2014 SEDAR 41 South Atlantic Red Snapper Assessment Report

SEDAR 41

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Southeast Data, Assessment, and Review

SEDAR 41

Stock Assessment Report – Revision 1

South Atlantic Red Snapper

April 2017

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South Atlantic Red Snapper

SECTION I: Introduction

April 2016

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Executive Summary

SEDAR 41 addressed the stock assessments for South Atlantic gray triggerfish and red snapper. The assessments consisted of four in-person workshops, as well as a series of webinars. Two Data Workshops (DW) were held in Charleston, SC, the first August 4-8, 2014 and the second August 4-6, 2015. The SEDAR 41 Assessment Process was conducted through a combination of an in-person workshop, held December 14-17, 2015 in Morehead City, NC, and a series of webinars held from October 2015 to February 2016. The Review Workshop (RW) took place March 15-18, 2016 in North Charleston, SC.

The Stock Assessment Report is organized into six sections. Section I is the Introduction which contains a brief description of the SEDAR Process, Assessment, and Management Histories for the species of interest, and the management specifications requested by the Cooperator. Section II is the Data Workshop Report. It documents the discussions and data recommendations from the Data Workshop Panel. Section III is the Assessment Report. This section details the assessment model, as well as documents any changes to the data recommendations that may have occurred after the Data Workshop. Consolidated Research Recommendations from all three stages of the process (data, assessment, and review) can be found in Section IV for easy reference. Section V documents the discussions and findings of the Review Workshop. Finally, Section VI is the Addenda and Post-Review Workshop Documentation which consists of any analyses conducted during or after the RW to address reviewer concerns or requests. It may also contain documentation of the final RW-recommended base model, should it differ from the model put forward in the Assessment Report for review.

The final Stock Assessment Report (SAR) for South Atlantic Red Snapper was disseminated to the public in April 2016. The Council's Scientific and Statistical Committee (SSC) will review the SAR for its stock. The SSCs are tasked with recommending whether assessments represent Best Available Science, whether the results presented in the SARs are useful for providing management advice, and developing fishing level recommendations for the Council. An SSC may request additional analyses be conducted or may use the information provided in the SAR as the basis for their fishing level recommendations (e.g. Overfishing Limit and Acceptable Biological Catch). The South Atlantic Fishery Management Council's SSC will review the assessment at its May 2016 meeting, followed by the Council receiving that information at its June 2016 meeting. Documentation on SSC recommendations is not part of the SEDAR process and is handled through each Council.

During the March 2016 RW, the RW Panel evaluated outputs and results from the Beaufort Assessment Model (BAM), the primary assessment model that implements a statistical catch-at-age framework; and a secondary, surplus-production model (ASPIC) which provided a comparison of model results. The RW Panel accepted the new BAM base model with the corrected age compositions for the Southeast Reef Fish Survey (SERFS) combined chevron trap and video (CVID) survey index as the best available model to provide catch or management advice for the South Atlantic red snapper fishery. The RW Panel concluded that the data used in the assessment were generally sound and robust. Likewise, data generally were applied properly, and uncertainty in data inputs was appropriately acknowledged. Numerous sensitivity analyses and exploration of alternative scenarios of the BAM model were also presented during the RW, all of which agreed with the base model run conclusions of stock status. Based on these results, the Review Panel concluded that the stock is overfished and overfishing is occurring. Although the Review Panel concluded that assessment results represent the best available science, there were significant areas of uncertainty identified in both the data and in components to the model. The most significant sources of this uncertainty included: the composition and magnitude of recreational discards, the stock-recruitment relationship, potential changes in CPUE catchability, and the selectivities for the different fishery fleets. The Review Panel recognized that the perception of current selectivity used to derive reference points and projections is conditional on poorly-informed assumptions regarding recent fishing behavior. During the most recent years of the stock assessment series (i.e., the 2010-2014 moratorium), recreational discards were one of the most important and most uncertain sources of information. Also, a retrospective pattern in apical F indicated the base BAM model was very sensitive to the terminal year of data and suggests higher uncertainty in exploitation status.

During the assessment process several data and modeling topics received a lot of discussion. Some of these topics included:

- *Southeast Region Headboat Survey (SRHS) Data Evaluation*: After the 2014 DW, a working paper was submitted questioning the validity of data collected during the early years of the SRHS. The assessment was delayed in order to investigate these potential issues. Prior to the 2015 DW, the SEFSC did a comprehensive evaluation of the SRHS program that indicated no evidence of chronic, widespread misreporting, no evidence of an apparent temporal pattern in potentially misreported data, and minimal spatial patterns in potentially misreported data.
- *Marine Recreational Information Program (MRIP) Access Point Angler Intercept Survey (APAIS) adjustment:* Starting in wave 2 of 2013, the MRIP APAIS implemented a revised sampling design. To address this new survey design change, a Calibration Workshop was held in 2014. The final report recommended an additional calibration for catch estimates and recommended an interim 'simple ratio' method using 2013 data. SEDAR 41 was the first time this method was used in a South Atlantic SEDAR assessment.
- *Recreational Red Snapper Charter and Private Mini Season Landings and Discard Estimates*: In 2012 through emergency action and 2013 and 2014 through a process developed in Amendment 28 to the Snapper Grouper Fishery, the red snapper fishery was opened for a very short duration. MRIP was not designed to capture short pulses of fishing. State partners in the South Atlantic supplied data from studies conducted in each state during the mini-seasons as an attempt to supplement the MRIP data. The DW Panel

developed a set of rules in order to determine which dataset (MRIP vs. state partners) was more appropriate for landings and discards by state, mode, and wave.

- *Natural Mortality*: Both the DW and Assessment Workshop (AW) panels had lengthy discussions about natural mortality. The final recommendation was to use the Charnov et al. (2013) age-varying natural mortality curve scaled to the Then et al. (2015) point estimate for those ages fully recruited to the fishery. SEDAR 41 was the first time the Then et al. (2015) estimator has been used in a South Atlantic SEDAR assessment.
- *SERFS Chevron Trap Index Time Series:* The DW Panel recommended using the SERFS trap index from 2010-2014. Chevron trap survey data were available prior to 2010, and the Panel discussed potentially starting the trap index in 2005. However, due to the low incidence of red snapper catches prior to 2010, the Panel recommended using the trap index starting in 2010 and exploring the effect of the longer time series through a sensitivity run.
- *SERFS Chevron Trap and Video Indices – Independence and Selectivity:* The AW Panel recommended combining the trap and video indices into one index (CVID) since the data are collected from the same sampling platform (e.g. cameras are mounted on the traps). Age composition data were not available for the video index, so the selectivity for the combined CVID index was informed by age composition of red snapper caught in chevron traps.
- *Stock Recruitment Curve and Steepness:* Many initial attempts were made to estimate steepness resulting in a value near its upper bound. The AW Panel discussed whether to fix steepness or assume an average annual recruitment while estimating lognormal deviations around that average by setting steepness to 0.99. The AW Panel opted for the latter, acknowledging this would require using spawning potential ratio (SPR) benchmarks to determine stock status rather than MSY-benchmarks.
- *Start Year of Model*: The AW Panel had discussions regarding the start year of the assessment. They weighed the options of starting in 1950 vs. 1978. Only landings data were available for the historic time period (1950 – mid-1970's). No age or length composition data were available. The AW Panel recommended 1950 as the starting year and included a model run with the 1978 start year as a sensitivity run.
- *SERFS Revised Chevron Trap Age Compositions:* An error with the chevron trap survey age composition data was discovered during the RW. The age compositions used at the AW were based on the number of annuli and the corrected data were based on calendar-year age. Revised age compositions along with preliminary assessment results were presented at the RW and accepted for use in the base run of the model.
- *Selectivity for General Recreational Fleet from 2010-2014*: Selectivity of the general recreational fleet was assumed to be flat-topped for the 2010-2014 time block. The RW Panel could not agree on whether the flat-topped assumption was well justified and requested a sensitivity analysis where the selectivity for this time period mirrored the headboat dome-shaped selectivity.
- *Recreational Discard Estimates:* The RW Panel noted that during the most recent years of the assessment (2010-2014 moratorium period), recreational discards were one of the most important sources of information for the assessment. Recreational discards were

also noted as one of the most uncertain sources of information. Despite the uncertainty of recreational catch estimates, the BAM base configuration is conditional on catch estimates. The impact of the uncertainty in discards and landings on stock status was explored through the MCB uncertainty analysis and sensitivity runs.

- *Evaluating Trends of Fishing Mortality (F) Over Time:* The RW Panel noted that evaluating trends in F across time requires a metric that is comparable among years and reflects exploitation across a range of ages. In this assessment, apical F (maximum F at age) is based on a different range of ages among years because of changing fleet contributions and fleet selectivities. The RW Panel discussed other potential F metrics and noted deciding on a more appropriate metric of F was challenging due to the complexity of patterns in estimated F at age. The RW Panel noted the potential large uncertainty in the F estimates including the terminal year of the assessment (2014).

I. Introduction

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. The improved stock assessments from the SEDAR process provide higher quality information to address fishery management issues. SEDAR emphasizes constituent and stakeholder participation in assessment development, transparency in the assessment process, and a rigorous and independent scientific review of completed stock assessments.

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

SEDAR is typically organized around three stages. First is the Data Stage, where a workshop is held during which fisheries, monitoring, and life history data are reviewed and compiled. Second is the Assessment Stage, which is conducted via a workshop and/or series of webinars, during which assessment models are developed and population parameters are estimated using the information provided from the Data Workshop. The final stage is the Review Workshop, during which independent experts review the input data, assessment methods, and assessment products. The completed assessment, including the reports of all 3 workshops and all supporting documentation, is then forwarded to the Council SSC for certification as 'appropriate for management' and development of specific management recommendations.

SEDAR workshops are public meetings organized by SEDAR staff and the lead Council. 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.

SEDAR Review Workshop Panels consist of a chair, three reviewers appointed by the Center for Independent Experts (CIE), and one or more SSC representatives appointed by each council having jurisdiction over the stocks assessed. The Review Workshop Chair is appointed by the council having jurisdiction over the stocks assessed and is a member of that council's SSC. Participating councils may appoint representatives of their SSC, Advisory, and other panels as observers.

2. Management Overview

2.1 Fishery Management Plan and Amendments

The following summary describes only those management actions that likely affect red snapper fisheries and harvest.

Original Snapper Grouper Fishery Management Plan

The Fishery Management Plan (FMP), Regulatory Impact Review, and Final Environmental Impact Statement for the Snapper Grouper Fishery of the South Atlantic Region, approved in 1983 and implemented in August of 1983, establishes a management regime for the fishery for snappers, groupers and related demersal species of the continental shelf of the southeastern United States in the exclusive economic zone (EEZ) under the area of authority of the South Atlantic Fishery Management Council (Council) and the territorial seas of the states, extending from the North Carolina/Virginia border through the Atlantic side of the Florida Keys to 83^o W longitude. In the case of the sea basses and scup, the management regime applies only to south of Cape Hatteras, North Carolina. Regulations apply only to federal waters.

SAFMC FMP Amendments affecting red snapper

Description of Action	FMP/Amendment	Effective Date
4" Trawl mesh size and a 12" TL minimum size limit for red snapper.	Snapper Grouper FMP	8/31/1983
Prohibit trawls.	Amendment # 1	1/12/1989
Required permit to fish for, land or sell snapper grouper species.	Amendment # 3	1/31/1991
Prohibited gear: fish traps except bsb traps north of Cape Canaveral, FL; entanglement nets; longline gear inside 50 fathoms; bottom longlines to harvest wreckfish; powerheads and bangsticks in designated SMZs off S. Carolina. Established 20" TL minimum size for red snapper and a 10 snapper/person/day bag limit, excluding vermilion snapper, and allowing no more than 2 red snapper.	Amendment # 4	1/1/1992
Oculina Experimental Closed Area.	Amendment # 6	6/27/1994
Limited entry program; transferable permits and 225 lb non-transferable permits.	Amendment # 8	12/14/1998

Vessels with longline gear aboard may only possess snowy grouper, warsaw grouper, yellowedge grouper, misty grouper, golden tilefish, blueline tilefish, and sand tilefish.	Amendment # 9	2/24/1999
Approved definitions for overfished and overfishing. MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}. MFMT = F_{MSY}	Amendment # 11	12/2/1999
Extended for an indefinite period the regulation prohibiting fishing for and possessing snapper grouper species within the *Oculina* Experimental Closed Area.	Amendment # 13A	4/26/2004
Established eight deepwater Type II marine protected areas to protect a portion of the population and habitat of long-lived deepwater snapper grouper species. Also protected known spawning areas of many snapper grouper species including red snapper.	Amendment #14 (2007)	2/12/09
Prohibited harvest and possession of red snapper from January 4, 2010 to June 2, 2010. Was extended for 186 days.	Red Snapper Interim Rule	12/4/2009
Specified an ACL=0 for red snapper. Specified a rebuilding plan for red snapper. Specified status determination criteria for red snapper. Specified a monitoring program for red snapper. Required use of non-stainless steel circle hooks when fishing for snapper grouper species with hook-and-line gear north of 28 deg. N latitude in the South Atlantic EEZ. Implemented an area closure for South Atlantic snapper grouper extending from southern Georgia to northern Florida where harvest and possession of all snapper grouper species was prohibited (except when fishing with black sea bass pots or spearfishing gear for species other than red snapper).	Amendment # 17A	12/3/2010 red snapper closure; circle hooks 3/3/2011

Established red snapper seasons for the commercial and recreational sectors in South Atlantic federal waters in 2012. The commercial and recreational annual catch limits for 2012 were 20,818 pounds gutted weight and 9,399 fish, respectively. During the open season, the commercial trip limit was 50 pounds gutted weight, the recreational bag limit was 1 fish per person per day, and there was no minimum size limit for red snapper for either sector. The fishing seasons in 2012 for the commercial and recreational sectors were 14 and 6 days, respectively.	Red Snapper Emergency Rule	8/28/2012
Established regulations to allow limited harvest of red snapper on an annual basis. Also specified the commercial and recreational annual catch limits for red snapper in 2013. The commercial and recreational annual catch limits were 21,447 pounds gutted weight and 9,585 fish, respectively. During the open season, the commercial trip limit was 75 pounds gutted weight, the recreational bag limit was 1 fish per person per day, and there is no minimum size limit for red snapper for either sector. The fishing seasons in 2013 for the commercial and recreational sectors were 43 and 3 days, respectively. The fishing seasons in 2014 for the commercial and recreational sectors were 57 and 8 days, respectively.	Amendment # 28	8/23/2013

SAFMC Regulatory Amendments affecting red snapper

Description of Action	FMP/Amendment	Effective Date
Prohibited fishing in SMZs except with hand-held hook-and-line and spearfishing gear.	Regulatory Amendment # 1	3/27/1987
Established 2 artificial reefs off Ft. Pierce, FL as SMZs.	Regulatory Amendment # 2	3/30/1989
Established artificial reef at Key Biscayne, FL as SMZ.	Regulatory Amendment # 3	11/02/1990
Established 8 SMZs off S. Carolina, where only hand-held, hook-and-line gear and spearfishing (excluding powerheads) was allowed.	Regulatory Amendment # 5	7/31/1993
Established 10 SMZs at artificial reefs off South Carolina,	Regulatory Amendment # 7	1/29/1999
Established 12 SMZs at artificial	Regulatory Amendment # 8	11/15/2000

reefs off Georgia; revised boundaries of 7 existing SMZs off Georgia to meet CG permit specs; restricted fishing in new and revised SMZs.		
Eliminated closed area for snapper grouper species approved in Amendment 17A.	Regulatory Amendment # 10	5/31/2011
Change MSST for 8 snapper grouper species including red snapper from MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY} to 0.75*B_{MSY}	Regulatory Amendment #21	11/6/2014

2.2 Emergency and Interim Rules (if any)

Emergency Rule effective 9/3/1999: Reopened the Amendment 8 permit application process.

Interim Rule effective 12/4/2009: Prohibited harvest and possession of red snapper from January 4, 2010 to June 2, 2010. Was extended for 186 days.

Emergency Rule effective 12/3/2010: Delay the effective date of the area closure for snapper grouper species implemented through Amendment 17A.

Emergency Rule effective 8/28/2012: Established red snapper seasons for the commercial and recreational sectors in South Atlantic federal waters. The commercial and recreational annual catch limits for 2012 were 20,818 pounds gutted weight and 9,399 fish, respectively. During the open season, the commercial trip limit was 50 pounds gutted weight, the recreational bag limit was 1 fish per person per day, and there was no minimum size limit for red snapper for either sector. The fishing seasons in 2012 for the commercial and recreational sectors were 14 and six days, respectively.

2.3 Secretarial Amendments (if any)

None

2.4 Control Date Notices (if any)

Notice of Control Date effective July 30, 1991: Anyone entering federal snapper grouper fishery (other than for wreckfish) in the EEZ off S. Atlantic states after 7/30/91 was not assured of future access if limited entry program developed.

Notice of Control Date effective October 14, 2005: The Council is considering management measures to further limit participation or effort in the commercial fishery for snapper grouper species (excluding Wreckfish).

Notice of Control Date effective March 8, 2007: The Council may consider measures to limit participation in the snapper grouper for-hire fishery.

Notice of Control Date effective January 31, 2011: Anyone entering federal snapper grouper fishery off South Atlantic states after 9/17/10 was not assured of future access if limited entry program is developed.

2.5 Management Program Specifications

Table 2.5.1. General Management Information

South Atlantic

Species	Red Snapper
Management Unit	Southeastern US
Management Unit Definition	All waters within South Atlantic Fishery Management Council Boundaries
Management Entity	South Atlantic Fishery Management Council
Management Contacts SERO / Council	SAFMC: Myra Brouwer/Gregg Waugh SERO: Jack McGovern/Rick DeVictor
Current stock exploitation status	Overfishing
Current stock biomass status	Overfished

Table 2.5.2 Management Parameters

See November 2010 SEFSC report (SEDAR41-RD09) **for updated values from SEDAR 24 based on headboat weight of 0.30.**

Criteria	South Atlantic – Current (SEDAR 24)	
	Definition	Value
MSST[1]	MSST = [(1-M) or 0.5 whichever is greater]*SSB_{MSY}	317,465 lbs ww
	Regulatory Amendment # 21 (effective 11/6/2014) changed definition to MSST = 75%*SSB_{MSY}	258,000 lbs ww
MFMT	$F_{30\%SPR}$ proxy for F_{MSY}	0.204
MSY	Yield at F_{MSY} (1,000 pounds)	1,926
F_{MSY}	$F_{30\%SPR}$	0.204[2]
OY	Yield at F_{OY} (1,000 pounds) Values based on F_{MSY} = 0.206[2]	65%F_{MSY} = 1,794 75%F_{MSY} = 1,863 85%F_{MSY} = 1,905

		$98\%F_{30\%SPR}$ adopted as OY but no equilibrium value
R_{MSY}	Recruitment at MSY (1,000 age-1 fish)	608
F Target		
Yield at F_{TARGET} (equilibrium)		
F_{OY}	F_{OY} = 65%,75%, 85%, 98% F_{MSY}	$65\%F_{MSY} = 0.133$ $75\%F_{MSY} = 0.153$ $85\%F_{MSY} = 0.173$ $98\%F_{30\%SPR} = .200$
M	M	0.08
Terminal F	Geometric mean of the fishing mortality rates in 2007-2009 (Fcurrent)	0.569
Terminal Biomass[1]	SSB_{2009} (metric tons)	24
Exploitation Status	$F_{2007-2009}/F_{30\%SPR}$	2.79
Biomass Status[1]	SSB_{2009}/MSST	0.15
Generation Time		25 years
$T_{REBUILD}$ (if appropriate)		

Criteria	South Atlantic – Proposed (Values from SEDAR 41)		
	Definition	Base Run Values	Median of Base Run MCBs
MSST[1]	MSST* = [(1-M) or 0.5 whichever is greater]*SSB_{MSY} Regulatory Amendment # 21 (effective 11/6/2014) changed definition to MSST = 75%*SSB_{MSY}		
MFMT	$F_{30\%SPR}$ proxy for F_{MSY}		
MSY	Yield at F_{MSY}		
F_{MSY}	F_{MAX}		
OY	Yield at F_{OY} (defined as 98%F30%SPR)		
R_{MSY}	Recruits as MSY		
F Target			
Yield at F_{TARGET} (equilibrium)	Landings and discards, pounds and numbers		
F_{OY}	F_{OY} = 65%,75%, 85% F_{MSY} $F_{OY} = 98\%F_{30\%SPR}$		
M	M		
Terminal F	Exploitation		

Terminal Biomass[1]	Biomass		
Exploitation Status	F/MFMT		
Biomass Status[1]	SSB/MSST SSB/SSB_{MSY}		
Generation Time			
$T_{REBUILD}$ (if appropriate)			

1. Biomass values reported for management parameters and status determinations should be based on the biomass metric recommended through the assessment process and Council's Scientific and Statistical Committee (SSC). This may be total, spawning stock or some measure thereof, and should be applied consistently in this table.

2. SAFMC defined F_{MSY}=$F_{30\%SPR}$ (or stated F_{OY}=98%$F_{30\%SPR}$). SEDAR 24 determined F_{MSY}=0.178. SEFSC projections were completed (see Table 1 in SEDAR41-RD09) and determined the following: $F_{30\%SPR}$=0.204, F_{MSY}=0.206. (Both of these values use a headboat weight of 0.30). The SAFMC determined that $F_{30\%SPR}$ is used as a proxy for F_{MSY}.

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

Table 2.5.3. Stock Rebuilding Information

Amendment 17A to the FMP specified a 35 year rebuilding schedule with the rebuilding time period ending in 2044. The rebuilding schedule is based on T_{MIN} + one generation Time; SEDAR 15 2008 was the source of the generation time.

Table 2.5.4. General Projection Specifications

South Atlantic

Requested Information	Value
First Year of Management	Assume management begins in 2018. However, if there are no changes to reference points and rebuilding plan, a projection with the revised ABC and OFL should be provided assuming that landings limits are changed in the 2017 fishing year.
Interim basis	ABC, if landings are within 10% of the ABC; average landings since 2012 (implementation of emergency rule and Amendment 28) otherwise.
Current Acceptable Biological (ABC) Value (1,000 fish (landings + dead discards))	2014: 106 2015: 114 2016: 121 2017: 128

	2018: 135 2019: 142
Projection Outputs	
Landings	Pounds and numbers
Discards	Pounds and numbers
Exploitation	F & Probability F>MFMT
Biomass (total or SSB, as appropriate)	B & Probability B>MSST (and Prob. B>B_{MSY} if under rebuilding plan)
Recruits	Number

Table 2.5.5. Base Run Projections Specifications. Long Term and Equilibrium conditions.

Red snapper is currently in a rebuilding plan, implemented in Snapper Grouper Amendment 17A. The rebuilding period is 35 years, ending in 2044. Rebuilding is based on fixed exploitation at F=98% of F30%SPR.

Criteria	Definition	If overfished	If rebuilt
Projection Span	Years	to 2044	10
Projection Values	$F_{CURRENT}$	X	X
	F_{MSY}	X	X
	75% F_{MSY}	X	X
	$F_{REBUILD = 98\%F30\%SPR}$	X	

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

Table 2.5.6. Short term projections (P* or exploitation based). 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. Projections based on exploitation rates should provide probabilities of both overfishing and overfished conditions.

Basis	Value	Years to Project	P* applies to
P*	50%	Interim + 5	Probability of overfishing
Exploitation	98% of F30%SPR	Interim + 5	NA

Table 2.5.7. Quota Calculation Details

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

Red snapper is managed by catch limits that are established annually, after the results of the prior fishing year are evaluated. Calculation of these catch limits is specified in Snapper Grouper Amendment 28, values are not required to be calculated in this assessment.

2.6 Management and Regulatory Timeline

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

Table 2.6.1. Annual Commercial Red Snapper Regulatory Summary (please fill out as appropriate)

Year	Fishing Year	Size Limit	Possession Limit	Open Date	Close Date	Other
1992	Calendar	20"	None	January 1		
1993	Calendar	20"	None	January 1		
1994	Calendar	20"	None	January 1		
1995	Calendar	20"	None	January 1		
1996	Calendar	20"	None	January 1		
1997	Calendar	20"	None	January 1		
1998	Calendar	20"	None	January 1		
1999	Calendar	20"	None	January 1		
2000	Calendar	20"	None	January 1		
2001	Calendar	20"	None	January 1		
2002	Calendar	20"	None	January 1		
2003	Calendar	20"	None	January 1		
2004	Calendar	20"	None	January 1		
2005	Calendar	20"	None	January 1		
2006	Calendar	20"	None	January 1		
2007	Calendar	20"	None	January 1		
2008	Calendar	20"	None	January 1		
2009	Calendar	20"	None	January 1		
2010	Calendar	20"	Zero	January 1	December 3	** see note below
2011	Calendar	No Harvest				
2012	Calendar	No min size limit	50 lb per trip	September 17	September 24	Reopened November 13-21 and December 12-19
2013	Calendar	No min size limit	75 lb per trip	August 26	October 8	
2014	Calendar	No min size limit	75 lb per trip	July 14	September 9	

**Red snapper interim rule prohibited harvest and possession of red snapper from January 4, 2010 to June 2, 2010 and was extended for 186 days. Existing size limits were not changed in the interim rule, but the prohibition of harvest trumped these regulations.

Table 2.6.2. Annual Recreational Red Snapper Regulatory Summary (Please fill out as appropriate)

Year	Fishing Year	Size Limit	Bag Limit	Open Date	Close Date	Other
1992	Calendar	20”	aggregate snapper bag limit – 10/person/day, excluding vermilion snapper and allowing no more than 2 red snappers	January 1		
1993	Calendar	20”	aggregate snapper bag limit – 10/person/day, excluding vermilion snapper and allowing no more than 2 red snappers	January 1		
1994	Calendar	20”	2	January 1		
1995	Calendar	20”	2	January 1		
1996	Calendar	20”	2	January 1		
1997	Calendar	20”	2	January 1		
1998	Calendar	20”	2	January 1		
1999	Calendar	20”	2	January 1		
2000	Calendar	20”	2	January 1		
2001	Calendar	20”	2	January 1		
2002	Calendar	20”	2	January 1		
2003	Calendar	20”	2	January 1		
2004	Calendar	20”	2	January 1		
2005	Calendar	20”	2	January 1		
2006	Calendar	20”	2	January 1		
2007	Calendar	20”	2	January 1		
2008	Calendar	20”	2	January 1		
2009	Calendar	20”	2	January 1		
2010	Calendar	20”	2	January 1	December 3	** see note below
2011	Calendar	No harvest				
2012	Calendar	No min size limit	1	Sept 14-17, and Sept 21-24	Sept 17; Sept 24	Two 3-day weekends
2013	Calendar	No min size limit	1	August 23	August 26	One 3-day weekend
2014	Calendar	No Min size limit	1	Jul 11-14, Jul 18-21, Jul 25-27	Jul 14; Jul 21; Jul 27	Two 3-day weekends and 1 two-day weekend

**Red snapper interim rule prohibited harvest and possession of red snapper from January 4, 2010 to June 2, 2010 and was extended for 186 days. Existing size and bag limits were not changed in the interim rule, but the prohibition of harvest trumped these regulations.

2.6.3 Closures due to Meeting Commercial Quota or Commercial/Recreational ACL

Commercial: See Table 2.6.1

Recreational: See Table 2.6.2

Table 7. State Regulatory History

North Carolina:
There are currently no North Carolina state-specific regulations for red snapper. North Carolina has complemented federal regulations for all snapper grouper species via proclamation authority since 1991. Between 1992 and 2005, species-specific regulations were added to the proclamation authority contained in rule 15A NCAC 03M .0506. In 2002, North Carolina adopted its Inter-Jurisdictional Fishery Management Plan (IJ FMP), which incorporates all Atlantic States Marine Fisheries Commission and Council-managed species by reference, and adopts all federal regulations as minimum standards for management. In completing the 2008 update to the IJ FMP, all species-specific regulations were removed from rule 15A NCAC 03M .0506, and proclamation authority to implement changes in management was moved to rule 15A NCAC 03M .0512. Since this time, all snapper grouper regulations have been contained in a single proclamation, which is updated anytime an opening/closing of a particular species in the complex occurs, as well as any changes in allowable gear, required permits, etc. Beginning in 2015, commercial and recreational regulations are contained in separate proclamations. The most current snapper grouper proclamations (and all previous versions) can be found using this link: http://portal.ncdenr.org/web/mf/proclamations.

15A NCAC 03M .0506 SNAPPER-GROUPER COMPLEX
(a) In the Atlantic Ocean, it is unlawful for an individual fishing under a Recreational Commercial Gear License with seines, shrimp trawls, pots, trotlines or gill nets to take any species of the Snapper-Grouper complex.
(b) The species of the snapper-grouper complex listed in the South Atlantic Fishery Management Council Fishery Management Plan for the Snapper-Grouper Fishery of the South Atlantic Region are hereby incorporated by reference and copies are available via the Federal Register posted on the Internet at www.safmc.net and at the Division of Marine Fisheries, P.O. Box 769, Morehead City, North Carolina 28557 at no cost.
History Note: Authority G.S. 113-134; 113-182; 113-221; 143B-289.52;
Eff. January 1, 1991;
Amended Eff. April 1, 1997; March 1, 1996; September 1, 1991;
Temporary Amendment Eff. December 23, 1996;
Amended Eff. August 1, 1998; April 1, 1997;
Temporary Amendment Eff. January 1, 2002; August 29, 2000; January 1, 2000; May 24, 1999;
Amended Eff. October 1, 2008; May 1, 2004; July 1, 2003; April 1, 2003; August 1, 2002.

15A NCAC 03M .0512 COMPLIANCE WITH FISHERY MANAGEMENT PLANS

(a) In order to comply with management requirements incorporated in Federal Fishery Management Council Management Plans or Atlantic States Marine Fisheries Commission Management Plans or to implement state management measures, the Fisheries Director may, by proclamation, take any or all of the following actions for species listed in the Interjurisdictional Fisheries Management Plan:

(1) Specify size;
(2) Specify seasons;
(3) Specify areas;
(4) Specify quantity;
(5) Specify means and methods; and
(6) Require submission of statistical and biological data.

(b) Proclamations issued under this Rule shall be subject to approval, cancellation, or modification by the Marine Fisheries Commission at its next regularly scheduled meeting or an emergency meeting held pursuant to G.S. 113-221.1.

History Note: Authority G.S. 113-134; 113-182; 113-221; 113-221.1; 143B-289.4;
Eff. March 1, 1996;
Amended Eff. October 1, 2008.

South Carolina:

Sec. 50-5-2730 of the SC Code states:

"Unless otherwise provided by law, any regulations promulgated by the federal government under the Fishery Conservation and Management Act (PL94-265) or the Atlantic Tuna Conservation Act (PL 94-70) which establishes seasons, fishing periods, gear restrictions, sales restrictions, or bag, catch, size, or possession limits on fish are declared to be the law of this State and apply statewide including in state waters."

As such, South Carolina red snapper regulations are (and have been) pulled directly from the federal regulations as promulgated under the Magnuson-Stevens Fishery Conservation and Management Act. There are no know separate red snapper regulations that have been codified in the South Carolina Code.

Georgia:

Georgia state regulations for red snapper are currently:

- 2 fish per person daily creel limit
- 20 inch TL minimum size limit
- Season open year round

The law with these measures was originally enacted on July 1, 1989 with regulations following on September 13, 1989. The Official Code of Georgia Annotated (O.C.G.A.) and regulations sections have changed over time, but management measures have not. The current regulations are found in O.C.G.A 27-4-10 and DNR Rule 391-2-4-.04. Both documents are available upon request.

Florida:

Florida Atlantic Red Snapper Regulatory History

Year	Size Limit	Possession Limit	Other Regulation Changes
1985	12" TL		
1986	12" TL	10 per person per day aggregate snapper bag limit; off-the-water possession limit of 20 per person	Commercial longline gear prohibited; stab or sink nets prohibited off Monroe county; 5% of grouper in possession may be smaller than minimum size; all snappers must be landed in whole condition.
1987	12" TL	"	
1988	12" TL	"	
1989	12" TL	"	
1990	13" TL	2 per person per day within the 10 snapper aggregate; off-the-water possession limit of 4 red snapper	Red snapper designated as a protected species; Hook and line, black sea bass trap, spear, gig, or lance defined as allowable gear; off the water possession limit of 4 red snapper per recreational angler; commercial harvest of any species of snapper is prohibited in state waters if harvest of that species is prohibited in adjacent federal waters.
1991	13" TL	"	
1992	20" TL	"	
1993	20" TL	"	
1994	20" TL	"	Allows a two-day possession limit for reef fish statewide for persons aboard charter and headboats on trips exceeding 24 hours provided the vessel has a permanent berth for each passenger and each passenger has a receipt verifying the length of the trip.

1995	20" TL	"	
1996	20" TL	"	
1997	20" TL	"	
1998	20" TL	"	
1999	20" TL	"	
2000	20" TL	"	
2001	20" TL	"	
2002	20" TL	"	
2003	20" TL	"	Imported reef fish must comply with Florida's minimum size limits; red snapper removed as a protected species.
2004	20" TL	"	
2005	20" TL	"	
2006	20" TL	"	
2007	20" TL	"	Sets commercial trip limits in Florida's Atlantic state waters to be the same as commercial trip limits in adjacent federal waters.
2008	20" TL	"	
2009	20" TL	"	
2010	20" TL	"	Requires use of dehooking tools for all Atlantic reef fish.
2011	20" TL	"	
2012	20" TL	"	
2013	20" TL	"	
2014	20" TL	"	

[1985]

SNAPPER, CH 46-14, F.A.C. (Effective July 29, 1985)

- Implements 12 inch minimum size limits for red snapper, mutton snapper, and yellowtail snapper

[1986]

REEF FISH, CH 46-14, F.A.C. (Effective December 11, 1986)

- Establishes snapper bag limit: 10 per person daily, with an off-the-water possession limit of 20 per person, for any combination of snapper, excluding lane, vermillion, and yelloweye

- Prohibits the use of long line gear in state waters for harvesting snapper, but allowed a 5% bycatch allowance under specific circumstances
- Prohibits use of stab nets (or sink nets) to take snapper in Atlantic waters of Monroe County
- Allows 5% of snapper in possession of harvester to be smaller than the minimum size limit
- Must be landed in whole condition (head and tail intact)

[1990]

REEF FISH, CH 46-14, F.A.C. (Effective February 1, 1990)

- Designates all **snapper** as "restricted species"
- Designates **red snapper** as protected species
- Establishes minimum size limits:
  - Red snapper - 13 inches
- Recreational bag limits: 10 daily per person for any combination of snapper, not including lane and vermillion (no more than 5 may be gray/mangrove snapper and no more than 2 may be red snapper)
- Off-the-water recreational possession limits: 20 per person for any combination of snapper, not including lane and vermillion (no more than 10 may be gray/mangrove snapper and no more than 4 may be red snapper)
- Establishes the following allowable gear: Hook and line, black sea bass trap, spear, gig, or lance (except powerheads, bangsticks, or explosive devices) for snapper
- Prohibits all commercial harvest of any species of snapper in state waters whenever harvest of that species is prohibited in adjacent federal waters
- Requires snapper to be landed in whole condition

[1992]

REEF FISH, CH 46-14, F.A.C. (Effective December 31, 1992)

- Requires the appropriate federal permit in order to exceed **snapper/grouper** bag limits and to purchase or sell snapper/grouper on the state's Gulf coast
- Establishes a minimum size limit of 20 inches for **red snapper** on the state's Atlantic coast

[1994]

REEF FISH, CH 46-14, F.A.C. (Effective March 1, 1994)

- Allows a two-day possession limit for reef fish statewide for persons aboard charter and headboats on trips exceeding 24 hours provided that the vessel is equipped with a permanent berth for each passenger aboard, and each passenger has a receipt verifying the trip length

[2003]
REEF FISH, CH 68B-14, F.A.C. (Effective January 1, 2003)
- Clarifies that imported reef fishes must comply with Florida's legal minimum size limits
- Deletes the rule designation of **red snapper** as protected species

[2007]
REEF FISH, CH 68B-14, F.A.C. (Effective July 1, 2007)
- Sets commercial trip limits in the Atlantic that are the same as trip limits in federal waters

[2010]
REEF FISH, CH 68B-14, F.A.C. (Effective January 19, 2010)
- Requires dehooking tools to be aboard commercial and recreational vessels for anglers to use as needed to remove hooks from Atlantic reef fish

References
None provided.

3. Assessment History and Review

In the early 1990s, a series of reports were prepared by the SAFMC Plan Development Team (in 1990) and by the NOAA-Beaufort Reef Fish Team (in 1991 and 1992), intended for prioritizing stocks for assessment. Those reports described “snapshot” analyses conducted on several snapper-grouper species, including red snapper. The analyses included the estimation of SPR (spawning potential ratio) based on a single year of data.

The first formal assessment of red snapper in the U.S. Atlantic was conducted by Manooch et al. (1998; abstract below). In that assessment, two age-structured models were used: an un-calibrated separable VPA and FADAPT. The results from FADAPT were downplayed because the model was calibrated to an abundance index derived from MARMAP chevron trap data, which had very low sample sizes. Manooch et al. (1998) concluded that “the status is less than desirable, but does appear to be responsive to recent management actions.” They found that the fishing mortality rate (F) should be reduced by 33% to 68%, depending on the natural mortality rate and desired SPR. Prior to publication, a report of that assessment was submitted to the SAFMC. After publication, the results were revisited by Potts and Brennan (2001) in a trends report, also prepared for the SAFMC. Potts and Brennan (2001) repeated the findings of Manooch et al. (1998), but suggested a broader range of reduction in F, from 30% to 80%.

This stock of red snapper was first assessed through the SEDAR process in 2007 (SEDAR review held Jan. 28 – Feb. 1, 2008). That assessment applied a statistical catch-age model using data through 2006 (SEDAR 15, 2008). Because the spawner-recruit parameter of steepness was not estimable (hit its upper bound), the SEDAR review panel recommended using proxies for MSY-related benchmarks based on $SPR_{40\%}$. Relative to those benchmarks, the assessment found that since the 1960s, overfishing had been occurring and the stock had been overfished. In the terminal year, the assessment estimated $F_{2006}/F_{40\%}=7.7$ and $SSB_{2006}/SSB_{F40\%}=0.03$. Although quantitative results varied, these qualitative results of overfishing a depleted stock were consistent across all catch-age model configurations examined during and after the assessment process (~40 sensitivity runs), as well as with an alternative model formulation (surplus-production model). SEDAR24–AW–012.

SEDAR 24 (concluded October, 2010) was a benchmark assessment using the Beaufort Assessment Model (BAM) with data through 2009. BAM is a statistical catch-age model developed by the analysts at the Beaufort, NC NMFS laboratory, and is customizable to the data available. A surplus production model called ASPIC (Prager 1994, Prager 2004) was used as a complement for comparison purposes. Based on the assessment provided from the BAM, the Review Panel concluded that the stock was overfished with overfishing occurring. The SSB in the terminal year was estimate to be about 9% of MSST ($SSB_{2009}/MSST = 0.09$) and the fishing level at more than four times F_{MSY} ($F_{2007-2009}/F_{MSY} = 4.12$). Similar to SEDAR 15, more than 40 sensitivities were run, all of which resulted in the same status determinations.

References

Manooch, C.S., III, J.C. Potts, D.S. Vaughan, and M.L. Burton. 1998. Population assessment of the red snapper from the southeastern United States. Fisheries Research 38:19–32.

Potts, J.C. and K. Brennan. 2001. Trends in catch data and estimated static SPR values for fifteen species of reef fish landed along the southeastern United States. Report prepared for SAFMC.

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

Prager, M. H., 2004. User's Manual for ASPIC: A Stock-Production Model Incorporating Covariates (ver.5) And Auxiliary Programs. National Marine Fisheries Service Beaufort Laboratory Document BL-2004-01, 1-25.

SEDAR. 2008. SEDAR 15 - Stock assessment report (SAR 1) South Atlantic red snapper. SEDAR, North Charleston, SC. 511 p. Available online at http://www.sefsc.noaa.gov/sedar/download/S15%20SAR%201%20Revised%203-09.pdf?id=DOCUMENT

SEDAR. 2010. SEDAR 24 - Stock assessment report South Atlantic Red Snapper. 524 p. Available at http://www.sefsc.noaa.gov/sedar/download/SEDAR%2024_SAR_October%202010_26.pdf?id=DOCUMENT

Abstract from Manooch et al. (1998): Changes in the age structure and population size of red snapper, *Lutjanus campechanus*, from North Carolina through the Florida Keys were examined using records of landings and size frequencies of fish from commercial, recreational, and headboat fisheries from 1986 to 1995. Population size in numbers at age was estimated for each year by applying separable virtual population analysis (SVPA) to the landings in numbers at age. SVPA was used to estimate annual, age- specific fishing mortality (*F*) for four levels of natural mortality (*M*=0.15, 0.20, 0.25, and 0.30). Although landings of red snapper for the three fisheries have declined, minimum fish size regulations have also resulted in an increase in the mean size of red snapper landed. Age at entry and age at full recruitment were age-1 for 1986-1991, compared with age-2 and age-6, respectively, for 1992-1995. Levels of mortality from fishing (*F*) ranged from 0.31 to 0.69 for the entire period. Spawning potential ratio (SPR) increased from 0.09 to 0.24 (*M*=0.25) from 1986 to 1995. The SPR level could be improved with a decrease in *F*, or an increase in age at entry to the fisheries. The latter could be enhanced now if fishermen, particularly recreational fishermen, comply with minimum size regulations.

4. Regional Maps

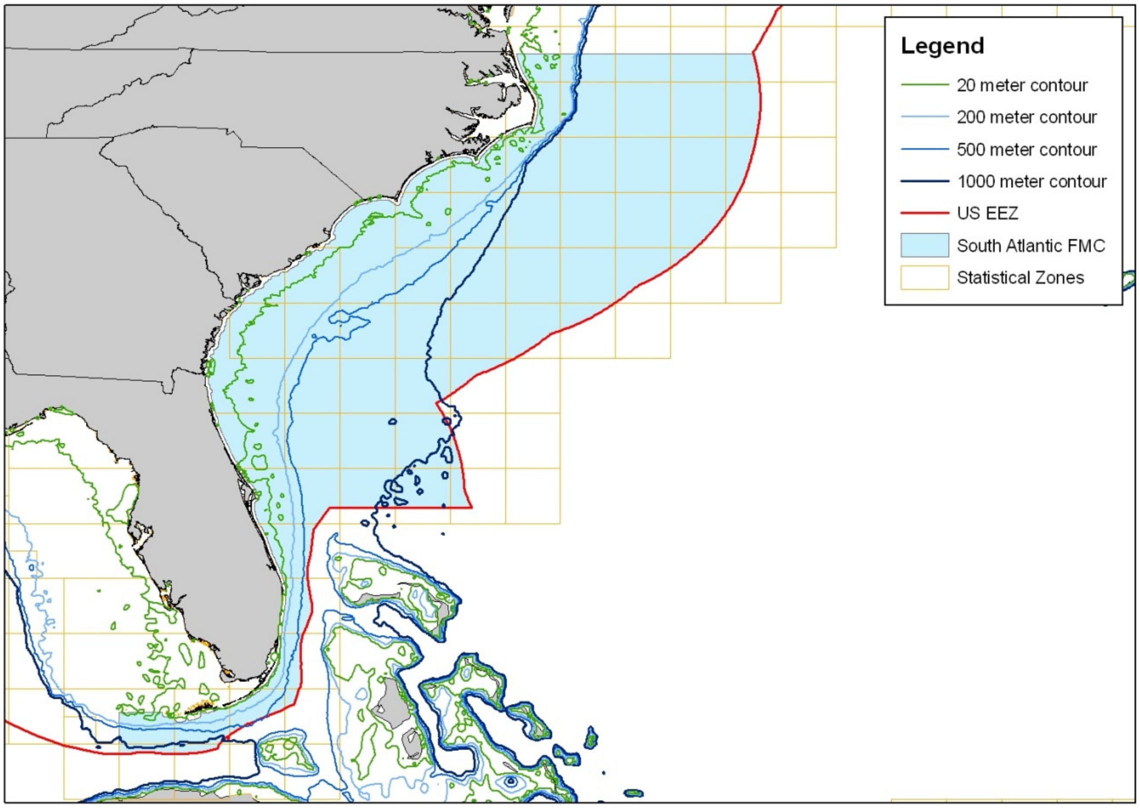

Figure 4.1: South Atlantic Fishery Management Council and EEZ boundaries.

5. SEDAR Abbreviations

APAIS	Access Point Angler Intercept Survey
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
M	natural mortality (instantaneous)
MARMAP	Marine Resources Monitoring, Assessment, and Prediction
MDMR	Mississippi Department of Marine Resources
MFMT	maximum fishing mortality threshold, a value of F above which overfishing is deemed to be occurring
MRFSS	Marine Recreational Fisheries Statistics Survey; 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
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 41

South Atlantic Red Snapper

SECTION II: Data Workshop Report

September 12, 2015

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

1. Introduction

1.1 Workshop Time and Place

The initial SEDAR 41 Data Workshop (DW) was held August 4 – 8, 2014 in Charleston, South Carolina. A data scoping call was held May 28, 2014 and webinars were held July 2, 2014, August 15, 2014 September 11, 2014, and September 26, 2014.

A working paper submitted after the DW questioned the validity of data collected during the early years of the Southeast Region Headboat Survey (SRHS). The Data Workshop Panel discussed this issue on a post-DW webinar and recommended stopping the SEDAR 41 assessments for both species to investigate the headboat issues and delaying both assessments until the issues are resolved. The SAFMC and SEDAR Steering Committee were briefed on this recommendation in fall 2014. A new schedule was approved in December 2014 delaying the assessment approximately one year and the terminal year of the assessment was changed to 2014.

The second abbreviated DW was held August 4-6, 2015 in Charleston, SC. This workshop built on the work done at the 2014 DW, revisiting decisions only if new information or analyses were available. Otherwise datasets were updated with 2014 data using decisions from the 2014 DW. Two data webinars were held before the workshop on April 15 and July 1, 2015 and a post-DW webinar was held August 20, 2015.

Between the 2014 and 2015 DW's, the Southeast Fisheries Science Center conducted a headboat data evaluation and submitted a working paper (SEDAR41-DW46) for review at the 2015 DW.

1.2 Terms of Reference

1. Review stock structure and unit stock definitions and consider whether changes are required.
2. Review, discuss, and tabulate available life history information.
   - Evaluate age, growth, natural mortality, and reproductive characteristics.
   - Provide appropriate models to describe growth, maturation, and fecundity by age, sex, or length as applicable.
   - Evaluate the adequacy of available life-history information for conducting stock assessments and recommend life history information for use in population modeling.
   - Evaluate, discuss, and characterize the sources of uncertainty, and data limitations (such as temporal and spatial coverage) for each data source. Provide ranges and/or distributions of uncertainty for data sources used in the stock assessment models[1].

3. Compare and contrast life history traits between the Gulf of Mexico and South Atlantic stocks.
4. Recommend discard mortality rates.
    - Review available research and published literature.
    - Consider research directed at these species as well as similar species from the SE and other areas.
    - Provide estimates of discard mortality rate by fishery, gear type, depth, and other feasible or appropriate strata.
    - Include thorough rationale for recommended discard mortality rates.
    - Provide justification for any recommendations that deviate from the range of discard mortality provided in the last benchmark or other prior assessment.
    - Evaluate, discuss, and characterize the sources of uncertainty, and data limitations (such as temporal and spatial coverage) for each data source. Provide ranges and/or distributions of uncertainty for data sources used in the stock assessment models[1].
5. Provide measures of population abundance that are appropriate for stock assessment.
    - Consider and discuss all available and relevant fishery dependent and independent data sources.
    - Document all programs evaluated; address program objectives, methods, coverage, sampling intensity, and other relevant characteristics.
    - Provide maps of fishery and survey coverage.
    - Develop fishery and survey CPUE indices by appropriate strata (e.g., age, size, area, and fishery) and include measures of precision and accuracy.
    - Discuss the degree to which available indices adequately represent fishery and population conditions.
    - Recommend which data sources adequately and reliably represent population abundance for use in assessment modeling.
    - Evaluate, discuss, and characterize the sources of uncertainty, and data limitations (such as temporal and spatial coverage) for each data source. Provide ranges and/or distributions of uncertainty for data sources used in the stock assessment models[1].
    - Complete the SEDAR index evaluation worksheet for each index considered.
    - Rank the available indices with regard to their reliability and adequacy for use in assessment modeling.
6. Provide commercial catch statistics, including both landings and discards in both pounds and number.

- Evaluate and discuss the adequacy of available data for accurately characterizing harvest and discard by species and fishery sector or gear.
- Evaluate, discuss, and characterize the sources of uncertainty, and data limitations (such as temporal and spatial coverage) for each data source. Provide ranges and/or distributions of uncertainty for data sources used in the stock assessment models[1].
- Provide length and age distributions for both landings and discards if feasible.
- Provide maps of fishery effort and harvest by species and fishery sector or gear.

7. Provide recreational catch statistics, including both landings and discards in both pounds and number.
    - Evaluate and discuss the adequacy of available data for accurately characterizing harvest and discard by species and fishery sector or gear.
    - Evaluate, discuss, and characterize the sources of uncertainty, and data limitations (such as temporal and spatial coverage) for each data source. Provide ranges and/or distributions of uncertainty for data sources used in the stock assessment models[1].
    - Provide length and age distributions for both landings and discards if feasible.
    - Provide maps of fishery effort and harvest by species and fishery sector or gear.
8. Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment. Include specific guidance on sampling intensity (number of samples including age and length structures) and appropriate strata and coverage.
9. Prepare the Data Workshop report providing complete documentation of workshop actions and decisions in accordance with project schedule deadlines (Section II. of the SEDAR assessment report).

[1.] In providing ranges for uncertain or incomplete information, data workshop groups should consider and distinguish between those ranges and bounds that represent probable values (i.e., likely alternative states) to be included in structured uncertainty analyses, and those that represent extreme values to be considered in evaluating model performance through sensitivity analyses.

1.3 List of Participants

2014 Data Workshop Panelists

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* Appointees marked with an * were appointed to the workshop panel but did not attend the workshop. They provided data and reviewed the use of the data, and were available via email or phone for questions as needed.

2015 Data Workshop Panelists

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1.4 List of Data Workshop Working Papers

South Atlantic red snapper and gray triggerfish data workshop document list. Working papers that were updated from the 2014 DW or were new for the 2015 DW are labeled as such.

Document #	Title	Authors
	Documents Prepared for the Data Workshop (DW)	
SEDAR41-DW01	**UPDATED:** Georgia Headboat Red Snapper Catch and Effort Data, 1983-2013	Amick and Knowlton 2014
SEDAR41-DW02	**UPDATED:** Georgia Red Snapper Catch & Effort Collection during Mini-Seasons, 2012-2014	Knowlton 2015
SEDAR41-DW03	Standardized video counts of Southeast U.S. Atlantic gray triggerfish (*Balistes capriscus*) from the Southeast Reef Fish Survey ****See SEDAR41-DW44 for index updated through 2014**	Purcell et al. 2014
SEDAR41-DW04	Standardized video counts of Southeast U.S. Atlantic red snapper (*Lutjanus campechanus*) from the Southeast Reef Fish Survey ****See SEDAR41-DW45 for index updated through 2014**	Purcell et al. 2014
SEDAR41-DW05	Gray Triggerfish Fishery-Independent Indices of Abundance in US South Atlantic Waters Based on a Chevron Trap Survey	Ballenger et al. 2014

	****See SEDAR41-DW52 for index recommended from 2015 DW**	
SEDAR41-DW06	Red Snapper Fishery-Independent Indices of Abundance in US South Atlantic Waters Based on a Chevron Trap Survey ****See SEDAR41-DW53 and SEDAR41-DW54 for index recommendations from 2015 DW**	Ballenger et al. 2014
SEDAR41-DW07	Age Truncation and Reproductive Resilience of Red Snapper (*Lutjanus campechanus*) Along the East Coast of Florida **(has since been published – see SEDAR41-RD57)**	Lowerre-Barbieri et al. 2014
SEDAR41-DW08	The utility of a hooked gear survey in developing a fisheries-independent index of abundance for red snapper along Florida's Atlantic coast	Guenther et al. 2014
SEDAR41-DW09	Size and age composition of red snapper, *Lutjanus campechanus*, collected in association with fishery-independent and fishery-dependent projects off of Florida's Atlantic coast during 2012 and 2013	Switzer et al. 2014
SEDAR41-DW10	Overview of Florida's Cooperative East Coast Red Snapper Tagging Program, 2011-2013	Brodie et al. 2014
SEDAR41-DW11	Habitat models for Gray Triggerfish collected in fishery-independent trap surveys off the southeastern United States	Muhling et al. 2014
SEDAR41-DW12	**UPDATED:** Preliminary standardized catch rates of Southeast US Atlantic red snapper (*Lutjanus campechanus*) from headboat logbook data	SFB-NMFS 2015
SEDAR41-DW13	**UPDATED:** Preliminary standardized catch rates of Southeast US Atlantic gray triggerfish (*Balistes capriscus*) from headboat logbook data	SFB-NMFS 2015
SEDAR41-DW14	**UPDATED:** Standardized catch rates of red snapper (*Lutjanus campechanus*) from headboat at-sea-observer data	SFB-NMFS 2015
SEDAR41-DW15	Standardized catch rates of gray triggerfish (*Balistes capriscus*) from headboat at-sea-observer data	SFB-NMFS 2014
SEDAR41-DW16	**UPDATED:** Report on Life History of South Atlantic Gray Triggerfish, *Balistes capriscus*, from Fishery-Independent Sources	Kolmos et al. 2015
SEDAR41-DW17	**UPDATED:** Estimates of Historic Recreational	Brennan 2015

	Landings of Red Snapper in the South Atlantic Using the FHWAR Census Method	
SEDAR41-DW18	**UPDATED**: South Carolina Red Snapper Catch and Biological Data Collection during Mini-Seasons, 2012-2014	Dukes & Hiltz 2015
SEDAR41-DW19	**UPDATED**: Standardized catch rates of red snapper (*Lutjanus campechanus*) in the southeast U.S. from commercial logbook data	SFB-NMFS 2015
SEDAR41-DW20	**UPDATED**: Standardized catch rates of gray triggerfish (*Balistes capriscus*) in the southeast U.S. from commercial logbook data	SFB-NMFS 2015
SEDAR41-DW21	North Carolina Division of Marine Fisheries Red Snapper Carcass Collections, 2012-2013	NCDMF 2014
SEDAR41-DW22	SEDAR 41 Red snapper stock assessment must utilize “direct” estimates of gear selectivity	Barile and Nelson 2014
SEDAR41-DW23	Atlantic Red Snapper (*Lutjanus campechanus*) Fishing History Timeline	Hudson 2014
SEDAR41-DW24	Atlantic Red Snapper (*Lutjanus campechanus*) Historical Fishing Pictures	Hudson 2014
SEDAR41-DW25	Historical For-Hire Fishing Vessels: South Atlantic Fishery Management Council, 1930’s to 1985	Hudson 2014
SEDAR41-DW26	SEDAR 41 Atlantic Red Snapper and Gray Triggerfish Data Workshop Historical Photographs of For-Hire Vessels 1930’s to 1985	Hudson 2014
SEDAR41-DW27	Red snapper mini season ad-hoc working group report	Red Snapper Mini Season Ad-hoc Group 2014
SEDAR41-DW28	Red Snapper *Lutjanus campechanus* in Gulf of Mexico versus southeast US Atlantic Ocean waters: gaps in knowledge and implications for management	Rindone et al. 2014
SEDAR41-DW29	Discards of red snapper (*Lutjanus campechanus*) for the headboat fishery in the US South Atlantic ****See SEDAR41-AW01 for updated HB discards WP**	FEB-NMFS 2014
SEDAR41-DW30	Discards of gray triggerfish (*Balistes capriscus*) for the headboat fishery in the US South Atlantic ****See SEDAR41-AW02 for updated HB discards WP**	FEB-NMFS 2014

SEDAR41-DW31	Red Snapper Preliminary Genetic Analysis Temporal Genetic Diversity Trends in the South Atlantic Bight	O'Donnell and Darden 2014
SEDAR41-DW32	SCDNR Charterboat Logbook Program Data, 1993-2013	Hiltz 2014
SEDAR41-DW33	**UPDATED:** Size Distribution, Release Condition, and Estimated Discard Mortality of Red Snapper Observed in For-Hire Recreational Fisheries in the South Atlantic	Sauls et al. 2015
SEDAR41-DW34	**UPDATED:** Size Distribution, Release Condition, and Estimated Discard Mortality of Gray Triggerfish Observed in For-Hire Recreational Fisheries in the South Atlantic	Sauls et al. 2015
SEDAR41-DW35	**UPDATED:** Marine Resources Monitoring, Assessment and Prediction Program: Report on Atlantic Red Snapper, *Lutjanus campechanus*, Life History for the SEDAR 41 Data Workshop	White et al. 2014 Wyanski et al. 2015
SEDAR41-DW36	**UPDATED:** Discards of Red Snapper Calculated for Commercial Vessels with Federal Fishing Permits in the US South Atlantic	McCarthy 2015
SEDAR41-DW37	**UPDATED:** Calculated Discards of Gray Triggerfish from US South Atlantic Commercial Fishing Vessels	McCarthy 2015
SEDAR41-DW38	Historic catch of red snapper by headboats through historic photograph analysis	Gray et al. 2014
SEDAR41-DW39	Index report cards	Index Working Group 2014
SEDAR41-DW40	Problems with Headboat Index of Abundance Confounds Use in SEDAR 41 Red Snapper	Nelson et al. 2014
SEDAR41-DW41	Commercial Fishing Targeting Changes	Fex 2014
SEDAR41-DW42	**NEW:** South Atlantic Red Snapper (*Lutjanus campechanus*) monitoring in Florida: Revised recreational private boat mode estimates for 2012 and 2013 mini-seasons, and new private boat mode estimates for the 2014 mini-season	Sauls 2015
SEDAR41-DW43	**NEW:** Hook Selectivity in gray triggerfish observed in the for-hire fishery off the Atlantic coast of Florida	Gray and Sauls 2015
SEDAR41-DW44	**NEW:** Standardized video counts of Southeast U.S. Atlantic gray triggerfish (*Balistes capriscus*)	Ballew et al. 2015

	from the Southeast Reef Fish Survey	
SEDAR41-DW45	**NEW:** Standardized video counts of Southeast U.S. Atlantic red snapper (*Lutjanus campechanus*) from the Southeast Reef Fish Survey	Ballew et al. 2015
SEDAR41-DW46	**NEW:** Headboat Data Evaluation	NMFS-SEFSC 2015
SEDAR41-DW47	**NEW:** Development of an ageing error matrix for U.S. gray triggerfish *(Balistes capriscus)*	SFB-NMFS 2015
SEDAR41-DW48	**NEW:** Development of an ageing error matrix for U.S. red snapper *(Lutjanus campechanus)*	SFB-NMFS 2015
SEDAR41-DW49	**NEW:** Estimates of reproductive activity in red snapper by size, season, and time of day with nonlinear models	Klibansky 2015
SEDAR41-DW50	**NEW:** Hook Selectivity in red snapper observed in the for-hire fishery off the Atlantic coast of Florida	Gray and Sauls 2015
SEDAR41-DW51	**NEW:** SERFS Chevron Trap Red Snapper Index of Abundance: An Investigation of the Utility of Historical (1990-2009) Chevron Trap Catch Data	Ballenger 2015
SEDAR41-DW52	**NEW:** Gray Triggerfish Fishery-Independent Index of Abundance in US South Atlantic Waters Based on a Chevron Trap Survey (1990-2014)	Ballenger and Smart 2015
SEDAR41-DW53	**NEW:** Red Snapper Fishery-Independent Index of Abundance in US South Atlantic Waters Based on a Chevron Trap Survey (2005-2014)	Ballenger and Smart 2015
SEDAR41-DW54	**NEW:** Red Snapper Fishery-Independent Index of Abundance in US South Atlantic Waters Based on a Chevron Trap Survey (2010-2014)	Ballenger and Smart 2015
Reference Documents		
SEDAR41-RD01	List of documents and working papers for SEDAR 32 (South Atlantic Blueline Tilefish and Gray Triggerfish) – all documents available on the SEDAR website.	SEDAR 32
SEDAR41-RD02	List of documents and working papers for SEDAR 9 (Gulf of Mexico Gray Triggerfish, Greater Amberjack, and Vermilion Snapper) – all documents available on the SEDAR website.	SEDAR 9
SEDAR41-RD03	2011 Gulf of Mexico Gray Triggerfish Update Assessment	SEDAR 2011
SEDAR41-RD04	List of documents and working papers for SEDAR 24 (South Atlantic red snapper) – all documents	SEDAR 24

	available on the SEDAR website.	
SEDAR41-RD05	List of documents and working papers for SEDAR 31 (Gulf of Mexico red snapper) – all documents available on the SEDAR website.	SEDAR 31
SEDAR41-RD06	List of documents and working papers for SEDAR 15 (South Atlantic red snapper and greater amberjack) – all documents available on the SEDAR website.	SEDAR 15
SEDAR41-RD07	2009 Gulf of Mexico red snapper update assessment	SEDAR 2009
SEDAR41-RD08	List of documents and working papers for SEDAR 7 (Gulf of Mexico red snapper) – all documents available on the SEDAR website.	SEDAR 7
SEDAR41-RD09	SEDAR 24 South Atlantic Red Snapper: management quantities and projections requested by the SSC and SERO	NMFS - Sustainable Fisheries Branch 2010
SEDAR41-RD10	Total removals of red snapper (*Lutjanus campechanus*) in 2012 from the US South Atlantic	NMFS - Sustainable Fisheries Branch 2013
SEDAR41-RD11	Amendment 17A to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region	SAFMC 2010
SEDAR41-RD12	Amendment 28 to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region	SAFMC 2013
SEDAR41-RD13	Total removals of red snapper (*Lutjanus campechanus*) in 2013 from the U.S. South Atlantic	NMFS - Sustainable Fisheries Branch 2014
SEDAR41-RD14	South Atlantic red snapper (*Lutjanus campechanus*) monitoring in Florida for the 2012 season	Sauls et al. 2013
SEDAR41-RD15	South Atlantic red snapper (*Lutjanus campechanus*) monitoring in Florida for the 2013 season	Sauls et al. 2014
SEDAR41-RD16	A directed study of the recreational red snapper fisheries in the Gulf of Mexico along the West Florida shelf	Sauls et al. 2014
SEDAR41-RD17	Using generalized linear models to estimate selectivity from short-term recoveries of tagged red drum *Sciaenops ocellatus*: Effects of gear,	Bacheler et al. 2009

	fate, and regulation period	
SEDAR41-RD18	Direct estimates of gear selectivity from multiple tagging experiments	Myers and Hoenig 1997
SEDAR41-RD19	Examining the utility of alternative video monitoring metrics for indexing reef fish abundance	Schobernd et al. 2014
SEDAR41-RD20	An evaluation and power analysis of fishery independent reef fish sampling in the Gulf of Mexico and U.S. South Atlantic	Conn 2011
SEDAR41-RD21	Consultant's Report: Summary of the MRFSS/MRIP Calibration Workshop	Boreman 2012
SEDAR41-RD22	2013 South Atlantic Red Snapper Annual Catch Limit and Season Length Projections	SERO 2013
SEDAR41-RD23	Southeast Reef Fish Survey Video Index Development Workshop	Bacheler and Carmichael 2014
SEDAR41-RD24	Observer Coverage of the 2010-2011 Gulf of Mexico Reef Fish Fishery	Scott-Denton and Williams
SEDAR41-RD25	Circle Hook Requirements in the Gulf of Mexico: Application in Recreational Fisheries and Effectiveness for Conservation of Reef Fishes	Sauls and Ayala 2012
SEDAR41-RD26	GADNR Marine Sportfish Carcass Recovery Project	Harrell 2013
SEDAR41-RD27	Catch Characterization and Discards within the Snapper Grouper Vertical Hook-and-Line Fishery of the South Atlantic United States	Gulf and South Atlantic Fisheries Foundation 2008
SEDAR41-RD28	A Continuation of Catch Characterization and Discards within the Snapper Grouper Vertical Hook-and-Line Fishery of the South Atlantic United States	Gulf and South Atlantic Fisheries Foundation 2010
SEDAR41-RD29	Continuation of Catch Characterization and Discards within the Snapper Grouper Vertical Hook-and-Line Fishery of the South Atlantic United States	Gulf and South Atlantic Fisheries Foundation 2013
SEDAR41-RD30	Amendment 1 and Environmental Assessment and Regulatory Impact Review to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region	SAFMC 1988
SEDAR41-RD31	Final Rule for Amendment 1 to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region	Federal Register 1989

SEDAR41-RD32	Population Structure and Genetic Diversity of Red Snapper (Lutjanus campechanus) in the U.S. South Atlantic and Connectivity with Red Snapper in the Gulf of Mexico	Gold and Portnoy 2013
SEDAR41-RD33	Oogenesis and fecundity type of Gulf of Mexico gray triggerfish reflects warm water environmental and parental care	Lang and Fitzhugh 2014
SEDAR41-RD34	Depth-related Distribution of Postjuvenile Red Snapper in Southeastern U.S. Atlantic Ocean Waters: Ontogenetic Patterns and Implications for Management	Mitchell et al. 2014
SEDAR41-RD35	Gray Triggerfish Age Workshop	Potts 2013
SEDAR41-RD36	Age, Growth, and Reproduction of Gray Triggerfish *Balistes capriscus* Off the Southeastern U.S. Atlantic Coast	Kelly 2014
SEDAR41-RD37	Assessment of Genetic Stock Structure of Gray Triggerfish (*Balistes capriscus*) in U.S. Waters of the Gulf of Mexico and South Atlantic Regions	Saillant and Antoni 2014
SEDAR41-RD38	Genetic Variation of Gray Triggerfish in U.S. Waters of the Gulf of Mexico and Western Atlantic Ocean as Inferred from Mitochondrial DNA Sequences	Antoni et al. 2011
SEDAR41-RD39	Characterization of the U.S. Gulf of Mexico and South Atlantic Penaeid and Rock Shrimp Fisheries Based on Observer Data	Scott-Denton et al. 2012
SEDAR41-RD40	Does hook type influence the catch rate, size, and injury of grouper in a North Carolina commercial fishery	Bacheler and Buckel 2004
SEDAR41-RD41	Fishes associated with North Carolina shelf-edge hardbottoms and initial assessment of a proposed marine protected area	Quattrini and Ross 2006
SEDAR41-RD42	Growth of grey triggerfish, *Balistes capriscus*, based on growth checks of the dorsal spine	Ofori-Danson 1989
SEDAR41-RD43	Age Validation and Growth of Gray Triggerfish, *Balistes capriscus*, In the Northern Gulf of Mexico	Fioramonti 2012
SEDAR41-RD44	A review of the biology and fishery for Gray Triggerfish, *Balistes capriscus*, in the Gulf of Mexico	Harper and McClellan 1997
SEDAR41-RD45	Stock structure of gray triggerfish, *Balistes capriscus*, on multiple spatial scales in the Gulf of	Ingram 2001

	Mexico	
SEDAR41-RD46	Evaluation of the Efficacy of the Current Minimum Size Regulation for Selected Reef Fish Based on Release Mortality and Fish Physiology	Burns and Brown-Peterson 2008
SEDAR41-RD47	Population Structure of Red Snapper from the Gulf of Mexico as Inferred from Analysis of Mitochondrial DNA	Gold et al. 1997
SEDAR41-RD48	Successful Discrimination Using Otolith Microchemistry Among Samples of Red Snapper *Lutjanus campechanus* from Artificial Reefs and Samples of *L.campechanus* Taken from Nearby Oil and Gas Platforms	Nowling et al. 2011
SEDAR41-RD49	Population Structure and Variation in Red Snapper (Lutjanus campechanus) from the Gulf of Mexico and Atlantic Coast of Florida as Determined from Mitochondrial DNA Control Region Sequence	Garber et al. 2003
SEDAR41-RD50	Population assessment of the red snapper from the southeastern United States	Manooch et al. 1998
SEDAR41-RD51	Otolith Microchemical Fingerprints of Age-0 Red Snapper, *Lutjanus campechanus*, from the Northern Gulf of Mexico	Patterson et al. 1998
SEDAR41-RD52	Implications of reef fish movement from unreported artificial reef sites in the northern Gulf of Mexico	Addis et al. 2013
SEDAR41-RD53	Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species	Then et al. 2014
SEDAR41-RD54	Length selectivity of commercial fish traps assessed from in situ comparisons with stereo-video: Is there evidence of sampling bias?	Langlois et al. 2015
SEDAR41-RD55	MRIP Calibration Workshop II – Final Report	Carmichael and Van Vorhees (eds.) 2015
SEDAR41-RD56	Total Removals of red snapper (*Lutjanus campechanus*) in 2014 from the U.S. South Atlantic	SEFSC 2015
SEDAR41-RD57	Assessing reproductive resilience: an example with South Atlantic red snapper *Lutjanus campechanus*	Lowerre-Barbiere et al. 2015
SEDAR41-RD58	Overview of sampling gears and standard protocols used by the Southeast Reef Fish Survey and its partners	Smart et al. 2014

SEDAR41-RD59	MRIP Transition Plan for the Fishing Effort Survey	Atlantic and Gulf Subgroup of the MRIP Transition Team 2015

2. Life History

2.1 Overview (Group Membership, Leader, Issues)

The life history working group (LHWG) was tasked with reviewing the new data and analysis available (mostly as a result of adding the 2014 data) since the 2014 DW, and combining data from the South East Fisheries Science Center Beaufort Laboratory (SEFSC, NOAA/NMFS-Beaufort), South Carolina Department of Natural Resources (SCDNR), North Carolina Division of Marine Fisheries (NCDMF), Florida Wildlife Research Institute (FWRI), and Georgia Department of Natural Resources (GA-DNR). This combined data set could then be used for analysis of life history parameters for Red Snapper. Note that the collaborative fishery independent snapper grouper monitoring conducted by the Marine Resources Monitoring, Assessment, and Prediction Program (MARMAP), the South East Area Monitoring and Assessment Program-South Atlantic (SEAMAP-SA) (both housed at SC-DNR's Marine Resources Research Institute), and the South East Fishery Independent Survey (SEFIS) (NMFS project housed at SEFSC, Beaufort, NC) are now collectively referred to as the South East Reef Fish Survey (SERFS). Data from all SERFS components were combined for analyses. The SEFSC data predominantly came from various fishery dependent sources. Discussions involved age, growth, reproduction, stock structure, natural mortality, movements, and discard mortality of Atlantic Red Snapper and comparison with Gulf of Mexico (GoM) Red Snapper.
The LHG was tasked with reviewing the data age from the different labs, develop models that describe growth and reproduction most appropriately, determine the biological unit stock based on literature, develop estimates of natural mortality and select a preferred estimate, describe the migration and movements of Red Snapper, and develop a model or point estimate of discard mortality. Additionally the LHWG provided a comparison between estimates/methods proposed for use in SEDAR 41 with estimates/methods used in SEDAR 31for Gulf of Mexico Red Snapper. Note that the development of estimates for discard mortality was discussed by an ad hoc working group formed prior to the 2014 DW.

Life History Work Group (LHWG) Membership for the Data Workshop in August 2014
Panel members
Marcel Reichert - SCDNR/SA-SSC (LH Working Group Leader)
Jennifer Potts - NMFS (Red Snapper Subgroup Leader)
Walter Bubley - SCDNR
Michael Cooper - NMFS
Tanya Darden - SCDNR
Shelly Falk - SCDNR
Cameron Guenther - FWRI
Susan Lowerre - Barbieri - FWRI
Adam Lytton - SCDNR
Todd Kellison - NMFS

Amanda Kelly - SCDNR
Kevin Kolmos - SCDNR*
George Sedberry - NOAA/SSC
Byron White - SCDNR
David Wyanski - SCDNR (Gray Triggerfish Subgroup Leader)
Chip Collier - SAFMC (Bycatch Mortality Subgroup Leader)
Kevin Craig – SEFSC Assessment staff
David Nelson – DW Panel member

* Denotes that Panel Member was not present at the Data Workshop, but participated in data collection, analyses, pre- and post-DW calls and webinars, and report preparation.

Observers
Jessica Lewis - NMFS
Kevin Spanik – SCDNR
Michelle Willis - SCDNR

Note that the Observers played a very active role in assisting with the data compilation and analysis, and their help was much appreciated by the panel members.

LHWG Membership for the Data Workshop in August 2015
Panel members
Marcel Reichert - SCDNR/SA-SSC (LH Working Group Leader)
David Wyanski - SCDNR
Walter Bubley - SCDNR
Jennifer Potts – NMFS (Red Snapper Subgroup Leader)
George Sedberry - NOAA/SSC
Nikolai Klibansky - SEFSC
Kevin Craig - SEFSC Assessment Staff
David Nelson - DW Panel member

Note that Panel members that participated in the 2014 DW, but were not present at the 2015 DW contributed to webinars and assisted with the compiling the data updates and analyses for the 2015 DW.

2.2 Review of Working Papers

SEDAR41-DW02
Georgia Red Snapper Catch & Effort Collection during Mini-Seasons, 2012-2014. Knowlton 2015.

Synopsis
The reviewed paper discusses the methods and results from opportunistic sampling of Red Snapper for biological data and trip survey information via telephone calls and other electronic means during the so-called "mini-seasons" in 2012, 2013 and 2014 in Georgia by GA DNR. Biological sampling included GA DNR staff working dockside as well as donated carcasses deposited into freezers at various locations throughout coastal Georgia . The scope of data collection expanded each year. Initially, dockside sampling targeted one headboat and five charter boats trips, and 24 carcasses were left primarily by private recreational fishers. In 2013, sampling was expanded to intercept commercial fishing trips, for a total of 2 headboat trips, 2 charter boat trips and 6 commercial trips. A total of 42 carcasses were donated, of which 14 came from private recreational fishers. By 2014, GA DNR staff intercepted 6 headboat trips, 10 charter boat trips and 3 commercial trips. An additional 124 carcasses, of which 89 were donated from private recreational fishers.

Critique
The biological data and information are pertinent to SEDAR 41. The details of biological sampling methodology is sufficient to determine which samples with age data are usable in growth modeling and age composition of the recreational and commercial fisheries.

SEDAR41-DW07
Age Truncation and Reproductive Resilience of Red Snapper (*Lutjanus campechanus*) Along the East Coast of Florida. Lowerre-Barbieri, et al. 2014.

Synopsis:
The document describes the assessment of the age structure of red snapper off the east coast of Florida and demographic trends in reproductive traits which might be impacted by age truncation. The population exhibited age truncation, as the maximum sampled age (21 y) was less than half the expected life span (50+ y) and 84% of the sampled fish were < age 7. Virtually all females sampled (99%, n=696) were mature and although two-year-olds were not fully-recruited, 94% (n= 119) were mature. The population spawning season was from April through September, but the probability of being spawning capable within this time differed significantly by size and age, with June being the only month with predicted probabilities > 90% for all fish. Similarly, spawning fraction peaked in June, although older fish had more temporally distributed spawning activity. Red snapper spawned throughout the day and at multiple sites, with relatively few spawning females collected per site (maximum=13 fish). Batch fecundity increased significantly with size and in more northern zones but was highly variable. Egg dry weight did not differ significantly with size or age. Red snapper reproductive physiology suggests they are resilient and highly adaptive. However, age truncation appears to have restricted the time period over which spawning occurs and potentially has caused earlier maturation. Thus, recovery rates

are expected to be affected by environmental conditions in June and if the observed early maturation is due to fisheries-induced evolution.

Critique:
The document contains relevant information and some information, in particular combined with other studies, was included in the LHWG analyses. Note that the report does not identify the length, but the used length was MaxTL (Pers. Comm. by authors).The methodology used to conduct this study was well planned and executed. The analyses were very informative to the reproductive biology of the South Atlantic stock. Two drawbacks to the study include the one year duration of sampling and the range of samples was limited, though did target the center of abundance of the population. For these reasons, some caution should be taken when making inferences to the stock as a whole and to possible changes over time. This study does point out a much needed data inputs to improve the stock assessment and that is to collect routine, annual reproductive tissue samples from red snapper landed in the fishery and in fishery-independent surveys.

SEDAR41-DW09
Size and age composition of Red Snapper, *Lutjanus campechanus*, collected in association with fishery-independent and fishery-dependent projects off of Florida's Atlantic coast during 2012 and 2013. Switzer, et al. 2014.

Synopsis:
The South East Reef Fish Survey, which utilizes chevron traps, has been able to provide some life-history data for Red Snapper during the closure (since 2010). The mini seasons in 2012-13 provided the only fishery-dependent data available since the 2010 Red Snapper closure. Florida's Fish and Wildlife Conservation Commission (FFWCC) collected life history samples from Red Snapper during fishery-independent and fishery-dependent research and monitoring activities along the Atlantic coast of Florida. (A) Most fishery-independent samples were collected in 2012 in association with a one-year pilot study to explore the utility of various fishery-independent, hooked-gear methods. Additional samples were collected in 2012 and 2013 in association with a three-year tagging study to examine movement of Red Snapper. During both studies Red Snapper were culled for life history analyses using random culls with the additional selection of some larger individuals to better characterize the age distribution of larger Red Snapper. (B) Fishery-dependent samples were collected during the limited recreational and commercial harvest seasons in 2012 and 2013. Collections were derived from recreational private boats, charterboats, headboats, and the commercial TIP. During the 2012 and 2013 Red Snapper mini-seasons, parties returning from offshore recreational trips were sampled (random intercept locations). In addition, Red Snapper were targeted for biological sampling at private boat landing sites (not random). Private recreational anglers also donated Red Snapper carcasses at select locations on the east coast of Florida during the 2012 and 2013 season (sample bias unknown),

and Red Snapper were sampled at charter and headboat landing sites (not random). In 2013, FFWCC observers on random charter vessels measured all Red Snapper caught and fish houses were sampled during the commercial season.

Ages of fishery-independent (sampling and tagging) individuals ranged from 1 to 21 years of age, although 90% of individuals were six years old or younger. The age distribution was bimodal, with exceptionally high numbers of age-3 and age-5 Red Snapper, corresponding to the 2009 and 2007 year classes, respectively. Maximum size at age was just over 800 mm TL at approximately 8 – 10 years of age. No notable differences in age distribution or size at age were evident between males and females. An examination of age-specific depths of capture did not identify a significant increase in depth with age. Overall, the results from the fishery-dependent sources mirrored those from the fishery-independent sources.

Critique:
SEDAR41-DW09 was reviewed and deemed pertinent for the SEDAR process. Although each of these data sets contains their own set of biases (as identified by the authors), these are the best available data sources. When sampled in a standardized manner, as has been done over this short period, they can be useful and indicative of changes in the Red Snapper population under management. We recommend the data be incorporated into the SEDAR process as appropriate and the biases considered in their interpretation – the fishery-dependent data are not representative of the population, but the fishery-dependent data are useful for characterizing the size and age of the harvested population.

SEDAR41-DW10
Overview of Florida's Cooperative East Coast Red Snapper Tagging Program, 2011-2013. FWRI, 2014.

Synopsis:
In an effort to better understand red snapper population dynamics off the east coast of Florida, the Florida Fish and Wildlife Conservation Commission (FWC) with federal and industry funding worked cooperatively with various sectors of the recreational, for-hire, and commercial fisheries to initiate a Cooperative East Coast Red Snapper Tagging program in 2011.The program was designed to aid fishery managers in better understanding patterns of distribution, seasonal and spatial dynamics of movement patterns, ontogenetic changes in habitat selectivity, and site fidelity of Red Snapper based on recapture rates throughout the study area. This angler-based tagging program was overseen by FWC personnel who were responsible for coordinating regional training workshops for interested participants, distribution of tagging kits, tagging database management, responding to tag returns, and all aspects of public outreach associated with this project. All Red Snapper released by participating fishermen were tagged externally with a 100-mm Hallprint dart tag. Additional information recorded by the fisher to aid in the

understanding of Red Snapper population dynamics included the coordinates of capture, water depth, and associated catch-specific information (e.g., total length, release condition). A total of 3,441 Red Snapper were tagged by all participating sectors of the Cooperative East Coast Red Snapper Tagging program from 2011 through 2013. There were a total of 211 Red Snapper recaptured from 2011 through 2013, for an overall tag return rate of 6.1%. The time-at-large (days between initial tagging and recapture) of tagged fish ranged from 0 to 887 days. The distance traveled of tagged fish from the initial tag location ranged from 0 to 237 km. Eight fish were recaptured twice and one fish was recaptured three times. The majority of recaptured fish with confirmed location information were caught <1 km from where they were initially tagged, which is indicative of high site fidelity. Analysis of distance traveled in regards to direction of movement (bearing) from initial tag position for fish that moved 3-16 km (n=36) showed no clear ontogenetic movement patterns. Fish were seen to travel in all directions from their initial tag locations. These relatively small movement patterns are most likely a result of fish moving short distances within similar depth strata to nearby available habitat. Generally speaking, water depths and habitat types within the study area, over relatively short distances (3-16 km), change very little. Analysis of fish that moved >16 km from their initial tagging location (n=14), showed a general north-south movement pattern.

Critique:
This document is very relevant and information was considered by the LHWG. The relevance will increase with increasing returns and possible continuation of tagging efforts. Data from this study should be considered in future Red Snapper assessments.

SEDAR41-DW18
South Carolina Red Snapper Catch and Biological Data Collection during Mini-Seasons, 2012-2013. Dukes & Hiltz, 2014.

Synopsis:
This document reviews the collection of biological samples for Red Snapper by the South Carolina DNR during the 2012 and 2013 mini seasons. The SCDNR collected samples from three sources; private recreational vessels, for-hire vessels, and from an online survey. The majority of samples during both years were collected from the private recreational sector (N=43 and 39, respectively), followed by the for-hire sector (N=10 and 14, respectively), and lastly, from the online survey (N=6 and 1 respectively). Private sector samples were obtained through a combination of dockside sampling and carcass donations from participating anglers. For-hire samples were collected through cooperation between SCDNR staff and participating charter/headboats that fish primarily offshore waters. Online survey samples were completed by participating anglers that targeted Red Snapper and included trips where Red Snapper where not caught but were targeted.

Critique:
The document is brief and does not include any information on spatial coverage of the samples from any of the sectors or if there was overlap with other surveys including the SC finfish survey or MRIP sampling. Other concerns include a lack of description on how biological measurements were taken, or by whom they were taken. The samples sizes from the private and for-hire sectors are small. In the absence of more information, is not possible to assess whether or not the length and weight samples were reliably measured, and whether or not the samples are representative of the population. The samples from the online survey are very small and there is concern over the reliability of any reported measurements.

The LHWG reviewers recommend that the biological samples could possibly be included for biological characterization of the population, but due to concerns regarding small sample size, possible overlap between sampling, and non-random nature of the collections, it is not recommended these data are used for catch characterization during the mini-seasons.

SEDAR41-DW21
North Carolina Division of Marine Fisheries Red Snapper Carcass Collections, 2012-2013. NCDMF, 2014.

