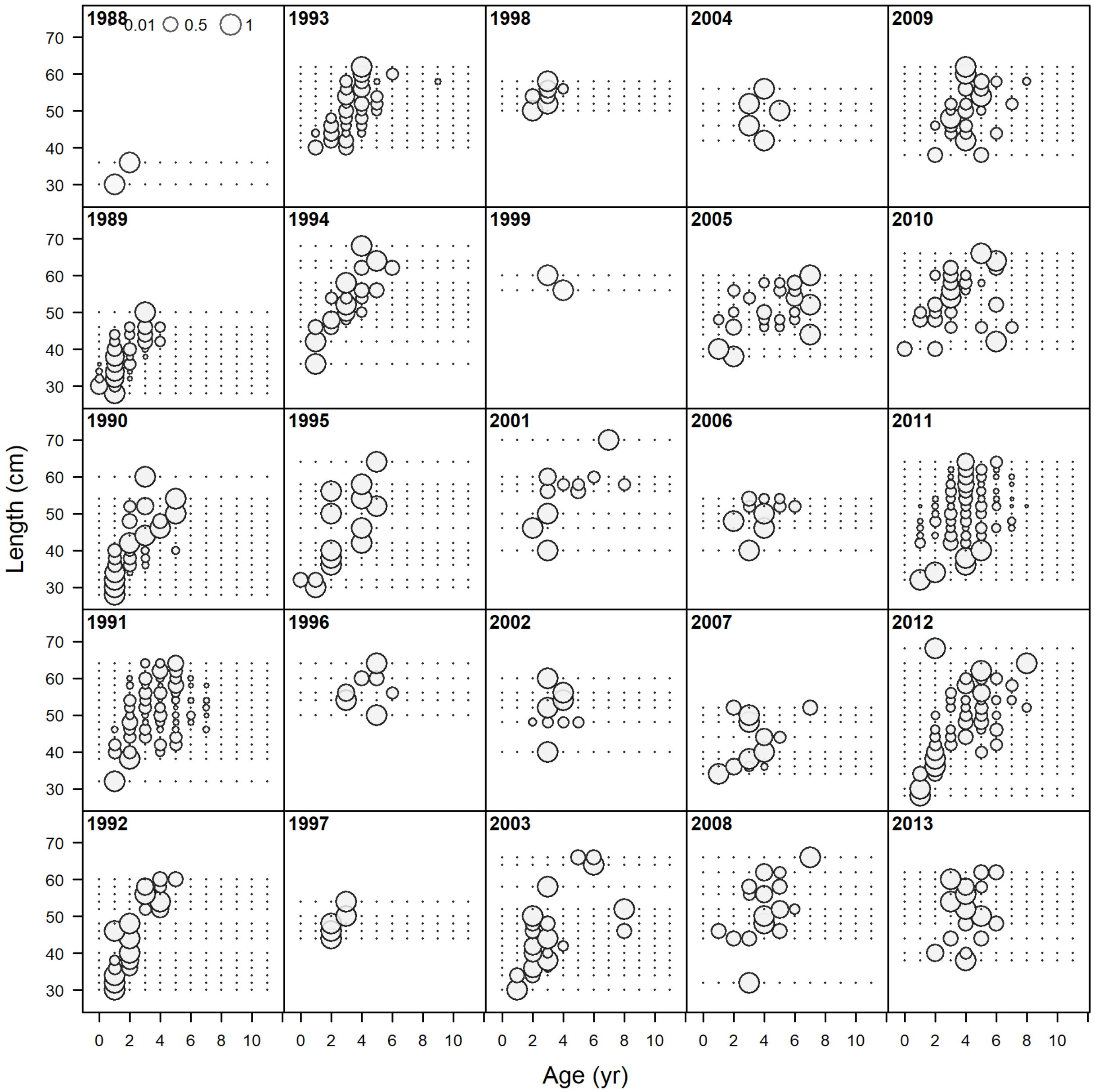


Figure 24. Observed conditional age at length composition data (retained) of Gulf of Mexico Spanish Mackerel in the Commercial Handline + Other fleet.

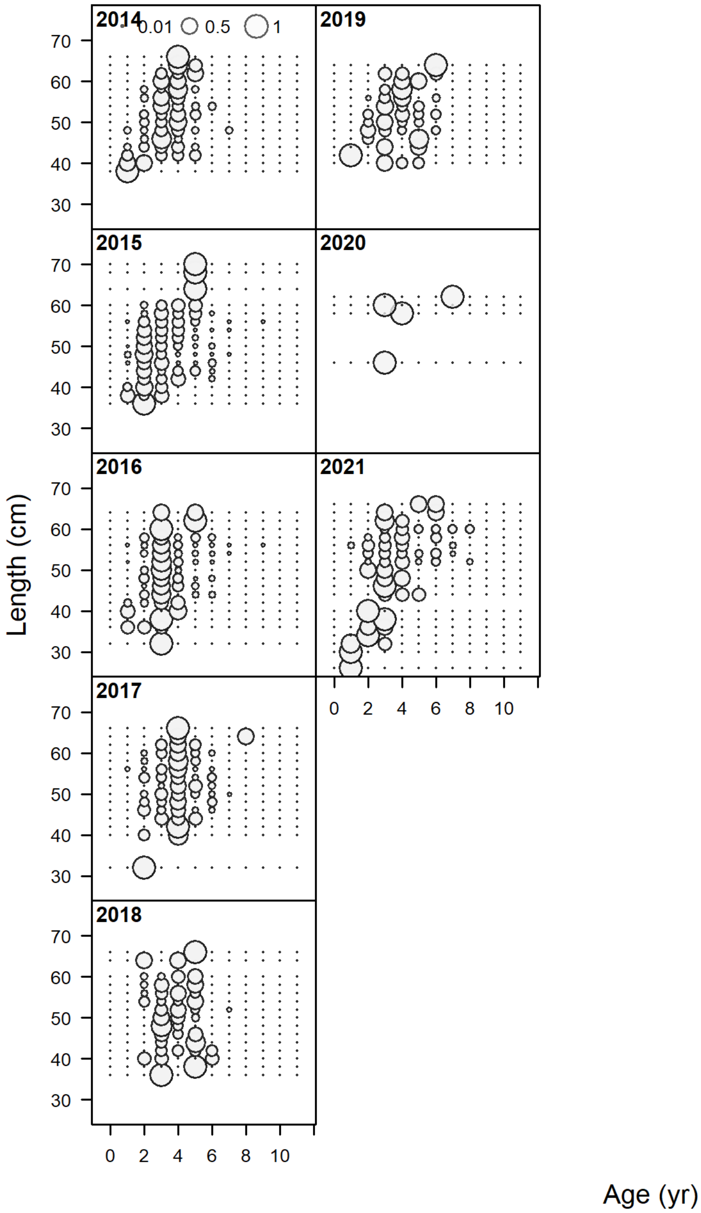


Figure 24 Continued. Observed conditional age at length composition data (retained) of Gulf of Mexico Spanish Mackerel in the Commercial Handline + Other fleet.

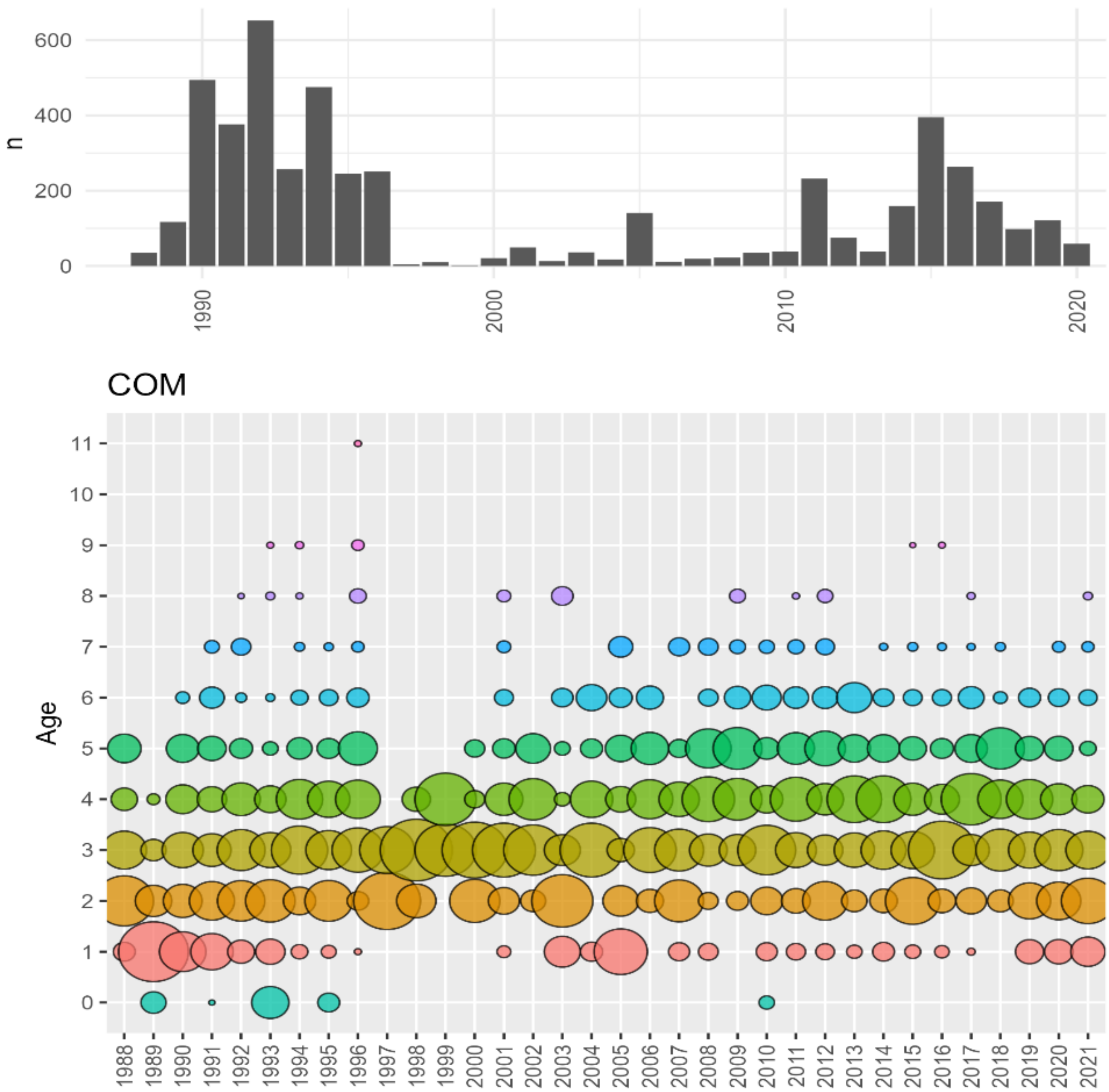


Figure 25. Observed relative age proportions (bubbles) in each year for Gulf of Mexico Spanish Mackerel collected from the commercial sector. The histogram shows annual sample sizes. Cohort progressions are evident.

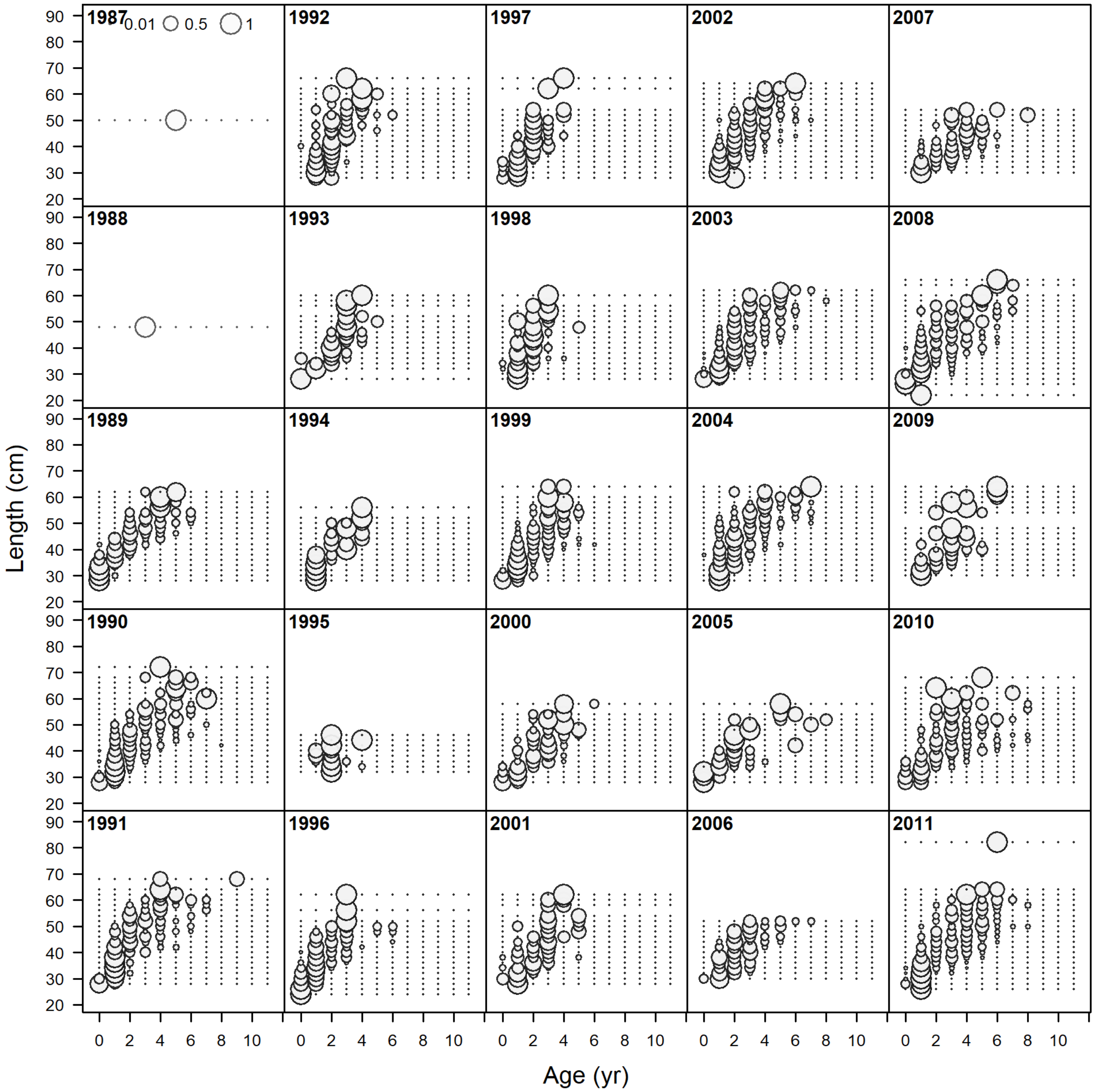


Figure 26. Observed conditional age at length composition data (retained) of Gulf of Mexico Spanish Mackerel in the Recreational Headboat + Charterboat fleet.

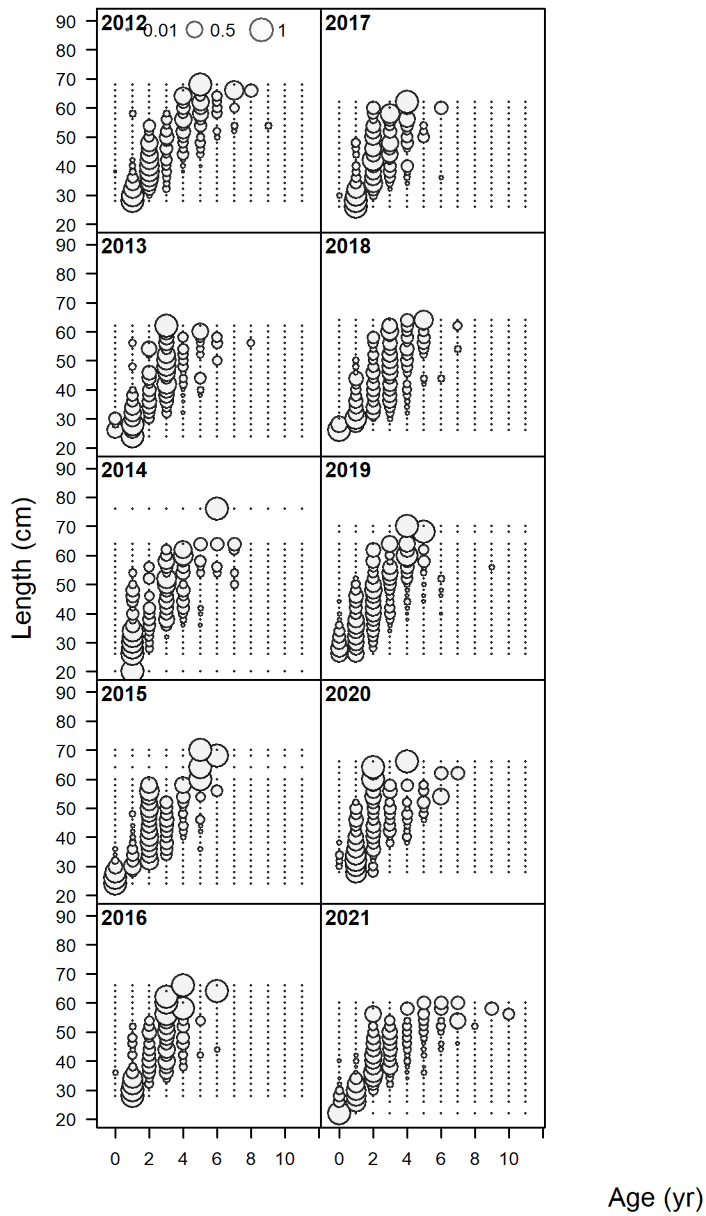


Figure 26 Continued. Observed conditional age at length data (retained) of Gulf of Mexico Spanish Mackerel in the Recreational Headboat + Charterboat fleet.

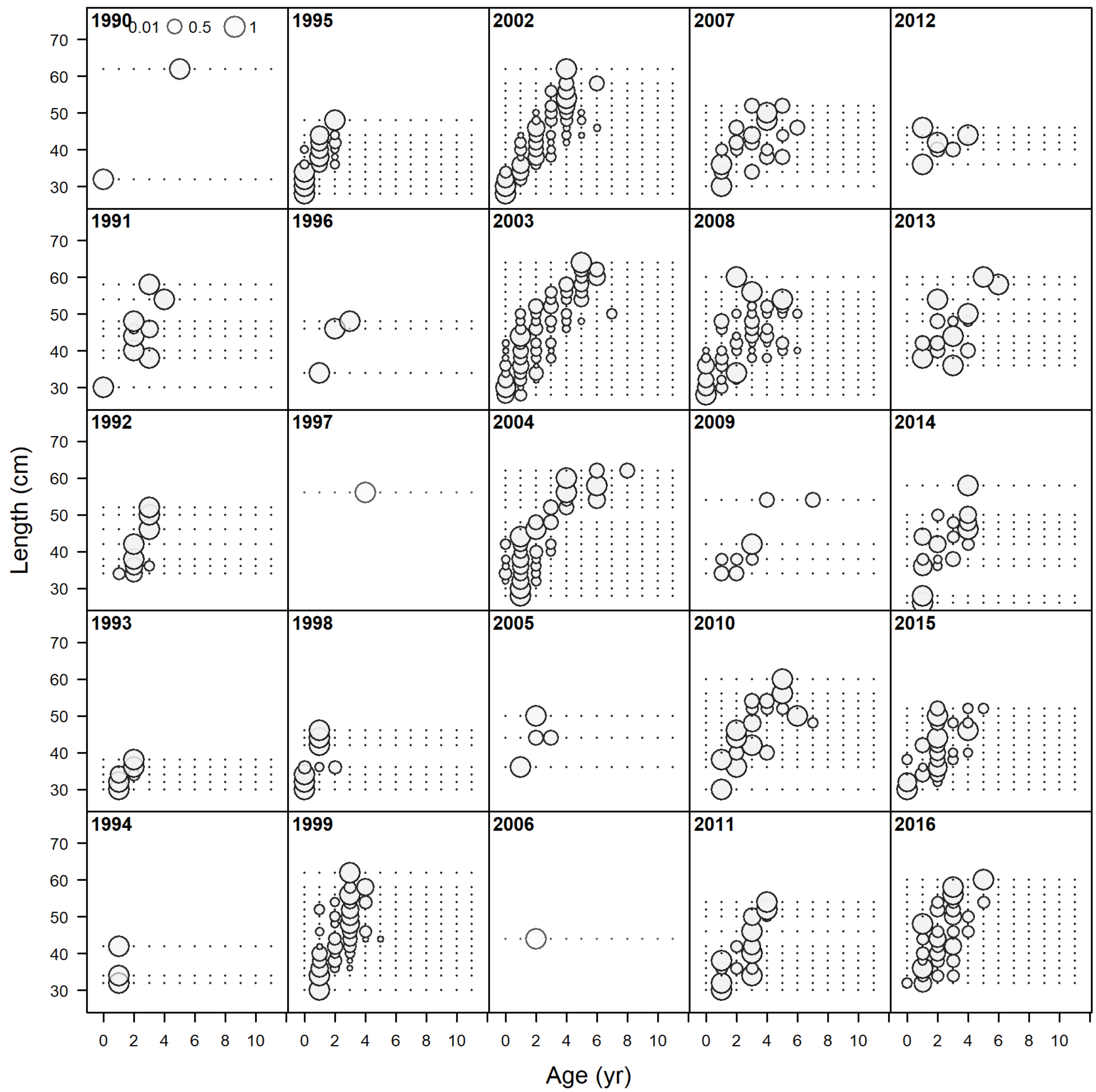


Figure 27. Observed conditional age at length composition data (retained) of Gulf of Mexico Spanish Mackerel in the Recreational Private fleet.

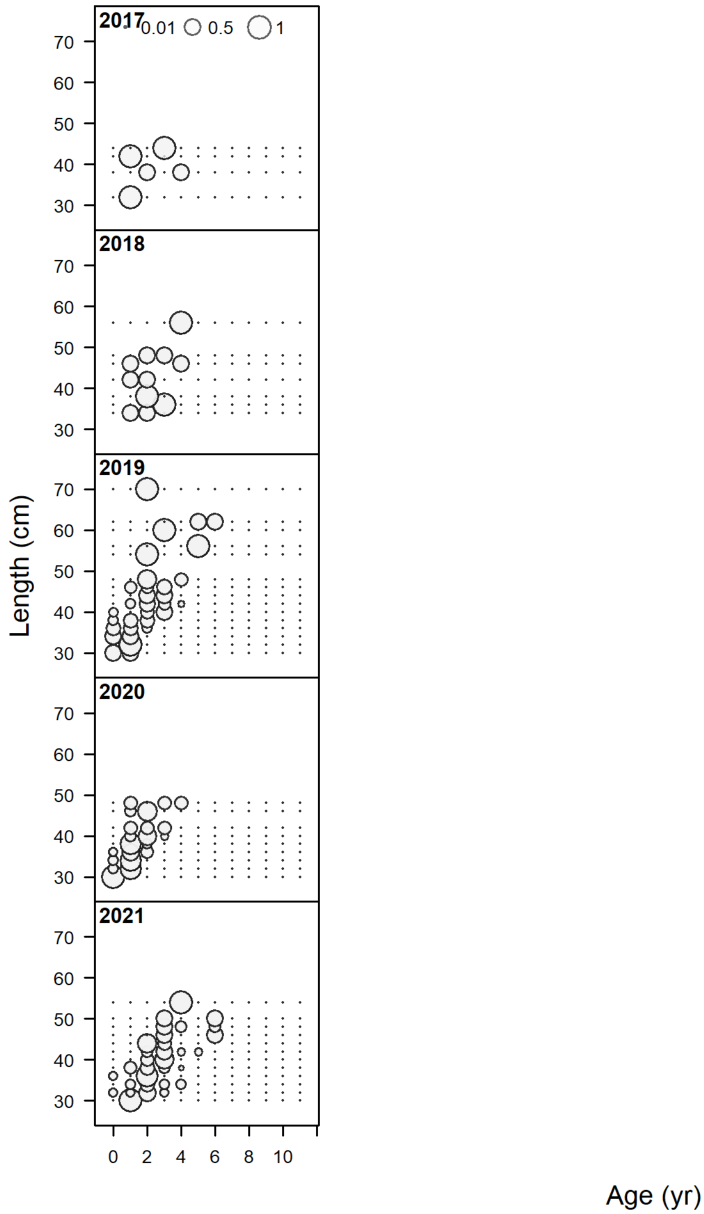


Figure 27 Continued. Observed conditional age at length composition data (retained) of Gulf of Mexico Spanish Mackerel in the Recreational Private fleet.

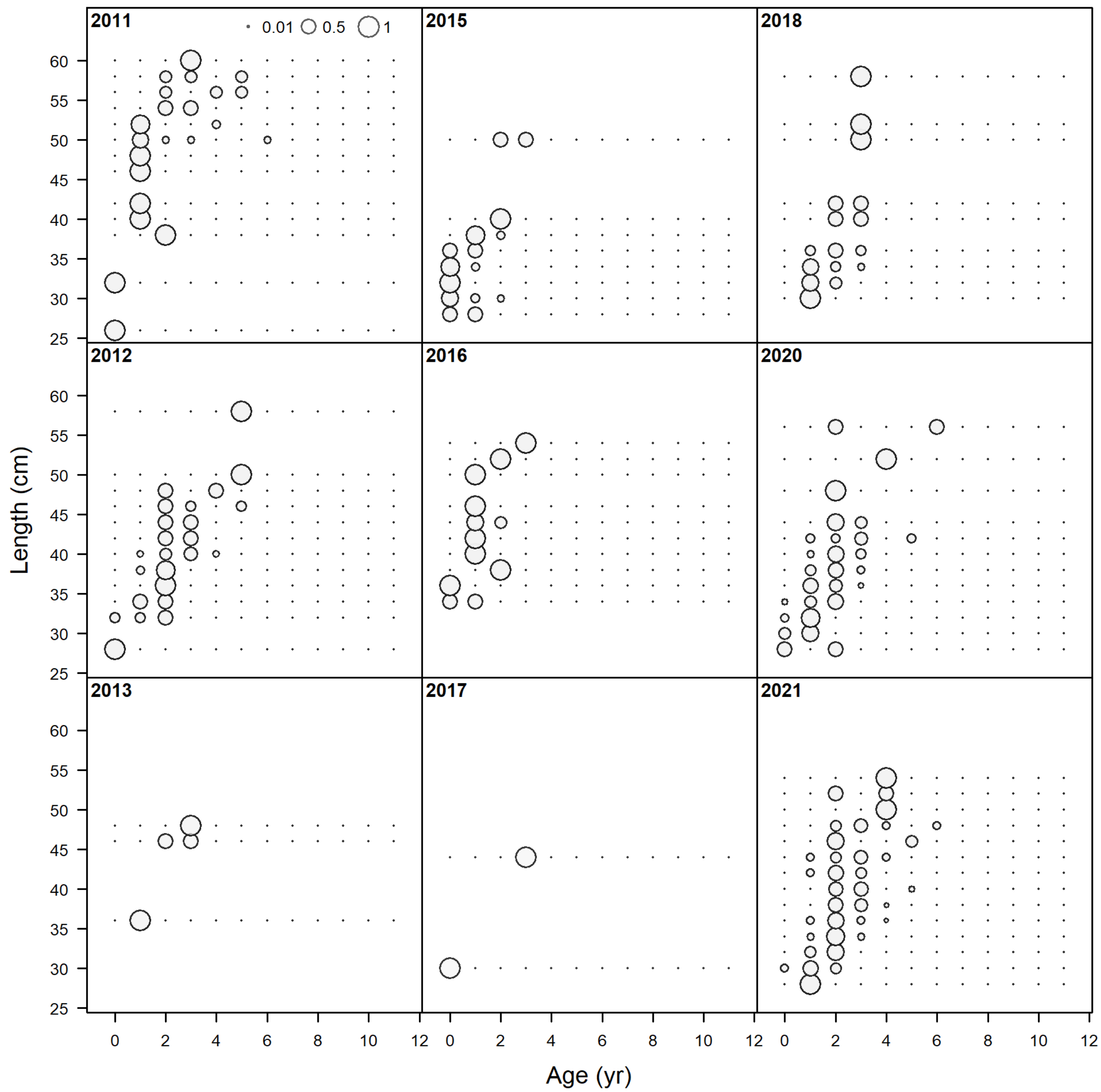


Figure 28. Observed conditional age at length composition data (retained) of Gulf of Mexico Spanish Mackerel in the Recreational Shore fleet.

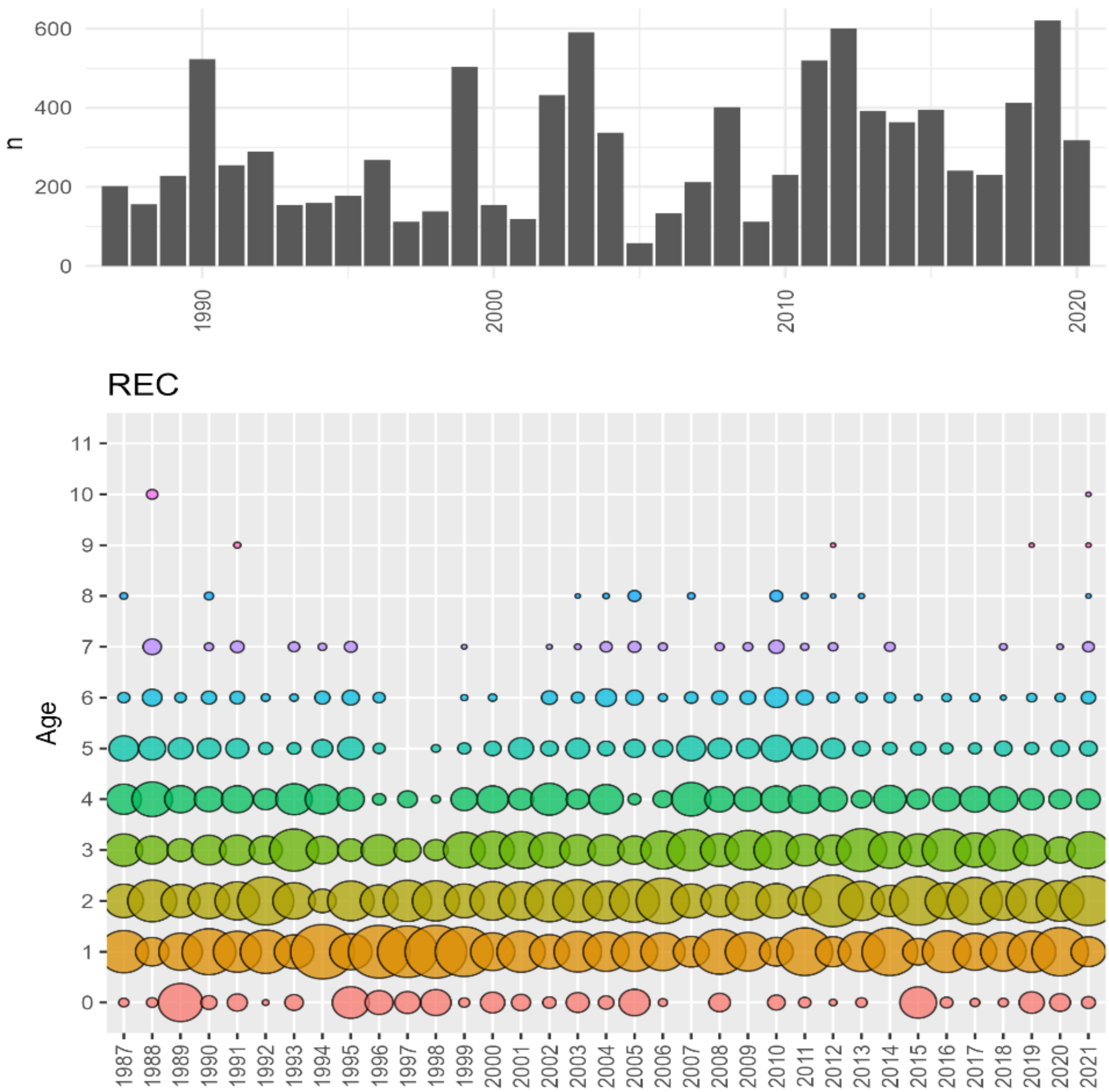


Figure 29. Observed relative age proportions (bubbles) in each year for Gulf of Mexico Spanish Mackerel collected from the recreational sector. The histogram shows annual sample sizes. Cohort progressions are evident.

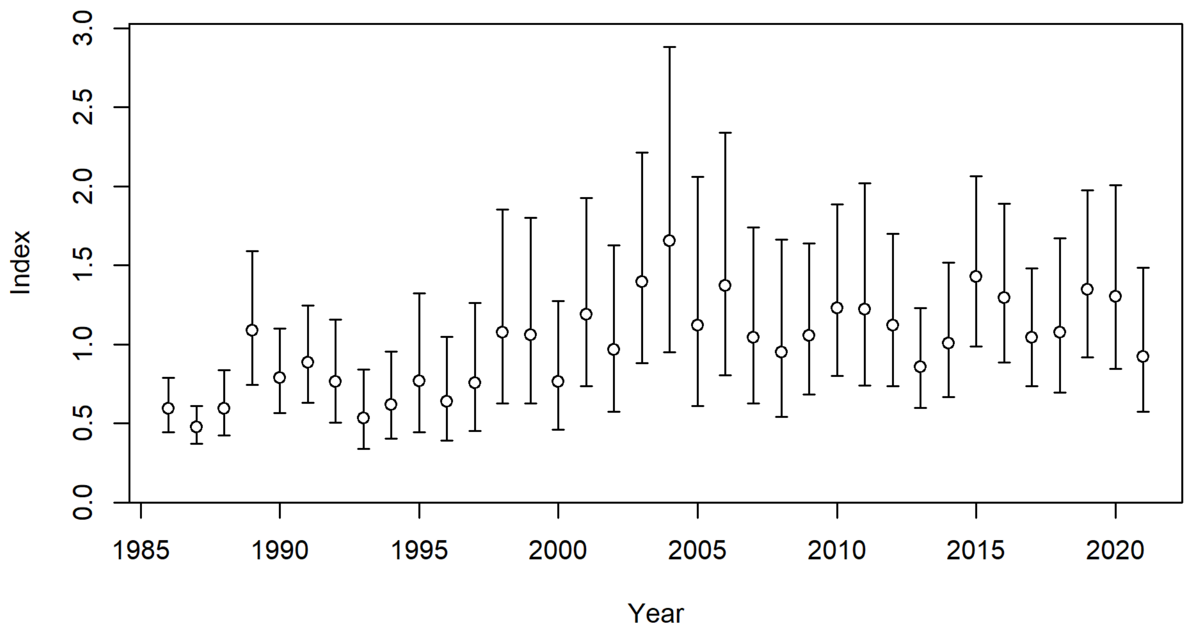


Figure 30. Standardized index of relative abundance for VL CPUE and associated 95% uncertainty interval around index values based on the model assumption of lognormal error for Gulf of Mexico Spanish Mackerel.

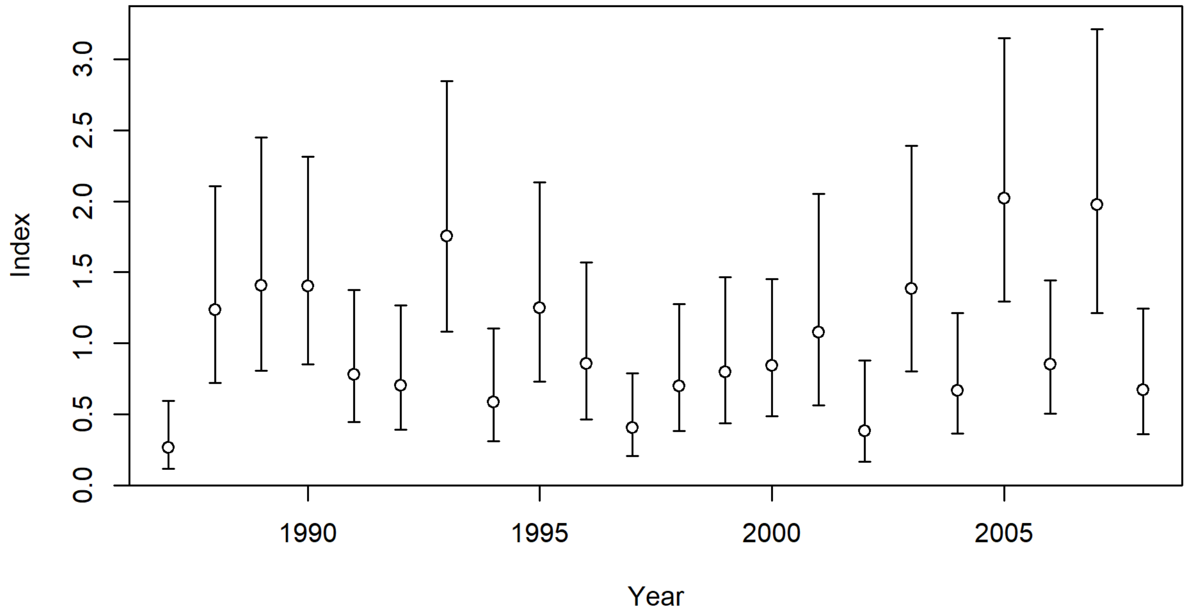


Figure 31. Standardized index of relative abundance for SEAMAP Trawl Survey Early and associated 95% uncertainty interval around index values based on the model assumption of lognormal error for Gulf of Mexico Spanish Mackerel.

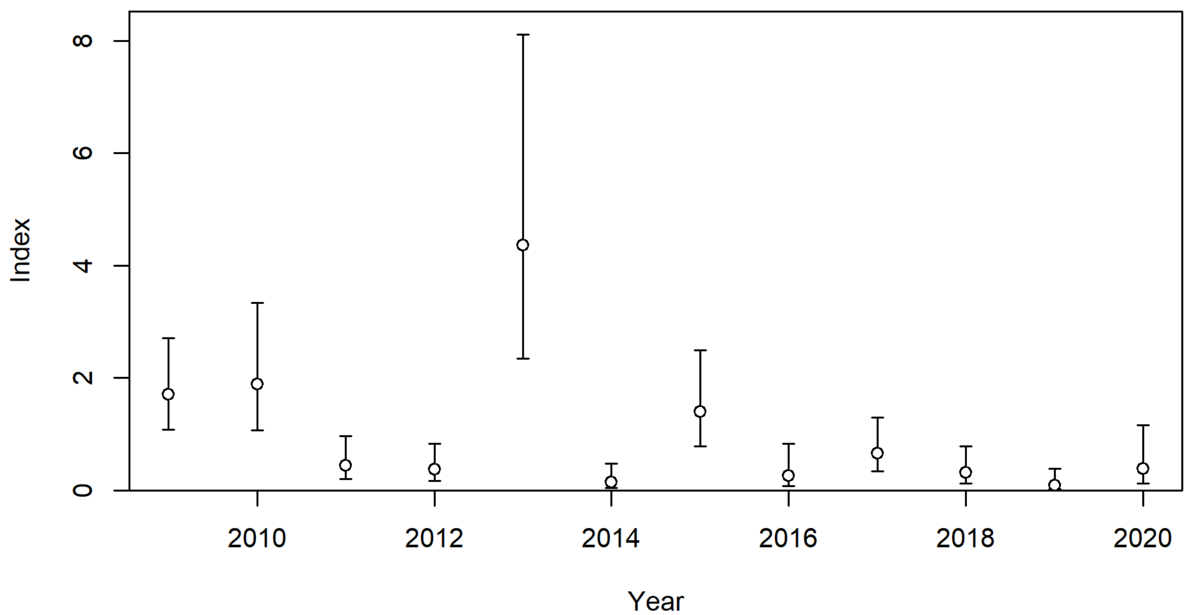


Figure 32. Standardized index of relative abundance for SEAMAP Trawl Survey Late and associated 95% uncertainty interval around index values based on the model assumption of lognormal error for Gulf of Mexico Spanish Mackerel.

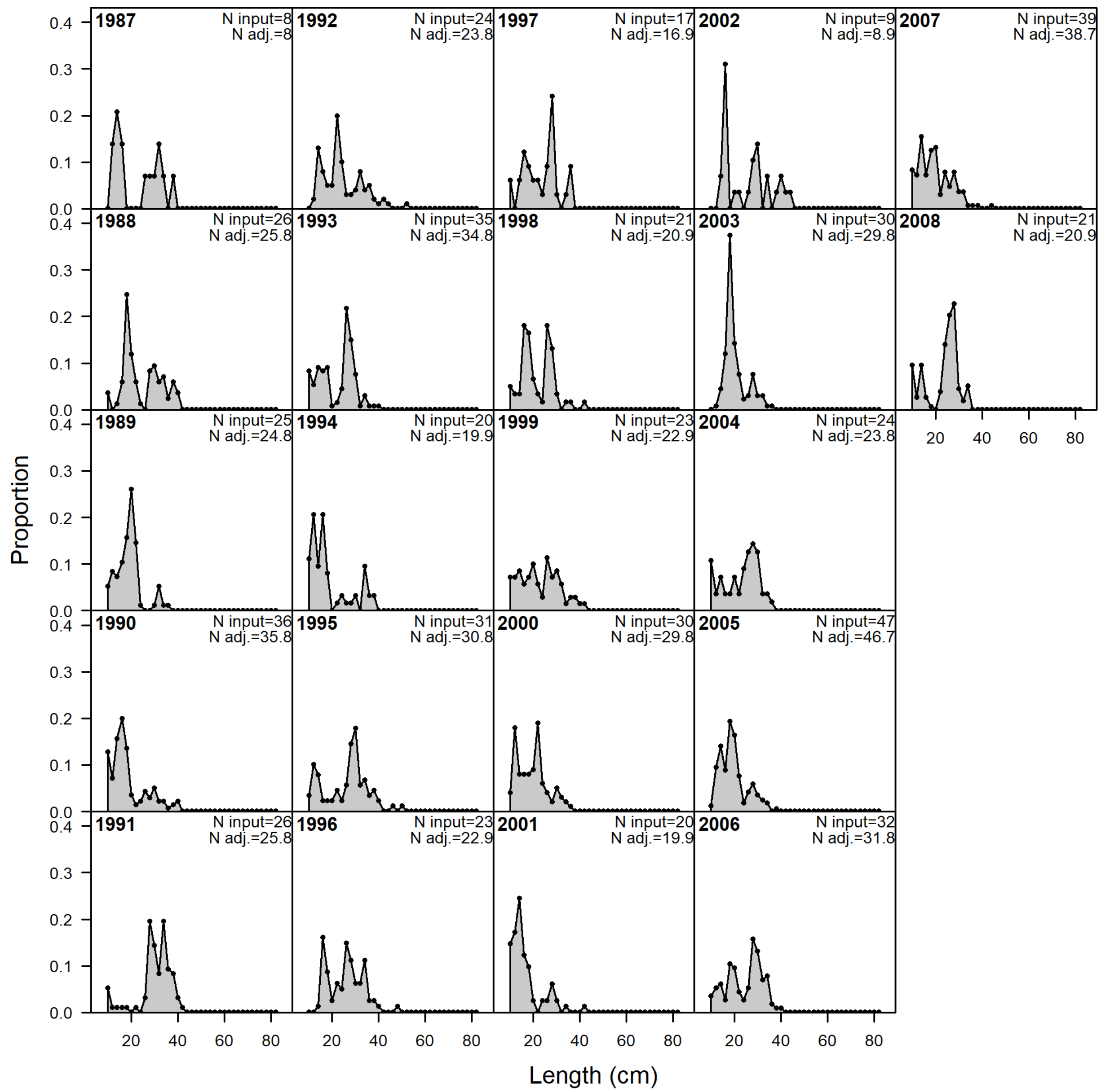


Figure 33. Observed length composition data of Gulf of Mexico Spanish Mackerel from the SEAMAP Trawl Survey Early.

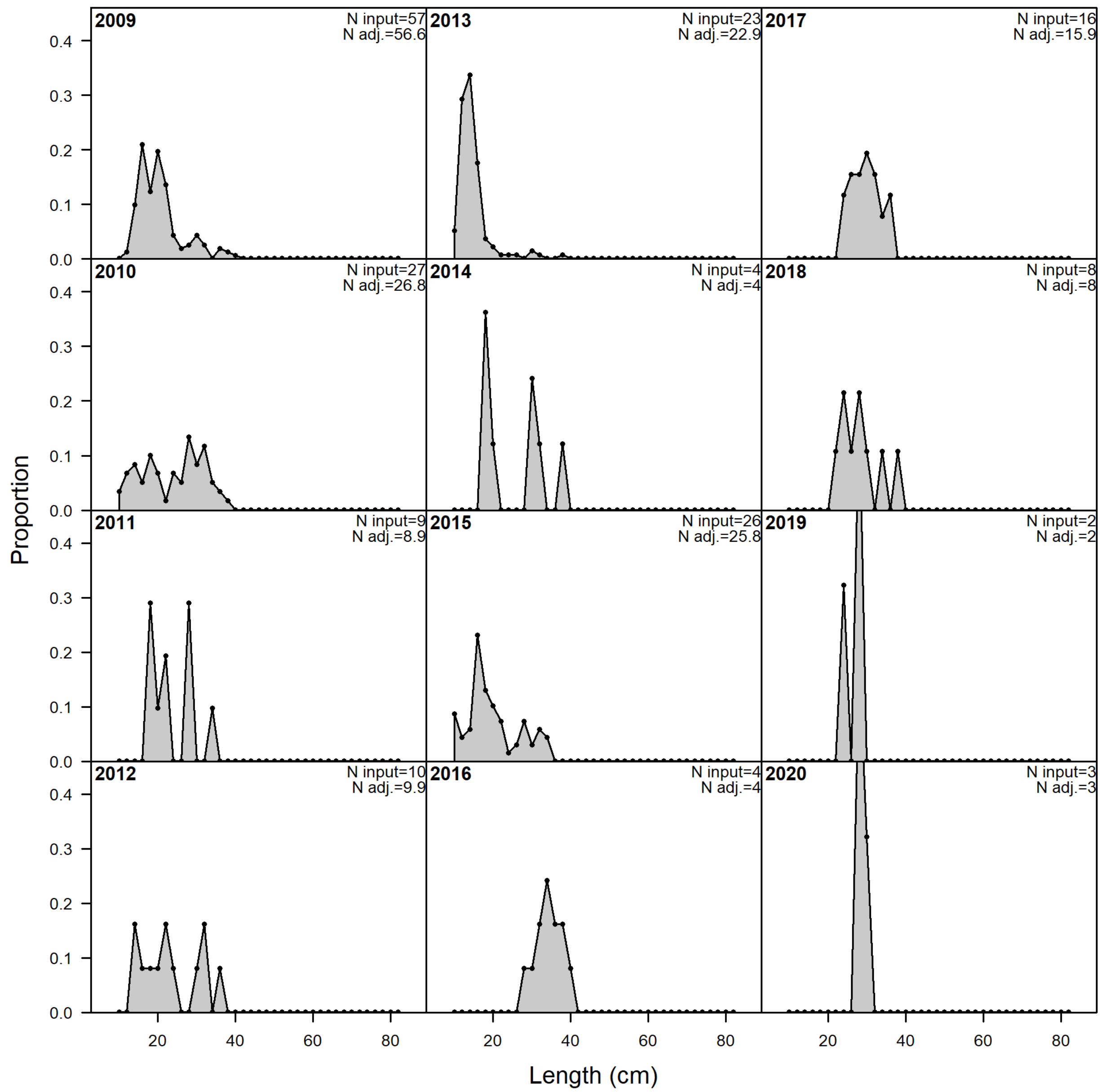


Figure 34. Observed length composition data of Gulf of Mexico Spanish Mackerel from the SEAMAP Trawl Survey Late.

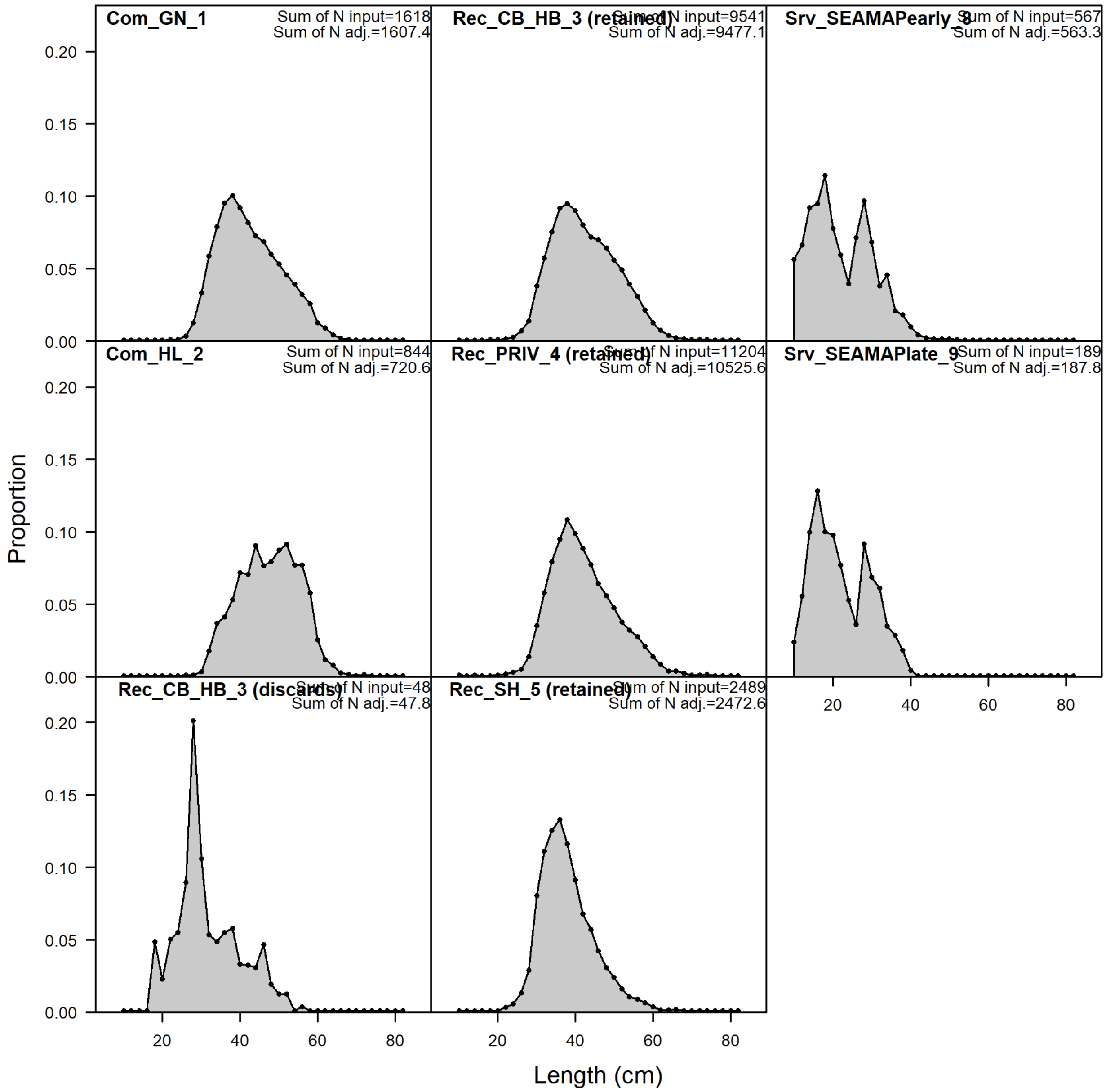


Figure 35. Length comps, aggregated across time by fleet.

