SEDAR

Southeast Data, Assessment, and Review

SEDAR 45

Stock Assessment Report

Gulf of Mexico Vermilion Snapper

April 2016

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

Table of Contents

SEDAR

Southeast Data, Assessment, and Review

SEDAR 45

Gulf of Mexico Vermilion Snapper

SECTION I: Introduction

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

1. SEDAR PROCESS DESCRIPTION

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

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

SEDAR workshops and webinars 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 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.	Amendment 1	January 1990
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	Amendment 31	May 2010

fathoms and implementing the maximum hook provisions.		
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

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	Steven Atran, Dr. Carrie Simmons - GMFMC Peter Hood
Current stock exploitation status	Not experiencing overfishing (2012)
Current stock biomass status	Not overfished (2012)

Table 2.5.2. Specific Management Criteria

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

Criteria	Current- 2011 Update Assessment (2011)		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 45
MFMT	F_{MSY}	0.76	F_{MSY} or proxy from the most recent stock assessment (median from probabilistic analysis)	SEDAR 45
MSY	F_{MSY}	0.76	Yield at F_{MSY} , landings and discards, pounds and numbers (median from probabilistic analysis)	SEDAR 45
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 45
F Targets (i.e., F_{OY})	75% of F_{MSY}	0.57	75% F_{MSY}	SEDAR 45
Yield at F_{Target} (Equilibrium)	Equilibrium Yield @ FOY	7.35 mp ww	landings and discards, pounds and numbers	SEDAR 45
M		0.25	Natural Mortality, average across ages	SEDAR 45
Terminal F	F_{2010}	0.24	Exploitation	SEDAR 45
Terminal Biomass[1]	SSB_{2010}	108 trillion eggs	Biomass	SEDAR 45
Exploitation Status	$F_{CURRENT}$/MFMT	0.32	F/MFMT	SEDAR 45
Biomass Status[1]	$SSB_{CURRENT}$/MSST	1.60	B/MSST B/B_{MSY}	SEDAR 43

[1]SSB measures in number of eggs

Table 2.5.3. General projection information.

First Year of Management	2017 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 (2015)	4.33 mp ww (ABC)
Next Scheduled Quota Change	2016
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.

2.6. Management and Regulatory Timeline

Table 2.6.1. Annual Recreational Regulatory Summary

Note: ABC is in pounds whole weight. ABCs are combined for recreational and commercial sectors.

Year	ABC	Season Open	Seasonal Closure	Season Close	Bag Limit	Size Limit	Effective Date(s):
1990 - 1996	N/A	Jan 1	None	Dec 31	None	8" TL	Jan 1, 1990
1997 - 1998	"	"	"	"	Part of 20 reef fish aggregate limit	10" TL	Jan 15, 1997 (bag) Sep 14, 1997 (size)
1999 - 2004	3.42	"	"	"	"	"	
2005-2007	"	"	"	"	10/person/day	11" TL	July 8, 2005
2008 - 2011	"	"	"	"	Part of 20 reef fish aggregate limit	10" FL	Feb 4, 2008
2012	4.68	"	"	Dec 31	"	"	May 14, 2012
2013	4.41	"	"	"	10/person/day	"	Sep 3, 2013
2014	4.34	"	"	"	"	"	
2015	4.33	"	"	"	"	"	

Notes:

1 Dates listed in "Season Open" or "Season Close" indicate days when fishing is still permitted

2 "Part of 20 reef fish aggregate bag limit" means up to 20 vermilion could be kept per person with no other "reef fish" kept by the same person

3 Managed species: http://www.gulfcouncil.org/fishery_management_plans/Beta/GMFMCWeb/downloads/species%20managed.pdf

Table 2.6.2. Annual Commercial Regulatory Summary

Note: ABC is in pounds whole weight. ABCs are combined for recreational and commercial sectors.

Year	ABC	Season Open	Seasonal Closure	Season Close	Bag Limit	Size Limit	Effective Date(s):
1990 - 1996	N/A	Jan 1	None	Dec 31	Part of 10 snapper aggregate limit	8" TL	Jan 1
1997 - 1998	"	"	"	"	Part of 20 reef fish aggregate limit	"	Jan 1
1999 - 2004	3.42	"	"	"	"	"	
2005	"	"	"	"	10/person/day	11" TL	July 1
2006	"	"	Apr 22 – May 31	"	"	"	
2007	"	"	"	"	Part of 20 reef fish aggregate limit	10" FL	July 3
2008 - 2011	"	"	None	"	"	"	"
2012	4.68	"	"	Dec 31	"	"	May 14
2013	4.41	"	"	"	10/person/day	"	June 10
2014	4.34	"	"	"	"	"	
2015	4.33	"	"	"	"	"	

Notes:

1 Commercial longlining restricted to waters deeper than 50 fathoms west and 20 fathoms east of Cape San Blas as of Jan 1, 1990

2 Commercial longlining restricted to waters deeper than 35 fathoms from June 1 to August 31 as of May 26, 2010

3 Commercial longlining limited to 750 hooks per set beginning in 2010, with an extra 250 hooks in reserve on the boat as of May 26, 2010

4 "Season Open" or "Season Close" dates indicate permitted fishing days. "Seasonal Closure" dates indicate days when fishing is prohibited.

5 Commercial fish traps were phased out over 10 years beginning in March 1997, with all traps banned on Jan 1, 2006

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 overfished ($F/F_{MSY} = 0.65$ and $F/F_{SPR30\%} = 0.67$) nor undergoing overfishing ($SSB/SSB_{MSY} = 1.80$, $SSB/SSB_{SPR30\%} = 1.75$) at the end of 2004. 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 2001 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.

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.

Schirripa, M.J. 1998. Status of the vermilion snapper fishery of the Gulf of Mexico: assessment 4.0. NMFS/SEFSC Miami Laboratory, Sustainable Fisheries Division Contribution No. SFD-97/98-09A. 78pp.

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.

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 MAP

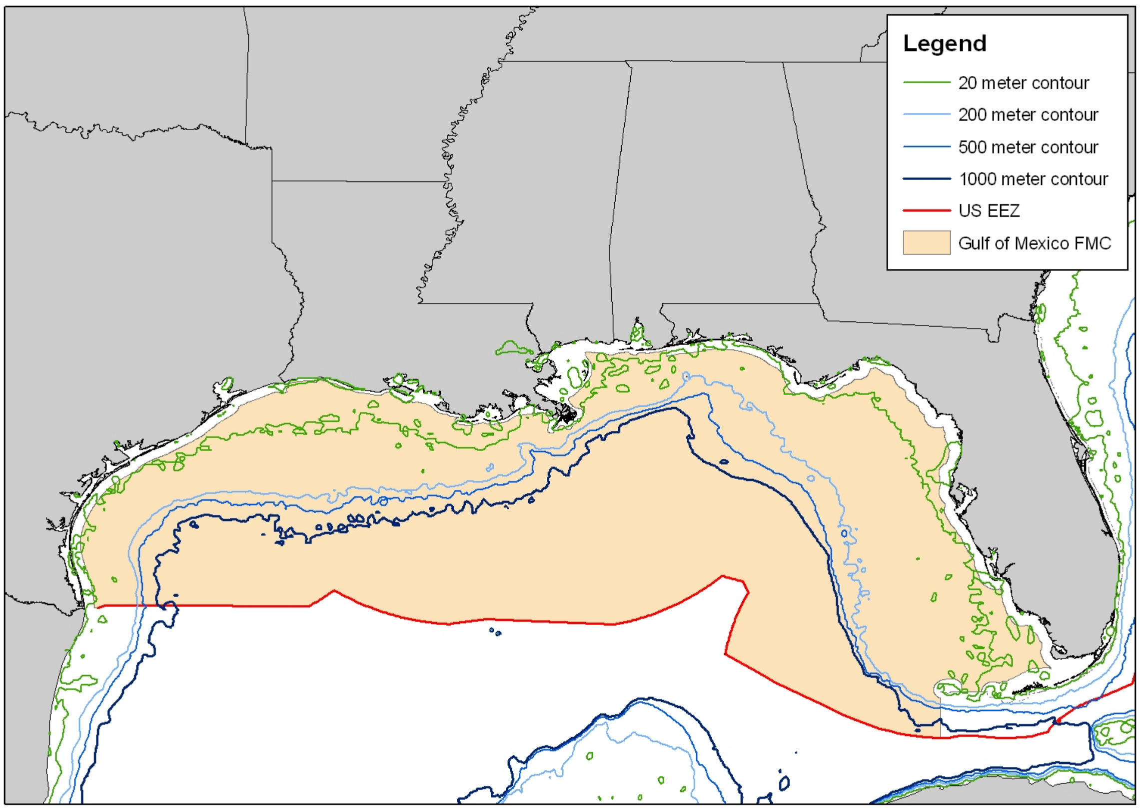


Figure 4.1 Southeast Region including Council and EEZ Boundaries.

5. SEDAR ABBREVIATIONS

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

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
LGL	LGL Ecological Research Associates
M	natural mortality (instantaneous)
MARMAP	Marine Resources Monitoring, Assessment, and Prediction
MCC	Mary Christman Consulting

MDMR	Mississippi Department of Marine Resources
MFMT	maximum fishing mortality threshold, a value of F above which overfishing is deemed to be occurring
MRFSS	Marine Recreational Fisheries Statistics Survey; combines a telephone survey of households to estimate number of trips with creel surveys to estimate catch and effort per trip
MRIP	Marine Recreational Information Program
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 45

Gulf of Mexico Vermilion Snapper
SECTION II: Assessment Process Report

April 2016

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

1. Workshop Proceedings

1.1. Introduction

1.2. Workshop time and Place

The Southeast Data, Assessment, and Review (SEDAR) 45 Gulf of Mexico vermilion snapper (*Rhomboplites aurorubens*) workshop was held November 17-19, 2015 in Miami, Florida. In addition to the workshop, several additional webinars were conducted between December 2015 and January 2016 to finalize the assessment.

1.3. Terms of Reference

1. Provide a continuity run that preserves the model structure and assumptions of Gulf of Mexico vermilion snapper assessment as reviewed and approved by the SSC during the 2011 update assessment, using data through 2014. Evaluate the effect of any changes in model inputs or parameterization approved during this assessment.

2. Evaluate and document the following specific changes in input data or deviations from the benchmark model previous assessment model.
   - Consider the inclusion of newly available FI indices of abundance, if any.
   - Evaluate discards and include as appropriate
   - Evaluate the impact of episodic events (as it impacts M) if sufficient information is made available in time for this assessment

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 analysis 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. Landings fixed at 2014 target.
   2. FOY= 75% FMSY (project when OY will be achieved)
   3. FREBUILD (if necessary)
   4. F=0 (if necessary)
   5. If short-term projections indicate declining retained yield, develop a constant catch projection.

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

1.4. List of Participants

Workshop Panel

Dan Goethel, Co-Lead Analyst........ NMFS Miami
Matthew Smith, Co-Lead Analyst........ NMFS Miami
Robert Allman........ NMFS Panama City
Donna Bellais........ GSMFC
Shannon Cass-Calay........ NMFS Miami
Mary Christman........ MCC
Gary Fitzhugh........ NMFS Panama City
Bob Gill........ SSC
David Hanisko........ NMFS Pascagoula
John Mareska........ SSC
Paul Mickle........ SSC
Clay Porch........ NMFS Miami
Adam Pollack........ NMFS Pascagoula
Sean Powers........ SSC
Beverly Sauls........ FWC
Ted Switzer........ FWC
Jim Tolan........ SSC

Appointed Observers

Jim Green........ Destin CB Association
Buddy Guindon........ Katies's Seafood
David Krebs........ Ariel Seafood

Attendees

Ching-Ping Chih........ NMFS Miami
Nick Farmer........ NMFS SERO
Vivian Matter........ NMFS Miami
Kevin McCarthy........ NMFS Miami
Trevor Moncrief........ GCRL
Kevin Thompson........ FWC

Staff

Julie Neer........ SEDAR
Ryan Rindone........ GMFMC
Charlotte Schiaffo........ GMFMC

Additional Participants via Webinars

Ken Brennan........ NMFS Beaufort
Nancie Cummings........ NMFS Miami
Doug DeVries........ NMFS Panama City
Kelly Fitzpatrick........ NMFS Beaufort
Jeff Isley........ NMFS Miami
Liz Scott-Denton........ NMFS Galveston

1.5. List of Working Documents and Reference Papers

Document #	Title	Authors	Date Submitted
Documents Prepared for the Data and Assessment Workshop			
SEDAR45-WP-01	Description of age data and estimated growth for Vermilion Snapper from the northern Gulf of Mexico: 1994-2014	Lombard, L., R. Allman, L. Thornton and C. Palmer	14 Oct 2015
SEDAR45-WP-02	Reproductive Parameters for Gulf of Mexico Vermilion Snapper, *Rhomboplites aurorubens*, 1991-2014	G.R. Fitzhugh, H. M. Lyon and B.K. Barnett	14 Oct 2015
SEDAR45-WP-03	Utilizing Paired Readings and an Otolith Reference Collection to Determine Ageing Precision of Vermilion Snapper, (*Rhomboplites aurorubens)*	Thornton, L., C. Palmer, L. Lombardi, and R. Allman	5 Oct 2015
SEDAR45-WP-04	Standardized Catch Rate Indices for Gulf of Mexico Vermilion Snapper (*Rhomboplites aurorubens*) Commercial Handline Fishery, 1993-2014	Mathew W. Smith and Daniel R. Goethel	29 Oct 2015
SEDAR45-WP-05	Vermilion snapper (*Rhomboplites aurorubens*) larval indices of relative abundance from SEAMAP Fall Plankton Surveys, 1986 to 2012	David S. Hanisko, Adam Pollack and Glenn Zapfe	3 Nov 2015
SEDAR45-WP-06	Pricing Summary for Purchases of Vermilion Snapper by WILD SEAFOOD Co., LLC, 2014-2015	Jason Delacruz	27 Aug 2015
SEDAR45-WP-07	Size Distribution of Vermilion Snapper Discards Observed from For-Hire Recreational Vessels in the Eastern Gulf of Mexico	Beverly Sauls	6 Nov 2015 Updated: 24 Nov 2015
SEDAR45-WP-08	Length and age frequency distributions for vermilion snappers collected in the Gulf of Mexico from 1981 to 2014	Ching-Ping Chih	9 Nov 2015
SEDAR45-WP-09	Vermilion Snapper Reef Fish Video Index for the Eastern Gulf of Mexico: A	Adam G. Pollack, G. Walter Ingram, Jr., Matthew D. Campbell,	17 Nov 2015

	Combined Index from Three Fishery-Independent Surveys	Douglas A. DeVries, Chris L. Gardner and Theodore S. Switzer	
SEDAR45-WP-10	Vermilion Snapper Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of Mexico	Adam G. Pollack and G. Walter Ingram, Jr.	9 Sept 2015
SEDAR45-WP-11	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	18 Nov 2015
SEDAR45-WP-12	Vermilion snapper *Rhomboplites aurorubens* Findings from the NMFS Panama City Laboratory Trap & Camera Fishery-Independent Survey 2004-2014	D.A. DeVries, C.L. Gardner, and P. Raley	19 Nov 2015
Final Stock Assessment Reports			
SEDAR45-SAR1	Gulf of Mexico vermilion snapper	SEDAR 45 Panel	
Reference Documents			
SEDAR45-RD01	Estimating relative abundance and species richness from video surveys of reef fishes	Nathan M. Bacheler and Kyle W. Shertzer	
SEDAR45-RD02	Influence of soak time and fish accumulation on catches of reef fishes in a multispecies trap survey	Nathan M. Bacheler, Valerio Bartolino, and Marcel J. M. Reichert	
SEDAR45-RD03	Environmental conditions and habitat characteristics influence trap and video detection probabilities for reef fish species	Nathan M. Bacheler, David J. Berrane, Warren A. Mitchell, Christina M. Schobernd, Zebulon H. Schobernd, Bradford Z. Teer, Joseph C. Ballenger	
SEDAR45-RD04	Estimation of Hook Selectivity of Red Snapper and Vermilion Snapper from Fishery-Independent Surveys of Natural Reefs in the Northern Gulf of Mexico	Matthew D. Campbell, Adam G. Pollack, William B. Driggers & Eric R. Hoffmayer	
SEDAR45-RD05	Comparison of relative abundance indices calculated from two methods of generating video count data	Matthew D. Campbell, Adam G. Pollack, Christopher T. Gledhill, Theodore S. Switzer Douglas A. DeVries	
SEDAR45-RD06	Fish community and trophic structure at artificial reef	Michael A Dance, William F Patterson III, and Dustin T Addis	

	sites in the northeastern Gulf of Mexico	
SEDAR45-RD07	Ecological and Fisheries Management Implications of Competition Between Red Snapper and Vermilion Snapper	William T. Davis
SEDAR45-RD08	Direct observation of fishing effort, catch, and discard rates of charter boats targeting reef fishes in the northern Gulf of Mexico	Steven B. Garner and William F. Patterson
SEDAR45-RD09	Characterization of the Recreational Fisheries associated with the Flower Garden Banks National Marine Sanctuary (USA)	J.C. Levesque1 & A. Richardson
SEDAR45-RD10	Modeling the spatial distribution of commercially important reef fishes on the West Florida Shelf	S.E. Saul, J.F. Walter II, D.J. Dieb, D.F. Naarc, B.T. Donahuec
SEDAR45-RD11	Circle Hook Requirements in the Gulf of Mexico: Application in Recreational Fisheries and Effectiveness for Conservation of Reef Fishes	Beverly Sauls and Oscar Ayala
SEDAR45-RD12	The impact of IFQs on the productivity of the US Gulf of Mexico Red Snapper Fishery	Daniel Solis, Juan J. Agar, and Julio del Corral

2. Data Review and Update

A variety of data sources were used in the SEDAR 45 assessment. For the most part, the SEDAR 45 model used the same data sets as the SEDAR 9 base model and the 2011 SEDAR 9 Update assessment with updated timeseries through 2014. However, a handful of new data sets were provided for the SEDAR 45 analysis some of which were included in the final SEDAR 45 model (e.g., three fishery-independent surveys), but other data sources (e.g., commercial and recreational discards) were deemed insignificant and not included. The available data are summarized below:

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

Fishery-Dependent Data
- Commercial Landings
- Recreational Landings
- Commercial Discards (not used in assessment model)
- Recreational Discards (not used in assessment model)
- Shrimp Bycatch
- Commercial Age Compositions
- Recreational Age Compositions
- Shrimp Bycatch Age Compositions (no new analysis available; not used in model)

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

Fishery-Independent Surveys
- Southeast Area Monitoring and Assessment Program (SEAMAP) Groundfish Survey
- Southeast Area Monitoring and Assessment Program (SEAMAP) Larval Survey
- Southeast Area Monitoring and Assessment Program (SEAMAP) Video Survey

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 9 (2006) and the 2011 Update assessment (SEDAR, 2011), the SEDAR 45 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 updated for the SEDAR 45 standard assessment.

2.2.1. *Morphometric and Conversion Factors*

Vermilion snapper lengths were generally recorded as either total length (TL) or fork length (FL). The SEDAR 9 and 2011 update assessments both utilized total length as the unit of measure. The SEDAR 45 standard assessment used fork length as the unit of measure as it is generally considered to be a more accurate and consistent way to measure fish length. Consequently, updated morphometric equations and conversion factors were required. Conversions for length and weight were summarized in Table 1 and Table 2.

2.2.2. *Growth*

The age and growth of vermilion snapper were described in SEDAR45-WP-01. A total of 43,343 vermilion snapper were aged from otoliths collected from 1994 to 2014. The gear type recorded most often was commercial hand-line followed by recreational hand-line. Commercial longline samples accounted for about 2% of ages. A small number of spear, vertical long-line, trap, cast net, kali pole and gear unknown were also recorded. 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%). To date, the recreational fishery remains largely sampled by the Southeast Recreational Fisheries Information Network (RECFIN) through the Gulf States Marine Fisheries Commission (GSMFC). Otoliths collected from FL, TX and LA made up the majority of collections (61%, 17% and 15%, respectively), while AL and MS together contributed about 7%.

A comparison of age distributions by fishing mode indicated differences by fishing mode and by sampling year. Vermilion snapper ranged in age from young-of-the-year (<1 year) to 26 years. The commercial long-line selected the oldest individuals with fish first fully recruited to the fishery by age 7 with a mean age of 7.9 years and 26% of individuals 10 years or older. The recreational fishery selected younger fish with fish first entering the fishery at 3 years with 64% of individuals ages 3 to 5 (mean 4.6 years) and only 2% of fish 10 years or older. The commercial hand-line recruited to the fishery by age 4 with a mean age of 5.3 years and 7.3% of fish 10 years or greater. Vermilion snapper recruited to the fishery independent trawl gear by age 1 with a mean age of 2.5 years and most fish (59%) 1 or 2 years old. Fishery independent trap and hand-line age distributions were similar, with fish recruiting to both gears by age 3 and mean ages of 5.2 and 5 respectively.

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 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 SEDAR 45-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.

Observations of vermilion snapper sex were obtained during the collection of hard parts for aging. Collection modes included commercial, charter, headboat and scientific survey sources. Females tended to dominate routine fishery sample collections accounting for about 58% of vermilion snapper sexed in the field. This result (more females than males) was consistent among commercial and recreational modes and scientific surveys. The SEDAR 45 assessment model assumed a roughly equal sex ratio (50% females).

Based upon histological preparations of ovary sections, females with vitellogenic or more advanced oocytes were denoted as mature. Females with primary growth oocytes and no indicators of prior spawning were denoted as immature. Females with primary growth or cortical alveolar oocytes as leading stage but displaying potential atretic yolked oocytes were noted to be of uncertain maturity and maturity class was not assigned. Macroscopic/microscopic readings were used for small females (<=200 mm FL). Macroscopic criteria for maturity included females with yolked oocytes, and running ripe and spent females. Visually undifferentiated individuals and undeveloped females were considered immature. Only female records from the reproductive period April – August were retained for assigning maturity.

Adoption of fork length and addition of macroscopic records from small vermilion snapper, largely from trawl surveys, enabled a logit fit of a maturity function to binary data using logistic regression (Table 2). Fork length (FL) at 50% maturity (M) was 138 mm. Re-parameterization of the maturity equation was required for use in SS3. 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.

There is an improved fit but little change in the batch fecundity (BF) relationship used in the previous assessment as n=24 new records were added. 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). As with maturity, SS3 requires that the fecundity relationship be calculated in centimeters rather than millimeters. Conversion to centimeters resulted in the parameter estimates shown in Table 2 and Figure 3, which were input as fixed parameters in the model.

Annual fecundity was estimated at 82 * batch fecundity, based upon a 219 d 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*

During the SEDAR 9 data workshop, the analytical team attempted to use the method of Hoenig (1983) to estimate natural mortality rate based on a maximum age of 26 years. This approach resulted in an estimate of M = 0.16, which was below the values previously applied to vermilion snapper and did not agree with the current knowledge of vermilion snapper life history. Consequently, the data workshop panel recommended using M = 0.25 with sensitivity runs ranging from 0.15 to 0.35. The 2011 update assessment used M = 0.25 as the natural mortality rate and specified that it was constant with age.

For SEDAR 45, an age invariant M of 0.25 was used for the continuity model. For the base model, age-specific natural mortality rates were used that followed the 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 is shown in Table 3 and Figure 4.

2.2.5. *Release Mortality*

Discard data for the recreational and commercial fleets had not been included in previous assessments of Gulf of Mexico vermilion snapper and are not included in this assessment. Exploratory analysis of the magnitude of total discards and dead discards was completed as part of the data workshop. Dead discards were calculated as total discards multiplied by the assumed release mortality rate of 0.15. No studies of release mortality rate in Gulf of Mexico vermilion snapper were available at the time of the SEDAR 45 assessment. Studies conducted on vermilion snapper in the South Atlantic indicate that release mortality is low, on the order of 0.15, for shallow caught fish (Guccione, 2005); however, the magnitude of mortality can increase substantially for deeper caught fish and fish that were hooked in locations other than the jaw (Rudershausen *et al.*, 2007).

2.3. Fishery Dependent Data

2.3.1. *Landings*

Commercial Landings

The primary commercial gear used for Gulf of Mexico vermilion snapper is vertical hook and 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 45 through 2014 for both regions.

Ending in 2012 and beginning in 2013 the reporting of fishing areas in the coastal logbook for the Gulf of Mexico has been changed from the old statistical area system (shrimp grids 1 to 21) to a latitude-longitude reporting system. This is relevant for the assessment of vermilion snapper because the fishing areas reported in the fishermen's logbook are used to assign the landings to geographical area and to the corresponding fisheries management unit (i.e., Gulf of Mexico or South Atlantic).

Total landings for the commercial fishery were input into the assessment model for SEDAR 45 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.

During the update 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 (Figure 5). Landings show a generally strong downward trend in both areas over the last three years. The eastern area typically supports higher landings than the western area.

Recreational Landings

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

1) Marine Recreational Fisheries Statistics Survey (MRFSS) and the Marine Recreational Information Program (MRIP)
2) Southeast Region Headboat Survey (SRHS)
3) Texas Parks and Wildlife Department (TPWD)
4) LA Creel Survey

MRFSS/MRIP provided a long timeseries of estimated catch-per-unit effort, total effort, landings, and discards for six two-month periods (waves) each year. MRFSS/MRIP provided 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 MRFSS/MRIP survey covers coastal Gulf of Mexico states from Florida to Louisiana. The state of Texas was included in the survey from 1981-1985, although not all modes and waves were covered.

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 were 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 timeseries compatible with the MRFSS/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 sampled 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. No information is collected on released fish.

A number of adjustments and modifications have been made to the various surveys over the last two decades in attempts to improve sampling and produce more reliable estimates of landings and bycatch. The most important changes in survey protocols and estimation techniques for vermilion snapper include:

- The For-Hire Telephone Survey (FHS) was developed to estimate effort in the for-hire mode. Conversion factors have been estimated to calibrate the traditional MRFSS charter boat estimates with the FHS for 1986-1997 in the Gulf of Mexico (SEDAR7-AW-03).
- The Marine Recreational Information Program (MRIP) was developed to generate more accurate recreational catch rates by re-designing the MRFSS sampling protocol to address potential biases including port activity and time of day. Starting in 2013, wave 2, the MRIP Access Point Angler Intercept Survey (APAIS) implemented a revised

sampling design. As new MRIP APAIS estimates are available for a portion of the recreational timeseries that MRFSS covers, conversion factors between the MRFSS estimates and the MRIP APAIS estimates were developed in order to maintain one consistent time series for the recreational catch estimates. Ratio estimators, based on the ratios of the means, were developed for Gulf of Mexico vermilion snapper to hind-cast catch and variance estimates by fishing mode. In order to apply the charter boat ratio estimator back in time to 1981, charter boat landings were isolated from the combined charter boat /headboat mode for 1981-1985. The MRFSS to MRIP APAIS calibration process is the same as the original MRFSS to MRIP adjustment that has been used since 2012, which is detailed in SEDAR31-DW25 and SEDAR32-DW02.

- MRIP shore mode estimates have been excluded.
- Missing estimates from MRIP 1981, wave 1 have been filled in using the proportion of catch in wave 1 to catch in all other waves for 1982-1984 by fishing mode and area.
- Monroe County MRIP landings are included in the Gulf of Mexico vermilion snapper estimates. There was no need to post-stratify the West Florida MRFSS estimates or use MRIP domain estimates to isolate Monroe County from the West Florida estimates.
- The MRFSS and the MRIP surveys use different methodologies to estimate landings in weight. To apply a consistent methodology over the entire recreational time series, the Southeast Fisheries Science Center (SEFSC) implemented a method for calculating average weights for the MRIP (and MRIP adjusted) landings. This method is detailed in SEDAR32-DW-02. The length-weight equation developed by the Panama City lab was used to convert vermilion snapper sample lengths into weights, when no weight was recorded. This method was used to calculate landings estimates in weight from the MRIP, TPWD, and LA Creel programs.
- Variances are provided by MRFSS/MRIP for their recreational catch estimates. Variances are adjusted to take into account the variance of the conversion factor when an adjustment to the estimate has been made (FHS and MRIP conversions). However, the variance estimates of the charter and headboat modes in 1981-1985 are missing. This is due to the MRIP calibration procedure, which requires the combined charter/headboat mode to be split in order to apply the MRIP adjustment to the charter mode back to 1981. In addition, variance estimates are not available for weight estimates generated through the SEFSC method described above.
- Headboat landings for Texas from 1981 to 1985 were estimated using a 3 year average (1986-1988) from SRHS Texas landings.
- Texas charter and private mode estimates do not exist from the start of 1981 to May of 1983. Averages from TPWD in 1983-1985 by mode and wave were used to fill in the missing estimates.
- LA Creel landings estimates were used for LA 2014 when MRIP estimates were missing.

In general, the 2011 Update assessment recreational landings estimates are quite close to the SEDAR 45 values (Figure 6). Minor discrepancies existed from1981-1985 (due to historical calibration ratio changes) and 2004-2012 (due to APAIS calibration adjustments). Recreational landings peaked in the 1990s before declining to relatively low levels through the 2000s. Landings have increased again over the last few years to average levels from the 1990s. 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). Catch in the west is dominated by the headboat sector, but in the east charter and headboats account for approximately equivalent catches and show similar trends (Table 6).

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

2.3.2. *Discards*

Commercial Discards

Discard data from the commercial fishery were investigated during the data and assessment webinars, but were ultimately not included in the SEDAR 45 assessment. Discards from commercial logbooks were available from 2002-2014, but underreporting of fisherman-reported discards has been noted in prior SEDAR assessments (McCarthy, 2011). Final discard estimates were limited to observer program records from 2007 to 2014, but resulted in much lower sample sizes than if logbook data had been included. Data from two observer programs that included trips by commercial vessels in the reef fish vertical line (handline and electric/hydraulic reel) and bottom longline fisheries along with commercial vessels in the shark bottom longline fishery in the Gulf of Mexico were used to calculate vermilion snapper discards. Vermilion snapper discards were calculated, following the methods of SEDARs 42 and 43 (Gulf of Mexico red grouper and gray triggerfish), as:

(observer discard rate/observer kept rate)*vermilion snapper landings

Data were further stratified by: year, subregion (east = shrimp grids 1-8, west = 9-21; i.e., east and west of Cape San Blas, Florida), minimum size (periods with 10 or 11 inch minimum size), season (vermilion snapper season – open or closed), IFQ allocation available to a vessel during a trip (none or 1+ pounds), seasonal depth closures (applies to bottom longline only; 20 fathom closure, 35 fathom closure, or no closure).

Discards were calculated for each gear/year/subregion/minimum size/season/IFQ allocation category (and depth closure for bottom longline calculations). Calculated discards in the vertical line fishery, summed across strata within each year and subregion, are provided in Table 7. Discards were not calculated for years prior to 2007 due to a regulatory change in the minimum size for retention of vermilion snapper in the commercial fishery. That change was effective July 3, 2007 and the limited observer reported discard data available prior to the minimum size change (January-June, 2007) were insufficient for reliable calculation of discards before 2007.

Calculated longline discards were less than one percent of the calculated vertical line discards per year. No discards of vermilion snapper were reported from the longline fishery in the western Gulf of Mexico; perhaps due to depth restrictions in that fishery (no fishing in less than 50 fathoms of water). Bottom longline calculated discards were not provided as a data input for the assessment.

The overall magnitude of the commercial discards relative to the landings was small (ranging from 5-30%; Table 7). Discussion at the SEDAR 45 Data and Assessment Review Meeting regarding potential discard mortality rates resulted in a most likely range of mortality from 5-15% based on literature review, expert opinion, and similar species (i.e., 10% was assumed for red snapper). When discard estimates were presented to the Review Group it was determined that, given the most likely discard mortality rate of 15% (see Section 2.2.5), dead discards represented an insignificant source of mortality (Table 7 and Figure 7). The short timeseries and relatively low sample sizes available for commercial discards were also a factor in the SEDAR 45 Review Group's decision to not pursue inclusion of discards in the final assessment model. Discard data will continue to be evaluated in future assessments, especially as timeseries length and sample sizes improve. Size and age composition of the discards was not calculated after it was determined that discards would not be included in the SEDAR 45 base model.

Recreational Discards

Discarded live fish are reported by the anglers interviewed by the MRIP/MRFSS. Consequently, neither the identity nor the quantities reported are verified. MRFSS/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...; see Section 2.3.1.2).

SRHS discards are available from 2004 to the present. In 2013 the SRHS ceased recording the condition of released fish (live versus 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 and LA Creel surveys do not estimate discards. LA discards for 2014 were calculated using MRIP LA discard rates from 1997 to 2013. This timeperiod was chosen because vermilion snapper were included in the 20 fish aggregate bag limit starting in January 1997. The ratio of the mean discard rates for these years were calculated with all modes combined. TPWD discards were calculated using Gulf-wide discard rates from MRIP and LA Creel estimates by mode. This is an alternative recommended by SEDAR Best Practices when the preferred approach (using LA discard rates by mode) results in unstable discard rates, as was the case for vermilion snapper.

The overall magnitude of the recreational discards relative to the landings was generally small but did have some strong peaks in the mid-1990s (percent of landings ranged from 1-50%; Figure 7). However, discards have been relatively minor since the late 1990s (typically fluctuating between 5-20%). Given the most likely discard mortality rate of 15% (see Section 2.2.5), the SEDAR 45 Data and Assessment Review Group determined that dead discards represented an insignificant source of mortality (Table 8 and Figure 7). The high uncertainty associated with recreational discard estimates was also a factor in the SEDAR 45 Review Group's decision to not pursue inclusion of discards in the final assessment model. Discard data will continue to be evaluated in future assessments. Size and age composition of the discards was not calculated after it was determined that discards would not be included in the SEDAR 45 base model.

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). 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 in order 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).

The observed and predicted bycatch (in numbers of fish) are summarized in Table 9 and Figure 8. In the 2011 SEDAR 9 Update Assessment, inputs from 2003-2008 were restricted to research vessel data (i.e., SEAMAP groundfish survey CPUE) and did not include data from the shrimp observer program. For the SEDAR 45 analysis, the full observer program data set, which had a lower CPUE, was included, and accounted for much of the disparity in vermilion snapper bycatch between the 2011 Update assessment and the SEDAR 45 assessment. 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 timeseries lows for the last six years and have shown little variation. The estimated median bycatch has declined from 8.87 million to 4.49 million fish. In both the 2011 Update and the SEDAR 45 assessment models it is assumed that 75% of shrimp bycatch is age-1+ (i.e., 25% is 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 final median values for the 2011 Update and SEDAR 45 models of 6.65 million and 3.37 million fish, respectively.

2.3.3. *Size and Age Composition of Landings*

Commercial Age Composition

Only age composition data from the commercial hand line fleet were used to construct age frequency distributions, because this represents the majority fleet in the landings. 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. Final age frequency distributions (AFDs) were estimated by reweighting the raw AFDs by the corresponding length frequency distributions for each region (SEDAR45-WP-08; Chih, 2009). This method differs from what was used in the SEDAR 2011 Update where raw observed AFDs were used (i.e., sampling was assumed to be representative) with the sample size capped at 25. For commercial hand line fishery landings, age compositions were estimated for the east and west regions (SEDAR45-WP-08). Age composition was sparse and not routinely collected for the commercial fleets until 2000 (Figure 9). There are significant differences in the AFDs between the east and west regions, which may be due, in part, to age-related 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 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 (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; Chih, 2009). Age composition has been collected for the recreational fleet since 1994. However, 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 a much younger age composition with very little catch of older fish in comparison to either commercial fleet (Figure 9).

Shrimp Bycatch Age Composition

No direct age data were available for vermilion snapper from the shrimp observer data. Exploratory analysis, as suggested by the SEDAR 45 Data and Assessment Review Group, investigated the possibility of using the annual age 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 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 and SEDAR 45 Review Group consensus, it was determined that the groundfish survey age composition did not accurately reflect the age 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 1981-2014 (Nance, 2004).

Following the decisions made during SEDAR 9 and used during the 2011 Update 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. The SEDAR 45 Data and Assessment Working Group agreed that scaling effort by shrimp grids according to the observed distribution of vermilion snapper would help to further improve the shrimp effort estimates by upweighting effort in areas where vermilion snapper are relatively more common and more likely to interact with the shrimp fisheries. The reweighting procedure used the average catch-per-tow over the last 6 years (these were the only years when the entire Gulf of Mexico was reliably sampled for the groundfish survey) and determined the proportional catch from each of the four area strata used to report shrimp effort (i.e., Florida--shrimp grids 1-9, Mississippi/Alabama--shrimp grids 10-12, Louisiana--shrimp grids 13-17, and Texas--shrimp grids 18-21). The proportional catch by area was then multiplied by the observed effort by area to determine the reweighted effort. Effort was then summed and normalized to the total mean (Table 12, Figure 10).

The reweighting procedure led to some slight discrepancies between the SEDAR 45 effort timeseries and that used in the 2011 SEDAR 9 Update assessment (Figure 10). Effort from the eastern area tended to be upweighted, while that from the western area was deemphasized. Relatively fewer young vermilion snapper are observed in the west, but shrimp effort tends to be much higher. Historically shrimp effort was quite high, but decreased by 75% between 2002 and 2008. Effort has remained at timeseries low values since 2008. It is believed that the current reweighted effort timeseries better reflects the levels and interannual variation in shrimp effort that is likely to interact with vermilion snapper. 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 45 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 2014. During the standardization process, 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. Given the uncertainty in the post IFQ data (2007 – 2014), the SEDAR 45 Data and Assessment Review Group decided to use truncated indices with terminal year 2006 for the continuity model. For the base model, a split series approach was utilized 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. Both the pre-IFQ (1993 – 2006) and post IFQ indices were included in the base model (Table 13 and Figure 11). To account for potential changes in the fishery, separate selectivity timeblocks were also allowed in each commercial fleet that corresponded to the index timeseries.

The truncated commercial timeseries tend to overlap well with the 2011 SEDAR 9 Update assessment indices (Figure 11). Not surprisingly, the IFQ indices show differing trends from the non-IFQ Update assessment indices and from the full timeseries no IFQ index (not used, shown for illustrative purposes only; Figure 11). Over the last seven years the IFQ index for the western stock has fluctuated without trend, whereas the full timeseries IFQ index shows dramatic increases in 2014. On the other hand, the eastern region IFQ index has been steadily increasing since 2007, while the full timeseries IFQ index has shown the opposite trend. Clearly, the decision on whether or not to standardize for red snapper IFQ has important implications for index trends. By accounting for available IFQ, the Review Group felt that a more reliable standardization was obtained that better accounted for potential changes in fishing behavior caused by limited IFQ (i.e., increased targeting of vermilion snapper as red snapper IFQ declined). However, the new standardization approach has not been reviewed and further investigations are warranted to determine the best approach for incorporating the red snapper IFQ variable.

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. The MRFSS index was constructed for the period 1986 to 2014. 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 2014 with large sample sizes each year. 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. Data for the indices were split at the Mississippi River using the old shrimp statistical grids such that records identified from grids 1-12 were classified as east and those in grids 13-21 were classified as west. 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 considering the following factors: year, month, season, area, vessel, time of day, trip duration, and whether or not the red snapper season was open (since this could influence fisher behavior). The eastern Gulf headboat index followed a pattern similar to the eastern MRFSS index. The western Gulf headboat index demonstrated less contrast, but with interannual variability, and had a general downward trajectory during the timeseries (Table 14, Figure 12).

2.4. Fishery-Independent Data

2.4.1. *SEAMAP Groundfish Survey*

Trawl data for vermilion snapper (*Rhomboplites aurorubens*) from the Southeast Area Monitoring and Assessment Program (SEAMAP) was used to produce a relative abundance index for the eastern Gulf of Mexico (GOM) from 2009 – 2014 (SEDAR45-WP-10). 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. 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, 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 (Table 15, Figure 13). Length composition data for the groundfish survey were tabulated in 5 cm bins.

2.4.2. *SEAMAP Larval Survey*

Vermilion snapper (*Rhomboplites aurorubens*) larvae captured during Southeast Area Monitoring and Assessment Program (SEAMAP) Fall Plankton Surveys from 1986 to 2012 were used to develop indices of relative abundance from 1982 to 2012 (SEDAR45-WP-05). The larval indices are intended to capture trends in the adult spawning stock biomass. Separate delta-lognormal indices were developed for the entire Gulf of Mexico, Western GOM, and Eastern GOM. The SEDAR 45 Data and Assessment Review Group recommended that the gulf-wide index be included in the assessment. Larvae were collected using a 61 cm or 60 cm (inside diameter) bongo nets fitted with 0.335 mm mesh netting fished in an oblique tow path from a maximum depth of 200 m or to 2-5 m off the bottom at station depths less than 200 m. 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 13 of the 19 years with consistent spatial coverage. Preliminary analysis examined indices of raw abundance and larval abundance corrected for inter-annual differences in age/size composition, but found little differences in trends between them. Therefore, the final delta-lognormal indices were based solely on raw abundance. The recommended gulf-wide index showed increased abundance during the early and latter part of the time series. However, the high degree of variability in annual means and the reduction in the number years with full sampling coverage make it difficult to discern any trend (Table 15, Figure 13).

2.4.3. *SEAMAP Reef Fish Video Survey*

The primary objective of the annual Southeast Area Monitoring and Assessment Program (SEAMAP) reef fish video survey is to provide an index of the relative abundances of fish species associated with topographic features (e.g., reefs, banks, and ledges) located on the continental shelf of the Gulf of Mexico (GoM) from Brownsville, TX to the Dry Tortugas, FL (SEDAR45-WP-11). Secondary objectives include quantification of habitat types sampled (optical and acoustic data), and collection of environmental data throughout the survey. Because the survey is conducted on topographic features, the species assemblages targeted are typically classified as reef fish (e.g., red snapper, *Lutjanus campechanus*), but occasionally fish more commonly associated with pelagic environments are observed (e.g., amberjack, *Seriola dumerili*).

The survey was carried out in 1992-1997, 2001-2002, and 2004-present, and historically takes place from April – May. However, in certain years the survey was conducted through the end of August. The 2001 survey was abbreviated due to ship scheduling issues and the only sites that were completed were located in the western Gulf of Mexico. Types of data collected on the survey include diversity, abundance (min-count), fish length, habitat type, habitat coverage, bottom topography, and water quality. The size of fish sampled with the video gear is species specific and vermilion snapper sampled over the history of the survey had fork lengths ranging from 84 – 685 mm, and mean annual fork lengths ranging from 243 – 307 mm. Age and reproductive data cannot be collected with the camera gear, but, beginning with the 2012 survey, a vertical line component was coupled with the video drops to collect hard parts, fin clips, and gonads.

A combined video index that pooled data from three different video surveys (NMFS Panama City, NMFS Mississippi Labs, and FWC) was considered during the SEDAR 45 Data and Assessment workshop. However, there were differences in the length composition between the surveys that caused some concern. There appears to be a longitudinal difference in length-frequencies with shorter fish observed in southern stations. Additionally the NMFS Panama City index was showing a decrease in min-count in the final years, whereas the FWC and NMFS Mississippi Labs surveys were showing increases. For these reasons, the surveys were thought to be indexing different segments of the population. 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 FWC video surveys so that the data could be reliably combined into a single index in future assessments.

Vermilion snapper were observed throughout the eastern and western Gulf of Mexico in most years and the spatial distributions observed are highly reflective of the reef sampling universe used to select sampling sites. The Dry Tortugas are the shallowest reefs available for sampling and in that region vermilion snapper were never observed, and thus those shallow sites were dropped from use in index estimation. Sites shallower than 20m in the Panama City video index also do not observe vermilion snapper. Gaps in mapping and habitat information exist on the central portion of the west Florida shelf, Mississippi river delta region, and portions of the Texas coast, but those are slowly being investigated and filled. In most years the survey shows good coverage in the defined sampling universe, and coverage improved through time as the sampling universe expanded and more sites were added to the survey. The most recent mapping and sampling efforts in south Texas and in the central portion of the west Florida shelf were accomplished in 2012-14 and beginning in 2014 are being incorporated into sampling.

Initial runs of the Poisson and negative-binomial models produced poor fits to the data that were non-linear (e.g., 'S-shaped' Q-Q plots), whereas the delta lognormal model showed a mostly linear fit with some tailing. Additional evaluation of error distributions showed improved fit statistics for the delta lognormal model in which only year was retained as a variable. Delta lognormal models consistently showed lower AIC and conditional likelihood values. Pearson chi-square/DF measures of fit were not used to compare model runs as that information is not produced for the delta lognormal models. However, both the Poisson and negative binomial models had values exceeding 1 indicating poor fit for those distributions. Finally, all of the delta lognormal models produced nearly linear Q-Q plots indicating good fitting models. Therefore, the delta lognormal models were selected as the best fitting model.

In all three spatial runs (east, west, and GoM wide) year, reef, and depth were significant variables for both the binomial and lognormal submodels. Through time it appears that the GoM wide index shows a peak in 1994 followed by a decrease and generally stable values through 2007. From 2007 through 2011, index values trended up followed by a two year dip with a final increase back to 2011 levels in 2014. Highest min-counts were observed in 1994, 2011, and 2014, and the lowest was observed in 2007. Since 2002 min-count indices of vermilion snapper appear to be to be on the rise in the GoM wide model with the exception of two low years in 2012 and 2013. Proportion positives are largely reflective of the abundance trends.

The east GoM trends were quite similar to the GoM wide trends. Highest index values were observed in 1994, 2011 and 2014 as was the case in the GoM wide model. Similar to the GoM wide model, the population appeared to stabilize around 2002, then increase in abundance through 2011. The west GoM model shows generally similar trends to both the east and GoM wide models with a few exceptions. The west GoM model showed higher CVs likely due to less consistent sampling in that region. The differences in trends are likely due to the decreasing detection probability that occurs with less frequent sampling. The highest min-counts were observed in 1993, 1997, 2012, and 2013. Similar to the other models, since 2002 the population appears to be stable with a general increasing trend in abundance, although with higher variability than the other two models.

Annual mean fork lengths are showing a decreasing trend GoM wide. East GoM vermilion ranged from 207 – 359 mm mean annual fork length. West GoM vermilion snapper ranged from 209 – 320 mm mean annual fork length. Mean length was larger in the west than the east GoM, but generally showed overlapping length frequency histograms.

The final video survey index used for the SEDAR 45 assessment showed moderate annual variability with little to no trend in abundance during much of the available time series (Table 15, Figure 13). Length composition data for the SEAMAP video survey were tabulated in 5 cm bins.

3. Stock Assessment Model and Results

3.1. Stock Synthesis Model Configuration

For the purposes of the SEDAR 45 vermilion snapper assessment the Stock Synthesis 3 (SS3) software package was utilized (v3.24Y; 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 data for 3 modeled fleets (commercial east, commercial west, and recreational) along with associated age composition, 1 bycatch fleet (shrimp), 7 CPUE indices corresponding to the 3 primary fleets (commercial east before red snapper IFQ, commercial east after red snapper IFQ, commercial west before red snapper IFQ, commercial west after 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 timeseries (shrimp effort), 1 index of spawning stock biomass (larval survey), and 2 fishery-independent (video and groundfish) surveys 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 timeseries 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 2014. Little documented catch of vermilion is available prior to 1963 (the start of the commercial fisheries landings timeseries) 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 45 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 had 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 45 base model assumes that the natural mortality rate decreases as a function of age based on the Lorenzen (1996) function (Table 3, Figure 4). The age-invariant natural mortality rate of 0.25 used in the continuity model (established during SEDAR 9) provided the scaling term for the Lorenzen curve. Age-varying natural mortality was deemed a more appropriate approach compared to age-invariant mortality given the life history of vermilion snapper and the comparatively higher juvenile mortality associated with many reef fish. 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 estimated 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. Due to high correlation, the resulting individual parameter values may not reflect the ‘true’ biology, but act more as a single amalgamated parameter (in conjunction with associated deviations from the stock-recruit curve) that provides the most reliable yearly recruitment estimates given the available data. In such instances, it may not be appropriate to use the estimated spawner-recruit curve for the basis of forecast recruitment. Instead, assuming that recent recruitment is likely to continue in the near future and sampling from a distribution of recent recruitment estimates may provide more reliable forecasts. Essentially, the latter approach would be the same as estimating mean recruitment with deviations for the assessment and sampling from recent deviations during the forecast, but this stock-recruit option has not yet been implemented in SS3.

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 (2015), but only to the data-rich years in the assessment (i.e., those with age composition data). 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, 2015). No bias adjustment was applied prior to 1986, when only catch data were available. The bias adjustment was then phased in until the full adjustment was implemented in 1995 when age compositions became available. The full bias adjustment was then phased out again starting in 2011, 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 that there were sufficiently different 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 timeseries 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 and were not compared in the model. 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), a gulf-wide reef fish video survey (NMFS Mississippi lab results only; 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. Surveys were assumed to run continuously across a given year, which may not reflect reality, but timing was often fluid and the model was not sensitive to survey timing.

3.1.7. *Selectivity*

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 45 vermilion snapper assessment two types of selectivity functions were utilized: a two parameter logistic function and the 6 parameter double normal (see Methot, 2015). 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.

On the other hand, the SEDAR 45 Data and Assessment Review Group suggested that 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. A sensitivity run was examined with logistic recreational selectivity, but model fit to observed age compositions was substantially worse (see Section 3.2.10).

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, and we maintain this assumption.

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.

Only the commercial fleets were assumed to have time-varying selectivity and only two timeblocks were assumed. The reason for only allowing time-varying selectivity in the commercial fleet was the implementation of red snapper individual fishing quotas (IFQs) in 2007, which were believed to have altered fishermen's targeting habits on vermilion snapper and was seen to impact vermilion snapper commercial fishery catch-per-unit effort (SEDAR-WP-04). Based on this assumption, selectivity for the commercial fleets was allowed to change starting in 2007 (i.e., there was one selectivity timeblock for the pre-IFQ fishery, 1950-2006, and one selectivity timeblock for the IFQ fishery, 2007-2014). Although other management actions could have acted to alter selectivity patterns, exploratory analysis did not uncover any major changes in fishing patterns in either the commercial or recreational fisheries that were deemed significant enough to develop alternate selectivity timeblocks.

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*

For shrimp discards the 'super-year' approach was utilized to avoid fitting to the extremely noisy and uncertain yearly estimates of shrimp bycatch (see SEDAR 31 and the SEDAR 9 Update Assessment). The premise of a super-year is that, instead of fitting each observation directly, a measure of central tendency for the entire timeseries 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 45 vermilion snapper assessment (based on decisions made at the SEDAR 9 Update). The model still predicts annual bycatch values, but does not attempt to fit these to the annual observations. The super-year covers years 1972-2014 (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 all years with help from the shrimp effort series, but the predicted median covers only the period for which observations of shrimp bycatch are available.

Discards from the commercial and recreational fleets were deemed insignificant in comparison to landings by the SEDAR 45 Data and Assessment Working Group and were not modeled in the assessment.

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 timeseries of effort allows the model the flexibility to fit the median without being constrained to 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 timeseries was assumed to reflect annual variation in population trajectories. Each commercial fleet had two corresponding CPUE indices. One timeseries represents the time period prior to red snapper IFQ implementation (1993-2006) and one represents the period with red snapper IFQ (2007-2014). The two timeseries are essentially a single timeseries, but, because the standardization process for the observed CPUE changed to account for red snapper IFQ, it was deemed appropriate to split each commercial index. In addition, the selectivity was allowed to change so the split index approach should better reflect the change in dynamics.

There are three recreational CPUE indices: MRFSS east (1986-2014), headboat east (1986-2014), and headboat west (1986-2014). Each index uses assumes the same selectivity (that of the combined recreational fleet). Ideally, the recreational fleet would have been separated by mode and region, but a representative CPUE index was not available for the western MRFSS and sample size limitations did not allow separating the recreational fleet (see Section 3.1.6).

