SEDAR

Southeast Data, Assessment, and Review

SEDAR 67

Stock Assessment Report

Gulf of Mexico Vermilion Snapper

Original Release Date: April 2020

Updated: July 2020

SEDAR

4055 Faber Place Drive, Suite 201

North Charleston, SC 29405

Changes made to SEDAR 67 Stock Assessment Report

7/16/2020

- Page 22 of SECTION I: Introduction. The following text was changed from:

  Based on the SSASPM model, the stock was not overfished (F/FMSY = 0.65 and $F/F_{SPR30\%}$ = 0.67) nor undergoing overfishing (SSB/SSB_{MSY} = 1.80, $SSB/SSB_{SPR30\%}$ = 1.75) at the end of 2004.

  To:

  Based on the SSASPM model, the stock was not undergoing overfishing (F/F_{MSY} = 0.65 and $F/F_{SPR30\%}$ = 0.67) nor overfished (SSB/SSB_{MSY} = 1.80, $SSB/SSB_{SPR30\%}$ = 1.75) at the end of 2004.

- Page 23 of SECTION II: Assessment Process Report. “Not” was added to the sentence shown below in section 2.4.4 *Other Surveys*

  Therefore, the SEDAR 67 panel did **not** suggest further exploration of their use in the SEDAR 67 assessment.

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SEDAR 67

Gulf of Mexico Vermilion Snapper

SECTION I: Introduction

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4055 Faber Place Drive, Suite 201
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Introduction

SEDAR 67 addressed the stock assessment for Gulf of Mexico vermilion snapper. The assessment process consisted of a series of webinars. Data and Assessment webinars were held between November 2019 and January 2020.

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 Reports (SAR) for Gulf of Mexico vermilion snapper was disseminated to the public in April 2020. 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 2020 meeting, followed by the Council receiving that information at its August 2020 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 is normally organized around two workshops and a series of webinars. First is the Data Workshop, during which fisheries, monitoring, and life history data are reviewed and compiled. The second stage is the Assessment Process, which is conducted via a workshop and/or a series of webinars, during which assessment models are developed and population parameters are estimated using the information provided from the Data Workshop. The final step is the Review Workshop, during which independent experts review the input data, assessment methods, and assessment products. The completed assessment, including the reports of all 3 stages and all supporting documentation, is then forwarded to the Council SSC for certification as 'appropriate for management' and development of specific management recommendations.

SEDAR workshops are public meetings organized by SEDAR staff and the lead 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. Reef Fish Fishery Management Plan and Amendments

Original FMP:

The Reef Fish Fishery Management Plan was implemented in November 1984. The regulations, designed to rebuild declining reef fish stocks, included: (1) prohibitions on the use of fish traps, roller trawls, and powerhead-equipped spear guns within an inshore stressed area; and, (2) data reporting requirements.

Actions affecting Gulf of Mexico Vermilion Snapper:

Description of Action	FMP/Amendment	Effective Date
Allowed 2-day charter-for-hire possession limit on trips that extend beyond 24 hours, provided the vessel has two licensed operators aboard, and each passenger can provide a receipt to verify the length of the trip. Limited other	Amendment 1	January 1990

fishermen fishing under a bag limit to a single day possession limit. Established a longline and buoy gear boundary at approximately the 50 fathom depth contour west of Cape San Blas, Florida and the 20 fathom depth contour east of Cape San Blas, inshore of which the directed harvest of reef fish with longlines and buoy gear was prohibited and the retention of reef fish captured incidentally in other longline operations (e.g., sharks) was limited to the recreational bag limit. Limited trawl vessels to the recreational size and bag limits of reef fish. Established fish trap permits, allowing up to a maximum of 100 fish traps per permit holder. Prohibited the use of entangling nets for directed harvest of reef fish. Retention of reef fish caught in entangling nets for other fisheries was limited to the recreational bag limit. Established the fishing year to be January 1 through December 31. Set an 8-inch total length minimum size limit on lane and vermilion snappers. Set a 10-snapper recreational bag limit on snappers in aggregate, excluding red, lane, and vermilion snapper.		
Commercial reef fish permit moratorium established for three years	Amendment 4	May 1992
Fish trap endorsement and three year moratorium established	Amendment 5	February 1994
Extended commercial reef fish permit moratorium until January 1996.	Amendment 9	July 1994
Commercial reef fish permit moratorium extended until December 30, 2000. Reef fish permit requirement established for headboats and charter vessels.	Amendment 11	January 1996
Created an aggregate bag limit of 20 reef fish for all reef fish species not having a bag limit.	Amendment 12	January 1997
10-year phase-out of fish traps in EEZ established (February 7, 1997 – February 7, 2007).	Amendment 14	March 1997
Increased the vermilion snapper minimum size limit from 8” TL to 10” TL.	Amendment 15	January 1998

Commercial reef fish permit moratorium extended until December 31, 2005.	Amendment 17	August 2000
(1) Prohibits vessels from retaining reef fish caught under recreational bag/possession limits when commercial quantities of Gulf reef fish are aboard, (2) adjusts the maximum crew size on charter vessels that also have a commercial reef fish permit and a USCG certificate of inspection (COI) to allow the minimum crew size specified by the COI when the vessel is fishing commercially for more than 12 hours, (3) prohibits the use of reef fish for bait except for sand perch or dwarf sand perch, and (4) requires electronic VMS aboard vessels with federal reef fish permits, including vessels with both commercial and charter vessel permits (implemented May 6, 2007).	Amendment 18A	2006
Also known as Generic Essential Fish Habitat (EFH) Amendment 2. Established two marine reserves off the Dry Tortugas where fishing for any species and anchoring by fishing vessels is prohibited.	Amendment 19	August 2002
3-year moratorium on reef fish charter/headboat permits established	Amendment 20	June 2003
Continued the Steamboat Lumps and Madison-Swanson reserves for an additional six years, until June 2010. In combination with the initial four-year period (June 2000-June 2004), this allowed a total of ten years in which to evaluate the effects of these reserves. Allowed surface trolling during the months of May through October.	Amendment 21	July 2004
Established a rebuilding plan and set the SFA parameters for vermilion snapper. Set the minimum size limit at 11" TL. Established a commercial closed season of April 22 through May 31. Set a recreational bag limit of 10 vermilion snapper within the 20-reef fish aggregate limit.	Amendment 23	July 2005
Permanent moratorium established for commercial reef fish permits.	Amendment 24	August 2005

Permanent moratorium established for charter and headboat reef fish permits, with periodic reviews at least every 10 years.	Amendment 25	June 2006
Addressed the use of non-stainless steel circle hooks when using natural baits to fish for Gulf reef fish effective June 1, 2008, and required the use of venting tools and dehooking devices when participating in the commercial or recreational reef fish fisheries effective June 1, 2008.	Amendment 27	February 2008
Established additional restrictions on bottom longline gear in the eastern Gulf of Mexico to reduce bycatch of endangered sea turtles. (1) Prohibits the use of bottom longline gear shoreward of the 35-fathom contour from June through August; (2) reduces the number of longline vessels operating in the fishery through an endorsement provided only to vessel permits with a demonstrated history of landings, on average, of at least 40,000 pounds of reef fish annually with fish traps or longline gear during 1999-2007; and (3) restricts the total number of hooks that may be possessed onboard each reef fish bottom longline vessel to 1,000, only 750 of which may be rigged for fishing. The boundary line was initially moved from 20 to 50 fathoms by emergency rule effective May 18, 2009. That rule was replaced on October 16, 2009 by a rule under the Endangered Species Act moving the boundary to 35 fathoms and implementing the maximum hook provisions.	Amendment 31	May 2010
Dually permitted vessels are vessels with both a charter for-hire permit and a commercial reef fish permit. The amendment eliminates the earned income qualification requirement for the renewal of commercial reef fish permits and increases the maximum crew size from three to four	Amendment 34	November 2012
Standardized the minimum stock size threshold for certain reef fish species. The minimum stock size threshold for vermilion snapper is equal to 50% of the biomass at maximum sustainable yield. The minimum stock size threshold is not expected to affect management action as fishing is primarily constrained by the overfishing	Amendment 44	December 2017

definition. As long as overfishing is prevented, the stock biomass should never drop to the MSST level.		
Set the vermilion snapper annual catch limit at 3,110,000 pounds through 2021. Set the vermilion snapper maximum sustainable yield (MSY) proxy equal to the yield when fishing at $F_{30\%SPR}$.	Amendment 47	June 2018

2.2. Generic Amendments

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

Generic ACL/AM Amendment: Established in-season and post-season accountability measures for all stocks that did not already have such measures defined. The accountability measure states that if an ACL is exceeded, in subsequent years an in-season accountability measure will be implemented that would close fishing when the ACL is reached or projected to be reached.

2.3. Regulatory Amendments

August 1999: Closed two areas (i.e., created two marine reserves), known as Steamboat Lumps and Madison-Swanson (104 and 115 nautical square miles respectively), year-round to all fishing under the jurisdiction of the Gulf Council with a four-year sunset closure.

February 2007: Revised management measures for vermilion snapper to those prior to implementation of Reef Fish Amendment 23 by reducing the minimum size limit for from 11 inches to 10 inches TL; eliminating the 10 fish bag limit for vermilion snapper and retaining the current 20-fish aggregate bag limit for those reef fish species without a species-specific bag limit; and eliminating the April 22 through May 31 commercial closed season for vermilion snapper.

September 2010: Provides a more specific definition of buoy gear by limiting the number of hooks, limiting the terminal end weight, restricting materials used for the line, restricting the length of the drop line, and where the hooks may be attached. In addition, the Council requested that each buoy must display the official number of the vessel (USCG documentation number or state registration number) to assist law enforcement in monitoring the use of the gear, which requires rulemaking.

June 2013: Modifies the frequency of headboat reporting to be on a weekly basis (or intervals shorter than a week if notified by the SRD) via electronic reporting, and will be due by 11:59 p.m., local time, the Sunday following a reporting week. If no fishing activity occurs during a reporting week, an electronic report so stating must be submitted for that week.

September 2013: Establishes a 10-vermilion snapper recreational bag limit within the 20-reef fish aggregate, and removes the requirement to have onboard and use venting tools when releasing reef fish.

2.4. Emergency and Interim Rules

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

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

2.5. Management Parameters and Projection Specifications

Table 2.5.1. General Management Information

Species/Management Unit	Vermilion Snapper
Management Unit Definition	Gulf of Mexico
Management Entity	Gulf of Mexico Fishery Management Council
Management Contacts SERO / Council	Ryan Rindone – GMFMC Peter Hood – SERO
Current stock exploitation status	Not experiencing overfishing (2015; SEDAR 45)
Current stock biomass status	Not overfished (2015; SEDAR 45)

Table 2.5.2. Specific Management Criteria

Note: mp = million pounds; ww = whole weight.

Criteria	Current- SEDAR 45 (2016)		Proposed	
	Definition	Value	Definition	Value
MSST	(1-M)*SSB_{MSY} M=0.25	52.7 trillion eggs	Value from the most recent stock assessment based on MSST = [(1-M) or 0.5 whichever is greater]*BMSY	SEDAR 67
MFMT	F_{MSY}	0.76	F_{MSY} or proxy from the most recent stock assessment (median from probabilistic analysis)	SEDAR 67
MSY	F_{MSY}	0.76	Yield at F_{MSY} , landings and discards, pounds and numbers (median from probabilistic analysis)	SEDAR 67
F_{MSY}	F_{MAX}	0.76		
SSB_{MSY}[1]	Equilibrium SSB @ F_{MSY}	67.3 trillion eggs	Spawning stock biomass (median from probabilistic analysis)	SEDAR 67
F Targets (i.e., F_{OY})	75% of F_{MSY}	0.57	75% F_{MSY}	SEDAR 67
Yield at F_{Target} (Equilibrium)	Equilibrium Yield @ FOY	7.35 mp ww	landings and discards, pounds and numbers	SEDAR 67
M		0.25	Natural Mortality, average across ages	SEDAR 67
Terminal F	F_{2010}	0.24	Exploitation	SEDAR 67
Terminal Biomass[1]	SSB_{2010}	108 trillion eggs	Biomass	SEDAR 67
Exploitation Status	$F_{CURRENT}$/MFMT	0.32	F/MFMT	SEDAR 67
Biomass Status[1]	$SSB_{CURRENT}$/MSST	1.60	B/MSST B/B_{MSY}	SEDAR 67

[1]SSB measures in number of eggs

Table 2.5.3. General projection information.

First Year of Management	2021 Fishing Year
Interim basis	- ACL, if ACL is met - Average exploitation, if ACL is not met
Projection Outputs	By stock and fishing year
Landings	pounds and numbers
Discards	pounds and numbers
Exploitation	F & Probability F>MFMT
Biomass (total or SSB, as appropriate)	SSB & Probability SSB>MSST (and Prob. SSB>B_{MSY} if under rebuilding plan)
Recruits	Number

Table 2.5.4. Base Run Projections Specifications. Long Term and Equilibrium conditions.

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

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

Table 2.5.5. P-Star Projections. Short term specifications for OFL and ABC recommendations. Additional P-star projections may be requested by the SSC once the ABC control rule is applied.

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

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

- OFL: yield at F_{MSY} (or $F_{30\%\ SPR}$ proxy)
- OY: yield at 75% for $F_{30\%\ SPR}$
- Equilibrium MSY and equilibrium OY

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

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

The SSC typically recommends OFL and ABC yield streams for 3-5 years out. Yield streams provided by assessment scientists should:

- Go beyond five years
- Include constant catch scenarios for three and five years
- If a 10-year rebuilding plan is needed, yield streams should be provided for 10 years

Table 2.5.6. Quota Calculation Details

Note: mp = million pounds; ww = whole weight. ACT = annual catch target.

Current Quota Value (2020)	3.11 mp ww (ACL)
Next Scheduled Quota Change	-
Annual or averaged quota?	Annual
Does the quota include bycatch/discard?	No- Landed only

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

2.5. Management and Regulatory Timeline

Table 2.5.1. Pertinent Federal Management Regulations

Harvest Restrictions – Trip Limits

*Trip limits do not apply during closures (if season is closed, then trip limit is zero.)

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
1990	1/1/90	Present	Comm	-	-	Gulf of Mexico		Original Reef Fish FMP
1990	1/1/90	1/14/97	Rec	-	-	Gulf of Mexico		
1997	1/15/97	5/7/05	Rec	20 reef fish aggregate	-	Gulf of Mexico		Reef Fish Amendment 12
2005	5/8/05	2/3/08	Rec	10/person/day	-	Gulf of Mexico		Reef Fish Amendment 23
2008	2/4/08	9/2/13	Rec	20 reef fish aggregate	-	Gulf of Mexico		Reef Fish Framework Action
	9/3/13	Present	Rec	10/person/day	-	Gulf of Mexico		Reef Fish Framework Action

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	Amendment Number or Rule Type
1990	1/1/90	9/13/97	Both	8"	TL	Gulf of Mexico	Original RF FMP
1997	9/14/97	7/7/05	Rec	10"	TL	Gulf of Mexico	Reef Fish Amendment 23
2005	7/8/05	2/3/08	Both	11"	TL	Gulf of Mexico	Reef Fish Framework Action
2008	2/4/08	Present	Both	10"	TL	Gulf of Mexico	Reef Fish Framework Action

Harvest Restrictions – Fishery Closures*

*Area specific regulations are documented under spatial restrictions

First Yr In Effect	Effective Date	End Date	Fishery	Closure Type	First Day Closed	Last Day Closed	Region Affected	Amendment Number or Rule Type
2006	4/22/06	5/31/06	Comm	ER	4/22/06	5/31/06	Gulf of Mexico	Amendment 23 put the season in place and the follow-up framework action removed the season

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
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
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 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	6/19/00	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
Steamboat Lumps	2000	6/19/00	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
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
DWH Oil Spill closure	2010	5/2/10	11/15/10	Both			All fishing prohibited in designated areas	75 FR 24822	

[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 – Gears*

*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 permitted 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
Longline	2009	10/16/09		750 hooks fishing	Gulf of Mexico EEZ		Endangered Species Act and regulatory action

Quota Information

First Yr In Effect	**Effective Date**	**End Date**	**Quota or ACL**	**Region Affected**	**Amendment Number or Rule Type**
1990	1/1/90	1/29/12	-	Gulf of Mexico	
2012	1/30/12	Present	3.42 mp ww	Gulf of Mexico	Generic ACL/AM Amendment

Closures Due to Deepwater Horizon

Closure Date	Area (sq mi)	Area (sq km)	% Coverage of Gulf EEZ	% Change in Coverage
2-May	6,817	17,648	2.8	N/A
7-May	10,807	27,989	4.5	58.5
11-May	16,027	41,511	6.6	48.3
12-May	17,651	45,717	7.3	10.1
14-May	19,377	50,187	8	9.8
17-May	24,241	62,784	10	25.1
18-May	45,728	118,435	18.9	88.6
21-May	48,005	124,333	19.8	5
25-May	54,096	140,109	22.4	12.7
28-May	60,683	157,169	25.1	12.2
31-May	61,854	160,200	25.6	1.9
1-Jun	75,920	196,633	31.4	22.7
2-Jun	88,522	229,270	36.6	16.6
4-Jun	78,182	202,491	32.3	-11.7
5-Jun	78,603	203,582	32.5	0.5
7-Jun	78,264	202,703	32.3	-0.4
16-Jun	80,806	209,286	33.4	3.2
21-Jun	86,985	225,290	35.9	7.6
23-Jun	78,597	203,564	32.5	-9.6
28-Jun	80,228	207,790	33.2	2.1
4-Jul	81,181	210,259	33.5	1.2
12-Jul	84,101	217,821	34.8	3.6
13-Jul	83,927	217,371	34.7	-0.2
22-Jul	57,539	149,026	23.8	-31.4
10-Aug	52,395	135,703	21.7	-8.9
27-Aug	48,114	124,614	19.9	-8.2
2-Sep	43,000	111,369	17.8	-10.6
3-Sep	39,885	103,303	16.5	-7.2
21-Sep	31,915	82,659	13.2	-20
1-Oct	26,287	68,083	10.9	-17.6
5-Oct	23,360	60,502	9.7	-11.1
15-Oct	16,481	42,686	6.8	-29.4
22-Oct	9,444	24,461	3.9	-42.7
15-Nov	1,041	2,697	0.4	-89

3 ASSESSMENT HISTORY AND REVIEW

Vermilion snapper is managed as part of the Gulf of Mexico Reef Fish FMP, which includes 40 species. The management unit for Gulf of Mexico (GoM) vermilion snapper extends from the United States–Mexico border in the west through the northern Gulf of Mexico waters and west of the Dry Tortugas and the Florida Keys (i.e., waters within the Gulf of Mexico Fishery Management Council boundaries). The Reef Fish FMP (with its associated EIS) was implemented in November 1984.

The status of GoM vermilion snapper was first assessed in 1991 (Goodyear and Schirripa, 1991). Few data existed at that time on vermilion snapper age and growth, but two different growth curve models were developed from the literature. Analysis of the growth and catch curves indicated widely varying estimates of fishing mortality. Given the limited and unreliable age data available, it was not possible to develop any type of age-structured assessment model or yield-per-recruit models.

In 1992, vermilion snapper growth curves were reevaluated (Schirripa, 1992). Based on the results of an updated age and growth study and YPR analysis, fishing mortality (F; from catch curve analysis) was estimated to be near F_{MAX}. Spawner-per-recruit (SPR) analysis estimated that the stock was around 34% of its virgin condition.

The 1996 assessment indicated the Gulf vermilion snapper stock was showing signs typical of a stock undergoing overfishing including (Schirripa, 1996): decreased landings, fishery spatial contraction, declining average size of landed fish, decreasing CPUE, and reduced recruitment. An exploratory virtual population analysis (VPA) was investigated in addition to the previously used catch curve analysis. There was general agreement across approaches that vermilion snapper were likely being overharvested and that SPR was around 20%.

The VPA approach was used by Schirripa (1998) and SPR was estimated to be around 25%. However, the VPA results were highly variable due to lack of age samples. The stock was not overfished relative to a threshold of 20% SPR.

By the 2000 vermilion snapper assessment, a transition had occurred to define overfishing as fishing in excess of F_{MSY}. In the assessment, Schirripa and Legault (2000) used $F_{30\%\ SPR}$ as a proxy for F_{MSY}. Likewise, B_{MSY} was defined as the equilibrium spawning stock size that could support MSY. Based on these thresholds and results from VPA analyses, there was a 73% chance overfishing occurred in 1999 ($F_{1999} > F_{MSY}$) and a 59% chance stock biomass was below MSST (i.e., overfished).

Porch and Cass-Calay (2001) considered virtual population analysis (VPA) methods employed in previous assessments, as well as a state-space implementation of the Pella-Tomlinson non-equilibrium surplus production model that represented a significant departure in methodology from earlier VPA assessments. The surplus production models were developed due to concerns that the VPA models were over-reliant on poorly-determined catch-at-age data. The age data was derived from length using a highly imprecise growth curve that suffered from large variance in age-at-length and potentially high, but unknown reader biases. The production model approach did not require the use of age data, but assumed that biomass and production were independent of age structure. Although the various models gave differing results, the general consensus was that the stock had become overfished and that overfishing was occurring. Using the base model, MSY was estimated to be 3.37 million pounds based on a F_{MSY} of 0.32, while B_{MSY} was 10.6 million pounds and MSST was 7.95 million pounds. Fishing mortality in 1999 was twice the MFMT, while biomass in 2000 was at 32% of B_{MSY}.

In 2004 Amendment 23 to the Reef Fish FMP was passed in order to establish a rebuilding plan for vermilion snapper. The rebuilding plan specified that the stock should be rebuilt in ten years using a stepped strategy that held harvest constant for an initial four year interval consistent with the average of the same four years under a constant fishing mortality rate, then three-year intervals thereafter. The allowable harvest starting in 2004 was 1.475 million pounds and equated to a 25.5 percent reduction in directed harvest based on 2003 estimated landings. In 2008 allowable harvest would increase to 2.058 million pounds and in 2011 harvest would increase to 2.641 million pounds. The minimum size for recreationally and commercially caught vermilion snapper was 11 inches TL; the recreational bag limit was 10 fish within the 20-reef fish aggregate bag limit; and a commercial closed season was established from April 22 through May 31.

Amendment 23 also officially defined MSY for vermilion snapper as the yield associated with F_{MSY} (or associated proxy) when the stock was at equilibrium. The OY was the yield corresponding to a fishing mortality rate (F_{OY}) defined as 0.75*F_{MSY} (or associated proxy) when the stock was at equilibrium. The maximum Fishing Mortality Threshold (MFMT) was set equal to F_{MSY}. The Minimum Stock Size Threshold (MSST) was set equal to (1-M)*B_{MSY} (or associated proxy) where M=0.25.

In 2006 a benchmark review occurred for vermilion snapper as part of SEDAR 9 (SEDAR, 2006). The final accepted model was the State-Space Age-Structured Production Model (SSASPM). Given the extended temporal extent of age sampling and the increased reliability of age readings, it was deemed that an age-structured model could be implemented. In addition, the statistical catch-at-age framework was better able to deal with sampling error than the VPA framework. Based on the SSASPM model, the stock was not undergoing overfishing (F/F_{MSY} = 0.65 and $F/F_{SPR30\%}$ = 0.67) nor overfished (SSB/SSB_{MSY} = 1.80, $SSB/SSB_{SPR30\%}$ = 1.75) at the end of 2004. According to the base model chosen by the SEDAR9-AWG panel, the Gulf of Mexico stock of vermilion snapper had never been overfished, and had never undergone overfishing. However, the SSB had been in decline for much of the timeseries, while fishing mortality had been continually increasing.

Because of the change in models and resulting change in population status, the rebuilding plan established in 2004 was no longer needed. A February 2007 regulatory amendment repealed the vermilion snapper regulations that were implemented by Amendment 23. The minimum size limit was reduced from 11 inches to 10 inches TL, the 10 fish vermilion snapper bag limit restriction within the 20 reef fish aggregate limit was eliminated, and the April 22 through May 31 commercial closed season was eliminated.

Update assessments were carried out on the SEDAR 9 models in 2011 (SEDAR, 2011a). Although it was meant to be a strict update, a change in methodology for dealing with shrimp bycatch was implemented. Previously, the median value of shrimp bycatch was fit in each year of the model, which had important implications as the shrimp effort declined. To better deal with shrimp bycatch, the 'super-year' approach was implemented where the median was fit directly instead of assuming it was a constant catch in every year. General trends and population trajectories were not strongly impacted by the change in assumption, but fishing mortality and stock-recruit parameters were affected by the new shrimp bycatch assumption. However, no changes in stock status occurred with 2010 fishing mortality equal to 36% of the F_{MSY} proxy (F that achieve equilibrium SPR 30%) and SSB around 160% of SSB at SPR 30%.

Yield projections were run using both $F_{SPR\ 30\%}$ and F_{MAX} as proxies for F_{MSY} (SEDAR, 2012). In general, F_{MAX} will be greater than or equal to F_{MSY}, except in unusual cases where recruitment decreases rapidly as spawning biomass increases beyond a certain threshold (i.e., strong compensation as seen with Ricker-type stock-recruit curves). Examination of the YPR curve for vermilion snapper revealed that $F_{SPR30\%}$ was greater than F_{MAX} for this stock under directed yield projections. For this reason, the SSC felt that F_{MAX} should be used as the proxy rather than $F_{SPR30\%}$ in this case. Stock status did not change using the F_{MAX} as the new proxy, but the decrease in the F proxy and associated increase in SSB proxy did bring the stock closer to the overfishing and overfished thresholds. The relative fishing mortality (F/MFMT) became 0.83, while the relative SSB (SSB/MSST) was 1.23 (SSB/SSB_{MSY} was 0.92).

For the projections of ABC, a P* value of 39.8% was chosen (Tier 1 uncertainty). The 2011 Generic Annual Catch Limits/Accountability Measures Amendment established annual catch limits, optional annual catch targets, and accountability measures for all stocks under Gulf Council management that required such parameters and did not already have them. For vermilion snapper, the amendment established an ACL of 3.42 million pounds whole weight, and an ACT of 2.94 million pounds whole weight. However, the numbers were based on data poor methods using SEDAR 9 assessment results. Projections implemented during the 2011 assessment that suggested a higher ACL was appropriate were considered during the 2012 'Framework Action to Set the Annual Catch Limit & Optionally the Annual Catch Target For the Vermilion Snapper Fishery', but the lower ACLs were maintained (50 CFR §622, 2013).

During the 2011 SEDAR 9 Update assessment process a Stock Synthesis 3 (SS3) model was also developed as an exploratory tool. The SS3 model was compared to the continuity model in order to determine if it could mimic the results of the SSASPM framework. Results were exceptionally similar despite differences in how historical catch and effort were interpolated. Model fit to the various data sources was the same as those from SSASPM and terminal stock status was nearly identical with slightly lower fishing mortality and spawning stock biomass ratios (SEDAR, 2011b). The SSC reviewed the exploratory SS3 model run and agreed that it was appropriate to use as the base model in the next assessment.

In 2016, a standard assessment was completed for vermilion snapper as part of SEDAR 45 (SEDAR, 2016). Along with updating all data series through the new 2014 terminal year, the 2016 assessment updated all meristic formulas and life history parameters and incorporated a number of major data and modeling changes. All meristic equations were updated to incorporate additional samples and to switch from total length to fork length as the unit of measure for the assessment. Life history updates included, switching from constant natural mortality with age to a Lorenzen natural mortality function and re-estimating all aspects of the growth, reproduction and length-weight relationships using the same methodologies as the previous assessment.

Major changes to the data included re-weighing all commercial and recreational age frequency distributions by their corresponding length frequency distributions for each region; re-weighting the shrimp effort time-series by the SEAMAP trawl survey data; including three new fishery independent indices of abundance (SEAMAP Groundfish Survey, SEAMAP Larval Survey, and SEAMAP Video Survey); and splitting the eastern and western commercial indices of abundance at 2007 to account for any influence the implementation of red snapper IFQ might have had on commercial fisher behavior.

The most significant modeling change between SEDAR 45 and the SEDAR 9 update assessment was the transition from SSASPM to Stock Synthesis (SS). The shift to SS allowed for some additional modeling flexibility, which was used by the assessment team to make several changes to the model structure. Of note were the decisions to freely estimate all stock-recruit parameters simultaneously; update data input standard errors (i.e., data weights) to better reflect the variance associated with each data set; allow interannual variation in CPUE/survey data weights; use an iterative re-weighting process to determine the effective sample sizes for compositional data; and increase the effective sample size cap from 25 to 100.

In addition to the data and modeling changes, SEDAR 45 introduced a management change by reverting the MSY proxy from F_{MAX} back to $F_{SPR30\%}$. Both F_{MAX} and $F_{SPR30\%}$ were estimated for SEDAR 45 and F_{MAX} was found to be higher than $F_{SPR30\%}$ and result in a lower equilibrium SPR. This result was in contrast to the result obtained during the SEDAR 9 update assessment and led the assessment panel to recommend adopting the harvest rate that achieves SPR 30% as an appropriate MSY proxy for vermilion snapper (given that MSY could not be directly calculated due to uncertainty in the stock-recruit relationship). Based on the new MSY proxy, the SEDAR 45 assessment found the Gulf of Mexico stock of vermilion snapper to be in a healthy state with no overfishing occurring, and the stock not overfished. The terminal year SPR was estimated at 32%, which was slightly above the target value of 0.3 and the SSB was determined to have been above the minimum stock size threshold for its entire history (i.e., no evidence of being overfished in the past). The assessment also indicated that the stock had not experienced overfishing since 2012.

For the projections of ABC, the optimum yield (75% $F_{SPR30\%}$) was preferred over the P* approach used during the SEDAR 9 update. The SEDAR 45 assessment produced unexpectedly small uncertainty estimates in the OFL which effectively eliminated the buffering capability of the P* approach. The reduced uncertainty estimates for vermilion snapper are thought to have resulted from a combination of fixed inputs (e.g., natural mortality, length-weight relationship, etc…) that lacked directly specified uncertainty and a very small stock recruitment variance term ($\sigma_R = 0.23$). Consequently, the panel and SSC determined that uncertainty for SEDAR 45 might be better accounted for by using the OY as the basis for the ABC instead of the *P** approach. Adoption of the OY for the ABC resulted in a 10 yr average catch recommendation of 3.11 million pounds.

Chronological Vermilion Snapper Stock Assessment Reports

Goodyear, C.P., and Schirripa, M.J. 1991. A biological profile for vermilion snapper with a description of the fishery in the Gulf of Mexico. NMFS/SEFSC Miami Laboratory. Contribution No. MIA-90/91-78. 53pp.

Schirripa, M.J. 1992. Analyses of the age and growth of vermilion snapper with an assessment of the fishery in the Gulf of Mexico. NMFS/SEFSC Miami Laboratory. Contribution No. MIA-91/92-74. 47pp.

Schirripa, M.J. 1996a. Status of the vermilion snapper fishery of the Gulf of Mexico: assessment 3.0. NMFS/SEFSC Miami Laboratory Contribution No. MIA-95/96-61. 17pp. + 53 figs. + 35 tables.

Schirripa, M.J. 1996b. Status of the vermilion snapper fishery of the Gulf of Mexico: assessment 3.0, addendum 1. NMFS/SEFSC Miami Laboratory Contribution No. MIA-96/97-19. 11pp.

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Schirripa, M.J., and Legault, C.M. 2000. Status of the vermilion snapper fishery of the Gulf of Mexico: assessment update (version 4.5). NMFS/SEFSC Miami Laboratory, Sustainable Fisheries Division Contribution No. SFD-99/00-108. 33pp.

Porch, C.E., and Cass-Calay, S.L. 2001. Status of the vermilion snapper fishery in the Gulf of Mexico: assessment 5.0. NMFS/SEFSC Miami Laboratory, Sustainable Fisheries Division contribution SFD-01/02-129. 40 p. + figs. 21 p.

SEDAR (Southeast Data, Assessment, and Review). 2006. Stock Assessment Report of SEDAR 9: Gulf of Mexico Vermilion Snapper. Assessment Report 3.

SEDAR. 2011a. SEDAR 9 Update Stock Assessment Report: Gulf of Mexico Vermilion Snapper, an Alternative SSASPM Stock Assessment of Gulf of Mexico Vermilion Snapper that Incorporates the Recent Decline in Shrimp Effort. 22pp.

SEDAR. 2011b. SEDAR 9 Update Stock Assessment Report: Gulf of Mexico Vermilion Snapper, an Application of the Stock Synthesis Model to Vermilion Snapper in the Gulf of Mexico. 87pp. + Addendum.

SEDAR. 2012. SEDAR 9 Update Stock Assessment of Vermilion Snapper in the Gulf of Mexico: Revised Projections. 24pp.

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Fisheries of the Caribbean, Gulf of Mexico, and South Atlantic: Reef Fish Fishery of the Gulf of Mexico; Reef Fish Management Measures. 2013. 2013-186784, Federal Register (August 2, 2013). 46820-46822.

4 REGIONAL MAPS

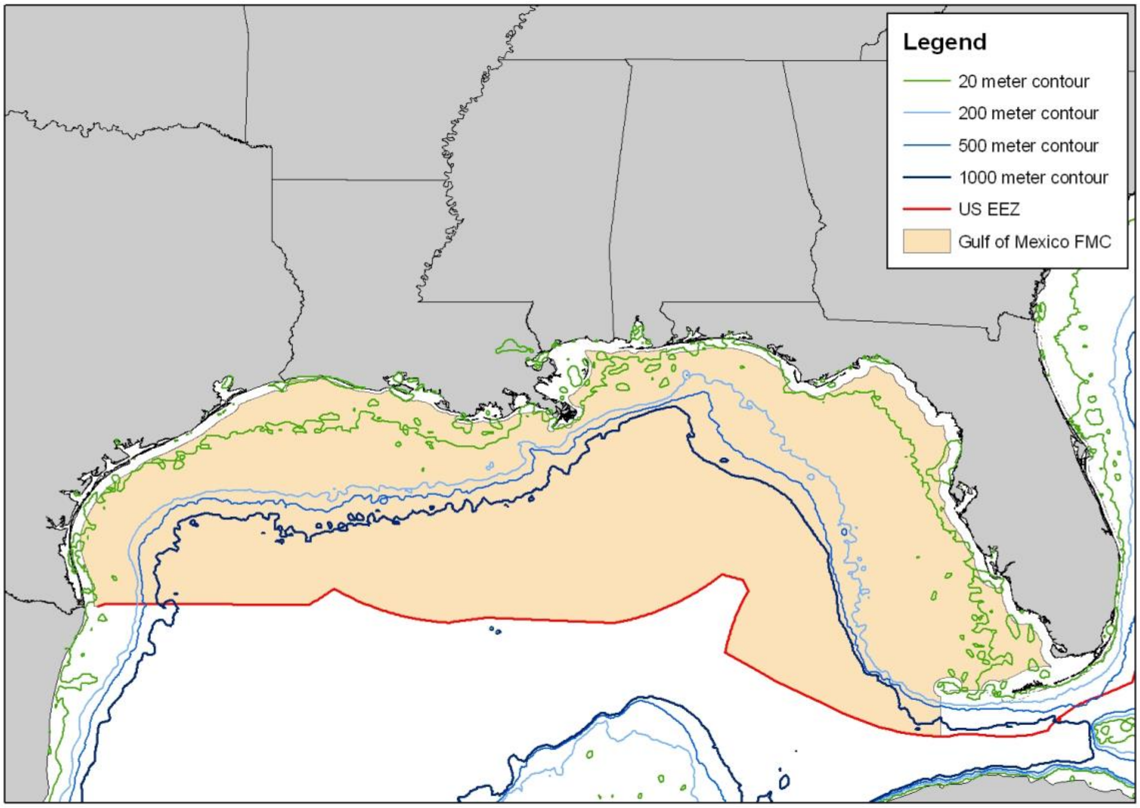

Figure 4.1 Southeast Region including Council and EEZ Boundaries.

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
ASMFC	Atlantic States Marine Fisheries Commission
B	stock biomass level
BAM	Beaufort Assessment Model

BMSY	value of B capable of producing MSY on a continuing basis
CFMC	Caribbean Fishery Management Council
CIE	Center for Independent Experts
CPUE	catch per unit of effort
EEZ	exclusive economic zone
F	fishing mortality (instantaneous)
FMSY	fishing mortality to produce MSY under equilibrium conditions
FOY	fishing mortality rate to produce Optimum Yield under equilibrium
FXX% SPR	fishing mortality rate that will result in retaining XX% of the maximum spawning production under equilibrium conditions
FMAX	fishing mortality that maximizes the average weight yield per fish recruited to the fishery
F0	a fishing mortality close to, but slightly less than, Fmax
FL FWCC	Florida Fish and Wildlife Conservation Commission
FWRI	(State of) 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)
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
MRIP	Marine Recreational Information Program
MSST	minimum stock size threshold, a value of B below which the stock is deemed to be overfished

MSY	maximum sustainable yield
NC DMF	North Carolina Division of Marine Fisheries
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
OY	optimum yield
SAFMC	South Atlantic Fishery Management Council
SAS	Statistical Analysis Software, SAS Corporation
SC DNR	South Carolina Department of Natural Resources
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
SERO	Fisheries Southeast Regional Office, National Marine Fisheries Service
SPR	spawning potential ratio, stock biomass relative to an unfished state of the stock
SSB	Spawning Stock Biomass
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 67

Gulf of Mexico Vermilion Snapper
SECTION II: Assessment Process Report

Original Release Date: April 2020
Updated: July 2020

SEDAR
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1. Workshop Proceedings

1.1. Introduction

This document summarizes the SEDAR 67 standard assessment of vermilion snapper (*Rhomboplites aurorubens*) in the U.S. Gulf of Mexico using updated data inputs through 2017 as implemented in the Stock Synthesis 3 modeling framework (Methot and Wetzel 2013). The standard assessment approach updates the SEDAR 45 standard assessment, but allows for updated methodology and new data. Except as otherwise noted, the specifications of the model and data streams are identical to those of the base model identified in the SEDAR 45 final report (SEDAR, 2016). The major changes between the SEDAR 45 and SEDAR 67 base models include incorporation of the Fishing Effort Survey (FES) adjustments to the recreational catch estimates, incorporation of the refined combined video index (as opposed to using only the Mississippi Labs video index), and inclusion of regulatory discards (discards due to size limits). Overfishing limits (OFL) and acceptable biological catch advice are included in this report; however, the ABC and sustainable yield recommendations provided within are tentative pending approval an adoption by the Gulf of Mexico Fisheries Management Council and their Science and Statistical Committee.

1.2. Workshop time and Place

SEDAR 67 Gulf of Mexico vermilion snapper assessment process consisted of a series of webinars. Data and Assessment webinars were held between November 2019 and January 2020.

1.3. Terms of Reference

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

1. Update the approved Gulf of Mexico vermilion base model from SEDAR 45 with data through 2017. Provide a model consistent with the previous assessment configuration to incorporate and evaluate any changes allowed for during this assessment.
2. Evaluate and document the following specific changes in input data or deviations from the benchmark model previous assessment model.
    - Explore the effect of the IFQ program on commercial CPUE, and examine model sensitivity to plausible alternative commercial CPUE time-series.
    - Conduct a sensitivity run with all fishery dependent indices of abundance removed from the model.
    - Pending new information on discard mortality rates or large increases in discard levels, explore model sensitivity to including discards.
    - Investigate the impact of FES adjusted MRIP data, if available, on model outputs.
    - Combine FWC and NMFS video surveys into a single index, if possible.
    - Obtain age or length composition data from shrimp bycatch fisheries to better inform shrimp selectivity estimates, if possible.
3. Document any revisions or corrections made to the model and input datasets, and provide updated input data tables. Provide commercial and recreational landings and discards in numbers and weight (pounds).
4. Update model parameter estimates and their variances, model uncertainties, and estimates of stock status and management benchmarks. In addition to the base model, conduct sensitivity

analyses to address uncertainty in data inputs and model configuration and consider runs that represent plausible, alternate states of nature.

5. Project future stock conditions regardless of the status of the stock. Develop rebuilding schedules, if warranted. Provide the estimated generation time for each unit stock. Stock projections shall be developed in accordance with the following:

Scenarios to Evaluate (preliminary, to be modified as appropriate)

1. F_{OY}= 75% F_{MSY} (project when OY will be achieved)

2. $F_{REBUILD}$ (if necessary)

3. F=0 (if necessary)
4. Equilibrium yield at F_{MSY}

6. Develop a stock assessment report to address these TORs and fully document the input data, methods, and results.

1.4. List of Participants

Panelists

Matt Smith (Co-Lead analyst) .... NMFS Miami
Dan Goethel (Co-Lead analyst) .... NMFS Miami
Shannon Cass-Calay .... NMFS Miami
Keith Guindon .... Industry Rep
David Hanisko .... NMFS Pascagoula
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Kai Lorenzen .... SSC/UF, Gainesville
Vivian Matter .... NMFS Miami
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Refik Orhun .... NMFS Miami
Will Patterson .... SSC/UF
Adam Pollack .... NMFS Pascagoula
Sean Powers .... SSC/South Alabama
Adyan Rios .... NMFS Miami
Skyler Sagarese .... NMFS, Miami
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Beth Wrege .... NMFS Miami

Attendees

Robert Allman .... NMFS Panama City
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Ken Brennan .... NMFS Beaufort
Heather Christiansen .... FWC
Nancie Cummings .... NMFS Miami
Kelly Fitzpatrick .... NMFS Beaufort
Jeff Isely .... NMFS Miami

Kevin McCarthy .... NMFS Miami
Meg Oshima.. Univ. Southern MS, Ocean Springs, MS
Allison Shideler ....UM-CIMAS, Miami
Katie Siegfried..NMFS Beaufort
Molly Stevens .... NMFS Miami
David Walker..Industry Rep

Staff

Julie Neer..SEDAR
Chip Collier .... SAFMC Staff
Ryan Rindone .... GMFMC Staff

1.5. 1.4 List of Working Papers and Reference Documents

Document #	Title	Authors	Date Submitted
Documents Prepared for the Assessment Process			
SEDAR67-WP-01	Commercial Discard Length Composition for Gulf of Mexico Vermilion Snapper	Sarina F. Atkinson and Kevin J. McCarthy	19 November 2019
SEDAR67-WP-02	SEAMAP Reef Fish Video Survey: Relative Indices of Abundance of Vermilion Snapper	Matthew D. Campbell, Kevin R. Rademacher, Michael Hendon, Paul Felts, Brandi Noble, Joseph Salisbury, and John Moser	23 September 2019
SEDAR67-WP-03	Indices of abundance for Vermilion Snapper (*Rhomboplites aurorubens*) using combined data from three independent video surveys	Kevin A. Thompson, Theodore S. Switzer, Mary C. Christman, Sean F. Keenan, Christopher Gardner, Katherine E. Overly, Matt Campbell	25 September 2019
SEDAR67-WP-04	Indices of abundance for Vermilion Snapper (*Rhomboplites aurorubens*) from the Florida Fish and Wildlife Research Institute (FWRI) vertical long line survey in the eastern Gulf of Mexico	Heather M. Christiansen, Theodore S. Switzer, and Brent L. Winner	23 September 2019
SEDAR67-WP-05	Indices of abundance for Vermilion Snapper (*Rhomboplites aurorubens*) from	Heather M. Christiansen, Theodore S. Switzer, and Brent L. Winner	23 September 2019

	the Florida Fish and Wildlife Research Institute (FWRI) repetitive timed drop survey in the eastern Gulf of Mexico		
SEDAR67-WP-06	Sample size sensitivity analysis for calculating MRIP weight estimates	Kyle Dettloff and Vivian Matter	18 October 2019
SEDAR67-WP-07	A Summary of Observer Data from the Size Distribution and Release Condition of Vermilion Snapper Discards from Recreational Fishery Surveys in the Eastern Gulf of Mexico	Dominique Lazarre	2 November 2019
SEDAR67-WP-08	Standardized Catch Rate Indices for Vermilion Snapper (*Rhomboplites aurorubens*) during 1986-2017 by the U.S. Gulf of Mexico Headboat Recreational Fishery	Skyler R. Sagarese	4 November 2019
SEDAR67-WP-09	Standardized Catch Rate Indices for Vermilion Snapper (*Rhomboplites aurorubens*) during 1986-2017 by the U.S. Gulf of Mexico Charterboat and Private Boat Recreational Fishery	Skyler R. Sagarese	4 November 2019
SEDAR67-WP-10	Vermilion Snapper *Rhomboplites aurorubens* Findings from the NMFS Panama City Laboratory Camera & Trap Fishery-Independent Survey 2004-2017	K.E. Overly, C.L. Gardner	8 November 2019
SEDAR67-WP-11	Vermilion snapper (*Rhomboplites aurorubens*) larval indices of relative abundance from SEAMAP Fall Plankton Surveys, 1986 to 2017	David S. Hanisko, Glenn A. Zapfe Adam G. Pollack, Denice M. Drass, Pamela J. Bond, Christina Stepongzi, Taniya Wallace and Andrew Millet	12 November 2019
SEDAR67-WP-12	CPUE Expansion Estimation for Total Discards of Gulf of Mexico Vermilion Snapper	Steven G. Smith, Allison C. Shideler, Kevin J. McCarthy	8 November 2019
SEDAR67-WP-13	Vermilion Snapper Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of Mexico	Adam G. Pollack, David S. Hanisko and G. Walter Ingram, Jr.	12 November 2019

SEDAR67-WP-14	Commercial Landings of Vermillion Snapper (*Rhomboplites aurorubens)* In the Gulf of Mexico	M. Refik Orhun and Beth M. Wrege	12 November 2019
SEDAR67-WP-15	Shrimp Fishery Bycatch Estimates for Gulf of Mexico Vermilion Snapper, 1972-2017	Zhang, X. and J. Isely	5 February 2020
SEDAR67-WP-16	Model-based size composition of vermilion snapper obtained from three visual surveys	John Walter, Kevin Thompson and Ted Switzer	5 February 2020
Final Stock Assessment Reports			
SEDAR67-SAR	Gulf of Mexico Vermilion Snapper	SEDAR 67 Panel	
Reference Documents			
SEDAR67-RD01	SEDAR64-RD-12: Model-estimated conversion factors for calibrating Coastal Household Telephone Survey (CHTS) charterboat catch and effort estimates with For Hire Survey (FHS) estimates in the Atlantic and Gulf of Mexico with application to red grouper and greater amberjack	Kyle Dettloff and Vivian Matter	
SEDAR67-RD02	Sink or swim? Factors affecting immediate discard mortality for the Gulf of Mexico commercial reef fish fishery	Jeff R. Pulver	

2. Data Review and Update

A variety of data sources were used in the SEDAR 67 assessment. For the most part, the SEDAR 67 model used the same data sets as the SEDAR 45 base model with updated time series through 2017. However, a handful of new or alternately constructed data sets were provided for the SEDAR 67 analysis, which were included in the final SEDAR 67 model (e.g., updated recreational landing statistics that incorporate the NOAA fishing effort survey (FES), a fishery-independent combined video survey, and fishery discards). The data utilized in the SEDAR 67 base model are summarized below:

Life History
- Length-Weight Conversions
- Growth
- Reproduction
- Natural Mortality
- Release Mortality

Fishery-Dependent Data
- Commercial Landings
- Recreational Landings
- Commercial Discards
- Recreational Discards
- Shrimp Bycatch
- Commercial Age Compositions
- Recreational Age Compositions

Fishery-Dependent Indices
- Commercial CPUE
- Recreational CPUE (MRIP and Headboat)
- Shrimp Effort

Fishery-Independent Surveys
- Southeast Area Monitoring and Assessment Program (SEAMAP) Larval Survey
- SEAMAP Groundfish Summer East Survey
- Combined (SEAMAP MS Labs, PC Lab, FWRI) Video Survey
- SEAMAP Groundfish Survey Length Compositions
- Combined Video Survey Length Compositions

2.1. Stock Structure and Management Unit

The management unit for Gulf of Mexico vermilion snapper extends from the United States-Mexico border in the west through northern Gulf of Mexico waters to the western Dry Tortugas and the Florida Keys (water within the Gulf of Mexico Fishery Management Council boundaries). Consistent with the findings of SEDAR 45, the SEDAR 67 standard assessment assumes that Gulf of Mexico vermilion snapper comprise a single unit stock, which agrees with current management boundary delineations used by the Gulf of Mexico Fisheries Management Council. While the stock is currently managed as a single unit, there was some evidence indicating that differences in stock structure likely exist between the west and eastern vermilion snapper populations. However, sample sizes were often insufficient to separate into western and eastern geographical regions making any spatial modeling attempts impossible. Data from the commercial fisheries were the sole data sources extensive enough to allow separation by region. For practical purposes, the eastern and western Gulf of Mexico was defined based on Gulf shrimp statistical grids (grid 1 to 12 for the eastern Gulf and grid 13 to 21 for the western Gulf). The areas are illustrated in Figure 1.

2.2. Life History Parameters

The life history parameters of Gulf of Mexico vermilion snapper were not updated for the SEDAR 67 standard assessment and all values represent those provided during SEDAR 45.

Given the limited time between subsequent assessments and lack of any new data to suggest changes in life history parameters may have occurred, the SEDAR 67 panel agreed that reestimation of these parameters was unnecessary at this time.

2.2.1. *Morphometric and Conversion Factors*

Vermilion snapper lengths are generally recorded as either total length (TL) or fork length (FL). The SEDAR 45 standard assessment used fork length as the unit of measure as it is generally considered a more accurate and consistent way to measure fish length. Conversions for length and weight utilized in SEDAR 67 are summarized in Table 1 and Table 2.

2.2.2. *Growth*

The age and growth of vermilion snapper were described in SEDAR45-WP-01. 47,343 vermilion snapper were aged from otoliths collected from 1994 to 2014 for estimating growth. The majority of vermilion snapper were sampled through the Trip Interview Program (TIP). Commercial samples annually accounted for 56% of otoliths aged followed by recreational (26%) and fishery-independent samples (18%).

The growth parameters were estimated for SEDAR 45 by fitting a series of size-modified (i.e., censored regressions to account for minimum size regulations) von Bertalanffy growth models under a suite of variability assumptions (SEDAR45-WP-01). The preferred model based on minimum AIC was one that assumed constant coefficient of variation at age. Parameters from this model fit and the fit of the model to the data are shown in Table 2 and Figure 2. The values from SEDAR 45 were maintained for SEDAR 67 with no update to the growth model.

The growth curve as estimated in Table 2 was fit to biological age-at-size. In SS3, fish have an assumed birthdate of January 1 of each calendar year. The assumed birth date does not accurately reflect the life history of vermilion snapper, which reproduce throughout the year. In an attempt to make the growth curve in the model more accurately reflect vermilion snapper biology, the 'biological age' growth curve (i.e., externally estimated growth curve) was converted to an 'SS3 age' growth curve by adding 0.5 to t_0 ($t_{0adjusted}$ = -0.2953). The adjustment factor assumes that the average birth date occurs in the middle of the year (i.e., June), thereby reducing the average size at age-0 to account for a later average date of birth (compared to the SS3 assumption). The variation in size-at-age was assumed to be normally distributed with a constant coefficient of variation equal to 0.2535 (SEDAR45-WP-01).

2.2.3. *Reproduction*

The reproductive parameters of vermilion snapper sex ratio, maturity, and fecundity were described in SEDAR45-WP-02. For the purpose of the assessment, the reproductive potential (i.e., SSB) was in number of eggs (as opposed to biomass). Reproductive potential was based upon the female sex ratio and the product of female maturity, female batch fecundity, and the estimate of the average number of female spawns per year. The SEDAR 67 assessment model assumed a roughly equal sex ratio (50% females). A logit fit maturity function was implemented using logistic regression (Table 2). The functional form of the logistic equation used by SS3 and the parameter estimates input into SS3 are shown in Table 2 and Figure 3. Average batch fecundity was 76,465 (standard deviation of 79,093) eggs. Average relative fecundity (eggs/gram of ovary free body weight) was 224 (standard deviation of 112). Table 2 and Figure 3 provide the maturity parameter values used in the SS3 model, which were input as fixed parameters. Annual fecundity was estimated at 82 * batch fecundity, based upon a 219 day spawning season (end of March to end of October with a spawning peak from May to August) and the average daily probability of spawning (0.38, all female sizes). Fecundity-at-length for the final SS3 model is shown in Figure 3.

2.2.4. *Natural Mortality Rate*

In SEDAR 45, an age-specific natural mortality rate was implemented using a Lorenzen (1996) curve scaled to an average M equal to 0.25. Age-0 natural mortality was adjusted to account for the true midyear birthdate (i.e., age-0 fish only underwent a half-year of mortality). The final base vector of natural mortality rate at age used in SEDAR 67 is shown in Table 3 and Figure 4.

2.2.5. *Release Mortality*

The SEDAR 67 base model incorporated fishery discards to better address mortality due to undersized vermilion snapper being caught and released. Dead discards were the fraction of total discards that were assumed to not survive the release process based on an assumed release mortality rate of 0.15. The assumed discard mortality rate was based on studies conducted on vermilion snapper in the South Atlantic, because no comprehensive studies across gear types were available from the Gulf of Mexico. South Atlantic studies indicated that release mortality was low, on the order of 15%, for shallow caught fish (Guccione, 2005); however, the magnitude of mortality likely increases substantially for deeper caught fish and fish that are hooked in locations other than the jaw (Rudershausen *et al.*, 2007). However, a Gulf of Mexico release mortality study was presented to the SEDAR 67 panel late in the assessment process (i.e., during the final assessment webinar), which indicated that immediate release mortality of vermilion snapper from the commercial sector was likely around 50% (Pulver, 2017). However, observer data in the recreational fisheries in Florida (SEDAR67-WP-07) suggested that immediate release mortality in that sector was below 1%. Given the discrepancy in discard mortality rates presented and the lack of information across all sectors and regions, the panel decided to maintain the SEDAR 45 discard mortality rate of 15%. However, a sensitivity run with the SEDAR 67 base model was developed to explore the impact of assuming a 50% discard mortality rate across all sectors.

2.3. Fishery Dependent Data

2.3.1. *Landings*

Commercial Landings

The primary commercial gear used for Gulf of Mexico vermilion snapper is hand line (vertical lines, bandit rigs, rod and reel, etc…). Vermilion snapper are occasionally captured on long line gear and in the trap fishery. In most years, the take from the trap and long line fisheries were a small fraction of the total landings. The data collected from these fisheries included landings, discards, catch-per-unit effort, and age composition. Commercial data were tabulated by broad geographical region loosely separated by the Mississippi River and was updated for SEDAR 67 through 2017 for both regions (landings are provided in Table 4; SEDAR67-WP-14).

During the SEDAR 45 assessment, only hand line landings were used as inputs for the assessment model. As previously stated, the contribution of the longline and trap catches was small in most years such that the difference between total landings and hand line landings was insignificant in most years (Table 5) and SEDAR 67 maintained the SEDAR 45 approach. A small QA/QC issue was rectified from the SEDAR 45 assessment, which resulted in the 2014 data point for the commercial landings being revised upwards slightly for both regions (Figure 5).

After a strong downward trend in both areas from 2009 to 2013, landings have fluctuated without trend over the last four years (Figure 5). Higher landings are normally observed from the eastern area compared to the western area. Total landings for the commercial fishery were input into the assessment model for SEDAR 67 in metric tons (Table 4). Estimates of commercial landings (pounds, whole weight) were available since 1963 for the hand-line fishery, 1980 for the longline fishery, and 1985 for the trap fishery (Table 5). Landings prior to 1963 were linearly interpolated to virgin conditions (no catch) in 1950 and fit as observed landings in the model.

<u>Recreational Landings</u>

The recreational landings for vermilion snapper were obtained from the following separate sampling programs:

1. Marine Recreational Information Program (MRIP)
2. Southeast Region Headboat Survey (SRHS)
3. Texas Parks and Wildlife Department (TPWD)
4. LA Creel Survey (used for LA estimates starting in 2014)

MRIP provides a long time series of estimated catch per unit effort, total effort, landings, and discards for six two-month periods (waves) each year. MRIP provides estimates for three recreational fishing modes: shore-based fishing (SH), private and rental boat fishing (PR), and for-hire charter and guide fishing (CH). When the survey first began in Wave 2 (Mar/Apr), 1981, headboats were included in the for-hire mode, but were excluded after 1985 in the South Atlantic and Gulf of Mexico to avoid overlap with the Southeast Region Headboat Survey (SRHS) conducted by the NMFS Beaufort, NC lab. The MRIP survey covers coastal Gulf of Mexico states from Florida to Mississippi. Louisiana was included in MRIP until 2013. Recreational estimates from Louisiana starting in 2014 are obtained from the state-run LA Creel Survey. Survey methodologies have changed over time. Two of the most recent changes are discussed below.

- The Marine Recreational Information Program completed a three year transition in 2018 (NOAA Fisheries 2018). Estimates of fishing effort for the private and shore modes are now obtained from a Fishing Effort Survey conducted via mail, which uses angler license and registration information to identify and contact anglers as well as supplemental data from the U.S. Postal Service that includes nearly all U.S. households. Effort estimates for charter and party boats are still obtained from the For-Hire Telephone Survey and are not affected by the new Fishing Effort Survey. Previously, estimates of private and shore fishing effort came from the legacy Coastal Household Telephone Survey, which used random-digit dialing of homes in coastal counties to contact anglers. Concerns over low response rates, due in part to homes transitioning away from landlines toward cellular phone only, the gatekeeper effect (i.e., speaking to someone other than the angler), the tendency to ignore unknown callers, and coverage limited to only coastal counties in the Coastal Household Telephone Survey were motivation for the new survey, which is considered to provide more accurate estimates of trips. By design, the Fishing Effort Survey is reaching more anglers, getting into the right hands, providing a higher response rate, and extracting more information from anglers with an improved survey questionnaire. Benchmarking of the Fishing Effort Survey alongside the Coastal Household Telephone Survey for three years allowed for apples-to-apples comparisons between data from the two different surveys and the creation of a peer-reviewed calibration model. The calibration model was peer reviewed by reviewers appointed by the Center for Independent Experts (see Rago et al. (2017)). Additional details can be found at: https://www.fisheries.noaa.gov/event/fishing-effort-survey-calibration-model-peer-review.

- The MRIP transition also accounted for the 2013 design change in the Access Point Angler Intercept Survey (APAIS, Foster et al. 2018). Improved survey procedures were incorporated that better account for all types of completed trips and remove potential sources of bias from the survey design. For example, the new sampling design provides more complete coverage of angler fishing trips ending throughout the day and night, whereas the old design often missed nighttime trips or off-peak daytime trips. In addition, conversion factors were developed to account for any consistent effects of the redesign on catch rate estimates produced by APAIS. The new APAIS design uses a sample weight adjustment method and is more statistically sound because it more strictly adheres to formal probability sampling protocols. The APAIS calibration model developed by MRIP and the statistical approach proposed for the conversion of catch estimates by MRIP were peer reviewed by reviewers appointed by the Center for Independent Experts. Additional details can be found at: https://www.fisheries.noaa.gov/event/access-point-angler-intercept-survey-calibration-workshop.

The Southeast Region Headboat Survey (SRHS) estimates landings and effort for headboats in the South Atlantic and Gulf of Mexico. The SRHS began in the South Atlantic in 1972 and Gulf of Mexico in 1986 and extends from the North Carolina\Virginia border to the Texas\Mexico border. Mississippi headboats were added to the survey in 2010. The South Atlantic and Gulf of Mexico Headboat Surveys generally include 70-80 vessels participating in each region annually.

The TPWD Sport-boat Angling Survey was implemented in May 1983 and samples fishing trips made by sport-boat anglers fishing in Texas marine waters. All sampling takes place at recreational boat access sites. The raw data include information on catch, effort and length composition of the catch for sampled boat-trips. These data are used by TPWD to generate recreational catch and effort estimates. The survey is designed to estimate landings and effort by high-use (May 15-November 20) and low-use seasons (November 21-May 14). In SEDAR 16

TPWD seasonal data was disaggregated into months. Since then SEFSC personnel has disaggregated the TPWD seasonal estimates into waves (2 month periods) using the TPWD intercept data. This was done to make the TPWD time series compatible with the MRIP time series. TPWD surveys private and charterboat fishing trips. While TPWD samples all trips (private, charterboat, ocean, bay/pass), most of the sampled trips are associated with private boats fishing in bay/pass, as these trips represent most of the fishing effort. Charterboat trips in ocean waters are the least encountered in the survey.

The Louisiana Department of Wildlife and Fisheries (LDWF) began conducting the Louisiana Creel (LA Creel) survey program for monitoring marine recreational fishery catch and effort on January 1, 2014. Private and charter modes of fishing are sampled. The program is comprised of three separate surveys: a shoreside intercept survey, a private telephone survey, and a for-hire telephone survey. The shoreside survey is used to collect data needed to estimate the mean numbers of fish landed by species for each of five different inshore basins and one offshore area. The private telephone survey samples from a list of people who possess either a LA fishing license or a LA offshore fishing permit and provided a valid telephone number. The for-hire telephone survey samples from a list of Louisiana's registered for-hire captains who provided a valid telephone number. Both telephone surveys are conducted weekly.

Adjustments and modifications

- The MRIP transition resulted in the release of new recreational catch estimates for all species and all modes, including charter mode estimates. As a result, the SEFSC conducted a calibration analysis using the newly released data to correct for this change from the Coastal Household Telephone Survey to the For-Hire Telephone Survey (SEDAR61-WP-19). The analysis uses a statistically sound, consistent methodology to provide improved calibrations for estimating ForHire Telephone Survey charterboat effort and landings with associated uncertainties from Coastal Household Telephone Survey estimates. Additional details are provided in SEDAR61-WP-19.
- MRIP shore mode estimates have been excluded, following SEDAR 45 recommendations.
- Monroe County MRIP landings are included in the Gulf of Mexico vermilion snapper estimates.
- To apply a consistent weight estimation methodology over the entire recreational time series, the Southeast Fisheries Science Center (SEFSC) implemented a method for calculating average weights for the MRIP landings. This method is detailed in SEDAR32-DW-02. Recently, the minimum number of weights required at each strata was changed from 30 to 15 (SEDAR67-DW-06). This method was used to calculate landings estimates in weight from the MRIP, TPWD, and LA Creel programs.
- Headboat landings for Texas 1981 to 1985 were estimated using a 3yr average (1986-1988) from SRHS Texas landings.

Due to the FES, APAIS, and FHS adjustments discussed above, recreational landings estimates differ between SEDAR 45 and SEDAR 67 (Figure 6). Although trends are similar, the FES estimates used in SEDAR 67 are consistently higher than the values used in SEDAR 45. Recreational landings were high in the 1990s before declining to relatively low levels through the 2000s. Landings have increased again since the mid-2000s and have reached time series highs in the last two years. The recreational catch is dominated by landings from the eastern region and recent increases are almost solely due to landings in the eastern Gulf of Mexico (Figure 6). The majority of the recreational landings in both regions over the last two decades has come from the private sector. This is a change from the 1980s and 1990s when the majority of recreational landings came from the charterboat mode (Table 6).

Landings from the recreational fleet date back to 1981. Landings prior to when data were available were linearly interpolated to virgin conditions (no catch) in 1950 and fit as true landings in the model.

2.3.2. *Discards*

Commercial Discards

Estimates for commercial discards of vermilion snapper were developed using the CPUE expansion method outlined in SEDAR67-WP-12. The general approach for estimating discards for the commercial reef fish fleet in the Gulf of Mexico utilizes catch-per-unit-effort (CPUE) from the coastal reef fish observer program and total fishing effort from the commercial reef logbook program to estimate total catch:

Total Discards = $\text{CPUE}_{\text{Discards}}$ x Total Effort.

For discard estimation, CPUE is computed for total discards, including fish released alive, released dead, and released in unknown condition. The primary metric for the coastal observer program is CPUE by species and gear. Catch per unit effort was determined from the coastal reef fish observer program in which scientific observers on commercial fishing vessels recorded detailed information on catch and effort for a subset of trips. Catch by species was recorded according to disposition category: kept (landed), released alive, released dead, released undetermined, and used for bait. Length and weight were recorded for a subsample of individual fish. The coastal reef fish observer program began in July 2006; for GOM vermilion snapper discard estimation, complete calendars years 2007-2017 were used. Time periods for the methodology can be defined in terms of the observer program, with the pre-observer time period representing years prior to 2007, and the observer time period representing years 2007 to 2017. Total effort was determined from the commercial coastal logbook program in which fishers reported basic information on effort and catch by species for every trip. The reef logbook program began in 1990 for a subset of vessels in the GOM, and expanded to all vessels in 1993; for Gulf of Mexico vermilion snapper discard estimation, complete calendar years 1993-2017 were used. Two management changes to the commercial GOM vermilion snapper fishery were accounted for in this analysis: (1) minimum size was increased in July 2005 from 8 inches total length (182 mm fork length) to 11 inches total length (250 mm fork length), and (2) minimum size was subsequently reduced in February 2008 to 10 inches total length (227 mm fork length).

Calculated discards are provided in Table 7. The overall magnitude of the commercial discards relative to the landings was small (ranging from 0 - 17%; Table 7). Discards peaked in the mid-2000s with the implementation of the 11-inch minimum size limit in 2005 and have decreased and stabilized around 11 – 15mt in the east and 1.5mt in the west over the last five years. A majority of discards are from the eastern region.

The discard estimation procedure has been much improved since the SEDAR 45 assessment, but a number of uncertainties still exist. For example, vermilion snapper with disposition 'used for bait' were not included in the discard estimates. Although the extent of vermilion snapper used for bait is not known precisely, the exclusion of this disposition in the analysis is likely to lead to the calculated discards being underestimated. The SEDAR 67 panel determined that the best approach for handling discard observations in the model was to treat the data as uncertain and to examine a number of approaches for fitting the data by using varying data weighting factors. Ultimately, due to modeling issues that developed when trying to fit the observed discards, the SEDAR 67 panel determined that the discard data should not be fit directly. The predicted discards were calculated based on a retention function with no weighting emphasis given to the observed discard values (see Section 3.1.9 for more information on the discard modeling approach).

Recreational Discards

Discarded live fish are reported by the anglers interviewed by the MRIP. Consequently, neither the identity nor the quantities reported are verified. MRIP estimates of live released fish (B2 fish) were adjusted in the same manner as the landings (i.e., using charter boat calibration factors, MRIP adjustment, substitutions, etc. described in section above).

SRHS discards are available from 2004 to the present. In 2013 the SRHS ceased recording the condition of released fish (live vs dead). All releases are recorded as "Estimated alive" starting that year. For consistency, all discards from 2004 to 2012 are categorized as b2 fish (released alive).