Synopsis
North Carolina Department of Marine Fisheries attempted to obtain biological sampling of recreational fisherman during the Red Snapper mini-season to supplement existing fishery-dependent sampling which focused on sampling from the commercial sector in 2012 and 2013. Two methods were used to accomplish this: 1. Carcass collection using freezers placed at strategic locations along the coast. 2. Online survey for those fishermen unable or unwilling to donate, but still report their catch. Less than 85 samples were obtained both years and many of the headboat samples were obtained after port samplers had already extracted one of the otoliths and obtained measurements, further decreasing the sample size. The online survey had low levels and none of the submitted data were included in harvest reports.

Critique
There was some concern about the overlap with port samplers due to possibility of duplication of biological samples and measurements. The privately donated fish from the freezers cannot be considered randomly sampled, are likely subject to selectivity biases, and should not be used to characterize the catch. As only otoliths were removed no other biological information such as for reproduction was available.

The data could possibly be used to characterize the biological samples as they may be under-represented size classes at the tails of the distribution, but due to non-random sampling, small sample size, and duplication with other sampling methods, the data should not be considered for catch characterization during the Red Snapper mini-season.

SEDAR41-DW28

Red Snapper *Lutjanus campechanus* in GoM versus southeast US Atlantic Ocean waters: gaps in knowledge and implications for management. Rindone et al., 2014.

Synopsis

This document reviews the relative availability of information supporting Red Snapper assessment and management between the Gulf of Mexico (GoM) and southeastern US Atlantic Ocean (SA). The authors conducted a comprehensive review of available literature and historical records for both mature and juvenile Red Snapper. Of the 110 peer reviewed publications found, 94% were GoM centric. Of the twenty eight available manuscripts focusing on juvenile (<150 mm), none were identified from the SA. Queries of all fisheries independent survey databases from North Carolina through Florida identified only 132 juvenile Red Snapper records out of >75,000 gear deployments and institutional collections. For reference, in a single GoM trawl database, more than 50,000 records of juvenile Red Snapper were found. The results of this review serve to highlight the paucity and need for additional data on Red Snapper (juvenile and mature) in the US south Atlantic.

Critique

While this document does not directly provide any biological information to the life history group, it does serve to highlight and document the severe paucity of data for Red Snapper in the US south Atlantic, especially for juveniles, and provides suggestions for future research directives. The LHWG recommends this working paper for acceptance as it serves as a point of reference for the lack of available data, especially in comparison to Red Snapper in the GoM.

SEDAR41-DW31

Red Snapper Preliminary Genetic Analysis Temporal Genetic Diversity Trends in the South Atlantic Bight. O'Donnell and Darden, 2014.

Synopsis:

There has been only slight fluctuation in genetic diversity of Red Snapper from 1975 to 2012, thus indicating a lack of a population bottleneck or severe reduction in abundance. However, estimates of effective population size from the same samples suggest that Red Snapper experienced a genetic bottleneck that was not detected in genetic diversity estimates due to a lack of samples prior to 1975 (i.e., before the population experienced overfishing). Contemporary estimates of effective population size and inbreeding coefficients provide genetic evidence of population recovery in the Atlantic. Inbreeding coefficient estimates were substantially higher in the 1970s and 1980s, but have been decreasing (i.e., improving) since 2005, indicating a larger breeding population in recent years.

Critique:
Sample sizes are somewhat small for some years, and do not equally represent all states (however they do reflect state-by-state landings and abundance indices). All samples analyzed were collected after the largest reduction in population abundance (hence relatively stable values within the sample period). There was good agreement in effective population size index in the genetic data and census size (SEDAR), providing support for validity of detected trends. This paper should be used in the assessment.

SEDAR41-DW33
Size Distribution, Release Condition, and Estimated Discard Mortality of Red Snapper Observed in For-Hire Recreational Fisheries in the South Atlantic. Sauls et al., 2014.

Synopsis
The working paper provides a description of the size distribution, release condition, and estimated discard mortality of Red Snapper in for-hire recreational fishery. The paper includes the time series and the geographic coverage of the data collected and methods used to develop the estimates from the at-sea observer program for the south Atlantic.

The At-sea observer program started in 2004 for headboats in the South Atlantic and 2010 for charter boats in Florida. Florida has slightly different methodology than other states and collects more information on the observer trips than other states collect. This allowed for estimates of hook type usage, description of depth for released fish, and an overall estimate of discard mortality for the recreational for-hire fishery in the Red Snapper fishery off Florida.

Critique
The working paper is acceptable for use in the stock assessment. The paper provides needed information on the methods used to estimate the number and lengths of discarded fish and the potential fate of the fish. Additionally this working paper provided the estimate of discard mortality that was recommended for use in the stock assessment for the recreational fishery.

SEDAR41-DW35
Marine Resources Monitoring, Assessment and Prediction Program: Report on Atlantic Red Snapper, *Lutjanus campechanus*, Life History for the SEDAR 41 Data Workshop. White et al., 2014.

Synopsis
This working paper summarizes the data and analyses of Red Snapper as collected by fishery independent monitoring effort in waters off the southeastern US to prepare for the SEDAR 41 Data Workshop. It describes aspects of Red Snapper life history, including depth of capture in fishery-independent and fishery-dependent surveys, length-length and length-weight conversions, length at age, age- and length-at-maturity, sex ratio, spawning seasonality, and spawning frequency.

Critique
SEDAR 41 Reference Document 35 was reviewed and deemed pertinent for the SEDAR process. Data and analyses from this DW were discussed and used during the DW, and are reported in the LHWG DW report. Comments and updated analyses were incorporated I an updated WD.

SEDAR41-DW48
Development of an ageing error matrix for U.S. red snapper (*Lutjanus campechanus*)
Sustainable Fisheries Branch, National Marine Fisheries Service, Eric Fitzpatrick.

Synopsis
The WD describes the age error matrix for use in the SEDAR41 assessment. This analysis was done after the 2014 DW and no update was needed for the 2015 DW.

Critique
The LHWG reviewed the data and analysis and agreed that the presented information should be used to characterize the uncertainty in age estimates based on the variability in age readings between readers and labs. Note that the additional information on the age determination process is provided in section 2.6 of this LHWG report.

SEDAR41-DW49
Estimates of reproductive activity in red snapper by size, season, and time of day with nonlinear models. N. Klibansky

Synopsis
This paper describes a modeling approach to address the spawning season and spawning fraction that may result in more realistic estimates of both.

Critique
The novel modeling approach presented in this WD was considered to be more appropriate than that used in previous assessments. This approach does not assume that all fish start and stop spawning at the same date, and does not assume that fish of all sizes have an equally long spawning season. The presented analysis provides estimates of the proportion spawners by

length (age) during the spawning season. As such, the estimates derived using the approach presented in this paper represent a more realistic evaluation of the reproductive output.

2.3 Stock Definition and Description

Red Snapper are known to utilize both low- and high-relief hard bottom habitats in depths typically ranging from 50-100 m of water. Geographically, Red Snapper distribution ranges from the Yucatan Peninsula throughout the GoM and along the U.S. Atlantic coast north to North Carolina, with occasional occurrences north to Massachusetts (Manooch et al., 1998). Additionally, a disparate portion of the distribution occurs along the north coast of South American (Figure 2.1).

Genetic stock structure of Red Snapper between the GoM and western Atlantic was initially evaluated by Garber et al. (2004) using the mitochondrial control region identified homogeneity in haplotype frequencies among all locations included (four in GoM and one in Atlantic), suggesting Red Snapper in U.S. waters represented a single, panmictic population.

Additional studies limited to GoM collections using both mitochondrial and nuclear markers failed to identify any significant genetic structure (Gold et al., 1997; Pruett et al., 2005; Sallient and Gold, 2006); however, Sallient et al. (2010) evaluating microsatellite genotypes of young of year fish collected from the GoM detected significant spatial autocorrelations indicating small-scale genetic heterogeneity. The authors suggest Red Snapper in the GoM may represent metapopulation population dynamics. Numerous otolith microchemistry studies also provide evidence of regional patterns in the GoM (Patterson et al., 1998; 2001; Nowling et al., 2011; Sluis, 2011).

The most recent genetic evaluation (Gold and Portnoy, 2013 MARFIN Final Report) used both microsatellite and mtND4 data to evaluate gene flow patterns of Red Snapper within and between the U.S. Atlantic and GoM waters. All conventional data analyses failed to identify any level of genetic structuring, but a very weak pattern of isolation by distance was detected only in the mitochondrial data. They conducted an alternative Bayesian analysis which detected significant genetic heterogeneity within the Atlantic (5 locations), within the GoM (3 locations), and between the Atlantic and GoM. However, the new analyses (or at least it is not reported) does not identify locations of gene flow breaks and is in contradiction to all prior results.

During the SEDAR 24 Data Workshop, the Life History Working Group investigated the potential for spatial differences in maturity, growth, and length at age of U.S. Atlantic Red Snapper. They determined that fish in the Florida-Georgia (South) region may mature younger and at smaller sizes than fish in the Carolinas (North) region (See section 2.8 of the SEDAR 24 Data Workshop Report). They detected no difference in mean length-at-age or growth rates between the two regions (SEDAR 24 Data Workshop Report, Figure 2.7.1).

Tagging studies do not provide any additional evidence that suggests movement between GoM and Atlantic stocks, other than one fish tagged off Pensacola, FL was recaptured off St. Augustine, FL (Burns et al. 2008). Fishermen have suggested seasonal migration of fish occurs among regions of the South Atlantic.

During the 2015 DW, no new information was available, therefore, there are no indications from conventional methods that U.S. Red Snapper represent multiple stocks, either between the western Atlantic and GoM or regionally within the western Atlantic. Therefore, the continuation of single stock management of U.S. Atlantic Red Snapper appears to be biologically appropriate based on population genetics and life history trait patterns. However, for the purposes of this assessment, Red Snapper stock definition is from the Florida Keys (Atlantic side) to as for north as landings are recorded.

Recommendation

The Red Snapper stock be defined as the SAFMC jurisdiction of the Florida Keys north to as far as landings are recorded.

2.4 Natural Mortality

2.4.1 Juvenile (YOY)

Juvenile Red Snapper are rarely encountered in a nearshore (<30 ft) fishery-independent trawling program (SEAMAP-SA Coastal Trawl Survey) in the Atlantic. Estimates of juvenile Red Snapper mortality have been developed in the Gulf of Mexico (SEDAR-31), however, little information is available for the US South Atlantic. As with previous Red Snapper assessments from the South Atlantic region off the coast of the United States (SEDAR-32), age 0 fish will not be included as inputs into the stock assessment model and so all calculations regarding natural mortality will involve fish aged 1+.

2.4.2 Adult

Natural mortality (M) of Red Snapper was estimated using several methods. The LHWG also discussed the likelihood that natural mortality rate varies by age and an age-varying approach was advocated (e.g., SEDAR 32). Two methods for estimating age-dependent natural mortality using fitted von Bertalanffy growth models were discussed - Lorenzen (1996), a weight based estimator using length-weight conversions to provide values, and Charnov et al. (2013), using lengths directly from the growth model. Charnov et al. (2013) provides an equation which is an improvement to the empirical equation in Gislason et al. (2010), as well as meta-analyses of other estimators of M, including Lorenzen (1996). They also take into account various aspects of life history traits and habitat of a wide variety of exploited marine and brackish water fishes, leading the LHWG to recommend the Charnov et al. (2013) equation, which utilizes von Bertalanffy growth parameters L_∞ and k, as the best initial estimate of M-at-age:

$M = ((\text{Length-at-age}/L_\infty)\text{\^{}}(-1.5))*k$

To apply the Charnov et al. (2013) method, the von Bertalanffy growth model was fit as the population growth model was, but with t_0 fixed at 0. The von Bertalanffy parameters used were:

$L_\infty = 883.41$ mm
k = 0.279
fixed $t_0 = 0$

The Charnov model provided an age-specific estimate of natural mortality that ranged from 1.395 – 0.279 for fish aged 1 to 51, respectively (Table 2.1). The survivorship to the oldest age using the Charnov et al. (2013) age varying method was unrealistically low ($1.082 * 10^{-6}$), considering the amount of fish caught at older ages. Because the age data, limited as they are at the upper tail, do include fish that are in their 30s, 40s, and 50s, it is more biologically reasonable to assume survivorship to these older ages is greater than zero. Considering the longevity of the species, as well as consistency with past SEDARs, the Charnov M curve was scaled to a point estimate based on the survivorship of the fully recruited ages (4+). Point estimates were generated using empirical models based on maximum observed age (t_{max} = 51 years). The LHWG determined the Then et al. (2015) method ($M = 4.899*t_{max}^{-0.916}$) was the most appropriate means for estimating a point estimate for natural mortality in Red Snapper. It should be noted that the Hoenig (1983) method had been used previously, but Hoenig (a co-author on Then et al. 2015) conceded that Then et al. 2015 is a superior means of obtaining a point estimate of natural mortality. The point estimate is applicable only to those ages that were fully recruited to the fishery. Because the point estimate does not vary with age, it is assumed that the estimate is the average mortality per year from the time at full recruitment. Age at full recruitment was 4+ years, as determined by the mode of the age in the fishery-dependent catch (3 years) and adding 1. The annual instantaneous mortality rate calculated for Red Snapper using the empirical estimator from Then et al. (2015) was 0.134. This resulted in a scaled estimate of natural mortality at age ranging from 0.625 to 0.125 for ages 1-51, respectively (Table 2.1), with the cumulative survival to maximum age at 0.2%.

To incorporate variance around the age-varying natural mortality estimate, the standard deviation (2.89 yr; n = 3) was calculated around the inter-reader variability for the fish with the maximum observed age. Confidence intervals (95%) around the maximum age were calculated from the variance. This, in turn, was used with the Then et al. (2015) method to create natural mortality point estimates based on the upper maximum age (Age = 54.3 yr; M = 0.126) and the lower maximum age (Age = 47.7 yr; M = 0.142). The age-varying natural mortality curve was then scaled to the point estimates calculated from these upper and lower maximum ages, resulting in natural mortality estimates at age for the low end (range = 0.603 - 0.121; cumulative survival = 0.3%) and for the high end (0.678 - 0.136; cumulative survival = 0.1%) for ages 1-51 (Table 2.1).

Recommendations

1. The LHWG recommends using the Charnov age-varying natural mortality curve scaled to the Then et al (2015) point estimate for those ages fully recruited to the fishery (4+).
2. The LHWG recommends that variance about the M age-varying curve be investigated using the inter-reader variation of the oldest aged fish, with 95% confidence intervals being produced to provide an upper and lower maximum age, which in turn is used in the Then et al. (2015) point estimate. The age-varying natural mortality curve was then scaled to these natural mortality point estimates calculated from the upper and lower maximum age estimates.

2.5 Discard Mortality

Note: Discard mortality estimates were developed during the 2014 DW. No new information or analyses were available, so discard mortality estimates were not revisited at the 2015 DW.

Discard Mortality Participants	
Zack Bowen	Jimmy Hull
Mark Brown	Robert Johnson
Chip Collier	David Nelson
Chris Conklin	Paul Nelson
Jack Cox	Beverly Sauls
Sonny Davis	Bill Shearin
Kenny Fex	Kate Siegfried
Rusty Hudson	Erik Williams

Discard mortality is an important estimation included in stock assessments and should be considered in evaluating the effectiveness of regulatory actions to reduce harvest. Several studies have been conducted to estimate a discard mortality rate for Red Snapper with values varying from 1 to 93% (see SEDAR 24 and 31 for reviews). Most of these studies have focused on Red Snapper in the GoM where the commercial Red Snapper fishery operates much differently from the snapper grouper fishery off the US South Atlantic both in depths fished and gear used to target Red Snapper (gear differences were displayed at the data workshop). Additionally, other factors that influence discard mortality likely vary between the South Atlantic and GoM including: depths fished by fishing sectors and fishing areas, fishing behavior between sectors and areas, bottom and surface temperature, and usage of circle hooks and dehooking devices.

Therefore, the stock assessments in the South Atlantic have used different discard mortality rates than what has been used in the GoM (Table 2.2).

The estimates of discard mortality used in SEDAR 15 were 90% for the commercial fishery and 40% for the recreational fishery. The SEDAR 15 discard mortality estimates for the recreational (40%) and commercial (90%) fleets were based on the discard mortality estimate for Red Snapper from the GoM for fish caught in waters deeper than 20 meters (SEDAR 7). The values used in SEDAR 24 were 39 to 41% for the recreational sector which was similar to the SEDAR 15 estimate and 48% for the commercial sector. These estimates were based on a depth related discard mortality model developed by Burns et al. (2002). A formal working paper (SEDAR 24 DW-12) was developed for SEDAR 24 and includes a more in depth discussion of discard mortality.

Consideration of Depth Effects

Several studies have focused on depth as an important factor in determining discard mortality due to the visible impact of barotrauma. Studies conducted in depth of less than 35 meters (115 feet) estimated discard mortality rates of 20% or less (Parker 1985, Render and Wilson 1994, Patterson et al. 2002, Burns et al. 2006). Studies conducted in greater than 35 meters generally estimated higher discard mortality rates ranging from 17% to 93% (Gitschlag and Renaud 1994, Burns et al. 2004, Nieland et al. 2007, Burns 2009, Diamond and Campbell 2009, Stephen and Harris 2009). This increase in discard mortality rate with increasing depth is an expected result and has been described for Red Snapper and other snapper grouper species (Patterson et al. 2001, Burns et al. 2002, Patterson et al. 2002, Rudershausen et al. 2007, Stephen and Harris 2009).

To account for increasing discard mortality rate with increasing depth, three models were reviewed in SEDAR 24. Two of the models (Burns et al. 2002, Diamond et al. unpublished data) used a logistic regression function to model the mortality rate (Figure 2.2) and one used a linear trend (Nieland et al. 2007). All three of the models had overlap in the estimation of discard mortality particularly between 50 and 90 meters (see SEDAR 24 DW 12 reference for plots). The linear model had a higher discard mortality rate for Red Snapper caught in depths less than 40 meters than the other two studies (Nieland et al. 2007), likely due to commercial fishing practices observed in the GoM. These fishermen were fishing bandit fishing reels with terminal gear consisting of 20 hooks spread over 4.5 to 6 meters (S. Baker, Jr, personal communication). Typical recreational fishermen in the South Atlantic and GoM as well as commercial fishermen in the South Atlantic fish for snapper/grouper species with terminal gear having less than 5 hooks (Gulf and South Atlantic Fisheries Foundation 2008). The other two models describing discard mortality also included delayed discard mortality in their discard mortality estimate. Koenig (Burns et al. 2002) used a cage study to determine the effects of depth on Red Snapper. Additionally, Red Snapper and gag grouper data were combined in the model since there was no significant difference in the percent mortality at depth. The Diamond et al. (unpublished) combined data from several different studies including the Burns et al. (2002) and Nieland et al. (2007). The discard mortality curves from these two studies were similar with less than 20% discard mortality for fish caught in less than 20 meters increasing to 100% mortality for fish caught in greater than 90 meters.

Consideration of Hook Effects

Hooking related injuries are also important when trying to determine discard mortality (Rummer 2007, Burns et al. 2008). Necropsy results from headboat caught fish showed Red Snapper suffered greatest from acute hook trauma (49.1%), almost equaling all other sources of Red Snapper mortality combined in the headboat fishery in waters less than 42 meters (50.9%, Burns et al. 2008). These hook related injuries caused both immediate and delayed mortality in Red Snapper. The delayed mortality was a result of the hook nicking an internal organ, causing the fish to slowly bleed internally eventually leading to death after a few days (Burns et al. 2004). Circle hooks are generally thought to reduce the discard mortality rate for Red Snapper (SEDAR 7; Rummer 2007); however, Burns et al. (2004) did not observe decreased discard mortality rate when comparing recapture rates of Red Snapper caught on circle and j-hooks. Recent work by Sauls et al. indicated that circle hooks reduced discard mortality for Red Snapper and SEDAR 31 used a discount for regulations that were established in 2008 for the GoM (circle hooks, dehooking devices, and venting). In SEDAR 31, it was stated that the requirement to vent was not quantifiable, but it was included in their model (SEDAR 31).

Consideration of Additional Factors

Additional factors that influence discard mortality rate, such as size of the fish, temperature, and predation, have been considered for Red Snapper but currently data are too limited to include these parameters in a quantifiable estimation of discard mortality. Temperature has been noted in some studies as a significant factor determining discard mortality rate for Red Snapper (Render and Wilson 1994, Rummer 2007, Diamond and Campbell 2009). In these studies, the discard mortality rate increased with increasing temperature. More importantly, both Rummer (2007) and Diamond and Campbell (2009) found the temperature differential between surface and bottom water was more important in determining the discard mortality rate than water temperature alone. A greater differential between the surface and bottom temperature resulted in a higher discard mortality rate.

Red Snapper are preyed upon by several different species including barracuda, sharks, and amberjack (Parker 1985). Dolphins have been listed as a predator in the GoM but this behavior has not been observed in the South Atlantic. In the South Atlantic, the predators of Red Snapper are generally present during months when water temperatures are warmer (personal communication with commercial fishermen).

Descending Devices

Descending devices were mentioned as a potential tool to reduce discard mortality. One fisherman brought in his homemade descending device which he started using in 2014. Currently, the change in discard mortality rate due to descending devices is unknown. There is some research being conducted to determine if descending devices reduce discard mortality. The fishermen pointed out that very few people are using descending devices. Descending devices were not considered for the discard mortality rate.

SEDAR 41 DW Comments and Recommendations

The ad hoc Discard Mortality group's first task was to review the decisions of SEDAR 24. The SEDAR 24 DW recommended using an estimate that included delayed mortality since this would be a better estimate of discard mortality than just surface release information. Immediate mortality is easier to quantify and can be observed at the surface but this value is unlikely to be an accurate estimate of discard mortality for Red Snapper. Delayed mortality is able to incorporate mortality due to hook related injuries, predation, and barotraumas that are not observed at the surface or on board boats. The group felt that delayed mortality rate was more appropriate to describe the fate of discarded Red Snapper.

The SEDAR 24 DW further recommended using a discard mortality model since depth is an important factor in determining discard mortality rate. Some of the participants mentioned that few fish die in the shallow water typically fished for Red Snapper. The plenary decided on using the depth model presented in Burns et al. (2002) to estimate discard mortality (Table 2.3). This model included information on Red Snapper in the South Atlantic and GoM and Gag in the South Atlantic. The model was based on several pieces of information including tag/return data, barotrauma and surface observations. To use the model, depth of discards was developed for each sector. The commercial discard mortality depth estimates came from observer data from the Gulf and South Atlantic Observer study (2008) since this study had depth information combined with catch information. The discard mortality rate estimate of the commercial fishery was 48%. The headboat at sea observer program and logbook data was used to estimate the headboat and charter boat depth distribution. The discard mortality rate estimate for these two sectors was 41%. Private boat depth data was very limited but used depth information from South Carolina DNR tagging study and depths recorded from biological samples from Florida and Georgia fishermen. The private boat discard mortality rate estimate was 39%.

The ad hoc Discard Mortality Working group for this SEDAR agreed with many of the decisions from SEDAR 24. The discard mortality value should include information on delayed mortality and information on depth should be incorporated into the estimate.

Recreational
New methodology using a tag/return model described in Sauls et al. 2014 (SEDAR 41 DW33) was used to condition a model that estimated discard mortality based on release condition and would include information on delayed mortality. The conditions included not impaired/not vented, not impaired/ vented, and impaired for 1,892 Red Snapper. The fish included in this study were post regulation (circle hook requirement and dehooking tool in both areas and venting in the GoM only). The tag/return discard mortality model includes delayed mortality based on the recapture information and a proxy for depth based on condition of the fish. This method was the preferred method to estimate the discard mortality for recreational Red Snapper.

The tag/return condition model estimate was 26.7% for the charter boat fishery and 28.5% for the headboat fishery (Table 2.3). Since the depth profiles were similar among the recreational fisheries (Figure 2.3), a single estimate of discard mortality was recommended. The estimate of discard mortality from the headboat fishery was the preferred estimate (28.5%) because of the higher sample number compared to the charter boat sample number (1,445 headboat, 447 charter boat).

Since this estimate was made based on post-regulation data for circle hooks and dehooking tools in the South Atlantic, an estimate of pre-regulation discard mortality was developed. An estimate of the proportion of discard mortality due to regulation was projected using a regression model from data in SEDAR 31 (data from SEDAR 31 Stock Assessment Report). In general, when discard mortality was low, the proportion of discard mortality due to hooking and releasing was greater than when discard mortality was high, where most of the discard mortality would be associated with barotrauma. This model assumes compliance with the regulations. However, based on observer work and communication with fishermen, compliance with circle hook regulations varied by area (state) and sector. The only compliance data recreational available at the workshop was for the recreational fisheries in Florida. It was estimated that approximately 50% of the trips targeting snapper/grouper were using circle hooks since 2011 (Sauls et al. 2014, SEDAR 41 DW 33). The reduction in discard mortality due to regulations was reduced by 50% based on compliance. The usage of circle hooks prior to 2011 is unknown, but Burns et al. (2002) reported that circle hook usage while snapper/ grouper fishing was minimal in the South Atlantic prior to their study. Using the equation in Figure 2.4 and reducing by 50% for compliance, the pre-regulation discard mortality was 36%.

In an effort to corroborate the method used to calculate discard mortality for the recreational sector, the depth information for the recreational sector was placed into the Burns et al. (2002) model to compare with the results from the tag/return condition model. The Burns et al (2002) model was considered the pre-regulation estimate and the depth related estimate was decreased for a post-regulation estimate due to the limited usage of circle hooks reported in the Burns et al. study. Depth information was obtained from the Florida fishery because this is the only state with depth specific information on discards and is the heart of the Red Snapper fishery. The depth model estimated that post-regulation discard mortality ranged between 23% and 28%. These estimates of post-regulation discard mortality were very similar to the tag/return model estimates and are in the range of sensitivities recommended for use in the assessment.

Commercial

The commercial fishery did not have information on condition of discarded fish; and, therefore the tag/return model based on fish condition could not be used. Instead the depth model (Burns et al. 2002) used in SEDAR 24 was the preferred model. Observer information was used to estimate the depth of discards. Similar to SEDAR 24, the commercial discard mortality was estimate to be 48%. This estimate was developed primarily with information on fish caught with j-hooks which have a significantly higher proportion of potentially lethal hooking interactions (Sauls et al. 2014). To account for the usage of circle hooks, an estimate of post-regulation discard mortality was developed. Observers reported commercial fishermen using circle hooks on approximately 50% of the drops from 2007 to 2011. No other reports were available since 2011 but fishermen at the data workshop indicated the compliance with the circle hook regulation varied by area (state) and sector. They indicated the compliance of 50% was possible but should be investigated before use in other assessments. Using the same method to increase the recreational sector for pre-regulation discard mortality, reduced discard mortality was developed for post 2007 due to the usage of circle hooks. The commercial sector discard mortality rate for 2007 to present was 38%.

The discard mortality for the commercial fishery is much less than the GoM's commercial discard mortality for two main reasons: depth fished and handling time. The modal depth fished for the commercial fishery in the South Atlantic was 31 to 40 meters. The average depth fished in the GoM ranged from 42 to 84 meters. Handling time was noted in SEDAR 31 in the GoM commercial fishery where the commercial fishermen averaged using seven hooks per rig (Scott-Denton et al. 2011). In the South Atlantic, commercial fishermen typically fish one to three hooks and up to five hooks on a rig (Gulf and South Atlantic Fisheries Foundation 2013, commercial fishermen at data workshop). The fewer number of hooks in the South Atlantic leads to less time fighting the fish and also less time dehooking on the deck of the boat.

Discard Mortality Values and Range of Plausible Estimates

Recreational 2011 to present – 28.5% (20% to 36%)
Recreational pre-2011 – 37% (27% to 45%)
Commercial 2007 to present – 38% (28% to 48%)
Commercial pre-2007 – 48% (38% to 58%)

2.6 Age

General introduction
For the 2015 DW, age data were updated and reanalyzed. Juvenile Red Snapper are rarely encountered in the U.S. South Atlantic. SEAMAPs fishery-independent trawling program captured three in 1999, two in 2000, seven in 2013 and four in 2014 in nearshore (<30 ft deep) habitat. One age-0 Red Snapper was landed by a headboat fisherman during the 2012 mini-season. One age-0 fish was landed in the commercial fishery in 1980. Fishermen have reported observing juvenile Red Snapper on artificial reefs in shallow water. Estimates of juvenile Red Snapper mortality have been developed in the Gulf of Mexico; however, little information is available for the US South Atlantic.

The SEFSC, the SCDNR, the GA-DNR, and the FWRI contributed both fishery-dependent and fishery-independent age data for this assessment. The final age data set included samples collected from 1977 – 2014. Most of the age samples were randomly collected by port agents intercepting fishing trips between 1977 and 2014: commercial n = 6,624; charter boat n = 4,025; private boat n = 4,470; headboat n = 6,355; unknown fishery type n = 57. (See Tables 2.4 and 2.5 for randomly collected commercial and recreational fishery age samples and number of trips intercepted.) Some age samples (n = 1,941) were collected from the commercial and recreational fisheries in a non-random way (GADNR and FWRI in 2009 and all states during mini-seasons in 2012 - 2014), and the decision on the treatment of the samples are discussed below. An additional 4,224 samples came from fishery-independent studies. All age data included an increment count, an adjusted calendar age based on timing of annulus formation and an estimate of the amount of translucent edge present, and the determined fractional age using a July 1 birth date.

Issues – 2009 sampling intensity and 2012-2014 mini-seasons
As noted in SEDAR24, sampling intensity for Red Snapper was greatly increased in 2009 for fish landed in Georgia. Also, fishermen donated large Red Snapper landed in Florida and Georgia to FWRI and GADNR during that year. The donated fish were considered non-random and were not used to characterize the landings, but were used in the population growth model. The other samples from GADNR were reviewed and the same conclusions made during SEDAR24 were accepted by the LHWG. The following excerpt from SEDAR24 report is included:

> *GADNR conducted a complete census of Red Snapper landed during May 2009 by three recreational vessels. Concern was raised that the high number of samples (nMay = 284) from one month in the year may bias the overall age structure of the Red Snapper landings for the entire year (nyear = 679). This issue was particularly noted by industry*

representatives who have commented that Red Snapper seem to move through the fishing grounds either latitudinally or longitudinally.
A few of the 2009 samples (n = 68) from the commercial and headboat fisheries were selected by fishermen for the largest fish in the catch.

Recommendations
1. GADNR May census data were plotted against the GADNR random samples for the entire year. No discernible difference was noted in the age frequency or the length distribution between the two sets of data. LHWG recommended keeping the May census data in the dataset used for age composition of the recreational fishery.
2. The fishermen selected samples were identified and will not be used in the age composition data to characterize the fishery, but will be used in the growth model and analysis of fishing by depth of water.

Other directed sampling efforts to obtain biological information on Red Snapper in 2012 - 2014 were undertaken by each state in the U.S. South Atlantic. Following the closure of the Red Snapper fishery in 2010 and 2011, the SAFMC re-opened the recreational fishery in 2012 - 2014 as "mini-seasons" and the commercial fishery as limited harvest. Each state agency provided documentation of methodology to collect Red Snapper samples through carcass collection programs and targeted intercepts of fishing trips by biologist (SEDAR41-DW02, SEDAR41-RD14, SEDAR-RS15, SEDAR41-DW18, and SEDAR41-DW21). These special collections were obtained outside of regular, routine sampling by the Southeast Region Headboat Survey (SRHS), MRIP, and TIP. The length data associated with these age samples would not be included in three fishery surveys, but may be made available to the Commercial and Recreational Work Groups for length composition of the respective fisheries. The LH group reviewed the documents, talked with the state agency representatives, and then assigned random or non-random to the age samples provided. Those samples deemed randomly collected during the directed effort were considered useable for characterizing the catch by fishery, gear, and mode. Those samples deemed non-random were used to model the fish growth at the population level, but were considered not useable for characterizing the catch. Samples considered non-random were those collected from donated fish carcasses into freezers or samples that were collected from tournaments. Tables 2.6 – 2.8 provide the number of samples by state, fishery, and mode, and include the designation of "random" or "not random".

Recommendations

1. Use age samples from the state collections during the 2012-2014 mini-seasons and considered as randomly sampled to characterize the landings of the fishery and mode from which they came.

2. Age samples collected from a non-random sample or carcass can be used in the overall population growth analysis, but will not be used to characterize the catch.

Review of data collection of the "mini-season" and recommendations for data collection improvements.
Discussion by the LHWG, in particular relative to the relevant WDs reviews, resulted in several recommendations to potentially improve the data collection during possible future Red Snapper mini seasons. The LHWG reviewers recommended that if this program is to continue in the future, an exploration of methods to further incentivize angler participation is warranted, especially with such limited contribution from the private sector in some states. After brief interviews with participants from the recreational fishers group, the following suggestions were provided to increase participation in the private sector*:

- Free fish cleaning at donation site.
- Short questionnaire from a biologist on-site instead of them filling out a form. People are TIRED after being out all day, boat ramps are busy.
- Advertise at local bait & tackle shops.
- NOAA has announcement system on weather radio channel where they also announce season closures, etc. Since fishermen are frequently monitoring this channel for weather updates, it could be an effective communication route to announce the collection information (drop locations, reward information, etc.).
- Dry storage areas are a good place to sample fish as many people store boats there instead of trailering them home.
- Standardization of survey methods across states should be investigated.

*: Suggestions from various recreational fishermen and in particular, David Nelson (SEFA ECS).
The reviewers understand the cost and effort associated with some of these suggestions, making it difficult to implement all of them.

2.6.1 Age Reader Precision and Ageing Error Matrix

To combine age data from various labs, consistency in readings needed to be assessed. The age data were provided from readings by staff at three laboratories – SEFSC, SCDNR, and FWRI. All age readers have been involved in age workshops for Red Snapper from the U.S. South Atlantic. FWRI staff have the added benefit of yearly age workshops with experts from the Gulf of Mexico. Because the South Atlantic stock of Red Snapper were assessed in 2010, the age readers felt that it would be important to read a calibration set of otolith sections to insure consistency had been maintained. A set of 300 samples was created by SEFSC and exchanged between each of the labs.

The results of the calibration readings showed good consistency between labs. One measure of consistency is the Average Percent Error (APE) between paired readers and between all readers. Another consideration is whether one lab shows a bias in readings compared to the other labs.

APEs ranged from 8% between SEFSC and FWRI to 8.5% between FWRI and SCDNR to 11% between SCDNR and SEFSC. The overall APE amongst all readers was 11.4%. These values are higher than the desired level of ≤5%, but most of the variability in the age readings was from those fish aged 8+. Most of the life history parameters have met saturation by that age (maturity, maximum growth, etc.). The bias plots also indicate little bias in aging between the labs (Figure 2.5).

Accounting for error in age estimation is important for age composition data used in stock assessments (Punt et al. 2008). Thus, to account for any error associated with the age estimation process for South Atlantic Red Snapper and to get contemporary precision estimates, an aging error analysis will be completed for the assessment using a program called "agemat" provided by André Punt. Agemat can use age estimation data from multiple readers in order to estimate the coefficient of variation and standard deviation associated with age estimates and to provide an aging error matrix. This program has been used by other SEDAR assessments (ASFMC 2010).

The ageing error matrix was provided after the 2014 DW (SEDAR41-DW48) and reviewed during the 2015 DW (see above).

Recommendation

The age error matrix as provided in the working paper should be used to characterize the uncertainty in the age estimates as a result of the variability in age reading between readers and labs.

Research recommendation:

Continuing the age reading comparisons and calibrations between labs on a reference collection of known age fish would be beneficial for determining a more accurate aging error matrix and would provide accuracy to the age composition data.

2.6.2 Max Age

The 2014 age data did not yield older fish and the maximum observed age for Red Snapper remains 51 years in the combined data set. This fish was a 904 mm maximum TL female, and was caught in 2003 at 67 meters depth off Florida by a charter boat fisher. The maximum age of Red Snapper in SEDAR24 was 54 years. The otolith preparation from this fish was examined by multiple readers at the SEFSC, SCDNR, and FWRI labs. The age was adjusted to 48 years based on consensus by the readers. Note that there were 12 fish with an age of 40 years or more in the data base.

Recommendation

Use 51 years as the maximum age for Red Snapper in the Assessment. This is similar to the 48 years used in the Gulf of Mexico assessment and the 54 years used in SEDAR 24 assessment.

2.7 Growth

Since SEDAR 24, 14,700 additional aged samples were added to the data-set for a total of 27,696 fish for this workshop, thus increasing the temporal and regional coverage of each fishing mode (commercial, recreational, fishery-independent). For all growth models, fractional ages and maximum TL mm (pinched tail) were used, whether it was given with the data or converted using the determined meristics conversions (see Meristics sections). Growth models were constructed using a correction for the truncated normal distribution of size at age due to minimum size limit regulations across time (Diaz correction: Diaz et al. 2004; McGarvey and Fowler 2002).

Growth parameters were estimated on all available data, which represented the population and the fishery-dependent data separately (Table 2.9). Estimated von Bertalanffy growth parameters included L_∞ (the asymptotic fish length, mm maxTL), k (growth coefficient), and t_0 (birth date, yr). The von Bertalanffy population growth model was freely estimated and the Díaz correction was applied to fish restricted by a minimum size limit. The resulting parameter values were L_∞ = 911.36, k = 0.24, and t_0 = -0.33 (Figure 2.6). The model did not require any weighting scheme because sufficient samples at both tails of the data exist and the model was able to fit them well. The fishery-dependent growth model was also freely estimated and did not require inverse weighting of sample size at age, but no Diaz-correction was applied to the data in this model (Figure 2.7). This growth model will be used to estimate size of Red Snapper landed in the fisheries of the U.S. South Atlantic.

The potential of dimorphic growth in this species was investigated by comparing size-at-age analysis for both male and female fish, for fish in which the sex was determined. No discernible difference was found between male (n=4,976) and female (n=5,322) size-at-age (Figure 2.8), therefore spawning biomass should include all data and not discriminate between sex-based growth models.

Recommendation

1. Use combined data, unweighted, freely estimated, Diaz-corrected von Bertalanffy growth model to represent the population.
2. Use the fishery-dependent age data only, unweighted, and freely estimated, von Bertalanffy growth model to estimate the size of fish landed in the fishery.

2.8 Reproduction

2.8.1 Reproductive Strategy and Data Availability

Red Snapper are batch spawners with indeterminate fecundity that do not change sex during their lifetime (gonochorism). The MARMAP study by White and Palmer (2004 - SEDAR24-RD01) and additional samples collected by SERFS since 2001 provide extensive data on the South Atlantic Red Snapper reproductive biology over a large spatial and temporal range. Specimens with reproductive data were collected from 1979 to 2014 and the majority (82% of 3,221) came from fishery-independent sampling, primarily chevron trap catches (Tables 2.21 – 2.28). Many of the commercial fishermen involved in the collection of specimens since 1999 were permitted to land undersized specimens. Data from a published study by FWRI (Lowerre-Barbieri et al. 2015 - SEDAR41-RD57) assessing Red Snapper reproduction off the east coast of Florida, the stock's center of abundance, were also used for SEDAR41. The FWRI data were based on a fishery-independent hooked gear survey (n=1,305), with 696 females that had gonadal development assessed histologically. Although the Lowerre-Barbieri et al. (2015) study collected data from only the 2012 spawning season, it assesses a range of factors affecting reproductive resilience, including the distribution of spawning activity over space and time and if larger, older females exhibit differences in: spawning habitat, reproductive timing, batch fecundity, or egg quality. In SEDAR41, the data from MARMAP/SERFS and FWRI were combined, for a total of 3,917 specimens with reproductive data. All age-related results presented in this section were based on calendar age and maximum (pinched tail) total length. Information below on sexual maturity, sex ratio, spawning seasonality, spawning fraction, and spawning frequency are based on histology, the most accurate technique utilized to assess reproductive condition in fishes.

2.8.2 Spawning Seasonality

Based on the presence of females with spawning indicators (i.e., the occurrence of hydrated oocytes and/or postovulatory follicles) spawning along the Atlantic coast of the southeastern U.S. generally occurs from April through October and peaks during June through August (Figure 2.9). Off the east coast of Florida, spawning indicators occurred from 4 April to 20 September 2012 and the proportion of females with spawning indicators peaked in June (Lowerre-Barbieri et al. 2015). These results are generally similar to those reported in previous assessments (SEDAR24-RD01, Brown-Peterson et al. 2009). During the period April – October, the dataset analyzed for the assessment revealed the occurrence of spawning as early as April 4th (northern Florida) and as late as October (27th) off South Carolina. In addition, specimens with spawning indicators were noted in 2000 (Ft. Pierce, FL: Nov. 13 & 16, n=2; Dec. 15, n=1. Carolinas: Jan. 3, n=1). Spawning females were captured at inner-shelf to shelf-break depths (15-74 m) from St. Lucie Inlet (FL) to the north side of Cape Lookout (NC; Figures 2.10 & 2.11). In the previous assessment, spawning depth was described as mid-shelf to shelf-break (23-72 m) and the latitudinal range was narrower, from Cape Fear, NC, to Melbourne, FL (SEDAR24-RD01).

Recommendation

The LHWG recommends using a spawning season for Red Snapper of April – September.

2.8.3 Sexual Maturity

The LHWG evaluated maturity data to determine if there has been a temporal shift in age at maturity. SERFS data were divided into two periods, the early period (1980-2000) representing SERFS data from a published study of Red Snapper life history (White and Palmer 2004) and the recent period representing data collected by SERFS during 2001-2013 (SEDAR41-DW35) and FWRI data. Note that fishery independent sampling efforts have changed over time with sampling in earlier years (MARMAP) being more concentrated off South Carolina and Georgia, while in more recent years a large number of sampling stations was added off North Carolina, Florida, and Georgia. Probit analysis using the logistic model (proportion mature = 1 - 1/(1 + exp(a+b*age)) showed that female age at 50% maturity (A50) declined from 2.0 yr (95% CI = 1.6-2.2) in the early period to 1.3 yr (95% CI = 1.1-1.5) in the recent period (Table 2.11). However, a plot of the capture location of Ages 1-3 females revealed that specimens were captured primarily off South Carolina and Georgia in the early period versus being caught primarily off Florida in the recent period (Figure 2.12). Given the lack of comparable historic and current samples to confirm changes over time one maturity curve was estimated based on all specimens, including those collected in 2014. The estimate of female A50 was 1.3 yr (95% CI = 1.0-1.4). Mature gonads were present in 38% of females at Age 1, 81% at Age 2, 93% at Age 3, 96% at Age 4, and 100% at Ages > 4 (Table 2.12). The length at 50% maturity (L50) for female Red Snapper from 1979-2000 and 2001-2013 was 381 mm TL (Gompertz, [prop. mature = 1 - exp(-exp(a+b*age))], 95% CI = 366-392) and 328 mm TL (Logistic, 95% CI = 273-356; Table 2.13), respectively. The overall estimate of L50 for females, based on data from 1979-2014, was 325 mm TL (Logistic, 95% CI = 317-331 mm). However, Lowerre-Barbieri et al. (2015) showed Red Snapper are maturing earlier than expected based on Beverton-Holt life history invariants and also earlier than the mean age at maturity for lutjanids (3.5 yr), even though the red snapper potential reproductive lifespan is considerably longer (45 to 49 yr) than the mean for lutjanids (11.7 yr; Martinez-Andrade 2003).

Age at maturity in male Red Snapper was assessed with SERFS data alone. Mature gonads were present in 94% of males at Age 1, 98% at Age 2, 99% at Age 3, and 100% at Ages > 3 (Table 2.14). The logistic model could not be fit to the data to produce a reliable estimate of A50 (i.e., value was negative). Data from 1979-2014 were used to estimate that the L50 for males was 166 mm TL (Logistic, 95% CI = 95-205 mm; Table 2.15).

Recommendation

Given the differing spatial distribution of the specimens between periods, the LHWG recommend use of one maturity curve, based on all specimens, for the assessment. The estimate of female A50 was 1.3 yr (95%CI = 1.0-1.4).

2.8.4 Sex Ratio

Only the SERFS data were used for this and the analyses indicated that there are differences from a 1:1 sex ratio for Red Snapper among certain age and size classes (Table 2.16). In general, males were more common at sizes less than 400 mm TL and Ages < 3 and females were more common at sizes greater than 600 mm TL and Ages >10. The overall sex ratio for all Red Snapper assigned an age, including data from 2014, was not significantly different from the expected 1:1 (n=2,845, Chi-Square=0.84, DF=1, P=36); restricting the analysis to Chevron trap data from 1990-2013 yielded the same result (n=1276, Chi-Square=0.614, DF=1, P=0.43). A length-based (mm TL) analysis of data from 1979-2013 yielded the same 1:1 ratio (n=2196, Chi-Square=0.117, DF=1, P=0.73).

Recommendation

Use a population sex ratio of 1:1 (female : male), since there was no statistical difference in the sex ratio. However, it was noted that the sex ratio varies with calendar age.

2.8.5 Fecundity and Spawning Frequency

Batch Fecundity (BF)

In SEDAR24, a proxy relating gonad weight to whole fish weight was chosen to estimate fecundity because the one estimate of batch fecundity available for Atlantic coast Red Snapper (Brown-Peterson et al. 2009) was based on 12 specimens of a limited size range (560-937 mm TL) captured from a limited geographic area (St. Augustine to Melbourne). An estimate of fecundity at age from the GoM was also considered, but this equation was not as predictive as an estimate of fecundity at length (see Woods 2003; SEDAR7-DW-35) because batch fecundity reached an asymptote at an age of approximately 10-12 yr. In a recent study along the Atlantic coast of Florida by Lowerre-Barbieri et al. (2015), batch fecundity was estimated in 44 specimens ranging in size from 391-846 mm TL. These data were combined with an additional 25 batch fecundities from SERFS, and the combined data set showed larger females produced significantly more eggs per batch than smaller females (Figure 2.13). Batch fecundities ranged from 14 - 4,200 (x 10^3) eggs per female, and significantly increased with TL (BF=3.012 X 10^{-8} $TL^{4.775}$, 375-862 mm TL, n=69; see SEDAR41-DW49).

Spawning fraction, spawning interval, and spawning frequency

Because the terminology associated with spawning frequency can be confusing, we define them here. Spawning fraction measures the proportion of mature females spawning daily (Hunter and Macewicz 1985; Murua et al. 2003). Spawning interval refers to the time period between spawning events and at the population level is estimated as the reciprocal of the spawning fraction. Spawning frequency refers to the number of spawning events within a spawning season and is traditionally calculated by dividing the number of days within this spawning season by the spawning interval. These definitions follow Lowerre-Barbieri et al. 2011.

To evaluate the level of reproductive activity in the population over the spawning season, an analysis was run using SERFS data to calculate the proportion of spawners among all adult females (active + inactive) in preparation for the SEDAR41 Data Workshop in August 2014. The results showed that the proportion of female Red Snapper with at least one indicator of imminent spawning (migratory nucleus or hydrated oocytes(HO)) or recent spawning (postovulatory complexes, POCs) is consistently around 0.5, as the proportion ranged from 0.41 to 0.54 during June through September, which includes the peak of spawning. These spawning indicators as a group have an estimated duration of 34 hr (SEDAR31-DW07), thus proportionally reducing the range of values to a 24-hr period resulted in a spawning fraction of 0.29 to 0.38. Using traditional methods to assess spawning interval, these proportions correspond to one spawn approximately every 3 days or 70 spawning events in a 210 day (April-October) spawning season. An age-based analysis revealed that there is minimal variation in spawning frequency from Age 2 through Age 38, with no evidence of a clear increasing or decreasing trend (Table 2.10).

Lowerre-Barbieri et al. (2015) using hook-and-line sampling showed slightly higher spawning activity, with an overall spawning fraction of 0.33 for the HO method and 0.18 based on day 1 post-ovulatory follicles (POFs). Using traditional methods to assess spawning interval, these proportions correspond to one spawn approximately every 3 days (HO) or once every 5.7 d (POFs). Based on the proportion of spawning capable females with spawning indicators (i.e., undergoing hydration or with signs of recent spawning), spawning activity was not evenly distributed throughout the spawning season, exhibiting a clear maximum in June. Although the temporal pattern of spawning activity with size was not statistically significant, large fish (≥ 700 mm TL) demonstrated a more even distribution of spawning activity over the months of May (0.64), June (0.75), and July (0.63) than smaller fish .

Spawning frequency by size

Since Red Snapper exhibit indeterminate fecundity, the number of eggs produced per female per year (i.e. annual fecundity) is calculated as the product of batch fecundity (described above) and spawning frequency (the number of batches produced per female per year). Spawning frequency is typically estimated by multiplying the estimated spawning duration by the spawning rate, known as spawning fraction (Murua et al. 2003). This method is analogous to calculating a definite integral (i.e. calculus); essentially, determining the area under a function over an interval. In this case, the function is a horizontal line with a y-intercept equal to the overall spawning fraction, and the interval is the estimated duration of the spawning season, which often increases in batch spawners with size and age (Fitzhugh et al. 2012; Cooper et al. 2013), and was shown to do so in Red Snapper (Lowerre-Barbieri et al. 2015). Since the function is linear, the calculation is simple and it is not usually thought of as a definite integral, though it is. In SEDAR41-DW49, Klibansky fit a more complex, four-parameter plateau-shaped function to the 1979-2014 SERFS (=SCDNR) data. Since the curve is symmetrical and asymptotically approaches the x-axis early and late in the year, the area under this curve can be calculated over the entire year, to estimate spawning frequency. Since spawning fraction has been shown to increase with size or age in multiple species the plateau function was extended by replacing the mean spawning period duration parameter d with a linear function of total length, such that $d = d_0$ -+ d_1TL. Both the basic plateau model and the size-dependent plateau model were separately fit to the data, and the fits of the models compared with Akaike's Information Criterion (AIC). The size-dependent model produced a much stronger fit than the basic model, improving AIC by 42.5 (note that improvements >10 are considered strong; Bolker 2008) and was therefore accepted as the preferred model. The estimate of the slope parameter d_1 was positive (0.42) suggesting an increase in spawning period duration of 4.2 days for every 10 mm of TL. Taking the integral of this model at a particular TL provides an approximation of spawning frequency, which are provided in (SEDAR41-DW49).

Recommendation

The LHWG recommended using the equation, generated from the combined FWRI and SCDNR data, relating total length to batch fecundity, and the relationship between spawning frequency and TL presented in SEDAR41-DW49. Utilizing the total egg production (TEP) method of estimating stock reproductive potential, the equation is:
TEP = proportion female x proportion mature x batch fecundity x spawning frequency. The age-specific estimates of spawning frequency are given in SEDAR41-DW49.

2.9 Movements and Migrations

Since the 2014 DW review of the available literature, no new information became available and the 2014 LHWG recommendations did not change. Red snapper show great site fidelity as adults, which may result in slower replenishment of areas subject to local depletion (Johnson 2013). However, there is increased movement during tropical storms, which may explain reappearance of Red Snapper in formerly depleted areas, in spite of their sedentary nature (Cowan 2011).

Red Snapper undertake short-term movements associated with daily feeding excursions and spawning activities during summer. Adults prefer deeper waters and more complex habitats, so there are apparently ontogenetic movements as well. Red Snapper juveniles are attracted to structure and the dimension and complexity of their habitat increases with fish size (Patterson 2007; Diamond *et al.* 2010). In the South Atlantic, more complex (higher relief; mixture of bottom types) habitats are found in deeper mid-shelf and shelf-edge reefs. This may result in larger fish moving further offshore into more complex reefs as they grow. It should be noted, however, that there was no discernible difference in the distribution of fish by size or age over different depths in the South Atlantic (SEDAR 24).

There have been several tagging studies of Red Snapper, particularly on artificial structures in the GoM, and some recent large efforts in the Atlantic off of Florida. The results confirm long-term site fidelity (months to years), punctuated by very short feeding and spawning excursions.

Addis *et al.* (2013) found that, in spite of previous reports of relative immobility of Red Snapper, they showed the greatest movement among 12 reef fish species tagged on artificial reef sites in the GoM. Mean distance moved among recaptures (173 of 2114 tagged) was 37.1 km (20 nautical miles). During the study, a hurricane passed over the study area, thus adding an unplanned factor to movement analyses. Fish size, reef depth, days at large, and hurricane exposure significantly affected the likelihood of Red Snapper movement, but only fish size significantly affected distance moved (Addis *et al*. 2013).

In another study on artificial reefs in the Gulf, Red Snapper stayed near the artificial reefs (<100 m movement, with 75% of movements within 30 m of the structure), but were significantly farther from the reefs at night (mean = 27.5 m, SD = 7.1) than day (mean = 19.1 m, SD = 8.2). Home range and mean distance from the reef increased with fish size. These fish also showed long-term residence of 332–958 d based on passive acoustic monitoring (Topping and Szedlmayer 2011a).

Tagging data from a number of artificial-reef studies in the GoM demonstrate that, while a substantial percentage of tagged fish were recaptured near their release sites, movement on the scale of hundreds of km also occurs. Because of occasional longer movements, there is sufficient mixing to promote genetic exchange within regions, but overall movement is likely insufficient to affect population demographic differences observed among regions (Patterson 2007).

On natural reefs in the Gulf, Beaumariage (1969) found that 90% of recaptured Red Snapper (of 1,126 tagged) were caught within 5 km of their release site. With very rare exception, there is no reported movement of Red Snapper between the Gulf and South Atlantic (Burns *et al.* 2004). In the Red Snapper largest tagging study, Burns *et al.* (2004) tagged and released 5,272 Red Snapper in the GoM (from Naples, FL, to the eastern border of Texas) and Atlantic (from Cape Canaveral, FL, to Georgia) over a 13-yr period. Approximately 40% of these fish were tagged in the Atlantic. Forty-four percent of the specimens were recaptured within 1.9 km of the tagging site. Less than 10 of the 410 recapture events showed movement >100 miles and movement between the GoM and the Atlantic coast is not mentioned in the report. In a later study, Burns *et al.* (2008) reported 529 Gulf and Atlantic Red Snapper recaptures. Approximately 28.7% were recaptured within 3 km, 15.1% were recaptured within 10 km, and only 3.8% were recaptured more than 50 km of the original tag site. In general, recaptures indicated north/south movement on the Atlantic coast and east and southeast movement (from the Panhandle) in the GoM. A single Red Snapper tagged in the Florida panhandle (during a previous study) was recaptured on the Atlantic coast of Florida.

The results of two smaller studies also indicate minimal movement in Atlantic Red Snapper. The SC Marine Gamefish Tagging Program reported 1,597 Red Snapper tagged with 171 recaptures. Ninety-three percent were recaptured within 2 km of the tagging site. SCDNR (MARMAP) data included 45 tagged Red Snapper with two recaptures, one of which was recaptured in the same vicinity as tagged. The other recapture had no location data.

In a large recent study in the South Atlantic, Brodie *et al.* (2013) tagged 3,441 Red Snapper and reported 211 recaptures (6.1%). Days at large ranged from 0 to 887, and distance traveled ranged from 0 to 237 km (128 nautical miles). Eight fish were recaptured twice and one fish was recaptured three times. The majority of recaptured fish with confirmed location information were caught <1 km from where they were initially tagged, indicating high site fidelity.

Two Red Snapper successfully tagged with acoustic tags at Gray's Reef National Marine Sanctuary (~20 m depth off Sapelo Island GA) were very active on a small spatial scale, appearing on multiple receivers within the 12.6 ha (31 acre) area of the receiver array (Carroll 2010). They exhibited high short-term (several months) site fidelity. One Red Snapper was present 112 d (out of 340 d at large) at the site where it was released and the other was present 580 d (out of 730 d at large) at a site near where it was released. Both individuals were detected on multiple receivers around the array, but returned to a single receiver site on a daily basis. Detections of both Red Snapper were low to absent during the spawning season (May to October), indicating that Red Snapper may move to aggregation sites or into deeper water to spawn, but return to a home territory.

In a larger acoustic tagging study on artificial reefs in the GoM, Topping and Szedlmayer (2011b) found a median residence time of 542 d, ranging from 1 to 1099 d, with 72% of fish staying at least 1 yr at the site. Some fish (n = 12) showed seasonal and directed movements to other sites (up to 8 km away) and returned to original sites up to 7 months later. Diel movements away from the structure tended to occur at night, similar to the pattern seen at Gray's Reef off Georgia. Site fidelity and residence times of Red Snapper found by Topping and Szedlmayer (2011b) were greater than in any previous study, but similar to those found by Carroll (2010).

Recommendation

Available data and the results of studies in the GoM indicate high site fidelity, but that tropical storms may cause greater than normal movement that might help dispersal to depleted areas. This needs to be confirmed in the South Atlantic. More research on Red Snapper movements and migrations in Atlantic waters is needed. Additional acoustic and traditional tagging is needed on known spawning locations to document spawning migrations or aggregations, and return of fish to non-spawning areas.

2.10 Meristic Conversion Factors

Due the large data set, the addition of the 2014 was unlikely to change the conversion factors and the SEDAR41 panel recommended to use the conversions presented at the 2014 DW (Tables 2.17 and 2.18). Data for the length-length, whole weight – gutted weight, and whole weight (g) – length (mm) regressions were pulled from the Southeast Region Headboat Survey (Atlantic portion only), Southeast fishery-independent survey (SCDNR MARMAP and SEFIS), MRIP and Florida FWRI. Maximum total length was agreed upon to be the length type used in the assessment. Linear regressions were run to convert natural total length (TL_{nat}), fork length (FL) and standard length (SL) to maximum total length (TL_{max}, Table 2.17). A no intercept regression was run to convert gutted weight to whole weight. Natural log (Ln) transformed whole weight and length regressions were run for all four length types (Table 2.18). The regression equations were then converted to power equations which included ½ mean squared error (MSE) to account for the transformation bias. Regression parameters are included in Tables 2.17 and 2.18, and Figures 2.14 and 2.15 to illustrate the scatter plot of data points with obvious outliers excluded. Each data source was reviewed before final inclusion in the regression analyses. Outliers were identified and removed from the data set used for meristic conversions. For the whole weight – gutted weight regression, only data from the fishery-independent source were used. Data provided by Florida FWRI was found to not be reliable and removed at the recommendation of the data provider.

2.11 Sample Sizes Available for Analyses

An overview of the available sample sizes and trips by year and state for the various analyses used by the LHWG is provided in Tables 2.19 - 2.26.

2.12 Recommendations for Alternative Parameters Estimates and Comparison of Recommended Parameter Choices between South Atlantic and Gulf of Mexico

Note that alternative parameters estimates and approached recommended by the LHWG are listed under the various chapters discussing the analyses and parameter choices.

An overview of a comparison of parameter choices recommended by the SEDAR 41 LH WG and those used in previous GoM assessments for Red Snapper are given in Table 2.27. As the parameter choice is not always straight forward, the LH WG recommends reviewing the appropriate section of the stock assessment reports for details on the parameter choices.

2.13 Itemized List of Tasks for Completion Following Workshop

- Updating the Life History Working Group report section.
- Completing comparison of parameters and approaches between the South Atlantic and Gulf of Mexico.

2.14 Literature Cited

Addis, D.T., W.F. Patterson III, M.A. Dancea and G.W. Ingram Jr. 2013. Implications of reef fish movement from unreported artificial reef sites in the northern GoM. Fish. Res. 147:349–358.

Beaumariage, D.S. 1969. Returns from the 1965 Schlitz tagging program including a cumulative analysis of previous results. Florida Department of Natural Resources Technical Series 59:1–38.

Brodie, R. B., J. J. Solomon, R. Paperno, T. S. Switzer, C. B. Guenther, B. Sauls. 2014. Overview of Florida's Cooperative East Coast Red Snapper Tagging Program, 2011-2013. SEDAR41-DW10. SEDAR, North Charleston, SC. 25 pp.

Brown-Peterson, N.J., K.M. Burns and R.M. Overstreet. 2009. Regional differences in Florida Red Snapper reproduction. Proceedings of the Gulf and Caribbean Fisheries Institute 61: 149-155.

Burns K. M., Brown-Peterson N. J., Overstreet R. M., Gannon J., Simmons P., Sprinkle J., and Weaver C. (2008) Evaluation of the Efficacy of the Current Minimum Size Regulation for Selected Reef Fish Based on Release Mortality and Fish Physiology. Mote Marine Laboratory Technical Report No. 1176 funded by NOAA under MARFIN Grant # NA17FF2010. 75pp.

Burns, K. M., C. C. Koenig, and F. C. Coleman. 2002. Evaluation of multiple factors involved in release mortality of undersized red grouper, gag, red snapper, and vermilion snapper. Mote Marine Laboratory Technical Report No. 814. MARFIN Grant NA87FF042. 60 p.

Burns, K. M., N. Parnell and R. Wilson. 2004. Partitioning release mortality in the undersized red snapper bycatch: comparison of depth versus hooking effects. MARFIN final report No. NA97FF0349, Mote Marine Laboratory Technical Report 932. 36 p.

Burns, K. M., N. J. Brown-Peterson, and R. M. Overstreet. 2006. Geographic comparison of age, growth, reproduction, movement, and survival of red snapper off the state of Florida. Mote Marine Laboratory Technical Report 1147 (MARFIN Grant # NA17FF288). 80 p.

Burns, K.M., N.J. Brown-Peterson, R.M. Overstreet, J. Gannon, P. Simmons, J. Sprinkle and C. Weaver. 2008. Evaluation of the Efficacy of the Current Minimum Size Regulation for Selected Reef Fish Based on Release Mortality and Fish Physiology. Mote Marine Laboratory Technical Report No. 1176 (MARFIN Grant # NA17FF2010) 75 p.

Burns, K. M. 2009. Evaluation of the Efficacy of the Minimum Size Rule in the Red Grouper and Red Snapper Fisheries With Respect to J and Circle Hook Mortality and Barotrauma and the Consequences for Survival and Movement. Dissertation to College of Marine Science, University of South Florida. 201 pp.

Campbell, M. D., Patino, R., Tolan, J., Strauss, R., and Diamond, S. L. 2010. Sublethal effects of catch-and-release fishing: measuring capture stress, fish impairment, and predation risk using a condition index. – ICES Journal of Marine Science, 67: 513–521.

Carroll, C.J. 2010. Using acoustic telemetry to track Red Snapper, Gag, And Scamp at Gray's Reef National Marine Sanctuary. MS Thesis, Savannah State University.

Charnov, E.L., H. Gislason, and J.G. Pope. 2013. Evolutionary assembly rules for fish life histories. Fish and Fisheries 14(2): 213-224.

Cowan, J.H. Jr. 2011. Red Snapper in the GoM and U.S. South Atlantic: data, doubt, and debate. Fisheries, 36(7):319-331.

Diamond, S., and Campbell, M. D. 2009. Linking "sink or swim" indicators to delayed discard mortality in red snapper. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science, 1: 107–120.

Diamond S.L., Campbell M.D., Olsen D., Wang Y., Zeplin J., Qualia S. (2007) Movers and stayers: individual variability in site fidelity and movements of red snapper off Texas. In: Patterson W.F., Cowan J.H. Jr, Fitzhugh G.R., Nieland D.L. (eds) Red Snapper ecology and fisheries in the US GoM. American Fisheries Society, Symposium 60, Bethesda, Maryland, pp 163–188.

Diamond, S.L., K.M. Kleisner, D.E.t Duursma and Y. Wang. 2010. Designing marine reserves to reduce bycatch of mobile species: a case study using juvenile red snapper (*Lutjanus campechanus*). Can. J. Fish. Aquat. Sci. 67:1335-1349.

Diaz, G. A., C. E. Porch, and M. Ortiz. 2004. Growth models for red snapper in U. S. Gulf of Mexico waters estimated from landings with minimum size limit restrictions. Southeast Fisheries Science Center, Sustainable Fisheries Division Contribution: SFD-2004-038, SEDAR7-AW-01, 13 pp.

Garber A. F., Tringali M. D., and Stuck K. C. (2004) Population structure and variation in red snapper (*Lutjanus campechanus*) from the GoM and Atlantic coast of Florida as determined from mitochondrial DNA control region sequence. Marine Biotechnology 6: 175–85.

Gislason, H., N. Daan, J.A. Rice, and J.G. Pope. 2010. Size, growth, temperature and natural mortality of marine fish. Fish and Fisheries 11: 149-158.

Gitschlag, G.R. and M.L. Renaud. 1994. Field experiments on survival rates of cages and released red snapper. *North American Journal of Fisheries Management* 14:131-136.

Gold J. R, and Portnoy D.S. (2013) Population structure and genetic demography of red snapper (*Lutjanus campechanus*) in the U.S. south Atlantic and connectivity with red snapper in the GoM. Final Report to MARFIN No. NA10NMF4330114.

Gold J. R., Sun F., and Richardson L. R. (1997) Population Structure of Red Snapper from the GoM as Inferred from Analysis of Mitochondrial DNA. Transactions of the American Fisheries Society 126: 386–396.

Grimes, C.B., C.S. Manooch III, G.R. Huntsman and R.L. Dixon. 1977. Red snappers of the Carolina Coast. Mar. Fish. Rev. 39(1):12-15.

Gulf and South Atlantic Fisheries Foundation. 2013. Continuation of catch characterization and discards within the snapper-grouper vertical hook-and-line fishery of the South Atlantic United States. Final Report to NOAA NA10NMF4540102 (GSAFFI #113). Tampa, FL, 40 pp.

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

Hunter, J. R. & Macewicz, B. J. 1985. Measurement of spawning frequency in multiple spawning fishes. NOAA Technical Report NMFS 36, 79-94.

Johnson, D.R., H.M. Perry and J. Lyczkowski-Shultz. 2013. Connections between Campeche Bank and Red Snapper populations in the GoM via modeled larval transport, Trans. Amer. Fish. Soc. 142:50-58.

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.

Lowerre-Barbieri, S., K. Ganias, F. Saborido-Rey, H. Murua, and J. Hunter. 2011. Reproductive timing in marine fishes: variability, temporal scales, and methods. Marine and Coastal Fisheries: Dynamics. Management, and Ecosystem Science [online serial] **3**:71-91.

Lowerre-Barbieri, S., L. Crabtree, T. Switzer, S. Walters Burnsed, and C. Guenther. 2015. Assessing reproductive resilience: an example with South Atlantic red snapper *Lutjanus campechanus*. Marine Ecology Progress Series **526**:125-141. (SEDAR41-RD57)

Manooch, C. S., III., J. C. Potts, D. S. Vaughan, and M. L. Burton. 1998. Population assessment of the red snapper from the southeastern United States. Fisheries Research 38:19-32.

McGarvey, R., and A. J. Fowler. 2002. Seasonal growth of King George whiting (*Sillaginodes punctata*) estimated from length-at-age samples of the legal-size harvest. U.S. National Marine Fisheries Service Fishery Bulletin 100:545–558.

Murua, H., Kraus, G., Saborido-Rey, F., Witthames, P. R., Thorsen, A. & Junquera, S. 2003. Procedures to estimate fecundity of marine fish species in relation to their reproductive strategy. Journal of Northwest Atlantic Fisheries Science 33, 35-54.

Nieland, D. L., Fischer, A. J., Baker, M. S., and Wilson, C. A. 2007. Red snapper in the northern GoM: age and size composition of the commercial harvest and mortality of regulatory discards. American Fisheries Society Symposium, 60: 301–310.

Nowling, L., Gauldie, R. W., Cowan, J. H., and DeCarlo, E. (2011) Successful discrimination using otolith microchemistry among samples of red snapper *Lutjanus campechanus* from artificial reefs and samples of *L. campechanus* taken from nearby oil and gas platforms. The Open Fish Science Journal 4: 1-9.

Parker, R. O. Jr. 1985. Survival of released red snapper progress report. NOAA, National Marine Fisheries Service, Southeast Fisheries Center, Beaufort Laboratory, Beaufort, NC. 8pp.

Patterson, W.F. III. 2007. A review of movement in GoM red snapper: implications for population structure. American Fisheries Society Symposium 60:221–235.

Patterson, W. F. III, G. W. Ingram Jr., R. L. Shipp, J. H. Cowan Jr. 2002. Indirect estimation of red snapper (*Lutjanus campechanus*) and gray triggerfish (*Balistes capriscus*) release mortality. Gulf and Caribbean Fisheries Institute 53: 526-536.

Patterson,W.F. III, Cowan, J. I., Graham, E. Y., and Lyons W.B. (1998) Otolith microchemical fingerprints of age-0 red snapper, *Lutjanus campechanus*, from the northern GoM. GoM Science (1): 83-91.

Pruett C. L., Saillant E., and Gold J. R. (2005) Historical population demography of red snapper (*Lutjanus campechanus*) from the northern GoM based on analysis of sequences of mitochondrial DNA. Marine Biology 147: 593–602.

Render, JH. and C.A. Wilson. 1994. Hook-and-line mortality of caught and release red snapper around oil and gas platform structural habitat. *Bulletin of Marine Science* 55:1106-1111.

Rummer, J. L. 2007. Factors affecting catch and release (CAR) mortality in fish: Insight into CAR mortality in red snapper and the influence of catastrophic decompression. American Fisheries Society Symposium 60: 123-144.

Saillant E., Bradfield S. C., and Gold J. R. (2010) Genetic variation and spatial autocorrelation among young-of-the-year red snapper (*Lutjanus campechanus*) in the northern GoM. ICES Journal of Marine Science 67: 1240–1250.

Saillant E. and Gold J. R. (2006) Population structure and variance effective size of red snapper (*Lutjanus campechanus*) in the northern GoM. Fisheries Bulletin 104: 136–148.

Saul, S.E., J.F. Walter III, D.J. Die, D.F. Naar and B.T. Donahue. 2013. Modeling the spatial distribution of commercially important reef fishes on the West Florida Shelf. Fish. Res. 143:12-20.

Sauls, B., C. Wilson, K. Fitzpatrick. 2014. Size distribution, release condition, and estimated discard mortality of Red Snapper observed in for-hire recreational fisheries in the South Atlantic. SEDAR 41-DW33. SEDAR, North Charleston, SC. 13 pp.

Scott-Denton, E., P.F. Cryer, J.P. Gocke, M.R. Harrelson, D.L. Kinsella, J.R. Pulver, R.C. Smith, and J.A. Williams. 2011. Descriptions of the U.S. GoM reef fish bottom longline and vertical line fisheries based on observer data. Marine Fisheries Review 73(2): 1-26.

SEDAR 7. 2004. Southeast data assessment and review: stock assessment report of GoM red snapper. National Marine Fisheries Service, Southeast Fisheries Science Center, National Oceanic and Atmospheric Administration, Miami, FL.

SEDAR7-DW-33. Red snapper (*Lutjanus campechanus*) otolith aging summary 1980 & 1991-2002. NOAA, NMFS, Panama City Laboratory. Contrib. Series: 04-03. Allman, R.J. et al.

SEDAR7-DW-35. Characterization of red snapper (*Lutjanus campechanus)* reproduction: for the 2004 GoM SEDAR. NOAA, NMFS, Panama City Laboratory. Contribution Series: 04-01. Fitzhugh, G.R., et al.

SEDAR 15. 2007. Southeast data assessment and review: stock assessment report of South Atlantic red snapper. National Marine Fisheries Service, Southeast Fisheries Science Center, National Oceanic and Atmospheric Administration, Miami, FL.

SEDAR 24. 2010. Southeast data assessment and review: stock assessment report of South Atlantic red snapper. National Marine Fisheries Service, Southeast Fisheries Science Center, National Oceanic and Atmospheric Administration, Miami, FL.

SEDAR 24 DW12. Red Snapper discard mortality working paper. SEDAR 24-DW12. SEDAR, North Charleston, SC. 13 pp.

SEDAR 31. 2013. Southeast data assessment and review: stock assessment report of GoM red snapper. National Marine Fisheries Service, Southeast Fisheries Science Center, National Oceanic and Atmospheric Administration, Miami, FL.

SEDAR31-DW07. Expanded Annual Stock Assessment Survey 2011: Red Snapper Reproduction. Fitzhugh, G.R. et al. 2012. SEDAR, North Charleston, SC. 33 pp.

SEDAR41-DW07. Age Truncation and Reproductive Resilience of Red Snapper (*Lutjanus campechanus*) Along the East Coast of Florida. Lowerre-Barbieri, S. et al. 2014. SEDAR, North Charleston, SC. 37 pp.

SEDAR41-DW49. Estimates of reproductive activity in red snapper by size, season, and time of day with nonlinear models. Klibansky, N. 2015. SEDAR, North Charleston, SC. 22 pp.

Sluis, M. Z. (2011) Variability in red snapper otolith microchemistry among GoM Regions. Ph.D. Dissertation, Louisiana State University, 144 pp.

Stephen, J. A. and P. J. Harris. 2010. Commercial catch composition with discard and immediate release mortality proportions off the southeastern coast of the United States. Fisheries Research 103: 18-24.

Then, A.Y., Hoenig, J.M., Hall, N.G., and D.A. Hewitt. 2015. Evaluating the predictive performance of natural mortality rate using information on over 200 fish species. ICES Journal of Marine Science 72(1): 82-92.

Topping, D.T., and S.T. Szedlmayer. 2011a. Home range and movement patterns of red snapper (*Lutjanus campechanus*) on artificial reefs. Fish. Res. 112:77– 84.

Topping, D.T. and S.T. Szedlmayer. 2011b. Site fidelity, residence time and movements of red snapper *Lutjanus campechanus* estimated with long-term acoustic monitoring. Mar. Ecol. Prog. Ser. 437:183–200.

White and Palmer. 2004. Age, growth, and reproduction of the red snapper, *Lutjanus campechanus,* from the Atlantic waters of the southeastern U.S. Bull. Mar. Sci. 75:335-360. (SEDAR24-RD01)

Woods, M. K. 2003. Demographic differences in reproductive biology of female red snapper (*Lutjanus campechanus)* in the northern Gulf of Mexico. Masters Thesis. The University of South Alabama. 129 p.

2.15 Tables

Table 2.1

Age-varying mortality estimates for Red Snapper. The recommended estimate, Charnov et al. (2013) scaled from the age at full recruitment (4+) to the point estimator obtained using the Then et al. (2015) method, is highlighted. Lower and upper represent 95% confidence intervals of natural mortality calculated from inter-reader variation for age estimates of the oldest observed fish.

Age	Charnov	Scaled Charnov	Lower	Upper
1	1.395	0.638	0.603	0.678
2	0.784	0.359	0.339	0.381
3	0.567	0.259	0.245	0.275
4	0.461	0.211	0.199	0.224
5	0.402	0.184	0.173	0.195
6	0.364	0.167	0.157	0.177
7	0.340	0.155	0.147	0.165
8	0.323	0.148	0.140	0.157
9	0.311	0.142	0.135	0.151
10	0.303	0.139	0.131	0.147
11	0.297	0.136	0.128	0.144
12	0.292	0.134	0.126	0.142
13	0.289	0.132	0.125	0.140
14	0.286	0.131	0.124	0.139
15	0.285	0.130	0.123	0.138
16	0.283	0.130	0.122	0.138
17	0.282	0.129	0.122	0.137
18	0.281	0.129	0.122	0.137
19	0.281	0.128	0.121	0.136
20	0.280	0.128	0.121	0.136
21	0.280	0.128	0.121	0.136
22	0.280	0.128	0.121	0.136
23	0.280	0.128	0.121	0.136
24	0.279	0.128	0.121	0.136
25	0.279	0.128	0.121	0.136
26	0.279	0.128	0.121	0.136
27	0.279	0.128	0.121	0.136
28	0.279	0.128	0.121	0.136
29	0.279	0.128	0.121	0.136
30	0.279	0.128	0.121	0.136
31	0.279	0.128	0.121	0.136
32	0.279	0.128	0.121	0.136
33	0.279	0.128	0.121	0.136
34	0.279	0.128	0.121	0.136
35	0.279	0.128	0.121	0.136

36	0.279	0.128	0.121	0.136
37	0.279	0.128	0.121	0.136
38	0.279	0.128	0.121	0.136
39	0.279	0.128	0.121	0.136
40	0.279	0.128	0.121	0.136
41	0.279	0.128	0.121	0.136
42	0.279	0.128	0.121	0.136
43	0.279	0.128	0.121	0.136
44	0.279	0.128	0.121	0.136
45	0.279	0.128	0.121	0.136
46	0.279	0.128	0.121	0.136
47	0.279	0.128	0.121	0.136
48	0.279	0.128	0.121	0.136
49	0.279	0.128	0.121	0.136
50	0.279	0.128	0.121	0.136
51	0.279	0.128	0.121	0.136
Cumulative survival (Age 4+)	**1.082E-06**	**0.002**	**0.003**	**0.001**

Table 2.2

Discard mortality rates used in SEDARs for Red Snapper.

	GoM			South Atlantic			
	SEDAR 7	SEDAR31		SEDAR 15	SEDAR 24	SEDAR 41	
Sector		Pre-Regulation	Post-Regulation			Pre-Regulation	Post-Regulation
Recreational	15-40%	21-22%	10-11%	40%	39-41%	37%	28.5%
Commercial	71-88%	74-87%	55-74%	90%	48%	48%	38%

Table 2.3

Estimate of discard mortality for South Atlantic Red Snapper using a depth model (Burn et al. 2002) and a tag/return model (Sauls et al. 2014). The estimated regulation reduction was applied to the depth model to compare pre- and post-regulation estimates of discard mortality. The reduction was derived from the SEDAR 31 model and estimated using the function in Figure 2.4.

Fleet	Burns et al. 2002	Estimated Regulation Reduction	Sauls et al. 2014 DW 33
Charter	36%	28%	26.7%
Headboat	31%	23%	28.5%
Recreational	35%	27%	N/A
Commercial	48%	38%	N/A

Table 2.4

Number of commercial trips intercepted and number of individual age samples between brackets of Red Snapper landed in the commercial fishery from North Carolina through the east coast of Florida, including the Keys.

	Handline				Other		
Year	FL	GA	NC	SC	FL	NC	SC
1988				7 (32)			
1989				4 (5)			
1990				11 (29)			
1991				3 (6)			
1992	3 (15)			8 (23)			
1993	1 (7)			8 (12)			
1994	1 (1)			14 (20)			
1995	2 (16)			5 (5)	1 (4)		
1996	16 (118)			32 (86)	1 (11)		
1997	16 (63)			29 (111)			
1998	14 (50)				1 (1)		
1999	5 (13)			10 (151)			
2000	21 (141)	1 (16)		6 (131)	7 (122)		
2001	23 (115)				4 (58)		
2002	5 (30)			2 (3)	1 (1)		
2003	10 (59)						
2004	12 (57)		13 (21)				
2005	6 (38)		35 (64)	12 (33)			
2006	9 (80)		24 (34)	51 (115)			
2007	14 (79)		51 (80)	67 (108)	1 (1)		2 (4)
2008	5 (39)		68 (156)	85 (194)	1 (7)	3 (4)	

2009	106 (2047)		60 (152)	97 (233)	14 (75)		9 (15)
2010	1 (30)						
2011			1 (1)				
2012	22 (106)		4 (9)	13 (33)	4 (17)	2 (4)	
2013	71 (597)	4 (15)	24 (74)	10 (36)	14 (106)	3 (12)	
2014	27 (297)		24 (100)	13 (68)	1 (7)	4 (15)	

Table 2.5

Number of trips intercepted and (number of individual age samples) of Red Snapper landed in the recreational fishery from North Carolina through the east coast of Florida, including the Keys.

	Charter Boat		Headboat				Private	
Year	FL	GA	FL	GA	NC	SC	FL	GA
1977			17 (60)			5 (12)		
1978			76 (270)	4 (5)	1 (1)	2 (2)		
1979			31 (46)			1 (1)		
1980			30 (87)		2 (2)	4 (5)		
1981			141 (405)		3 (3)			
1982			55 (131)		1 (3)			
1983			167 (741)		2 (3)	4 (5)		
1984			147 (553)			19 (28)		
1985			150 (491)			10 (13)		
1986			91 (173)	1 (1)	1 (2)	4 (8)		
1987			60 (86)		1 (1)			
1988			17 (19)		3 (3)			
1989			9 (15)		5 (11)	17 (23)		
1990			13 (20)		6 (8)	4 (5)		
1991			13 (21)		4 (4)	1 (1)		
1992			2 (2)		2 (3)	1 (1)		
1993			6 (9)		2 (2)	5 (7)		
1994	2 (7)		6 (10)		3 (5)	1 (1)		
1995			5 (11)		2 (3)	1 (4)		
1996			11 (16)	1 (1)	2 (2)	13 (31)		

1997			12 (13)					
1998			6 (7)			2 (21)		
2000	4 (7)		2 (2)					
2001	14 (42)		2 (2)				1 (1)	
2002	81 (253)		3 (9)			3 (3)	3 (9)	
2003	91 (352)		6 (10)		1 (1)		2 (2)	
2004	83 (309)		9 (27)		3 (3)		2 (3)	
2005	87 (338)		23 (60)		1 (3)			
2006	43 (169)		61 (150)	5 (5)	1 (1)	7 (7)		
2007	11 (27)		20 (56)	4 (4)	1 (1)	10 (10)	1 (2)	
2008			36 (117)	1 (1)	6 (9)	4 (6)		
2009	51 (271)	26 (169)	193 (839)	56 (381)	7 (8)	8 (11)	7 (18)	1 (5)
2010			1 (2)					
2012	113 (679)	7 (36)	47 (571)	1 (5)	5 (24)	1 (4)	300 (965)	
2013	82 (425)	3 (18)	30 (197)	2 (13)	6 (31)	1 (1)	355 (1049)	
2014	150 (830)	22 (93)	35 (200)	7 (82)	10 (63)	4 (19)	810 (2416)	

Table 2.6

Red Snapper age samples collected by NCDMF during the 2012 - 2014 mini-seasons. All samples were from donated carcasses and considered non-random.

Mode	2012	2013	2014
Charter Boat	5	2	35
Headboat	43		79
Private	2	2	15
Unknown Fishery	2		62

Table 2.7

Red Snapper age samples collected by SCDNR during the 2012 - 2014 mini-seasons. All samples were considered non-randomly collected.

Mode	2012	2013	2014
Charter Boat		2	
Headboat	6	11	40
Private	37	31	33
Unknown Fishery			34

Table 2.8

Red Snapper age samples collected by GADNR and FWRI during the 2012 and 2013 mini-seasons. (Note: data were combined due to confidentiality of data.) Samples were collected by a combination of intercepted trips and carcass donations. "No" indicates donated fish/carcasses that were considered non-randomly collected and not used to characterize age structure of the landings. "Yes" indicates samples collected by state agency personnel who intercepted trips and followed random sample design, but may have collected samples outside of regular MRIP, Headboat, or commercial TIP surveys.

	2012		2013		2014	
Mode	No	Yes	No	Yes	No	Yes
Carcass Program	23		34		94	
Charter Boat	33	714	21	443	402	923
Commercial	7		5	15	13	
Headboat		501	10	91	165	189
Private		965		1049	198	2416
Tournament	234		64			
Unknown Fishery	39		27			

Table 2.9

Summary of von Bertalanffy growth model parameters for the population and fishery-dependent data.