3.1.12. *Fishery-Independent Surveys*

Three fishery-independent SEAMAP surveys (larval, video and 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 the same 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 is 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 is determined by the difference in observed and predicted values along with the assumed variance of the error distribution. The total likelihood is the sum of each individual component. A nonlinear iterative search algorithm is used to minimize the total negative log-likelihood across the multidimensional parameter space in order to determine the parameter values that provide the global best fit to all the data. With this type of integrated modeling approach data weighting (i.e., the variance associated with each data set) can greatly 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 timeperiod, 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 MRIP survey, 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 (see the 2011 SEDAR 9 Update assessment for a discussion of the super-year likelihood component). 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 timeseries, but the relative annual variation was maintained in the scaling. The shrimp effort series was also given an average standard error of 0.2. It was believed based on expert opinion from the analysts and feedback from the SEDAR 45 Data and Assessment Working Group that these input standard errors would best reflect the relative representativeness of each of the error sources.

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 45 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).

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 estimated 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, 2015). 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 309 parameters were estimated for the base model (Table 16). These include year specific fishing mortality for the 3 directed fleets and shrimp bycatch fleet (260 total), logistic selectivity parameters for each of the commercial fleets for both selectivity timeblocks (8 total), domed selectivity parameters for the recreational fleet and the two surveys (18 total), a catchability coefficient for the shrimp effort series (1 total), the parameters used to define the stock-recruit relationship (3 total), and the stock-recruit deviations for the data-rich time-period (19 total).

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 mode 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 45 vermilion snapper assessment and correlations with an absolute value greater than 0.7 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 each of the two parameters is 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 45 assessment model, profiles were carried out for steepness, virgin recruitment, stock-recruit variance, and a combination of steepness and stock-recruit variance.

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). Generally, consistency across bootstrap runs and base model runs indicates that the model is performing well and relatively stable. 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. Care must be taken when timeblocks exist for selectivity parameters or when there are any short data timeseries that span only the last few years of the model, because removing a few years of data may cause the model to become unstable when not enough data are available to estimate parameters for these short data sets. The instability is not a reflection of poor model performance, but simply an issue of overparametrization caused by a short timeseries. A five year retrospective was carried out for the vermilion assessment, but, due to the short timeseries of the summer groundfish survey and the recent commercial selectivity timeblock (the period with red snapper IFQ), care should be taken when analyzing more than the first few years of data peels.

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). A full index jack-knife was done for the vermilion snapper assessment where each index was removed and the model rerun. 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

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 in 2011, but using updated values for each of the data sets through the new terminal year (2014). Developing a continuity model is a useful tool for comparing model performance and addressing the impact of any changes in model assumptions. In the case of vermilion snapper, building a true continuity model was difficult, because the previous assessment used the state-space age-structured production model (SSASPM). However, during the 2011 Update, an exploratory SS3 model was also developed for comparison with the SSASPM framework. The SSC reviewed both models and decided to use the SSASPM results as the basis for management (likely for consistency with the SEDAR 9 benchmark), but concluded that the SS3 formulation was appropriate for future use. However, modeling changes were implemented in SSASPM after the comparison, which were not implemented in the SS3 model developed in 2011.

We developed a continuity that best represented the final SSASPM framework used for management advice. We also provided results for a model run that attempted to mimic the final SS3 run developed in 2011. 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 2.1) were: stock-recruit parameters were not freely estimated (steepness was estimated with a lognormal prior and σ_R was fixed at 0.2); natural mortality was fixed at 0.25 instead of assuming a Lorenzen curve; input standard errors were update to better reflect the variance associated with each data set in the base model (and no interannual variation was included in CPUE indices in the continuity model); effective sample size was capped at a maximum value of 25 and no iterative reweighting process was implemented; no fishery-independent indices were included; the commercial CPUE was truncated in 2006 and only a single commercial fishery timeblock was allowed. The only important difference that was noted between the final 2011 Update model (SSASPM) and the continuity model (besides a change in modeling framework) was the way the commercial CPUE was handled (the 2011 Update ignored the influence of red snapper IFQ and did not truncate the commercial index).

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. The two most important sensitivity runs involved the estimates of median bycatch and the form of selectivity for the recreational fishery. A run assuming the SEDAR 9 Update value of median shrimp bycatch was implemented in order to determine model sensitivity to this estimate. This run was important because shrimp bycatch acts as a scalar for virgin recruitment and SSB (due to the assumption that most of the bycatch is age-1 recruits), and large differences in estimated median shrimp bycatch occurred between the 2011 Update and SEDAR 45 (see Section 2.3.2.3). The sensitivity run investigating the impact of the functional form assumed for the recreational selectivity was deemed important because the previous assessment assumed logistic selectivity, while investigations with the base model indicated better fit to the observed data using domed selectivity. Given the potential implications that domed selectivity can have for biomass estimates (e.g., due to the introduction of ‘cryptic’ biomass), a sensitivity assuming logistic selectivity was warranted.

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 asymptotic standard errors. Most parameter estimates appear reasonable and coefficients of variation (*CV*; standard error divided by parameter estimate) were low 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 until the 1980s when all three fisheries and the shrimp bycatch fleet became simultaneously active. Exploitation continued to climb until the mid-1990s when harvest rate peaked around 20%. Since that time, exploitation rate has seen a relatively steady decline to a 2014 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 timeseries up until the mid-2000s. Since that time, the commercial east fleet has been the dominant component with the commercial west fleet exhibiting similar, but typically lower fishing mortality. The recreational fleet is often the smallest component of fishing mortality, but has seen a sharp increase since 2010 and was actually the dominant component in the terminal year. All of the directed fleets have shown a generally increasing trend in fishing mortality since the 1980s. However, the commercial west fleet then showed a declining trend from the mid-2000s to the terminal year. The commercial east fishery showed two large peaks (timeseries highs) in 2009 and 2011, but has been declining from 2012-2014. Terminal year fishing mortality rates for the commercial east, commercial west, recreational, and shrimp bycatch fleets were 0.05, 0.06, 0.08, and 0.06, respectively.

3.2.1.3 Selectivity

The estimated selectivity functions are provided in Figures 16-20. Both of the commercial fleet selectivity curves (Figure 16 and 17) quickly reached full selection (around age-4 for the eastern fishery and age-6 for the western fishery) and exhibited relatively young ages at 50% selectivity (between ages 2 and 3 for the east and ages 3 and 4 for the west), while neither fleet selected age-1 fish. 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). After implementation of the red snapper IFQ, selectivity in the eastern fishery did not change in any significant respect. There was a slight decrease in the lower selectivity quantiles, but no change in age of full selection. On the other hand, the western fishery demonstrated a relatively strong shift to older fish with similar increases in age for the lower 20% quantiles. Fewer younger fish were selected and the age of maximum selection increased by about one age group.

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 4-6 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. Based on exploratory analysis (see Section 3.2.10), domed selectivity provided better fits to recreational age compositions than logistic selectivity and, based on discussions within the SEDAR 45 Data and Assessment Review Group, it may be appropriate given the gear type and targeting of at least a portion of the recreational fleet.

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 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 location (i.e., relative availability of fish) and protocols of each survey. The groundfish survey catches almost exclusively fish between 5 and 20cm, while the video survey has a much more protracted size range.

3.2.1.4 Recruitment

The stock-recruit parameters were freely estimated, resulting in a steepness of 0.57, a virgin recruitment estimate of 26,678,000 fish, and a recruitment variance of 0.23. Although the parameters were freely estimated, there was a high degree of correlation between steepness and the recruitment variance term (see Section 3.2.1.4), while a moderate degree of correlation existed between virgin recruitment and commercial fishing mortality in the historic period of the timeseries (see Section 3.2.1.3). 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). It is not surprising then that steepness is not well estimated or that it is highly correlated with σ_R. 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 timeseries.

It has been noted by Methot (2015) that the best estimates of recruitment are likely to result from allowing all the stock-recruit parameters to be freely estimated (if estimation does not cause model stability issues), even if the resulting parameter values are not necessarily reflective of stock biology. In such instances, the estimated recruitment will still be the best estimate given the data, but the stock-recruit curve may not be appropriate as the basis for projections, and alternate recruitment scenarios should be utilized for forecasts (e.g., sampling from recent total recruitment levels and not using the stock-recruit curve directly). On the other hand, fixing any of the stock-recruit parameters at a predetermined value can cause the model to become overly constrained and lead to tension within the model and less reliable recruitment estimates. In addition, when high correlation exists, fixing one parameter essentially acts to fix any other highly correlated recruitment parameters (e.g., in the current case fixing steepness would essentially fix σ_R; see Section 3.2.1.4).

Based on the recommendations of SS3 experts, the SEDAR 45 Data and Assessment Review Group decided that it would be best to freely estimate the stock-recruit parameters in order to get the most reliable estimates of recruitment. However, given the low estimate of steepness and the stock-recruit caveats discussed above, it was determined that the estimated stock-recruit curve was unlikely to be representative of vermilion snapper especially at low stock sizes. For these reasons, it was determined that the forecasted recruitment would not use the estimated stock-recruit curve, but instead would utilize recent recruitment estimates (see Section 4.1).

Recruitment was forced to follow the stock-recruit curve for the historical timeperiod 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 12 and 25 million fish with no consistent trend (Figure 22). Recruitments since 2010 have been generally above the average level (for the timeperiod where recruit deviations are estimated) with strong yearclasses predicted from 2010-2012 (~20 million fish), which is slightly less than the modern era timeseries high recruitment (~25 million fish in 2006) for the modern period. The terminal year recruitment was estimated to be 19 million fish.

3.2.1.5 Biomass and Abundance Trajectories

Spawning stock biomass (number of eggs) and total biomass (metric tons) have followed similar trends over the entire timeseries (Figures 22 and 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 experience 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. Timeseries lows were reached in the late 1990s corresponding to the maximum bycatch mortality rates. With the reduction in shrimp effort and bycatch mortality in the late 1990s and early 2000s, the stock rebounded slightly and has seen a gradually increasing trend over the last two decades. Despite the decline in shrimp mortality being partially replaced by higher directed fishing mortality (compared to levels seen in the 1980s), the terminal biomass (10,952mt) is estimated to be at its highest point since 1995 and the same is true for terminal SSB (2.06E+14 eggs). 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 and in 2014 was at 31%, the highest level since 1996.

Similarly, 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). From timeseries lows in the late 1990s, abundance has shown a stronger increasing trend than biomass and reached its highest level since 1994 in 2013 and 2014 (terminal year estimate of 45 million fish). Abundance trends are characterized by periodic troughs due to below average recruitment events, but age structure has been steadily rebuilding since the late 1990s due to strong cohorts over the last decade and a half (Figure 23). Average age in the stock at virgin conditions was between 3 and 4 years of age. Average age is now around age-2.

3.2.2. *Model Fit and Residual Analysis*

3.2.2.1 Landings

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 timeseries high data point in the commercial east fishery. On the other hand, the recreational landings were slightly overestimated for a few points in the 1990s, with later underestimation for a handful of years in the 2000s. 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 0.804, 0.301, and 1.776, respectively.

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 as well (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 most likely a function of the sharp decline in shrimp effort. The bycatch mortality estimates are closely linked to the shrimp effort series in the assessment model and shrimp effort is also a critical input of the WinBugs program used to calculate observed bycatch. The negative log-likelihood value for shrimp bycatch was -2.009.

3.2.2.3 Shrimp Effort

Model fit to the shrimp effort series is good (RMSE of 0.096), even though it was given a relatively high standard error matching the other surveys (Figure 26; Table 12). The shrimp effort scaling coefficient (q) was estimated to be 4.21 (1.44 in log-space; Table 16). 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 most likely cause is a series of low recruitment events (probably informed by the age composition data) that force the model to have high shrimp bycatch mortality (due to the shrimp selectivity being 100% at age-1).

Because effort and shrimp bycatch mortality are directly linked, the predicted effort must reflect this high mortality. However, the observed effort does not reflect this increased mortality event thereby causing the mismatch in the observed and predicted values. There is a slight residual pattern from the mid-1980s to the mid-1990s, but this is likely a result of slightly different signals between the age composition data and the shrimp effort series (as described), and is not likely to be overly detrimental. The negative log-likelihood component for the shrimp effort series is -97.118.

3.2.3.4 CPUE Indices

Observed and predicted CPUE are provided in Figures 27-30 and Tables 13-14. The model fits the eastern commercial CPUE prior to IFQ well (RMSE of 0.189; negative log-likelihood of -10.099), while the commercial west CPUE prior to IFQ is moderate (RMSE of 0.323; negative log-likelihood of -8.410). 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 timeseries, 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.

Following the implementation of red snapper IFQ, both observed commercial CPUE indices vary without any significant trend (Figure 28; Table 13). The model predicts relatively flat CPUE for both indices resulting in relatively good fit (eastern RMSE of 0.375, western RMSE of 0.231; eastern negative log-likelihood of -3.927, western negative log-likelihood of -4.377). Given the short timeseries, assessing trends in residuals is difficult. There is some slight patterning pre- and post-2010, but it is likely to be insignificant.

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 timeseries, but does not fit the annual values well (Figure 29; Table 14). It does a better job of fitting the slight increasing trend over the last two decades, but tends to overestimate in any given year. The overall fit is the poorest of the CPUE indices (RMSE of 0.489; negative log-likelihood of 38.682). Some strong positive residual patterns exist in the early part of the timeseries followed by negative residuals for much of the remainder of the timeseries.

The observed headboat east index demonstrates similar trends as the MRFSS east index with strong variation early in the timeseries followed by a consistently flat trend over the last two decades. The model has similar issues fitting this timeseries, predicting a downward trend until 1997 followed by a constant trend over the next two decades (Figure 30; Table 14). Model fit is comparatively poor compared to the other indices (RMSE of 0.474; negative log-likelihood of 39.380). Residual patterns are quite similar as for the MRFSS east index.

Model fit to the headboat west index is moderate with the model predicting a decline for the early part of the timeseries and leveling off over the last two decades (Figure 30; Table 14). The observed index does not fluctuate as heavily in the early part of the timeseries as the other recreational indices, but varies much more than those indices over the last two decades. 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 (RMSE of 0.382; negative log-likelihood of 4.042).

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 without trend for much of the remainder of the timeseries. 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. A jack-knife analysis was undertaken to investigate whether any single index was dominating the model and giving conflicting signals to the other data (see Section 3.2.8), but results indicated that this was not the case.

3.2.3.5 Fishery-Independent Surveys

Observed and predicted fishery-independent survey values are provided in Figure 31 and Table 15. The observed video survey was highly variable and there was no discernible trend. The model predictions were flat across the timeseries and no strong residual patterns were present (Figure 31). Due to the large fluctuations and the predicted flat index, model fit was poor (RMSE of 0.682; negative log-likelihood of 76.885).

The groundfish survey had an extremely short timeseries (5 years) and was generally flat over this time. The model predicted index was also flat and no residual patterns were evident (Figure 31). Model fit was good (RMSE of 0.274; negative log-likelihood of -4.386).

The larval index showed large fluctuations with a possible upward trend from the early half of the timeseries to the latter half of the timeseries. The model did not fit this data set well (RMSE of 0.471; negative log-likelihood of 12.068), demonstrating a similar pattern as for the various CPUE indices with strong declines early in the series and flattening out over the latter half (Figure 31). Residual patterns are evident with negative residuals early in the timeseries and positive residuals over the last decade.

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. None of the surveys indicate any strong time trends, but for the most part agree with the fishery-dependent CPUE indices that the stock has been fluctuating without trend over the last decade. The model predictions cause some residual patterning, but the trends generally agree with the surveys, and indicate a stock fluctuating without trend.

3.2.3.6 Age Composition Data

Model fits to the derived age composition data along with Pearson residuals are provided in Figures 32-36. 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 timeseries 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 32). There was a slight tendency to overestimate the catch of young and old fish, while underestimating fish age 5 to 10 years. However, the residual trends are minimal with no strong temporal patterns (Figure 35).

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 timeseries (Figure 33). Observed and predicted values are similar and residuals appear to be more or less randomly distributed. However, a strong age trend does appear over the last three years with the model predicting more young fish and fewer old fish than observed (Figure 35). It is possible that this may just be a sampling issue, because the effective sample sizes have dropped dramatically over the last three years.

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 34). Residuals seem to be well distributed with no strong patterning (Figure 35). The residual patterns clearly favored domed selectivity over logistic selectivity for the recreational fleet (see Section 3.2.10), which was demonstrated by the removal of a strong block of negative residuals for the older ages, especially in the last five years, when domed selectivity was implemented.

The aggregated age compositions are extremely good for all three fleets. All fleets tend to slightly underestimate age-3 and age-4 catch, and the commercial fleets slightly underestimate catches for ages 7-10 (Figure 36).

3.2.3.7 Length Compositions

Model fits to the length composition data are provided in Figures 37-39. 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 timestep 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). After exploratory analysis, it was determined that aggregating by 5cm length bins allowed the model to best fit the length data. The video survey had a tendency to overestimate the 20-30cm length bins and underestimate length bins greater than 30cm (Figure 37). The groundfish survey tended to overestimate the 10cm length bin (Figure 38). The aggregate fit to the length composition data were relatively good and no strong residual patterning was evident (Figure 39).

3.2.3. *Correlation Analysis*

Based on model estimated correlation factors, only the selectivity parameters demonstrated issues with high correlation (Table 19). This is not surprising, especially for the double normal parameters (which demonstrated the most severe correlation), 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.

There was also some minor autocorrelation in the western commercial fishery fishing mortality over the last few years, while virgin recruitment was mildly correlated with commercial fleet fishing mortality in the historic part of the timeseries. Correlation coefficients were not generally large and, thus, neither issue appeared to hinder model performance.

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. The steepness estimate showed a strong trough around 0.55, but the change in likelihood was dominated by the recruitment penalty term increasing rapidly at higher steepness values. This indicates that there was correlation with the recruitment variance term, which forced the model-estimated steepness towards a low level. The age composition data, which was also an influential likelihood component, and probably the most information-rich data source for stock-recruit parameters, preferred a steepness of at least 0.5 but values greater than this were given relatively equivalent likelihood (i.e., the response surface was mostly flat above 0.5). The final model solution balanced the age composition preference with that of the stock-recruit penalty and settled on a final estimated value of 0.57.

Many of the response surfaces for σ_R (recruitment variance) were flat, indicating that this parameter was poorly estimated (Figure 40). The recruit penalty dominated the change in likelihood and preferred a σ_R around 0.1. The index and age composition data were the second and third most influential data sets and preferred values between 0.2 and 0.4, which is near the model estimated σ_R of 0.23.

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 40). The age data were the most influential and preferred a slightly higher value, while the shrimp bycatch super-year likelihood was the next most influential and tended to prefer a slightly lower value. The final model estimated value balanced these two data sets and settled on a value of 10.19.

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 41).

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, which indicated that steepness and σ_R might be correlated. A contour plot of σ_R against steepness demonstrated the clear relationship between the two parameters (Figure 42). The contours are fairly steep on three sides, but quite shallow tailing off towards high steepness and high σ_R combinations. Although the final model estimate of σ_R and steepness provide the smallest negative log-likelihood value, a number of alternate pairings give approximately similar negative log-likelihood values. Steepness values ranging from 0.55 to 0.8 and the associated σ_R pairings from 0.2 to 0.65 are almost equally probably given the data. For the model these two parameters are essentially acting as a single parameter (e.g., neither is freely estimated).

Unfortunately, there is no best modeling approach to deal with correlated stock-recruit parameters. The current combination gives the best estimates of total recruitment, but unexpectedly low estimates of steepness given the highly productive nature of the stock (see Section 3.2.1.4). The SEDAR 45 Data and Assessment Working Group decided to maintain the stock-recruit parameters as freely estimated, but not to use them for the purpose of forecasting recruitment as the resulting stock-recruit curve may not reflect true productivity. Instead the decision was made to use recent total recruitment as the basis for projected recruitment (see Section 4.1)

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 43). 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 44). 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 timeseries is minimal and there is no constant trend that might indicate model issues. It should be noted that due to the short timeseries of the groundfish survey data and the high correlation seen amongst the groundfish survey parameters, data peels greater than 2 years are likely to lead to severe model instability. The data peels of 3, 4, and 5 years should be analyzed cautiously given that the model is being forced to estimate groundfish survey selectivity parameters with only 2-4 years of data.

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 the base model solution in all but a handful (>90%) of the 200 jitter runs (Figure 45). 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 46 illustrates the results of a jack-knife analysis that ran the model with one index removed at a time. The commercial east CPUE and the larval survey appear to be driving the model towards lower SSB_0 and R_0, because when either is removed these quantities tend to increase. However, results do not differ greatly for any of the jack-knife runs indicating that no single index is dominating the model or giving a vastly differing signal from the other indices.

3.2.9. *Continuity Model Comparison*

The base and continuity model demonstrated similar trends and population trajectories, but differed in terms of recruitment estimates (Figure 47). Ultimately, differences between the models is not surprising given the number of changes that occurred between the continuity model and the base case (e.g., removing the prior on steepness, estimating σ_R, allowing domed recruitment selectivity, including an IFQ timeseries for the commercial fisheries, adding three fishery independent surveys, and iteratively reweighting the effective sample sizes). Based on model building exercises, the changes that had the largest influence were likely allowing domed recreational selectivity and altering the effective sample sizes (the continuity model uses the observed sample sizes with a maximum cap of 25). The biggest change between the continuity and the base model is an increase in the virgin recruitment estimate, which leads to higher total recruitment estimates throughout the timeseries.

It should be noted that the exploratory 2011 Update SS3 model (as updated with the current version of SS3) is included in Figure 47 for comparison purposes. Even though in 2011 the SS3 model compared favorably with SSASPM (and was deemed a valid alternative for future assessments by the SSC), it was not updated with certain features used by the final accepted SSASPM base model. Most importantly, the super-year approach had not yet been implemented in SS3, and the 2011 Update SS3 model maintained the SEDAR 9 shrimp bycatch assumption that the median value was caught in each year (i.e., constant catch). Because the final SEDAR 45 continuity model implements more of the features used by the final SSASPM base model, it is a better reflection of the final model used in the 2011 Update than the 2011 Update SS3 model presented in Figure 47.

Figure 47 also presents two versions of the continuity model in order to illustrate the differences that result from treatment of the commercial CPUE (i.e., truncation compared to splitting the index). The SEDAR 45 Data and Assessment Review Group's preferred continuity model used the truncated commercial CPUE index, but, because the base model assumes a split index, this model is also presented as an alternative continuity run. Results are generally quite similar among these two continuity models.

3.2.10. *Sensitivity Model Runs*

The results of two main sensitivity runs are presented in Figure 48: a model using the old observed median shrimp bycatch estimate of 6.65 million fish and a run allowing for logistic recreational selectivity. Not surprisingly, increasing the observed median bycatch causes the estimate of virgin recruitment along with virgin spawning biomass to increase substantially, because the model must account for the increased by age-1 mortality by increasing productivity, which leads to slightly increased recruitment estimates for much of the timeseries. However, despite having similar terminal year SSB and recruitment estimates, the level of depletion is quite a bit lower due to the higher SSB_0. The observed median shrimp bycatch is clearly an important scalar for the model. The SEDAR 45 Data and Assessment Review Group agreed that the current estimate is the best data available, but that careful consideration should be taken in the future in estimating shrimp bycatch, because it clearly has a strong influence on model outputs.

On the other hand, allowing for logistic recreational selectivity instead of domed selectivity acts to reduce R_0 and SSB_0, but not to a substantial degree. The timeseries of recruitment between the two models is nearly identical as is that of SSB. Given that domed selectivity greatly reduced residual patterns in fit to the recreational age compositions, the SEDAR 45 Data and Assessment Review Group decided that maintaining domed selectivity for the recreational fishery was the best course of action.

3.3. Discussion

The 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 has stabilized and has demonstrated a slight upwards trend over the last few years. Terminal harvest rate is at the lowest level seen since the early 1980s when the directed fisheries were just beginning to develop. Recent recruitment has been above average and periodic strong yearclasses over the last decade have helped to recover the age structure of the stock. Overall, the stock is estimated to be in good condition and has maintained a stable depletion level of around 30% (i.e., $SSB/SSB_0 = 0.30$) for over a decade.

The model generally fit each of the data sources well with limited residual patterns, but did not tightly fit annual values for each of the indices. However, the trends among observed and predicted indices were in general agreement. Landings and age composition showed acceptable fits with no strong residual patterns. Length composition data from the video and groundfish survey were not as well fit as the age composition data, but this is not unexpected when fitting length data within an age structure model, particularly with a fast growing fish like vermilion snapper. There was some strong parameter correlation, particularly in domed selectivity parameters and between steepness and the stock-recruit variance (σ_R) term, which may be the cause of slight model instability. However, the bootstrap and jitter analysis indicated that these correlations were not causing excessive model instability as most runs converged to the same solution space. No retrospective trends were present indicating internal consistency within the model. In general, the model appears to be performing well with no convergence issues or any major instability. 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 found.

As is typically the case with statistical catch-at-age stock assessment models, the parameters defining the stock-recruit curve were highly correlated and not well estimated. Profile analysis indicated that steepness and σ_R were highly correlated with paired parameter values ranging from 0.55 to 0.8 and 0.2-0.65 for steepness and σ_R, respectively, resulting in similar negative log-likelihood values. Although the final steepness value (0.57) is not likely an accurate representation of the productivity of vermilion snapper considering its fast growth, early maturation, and high fecundity, allowing the model to estimate all of the stock-recruit parameters freely is likely to produce the annual recruitments that are most consistent with the observed data (Methot, 2015). Fixing either parameter at biologically realistic levels may lead to model instability and cause tension among data sets, which can cause recruitment estimates that are not supported by the observations. The SEDAR 45 Data and Assessment Working Group decided to maintain the estimated stock-recruit relation for the purpose of estimating recruitment, but to use recent recruitment estimates 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.

The final continuity model attempted to represent, as best as possible, the 2011 SEDAR 9 Update Assessment. Although the SEDAR 45 base model implemented major changes from the continuity model, the general trends and stock depletion estimates remained similar. A number of sensitivity runs were undertaken to test various model decisions. The value of the median super-year shrimp bycatch was found to be one of the most influential input data sources, because it acted as a strong scalar on virgin recruitment and spawning stock biomass. Accurate estimation of shrimp bycatch is clearly a critical component of an accurate vermilion snapper stock assessment.

4. Projections

4.1. Introduction

The SEDAR 45 terms of reference (TORs) requested projections be undertaken to determine appropriate management benchmarks and to specify near-term annual overfishing limits (OFL's). If possible, projections were to be based on forecasting F_{MSY} using the base assessment model configuration. However, the base model for vermilion snapper had difficulty freely estimating all of the stock-recruit parameters due to high correlation between the stock-recruit variance term, σ_R, and the steepness, h, which resulted in unrealistically low estimates of productivity for this species (i.e., the stock-recruit curve had an uncharacteristically small initial slope; see Sections 3.3.1.4 and 3.2.4). Based on discussions within the SEDAR 45 Data and Assessment Review Group along with expert guidance (Methot, 2015), it was determined that the best approach for the purpose of forecasted recruitment would be to use average recent recruitment instead of relying on the estimates of recruitment from the stock-recruit curve. The basic premise behind this approach is that the best predictor of recruitment in the near future is the recent past, especially considering the slight 2-3 year autocorrelation seen in the estimated recruit deviations.

It is not possible to calculate MSY and its associated reference points (F_{MSY} and B_{MSY}) when the spawner-recruit relationship is unknown or considered unreliable; therefore, a proxy for F_{MSY} is required. In past vermilion snapper assessments, the fishing mortality rates that achieve a given spawning potential ratio (F_{SPR}) or maximize the yield-per-recruit (F_{MAX}) have been used as F_{MSY} proxies. SPR values of 30-40% are commonly used in the assessment of moderately fecund and fast growing species, such as most reef fish. An SPR of 30% has typically been used as an SPR proxy in previous assessments of Gulf of Mexico vermilion snapper (see Assessment History section). In the 2011 SEDAR 9 update assessment, maximum yield-per-recruit proxies were also investigated. The classic way to compute F_{MAX} is to find the fishing mortality rate and age at first capture that produces the maximum yield per recruit, sometimes referred to as the global maximum yield per recruit. In practice the global maximum yield per recruit is difficult to achieve because fisheries cannot easily avoid catching fish that are younger than the optimal age at first capture and must discard them. However, it is possible to achieve the estimated equilibrium spawning stock biomass and corresponding SPR value associated with F_{MAX} and these remain viable candidates for defining the minimum stock size threshold (MSST).

Another yield per recruit metric that has been used is the fishing mortality rate that maximizes yield-per-recruit conditional on a prescribed selection pattern, hereafter referred to as F_{CMAX}. One might chose, for example, a selection pattern that is based on extant fishing conditions (current sub-optimal fleet selectivity patterns along with bycatch and discard mortality). Of course, there are an infinite number of selection patterns that can be assumed for calculating a conditional YPR (e.g., fixing bycatch versus linking directed and bycatch fishing mortality in a constant proportion). In the case of the 2011 SEDAR 9 update assessment, F_{CMAX} was computed assuming that the relative fishing mortality rates exerted by each fleet (including shrimp bycatch) would be the same as in the recent past and that the absolute fishing mortality rate could be scaled up or down for each fleet in exactly the same proportion (sometimes referred to as the 'linked' scenario). In that case, the value of F_{CMAX} was lower than $F_{SPR30\%}$, and F_{CMAX} was subsequently selected as the better proxy for F_{MSY}.

In compliance with the TORs, overfishing limits (OFLs; retained yield streams that achieve the biomass proxy or maximized yield in equilibrium) were calculated for each of the potential MSY proxies (i.e., $F=F_{SPR30\%}$, $F=F_{MAX}$, and $F=F_{CMAX}$) along with three additional requested projections: F_{OY} (F = 75% of Directed Fishing Mortality at $F_{MSYProxy}$), future landings equal to 2014 annual catch targets (ACTs), and constant catch (yield equivalent to 2017-2021 average OY assuming $F_{SPR\ 30\%}$ as the MSY proxy).

4.2. Projection methods

The simulated dynamics used for projections assumed the same parameter values and population dynamics as the base model (see Table 20 for a summary of projection settings). The only exception being that the stock-recruit function was replaced with an average recruitment assumption, as discussed above. In each year of the projections, recruitment was assumed to be constant at the geometric mean of the model estimated recruitment values (~17.3 million fish) from the last ten years of the assessment (2004-2014) regardless of projected spawning stock biomass levels. For all years of the projections it was assumed that recent fishery dynamics would continue indefinitely. The selectivity 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 (2012 – 2014) values.

Because the shrimp fishery is managed independent 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 (2012 – 2014; fishing mortality=0.074). Given the recently low and relatively constant (over the last seven years; Figures 8 and 10) levels of shrimp effort and bycatch compared to historically high levels, it is not unreasonable to assume that bycatch fishing mortality will stay relatively static in the near-term. The conditional maximum yield-per-recruit was then calculated by maximizing the landings-per-recruit of the directed fishery assuming the fishing mortality rates exerted by the directed fleets could be scaled up or down by the same proportional amount while the fishing mortality rates exerted by the shrimp fleet would remain constant (i.e., the shrimp bycatch mortality rate is treated similar to the natural mortality rate in the calculation). Spawner-per-recruit analysis was carried out in the same way (i.e., with a fixed shrimp bycatch and scaling the fishing mortality of the directed fleets), but instead of maximizing landings the goal was to achieve the given SPR target value. In contrast to these approaches, the 2011 SEDAR 9 update assessment computed the conditional maximum yield-per-recruit assuming the shrimp bycatch mortality rate was scaled up or down by the same proportion as the directed fleets. In order to facilitate the comparison between the 2011 and present assessment, the 2011 "linked" approach was also applied, but the results are still not exactly comparable because the reference shrimp bycatch mortality rate was higher for the 2011 assessment (being based on the years 2008-2010).

Due to the lag in reporting and verification of fishery statistics, finalized landings statistics were only available through 2014. For the purpose of projections, provisional landings data were made available through 2015 for the commercial (through December 28th, 2015, but believed to accurately reflect the full commercial landings for the year) and recreational (through the end of August with missing months being extrapolated based on previous years relative quota caught in September through December) fleets (total of 2,311,176 pounds). In addition, because the quotas have already been set for 2016, the total landings for 2016 were estimated by multiplying the 2016 annual catch limit (ACL) of 3,420,000 pounds whole weight by the average percent of the ACL landed from 2012 – 2015 (~80% caught on average leading to 2016 landings of 2,733,851 pounds). Relative directed harvest rates were used to iteratively adjust the directed fleet specific fishing mortalities in order to obtain the total estimated landings for 2015 and 2016 and then these fishing mortalities were input into the projections as fixed values (note that shrimp bycatch was held constant for all years as described above).

Each of the potential proxies for F_{MSY} ($F_{SPR30\%}$, F_{CMAX}, and F_{MAX}) were determined using long-term 60 year projections assuming that equilibrium was obtained over the last 10 years (2065-2074). For SPR-based analysis, the harvest rate (total number killed/total abundance) that led to SPR 30% (SSB_{EQUIL}/SSB_0=0.3) was obtained by iteratively adjusting yield streams. F_{CMAX} was calculated conditional on extant selectivity, discard mortality, and relative harvest rates for the directed fleets as well as the fixed level of shrimp bycatch (described above except for the analysis with linked proportional fishing mortalities) and determined by adjusting the directed fleet fishing mortality rates until equilibrium yield was maximized. F_{MAX} was calculated using one 'optimal' fleet with near infinite fishing mortality and knife-edge selectivity at the age that produced the highest yield-per-recruit. The resulting maximum yield-per-recruit was the global maximum possible given the life history characteristics of vermilion snapper, and balanced gains due to growth and recruitment versus losses due to natural mortality.

Where appropriate, the minimum stock size threshold (MSST) was determined by multiplying the SSB proxy by (1-M) where M was assumed to be 0.25 (i.e., the base M used to determine age-varying M from the Lorenzen function). The MSST was used to determine stock status (i.e., whether or not vermilion snapper was considered overfished). The maximum fishing mortality threshold (MFMT) was equivalent to the equilibrium harvest rate (age-1+ number killed/age-1+ abundance) that achieved the associated SSB proxy, and was used to assess whether overfishing was occurring in a given year.

Once the proxy values were calculated, 2014 stock status was used to determine whether or not a rebuilding plan was required (i.e., if SSB<MSST then vermilion snapper were overfished and a rebuilding plan was required). Because vermilion snapper have not been declared overfished since the SEDAR 9 assessment was implemented, no rebuilding plan is currently in place. If the SEDAR 45 assessment deemed that they were 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 to the accepted SSB proxy by a specified date.

However, if vermilion is deemed to still be above the MSST, then no rebuilding plan is necessary and OFLs would be based on the yields that achieve the SSB target in equilibrium (i.e., the fishing mortality is set equal to that which achieves and maintains the stock at the given SSB proxy value in equilibrium; $F=F_{MSYProxy}$ for every year of the projection).

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 allows them to reach a large fraction of their potential size and fecundity at very young ages with a generation time of only 7.22 years. Not surprisingly, the conditional YPR curve is rather flat (Figure 49) and the maximum YPR (when shrimp bycatch is treated as a fixed input mortality) is achieved with rather high harvest rates (F_{CMAX}=0.246; see Table 21 for a summary of MSRA benchmarks and biological reference points). However, the corresponding SPR value is only 12%, suggesting this is a poor proxy for MSY. When instead the conditional YPR is computed assuming the shrimp bycatch mortality rate can be adjusted in proportion to the directed fishing mortality rate, the value of F_{CMAX} is lower (harvest rate=0.16) with a higher corresponding SPR (22%), but it is still well below SPR 30%.

It is important to remember that YPR analyses do not take the nature of the stock-recruit relationship into account. The fishing mortality rate that produces the maximum yield tends to exceed F_{MSY} unless there is truly no relationship between spawners and recruits and fishing-related mortality is negligible for fish below the optimal age at first capture. However, the uncertainty about the nature of the spawner recruit relationship expressed in this assessment should not be interpreted as a presumption that one does not exist. The adoption of any proxy for MSY that results in low equilibrium SPR values may result in substantial age truncation in the population and recruitment overfishing (e.g., the F_{CMAX} equilibrium SPR of only 12%). A higher SPR proxy (e.g., 30%) will result in a more protracted age-structure and higher spawning biomass. The harvest rate that results in SPR 30% over the long-term was around 0.103, which is well below that of F_{CMAX} (Table 21). The resulting SSB at SPR 30% was 1.97E+14 eggs and the MSST, assuming a natural mortality of 0.25, was 1.48E+14 eggs. Given the caveats and limitations of the current approach, SPR 30% appears to be an appropriate proxy for SSB_{MSY} and is used for the basis of stock status determinations and OFL calculations.

Projections to determine global F_{MAX} were also conducted and the results are illustrated in Figure 50. Given the high rate of growth mentioned previously, this analysis also suggested fishing relatively hard at younger ages. Maximum yield was obtained when knife-edge selectivity occurred between ages 3 and 4 and resulted in an SPR between 13 and 20%. Although the resulting SPR is low, SPR 20% is perhaps not an unreasonable SPR target for fast growing and highly fecund species such as vermilion snapper. The result further illustrates the danger of computing maximum YPR conditioned on a fixed shrimp bycatch mortality rate (as though it were an intrinsic property of the stock like natural mortality rate), because the equilibrium SPR obtained by fishing at F_{CMAX} (12%) was calculated to be below the global F_{MAX} SPR. The SPR corresponding to the global F_{MAX} should be considered a lower limit for sustainable spawning stock biomass, because it represents the SPR that results when maximizing yield in the absence of any relationship between spawners and recruits. Accounting for the decline in recruitment as the number of spawners decreases (i.e., including a stock-recruit relationship) would generally result in a higher equilibrium SPR if global MSY could be calculated directly.

4.3.2. *Stock Status*

Using SPR 30% as the basis for defining MSST and MFMT, stock status appears to be healthy. In 2014, the stock was around 73% of MFMT, 140% of MSST, and 105% of $SSB_{SPR30\%}$ with an SSB_{2014}/SSB_0 of 32% (Tables 21 and 22). The Kobe plot (Figure 51) indicates that over the course of its history, overfishing occurred on vermilion snapper from 1986-2006, but this mostly corresponded to fishing down from equilibrium conditions (e.g., towards SPR 30%). Over the last decade, overfishing has generally not occurred except in a few years. On the other hand, vermilion has never been overfished. After the intense fishing pressure of the late 1980s and early 1990s, SSB did decline below that at SPR 30%, but never went below the MSST. With the recent decline in fishing mortality and the increase 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 2017, because the 2015 fishing year is already completed and TACs have already been set for 2016. Since the stock is currently above the SPR 30% target, forecasts indicate that a declining yield stream (with initial increases from the 2016 TAC) is possible in the near-term in order to fish the stock down towards the target SPR (Figure 52 and Table 23). 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 24 and Figure 53. The trends are the same as the OFL run, but result in a relatively higher SPR (34%) with slightly lower annual yield.

The TORs requested two constant catch projection scenarios. The first projected annual yield that was held constant at the 2014 annual catch target (ACT) and the second assumed a constant catch variant of the $F_{SPR30\%}$ projection scenario. The 2014 annual catch target was equal to 2.94 million pounds which was used as the yield target for the first scenario. For the second scenario, the average yield of the first five years (2017 – 2021) of the optimum yield projections (3.11 million pounds) was used as the annual yield target (as prescribed by the Gulf of Mexico SSC). Results of these projections are presented in Table 25. Projecting constant catch at the 2014 target level resulted in the stock remaining not overfished and not experiencing overfishing (2026 F/MFMT and SSB/MSST equal to 0.83 and 1.53, respectively). The scenario that projected the average OY yield of 3.11 million pounds also resulted in the stock not being overfished (SSB/MSST = 1.48 in 2026) and not experiencing overfishing (F/MFMT = 0.89 in 2026).

4.4. Discussion

Based on the current projections, it appears that fishing at the harvest rate that achieves SPR 30% provides an appropriate MSY proxy for vermilion snapper (given that MSY could not be directly calculated due to uncertainty in the stock-recruit relationship). The value of F_{CMAX} calculated here assuming either fixed or scalable shrimp bycatch mortality rates was higher than $F_{SPR30\%}$, which is in contrast to the results obtained during the 2011 SEDAR 9 update assessment (which made the calculation assuming shrimp bycatch would be scaled in proportion to the directed fleet). Because YPR analysis does not account for the possibility of recruitment overfishing, the high F_{CMAX} value was not viewed as a sustainable proxy for MSY. Global F_{MAX} analysis indicated that lower SPR targets may be viable for vermilion snapper given the fast growth and maturity observed, but, again, there is some potential for recruitment overfishing at this lower SPR target.

During the 2011 update assessment F_{CMAX} was calculated assuming that bycatch fishing mortality was linked in a constant proportion to the directed fishing mortality, and using the 'linked' conditional YPR analysis resulted in F_{CMAX} being lower than $F_{SPR30\%}$. For SEDAR 45, the 'linked' conditional YPR gave higher SPR and lower F_{CMAX} than assuming fixed shrimp bycatch, but for all YPR analyses resulting SPR was still much lower than SPR 30% and F_{CMAX} was greater than FSPR30%. It is believed that model inputs and forecast recruitment assumptions are largely responsible for the performance differences between the 2011 SEDAR 9 update assessment projections of F_{CMAX} and those carried out for SEDAR 45. Shrimp bycatch levels have declined since the previous assessment, which can have important impacts on the various YPR analyses. In particular, increasing the relative contribution of shrimp bycatch to overall fishing mortality acts to decrease F_{CMAX} and increase SPR when using the 'linked' YPR method. In addition, projections in the 2011 update assessment used fixed re-estimated stock-recruit parameters from the recent timeperiod assuming a steepness value of 0.80. However, when stock-recruit parameters are not well estimated, fixing steepness can have unintended consequences and may impact the reliability of resulting YPR analysis.

The SEDAR 45 Data and Assessment Review Group decided that recent recruitment was a better assumption for the basis of projections, because the estimated stock-recruit parameters were likely inappropriate (i.e., steepness was too low) for such a highly productive species. Fixing the parameters (e.g., steepness) would have allowed calculation of MSY directly, but assuming constant near-term recruitment was deemed a more appropriate procedure for determining near-term population dynamics. However, because the dependency between spawners and recruits is eliminated, recruitment never falters even at extremely low stock sizes (i.e., recruitment overfishing is not possible). Clearly, some relationship must exist between mature fish and resulting recruits (i.e., there must be spawning fish to make progeny). 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 should not be used for equilibrium calculations (i.e., catch limits based on SPR 30% should be updated regularly to account for changes in recruitment dynamics).

The Stock Synthesis 3 modeling platform used for SEDAR 45 uses the terminal year (i.e., 2014) parameter uncertainty estimates (e.g., recruitment and abundance) to project error distributions throughout the forecast timeframe for derived quantities (e.g., yield). Since SS3 was implemented for SEDAR assessments, acceptable biological catches (ABCs) have been typically calculated from the OFL (retained yield) based on the projected uncertainty estimates output by SS3. However, recent SEDAR assessments have indicated unexpectedly small uncertainty estimates in the OFL, which also occurred in SEDAR 45. The reduced uncertainty estimates for vermilion snapper are thought to result from a combination of fixed inputs (e.g., natural mortality, length-weight relationship, etc…) that lack directly specified uncertainty and a very small stock recruitment variance term ($\sigma_R = 0.23$). Given the life history of vermilion snapper and lack of a discernable relationship in the stock recruitment data, the magnitude of σ_R is quite small. Therefore, assessment uncertainty for SEDAR 45 might be better accounted for by using the OY as the basis for the ABC instead of the P^* approach. In addition, using the OY (10 year average = 3.11 million pounds) as the ABC would correspond well with recent total catches, which have ranged from 2.5 to 3.1 million pounds over the last three years (and on average are only 80% of the current 3.42 million pound ACL).

The Gulf of Mexico stock of vermilion snapper appears 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 32%), is slightly above the target value of 0.3 and the SSB has been above the MSST for its entire history, while fishing mortality has been below the MFMT since 2012. Forecasts suggest that near-term yield could be moderately increased to fish the stock down towards SPR 30%, but current yields are on par with projected ABCs (based on OY) given the level of uncertainty in stock-recruit parameters.

5. Acknowledgements

Completion of the SEDAR 45 assessment would not have been possible without the help and input of a vast array of participants, particularly those involved with data collection and analysis. We thank the efforts of Refik Orhun (Commercial Catch); Vivian Matter (Recreational Catch and Discards); Kevin McCarthy (Commercial discards and CPUE); Adyan Rios (Recreational CPUE); Robert Allman, Linda Lombardi, Gary Fitzhugh (Age, Growth, and Reproduction); Adam Pollock, David Hanisko, Walter Ingram, and Matthew Campbell (Fishery-Independent Surveys); Rick Hart and Jeff Isely (Shrimp Effort and Bycatch); Ching-Ping Chih (Size and Age composition); Beverly Sauls (Headboat Discard Age Composition). A team of analysts were responsible for the final assessment model including Shannon Cass-Calay, Jeff Isely, Adyan Rios, John Walters, and Clay Porch. We would like to especially thank the SEDAR staff for organizing meetings, webinars, and general discussion, while providing critical feedback and guidance. Finally, we appreciate the feedback and comments provided on modeling aspects and the final report from all members of the SEDAR 45 Data and Assessment Review Group.

6. Research Recommendations

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.

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 discards by fleet and incorporate them if they become significant portions of total catch.

Evaluate discard mortality.

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.

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

Perform simulation validation of IFQ standardization techniques.

7. References

Chih, C.-P. 2009. Evaluation of the sampling efficiency of three otolith sampling methods for commercial king mackerel fisheries. Transactions of the American Fisheries Society, 138: 990-999.

Clarke, W.G. 1993. The effect of recruitment variability on the choice of a target level of spawning biomass per recruit. Proceedings of the International Symposium on Management Strategies of Exploited Fish Populations, Alaska Sea Gran College Program, AK-SG-93-02.

Guccione, D. 2005. Hooking mortality of reef fishes in the snapper-grouper commercial fishery of the southeast United States. M.Sc. Thesis. University of North Carolina-Wilmington.

Hulson, P.-J., Hanselman, D., Quinn, T. 2012. Determining effective sample size in integrated age-structured assessment models. ICES Journal of Marine Science, 69: 281-292.

Linton, B. 2012. Shrimp fishery bycatch estimates for Gulf of Mexico red snapper, 1972-2011. SEDAR31-DW30.

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

MacAllister, M., and Ianelli, J. 1997. Bayesian stock assessment using catch-age data and the sampling-importance resampling algorithm. Canadian Journal of Fisheries and Aquatic Sciences, 54: 284-300.

Maunder, M., and Punt, A. 2013. A review of integrated analysis in fisheries stock assessment. Fisheries Research, 142: 61-74.

McCarthy, K. 2011. Calculated discards of yellowtail snapper from commercial vertical line fishing vessels in southern Florida. SEDAR27-RD02. Sustainable Fisheries Division Contribution SFD-2011-016.

Methot, R. 2015. User Manual for Stock Synthesis: Model Version 3.30. NOAA Fisheries. Seattle, WA.

Methot, R., and Wetzel, C. 2013. Stock Synthesis: a biological and statistical framework for fish stock assessment and fishery management. Fisheries Research, 142: 86-99.

Nance, J. 2004. Estimation of effort in the offshore shrimp trawl fishery of the Gulf of Mexico. NOAA Southeast Fisheries Science Center, Galveston Laboratory. SEDAR7-DW24.

Nichols, S. 2004a. Some Bayesian approaches to estimation of shrimp fleet bycatch. NOAA Southeast Fisheries Science Center, Pascagoula Laboratory. SEDAR7-DW03.

Nichols, S. 2004b. Update for the Bayesian estimation of shrimp fleet bycatch. NOAA Southeast Fisheries Science Center, Pascagoula Laboratory. SEDAR7-DW54.

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.

Rudershausen, P., Buckel, J., and Williams, E. 2007. Discard composition and release fate in the snapper and grouper commercial hook-and-line fishery in North Carolina, USA. Fisheries Management and Ecology, 14: 103-113.

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

SEDAR. 2011. 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.

SEDAR. 2013. Stock Assessment Report of SEDAR 31: Gulf of Mexico Red Snapper.

SEDAR. 2015. SEDAR 31 Update Stock Assessment Report: Stock Assessment of Red Snapper in the Gulf of Mexico 1872-2013 with Provisional 2014 Landings.

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

8. Tables

Table 1: Weight-length regression parameters for Vermilion Snapper from the Gulf of Mexico using data collected from 2000 to 2014. 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.