TPWD survey does not estimate discards. The LA Creel survey began estimating discards for a small number of species in 2016. No information is available on released vermilion snapper from LA Creel. Discards for Texas and Louisiana (2014+) are assumed to be negligible based on negligible TPWD landings and sporadic Louisiana MRIP discards prior to 2014.

Three management changes to the recreational Gulf of Mexico vermilion snapper fishery impacted discarding rate: (1) minimum size was increased in 1998 from 8 inches total length (182 mm fork length) to 10 inches total length (227 mm fork length), (2) minimum size was subsequently increased in 2005 to 11 inches total length (250 mm fork length), and (3) minimum size was again reduced in 2008 to 10 inches total length (227 mm fork length).

The overall magnitude of the recreational discards relative to the landings was generally small but did have some strong peaks (greater than 20% of landings) in the mid-1990s and since the late 2000s (Table 8 and Figure 7). Discards have been increasing rapidly in recent years in conjunction with the precipitous rise in recreational landings since around 2005. Given the number of uncertainties in calculating recreational discard data for vermilion snapper, a number of approaches for fitting the data were examined in the model by using varying weighting factors. As was the case with commercial discards, recreational discards were not fit directly in the final model (see Section 3.1.9 for more information on the discard modeling approach).

Shrimp Bycatch

Shrimp bycatch estimates for Gulf of Mexico vermilion snapper were generated using a Bayesian GLM approach (implemented in WinBugs) developed by Scott Nichols during the SEDAR 7 Gulf of Mexico red snapper assessment (Nichols, 2004a,b) and updated during SEDAR 9. The primary data on catch-per-unit effort (CPUE) in the shrimp fishery came from a series of shrimp observer programs, which began in 1972 and extend to the current shrimp observer program. Additional CPUE data were obtained from the SEAMAP groundfish survey by using the ratio between SEAMAP CPUE and observer program CPUE for overlapping years to fill spatio-temporal data gaps in shrimp observer coverage. Point estimates and associated standard errors of shrimp effort were generated by the NMFS Galveston Lab using their SN-pooled model (Nance, 2004). Most CPUE data were reported in fish per net-hour, while the shrimp effort data were reported in vessel-days. Therefore, data from the Vessel Operating Units File (VOUF) were needed to estimate the average number of nets per vessel for the shrimp fishery and used to convert total shrimp effort to net-hours. A detailed description of the data and methods used to produce the shrimp bycatch estimates can be found in Linton (2012) and is summarized in SEDAR67-WP-15.

Shrimp bycatch (in numbers of fish) are summarized in Table 9 and Figure 8. Estimates of shrimp fishery discards for years of 1972-2017 range from 0.155 - 61.300 million fish. Annual shrimp bycatch estimates are characterized by strong interannual variation, but have declined from generally high levels during the 1990s. Bycatch estimates have been at time series lows for the last decade and have shown little variation. The estimated median bycatch was 5.039 million fish. In the SEDAR 45 assessment it was assumed that 75% of shrimp bycatch was age-1+ (i.e., 25% were age-0 and not input into the model). Therefore, the final shrimp bycatch median value is multiplied by 0.75 before being input to the assessment model, which results in a final median value of 3.78 million fish for SEDAR 67 (compared to 3.37 million fish in SEDAR 45).

2.3.3. *Fishery-dependent Size and Age Composition*

Commercial Landings Age Composition

Only age composition data from the commercial hand line fleet were used to construct age frequency distributions, because this fleet represents the majority of the landings (and was the only fleet modeled). Age samples from the longline and trap fisheries were small or non-existent and not included. Age sample sizes (otoliths read) for the commercial east and west hand line fishery are shown in Table 10. Minor discrepancies between the SEDAR 45 and SEDAR 67 samples existed (Table 10) due to changes in data filtering protocols, but these differences were minor and had little impact on the final age compositions utilized in the model. Final age frequency distributions (AFDs) were estimated by reweighting the raw AFDs by the corresponding length frequency distributions for each region following methodology outlined in SEDAR 45 (SEDAR45-WP-08). For commercial hand line fishery landings, age compositions were estimated for the east and west regions. Age composition was sparse and not routinely collected for the commercial fleets until 2000 (Figure 9). There are differences in the AFDs between the east and west regions, which may be due, in part, to age-based movement or targeting behavior. In general, the western fleet is characterized by a more balanced age composition with a higher frequency of older fish compared to the eastern commercial fleet (Figure 9).

Recreational Landings Age Composition

For recreational landings, age samples from charter boats, head boats and private boats from the east and west regions were aggregated due to small sample sizes in some strata, which matched the approach used in SEDAR 45 (Table 11). A reweighting approach identical to that used for the commercial age data was used to reweight the recreational age data (SEDAR45-WP-08). Age composition has been collected for the recreational fleet since 1994. The increased recreational fleet sample size compared to that in the commercial fleets is due to the aggregation across modes and regions. The resulting age composition reflects multiple fisheries and associated selectivities, which likely makes it a less reliable data source. The recreational fleet tends to have little catch of older fish and the age composition generally resembles that of the eastern commercial fleet (Figure 9).

Commercial Discards Size Composition

Size composition from the reef fish observer program was summarized in SEDAR67-WP-01 and SEDAR67-WP-12. Over 97% of sampled discards were regulatory discards due to fish being below the minimum size limit. Therefore, the SEDAR 67 panel determined that length composition information would not be directly fit in the assessment model. All discards were assumed to be regulatory discards below the minimum size limit, which were determined using a size based retention function in the assessment model (i.e., all fish selected but below the minimum size for the sector were treated as discards).

Recreational Landings Age Composition

Comprehensive length composition across recreational sectors and regions is not available for vermilion snapper discards. Based on observer coverage in Florida on for-hire charter and headboats, the size composition of the discards was deemed to be primarily undersize fish (SEDAR67-WP-07). Therefore, given limited size composition data, actual discard length observations were not fit in the SEDAR 67 base model. Instead, all discards were assumed to be regulatory discards below the minimum size limit, which were determined using a size based retention function in the assessment model (i.e., all fish selected but below the minimum size for the sector were treated as discards).

Shrimp Bycatch Length/Age Composition

No direct age data were available for vermilion snapper from the shrimp observer data. Exploratory analysis during SEDAR 45 investigated the possibility of using the annual length composition obtained from the SEAMAP groundfish survey as a possible surrogate to inform shrimp bycatch fleet selectivity. The groundfish survey typically overlaps with the shrimp fleet and uses similar net configurations. However, the groundfish data had an overabundance of anomalously larger/old fish, which was likely due to the SEAMAP groundfish trawls not using bycatch reduction or turtle excluder devices that are mandated for use on commercial boats. According to expert opinion during SEDAR 45, it was determined that the groundfish survey length composition did not accurately reflect the length composition of the commercial shrimp bycatch.

Previous analysis of limited length-distributions obtained from the shrimp observer program noted that length frequencies were bimodal and suggested that 25% were age-0 with the remainder (75%) age-1+ (Porch and Cass-Calay, 2001). Given the lack of new information, the previous assessment assumption (established during SEDAR 9 based on the work from the 2001 assessment) was retained, which fixed the shrimp bycatch selectivity at 100% vulnerability for age-1, 30% for age-2, 3% for age-3, and 0% for ages-4+. As mentioned (see Section 2.3.2.3), the observed median shrimp bycatch is also multiplied by 0.75 to account for the assumption that shrimp bycatch is 75% age-1+, and age-0 catch is not included in the base SS3 model.

2.3.4. *Fishery-Dependent Indices*

Shrimp Effort

In order to scale interannual variation in shrimp bycatch fishing mortality within the assessment, an index of shrimp effort was used. Shrimp effort was collected by the NMFS Galveston laboratory based on commercial shrimp logbook data and was reported by year, area, season, and depth zone. Point estimates and associated standard errors of shrimp effort were generated by the NMFS Galveston Lab using their SN-pooled model for the years 1981-2017 (Nance, 2004). Following the decisions made during SEDAR 9 and used during the SEDAR 45 assessment, only shrimp effort greater than 10fm was included. It is believed that the majority of the interactions between shrimp gear and vermilion snapper occur at these depths, and effort from depths less than 10fm would be unlikely to cause large vermilion snapper bycatch. Therefore, including the effort from the less than 10fm depth zone would tend to overinflate shrimp bycatch fishing mortality estimates in the assessment model.

In addition, a simple reweighting procedure was done to scale effort by the observed distribution of vermilion snapper from the SEAMAP groundfish survey as was done during SEDAR 45. It is believed that the reweighted effort time series better reflects the levels and interannual variation in shrimp effort that is likely to interact with vermilion snapper. The reweighting procedure multiplies the SEAMAP catch in each area by the observed effort in each area to determine the reweighted effort. Effort was then summed and normalized to the time series mean (Table 12, Figure 10).

Historically shrimp effort was quite high, but decreased by 75% between 2002 and 2008 (Figure 10). Effort has remained at time series low values since 2008. Historical shrimp effort prior to 1981 was linearly interpolated back to virgin conditions (zero effort) in 1950. The assessment model fit these interpolated effort values as observed data.

Commercial Catch-per-Unit Effort (CPUE)

Data from the National Marine Fisheries Service reef fish logbook program were used during SEDAR 67 to construct standardized indices of abundance for vermilion snapper for the east and west portions of the Gulf of Mexico. The indices used the self-reported catch rate information for the vertical hand line fishery from 1993 to 2006. During SEDAR 45, it became apparent that the implementation of the red snapper IFQ program in 2007 had the potential to alter the CPUE of the commercial vermilion snapper fleet in a way that could not be accounted for with the methodology employed during SEDAR 9 and the 2011 update assessment. The SEDAR 45 base model assumed a split time series where separate indices were fit to the post IFQ data (2007-2014), and a new red snapper IFQ variable was included in the standardization routine for the post IFQ indices. However, given the limited knowledge of how red snapper IFQ (or lack thereof) impacts vermilion snapper targeting and catch rates, the adequacy of the standardization process for the post-IFQ index is difficult to verify. During SEDAR 67, a split series approach was again utilized to provide a continuity model with a pre- and post-IFQ time series (i.e., 1993-2006 and 2007-2017, respectively) to match the SEDAR 45 model. However, given the uncertainty in the post-IFQ series, exploratory runs were carried out using a truncated time series in 2006. Ultimately, the SEDAR 67 panel decided to use the truncated series for the SEDAR 67 base model, which was based on the uncertainty in the series, the limited impact that the post-IFQ series has on model results, and followed the decision made in the SEDAR 52 red snapper assessment to likewise truncate the commercial indices when IFQs were implemented. The standardized truncated commercial CPUE indices used in the base model are provided in Table 13 and Figure 11. The truncated commercial time series are very consistent with the SEDAR 45 indices (Figure 11).

Recreational Catch-per-Unit Effort (CPUE)

Abundance indices were developed for Gulf of Mexico vermilion snapper using data from the Marine Recreational Fisheries Statistics Survey (MRFSS) and the NMFS Southeast Zone Headboat Survey. A single index for the eastern region was constructed from the MRFSS data on hook and line trips (SEDAR67-WP-07). The MRFSS index was constructed for the period 1986 to 2017. Only data from the east were used, because of data limitations and lack of representative sampling in the western area. Trips before 1986 were excluded because vermilion snapper were rarely reported. There was concern that inclusion of all fishing trips would contaminate the CPUE series by including trips that fished outside of vermilion snapper ‘habitat’, thereby violating the statistical assumptions of the binomial component of the delta-lognormal model. Therefore, the Stephens and MacCall (2004) species association approach was used to identify trips that were more likely to observe vermilion snapper based on the composition of other species observed. Using the filtered trips, a delta-lognormal model was constructed. The resulting standardized index indicates catch rates were relatively high from 1990-1995, but declined substantially thereafter. The index fluctuated without trend for much of the late 1990s and early 2000s, but has indicated a general increase since 2008 (Table 14, Figure 12)

The NMFS Southeast Zone Headboat Survey indices covered 1986 to 2017 with large sample sizes each year (SEDAR67-WP-08). Additionally, vessels could be tracked individually. Vermilion snapper was the most common species in the Gulf of Mexico headboat dataset. Based upon the geographic distribution of average vermilion snapper catch rates, an east and a west headboat survey index were constructed. For reasons similar to the MRFSS index, the Stephens and MacCall (2004) species association approach was used to identify trips that were likely to catch vermilion snapper based on the composition of other species landed. For each index, a delta-lognormal model was constructed. The eastern Gulf headboat index followed a pattern similar to the eastern MRFSS index. The western Gulf headboat index demonstrated less contrast, but with high interannual variability. The headboat west index had a general downward trajectory during much of the time series, but has been relatively stable and time series mean values for the last seven year (Table 14, Figure 12).

2.4. Fishery-Independent Data

2.4.1. *SEAMAP Groundfish Survey*

Trawl data for vermilion snapper (*Rhomboplites aurorubens*) from the summer Southeast Area Monitoring and Assessment Program (SEAMAP) was used to produce a relative abundance index for the eastern GoM from 2009 – 2017 (SEDAR67-WP-13). SEAMAP is a collaborative effort between federal, state and university programs, designed to collect, manage and distribute fishery independent data throughout the region. The primary objective of this trawl survey is to collect data on the abundance and distribution of demersal organisms in the northern GoM. The survey samples from 9 – 110 m from Brownsville, TX to the Florida Keys, FL. Based on decisions made during SEDAR 45 only data collected east of the Mississippi River were used for the vermilion snapper index, because of the scarcity of the vermilion snapper in the samples to the west of the river. The survey runs on a biannual basis in the summer and fall. However, only data from the summer survey were used for the vermilion snapper index also based on decisions made during SEDAR 45, because of gaps in the spatial coverage during the fall survey. Delta-lognormal modeling methods were used to estimate relative abundance indices for vermilion snapper and indicated a relatively flat trend in abundance with a small peak in 2011 (Table 15, Figure 13). Length composition data for the SEAMAP groundfish survey were tabulated in 5 cm bins and demonstrate that the survey catches primarily small, young fish (Figure 9).

2.4.2. *SEAMAP Larval Survey*

Vermilion snapper (*Rhomboplites aurorubens*) larvae captured during Southeast Area Monitoring and Assessment Program (SEAMAP) Fall Plankton Surveys were used to develop indices of relative SSB from 1986 to 2016 (SEDAR67-WP-11). The larval indices are intended to capture trends in the adult spawning stock biomass. The SEDAR 45 panel recommended that the gulf-wide index be included in the assessment. Catches of larvae in bongo net samples were standardized to account for sampling effort and expressed as number under 10 m^2 sea surface (CPUA, Catch-per-Unit Area). CPUAs used in the indices were based only on larvae greater than 3.4 mm and less than 6.5 mm in body length to account for the identification uncertainty of smaller snapper larvae and the effects of gear avoidance by larger rarely caught larvae.

Year to year variability in spatial coverage during the Fall Plankton Survey was addressed by limiting observations to samples taken at SEAMAP stations that were sampled during at least 66% of all years for which there was consistent spatial coverage. Gulf-wide indices of abundance included all samples taken during at least 14 of the 22 years with consistent spatial coverage. A negative binomial index indicated better residual fit to the observations than the SEDAR 45 delta-lognormal approach and was utilized in the SEDAR 67 assessment model. The gulf-wide index is highly variable, but showed increased abundance during the early and middle part of the time series with a slight decline over the last decade (Table 15, Figure 13). However, the high degree of variability in annual means and the reduction in the number of years with full sampling coverage make it difficult to discern any trend.

2.4.3. *Combined Video Survey*

Currently there are three different stationary video surveys for reef fish conducted in the eastern Gulf of Mexico. The NMFS SEAMAP reef fish video survey, carried out by NMFS Mississippi Laboratory (MS Labs; SEDAR67-WP-02), has the longest running time series (1992-1997, 2002, and 2004+), followed by the NMFS Panama City lab survey (2005+; SEDAR67-WP-10), with the most recent survey being the Florida Fish and Wildlife Research Institute SEAMAP survey (FWRI, starting year 2008). While the surveys use standardized deployment, camera field of view, and fish abundance methods to assess fish abundancies on reef or structured habitat, there are variations in survey design and habitat characteristics collected in addition to the time period and area sampled. A combined video index that pooled data from the three different video surveys using a habitat-based approach to combine relative abundance data throughout the eastern GoM was considered during the SEDAR 45 assessment. However, there were differences in the length composition between the surveys that caused some concern. The decision was made to only include the NMFS Mississippi Laboratories index due its enhanced spatio-temporal coverage compared to the other surveys. Recommendations were made to evaluate best practices of both the NMFS and FWRI video surveys so that the data could be reliably combined into a single index in future assessments.

During SEDAR 67, the three independent along with the combined video index (SEDAR67-WP-03) were again presented. In addition, a multinomial regression model was presented to standardize length composition across the surveys for the combined video index (SEDAR67-WP-16), thereby addressing one of the primary limitations of the combined index presented during SEDAR 45. The multinomial approach, which was developed and implemented for combining length composition data for remotely operated vehicle surveys of red snapper and included in the SEDAR 52 assessment, accounts for habitat quality, depth, reef type, location, and survey to standardize the length composition data.

The combined video index showed moderate annual variability with little to no trend in abundance during much of the available time series, but has shown a strong increase in abundance over the last seven years, including a time series high in 2016 (Table 15, Figure 13). However, the SEDAR 67 panel raised concern that the continuity (MS Labs only) video index demonstrated an opposite trend compared to the combined video index in 2016 and 2017 (Figure 13). Exploration of the individual indices demonstrated that the FWRI and PC lab surveys were at time series highs in 2016 with a slight decrease in 2017 (albeit still at the second highest level across the time series). The MS lab survey values in those years were still above the time series average and demonstrated a strong increase from 2016 to 2017. Additionally, the two primarily inshore surveys (i.e., FWRI and PC) tend to survey smaller size classes, whereas the primarily offshore MS lab survey tends to survey larger size classes. Based on these data, the SEDAR 67 panel hypothesized that the inshore surveys were likely sampling a large 2015 yearclass in 2016, which was slightly delayed in moving into the MS lab’s offshore strata beginning in 2017. Other data sources (e.g., age composition and CPUE) also generally support the hypothesis of a strong 2015 yearclass.

For continuity purposes, the SEAMAP MS Labs video index was maintained for continuity runs in SEDAR 67. However, the SEDAR 67 panel determined that the combined video index with the length composition data standardized using the multinomial regression model was the preferred alternative for the SEDAR 67 base model. Combining indices across datasets likely increases predictive capabilities by allowing for the largest possible sample sizes in model fitting, whereas the multinomial regression adequately combines length composition across surveys to account for spatial and habitat differences in sampling. Additionally, the combined video index was deemed the best approach and was utilized in the recent assessments of red grouper (SEDAR 61) and gray triggerfish (SEDAR 62).

Length composition data for the combined video survey were tabulated in 5 cm bins and demonstrate that the survey primarily catches small, young fish similar to the SEAMAP groundfish survey, but that there has been an increase in smaller fish over the last few years (Figure 9).

2.4.4. *Other Surveys*

Two additional surveys were provided for consideration during the SEDAR 67 assessment: the FWRI vertical longline survey (SEDAR67-WP-04) and the FWRI repetitive timed drop survey (SEDAR67-WP-05). However, both surveys exhibit very short time series (2014-2017) and limited spatial coverage. Therefore, the SEDAR 67 panel did not suggest further exploration of their use in the SEDAR 67 assessment. However, if the time series length and spatial coverage are expanded, future explorations should be undertaken to incorporate them into future SEDAR assessment models.

3. Stock Assessment Model and Results

3.1. Stock Synthesis Model Configuration

For the purposes of the SEDAR 67 vermilion snapper assessment the Stock Synthesis 3 (SS3) software package was utilized (v3.30.14; Methot and Wetzel, 2013). Stock Synthesis is an integrated statistical catch-at-age (SCAA) model, which projects forward from initial conditions using age-structured population dynamics equations. SCAA models are comprised of three modeling modules: the population dynamics module, an observation module, and a likelihood function. Each of the modules is closely linked. Stock synthesis uses input biological parameters (e.g., growth, fecundity, and natural mortality) to propagate abundance and biomass forward from initial conditions (population dynamics model) and develops predicted data sets based on estimates of fishing mortality, selectivity, and catchability (the observation model). Finally, the observed and predicted data are compared (the likelihood module) to determine best-fit parameter estimates using a statistical maximum likelihood framework (see Methot and Wetzel, 2013 for a description of equations and complete modeling framework). The integrated approach to natural resource modeling aims to utilize available data in the least processed form possible in order to maintain consistency in error structure across data analysis and modeling assumptions, while more reliably propagating uncertainty estimates, especially in critical population parameters such as stock status and projected yield (Maunder and Punt, 2013).

Because of its extreme flexibility, there is not a single prototypical Stock Synthesis model. Depending on the life history and data availability of the modeled species, SS3 models can range from highly complex and data rich individual-based models to relatively simpler age-structured production models. The flexibility allows the user to input all data sources that are available, but can also lead to overparametrization if careful attention is not paid to model configuration and diagnostics. Although SS3 makes it relatively easy to implement highly complex models, models of moderate complexity are often best given the data limitations in most fisheries. Many of the modeling assumptions in Stock Synthesis have been thoroughly simulation tested. The framework is used for fisheries management of a wide variety of marine species worldwide, most notably for United States federally managed fish stocks in the northwest Pacific and Gulf of Mexico.

For vermilion snapper a model of moderate complexity was implemented. The model produces predicted catch and discard data for 3 modeled fleets (commercial east, commercial west, and recreational) along with associated age composition, 1 bycatch fleet (shrimp), 5 CPUE indices corresponding to the 3 primary fleets (commercial east before red snapper IFQ, commercial west before red snapper IFQ, MRFSS east, headboat east, and headboat west; note that all 3 recreational CPUE indices assume a single selectivity that mirrors the aggregated recreational fleet), 1 effort time series (shrimp effort), 1 index of spawning stock biomass (larval survey), and 2 fishery-independent surveys (combined video and SEAMAP groundfish) with corresponding length compositions (Figure 14 summarizes the input data used and corresponding temporal length). Estimated parameters include fishing mortality for each fleet for each year it was operating, selectivity parameters for each fleet (excluding shrimp bycatch parameters, which were fixed), the parameters describing the stock-recruit function, stock-recruit deviation parameters for years with age composition data, and a scaling parameter for the shrimp effort series. A variety of derived quantities are produced including full time series of recruitment, abundance, biomass, spawning stock biomass, and harvest rate. Projections are implemented within SS3 starting from the year succeeding the terminal year of the assessment model utilizing the same population dynamics equations and modeling assumptions (with some minor alterations in assumptions to account for forecasting recruitment). The final base model SS3 files are provided in Appendix A, which describe the model configuration (starter and control file, Section A.1), the input data sources (data file, Section A.2), and the projection settings (forecast file, Section A.3).

3.1.1. *Initial Conditions*

The model begins in 1950 when the resource is assumed to be at near virgin conditions and has a terminal year of 2017. Little documented catch of vermilion is available prior to 1963 (the start of the commercial fisheries landings time series) and so it was assumed that total removals were negligible before 1950.

3.1.2. *Temporal Structure*

Fish are modeled from age-0 through age-14 (the last age is a plus group). Despite SS3 calculating the number of fish at age-0, it assumes that recruitment to the fishery occurs at age-1 (i.e., there is no data or fishing mortality estimates for age-0 fish). The SEDAR 67 SS3 parametrization for vermilion snapper essentially results in an age-1+ model where the number of age-0 fish is a scalar multiple of the number of age-1 fish (based on the level of age-0 natural mortality). No seasonality was included in the model and fishing and spawning seasons were assumed to be continuous and homogenously distributed throughout the year.

3.1.3. *Spatial Structure*

A single area model was implemented where recruits are assumed to homogenously settle across the entire Gulf of Mexico. Although a two area model (eastern and western Gulf of Mexico) may be appropriate for this stock given differences in age structure and fishing behavior across the Gulf, lack of sufficient sampling in the western stock area precluded such a formulation (see Section 2.3.3.2 on recreational age composition data). The model implicitly accounts for spatial structure in the commercial fishery by modeling the eastern and western fleets separately and allowing each to have its own selectivity, while the recreational fishery is combined into a single aggregated gulf-wide fleet.

3.1.4. *Life History*

All life history parameters (e.g., growth, length-weight conversions, maturity, fecundity, and natural mortality) were estimated external to the model and input as fixed values. The Stock Synthesis 3 (SS3) framework is capable of estimating many of these parameters internally if given the appropriate data. However, the ability to estimate growth parameters has not been widely tested for SEFSC assessed stocks and little was known about potential overparametrization in regards to SS3 life history parameter estimation.

Stock Synthesis 3 uses these parameters to move fish among age classes and length bins on January 1st of each modeled year starting from birth at age-0. Because the ‘true’ birth date often does not occur until later in the year, some slight alterations in growth and natural mortality parameters are required to account for the approximately half year difference between true age and modeled age when parameters are input instead of estimated (e.g., age-0 natural mortality and t_0, age at zero size, must be prorated to account for ‘birth’ occurring six months later than modeled in SS3). In addition, the length-weight relationship is used to convert from size to biomass, and the maturity and fecundity parameters are used to assign a spawning output to each modeled fish.

Evaluation and estimation of life history parameters is detailed in Section 2.2, while equations and values are provided in Table 2. A von Bertalanffy model is used to describe growth where a constant variability in size-at-age is assumed (constant CV model), which requires two additional parameters representing the coefficient of variability (CV) in size at the minimum (age-1) and maximum (age-14) observed ages. The SS3 growth formulation requires five parameters: length at minimum age (L_{min} = 11.83 cm FL), length at maximum age (essentially L_∞; L_{max} = 34.4 cm FL), the von Bertalanffy growth parameter (k = 0.3254), the coefficient of variation at the minimum age (CV_{Amin} = 0.2535), and the coefficient of variation at the maximum age (CV_{Amax} = 0.2535; see SEDAR45-WP-1 for growth model estimates).

A fixed power function length-weight relationship was used to convert body length (cm) to body weight (kg; Table 2). Maturity was modeled as a length logistic function where length at 50% maturity was estimated to be near 14cm (SEDAR45-WP-2; Table 2, Figure 3). However, the assessment model is coded so that all age-0 fish, regardless of size, are not mature (i.e., do not add to the spawning stock biomass). Batch fecundity was also assumed to be a function of length and followed a power function assuming an estimated spawning frequency of 82 spawning events per year (SEDAR45-WP-2; Table 2, Figure 3).

The SEDAR 67 base model assumes that the natural mortality rate decreases as a function of age based on the Lorenzen (1996) function (Table 3, Figure 4). Age-0 natural mortality is discounted by a half year to account for the difference in true and SS3 modeled birth date.

3.1.5. *Stock-Recruit*

A Beverton-Holt stock-recruit function was used to parametrize the relationship between spawning output and resulting age-0 fish. However, recruitment to the fishery does not occur until age-1. The stock-recruit function (representing the arithmetic mean spawner-recruit levels) requires three parameters: 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); the virgin recruitment (R_0; estimated in log space) represents the asymptote or unfished recruitment levels; and the variance term (‘sigma_R’, σ_R) is the standard deviation 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). Although these parameters are often highly correlated, they can be simultaneously estimated in SS3. In SEDAR 45, the three stock-recruit parameters were directly estimated. However, exploratory runs with the updated data in SEDAR 67 indicated that this approach led to moderate model instability. Therefore, the SEDAR 67 panel decided to fix the recruitment variance term at 0.3. The value was chosen based on exploratory model runs with the variance term estimated along with likelihood profiles of the stock-recruit parameters (see Section 3.2.4). For forecasts, it was assumed that average recent recruitment would continue into the future instead of using the stock-recruit relationship directly. Given the uncertainty in stock-recruit parameter estimates along with the impact of fixing one of these parameters (considering the high correlation among them), it is unlikely the stock-recruit function provides an accurate representation of stock productivity dynamics.

Annual deviations from the stock-recruit function were estimated in SS3 as a vector of deviations forced to sum to zero and assuming a lognormal error structure. A lognormal bias adjustment factor is applied to recruitment estimates as recommended by Methot et al. (2019), but only to the data-rich years in the assessment. This is done so that SS will apply the full bias-correction only to those recruitment deviations that have enough data to inform the model about the full range of recruitment variability (Methot et al., 2019). The bias adjustment was phased in until the full adjustment was implemented in 1999. The full bias adjustment was then phased out again starting in 2014, because the age composition data contains little information on younger year classes for the most recent years. Prior to 1994, recruitment is estimated as a function of spawning stock biomass based on the stock-recruit parameters (i.e., there is no deviation in recruitment estimates from the stock-recruit curve).

3.1.6. *Fleet Structure and Surveys*

Three fishing fleets were modeled: commercial east, commercial west, and an aggregated gulf-wide recreational fleet. Fleet structure was ultimately dictated by the availability of age composition data and resulting sample sizes, while also accounting for spatial heterogeneity in fishing behavior and potential stock structure and availability. The commercial fishery had sufficient sampling coverage to separate age composition by eastern (shrimp grids 1-12) and western (shrimp grids 13-21) Gulf of Mexico (see Figure 1). Because of differences in age composition (the western fishery consistently caught older fish) and expert opinion regarding targeting behavior and potential availability, it was determined that the two fisheries should be modeled separately with unique selectivity functions. On the other hand, the various modes of the recreational fleet were not adequately sampled nor was the western region (SEDAR45-WP-8). Despite potential differences across modes and regions, the recreational sector was modeled as a single aggregated fleet due to the limited sample sizes. Recreational landings and age compositions were summed across modes and regions and a single selectivity curve and time series of fishing mortality were estimated. Fishing was assumed to be continuous and homogenous across the entire year.

In addition, a gulf-wide shrimp bycatch fleet was included in the model. Shrimp bycatch was assumed to be 100% dead discards with no landings (dummy parameters were included for shrimp fleet landings but the likelihood component was set to 0). Age composition data was not available for this fishery so selectivity was fixed based on assumptions agreed upon at SEDAR 9. The shrimp fishery was assumed to operate continuously across the entire year with no seasonality.

Three fishery-independent surveys were also modeled including: a larval survey that indexed spawning stock biomass (see Section 2.4.2), an eastern region reef fish combined video survey (see Section 2.4.3), and the eastern region SEAMAP summer groundfish survey (see Section 2.4.1). The larval survey acted as a scalar that was directly linked to model estimated spawning stock biomass and did not require an estimate of selectivity. Both the video and groundfish surveys included length composition information, which was fit directly in the model. Because SS3 includes the growth equations directly and models fish from birth, it actually grows fish by length bins before eventually converting to age (based on the growth curve). As such, it is possible to fit both age and length composition. Because no age information was available for the surveys, the length composition was fit directly based on estimated length-based selectivity functions.

3.1.7. *Selectivity and Retention*

Selectivity represents the probability of capture by age or length for a given fishery and subsumes a number of interrelated dynamics (e.g., gear type, targeting, and availability of fish due to spatial structure). For the SEDAR 67 vermilion snapper assessment, two types of selectivity functions were utilized: a two-parameter logistic function and the 6-parameter double normal (see Methot et al., 2019). The latter allows for domed selectivity and is a combination of two normal distributions; the first describes the ascending limb, while the second describes the descending limb, and the maximum selectivity of the two functions is joined by a line segment.

The double normal function is extremely flexible and can allow for domes or essentially logistic selectivity. However, due to the increased number of parameters, it can be more unstable than the simple logistic. Unless strong evidence exists for domed selectivity, it is generally advisable to use the logistic model.

Both of the commercial fleets assumed logistic selectivity as there was little evidence suggesting availability issues that might make older fish less vulnerable to fishing effort in either region. There was some evidence in the observed age composition data that the western fishery tended to catch older fish. However, this was likely due to higher fishing pressure in the eastern area and not severe selectivity differences between regions in the commercial fleets. In SEDAR 45, the commercial selectivity included two commercial time blocks to account for potential changes in fishery targeting due to the implementation of red snapper IFQs (and to reflect the two commercial CPUE time series model pre- and post-IFQ). However, SEDAR 67 dropped the post-IFQ CPUE index and exploratory runs indicated that there was little difference in the selectivity estimates before and after the implementation of IFQs (pre- and post-2007). Therefore, the SEDAR 67 base model did not incorporate time blocks of selectivity parameters.

On the other hand, the aggregated recreational fleet was likely to exhibit domed selectivity due to targeting and gear issues that could cause older fish to not be caught by the aggregated fishery. In addition, domed selectivity allowed more flexibility for the recreational fishery (a double normal approach was taken such that an essentially logistic curve could be estimated), which was warranted given the aggregation across modes and regions.

Each of the directed fisheries was also assumed to have regulatory discards based on selection (catch) of fish below the minimum size limit (i.e., all fish below this size were discarded). A knife-edge (vertical) retention function with fixed input parameters was included to account for changing minimum sizes across years and fleets. For the commercial fleets the implemented minimum sizes based on enacted management measures included: 8 inches from 1990 to 2004, 11 inches from 2005 – 2007, and 10 inches since 2008. For the recreational fleet the minimum size limits were 8 inches from 1990 to 1997, 10 inches from 1998 to 2004, 11 inches from 2005 to 2007, and 10 inches since 2008.

Given that no age or length composition data were available for shrimp bycatch, the selectivity curve had to be fixed. Based on analysis during SEDAR 9 using the few available observer data on vermilion bycatch in the shrimp fishery, it was determined that approximately 75% of the fish were age-1+ (25% were age-0 and not included in the model) and that a majority of these were age-1 and age-2. Based on these findings a fixed selectivity that assumed 100% vulnerability at age-1, 30% at age-2, 3% at age-3, and 0% at ages 4-14+ was determined to best represent the available data.

The larval survey did not require a selectivity as it indexed total spawning stock biomass, while the video and groundfish surveys assumed length-based domed selectivity. Given the observed length composition and the spatial coverage of each of the surveys, it was determined that there were likely to be both availability and vulnerability limitations such that the largest fish were unlikely to be represented in either survey. Assuming domed selectivity was deemed the most appropriate approach for the fishery-independent surveys.

3.1.8. *Landings and Age Composition*

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

3.1.9. *Discards and Bycatch*

As noted in section 3.1.7, directed fleet discards were modeled using a size-based retention function where all selected fish below the time-varying minimum size were discarded. An input discard mortality rate of 0.15 was then applied to the discarded fish to determine the level of dead discards from each fleet. Observed discards were not directly fit in the final base model (i.e., a data weighting factor of 0 was applied to observed discards) due to issues within the model in rectifying the low discard values with the levels of landings and observed age compositions (see discussion in section 3.2.9). Additionally, given the limited spatiotemporal coverage of discard sampling across fleets and the high percentage of discards that were below the minimum size, discard length compositions were not fit in the model. Instead, the retention function parameters were fixed and input into the model assuming all fish below the minimum size were discarded and fish above the minimum size were kept.

For shrimp bycatch, the 'super-year' approach was utilized to avoid fitting to the extremely noisy and uncertain yearly estimates of shrimp bycatch. The premise of a super-year is that, instead of fitting each observation directly, a measure of central tendency for the entire time series is fit. In the case of shrimp bycatch, the median has typically been utilized (i.e., the observed median is fit to the predicted median) and was implemented for the SEDAR 67 vermilion snapper assessment. The model still predicts annual bycatch values, but does not attempt to fit these to the annual observations. The super-year covers years 1972-2017 (i.e., the median values correspond to observed and predicted bycatch values for these years), which are the years that estimates of shrimp bycatch were available. The model estimates shrimp bycatch in years prior to 1972 with help from the shrimp effort series, but the predicted median covers only the period for which observations of shrimp bycatch are available.

3.1.10. *Shrimp Effort*

Shrimp effort was also incorporated into the model as an index of shrimp bycatch fishing mortality (the observed effort series helps inform annual estimates of shrimp fishing mortality and stabilizes annual estimates of shrimp bycatch). Essentially, a catchability parameter (q) is estimated to scale the effort series to the fishing mortality rates. Because annual estimates of shrimp bycatch are not fit directly, the super-year approach can create an unstable model if there is no information on annual variability (e.g., in fishing mortality or catch) for the fleet that contains the super-year. Essentially there is an infinite combination of annual values that could lead to the given median, which can create a flat likelihood response surface and cause model instability. Using the super-year approach while fitting to a time series of effort allows the model the flexibility to fit the median without being constrained to fit uncertain annual bycatch estimates, but constrains the model enough to maintain the bycatch estimates within feasible fishing mortality bounds and avoids overly strong year-to-year deviations.

3.1.11. *Catch-per-Unit Effort (CPUE) Indices*

Indices of CPUE were included for each fleet. CPUE was treated as an index of biomass or abundance (depending on whether the corresponding catch was in weight or numbers) where the observed standardized CPUE time series was assumed to reflect annual variation in population trajectories. The two commercial CPUE indices (east and west, 1993-2006) and the three recreational CPUE indices (MRFSS east, 1986-2017, headboat east, 1986-2017, and headboat west, 1986-2017) were modeled and fit in the SEDAR 67 assessment.

3.1.12. *Fishery-Independent Surveys*

Three fishery-independent surveys (larval, combined video, and SEAMAP groundfish) were included in the model. The larval survey was treated as a direct index of spawning stock biomass and was used to directly scale trends in SSB. The other two surveys were typical fishery-independent surveys of abundance and treated in a similar way as CPUE indices. The main difference being that each survey had its own unique selectivity and length composition and was independent of any fishery.

3.1.13. *Goodness of Fit and Assumed Error Structure*

A maximum likelihood approach was used to assess goodness of fit to each of the data sources. Each data set has an assumed error distribution and an associated likelihood component, 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. Ideally, the model would allow the data to 'self-weight' in order to determine the relative variance among data sets. However, it is seldom possible to freely estimate all the variance terms in addition to the set of model parameters, and variance terms must be input based on calculated variance from the observed data. The latter approach suffers from a lack of information regarding relative variance among different data sets. Ultimately, expert judgement usually must be used to input relative variance components, and this is the approach used in SS3.

The landings data, CPUE indices, surveys, and shrimp bycatch super-year all assume a lognormal error structure. The commercial landings are assumed to be the most representative and reliable data source in the model, especially over the most recent time period, because this information is collected in the form of a census, as opposed to being collected as part of a survey like most other input data. The recreational landings are assumed to be slightly less representative, because the charter/private component is collected using the Fishing Effort Survey (FES), albeit with a relatively large sample size. The CPUE and survey indices are assumed to be slightly noisier, mainly due to lower sample sizes and uncertainty in the relationship between CPUE and abundance trends. Although the annual estimates of shrimp bycatch are assumed to be extremely noisy, the median is expected to be fairly representative of the scale of discards of the shrimp fleet. The landings data were assumed to have a constant variance, while interannual variation in the CPUE and survey indices was estimated through the standardization techniques used to determine the final observed index values. For the indices, the coefficient of variation (CV; standard error divided by mean) was converted to a standard error (SE) in log space (required for input to SS3 for lognormal error structures) using;

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

The shrimp effort series was treated in a similar way to the other indices, but a normal error structure was assumed instead of lognormal. It was believed that the relative representativeness of the data was similar to that of the other indices. No estimates of interannual variation in effort were available so a time-invariant error structure was assumed.

The input standard error for the landings was set to 0.05 for the commercial fisheries and 0.15 for the recreational fishery. The super-year median bycatch was assumed to have a standard error of 0.10. Each of the indices was scaled to an average standard error of 0.2 across the entire time series, but the relative annual variation was maintained in the scaling. The shrimp effort series was also given an average standard error of 0.2.

The age and length composition data for the various fisheries and surveys were assumed to follow a multinomial error structure where the variance was determined by the input effective sample size (N_{eff}). For the multinomial, a smaller sample size represents higher variance and vice versa, because the number is meant to represent the number of fish sampled each year to determine the composition. Observed sample sizes are often overestimated for fisheries data, because samples are rarely truly random or independent (Hulson *et al.*, 2012). In addition, using higher effective sample sizes can lead to the composition data dominating the likelihood and reduce fit to other data sources. Iterative reweighting is often undertaken in order to adjust the effective sample size to better represent the residual variance between observed and predicted values (Methot and Wetzel, 2013). For the SEDAR 67 vermilion snapper model, observed sample sizes were used, but capped at 100 to prevent overfitting the compositional data. The iterative reweighting process described by MacAllister and Ianelli (1997) was then utilized to determine the effective sample sizes that most accurately reflected the data (i.e., the input effective sample size converged to the estimated effective sample size based on residual variance). However, a cap of 100 individuals was kept regardless of estimated effective sample size. The final effective sample sizes for each year are provided on the figures illustrating the age composition and length composition (given by N in each panel).

Directed fleets discard data was not directly fit in the model, despite the calculation and incorporation of discards in the base assessment models. Preliminary runs with lognormal error structure and low data weight (e.g., standard error of 0.3-0.75) indicated that fitting the discards directly led to poor fit to the landings and age composition data, as well as, unrealistic parameter values (e.g., for commercial selectivity). Given these findings along with the importance of accounting for mortality due to discarding of fish, the SEDAR 67 panel decided to incorporate discards through a fixed input retention function that accounted for regulatory discards below a minimum size but observed discard data was not fit directly (i.e., it was given no emphasis in the likelihood function).

A penalty on deviations from the stock-recruit curve was also included (essentially a Bayesian prior) in order to limit recruitment deviations from differing too greatly from the assumed relationship. The variance term was controlled by the fixed σ_R parameter.

Weak penalty functions were implemented to keep parameter estimates from hitting their bounds, which includes a symmetric-beta penalty on selectivity parameters (Methot et al., 2019). Parameter bounds were set to be relatively wide and were unlikely to truncate the search algorithm.

Uncertainty estimates for estimated and derived quantities were calculated based on the asymptotic standard error determined from the inversion of the Hessian matrix (i.e., the matrix of second derivatives is used to determine the level of curvature in the parameter phase space and calculate parameter correlation; Methot and Wetzel, 2013).

3.1.14. *Estimated Parameters*

A total of 322 parameters were estimated for the base model (Table 16). These include year specific fishing mortality for the three directed fleets and shrimp bycatch fleet, logistic selectivity parameters for each of the commercial fleets, six domed selectivity parameters for the recreational fleet and the two surveys, a catchability coefficient for the shrimp effort series, the parameters used to define the stock-recruit relationship, and the stock-recruit deviations for the data-rich time-period.

3.1.15. *Model Diagnostics*

3.1.15.1 Residual Analysis

A wide variety of model diagnostics were implemented and analyzed to determine model performance, stability, uncertainty, and fit to the data. The primary approach used to address model fit and performance was residual analysis of model fit to each of the data sets. Any temporal trends in model residuals (or trends with age or length for compositional data) can be indicative of model misspecification and poor performance. It is not expected that any model will perfectly fit any of the observed data sets, but, ideally, residuals will be randomly distributed and conform to the assumed error structure for that data source. Any extreme patterns of positive or negative residuals are indicative of poor model performance and potential unaccounted for process or observation error.

3.1.15.2 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 parametrizations can be highlighted. Because of the highly parametrized 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 parametrization. A correlation analysis was carried out for the SEDAR 67 vermilion snapper assessment and correlations with an absolute value greater than 0.9 were reported.

3.1.15.3 Profile Likelihood

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 where each individual data source wants the parameter estimate to be. The analysis is performed by holding the given parameter at a constant value and rerunning the model. This is done for a range of reasonable parameter values. Ideally, the graph of likelihood value against parameter value will give a well-defined minimum indicating that each data source is in agreement. When a given parameter is not well estimated, the profile plot will 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, as the model is unstable and generally unreliable.

A similar procedure can be utilized to assess parameter correlation where two parameters are fixed across a range of values and the model is rerun for each combination of the fixed parameters. A contour plot, where the z-axis provides the negative log-likelihood value, can then be examined to determine the relationship between the parameters.

Typically, profiling is carried out for a handful of problematic (and often correlated) parameters, particularly those defining the stock-recruit relationship. For the SEDAR 67 assessment model, profiles were carried out for steepness, virgin recruitment, stock-recruit variance, and a combination of steepness and stock-recruit variance. These runs were utilized to aid in determining the best value to fix the recruit variance term in the final base model to help improve model stability.

3.1.15.4 Bootstrap

Parametric bootstrap analysis is a convenient way to analyze model performance and variance estimation. With bootstrapping, the assumed error structure is used to create a new random set of observations using the same variance characteristics as the original data. Because the bootstrapped data strictly conforms to the error distribution and do not include any process error, the resulting fit to the data should be randomly distributed according to the assumed error distribution (i.e., there is no autocorrelation among data points, which is often an issue with observed data; Methot and Wetzel, 2013). Therefore, analysis of residual patterns in bootstrapped data can elucidate potentially detrimental modeling assumptions. Similarly, if parameter estimates differ between bootstrap runs and the base model fit to the observed data, it can be indicative of data conflict (similar to flat profile likelihood surfaces). 1000 bootstrap runs were carried out and summary statistics were generated to characterize model performance.

3.1.15.5 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 assured that a global minima has been obtained. Of course, 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 0.2 was applied to the starting values and 200 runs were completed.

3.1.15.6 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. Typically, 5-10 year retrospective analyses are completed. A five-year retrospective was carried out for SEDAR 67.

3.1.15.7 Jack-knife

Another type of data exclusion analysis is the jack-knife approach where individual data sets are removed and the model is rerun with the remaining data. The goal of this analysis is to determine if any single data set is having undue influence on the model and causing tension with other data in terms of estimating parameters. The approach can be especially useful for identifying indices that may be giving conflicting abundance trend signals compared to the other indices. If removing a data set leads to dramatically different results, it suggests that the data set should be reexamined to determine if the sampling procedures are consistent and appropriate (e.g., an index may only be sampling a sub-unit of the stock and resulting abundance signals may only reflect a local sub-population and not the trend in the entire stock). For SEDAR 67 each fishery-independent index was removed and the model rerun. Additionally, all of the fishery-dependent CPUE indices were removed simultaneously. Other data sets (i.e., landings and compositional data) were deemed fundamentally necessary to stabilize the assessment and were not included in the analysis.

3.1.15.8 Continuity Model and Model Building Runs

The first step in model development was to create a continuity model that attempted to replicate, in as feasible a way as possible, the previous vermilion snapper assessment undertaken during SEDAR 45. A strict continuity model was not feasible for SEDAR 67, because the recreational data underwent a complete overhaul in methodology and updated data through 2017 was not available using the same methodology as used during SEDAR 45. Therefore, continuity model building went through multiple stages in building a pseudo continuity model. This included updating the recreational landings data to the new FES estimates (through 2014 to demonstrate the impact of only the new recreational landings methodology on SEDAR 45 outputs), updating SS3 from version 3.24 to 3.3 (to incorporate the improved estimation methodology in newer SS versions), and updating all the data through 2017. Developing a continuity model is a useful tool for comparing model performance and addressing the impact of any further changes in model assumptions.

A comprehensive model building exercise was then implemented to incorporate new data sources and address any model stability issues. The major changes between the final continuity model (not including updated data) and the final base model (i.e., the model parametrization described throughout Section 3.1) were: the combined video index replaced the continuity (MS Labs) video index, the commercial CPUE time series was truncated in 2006 (as opposed to also including the post-IFQ indices), discards were incorporated through a knife-edge retention function but discard observations were not directly fit, a single time block for commercial selectivity was assumed (i.e., the post-IFQ time block was removed), and recruit variance was fixed at 0.3 (instead of freely estimated).

3.1.15.9 Sensitivity Runs

Several sensitivity runs were also implemented with the base model in order 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 here, but many additional exploratory runs were also implemented. Critical sensitivity runs involved different formulations of the video index (continuity vs. combined) and removing the video index, increasing discard mortality to 0.5, and removing the CPUE indices.

3.2. Model Results

3.2.1. Estimated Parameters and Derived Quantities

Tables 16-18 summarize the estimated parameters and derived quantities as well as the SS3 estimated standard deviations. Most parameter estimates and variance appear reasonable indicating relatively well-estimated parameters.

3.2.1.2 Fishing Mortality

Total harvest rate (total numbers killed divided by total exploitable numbers, age-1+) for the entire stock and fishing mortality by fleet (continuous rates) are provided in Figure 15 and Table 17. As the stock became exploited in the early 1960s and moved away from virgin conditions, the harvest rate remained at relatively low levels and slowly climbed into the 1980s when all three fisheries and the shrimp bycatch fleet became simultaneously active. Exploitation continued until the mid-1990s when harvest rate peaked around 25%. Since that time, exploitation rate has seen a relatively steady decline to a 2017 value (.08) that is equivalent to values in the early 1980s when the recreational fleet first became active. Much of the decline is attributed to a precipitous drop in shrimp bycatch fishing mortality, which was the dominant source of removals for the entire time series up until the mid-2000s (Figure 15). The directed fleets demonstrated a generally increasing trend in fishing mortality from 1980 to the late 2000s. Since 2010, the commercial fleet have demonstrated a declining trend. However, the recreational fleet has had a rapidly increasing mortality rate over the last seven years and is now the dominant source of mortality for vermilion snapper. Terminal year fishing mortality rates for the commercial east, commercial west, recreational, and shrimp bycatch fleets were 0.038, 0.043, 0.141, and 0.076, respectively.

3.2.1.3 Selectivity

The estimated selectivity functions for the directed fleets are provided in Figures 16 - 18. Both of the commercial fleet selectivity curves (Figures 16 and 17) reach full selection (around age-4 for the eastern fishery and age-7 for the western fishery) and exhibit relatively young ages at 50% selectivity (between ages 2 and 3 for the east and ages 3 and 4 for the west). The eastern fishery exhibited a stronger selection pattern for younger fish, whereas the western fishery demonstrated a more gradual incline with much lower selectivity from ages 2-4. These results are in agreement with the observed age compositions from the two fisheries given the increased proportion of younger fish in the eastern fishery (Figure 8).

The recreational fishery selectivity curve demonstrated a strong dome (Figure 18) with an ascending limb that closely resembled the eastern fishery. Full selection occurred at ages 3 - 5 and the descending limb declined rapidly, but not as steeply as the ascending limb. Selectivity of older fish was less than 20%. Given the observed age composition (Figure 8), the estimated selectivity curve is not surprising. The recreational fishery showed similar composition as the eastern commercial fishery with a large portion of the landings around ages 2-6, but almost no landings older than age-8, whereas the commercial east fishery exhibited some catch in the older age classes, especially in recent years. Because the recreational selectivity curve is aggregated across multiple modes and regions, it is difficult to assess whether it accurately reflects the probability of capture or availability of fish for any given real-world fleet.

Retention functions for the directed fleets are also provided in Figures 16 – 18 and simply reflect the minimum size limits for each fleet, given that the parameters were fixed to reflect full retention above the minimum size.

Because there were no age or length composition data available for the shrimp bycatch fleet, selectivity was fixed based on expert judgement from SEDAR 9. The selectivity curve assumes 100% vulnerability at age-1, 30% at age-2, 3% at age-3, and 0% at ages 4-14+ (Figure 19).

Both of the fishery-independent surveys assumed length-based domed selectivity (Figure 20). The video survey selected larger fish (length at 100% selectivity around 25cm) and did not have as strong a dome as the groundfish survey. The descending limb for the video survey selectivity curve leveled out around 75% for the largest size classes. The SEAMAP groundfish survey had high selection for small fish and a rapidly ascending limb at relatively small sizes (50% selectivity between 10 and 15cm and 100% selectivity between 15 and 20cm) with a very strong dome and steep descending limb and 0% selectivity for size bins over 30cm. These results are not surprising given the groundfish survey catches almost exclusively fish between 5 and 20cm, while the video survey has a more protracted, but still limited, size range.

3.2.1.4 Recruitment

With the recruit variance term fixed at 0.3, the steepness was estimated to be 0.712 and virgin recruitment was estimated at 27,365,700 fish. The estimate of steepness for vermilion snapper appears to be relatively low given its highly productive nature (i.e., it grows quickly, matures rapidly, and is relatively fecund). However, because the species has never been heavily exploited, no information exists at the lower end of the stock-recruit curve (i.e., at low spawning stock biomass; see Figure 21). Therefore, no information exists to estimate the ascending limb, and so the steepness estimate essentially becomes an interpolation. In addition, many of the estimated recruitments (i.e., during the data-rich period of the assessment) are essentially a scatter plot with no well-defined underlying curve (Figure 21). A small degree of autocorrelation can be seen in recruitment deviations (Figure 21) over 3-5 year spans, but fluctuations do not have any strong trends with approximately equivalent positive and negative deviations across the time series. Recruitment was forced to follow the stock-recruit curve for the historical time period and slowly decreased from virgin conditions as the stock became exploited (Figures 21 and 22; Table 18). Since the mid-1990s (when recruitment deviations were estimated), recruitment has fluctuated between 15 and 52 million fish with no consistent trend (Figure 22). Recruitments since 2010 have been generally above the average level with an exceptionally strong yearclass estimated in 2015 (~52 million fish) followed by the second highest recruitment class in the time series in 2016 (~35 million fish). The terminal year recruitment was estimated to be slightly below average (~21 million fish).

3.2.1.5 Biomass and Abundance Trajectories

Spawning stock biomass (number of eggs), abundance (number of fish), and total biomass (metric tons) have followed similar trends over the entire time series (Figures 21 - 23; Table 18). Steady declines occurred as the stock moved away from virgin conditions and was lightly exploited by the commercial fisheries up until the early 1980s, but simultaneously experienced comparatively high shrimp bycatch mortality. In the early 1980s, the recreational fleet began to exploit the resource and commercial mortality concomitantly increased causing a rapid decline in biomass until the late 1990s. Time series lows were reached in the late 1990s corresponding to the maximum shrimp bycatch mortality rates. With the reduction in shrimp effort and bycatch mortality in the late 1990s and early 2000s, the stock rebounded slightly. Despite the decline in shrimp mortality being partially replaced by higher directed fishing mortality, the stock has seen a gradually increasing trend over the last two decades. Since 2014, the population has increased dramatically and the terminal biomass (18,868mt) is estimated to be at its highest point since the late 1980s and the same is true for terminal SSB (3.53E+14 eggs). Total abundance has shown similar trends as biomass and SSB, but is slightly more volatile because of its sensitivity to recruitment values (Figure 23; Table 18). Depletion levels (SSB/SSB_0) reached a low point of 26% in 1999 and 2000 and fluctuated around 30% for all of the 2000s. In the last few years, depletion has decreased dramatically and in 2017 was estimated to be at 52%, the highest level since 1988. Average age in the stock at virgin conditions was between 3 and 4 years of age.

Average age is now around age-2, but age structure appears to be rebuilding quickly due to recent strong recruitment events (Figure 23).

3.2.2. *Model Fit and Residual Analysis*

3.2.2.1 Landings and Discards

Due to the comparatively small standard error assumed for the commercial and, to a lesser extent, recreational landings, all three of these data sources were fit quite well (Figure 24; Table 4). The commercial landings were fit almost exactly except for a time series high data point in the commercial east fishery. On the other hand, the recreational landings were slightly underestimated for a few points in the early 2000s, with later overestimation for a handful of years in the mid-2010s. Overall, no strong residual patterns were noticeable and fits to the landings data were good. The negative log-likelihood values for the east commercial, west commercial, and recreational fleet were 0.366, 0.145, and 3.22, respectively.

Commercial discards were low until the implementation of the 11-inch minimum size in 2005 and have been generally decreasing since that time (Figure 24; Table 7). On the other hand, recreational discards have been steadily increasing since the early 2000s, including a peak following the 11-inch minimum size limit implementation in 2005, and reached a time series high in the terminal year (Figure 24; Table 8). The increasing trend in the recreational discards mirrors the rapidly increasing landings and effort from this fleet over the last decade. Because the observed discards are not fit in the model, the predicted values tend to be much higher than the observations (Figure 24).

3.2.2.2 Shrimp Bycatch

Because of the small standard error assumed for shrimp bycatch, the fit to the super-year median was good (Figure 25; Table 9). As expected, the predicted annual estimates of bycatch did not vary as strongly as the observed values nor were they similar in magnitude. However, both showed a strong decline over the last seven years, which is a function of the sharp decline in shrimp effort (Table 9). The negative log-likelihood value for shrimp bycatch was -1.724.

3.2.2.3 Shrimp Effort

Model fit to the shrimp effort series is good, even though it was given a relatively high standard error matching the other surveys (Figure 26; Table 12). In most years, the observed and predicted values are nearly identical except for some underestimation in the late 1980s followed by overestimation in the early 1990s. The largest discrepancies occur in the mid-1990s when the model overestimates shrimp effort. The negative log-likelihood component for the shrimp effort series is -101.61.

3.2.3.4 CPUE Indices

Observed and predicted CPUE are provided in Figures 27 - 29 and Tables 13 - 14. The model fits the eastern and western commercial CPUE moderately well (Figure 27; likelihood component of

-9.92 and -8.97, respectively). Both observed indices indicate a declining trend from the early 1990s until 2000 followed by a slight increase. The eastern stock shows a continued increase until the terminal year (2006), but the western stock declines rapidly in 2005 and 2006. The model is able to mimic the declines in the first part of the time series, but is forced to balance the decline seen in the western stock with the increase in the eastern stock resulting in generally flat trends for both predicted indices (Figure 27; Table 13). The eastern index shows strong negative residual patterns in the early era followed by positive residuals in the recent era. The western index has a slightly more balanced residual pattern.

The observed MRFSS east CPUE (linked to the recreational fleet) varies widely prior to 1995, but with a generally downward trend. The index then levels out with a mostly flat or slightly increasing trend from 1996-2014. The model estimates the downward trend in the first part of the time series, but does not fit the annual values well (Figure 28; Table 14). It does a better job of fitting the slight increasing trend over the last two decades. Some strong positive residual patterns exist in the early part of the time series followed by negative residuals for the middle part of the time series. The likelihood component for the MRFSS east CPUE index is 6.41.

The observed headboat east index exhibits a downward trend early in the time series followed by a slightly upward trend over the last two decades. The model predicts the downward trend until 1997 followed by a stronger upward trend over the next two decades (Figure 29; Table 14). Some strong residual patterns result with positive residuals in the early part of the time series and negative residual in the middle section. The likelihood component for the headboat east CPUE index is 30.80.

The headboat west observed index does not fluctuate as heavily in the early part of the time series as the other recreational indices, but varies much more than those indices over the last two decades with no strong discernible trend. The model more or less splits the annual observations as they fluctuate from year-to-year leading to a lack of residual trends, but only moderate fit to the overall data set (likelihood component of -5.74).

Overall, the model is only moderately able to fit the CPUE indices. However, all indices give a generally similar trend of declining CPUE in the early 1980s and 1990s before stabilizing in the mid-1990s and fluctuating with generally upward trends for much of the remainder of the time series. The model predicted indices are able to match this trend, but do not fit the annual data points well. These results are not surprising given the noisy nature of CPUE data sets, especially in the Gulf of Mexico fisheries. The residual trends are not ideal, but not overly problematic and likely a factor of the high interannual noise in most of the indices.

3.2.3.5 Fishery-Independent Surveys

Observed and predicted fishery-independent survey values are provided in Figure 30 and Table 15. The observed video survey was highly variable with no discernible trend until the strong increases in the last three years. The model predictions were flat across the time series with a slight increase in the last few years. No strong residual patterns were present (Figure 3). The likelihood component was 95.90.

The groundfish survey had a short time series (8 years) and was generally flat over this time with one peak in 2011. The model predicted index had a generally increasing trend that reflected the predicted video index (Figure 30), which led to strong positive residuals prior to 2013 and negative residuals thereafter. The likelihood component was 3.29.

The larval index showed large fluctuations with a possible upward trend from the early half of the time series to the mid-2000s, and a decreasing trend since that time. The model did not fit this data set well, demonstrating a similar pattern as for the various CPUE indices with strong declines early in the series and gradual increases out over the latter half (Figure 30; Table 15). Residual patterns are evident with negative residuals early in the time series and positive residuals over the last decade. The likelihood component was 11.24.

The lack of fit to the indices is not surprising given the strong fluctuations in the observed data and the lack of consistent or extended temporal coverage. The general pattern across abundance indices has been a declining stock early in the time series followed a generally flat trend during the late 1990s and early 2000s with gradual increases over the last few years. The model predictions cause some residual patterning, but the trends generally agree with the surveys.

3.2.3.6 Age Composition Data

Model fits to the derived age composition data along with Pearson residuals are provided in Figures 31-35. Following the iterative reweighting of the effective sample size, model fits were good for all three fleets and input sample size was nearly identical to the calculated effective sample size (provided on each panel of the figures) except when sample size was capped at 100 and the estimated effective sample size was much higher. There were a few years in the early part of the time series when sample sizes were extremely low leading to poor model fit (e.g., the early and mid-1990s).

The eastern commercial age compositions demonstrated strong model fits (Figure 31). There was a slight tendency to overestimate the catch of old fish, while underestimating young fish. However, the residual trends are minimal with no strong temporal patterns (Figure 34).

The western commercial age compositions were not fit as well as the eastern commercial, but this is likely due to lower sample sizes throughout much of the time series (Figure 32). A strong age trend does appear over from 2012-2014 with the model predicting more young fish and fewer old fish than observed (Figure 34).

The fit to the age compositions for the recreational fleet vary with relatively poor fit in the early period when sample sizes are low, while fit has improved dramatically over the last decade as sampling has improved (Figure 33). Residuals seem to be well distributed with only slight patterning due to limited overestimation of older fish over the last decade (Figure 34).

The aggregated age compositions are extremely good for all three fleets (Figure 35).

3.2.3.7 Length Compositions

Model fits to the length composition data are provided in Figures 36 - 38. Following the iterative reweighting of the effective sample size, model fits were acceptable for both surveys and input sample sizes were close to the calculated effective sample size (provided on each panel of the figures). Although the fits to the length composition were generally good, they were relatively worse than fits to the age composition data. There are likely two factors at work: sample sizes were generally smaller than for the age samples, and the fast growth of vermilion snapper made it difficult to fit certain length bins given the yearly time step in the model (i.e., each age is assumed to have a given length so length bins that fall in between ages were impossible to fit). There was a tendency in the model to underestimate the number of fish in the 20-30cm length bins for the video survey (Figure 36). The SEAMAP groundfish survey tended to overestimate the 10cm length bin (Figure 37). The aggregate fit to the length composition data were relatively good and no strong residual patterning was evident (Figure 38).

3.2.3. *Correlation Analysis*

Based on model estimated correlation factors, only the double normal selectivity parameters for the fishery-independent surveys demonstrated issues with high correlation (Table 19). This is not surprising, because the parameters of selectivity functions are inherently correlated (i.e., as the value of one parameter changes the other value will compensate). Typically, priors are used to inform selectivity parameter estimates and stabilize the model. However, priors were not used here, but given the relative stability of the model (see diagnostics sections below), it was not deemed necessary to put priors on the double normal parameters and the correlation was not problematic.

3.2.4. *Profile Likelihoods*

Profile likelihoods were done for each of the stock-recruit parameters and a contour likelihood was developed for the combination of steepness and recruitment variance. Virgin recruitment appeared to be well estimated with most data sources agreeing on a value between 10.0 and 10.3 (in log space; Figure 39), while the final model estimated value was 10.22. The response surfaces for σ_R (recruitment variance) were relatively flat between 0.3 and 0.6 (when the recruitment penalty term is ignored as this is inversely related to the square of the recruit variance value), indicating that this parameter was poorly estimated (Figure 39). The variance term in the base model was fixed to increase model stability and a value of 0.3 was chosen, as this was the estimated value from the model with the lowest likelihood (when all stock-recruit parameters were freely estimated). The steepness profiles indicated that the model favored values above 0.6, but there was not a strong trough, which indicated that steepness was not well estimated and values between 0.6 and 0.99 were more or less equally likely (Figure 39). The model-estimated value for steepness was 0.71. Across the range of parameter values tested in the various profile likelihood runs, the model tended to converge towards similar terminal year spawning stock biomass estimates (Figure 40). The model was particularly robust to changes in the recruit variance term. The fact that all models tended to converge rather than diverge indicates that the model is relatively robust to stock-recruit parameter estimates, and stock size and mortality estimates are not strongly impacted by changes in recruit parameters.

The two-parameter profile likelihood further elucidated the findings in the single parameter profiles. A contour plot of σ_R against steepness demonstrated the clear relationship between the two parameters (Figure 41). The contours are fairly steep on three sides, but quite shallow tailing off towards high steepness and moderate σ_R combinations. Although the final model estimates of σ_R (0.3; eventually fixed at this value in the base model) and steepness (0.71) provide the smallest negative log-likelihood value, a number of alternate pairings give approximately similar negative log-likelihood values. Steepness values ranging from 0.6 to 0.9 and the associated σ_R pairings from 0.2 to 0.6 are almost equally probably given the data. Based on these findings and an exploratory run where the recruit variance term was freely estimated with a resultant value of 0.3, the SEDAR 67 panel determined that fixing recruit variance at 0.3 was appropriate to improve model stability. Although a range of values were equally plausible, the likelihood profiles indicate that alternate values would be unlikely to alter the assessment results to any great degree.

3.2.5. *Bootstrap Analysis*

Results of the 1000 bootstraps indicate that the model performed well and was relatively stable, because parameter estimates converged towards the same solutions as the base model fit to the observed data (Figure 42). Additionally, all of the derived quantities are closely distributed around the base model estimates. Although some slight spread exists, this is to be expected when fitting the model to 1000 randomly selected data sets.

3.2.6. *Retrospective Analysis*

Results of the retrospective illustrate a strong level of consistency within the model. As data are peeled off, the model estimates of spawning stock biomass in each successive terminal year do not change by a large margin and show no pathological trend of over or underestimation (Figure 43). However, the longer peels (beyond one year) indicate that the model may have a slight tendency to overestimate SSB. Recruitment estimates are slightly more variable with some peels demonstrating overestimation and others underestimation. However, the magnitude of differences compared to the base model with the full data time series is minimal and there is no constant trend that might indicate model issues.

3.2.7. *Jitter Analysis*

Despite a relatively large jitter value (0.2) that was randomly added to each of the starting parameter values, the model was able to converge to within 10 likelihood units of the base model in 70% of runs and no runs demonstrated a lower negative log-likelihood solution (Figure 44). In the few instances that the base solution was not reached, the length or age composition data were often disproportionately dominating the total negative log-likelihood. Most likely this was due to difficulties estimating the selectivity parameters for one or all of the fleets with domed selectivity, especially considering the high level of correlation among selectivity parameters. Given that the total negative log-likelihood values were much higher for these runs, it is probably that non-optimal solutions were found (i.e., the model search was stuck in local minima). If priors had been placed on a handful of parameters as is often done with double normal selectivity curves, it is probable that a higher percentage of jitter runs would have converged back to the base solution. However, given the consistency in parameter estimates (e.g., steepness) and the relatively few runs that performed poorly, the jitter analysis indicates that the model is fairly stable.