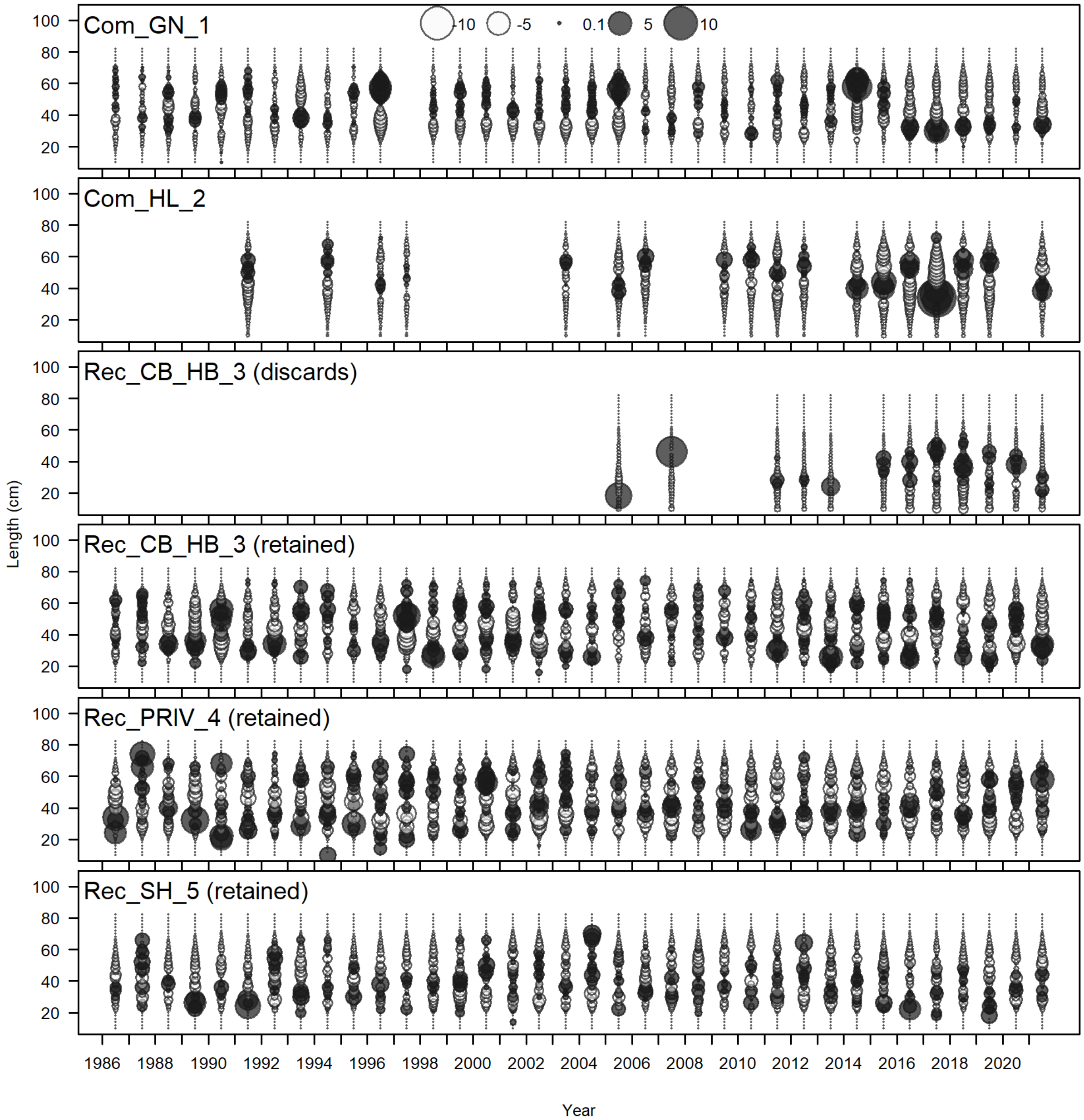


Figure 36. Pearson residuals for discard and retained length composition data by year compared across fleets and surveys for Gulf of Mexico Spanish Mackerel for SEDAR 81 and SEDAR 28. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

SEDAR 28

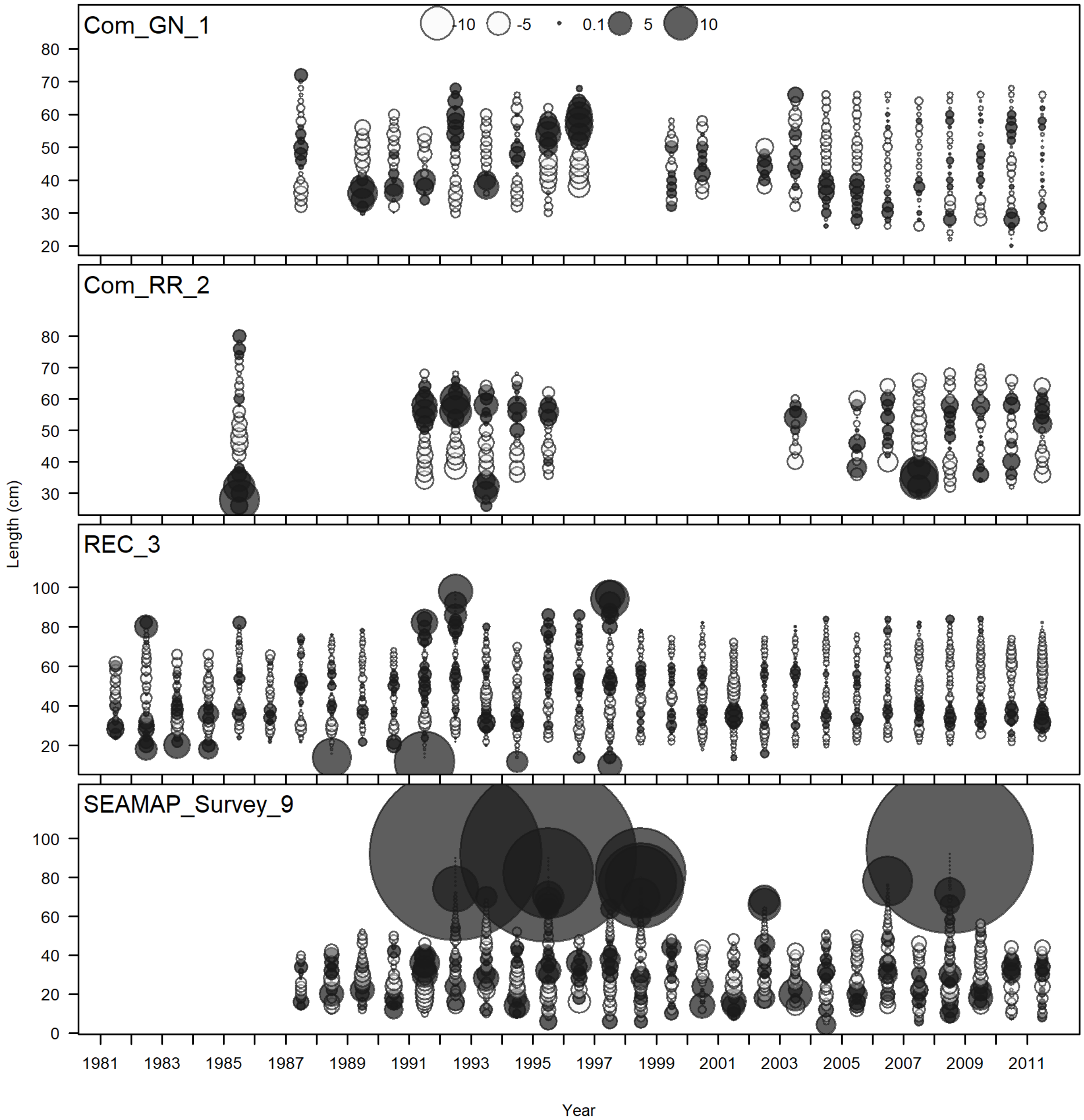


Figure 36 Continued. Pearson residuals for discard and retained length composition data by year compared across fleets and surveys for Gulf of Mexico Spanish Mackerel for SEDAR 81 and SEDAR 28. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

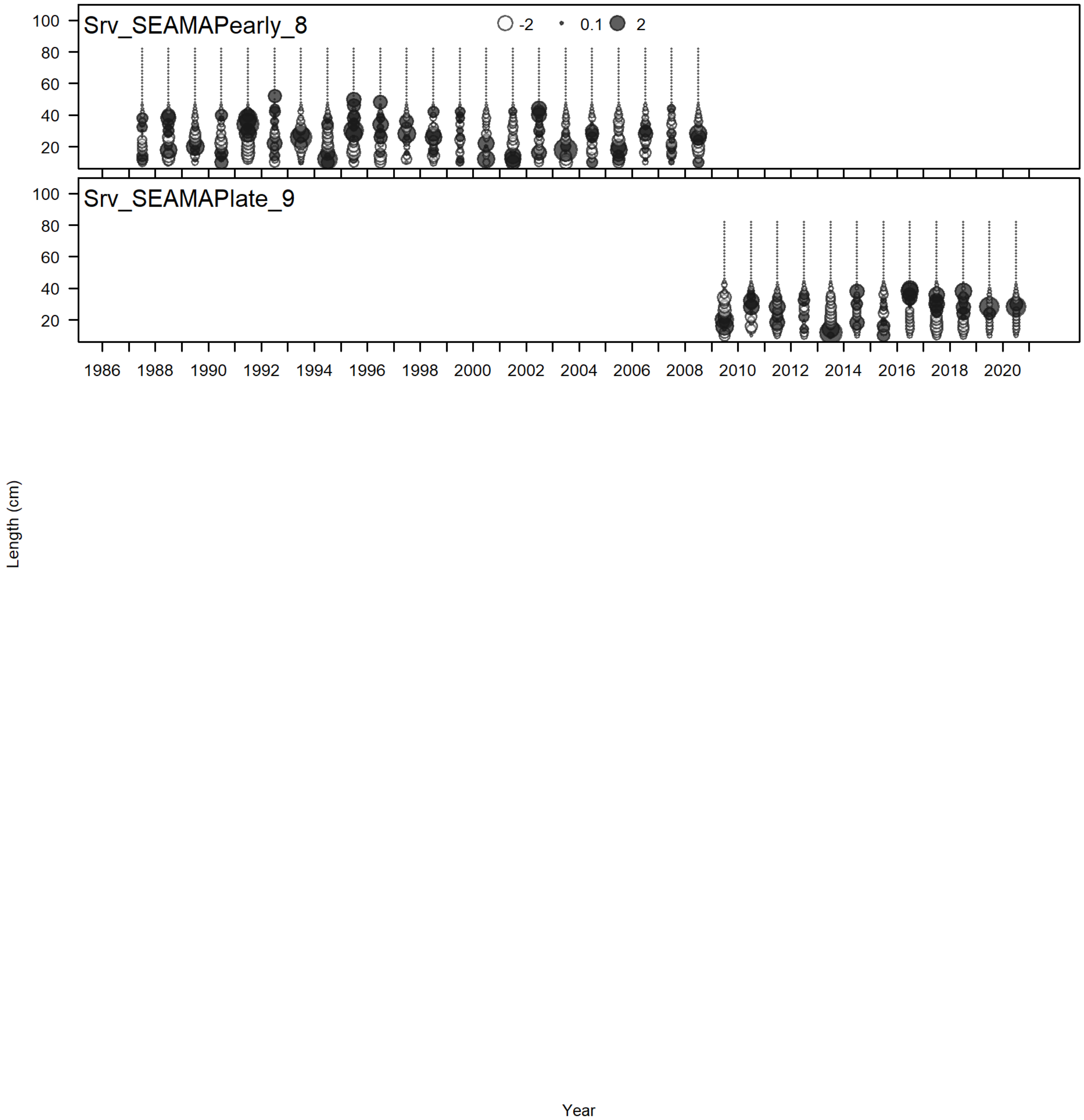


Figure 36 Continued. Pearson residuals for discard and retained length composition data by year compared across fleets and surveys for Gulf of Mexico Spanish Mackerel for SEDAR 81 and SEDAR 28 . Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

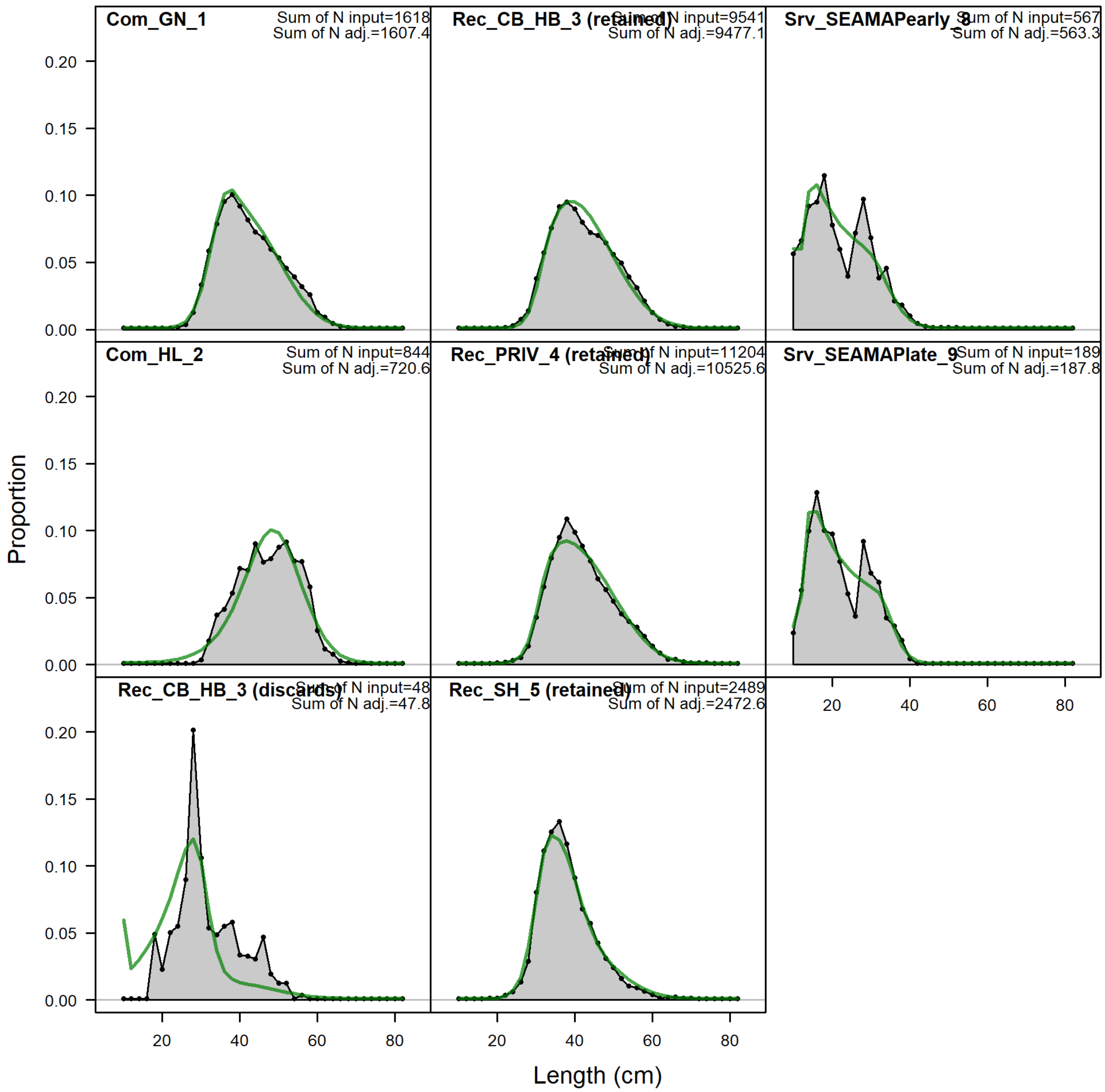


Figure 37. Model fits to the length composition of discarded or retained catch aggregated across years within a given fleet for Gulf of Mexico Spanish Mackerel. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions. For SEDAR 81, 'Sum of N input' is the total input sample size and 'Sum of N adj.' is the total sample size after adjustment by the Dirichlet-Multinomial parameter. For SEDAR 28, 'Sum of N adj.' is the input sample size and 'Sum of N eff.' can be ignored as it was not used.

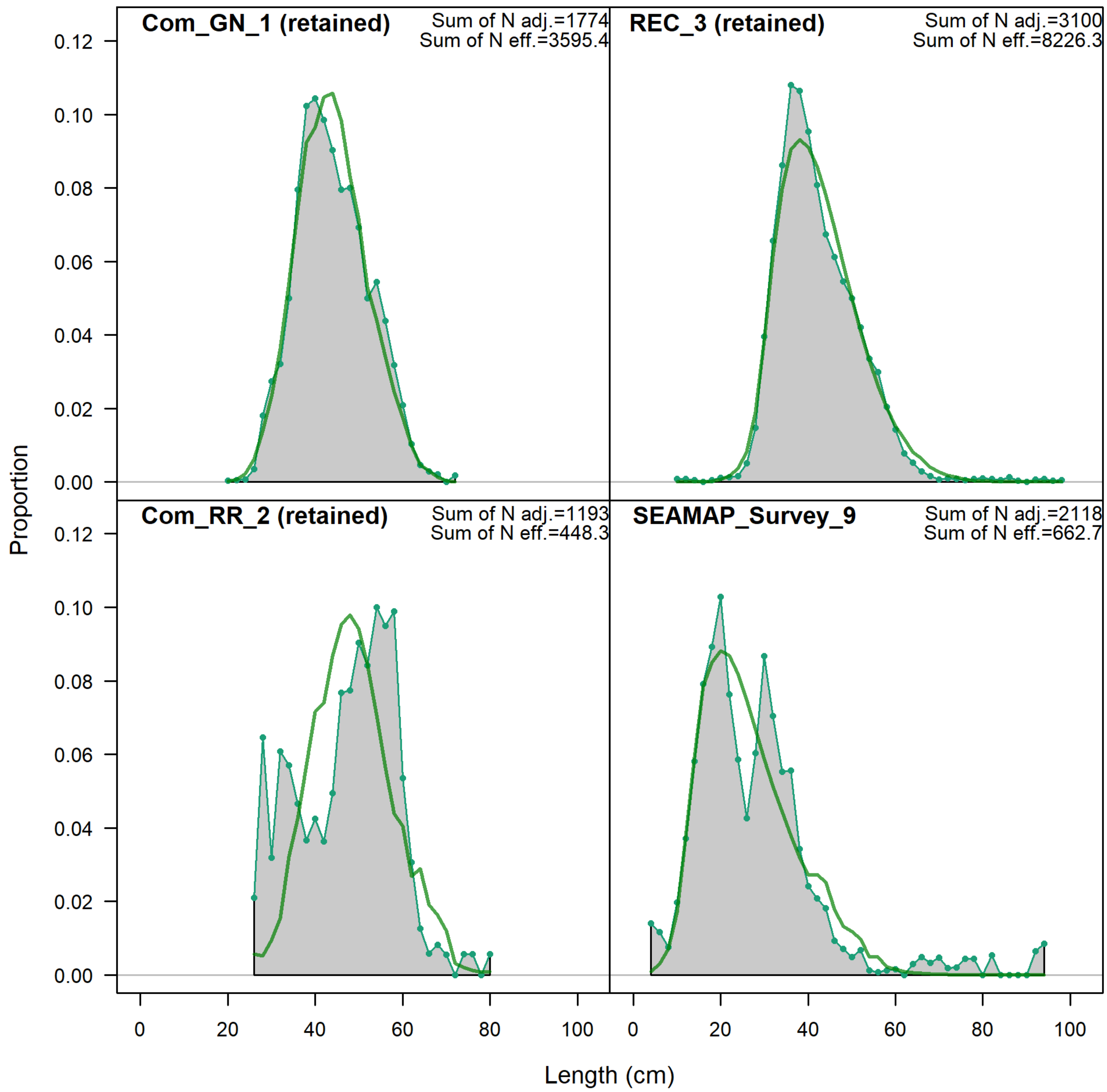


Figure 37 Continued. Model fits to the length composition of discarded or retained catch aggregated across years within a given fleet for Gulf of Mexico Spanish Mackerel. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions. For SEDAR 81, 'Sum of N input' is the total input sample size and 'Sum of N adj.' is the total sample size after adjustment by the Dirichlet-Multinomial parameter. For SEDAR 28, 'Sum of N adj.' is the input sample size and 'Sum of N eff.' can be ignored as it was not used.

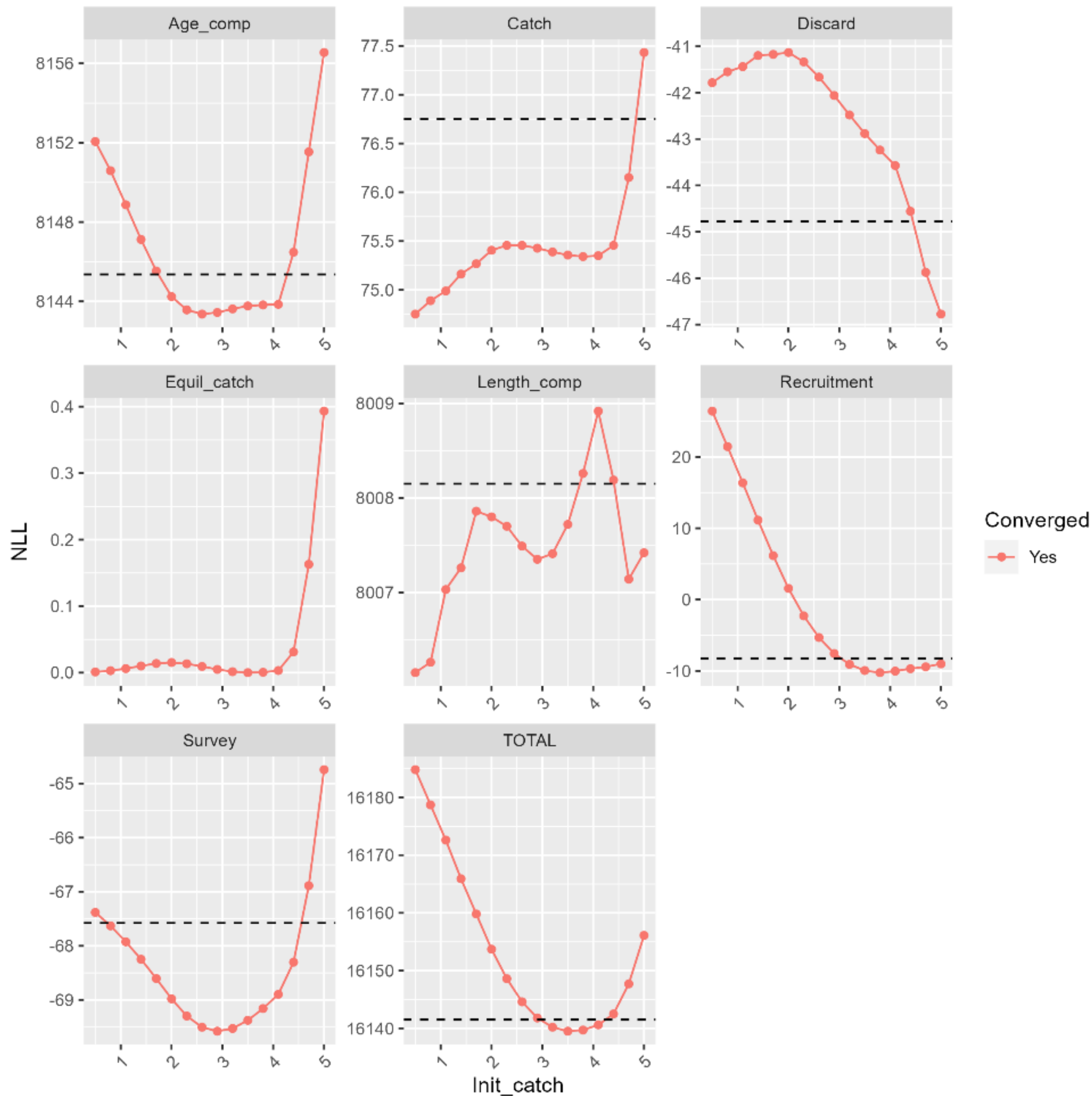


Figure 38. Likelihood profile for the scalar value search. A scalar of 3.5 was found to be most likely given the information present in the other datasets. Points that fall below the dashed lines are within 2 likelihood units of the minimum.

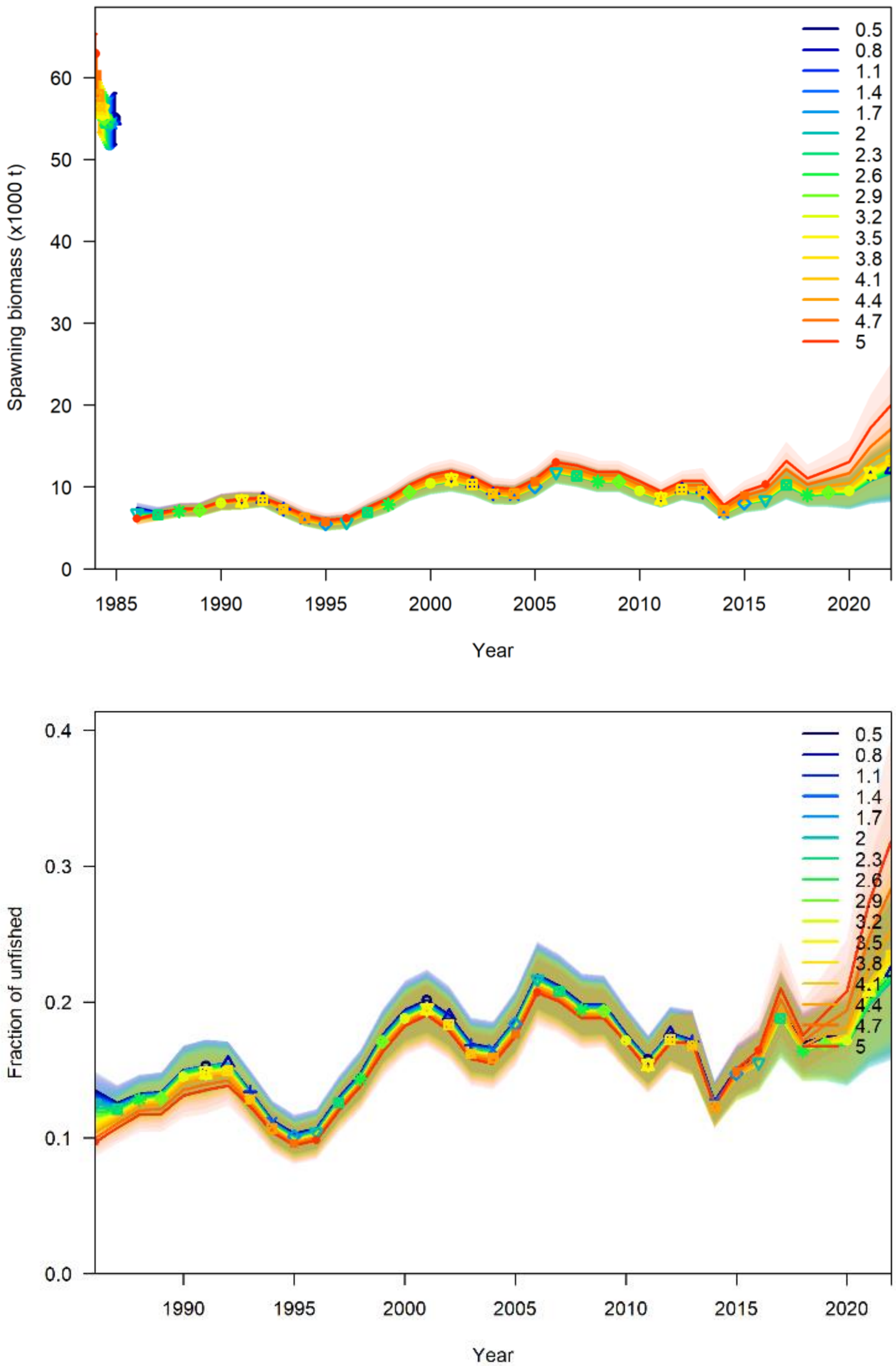


Figure 39. Comparison of SSB and fraction unfished (SSB/SSB0) time series between the various scalings of initial equilibrium catches. A scalar of 3.5 was determined to be the best fit.

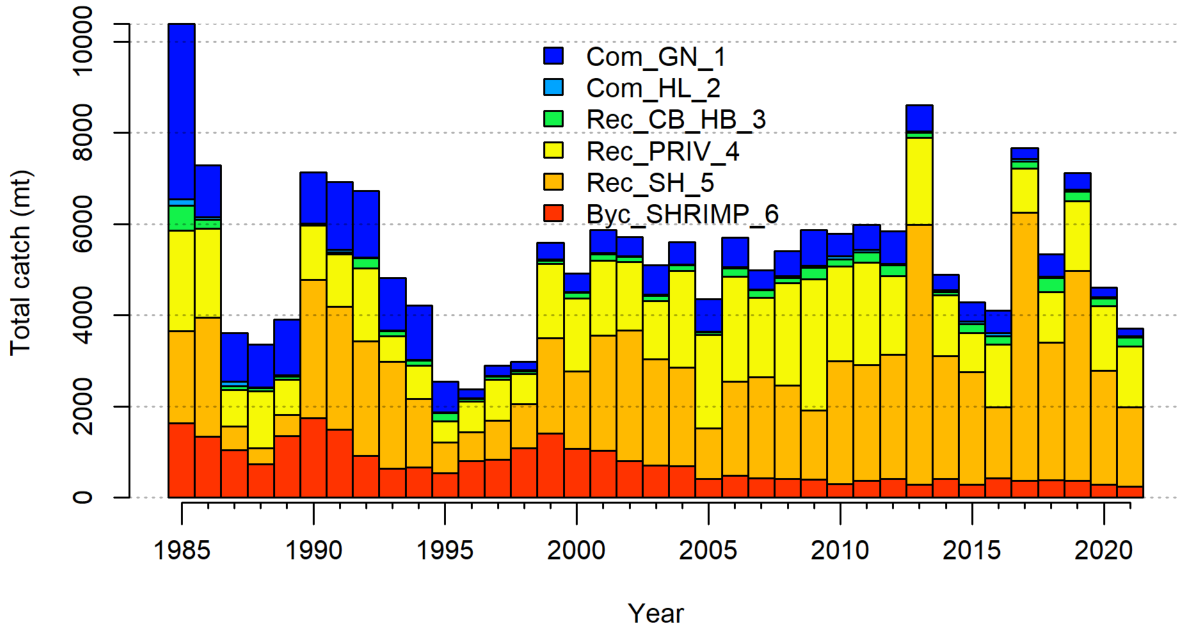


Figure 40. Expected total catch by fleet.

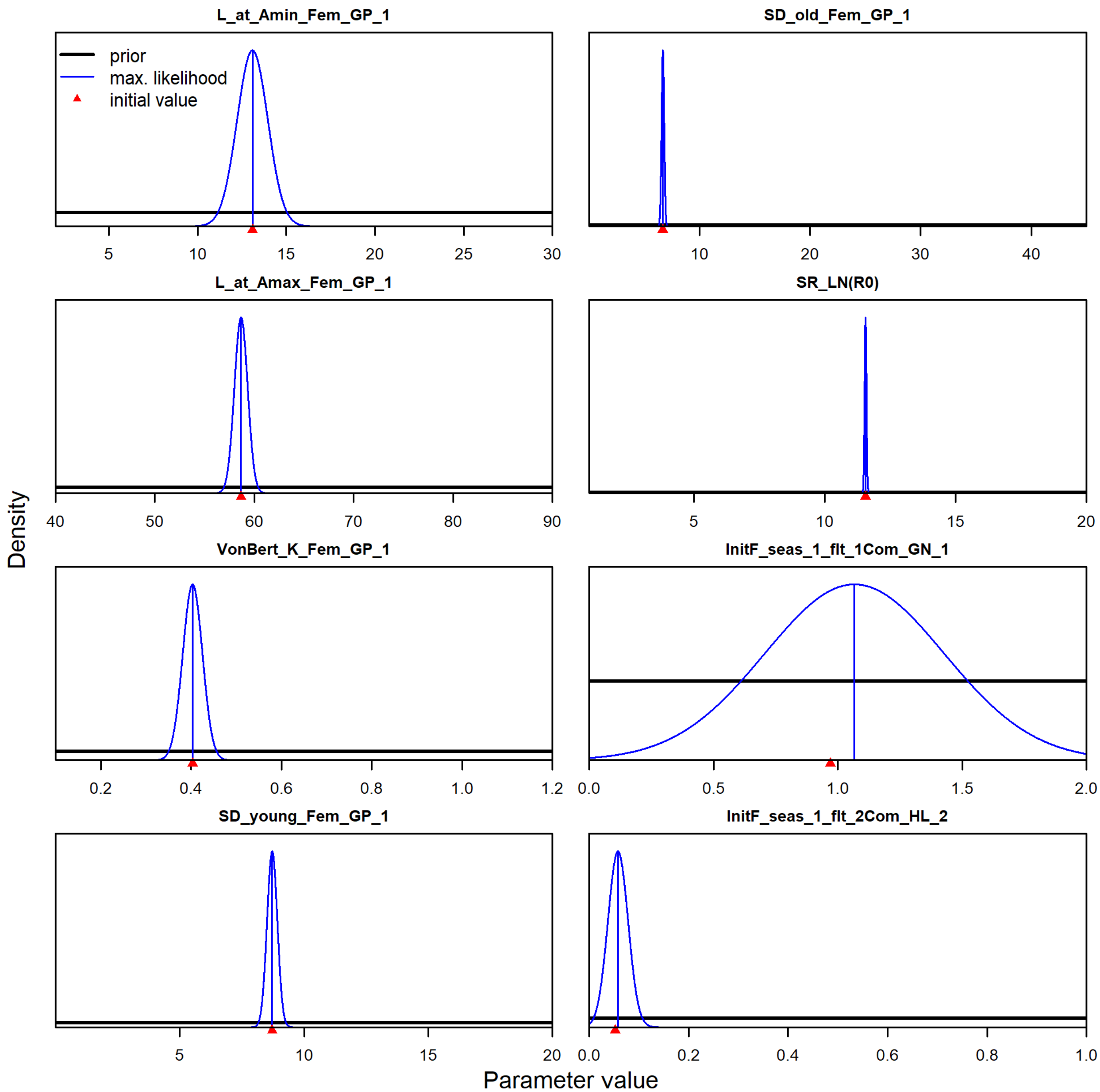


Figure 41. Parameter distribution (blue line) plots along with starting values (red arrow), bounds (y axis limits), and priors (black lines). Deviation parameters are not included. F parameters are not included. Note: parameter point estimates from a previous model fit were used as the starting values for this final model run.

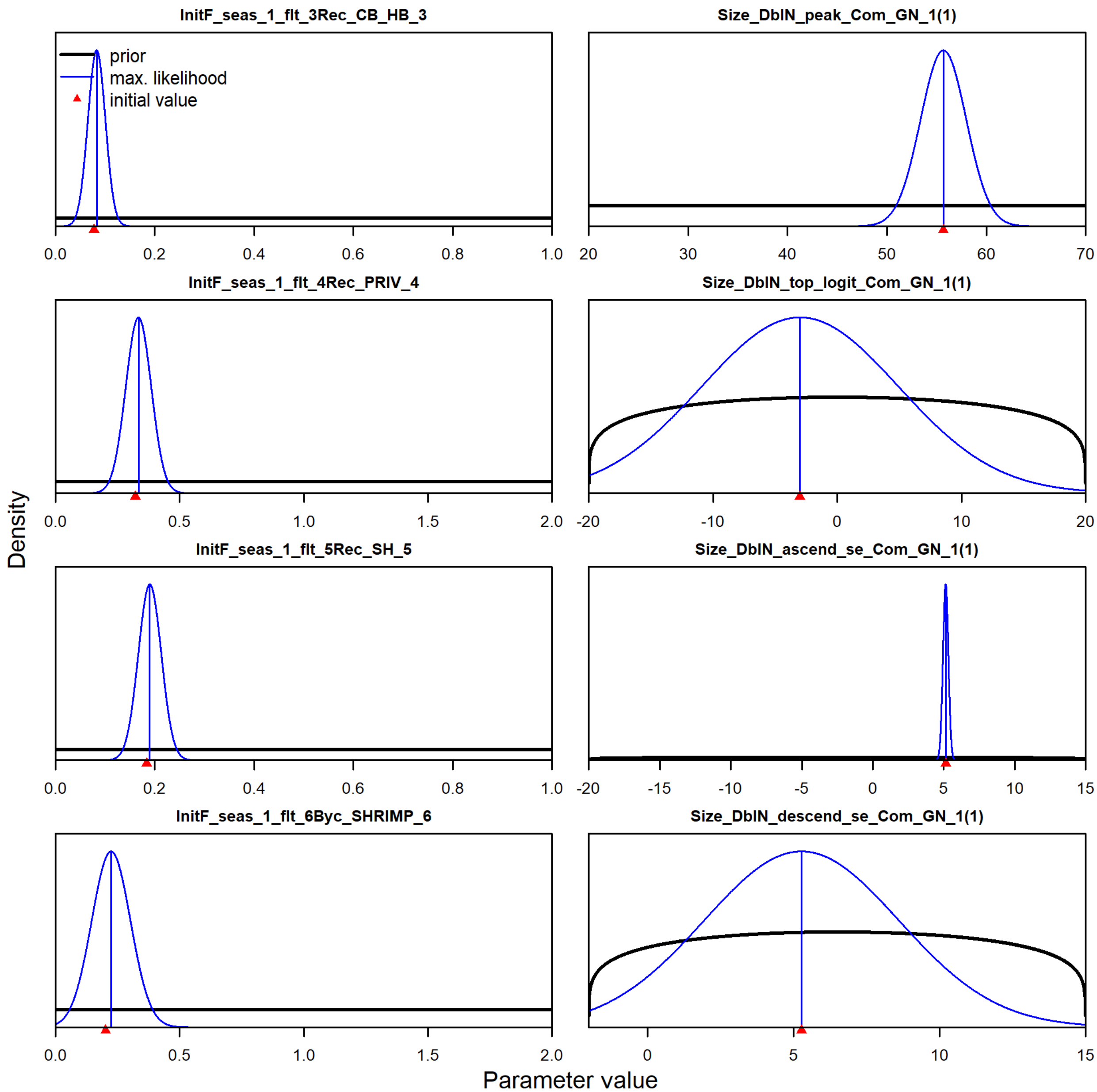


Figure 41 Continued. Parameter distribution (blue line) plots along with starting values (red arrow), bounds (y axis limits), and priors (black lines). Deviation parameters are not included. F parameters are not included. Note: parameter point estimates from a previous model fit were used as the starting values for this final model run.

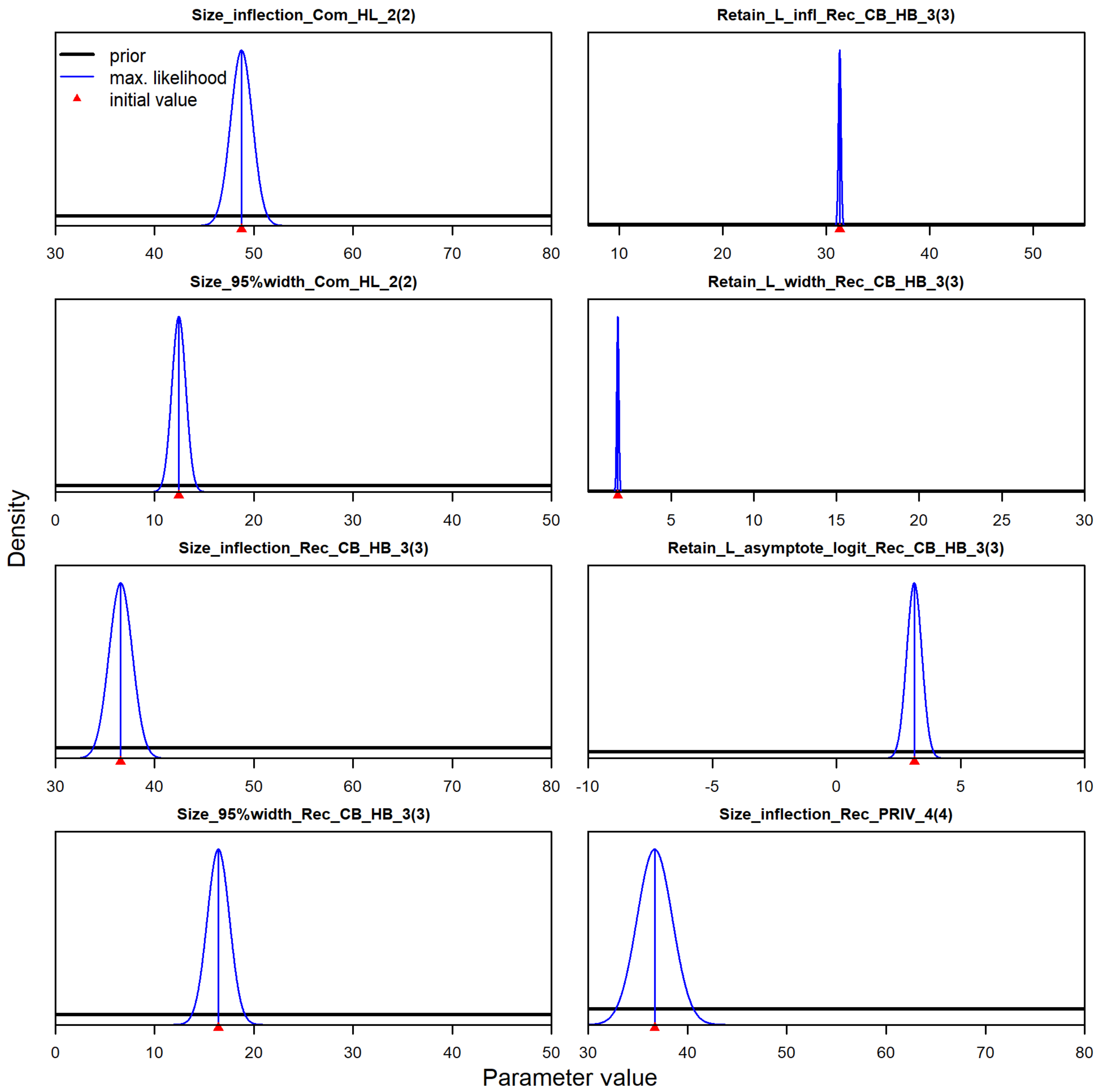


Figure 41 Continued. Parameter distribution (blue line) plots along with starting values (red arrow), bounds (y axis limits), and priors (black lines). Deviation parameters are not included. F parameters are not included. Note: parameter point estimates from a previous model fit were used as the starting values for this final model run.

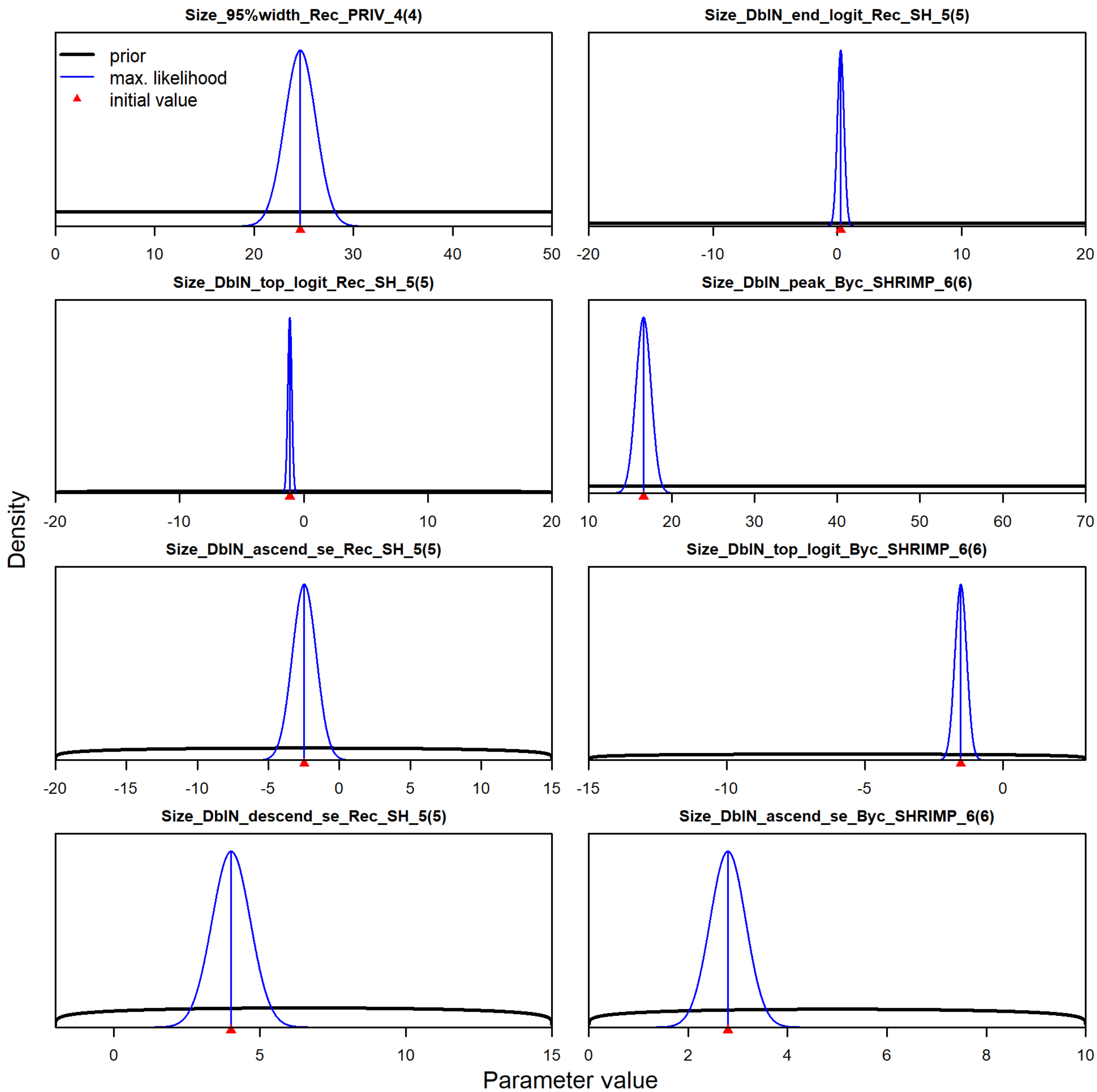


Figure 41 Continued. Parameter distribution (blue line) plots along with starting values (red arrow), bounds (y axis limits), and priors (black lines). Deviation parameters are not included. F parameters are not included. Note: parameter point estimates from a previous model fit were used as the starting values for this final model run.

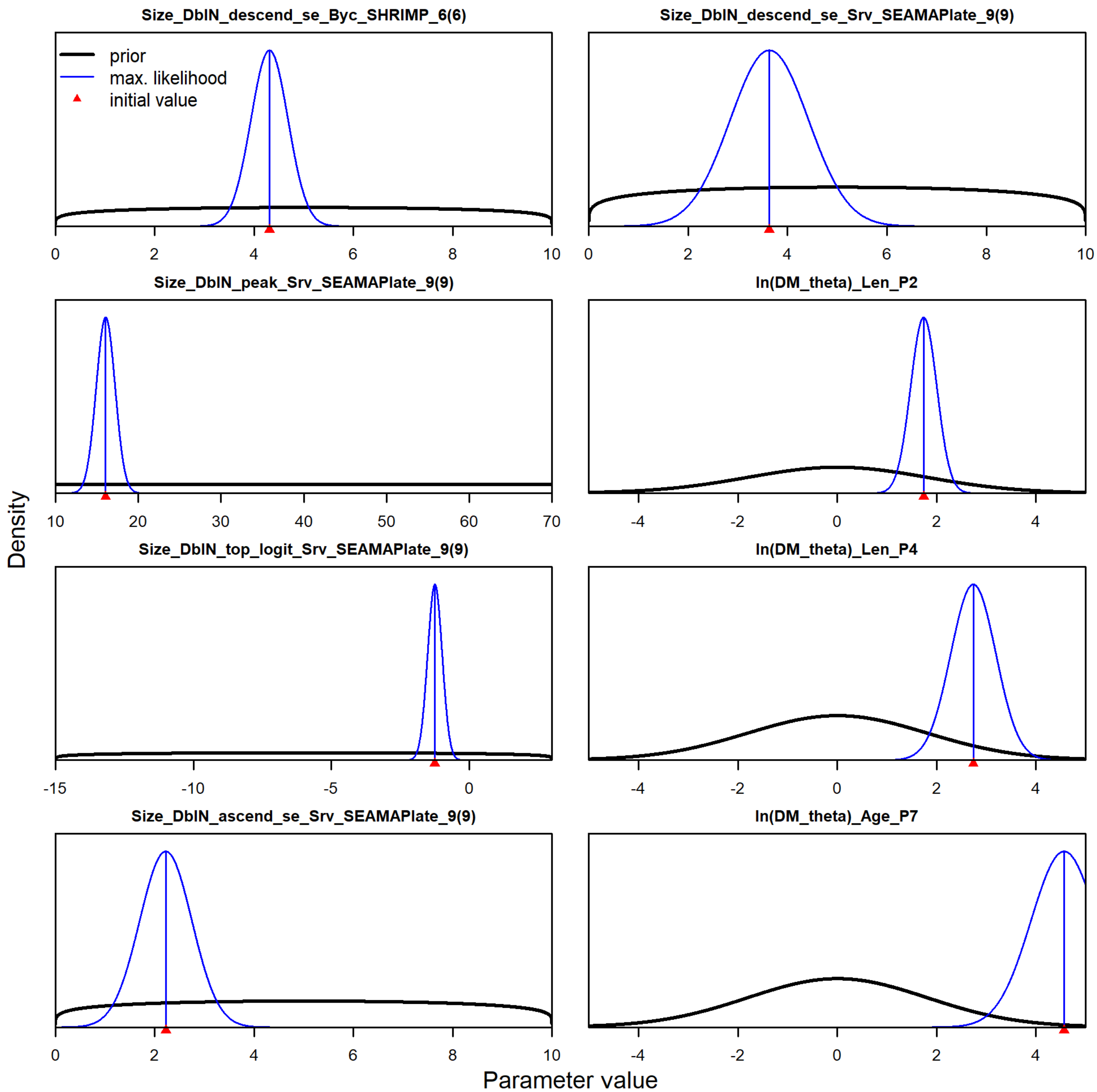


Figure 41 Continued. Parameter distribution (blue line) plots along with starting values (red arrow), bounds (y axis limits), and priors (black lines). Deviation parameters are not included. F parameters are not included. Note: parameter point estimates from a previous model fit were used as the starting values for this final model run.

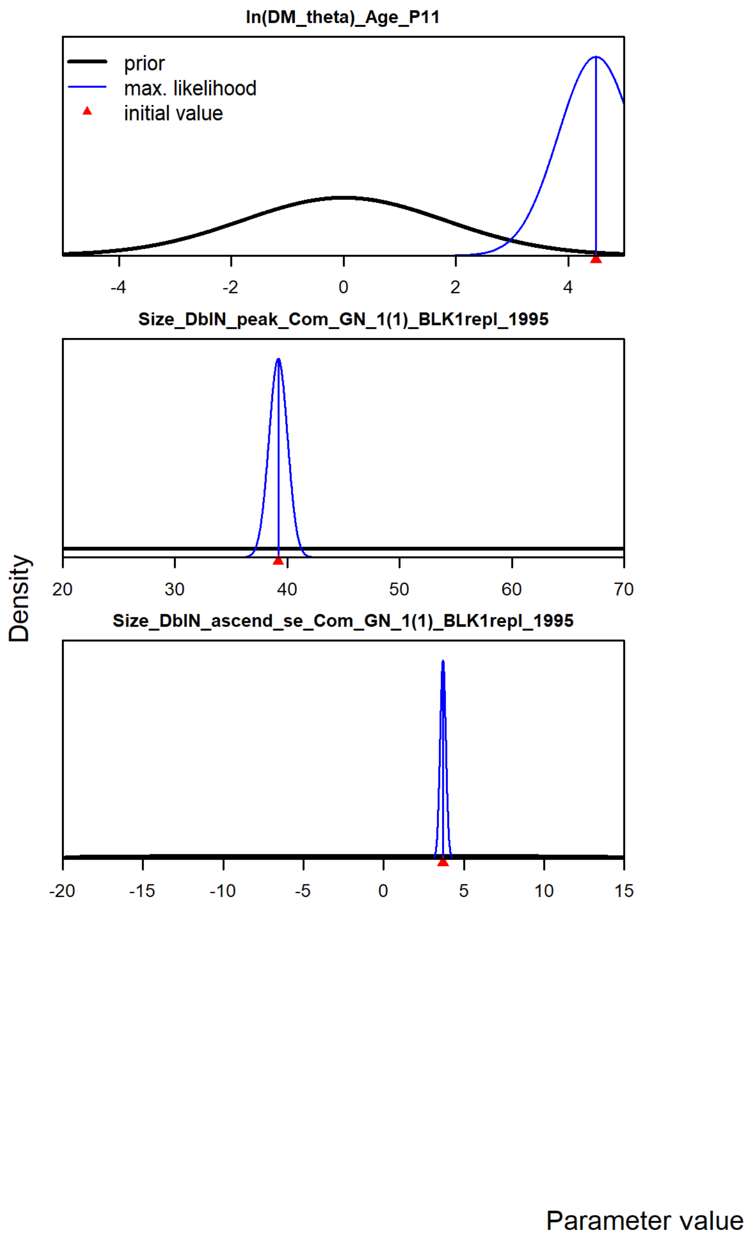
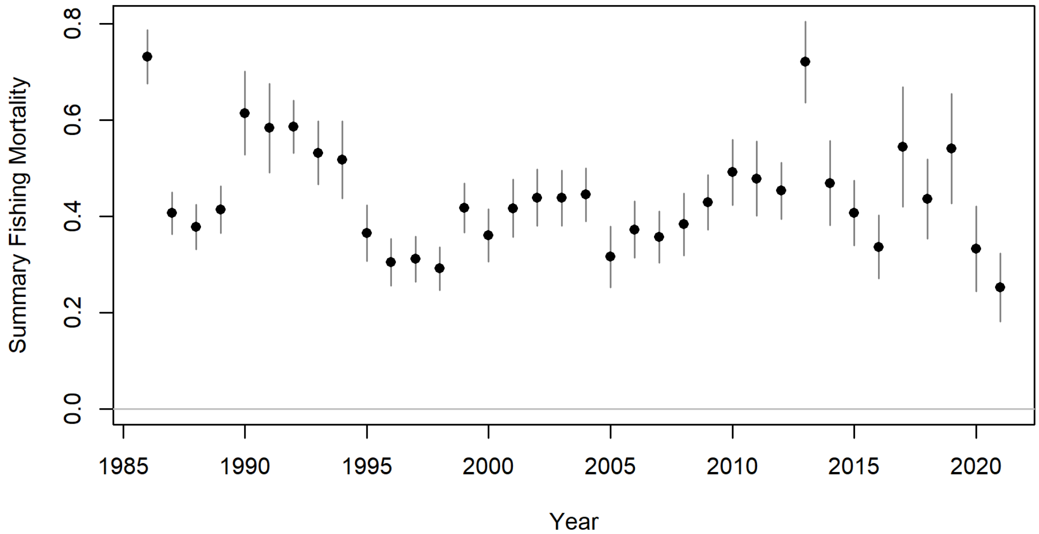


Figure 41 Continued. Parameter distribution (blue line) plots along with starting values (red arrow), bounds (y axis limits), and priors (black lines). Deviation parameters are not included. F parameters are not included. Note: parameter point estimates from a previous model fit were used as the starting values for this final model run.

SEDAR 81



SEDAR 28

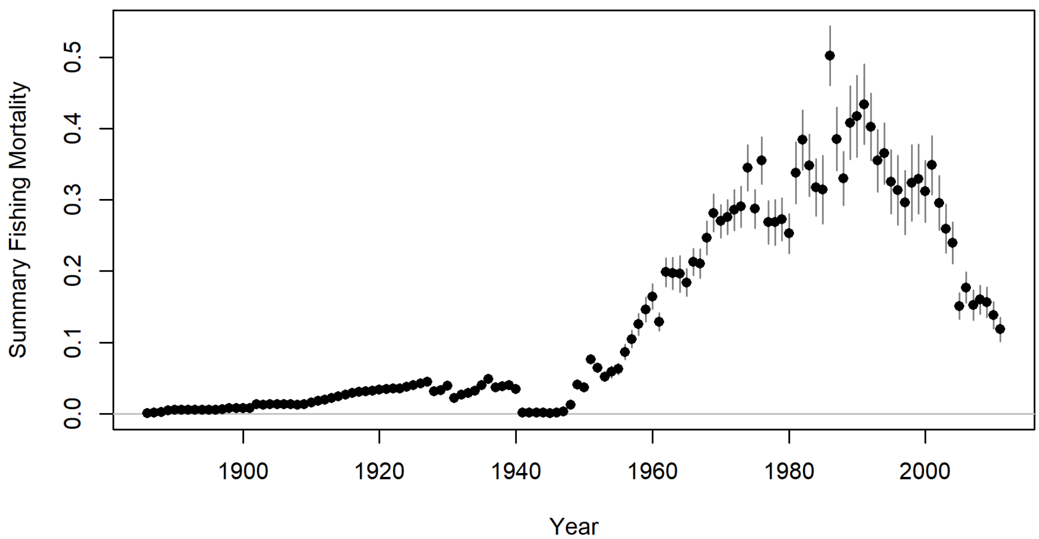
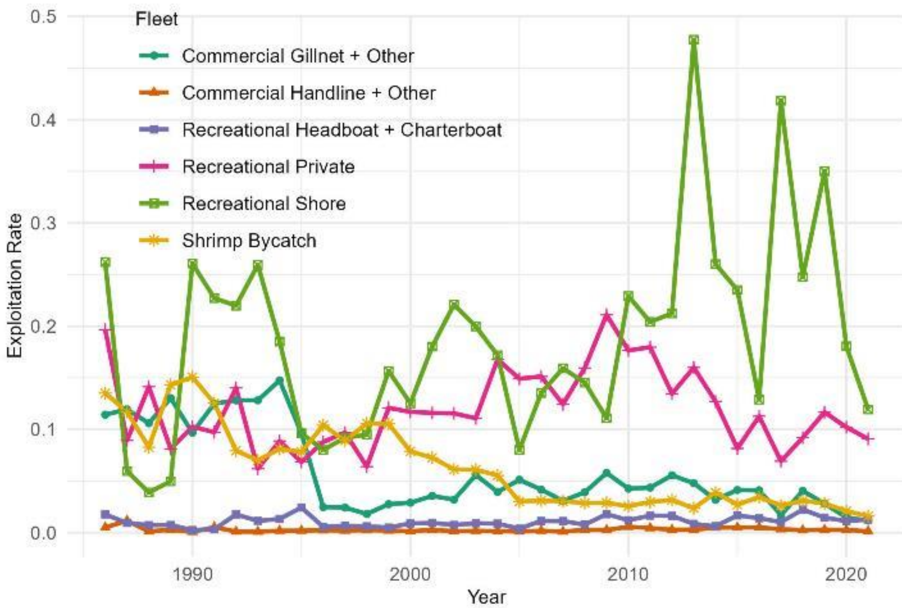


Figure 42. Annual exploitation rate estimates (total biomass killed / total biomass age 1+) for Gulf of Mexico Spanish Mackerel.

SEDAR 81



SEDAR 28

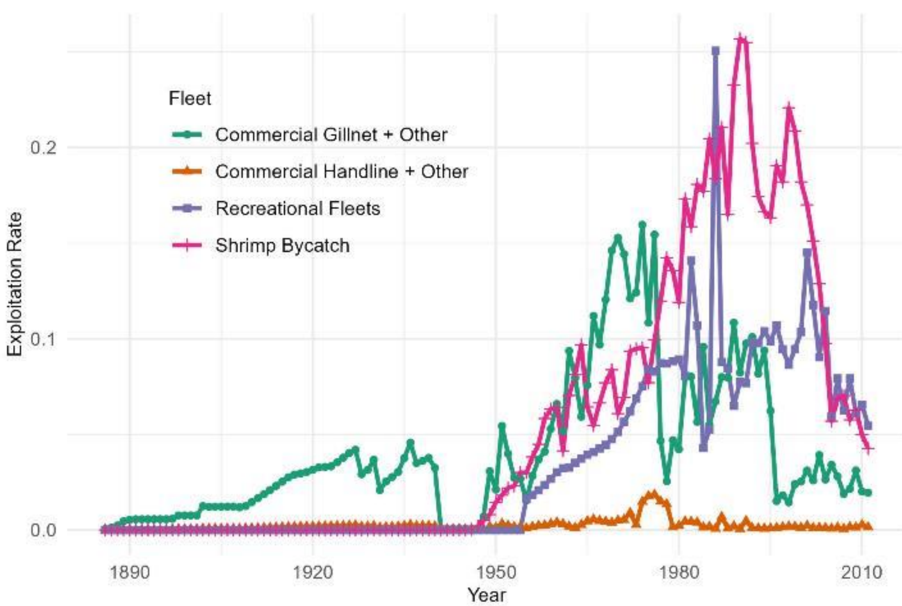
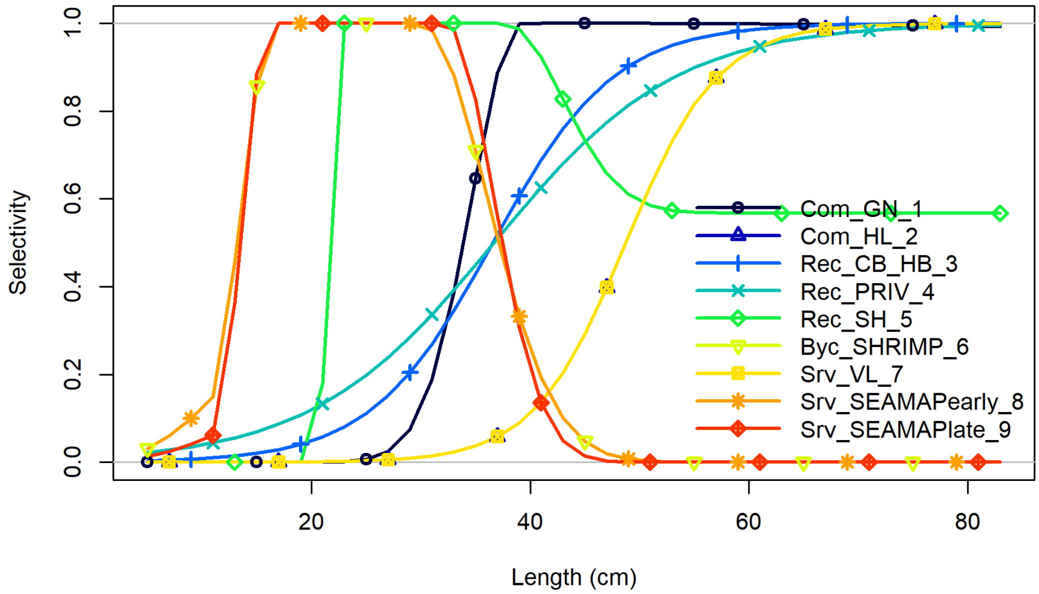


Figure 43. Annual exploitation rate (total biomass killed / total biomass age 1+) by fleet for Gulf of Mexico Spanish Mackerel.

SEDAR 81



SEDAR 28

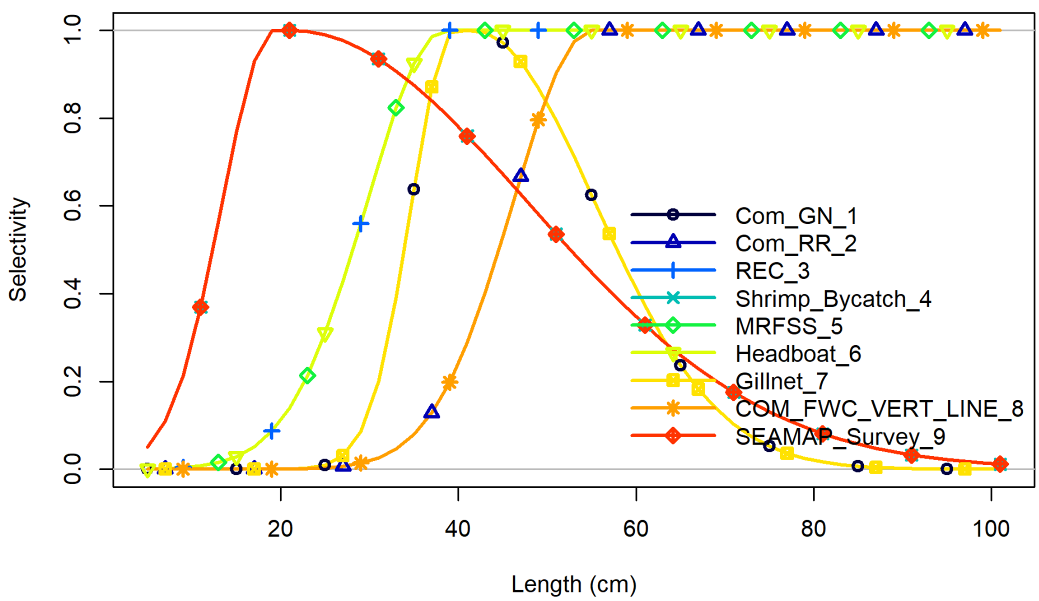
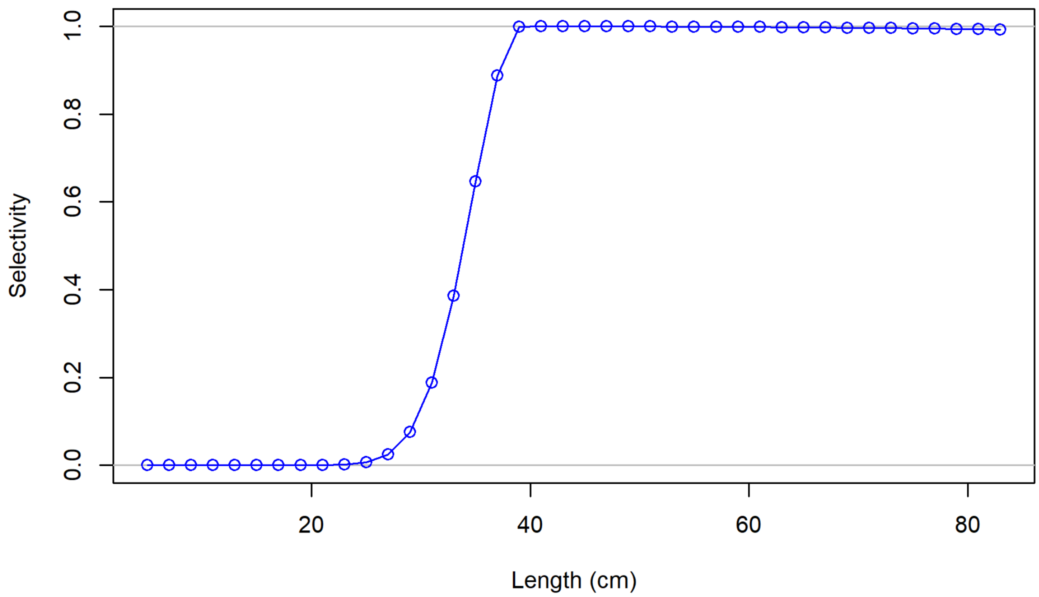


Figure 44. Length-based selectivity for each fleet for Gulf of Mexico Spanish Mackerel in the terminal year of the assessment.