	Commercial East (mt)		Commercial West (mt)		Recreational (1000s)	
Year	Observed	Predicted	Observed	Predicted	Observed	Predicted
1950	1.00	1.00	0.73	0.73	6.03	6.03
1951	1.99	1.99	1.46	1.46	12.07	12.07
1952	2.99	2.99	2.19	2.19	18.10	18.10
1953	3.98	3.98	2.92	2.92	24.13	24.13
1954	4.98	4.98	3.65	3.65	30.17	30.17
1955	5.98	5.98	4.38	4.38	36.20	36.20
1956	6.97	6.97	5.11	5.11	42.23	42.23
1957	7.97	7.97	5.84	5.84	48.26	48.26
1958	8.97	8.97	6.57	6.57	54.30	54.30
1959	9.96	9.96	7.30	7.30	60.33	60.33
1960	10.96	10.96	8.03	8.03	66.36	66.36
1961	11.95	11.95	8.76	8.76	72.40	72.40
1962	12.95	12.95	9.49	9.49	78.43	78.44
1963	13.95	13.95	10.22	10.22	84.46	84.47
1964	15.26	15.26	10.67	10.67	90.50	90.51
1965	15.15	15.15	9.42	9.42	96.53	96.54
1966	7.90	7.90	3.02	3.02	102.56	102.58
1967	16.01	16.01	7.15	7.15	108.59	108.61
1968	31.82	31.82	22.81	22.81	114.63	114.66
1969	40.53	40.53	12.29	12.29	120.66	120.69
1970	37.81	37.81	20.14	20.14	126.69	126.73
1971	41.29	41.29	21.80	21.80	132.73	132.78
1972	36.45	36.45	21.10	21.10	138.76	138.83
1973	61.48	61.48	24.92	24.92	144.79	144.87
1974	58.35	58.35	30.31	30.31	150.83	150.93
1975	126.98	127.00	49.59	49.59	156.86	156.98
1976	111.57	111.59	27.44	27.44	162.89	163.04
1977	151.22	151.25	88.51	88.52	168.92	169.11
1978	129.98	130.01	74.05	74.06	174.96	175.19
1979	99.08	99.10	99.99	100.01	180.99	181.27
1980	72.42	72.43	67.34	67.35	187.02	187.34
1981	105.02	105.04	52.46	52.47	194.36	194.73
1982	108.57	108.60	66.45	66.46	591.20	594.62
1983	171.33	171.40	73.37	73.39	170.86	171.11
1984	241.32	241.43	384.78	385.18	240.47	240.75
1985	304.88	305.00	334.57	334.83	414.88	414.74

1986	312.81	312.95	425.94	426.37	992.11	991.78
1987	242.45	242.57	455.15	455.84	1,033.52	1,035.98
1988	222.91	223.02	449.83	450.65	1,385.55	1,386.65
1989	217.18	217.26	454.87	455.86	866.96	863.96
1990	517.41	517.72	436.21	436.94	1,164.61	1,150.02
1991	420.91	421.87	366.40	367.53	1,148.51	1,158.82
1992	538.57	541.76	476.53	479.59	1,365.73	1,427.17
1993	743.03	749.09	463.24	466.25	1,198.84	1,250.23
1994	712.51	720.43	471.80	475.75	982.38	1,040.95
1995	678.87	691.17	296.76	298.83	1,216.10	1,406.71
1996	523.97	532.15	295.68	298.00	580.19	630.57
1997	469.46	474.81	486.52	492.61	612.02	661.45
1998	365.30	366.89	406.03	408.50	309.98	315.38
1999	416.70	417.11	497.89	498.48	421.77	421.42
2000	315.59	315.08	343.93	343.23	330.47	326.22
2001	362.53	361.02	410.11	408.06	631.77	605.69
2002	452.12	448.37	453.47	449.92	521.71	497.29
2003	523.30	518.13	571.01	564.13	604.38	570.08
2004	420.92	417.67	552.27	546.54	828.28	769.91
2005	444.31	442.41	401.91	400.42	625.45	604.91
2006	505.42	504.60	288.56	288.31	543.88	537.09
2007	527.65	523.39	548.36	542.75	502.08	484.78
2008	810.03	789.24	458.62	451.56	530.48	495.88
2009	1,274.05	1,215.93	444.34	436.43	727.98	655.77
2010	598.81	588.87	356.68	351.33	432.57	410.44
2011	1,102.13	1,102.79	329.52	327.97	1,130.42	1,138.66
2012	720.63	735.02	371.01	373.58	632.07	688.41
2013	416.09	419.48	226.29	227.03	1,098.02	1,226.32
2014	346.69	347.39	271.67	272.11	1,108.33	1,148.50

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

	East				West			
Year	**Handline**	**Longline**	**Trap**	**Total**	**Handline**	**Longline**	**Trap**	**Total**
1963	30,747			30,747	22,533			22,533
1964	33,633			33,633	23,532			23,532
1965	33,411			33,411	20,757			20,757
1966	17,427			17,427	6,660			6,660
1967	35,298			35,298	15,762			15,762
1968	70,152			70,152	50,283			50,283
1969	89,355			89,355	27,084			27,084
1970	83,361			83,361	44,400			44,400
1971	91,020			91,020	48,063			48,063
1972	80,364			80,364	46,509			46,509
1973	135,531			135,531	54,945			54,945
1974	128,649			128,649	66,822			66,822
1975	279,942			279,942	109,335			109,335
1976	245,976			245,976	60,495			60,495
1977	333,375			333,375	195,126			195,126
1978	286,552			286,552	163,261			163,261
1979	218,438			218,438	220,445			220,445
1980	159,658	444		160,102	148,455			148,455
1981	231,522	10,131		241,653	115,663	4,549		120,212
1982	239,367	7,188		246,555	146,490	4,662		151,152
1983	377,712	23,936		401,648	161,754	7,102		168,855
1984	532,029	15,834		547,863	848,288	41,392		889,680
1985	672,148	14,765	109	687,022	737,600	53,910		791,510
1986	689,625	1,184		690,809	939,041	119,597		1,058,638
1987	534,518	4,792		539,310	1,003,433	62,662		1,066,095
1988	491,437	15,460		506,897	991,713	54,372		1,046,085
1989	478,794	114,692	2,911	596,397	1,002,816	59,609		1,062,425
1990	1,140,697	2,035	349,837	1,492,569	961,690	613		962,303
1991	927,955	15,594	41,993	985,542	807,767	1,683	33	809,483
1992	1,187,338	1,486	109,208	1,298,033	1,050,576	12,514	196	1,063,286
1993	1,638,102	3,591	29,284	1,670,977	1,021,272	24,197	3,064	1,048,533
1994	1,570,813	3,485	11,306	1,585,603	1,040,141	13,494		1,053,635
1995	1,496,663	3,013	9,421	1,509,097	654,243	14,700		668,943
1996	1,155,153	3,426	11,284	1,169,864	651,873	5,545		657,419
1997	1,034,972	4,779	5,359	1,045,110	1,072,585	8,120		1,080,705
1998	805,347	22,925	2,867	831,140	895,148	6,390		901,538
1999	918,661	10,033	2,809	931,504	1,097,670	7,424		1,105,093

2000	695,756	1,795	2,321	699,872	758,231	712		758,943
2001	799,252	6,553	3,426	809,231	904,136	1,366		905,502
2002	996,757	2,184	8,992	1,007,933	999,739	445		1,000,184
2003	1,153,684	622	1,784	1,156,090	1,258,857	663		1,259,520
2004	927,966	941	4,213	933,120	1,217,554	11,575		1,229,128
2005	979,544	2,792	1,717	984,053	886,061	771		886,832
2006	1,114,257	13,134	219	1,127,609	636,161	1,814		637,974
2007	1,163,278	11,447		1,174,725	1,208,917	7		1,208,925
2008	1,785,804	5,567		1,791,371	1,011,088	872		1,011,959
2009	2,808,803	5,641		2,814,445	979,593	443		980,036
2010	1,320,158	1,908		1,322,066	786,340	515		786,855
2011	2,429,777	3,472		2,433,249	726,468	87		726,555
2012	1,588,722	2,966		1,591,688	817,948	207		818,155
2013	917,319	415		917,734	498,883	1,102		499,985
2014	764,313	728		765,041	598,921	2,738		601,659

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

	East				West			
Year	**Charter**	**Private**	**Headboat**	**Total**	**Charter**	**Private**	**Headboat**	**Total**
1981	15,444	90,527	10,010	115,982	-	25,631	52,746	78,377
1982	287,157	1,026	186,131	474,314	47,185	12,686	57,020	116,891
1983	59,966	-	38,869	98,836	-	19,282	52,746	72,028
1984	99,112	23,707	64,243	187,062	-	665	52,746	53,411
1985	35,796	260,046	23,202	319,044	16,905	24,657	54,278	95,839
1986	335,673	84,260	517,702	937,635	1,185	-	53,291	54,476
1987	344,791	155,746	473,804	974,342	2,236	286	56,661	59,183
1988	355,586	321,691	657,057	1,334,333	-	489	50,724	51,213
1989	218,226	194,492	379,291	792,009	-	362	74,591	74,953
1990	499,792	124,265	435,185	1,059,242	1,901	-	103,467	105,368
1991	572,027	63,972	423,023	1,059,021	6,153	-	83,335	89,488
1992	422,677	280,768	565,532	1,268,976	1,290	18,461	77,003	96,753
1993	487,091	189,638	442,980	1,119,709	48	2,482	76,606	79,135
1994	388,263	96,605	374,812	859,680	3,889	894	117,920	122,703
1995	639,966	136,677	333,509	1,110,152	1,777	1,912	102,258	105,947
1996	244,213	39,270	219,191	502,674	367	2,196	74,955	77,518
1997	266,143	61,355	201,468	528,965	405	6,149	76,505	83,059
1998	135,119	13,061	96,353	244,533	223	3,420	61,800	65,443
1999	156,972	82,261	137,670	376,904	820	2,745	41,300	44,866
2000	125,551	30,250	131,627	287,427	103	420	42,517	43,040
2001	159,837	247,820	148,702	556,359	932	7,391	67,091	75,414
2002	106,510	191,756	146,890	445,156	4,154	1,987	70,418	76,559
2003	113,502	183,851	215,685	513,039	1,608	6,197	83,534	91,340
2004	255,870	202,692	236,173	694,735	27,187	4,955	101,399	133,541
2005	172,041	160,988	203,500	536,529	2,316	1,208	85,399	88,923
2006	191,948	87,518	198,315	477,781	11,982	1,625	52,496	66,103
2007	116,719	148,841	132,291	397,851	8,740	4,640	90,846	104,227
2008	212,108	85,046	193,837	490,991	1,856	9,135	28,496	39,487
2009	236,602	189,370	266,145	692,116	639	1,095	34,130	35,864
2010	117,574	92,381	164,181	374,136	-	74	58,363	58,437
2011	455,592	228,281	376,813	1,060,686	74	405	69,251	69,730
2012	171,347	156,304	240,140	567,790	28	16	64,237	64,281
2013	342,386	411,103	266,618	1,020,107	731	1,526	75,653	77,910
2014	475,143	264,930	297,933	1,038,005	405	2,457	67,465	70,327

Table 7: Commercial hand line total discards by area in pounds whole weight and as a percentage of landings. The SEDAR 45 Data and Assessment Review Group determined that, given the best estimate of discard mortality of 15%, dead discards were an insignificant portion of total removals, and discards were not included in the final assessment model. Note that the percent of landings calculations uses total discards and not dead discards, which would be much lower.

	Total Discards		**Percent of Landings**	
	East	**West**	**East**	**West**
2007	269,516	336,991	23%	28%
2008	66,032	201,957	4%	20%
2009	234,997	190,787	8%	19%
2010	158,173	34,410	12%	4%
2011	84,410	46,173	3%	6%
2012	140,654	185,511	9%	23%
2013	41,194	50,294	4%	10%
2014	99,153	94,314	13%	16%

Table 8: Total recreational discards (Type B2, released alive) by mode and area in numbers of fish. The SEDAR 45 Data and Assessment Review Group determined that, given the best estimate of discard mortality of 15%, dead discards were an insignificant portion of total removals, and discards were not included in the final assessment model. Note that these are total discards and not dead discards, which would be much lower.

	East				West			
Year	**Private**	**Charter**	**Headboat**	**Total**	**Private**	**Charter**	**Headboat**	**Total**
1981	0	0	0	0	0	0	0	0
1982	5,444	0	1,258	6,702	0	0	0	0
1983	30,453	0	7,036	37,489	0	0	0	0
1984	12,634	0	2,919	15,553	0	0	0	0
1985	19,169	0	4,429	23,598	0	6,854	0	6,854
1986	22,736	73,228	0	95,964	0	0	0	0
1987	8,145	21,339	0	29,484	0	39	0	39
1988	227,590	34,199	0	261,790	0	52	0	52
1989	44,471	49,202	0	93,674	0	92	0	92
1990	79,432	3,466	0	82,897	0	0	0	0
1991	52,106	170,093	0	222,200	0	0	0	0
1992	143,918	150,171	0	294,089	0	43	0	43
1993	351,813	237,553	0	589,367	0	1,677	0	1,677
1994	87,098	83,589	0	170,687	0	774	0	774
1995	412,306	128,259	0	540,565	0	15,870	0	15,870
1996	78,263	78,290	0	156,552	0	793	0	793
1997	56,462	16,999	0	73,461	31	1,570	0	1,600
1998	38,000	14,152	0	52,153	53	698	0	751
1999	26,396	49,595	0	75,992	75	9,537	0	9,612
2000	21,887	19,287	0	41,174	18	3,567	0	3,585
2001	28,226	52,878	0	81,105	165	162	0	327
2002	8,416	103,905	0	112,322	39	1,077	0	1,116
2003	10,381	91,631	0	102,012	5	176	0	181
2004	60,313	75,422	3,542	139,277	14	1,350	60	1,425
2005	48,869	172,177	3,465	224,512	4	468	435	908
2006	79,327	89,744	2,708	171,779	725	1,666	280	2,672
2007	31,185	57,363	4,807	93,355	1,819	4,814	1,056	7,688
2008	37,618	60,927	13,971	112,516	30	2,951	159	3,139
2009	13,776	65,584	10,969	90,329	28	27,327	437	27,792
2010	8,641	8,081	2,562	19,285	0	6	347	353
2011	51,001	37,799	7,124	95,925	8	67	767	842
2012	17,670	76,626	8,744	103,039	3	8	112	123
2013	5,635	199,806	22,667	228,108	12	2,727	1,304	4,043
2014	32,113	97,576	23,990	153,679	130	1,356	945	2,431

Table 9: Observed and predicted shrimp bycatch in 1000s of fish. Observed shrimp bycatch is calculated using a Bayesian WinBugs program (SEDAR 7-DW-3), 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 of the observed values provided below. Similarly, since the assessment model is configured to fit the Bayesian super-year median, it has extreme flexibility in yearly estimates of bycatch, and it is not directly constrained to fit the observed bycatch values (yearly fluctuations in catch are constrained by forcing the model to fit the shrimp effort timeseries). Following SEDAR 9 recommendations, it is assumed that 75% of shrimp bycatch is age-1+ (i.e., the super-year medians represent 75% of the true estimates). The observed 2014 values is calculated by multiplying the 2013 value by the ratio of 2013 and 2014 shrimp effort, because not all data sets were available for the terminal year for the WinBugs program.

Year	Observed (WinBugs)	Predicted (Assessment)
Super-year Median	**3,368**	**3,636**
1972	47,780	4,022
1973	13,620	4,069
1974	3,817	4,043
1975	3,482	4,059
1976	1,268	4,189
1977	1,424	4,528
1978	9,395	4,719
1979	11,060	4,867
1980	863	4,910
1981	7,996	4,639
1982	2,754	4,246
1983	3,259	4,311
1984	7,928	4,755
1985	7,001	4,586
1986	16,650	5,018
1987	22,810	4,230
1988	7,748	3,825
1989	12,000	3,831
1990	16,870	3,693
1991	40,170	3,940
1992	5,483	4,685
1993	1,503	5,511
1994	1,303	6,362
1995	11,400	3,912
1996	6,260	4,208
1997	10,540	4,321
1998	62,600	5,306

1999	23,250	2,861
2000	22,170	3,409
2001	19,560	3,709
2002	3,916	4,379
2003	24,270	3,657
2004	1,552	3,628
2005	1,357	2,376
2006	8,369	1,608
2007	9,388	1,501
2008	799	942
2009	1,077	1,328
2010	733	897
2011	1,465	1,263
2012	396	1,288
2013	298	1,364
2014	339	951

Table 10: Otolith samples from the commercial fleet analyzed for age composition by year and area. Age frequency distributions calculated from otolith samples utilized a reweighting algorithm based on length frequency (Chih, 2009) in order to account for non-representative sampling of otoliths.

Year	East	West	Total
1994	1	15	16
1995	18	41	59
1998	138	0	138
2000	227	26	253
2001	1292	56	1348
2002	1332	97	1429
2003	2135	552	2687
2004	667	487	1154
2005	731	807	1538
2006	775	868	1643
2007	731	1187	1918
2008	885	1203	2088
2009	1102	975	2077
2010	781	1064	1845
2011	2935	869	3804
2012	661	574	1235
2013	522	496	1018
2014	529	518	1047

Table 11: Otolith samples from the recreational fleet analyzed for 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 (Chih, 2009). Note that due to low sample sizes in the western region, a single gulf-wide recreational fleet was modeled in the assessment with a combined age composition.

Year	East	West	Total
1994	33	0	33
1995	9	0	9
1996	217	44	261
1997	42	0	42
1998	14	0	14
1999	246	0	246
2000	187	23	210
2001	115	25	140
2002	258	0	258
2003	90	1	91
2004	88	39	127
2005	144	25	169
2006	170	1	171
2007	126	330	456
2008	551	468	1019
2009	993	307	1300
2010	987	212	1199
2011	850	455	1305
2012	1046	838	1884
2013	1021	710	1731
2014	1077	329	1406

Table 12: Observed and predicted normalized (to the timeseries mean) shrimp effort greater than 10 fathoms and assumed lognormal standard error. 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 (i.e., to deemphasize bycatch in the western stock area where relatively fewer young vermilion snapper are observed, but where high shrimping effort is observed). Values prior to 1981 represent a linear interpolation to virgin conditions.

Year	Observed	Predicted	Standard Error
1950	0.195	0.314	0.2
1951	0.265	0.330	0.2
1952	0.314	0.427	0.2
1953	0.330	0.446	0.2
1954	0.427	0.570	0.2
1955	0.445	0.653	0.2
1956	0.569	0.799	0.2
1957	0.652	0.862	0.2
1958	0.798	0.862	0.2
1959	0.860	0.653	0.2
1960	0.860	0.629	0.2
1961	0.652	0.717	0.2
1962	0.627	0.758	0.2
1963	0.715	0.842	0.2
1964	0.755	0.829	0.2
1965	0.838	0.904	0.2
1966	0.825	0.920	0.2
1967	0.899	1.047	0.2
1968	0.913	0.987	0.2
1969	1.038	0.943	0.2
1970	0.978	0.927	0.2
1971	0.932	0.941	0.2
1972	0.928	0.938	0.2
1973	0.935	0.945	0.2
1974	0.930	0.981	0.2
1975	0.936	1.075	0.2
1976	0.971	1.134	0.2
1977	1.063	1.182	0.2
1978	1.124	1.202	0.2
1979	1.178	1.134	0.2
1980	1.209	1.029	0.2
1981	1.157	1.046	0.2
1982	1.068	1.173	0.2

1983	1.116	1.137	0.2
1984	1.278	1.268	0.2
1985	1.211	1.063	0.2
1986	1.404	0.958	0.2
1987	1.268	0.969	0.2
1988	1.096	0.946	0.2
1989	1.122	1.025	0.2
1990	1.034	1.268	0.2
1991	1.076	1.568	0.2
1992	1.322	1.935	0.2
1993	1.086	1.578	0.2
1994	1.147	1.563	0.2
1995	1.298	1.604	0.2
1996	1.562	2.022	0.2
1997	1.555	1.258	0.2
1998	1.940	0.901	0.2
1999	1.183	1.030	0.2
2000	0.962	1.254	0.2
2001	1.122	1.111	0.2
2002	1.367	1.151	0.2
2003	1.182	0.930	0.2
2004	1.214	0.544	0.2
2005	0.937	0.346	0.2
2006	0.554	0.273	0.2
2007	0.365	0.468	0.2
2008	0.283	0.367	0.2
2009	0.463	0.376	0.2
2010	0.352	0.320	0.2
2011	0.361	0.344	0.2
2012	0.308	0.266	0.2
2013	0.342	0.314	0.2
2014	0.267	0.330	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, two different models were fit (differing by whether an IFQ factor was included in the standardization routine or not) pre/post 2007. The assessment model treats each as a separate index.

	East						West					
	No IFQ			IFQ			No IFQ			IFQ		
Year	OBS	PRED	Std. Err.	OBS	PRED	Std. Err.	OBS	PRED	Std. Err.	OBS	PRED	Std. Err.
1993	1.036	1.470	0.116				1.061	1.589	0.349			
1994	1.252	1.339	0.099				1.463	1.448	0.286			
1995	0.894	1.207	0.111				0.934	1.307	0.296			
1996	0.946	1.102	0.099				1.017	1.196	0.254			
1997	0.882	0.997	0.104				1.294	1.096	0.195			
1998	0.872	0.930	0.105				1.018	1.000	0.218			
1999	0.933	0.875	0.096				1.054	0.933	0.188			
2000	0.798	0.834	0.112				0.722	0.884	0.225			
2001	0.869	0.823	0.106				0.765	0.851	0.236			
2002	0.944	0.893	0.098				1.002	0.844	0.205			
2003	1.001	0.921	0.094				1.262	0.891	0.184			
2004	0.980	0.924	0.101				1.245	0.912	0.182			
2005	1.284	0.929	0.099				0.770	0.929	0.214			
2006	1.309	0.937	0.110				0.393	0.953	0.267			
2007				0.383	0.915	0.374				0.857	1.028	0.148
2008				0.844	0.923	0.364				1.110	0.977	0.138
2009				0.897	0.984	0.358				1.322	1.028	0.134
2010				0.911	0.992	0.371				1.000	0.948	0.140
2011				1.386	0.940	0.366				1.412	0.922	0.134
2012				1.187	0.859	0.366				0.837	0.994	0.130
2013				1.140	0.912	0.374				0.710	0.939	0.139
2014				1.252	1.034	0.379				0.753	0.998	0.139

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 East			Headboat East			Headboat West		
Year	**OBS**	**PRED**	**Std. Err.**	**OBS**	**PRED**	**Std. Err.**	**OBS**	**PRED**	**Std. Err.**
1986	2.649	1.112	0.174	0.946	1.353	0.283	1.781	1.400	0.194
1987	1.171	1.057	0.289	0.962	1.286	0.275	1.328	1.330	0.213
1988	1.270	1.008	0.255	2.295	1.227	0.188	0.985	1.269	0.196
1989	0.931	0.983	0.393	1.356	1.195	0.190	1.323	1.237	0.183
1990	2.683	0.963	0.301	1.675	1.172	0.175	1.638	1.212	0.194
1991	1.773	0.937	0.226	1.804	1.140	0.171	1.000	1.179	0.182
1992	1.726	0.902	0.167	2.660	1.097	0.158	0.919	1.135	0.166
1993	1.878	0.845	0.212	1.634	1.028	0.168	1.181	1.064	0.162
1994	1.491	0.780	0.274	1.851	0.949	0.170	1.115	0.981	0.162
1995	2.033	0.706	0.299	1.546	0.859	0.181	1.175	0.888	0.171
1996	0.992	0.646	0.341	0.890	0.786	0.193	0.822	0.813	0.217
1997	0.464	0.587	0.245	0.771	0.714	0.199	0.694	0.738	0.177
1998	0.394	0.549	0.221	0.179	0.668	0.217	0.790	0.691	0.201
1999	0.409	0.525	0.156	0.414	0.638	0.231	0.755	0.660	0.196
2000	0.346	0.508	0.158	0.345	0.617	0.217	0.538	0.639	0.189
2001	0.394	0.513	0.158	0.424	0.625	0.210	0.892	0.646	0.175
2002	0.306	0.575	0.161	0.459	0.699	0.210	1.061	0.723	0.176
2003	0.376	0.620	0.147	0.556	0.754	0.207	0.647	0.780	0.172
2004	0.524	0.626	0.111	0.625	0.761	0.200	1.096	0.787	0.169
2005	0.595	0.630	0.123	0.795	0.766	0.203	1.280	0.793	0.186
2006	0.598	0.631	0.137	0.536	0.768	0.220	0.716	0.795	0.178
2007	0.391	0.612	0.163	0.355	0.744	0.229	1.575	0.770	0.292
2008	0.465	0.624	0.170	0.546	0.759	0.197	0.315	0.785	0.225
2009	0.695	0.677	0.166	0.642	0.823	0.196	0.277	0.852	0.212
2010	0.448	0.695	0.174	0.737	0.845	0.212	1.099	0.874	0.219
2011	0.961	0.645	0.116	0.809	0.784	0.193	1.297	0.811	0.248
2012	0.482	0.586	0.141	0.546	0.713	0.189	0.871	0.737	0.219
2013	0.600	0.627	0.192	0.682	0.763	0.156	0.599	0.789	0.318
2014	0.954	0.724	0.134	0.677	0.880	0.163	0.616	0.910	0.109

Table 15: Observed and predicted standardized fishery-independent surveys 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 survey to preserve interannual variability in the weighting of data sets in the assessment.

	Larval			Video			Groundfish		
Year	**OBS**	**PRED**	**Std. Err.**	**OBS**	**PRED**	**Std. Err.**	**OBS**	**PRED**	**Std. Err.**
1986	0.503	1.760	0.292						
1987	1.185	1.668	0.190						
1988									
1989									
1990	0.800	1.488	0.223						
1991	1.570	1.421	0.203						
1992									
1993	0.573	1.283	0.205	0.825	1.171	0.333			
1994	0.929	1.177	0.185	2.211	1.064	0.236			
1995	0.616	1.049	0.214	1.658	0.935	0.298			
1996	0.859	0.941	0.192	0.278	0.868	0.244			
1997	0.936	0.886	0.175	1.191	0.825	0.176			
1998									
1999	0.625	0.772	0.218						
2000	0.749	0.763	0.204						
2001	0.836	0.810	0.199						
2002				0.398	0.926	0.262			
2003	1.313	0.856	0.182						
2004				0.772	0.892	0.242			
2005				0.624	0.851	0.142			
2006	1.247	0.818	0.190	0.263	0.871	0.198			
2007	1.570	0.865	0.192	0.213	0.958	0.188			
2008				0.773	0.988	0.168			
2009	1.189	0.909	0.192	1.219	0.937	0.130	0.847	0.800	0.195
2010	1.138	0.846	0.185	1.397	0.888	0.159	0.739	0.874	0.213
2011	1.122	0.867	0.178	1.594	0.897	0.109	1.609	1.013	0.209
2012	1.240	0.839	0.181	1.124	0.948	0.154	1.244	1.075	0.169
2013				0.794	1.018	0.210	0.853	1.046	0.204
2014				1.666	1.061	0.151	0.708	1.032	0.209

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)	10.1916	0.054803	Estimated
SR_BH_steep	0.572558	0.03089	Estimated
SR_sigmaR	0.226101	0.04857	Estimated
Main_RecrDev_1994	-0.3097	0.127298	Estimated
Main_RecrDev_1995	-0.1173	0.107095	Estimated
Main_RecrDev_1996	-0.08586	0.107003	Estimated
Main_RecrDev_1997	-0.04322	0.113269	Estimated
Main_RecrDev_1998	-0.24928	0.102637	Estimated
Main_RecrDev_1999	0.333137	0.079011	Estimated
Main_RecrDev_2000	0.201866	0.082366	Estimated
Main_RecrDev_2001	0.187866	0.083479	Estimated
Main_RecrDev_2002	0.093485	0.078775	Estimated
Main_RecrDev_2003	0.047036	0.077845	Estimated
Main_RecrDev_2004	-0.22197	0.07879	Estimated
Main_RecrDev_2005	-0.03557	0.071188	Estimated
Main_RecrDev_2006	0.354225	0.066614	Estimated
Main_RecrDev_2007	-0.04889	0.079164	Estimated
Main_RecrDev_2008	-0.20638	0.089611	Estimated
Main_RecrDev_2009	-0.35949	0.093917	Estimated
Main_RecrDev_2010	0.081319	0.085716	Estimated
Main_RecrDev_2011	0.210623	0.10562	Estimated
Main_RecrDev_2012	0.168093	0.154244	Estimated
F_fleet_1_YR_1950_s_1	3.54E-05	2.81E-06	Estimated
F_fleet_1_YR_1951_s_1	7.07E-05	5.61E-06	Estimated
F_fleet_1_YR_1952_s_1	0.000107	8.46E-06	Estimated
F_fleet_1_YR_1953_s_1	0.000144	1.14E-05	Estimated
F_fleet_1_YR_1954_s_1	0.000183	1.43E-05	Estimated
F_fleet_1_YR_1955_s_1	0.000222	1.74E-05	Estimated
F_fleet_1_YR_1956_s_1	0.000263	2.05E-05	Estimated
F_fleet_1_YR_1957_s_1	0.000305	2.37E-05	Estimated
F_fleet_1_YR_1958_s_1	0.00035	2.70E-05	Estimated
F_fleet_1_YR_1959_s_1	0.000397	3.05E-05	Estimated
F_fleet_1_YR_1960_s_1	0.000447	3.43E-05	Estimated
F_fleet_1_YR_1961_s_1	0.000499	3.81E-05	Estimated
F_fleet_1_YR_1962_s_1	0.000552	4.21E-05	Estimated
F_fleet_1_YR_1963_s_1	0.000603	4.59E-05	Estimated
F_fleet_1_YR_1964_s_1	0.000667	5.06E-05	Estimated

F_fleet_1_YR_1965_s_1	0.00067	5.07E-05	Estimated
F_fleet_1_YR_1966_s_1	0.000354	2.67E-05	Estimated
F_fleet_1_YR_1967_s_1	0.000727	5.47E-05	Estimated
F_fleet_1_YR_1968_s_1	0.001466	0.00011	Estimated
F_fleet_1_YR_1969_s_1	0.001897	0.000142	Estimated
F_fleet_1_YR_1970_s_1	0.001799	0.000135	Estimated
F_fleet_1_YR_1971_s_1	0.002	0.000149	Estimated
F_fleet_1_YR_1972_s_1	0.001792	0.000134	Estimated
F_fleet_1_YR_1973_s_1	0.00306	0.000228	Estimated
F_fleet_1_YR_1974_s_1	0.002938	0.000219	Estimated
F_fleet_1_YR_1975_s_1	0.006476	0.000483	Estimated
F_fleet_1_YR_1976_s_1	0.005762	0.00043	Estimated
F_fleet_1_YR_1977_s_1	0.007918	0.000591	Estimated
F_fleet_1_YR_1978_s_1	0.006915	0.000516	Estimated
F_fleet_1_YR_1979_s_1	0.005359	0.000399	Estimated
F_fleet_1_YR_1980_s_1	0.00398	0.000296	Estimated
F_fleet_1_YR_1981_s_1	0.005861	0.000435	Estimated
F_fleet_1_YR_1982_s_1	0.006185	0.000459	Estimated
F_fleet_1_YR_1983_s_1	0.009938	0.000739	Estimated
F_fleet_1_YR_1984_s_1	0.014296	0.001063	Estimated
F_fleet_1_YR_1985_s_1	0.018691	0.001394	Estimated
F_fleet_1_YR_1986_s_1	0.02014	0.001515	Estimated
F_fleet_1_YR_1987_s_1	0.016542	0.001261	Estimated
F_fleet_1_YR_1988_s_1	0.016126	0.001246	Estimated
F_fleet_1_YR_1989_s_1	0.0164	0.001281	Estimated
F_fleet_1_YR_1990_s_1	0.040735	0.003196	Estimated
F_fleet_1_YR_1991_s_1	0.034798	0.002754	Estimated
F_fleet_1_YR_1992_s_1	0.047191	0.003773	Estimated
F_fleet_1_YR_1993_s_1	0.070643	0.005747	Estimated
F_fleet_1_YR_1994_s_1	0.074551	0.006178	Estimated
F_fleet_1_YR_1995_s_1	0.07939	0.006698	Estimated
F_fleet_1_YR_1996_s_1	0.066956	0.005694	Estimated
F_fleet_1_YR_1997_s_1	0.065982	0.005595	Estimated
F_fleet_1_YR_1998_s_1	0.054671	0.004634	Estimated
F_fleet_1_YR_1999_s_1	0.066039	0.005563	Estimated
F_fleet_1_YR_2000_s_1	0.052372	0.004397	Estimated
F_fleet_1_YR_2001_s_1	0.060783	0.005103	Estimated
F_fleet_1_YR_2002_s_1	0.069628	0.005769	Estimated
F_fleet_1_YR_2003_s_1	0.07797	0.006203	Estimated
F_fleet_1_YR_2004_s_1	0.062659	0.004975	Estimated
F_fleet_1_YR_2005_s_1	0.065983	0.00523	Estimated
F_fleet_1_YR_2006_s_1	0.074652	0.00587	Estimated
F_fleet_1_YR_2007_s_1	0.080903	0.006503	Estimated

F_fleet_1_YR_2008_s_1	0.120963	0.009969	Estimated
F_fleet_1_YR_2009_s_1	0.17475	0.014414	Estimated
F_fleet_1_YR_2010_s_1	0.083961	0.006839	Estimated
F_fleet_1_YR_2011_s_1	0.165966	0.01381	Estimated
F_fleet_1_YR_2012_s_1	0.121066	0.011093	Estimated
F_fleet_1_YR_2013_s_1	0.065035	0.006202	Estimated
F_fleet_1_YR_2014_s_1	0.047503	0.004541	Estimated
F_fleet_2_YR_1950_s_1	2.95E-05	2.44E-06	Estimated
F_fleet_2_YR_1951_s_1	5.90E-05	4.88E-06	Estimated
F_fleet_2_YR_1952_s_1	8.88E-05	7.32E-06	Estimated
F_fleet_2_YR_1953_s_1	0.000119	9.80E-06	Estimated
F_fleet_2_YR_1954_s_1	0.000151	1.23E-05	Estimated
F_fleet_2_YR_1955_s_1	0.000184	1.50E-05	Estimated
F_fleet_2_YR_1956_s_1	0.000217	1.76E-05	Estimated
F_fleet_2_YR_1957_s_1	0.000252	2.04E-05	Estimated
F_fleet_2_YR_1958_s_1	0.000288	2.32E-05	Estimated
F_fleet_2_YR_1959_s_1	0.000327	2.62E-05	Estimated
F_fleet_2_YR_1960_s_1	0.000368	2.93E-05	Estimated
F_fleet_2_YR_1961_s_1	0.000411	3.26E-05	Estimated
F_fleet_2_YR_1962_s_1	0.000455	3.61E-05	Estimated
F_fleet_2_YR_1963_s_1	0.0005	3.97E-05	Estimated
F_fleet_2_YR_1964_s_1	0.000529	4.20E-05	Estimated
F_fleet_2_YR_1965_s_1	0.000472	3.74E-05	Estimated
F_fleet_2_YR_1966_s_1	0.000153	1.21E-05	Estimated
F_fleet_2_YR_1967_s_1	0.000367	2.89E-05	Estimated
F_fleet_2_YR_1968_s_1	0.001189	9.33E-05	Estimated
F_fleet_2_YR_1969_s_1	0.000651	5.10E-05	Estimated
F_fleet_2_YR_1970_s_1	0.001084	8.48E-05	Estimated
F_fleet_2_YR_1971_s_1	0.001194	9.32E-05	Estimated
F_fleet_2_YR_1972_s_1	0.001175	9.17E-05	Estimated
F_fleet_2_YR_1973_s_1	0.001409	0.00011	Estimated
F_fleet_2_YR_1974_s_1	0.001737	0.000136	Estimated
F_fleet_2_YR_1975_s_1	0.00288	0.000226	Estimated
F_fleet_2_YR_1976_s_1	0.001616	0.000127	Estimated
F_fleet_2_YR_1977_s_1	0.005288	0.000415	Estimated
F_fleet_2_YR_1978_s_1	0.004494	0.000353	Estimated
F_fleet_2_YR_1979_s_1	0.006163	0.000484	Estimated
F_fleet_2_YR_1980_s_1	0.004214	0.00033	Estimated
F_fleet_2_YR_1981_s_1	0.003333	0.000261	Estimated
F_fleet_2_YR_1982_s_1	0.004316	0.000338	Estimated
F_fleet_2_YR_1983_s_1	0.004873	0.000383	Estimated
F_fleet_2_YR_1984_s_1	0.026241	0.002076	Estimated
F_fleet_2_YR_1985_s_1	0.023667	0.001888	Estimated

F_fleet_2_YR_1986_s_1	0.031706	0.002557	Estimated
F_fleet_2_YR_1987_s_1	0.03612	0.002964	Estimated
F_fleet_2_YR_1988_s_1	0.038114	0.003188	Estimated
F_fleet_2_YR_1989_s_1	0.040756	0.003476	Estimated
F_fleet_2_YR_1990_s_1	0.041058	0.00356	Estimated
F_fleet_2_YR_1991_s_1	0.036432	0.003209	Estimated
F_fleet_2_YR_1992_s_1	0.050458	0.004521	Estimated
F_fleet_2_YR_1993_s_1	0.053317	0.0049	Estimated
F_fleet_2_YR_1994_s_1	0.059707	0.005626	Estimated
F_fleet_2_YR_1995_s_1	0.041549	0.003981	Estimated
F_fleet_2_YR_1996_s_1	0.045296	0.00439	Estimated
F_fleet_2_YR_1997_s_1	0.081695	0.007916	Estimated
F_fleet_2_YR_1998_s_1	0.074234	0.007206	Estimated
F_fleet_2_YR_1999_s_1	0.097086	0.009485	Estimated
F_fleet_2_YR_2000_s_1	0.070587	0.006884	Estimated
F_fleet_2_YR_2001_s_1	0.087183	0.008397	Estimated
F_fleet_2_YR_2002_s_1	0.096816	0.009698	Estimated
F_fleet_2_YR_2003_s_1	0.115018	0.011687	Estimated
F_fleet_2_YR_2004_s_1	0.10891	0.010637	Estimated
F_fleet_2_YR_2005_s_1	0.078301	0.007504	Estimated
F_fleet_2_YR_2006_s_1	0.054975	0.005178	Estimated
F_fleet_2_YR_2007_s_1	0.119141	0.01161	Estimated
F_fleet_2_YR_2008_s_1	0.104307	0.010356	Estimated
F_fleet_2_YR_2009_s_1	0.104946	0.011057	Estimated
F_fleet_2_YR_2010_s_1	0.079449	0.008597	Estimated
F_fleet_2_YR_2011_s_1	0.072028	0.007485	Estimated
F_fleet_2_YR_2012_s_1	0.088951	0.009499	Estimated
F_fleet_2_YR_2013_s_1	0.055597	0.006163	Estimated
F_fleet_2_YR_2014_s_1	0.061781	0.007122	Estimated
F_fleet_3_YR_1950_s_1	0.000161	2.82E-05	Estimated
F_fleet_3_YR_1951_s_1	0.000324	5.67E-05	Estimated
F_fleet_3_YR_1952_s_1	0.000491	8.60E-05	Estimated
F_fleet_3_YR_1953_s_1	0.000666	0.000117	Estimated
F_fleet_3_YR_1954_s_1	0.000848	0.000148	Estimated
F_fleet_3_YR_1955_s_1	0.001036	0.000181	Estimated
F_fleet_3_YR_1956_s_1	0.001232	0.000215	Estimated
F_fleet_3_YR_1957_s_1	0.001437	0.000251	Estimated
F_fleet_3_YR_1958_s_1	0.001655	0.000289	Estimated
F_fleet_3_YR_1959_s_1	0.001889	0.000329	Estimated
F_fleet_3_YR_1960_s_1	0.002139	0.000373	Estimated
F_fleet_3_YR_1961_s_1	0.002401	0.000419	Estimated
F_fleet_3_YR_1962_s_1	0.002654	0.000463	Estimated
F_fleet_3_YR_1963_s_1	0.002882	0.000503	Estimated

F_fleet_3_YR_1964_s_1	0.003101	0.00054	Estimated
F_fleet_3_YR_1965_s_1	0.00333	0.000579	Estimated
F_fleet_3_YR_1966_s_1	0.003572	0.000621	Estimated
F_fleet_3_YR_1967_s_1	0.003825	0.000664	Estimated
F_fleet_3_YR_1968_s_1	0.004091	0.000711	Estimated
F_fleet_3_YR_1969_s_1	0.00437	0.000759	Estimated
F_fleet_3_YR_1970_s_1	0.004667	0.000811	Estimated
F_fleet_3_YR_1971_s_1	0.004978	0.000866	Estimated
F_fleet_3_YR_1972_s_1	0.005279	0.000918	Estimated
F_fleet_3_YR_1973_s_1	0.00556	0.000967	Estimated
F_fleet_3_YR_1974_s_1	0.005836	0.001015	Estimated
F_fleet_3_YR_1975_s_1	0.00612	0.001064	Estimated
F_fleet_3_YR_1976_s_1	0.006407	0.001113	Estimated
F_fleet_3_YR_1977_s_1	0.006708	0.001165	Estimated
F_fleet_3_YR_1978_s_1	0.007036	0.001222	Estimated
F_fleet_3_YR_1979_s_1	0.00739	0.001283	Estimated
F_fleet_3_YR_1980_s_1	0.00776	0.001348	Estimated
F_fleet_3_YR_1981_s_1	0.008193	0.001423	Estimated
F_fleet_3_YR_1982_s_1	0.025556	0.004461	Estimated
F_fleet_3_YR_1983_s_1	0.007463	0.001295	Estimated
F_fleet_3_YR_1984_s_1	0.01064	0.001844	Estimated
F_fleet_3_YR_1985_s_1	0.018801	0.003252	Estimated
F_fleet_3_YR_1986_s_1	0.046914	0.008123	Estimated
F_fleet_3_YR_1987_s_1	0.051555	0.008941	Estimated
F_fleet_3_YR_1988_s_1	0.072351	0.012531	Estimated
F_fleet_3_YR_1989_s_1	0.046253	0.007978	Estimated
F_fleet_3_YR_1990_s_1	0.062801	0.010731	Estimated
F_fleet_3_YR_1991_s_1	0.065065	0.011158	Estimated
F_fleet_3_YR_1992_s_1	0.083255	0.014356	Estimated
F_fleet_3_YR_1993_s_1	0.07781	0.013436	Estimated
F_fleet_3_YR_1994_s_1	0.070236	0.012237	Estimated
F_fleet_3_YR_1995_s_1	0.104843	0.018612	Estimated
F_fleet_3_YR_1996_s_1	0.051342	0.009084	Estimated
F_fleet_3_YR_1997_s_1	0.059321	0.010428	Estimated
F_fleet_3_YR_1998_s_1	0.030233	0.005248	Estimated
F_fleet_3_YR_1999_s_1	0.042253	0.007248	Estimated
F_fleet_3_YR_2000_s_1	0.033812	0.005786	Estimated
F_fleet_3_YR_2001_s_1	0.06206	0.010395	Estimated
F_fleet_3_YR_2002_s_1	0.045522	0.007663	Estimated
F_fleet_3_YR_2003_s_1	0.048363	0.008023	Estimated
F_fleet_3_YR_2004_s_1	0.064737	0.010619	Estimated
F_fleet_3_YR_2005_s_1	0.050529	0.008478	Estimated
F_fleet_3_YR_2006_s_1	0.04475	0.007606	Estimated

F_fleet_3_YR_2007_s_1	0.041675	0.007051	Estimated
F_fleet_3_YR_2008_s_1	0.041813	0.007039	Estimated
F_fleet_3_YR_2009_s_1	0.050968	0.00847	Estimated
F_fleet_3_YR_2010_s_1	0.031087	0.005246	Estimated
F_fleet_3_YR_2011_s_1	0.09292	0.015829	Estimated
F_fleet_3_YR_2012_s_1	0.061806	0.01128	Estimated
F_fleet_3_YR_2013_s_1	0.102864	0.019225	Estimated
F_fleet_3_YR_2014_s_1	0.083509	0.01543	Estimated
F_fleet_4_YR_1950_s_1	0.046194	0.010101	Estimated
F_fleet_4_YR_1951_s_1	0.063006	0.013778	Estimated
F_fleet_4_YR_1952_s_1	0.074432	0.016277	Estimated
F_fleet_4_YR_1953_s_1	0.078235	0.01711	Estimated
F_fleet_4_YR_1954_s_1	0.101452	0.02219	Estimated
F_fleet_4_YR_1955_s_1	0.105762	0.023134	Estimated
F_fleet_4_YR_1956_s_1	0.135253	0.02959	Estimated
F_fleet_4_YR_1957_s_1	0.154872	0.033888	Estimated
F_fleet_4_YR_1958_s_1	0.189749	0.041529	Estimated
F_fleet_4_YR_1959_s_1	0.204613	0.044792	Estimated
F_fleet_4_YR_1960_s_1	0.204632	0.044805	Estimated
F_fleet_4_YR_1961_s_1	0.154967	0.033927	Estimated
F_fleet_4_YR_1962_s_1	0.149247	0.03268	Estimated
F_fleet_4_YR_1963_s_1	0.170253	0.037295	Estimated
F_fleet_4_YR_1964_s_1	0.179929	0.039428	Estimated
F_fleet_4_YR_1965_s_1	0.199884	0.043822	Estimated
F_fleet_4_YR_1966_s_1	0.19682	0.043164	Estimated
F_fleet_4_YR_1967_s_1	0.214626	0.047097	Estimated
F_fleet_4_YR_1968_s_1	0.218287	0.047922	Estimated
F_fleet_4_YR_1969_s_1	0.248526	0.054609	Estimated
F_fleet_4_YR_1970_s_1	0.234332	0.05151	Estimated
F_fleet_4_YR_1971_s_1	0.223769	0.049268	Estimated
F_fleet_4_YR_1972_s_1	0.219978	0.046741	Estimated
F_fleet_4_YR_1973_s_1	0.223402	0.048349	Estimated
F_fleet_4_YR_1974_s_1	0.222655	0.048212	Estimated
F_fleet_4_YR_1975_s_1	0.224283	0.048576	Estimated
F_fleet_4_YR_1976_s_1	0.232866	0.05041	Estimated
F_fleet_4_YR_1977_s_1	0.255111	0.055128	Estimated
F_fleet_4_YR_1978_s_1	0.269042	0.057985	Estimated
F_fleet_4_YR_1979_s_1	0.280531	0.060212	Estimated
F_fleet_4_YR_1980_s_1	0.28521	0.060855	Estimated
F_fleet_4_YR_1981_s_1	0.269107	0.057041	Estimated
F_fleet_4_YR_1982_s_1	0.244297	0.051382	Estimated
F_fleet_4_YR_1983_s_1	0.248183	0.051389	Estimated
F_fleet_4_YR_1984_s_1	0.278441	0.056948	Estimated

F_fleet_4_YR_1985_s_1	0.26979	0.055751	Estimated
F_fleet_4_YR_1986_s_1	0.300923	0.060698	Estimated
F_fleet_4_YR_1987_s_1	0.252188	0.049074	Estimated
F_fleet_4_YR_1988_s_1	0.227474	0.045033	Estimated
F_fleet_4_YR_1989_s_1	0.230018	0.044783	Estimated
F_fleet_4_YR_1990_s_1	0.224474	0.044401	Estimated
F_fleet_4_YR_1991_s_1	0.243216	0.047701	Estimated
F_fleet_4_YR_1992_s_1	0.301	0.055877	Estimated
F_fleet_4_YR_1993_s_1	0.37227	0.077806	Estimated
F_fleet_4_YR_1994_s_1	0.459271	0.08898	Estimated
F_fleet_4_YR_1995_s_1	0.374443	0.085402	Estimated
F_fleet_4_YR_1996_s_1	0.370918	0.075838	Estimated
F_fleet_4_YR_1997_s_1	0.380803	0.078894	Estimated
F_fleet_4_YR_1998_s_1	0.479914	0.096606	Estimated
F_fleet_4_YR_1999_s_1	0.298513	0.065419	Estimated
F_fleet_4_YR_2000_s_1	0.213855	0.043848	Estimated
F_fleet_4_YR_2001_s_1	0.244391	0.049399	Estimated
F_fleet_4_YR_2002_s_1	0.297596	0.05931	Estimated
F_fleet_4_YR_2003_s_1	0.263727	0.053617	Estimated
F_fleet_4_YR_2004_s_1	0.273101	0.055723	Estimated
F_fleet_4_YR_2005_s_1	0.220634	0.046995	Estimated
F_fleet_4_YR_2006_s_1	0.129154	0.027711	Estimated
F_fleet_4_YR_2007_s_1	0.082013	0.017288	Estimated
F_fleet_4_YR_2008_s_1	0.064782	0.013847	Estimated
F_fleet_4_YR_2009_s_1	0.111123	0.02434	Estimated
F_fleet_4_YR_2010_s_1	0.087035	0.019479	Estimated
F_fleet_4_YR_2011_s_1	0.089161	0.019868	Estimated
F_fleet_4_YR_2012_s_1	0.075894	0.016888	Estimated
F_fleet_4_YR_2013_s_1	0.08155	0.017793	Estimated
F_fleet_4_YR_2014_s_1	0.06324	0.013753	Estimated
LnQ_base_4_SMP_BYC	1.43823	0.088338	Estimated
SizeSel_10P_1_VIDEO	27.3943	0.279056	Estimated
SizeSel_10P_2_VIDEO	-8.52527	30.4618	Estimated
SizeSel_10P_3_VIDEO	4.16955	0.09621	Estimated
SizeSel_10P_4_VIDEO	-3.81667	5.44402	Estimated
SizeSel_10P_5_VIDEO	-5.38037	1.37413	Estimated
SizeSel_10P_6_VIDEO	1.07568	0.525359	Estimated
SizeSel_11P_1_GROUNDFISH	13.0293	12.734	Estimated
SizeSel_11P_2_GROUNDFISH	-5.38036	70.6612	Estimated
SizeSel_11P_3_GROUNDFISH	-0.52125	48.3058	Estimated
SizeSel_11P_4_GROUNDFISH	3.6083	0.684615	Estimated
SizeSel_11P_5_GROUNDFISH	-0.44483	0.716334	Estimated
SizeSel_11P_6_GROUNDFISH	-5.8722	4.77931	Estimated

AgeSel_1P_1_CM_E	2.40093	0.111846	Estimated
AgeSel_1P_2_CM_E	0.815116	0.147362	Estimated
AgeSel_2P_1_CM_W	3.43436	0.163385	Estimated
AgeSel_2P_2_CM_W	1.36515	0.172859	Estimated
AgeSel_3P_1_REC	3.8971	0.105905	Estimated
AgeSel_3P_2_REC	-1.95988	1.29777	Estimated
AgeSel_3P_3_REC	0.476059	0.111911	Estimated
AgeSel_3P_4_REC	3.38152	0.936125	Estimated
AgeSel_3P_5_REC	-14.188	19.2499	Estimated
AgeSel_3P_6_REC	-2.49577	1.03735	Estimated
AgeSel_4P_1_SMP_BYC	0.5	NA	Fixed
AgeSel_4P_2_SMP_BYC	100	NA	Fixed
AgeSel_4P_3_SMP_BYC	1.5	NA	Fixed
AgeSel_4P_4_SMP_BYC	2.4096	NA	Fixed
AgeSel_4P_5_SMP_BYC	0	NA	Fixed
AgeSel_4P_6_SMP_BYC	0	NA	Fixed
AgeSel_1P_1_CM_E_BLK1repl_2007	2.47319	0.102337	Estimated
AgeSel_1P_2_CM_E_BLK1repl_2007	0.838296	0.12417	Estimated
AgeSel_2P_1_CM_W_BLK1repl_2007	3.91039	0.136103	Estimated
AgeSel_2P_2_CM_W_BLK1repl_2007	1.4895	0.132145	Estimated

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	0.046	0.011
1951	0.000	0.000	0.000	0.063	0.015
1952	0.000	0.000	0.000	0.074	0.018
1953	0.000	0.000	0.001	0.078	0.019
1954	0.000	0.000	0.001	0.101	0.025
1955	0.000	0.000	0.001	0.106	0.026
1956	0.000	0.000	0.001	0.135	0.033
1957	0.000	0.000	0.001	0.155	0.038
1958	0.000	0.000	0.002	0.190	0.046
1959	0.000	0.000	0.002	0.205	0.050
1960	0.000	0.000	0.002	0.205	0.050
1961	0.000	0.000	0.002	0.155	0.040
1962	0.001	0.000	0.003	0.149	0.039
1963	0.001	0.000	0.003	0.170	0.044
1964	0.001	0.001	0.003	0.180	0.047
1965	0.001	0.000	0.003	0.200	0.051
1966	0.000	0.000	0.004	0.197	0.051
1967	0.001	0.000	0.004	0.215	0.056
1968	0.001	0.001	0.004	0.218	0.058
1969	0.002	0.001	0.004	0.249	0.065
1970	0.002	0.001	0.005	0.234	0.062
1971	0.002	0.001	0.005	0.224	0.061
1972	0.002	0.001	0.005	0.220	0.060
1973	0.003	0.001	0.006	0.223	0.062
1974	0.003	0.002	0.006	0.223	0.062
1975	0.006	0.003	0.006	0.224	0.065
1976	0.006	0.002	0.006	0.233	0.067
1977	0.008	0.005	0.007	0.255	0.075
1978	0.007	0.004	0.007	0.269	0.078
1979	0.005	0.006	0.007	0.281	0.081
1980	0.004	0.004	0.008	0.285	0.081
1981	0.006	0.003	0.008	0.269	0.079
1982	0.006	0.004	0.026	0.244	0.080
1983	0.010	0.005	0.007	0.248	0.077
1984	0.014	0.026	0.011	0.278	0.095
1985	0.019	0.024	0.019	0.270	0.098
1986	0.020	0.032	0.047	0.301	0.119
1987	0.017	0.036	0.052	0.252	0.110

1988	0.016	0.038	0.072	0.227	0.110
1989	0.016	0.041	0.046	0.230	0.104
1990	0.041	0.041	0.063	0.224	0.118
1991	0.035	0.036	0.065	0.243	0.120
1992	0.047	0.050	0.083	0.301	0.151
1993	0.071	0.053	0.078	0.372	0.178
1994	0.075	0.060	0.070	0.459	0.203
1995	0.079	0.042	0.105	0.374	0.182
1996	0.067	0.045	0.051	0.371	0.171
1997	0.066	0.082	0.059	0.381	0.186
1998	0.055	0.074	0.030	0.480	0.200
1999	0.066	0.097	0.042	0.299	0.159
2000	0.052	0.071	0.034	0.214	0.131
2001	0.061	0.087	0.062	0.244	0.143
2002	0.070	0.097	0.046	0.298	0.160
2003	0.078	0.115	0.048	0.264	0.158
2004	0.063	0.109	0.065	0.273	0.159
2005	0.066	0.078	0.051	0.221	0.131
2006	0.075	0.055	0.045	0.129	0.104
2007	0.081	0.119	0.042	0.082	0.093
2008	0.121	0.104	0.042	0.065	0.094
2009	0.175	0.105	0.051	0.111	0.138
2010	0.084	0.079	0.031	0.087	0.091
2011	0.166	0.072	0.093	0.089	0.136
2012	0.121	0.089	0.062	0.076	0.100
2013	0.065	0.056	0.103	0.082	0.088
2014	0.048	0.062	0.084	0.063	0.076

Table 18: Model beginning of year 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	33,700	6.57E+14	91,655	26,678	1.00
1951	33,526	6.54E+14	90,800	26,653	1.00
1952	33,259	6.49E+14	89,837	26,614	0.99
1953	32,929	6.42E+14	88,863	26,564	0.98
1954	32,580	6.35E+14	87,999	26,510	0.97
1955	32,161	6.27E+14	86,880	26,444	0.95
1956	31,737	6.19E+14	85,889	26,375	0.94
1957	31,237	6.09E+14	84,572	26,292	0.93
1958	30,690	5.98E+14	83,182	26,200	0.91
1959	30,057	5.86E+14	81,496	26,089	0.89
1960	29,400	5.73E+14	79,898	25,969	0.87
1961	28,775	5.61E+14	78,569	25,851	0.85
1962	28,344	5.52E+14	78,178	25,764	0.84
1963	28,006	5.45E+14	77,844	25,695	0.83
1964	27,668	5.38E+14	77,186	25,626	0.82
1965	27,339	5.32E+14	76,479	25,557	0.81
1966	26,982	5.25E+14	75,588	25,482	0.80
1967	26,666	5.19E+14	74,917	25,414	0.79
1968	26,312	5.12E+14	74,062	25,336	0.78
1969	25,938	5.04E+14	73,247	25,252	0.77
1970	25,510	4.96E+14	72,129	25,155	0.76
1971	25,135	4.89E+14	71,397	25,066	0.74
1972	24,817	4.82E+14	70,886	24,988	0.73
1973	24,554	4.77E+14	70,475	24,922	0.73
1974	24,290	4.72E+14	70,004	24,856	0.72
1975	24,057	4.67E+14	69,591	24,796	0.71
1976	23,764	4.61E+14	69,058	24,720	0.70
1977	23,514	4.56E+14	68,519	24,654	0.69
1978	23,133	4.49E+14	67,602	24,552	0.68
1979	22,772	4.42E+14	66,699	24,454	0.67
1980	22,405	4.34E+14	65,803	24,351	0.66
1981	22,101	4.29E+14	65,074	24,264	0.65
1982	21,837	4.23E+14	64,625	24,186	0.64
1983	21,454	4.16E+14	64,148	24,068	0.63
1984	21,263	4.12E+14	63,870	24,009	0.63
1985	20,641	3.99E+14	62,590	23,812	0.61
1986	20,005	3.87E+14	61,381	23,600	0.59

1987	18,986	3.67E+14	59,234	23,242	0.56
1988	18,196	3.51E+14	57,946	22,941	0.53
1989	17,425	3.35E+14	56,740	22,628	0.51
1990	17,007	3.27E+14	55,975	22,450	0.50
1991	16,265	3.12E+14	54,605	22,120	0.48
1992	15,708	3.01E+14	53,306	21,861	0.46
1993	14,720	2.82E+14	50,846	21,371	0.43
1994	13,529	2.59E+14	47,670	14,940	0.39
1995	11,999	2.31E+14	39,639	17,291	0.35
1996	10,807	2.07E+14	37,629	17,034	0.31
1997	10,203	1.95E+14	36,479	17,326	0.30
1998	9,508	1.81E+14	35,467	13,643	0.28
1999	8,889	1.70E+14	31,521	23,716	0.26
2000	8,939	1.68E+14	38,307	20,684	0.26
2001	9,486	1.78E+14	40,681	20,971	0.27
2002	9,847	1.85E+14	42,048	19,412	0.28
2003	9,985	1.88E+14	41,119	18,674	0.29
2004	9,898	1.87E+14	40,111	14,225	0.28
2005	9,527	1.81E+14	35,946	16,896	0.28
2006	9,490	1.80E+14	36,478	24,880	0.27
2007	10,142	1.90E+14	43,916	17,046	0.29
2008	10,490	1.98E+14	42,762	14,821	0.30
2009	10,534	2.00E+14	40,426	12,770	0.30
2010	9,772	1.86E+14	35,838	19,229	0.28
2011	10,073	1.91E+14	39,538	22,158	0.29
2012	9,841	1.84E+14	42,610	21,062	0.28
2013	10,329	1.94E+14	44,854	18,442	0.29
2014	10,952	2.06E+14	44,777	18,960	0.31

Table 19: Model estimated correlation coefficients for correlations above the minimum threshold of 0.70.