3.2.8. *Index Jack-knife Analysis*

Figure 45 illustrates the results of a jack-knife analysis that ran the model with one index removed at a time. The video index has a strong influence on both SSB and recruitment where both are estimated to be much lower in the terminal three years when it is removed. Removing the CPUE data does not greatly influence the time series estimates, but it does reduce virgin values (R_0 and SSB_0), which results in a lower level of depletion in recent years. Removing the SEAMAP and larval indices had limited impact on model results.

3.2.9. *Continuity Model and Model Building Runs*

As noted, a strict continuity model was not feasible due to the FES adjustments to the recreational catch and the methodology used to estimate recreational catch in 2014 no longer being supported (i.e., to estimate recreational catch through 2017 using the old methodology). Therefore, the SEDAR 45 base model was rerun with the FES adjusted catch through 2014, which was used as the basis of comparison for running the SEDAR 45 model with updated data through 2014. Additionally, the SEDAR 45 model was transitioned into the SS3.3 framework to utilize the improved estimation methodology and other improvements in the program. Updating the SS version had no impact on the model (Figure 46). However, updating the recreational data led to higher estimates of SSB and recruitment along with reduced estimates of depletion (Figure 46). The latter is not surprising given the large increase in landings calculated using the FES adjustments. Given these increased landings streams and holding all other data sources constant, the model essentially estimates that the stock is more productive and must be at a higher biomass (compared to estimates from SEDAR 45), especially in the recent time period when recreational catch has increased dramatically (see Figure 6). When all of these changes are combined with the updated data through 2017 (which includes a steadily increasing video index over the last 5 years; see Figure 13) in the continuity model, the result is a rescaling of the assessment with much higher productivity (SSB_0 and R_0) estimates (Figure 46). Additionally, a time series high recruitment estimate is estimated in 2015, which helps to rapidly increase SSB. Ultimately, the trends of the continuity model closely match those of the SEDAR 45 base model, particularly in levels of depletion. However, the continuity model has been slightly better off over the last decade than previous predicted during SEDAR 45 and has been rapidly increasing since 2014.

A number of changes were made during the model building exercise from the continuity model to the final SEDAR 67 base model. The largest changes implemented were incorporation of the combined video index (instead of using just the MS labs video index) and the modeling of discards. Utilizing the combined video index had the largest impact, because it led to an even larger estimate of the size of the 2015 yearclass along with increased estimates of other recruitment events over the last two decades (Figure 47). These increases in recruitment have similarly increased the SSB since 2000 and led to dramatic increases in 2016 and 2017 when the 2015 yearclass began to mature. Although there is some discrepancy in the size of the 2015 yearclass depending on which version of the video index is used, it is clear that a large recruitment event occurred based on the video index along with associated length composition data and age composition data from the fisheries. It may also partially explain recent dramatic increases in recreational landings of vermilion snapper. Based on the generally improved methodology of the combined index, which incorporates sampling coverage from across the eastern Gulf of Mexico (instead of only offshore sampling from the MS labs only index), the SEDAR 67 panel determined that the combined index should be utilized in the final SEDAR 67 base model. However, there remains uncertainty as to the strength of the 2015 yearclass and resulting increases in terminal year SSB, particularly until the yearclass has fully entered the directed fisheries and the cohort can be clearly discerned as it moves through the age compositions.

Incorporating discards into the model proved difficult due to the extremely low discard observations compared to the extent of observed landings (see Figure 7). When the discard data was fit directly in the assessment model, it caused the landings data and age composition data to be poorly fit (Table 20). Additionally, it led to unreasonable parameter estimates, particularly of the commercial selectivity (i.e., very low selectivity with full selection delayed until age-10 or later). The main issue was that the model could not rectify the moderate level of fishing effort and landings against the very low level of discard mortality, while also accounting for the young age of full selection in many fisheries (e.g., around age 3, see Figures 16 – 18) and the large recruitment events of young, small fish observed in the survey data. Given that the model assumed all discards were regulatory discards of small fish below the minimum size (which matched observations of discard length composition data), adequately fitting the low discard observations would require that selectivity of small fish and fishing mortality were very low and/or that there was essentially a complete recruitment failure in the fishery for the entire time series of discard observations. Conversely, regulatory discards could be modeled, but the discard observations could be ignored (i.e., not fit directly in the objective function). Given the uncertainties in the discard data discussed in section 2.3.2, the SEDAR 67 panel determined that it was important to account for removals due to dead discards, but that fitting the discard observations was not feasible using the current observations and model structure. Therefore, regulatory discards were included by using a retention function that assumed all fish above the minimum size were retained and all those below were discarded. The discard observations were then ignored and not directly fit in the model. The result of this approach to modeling discards was reduction in estimates of recent increases in biomass from both the continuity and combined video index (Figure 47). It appears that the increased mortality of young, small fish due to regulatory discards essentially tampers the positive impact of the strong recruitment events observed in the video indices, albeit only slightly especially when considering estimated depletion levels (Figure 47). Other changes that were incorporated into the base model included removing the second time block on commercial selectivity (associated with the implementation of red snapper IFQ in 2007) and fixing the recruit variance term at 0.3 (based on the results of the stock-recruit parameter likelihood profiles). Both of these decisions were made to improve model stability and reduce the number of parameters, while also considering the impacts on the assessment results. Given the improved model performance and lack of discernible impact on assessment estimates (Figure 47), the SEDAR 67 panel determined that these modifications should be incorporated into the base model.

3.2.10. *Sensitivity Model Runs*

The results of four alternate base model configurations are presented in Figure 48 including: replacing the combined video index with the continuity video index, dropping the video index completely, dropping all of the CPUE indices, and increasing the discard mortality to 0.5. The results of the continuity video index and dropping the video index are similar with much lower

SSB and recruitment estimates in the last 3-5 years. These results suggest that the combined video index has a strong influence on recent recruitment estimates, which is not surprising given that it samples small, young fish in inshore areas where juvenile vermilion snapper are often more prevalent. Given the increased spatiotemporal coverage attained by using the combined video index and the improved methods for combining length composition data across the video surveys using the multinomial regression approach, the SEDAR 67 panel determined that the combined video index represented the best available approach to incorporating abundance estimates from the various available video surveys. The sensitivity run with increased discard mortality resulted in slightly increased estimates of SSB and lower depletion levels compared to the base model (Figure 48). However, differences between this model and the base model were relatively minor. The SEDAR 67 panel decided to maintain the current discard mortality rate of 0.15, but noted it was likely too low and suggested that future vermilion snapper assessments should consider increasing the discard mortality rate, especially if further data on discard mortality can be collected from the recreational fisheries. Dropping the CPUE indices led to lower estimates of virgin SSB and recruitment, but higher terminal year SSB and lower depletion compared to the base model. Further work is needed to determine whether enough fishery-independent data exists to allow dropping the CPUE indices from future vermilion stock assessments. These results indicate that the CPUE data has limited influence on the model outcomes. Given the difficulties in standardizing catch rates when complex spatiotemporal management actions are enacted, the ability to remove CPUE from future assessments might be an important advancement to eliminate these potentially unreliable data sources.

3.3. Discussion

The SEDAR 67 base model estimates that biomass was decreasing until the mid-1990s, but, largely due to a precipitous decline in shrimp bycatch mortality from the late 1990s to the late 2000s, biomass stabilized and demonstrated a slight upwards trend throughout the 2000s. Since SEDAR 45, the biomass has increased drastically, primarily due to an unprecedented 2015 recruitment event. Additionally, harvest rates have been at relatively low levels over the recent time period matching those from the late 1970s and early 1980s when the directed fisheries were just beginning to develop. This combination of well above average recent recruitment and low fishing mortality have helped to recover the age structure of the stock. Overall, the stock is estimated to be in excellent condition and has been steadily growing with a terminal year (2017) depletion level of around 50% (i.e., SSB/SSB_0 = 0.50). The stock is not overfished and overfishing is not occurring.

A number of changes to the data inputs and stock synthesis model configuration have occurred since the last assessment in 2016 (SEDAR 45). The primary impacts include incorporation of FES adjusted recreational landings, the inclusion of a combined video index, and the modeling of regulatory discards from the directed fisheries. The FES adjusted landings led to increased estimates of productivity of the stock due to much higher estimated landings. Updating all of the data through 2017 led to dramatic increases in biomass since the SEDAR 45 assessment terminal year (2014) due to large increases in the video index of abundance, continually increasing recreational landings, and increasing catch of young fish in the commercial and recreational age composition data over the recent (2014-2017) time period. Incorporating the combined video index (as opposed to using just the MS labs index as was done in SEDAR 45) further increased estimates of recent yearclass strength and led to improved estimates of stock status. However, these effects were dampened by incorporating regulatory discards (i.e., accounting for minimum size limits) in the model, because discards simultaneously increased the mortality rate on the newly recruiting young fish. Although these changes have added some uncertainty into the model (i.e., the actual size of the 2015 yearclass and the reliability of predicted discard estimates since the low observed discard levels were not fit in the assessment), the SEDAR 67 panel determined using the combined video index and accounting for regulatory discards represented the best assessment configuration for vermilion snapper at this time. Other minor changes that occurred and had limited impact on the assessment results included switching from SSv3.24 to SSv3.3, truncating the commercial CPUE indices in 2006 to avoid standardization issues caused by implantation of red snapper IFQ, removing a selectivity time block for the commercial fleets that corresponded to the red snapper IFQ period, and fixing the recruit variance term at 0.3 (the latter two changes were primarily to improve model stability and reduce the number of estimated parameters).

Despite the plethora of data and modeling changes that have occurred since SEDAR 45, the SEDAR 67 model maintains relatively strong consistency in management advice (Figure 49). In terms of estimates of depletion levels, both models match up precisely until the mid-2000s at which point the SEDAR 67 model slowly becomes more optimistic. These differences are likely due to a combination of the increased FES recreational catch utilized in SEDAR 67 and the use of the combined video index, which caused an increase in recruitment estimates over the recent time period (while also driving the rapid growth predicted over the last three years). Although many uncertainties exist in the SEDAR 67 modeling framework, it is believed that changes made since SEDAR 45 have led to a more reliable assessment of vermilion snapper in the Gulf of Mexico.

Overall, the SEDAR 67 model generally fit most of the data sources well with limited residual patterns. There was some strong parameter correlation, particularly in domed selectivity parameters, but these did not appear to be the source of any major model stability issues. Bootstrap and jitter analyses did not indicate instability as most runs converged to the same solution space. No retrospective trends were present indicating internal consistency within the model. This is not to say it is the best possible model or the most accurate, but, given the available data and the results of a suite of diagnostic analyses, no pathological faults have been identified. Likelihood profiles indicated that steepness and σ_R were highly correlated with paired parameter values ranging from 0.6 to 0.9 and 0.2-0.6 for steepness and σ_R, respectively, resulting in similar negative log-likelihood values. The final steepness value (0.71) is not likely an accurate representation of the productivity of vermilion snapper considering its fast growth, early maturation, and high fecundity. Therefore, recent recruitment estimates were used for projection purposes instead of relying on the stock-recruit curve. The basic sentiment was that the model estimates of total recruitment were reasonable, despite the stock-recruit curve not necessarily being plausible.

Future work is needed to further improve calculation of observed discards (especially accounting for any use of vermilion snapper as bait), while also exploring alternate approaches to modeling discards. Similarly, consideration should be given to redefining fleet and spatial structure to better account for sample size limitations and varying age- and fleet-based dynamics across the

Gulf of Mexico. Considering the fast growing, early maturing nature of vermilion snapper along with limitations in obtaining representative age samples across all fishing sectors and areas, it may also be worthwhile converting to a length-based assessment model. Similarly, reassessing the approach used for modeling shrimp bycatch may be warranted given the large impact that the bycatch fleet has on model outcomes and recent mismatches in observed bycatch and effort compared to model predicted levels of bycatch (i.e., bycatch estimates appear to be much higher than observed due to the way the super-year approach is implemented).

4. Projections

4.1. Introduction

The SEDAR 67 terms of reference (TORs) requested stock projections to establish biological reference points and determine stock status. Projections were to be completed by forecasting F_{MSY} using the base assessment model configuration. However, it was not possible to calculate MSY and its associated reference points (F_{MSY} and B_{MSY}) since the spawner-recruit relationship was deemed unreliable for Gulf of Mexico vermilion snapper; therefore, a proxy for F_{MSY} was required. During SEDAR 45, $F_{SPR\ 30\%}$ (i.e., the fishing mortality rate that results in a spawning potential ratio of 30% in equilibrium) and the associated $SSB_{SPR30\%}$ were selected by the Gulf Council, science and statistical committee as the most appropriate proxies for the MSY based reference points. The SPR 30% based proxies were subsequently codified for use in vermilion snapper assessments in amendment 47 to the Gulf of Mexico Reef Fish Fisheries Management Plan. Therefore, projections were carried out to determine the SPR based reference points, establish stock status and forecast near-term catch limits.

Towards meeting the SEDAR 67 TORs, annual overfishing limits (OFLs; retained yield streams that achieve $SSB_{SPR30\%}$ in equilibrium) were calculated. Also, two additional acceptable biological catch (ABC) yield streams were produced: 1) one utilizing the P* approach commonly implemented in Gulf of Mexico assessments and 2) one projecting at F_{OY} (F = 75% of Directed Fishing Mortality at $F_{SPR\ 30\%}$). Both the P* and OY projections have been used to establish ABC for vermilion snapper in past assessments and were considered for SEDAR 67.

It is worth mentioning that transitioning from recreational landings estimated using the costal household telephone survey to landings estimated using the fishing effort survey (FES) was expected to increase catch limit recommendations relative to past assessments. Understanding the magnitude of the increase due to the landings data transition would help establish a baseline from which to evaluate any changes in catch limits due to changes in biomass, recruitment or productivity. Analyses aimed at quantifying the magnitude of the catch limit increase were not requested in the TORs, but were included to aid in interpreting the catch advice and are provided herein.

4.2. Projection methods

The simulated dynamics used for projections assumed nearly identical parameter values and population dynamics as the SS base model (Table 21 provides a summary of projection settings).

One exception was that the stock-recruit function was replaced with the mean recruitment from 2005-2014 (~22 million fish). These years were chosen because they represent typical recruitment levels from years with the most reliable estimates of year class strength. For all years of the projections, it was assumed that recent fishery dynamics would continue indefinitely. The selectivity and retention for each fleet was taken from the terminal year of the assessment and relative harvest rates for the directed fisheries (excluding shrimp bycatch) were assumed to stay in proportion to the terminal three year average (2015 – 2017) values. Because the shrimp fishery is managed independently of the directed fisheries for vermilion snapper, it was assumed that the fishing mortality for the shrimp bycatch fishery would be constant throughout all years of the projections based on the terminal three year average (2015 – 2017; fishing mortality = 0.075).

Due to the lag in reporting and verification of fishery statistics, finalized landings statistics were only available through 2017 at the onset of the assessment cycle. For the purpose of projections, updated landings data and a terminal year averaging approach were used to bridge the gap between the terminal assessment year (2017) and the first year of management advice (2021). The final 2018 landings were available by the time projections were undertaken and were therefore included in the time series of landings. Landings for 2019 and 2020 were estimated using the average landings from 2016-2018 (4,366,021 lbs.).

$F_{SPR30\%}$ was determined using long-term 100 year projections assuming that equilibrium was obtained over the last 10 years (2108-2117). For SPR-based analysis, the harvest rate (number killed / abundance) that led to SPR 30% (SSB_{EQUIL} / SSB_0 = 0.3) was obtained by iteratively adjusting yield streams. In other words, the directed fleets fishing mortality rates were scaled up or down by the same proportional amount, while the fishing mortality rates exerted by the shrimp fleet remained constant (i.e., the shrimp bycatch mortality rate was treated in a similar way as natural mortality), until the yield that achieved SPR 30% was achieved.

The minimum stock size threshold (MSST) was determined by multiplying the reference spawning stock biomass, $SSB_{SPR30\%}$, by 0.5 and was used to determine stock status. The maximum fishing mortality threshold (MFMT) was equivalent to the equilibrium harvest rate ($F_{SPR\ 30\%}$; number killed / abundance) that achieved $SSB_{SPR30\%}$, and was used to assess whether overfishing was occurring in a given year.

Once the proxy values were calculated, 2017 stock status was used to determine whether a rebuilding plan was required (i.e., if SSB < MSST then vermilion snapper would be considered overfished and a rebuilding plan would be required). Because vermilion snapper have not been declared overfished since the SEDAR 9 assessment was completed, a rebuilding plan is not currently in place. If the SEDAR 67 assessment deemed that vermillion snapper is now overfished, a rebuilding plan would need to be enacted by the Gulf of Mexico Fisheries Management Council and Science and Statistical Committee (SSC) to rebuild the stock by a specified date.

Projections undertaken to quantify the effect of transitioning the recreational landings data were conducted using the SEDAR 45 base model (terminal year 2014) with the recreational data updated to the new FES values. Preliminary landings estimates from 2015 and assumed 2016 removals were used during SEDAR 45 projections to provide management advice beginning in

2017. These values were left unchanged for the current FES exploratory projection with the exception of the recreational landings, which were replaced with the finalized FES based landings of 1,491,550 and 1,639,270 fish, for 2015 and 2016, respectively.

4.3. Projection Results

4.3.1. *Biological Reference Points*

The exceptionally fast growing nature of vermilion snapper combined with the moderate level of natural mortality (~ 0.25) allows them to reach a large fraction of their potential size and fecundity at very young ages with a generation time of only 7.23 years. The harvest rate that results in SPR 30% over the long-term (100 years) was 0.135 (Table 22). The resulting SSB at SPR 30% was 2.02E+14 eggs and the MSST was 1.01E+14 eggs.

4.3.2. *Stock Status*

Using SPR 30% as the basis for defining MSST and MFMT, stock status appears to be healthy. In 2017, the stock was being harvested at 56% of MFMT, SSB was 350% of MSST and 175% of $SSB_{SPR30\%}$ with a terminal year depletion level (SSB_{2017}/SSB_0) of 52% (Tables 22 and 23). The Kobe plot (Figure 50; Table 23) indicates that over the course of the years included in the assessment (i.e., 1950 - 2017), overfishing occurred from 1992 - 2004; however, over the last decade, overfishing has not occurred and the stock has never been overfished. After the intense fishing pressure of the late 1980s and early 1990s, SSB showed declines below that at SPR 30% from 1998 to 2005, but never declined below the MSST. With the recent (2007 - 2017) declines in fishing mortality, strong recruitment events, and the subsequent increases in SSB, vermilion snapper is currently not overfished and overfishing is not occurring.

4.3.3. *Overfishing Limits*

Because stock status indicated that the stock was not overfished, no rebuilding plan is necessary for vermilion snapper. Therefore, short-term (10 year) forecasts were carried out at the MSY proxy (i.e., $F = F_{FSPR30\%}$) in order to determine the overfishing limits. Forecasts begin in 2021, because the 2018 and 2019 fishing years are already completed and TACs have already been set for 2020. Since the stock is currently above the SPR 30% target, forecasts indicate that a declining yield stream is possible in the near-term in order to fish the stock down towards the target SPR (Table 24). An optimum yield (OY; yield resulting from fishing at 75% of $F_{FSPR30\%}$) projection was also completed. The results of the OY runs are presented in Table 25. The trends are the same as the OFL run, but result in a relatively higher SPR (35%) with slightly lower annual yield.

Constant catch projections were not explicitly requested in the TOR's. However, since the Gulf of Mexico Fisheries Management Council often adopts constant TACs for management, various averages of the P* based ABC and OY yield streams (Tables 24 and 25) were calculated to provide constant catch management alternatives. Using the ABC yield stream in Table 24, the 5-year (2021 – 2025) average yield was 8.43 million pounds and the 10-year (2021 – 2030) average yield was 7.23 million pounds. Using the OY yield stream in Table 25, the 5-year (2021

– 2025) average yield was 7.27 million pounds and the 10-year (2021 – 2030) average yield was 6.42 million pounds.

4.3.4. *FES only projections*

Updating the SEDAR 45 base model with the FES recreational landings resulted in notably increased estimates of spawning stock biomass, recruitment, sustainable fishing mortality rate, and projected yields (Table 26). The difference in estimated spawning stock biomass increased with time. The FES adjusted model estimated between 0 and 10% more SSB from 1995 – 2005 and between 10 and 30% more SSB between 2006 and 2014. Overall estimates of stock productivity varied little between the original SEDAR 45 model (ln(R0) = 10.19) and the FES adjusted model (ln(R0) = 10.18). However, estimated recruitment in the decade preceding the terminal year (2005 - 2014) increased by an average of ~5 million fish per year with the FES data. When carried forward into the projections, the elevated spawning stock biomass and recruitment estimates resulted in predictable increases to the sustainable fishing mortality rate and yield estimates.

4.4. Discussion

Gulf of Mexico vermilion snapper appear to be in a healthy state with no overfishing currently occurring, while it is also not overfished (based on an SPR 30% proxy). The current SPR, (SPR 52%), is above the target value of 0.3 and the SSB has been above the MSST for the entire time series (1950-2017), while fishing mortality has been below the MFMT since 2004.

The SEDAR 67 Assessment Panel decided that recent recruitment was an appropriate assumption for the basis of projections because the estimated stock-recruit parameters were likely inappropriate (i.e., steepness was relatively low) for such a highly productive species. However, because the dependency between spawners and recruits is eliminated through using a mean recruitment and removing the S/R function in the projections, recruitment never falters even at extremely low levels of SSB (i.e., recruitment overfishing is not possible). Clearly, some relationship must exist between mature fish and resulting recruits. The constant recruitment assumption is appropriate for short-term projections where SSB is not likely to decrease rapidly, but can lead to inappropriate long-term or equilibrium projections. Therefore, the current projections must be interpreted carefully due to the strong assumptions that were made and catch limits based on SPR 30% should be updated regularly to account for changes in recruitment dynamics. Additionally, parameter uncertainty estimates used to project error distributions in SS3 throughout the forecast timeframe for derived quantities (e.g., yield) are unrealistically small. The reduced uncertainty estimates result from a combination of fixed inputs (e.g., natural mortality, length-weight relationship, growth, etc…) that lack directly specified uncertainty and a small stock recruitment variance term ($\sigma_R = 0.3$). Therefore, assessment uncertainty for SEDAR 67 may be better accounted for by using the OY as the basis for the ABC instead of the P^* approach. In addition, using the 10 year average OY (6.42 million pounds) would provide consistent management for the fishery and ensure that the ABC is less than the OFL through the completion of the 2025 fishing season.

Proposing to increase the stock ACL from 3.11 million pounds to 6.42 million pounds seems extreme if taken out of context, and without clarification could introduce doubts over the validity of the assessment or the projection methodology. Two main factors contributed to the increase in projected yield. First, the transition from the coastal household telephone survey recreational landings estimates to the FES recreational landings estimates contributed to the majority of the change in yield recommendations. As summarized in Table 26, had the FES recreational landings been available during SEDAR 45 the equilibrium yield estimate would have been about 5.19 million pounds rather than the 3.35 million pounds estimated at the time. Assuming the ABC from the hypothetical SEDAR 45 FES run had been about 5 million pounds, the current recommendation of 6.42 million pounds would represent a roughly 30% increase in yield rather than the 100+% increase in yield that it appears to be. Second, the additional data years (2015-2017) included in SEDAR 67 indicated that the stock has experienced well above average recruitment since 2014, with the 2015 and 2016 year classes being the largest and second largest recruitment events on record. These recruitment events created a substantial amount of biomass that has become fully available to all sectors of the directed fishery, resulting in a predictable increase in recommended ABC. There was broad support for the existence of these recruitment events in the data; however, the estimated magnitude of the recruitment events will likely change as additional years of composition data become available. Therefore, the recommendation to use a time-series average yield over the annualized yield stream seemed prudent as it allows for a short-term increase in yield to capitalize on recent recruitment, while limiting the probability of overfishing if future data indicates the magnitude of the recruitment events was less than currently estimated.

Given the recent recruitment events influence on projected yield and the uncertainty around these estimates, vermilion snapper should be considered as a moderate to high priority candidate for interim analysis. Management strategy evaluation has yet to be conducted to determine the best index based harvest control rule for the interim management of vermilion snapper. However, several high quality fishery independent indices exist (e.g., Combined video survey and the SEAMAP trawl survey) for vermilion snapper as shown in the recent SEDAR 67 assessment and interim management advice could be provided while the MSE process is completed. Once the interim analysis process is fully operational, annual updates to catch advice could routinely be provided as part of the vermilion snapper assessment.

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6. Research Recommendations

Develop or expand fishery-independent survey coverage to the western Gulf of Mexico and improve age composition sampling of commercial and recreational catch from the western Gulf of Mexico.

Improve sample sizes in the recreational fisheries, particularly for age composition data, so that the recreational fleet can be modeled by mode and/or region.

Given the fast growth and limited age composition information for vermilion snapper, explore the use of a length-based assessment model.

Barring improvement in sampling data from the western Gulf of Mexico, reconsider fleet structure in the assessment to model only a single Gulf-wide unit (i.e., combine data across regions instead of splitting out the western commercial fleet and western headboat CPUE).

Pending improved sampling in the western region, investigate a two-region model that may be better able to account for differences in age structure and recruitment across the Gulf of Mexico.

Continue to evaluate methods to better estimate discards by fleet and attempt to directly fit this data in the assessment model.

Evaluate discard mortality rates and increase the value utilized in the model as appropriate.

Further explore the implications of dropping fishery-dependent CPUE indices from the assessment.

Evaluate the protocol for estimating shrimp bycatch and update the WinBugs program with any changes to data collection protocols that may have occurred over the last decade.

Reevaluate the super-year approach for modeling shrimp bycatch to better reflect the low observed bycatch levels in recent years (i.e., using two super-years to reflect the high and low effort regimes pre- and post-2000)

Explore reparametrization of the double normal selectivity curves for the fishery-independent surveys to reduce correlations and improve model stability.

Obtain age or length compositions from the shrimp bycatch fisheries to better inform shrimp selectivity estimates.

Pending expansion of the spatiotemporal coverage of the FWRI repetitive timed drop and vertical longline surveys, explore their use in future assessments.

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8. Tables

Table 1: Weight-length regression parameters for vermilion snapper from the Gulf of Mexico using data collected from 2000 to 2014 (from SEDAR 45). Data were combined from all available data sources including both fishery dependent and independent information. Length Type: Max TL – Maximum Total Length, FL – Fork Length, Nat TL – Natural Total Length, SL – Standard Length. Weight Type: G WT – Gutted Weight, W WT – Whole Weight. Units: length (mm) and weight (kg). Linear and non-linear regressions were calculated using the R statistical package (lm and nls functions, respectively). Unless otherwise noted length measurements in the remainder of the document are in fork length and weight is in whole weight.

Regression	Equation	Statistic	N
Max TL to FL	FL = Max_TL * 0.8876 + 1.980	r^2 = 0.9982	11700
Nat TL to FL	FL = Nat_TL * 0.8828 + 8.6645	r^2 = 0.9813	10036
SL to FL	FL = SL * 1.1515 + 2.1327	r^2 = 0.9956	4434
Max TL to W WT	W WT = 1.97 x 10^{-08} * $Max\_TL^{2.916}$	RSE = 0.045	5449
Max TL to G WT	G WT = 1.83 x 10^{-08} * $Max\_TL^{2.921}$	RSE = 0.054	1748
Nat TL to W WT	W WT = 2.48 x 10^{-08} * $Nat\_TL^{2.877}$	RSE = 0.083	9600
Nat TL to G WT	G WT = 2.85 x 10^{-08} * $Nat\_TL^{2.851}$	RSE = 0.073	293
FL to W WT	W WT = 2.66 x 10^{-08} * $FL^{2.916}$	RSE = 0.064	16716
FL to G WT	G WT = 3.26 x 10^{-08} * $FL^{2.877}$	RSE = 0.059	22081

Table 2: Life history parameters and associated equations used as input into the assessment model. Units of length are in cm and weight is in kg.

Type	Equation	Parameter Values
Growth (Von Bertalanffy)	$Length = L_{\infty}(1 - e^{-k(t-t_0)})$	L_{∞} = 34.4 k = 0.3254 t_0 = -0.7953
Length-Weight (Power)	$Weight = \alpha * Length^{\beta}$	α = 2.19 x 10^{-5} β = 2.916
Maturity (Length Logistic)	$Prop\ Mat = \frac{1}{1 + e^{Slope*(Length - Length_{50\%})}}$	Slope = -0.574 $Length_{50\%}$ = 14.087
Batch Fecundity (Power)	$Eggs = \alpha * Spawn\ Freq * Length^{\beta}$	α = 3.399 Spawn Frequency = 82 β = 3.042

Table 3: Natural mortality rate by age used as input to the stock assessment model. Values are based on the Lorenzen function (Lorenzen, 1996) assuming a target M of 0.25 and accounting for the assumed half-year difference in model and true age-0 birth date. Age-0 mortality is also prorated by half a year to account for birth at mid-year (resulting in age-0 mortality being less than subsequent natural mortality-at-age).

Age	Natural Mortality
0	0.234
1	0.342
2	0.287
3	0.257
4	0.239
5	0.228
6	0.220
7	0.215
8	0.212
9	0.209
10	0.207
11	0.206
12	0.205
13	0.204
14	0.204
15	0.204

Table 4: Observed and predicted landings by fleet in metric tons for the commercial sector and 1000s of fish for the recreational sector. Observed landings prior to 1963 for the commercial fishery and prior to 1981 for the recreational fishery are a linear extrapolation from virgin conditions. Note that the standard error for the commercial landings was 0.05, whereas it was 0.15 for the recreational landings. Therefore, the model was forced to fit the commercial data more closely, because there is less uncertainty in the commercial landings data.

	Commercial East		**Commercial West**		**Recreational**	
Year	Observed (mt)	Predicted (mt)	Observed (mt)	Predicted (mt)	Observed (1000s of Fish)	Predicted (1000s of Fish)
1950	1.00	1.00	0.73	0.73	6.03	6.03
1951	1.99	1.99	1.46	1.46	16.20	16.20
1952	2.99	2.99	2.19	2.19	26.38	26.38
1953	3.98	3.98	2.92	2.92	36.55	36.55
1954	4.98	4.98	3.65	3.65	46.72	46.72
1955	5.98	5.98	4.38	4.38	56.89	56.89
1956	6.97	6.97	5.11	5.11	67.07	67.07
1957	7.97	7.97	5.84	5.84	77.24	77.24
1958	8.97	8.97	6.57	6.57	87.41	87.42
1959	9.96	9.96	7.30	7.30	97.59	97.59
1960	10.96	10.96	8.03	8.03	107.76	107.76
1961	11.95	11.95	8.76	8.76	117.93	117.94
1962	12.95	12.95	9.49	9.49	128.11	128.12
1963	13.94	13.94	10.21	10.21	138.28	138.29
1964	15.24	15.24	10.67	10.67	148.45	148.47
1965	15.14	15.14	9.41	9.41	158.62	158.65
1966	7.90	7.90	3.02	3.02	168.80	168.83
1967	16.00	16.00	7.14	7.14	178.97	179.02
1968	31.79	31.79	22.79	22.79	189.14	189.20
1969	40.50	40.50	12.28	12.28	199.32	199.39
1970	37.78	37.78	20.12	20.12	209.49	209.59
1971	41.25	41.25	21.78	21.78	219.66	219.79
1972	36.42	36.42	21.08	21.08	229.83	230.00
1973	61.43	61.43	24.90	24.90	240.01	240.22
1974	58.31	58.31	30.29	30.29	250.18	250.44
1975	126.88	126.89	49.55	49.56	260.35	260.68
1976	111.48	111.50	27.42	27.42	270.53	270.94
1977	151.09	151.13	88.44	88.45	280.70	281.22
1978	129.87	129.90	73.99	74.00	290.87	291.52
1979	99.00	99.02	99.91	99.93	301.04	301.85
1980	72.36	72.37	67.28	67.29	311.22	312.19

Table 4 (cont.): Observed and predicted catch.

Year	Commercial East Observed (mt)	Commercial East Predicted (mt)	Commercial West Observed (mt)	Commercial West Predicted (mt)	Recreational Observed (1000s of Fish)	Recreational Predicted (1000s of Fish)
1981	104.93	104.96	52.42	52.43	321.39	322.53
1982	108.49	108.52	66.39	66.41	705.74	711.56
1983	171.19	171.28	73.31	73.33	271.95	272.78
1984	241.13	241.30	384.46	384.99	418.87	420.51
1985	304.63	304.88	334.30	334.70	799.70	803.18
1986	312.55	312.64	425.60	425.89	1111.40	1109.78
1987	242.26	242.38	454.78	455.43	1366.06	1371.77
1988	222.73	222.80	449.47	450.10	2019.03	2006.49
1989	217.00	217.07	454.50	455.36	1106.63	1099.07
1990	516.75	517.12	436.02	436.74	1266.87	1254.58
1991	420.57	421.38	366.10	367.06	1600.51	1616.96
1992	538.13	539.73	476.15	478.24	1967.02	1996.05
1993	742.43	744.27	462.86	464.42	1480.46	1472.19
1994	711.93	715.27	471.42	473.28	1201.99	1222.01
1995	678.32	685.17	296.52	297.55	1476.30	1634.79
1996	523.54	529.03	295.44	296.80	586.05	624.63
1997	469.07	473.40	486.12	490.81	689.46	748.92
1998	365.00	366.44	405.70	407.98	362.77	370.66
1999	416.38	416.15	497.47	497.79	707.58	698.44
2000	315.33	314.59	343.65	342.92	412.82	402.34
2001	362.24	360.59	409.77	407.82	1227.99	1104.38
2002	451.75	448.68	453.10	449.79	1119.19	1012.05
2003	522.88	519.97	570.54	566.19	1065.60	994.53
2004	420.59	418.71	551.82	548.64	1101.10	1029.23
2005	443.95	442.71	401.58	400.59	791.40	756.88
2006	505.01	504.23	288.32	287.89	764.25	755.09
2007	527.22	525.00	547.91	544.40	762.78	745.00
2008	809.37	797.86	466.47	462.51	681.83	649.61
2009	1273.01	1233.92	443.97	439.22	1105.57	977.23
2010	598.16	589.07	356.55	352.61	758.40	694.86
2011	1101.23	1085.40	329.25	326.93	1635.35	1535.74
2012	720.12	721.45	384.45	383.67	1018.59	1080.60
2013	416.26	417.74	225.62	225.65	1636.36	1926.81
2014	502.12	505.82	298.64	299.85	1588.11	1928.28
2015	300.37	301.66	317.71	319.66	1491.55	1707.06
2016	361.17	361.91	353.97	355.09	1639.27	1720.15
2017	422.49	422.60	312.98	313.13	2336.51	2344.45

Table 5: Commercial landings by fleet and area in pounds whole weight.

	Eastern Gulf of Mexico				Western Gulf of Mexico			
	Handline	Longline	Trap	Total	Handline	Longline	Trap	Total
1963	30,747			30,747	22,533	10		22,543
1964	33,633			33,633	23,532	11		23,543
1965	33,411			33,411	20,757	9		20,766
1966	17,427			17,427	6,660	3		6,663
1967	35,298			35,298	15,762	7		15,769
1968	70,152			70,152	50,283	23		50,306
1969	89,355			89,355	27,084	12		27,096
1970	83,361			83,361	44,400	20		44,420
1971	91,020			91,020	48,063	22		48,085
1972	80,364			80,364	46,509	21		46,530
1973	135,531			135,531	54,945	25		54,970
1974	128,649			128,649	66,822	30		66,852
1975	279,942			279,942	109,335	50		109,385
1976	245,976			245,976	60,495	27		60,522
1977	333,375			333,375	195,126	88		195,214
1978	286,552			286,552	163,261	74		163,335
1979	218,438			218,438	220,445	100		220,545
1980	159,658	444		160,102	148,455	67		148,522
1981	231,522	10,131		241,653	115,663	52	4,549	120,264
1982	239,367	7,188		246,555	146,490	66	4,662	151,218
1983	377,712	23,936		401,648	161,754	73	7,102	168,929
1984	532,029	15,834		547,863	848,288	384	41,392	890,064
1985	672,148	14,765	109	687,022	737,600	334	53,910	791,844
1986	689,625	1,184		690,809	939,041	426	119,597	1,059,064
1987	534,518	4,792		539,310	1,003,433	455	62,662	1,066,550
1988	491,437	15,460		506,897	991,713	449	54,372	1,046,534
1989	478,794	114,692	2,911	596,397	1,002,816	454	59,609	1,062,879
1990	1,140,157	2,041	350,014	1,492,212	962,046	436	614	963,096
1991	927,955	15,594	41,993	985,542	807,767	366	1,683	809,816
1992	1,187,338	1,486	109,208	1,298,033	1,050,576	476	12,514	1,063,567
1993	1,638,102	3,591	29,284	1,670,977	1,021,272	463	24,197	1,045,932
1994	1,570,813	3,485	11,306	1,585,603	1,040,141	471	13,494	1,054,106
1995	1,496,663	3,013	9,421	1,509,097	654,243	297	14,700	669,240
1996	1,155,153	3,426	11,284	1,169,864	651,873	295	5,545	657,714
1997	1,034,972	4,779	5,359	1,045,110	1,072,585	486	8,120	1,081,191
1998	805,347	22,925	2,867	831,140	895,148	406	6,390	901,944
1999	918,719	10,025	2,807	931,551	1,097,635	497	7,419	1,105,552
2000	695,756	1,795	2,321	699,871	758,230	344	712	759,285
2001	799,251	6,553	3,426	809,230	904,132	410	1,366	905,908
2002	996,757	2,184	8,992	1,007,933	999,738	453	445	1,000,636
2003	1,153,684	622	1,784	1,156,090	1,258,858	571	663	1,260,091
2004	928,006	941	4,213	933,160	1,217,555	552	11,575	1,229,681
2005	979,544	2,792	1,717	984,053	886,061	402	771	887,233
2006	1,114,269	13,134	219	1,127,621	636,146	288	1,815	638,250
2007	1,163,278	11,447		1,174,725	1,208,917	548	7	1,209,473
2008	1,785,804	5,567		1,791,371	1,029,233	466	909	1,030,609
2009	2,808,802	5,642		2,814,444	979,594	444	443	980,481
2010	1,319,794	1,911		1,321,705	786,699	357	515	787,571
2011	2,429,777	3,472		2,433,249	726,468	329	87	726,884
2012	1,588,889	2,958		1,591,847	848,266	384	207	848,858
2013	918,442	427		918,868	497,812	226	1,044	499,082
2014	1,107,886	2,245		1,110,131	658,918	299	2,497	661,714
2015	662,733	2,033		664,766	701,006	318	1,526	702,850
2016	796,884	4,233		801,117	781,012	354	1,672	783,038
2017	932,179	6,592		938,771	690,554	313	203	691,069

Table 6: Recreational landings by mode and area in numbers of fish.

	Eastern Gulf of Mexico				Western Gulf of Mexico			
Year	Charter	Private	Headboat	Total	Charter	Private	Headboat	Total
1981	23,693	164,916		188,610	0	65,837	66,943	132,780
1982	565,216	5,138		570,355	28,430	40,015	66,943	135,388
1983	147,301	0		147,301	0	57,701	66,943	124,645
1984	304,669	44,873		349,542	0	2,387	66,943	69,330
1985	124,021	531,493		655,514	34,829	42,416	66,943	144,189
1986	449,890	88,077	517,702	1,055,669	2,445	0	53,291	55,736
1987	513,175	320,219	473,804	1,307,198	1,915	286	56,661	58,862
1988	480,810	829,949	657,057	1,967,817	0	489	50,724	51,213
1989	300,482	351,908	379,291	1,031,682	0	362	74,591	74,953
1990	505,893	221,558	435,185	1,162,637	763	0	103,467	104,230
1991	948,256	139,823	423,023	1,511,102	6,071	0	83,335	89,406
1992	626,156	643,277	565,532	1,834,965	3,796	51,251	77,003	132,050
1993	568,268	388,586	442,980	1,399,833	31	3,988	76,606	80,625
1994	475,094	231,726	374,812	1,081,631	1,541	894	117,920	120,355
1995	756,078	281,875	333,509	1,371,463	138	2,439	102,258	104,835
1996	201,810	87,333	219,191	508,334	58	2,705	74,955	77,718
1997	259,111	143,356	201,468	603,935	433	8,583	76,505	85,521
1998	144,372	52,258	96,353	292,983	295	7,694	61,800	69,789
1999	267,255	252,940	137,670	657,865	2,102	6,311	41,300	49,714
2000	124,869	113,280	131,627	369,776	103	420	42,517	43,040
2001	158,816	835,912	148,702	1,143,430	932	16,539	67,091	84,562
2002	99,294	791,509	146,890	1,037,693	9,095	1,987	70,418	81,500
2003	131,179	620,026	215,685	966,890	1,499	13,673	83,534	98,706
2004	254,954	480,841	236,173	971,968	20,460	7,271	101,399	129,129
2005	186,917	313,163	203,500	703,579	1,391	1,027	85,399	87,817
2006	199,991	297,538	198,315	695,844	14,287	1,625	52,496	68,408
2007	118,624	406,291	132,291	657,206	8,597	6,134	90,846	105,577
2008	220,792	208,860	193,837	623,489	9,416	20,425	28,496	58,337
2009	234,350	569,249	266,145	1,069,744	599	1,095	34,130	35,824
2010	126,394	409,384	164,181	699,959	0	74	58,363	58,437
2011	463,269	725,534	376,813	1,565,615	74	405	69,251	69,730
2012	167,489	546,684	240,140	954,312	28	16	64,237	64,281
2013	342,495	948,738	266,618	1,557,851	731	2,128	75,653	78,512
2014	442,970	775,755	297,933	1,516,658	317	3,666	67,465	71,448
2015	414,132	703,165	295,950	1,413,247	891	7,176	70,238	78,305
2016	569,949	651,814	336,542	1,558,304	1,046	9,362	70,561	80,969
2017	698,190	1,156,990	422,401	2,277,581	767	6,462	51,697	58,926

Table 7: Commercial handline observed and predicted discards by area in metric tons along with observed discards as a percentage of landings.

	Eastern Gulf of Mexico			Western Gulf of Mexico		
Year	Observed Discards (mt)	% of Landings	Predicted Discards (mt)	Observed Discards (mt)	% of Landings	Predicted Discards (mt)
1993	0.59	0%	18.02	0.11	0%	7.53
1994	0.80	0%	17.32	0.12	0%	7.63
1995	0.79	0%	15.80	0.10	0%	4.60
1996	0.66	0%	11.43	0.10	0%	4.53
1997	0.58	0%	10.51	0.19	0%	7.51
1998	0.52	0%	8.60	0.16	0%	6.41
1999	0.58	0%	10.14	0.18	0%	8.30
2000	0.45	0%	8.53	0.11	0%	6.51
2001	0.47	0%	11.81	0.14	0%	8.59
2002	0.58	0%	15.19	0.16	0%	10.20
2003	0.67	0%	16.96	0.21	0%	12.98
2004	0.49	0%	13.45	0.21	0%	12.28
2005	63.57	14%	222.98	13.39	3%	139.08
2006	74.14	15%	241.91	10.17	4%	97.73
2007	87.67	17%	249.26	18.84	3%	182.00
2008	28.13	3%	122.60	2.51	1%	46.06
2009	43.93	3%	179.32	2.31	1%	43.28
2010	20.33	3%	78.20	1.57	0%	33.01
2011	35.91	3%	135.88	1.54	0%	29.07
2012	24.33	3%	96.49	1.80	0%	34.84
2013	14.16	3%	64.15	1.49	1%	22.14
2014	14.95	3%	83.18	1.42	0%	31.69
2015	11.13	4%	48.43	1.67	1%	34.99
2016	12.35	3%	58.61	1.86	1%	39.91
2017	13.50	3%	76.21	1.64	1%	35.81

Table 8: Observed and predicted recreational discards (Type B2, released alive) in thousands of fish along with observed discards as a percentage of landings.

Year	Observed (1000s of Fish)	% of Landings	Predicted (1000s of Fish)
1982	1.08	0%	5.07
1983	53.25	20%	1.96
1984	24.87	6%	3.03
1985	24.21	3%	5.80
1986	85.09	8%	8.08
1987	89.93	7%	10.13
1988	356.31	18%	15.17
1989	174.20	16%	8.44
1990	144.95	11%	254.35
1991	318.92	20%	331.02
1992	281.26	14%	410.66
1993	560.69	38%	302.93
1994	172.21	14%	249.15
1995	566.90	38%	314.40
1996	204.74	35%	116.77
1997	57.27	8%	442.24
1998	46.01	13%	230.51
1999	144.56	20%	445.75
2000	60.79	15%	281.35
2001	127.42	10%	871.86
2002	289.93	26%	790.92
2003	308.97	29%	733.72
2004	201.60	18%	739.51
2005	363.13	46%	1499.90
2006	228.60	30%	1424.05
2007	194.46	25%	1418.36
2008	161.31	24%	463.38
2009	210.79	19%	655.10
2010	84.16	11%	432.25
2011	167.81	10%	935.44
2012	209.70	21%	725.43
2013	477.05	29%	1460.59
2014	393.95	25%	1496.76
2015	291.03	20%	1272.07
2016	328.60	20%	1320.91
2017	593.98	25%	1900.08

Table 9: Observed and predicted shrimp bycatch in 1000s of fish. Observed shrimp bycatch is calculated using a Bayesian WinBugs program (SEDAR67-WP-15), which provides median estimates by year and 'super-year'. Because the super-year median is itself a Bayesian estimate, it does not represent the frequentist median. Similarly, since the assessment model is configured to fit the Bayesian super-year median, it is not directly constrained to fit the observed bycatch values (yearly fluctuations in bycatch are constrained by forcing the model to fit the shrimp effort time series). Following SEDAR 45 recommendations, it is assumed that 75% of shrimp bycatch is age-1+ (i.e., the super-year medians are actually 75% of the actual median).

Year	Observed	Predicted
Super-year Median	3,779	4,209
1972	43,450	4,503
1973	28,340	4,571
1974	6,814	4,552
1975	4,828	4,581
1976	3,505	4,741
1977	2,110	5,146
1978	10,090	5,391
1979	9,445	5,598
1980	1,442	5,689
1981	12,630	5,207
1982	4,254	4,994
1983	5,555	5,049
1984	12,770	5,624
1985	11,430	5,414
1986	21,760	5,820
1987	23,390	4,887
1988	8,487	4,510
1989	12,920	4,894
1990	17,150	4,307
1991	61,300	4,474
1992	4,194	5,444
1993	2,023	5,962
1994	2,439	8,293
1995	9,974	4,182
1996	11,910	4,494
1997	11,070	4,653
1998	36,260	5,701
1999	7,996	3,563
2000	8,949	4,696
2001	5,545	5,097
2002	5,394	6,023
2003	9,549	5,060
2004	2,561	4,718
2005	4,778	3,241
2006	4,189	2,358
2007	6,844	2,086
2008	1,038	1,124
2009	2,106	1,557
2010	1,111	1,006
2011	852	1,481
2012	443	1,816
2013	574	2,304
2014	291	1,704
2015	179	1,592
2016	155	2,807
2017	212	2,389

Table 10: Number of otoliths sampled from the commercial fleet that were used to determine age composition by year and area. Age frequency distributions calculated from otolith samples utilized a reweighting algorithm based on length frequency in order to account for non-representative sampling of otoliths. Values from SEDAR 45 are provided for comparison.

	SEDAR 45			SEDAR 67		
Year	East	West	Total	East	West	Total
1994	1	15	16		62	62
1995	18	41	59	8	52	60
1998	138	0	138	138	0	138
2000	227	26	253	187	66	253
2001	1292	56	1348	1297	56	1353
2002	1332	97	1429	1334	97	1431
2003	2135	552	2687	2152	559	2711
2004	667	487	1154	667	509	1176
2005	731	807	1538	749	812	1561
2006	775	868	1643	804	871	1675
2007	731	1187	1918	761	1273	2034
2008	885	1203	2088	926	1355	2281
2009	1102	975	2077	1243	1085	2328
2010	781	1064	1845	805	1175	1980
2011	2935	869	3804	3013	889	3902
2012	661	574	1235	780	776	1556
2013	522	496	1018	588	529	1117
2014	529	518	1047	581	518	1099
2015				633	605	1238
2016				644	621	1265
2017				559	479	1038

Table 11: Number of otoliths sampled from the recreational fleet that were used to determine age composition by year. Age frequency distributions calculated from otolith samples utilized a reweighting algorithm based on length frequency in order to account for non-representative sampling of otoliths. Values from SEDAR 45 are provided for comparison. Note that due to low sample sizes in the western region, a single gulf-wide age composition for a single recreational fleet was developed which matched SEDAR 45.

	SEDAR 45	**SEDAR 67**
Year	Total	Total
1994	33	33
1995	9	9
1996	261	262
1997	42	45
1998	14	14
1999	246	146
2000	210	210
2001	140	141
2002	258	258
2003	91	91
2004	127	129
2005	169	169
2006	171	171
2007	456	505
2008	1019	1046
2009	1300	1300
2010	1199	1200
2011	1305	1311
2012	1884	1904
2013	1731	1740
2014	1406	1447
2015		4492
2016		3679
2017		2545

Table 12: Observed and predicted normalized (to the time series mean) shrimp effort greater than 10 fathoms. Observed values were standardized by SEAMAP summer groundfish survey catch rates of vermilion snapper in order to account for the spatial overlap of shrimp effort and vermilion snapper distribution. Values prior to 1981 represent a linear interpolation to virgin conditions. Observed values from SEDAR 45 are included for comparison, as well as, the assumed lognormal standard error used in the assessment model.

Year	SEDAR 45 Observed	SEDAR 67 Observed	SEDAR 67 Predicted	Standard Error
1950	0.195	0.1989	0.19892	0.2
1951	0.265	0.2712	0.271243	0.2
1952	0.314	0.3203	0.32037	0.2
1953	0.33	0.3368	0.336891	0.2
1954	0.427	0.4366	0.436776	0.2
1955	0.445	0.4551	0.455323	0.2
1956	0.569	0.5818	0.582216	0.2
1957	0.652	0.6661	0.666724	0.2
1958	0.798	0.8157	0.816762	0.2
1959	0.86	0.8793	0.880726	0.2
1960	0.86	0.879	0.880692	0.2
1961	0.652	0.6658	0.666994	0.2
1962	0.627	0.6411	0.642414	0.2
1963	0.715	0.7308	0.732769	0.2
1964	0.755	0.7719	0.774436	0.2
1965	0.838	0.8567	0.860297	0.2
1966	0.825	0.8431	0.847161	0.2
1967	0.899	0.9184	0.923953	0.2
1968	0.913	0.9332	0.939818	0.2
1969	1.038	1.0604	1.07016	0.2
1970	0.978	0.9991	1.00935	0.2
1971	0.932	0.9527	0.964356	0.2
1972	0.928	0.9488	0.944725	0.2
1973	0.935	0.955	0.961568	0.2
1974	0.93	0.9505	0.959348	0.2
1975	0.936	0.9562	0.967807	0.2
1976	0.971	0.9919	1.00727	0.2
1977	1.063	1.0865	1.10795	0.2
1978	1.124	1.1485	1.17475	0.2
1979	1.178	1.2041	1.23316	0.2
1980	1.209	1.2359	1.26292	0.2

Table 12 (cont.): Observed and predicted shrimp effort.

Year	SEDAR 45 Observed	SEDAR 67 Observed	SEDAR 67 Predicted	Standard Error
1981	1.157	1.1323	1.14694	0.2
1982	1.068	1.0946	1.09277	0.2
1983	1.116	1.132	1.10506	0.2
1984	1.278	1.3325	1.25314	0.2
1985	1.211	1.2756	1.21162	0.2
1986	1.404	1.428	1.32234	0.2
1987	1.268	1.2585	1.09759	0.2
1988	1.096	1.1531	1.0049	0.2
1989	1.122	1.2553	1.10323	0.2
1990	1.034	1.143	0.969351	0.2
1991	1.076	1.2043	1.01179	0.2
1992	1.322	1.4239	1.27457	0.2
1993	1.086	1.2065	1.44278	0.2
1994	1.147	1.2105	2.19942	0.2
1995	1.298	1.3497	1.70694	0.2
1996	1.562	1.5532	1.6097	0.2
1997	1.555	1.6139	1.65707	0.2
1998	1.94	1.9655	2.01103	0.2
1999	1.183	1.2638	1.31284	0.2
2000	0.962	1.1051	1.05113	0.2
2001	1.122	1.2471	1.16312	0.2
2002	1.367	1.4721	1.44003	0.2
2003	1.182	1.2373	1.23312	0.2
2004	1.214	1.2403	1.1368	0.2
2005	0.937	0.9899	0.94786	0.2
2006	0.554	0.6319	0.617708	0.2
2007	0.365	0.4591	0.427513	0.2
2008	0.283	0.3236	0.304865	0.2
2009	0.463	0.4905	0.489772	0.2
2010	0.352	0.3512	0.36568	0.2
2011	0.361	0.4088	0.437748	0.2
2012	0.308	0.3685	0.390047	0.2
2013	0.342	0.42	0.435164	0.2
2014	0.267	0.3439	0.347383	0.2
2015		0.292	0.285408	0.2
2016		0.303	0.293625	0.2
2017		0.3191	0.318287	0.2

Table 13: Observed and predicted standardized commercial fishery-dependent catch-per-unit effort (CPUE) indices and associated lognormal standard error (as estimated by the GLM standardization model). Values are normalized to the mean and standard error has been normalized to an average value of 0.2 within each sector to preserve interannual variability in the weighting of data sets in the assessment. Due to the implementation of red snapper individual fishing quotas (IFQs) in 2007, which has made standardizing catch rates difficult, the time series was truncated in 2006.

	Eastern Gulf of Mexico			**Western Gulf of Mexico**		
Year	Observed	Predicted	Standard Error	Observed	Predicted	Standard Error
1993	1.036	1.504	0.224	1.061	1.618	0.295
1994	1.232	1.399	0.192	1.463	1.502	0.242
1995	0.897	1.278	0.215	0.934	1.384	0.250
1996	0.951	1.161	0.191	1.017	1.285	0.216
1997	0.888	1.047	0.201	1.294	1.180	0.166
1998	0.878	0.967	0.202	1.018	1.069	0.185
1999	0.946	0.897	0.186	1.054	0.972	0.160
2000	0.792	0.853	0.217	0.722	0.904	0.191
2001	0.866	0.871	0.205	0.765	0.868	0.201
2002	0.944	0.932	0.189	1.002	0.853	0.174
2003	0.995	0.962	0.182	1.262	0.881	0.157
2004	0.983	0.978	0.194	1.245	0.915	0.155
2005	1.285	0.700	0.191	0.770	0.730	0.182
2006	1.308	0.746	0.212	0.393	0.786	0.226

Table 14: Observed and predicted standardized recreational fishery-dependent catch-per-unit effort (CPUE) indices and associated lognormal standard error (as estimated by the GLM standardization model). Values are normalized to the mean and standard error has been normalized to an average value of 0.2 within each sector to preserve interannual variability in the weighting of data sets in the assessment.

	MRFSS			**Headboat East**			**Headboat West**		
Year	Observed	Predicted	Standard Error	Observed	Predicted	Standard Error	Observed	Predicted	Standard Error
1986	2.800	1.772	0.134	0.900	1.215	0.287	1.752	1.315	0.208
1987	1.179	1.697	0.240	1.009	1.163	0.275	1.223	1.260	0.199
1988	1.911	1.631	0.270	2.163	1.117	0.193	0.928	1.210	0.215
1989	0.886	1.610	0.330	1.343	1.104	0.193	1.291	1.196	0.205
1990	2.229	1.341	0.246	1.689	1.097	0.180	1.767	1.188	0.190
1991	1.470	1.319	0.180	1.803	1.081	0.178	0.983	1.170	0.195
1992	1.382	1.280	0.136	2.499	1.048	0.171	0.945	1.135	0.183
1993	1.536	1.215	0.170	1.599	0.995	0.177	1.150	1.077	0.171
1994	1.434	1.144	0.232	1.766	0.934	0.174	1.138	1.012	0.167
1995	1.983	1.037	0.232	1.489	0.839	0.186	1.214	0.909	0.166
1996	1.007	0.923	0.302	0.822	0.744	0.199	0.886	0.806	0.172
1997	0.274	0.613	0.220	0.736	0.662	0.196	0.837	0.717	0.184
1998	0.361	0.568	0.198	0.190	0.626	0.219	0.796	0.678	0.177
1999	0.387	0.533	0.141	0.421	0.592	0.233	0.687	0.641	0.204
2000	0.347	0.519	0.213	0.354	0.600	0.222	0.519	0.649	0.198
2001	0.488	0.552	0.205	0.442	0.671	0.214	0.836	0.726	0.190
2002	0.363	0.636	0.202	0.483	0.769	0.212	0.974	0.833	0.179
2003	0.422	0.681	0.179	0.587	0.803	0.209	0.636	0.869	0.177
2004	0.543	0.703	0.144	0.629	0.820	0.204	1.091	0.888	0.174
2005	0.581	0.420	0.166	0.812	0.852	0.206	1.218	0.922	0.172
2006	0.537	0.447	0.182	0.561	0.878	0.221	0.652	0.951	0.187
2007	0.425	0.454	0.211	0.372	0.897	0.232	1.438	0.972	0.181
2008	0.662	0.832	0.224	0.667	0.969	0.201	0.261	1.049	0.285
2009	1.024	0.876	0.225	0.790	0.993	0.197	0.344	1.075	0.219
2010	0.561	0.848	0.241	0.860	0.936	0.215	1.140	1.014	0.209
2011	1.311	0.779	0.156	1.058	0.850	0.194	1.165	0.921	0.209
2012	0.881	0.704	0.185	0.656	0.799	0.194	0.913	0.865	0.219
2013	1.022	0.725	0.213	0.892	0.866	0.179	1.103	0.937	0.221
2014	1.186	0.819	0.150	0.948	0.988	0.168	0.896	1.070	0.249
2015	0.958	0.934	0.156	0.898	1.109	0.167	1.053	1.201	0.218
2016	0.679	1.042	0.156	0.957	1.253	0.159	1.151	1.357	0.227
2017	1.176	1.244	0.160	1.603	1.532	0.149	1.015	1.659	0.252

Table 15: Observed and predicted standardized fishery-independent surveys and associated lognormal standard error (as estimated by the GLM standardization models). Values are normalized to the mean and standard error has been normalized to an average value of 0.2 within each survey to preserve interannual variability in the weighting of data sets in the assessment. Note that surveys were not conducted every year and a blank row indicates that there was no survey conducted that year.

	Larval			Combined Video			SEAMAP Trawl Eastern Gulf		
Year	Observed	Predicted	Standard Error	Observed	Predicted	Standard Error	Observed	Predicted	Standard Error
1986	0.45421	1.61415	0.229322						
1987	1.48596	1.53591	0.18555						
1990	0.64378	1.36537	0.25466						
1991	1.42365	1.31909	0.220455						
1993	0.57936	1.19858	0.215298	0.66044	0.992341	0.295683			
1994	0.96553	1.1224	0.188572	1.1061	0.868197	0.216693			
1995	0.7263	0.995964	0.203662	0.522724	0.748168	0.507363			
1996	0.66782	0.889611	0.20671	0.294763	0.701215	0.291294			
1997	1.11842	0.836673	0.185845	0.673943	0.675989	0.196541			
1999	0.58313	0.72759	0.204291						
2000	0.85527	0.721748	0.207054						
2001	0.85016	0.777447	0.196769						
2002				1.48573	0.851601	0.223033			
2003	1.36716	0.819487	0.182395						
2004				0.359828	0.827997	0.213692			
2005				0.558559	0.815683	0.160119			
2006	1.3578	0.850972	0.192207	1.14229	0.872043	0.32592			
2007	1.61157	0.911361	0.177098	0.113646	0.910385	0.156685			
2008				0.89507	0.890288	0.209761			
2009	1.27462	0.963462	0.186419	0.952484	0.823725	0.173403	0.803201	0.591761	0.243001
2010	1.05739	0.907005	0.192591	1.18098	0.790515	0.157207	0.73555	0.587451	0.265449
2011	1.042	0.91158	0.194557	1.26554	0.824178	0.111457	1.64607	0.684424	0.261243
2012	1.07611	0.878722	0.190458	0.899353	0.912816	0.133449	1.20746	0.809841	0.207352
2013	0.96777	0.926344	0.196107	0.96895	0.992995	0.141149	0.875348	0.857488	0.253906
2014	1.06004	0.985557	0.194256	1.14974	1.06097	0.11175	0.732375	0.905989	0.260064
2015				1.50006	1.28378	0.132806	0.736247	1.21274	0.226881
2016	0.83197	1.24948	0.195724	2.45965	1.5117	0.117429	0.827883	1.36255	0.228247
2017				1.81015	1.52575	0.124566	0.693874	1.17683	0.250359

Table 16: Estimated and fixed parameter values and associated standard deviations from the stock synthesis base assessment model. Fleet numbers 1 through 4 represent Commercial East, Commercial West, Recreational, and Shrimp Bycatch, respectively.

Parameter	Value	Standard Deviation	Fixed or Estimated
SR_LN(R0)	10.217	0.056	Estimated
SR_BH_steep	0.712	0.050	Estimated
SR_sigmaR	0.300	NA	Fixed
Main_RecrDev_1994	-0.492	0.143	Estimated
Main_RecrDev_1995	-0.244	0.121	Estimated
Main_RecrDev_1996	-0.233	0.120	Estimated
Main_RecrDev_1997	-0.162	0.127	Estimated
Main_RecrDev_1998	-0.262	0.111	Estimated
Main_RecrDev_1999	0.286	0.086	Estimated
Main_RecrDev_2000	0.196	0.089	Estimated
Main_RecrDev_2001	0.167	0.095	Estimated
Main_RecrDev_2002	0.126	0.087	Estimated
Main_RecrDev_2003	0.120	0.081	Estimated
Main_RecrDev_2004	-0.148	0.081	Estimated
Main_RecrDev_2005	-0.014	0.071	Estimated
Main_RecrDev_2006	0.210	0.062	Estimated
Main_RecrDev_2007	-0.231	0.074	Estimated
Main_RecrDev_2008	-0.310	0.080	Estimated
Main_RecrDev_2009	-0.478	0.082	Estimated
Main_RecrDev_2010	-0.174	0.076	Estimated
Main_RecrDev_2011	0.150	0.070	Estimated
Main_RecrDev_2012	0.259	0.071	Estimated
Main_RecrDev_2013	0.119	0.080	Estimated
Main_RecrDev_2014	0.270	0.091	Estimated
Main_RecrDev_2015	0.846	0.111	Estimated
Late_RecrDev_2016	0.395	0.206	Estimated
Late_RecrDev_2017	-0.151	0.226	Estimated
F_fleet_1_YR_1950_s_1	0.000	0.000	Estimated
F_fleet_1_YR_1951_s_1	0.000	0.000	Estimated
F_fleet_1_YR_1952_s_1	0.000	0.000	Estimated
F_fleet_1_YR_1953_s_1	0.000	0.000	Estimated
F_fleet_1_YR_1954_s_1	0.000	0.000	Estimated
F_fleet_1_YR_1955_s_1	0.000	0.000	Estimated
F_fleet_1_YR_1956_s_1	0.000	0.000	Estimated
F_fleet_1_YR_1957_s_1	0.000	0.000	Estimated
F_fleet_1_YR_1958_s_1	0.000	0.000	Estimated
F_fleet_1_YR_1959_s_1	0.000	0.000	Estimated
F_fleet_1_YR_1960_s_1	0.000	0.000	Estimated
F_fleet_1_YR_1961_s_1	0.000	0.000	Estimated
F_fleet_1_YR_1962_s_1	0.001	0.000	Estimated
F_fleet_1_YR_1963_s_1	0.001	0.000	Estimated
F_fleet_1_YR_1964_s_1	0.001	0.000	Estimated
F_fleet_1_YR_1965_s_1	0.001	0.000	Estimated

Table 16 (cont.): Estimated parameter values.

Parameter	Value	Standard Deviation	Fixed or Estimated
F_fleet_1_YR_1966_s_1	0.000	0.000	Estimated
F_fleet_1_YR_1967_s_1	0.001	0.000	Estimated
F_fleet_1_YR_1968_s_1	0.001	0.000	Estimated
F_fleet_1_YR_1969_s_1	0.002	0.000	Estimated
F_fleet_1_YR_1970_s_1	0.002	0.000	Estimated
F_fleet_1_YR_1971_s_1	0.002	0.000	Estimated
F_fleet_1_YR_1972_s_1	0.002	0.000	Estimated
F_fleet_1_YR_1973_s_1	0.003	0.000	Estimated
F_fleet_1_YR_1974_s_1	0.003	0.000	Estimated
F_fleet_1_YR_1975_s_1	0.006	0.000	Estimated
F_fleet_1_YR_1976_s_1	0.005	0.000	Estimated
F_fleet_1_YR_1977_s_1	0.008	0.001	Estimated
F_fleet_1_YR_1978_s_1	0.007	0.000	Estimated
F_fleet_1_YR_1979_s_1	0.005	0.000	Estimated
F_fleet_1_YR_1980_s_1	0.004	0.000	Estimated
F_fleet_1_YR_1981_s_1	0.006	0.000	Estimated
F_fleet_1_YR_1982_s_1	0.006	0.000	Estimated
F_fleet_1_YR_1983_s_1	0.009	0.001	Estimated
F_fleet_1_YR_1984_s_1	0.014	0.001	Estimated
F_fleet_1_YR_1985_s_1	0.018	0.001	Estimated
F_fleet_1_YR_1986_s_1	0.019	0.001	Estimated
F_fleet_1_YR_1987_s_1	0.016	0.001	Estimated
F_fleet_1_YR_1988_s_1	0.015	0.001	Estimated
F_fleet_1_YR_1989_s_1	0.016	0.001	Estimated
F_fleet_1_YR_1990_s_1	0.039	0.003	Estimated
F_fleet_1_YR_1991_s_1	0.033	0.003	Estimated
F_fleet_1_YR_1992_s_1	0.045	0.003	Estimated
F_fleet_1_YR_1993_s_1	0.067	0.005	Estimated
F_fleet_1_YR_1994_s_1	0.069	0.005	Estimated
F_fleet_1_YR_1995_s_1	0.072	0.006	Estimated
F_fleet_1_YR_1996_s_1	0.061	0.005	Estimated
F_fleet_1_YR_1997_s_1	0.061	0.005	Estimated
F_fleet_1_YR_1998_s_1	0.051	0.004	Estimated
F_fleet_1_YR_1999_s_1	0.063	0.005	Estimated
F_fleet_1_YR_2000_s_1	0.050	0.004	Estimated
F_fleet_1_YR_2001_s_1	0.056	0.004	Estimated
F_fleet_1_YR_2002_s_1	0.065	0.005	Estimated
F_fleet_1_YR_2003_s_1	0.073	0.005	Estimated
F_fleet_1_YR_2004_s_1	0.058	0.004	Estimated
F_fleet_1_YR_2005_s_1	0.085	0.006	Estimated
F_fleet_1_YR_2006_s_1	0.091	0.007	Estimated

Table 16 (cont.): Estimated parameter values.