Source	N	Linf	StDev	K	StDev	t_0	StDev
Population	27,696	911.36	2.1189	0.24	0.00187	-0.33	0.0155
Fishery-Dependent	23,472	901.72	2.1531	0.24	0.00205	-0.65	0.0191

Table 2.10

The proportion of Red Snapper spawners (# female spawners/# adult females) by increment group in SERFS histological data from April through September of 1978-2014, including all projects, and gears. A spawner had one or more indicators of spawning, which have a combined duration of approximately 34 h (See SEDAR31-DW07). Spawning season duration represents the # of days between the first and last occurrence of spawners by age class. Cal. Age = calendar age, HO = hydrated oocytes, OM = oocyte maturation, POC = postovulatory complex.

Cal. Age (yr)	N	Prop. Spawners (OM, HO, POC; ~34 h)	Est. Spawning Season Duration (d)	# Batches/ind.fish by Age
1	34	0.12	1	0.1
2	230	0.55	138	53.6
3	295	0.42	152	45.1
4	166	0.34	167	40.1
5	158	0.43	158	48.0
6	99	0.41	164	47.5
7	81	0.46	118	38.3
8	51	0.41	133	38.5
9-11	30	0.37	83	21.7
12-14	19	0.47	72	23.9
15-38	17	0.47	121	39.9
2+	1146	0.42	131	38.7
Total	1180			

batches = (24 hr*Proportion Spawners/34 hr) x Spawning Season Duration

Table 2.11

Results of various regression model analyses for age and length at maturity for male & female Red Snapper, by period. Data from all sources (SERFS and FWRI) and gears were combined, with the exception of male length at maturity (SERFS data used only). Age is expressed in calendar age (Cal.Age) and length is maximum (pinched tail) total length in mm. n=number of fish used in analyses, A_{50}= age at which 50% of population has reached sexual maturity, L_{50}=length at which 50% of the population has reached sexual maturity.

						Parameter	Estimate
Analysis	Period	Model	n	A_{50}/L_{50}	95% CI	**Intercept (Std Err)**	**Cal.Age or MaxTL (Std Err)**
Females Age at Maturity	1980-2000	Logistic	476	2.0	1.6-2.2	-3.204 (0.653)	1.612 (0.224)
Females Age at Maturity	2001-2013	Logistic	1332	1.3	1.1-1.5	-2.651 (0.428)	1.993 (0.201)
Females Age at Maturity	1980-2014	Logistic	2321	1.3	1.0-1.4	-1.556 (0.247)	1.283 (0.102)
Female Length at Maturity	1979-2000	Gompertz	517	381	366-392	-9.538 (1.481)	0.024 (0.004)
Female Length at Maturity	2001-2013	Logistic	1359	314	-	-14.068 (49.099)	0.045 (0.146)
Female Length at Maturity	1979-2014	Logistic	2399	325	317-331	-11.491 (0.829)	0.035 (0.002)
Male Length at Maturity	1979-2014	Logistic	1482	166	95-205	-3.346 (1.040)	0.020 (0.003)

Table 2.12

Percentage of mature specimens by calendar age for female Red Snapper, by period. Specimens in the developing, spawning, regressing, or regenerating states were considered mature. *n*=number of specimens available from all sources (SERFS and FWRI) and gears.

	1980-2014 *n*=2,321	**1980-2000** *n*=476	**2001-2013** *n*=1,332
Age	**% Mature**	**% Mature**	**% Mature**
0	--	--	--
1	38	0	31
2	81	50	79
3	93	85	98
4	96	94	98
5	100	100	100
6	100	100	100
7	100	100	100
8	100	100	100
9	100	100	100
10	100	100	100
11	100	100	100
12	100	100	100

Table 2.13

Percentage of mature specimens by maximum (pinched tail) total length interval (TL, mm) for female Red Snapper, by period. Specimens in the developing, spawning, regressing, or regenerating states were considered mature. *n*=number of specimens available from all sources (SERFS and FWRI) and gears.

	1979-2000		2001-2013	
	n=517		*n*=1,359	
Length (TL mm)	**%**	***n***	**%**	***n***
201-225	0	2	0	7
226-250	0	7	0	17
251-275	0	7	5	22
276-300	25	8	10	20
301-325	29	7	52	23
326-350	20	15	86	43
351-375	17	18	91	75
376-400	57	28	97	70
401-425	87	31	99	83
426-450	85	20	99	72
451-475	100	9	100	64
476-500	100	27	100	55
501-525	100	55	100	37
526-550	100	76	100	36
551-575	100	52	100	41
576-600	100	41	100	53
601-625	100	27	100	71
626-650	100	18	100	66
651-675	100	7	100	62
676-700	100	7	100	79
701-725	100	13	100	94
726-750	100	11	100	64
751-775	100	7	100	71
776-800	100	8	100	62
801-825	100	2	100	30
826-850	100	3	100	14
851-875	100	4	100	13
876-900	100	4	100	9
901-925			100	4
926-950	100	2		
951-975				
976-1000	100	1	100	1

Table 2.14

Percentage of mature specimens by calendar age for male Red Snapper, by period. *n*= number of specimens available from all projects and gears (SERFS data only).

	1980-2014 *n*=1,419	1980-2000 *n*=430	2000-2013 *n*=625
Age	% mat	% mat	% mat
0	0	0	--
1	94	88	94
2	98	90	98
3	99	98	99
4	100	99	100
5	100	100	100
6	100	100	100
7	100	100	100
8	100	100	100
9	100	100	100
10	100		100
11	100		100
12	100		100

Table 2.15

Red Snapper sex ratio by calendar age, 1980-2014, based on data from all sources (SERFS and FWRI) and gears.

Calendar Age (yr)	# Male	# Female	Obs. Prop. Female
1	91	35	0.28
2	359	241	0.40
3	397	403	0.51
4	280	251	0.47
5	112	184	0.62
6	60	108	0.64
7	36	94	0.72
8	23	53	0.70
9	13	26	0.67
10	7	8	0.53
11	1	4	0.80
12	3	6	0.67
13	1	7	0.88
14	2	7	0.78
15	2	4	0.67
16	0	5	1.00
17	2	1	0.33
18	1	0	0.00
19	1	3	0.75
20			
21	3	0	0.00
22	0	1	1.00
23	0	1	1.00
24			
25	1	1	0.50
26	1	0	0.00
27			
28	0	2	1.00
29			
30-46	2	2	0.50
Total	1398	1447	0.51

Table 2.16

Red Snapper sex ratio by maximum Total Length (mm) 1979-2013, based on data from all sources (SERFS and FWRI) and gears.

Total Length	Female: Male	Male n	Female n	Proportion female	Total n
201-225		4	0	0.00	4
226-250		9	0	0.00	9
251-275	0.03	30	1	0.03	31
276-300	0.11	37	4	0.10	41
301-325	0.34	35	12	0.26	47
326-350	0.60	42	25	0.37	67
351-375	0.55	66	36	0.35	102
376-400	0.57	76	43	0.36	119
401-425	0.99	70	69	0.50	139
426-450	0.98	53	52	0.50	105
451-475	1.00	43	43	0.50	86
476-500	1.21	48	58	0.55	106
501-525	1.09	77	84	0.52	161
526-550	1.07	99	106	0.52	205
551-575	0.95	86	82	0.49	168
576-600	1.05	64	67	0.51	131
601-625	1.45	42	61	0.59	103
626-650	1.18	38	45	0.54	83
651-675	1.73	15	26	0.63	41
676-700	1.39	31	43	0.58	74
701-725	1.93	28	54	0.66	82
726-750	1.57	28	44	0.61	72
751-775	2.14	21	45	0.68	66
776-800	2.81	16	45	0.74	61
801-825	1.58	12	19	0.61	31
826-850	1.38	8	11	0.58	19
851-875	1.38	8	11	0.58	19
876-900	3.00	4	12	0.75	16
901-925		0	4	1.00	4
926-950		0	2	1.00	2
951-975					0
976-1000		0	2	1.00	2
Total		**1090**	**1106**		**2196**

Table 2.17

Red Snapper length – length conversion equations and whole weight – gutted weight no intercept equation. TL_{max}: maximum Total Length (with "pinched" caudal fin), TL_{nat}: Natural Total Length (with caudal fin spread) FL: Fork length, SL: Standard length, WW: whole wet weight, GW: gutted wet weight. Range is length or weight range. **Linear regression: y=a*x+b.** Note that the assessment units will be Maximum Total Length (TL_{max}) in mm for length and pound for weight. See also Figures 2.17.

Variables	Units	a (SE)	b (SE)	n	R^2	Range of X
TL_{max} = TL_{nat}	mm	4.62 (1.16)	1.02 (0.00)	1,872	0.99	321 - 943
TL_{max} = FL	mm	2.22 (0.45)	1.07 (0.00)	4,691	0.997	64 - 955
TL_{max} = SL	mm	22.09 (0.83)	1.22 (0.00)	4,622	0.99	54 - 825
TL_{nat} = FL	mm	14.45 (1.32)	1.03 (0.00)	4,108	0.98	240 - 910
TL_{nat} = SL	mm	38.83 (2.06)	1.15 (0.00)	1,832	0.98	242 - 770
TL_{nat} = TL_{max}	mm	-0.54 (1.14)	0.97 (0.00)	1,872	0.99	324 - 970
FL = TL_{nat}	mm	-1.89 (1.29)	0.95 (0.00)	4,108	0.98	262 - 970
FL = SL	mm	19.36 (0.73)	1.14 (0.00)	4,559	0.99	54 - 825
FL = TL_{max}	mm	-0.58 (0.42)	0.93 (0.00)	4,691	0.997	70 - 997
SL = FL	mm	-12.98 (0.66)	0.87 (0.00)	4,559	0.99	64 - 955
SL = TL_{nat}	mm	-21.24 (1.86)	0.85 (0.00)	1,832	0.98	321 - 946
SL = Tl_{max}	mm	-13.44 (0.70)	0.81 (0.00)	4,622	0.99	70 - 997
WW = GW	g	no intercept	1.10 (0.00)	937	0.999	148 - 14,710

Table 2.18

Red Snapper Ln – Ln transformed whole weight (g)– length (mm) and the inverse of that regression converted to the power equation . TL_{max}: maximum Total Length (with "pinched" caudal fin), TL_{nat}: Natural Total Length (with caudal fin spread) FL: Fork length, SL: Standard length, W: whole wet weight. Range is length or weight range. Note that the assessment units will be Maximum Total Length (TL_{max}) in mm for length and pound for weight. See also Figure 2.18.

Variables	Units	a (SE)	b (SE)	MSE	n	R^2	Range of X	Converted Power Equation
W = TL_{max}	g, mm	-11.06 (0.04)	2.99 (0.01)	0.01	2,930	0.99	90 - 997	$W = 1.65*10^{-5} L^{2.99}$
W = TL_{nat}	g, mm	-11.17 (0.03)	3.01 (0.00)	0.02	13,565	0.97	197 - 1024	$W = 1.42*10^{-5} L^{3.01}$
W = FL	g, mm	-11.07 (0.04)	3.03 (0.01)	0.03	7,106	0.97	47 - 955	$W = 1.58*10^{-5} L^{3.03}$
W = SL	g, mm	-9.69 (0.05)	2.88 (0.01)	0.02	2,893	0.98	71 - 813	$W = 6.25*10^{-5} L^{2.88}$
TL_{max} = W	mm, g	3.73 (0.01)	0.33 (0.00)	0	2,936	0.98	12 - 15,850	$L = 41.89 W^{0.33}$
TL_{nat} = W	mm, g	3.78 (0.00)	0.32 (0.00)	0	13,565	0.97	80 - 18,000	$L = 43.82 W^{0.32}$
FL = W	mm, g	3.74 (0.01)	0.32 (0.00)	0	7,106	0.97	12 - 15,850	$L = 42.10 W^{0.32}$

Table 2.19

Number of trips (gear deployments) that collected Red Snapper, by gear type, and year, from Fishery Independent Surveys (MARMAP/SEAMAP-SA, and SEFIS) used by LHWG. Gear codes on the top row are SCDNR Marine Resources Research Institute (MRRI) gear codes: 000=unknown. 014= hook and line; 022=Yankee trawl; 041=mini Antillean s-trap- baited; 043=snapper/bandit reel, electric or manual; 053=blackfish trap; 065=spear gun; 071=flatline otter trawl; 073=experimental trap; 074=Florida Antillean trap; 233=75' Falcon Trawl without TED; 324=chevron trap.

	SCDNR MRRI Gear code													
Year	**000**	**014**	**022**	**041**	**043**	**053**	**061**	**065**	**071**	**073**	**074**	**226**	**233**	**324**	**Totals**
1977	0	0	1	0	2	0	0	0	0	0	0	0	0	0	**3**
1978	0	0	1	1	1	0	0	0	0	0	0	0	0	0	**3**
1979	2	0	0	0	6	0	0	0	2	0	0	0	0	0	**10**
1980	0	0	0	0	5	0	0	0	0	0	0	1	0	0	**6**
1981	0	0	0	0	2	0	0	0	0	0	2	0	0	0	**4**
1982	0	0	0	0	3	0	0	0	0	0	1	0	0	0	**4**
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1984	0	0	0	0	6	0	0	0	0	0	0	0	0	0	**6**
1985	0	0	0	0	0	2	0	0	0	0	1	0	0	0	**3**
1986	1	0	0	0	1	1	0	0	0	0	1	0	1	0	**5**
1987	0	1	0	0	2	1	0	0	0	0	0	0	0	0	**4**
1988	0	1	0	0	4	1	0	0	0	0	1	0	0	7	**14**
1989	0	3	0	0	1	0	0	0	0	0	0	0	0	4	**8**
1990	0	2	0	0	1	0	0	0	0	0	0	0	0	8	**11**
1991	0	2	0	0	0	0	0	0	0	0	0	0	0	9	**11**
1992	0	1	0	0	0	0	0	0	0	0	0	0	0	9	**10**
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	12	**12**
1994	0	2	0	0	2	0	0	0	0	0	0	0	0	19	**23**
1995	0	4	0	0	0	0	0	1	0	0	0	0	0	14	**19**
1996	0	1	0	0	17	0	0	0	0	0	0	0	0	9	**27**
1997	0	0	0	0	41	0	0	0	0	0	0	0	0	7	**48**
1998	0	1	0	0	2	0	0	0	0	0	0	0	0	8	**11**
1999	0	0	0	0	15	0	0	0	0	0	0	0	2	4	**21**
2000	0	0	0	0	25	0	0	7	0	0	0	0	2	8	**42**
2001	0	0	0	0	7	0	0	3	0	0	0	0	0	7	**17**
2002	0	0	0	0	2	0	0	0	0	0	0	0	0	15	**17**
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	4	**4**
2005	0	0	0	0	1	0	0	0	0	0	0	0	0	7	**8**
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	5	**5**
2007	0	2	0	0	0	0	1	0	0	0	0	0	0	8	**11**
2008	0	2	0	0	2	0	0	0	0	0	0	0	0	11	**15**
2009	0	3	0	0	7	0	0	1	0	1	0	0	0	9	**21**
2010	0	3	0	0	1	0	0	0	0	0	0	0	1	73	**78**
2011	0	6	0	0	0	0	1	0	0	0	0	0	0	70	**77**
2012	0	29	0	0	10	0	1	3	0	0	0	0	0	155	**198**
2013	0	47	0	0	12	0	0	0	0	0	0	0	4	142	**205**
Total	**3**	**110**	**2**	**1**	**178**	**5**	**3**	**15**	**2**	**1**	**6**	**1**	**10**	**625**	**962**

Table 2.20

<u>Number of Red Snapper specimens</u> with life history data, by gear type, and year, collected by fishery independent Surveys (MARMAP, SEAMAP-SA, and SEFIS) used by LHWG. Gear codes in top row are SCDNR Marine Resources Research Institute (MRRI) gear codes: 000=unknown. 014= hook and line; 022=Yankee trawl; 041=mini Antillean s-trap- baited; 043=snapper/bandit reel, electric or manual; 053=blackfish trap; 065=spear gun; 071=flatline otter trawl; 073=experimental trap; 074=Florida Antillean trap; 233=75' Falcon Trawl without TED; 324=chevron trap.

	SCDNR MRRI Gear Code													
Year	**000**	**014**	**022**	**041**	**043**	**053**	**061**	**065**	**071**	**073**	**074**	**226**	**233**	**324**	**Total**
1977	0	0	1	0	2	0	0	0	0	0	0	0	0	0	**3**
1978	0	0	1	2	1	0	0	0	0	0	0	0	0	0	**4**
1979	6	0	0	0	42	0	0	0	19	0	0	0	0	0	**67**
1980	0	0	0	0	11	0	0	0	0	0	0	5	0	0	**16**
1981	0	0	0	0	3	0	0	0	0	0	8	0	0	0	**11**
1982	0	0	0	0	39	0	0	0	0	0	1	0	0	0	**40**
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1984	0	0	0	0	37	0	0	0	0	0	0	0	0	0	**37**
1985	0	0	0	0	0	2	0	0	0	0	1	0	0	0	**3**
1986	7	0	0	0	1	1	0	0	0	0	1	0	1	0	**11**
1987	0	2	0	0	2	1	0	0	0	0	0	0	0	0	**5**
1988	0	5	0	0	14	1	0	0	0	0	1	0	0	29	**50**
1989	0	4	0	0	2	0	0	0	0	0	0	0	0	5	**11**
1990	0	3	0	0	1	0	0	0	0	0	0	0	0	24	**28**
1991	0	10	0	0	0	0	0	0	0	0	0	0	0	22	**32**
1992	0	11	0	0	0	0	0	0	0	0	0	0	0	21	**32**
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	31	**31**
1994	0	6	0	0	7	0	0	0	0	0	0	0	0	44	**57**
1995	0	7	0	0	0	0	0	4	0	0	0	0	0	29	**40**
1996	0	3	0	0	44	0	0	0	0	0	0	0	0	11	**58**
1997	0	0	0	0	145	0	0	0	0	0	0	0	0	26	**171**
1998	0	2	0	0	23	0	0	0	0	0	0	0	0	25	**50**
1999	0	0	0	0	187	0	0	0	0	0	0	0	3	22	**212**
2000	0	0	0	0	261	0	0	138	0	0	0	0	2	17	**418**
2001	0	0	0	0	11	0	0	51	0	0	0	0	0	9	**71**
2002	0	0	0	0	3	0	0	0	0	0	0	0	0	39	**42**
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	7	**7**
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	5	**5**
2005	0	0	0	0	1	0	0	0	0	0	0	0	0	12	**13**
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	6	**6**
2007	0	5	0	0	0	0	1	0	0	0	0	0	0	29	**35**
2008	0	3	0	0	10	0	0	0	0	0	0	0	0	29	**42**
2009	0	3	0	0	27	0	0	2	0	7	0	0	0	11	**50**
2010	0	3	0	0	1	0	0	0	0	0	0	0	1	168	**173**
2011	0	8	0	0	0	0	1	0	0	0	0	0	0	121	**130**
2012	0	70	0	0	23	0	1	5	0	0	0	0	0	430	**529**
2013	0	132	0	0	15	0	0	0	0	0	0	0	7	375	**529**
Total	**13**	**277**	**2**	**2**	**913**	**5**	**3**	**200**	**19**	**7**	**12**	**5**	**14**	**1547**	**3019**

Table 2.21

Number of Red Snapper specimens with age data, by gear type, and year, collected by fishery independent surveys (MARMAP, SEAMAP-SA, and SEFIS) used by LHWG. Gear codes in top row are SCDNR Marine Resources Research Institute (MRRI) gear codes: 000=unknown. 014= hook and line; 022=Yankee trawl; 041=mini Antillean s-trap- baited; 043=snapper/bandit reel, electric or manual; 053=blackfish trap; 065=spear gun; 071=flatline otter trawl; 073=experimental trap; 074=Florida Antillean trap; 233=75’ Falcon Trawl without TED; 324=chevron trap.

	SCDNR MRRI Gear Code														
Year	**000**	**014**	**022**	**041**	**043**	**053**	**061**	**065**	**071**	**073**	**074**	**226**	**233**	**324**	**Totals**
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1980	0	0	0	0	10	0	0	0	0	0	0	4	0	0	**14**
1981	0	0	0	0	3	0	0	0	0	0	8	0	0	0	**11**
1982	0	0	0	0	36	0	0	0	0	0	0	0	0	0	**36**
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1984	0	0	0	0	2	0	0	0	0	0	0	0	0	0	**2**
1985	0	0	0	0	0	2	0	0	0	0	1	0	0	0	**3**
1986	0	0	0	0	1	1	0	0	0	0	1	0	0	0	**3**
1987	0	1	0	0	1	1	0	0	0	0	0	0	0	0	**3**
1988	0	4	0	0	14	1	0	0	0	0	1	0	0	28	**48**
1989	0	2	0	0	2	0	0	0	0	0	0	0	0	4	**8**
1990	0	3	0	0	1	0	0	0	0	0	0	0	0	24	**28**
1991	0	7	0	0	0	0	0	0	0	0	0	0	0	19	**26**
1992	0	11	0	0	0	0	0	0	0	0	0	0	0	20	**31**
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	29	**29**
1994	0	6	0	0	7	0	0	0	0	0	0	0	0	42	**55**
1995	0	7	0	0	0	0	0	4	0	0	0	0	0	28	**39**
1996	0	2	0	0	37	0	0	0	0	0	0	0	0	10	**49**
1997	0	0	0	0	138	0	0	0	0	0	0	0	0	24	**162**
1998	0	2	0	0	21	0	0	0	0	0	0	0	0	25	**48**
1999	0	0	0	0	180	0	0	0	0	0	0	0	3	19	**202**
2000	0	0	0	0	251	0	0	124	0	0	0	0	2	15	**392**
2001	0	0	0	0	9	0	0	30	0	0	0	0	0	7	**46**
2002	0	0	0	0	3	0	0	0	0	0	0	0	0	38	**41**
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	7	**7**
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	5	**5**
2005	0	0	0	0	1	0	0	0	0	0	0	0	0	12	**13**
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	6	**6**
2007	0	5	0	0	0	0	1	0	0	0	0	0	0	29	**35**
2008	0	3	0	0	10	0	0	0	0	0	0	0	0	29	**42**
2009	0	3	0	0	26	0	0	2	0	7	0	0	0	11	**49**
2010	0	3	0	0	0	0	0	0	0	0	0	0	0	167	**170**
2011	0	8	0	0	0	0	1	0	0	0	0	0	0	120	**129**
2012	0	62	0	0	18	0	1	5	0	0	0	0	0	416	**502**
2013	0	129	0	0	13	0	0	0	0	0	0	0	7	368	**517**
Totals	**0**	**258**	**0**	**0**	**784**	**5**	**3**	**165**	**0**	**7**	**11**	**4**	**12**	**1502**	**2751**

Table 2.22

Number of Red Snapper specimens with reproductive data, by gear type, and year, collected by fishery independent surveys (MARMAP, SEAMAP-SA, and SEFIS) used by LHWG. Gear codes in top row are SCDNR Marine Resources Research Institute (MRRI) gear codes: 000=unknown. 014= hook and line; 022=Yankee trawl; 041=mini Antillean s-trap- baited; 043=snapper/bandit reel, electric or manual; 053=blackfish trap; 065=spear gun; 071=flatline otter trawl; 073=experimental trap; 074=Florida Antillean trap; 233=75' Falcon Trawl without TED; 324=chevron trap.

	SCDNR MRRI Gear Code														
Year	**000**	**014**	**022**	**041**	**043**	**053**	**061**	**065**	**071**	**073**	**074**	**226**	**233**	**324**	**Total**
1979	0	0	0	0	15	0	0	0	0	0	0	0	0	0	**15**
1980	0	0	0	0	11	0	0	0	0	0	0	5	0	0	**16**
1981	0	0	0	0	2	0	0	0	0	0	8	0	0	0	**10**
1982	0	0	0	0	2	0	0	0	0	0	1	0	0	0	**3**
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1984	0	0	0	0	9	0	0	0	0	0	0	0	0	0	**9**
1985	0	0	0	0	0	1	0	0	0	0	0	0	0	0	**1**
1986	0	0	0	0	1	1	0	0	0	0	1	0	1	0	**4**
1987	0	2	0	0	2	0	0	0	0	0	0	0	0	0	**4**
1988	0	5	0	0	14	1	0	0	0	0	1	0	0	29	**49**
1989	0	3	0	0	2	0	0	0	0	0	0	0	0	4	**9**
1990	0	3	0	0	1	0	0	0	0	0	0	0	0	24	**28**
1991	0	10	0	0	0	0	0	0	0	0	0	0	0	22	**32**
1992	0	11	0	0	0	0	0	0	0	0	0	0	0	21	**32**
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	31	**31**
1994	0	6	0	0	7	0	0	0	0	0	0	0	0	44	**57**
1995	0	2	0	0	0	0	0	0	0	0	0	0	0	12	**14**
1996	0	0	0	0	19	0	0	0	0	0	0	0	0	10	**29**
1997	0	0	0	0	56	0	0	0	0	0	0	0	0	26	**82**
1998	0	2	0	0	21	0	0	0	0	0	0	0	0	25	**48**
1999	0	0	0	0	152	0	0	0	0	0	0	0	0	22	**174**
2000	0	0	0	0	250	0	0	132	0	0	0	0	0	15	**397**
2001	0	0	0	0	3	0	0	40	0	0	0	0	0	9	**52**
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	38	**38**
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	7	**7**
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	5	**5**
2005	0	0	0	0	1	0	0	0	0	0	0	0	0	12	**13**
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	6	**6**
2007	0	5	0	0	0	0	1	0	0	0	0	0	0	27	**33**
2008	0	3	0	0	0	0	0	0	0	0	0	0	0	28	**31**
2009	0	3	0	0	0	0	0	0	0	7	0	0	0	10	**20**
2010	0	3	0	0	1	0	0	0	0	0	0	0	1	164	**169**
2011	0	8	0	0	0	0	1	0	0	0	0	0	0	120	**129**
2012	0	53	0	0	18	0	1	5	0	0	0	0	0	430	**507**
2013	0	76	0	0	14	0	0	0	0	0	0	0	0	374	**464**
Total	**0**	**195**	**0**	**0**	**601**	**3**	**3**	**177**	**0**	**7**	**11**	**5**	**2**	**1515**	**2519**

Table 2.23

Number of Red Snapper specimens with reproductive data, by state, and year, collected by fishery independent surveys (MARMAP, SEAMAP-SA, and SEFIS) used by LHWG.

Year	FL	GA	SC	NC	Total
1979	0	0	0	0	**0**
1980	0	0	0	0	**0**
1981	0	0	0	0	**0**
1982	0	0	0	0	**0**
1983	0	0	0	0	**0**
1984	0	0	0	0	**0**
1985	0	0	0	0	**0**
1986	0	0	0	0	**0**
1987	0	0	0	0	**0**
1988	0	0	24	0	**24**
1989	0	0	4	0	**4**
1990	0	0	24	0	**24**
1991	0	0	22	0	**22**
1992	0	0	20	1	**21**
1993	0	3	28	0	**31**
1994	0	7	37	0	**44**
1995	0	3	9	0	**12**
1996	1	1	8	0	**10**
1997	14	0	12	0	**26**
1998	0	9	16	0	**25**
1999	21	0	1	0	**22**
2000	1	4	10	0	**15**
2001	0	6	3	0	**9**
2002	27	6	5	0	**38**
2003	7	0	0	0	**7**
2004	0	2	3	0	**5**
2005	1	6	5	0	**12**
2006	1	3	2	0	**6**
2007	4	21	2	0	**27**
2008	7	9	12	0	**28**
2009	2	6	2	0	**10**
2010	129	28	6	1	**164**
2011	102	11	7	0	**120**
2012	311	22	16	81	**430**
2013	256	36	24	58	**374**
Total	**884**	**183**	**302**	**141**	**1510**

Table 2.24

Number of positive trap deployments with Red Snapper, by year, and state, collected by fishery independent surveys (MARMAP, SEAMAP-SA, and SEFIS) used by LHWG.

Year	FL	GA	SC	NC	Totals
1979	0	0	0	0	**0**
1980	0	0	0	0	**0**
1981	0	0	0	0	**0**
1982	0	0	0	0	**0**
1983	0	0	0	0	**0**
1984	0	0	0	0	**0**
1985	0	0	0	0	**0**
1986	0	0	0	0	**0**
1987	0	0	0	0	**0**
1988	1	0	6	0	**7**
1989	1	0	3	0	**4**
1990	0	0	8	0	**8**
1991	0	0	9	0	**9**
1992	0	0	8	1	**9**
1993	0	2	10	0	**12**
1994	0	4	15	0	**19**
1995	0	2	12	0	**14**
1996	1	1	7	0	**9**
1997	3	0	4	0	**7**
1998	0	4	4	0	**8**
1999	3	0	1	0	**4**
2000	1	3	4	0	**8**
2001	0	4	3	0	**7**
2002	7	4	4	0	**15**
2003	1	0	0	0	**1**
2004	0	2	2	0	**4**
2005	1	3	3	0	**7**
2006	1	2	2	0	**5**
2007	3	4	1	0	**8**
2008	6	1	4	0	**11**
2009	2	5	2	0	**9**
2010	47	20	5	1	**73**
2011	54	10	6	0	**70**
2012	93	11	10	41	**155**
2013	90	20	11	21	**142**
Totals	**315**	**102**	**144**	**64**	**625**

Table 2.25

Number of Red snapper captured by year, and state, collected by fishery independent surveys (MARMAP, SEAMAP-SA, and SEFIS) used by LHWG.

Year	FL	GA	SC	NC	Total
1979	0	0	0	0	**0**
1980	0	0	0	0	**0**
1981	0	0	0	0	**0**
1982	0	0	0	0	**0**
1983	0	0	0	0	**0**
1984	0	0	0	0	**0**
1985	0	0	0	0	**0**
1986	0	0	0	0	**0**
1987	0	0	0	0	**0**
1988	0	0	24	0	**24**
1989	0	0	4	0	**4**
1990	0	0	24	0	**24**
1991	0	0	22	0	**22**
1992	0	0	20	1	**21**
1993	0	3	28	0	**31**
1994	0	7	37	0	**44**
1995	0	3	26	0	**29**
1996	1	1	9	0	**11**
1997	14	0	12	0	**26**
1998	0	9	16	0	**25**
1999	21	0	1	0	**22**
2000	2	5	10	0	**17**
2001	0	6	3	0	**9**
2002	27	7	5	0	**39**
2003	7	0	0	0	**7**
2004	0	2	3	0	**5**
2005	1	6	5	0	**12**
2006	1	3	2	0	**6**
2007	4	23	2	0	**29**
2008	8	9	12	0	**29**
2009	2	7	2	0	**11**
2010	129	32	6	1	**168**
2011	103	11	7	0	**121**
2012	311	22	16	81	**430**
2013	256	36	24	59	**375**
Total	**887**	**192**	**320**	**142**	**1541**

Table 2.26

Number of Red Snapper specimens with age data, by state, and year, collected by fishery independent surveys (MARMAP, SEAMAP-SA, and SEFIS) used by LHWG.

Year	FL	GA	SC	NC	Total
1979	0	0	0	0	**0**
1980	0	0	0	0	**0**
1981	0	0	0	0	**0**
1982	0	0	0	0	**0**
1983	0	0	0	0	**0**
1984	0	0	0	0	**0**
1985	0	0	0	0	**0**
1986	0	0	0	0	**0**
1987	0	0	0	0	**0**
1988	0	0	24	0	**24**
1989	0	0	4	0	**4**
1990	0	0	24	0	**24**
1991	0	0	19	0	**19**
1992	0	0	19	1	**20**
1993	0	3	26	0	**29**
1994	0	7	35	0	**43**
1995	0	3	25	0	**28**
1996	1	1	8	0	**10**
1997	13	0	11	0	**24**
1998	0	9	16	0	**25**
1999	18	0	1	0	**19**
2000	2	4	9	0	**15**
2001	0	5	2	0	**7**
2002	26	7	5	0	**38**
2003	7	0	0	0	**7**
2004	0	2	3	0	**5**
2005	1	6	5	0	**12**
2006	1	3	2	0	**6**
2007	4	23	2	0	**29**
2008	8	9	12	0	**29**
2009	2	7	2	0	**11**
2010	128	32	6	1	**167**
2011	102	11	7	0	**120**
2012	306	21	15	74	**416**
2013	250	36	23	59	**368**
Total	**869**	**189**	**305**	**135**	**1498**

Table 2.27

Comparison of LH DW parameter recommendations for SEDAR 41 (SA) and those used in the GoM in previous SEDAR assessments.

Parameter	SEDAR 41	GOM value	SEDAR 31 SAR page #	SA value	SEDAR 24 SAR page #	Notes
M	Age varying, scaled (1.395 age 1 - 0.279 age 51)	0.094277 (age-variant)	437	0.08 (age-varying, scaled)	346	
Linf	911.4 mmTL	856.374	438	902	344	
k	0.24	0.191852	438	0.24	344	
t0	-0.33	-0.394525	438	-0.03	344	
Annual fecundity	See section 2.8.5. of LH report	See Table 2.1.4.1	438	Gonad weight and GSI	81 & 347	
Sex ratio	1:1	1 to 1	84	1 to 1	347	
Maximum age	51	57 (see inserted comment)	437	54	15	
age	otoliths - sectioned Calendar age					
Age at maturity	Female A50=1.3 yr; males: 94% age 1, 98% age 2, 99% age 3, 100% age 4+	2	86	See Table 5.2 and Table 5	19 & 344	
length at maturity	Fenale L50=325 mmTL; male L50=166 mm TL					
Maturity schedule		?	84 & 86	See Table 5.2 and Table 5	19 & 344	
Spawning seasonality	April - September	May through September, peak spawning June – August	86		79	
Spawning frequency	See section 2.8.5. of LH report	?	86 #s 8-10		80	
Discard mortality SA Recreational 2011 to present	28.5% (20% to 36%)					
Discard mortality SA Recreational pre-2011	37% (27% to 45%)					
Discard mortality SA Commercial 2007 to present	38% (28% to 48%)					
Discard mortality SA Commercial pre-2007	48% (38% to 58%)					
Discard mortality - for-hire				0.41	347	
Discard mortality - private				0.39	347	
Discard mortality - commercial handline; eastern GOM; closed season; no venting		0.74	443 & 457			For GOM, see Table 2.7.3
Discard mortality - commercial handline; eastern GOM; closed season; venting		0.55	443 & 457			
Discard mortality - commercial handline; eastern GOM; open season; no venting		0.75	443 & 457			
Discard mortality - commercial handline; eastern GOM; open season; venting		0.56	443 & 457			
Discard mortality - commercial handline; western GOM; closed season; no venting		0.87	443 & 457			
Discard mortality - commercial handline; western GOM; closed season; venting		0.74	443 & 457			
Discard mortality - commercial handline; western GOM; open season; no venting		0.78	443 & 457			
Discard mortality - commercial handline; western GOM; open season; venting		0.6	443 & 457			
Discard mortality - commercial longline eastern GOM; closed season; no venting		0.82	443 & 457			
Discard mortality - commercial longline eastern GOM; closed season; venting		0.66	443 & 457			
Discard mortality - commercial longline eastern GOM; open season; no venting		0.81	443 & 457			
Discard mortality - commercial longline eastern GOM; open season; venting		0.64	443 & 457			
Discard mortality - commercial longline western GOM; closed season; no venting		0.95	443 & 457			
Discard mortality - commercial longline western GOM; closed season; venting		0.88	443 & 457			
Discard mortality - commercial longline western GOM; open season; no venting		0.91	443 & 457			
Discard mortality - commercial longline western GOM; open season; venting		0.81	443 & 457			
Discard mortality - recreational; eastern GOM; closed season; no venting		0.21	443 & 457			
Discard mortality - recreational; eastern GOM; closed season; venting		0.1	443 & 457			
Discard mortality - recreational; eastern GOM; open season; no venting		0.21	443 & 457			
Discard mortality - recreational; eastern GOM; open season; venting		0.1	443 & 457			
Discard mortality - recreational; western GOM; closed season; no venting		0.22	443 & 457			
Discard mortality - recreational; western GOM; closed season; venting		0.11	443 & 457			
Discard mortality - recreational; western GOM; open season; no venting		0.22	443 & 457			
Discard mortality - recreational; western GOM; open season; venting		0.1	443 & 457			

2.16 Figures

Figure 2.1

Computer Generated Native Distribution Map for Red Snapper (*Lutjanus campechanus*) in red and modeled future range map based on IPCC A2 emissions scenario in yellow. www.aquamaps.org, version of Aug. 2013. Web. Accessed 5 Aug. 2014.

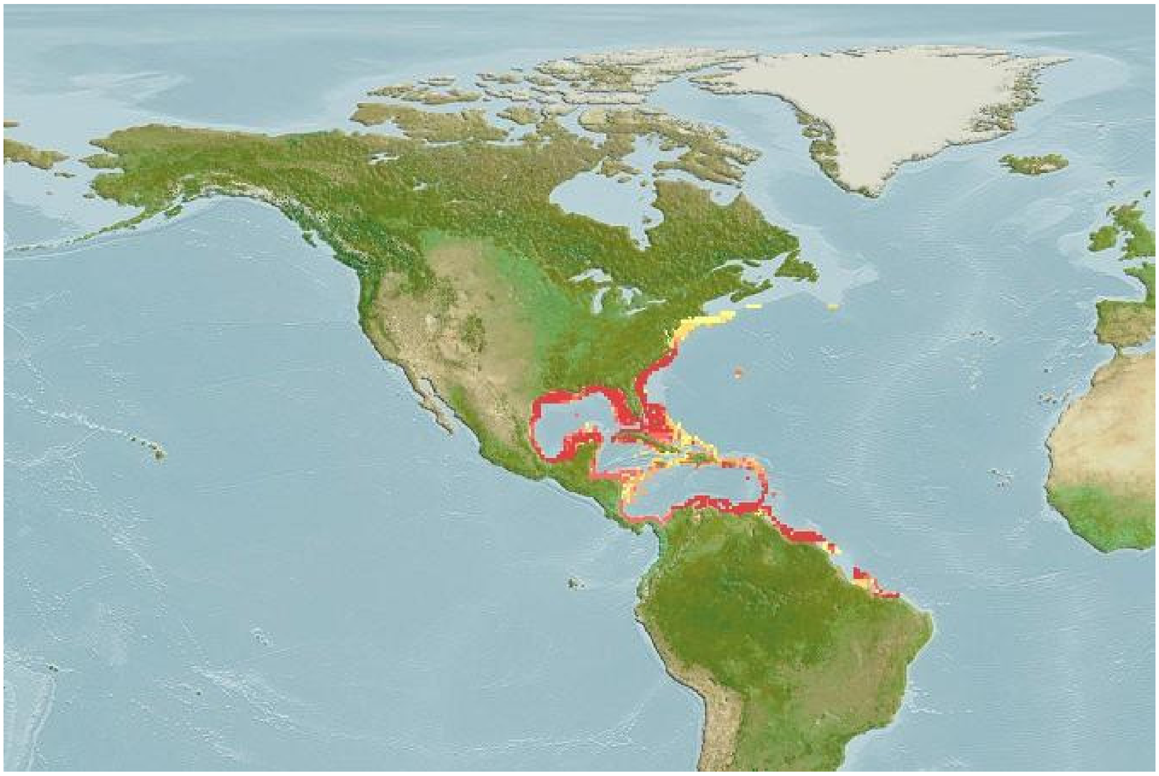

Figure 2.2

Discard mortality function by depth (m) for Red Snapper derived from Burns et al. (2002) and used in SEDAR 24. This is the preferred function to estimate the pre-regulation discard mortality for the commercial sector in SEDAR 41.

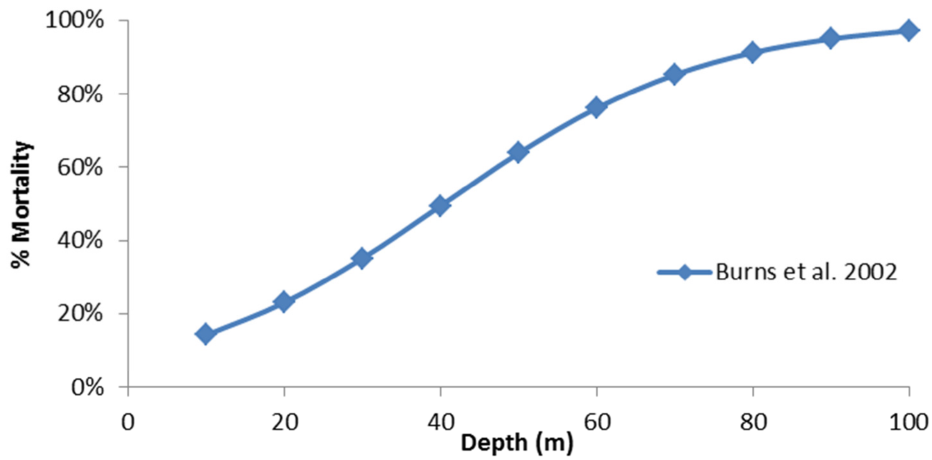

Figure 2.3

Proportion of total discards by depth of observed discards for Red Snapper in the charter boat and headboat fishery off Florida, observed discards for Red Snapper in commercial fishery in the South Atlantic, and reported depths fished during the Red Snapper mini-season off Florida.

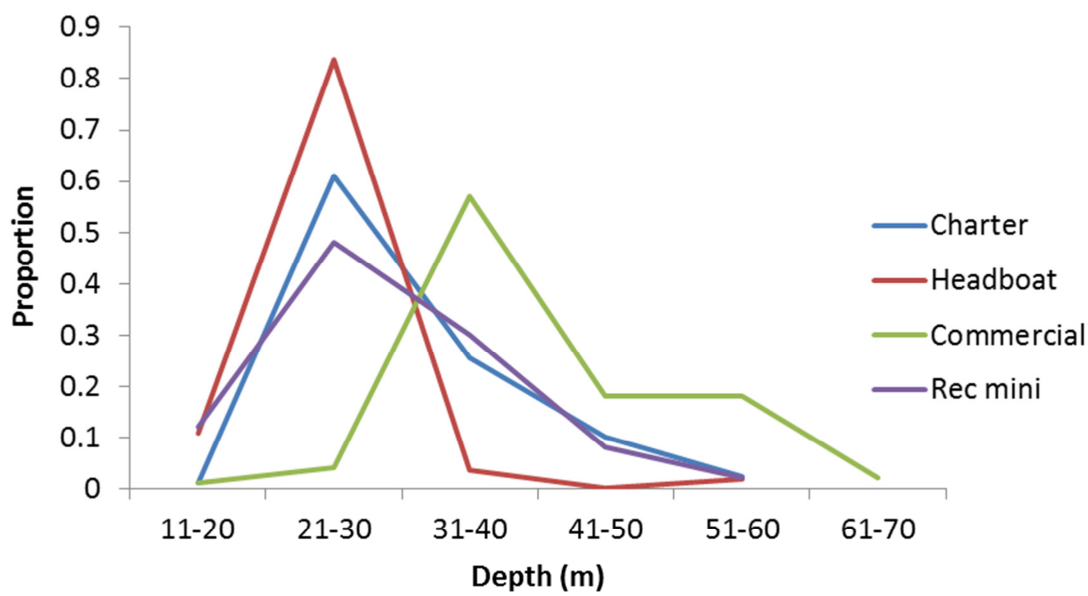

Figure 2.4

The percent of discard mortality associated with regulations plotted with total discard mortality based on data from SEDAR 31 for Red Snapper in the GoM. Linear regression analysis results are given in the legend.

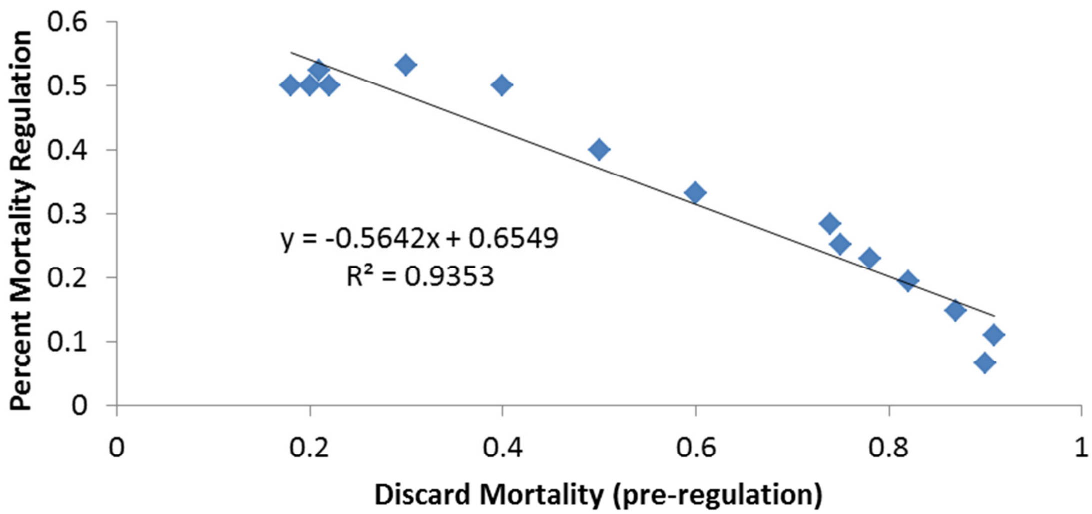

Figure 2.5

Between lab age reading bias plots of Red Snapper calibration set. Error bars represent 95% confidence intervals.

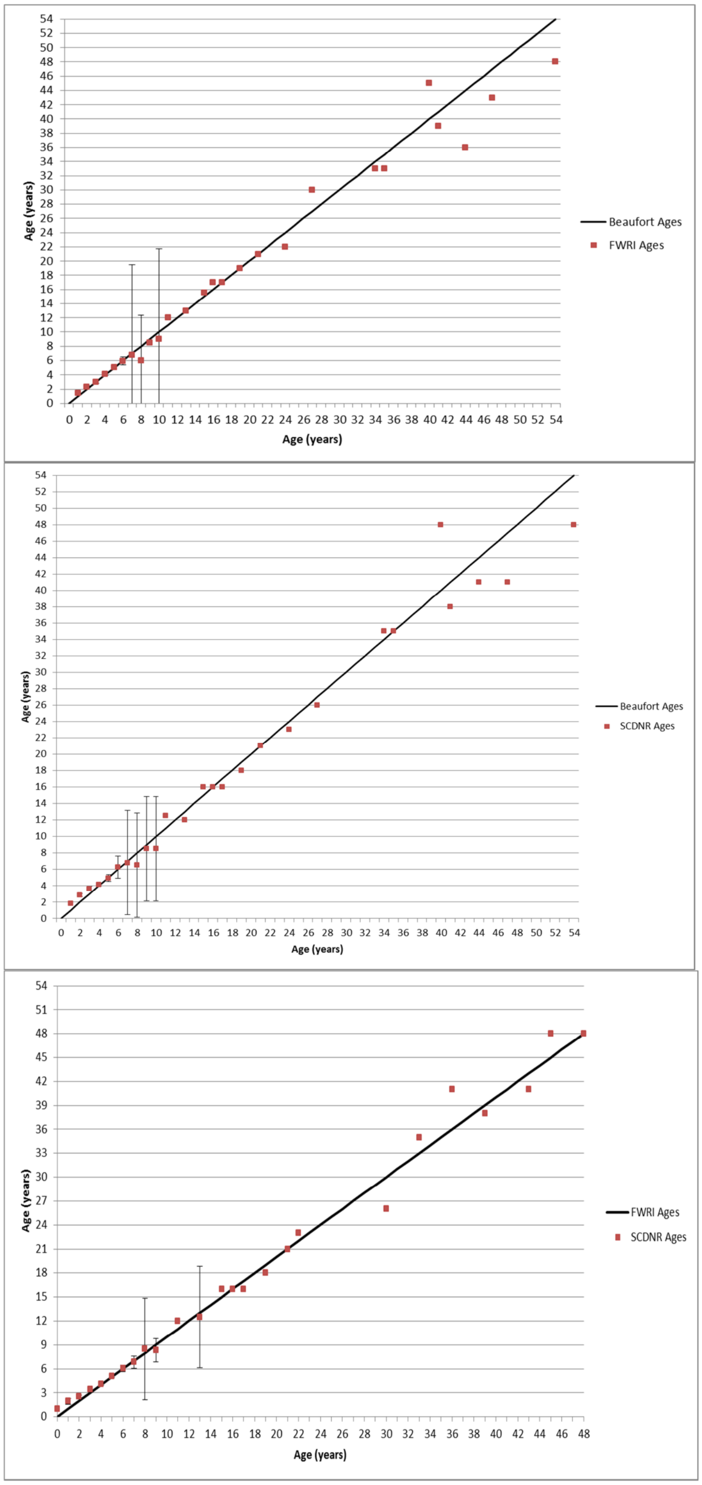

Figure 2.6

Population growth model of U.S. South Atlantic Red Snapper,

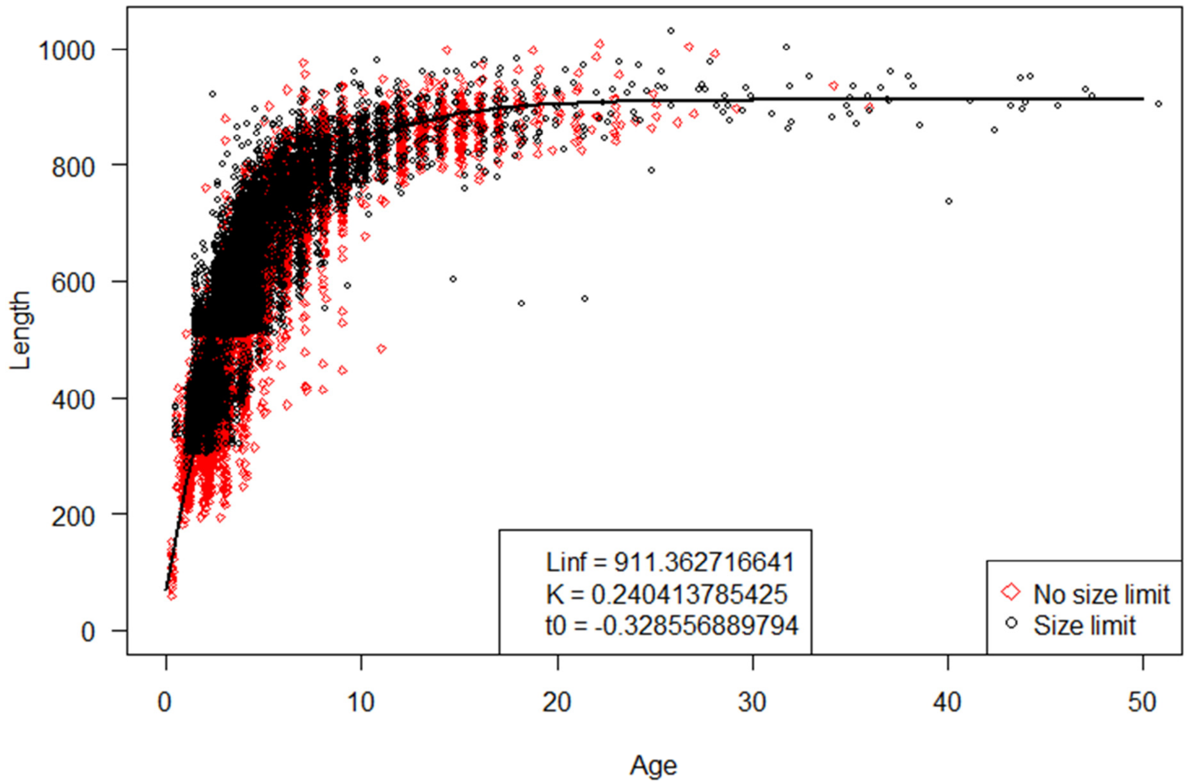

Figure 2.7

Fishery-dependent growth model of U.S. South Atlantic Red Snapper,

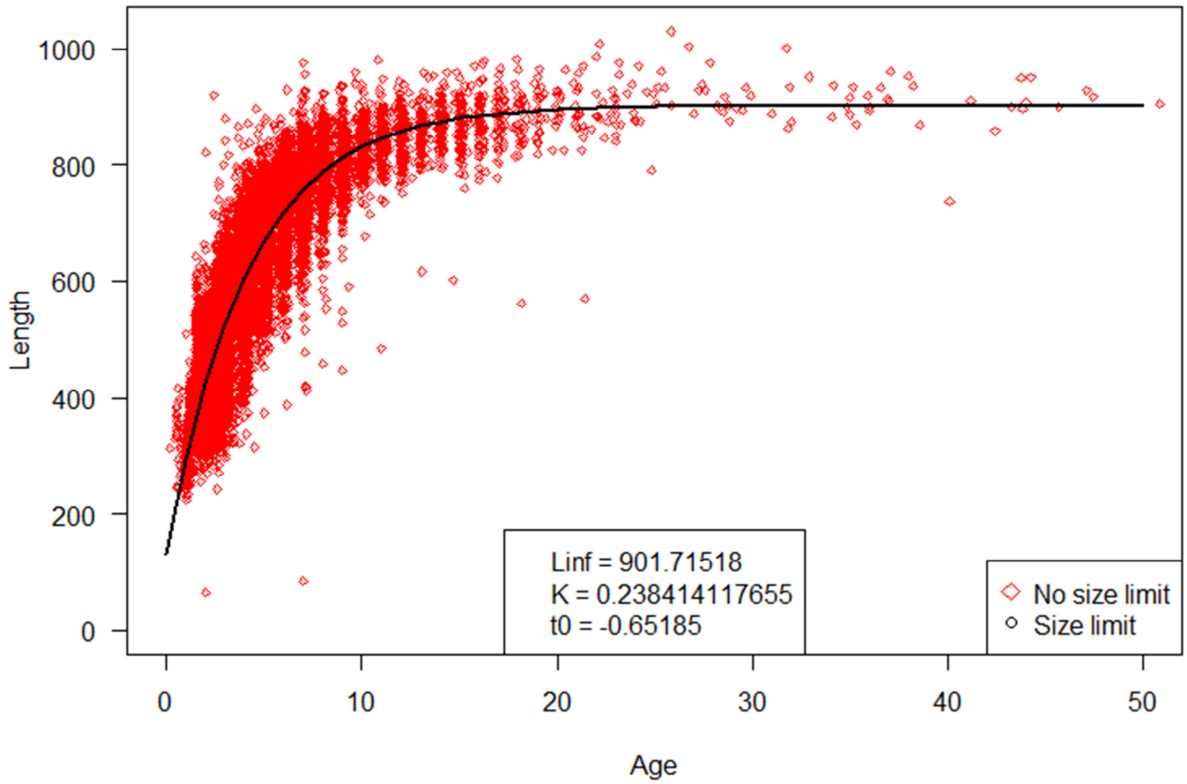

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Figure 2.8

U.S. South Atlantic Red Snapper male and female maximum total length at age. Error bars represent 95% confidence intervals.

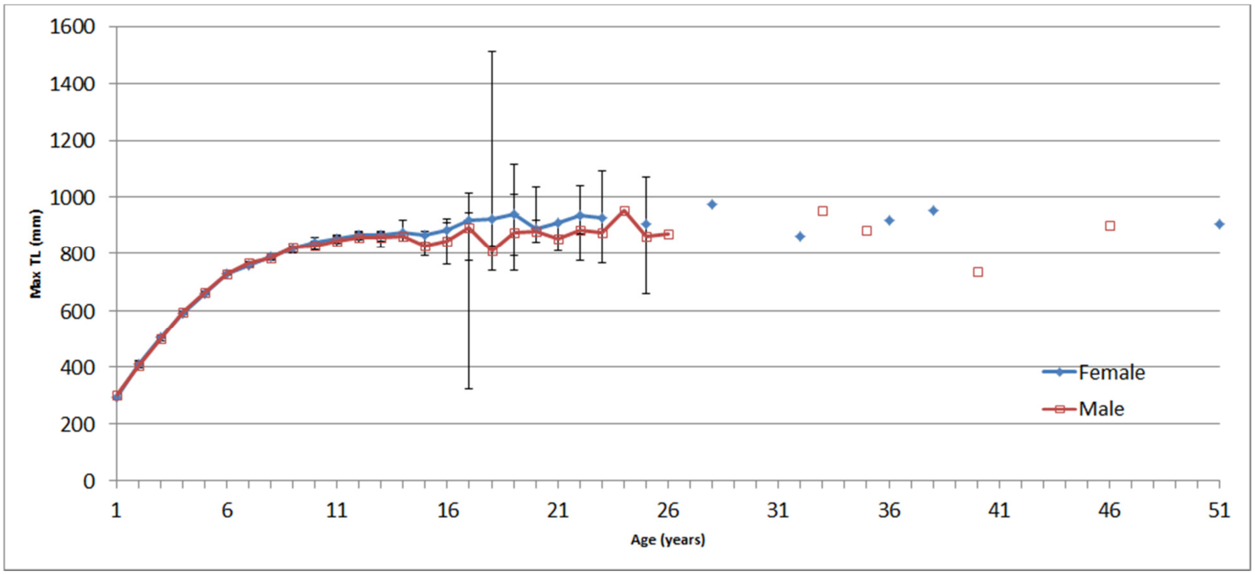


Figure 2.9

Female Red Snapper spawning seasonality, 1979-2013. Developing= Primary growth oocytes and cortical alveoli stage through partially yolked oocytes, Regenerating= Primary growth oocytes only, may have traces of late-stage atresia, Vitellogenic= mid- to late-vitellogenic oocytes present, Immature=Primary growth oocytes only, Regressing=More than 50% of vitellogenic oocytes undergoing alpha or beta atresia, Spawning= Completion of yolk coalescence & hydration and/or presence of POCs.

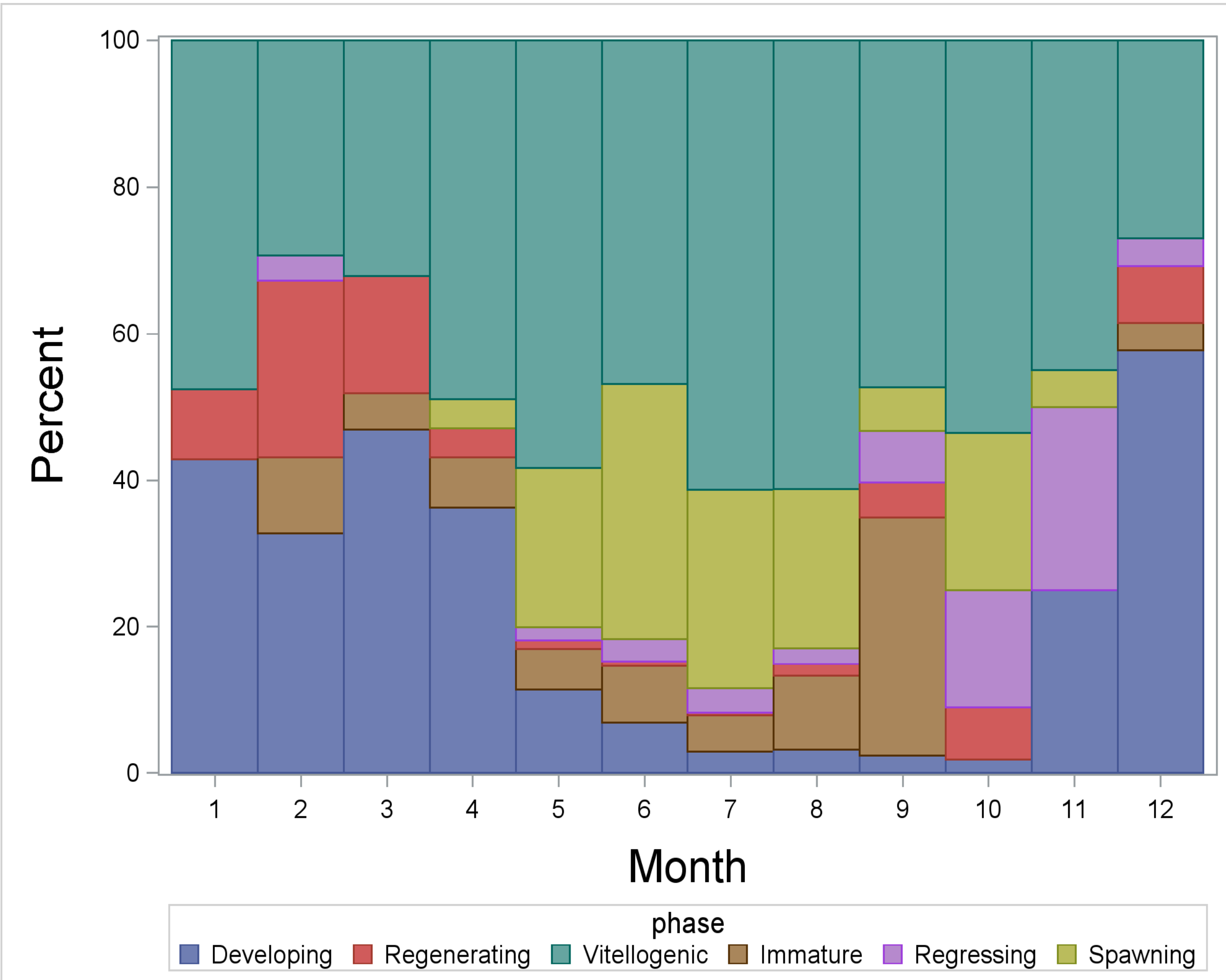


Figure 2.10

Locations where spawning female Red Snapper were collected by fishery-independent sources, 1977-2013.

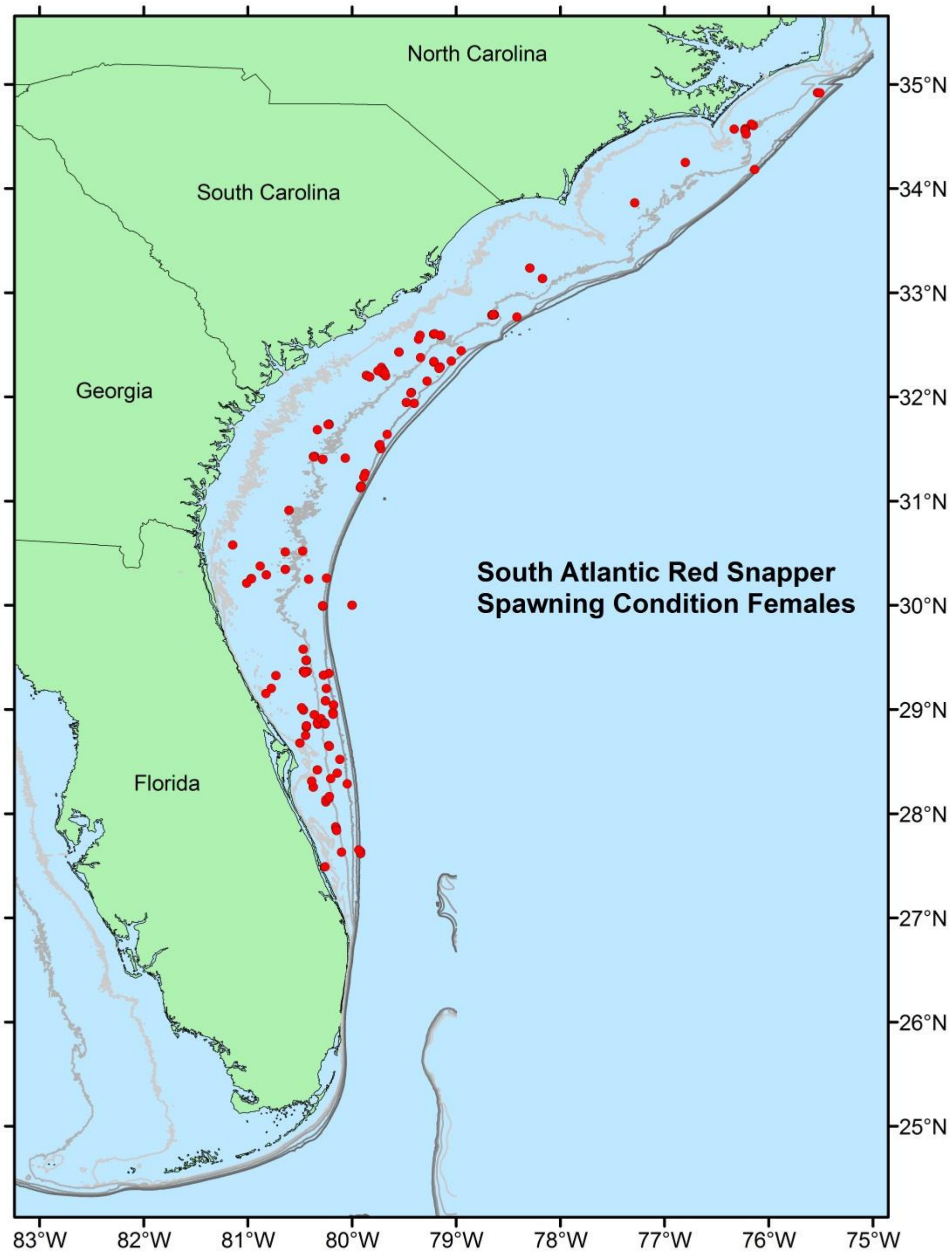


Figure 2.11

Locations where specimens of age 1 female Red Snapper were collected by fishery-independent sources, 1977-2013. Immature females collected 21-42 meters depth. Mature females collected 22-42 meters depth.

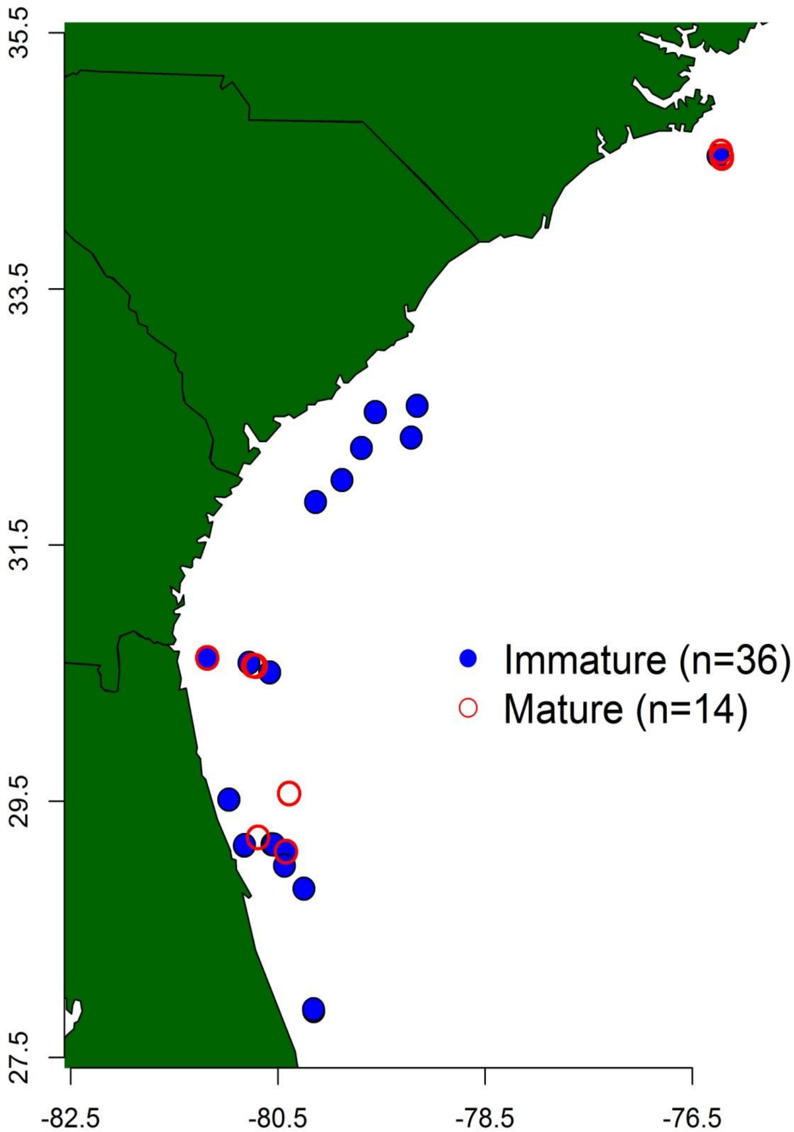


Figure 2.12

Locations where mature female Red Snapper, age 1-3, were collected by fishery-independent sources, by period.

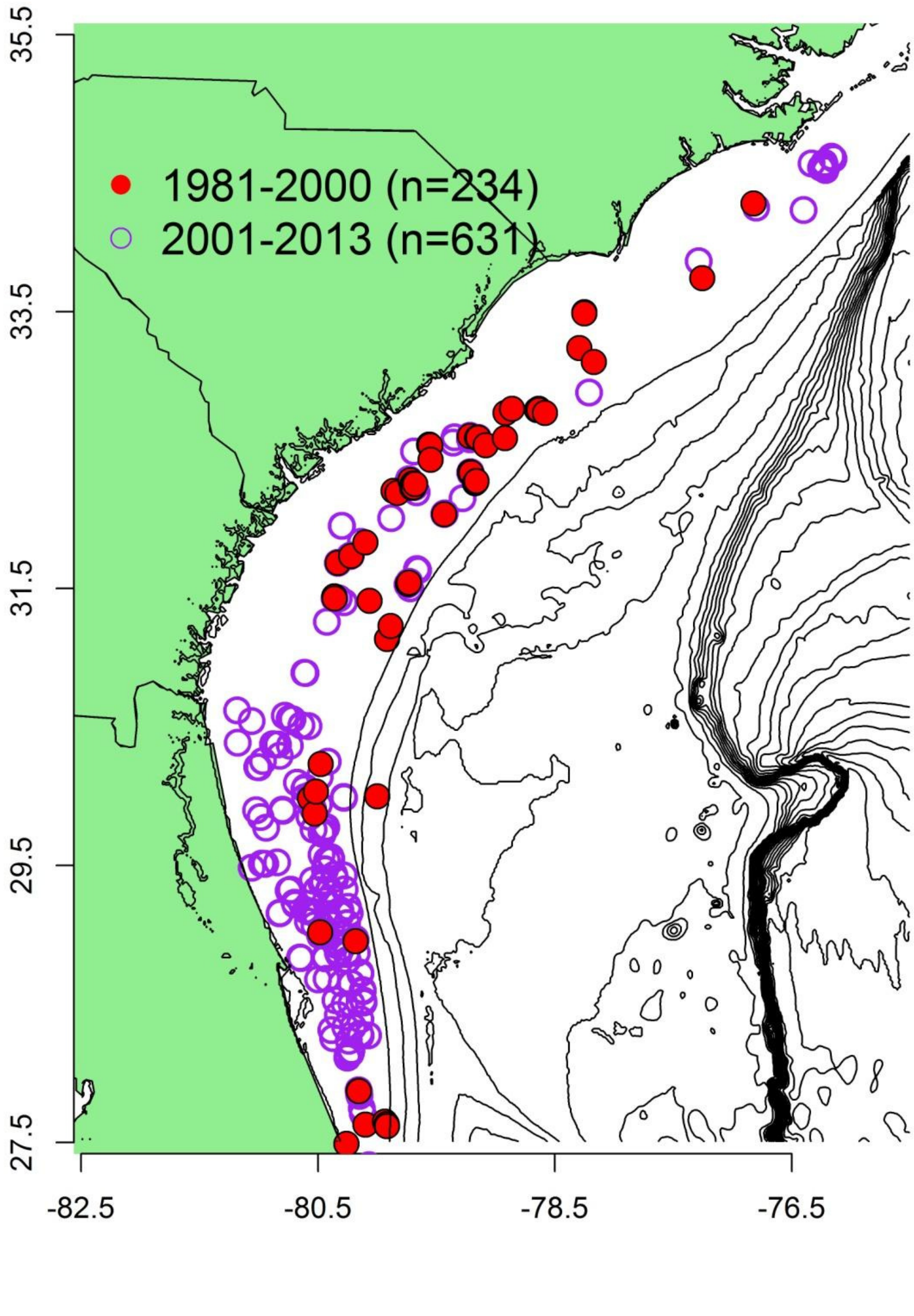


Figure 2.13

Scatterplot of Red Snapper batch fecundity estimates by max total length (TL; mm). Black points represent observed values, while lines indicated models fit by several methods. The solid blue line is a power model fit with negative binomial error (i.e. the recommended method) and the shaded area represents the 95% CI around that line. The dashed line represents a linear fit to log transformed TL and batch fecundity, while the dotted represents this same fit, incorporating a bias correction (Figure from SEDAR41-DW49).

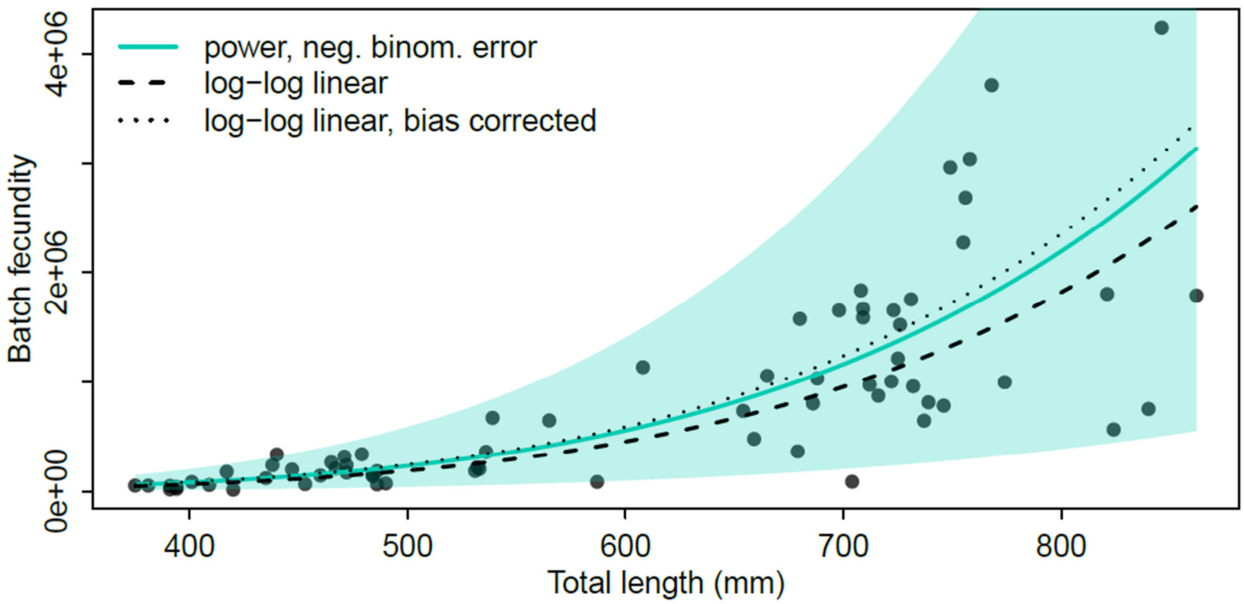
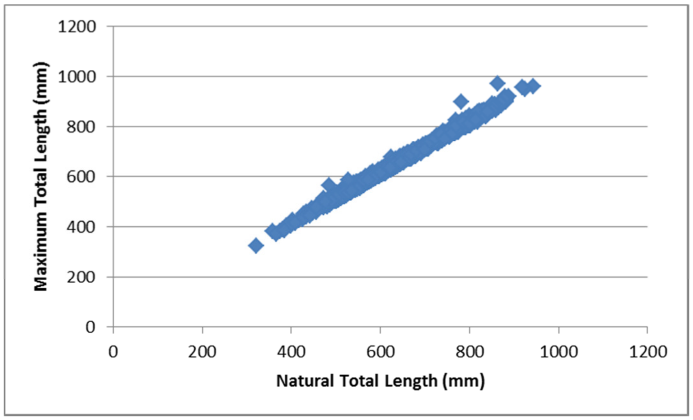
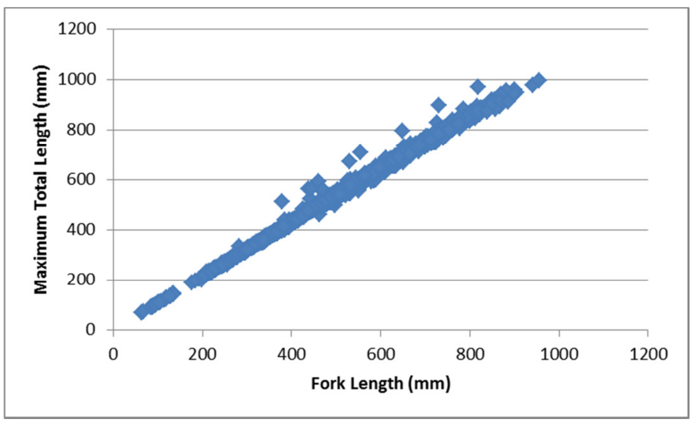


Figure 2.14

Red Snapper scatter plot of raw data used in conversion equations. The various plots represent the various length – length relationships. Data from a variety of fishery dependent and fishery independent sources were used. See Table 2.20 for equations and statistics.





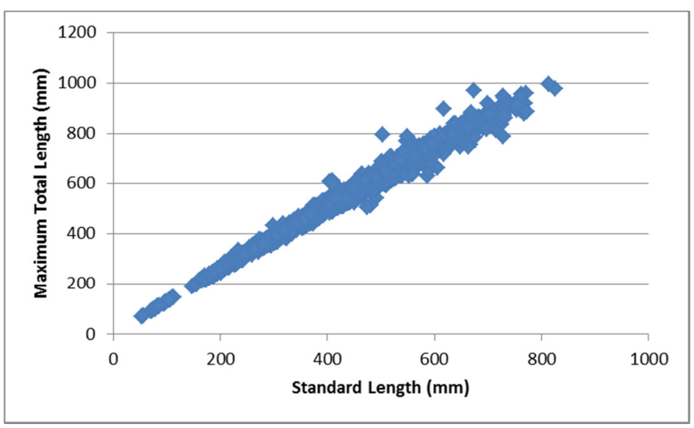
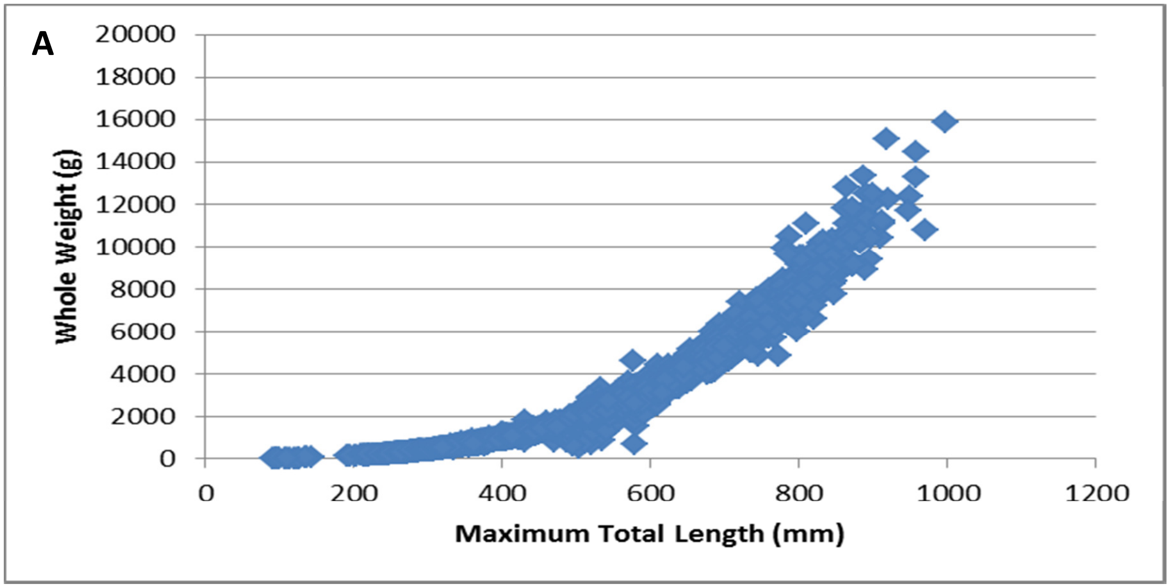
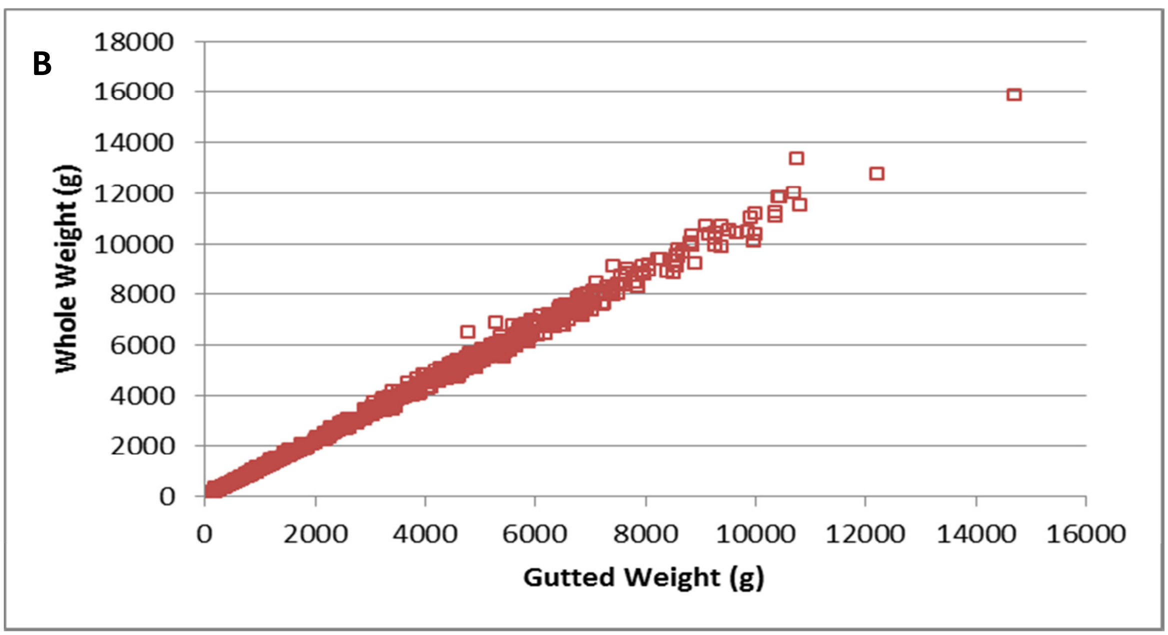


Figure 2.15

Red Snapper scatter plot of raw data used in conversion equations. Whole Weight – Maximum Total Length (A) and Whole Weight – Gutted Weight (B). Data from a variety of fishery dependent and fishery independent sources were used for analysis. See Table 2.21 for equations and statistics.





3. Commercial Fishery Statistics

3.1 Overview

Stock boundaries for red snapper in SEDAR 24 were between the GMFMC/SAFMC jurisdiction line in the Florida Keys to the NC/VA border. For SEDAR 41, the Life History Workgroup recommended using all data north of North Carolina.

Topics discussed by the Commercial Workgroup began with a discussion of stock boundaries, both the southern boundary with the Gulf of Mexico and the northern boundary (north of North Carolina).

To develop annual landings by gear and state, no adjustments were deemed necessary for misidentification of red snapper with other snapper species or inclusion of unclassified snappers that would have been analogous to SEDAR assessments for other snapper-grouper species. Commercial landings for the U.S. South Atlantic red snapper stock were developed by gear (handline, diving/spears, other) in whole weight for the period 1950 through 2014 based on federal and state databases. Intermittent landings estimates from historical reports were also consulted for 1902-1949. Data were more consistent after 1926 so historic data from 1927-1949 will be provided. Interpolated data for years when no red snapper were reported between 1927 and 1949 were calculated based on ratios of reported landings by state during years when at least one state reported. Corresponding landings in numbers were estimated from mean weights estimated from TIP by gear, state, and year for 1950-2014.