Parameter 1	Parameter 2	Correlation Coefficient
F_fleet_1_YR_1950_s_1	SR_LN(R0)	-0.706462
F_fleet_1_YR_1951_s_1	SR_LN(R0)	-0.705903
F_fleet_1_YR_1952_s_1	SR_LN(R0)	-0.704011
F_fleet_1_YR_1953_s_1	SR_LN(R0)	-0.701118
F_fleet_2_YR_2009_s_1	F_fleet_2_YR_2008_s_1	0.70289
F_fleet_2_YR_2010_s_1	F_fleet_2_YR_2009_s_1	0.725396
F_fleet_2_YR_2011_s_1	F_fleet_2_YR_2010_s_1	0.718963
F_fleet_2_YR_2012_s_1	F_fleet_2_YR_2011_s_1	0.707596
F_fleet_2_YR_2013_s_1	F_fleet_2_YR_2012_s_1	0.730821
F_fleet_2_YR_2014_s_1	F_fleet_2_YR_2012_s_1	0.701514
F_fleet_2_YR_2014_s_1	F_fleet_2_YR_2013_s_1	0.741111
SizeSel_10P_4_VIDEO	SizeSel_10P_1_VIDEO	-0.81942
SizeSel_11P_2_GROUNDFISH	SizeSel_11P_1_GROUNDFISH	-0.981534
SizeSel_11P_3_GROUNDFISH	SizeSel_11P_1_GROUNDFISH	0.999775
SizeSel_11P_3_GROUNDFISH	SizeSel_11P_2_GROUNDFISH	-0.980279
AgeSel_1P_2_CM_E	AgeSel_1P_1_CM_E	0.852467
AgeSel_2P_2_CM_W	AgeSel_2P_1_CM_W	0.80111
AgeSel_3P_3_REC	AgeSel_3P_1_REC	0.915949
AgeSel_3P_4_REC	AgeSel_3P_2_REC	-0.841894
AgeSel_1P_2_CM_E_BLK1repl_2007	AgeSel_1P_1_CM_E_BLK1repl_2007	0.861689
AgeSel_2P_2_CM_W_BLK1repl_2007	AgeSel_2P_1_CM_W_BLK1repl_2007	0.786748

Table 20: Settings used for vermilion snapper projections and forecasts.

Parameter	Value	Comment
Relative F	Average from 2012 – 2014	Average relative fishing mortality over terminal three years (2012-2014) of model
Selectivity	Estimates from 2014	Fleet specific selectivity estimated in terminal year
Recruitment	17,343,300	Bias adjusted geometric mean recruitment over recent time period (2004 – 2014) Time-invariant in projections
Shrimp Bycatch	F = 0.0735	Average shrimp bycatch fishing mortality over terminal three years (2012-2014) of model Time-invariant in projections
2015 Landings	2,311,176 lbs. WW	Provisional landings
2016 Landings	2,733,851 lbs. WW	Terminal three year (2012-2014) average (80%) of ACL (3.42 million lbs. WW) caught

Table 21: Summary of MSRA benchmarks and reference points for the Gulf of Mexico vermilion snapper SEDAR 45 assessment. Note that SSB values are in number of eggs and fishing mortality is presented as a harvest rates (age-1+ number killed/age-1+ abundance). Note that harvest rates from the global YPR analysis are not directly comparable to other values, because it assumes a single optimal fleet (as opposed to extant selectivity conditions used for all other analyses)

Criteria	Definition	SEDAR 45 Value
Base M	Fully selected ages of Lorenzen M	0.25
Steepness	Estimated SR parameter (not used in projections)	0.574
Virgin Recruitment	Estimated SR parameter (not used in projections)	2.66E+07
Generation Time	Fecundity-weighted mean age	7.22
SSB Unfished	Estimated virgin population egg production	6.56E+14
Mortality Rate Criteria		
$F_{SPR30\%}$	Equilibrium F that achieves $SPR_{30\%}$	0.103
F_{CMAX}	Equilibrium F that achieves maximum yield (conditional YPR)	0.246
MFMT $F_{SPR30\%}$	$F_{SPR30\%}$	0.103
MFMT F_{CMAX}	F_{CMAX}	0.246
F at Optimum Yield	0.75 * Directed F at $F_{SPR30\%}$	0.087
F_{MAX}	Equilibrium F that achieves max yield assuming optimal selectivity (global YPR)	0.081
$F_{Current}$	F_{2014}	0.075
$F_{Current}/MFMT_{FSPR30\%}$	Current stock status based on $F_{SPR30\%}$	0.73
$F_{Current}/MFMT_{FCMAX}$	Current stock status based on F_{MAX}	0.31
Biomass Criteria		
$SSB_{FSPR30\%}$	Equilibrium SSB at $F_{SPR30\%}$	1.97E+14
SSB_{FCMAX}	Equilibrium SSB at F_{CMAX}	8.14E+13
MSST $_{FSPR30\%}$	(1-M)*$SSB_{FSPR30\%}$	1.48E+14
MSST $_{FCMAX}$	(1-M)*SSB_{FCMAX}	6.11E+13
SSB at Optimum Yield	Equilibrium SSB when Directed F = 0.75 * Directed F at $F_{SPR30\%}$	2.22E+14
SSB at Global YPR	Equilibrium SSB achieved by fishing at F_{MAX}	8.66E+13
SSB_0	Virgin SSB	6.56E+14
$SSB_{Current}$	SSB_{2014}	2.08E+14
$SSB_{Current}/SSB_{FSPR30\%}$	Current stock status based on $SSB_{FSPR30\%}$	1.05
$SSB_{Current}/SSB_{FCMAX}$	Current stock status based on SSB_{FCMAX}	2.55
$SSB_{Current}/MSST_{FSPR30\%}$	Current stock status based on $MSST_{FSPR30\%}$	1.40
$SSB_{Current}/MSST_{FCMAX}$	Current stock status based on $MSST_{FCMAX}$	3.40
$SSB_{Current}/SSB_0$	2014 SPR	0.32

Table 22: Timeseries 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 $SSB_{FSPR30\%}$ *(1-M) where M is the average natural mortality rate (0.25). SPR was calculated as annual SSB divided by SSB_0 (6.56E+14 eggs).

YEAR	F	F/FSPR30%	SSB	$SSB/SSB_{FSPR30\%}$	$SSB/MSST_{FSPR30\%}$	SPR
1950	0.01	0.11	6.56E+14	3.33	4.44	1.00
1951	0.02	0.15	6.53E+14	3.31	4.42	1.00
1952	0.02	0.17	6.48E+14	3.29	4.38	0.99
1953	0.02	0.18	6.42E+14	3.26	4.34	0.98
1954	0.02	0.24	6.35E+14	3.22	4.29	0.97
1955	0.03	0.25	6.27E+14	3.18	4.24	0.95
1956	0.03	0.32	6.18E+14	3.14	4.18	0.94
1957	0.04	0.37	6.08E+14	3.09	4.12	0.93
1958	0.05	0.45	5.98E+14	3.03	4.04	0.91
1959	0.05	0.48	5.85E+14	2.97	3.96	0.89
1960	0.05	0.49	5.73E+14	2.91	3.87	0.87
1961	0.04	0.39	5.60E+14	2.84	3.79	0.85
1962	0.04	0.38	5.51E+14	2.80	3.73	0.84
1963	0.04	0.43	5.45E+14	2.76	3.68	0.83
1964	0.05	0.45	5.38E+14	2.73	3.64	0.82
1965	0.05	0.50	5.31E+14	2.70	3.60	0.81
1966	0.05	0.49	5.24E+14	2.66	3.55	0.80
1967	0.06	0.54	5.18E+14	2.63	3.51	0.79
1968	0.06	0.56	5.11E+14	2.59	3.46	0.78
1969	0.07	0.63	5.04E+14	2.56	3.41	0.77
1970	0.06	0.61	4.95E+14	2.51	3.35	0.76
1971	0.06	0.59	4.88E+14	2.48	3.30	0.74
1972	0.06	0.59	4.82E+14	2.44	3.26	0.73
1973	0.06	0.60	4.76E+14	2.42	3.22	0.73
1974	0.06	0.60	4.71E+14	2.39	3.19	0.72
1975	0.07	0.63	4.67E+14	2.37	3.16	0.71
1976	0.07	0.65	4.61E+14	2.34	3.12	0.70
1977	0.07	0.73	4.56E+14	2.31	3.08	0.69
1978	0.08	0.76	4.48E+14	2.27	3.03	0.68
1979	0.08	0.79	4.41E+14	2.24	2.99	0.67
1980	0.08	0.79	4.34E+14	2.20	2.94	0.66
1981	0.08	0.76	4.28E+14	2.17	2.90	0.65
1982	0.08	0.78	4.23E+14	2.15	2.86	0.64
1983	0.08	0.75	4.15E+14	2.11	2.81	0.63
1984	0.10	0.93	4.11E+14	2.09	2.78	0.63

1985	0.10	0.95	3.99E+14	2.02	2.70	0.61
1986	0.12	1.16	3.86E+14	1.96	2.61	0.59
1987	0.11	1.07	3.66E+14	1.86	2.48	0.56
1988	0.11	1.07	3.51E+14	1.78	2.37	0.53
1989	0.10	1.01	3.35E+14	1.70	2.27	0.51
1990	0.12	1.15	3.27E+14	1.66	2.21	0.50
1991	0.12	1.17	3.12E+14	1.58	2.11	0.48
1992	0.15	1.46	3.01E+14	1.53	2.04	0.46
1993	0.18	1.74	2.82E+14	1.43	1.91	0.43
1994	0.20	1.98	2.59E+14	1.31	1.75	0.39
1995	0.18	1.77	2.30E+14	1.17	1.56	0.35
1996	0.17	1.66	2.07E+14	1.05	1.40	0.31
1997	0.19	1.81	1.95E+14	0.99	1.32	0.30
1998	0.20	1.95	1.81E+14	0.92	1.22	0.28
1999	0.16	1.55	1.70E+14	0.86	1.15	0.26
2000	0.13	1.27	1.68E+14	0.85	1.13	0.26
2001	0.14	1.40	1.78E+14	0.90	1.20	0.27
2002	0.16	1.56	1.85E+14	0.94	1.25	0.28
2003	0.16	1.54	1.88E+14	0.95	1.27	0.29
2004	0.16	1.55	1.87E+14	0.95	1.26	0.28
2005	0.13	1.28	1.81E+14	0.92	1.22	0.28
2006	0.10	1.01	1.80E+14	0.91	1.22	0.27
2007	0.09	0.90	1.90E+14	0.96	1.29	0.29
2008	0.09	0.91	1.98E+14	1.00	1.34	0.30
2009	0.14	1.34	2.00E+14	1.01	1.35	0.30
2010	0.09	0.89	1.86E+14	0.94	1.26	0.28
2011	0.14	1.32	1.90E+14	0.97	1.29	0.29
2012	0.10	0.97	1.84E+14	0.94	1.25	0.28
2013	0.09	0.86	1.94E+14	0.98	1.31	0.29
2014	0.08	0.73	2.08E+14	1.05	1.40	0.32
2015	0.07	0.69	2.19E+14	1.11	1.48	0.33
2016	0.08	0.78	2.29E+14	1.16	1.55	0.35

Table 23: 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, and overfishing limit (OFL; retained yield in millions of pounds that achieves SPR 30% in equilibrium).

YEAR	R	F	F/MFMT	SSB	SSB/ $SSB_{FSPR30\%}$	SSB/ MSST	SSB/ SSB_0	OFL
2017	17343.3	0.110	1.073	2.32E+14	1.18	1.57	0.35	4.17
2018	17343.3	0.107	1.045	2.21E+14	1.12	1.50	0.34	3.91
2019	17343.3	0.106	1.027	2.13E+14	1.08	1.44	0.32	3.71
2020	17343.3	0.104	1.016	2.08E+14	1.05	1.41	0.32	3.58
2021	17343.3	0.104	1.009	2.04E+14	1.04	1.38	0.31	3.49
2022	17343.3	0.103	1.005	2.02E+14	1.02	1.37	0.31	3.44
2023	17343.3	0.103	1.003	2.00E+14	1.02	1.36	0.31	3.41
2024	17343.3	0.103	1.002	1.99E+14	1.01	1.35	0.30	3.39
2025	17343.3	0.103	1.001	1.99E+14	1.01	1.34	0.30	3.37
2026	17343.3	0.103	1.001	1.98E+14	1.01	1.34	0.30	3.37

Table 24: 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 overfishing limit (OFL; retained yield in millions of pounds).

YEAR	R	F	F/MFMT	SSB	SSB/ $SSB_{FSPR30\%}$	SSB/ MSST	SSB/ SSB_0	OFL
2017	17343.3	0.090	0.876	2.32E+14	1.18	1.57	0.35	3.21
2018	17343.3	0.089	0.867	2.29E+14	1.16	1.55	0.35	3.15
2019	17343.3	0.088	0.860	2.27E+14	1.15	1.54	0.35	3.10
2020	17343.3	0.088	0.856	2.25E+14	1.14	1.53	0.34	3.05
2021	17343.3	0.088	0.854	2.24E+14	1.14	1.52	0.34	3.03
2022	17343.3	0.088	0.852	2.23E+14	1.13	1.51	0.34	3.01
2023	17343.3	0.088	0.851	2.23E+14	1.13	1.51	0.34	3.00
2024	17343.3	0.087	0.851	2.22E+14	1.13	1.51	0.34	2.99
2025	17343.3	0.087	0.851	2.22E+14	1.13	1.50	0.34	2.98
2026	17343.3	0.087	0.851	2.22E+14	1.13	1.50	0.34	2.98

Table 25: Results of projections at a constant catch rate equal to the 2014 ACT (top table) and the average of the projected 2017-2021 optimum yield OFL's (bottom table). 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 overfishing limit (OFL; retained yield in millions of pounds).

Project Constant Catch at 2014 ACT								
YEAR	**R**	**F**	**F/MFMT**	**SSB**	**SSB/ $SSB_{FSPR30\%}$**	**SSB/ MSST**	**SSB/ SSB_0**	**OFL**
2017	17343.3	0.084	0.82	2.32E+14	1.18	1.57	0.353	2.94
2018	17343.3	0.084	0.82	2.32E+14	1.18	1.57	0.353	2.94
2019	17343.3	0.084	0.82	2.31E+14	1.17	1.56	0.352	2.94
2020	17343.3	0.084	0.82	2.30E+14	1.17	1.56	0.351	2.94
2021	17343.3	0.085	0.82	2.29E+14	1.16	1.55	0.350	2.94
2022	17343.3	0.085	0.83	2.29E+14	1.16	1.55	0.348	2.94
2023	17343.3	0.085	0.83	2.28E+14	1.16	1.54	0.347	2.94
2024	17343.3	0.085	0.83	2.27E+14	1.15	1.54	0.347	2.94
2025	17343.3	0.085	0.83	2.27E+14	1.15	1.54	0.346	2.94
2026	17343.3	0.086	0.83	2.26E+14	1.15	1.53	0.345	2.94

Project Constant Catch at 2017 - 2021 Average OY								
YEAR	**R**	**F**	**F/MFMT**	**SSB**	**SSB/ $SSB_{FSPR30\%}$**	**SSB/ MSST**	**SSB/ SSB_0**	**OFL**
2017	17343.3	0.088	0.86	2.32E+14	1.18	1.57	0.353	3.11
2018	17343.3	0.088	0.86	2.30E+14	1.17	1.56	0.351	3.11
2019	17343.3	0.088	0.86	2.28E+14	1.16	1.54	0.348	3.11
2020	17343.3	0.089	0.87	2.26E+14	1.15	1.53	0.345	3.11
2021	17343.3	0.089	0.87	2.25E+14	1.14	1.52	0.342	3.11
2022	17343.3	0.090	0.87	2.23E+14	1.13	1.51	0.340	3.11
2023	17343.3	0.090	0.88	2.22E+14	1.12	1.50	0.338	3.11
2024	17343.3	0.091	0.88	2.20E+14	1.12	1.49	0.336	3.11
2025	17343.3	0.091	0.88	2.19E+14	1.11	1.48	0.334	3.11
2026	17343.3	0.091	0.89	2.18E+14	1.11	1.48	0.333	3.11

9. Figures

Figure 1: Model domain and area designations used to delineate commercially exploited stocks of vermilion snapper. The eastern stock is represented by areas 1-12 and the western stock 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. 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.

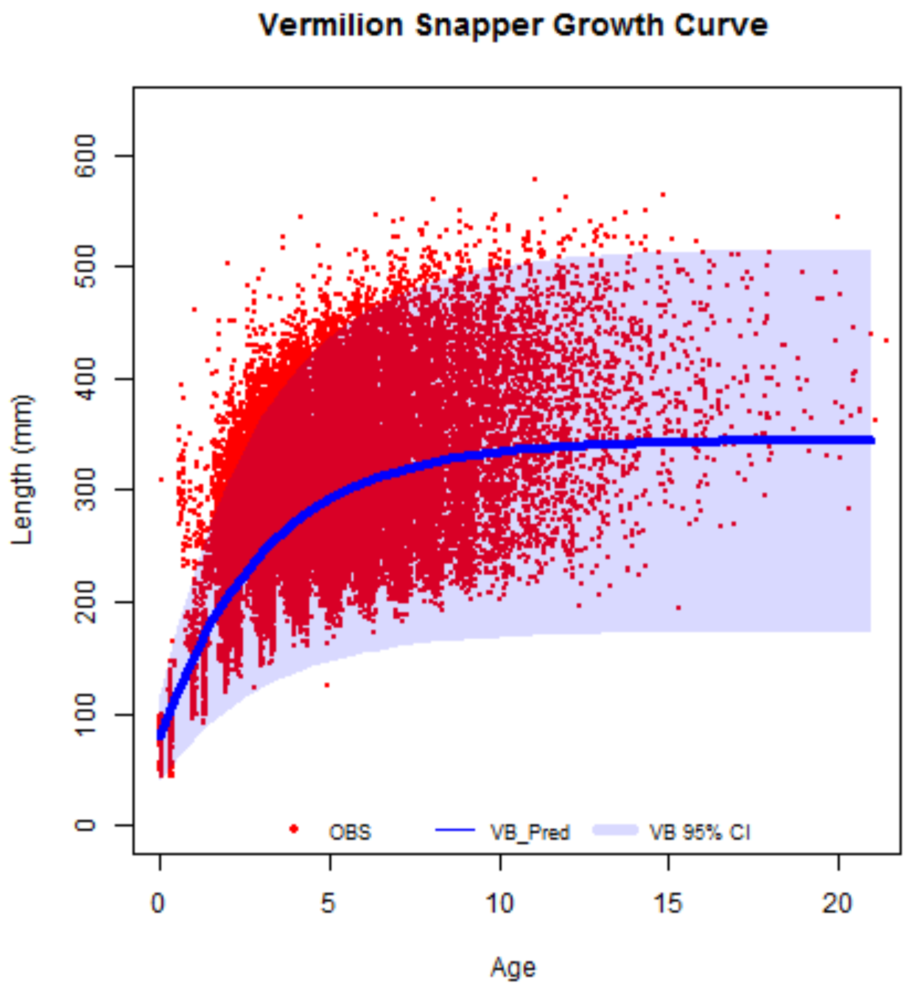


Figure 3: Maturity (top panel) and fecundity (bottom panel). A length logistic function is used to model maturity at length and fecundity (spawning output is in total eggs produced) assumes a power function (see Table 2 for parameter values). The assessment model assumes that no fish younger than age-1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

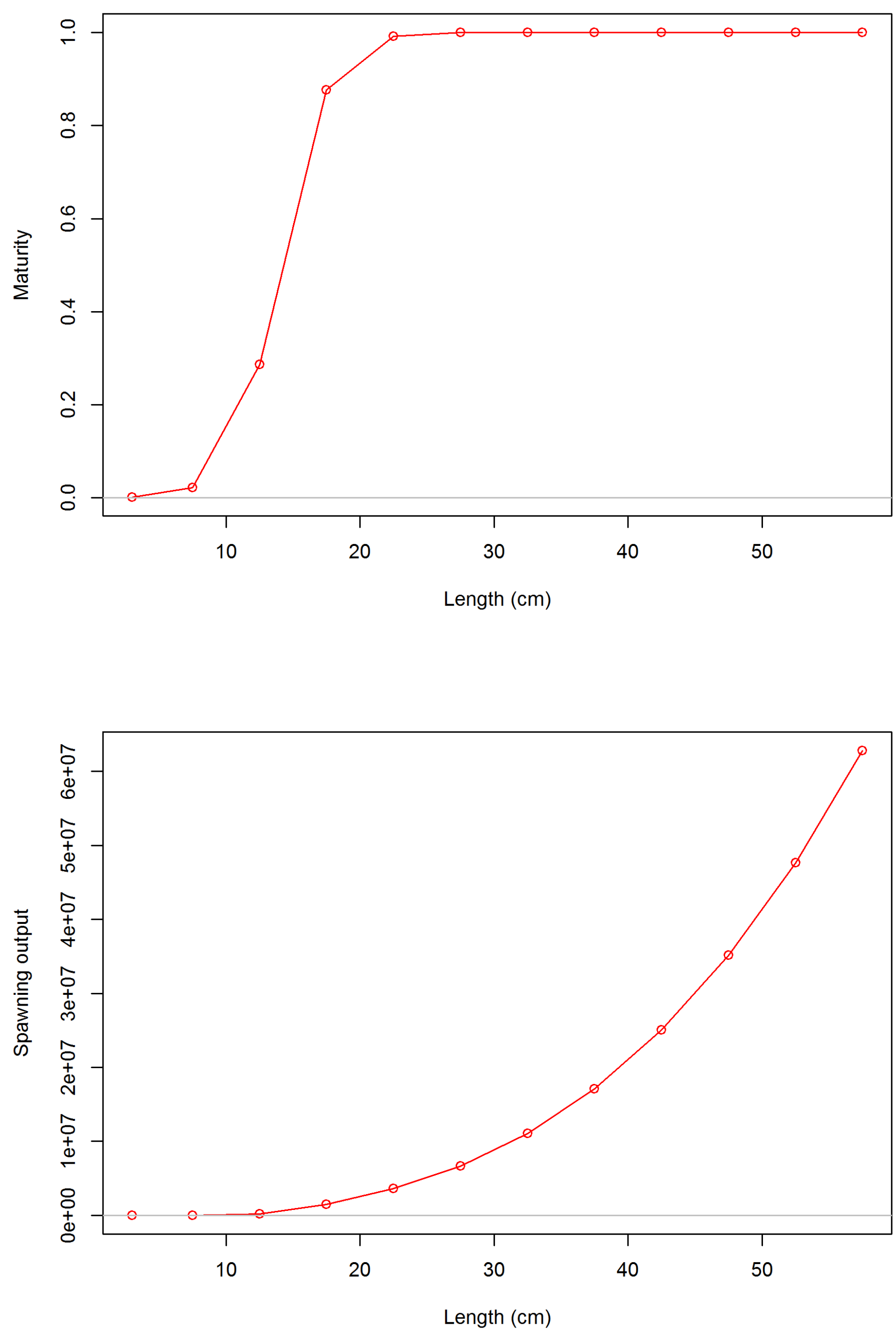


Figure 4: Natural mortality rate (M) by age. The Lorenzen curve is used to calculate age-varying natural mortality with a target rate of 0.25 (which is equivalent to the age-invariant natural mortality used in the previous vermilion assessment).

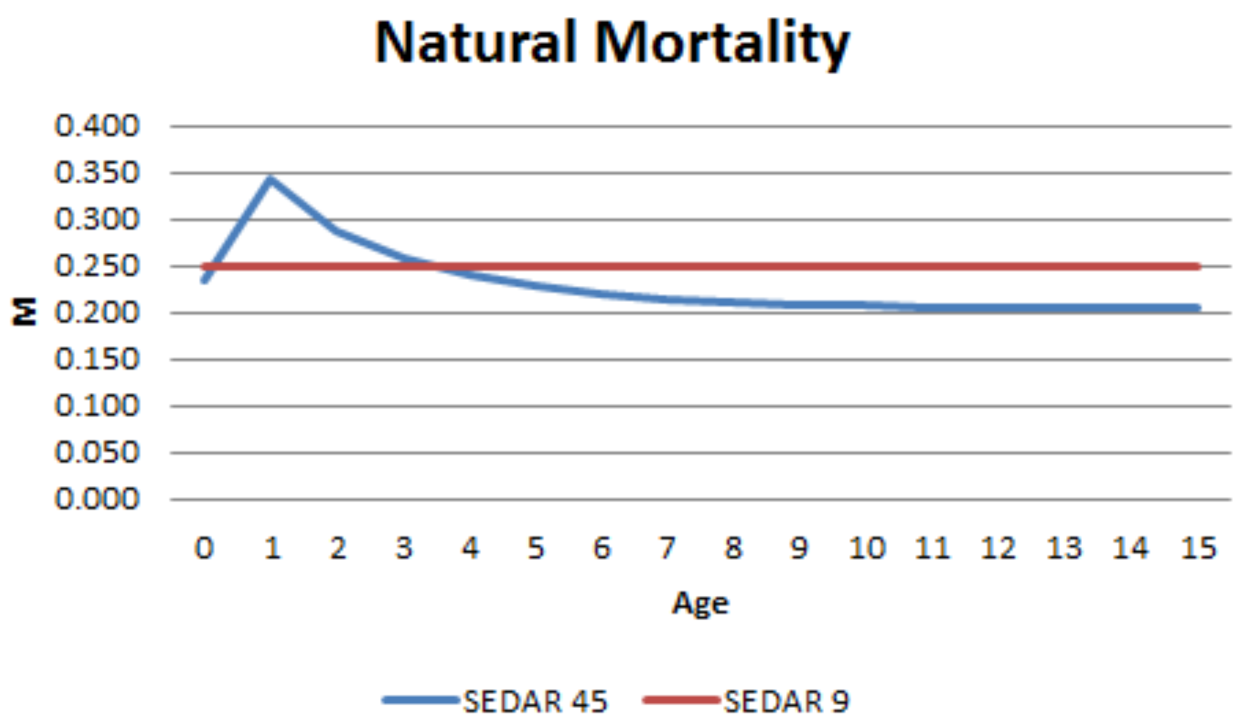
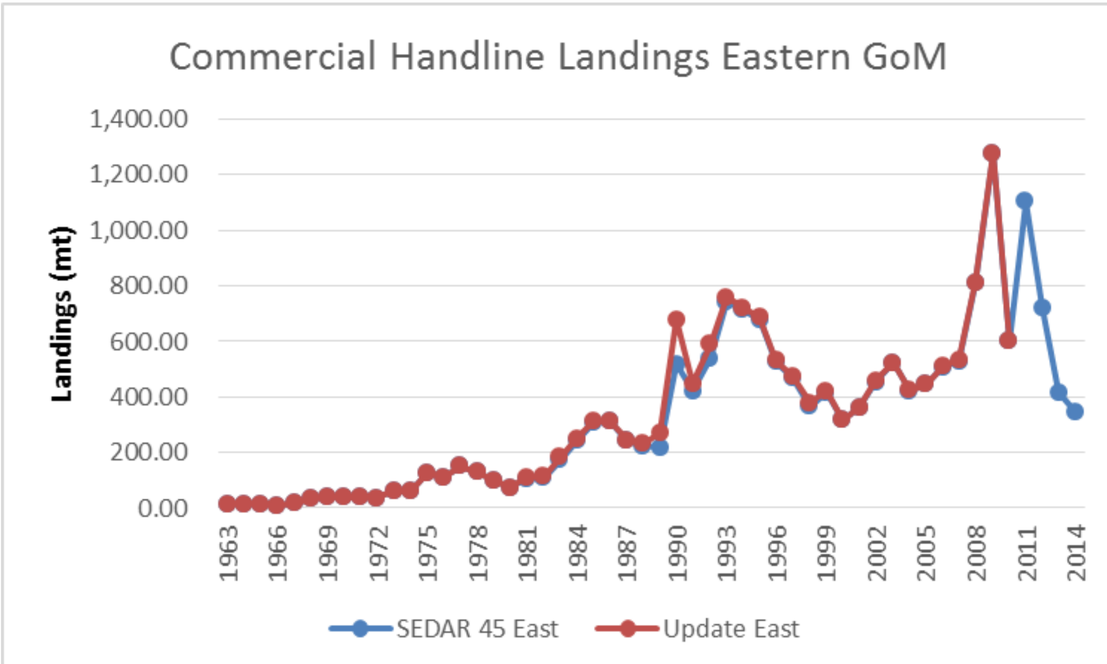


Figure 5: Final SEDAR 45 commercial landings in metric tons (mt) by region (blue lines). Some minor adjustments have been made since the 2011 update assessment (red lines). Landings show strong downward trends in both over the last three years. The eastern area (top panel) typically supports higher landings than the western area (bottom panel).



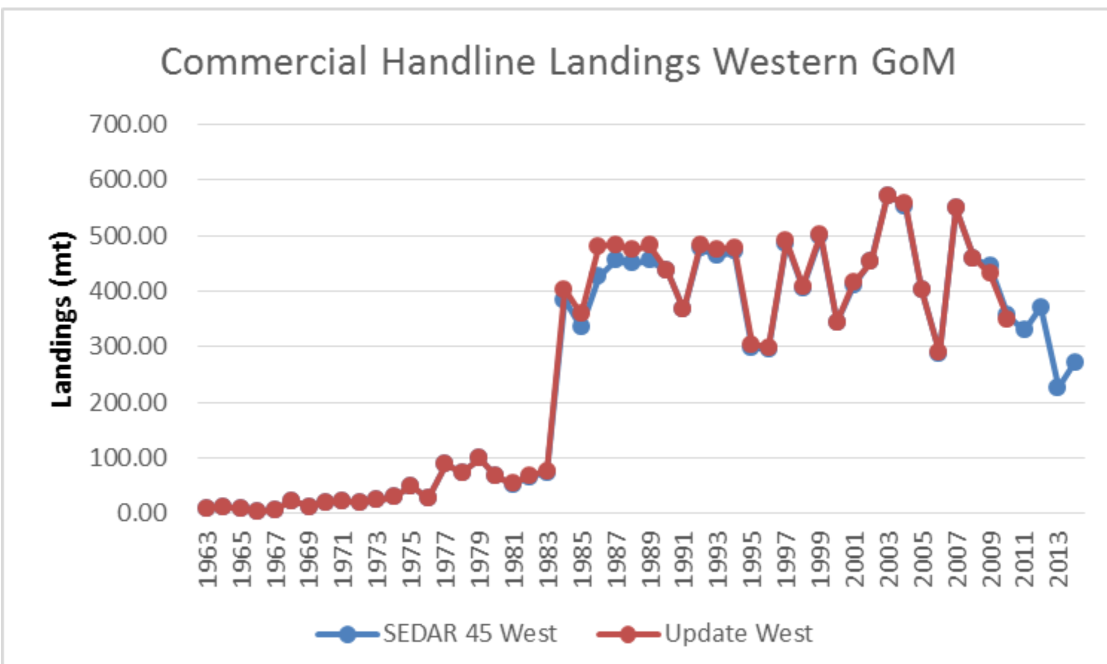
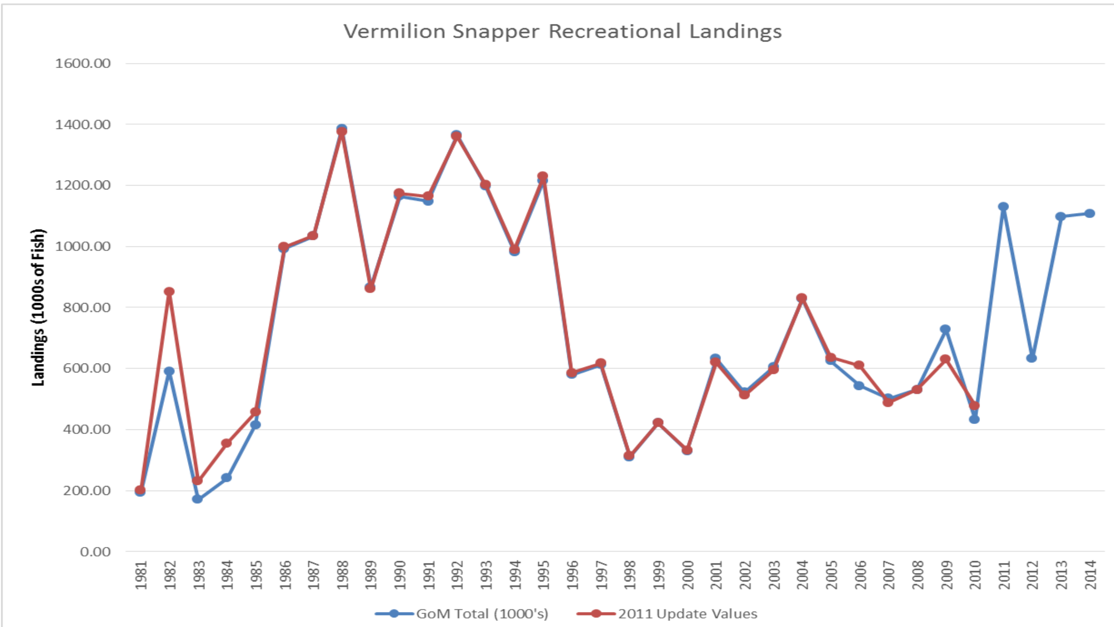


Figure 6: Final SEDAR 45 total recreational landings (blue line, top panel) and landings by area (bottom panel) in number of fish. Some minor adjustments have been made since the 2011 update assessment (red lines) mainly due to the recent APAIS adjustment (for years 2004-2012) and a change in historic calibration ratios (1981-1985) that occurred after the 2011 update. A majority of the recreational fishery occurs in the eastern area. Due to comparatively low catches and limited length and age sampling in the western area, a single combined gulfwide recreational fleet was modeled in the assessment.



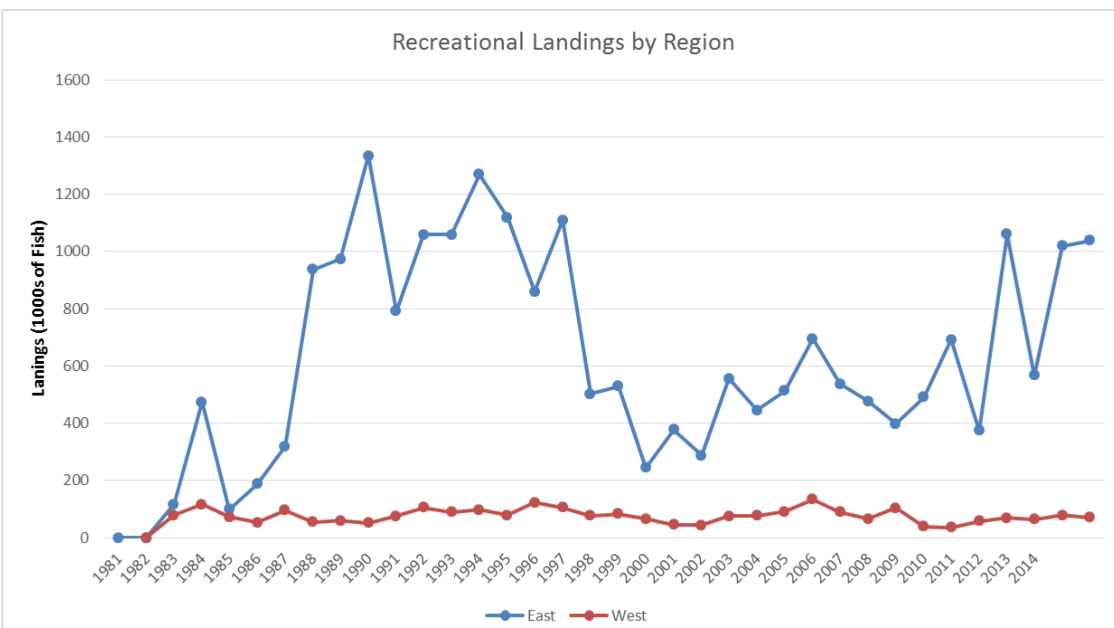


Figure 7: Commercial discards and landings (top panel, in metric tons) and recreational discards and landings (bottom panel, in number of fish). The data and assessment review group deemed that for all sectors discard fractions were insignificant in comparison to landings, especially given low assumed discard mortality rates (~15% based on literature review and expert opinion).

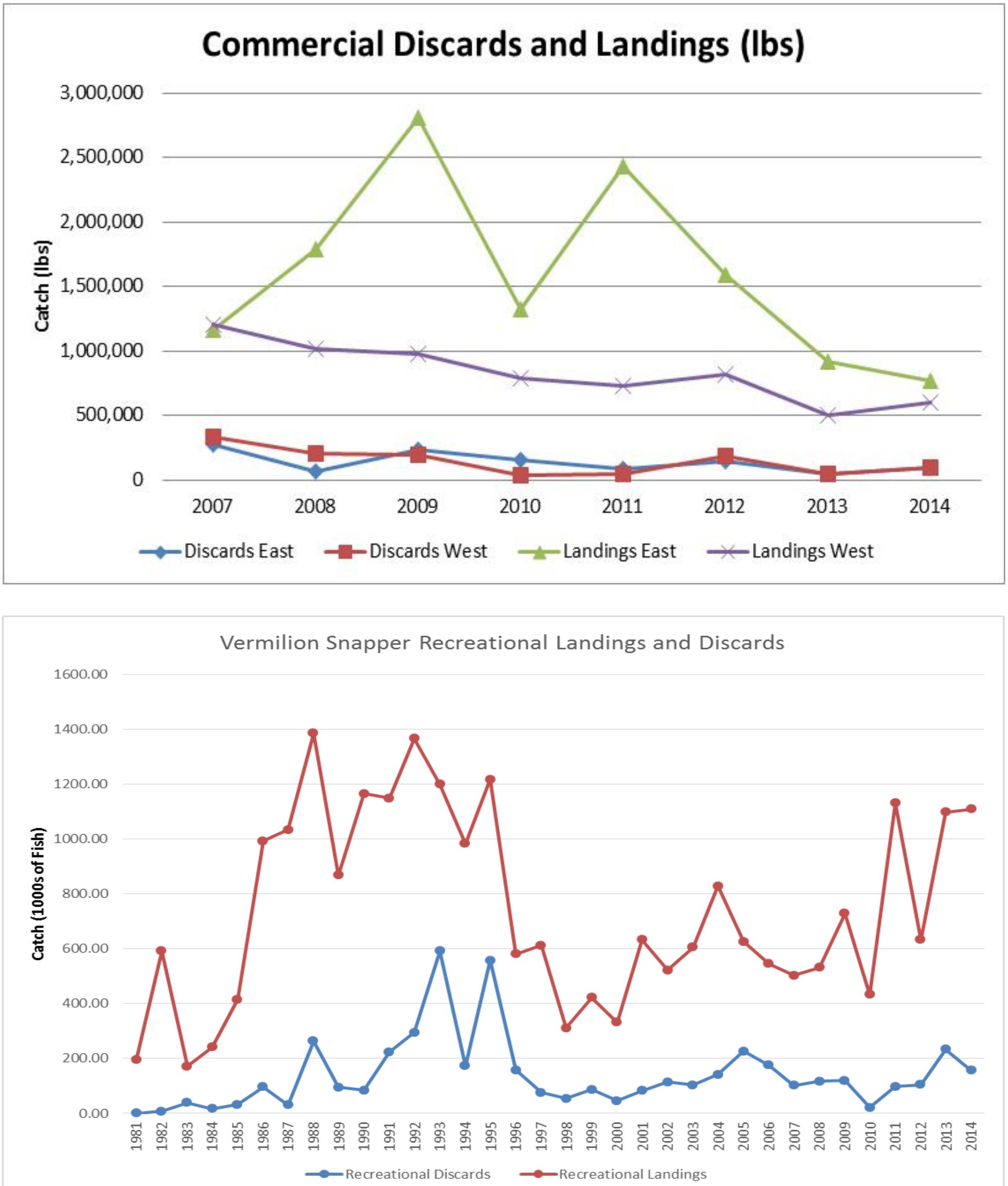


Figure 8: Calculated shrimp bycatch (number of fish) from the Bayesian GLM program. In the 2011 SEDAR 9 Update Assessment (red line), the program inputs in 2003-2008 were restricted to research vessel data (i.e., groundfish survey CPUE) and did not include information from the shrimp observer program. The SEDAR 45 estimates (blue line) incorporated the full timeseries of observer data. Because the observer data had a lower catch-per-unit effort (CPUE), the inclusion of observer program data accounts for the disparity in vermilion snapper bycatch between the 2011 Update and the 2014 assessment. 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; horizontal lines).

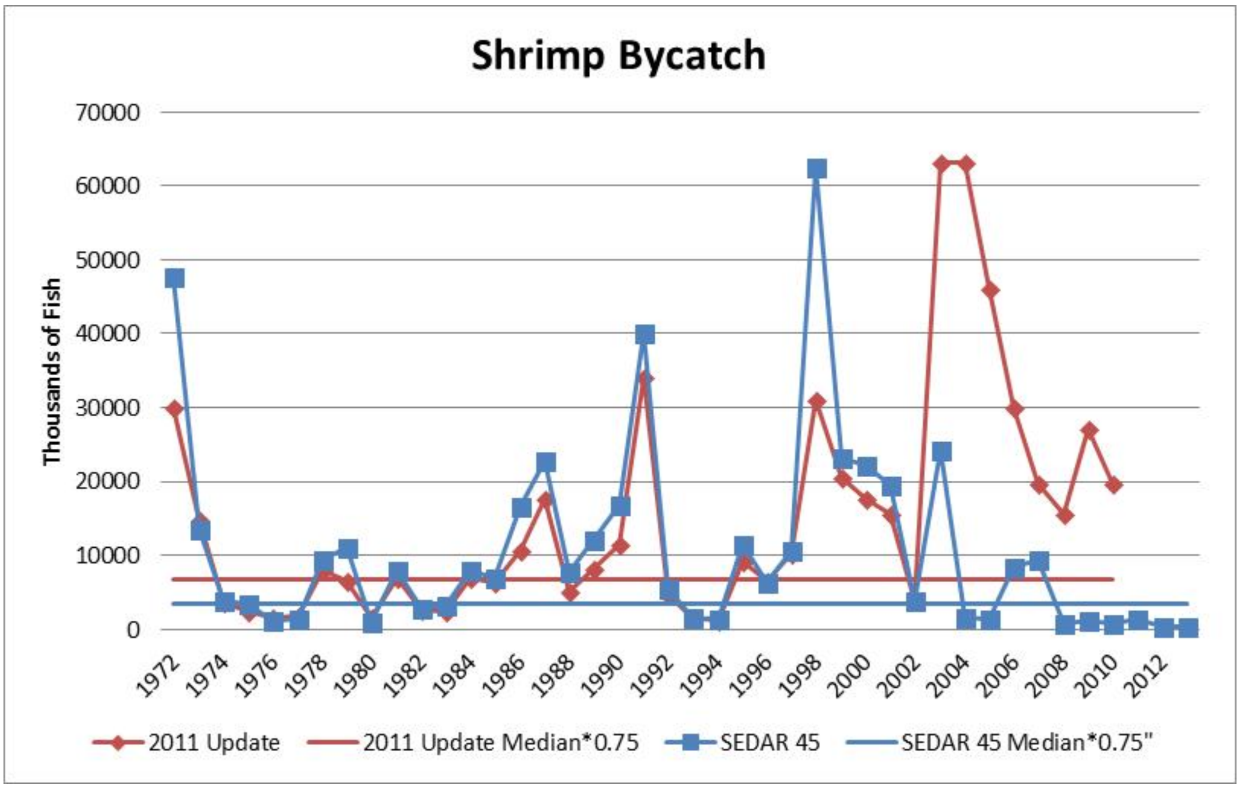


Figure 9: Observed age composition of the commercial and recreational fleets. The recreational fishery tends to focus on slightly younger fish than the commercial sector, while the commercial fishery in the western area tends to catch older fish than that in the eastern area.

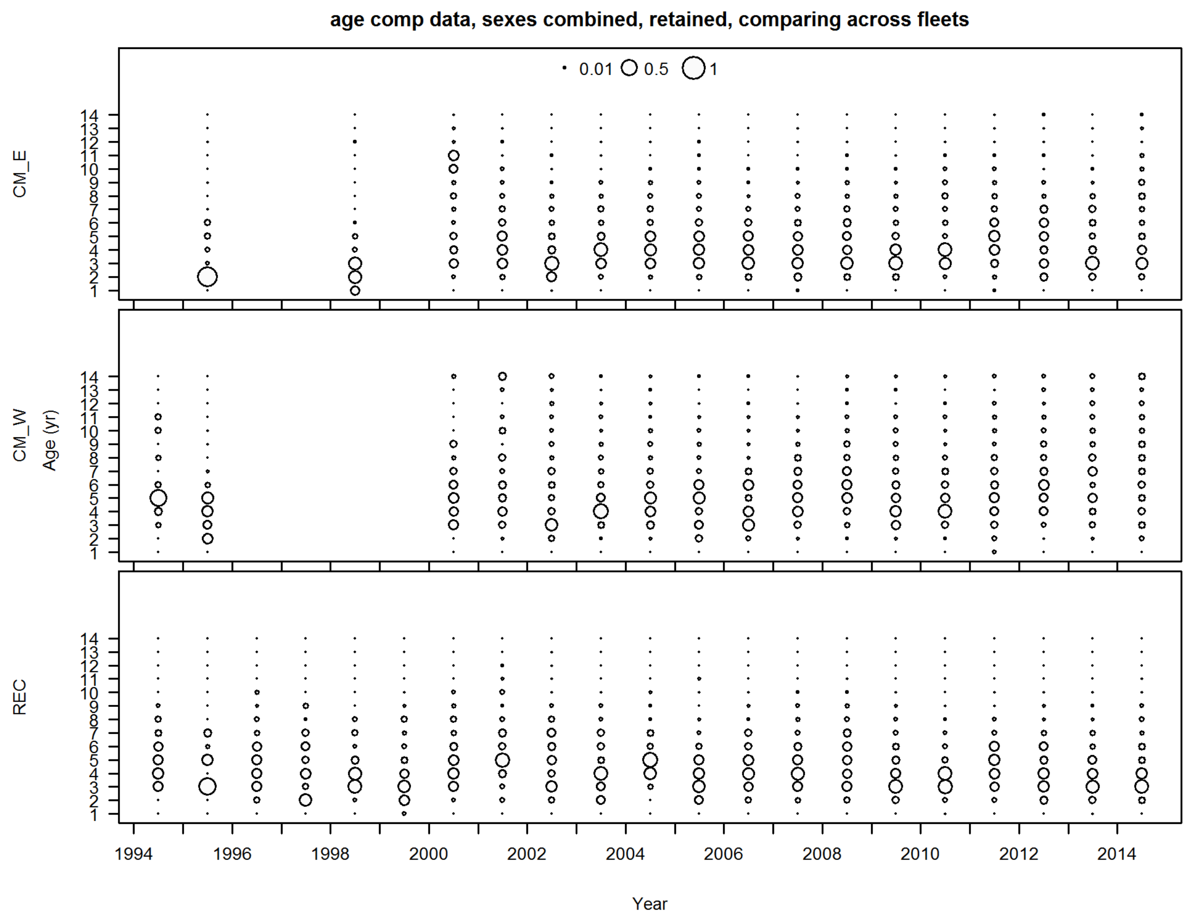


Figure 10: Normalized (to the timeseries mean) shrimp effort greater than 10 fathoms. Final SEDAR 45 values (blue line) were standardized by groundfish survey catch rates of vermilion snapper in order to account for the spatial overlap of shrimp effort and vermilion snapper distribution (i.e., to deemphasize bycatch in the western stock area where relatively fewer young vermilion snapper are observed, but where high shrimp effort is observed). Unweighted effort (green line) did not change from the 2011 update values (red lines). Slight discrepancies exist between the weighted and unweighted effort, which reflect the higher weight given to effort in the eastern area.