SEDAR 81



SEDAR 28

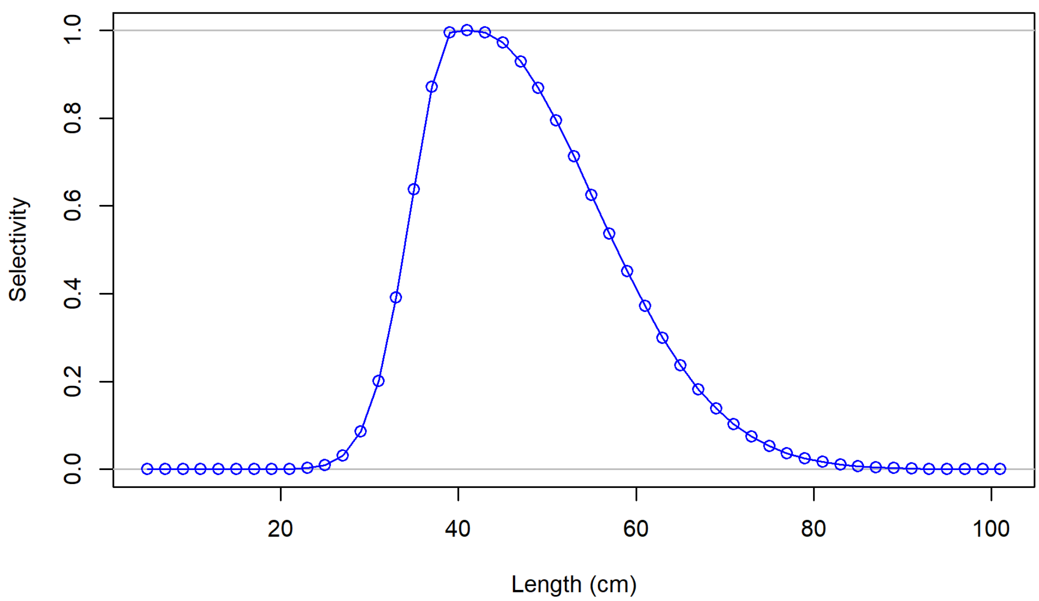
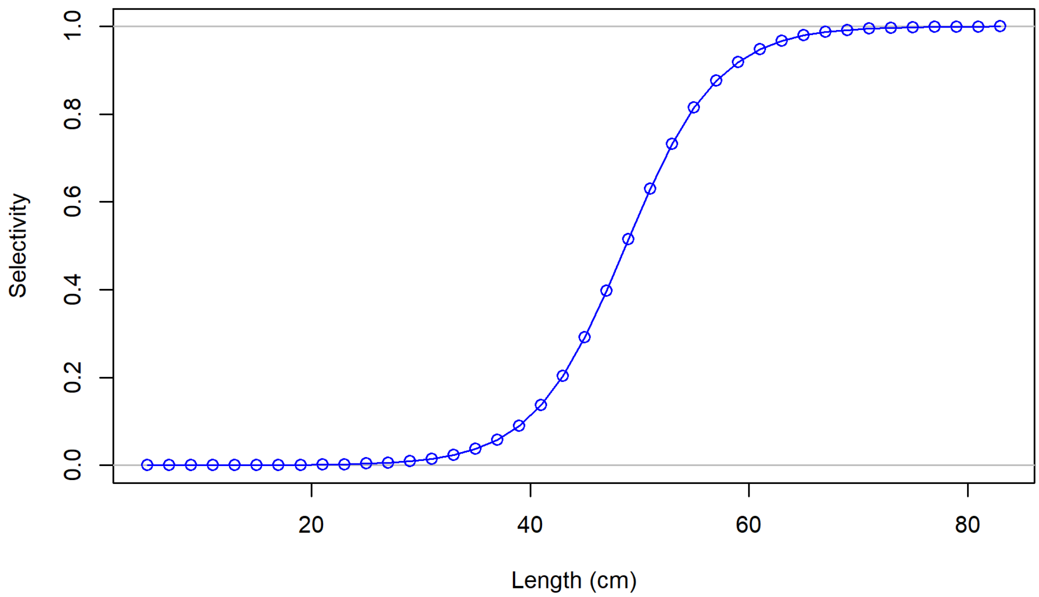


Figure 45. Length-based selectivity for the Commercial Gillnet + Other fleet in the end year of the assessment.

SEDAR 81



SEDAR 28

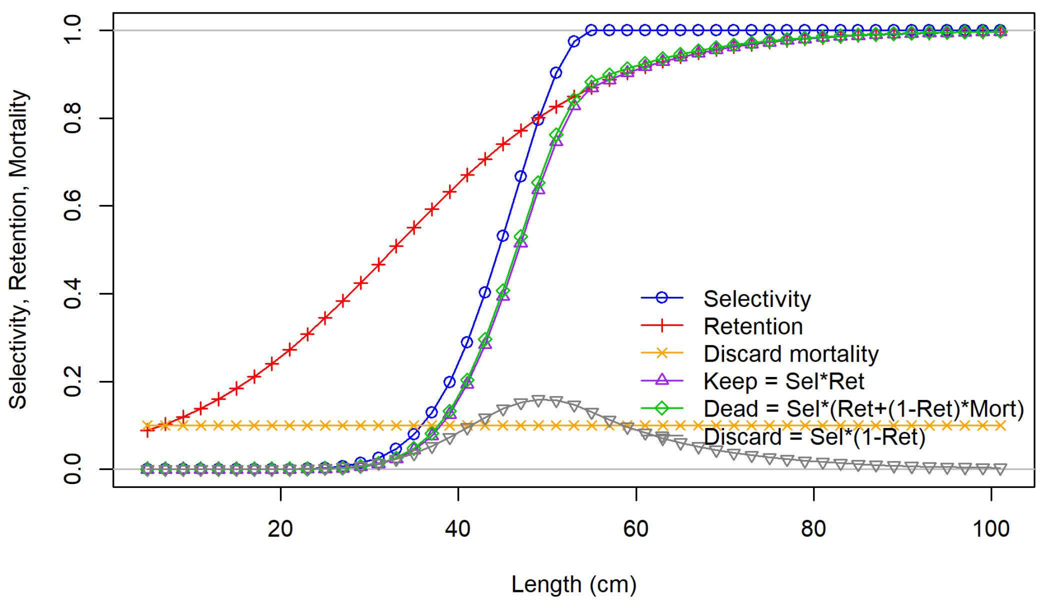
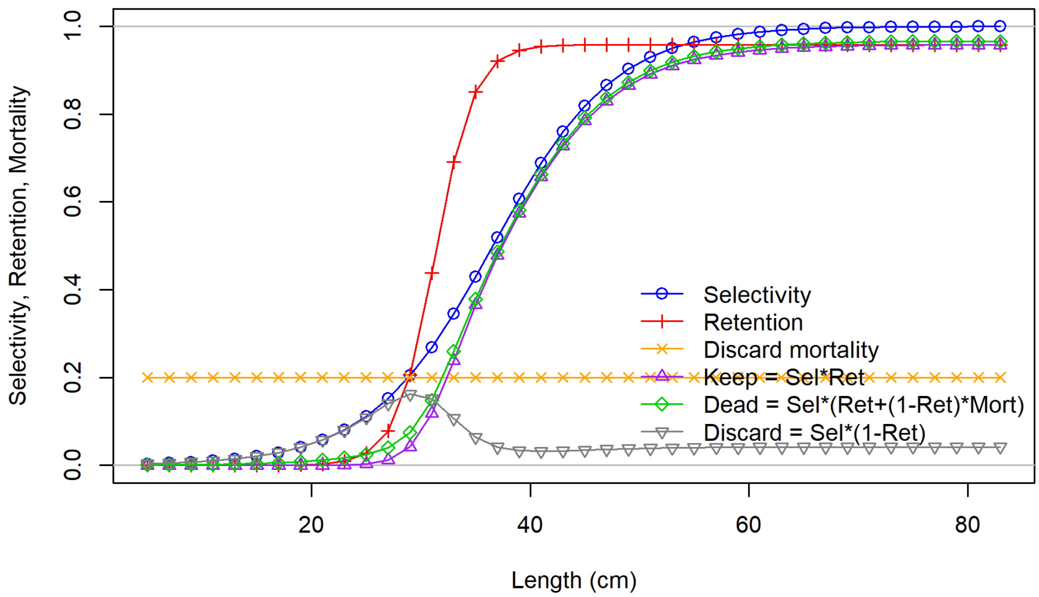


Figure 46. Length-based selectivity for the Commercial Handline + Other fleet. Selectivity (blue line) is constant over the entire assessment time period (1986 - 2021). For SEDAR 28, retention (red line) is shown for the most recent time period (1993+). Discard mortality (orange line) is constant at 10%. For SEDAR 81, Commercial Handline + Other is modelled as landings + dead discards (i.e. no retention curve/discard mortality specified in SS).

SEDAR 81



SEDAR 28

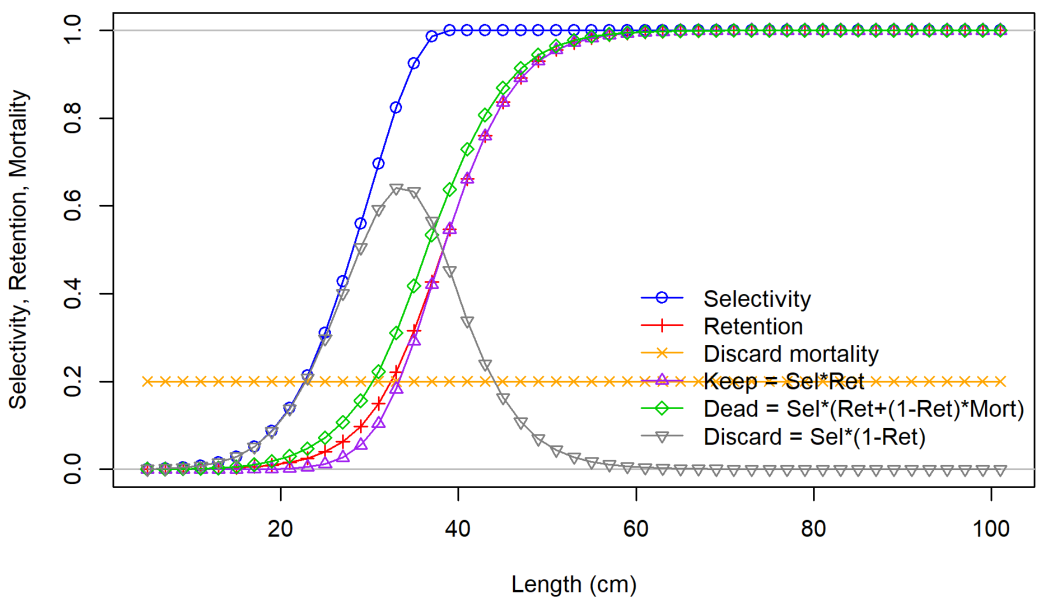
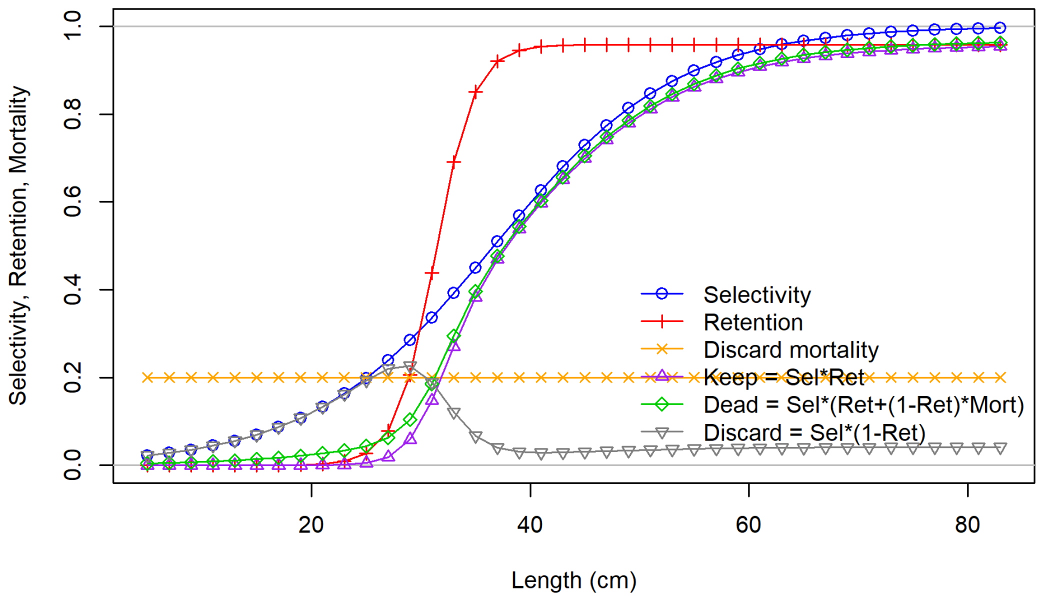


Figure 47. Length-based selectivity for the Recreational Headboat + Charterboat fleet. Selectivity (blue line) is constant over the entire assessment time period (1986 - 2021). Retention (red line) is shown for the most recent time period. Discard mortality (orange line) is constant at 0.2.

SEDAR 81



SEDAR 28

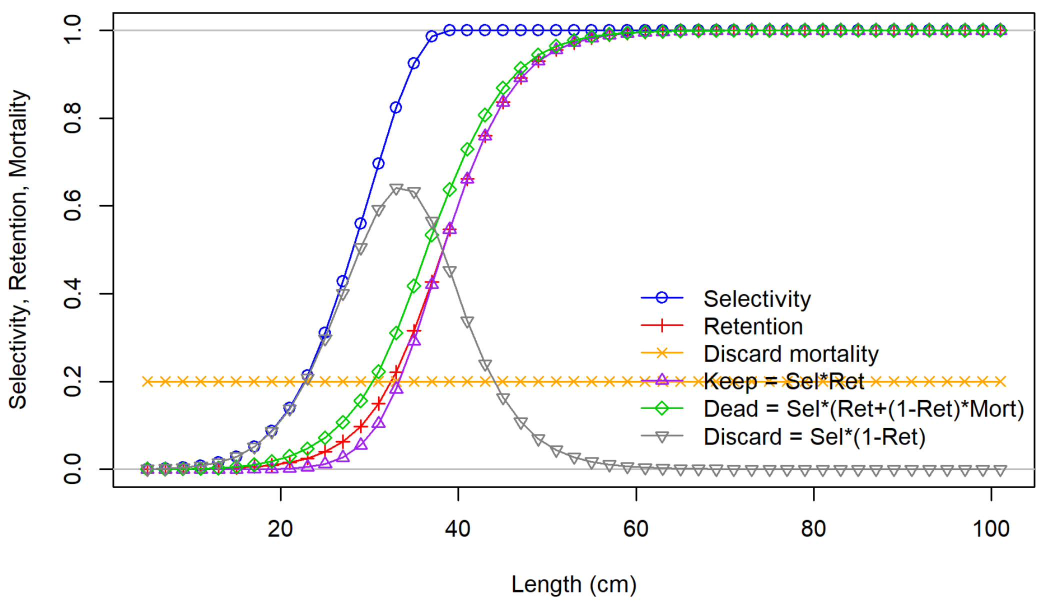
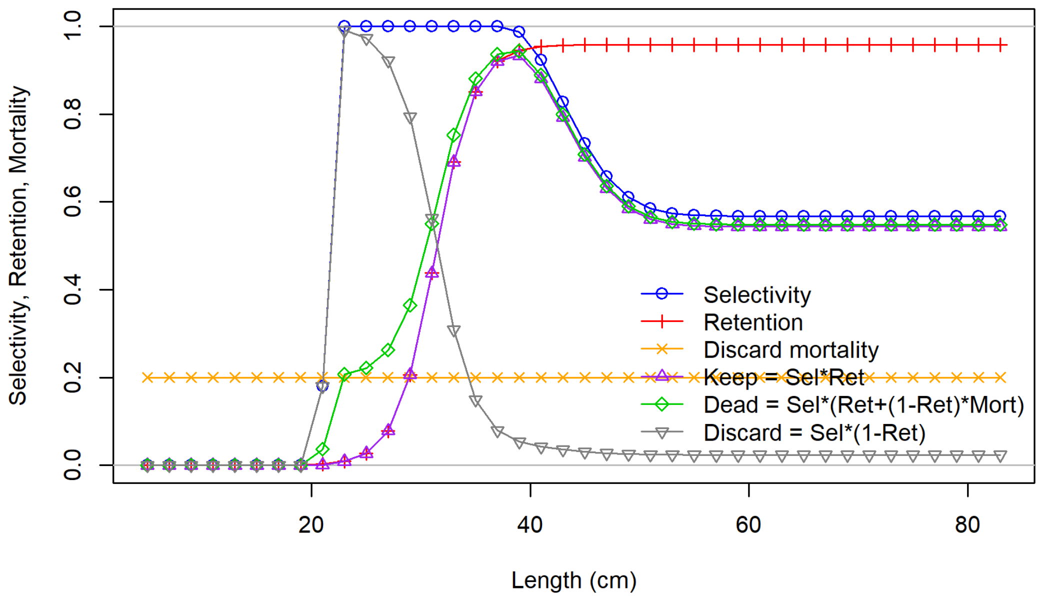


Figure 48. Length-based selectivity for the Recreational Private fleet. Selectivity (blue line) is constant over the entire assessment time period (1986 - 2021). Retention (red line) is shown for the most recent time period. Discard mortality (orange line) is constant at 0.2.

SEDAR 81



SEDAR 28

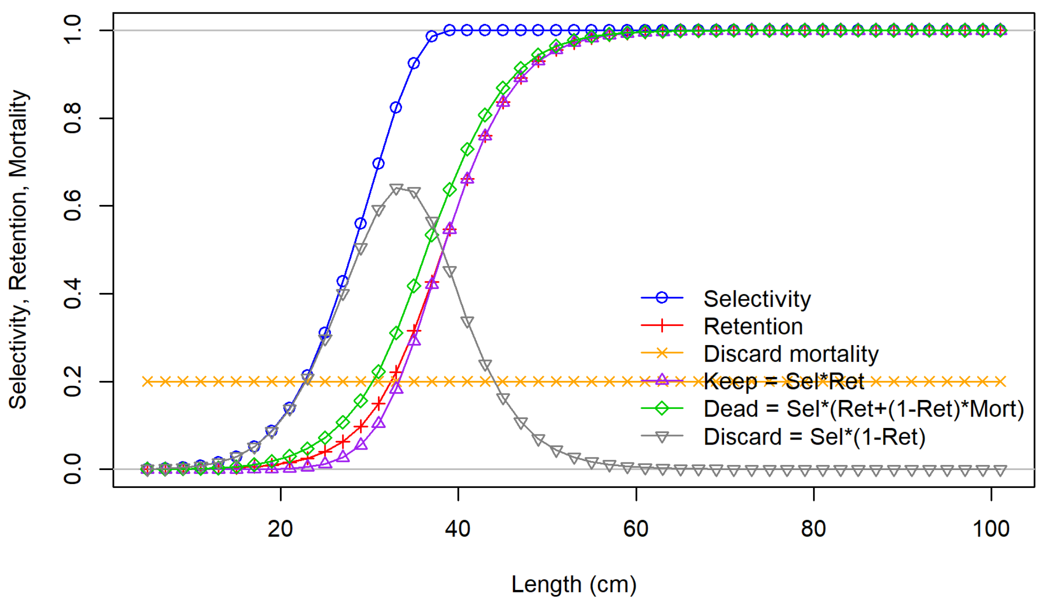


Figure 49. Length-based selectivity for the Recreational Shore fleet. Selectivity (blue line) is constant over the entire assessment time period (1986 - 2021). Retention (red line) is shown for the most recent time period. Discard mortality (orange line) is constant at 0.2.

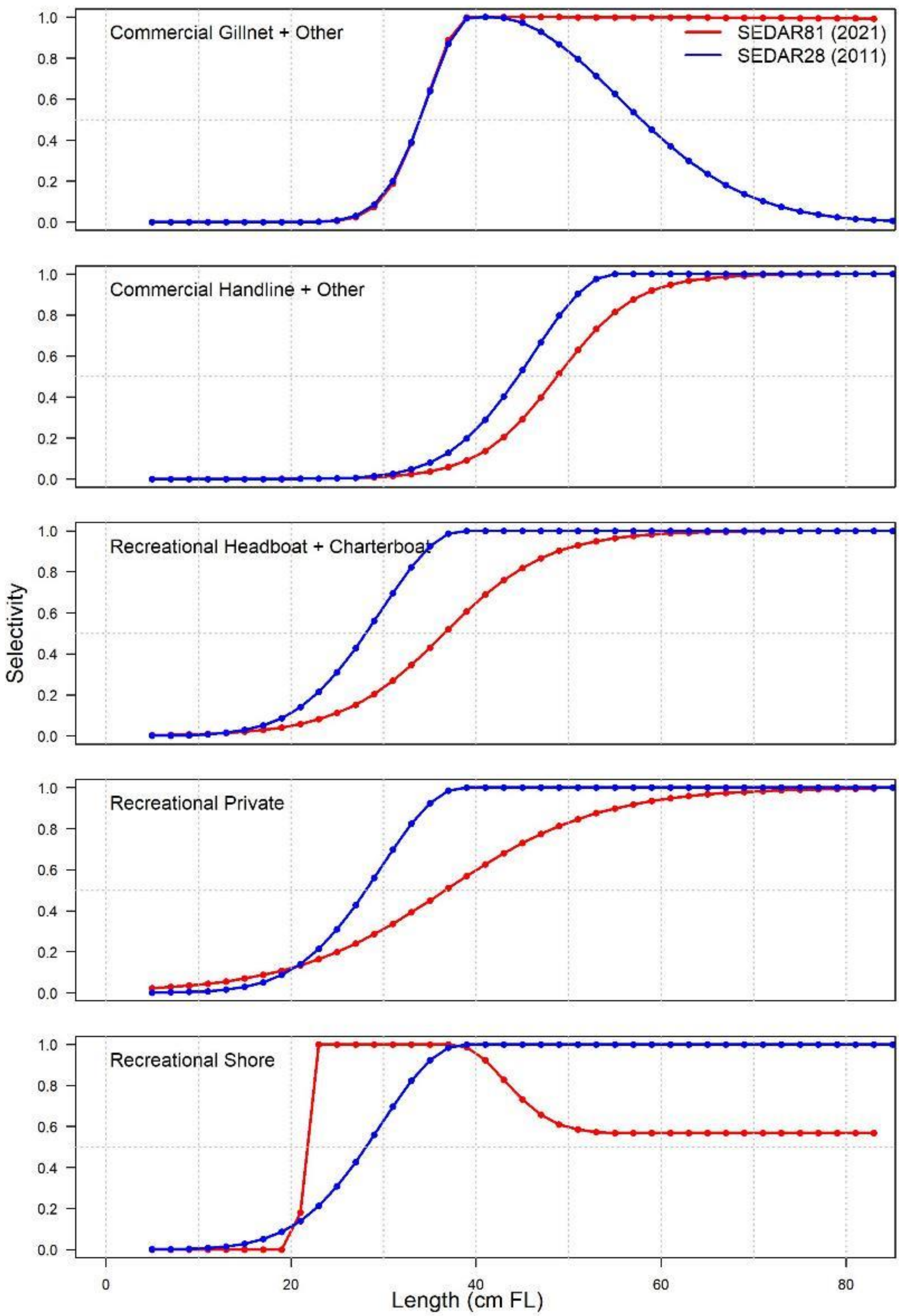


Figure 50. Length-based selectivity for each fleet for Gulf of Mexico Spanish Mackerel in the terminal year of the assessment (given in parentheses). Dashed horizontal line indicates 50%, whereas the dashed vertical lines identify lengths in 10 cm FL intervals. Note: the recreational fleet in SEDAR 28 was modelled as a single fleet with all modes aggregated.

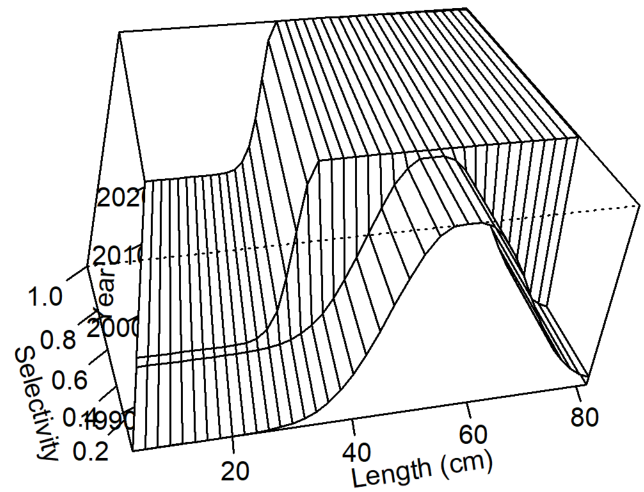


Figure 51. Time varying selectivity (1995 time block) for the Commercial Gillnet + Other fleet.

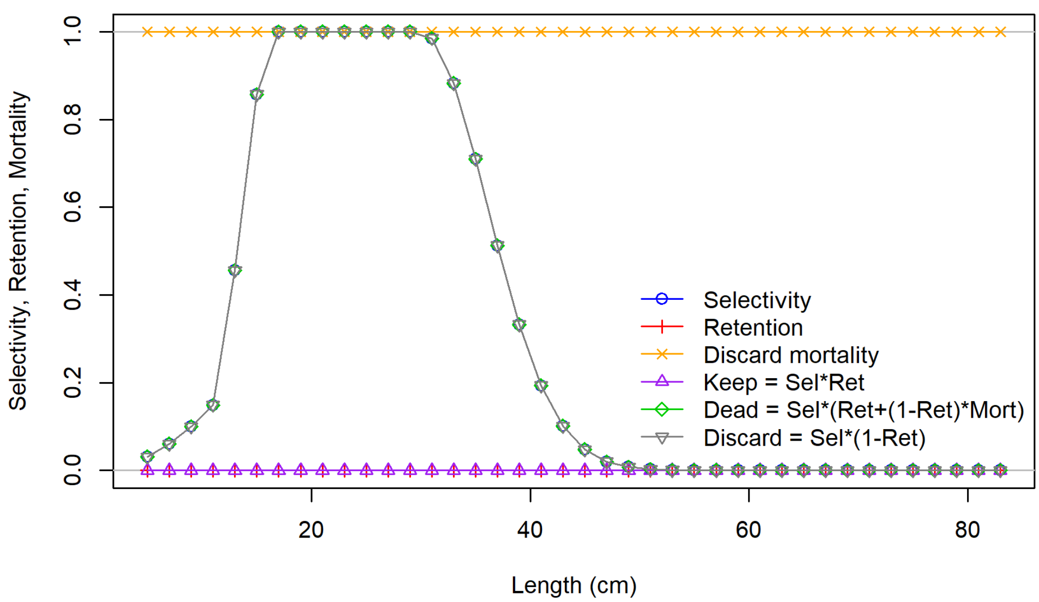


Figure 52. Length-based selectivity for the Shrimp Bycatch fleet. Selectivity is constant over the entire assessment time period (1986 - 2021). All selected fish are discarded.

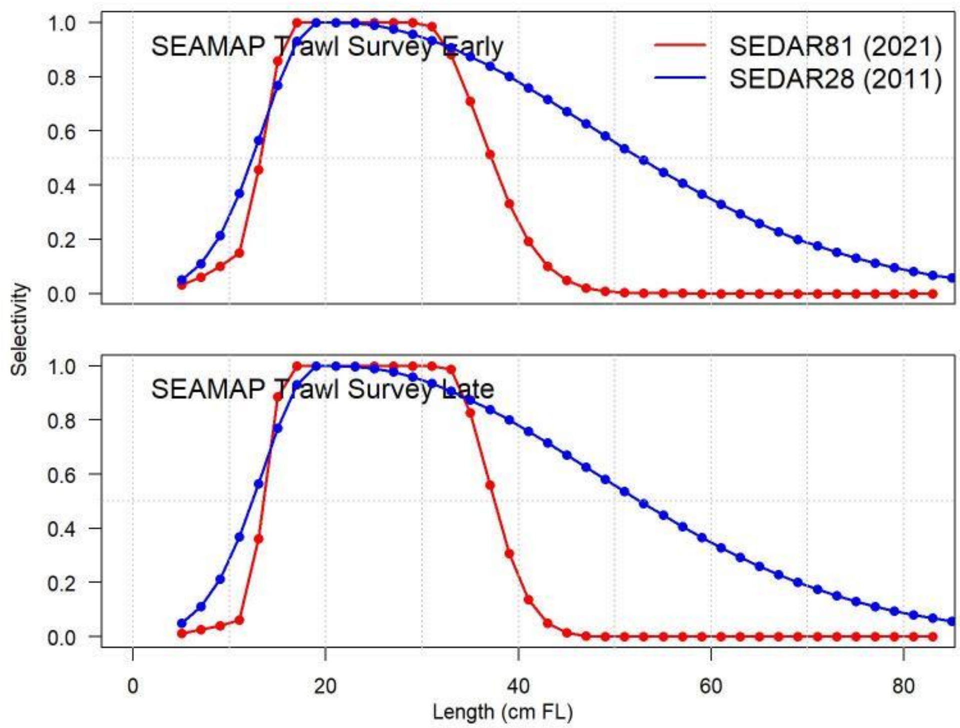


Figure 53. Length-based selectivity for each SEAMAP survey for Gulf of Mexico Spanish Mackerel for SEDAR 28 vs. SEDAR 81. Dashed horizontal line indicates 50%, whereas the dashed vertical lines identify lengths in 10 cm FL intervals.

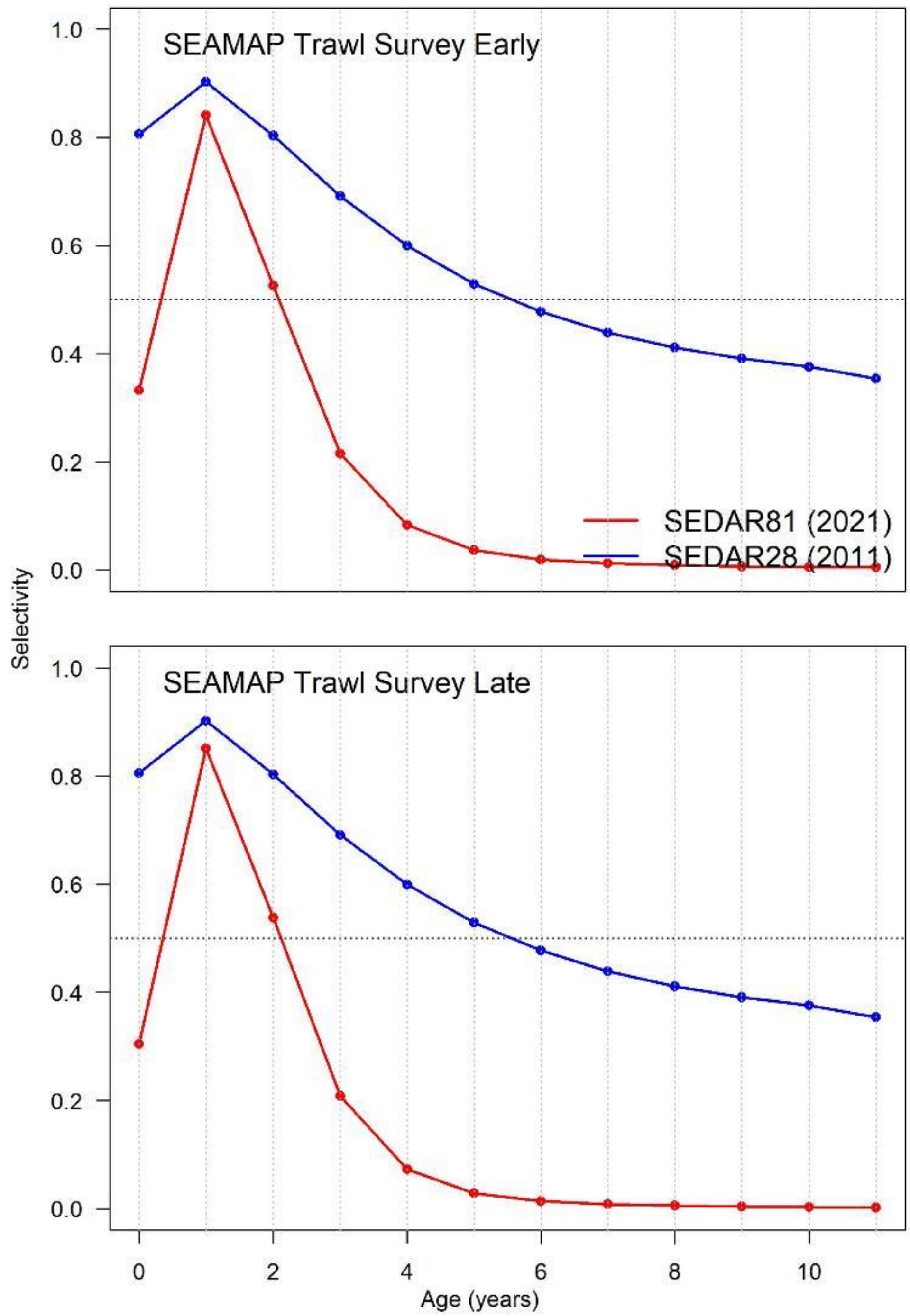


Figure 54. Derived age-based selectivity for each survey for Gulf of Mexico Spanish Mackerel for SEDAR 28 vs. SEDAR 81.

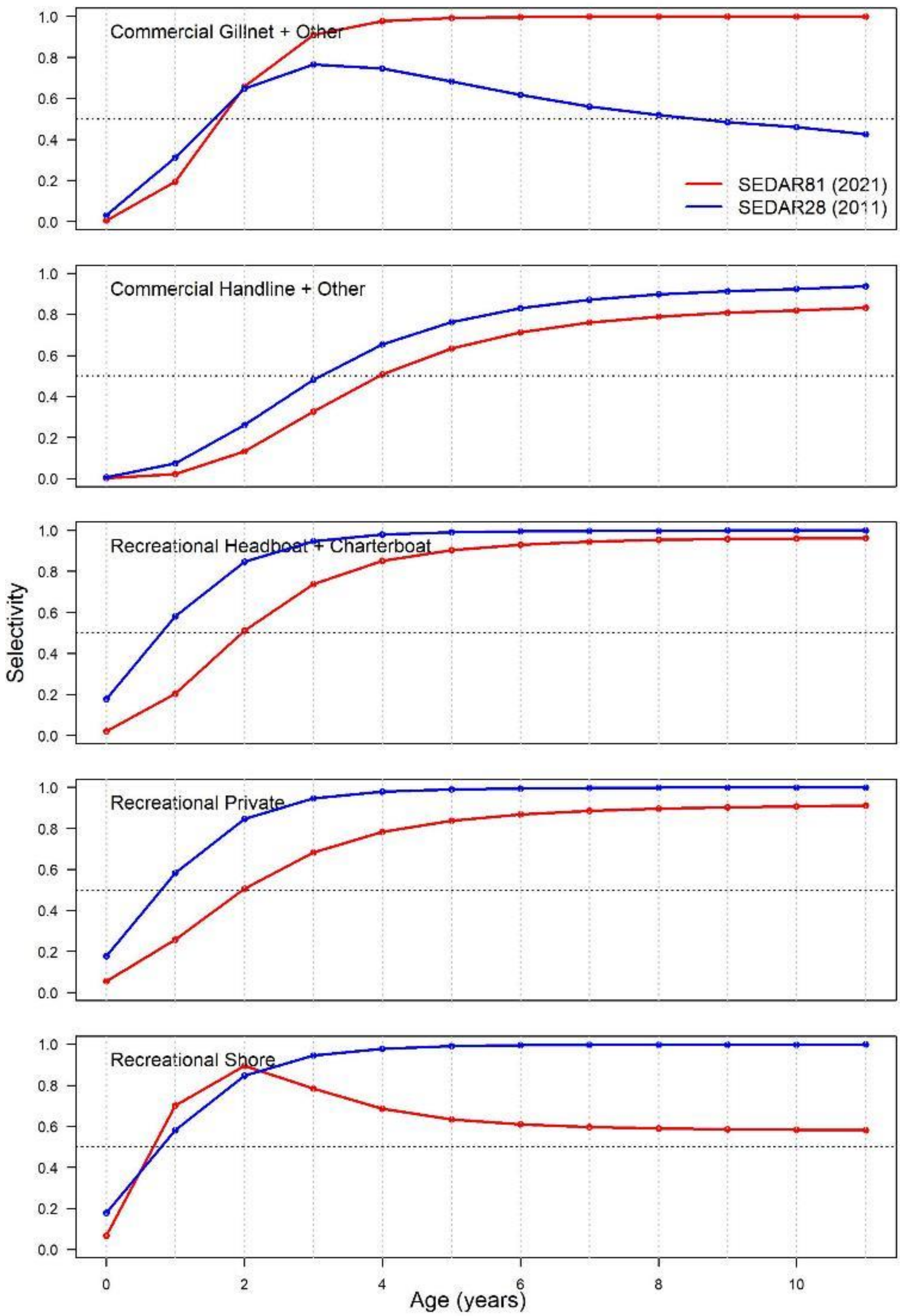


Figure 55. Derived age-based selectivity for each fleet for Gulf of Mexico Spanish Mackerel in the terminal year of the assessment for SEDAR 28 vs. SEDAR 81.

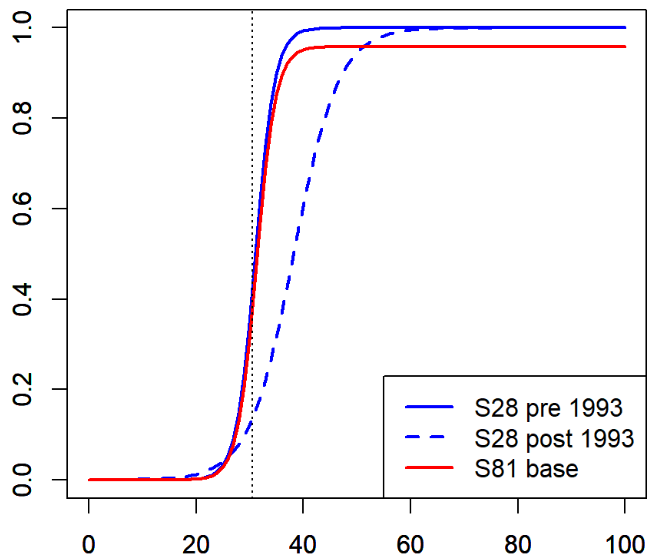
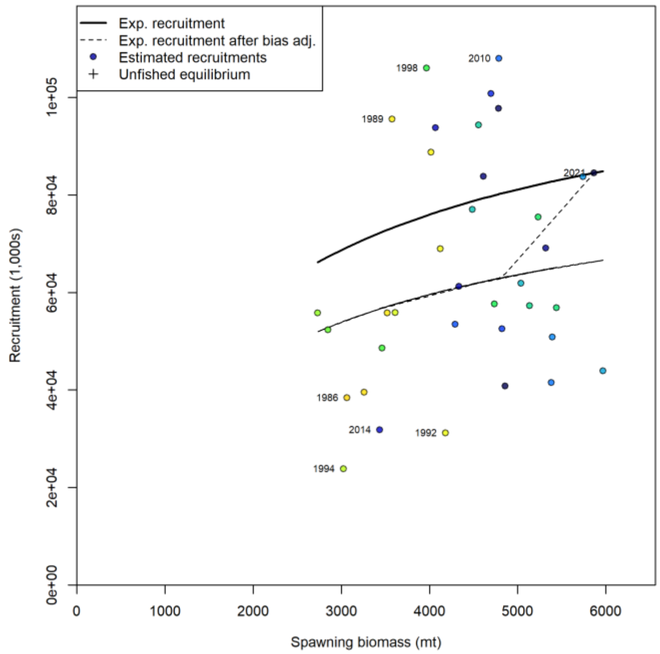


Figure 56. Retention functions for the recreational fleets for Gulf of Mexico Spanish Mackerel from SEDAR 81 and SEDAR 28. Note: the size limit time block was erroneously set to 1993 instead of 1983 in SEDAR 28.

SEDAR 81



SEDAR 28

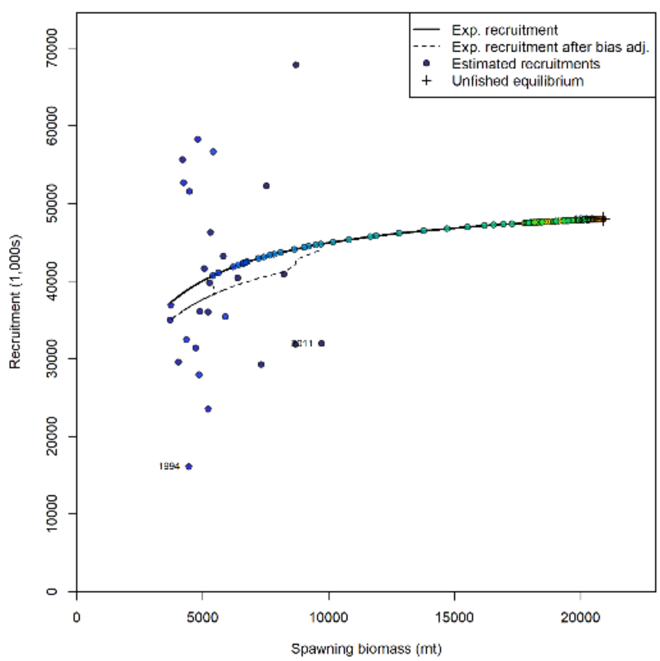
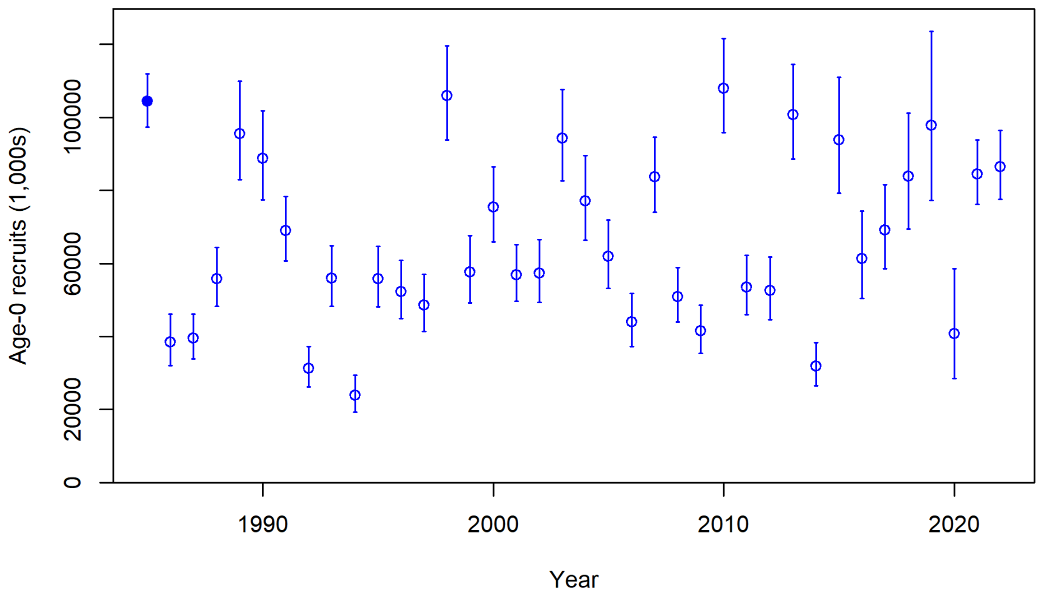


Figure 57. Predicted stock-recruitment relationship for Gulf of Mexico Spanish Mackerel (steepness and SigmaR were fixed at 0.8 and 0.7, respectively). Plotted are predicted annual recruitments from Stock Synthesis (circles), expected recruitment from the stock-recruit relationship (black line), and bias adjusted recruitment from the stock-recruit relationship (dashed line).

SEDAR 81



SEDAR 28

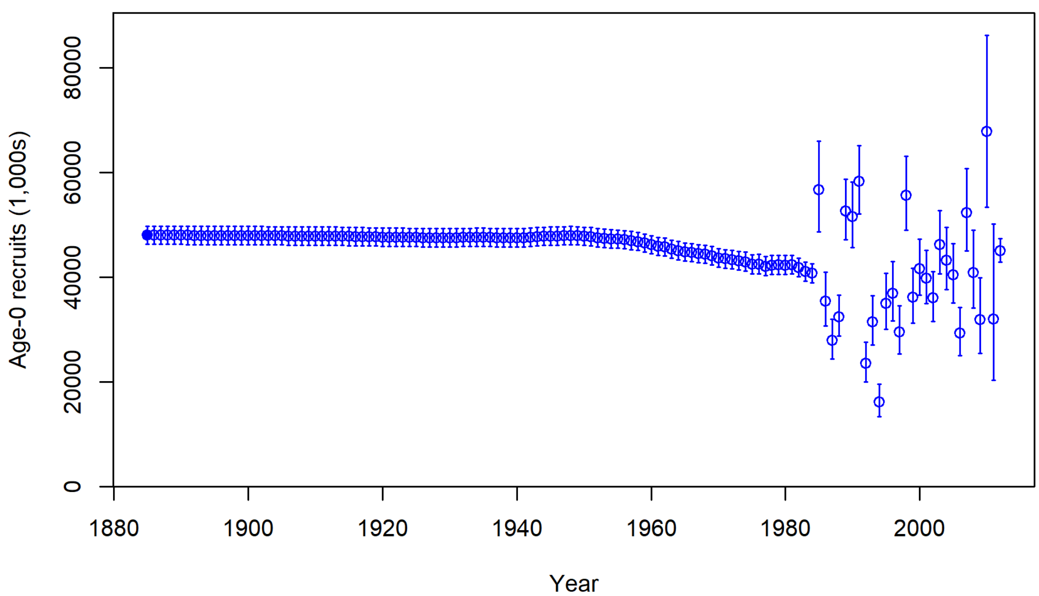
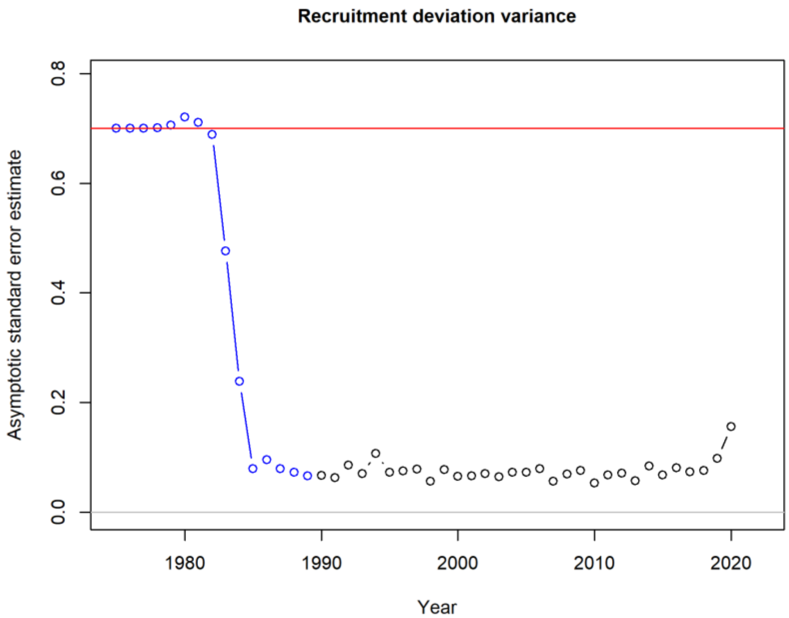


Figure 58. Estimated Age-0 recruitment with 95% confidence intervals for Gulf of Mexico Spanish Mackerel (steepness and SigmaR were fixed at 0.8 and 0.7, respectively).

SEDAR 81



SEDAR 28

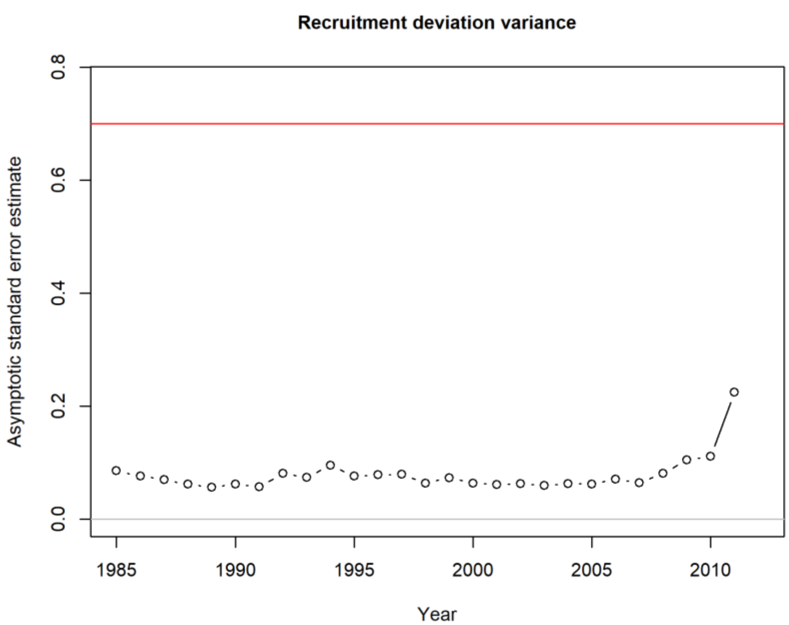


Figure 59. Asymptotic standard errors for recruitment deviations for Gulf of Mexico Spanish Mackerel. The red line represents the fixed value of SigmaR of 0.7 used in the SEDAR 81 and SEDAR 28 models.

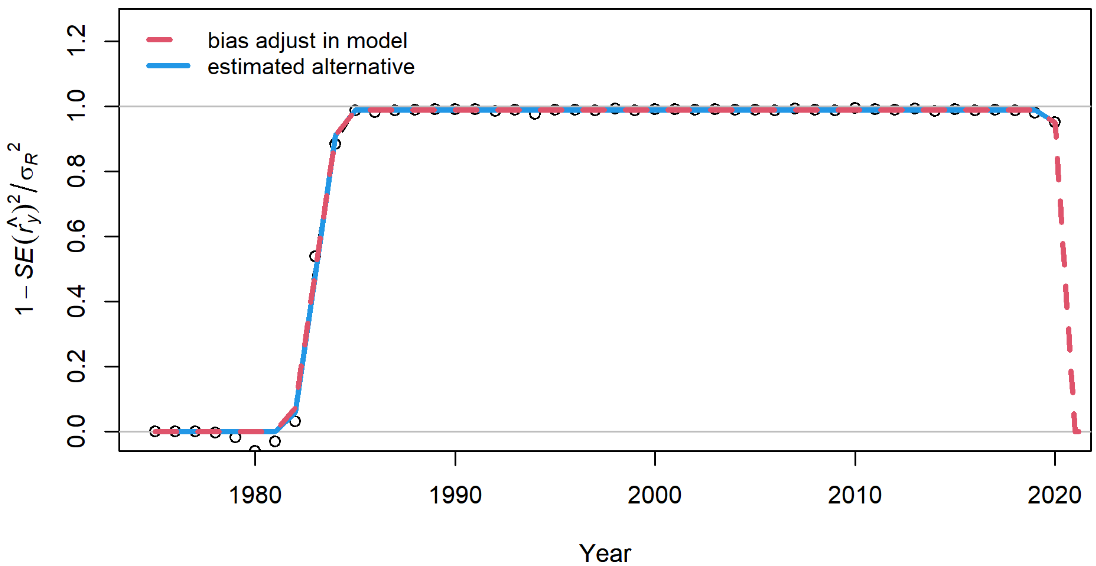
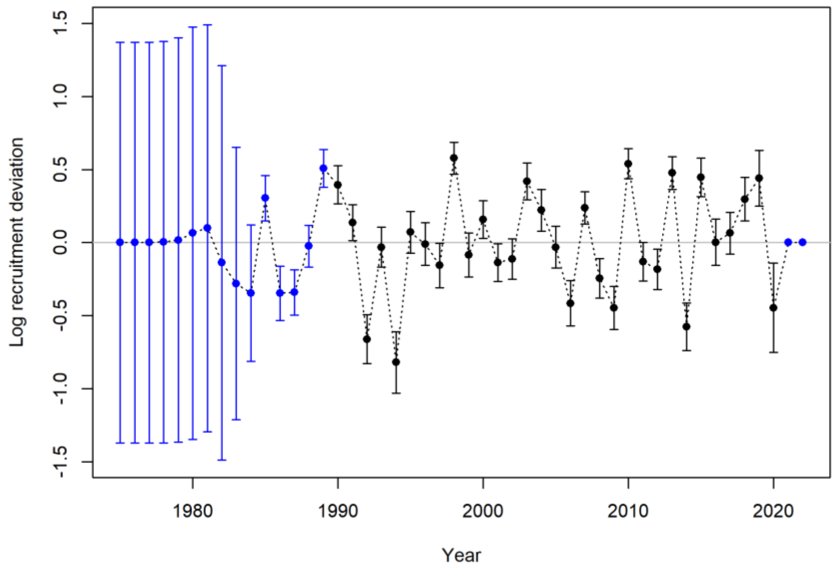


Figure 60. Points are transformed variances. Red line shows current settings for bias adjustment specified for the Base Run, which coincides with the least squares estimate of alternative bias adjustment relationship for recruitment deviations (dashed orange line). For more information, see Methot and Taylor 2011.

SEDAR 81



SEDAR 28

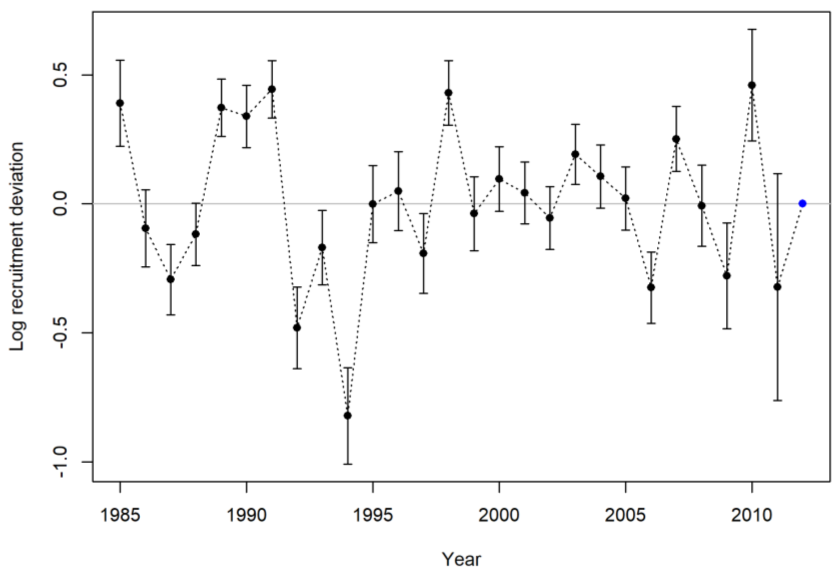


Figure 61. Estimated log recruitment deviations for Gulf of Mexico Spanish Mackerel (steepness and SigmaR were fixed at 0.8 and 0.7, respectively).

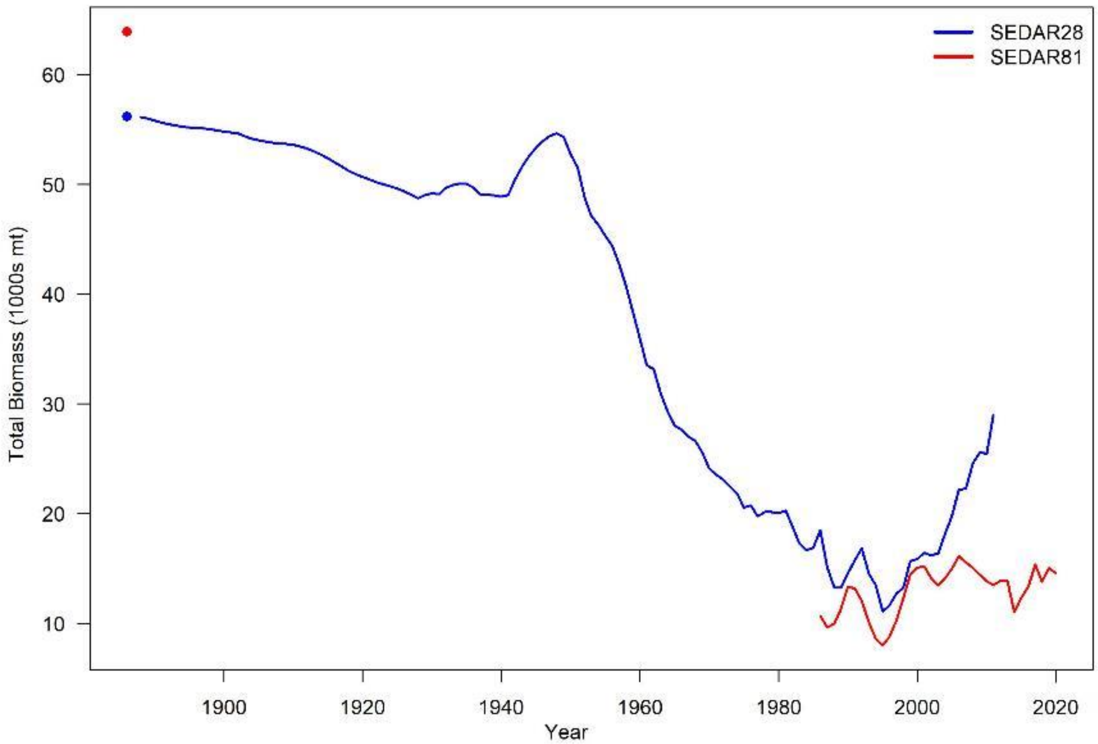


Figure 62. Estimate of total biomass (in 1000s of metric tons) for Gulf of Mexico Spanish Mackerel.

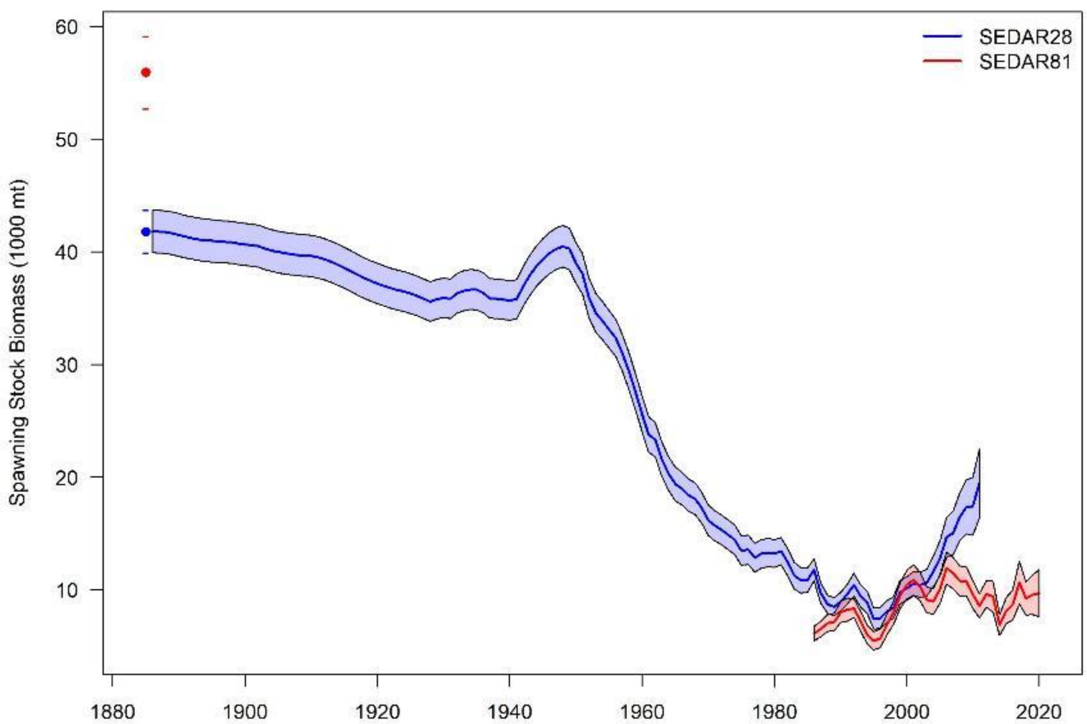


Figure 63. Estimate of spawning stock biomass (in 1000s of metric tons) and associated 95% confidence intervals for Gulf of Mexico Spanish Mackerel.