Discards, developed from the snapper-grouper logbook, were estimated for recent years (1993-2014) subsequent to the last change in minimum size limit for red snapper along the U.S. South Atlantic coast. Sampling intensity for lengths and age by gear, state and year were considered, and length and age compositions will be developed by gear and year for which sample size was deemed adequate.

Several research recommendations were updated and amended from SEDAR 24.

3.1.1 Commercial Workgroup Participants

Julie DeFilippi	Workgroup co-leader/ Data Provider	ACCSP
Kevin McCarthy	Workgroup co-leader/ Data Provider	SEFSC Miami
Joe Myers	Rapporteur/Data Provider	ACCSP
Steve Brown*	Data provider	FL FWC
Julie Califf	Data provider	GA DNR

Amy Dukes	Data provider	SC DNR
Kenny Fex	Commercial	NC/Snapper-Grouper AP
Stephanie McInerny*	Data provider	NC DMF
David Nelson	Commercial	FL
Larry Beerkircher*	Data provider	SEFSC Miami
2014 Only Workshop		
Neil Baertlein	Workgroup leader	SEFSC Miami
Zach Bowen	Commercial	GA/SAFMC
Chris Conklin	Commercial	SC/SAFMC
Jack Cox	Commercial	NC/SAFMC
Refik Orhun*	Data provider	SEFSC Miami

3.1.2 Issues Discussed at the Data Workshop

Landings issues discussed at the data workshop historic included landings, apportionment of Florida landings, and quantifying uncertainty. Historic reported landings, pre-1950, are largely incomplete and likely inaccurate. Whether or not to interpolate landings was discussed. Landings collected by the Florida Trip Ticket program are often felt to have mis-reported gear and area. NOAA's Coastal Fisheries Logbook data were used to correct for this, however 2010-2014 data could not be used for mean proportions for landings prior to 1993. Since landings data are simply summed, no value of uncertainty could be calculated. It was therefore discussed to use the methodologies used in SEDAR24 to estimate CVs based on method of data collection.

Discard issues discussed primarily involved the inclusion and exclusion of open and closed season discard rates from 2010-2014. Ultimately these years were treated separately.

Methods of extracting and filtering TIP length data were also discussed by the workgroup.

3.2 Review of Working Papers

SEDAR41-DW09: This report discussed fishery-independent and fishery-dependent sampling of red snapper during 2012 and 2013 when there were limited commercial seasons. It was determined that TIP samplers in Florida were actively targeting red snapper while sampling, therefore, estimated trip compositions during these years may have higher red snapper counts compared to years when red snapper sampling was random.

SEDAR41-DW22: This report suggested a re-evaluation of the gear selectivities used in the red snapper stock assessment for South Atlantic hook and line fleets.

SEDAR41-DW23: This report documented the development of the red snapper fishery in the US South Atlantic over time and discusses decadal advances in equipment and gear since the late 1800s.

SEDAR41-RD10: This report presented estimates of red snapper landings and discards from the commercial and recreational fisheries in 2012. Landings and discards were not provided by gear grouping. In the South Atlantic, commercial landings data from recent years are typically provided by the state for stock assessments to ensure edits performed after the data are sent to ACCSP are captured. These estimates were not used by the Commercial Workgroup.

SEDAR41-RD13: This report presented estimates of red snapper landings and discards from the commercial and recreational fisheries in 2013. Landings and discards were not provided by gear grouping. In the South Atlantic, commercial landings data from recent years are typically provided by the state for stock assessments to ensure edits performed after the data are sent to ACCSP are captured. These estimates were not used by the Commercial Workgroup.

SEDAR41-RD39: This report discussed data from 2007-2010 collected by an observer program tasked to characterize the shrimp fisheries in the US Gulf of Mexico and South Atlantic. Data for the South Atlantic penaeid and rock shrimp fisheries are available back to 2008. Red snapper bycatch between 2008 and 2010 was very minimal. The total impact of shrimp trawls on the red snapper fishery was determined by the Commercial Workgroup to be negligible.

Review and final decisions determined during 2014 workshop.

3.3 Commercial Landings

DW ToR #6: *Provide commercial catch statistics, including both landings and discards in both pounds and number. Evaluate and discuss the adequacy of available data for accurately characterizing harvest and discard by species and fishery sector or gear. Evaluate, discuss, and characterize the sources of uncertainty, and data limitations (such as temporal and spatial coverage) for each data source. Provide ranges and/or distributions of uncertainty for data sources used in the stock assessment models. Provide length and age distributions for both landings and discards if feasible. Provide maps of fishery effort and harvest by species and fishery sector or gear.*

Commercial landings of red snapper were compiled from 1950 through 2014 for the entire US Atlantic Coast. Sources for landings in the US South Atlantic (Florida through North Carolina) included the Florida Trip Ticket program (FTT), South Carolina Department of Natural Resources (SCDNR), North Carolina Division of Marine Fisheries (NCDMF), and the Atlantic Coastal Cooperative Statistics Program (ACCSP). Landings from the Mid- and North Atlantic (north of the NC-VA border) were solely from ACCSP. Further discussion of how landings were compiled from the above sources can be found in section 3.3.5.

3.3.1 Commercial Gears Considered

In preparation for the SEDAR 41 Data Workshop, the commercial working group settled on the following numerical gear codes (ACCSP) for dividing red snapper commercial landings into three categories for consideration by the Workgroup. These gears are detailed in Table 3.1 and included:

Handline (300-303, 320, 700, 701),
Diving (660, 661, 750), and
Other (remaining gear codes including unknown).

Separating handline and diving gears was done because there are differences in the discard mortality and there may be differences in the selectivity and, therefore, length data between the two gears. Diving gear may catch larger red snapper on average.

These were the same gear groupings chosen in SEDAR 24; however, for SEDAR 24, landings with "other" gear type were pooled with handlines, the dominant gear. After further consideration by the Commercial Workgroup, the "other" gear type will be provided separately for SEDAR 41.

Decision 1: The Commercial Workgroup suggested grouping red snapper landings into three gear categories: Handline, Diving/Spears, and Others. The "other" gear category can be lumped into Handline if necessary.

This decision was approved by the plenary.

3.3.2 Stock Boundaries

DW ToR #1*: Review stock structure and unit stock definitions and consider whether changes are required.*

Landings will be provided from the GMFMC/SAFMC boundary in the Florida Keys and extend to north to the most northern extent of reported red snapper landings. The extent of the range can be seen in Figure 3.1 and the GMFMC/SAFMC boundary in Figure 3.2. Landings were obtained from the states north of North Carolina (ACCSP). Prior to 1987, reported red snapper landings were infrequent, occurring only in 1950 (300 lbs whole weight), 1970 (300 lbs), and 1983 (100 lbs). Landings became more frequent beginning in 1987, with positive landings for 1987-1988, 1992-1999, and 2001-2014. If we assume landings were truly 0 in those years none were reported for 1950-2014, then the average annual reported landings of red snapper from north of North Carolina was 98pounds (whole weight). While assuming years with no landings were zero, average landings beginning in 1987 was 234 pounds.

Decision 2: The Life History Workgroup recommended using all available data from the GMFMC/SAFMC jurisdiction line in the Florida Keys to as far north as landings were reported on the Atlantic coast. Because very few red snapper landings were reported north of North Carolina, the addition of these landings should not have an effect on overall landings trends.

This decision was approved by the plenary.

3.3.3 Misidentification and Unclassified Snappers

The next topics of discussion included whether misidentification of red snapper with other snapper species was a concern and whether red snapper landings may be incorporated in significant quantities in the unclassified snapper category. Neither of these issues was considered significant by the SEDAR 15 and SEDAR 24 Commercial Workgroups. The SEDAR 41 Commercial WG discussed and agreed with this decision. There are similar species to red snapper being landed but markets and regulations are different so there should be no misidentifications. Also red snapper have always been kept separate from the unclassified snappers because of their value. If any unclassified snappers were actually red snapper then it was insignificant. Data supporting this is anecdotal.

Decision 3: The Workgroup concurs with prior SEDAR decisions that concerns about mis-identification and unclassified snappers are not significant, and no adjustments are needed.

This decision was approved by the plenary.

3.3.4 Historical Commercial Landings

Historic landings were obtained from NOAA Fisheries' Office of Science and Technology which has available landings from 1880-1949. While reported landings are available back to 1880, consistent landings aren't seen until the 1920s. For this reason, we are providing landings from 1927 through 1949. This is also consistent with what was provided in SEDAR 24. After 1927 there are some gaps in reported landings, including 1933, 1935 and most of the 1940s. For these years when no landings were reported, linear interpolations were made using the first year before and first year after the gap in reporting. Interpolated values were for the years' total landings. Apportionments to state were based on a state's average proportion for years known. For years when at least 1 state reported, null landings were treated as zero. Treating these nulls as missing and inserting a given states' proportion based on 'complete' years, resulted in unrealistically high landings. Landings for the years 1942-1944 were made zero due to the port closures during

World War II. Reported and interpolated landings will be provided with the interpolated landings marked as such for possible exclusion in the assessment (Table 3.2, Figure 3.3).

Decision 4: Provide historic landings for 1927-1949. Interpolated values will be provided and noted.

This decision was approved by the plenary.

3.3.5 Commercial Landings by Gear and State

Statistics on commercial landings (1950 to present) for all species on the Atlantic coast are maintained in the Atlantic Coastal Cooperative Statistics Program (ACCSP) Data Warehouse. The Data Warehouse is an online database of fisheries dependent data provided by the ACCSP state and federal partners. Data sources and collection methods are illustrated by state in Figure 3.4. The Data Warehouse was queried in August 2015 for all red snapper landings (annual summaries by state and gear category) from 1950–2014 from Florida (Atlantic coast plus Monroe County) through Maine (ACCSP 2015). Data are presented using the gear categories as determined at the workshop. The specific ACCSP gears in each category are listed in Table 3.1. Commercial landings in pounds (whole weight) were developed based on classified red snapper by the Workgroup from each state as available by gear for 1950-2014.

<u>Florida</u>

Comparisons were made between Florida's commercial trip ticket data (1986-2014) and the NMFS logbook data (1992-2014). Both datasets were very similar in landings trends and level of landings reported for matching years by gear. The workgroup decided to use the total red snapper landings from the Florida trip ticket data over the logbook data primarily because the logbook data were of a shorter time series and trip ticket data are more complete from year to year. Red snapper have always been reported to species in Florida trip ticket. Final landings are reported as whole weight pounds.

One issue that arose with regard to red snapper landings from Florida South Atlantic waters in the trip ticket data was how to separate South Atlantic from Gulf of Mexico landings in Monroe county (Florida Keys). Red snapper landings in Monroe county have historically been a small portion of the Florida SA landings averaging about 4% annually. However, regulations limiting East coast harvest in recent years caused an increase in the proportion of Monroe South Atlantic red snapper to total Florida South Atlantic red snapper to as much as 10% in 2010 per NMFS logbook. It was decided to use the NMFS logbook data to proportion out South Atlantic red snapper in the trip ticket data since it is believed that fisher reported area fished data were generally more accurate than area fished data reported by dealers. Additionally, it was decided to use NMFS logbook data to apportion landings by gear in the trip ticket data. While both

programs collected gear by trip over the same time series (since 1992), the workgroup decided that gear reported by fisher would generally be more accurate than dealer reported gears.
The total amount of South Atlantic red snapper by year in the Florida was determined by first calculating the proportion of Monroe county South Atlantic red snapper in the logbook data for years 1993-2014. This was done by dividing the amount of SA red snapper into total red snapper landings for Monroe county only, then applying those proportions to the corresponding years for Monroe county total red snapper landings from the trip ticket data. An average proportion for SA Monroe county was calculated from the combined 1993-2014 logbook data and applied to corresponding total Monroe red snapper landings in the trip ticket data from 1986-1992. South Atlantic Monroe county and non-Monroe South Atlantic landings from trip ticket data were then combined into total South Atlantic red snapper landings for Florida. NMFS logbook data were then used to calculate proportions of Florida South Atlantic red snapper harvest by gear. This was done by dividing landings for each gear into total Florida South Atlantic landings, then applying those proportions to the total South Atlantic red snapper landings for Florida by year from 1993-2014. The average proportion of logbook landings over all years by gear was then applied to trip ticket landings from 1986-1992.

Landings from the ACCSP database were selected for 1950-1985.

Decision 5: The Workgroup recommends using 1993-2014 logbook data to apportion Florida landings prior to 1993.

This decision was approved by the plenary.

Georgia

GA DNR staff examined ACCSP landings and compared them to state held versions. It was determined that ACCSP landings were a match and would be used in place of state provided data for the entire time series.

South Carolina

Landings data for red snapper in South Carolina came from two different data sources. The old NMFS Canvass system data, supplied by ACCSP, provided landings data for the state from 1956 to 1971. Data from 1972 to 2014 was provided by SCDNR. This incorporated two different data reporting styles, the first from 1972 to 2003, allowed wholesale seafood dealers to report total monthly landings by species. The second data reporting style, 2004 to 2014, required wholesale seafood dealers to complete individual trip-level. All landings data are provided by year and approved gear type.

Red snapper were landed in gutted pounds. The South Carolina conversion factor used (1.075) to calculate whole pounds was different then the recommended and approved SEDAR 41 conversion factor (1.10). From 1972 to 2003, landings were only available in whole pounds, and since 2004, both gutted and whole pounds were available. To be consistent, all whole pounds were back calculated using the state applied conversion to determine gutted pounds and then the SEDAR 41 conversion factor was applied to determine whole pounds for all years of data. Gear combinations recommended by the Commercial Workgroup for Red Snapper were Handline, Diving/Spears, and Other.

North Carolina

Prior to 1978, the National Marine Fisheries Service collected commercial landings data for North Carolina. Port agents would conduct monthly surveys of the state's major commercial seafood dealers to determine the commercial landings for the state. Starting in 1978, the North Carolina Division of Marine Fisheries entered into a cooperative program with the National Marine Fisheries Service to maintain the monthly surveys of North Carolina's major commercial seafood dealers and to obtain data from more dealers.

The North Carolina Division of Marine Fisheries Trip Ticket Program (NCTTP) began on 1 January 1994. The NCTTP was initiated due to a decrease in cooperation in reporting under the voluntary NMFS/North Carolina Cooperative Statistics Program in place prior to 1994, as well as an increase in demand for complete and accurate trip-level commercial harvest statistics by fisheries managers. The detailed data obtained through the NCTTP allows for the calculation of effort (i.e. trips, licenses, participants, vessels) in a given fishery that was not available prior to 1994 and provides a much more detailed record of North Carolina's seafood harvest.

North Carolina commercial landings of red snapper were provided for 1972-2014 by year and gear type. Landings for North Carolina before 1972 were provided by ACCSP. Gears were grouped into the following categories: Handlines, Diving/Spears, and Others[1]. Most red snapper in North Carolina are reported in gutted condition. From 1972-1993, whole pounds were converted back to gutted using the state conversion code of 1.08 and reconverted to whole pounds using the conversion factor provided by the Life History Workgroup (1.10). From 1994-2014, landings reported as gutted were converted to whole pounds using 1.10. Landings reported as whole were not reconverted.

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[1] SAS code used to group trip ticket gears into these categories:

```
If Gear1=480 and Gear2=610 and Gear3=. Then Gear1=610;
If Gear1=676 and Gear2=660 and Gear3=. Then Gear1=610;
If Gear1=677 and Gear2=610 and Gear3=. Then Gear1=610;
```

```
Length Geartype $ 15;
If (600 LE Gear LE 616) or Gear in (660,665) Then Geartype='Handlines';
Else if Gear in (760,943) Then Geartype='Spears';
Else Geartype='Others';
```

Combined State Results

Landings are presented in Tables 3.3 and 3.5 and Figures 3.5-3.6. Since 1950, Florida produced over 81% of the commercial harvest, Georgia 4.7%, South Carolina 7.6% and North Carolina 6.1%. Since 1950 handlines have represented about 97% of the catch compared with 2% for diving, and just under 1% other gears.

Decision 6: The Workgroup made the following decisions for reporting commercial landings:

- Landings should be reported as whole weight in pounds and number of fish
- Final landings data would come from the following sources:
    - VA-North: 1950-2014 (ACCSP)
    - NC: 1950-1993 (ACCSP)
      1994-2014 (NCDMF)
    - SC: 1950-1979 (ACCSP)
      1980-2014 (SCDNR)
    - GA: 1950-2014 (ACCSP)
    - FL: 1950-1985 (ACCSP)
      1986-2014 (FL FWC)

This decision was approved by the plenary.

Whole vs. Gutted Weight

Historically, conversions between whole and gutted weight have been based on state specific values. The standard conversion of snappers for Georgia and Florida from gutted weight to whole weight is by multiplying gutted weight by 1.11. South Carolina uses a conversion of about 1.075, obtained by dividing gutted weight by 0.93. North Carolina uses a conversion multiplier of 1.08. For all states North of North Carolina because the conversion factors typically used by each state was not known at the Data Workshop, the federal conversion of 1.08 was assumed. During SEDAR 41, data by state were converted back from whole pounds to gutted weight using the above mentioned conversions and then from gutted weight to whole weight based on data from the Life History Workgroup. The no-intercept regression estimate for slope is 1.10 (the ratio of means for gutted weight to whole weight).

Decision 7: The Commercial Workgroup will provide red snapper landings in pounds whole weight.

This decision was approved by the plenary.

Confidentiality Issues

Landings of red snapper were pooled across states by gear to meet the rule of 3 and ensure confidential landings were not presented in this report. Landings by state and gear will be provided to the data compiler for use in the assessment.

Uncertainty (2015 data workshop)

The commercial workgroup estimated uncertainty in commercial fishery landings, after consultation with assessment biologists, by modifying the methodology used in SEDAR 24. These estimates of uncertainty are not coefficients of variation, but are estimates of possible reporting error; i.e., represent the range in actual commercial landings relative to the reported landings.

In making these uncertainty estimates, two assumptions were made:

1. *Landings may be underreported during all years; however, underreporting was likely highest during early years of the time series and were more accurate in recent years.* This assumption was based upon the following information and data workshop expert testimony: during the period 1950 (beginning of landings time series) to 1961 landings were summarized annually by state and likely did not include landings from small scale dealers. In the years 1962-1977 landings data were collected annually, but under a more all-inclusive program (General Canvass). Monthly landings summaries were collected during the period 1978 to the beginning of trip ticket data collection (starting dates vary among states). The most recent landings data, collected through state trip ticket programs, were assumed to be most reliable and inclusive of all red snapper commercial landings.
2. *Landings may be overestimated during the years 1950-1977 because vermilion snapper may have been reported as red snapper landings.* Market values of similarly sized vermilion snapper and small red snapper were identical and no effort was made to differentiate species specific landings. This practice was phased out during the mid to late 1970's. The workgroup chose 1977 as the final year of misreporting based

upon expert testimony and observed increases in reported vermilion snapper landings. The workgroup recognizes that misreporting of vermilion snapper landings as red snapper landings diminished gradually over time, but lacks sufficient data to accurately characterize that trend.

During workgroup discussions it was recognized that using the levels of landings uncertainty recommended during SEDAR 24 (40-50% uncertainty) would poorly inform the assessment model of landings during the early years of the time series (1950-1977). The group agreed, based upon expert opinion, that an upper bound ½ that recommended during SEDAR 24 be used for the period from 1950-1977 (i.e., 25% landings during 1950-1961, 20% during 1962-1977, 10% during the period 1978 until implementation of state trip ticket programs (varies by state), and 5% during the period of trip ticket reporting (state specific starting years). See Table 3.5, Figure 3.4 for state specific bounds.

The workgroup recommended that a lower bound be set to account for vermilion snapper misreported as red snapper. The workgroup recognized the possibility that such misreporting may have resulted in an underestimate of the true red snapper landings. The lower bound for commercial landings uncertainty was set based upon expert opinion because the workgroup was aware of no available data by which a direct estimate of vermilion snapper misreporting could be estimated. The lower bound of landings uncertainty was set as symmetric with the upper bound for the period from 1950-1977, following the modified SEDAR 24 recommendation (Table 3.4, Figure 3.4).

Decision 8: The Workgroup recommends estimating landings uncertainty following modified (as per discussions with assessment biologists) SEDAR 24 recommendations for landings upper bound and lower bounds.

This decision was approved by the plenary.

3.3.6 Converting Landings in Weight to Landings in Numbers

Commercial landings in weight were converted to commercial landings in numbers based on average weight (in pounds whole weight) from the TIP data for each state, gear, and year. These data were generally available from 1983 to 2014 for handlines. Data for the remaining gear types were sparse, with much more limited data from diving and other gear types available (annual sample sizes by gear, state and year are summarized in Table 3.12). For 1983-2014 annual estimates of mean weight by state and year for handline were applied to the corresponding landings in weight when sample size greater than or equal to 50 (Table 3.6). For years when samples size was less than 50, a mean weight calculated from all years was applied by state. Since no lengths were available for northern states (Virginia through Maine), a mean across all states was applied. The mean weight as calculated from all years was also applied to those years from 1950-1982.

Samples for diving and other gear was limited and sporadic, which would have resulted in a collapsing strata to a single overall mean weight for a gear in order to yield adequate sample sizes. Additionally, large sample sizes in longline and trawl in the 'Other' gear skewed means. More detailed discussion can be found section 3.6.1. The workgroup determined that mean weights as calculated for the handline would be applied to all landings. Calculated numbers of fish can be found in Table 3.5 and Figure 3.6. Mean weights by state and year are provided in Table 3.6.

3.4 Commercial Discards

3.4.1 Directed Fishery Discards

2015 updated analyses

Calculations of the total number of red snapper discarded or kept as bait/eaten from the commercial fishery were updated to include data from 2014. For the 2015 Data Workshop, discards from the trolling fishery were also calculated because some red snapper discards were reported by those vessels. Methods were otherwise unaltered from those recommended during the initial SEDAR41 data workshop in August 2014. Updated calculated discards are provided in Tables 3.7-3.10. Calculated discards for all gears other than vertical line (handline and electric/hydraulic gear) were low. The number of calculated red snapper kept for bait or eaten never exceeded 54 fish in any year for all gears combined and were fewer than 12 fish in all other years. Tables of red snapper kept for bait or eaten have not been provided. Very minor differences in calculated discards between the 2014 data workshop calculations and the 2015 calculations were likely due to updates or edits to the discard logbook and/or coastal logbook data sets.

2014 analyses

Commercial discards were calculated for vertical line (handline and electric/hydraulic reel) vessels in the US South Atlantic using methods described in SEDAR41-DW36. Other gears reported 51 or fewer total trips (per gear) with red snapper discards during the period 2002-2013.

Two methods were used to calculate total discards. A continuity approach followed the methods of SEDAR24 and the 2010 update assessment. Those assessments used delta-lognormal model generated least squares means of year-specific discard rate to calculate total yearly discards for the period 2002-2013 (when discard data were reported). Discard rate for the period 1992-2001 (prior to discard reporting) was assumed to be the mean discard rate over the years 2002-2013, weighted by sample size. An alternative method used yearly nominal discard rates for the years

2002-2013. Separate discard rates were calculated for open and closed red snapper fishing seasons. Calculation of discards for the years 1992-2001 used the mean discard rate for the years 2002-2009 (years with no closed seasons). Both methods used discard rates multiplied by year specific total vertical line effort reported to the coastal logbook program to calculate total discards. Discards were reported in numbers of red snapper.

The working group recommendation and the final recommendation made in plenary session were to calculate total discards using nominal discard rates. To address likely underreporting of discards (reporting “no discards” allows the fisher to remain in compliance for renewing federal fishing permits), data included in that calculation were filtered to remove records from vessels that never reported discards of any species during a year. In addition, data from vertical line vessels that reported more than 17 trips without reporting discards of any species (17=the mean number of reported trips prior to the first trip with reported discard plus two standard deviations of that mean) were excluded. Those data filters were used following the recommendation of the SEDAR32 data workshop. Including data from those fishers that habitually reported no discards would have resulted in discard rates that were erroneously low. Trips targeting mackerel are unlikely to have discards of red snapper, therefore, trips that reported only landings of mackerel species were excluded from this analysis. Additional data filters included the removal of clearly erroneous data (values of gear-specific effort data beyond the 99.9 percentile of the data). Discard logbook data with multiple gears fished on a trip were also excluded because discards could not be unambiguously attributed to a particular gear. That data filtering step was not necessary when summing total effort from the logbook data because reported effort data was gear-specific.

Decision 9: The Workgroup accepts the discard estimates of red snapper for 1992-2014 as developed in working paper S41-DW36.

This decision was approved by the plenary.

The commercial working group accepted the methods described in SEDAR41-DW36 for calculating commercial vertical line vessel red snapper discards for the years 1992-2013. Red snapper discards were reported from 51 or fewer trips with gear other than vertical lines, suggesting that discards from other commercial gears was minimal. The specific method chosen by the working group was the use of year and fishing season (open/closed) specific nominal discard rates. Those discard rates were used with corresponding year and season specific total vertical line effort reported to the coastal logbook program to calculate total discards. The working group also endorsed using the mean discard rate over the years 2002-2009 (years with no red snapper seasonal closures), weighted by sample size, as the discard rate for the period 1992-2001 (prior to discard reporting). During 1992 only 20% of vessels in Florida were required to report to the logbook program; effort reported for Florida was expanded by a factor of five. No effort data were available for calculating discards prior to 1992.

The discard calculations rely on self-reported discard and effort data. Perhaps the most important source of error in the commercial discard calculations was misreporting and non- reporting of discards, both of red snapper and other species. An effort was made to minimize that potential error by removing data from vessels that never reported discards of any species during a year. In addition, data from vertical line vessels that reported more than 17 trips without reporting discards of any species (the mean number of reported trips prior to the first trip with reported discard plus two standard deviations of that mean) were excluded. Although such clear instances of discard non-reporting were identified and excluded, other cases of non-reporting and misreporting have not been quantified. The degree to which continued non or misreporting may have affected the discard calculations is unknown.

The total commercial discards provided in SEDAR41-DW36 may represent a minimum estimate of the number of red snapper discarded from the commercial fishery.

Decision 10: The conclusion of the commercial working group was that given the very limited observer data, fisher reported discard data represent the best available information on commercial red snapper discards.

This decision was approved in plenary.

3.4.2 Shrimp Bycatch

The possibility of constructing red snapper bycatch estimates from the south Atlantic shrimp fishery was investigated. Beginning in 2007, a mandatory observer program was put in place to sample trips in the penaeid and rock shrimp fisheries. During this time only 7 fish, from 872,192 pounds of samples (shrimp and fish), were encountered. These seven red snapper were caught only in rock shrimp trips. Additionally, several fishers present at the data workshop, who have fished in the shrimp fishery, corroborated this extremely low encounter rate. The workgroup felt that total bycatch is negligible in the shrimp fishery and therefore recommended not modelling shrimp bycatch.

Decision 11: Red snapper bycatch from the shrimp fishery will not be constructed as bycatch is negligible.

This decision was approved by the plenary.

Review and final decisions determined during 2014 workshop.

3.5 Commercial Effort

The distribution of directed commercial effort in trips by year was compiled from the Coastal Fisheries Logbook Program (CFLP) for 1993-2013 and supplied here for informational purposes. These data are presented in Figure 3.7. The distribution of harvest by statistical grid, as reported to the CFLP, is a displayed in Figure 3.8. Figure 3.9 shows a distribution of harvest by depth and latitude.

Review and final decisions determined during 2014 workshop. Not updated at 2015 workshop.

3.6 Biological Sampling

<u>Length Samples</u>

Commercial length data were available from the SEFSC Trip Interview Program for all years, 1983 to 2014. TIP data were pulled from the SEFSC TIPONLINE.TIP_MV table, which is a master view table that collapses the one-to many relational tables in the main TIP database tables. The TIP_MV table is audited weekly to insure that the contents agree with the master data tables.

REGIONS other than South Atlantic are filtered out. Data were assigned as South Atlantic samples via a hierarchal procedure. If area fished was in the interview's effort information (e.g. usually derived from captain), this information was used. If the Captain's information was not available, but area fished was provided in the interview's landings information (e.g. derived from the dealer's records/trip tickets), then the landings information was used. If area fished was in neither the effort nor the landings information, then the state and county of landing were used to make a region assignment (e.g., all records not previously resolved that landed in NC, SC, or GA were assumed to be south Atlantic samples, and all records not previously resolved that landed in FL's east coast counties (Dade county northward) were also assumed to be south Atlantic samples).

IS_DISABLED='Y' TRIPS are filtered out. TIP allows errant data to exist in the database until such time as the issue can be resolved. TIP also allows testing trips in the production database. These only make up 0.2 % of all south Atlantic TIP interviews. It is unlikely that BSD would import these records and that agents would send age structures from errant trips. Agents cannot disable trips, only system and database administrators can.

FISHING_MODE<>'COMMERCIAL' are filtered out. TIP is meant to be a commercial representative sampling program, however the TIP database has been used to house recreational, scientific, experimental, etc. data collections. Non-commercial trips make up 14% of south Atlantic TIP interviews.

BIAS_TYPE<>'NO BIAS KNOWN' are filtered out. In the past, samplers where asked to record if they felt the trip was representative, or biased for some particular reason. Trips with a bias indicated make up 1.9% of south Atlantic TIP interviews.

INTERVIEW_TYPE='TRIP_SURVEY' are filtered out. An interview type coded Trip Survey means that the sampling was taken from the aggregated landings of more than one trip (this could involve a single vessel but multiple trips, or multiple vessels). In these cases, if the sampler knew that the gear type and/or area fished varied among the trips included in the trip survey, historical practice was to assign area fished and gear type to what the sampler believed characterized the "majority" of the catch (and therefore in theory the majority of the sampled specimens). Since area fished and gear type cannot be conclusively identified for a trip survey, then if these variables are necessary for the assessment, they should be filtered out. It should be noted that this filter disproportionately affects the lengths available from South Carolina samples in the 1980's and early 1990's. For example, in the south Atlantic data overall trip survey lengths are about 2% of the data, but for South Carolina trip survey lengths account for 41% of the length data. Filtering out these records results in zero lengths for South Carolina in the years 1985, 1986, 1987, 1989, 1990, 1992, and 1995.

GEAR TYPE: Will be determined by the first gear type listed in the trip record. The assumption is that if a trip uses multiple gear types, a single gear type is the primary type used, and is listed by the sampler first. Where a gear type was not obtained via an interview, then the gear information from the dealer was used.

OBSERVATION-SPECIFIC FILTERING:

SAMPLE_RANDOM=NO are filtered out. Samples coded as 'NO" for this variable are assume to have some type of sampling issue; the sample was selected by a non-random or targeted method. These observations may not be representative of the trip's catch and should not be used. For red snapper, samples identified as non-random are 3% of the observations (after above trip filtering is applied as well).

CONDITION_TYPE='GUTTED-HEAD OFF' were removed as length collection should be impossible if the fish was in such condition. Null values for condition type were left in, as it was historically standard practice by many samplers to only record a condition when a weight was taken, also many samplers seemed to operate under the impression that leaving this value as null meant the fish was in standard industry condition (for red snapper, this means the head is left on). Only 4 records were affected by this filter.

LENGTH1_MM= NULL or 0 will be filtered out. A very small number of observations in TIP do not have length data. Some unreasonable lengths were filtered out: for red snapper two lengths of 59 and 70 mm were deleted as unreasonably small, and two lengths of 14541.5 and 5500 mm were deleted as unreasonably large, leaving the length range as 185 mm to 1120 mm.

Age Samples

Most of the age structures were obtained from TIP port agents and ageing analyst coordinated with TIP data collection experts to obtain consistency in filtering data. Ageing analysts contacted state sampling representatives to determine if increased sampling outside the TIP program in recent years were biased in any way. The increased sampling for red snapper since 2009 outside the TIP program accounts for the years with more ages than lengths. Given the complexities of the length and age databases, determining individual lengths not included in the length data may increase the probability of duplicating records and other errors.

3.6.1 Sampling Intensity

Length samples

Gear-specific summaries of the quantity and quality of the length data show that the majority of the length data available for red snapper are from the handline fishery (Table 3.11). All other gears are characterized by relatively poor annual sample sizes, coverage, and variability in the mean length and weight across gears. Annual sample sizes of lengths and number of trips sampled are summarized in Tables 3.12 and 3.13, respectively, by gear and state for red snapper in the U.S. South Atlantic from the TIP database for 1983-2014. The state-specific sample sizes are inadequate to weight samples for any of the gears. Even the most abundant gear, handline, has no length samples for many year/state combinations. A value of zero cannot be weighted and small sample sizes cause spikes in a composition for areas with average or greater landings. A comparison of the relative number of fish sampled across states to the relative landings across states is shown in Figure 3.11. Overall, North Carolina is relatively over-sampled for most of the time period, South Carolina is sporadic with many zero years prior to 1996 where it is then relatively oversampled, Georgia is sporadic through about 1994 with adequate sampling through 2006 and then undersampled, Florida, the state that dominates the landings, is relatively undersampled until about 1992 and then adequately sampled with the exception of a few low years. The workgroup recommends combining North Carolina and South Carolina length samples and weighting by the combined landings for handline gear. The workgroup recommends combining Georgia and Florida length samples and weighting by the combined landings for handline gear. The regional relationship between handline length samples and landings is shown in Figure 3.12. Diving sample sizes are inadequate to develop annual length comps with the exception of a few years. However, a qualitative comparison of the 6 years with 30 or more diving samples shows a general agreement with the handline gear with a shift towards slightly larger fish (Figure 3.10). The “other” gear includes sporadic sampling by states and very different gear types (e.g. longline and trawl).

Age samples
Annual sample sizes for commercial handline and other gears by state are given in Tables 3.14 and 3.15. The age samples are dominated by South Carolina through 1995, then Florida provides the majority if not all of the length samples by trip from 1998-2003. From 2004 to 2008 sampling is greater in the Carolinas.

3.6.2 Length/Age Distribution

Length distributions - Landings
All red snapper lengths were converted to maximum TL in mm using the formula provided by the SEDAR 41 Life History Workgroup and binned into one centimeter groups with a floor of 0.6 cm and a ceiling of 0.5 cm. The length data and landings data were divided into handline, diving/spears, and other gears. Unweighted red snapper handline annual length compositions are provided in the SEDAR 41 data workbook and shown in Figure 3.13.

Age distributions – Landings
Calendar ages were determined by ageing experts and provided to commercial composition analysts for summary. . Unweighted red snapper handline annual age compositions are provided in the SEDAR 41 data workbook and shown in Figure 3.14 (to a maximum of 47 years) and Figure 3.15 (pooled at 15 years).

Length distribution - Discards
Observer reported length frequency data of discarded red snapper were available for use in the SEDAR41 stock assessment. Sampling protocols and collection procedures of those data are reported in GSAFF (2008). Those data were collected from vessels fishing vertical line gear (handline and electric/hydraulic reels) between latitudes 30N and 33N during 2007-2011. A length composition was developed combined across years to represent discard sizes for years with a 20 inch size limit and after the 2010 closure. Data from 2007-2009 with 144 fish and 13 trips was used to develop the 20 inch size limit discard size distribution (provided in the SEDAR 41 data workbook and shown in Figure 3.16).

3.6.3 Adequacy for Characterizing Catch

Length samples
The TIP sample sizes for the development length distributions appear to be adequate for the commercial handline fishery with the exception of 1983 were only 35 fish were collected from 12 trips in North Carolina and 2010 where all fish come from 4 trips. Overall there is more uncertainty in the handline length data prior to 1996 and after 2009. Lack of coverage is the

primary reason for the increased uncertainty in the early and late years with the combined effect of the closure and mini-seasons for 2010-2014.

Lengths samples from the diving and other gear activities were limited. Ultimately the workgroup felt the length distributions for diving could be informed by the handline length distributions (Figure 3.10). Development of any length distributions from other gears would be uninformative due to the lack of spatial and temporal coverage and the disparity in mean length for the different gears. The total landings for all gears other than handline represents only about 6% of the overall landings and assuming they are represented by the handline length compositions would very minimally increase the uncertainty of an assessment.

Age samples

Age samples prior to 1996 when Florida samples are modestly represented may not adequately characterize catch as most if not all samples come from South Carolina. Weighting age compostions by length compostions can correct for bias in sampling age structures from the overall sample as well as region-specific differences.

Decision 12: The Workgroup recommends only development of a handline length distribution which should be weighted regionally (Car and GFL). Years with limited trips or very limited spatial coverage should not be used to characterize catch (including but not limited to 1983 and 2010). The workgroup recommends development of annual handline age compositons weighted by the annual handline length compositions. Years with limited trips or very limited spatial coverage should not be used to characterize catch.

3.7 Comments on Adequacy of Data for Assessment Analyses

Landings

The working group considered the majority of landings data from the U.S. south Atlantic to be adequate for assessment analyses. Data appeared to be most accurate and reliable from the various state data bases in the most recent years. This is likely due to the implementation of state trip ticket programs, beginning with Florida in 1986. Reliable monthly landings data can be found back to 1978. Historic landings prior to 1950 were found to be the least reliable, as there appears to be missing data for various years and states. It was also felt that proper species identification for reporting were made as red snapper is a highly sought fish and therefore handled separately from other snappers.

Discards

Discards estimates may be less adequate for assessment analyses. The only discard data available is from a self-reported data collection program. It is likely that recollections of fish thrown back are not always accurate and will vary from fisher to fisher. There is also an issue of 'no discard' trips reported. The frequency of 'no discard' trips has risen over the past 10 years, from 30% to over 60% of all discard reports submitted. It is unknown which of these are real and which reports were submitted simply to comply with reporting requirements. Observer data were investigated, but data were deemed insufficient for discard estimation.

Length and age samples

Length and age samples from the handline fishery are adequate for assessment analyses. The increased uncertainty for years with limited coverage could be modeled by reducing the weighting factor (typically trip sample size) by the proportion landings represented by missing states. However, length and age samples from diving and other gears are insufficient for analyses.

3.8 Relative Selectivity for Commercial Gears

To potentially address gear selectivity, SEDAR41 assessment scientists requested additional information concerning hook types and sizes used in the red snapper fishery through time. Most fishery dependent data collection programs do not collect this information including the various state trip ticket programs and the Coastal Fisheries Logbook Program. There is however, data available from a south Atlantic observer program that ran from mid-2006 through 2011. There were limited observer data that included hook size recorded from reels with red snapper catch. A total of 38 trips by 17 vessels with red snapper catch were observed from 2006 (1 vessel/1 trip) to 2011 (6 vessels/10 trips). All were vertical line (handline/bandit rig) trips. There were 785 red snapper observed: 456 discards, 320 landed, 6 kept as bait, and 3 with unknown disposition. Manufacturer hook sizes were recorded for 161 caught fish and there were 104 unique trip/set/reel/hook size combinations. Observers directly measured hook size more frequently than they recorded the manufacturer's hook size: 446 discarded red snapper and 317 landed red snapper have measured hooks size. These data along with further analyses will be provided at the SEDAR 41 Assessment workshop.

In addition to observer data, anecdotal data were provided by commercial fishermen. Captain Kenny Fex state that in the mid-1980s, off North Carolina, 5/0 J-hooks were used for small fish, while 10/0 J-hooks and 13/0 circle hooks were used for large grouper and snapper. By the mid-1990s J-hooks were no longer used as circle hooks were found to be more effective. In more recent years 4/0 and 12/0 circle hooks have been used for small and big fish. Two hooks per line has been the gear configurations consistently through this time period. Captain Chris Conklin also added that 10/0 and 12/0 circle hooks have been consistently used.

Lastly, it is worth noting that circle hooks sizes may vary between manufacturers (Serafy 2012). For example, a 10/0 circle hook manufactured by Mustad may be a different size than Eagle Claw's 10/0 circle hook.

Not updated at 2015 workshop.

3.9 Literature Cited

Atlantic Coastal Cooperative Statistics Program. 2015. Annual landings by custom gear category; generated by Julie Defilippi using ACCSP Data Warehouse, Arlington, VA: accessed August 2015.

Burns, Karen M, Nicholas F. Parnell, Raymond R. Wilson. 2004. Partitioning release mortality in the undersized red snapper bycatch: Comparison of depth vs. hooking effects. MARFIN Grant No. NA97FF0349, Mote Marine Laboratory Tech. Rep. No. 932, Sarasota, FL.

Chestnut, A.F. and H.S. Davis. 1975. Synopsis of marine fisheries of North Carolina. Part I: Statistical Information, 1880-1973. University of North Carolina Sea Grant Program Publication UNC-SG-75-12. 425 pp.

Fisheries Statistics Division. 1990. Historical Catch Statistics, Atlantic and Gulf Coast States, 1879-1989. Current Fishery Statistics No. 9010, Historical Series Nos. 5-9 Revised. (NTIS No. PB-93-174274)

Gulf and South Atlantic Fisheries Foundation (GSAFF). 2008. Catch characterization and discard within the snapper grouper vertical hook-and-line fishery of the South Atlantic United States. Final Report, Gulf and South Atlantic Fisheries Foundation, 5401 W. Kennedy Blvd, Suite 740, Tamp, Florida 33609-2447 (SEDAR24-RD61).

McCarthy, K. 2014. Discards of Red Snapper Calculated for Commercial Vessels with Federal Fishing Permits in the US South Atlantic. SEDAR41-DW36. Sustainable Fisheries Division Contribution SFD-2014-012.

Serafy JE, Cooke SJ, Diaz GA, Graves JE, Hall M, Shivji M, Swimmer Y. 2012. Circle hooks in commercial, recreational, and artisanal fisheries: Research status and needs for improved conservation and management. Bull mar sci. 88(3):371-391. http://dx.doi.org/10.5343/bms.2012.1038

3.10 Research Recommendations

The Workgroup reviewed recommendations from SEDAR 24 and offers additional recommendations:

Landings

- Improve gear and effort data for each trip.
- Standardize methodology for developing average proportions to parse out unclassified landings.

Discards

- Investigate the validity and magnitude of “no discard” trips. This may include fisher interviews throughout the region.
- Examine potential impacts of “no discard” trips on estimated discards.
- Improve discard logbook data collections via program expansion or more detailed reporting (i.e. electronic logbooks, etc.)
- Establish an observer program that is representative of the fisheries in the South Atlantic.

Biosampling

- Establish an observer program that is representative of the fisheries in the South Atlantic.
- Angler education with regards to recording depths on paper logbooks (i.e. standardized units); validation of additions to the logbook form still needed.
- Standardize TIP sampling protocol to get representative samples at the species level.
- Standardize TIP data extraction.

These recommendations were approved by the plenary.

3.11 Tables

Table 3.1 Specific ACCSP gears in each gear category for red snapper commercial landings.

HANDLINE

GEAR_CODE	*GEAR_NAME*	*TYPE_CODE*	*TYPE_NAME*	*SEDAR 41 CATEGORY*
300	HOOK AND LINE	007	HOOK AND LINE	HANDLINE
301	HOOK AND LINE, MANUAL	007	HOOK AND LINE	HANDLINE
302	HOOK AND LINE, ELECTRIC	007	HOOK AND LINE	HANDLINE
303	ELECTRIC/HYDRAULIC, BANDIT REELS	007	HOOK AND LINE	HANDLINE
320	TROLL LINES	007	HOOK AND LINE	HANDLINE
700	HAND LINE	013	HAND LINE	HANDLINE
701	TROLL AND HAND LINES CMB	013	HAND LINE	HANDLINE

DIVING

GEAR_CODE	*GEAR_NAME*	*TYPE_CODE*	*TYPE_NAME*	*SEDAR 41 CATEGORY*
660	SPEARS	012	SPEARS AND GIGS	DIVING
661	SPEARS, DIVING	012	SPEARS AND GIGS	DIVING
750	BY HAND, DIVING GEAR	014	BY HAND	DIVING

***ALL OTHER GEARS ARE GROUPED AS OTHER**

Table 3.2 Historical red snapper landings, in thousands of whole weight pounds, from 1927-1949. Interpolated values are in the shaded rows. Null pounds for non-interpolated years have been assumed '0'.

Year	FL	GA	NC	SC
1927	59	64	1	0
1928	47	22	2	0
1929	19	33	15	0
1930	34	30	5	0
1931	112	0	2	0
1932	49	0	0	0
1933	90	8	2	0
1934	152	0	0	0
1935	131	12	3	0
1936	140	0	0	0
1937	210	0	0	0
1938	117	0	1	0
1939	96	0	2	0
1940	14	0	0	0
1941	55	5	1	0
1942	0	0	0	0
1943	0	0	0	0
1944	0	0	0	0
1945	246	0	4	0
1946	245	22	5	1
1947	265	24	5	1
1948	286	26	6	1
1949	306	28	6	1

Table 3.3 Red snapper landings (pounds whole weight) by gear (handline, diving, other) from the U.S. Atlantic, 1950-2014. Confidential landings have been replaced with a '*'.

Year	Hand Line	Diving	Other
1950	354,973		13,684
1951	491,135	991	7,639
1952	380,838		5,093
1953	397,883	396	
1954	593,207		
1955	493,315		
1956	483,907		
1957	867,192		99
1958	612,508		
1959	657,736		
1960	670,877		198
1961	791,813		4,561
1962	645,290		694
1963	488,216		573
1964	537,490		99
1965	558,108		
1966	553,386		1,120
1967	724,586		917
1968	865,223		297
1969	523,468		14,723
1970	508,071		4,951
1971	457,393		
1972	383,123		23,518
1973	290,995		5,565
1974	476,366		1,986
1975	600,790		
1976	562,783		8,721
1977	593,664		2,676
1978	547,791	39,988	6,578
1979	392,069	27,184	1,684
1980	352,661	24,856	7,968
1981	342,731	21,645	14,382
1982	285,550	17,115	5,779
1983	294,240	18,378	4,199
1984	234,976	15,719	2,736
1985	231,294	16,904	2,626
1986	203,344	14,568	1,529
1987	173,914	14,113	3,674
1988	159,261	11,946	2,482
1989	250,199	14,316	2,427
1990	209,566	12,227	4,749
1991	128,782	8,183	6,581
1992	96,293	7,459	621
1993	212,970	6,203	980

1994	188,150	4,825	2,344
1995	170,237	6,209	866
1996	126,408	8,933	3,330
1997	100,811	8,913	871
1998	78,893	9,516	1,192
1999	83,235	8,740	1,621
2000	93,365	9,575	1,225
2001	180,055	15,442	1,201
2002	170,427	16,989	550
2003	123,583	14,066	692
2004	154,172	17,543	368
2005	118,882	10,032	785
2006	78,730	7,026	626
2007	101,180	13,452	341
2008	241,956	9,995	196
2009	345,487	16,233	665
2010	4,389	538	1,520
2011	*	*	*
2012	6,107	1,679	357
2013	23,995	6,417	1,187
2014	56,828	7,262	1,353

Table 3.4 Commercial landings uncertainty upper and lower bounds.

Year Range	VA North	NC	GA	SC	FL	
1950-1961	0.25	0.25	0.25	0.25	0.25	High and Low
1962-1977	0.2	0.2	0.2	0.2	0.2	
1978-1985	0.2	0.1	0.1	0.1	0.1	High Only
1986-1989	0.2	0.1	0.1	0.1	0.05	
1990-1993	0.1	0.1	0.1	0.1	0.05	
1994-2001	0.1	0.05	0.1	0.1	0.05	
2002-2003	0.1	0.05	0.05	0.1	0.05	
2004-present	0.05	0.05	0.05	0.05	0.05	

Table 3.5 Red snapper landings (number of fish) by gear (handline, diving, other) from the U.S. Atlantic, 1950-2014.

Year	Hand Line	Diving	Other
1950	43,433		1,676
1951	60,093	121	907
1952	46,597		605
1953	48,683	49	
1954	72,647		
1955	60,359		
1956	58,687		
1957	105,277		14
1958	74,841		
1959	80,353		
1960	82,241		29
1961	96,498		562
1962	78,932		85
1963	59,763		70
1964	65,739		14
1965	68,240		
1966	67,676		133
1967	89,822		109
1968	105,944		43
1969	64,250		1,834
1970	62,437		636
1971	57,118		
1972	47,670		3,166
1973	35,980		671
1974	59,133		269
1975	74,154		
1976	69,742		1,258
1977	73,851		386
1978	68,659	4,893	891
1979	48,087	3,326	206
1980	42,948	3,041	1,082
1981	41,696	2,648	1,970
1982	34,592	2,094	796
1983	35,595	2,249	574
1984	41,374	1,963	545
1985	46,646	4,056	475
1986	32,249	2,650	245
1987	22,465	1,728	455
1988	22,944	1,479	401
1989	31,501	1,748	373
1990	30,961	2,140	621
1991	19,512	1,014	1,182
1992	9,583	667	60
1993	22,892	557	94

1994	24,924	551	273
1995	19,452	698	97
1996	13,425	958	355
1997	10,359	916	93
1998	9,659	1,190	145
1999	10,366	1,015	198
2000	11,693	1,225	157
2001	25,747	2,026	159
2002	23,078	2,230	73
2003	16,118	1,798	88
2004	18,077	2,115	41
2005	12,119	1,027	77
2006	8,079	742	63
2007	11,084	1,542	37
2008	38,486	1,665	27
2009	43,320	2,022	83
2010	696	88	235
2011	*	*	*
2012	720	185	44
2013	2,832	762	147
2014	6,889	880	164

Table 3.6 Mean whole weight (pounds) of red snapper derived from the length compositions using the U.S. South Atlantic TIP database, 1984-2014. Average weights applied to earlier years, 1950-1983 and years where sample size was less than 50.

Year	FL	GA	SC	NC	VA-North
1950-1982	8.173	6.935	8.422	7.720	7.812
1983	8.173	6.935	8.422	7.720	7.812
1984	8.173	4.162	4.149	4.032	5.129
1985	4.167	5.554	8.422	5.684	5.957
1986	5.484	7.393	8.422	5.745	6.761
1987	8.173	5.103	8.422	5.875	6.893
1988	8.173	5.652	5.608	3.904	5.834
1989	8.173	5.189	8.422	5.637	6.855
1990	5.714	6.935	8.422	5.654	6.681
1991	8.076	5.797	5.414	6.631	6.480
1992	11.501	9.069	8.422	8.934	9.481
1993	11.637	7.757	8.422	6.367	8.545
1994	9.044	7.475	6.705	7.747	7.743
1995	8.866	9.259	8.422	10.079	9.156
1996	9.326	9.225	9.720	8.294	9.141
1997	9.736	6.935	11.290	7.720	8.920
1998	8.000	6.935	9.425	7.720	8.020
1999	8.611	6.935	7.764	6.485	7.449
2000	7.815	8.044	8.389	8.669	8.229
2001	7.627	4.928	7.389	6.842	6.697
2002	7.632	7.182	7.205	7.648	7.417
2003	7.803	6.546	8.166	9.897	8.103
2004	8.250	7.878	9.245	13.373	9.686
2005	9.705	8.614	10.369	12.981	10.417
2006	9.361	6.935	11.819	11.513	9.907
2007	8.674	6.935	11.996	8.883	9.122
2008	5.950	6.935	8.443	6.647	6.994
2009	8.023	6.935	8.493	6.201	7.413
2010	6.114	6.935	8.422	7.720	7.298
2012	8.709	6.935	8.422	7.720	7.946
2013	8.433	6.935	8.422	8.010	7.950
2014	8.237	6.935	8.422	8.993	8.147

Table 3.7 Calculated yearly total discards of red snapper (in numbers of fish) by vertical line vessels including 2014 discards. Vertical line vessels accounted for approximately 97% of calculated discards. Yearly nominal discard rates calculated separately for open and closed red snapper seasons. Effort is in hook hours fished. Discard rate used for the years 1992-2001 was the weighted mean rate for the years 2002-2009. Trips (discards) = trips reporting to the discard logbook program. Trips (total effort) = number of trips reporting to the coastal logbook program.

Year	Season	Trips (discards)	Trips (total effort)	Discard Rate	Discard Rate CV	Total Effort	Calculated Discards
1992*	Open		4,428	0.0124		1,557,323	19,339
1993	Open		11,846	0.0124		1,331,155	16,530
1994	Open		14,446	0.0124		1,680,269	20,865
1995	Open		14,468	0.0124		1,676,441	20,818
1996	Open		15,395	0.0124		1,647,052	20,453
1997	Open		17,642	0.0124		1,778,302	22,083
1998	Open		15,863	0.0124		1,280,778	15,905
1999	Open		14,462	0.0124		1,079,870	13,410
2000	Open		13,298	0.0124		1,155,724	14,352
2001	Open		13,927	0.0124		1,202,087	14,927
2002	Open	1,169	14,575	0.0251	9.97	1,156,630	29,020
2003	Open	1,544	14,062	0.0085	14.57	982,399	8,372
2004	Open	1,032	13,178	0.0025	7.75	874,447	2,192
2005	Open	1,230	11,843	0.0122	14.31	807,361	9,823
2006	Open	880	11,654	0.0054	10.64	880,385	4,739
2007	Open	1,757	12,801	0.0140	21.15	946,780	13,249
2008	Open	3,098	13,036	0.0130	10.28	962,163	12,514
2009	Open	1,715	14,352	0.0144	7.61	1,007,193	14,466
2010	Open	153	757	0.0471	10.96	35,816	1,688
2011	Open**						
2012	Open	232	706	0.0051	5.97	38,923	200
2013	Open	334	1,423	0.0096	9.28	100,868	968
2014	Open	533	2,264	0.0137	5.10	144,207	1,978
2010	Closed	2,800	12,012	0.0167	6.19	783,389	13,121
2011	Closed	3,250	13,093	0.0500	8.16	784,566	39,240
2012	Closed	3,156	11,634	0.0269	8.10	662,827	17,833
2013	Closed	2,516	10,578	0.0258	7.01	650,090	16,798
2014	Closed	2,692	11,822	0.0375	5.06	625,031	23,455

*in 1992 only 20% of vessels in Florida were required to report to the logbook program; effort for areas off Florida were expanded by a factor of five.

**No open season for red snapper during 2011

Table 3.8 Calculated yearly total discards of red snapper (in numbers of fish) by dive vessels including 2014 discards. Dive vessels accounted for approximately 1.4% of calculated discards. Yearly nominal discard rates calculated separately for open and closed red snapper seasons. Effort is in diver hours fished. Discard rate used for the years 1992-2001 was the weighted mean rate for the years 2002-2009. Trips (discards) = trips reporting to the discard logbook program. Trips (total effort) = number of trips reporting to the coastal logbook program.

Year	Season	Trips (discards)	Trips (total effort)	Discard Rate	Discard Rate CV	Total Effort	Calculated Discards
1992*	Open		506	0.0057		22,041	126
1993	Open		976	0.0057		14,084	80
1994	Open		927	0.0057		19,384	111
1995	Open		753	0.0057		17,976	103
1996	Open		978	0.0057		20,472	117
1997	Open		1,243	0.0057		25,297	144
1998	Open		1,196	0.0057		21,984	125
1999	Open		893	0.0057		17,636	101
2000	Open		963	0.0057		17,667	101
2001	Open		1,011	0.0057		17,297	99
2002	Open	10	929	0.0200	3.16	17,330	347
2003	Open	48	894	0.0000		13,609	0
2004	Open	57	772	0.0175	7.55	13,284	233
2005	Open	23	681	0.0290	4.80	12,219	354
2006	Open	20	687	0.0063	4.47	12,369	77
2007	Open	67	856	0.0000		16,941	0
2008	Open	141	745	0.0027	11.87	14,340	38
2009	Open	49	769	0.0000		12,596	0
2010	Open	11	44	0.0000		1,116	0
2011	Open**						
2012	Open	6	83	0.0000		1,105	0
2013	Open	28	199	0.0000		2,779	0
2014	Open	39	280	0.0000		5,094	0
2010	Closed	91	730	0.0680	3.91	14,051	956
2011	Closed	136	926	0.0223	4.13	16,238	362
2012	Closed	120	839	0.0551	3.82	16,263	896
2013	Closed	86	801	0.0518	5.75	13,799	715
2014	Closed	113	744	0.0487	8.23	13,726	668

*in 1992 only 20% of vessels in Florida were required to report to the logbook program; effort for areas off Florida were expanded by a factor of five.

**No open season for red snapper during 2011

Table 3.9 Calculated yearly total discards of red snapper (in numbers of fish) by trap vessels including 2014 discards. Trap vessels accounted for approximately 1.4% of calculated discards. Yearly nominal discard rates calculated separately for open and closed red snapper seasons. Effort is in traps fished. Discard rate used for the years 1992-2001 was the weighted mean rate for the years 2002-2009. Trips (discards) = trips reporting to the discard logbook program. Trips (total effort) = number of trips reporting to the coastal logbook program.

Year	Season	Trips (discards)	Trips (total effort)	Discard Rate	Discard Rate CV	Total Effort	Calculated Discards
1992*	Open		595	0.0026		52,540	139
1993	Open		1,023	0.0026		43,311	114
1994	Open		1,195	0.0026		59,745	158
1995	Open		1,032	0.0026		55,765	147
1996	Open		1,168	0.0026		59,422	157
1997	Open		1,353	0.0026		62,406	165
1998	Open		1,201	0.0026		53,588	142
1999	Open		1,075	0.0026		49,538	131
2000	Open		829	0.0026		37,859	100
2001	Open		1,096	0.0026		43,626	115
2002	Open	51	826	0.0134	6.31	35,942	482
2003	Open	89	783	0.0000		31,505	0
2004	Open	38	820	0.0000		31,221	0
2005	Open	12	596	0.0000		24,787	0
2006	Open	5	786	0.0000		32,018	0
2007	Open	52	616	0.0200	5.15	26,389	529
2008	Open	209	561	0.0000		18,820	0
2009	Open	197	772	0.0000		28,804	0
2010	Open	18	55	0.0000		1,683	0
2011	Open**						
2012	Open	8	17	0.0000		451	0
2013	Open	55	99	0.0044	5.49	2,494	11
2014	Open	24	44	0.0556	4.90	1,131	63
2010	Closed	136	349	0.1104	11.65	13,878	1,533
2011	Closed	51	237	0.0719	7.14	6,986	502
2012	Closed	127	307	0.0099	4.52	8,284	82
2013	Closed	111	268	0.1068	9.35	6,850	732
2014	Closed	108	218	0.0852	3.36	5,313	453

*in 1992 only 20% of vessels in Florida were required to report to the logbook program; effort for areas off Florida were expanded by a factor of five.

**No open season for red snapper during 2011

Table 3.10 Calculated yearly total discards of red snapper (in numbers of fish) by trolling vessels including 2014 discards. Trolling vessels accounted for approximately 0.2% of calculated discards. Yearly nominal discard rates calculated separately for open and closed red snapper seasons. Effort is in hook hours fished. Discard rate used for the years 1992-2001 was the weighted mean rate for the years 2002-2009. Trips (discards) = trips reporting to the discard logbook program. Trips (total effort) = number of trips reporting to the coastal logbook program.

Year	Season	Trips (discards)	Trips (total effort)	Discard Rate	Discard Rate CV	Total Effort	Calculated Discards
1992*	Open		576	0.0000		69,458	0
1993	Open		1,095	0.0000		75,520	0
1994	Open		1,241	0.0000		103,442	0
1995	Open		1,435	0.0000		78,334	0
1996	Open		1,181	0.0000		72,067	0
1997	Open		1,295	0.0000		77,154	0
1998	Open		3,227	0.0000		204,204	0
1999	Open		3,470	0.0000		202,641	0
2000	Open		4,576	0.0000		265,989	0
2001	Open		4,781	0.0000		203,199	0
2002	Open	273	4,349	0.0000		172,868	0
2003	Open	241	3,823	0.0000		134,453	0
2004	Open	224	3,123	0.0000		114,811	0
2005	Open	183	2,855	0.0000		101,320	0
2006	Open	125	2,918	0.0000		104,919	0
2007	Open	482	3,668	0.0000		127,460	0
2008	Open	1,009	3,750	0.0000		114,901	0
2009	Open	634	4,107	0.0000		135,729	0
2010	Open	59	302	0.0000		9,295	0
2011	Open**						
2012	Open	54	160	0.0026	7.35	5,157	14
2013	Open	88	309	0.0000		11,854	0
2014	Open	141	547	0.0003	11.87	17,357	5
2010	Closed	854	3,560	0.0013	27.31	111,864	140
2011	Closed	573	3,392	0.0000	23.94	110,991	3
2012	Closed	798	3,090	0.0018	13.59	103,963	189
2013	Closed	661	2,775	0.0009	9.15	92,440	79
2014	Closed	882	3,074	0.0039	5.58	98,811	387

*in 1992 only 20% of vessels in Florida were required to report to the logbook program; effort for areas off Florida were expanded by a factor of five.

**No open season for red snapper during 2011

Table 3.11 Gear-specific relative percentage of length samples , total number of years with samples (Years), the number of years with 30 or more fish measured (Years>30 (31 Total)), the proportion of years with only one state contributing to the annual length samples (Years1state), mean total length in millimeters (meanTLmm), and mean weight in pounds (meanWt_lb).

Gear	Length Samples	Years	Years>30 (32 Total)	Years 1 state	meanTLmm	meanWt_lb
Lines	92.9%	32	31	0.06	597	7.3
Diving	3.2%	21	6	0.76	639	8.9
Pots	0.9%	11	3	0.63	564	6.1
Longline	1.2%	20	3	0.69	690	11.2
Trawl	0.8%	4	3	1	428	2.7
Other	1.0%	8	0	1	582	6.7

Table 3.12 Number of red snapper fish sampled for lengths by gear (handline, diving, other) and state from the U.S. South Atlantic TIP database, 1983-2014.

	Handline				Diving			Other			
Year	NC	SC	GA	FL	SC	GA	FL	NC	SC	GA	FL
1983	35										
1984	1069	970	50					3	34		
1985	731		203	1228				14		33	36
1986	659		144	130				2			40
1987	394		354					73		47	
1988	200	101	233	5				24	138		
1989	600		191	37				10			
1990	435			173				5			49
1991	197	59	196	75				5	53	1	11
1992	78		110	178			4				13
1993	229	7	128	364			8	1			18
1994	451	58	77	187		1	1	1			37
1995	127		101	872			25				47
1996	58	282	105	427	7		21		6		17
1997	1	177	43	239			10		1		20
1998	17	228	14	208			7				15
1999	187	523	42	274			83	1	3		
2000	59	434	65	387			129				11
2001	270	453	369	802			87		1		29
2002	196	460	124	229			9				
2003	164	667	153	401			222				
2004	90	451	214	125	8						1
2005	94	377	94	50	3			8			
2006	65	143	16	212	15		7				
2007	102	166		320			17	2	1		
2008	170	266	18	219	2		27	2	1		7
2009	162	470		1916	7		63	1	16		143
2010	2			66							
2011											
2012	14	33		92			6				3
2013	79	34		345			110	13			75
2014	98			269			28				

Table 3.13 Number of trips sampled for red snapper lengths by gear (handline, diving, other) and state from the U.S. South Atlantic TIP database, 1983-2014.

	Handline				Diving			Other			
Year	NC	SC	GA	FL	SC	GA	FL	NC	SC	GA	FL
1983	12										
1984	78	43	4					2	2		
1985	94		15	30				5		1	5
1986	70		20	4				2			1
1987	57		32					7		1	
1988	38	22	22	2				10	6		
1989	74		12	2				2			
1990	54			9				2			2
1991	48	10	39	9				3	6	1	4
1992	30		22	30			2				9
1993	49	1	24	42			3	1			8
1994	60	8	16	18		1	1	1			5
1995	49		15	63			5				13
1996	15	73	19	50	2		4		2		6
1997	1	59	10	35			1		1		11
1998	10	66	4	41			2				6
1999	28	83	10	46			13	1	1		
2000	26	67	11	45			9				2
2001	53	80	10	53			6		1		2
2002	43	73	10	18			3				
2003	33	76	11	35			15				
2004	41	70	18	9	1						1
2005	44	75	4	10	1			1			
2006	38	52	4	39	5		5				
2007	58	77		50			7	2	1		
2008	68	86	1	17	1		3	2	1		1
2009	56	110		95	4		16	1	1		9
2010	2			2							
2011	7	13		20							
2012	25	9		58			2				2
2013	23			38			14	3			7
2014	98			269			3				

Table 3.14 Number of fish sampled for red snapper ages by gear (handline, other including diving) and state from the U.S. South Atlantic commercial fishery.

	Handline				Other		
Year	NC	SC	GA	FL	NC	SC	FL
1988		32					
1989		5					
1990		29					
1991		6					
1992		23		15			
1993		12		7			
1994		20		1			
1995		5		16			4
1996		86		118			11
1997		111		63			
1998				50			1
1999		151		13			
2000		131	16	141			122
2001				115			58
2002		3		30			1
2003				59			
2004	21			57			
2005	64	33		38			
2006	34	115		80			
2007	80	108		79		4	1
2008	156	194		39	4		7
2009	152	233		2047		15	75
2010				30			
2011	1						
2012	9	33		106	4		17
2013	74	36	15	597	12		106
2014	100	68		297	15		7

Table 3.15 Number of trips sampled for red snapper ages by gear (handline, other including diving) and state from the U.S. South Atlantic commercial fishery.

	Handline				Other		
Year	NC	SC	GA	FL	NC	SC	FL
1988		7					
1989		4					
1990		11					
1991		3					
1992		8		3			
1993		8		1			
1994		14		1			
1995		5		2			1
1996		32		16			1
1997		29		16			
1998				14			1
1999		10		5			
2000		6	1	21			7
2001				23			4
2002		2		5			1
2003				10			
2004	13			12			
2005	35	12		6			
2006	24	51		9			
2007	51	67		14		2	1
2008	68	85		5	3		1
2009	60	97		106		9	14
2010				1			
2011	1						
2012	4	13		22	2		4
2013	24	10	4	71	3		14
2014	24	13		27	4		1

3.12 Figures

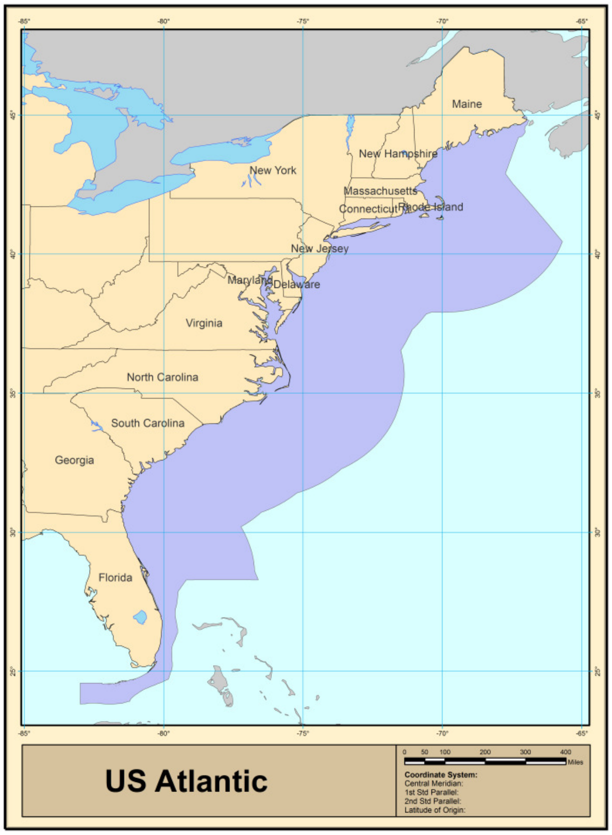

Figure 3.1 Region of red snapper landings.

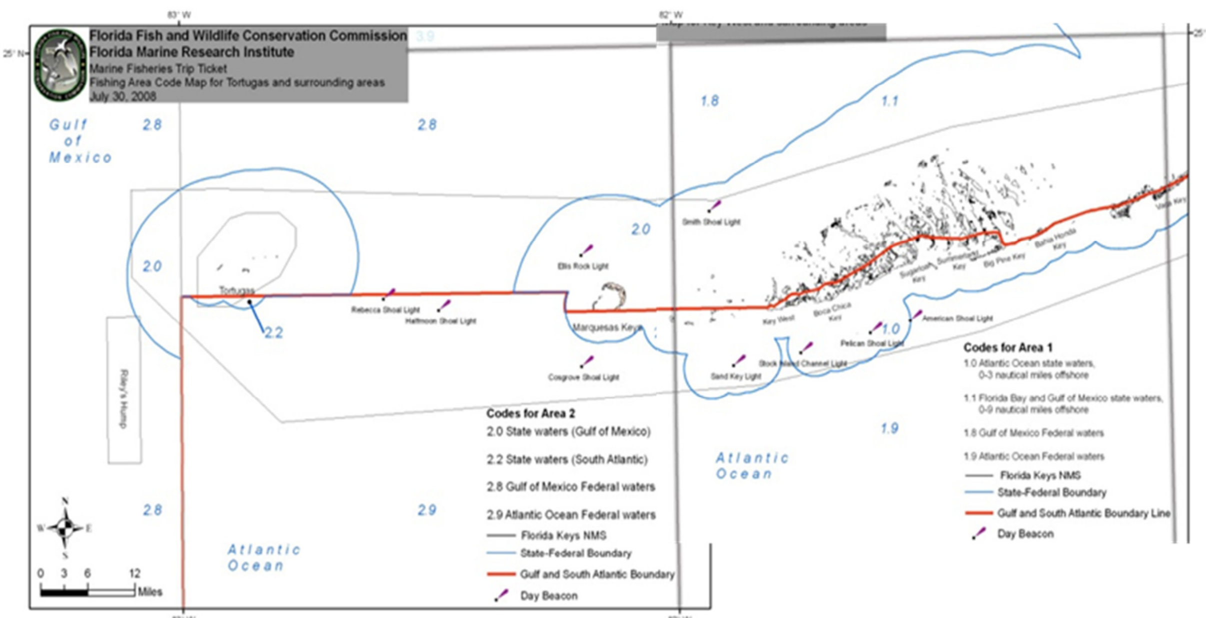

Figure 3.2 Close-up of the southern boundary as defined by the Gulf of Mexico/South Atlantic Council boundary.

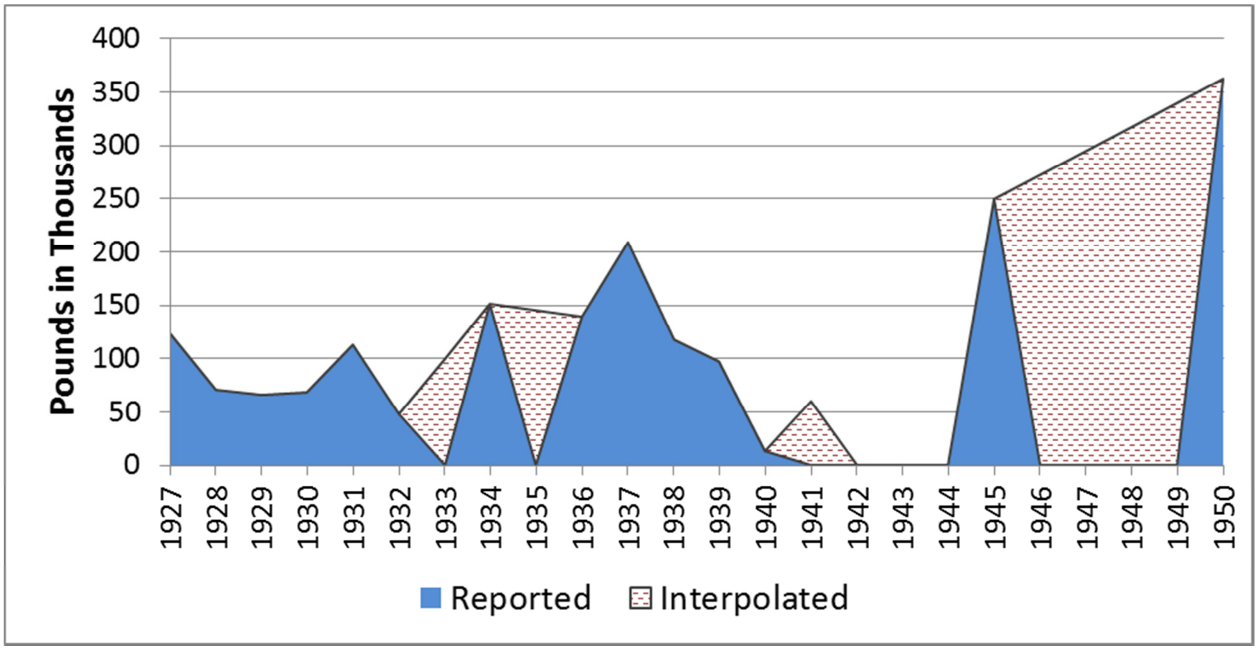

Figure 3.3 Historical red snapper landings, in thousands of whole weight pounds, from 1927-1949.

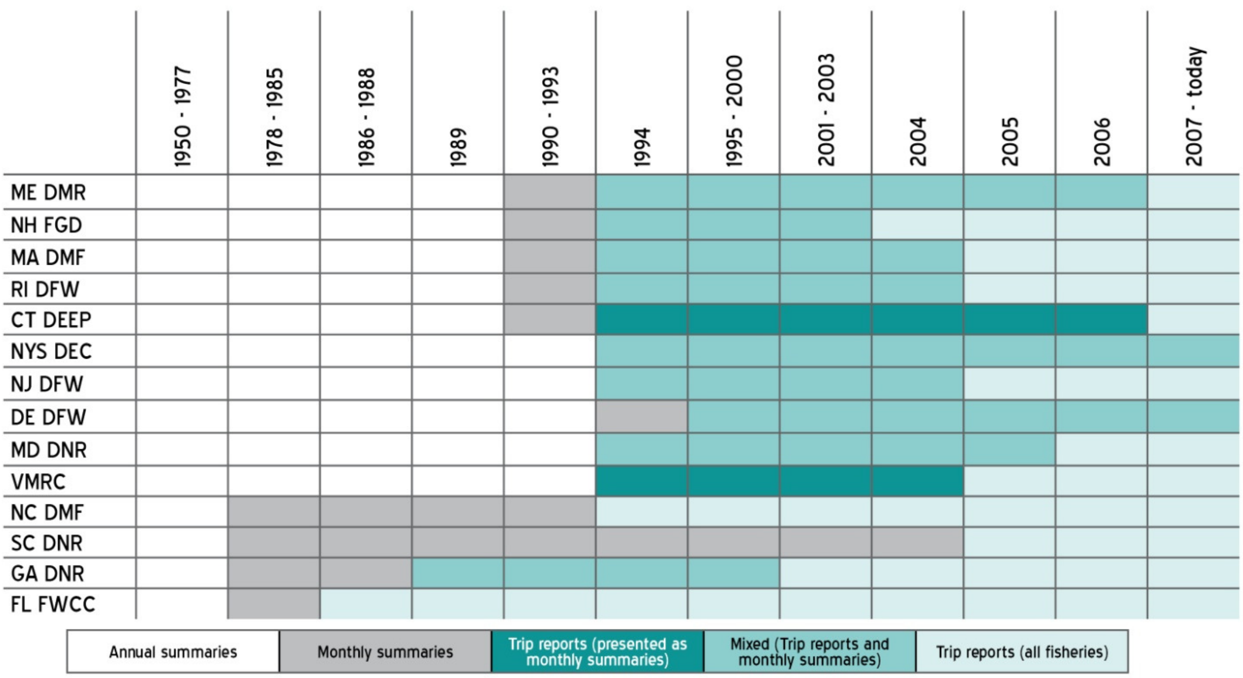

Figure 3.4 Atlantic Coastal Cooperative Statistics Program (ACCSP) Data Warehouse - data sources and collection methods by state.

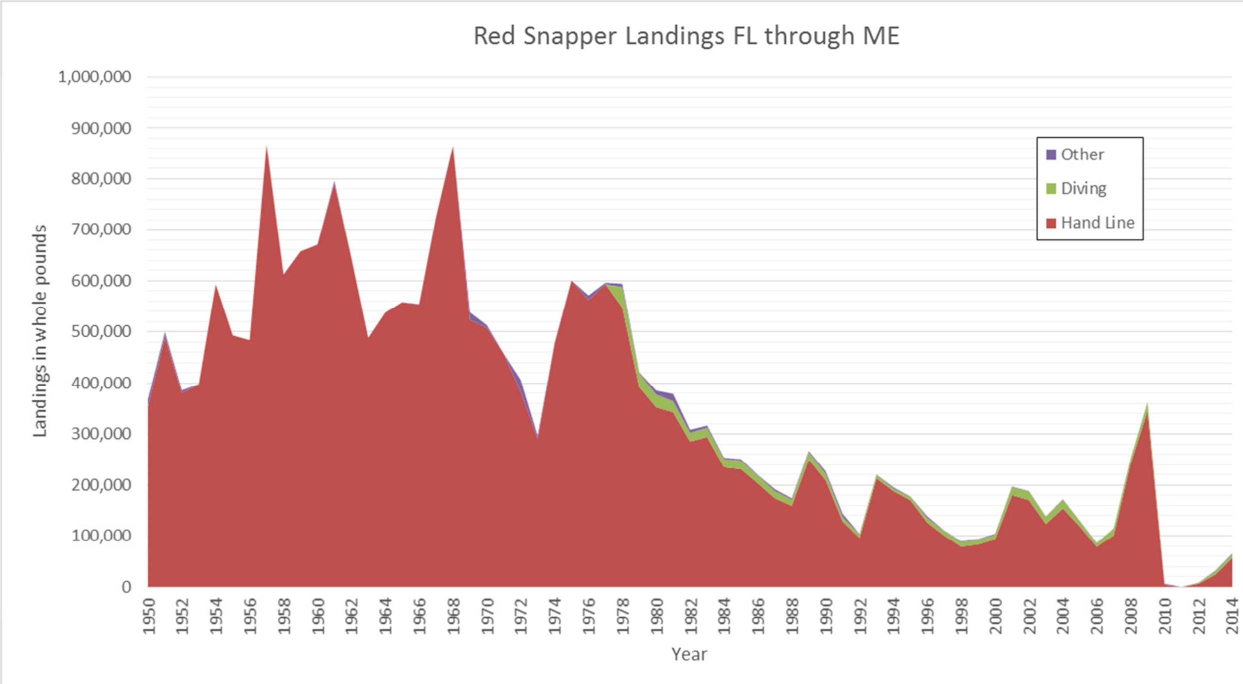

Figure 3.5 Red snapper landings, in pounds (whole weight), for all states (FL-ME) by gear, 1950-2014.

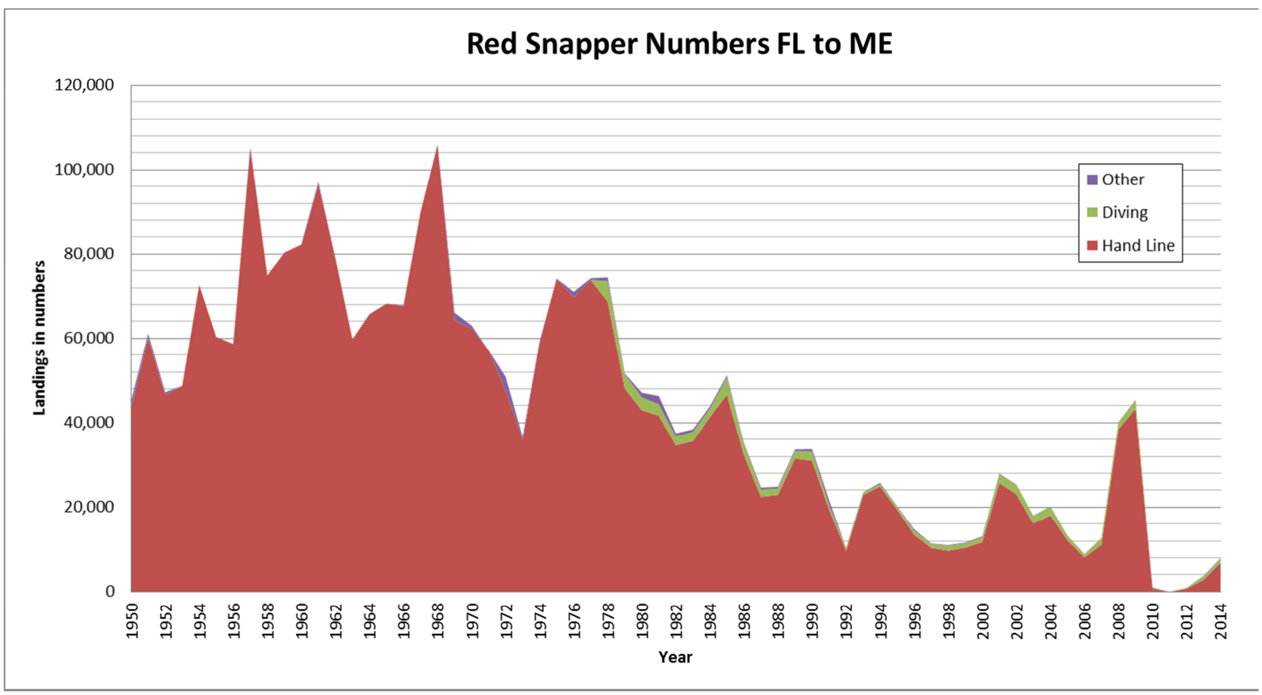

Figure 3.6 Red snapper landings, in numbers of fish, for all states (FL-ME) by gear, 1950-2014.