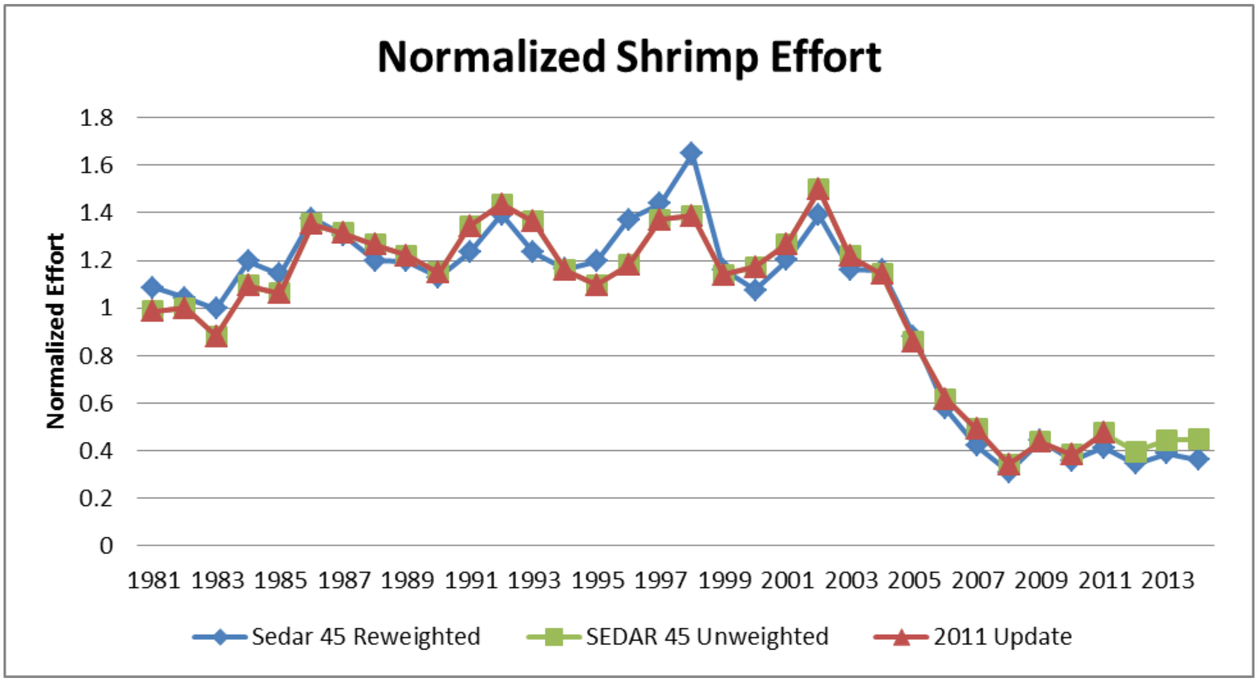


Figure 11: Standardized catch-per-unit effort (CPUE) for the commercial handline fishery in the eastern (top panel) and western (bottom panel) Gulf of Mexico. In the 2011 update (red lines) no factor was included in the standardization process to account for the implementations of red snapper IFQs in 2007. Given that red snapper IFQs may impact vermilion snapper CPUE (due to potential changes in targeting behavior), it was deemed inappropriate to continue to ignore the IFQ variable. To account for red snapper IFQs, the commercial CPUE indices were truncated in 2006 (blue lines) assuming no IFQ variable and a new timeseries was begun in 2007 (purple lines) with the IFQ variable included. The non-truncated timeseries with no IFQ variable (green lines) is shown for comparison to the 2011 update indices. The truncated timeseries with no IFQ show similar patterns to the 2011 update, while the new IFQ timeseries, not surprisingly, show different trends from the 2011 update. Since 2007, the western stock has been relatively stable, whereas the eastern stock has shown a generally increasing trend that has leveled off over the last three years. All indices are normalized to their mean.

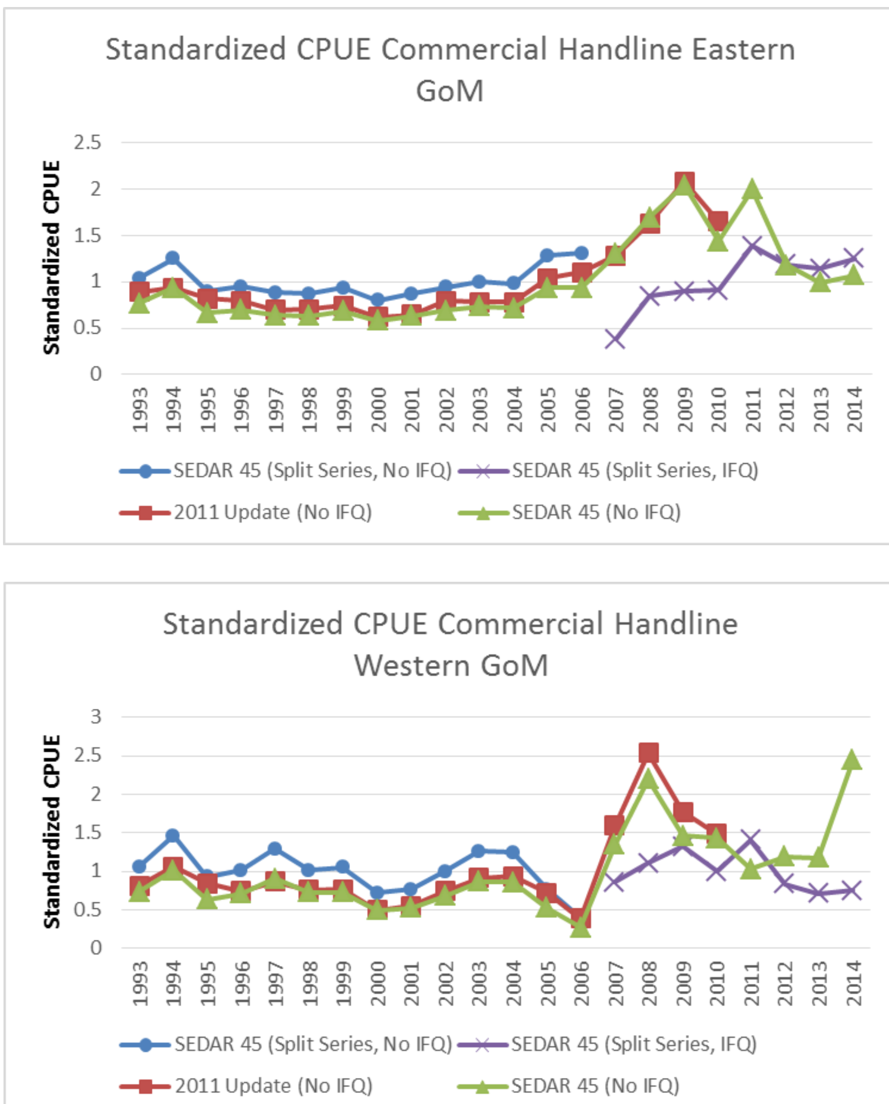


Figure 12: Standardized catch-per-unit effort (CPUE) for the recreational private/charter (MRFSS) fishery in the eastern Gulf of Mexico (top panel), the eastern headboat fishery (middle panel), and the western headboat fishery (bottom panel). Some discrepancies exist between the 2011 update timeseries (red lines) and the final SEDAR 45 indices (blue lines), but trends are generally similar.

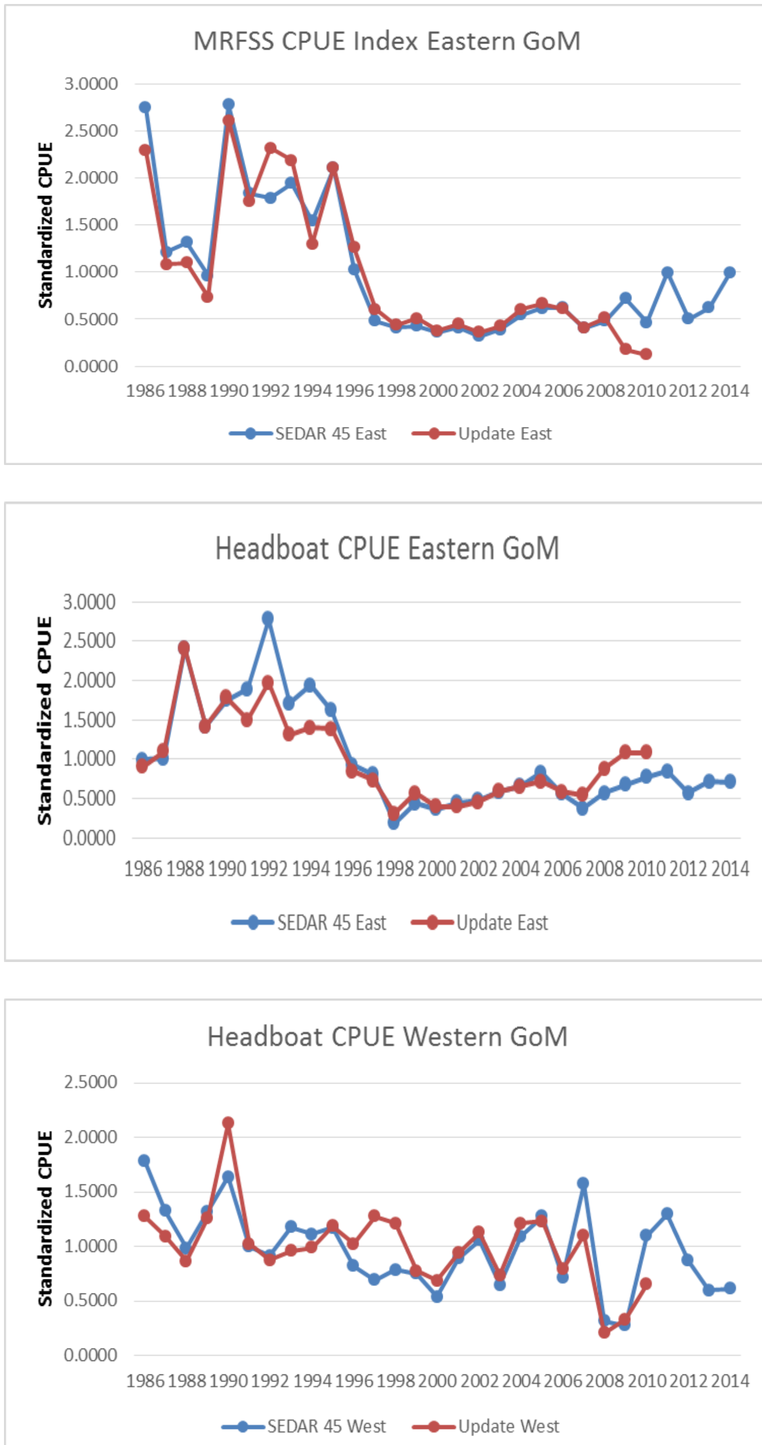


Figure 13: Standardized catch-per-unit effort (the larval index is in catch-per-unit area) for the three fishery-independent SEAMAP surveys: larval (red), groundfish east (green), and video (purple).

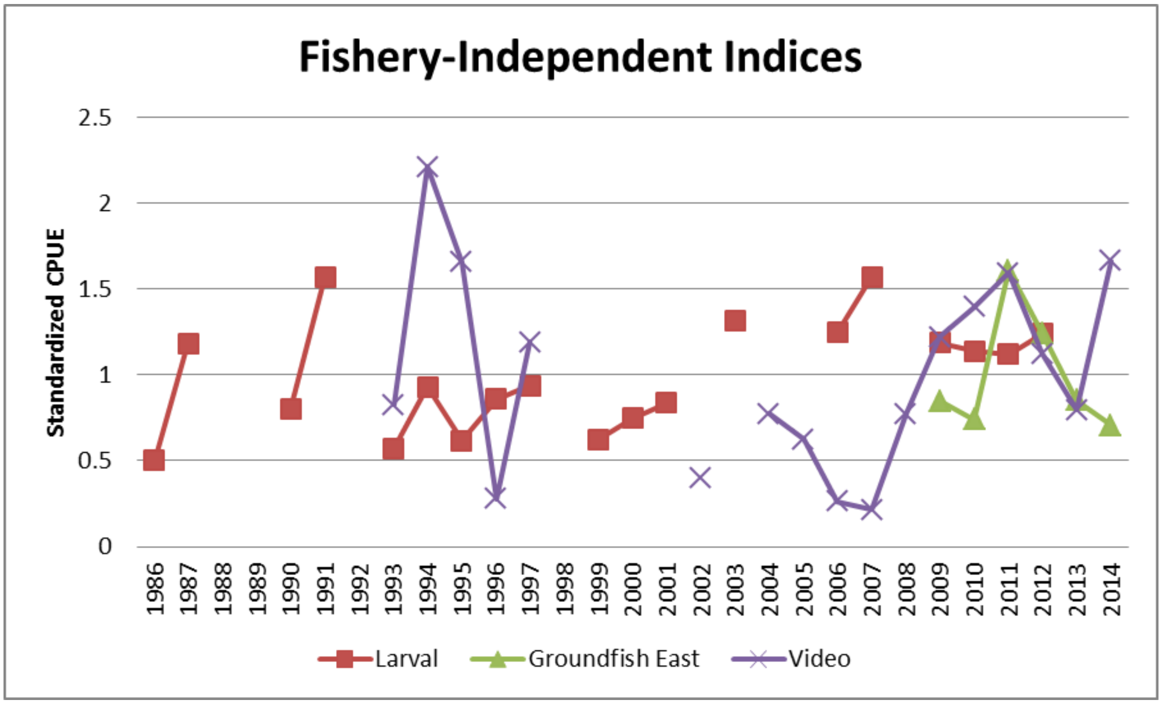


Figure 14: Data inputs used for the base model. Note that SEAMAP refers to the SEAMAP summer groundfish survey, SMP_BYC under the 'catch' heading is simply a placeholder for the shrimp bycatch fleet (no actual data were input here since shrimp bycatch is input under the 'discards' heading), and the SMP_BYC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

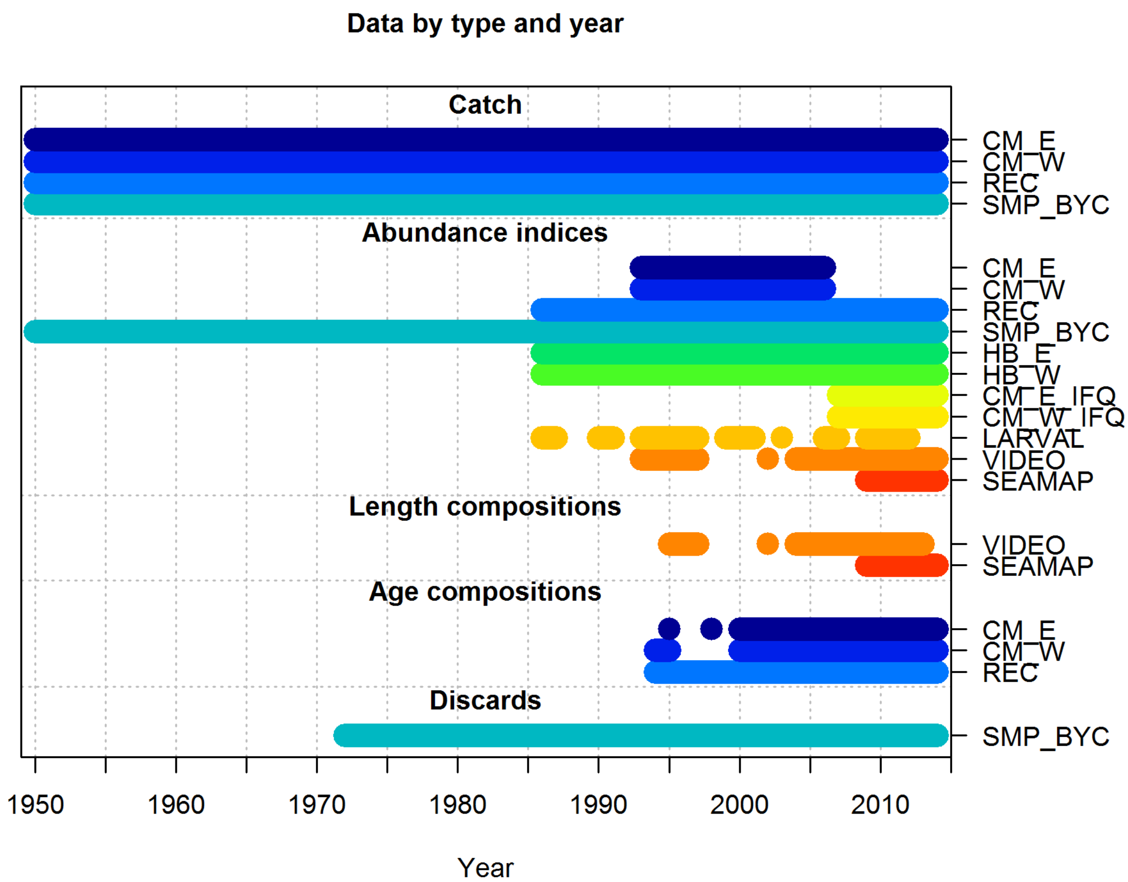
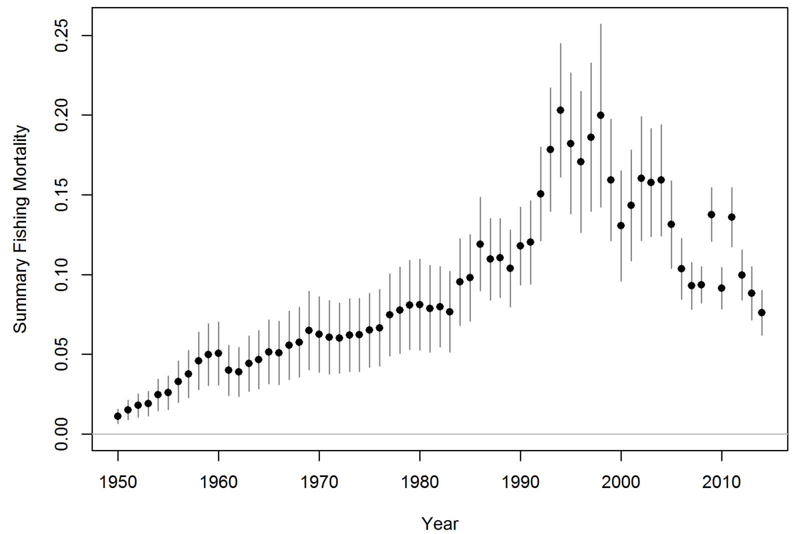


Figure 15: Total harvest rate (top panel, killed fish divided by exploitable numbers) with 95% confidence intervals and fishing mortality (continuous rates) by fleet (bottom panel). Total fishing mortality reached its peak in the mid-1990s and has been steadily declining for the last decade. For much of the timeseries the predominant source of mortality has been due to shrimp bycatch of new recruits, but over the last decade the commercial sectors have composed the majority source of fishing mortality largely due to tumultuous declines in shrimp effort. The recreational sector has typically made up the smallest component of mortality until the terminal year of the model when it was the largest source, albeit only slightly higher than the other three sectors.



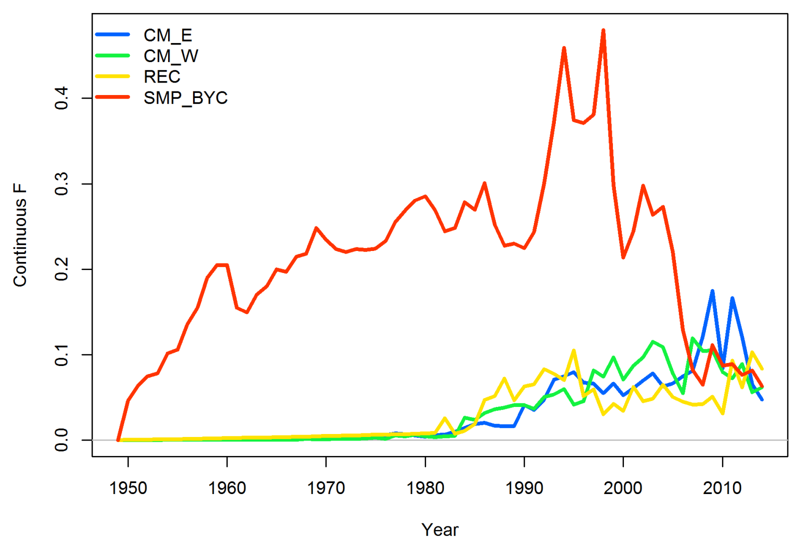


Figure 16: Eastern Gulf of Mexico estimated logistic commercial selectivity. The top left panel represents selectivity before red snapper IFQs were implemented (prior to 2007) and the top right panel illustrates selectivity after red snapper IFQs were implemented (2007-2014). The bottom panel illustrates the change in age of 20% selectivity quantiles before and after the 2007 change in selectivity was implemented. There was a slight shift towards older fish after the implementation of red snapper IFQs.

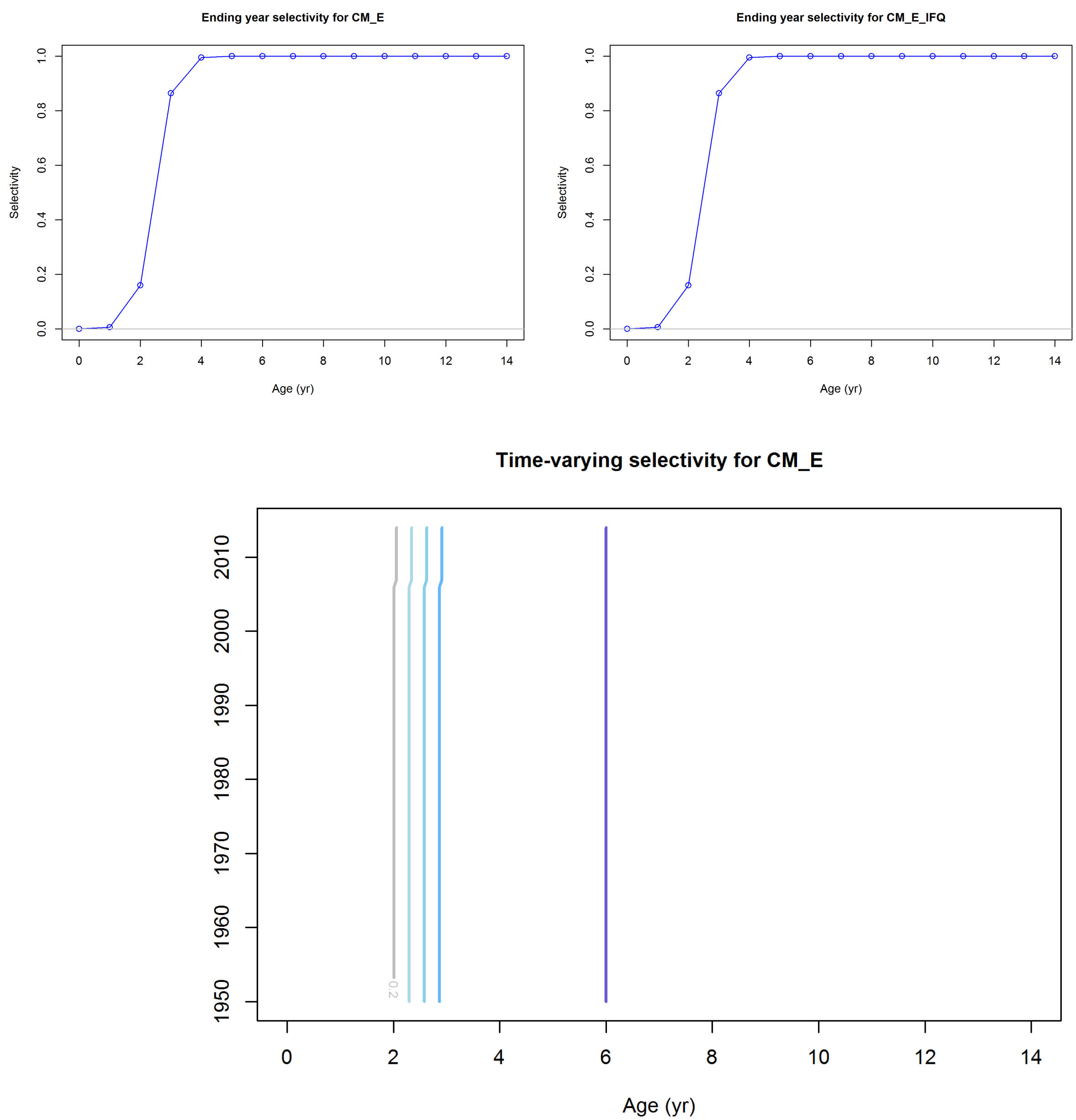


Figure 17: Western Gulf of Mexico estimated logistic commercial selectivity. The top left panel represents selectivity before red snapper IFQs were implemented (prior to 2007) and the top right panel illustrates selectivity after red snapper IFQs were implemented (2007-2014). The bottom panel illustrates the change in age of 20% selectivity quantiles before and after the 2007 change in selectivity was implemented. There was a shift towards older fish after the implementation of red snapper IFQs with the age of maximum selectivity shifting from age-10 to age-11.

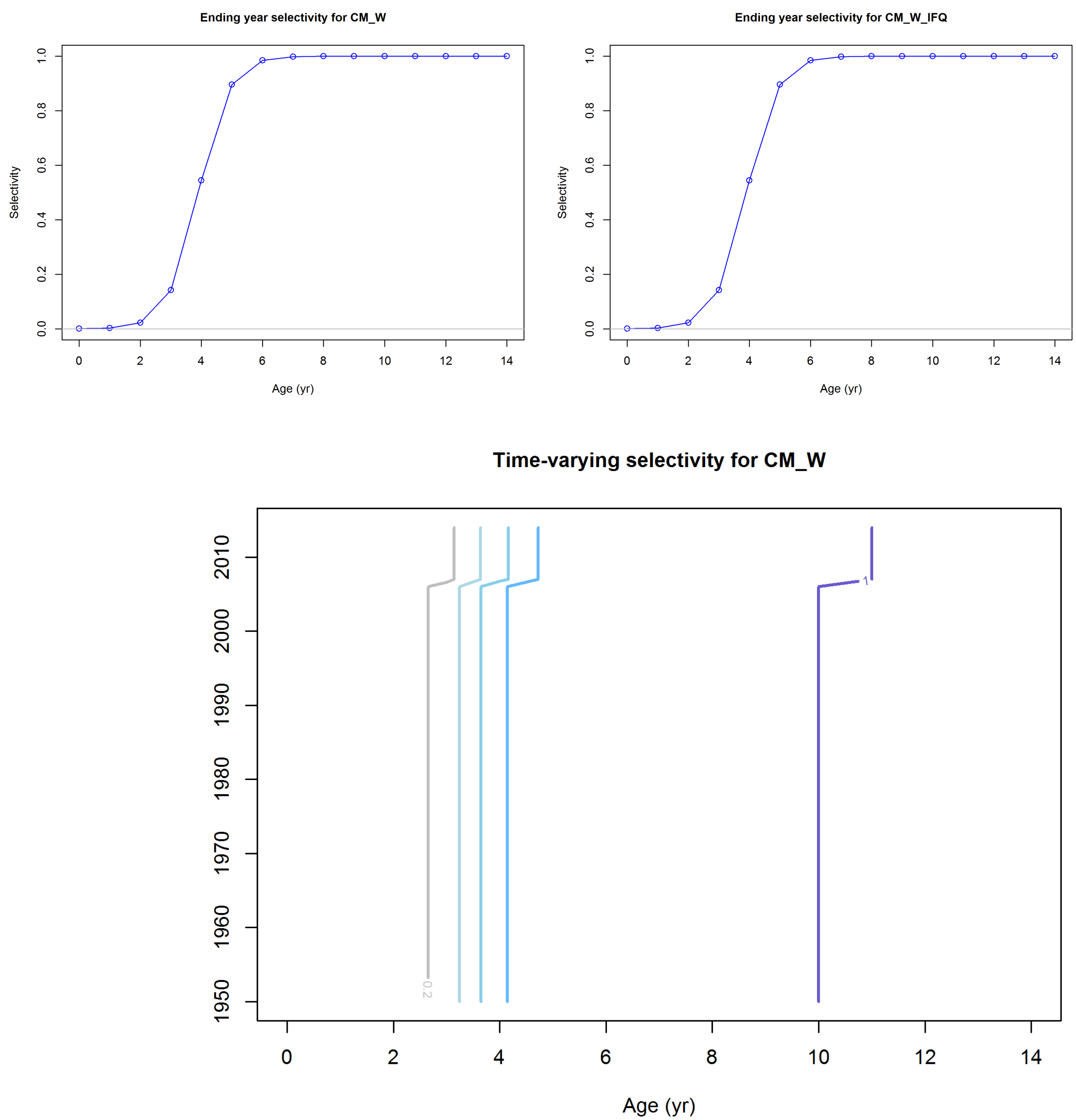


Figure 18: Gulf-wide estimated domed recreational selectivity. Because age sample sizes were limited across fleets and areas within the recreational sector, a single set of age compositions were used which forced the model to estimate a single recreational selectivity curve. Therefore, the recreational selectivity was spatially and temporally invariant and shared between the private/charter and headboat fleets. The resulting curve represents an amalgamation of age composition data and may not accurately reflect the true selectivity of any single fleet. A double normal curve was implemented based on expert opinion that the recreational fleets may exhibit gear and availability issues that may limit targeting of older fish along with an improved fit to recreational age compositions with reduced residual patterning compared to exploratory runs assuming logistic selectivity.

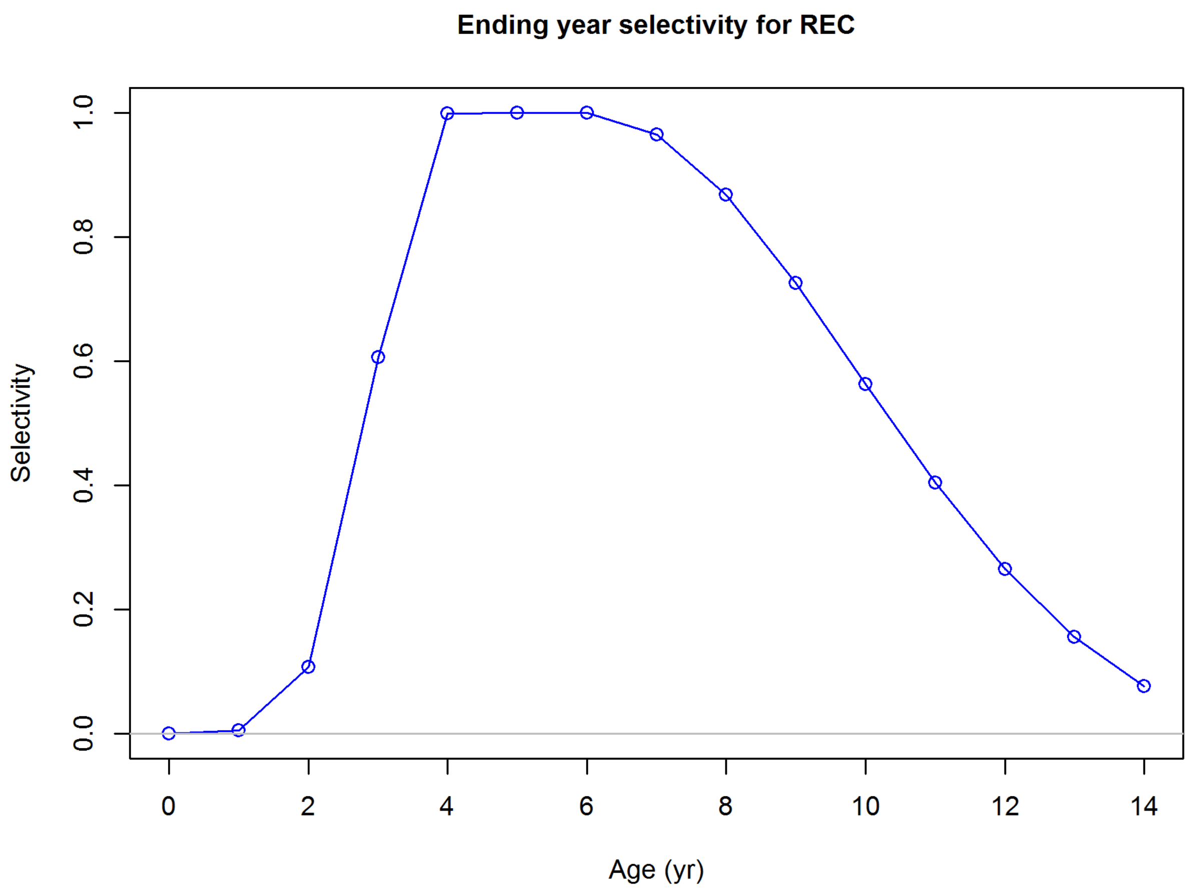


Figure 19: Gulf-wide fixed shrimp bycatch selectivity. The selectivity of shrimp bycatch was fixed at the values agreed upon during SEDAR 9 based on limited shrimp observer length samples (100% vulnerability at age-1, 30% at age-2, 3% at age-3 and 0% at ages 4-14+), because no age composition is available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

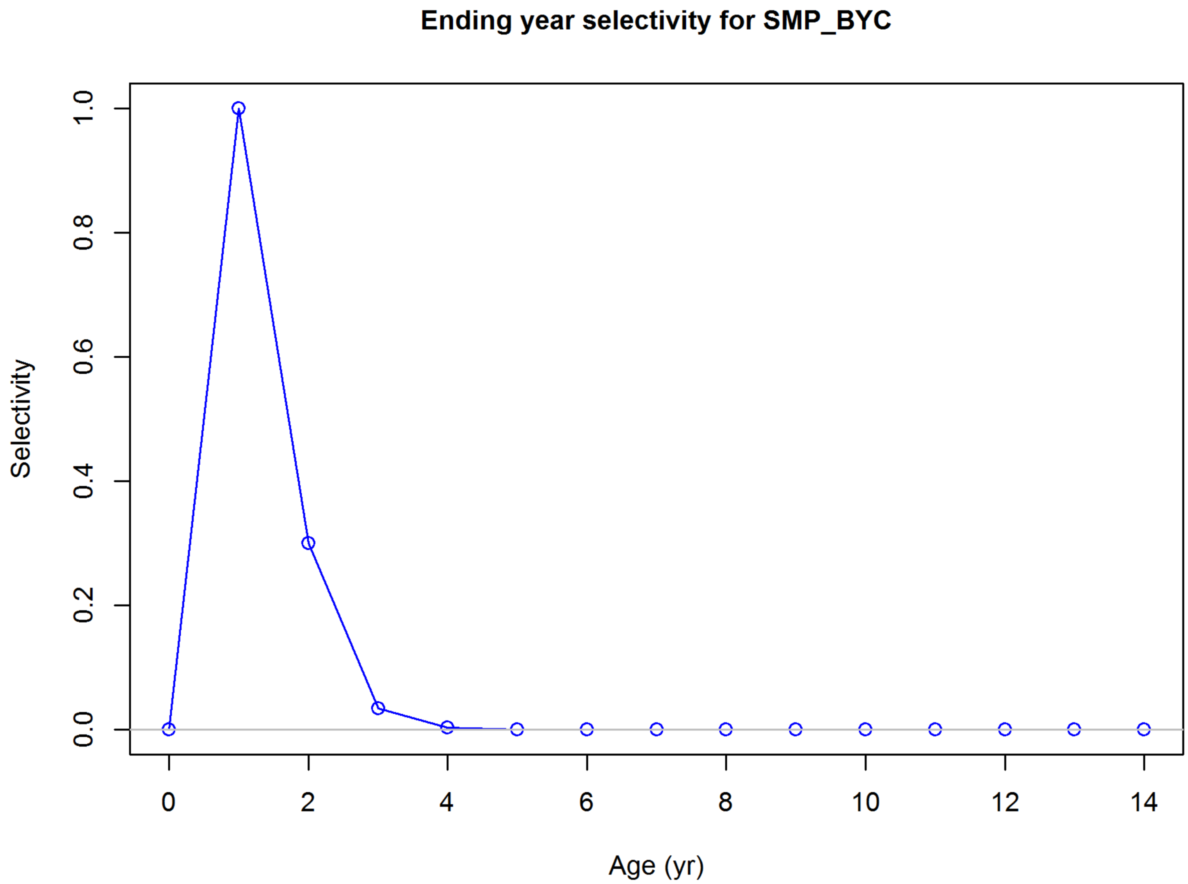


Figure 20: Estimated selectivity for the fishery-independent surveys. Because no age composition information was available, both the video (top panel) and summer groundfish (bottom panel) surveys used length composition and fit domed selectivity by length. Domed selectivity for these surveys were deemed appropriate by expert opinion based on the spatial coverage (availability issues) and the lack of older, larger fish in the length frequencies. Exploratory runs with logistic selectivity for each survey indicated poor model fit with strong residual patterns.

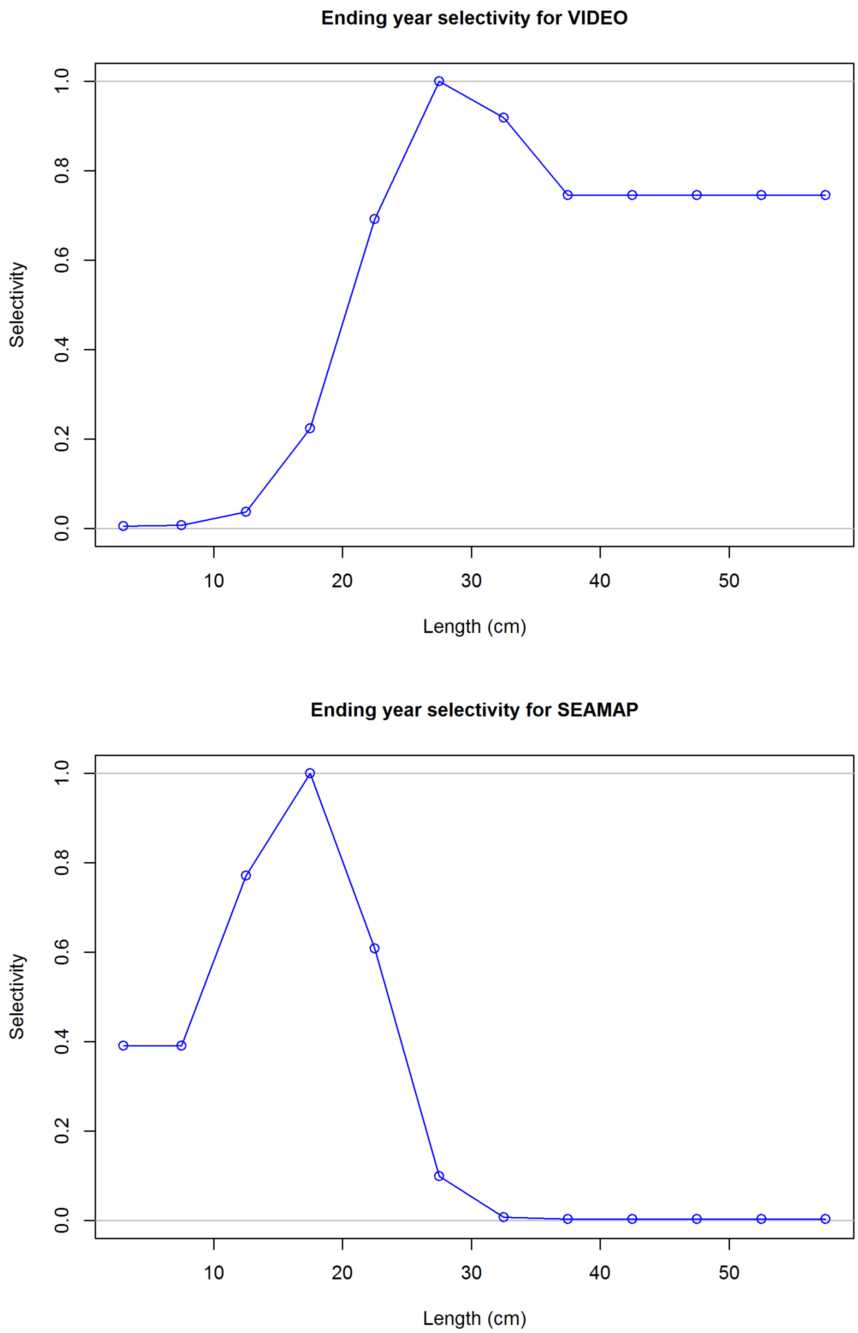


Figure 21: Predicted Beverton-Holt stock-recruit relationship (black line) with estimated recruitment values (red dots; top panel) and yearly lognormal recruitment deviations with 95% confidence intervals (bottom panel). Given the lack of depletion seen in the stock, little information is available to 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.

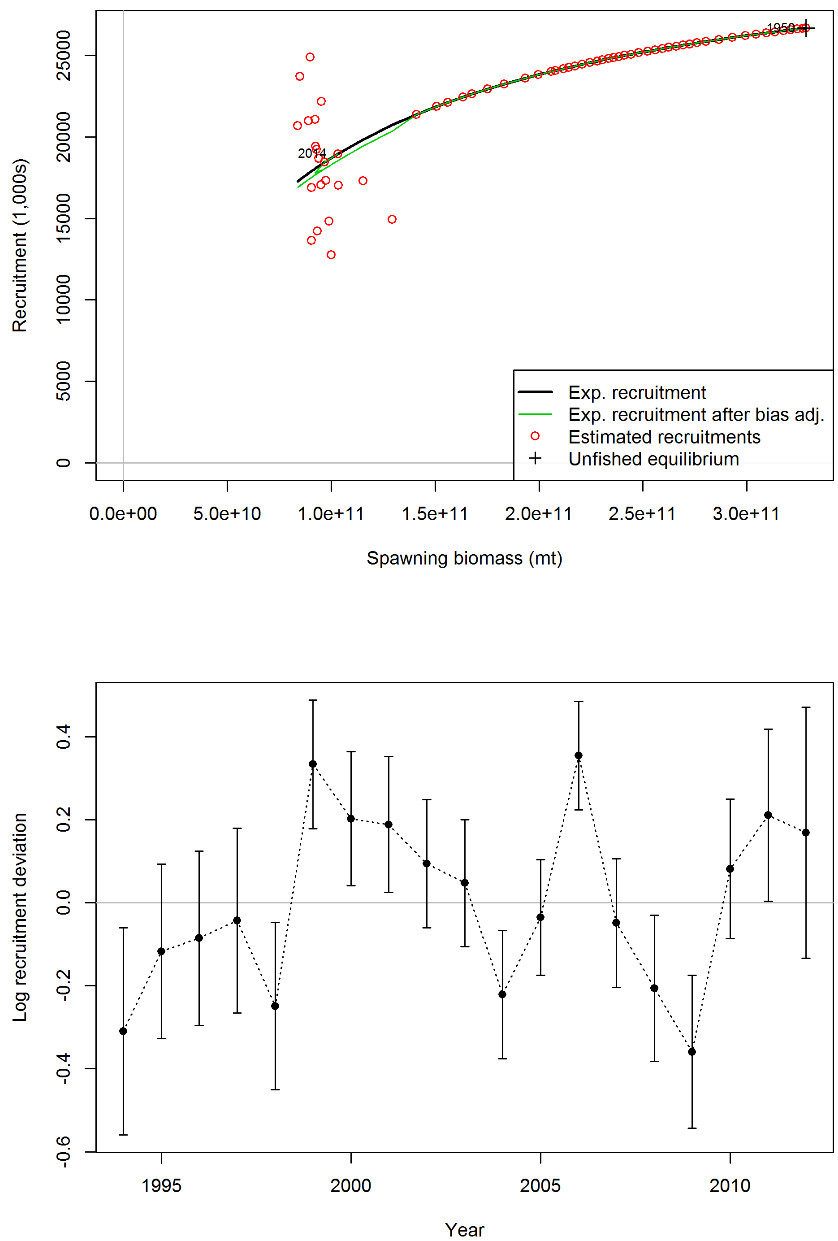


Figure 22: Estimated spawning stock biomass (1000s of eggs, blue line) and recruitment (1000s of fish, red line). SSB has been relatively steady over the last decade, while recruitment has varied with no strong trends.

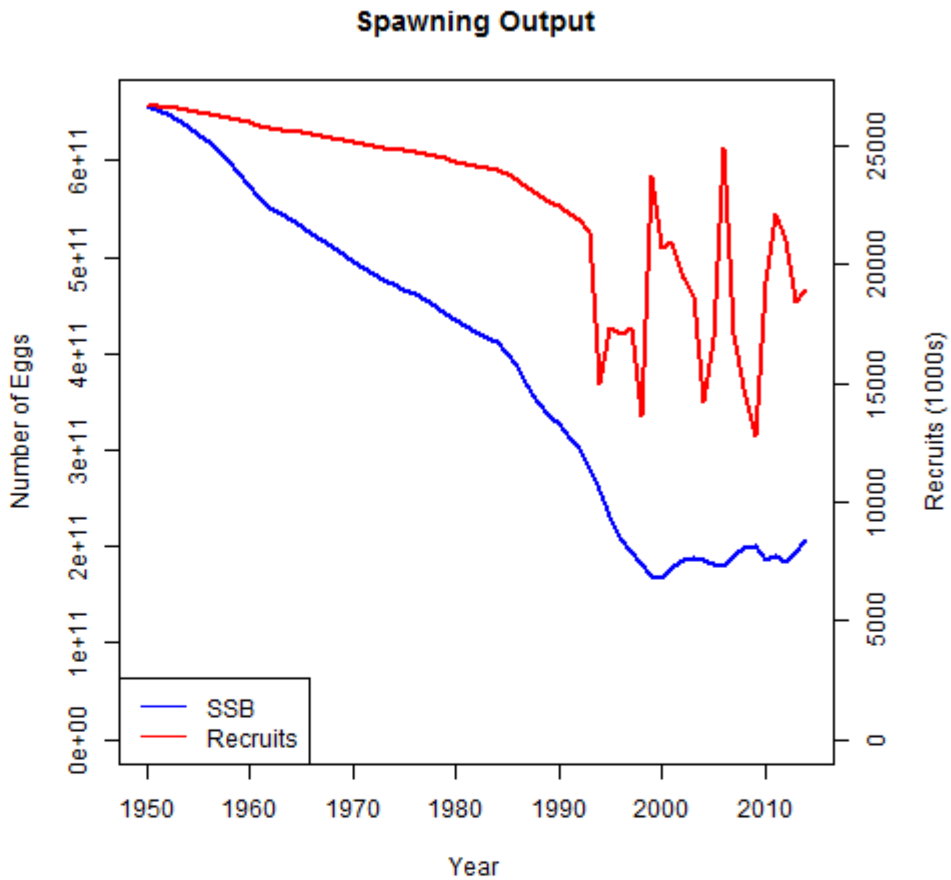


Figure 23: Total biomass (mt, top panel), total abundance (1000s of fish, bottom left panel), and numbers at age (bottom right panel). The population initially decreased from virgin conditions, but has been without trend for the last decade or more and shows a generally upward trend in abundance with 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.

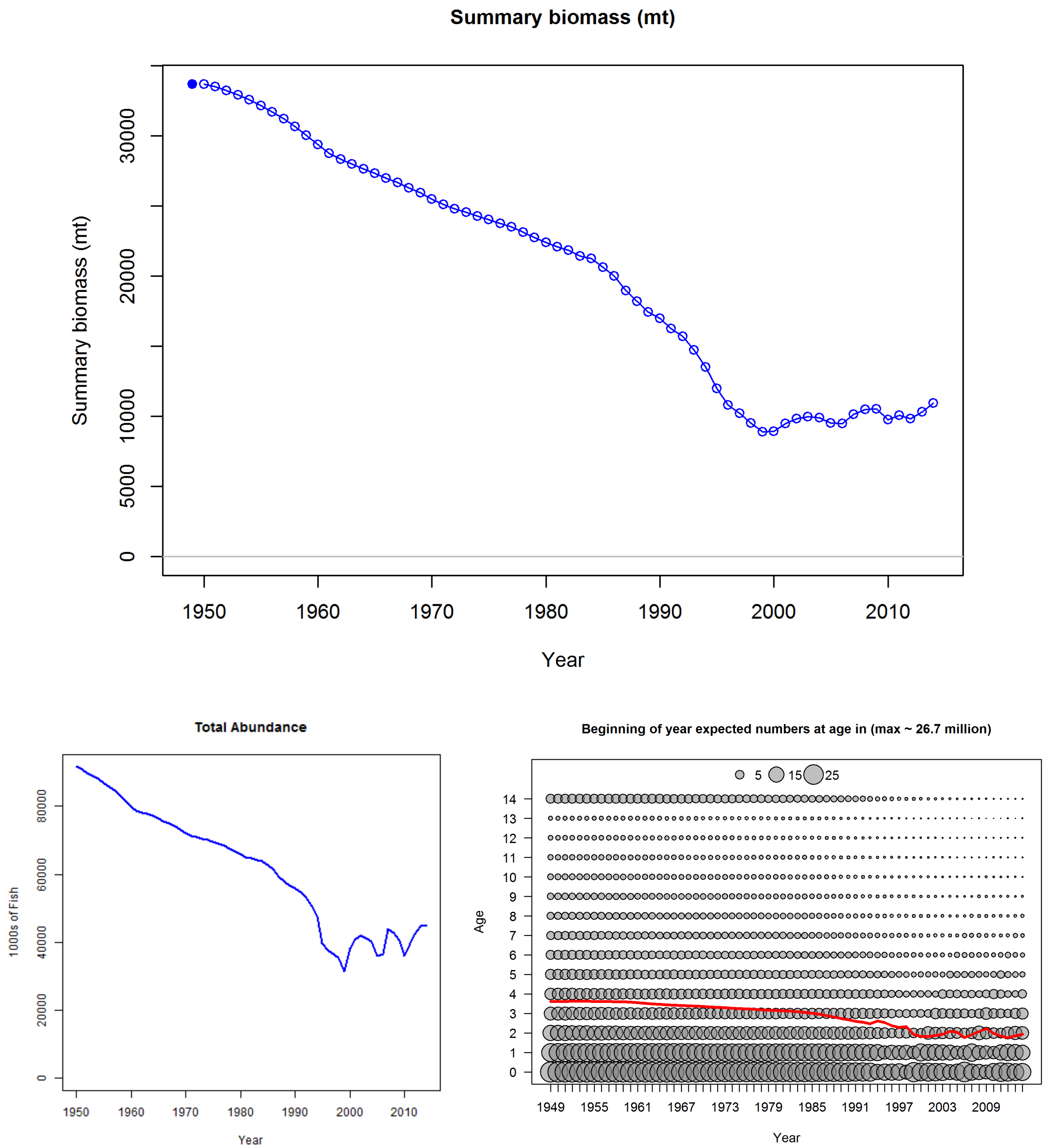
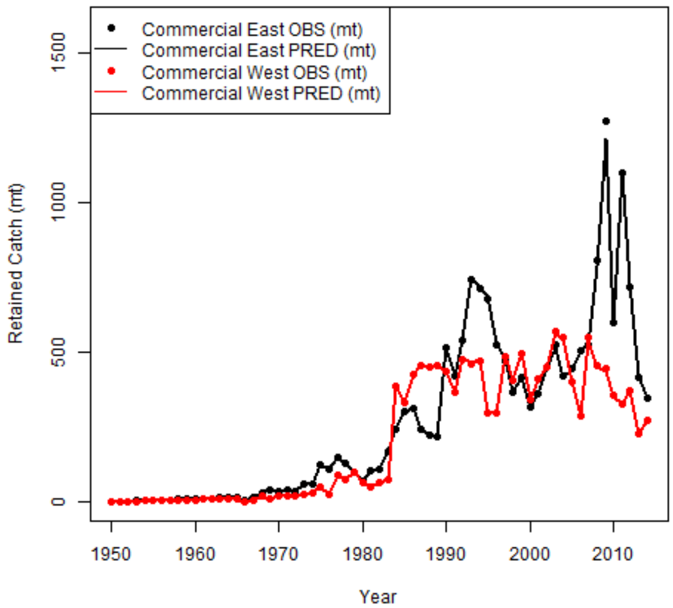


Figure 24: Observed and predicted commercial (top panel, mt) and recreational landings (bottom panel, 1000s of fish). Fits to both the commercial east (black) and west (red) are very tight, while the recreational catch shows slightly more residual error. These results are to be expected given the relatively 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).