Parameter	Value	Standard Deviation	Fixed or Estimated
F_fleet_1_YR_2007_s_1	0.092	0.007	Estimated
F_fleet_1_YR_2008_s_1	0.103	0.008	Estimated
F_fleet_1_YR_2009_s_1	0.152	0.011	Estimated
F_fleet_1_YR_2010_s_1	0.073	0.005	Estimated
F_fleet_1_YR_2011_s_1	0.142	0.011	Estimated
F_fleet_1_YR_2012_s_1	0.102	0.008	Estimated
F_fleet_1_YR_2013_s_1	0.059	0.005	Estimated
F_fleet_1_YR_2014_s_1	0.066	0.006	Estimated
F_fleet_1_YR_2015_s_1	0.035	0.003	Estimated
F_fleet_1_YR_2016_s_1	0.038	0.003	Estimated
F_fleet_1_YR_2017_s_1	0.038	0.003	Estimated
F_fleet_2_YR_1950_s_1	0.000	0.000	Estimated
F_fleet_2_YR_1951_s_1	0.000	0.000	Estimated
F_fleet_2_YR_1952_s_1	0.000	0.000	Estimated
F_fleet_2_YR_1953_s_1	0.000	0.000	Estimated
F_fleet_2_YR_1954_s_1	0.000	0.000	Estimated
F_fleet_2_YR_1955_s_1	0.000	0.000	Estimated
F_fleet_2_YR_1956_s_1	0.000	0.000	Estimated
F_fleet_2_YR_1957_s_1	0.000	0.000	Estimated
F_fleet_2_YR_1958_s_1	0.000	0.000	Estimated
F_fleet_2_YR_1959_s_1	0.000	0.000	Estimated
F_fleet_2_YR_1960_s_1	0.000	0.000	Estimated
F_fleet_2_YR_1961_s_1	0.000	0.000	Estimated
F_fleet_2_YR_1962_s_1	0.000	0.000	Estimated
F_fleet_2_YR_1963_s_1	0.001	0.000	Estimated
F_fleet_2_YR_1964_s_1	0.001	0.000	Estimated
F_fleet_2_YR_1965_s_1	0.000	0.000	Estimated
F_fleet_2_YR_1966_s_1	0.000	0.000	Estimated
F_fleet_2_YR_1967_s_1	0.000	0.000	Estimated
F_fleet_2_YR_1968_s_1	0.001	0.000	Estimated
F_fleet_2_YR_1969_s_1	0.001	0.000	Estimated
F_fleet_2_YR_1970_s_1	0.001	0.000	Estimated
F_fleet_2_YR_1971_s_1	0.001	0.000	Estimated
F_fleet_2_YR_1972_s_1	0.001	0.000	Estimated
F_fleet_2_YR_1973_s_1	0.001	0.000	Estimated
F_fleet_2_YR_1974_s_1	0.002	0.000	Estimated
F_fleet_2_YR_1975_s_1	0.003	0.000	Estimated
F_fleet_2_YR_1976_s_1	0.002	0.000	Estimated
F_fleet_2_YR_1977_s_1	0.005	0.000	Estimated
F_fleet_2_YR_1978_s_1	0.005	0.000	Estimated
F_fleet_2_YR_1979_s_1	0.006	0.000	Estimated
F_fleet_2_YR_1980_s_1	0.004	0.000	Estimated
F_fleet_2_YR_1981_s_1	0.003	0.000	Estimated
F_fleet_2_YR_1982_s_1	0.004	0.000	Estimated
F_fleet_2_YR_1983_s_1	0.005	0.000	Estimated
F_fleet_2_YR_1984_s_1	0.027	0.002	Estimated
F_fleet_2_YR_1985_s_1	0.024	0.002	Estimated

Table 16 (cont.): Estimated parameter values.

Parameter	Value	Standard Deviation	Fixed or Estimated
F_fleet_2_YR_1986_s_1	0.032	0.003	Estimated
F_fleet_2_YR_1987_s_1	0.037	0.003	Estimated
F_fleet_2_YR_1988_s_1	0.039	0.003	Estimated
F_fleet_2_YR_1989_s_1	0.042	0.004	Estimated
F_fleet_2_YR_1990_s_1	0.043	0.004	Estimated
F_fleet_2_YR_1991_s_1	0.038	0.003	Estimated
F_fleet_2_YR_1992_s_1	0.053	0.005	Estimated
F_fleet_2_YR_1993_s_1	0.055	0.005	Estimated
F_fleet_2_YR_1994_s_1	0.060	0.006	Estimated
F_fleet_2_YR_1995_s_1	0.041	0.004	Estimated
F_fleet_2_YR_1996_s_1	0.044	0.004	Estimated
F_fleet_2_YR_1997_s_1	0.080	0.007	Estimated
F_fleet_2_YR_1998_s_1	0.073	0.007	Estimated
F_fleet_2_YR_1999_s_1	0.098	0.009	Estimated
F_fleet_2_YR_2000_s_1	0.073	0.007	Estimated
F_fleet_2_YR_2001_s_1	0.090	0.008	Estimated
F_fleet_2_YR_2002_s_1	0.101	0.010	Estimated
F_fleet_2_YR_2003_s_1	0.123	0.012	Estimated
F_fleet_2_YR_2004_s_1	0.115	0.011	Estimated
F_fleet_2_YR_2005_s_1	0.105	0.010	Estimated
F_fleet_2_YR_2006_s_1	0.070	0.007	Estimated
F_fleet_2_YR_2007_s_1	0.126	0.012	Estimated
F_fleet_2_YR_2008_s_1	0.086	0.008	Estimated
F_fleet_2_YR_2009_s_1	0.080	0.007	Estimated
F_fleet_2_YR_2010_s_1	0.061	0.006	Estimated
F_fleet_2_YR_2011_s_1	0.057	0.005	Estimated
F_fleet_2_YR_2012_s_1	0.073	0.007	Estimated
F_fleet_2_YR_2013_s_1	0.045	0.004	Estimated
F_fleet_2_YR_2014_s_1	0.059	0.006	Estimated
F_fleet_2_YR_2015_s_1	0.057	0.006	Estimated
F_fleet_2_YR_2016_s_1	0.056	0.006	Estimated
F_fleet_2_YR_2017_s_1	0.043	0.005	Estimated
F_fleet_3_YR_1950_s_1	0.000	0.000	Estimated
F_fleet_3_YR_1951_s_1	0.000	0.000	Estimated
F_fleet_3_YR_1952_s_1	0.001	0.000	Estimated
F_fleet_3_YR_1953_s_1	0.001	0.000	Estimated
F_fleet_3_YR_1954_s_1	0.001	0.000	Estimated
F_fleet_3_YR_1955_s_1	0.002	0.000	Estimated
F_fleet_3_YR_1956_s_1	0.002	0.000	Estimated
F_fleet_3_YR_1957_s_1	0.002	0.000	Estimated
F_fleet_3_YR_1958_s_1	0.002	0.000	Estimated
F_fleet_3_YR_1959_s_1	0.003	0.000	Estimated
F_fleet_3_YR_1960_s_1	0.003	0.001	Estimated
F_fleet_3_YR_1961_s_1	0.004	0.001	Estimated
F_fleet_3_YR_1962_s_1	0.004	0.001	Estimated

Table 16 (cont.): Estimated parameter values.

Parameter	Value	Standard Deviation	Fixed or Estimated
F_fleet_3_YR_1963_s_1	0.004	0.001	Estimated
F_fleet_3_YR_1964_s_1	0.005	0.001	Estimated
F_fleet_3_YR_1965_s_1	0.005	0.001	Estimated
F_fleet_3_YR_1966_s_1	0.005	0.001	Estimated
F_fleet_3_YR_1967_s_1	0.006	0.001	Estimated
F_fleet_3_YR_1968_s_1	0.006	0.001	Estimated
F_fleet_3_YR_1969_s_1	0.007	0.001	Estimated
F_fleet_3_YR_1970_s_1	0.007	0.001	Estimated
F_fleet_3_YR_1971_s_1	0.008	0.001	Estimated
F_fleet_3_YR_1972_s_1	0.008	0.001	Estimated
F_fleet_3_YR_1973_s_1	0.008	0.001	Estimated
F_fleet_3_YR_1974_s_1	0.009	0.002	Estimated
F_fleet_3_YR_1975_s_1	0.009	0.002	Estimated
F_fleet_3_YR_1976_s_1	0.010	0.002	Estimated
F_fleet_3_YR_1977_s_1	0.010	0.002	Estimated
F_fleet_3_YR_1978_s_1	0.011	0.002	Estimated
F_fleet_3_YR_1979_s_1	0.011	0.002	Estimated
F_fleet_3_YR_1980_s_1	0.012	0.002	Estimated
F_fleet_3_YR_1981_s_1	0.012	0.002	Estimated
F_fleet_3_YR_1982_s_1	0.028	0.005	Estimated
F_fleet_3_YR_1983_s_1	0.011	0.002	Estimated
F_fleet_3_YR_1984_s_1	0.017	0.003	Estimated
F_fleet_3_YR_1985_s_1	0.033	0.006	Estimated
F_fleet_3_YR_1986_s_1	0.047	0.008	Estimated
F_fleet_3_YR_1987_s_1	0.060	0.011	Estimated
F_fleet_3_YR_1988_s_1	0.092	0.016	Estimated
F_fleet_3_YR_1989_s_1	0.051	0.009	Estimated
F_fleet_3_YR_1990_s_1	0.070	0.012	Estimated
F_fleet_3_YR_1991_s_1	0.091	0.016	Estimated
F_fleet_3_YR_1992_s_1	0.116	0.020	Estimated
F_fleet_3_YR_1993_s_1	0.090	0.015	Estimated
F_fleet_3_YR_1994_s_1	0.080	0.014	Estimated
F_fleet_3_YR_1995_s_1	0.118	0.020	Estimated
F_fleet_3_YR_1996_s_1	0.050	0.009	Estimated
F_fleet_3_YR_1997_s_1	0.091	0.016	Estimated
F_fleet_3_YR_1998_s_1	0.049	0.008	Estimated
F_fleet_3_YR_1999_s_1	0.098	0.017	Estimated
F_fleet_3_YR_2000_s_1	0.058	0.010	Estimated
F_fleet_3_YR_2001_s_1	0.149	0.024	Estimated
F_fleet_3_YR_2002_s_1	0.119	0.019	Estimated
F_fleet_3_YR_2003_s_1	0.109	0.018	Estimated
F_fleet_3_YR_2004_s_1	0.109	0.018	Estimated
F_fleet_3_YR_2005_s_1	0.134	0.022	Estimated

Table 16 (cont.): Estimated parameter values.

Parameter	Value	Standard Deviation	Fixed or Estimated
F_fleet_3_YR_2006_s_1	0.126	0.021	Estimated
F_fleet_3_YR_2007_s_1	0.122	0.021	Estimated
F_fleet_3_YR_2008_s_1	0.058	0.010	Estimated
F_fleet_3_YR_2009_s_1	0.083	0.014	Estimated
F_fleet_3_YR_2010_s_1	0.061	0.010	Estimated
F_fleet_3_YR_2011_s_1	0.147	0.024	Estimated
F_fleet_3_YR_2012_s_1	0.114	0.020	Estimated
F_fleet_3_YR_2013_s_1	0.198	0.036	Estimated
F_fleet_3_YR_2014_s_1	0.176	0.034	Estimated
F_fleet_3_YR_2015_s_1	0.136	0.026	Estimated
F_fleet_3_YR_2016_s_1	0.123	0.023	Estimated
F_fleet_3_YR_2017_s_1	0.141	0.026	Estimated
F_fleet_4_YR_1950_s_1	0.050	0.011	Estimated
F_fleet_4_YR_1951_s_1	0.068	0.015	Estimated
F_fleet_4_YR_1952_s_1	0.080	0.017	Estimated
F_fleet_4_YR_1953_s_1	0.084	0.018	Estimated
F_fleet_4_YR_1954_s_1	0.109	0.024	Estimated
F_fleet_4_YR_1955_s_1	0.114	0.025	Estimated
F_fleet_4_YR_1956_s_1	0.146	0.032	Estimated
F_fleet_4_YR_1957_s_1	0.167	0.036	Estimated
F_fleet_4_YR_1958_s_1	0.204	0.045	Estimated
F_fleet_4_YR_1959_s_1	0.220	0.048	Estimated
F_fleet_4_YR_1960_s_1	0.220	0.048	Estimated
F_fleet_4_YR_1961_s_1	0.167	0.036	Estimated
F_fleet_4_YR_1962_s_1	0.161	0.035	Estimated
F_fleet_4_YR_1963_s_1	0.183	0.040	Estimated
F_fleet_4_YR_1964_s_1	0.194	0.042	Estimated
F_fleet_4_YR_1965_s_1	0.215	0.047	Estimated
F_fleet_4_YR_1966_s_1	0.212	0.046	Estimated
F_fleet_4_YR_1967_s_1	0.231	0.051	Estimated
F_fleet_4_YR_1968_s_1	0.235	0.052	Estimated
F_fleet_4_YR_1969_s_1	0.267	0.059	Estimated
F_fleet_4_YR_1970_s_1	0.252	0.055	Estimated
F_fleet_4_YR_1971_s_1	0.241	0.053	Estimated
F_fleet_4_YR_1972_s_1	0.236	0.050	Estimated
F_fleet_4_YR_1973_s_1	0.240	0.052	Estimated
F_fleet_4_YR_1974_s_1	0.240	0.052	Estimated
F_fleet_4_YR_1975_s_1	0.242	0.052	Estimated
F_fleet_4_YR_1976_s_1	0.252	0.055	Estimated
F_fleet_4_YR_1977_s_1	0.277	0.060	Estimated
F_fleet_4_YR_1978_s_1	0.294	0.064	Estimated
F_fleet_4_YR_1979_s_1	0.308	0.067	Estimated
F_fleet_4_YR_1980_s_1	0.316	0.068	Estimated
F_fleet_4_YR_1981_s_1	0.287	0.062	Estimated
F_fleet_4_YR_1982_s_1	0.273	0.058	Estimated
F_fleet_4_YR_1983_s_1	0.276	0.058	Estimated
F_fleet_4_YR_1984_s_1	0.313	0.064	Estimated

Table 16 (cont.): Estimated parameter values.

Parameter	Value	Standard Deviation	Fixed or Estimated
F_fleet_4_YR_1985_s_1	0.303	0.063	Estimated
F_fleet_4_YR_1986_s_1	0.330	0.067	Estimated
F_fleet_4_YR_1987_s_1	0.274	0.054	Estimated
F_fleet_4_YR_1988_s_1	0.251	0.050	Estimated
F_fleet_4_YR_1989_s_1	0.276	0.054	Estimated
F_fleet_4_YR_1990_s_1	0.242	0.047	Estimated
F_fleet_4_YR_1991_s_1	0.253	0.048	Estimated
F_fleet_4_YR_1992_s_1	0.319	0.059	Estimated
F_fleet_4_YR_1993_s_1	0.361	0.072	Estimated
F_fleet_4_YR_1994_s_1	0.550	0.102	Estimated
F_fleet_4_YR_1995_s_1	0.427	0.099	Estimated
F_fleet_4_YR_1996_s_1	0.402	0.085	Estimated
F_fleet_4_YR_1997_s_1	0.414	0.086	Estimated
F_fleet_4_YR_1998_s_1	0.503	0.102	Estimated
F_fleet_4_YR_1999_s_1	0.328	0.071	Estimated
F_fleet_4_YR_2000_s_1	0.263	0.054	Estimated
F_fleet_4_YR_2001_s_1	0.291	0.059	Estimated
F_fleet_4_YR_2002_s_1	0.360	0.074	Estimated
F_fleet_4_YR_2003_s_1	0.308	0.065	Estimated
F_fleet_4_YR_2004_s_1	0.284	0.057	Estimated
F_fleet_4_YR_2005_s_1	0.237	0.049	Estimated
F_fleet_4_YR_2006_s_1	0.154	0.033	Estimated
F_fleet_4_YR_2007_s_1	0.107	0.022	Estimated
F_fleet_4_YR_2008_s_1	0.076	0.016	Estimated
F_fleet_4_YR_2009_s_1	0.122	0.027	Estimated
F_fleet_4_YR_2010_s_1	0.091	0.020	Estimated
F_fleet_4_YR_2011_s_1	0.109	0.025	Estimated
F_fleet_4_YR_2012_s_1	0.097	0.022	Estimated
F_fleet_4_YR_2013_s_1	0.109	0.024	Estimated
F_fleet_4_YR_2014_s_1	0.087	0.019	Estimated
F_fleet_4_YR_2015_s_1	0.071	0.015	Estimated
F_fleet_4_YR_2016_s_1	0.073	0.016	Estimated
F_fleet_4_YR_2017_s_1	0.080	0.017	Estimated
LnQ_base_CM_E(1)	-8.912	NA	Fixed
LnQ_base_CM_W(2)	-8.559	NA	Fixed
LnQ_base_REC(3)	-9.504	NA	Fixed
LnQ_base_SMP_BYC(4)	1.387	0.088	Estimated
LnQ_base_HB_E(5)	-9.883	NA	Fixed
LnQ_base_HB_W(6)	-9.804	NA	Fixed
LnQ_base_LARVAL(7)	-26.217	NA	Fixed
LnQ_base_VIDEO(8)	-10.473	NA	Fixed
LnQ_base_SEAMAP(9)	-10.563	NA	Fixed
Retain_L_infl_CM_E(1)	10.160	NA	Fixed
Retain_L_width_CM_E(1)	0.000	NA	Fixed
Retain_L_asymptote_logit_CM_E(1)	10.000	NA	Fixed
Retain_L_maleoffset_CM_E(1)	0.000	NA	Fixed
DiscMort_L_infl_CM_E(1)	-5.000	NA	Fixed
DiscMort_L_width_CM_E(1)	0.000	NA	Fixed
DiscMort_L_level_old_CM_E(1)	0.150	NA	Fixed
DiscMort_L_male_offset_CM_E(1)	0.000	NA	Fixed

Table 16 (cont.): Estimated parameter values.

Parameter	Value	Standard Deviation	Fixed or Estimated
Retain_L_infl_CM_W(2)	10.160	NA	Fixed
Retain_L_width_CM_W(2)	0.000	NA	Fixed
Retain_L_asymptote_logit_CM_W(2)	10.000	NA	Fixed
Retain_L_maleoffset_CM_W(2)	0.000	NA	Fixed
DiscMort_L_infl_CM_W(2)	-5.000	NA	Fixed
DiscMort_L_width_CM_W(2)	0.000	NA	Fixed
DiscMort_L_level_old_CM_W(2)	0.150	NA	Fixed
DiscMort_L_male_offset_CM_W(2)	0.000	NA	Fixed
Retain_L_infl_REC(3)	10.160	NA	Fixed
Retain_L_width_REC(3)	0.000	NA	Fixed
Retain_L_asymptote_logit_REC(3)	10.000	NA	Fixed
Retain_L_maleoffset_REC(3)	0.000	NA	Fixed
DiscMort_L_infl_REC(3)	-5.000	NA	Fixed
DiscMort_L_width_REC(3)	0.000	NA	Fixed
DiscMort_L_level_old_REC(3)	0.150	NA	Fixed
DiscMort_L_male_offset_REC(3)	0.000	NA	Fixed
Size_DblN_peak_VIDEO(8)	19.229	25.397	Estimated
Size_DblN_top_logit_VIDEO(8)	-1.575	28.424	Estimated
Size_DblN_ascend_se_VIDEO(8)	1.103	29.374	Estimated
Size_DblN_descend_se_VIDEO(8)	1.306	97.771	Estimated
Size_DblN_start_logit_VIDEO(8)	-1.483	0.154	Estimated
Size_DblN_end_logit_VIDEO(8)	0.596	0.461	Estimated
Size_DblN_peak_SEAMAP(9)	14.774	30.615	Estimated
Size_DblN_top_logit_SEAMAP(9)	-4.090	50.082	Estimated
Size_DblN_ascend_se_SEAMAP(9)	1.277	26.924	Estimated
Size_DblN_descend_se_SEAMAP(9)	3.140	0.304	Estimated
Size_DblN_start_logit_SEAMAP(9)	-1.223	0.307	Estimated
Size_DblN_end_logit_SEAMAP(9)	-5.290	2.303	Estimated
Age_inflection_CM_E(1)	2.120	0.056	Estimated
Age_95%width_CM_E(1)	0.916	0.129	Estimated
Age_inflection_CM_W(2)	3.681	0.135	Estimated
Age_95%width_CM_W(2)	2.097	0.186	Estimated
Age_DblN_peak_REC(12)	3.333	0.185	Estimated
Age_DblN_top_logit_REC(12)	-9.164	19.799	Estimated
Age_DblN_ascend_se_REC(12)	0.550	0.245	Estimated
Age_DblN_descend_se_REC(12)	2.953	0.337	Estimated
Age_DblN_start_logit_REC(12)	-12.110	49.342	Estimated
Age_DblN_end_logit_REC(12)	-1.827	0.621	Estimated
AgeSel_P1_SMP_BYC(4)	0.500	NA	Fixed
AgeSel_P2_SMP_BYC(4)	100.000	NA	Fixed
AgeSel_P3_SMP_BYC(4)	1.500	NA	Fixed
AgeSel_P4_SMP_BYC(4)	2.410	NA	Fixed
AgeSel_P5_SMP_BYC(4)	0.000	NA	Fixed
AgeSel_P6_SMP_BYC(4)	0.000	NA	Fixed

Table 16 (cont.): Estimated parameter values.

Parameter	Value	Standard Deviation	Fixed or Estimated
Retain_L_infl_CM_E(1)_BLK1repl_1990	20.320	NA	Fixed
Retain_L_infl_CM_E(1)_BLK1repl_2005	27.940	NA	Fixed
Retain_L_infl_CM_E(1)_BLK1repl_2008	25.400	NA	Fixed
Retain_L_asymptote_logit_CM_E(1)_BLK1repl_1990	10.000	NA	Fixed
Retain_L_asymptote_logit_CM_E(1)_BLK1repl_2005	10.000	NA	Fixed
Retain_L_asymptote_logit_CM_E(1)_BLK1repl_2008	10.000	NA	Fixed
DiscMort_L_level_old_CM_E(1)_BLK3repl_2008	0.150	NA	Fixed
Retain_L_infl_CM_W(2)_BLK1repl_1990	20.320	NA	Fixed
Retain_L_infl_CM_W(2)_BLK1repl_2005	27.940	NA	Fixed
Retain_L_infl_CM_W(2)_BLK1repl_2008	25.400	NA	Fixed
Retain_L_asymptote_logit_CM_W(2)_BLK1repl_1990	10.000	NA	Fixed
Retain_L_asymptote_logit_CM_W(2)_BLK1repl_2005	10.000	NA	Fixed
Retain_L_asymptote_logit_CM_W(2)_BLK1repl_2008	10.000	NA	Fixed
DiscMort_L_level_old_CM_W(2)_BLK3repl_2008	0.150	NA	Fixed
Retain_L_infl_REC(3)_BLK2repl_1990	20.320	NA	Fixed
Retain_L_infl_REC(3)_BLK2repl_1997	25.400	NA	Fixed
Retain_L_infl_REC(3)_BLK2repl_2005	27.940	NA	Fixed
Retain_L_infl_REC(3)_BLK2repl_2008	25.400	NA	Fixed
Retain_L_asymptote_logit_REC(3)_BLK2repl_1990	10.000	NA	Fixed
Retain_L_asymptote_logit_REC(3)_BLK2repl_1997	10.000	NA	Fixed
Retain_L_asymptote_logit_REC(3)_BLK2repl_2005	10.000	NA	Fixed
Retain_L_asymptote_logit_REC(3)_BLK2repl_2008	10.000	NA	Fixed
DiscMort_L_level_old_REC(3)_BLK3repl_2008	0.150	NA	Fixed

Table 17: Model estimated apical fishing mortality by fleet and total harvest rate (number killed/exploitable number).

Year	Commercial East	Commercial West	Recreational	Shrimp Bycatch	Harvest Rate
1950	0.000	0.000	0.000	0.050	0.012
1951	0.000	0.000	0.000	0.068	0.016
1952	0.000	0.000	0.001	0.080	0.019
1953	0.000	0.000	0.001	0.084	0.021
1954	0.000	0.000	0.001	0.109	0.027
1955	0.000	0.000	0.002	0.114	0.028
1956	0.000	0.000	0.002	0.146	0.036
1957	0.000	0.000	0.002	0.167	0.041
1958	0.000	0.000	0.002	0.204	0.050
1959	0.000	0.000	0.003	0.220	0.054
1960	0.000	0.000	0.003	0.220	0.055
1961	0.000	0.000	0.004	0.167	0.044
1962	0.001	0.000	0.004	0.161	0.043
1963	0.001	0.001	0.004	0.183	0.048
1964	0.001	0.001	0.005	0.194	0.051
1965	0.001	0.000	0.005	0.215	0.056
1966	0.000	0.000	0.005	0.212	0.056
1967	0.001	0.000	0.006	0.231	0.061
1968	0.001	0.001	0.006	0.235	0.063
1969	0.002	0.001	0.007	0.267	0.071
1970	0.002	0.001	0.007	0.252	0.069
1971	0.002	0.001	0.008	0.241	0.067
1972	0.002	0.001	0.008	0.236	0.066
1973	0.003	0.001	0.008	0.240	0.068
1974	0.003	0.002	0.009	0.240	0.069
1975	0.006	0.003	0.009	0.242	0.072
1976	0.005	0.002	0.010	0.252	0.074
1977	0.008	0.005	0.010	0.277	0.083
1978	0.007	0.005	0.011	0.294	0.087
1979	0.005	0.006	0.011	0.308	0.091
1980	0.004	0.004	0.012	0.316	0.092
1981	0.006	0.003	0.012	0.287	0.086
1982	0.006	0.004	0.028	0.273	0.090
1983	0.009	0.005	0.011	0.276	0.087
1984	0.014	0.027	0.017	0.313	0.108
1985	0.018	0.024	0.033	0.303	0.114
1986	0.019	0.032	0.047	0.330	0.130

Table 17 (cont.): Model estimated fishing mortality rates.

Year	Commercial East	Commercial West	Recreational	Shrimp Bycatch	Harvest Rate
1987	0.016	0.037	0.060	0.274	0.122
1988	0.015	0.039	0.092	0.251	0.128
1989	0.016	0.042	0.051	0.276	0.122
1990	0.039	0.043	0.070	0.242	0.124
1991	0.033	0.038	0.091	0.253	0.130
1992	0.045	0.053	0.116	0.319	0.164
1993	0.067	0.055	0.090	0.361	0.177
1994	0.069	0.060	0.080	0.550	0.225
1995	0.072	0.041	0.118	0.427	0.189
1996	0.061	0.044	0.050	0.402	0.173
1997	0.061	0.080	0.091	0.414	0.193
1998	0.051	0.073	0.049	0.503	0.206
1999	0.063	0.098	0.098	0.328	0.176
2000	0.050	0.073	0.058	0.263	0.151
2001	0.056	0.090	0.149	0.291	0.171
2002	0.065	0.101	0.119	0.360	0.190
2003	0.073	0.123	0.109	0.308	0.179
2004	0.058	0.115	0.109	0.284	0.167
2005	0.085	0.105	0.134	0.237	0.129
2006	0.091	0.070	0.126	0.154	0.103
2007	0.092	0.126	0.122	0.107	0.093
2008	0.103	0.086	0.058	0.076	0.085
2009	0.152	0.080	0.083	0.122	0.124
2010	0.073	0.061	0.061	0.091	0.084
2011	0.142	0.057	0.147	0.109	0.132
2012	0.102	0.073	0.114	0.097	0.103
2013	0.059	0.045	0.198	0.109	0.105
2014	0.066	0.059	0.176	0.087	0.097
2015	0.035	0.057	0.136	0.071	0.077
2016	0.038	0.056	0.123	0.073	0.073
2017	0.038	0.043	0.141	0.080	0.076

Table 18: Model estimated biomass (metric tons), spawning stock biomass (number of eggs), abundance (1000s of fish), age-0 recruitment (1000s of fish), and depletion level compared to virgin conditions (SSB/SSB_0).

Year	Biomass (mt)	Spawning Output (# Eggs)	Abundance (1000s)	Recruits (1000s)	Depletion (SSB/SSB0)
1950	34,570	6.74E+14	94,019	27,366	1.00
1951	34,378	6.70E+14	93,078	27,351	0.99
1952	34,084	6.65E+14	92,025	27,328	0.99
1953	33,722	6.58E+14	90,973	27,298	0.98
1954	33,340	6.50E+14	90,051	27,265	0.96
1955	32,884	6.41E+14	88,860	27,226	0.95
1956	32,424	6.32E+14	87,820	27,185	0.94
1957	31,884	6.22E+14	86,434	27,135	0.92
1958	31,297	6.10E+14	84,979	27,080	0.91
1959	30,619	5.97E+14	83,215	27,013	0.89
1960	29,918	5.83E+14	81,563	26,942	0.87
1961	29,258	5.70E+14	80,220	26,871	0.85
1962	28,814	5.61E+14	79,916	26,820	0.83
1963	28,475	5.54E+14	79,667	26,780	0.82
1964	28,137	5.47E+14	79,054	26,740	0.81
1965	27,809	5.41E+14	78,383	26,701	0.80
1966	27,451	5.34E+14	77,505	26,658	0.79
1967	27,136	5.28E+14	76,868	26,619	0.78
1968	26,779	5.21E+14	76,024	26,574	0.77
1969	26,403	5.13E+14	75,231	26,525	0.76
1970	25,965	5.05E+14	74,102	26,467	0.75
1971	25,587	4.97E+14	73,408	26,415	0.74
1972	25,272	4.91E+14	72,955	26,370	0.73
1973	25,018	4.86E+14	72,622	26,333	0.72
1974	24,765	4.81E+14	72,208	26,295	0.71
1975	24,543	4.76E+14	71,851	26,262	0.71
1976	24,262	4.70E+14	71,362	26,219	0.70
1977	24,020	4.66E+14	70,855	26,181	0.69
1978	23,636	4.58E+14	69,924	26,121	0.68
1979	23,264	4.51E+14	68,995	26,061	0.67
1980	22,877	4.43E+14	68,057	25,997	0.66
1981	22,547	4.37E+14	67,282	25,940	0.65
1982	22,294	4.32E+14	66,991	25,895	0.64
1983	21,931	4.24E+14	66,516	25,829	0.63
1984	21,744	4.21E+14	66,297	25,793	0.62
1985	21,080	4.07E+14	64,895	25,667	0.60

Table 18 (cont.): Model estimated population parameters.

Year	Biomass (mt)	Spawning Output (# Eggs)	Abundance (1000s)	Recruits (1000s)	Depletion (SSB/SSB0)
1986	20,332	3.93E+14	63,496	25,515	0.58
1987	19,370	3.73E+14	61,502	25,306	0.55
1988	18,574	3.58E+14	60,381	25,117	0.53
1989	17,713	3.40E+14	59,106	24,895	0.50
1990	17,302	3.32E+14	58,370	24,784	0.49
1991	16,744	3.21E+14	57,648	24,623	0.48
1992	16,235	3.11E+14	56,706	24,470	0.46
1993	15,259	2.91E+14	54,330	24,158	0.43
1994	14,308	2.73E+14	51,953	14,074	0.41
1995	12,578	2.42E+14	40,466	17,531	0.36
1996	11,281	2.16E+14	38,177	17,207	0.32
1997	10,631	2.03E+14	36,940	18,143	0.30
1998	9,852	1.88E+14	36,215	16,030	0.28
1999	9,284	1.77E+14	33,675	27,218	0.26
2000	9,392	1.76E+14	41,877	24,812	0.26
2001	10,121	1.89E+14	45,428	24,633	0.28
2002	10,479	1.96E+14	46,763	23,866	0.29
2003	10,637	1.99E+14	46,261	23,846	0.30
2004	10,727	2.01E+14	46,421	18,283	0.30
2005	10,625	2.01E+14	42,616	20,890	0.30
2006	10,960	2.07E+14	43,903	26,356	0.31
2007	11,794	2.22E+14	49,977	17,269	0.33
2008	12,175	2.31E+14	47,083	16,113	0.34
2009	12,294	2.34E+14	44,816	13,679	0.35
2010	11,530	2.21E+14	39,977	18,257	0.33
2011	11,629	2.22E+14	41,921	25,265	0.33
2012	11,348	2.14E+14	46,895	27,911	0.32
2013	12,036	2.25E+14	53,018	24,603	0.33
2014	12,761	2.40E+14	54,300	29,042	0.36
2015	13,733	2.57E+14	59,160	52,719	0.38
2016	16,468	3.04E+14	82,095	35,228	0.45
2017	18,868	3.53E+14	83,617	21,237	0.52

Table 19: Model estimated correlation coefficients for correlations above 0.90.

Parameter 1	Parameter 2	Correlation Coefficient
Size_DblN_ascend_se_VIDEO(8)	Size_DblN_peak_VIDEO(8)	0.999983
Size_DblN_descend_se_VIDEO(8)	Size_DblN_top_logit_VIDEO(8)	-0.987138
Size_DblN_top_logit_SEAMAP(9)	Size_DblN_peak_SEAMAP(9)	-0.999564
Size_DblN_ascend_se_SEAMAP(9)	Size_DblN_peak_SEAMAP(9)	0.999964
Size_DblN_ascend_se_SEAMAP(9)	Size_DblN_top_logit_SEAMAP(9)	-0.999491
Age_DblN_ascend_se_REC(12)	Age_DblN_peak_REC(12)	0.942607

Table 20: Likelihood comparisons across various model building runs that either use the continuity (Mississippi Labs only) or combined video index, incorporate (using various coefficients of variation to weight the model fit to discard data) or do not incorporate discards, or include discards but do not fit the observed discard values (i.e., give no emphasis to the discard data; -LL = 0 for discard data). Given the different data inputs to each model, the likelihood values are not directly comparable. However, the comparison across models demonstrates the difficulties that result from trying to fit discard observations and the inconsistencies among data observations (i.e., tradeoffs in model fit for each data source). Fitting the discard data results in severely reduced fit to the landings data (believed to be one of the most reliable model inputs) as well as the age composition data from the landings.

Likelihood Components	Continuity Model No Discards	Continuity with Discards (CV = 0.3)	Continuity with Discards (-LL = 0)	Combined Video No Discards	Combined Video with Discards (CV = 0.3)	Combined Video with Discards (CV = 0.5)	Combined Video with Discards (-LL = 0)	Base
Total	314.13	2210.52	305.81	351.10	1896.62	963.44	349.50	359.70
Catch	3.68	130.18	3.23	4.07	121.16	22.83	3.32	3.73
Survey	-23.17	-46.28	-30.45	26.52	-6.43	-4.08	18.51	21.40
Discard	-1.06	1587.75	-1.77	-0.87	1309.49	590.87	-1.82	-1.72
Length Composition	92.28	101.57	98.39	84.39	81.87	86.58	88.59	88.45
Age Composition	254.69	446.98	257.68	250.27	395.90	272.95	254.79	260.72
Recruitment	-12.42	-10.04	-21.43	-13.77	-5.75	-6.23	-14.91	-13.88
Parameter Bounds	0.02	0.01	0.02	0.01	0.02	0.01	0.01	0.01

Table 21: Settings used for vermilion snapper projections and forecasts.

Parameter	Value	Comment
Relative F	Average from 2015 – 2017	Average relative fishing mortality over terminal three years (2015-2017) of model
Selectivity and retention	Estimates from 2017	Fleet specific selectivity estimated in terminal year
Recruitment	21,965,800	Mean recruitment (2005 – 2014)Time-invariant in projections
Shrimp Bycatch	F = 0.075	Average shrimp bycatch fishing mortality over terminal three years (2015-2017) of model Time-invariant in projections
2018 Landings	4,840,039 lbs. WW	Finalized Landings (SEFSC)
2019 Landings	4,366,021 lbs. WW	Three year (2016 – 2018) average
2020 Landings	4,366,021 lbs. WW	Three year (2016 – 2018) average

Table 22: Summary of MSRA benchmarks and reference points for the Gulf of Mexico vermilion snapper SEDAR 67 assessment. Note that SSB values are in number of eggs and fishing mortality is presented as a harvest rates (number killed / abundance).

Criteria	Definition	SEDAR 67 Value
Base M	Fully selected ages of Lorenzen M	0.25
Steepness	Estimated SR parameter (not used in projections)	0.713
Virgin Recruitment	Estimated SR parameter (not used in projections)	2.73E+07
Generation Time	Fecundity-weighted mean age	7.23
SSB Unfished	Estimated virgin population egg production	6.73E+14
	Mortality Rate Criteria	
$F_{SPR30\%}$	Equilibrium F that achieves $SPR_{30\%}$	0.135
MFMT $F_{SPR30\%}$	$F_{SPR30\%}$	0.135
F at Optimum Yield	0.75 * Directed F at $F_{SPR30\%}$	0.115
$F_{Current}$	F_{2017}	0.076
$F_{Current}/MFMT_{FSPR30\%}$	Current stock status based on $F_{SPR30\%}$	0.56
	Biomass Criteria	
$SSB_{FSPR30\%}$	Equilibrium SSB at $F_{SPR30\%}$	2.02E+14
$MSST_{FSPR30\%}$	$(0.5)*SSB_{FSPR30\%}$	1.01E+14
SSB at Optimum Yield	Equilibrium SSB when Directed F = 0.75 * Directed F at $F_{SPR30\%}$	2.32E+14
SSB_0	Virgin SSB	6.73E+14
$SSB_{Current}$	SSB_{2017}	3.53E+14
$SSB_{Current}/ SSB_{FSPR30\%}$	Current stock status based on $SSB_{FSPR30\%}$	1.75
$SSB_{Current}/ MSST_{FSPR30\%}$	Current stock status based on $MSST_{FSPR30\%}$	3.5
$SSB_{Current}/ SSB_0$	2017 SPR	0.52

Table 23: Time series of fishing mortality and SSB relative to associated SPR based biological reference points (i.e., $F_{SPR30\%}$ and $SSB_{FSPR30\%}$). $MSST_{FSPR30\%}$ is calculated as 0.5 * $SSB_{FSPR30\%}$. SPR was calculated as annual SSB divided by SSB_0 (6.73E+14 eggs).

YEAR	F	F/FSPR30%	SSB	SSB/$SSB_{FSPR30\%}$	SSB/$MSST_{FSPR30\%}$	SPR
1950	0.01	0.09	6.73E+14	3.33	6.67	1.00
1951	0.02	0.12	6.69E+14	3.32	6.63	0.99
1952	0.02	0.14	6.63E+14	3.29	6.58	0.99
1953	0.02	0.15	6.56E+14	3.25	6.51	0.98
1954	0.03	0.20	6.49E+14	3.22	6.43	0.96
1955	0.03	0.21	6.40E+14	3.17	6.35	0.95
1956	0.04	0.26	6.31E+14	3.13	6.26	0.94
1957	0.04	0.30	6.21E+14	3.08	6.15	0.92
1958	0.05	0.37	6.09E+14	3.02	6.04	0.91
1959	0.05	0.40	5.96E+14	2.95	5.91	0.89
1960	0.05	0.41	5.82E+14	2.89	5.77	0.87
1961	0.04	0.32	5.69E+14	2.82	5.64	0.85
1962	0.04	0.32	5.60E+14	2.78	5.55	0.83
1963	0.05	0.36	5.53E+14	2.74	5.49	0.82
1964	0.05	0.38	5.47E+14	2.71	5.42	0.81
1965	0.06	0.42	5.40E+14	2.68	5.35	0.80
1966	0.06	0.41	5.33E+14	2.64	5.29	0.79
1967	0.06	0.45	5.27E+14	2.61	5.22	0.78
1968	0.06	0.47	5.20E+14	2.58	5.15	0.77
1969	0.07	0.53	5.13E+14	2.54	5.08	0.76
1970	0.07	0.51	5.04E+14	2.50	5.00	0.75
1971	0.07	0.50	4.97E+14	2.46	4.92	0.74
1972	0.07	0.49	4.90E+14	2.43	4.86	0.73
1973	0.07	0.51	4.85E+14	2.40	4.81	0.72
1974	0.07	0.51	4.80E+14	2.38	4.76	0.71
1975	0.07	0.53	4.76E+14	2.36	4.72	0.71
1976	0.07	0.55	4.70E+14	2.33	4.66	0.70
1977	0.08	0.61	4.65E+14	2.31	4.61	0.69
1978	0.09	0.64	4.58E+14	2.27	4.54	0.68
1979	0.09	0.67	4.50E+14	2.23	4.47	0.67
1980	0.09	0.68	4.43E+14	2.20	4.39	0.66

Table 23 (cont.): Time series of stock status.

YEAR	F	F/FSPR30%	SSB	SSB/SSB$_{FSPR30\%}$	SSB/MSST$_{FSPR30\%}$	SPR
1981	0.09	0.64	4.36E+14	2.16	4.33	0.65
1982	0.09	0.67	4.31E+14	2.14	4.28	0.64
1983	0.09	0.64	4.24E+14	2.10	4.20	0.63
1984	0.11	0.80	4.20E+14	2.08	4.17	0.62
1985	0.11	0.84	4.07E+14	2.02	4.04	0.61
1986	0.13	0.96	3.92E+14	1.94	3.89	0.58
1987	0.12	0.90	3.73E+14	1.85	3.70	0.56
1988	0.13	0.95	3.57E+14	1.77	3.54	0.53
1989	0.12	0.90	3.40E+14	1.69	3.37	0.51
1990	0.12	0.92	3.32E+14	1.65	3.29	0.49
1991	0.13	0.97	3.21E+14	1.59	3.18	0.48
1992	0.16	1.21	3.11E+14	1.54	3.08	0.46
1993	0.18	1.31	2.91E+14	1.44	2.89	0.43
1994	0.22	1.67	2.73E+14	1.35	2.71	0.41
1995	0.19	1.40	2.42E+14	1.20	2.40	0.36
1996	0.17	1.28	2.16E+14	1.07	2.14	0.32
1997	0.19	1.43	2.03E+14	1.01	2.02	0.30
1998	0.21	1.52	1.88E+14	0.93	1.86	0.28
1999	0.18	1.30	1.77E+14	0.88	1.75	0.26
2000	0.15	1.12	1.76E+14	0.87	1.74	0.26
2001	0.17	1.27	1.89E+14	0.94	1.87	0.28
2002	0.19	1.41	1.96E+14	0.97	1.94	0.29
2003	0.18	1.33	1.99E+14	0.99	1.98	0.30
2004	0.17	1.23	2.01E+14	1.00	1.99	0.30
2005	0.13	0.96	2.01E+14	0.99	1.99	0.30
2006	0.10	0.77	2.07E+14	1.03	2.05	0.31
2007	0.09	0.69	2.22E+14	1.10	2.20	0.33
2008	0.09	0.63	2.31E+14	1.14	2.29	0.34
2009	0.12	0.92	2.34E+14	1.16	2.32	0.35
2010	0.08	0.62	2.21E+14	1.09	2.19	0.33
2011	0.13	0.98	2.22E+14	1.10	2.20	0.33
2012	0.10	0.77	2.14E+14	1.06	2.12	0.32
2013	0.10	0.78	2.26E+14	1.12	2.24	0.34
2014	0.10	0.72	2.40E+14	1.19	2.38	0.36
2015	0.08	0.57	2.58E+14	1.28	2.55	0.38
2016	0.07	0.54	3.04E+14	1.51	3.02	0.45
2017	0.08	0.56	3.53E+14	1.75	3.50	0.52

Table 24: Results of projections at $F_{SPR30\%}$ including recruitment (R in number of fish), fishing mortality (F), F/MFMT (MFMT = $F_{SPR30\%}$), spawning biomass (SSB in eggs), $SSB/SSB_{FSPR30\%}$, $SSB/MSST_{FSPR30\%}$, SSB/SSB_0, overfishing limit (OFL; retained yield in millions of pounds that achieves SPR 30% in equilibrium), and acceptable biological catch (ABC; retained yield in millions of pounds based on P* of 0.398).

YEAR	R	F	F/MFMT	SSB	$SSB/SSB_{FSPR30\%}$	SSB/MSST	SSB/SSB_0	OFL	ABC
2021	21965.8	0.167	1.239	3.73E+14	1.85	3.70	0.55	12.03	11.73
2022	21965.8	0.153	1.139	3.09E+14	1.53	3.06	0.46	9.45	9.25
2023	21965.8	0.145	1.073	2.68E+14	1.33	2.66	0.40	7.90	7.77
2024	21965.8	0.140	1.037	2.43E+14	1.21	2.41	0.36	7.04	6.94
2025	21965.8	0.137	1.019	2.28E+14	1.13	2.26	0.34	6.57	6.48
2026	21965.8	0.136	1.010	2.19E+14	1.09	2.17	0.33	6.31	6.22
2027	21965.8	0.136	1.006	2.13E+14	1.06	2.11	0.32	6.16	6.07
2028	21965.8	0.135	1.003	2.09E+14	1.04	2.07	0.31	6.07	5.98
2029	21965.8	0.135	1.002	2.07E+14	1.02	2.05	0.31	6.01	5.93
2030	21965.8	0.135	1.001	2.05E+14	1.02	2.03	0.30	5.97	5.89

Table 25: Results of projections at optimum yield (directed F = 0.75*Directed F at $F_{SPR30\%}$) including recruitment (R in number of fish), fishing mortality (F), F/MFMT (MFMT = $F_{SPR30\%}$), spawning biomass (SSB in eggs), SSB/$SSB_{FSPR30\%}$, SSB/$MSST_{FSPR30\%}$, SSB/SSB_0, and optimum yield (OY; retained yield in millions of pounds).

YEAR	R	F	F/MFMT	SSB	SSB/$SSB_{FSPR30\%}$	SSB/MSST	SSB/SSB_0	OY
2021	21965.8	0.134	0.997	3.73E+14	1.85	3.70	0.55	9.37
2022	21965.8	0.127	0.940	3.28E+14	1.62	3.25	0.49	7.87
2023	21965.8	0.121	0.901	2.96E+14	1.47	2.94	0.44	6.89
2024	21965.8	0.118	0.878	2.75E+14	1.36	2.73	0.41	6.29
2025	21965.8	0.117	0.867	2.61E+14	1.30	2.59	0.39	5.95
2026	21965.8	0.116	0.861	2.52E+14	1.25	2.50	0.37	5.74
2027	21965.8	0.116	0.858	2.46E+14	1.22	2.44	0.37	5.62
2028	21965.8	0.115	0.857	2.42E+14	1.20	2.40	0.36	5.54
2029	21965.8	0.115	0.856	2.39E+14	1.18	2.37	0.35	5.48
2030	21965.8	0.115	0.855	2.37E+14	1.17	2.34	0.35	5.45

Table 26: Summary of projections at $F_{SPR30\%}$ completed using the original SEDAR 45 base model, the SEDAR 45 base model with the recreational data updated to the FES values, and the SEDAR 67 base model. Shown are the terminal data year of each assessment, average (2004 – 2014) spawning stock biomass (SSB in eggs), average (2004 – 2014) recruitment (R in number of fish), $F_{SPR30\%}$ (MFMT), virgin spawning biomass (SSB_0 in eggs), $SSB_{FSPR30\%}$, and equilibrium yield (retained yield in millions of pounds).

Model	Terminal Year	SSB	R	F_{SPR30}	SSB_0	SSB_{FSPR30}	Equil. Yield
SEDAR 45	2014	1.91E+14	17343.3	0.103	6.56E+14	1.97E+14	3.35
SEDAR 45 FES	2014	2.28E+14	22561.0	0.14	6.51E+14	1.96E+14	5.19
SEDAR 67 Base	2017	2.22E+14	21965.8	0.135	6.73E+14	2.02E+14	5.91

9. Figures

Figure 1: Model domain and area designations used to delineate commercially exploited stocks of vermilion snapper. A single population of vermilion snapper is assumed across the Gulf of Mexico in the assessment model, but the commercial fleet is assumed to have differing dynamics by region (the eastern fleet is represented by areas 1-12 and the western fleet is represented by areas 13-21).

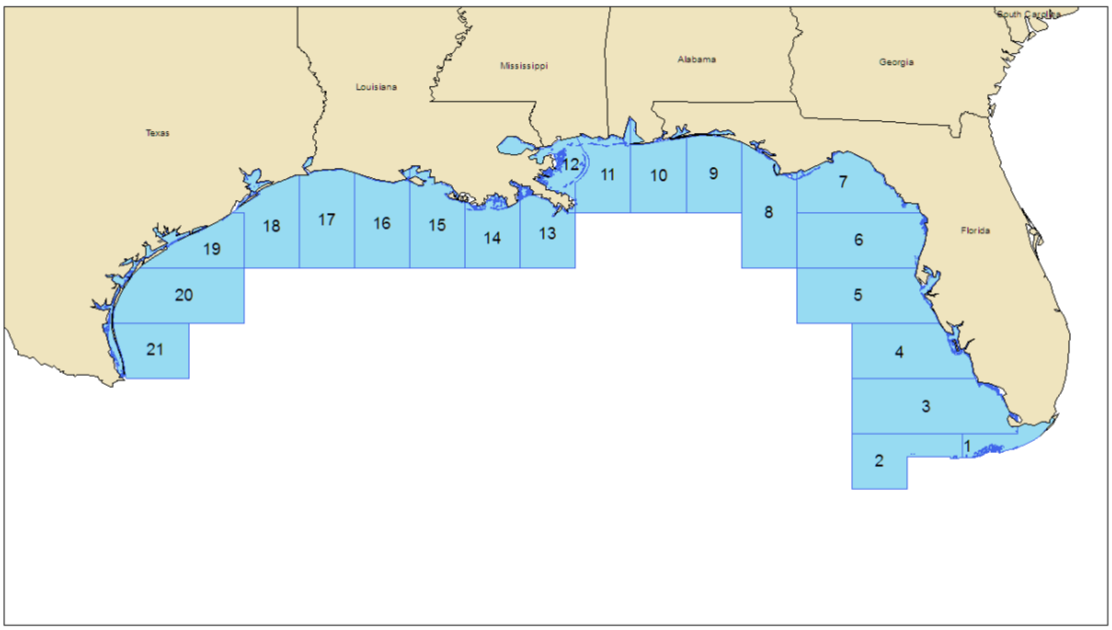


Figure 2: Observed and predicted growth. Observations (red dots) are based on a sample size of 47,343 age-length pairings including both fishery-dependent and independent samples from 1994-2014 (based on work from SEDAR 45 that was not updated in SEDAR 67). A size modified von Bertalanffy growth model (blue line) was fit to the data assuming constant coefficient of variation with age, which accounted for minimum size limits in the fishery to adjust the lower end of the growth curve and allowed variation in size at age (95% confidence intervals are represented by light blue shading). See Table 2 for parameter values.

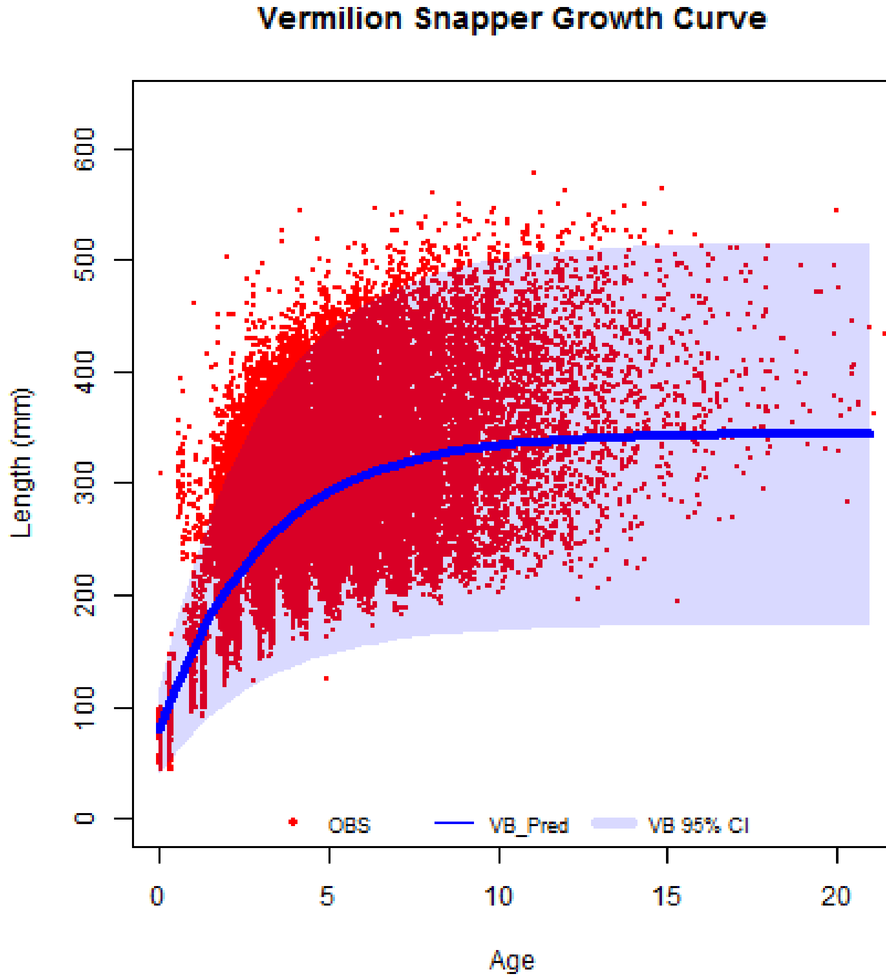
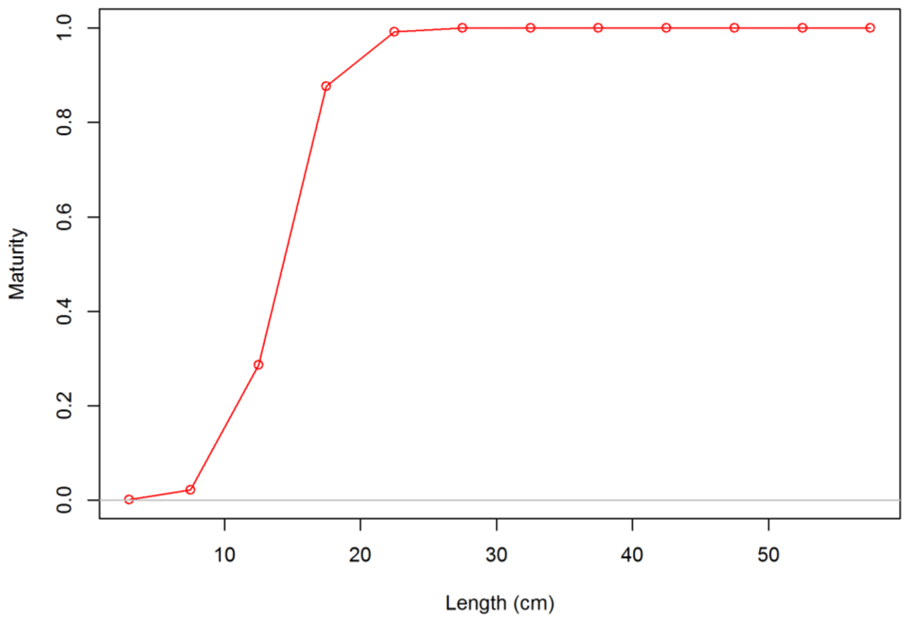


Figure 3: Maturity (top panel) and fecundity (bottom panel). A length logistic function is used to model maturity at length and fecundity (spawning output is in total eggs produced) assumes a power function (see Table 2 for parameter values). The assessment model assumes that no fish younger than age-1 are mature regardless of length.



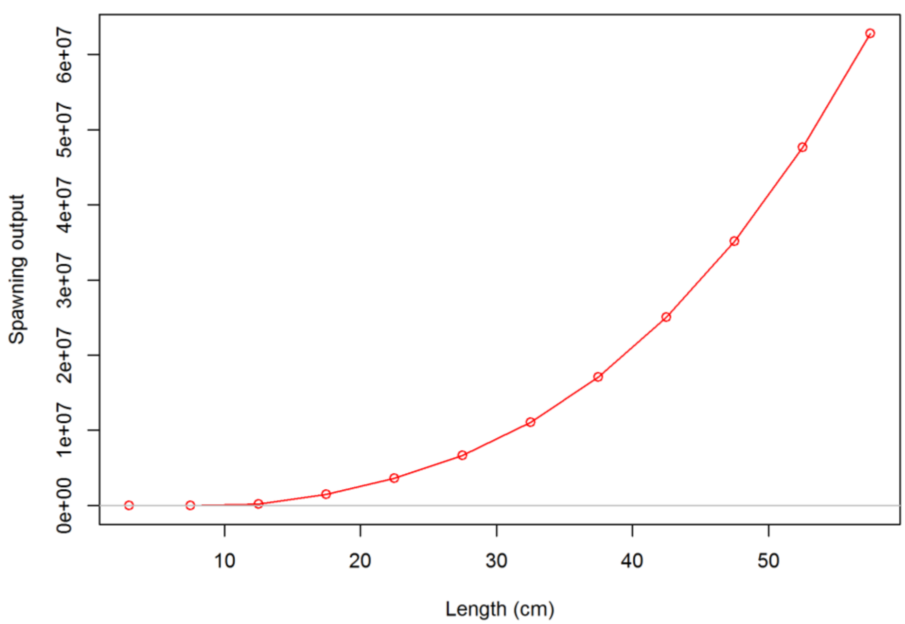


Figure 4: Natural mortality rate (M) by age. The Lorenzen curve is used to calculate age-varying natural mortality with a target rate of 0.25.

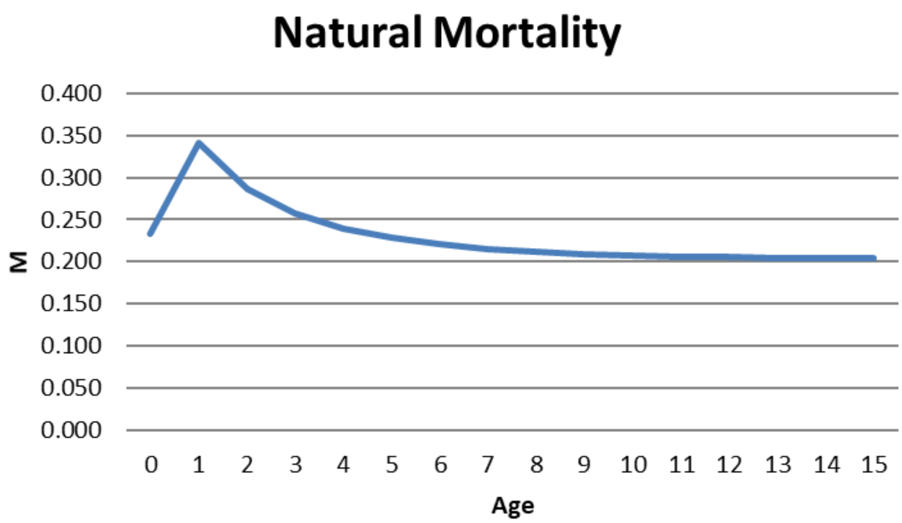


Figure 5: Final SEDAR 67 commercial landings in metric tons (mt) by region (red lines). Minor QA/QC adjustments have been made since the SEDAR 45 assessment (blue lines). The eastern area (top panel) typically supports higher landings than the western area (bottom panel).

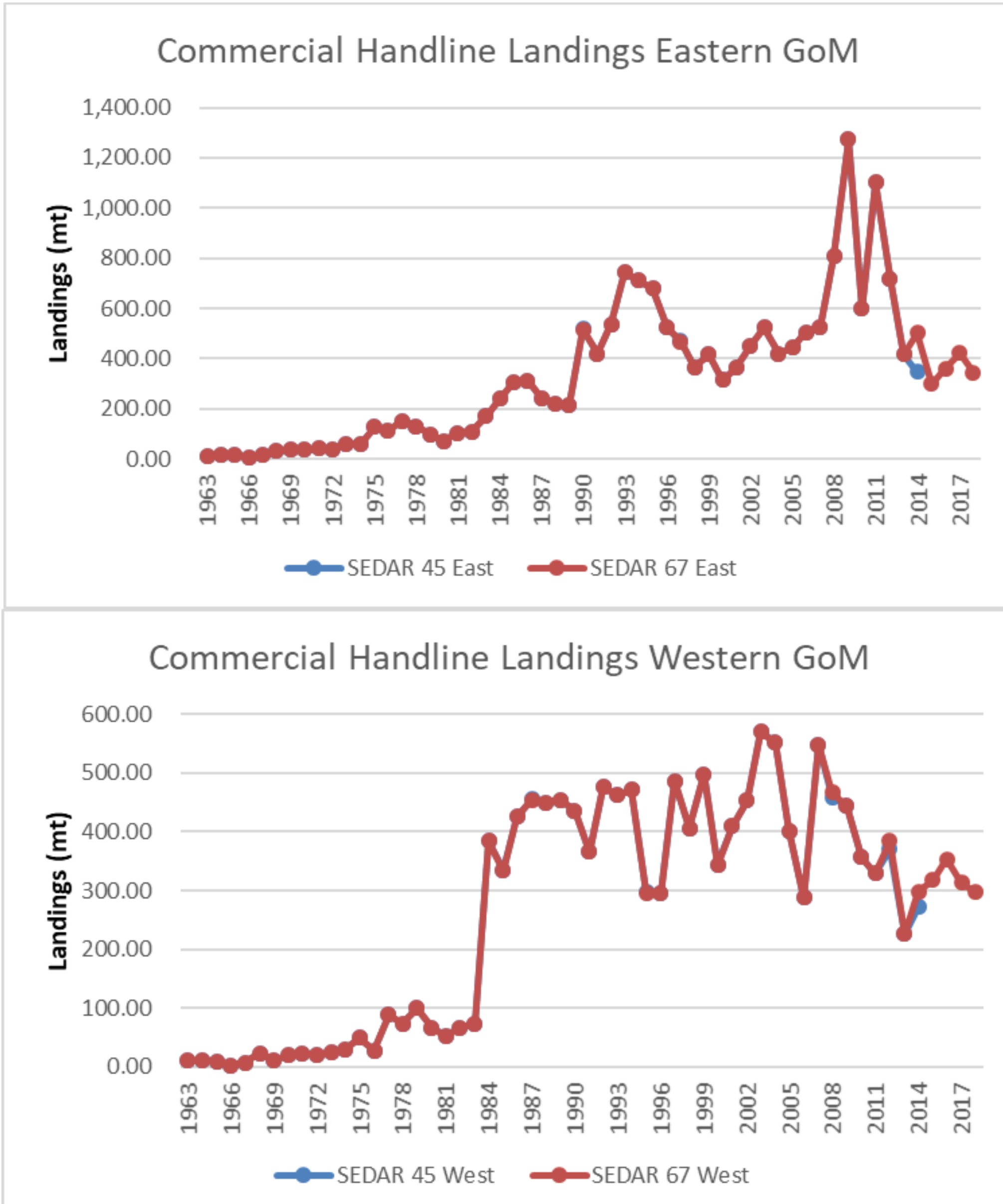
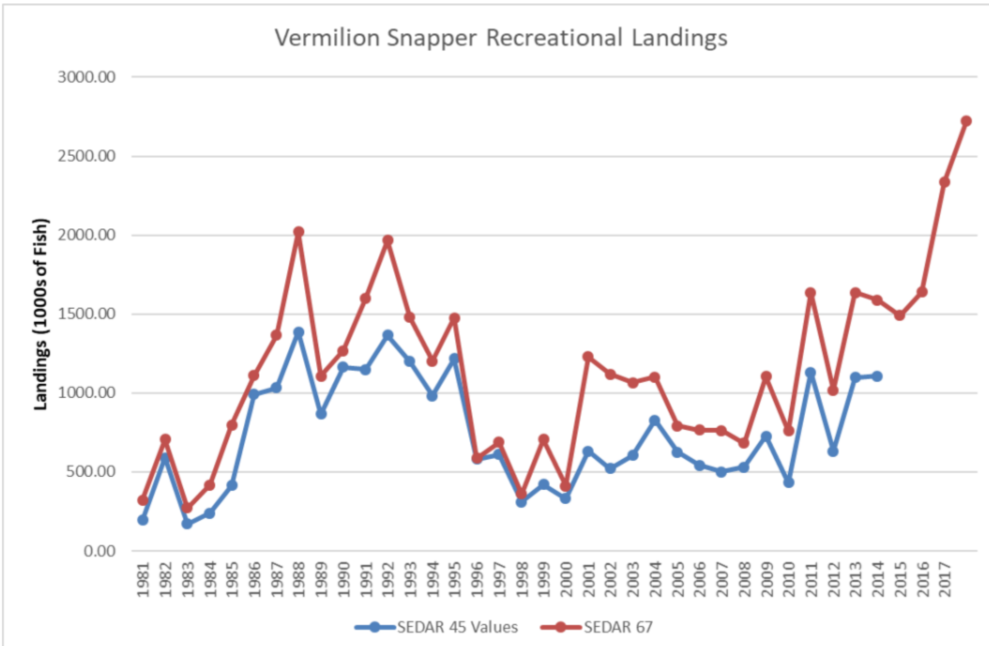


Figure 6: Final SEDAR 67 total recreational landings (red line, top panel) and landings by area (bottom panel) in number of fish. Due to the FES adjustment to the recreational catch, the recreational landings stream has greatly increased since SEDAR 45 (red line, top panel). A majority of the recreational fishery occurs in the eastern area (blue line, bottom panel). Due to comparatively low catches and limited length and age sampling in the western area, a single combined gulf-wide recreational fleet was modeled in the assessment.