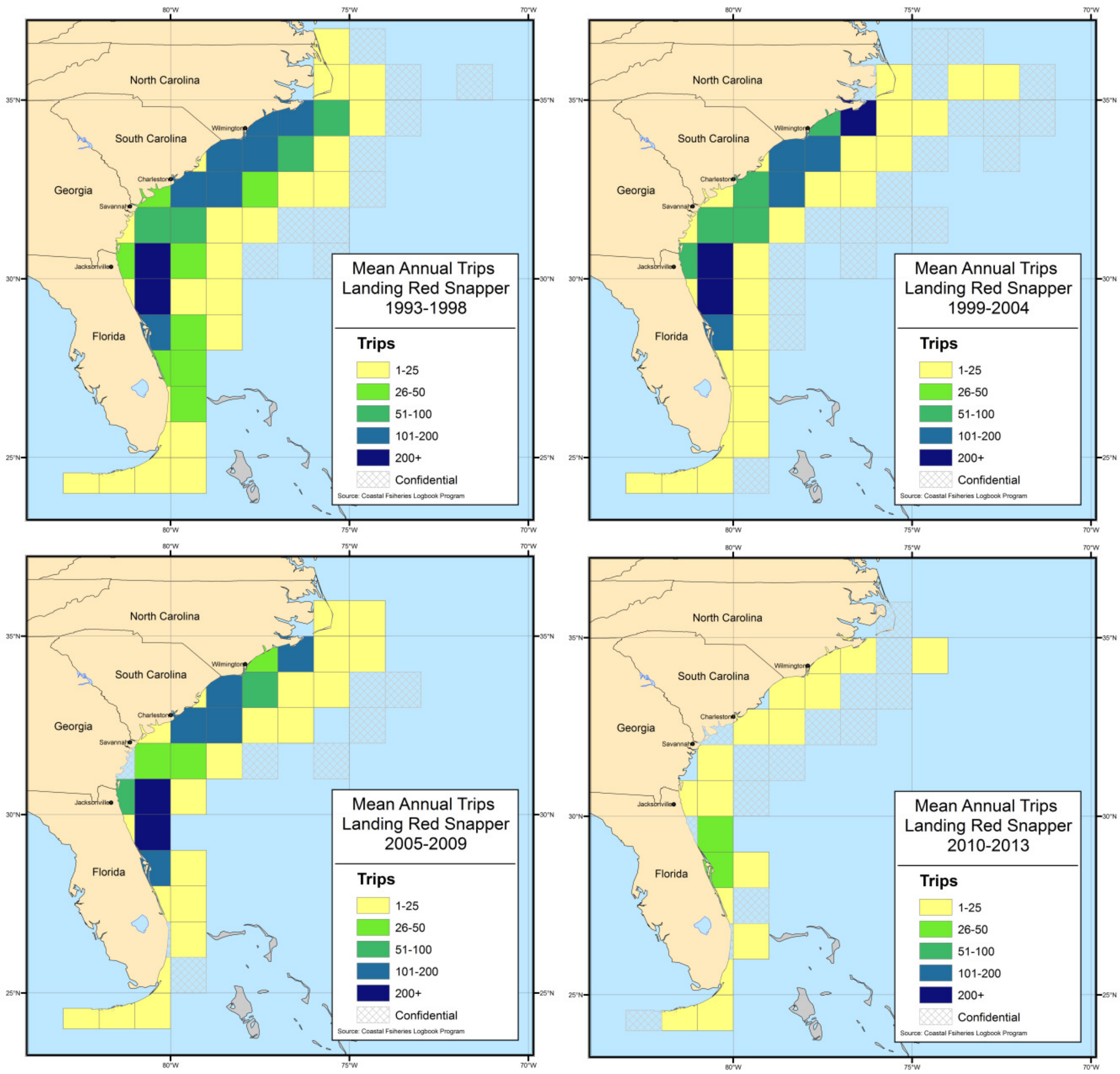

Figure 3.7 Average number of trips landing red snapper, by statistical grid, in the U.S. South Atlantic as reported to the CFLP.

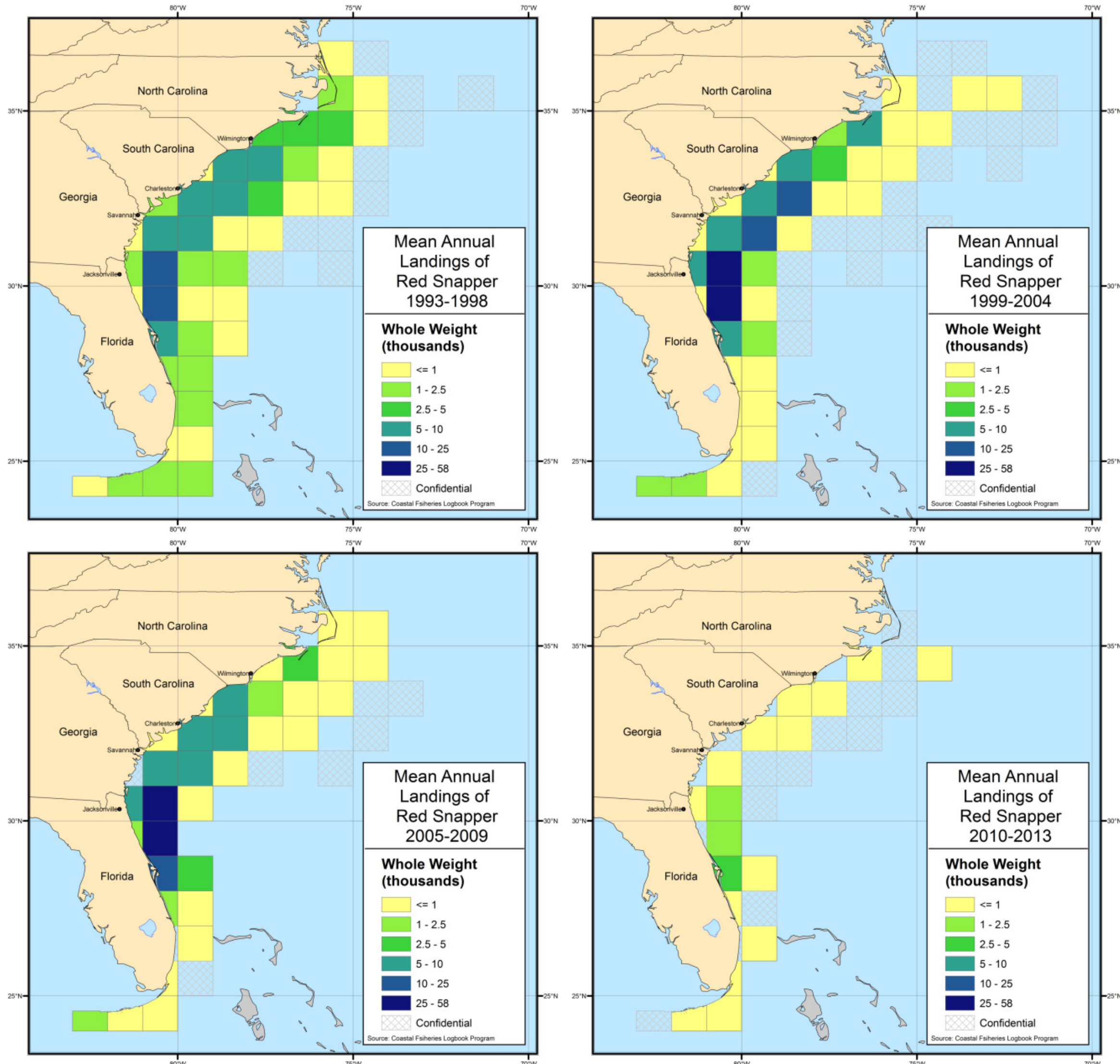

Figure 3.8 Average annual harvest of red snapper, by statistical grid, in the U.S. South Atlantic as reported to the CFLP.

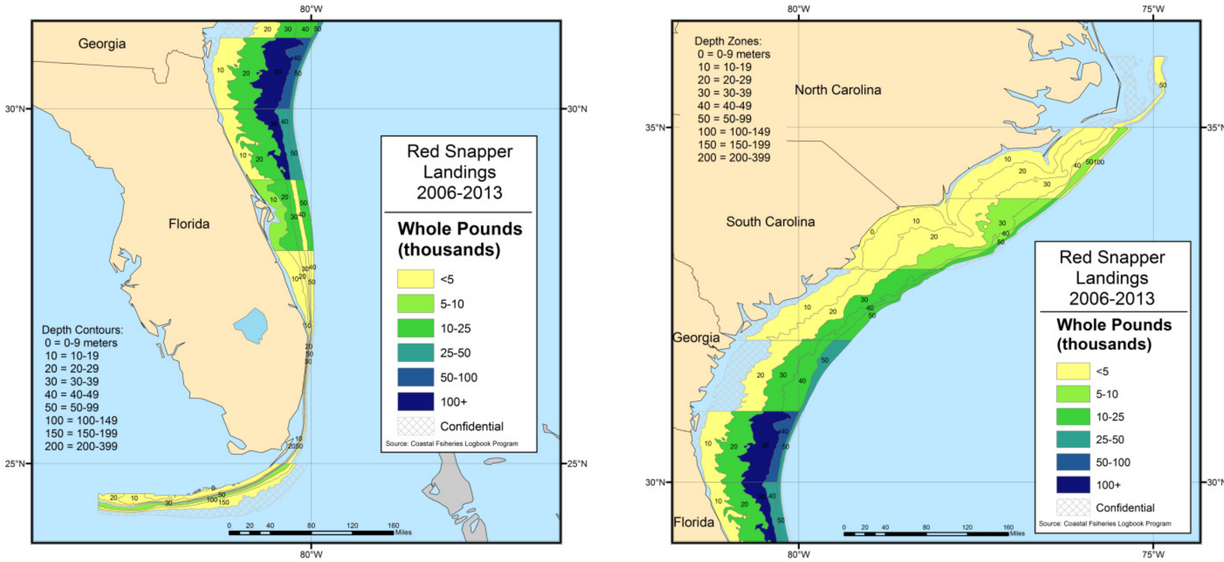

Figure 3.9 Total harvest of red snapper by depth and degrees latitude in the U.S. South Atlantic as reported to the CFLP.

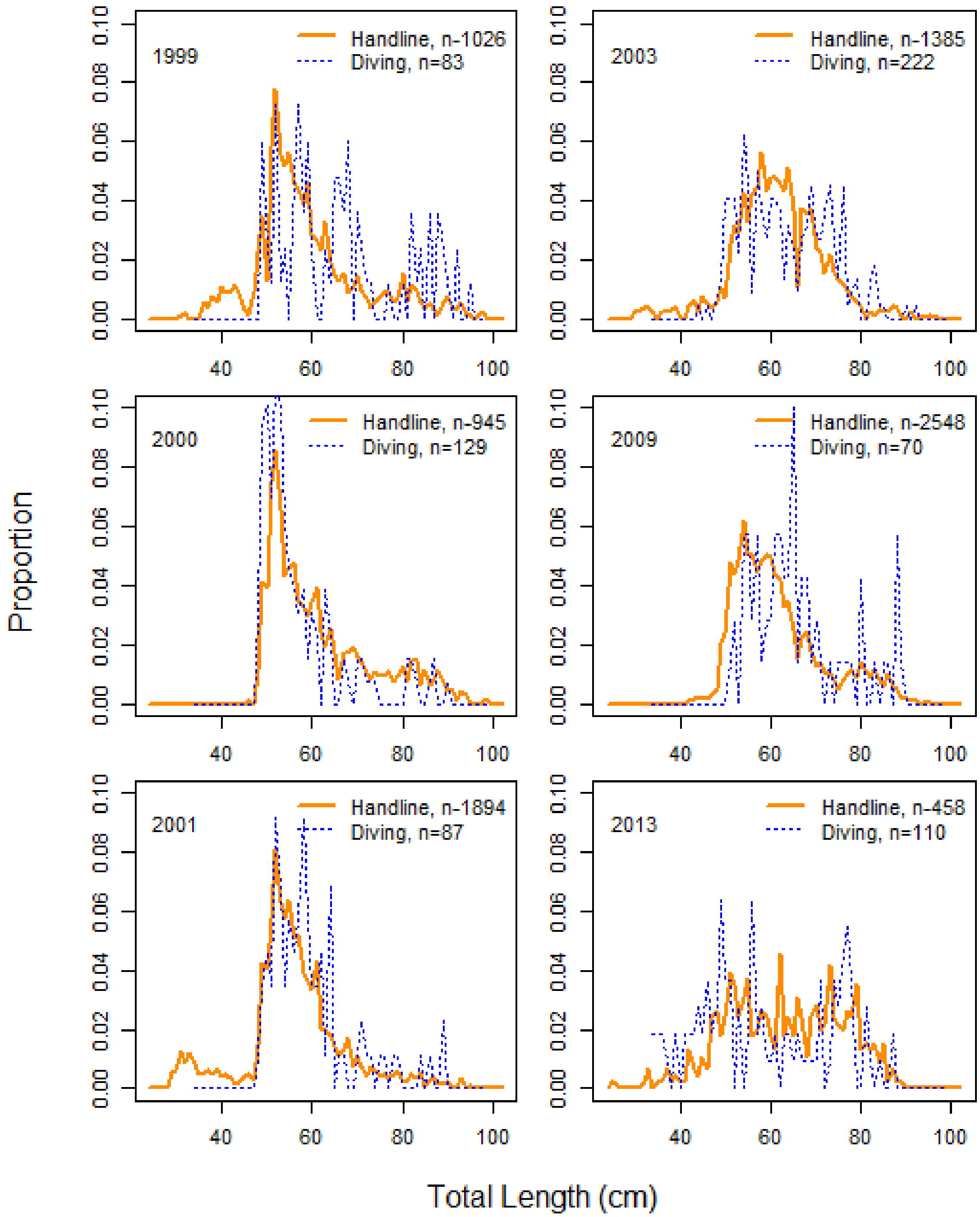

Figure 3.10 Comparison of commercial line and diving length compositions for years with 30 or more diving samples.

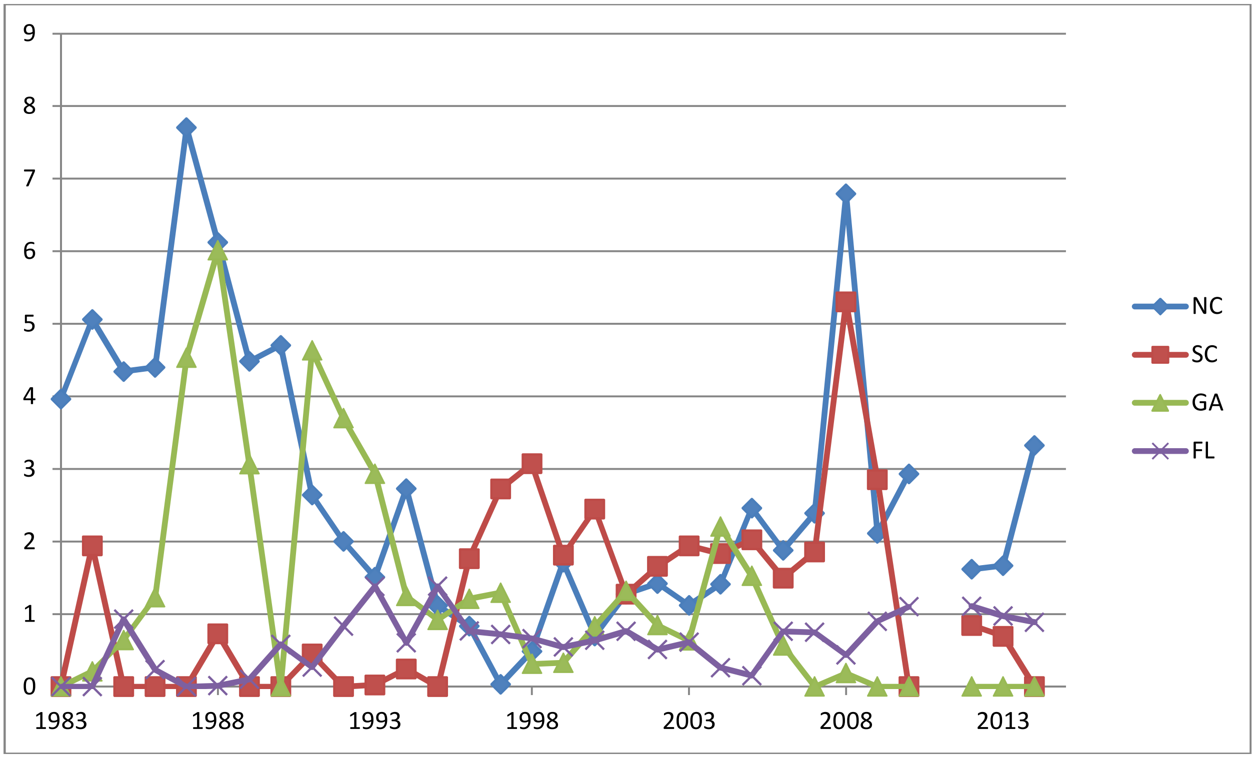

Figure 3.11 Relative comparison of sampled fish to landings in pounds (e.g. if all fish measured are from one state that has 25% of the landings the value would be 4; if 25% of fish sampled are from one state and 25% of the landings are from that state, the value would be 1).

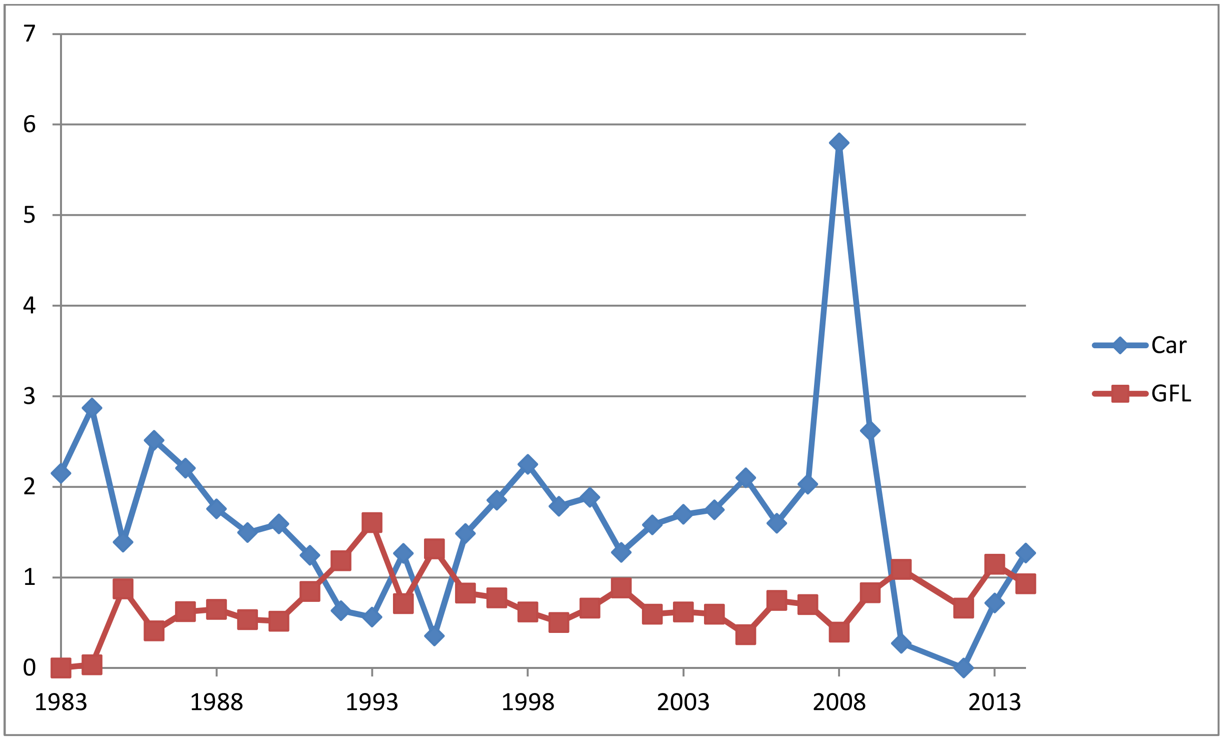

Figure 3.12 Relative comparison of sampled fish to landings in pounds by region (a value of 1 means the fish were sampled proportional to landings).

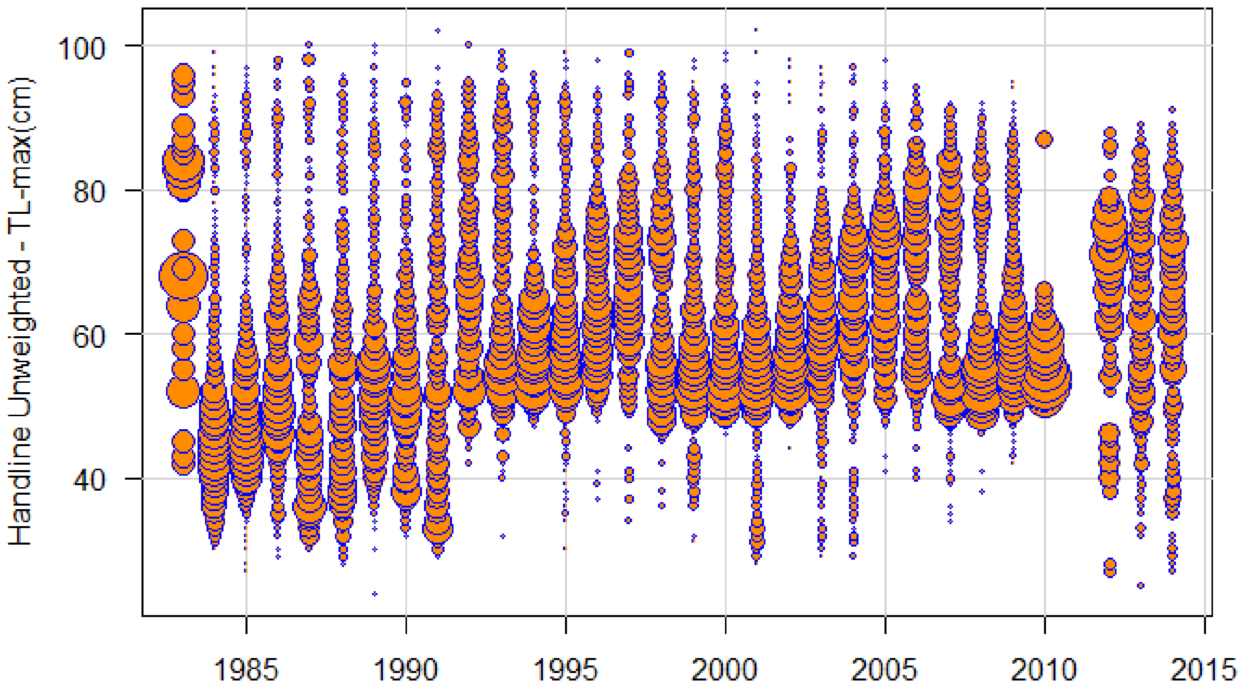

Figure 3.13 Red snapper nominal handline length compositions (area of bubble relative to annual proportion at length in 1 cm bins).

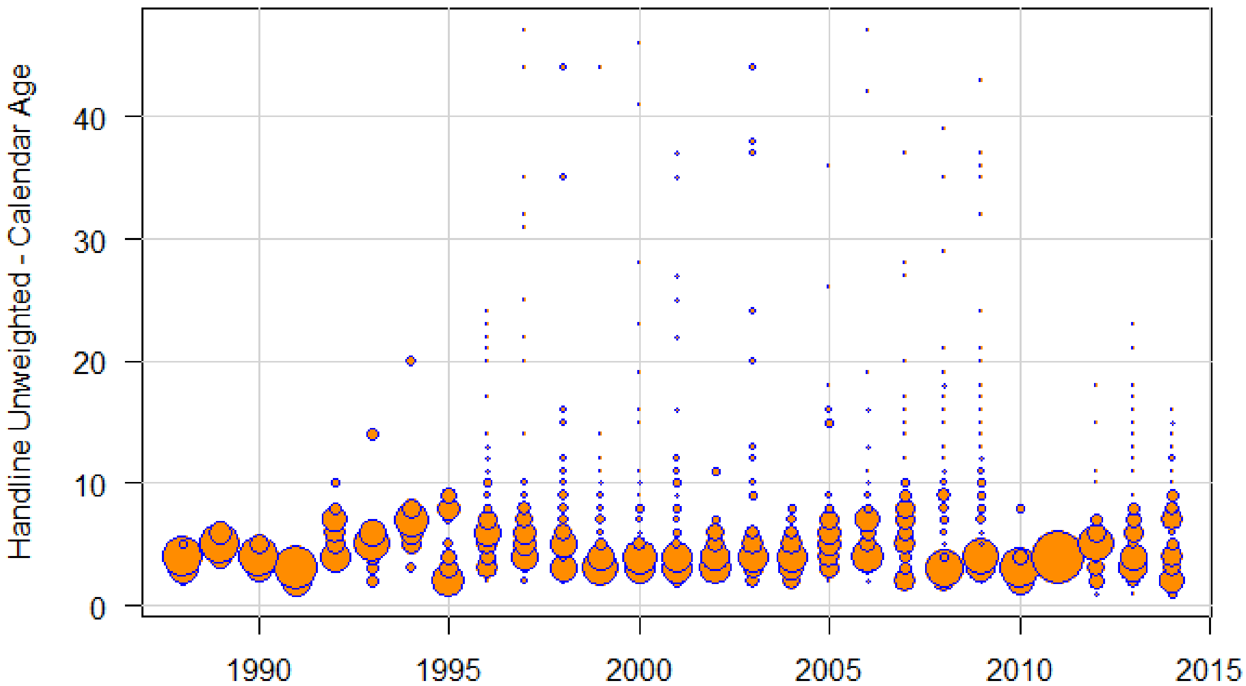

Figure 3.14 Red snapper nominal age composition to a maximum calendar age of 47 years (area of bubble relative to annual proportion at calendar age).

Figure 3.15 Red snapper nominal age composition pooled at 15 years (area of bubble relative to annual proportion at calendar age).

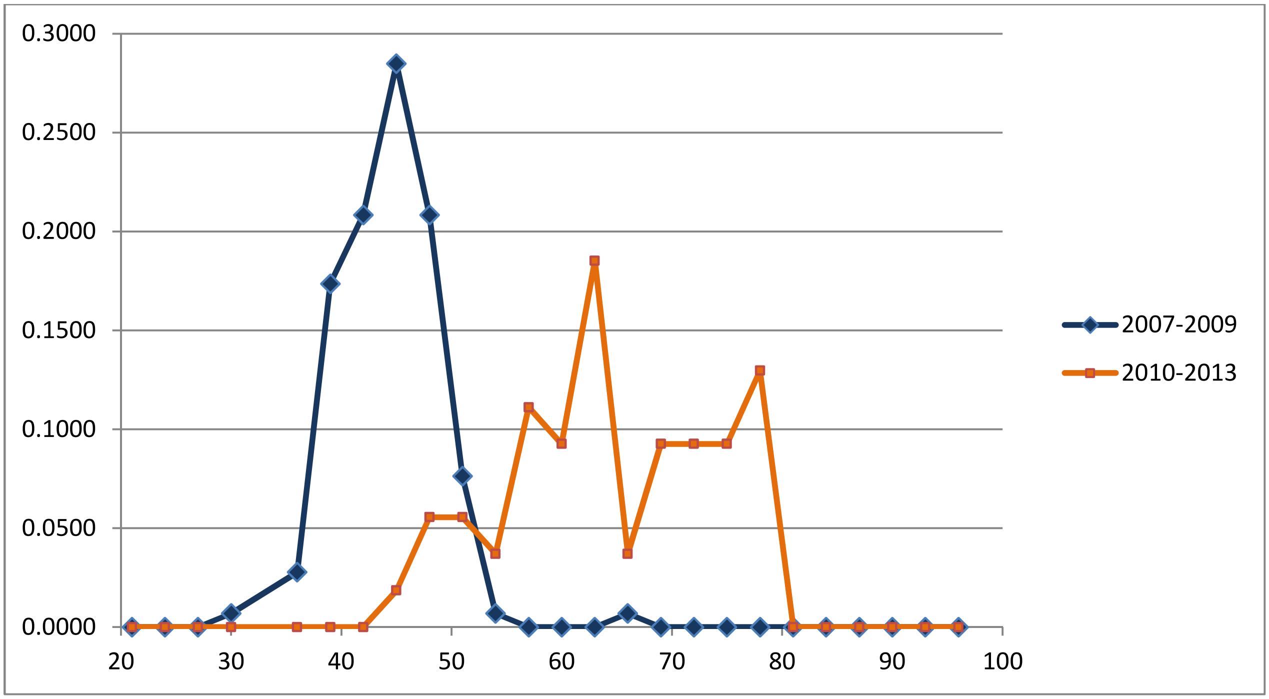

Figure 3.16 Commercial discard length distribution for the period with a 20 inch size limit (2007-2009) and during the closure (2010-2013). These were estimated from limited commercial observer data from 2007-2013.

Appendix A

NMFS SECPR Accumulated Landings System (ALS)

Information on the quantity and value of seafood products caught by fishermen in the U.S. has been collected starting in the late 1800s (inaugural year is species dependent). Fairly serious collection activity began in the 1920s. The data set maintained by the Southeast Fisheries Science Center (SEFSC) in the SECPR database management system is a continuous dataset that begins in 1962.

In addition to the quantity and value, information on the gear used to catch the fish, the area where the fishing occurred and the distance from shore are also recorded. Because the quantity and value data are collected from seafood dealers, the information on gear and fishing location are estimated and added to the data by data collection specialists. In some states, this ancillary data are not available.

Commercial landings statistics have been collected and processed by various organizations during the 1962-to-present period that the SECPR data set covers. During the 16 years from 1962 through 1978, these data were collected by port agents employed by the Federal government and stationed at major fishing ports in the southeast. The program was run from the Headquarters Office of the Bureau of Commercial Fisheries in Washington DC until 1970. After 1970 it was run by the newly created National Marine Fisheries Service, which had replaced the Bureau of Commercial Fisheries. Data collection procedures were established by Headquarters and the data were submitted to Washington for processing and computer storage. In 1978, the responsibility for collection and processing were transferred to the SEFSC.

In the early 1980s, the NMFS and the state fishery agencies within the Southeast began to develop a cooperative program for the collection and processing of commercial fisheries statistics. With the exception of two counties, one in Mississippi and one in Alabama, all of the general canvass statistics are collected by the fishery agency in the respective state and provided to the SEFSC under a comprehensive Cooperative Statistics Program (CSP).

The purpose of this documentation is to describe the current collection and processing procedures that are employed for the commercial fisheries statistics maintained in the SECPR database.

1960 - Late 1980s
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Although the data processing and database management responsibility were transferred from the Headquarters in Washington DC to the SEFSC during this period, the data collection procedures remained essentially the same. Trained data collection personnel, referred to as fishery reporting specialists or port agents, were stationed at major fishing ports throughout the Southeast Region. The data collection procedures for commercial landings included two parts.

The primary task for the port agents was to visit all seafood dealers or fish houses within their assigned areas at least once a month to record the pounds and value for each species or product type that were purchased or handled by the dealer or fish house. The agents summed the landings and value data and submitted these data in monthly reports to their area supervisors. All of the monthly data were submitted in essentially the same form.

The second task was to estimate the quantity of fish that were caught by specific types of gear and the location of the fishing activity. Port agents provided this gear/area information for all of the landings data that they collected. The objective was to have gear and area information assigned to all monthly commercial landings data.

There are two problems with the commercial fishery statistics that were collected from seafood dealers. First, dealers do not always record the specific species that are caught and second, fish or shellfish are not always purchased at the same location where they are unloaded, i.e., landed. Dealers have always recorded fishery products in ways that meet their needs, which sometimes make it ambiguous for scientific uses. Although the port agents can readily identify individual species, they usually were not at the fish house when fish were being unloaded and thus, could not observe and identify the fish.

The second problem is to identify where the fish were landed from the information recorded by the dealers on their sales receipts. The NMFS standard for fisheries statistics is to associate commercial statistics with the location where the product was first unloaded, i.e., landed, at a shore-based facility. Because some products are unloaded at a dock or fish house and purchased and transported to another dealer, the actual 'landing' location may not be apparent from the dealers' sales receipts. Historically, communications between individual port agents and the area supervisors were the primary source of information that was available to identify the actual unloading location.

Cooperative Statistics Program
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In the early 1980s, it became apparent that the collection of commercial fisheries statistics was an activity that was conducted by both the Federal government and individual state fishery agencies. Plans and negotiations were initiated to develop a program that would provide the fisheries statistics that are needed for management by both Federal and state agencies. By the mid-1980s, formal cooperative agreements had been signed between the NMFS/SEFSC and each of the eight coastal states in the southeast, Puerto Rico and the US Virgin Islands.

Initially, the data collection procedures that were used by the states under the cooperative agreements were essentially the same as the historical NMFS procedures. As the states developed their data collection programs, many of them promulgated legislation that authorized their fishery agencies to collect fishery statistics. Many of the state statutes include mandatory data submission by seafood dealers.

Because the data collection procedures (regulations) are different for each state, the type and detail of data varies throughout the Region. The commercial landings database maintained in SECPR contains a standard set of data that is consistent for all states in the Region.

A description of the data collection procedures and associated data submission requirements for each state follows.

Florida
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Prior to 1986, commercial landings statistics were collected by a combination of monthly mail submissions and port agent visits. These procedures provided quantity and value, but did not provide information on gear, area or distance from shore. Because of the large number of dealers, port agents were not able to provide the gear, area and distance information for monthly data. This information, however, is provided for annual summaries of the quantity and value and known as the Florida Annual Canvas data (see below).

Beginning in 1986, mandatory reporting by all seafood dealers was implemented by the State of Florida. The State requires that a report (ticket) be completed and submitted to the State for every trip. Dealers have to report the type of gear as well as the quantity (pounds) purchased for each species. Information on the area of catch can also be provided on the tickets for individual trips. As of 1986 the ALS system relies solely on the Florida trip ticket data to create the ALS landings data for all species other than shrimp.

Georgia
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Prior to 1977, the National Marine Fisheries Service collected commercial landings data Georgia. From 1977 to 2001 state port agents visited dealers and docks to collect the information on a regular basis. Compliance was mandatory for the fishing industry. To collect more timely and accurate data, Georgia initiated a trip ticket program in 1999, but the program was not fully implemented to allow complete coverage until 2001. All sales of seafood products landed in Georgia must be recorded on a trip ticket at the time of the sale. Both the seafood dealer and the seafood harvester are responsible for insuring the ticket is completed in full.

South Carolina
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Prior to 1972, commercial landings data were collected by various federal fisheries agents based in South Carolina, either U.S. Fish or Wildlife or National Marine Fisheries Service personnel. In 1972, South Carolina began collecting landings data from coastal dealers in cooperation with federal agents. Mandatory monthly landings reports on forms supplied by the Department are required from all licensed wholesale dealers in South Carolina. Until fall of 2003, those monthly reports were summaries collecting species, pounds landed, disposition (gutted or whole) and market category, gear type, and area fished; since September 2003, landings have been reported by a mandatory trip ticket system collecting landings by species, disposition and market category, pounds landed, ex-vessel prices with associated effort data to include gear type and amount, time fished, area fished, along with vessel and fisherman information.

South Carolina began collecting TIP length frequencies in 1983 as part of the Cooperative Statistics Program. Target species and length quotas were supplied by NMFS and sampling targets were established for monthly commercial trips by gear sampling was set to collect those species with associated length frequencies. In 2005, SCDNR began collecting age structures (otoliths and spines) in addition to length frequencies, using ACCSP funding to supplement CSP funding. Typically for every four fish measured a single age structure was collected. This sampling periodicity was changed in 2010 to collect both a length and age structure from every fish intercepted as a recommendation from the SEFSC.

North Carolina
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The National Marine Fisheries Service prior to 1978 collected commercial landings data for North Carolina. Port agents would conduct monthly surveys of the state's major commercial seafood dealers to determine the commercial landings for the state. Starting in 1978, the North Carolina Division of Marine Fisheries entered into a cooperative program with the National Marine Fisheries Service to maintain the monthly surveys of North Carolina's major commercial seafood dealers and to obtain data from more dealers.

The North Carolina Division of Marine Fisheries Trip Ticket Program (NCTTP) began on 1 January 1994. The NCTTP was initiated due to a decrease in cooperation in reporting under the voluntary NMFS/North Carolina Cooperative Statistics Program in place prior to 1994, as well as an increase in demand for complete and accurate trip-level commercial harvest statistics by fisheries managers. The detailed data obtained through the NCTTP allows for the calculation of effort (i.e. trips, licenses, participants, vessels) in a given fishery that was not available prior to 1994 and provides a much more detailed record of North Carolina's seafood harvest.

NMFS SECPR Annual Canvas Data for Florida

The Florida Annual Data files from 1976–1996 represent annual landings by county (from dealer reports) which are broken out on a percentage estimate by species, gear, area of capture, and distance from shore. These estimates are submitted by Port agents, which were assigned responsibility for the particular county, from interviews and discussions from dealers and fishermen collected throughout the year. The estimates are processed against the annual landings totals by county on a percentage basis to create the estimated proportions of catch by the gear, area and distance from shore. The sum of percentages for a given Year, State, County, Species combination will equal 100.

Area of capture considerations: ALS is considered to be a commercial landings database which reports where the marine resource was landed. With the advent of some State trip ticket programs as the data source the definition is more loosely applied. As such one cannot assume reports from the ALS by State or county will accurately inform you of Gulf vs. South Atlantic vs. Foreign catch. To make that determination you must consider the area of capture.

4. Recreational Fishery Statistics

4.1 Overview

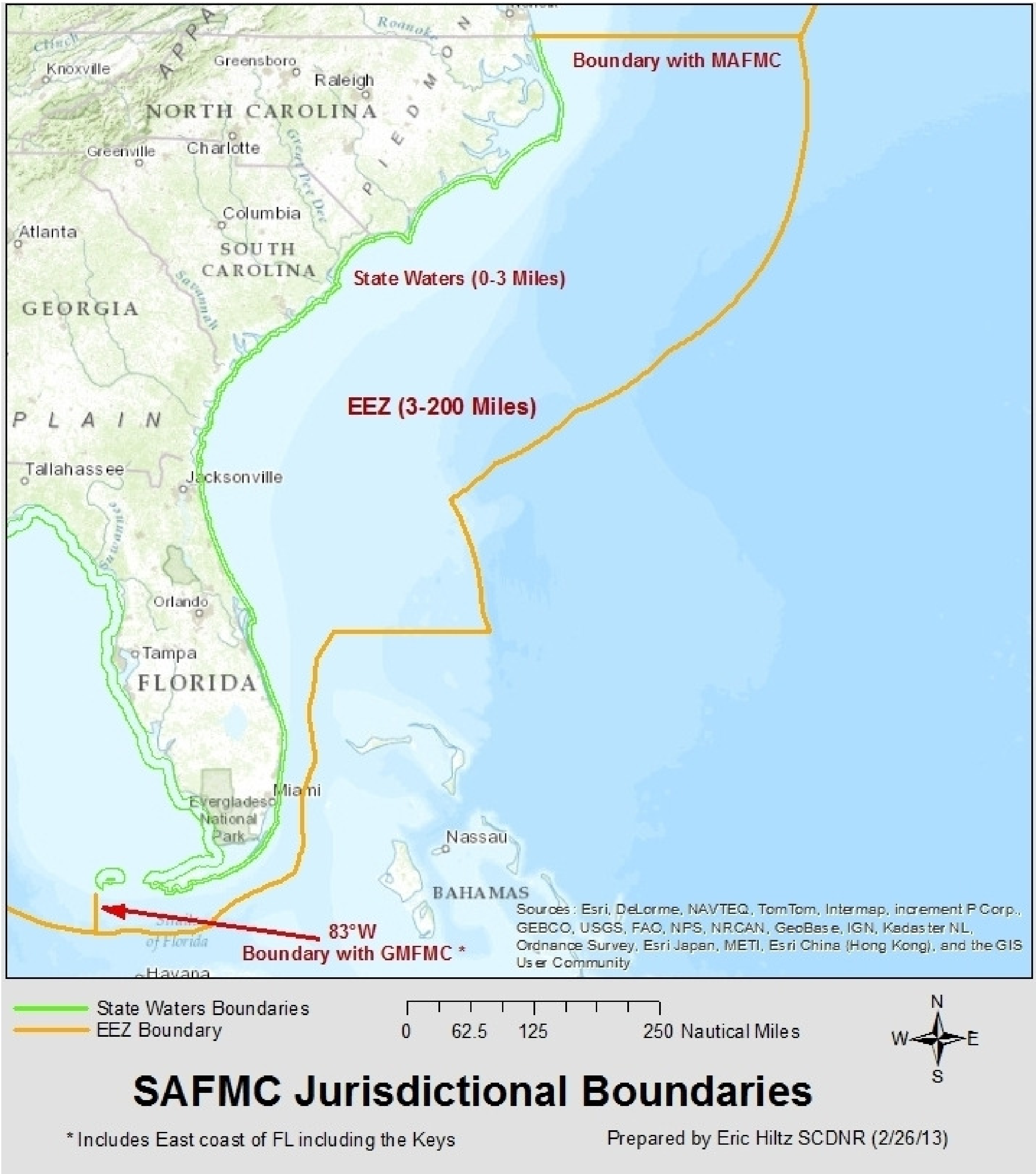
4.1.1 Recreational Working Group (RWG) Membership

Members- Ken Brennan (Leader, NMFS Beaufort, NC), Mark Brown (SAFMC Appointee/Industry rep SC), Sonny Davis (SAFMC Appointee\ Industry rep NC), Kelly Fitzpatrick (NMFS Beaufort, NC), Dawn Franco (GADNR), Eric Hiltz (SCDNR), Rusty Hudson (SAFMC Appointee\ Industry rep FL) Robert Johnson (SAFMC Appointee\ Industry rep FL), Mike Larkin (SERO), Vivian Matter (NMFS SEFSC), Beverly Sauls (FWC, FL), Bill Shearin (SAFMC Appointee\ Industry rep GA), Erik Williams (NMFS Beaufort, NC) and Chris Wilson (NCDNR)

4.1.2 Issues

1) Allocation of Monroe county catches to the Atlantic or the Gulf of Mexico: may vary by data source depending on differing spatial resolutions of the datasets.
2) Headboat estimated landings start in 1972 for NC and SC, 1977 in GA\NEFL and 1981 in SEFL. Estimating red snapper headboat landings from 1972 to1980 (date dependent on region) for periods of partial geographic coverage in the SRHS.
3) Headboat discards. Data are available from the SRHS since 2004. Review whether they are reliable for use, and determine if there are other sources of data prior to 2004 that could be used as a proxy to estimate headboat discards.
4) Calibration of Marine Recreational Fisheries Statistics Survey (MRFSS) to Marine Recreational Information Program (MRIP) 1981-2003.
5) Charter boat landings: MRFSS charter survey methods changed in 2003 in East Florida and in 2004 for Georgia and north.
6) Combined charter boat/headboat landings, 1981-1985: Official headboat landings are available from the SRHS. Therefore, the headboat component of the MRFSS combined charter boat/headboat mode must be parsed out.
7) Usefulness of historical data sources to generate estimates of landings prior to 1981. Review previous methods (SEDAR 24) and other data sources.
8) Review data sources provided for landings and discards in 2012, 2013, and 2014 and decide which will be used for final numbers/estimates.
9) MRIP APAIS adjustment: change in survey protocols starting in 2013.

4.1.3 South Atlantic Fishery Management Council Jurisdictional Boundaries



4.2 Review of Working Papers

SEDAR41-DW-01, *Georgia Headboat Red Snapper Catch & Effort Data, 1983-2014. Capt. Steve Amick and Kathy Knowlton 2015.*
This working paper presents detailed red snapper catch records from a GA headboat. The captain, Steve Amick, recorded his catch records in personal logbooks at the end of every fishing day, including number of released fish (a data element not available for headboats from the NMFS survey until 2004). He offered to provide these data through a cooperative effort with personnel at the Georgia Department of Natural Resources for consideration at SEDAR41. A portion of these data (percent released fish) was used to estimate headboat discards prior to 2007 in SEDAR24. Data elements included vessel, trip type, number red snapper released alive, number red snapper harvested, number of anglers, number of vessel trips and, since 2010, lengths of released fish. Throughout the entire time period (1983 through 2014), Captain Amick typically fished depths of 90-120 feet in the NMFS headboat survey grid 31-80 southeast of Savannah, GA. However, once the moratorium on red snapper harvest began in 2010, Captain Amick's fishing methods changed in an effort to capture and release fewer red snapper. These changes include number of hooks per angler, rigging, bait type, maximum depth fished and angler experience. These changes were significant, and caution should be used when comparing data in the time series from 2010-2014 to those data prior to 2010. Combined, these data represent ~4,400 snapper-grouper fishing trips in which ~45,000 anglers caught ~48,000 and harvested ~22,000 red snapper. They also represent lengths of ~2,000 red snapper released during 2010-2014. The RFWG accepted this working paper and data within for further detailed review.

SEDAR41-DW02, *Georgia Red Snapper Catch and Effort Data Collection during Mini-seasons, 2012-2014. Kathy Knowlton 2015.*
The Georgia red snapper catch and effort data collection during mini-seasons 2012 thru 2014 included phone surveys and biological data collection from for-hire captains, a coast wide carcass collection program, and an electronic survey open to private anglers. Commercial biological sampling was conducted in 2013 and 2014. Biological data collected included centerline length, whole weight (if applicable), sex, and otoliths. General fishing location or depth were also requested for each angler trip. Dockside sampling was mostly from two for-hire captains, at one location, that had previously participated extensively in voluntary red snapper research. A second dockside sampling location was added in 2014. For-hire catch and effort data were collected via telephone interviews with the Georgia for-hire captains who actively fished with and possessed the federal snapper-grouper CH/HB permit. Calls were placed on the Mondays following the fishing weekend, or following the season, and repeated attempts were made throughout the week until the captains were reached. Data elements included whether the trip did or did not target red snapper, number of anglers, and number of fish released and harvested. A voluntary electronic catch survey was available to the public to submit any fishing

trips that targeted red snapper (including trips that targeted but did not catch red snapper). Data elements included trip date and duration, trip departure location, depth fished, number of anglers, number and size of harvested and released fish, and whether the harvested fish were donated to a GADNR carcass freezer. Biological data collected in 2012 included 64 fish via dockside and carcass program sampling (40 whole for-hire fish and 24 carcasses). Effort data collected in 2012 included 16 for-hire trips (2 HB and 14 CH) equaling 100 angler trips (24 HB and 76 CH) and 8 private boat mode vessel trips equaling 31 angler trips. Biological data collected in 2013 included 91 fish via dockside and carcass program sampling (28 whole for-hire fish, 21 gutted commercial fish, and 42 carcasses). Effort data collected in 2013 included 11 for-hire trips (2 HB and 9 CH) equaling 70 angler trips (23 HB and 47 CH) and 13 private boat mode vessel trips equaling 53 angler trips. Biological data collected in 2014 included 283 fish via dockside and carcass program sampling (146 whole for-hire fish, 13 gutted commercial fish, and 124 carcasses). Effort data collected in 2014 included 45 for-hire trips (10 HB and 35 CH) equaling 312 angler trips (132 HB and 180 CH) and 21 private boat mode vessel trips equaling 120 angler trips.

SEDAR41-DW17, *Estimates of Historic Recreational Landings of Red Snapper in the South Atlantic Using the FHWAR Census Method. Brennan, K 2014.*
The National Survey of Fishing, Hunting, and Wildlife-Associated Recreation Survey (FHWAR) has been conducted every 5 years since 1955 and is one of the oldest and most comprehensive recreational surveys. The FHWAR census method utilizes information from these surveys including U.S. angler population estimates and angling effort estimates from 1955–1985 for the South Atlantic region. To obtain historical red snapper landings prior to 1981, estimated saltwater angler trips (1955-1980) are multiplied by average catch rates that are calculated from early years (1981-1985) of the MRFSS/MRIP data. Interpolation is used to complete time series.

SEDAR41-DW18, *South Carolina Red Snapper Catch & Biological Sampling Data Collection during Mini-Seasons, 2012-2013. Duke, A and E. Hiltz 2014.*
Red snapper carcasses were donated to the South Carolina Department of Natural Resources (SCDNR) by private anglers via a freezer collection program and dockside sampling. The mandatory charter logbook information that the SCDNR collects was also used to help access the mini-seasons. Additionally, an online survey was created for anglers to use to tell us about their red snapper catch.

SEDAR41-DW21, *North Carolina Division of Marine Fisheries Red Snapper Carcass Collections, 2012-2013. Duvall, M 2013.*
A pilot carcass collection program was initiated in September 2012 and continued during the 2013 red snapper season to collect biological information for the SEDAR 41 stock assessment. Eight carcass drop-off locations equipped with freezers, informational pamphlets and supplies were strategically chosen at facilities along the coast. Catch cards were used to record trip data

(date, depth, mode of fishing, effort in terms of party size and hours fished, catch information, and contact information) for each donated carcass. Incentives were offered for participation and included fish citation certificates, fish towels, and drink koozies. A total of 82 red snapper carcasses were collected (40 charter boat, 39 headboat, and 3 private boats) during 2012. In 2013, a total of 34 red snapper carcasses were collected (2 charter boat, 29 headboat, and 3 private boats).

SEDAR41-DW23, *Atlantic Red Snapper (Lutjanus campechanus) Fishing History Timeline Hudson, R 2014.*
Southeastern Fisheries Association- East Coast Fisheries Section provides the SEDAR 41 data workshop (DW) working paper to establish a historical timeline of the development of the US Atlantic Red snapper fishery, and follows various events that affected the prosecution of that fishery across time.

SEDAR41-DW24, *Atlantic Red Snapper (Lutjanus campechanus) and Gray triggerfish (Balistes capriscus) Historical Fishing Pictures Summary Hudson, R 2014.*
Southeastern Fisheries Association- East Coast Fisheries Section provides the SEDAR 41 data workshop (DW) a cache of historical deep sea for-hire fishing pictures accurately dated during the 1950's to the 1970's. This collection is from the Ponce de Leon Inlet, Greater Daytona Beach, Volusia County, Florida region. The historically professional photographs are significant as they demonstrate, visually, the for-hire recreational landings of Atlantic Red snapper and Red snapper by day, month and year for this region.

SEDAR41-DW25, *Atlantic Red Snapper (Lutjanus campechanus) and Gray triggerfish (Balistes capriscus) Index of For-Hire Vessels from the SAFMC region Hudson, R 2014.*
Southeastern Fisheries Association- East Coast Fisheries Section provides the SEDAR 41 data workshop (DW) an index of for-hire vessels from the South Atlantic Fishery Management Council (SAFMC) region that mostly participated in the fisheries for Atlantic Red snapper and Red snapper.

SEDAR41-DW26, *Atlantic Red Snapper (Lutjanus campechanus) and Gray triggerfish (Balistes capriscus) Photographic and Other Evidence of For-Hire Vessels in the SAFMC region Hudson, R 2014.*
Southeastern Fisheries Association- East Coast Fisheries Section provides the SEDAR 41 data workshop (DW) photographic and other evidence of for-hire vessels from the South Atlantic Fishery Management Council (SAFMC) region that mostly participated in the fisheries for Atlantic Red snapper and Red snapper.

SEDAR41-DW-27, *Red snapper mini-season ad-hoc working group report. Siegfried, K 2014.*

The main objective of the red snapper mini season ad hoc working group is to inform the decision that the recreational workgroup will make on which landings and discards to report for red snapper during the mini seasons in 2012 and 2013. In 2009, an interim rule was enacted to prohibit harvest of red snapper from January 4, 2010 to June 2, 2010. This rule was extended until December and an emergency rule was used to prohibit harvest through 2011. In 2012 and 2013, emergency rules were used to re-open the fishery for a very short duration. The 2012 mini-season was six days long: 9/14-9/16 & 9/21-9/23. The 2013 mini-season was three days long: 8/23-8/25. The key issue is that MRIP was not designed to capture short pulses of fishing, but rather to capture 2-month intervals (waves) of landings, discards, and effort. When a short opening occurs in a fishery, it is unlikely that MRIP will capture the event during its random sampling. If MRIP does happen to capture the event in terms of catch rate, the event will be scaled up by effort in that wave. State partners from North Carolina, South Carolina, Georgia, and Florida supplied data from studies conducted in each state during the 2012 and 2013 mini-season as an attempt to supplement the MRIP data. A detailed explanation of how MRIP estimates are calculated was included in this document. Full descriptions of methods and data collected are available in the working papers SEDAR41-DW-21 (North Carolina), SEDAR41-DW18 (South Carolina), SEDAR41-DW02 (Georgia), and SEDAR41-RD14 and SEDAR41-RD15 (Florida). Merits and deficiencies of each study were briefly outlined, as well as any potential bias.

SEDAR41-DW32, *SCDNR Charterboat Logbook Program Data, 1993 – 2013. Hiltz, E 2014.*
The South Carolina Department of Natural Resources (SCDNR) charterboat logbook program was used to develop indices of abundance for red snapper from 1993 – 2012. The indices of abundance are standardized catch per unit effort (CPUE; catch per angler hour). For red snapper, a delta GLM was used to produce annual abundance estimates. The indices are meant to describe the population trends of fish caught by V1 (6-pack) charter vessels operating in or off of South Carolina.

SEDAR41-DW33, *Size Distribution, Release Condition, and Estimated Discard Mortality of Red Snapper Observed in For-Hire Recreational Fisheries in the South Atlantic, Sauls, B., C. Wilson and K. Fitzpatrick.*
Since 2004, trained fishery observers have been employed on randomly selected headboat fishing trips to observe angler fishing activity and collect detailed information on discarded fish. In addition, observers were employed on charter vessels on the Atlantic coast of Florida in 2013. This paper summarizes the number of sampled trips by state, generates sample weights, and plots weighted length frequencies for all observed red snapper (both harvested and discarded) from headboats. Additional data collected in Florida on hook type, fishing depth, and release condition of observed discards is also synthesized.

SEDAR41-DW38, *Historic catch rates of Red Snapper by headboats through historic photograph analysis. Gray et al. 2014*.
Photographs that span 1951 through 1974 represent historic evidence of catch rates of common recreational species in the Daytona Beach area during that time, including catch rates for Red Snapper. These photographs precede fisheries dependent monitoring estimates, providing historic catch per unit effort (CPUE) rates for stock assessments. Results presented here are a preliminary analysis for Red Snapper CPUE.

SEDAR41-DW42, *South Atlantic Red Snapper (Lutjanus campechanus) monitoring in Florida: Revised recreational private boat mode estimates for 2012 and 2013 mini-seasons, and new private boat mode estimates for the 2014 mini-season. Sauls, B.*
This report provides revised estimates of Red Snapper recreational harvest during mini-season openings in 2012 and 2013 for the private boat segment off the Atlantic Coast of Florida. Methods and results were previously described in reference documents for the first Data Workshop for SEDAR41 (SEDAR41-RD14, SEDAR41-RD15). New results for the 2014 fishing season are also presented in this paper.

4.3 Recreational Landings

Total recreational landings are summarized below by survey. A map and figures summarizing the total recreational red snapper landings are included in Figure 4.11.1.

4.3.1 Marine Recreational Fisheries Statistics Survey (MRFSS) and Marine Recreational Information Program (MRIP)

Introduction
The Marine Recreational Fisheries Statistics Survey (MRFSS) and the Marine Recreational Information Program (MRIP) provide a long time series of estimated catch per unit effort, total effort, landings, and discards for six two-month periods (waves) each year. MRFSS/MRIP provides estimates for three recreational fishing modes: shore-based fishing (SH), private and rental boat fishing (PR), and for-hire charter and guide fishing (CH). When the survey first began in Wave 2 (Mar/Apr), 1981, headboats were included in the for-hire mode, but were excluded after 1985 in the South Atlantic and Gulf of Mexico to avoid overlap with the Southeast Region Headboat Survey (SRHS) conducted by the NMFS Beaufort, NC lab.

The MRFSS/MRIP survey covers coastal Atlantic coast states from Maine to Florida. The state of Florida is sampled as two sub-regions. The east Florida sub-region includes counties adjacent to the Atlantic coast from Nassau County south through Miami-Dade County, and the west Florida sub-region includes Monroe County (Florida Keys) and counties adjacent to the Gulf of Mexico. Separate estimates are generated for each Florida sub-region, and those estimates may be post-stratified into smaller regions based on proportional sampling. Sampling is not conducted in Wave 1 (Jan/Feb) north of Florida because fishing effort is very low or non-existent, with the exception of NC, where wave 1 has been sampled since 2006.

The MRFSS/MRIP design incorporates three complementary survey methods for estimating catch and effort. Catch data are collected through angler interviews during dockside intercept surveys of recreational fishing trips after they have been completed. Effort data are collected using two telephone surveys. The Coastal Household Telephone Survey (CHTS) uses random digit dialing of coastal households to obtain detailed information about the previous two months of recreational fishing trips from the anglers. The weekly For-Hire Survey was implemented in the South Atlantic in the 2000's and interviews charterboat operators (captains or owners) to obtain the trip information with only one-week recall period. Effort estimates from the two telephone surveys are aggregated to produce total effort estimates by wave. Catch rates from dockside intercept surveys are combined with estimates of effort from telephone interviews to estimate total landings and discards by wave, mode, and area fished (inland, state, and federal waters).

Catch estimates from early years of the survey are highly variable with high proportional standard errors (PSE's), and sample size in the dockside intercept portion have been increased over time to improve precision of catch estimates. Several quality assurance and quality control improvements were implemented for the intercept surveys in 1990. Prior to 1990 the contractor did not have regional representatives hired to supervise the samplers in any given area. All samplers were hired as independent sub-contractors and communicated directly with the contractor's home office staff. It is much more likely that the samplers who worked in the 80's would have varied more in their interpretation of sampling protocols and their ability to identify at least some of the more difficult-to-recognize species. There were a number of other changes made to enhance consistency in sampling protocols and improve error-checking in the Statement of Work for the 1990-1992 contracts. Improvements have continued over the years, but the biggest changes happened at that time (personal communication, NMFS). Full survey documentation and ongoing efforts to review and improve survey methods are available at: http://www.st.nmfs.noaa.gov/recreational-fisheries/MRIP/program-evolutionSurvey methods for the for-hire fishing mode have seen the most improvement over time. Catch rate data have improved through increased sample quotas and additional sampling (requested and funded by the states) to the intercept portion of the survey. It was also recognized that the random household telephone survey was intercepting relatively few anglers in the for-hire fishing mode and the For-Hire Telephone Survey (FHS) was developed to estimate effort in the for-hire mode. The new method draws a random sample of known for-hire charter and guide vessels each week and vessel operators are called and asked directly to report their fishing activity. The FHS was officially adopted in the Gulf coast states (including Monroe County in West Florida) in 2000, in East Florida in 2003, and in Georgia through Maine in 2005. The FHS was pilot tested in the

Gulf of Mexico in 1998 and 1999 and in Georgia through Maine in 2004. The FHS does not consider the estimates during pilot years as official estimates; however, FHS data for these years have been used since 2005(e.g. SEDAR 7 red snapper, SEDAR 16 king mackerel, SEDAR 25 black sea bass, etc.).

A further improvement in the FHS method was the pre-stratification of Florida into smaller sub-regions for estimating effort. Pre-stratification defines the sample unit on a sub-state level to produce separate effort estimates by these finer geographical regions. The FHS sub-regions include three distinct regions bordering the Atlantic coast: Monroe County (sub-region 3), SE Florida from Dade through Indian River counties (sub-region 4), and NE Florida from Martin through Nassau counties (sub-region 5). The coastal household telephone survey method for the for-hire fishing mode continues to run concurrently with the newer FHS method.

Calibration of traditional MRFSS charter boat estimates

Conversion factors have been estimated to calibrate the traditional MRFSS charterboat estimates with the FHS for 1986-2003 in the South Atlantic (SEDAR16-DW-15, Sminkey, 2008) and for 1981-2003 in the mid-Atlantic (SEDAR17-Data Workshop Report, 2008). 1986-2003 South Atlantic calibration factors were updated in 2011 (SEDAR25-Data Workshop Report, 2011). The relationship between the old charterboat method estimates of angler trips and the FHS estimates of angler trips was used to estimate the conversion factors. Since these factors are based on effort, they can be applied to all species' landings. In the Gulf of Mexico and the South Atlantic, the period of 1981-1985 could not be calibrated with the same ratios developed for 1986+ because in the earlier 1981-1985 time period, MRFSS considered charterboat and headboat as a single combined mode. Thus, in order to properly calibrate the estimates from 1981-1985, headboat data from the Southeast Region Head-boat Survey (SRHS) were included in the analysis. To calibrate the MRFSS combined charterboat and headboat mode effort estimates in 1981-1985, conversion factors were estimated using 1986-1990 effort estimates from both modes, in equivalent effort units, an angler trip (SEDAR28-DW-12). These calibration factors were applied to the charterboat estimates and are tabulated in Table 4.10.1. The calibration factors have been updated or developed since SEDAR 24.

Separation of SA combined charter/headboat mode

In the South Atlantic, 1981-1985 charter and headboat modes were combined into one single mode for estimation purposes. Since the NMFS Southeast Region Headboat Survey (SRHS) began in this region in 1981, the MRFSS combined charter/headboat mode must be split in order to not double estimate the headboat mode for these years. MRFSS charter/headboat mode was split in these years by using a ratio of SRHS headboat angler trip estimates to MRFSS charter boat angler trip estimates for 1986-1990. This method has been used in the past (SEDAR 28-Spanish mackerel and cobia). The mean ratio was calculated by state (or state equivalent to match SRHS areas to MRFSS states) and then applied to the 1981-1985 estimates to strip out the headboat component. These headboat estimates were then eliminated from the MRFSS estimates.

MRIP weighted estimates, APAIS changes, and the calibration of MRFSS estimates

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. Revised catch and effort estimates from 2004 to 2012, based on MRIP's improved estimation methodology, were released on January 25, 2012. For estimates prior to 2004, an MRIP Calibration Workshop was held in 2012, and the Consultant's Report recommended that MRFSS estimates prior to 2004 be calibrated to the new MRIP estimation method (Boreman, 2012) using a method developed by an MRFSS/MRIP Calibration Ad-hoc Working Group following the Calibration Workshop (Salz et al. 2012).

Starting in 2013, wave 2, the MRIP Access Point Angler Intercept Survey (APAIS) implemented a "revised sampling design that includes an updated sampling frame; eliminates interviewer latitude in selecting interviewing sites; establishes discrete sampling periods of fixed duration, including nighttime sampling; and requires interviewers to collect detailed information about the number of completed boat and angler fishing trips during the sampling period" (MRIP Implementation Plan 2011). To address this new survey design change, a second Calibration Workshop was held in 2014 and the final report from that workshop recommended an additional calibration for catch estimates (Carmichael and Van Vorhees 2015). The recommended interim calibration approach, found in Appendix 2 of the report, uses the ratio of the catch estimated in 2013 using the entire sampling period for the new MRIP APAIS design, versus catch estimated in 2013 using only during peak sampling periods in the old MRFSS survey design. Red snapper catch for all years prior to 2013 was re-estimated using this ratio, based on a single year of data from the new APAIS design (2013), for each sub-region, state, and mode combination with all waves and areas combined. Tables 4.10.2 and 4.10.3 show the differences between the South Atlantic red snapper MRIP APAIS landing and discard estimates and the MRIP estimates for the time period 2004-2012.

As new MRIP APAIS estimates are available for a portion of the recreational time series that the 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 South Atlantic red 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. Table 4.10.4 shows the ratio estimators used in the calibration. Figure 4.11.2 shows the MRIP versus MRIP APAIS adjusted estimates for South Atlantic red snapper along with the 95% confidence intervals. The RWG expressed concern with basing the MRIP APAIS adjustment on 2013 red snapper MRIP data. The mini season in this year consisted of three fishing days which resulted in low sample sizes in the MRIP database. The group had reservations about using an adjustment based on so little data. The RWG suggested using an additional year of data from 2014 to increase the amount of information used in the adjustment. This was not feasible for this assessment due to limited MRIP staff time. In accordance with the recommendations set forth by the MRIP Calibration Workshop II, MRIP personnel will continue to investigate the remaining two methods described in the report. It is possible that one of them will be determined to be a better method at some future date. In the interim, the simple ratio method is recommended by the MRIP Calibration Workshop II and the RWG.

Monroe County

Monroe County MRFSS landings from 1981 to 2003 can be post-stratified to separate them from the MRFSS West Florida estimates. Post-stratification proportionally distributes the state-wide (FLE and FLW) effort into finer scale sub-regions and then produces effort estimates at this finer geographical scale. This is needed for the private and shore modes (all years) and charter boat mode (prior to FHS). FHS charter boat mode estimates are already pre-stratified, as discussed above. Monroe County MRIP landings starting in 2004 can be estimated separately from the remaining West Florida estimates using domain estimation. The Monroe County domain includes only intercepted trips returning to that county as identified in the intercept survey data. Estimates are then calculated within this domain using standard design-based estimation which incorporates the MRIP design stratification, clustering, and sample weights.

Although Monroe county estimates can be separated using these processes, they cannot be partitioned into those from the Atlantic Ocean and those from the Gulf of Mexico. Red snapper are less common on the extreme south Atlantic coast of Florida. In accordance with SEDAR 24 (SA red snapper) and SEDAR 31 (Gulf red snapper), the recreational workgroup recommends allocating Monroe County estimates from MRIP to the Gulf of Mexico.

Shore Estimates

Red snapper is an offshore species with a strong association with reefs and hard bottom. Several species of nearshore fish are often referred to as “red snapper” by anglers, which may explain the infrequent red snapper shore landings in the MRIP time series. In accordance with SEDAR 24, the recreational workgroup recommends omitting the MRIP shore mode estimates.

Calculating landings estimates in weight

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 Life History Working Group (W=1.58E-5*(L^3.03)) was used to convert red snapper sample lengths into weights, when no weight was recorded. W is whole weight in grams and L is fork length in millimeters.

1981, wave 1

MRFSS began in 1981, wave 2. In the east coast of Florida, catch for 1981 wave 1 was estimated by determining the proportion of catch in wave 1 to catch in all other waves for 1982-1984 by fishing mode and area. These proportions were then used to estimate wave 1 in 1981 from the estimated catches in other waves of that year. This methodology is consistent with past SEDARs (e.g. SEDAR 28 Spanish mackerel and cobia).

Variances

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.

Results

MRIP landings in numbers of fish and in whole weight in pounds are presented in Table 4.10.5. CVs associated with estimated landings in numbers are also shown. South Atlantic red snapper estimates include North Carolina through East Florida, not including Monroe County, FL. There are no red snapper estimates in MRIP north of North Carolina. MRIP estimates shown are through 2011. Mini season estimates from 2012 to 2014 will be discussed separately.

The RWG examined the high MRIP estimate in 1985 (288,971 fish). The 1984 estimate (212,547 fish) was also quite high, showing an increase in landings these two years. As stated above, the estimates in these early years of the survey are highly variable. The 1985 estimate is made up of a number of cells: FLE, PR, ocean>3mi, wave 1 (81,635 fish); FLE, PR, ocean>3mi, wave 5 (51,675 fish); FLE, CH, ocean>3mi, wave 4 (42,631 fish); NC, CH, ocean>3mi, wave 4 (50,776 fish) among others. Table 4.10.6 shows the estimates for 1984 and 1985 by state, wave, and mode. The RWG investigated two estimates which occurred in waves 1 and 2 that were particularly concerning due to the time of year they occurred. These are highlighted in the table in yellow. The 1984 wave 2 private mode estimate from Florida was based on 3 trips, all with an area greater than 3 miles

1a) Volusia County, March, 2 anglers, 1 fish, size: 330mm; 0.6kg

2a) St. John County, April, 4 anglers, 35 fish, no size information

3a) Duval County, April, 2 anglers, 35 fish, sizes: 232-329mm; 0.2- 0.5kg

The 1985 wave 1 private mode estimate from Florida was based on 4 trips, all occurring in February.

1b) Indian River County, >3 miles, 1 angler, 6 fish, no size information

2b) Indian River County, >3 miles, 4 anglers, 16 fish, sizes: 430-530mm; 1.4- 2.3kg

3b) Dade County, <3 miles, 2 anglers, 1 fish, size: 430mm; 0.9kg

4b) Dade County, <3 miles, 4 anglers, 1 fish, size: 410mm, 1.3kg

The RWG speculated that the red snapper intercepted in trips 1a, 3a, 3b, and 4b were probably vermilion snapper due to their small sizes and in the cases of 3b and 4b, the location of where they were caught. In the case of the 1985 wave 1 private mode estimate from Florida, suspected trips only account for less than 10% of that particular estimate. This was determined using the breakdown of the final estimate by area fished. Less than 10% of that estimate came from area fished less than 3 miles (trips 3b and 4b). It is difficult to make changes to the intercept data many years after the data is collected and the RWG recommends using the resulting estimates "as is" and taking into consideration an appropriate measure of the precision (personal communication, NMFS). Further changes preferred by the assessment panel could include modeling, substitutions, or sensitivity runs. These should be fully documented and approved at the Assessment Workshop.

4.3.2 Southeast Region Headboat Survey

Introduction

The Southeast Region Headboat Survey (SRHS) estimates landings and effort for headboats in the South Atlantic and Gulf of Mexico. The Headboat Survey began in 1972 in North Carolina and South Carolina. In 1976 the survey was expanded to northeast Florida (Nassau-Indian River counties) and Georgia, followed by southeast Florida (St. Lucie-Monroe counties) in 1978. Due to headboat area definitions and confidentiality issues, Georgia and East Florida data must be combined. The SRHS began in the Gulf of Mexico in 1986 and extends from Naples, FL to South Padre Island, TX. The South Atlantic and Gulf of Mexico headboat surveys generally include 70-80 vessels participating in each region annually.

The SRHS incorporates two components for estimating catch and effort. 1) Biological information: size of the fish landed are collected by port samplers during dockside sampling, where fish are measured to the nearest mm and weighed to the nearest 0.01 kg. These data are used to generate mean weights for all species by area and month. Port samplers also collect otoliths and spines for ageing studies during dockside sampling events. 2) Information about total catch and effort are collected via a logbook form that is filled out by vessel personnel for individual trips. These logbooks are summarized by vessel to generate estimated landings by species, area, and time strata. Most recently, the SRHS implemented electronic logbook reporting in the South Atlantic and Gulf of Mexico as of Jan 1, 2013. Headboat personnel now have the ability to report trip information via a website or mobile application.

In the early years of the SRHS, there was only partial geographic coverage in the South Atlantic. Red snapper landings are available in NC and SC beginning in 1972. Landings are not available for GA/NEFL from 1974-1975 or SEFL from 1972-1980. For SEDAR 24, estimates for these areas/time periods were calculated using the ratio of NC and SC landings from 1972-1980 for periods of partial coverage. A three year ratio was used to estimate landings for the areas and time periods without coverage. For GA/NEFL a three year ratio is calculated by dividing the total landings for NEFL (1976-1978) by NC and SC combined total landings (1976-1978). This ratio is then multiplied to the 1974 and1975 combined total landings for NC and SC, resulting in the total landings for NEFL for 1974 and 1975. The same approach was used to calculate landings for SEFL 1972-1980 by using the total landings from 1981- 1983. This same method and landings were accepted for use in SEDAR 41.

Catch Estimates

Final SRHS landings estimates are shown in Table 4.10.7, by year and state in Figure 4.11.3. SRHS areas 1-17 are included in the red snapper stock.

Characterizing sources of uncertainty

Variances estimates are not currently available for the SRHS catch estimates. Further research is required to develop a suitable method to calculate variance. The RWG included this as a research recommendation.

4.3.3 Red Snapper Mini-Season Landings

Introduction

The main objective of the red snapper mini season ad hoc working group was to provide information to the recreational workgroup to aid in decisions that were needed on which landings and discards to report for red snapper during the mini seasons in 2012, 2013 and 2014. In 2009, an interim rule was enacted to prohibit harvest of red snapper from January 4, 2010 to June 2, 2010. This rule was extended until December and an emergency rule was used to prohibit harvest through 2011. In 2012, 2013 and 2014, emergency rules were used to re-open the fishery for a very short duration. The 2012 mini-season was six days long: 9/14-9/16 & 9/21-9/23. The 2013 mini-season was three days long: 8/23-8/25. The 2014 mini-season was 8 days long: 7/11-7/13, 7/18-7/20, and 7/25-7/26. The key issue is that MRIP was not designed to capture short pulses of fishing, but rather to capture 2-month intervals (waves) of landings, discards, and effort. When a short opening occurs in a fishery, it is unlikely that MRIP will capture the event during its random sampling. If MRIP does happen to capture the event in terms of catch rate, that event will be scaled up by effort in that wave.

The sources of mini-season data that were reviewed for potential use are as follows:

- Marine Recreational Information Program (MRIP)
- North Carolina Department of Marine Fishers (NCDMF) state survey
- South Carolina Department of Natural Resources (SCDNR) state survey
- Georgia Department of Natural Resources (GADNR) state survey
- Florida Fish and Wildlife Conservation (FWC) Commission state survey

State partners in the South Atlantic supplied data from studies conducted in each state during the 2012, 2013 and 2014 mini-seasons as an attempt to supplement the MRIP data. Brief synopses of the type of data provided are illustrated in Table 4.10.8. Full descriptions of methods and data collected are available in the working papers SEDAR41-DW27 (MRIP), SEDAR41-DW-21 (NC), SEDAR41-DW18 (SC), SEDAR41-DW02 (GA), SEDAR41-DW-42 (FL).

The recreational workgroup developed a set of rules in order to determine which data set was more appropriate for landings by state (NC, SC, GA, and FLE), mode (charter and private), and wave (1-6):
Either MRIP or state available
• Use state number if no MRIP number exists, making note of any potential bias
• Use MRIP number if no state number exists

Both MRIP and state numbers available
• Landings - Recommend using the estimate/number (MRIP or State) that is more reliable (e.g. larger sample size). In 2014, this option was clarified to include accounting for CV's, and/or biases associated with each survey.

The majority of the waves had either MRIP or State survey data available. When only the state survey data was available, potential sources of bias were considered, and noted in the decisions below. However, using the only available data for the wave was favored over using no data at all. There were several cases of overlap for landings data in 2012 (Table 4.10.9) and 2014 (Table 4.10.11). Florida was the only state that had an overlap of landings data in 2013 (Table 4.10.10).

Issue: *How to characterize the recreational landings during mini-seasons in 2012 for each state, mode, and wave.*

Option 1: Use State number if no MRIP number is available, making note of any potential bias
Option 2: Use MRIP number if no State number is available
Option 3: Use the estimate/number (MRIP or State) that is more reliable (e.g. larger sample size) when both MRIP and State numbers were available.

Decision(s):
Option 1.

- State Charter (CH) - SC (waves 3, 4, and 5) and FLE (wave 5).
- State Private (PR) - NC (wave 5) and SC (Wave 5)

The CH landings from SC and FLE were self-reported through either the logbook program (SC) or telephone survey (FLE) without methods to validate the reported landings. The PR landings from NC were primarily based on number of donated carcasses and are therefore not considered to be a random sample. Some of the PR landings from SC were from donated carcasses but also include intercepts from the SFS.

Option 2.

- MRIP FLE (wave 2).

Option 3.

- MRIP CH - NC (wave 5) - The NC charter MRIP estimate was selected over the state number because the state number was based on donated carcasses and is therefore not considered to be a random sample.
- MRIP PR - GA (wave 5) – The GA private MRIP estimate was selected over the state number because the state number was based on a voluntary self-reported online survey with a very small sample size and was not a random sample.
- State CH – GA (wave5) - The GA state CH numbers were selected over MRIP because the state survey was a census of all active captains that held federally permitted snapper grouper licenses and also had a larger sample size.
- State PR – FLE (wave 5)- The PR landings from FLE did not capture what might have occurred outside of the mini-season, however, the FLE state PR estimate were selected over MRIP due to larger sample sizes along with randomly selected intercept sites, and weighted estimates and was considered a more reliable estimate.

Issue 2: *How to characterize the recreational landings during mini-season in 2013 for each state, mode, and wave.*

Option 1: Use state number if no MRIP number is available, making note of any potential bias
Option 2: Use MRIP number if no state number is available
Option 3: Use the estimate/number (MRIP or State) that is more reliable (e.g. larger sample size) when both MRIP and state numbers were available.

Decision(s):
Option 1.

- State CH and PR – all of 2013 for NC, SC, and GA

The CH landings from NC were based on donated carcasses. The CH landings from SC and GA were self-reported through either the logbook program (SC) or telephone survey (GA) without methods to validate the reported landings but are considered to be a census of all charter captains that would have been fishing during the mini-season. The PR landings from NC and SC were primarily based on number of donated carcasses and are therefore not considered to be a random sample. The PR landings from GA were collected through a voluntary self-reported online survey with a very small sample size.

Option 2.

- MRIP CH - FLE (wave 5)

Option 3.

- State CH and PR - FLE (wave 4).

The state surveys were selected over MRIP due to larger sample sizes for the state survey and that MRIP estimated catch could have potentially been scaled up by effort in the whole 2 month time period.

Issue 3: *How to characterize the recreational landings during mini-season in 2014 for each state, mode, and wave.*

Option 1: Use State number if no MRIP number is available, making note of any potential bias
Option 2: Use MRIP number if no State number is available
Option 3: Use the estimate/number (MRIP or State) that is more reliable (taking into account sample sizes, CV's, and/or biases associated with the survey) when both MRIP and State numbers were available.

Decision(s):
Option1.

- State Charter (CH) – SC (Wave 3 and 4) - The CH landings from SC were self-reported through the logbook program without methods to validate the reported landings.
- State Private (PR) – NC (wave 4) - The PR landings from NC were based on number of donated carcasses and are therefore not considered a random sample.

Option 2.

- MRIP (PR) – FLE (Wave 1,3, and 6)

Estimates for MRIP based on 1 angler trip for each wave with high CV (>1.0) and therefore could be an overestimate of actual landings. These intercepts were verified by looking at the field data sheets.

Option 3.

- MRIP (CH) – NC (Wave 4) - The MRIP estimates were selected for CH in NC (wave 4) due to fact that the state survey number was based on carcass donations and likely to be an underestimate of statewide landings and had a larger associated bias compared with the MRIP survey methodology. The number of angler trips for NC was low (3) but the group felt that there was less potential for bias in the MRIP survey than the NC state survey.
- State (PR) – SC (Wave 4) - The SC state survey also relied solely on carcass donations but the state survey number was determined to be a more accurate representation, in this case, due to the fact that the MRIP estimate was derived from only one angler trip. The number of angler trips was not reported from the SC state survey, only conclusion was the value was greater than 1.
- State (CH) – GA (Wave 4) - The GA state CH number was selected over MRIP because the state survey was a census of all active captains that held federal snapper/grouper permits and also had a larger sample size (180) than MRIP (1).
- MRIP (PR) – GA (Wave 4) - The MRIP PR estimate was chosen over the GA state survey because the state survey information was voluntary angler reported data with no way of validating information or accounting for non-reporting.
- State (CH) – FLE (Wave 4)
- State (PR) – FLE (Wave 4)

The FLE state CH and PR estimates (wave 4) were selected over MRIP due to larger sample sizes and robust survey methodology that included randomly selected intercept sites and weighted estimates. However, it was noted that the FLE state survey could likely be an underestimate of recreational landings since there was no accounting for any fishing that may have occurred outside of the season. There were reported landings in FLE through MRIP on the day following the end of the season, Sunday July 27.

Uncertainty concerning data sources

There was extensive discussion about which data source to choose when both MRIP and state survey data were available for an individual mode and wave. The merits and deficiencies of each data source were discussed at length for the red snapper mini-seasons in 2012, 2013 and 2014. Several RWG members expressed concerns that MRIP is likely to overestimate landings of red snapper because of expansion by effort from the entire wave. Each state survey was unique and there was little similarity in methods used. The SC logbook was a census of all charter captains that would have been targeting Snapper/Grouper species during the mini-season, but it was also noted that these data are self-reported without validation and that there may be some recall bias when logs are handed in one month after the fishing occurred. The GA CH telephone survey was a census of all active CH captains that held federal permits for Snapper/Grouper species, with minimal recall bias because phone calls were made the Monday following each weekend within the mini-season in 2012 and 2013, and the Monday following the end of the mini-season in 2014, but like SC, these are all self-reported data without validation. The FLE CH telephone survey attempted to reach all captains that would have targeted red snapper during the mini-season, data were expanded to account for all captains that were not reached, recall bias was minimal because phone calls were made the week following each weekend opening, but was not a representation of any fishing that might have occurred outside of the mini-season. The SC State Finfish Survey (SFS) was only conducted in 2012 and were solely a record of number of specimens sampled without any effort information. The GA online survey was self-reported information that included number of fish harvested and/or released and number of anglers but could not be used to expand data into an estimate. A consistent comment concerning voluntary angler reported data was that it was likely to produce an underestimate since not all anglers who caught fish will participate. The FLE private boat intercept survey directly targeted the mini-season and should be an accurate estimate of total catch and effort during the mini-season, but as stated above is not a representation of any harvest that might have occurred outside the mini-season. The RWG took all of these points under consideration when deciding which data to use and felt confident in the choices that were made.

4.3.4 Historic Recreational Landings

Introduction

The historic recreational landings time period is defined as pre-1981 for the charter boat, headboat, private boat, and shore fishing modes, which represents the start of the Marine Recreational Fisheries Statistics Survey (MRFSS) and availability of landings estimates for red snapper. The Recreational Working Group was tasked with reviewing all available historical sources of red snapper landings to evaluate potential methods to compile landings prior to the available time series of MRFSS and headboat estimated landings.

The sources of historical landings that were reviewed for potential use are as follows:

- Review and Analysis of Methods to Estimate Historic Recreational Red Snapper Landings in the South Atlantic, SEDAR24-DW11.
- Anderson, 1965.
- The National Survey of Fishing, Hunting, and Wildlife-Associated Recreation Survey (FHWAR) census method, SEDAR41-DW17.
- Review of red snapper historical photos; SEDAR41-DW 24 and SEDAR41-DW 26.
- Preliminary analysis of historical photos: SEDAR41-DW 38.

SEDAR24-DW11

The SEDAR 24 Historic Fisheries Working Group (HFWG) considered several historic data sets for comparison with available recreational data sets as a possible means for regressing recreational statistics back in time. The HFWG recommended the methods that use (1) the ratios with the commercial red snapper landings and (2) the post-adjusted U.S. Fish and Wildlife Saltwater Angling Survey estimates, be considered by the data workshop for inclusion in the stock assessment. The final decision for SEDAR 24 was to use the ratios with the commercial red snapper landings

Anderson, 1965

The RWG discussed the Anderson study as a possible source of information for historical red snapper landings. The study area designated as the Cape Canaveral area included Brevard and Volusia counties in Florida. The recreational data was obtained from field surveys from February to October, 1963 and was further limited to the southern portion of the study area. The RWG considered this spatially and temporally limiting for possibly expanding estimated landings prior to 1981. However, the RWG did conclude that the data could be used as a reference point for comparison to other methods (i.e. FWHAR method)

Preliminary analysis of historical photos

After reviewing numerous black and white photos from the east coast of Florida charter boat and headboat fishery (courtesy of R. Hudson, see below) back to the early 1950's; it was apparent that red snapper was a common recreational species in the Daytona Beach area during that time. As part of a preliminary analysis of photographs that span 1951 through 1974, 377 photographs with red snapper present were examined for historic catch rates. Red Snapper and anglers were counted and recorded from each picture in order to calculate catch per unit effort (CPUE). The results are reported in SEDAR41-DW38. Although the results were preliminary for this data workshop, the RWG agreed this analysis shows great potential for providing historic CPUE rates for future stock assessments. A proposal is being developed to provide a more complete analysis of the photographs.

FHWAR census method

The FHWAR method (SEDAR41-DW17) was first used in SEDAR 28 to reconstruct landings back to 1950. The two key components from these FHWAR surveys that they used in the census method to produce both estimates of U.S. saltwater anglers and the estimates of U.S. saltwater days. The first objective was to determine the total saltwater anglers and saltwater days for the South Atlantic (SA) by using the summary information of U.S. anglers and U.S. saltwater anglers from the FHWAR surveys. The ratio of U.S saltwater anglers to the total U.S anglers was applied to the total number of anglers for the SA to yield the total saltwater anglers for SA. The same method was used to calculate the total saltwater days for the SA from the FHWAR surveys 1955-1985.

In the FHWAR surveys the South Atlantic included the entire state of Florida, east and west coasts. In order to address the management boundaries for red snapper the saltwater angler days for Florida's west coast (FLW) were separated from the SA saltwater angler days using the ratio of the MRFSS total angler trips for FLW to the MRFSS total angler trips for the South Atlantic (Delaware to FLW). The average ratio from 1984-1986 was applied to the total saltwater days for the SA 1955-1985 to remove FLW effort.