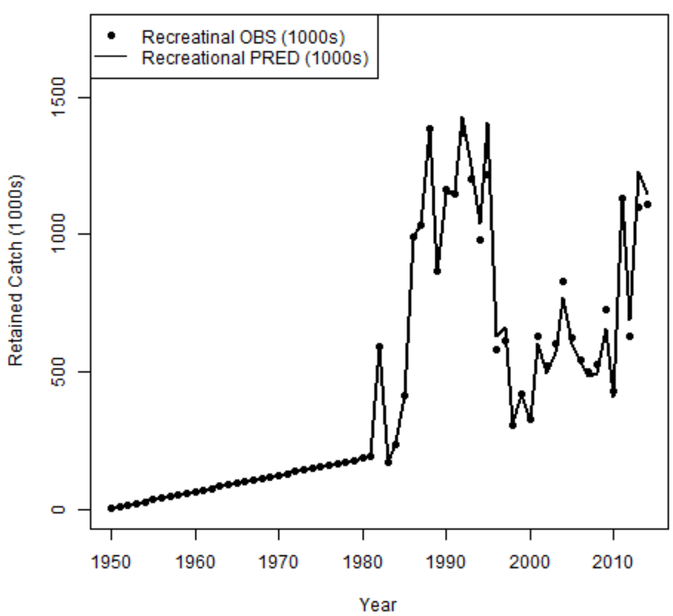


Figure 25: Observed and predicted shrimp bycatch super-year medians in number of dead discards. The blue line represents the model estimated median and the black circles are the bycatch estimates produced by the WinBugs program where the first value represents the Bayesian median that the assessment 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).

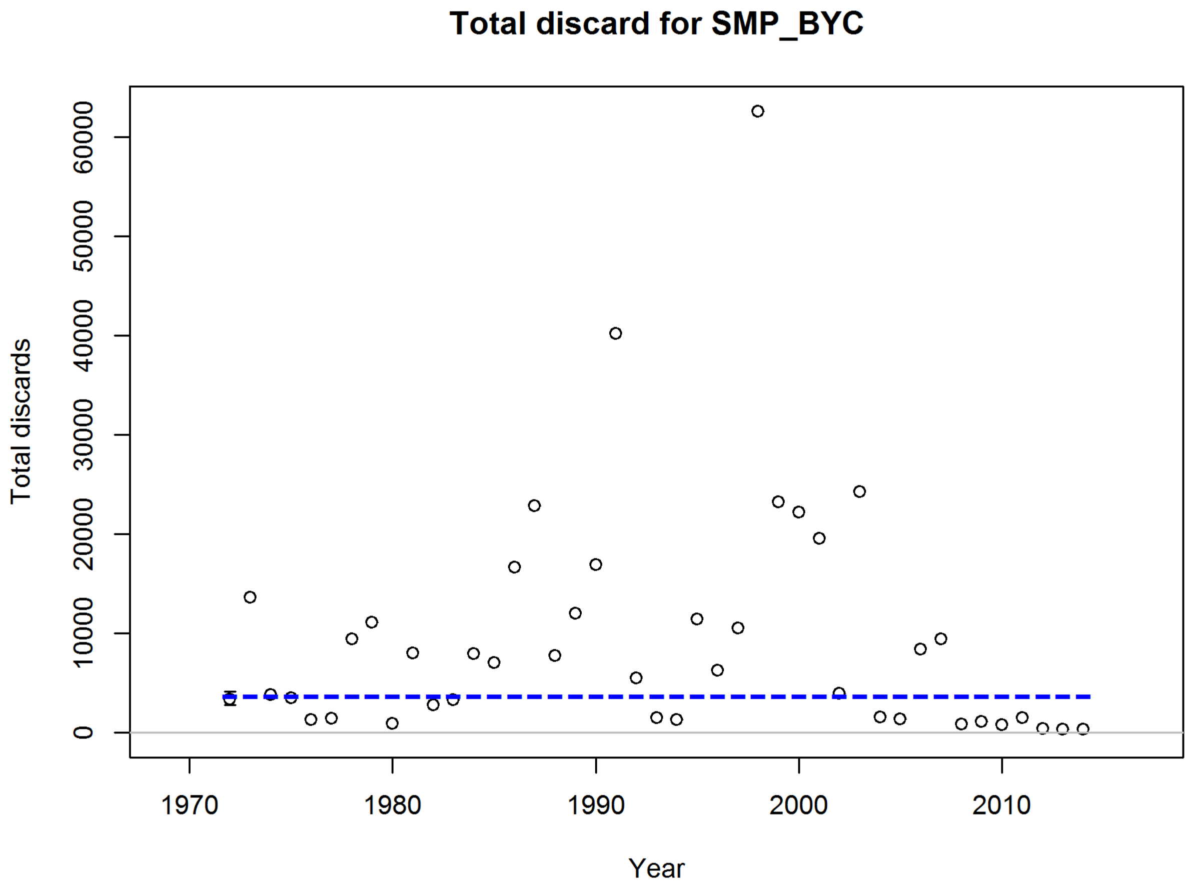


Figure 26: Observed (red points) and predicted (blue line) shrimp effort.

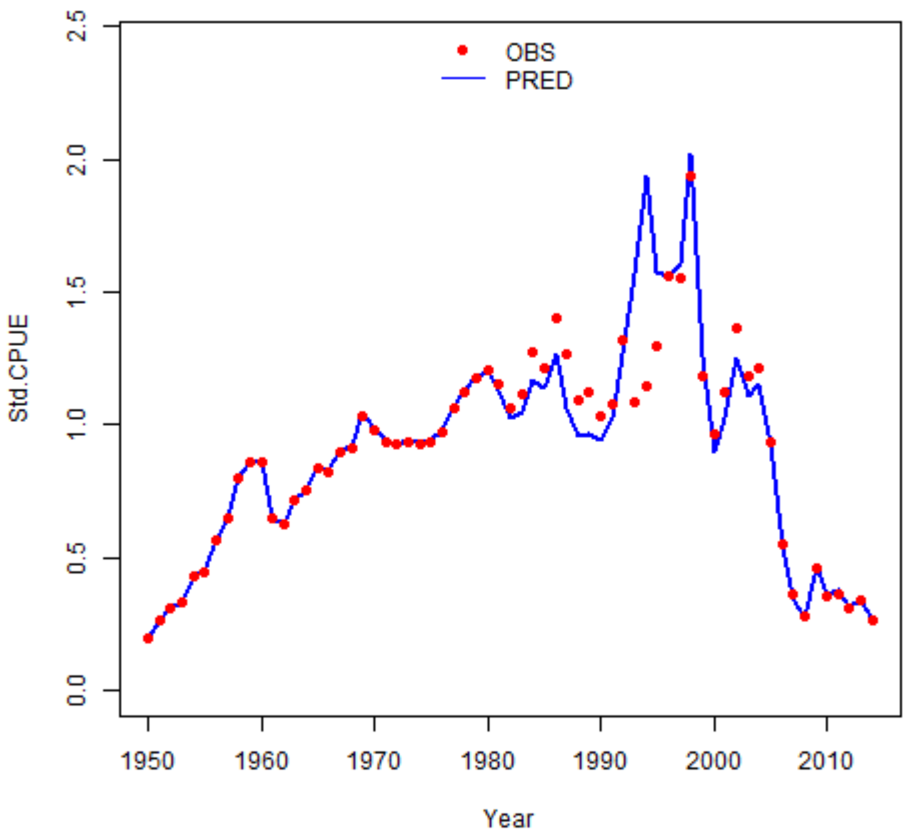
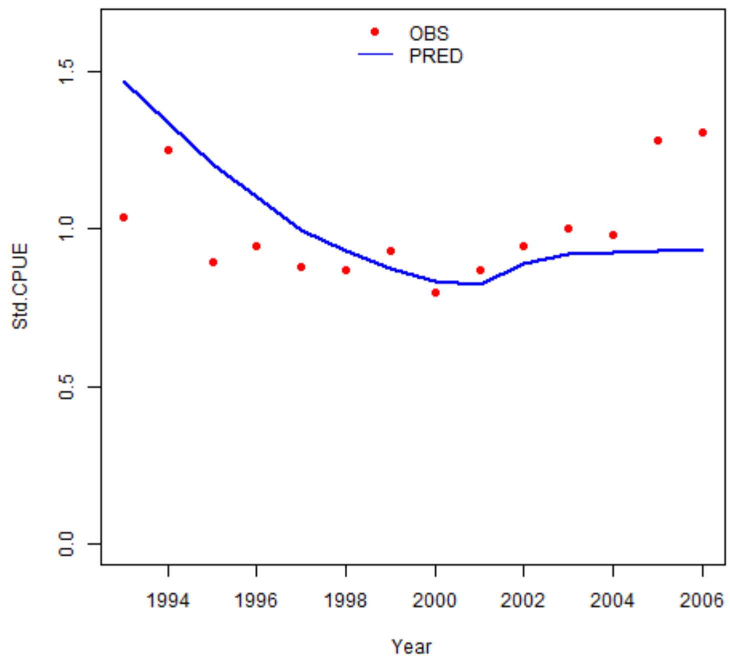


Figure 27: Observed (red points) and predicted (blue line) commercial CPUE for the pre-IFQ (1993-2006) indices in the eastern (top panel) and western (bottom panel) Gulf of Mexico.



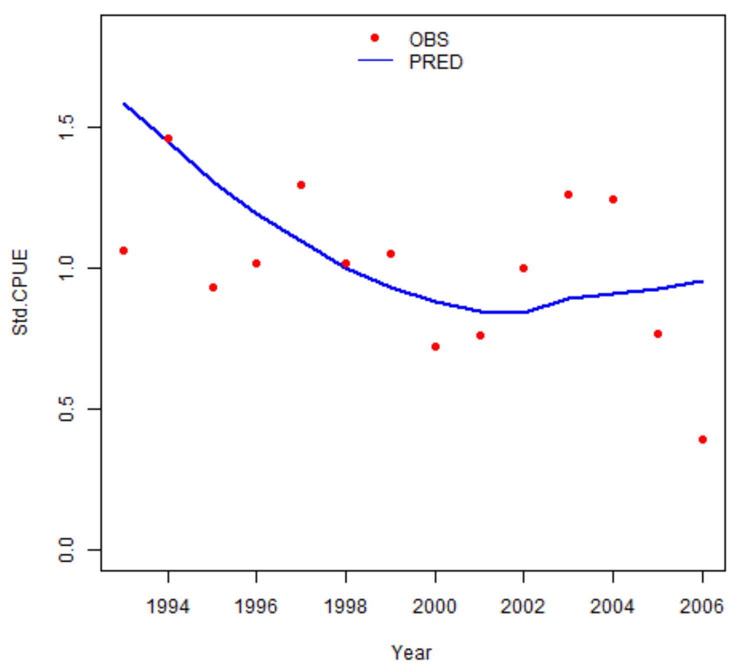
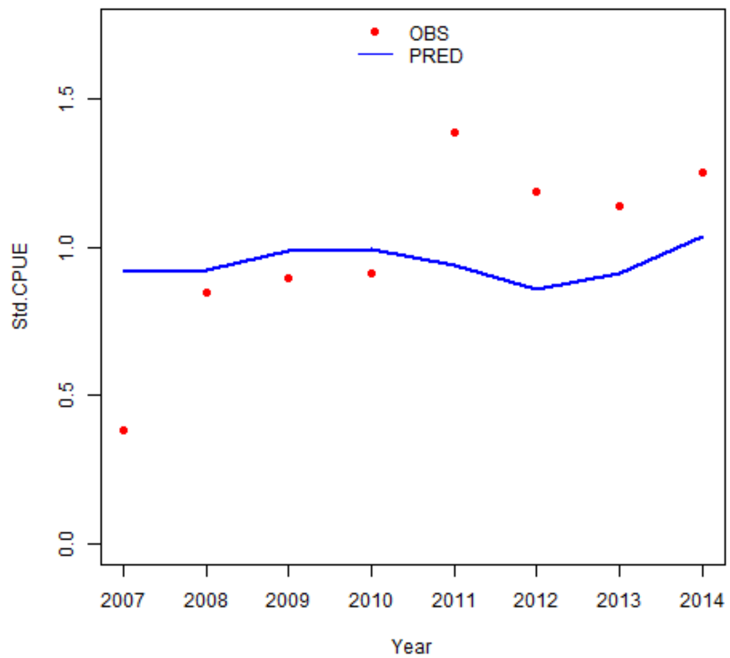


Figure 28: Observed (red points) and predicted (blue line) commercial CPUE for the post-IFQ (2007-2014) indices in the eastern (top panel) and western (bottom panel) Gulf of Mexico.



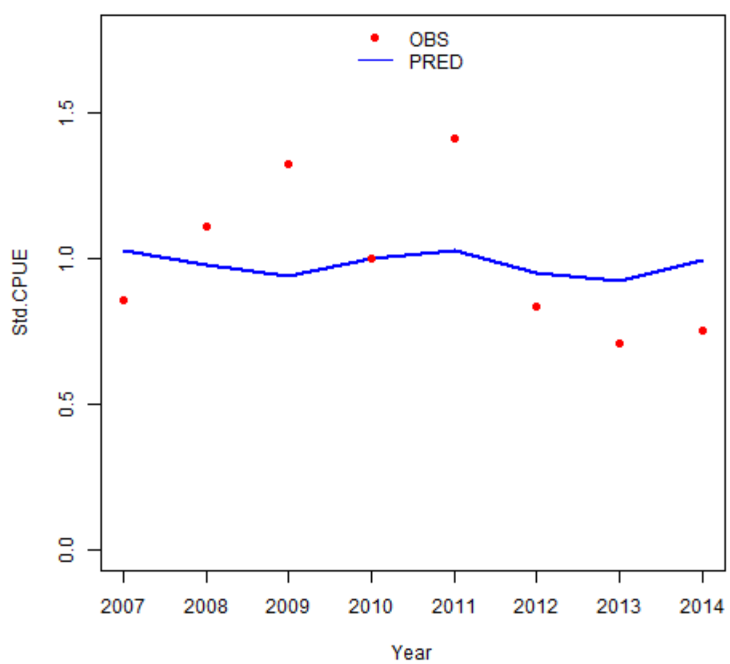


Figure 29: Observed (red points) and predicted (blue line) MRFSS CPUE index for the eastern Gulf of Mexico.

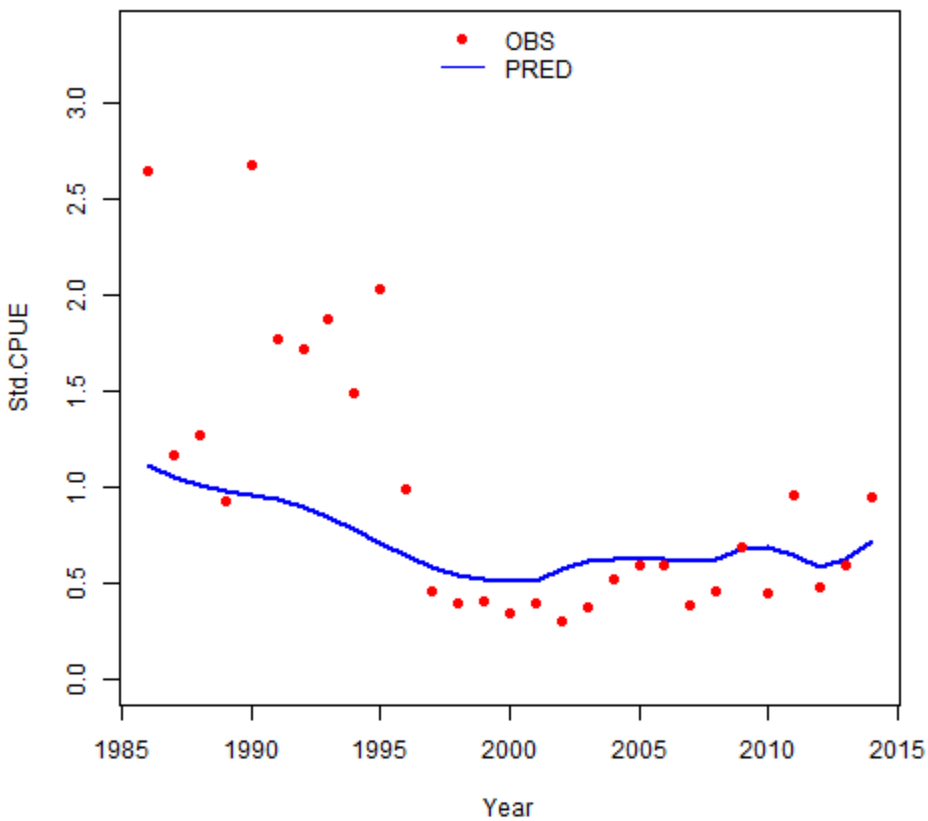
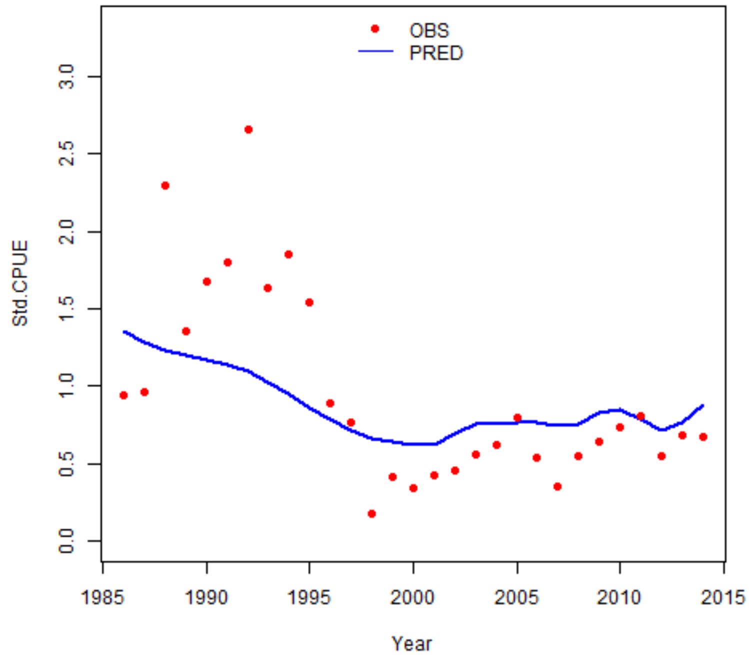


Figure 30: Observed (red points) and predicted (blue line) headboat CPUE indices for the eastern (top panel) and western (bottom panel) Gulf of Mexico.



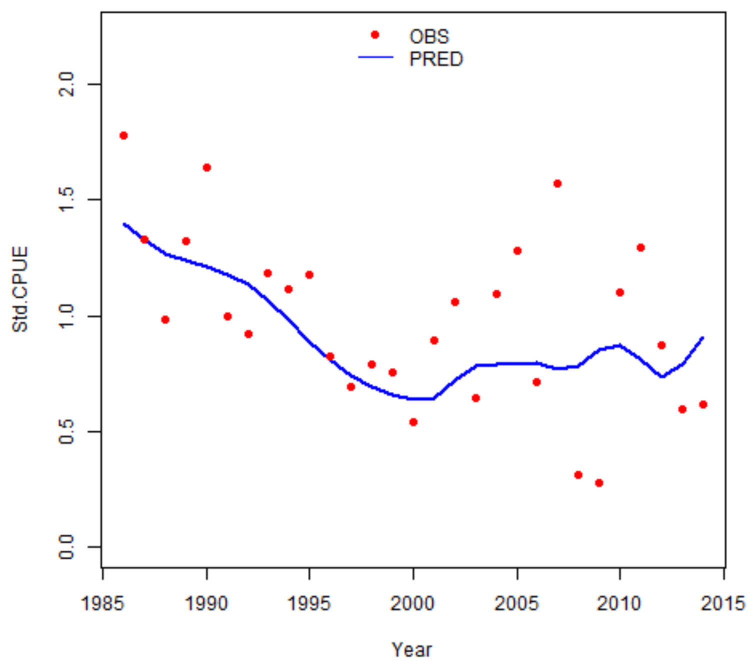


Figure 31: Observed (red points) and predicted (blue line) fishery independent Video (top panel), groundfish (middle panel), and larval (bottom panel) survey indices.

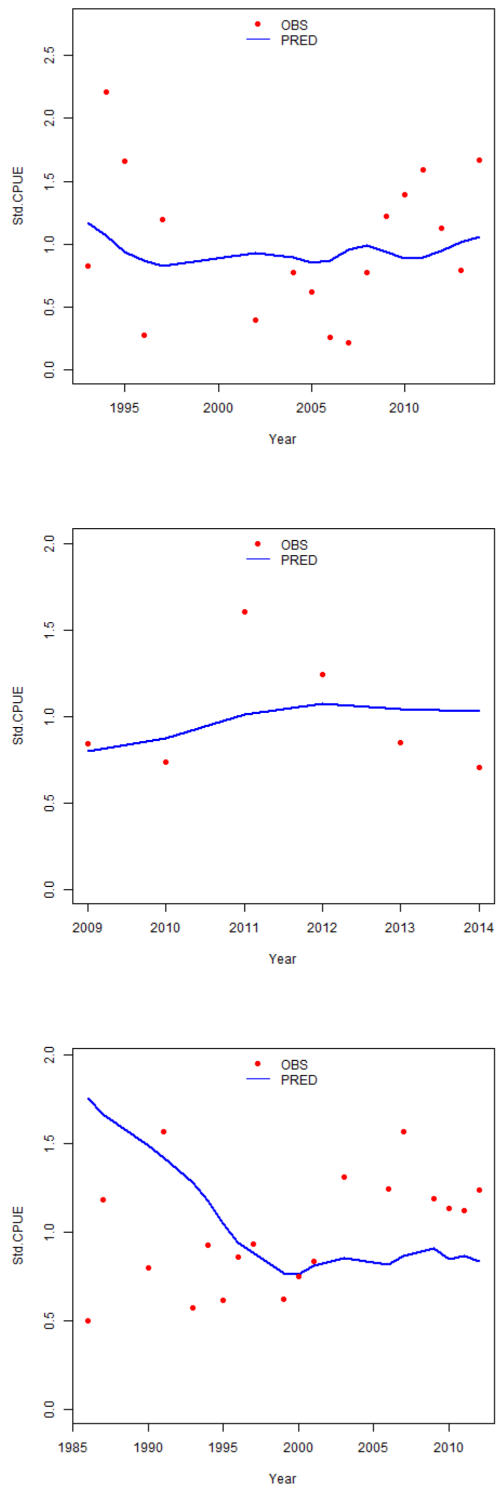


Figure 32: Observed (black lines) and predicted (green lines) age compositions for the eastern Gulf of Mexico commercial fishery. Input sample sizes (N; after reweighting) along with the effective sample size (effN) are also reported. Sample sizes were capped at a maximum of 100.

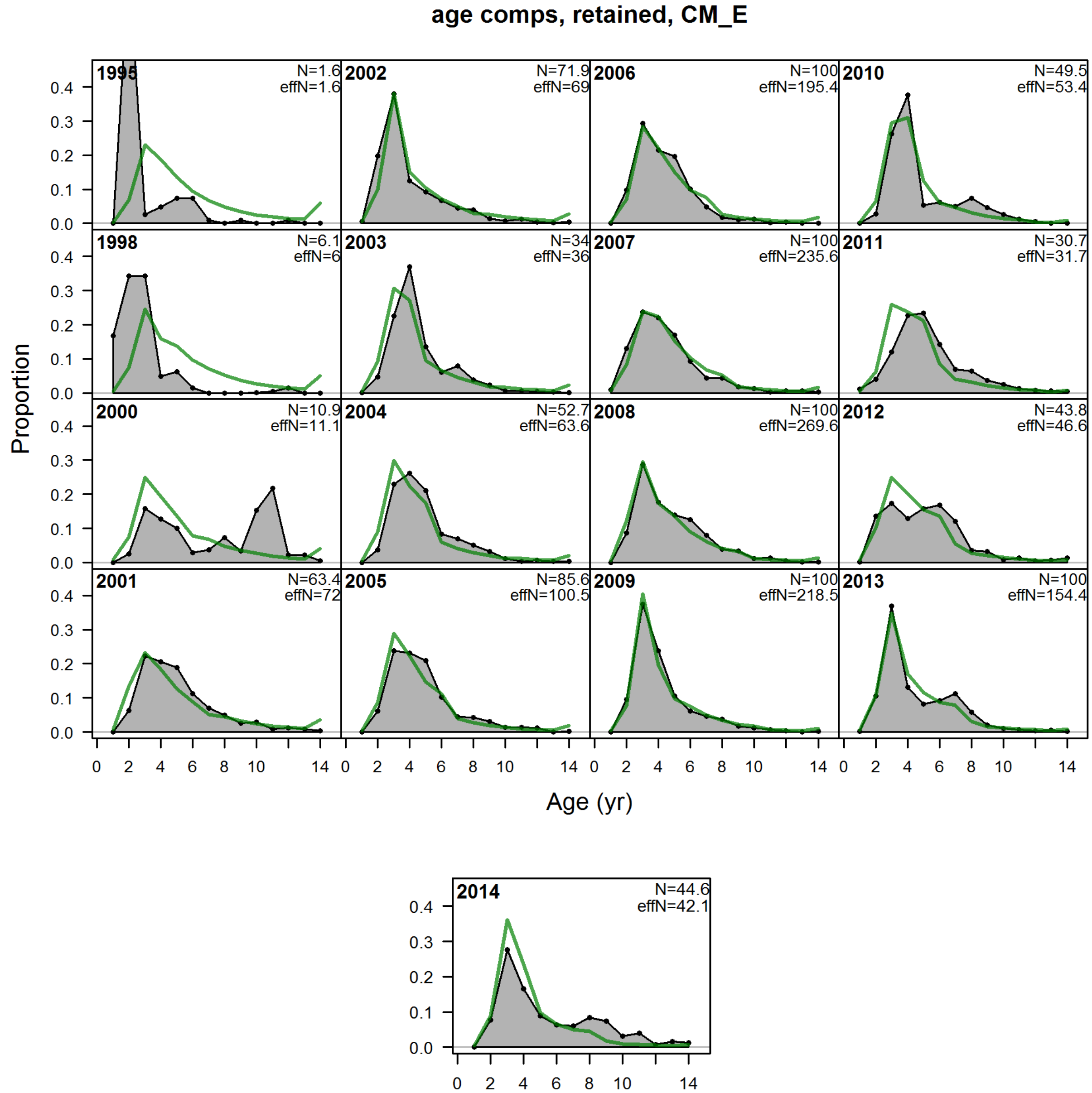


Figure 33: Observed (black lines) and predicted (green lines) age compositions for the western Gulf of Mexico commercial fishery. Input sample sizes (N; after reweighting) along with the effective sample size (effN) are also reported. Sample sizes were capped at a maximum of 100.

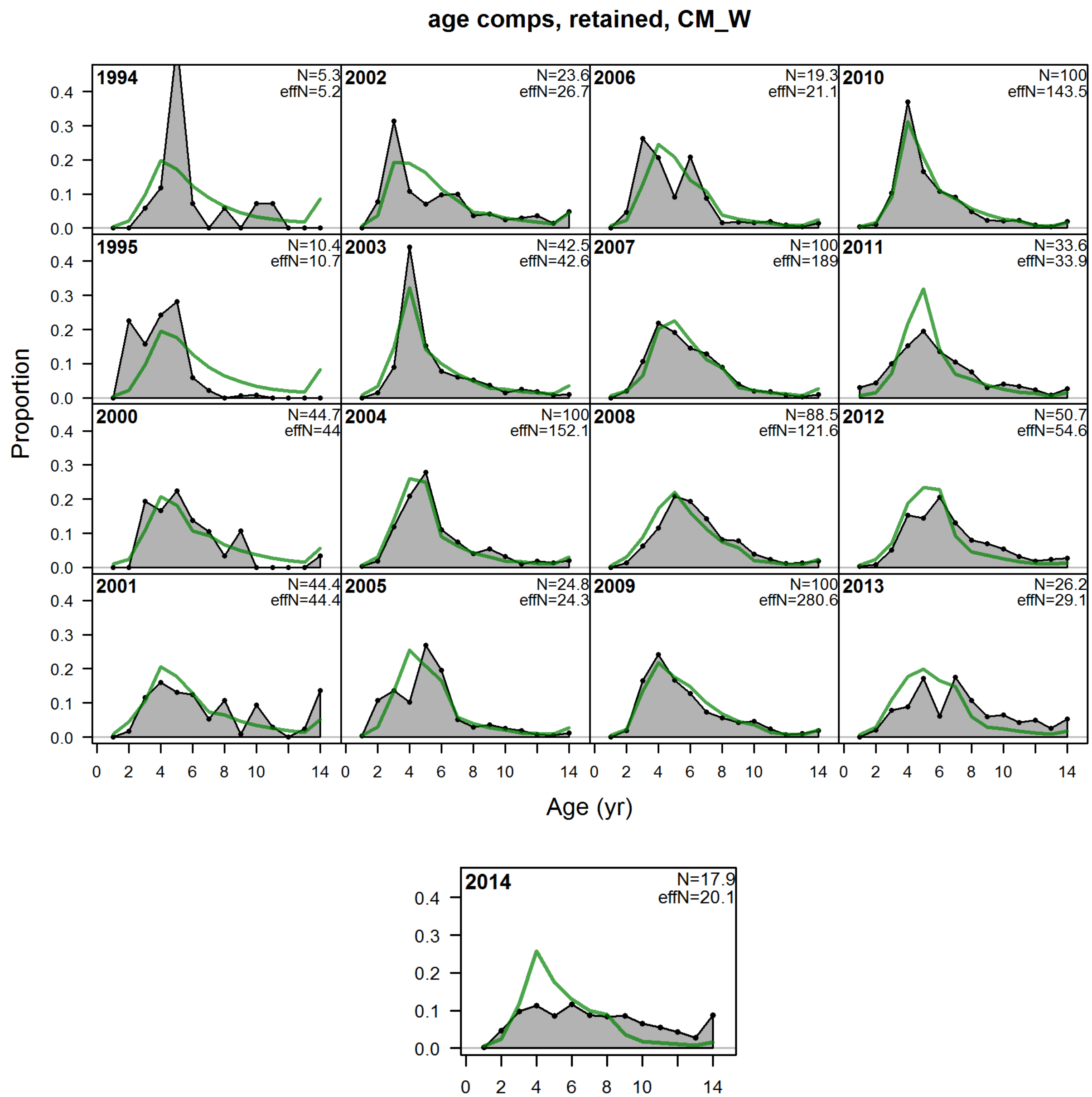


Figure 34: Observed (black lines) and predicted (green lines) age compositions for the gulf-wide recreational fishery. Input sample sizes (N; after reweighting) along with the effective sample size (effN) are also reported. Sample sizes were capped at a maximum of 100.

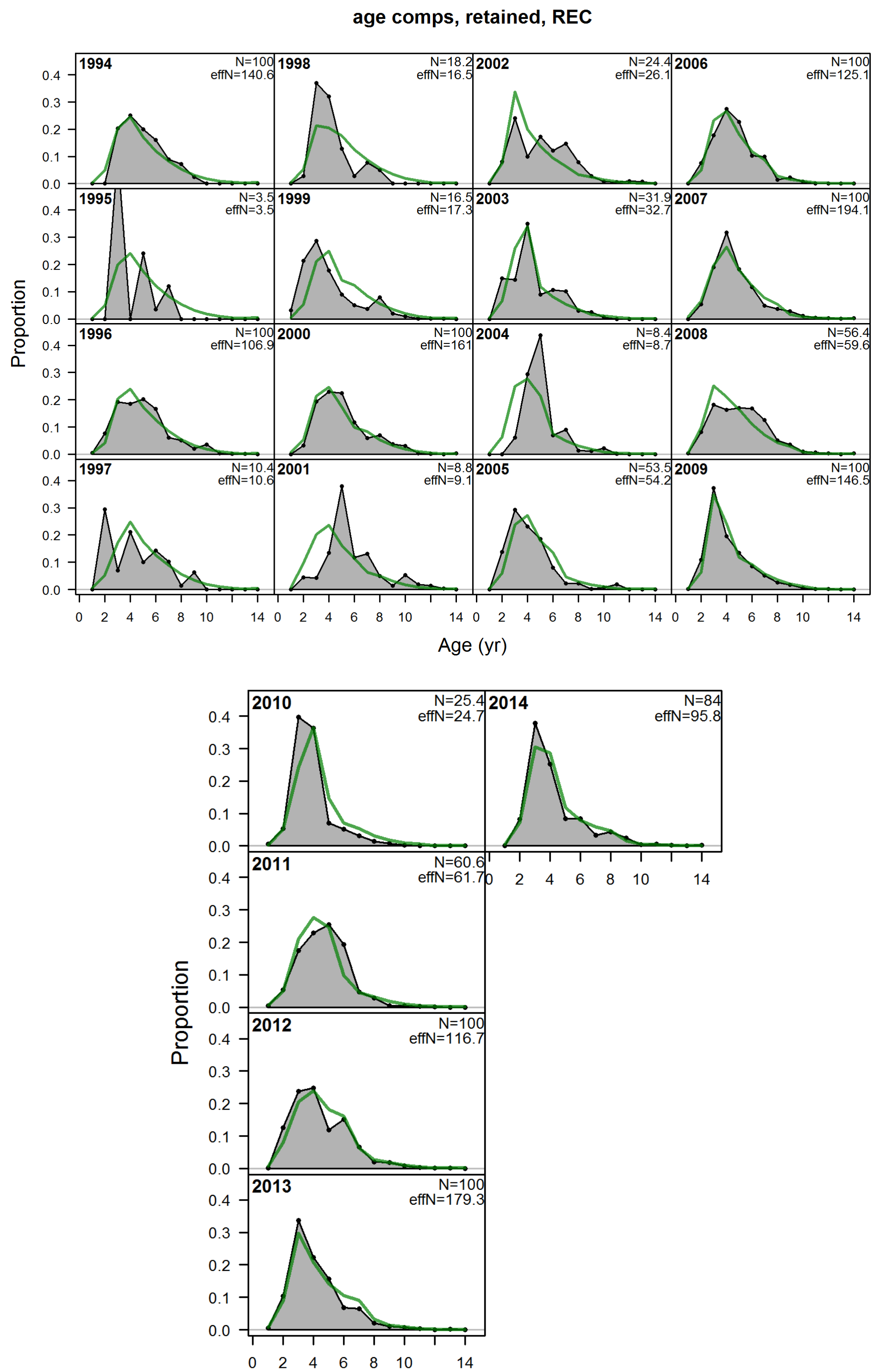


Figure 35: Pearson residuals of age composition fits for the commercial east (top panel), commercial west (middle panel), and recreational (bottom panel) fisheries. Grey bubbles represent positive residuals (observed greater than predicted) and unfilled bubbles represent negative residuals (predicted greater than observed).

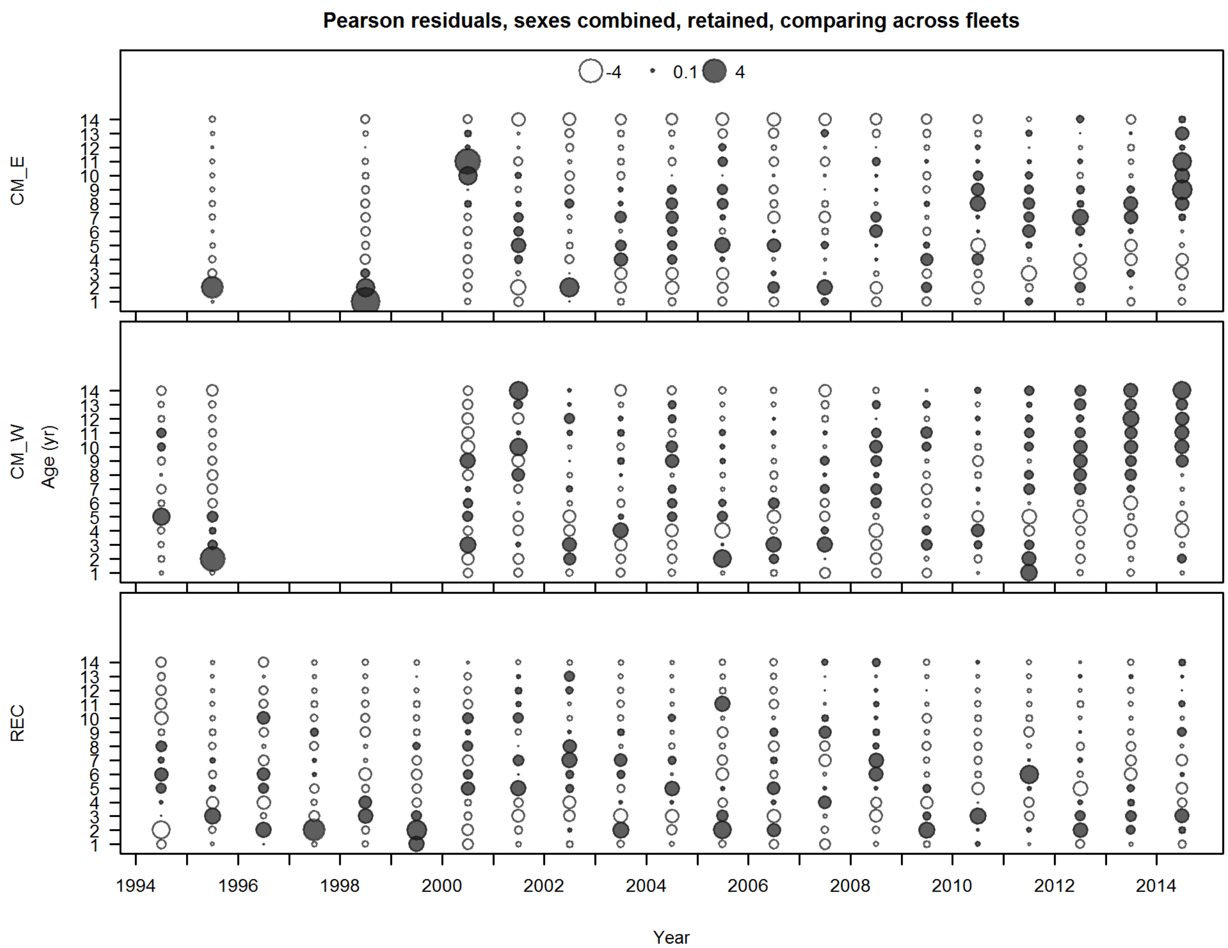


Figure 36: Observed and predicted age compositions aggregated across years for the commercial east (top left panel), commercial west (bottom left panel), and recreational (top right panel) fleets.

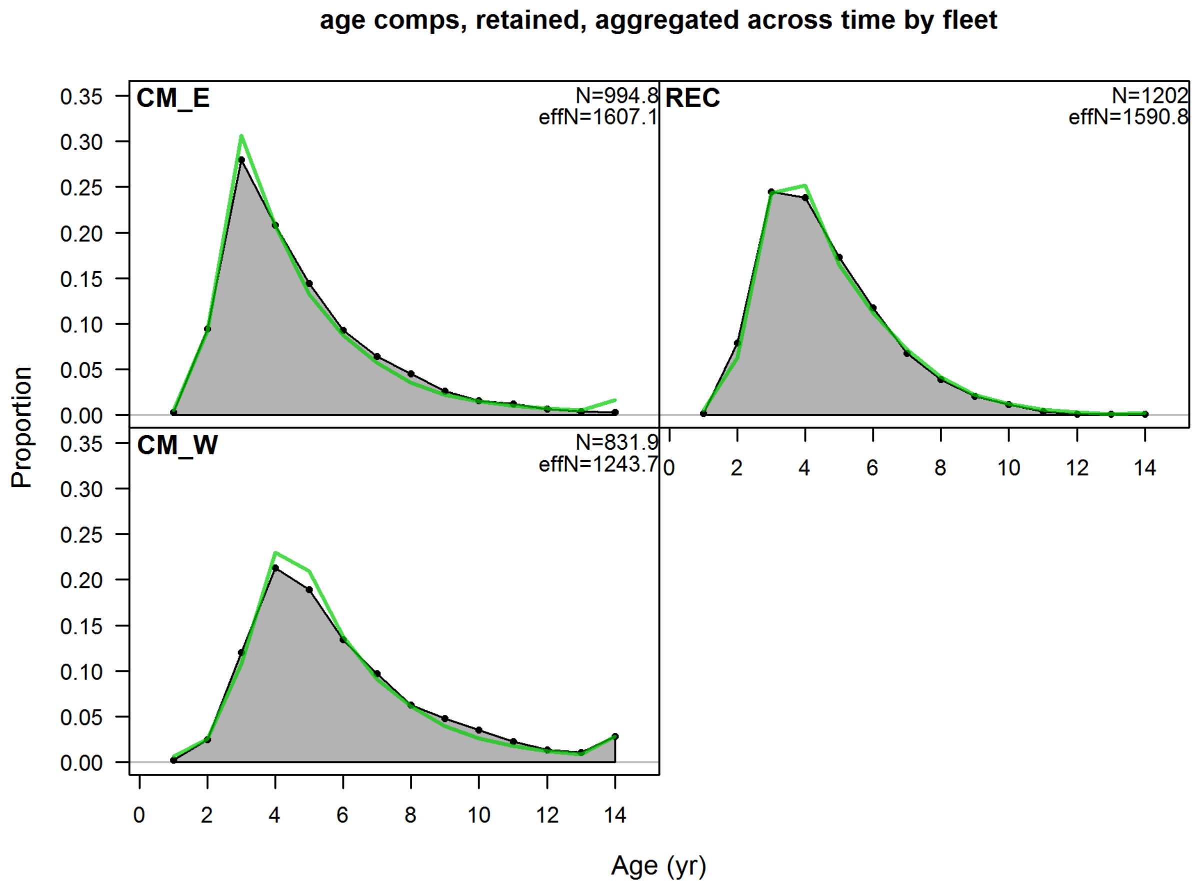


Figure 37: Observed (black lines) and predicted (green lines) length compositions for the video survey. Input sample sizes (N; after reweighting) along with the effective sample size (effN) are also reported. Sample sizes were capped at a maximum of 100.

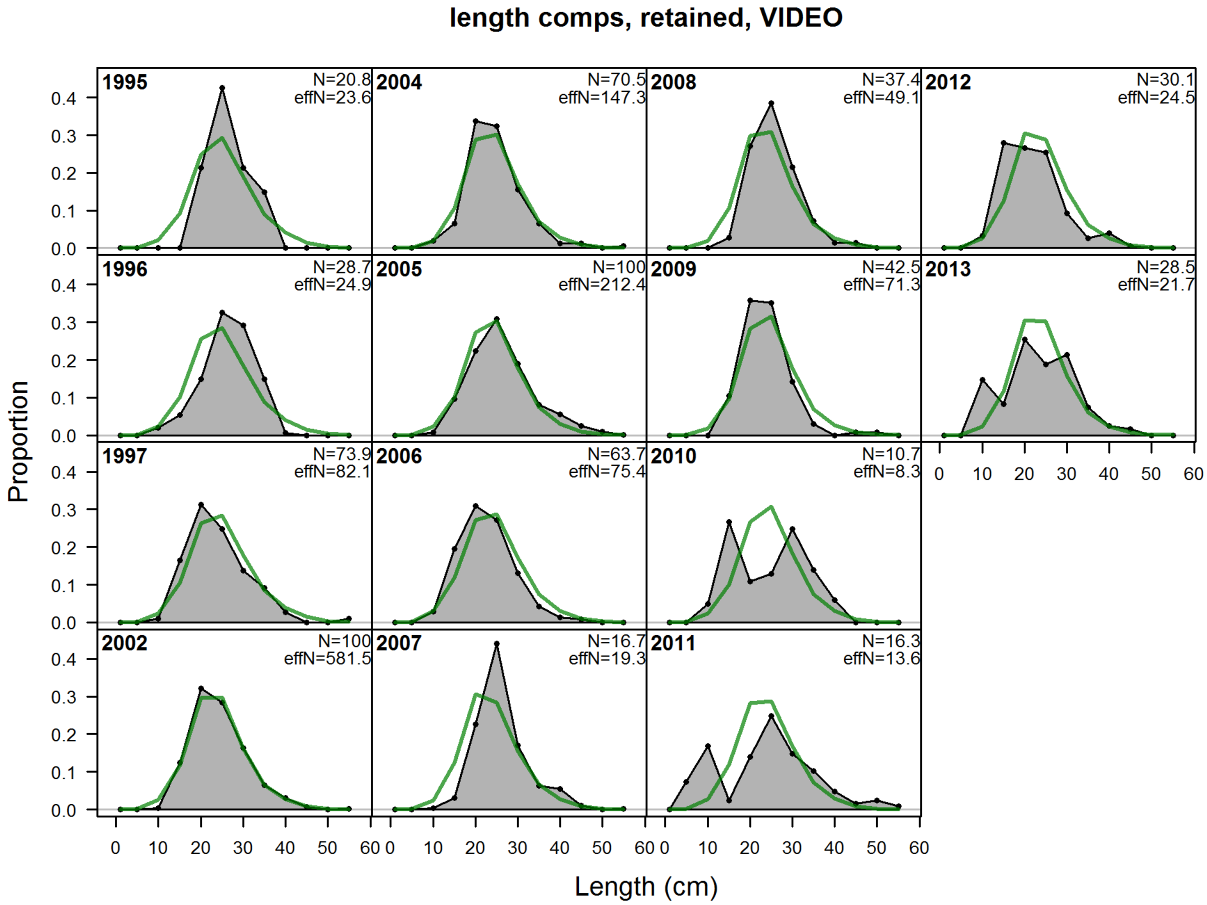


Figure 38: Observed (black lines) and predicted (green lines) length compositions for the groundfish survey. Input sample sizes (N; after reweighting) along with the effective sample size (effN) are also reported. Sample sizes were capped at a maximum of 100.

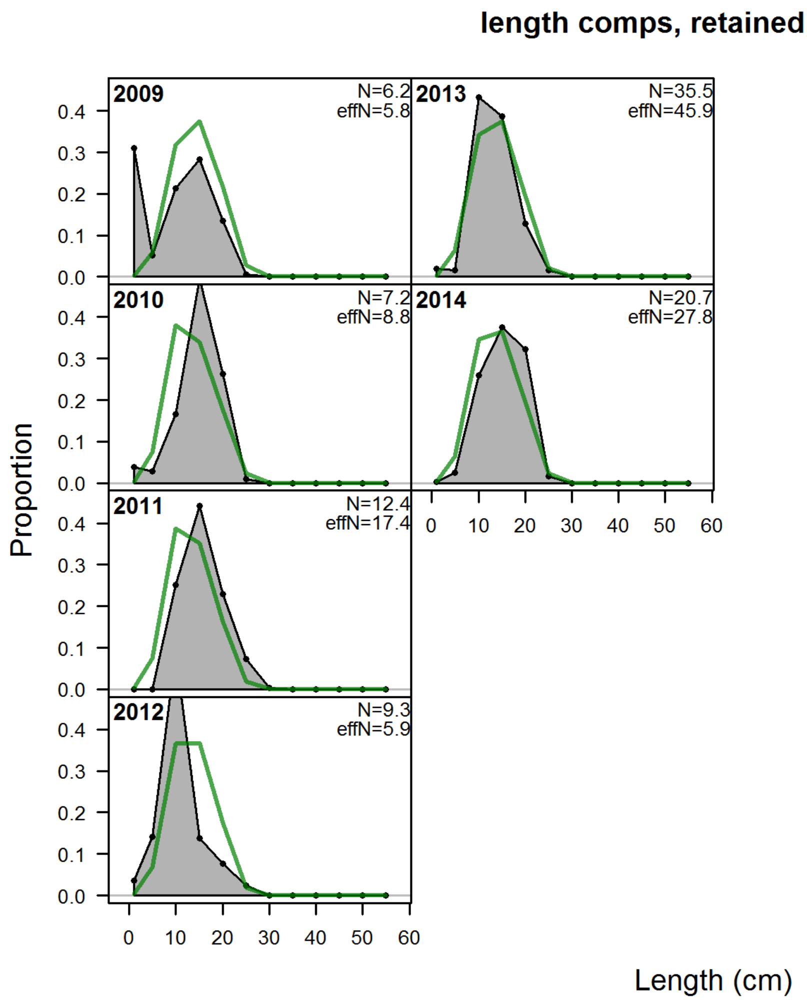
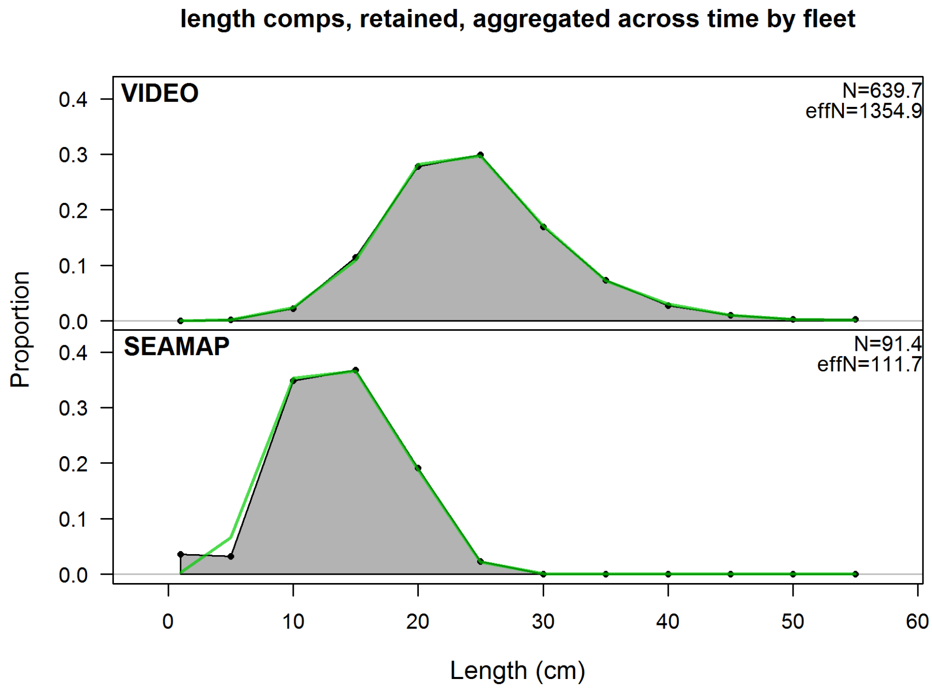


Figure 39: Observed and predicted length compositions aggregated across years (top panel) and Pearson residuals (bottom panel) for the video and groundfish surveys.



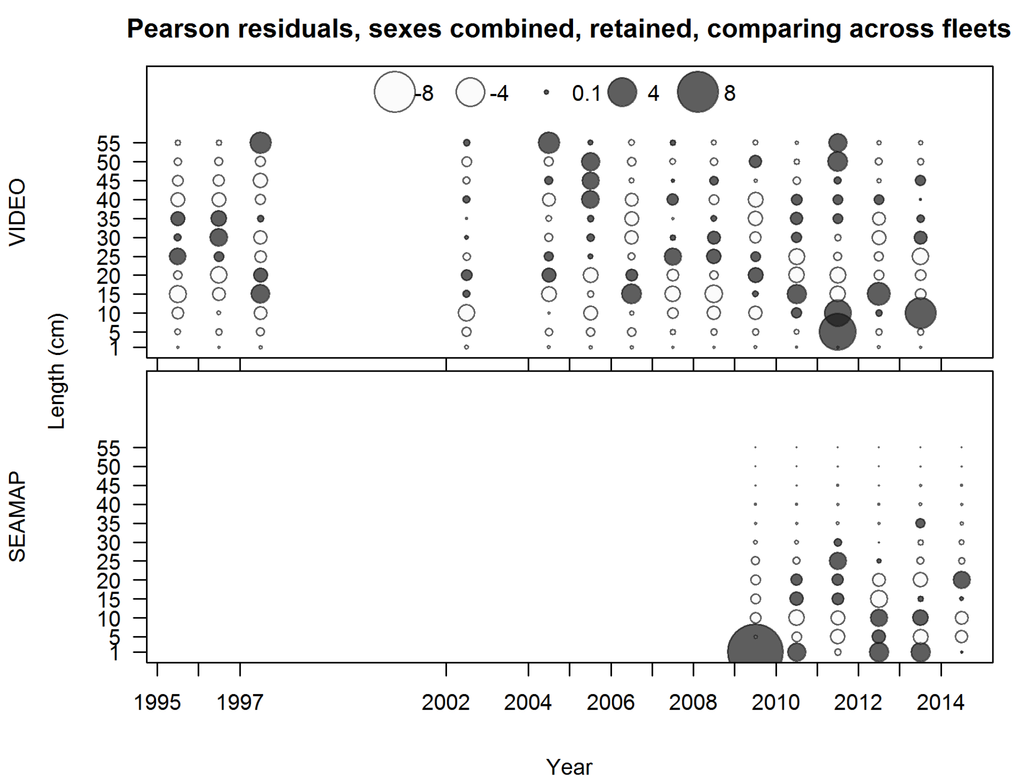


Figure 40: Profile likelihood plots for steepness (*h*; top panel), recruitment variance (σ_R; middle panel), and the natural log of virgin recruitment (ln_R_0; bottom plot). The y-axis provides the change in negative log-likelihood and, therefore, represents increases in likelihood relative to the best fit model.