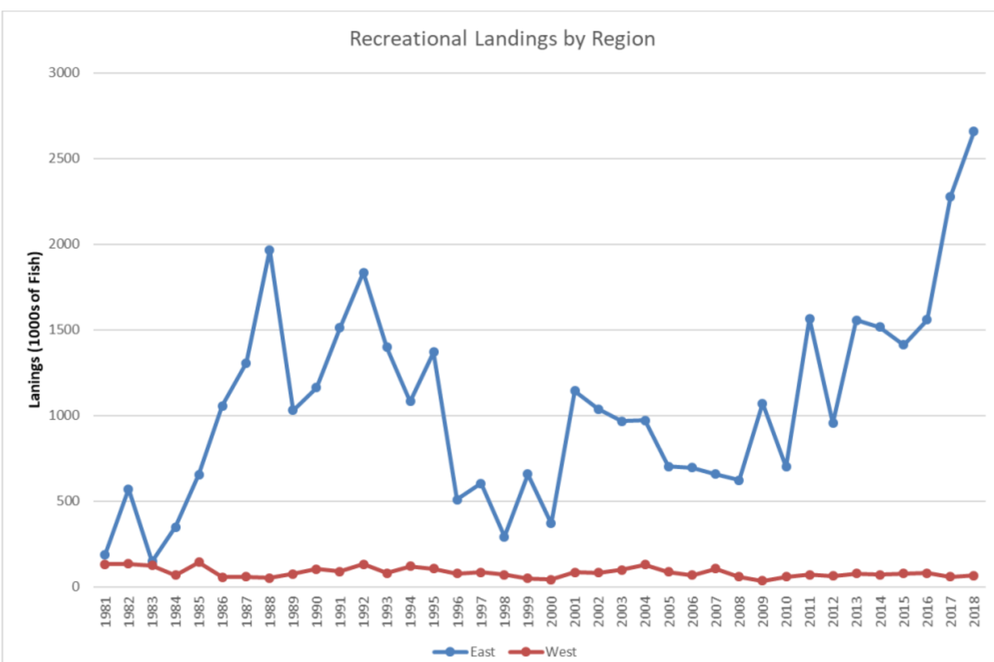


Figure 7: Observed commercial discards and landings (top panel, in metric tons) and recreational discards and landings (bottom panel, in number of fish).

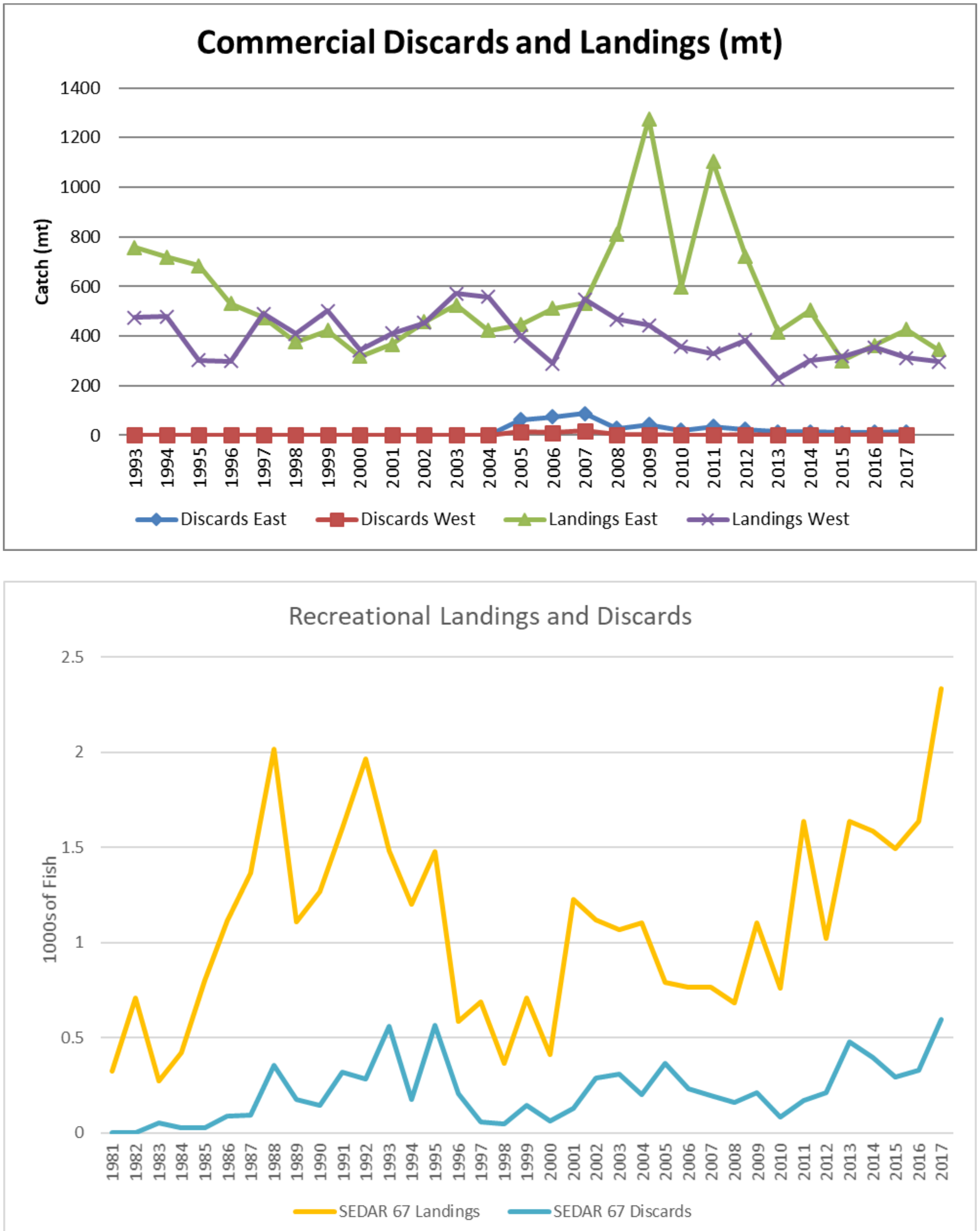


Figure 8: Calculated 'observed' shrimp bycatch (number of fish) from the Bayesian GLM program for SEDAR 67 (red lines) and from SEDAR 45 (blue lines). Note that the assessment model utilizes a 'super-year' approach and fits only the Bayesian median bycatch (multiplied by 0.75 to account for 25% age-0 fish in the shrimp bycatch; first data point).

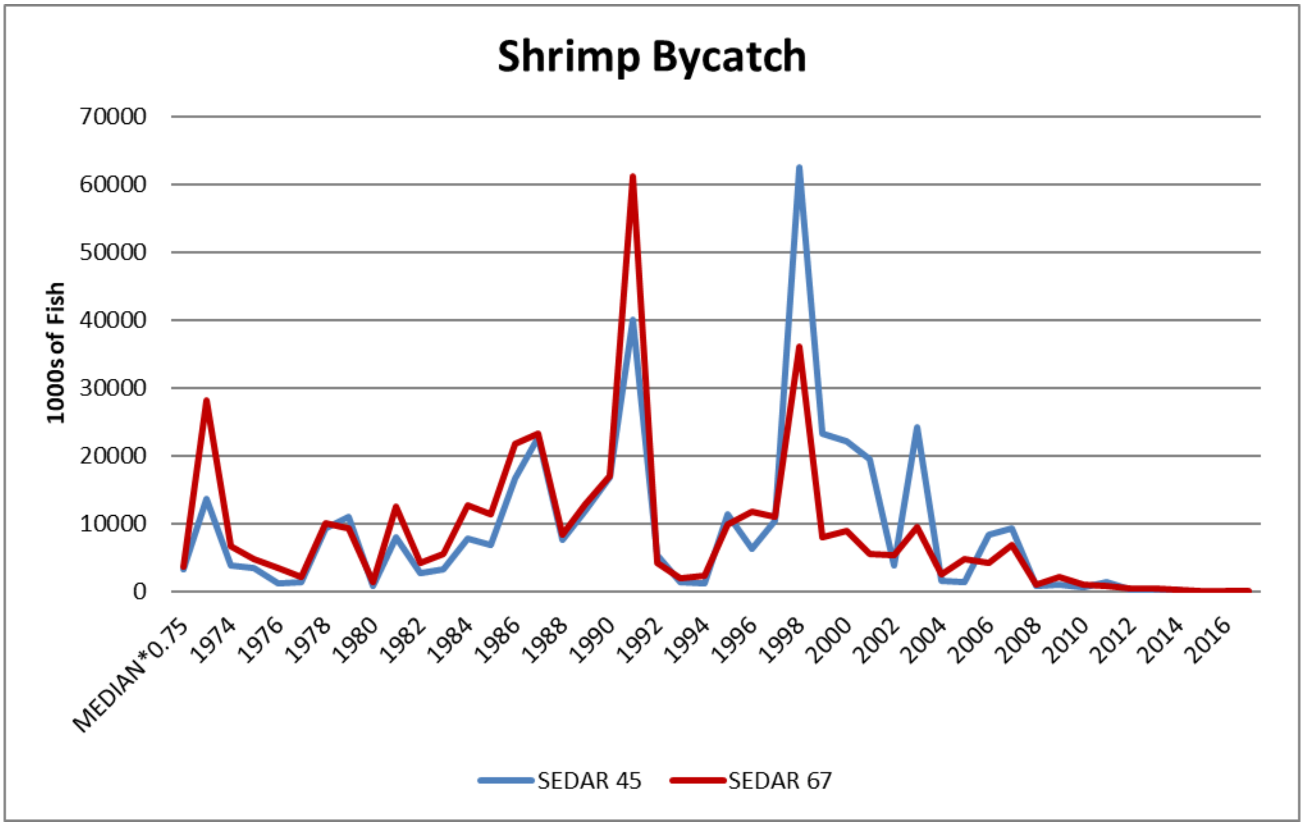


Figure 9: Observed age composition for the commercial and recreational fleets (top 3 panels) and observed length composition for two fishery-independent surveys (combined video index and SEAMAP east summer groundfish; bottom two panels). The commercial fishery in the western area tends to catch older fish compared to the commercial fleet in the eastern area or the recreational fleet.

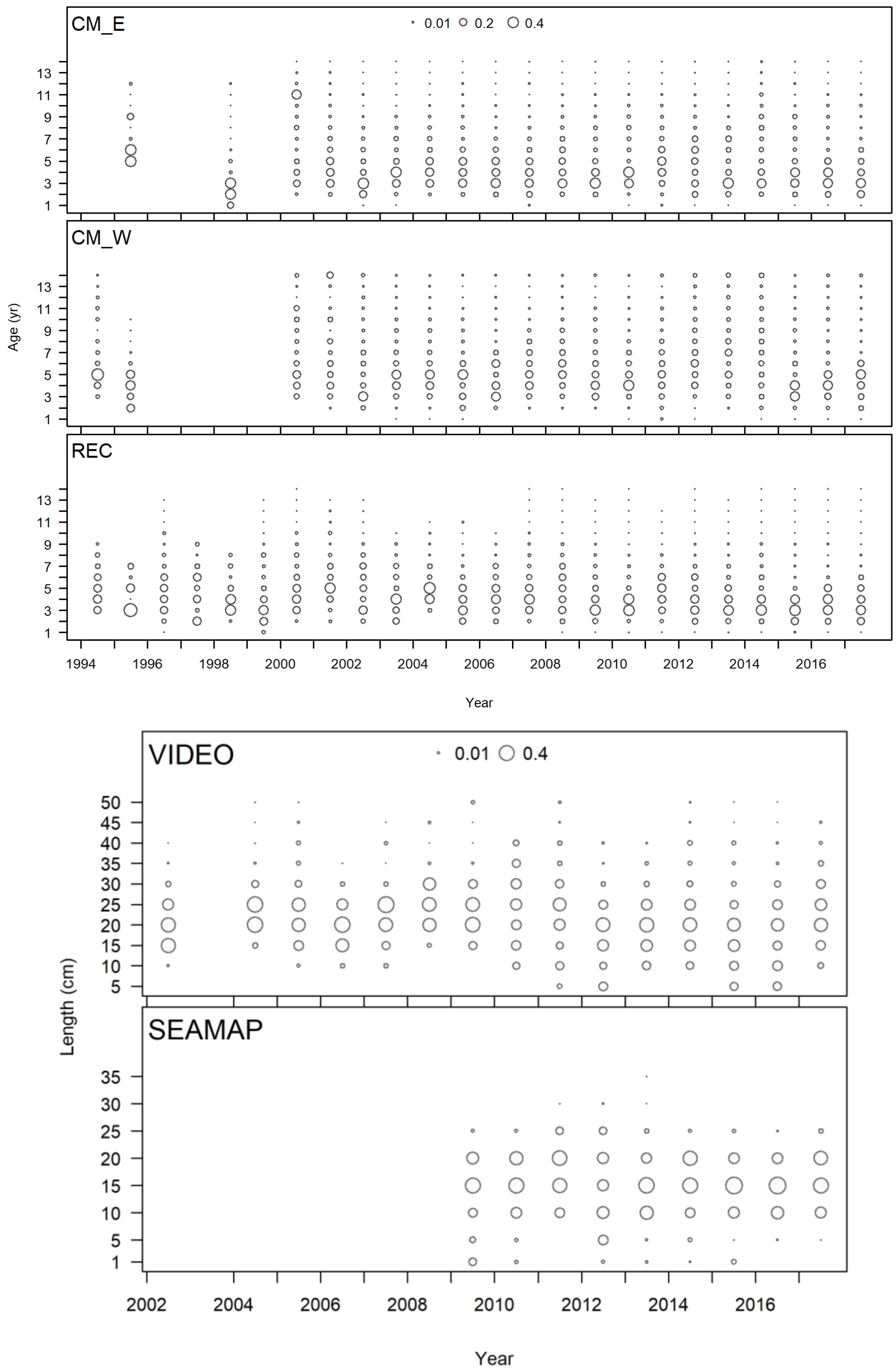


Figure 10: **S**hrimp effort greater than 10 fathoms normalized to the time series mean for SEDAR 67 (red line) and from SEDAR 45 (blue line). Effort values were standardized by SEAMAP groundfish survey catch rates of vermilion snapper in order to account for the spatial overlap of shrimp effort and vermilion snapper distribution.

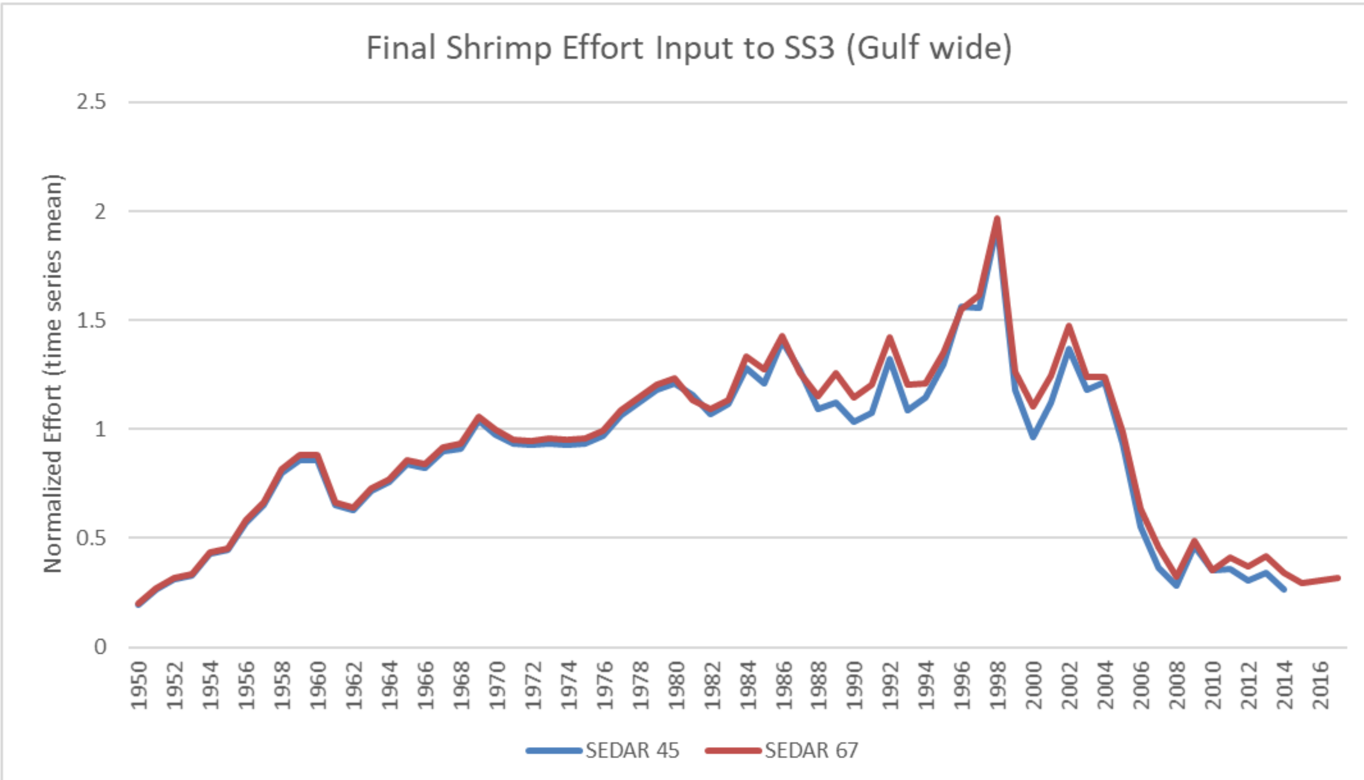


Figure 11: Standardized catch-per-unit effort (CPUE) for the commercial handline fishery in the eastern (top panel) and western (bottom panel) Gulf of Mexico for SEDAR 67 (red lines) and from SEDAR 45 (blue lines). Given difficulties in standardizing catch rates after IFQs were implemented in the Gulf of Mexico in 2007, the SEDAR 67 panel decided to truncate the CPUE time series in 2006. All indices are relativized to a mean over a common time series (i.e., initial year through 2014).

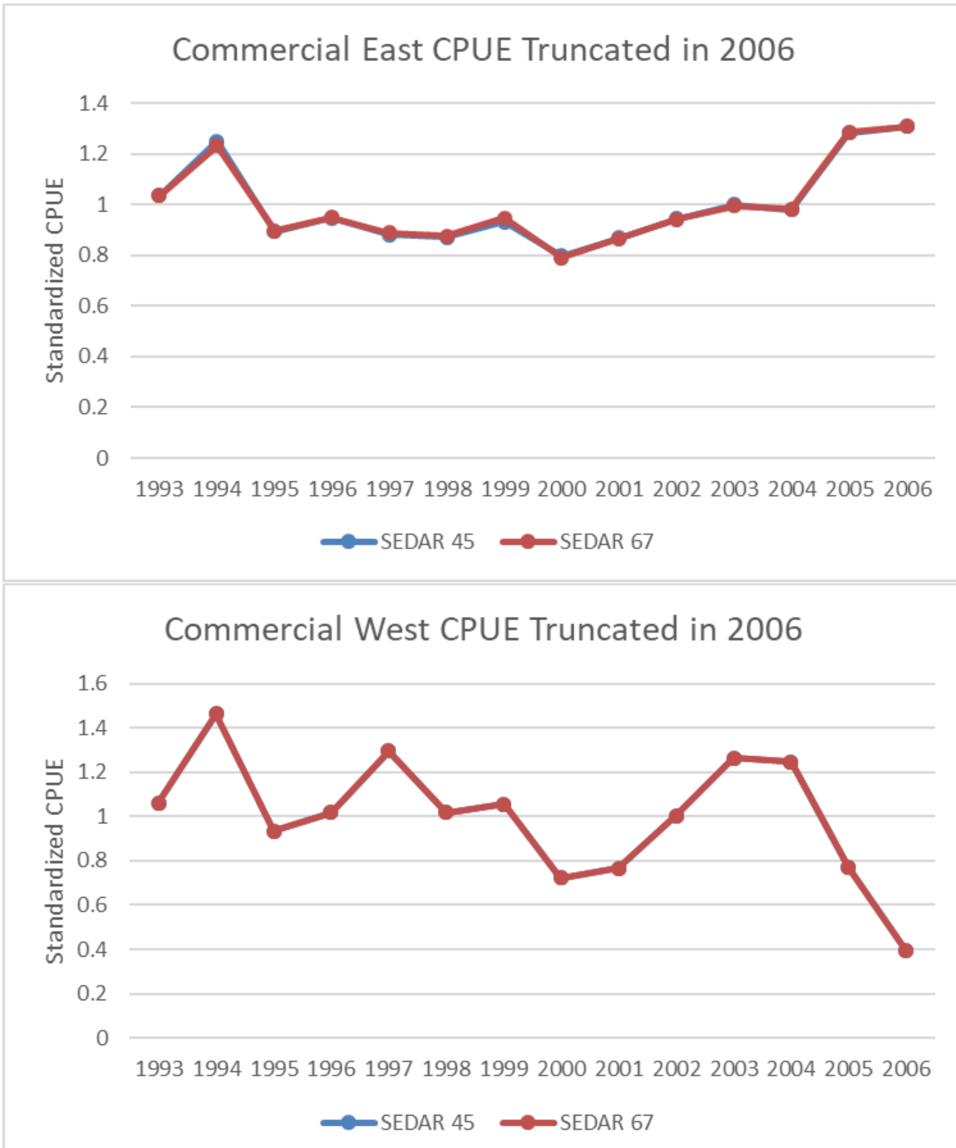


Figure 12: Standardized catch-per-unit effort (CPUE) for the recreational private/charter (MRFSS) fishery in the eastern Gulf of Mexico (top panel), the eastern headboat fishery (middle panel), and the western headboat fishery (bottom panel). Some discrepancies exist between the SEDAR 45 time series (blue lines) and the final SEDAR 67 indices (red lines), but trends are similar. All indices are relativized to a mean over a common time series (i.e., initial year through 2014).

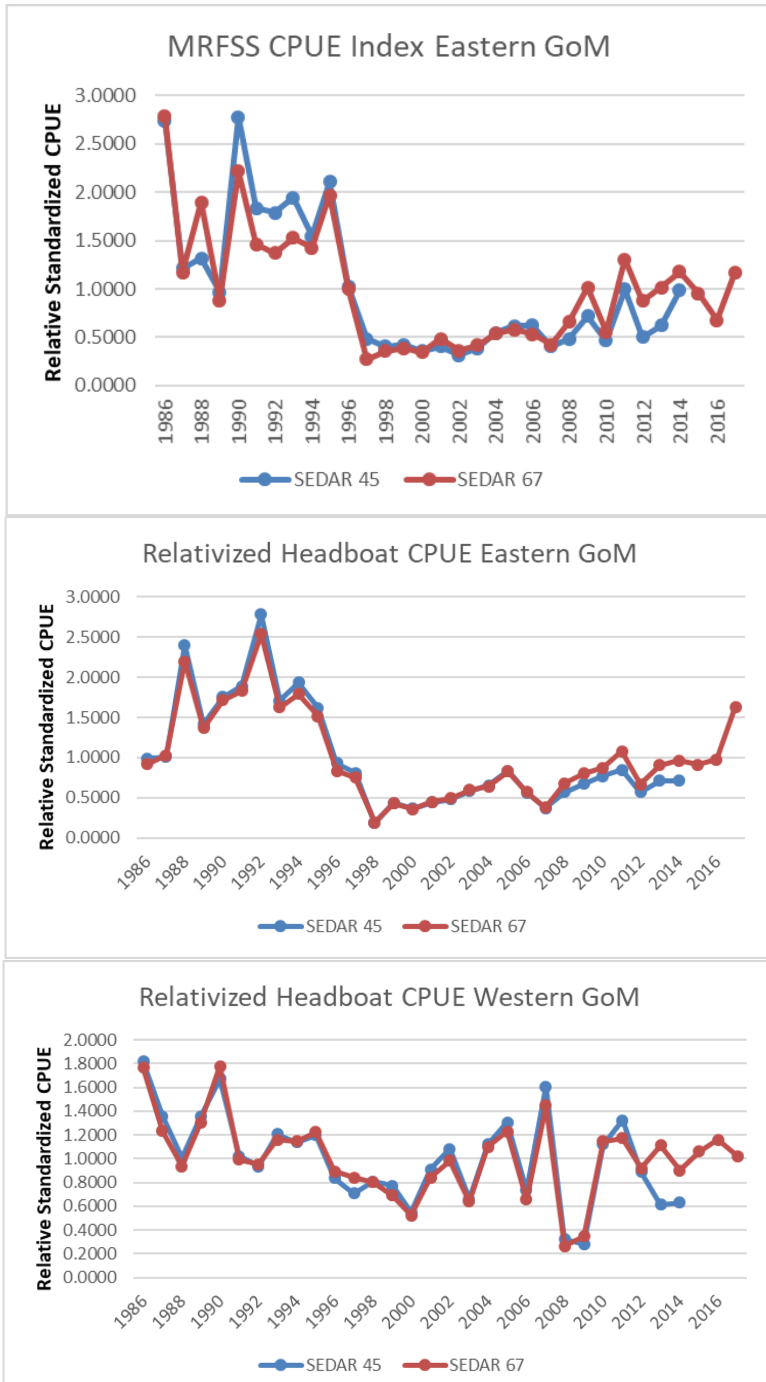


Figure 13: Standardized catch-per-unit effort (the larval index is in catch-per-unit area) for the three fishery-independent surveys: groundfish summer east (top panel), larval (middle panel), and video (bottom panel). The blue lines represents SEDAR 45 values and the red lines represent SEDAR 67 values. Three values are presented for the video survey, because a change was made to use the combined video index (black line) for the SEDAR 67 base model as opposed to the Mississippi Labs only index used in SEDAR 45 and the SEDAR 67 continuity model. All indices are relativized to a mean over a common time series (i.e., initial year through 2014).

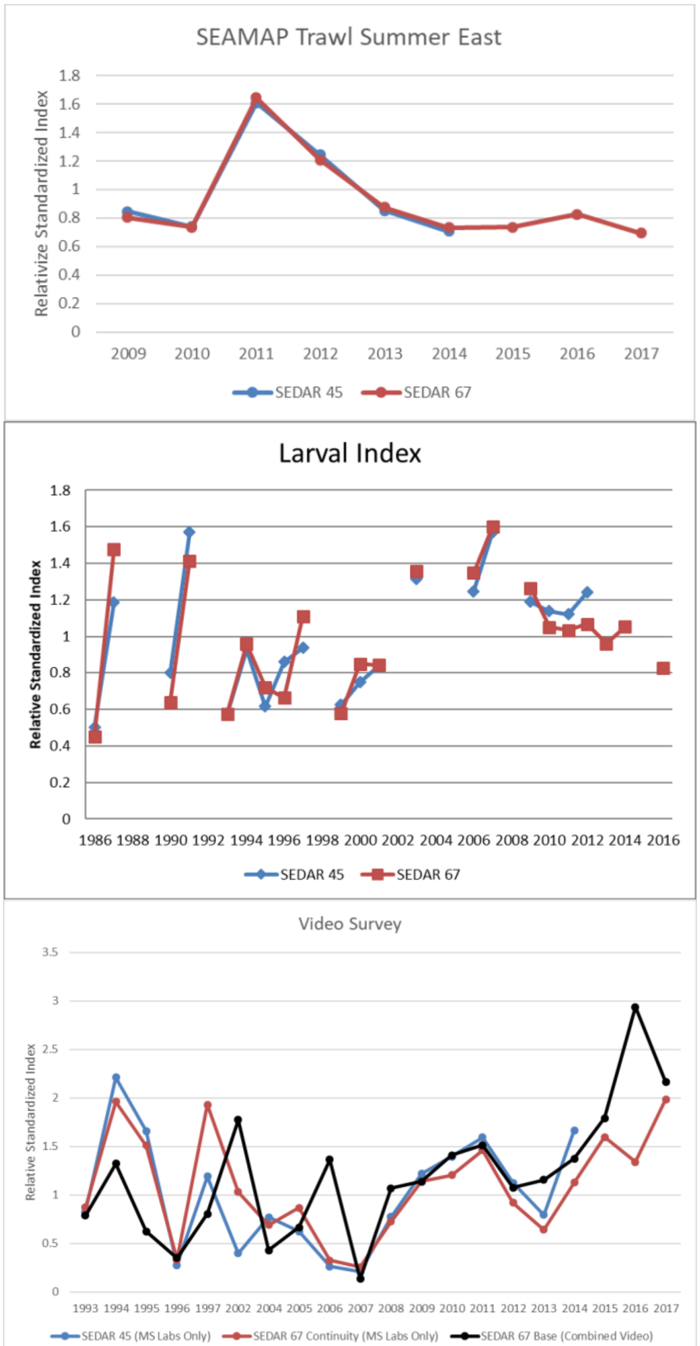


Figure 14: Data inputs used for the base model. Note that SEAMAP refers to the SEAMAP summer groundfish survey, SMP_BYC under the 'catch' heading is simply a placeholder for the shrimp bycatch fleet (no actual data were input here since shrimp bycatch is input under the 'discards' heading), and the SMP_BYC abundance index refers the to the shrimp effort series and is an index of effort not abundance.

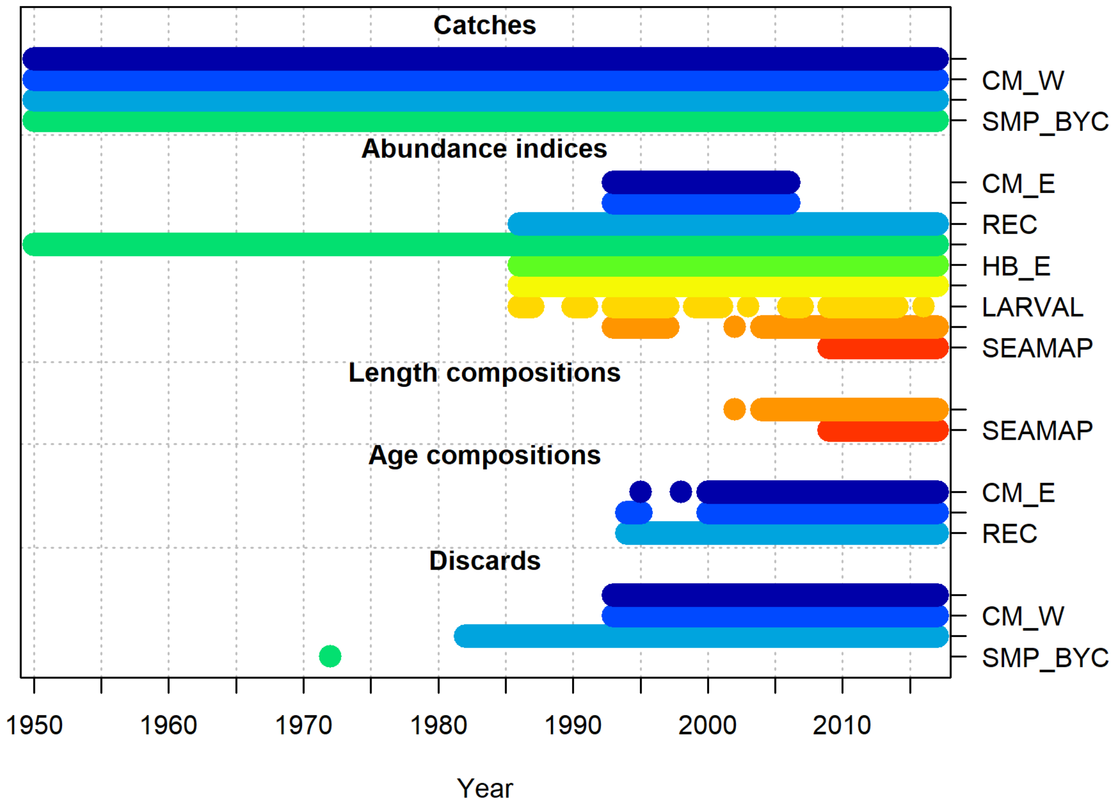
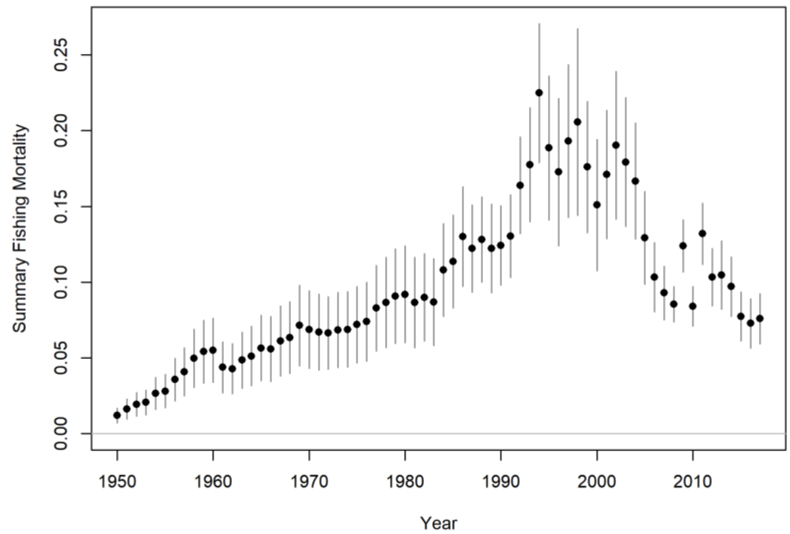


Figure 15: Total harvest rate (top panel, killed fish divided by exploitable numbers) with 95% confidence intervals and fishing mortality (continuous rates) by fleet (bottom panel). Total fishing mortality reached its peak in the mid-1990s and has been declining for most of the last decade.



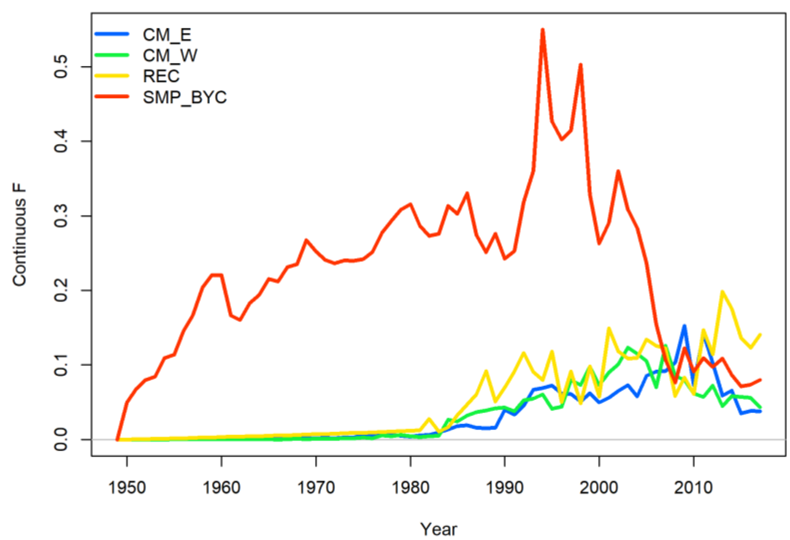


Figure 16: Estimated age-based, time-invariant logistic selectivity for the commercial fishery in the eastern Gulf of Mexico (top panel) and size-based, time-varying retention fixed as knife-edge (vertical) at the minimum size limit (bottom panel).

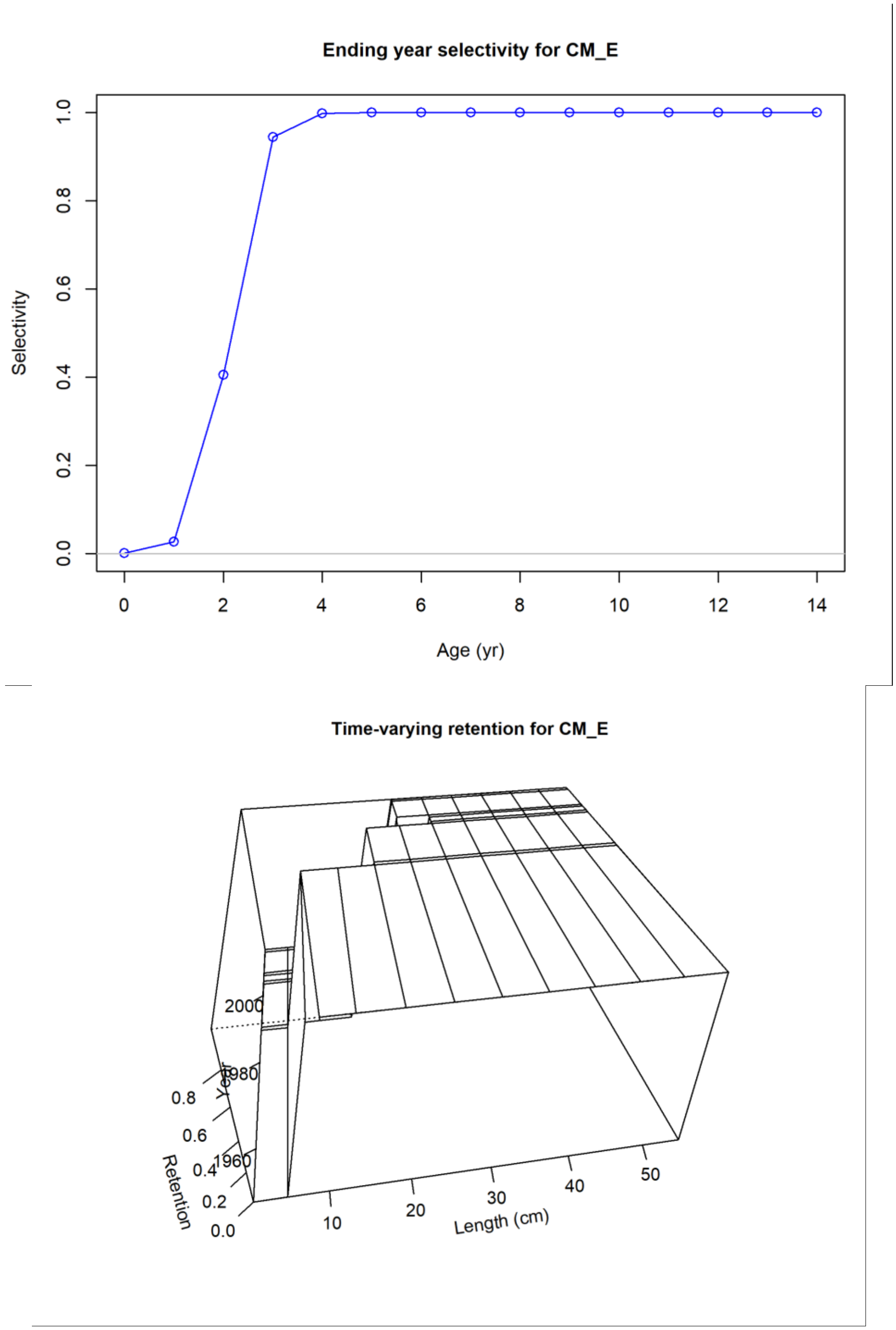


Figure 17: Estimated age-based, time-invariant logistic selectivity for the commercial fishery in the western Gulf of Mexico (top panel) and size-based, time-varying retention fixed as knife-edge (vertical) at the minimum size limit (bottom panel).

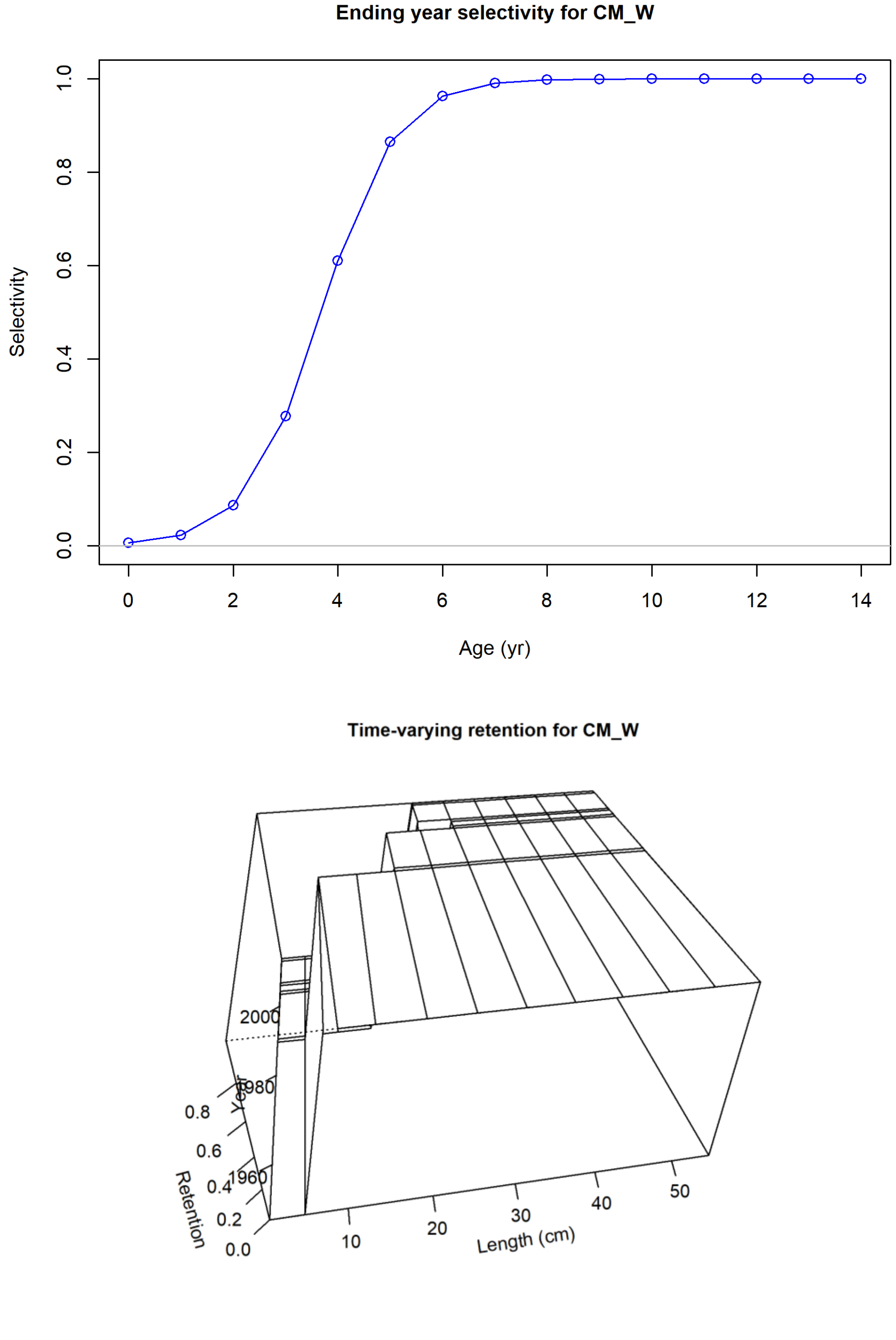
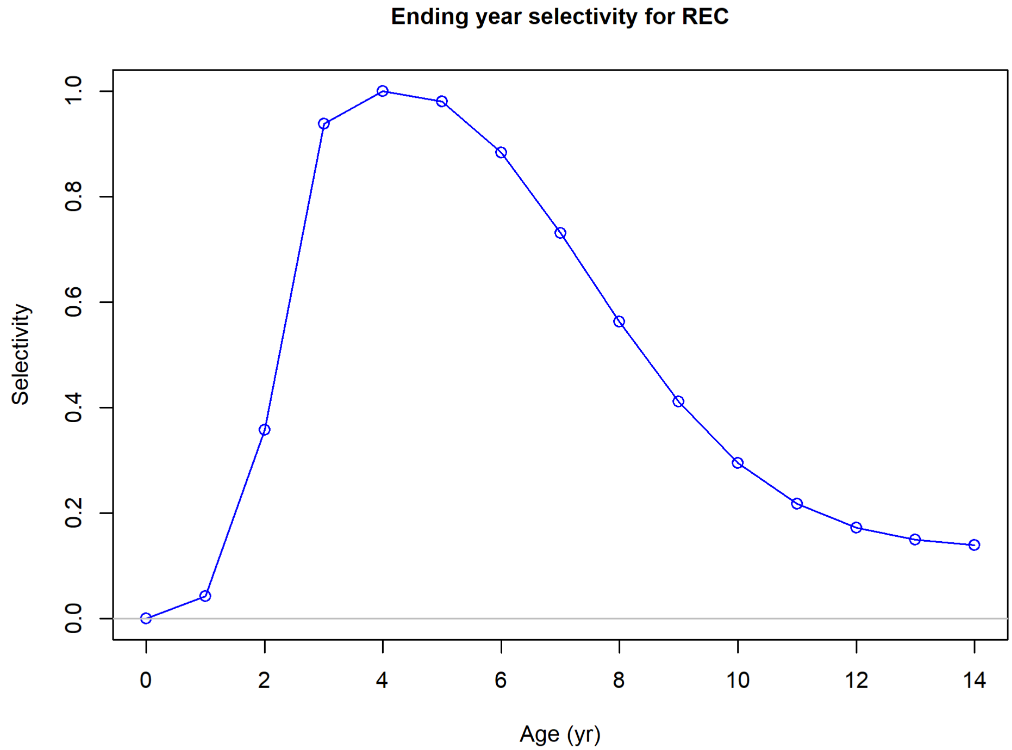


Figure 18: Estimated age-based, time-invariant double normal selectivity for the recreational fishery (top panel) and size-based, time-varying retention fixed as knife-edge (vertical) at the minimum size limit (bottom panel).



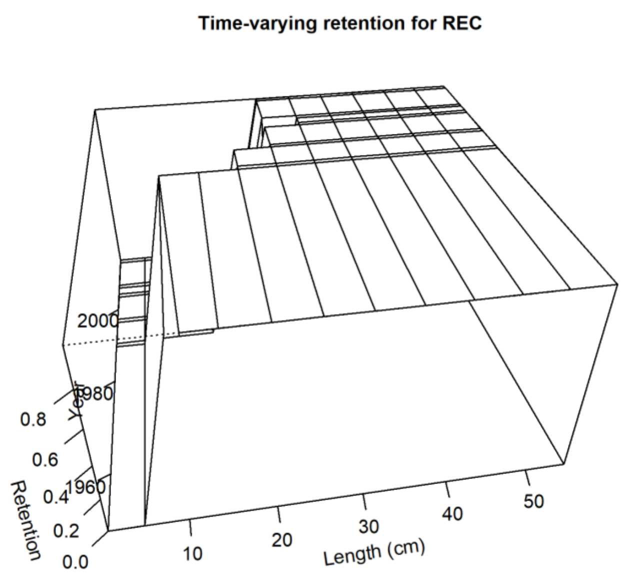


Figure 19: Gulf-wide fixed shrimp bycatch selectivity. The selectivity of shrimp bycatch was fixed at the values agreed upon during SEDAR 9 based on limited shrimp observer length samples (100% vulnerability at age-1, 30% at age-2, 3% at age-3 and 0% at ages 4-14+), because no age composition is available to estimate shrimp bycatch selectivity.

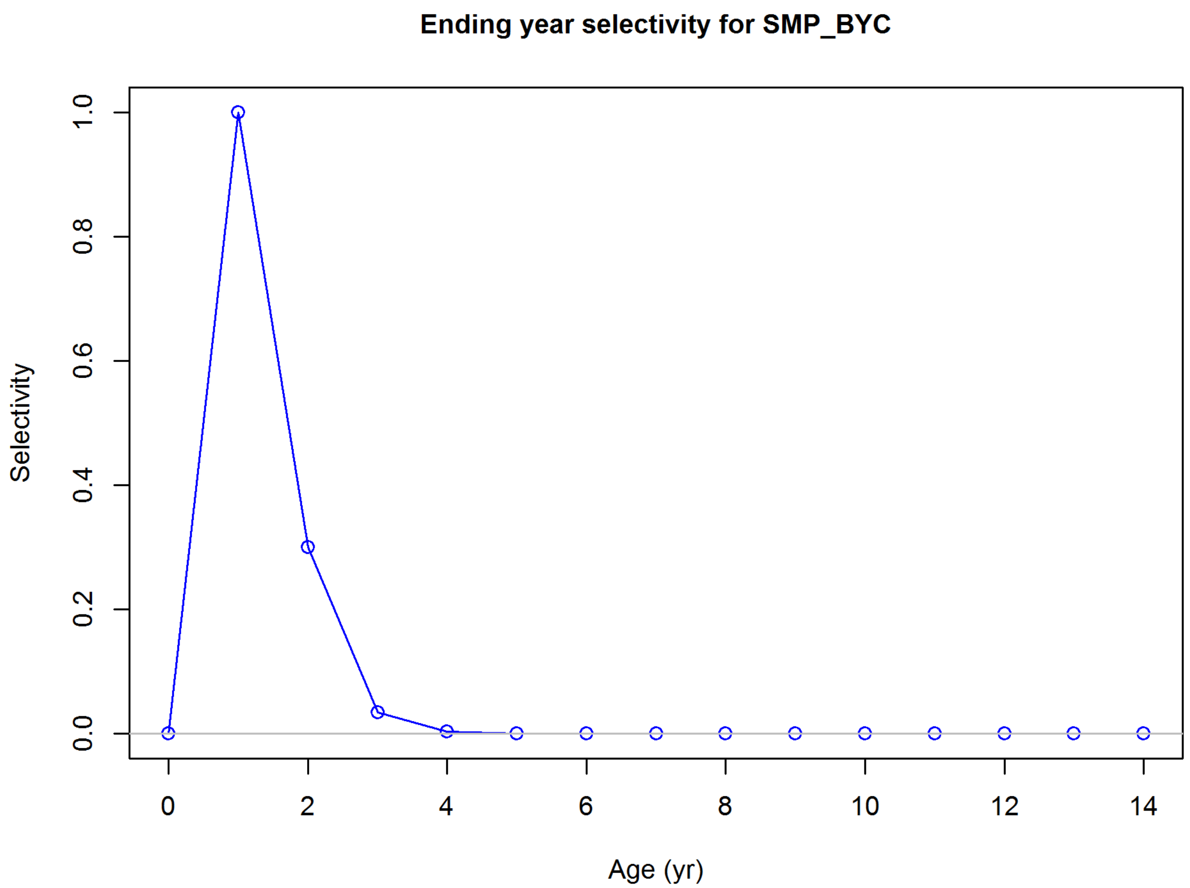


Figure 20: Estimated selectivity for the fishery-independent surveys. Because no age composition information was available, both the video (top panel) and SEAMAP summer groundfish (bottom panel) surveys used length composition and fit domed selectivity by length. Domed selectivity for these surveys was chosen in SEDAR 45 based on the spatial coverage (availability issues) and the lack of older, larger fish in the length frequencies.

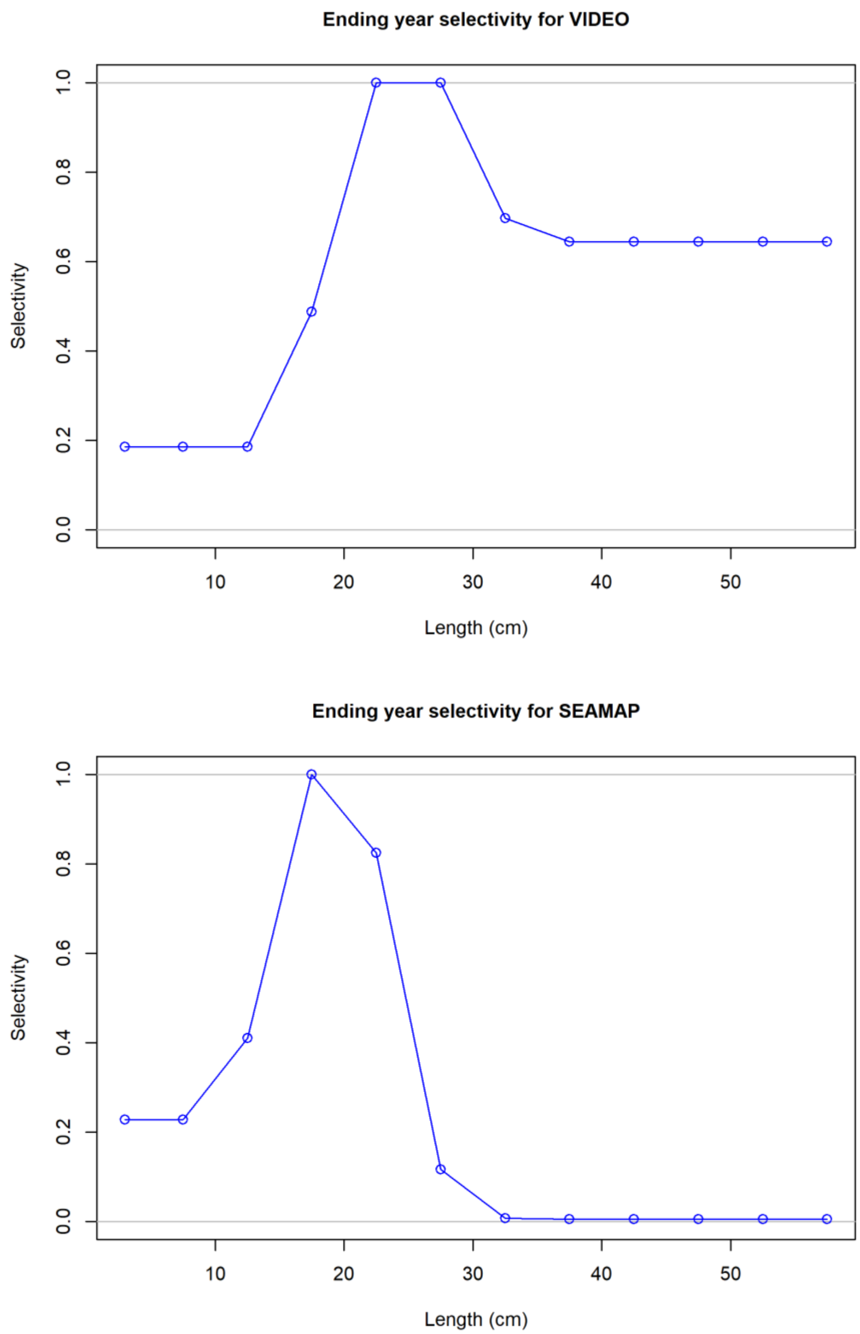


Figure 21: Predicted Beverton-Holt stock-recruit relationship (black line) with estimated recruitment values (dots; top panel) and yearly lognormal recruitment deviations with 95% confidence intervals (bottom panel). Given the lack of depletion seen in the stock, little information is available to estimate the ascending limb (steepness) of the stock-recruit curve. Over the last two decades, recruitment has shown minor autocorrelation in three to four year intervals, but has generally fluctuated above and below the predicted stock-recruit curve with no strong temporal trends. An apparent extreme recruitment event was estimated to occur in 2015.

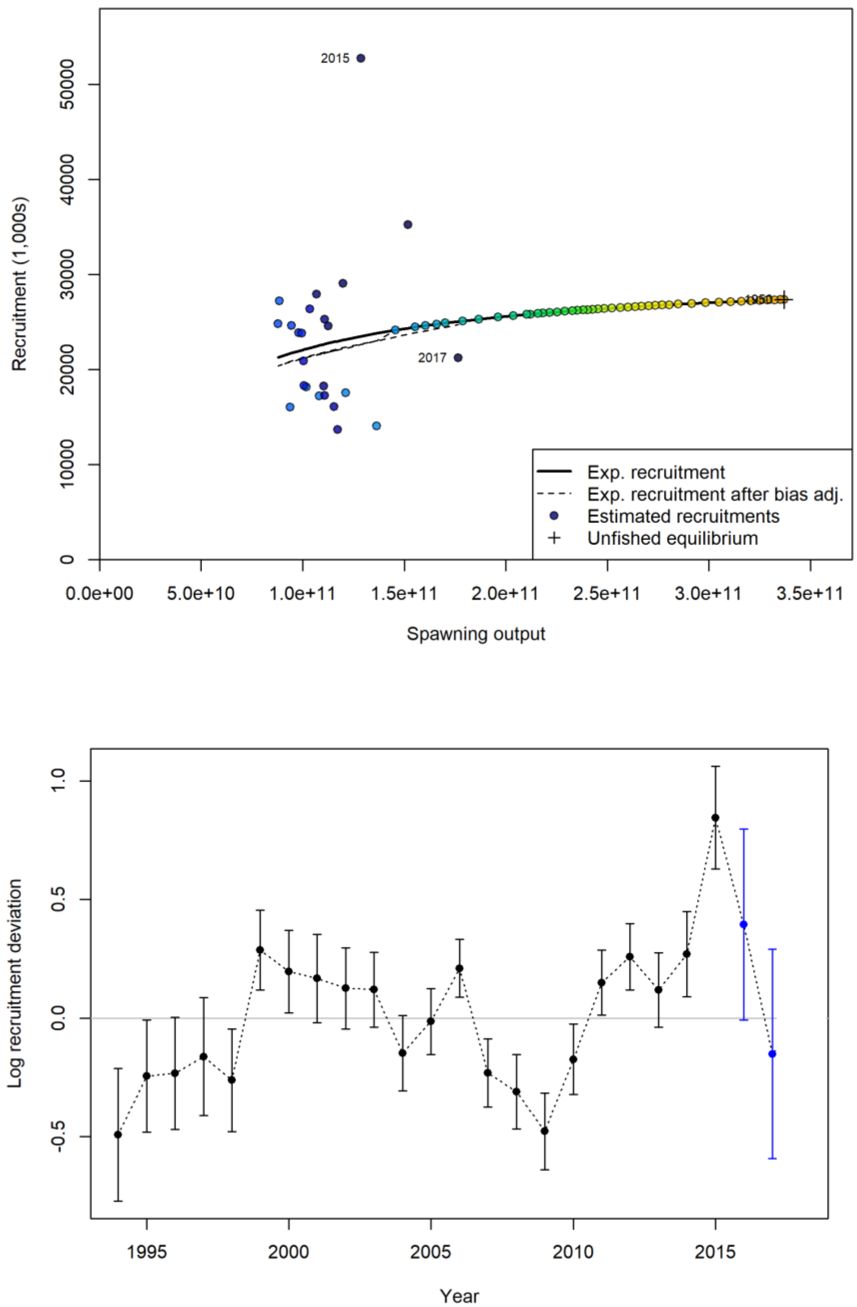


Figure 22: Estimated spawning stock biomass (1000s of eggs, blue line) and recruitment (1000s of fish, red line). SSB has been relatively steady for much of the 2000s, while recruitment has varied with no strong trends. However, in the last three years SSB has rapidly increased partially due to the large 2015 yearclass becoming mature fish.

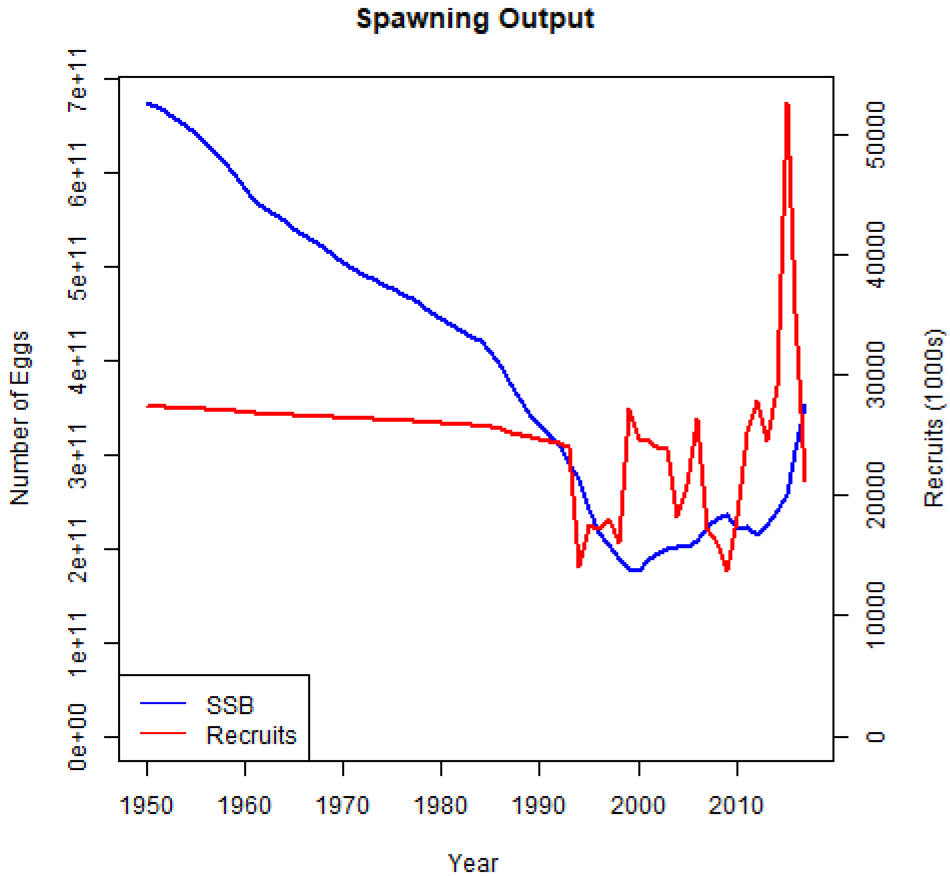


Figure 23: Total biomass (mt, top panel), total abundance (1000s of fish, bottom left panel), and numbers at age (bottom right panel). The population initially decreased from virgin conditions, but has been without trend for most of the 2000s and shows a strong upward trend in abundance with a similar but not quite as pronounced trend in total biomass. The average age has decreased slightly from just over three years old to around two.

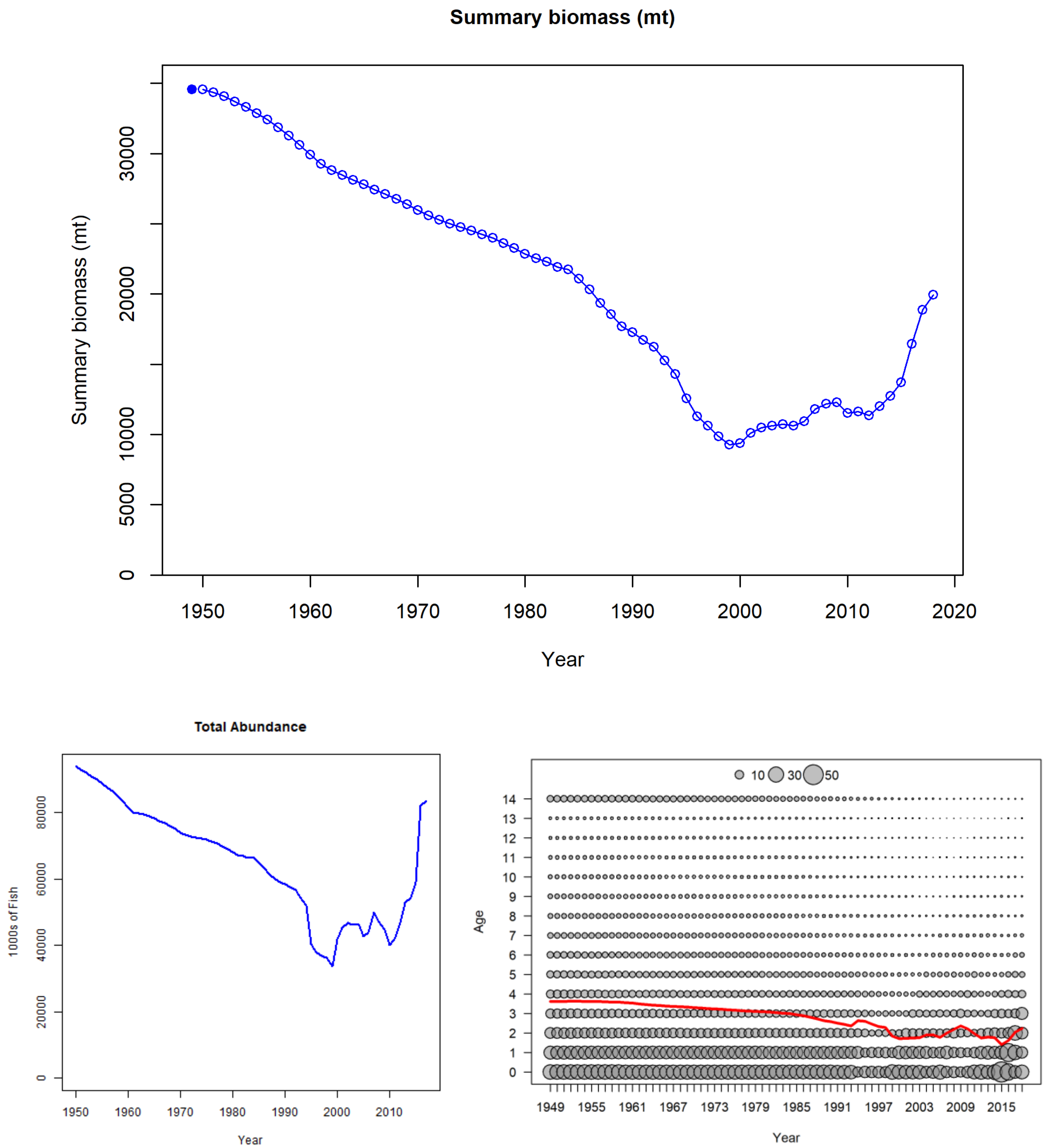


Figure 24: Observed and predicted commercial landings (top left panel, mt; east in black and west in red), commercial east discards (top middle panel, mt), commercial west discards (top right panel, mt), recreational landings (bottom left panel, 1000s of fish), and recreational discards (bottom right panel, 1000s of fish). Fits to both the commercial east (black) and west (red) are very good, while the recreational catch shows slightly more residual error. These results are to be expected given the relatively smaller standard error input to the assessment model for commercial compared to recreational landings (recreational standard error, 0.15, was three times that of the commercial, 0.05). Discard observations are not fit directly in the model and are just shown for comparison to the model predicted discard levels.