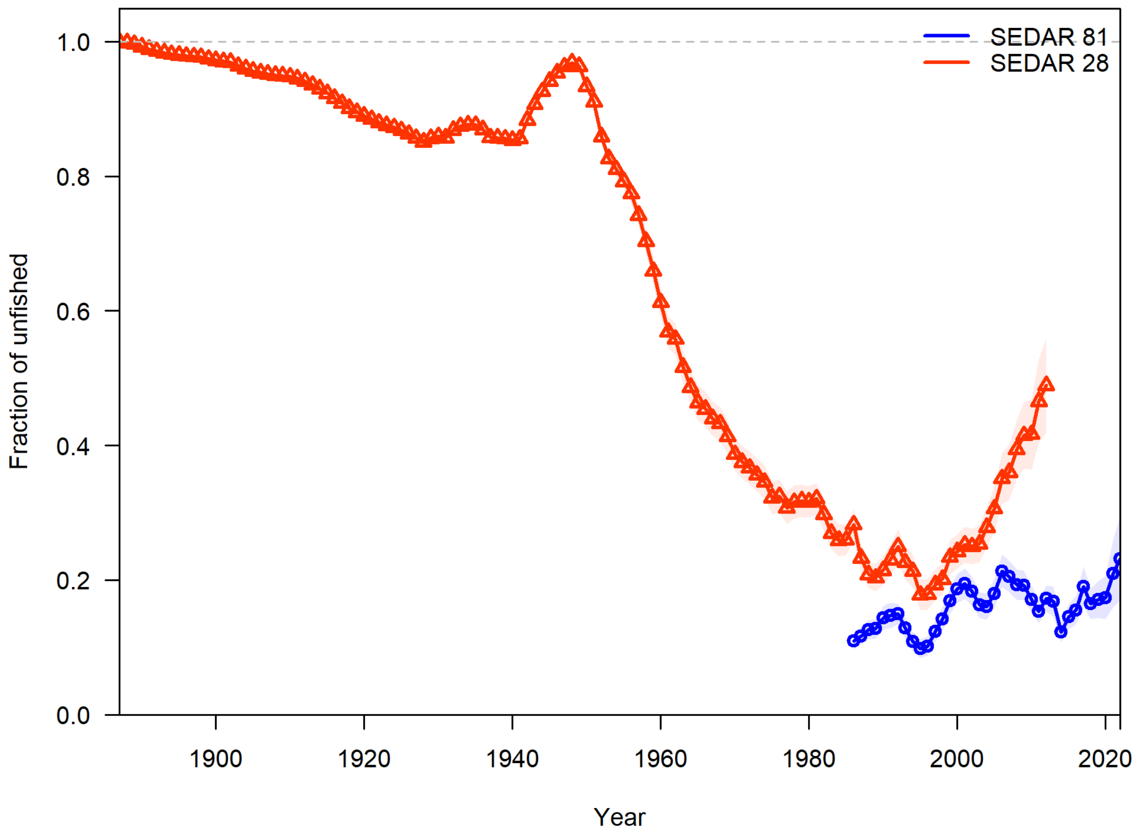


Figure 64. Differences in estimates of fraction of unfished SSB (SSB/SSB0) and associated 95% confidence intervals for Gulf of Mexico Spanish Mackerel between SEDAR 28 and SEDAR 81.

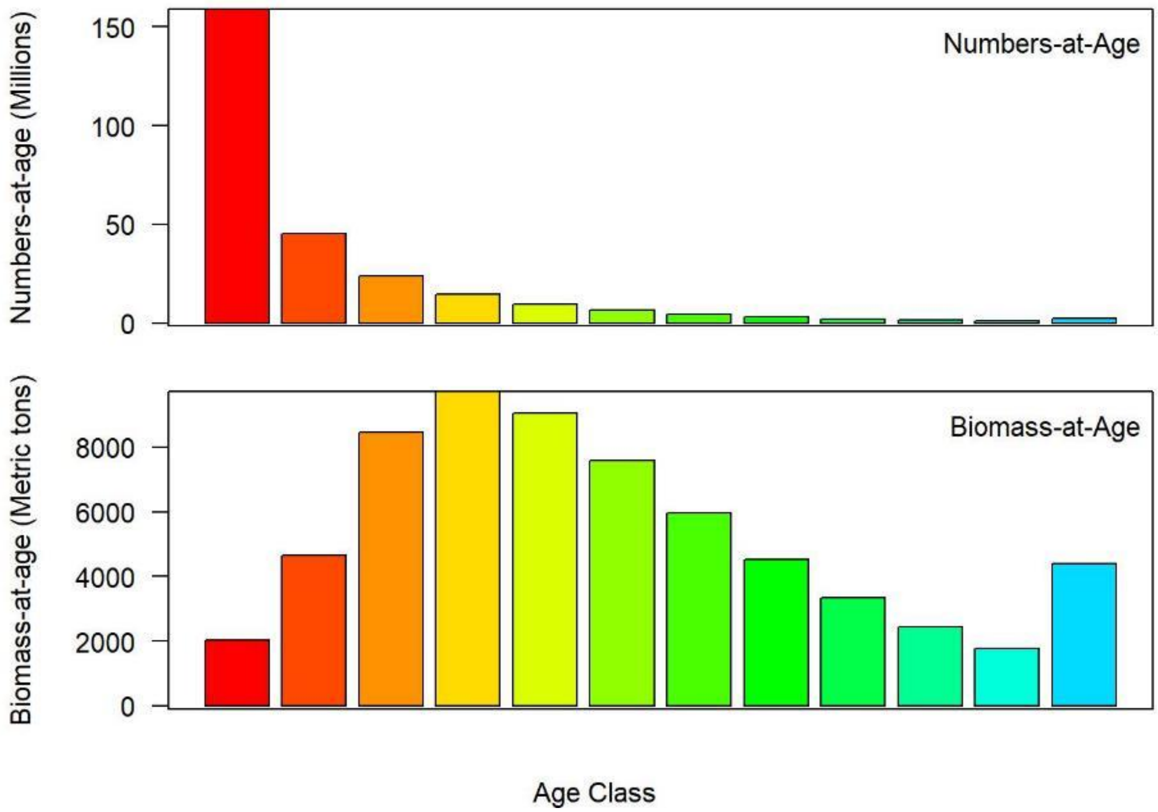
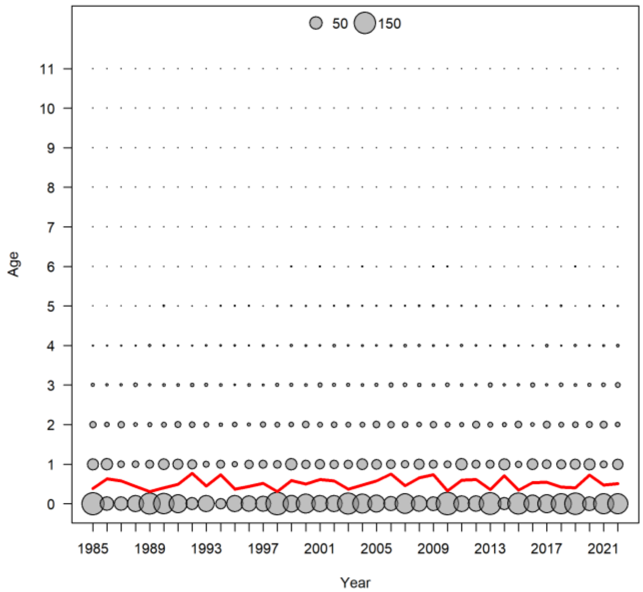


Figure 65. Expected numbers-at-age and biomass-at-age for female and male Spanish Mackerel in the Gulf of Mexico at virgin stock conditions.

SEDAR 81



SEDAR 28

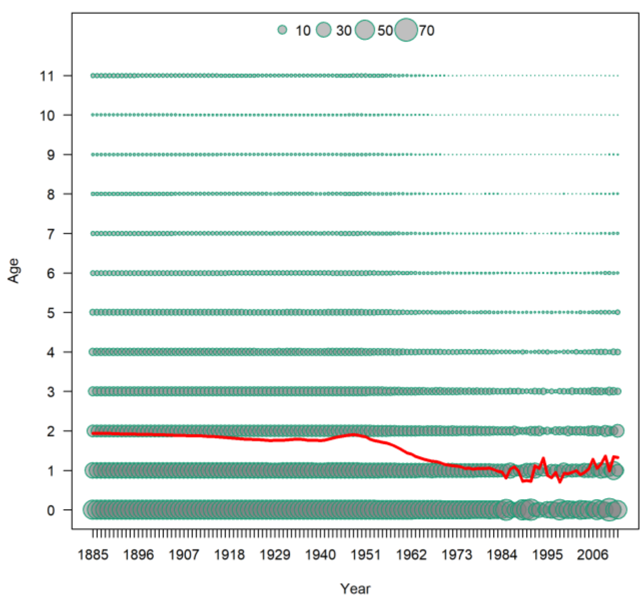


Figure 66. Predicted beginning of year mean age in the population for Gulf of Mexico Spanish Mackerel.

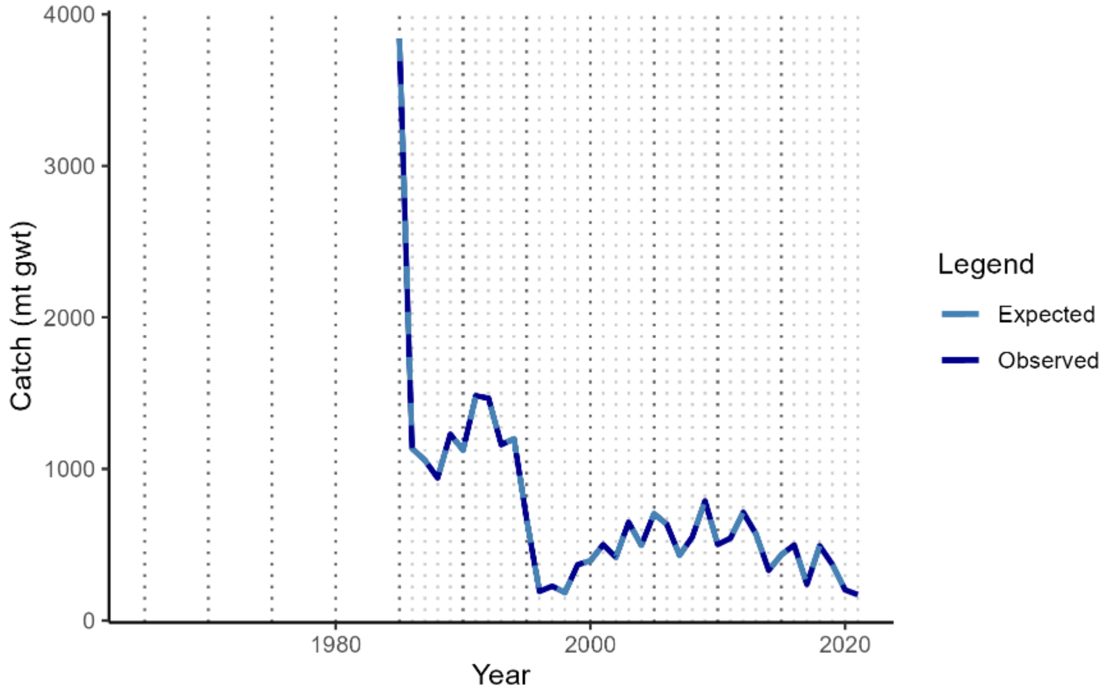


Figure 67. Observed and expected landings by the Commercial Gillnet + Other fleet for Gulf of Mexico Spanish Mackerel. The model starts in fished conditions 1986. 1985 shows equilibrium catches at the start of the model.

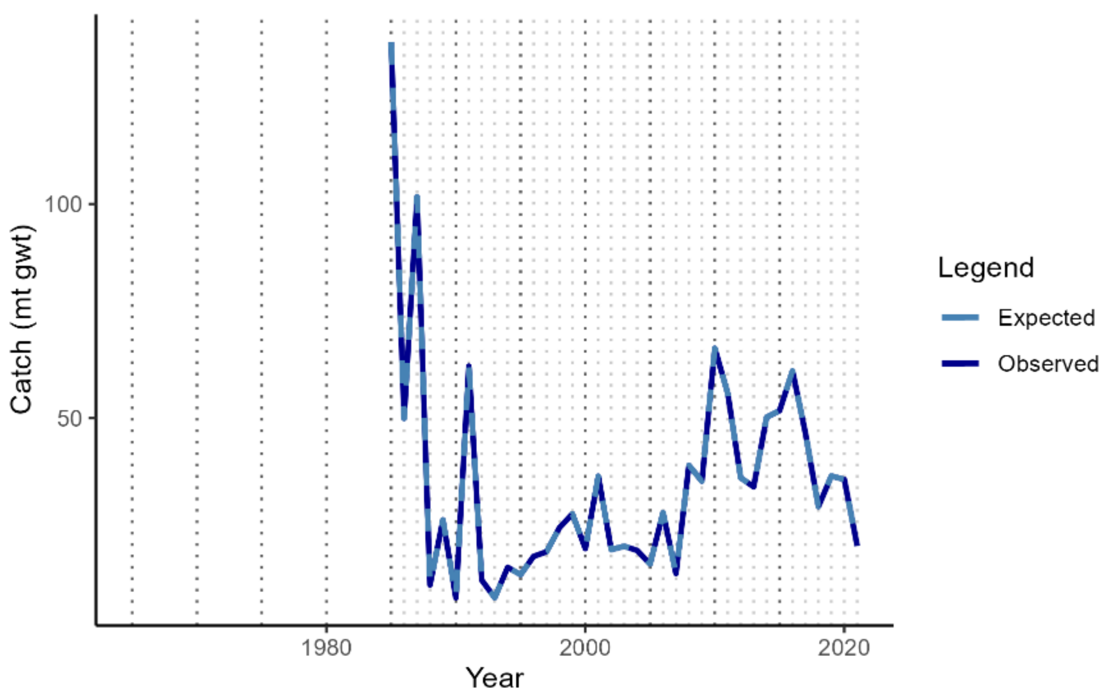


Figure 68. Observed and expected total catch (landings + dead discards) by the Commercial Handline + Other fleet for Gulf of Mexico Spanish Mackerel. The model starts in fished conditions 1986. 1985 shows equilibrium catches at the start of the model.

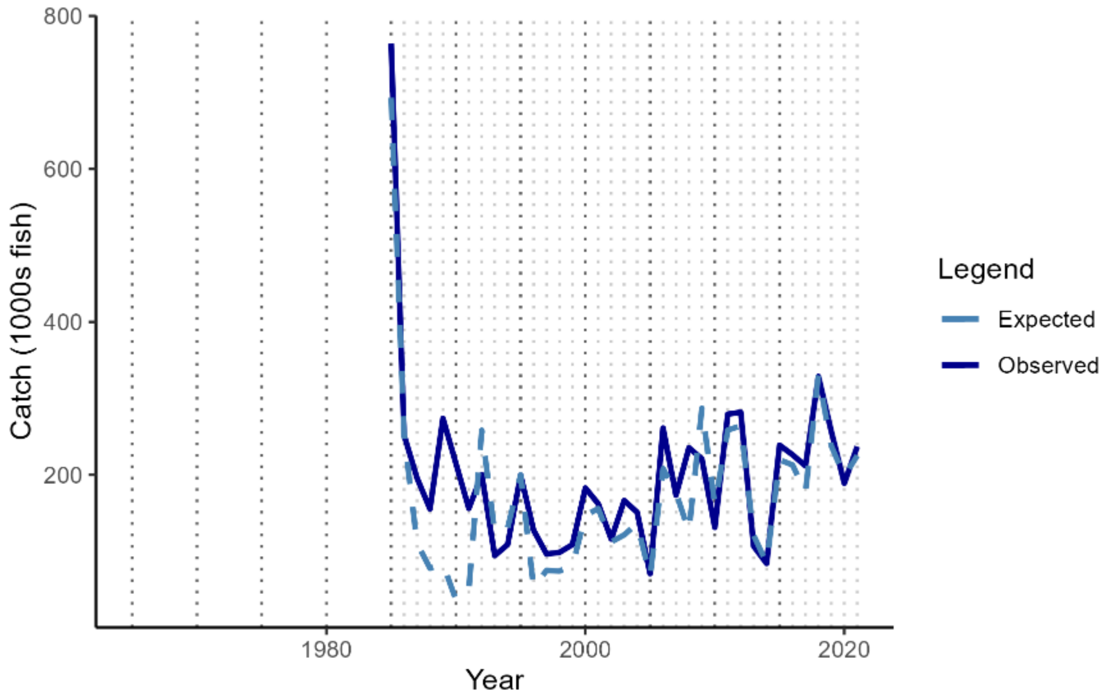


Figure 69. Observed and expected landings by the Recreational Headboat + Charterboat fleet for Gulf of Mexico Spanish Mackerel. The model starts in fished conditions 1986. 1985 shows equilibrium catches at the start of the model.

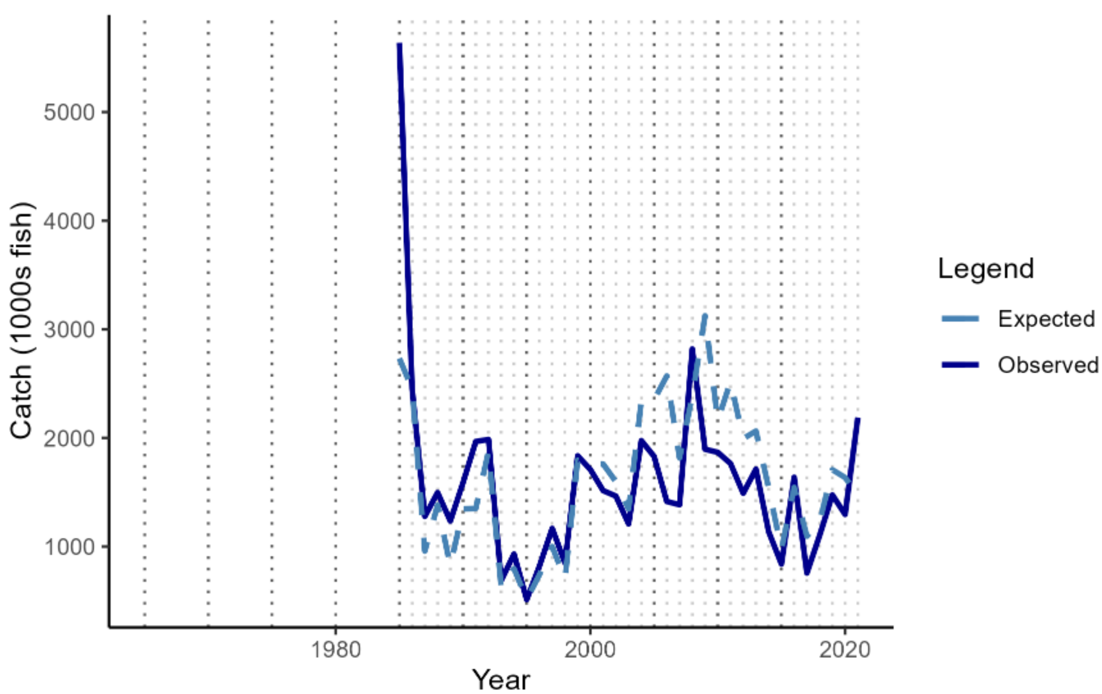


Figure 70. Observed and expected landings by the Recreational Private fleet for Gulf of Mexico Spanish Mackerel. The model starts in fished conditions 1986. 1985 shows equilibrium catches at the start of the model.

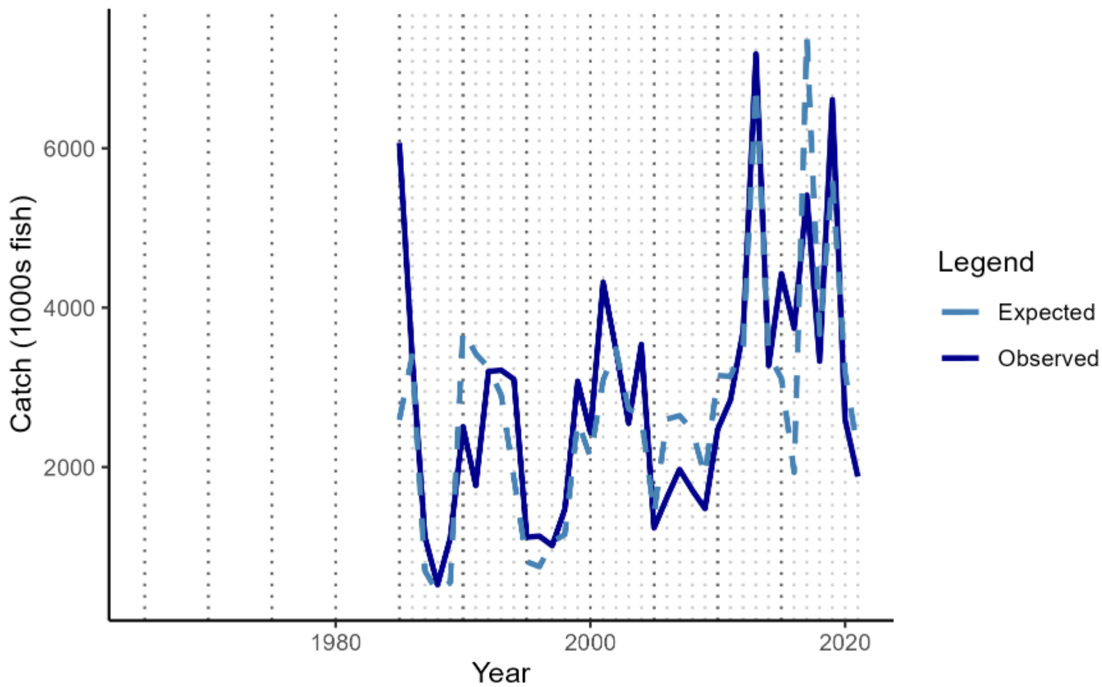


Figure 71. Observed and expected landings by the Recreational Shore fleet for Gulf of Mexico Spanish Mackerel. The model starts in fished conditions 1986. 1985 shows equilibrium catches at the start of the model.

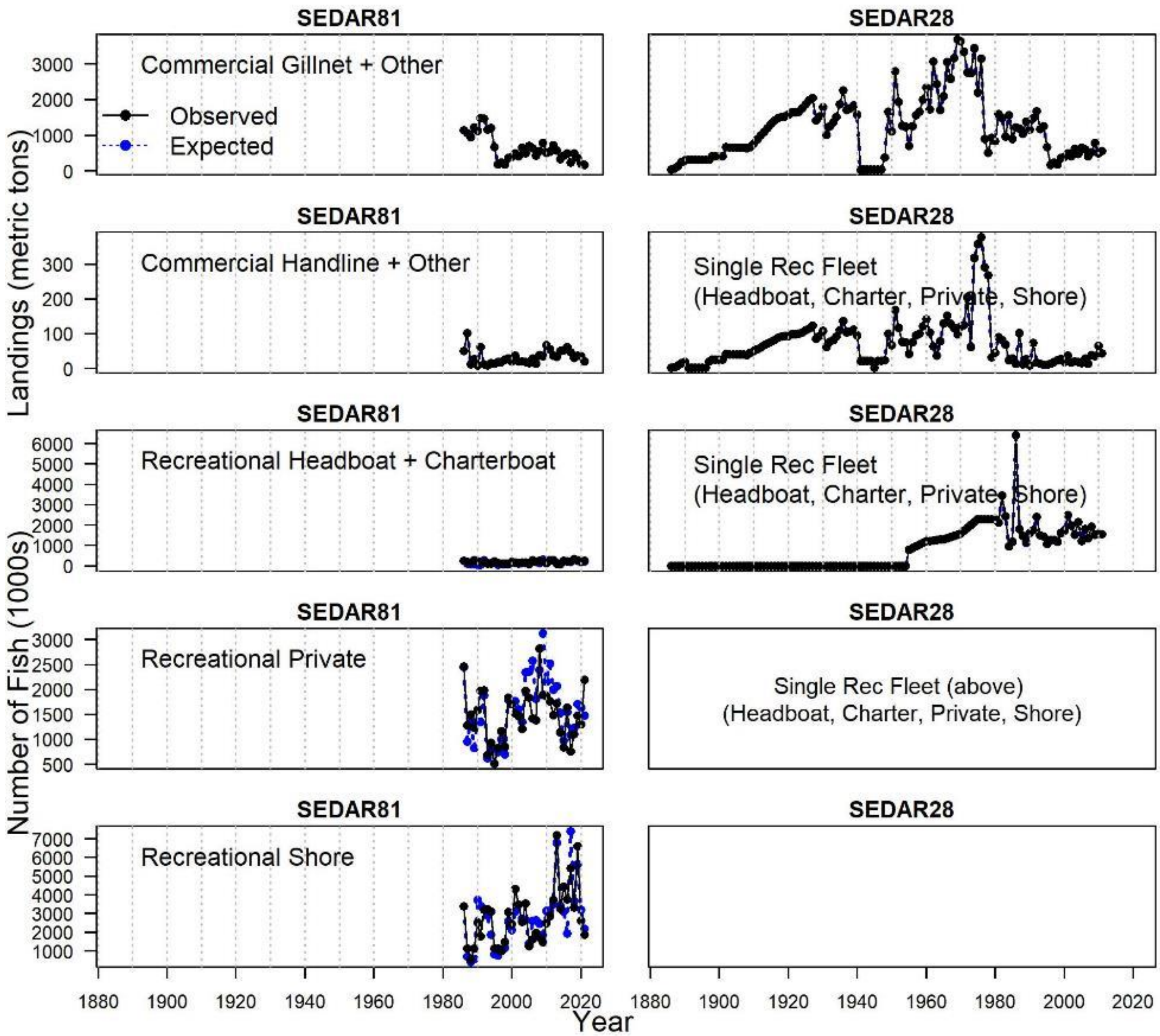


Figure 72. Gulf of Mexico Spanish Mackerel observed and expected landings by fleet for SEDAR 81 (left panels) and SEDAR 28 (right panels). Commercial and recreational landings are in metric tons and numbers of fish, respectively. Dashed vertical lines identify ten year intervals.

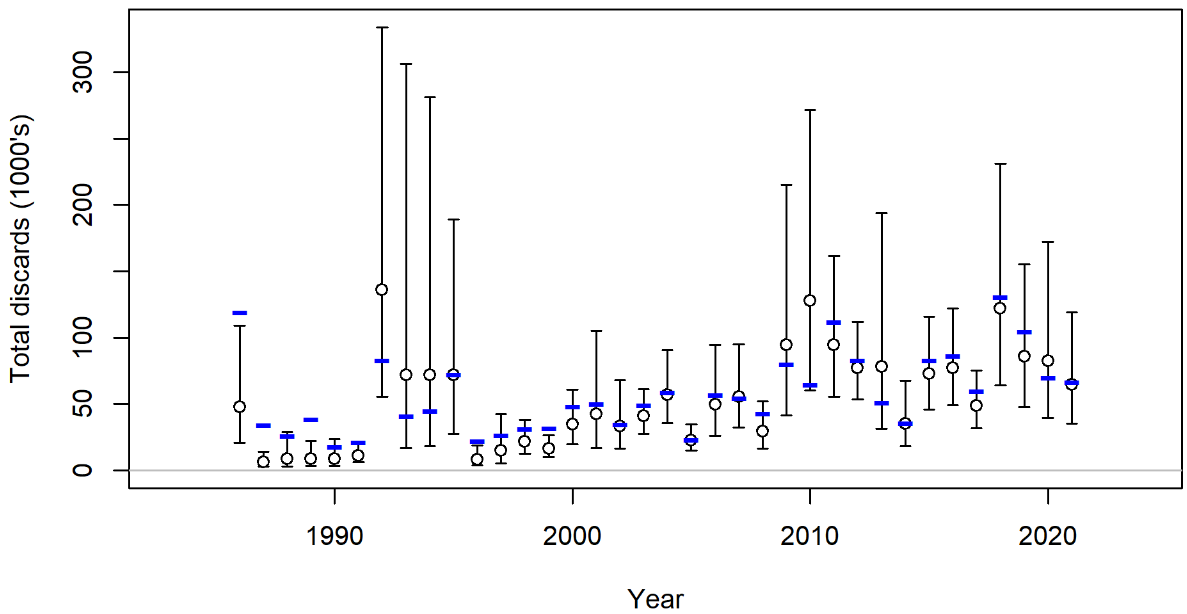


Figure 73. Input (dots with 95% confidence intervals) and expected (blue lines) discards by the Recreational Headboat + Charterboat for Gulf of Mexico Spanish Mackerel. Discards are in numbers of fish (1,000s) and reflect released fish (i.e., before discard mortality has been applied).

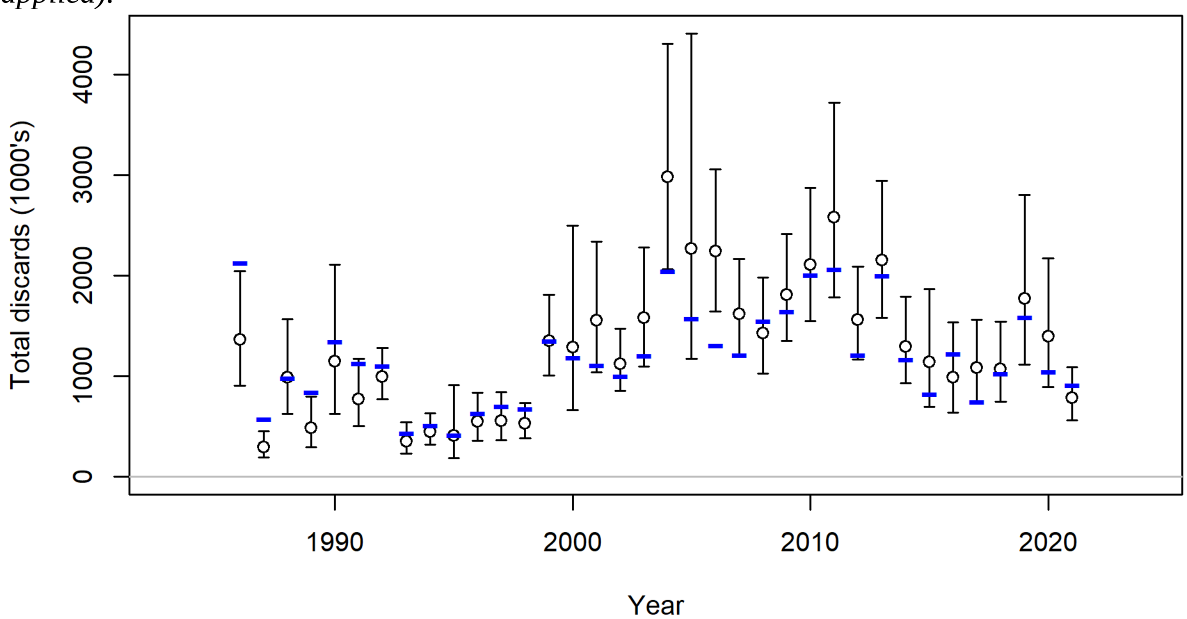


Figure 74. Input (dots with 95% confidence intervals) and expected (blue lines) discards by the Recreational Private for Gulf of Mexico Spanish Mackerel. Discards are in numbers of fish (1,000s) and reflect released fish (i.e., before discard mortality has been applied).

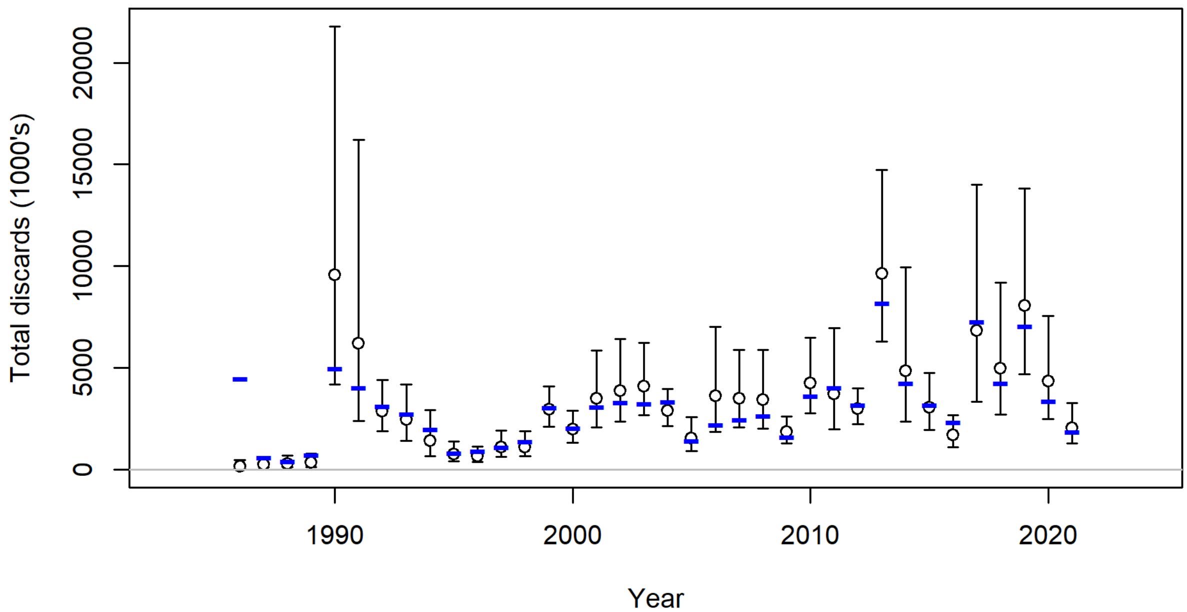


Figure 75. Input (dots with 95% confidence intervals) and expected (blue lines) discards by the Recreational Shore for Gulf of Mexico Spanish Mackerel. Discards are in numbers of fish (1,000s) and reflect released fish (i.e., before discard mortality has been applied).

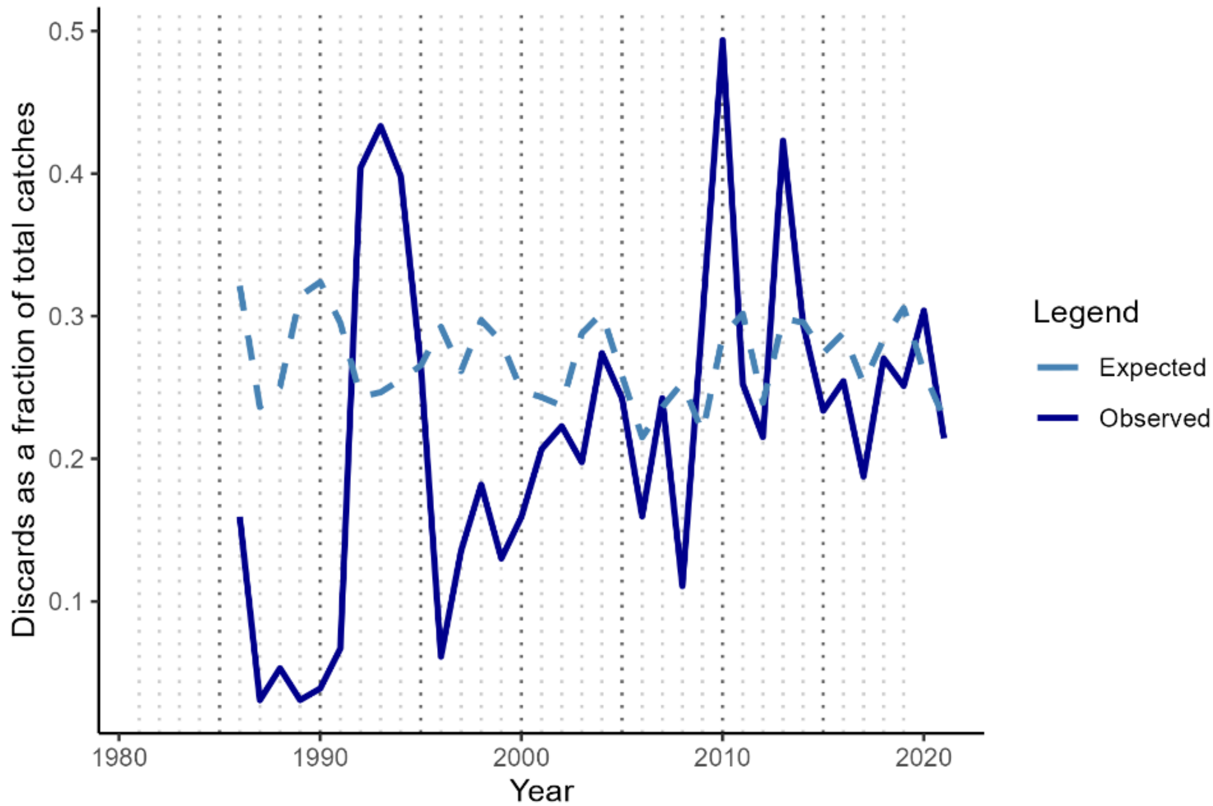


Figure 76. Observed and expected discard rates by the Recreational Headboat + Charterboat fleet for Gulf of Mexico Spanish Mackerel.

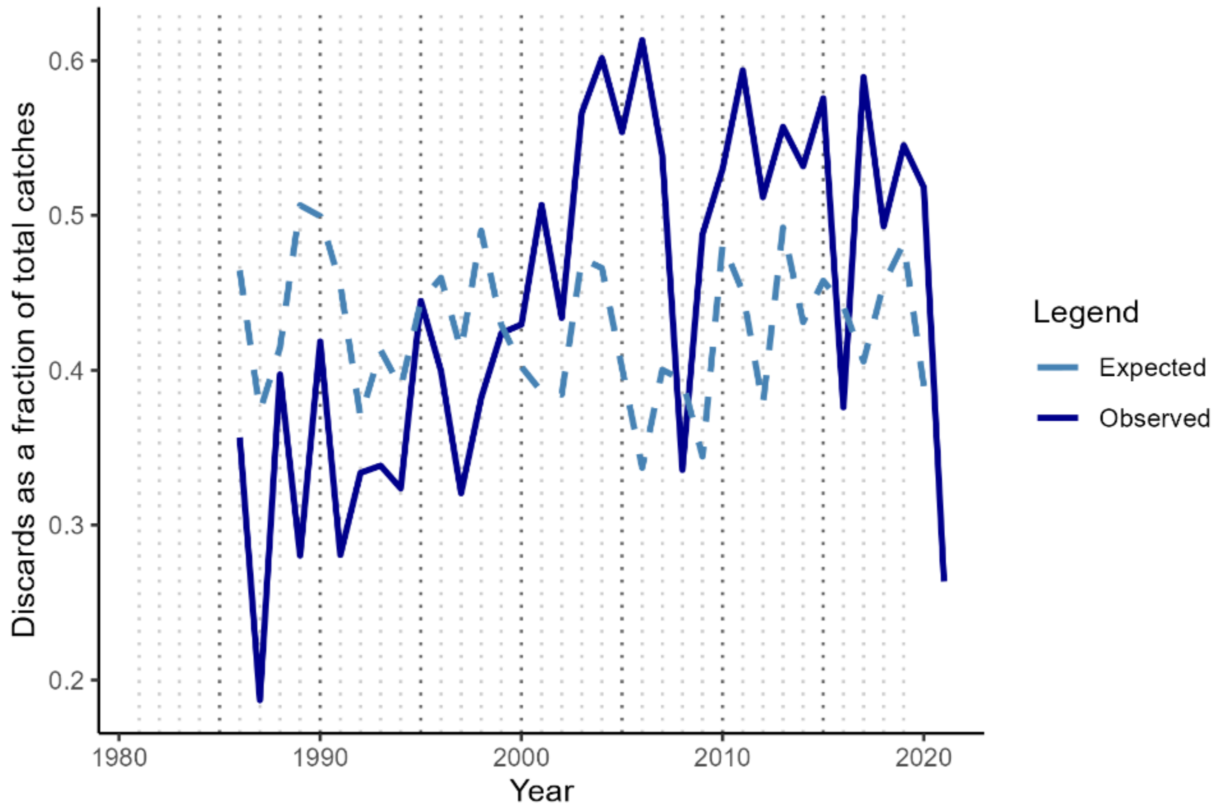


Figure 77. Observed and expected discard rates by the Recreational Private mode for Gulf of Mexico Spanish Mackerel.

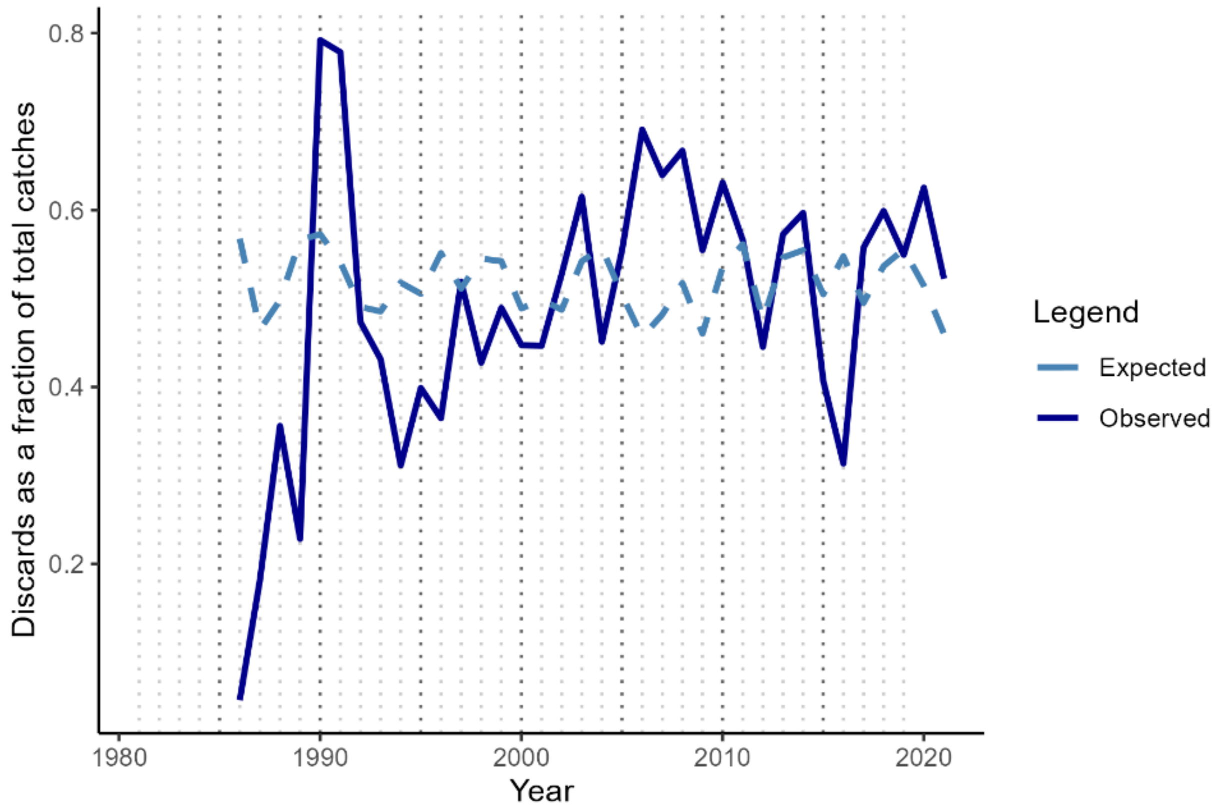


Figure 78. Observed and expected discard rates by the Recreational Shore mode for Gulf of Mexico Spanish Mackerel.

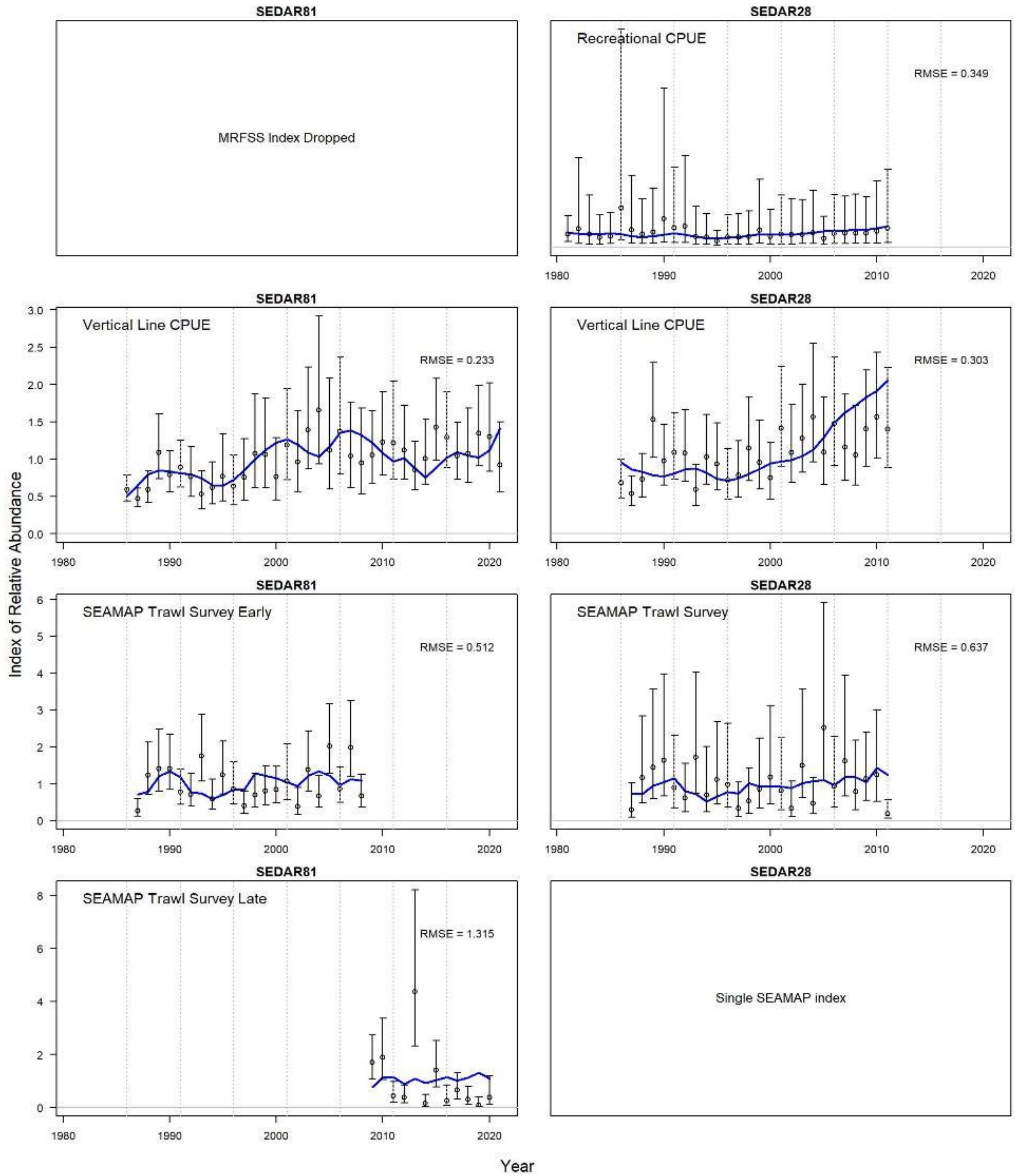


Figure 79. Gulf of Mexico Spanish Mackerel observed and expected indices for SEDAR 81 (left panels) and SEDAR 28 (right panels). Dashed vertical lines identify five year intervals. The root mean squared error (RMSE) is also provided.

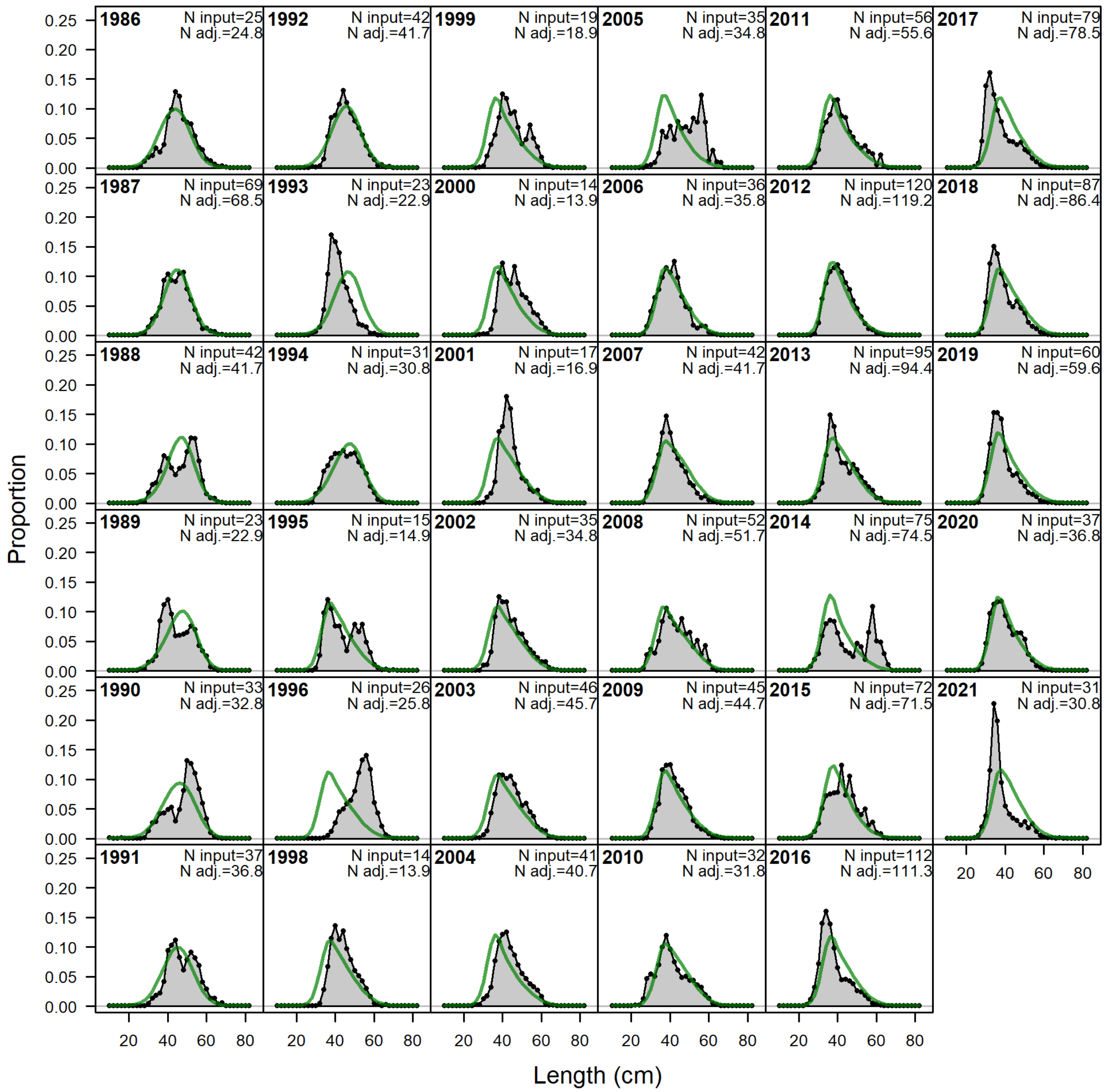


Figure 80. Observed and predicted length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Commercial Gillnet + Other fleet for SEDAR 81 and SEDAR 28. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions.

SEDAR 28

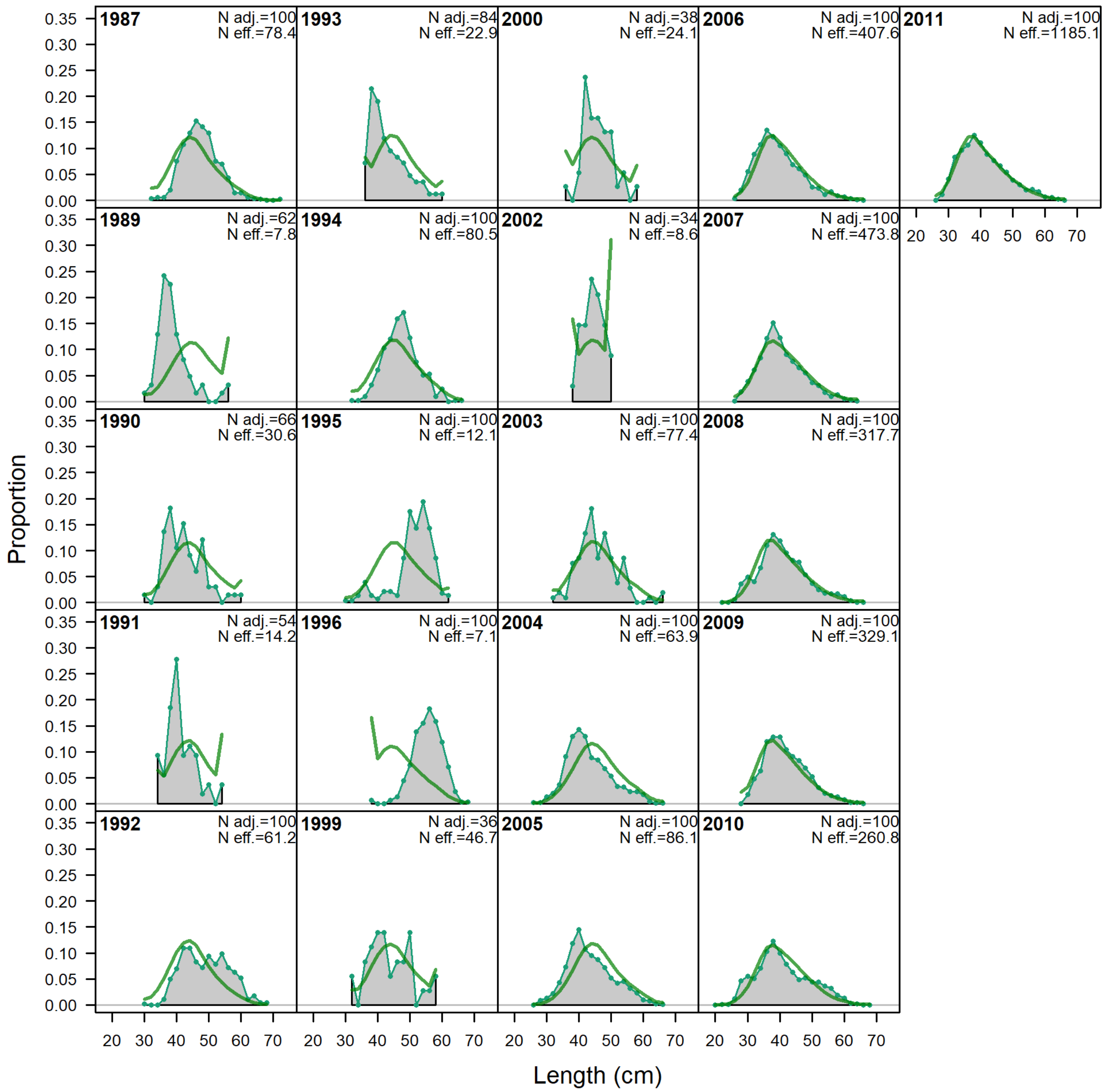


Figure 80 Continued. Observed and predicted length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Commercial Gillnet + Other fleet for SEDAR 81 and SEDAR 28. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions.

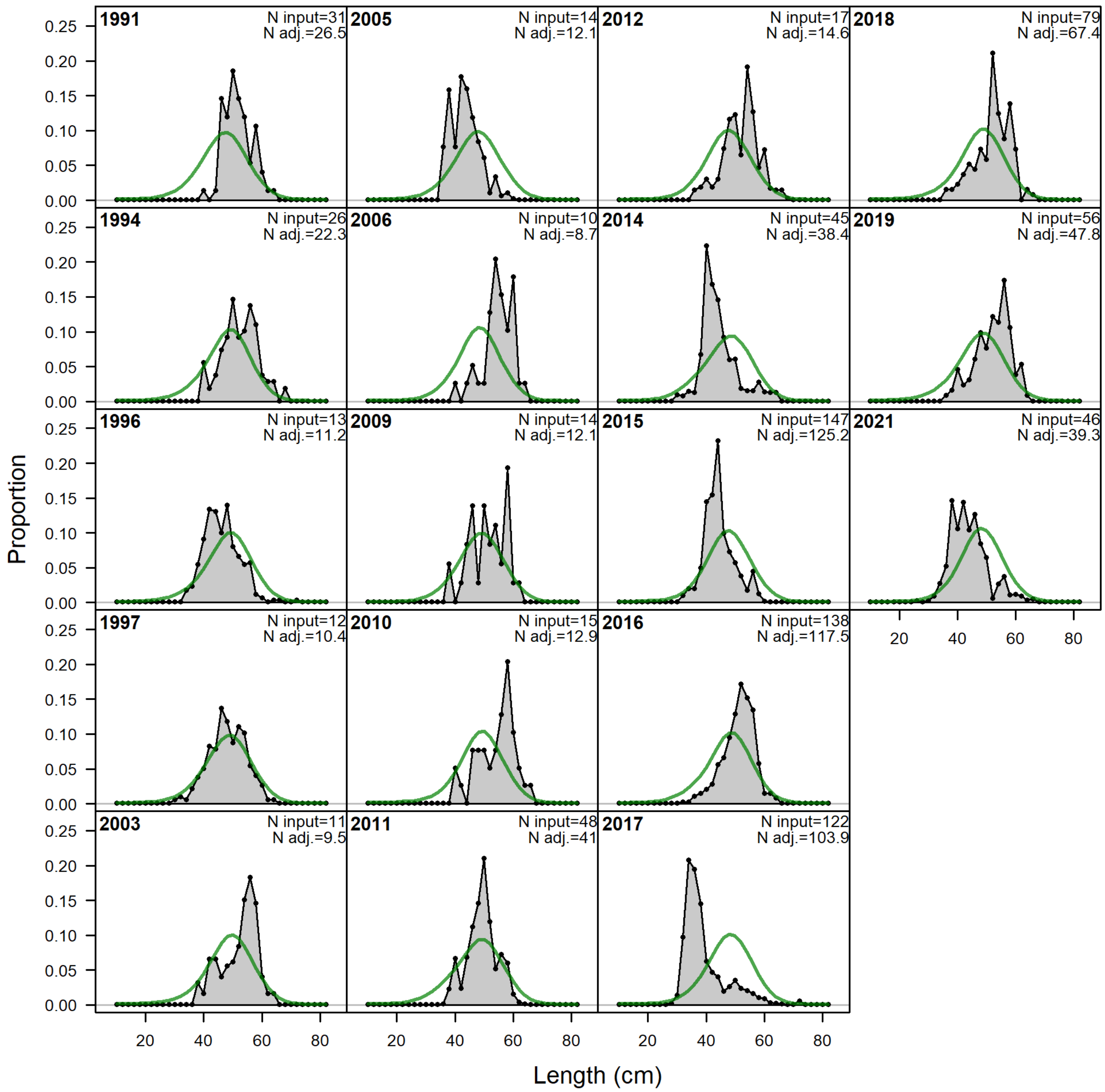


Figure 81. Observed and predicted length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Commercial Handline + Other fleet for SEDAR 81 and SEDAR 28. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions.