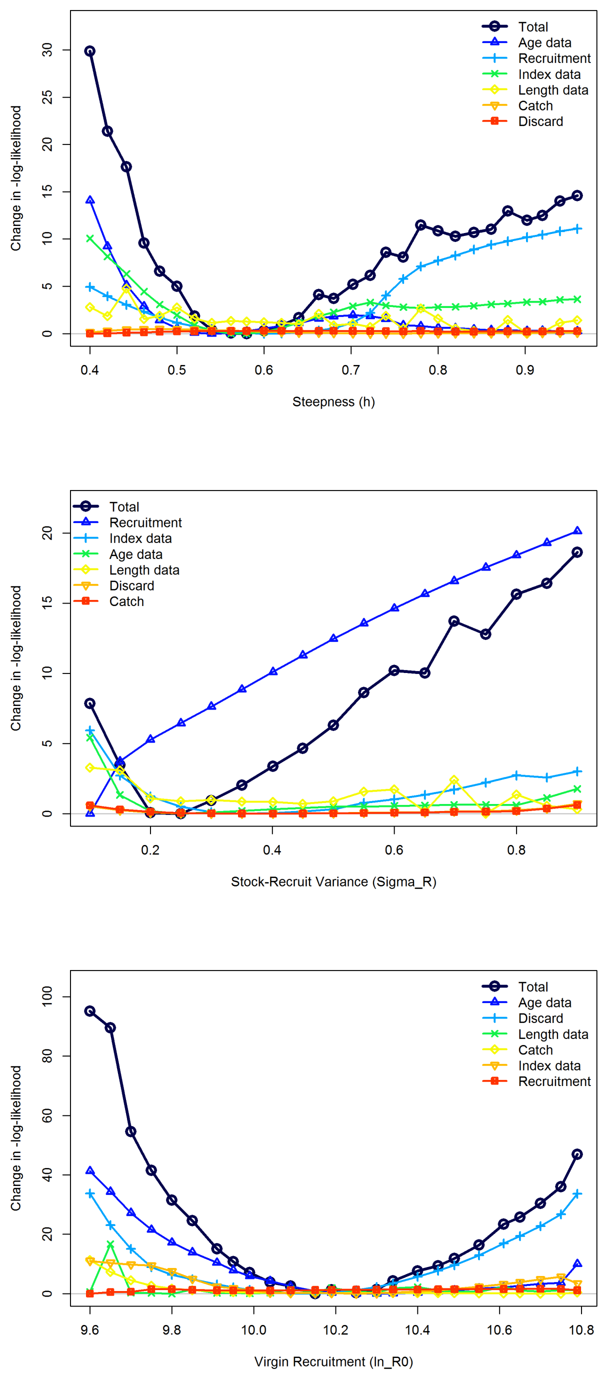


Figure 41: Spawning stock biomass (1000s of eggs) plots for each of the profile likelihood runs provided in Figure 42. The top panel illustrates runs at different steepness levels, the middle plot represents runs at different recruitment variance levels, and the bottom plot shows runs for different natural log of virgin recruitment levels. In general, all runs converge to similar current biomass levels demonstrating strong model stability.

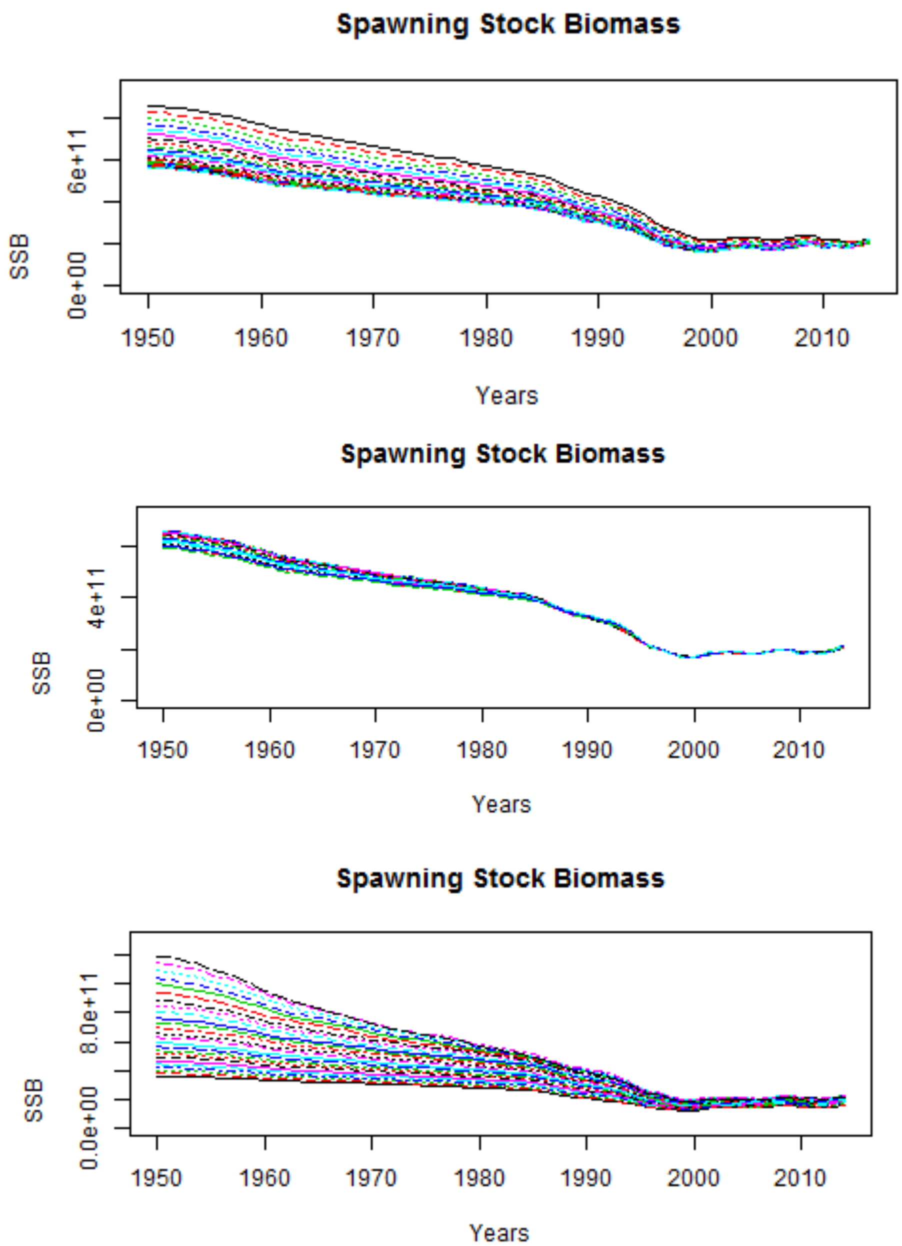


Figure 42: Profile likelihood contour plot of recruitment variance against steepness. Contours illustrate negative log-likelihood values (lower values demonstrate stronger fit to the data). The nearly level contours that trail to the top right indicate the highly correlated nature of these parameters. Although the model estimates steepness around 0.55 and recruitment variance around 0.25, steepness values from 0.5 - 0.8 with corresponding recruitment variances from 0.2 - 0.65 provide nearly identical fits to the data and are likely to be equally probable.

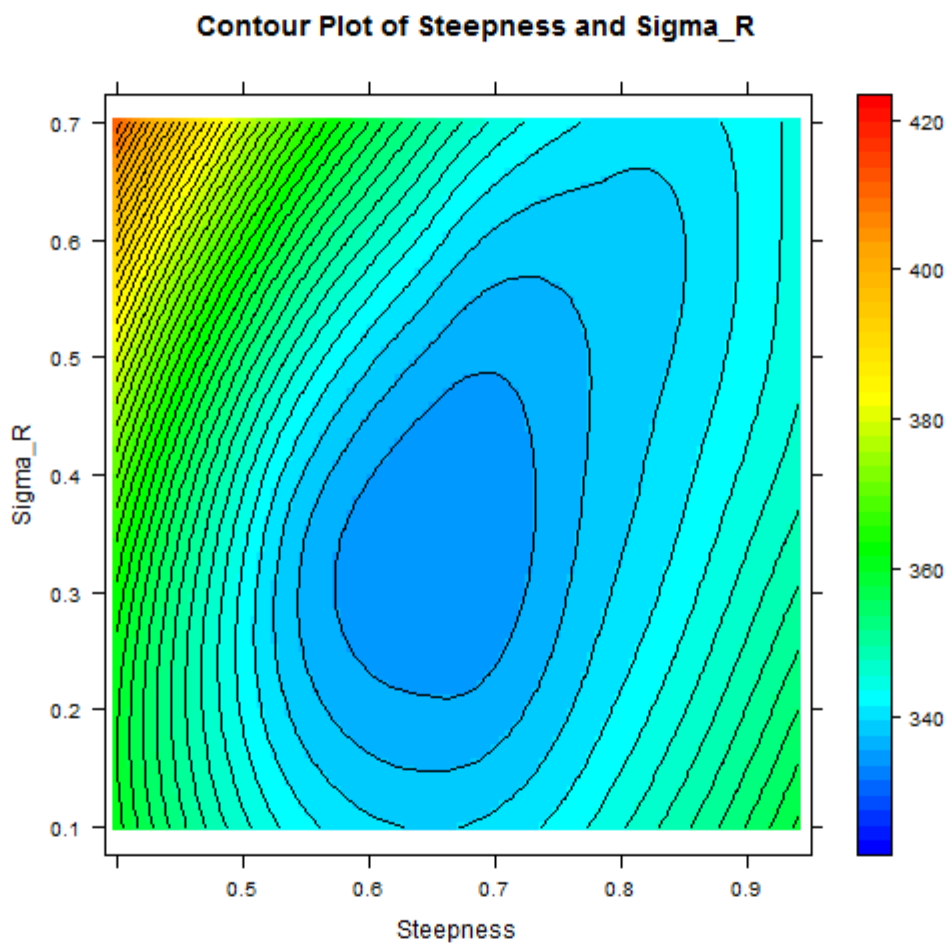


Figure 43: Results of the 1000 bootstrap analyses for various estimated parameters and population quantities. Although some spread exists in the final estimates, model results are fairly consistent across runs indicating high model stability. SSB is in 1000s of eggs.

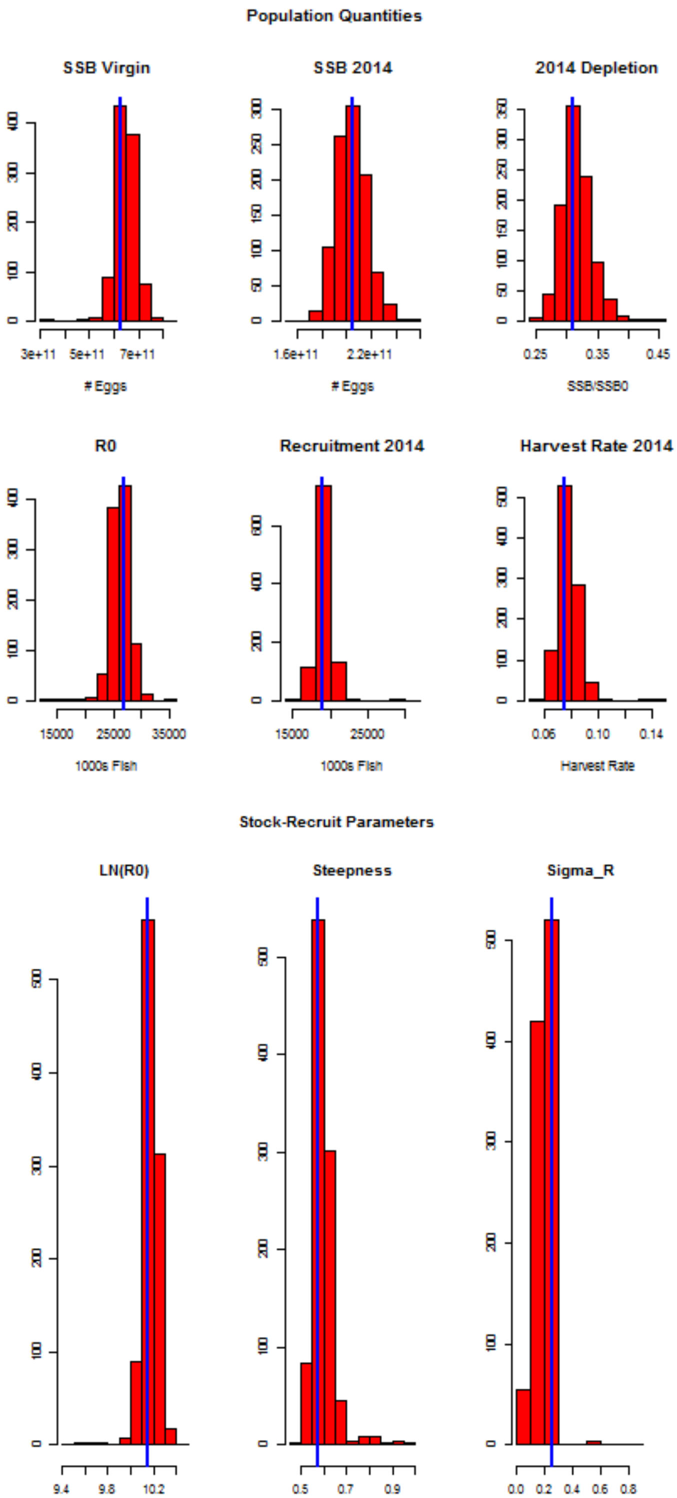
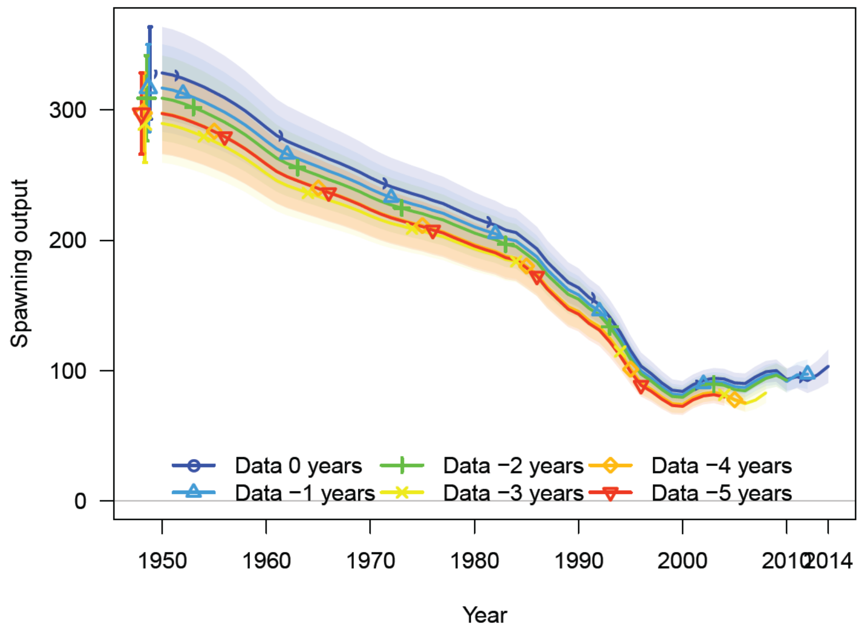


Figure 44: Results of a five year retrospective analysis for spawning output (0.5*trillion eggs; top panel) and recruitment (million fish; bottom panel). There is no discernible systematic bias, because each data peal is not consistently over or underestimating any of the population quantities. It should be noted that due to the successively shortened timeseries for the commercial IFQ CPUE indices and the groundfish fishery-independent survey, model results are likely to be more unstable with each successive peal and results with more than a three year peal may not be truly representative.



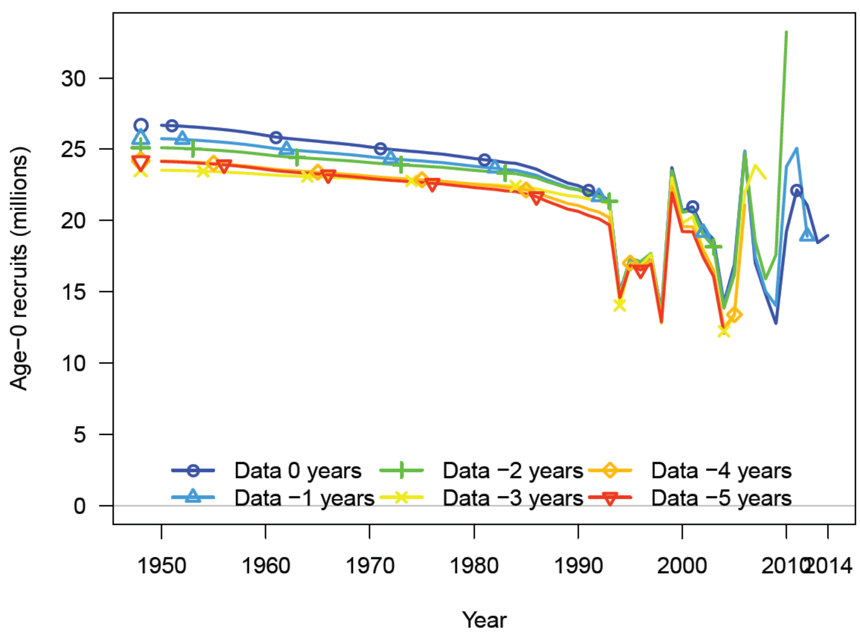


Figure 45: Results of the jitter analysis for various likelihood components (top left and bottom panels) and steepness estimates (top right panel). Each graph gives the results of 200 model runs where the starting parameter values for each run were randomly changed ('jittered') by 0.2 from the base model 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 6 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.

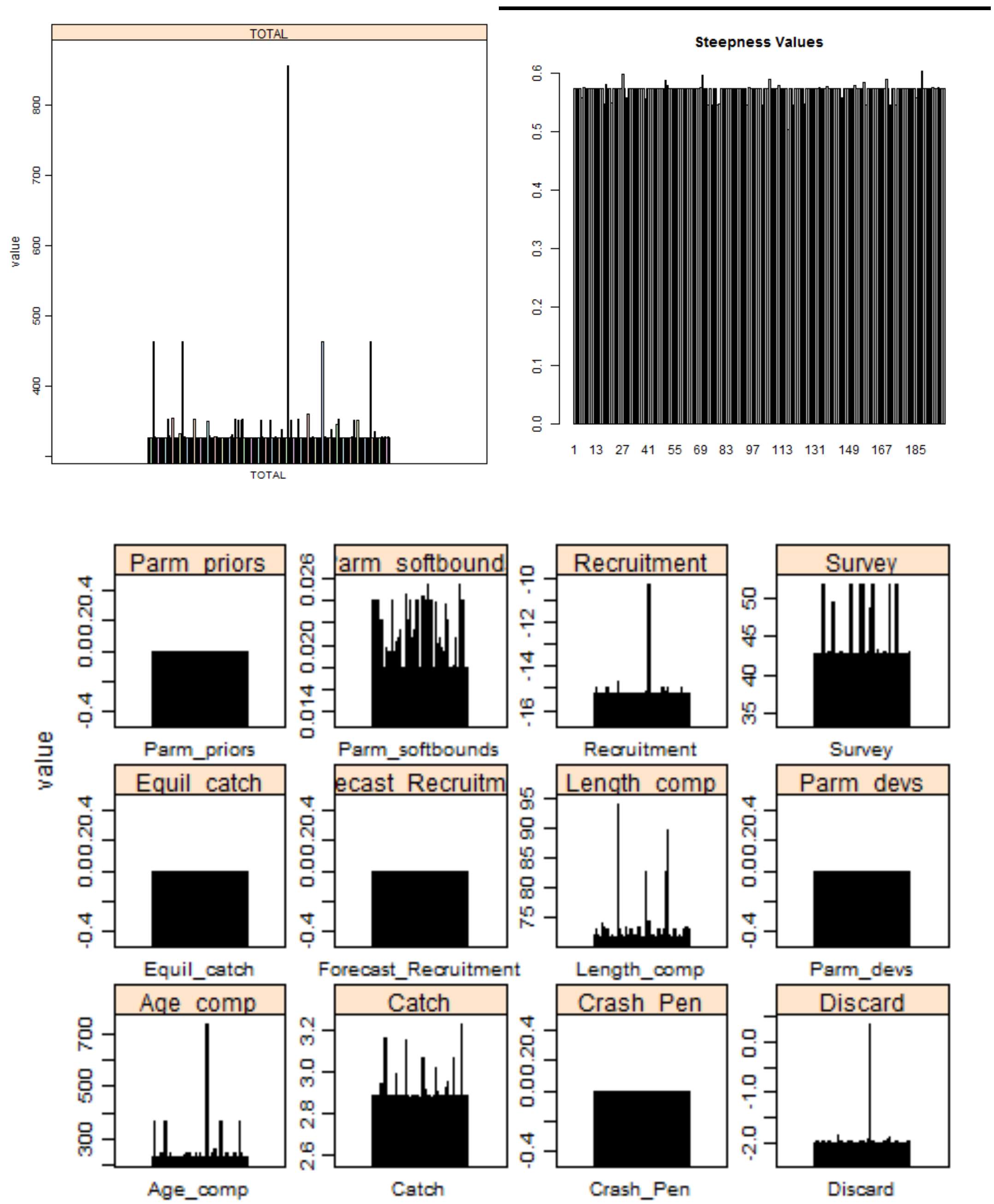


Figure 46: Results of a 'jack-knife' analysis with the fishery-dependent and independent indices. Spawning stock biomass (0.5*trillion eggs; top panel) and recruitment (million fish; bottom panel) are shown. The analysis was performed by running the base model with one of the indices removed in order to determine if any given index had undue influence on model results or indicated widely differing trends in population trajectories. The results indicate that all of the indices are generally in agreement and no one index seems to be driving the assessment.

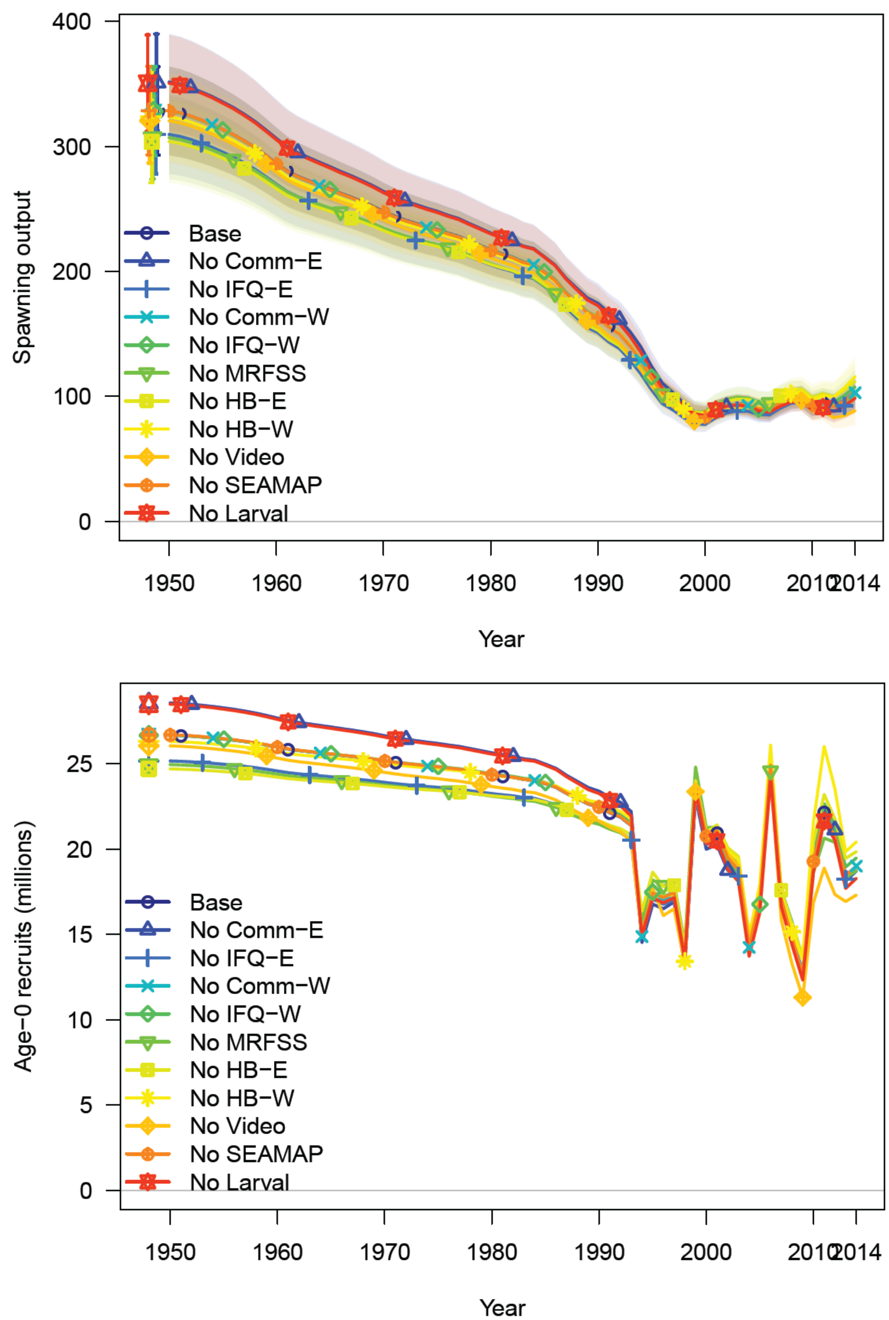
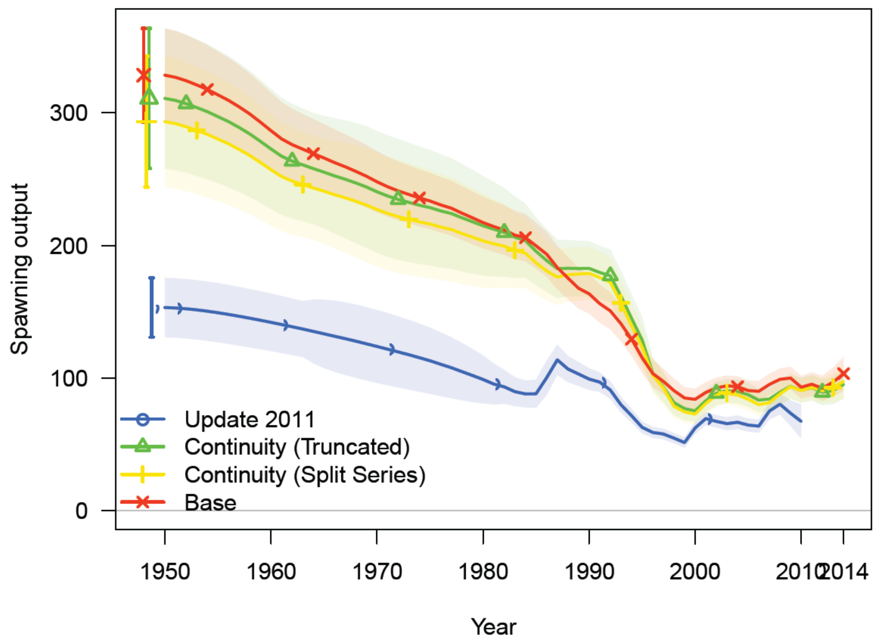


Figure 47: Comparison between the base (red), continuity (green), and 2011 update (blue) models for spawning stock biomass (0.5*trillion eggs; top panel) and recruitment (million fish; bottom panel). A model run (yellow) that uses the same settings as the continuity model but accounts for red snapper IFQ in the commercial CPUE indices (i.e., uses the same split series approach as the base model) is shown for comparison. The major reason for discrepancy between the 2011 update and other runs is that the shrimp bycatch median value was fit in each year (instead of using the super-year approach), which led to quite different virgin conditions and stock-recruit parameters.



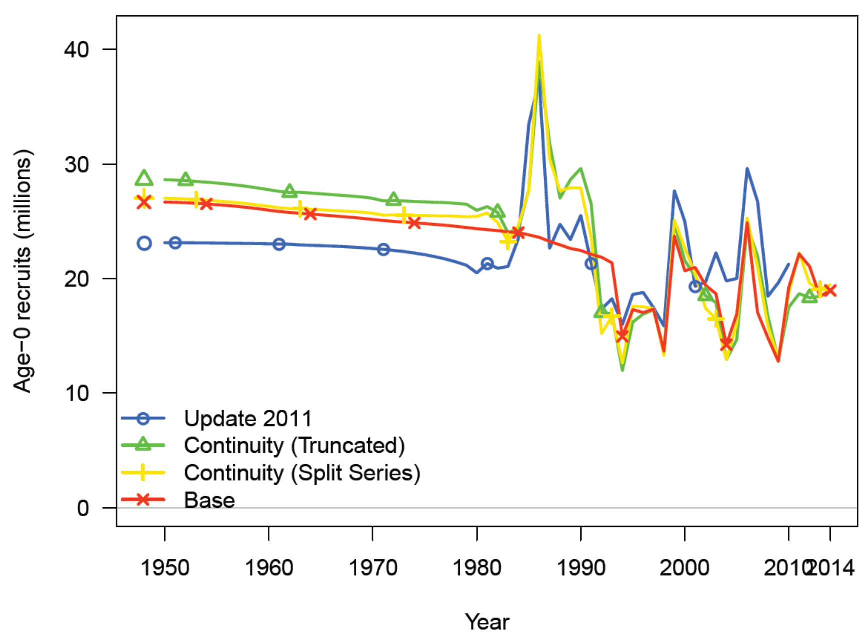


Figure 48: Comparison between the base model (blue), the base model using the 2011 update value of shrimp bycatch (red), and the base model assuming logistic selectivity for the recreational fishery (green) for spawning stock biomass (0.5*trillion eggs; top panel) and recruitment (million fish; bottom panel). The shrimp bycatch sensitivity run clearly illustrates the strong impact that median shrimp bycatch estimates have on estimates of virgin conditions (SSB_0 and R_0) and recruitment, but indicate limited changes in recent SSB. The recreational selectivity assumption does not have as strong an influence, but, not surprisingly, allowing for domed selectivity tends to provide more optimistic estimates of SSB since older fish are not as strongly impacted by recreational fishing mortality.

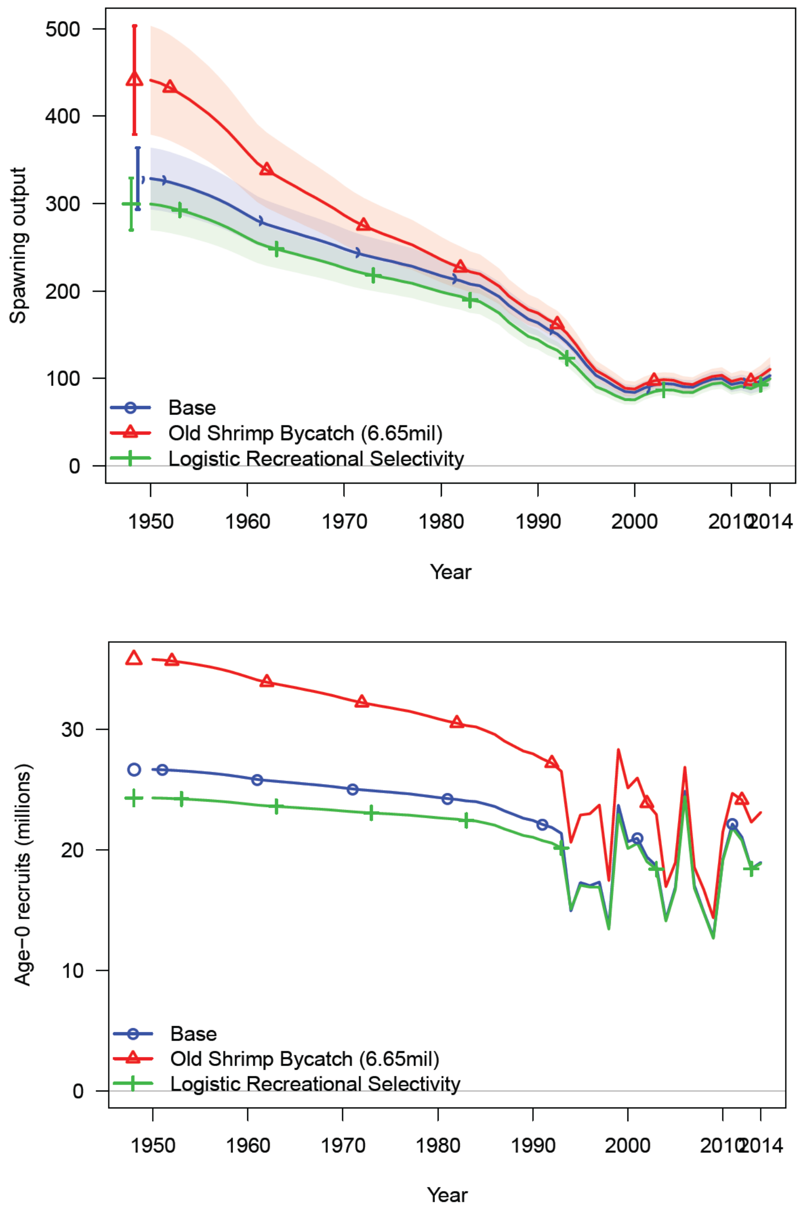


Figure 49: The conditional yield-per-recruit curve for vermilion snapper assuming fixed shrimp bycatch. Fast growth of vermilion leads to a flat YPR curve and results in a high estimate of F_{CMAX}. F is presented as a harvest rate (age-1+ numbers killed/age-1+ abundance).

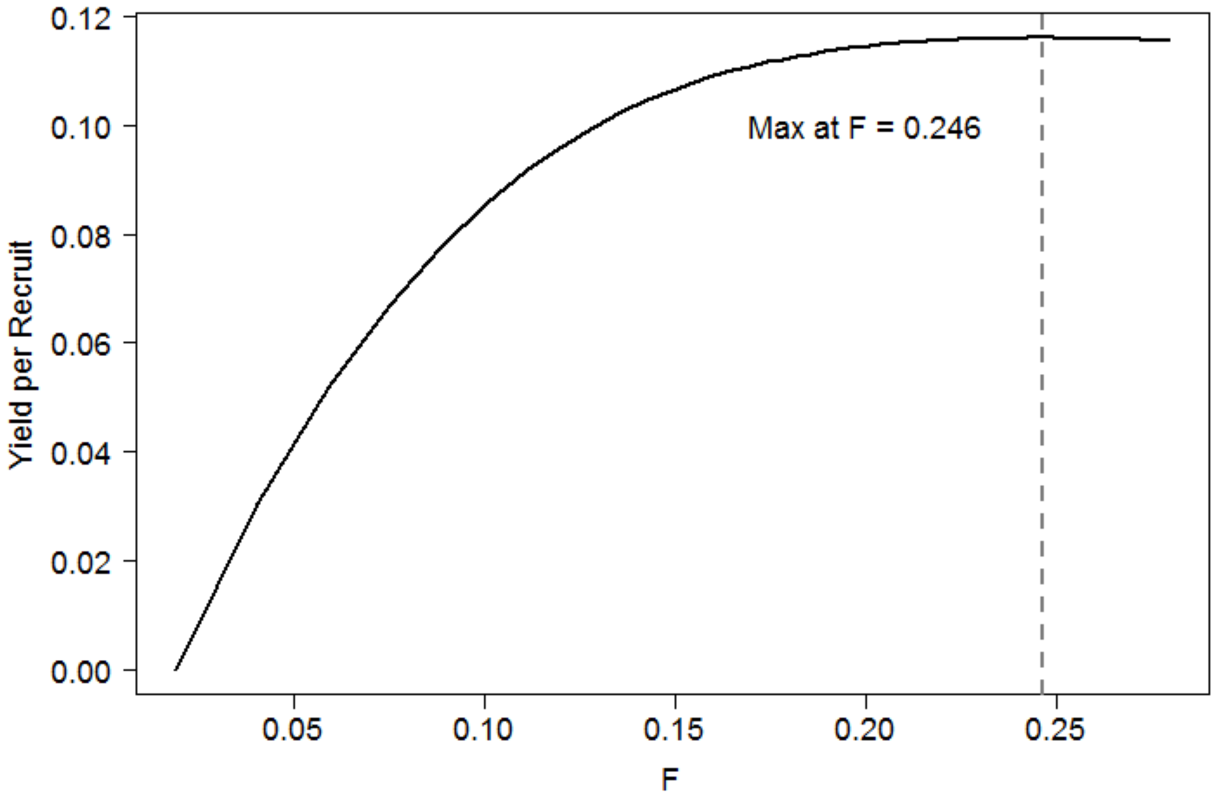


Figure 50: Results of the global YPR projections assuming a single fleet with optimal knife-edge selectivity at a given age, no bycatch or discards, and near infinite fishing mortality. Projections were based on the assumption that average recent recruitment would continue in the future. The top panel shows the yield curve, while the bottom panel shows the resulting SPR ratio. The maximum yield occurs with recruitment to the fishery between ages 3 and 4 and results in a SPR between 13 and 20%.

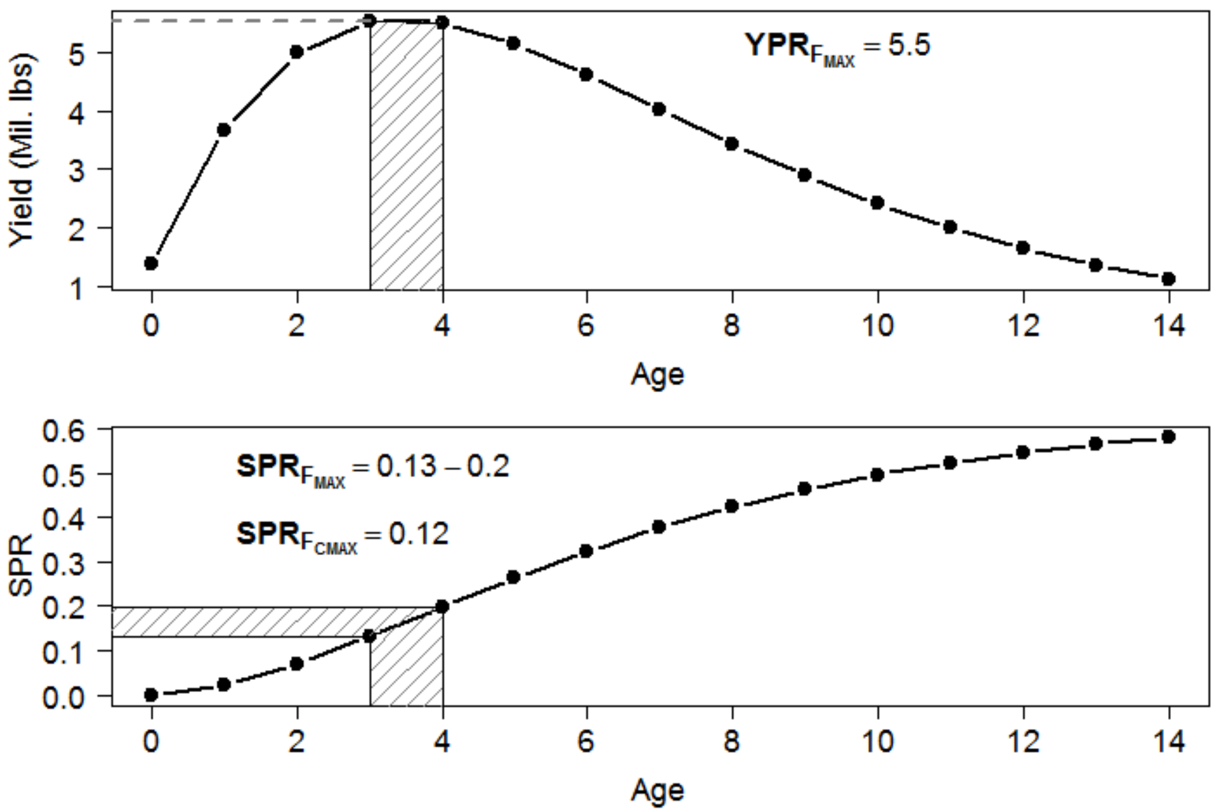


Figure 51: Kobe plot illustrating the trajectory of stock status. The orange coloring indicates regions where the stock is below the biomass target but above the biomass threshold (MSST).

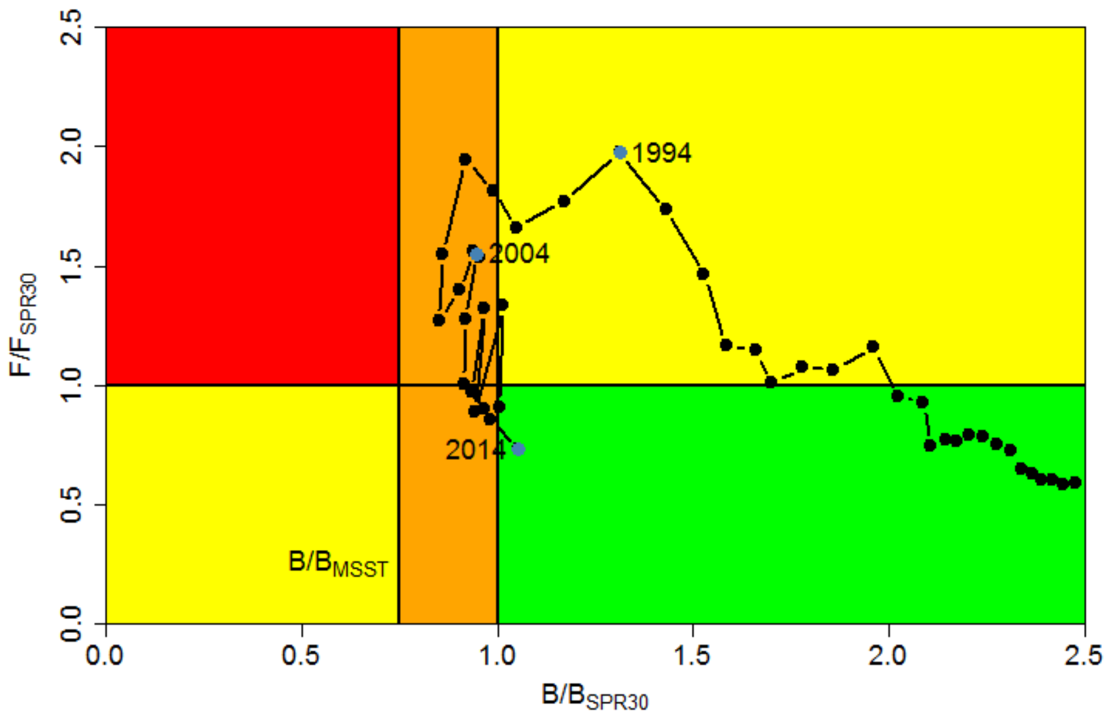


Figure 52: Overfishing limit (retained yield) and resulting spawning potential ratio (SPR) for projections with F = $F_{SPR30\%}$ assuming recent average recruitment.

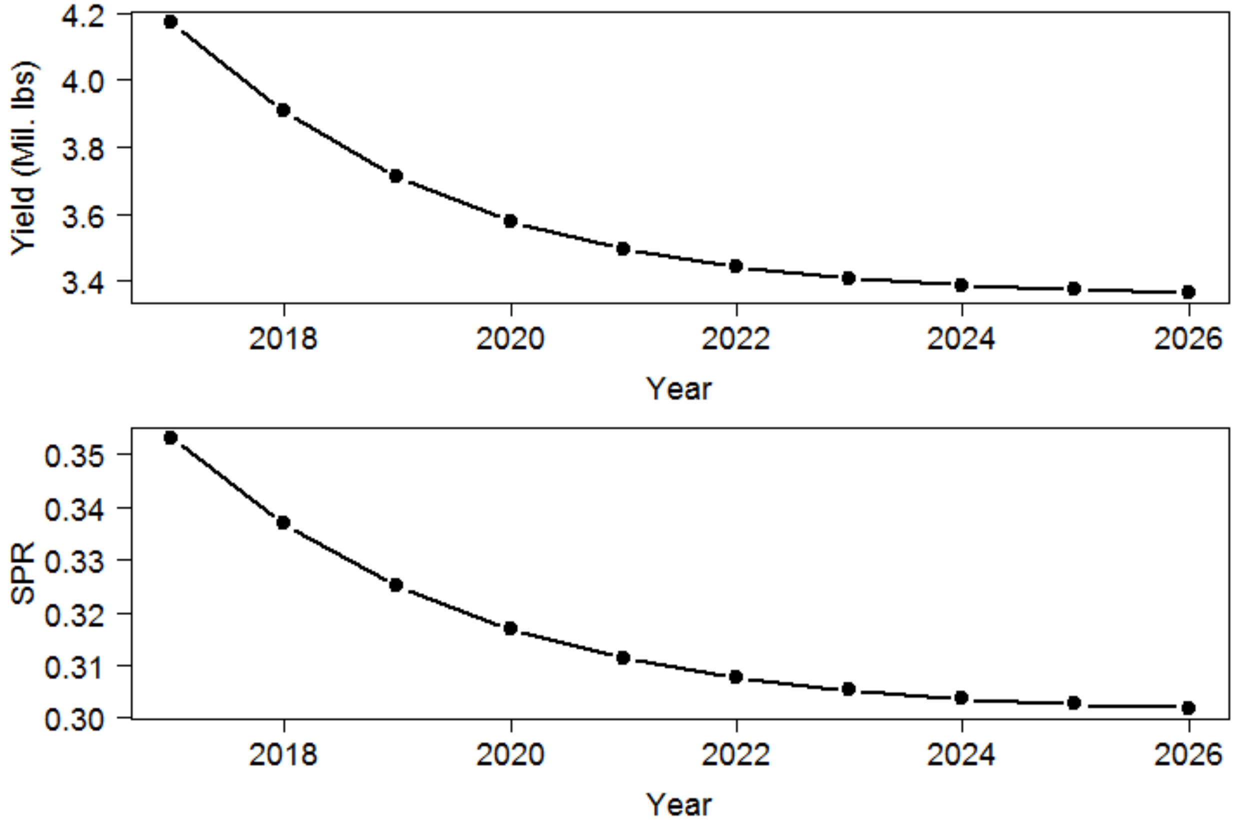
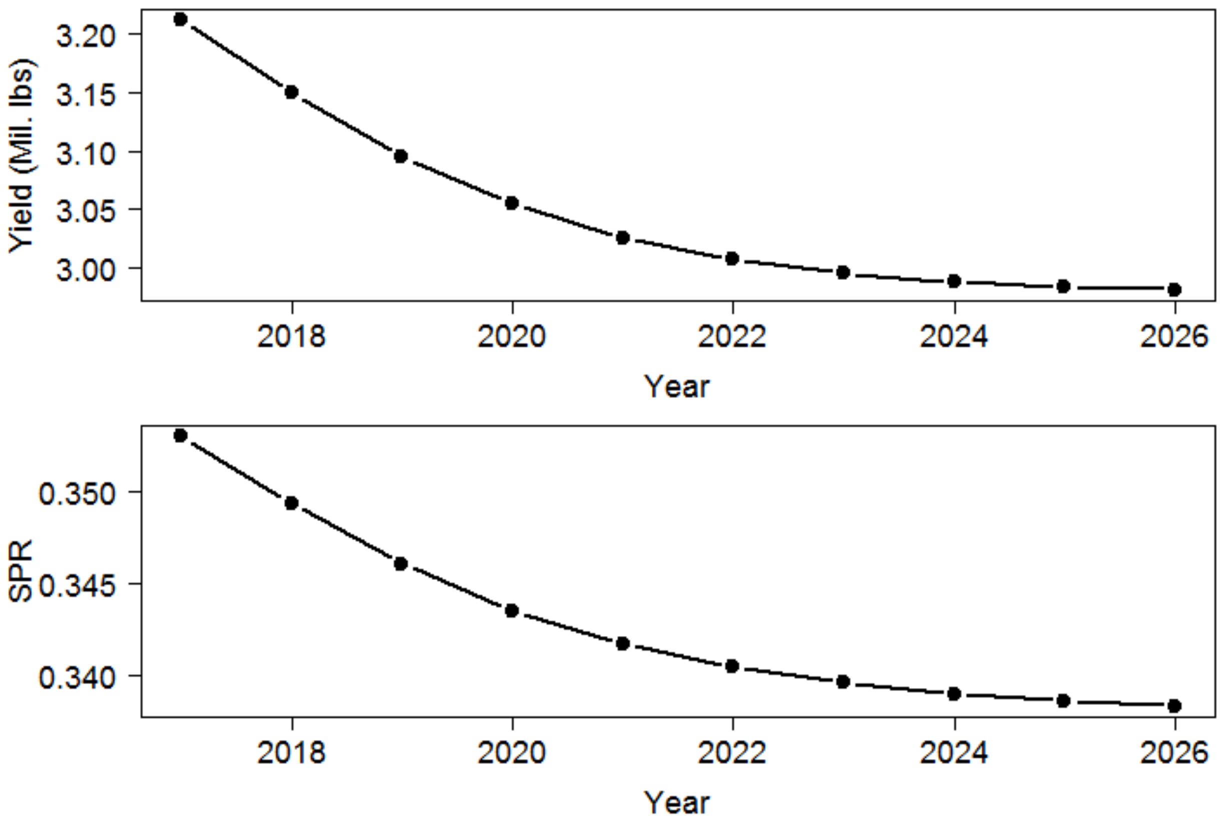


Figure 53: Overfishing limits based on OY projections (directed F = 0.75 * directed F at $F_{SPR30\%}$) assuming recent average recruitment.