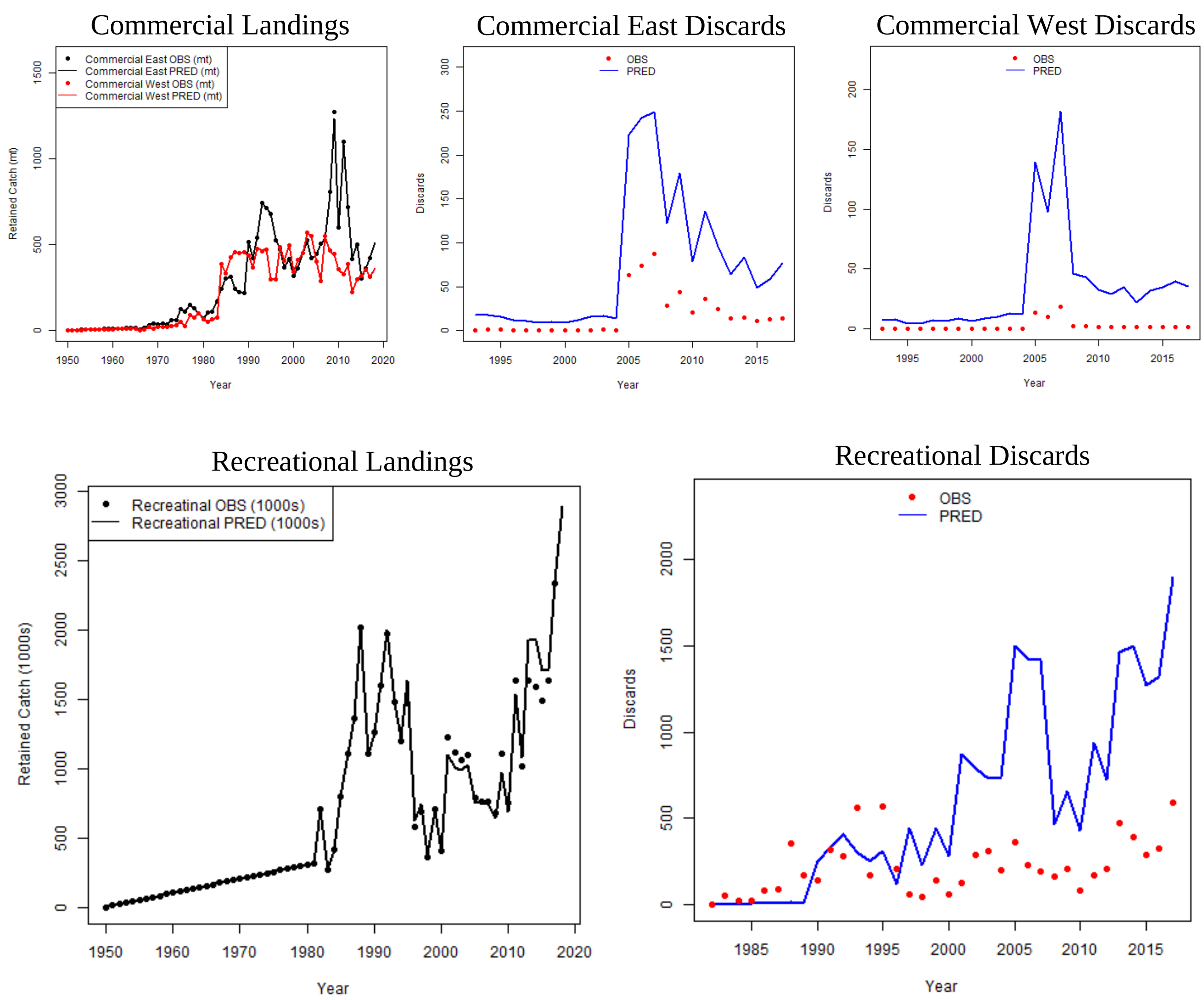


Figure 25: Observed and predicted shrimp bycatch super-year medians in 1000s of dead discards. The blue line represents the assessment model estimated median and the black circles are the bycatch observations produced by the WinBugs program. The first circle represents the Bayesian median that the assessment model is attempting to fit. The model fits the median value quite closely due to the relatively high standard error assumed by the assessment model (i.e., 0.10).

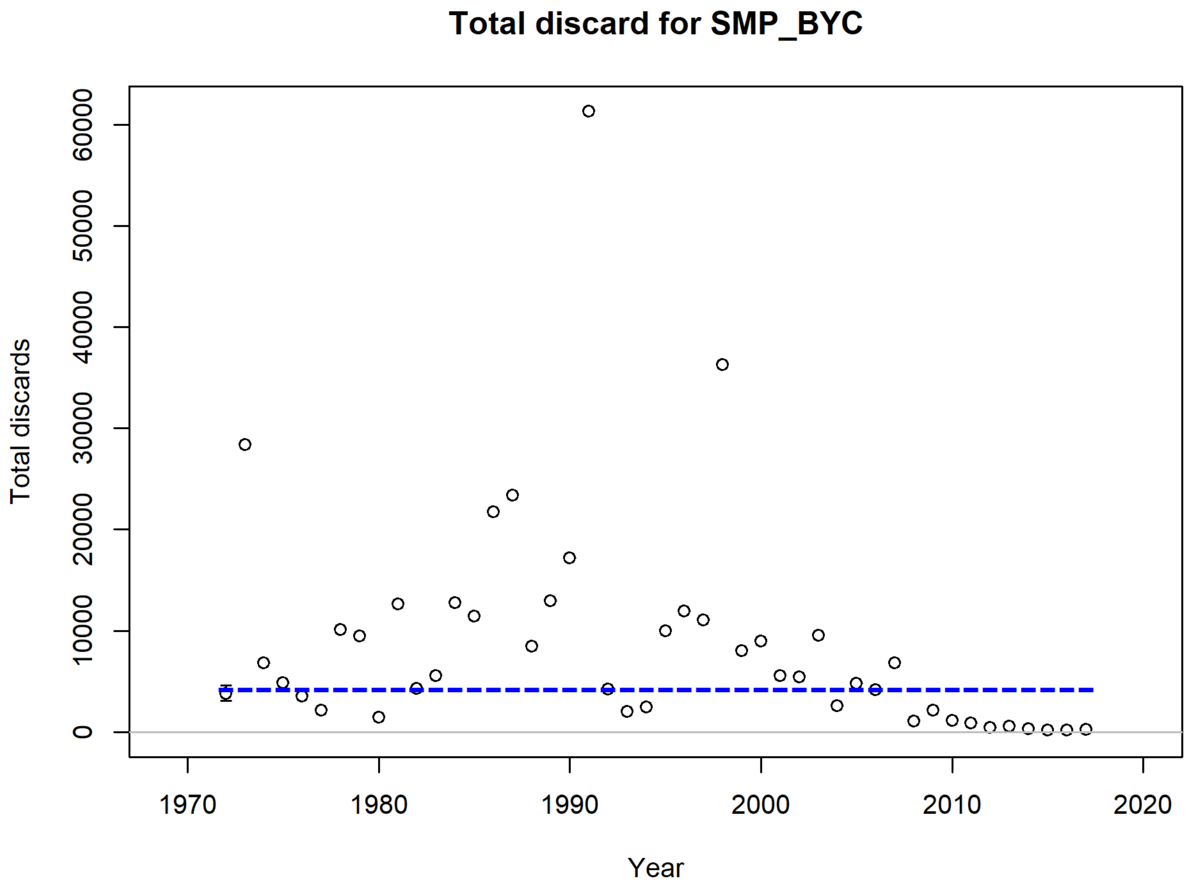


Figure 26: Observed (red points) and predicted (blue line) shrimp effort.

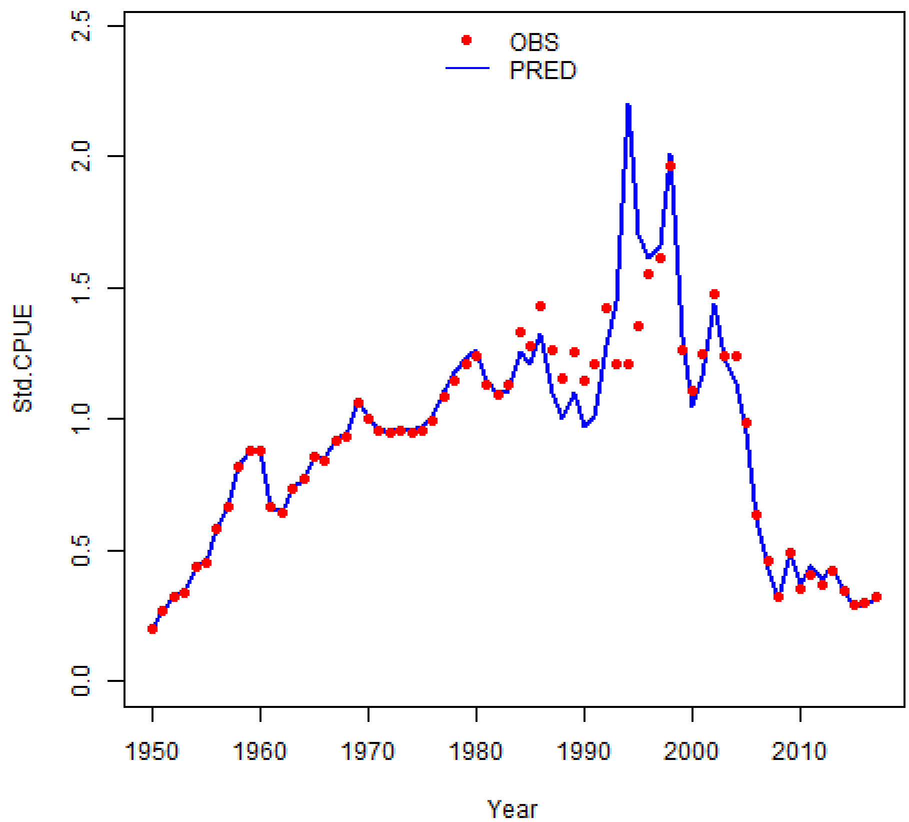
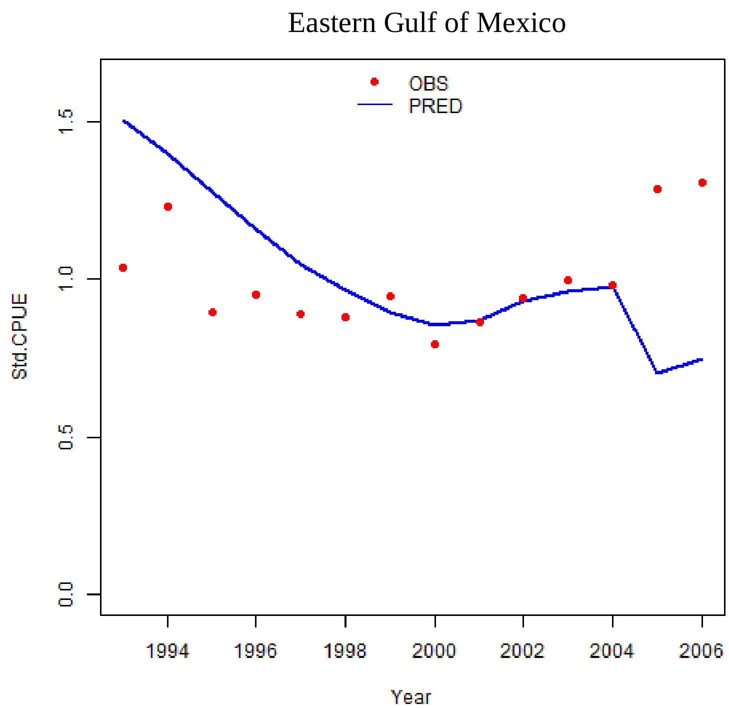


Figure 27: Observed (red points) and predicted (blue line) commercial CPUE indices in the eastern (top panel) and western (bottom panel) Gulf of Mexico.



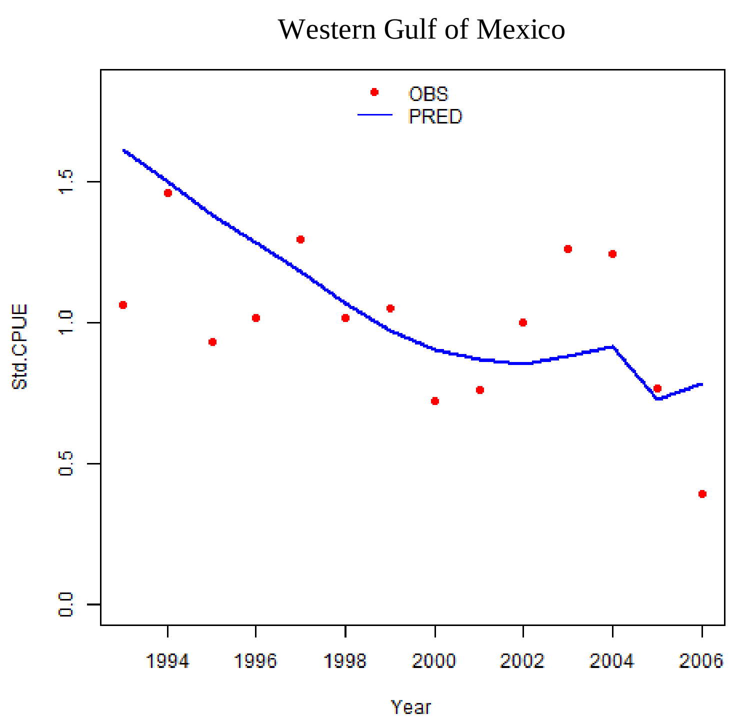


Figure 28: Observed (red points) and predicted (blue line) MRFSS CPUE index for the eastern Gulf of Mexico.

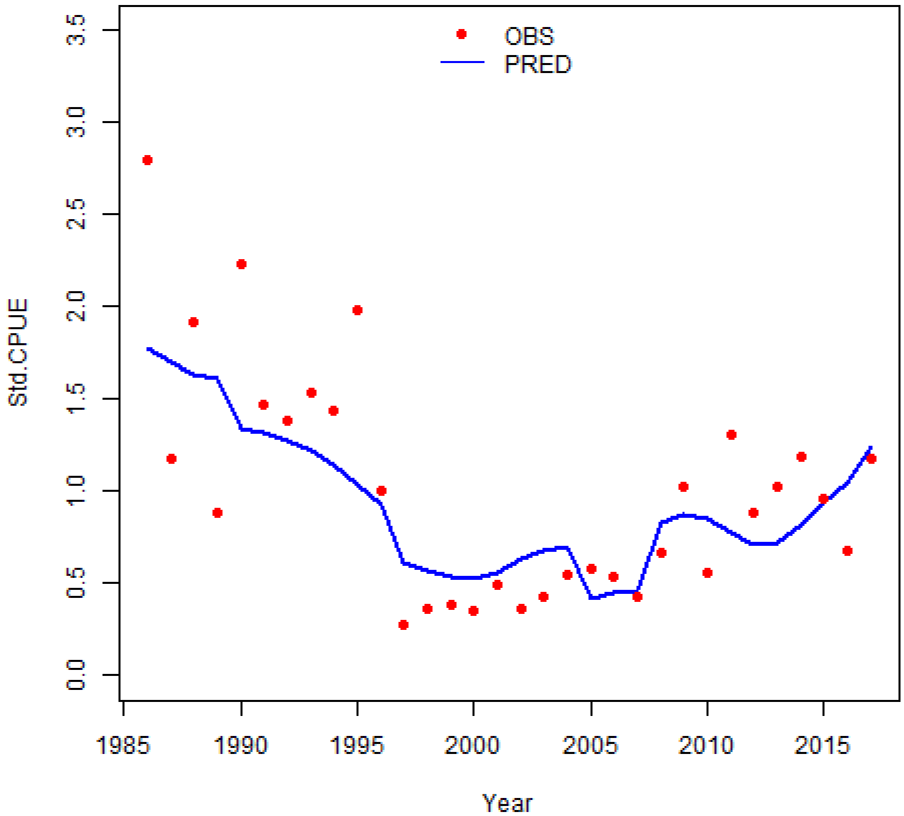


Figure 29: Observed (red points) and predicted (blue line) headboat CPUE indices for the eastern (top panel) and western (bottom panel) Gulf of Mexico.

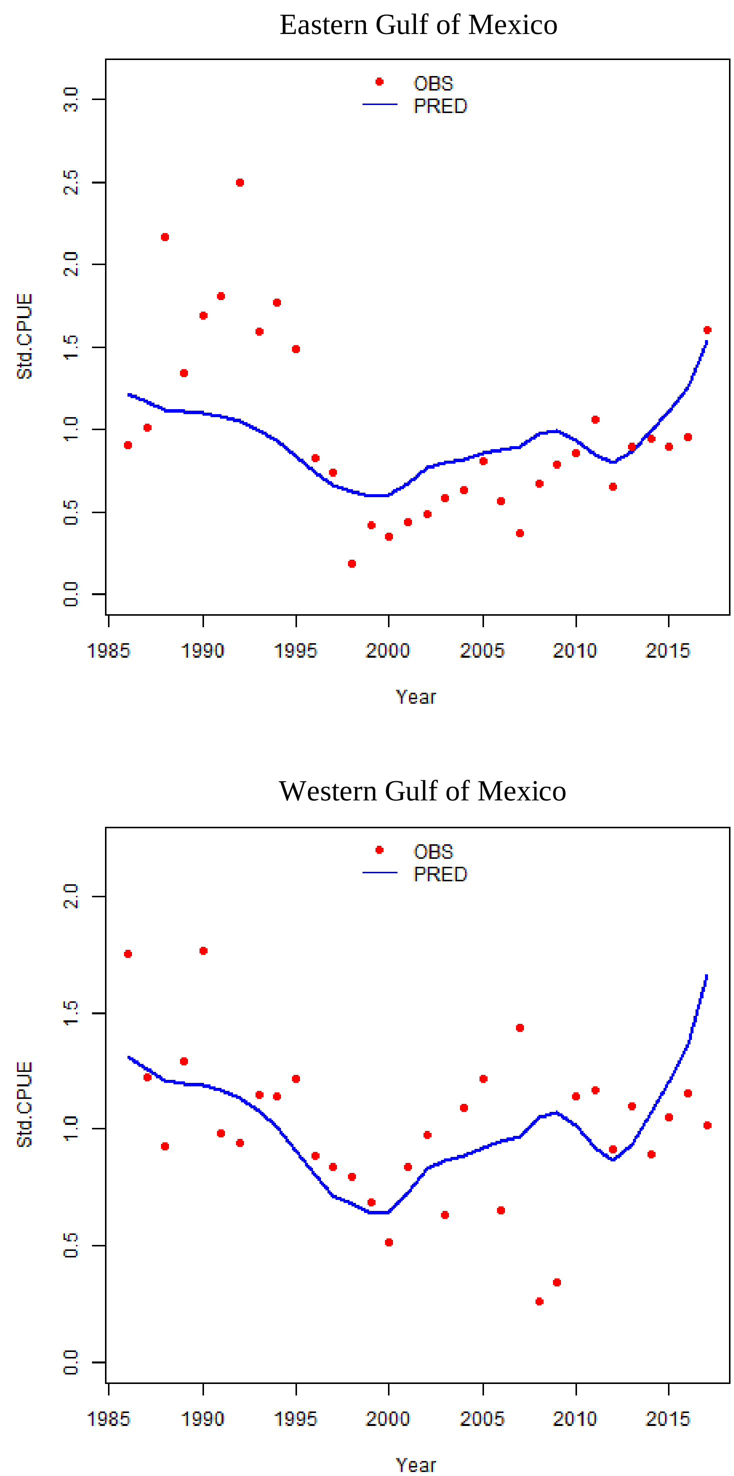


Figure 30: Observed (red points) and predicted (blue line) fishery independent video (top panel), SEAMAP summer east groundfish (middle panel), and larval (bottom panel) survey indices.

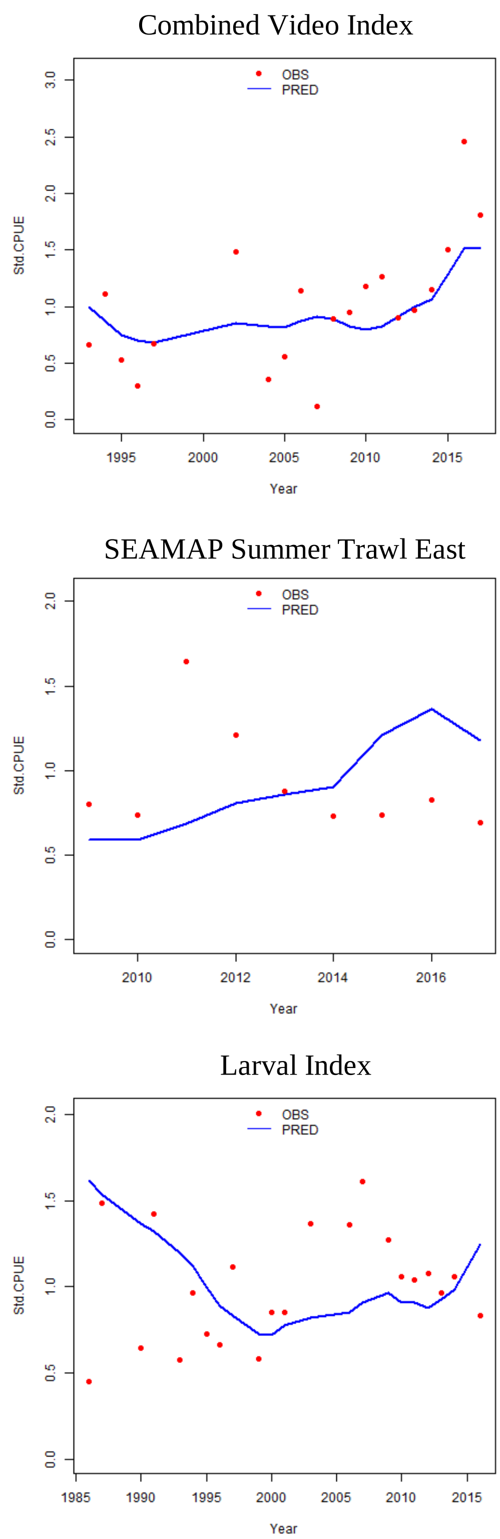


Figure 31: Observed (black lines) and predicted (green lines) age compositions for the eastern Gulf of Mexico commercial fishery. Input sample sizes (*N*; after reweighting) along with the effective sample size (N_{eff}) are also reported. Sample sizes were capped at a maximum of 100.

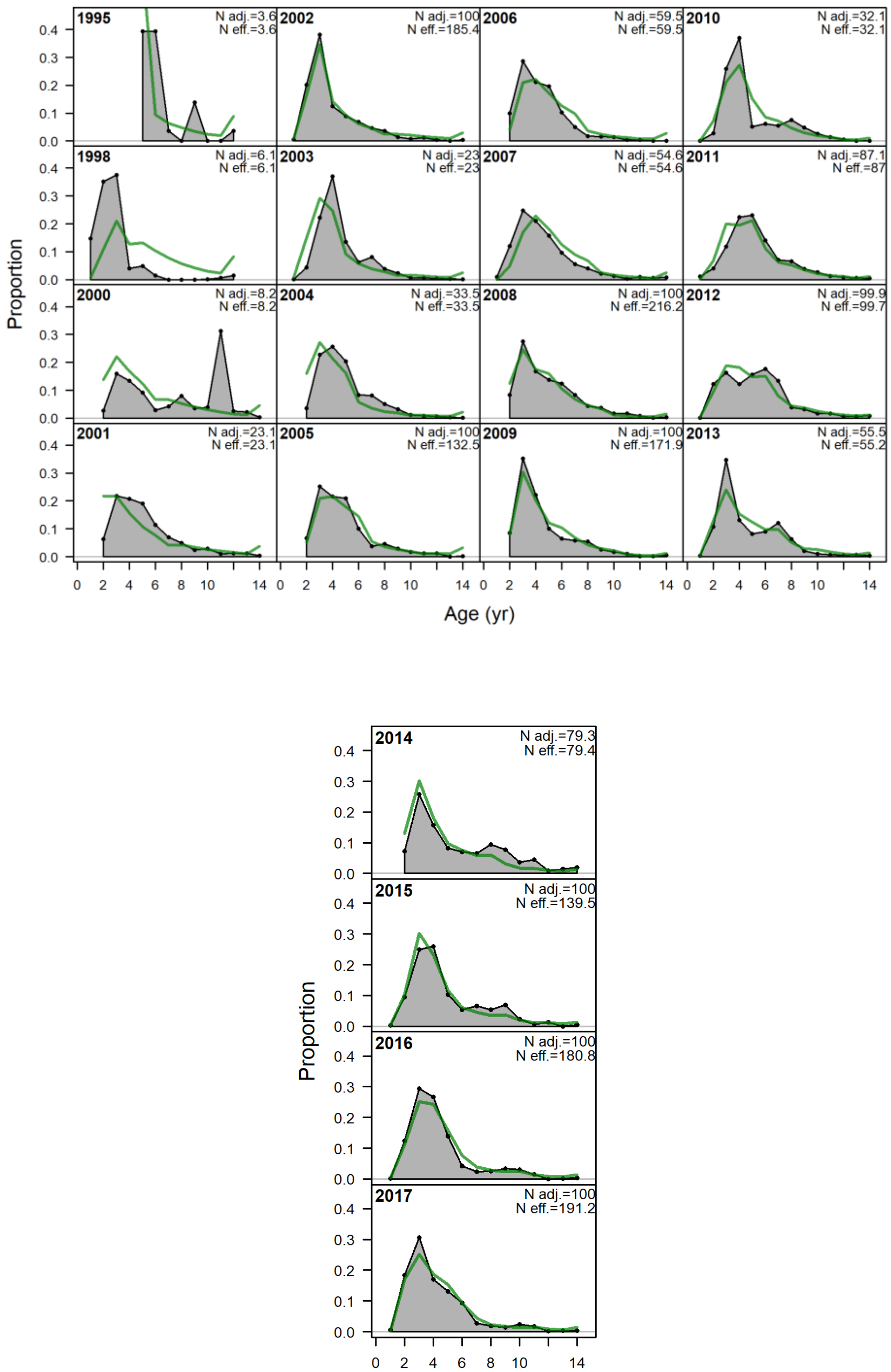
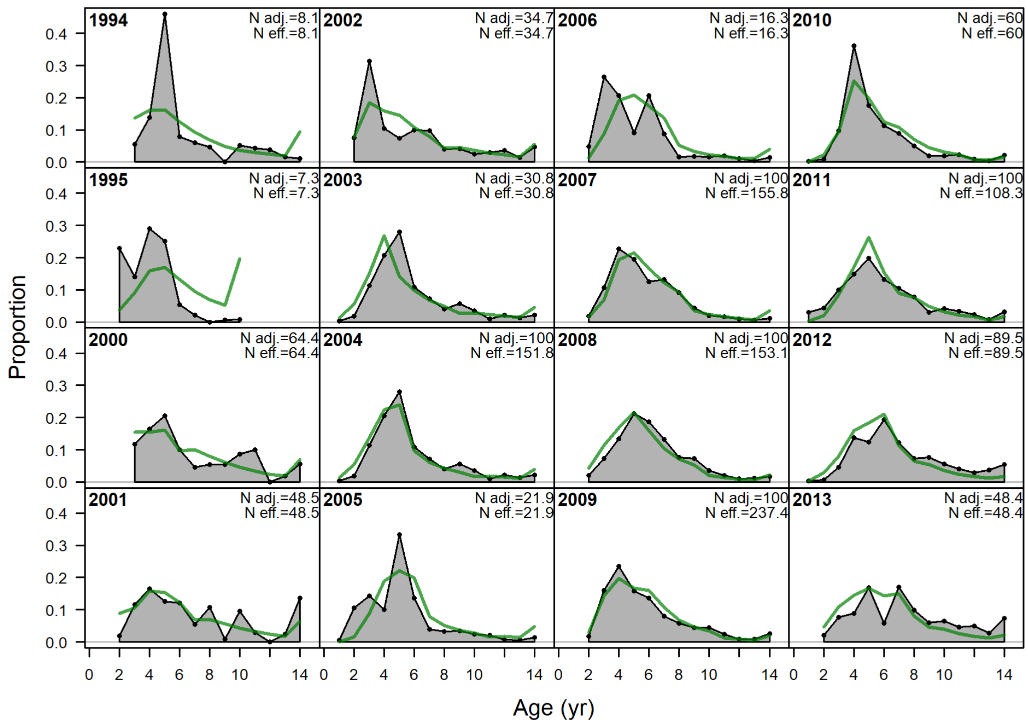


Figure 32: Observed (black lines) and predicted (green lines) age compositions for the western Gulf of Mexico commercial fishery. Input sample sizes (N; after reweighting) along with the effective sample size (N_{eff}) are also reported. Sample sizes were capped at a maximum of 100.



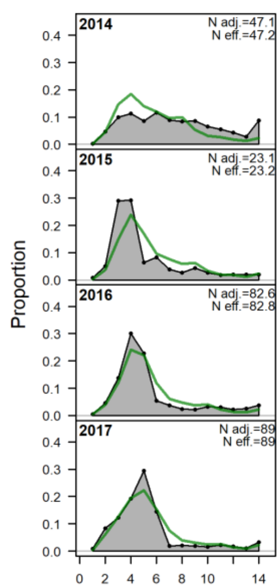


Figure 33: Observed (black lines) and predicted (green lines) age compositions for the gulf-wide recreational fishery. Input sample sizes (N; after reweighting) along with the effective sample size (N_{eff}) are also reported. Sample sizes were capped at a maximum of 100.

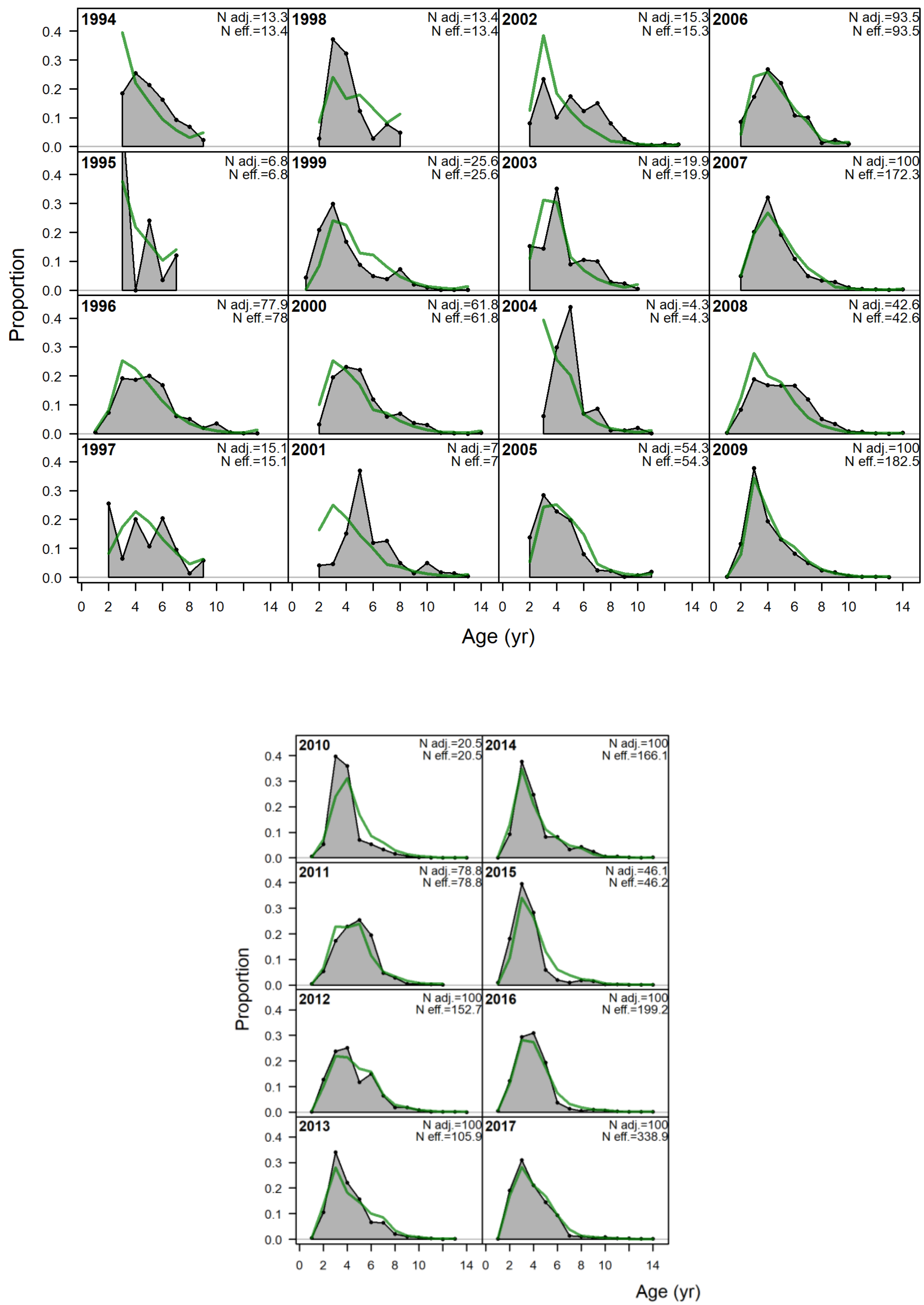


Figure 34: Pearson residuals of age composition fits for the commercial east (top panel), commercial west (middle panel), and recreational (bottom panel) fisheries. Grey filled bubbles represent positive residuals (observed greater than predicted) and unfilled bubbles represent negative residuals (predicted greater than observed).

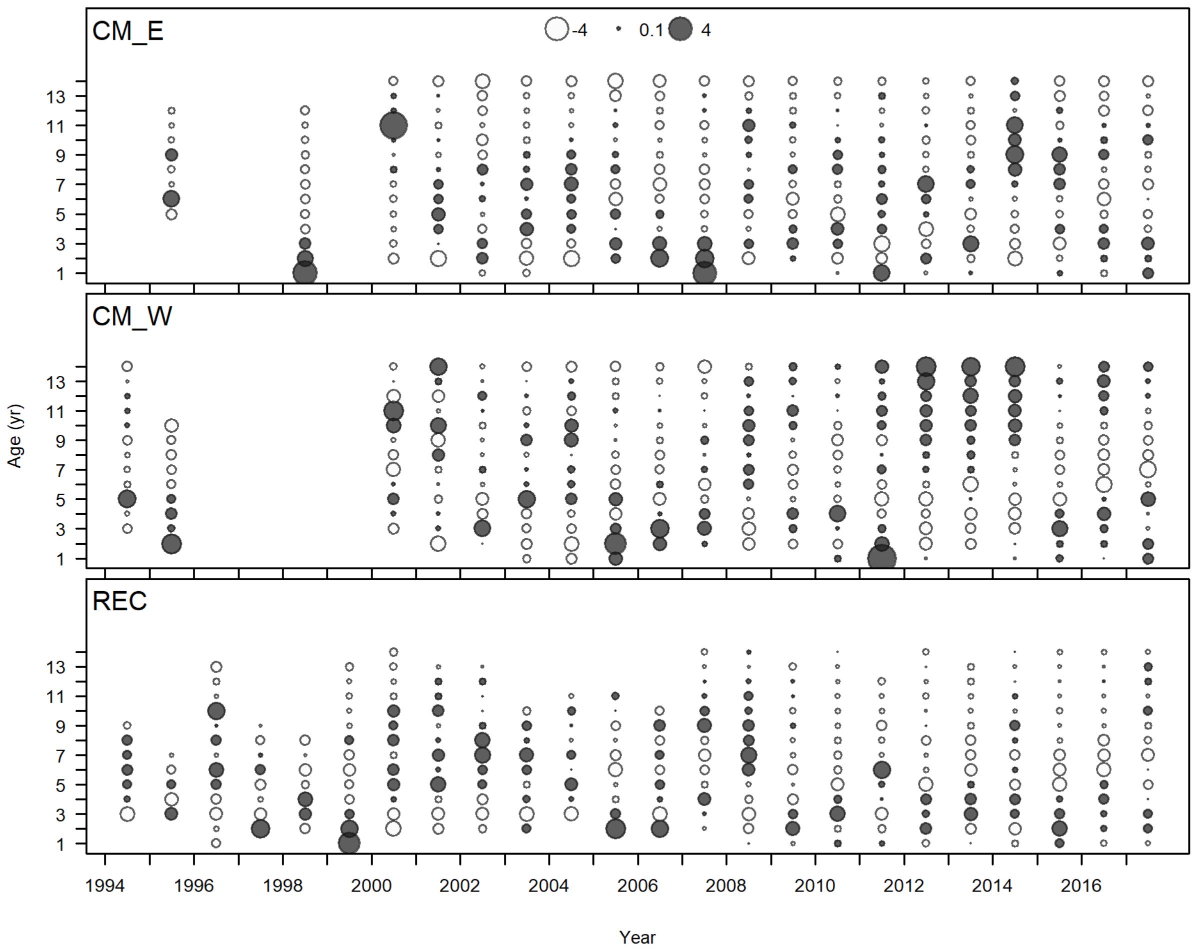


Figure 35: Observed and predicted age compositions aggregated across years for the commercial east (top left panel), commercial west (bottom left panel), and recreational (top right panel) fleets.

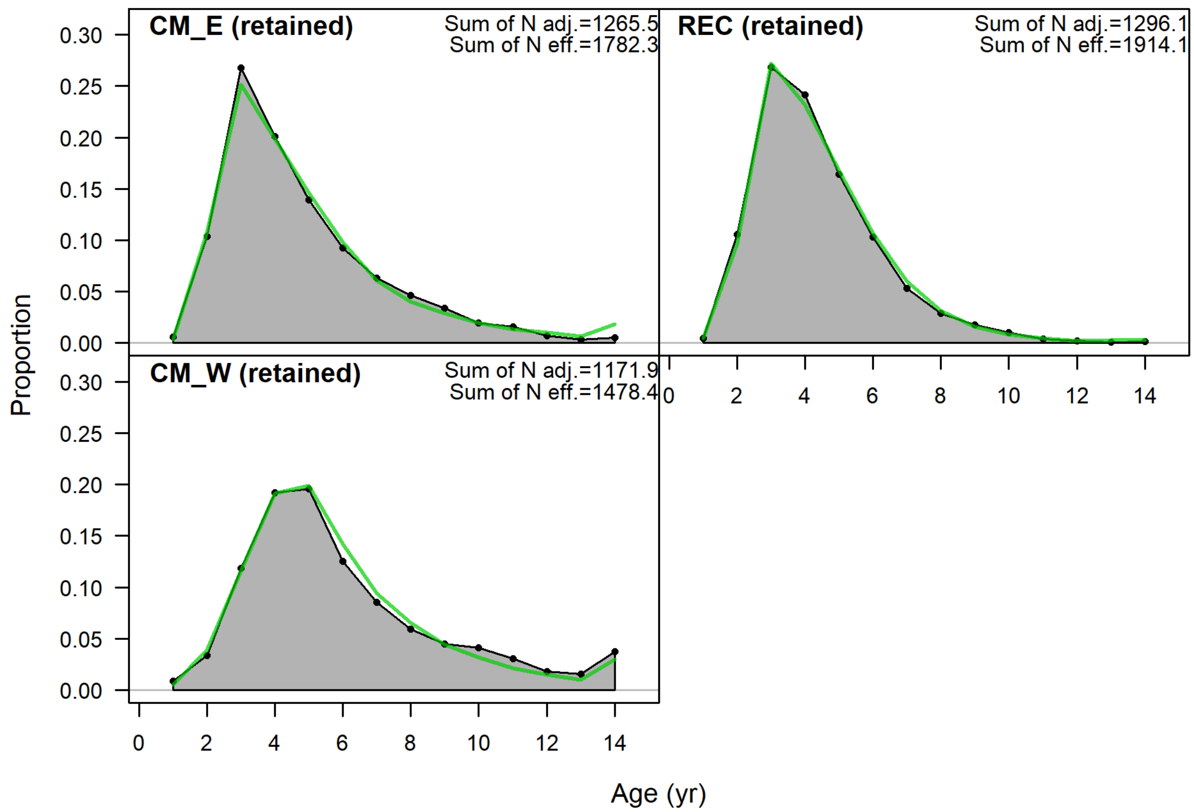


Figure 36: Observed (black lines) and predicted (green lines) length compositions for the combined video survey. Input sample sizes (N; after reweighting) along with the effective sample size (N_{eff}) are also reported. Sample sizes were capped at a maximum of 100.

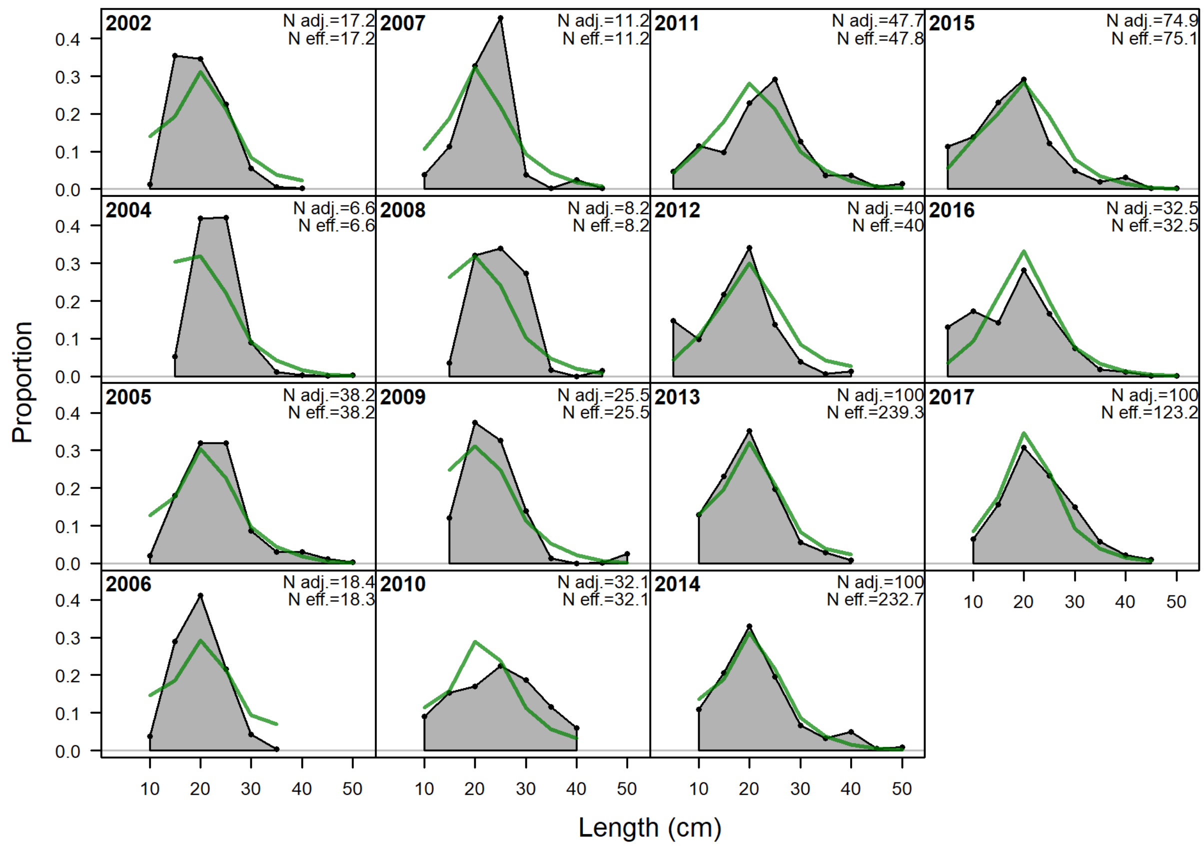


Figure 37: Observed (black lines) and predicted (green lines) length compositions for the SEAMAP summer east groundfish survey. Input sample sizes (N; after reweighting) along with the effective sample size (N_{eff}) are also reported. Sample sizes were capped at a maximum of 100.

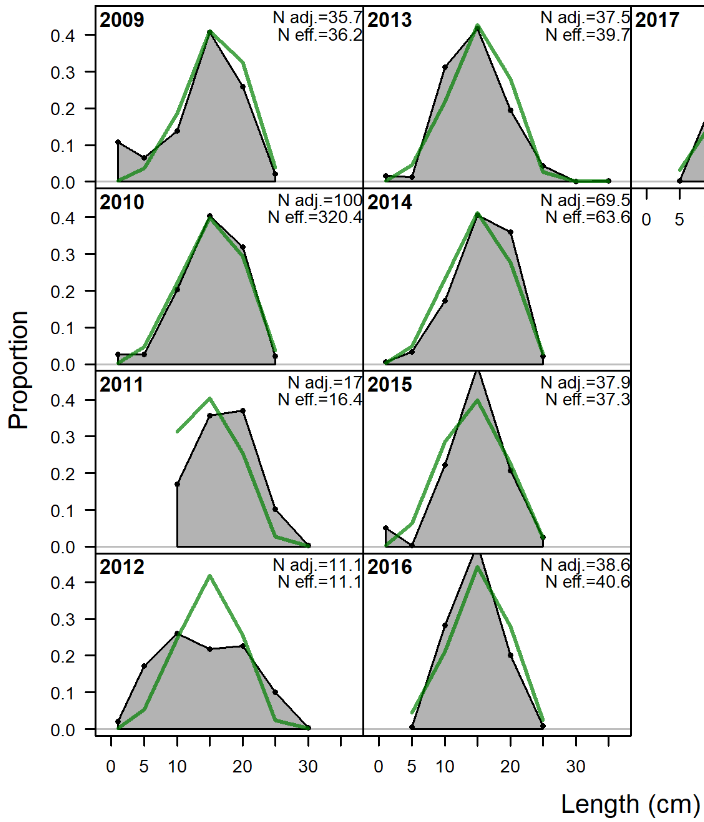
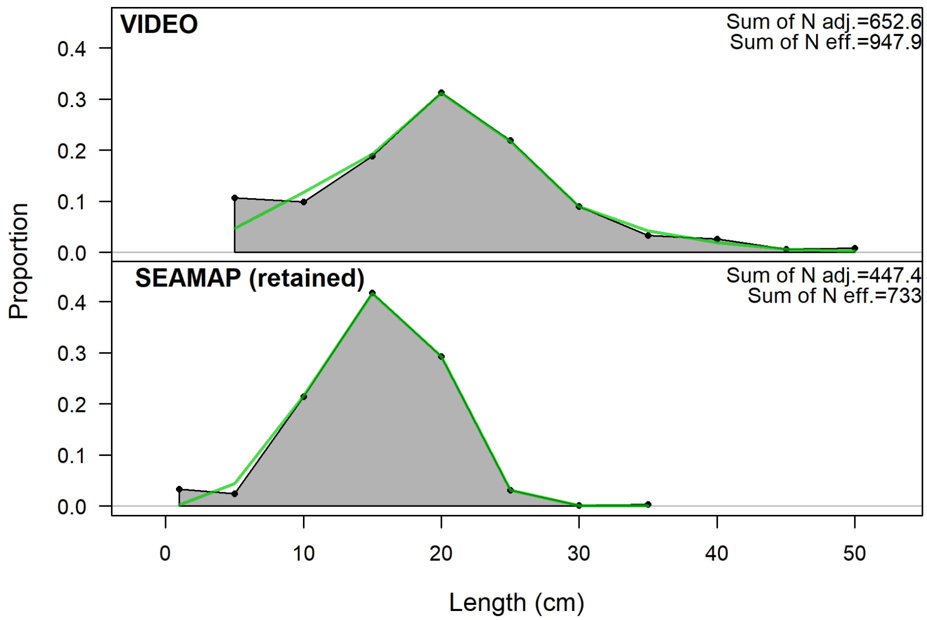


Figure 38: Observed and predicted length compositions aggregated across years (top panel) and Pearson residuals (bottom panel) for the video and SEAMAP summer east groundfish surveys.



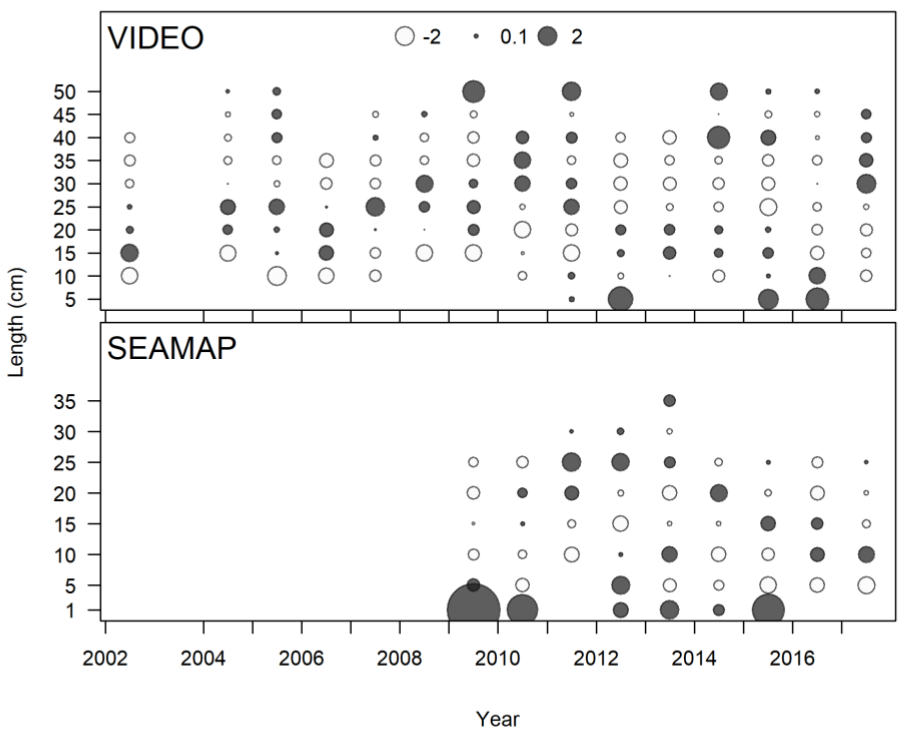


Figure 39: Profile likelihood plots for the natural log of virgin recruitment (*ln_R0*; top plot), recruitment variance (σ_R; middle panel), and steepness (*h*; bottom panel). The y-axis provides the change in negative log-likelihood and, therefore, represents increases in likelihood relative to the best-fit model.

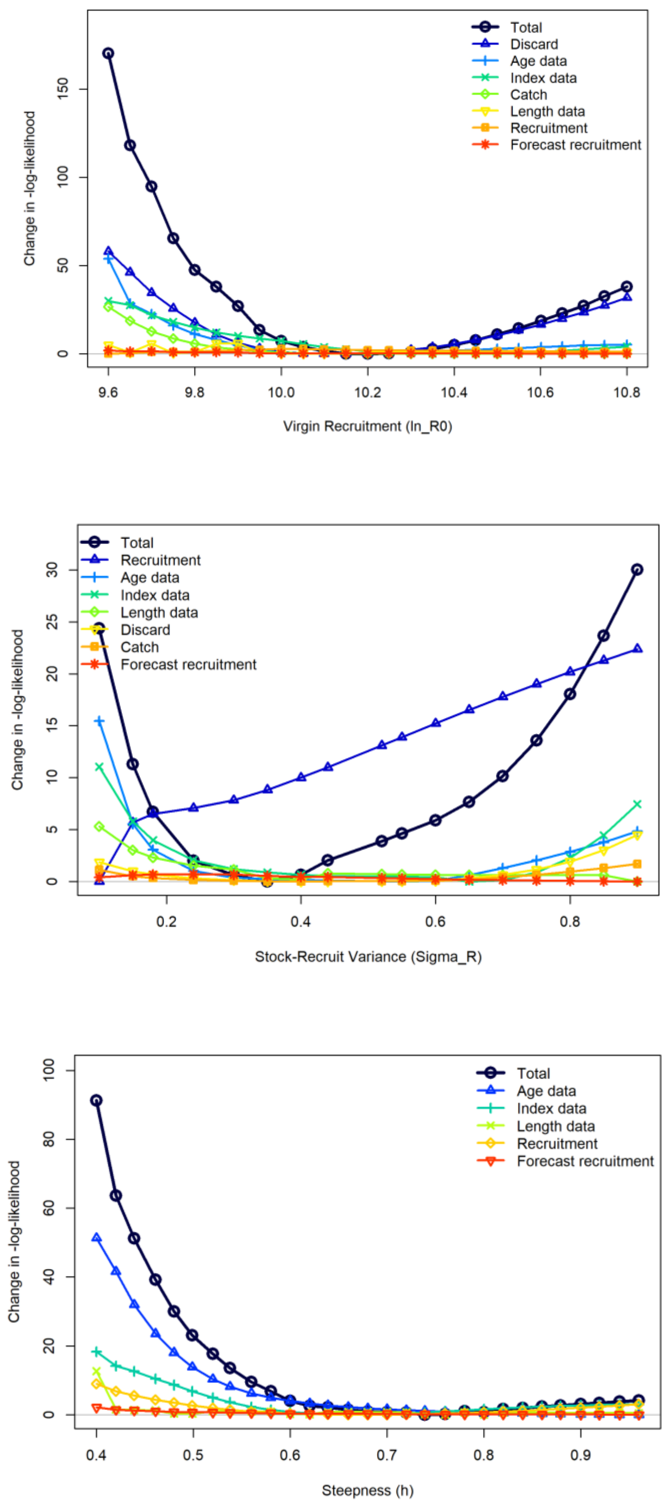


Figure 40: Spawning stock biomass (1000s of eggs) plots for each of the profile likelihood runs provided in Figure 39. The top panel illustrates runs at different virgin recruitment (R_0) levels, the middle plot represents runs at different recruitment variance levels, and the bottom plot shows runs for different steepness values. In general, all runs converge to similar current SSB levels demonstrating relatively good model stability.

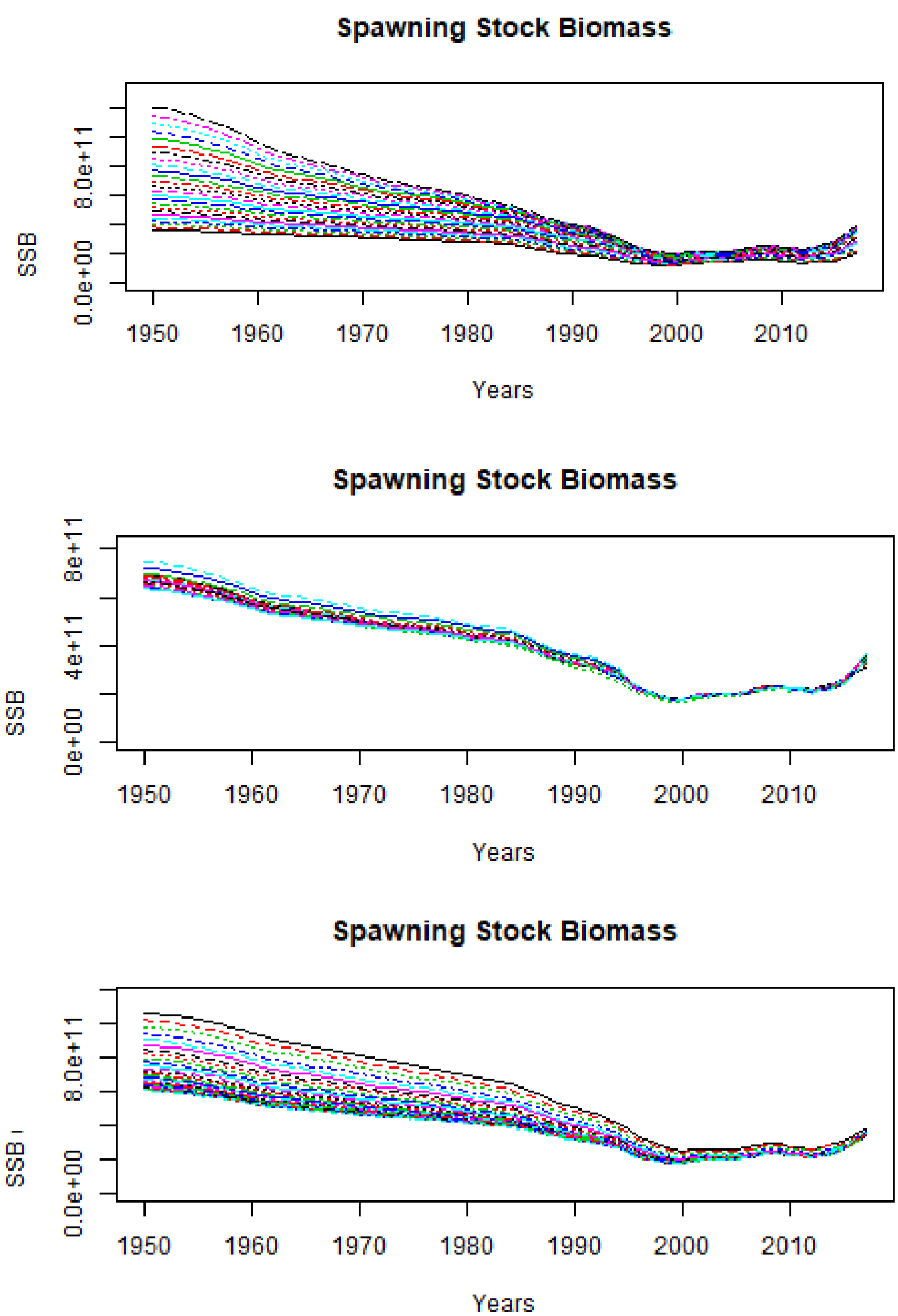


Figure 41: Profile likelihood contour plot of recruitment variance against steepness. Contours illustrate negative log-likelihood values (lower values demonstrate stronger fit to the data). The nearly level contours that trail to the top right indicate the highly correlated nature of these parameters. Although the model estimates steepness around 0.7 and recruitment variance around 0.3, steepness values from 0.6 - 0.9 with corresponding recruitment variances from 0.2 - 0.6 provide nearly identical fits to the data and are likely to be equally probable.

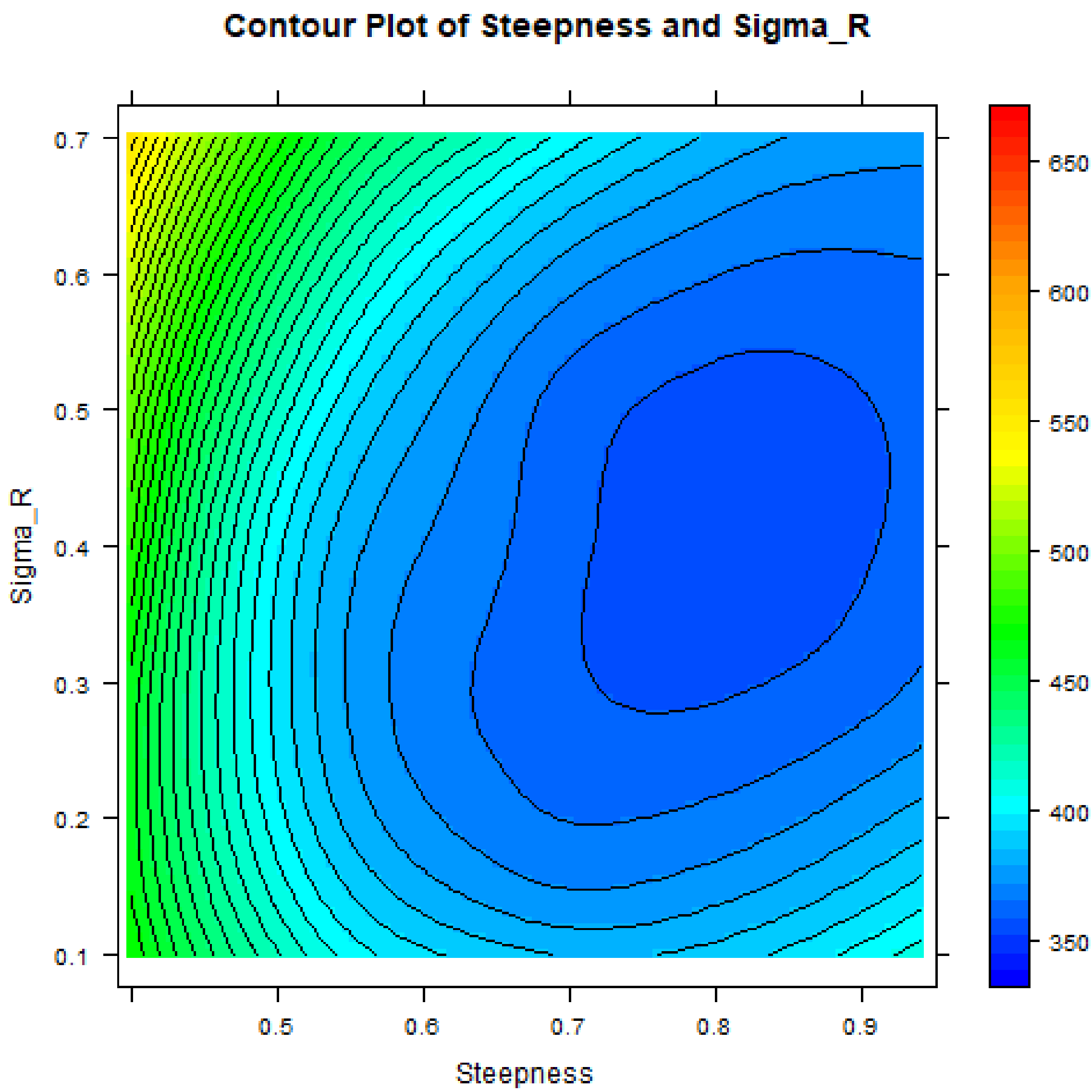


Figure 42: Results of the 1000 bootstrap analyses for various estimated parameters and population quantities. Although some spread exists in the final estimates, model results are consistent across runs indicating high model stability. SSB is in 1000s of eggs.

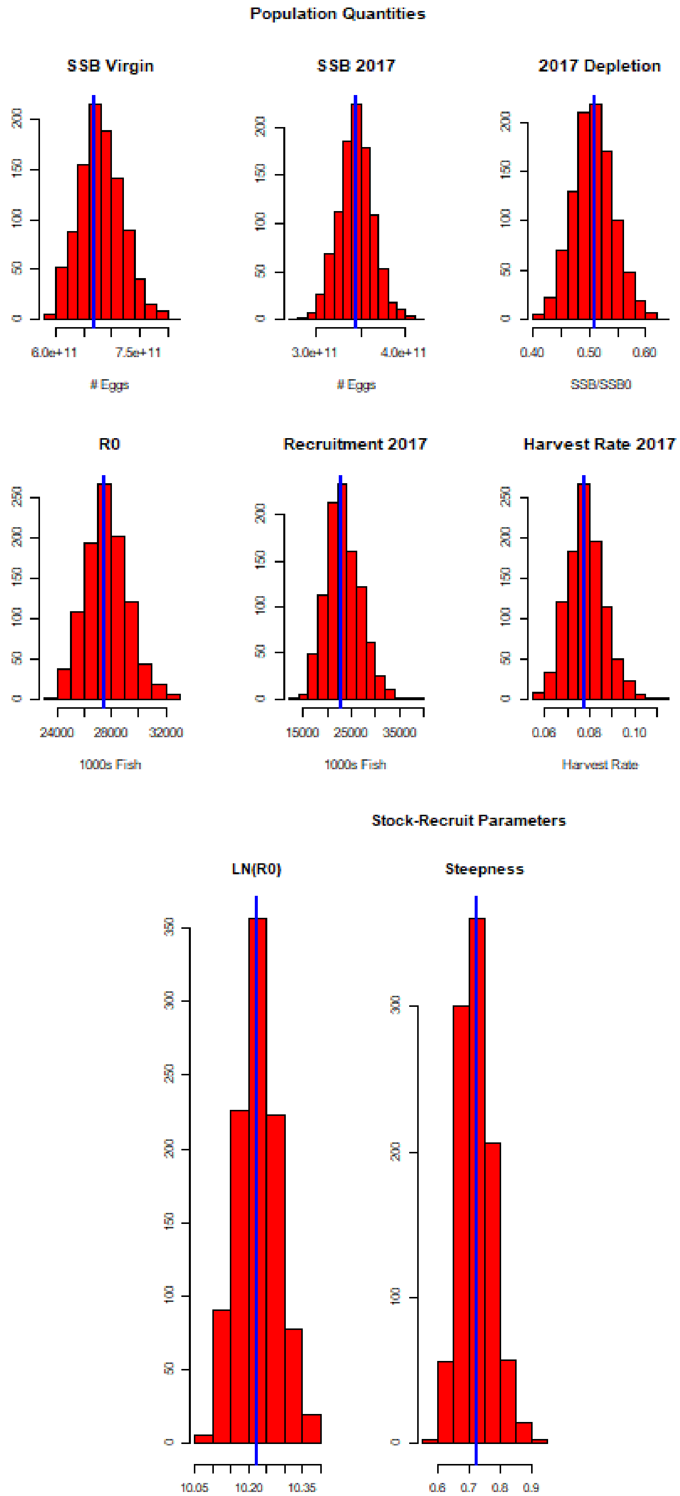


Figure 43: Results of a five-year retrospective analysis for spawning output and recruitment (million fish; bottom panel). There is no discernible systematic bias, because each data peal is not consistently over or underestimating any of the population quantities. However, successive peals after removing the terminal year of data demonstrate a slight consistent underestimation of SSB.