SEDAR 28

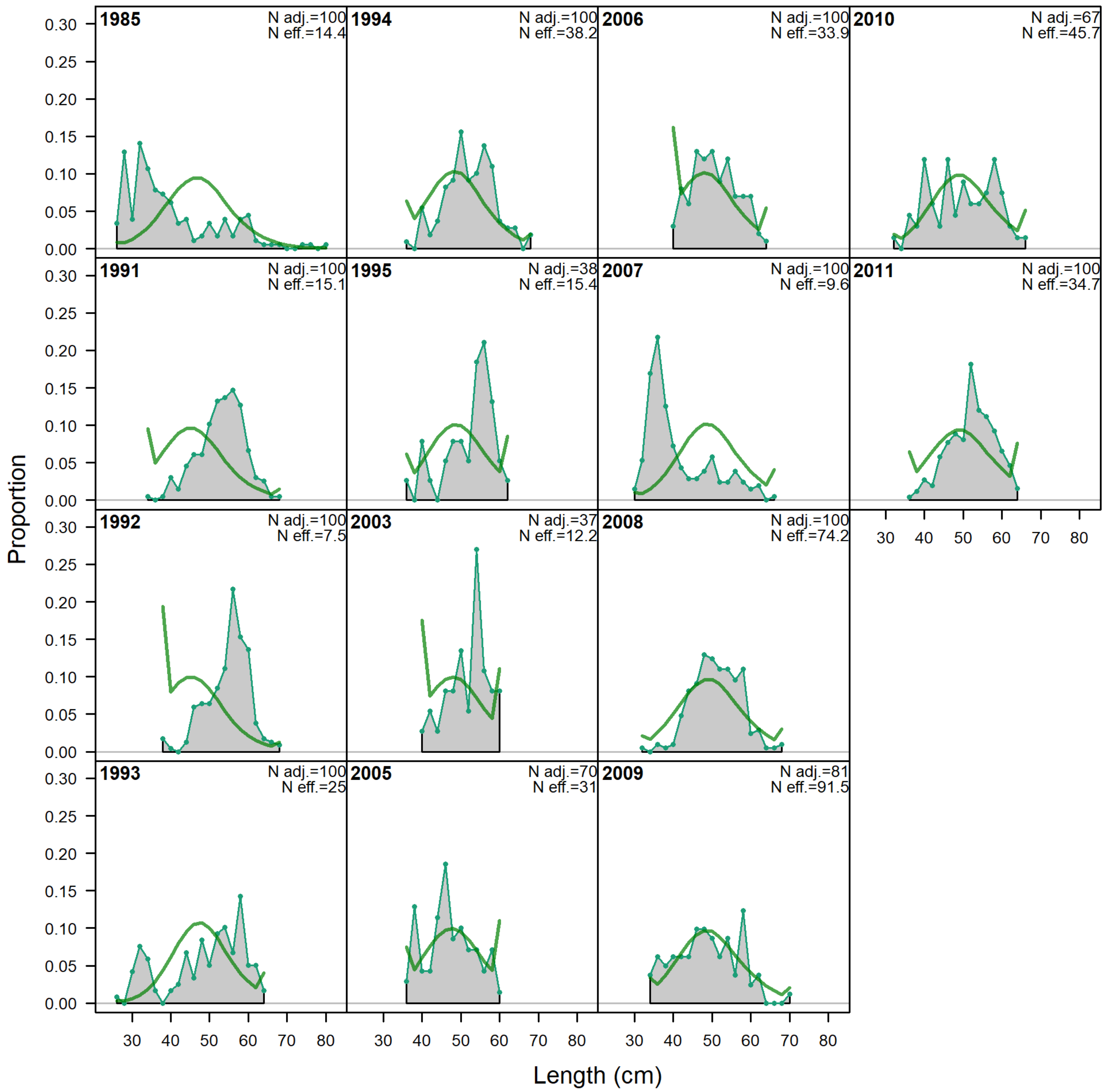


Figure 81 Continued. Observed and predicted length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Commercial Handline + Other fleet for SEDAR 81 and SEDAR 28. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions.

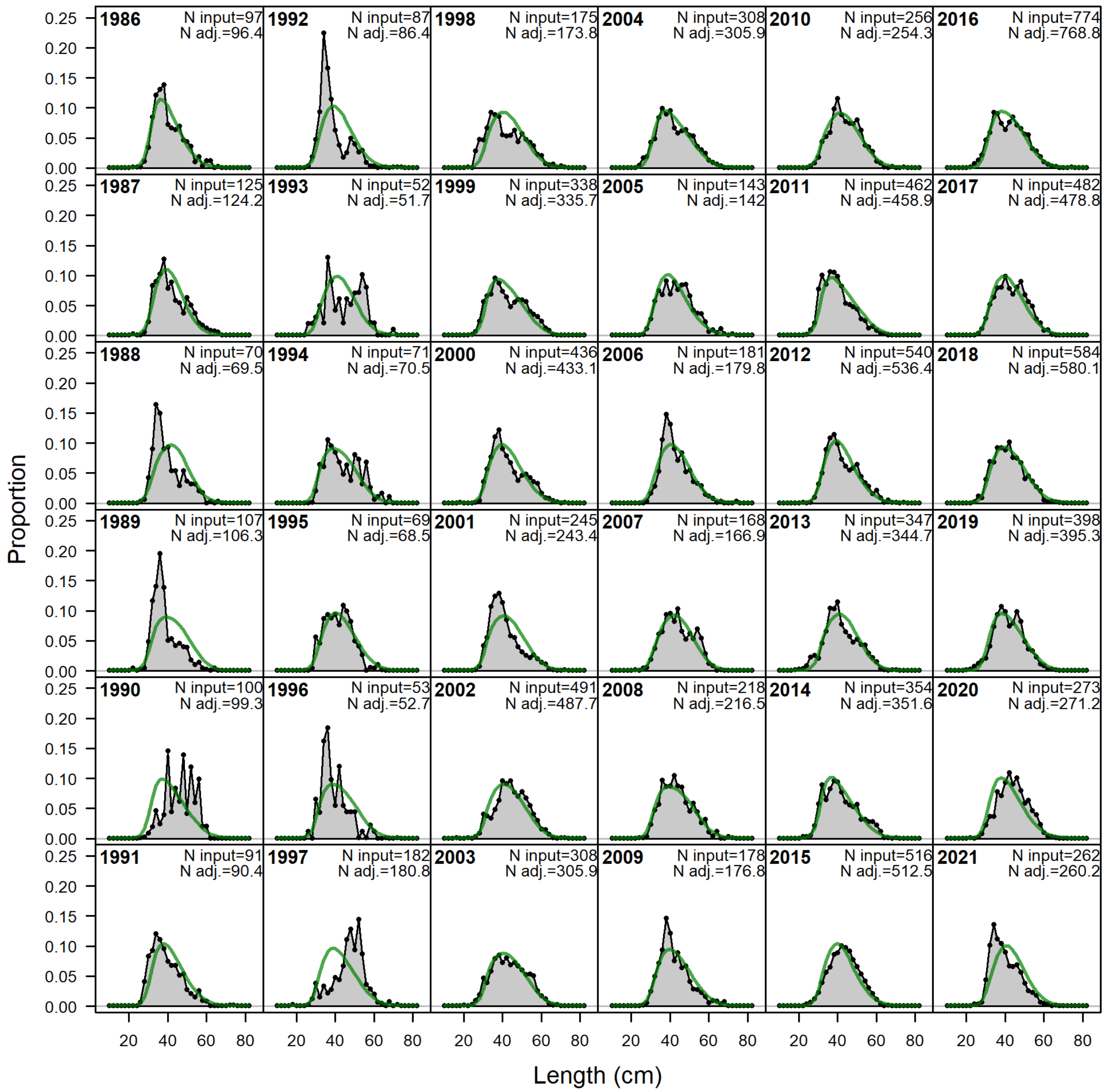


Figure 82. Observed and predicted length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Recreational Headboat + Charterboat fleet (SEDAR 81) and aggregated recreational fleet (SEDAR 28). Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions.

SEDAR 28

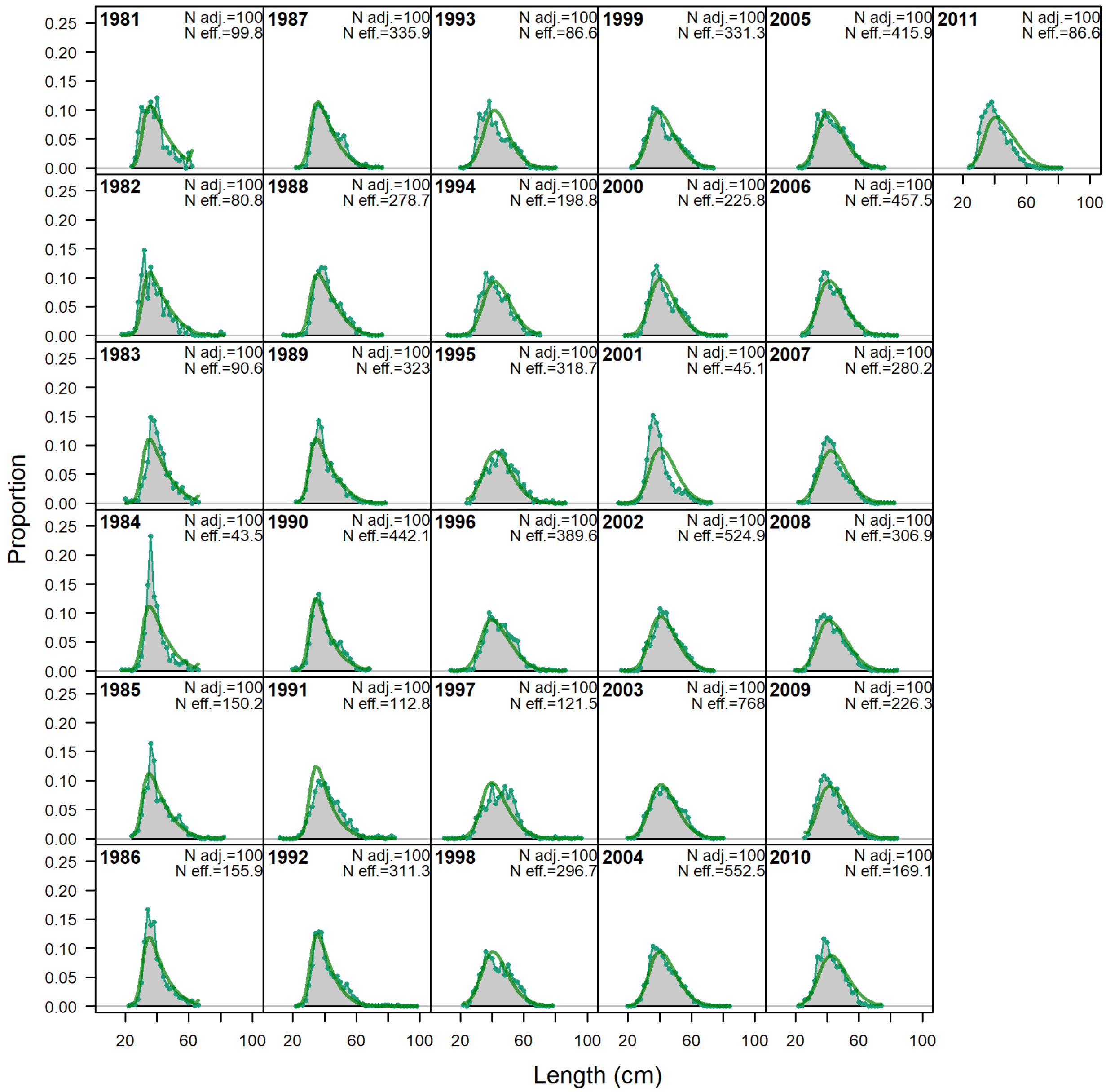


Figure 82 Continued. Observed and predicted length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Recreational Headboat + Charterboat fleet (SEDAR 81) and aggregated recreational fleet (SEDAR 28). Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions.

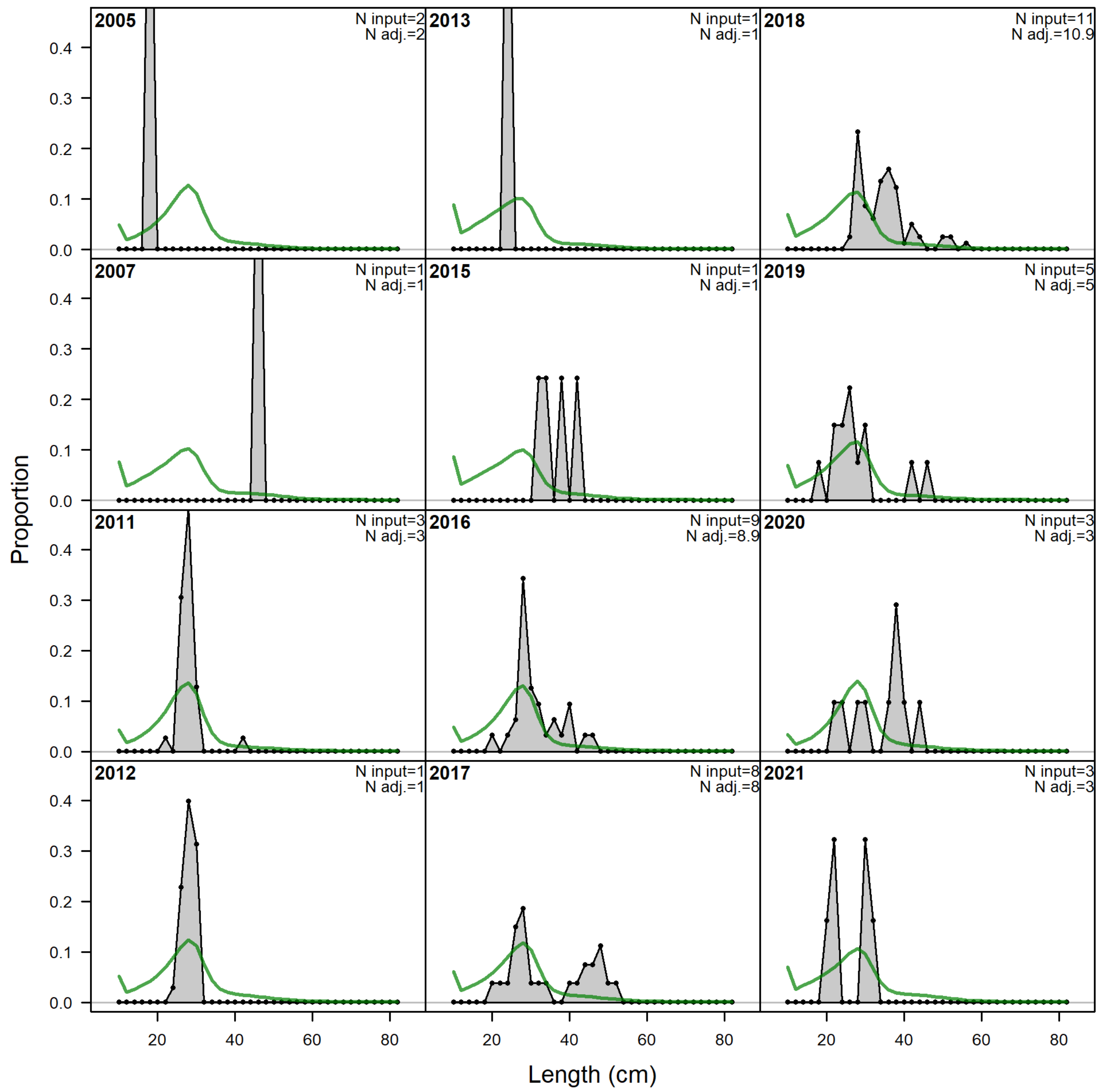


Figure 83. Observed and predicted length compositions (discarded) for Gulf of Mexico Spanish Mackerel in the Recreational Headboat + Charterboat fleet for SEDAR 81. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions.

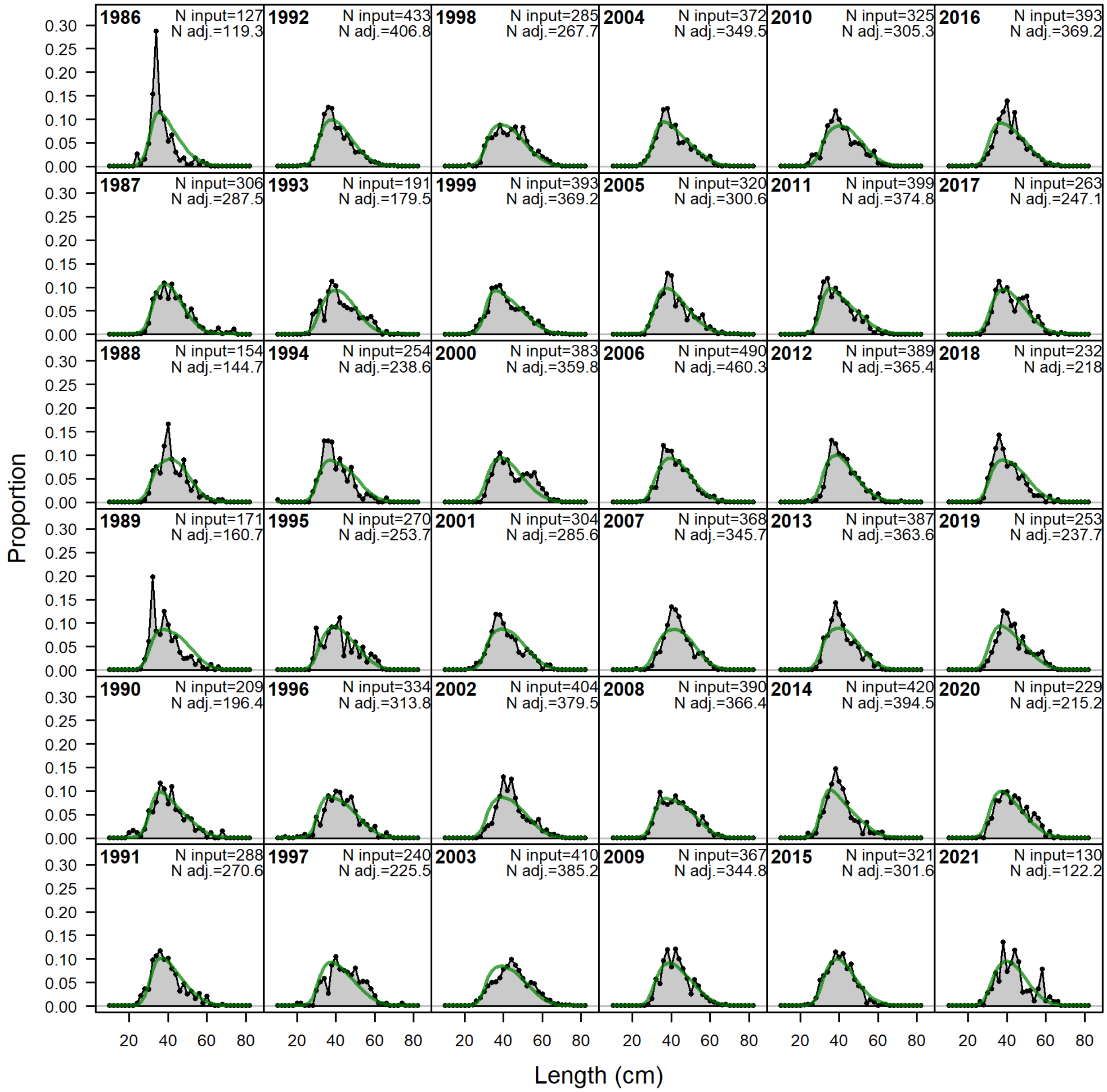


Figure 84. Observed and predicted length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Recreational Private fleet for SEDAR 81. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions.

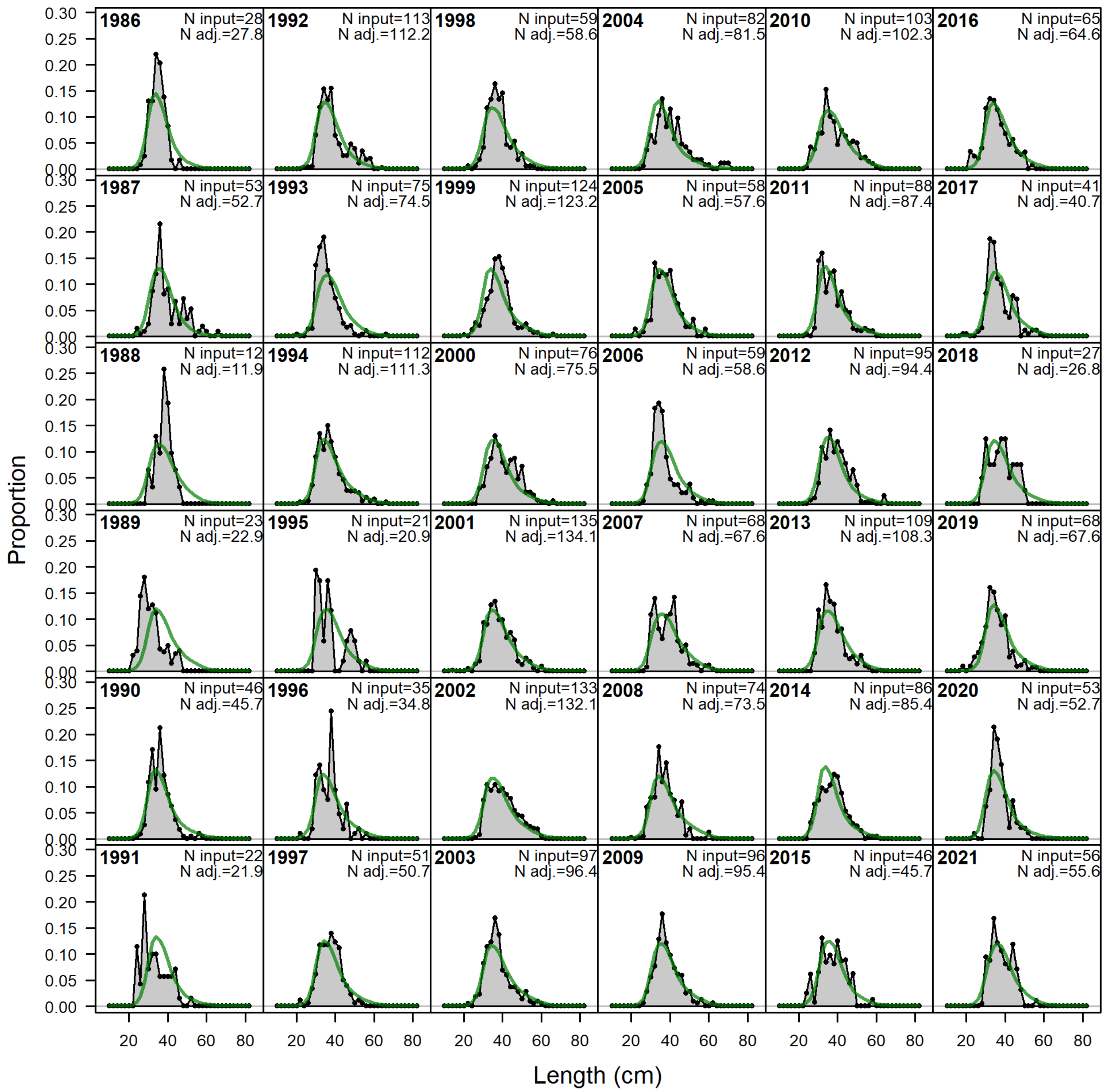


Figure 85. Observed and predicted length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Recreational Shore fleet for SEDAR 81. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions.

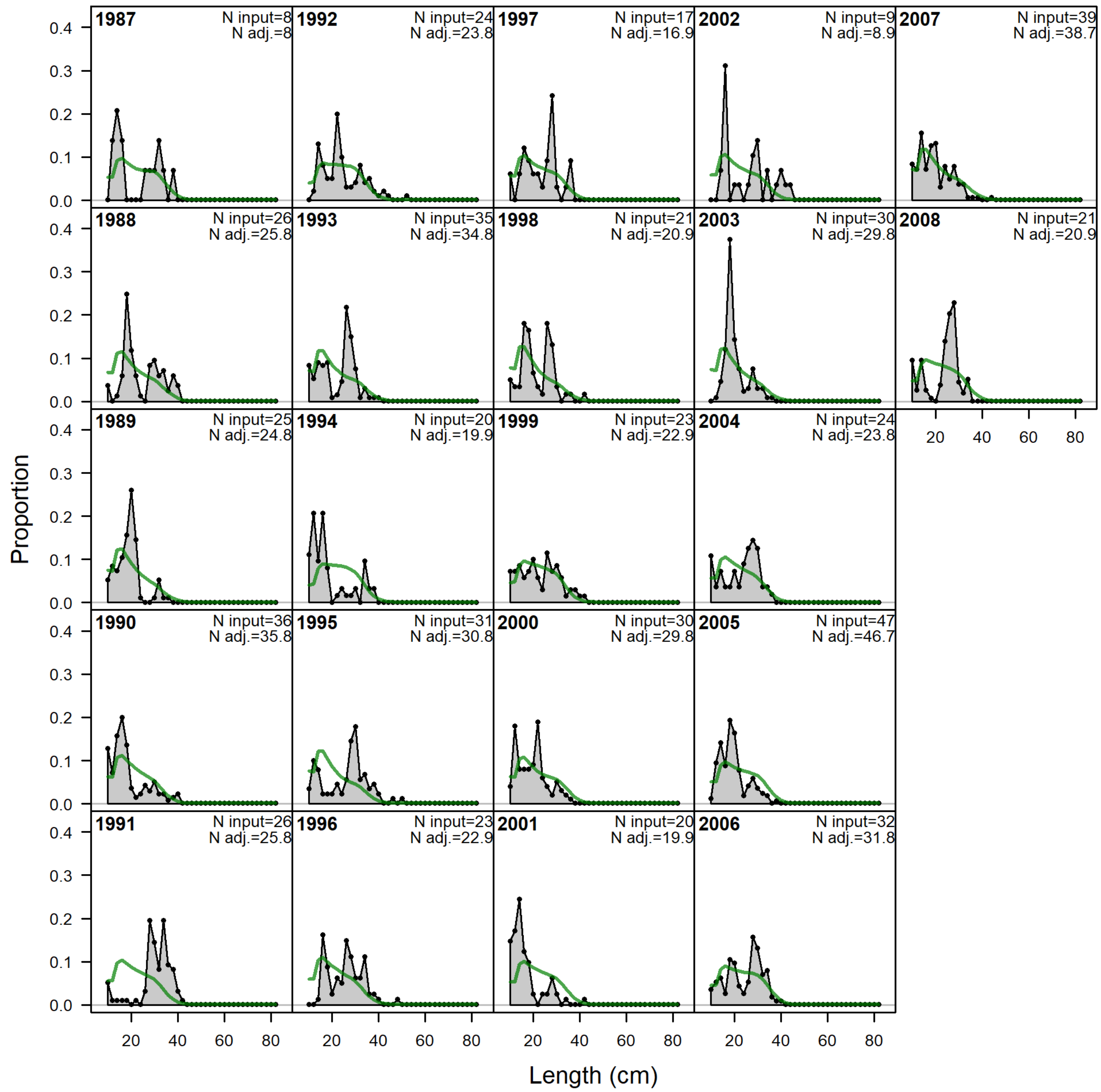


Figure 86. Observed and predicted length compositions for Gulf of Mexico Spanish Mackerel in the SEAMAP Trawl Survey Early survey. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions.

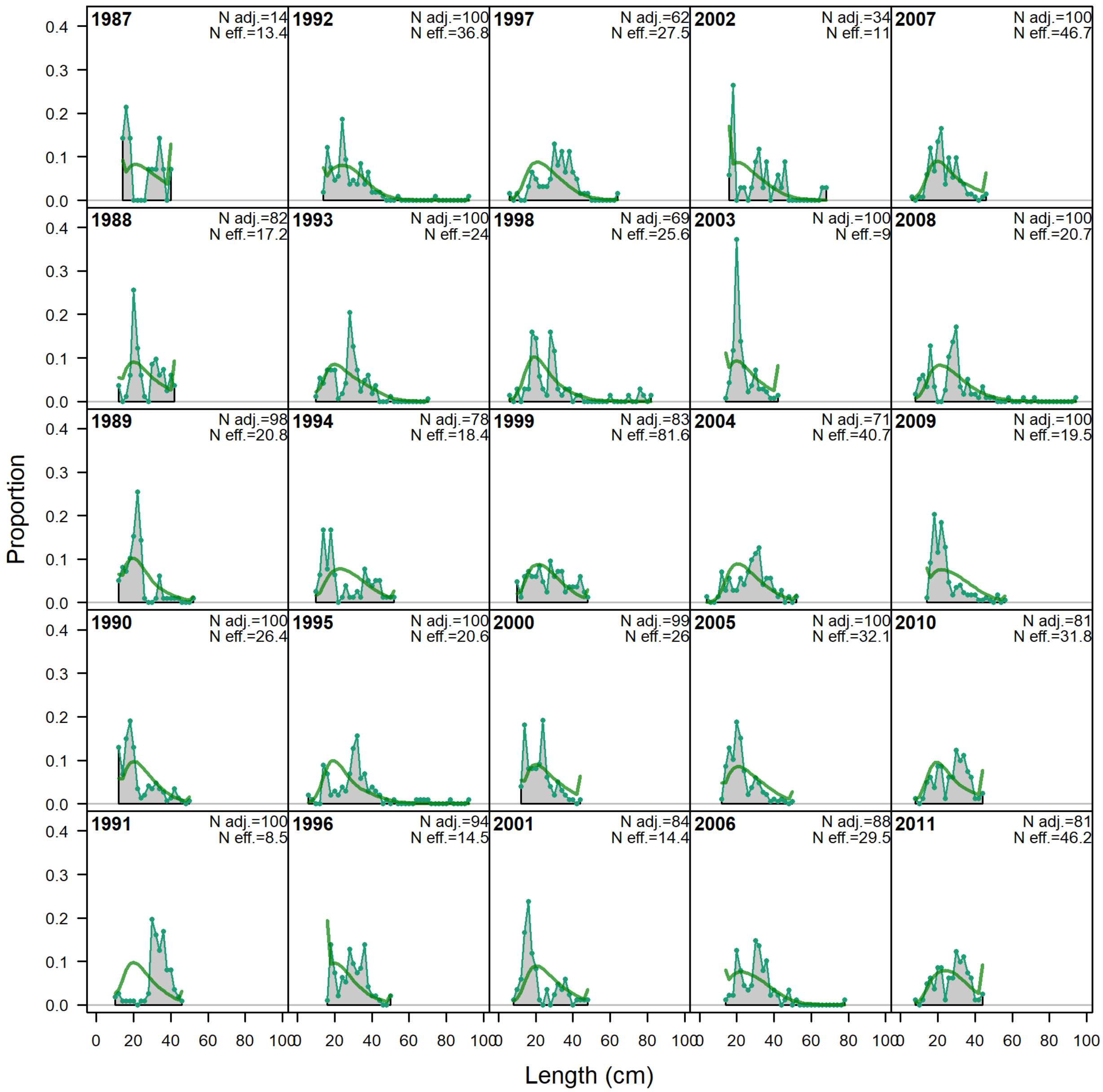


Figure 86 Continued. Observed and predicted length compositions for Gulf of Mexico Spanish Mackerel in the SEAMAP Trawl Survey Early survey. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions.

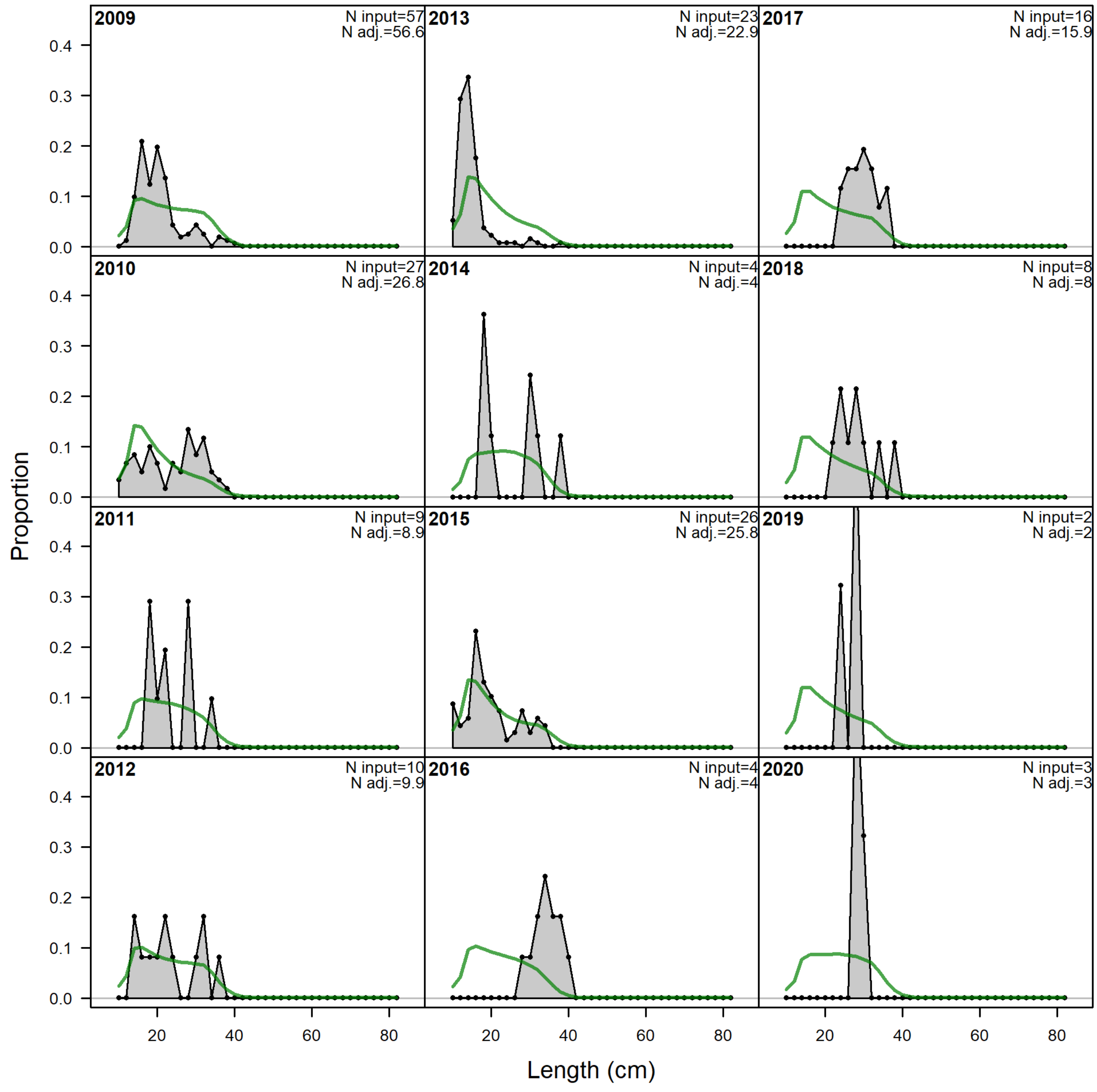


Figure 87. Observed and predicted length compositions for Gulf of Mexico Spanish Mackerel in the SEAMAP Trawl Survey Late survey for SEDAR 81. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions.

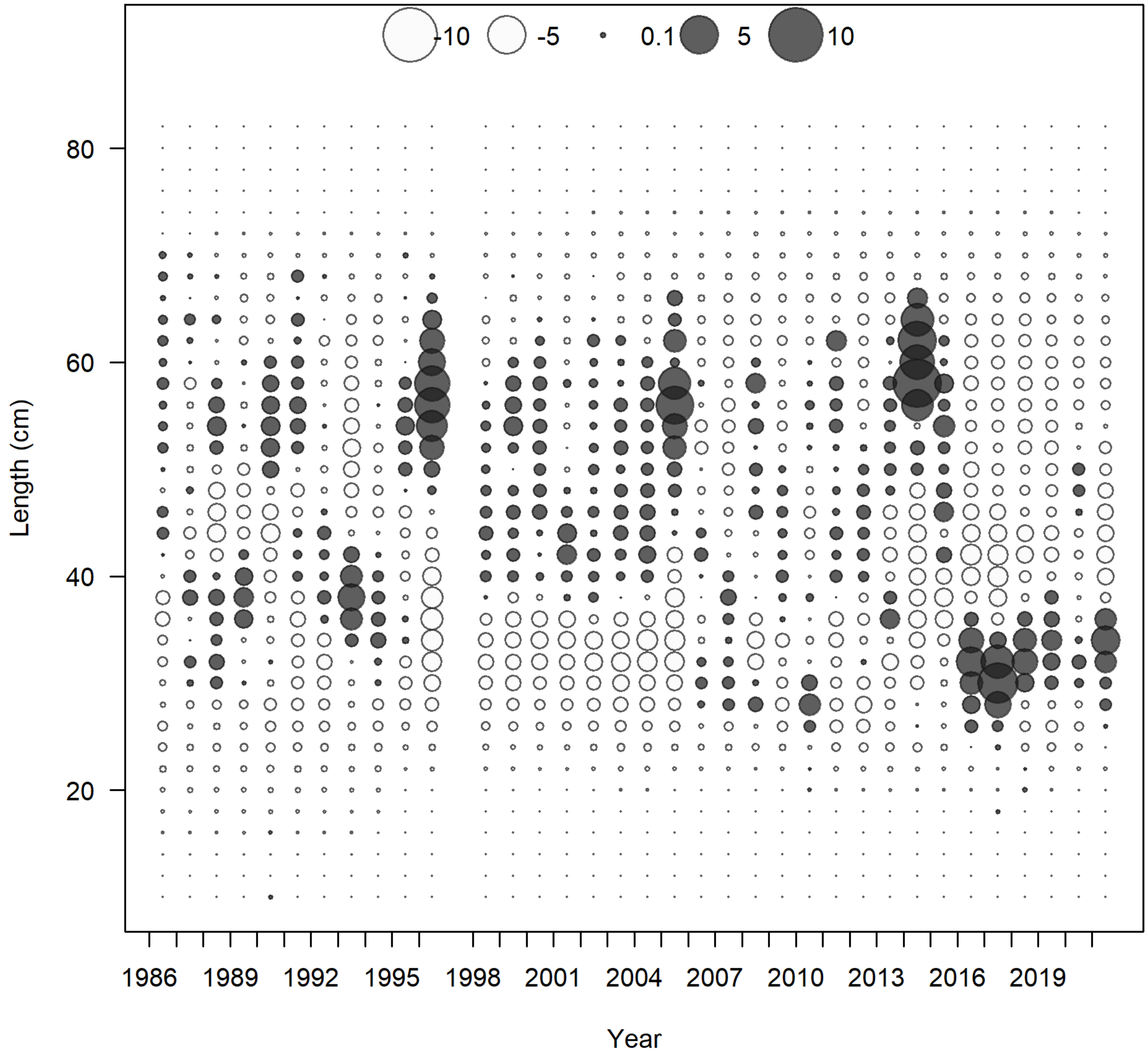


Figure 88. Pearson residuals for retained length composition data by year for Commercial Gillnet + Other for Gulf of Mexico Spanish Mackerel for SEDAR 81. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

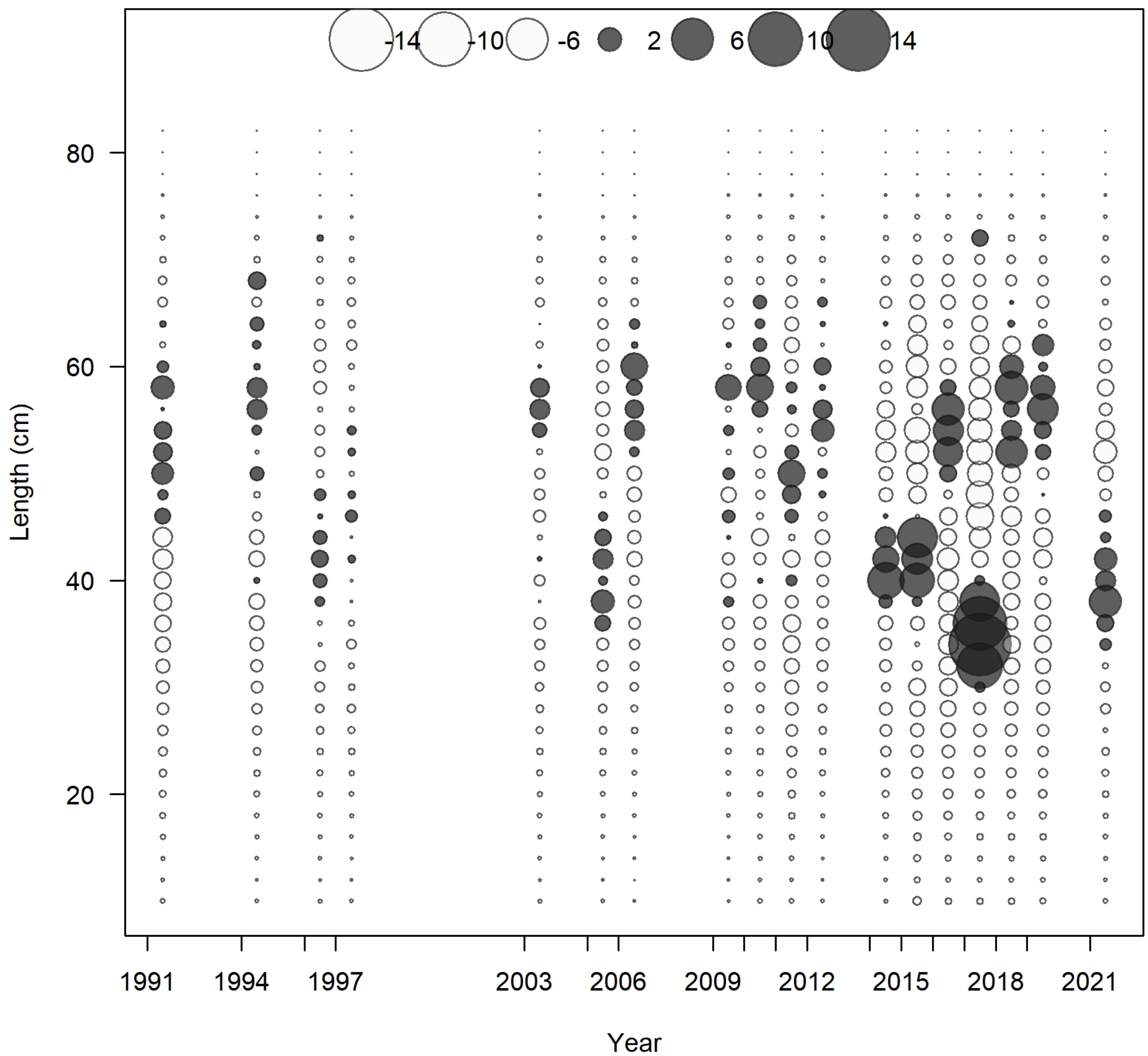


Figure 89. Pearson residuals for retained length composition data by year for Commercial Handline + Other for Gulf of Mexico Spanish Mackerel for SEDAR 81. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

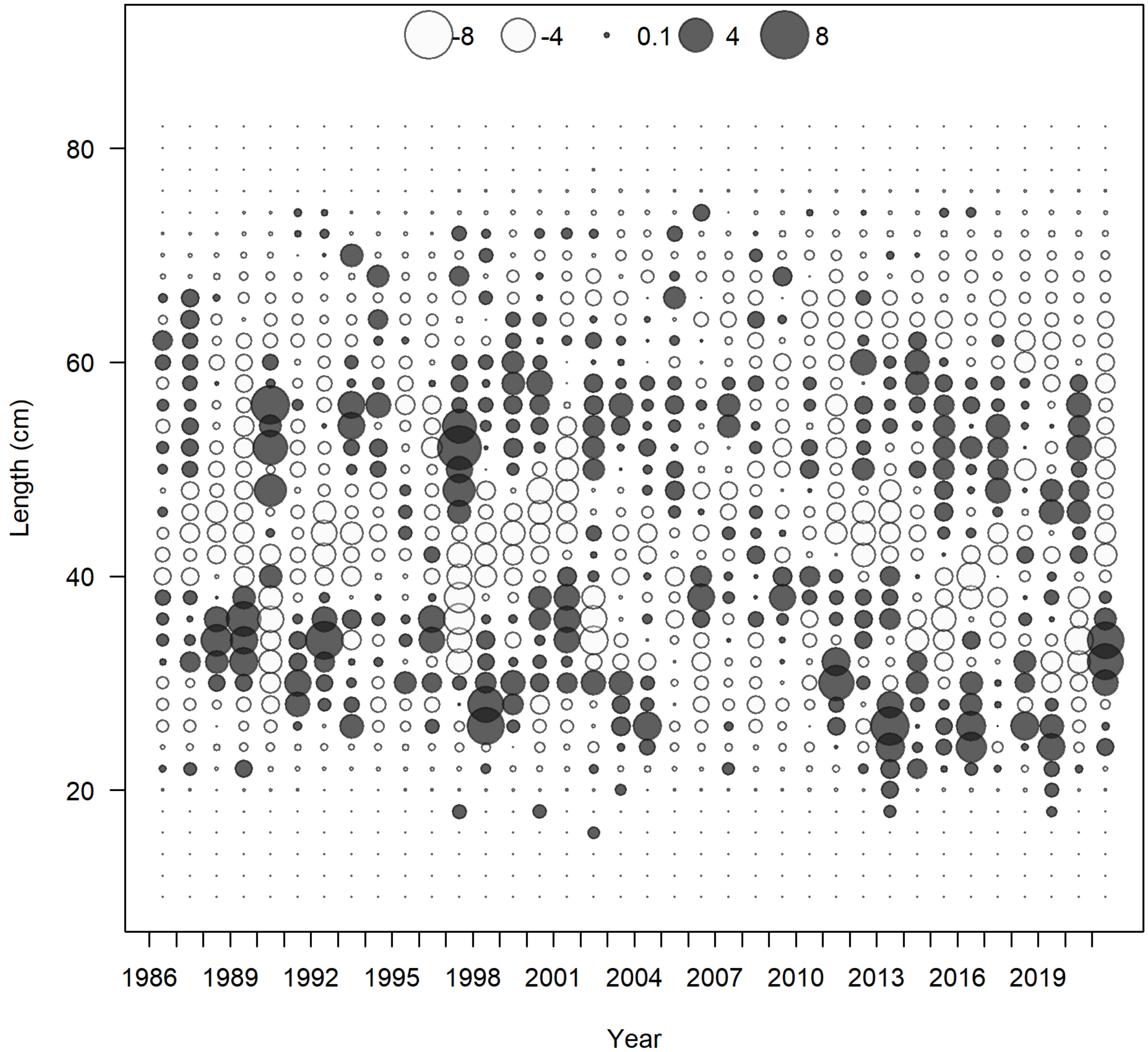


Figure 90. Pearson residuals for retained length composition data by year for Recreational Headboat + Charterboat for Gulf of Mexico Spanish Mackerel for SEDAR 81. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

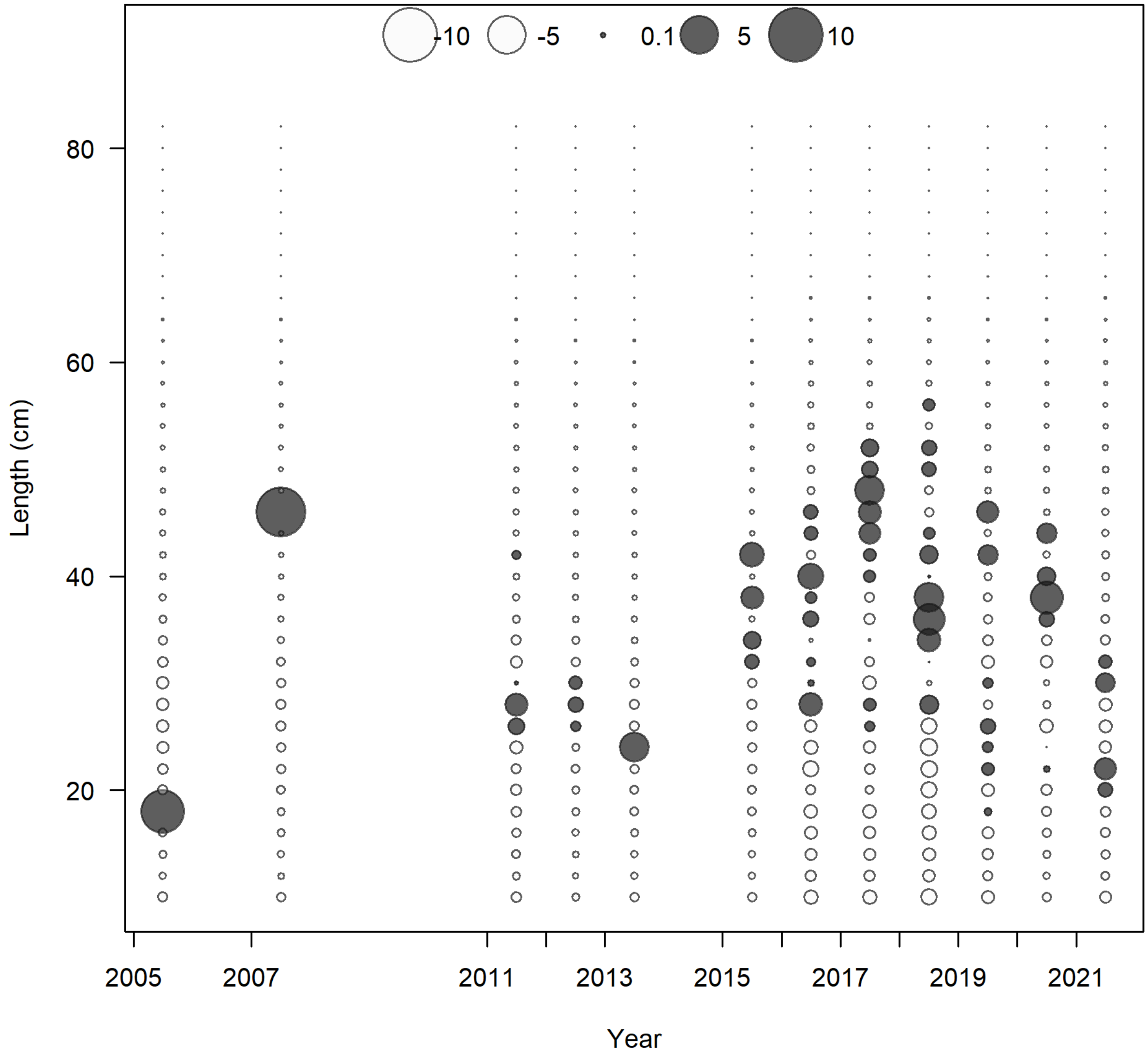


Figure 91. Pearson residuals for discard length composition data by year for Recreational Headboat + Charterboat for Gulf of Mexico Spanish Mackerel for SEDAR 81. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

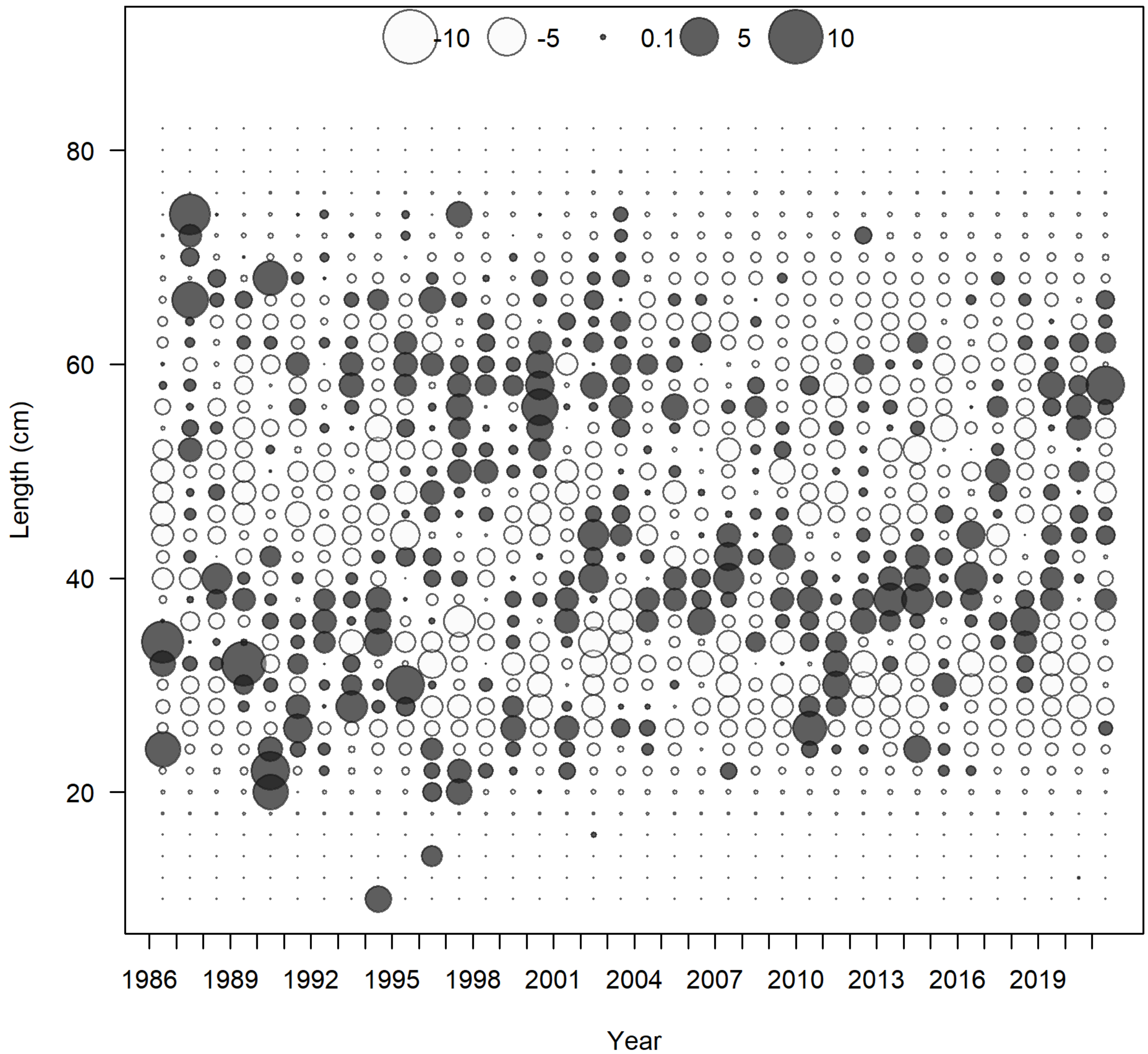


Figure 92. Pearson residuals for retained length composition data by year for Recreational Private for Gulf of Mexico Spanish Mackerel for SEDAR 81. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

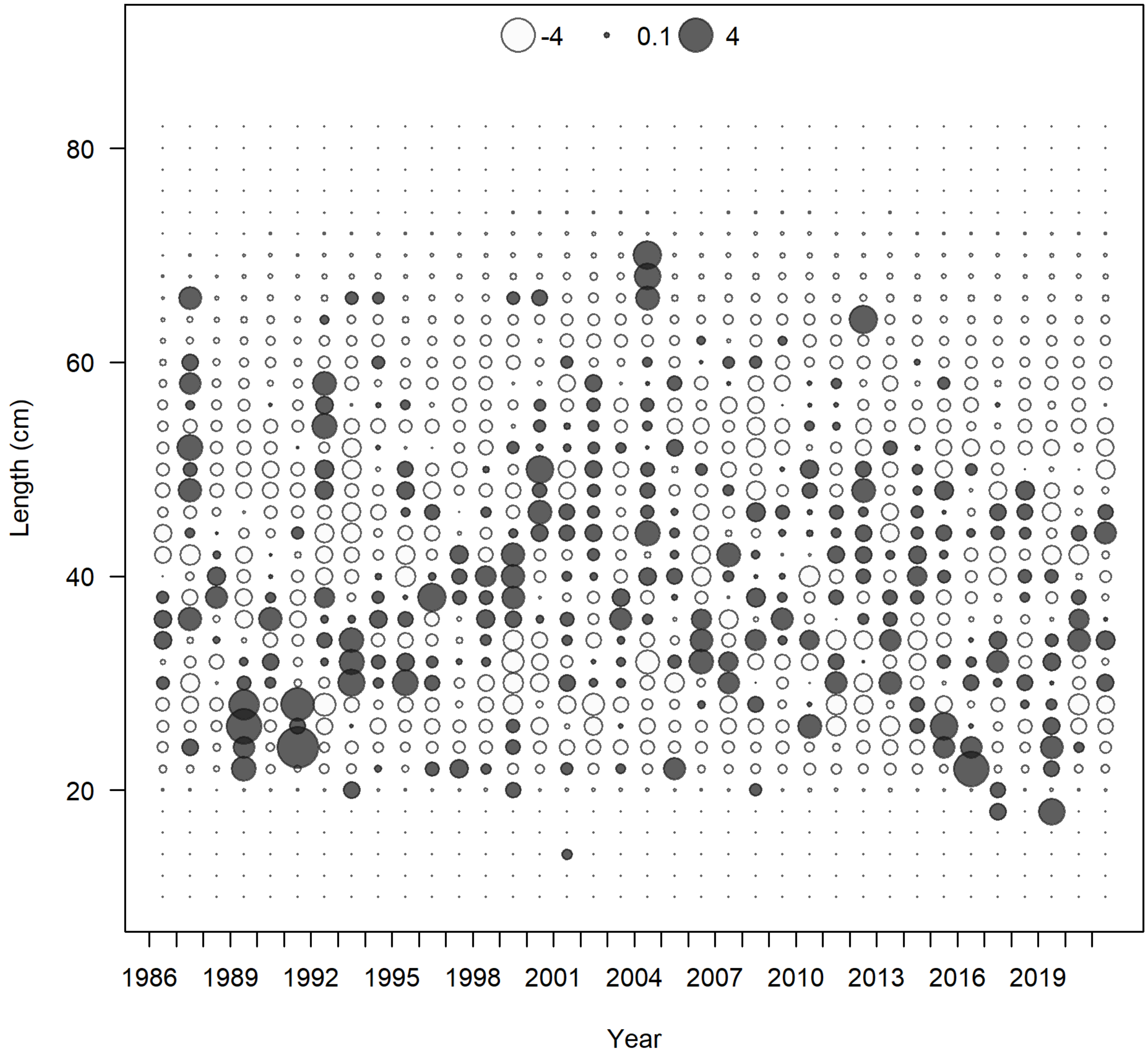


Figure 93. Pearson residuals for retained length composition data by year for Recreational Shore for Gulf of Mexico Spanish Mackerel for SEDAR 81. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