Similar to the SWAS there was a 12 month recall period for respondents, which resulted in greater reporting bias. Research concluded this bias resulted in overestimates of both the catch and effort estimates in the FHWAR surveys from 1955 to 1985. Consequently, as was case in SEDAR 28, an adjustment for recall bias was necessary. The total saltwater days for the SA 1955-1985 were adjusted for recall bias in the FHWAR surveys. The MRFSS total angler trips (private and charter boat modes) for the SA 1984 to1986 was averaged and divided by the total saltwater days for 1985 from the FHWAR survey. This multiplier was then applied to the total SA saltwater days 1955-1985 to adjust for recall bias. In 1984 a 12 inch size limit was instituted in the SA. In order to reflect the discard history prior to 1984 a mean CPUE for red snapper in the SA from the combined estimates from MRFSS and SRHS for 1981 to 1983 was then applied to the adjusted saltwater angler days for the SA 1955-1985 to estimate the historical red snapper landings for those years (Table 4.10.12).

Issue: Available historical red snapper landings prior to 1981.

Option 1: Use the ratio of historic commercial landings as a proxy for recreational catch (SEDAR 24 method)

Option 2: Use FHWAR census method to estimate red snapper landing 1955-1980 in the South Atlantic. Use interpolation to complete time series.

Option 3: Use available recreational time series for the MRFSS\MRIP 1981to 2013and headboat estimates 1972 - 2014.

Decision: *Option 2*.
Option #2: Use FHWAR census method with modifications to estimate red snapper landing back in time.

Historical Catch Estimates
Final historical landings estimates are shown in Table 4.10.13. and Figure 4.11.4.

Uncertainty concerning the FHWAR census method
Standard deviations and variances are provided for the historical recreational catch estimates using the FHWAR census method Table 4.10.12.

4.3.5 Potential Sources for Additional Landings Data

SCDNR Charter boat Logbook Program Data, 1993 – 2014

The Recreational Fisheries Working Group discussed the possibility of replacing the MRIP charter mode estimates for South Carolina from 1993 to 2014 with the SCDNR Charter boat Logbook Program estimates. The SCDNR Charter boat Logbook Program is a mandatory logbook program and is a complete census. However, the data are self-reported and no field validation is done on catch or effort. SCDNR charter boat logbook data were compared with MRIP charter mode estimates (Figure 4.11.5). The Recreational Fisheries Working Group recommended not replacing the MRIP charter boat estimates with the SCDNR Charter boat Logbook Program estimates for 1993 – 2014. The MRIP estimates represent a longer time series and switching from the MRFSS dataset (1981 – 1992) to the SCDNR Charter boat logbook dataset (1993-2014) would artificially reduce the total catch potentially due to the change in methodology that would not necessarily be indicative of a change in the red snapper population which could affect the stock assessment model. Concern was also expressed about replacing the MRIP dataset with the SCDNR Charter boat logbook dataset because the data would only be replaced for one state (SC) and one mode (charter). Additionally since MRFSS/MRIP estimates are currently used to monitor annual catch limits (ACL's), the group thought it would be appropriate to use these estimates for the recreational landings data.

4.4 Recreational Discards

Total recreational discards are summarized below by survey. A map and figures summarizing the total recreational red snapper discards are included in Figure 4.11.6.

4.4.1 MRFSS/MRIP Discards

Discarded live fish are reported by the anglers interviewed by the MRIP/MRFSS. Consequently, neither the identity nor the quantities reported are verified. Lengths and weights of discarded fish are not sampled or estimated by the MRFSS/MRIP.

MRFSS/MRIP estimates of live released fish (B2 fish) were adjusted in the same manner as the landings (i.e. using charterboat calibration factors, MRIP adjustment, substitutions, etc. described above in section 4.3.1).

MRIP discards in numbers of fish and associated CVs are presented in Table 4.10.14. South Atlantic red snapper estimates include North Carolina through East Florida, not including Monroe County, FL. There are no red snapper estimates in MRIP north of North Carolina.

4.4.2 Headboat At-Sea Observer Survey Discards

An observer survey of the recreational headboat fishery was launched in NC and SC in 2004 and in GA and FL in 2005 to collect more detailed information on recreational headboat catch, particularly for discarded fish. Headboat vessels are randomly selected throughout the year in each state, and the east coast of Florida is further stratified into northern and southern sample regions. Biologist's board selected vessels with permission from the captain and observe anglers as they fish on the recreational trip. Data collected include number and species of fish landed and discarded, size of landed and discarded fish, and the release condition of discarded fish (FL only) Data are also collected on the length of the trip, area fished (inland, state, and federal waters) and, in Florida, the minimum and maximum depth fished. In the Florida Keys (sub-region 3) some vessels that run trips that span more than 24 hours are also sampled to collect information on trips that fish farther offshore and for longer durations, primarily in the vicinity of the Dry Tortugas. The red snapper discard data from the MRFSS At-Sea Observer Headboat program and the Southeast Region Headboat Survey (SRHS) logbook were compared (SEDAR 41-DW_29, 2014). Based on the results of these comparisons, it was determined that the SRHS discard rates was validated by the MRFSS/MRIP At-Sea Observer data. Therefore, the SRHS discard estimates would be used and the MRFSS/MRIP At-Sea Observer data was not recommended for use in this assessment.

4.4.3 Headboat Logbook Discards

The Southeast Region Headboat Survey logbook form was modified in 2004 to include a category to collect self-reported discards for each reported trip. This category was described on the form as the number of fish by species released alive and number released dead. Port agents instructed each captain on criteria for determining the condition of discarded fish. A fish was considered "released alive" if it was able to swim away on its own. If the fish floated off or was obviously dead or unable to swim, it was considered "released dead". As of Jan 1, 2013 the SRHS began collecting logbook data electronically. Changes to the trip report were also made at this time, one of which removed the condition category for discards i.e., released alive vs. released dead. The new form now collects only the total number of fish released regardless of condition. These self-reported data are currently not validated within the Headboat Survey. It was determined that the logbook discard data would be used from 2004-2014. This analysis was updated to include the 2014 data, which supported the decision to use the logbook discard data (SEDAR 41-DW_29, 20142015). The RWG concluded that a proxy should be used to estimate the headboat red snapper discards for years prior to 2004. The RWG considered the following three possible data sources to be used as a proxy for estimated headboat discards for 1981-2003 (Figure 4.11.7a & 4.11.7b).

- MRIP CH discard ratio proxy method 1981-2003.
- Captain Steven Amick's discard ratio proxy method 1983-2003. (SEDAR 28-Data Workshop Report, 2010).
- MRIP CH:SRHS discard ratio proxy method 1981-2003 (SEDAR 28-Assessment Workshop Report, 2012).
- SRHS Dockside sample method

Issue: Discard information not available prior to 2004, need a proxy for estimated headboat discards from 1981-2003.

Option 1: MRIP CH: Apply the MRFSS charter boat discard:landings ratio to estimated headboat landings in order to estimate headboat discards from 1981-2003; then apply a 3 year (1981-1983) mean discard:landings ratio to estimated headboat landings in order to estimate headboat discards from 1972-1980.

Option 2: Captain Steve Amick's discard:landings ratio: Apply ratio to estimated headboat landings in order to estimate headboat discards from 1983-2003; then apply a 3 year mean discard:landings ratio to estimated headboat landings in order to estimate headboat discards from 1972-1983.

Option 3: MRIP CH:SRHS: Calculate a ratio of the mean ratio of SRHS discard:landings (2004-2013) and MRIP CH discard:landings (2004-2013). Apply this ratio to the yearly MRIP charter boat discard:landings ratio (1981-2003) in order to determine the yearly SRHS discard:landings ratio (1981-2003). This ratio is then applied to the SRHS landings (1981-2003) in order to estimate headboat discards (1981-2003). Then apply a 3 year (1981-1983) mean discard:landings ratio to estimated headboat landings in order to estimate headboat discards from 1972-1980.

Option 4: SRHS Dockside sample method: From the SRHS dockside samples calculate the mean ratio of fish less than 12in TL (1981-1983) and subtract from that the mean ratio of fish less than 12in TL (1992-2003); apply that to the SRHS landings (1984-2003) to get the number of fish <12in TL discarded (1984-2003). Calculate the mean ratio of fish 12in TL to less than 20in TL (1984-1991) and subtract from that the mean ratio of fish less 12in TL to less than 20in TL (1992-2003); apply that to the SRHS landings (1992-2003) to estimate the number of fish 12in TL to less than 20in TL discarded (1992-2003).

Decision: Option 4. The SRHS dockside sample method uses information collected directly from the SRHS to estimate discards based management measures (i.e. size limits). It was concluded this method would most accurately reflect changes in discards which were due in large part to changes in management. Both the MRIP CH:SRHS discard ratio method and the MRIP CH discard ratio method followed the same pattern, or agreed well with the SRHS discard ratio in 2004-2009. However, these methods produce highly variable discard estimates for this species. Captain Steve Amick's discard ratio was not recommended due to the reduced time series and limited geographical range. While the MRIP PR discard method did follow a similar pattern as the SRHS in 2004-2009, this method would have caused increased variability in the discard estimate and therefore this method was not recommended. Final discard estimates from the SRHS are shown in Table 4.10.15 by year and state and in Figure 4.11.8.

4.4.4 Red Snapper Mini-season Discards

Introduction

The main objective of the red snapper mini season ad hoc working group was to provide information to the recreational workgroup to aid in decisions that were needed on which discards to report for red snapper during the mini seasons in 2012, 2013 and 2014. The 2012 mini-season was six days long: 9/14-9/16 & 9/21-9/23. The 2013 mini-season was three days long: 8/23-8/25. The 2014 mini-season was 8 days long: 7/11-7/13, 7/18-7/20, and 7/25-7/26. The key issue was that MRIP would be more likely to encompass the entire two month time period while some state surveys only captured the short time interval during the mini-season.

The sources of mini-season data that were reviewed for potential use are as follows:

- Marine Recreational Information Program (MRIP)
- North Carolina Department of Marine Fishers (NCDMF) state survey
- South Carolina Department of Natural Resources (SCDNR) state survey
- Georgia Department of Natural Resources (GADNR) state survey
- Florida Fish and Wildlife Conservation (FWC) Commission state survey

State partners in the South Atlantic supplied data from studies conducted in each state during the 2012, 2013 and 2014 mini-season as an attempt to supplement the MRIP data. Brief synopses of the type of data provided are illustrated in Table 4.10.16. Full descriptions of methods and data collected are available in the working papers SEDAR41-DW27(MRIP), SEDAR41-DW-21 (NC), SEDAR41-DW18 (SC), SEDAR41-DW02 (GA), SEDAR41-RD14 and SEDAR41-RD15 (FL).

The recreational workgroup developed a set of rules in order to determine which data set was more appropriate for discards by state (NC, SC, GA, and FLE), mode (charter and private), and wave (1-6):

Either MRIP or state available

• Use state number if no MRIP number exists, making note of any potential bias

• Use MRIP number if no state number exists

Both MRIP and state numbers available

• Discards - Recommend using the estimate/number (MRIP or State)

that is more reliable or encompasses the whole 2 month time period. In 2014, this option was clarified to include accounting for CV's, and/or biases associated with each survey.

The majority of the waves had either MRIP or State survey data available. When only the state survey data was available, potential sources of bias were considered, and noted in the decisions below. However, using the only available data for the wave was favored over using no data at all.

Florida, Georgia and South Carolina had cases of overlap for discard data in 2012 (Table 4.10.16). Florida and Georgia had cases of overlap for discard data in 2013 and 2014 (Table 4.10.17 and 4.10.18).

Issue 1: How to characterize the recreational discards during mini-seasons in 2012 for each state, mode, and wave.

Option 1: Use State number if no MRIP number is available, making note of any potential bias
Option 2: Use MRIP number if no state number is available
Option 3: Use the estimate/number (MRIP or state) that is more reliable (e.g. larger sample size or that encompasses the whole 2 month time period) when both MRIP and State numbers were available.

Decision(s):
Option 1.

- State CH - SC (waves 2, 3, & 6)
- State PR - SC (wave 5)

The CH discards from SC were self-reported data through the logbook without methods for validation but were considered to be a census of all charter captains fishing during the mini-season. The PR discards from SC were reported through the SFS survey were raw numbers (i.e. not an estimate).

Option 2.

- MRIP CH - NC and FLE for all of 2012 and GA (wave 3).
- MRIP PR - NC (wave 5), SC (wave 3), and FLE (waves 2, 3, 4, & 6)

Option 3.

- State CH - SC (waves 4 & 5) - The SC state survey was selected over MRIP due to larger sample size and because it also encompassed the entire 2 month period.
- MRIP CH - GA (wave 5)
- MRIP PR - GA (wave 5) and FLE (wave 5)

MRIP was selected over the state surveys, even though the state surveys had a larger sample size, because MRIP encompassed the entire two month period and not just the mini season.

Issue 2: How to characterize the recreational discards during mini-season in 2013 for each state, mode, and wave.

Option 1: Use State number if no MRIP number is available, making note of any potential bias
Option 2: Use MRIP number if no state number is available

Option 3: Use the estimate/number (MRIP or state) that is more reliable (e.g. larger sample size or that encompasses the whole 2 month time period) when both MRIP and state numbers were available.

Decision:
Option 1.

- State CH - SC (all waves 2013)
- State PR - GA (wave 4)

The CH discards from SC were self-reported data through the logbook without methods for validation. The PR discards from GA were collected through a voluntary self-reported online survey with a very small sample size.

Option 2.

- MRIP CH - NC (all waves 2013), GA (wave 5) and FLE (waves 1, 5 & 6).
- MRIP PR - NC and SC (all waves 2013), GA (wave 5), and FLE (waves 2, 3 & 5)

Option 3.

- MRIP CH - GA and FL (wave 4)
- MRIP PR - FLE (wave 4)

MRIP was selected over the state surveys, even though the state surveys had a larger sample size, because MRIP encompassed the entire two month period and not just the mini season.

Issue 3: *How to characterize the recreational discards during mini-seasons in 2014 for each state, mode, and wave.*

Option 1: Use State number if no MRIP number is available, making note of any potential bias
Option 2: Use MRIP number if no State number is available
Option 3: Use the estimate/number (MRIP or State) that is more reliable (taking into account sample sizes, CV's, and/or biases associated with the survey) when both MRIP and State numbers were available.

Decision(s): Option1.

- State Charter (CH) – SC (Wave 2 through 6) - The CH discards from SC were self-reported data through the logbook and, as stated for previous years, lack validation methods and had a high potential for recall bias.
- State Charter (CH) – GA (Wave 4) - The CH discards for GA were also self-reported through telephone census of charter captains that held a federal snapper/grouper permit with no method of validation but a lower potential recall bias since numbers were submitted immediately after the mini-season. These discards are raw numbers (i.e. not an estimate).

Option 2.

- MRIP (CH) – NC (Wave 3 and 4)
- MRIP (CH) – GA (Wave 2 and 3)
- MRIP (CH) – FLE (Wave 1, 2, 3, 5 and 6)
- MRIP (PR) – NC (Wave 4)
- MRIP (PR) – SC (Wave 3, 4 and 6)
- MRIP (PR) – GA (Wave 2 and 3)
- MRIP (PR) – FLE (Wave 1, 2, 3, 5 and 6)

Some of the estimated discards are based on a fairly low number of angler trips (e.g. 1 or 2 trips) and have high CV's (>1.0).

Option 3.

- MRIP (PR) – GA (Wave 4)
- MRIP (CH) – FLE (Wave 4)
- MRIP (PR) – FLE (Wave 4)

MRIP estimated discards was preferred over state surveys because MRIP encompassed the entire two month period (i.e. complete wave).

Uncertainty concerning data sources

In most cases, only MRIP or state survey information, but not both, were available for each individual wave. The main concern of potential bias with state survey information was that data were self-reported without means of validation. There was also concern that the state surveys were unlikely to represent discards outside of the mini-season while MRIP would represent discards for each wave. The SC logbook was the only exception since the discards were reported for an entire month, not just the mini-season. However, as stated in 4.3.3, the logbook data are self-reported and there is potential for recall bias. The merits and deficiencies of each data source discussed in 4.3.3 were considered when making decisions. The RWG took all of these points under consideration when deciding which data to use and felt confident in the choices that were made.

Total recreational catch from all surveys and all years are presented in Table 4.10.19.

4.5 Biological Sampling

4.5.1 Sampling Intensity Length/Age/Weight

Length samples from recreational landings were obtained from the Marine Recreational Fisheries Statistics Survey and the Southeast Region Headboat Survey.

Any existing natural total length measurements were converted to maximum total length using the following equation derived for the combined South Atlantic stock by the Life History Working Group at the SEDAR 32 data workshop:

$TL_{max}= 4.62 + 1.02TL_{nat}$ ($R^2 = 0.99$)

MRFSS/MRIP Biological Sampling

The MRFSS/MRIP angler intercept survey includes the sampling of fish lengths from the harvested (landed, whole condition) catch. Up to 15 of each species landed per angler interviewed are measured to the nearest mm along a center line (defined as tip of snout to center of tail along a straight line, not curved over body). In those fish with a forked tail, this measure would typically be referred to as a fork length, and in those fish that do not have a forked tail it would typically be referred to as a total length with the exception of some fishes that have a single, or few, caudal fin rays that extend further. Weights are typically collected for the same fish measured although weights are not preferred when time is constrained. Aging structures and other biological samples are not collected during MRFSS/MRIP assignments because of concerns over the introduction of bias to survey data collection.

The number of red snapper measured in the South Atlantic (NC to FLE) from MRFSS/MRIP by year, mode, and state are summarized in Table 4.10.20. The number of angler trips with measured red snapper measured in the South Atlantic (NC to FLE) in the MRFSS/MRIP by year, mode, and state are summarized in Table.4.10.21 There were concerns about low sample sizes for lengths from 1987 to 1998. Caution should be used for these years since the lengths collected may not necessarily be representative of the fishery. Information on the weights collected (number, mean, minimum, and maximum weights) by year and state from the MRFSS/MRIP is tabulated in Table 4.10.22

In 1986 suspect intercepts were found with 155 red snapper weighing 0.1 kg and measuring 197-210mm. Samples came from Volusia County, charter mode, ocean>3mi, wave 1 from multiple days with the same interviewer. In 1988 suspect intercepts were found with 25 red snapper weighing 0.1 kg and measuring 93-212mm. Samples came from Miami-Dade County, private mode, mostly inshore from multiple waves with a different sampler than the 1986 suspect intercepts. Other years, states, FL counties, and samplers show similar low weight red snappers. The RWG speculated that these red snapper were probably vermilion snapper, however, as these intercepts are many and varied it is difficult to make any adjustments as this would introduce additional bias. In general, it is difficult to make changes many years after the data is collected and the RWG recommends using the resulting estimates “as is” and taking into consideration an appropriate measure of the precision, which is most likely nearly twice as high in these early years than the survey data suggests (personal communication, NMFS).

Headboat Survey Biological Sampling

Lengths were collected from 1972 to 2014 by headboat dockside samplers. From 1972 to 1975, only North Carolina and South Carolina were sampled whereas Georgia and northeast Florida were sampled beginning in 1976. The Southeast Region Headboat Survey conducted dockside sampling for the entire range of Atlantic waters along the southeast portion of the US from the NC-VA border through the Florida Keys beginning in 1978. Weights are typically collected for the same fish measured during dockside sampling. Also, biological samples (scales, otoliths, spines, stomachs and gonads) are collected routinely and processed for aging, diet studies, and maturity studies.

Annual numbers of red snapper measured for length in the headboat fleet and the number of trips from which red snapper were measured are summarized in Table 4.10.23. Dockside mean weights for the headboat fishery are tabulated for 1972-2014 in Table 4.10.24

State of Florida Mini-Season Surveys

Red Snapper lengths were collected during random intercept surveys of private recreational boats in Florida during the recreational harvest season openings in 2012, 2013, and 2014. Site selection methods and intercept survey procedures are detailed in SEDAR41-DW42. Length frequency distributions for harvested Red Snapper by year and sample size (numbers of trips) were provided to the SEDAR41 data compiler. Mean weight of harvested Red Snapper during each season is also provided in Table 4.10.25.

SCDNR State Finfish Survey (SFS)

Red Snapper lengths were collected through the SCDNR State Finfish Survey (SFS) from 1988 to 2012. Starting in 2013 SCDNR took over MRIP sampling responsibilities in SC. Because of this the SFS survey was terminated except for January and February sampling. No Red Snapper were sampled during those months in 2013 and 2014. The SFS collects finfish intercept data in South Carolina through a non-random intercept survey at public boat landings along the SC coast. The survey focuses on known productive sample sites, targets primarily private boat mode, and is conducted year-round (January- December) using a questionnaire and interview procedure similar to the intercept portion of the MRIP. From 1988 through March 2009 mid-line lengths were measured and from April 2009 to 2011 total lengths were measured. From 1988 to 2012 85 red snapper lengths were collected by SFS personnel. The Recreational Fisheries Working Group recommended the SCDNR SFS length data for all modes be used to supplement the MRFSS/MRIP length data for length compositions. Mid-line (fork) measurements from 1988-2009 were converted to total length measurements using the following equation from the Life History Working Group at the SEDAR 41 data workshop:

$TL_{MAX} = 2.22 + 1.07*FL$

Summarized length data from 1988 – 2012 can be found in Table 4.10.26.

Headboat At-Sea Sampling (NC-east FL)
Length frequencies and sample sizes for Red Snapper discards observed by state biologists during Headboat At-Sea sampling from North Carolina through the east coast of Florida, and methods used to weight samples by state, are summarized in SEDAR41-DW33. Overall weighted length frequency distributions for observed Red Snapper discards by year were provided to the SEDAR41data compiler. Raw sample sizes for numbers of discarded fish measured and numbers of trips sampled are provided in Table 4.10.27.

Aging data
The number of red snapper aged from the recreational fishery and the number of trips with aged red snapper by year, state, and mode is summarized in Table 4.11.28. The number of trips provided is a combination of angler and vessel trips. It should be noted that for all modes, the number of age samples were low for certain years.

4.6 Recreational Effort

Total recreational effort is summarized below by survey. Effort is summarized for all marine fishing by mode, regardless of what was caught. A map and figures summarizing MRFSS/MRIP effort in angler trips are included in Figure 4.11.9. A map and figures summarizing SRHS effort in angler days are included in Figure 4.11.10.

4.6.1 MRFSS/MRIP Effort

Effort estimates for the recreational fishery survey are produced via telephone surveys of both anglers (private/rental boats and shore fishers) and for-hire boat operators (charterboat anglers, and in early years, party or charter anglers). The methods have changed during the full time series (see section 4.3 for descriptions of survey method changes and adjustments to survey estimates for uniform time-series of catch estimates). An angler-trip is defined as a single day of fishing by a single angler in the specified mode, not to exceed 24 hours. MRFSS effort estimates are presented from 1981 to 2003. MRIP effort estimates are presented starting in 2004. Angler trip estimates are tabulated in Table 4.10. 29 by year and mode and include all South Atlantic states from North Carolina through East Florida.

4.6.2 Headboat Effort

Catch and effort data are reported on logbooks provided to all headboats in the survey. These forms are completed by the captain or designated crew member after each trip and represent the total number and weight of all the species kept, along with the total number of fish discarded for each species. Data on effort are provided as number of anglers on a given trip. Numbers of anglers are standardized, depending on the type of trip (length in hours), by converting number of anglers to “angler days” (e.g., 40 anglers on a half-day trip would yield 40 * 0.5 = 20 angler days). Angler days are summed by month for individual vessels. Each month, port agents collect these logbook trip reports and check for accuracy and completeness. Although reporting via the logbooks is mandatory, compliance is not 100% and is variable by location. To account for non-reporting, a correction factor is developed based on sampler observations, angler numbers from office books and all available information. This information is used to provide estimates of total catch (expanded or corrected for non-reporting) by month and area, along with estimates of effort.

Estimated headboat angler days have decreased in the South Atlantic in recent years (Table 4.10.30). The most obvious factor which impacted the headboat fishery in the Atlantic was the high price of fuel. This coupled with the economic down turn starting in 2008 resulted in a marked decline in angler days in the South Atlantic headboat fishery. Reports from industry staff, captains\owners, and port agents indicated fuel prices, the economy and fishing regulations are the factors that most affected the amount of trips, number of passengers, and overall fishing effort. However, estimated angler days have risen in recent years (2012-2014).

4.8 Itemized List of Tasks for Completion Following Workshop

The length and age distributions will be prepared and discussed in a working paper for the Assessment Workshop.

4.9 Literature Cited

Anderson, W.W. and J.W. Gehringer, 1965. Biological-Statistical Census of the Species Entering Fisheries in the Cape Canaveral Area. U.S. Department of the Interior, Fish and Wildlife Service; Special Report – Fisheries No. 514.

Boreman, J. 2012. Consultant's Report: Summary of the MRFSS/MRIP Calibration Workshop. March 27-29, Raleigh, NC. Available online at: http://sedarweb.org/otw-01-mrfssmrip-calibration-workshop-final-report

Carmichael, J. and D. Van Voorhees (editors). 2015. MRIP Calibration Workshop II. Report of a workshop on calibrating MRIP catch estimates, September 8-10, 2014. SAFMC/SEDAR, North Charleston, SC.

Fisheries Ecosytems Branch, National Marine Fisheries Service, Southeast Fisheries Science Center, Beaufort, NC. 2013. Discards of red snapper (*Lutjanus campechanus*) for the headboat fishery in the US South Atlantic. SEDAR41-DW29. SEDAR, North Charleston, SC. 15 pp.

Matter, V. and S. Turner 2010. Estimated Recreational Catch in Weight: Method for Filling in Missing Weight Estimates from the Recreational Surveys with Application to Yellowedge

Grouper, Tilefish (golden), and Blueline Tilefish (SEDAR 22-DW-16), National Marine Fisheries Service, Southeast Fisheries Science Center, Sustainable Fisheries Division (SFD-2010-003).

Matter, V.M. and A. Rios. 2013. SEDAR32-DW02. MRFSS to MRIP Adjustment Ratios and Weight Estimation Procedures for South Atlantic and Gulf of Mexico Managed Species. National Marine Fisheries Service Southeast Fisheries Science Center, Fisheries Statistics Division, Miami, FL and National Marine Fisheries Service Southeast Fisheries Science Center, Sustainable Fisheries Division, Miami, FL.

Marine Recreational Information Program. Implementation Plan: 2011/2012 Update. October 2011.

Personal communication from the National Marine Fisheries Service, Fisheries Statistics Division. February 2012.

Rios, A, V.M. Matter, J.F. Walter, N. Farmer, and S.J. Turner. 2012. SEDAR31-DW25 Estimated Conversion Factors for Adjusting MRFSS Gulf of Mexico Red Snapper Catch Estimates and Variances in 1981-2003 to MRIP Estimates and Variances. National Marine Fisheries Service Southeast Fisheries Science Center, Sustainable Fisheries Division, Miami, FL, National Marine Fisheries Service Southeast Fisheries Science Center, Fisheries Statistics Division, Miami, FL, and National Marine Fisheries Service Southeast Regional Office, Saint Petersburg, FL.

Salz, R., T. Williams, E. Williams, J. Walter, K. Drew and G. Bray. 2012. MRFSS/MRIP Calibration Workshop Ad-Hoc Working Group Report. Available online at: http://sedarweb.org/otw-01-calibration-workshop-ad-hoc-group-report-may-2012.

SEDAR. 2010. SEDAR 24 – South Atlantic Red Snapper Stock Assessment Report. SEDAR, North Charleston SC. 524 pp. Available online at: http://www.sefsc.noaa.gov/sedar/Sedar_Workshops.jsp?WorkshopNum=24

SEDAR. 2013. SEDAR 28 – Gulf of Mexico Cobia Stock Assessment Report. SEDAR, North Charleston SC. 616 pp. Available online at: http://www.sefsc.noaa.gov/sedar/Sedar_Workshops.jsp?WorkshopNum=28

4.10 Tables

Table 4.10.1 South Atlantic MRFSS charterboat conversion factors and standard errors (in parentheses).

a) Apply to 1981-1985 charterboat/headboat mode in the South Atlantic and Gulf of Mexico.

	WAVE					
STATE	1	2	3	4	5	6
NC	-	2.151 (0.12)	2.294 (0.12)	1.444 (0.12)	1.763 (0.12)	0.857 (0.12)
SC	-	1.035 (0.04)	1.085 (0.04)	1.437 (0.04)	0.891 (0.04)	0.750 (0.04)
GFE	0.845 (0.02)	0.951 (0.02)	0.985 (0.02)	1.016 (0.02)	0.811 (0.02)	0.696 (0.02)
AFW	0.883 (0.03)	0.883 (0.03)	1.104 (0.05)	1.104 (0.05)	0.883 (0.03)	0.883 (0.03)
MS	1.155 (0.11)	1.155 (0.11)	2.245 (0.11)	2.245 (0.11)	1.155 (0.11)	1.155 (0.11)
LA	0.962 (0.09)	0.962 (0.09)	2.260 (0.13)	2.260 (0.13)	0.962 (0.09)	0.962 (0.09)

b) Apply to 1986- 2002 charterboat mode in FLE

	WAVE					
Area	1	2	3	4	5	6
Inshore	1.600 (0.65)	2.786 (0.65)	2.201 (0.65)	2.894 (0.65)	1.630 (0.65)	2.386 (0.65)
Ocean	0.664 (0.10)	0.852 (0.10)	0.828 (0.10)	1.006 (0.10)	0.478 (0.10)	0.549 (0.10)

c) Apply to 1986- 2003 charterboat mode in GA and SC

	WAVE					
Area	1	2	3	4	5	6
Inshore	-	1.635 (0.90)	3.100 (0.90)	2.092 (0.90)	0.931 (0.90)	0.757 (0.90)
Ocean	-	0.939 (0.36)	1.272 (0.33)	2.161 (0.32)	0.835 (0.33)	0.638 (0.36)

d) Apply to 1986- 2003 charterboat mode in NC

	WAVE					
Area	1	2	3	4	5	6
Inshore	-	11.850 (3.48)	10.026 (2.63)	6.616(2.84)	3.766 (2.84)	9.415 (3.11)
Ocean	-	2.188 (0.58)	2.504 (0.58)	1.565 (0.60)	2.102 (0.60)	0.661 (0.60)

Table 4.10.2. Red snapper MRIP vs MRIP APAIS estimates of landings (number of fish) for the South Atlantic (sub-region 6) 2004-2012. See accompanying graph below table which includes the ratio of the MRIP APAIS to MRIP discards (value on right axis).

year	MRIP ab1	MRIP CV_ab1	MRIP APAIS ab1	MRIP APAIS CV_ab1
2004	495,942	0.08	563,576	0.16
2005	217,464	0.09	184,447	0.15
2006	138,513	0.11	150,111	0.24
2007	147,851	0.10	161,419	0.23
2008	137,920	0.10	138,779	0.16
2009	116,190	0.13	149,896	0.23
2010	107,995	0.12	157,981	0.21
2011	112,871	0.10	118,887	0.16
2012	283,304	0.09	341,232	0.18

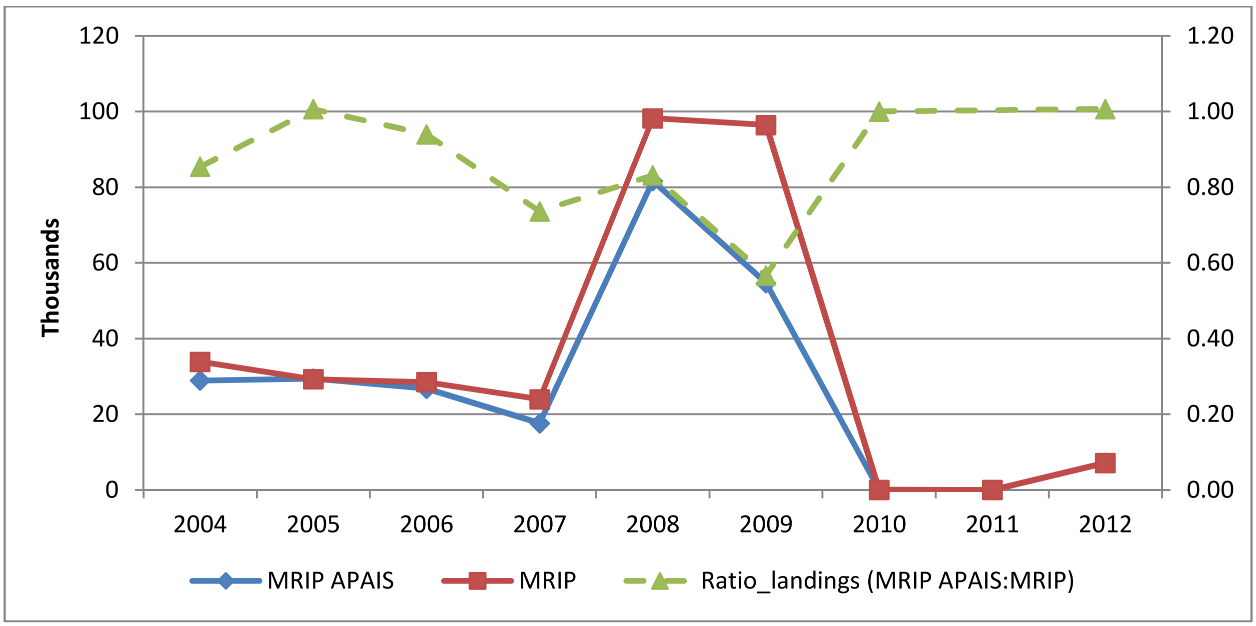


Table 4.10.3. Red snapper MRIP vs MRIP APAIS estimates of discards (number of fish) for the South Atlantic (sub-region 6) 2004-2012. See accompanying graph below table which includes the ratio of the MRIP APAIS to MRIP discards (value on right axis).

year	MRIP b2	MRIP CV_b2	MRIP APAIS b2	MRIP APAIS CV_b2
2004	191,820	0.20	199,638	0.29
2005	62,471	0.20	72,855	0.23
2006	96,517	0.24	119,735	0.31
2007	315,321	0.21	288,276	0.26
2008	394,122	0.22	511,984	0.36
2009	209,211	0.22	240,516	0.38
2010	102,867	0.27	138,478	0.39
2011	56,455	0.36	33,484	0.34
2012	105,477	0.27	142,961	0.39

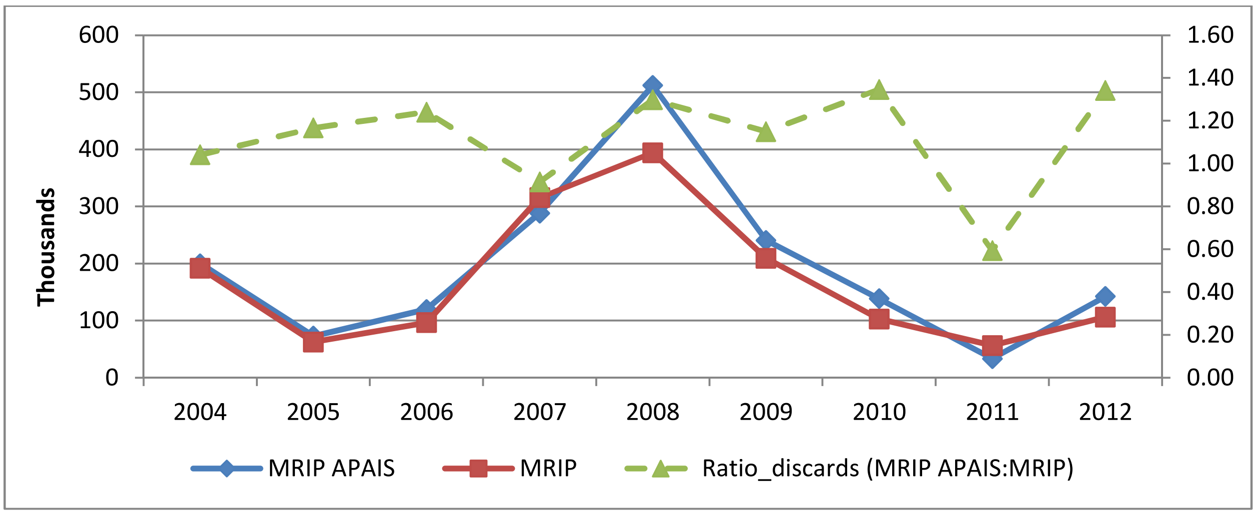


Table 4.10.4. South Atlantic red snapper ratio estimators for adjusting MRFSS numbers and variance estimates (AB1 and B2) to MRIP APAIS numbers and variances for 1981-2003. The variances of the numbers ratio estimators are also shown.

	Numbers Ratio Estimator		Variance Ratio Estimator		Variance of Numbers Ratio Estimator	
MODE	**AB1**	**B2**	**AB1**	**B2**	**AB1**	**B2**
Charterboat	0.699218	0.690369	0.834794	0.090876	0.007867	0.004632992
Private	0.626075	1.039297	1.135478	7.992752	0.011073	0.018337647

Table 4.10.5. South Atlantic (NC-FLE) red snapper landings (numbers of fish and whole weight in pounds) by year and mode (MRFSS, NMFS, 1981-2003; MRIP, NMFS, 2004+). MRFSS estimates adjusted to MRIP estimates prior to 2004. CH mode adjusted for FHS conversion prior to 2004. *CVs for CH mode 1981-1985 are unavailable. 2012-2014 (Mini season years) are presented separately.

	Estimated CH Landings			Estimated PR Landings			ALL MODES Landings			
YEAR	Number	CV*	Pounds	Number	CV	Pounds	Number	CV	Pounds	Avg. Wgt.
1981	19,076		113,181	74,382	0.34	441,339	93,458	0.27*	554,520	5.93
1982	1,958		11,620	34,335	0.36	203,727	36,294	0.34*	215,347	5.93
1983	45,093		267,557	23,375	0.52	138,695	68,469	0.18*	406,253	5.93
1984	72,449		94,618	140,098	0.33	211,013	212,547	0.22*	305,631	1.44
1985	125,843		356,840	163,128	0.36	480,359	288,971	0.20*	837,199	2.90
1986	57,318	0.40	16,274	43,419	0.41	17,754	100,736	0.29	34,029	0.34
1987	15,482	0.34	43,458	31,891	0.25	74,498	47,373	0.20	117,956	2.49
1988	20,885	0.34	34,036	59,936	0.36	42,804	80,821	0.28	76,840	0.95
1989	15,718	0.29	32,352	81,429	0.24	102,203	97,147	0.21	134,555	1.39
1990	5,492	0.33	32,585	6,600	0.45	39,159	12,092	0.29	71,745	5.93
1991	13,382	0.25	79,399	21,335	0.48	126,592	34,717	0.31	205,991	5.93
1992	27,489	0.19	125,522	24,419	0.35	111,504	51,908	0.19	237,026	4.57
1993	4,581	0.27	38,006	6,745	0.32	55,961	11,326	0.22	93,968	8.30
1994	9,618	0.28	67,357	8,695	0.47	60,895	18,313	0.27	128,252	7.00
1995	11,997	0.31	57,623	1,485	0.63	7,130	13,482	0.29	64,754	4.80
1996	2,050	0.36	12,166	7,291	0.53	43,261	9,342	0.42	55,427	5.93
1997	32,030	0.55	94,556	2,208	0.65	6,517	34,238	0.52	101,073	2.95
1998	8,247	0.29	45,841	4,768	0.40	26,500	13,015	0.24	72,341	5.56
1999	25,568	0.33	54,052	14,010	0.28	81,193	39,579	0.23	135,245	3.42
2000	7,606	0.20	42,391	37,741	0.27	223,440	45,347	0.23	265,831	5.86
2001	6,828	0.19	45,947	24,759	0.23	166,069	31,587	0.18	212,016	6.71
2002	13,570	0.19	86,908	21,492	0.25	168,184	35,062	0.17	255,092	7.28
2003	15,961	0.28	120,399	10,016	0.26	76,854	25,977	0.20	197,253	7.59
2004	9,589	0.24	71,809	19,325	0.29	144,300	28,914	0.21	216,109	7.47
2005	11,937	0.33	96,154	17,507	0.35	134,796	29,443	0.24	230,950	7.84
2006	14,156	0.34	143,419	12,613	0.42	119,508	26,769	0.26	262,927	9.82
2007	6,273	0.19	52,298	11,373	0.36	95,065	17,646	0.24	147,363	8.35
2008	11,401	0.35	73,872	70,236	0.31	456,070	81,638	0.27	529,942	6.49
2009	17,061	0.06	111,994	37,605	0.37	268,222	54,666	0.25	380,216	6.96
2010	62	1.00	369	0	0.00	0	62	1.00	369	5.93.
2011	0	0.00	0	0	0.00	0	0	0.00	0	0.00

Table 4.10.6. MRIP landings estimates for 1984 and 1985 by state, mode, and wave. Further information on highlighted estimates can be found in the text.

Sum of ab1			WAVE						
YEAR	mode	state	1	2	3	4	5	6	Grand Total
1984	Cbt	FLE	6,735	9,356	21,488	19,515	384		57,479
		GA			0	1,061			1,061
		NC				8,626			8,626
		SC			500	688	4,096		5,284
	Priv	FLE	12,379	105,256	22,463				140,098
1984 Total			19,114	114,612	44,451	29,890	4,480		212,547
1985	Cbt	FLE	1,344	4,620		42,631	9,039	1,012	58,646
		GA			772	30			802
		NC				50,776			50,776
		SC		3,720	5,064		6,834		15,618
	Priv	FLE	81,635	16,141	3,190	7,421	51,675		160,062
		GA			1,992	59			2,051
		SC			1,015				1,015
1985 Total			82,979	24,481	12,033	100,917	67,549	1,012	288,971

Table 4.10.7. Estimated headboat landings of red snapper in the South Atlantic 1972-2014. Due to headboat area definitions and confidentiality issues, Georgia and East Florida landings must be combined. A 3 year average ratio of NC/SC was used to calculate landings for GA/NEFL 1972-1975 and SEFL 1972-1980.

	Number				Weight (lb)				
Year	NC	SC	GA/FLE	South Atlantic	NC	SC	GA/FLE	South Atlantic	Avg Weight (lb)
1972	1,222	965	35,239	37,426	22,042	18,874	124,134	165,049	4.41
1973	2,367	1,615	64,162	68,144	32,456	27,758	226,017	286,232	4.20
1974	1,885	1,511	54,719	58,115	22,727	14,077	192,756	229,560	3.95
1975	1,351	3,872	84,158	89,381	12,842	26,954	296,456	336,252	3.76
1976	2,212	3,546	60,347	66,105	14,961	39,959	180,022	234,941	3.55
1977	1,049	1,316	42,706	45,071	7,233	11,083	176,882	195,198	4.33
1978	959	1,248	43,635	45,842	12,421	8,962	150,071	171,454	3.74
1979	441	668	31,257	32,366	5,101	9,127	169,291	183,519	5.67
1980	424	2,893	18,281	21,598	2,950	11,649	59,902	74,501	3.45
1981	1,194	1,371	33,466	36,031	7,742	8,762	101,526	118,031	3.28
1982	747	1,612	17,194	19,553	10,487	14,535	98,024	73,002	3.73
1983	416	1,844	28,438	30,698	5,316	10,179	74,004	58,508	1.91
1984	740	1,841	28,565	31,146	4,582	6,875	81,417	69,960	2.25
1985	8,426	2,183	39,727	50,336	31,330	11,768	132,084	88,985	1.77
1986	997	881	14,747	16,625	7,129	4,515	54,381	42,736	2.57
1987	5,346	1,934	17,716	24,996	21,518	6,310	81,840	54,012	2.16
1988	9,555	5,235	21,737	36,527	36,829	15,250	130,070	77,991	2.14
1989	1,134	6,207	16,112	23,453	6,691	26,459	70,796	37,646	1.61
1990	525	3,650	16,744	20,919	2,749	13,341	65,686	49,596	2.37
1991	725	3,290	9,842	13,857	15,991	21,781	72,030	34,258	2.47
1992	2,306	1,275	1,720	5,301	12,049	5,924	28,916	10,943	2.06
1993	1,639	3,623	2,085	7,347	9,043	19,865	42,718	13,809	1.88
1994	567	2,454	5,204	8,225	3,632	6,349	43,017	33,036	4.02
1995	3,791	866	4,169	8,826	23,728	6,340	57,474	27,406	3.11
1996	335	2,374	2,834	5,543	3,130	23,837	46,235	19,267	3.48
1997	1,779	557	3,434	5,770	20,969	6,746	51,205	23,490	4.07
1998	445	696	3,600	4,741	1,082	6,235	26,848	19,530	4.12
1999	973	1,749	4,114	6,836	6,957	11,257	43,559	25,345	3.71
2000	777	984	6,676	8,437	5,946	6,562	49,403	36,894	4.37
2001	1,816	3,878	6,334	12,028	9,605	20,513	68,385	38,267	3.18
2002	2,637	4,345	5,949	12,931	14,194	21,727	70,797	34,877	2.70
2003	399	1,346	3,961	5,706	3,679	12,133	41,353	25,541	4.48
2004	1,274	1,672	7,896	10,842	12,300	16,111	80,349	51,938	4.79
2005	106	1,004	7,797	8,907	1,114	10,399	58,695	47,183	5.30
2006	33	303	5,609	5,945	384	3,540	41,432	37,508	6.31
2007	52	701	6,136	6,889	389	5,016	37,460	32,055	4.65
2008	162	1,551	17,230	18,943	888	8,076	115,309	106,344	5.61
2009	263	373	20,871	21,507	2,368	5,105	141,087	133,615	6.21
2010	4	180	293	477	17	870	2,610	1,723	3.61
2011	9	4	1,346	1,359	39	17	8,660	8,605	6.33
2012	110	11	2,006	2,127	415	82	10,471	9,975	4.69
2013	53	13	1,454	1,520	240	125	12,036	11,671	7.68
2014	862	202	4,840	5,904	3,930	1,939	44,900	39,031	6.61

Table 4.10.8. Summary of different methods used by the Marine Recreational Information Program (MRIP) and states along the southeast Atlantic to collect charter (CH) and private (PR) recreational data for mini-seasons 2012- 2014. A dash (-) indicates that there was no method available. (FHS=For-Hire survey, APAIS=Access Point Atlantic Intercept Survey, CHTS=Coastal Household Telephone Survey, SFS=State Finfish Survey).

	MRIP	NC	SC	GA	FL
Estimate/#	Estimate	#	#	#	Estimate
CH effort	Phone survey (FHS)	-	Logbook	Phone survey	Phone survey
CH harvest (a+b1)	APAIS	-	Logbook	Phone survey	Phone survey
CH discards (b2)	APAIS	-	Logbook	Phone survey	Phone survey
Private effort	Phone survey (CHTS)	-	SFS (2012)	Online survey	Vessel counts
PR harvest (a + b1)	APAIS	-	Carcass	Online survey	Intercept survey
PR discards (b2)	APAIS	-	SFS (2012)	Online survey	Intercept survey
Effort unit	Angler trips	-	Boat trips	Angler trips	Boat trips
Weighted estimates	Y	N	N	N	Y
Random sampling	Y	N	N	N	Y
Carcass freezers	N	Y	Y	Y	Y

Table 4.10.9. Recreational mini-season landings for 2012. Bold text indicates an overlap of MRIP with State surveys within a specific mode and wave. The estimate/number selected by the RWG is highlighted in yellow. After APAIS adjustment, 2012 MRIP estimates are only available by year, not by wave.

		2012 LANDINGS AB1 (N)											
		CHARTER						PRIVATE					
		MRIP			State Surveys			MRIP			State Surveys		
State	Wave	Est	#trips	CV	Est/#	#trips	CV	Est	#trips	CV	Est/#	#trips	CV
NC	1												
	2												
	3												
	4												
	5				40						3		
	6												
NC Total		**2,484**	**7**	**0.54**	**40**						3		
SC	1												
	2												
	3				3	1	NA						
	4				1	1	NA						
	5				21	5	NA				43		NA
	6												
SC Total					25	7	NA				43		NA
GA	1												
	2												
	3												
	4												
	5				52	76	NA				22	31	NA
	6												
GA Total		96	2	0.82	52	76	NA	1,409	1	1.00	22	31	NA
FLE	1												
	2												
	3												
	4												
	5				882	227	0.73				10,729	390	0.15
	6												
FLE Total					882		0.73	3,205	4	1.00	10,729		

Table 4.10.10. Recreational mini-season landings for 2013. Bold text indicates an overlap of MRIP with State surveys within a specific mode and wave. The estimate/number selected by the RWG is highlighted in yellow.

		2013 LANDINGS AB1 (N)											
		CHARTER						PRIVATE					
		MRIP			State Surveys			MRIP			State Surveys		
State	Wave	Est	#trips	CV	Est/#	#trips	CV	Est	#trips	CV	Est/#	#trips	CV
NC	1												
	2												
	3												
	4				2						3		
	5												
	6												
SC	1												
	2												
	3												
	4				17	6	NA				39		NA
	5				1	1	NA						
	6												
GA	1												
	2												
	3												
	4				28	47	NA				41	53	NA
	5												
	6												
FLE	1												
	2												
	3												
	4	**873**	**2**	**0.87**	**971**	**515**		**17,463**	**9**	**0.80**	**6,428**	**549**	**0.16**
	5	58	1	1.01									
	6												

Table 4.10.11. Recreational mini-season landings for 2014. Bold text indicates an overlap of MRIP with State surveys within a specific mode and wave. The estimate/number selected by the RWG is highlighted in yellow.

		2014 LANDINGS AB1 (N)											
		CHARTER						PRIVATE					
		MRIP			State Surveys			MRIP			State Surveys		
State	Wave	Est	#trips	CV	Est/#	#trips	CV	Est	#trips	CV	Est/#	#trips	CV
NC	1												
	2												
	3												
	4	**116**	**3**	**0.76**	**41**		**NA**				14		NA
	5												
	6												
SC	1												
	2												
	3				3		NA						
	4				46		NA	**506**	**1**	**1.01**	**76**	**>1**	**NA**
	5												
	6												
GA	1												
	2												
	3												
	4	**258**	**1**	**0.83**	**150**	**180**	**NA**	**1,014**	**3**	**0.70**	**106**	**120**	**NA**
	5												
	6												
FLE	1							1,151	1	1.01			
	2												
	3							623	1	1.00			
	4	**5,197**	**30**	**0.33**	**2,377**	**136**	**0.39**	**79,618**	**53**	**0.35**	**22,282**	**1,377**	**0.11**
	5												
	6							334	1	0.95			

Table 4.10.12. Estimated red snapper landings using the FHWAR census method, 1955-1985.

Year	Total U.S. Saltwater Days	Adjusted Saltwater Days - South Atlantic	Avg CPUE MRFSS & SRHS 81-83	Historic Catch (number)	CV
1955	4,820,112	2,022,131	0.0181	36,536	0.65
1960	7,038,690	2,952,867	0.0181	53,353	0.65
1965	10,225,693	4,289,877	0.0181	77,510	0.65
1970	10,525,159	4,415,509	0.0181	79,780	0.65
1975	15,726,330	6,597,502	0.0181	119,204	0.65
1980	16,613,593	6,969,725	0.0181	125,929	0.65

Table 4.10.13. Estimated recreational landings of red snapper in the South Atlantic 1955-2014.

Year	Number	Year	Number
1955	36,536	1985	339,307
1956	39,899	1986	117,361
1957	43,263	1987	72,369
1958	46,626	1988	117,348
1959	49,989	1989	120,600
1960	53,353	1990	33,011
1961	58,184	1991	48,574
1962	63,015	1992	57,209
1963	67,847	1993	18,673
1964	72,678	1994	26,538
1965	77,510	1995	22,308
1966	77,964	1996	14,885
1967	78,418	1997	40,008
1968	78,872	1998	17,756
1969	79,326	1999	46,415
1970	79,780	2000	53,784
1971	87,665	2001	43,615
1972	95,549	2002	47,993
1973	103,434	2003	31,683
1974	111,319	2004	39,756
1975	119,204	2005	38,350
1976	120,549	2006	32,714
1977	121,894	2007	24,535
1978	123,239	2008	100,581
1979	124,584	2009	76,173
1980	125,929	2010	539
1981	129,177	2011	1,359
1982	55,847	2012	17,755
1983	99,167	2013	9,108
1984	243,693	2014	34,090

Table 4.10.14. MRIP South Atlantic (NC-FLE) red snapper discards (numbers of fish released alive) by year and mode (MRFSS, NMFS, 1981-2003; MRIP, NMFS, 2004+). MRFSS estimates adjusted to MRIP estimates prior to 2004. CH mode adjusted for FHS conversion prior to 2004. *CVs for CH mode 1981-1985 are unavailable. 2012-2014(Mini season years) are presented separately.

	Estimated CH Discards		Estimated PR Discards		ALL MODES Discards	
YEAR	Number	CV*	Number	CV	Number	CV
1981	709	0.00	0	0.00	709	0.00
1982	0	0.00	0	0.00	0	0.00
1983	12,599	0.00	0	0.00	12,599	0.00
1984	38,082	0.00	23,743	1.45	61,825	0.56
1985	15,426	0.00	65,996	1.65	81,422	1.34
1986	0	0.00	0	0.00	0	0.00
1987	97	0.32	110,748	1.63	110,844	1.62
1988	0	0.00	50,274	1.33	50,274	1.33
1989	0	0.00	20,826	1.18	20,826	1.18
1990	0	0.00	0	0.00	0	0.00
1991	62	0.32	37,262	1.45	37,324	1.45
1992	7,736	0.14	20,258	1.09	27,994	0.79
1993	17,236	0.17	50,913	0.91	68,149	0.68
1994	1,504	0.14	65,036	0.83	66,540	0.81
1995	11,468	0.12	39,422	0.69	50,890	0.53
1996	2,124	0.13	18,321	1.20	20,445	1.07
1997	7,554	0.16	9,020	0.99	16,574	0.54
1998	2,917	0.13	23,872	1.07	26,789	0.96
1999	24,833	0.08	137,877	0.55	162,710	0.47
2000	16,486	0.07	232,111	0.48	248,597	0.45
2001	16,357	0.06	186,309	0.45	202,665	0.42
2002	13,310	0.06	110,052	0.63	123,362	0.56
2003	14,451	0.07	144,879	0.52	159,329	0.47
2004	22,148	0.18	177,490	0.33	199,638	0.29
2005	27,447	0.09	45,408	0.37	72,855	0.23
2006	18,675	0.34	101,060	0.37	119,735	0.31
2007	62,442	0.06	225,834	0.33	288,276	0.26
2008	26,072	0.20	485,912	0.38	511,984	0.36
2009	22,000	0.05	218,516	0.42	240,516	0.38
2010	16,434	0.04	122,044	0.44	138,478	0.39
2011	12,591	0.04	20,892	0.54	33,484	0.34

Table 4.10.15. Estimated South Atlantic red snapper discards for SRHS by year and state. Due to headboat area definitions and confidentiality issues, Georgia and East Florida discards must be combined. 2004-2014 uses the SRHS logbook discards. 1981-2003 HB mode uses SRHS dockside sample discard ratio proxy method. Zero discards are assumed prior to 1983.

Year	NC	SC	GA/FLE	South Atlantic
1972	-	-	-	-
1973	-	-	-	-
1974	-	-	-	-
1975	-	-	-	-
1976	-	-	-	-
1977	-	-	-	-
1978	-	-	-	-
1979	-	-	-	-
1980	-	-	-	-
1981	-	-	-	-
1982	-	-	-	-
1983	-	-	-	-
1984	2	4	63	69
1985	19	5	87	111
1986	2	2	32	37
1987	12	4	39	55
1988	21	12	48	80
1989	2	14	35	52
1990	1	8	37	46
1991	2	7	22	30
1992	1,092	604	814	2,510
1993	776	1,715	987	3,478
1994	268	1,162	2,464	3,894
1995	1,795	410	1,974	4,178
1996	159	1,124	1,342	2,624
1997	842	264	1,626	2,732
1998	211	329	1,704	2,244
1999	461	828	1,948	3,236
2000	368	466	3,160	3,994
2001	860	1,836	2,999	5,694
2002	1,248	2,057	2,816	6,122
2003	189	637	1,875	2,701
2004	26	545	18,219	18,790
2005	12	166	9,698	9,876
2006	1,174	68	15,991	17,233
2007	2,370	1,001	68,515	71,886
2008	1,293	1,062	71,254	73,609
2009	402	390	56,535	57,327
2010	1,245	738	36,460	38,443
2011	170	1,037	40,184	41,391
2012	401	393	45,988	46,782
2013	438	154	46,148	46,740
2014	1,043	358	45,211	46,612

Table 4.10.16. Recreational mini-season discards for 2012. Bold text indicates an overlap of MRIP with State surveys within a specific mode and wave. The estimate/number selected by the RWG is highlighted in yellow.

		2012 DISCARDS B2 (N)											
		CHARTER						PRIVATE					
		MRIP			State Surveys			MRIP			State Surveys		
State	Wave	Est	#trips	CV	Est/#	#trips	CV	Est	#trips	CV	Est/#	#trips	CV
NC	1												
	2												
	3												
	4												
	5												
	6												
NC Total		3,130	23	0.74				323	1	1.00			
SC	1												
	2				24	6	NA						
	3				298	50	NA						
	4				207	42	NA						
	5				114	13	NA				9		NA
	6				13	3	NA						
SC Total		14	5	1.00	656	114	NA	16,130	3	1.00	9		NA
GA	1												
	2												
	3												
	4												
	5				25	76	NA				6	31	NA
	6												
GA Total		287	6	0.71	25	76	NA	787	1	1.00	6	31	NA
FLE	1												
	2												
	3												
	4												
	5										**8,065**	**390**	**0.3**
	6												
FLE Total		11,670	32	0.00				109,969	41	0.48	8,065		

Table 4.10.17. Recreational mini-season discards for 2013. Bold text indicates an overlap of MRIP with State surveys within a specific mode and wave. The estimate/number selected by the RWG is highlighted in yellow.

		2013 DISCARDS B2 (N)											
		CHARTER						PRIVATE					
		MRIP			State Surveys			MRIP			State Surveys		
State	Wave	Est	#trips	CV	Est/#	#trips	CV	Est	#trips	CV	Est/#	#trips	CV
NC	1												
	2												
	3	137	5	0.55				243	1	1.06			
	4	276	2	1.01									
	5	16	2	1.04									
	6												
SC	1												
	2				21	5	NA						
	3				165	33	NA						
	4				173	44	NA	1,025	1	0.65			
	5				104	27	NA						
	6				9	2	NA						
GA	1												
	2												
	3												
	4	**210**	**1**	**0.85**	**5**	**47**	**NA**				13	53	NA
	5	214	2	0.45				4,668	5	0.87			
	6												
FLE	1	379	4	0.54									
	2							11,796	4	0.96			
	3							6,919	15	0.63			
	4	**323**	**8**	**0.19**	**1,494**	**515**		**21,750**	**16**	**0.69**	**3,144**	**549**	**0.24**
	5	5,161	42	0.53				30,244	8	0.55			
	6	147	3	0.69									

Table 4.10.18. Recreational mini-season discards for 2014. Bold text indicates an overlap of MRIP with State surveys within a specific mode and wave. The estimate/number selected by the RWG is highlighted in yellow.

		2014 DISCARDS B2 (N)											
		CHARTER						PRIVATE					
		MRIP			State Surveys			MRIP			State Surveys		
State	Wave	Est	#trips	CV	Est/#	#trips	CV	Est	#trips	CV	Est/#	#trips	CV
NC	1												
	2												
	3	325	2	0.99									
	4	524	6	0.68				4,400	4	0.85			
	5												
	6												
SC	1												
	2				29		NA						
	3				242		NA	1,357	4	0.83			
	4				184		NA	1,453	2	1.03			
	5				73		NA						
	6				53		NA	290	1	1.04			
GA	1												
	2	55	1	1.05				388	2	1.14			
	3	207	2	0.39				9,859	2	0.97			
	4				75	180	NA	**1,689**	**5**	**0.88**	**265**	**120**	**NA**
	5												
	6												
FLE	1	27	4	1.06				16,014	7	0.79			
	2	1,422	2	0.78				1,592	1	1.00			
	3	4,883	20	0.42				41,637	43	0.32			
	4	**13,347**	**61**	**0.40**	**2,871**	**136**	**0.28**	**136,175**	**73**	**0.37**	**9,960**	**1,377**	**0.17**
	5	3,190	45	0.51				1,281	3	0.64			
	6	11,428	17	0.65				33,762	9	0.74			

Table 4.10.19. Total recreational catch (landings and discards) from all sources and years from 1955-2014.

	Number of fish				Number of fish		
Year	Landings	Discards	Total Catch	Year	Landings	Discards	Total Catch
1955	36,536		36,536	1985	339,307	81,533	420,840
1956	39,899		39,899	1986	117,361	37	117,398
1957	43,263		43,263	1987	72,369	110,899	183,268
1958	46,626		46,626	1988	117,348	50,354	167,702
1959	49,989		49,989	1989	120,600	20,877	141,477
1960	53,353		53,353	1990	33,011	46	33,057
1961	58,184		58,184	1991	48,574	37,354	85,928
1962	63,015		63,015	1992	57,209	30,503	87,713
1963	67,847		67,847	1993	18,673	71,627	90,301
1964	72,678		72,678	1994	26,538	70,434	96,972
1965	77,510		77,510	1995	22,308	55,068	77,376
1966	77,964		77,964	1996	14,885	23,069	37,954
1967	78,418		78,418	1997	40,008	19,305	59,313
1968	78,872		78,872	1998	17,756	29,033	46,789
1969	79,326		79,326	1999	46,415	165,946	212,361
1970	79,780		79,780	2000	53,784	252,591	306,375
1971	87,665		87,665	2001	43,615	208,359	251,974
1972	95,549		95,549	2002	47,993	129,483	177,476
1973	103,434		103,434	2003	31,683	162,031	193,714
1974	111,319		111,319	2004	39,756	218,428	258,183
1975	119,204		119,204	2005	38,350	82,731	121,081
1976	120,549		120,549	2006	32,714	136,968	169,682
1977	121,894		121,894	2007	24,535	360,162	384,697
1978	123,239		123,239	2008	100,581	585,593	686,174
1979	124,584		124,584	2009	76,173	297,843	374,016
1980	125,929		125,929	2010	539	176,921	177,460
1981	129,489	709	130,198	2011	1,359	74,875	76,234
1982	55,847		55,847	2012	17,755	189,743	207,497
1983	99,167	12,599	111,765	2013	9,108	130,732	139,840
1984	243,693	61,893	305,587	2014	34,090	332,574	366,664

Table 4.10.20. Number of red snapper measured in the South Atlantic (NC-FLE) in the MRFSS/MRIP by year, mode, and state from 1981-2014.

	CH					PR				
YEAR	FLE	GA	SC	NC	All	FLE	GA	SC	NC	All
1981						25				25
1982						28				28
1983	3		5		8	11	2			13
1984	16	10	1	7	34	41				41
1985		4			4	32	4			36
1986	205		1		206	19	1			20
1987		1		24	25	17	9		12	38
1988	8			13	21	38			14	52
1989	5	4	4	8	21	32	5	1		38
1990				14	14	2			2	4
1991		3		10	13	1			2	3
1992	4	1		3	8	6	1		2	9
1993		11		4	15	8				8
1994	3	18		14	35	2				2
1995	4	9		11	24	2				2
1996		3	2	4	9	4			2	6
1997	2	2	16		20					
1998	4	11	11		26	6		1		7
1999	14	17	68	8	107	25				25
2000	51	4	20	1	76	14		2		16
2001	70	3	10	7	90	32				32
2002	181	2	4	12	199	33				33
2003	126	9	1	21	157	7		2		9
2004	83	37	6	1	127	25	3		1	29
2005	50	11		2	63	11			2	13
2006	38	10	3	12	63	9	4		1	14
2007	26	18	1		45	15	1	2		18
2008	34	49	2	10	95	91	8			99
2009	39	60		5	104	108	1		4	113
2010			1		1					
2011										
2012		9		35	44	3	4			7
2013	4				4	12				12
2014	100	2			102	89	8	4		101

Table 4.10.21. Number of angler trips with measured red snapper in the South Atlantic (NC-FLE) in the MRFSS/MRIP by year, mode, and state from 1981-2014.

	CH					PR				
YEAR	FLE	GA	SC	NC	All	FLE	GA	SC	NC	All
1981						10				10
1982						10				10
1983	2		2		4	2	1			3
1984	2	1	1	2	6	9				9
1985		1			1	11	3			14
1986	73		1		74	8	1			9
1987		1		5	6	5	2		3	10
1988	4			7	11	12			4	16
1989	2	1	3	6	12	11	1	1		13
1990				3	3	2			2	4
1991		2		5	7	1			1	2
1992	2	1		3	6	3	1		1	5
1993		8		3	11	6				6
1994	2	10		11	23	2				2
1995	1	4		5	10	2				2
1996		3	2	1	6	4			1	5
1997	1	2	2		5					
1998	2	5	3		10	6		1		7
1999	8	5	11	3	27	12				12
2000	19	2	4	1	26	12		1		13
2001	27	3	2	6	38	17				17
2002	34	1	2	8	45	11				11
2003	35	5	1	7	48	5		1		6
2004	25	13	6	1	45	14	3		1	18
2005	18	6		1	25	6			2	8
2006	13	4	3	3	23	6	1		1	8
2007	9	7	1		17	7	1	1		9
2008	9	12	1	5	27	33	4			37
2009	10	14		3	27	25	1		3	29
2010			1		1					
2011										
2012		2		7	9	3	1			4
2013	3				3	9				9
2014	21	1			22	32	2	1		35

Table 4.10.22. Number, mean, minimum, and maximum weights of red snapper in the South Atlantic (NC-FLE) in the MRFSS/MRIP by year and state from 1981-2014.

	FLE				GA				SC				NC			
YEAR	N	Mean (lbs)	Min (lbs)	Max (lbs)	N	Mean (lbs)	Min (lbs)	Max (lbs)	N	Mean (lbs)	Min (lbs)	Max (lbs)	N	Mean (lbs)	Min (lbs)	Max (lbs)
1981	27	2.39	0.44	8.82												
1982	20	4.10	0.22	21.83												
1983	15	2.09	0.22	7.94	3	9.33	1.32	25.35	4	9.76	8.38	11.46				
1984	48	1.24	0.22	2.65	10	1.19	0.66	2.65	1	24.25	24.25	24.25	7	2.11	0.88	3.31
1985	32	2.95	0.66	5.73	8	2.07	0.66	2.65	1	1.32	1.32	1.32				
1986	224	0.41	0.22	2.65	1	3.31	3.31	3.31	1	2.65	2.65	2.65	1	2.20	2.20	2.20
1987	20	1.17	0.44	4.63	4	1.38	1.10	2.20	1	2.20	2.20	2.20	38	2.81	0.44	9.70
1988	52	1.34	0.22	7.94					2	5.62	1.10	10.14	22	3.93	0.88	10.14
1989	41	1.77	0.22	9.70	9	1.20	0.44	3.09	7	3.56	1.76	4.85	8	4.05	0.66	7.72
1990	2	10.58	3.53	17.64									8	6.61	0.44	22.93
1991	5	4.50	1.54	7.72	3	10.88	9.04	14.55	1	3.09	3.09	3.09	7	2.20	0.66	4.85
1992	15	4.81	1.10	18.52	10	4.81	1.98	7.72					6	4.01	1.98	5.95
1993	9	6.86	0.44	14.55	16	10.06	1.10	27.56					4	5.18	3.31	6.83
1994	9	3.86	0.66	14.99	21	9.28	2.20	27.12					14	5.97	0.66	14.99
1995	6	5.73	3.53	10.58	15	6.63	3.53	12.90					11	2.32	0.44	5.73
1996	6	7.68	5.51	12.57	5	10.85	5.07	18.96	2	1.05	0.88	1.21	4	3.22	1.32	4.85
1997	3	11.57	9.92	13.23	3	8.52	6.83	11.46	26	1.31	0.44	9.92				
1998	10	9.57	1.17	25.13	9	6.41	0.66	16.53	12	1.75	0.55	12.35				
1999	43	5.57	0.99	17.64	17	2.94	0.44	11.24	71	1.33	0.44	8.82	8	2.26	1.10	6.17
2000	62	6.10	3.09	18.81	4	6.20	1.21	14.77	22	2.93	0.77	12.13	1	14.33	14.33	14.33
2001	102	6.69	1.06	25.35	2	20.17	19.40	20.94	10	6.92	1.21	8.82	7	5.32	4.41	6.61
2002	210	6.43	2.49	23.59	2	8.27	6.17	10.36	4	3.64	2.09	4.85	12	7.49	4.12	12.30
2003	128	7.64	0.93	25.13	10	13.37	4.41	31.97	3	7.72	6.61	8.82	15	3.18	1.54	10.19
2004	105	7.21	2.07	21.14	41	9.18	3.75	25.13	6	8.97	5.29	11.02	2	10.35	10.23	10.47
2005	59	7.64	0.93	22.18	5	13.01	5.51	16.98					4	9.65	3.92	19.49
2006	41	9.94	3.64	27.20	11	6.15	3.97	12.79	5	6.22	1.10	16.53	13	3.67	0.22	14.37
2007	41	8.37	1.32	23.15	19	6.17	2.98	11.90	1	17.64	17.64	17.64				
2008	124	6.48	3.44	24.80	55	6.27	1.76	17.64	2	5.51	4.85	6.17	9	5.54	4.74	8.60
2009	148	6.95	3.53	24.80	61	7.01	3.31	13.67					8	8.65	4.41	22.05
2010									1	2.31	2.31	2.31				
2011																
2012	3	5.43	1.34	13.23	12	8.78	2.09	16.31					35	10.60	2.76	25.90
2013	16	10.04	1.41	15.08												
2014	188	12.98	1.32	21.96	9	7.35	1.54	20.28	4	14.00	8.60	18.96				

Table 4.10.23. Number of red snapper measured and number of trips with measured red snapper in the SRHS by year and state 1972-2014.

	Fish(N)				Trips(N)			
Year	NC	SC	GA/FLE	South Atlantic	NC	SC	GA/FLE	South Atlantic
1972	18	30		48	11	19		30
1973	12	20		32	8	18		26
1974	29	66		95	19	33		52
1975	69	86		155	38	36		74
1976	143	51	303	497	44	28	45	117
1977	59	82	577	718	29	43	125	197
1978	49	45	646	740	22	25	161	208
1979	7	8	230	245	5	6	80	91
1980	10	14	234	258	9	10	73	92
1981	17	3	652	672	13	3	183	199
1982	30	6	421	457	16	5	133	154
1983	53	24	929	1,006	32	18	203	253
1984	48	103	1,170	1,321	26	59	229	314
1985	170	51	970	1,191	59	22	217	298
1986	51	30	354	435	35	16	139	190
1987	50	53	203	306	30	28	100	158
1988	63	43	98	204	36	29	51	116
1989	38	53	274	365	22	33	102	157
1990	31	43	293	367	17	19	101	137
1991	7	29	116	152	7	14	43	64
1992	20	25	28	73	16	16	17	49
1993	22	128	53	203	15	52	29	96
1994	14	46	60	120	11	17	29	57
1995	13	41	93	147	9	22	43	74
1996	7	16	55	78	6	11	29	46
1997	4	6	57	67	3	6	33	42
1998	11	25	113	149	7	15	56	78
1999	7	15	140	162	6	12	73	91
2000	7	9	107	123	6	5	59	70
2001	17		239	256	15		103	118
2002	8	12	341	361	7	8	142	157
2003	9	21	299	329	8	16	121	145
2004	3	10	290	303	3	7	102	112
2005	3	3	189	195	1	2	92	95
2006	4	9	159	172	4	7	91	102
2007	2	15	153	170	2	12	55	69
2008	10	12	435	457	6	4	81	91
2009	16	12	738	766	12	8	166	186
2010			4	4			1	1
2011			1	1			1	1
2012	28	4	100	132	5	1	10	16
2013	32	2	143	177	6	1	24	31
2014	66	22	203	291	10	4	28	42

Table 4.10.24. Mean weight (kg) of red snapper measured in the SRHS by year and state, 1972-2014.

	NC				SC				GA/FLE			
Year	N	Mean (kg)	Min (kg)	Max (kg)	N	Mean (kg)	Min (kg)	Max (kg)	N	Mean (kg)	Min (kg)	Max (kg)
1972	18	7.57	1.77	11.80	30	8.37	0.73	15.89				
1973	12	9.63	6.63	11.71	20	7.78	2.00	10.62				
1974	29	5.49	0.45	11.35	66	4.04	0.86	14.21				
1975	69	4.27	0.45	16.12	86	2.84	0.59	11.85				
1976	143	3.93	0.36	14.07	51	4.63	1.59	11.58	303	1.30	0.09	12.03
1977	59	4.64	0.91	11.58	82	3.91	1.09	11.35	577	1.51	0.14	12.49
1978	49	6.57	1.73	16.34	45	3.43	0.15	12.35	646	1.61	0.15	25.50
1979	7	7.07	4.00	11.75	8	3.58	1.20	10.50	230	2.44	0.16	16.00
1980	10	6.20	1.30	20.88	14	1.76	0.93	2.45	234	1.83	0.22	12.26
1981	17	3.07	1.37	10.22	3	1.92	0.87	3.65	652	1.52	0.14	18.00
1982	30	6.17	0.33	13.62	6	4.91	0.62	10.65	421	1.81	0.16	10.70
1983	53	5.57	0.43	12.94	24	2.47	0.63	7.90	929	0.94	0.18	10.70
1984	48	2.74	0.28	13.28	103	1.75	0.38	15.48	1,170	1.18	0.10	12.00
1985	170	1.68	0.18	16.53	51	2.14	0.20	13.70	970	1.02	0.14	13.80
1986	51	2.83	0.93	14.54	30	2.38	0.90	4.30	354	1.44	0.11	12.25
1987	50	1.93	0.44	5.42	53	1.45	0.35	4.70	203	1.24	0.12	8.89
1988	63	1.48	0.11	11.02	43	1.67	0.39	6.33	98	1.70	0.10	12.54
1989	38	1.80	0.59	2.98	53	1.83	0.65	6.40	274	1.12	0.08	11.66
1990	31	2.51	0.79	8.86	43	1.70	0.68	3.72	293	1.36	0.36	10.29
1991	7	2.11	0.49	6.17	29	2.75	0.10	11.21	116	1.61	0.41	11.33
1992	20	2.49	0.88	5.02	25	2.06	0.00	4.39	28	3.40	1.64	11.22
1993	22	2.43	1.08	5.16	128	2.55	1.20	10.48	53	2.82	1.18	12.27
1994	14	3.30	1.99	5.07	46	2.87	1.32	10.55	60	2.93	1.52	11.98
1995	13	2.55	1.76	4.38	41	3.29	0.91	6.92	93	3.07	1.47	12.28
1996	7	4.37	1.80	10.64	16	4.91	2.08	10.11	55	2.89	1.64	10.53
1997	4	4.72	1.16	7.12	6	4.92	2.71	6.05	57	3.32	0.36	11.22
1998	11	0.89	0.22	2.82	25	3.71	0.62	10.35	113	2.47	1.18	6.57
1999	7	3.77	0.63	8.15	15	2.91	1.59	8.14	140	2.76	0.90	12.95
2000	7	4.34	1.13	9.90	9	3.24	2.13	5.52	107	2.47	1.59	5.13
2001	17	2.46	1.84	3.57					239	2.93	1.34	12.34
2002	8	3.52	2.12	5.03	12	2.33	1.20	3.63	341	2.63	0.22	10.44
2003	9	4.31	2.94	6.41	21	4.09	1.30	12.07	299	2.75	0.81	12.19
2004	3	4.99	2.62	6.40	10	4.73	2.03	6.83	290	2.94	0.97	12.73
2005	3	5.69	5.25	6.12	3	7.51	4.04	10.93	189	2.92	1.35	9.21
2006	4	4.61	1.02	8.20	9	5.77	1.93	10.05	159	3.07	1.61	11.52
2007	2	2.05	2.05	2.05	15	4.53	1.74	8.80	153	2.63	1.37	11.58
2008	10	2.19	1.66	2.83	12	3.99	2.10	8.54	435	2.60	1.40	12.93
2009	16	2.91	1.72	5.46	12	3.19	1.93	8.48	738	2.87	0.11	13.18
2010									4	2.79	2.57	3.01
2011									1	3.52	3.52	3.52
2012	28	1.66	0.46	5.25	4	4.42	3.43	5.03	100	2.51	0.54	7.11
2013	32	2.09	0.41	6.54	2	5.69	5.48	5.89	143	3.36	0.28	12.55
2014	66	1.67	0.27	9.11	22	3.35	0.86	8.18	203	2.27	0.18	8.90

Table 4.10.25. State of Florida Red Snapper Mini-Season Surveys. Number of harvested Red Snapper measured, number of trips with measured Red Snapper, and mean weight of Red Snapper sampled by year for private boat mode.

Year	Fish (n)	Trips (n)	Mean weight (kg)
2012	440	167	4.09
2013	631	244	5.03
2014	1,718	583	5.02

Table 4.10.26. SCDNR State Finfish Survey number of red snapper measured (total and by mode), mean length, standard deviation of length, and minimum and maximum size range (all modes combined). No length measurements were recorded during1988, 1990, 1991, 1994-1998, 2004, 2006, 2007, 2010, and 2011.

Year	Total number measured	Total number measured by mode		Mean TLmax(mm)	StDev TLmax(mm)	Minimum TLmax(mm)	Maximum TLmax(mm)
		Charter	Private				
1988							
1989	1	0	1	437.18		437.18	437.18
1990							
1991							
1992	7	0	7	365.45	78.16	309.23	489.87
1993	2	0	2	341.48	56.26	301.70	381.27
1994							
1995							
1996							
1997							
1998							
1999	22	18	4	589.72	31.18	493.10	639.33
2000	17	15	2	739.84	124.11	471.59	847.94
2001	4	0	4	629.39	76.32	555.46	710.30
2002	15	0	15	607.22	112.48	441.48	774.82
2003	6	0	6	634.49	129.30	398.47	768.37
2004							
2005	2	0	2	806.00	153.59	697.40	914.60
2006							
2007							
2008	2	0	2	633.96	41.06	604.92	662.99
2009	4	0	4	582.76	47.89	540.00	650.00
2010							
2011							
2012	3	0	3	750.666667	85.33	670.00	840.00

Table 4.10.27. Headboat At-Sea Sampling. Number of discarded Red Snapper measured and number of trips sampled by observers by state and year.

	Number Fish (n)					Number Trips (n)				
Year	NC	SC	GA-NEFL	SEFL	Sum	NC	SC	GA-NEFL	SEFL	Sum
2005	0	0	366	48	414	97	57	49	93	296
2006	0	0	672	0	672	88	45	45	71	249
2007	13	2	1450	34	1499	91	52	57	69	269
2008	23	1	1626	28	1678	78	39	55	74	246
2009	3	0	425	8	436	69	34	61	76	240
2010	7	0	325	14	346	83	26	51	72	232
2011	8	0	307	0	315	79	22	51	68	220
2012	18	1	635	3	657	78	36	62	64	240
2013	28	0	472	1	501	55	41	61	79	236
2014	7	0	606	0	613	70	41	68	79	258

Table 4.10.28. Number of red snapper aged and number of trips with aged red snapper in the recreational fishery by year, state, and mode. Trips (N) are a combination of angler and vessel trips.

	Fish(N)							Trips(N)*						
	Charter		Headboat			Private		Charter		Headboat			Private	
Year	FL	GA	FLE/GA	NC	SC	FL	GA	FL	GA	FLE/GA	NC	SC	FL	GA
1977	-	-	60	-	12	-	-	-	-	17	-	5	-	-
1978	-	-	275	1	2	-	-	-	-	80	1	2	-	-
1979	-	-	46	-	1	-	-	-	-	31	-	1	-	-
1980	-	-	87	2	5	-	-	-	-	30	2	4	-	-
1981	-	-	405	3	-	-	-	-	-	141	3	-	-	-
1982	-	-	131	3	-	-	-	-	-	55	1	-	-	-
1983	-	-	741	3	5	-	-	-	-	167	2	4	-	-
1984	-	-	553	-	28	-	-	-	-	147	-	19	-	-
1985	-	-	491	-	13	-	-	-	-	150	-	10	-	-
1986	-	-	174	2	8	-	-	-	-	92	1	4	-	-
1987	-	-	86	1	-	-	-	-	-	60	1	-	-	-
1988	-	-	19	3	-	-	-	-	-	17	3	-	-	-
1989	-	-	15	11	23	-	-	-	-	9	5	17	-	-
1990	-	-	20	8	5	-	-	-	-	13	6	4	-	-
1991	-	-	21	4	1	-	-	-	-	13	4	1	-	-
1992	-	-	2	3	1	-	-	-	-	2	2	1	-	-
1993	-	-	9	2	7	-	-	-	-	6	2	5	-	-
1994	7	-	10	5	1	-	-	2	-	6	3	1	-	-
1995	-	-	11	3	4	-	-	-	-	5	2	1	-	-
1996	-	-	17	2	31	-	-	-	-	12	2	13	-	-
1997	-	-	13	-	-	-	-	-	-	12	-	-	-	-
1998	-	-	7	-	21	-	-	-	-	6	-	2	-	-
2000	7	-	2	-	-	-	-	4	-	2	-	-	-	-
2001	42	-	2	-	-	1	-	14	-	2	-	-	1	-
2002	253	-	9	-	3	9	-	81	-	3	-	3	3	-
2003	352	-	10	1	-	2	-	91	-	6	1	-	2	-
2004	309	-	27	3	-	3	-	83	-	9	3	-	2	-
2005	338	-	60	3	-	-	-	87	-	23	1	-	-	-
2006	169	-	155	1	7	-	-	43	-	66	1	7	-	-
2007	27	-	60	1	10	2	-	11	-	24	1	10	1	-
2008	-	-	118	9	6	-	-	-	-	37	6	4	-	-
2009	271	169	1,220	8	11	18	5	51	26	249	7	8	7	1
2010	-	-	2	-	-	-	-	-	-	1	-	-	-	-
2012	679	36	576	24	4	965	-	113	7	48	5	1	300	-
2013	425	18	210	31	1	1,049	-	82	3	32	6	1	355	-
2014	830	93	282	63	19	2,416	-	150	22	42	10	4	810	-

Table 4.10.29. South Atlantic (NC-FLE) estimated number of angler trips for charter boat mode, mode (MRFSS, NMFS, 1981-2003; MRIP, NMFS, 2004+). CH mode adjusted for FHS conversion prior to 2004. MRFSS headboat effort from the South Atlantic has been separated from the combined Cbt/Hbt mode and removed. *CVs for CH mode 1981-1985 are unavailable.