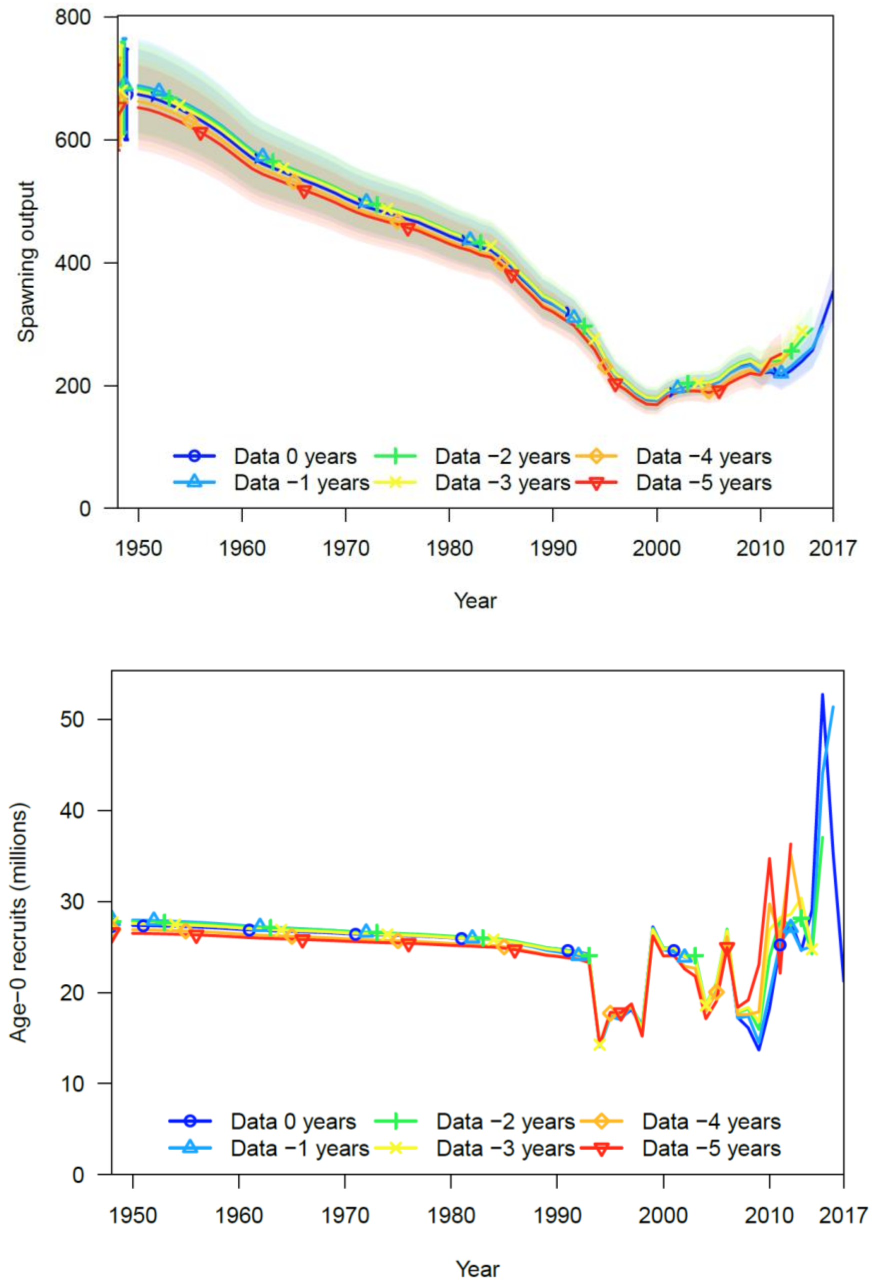


Figure 44: Results of the jitter analysis for various likelihood components (top left and bottom panels) and steepness estimates (top right panel). Each graph gives the results of 200 model runs where the starting parameter values for each run were randomly changed ('jittered') by 0.2 from the base model best-fit values. Overall, the model appears to be relatively stable with only a handful of runs resulting in model convergence issues. Given that the length and age composition dominate the likelihoods in these runs, it is likely that correlation in selectivity parameters (particularly the six parameters required to estimate domed selectivity for the recreational fishery and both the groundfish and video surveys) are the culprits for poor model performance in these instances.

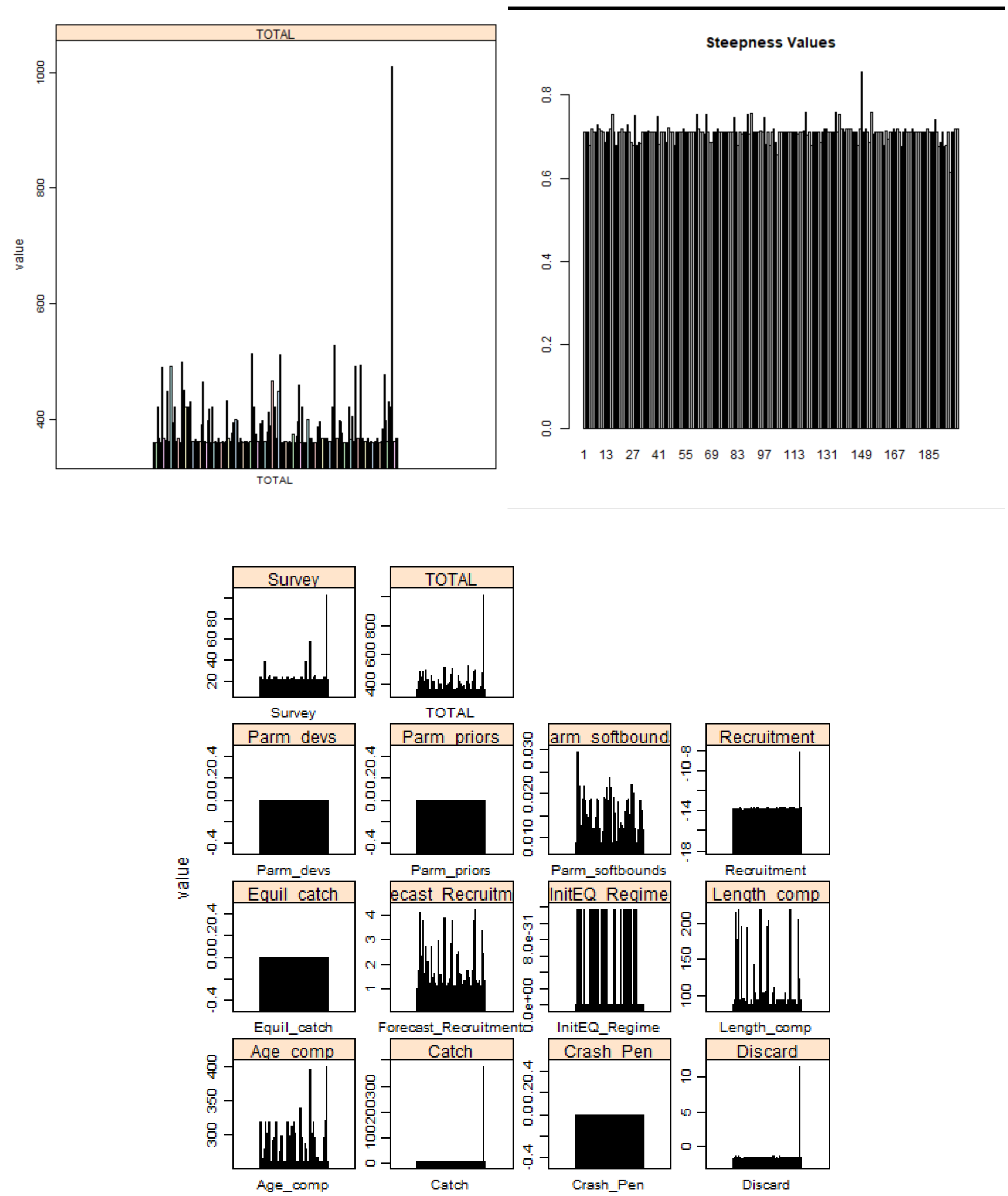


Figure 45: Results of a 'jack-knife' analysis with the fishery-dependent and independent indices. Spawning stock biomass and recruitment (million fish; bottom panel) are shown. The analysis was performed by running the base model with one of the indices removed (or all of the fishery-dependent CPUE indices) in order to determine if any given index had undue influence on model results or indicated widely differing trends in population trajectories. The results indicate most of the indices are generally in agreement, but the video index appears to be a strong driver in estimating the extreme 2015 recruitment event.

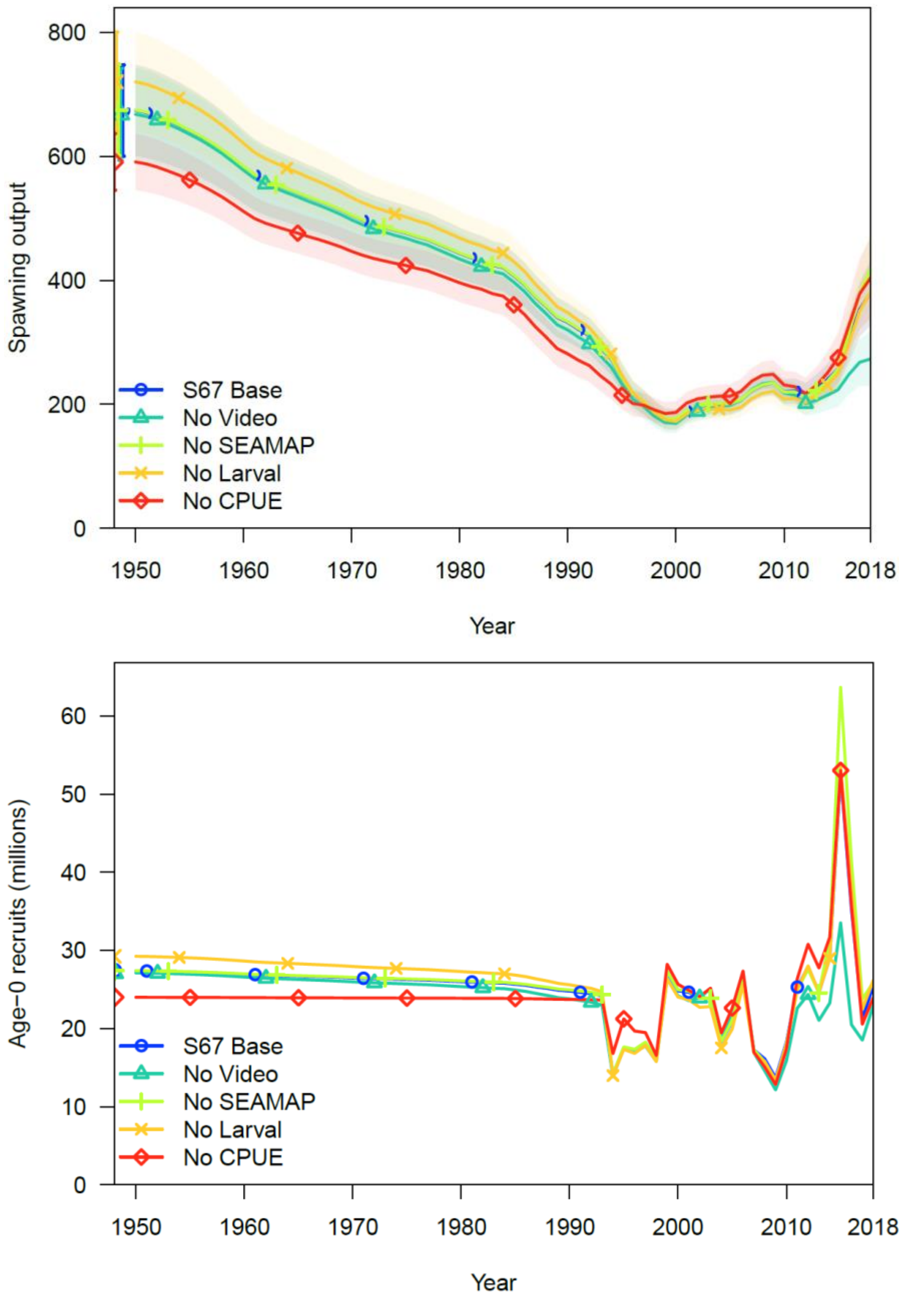


Figure 46: Comparison of continuity model building runs including: the SEDAR 45 base model (build in SS3.24; blue), the SEDAR 45 base model using the FES adjusted recreational catch (green), the SEDAR 45 base model converted to SS3.3 (yellow), and the SEDAR 67 continuity model (build in SS3.3) with updated data through 2017 along with the FES adjusted catch (red). Spawning stock biomass is shown in the top panel, recruitment (million fish) in the bottom left panel, and depletion (SSB/SSB_0) in the bottom right panel. The conversion to SS3.3 had no impact on the results of the SEDAR 45 model, whereas switching to the higher FES adjusted recreational landings led to increased biomass and recruitment along with improved stock status, especially over the last 5-10 years. The inclusion of these changes along with data updated through 2017 in the continuity model led to reestimation of R0 and SSB0 and a rescaling of the assessment. Trends and stock status remain similar to the SEDAR 45 model, while depletion has been steadily decreasing in the last three years since SEDAR 45 was completed.

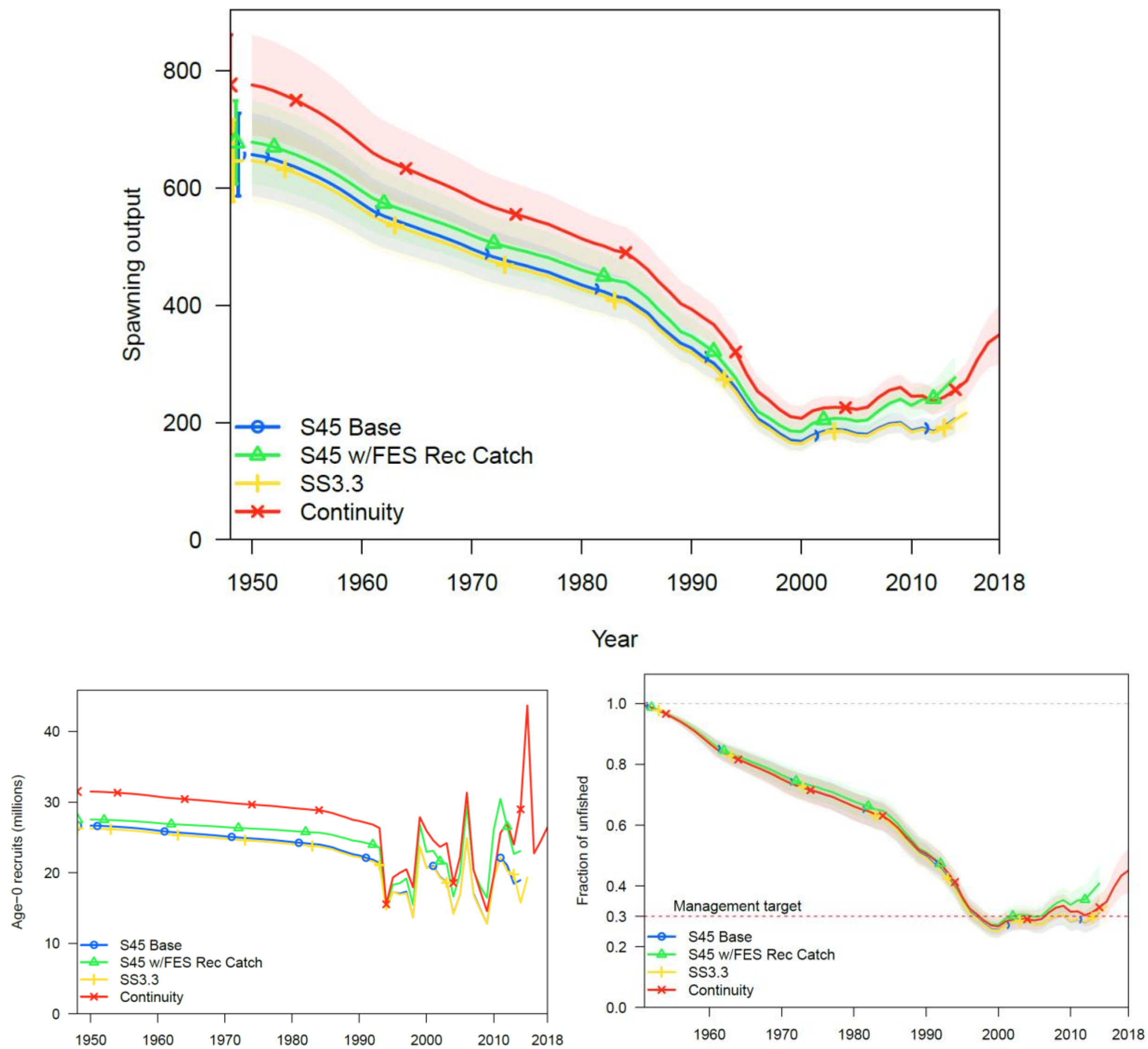


Figure 47: Comparison of base model building runs including: the continuity model (blue), the continuity model with truncated commercial CPUE indices (light blue), the continuity model using the combined video index (teal), the continuity model with discards modeled but not fit (green), the combination of the combined video index and discards modeled but not fit (yellow), the previous modeled with truncated commercial CPUE indices (gold), the previous model with no commercial selectivity time blocks (orange), and the base model (i.e., the previous model with the recruit variation fixed at 0.3; red). Spawning stock biomass is shown in the top panel, recruitment (million fish) in the bottom left panel, and depletion (SSB/SSB_0) in the bottom right panel. The biggest impact was due to using the combined video index, which led to strong increases in biomass and recruitment in the last three years (primarily due to a much greater estimate of the 2015 yearclass compared to the MS Labs only video index used in the continuity model). Modeling discards reduced estimates of recent increases in biomass from both the continuity and combined video index, but other changes had little impact.

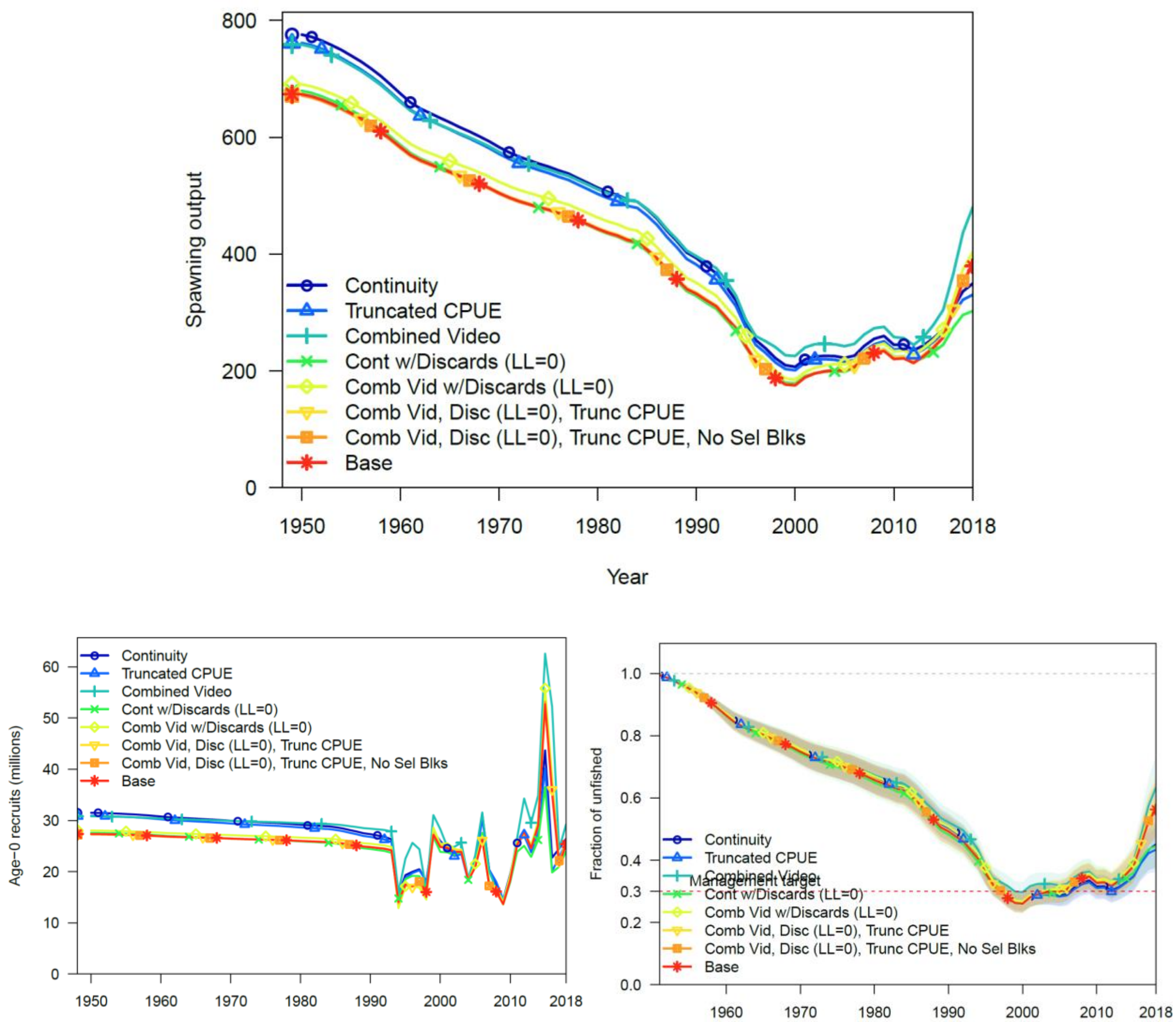


Figure 48: Comparison of model sensitivity runs including: the base model (blue), the base model using the continuity (Mississippi Labs only) video index (green), excluding the video index (yellow), excluding all fishery-dependent CPUE data (red), and increasing discard mortality across all fleets to 50%. Spawning stock biomass is shown in the top panel, recruitment (million fish) in the bottom left panel, and depletion (SSB/SSB_0) in the bottom right panel. The choice of how to handle the video index has a strong impact on the size of the 2015 yearclass and subsequent SSB and depletion. The choice of discard mortality rate has a relatively limited impact on results, whereas removing the CPUE indices has a strong positive influence on stock status.

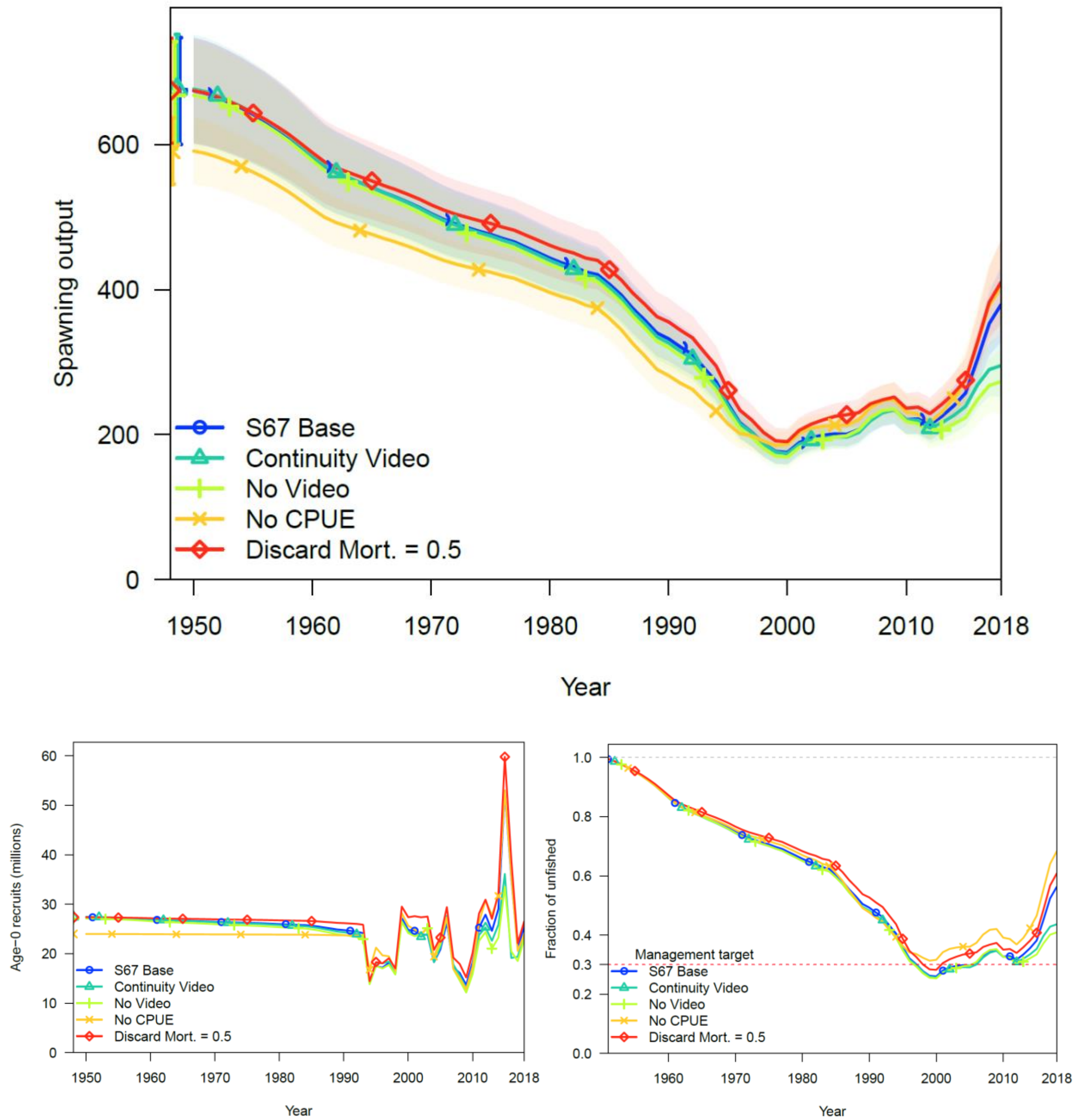


Figure 49: Assessment history plot comparing the results of the SEDAR 45 and SEDAR 67 base models based on depletion estimates (SSB/SSB_0).

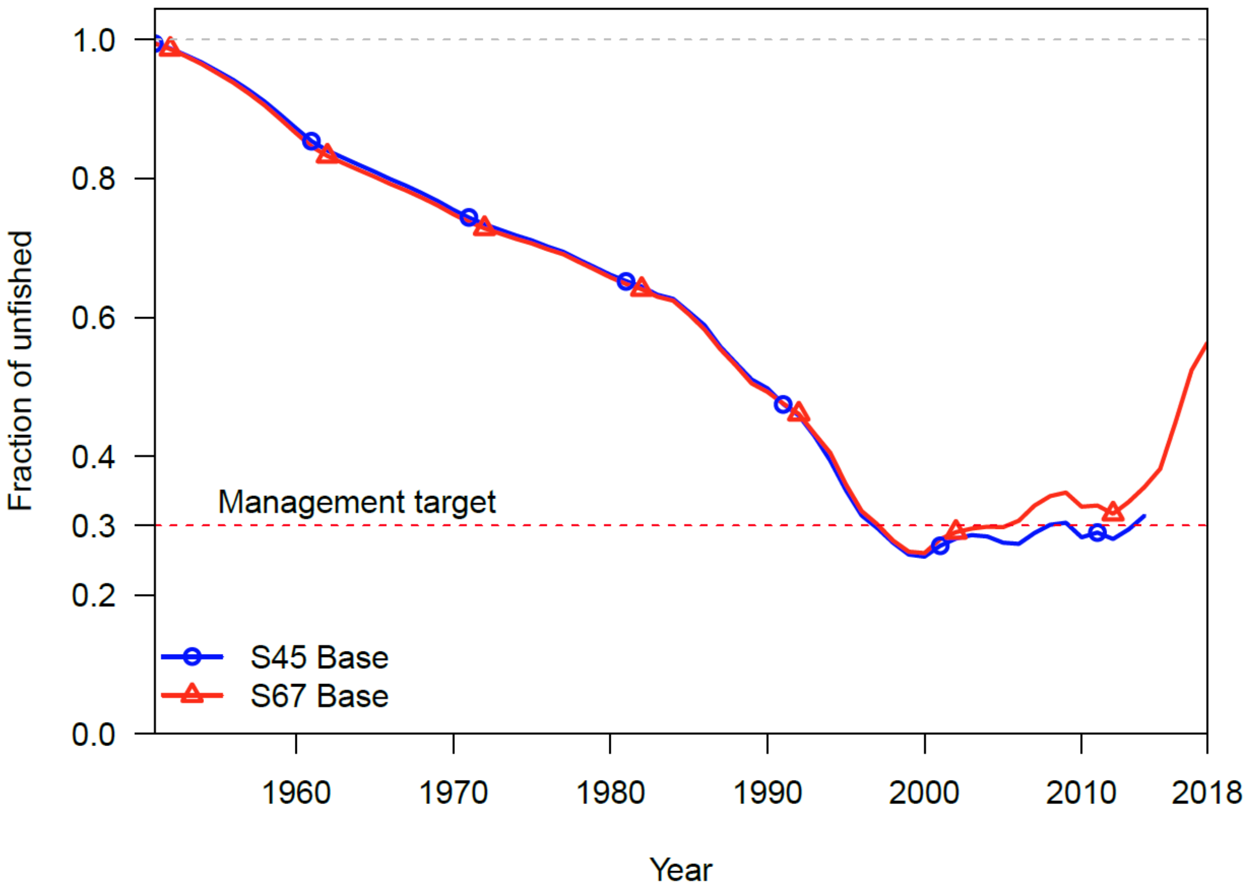
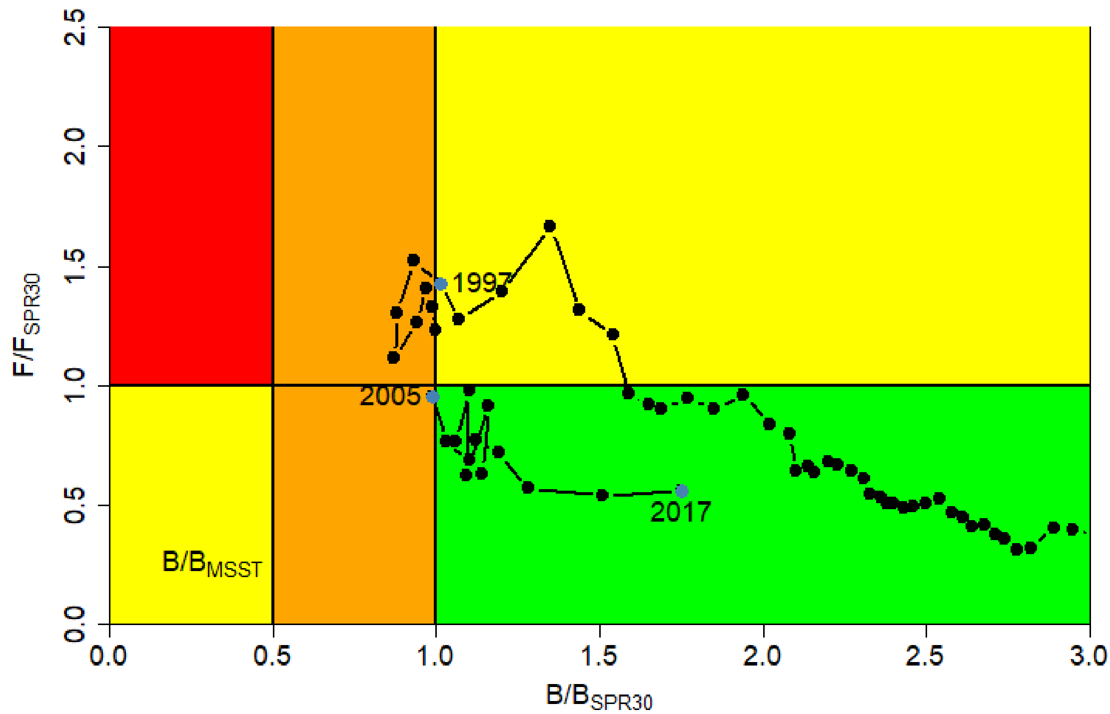


Figure 50: Kobe plot illustrating the trajectory of stock status. The orange coloring indicates regions where the stock is below the biomass target but above the biomass threshold (MSST).



10. Appendix A: Stock Synthesis 3 Input Files

10.1. DAT File

```
#V3.30
#C data file created using the SS_writedat function in the R package r4ss
#C should work with SS version:
#C file write time: 2020-01-23 16:14:32
#
1950 #_styr
2017 #_endyr
1 #_nseas
12 #_months_per_seas
2 #_Nsubseasons
1 #_spawn_month
1 #_Nsexes
14 #_Nages
1 #_Nareas
9 #_Nfleets
#_fleetinfo
#_type	surveytiming	area	units	need_catch_mult	fleetname
1	-1	1	1	0	CM_E	#_1
1	-1	1	1	0	CM_W	#_2
1	-1	1	2	0	REC	#_3
2	-1	1	2	0	SMP_BYC	#_4
3	1	1	1	0	HB_E	#_5
3	1	1	1	0	HB_W	#_6
3	1	1	1	0	LARVAL	#_7
3	1	1	1	0	VIDEO	#_8
3	1	1	1	0	SEAMAP	#_9
#Bycatch_fleet_input
#_fleetindex	includeinMSY	Fmult	F_or_first_year	F_or_last_year	unused
4	1	3	2011	2014	999	#_4
#_Catch data
#_year	season	fleet	catch	catch_se
1950	1	1	1.000	0.05	#_1
1951	1	1	1.990	0.05	#_2
1952	1	1	2.990	0.05	#_3
1953	1	1	3.980	0.05	#_4
1954	1	1	4.980	0.05	#_5
1955	1	1	5.980	0.05	#_6
1956	1	1	6.970	0.05	#_7
1957	1	1	7.970	0.05	#_8
1958	1	1	8.970	0.05	#_9
1959	1	1	9.960	0.05	#_10
1960	1	1	10.960	0.05	#_11
1961	1	1	11.950	0.05	#_12
1962	1	1	12.950	0.05	#_13
1963	1	1	13.935	0.05	#_14
1964	1	1	15.243	0.05	#_15
1965	1	1	15.143	0.05	#_16
1966	1	1	7.898	0.05	#_17
1967	1	1	15.998	0.05	#_18
1968	1	1	31.794	0.05	#_19
1969	1	1	40.498	0.05	#_20
1970	1	1	37.781	0.05	#_21
1971	1	1	41.252	0.05	#_22
1972	1	1	36.423	0.05	#_23
1973	1	1	61.426	0.05	#_24
1974	1	1	58.307	0.05	#_25
1975	1	1	126.876	0.05	#_26
1976	1	1	111.482	0.05	#_27
1977	1	1	151.093	0.05	#_28
1978	1	1	129.872	0.05	#_29
```

1979	1	1	99.001	0.05	#_30
1980	1	1	72.360	0.05	#_31
1981	1	1	104.931	0.05	#_32
1982	1	1	108.487	0.05	#_33
1983	1	1	171.188	0.05	#_34
1984	1	1	241.128	0.05	#_35
1985	1	1	304.633	0.05	#_36
1986	1	1	312.554	0.05	#_37
1987	1	1	242.256	0.05	#_38
1988	1	1	222.730	0.05	#_39
1989	1	1	217.000	0.05	#_40
1990	1	1	516.745	0.05	#_41
1991	1	1	420.571	0.05	#_42
1992	1	1	538.129	0.05	#_43
1993	1	1	742.425	0.05	#_44
1994	1	1	711.928	0.05	#_45
1995	1	1	678.322	0.05	#_46
1996	1	1	523.542	0.05	#_47
1997	1	1	469.073	0.05	#_48
1998	1	1	365.002	0.05	#_49
1999	1	1	416.384	0.05	#_50
2000	1	1	315.332	0.05	#_51
2001	1	1	362.239	0.05	#_52
2002	1	1	451.753	0.05	#_53
2003	1	1	522.876	0.05	#_54
2004	1	1	420.593	0.05	#_55
2005	1	1	443.952	0.05	#_56
2006	1	1	505.012	0.05	#_57
2007	1	1	527.224	0.05	#_58
2008	1	1	809.367	0.05	#_59
2009	1	1	1273.013	0.05	#_60
2010	1	1	598.161	0.05	#_61
2011	1	1	1101.231	0.05	#_62
2012	1	1	720.121	0.05	#_63
2013	1	1	416.259	0.05	#_64
2014	1	1	502.119	0.05	#_65
2015	1	1	300.366	0.05	#_66
2016	1	1	361.166	0.05	#_67
2017	1	1	422.485	0.05	#_68
1950	1	2	0.730	0.05	#_69
1951	1	2	1.460	0.05	#_70
1952	1	2	2.190	0.05	#_71
1953	1	2	2.920	0.05	#_72
1954	1	2	3.650	0.05	#_73
1955	1	2	4.380	0.05	#_74
1956	1	2	5.110	0.05	#_75
1957	1	2	5.840	0.05	#_76
1958	1	2	6.570	0.05	#_77
1959	1	2	7.300	0.05	#_78
1960	1	2	8.030	0.05	#_79
1961	1	2	8.760	0.05	#_80
1962	1	2	9.490	0.05	#_81
1963	1	2	10.212	0.05	#_82
1964	1	2	10.665	0.05	#_83
1965	1	2	9.408	0.05	#_84
1966	1	2	3.018	0.05	#_85
1967	1	2	7.144	0.05	#_86
1968	1	2	22.789	0.05	#_87
1969	1	2	12.275	0.05	#_88
1970	1	2	20.123	0.05	#_89
1971	1	2	21.783	0.05	#_90
1972	1	2	21.079	0.05	#_91
1973	1	2	24.902	0.05	#_92
1974	1	2	30.285	0.05	#_93
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1976	1	2	27.418	0.05	#_95

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1978	1	2	73.994	0.05	#_97
1979	1	2	99.911	0.05	#_98
1980	1	2	67.283	0.05	#_99
1981	1	2	52.421	0.05	#_100
1982	1	2	66.393	0.05	#_101
1983	1	2	73.310	0.05	#_102
1984	1	2	384.463	0.05	#_103
1985	1	2	334.297	0.05	#_104
1986	1	2	425.595	0.05	#_105
1987	1	2	454.779	0.05	#_106
1988	1	2	449.467	0.05	#_107
1989	1	2	454.499	0.05	#_108
1990	1	2	436.021	0.05	#_109
1991	1	2	366.098	0.05	#_110
1992	1	2	476.145	0.05	#_111
1993	1	2	462.864	0.05	#_112
1994	1	2	471.416	0.05	#_113
1995	1	2	296.518	0.05	#_114
1996	1	2	295.444	0.05	#_115
1997	1	2	486.120	0.05	#_116
1998	1	2	405.702	0.05	#_117
1999	1	2	497.473	0.05	#_118
2000	1	2	343.647	0.05	#_119
2001	1	2	409.773	0.05	#_120
2002	1	2	453.104	0.05	#_121
2003	1	2	570.543	0.05	#_122
2004	1	2	551.824	0.05	#_123
2005	1	2	401.583	0.05	#_124
2006	1	2	288.316	0.05	#_125
2007	1	2	547.909	0.05	#_126
2008	1	2	466.472	0.05	#_127
2009	1	2	443.974	0.05	#_128
2010	1	2	356.550	0.05	#_129
2011	1	2	329.252	0.05	#_130
2012	1	2	384.454	0.05	#_131
2013	1	2	225.620	0.05	#_132
2014	1	2	298.637	0.05	#_133
2015	1	2	317.712	0.05	#_134
2016	1	2	353.972	0.05	#_135
2017	1	2	312.975	0.05	#_136
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1951	1	3	16.203	0.15	#_138
1952	1	3	26.376	0.15	#_139
1953	1	3	36.549	0.15	#_140
1954	1	3	46.722	0.15	#_141
1955	1	3	56.894	0.15	#_142
1956	1	3	67.067	0.15	#_143
1957	1	3	77.240	0.15	#_144
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1964	1	3	148.451	0.15	#_151
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1969	1	3	199.315	0.15	#_156
1970	1	3	209.488	0.15	#_157
1971	1	3	219.661	0.15	#_158
1972	1	3	229.834	0.15	#_159
1973	1	3	240.007	0.15	#_160
1974	1	3	250.179	0.15	#_161

1975	1	3	260.352	0.15	#_162
1976	1	3	270.525	0.15	#_163
1977	1	3	280.698	0.15	#_164
1978	1	3	290.871	0.15	#_165
1979	1	3	301.044	0.15	#_166
1980	1	3	311.217	0.15	#_167
1981	1	3	321.390	0.15	#_168
1982	1	3	705.743	0.15	#_169
1983	1	3	271.946	0.15	#_170
1984	1	3	418.872	0.15	#_171
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1986	1	3	1111.405	0.15	#_173
1987	1	3	1366.060	0.15	#_174
1988	1	3	2019.030	0.15	#_175
1989	1	3	1106.635	0.15	#_176
1990	1	3	1266.867	0.15	#_177
1991	1	3	1600.508	0.15	#_178
1992	1	3	1967.015	0.15	#_179
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1994	1	3	1201.986	0.15	#_181
1995	1	3	1476.298	0.15	#_182
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1997	1	3	689.456	0.15	#_184
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1999	1	3	707.579	0.15	#_186
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2001	1	3	1227.992	0.15	#_188
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2007	1	3	762.783	0.15	#_194
2008	1	3	681.826	0.15	#_195
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2010	1	3	758.396	0.15	#_197
2011	1	3	1635.345	0.15	#_198
2012	1	3	1018.593	0.15	#_199
2013	1	3	1636.363	0.15	#_200
2014	1	3	1588.106	0.15	#_201
2015	1	3	1491.552	0.15	#_202
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2017	1	3	2336.507	0.15	#_204
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1952	1	4	0.001	0.10	#_207
1953	1	4	0.001	0.10	#_208
1954	1	4	0.001	0.10	#_209
1955	1	4	0.001	0.10	#_210
1956	1	4	0.001	0.10	#_211
1957	1	4	0.001	0.10	#_212
1958	1	4	0.001	0.10	#_213
1959	1	4	0.001	0.10	#_214
1960	1	4	0.001	0.10	#_215
1961	1	4	0.001	0.10	#_216
1962	1	4	0.001	0.10	#_217
1963	1	4	0.001	0.10	#_218
1964	1	4	0.001	0.10	#_219
1965	1	4	0.001	0.10	#_220
1966	1	4	0.001	0.10	#_221
1967	1	4	0.001	0.10	#_222
1968	1	4	0.001	0.10	#_223
1969	1	4	0.001	0.10	#_224
1970	1	4	0.001	0.10	#_225
1971	1	4	0.001	0.10	#_226
1972	1	4	0.001	0.10	#_227

1973	1	4	0.001	0.10	#_228
1974	1	4	0.001	0.10	#_229
1975	1	4	0.001	0.10	#_230
1976	1	4	0.001	0.10	#_231
1977	1	4	0.001	0.10	#_232
1978	1	4	0.001	0.10	#_233
1979	1	4	0.001	0.10	#_234
1980	1	4	0.001	0.10	#_235
1981	1	4	0.001	0.10	#_236
1982	1	4	0.001	0.10	#_237
1983	1	4	0.001	0.10	#_238
1984	1	4	0.001	0.10	#_239
1985	1	4	0.001	0.10	#_240
1986	1	4	0.001	0.10	#_241
1987	1	4	0.001	0.10	#_242
1988	1	4	0.001	0.10	#_243
1989	1	4	0.001	0.10	#_244
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1991	1	4	0.001	0.10	#_246
1992	1	4	0.001	0.10	#_247
1993	1	4	0.001	0.10	#_248
1994	1	4	0.001	0.10	#_249
1995	1	4	0.001	0.10	#_250
1996	1	4	0.001	0.10	#_251
1997	1	4	0.001	0.10	#_252
1998	1	4	0.001	0.10	#_253
1999	1	4	0.001	0.10	#_254
2000	1	4	0.001	0.10	#_255
2001	1	4	0.001	0.10	#_256
2002	1	4	0.001	0.10	#_257
2003	1	4	0.001	0.10	#_258
2004	1	4	0.001	0.10	#_259
2005	1	4	0.001	0.10	#_260
2006	1	4	0.001	0.10	#_261
2007	1	4	0.001	0.10	#_262
2008	1	4	0.001	0.10	#_263
2009	1	4	0.001	0.10	#_264
2010	1	4	0.001	0.10	#_265
2011	1	4	0.001	0.10	#_266
2012	1	4	0.001	0.10	#_267
2013	1	4	0.001	0.10	#_268
2014	1	4	0.001	0.10	#_269
2015	1	4	0.001	0.10	#_270
2016	1	4	0.001	0.10	#_271
2017	1	4	0.001	0.10	#_272
-9999	0	0	0.000	0.00	#_terminator

#_CPUE_and_surveyabundance_observations
#_Units: 0=numbers; 1=biomass; 2=F; >=30 for special types
#_Errtype: -1=normal; 0=lognormal; >0=T
#_SD_Report: 0=no sdreport; 1=enable sdreport

#_Fleet	Units	Errtype	SD_Report	
1	1	0	0	#_CM_E
2	1	0	0	#_CM_W
3	0	0	0	#_REC
4	2	0	0	#_SMP_BYC
5	0	0	0	#_HB_E
6	0	0	0	#_HB_W
7	30	0	0	#_LARVAL
8	0	0	0	#_VIDEO
9	0	0	0	#_SEAMAP

#
#_CPUE_data

#_year	seas	index	obs	se_log	
1993	7	1	1.036400	0.224000	#_1
1994	7	1	1.232100	0.192100	#_2
1995	7	1	0.897000	0.214800	#_3

1996	7	1	0.950600	0.190900	#_4
1997	7	1	0.887900	0.200700	#_5
1998	7	1	0.877700	0.202100	#_6
1999	7	1	0.946100	0.185700	#_7
2000	7	1	0.791500	0.217000	#_8
2001	7	1	0.866300	0.204500	#_9
2002	7	1	0.943500	0.189100	#_10
2003	7	1	0.994800	0.181700	#_11
2004	7	1	0.982500	0.194500	#_12
2005	7	1	1.285400	0.191300	#_13
2006	7	1	1.308200	0.211700	#_14
1993	7	2	1.061400	0.294600	#_15
1994	7	2	1.462800	0.242100	#_16
1995	7	2	0.933500	0.250200	#_17
1996	7	2	1.016800	0.215800	#_18
1997	7	2	1.294100	0.165700	#_19
1998	7	2	1.017900	0.185300	#_20
1999	7	2	1.054300	0.159700	#_21
2000	7	2	0.721700	0.191200	#_22
2001	7	2	0.764900	0.200600	#_23
2002	7	2	1.002100	0.174300	#_24
2003	7	2	1.262000	0.157100	#_25
2004	7	2	1.245300	0.154800	#_26
2005	7	2	0.770000	0.182300	#_27
2006	7	2	0.393100	0.226300	#_28
1986	7	5	0.900300	0.286700	#_29
1987	7	5	1.008700	0.274800	#_30
1988	7	5	2.163400	0.192500	#_31
1989	7	5	1.342900	0.193400	#_32
1990	7	5	1.689100	0.179800	#_33
1991	7	5	1.802900	0.178300	#_34
1992	7	5	2.499300	0.170700	#_35
1993	7	5	1.598900	0.176500	#_36
1994	7	5	1.766200	0.174200	#_37
1995	7	5	1.489400	0.186300	#_38
1996	7	5	0.822400	0.198800	#_39
1997	7	5	0.735600	0.196400	#_40
1998	7	5	0.190300	0.218800	#_41
1999	7	5	0.421100	0.232900	#_42
2000	7	5	0.354000	0.222000	#_43
2001	7	5	0.441800	0.213700	#_44
2002	7	5	0.482500	0.211800	#_45
2003	7	5	0.587300	0.209000	#_46
2004	7	5	0.628500	0.204000	#_47
2005	7	5	0.812100	0.205500	#_48
2006	7	5	0.560600	0.221000	#_49
2007	7	5	0.371900	0.231500	#_50
2008	7	5	0.667400	0.200900	#_51
2009	7	5	0.789900	0.197000	#_52
2010	7	5	0.860200	0.215000	#_53
2011	7	5	1.058300	0.193800	#_54
2012	7	5	0.656300	0.194400	#_55
2013	7	5	0.892200	0.178700	#_56
2014	7	5	0.947700	0.167800	#_57
2015	7	5	0.898300	0.166700	#_58
2016	7	5	0.957200	0.158600	#_59
2017	7	5	1.603400	0.148800	#_60
1986	7	6	1.751700	0.208300	#_61
1987	7	6	1.223000	0.198700	#_62
1988	7	6	0.928100	0.214600	#_63
1989	7	6	1.290800	0.204600	#_64
1990	7	6	1.766700	0.190400	#_65
1991	7	6	0.983400	0.194800	#_66
1992	7	6	0.944600	0.182900	#_67
1993	7	6	1.149600	0.171000	#_68
1994	7	6	1.137500	0.166900	#_69

1995	7	6	1.214200	0.165700	#_70
1996	7	6	0.885700	0.172200	#_71
1997	7	6	0.836600	0.184200	#_72
1998	7	6	0.796300	0.176800	#_73
1999	7	6	0.687000	0.203600	#_74
2000	7	6	0.519300	0.197500	#_75
2001	7	6	0.835600	0.190100	#_76
2002	7	6	0.974200	0.178700	#_77
2003	7	6	0.635500	0.177000	#_78
2004	7	6	1.091000	0.174100	#_79
2005	7	6	1.218400	0.171900	#_80
2006	7	6	0.651600	0.186800	#_81
2007	7	6	1.437900	0.180500	#_82
2008	7	6	0.261000	0.285000	#_83
2009	7	6	0.344400	0.219400	#_84
2010	7	6	1.139800	0.208900	#_85
2011	7	6	1.164700	0.209300	#_86
2012	7	6	0.912900	0.219100	#_87
2013	7	6	1.102600	0.221100	#_88
2014	7	6	0.896400	0.248600	#_89
2015	7	6	1.053400	0.217800	#_90
2016	7	6	1.151400	0.227300	#_91
2017	7	6	1.014500	0.252300	#_92
1986	7	3	2.800300	0.134300	#_93
1987	7	3	1.178800	0.240200	#_94
1988	7	3	1.911200	0.270200	#_95
1989	7	3	0.885500	0.329800	#_96
1990	7	3	2.228600	0.246200	#_97
1991	7	3	1.469600	0.180300	#_98
1992	7	3	1.382000	0.136400	#_99
1993	7	3	1.536200	0.169800	#_100
1994	7	3	1.433900	0.231500	#_101
1995	7	3	1.982500	0.232200	#_102
1996	7	3	1.007000	0.301800	#_103
1997	7	3	0.273800	0.220000	#_104
1998	7	3	0.360700	0.198200	#_105
1999	7	3	0.387100	0.140500	#_106
2000	7	3	0.346600	0.213300	#_107
2001	7	3	0.487500	0.205100	#_108
2002	7	3	0.362800	0.202300	#_109
2003	7	3	0.422000	0.179200	#_110
2004	7	3	0.542800	0.144000	#_111
2005	7	3	0.581400	0.165600	#_112
2006	7	3	0.536600	0.182300	#_113
2007	7	3	0.424800	0.211400	#_114
2008	7	3	0.661700	0.224300	#_115
2009	7	3	1.023500	0.225000	#_116
2010	7	3	0.561200	0.240600	#_117
2011	7	3	1.310800	0.155600	#_118
2012	7	3	0.881200	0.185000	#_119
2013	7	3	1.021900	0.213000	#_120
2014	7	3	1.185700	0.150100	#_121
2015	7	3	0.958100	0.156000	#_122
2016	7	3	0.678600	0.156300	#_123
2017	7	3	1.175900	0.159500	#_124
1950	7	4	0.198900	0.200000	#_125
1951	7	4	0.271200	0.200000	#_126
1952	7	4	0.320300	0.200000	#_127
1953	7	4	0.336800	0.200000	#_128
1954	7	4	0.436600	0.200000	#_129
1955	7	4	0.455100	0.200000	#_130
1956	7	4	0.581800	0.200000	#_131
1957	7	4	0.666100	0.200000	#_132
1958	7	4	0.815700	0.200000	#_133
1959	7	4	0.879300	0.200000	#_134
1960	7	4	0.879000	0.200000	#_135

1961	7	4	0.665800	0.200000	#_136
1962	7	4	0.641100	0.200000	#_137
1963	7	4	0.730800	0.200000	#_138
1964	7	4	0.771900	0.200000	#_139
1965	7	4	0.856700	0.200000	#_140
1966	7	4	0.843100	0.200000	#_141
1967	7	4	0.918400	0.200000	#_142
1968	7	4	0.933200	0.200000	#_143
1969	7	4	1.060400	0.200000	#_144
1970	7	4	0.999100	0.200000	#_145
1971	7	4	0.952700	0.200000	#_146
1972	7	4	0.948800	0.200000	#_147
1973	7	4	0.955000	0.200000	#_148
1974	7	4	0.950500	0.200000	#_149
1975	7	4	0.956200	0.200000	#_150
1976	7	4	0.991900	0.200000	#_151
1977	7	4	1.086500	0.200000	#_152
1978	7	4	1.148500	0.200000	#_153
1979	7	4	1.204100	0.200000	#_154
1980	7	4	1.235900	0.200000	#_155
1981	7	4	1.132300	0.200000	#_156
1982	7	4	1.094600	0.200000	#_157
1983	7	4	1.132000	0.200000	#_158
1984	7	4	1.332500	0.200000	#_159
1985	7	4	1.275600	0.200000	#_160
1986	7	4	1.428000	0.200000	#_161
1987	7	4	1.258500	0.200000	#_162
1988	7	4	1.153100	0.200000	#_163
1989	7	4	1.255300	0.200000	#_164
1990	7	4	1.143000	0.200000	#_165
1991	7	4	1.204300	0.200000	#_166
1992	7	4	1.423900	0.200000	#_167
1993	7	4	1.206500	0.200000	#_168
1994	7	4	1.210500	0.200000	#_169
1995	7	4	1.349700	0.200000	#_170
1996	7	4	1.553200	0.200000	#_171
1997	7	4	1.613900	0.200000	#_172
1998	7	4	1.965500	0.200000	#_173
1999	7	4	1.263800	0.200000	#_174
2000	7	4	1.105100	0.200000	#_175
2001	7	4	1.247100	0.200000	#_176
2002	7	4	1.472100	0.200000	#_177
2003	7	4	1.237300	0.200000	#_178
2004	7	4	1.240300	0.200000	#_179
2005	7	4	0.989900	0.200000	#_180
2006	7	4	0.631900	0.200000	#_181
2007	7	4	0.459100	0.200000	#_182
2008	7	4	0.323600	0.200000	#_183
2009	7	4	0.490500	0.200000	#_184
2010	7	4	0.351200	0.200000	#_185
2011	7	4	0.408800	0.200000	#_186
2012	7	4	0.368500	0.200000	#_187
2013	7	4	0.420000	0.200000	#_188
2014	7	4	0.343900	0.200000	#_189
2015	7	4	0.292000	0.200000	#_190
2016	7	4	0.303000	0.200000	#_191
2017	7	4	0.319100	0.200000	#_192
2009	7	9	0.803201	0.243001	#_193
2010	7	9	0.735550	0.265449	#_194
2011	7	9	1.646068	0.261243	#_195
2012	7	9	1.207458	0.207352	#_196
2013	7	9	0.875348	0.253906	#_197
2014	7	9	0.732375	0.260064	#_198
2015	7	9	0.736247	0.226881	#_199
2016	7	9	0.827883	0.228247	#_200
2017	7	9	0.693874	0.250359	#_201

1993	7	8	0.660440	0.295683	#_202
1994	7	8	1.106099	0.216693	#_203
1995	7	8	0.522724	0.507363	#_204
1996	7	8	0.294763	0.291294	#_205
1997	7	8	0.673943	0.196541	#_206
2002	7	8	1.485733	0.223033	#_207
2004	7	8	0.359828	0.213692	#_208
2005	7	8	0.558559	0.160119	#_209
2006	7	8	1.142290	0.325920	#_210
2007	7	8	0.113646	0.156685	#_211
2008	7	8	0.895070	0.209761	#_212
2009	7	8	0.952484	0.173403	#_213
2010	7	8	1.180982	0.157207	#_214
2011	7	8	1.265535	0.111457	#_215
2012	7	8	0.899353	0.133449	#_216
2013	7	8	0.968950	0.141149	#_217
2014	7	8	1.149743	0.111750	#_218
2015	7	8	1.500058	0.132806	#_219
2016	7	8	2.459650	0.117429	#_220
2017	7	8	1.810152	0.124566	#_221
1986	7	7	0.454210	0.229322	#_222
1987	7	7	1.485960	0.185550	#_223
1990	7	7	0.643780	0.254660	#_224
1991	7	7	1.423650	0.220455	#_225
1993	7	7	0.579360	0.215298	#_226
1994	7	7	0.965530	0.188572	#_227
1995	7	7	0.726300	0.203662	#_228
1996	7	7	0.667820	0.206710	#_229
1997	7	7	1.118420	0.185845	#_230
1999	7	7	0.583130	0.204291	#_231
2000	7	7	0.855270	0.207054	#_232
2001	7	7	0.850160	0.196769	#_233
2003	7	7	1.367160	0.182395	#_234
2006	7	7	1.357800	0.192207	#_235
2007	7	7	1.611570	0.177098	#_236
2009	7	7	1.274620	0.186419	#_237
2010	7	7	1.057390	0.192591	#_238
2011	7	7	1.042000	0.194557	#_239
2012	7	7	1.076110	0.190458	#_240
2013	7	7	0.967770	0.196107	#_241
2014	7	7	1.060040	0.194256	#_242
2016	7	7	0.831970	0.195724	#_243
-9999	0	0	0.000000	0.000000	#_terminator

4 #_N_discard_fleets
#_discard_units (1=same_as_catchunits(bio/num); 2=fraction; 3=numbers)
#_discard_errtype: >0 for DF of T-dist(read CV below); 0 for normal with CV; -1 for normal with se; -2 for lognormal
#
#_discard_fleet_info

#_Fleet	units	errtype	
1	1	-2	#_CM_E
2	1	-2	#_CM_W
3	1	-2	#_REC
4	1	-2	#_SMP_BYC

#
#_discard_data

#_Yr	Seas	Flt	Discard	Std_in	
1993	7	1	5.86621e-01	0.3	#_1
1994	7	1	7.96557e-01	0.3	#_2
1995	7	1	7.90099e-01	0.3	#_3
1996	7	1	6.61112e-01	0.3	#_4
1997	7	1	5.80075e-01	0.3	#_5
1998	7	1	5.17331e-01	0.3	#_6
1999	7	1	5.78534e-01	0.3	#_7
2000	7	1	4.46964e-01	0.3	#_8
2001	7	1	4.65931e-01	0.3	#_9
2002	7	1	5.76385e-01	0.3	#_10

2003	7	1	6.74005e-01	0.3	#_11
2004	7	1	4.92857e-01	0.3	#_12
2005	7	1	6.35689e+01	0.3	#_13
2006	7	1	7.41390e+01	0.3	#_14
2007	7	1	8.76670e+01	0.3	#_15
2008	7	1	2.81288e+01	0.3	#_16
2009	7	1	4.39287e+01	0.3	#_17
2010	7	1	2.03256e+01	0.3	#_18
2011	7	1	3.59141e+01	0.3	#_19
2012	7	1	2.43331e+01	0.3	#_20
2013	7	1	1.41581e+01	0.3	#_21
2014	7	1	1.49545e+01	0.3	#_22
2015	7	1	1.11334e+01	0.3	#_23
2016	7	1	1.23530e+01	0.3	#_24
2017	7	1	1.34989e+01	0.3	#_25
1993	7	2	1.13331e-01	0.3	#_26
1994	7	2	1.24854e-01	0.3	#_27
1995	7	2	9.52094e-02	0.3	#_28
1996	7	2	9.83132e-02	0.3	#_29
1997	7	2	1.89942e-01	0.3	#_30
1998	7	2	1.57947e-01	0.3	#_31
1999	7	2	1.78740e-01	0.3	#_32
2000	7	2	1.13289e-01	0.3	#_33
2001	7	2	1.42638e-01	0.3	#_34
2002	7	2	1.64756e-01	0.3	#_35
2003	7	2	2.12666e-01	0.3	#_36
2004	7	2	2.13955e-01	0.3	#_37
2005	7	2	1.33927e+01	0.3	#_38
2006	7	2	1.01688e+01	0.3	#_39
2007	7	2	1.88394e+01	0.3	#_40
2008	7	2	2.50550e+00	0.3	#_41
2009	7	2	2.31048e+00	0.3	#_42
2010	7	2	1.57023e+00	0.3	#_43
2011	7	2	1.53915e+00	0.3	#_44
2012	7	2	1.79913e+00	0.3	#_45
2013	7	2	1.48549e+00	0.3	#_46
2014	7	2	1.41520e+00	0.3	#_47
2015	7	2	1.66721e+00	0.3	#_48
2016	7	2	1.86036e+00	0.3	#_49
2017	7	2	1.64118e+00	0.3	#_50
1982	7	3	1.00000e+00	0.3	#_51
1983	7	3	5.30000e+01	0.3	#_52
1984	7	3	2.50000e+01	0.3	#_53
1985	7	3	2.40000e+01	0.3	#_54
1986	7	3	8.50000e+01	0.3	#_55
1987	7	3	9.00000e+01	0.3	#_56
1988	7	3	3.56000e+02	0.3	#_57
1989	7	3	1.74000e+02	0.3	#_58
1990	7	3	1.45000e+02	0.3	#_59
1991	7	3	3.19000e+02	0.3	#_60
1992	7	3	2.81000e+02	0.3	#_61
1993	7	3	5.61000e+02	0.3	#_62
1994	7	3	1.72000e+02	0.3	#_63
1995	7	3	5.67000e+02	0.3	#_64
1996	7	3	2.05000e+02	0.3	#_65
1997	7	3	5.70000e+01	0.3	#_66
1998	7	3	4.60000e+01	0.3	#_67
1999	7	3	1.45000e+02	0.3	#_68
2000	7	3	6.10000e+01	0.3	#_69
2001	7	3	1.27000e+02	0.3	#_70
2002	7	3	2.90000e+02	0.3	#_71
2003	7	3	3.09000e+02	0.3	#_72
2004	7	3	2.02000e+02	0.3	#_73
2005	7	3	3.63000e+02	0.3	#_74
2006	7	3	2.29000e+02	0.3	#_75
2007	7	3	1.94000e+02	0.3	#_76

2008	7	3	1.61000e+02	0.3	#_77
2009	7	3	2.11000e+02	0.3	#_78
2010	7	3	8.40000e+01	0.3	#_79
2011	7	3	1.68000e+02	0.3	#_80
2012	7	3	2.10000e+02	0.3	#_81
2013	7	3	4.77000e+02	0.3	#_82
2014	7	3	3.94000e+02	0.3	#_83
2015	7	3	2.91000e+02	0.3	#_84
2016	7	3	3.29000e+02	0.3	#_85
2017	7	3	5.94000e+02	0.3	#_86
1972	-7	4	3.77925e+03	0.1	#_87
1973	7	-4	2.83400e+04	0.5	#_88
1974	7	-4	6.81400e+03	0.5	#_89
1975	7	-4	4.82800e+03	0.5	#_90
1976	7	-4	3.50500e+03	0.5	#_91
1977	7	-4	2.11000e+03	0.5	#_92
1978	7	-4	1.00900e+04	0.5	#_93
1979	7	-4	9.44500e+03	0.5	#_94
1980	7	-4	1.44200e+03	0.5	#_95
1981	7	-4	1.26300e+04	0.5	#_96
1982	7	-4	4.25400e+03	0.5	#_97
1983	7	-4	5.55500e+03	0.5	#_98
1984	7	-4	1.27700e+04	0.5	#_99
1985	7	-4	1.14300e+04	0.5	#_100
1986	7	-4	2.17600e+04	0.5	#_101
1987	7	-4	2.33900e+04	0.5	#_102
1988	7	-4	8.48700e+03	0.5	#_103
1989	7	-4	1.29200e+04	0.5	#_104
1990	7	-4	1.71500e+04	0.5	#_105
1991	7	-4	6.13000e+04	0.5	#_106
1992	7	-4	4.19400e+03	0.5	#_107
1993	7	-4	2.02300e+03	0.5	#_108
1994	7	-4	2.43900e+03	0.5	#_109
1995	7	-4	9.97400e+03	0.5	#_110
1996	7	-4	1.19100e+04	0.5	#_111
1997	7	-4	1.10700e+04	0.5	#_112
1998	7	-4	3.62600e+04	0.5	#_113
1999	7	-4	7.99600e+03	0.5	#_114
2000	7	-4	8.94900e+03	0.5	#_115
2001	7	-4	5.54500e+03	0.5	#_116
2002	7	-4	5.39400e+03	0.5	#_117
2003	7	-4	9.54900e+03	0.5	#_118
2004	7	-4	2.56100e+03	0.5	#_119
2005	7	-4	4.77800e+03	0.5	#_120
2006	7	-4	4.18900e+03	0.5	#_121
2007	7	-4	6.84400e+03	0.5	#_122
2008	7	-4	1.03800e+03	0.5	#_123
2009	7	-4	2.10600e+03	0.5	#_124
2010	7	-4	1.11100e+03	0.5	#_125
2011	7	-4	8.52300e+02	0.5	#_126
2012	7	-4	4.43300e+02	0.5	#_127
2013	7	-4	5.73500e+02	0.5	#_128
2014	7	-4	2.90700e+02	0.5	#_129
2015	7	-4	1.78600e+02	0.5	#_130
2016	7	-4	1.54900e+02	0.5	#_131
2017	-7	-4	2.12300e+02	0.5	#_132
-9999	0	0	0.00000e+00	0.0	#_terminator