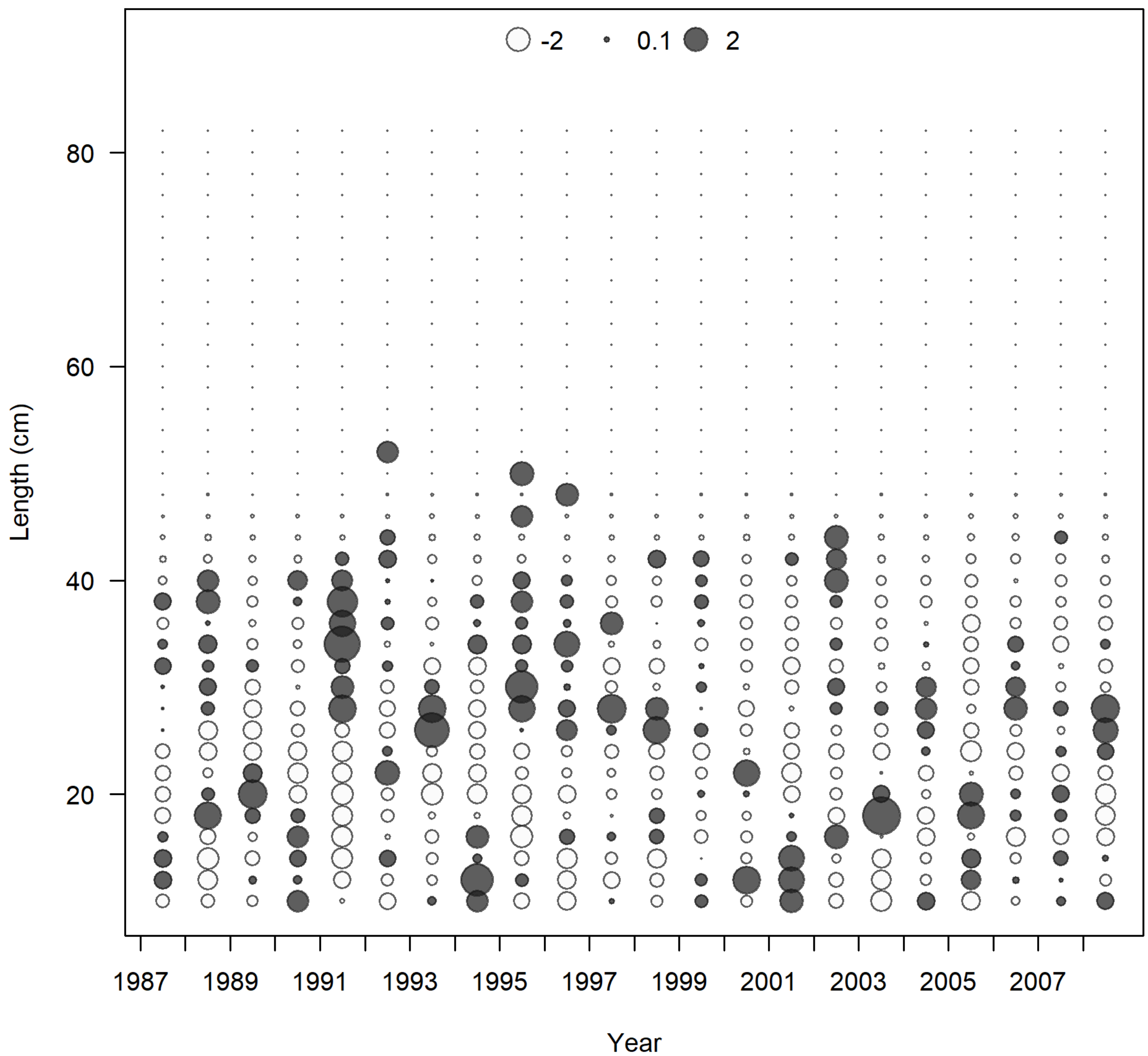


Figure 94. Pearson residuals for retained length composition data by year for the SEAMAP Trawl Survey Early index for Gulf of Mexico Spanish Mackerel for SEDAR 81. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

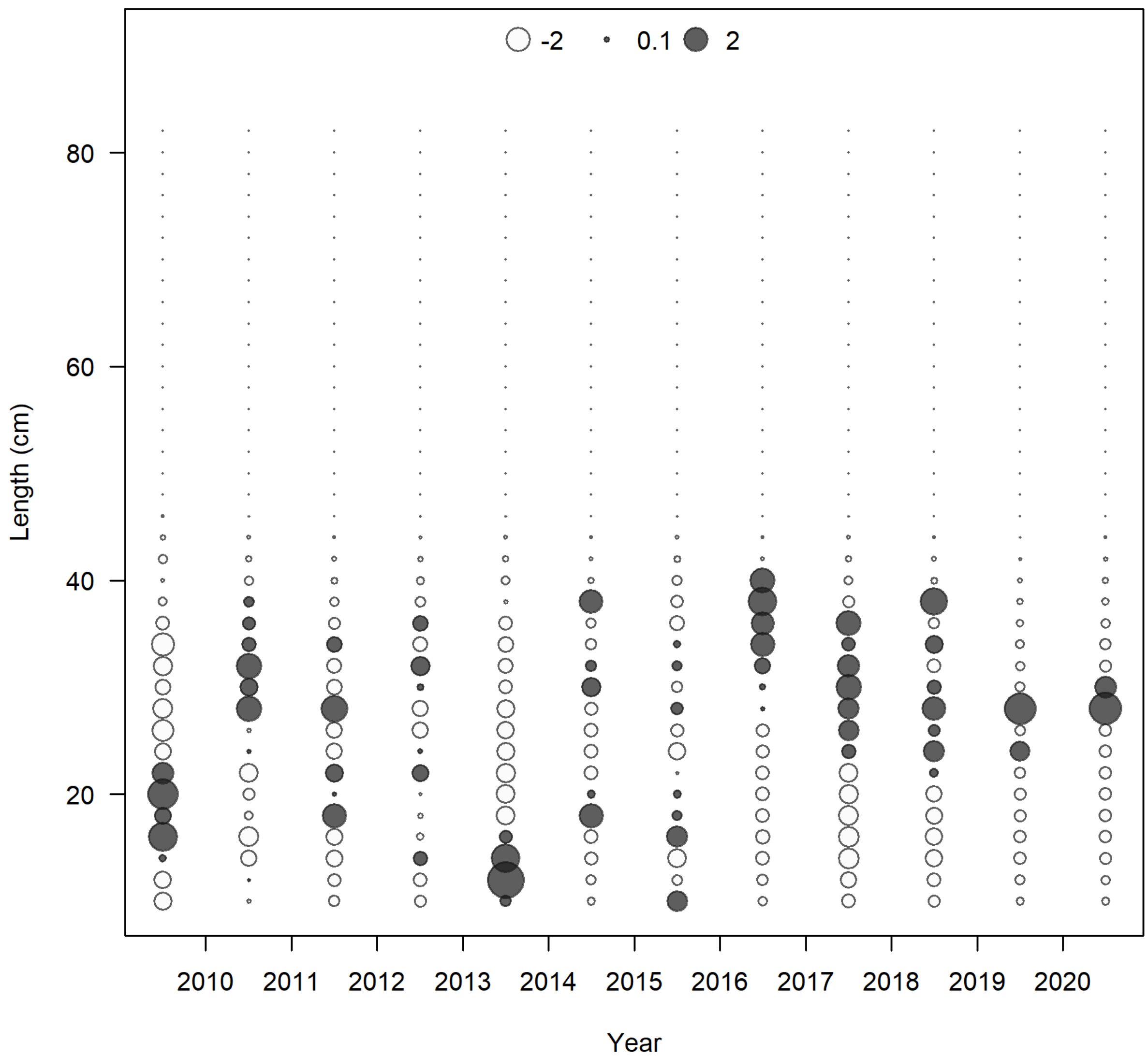


Figure 95. Pearson residuals for length composition data by year for the SEAMAP Trawl Survey Late index for Gulf of Mexico Spanish Mackerel for SEDAR 81. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

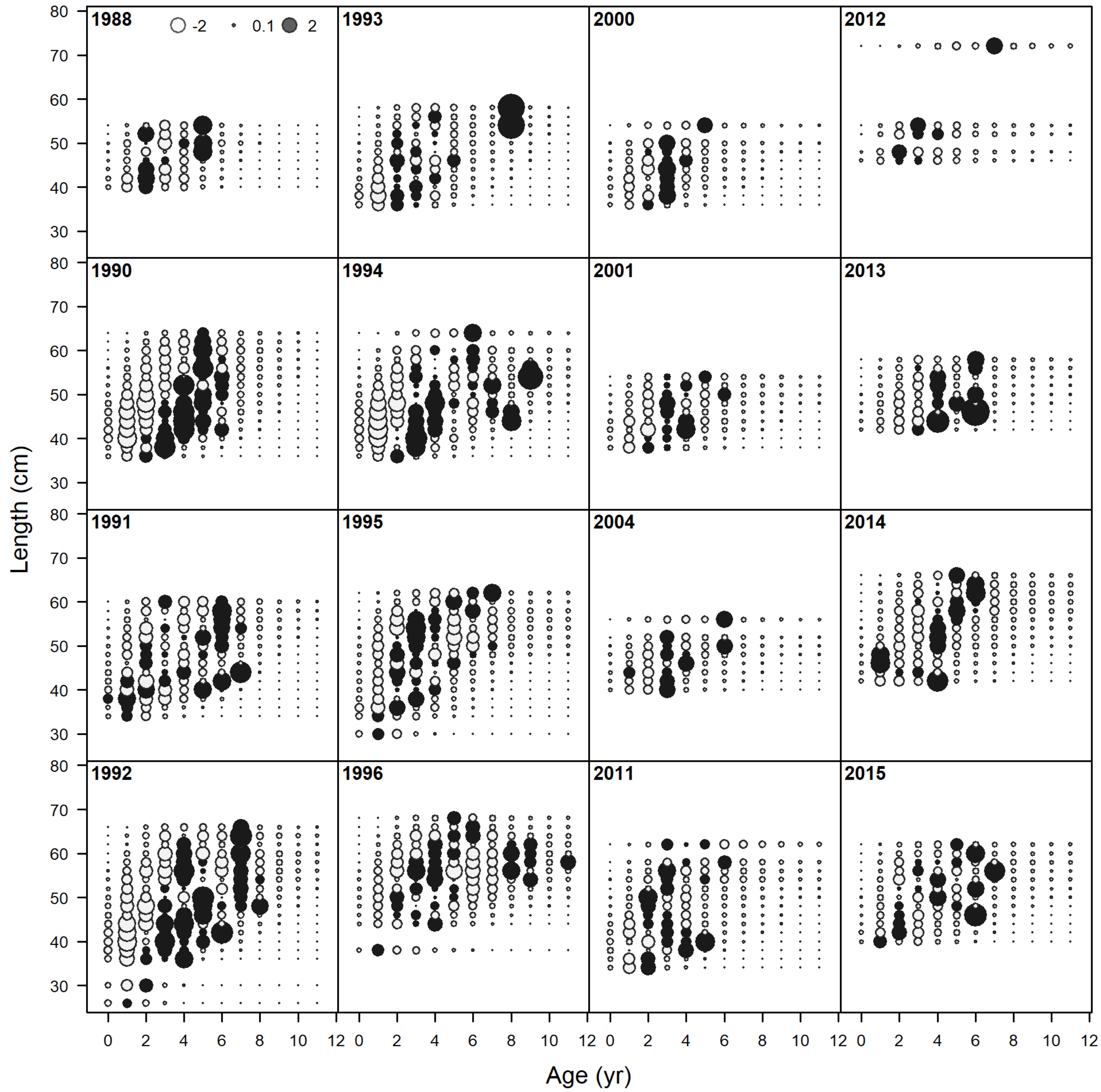


Figure 96. Observed and predicted conditional age at length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Commercial Gillnet + Other fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

SEDAR 28

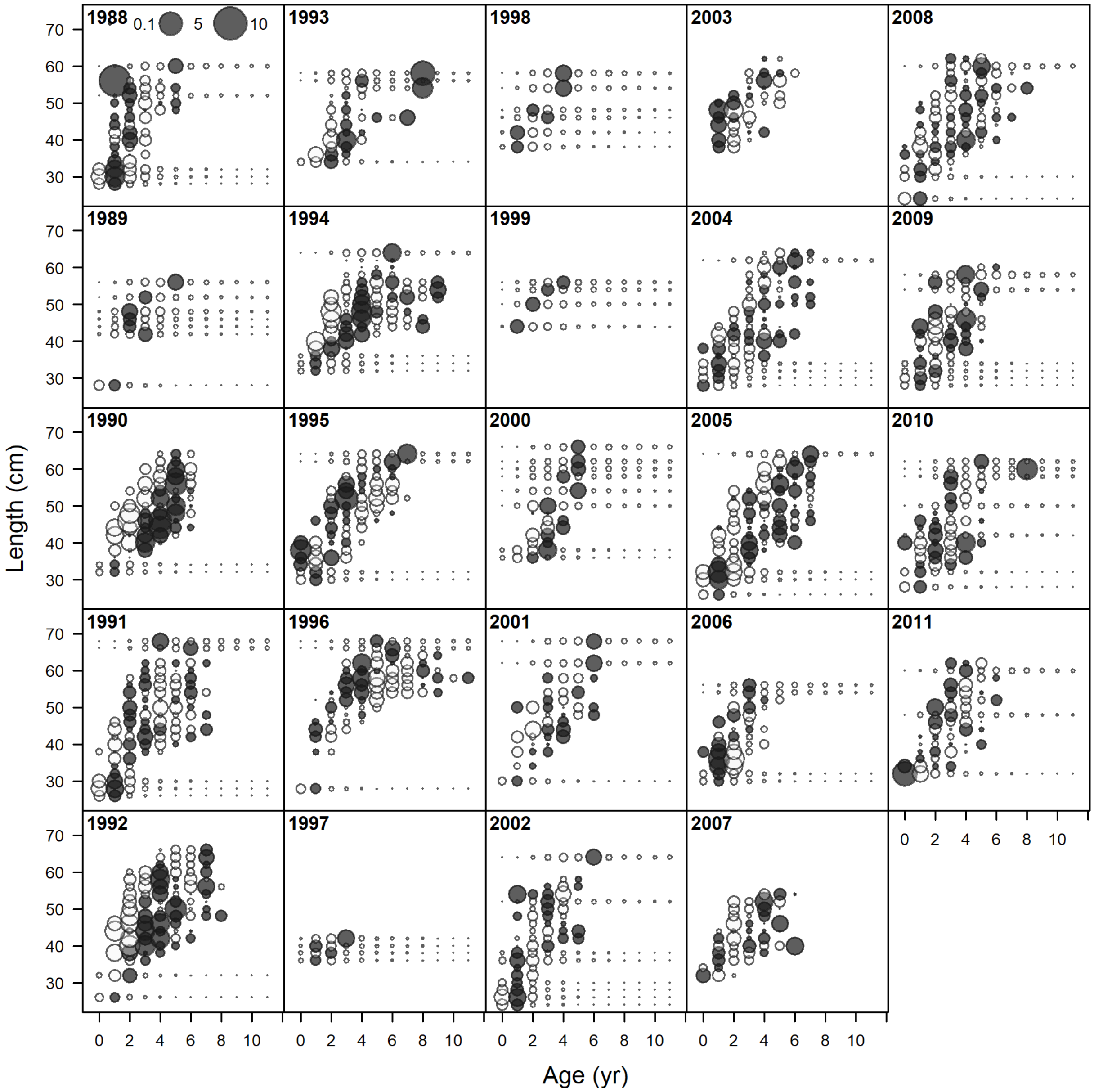


Figure 96 Continued. Observed and predicted conditional age at length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Commercial Gillnet + Other fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

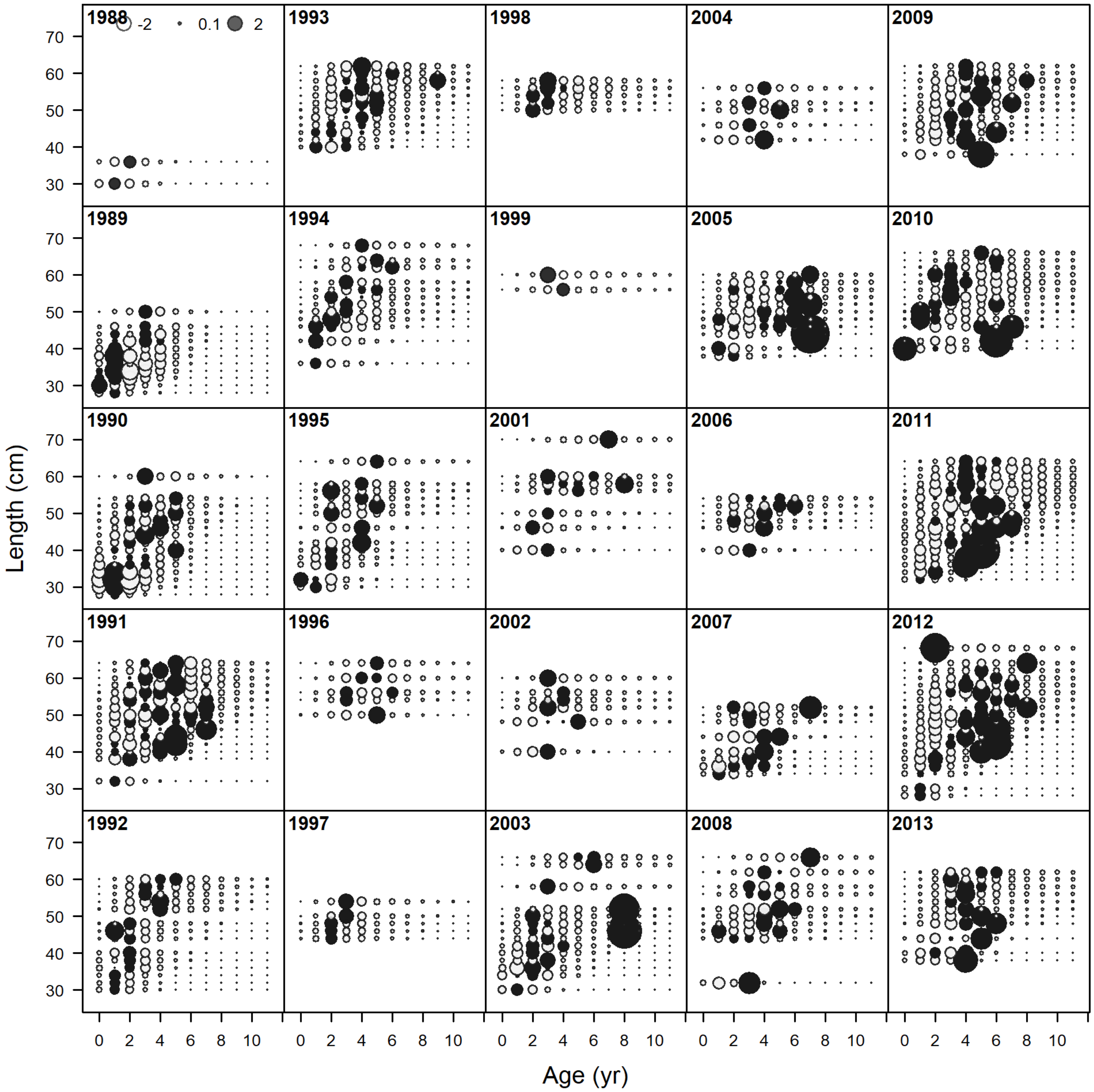


Figure 97. Observed and predicted conditional age at length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Commercial Handline + Other fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

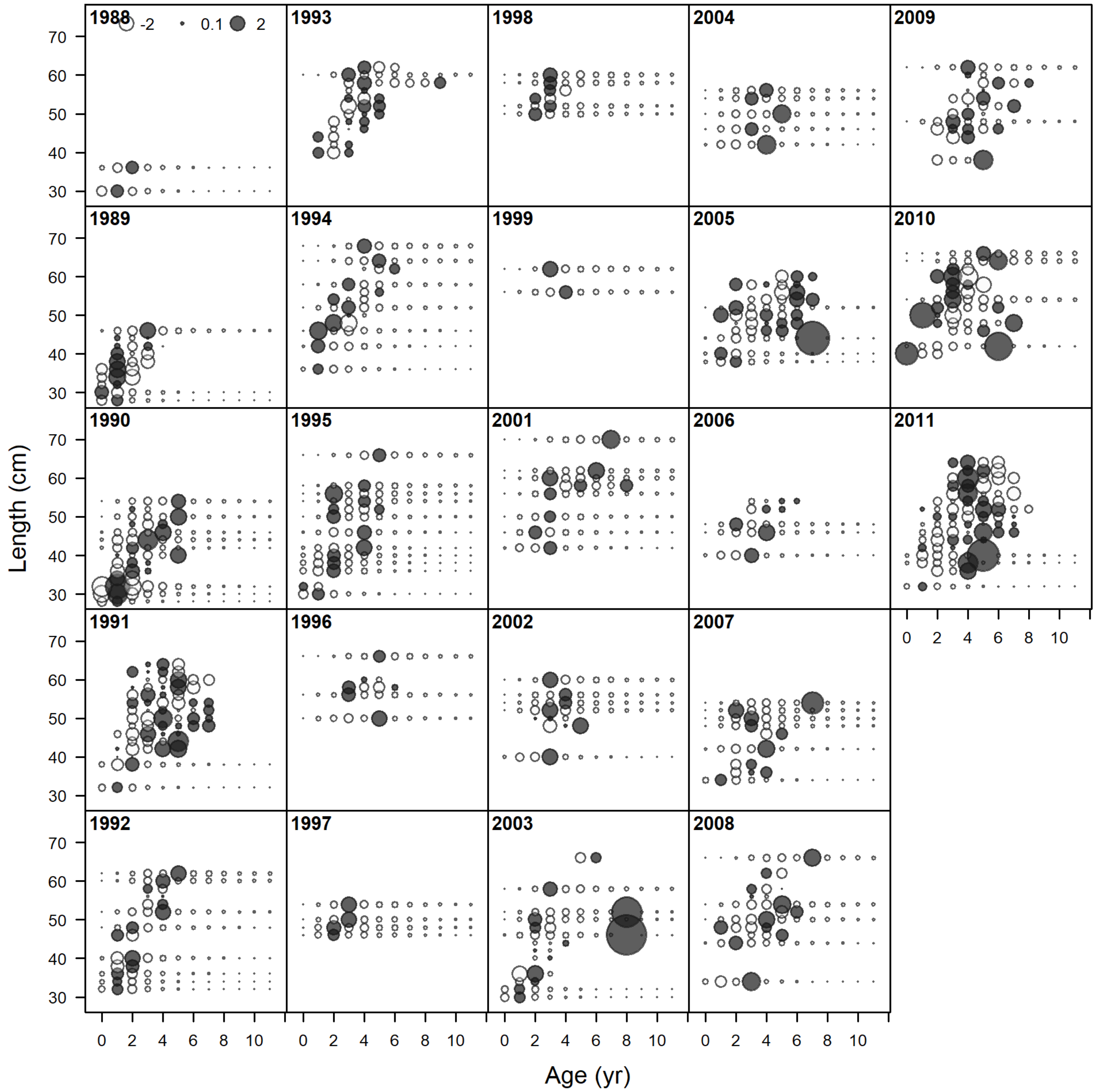


Figure 97 Continued. Observed and predicted conditional age at length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Commercial Handline + Other fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

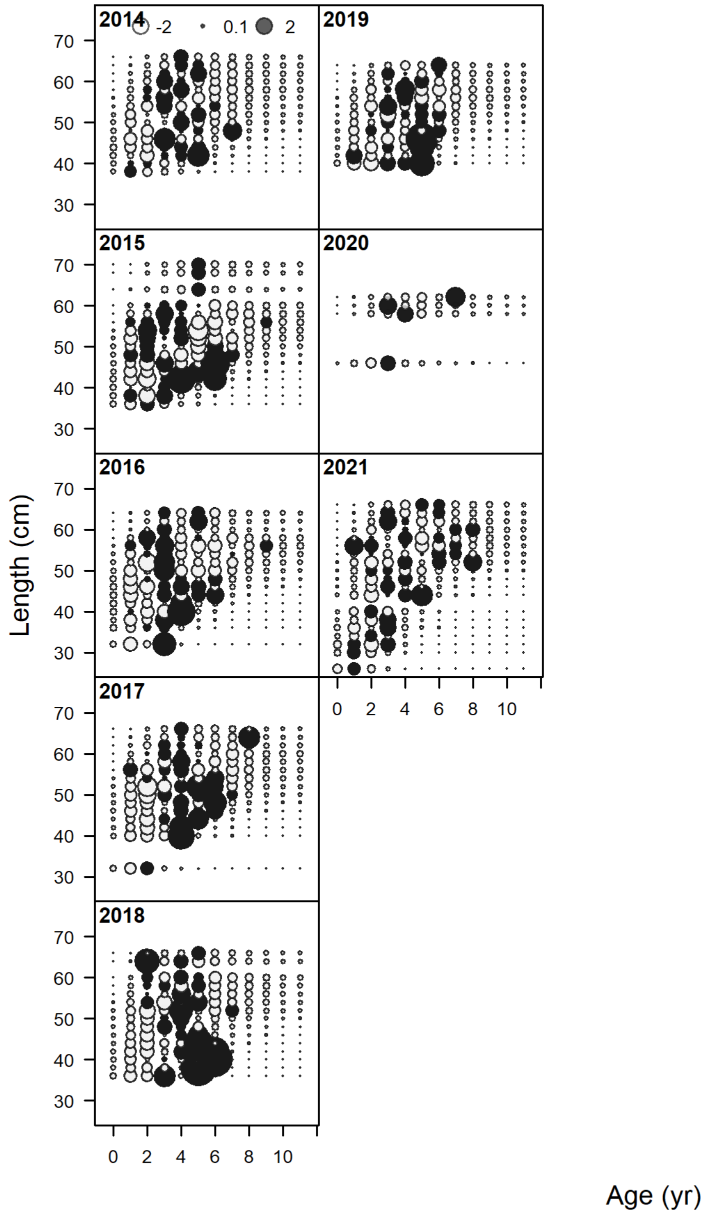


Figure 97 Continued. Observed and predicted conditional age at length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Commercial Handline + Other fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

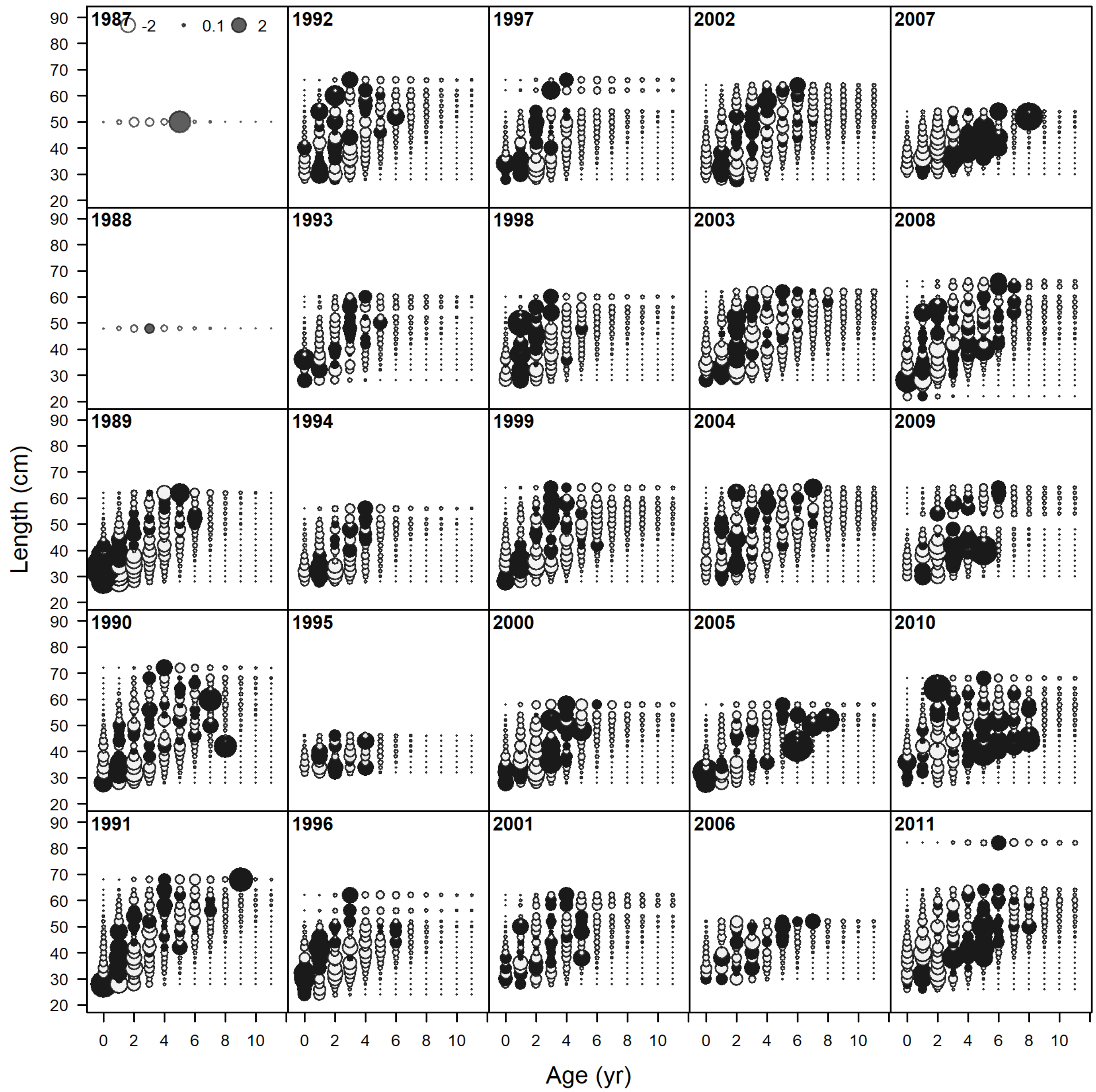


Figure 98. Observed and predicted conditional age at length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Recreational Headboat + Charterboat fleet (SEDAR 81) and aggregated recreational fleet (SEDAR 28). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

SEDAR 28

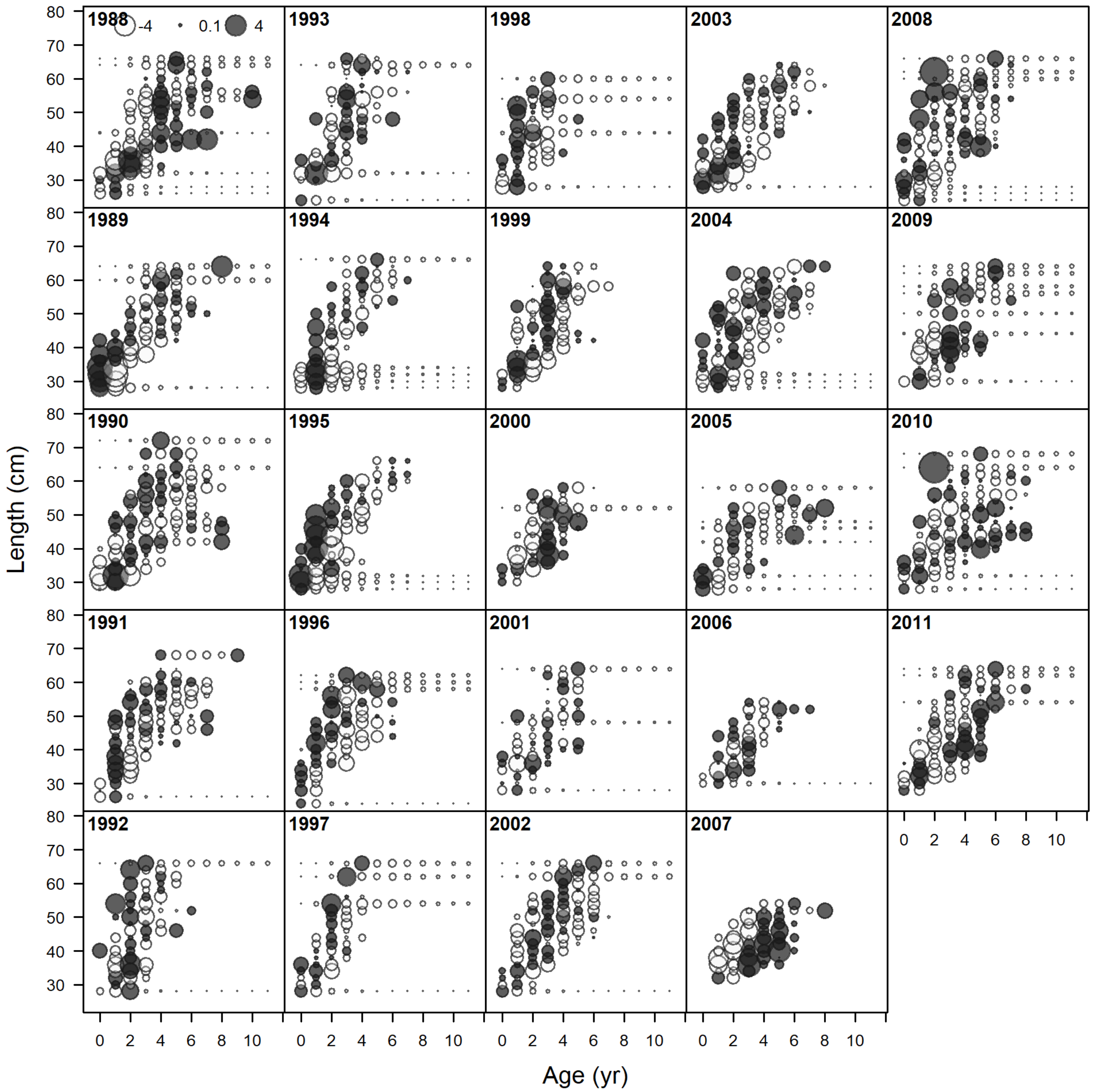


Figure 98 Continued. Observed and predicted conditional age at length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Recreational Headboat + Charterboat fleet (SEDAR 81) and aggregated recreational fleet (SEDAR 28). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

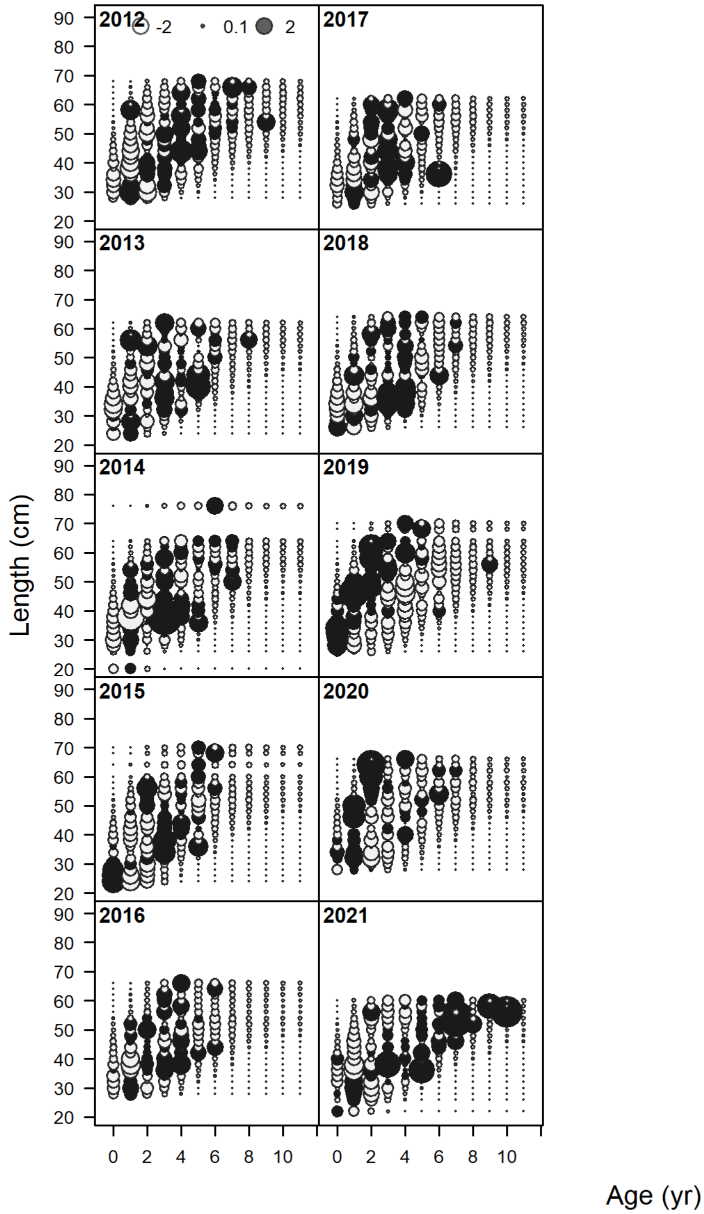


Figure 98 Continued. Observed and predicted conditional age at length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Recreational Headboat + Charterboat fleet (SEDAR 81) and aggregated recreational fleet (SEDAR 28). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

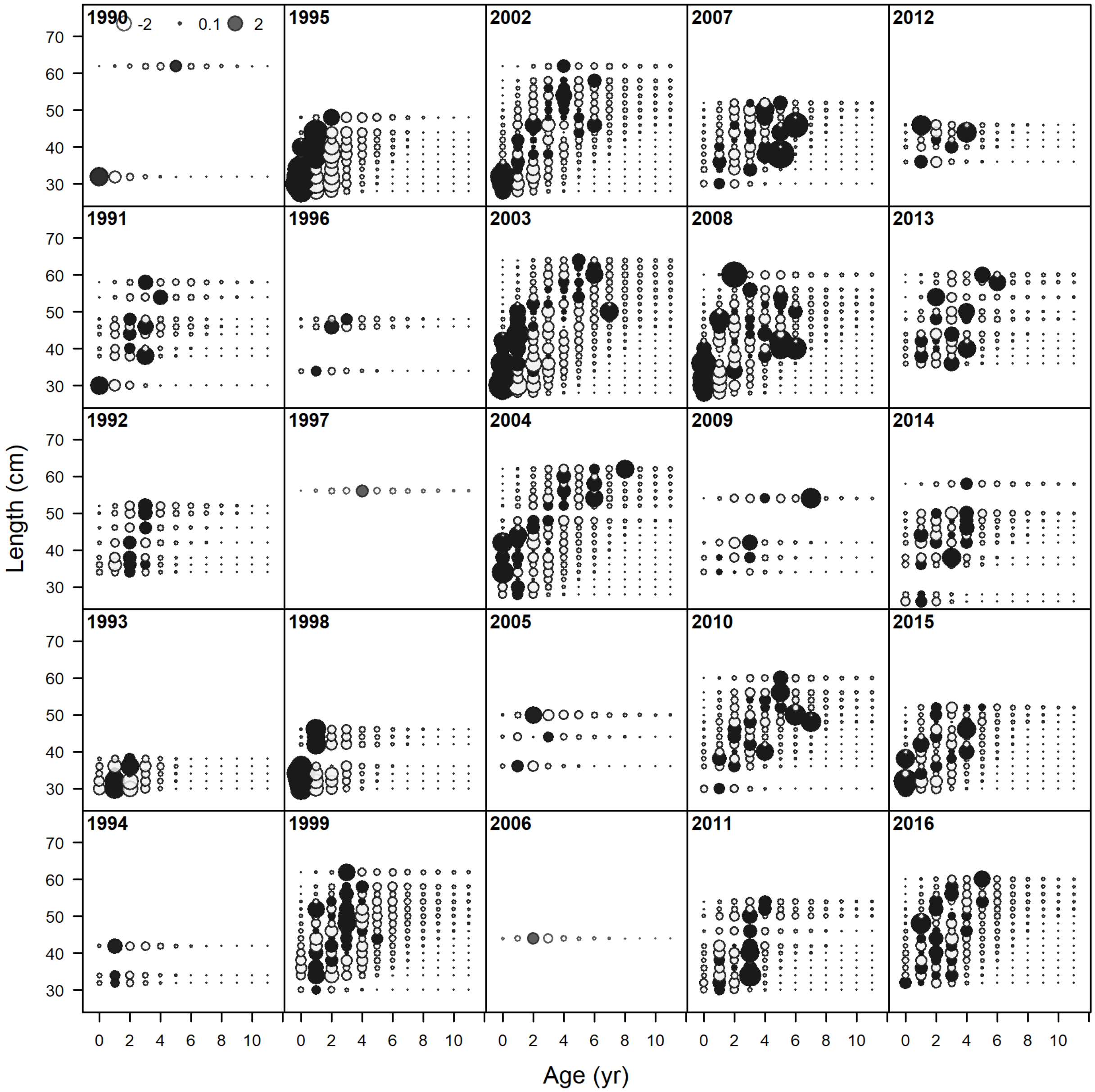


Figure 99. Observed and predicted conditional age at length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Recreational Private fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

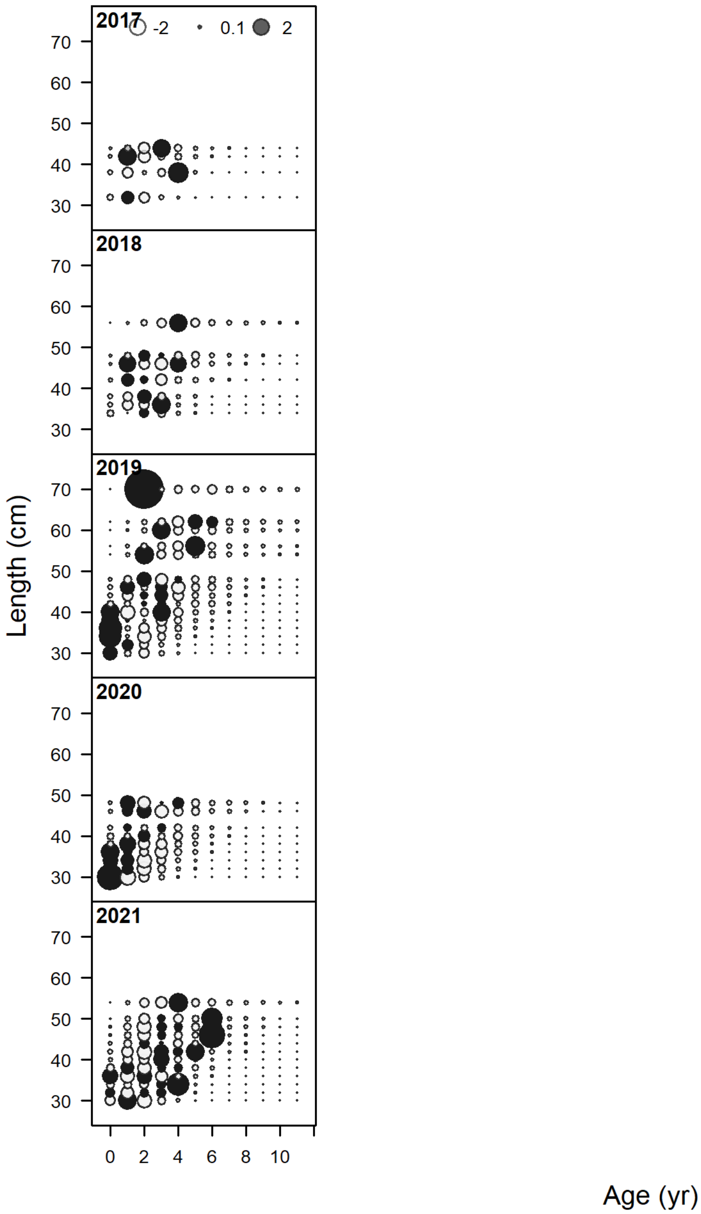


Figure 99 Continued. Observed and predicted conditional age at length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Recreational Private fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

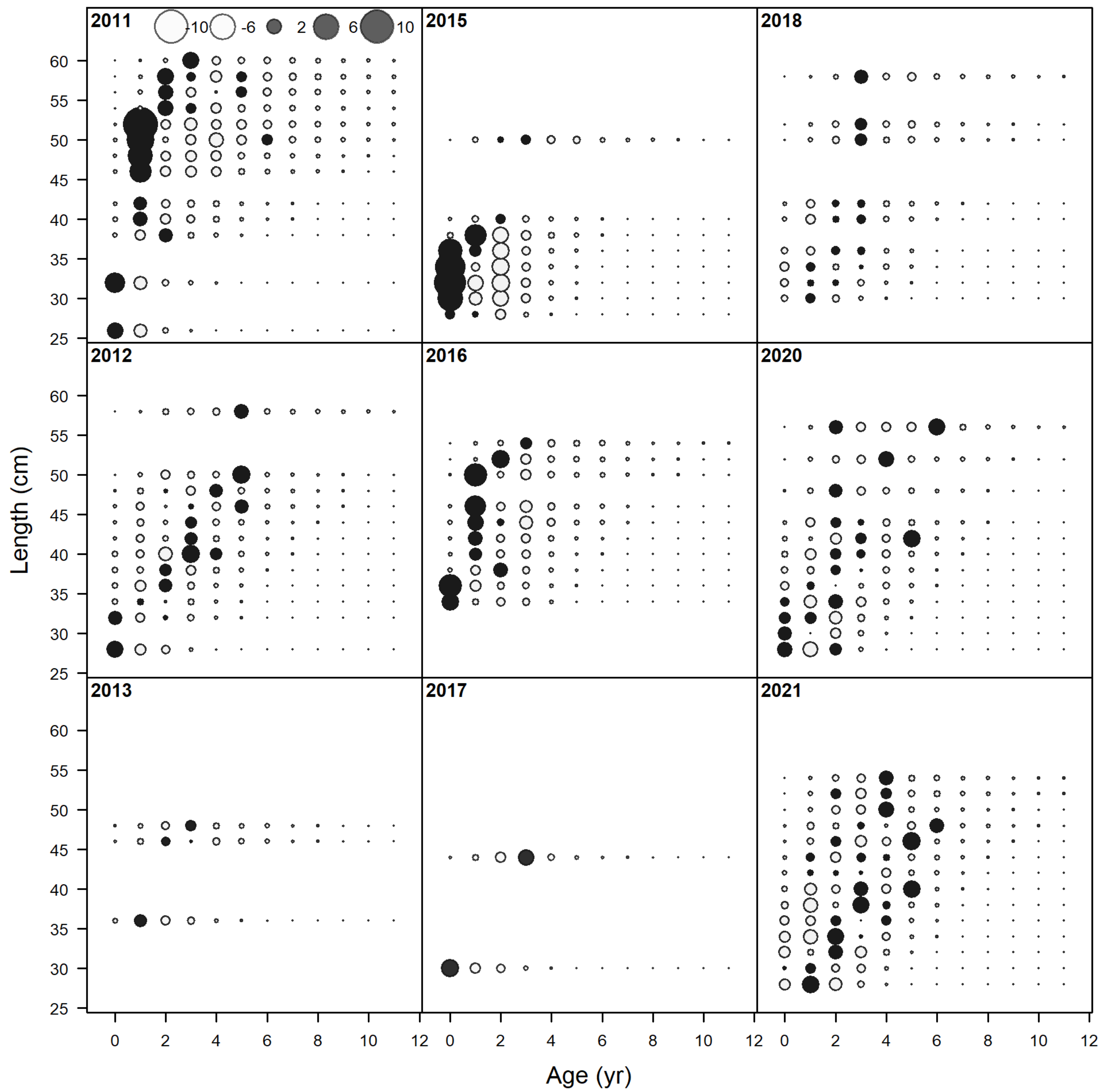


Figure 100. Observed and predicted conditional age at length compositions (retained) for Gulf of Mexico Spanish Mackerel in the Recreational Shore fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

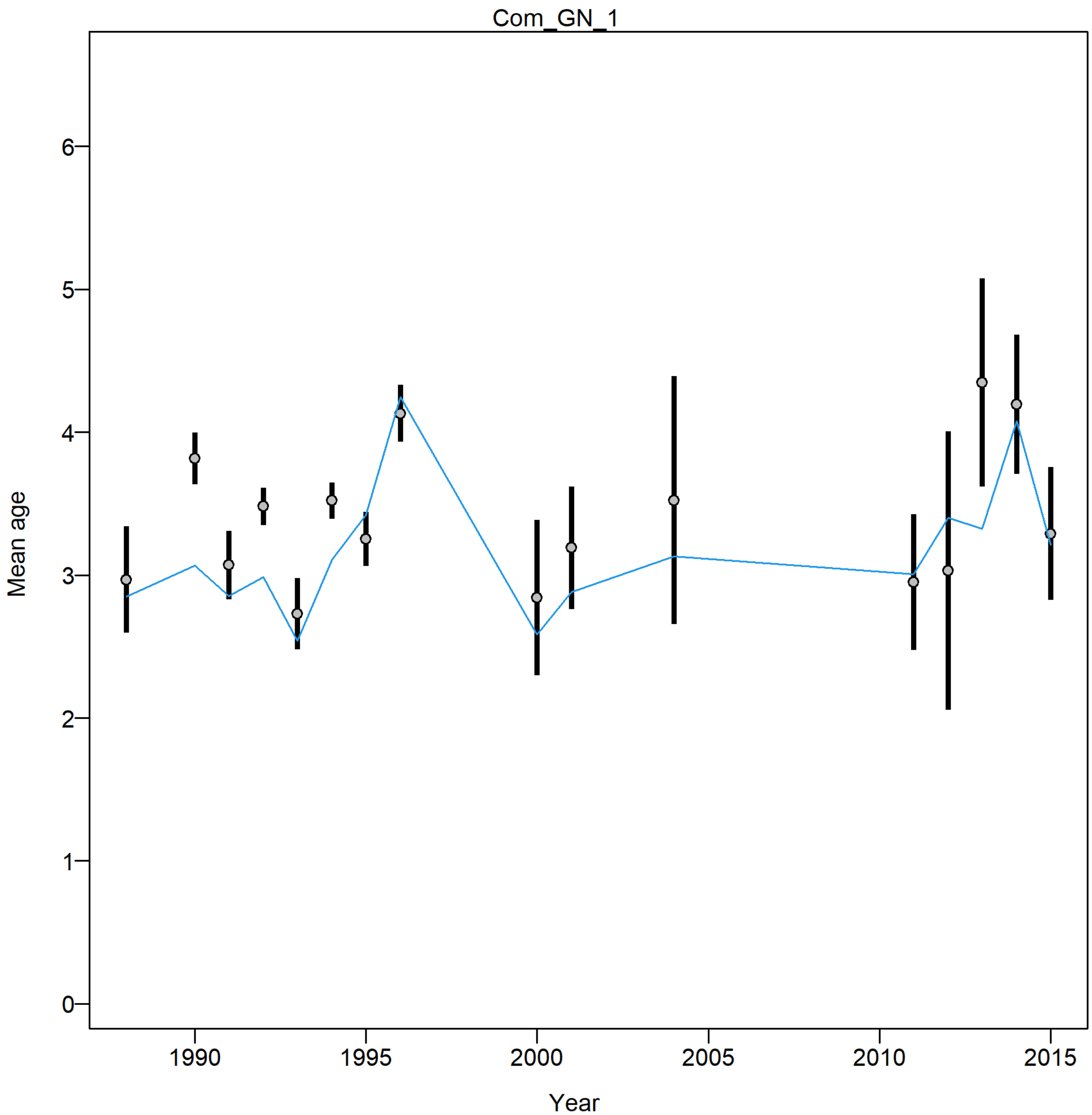


Figure 101. Mean age from conditional data (aggregated across length bins) for the Commercial Gillnet + Other fleet with 95% confidence intervals based on current samples sizes (including any D-M weighting).

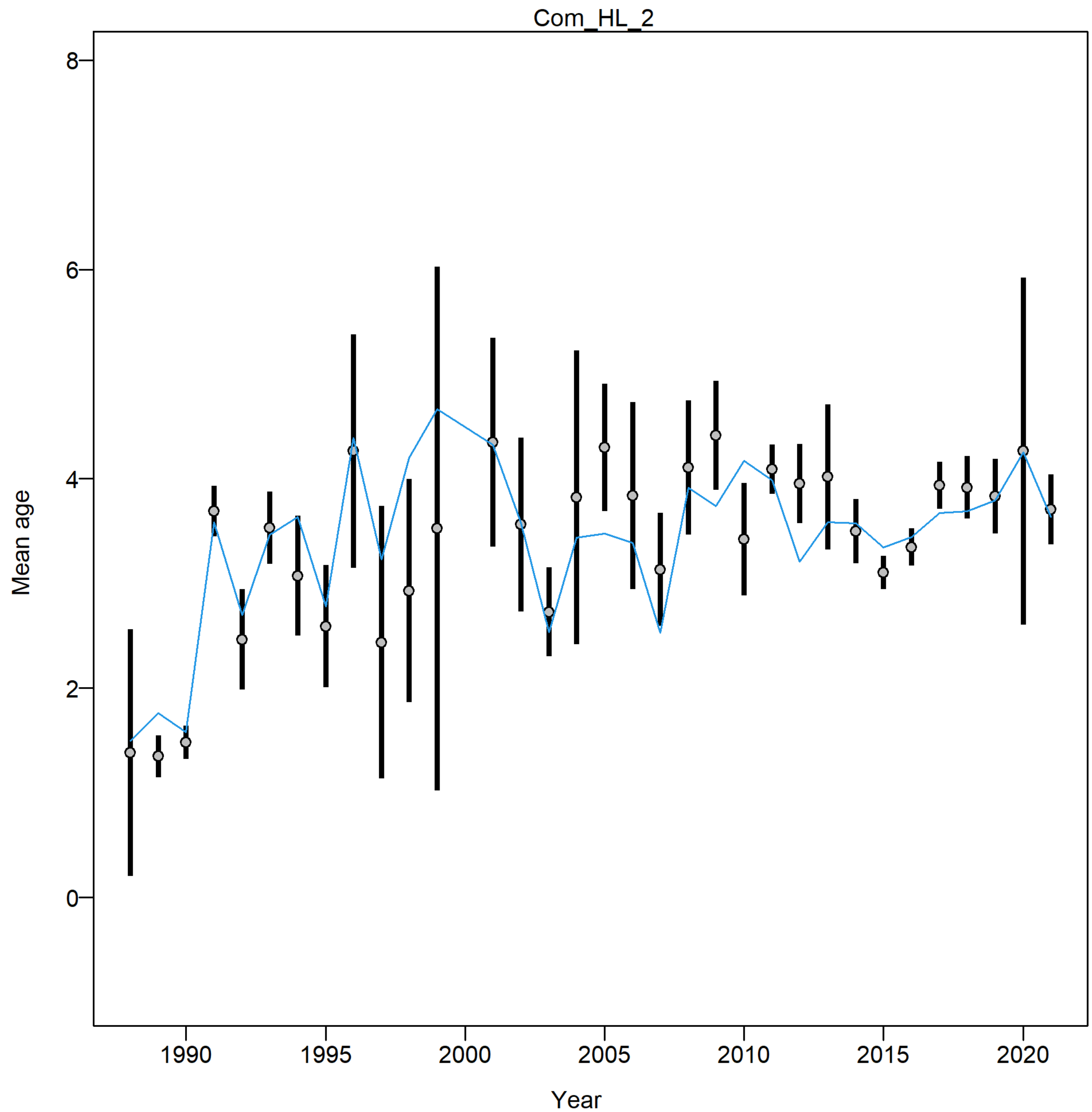


Figure 102. Mean age from conditional data (aggregated across length bins) for the Commercial Handline + Other fleet with 95% confidence intervals based on current samples sizes (including any D-M weighting).

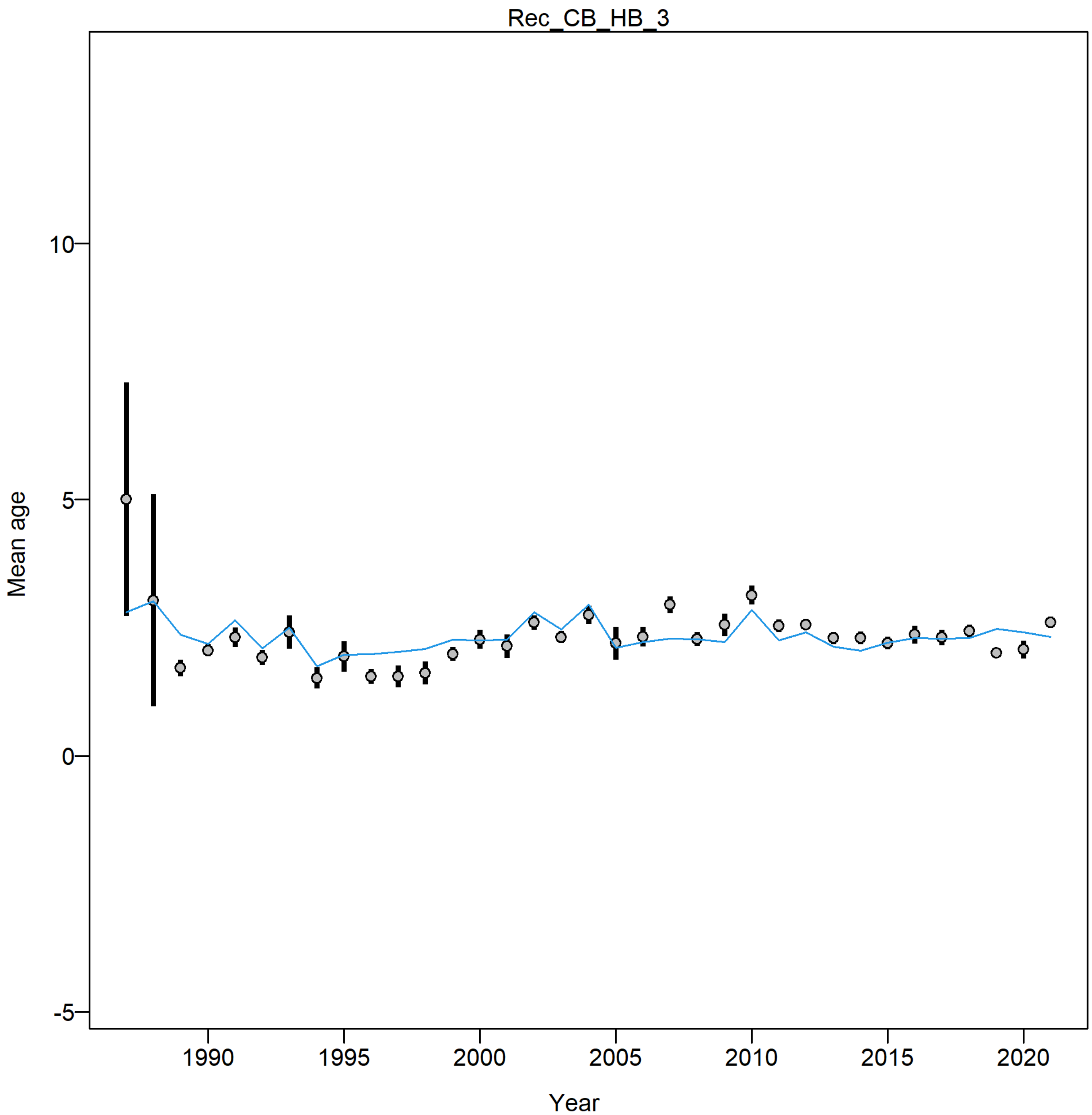


Figure 103. Mean age from conditional data (aggregated across length bins) for the Recreational Headboat + Charterboat fleet with 95% confidence intervals based on current samples sizes (including any D-M weighting).