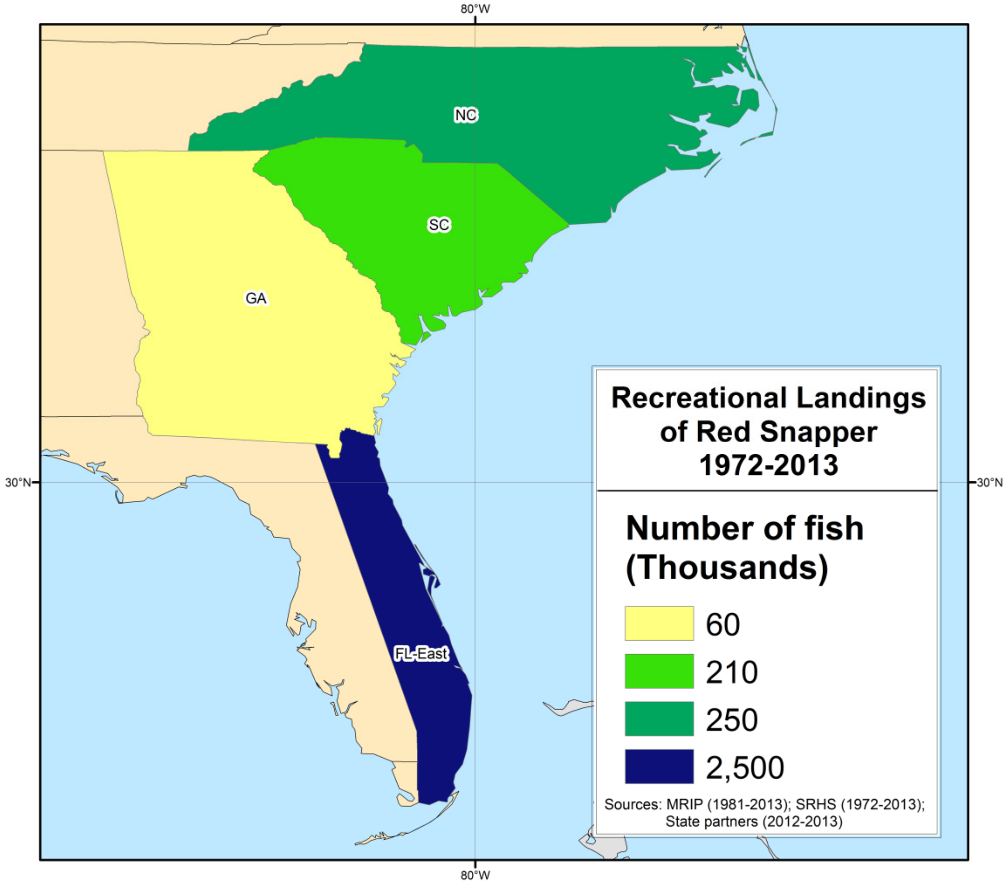
	Estimated CH Angler Trips		Estimated PR Angler Trips		ALL MODES Angler Trips	
YEAR	Trips	CV*	Trips	CV	Trips	CV
1981	686,826		3,042,475	0.06	3,729,301	0.05
1982	692,725		4,940,950	0.06	5,633,675	0.05
1983	1,269,339		5,723,506	0.06	6,992,845	0.05
1984	793,750		6,406,104	0.05	7,199,854	0.05
1985	964,607		6,287,166	0.06	7,251,772	0.05
1986	1,046,581	0.17	6,484,617	0.05	7,531,198	0.05
1987	744,484	0.15	7,753,996	0.04	8,498,480	0.03
1988	1,019,369	0.12	7,973,600	0.03	8,992,969	0.03
1989	795,017	0.13	7,072,914	0.04	7,867,931	0.04
1990	505,373	0.12	6,381,615	0.03	6,886,988	0.03
1991	528,549	0.10	7,222,081	0.03	7,750,630	0.03
1992	600,009	0.10	7,168,313	0.02	7,768,322	0.02
1993	784,034	0.08	6,846,164	0.02	7,630,198	0.02
1994	1,028,348	0.07	8,266,083	0.02	9,294,431	0.02
1995	1,178,551	0.07	7,666,576	0.02	8,845,128	0.02
1996	1,306,227	0.07	7,392,545	0.02	8,698,771	0.02
1997	1,279,959	0.08	8,276,257	0.02	9,556,217	0.02
1998	1,073,517	0.07	7,534,670	0.02	8,608,188	0.02
1999	874,133	0.08	6,935,225	0.02	7,809,358	0.02
2000	680,796	0.09	9,119,183	0.02	9,799,979	0.02
2001	685,504	0.09	9,565,115	0.02	10,250,619	0.02
2002	635,191	0.09	8,265,877	0.02	8,901,068	0.02
2003	619,013	0.10	9,962,637	0.02	10,581,649	0.02
2004	491,941	0.05	9,900,722	0.03	10,392,663	0.03
2005	502,579	0.06	9,896,001	0.03	10,398,580	0.03
2006	455,949	0.04	9,822,545	0.03	10,278,495	0.03
2007	503,429	0.04	11,536,245	0.03	12,039,673	0.03
2008	414,845	0.04	10,909,888	0.03	11,324,733	0.03
2009	390,551	0.04	8,922,867	0.03	9,313,417	0.03
2010	367,854	0.04	9,513,792	0.03	9,881,646	0.03
2011	372,379	0.05	8,663,086	0.03	9,035,465	0.03
2012	348,342	0.06	8,774,870	0.03	9,123,212	0.03
2013	336,441	0.04	7,877,791	0.03	8,214,232	0.03
2014	414,272	0.05	7,836,314	0.03	8,250,585	0.03

Table 4.10.30. South Atlantic headboat estimated angler days by year and state, 1981-2014.

Year	NC	SC	GA/FLE	South Atlantic
1981	19,374	59,030	298,883	377,287
1982	26,939	67,539	293,133	387,611
1983	23,830	65,733	277,863	367,426
1984	28,865	67,314	288,994	385,173
1985	31,384	66,001	280,845	378,230
1986	31,187	67,227	317,058	415,472
1987	35,261	78,806	333,041	447,108
1988	42,421	76,468	301,775	420,664
1989	38,678	62,708	316,864	418,250
1990	43,240	57,151	322,895	423,286
1991	40,936	67,982	280,022	388,940
1992	41,176	61,790	264,523	367,489
1993	42,786	64,457	236,973	344,216
1994	36,691	63,231	242,781	342,703
1995	40,295	61,739	210,714	312,748
1996	35,142	54,929	199,857	289,928
1997	37,189	60,150	173,273	270,612
1998	37,399	61,342	155,341	254,082
1999	31,596	55,499	164,052	251,147
2000	31,351	40,291	182,249	253,891
2001	31,779	49,265	163,389	244,433
2002	27,601	42,467	151,546	221,614
2003	22,998	36,556	145,011	204,565
2004	27,255	48,763	175,400	251,418
2005	31,573	34,036	172,839	238,448
2006	25,736	56,074	175,522	257,332
2007	29,002	60,729	157,150	246,881
2008	17,158	47,287	123,943	188,388
2009	19,468	40,919	136,420	196,807
2010	21,071	44,951	123,662	189,684
2011	18,457	44,645	132,492	195,594
2012	20,766	41,003	147,699	209,468
2013	20,547	40,963	165,679	227,189
2014	22,691	42,025	195,890	260,606

4.11 Figures

a) **Red Snapper Landings by State 1972-2013**



b) **Red Snapper Landings by State and Year 1972-2014**

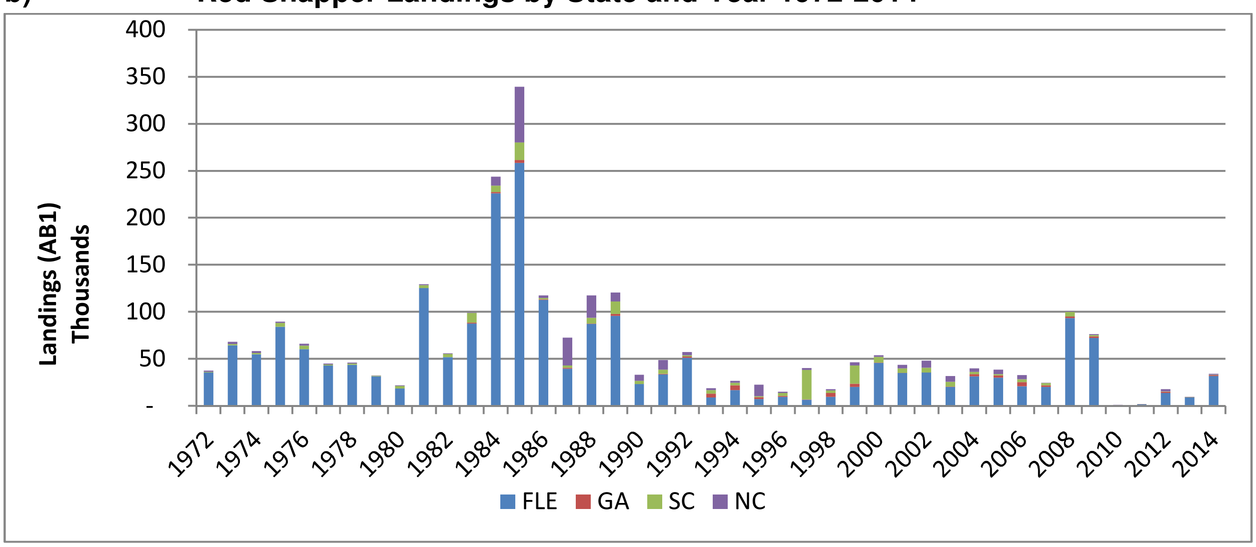
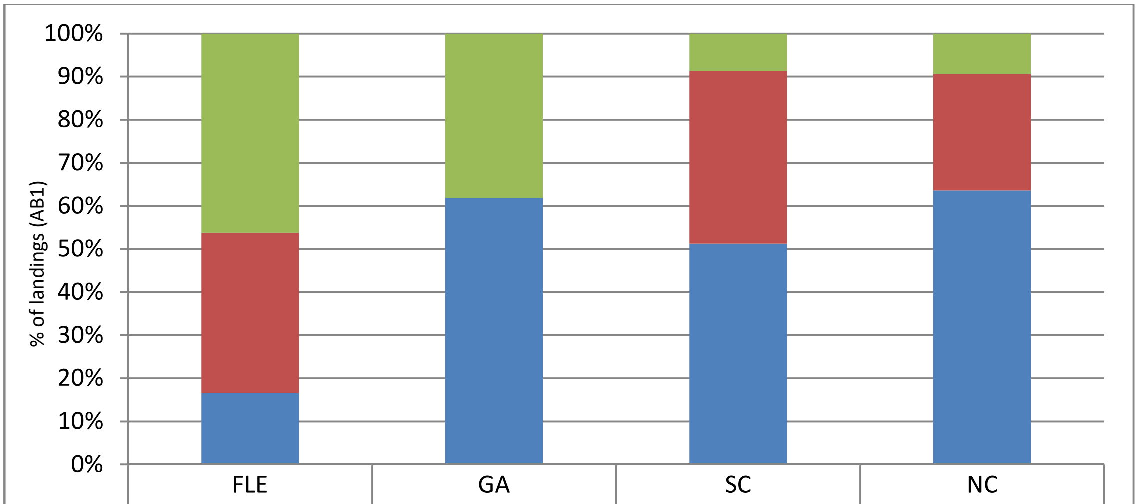


Figure 4.11.1. Estimated number of South Atlantic red snapper landings from MRIP (1981-2014), SRHS (1972-2014), and state partners (2012-2014) by state (a), by state and year (b), and by state and mode (c). SRHS landings for GA and FLE are grouped and shown in FLE due to vessel confidentiality issues.

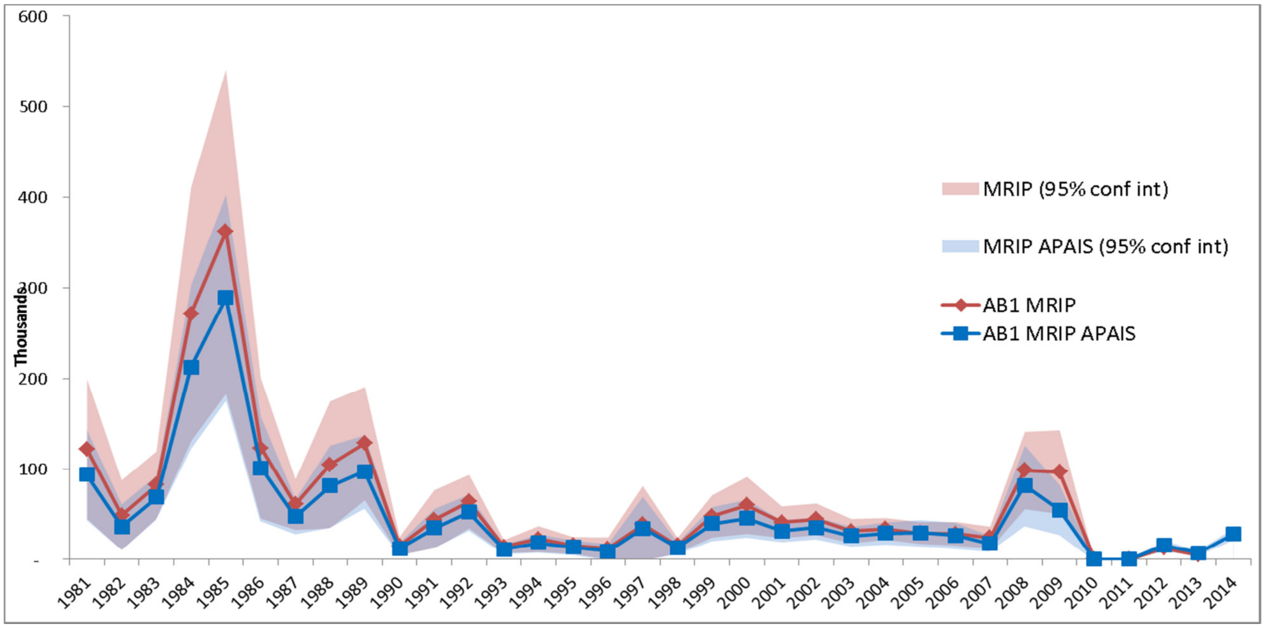
c) **Red Snapper Landings by State and Mode 1972-2014**



Landings	FLE	GA	SC	NC
Priv	998,996	18,854	16,883	21,672
Hbt	804,349		77,843	62,107
Cbt	359,483	30,640	99,695	146,116

Figure 4.11.1 (continued). Estimated number of South Atlantic red snapper landings from MRIP (1981-2014), SRHS (1972-2014), and state partners (2012-2014) by state (a), by state and year (b), and by state and mode (c). SRHS landings for GA and FLE are grouped and shown in FLE due to vessel confidentiality issues.

a) AB1 (number of fish) landed



b) B2 (number of fish) discarded alive

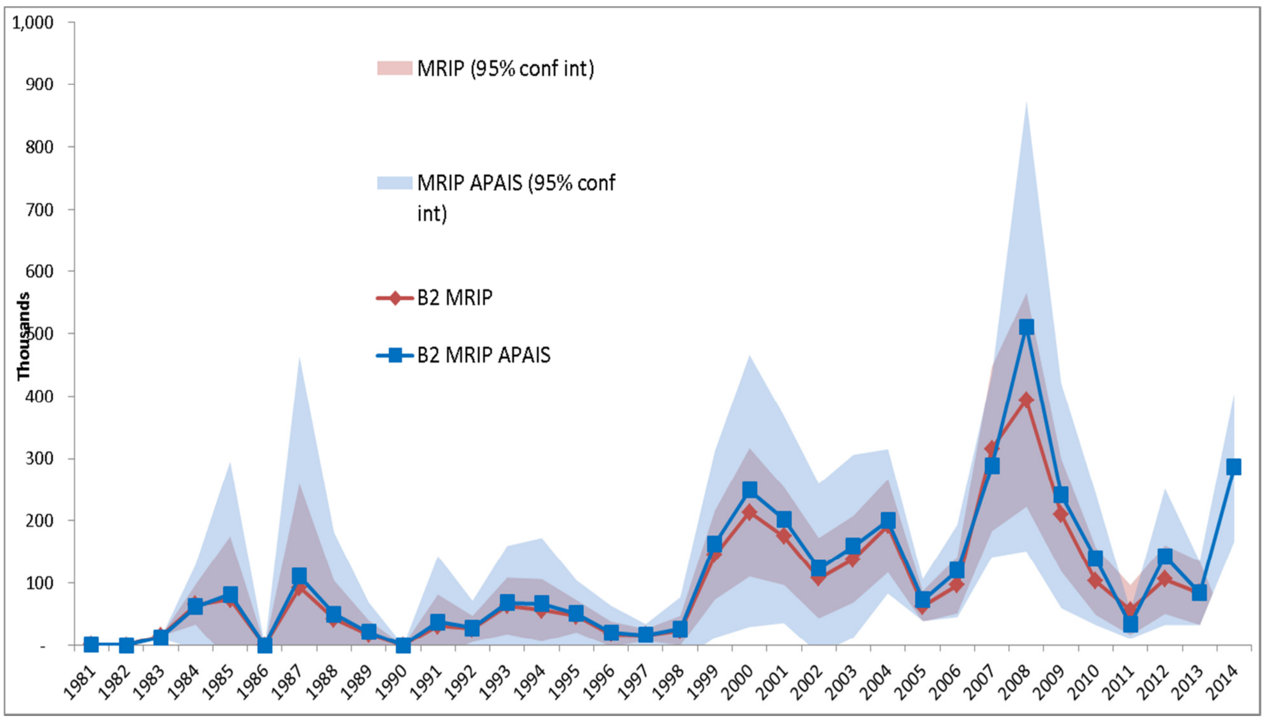


Figure 4.11.2. MRIP estimates versus MRIP adjusted estimates for South Atlantic red snapper 1981-2014. 95% confidence intervals are included.

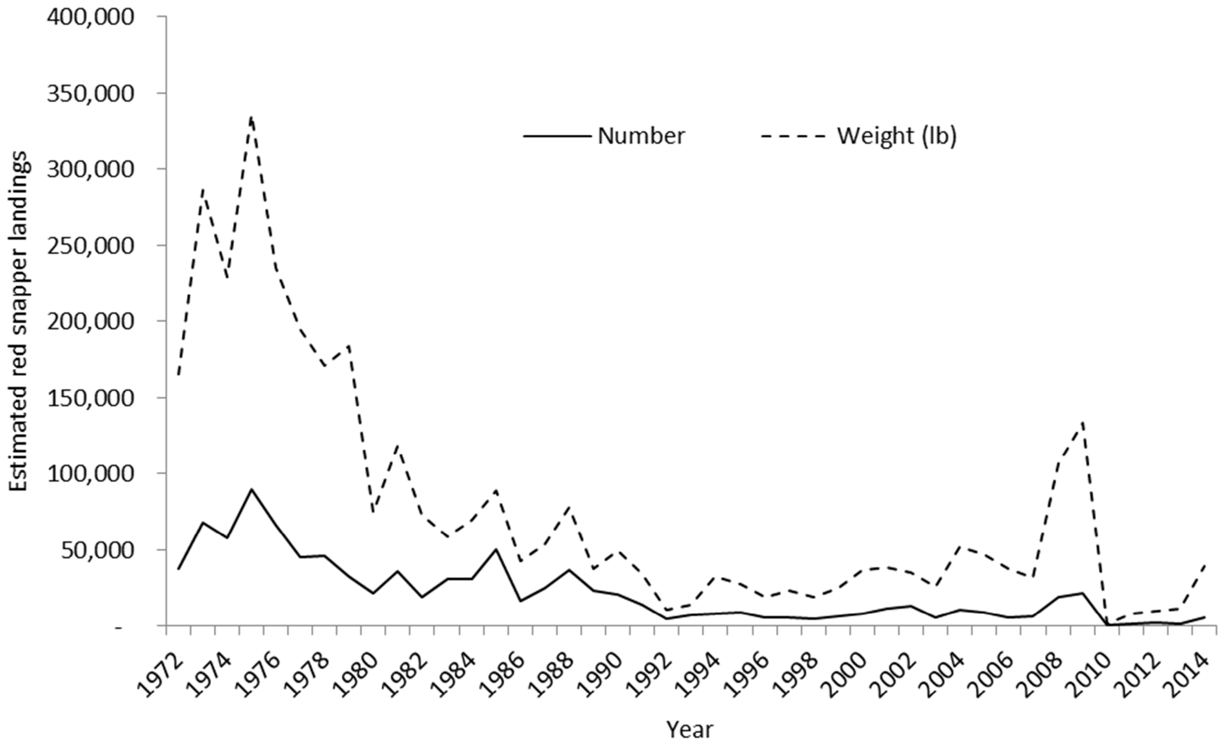


Figure 4.11.3. South Atlantic estimated red snapper landings (number and pounds) for the headboat fishery, 1972-2014.

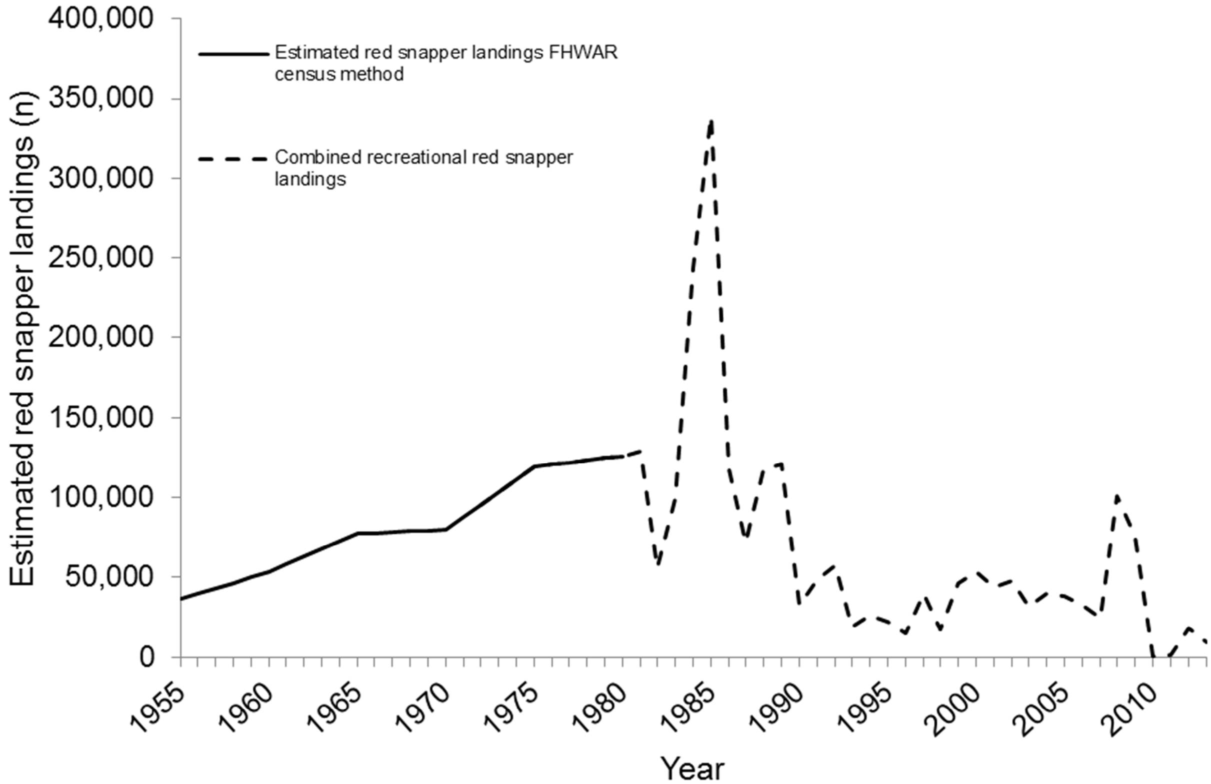


Figure 4.11.4. Estimated red snapper landings using the FHWAR census method, 1955 – 1980.

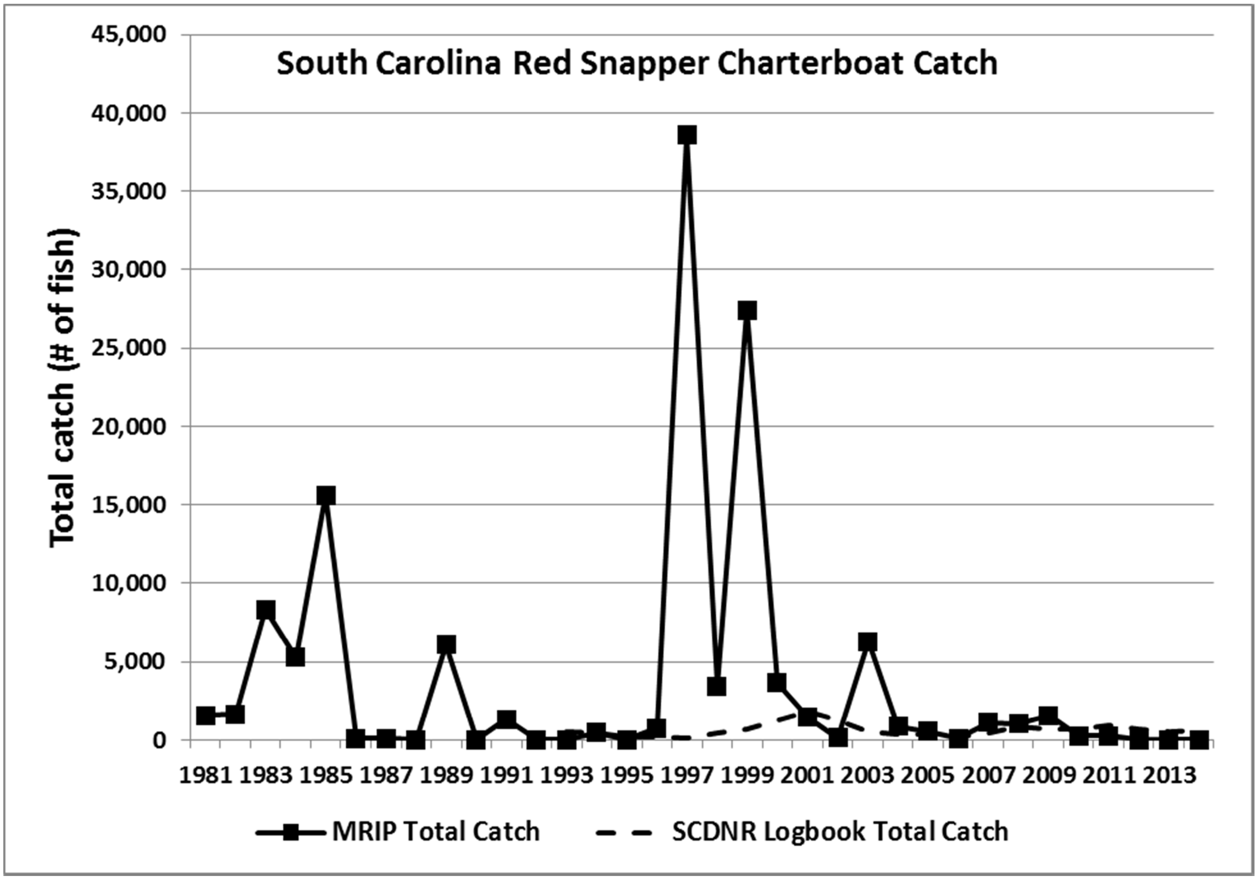
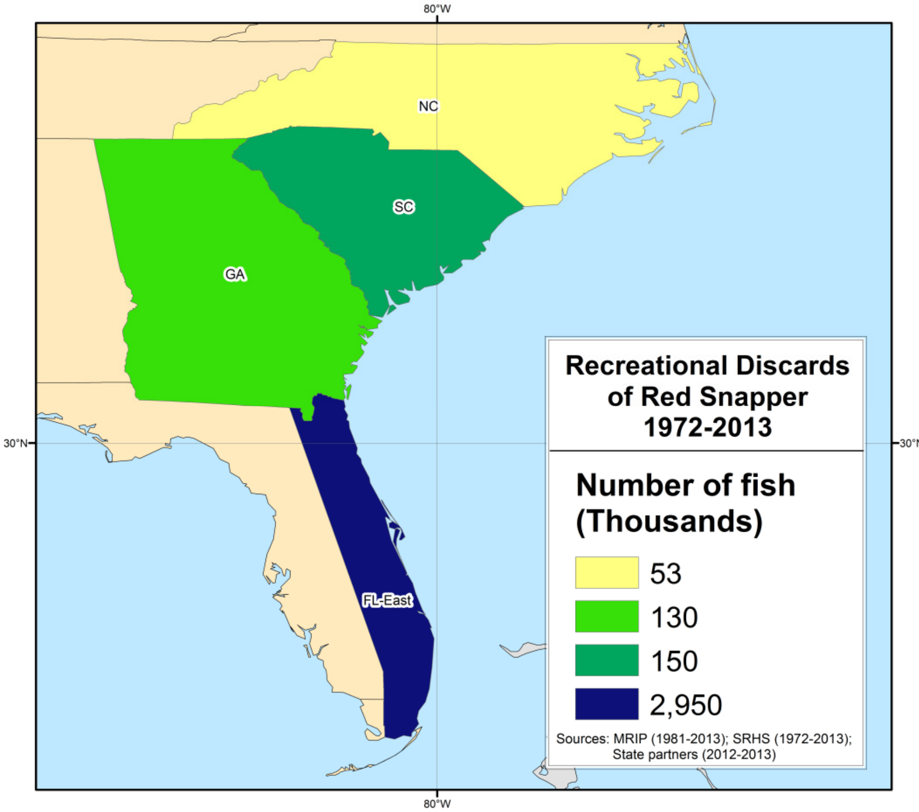


Figure 4.11.5. Comparison of SC total red snapper catch (a+b1+b2) from MRIP charter mode and SCDNR charter boat logbook program, 1993-2014.

a) Red Snapper Discards by State 1972-2013



b) Red Snapper Discards by State and Year 1972-2014

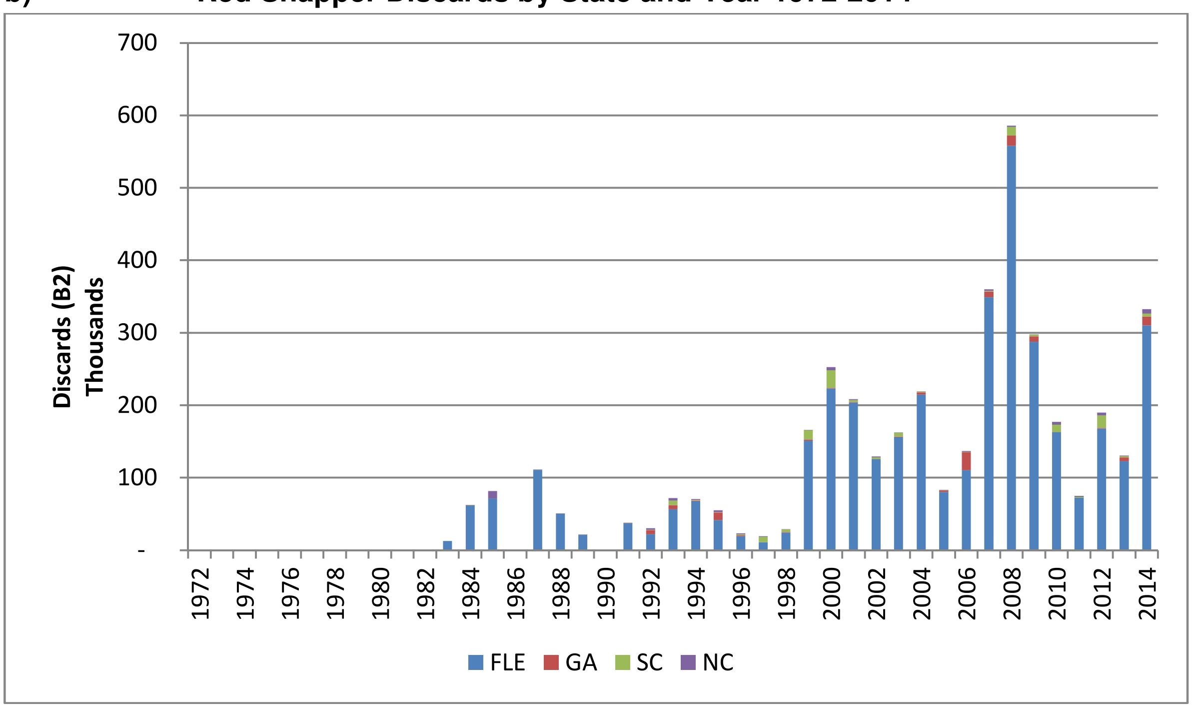
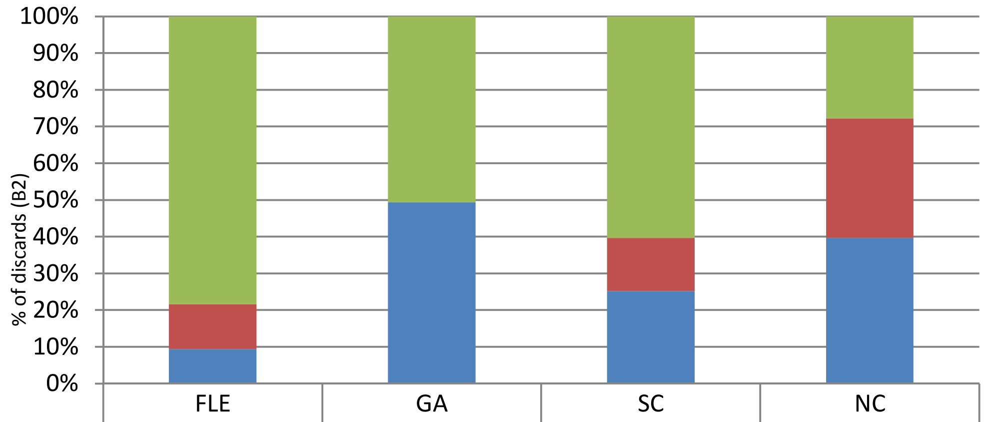


Figure 4.11.6. Estimated number of South Atlantic red snapper discards from MRIP (1981-2014), SRHS (1972-2014), and state partners (2012-2014) by state (a), by state and year (b), and by state and mode (c). SRHS discards for GA and FLE are grouped and shown in FLE due to vessel confidentiality issues.

c) **Red Snapper Discards by State and Mode 1972-2014**



Discards	FLE	GA	SC	NC
Priv	3,056,612	54,580	72,234	14,420
Hbt	478,274		17,399	16,902
Cbt	365,935	53,266	30,115	20,583

Figure 4.11.6 (continued). Estimated number of South Atlantic red snapper discards from MRIP (1981-2014), SRHS (1972-2014), and state partners (2012-2014) by state (a), by state and year (b), and by state and mode (c). SRHS discards for GA and FLE are grouped and shown in FLE due to vessel confidentiality issues.

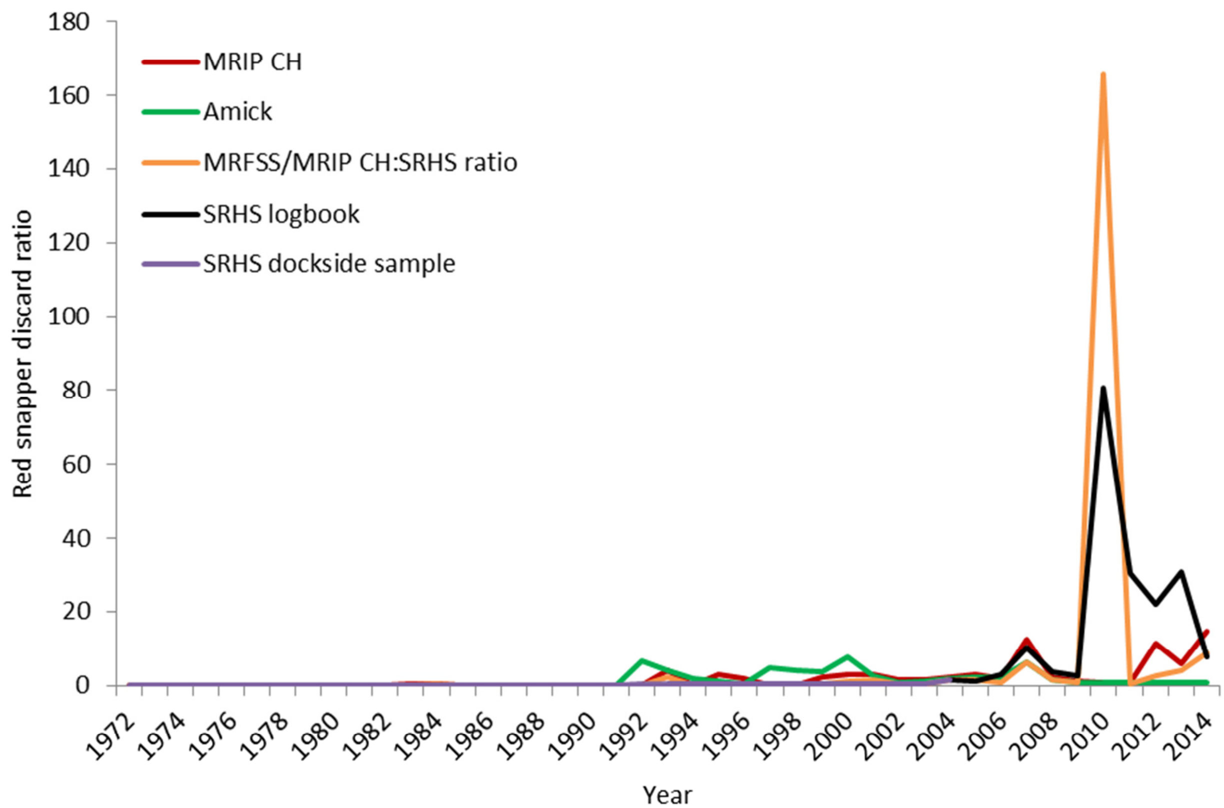


Figure 4.11.7a. MRIP CH (1981-2014), Amick (1983-2014), MRIP CH:SRHS discard ratio methods (1981-2014), SRHS dockside sample (1984-2003),and SRHS discard ratios (2004-2014).

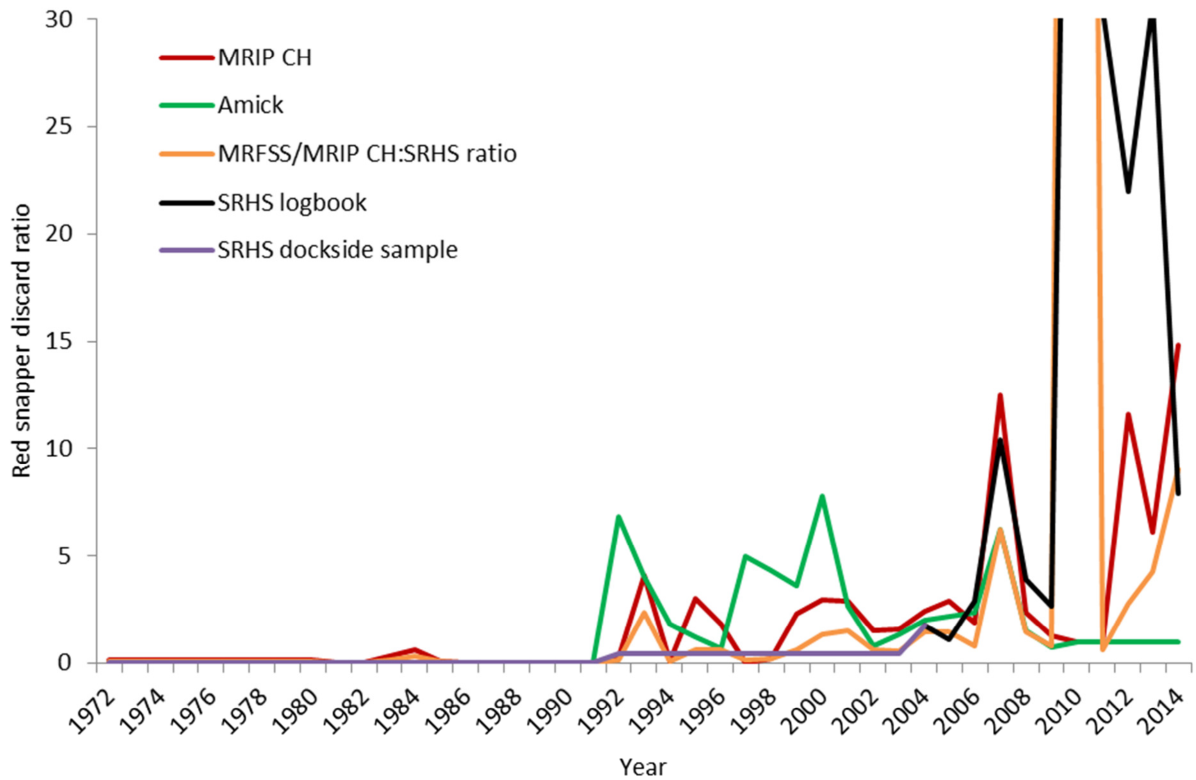


Figure 4.11.7b. MRIP CH (1981-2014), Amick (1983-2014), MRIP CH:SRHS discard ratio methods (1981-2014), SRHS dockside sample (1984-2003),and SRHS discard ratios (2004-2014) at reduced scale.

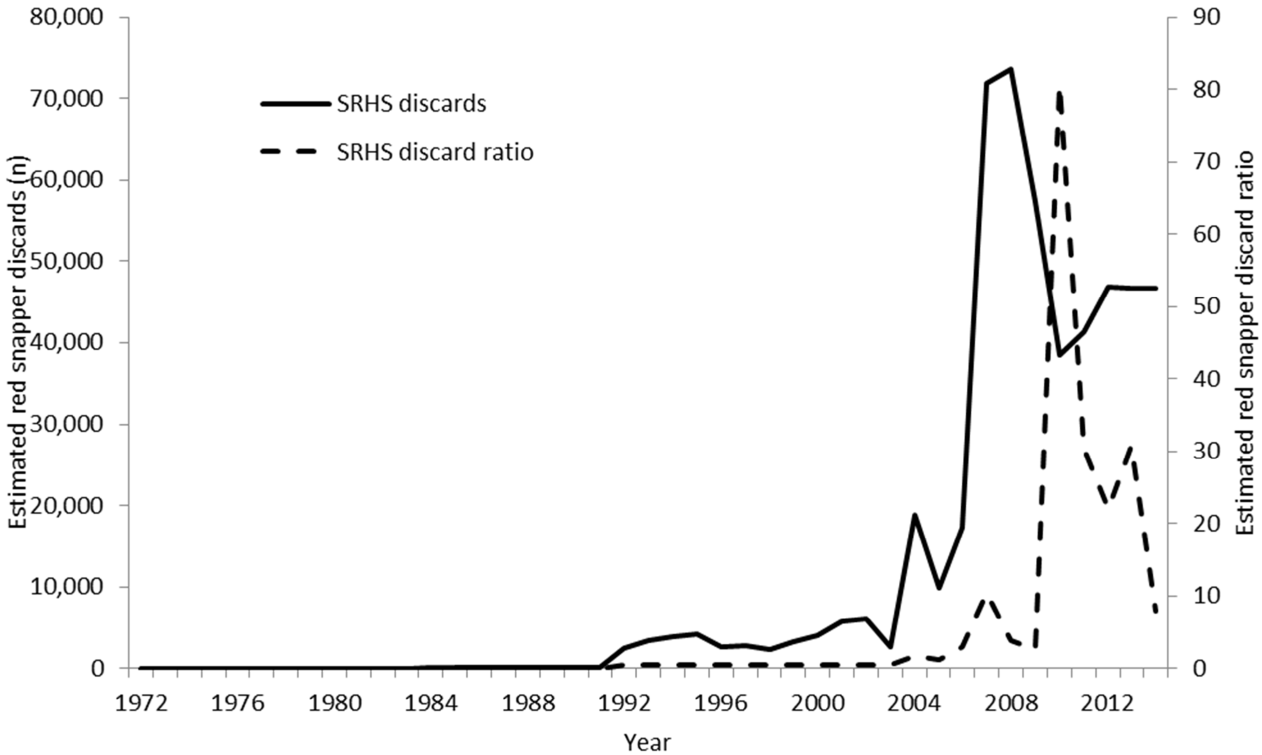
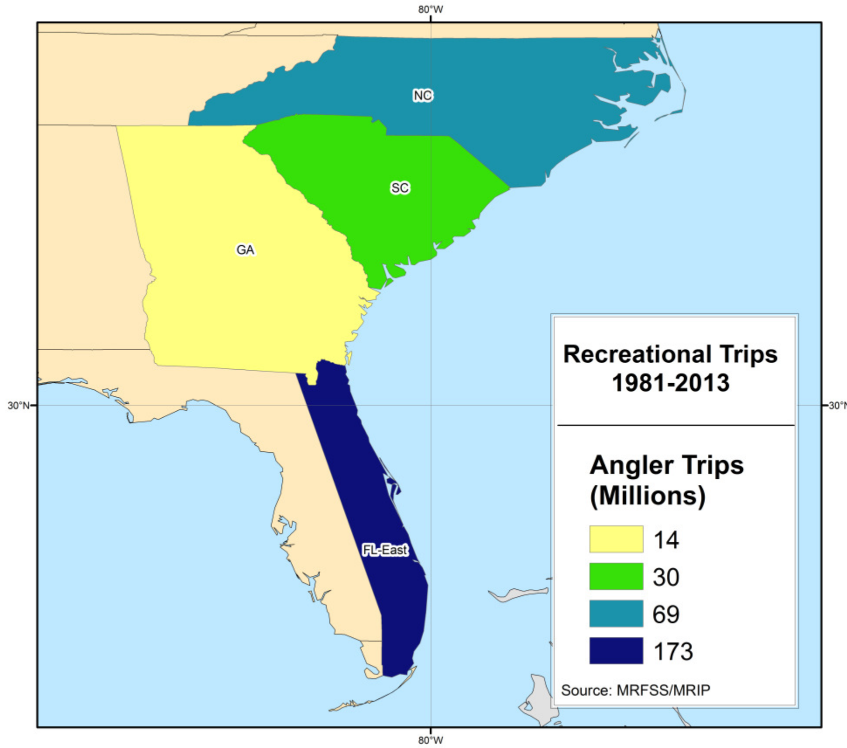


Figure 4.11.8. South Atlantic estimated red snapper discards and discard ratio for headboats assume zero discards 1972-1983; SRHS dockside sample proxy method 1984-2003; SRHS 2004-2014).

a) Angler Trips by State 1981-2013



b) Angler Trips by State and Year 1981-2014

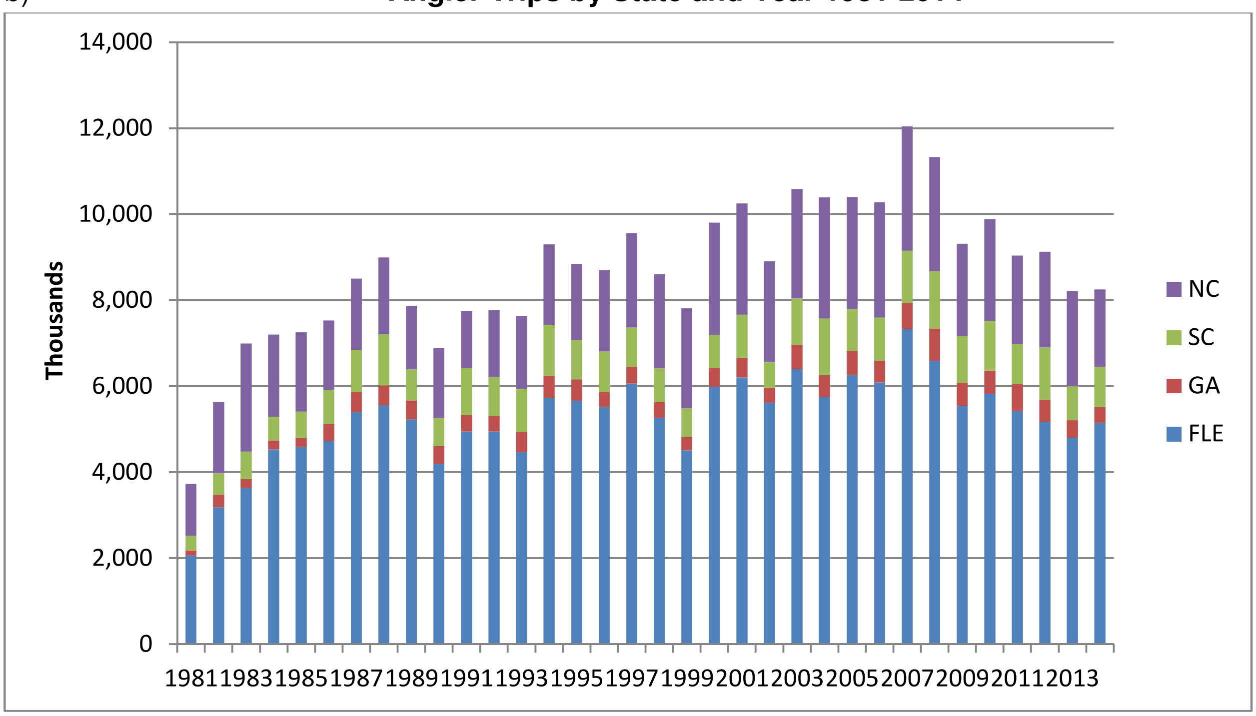
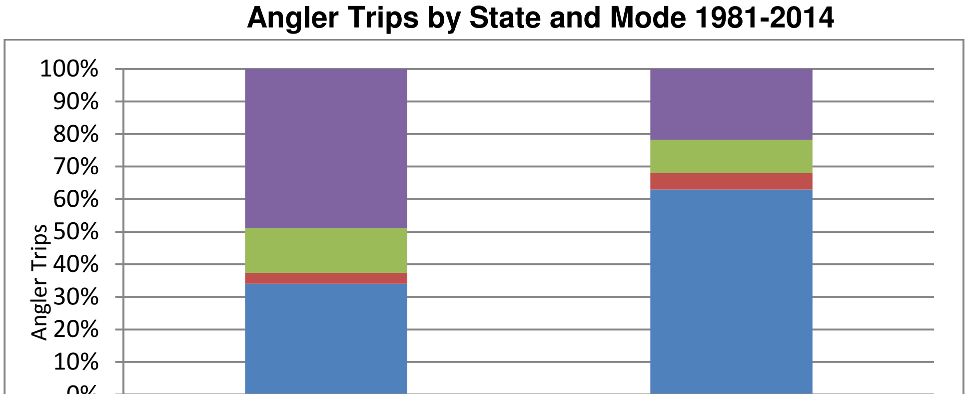


Figure 4.11.9. South Atlantic estimated number of angler trips from MRFSS/MRIP (1981-2014) by state (a), by state and year (b), and by state and mode (c). MRFSS/MRIP data from NC to FLE. MRFSS headboat effort has been removed from the South Atlantic.

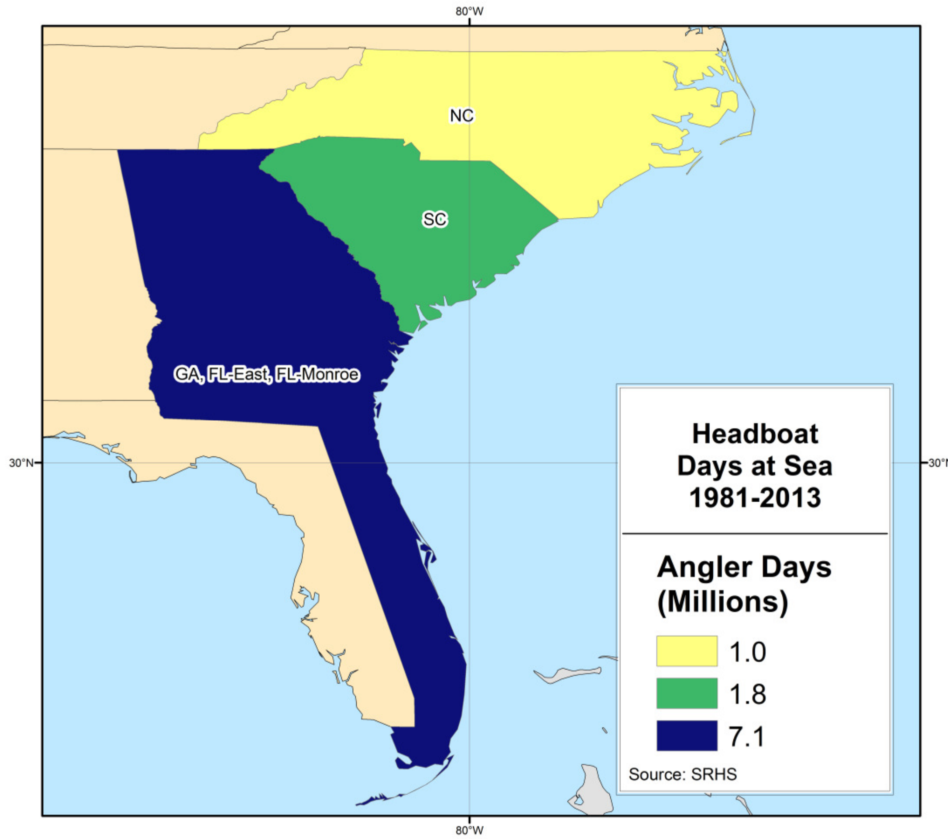
c)



	Cbt	Priv
NC	11,927,165	58,748,896
SC	3,342,427	27,366,768
GA	817,688	13,829,525
FLE	8,303,204	169,996,598

Figure 4.11.9. (continued). South Atlantic estimated number of angler trips from MRFSS/MRIP (1981-2014) by state (a), by state and year (b), and by state and mode (c). MRFSS/MRIP data from NC to FLE. MRFSS headboat effort has been removed from the South Atlantic.

a) **Angler Days by State 1981-2013**



b) **Angler Days by State and Year 1981-2014**

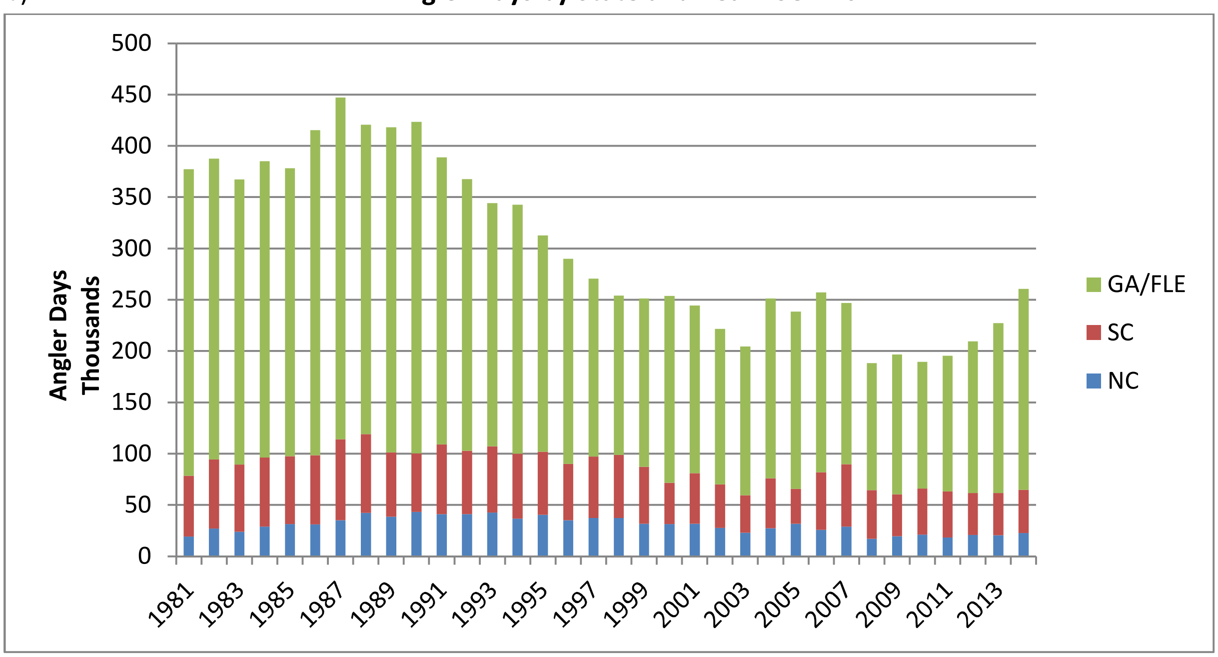


Figure 4.11.10. South Atlantic estimated number of headboat angler days from SRHS (1981-2014) by state (a) and by state and year (b). Due to confidentiality concerns, effort from Georgia has been grouped together with East Florida. SRHS data from NC to FLE, including Atlantic side of the Florida Keys.

5. Measures of Population Abundance

5.1 Overview

Seven fishery independent data sets were considered for use as an index of abundance (Table 5.1). During the data webinar prior to the DW, five of these datasets were discarded because of small sample sizes or limited geographic extent. Two fishery independent data sets were retained for further consideration at the DW: SERFS chevron traps and SERFS video survey.

Six fishery dependent data sets were considered for use as an index of abundance (Table 5.1). During the data webinars, five were recommended for further consideration at the DW. Ultimately, the DW recommended indices from three of these fishery dependent data sets for potential use in the assessment model: recreational headboat, headboat at-sea-observer data, and commercial handline.

In total, the DW recommended two fishery independent indices (SERFS chevron traps and video survey) and three fishery dependent indices (recreational headboat index, headboat at-sea observer index, and a commercial handline index) for potential use in the red snapper stock assessment. These indices are listed in Table 5.1, with pros and cons of each in Table 5.2.

Group Membership

Membership of this DW Index Working Group (IWG) included Nate Bacheler, Joey Ballenger, Nicholas Ballew, Peter Barile, Russ Brodie, Rob Cheshire, Kevin Craig, Eric Fitzpatrick, Kevin Purcell, Christina Schobernd, Kyle Shertzer (chair), Katie Siegfried, Tracy Smart, Ted Switzer, and Erik Williams. Several other DW panelists and observers contributed to the IWG discussions throughout the DW1 and DW2 workshops.

5.2 Review of Working Papers

The relevant working papers describing index construction were presented to the IWG. In most cases, the IWG recommended modifications to the initial modeling attempts, such that data treatments and/or model specifications were updated during the DW. Final working papers reflect decisions made during the DW, using addenda if necessary. In addition to working papers on index construction, the IWG also discussed any working papers available at the DW that were relevant to indices of abundance, namely SEDAR41-DW08, SEDAR41-DW11, and SEDAR41-DW46. SEDAR41-DW08 describes a pilot program for data collection using hook gear, SEDAR41-DW11 describes habitat models for gray triggerfish, and SEDAR41-DW46 describes evaluation of the headboat data set.

The index working papers provide information on sample sizes, diagnostics of model fits, and in some cases, maps of catch and effort. A summary of each index is provided below.

5.3 Fishery Independent Indices

Until 2009, virtually all fishery independent sampling of reef fishes in southeast U.S. Atlantic waters was conducted by the Marine Resources Monitoring, Assessment, and Prediction (MARMAP) program. In 2009, the Southeast Area Monitoring and Assessment Program – South Atlantic (SEAMAP-SA) program joined the chevron trap survey through their Reef Fish Complement. In 2010, the Southeast Fisheries Independent Survey (SEFIS) was created and joined the chevron trap survey. The partner-led survey is now referred to as the Southeast Reef Fish Survey (SERFS). With the advent of the partner programs, sampling coverage in the region has expanded, primarily in Florida. SERFS now samples between Cape Hatteras, North Carolina and St. Lucie Inlet, Florida, and it targets a sampling universe of approximately 3,000 sites of hard-bottom habitats between approximately 15 and 100 meters deep.

5.3.1 Chevron Trap

5.3.1.1 Methods, Gears, and Coverage

Chevron traps were baited with whole and cut Clupeids and deployed at stations randomly selected by computer from a database of live bottom stations on the continental shelf and shelf edge and soaked for approximately 90 minutes.

An index of abundance was developed by standardizing catch (number of Red Snapper caught) using a zero-inflated negative binomial model (SEDAR41-DW54; Zuur et al. 2009). Effort (trap soak minutes) was included as an offset in the regression. Analyses were computed using the *pscl* library in R (Jackman 2008; Zeileis et al 2008; R Development Core Team 2014). Model covariates included sampling characteristics and environmental data.

5.3.1.2 Sampling Intensity and Time Series

Chevron traps were deployed from 1990 through 2014, ranging from 219 to 1465 traps per year meeting the depth criteria for this analysis. Prior to 2010, red snapper were caught in chevron traps infrequently (SEDAR41-DW51). In 2010 with the advent of SERFS, sampling coverage in the region has expanded, primarily in Florida. Consequently, the spatial coverage of the survey after 2010 adequately covered the center of the distribution of red snapper and percent positives increased to levels high enough to develop an index. The time series was truncated for index development to 2010-2014 based on recommendations of the IWG. The annual number of traps (collections) used to compute the index is shown in Table 5.3.

5.3.1.3 Size/Age Data

The ages of red snapper collected by chevron traps (1990-2014) ranged from 0 to 26 (median = 2, mean = 3.3, n= 2085), and sizes ranged from 19 to 99 cm maximum (pinched tail) total length.

For the truncated time series (2010-2014), ages ranged from 0 to 26 (median = 2, mean = 3.4, n= 1686). Age composition data are available for estimating the selectivity of this gear.

5.3.1.4 Catch Rates

Standardized catch rates are shown in Table 5.3 and in Figure 5.1 (top panel). The units on catch rates are in numbers of fish. Effort was modeled as an offset, rather than as the denominator in the response variable.

5.3.1.5 Uncertainty and Measures of Precision

Measures of precision were computed using a bootstrap procedure (Efron and Tibshirani 1994), in which sampling events were drawn at random (by year) with replacement. The CVs are shown in Table 5.3.

5.3.1.6 Comments on Adequacy for Assessment

This index was considered to be adequate for the assessment. Recent years of the survey show that traps can and do catch red snapper, and sample sizes in the truncated time series were sufficiently large to create a meaningful index. Because the chevron trap index is fishery independent and has accompanying selectivity information (lengths and ages), it was considered by the IWG to be the highest ranking source of information on trends in population abundance.

Several issues were addressed or discussed. During DW1, models included covariates as categorical variables. For DW2, models applied the zero-inflated negative binomial but included covariates as continuous variables using polynomials and backward selection by Bayesian Information Criterion. The polynomial approach was ultimately adopted. In addition, the group discussed a modeling approach to project the index back in time when data were sparse (SEDAR41-DW51; SEDAR41-DW53). That longer time series (Figure 5.1, bottom panel) was not recommended as a primary index, but might reasonably be considered for a sensitivity analysis of the assessment model. One topic discussed by the group, but not explicitly addressed, was the non-independence between chevron traps and the video survey; this topic was identified for future research.

5.3.2 Video Survey

5.3.2.1 Methods, Gears, and Coverage

In 2010 the SERFS program began attaching video cameras to a limited number of chevron traps (Georgia and Florida only), with cameras being attached to all traps beginning in 2011 as a standard component of the sampling program. An index of abundance for red snapper was developed based on these videos using a zero-inflated negative binomial modeling approach

(SEDAR41-DW45, Zuur *et al*. 2009). All data manipulation and analyses were conducted using R (R Development Core Team 2014). Modeling was executed using the *zeroinfl* function in the *pscl* package (Jackman 2008; Zeileis et al. 2008).

5.3.2.2 Sampling Intensity and Time Series

The video index time series consists of only 5 years (2010-2014). Additionally, the first year of sampling was regionally limited to the coastal shelf of Georgia and Florida, representing approximately 20-33% of the sampling intensity in later years (SEDAR41-DW45). The IWG recognized differences in sampling in 2010 (more limited spatial coverage, different camera), but ultimately thought that 2010 should be included in the red snapper index for two reasons. First, the initial year of sampling was located in the core of red snapper's spatial distribution, and second, SERFS data provide the only information on relative abundance with fishery closures starting in 2010. Furthermore, a camera calibration study made it possible to adjust 2010 values for consistency with those from subsequent years. This decision was supported by the recommendations of the Video Index Development Panel, a special working group convened in the spring of 2014 to guide and recommend a set of best practices for the development of a video indices based on SERFS data in the south Atlantic (SEDAR41-RD23).

A total of 4923 videos were considered for development of the red snapper index. Of those, 514 were removed based on modeling considerations (SEDAR41-DW45), leaving a total of 4409 videos for index construction. These data span a wide latitudinal and depth range, covering a substantial region of the south Atlantic coastal shelf (SEDAR41-DW45, Figure 2). Detailed information on the depth, latitudinal, and seasonal distribution of sampling can be found in the index working paper (SEDAR41-DW45, Table 2).

5.3.2.3 Size/Age Data

As currently implemented, the size and age composition of populations sampled with the SERFS video survey gear are unknown, and therefore selectivity of the gear cannot be estimated from data. However, in a different system, Langlois et al. (2015) compared length compositions of snappers and groupers caught in traps to those observed on video cameras, and found those length compositions to be quite similar. Based on that, the IWG recommended applying selectivity of chevron traps to the video gear, in one of two ways: 1) if chevron trap selectivity is flat-topped, the video gear selectivity should mirror that of the chevron traps, or 2) if chevron trap selectivity is dome-shaped, the video gear selectivity should mirror only the ascending portion and then assume flat-topped selectivity. This recommendation was based on the expectation that the video gear should be flat-topped, because older, larger fish are present throughout the depths sampled and because there is no known reason why larger (older) individuals would be less observable on video than smaller (younger) individuals. The IWG recognized the need for age/size compositions of the video survey, and recommended future research to remedy this limitation.

5.3.2.4 Catch Rates

Annual standardized index values for red snapper, including CVs, are presented in Table 5.4 and in Figure 5.2.

5.3.2.5 Uncertainty and Measures of Precision

Using a bootstrap procedure with 1000 replicates, confidence intervals of 2.5% and 97.5% were calculated for each year of the survey (Figure 5.2), as were CVs (Table 5.4). Due to the changes in sampling distribution and equipment (SEDAR41-RD23), the nominal value for 2010 (2.61) was considerably higher than the standardized index value for 2010 (1.21), which was expected because of a camera calibration to the standardized index (SEDAR41-RD23, SEDAR41-DW45).

5.3.2.6 Comments on Adequacy for Assessment

The red snapper video index (2010-2014) was recommended for use in the assessment. The resulting index was ranked second of the two fishery independent sources based on the absence of information concerning the age composition of the video sampling gear. Non-independence between the video survey and chevron traps was discussed and identified as a topic for future research.

5.4 Fishery Dependent Indices

In general, indices from fishery independent data are believed to represent abundance more accurately than those from fishery dependent data. This is because fishery dependent indices can be strongly affected by factors other than abundance, such as management regulations on the focal or other species, shifts in targeting, changes in fishing efficiency (technology creep), and density dependent catchabililty (hyperdepletion or hyperstability). The standardization procedures attempt to account for some of these issues to the extent possible.

5.4.1 Recreational Headboat Index

The headboat fishery in the south Atlantic includes for-hire vessels that typically accommodate 11-70 passengers and charge a fee per angler. The fishery uses hook and line gear, generally targets hard bottom reefs as the fishing grounds, and generally targets species in the snapper-grouper complex. This fishery is sampled separately from other fisheries, and the available data were used to generate a fishery dependent index.

Headboats in the south Atlantic are sampled from North Carolina to the Florida Keys (Figure 5.3). Data have been collected since 1972, but logbook reporting did not start until 1973. In addition, only North Carolina and South Carolina were included in the earlier years of the data set. In 1976, data were collected from North Carolina, South Carolina, Georgia, and northern Florida, and starting in 1978, data were collected from southern Florida.

Variables reported in the data set include year, month, day, area, location, trip type, number of anglers, species, catch, and vessel identification. Biological data and discard data were recorded for some trips in some years.
The IWG, along with headboat captains, discussed several key issues related to this index:

- Beginning in 1992, a 20" TL minimum size regulation was implemented. In some cases, the size limit may have influenced the fishing behavior of headboats that relied heavily on red snapper catch. Thus, the IWG recommended modeling the change in selectivity that likely resulted from the size limit, and further acknowledged that the assessment model could be configured to allow for time-varying catchability.
- The red snapper closure starting in 2010 led to a shift in fishing behavior (avoidance). Because of that, and because this index is based on landings only (i.e., no discards included), the IWG decided to end the index in 2009.

5.4.1.1 Methods of Estimation

Data Filtering

The headboat data and programmatic evaluation (SEDAR41-46) found a small percentage of logbook reports to be extreme outliers. Those values were likely erroneous and were removed from the data set prior to deriving the index.

Trips to be included in the computation of the index need to be determined based on effective effort for red snapper. This may not be straightforward, because some trips caught red snapper only incidentally, and some trips likely directed effort at red snapper unsuccessfully. Given that direct information on species targeted is not available, effective effort must be inferred.

To determine which trips should be used to compute the index, the method of Stephens and MacCall (2004) was applied. The Stephens and MacCall method uses multiple logistic regression to estimate a probability for each trip that the focal species was caught, given other species caught on that trip. Species compositions differ across the south Atlantic; thus, the method was applied separately for two different regions: north (areas 2-10) and south (areas 11, 12, and 17) (Shertzer *et al.* 2009). To avoid rare species, the number of species in each analysis was limited to those species that occurred in 1% or more of trips. The most general model therefore included all species in the snapper-grouper complex which occurred in 1% or more of trips as main effects, excluding red porgy. Red porgy was removed because of regulations (closure followed by strict bag limits), which could erroneously remove trips likely to have caught red snapper in recent years. A backward stepwise AIC procedure (Venables and Ripley 1997) was then used to perform further selection among possible species as predictor variables. In this procedure, a generalized linear model with Bernoulli response was used to relate presence/absence of red snapper in headboat trips to presence/absence of other species.

Model Description

Response and explanatory variables

The response variable, catch per unit effort (CPUE), has units of fish/angler and was calculated as the number of red snapper caught divided by the number of anglers. All explanatory (predictor) variables were modeled as categorical, rather than as continuous.

Years **–** 1976-2009

Area – Areas were pooled into regions of North Carolina (NC=2,3,9,10), South Carolina (SC=4,5), Georgia and North Florida (GNFL=6,7,8), and south Florida (sFL=11,12,17).

Season – The seasons were defined as winter (January, February, March), spring (April, May, June), summer (July, August, September) and fall (October, November, December).

Party – Five categories for the number of anglers on a boat were considered in the standardization process. The categories included: ≤20 anglers, 21-40 anglers, 41-60 anglers, 61-80 anglers, and >80 anglers. The minimum number of anglers per vessel was set at 6, which excluded the lower 0.5% of trips. These trips were excluded because they were possibly misreported and likely don't reflect the behavior of headboats in general.

Trip Type – Trip types of half and full day trips were included in the analysis. Three-quarter day trips were pooled with half-day trips (<10%). Multi-day trips were removed because most were in Florida and likely targeting deepwater species for some portion of the trip.

Standardization

CPUE was modeled using the delta-glm approach (Lo *et al*. 1992; Dick 2004; Maunder and Punt 2004). In particular, fits of lognormal and gamma models were compared for positive CPUE. Also, the combination of predictor variables was examined to best explain CPUE patterns (both for positive CPUE and the Bernoulli submodels). All analyses were performed in the R programming language (R Development Core Team 2014), with much of the code adapted from Dick (2004).

Bernoulli submodel. One component of the delta-GLM is a logistic regression model that attempts to explain the probability of either catching or not catching red snapper on a particular trip. First, a model was fit with all main effects to determine which effects should remain in the binomial component of the delta-GLM. Stepwise AIC (Venables and Ripley1997) with a backward selection algorithm was then used to eliminate those that did not improve model fit. In this case, the stepwise AIC procedure did not remove any predictor variables. No concerning patterns were apparent in the quantile residuals (Dunn and Smyth 1996).

Positive CPUE submodel. To determine predictor variables important for describing positive CPUE, the positive portion of the model was fitted with all main effects using both the lognormal and gamma distributions. Stepwise AIC (Venables and Ripley1997) with a backward selection algorithm was then used to eliminate those that did not improve model fit. In this case, no predictor variables were removed for either error term.

Both submodels (Bernoulli and either lognormal or gamma) were then combined, and the models were compared using AIC. In this case, the delta-lognormal distribution performed best and used in the final analysis. No concerning patterns were apparent in standard diagnostic plots of residuals.

5.4.1.2 Sampling Intensity

The resulting data set contained more than 51,000 trips across years with approximately 30–80% positive for red snapper. Annual numbers of trips used to compute the index are shown in Table 5.5.

5.4.1.3 Size/Age Data

The sizes/ages represented in this index should be the same as those of landings from the corresponding fleet (See section 4 of the DW report).

5.4.1.4 Catch Rates

Standardized catch rates and associated error bars are shown in Figure 5.4, and tabulated in Table 5.5. The units on catch rates were number of fish landed per angler.

5.4.1.5 Uncertainty and Measures of Precision

Measures of precision were computed using the bootstrap procedure. Annual CVs of catch rates are tabulated in Table 5.5.

5.4.1.6 Comments on Adequacy for Assessment

The index of abundance created from the headboat data was considered by the IWG to be adequate for use in the assessment. The data cover a wide geographic range relative to most of the stock, and logbooks are intended to represent a census of the headboats. The data set has an adequately large sample size and has a long enough time series to provide potentially meaningful information for the assessment. For the duration of the index, sampling was consistent over time, and some of the data were verified by port samplers and observers.

After DW1, industry representatives questioned the headboat data set, in particular the "veracity of data reported by the fishery" prior to 1992 (SEDAR41-DW40). The DW panel recognized the importance of those concerns, and recommended that the assessment be paused until the headboat data set could be thoroughly evaluated. That evaluation (SEDAR41-DW46) was conducted and available to inform DW2. It found "no evidence of chronic misreporting by vessels, no evidence of apparent temporal trends in potentially misreported data, and minimal spatial trends in potentially misreported data." The evaluation did identify a small percentage of obviously erroneous data that were corrected or removed from the data base, and it recommended that standard data filtering techniques be applied when developing indices of abundance. Such techniques were applied for SEDAR41, and the DW2 index working group thought there was sufficient justification to recommend the headboat index for use in the assessment.

The primary caveat concerning this index was that it was derived from fishery dependent data. Headboat effort generally targets snapper-grouper species and not necessarily the focal species, which should minimize changes in catchability relative to fishery dependent indices that target more effectively. The closure of the red snapper was addressed by terminating the index in 2010, and changes in selectivity and possibly catchability (e.g, in 1992) could be addressed by the assessment model.

5.4.2 Headboat At-sea Observer Program

The data used for this index were all trips in the headboat at-sea observer database which discarded red snapper from 2005 to 2014. The at-sea-observer program occurred during 2004-2014 in North and South Carolina, but started in Florida and Georgia in 2005. In addition, coverage in the Florida Keys was not consistent across years and therefore not included. Observer coverage occurred on approximately 2% of headboat trips.

Trip-level information included state, county, Florida region, year, month, day, dock to dock hours (total trip hours), the number of hours fished (to the nearest half hour), the total number of anglers on the boat, the number of anglers observed on a trip, the number of red snapper discarded, minimum depth of the fishing trip, and maximum depth of the fishing trip. Depth information was not collected for South Carolina, North Carolina, and Georgia; therefore, it was not used in this analysis. Refer to working paper SEDAR41-DW33 for more details regarding this program.

5.4.2.1 Methods of Estimation

Data Treatment

Data from 2004 were dropped from the analysis because Georgia and Florida were not sampled. Trips that fished at night targeting sharks or trips that were designated drift fishing were removed from the analysis. All other trips were thought to be fishing for snapper-grouper species. Observer trips by year and area relative to all headboat trips, as well as total red snapper observed, are presented in SEDAR41-DW14.

A 20" TL minimum size regulation has been in place since 1992. In SEDAR 24, headboat at-sea observer data were used to index discards below 20" TL minimum. A 2010 closure has created a scenario where all fish observed are discarded (mini-seasons in 2012 and 2013 were removed). During this closure period, discards greater than 20" TL were removed.

Although the closure went into effect in 2010, the IWG recommended treating this index as a single time series, 2005-2014. This was because the index only included fish less than 20" TL, and it was believed that any attempts at avoiding these smaller fish began in 1992 with implementation of the minimum size limit and continued with the closure in 2010. That is, with respect to fish less than 20" TL, fishing behavior remained relatively consistent throughout the time series. This notion was corroborated by testimony of an industry representative who contributed to the group's discussions. Although the IWG recommended a single time series, the group acknowledged that the assessment model could account for time-varying catchability, if necessary.

Response and explanatory variables

The response variable, catch (≤20 inches) per unit effort (CPUE), is defined as units of fish/angler interviewed and was calculated as the number red snapper discarded divided by the number of anglers interviewed. All explanatory (predictor) variables were modeled as categorical, rather than as continuous.

Years – 2005-2014

Area –Area was defined as North Carolina, South Carolina and Georgia, north Florida (nFL), south Florida, (excluding the keys, flreg=3)

Season – The seasons were defined as winter (January, February, March), spring (April, May, June), summer (July, August, September) and fall (October, November, December).

Party – Four categories for the number of anglers on a vessel were considered in the standardization process.

Hrsf– Four categories for the number of hours fished were considered in the standardization process.

Standardization

CPUE was modeled using the delta-glm approach (Lo *et al*. 1992; Dick 2004; Maunder and Punt 2004). In particular, fits of lognormal and gamma models were compared for positive CPUE. Also, the combination of predictor variables was examined to best explain CPUE patterns (both for positive CPUE and the Bernoulli submodels). All analyses were performed in the R programming language (R Development Core Team 2014), with much of the code adapted from Dick (2004).

Bernoulli submodel. One component of the delta-GLM is a logistic regression model that attempts to explain the probability of either catching or not catching red snapper on a particular trip. First, a model was fit with all main effects to determine which effects should remain in the binomial component of the delta-GLM. Stepwise AIC (Venables and Ripley1997) with a backward selection algorithm was then used to eliminate those that did not improve model fit. In this case, the stepwise AIC procedure did not remove any predictor variables. No concerning patterns were apparent in the quantile residuals (Dunn and Smyth 1996).

Positive CPUE submodel. To determine predictor variables important for describing positive CPUE, the positive portion of the model was fitted with all main effects using both the lognormal and gamma distributions. Stepwise AIC (Venables and Ripley1997) with a backward selection algorithm was then used to eliminate those that did not improve model fit. In this case, no predictor variables were removed for either error distribution.

Both submodels (Bernoulli and either lognormal or gamma) were then combined, and the models were compared using AIC. Based on the selection criterion, the delta-lognormal model with all factors was used. No concerning patterns were apparent in standard diagnostic plots of residuals.

5.4.2.2 Sampling Intensity

The resulting data set contained 1700 trips across all years with approximately 15-30% of those trips having positive catches of red snapper. Annual numbers of trips used to compute the index are shown in Table 5.6.

5.4.2.3 Size/Age Data

The sizes/ages represented in this index should be the same as those of discards (≤20 inches) from the corresponding fleet (See section 4 of the DW report).

5.4.2.4 Catch Rates

Standardized catch rates and associated error bars are shown in Figure 5.5, and tabulated in Table 5.6. The units on catch rates were number of fish (≤20 inches) caught per angler.

5.4.2.5 Uncertainty and Measures of Precision

Measures of precision were computed using a jackknife procedure. Annual CVs of catch rates are tabulated in Table 5.6.

5.4.2.6 Comments on Adequacy for Assessment

The indices of abundance created from the headboat at-sea data were considered by the IWG to be adequate for use in the assessment. Because these data excluded fish greater than 20 inches, the index may provide information on recruitment prior to other indices. Lagged correlations with other indices suggested recruits would enter this index one year prior to indices from other fishery dependent data sources (Table 5.8).

5.4.3 Commercial Handline Index

Landings and fishing effort of commercial vessels operating in the southeast U.S. Atlantic have been monitored by the NMFS Southeast Fisheries Science Center through the Coastal Fisheries Logbook Program (CFLP). The program collects information about each fishing trip from all vessels holding federal permits to fish in waters managed by the Gulf of Mexico and South Atlantic Fishery Management Councils. Initiated in the Gulf in 1990, the CFLP began collecting logbooks from Atlantic commercial fishers in 1992, when 20% of Florida vessels were targeted. Beginning in 1993, sampling in Florida was increased to require reports from all vessels permitted in coastal fisheries, and since then has maintained the objective of a complete census of federally permitted vessels in the southeast U.S.

Catch per unit effort (CPUE) from the logbooks was used to develop an index of abundance for red snapper landed with vertical lines (manual handline and electric reel), the dominant gear for this red snapper stock. The time series used for construction of the index spanned 1993–2009, when all vessels with federal snapper-grouper permits were required to submit logbooks on each fishing trip. The January 2010 closure of the red snapper fishery prevented extending the series. The 2012-2014 red snapper mini-seasons had targeting issues as well as a 75 pound trip limit which confounds the catch rate from those trips.

5.4.3.1 Methods of Estimation

Data Treatment

For each fishing trip, the CFLP database included a unique trip identifier, the landing date, fishing gear deployed, areas fished, number of days at sea, number of crew, gear-specific fishing effort, species caught, and weight of the landings. Fishing effort data available for vertical line gear included number of lines fished, hours fished, and number of hooks per line. For this southeast U.S. Atlantic stock, areas used in analysis were those between 24 and 37 degrees latitude, inclusive of the boundaries (Figure 5.6).

Data were restricted to include only those trips with landings and effort data reported within 45 days of the completion of the trip. Reporting delays beyond 45 days likely resulted in less reliable effort data (landings data may be reliable even with lengthy reporting delays if trip ticket reports were referenced by the reporting fisher). Also excluded were records reporting multiple gears fished, which prevents designating catch and effort to specific gears. Therefore, only those trips that reported one gear fished were included in the analyses. Where trips reported multiple areas, the first area reported was used in the analysis. Only the latitude from the area designated was used in the analysis assuming most trips with multiple areas fished were moving across the shelf rather than north and south.

Clear outliers (>99.5 percentile) in the data were also excluded from the analyses. These outliers were identified for all snapper/grouper trip manual handlines as records reporting more than 6 lines fished, 8 hooks per line fished, 10 days at sea, 5 crew members or 105 hours fished; outliers were identified for electric reels as records reporting more than 6 lines fished, 10 hooks per line fished, 12 days at sea, 5 crew members or 143 hours fished. Trips reporting fewer than 4 hours fished for both gears were removed. Positive red snapper trips reporting greater than 24 pounds/hook-hr were excluded for both gears.

To determine which trips should be used to compute the index, the method of Stephens and MacCall (2004) was applied. The Stephens and MacCall method uses multiple logistic regression to estimate a probability for each trip that the focal species was caught, given other species caught on that trip. Species compositions differ across the south Atlantic; thus, the method was applied separately for areas north and south of Cape Canaveral, which has been identified as a zoogeographical boundary (Shertzer et al. 2009). Cape Canaveral falls in the middle of the one degree commercial sampling grid and was assigned to the south with the split at 29 degrees. To avoid rare species, the number of species in each analysis was limited to those species that occurred in 1% or more of trips. The most general model therefore included all species in the snapper-grouper complex which occurred in 1% or more of trips as main effects, excluding red porgy. Red porgy was removed because of regulations (closure followed by strict bag limits), which could erroneously remove trips likely to have caught red snapper in recent years. A backward stepwise AIC procedure (Venables and Ripley 1997) was then used to perform further selection among possible species as predictor variables. In this procedure, a generalized linear model with Bernoulli response was used to relate presence/absence of red snapper in commercial trips to presence/absence of other species. An alternative generalized linear model with Bernoulli response related the catch in pounds of other species to the presence/absence of red snapper. Although the alternative method theoretically may be more efficient at identifying species associations, the IWG rejected the method due to concerns that the increase in trip limits in recent years may bias the results.