#
#_meanbodywt
0 #_use_meanbodywt
#_DF_for_meanbodywt_T-distribution_like
#
#_population_length_bins
1 # length bin method: 1=use databins; 2=generate from binwidth,min,max below; 3=read vector
1 #_use_lencomp
#

```
#_len_info
#_mintailcomp addtocomp combine_M_F CompressBins CompErrorParmSelect minsamplesize
1e-04 1e-07 0 0 0 0 1 #_CM_E
1e-04 1e-07 0 0 0 0 1 #_CM_W
1e-04 1e-07 0 0 0 0 1 #_REC
1e-04 1e-07 0 0 0 0 1 #_SMP_BYC
1e-04 1e-07 0 0 0 0 1 #_HB_E
1e-04 1e-07 0 0 0 0 1 #_HB_W
1e-04 1e-07 0 0 0 0 1 #_LARVAL
1e-04 1e-07 0 0 0 0 1 #_VIDEO
1e-04 1e-07 0 0 0 0 1 #_SEAMAP
12 #_N_lbins
#_lbin_vector
1 5 10 15 20 25 30 35 40 45 50 55 #_lbin_vector
#
#_lencomp
#_Yr Seas FltSvy Gender Part Nsamp l1 l5 l10 l15 l20 l25 l30
 l35 l40 l45 l50 l55
2009 7 9 0 2 35.71090 0.10802469 0.06481481 0.138889 0.407407 0.259259
 0.0216049 0.00000000 0.00000000 0.000 0.000 0.000 0 #_1
2010 7 9 0 2 100.00000 0.02592593 0.02592593 0.203704 0.403704 0.318519
 0.0222222 0.00000000 0.00000000 0.000 0.000 0.000 0 #_2
2011 7 9 0 2 17.04720 0.00000000 0.00000000 0.169271 0.356771 0.369792
 0.1015625 0.00260417 0.00000000 0.000 0.000 0.000 0 #_3
2012 7 9 0 2 11.08360 0.02127660 0.17234043 0.259574 0.217021 0.225532
 0.1000000 0.00425532 0.00000000 0.000 0.000 0.000 0 #_4
2013 7 9 0 2 37.52000 0.01655629 0.01324503 0.311258 0.417219 0.195364
 0.0430464 0.00000000 0.00331126 0.000 0.000 0.000 0 #_5
2014 7 9 0 2 69.50690 0.00615385 0.03384615 0.172308 0.406154 0.360000
 0.0215385 0.00000000 0.00000000 0.000 0.000 0.000 0 #_6
2015 7 9 0 2 37.91520 0.05056180 0.00280899 0.221910 0.491573 0.207865
 0.0252809 0.00000000 0.00000000 0.000 0.000 0.000 0 #_7
2016 7 9 0 2 38.58700 0.00000000 0.00522193 0.281984 0.503916 0.201044
 0.0078329 0.00000000 0.00000000 0.000 0.000 0.000 0 #_8
2017 7 9 0 2 100.00000 0.00000000 0.00328947 0.217105 0.411184 0.332237
 0.0361842 0.00000000 0.00000000 0.000 0.000 0.000 0 #_9
2002 7 8 0 0 17.20420 0.00000000 0.00000000 0.012000 0.355000 0.346000
 0.2250000 0.05600000 0.00600000 0.002 0.000 0.000 0 #_10
2004 7 8 0 0 6.56797 0.00000000 0.00000000 0.000000 0.053000 0.419000
 0.4210000 0.09000000 0.01100000 0.003 0.001 0.003 0 #_11
2005 7 8 0 0 38.21350 0.00000000 0.00000000 0.020000 0.180000 0.319000
 0.3190000 0.08700000 0.03000000 0.030 0.012 0.004 0 #_12
2006 7 8 0 0 18.35090 0.00000000 0.00000000 0.038000 0.289000 0.412000
 0.2160000 0.04300000 0.00300000 0.000 0.000 0.000 0 #_13
2007 7 8 0 0 11.24900 0.00000000 0.00000000 0.039000 0.113000 0.327000
 0.4540000 0.03800000 0.00200000 0.025 0.002 0.000 0 #_14
2008 7 8 0 0 8.22767 0.00000000 0.00000000 0.000000 0.036000 0.321000
 0.3390000 0.27400000 0.01700000 0.000 0.014 0.000 0 #_15
2009 7 8 0 0 25.54670 0.00000000 0.00000000 0.000000 0.120000 0.373000
 0.3270000 0.13900000 0.01300000 0.000 0.002 0.026 0 #_16
2010 7 8 0 0 32.10910 0.00000000 0.00000000 0.090000 0.154000 0.170000
 0.2240000 0.18700000 0.11600000 0.060 0.000 0.000 0 #_17
2011 7 8 0 0 47.70040 0.00000000 0.04700000 0.115000 0.097000 0.229000
 0.2910000 0.12700000 0.03700000 0.036 0.006 0.015 0 #_18
2012 7 8 0 0 39.99490 0.00000000 0.14700000 0.098000 0.218000 0.342000
 0.1380000 0.03800000 0.00700000 0.013 0.000 0.000 0 #_19
2013 7 8 0 0 100.00000 0.00000000 0.00000000 0.129000 0.231000 0.351000
 0.1970000 0.05600000 0.02800000 0.008 0.000 0.000 0 #_20
2014 7 8 0 0 100.00000 0.00000000 0.00000000 0.109000 0.205000 0.330000
 0.1960000 0.06600000 0.03200000 0.049 0.005 0.008 0 #_21
2015 7 8 0 0 74.90480 0.00000000 0.11300000 0.138000 0.231000 0.292000
 0.1220000 0.04900000 0.02000000 0.031 0.002 0.002 0 #_22
2016 7 8 0 0 32.50870 0.00000000 0.13000000 0.173000 0.142000 0.282000
 0.1670000 0.07500000 0.01800000 0.011 0.002 0.002 0 #_23
2017 7 8 0 0 100.00000 0.00000000 0.00000000 0.064000 0.157000 0.307000
 0.2330000 0.15000000 0.05800000 0.022 0.010 0.000 0 #_24
```

```
-9999   0   0   0   0   0.00000   0.00000000   0.00000000   0.000000   0.000000   0.000000
        0.0000000 0.00000000   0.00000000   0.000   0.000   0.000   0   #_terminator
14 #_N_agebins
#
#_agebin_vector
1 2 3 4 5 6 7 8 9 10 11 12 13 14 #_agebin_vector
#
#_ageing_error
1 #_N_ageerror_definitions
#_age0  age1    age2    age3    age4    age5    age6    age7    age8    age9    age10   age11   age12
        age13   age14
0.500   1.500   2.500   3.500   4.500   5.500   6.500   7.500   8.500   9.500   10.500  11.500  12.500
        13.500  14.500  #_1
0.001   0.001   0.001   0.001   0.001   0.001   0.001   0.001   0.001   0.001   0.001   0.001   0.001
0.001   0.001   #_2
#
#_age_info
#_mintailcomp   addtocomp   combine_M_F   CompressBins   CompErrorParmSelect   minsamplesize
1e-04   1e-07   0   0   0   0   1   #_CM_E
1e-04   1e-07   0   0   0   0   1   #_CM_W
1e-04   1e-07   0   0   0   0   1   #_REC
1e-04   1e-07   0   0   0   0   1   #_SMP_BYC
1e-04   1e-07   0   0   0   0   1   #_HB_E
1e-04   1e-07   0   0   0   0   1   #_HB_W
1e-04   1e-07   0   0   0   0   1   #_LARVAL
1e-04   1e-07   0   0   0   0   1   #_VIDEO
1e-04   1e-07   0   0   0   0   1   #_SEAMAP
2 #_Lbin_method: 1=poplenbins; 2=datalenbins; 3=lengths
 #_combine males into females at or below this bin number
#_Yr    Seas    FltSvy  Gender  Part    Ageerr  Lbin_lo Lbin_hi Nsamp   a1      a2      a3      a4
        a5      a6      a7      a8      a9      a10     a11     a12     a13     a14
 1995   7   1   0   2   1   -1   -1   3.63217   0.000000000   0.00000000
        0.0000000 0.0000000 0.3943868 0.3943868 0.03617984   0.00000000   0.13886672   0.00000000
        0.00000000   0.036179835   0.000000000   0.000000000   #_1
 1998   7   1   0   2   1   -1   -1   6.09301   0.147308643   0.35066416
        0.3748876 0.0405359 0.0494876 0.0153515 0.00000000   0.00000000   0.00000000   0.00199403
        0.00568170   0.014088857   0.000000000   0.000000000   #_2
 2000   7   1   0   2   1   -1   -1   8.15637   0.000000000   0.02759924
        0.1590981 0.1344867 0.0912199 0.0288749 0.04147196   0.08016444   0.03497309   0.03950048
        0.31211846   0.025493171   0.022587162   0.002412420   #_3
 2001   7   1   0   2   1   -1   -1   23.08780   0.000000000   0.06305906
        0.2183648 0.2069760 0.1910284 0.1135757 0.06914352   0.04869192   0.02406210   0.02878172
        0.01005929   0.011604501   0.011271908   0.003381127   #_4
 2002   7   1   0   2   1   -1   -1   100.00000 0.006072072   0.20085090
        0.3822188 0.1250052 0.0891084 0.0684222 0.04665272   0.03707046   0.01490483   0.00716440
        0.01321485   0.004345556   0.001551394   0.003418214   #_5
 2003   7   1   0   2   1   -1   -1   23.02320   0.000506687   0.04432424
        0.2217771 0.3700341 0.1359717 0.0621314 0.08103227   0.03881434   0.02386336   0.00676217
        0.00560218   0.005134444   0.002471615   0.001574404   #_6
 2004   7   1   0   2   1   -1   -1   33.49580   0.000000000   0.03627299
        0.2283476 0.2559064 0.2037520 0.0829987 0.08126212   0.05074055   0.03128768   0.01176947
        0.00765161   0.006055743   0.002840928   0.001114263   #_7
 2005   7   1   0   2   1   -1   -1   100.00000 0.000000000   0.06645861
        0.2517338 0.2165096 0.2089614 0.0998956 0.03709530   0.04621111   0.02922199   0.01744127
        0.01276509   0.012289445   0.000000000   0.001416788   #_8
 2006   7   1   0   2   1   -1   -1   59.50300   0.000000000   0.09859294
        0.2857277 0.2113266 0.1956222 0.1028343 0.04937434   0.01716271   0.01643707   0.01413744
        0.00403031   0.003394538   0.000000000   0.001359889   #_9
 2007   7   1   0   2   1   -1   -1   54.58310   0.009993806   0.12058039
        0.2480810 0.2102620 0.1576323 0.0962265 0.05473196   0.04059793   0.02233950   0.01265415
        0.00262769   0.009934679   0.006127695   0.008210497   #_10
 2008   7   1   0   2   1   -1   -1   100.00000 0.000000000   0.08235332
        0.2747276 0.1688949 0.1371830 0.1244805 0.08373873   0.04374425   0.03798763   0.01719518
        0.01756760   0.007564847   0.001033724   0.003528750   #_11
```

2009	7	1	0	2	1	-1	-1	100.00000	0.000000000	0.08586034
	0.3519978	0.2213406	0.1011078	0.0654533	0.05725220		0.05423668		0.02612711	0.01700470
	0.01042925		0.002509138		0.001275617		0.005405413		#_12	
2010	7	1	0	2	1	-1	-1	32.12780	0.000826167	0.02776265
	0.2596585	0.3701400	0.0509793	0.0621234	0.05453874		0.07576431		0.04881835	0.02655395
	0.01453320		0.006149662		0.000656844		0.001494884		#_13	
2011	7	1	0	2	1	-1	-1	87.05650	0.010905664	0.03967093
	0.1183330	0.2235493	0.2308662	0.1412620	0.07020563		0.06516519		0.03908628	0.02654723
	0.01378213		0.008393644		0.006945464		0.005287330		#_14	
2012	7	1	0	2	1	-1	-1	99.85900	0.002049909	0.12244585
	0.1624207	0.1213789	0.1563963	0.1757948	0.13346637		0.03856953		0.03263893	0.01669230
	0.01719535		0.006637710		0.006019972		0.008293410		#_15	
2013	7	1	0	2	1	-1	-1	55.53890	0.003493089	0.10665461
	0.3471245	0.1313506	0.0810875	0.0902725	0.12152322		0.06352320		0.02132163	0.01076613
	0.00737979		0.005474433		0.006102211		0.003926494		#_16	
2014	7	1	0	2	1	-1	-1	79.34320	0.000000000	0.07228787
	0.2579510	0.1566679	0.0822727	0.0697315	0.06507658		0.09478151		0.07787374	0.03617641
	0.04418802		0.009854434		0.013708773		0.019429495		#_17	
2015	7	1	0	2	1	-1	-1	100.00000	0.003506958	0.09495417
	0.2489334	0.2597400	0.1027076	0.0535724	0.06626621		0.05399693		0.06922837	0.02259243
	0.00600518		0.013780603		0.000000000		0.004715785		#_18	
2016	7	1	0	2	1	-1	-1	100.00000	0.001621376	0.12427936
	0.2940913	0.2663640	0.1396405	0.0418199	0.02386994		0.02514294		0.03396592	0.02974260
	0.01510836		0.000000000		0.001079760		0.003274014		#_19	
2017	7	1	0	2	1	-1	-1	100.00000	0.005969491	0.18410069
	0.3062789	0.1696376	0.1314530	0.0934546	0.02803165		0.01877758		0.01289322	0.02310816
	0.01709591		0.001760357		0.004007158		0.003431671		#_20	
1994	7	2	0	2	1	-1	-1	8.14388	0.000000000	0.00000000
	0.0549348	0.1389875	0.4600735	0.0793384	0.06008279		0.04679029		0.00000000	0.05112450
	0.04365920		0.037474459		0.016423589		0.011111111		#_21	
1995	7	2	0	2	1	-1	-1	7.31632	0.000000000	0.22861842
	0.1400082	0.2905810	0.2519261	0.0540960	0.02080448		0.00000000		0.00683864	0.00712719
	0.00000000		0.000000000		0.000000000		0.000000000		#_22	
2000	7	2	0	2	1	-1	-1	64.38930	0.000000000	0.00000000
	0.1164311	0.1638813	0.2049552	0.1002812	0.04561863		0.05466256		0.05426357	0.08578811
	0.09991450		0.000000000		0.018087855		0.056116052		#_23	
2001	7	2	0	2	1	-1	-1	48.53930	0.000000000	0.01815887
	0.1150525	0.1650519	0.1250909	0.1200332	0.05447660		0.10761394		0.00885609	0.09615945
	0.02931902		0.000000000		0.023523985		0.136663563		#_24	
2002	7	2	0	2	1	-1	-1	34.72170	0.000000000	0.07623265
	0.3130089	0.1053708	0.0739565	0.0989993	0.09769087		0.03963488		0.04156982	0.02536874
	0.03044652		0.036166103		0.015233336		0.046321661		#_25	
2003	7	2	0	2	1	-1	-1	30.76170	0.003351159	0.01801783
	0.1139066	0.2061229	0.2797601	0.1080414	0.07201243		0.04098627		0.05667962	0.03487149
	0.00954053		0.021188293		0.013838902		0.021682467		#_26	
2004	7	2	0	2	1	-1	-1	100.00000	0.003351159	0.01801783
	0.1139066	0.2061229	0.2797601	0.1080414	0.07201243		0.04098627		0.05667962	0.03487149
	0.00954053		0.021188293		0.013838902		0.021682467		#_27	
2005	7	2	0	2	1	-1	-1	21.89890	0.004709523	0.10622190
	0.1437091	0.0997633	0.3340020	0.1363538	0.03841131		0.03269809		0.03380234	0.02454575
	0.02020187		0.007317253		0.004522999		0.013740677		#_28	
2006	7	2	0	2	1	-1	-1	16.33160	0.000000000	0.04759037
	0.2637634	0.2064132	0.0911024	0.2068105	0.08787745		0.01538206		0.01742186	0.01532793
	0.01957298		0.010199837		0.003580069		0.014958005		#_29	
2007	7	2	0	2	1	-1	-1	100.00000	0.000000000	0.01732201
	0.1058058	0.2275505	0.1941939	0.1257466	0.13187502		0.09156016		0.04421154	0.02059380
	0.01599486		0.008981178		0.005457464		0.010707194		#_30	
2008	7	2	0	2	1	-1	-1	100.00000	0.000000000	0.02093168
	0.0729436	0.1333585	0.2124050	0.1866351	0.13189394		0.07561589		0.07274677	0.03479451
	0.02012051		0.009661959		0.011999712		0.016892835		#_31	
2009	7	2	0	2	1	-1	-1	100.00000	0.000000000	0.01683925
	0.1606929	0.2355860	0.1588622	0.1358571	0.07922993		0.05739664		0.04396073	0.04432408
	0.02404712		0.008487249		0.009015501		0.025701426		#_32	
2010	7	2	0	2	1	-1	-1	59.97730	0.003231448	0.01011708
	0.0981075	0.3611226	0.1766021	0.1136797	0.09001357		0.04956792		0.02017877	0.02023953
	0.02264541		0.009691575		0.003888152		0.020914706		#_33	

2011	7	2	0	2	1	-1	-1	100.00000	0.029946989	0.04282045
	0.0994003	0.1489033	0.1979366	0.1316199	0.10445915		0.07693393		0.03037660	0.04136672
	0.03408993		0.022443180		0.007868450		0.031834475		#_34	
2012	7	2	0	2	1	-1	-1	89.48650	0.002871052	0.00686726
	0.0458322	0.1369926	0.1234721	0.1938824	0.12268320		0.07371141		0.07702008	0.05648191
	0.04092151		0.028113469		0.036869657		0.054281158		#_35	
2013	7	2	0	2	1	-1	-1	48.41730	0.000000000	0.02045838
	0.0762090	0.0879332	0.1688454	0.0583187	0.17062106		0.09924450		0.05944416	0.06490583
	0.04521618		0.048622374		0.027585292		0.072596014		#_36	
2014	7	2	0	2	1	-1	-1	47.09420	0.002794787	0.04604418
	0.0986899	0.1132997	0.0859126	0.1161872	0.08863979		0.08407640		0.08556917	0.06572834
	0.05531636		0.043679533		0.027265553		0.086796570		#_37	
2015	7	2	0	2	1	-1	-1	23.12460	0.008727483	0.05120011
	0.2895159	0.2919142	0.0635003	0.0832146	0.03782972		0.02748538		0.04340205	0.02582880
	0.01896033		0.019577182		0.019187405		0.019656500		#_38	
2016	7	2	0	2	1	-1	-1	82.64120	0.005217750	0.04617934
	0.1376878	0.3008347	0.2275922	0.0534811	0.03650004		0.02406694		0.02170780	0.03174443
	0.03032006		0.021918766		0.025328662		0.037420483		#_39	
2017	7	2	0	2	1	-1	-1	89.03280	0.008406399	0.08354915
	0.1225874	0.1918553	0.2949606	0.1439864	0.01874417		0.02047397		0.01834179	0.01600594
	0.02197685		0.016677245		0.010446289		0.031988482		#_40	
1994	7	3	0	2	1	-1	-1	13.34740	0.000000000	0.00000000
	0.1848385	0.2549163	0.2129922	0.1624145	0.09250177		0.06925254		0.02308418	0.00000000
	0.00000000		0.000000000		0.000000000		0.000000000		#_41	
1995	7	3	0	2	1	-1	-1	6.78476	0.000000000	0.00000000
	0.6039062	0.0000000	0.2408854	0.0347656	0.12044271		0.00000000		0.00000000	0.00000000
	0.00000000		0.000000000		0.000000000		0.000000000		#_42	
1996	7	3	0	2	1	-1	-1	77.88470	0.004341907	0.07311121
	0.1920265	0.1859978	0.2011672	0.1688284	0.06132886		0.05010359		0.02057450	0.03555358
	0.00407531		0.000991832		0.001899391		0.000000000		#_43	
1997	7	3	0	2	1	-1	-1	15.07320	0.000000000	0.25561655
	0.0647999	0.2008381	0.1074422	0.2042327	0.09523779		0.01351351		0.05831926	0.00000000
	0.00000000		0.000000000		0.000000000		0.000000000		#_44	
1998	7	3	0	2	1	-1	-1	13.40160	0.000000000	0.02850062
	0.3710834	0.3226235	0.1238715	0.0285006	0.07696052		0.04845990		0.00000000	0.00000000
	0.00000000		0.000000000		0.000000000		0.000000000		#_45	
1999	7	3	0	2	1	-1	-1	25.60130	0.043262381	0.20778623
	0.2982172	0.1680880	0.0878798	0.0487921	0.03918017		0.07268493		0.01910669	0.00917321
	0.00194313		0.001943133		0.001943133		0.000000000		#_46	
2000	7	3	0	2	1	-1	-1	61.77870	0.000000000	0.03164626
	0.1949859	0.2307705	0.2215960	0.1180383	0.05871068		0.06895858		0.03690470	0.02955700
	0.00344446		0.001967029		0.000000000		0.003420618		#_47	
2001	7	3	0	2	1	-1	-1	7.04041	0.000000000	0.04170246
	0.0460383	0.1511819	0.3697269	0.1190449	0.12602107		0.04875346		0.01322556	0.05020749
	0.01701005		0.012999338		0.004088501		0.000000000		#_48	
2002	7	3	0	2	1	-1	-1	15.25720	0.000000000	0.08023829
	0.2344416	0.1011166	0.1740183	0.1224092	0.15058785		0.08124035		0.02629339	0.00824163
	0.00556225		0.008633754		0.007216838		0.000000000		#_49	
2003	7	3	0	2	1	-1	-1	19.91550	0.000000000	0.15194980
	0.1436198	0.3514034	0.0891948	0.1055952	0.10007142		0.02900980		0.02387645	0.00527937
	0.00000000		0.000000000		0.000000000		0.000000000		#_50	
2004	7	3	0	2	1	-1	-1	4.26588	0.000000000	0.00000000
	0.0607816	0.2982631	0.4382811	0.0693127	0.08680275		0.01176538		0.01241222	0.02070227
	0.00167882		0.000000000		0.000000000		0.000000000		#_51	
2005	7	3	0	2	1	-1	-1	54.31110	0.000000000	0.13831663
	0.2847539	0.2276813	0.1967238	0.0807355	0.02321931		0.02150306		0.00195200	0.00673079
	0.01838369		0.000000000		0.000000000		0.000000000		#_52	
2006	7	3	0	2	1	-1	-1	93.46070	0.000000000	0.08585090
	0.1729546	0.2670766	0.2203566	0.1082755	0.10054561		0.01348117		0.02247010	0.00898893
	0.00000000		0.000000000		0.000000000		0.000000000		#_53	
2007	7	3	0	2	1	-1	-1	100.00000	0.000000000	0.04805185
	0.2010844	0.3212905	0.1914931	0.1077549	0.04849048		0.03428468		0.02823710	0.01049038
	0.00386277		0.002135097		0.000548564		0.002276235		#_54	
2008	7	3	0	2	1	-1	-1	42.57610	0.003004254	0.08354356
	0.1887186	0.1675858	0.1671313	0.1657303	0.11950150		0.05056845		0.03387669	0.00830090
	0.00596924		0.002190934		0.000441371		0.003437033		#_55	

```
2009  7          3          0          2          1          -1          -1    100.00000 0.001677916    0.11501152
      0.3769191  0.1942343  0.1312025  0.0816337  0.04988601            0.02424797      0.01648564     0.00488037
      0.00224683            0.001407874           0.000166339           0.000000000     #_56
2010  7          3          0          2          1          -1          -1    20.51610  0.006015366    0.05291132
      0.3966065  0.3595548  0.0709539  0.0536746  0.03240484            0.01555611      0.00695637     0.00243683
      0.00133330            0.000000000           0.000000000           0.001596145     #_57
2011  7          3          0          2          1          -1          -1    78.75770  0.004574421    0.05356050
      0.1732320  0.2287708  0.2544933  0.1953689  0.04749785            0.02861073      0.00490752     0.00487777
      0.00258259            0.001523615           0.000000000           0.000000000     #_58
2012  7          3          0          2          1          -1          -1    100.00000 0.001742165    0.12707357
      0.2377034  0.2510466  0.1177446  0.1490641  0.06457854            0.01839740      0.01868963     0.00812018
      0.00226338            0.001648764           0.001348830           0.000578870     #_59
2013  7          3          0          2          1          -1          -1    100.00000 0.004933819    0.10541994
      0.3405166  0.2203355  0.1567798  0.0663547  0.06395728            0.02013570      0.00986498     0.00711231
      0.00273648            0.000545259           0.001307604           0.000000000     #_60
2014  7          3          0          2          1          -1          -1    100.00000 0.001583921    0.09255744
      0.3759133  0.2465258  0.0821614  0.0832332  0.03339768            0.04389032      0.02447325     0.00527518
      0.00576190            0.002069669           0.000900335           0.002256566     #_61
2015  7          3          0          2          1          -1          -1    46.13140  0.009519689    0.18114400
      0.3959271  0.2833950  0.0594957  0.0192608  0.00963969            0.01787045      0.01538981     0.00342422
      0.00211739            0.001792841           0.000699004           0.000324215     #_62
2016  7          3          0          2          1          -1          -1    100.00000 0.004487488    0.12155069
      0.2938197  0.3099934  0.1933976  0.0366084  0.01307521            0.00495713      0.00928276     0.00646313
      0.00261390            0.001749928           0.001018079           0.000982482     #_63
2017  7          3          0          2          1          -1          -1    100.00000 0.002557483    0.19085241
      0.3103782  0.2109171  0.1440486  0.0933445  0.01456420            0.00972891      0.00504080     0.00896450
      0.00300496            0.003201788           0.002182856           0.001213659     #_64
-9999 0          0          0          0          0          0           0     0.00000   0.000000000    0.00000000
      0.0000000  0.0000000  0.0000000  0.0000000  0.00000000            0.00000000      0.00000000     0.00000000
      0.00000000            0.000000000           0.000000000           0.000000000     #_terminator
#
#_MeanSize_at_Age_obs
0 #_use_MeanSize_at_Age_obs
0 #_N_environ_variables
0 #_N_sizefreq_methods
0 #_do_tags
0 #_morphcomp_data
0 #_use_selectivity_priors
#
999
```

10.2. CTL File

```
#V3.30.14.05-safe;_2019_09_05;_Stock_Synthesis_by_Richard_Methot_(NOAA)_using_ADMB_12.0
#Stock Synthesis (SS) is a work of the U.S. Government and is not subject to copyright protection in the United States.
#Foreign copyrights may apply. See copyright.txt for more information.
#_user_support_available_at:NMFS.Stock.Synthesis@noaa.gov
#_user_info_available_at:https://vlab.ncep.noaa.gov/group/stock-synthesis
#_data_and_control_files: vermilion.dat // vermilion.ctl
0  # 0 means do not read wtatage.ss; 1 means read and use wtatage.ss and also read and use growth parameters
1  #_N_Growth_Patterns (Growth Patterns, Morphs, Bio Patterns, GP are terms used interchangeably in SS)
1 #_N_platoons_Within_GrowthPattern
#_Cond 1 #_Platoon_between/within_stdev_ratio (no read if N_platoons=1)
#_Cond  1 #vector_platoon_dist_(-1_in_first_val_gives_normal_approx)
#
4 # recr_dist_method for parameters:  2=main effects for GP, Area, Settle timing; 3=each Settle entity; 4=none (only when
N_GP*Nsettle*pop==1)
1 # not yet implemented; Future usage: Spawner-Recruitment: 1=global; 2=by area
1 #  number of recruitment settlement assignments
0 # unused option
#GPattern month  area  age (for each settlement assignment)
 1 1 1 0
#
#_Cond 0 # N_movement_definitions goes here if Nareas > 1
#_Cond 1.0 # first age that moves (real age at begin of season, not integer) also cond on do_migration>0
#_Cond 1 1 1 2 4 10 # example move definition for seas=1, morph=1, source=1 dest=2, age1=4, age2=10
#
3 #_Nblock_Patterns
 3 4 1 #_blocks_per_pattern
# begin and end years of blocks
 1990 2004 2005 2007 2008 2017
 1990 1996 1997 2004 2005 2007 2008 2017
 2008 2016
#
# controls for all timevary parameters
1 #_env/block/dev_adjust_method for all time-vary parms (1=warn relative to base parm bounds; 3=no bound check)
#
# AUTOGEN
 1 1 1 1 1 # autogen: 1st element for biology, 2nd for SR, 3rd for Q, 4th reserved, 5th for selex
# where: 0 = autogen time-varying parms of this category; 1 = read each time-varying parm line; 2 = read then autogen if parm min==-12345
#
#_Available timevary codes
#_Block types: 0: P_block=P_base*exp(TVP); 1: P_block=P_base+TVP; 2: P_block=TVP; 3: P_block=P_block(-1) + TVP
#_Block_trends: -1: trend bounded by base parm min-max and parms in transformed units (beware); -2: endtrend and infl_year direct values; -3:
end and infl as fraction of base range
#_EnvLinks:  1: P(y)=P_base*exp(TVP*env(y));  2: P(y)=P_base+TVP*env(y);  3: null;  4: P(y)=2.0/(1.0+exp(-TVP1*env(y) - TVP2))
#_DevLinks:  1: P(y)*=exp(dev(y)*dev_se;  2: P(y)+=dev(y)*dev_se;  3: random walk;  4: zero-reverting random walk with rho;  21-24 keep last
dev for rest of years
#
#_Prior_codes:  0=none; 6=normal; 1=symmetric beta; 2=CASAL's beta; 3=lognormal; 4=lognormal with biascorr; 5=gamma
#
# setup for M, growth, maturity, fecundity, recruitment distibution, movement
#
3 #_natM_type:_0=1Parm; 1=N_breakpoints;_2=Lorenzen;_3=agespecific;_4=agespec_withseasinterpolate
 #_Age_natmort_by sex x growthpattern
 0.234 0.342 0.287 0.257 0.239 0.228 0.22 0.215 0.212 0.209 0.207 0.206 0.205 0.204 0.204
#
1 # GrowthModel: 1=vonBert with L1&L2; 2=Richards with L1&L2; 3=age_specific_K_incr; 4=age_specific_K_decr; 5=age_specific_K_each;
6=NA; 7=NA; 8=growth cessation
0.5 #_Age(post-settlement)_for_L1;linear growth below this
999 #_Growth_Age_for_L2 (999 to use as Linf)
-999 #_exponential decay for growth above maxage (value should approx initial Z; -999 replicates 3.24; -998 to not allow growth above maxage)
0  #_placeholder for future growth feature
#
0 #_SD_add_to_LAA (set to 0.1 for SS2 V1.x compatibility)
1 #_CV_Growth_Pattern:  0 CV=f(LAA); 1 CV=F(A); 2 SD=F(LAA); 3 SD=F(A); 4 logSD=F(A)
#
1 #_maturity_option:  1=length logistic; 2=age logistic; 3=read age-maturity matrix by growth_pattern; 4=read age-fecundity; 5=disabled; 6=read
length-maturity
1 #_First_Mature_Age
```

```
2 #_fecundity option:(1)eggs=Wt*(a+b*Wt);(2)eggs=a*L^b;(3)eggs=a*Wt^b; (4)eggs=a+b*L; (5)eggs=a+b*W
0 #_hermaphroditism option:  0=none; 1=female-to-male age-specific fxn; -1=male-to-female age-specific fxn
1 #_parameter_offset_approach (1=none, 2= M, G, CV_G as offset from female-GP1, 3=like SS2 V1.x)
#
#_growth_parms
#_ LO HI INIT PRIOR PR_SD PR_type PHASE env_var&link dev_link dev_minyr dev_maxyr dev_PH Block Block_Fxn
# Sex: 1  BioPattern: 1  NatMort
# Sex: 1  BioPattern: 1  Growth
 0.0001 1e+006 11.83 11.83 0 0 -1 0 0 0 0 0 0 0 # L_at_Amin_Fem_GP_1
 0.0001 1e+006 34.4 34.4 0 0 -1 0 0 0 0 0 0 0 # L_at_Amax_Fem_GP_1
 0 1e+006 0.3254 0.3254 0 0 -1 0 0 0 0 0 0 0 # VonBert_K_Fem_GP_1
 0 1e+006 0.2535 0.0001 0 0 -1 0 0 0 0 0 0 0 # CV_young_Fem_GP_1
 0 1e+006 0.2535 0.0001 0 0 -1 0 0 0 0 0 0 0 # CV_old_Fem_GP_1
# Sex: 1  BioPattern: 1  WtLen
 0 1e+006 2.19e-005 2.19e-005 0 0 -1 0 0 0 0 0 0 0 # Wtlen_1_Fem_GP_1
 0 1e+006 2.916 2.916 0 0 -1 0 0 0 0 0 0 0 # Wtlen_2_Fem_GP_1
# Sex: 1  BioPattern: 1  Maturity&Fecundity
 0 1e+006 14.087 14.087 0 0 -1 0 0 0 0 0 0 0 # Mat50%_Fem_GP_1
 -1 1e+006 -0.574 -0.574 0 0 -1 0 0 0 0 0 0 0 # Mat_slope_Fem_GP_1
 0 1e+006 278.715 278.715 0 0 -1 0 0 0 0 0 0 0 # Eggs_scalar_Fem_GP_1
 0 1e+006 3.042 3.042 0 0 -1 0 0 0 0 0 0 0 # Eggs_exp_len_Fem_GP_1
# Hermaphroditism
#  Recruitment Distribution
#  Cohort growth dev base
 0.1 10 1 1 1 0 -1 0 0 0 0 0 0 0 # CohortGrowDev
#  Movement
#  Age Error from parameters
#  catch multiplier
#  fraction female, by GP
 1e-006 0.999999 0.5 0.5 0.5 0 -1 0 0 0 0 0 0 0 # FracFemale_GP_1
#
#_no timevary MG parameters
#
#_seasonal_effects_on_biology_parms
 0 0 0 0 0 0 0 0 0 0 #_femwtlen1,femwtlen2,mat1,mat2,fec1,fec2,Malewtlen1,malewtlen2,L1,K
#_ LO HI INIT PRIOR PR_SD PR_type PHASE
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no seasonal MG parameters
#
3 #_Spawner-Recruitment; Options: 2=Ricker; 3=std_B-H; 4=SCAA; 5=Hockey; 6=B-H_flattop; 7=survival_3Parm; 8=Shepherd_3Parm;
9=RickerPower_3parm
1  # 0/1 to use steepness in initial equ recruitment calculation
0  #  future feature:  0/1 to make realized sigmaR a function of SR curvature
#_       LO        HI        INIT       PRIOR       PR_SD       PR_type      PHASE    env-var    use_dev   dev_mnyr   dev_mxyr     dev_PH
Block    Blk_Fxn #  parm_name
            0      13.82      10.2164        6.91          0          0        1        0        0        0        0        0        0        0 # SR_LN(R0)
         0.22        0.96     0.714061         0.6        0.74          0        2        0        0        0        0        0        0        0 # SR_BH_steep
            0          2        0.3        0.2          0          0       -3        0        0        0        0        0        0        0 # SR_sigmaR
           -5          5          0          0          0          0       -3        0        0        0        0        0        0        0 # SR_regime
            0        0.5          0          0          0          0       -2        0        0        0        0        0        0        0 # SR_autocorr
#_no timevary SR parameters
1 #do_recdev:  0=none; 1=devvector (R=F(SSB)+dev); 2=deviations (R=F(SSB)+dev); 3=deviations (R=R0*dev; dev2=R-f(SSB)); 4=like 3 with
sum(dev2) adding penalty
1994 # first year of main recr_devs; early devs can preceed this era
2015 # last year of main recr_devs; forecast devs start in following year
3 #_recdev phase
1 # (0/1) to read 13 advanced options
 0 #_recdev_early_start (0=none; neg value makes relative to recdev_start)
 -4 #_recdev_early_phase
 5 #_forecast_recruitment phase (incl. late recr) (0 value resets to maxphase+1)
 1 #_lambda for Fcast_recr_like occurring before endyr+1
1970.0   #_last_early_yr_nobias_adj_in_MPD
1999.3   #_first_yr_fullbias_adj_in_MPD
2014.7   #_last_yr_fullbias_adj_in_MPD
2018.2   #_first_recent_yr_nobias_adj_in_MPD
0.9293   #_max_bias_adj_in_MPD (1.0 to mimic pre-2009 models)
 0 #_period of cycles in recruitment (N parms read below)
 -5 #min rec_dev
 5 #max rec_dev
 0 #_read_recdevs
#_end of advanced SR options
```

#
#_placeholder for full parameter lines for recruitment cycles
read specified recr devs
#_Yr Input_value
#
all recruitment deviations
1994R 1995R 1996R 1997R 1998R 1999R 2000R 2001R 2002R 2003R 2004R 2005R 2006R 2007R 2008R 2009R 2010R 2011R 2012R 2013R 2014R 2015R 2016F 2017F 2018F
-0.490348 -0.242193 -0.231156 -0.160269 -0.260471 0.285795 0.19588 0.166765 0.12511 0.119568 -0.148796 -0.0146184 0.20955 -0.230986 -0.311202 -0.481099 -0.167283 0.145358 0.259514 0.116869 0.260858 0.853155 0.39313 -0.114871 0
implementation error by year in forecast: 0
#
#Fishing Mortality info
0.5 # F ballpark
-2001 # F ballpark year (neg value to disable)
2 # F_Method: 1=Pope; 2=instan. F; 3=hybrid (hybrid is recommended)
3 # max F or harvest rate, depends on F_Method
no additional F input needed for Fmethod 1
if Fmethod=2; read overall start F value; overall phase; N detailed inputs to read
if Fmethod=3; read N iterations for tuning for Fmethod 3
0.05 1 0 # overall start F value; overall phase; N detailed inputs to read
#Fleet Yr Seas F_value se phase (for detailed setup of F_Method=2; -Yr to fill remaining years)

#
#_initial_F_parms; count = 0
#_ LO HI INIT PRIOR PR_SD PR_type PHASE
#2018 2038
F rates by fleet
Yr: 1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
seas: 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
CM_E 3.35642e-005 6.70799e-005 0.000101719 0.000136993 0.000173634 0.000211503 0.000250409 0.000291357 0.000334533 0.00038004 0.000428778 0.000478981 0.000528947 0.000576564 0.000638023 0.000641634 0.000339013 0.000695897 0.00140316 0.00181558 0.00172288 0.00191343 0.00171323 0.00292358 0.00280535 0.00617707 0.0054919 0.00754216 0.00658777 0.00510805 0.00379662 0.00559587 0.00589477 0.00945059 0.0135966 0.0178405 0.0192141 0.015754 0.0153669 0.0156343 0.0394273 0.0334753 0.0451458 0.0667222 0.0689394 0.0722888 0.0614297 0.0609565 0.0511046 0.0625665 0.0497076 0.0558122 0.0648911 0.0728792 0.0577289 0.0852835 0.0911045 0.0920053 0.102839 0.152304 0.0732397 0.142046 0.102519 0.0587922 0.0657483 0.0352883 0.0382144 0.0382333 0.0382333
CM_W 2.97616e-005 5.96173e-005 8.98152e-005 0.000120753 0.0001527 0.000185742 0.000219931 0.000255469 0.000292614 0.000331804 0.000373423 0.000417509 0.000463189 0.000508591 0.000539352 0.000481644 0.000156322 0.000374681 0.00121253 0.000663338 0.00110534 0.0012171 0.00119768 0.00143687 0.00177129 0.0029377 0.00164717 0.00538834 0.0045794 0.00628051 0.0042954 0.0033996 0.00439639 0.00495998 0.0267497 0.0242245 0.0324558 0.0369085 0.0390869 0.0420144 0.0429166 0.0379455 0.0525523 0.055091 0.0604697 0.041246 0.0443371 0.0797954 0.0732685 0.0982714 0.0728111 0.0901626 0.101156 0.123377 0.115058 0.105384 0.0703268 0.1261 0.0856603 0.0796273 0.0614443 0.0572594 0.0725951 0.0445782 0.0585716 0.0571478 0.0558899 0.04343 0.04343
REC 0.000146044 0.000396389 0.000657222 0.000929091 0.00121084 0.0015041 0.00180939 0.00213031 0.00247381 0.00284481 0.0032405 0.00363744 0.00399333 0.00430905 0.00463394 0.00498324 0.00535779 0.00574949 0.0061624 0.00660019 0.00706824 0.00753541 0.00795718 0.00835217 0.00874336 0.00915002 0.00956625 0.0100195 0.0105406 0.0111131 0.0117092 0.0123058 0.0275791 0.0106401 0.0165542 0.032521 0.0467499 0.0603293 0.091821 0.0509323 0.0698147 0.0914415 0.11636 0.0903718 0.0796988 0.117603 0.0505117 0.0911418 0.0486832 0.0978607 0.0578296 0.149162 0.118633 0.108944 0.109258 0.134443 0.126009 0.122353 0.0582702 0.0832678 0.0611143 0.146937 0.114544 0.198255 0.175589 0.136419 0.123313 0.140918 0.140918
SMP_BYC 0.0497649 0.0678587 0.0801493 0.0842824 0.109272 0.113912 0.145658 0.1668 0.204336 0.220338 0.22033 0.166867 0.160718 0.183323 0.193747 0.215227 0.211941 0.231153 0.235123 0.267733 0.252521 0.241266 0.236328 0.240558 0.240005 0.242124 0.252002 0.277197 0.293917 0.308541 0.315997 0.286983 0.273429 0.276505 0.313552 0.303182 0.330898 0.274654 0.251442 0.276051 0.242523 0.253171 0.318937 0.361006 0.550439 0.426907 0.402567 0.414399 0.502832 0.32835 0.262954 0.290981 0.360275 0.308514 0.284381 0.237136 0.154533 0.106944 0.0762657 0.122585 0.0913044 0.109893 0.097378 0.108884 0.0868988 0.0712916 0.0735476 0.0796385 0.100764
#
#_Q_setup for fleets with cpue or survey data
#_1: fleet number
#_2: link type: (1=simple q, 1 parm; 2=mirror simple q, 1 mirrored parm; 3=q and power, 2 parm; 4=mirror with offset, 2 parm)
#_3: extra input for link, i.e. mirror fleet# or dev index number
#_4: 0/1 to select extra sd parameter
#_5: 0/1 for biasadj or not
#_6: 0/1 to float

#_	fleet	link	link_info	extra_se	biasadj	float # fleetname
	1	1	0	0	0	1 # CM_E
	2	1	0	0	0	1 # CM_W
	3	1	0	0	0	1 # REC
	4	1	0	0	0	0 # SMP_BYC
	5	1	0	0	0	1 # HB_E

```
      6      1      0      0      0      1  #  HB_W
      7      1      0      0      0      1  #  LARVAL
      8      1      0      0      0      1  #  VIDEO
      9      1      0      0      0      1  #  SEAMAP
-9999 0 0 0 0 0
#
#_Q_parms(if_any);Qunits_are_ln(q)
#_      LO      HI      INIT      PRIOR      PR_SD      PR_type      PHASE   env-var   use_dev   dev_mnyr   dev_mxyr   dev_PH
Block   Blk_Fxn  #  parm_name
      -25      25   -8.91163      0      1      0      -1      0      0      0      0      0      0      0  #  LnQ_base_CM_E(1)
      -25      25   -8.55842      0      1      0      -1      0      0      0      0      0      0      0  #
LnQ_base_CM_W(2)
      -25      25   -9.50297      0      1      0      -1      0      0      0      0      0      0      0  #  LnQ_base_REC(3)
      -10      20    1.38557      0      0      0       2      0      0      0      0      0      0      0  #
LnQ_base_SMP_BYC(4)
      -25      25    -9.8828      0      1      0      -1      0      0      0      0      0      0      0  #  LnQ_base_HB_E(5)
      -25      25    -9.8033      0      1      0      -1      0      0      0      0      0      0      0  #  LnQ_base_HB_W(6)
      -25      25   -26.2164      0      1      0      -1      0      0      0      0      0      0      0  #
LnQ_base_LARVAL(7)
      -25      25   -10.4723      0      1      0      -1      0      0      0      0      0      0      0  #
LnQ_base_VIDEO(8)
      -25      25   -10.5735      0      1      0      -1      0      0      0      0      0      0      0  #
LnQ_base_SEAMAP(9)
#_no timevary Q parameters
#
#_size_selex_patterns
#Pattern:_0; parm=0; selex=1.0 for all sizes
#Pattern:_1; parm=2; logistic; with 95% width specification
#Pattern:_5; parm=2; mirror another size selex; PARMS pick the min-max bin to mirror
#Pattern:_15; parm=0; mirror another age or length selex
#Pattern:_6; parm=2+special; non-parm len selex
#Pattern:_43; parm=2+special+2;  like 6, with 2 additional param for scaling (average over bin range)
#Pattern:_8; parm=8; New doublelogistic with smooth transitions and constant above Linf option
#Pattern:_9; parm=6; simple 4-parm double logistic with starting length; parm 5 is first length; parm 6=1 does desc as offset
#Pattern:_21; parm=2+special; non-parm len selex, read as pairs of size, then selex
#Pattern:_22; parm=4; double_normal as in CASAL
#Pattern:_23; parm=6; double_normal where final value is directly equal to sp(6) so can be >1.0
#Pattern:_24; parm=6; double_normal with sel(minL) and sel(maxL), using joiners
#Pattern:_25; parm=3; exponential-logistic in size
#Pattern:_27; parm=3+special; cubic spline
#Pattern:_42; parm=2+special+3; // like 27, with 2 additional param for scaling (average over bin range)
#_discard_options:_0=none;_1=define_retention;_2=retention&mortality;_3=all_discarded_dead;_4=define_dome-shaped_retention
#_Pattern Discard Male Special
 0 2 0 0 # 1 CM_E
 0 2 0 0 # 2 CM_W
 0 2 0 0 # 3 REC
 0 3 0 0 # 4 SMP_BYC
 0 0 0 0 # 5 HB_E
 0 0 0 0 # 6 HB_W
 0 0 0 0 # 7 LARVAL
 24 0 0 0 # 8 VIDEO
 24 0 0 0 # 9 SEAMAP
#
#_age_selex_patterns
#Pattern:_0; parm=0; selex=1.0 for ages 0 to maxage
#Pattern:_10; parm=0; selex=1.0 for ages 1 to maxage
#Pattern:_11; parm=2; selex=1.0  for specified min-max age
#Pattern:_12; parm=2; age logistic
#Pattern:_13; parm=8; age double logistic
#Pattern:_14; parm=nages+1; age empirical
#Pattern:_15; parm=0; mirror another age or length selex
#Pattern:_16; parm=2; Coleraine - Gaussian
#Pattern:_17; parm=nages+1; empirical as random walk  N parameters to read can be overridden by setting special to non-zero
#Pattern:_41; parm=2+nages+1; // like 17, with 2 additional param for scaling (average over bin range)
#Pattern:_18; parm=8; double logistic - smooth transition
#Pattern:_19; parm=6; simple 4-parm double logistic with starting age
#Pattern:_20; parm=6; double_normal,using joiners
#Pattern:_26; parm=3; exponential-logistic in age
#Pattern:_27; parm=3+special; cubic spline in age
#Pattern:_42; parm=2+special+3; // cubic spline; with 2 additional param for scaling (average over bin range)
```

```
#_Pattern Discard Male Special
 12 0 0 0 # 1 CM_E
 12 0 0 0 # 2 CM_W
 20 0 0 0 # 3 REC
 19 0 0 0 # 4 SMP_BYC
 15 0 0 3 # 5 HB_E
 15 0 0 3 # 6 HB_W
 0 0 0 0 # 7 LARVAL
 0 0 0 0 # 8 VIDEO
 0 0 0 0 # 9 SEAMAP
#
#_ LO HI INIT PRIOR PR_SD PR_type PHASE env-var use_dev dev_mnyr dev_mxyr dev_PH
Block Blk_Fxn # parm_name
# 1 CM_E LenSelex
 10 100 10.16 10.16 -1 0 -3 0 0 0 0 0 1 2 #
Retain_L_infl_CM_E(1)
 -1 20 1e-006 1 -1 0 -3 0 0 0 0 0 0 0 #
Retain_L_width_CM_E(1)
 -10 10 10 10 -1 0 -2 0 0 0 0 0 1 2 #
Retain_L_asymptote_logit_CM_E(1)
 -1 2 0 0 -1 0 -4 0 0 0 0 0 0 0 #
Retain_L_maleoffset_CM_E(1)
 -10 10 -5 -5 -1 0 -2 0 0 0 0 0 0 0 #
DiscMort_L_infl_CM_E(1)
 -1 2 1e-006 1 -1 0 -4 0 0 0 0 0 0 0 #
DiscMort_L_width_CM_E(1)
 -1 2 0.15 0.15 -1 0 -2 0 0 0 0 0 3 2 #
DiscMort_L_level_old_CM_E(1)
 -1 2 0 0 -1 0 -4 0 0 0 0 0 0 0 #
DiscMort_L_male_offset_CM_E(1)
# 2 CM_W LenSelex
 10 100 10.16 10.16 -1 0 -3 0 0 0 0 0 1 2 #
Retain_L_infl_CM_W(2)
 -1 20 1e-006 1 -1 0 -3 0 0 0 0 0 0 0 #
Retain_L_width_CM_W(2)
 -10 10 10 10 -1 0 -2 0 0 0 0 0 1 2 #
Retain_L_asymptote_logit_CM_W(2)
 -1 2 0 0 -1 0 -4 0 0 0 0 0 0 0 #
Retain_L_maleoffset_CM_W(2)
 -10 10 -5 -5 -1 0 -2 0 0 0 0 0 0 0 #
DiscMort_L_infl_CM_W(2)
 -1 2 1e-006 1 -1 0 -4 0 0 0 0 0 0 0 #
DiscMort_L_width_CM_W(2)
 -1 2 0.15 0.15 -1 0 -2 0 0 0 0 0 3 2 #
DiscMort_L_level_old_CM_W(2)
 -1 2 0 0 -1 0 -4 0 0 0 0 0 0 0 #
DiscMort_L_male_offset_CM_W(2)
# 3 REC LenSelex
 10 100 10.16 10.16 -1 0 -3 0 0 0 0 0 2 2 #
Retain_L_infl_REC(3)
 -1 20 1e-006 1 -1 0 -3 0 0 0 0 0 0 0 #
Retain_L_width_REC(3)
 -10 10 10 10 -1 0 -2 0 0 0 0 0 2 2 #
Retain_L_asymptote_logit_REC(3)
 -1 2 0 0 -1 0 -4 0 0 0 0 0 0 0 #
Retain_L_maleoffset_REC(3)
 -10 10 -5 -5 -1 0 -2 0 0 0 0 0 0 0 #
DiscMort_L_infl_REC(3)
 -1 2 1e-006 1 -1 0 -4 0 0 0 0 0 0 0 #
DiscMort_L_width_REC(3)
 -1 2 0.15 0.15 -1 0 -2 0 0 0 0 0 3 2 #
DiscMort_L_level_old_REC(3)
 -1 2 0 0 -1 0 -4 0 0 0 0 0 0 0 #
DiscMort_L_male_offset_REC(3)
# 4 SMP_BYC LenSelex
# 5 HB_E LenSelex
# 6 HB_W LenSelex
# 7 LARVAL LenSelex
# 8 VIDEO LenSelex
```

7.5 52.5 19.2284 42.7 0.05 0 2 0 0 0 0 0.5 0 0 #
Size_DblN_peak_VIDEO(8)
-10 3 -1.57507 -0.4 0.05 0 3 0 0 0 0 0.5 0 0 #
Size_DblN_top_logit_VIDEO(8)
-6 12 1.10234 5.5 0.05 0 3 0 0 0 0 0.5 0 0 #
Size_DblN_ascend_se_VIDEO(8)
-4 6 1.30579 5.1 0.05 0 3 0 0 0 0 0.5 0 0 #
Size_DblN_descend_se_VIDEO(8)
-15 5 -1.48478 -4.2 0.05 0 2 0 0 0 0 0.5 0 0 #
Size_DblN_start_logit_VIDEO(8)
-8 5 0.594704 0.4 0.05 0 2 0 0 0 0 0.5 0 0 #
Size_DblN_end_logit_VIDEO(8)
# 9 SEAMAP LenSelex
7.5 52.5 14.8883 13 0.05 0 2 0 0 0 0 0.5 0 0 #
Size_DblN_peak_SEAMAP(9)
-10 3 -3.63803 -1.1 0.05 0 3 0 0 0 0 0.5 0 0 #
Size_DblN_top_logit_SEAMAP(9)
-6 12 1.34398 3.1 0.05 0 3 0 0 0 0 0.5 0 0 #
Size_DblN_ascend_se_SEAMAP(9)
-4 6 3.04162 5 0.05 0 3 0 0 0 0 0.5 0 0 #
Size_DblN_descend_se_SEAMAP(9)
-15 5 -1.25553 -4.5 0.05 0 2 0 0 0 0 0.5 0 0 #
Size_DblN_start_logit_SEAMAP(9)
-8 5 -5.4132 0.1 0.05 0 2 0 0 0 0 0.5 0 0 #
Size_DblN_end_logit_SEAMAP(9)
# 1 CM_E AgeSelex
0.5 14 2.12032 2.66 0 0 3 0 0 0 0 0 0 0 #
Age_inflection_CM_E(1)
0.5 14 0.91584 7.2774 0 0 1 0 0 0 0 0 0 0 #
Age_95%width_CM_E(1)
2 CM_W AgeSelex
0.5 14 3.68149 2.66 0 0 3 0 0 0 0 0 0 0 #
Age_inflection_CM_W(2)
0.5 14 2.09726 7.2774 0 0 1 0 0 0 0 0 0 0 #
Age_95%width_CM_W(2)
3 REC AgeSelex
1 10 3.33151 4.3 0.05 0 2 0 0 0 0 0.5 0 0 #
Age_DblN_peak_REC(12)
-10 3 -9.16309 -4.6 0.05 0 3 0 0 0 0 0.5 0 0 #
Age_DblN_top_logit_REC(12)
-6 12 0.547825 0.7 0.05 0 3 0 0 0 0 0.5 0 0 #
Age_DblN_ascend_se_REC(12)
-4 6 2.95149 2.7 0.05 0 3 0 0 0 0 0.5 0 0 #
Age_DblN_descend_se_REC(12)
-15 5 -12.1067 -11.2 0.05 0 2 0 0 0 0 0.5 0 0 #
Age_DblN_start_logit_REC(12)
-8 5 -1.82219 -3.3 0.05 0 2 0 0 0 0 0.5 0 0 #
Age_DblN_end_logit_REC(12)
# 4 SMP_BYC AgeSelex
1e-007 2 0.5 0.5 0 0 -4 0 0 0 0 0 0 0 #
AgeSel_P1_SMP_BYC(4)
0.5 1e+007 100 100 0 0 -4 0 0 0 0 0 0 0 #
AgeSel_P2_SMP_BYC(4)
0.3 3 1.5 1.5 0 0 -4 0 0 0 0 0 0 0 #
AgeSel_P3_SMP_BYC(4)
0.5 1e+007 2.4096 2.4096 0 0 -4 0 0 0 0 0 0 0 #
AgeSel_P4_SMP_BYC(4)
-1 1 0 0 0 0 -4 0 0 0 0 0 0 0 #
AgeSel_P5_SMP_BYC(4)
-1 1 0 0 0 0 -4 0 0 0 0 0 0 0 #
AgeSel_P6_SMP_BYC(4)
# 5 HB_E AgeSelex
# 6 HB_W AgeSelex
# 7 LARVAL AgeSelex
# 8 VIDEO AgeSelex
# 9 SEAMAP AgeSelex
# timevary selex parameters
#_ LO HI INIT PRIOR PR_SD PR_type PHASE # parm_name
10 100 20.32 20.32 -1 0 -4 # Retain_L_infl_CM_E(1)_BLK1repl_1990
10 100 27.94 27.94 -1 0 -4 # Retain_L_infl_CM_E(1)_BLK1repl_2005

```
 10   100   25.4   25.4   -1   0   -4  # Retain_L_infl_CM_E(1)_BLK1repl_2008
 -10   10   10   10   -1   0   -4  # Retain_L_asymptote_logit_CM_E(1)_BLK1repl_1990
 -10   10   10   10   -1   0   -4  # Retain_L_asymptote_logit_CM_E(1)_BLK1repl_2005
 -10   10   10   10   -1   0   -4  # Retain_L_asymptote_logit_CM_E(1)_BLK1repl_2008
 -1   2   0.15   0.15   -1   0   -4  # DiscMort_L_level_old_CM_E(1)_BLK3repl_2008
 10   100   20.32   20.32   -1   0   -4  # Retain_L_infl_CM_W(2)_BLK1repl_1990
 10   100   27.94   27.94   -1   0   -4  # Retain_L_infl_CM_W(2)_BLK1repl_2005
 10   100   25.4   25.4   -1   0   -4  # Retain_L_infl_CM_W(2)_BLK1repl_2008
 -10   10   10   10   -1   0   -4  # Retain_L_asymptote_logit_CM_W(2)_BLK1repl_1990
 -10   10   10   10   -1   0   -4  # Retain_L_asymptote_logit_CM_W(2)_BLK1repl_2005
 -10   10   10   10   -1   0   -4  # Retain_L_asymptote_logit_CM_W(2)_BLK1repl_2008
 -1   2   0.15   0.15   -1   0   -4  # DiscMort_L_level_old_CM_W(2)_BLK3repl_2008
 10   100   20.32   20.32   -1   0   -4  # Retain_L_infl_REC(3)_BLK2repl_1990
 10   100   25.4   25.4   -1   0   -4  # Retain_L_infl_REC(3)_BLK2repl_1997
 10   100   27.94   27.94   -1   0   -4  # Retain_L_infl_REC(3)_BLK2repl_2005
 10   100   25.4   25.4   -1   0   -4  # Retain_L_infl_REC(3)_BLK2repl_2008
 -10   10   10   10   -1   0   -4  # Retain_L_asymptote_logit_REC(3)_BLK2repl_1990
 -10   10   10   10   -1   0   -4  # Retain_L_asymptote_logit_REC(3)_BLK2repl_1997
 -10   10   10   10   -1   0   -4  # Retain_L_asymptote_logit_REC(3)_BLK2repl_2005
 -10   10   10   10   -1   0   -4  # Retain_L_asymptote_logit_REC(3)_BLK2repl_2008
 -1   2   0.15   0.15   -1   0   -4  # DiscMort_L_level_old_REC(3)_BLK3repl_2008
# info on dev vectors created for selex parms are reported with other devs after tag parameter section
#
0   #  use 2D_AR1 selectivity(0/1):  experimental feature
#_no 2D_AR1 selex offset used
#
# Tag loss and Tag reporting parameters go next
0  # TG_custom:  0=no read and autogen if tag data exist; 1=read
#_Cond -6 6 1 1 2 0.01 -4 0 0 0 0 0 0 0  #_placeholder if no parameters
#
# deviation vectors for timevary parameters
#  base   base first block   block  env  env   dev   dev   dev   dev   dev
#  type  index  parm trend pattern link  var  vectr link _mnyr  mxyr phase  dev_vector
#     5    1    1    1    2    0    0    0    0    0    0    0
#     5    3    4    1    2    0    0    0    0    0    0    0
#     5    7    7    3    2    0    0    0    0    0    0    0
#     5    9    8    1    2    0    0    0    0    0    0    0
#     5   11   11    1    2    0    0    0    0    0    0    0
#     5   15   14    3    2    0    0    0    0    0    0    0
#     5   17   15    2    2    0    0    0    0    0    0    0
#     5   19   19    2    2    0    0    0    0    0    0    0
#     5   23   23    3    2    0    0    0    0    0    0    0
     #
# Input variance adjustments factors:
 #_1=add_to_survey_CV
 #_2=add_to_discard_stddev
 #_3=add_to_bodywt_CV
 #_4=mult_by_lencomp_N
 #_5=mult_by_agecomp_N
 #_6=mult_by_size-at-age_N
 #_7=mult_by_generalized_sizecomp
#_Factor  Fleet  Value
 -9999   1    0  # terminator
#
10 #_maxlambdaphase
1 #_sd_offset; must be 1 if any growthCV, sigmaR, or survey extraSD is an estimated parameter
# read 3 changes to default Lambdas (default value is 1.0)
# Like_comp codes:  1=surv; 2=disc; 3=mnwt; 4=length; 5=age; 6=SizeFreq; 7=sizeage; 8=catch; 9=init_equ_catch;
# 10=recrdev; 11=parm_prior; 12=parm_dev; 13=CrashPen; 14=Morphcomp; 15=Tag-comp; 16=Tag-negbin; 17=F_ballpark; 18=initEQregime
#like_comp fleet  phase  value  sizefreq_method
 2 1 1 0 1
 2 2 1 0 1
 2 3 1 0 1
-9999  1  1  1  1  #  terminator
#
# lambdas (for info only; columns are phases)
#  1 1 1 1 1 1 1 1 1 1 #_CPUE/survey:_1
#  1 1 1 1 1 1 1 1 1 1 #_CPUE/survey:_2
#  1 1 1 1 1 1 1 1 1 1 #_CPUE/survey:_3
#  1 1 1 1 1 1 1 1 1 1 #_CPUE/survey:_4
```

```
#  1 1 1 1 1 1 1 1 1 1 #_CPUE/survey:_5
#  1 1 1 1 1 1 1 1 1 1 #_CPUE/survey:_6
#  1 1 1 1 1 1 1 1 1 1 #_CPUE/survey:_7
#  1 1 1 1 1 1 1 1 1 1 #_CPUE/survey:_8
#  1 1 1 1 1 1 1 1 1 1 #_CPUE/survey:_9
#  0 0 0 0 0 0 0 0 0 0 #_discard:_1
#  0 0 0 0 0 0 0 0 0 0 #_discard:_2
#  0 0 0 0 0 0 0 0 0 0 #_discard:_3
#  1 1 1 1 1 1 1 1 1 1 #_discard:_4
#  0 0 0 0 0 0 0 0 0 0 #_discard:_5
#  0 0 0 0 0 0 0 0 0 0 #_discard:_6
#  0 0 0 0 0 0 0 0 0 0 #_discard:_7
#  0 0 0 0 0 0 0 0 0 0 #_discard:_8
#  0 0 0 0 0 0 0 0 0 0 #_discard:_9
#  0 0 0 0 0 0 0 0 0 0 #_lencomp:_1
#  0 0 0 0 0 0 0 0 0 0 #_lencomp:_2
#  0 0 0 0 0 0 0 0 0 0 #_lencomp:_3
#  0 0 0 0 0 0 0 0 0 0 #_lencomp:_4
#  0 0 0 0 0 0 0 0 0 0 #_lencomp:_5
#  0 0 0 0 0 0 0 0 0 0 #_lencomp:_6
#  0 0 0 0 0 0 0 0 0 0 #_lencomp:_7
#  1 1 1 1 1 1 1 1 1 1 #_lencomp:_8
#  1 1 1 1 1 1 1 1 1 1 #_lencomp:_9
#  1 1 1 1 1 1 1 1 1 1 #_agecomp:_1
#  1 1 1 1 1 1 1 1 1 1 #_agecomp:_2
#  1 1 1 1 1 1 1 1 1 1 #_agecomp:_3
#  0 0 0 0 0 0 0 0 0 0 #_agecomp:_4
#  0 0 0 0 0 0 0 0 0 0 #_agecomp:_5
#  0 0 0 0 0 0 0 0 0 0 #_agecomp:_6
#  0 0 0 0 0 0 0 0 0 0 #_agecomp:_7
#  0 0 0 0 0 0 0 0 0 0 #_agecomp:_8
#  0 0 0 0 0 0 0 0 0 0 #_agecomp:_9
#  1 1 1 1 1 1 1 1 1 1 #_init_equ_catch
#  1 1 1 1 1 1 1 1 1 1 #_recruitments
#  1 1 1 1 1 1 1 1 1 1 #_parameter-priors
#  1 1 1 1 1 1 1 1 1 1 #_parameter-dev-vectors
#  1 1 1 1 1 1 1 1 1 1 #_crashPenLambda
#  0 0 0 0 0 0 0 0 0 0 # F_ballpark_lambda
0 # (0/1) read specs for more stddev reporting
 # 0 0 0 0 0 0 0 0 0 # placeholder for # selex_fleet, 1=len/2=age/3=both, year, N selex bins, 0 or Growth pattern, N growth ages, 0 or
NatAge_area(-1 for all), NatAge_yr, N Natages
 # placeholder for vector of selex bins to be reported
 # placeholder for vector of growth ages to be reported
 # placeholder for vector of NatAges ages to be reported
999
```

10.3. Forecast File

```
#V3.30.14.05-safe;_2019_09_05;_Stock_Synthesis_by_Richard_Methot_(NOAA)_using_ADMB_12.0
#Stock Synthesis (SS) is a work of the U.S. Government and is not subject to copyright protection in the United States.
#Foreign copyrights may apply. See copyright.txt for more information.
# for all year entries except rebuilder; enter either: actual year, -999 for styr, 0 for endyr, neg number for rel. endyr
1 # Benchmarks: 0=skip; 1=calc F_spr,F_btgt,F_msy; 2=calc F_spr,F0.1,F_msy
2 # MSY: 1= set to F(SPR); 2=calc F(MSY); 3=set to F(Btgt) or F0.1; 4=set to F(endyr)
0.373 # SPR target (e.g. 0.40)
0.3 # Biomass target (e.g. 0.40)
#_Bmark_years: beg_bio, end_bio, beg_selex, end_selex, beg_relF, end_relF, beg_recr_dist, end_recr_dist, beg_SRparm, end_SRparm (enter actual year, or values of 0 or -integer to be rel. endyr)
 0 0 0 0 -3 0 2005 2014 0 0
1 #Bmark_relF_Basis: 1 = use year range; 2 = set relF same as forecast below
#
1 # Forecast: 0=none; 1=F(SPR); 2=F(MSY) 3=F(Btgt) or F0.1; 4=Ave F (uses first-last relF yrs); 5=input annual F scalar
100 # N forecast years
1 # F scalar (only used for Do_Forecast==5)
#_Fcast_years:  beg_selex, end_selex, beg_relF, end_relF, beg_mean recruits, end_recruits  (enter actual year, or values of 0 or -integer to be rel. endyr)
0 0 -3 0 2005 2014
0 # Forecast selectivity (0=fcast selex is mean from year range; 1=fcast selectivity from annual time-vary parms)
2 # Control rule method (1: ramp does catch=f(SSB), buffer on F; 2: ramp does F=f(SSB), buffer on F; 3: ramp does catch=f(SSB), buffer on catch; 4: ramp does F=f(SSB), buffer on catch)
0.01 # Control rule Biomass level for constant F (as frac of Bzero, e.g. 0.40); (Must be > the no F level below)
0.001 # Control rule Biomass level for no F (as frac of Bzero, e.g. 0.10)
1 # Buffer:  enter Control rule target as fraction of Flimit (e.g. 0.75), negative value invokes list of [year, scalar] with filling from year to YrMax
3 #_N forecast loops (1=OFL only; 2=ABC; 3=get F from forecast ABC catch with allocations applied)
3 #_First forecast loop with stochastic recruitment
3 #_Forecast recruitment:  0= spawn_recr; 1=value*spawn_recr_fxn; 2=value*VirginRecr; 3=recent mean from yr range above (need to set phase to -1 in control to get constant recruitment in MCMC)
100 # value is ignored
0 #_Forecast loop control #5 (reserved for future bells&whistles)
2120  #FirstYear for caps and allocations (should be after years with fixed inputs)
0 # stddev of log(realized catch/target catch) in forecast (set value>0.0 to cause active impl_error)
0 # Do West Coast gfish rebuilder output (0/1)
2019 # Rebuilder:  first year catch could have been set to zero (Ydecl)(-1 to set to 1999)
2014 # Rebuilder:  year for current age structure (Yinit) (-1 to set to endyear+1)
1 # fleet relative F:  1=use first-last alloc year; 2=read seas, fleet, alloc list below
# Note that fleet allocation is used directly as average F if Do_Forecast=4
2 # basis for fcast catch tuning and for fcast catch caps and allocation  (2=deadbio; 3=retainbio; 5=deadnum; 6=retainnum); NOTE: same units for all fleets
# Conditional input if relative F choice = 2
# enter list of:  season,  fleet, relF; if used, terminate with season=-9999
# 1 1 0.417558
# 1 2 0.286807
# 1 3 0.295636
# 1 4 1e-006
# -9999 0 0  # terminator for list of relF
# enter list of: fleet number, max annual catch for fleets with a max; terminate with fleet=-9999
-9999 -1
# enter list of area ID and max annual catch; terminate with area=-9999
-9999 -1
# enter list of fleet number and allocation group assignment, if any; terminate with fleet=-9999
-9999 -1
#_if N allocation groups >0, list year, allocation fraction for each group
# list sequentially because read values fill to end of N forecast
# terminate with -9999 in year field
# no allocation groups
-1 # basis for input Fcast catch: -1=read basis with each obs; 2=dead catch; 3=retained catch; 99=input Hrate(F); NOTE: bio vs num based on fleet's catchunits
#enter list of Fcast catches; terminate with line having year=-9999
#_Yr Seas Fleet Catch(or_F)
-9999 1 1 0 99
#
999 # verify end of input
```