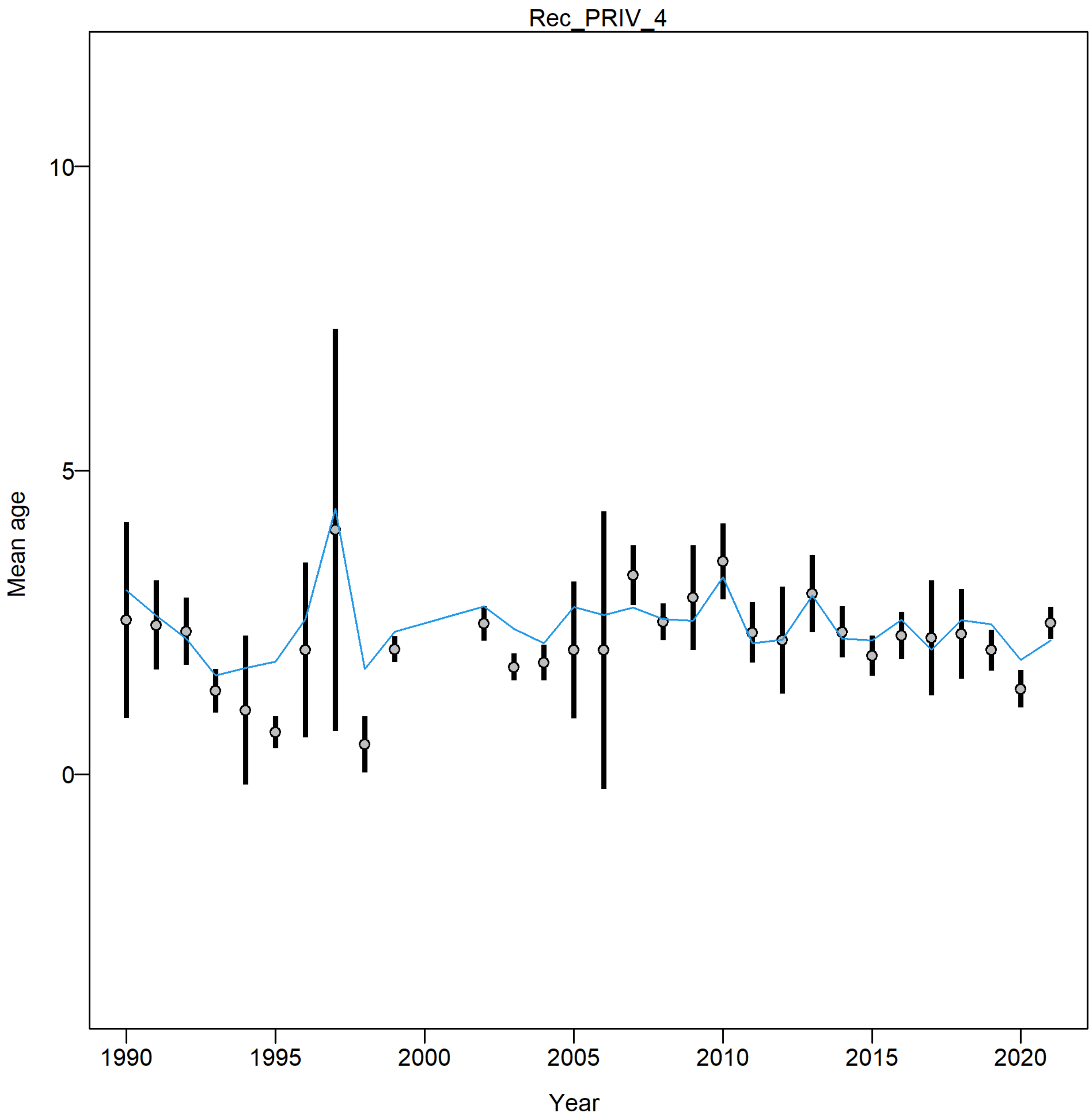


Figure 104. Mean age from conditional data (aggregated across length bins) for the Recreational Private fleet with 95% confidence intervals based on current samples sizes (including any D-M weighting).

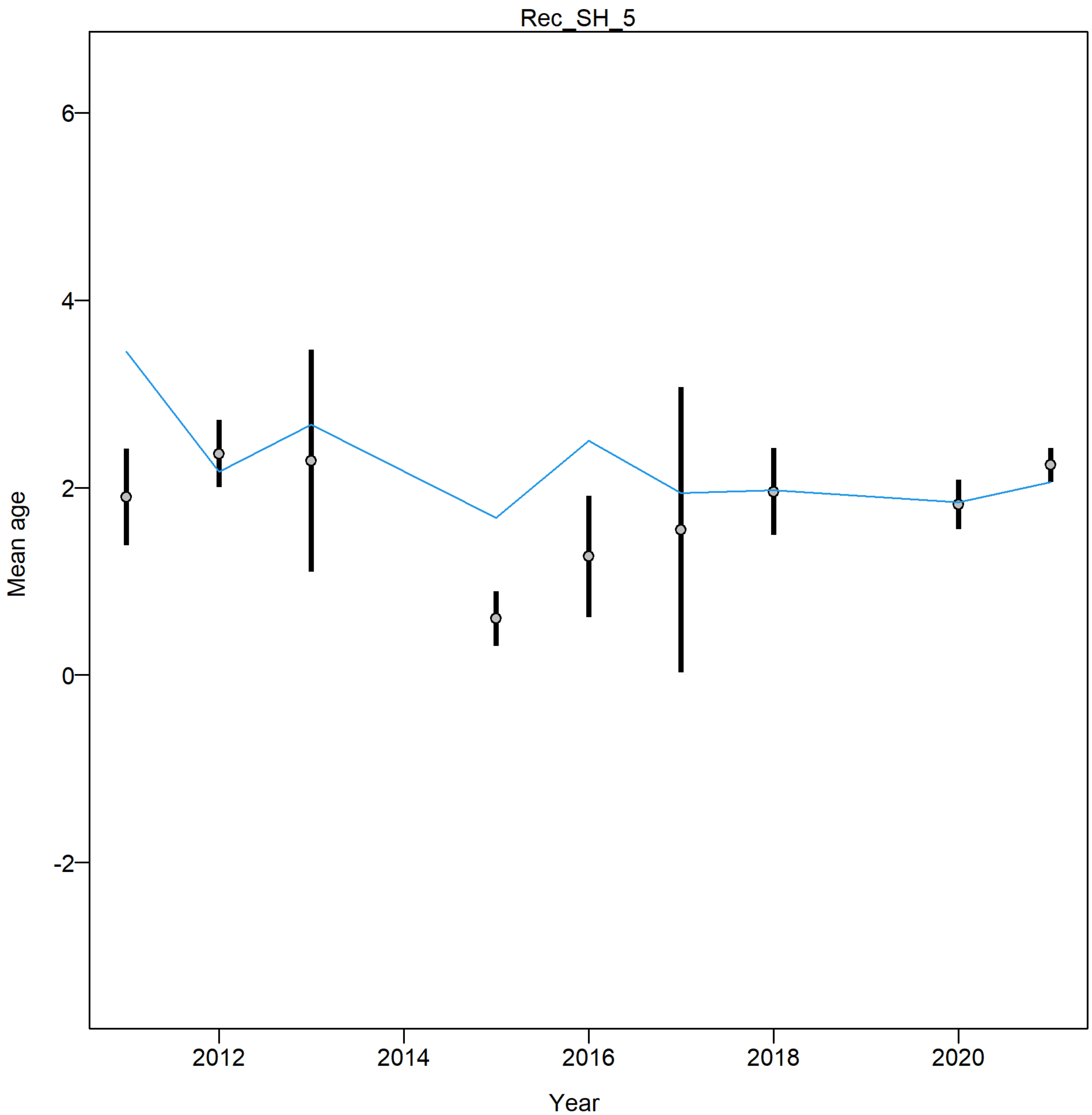


Figure 105. Mean age from conditional data (aggregated across length bins) for the Recreational Shore fleet with 95% confidence intervals based on current samples sizes (including any D-M weighting).

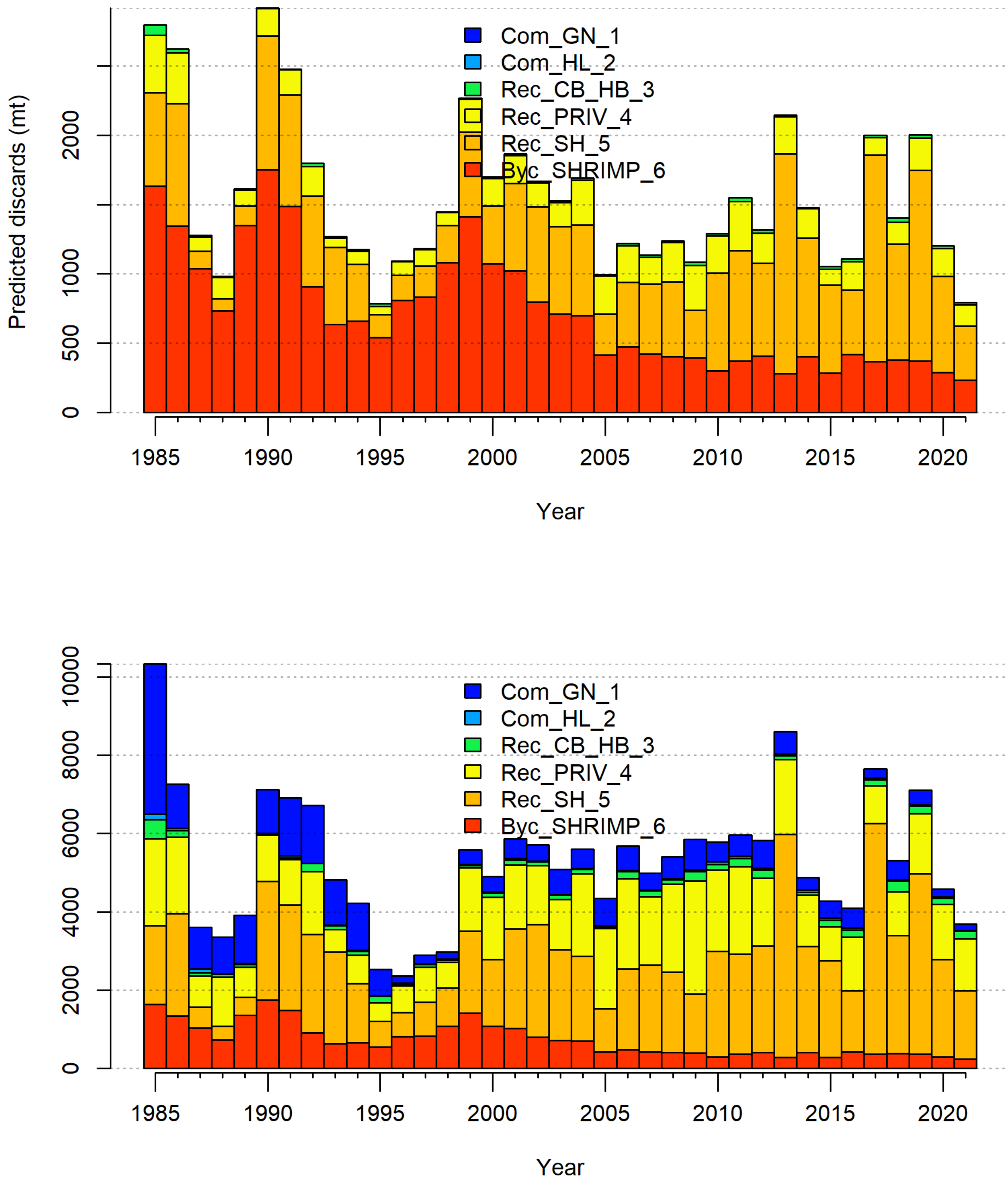


Figure 106. Predicted discards (top panel) and predicted landings + dead discards (bottom panel) by fleet for SEDAR 81.

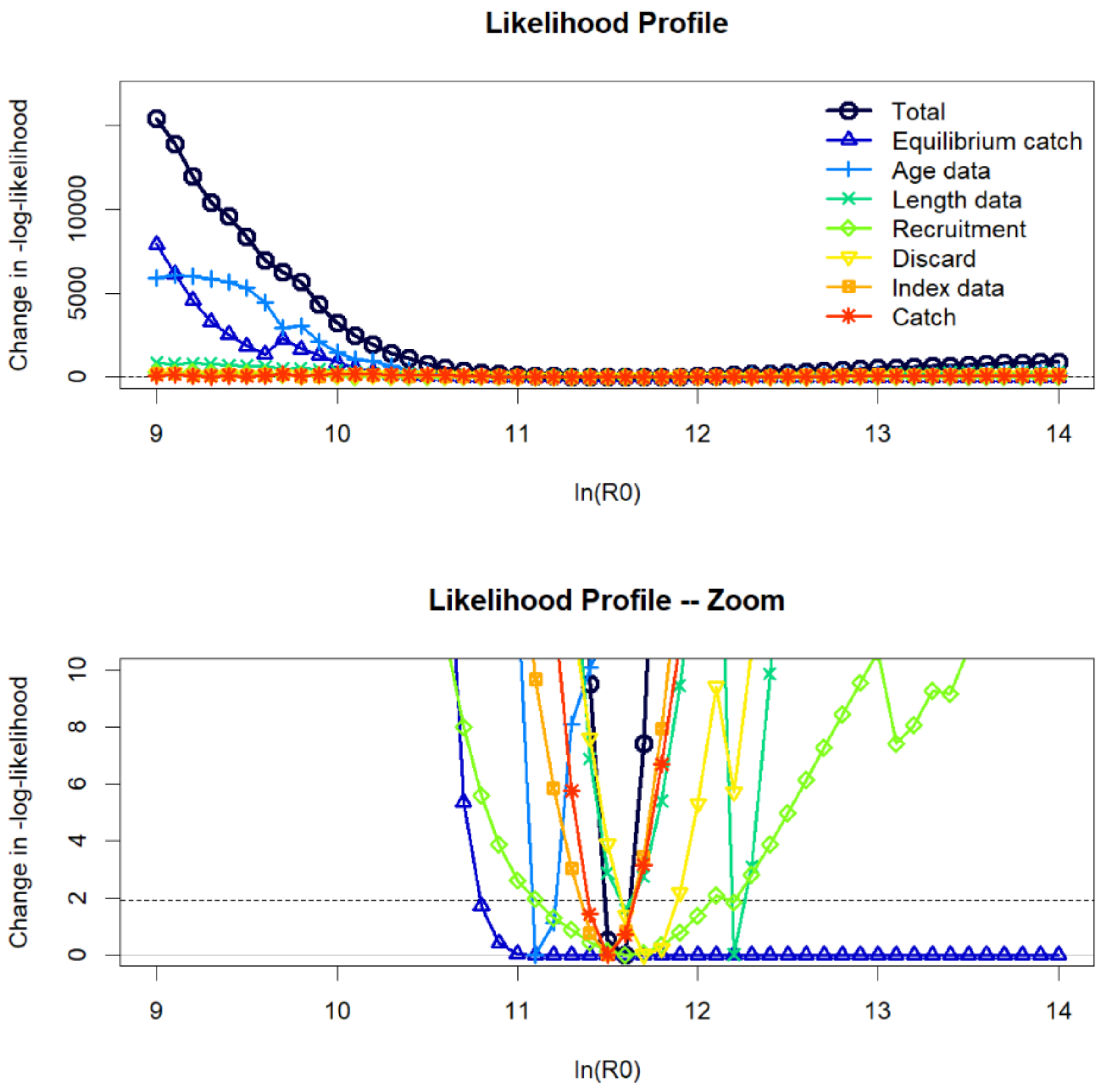


Figure 107. The profile likelihood for the natural log of the unfished recruitment parameter of the Beverton – Holt stock-recruit function for Gulf of Mexico Spanish Mackerel. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed R0 values tested in the profile diagnostic run. The MLE for the base model was 11.56. The bottom panel shows a close up of the top panel to better detect significant differences between runs.

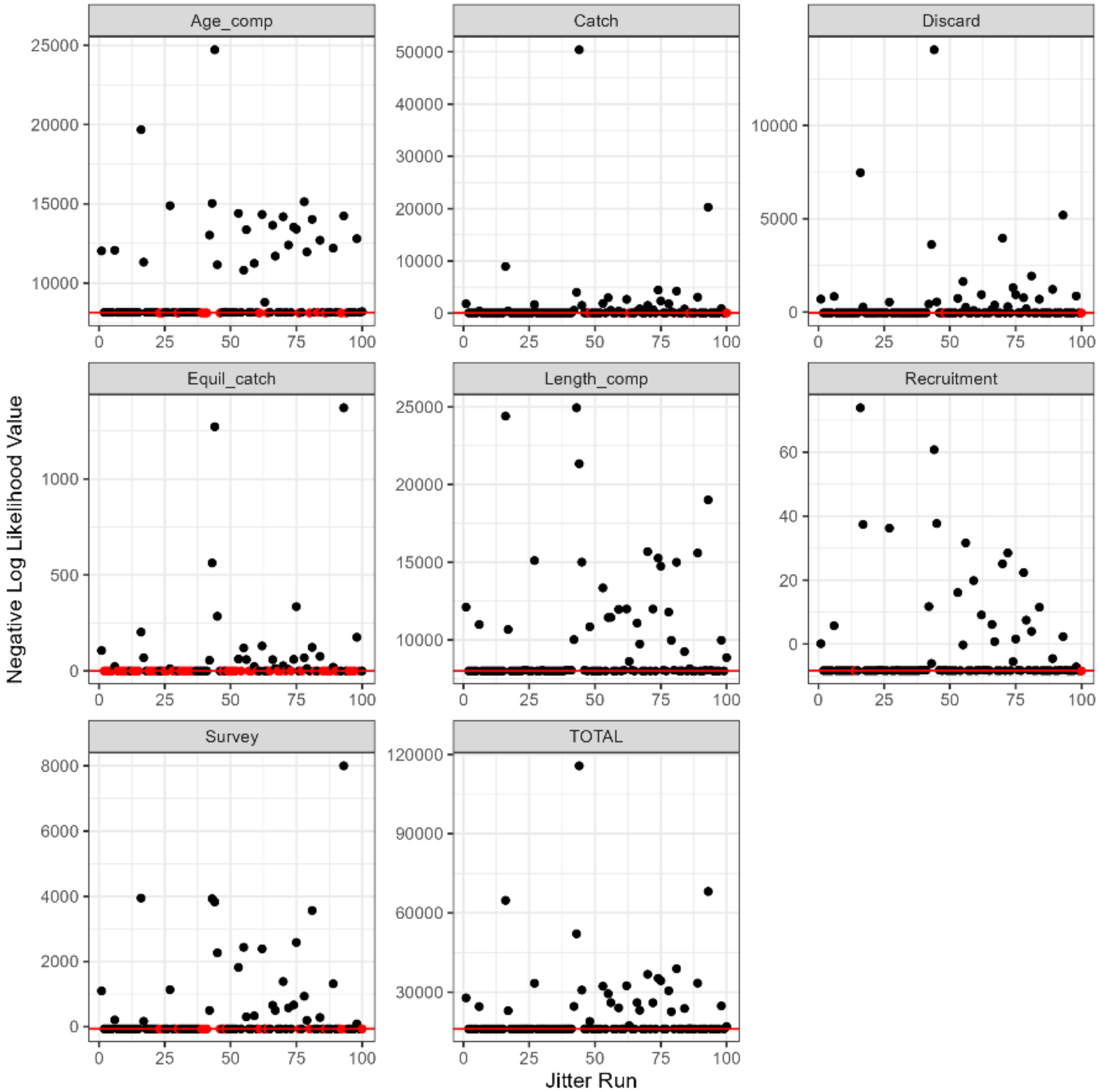


Figure 108. Results of the jitter analysis for various likelihood components for the Gulf of Mexico Spanish Mackerel Base Model. Each panel gives the results of 100 model runs where the starting parameter values for each run were randomly changed ('jittered') by 10% from the base model best fit values. The Base Run value for each panel is indicated by a red line.

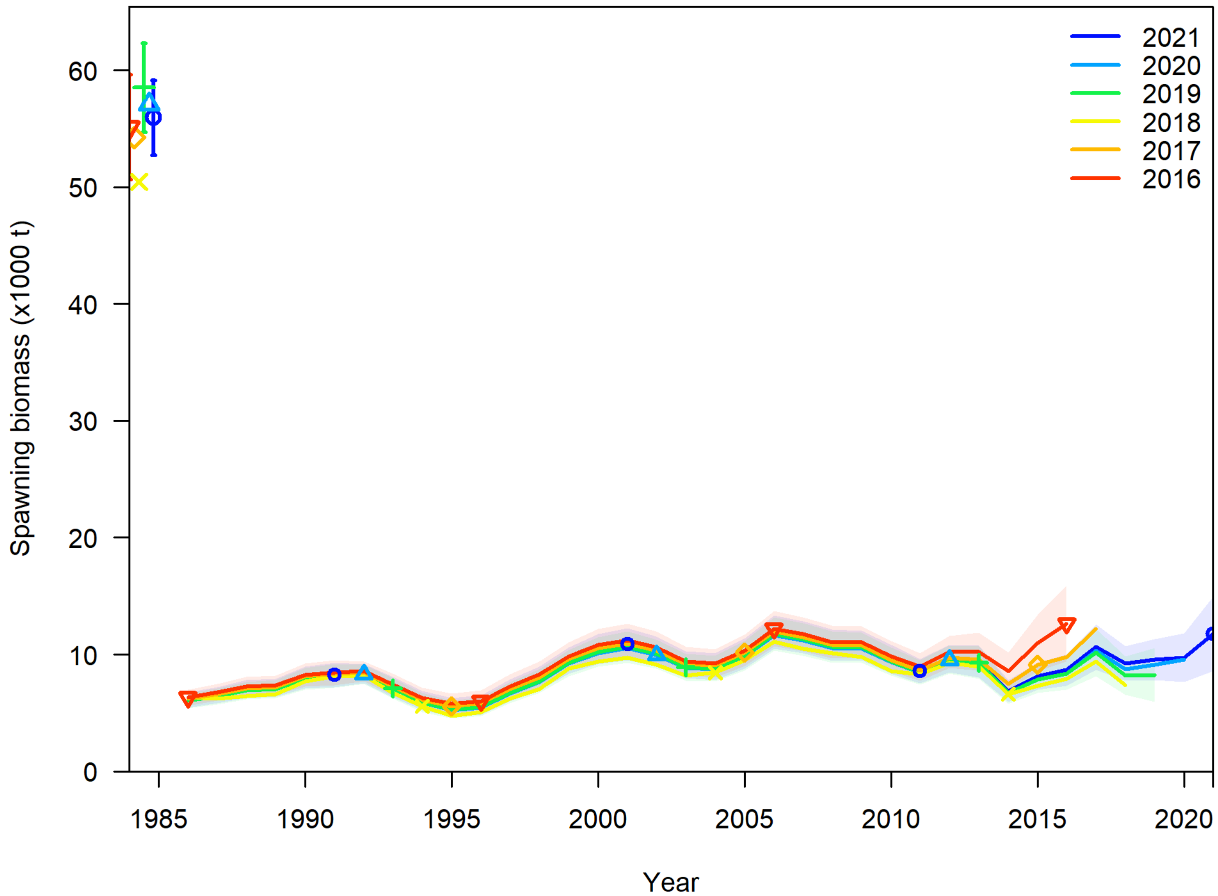


Figure 109. Results of a five year retrospective analysis for spawning biomass (metric tons) for the Gulf of Mexico Spanish Mackerel Base Model. There is no discernible systematic bias because each data peel is not consistently over or underestimating any of the population quantities.

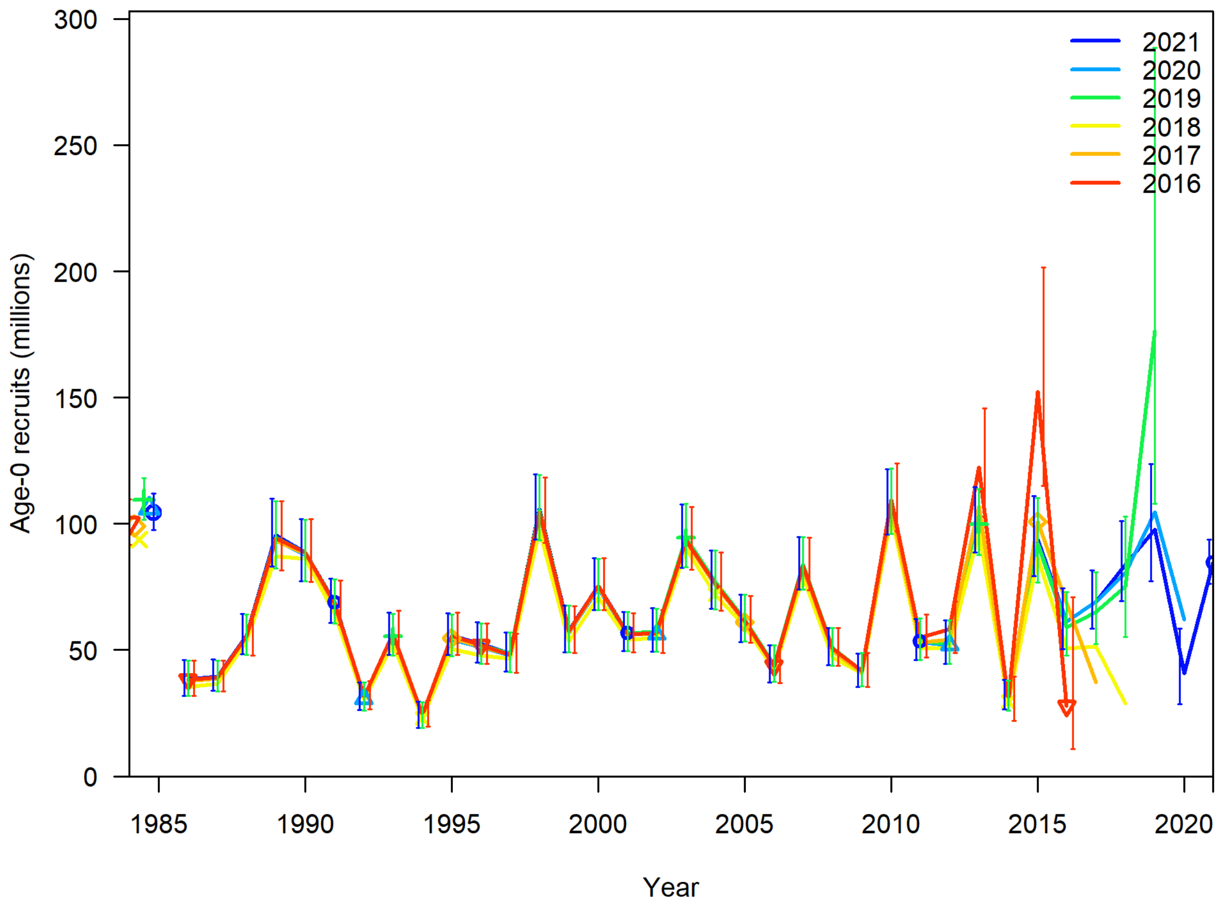


Figure 110. Results of a five year retrospective analysis for recruitment (millions of fish) for the Gulf of Mexico Spanish Mackerel Base Model. There is no discernible systematic bias because each data peel is not consistently over or underestimating any of the population quantities.

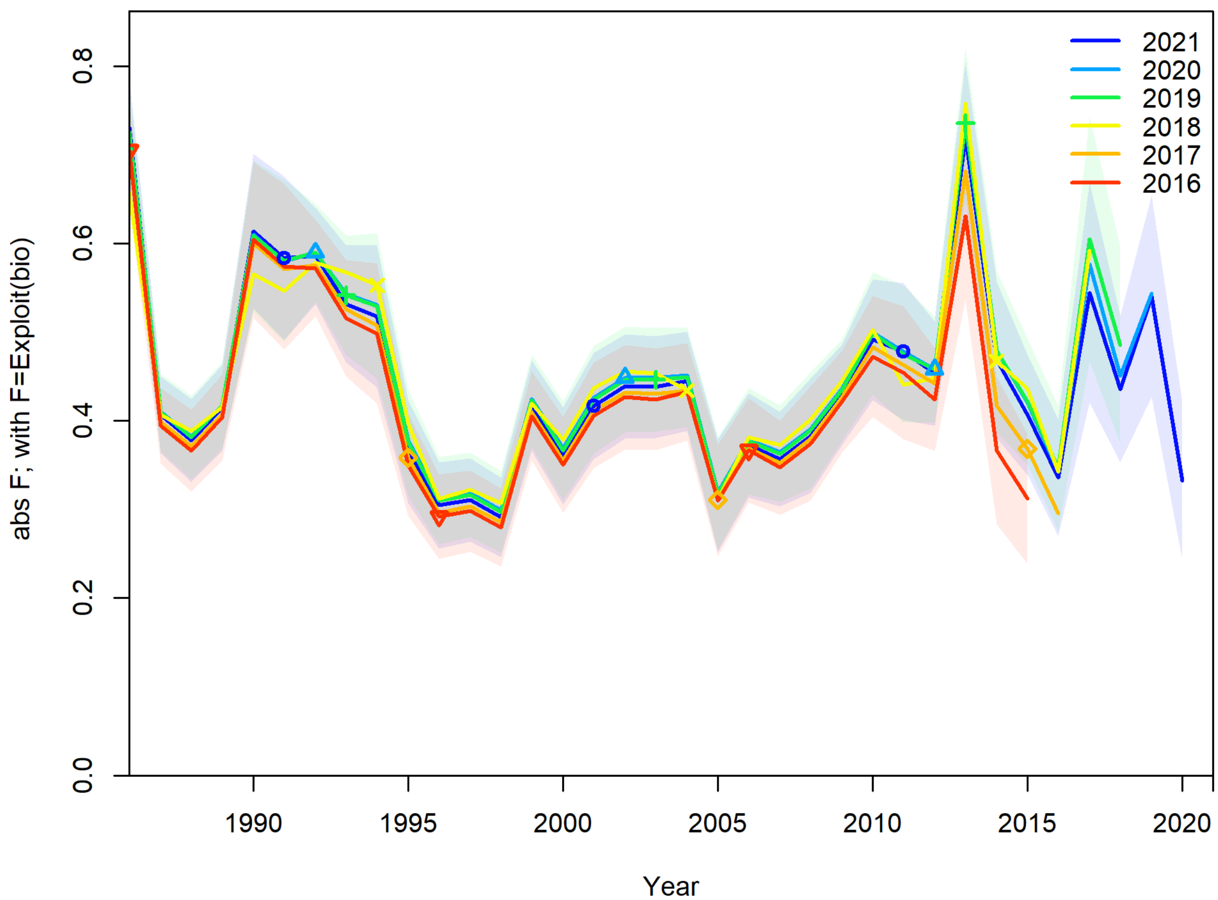


Figure 111. Results of a five-year retrospective analysis for spawning biomass fishing mortality (total biomass killed / total biomass age 1+) for the Gulf of Mexico Spanish Mackerel Base Model. There is no discernible systematic bias because each data peel is not consistently over or underestimating any of the population quantities.

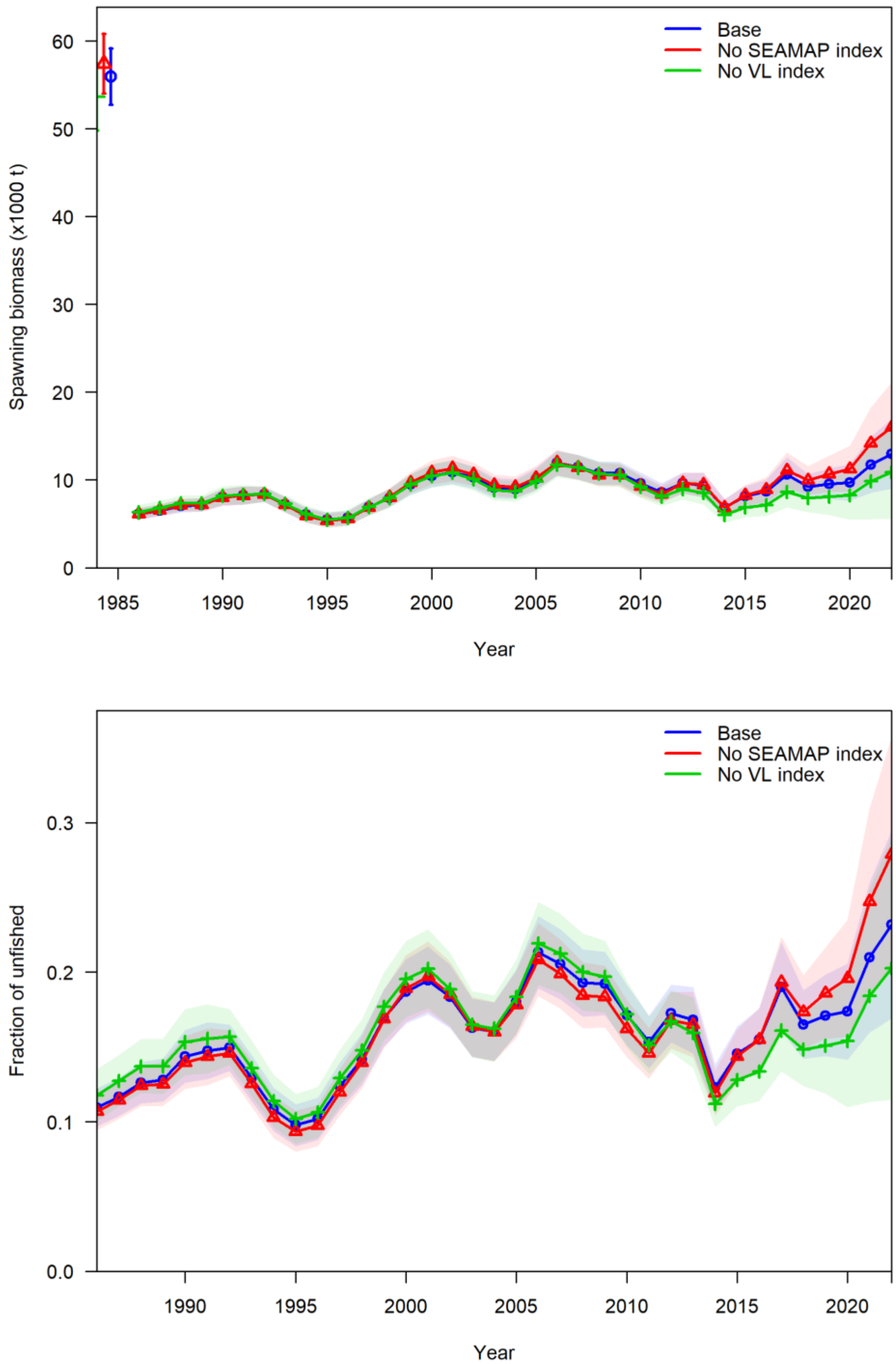


Figure 112. Differences in the time series of SSB and fraction unfished (SSB/SSB0) between the SEDAR 81 base model and jacknife runs (removing each index to test influence on results).

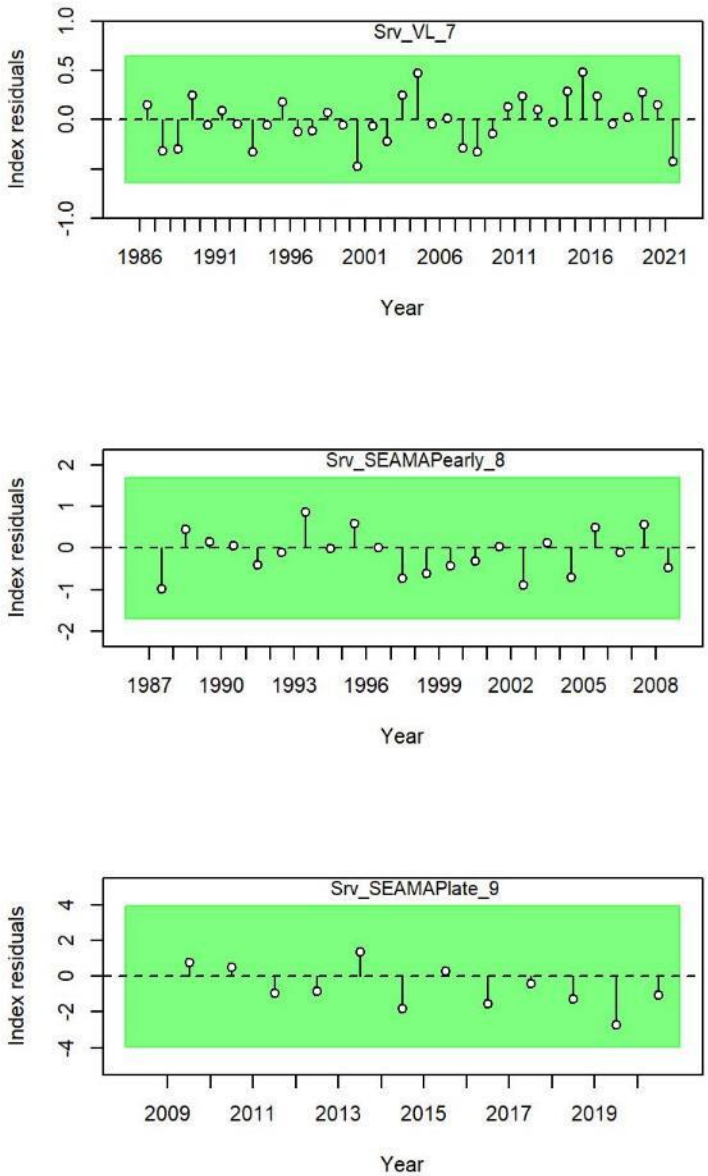


Figure 113. Runs tests results for the index fits in the base model run. Green shading indicates no evidence ($p \geq 0.05$) and red shading evidence ($p < 0.05$) to reject the hypothesis of a randomly distributed time-series of residuals, respectively. The shaded (green/red) area spans three residual standard deviations to either side from zero, and the red points outside of the shading violate the 'three-sigma limit' for that series.

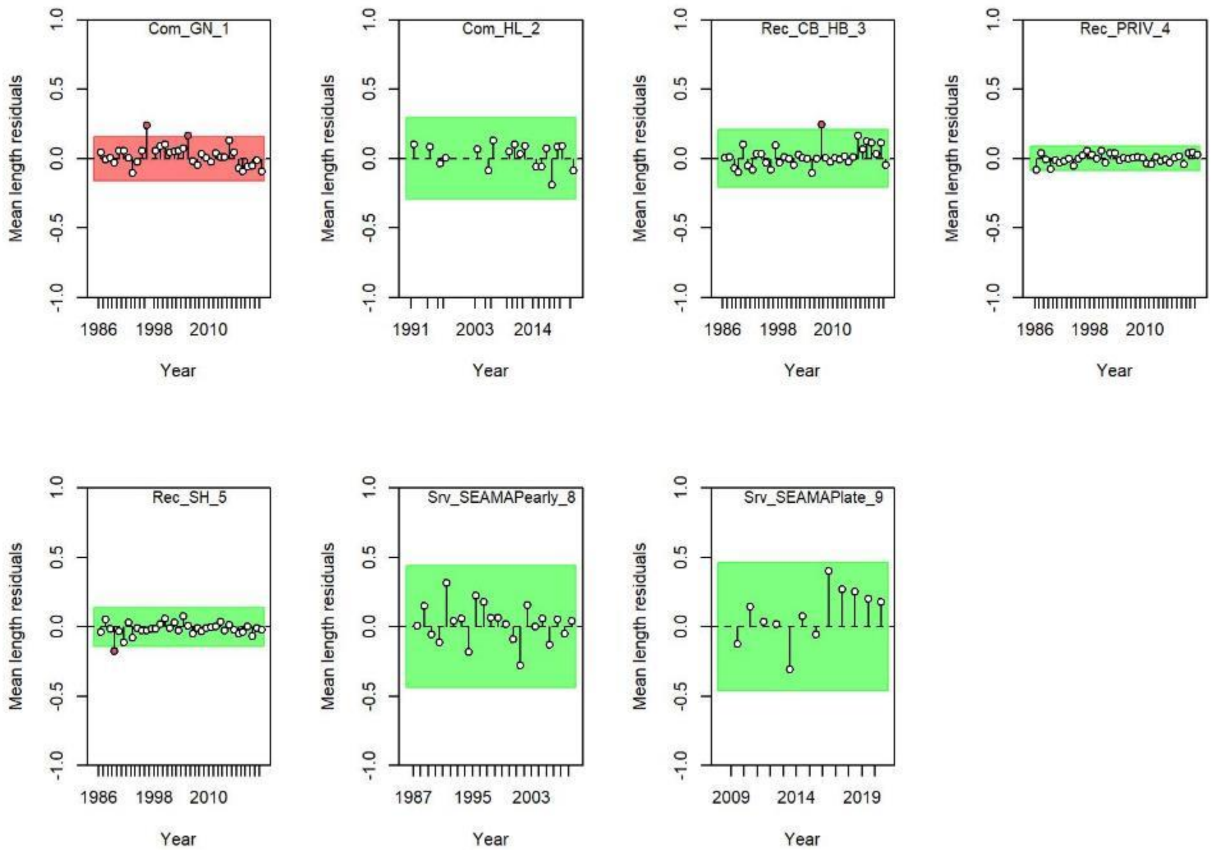


Figure 114. Runs tests results for the length compositions in the base model run. Green shading indicates no evidence ($p \geq 0.05$) and red shading evidence ($p < 0.05$) to reject the hypothesis of a randomly distributed time-series of residuals, respectively. The shaded (green/red) area spans three residual standard deviations to either side from zero, and the red points outside of the shading violate the 'three-sigma limit' for that series.

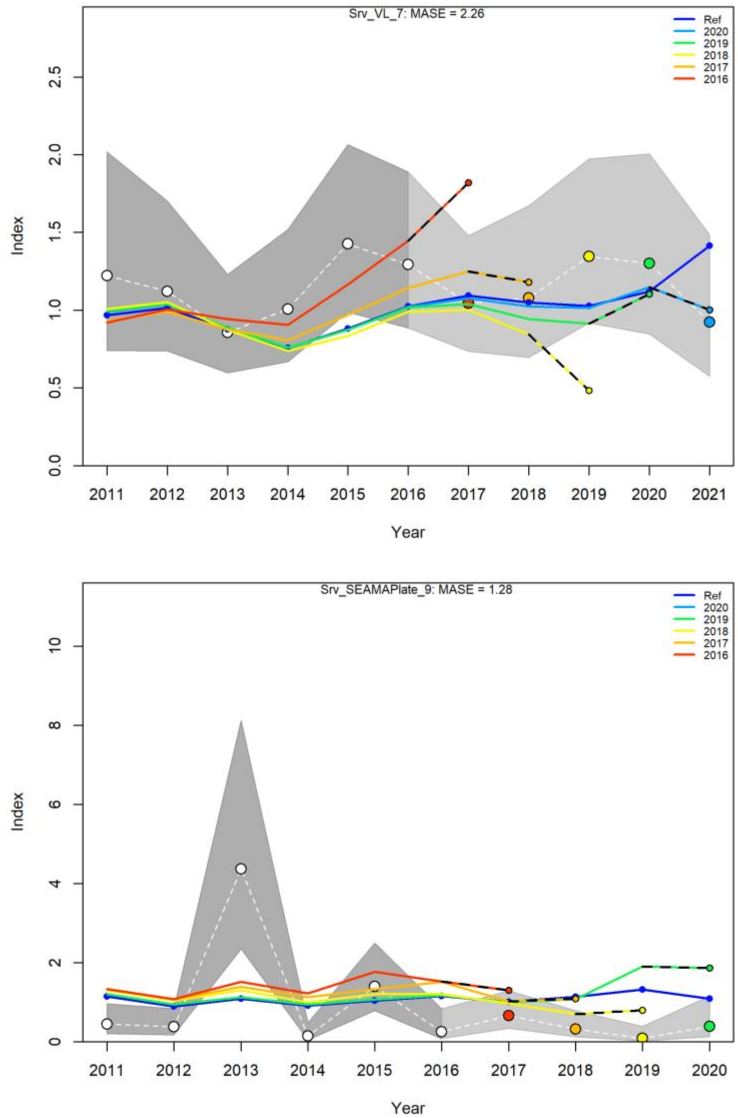


Figure 115. Hindcasting cross-validation (HCxval) results for the VL CPUE (top) and SEAMAP Trawl Survey Late (bottom) index fits, showing observed (large points connected with dashed line), fitted (solid lines) and one-year-ahead forecast values (small terminal points). HCxval was performed using one 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.

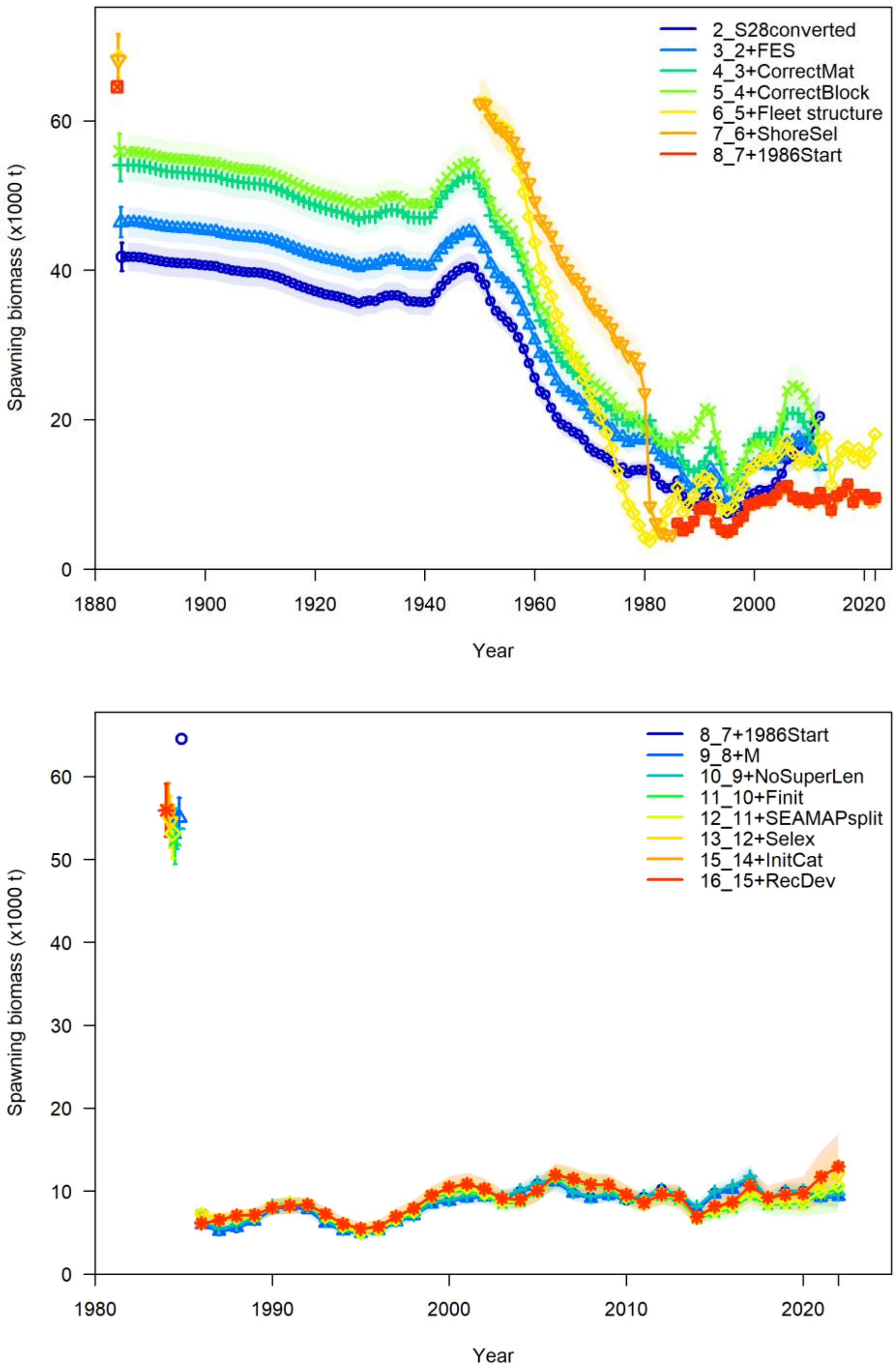
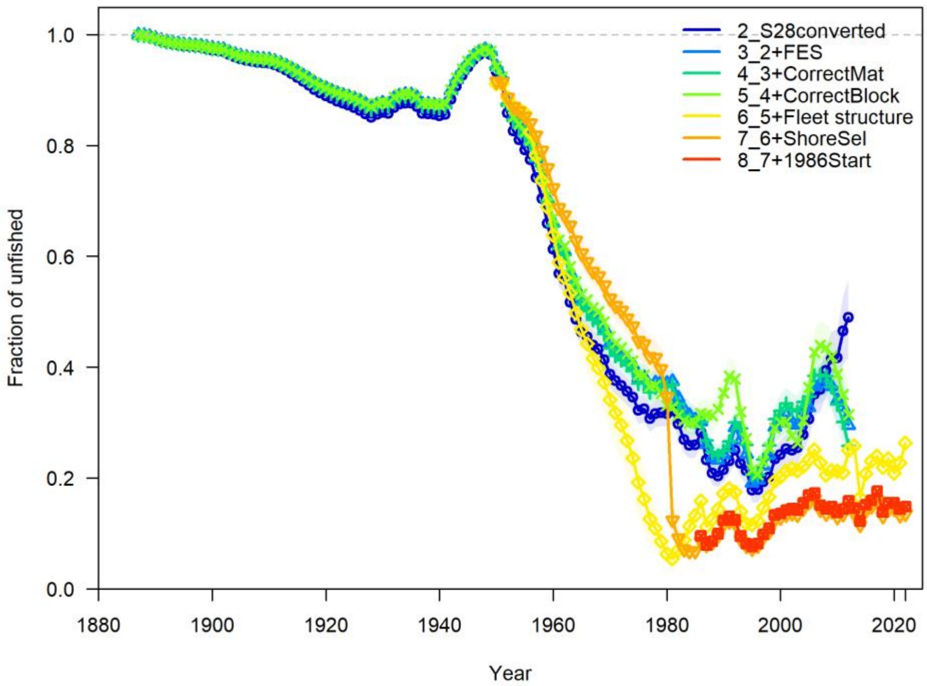


Figure 116. Bridging analysis showing changes in estimates of SSB and associated uncertainty through each major step of model building between SEDAR 28 and SEDAR 81.



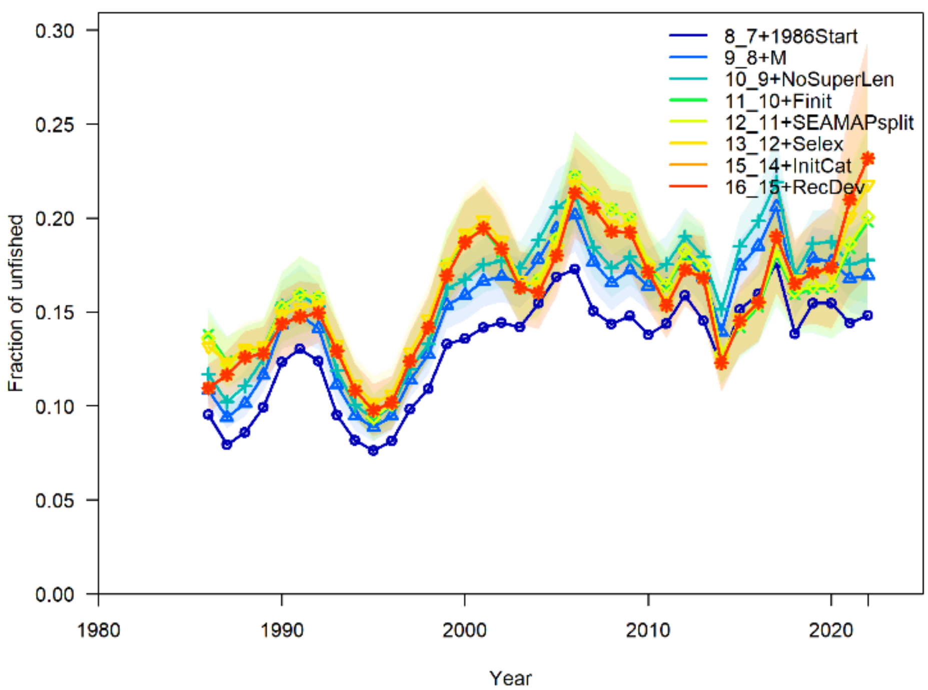


Figure 117. Bridging analysis showing changes in estimates of fraction unfished and associated uncertainty through each major step of model building between SEDAR 28 and SEDAR 81.

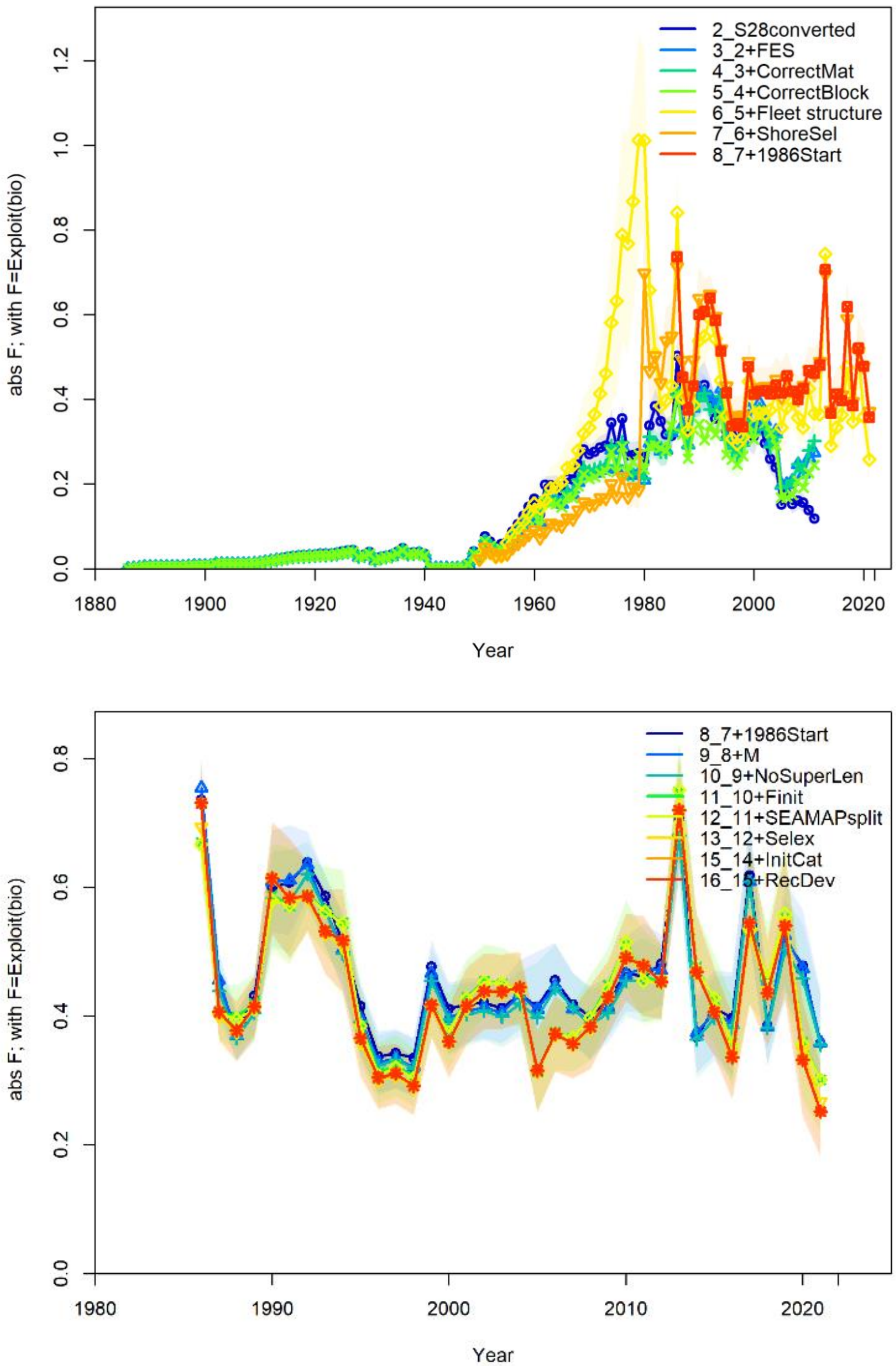


Figure 118. Bridging analysis showing changes in estimates of annual exploitation rates (total biomass killed age total biomass killed / total biomass age 1+) and associated uncertainty through each major step of model building between SEDAR 28 and SEDAR 81.

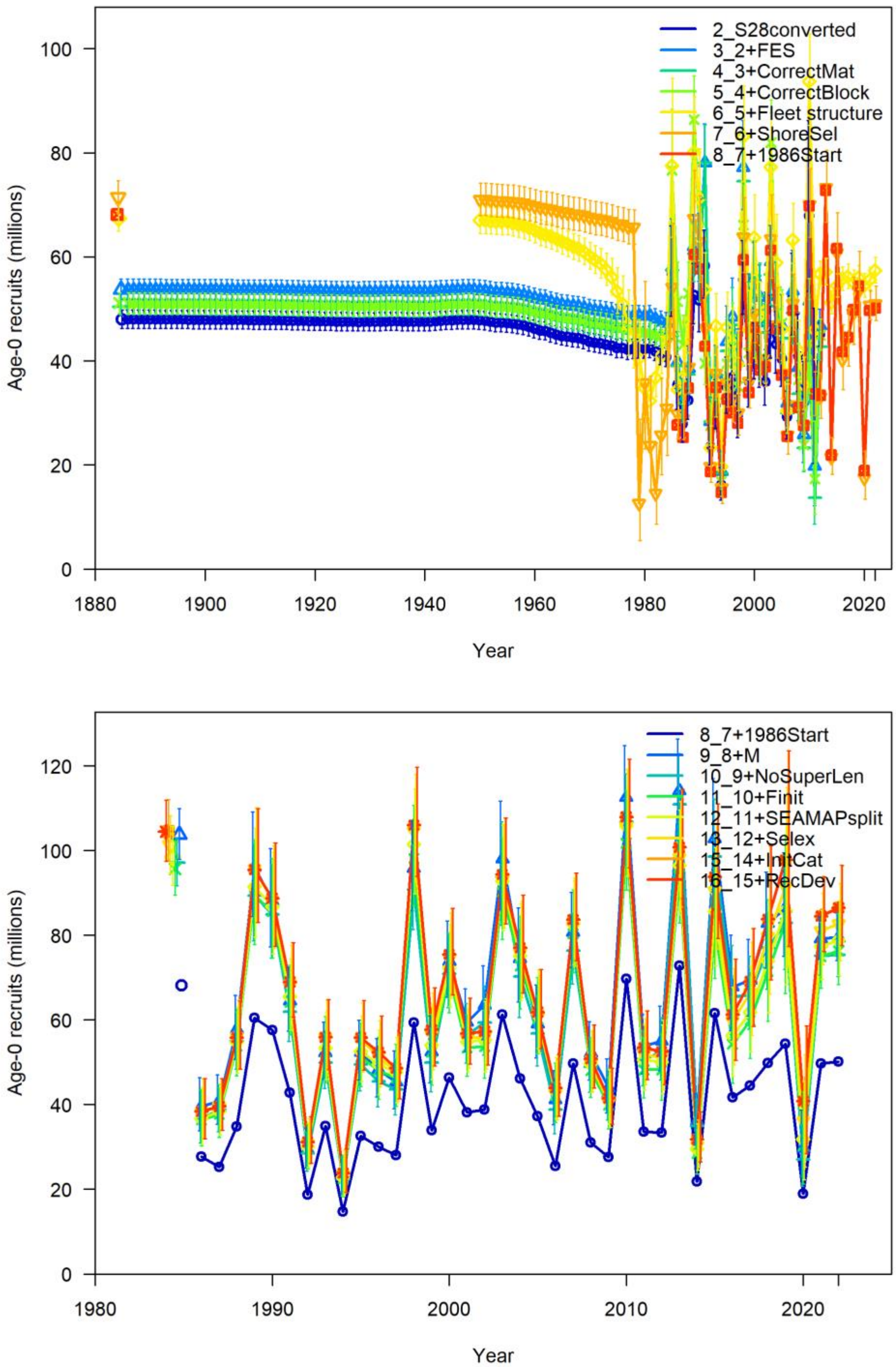


Figure 119. Bridging analysis showing changes in estimates of annual recruitment and associated uncertainty through each major step of model building between SEDAR 28 and SEDAR 81.