10. Appendix A: Stock Synthesis 3 Input Files

10.1. DAT File

```
#C data file created using the SS_writedat function in the R package r4ss
#C should work with SS version:
#C file write time: 2016-01-29 10:09:09
#
1950 #_styr
2014 #_endyr
1 #_nseas
12 #_months_per_seas
1 #_spawn_seas
4 #_Nfleet
7 #_Nsurveys
1 #_N_areas
CM_E%CM_W%REC%SMP_BYC%HB_E%HB_W%CM_E_IFQ%CM_W_IFQ%LARVAL%VIDEO%SEAMAP #_fleetnames
-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 #_surveytiming_in_season
1 1 1 1 1 1 1 1 1 1 1 #_area_assignments_for_each_fishery_and_survey
1 1 2 2 #_units of catch:  1=bio; 2=num
0.05 0.05 0.15 -2 #_se of log(catch) only used for init_eq_catch and for Fmethod 2 and 3
1 #_Ngenders
14 #_Nages
0 0 0 0 #_init_equil_catch_for_each_fishery
65 #_N_lines_of_catch_to_read
 #_CM_E   CM_W     REC SMP_BYC year seas
   1.00   0.73    6.03   0.001 1950    1
   1.99   1.46   12.07   0.001 1951    1
   2.99   2.19   18.10   0.001 1952    1
   3.98   2.92   24.13   0.001 1953    1
   4.98   3.65   30.17   0.001 1954    1
   5.98   4.38   36.20   0.001 1955    1
   6.97   5.11   42.23   0.001 1956    1
   7.97   5.84   48.26   0.001 1957    1
   8.97   6.57   54.30   0.001 1958    1
   9.96   7.30   60.33   0.001 1959    1
  10.96   8.03   66.36   0.001 1960    1
  11.95   8.76   72.40   0.001 1961    1
  12.95   9.49   78.43   0.001 1962    1
  13.95  10.22   84.46   0.001 1963    1
  15.26  10.67   90.50   0.001 1964    1
  15.15   9.42   96.53   0.001 1965    1
   7.90   3.02  102.56   0.001 1966    1
  16.01   7.15  108.59   0.001 1967    1
  31.82  22.81  114.63   0.001 1968    1
  40.53  12.29  120.66   0.001 1969    1
  37.81  20.14  126.69   0.001 1970    1
  41.29  21.80  132.73   0.001 1971    1
  36.45  21.10  138.76   0.001 1972    1
  61.48  24.92  144.79   0.001 1973    1
  58.35  30.31  150.83   0.001 1974    1
 126.98  49.59  156.86   0.001 1975    1
 111.57  27.44  162.89   0.001 1976    1
 151.22  88.51  168.92   0.001 1977    1
 129.98  74.05  174.96   0.001 1978    1
  99.08  99.99  180.99   0.001 1979    1
  72.42  67.34  187.02   0.001 1980    1
 105.02  52.46  194.36   0.001 1981    1
 108.57  66.45  591.20   0.001 1982    1
 171.33  73.37  170.86   0.001 1983    1
 241.32 384.78  240.47   0.001 1984    1
 304.88 334.57  414.88   0.001 1985    1
 312.81 425.94  992.11   0.001 1986    1
 242.45 455.15 1033.52   0.001 1987    1
 222.91 449.83 1385.55   0.001 1988    1
 217.18 454.87  866.96   0.001 1989    1
 517.41 436.21 1164.61   0.001 1990    1
 420.91 366.40 1148.51   0.001 1991    1
```

```
 538.57 476.53 1365.73   0.001 1992    1
 743.03 463.24 1198.84   0.001 1993    1
 712.51 471.80  982.38   0.001 1994    1
 678.87 296.76 1216.10   0.001 1995    1
 523.97 295.68  580.19   0.001 1996    1
 469.46 486.52  612.02   0.001 1997    1
 365.30 406.03  309.98   0.001 1998    1
 416.70 497.89  421.77   0.001 1999    1
 315.59 343.93  330.47   0.001 2000    1
 362.53 410.11  631.77   0.001 2001    1
 452.12 453.47  521.71   0.001 2002    1
 523.30 571.01  604.38   0.001 2003    1
 420.92 552.27  828.28   0.001 2004    1
 444.31 401.91  625.45   0.001 2005    1
 505.42 288.56  543.88   0.001 2006    1
 527.65 548.36  502.08   0.001 2007    1
 810.03 458.62  530.48   0.001 2008    1
1274.05 444.34  727.98   0.001 2009    1
 598.81 356.68  432.57   0.001 2010    1
1102.13 329.52 1130.42   0.001 2011    1
 720.63 371.01  632.07   0.001 2012    1
 416.09 226.29 1098.02   0.001 2013    1
 346.69 271.67 1108.33   0.001 2014    1
238 #_N_cpue
 #_Fleet Units Errtype
     1    1      0
     2    1      0
     3    0      0
     4    2      0
     5    0      0
     6    0      0
     7    1      0
     8    1      0
     9    0      0
    10    0      0
    11    0      0
 #_year seas index     obs    se_log
  1993    1     1 1.03600 0.1159000
  1994    1     1 1.25180 0.0991000
  1995    1     1 0.89420 0.1107000
  1996    1     1 0.94620 0.0985000
  1997    1     1 0.88210 0.1040000
  1998    1     1 0.87160 0.1049000
  1999    1     1 0.93280 0.0964000
  2000    1     1 0.79830 0.1121000
  2001    1     1 0.86920 0.1059000
  2002    1     1 0.94410 0.0980000
  2003    1     1 1.00130 0.0938000
  2004    1     1 0.98020 0.1010000
  2005    1     1 1.28350 0.0987000
  2006    1     1 1.30860 0.1096000
  2007    1     7 0.38320 0.3744000
  2008    1     7 0.84440 0.3639000
  2009    1     7 0.89660 0.3575000
  2010    1     7 0.91060 0.3707000
  2011    1     7 1.38640 0.3664000
  2012    1     7 1.18670 0.3657000
  2013    1     7 1.13990 0.3738000
  2014    1     7 1.25210 0.3790000
  1993    1     2 1.06140 0.3494000
  1994    1     2 1.46280 0.2858000
  1995    1     2 0.93350 0.2955000
  1996    1     2 1.01680 0.2542000
  1997    1     2 1.29410 0.1946000
  1998    1     2 1.01790 0.2178000
  1999    1     2 1.05430 0.1875000
  2000    1     2 0.72170 0.2249000
  2001    1     2 0.76490 0.2360000
  2002    1     2 1.00210 0.2048000
  2003    1     2 1.26200 0.1844000
```

2004	1	2	1.24530	0.1817000
2005	1	2	0.77000	0.2142000
2006	1	2	0.39310	0.2668000
2007	1	8	0.85660	0.1478000
2008	1	8	1.10960	0.1383000
2009	1	8	1.32220	0.1337000
2010	1	8	0.99950	0.1401000
2011	1	8	1.41200	0.1341000
2012	1	8	0.83710	0.1301000
2013	1	8	0.70960	0.1389000
2014	1	8	0.75340	0.1393000
1986	1	5	0.94580	0.2833000
1987	1	5	0.96180	0.2746000
1988	1	5	2.29470	0.1880000
1989	1	5	1.35630	0.1900000
1990	1	5	1.67520	0.1745000
1991	1	5	1.80350	0.1713000
1992	1	5	2.65980	0.1575000
1993	1	5	1.63400	0.1680000
1994	1	5	1.85050	0.1699000
1995	1	5	1.54560	0.1814000
1996	1	5	0.88980	0.1927000
1997	1	5	0.77080	0.1986000
1998	1	5	0.17850	0.2171000
1999	1	5	0.41440	0.2306000
2000	1	5	0.34490	0.2172000
2001	1	5	0.42420	0.2103000
2002	1	5	0.45930	0.2096000
2003	1	5	0.55580	0.2072000
2004	1	5	0.62480	0.2004000
2005	1	5	0.79510	0.2031000
2006	1	5	0.53590	0.2199000
2007	1	5	0.35470	0.2292000
2008	1	5	0.54600	0.1973000
2009	1	5	0.64170	0.1957000
2010	1	5	0.73690	0.2119000
2011	1	5	0.80890	0.1934000
2012	1	5	0.54570	0.1889000
2013	1	5	0.68170	0.1558000
2014	1	5	0.67730	0.1626000
1986	1	6	1.78100	0.1941000
1987	1	6	1.32780	0.2132000
1988	1	6	0.98530	0.1962000
1989	1	6	1.32340	0.1829000
1990	1	6	1.63800	0.1936000
1991	1	6	1.00010	0.1817000
1992	1	6	0.91850	0.1657000
1993	1	6	1.18100	0.1618000
1994	1	6	1.11460	0.1618000
1995	1	6	1.17500	0.1705000
1996	1	6	0.82150	0.2166000
1997	1	6	0.69350	0.1771000
1998	1	6	0.78970	0.2009000
1999	1	6	0.75530	0.1962000
2000	1	6	0.53790	0.1892000
2001	1	6	0.89220	0.1745000
2002	1	6	1.06060	0.1763000
2003	1	6	0.64710	0.1720000
2004	1	6	1.09590	0.1690000
2005	1	6	1.27980	0.1857000
2006	1	6	0.71640	0.1782000
2007	1	6	1.57450	0.2922000
2008	1	6	0.31480	0.2247000
2009	1	6	0.27740	0.2115000
2010	1	6	1.09880	0.2188000
2011	1	6	1.29660	0.2481000
2012	1	6	0.87090	0.2190000
2013	1	6	0.59930	0.3181000
2014	1	6	0.61550	0.1089000
1986	1	3	2.64900	0.1737000

1987	1	3	1.17140	0.2885000
1988	1	3	1.27000	0.2547000
1989	1	3	0.93050	0.3932000
1990	1	3	2.68300	0.3005000
1991	1	3	1.77260	0.2255000
1992	1	3	1.72600	0.1667000
1993	1	3	1.87830	0.2122000
1994	1	3	1.49050	0.2743000
1995	1	3	2.03300	0.2988000
1996	1	3	0.99210	0.3406000
1997	1	3	0.46410	0.2449000
1998	1	3	0.39350	0.2212000
1999	1	3	0.40900	0.1557000
2000	1	3	0.34600	0.1583000
2001	1	3	0.39370	0.1578000
2002	1	3	0.30610	0.1607000
2003	1	3	0.37600	0.1468000
2004	1	3	0.52410	0.1111000
2005	1	3	0.59450	0.1228000
2006	1	3	0.59820	0.1368000
2007	1	3	0.39070	0.1628000
2008	1	3	0.46540	0.1697000
2009	1	3	0.69450	0.1660000
2010	1	3	0.44790	0.1737000
2011	1	3	0.96140	0.1159000
2012	1	3	0.48160	0.1411000
2013	1	3	0.59990	0.1919000
2014	1	3	0.95350	0.1342000
1950	1	4	0.19460	0.2000000
1951	1	4	0.26540	0.2000000
1952	1	4	0.31350	0.2000000
1953	1	4	0.32950	0.2000000
1954	1	4	0.42720	0.2000000
1955	1	4	0.44530	0.2000000
1956	1	4	0.56930	0.2000000
1957	1	4	0.65170	0.2000000
1958	1	4	0.79810	0.2000000
1959	1	4	0.86030	0.2000000
1960	1	4	0.86010	0.2000000
1961	1	4	0.65150	0.2000000
1962	1	4	0.62730	0.2000000
1963	1	4	0.71510	0.2000000
1964	1	4	0.75530	0.2000000
1965	1	4	0.83830	0.2000000
1966	1	4	0.82500	0.2000000
1967	1	4	0.89860	0.2000000
1968	1	4	0.91310	0.2000000
1969	1	4	1.03760	0.2000000
1970	1	4	0.97760	0.2000000
1971	1	4	0.93220	0.2000000
1972	1	4	0.92840	0.2000000
1973	1	4	0.93450	0.2000000
1974	1	4	0.93000	0.2000000
1975	1	4	0.93560	0.2000000
1976	1	4	0.97060	0.2000000
1977	1	4	1.06310	0.2000000
1978	1	4	1.12380	0.2000000
1979	1	4	1.17810	0.2000000
1980	1	4	1.20930	0.2000000
1981	1	4	1.15670	0.2000000
1982	1	4	1.06750	0.2000000
1983	1	4	1.11560	0.2000000
1984	1	4	1.27810	0.2000000
1985	1	4	1.21110	0.2000000
1986	1	4	1.40400	0.2000000
1987	1	4	1.26830	0.2000000
1988	1	4	1.09580	0.2000000
1989	1	4	1.12170	0.2000000
1990	1	4	1.03400	0.2000000
1991	1	4	1.07550	0.2000000

1992	1	4	1.32200	0.2000000
1993	1	4	1.08580	0.2000000
1994	1	4	1.14700	0.2000000
1995	1	4	1.29810	0.2000000
1996	1	4	1.56180	0.2000000
1997	1	4	1.55460	0.2000000
1998	1	4	1.93990	0.2000000
1999	1	4	1.18310	0.2000000
2000	1	4	0.96230	0.2000000
2001	1	4	1.12150	0.2000000
2002	1	4	1.36710	0.2000000
2003	1	4	1.18200	0.2000000
2004	1	4	1.21440	0.2000000
2005	1	4	0.93660	0.2000000
2006	1	4	0.55390	0.2000000
2007	1	4	0.36470	0.2000000
2008	1	4	0.28250	0.2000000
2009	1	4	0.46320	0.2000000
2010	1	4	0.35230	0.2000000
2011	1	4	0.36140	0.2000000
2012	1	4	0.30810	0.2000000
2013	1	4	0.34200	0.2000000
2014	1	4	0.26740	0.2000000
1986	1	9	0.50284	0.2922895
1987	1	9	1.18459	0.1898002
1990	1	9	0.80000	0.2230372
1991	1	9	1.57023	0.2033735
1993	1	9	0.57312	0.2048949
1994	1	9	0.92934	0.1851080
1995	1	9	0.61600	0.2136733
1996	1	9	0.85945	0.1920561
1997	1	9	0.93643	0.1749742
1999	1	9	0.62495	0.2177606
2000	1	9	0.74864	0.2039696
2001	1	9	0.83615	0.1994003
2003	1	9	1.31337	0.1820065
2006	1	9	1.24663	0.1899028
2007	1	9	1.57014	0.1915909
2009	1	9	1.18862	0.1921586
2010	1	9	1.13796	0.1846889
2011	1	9	1.12178	0.1781241
2012	1	9	1.23976	0.1811909
1993	1	10	0.82455	0.3333037
1994	1	10	2.21078	0.2359475
1995	1	10	1.65847	0.2975903
1996	1	10	0.27796	0.2437763
1997	1	10	1.19120	0.1755371
2002	1	10	0.39751	0.2622836
2004	1	10	0.77195	0.2418611
2005	1	10	0.62408	0.1418021
2006	1	10	0.26325	0.1978080
2007	1	10	0.21306	0.1882542
2008	1	10	0.77278	0.1680346
2009	1	10	1.21908	0.1296484
2010	1	10	1.39669	0.1592513
2011	1	10	1.59370	0.1094947
2012	1	10	1.12444	0.1542140
2013	1	10	0.79439	0.2097655
2014	1	10	1.66610	0.1514274
2009	1	11	0.84718	0.1948670
2010	1	11	0.73923	0.2132045
2011	1	11	1.60868	0.2092737
2012	1	11	1.24379	0.1690601
2013	1	11	0.85308	0.2041356
2014	1	11	0.70805	0.2094591

1 #_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

#_Fleet units errtype

4 1 -2

```
43 #_N_discard
 #_Yr Seas Flt Discard Std_in
 1972   -1   4  3367.5    0.1
 1973    1  -4 13620.0    0.5
 1974    1  -4  3817.0    0.5
 1975    1  -4  3482.0    0.5
 1976    1  -4  1268.0    0.5
 1977    1  -4  1424.0    0.5
 1978    1  -4  9395.0    0.5
 1979    1  -4 11060.0    0.5
 1980    1  -4   863.3    0.5
 1981    1  -4  7996.0    0.5
 1982    1  -4  2754.0    0.5
 1983    1  -4  3259.0    0.5
 1984    1  -4  7928.0    0.5
 1985    1  -4  7001.0    0.5
 1986    1  -4 16650.0    0.5
 1987    1  -4 22810.0    0.5
 1988    1  -4  7748.0    0.5
 1989    1  -4 12000.0    0.5
 1990    1  -4 16870.0    0.5
 1991    1  -4 40170.0    0.5
 1992    1  -4  5483.0    0.5
 1993    1  -4  1503.0    0.5
 1994    1  -4  1303.0    0.5
 1995    1  -4 11400.0    0.5
 1996    1  -4  6260.0    0.5
 1997    1  -4 10540.0    0.5
 1998    1  -4 62600.0    0.5
 1999    1  -4 23250.0    0.5
 2000    1  -4 22170.0    0.5
 2001    1  -4 19560.0    0.5
 2002    1  -4  3916.0    0.5
 2003    1  -4 24270.0    0.5
 2004    1  -4  1552.0    0.5
 2005    1  -4  1357.0    0.5
 2006    1  -4  8369.0    0.5
 2007    1  -4  9388.0    0.5
 2008    1  -4   799.3    0.5
 2009    1  -4  1077.0    0.5
 2010    1  -4   732.5    0.5
 2011    1  -4  1465.0    0.5
 2012    1  -4   396.2    0.5
 2013    1  -4   298.2    0.5
 2014   -1  -4   339.3    0.5
0 #_N_meanbodywt
30 #_DF_for_meanbodywt_T-distribution_like
1 # length bin method: 1=use databins; 2=generate from binwidth,min,max below; 3=read vector
-0.001 #_comp_tail_compression
1e-07 #_add_to_comp
0 #_combine males into females at or below this bin number
12 #_N_lbins
#_lbin_vector
1 5 10 15 20 25 30 35 40 45 50 55
20 #_N_Length_comp_observations
 #_Yr Seas FltSvy Gender Part     Nsamp          l1          l5          l10         l15         l20         l25         l30         l35         l40         l45         l50         l55
 2009    1     11      0    2   6.22886 0.310072926 0.05182315 0.213719234 0.28281677 0.13518687 0.006381039 0.000000000 0.000000000
0.000000000 0.000000000 0.000000000 0.000000000
 2010    1     11      0    2   7.15957 0.038864307 0.02868732 0.166887906 0.49301868 0.26369223 0.008849558 0.000000000 0.000000000
0.000000000 0.000000000 0.000000000 0.000000000
 2011    1     11      0    2  12.42320 0.000000000 0.00000000 0.251728608 0.44161625 0.22994814 0.073465860 0.003241141 0.000000000
0.000000000 0.000000000 0.000000000 0.000000000
 2012    1     11      0    2   9.34591 0.035682819 0.14074890 0.585638767 0.13729075 0.07640969 0.023348018 0.000881057 0.000000000
0.000000000 0.000000000 0.000000000 0.000000000
 2013    1     11      0    2  35.50480 0.019130435 0.01673913 0.432771739 0.38722826 0.12760870 0.015434783 0.000000000 0.001086957
0.000000000 0.000000000 0.000000000 0.000000000
 2014    1     11      0    2  20.70090 0.003527337 0.02469136 0.259082892 0.37477954 0.32204585 0.015873016 0.000000000 0.000000000
0.000000000 0.000000000 0.000000000 0.000000000
 1995    1     10      0    2  20.84420 0.000000000 0.00000000 0.000000000 0.00000000 0.21276596 0.425531915 0.212765957 0.148936170
0.000000000 0.000000000 0.000000000 0.000000000
```

1996 1 10 0 2 28.66740 0.000000000 0.00000000 0.020408163 0.05442177 0.14965986 0.326530612 0.292517007 0.149659864 0.006802721 0.000000000 0.000000000 0.000000000
1997 1 10 0 2 73.91420 0.000000000 0.00000000 0.009174312 0.16513761 0.31192661 0.247706422 0.137614679 0.091743119 0.027522936 0.000000000 0.000000000 0.009174312
2002 1 10 0 2 100.00000 0.000000000 0.00000000 0.004347826 0.12500000 0.32065217 0.283695652 0.164130435 0.064130435 0.030434783 0.006521739 0.000000000 0.001086957
2004 1 10 0 2 70.49580 0.000000000 0.00000000 0.019480519 0.06493507 0.33766234 0.324675325 0.155844156 0.064935065 0.012987013 0.012987013 0.000000000 0.006493506
2005 1 10 0 2 100.00000 0.000000000 0.00000000 0.008620690 0.09568965 0.22413793 0.309482759 0.189655172 0.081034483 0.056034483 0.024137931 0.010344828 0.000862069
2006 1 10 0 2 63.67440 0.000000000 0.00000000 0.028764805 0.19458545 0.30964467 0.272419628 0.130287648 0.042301184 0.013536379 0.008460237 0.000000000 0.000000000
2007 1 10 0 2 16.66980 0.000000000 0.00000000 0.002710027 0.03116531 0.22628726 0.440379404 0.169376694 0.063685637 0.054200542 0.010840108 0.000000000 0.001355014
2008 1 10 0 2 37.39100 0.000000000 0.00000000 0.000000000 0.02857143 0.27142857 0.385714286 0.214285714 0.071428571 0.014285714 0.014285714 0.000000000 0.000000000
2009 1 10 0 2 42.53100 0.000000000 0.00000000 0.000000000 0.10447761 0.35820895 0.350746269 0.141791045 0.029850746 0.000000000 0.007462687 0.007462687 0.000000000
2010 1 10 0 2 10.72740 0.000000000 0.00000000 0.049504950 0.26732673 0.10891089 0.128712871 0.247524752 0.138613861 0.059405941 0.000000000 0.000000000 0.000000000
2011 1 10 0 2 16.25450 0.000000000 0.07250755 0.169184290 0.02416918 0.13897281 0.247734139 0.148036254 0.102719033 0.048338369 0.015105740 0.024169184 0.009063444
2012 1 10 0 2 30.07700 0.000000000 0.00000000 0.033333333 0.28000000 0.26666667 0.253333333 0.093333333 0.026666667 0.040000000 0.006666667 0.000000000 0.000000000
2013 1 10 0 2 28.45090 0.000000000 0.00000000 0.147540984 0.08196721 0.25409836 0.188524590 0.213114754 0.073770492 0.024590164 0.016393443 0.000000000 0.000000000
14 #_N_agebins
#_agebin_vector
1 2 3 4 5 6 7 8 9 10 11 12 13 14
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
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
55 #_N_agecomp
2 #_Lbin_method: 1=poplenbins; 2=datalenbins; 3=lengths
0 #_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 1 1 0 2 1 -1 -1 1.61009 0.0000 0.7485 0.0257 0.0490 0.0747 0.0747 0.0091 0.0000 0.0091 0.0000 0.0000 0.0091 0.0000 0.0000
1998 1 1 0 2 1 -1 -1 6.09799 0.1680 0.3432 0.3427 0.0491 0.0622 0.0143 0.0000 0.0000 0.0000 0.0020 0.0041 0.0144 0.0000 0.0000
2000 1 1 0 2 1 -1 -1 10.87850 0.0000 0.0248 0.1580 0.1267 0.1005 0.0288 0.0364 0.0734 0.0339 0.1527 0.2173 0.0213 0.0211 0.0051
2001 1 1 0 2 1 -1 -1 63.43520 0.0000 0.0636 0.2225 0.2063 0.1893 0.1122 0.0693 0.0502 0.0249 0.0294 0.0082 0.0120 0.0088 0.0035
2002 1 1 0 2 1 -1 -1 71.86790 0.0057 0.1979 0.3807 0.1253 0.0926 0.0675 0.0456 0.0405 0.0150 0.0073 0.0122 0.0045 0.0017 0.0035
2003 1 1 0 2 1 -1 -1 34.03000 0.0005 0.0463 0.2250 0.3708 0.1359 0.0612 0.0791 0.0380 0.0230 0.0061 0.0055 0.0051 0.0022 0.0015
2004 1 1 0 2 1 -1 -1 52.66150 0.0000 0.0366 0.2292 0.2613 0.2100 0.0824 0.0703 0.0509 0.0318 0.0120 0.0033 0.0068 0.0030 0.0024
2005 1 1 0 2 1 -1 -1 85.57200 0.0000 0.0607 0.2389 0.2307 0.2094 0.1019 0.0439 0.0423 0.0308 0.0136 0.0145 0.0117 0.0000 0.0016
2006 1 1 0 2 1 -1 -1 100.00000 0.0000 0.0975 0.2928 0.2159 0.1963 0.1003 0.0482 0.0184 0.0110 0.0125 0.0031 0.0041 0.0000 0.0000
2007 1 1 0 2 1 -1 -1 100.00000 0.0101 0.1305 0.2372 0.2210 0.1694 0.0926 0.0443 0.0443 0.0185 0.0127 0.0032 0.0064 0.0069 0.0027
2008 1 1 0 2 1 -1 -1 100.00000 0.0000 0.0865 0.2864 0.1769 0.1393 0.1255 0.0801 0.0387 0.0332 0.0123 0.0129 0.0057 0.0011 0.0016
2009 1 1 0 2 1 -1 -1 100.00000 0.0000 0.0956 0.3744 0.2380 0.1059 0.0607 0.0466 0.0380 0.0166 0.0115 0.0072 0.0029 0.0004 0.0023
2010 1 1 0 2 1 -1 -1 49.48670 0.0009 0.0281 0.2622 0.3769 0.0532 0.0625 0.0495 0.0744 0.0460 0.0258 0.0132 0.0058 0.0000 0.0015
2011 1 1 0 2 1 -1 -1 30.74290 0.0107 0.0404 0.1203 0.2271 0.2340 0.1423 0.0689 0.0638 0.0362 0.0242 0.0131 0.0079 0.0060 0.0051
2012 1 1 0 2 1 -1 -1 43.82600 0.0021 0.1362 0.1737 0.1283 0.1581 0.1680 0.1199 0.0355 0.0314 0.0086 0.0133 0.0053 0.0058 0.0137
2013 1 1 0 2 1 -1 -1 100.00000 0.0020 0.1053 0.3692 0.1310 0.0814 0.0922 0.1130 0.0577 0.0204 0.0107 0.0066 0.0033 0.0047 0.0025

2014 1 1 0 2 1 -1 -1 44.59000 0.0000 0.0772 0.2765 0.1661 0.0895 0.0635 0.0609 0.0838 0.0745 0.0322 0.0392 0.0078
0.0160 0.0127
1994 1 2 0 2 1 -1 -1 5.27232 0.0000 0.0000 0.0593 0.1186 0.5439 0.0730 0.0000 0.0593 0.0000 0.0730 0.0730 0.0000
0.0000 0.0000
1995 1 2 0 2 1 -1 -1 10.37500 0.0000 0.2252 0.1572 0.2420 0.2820 0.0587 0.0208 0.0000 0.0067 0.0075 0.0000 0.0000
0.0000 0.0000
2000 1 2 0 2 1 -1 -1 44.69460 0.0000 0.0000 0.1930 0.1667 0.2240 0.1380 0.1047 0.0333 0.1070 0.0000 0.0000 0.0000
0.0000 0.0333
2001 1 2 0 2 1 -1 -1 44.44050 0.0000 0.0174 0.1150 0.1600 0.1318 0.1244 0.0523 0.1068 0.0089 0.0942 0.0292 0.0000
0.0244 0.1356
2002 1 2 0 2 1 -1 -1 23.59970 0.0000 0.0778 0.3128 0.1080 0.0701 0.0979 0.0991 0.0363 0.0422 0.0250 0.0301 0.0371
0.0152 0.0482
2003 1 2 0 2 1 -1 -1 42.48870 0.0000 0.0150 0.0895 0.4413 0.1524 0.0771 0.0608 0.0516 0.0375 0.0154 0.0255 0.0174
0.0072 0.0094
2004 1 2 0 2 1 -1 -1 100.00000 0.0032 0.0193 0.1183 0.2094 0.2788 0.1098 0.0738 0.0401 0.0540 0.0317 0.0097 0.0178
0.0141 0.0203
2005 1 2 0 2 1 -1 -1 24.75960 0.0031 0.1074 0.1369 0.1024 0.2689 0.1960 0.0507 0.0297 0.0359 0.0258 0.0184 0.0073
0.0046 0.0128
2006 1 2 0 2 1 -1 -1 19.33600 0.0000 0.0471 0.2632 0.2058 0.0913 0.2082 0.0883 0.0154 0.0184 0.0153 0.0196 0.0098
0.0035 0.0140
2007 1 2 0 2 1 -1 -1 100.00000 0.0000 0.0195 0.1062 0.2193 0.1918 0.1450 0.1295 0.0903 0.0411 0.0203 0.0174 0.0077
0.0027 0.0091
2008 1 2 0 2 1 -1 -1 88.54840 0.0000 0.0140 0.0628 0.1161 0.2083 0.1935 0.1418 0.0809 0.0781 0.0392 0.0228 0.0109
0.0128 0.0187
2009 1 2 0 2 1 -1 -1 100.00000 0.0000 0.0186 0.1654 0.2409 0.1675 0.1269 0.0740 0.0567 0.0428 0.0465 0.0237 0.0072
0.0104 0.0194
2010 1 2 0 2 1 -1 -1 100.00000 0.0035 0.0105 0.1028 0.3706 0.1664 0.1072 0.0902 0.0487 0.0222 0.0210 0.0235 0.0093
0.0043 0.0199
2011 1 2 0 2 1 -1 -1 33.60650 0.0309 0.0438 0.0998 0.1529 0.1956 0.1347 0.1045 0.0761 0.0308 0.0400 0.0327 0.0227
0.0080 0.0275
2012 1 2 0 2 1 -1 -1 50.65380 0.0035 0.0090 0.0508 0.1526 0.1450 0.2063 0.1304 0.0795 0.0691 0.0534 0.0317 0.0184
0.0231 0.0272
2013 1 2 0 2 1 -1 -1 26.23520 0.0000 0.0205 0.0779 0.0890 0.1722 0.0618 0.1760 0.1074 0.0599 0.0641 0.0432 0.0499
0.0254 0.0529
2014 1 2 0 2 1 -1 -1 17.89660 0.0030 0.0468 0.0983 0.1130 0.0857 0.1165 0.0882 0.0838 0.0858 0.0655 0.0554 0.0438
0.0274 0.0868
1994 1 3 0 2 1 -1 -1 100.00000 0.0000 0.0000 0.2034 0.2502 0.1995 0.1606 0.0896 0.0725 0.0242 0.0000 0.0000 0.0000
0.0000 0.0000
1995 1 3 0 2 1 -1 -1 3.47009 0.0000 0.0000 0.6038 0.0000 0.2410 0.0347 0.1205 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000
1996 1 3 0 2 1 -1 -1 100.00000 0.0044 0.0755 0.1925 0.1853 0.2018 0.1661 0.0612 0.0503 0.0207 0.0354 0.0040 0.0010
0.0019 0.0000
1997 1 3 0 2 1 -1 -1 10.44530 0.0000 0.2950 0.0697 0.2112 0.1007 0.1433 0.1029 0.0138 0.0634 0.0000 0.0000 0.0000
0.0000 0.0000
1998 1 3 0 2 1 -1 -1 18.15730 0.0000 0.0282 0.3692 0.3197 0.1276 0.0282 0.0777 0.0495 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000
1999 1 3 0 2 1 -1 -1 16.52670 0.0313 0.2138 0.2872 0.1785 0.0888 0.0502 0.0377 0.0792 0.0193 0.0089 0.0018 0.0015
0.0018 0.0000
2000 1 3 0 2 1 -1 -1 100.00000 0.0000 0.0314 0.1928 0.2297 0.2234 0.1178 0.0594 0.0692 0.0373 0.0301 0.0036 0.0020
0.0000 0.0034
2001 1 3 0 2 1 -1 -1 8.75311 0.0000 0.0440 0.0429 0.1352 0.3798 0.1166 0.1308 0.0496 0.0133 0.0530 0.0180 0.0129
0.0040 0.0000
2002 1 3 0 2 1 -1 -1 24.44920 0.0000 0.0809 0.2409 0.0991 0.1722 0.1218 0.1475 0.0794 0.0276 0.0083 0.0056 0.0090
0.0076 0.0000
2003 1 3 0 2 1 -1 -1 31.87430 0.0000 0.1490 0.1446 0.3502 0.0893 0.1065 0.1010 0.0294 0.0246 0.0055 0.0000 0.0000
0.0000 0.0000
2004 1 3 0 2 1 -1 -1 8.44696 0.0000 0.0000 0.0608 0.2941 0.4373 0.0702 0.0893 0.0127 0.0122 0.0215 0.0018 0.0000
0.0000 0.0000
2005 1 3 0 2 1 -1 -1 53.48820 0.0000 0.1373 0.2925 0.2312 0.1854 0.0805 0.0227 0.0222 0.0017 0.0073 0.0191 0.0000
0.0000 0.0000
2006 1 3 0 2 1 -1 -1 100.00000 0.0000 0.0753 0.1769 0.2743 0.2267 0.1030 0.0992 0.0142 0.0223 0.0080 0.0000 0.0000
0.0000 0.0000
2007 1 3 0 2 1 -1 -1 100.00000 0.0000 0.0543 0.1907 0.3175 0.1832 0.1175 0.0496 0.0365 0.0290 0.0121 0.0041 0.0022
0.0007 0.0026
2008 1 3 0 2 1 -1 -1 56.44540 0.0030 0.0810 0.1818 0.1624 0.1697 0.1685 0.1253 0.0506 0.0356 0.0092 0.0061 0.0025
0.0006 0.0037
2009 1 3 0 2 1 -1 -1 100.00000 0.0017 0.1097 0.3717 0.1956 0.1337 0.0844 0.0518 0.0250 0.0170 0.0052 0.0023 0.0015
0.0003 0.0000
2010 1 3 0 2 1 -1 -1 25.36360 0.0058 0.0532 0.3978 0.3623 0.0713 0.0519 0.0314 0.0145 0.0069 0.0024 0.0013 0.0000
0.0000 0.0014

2011 1 3 0 2 1 -1 -1 60.57780 0.0046 0.0540 0.1741 0.2292 0.2547 0.1941 0.0470 0.0281 0.0050 0.0049 0.0027 0.0015 0.0000 0.0000
2012 1 3 0 2 1 -1 -1 100.00000 0.0017 0.1251 0.2373 0.2475 0.1193 0.1505 0.0663 0.0194 0.0185 0.0084 0.0025 0.0016 0.0014 0.0006
2013 1 3 0 2 1 -1 -1 100.00000 0.0050 0.1036 0.3363 0.2234 0.1562 0.0675 0.0652 0.0209 0.0103 0.0070 0.0029 0.0006 0.0012 0.0000
2014 1 3 0 2 1 -1 -1 83.97650 0.0007 0.0832 0.3781 0.2531 0.0843 0.0846 0.0329 0.0440 0.0243 0.0049 0.0055 0.0017 0.0009 0.0019
0 #_N_MeanSize_at_Age_obs
0 #_N_environ_variables
0 #_N_environ_obs
0 #_N_sizefreq_methods
0 #_do_tags
0 #_morphcomp_data
#
999

10.2. CTL File

```
#V3.24f
#_data_and_control_files:	data.ss	//	control.ss
#_SS-V3.24f-safe;_08/03/2012;_Stock_Synthesis_by_Richard_Methot_(NOAA)_using_ADMB_10.1
1	#_N_Growth_Patterns
1	#_N_Morphs_Within_GrowthPattern
#2	# N recruitment	designs	go here if N_GP*nseas*area>1 - Red Snapper is a 2 area model
#0	# placeholder for recruitment interaction request
#1 1 1	#_recruitment design element for GP=1, seas=1, area=1
#1 1 2	#_recruitment design element for GP=1, seas=1, area=2
#0	# N_movement_definitions goes here if N_areas >	1
#ADD A BLOCK TO RECREATIONAL SELECTIVITY 2010-2013
1	#_Nblock_Patterns
1	#_blocks_per_pattern
# begin	and end	years of blocks
2007 2014 #BLOCK 1 used for commercial size limit, and <100% retention during IFQ period
0.5	#_fracfemale
3	#_natM_type:_0=1Parm;	1=N_breakpoints;_2=Lorenzen;_3=agespecific;_4=agespec_withseasinterpolate
#3	#_reference	age	for	Lorenzen	function
#_Age_natmort_by	gender	x	growthpattern
0.234 0.342 0.287 0.257 0.239 0.228 0.220 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_speciific_K
.5	#_Growth_Age_for_L1
999	#_Growth_Age_for_L2	(999	to	use	as	Linf)
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=read	fec	and	wt	from	wtatage.ss
#0 3.16E+6 3.33E+6 3.51E+6 3.69E+6 3.87E+6 4.05E+6 4.23E+6 4.41E+6 4.59E+6 4.77E+6 4.94E+6 5.12E+6 5.30E+6 5.48E+6
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=age-specific	fxn
1	#_parameter_offset_approach	(1=none,	2=	M,	G,	CV_G	as	offset	from	female-
GP1,	3=like	SS2	V1.x)
2	#_env/block/dev_adjust_method	(1=standard;	2=logistic	transform	keeps	in	base	parm	bounds;
	3=standardw/	no	bound	check)
#	Prior	types	(-1	=	none,	0=normal,	1=symmetric	beta,	2=full	beta,
	3=lognormal)
#_growth_parms
#_LO	HI	INIT	PRIOR	PR_type	SD	PHASE	env-var	use_dev	dev_minyr dev_maxyrdev_stddev
	Block	Block_Fxn
#0.01	0.5	0.257	0.257	3	0.5	-1	0	0	0	0	0	0	0 #NatM_p_1_Fem_GP_1
0.0001	1000000 11.83	11.83	-1	0	-1	0	0	0	0	0	0	0 #L_at_Amin_Fem_GP_1
0.0001	1000000 34.4	34.4	-1	0	-1	0	0	0	0	0	0	0 #L_at_Amax_Fem_GP_1
0	1000000 0.3254	0.3254	-1	0	-1	0	0	0	0	0	0	0 #VonBert_K_Fem_GP_1
0	1000000 0.2535	0.0001 -1	0	-1	0	0	0	0	0	0	0 #CV_young_Fem_GP_1
0	1000000 0.2535	0.0001 -1	0	-1	0	0	0	0	0	0	0 #CV_old_Fem_GP_1
0	1000000 0.0000219 0.0000219 -1	0	-1	0	0	0	0	0	0	0 #Wtlen_1_Fem
0	1000000 2.916	2.916	-1	0	-1	0	0	0	0	0	0	0 #Wtlen_2_Fem
0	1000000 14.087 14.087	-1	0	-1	0	0	0	0	0	0	0 #Mat50%_Fem
0	1000000 -0.574 -0.574	-1	0	-1	0	0	0	0	0	0	0 #Mat_slope_Fem
0	1000000 278.7146 278.7146 -1	0	-1	0	0	0	0	0	0	0 # Fec_1_Fem
0	1000000 3.042	3.042 -1	0	-1	0	0	0	0	0	0	0 # Fec_2_Fem
-4	4	0	0	-1	99	-4	0	0	0	0	0	0	0 #RecrDist_GP_1
-4	4	1	1	-1	0.01	-4	0	0	0	0	0	0	0 #RecrDist_Area1
#-4	4	0	0	-1	1	-4	0	0	0	0	0	0	0
	0	#RecrDist_Area2
-4	4	1	1	-1	0.01	-4	0	0	0	0	0	0	0 #RecrDist_Seas_1
1	1	1	1	-1	0	-4	0	0	0	0	0	0	0 #CohortGrowDev
#
#_Cond	0	#custom_MG-env_setup	(0/1)
#_Cond	-2	2	0	0	-1	99	-2	#_placeholder	when	no	MG-
#_Cond	0	#custom_MG-block_setup	(0/1)
#_Cond	-2	2	0	0	-1	99	-2	#_placeholder	when	no	MG-block
#_Cond	No	MG	parm	trends
	0	0	0	0	0	0	0	0	0	0
	#_femwtlen1,femwtlen2,mat1,mat2,fec1,fec2,Malewtlen1,malewtlen2,L1,K
```

```
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no seasonal
MG parameters
#_Spawner-Recruitment
3 #_SR_function: 2=Ricker; 3=std_B-H; 4=SCAA; 5=Hockey;6=B-H_flattop; 7=survival_3Parm
#_LO HI INIT PRIOR PR_type SD PHASE
0.0 13.82 6.91 6.91 -1 0 1 #SR_LN(R0) 1 20 11.8 11.8 -1 1 1
0.22 0.96 0.6 0.6 -3 0.74 2 #SR_BH_steep 0.2 1 0.99 0.99 -1 1 -4
0 2 0.4 0.2 -1 0 3 #SR_sigmaR 0 2 0.3 0.3 -1 1 -4
-5 5 0 0 -1 0 -3 #SR_envlink -5 5 0 0 -1 1 3
-5 5 0 0 -1 0 -3 #SR_R1_offset -5 5 0 0 -1 1 -4
0 0.5 0 0 -1 0 -2 #SR_autocorr 0 0 0 0 -1 0 -99
0 #_SR_env_link
0 #_SR_env_target_0=none;1=devs;_2=R0;_3=steepness
1 #do_recdev: 0=none; 1=devvector; 2=simple deviations
1994 # first year of main recr_devs; early devs can preceed this era
2012 # 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 #0 #_forecast_recruitment phase (incl. late recr) (0 value resets to
maxphase+1)
1 #_lambda for Fcast_recr_like occurring before endyr+1
# Bias adjustment from R4SS output from 4.Video Survey Run
 1986.5277 #_last_early_yr_nobias_adj_in_MPD
 1995.8285 #_first_yr_fullbias_adj_in_MPD
 2010.7167 #_last_yr_fullbias_adj_in_MPD
 2014.1802 #_first_recent_yr_nobias_adj_in_MPD
   0.8538 #_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
#Fishing Mortality info
0.5 # F ballpark for tuning early phases
-2001 # F ballpark year (neg value to disable)
2 # F_Method:1=Pope; 2=instan. F; 3=hybrid (hybrid is recommended)
4 # 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
# 5 # if Fmethod=3; read N iterations for tuning for Fmethod
3
0.05 1 0 # overall start F value; overall phase; N detailed inputs
#_initial_F_parms
#_LO HI INIT PRIOR PR_type SD PHASE
0 1 0 0.01 0 99 -1 #_CME
0 1 0 0.01 0 99 -1 #_CMW
0 1 0 0.01 0 99 -1 #_Rec
0 1 0 0.01 0 99 -1 #_Shr
#_Q_setup
# Q_type options: <0=mirror,0=float_nobiasadj, 1=float_biasadj, 2=parm_nobiasadj, 3=parm_w_random_dev,
4=parm_w_randwalk, 5=mean_unbiased_float_assign_to_parm
#_for_env-var:_enter_index_of_the_env-var_to_be_linked
#_Den-depenv-var extra_se Q_type
0 0 0 0 # CM-E *NEW*
0 0 0 0 # CM-W *NEW*
0 0 0 0 # REC *NEW*
0 0 0 2 # SMP-BYC *NEW*
0 0 0 0 # HB-E *NEW*
0 0 0 0 # HB-W *NEW*
0 0 0 0 # CM-E-IFQ *NEW*
0 0 0 0 # CM-W-IFQ *NEW*
0 0 0 0 # LARVAL
0 0 0 0 # VIDEO
0 0 0 0 #SEAMAP
#_Cond 0 #_If q has random component, then 0=read one parm for
each fleet with random q; 1=read a parm for each year of
index
#_Q_parms(if_any)
```

```
#LO HI INIT PRIOR PR_type SD PHASE
-10 20 1 1 -1 1 1 # SMP-BYC
#
#_size_selex_types
#discard_options:_0=none;_1=define_retention;_2=retention&mortality;_3=all_discarded_dead
#_Pattern Discard Male Special
0 0 0 0 # CM_E
0 0 0 0 # CM_W
0 0 0 0 # REC
0 3 0 0 # SMP_BYC
0 0 0 0 # HB-E
0 0 0 0 # HB-W
0 0 0 0 # CM-E-IFQ
0 0 0 0 # CM-W-IFQ
30 0 0 0 #LARVAL
24 0 0 0 # VIDEO
24 0 0 0 # SEAMAP
#_age_selex_types
#_Pattern _Discard__ Male Special
12 0 0 0 # CM_E 12=logistic
12 0 0 0 # CM_W
20 0 0 0 # REC
19 0 0 0 # SMP_BYC 19=double logistic
15 0 0 3 # HB-E
15 0 0 3 # HB-W 15=mirror, special=fleet to mirror
15 0 0 1 # CM-E-IFQ
15 0 0 2 # CM-W-IFQ
10 0 0 0 # LARVAL
11 0 0 0 # VIDEO
11 0 0 0 # SEAMAP
#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn
7.5 52.5 42.7 42.7 -1 0.05 2 0 0 0 0 0.5 0 0
# PEAK
-10.0 3.0 -0.4 -0.4 -1 0.05 3 0 0 0 0 0.5 0
0 # TOP
-6.0 12.0 5.5 5.5 -1 0.05 3 0 0 0 0 0.5 0
0 # WIDTH
-4.0 6.0 5.1 5.1 -1 0.05 3 0 0 0 0 0.5 0
0 # WIDTH
-15.0 5.0 -4.2 -4.2 -1 0.05 2 0 0 0 0 0.5 0
0 # INIT
-8.0 5.0 0.4 0.4 -1 0.05 2 0 0 0 0 0.5 0
0 # FINAL
7.5 52.5 13.0 13.0 -1 0.05 2 0 0 0 0 0.5 0
0 # PEAK
-10.0 3.0 -1.1 -1.1 -1 0.05 3 0 0 0 0 0.5 0
0 # TOP
-6.0 12.0 3.1 3.1 -1 0.05 3 0 0 0 0 0.5 0
0 # WIDTH
-4.0 6.0 5.0 5.0 -1 0.05 3 0 0 0 0 0.5 0
0 # WIDTH
-15.0 5.0 -4.5 -4.5 -1 0.05 2 0 0 0 0 0.5 0
0 # INIT
-8.0 5.0 0.1 0.1 -1 0.05 2 0 0 0 0 0.5 0
0 # FINAL
0.5 14 2.66 2.66 -1 0 3 0 0 0 0 0 1 2 #CM_E_AgeSel_p1 size at inflection
0.5 14 7.2774 7.2774 -1 0 1 0 0 0 0 0 1 2 #CM_E_AgeSel_p2 width of 95% selection
0.5 14 2.66 2.66 -1 0 3 0 0 0 0 0 1 2 #CM_W_AgeSel_p1
0.5 14 7.2774 7.2774 -1 0 1 0 0 0 0 0 1 2 #CM_W_AgeSel_p2
1 10 4.3 4.3 -1 0.05 2 0 0 0 0 0.5 0
0 # PEAK value
-10.0 3.0 -4.6 -4.6 -1 0.05 3 0 0 0 0 0.5 0
0 # TOP logistic
-6.0 12.0 0.7 0.7 -1 0.05 3 0 0 0 0 0.5 0
0 # WIDTH exp
-4.0 6.0 2.7 2.7 -1 0.05 3 0 0 0 0 0.5 0
0 # WIDTH exp
-15.0 5.0 -11.2 -11.2 -1 0.05 2 0 0 0 0 0.5 0
0 # INIT logistic
```

-8.0 5.0 -3.3 -3.3 -1 0.05 2 0 0 0 0 0.5 0
0 # FINAL logistic
0.0000001 2.0 0.5 0.5 -1 0 -4 0 0 0 0 0 0 0 #SMP_BYC_AgeSel_p1
0.5 10000000.0 100.0 100.0 -1 0 -4 0 0 0 0 0 0 0 #SMP_BYC_AgeSel_p2
0.3 3.0 1.5 1.5 -1 0 -4 0 0 0 0 0 0 0 #SMP_BYC_AgeSel_p3
0.5 10000000.0 2.4096 2.4096 -1 0 -4 0 0 0 0 0 0 0 #SMP_BYC_AgeSel_p4
-1 1 0 0 -1 0 -4 0 0 0 0 0 0 0 #SMP_BYC_AgeSel_p5
-1 1 0 0 -1 0 -4 0 0 0 0 0 0 0 #SMP_BYC_AgeSel_p6
0 15 0.1 2.66 -1 0 -1 0 0 0 0 0 0 0 #VIDEO_AGESel_p1
0 15 14 7.2774 -1 0 -1 0 0 0 0 0 0 0 #VIDEO_AGESel_p2
0 15 0.1 2.66 -1 0 -1 0 0 0 0 0 0 0 #SEAMAP_AGESel_p1
0 15 14 7.2774 -1 0 -1 0 0 0 0 0 0 0 #SEAMAP_AGESel_p2
#_Cond 0 #_custom_sel-env_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no enviro fxns
1 #_custom_sel-blk_setup (0/1)
0.5 14 2.66 2.66 -1 0 3 #CM_E_AgeSel_p1
0.5 14 7.2774 7.2774 -1 0 1 #CM_E_AgeSel_p2
0.5 14 2.66 2.66 -1 0 3 #CM_W_AgeSel_p1
0.5 14 7.2774 7.2774 -1 0 1 #CM_W_AgeSel_p2
#_Cond No selex parm trends
#_Cond -4 # placeholder for selparm_Dev_Phase
3 #_env/block/dev_adjust_method (1=standard; 2=logistic trans to keep in base parm bounds; 3=standardw/ no bound check)
Tag loss and Tag reporting parameters go next
0 # TG_custom: 0=no read; 1=read if tags exist
#_Cond -6 6 1 1 2 0.01 -4 0 0 0 0 0 0 0 #_placeholder if no parameters
1 #_Variance_adjustments_to_input_values
#fleet_1 2 3 4 5 6 7 8 9 10 11
0 0 0 0 0 0 0 0 0 0 0 #_add_to_survey_CV
0 0 0 0 0 0 0 0 0 0 0 #_add_to_discard_stddev
0 0 0 0 0 0 0 0 0 0 0 #_add_to_bodywt_CV
1 1 1 1 1 1 1 1 1 1 1 #_mult_by_lencomp_N
1 1 1 1 1 1 1 1 1 1 1 #_mult_by_agecomp_N
1 1 1 1 1 1 1 1 1 1 1 #_mult_by_size-at-age_N
30 #_DF_for_discard_like *NEW* commented out
30 #_DF_for_meanbodywt_like *NEW* commented out
4 #_maxlambdaphase
1 #_sd_offset
#
0 # number of changes to make 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
0 # (0/1) read specs for more stddev reporting
999

10.3. Forecast File

```
#C forecast file written by R function SS_writeforecast
#C rerun model to get more complete formatting in forecast.ss_new
#C should work with SS version: SSv3.21_or_later
#C file write time: 2016-02-16 11:46:00
#
1 #_benchmarks
2 #_MSY
0.6571804 #_SPRtarget
0.3 #_Btarget
#_Bmark_years: beg_bio end_bio beg_selex end_selex beg_alloc end_alloc
-1 -1 -1 -1 2012 2014
1 #_Bmark_relF_Basis
1 #_Forecast
60 #_Nforecastyrs
0.2 #_F_scalar
#_Fcast_years:  beg_selex, end_selex, beg_relF, end_relF
-1 -1 2012 2014
2 #_ControlRuleMethod
0.01 #_BforconstantF
0.001 #_BfornoF
1 #_Flimitfraction
2 #_N_forecast_loops
3 #_First_forecast_loop_with_stochastic_recruitment
0 #_Forecast_loop_control_3
0 #_Forecast_loop_control_4
0 #_Forecast_loop_control_5
2074 #_FirstYear_for_caps_and_allocations
0 #_stddev_of_log_catch_ratio
0 #_Do_West_Coast_gfish_rebuilder_output
2011 #_Ydecl
-1 #_Yinit
1 #_fleet_relative_F
3 #_basis_for_fcast_catch_tuning
# max totalcatch by fleet (-1 to have no max)
-1 -1 -1 -1
# max totalcatch by area (-1 to have no max)
-1
# fleet assignment to allocation group (enter group ID# for each fleet, 0 for not included in an alloc group)
0 0 0 0
66 #_Ncatch
99 #_InputBasis
 #_Year Seas Fleet Catch_or_F
  2015    1     1 0.05492551
  2015    1     2 0.05005713
  2015    1     3 0.04969543
  2015    1     4 0.07356127
  2016    1     1 0.05971905
  2016    1     2 0.05442581
  2016    1     3 0.05403253
  2016    1     4 0.07356127
  2017    1     4 0.07356127
  2018    1     4 0.07356127
  2019    1     4 0.07356127
  2020    1     4 0.07356127
  2021    1     4 0.07356127
  2022    1     4 0.07356127
  2023    1     4 0.07356127
  2024    1     4 0.07356127
  2025    1     4 0.07356127
  2026    1     4 0.07356127
  2027    1     4 0.07356127
  2028    1     4 0.07356127
  2029    1     4 0.07356127
  2030    1     4 0.07356127
  2031    1     4 0.07356127
  2032    1     4 0.07356127
  2033    1     4 0.07356127
```

```
  2034   1     4 0.07356127
  2035   1     4 0.07356127
  2036   1     4 0.07356127
  2037   1     4 0.07356127
  2038   1     4 0.07356127
  2039   1     4 0.07356127
  2040   1     4 0.07356127
  2041   1     4 0.07356127
  2042   1     4 0.07356127
  2043   1     4 0.07356127
  2044   1     4 0.07356127
  2045   1     4 0.07356127
  2046   1     4 0.07356127
  2047   1     4 0.07356127
  2048   1     4 0.07356127
  2049   1     4 0.07356127
  2050   1     4 0.07356127
  2051   1     4 0.07356127
  2052   1     4 0.07356127
  2053   1     4 0.07356127
  2054   1     4 0.07356127
  2055   1     4 0.07356127
  2056   1     4 0.07356127
  2057   1     4 0.07356127
  2058   1     4 0.07356127
  2059   1     4 0.07356127
  2060   1     4 0.07356127
  2061   1     4 0.07356127
  2062   1     4 0.07356127
  2063   1     4 0.07356127
  2064   1     4 0.07356127
  2065   1     4 0.07356127
  2066   1     4 0.07356127
  2067   1     4 0.07356127
  2068   1     4 0.07356127
  2069   1     4 0.07356127
  2070   1     4 0.07356127
  2071   1     4 0.07356127
  2072   1     4 0.07356127
  2073   1     4 0.07356127
  2074   1     4 0.07356127
#
999 # verify end of input
```