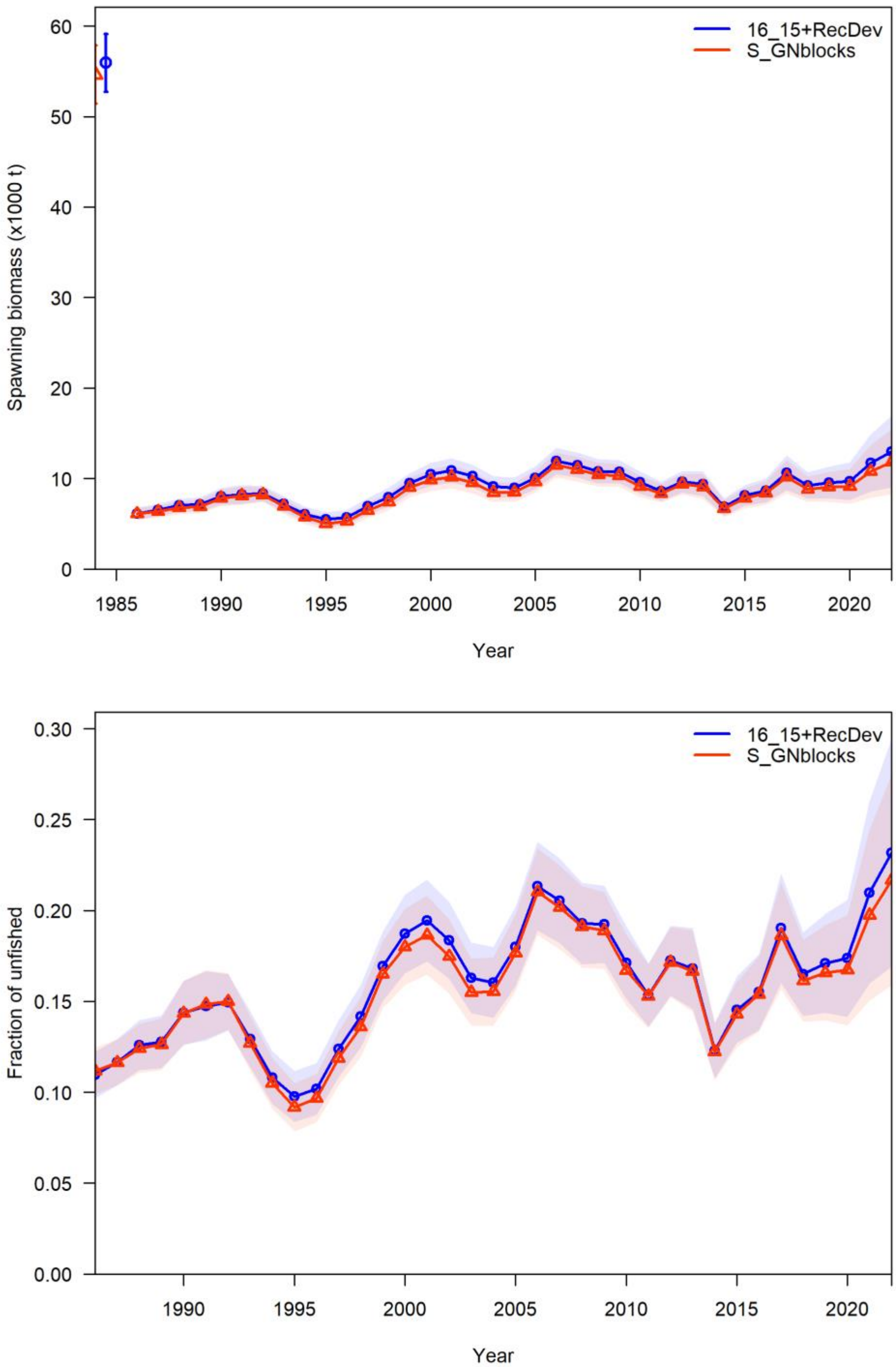


Figure 120. Differences in the time series of SSB and fraction unfished (SSB/SSB0) between the SEDAR 81 base model and the Gillnet selectivity time blocks sensitivity run.

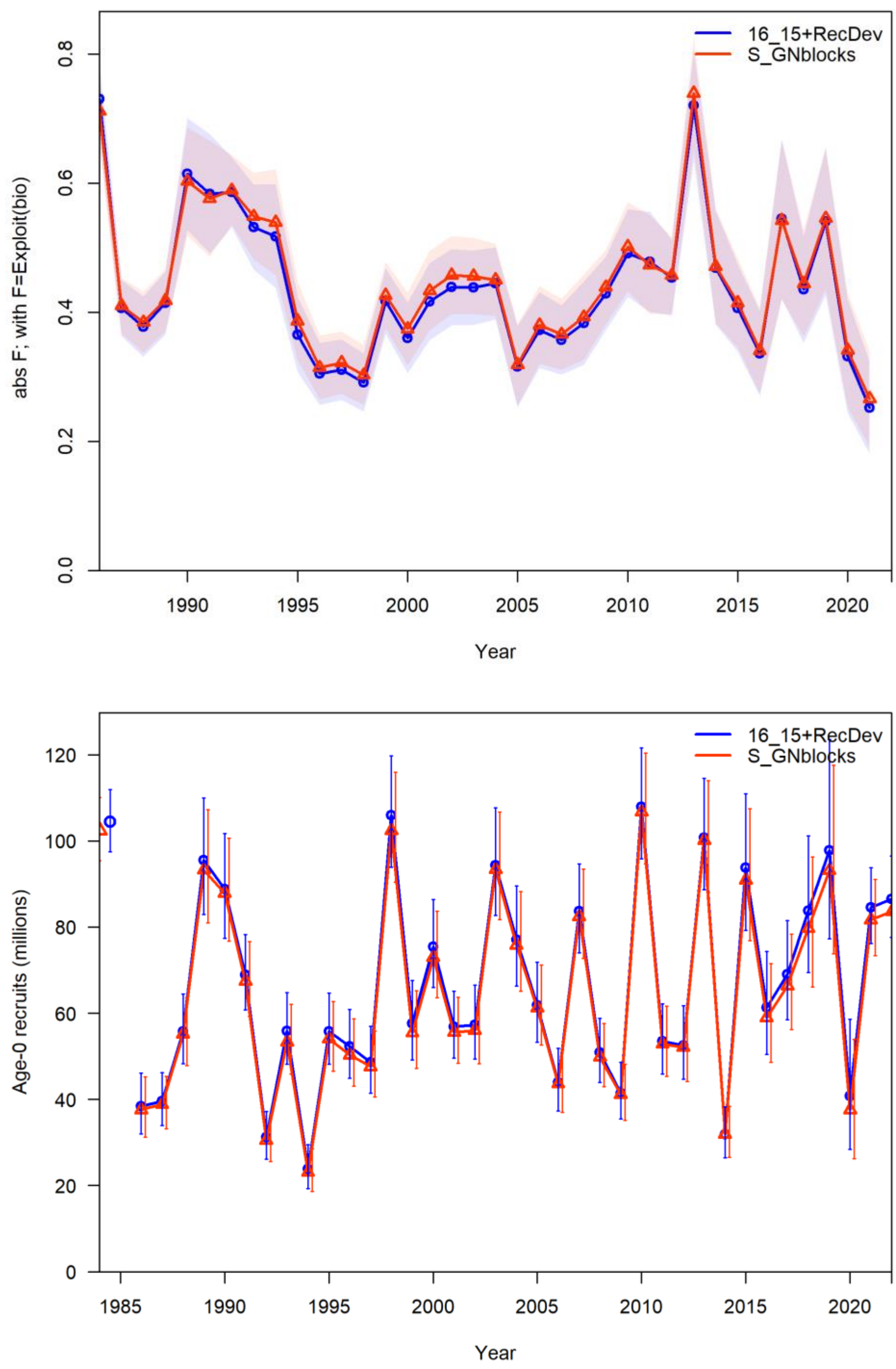


Figure 121. Differences in the time series of F and recruitment between the SEDAR 81 base model and the Gillnet selectivity time blocks sensitivity run.

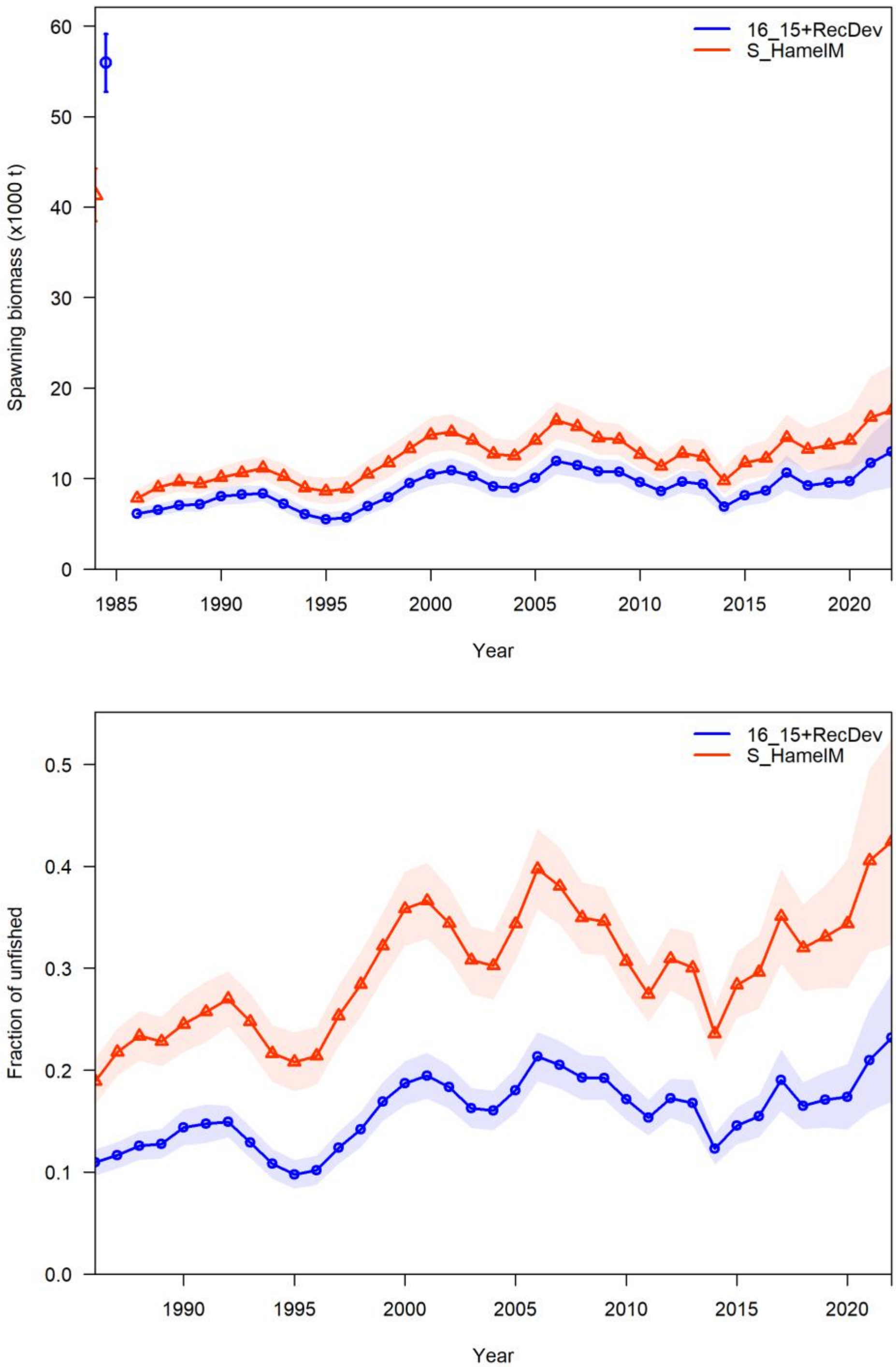
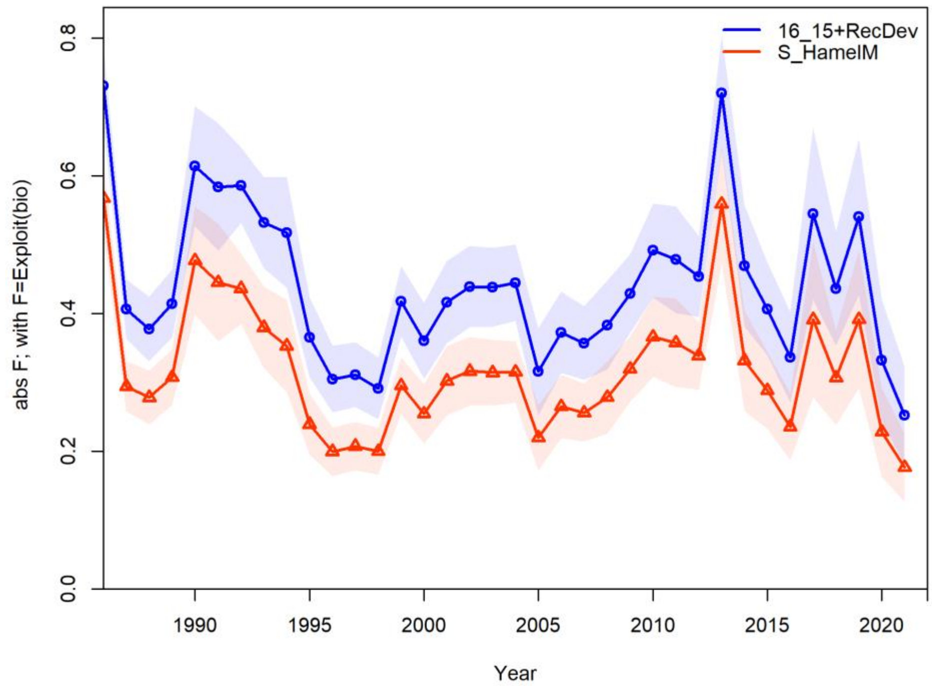


Figure 122. Differences in the time series of SSB and fraction unfished (SSB/SSB0) between the SEDAR 81 base model and the M sensitivity run.



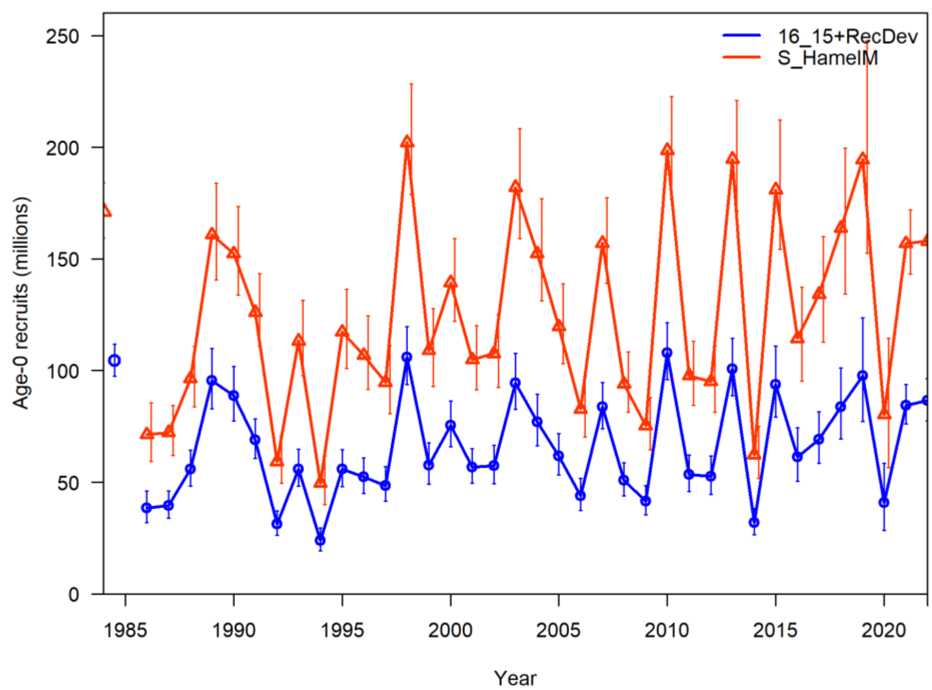


Figure 123. Differences in the time series of F and recruitment between the SEDAR 81 base model and the M sensitivity run.

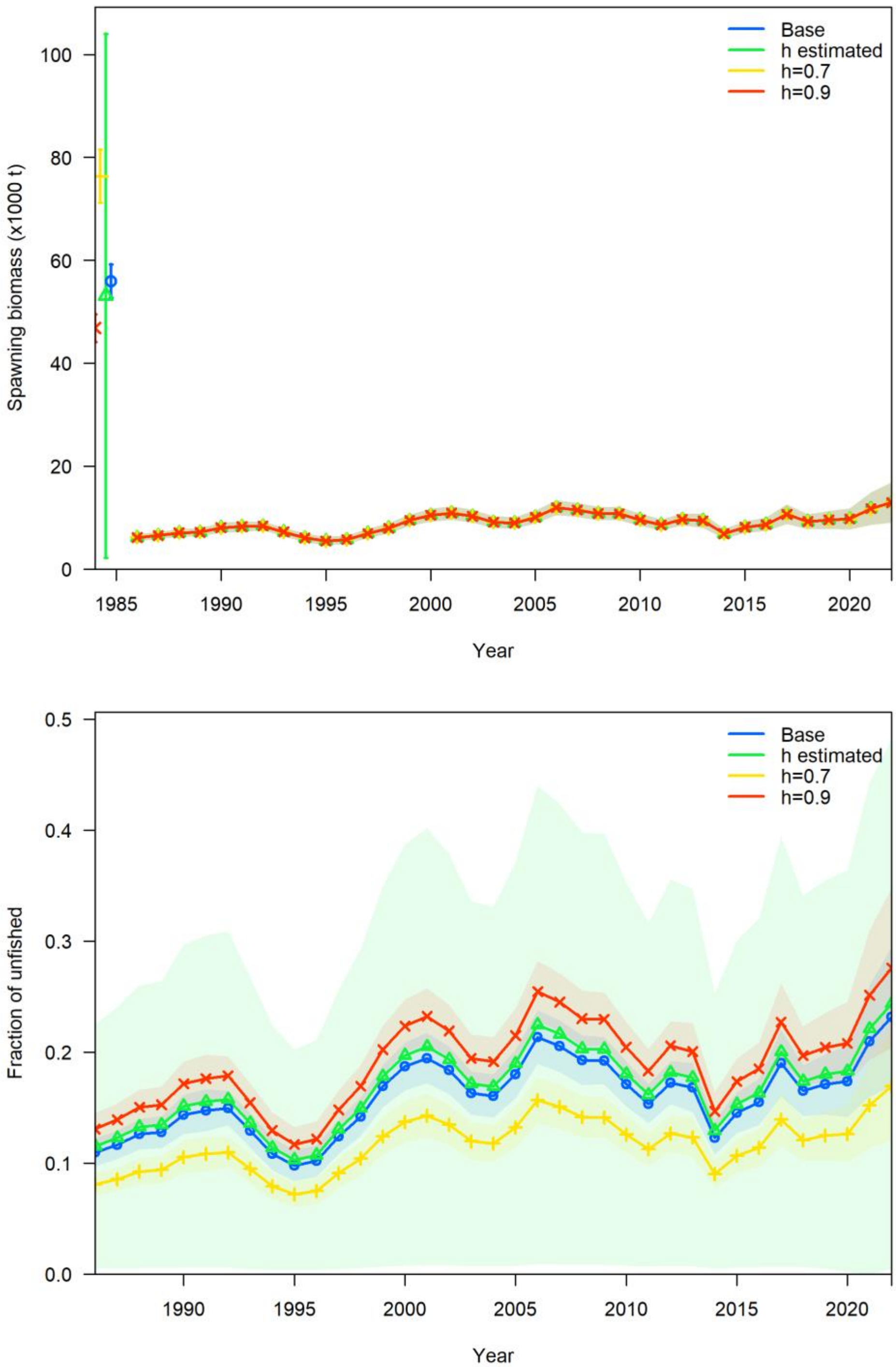
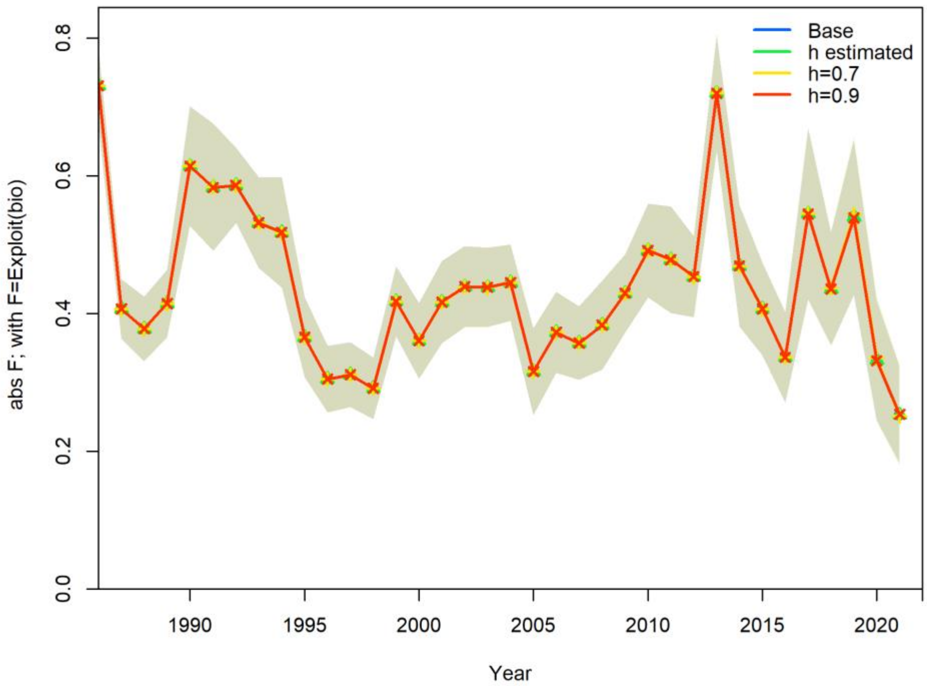


Figure 124. Differences in the time series of SSB and fraction unfished (SSB/SSB0) between the SEDAR 81 base model and the steepness sensitivity run.



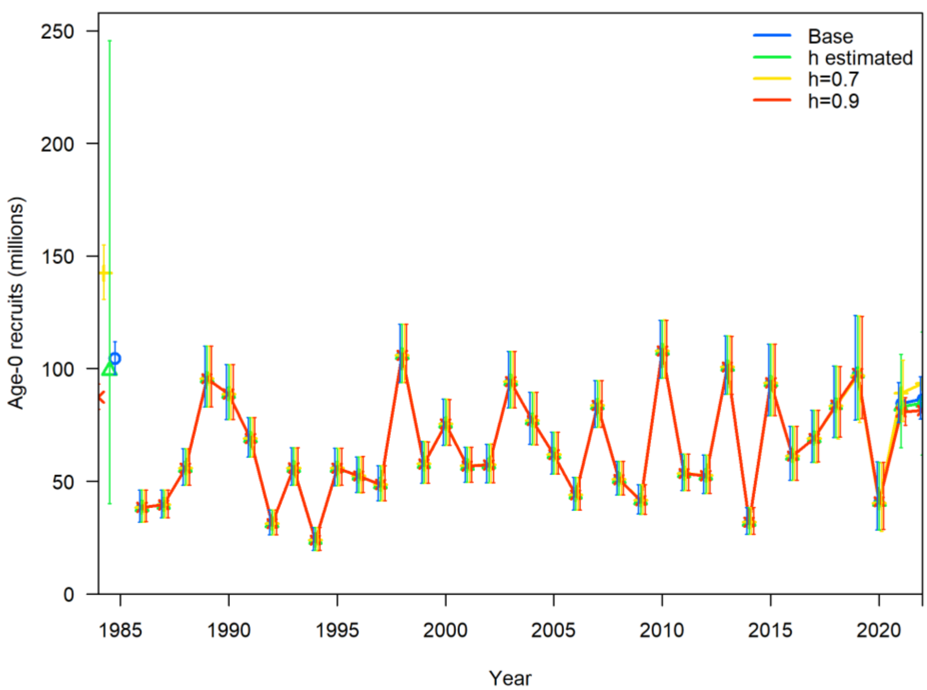


Figure 125. Differences in the time series of F and recruitment between the SEDAR 81 base model and the steepness sensitivity run.

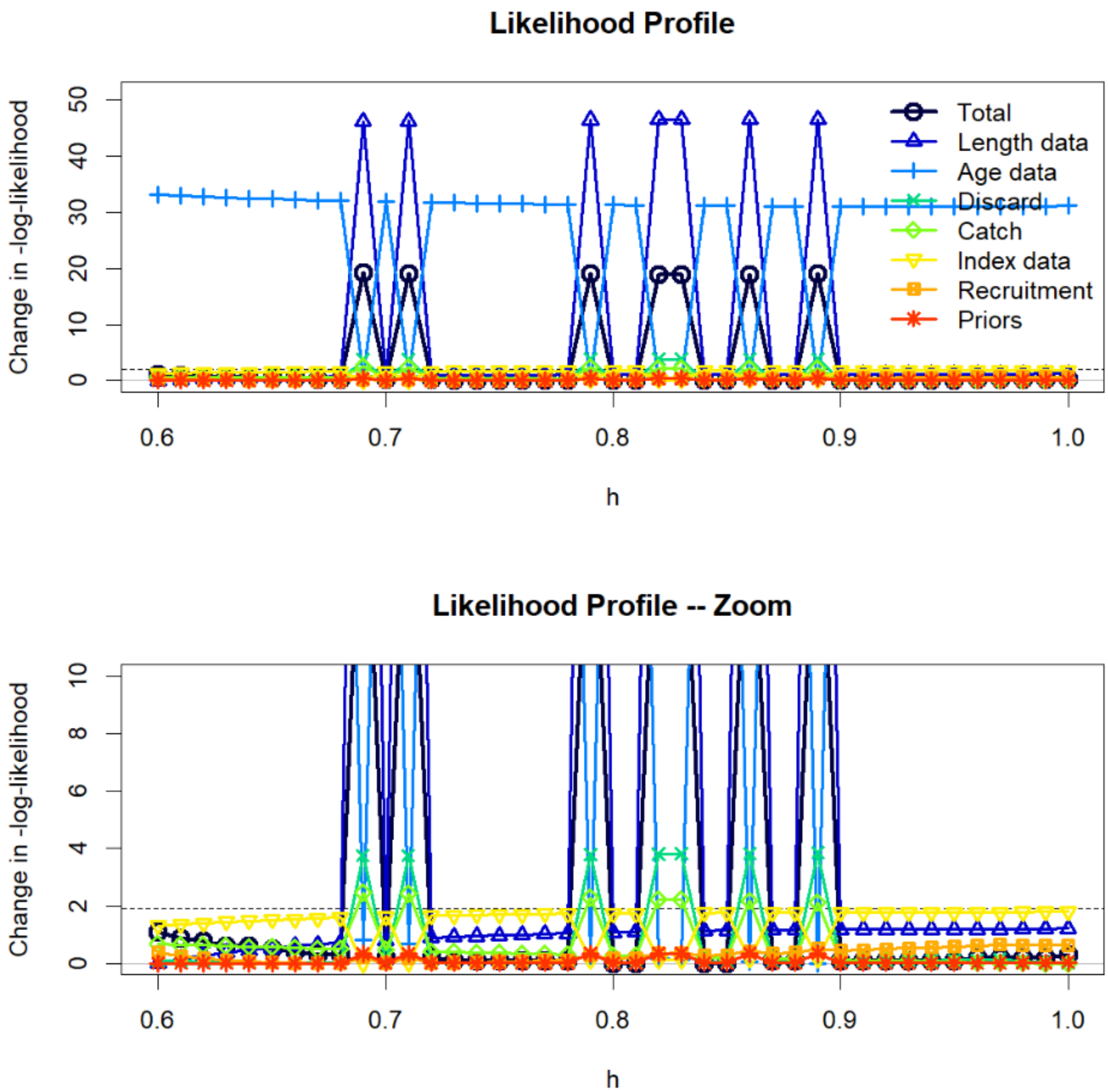


Figure 126. Profile likelihood for the steepness parameter of the Beverton – Holt stock-recruit function for Gulf of Mexico Spanish Mackerel. Each line represents the change in negative log-likelihood value for each of the data component fit in the model across the range of fixed steepness values tested. The fixed steepness value for the base model is 0.8. The bottom panel shows a close up of the top panel to better detect significant differences between runs.

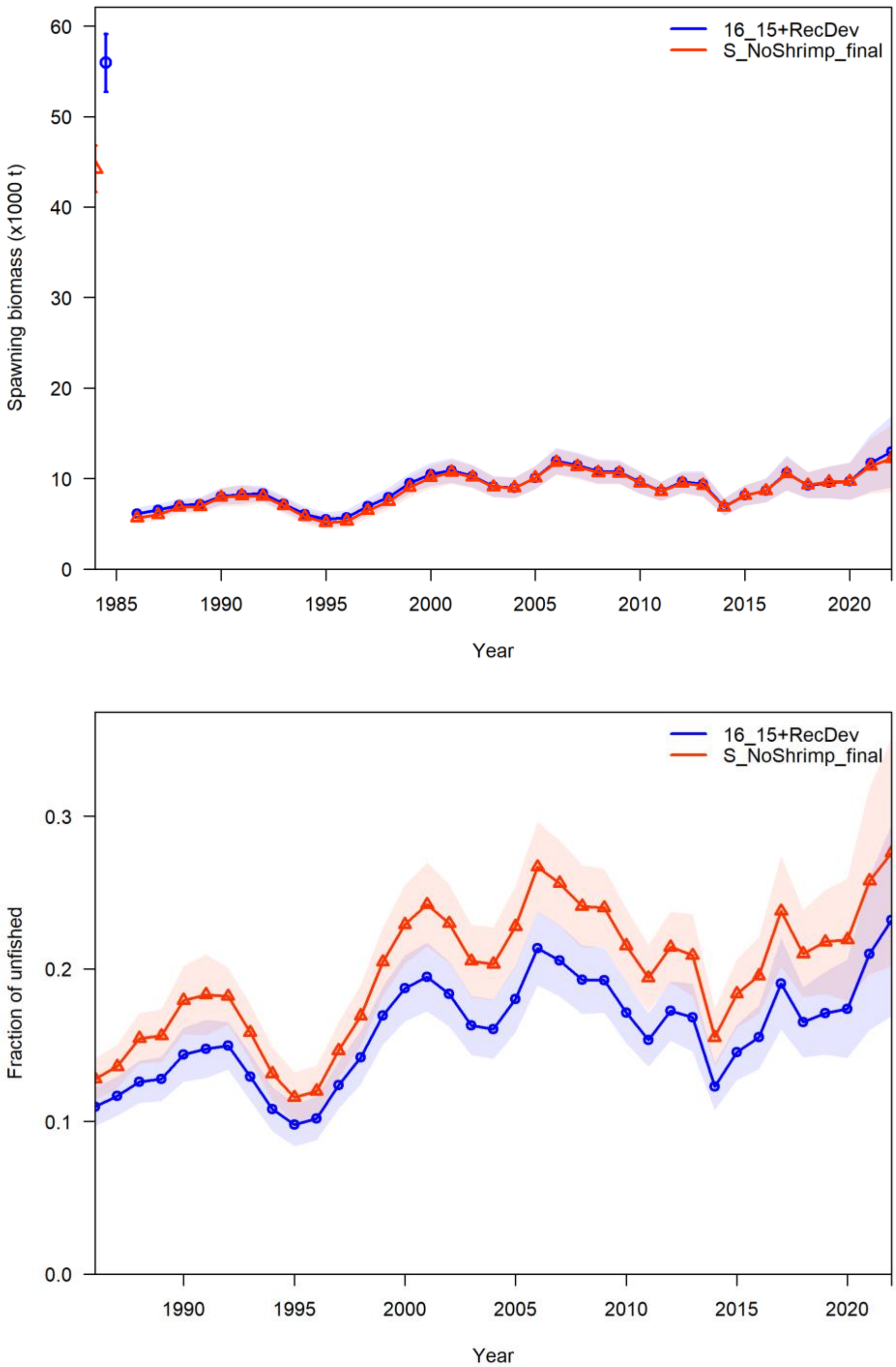


Figure 127. Differences in the time series of SSB and fraction unfished (SSB/SSB0) between the SEDAR 81 base model and the No Shrimp Bycatch sensitivity run.

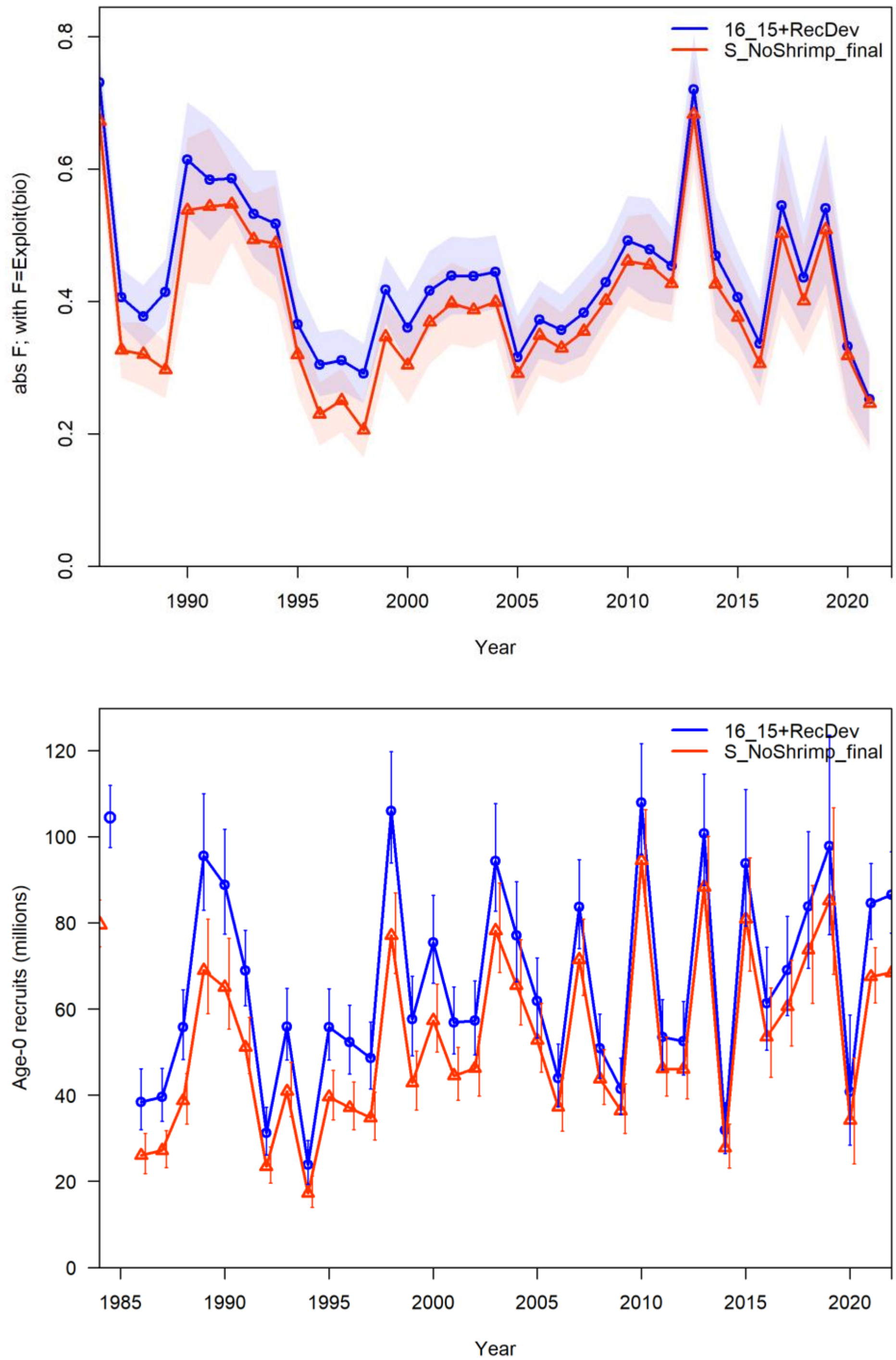


Figure 128. Differences in the time series of F and recruitment between the SEDAR 81 base model and the No Shrimp Bycatch sensitivity run.

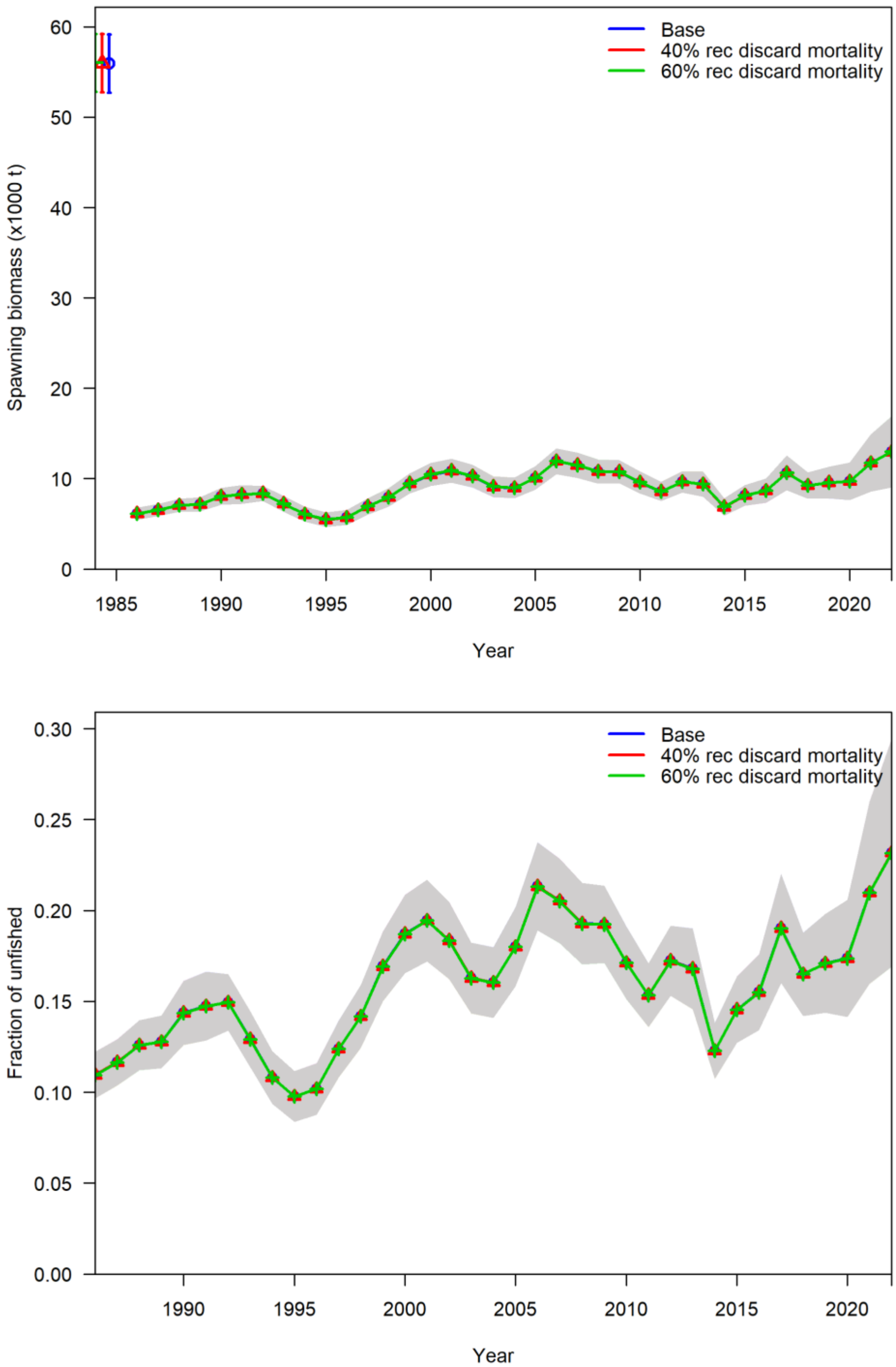


Figure 129. Differences in the time series of SSB and fraction unfished (SSB/SSB0) between the SEDAR 81 base model and the recreational discard mortality sensitivity run.

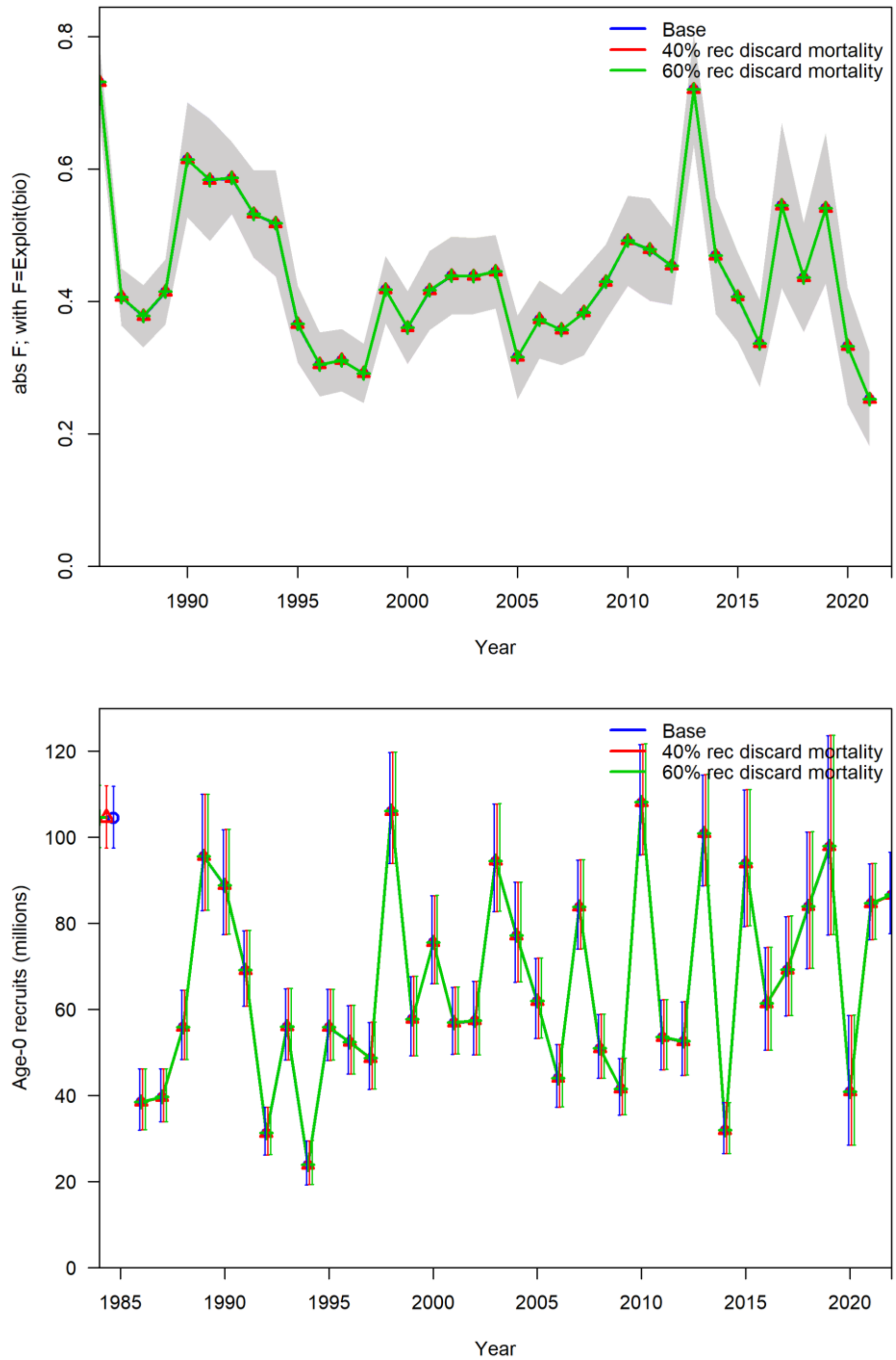


Figure 130. Differences in the time series of F and recruitment between the SEDAR 81 base model and the recreational discard mortality sensitivity run.

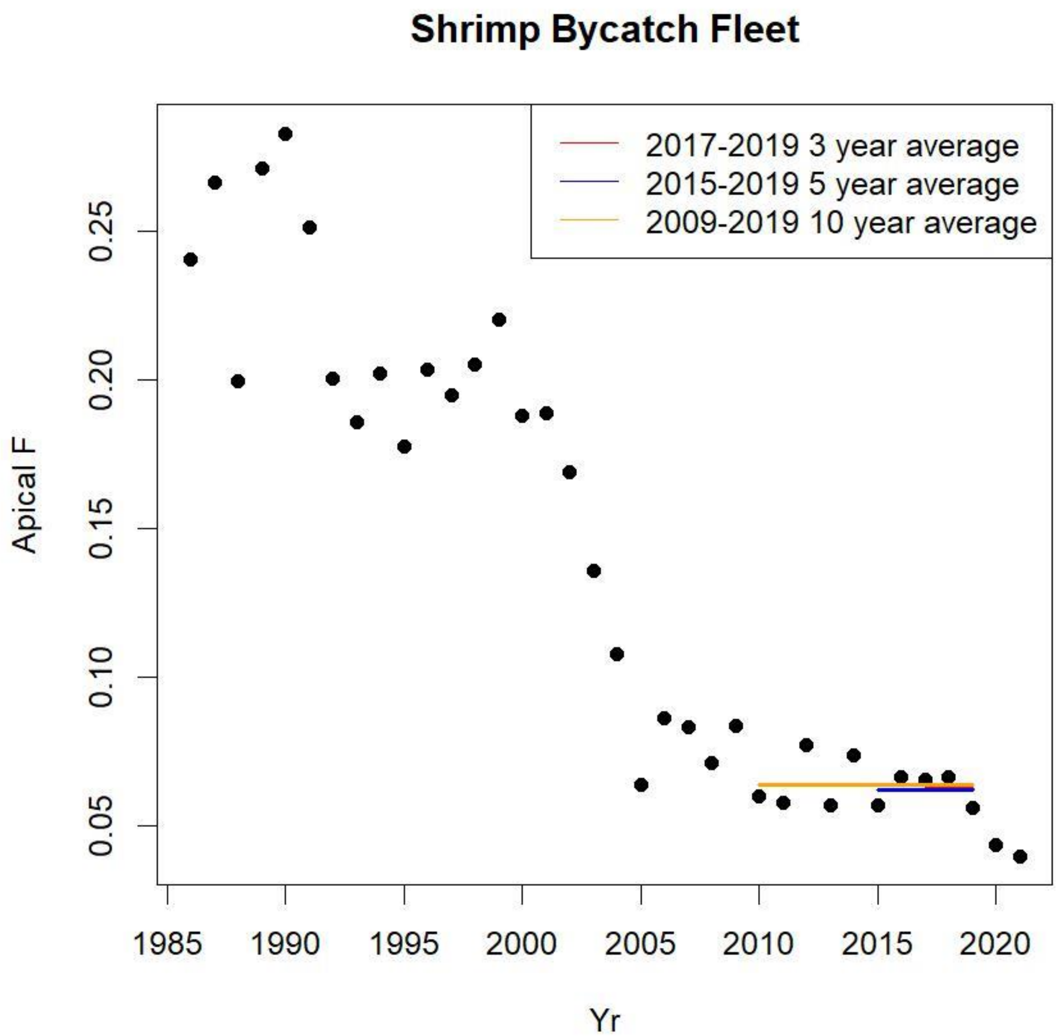


Figure 131. Time series of apical F for the Shrimp Bycatch fleet. 3, 5 and 10 year averages are shown (excluding 2020 and 2021 Covid years). The 5-year average was used in projections.

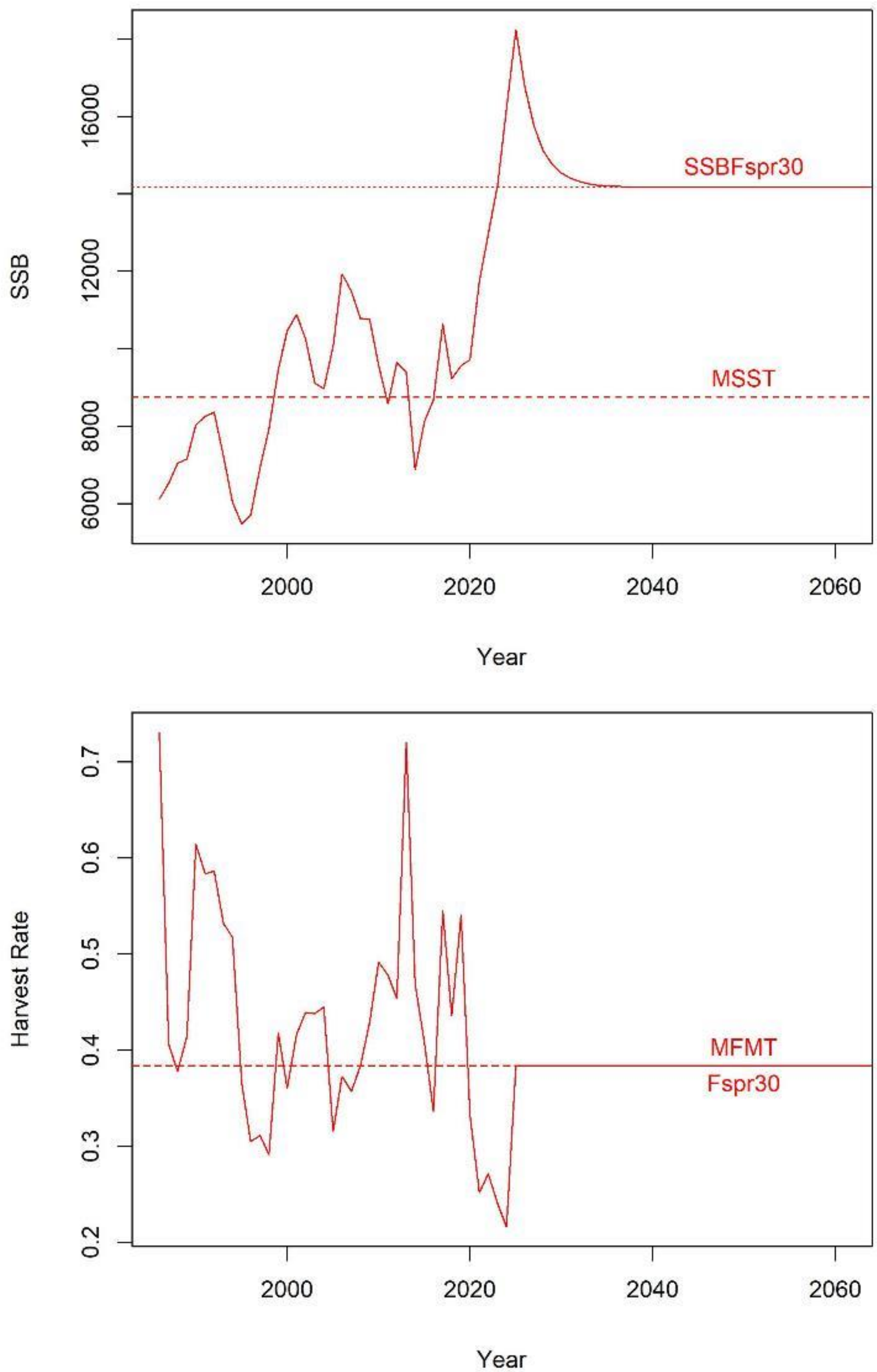


Figure 132. Time series of female SSB and harvest rate (total biomass killed / total biomass age 1+) with respect to status determination criteria for the SEDAR 81 Gulf of Mexico Spanish Mackerel assessment.

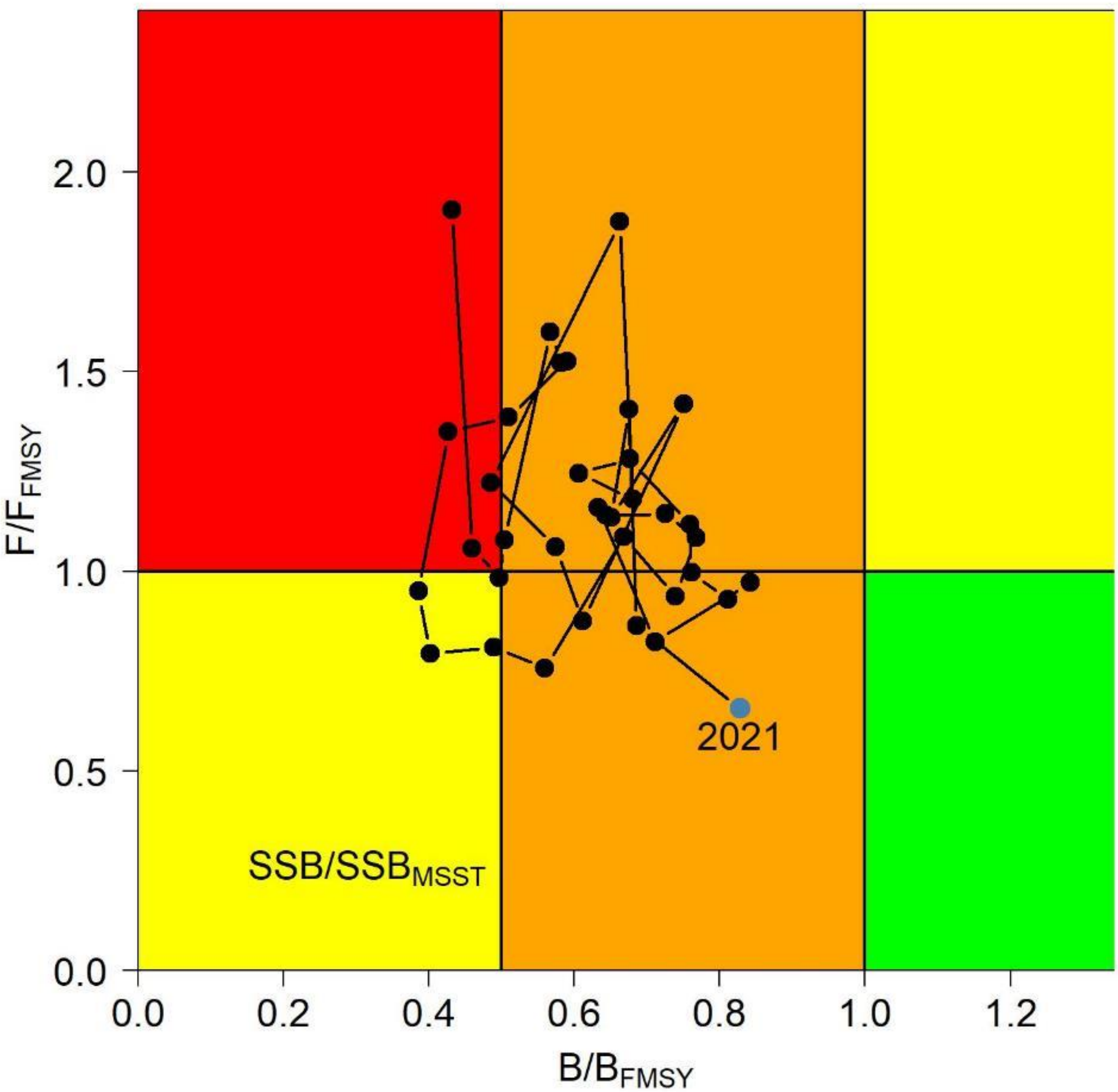


Figure 133. Kobe plot illustrating the trajectory of stock status. The orange coloring indicates regions where the stock is below the biomass target but above the biomass threshold (MSST = (1-M) SSB$_{F30\%SPR}$). The 2021 terminal year stock status is indicated by the gray dot.

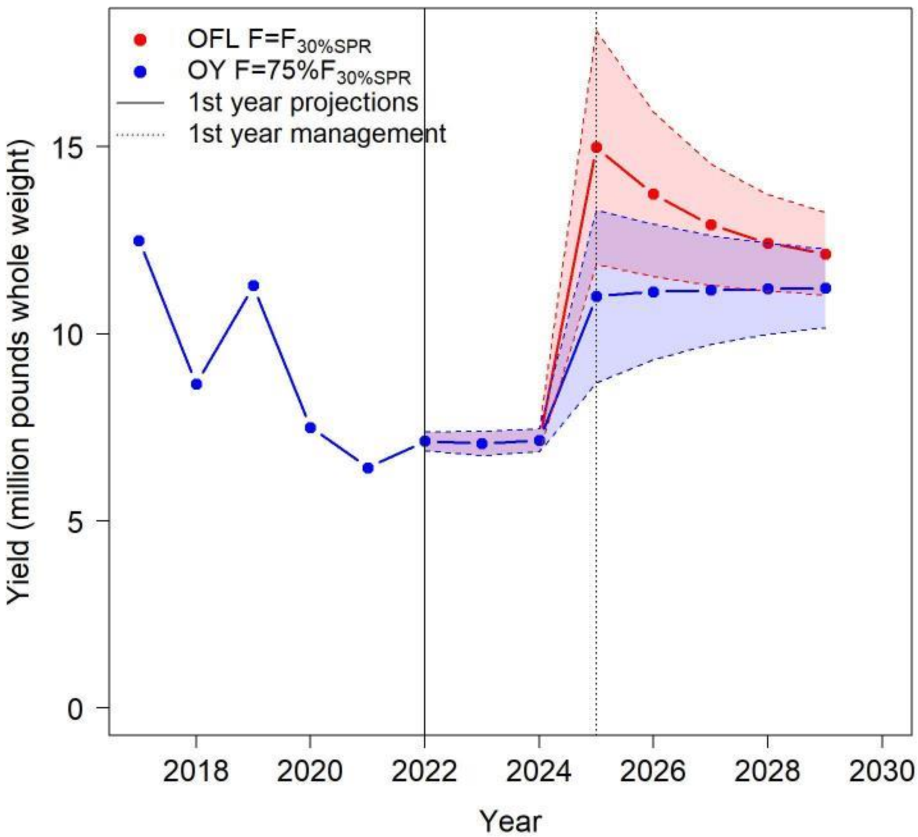


Figure 134. Historic and forecasted yields for the OFL and OY (F=75%$F_{30\%SPR}$) projections.