Model Description

Response and explanatory variables

The response variable, CPUE, was calculated for each trip as,

CPUE = pounds of red snapper/hook-hour

where hook-hours is the product of number of lines fished, number of hooks per line, and total hours fished. Explanatory variables, all categorical, are described below.

The explanatory variables were year, season, latitude, crew size, and days at sea, each described below:

Years – Year was necessarily included, as standardized catch rates by year are the desired outcome. Years modeled were 1993–2009.

Season – The seasons were defined as winter (January, February, March), spring (April, May, June), summer (July, August, September) and fall (October, November, December).

Lat – Location is reported as latitude and longitude in one degree increments centered at the middle (e.g., CFLP lat=28 is centered at 28.5 degrees). The few trips with latitude reported north of 34 degrees and south of 24 degrees were pooled into the 34 and 24 degree bins, respectively (Figure 5.6).

Crew size – Crew size (crew) was pooled into three levels: one, two, and three or more.

Days at sea – Days at sea (sea days) was pooled into three levels: one or two days, three or four days, and five or more days.

Standardization

CPUE was modeled using the delta-glm approach (Lo et al. 1992; Dick 2004; Maunder and Punt 2004). In particular, fits of lognormal and gamma models were compared for positive CPUE. Also, the combination of predictor variables was examined to best explain CPUE patterns (both for positive CPUE and the Bernoulli submodels). All analyses were performed in the R programming language (R Development Core Team 2014), with much of the code adapted from Dick (2004).

Bernoulli submodel. One component of the delta-GLM is a logistic regression model that attempts to explain the probability of either catching or not catching red snapper on a particular trip. First, a model was fit with all main effects to determine which effects should remain in the binomial component of the delta-GLM. Stepwise AIC (Venables and Ripley1997) with a backward selection algorithm was then used to eliminate those that did not improve model fit. In this case, the stepwise AIC procedure did not remove any predictor variables. No concerning patterns were apparent in the quantile residuals (Dunn and Smyth 1996).

Positive CPUE submodel. To determine predictor variables important for describing positive CPUE, the positive portion of the model was fitted with all main effects using both the lognormal and gamma distributions. Stepwise AIC (Venables and Ripley1997) with a backward selection algorithm was then used to eliminate those that did not improve model fit. In this application, the lognormal distribution outperformed the gamma distribution, and was therefore used to compute the index.

Both submodels (Bernoulli and lognormal) were then combined into a single delta-lognormal model (1993-2009), with all predictor variables used for both submodels. No concerning patterns were apparent in standard diagnostic plots of residuals.

5.4.3.2 Sampling Intensity
Annual numbers of trips used to compute the index is typically greater than 1000, as shown in Table 5.7.

5.4.3.3 Size/Age Data
The sizes/ages represented in this index should be the same as those of landings from the corresponding fleet (See section 3 of the DW report).

5.4.3.4 Catch Rates
Standardized catch rates and associated error bars are shown in Figure 5.7 and are tabulated in Table 5.7. The units on catch rates were pounds of fish landed per hook-hour.

5.4.3.5 Uncertainty and Measures of Precision
Estimates of variance were based on 1000 bootstrap runs where trips were chosen randomly with replacement (Efron and Tibshirani 1994). Annual CVs of catch rates are tabulated in Table 5.7.

5.4.3.6 Comments on Adequacy for Assessment

The index of abundance created from the commercial logbook data was considered by the IWG to be adequate for use in the assessment. The data cover a wide geographic range relative to that of the stock, and logbooks represent a census of the fleet. The data set has an adequately large sample size and has a long enough time series to provide potentially meaningful information for the assessment.

Several concerns were discussed by the IWG, all related to this index coming from fishery dependent data. First, commercial fishermen may target different species through time. If changes in targeting have occurred, effective effort can be difficult to estimate. However, the DW recognized that the method of Stephens and MacCall (2004), used here to identify trips for the analysis, can accommodate changes in targeting, as long as species assemblages are consistent. Second, the data are self-reported and largely unverified. Some attempts at verification have found the data to be reliable. Third and probably foremost, the data are obtained from a directed fishery and therefore the index could contain problems associated with any fishery dependent index. Fishing efficiency of the fleet has likely improved over time due to improved electronics. In addition, overall efficiency may have changed throughout the time series if fishermen of marginal skill have left the fishery at a greater rate than more successful fishermen. Also of concern is whether catch rates in a directed fishery are density-dependent. As fish abundance decreases, fishermen may maintain relatively high catch rates, and as fish abundance increases, catch rates may saturate.

5.4.4 Other Fishery Dependent Data Sources Considered During the DW

Several data sources were discussed during the pre-DW webinar for the potential to support indices of abundance, and some of these were discarded based on initial summaries of data. Two data sources were recommended during the webinar for further consideration, but were subsequently not recommended by the DW for use in the assessment: SCDNR charterboat logbooks and the MRFSS/MRIP data (Table 5.1). Reasons for their exclusion are provided in Table 5.2.

5.5 Consensus Recommendations and Survey Evaluations

The DW recommended two fishery independent (chevron traps and videos) and three fishery dependent indices (headboat logbooks, headboat at-sea observer data, commercial handline logbooks) for potential use in the red snapper stock assessment. Pearson correlations and significance values (p-values) between indices are presented in Table 5.8. All recommended indices and their CVs are in Table 5.9, and the indices are compared graphically in Figure 5.8.

The IWG discussed relative ranking of the ability of each index to represent true population abundance. Based on these discussions, the indices recommended for the assessment were ranked as follows, with pros and cons of each listed in Table 5.2.

1. Chevron traps
2. Video
3. Headboat index
4. Headboat at-sea observer index
5. Commercial handline index

Note that these rankings were made during the DW and are based solely on *a priori* information about each index. Therefore, the rankings should be considered preliminary, as they do not benefit from viewing indices for consistency with other data sets (e.g., age comp data). The assessment panel, with all data in hand, will be in a better position to judge the indices for use in the assessment.

5.6 Literature Cited

Dick, E.J. 2004. Beyond 'lognormal versus gamma': discrimination among error distributions for generalized linear models. Fish. Res. 70:351–366.

Dunn, K. P. and G.K. Smyth. 1996. Randomized quantile residuals. J. Comp. Graph. Stat. 5:1–10.

Efron, B. and R. J. Tibshirani. 1994. Modern An Introduction to the bootstrap. Chapnam & Hall/CRC, Boca Raton, FL.

Jackman S. 2008. *pscl*: Classes and Methods for R Developed in the Political Science Computational Laboratory, Stanford University. Department of Political Science, Stanford University. Stanford, California. R package version 1.04.1. https://pscl.stanford.edu/.

Langlois, T.J., Newman, S.J., Cappo, M., Harvey, E.S., Rome, B.M., Skepper, C.L., Wakefield, C.B. 2015. Length selectivity of commercial fish traps assessed from in situ comparisons with stereo-video: Is there evidence of sampling bias?. Fish. Res. 161:145–155.

Lo, N.C., Jacobson, L.D., Squire, J.L. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49:2515–2526.

Maunder, M.N., Punt, A.E. 2004. Standardizing catch and effort data: a review of recent approaches. Fish. Res. 70:141–159.

Shertzer, K.W., E.H. Williams, and J.C. Taylor. 2009. Spatial structure and temporal patterns in a large marine ecosystem: Exploited reef fishes of the southeast United States. Fish. Res. 100:126–133.

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

Venables, W.N. and B.D. Ripley. 1997. Modern Applied Statistics with S-Plus, 2nd Edition. Springer-Verlag, New York.

R Development Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org

Zeileis A., C. Kleiber, and S. Jackman. 2008. Regression modesl for count data in R. Journal of Statistical Software 27(8). http://www.jstatsoft.org/v27/i08/.

Zuur, A.F., E.N. Ieno, N.J. Walker, A.A. Saveliev, and G.M. Smith. 2009. Mixed Effects Models and Extensions in Ecology with R. Springer, New York.

5.7 Tables

Table 5.1. Table of the data sources considered for indices of abundance.

Fishery Type	Data Source	Area	Yrs	Units	Standardization Method	Issues	Use?
Recreational	Headboat	NC-FL	1976-2009	N kept/ angler	Delta-GLM	Fishery dependent, self reported	Yes
Recreational	MRFSS/ MRIP	NC-FL	1995-2013	N caught/ angler-hr	Nominal	Fishery dependent. Potential bias in intercepts. Not standardized	No
Recreational	Headboat-at-sea-observer	NC-FL	2005-2014	N caught ≤20"/ angler	Delta-GLM	Fishery dependent.	Yes
Recreational	SCDNR charterboat logbook	SC	1993-2013	N caught/ angler-hr	Delta-GLM	Limited geographic coverage; outside core red snapper habitat	No
Commercial	Commercial logbook handline	NC-FL	1993-2009	lb kept/ hook-hour	Delta-GLM	Fishery dependent, self reported	Yes
Commercial	Commercial logbook diving	NC-FL	1993-2009	lb kept/ hook-hour		Fishery dependent, self reported; small sample sizes, almost all from FL	No
Independent	SERFS: chevron trap	NC-FL	1990-2014	N caught	Zero inflated negative binomial	Expanded spatial coverage through time	Yes
Independent	SERFS: video survey	NC-FL	2010-2014	N observed	Zero inflated negative binomial	Ages/sizes unknown	Yes
Independent	SEAMAP trawl survey	SC				Few samples (~1 fish/yr)	No

Independent	MARMAP: blackfish trap	Mostly SC	1981-1987			Few samples	No
Independent	MARMAP: Florida trap	Mostly SC	1981-1987			Few samples	No
Independent	MARMAP: Short-bottom longline					Few samples	No
Independent	MARMAP: Kali pole					Few samples	No

Table 5.2. Table of the pros and cons for each data set considered at the data workshop. Note that several data sources were considered (Table 5.1), but discarded, prior to the DW.

<u>Fishery independent indices</u>

SERFS Chevron Trap Index (*Recommended for use*)
Pros:

- Fishery independent random hard bottom survey
- Adequate regional coverage
- Standardized sampling techniques
- All fish caught are aged and measured

Cons:

- Short time series

SERFS Video Index (*Recommended for use*)
Pros:

- Fishery independent random hard bottom survey
- Adequate regional coverage
- Standardized sampling techniques
- Relatively high detection probabilities
- Likely to be less selective than capture gears

Cons:

- Short time series, with sampling differences in the first year
- Ages/sizes observed are unknown

<u>Fishery dependent indices</u>

Recreational Headboat (*Recommended for use*)
Pros:

- Complete census
- Covers the entire management area
- Some data are verified by port samplers and observers
- Large sample size
- Strongly correlated with headboat at-sea-observer index
- Generally non-targeted for focal species, which should minimize changes in catchability relative to fishery dependent indices that target specific species

Cons:

- Fishery dependent (i.e., potentially affected by regulations, targeting, hyperdepletion, hyperstability)
- Little information on discard rates, particularly before mid-2000s
- Catchability may vary over time or with abundance

- Effective effort is difficult to identify

General recreational (MRFSS) (*Not recommended for use*)
Pros:

- Intercept data by port samplers
- Spans the management area
- Includes estimates of discards

Cons:

- Nominal index only, not standardized
- Fishery dependent (i.e., potentially affected by regulations, targeting, hyperdepletion, hyperstability)
- Catchability may vary over time or with abundance
- Potential bias in trips intercepted
- High variability
- Effective effort is difficult to identify

Commercial Logbook – Handline (*Recommended for use*)
Pros:

- Complete census
- Covers the entire management area
- Large sample size

Cons:

- Fishery dependent (i.e., potentially affected by regulations, targeting, hyperdepletion, hyperstability)
- Data are self-reported and largely unverified
- Catchability may vary over time or with abundance
- Landings could be cross-referenced with other data sources, but effective effort difficult to identify
- No information on discard rates
- Potential shifts in species targeted; commercial fishermen more skillful than general recreational fishermen at targeting focal species

Headboat at-sea observer index (*Recommended for use*)
Pros:

- Observer program
- Good discard data (provides amount of discards and length frequency)
- Random sampling design
- Broad spatial coverage

Cons:
- Fishery dependent (i.e., potentially affected by regulations, targeting, hyperdepletion, hyperstability)
- Relatively short time series
- Information overlaps with headboat index, but this was mitigated by using fish <20inches
- Coverage of fleet is ~2%, but varies across states

SCDNR Charterboat *(Not recommended for use)*
Pros:
- Census

Cons:
- Fishery dependent (i.e., potentially affected by regulations, targeting, hyperdepletion, hyperstability)
- South Carolina only, limited geographic coverage relative to south Atlantic
- Outside core habitat of red snapper
- No field validation

Table 5.3 The number of trapping events (N), standardized index, and CV for the red snapper index computed from SERFS chevron traps.

Year	N	Standardized index	CV
2010	695	0.66	0.18
2011	674	0.69	0.16
2012	1114	1.14	0.11
2013	1331	0.91	0.12
2014	1429	1.61	0.11

Table 5.4 The nominal index (*SumCount*), number of trapping events (N), proportion positive, standardized index, and CV for the red snapper index computed from the SERFS video survey.

Year	Relative nominal *SumCount*	N	Proportion positive	Standardized index	CV
2010	2.61	166	0.355	1.21	0.22
2011	0.43	575	0.233	0.59	0.17
2012	0.57	1075	0.241	1.06	0.14
2013	0.64	1219	0.267	0.80	0.12
2014	0.75	1374	0.218	1.35	0.14

Table 5.5 The number of trips (N), nominal CPUE, relative nominal CPUE, standardized index, and CV for red snapper from headboat logbook data, 1976-2009.

Year	N	Nominal CPUE	Relative nominal	Standardized CPUE	CV
1976	876	0.55	2.62	2.37	0.05
1977	900	0.47	2.21	2.16	0.08
1978	1576	0.48	2.26	2.13	0.03
1979	1293	0.46	2.20	2.23	0.05
1980	1409	0.31	1.45	1.45	0.05
1981	1092	0.51	2.40	2.95	0.04
1982	1347	0.20	0.97	1.20	0.05
1983	1579	0.31	1.47	1.64	0.05
1984	1477	0.34	1.60	1.42	0.03
1985	1741	0.35	1.67	2.07	0.05
1986	2185	0.11	0.54	0.48	0.07
1987	2199	0.14	0.65	0.58	0.05
1988	2061	0.16	0.73	0.56	0.06
1989	1438	0.20	0.94	0.90	0.05
1990	1468	0.16	0.78	0.87	0.06
1991	1463	0.14	0.65	0.69	0.04
1992	2156	0.03	0.15	0.08	0.10
1993	1981	0.06	0.27	0.16	0.08
1994	1633	0.09	0.42	0.26	0.05
1995	1523	0.08	0.36	0.28	0.06
1996	1130	0.07	0.31	0.25	0.06
1997	790	0.06	0.30	0.27	0.09
1998	1647	0.06	0.30	0.24	0.08
1999	1706	0.08	0.37	0.29	0.05
2000	1442	0.10	0.49	0.41	0.05
2001	1553	0.17	0.81	0.76	0.07
2002	1466	0.23	1.08	0.88	0.05
2003	1150	0.12	0.59	0.52	0.05
2004	1606	0.16	0.77	0.76	0.04
2005	1290	0.14	0.69	0.76	0.04
2006	1406	0.11	0.53	0.43	0.05
2007	1505	0.11	0.52	0.44	0.08
2008	1551	0.32	1.52	1.71	0.05
2009	1917	0.30	1.40	1.81	0.03

Table 5.6. The number of trips(N), nominal CPUE, relative nominal CPUE, standardized index, and CV for red snapper (≤20" TL) from the headboat at-sea observer data, 2005-2014.

Year	N	Nominal CPUE	Relative nominal	Standardized CPUE	CV
2005	204	0.10	0.50	0.33	0.34
2006	178	0.18	0.91	0.40	0.40
2007	200	0.37	1.89	2.49	0.19
2008	172	0.50	2.59	1.99	0.29
2009	164	0.17	0.86	0.95	0.26
2010	160	0.06	0.31	0.44	0.29
2011	151	0.11	0.56	0.46	0.34
2012	165	0.17	0.85	1.17	0.25
2013	154	0.13	0.68	0.95	0.27
2014	168	0.17	0.85	0.82	0.28

Table 5.7. The number of trips (N), proportion positive, relative nominal CPUE, standardized index, and CV for red snapper from commercial logbook data (handlines).

Year	N	Proportion Positive	Relative nominal	Standardized CPUE	CV
1993	772	0.72	0.571	1.086	0.063
1994	1210	0.70	0.521	0.891	0.051
1995	1400	0.66	0.716	0.891	0.046
1996	1101	0.57	0.525	0.612	0.055
1997	1390	0.53	0.662	0.589	0.054
1998	1222	0.53	0.694	0.659	0.055
1999	1068	0.56	0.507	0.798	0.060
2000	1067	0.55	0.746	0.737	0.056
2001	1282	0.70	0.940	1.274	0.049
2002	1386	0.73	0.903	1.383	0.046
2003	1117	0.66	0.699	1.042	0.053
2004	1030	0.65	0.840	1.423	0.054
2005	1067	0.61	0.786	1.188	0.058
2006	893	0.49	0.440	0.597	0.071
2007	1108	0.48	0.599	0.665	0.064
2008	955	0.56	1.933	1.223	0.066
2009	911	0.63	4.918	1.942	0.073

Table 5.8. Pearson correlation values for indices recommended for use. P-values (in parentheses) represent the probability of obtaining the Pearson value under the null hypothesis of correlation=0. The HB at-sea index was lagged by one year when compared with other fishery dependent indices, because it only included fish ≤20 inches and would therefore track recruits prior to the other indices. CVT=chevron traps, HB=headboats, and Comm=commercial handline.

	Headboat	HB at-sea	CVT	Video	Comm
Headboat	1.000				
HB at-sea	0.971 (0.006)	1.000			
CVT	-	0.569 (0.316)	1.000		
Video	-	0.166 (0.790)	0.613 (0.272)	1.000	
Comm	0.788 (0.000)	0.780 (0.120)	-	-	1.000

Table 5.9. Red snapper standardized indices of abundance and annual CVs recommended for potential use in the stock assessment. CVT=chevron traps, HB=headboats, and Comm=commercial handline. Each index is scaled to its mean.

	Standardized indices					CVs				
Year	HB	HB at-sea	CVT	Video	Comm	HB	HB at-sea	CVT	Video	Comm
1976	2.37					0.05				
1977	2.16					0.08				
1978	2.13					0.03				
1979	2.23					0.05				
1980	1.45					0.05				
1981	2.95					0.04				
1982	1.20					0.05				
1983	1.64					0.05				
1984	1.42					0.03				
1985	2.07					0.05				
1986	0.48					0.07				
1987	0.58					0.05				
1988	0.56					0.06				
1989	0.90					0.05				
1990	0.87					0.06				
1991	0.69					0.04				
1992	0.08					0.10				
1993	0.16				1.09	0.08				0.06
1994	0.26				0.89	0.05				0.05
1995	0.28				0.89	0.06				0.05
1996	0.25				0.61	0.06				0.06
1997	0.27				0.59	0.09				0.05
1998	0.24				0.66	0.08				0.06
1999	0.29				0.80	0.05				0.06
2000	0.41				0.74	0.05				0.06
2001	0.76				1.27	0.07				0.05
2002	0.88				1.38	0.05				0.05
2003	0.52				1.04	0.05				0.05
2004	0.76				1.42	0.04				0.05
2005	0.76	0.33			1.19	0.04	0.34			0.06
2006	0.43	0.40			0.60	0.05	0.40			0.07
2007	0.44	2.49			0.67	0.08	0.19			0.06
2008	1.71	1.99			1.22	0.05	0.29			0.07
2009	1.81	0.95			1.94	0.03	0.26			0.07
2010		0.44	0.66	1.21			0.29	0.18	0.22	
2011		0.46	0.69	0.59			0.34	0.16	0.17	
2012		1.16	1.14	1.06			0.25	0.11	0.14	
2013		0.96	0.91	0.80			0.27	0.12	0.12	
2014		0.82	1.61	1.35			0.28	0.11	0.14	

5.8 Figures

Figure 5.1. The nominal (red dots) and standardized index (solid black line) for red snapper computed from SERFS chevron traps. Gray shaded area represents 95% confidence interval as estimated from 10,000 bootstraps. (Top panel): the index recommended for use in the assessment. (Bottom panel): longer index developed for consideration as a sensitivity run.

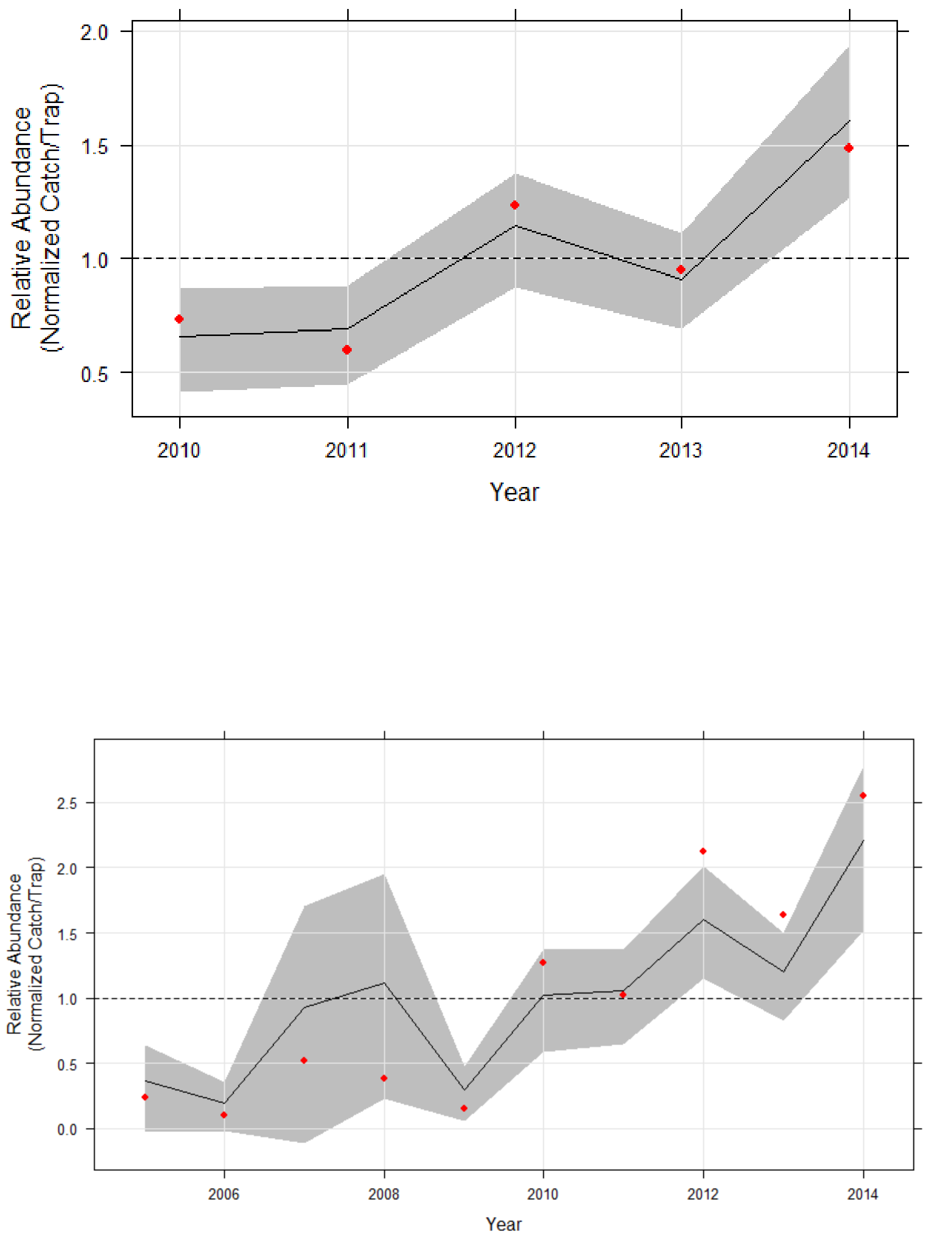


Figure 5.2. The nominal and standardized index for red snapper computed from the SERFS video survey.

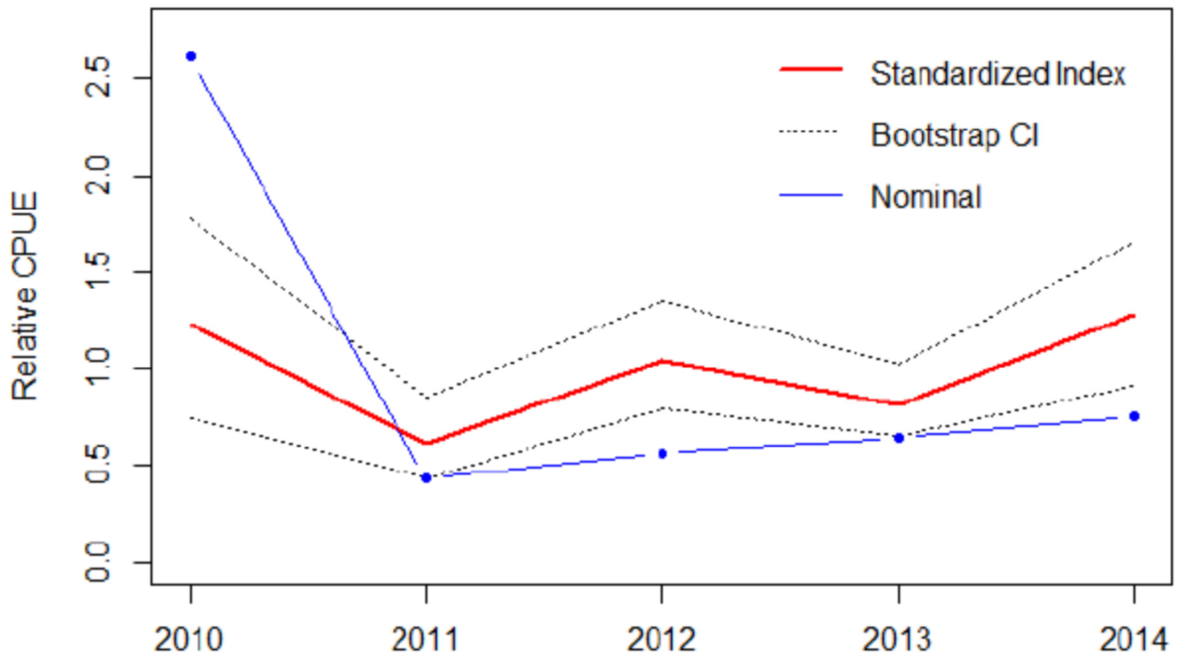


Figure 5.3. Map of headboat sampling area definitions. For analysis, areas were pooled as described in the text.

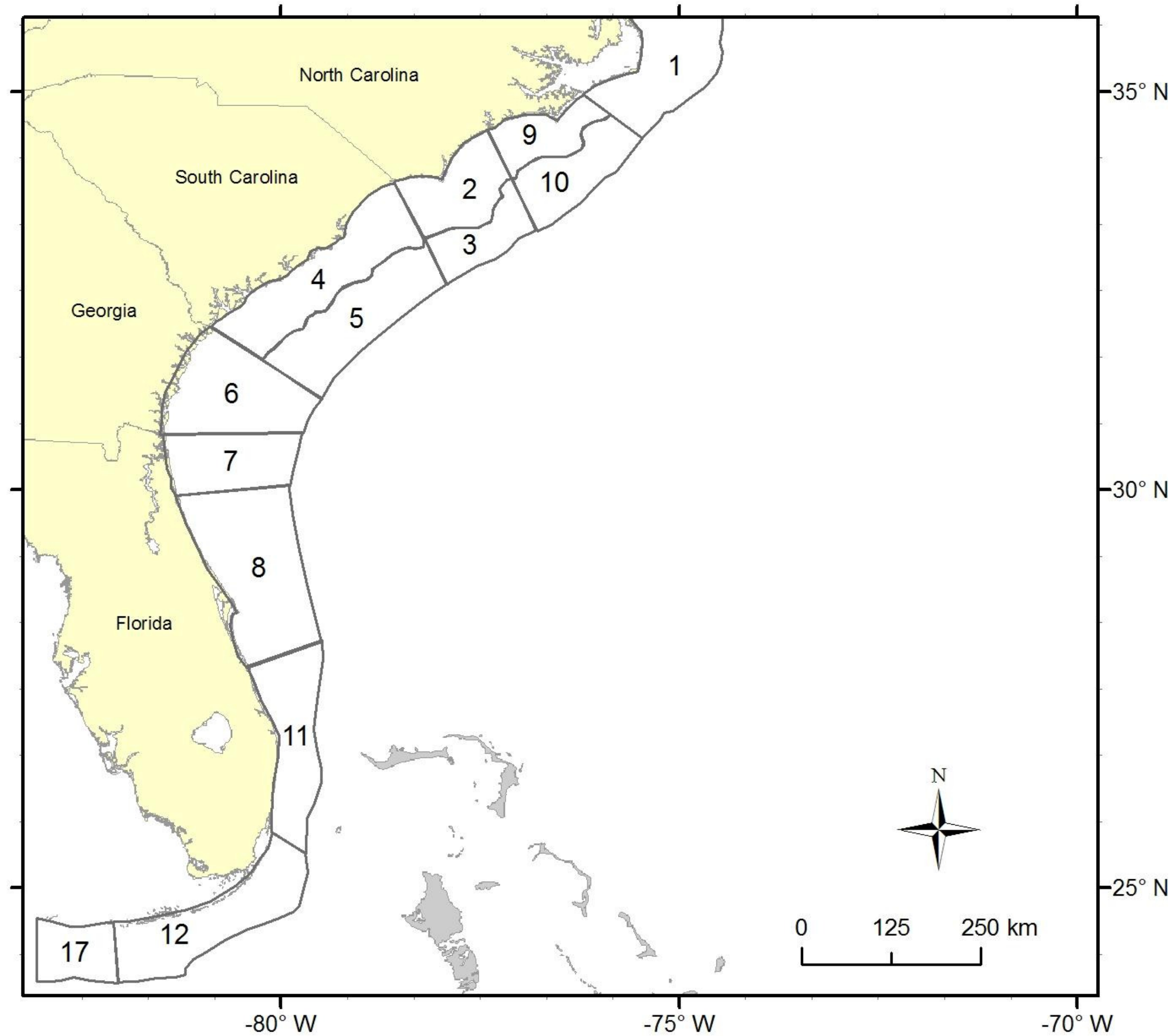


Figure 5.4. The nominal and standardized index for red snapper computed from headboat data, 1976-2009. Error bars represent approximate 95% confidence intervals.

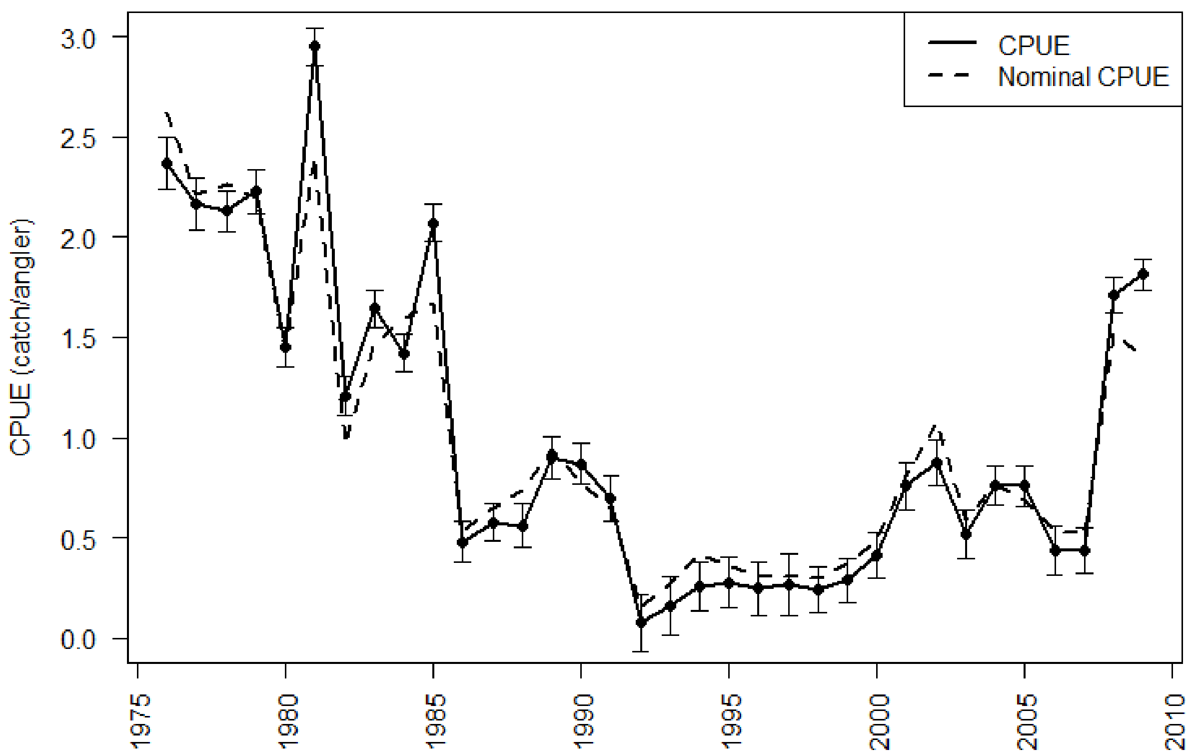


Figure 5.5. The standardized and nominal index with error bars at (+/-) 2 standard deviations computed for red snapper (≤20” TL) using the headboat at-sea observer data, 2005-2014.

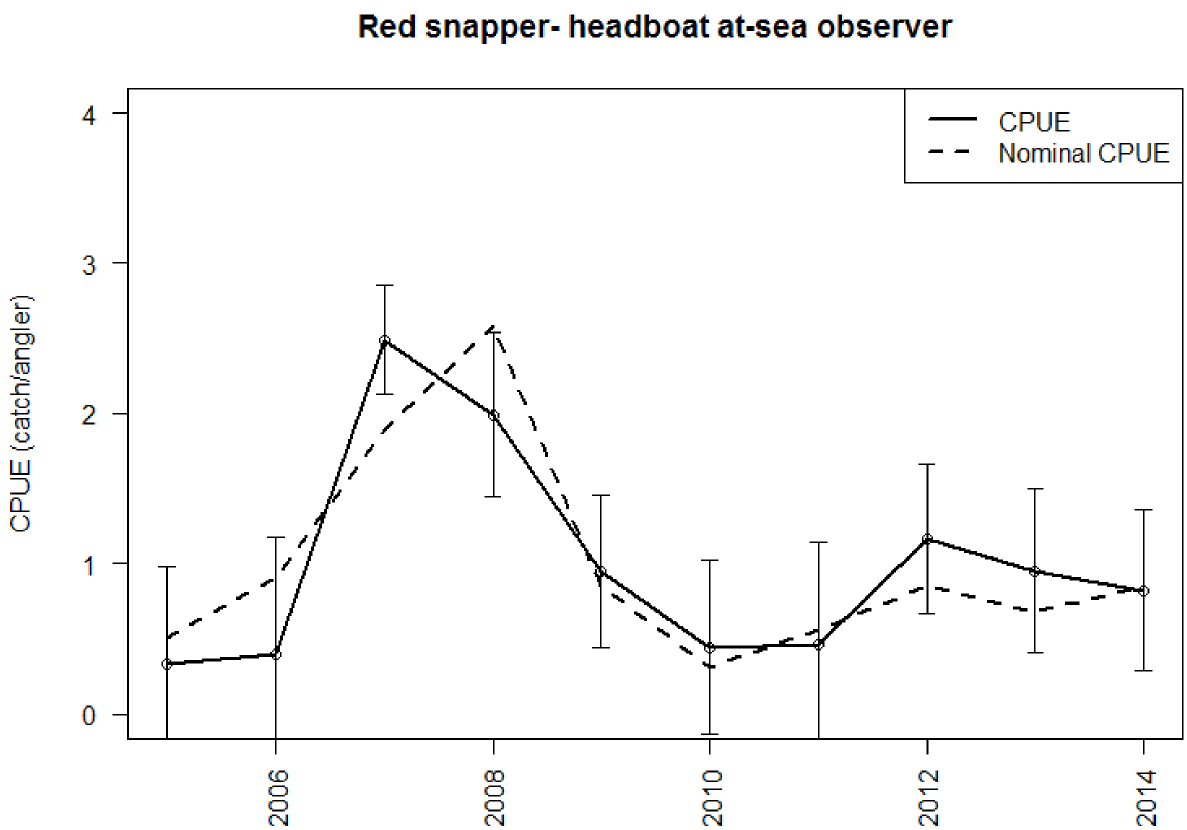


Figure 5.6. Latitude reported in the Coastal Fisheries Logbook Program (CFLP, commercial logbooks). Area is recorded in degrees where the first two digits signify degrees latitude, second two degrees longitude. Only latitude was used in this analysis.

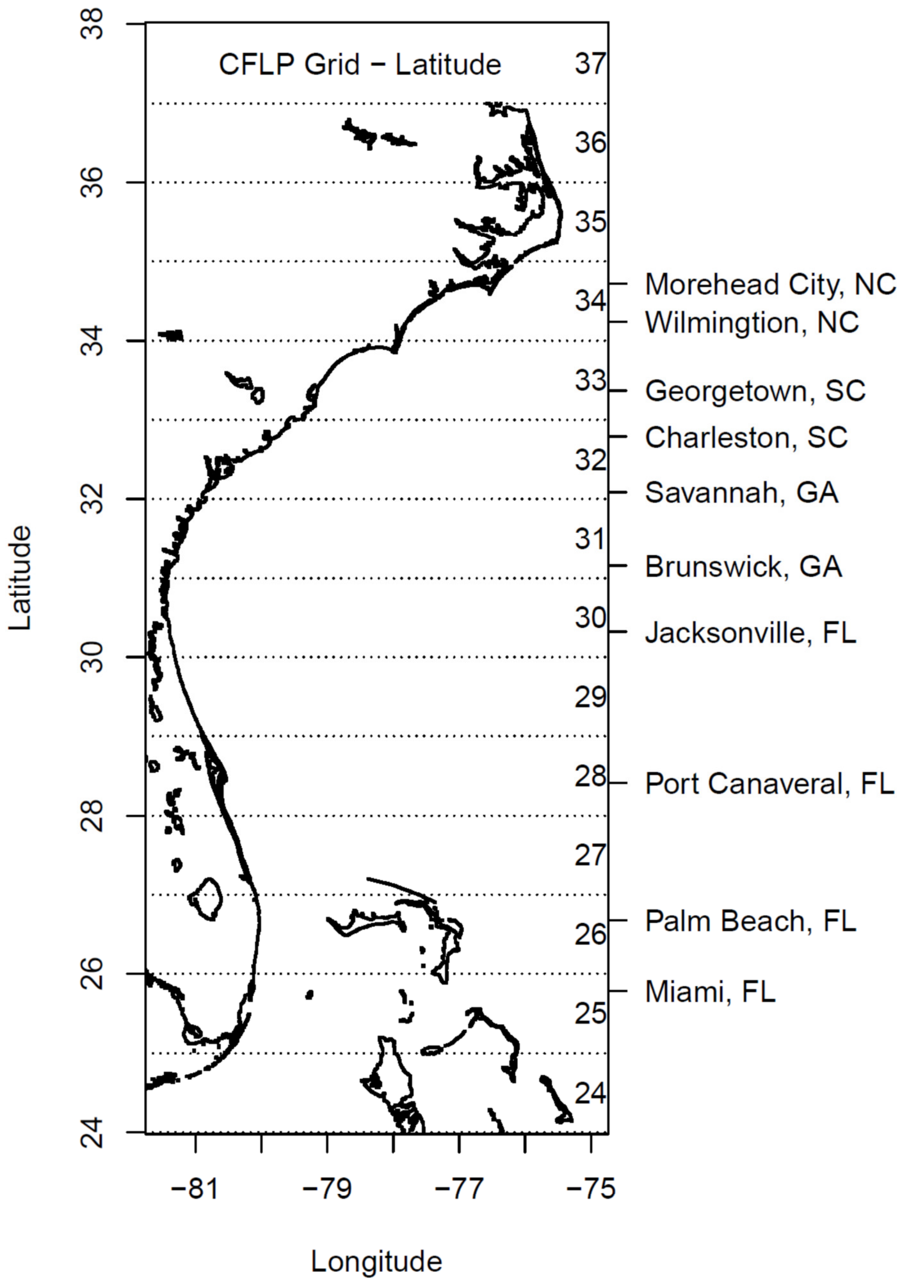


Figure 5.7. The nominal and standardized index for red snapper computed from commercial logbook handline data, 1993–2009. Error bars represent approximate 95% confidence intervals. The nominal (Nominal CPUE), Standardized Stephens and MacCall approach approved for use in SEDAR 41 (SandM.CPUE), and positive-only (SEDAR 41 Pos CPUE) runs are shown.

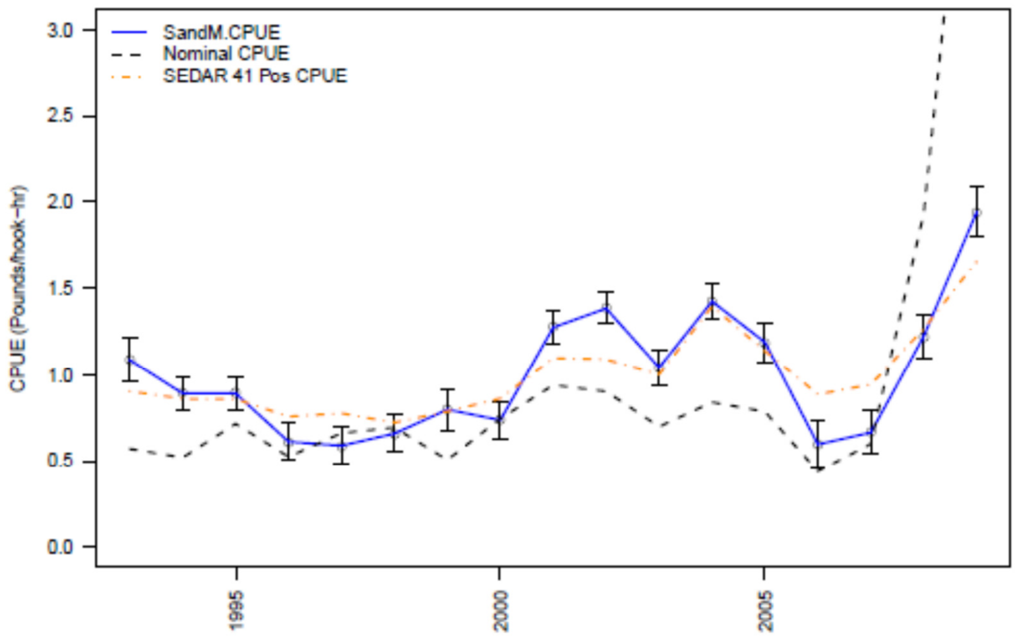
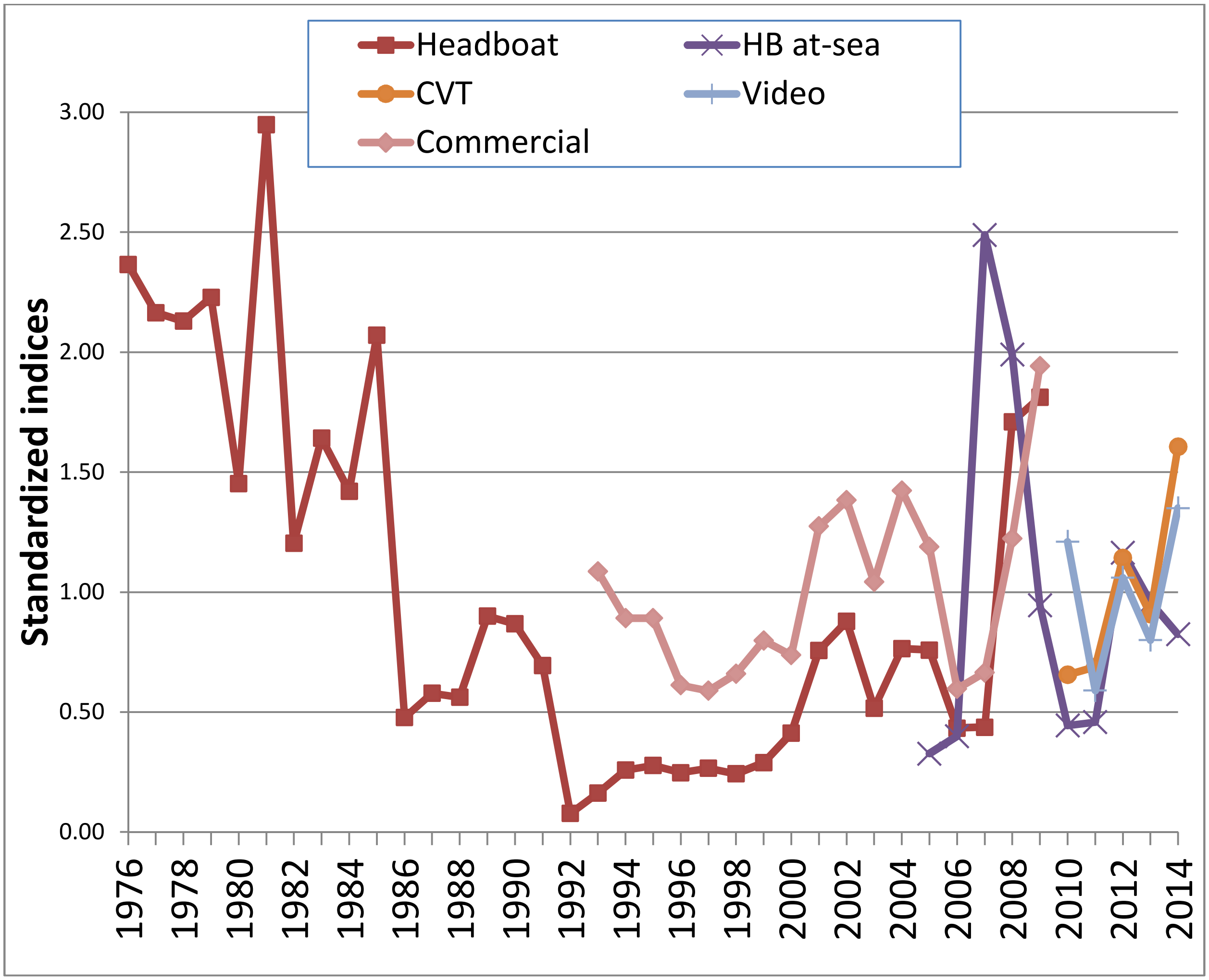


Figure 5.8. All indices (scaled to their respective means) recommended for potential use in the red snapper stock assessment. CVT=Chevron traps, and HB=Headboat.



6. Analytical Approach

Based on the reports received from the data workshops and the webinars held to date (8/20/2015), the data are sufficient to attempt to fit the BAM model with the ASPIC as a simpler complementary model. The data provided will include catches, discards, indices, length and age compositions, and life history information. This is consistent with the modeling approach and data available for SEDAR 24.

7. Research Recommendations

7.1 Life History

Red Snapper Mini Season

If this program, along with continued closure of the fishery, is to extend into future seasons, an exploration of methods to further incentivize angler participation would be useful. After brief interviews with participants from the recreational fishers group at SEDAR 41, the following suggestions were provided to increase angler participation:

- Free fish cleaning at donation site.
- As people may be tired after being out on the water all day and with busy boat ramps, short questionnaire from a biologist on-site could be used instead of the anglers filling the forms out or requiring fishermen to fill out a survey online after they return home.
- Advertise data collection at local bait & tackle shops.
- Use NOAA's announcement system on weather radio channel where they also announce season closures, etc. Since fishermen are frequently monitoring this channel for weather updates, it could be an effective communication route to announce the collection information (drop locations, reward information, etc.).
- Dry storage areas are a good place to sample; many people store boats there instead of trailering home.

Life History Research

- More research on red snapper movements and migrations in Atlantic waters is needed. Available data and the results of studies in the Gulf of Mexico indicate high site fidelity, but that tropical storms may cause greater than normal movement that might help dispersal to depleted areas. This needs to be confirmed in the South Atlantic. Additional acoustic and traditional tagging is needed on known spawning locations to document spawning migrations or aggregations, and return of fish to non-spawning areas.
- Evaluate more thoroughly the data/sample collection during the mini-season to improve utility for assessments. This should include what samples should be collected (e.g. reproductive information).

- Possible changes in life history parameters, in particular relative to reproduction, need to be further investigated.
- Much is unknown about the early life history of Red Snapper, in particular relative to spawning areas, larval and juvenile stages, including habitat and dispersal.
- Alternative methods of reproductive output. The methods described in Klibansky's SEDAR41-DW49 may provide a more accurate estimate of reproductive output than previously used. Further investigation into this modeling effort and use for future assessments should be investigated.
- Duration of spawning indicators. The definition of spawning indicators has received significant discussion recently. As this has significant implications for the estimates of reproductive output, further research is needed to define consistent criteria for spawning indicators in finfish.
- Continuing the age reading comparisons and calibrations between labs on a reference collection of known age fish would be beneficial for determining a more accurate aging error matrix and would provide accuracy to the age composition data.

7.2 Commercial

Landings

- Improve gear and effort data for each trip.
- Standardize methodology for developing average proportions to parse out unclassified landings.

Discards

- Investigate the validity and magnitude of "no discard" trips. This may include fisher interviews throughout the region.
- Examine potential impacts of "no discard" trips on estimated discards.
- Improve discard logbook data collections via program expansion or more detailed reporting (i.e. electronic logbooks, etc.)
- Establish an observer program that is representative of the fisheries in the South Atlantic

Biosampling

- Establish an observer program that is representative of the fisheries in the South Atlantic.
- Angler education with regards to recording depths on paper logbooks (i.e. standardized units); validation of additions to the logbook form still needed.
- Standardize TIP sampling protocol to get representative samples at the species level.
- Standardize TIP data extraction.

7.3 Recreational

- Complete analysis of available historic photos for trends in CPUE and mean size of landed Red Snapper and Gray Triggerfish for pre-1981 time period. (Ultimately all species).
- Formally archive data and photos for all other SEDAR target species.
- For Hire Survey (FHS) should collect additional variables (e.g. depth fished).
- Increasing sample sizes for at-sea headboat observers (i.e. number of trips sampled).
- Compute variance estimate for headboat landings.
- Mandatory logbooks for all federally permitted for-hire vessels.

7.4 Indices

- Compare existing methods and/or develop new methods to define effective effort in fishery dependent data.
- Estimate selectivity of video gear in the SERFS.
    - Tagging, stereo cameras
- For video reading, evaluate methods to score water clarity and habitat.
- Evaluate effect of (non) independence between chevron traps and videos, including methods to combine the indices.
- Continue exploring the use of continuous predictor variables (e.g., splines or polynomials) for ZIP and ZINB standardization models.
- Headboat at-sea observer program needs depth data from all states (not just FL) and increased coverage overall.
- SCDNR charterboat logbook program should be replicated by other states.
- Develop fishery independent hook-gear index (S41-DW08).

SEDAR

Southeast Data, Assessment, and Review

SEDAR 41

South Atlantic Red Snapper

SECTION III: Assessment Workshop Report

February 2016

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NOTE: Modifications to the model results reported in this report were made during the Review Workshop held March 15-18, 2016. For complete results reflecting those changes, please see Addenda 1 of the Stock Assessment Report (Section VI). In April 2017, the SEFSC discovered an error in the assessment and provided an updated Assessment Workshop Report. The corrected report can be found in Addenda 2 of the Stock Assessment Report (Section VII).

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1. Introduction

1.1 Workshop Time and Place

The SEDAR 41 Assessment Process was conducted through a combination of an in-person workshop and series of webinars held from October 2015 to February 2016. The in-person workshop was held December 14-17, 2015 in Morehead City, NC. The workshop was originally scheduled for November 2015, but was delayed approximately one month to ensure a preliminary base run would be available at the beginning of the workshop. Six assessment webinars were held, three pre-workshop and three post-workshop, on the following dates: November 2, November 17 and December 1, 2015 and January 11, January 27, and February 17, 2016.

1.2 Terms of Reference

1. Review any changes in data following the Data Workshop and any analyses suggested by the Data Workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.

2. Develop population assessment models that are compatible and appropriate with available data. Document input data, model assumptions and configuration, and equations for each model considered.

3. Provide estimates of stock population parameters, including:
   - Fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, and other parameters as necessary to describe the population.
   - Appropriate measures of precision for parameter estimates.

4. Characterize uncertainty in the assessment and estimated values.
   - Consider uncertainty in input data, modeling approach, and model configuration.
   - Provide a continuity model consistent with the prior assessment configuration, if one exists, updated to include the most recent observations. Alternative approaches to a strict continuity run that distinguish between model, population, and input data influences on findings, may be considered.
   - Consider and include other sources of uncertainty as appropriate for this assessment.
   - Provide appropriate statistical measures of model performance, reliability, and ‘goodness of fit’.
   - Provide measures of uncertainty for estimated parameters.

5. Provide estimates of yield and productivity.
   - Include yield-per-recruit, spawner-per-recruit, and stock-recruitment models.

6. Provide estimates of population benchmarks or management criteria consistent with the available data, applicable FMPs, proposed FMPs and Amendments, other ongoing or proposed management programs, and National Standards.
   - Evaluate existing or proposed management criteria as specified in the management summary.
   - Recommend proxy values when necessary.

7. Provide declarations of stock status relative to management benchmarks, or alternative data poor approaches if necessary.

8. Provide uncertainty distributions of proposed reference points and stock status metrics that provides the values indicated in the management specifications. Include probability density functions for biological reference point estimates and population metrics (e.g. biomass and exploitation) used to evaluate stock status.

9. Project future stock conditions (biomass, abundance, and exploitation; including probability density functions) and develop rebuilding schedules if warranted; include estimated generation time. Develop stock projections for the following circumstances, in accordance with the guidance on management needs provided in the management history:
   A) If stock is overfished:
      F=0, F=current, F=Fmsy, Ftarget
      F=Frebuild (max exploitation that rebuilds in the greatest allowed time)
      Fixed landings equal to the ABC
   B) If stock is overfishing
      F=Fcurrent, F=Fmsy, F=Ftarget, Fixed landings equal to the ABC
   C) If stock is neither overfished nor overfishing
      F=Fcurrent, F=Fmsy, F=Ftarget, Fixed landings equal to the ABC
   D) If data-limitations preclude classic projections (i.e. A, B, C above), explore alternate models to provide management advice.
   E) Gray triggerfish projections should account for changes in selectivity that may result from actions in Snapper Grouper Amendment 29.

10. Compare and contrast productivity measures and assessment assumptions between the Gulf of Mexico and South Atlantic stocks.

11. Provide recommendations for future research, data collection, and assessments.
    - Be as specific as practicable in describing sampling design and sampling intensity.
    - Emphasize items which will improve future assessment capabilities and reliability, and reduce uncertainty.
    - Consider data, monitoring, and assessment needs.

12. Complete the Assessment Workshop Report in accordance with project schedule deadlines (Section III of the SEDAR Stock Assessment Report).

1.3 List of Participants

ASSESSMENT PANELISTS
Kevin Craig - Lead Analyst Gray Triggerfish, SEFSC Beaufort
Kate Siegfried – Lead Analyst Red Snapper, SEFSC Beaufort
Rob Cheshire, SEFSC Beaufort
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Joey Ballenger, SCDNR
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Peter Barile, SFA
Jeff Buckel, NC State / SSC
Marcel Reichert, SCDNR / SSC
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Rusty Hudson, FL
Robert Johnson, FL
David Nelson, FL

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Chris Conklin, SAFMC

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John Carmichael, SEDAR / SAFMC
Chip Collier, SAFMC
Mike Errigo, SAFMC
Nick Farmer, SERO
Mike Larkin, SERO

WORKSHOP ATTENDEES
Nate Bacheler, SEFSC Beaufort
Ken Brennan, SEFSC Beaufort
David Bush, NCFA
Michelle Duval, NCDMF / SAFMC
Kelly Fitzpatrick, SEFSC Beaufort
Jared Flowers, NCDMF
Laura Lee, NCDMF
Genny Nesslage, UMCES
Amy Schueller, SEFSC Beaufort / SSC
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Roy Crabtree, SERO
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Kathy Knowlton, GADNR
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Paul Nelson, FL fisherman
George Sedberry, NOAA / SSC
Tom Sminkey, NOAA
Karolyn Stillman, SEFSC Beaufort
Yuying Zhang, FL International University

1.4 Document List

SEDAR 41 assessment working paper and reference document list.

Document #	Title	Authors
Documents Prepared for the Assessment Workshop		
SEDAR41-AW01	Addendum to SEDAR41-DW29: Discards of red snapper (*Lutjanus campechanus*) for the headboat fishery in the US South Atlantic	FEB-NMFS 2015
SEDAR41-AW02	Addendum to SEDAR41-DW30: Discards of gray triggerfish (*Balistes capriscus*) for the headboat fishery in the US South Atlantic	FEB-NMFS 2015
SEDAR41-AW03	South Atlantic U.S. red snapper (*Lutjanus campechanus*) age and length composition from the recreational fisheries	FEB-NMFS 2015
SEDAR41-AW04	South Atlantic U.S. gray triggerfish (*Balistes capriscus*) age and length composition from the recreational fisheries	FEB-NMFS 2015
SEDAR41-AW05	Commercial age and length composition weightings for Atlantic Red Snapper (*Lutjanus campechanus*)	SFB-NMFS 2015
SEDAR41-AW06	Commercial age and length composition weightings for Atlantic Gray Triggerfish (*Balistes capriscus*)	SFB-NMFS 2015
SEDAR41-AW07	Addendum to SEDAR41-DW17: Estimates of Historic Recreational Landings of Red Snapper in the South Atlantic Using the FHWAR Census Method	Brennan 2015
SEDAR41-AW08	South Atlantic U.S. red snapper (*Lutjanus campechanus*) catch curve analysis	SFB-NMFS 2015
Reference Documents		
SEDAR41-RD01	List of documents and working papers for SEDAR 32 (South Atlantic Blueline Tilefish and Gray Triggerfish) – all documents available on the SEDAR website.	SEDAR 32
SEDAR41-RD02	List of documents and working papers for SEDAR 9 (Gulf of Mexico Gray Triggerfish, Greater Amberjack, and Vermilion Snapper) – all documents available on the SEDAR website.	SEDAR 9
SEDAR41-RD03	2011 Gulf of Mexico Gray Triggerfish Update Assessment	SEDAR 2011

SEDAR41-RD04	List of documents and working papers for SEDAR 24 (South Atlantic red snapper) – all documents available on the SEDAR website.	SEDAR 24
SEDAR41-RD05	List of documents and working papers for SEDAR 31 (Gulf of Mexico red snapper) – all documents available on the SEDAR website.	SEDAR 31
SEDAR41-RD06	List of documents and working papers for SEDAR 15 (South Atlantic red snapper and greater amberjack) – all documents available on the SEDAR website.	SEDAR 15
SEDAR41-RD07	2009 Gulf of Mexico red snapper update assessment	SEDAR 2009
SEDAR41-RD08	List of documents and working papers for SEDAR 7 (Gulf of Mexico red snapper) – all documents available on the SEDAR website.	SEDAR 7
SEDAR41-RD09	SEDAR 24 South Atlantic Red Snapper: management quantities and projections requested by the SSC and SERO	NMFS - Sustainable Fisheries Branch 2010
SEDAR41-RD10	Total removals of red snapper (*Lutjanus campechanus*) in 2012 from the US South Atlantic	NMFS - Sustainable Fisheries Branch 2013
SEDAR41-RD11	Amendment 17A to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region	SAFMC 2010
SEDAR41-RD12	Amendment 28 to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region	SAFMC 2013
SEDAR41-RD13	Total removals of red snapper (*Lutjanus campechanus*) in 2013 from the U.S. South Atlantic	NMFS - Sustainable Fisheries Branch 2014
SEDAR41-RD14	South Atlantic red snapper (*Lutjanus campechanus*) monitoring in Florida for the 2012 season	Sauls et al. 2013
SEDAR41-RD15	South Atlantic red snapper (*Lutjanus campechanus*) monitoring in Florida for the 2013 season	Sauls et al. 2014
SEDAR41-RD16	A directed study of the recreational red snapper fisheries in the Gulf of Mexico along the West Florida shelf	Sauls et al. 2014
SEDAR41-RD17	Using generalized linear models to estimate	Bacheler et al. 2009

	selectivity from short-term recoveries of tagged red drum *Sciaenops ocellatus*: Effects of gear, fate, and regulation period	
SEDAR41-RD18	Direct estimates of gear selectivity from multiple tagging experiments	Myers and Hoenig 1997
SEDAR41-RD19	Examining the utility of alternative video monitoring metrics for indexing reef fish abundance	Schobernd et al. 2014
SEDAR41-RD20	An evaluation and power analysis of fishery independent reef fish sampling in the Gulf of Mexico and U.S. South Atlantic	Conn 2011
SEDAR41-RD21	Consultant's Report: Summary of the MRFSS/MRIP Calibration Workshop	Boreman 2012
SEDAR41-RD22	2013 South Atlantic Red Snapper Annual Catch Limit and Season Length Projections	SERO 2013
SEDAR41-RD23	Southeast Reef Fish Survey Video Index Development Workshop	Bacheler and Carmichael 2014
SEDAR41-RD24	Observer Coverage of the 2010-2011 Gulf of Mexico Reef Fish Fishery	Scott-Denton and Williams
SEDAR41-RD25	Circle Hook Requirements in the Gulf of Mexico: Application in Recreational Fisheries and Effectiveness for Conservation of Reef Fishes	Sauls and Ayala 2012
SEDAR41-RD26	GADNR Marine Sportfish Carcass Recovery Project	Harrell 2013
SEDAR41-RD27	Catch Characterization and Discards within the Snapper Grouper Vertical Hook-and-Line Fishery of the South Atlantic United States	Gulf and South Atlantic Fisheries Foundation 2008
SEDAR41-RD28	A Continuation of Catch Characterization and Discards within the Snapper Grouper Vertical Hook-and-Line Fishery of the South Atlantic United States	Gulf and South Atlantic Fisheries Foundation 2010
SEDAR41-RD29	Continuation of Catch Characterization and Discards within the Snapper Grouper Vertical Hook-and-Line Fishery of the South Atlantic United States	Gulf and South Atlantic Fisheries Foundation 2013
SEDAR41-RD30	Amendment 1 and Environmental Assessment and Regulatory Impact Review to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region	SAFMC 1988
SEDAR41-RD31	Final Rule for Amendment 1 to the Fishery	Federal Register

	Management Plan for the Snapper Grouper Fishery of the South Atlantic Region	1989
SEDAR41-RD32	Population Structure and Genetic Diversity of Red Snapper (Lutjanus campechanus) in the U.S. South Atlantic and Connectivity with Red Snapper in the Gulf of Mexico	Gold and Portnoy 2013
SEDAR41-RD33	Oogenesis and fecundity type of Gulf of Mexico gray triggerfish reflects warm water environmental and parental care	Lang and Fitzhugh 2014
SEDAR41-RD34	Depth-related Distribution of Postjuvenile Red Snapper in Southeastern U.S. Atlantic Ocean Waters: Ontogenetic Patterns and Implications for Management	Mitchell et al. 2014
SEDAR41-RD35	Gray Triggerfish Age Workshop	Potts 2013
SEDAR41-RD36	Age, Growth, and Reproduction of Gray Triggerfish *Balistes capriscus* Off the Southeastern U.S. Atlantic Coast	Kelly 2014
SEDAR41-RD37	Assessment of Genetic Stock Structure of Gray Triggerfish (*Balistes capriscus*) in U.S. Waters of the Gulf of Mexico and South Atlantic Regions	Saillant and Antoni 2014
SEDAR41-RD38	Genetic Variation of Gray Triggerfish in U.S. Waters of the Gulf of Mexico and Western Atlantic Ocean as Inferred from Mitochondrial DNA Sequences	Antoni et al. 2011
SEDAR41-RD39	Characterization of the U.S. Gulf of Mexico and South Atlantic Penaeid and Rock Shrimp Fisheries Based on Observer Data	Scott-Denton et al. 2012
SEDAR41-RD40	Does hook type influence the catch rate, size, and injury of grouper in a North Carolina commercial fishery	Bacheler and Buckel 2004
SEDAR41-RD41	Fishes associated with North Carolina shelf-edge hardbottoms and initial assessment of a proposed marine protected area	Quattrini and Ross 2006
SEDAR41-RD42	Growth of grey triggerfish, *Balistes capriscus*, based on growth checks of the dorsal spine	Ofori-Danson 1989
SEDAR41-RD43	Age Validation and Growth of Gray Triggerfish, *Balistes capriscus*, In the Northern Gulf of Mexico	Fioramonti 2012
SEDAR41-RD44	A review of the biology and fishery for Gray Triggerfish, *Balistes capriscus*, in the Gulf of Mexico	Harper and McClellan 1997

SEDAR41-RD45	Stock structure of gray triggerfish, *Balistes capriscus*, on multiple spatial scales in the Gulf of Mexico	Ingram 2001
SEDAR41-RD46	Evaluation of the Efficacy of the Current Minimum Size Regulation for Selected Reef Fish Based on Release Mortality and Fish Physiology	Burns and Brown-Peterson 2008
SEDAR41-RD47	Population Structure of Red Snapper from the Gulf of Mexico as Inferred from Analysis of Mitochondrial DNA	Gold et al. 1997
SEDAR41-RD48	Successful Discrimination Using Otolith Microchemistry Among Samples of Red Snapper *Lutjanus campechanus* from Artificial Reefs and Samples of *L.campechanus* Taken from Nearby Oil and Gas Platforms	Nowling et al. 2011
SEDAR41-RD49	Population Structure and Variation in Red Snapper (Lutjanus campechanus) from the Gulf of Mexico and Atlantic Coast of Florida as Determined from Mitochondrial DNA Control Region Sequence	Garber et al. 2003
SEDAR41-RD50	Population assessment of the red snapper from the southeastern United States	Manooch et al. 1998
SEDAR41-RD51	Otolith Microchemical Fingerprints of Age-0 Red Snapper, *Lutjanus campechanus*, from the Northern Gulf of Mexico	Patterson et al. 1998
SEDAR41-RD52	Implications of reef fish movement from unreported artificial reef sites in the northern Gulf of Mexico	Addis et al. 2013
SEDAR41-RD53	Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species	Then et al. 2014
SEDAR41-RD54	Length selectivity of commercial fish traps assessed from in situ comparisons with stereo-video: Is there evidence of sampling bias?	Langlois et al. 2015
SEDAR41-RD55	MRIP Calibration Workshop II – Final Report	Carmichael and Van Vorhees (eds.) 2015
SEDAR41-RD56	Total Removals of red snapper (*Lutjanus campechanus*) in 2014 from the U.S. South Atlantic	SEFSC 2015
SEDAR41-RD57	Assessing reproductive resilience: an example with South Atlantic red snapper *Lutjanus campechanus*	Lowerre-Barbiere et al. 2015

SEDAR41-RD58	Overview of sampling gears and standard protocols used by the Southeast Reef Fish Survey and its partners	Smart et al. 2014
SEDAR41-RD59	MRIP Transition Plan for the Fishing Effort Survey	Atlantic and Gulf Subgroup of the MRIP Transition Team 2015
SEDAR41-RD60	Technical documentation of the Beaufort Assessment Model (BAM)	Williams and Shertzer 2015
SEDAR41-RD61	Stock Assessment of Red Snapper in the Gulf of Mexico 1872-2013, with Provisional 2014 Landings: SEDAR Update Assessment	Cass-Calay et al. 2015
SEDAR41-RD62	Excerpt from the December 2013 SAFMC SEDAR Committee Minutes (pages 11-21 where SEDAR 41 ToR were discussed)	SAFMC SEDAR Committee
SEDAR41-RD63	Population structure of red snapper (*Lutjanus campechanus)* in U.S. waters of the western Atlantic Ocean and the northeastern Gulf of Mexico	Hollenbeck et al. 2015
SEDAR41-RD64	SEDAR31-AW04: The Effect of Hook Type on Red Snapper Catch	Saul and Walter 2013
SEDAR41-RD65	SEDAR31-AW12: Estimation of hook selectivity on red snapper (*Lutjanus campechanus*) during a fishery independent survey of natural reefs in the Gulf of Mexico	Pollack et al. 2013
SEDAR41-RD66	Effect of Circle Hook Size on Reef Fish Catch Rates, Species Composition, and Selectivity in the Northern Gulf of Mexico Recreational Fishery	Patterson et al. 2012
SEDAR41-RD67	Effect of trawling on juvenile red snapper (*Lutjanus campechanus*) habitat selection and life history parameters	Wells et al. 2008
SEDAR41-RD68	SEDAR24-AW05: Selectivity of red snapper in the southeast U.S. Atlantic: dome-shaped or flat topped?	SFB-SEFSC 2010
SEDAR41-RD69	Hierarchical analysis of multiple noisy abundance indices	Conn 2010
SEDAR41-RD70	Data weighting in statistical fisheries stock assessment models	Francis 2011
SEDAR41-RD71	Corrigendum to Francis 2011 paper	Francis
SEDAR41-RD72	Quantifying annual variation in catchability for	Francis et al. 2003

	commercial and research fishing	
SEDAR41-RD73	Evolutionary assembly rules for fish life histories	Charnov et al. 2012
SEDAR41-RD74	User's Guide for ASPIC Suite, version 7: A Stock-Production Model Incorporating Covariates and auxiliary programs	Prager 2015
SEDAR41-RD75	Standing and Special Reef Fish SSC, September 2015 Meeting Summary (see pages 4-7 for SEDAR 43 review)	Gulf of Mexico Standing and Special Reef Fish SSC
SEDAR41-RD76	Standing and Special Reef Fish SSC, January 2016 Meeting Summary (see pages 2-7 for SEDAR 43 review)	Gulf of Mexico Standing and Special Reef Fish SSC
SEDAR41-RD77	SEDAR 43 Gulf of Mexico Gray Triggerfish Stock Assessment Report	SEDAR 43

1.5 Statements Addressing Each Term of Reference

The following are the terms of reference with a statement explaining how each was addressed in the assessment report:

Assessment Workshop Terms of Reference

1. Review any changes in data following the data workshop and any analyses suggested by the data workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.

- *The data review and data updates are provided in Sections 2.1 and 2.2. Tables, figures and written justification are provided for each data change.*

2. Develop population assessment models that are compatible and appropriate with available data. Document input data, model assumptions and configuration, and equations for each model considered.

- *The stock assessment model configuration is described in Sections 3.1 through 3.16. The equations are provided in a technical memorandum referenced in Section 3.1.*

3. Provide estimates of stock population parameters, including: fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, and other parameters as necessary to describe the population. Provide appropriate measures of precision for parameter estimates.

- *Estimated parameters are listed in Section 4.2. Specific estimate sections are as follows: fishing mortality – Section 4.6, abundance – Section 4.3, biomass – Section 4.4, selectivities – Section 4.5, and stock-recruitment relationship – Section 4.7. Measures of precision are provided by the Monte Carlo Bootstrap uncertainty analysis and are described and displayed alongside the point estimates.*

4. Characterize uncertainty in the assessment and estimated values. Consider uncertainty in input data, modeling approach, and model configuration. Provide a continuity model consistent with the prior assessment configuration, if one exists, updated to include the most recent observations. Alternative approaches to a strict continuity run that distinguish between model, population, and input data influences on findings, may be considered. Consider and include other sources of uncertainty as appropriate for this assessment. Provide appropriate statistical measures of model performance, reliability, and 'goodness of fit'. Provide measures of uncertainty for estimated parameters.

- *Uncertainty in the assessment is captured by the analyses described in Section 3.24. The MCB analysis considered uncertainty in the data through the bootstrap step (described in Section 3.24.1), and used a probabilistic framework to capture uncertainty in key parameter estimates (Sections 3.25-3.28). A continuity run was done through sensitivity analysis where the key assumptions made for the previous benchmark assessment were adopted, but current data were used (Sections 3.20 and 4.11, sensitivity 24). Measures of goodness of fit are described in Section 3.18, and multiple supplementary plots are provided in SEDAR41-RW04. Measures of uncertainty for estimated parameters are provided by the MCB analysis.*

5. Provide estimates of yield and productivity. Include yield-per-recruit, spawner-per-recruit, and stock-recruitment models.

- *Per recruit and equilibrium analyses are provided in Section 4.8.*

6. Provide estimates of population benchmarks or management criteria consistent with the available data, applicable FMPs, proposed FMPs and Amendments, other ongoing or proposed management programs, and National Standards. Evaluate existing or proposed management criteria as specified in the management summary. Recommend proxy values when necessary.

- *The current proxy used in the rebuilding plan for Red Snapper is $F_{30\%}$, and that was used as a reference point for stock status determination. Those estimates are provided in Section 4.9.*

7. Provide declarations of stock status relative to management benchmarks, or alternative data poor approaches if necessary.

- *The measures of stock status are in Section 4.10 along with measures of their uncertainty.*

8. Provide uncertainty distributions of proposed reference points and stock status metrics that provides the values indicated in the management specifications. Include probability density functions for biological reference point estimates and population metrics (e.g., biomass and exploitation) used to evaluate stock status.

- *The distributions of the stock status are described in Section 4.10, and the corresponding plots are Figures 36, 38 and 39.*

9. Project future stock conditions (biomass, abundance, and exploitation; including probability density functions) and develop rebuilding schedules if warranted; include estimated generation time. Develop stock projections for the following circumstances, in accordance with the guidance on management needs provided in the management history:
A) If stock is overfished: F=0, F=current, F=Fmsy, Ftarget, F=Frebuild (max exploitation that rebuilds in greatest allowed time), Fixed landings equal to the ABC
B) If stock is overfishing: F=Fcurrent, F=Fmsy, F= Ftarget, Fixed landings equal to the ABC

- *The stock is estimated to be overfished with overfishing occurring, therefore five standard projections were performed: F=0, $F=F_{current}$, $F=_{Fmsy\ proxy}$, F_{target}, $F=F_{rebuild}$ (max exploitation that rebuilds in greatest allowed time). Section 3.29 contains the descriptions of the runs, and Section 4.12 contains the results. The fixed landings projection will be performed when the SSC provides suggested ABCs.*

10. Compare and contrast productivity measures and assessment assumptions between the Gulf of Mexico and South Atlantic stocks.

- *The table addressing this ToR is found in Section 9.*

11. Provide recommendations for future research, data collection and assessments. Be as specific as practicable in describing sampling design and sampling intensity. Emphasize items which will improve future assessment capabilities and reliability, and reduce uncertainty. Consider data, monitoring, and assessment needs.

- *Research recommendations are in Section 5.3.*

12. Complete the Assessment Workshop Report in accordance with project schedule deadlines (Section III of the SEDAR Stock Assessment Report) – *Report submitted on time.*

2 Data Review and Update

The input data for this assessment are described below, with focus on modifications from the SEDAR41 DW.

2.1 Data Review

In this benchmark assessment, the Beaufort assessment model (BAM) was fitted to data sources developed during the SEDAR 41 DW with some modifications and additions.

Model input compiled during the DW

- Life history: Life history meristics, population growth, female maturity, proportion female, number of batches at age, size-dependent batch fecundity, and discard mortality
- Landings and discards: Commercial handline landings and discards, Headboat landings and discards, Recreational landings and discards
- Indices of abundance: Commercial handline, Headboat, Headboat discards, SERFS chevron trap, SERFS video

Model input modified or developed after the DW

- Life history: Fishery-dependent growth estimates, Growth estimates during the 20 inch size regulation, Age–specific natural mortality
- Landings and discards: changes to the recreational discards
- Indices of abundance: Fishery–independent indices combined (Chevron trap and Video)
- Length compositions: Commercial handline, Headboat, Recreational
- Age compositions: Commercial handline, Headboat, Recreational, Chevron trap

2.2 Data Update

2.2.1 Life History

Estimates of the von Bertalanffy growth parameters were provided by the DW for the population as a whole: (911mm, 0yr^{-1}, and 0yr). Two alternative von Bertalanffy curves were generated: one for all fisheries when no size limit was in place, and another to represent the fish captured by all fisheries under a 20 inch size limit regulation. Age-specific mortality was updated due to an error in the original calculation which forced the t_0 value to 0. Life-history information is summarized in Tables 1 and 2.

2.2.2 Landings and Discards

The fleet structure to be modeled was decided after the DW. The general recreational fleet comprises the charterboat and private boat fleets, while the headboat fleet stands alone. The decision was made to separate headboat from all other recreational fishing modes because length compositions diverge later in the time series. The general recreational fleet discards contained some zeros (years 1982, 1986, and 1990) that the panel considered unlikely to be accurate due to the magnitude of the surrounding years' values. The decision was made by the panel to fill in the zeros with the lowest observed discards in the regulatory time block of the zero value. Total removals as used in the assessment are in Table 3.

2.2.3 Indices of Abundance

The DW provided a SERFS chevron trap and video index separately. However, because the data are collected from the same sampling platforms (i.e. cameras mounted on the chevron traps), the two indices are not independent measures of abundance. Therefore, the panel decided to combine the two using the Conn (2010) method for combining indices. All indices and their corresponding CVs are shown in Table 4, and Figure 1 shows the indices as recommended by the data workshop plotted with the new CVID index for comparison. Fishery dependent indices of abundance were assumed to have CVs of 0.2, which is consistent with Francis (2003).

2.2.4 Length Compositions

Length compositions for all data sources were developed in 3-cm bins over the range 21–99 cm (labeled at bin center). All lengths below and above the minimum and maximum bins were pooled. The commercial handline, general recreational and headboat lengths were weighted by the region and landings (SEDAR41-AW05 2015). For inclusion, length compositions in any given year had to meet the sample size criteria of $nfish > 30$ and $ntrips \geq 10$ (Table 5). Furthermore, the AW panel decided to eliminate length comps where age comps were available. There were conflicts between the length compositions and age compositions, and the panel thought, given the relative ease of ageing this species and the fact the model is age-structured, the age compositions would provide more informative signals of year-class strength and better represent the catch in each fleet or survey.

2.2.5 Age Compositions

For age composition data, the upper range was pooled at 13 years old because a very small proportion of the data exist past age 13. The age compositions were weighted by the length compositions in attempt to address bias in selection of fish to be aged. For inclusion, age compositions in any given year had to meet the sample size criteria of $nfish > 10$ and $ntrips \geq 10$ (Table 5). Age composition was preferred over length composition when both were available from a given fleet in a given year.

2.2.6 Additional Data Considerations

Size limits were in place beginning in 1983 (12 inch minimum size limit TL), and changed in 1992 (20 inch minimum size limit TL). A moratorium was put in place for Red Snapper in 2010, and three subsequent mini-seasons were allowed (2011-2014) with no size limit. The panel examined size composition data and determined that three time blocks should be used to account for size limits, or the lack thereof: 1950-1991, 1992-2009, and 2010-2014. Data available for this assessment are summarized in Tables 1–5.

3 Stock Assessment Methods

3.1 Overview

The primary model discussed during the Assessment Workshop (AW) was a statistical catch-age model implemented using the Beaufort Assessment Model (BAM) software (Williams and Shertzer 2015). BAM applies a statistical catch-age formulation, coded using AD Model Builder (Fournier et al. 2012). BAM is referred to as an integrated analysis because it uses all population dynamics-relevant data (e.g. removals, length and age compositions, and indices of abundance) in a single modeling framework. In contrast, production models (e.g. ASPIC or ASPM) or catch curve analyses only use subsets of the available data and often require simplifying assumptions. In essence, the catch-age model simulates a population forward in time while including fishing processes (Quinn and Deriso 1999; Shertzer et al. 2008). Quantities to be estimated are systematically varied until characteristics of the simulated population matches available data on the real population. The model is similar in structure to Stock Synthesis (Methot 1989; 2009). Versions of BAM have been used in previous SEDAR assessments of reef fishes in the U.S. South Atlantic, such as Red Porgy, Black Sea Bass, Tilefish, Blueline Tilefish, Gag, Greater Amberjack, Red Grouper, Snowy Grouper, and Vermilion Snapper, as well as in the previous SEDAR assessments of Red Snapper (SEDAR24 2010). In addition, a surplus production model implemented using ASPIC and a catch curve analysis (SEDAR41-AW08 2015) were used to provide supplementary information.

3.2 Data Sources

The catch-age model included data from three fleets that caught Red Snapper in southeastern U.S. waters: general recreational (charter and private boat), commercial handlines (hook-and-line), and recreational headboats. The model was fitted to data on annual landings (in numbers for the recreational fleets, in whole weight for commercial fleet); annual discards (in numbers for all fleets), annual length compositions of removals; annual age compositions of landings and surveys; three fishery dependent indices of abundance (commercial handlines, headboat, and headboat discards); and one fishery independent index of abundance (combined SERFS chevron trap and SERFS video index). Removals included landings and dead discards, assuming the mortality rates provided by the Data Workshop. Data used in the model are tabulated in §2 of this report.

3.3 Model Configuration

The assessment time period was 1950–2014. A general description of the assessment model follows.

3.4 Stock dynamics

In the assessment model, new biomass was acquired through growth and recruitment, while abundance of existing cohorts experienced exponential decay from fishing and natural mortality. The population was assumed closed to immigration and emigration. The model included age classes $1 - 20^{+}$, where the oldest age class 20^{+} allowed for the accumulation of fish (i.e., plus group).

3.5 Initialization

Initial (1950) numbers at age assumed the stable age structure computed from expected recruitment and the initial, age-specific total mortality rate. That initial mortality was the sum of natural mortality and fishing mortality, where fishing mortality was the product of an initial fishing rate (F_{init}) and F-weighted average selectivity. The initial fishing rate was estimated using a prior centered around $F_{\mathrm{init}} = 0.03$. The assumption matches what was used for SEDAR24 with the justification that the value should be small given the relatively low volume of landings prior to the assessment period. The initial recruitment in 1950 was assumed to be the expected value from the spawner-recruit curve. For the remainder of the initialization period (1950–1977), recruitment was assumed equal to expected values. Without sufficient age/length composition data prior to 1978, there is little information to estimate those historic recruitment deviations with accuracy.

3.6 Natural mortality rate

The natural mortality rate (M) was assumed constant over time, but decreasing with age. The form of M as a function of age was based on Charnov et al. (2013), a change from SEDAR24 which based natural mortality on the findings of Lorenzen (1996). The Charnov et al. (2013) approach inversely relates the natural mortality at age to somatic growth. As in previous SEDAR assessments, the age-dependent estimates of M_a were rescaled to provide the same fraction of fish surviving from age 4 through the oldest observed age (51 yr) as would occur with constant $M = 0.134$. This approach using cumulative mortality allows that fraction at the oldest age to be consistent with the findings of Then et al. (2014).

3.7 Growth

Mean size at age of the population, fishery removals under no size limit, and fishery removals under a 20 inch size limit (total length, TL) were modeled with the von Bertalanffy equation, and weight at age (whole weight, WW) was modeled as a function of total length (Figure 2, Table 2). Parameters of growth and conversions (TL-WW) were treated as input to the assessment model. For fitting length composition data, the distribution of size at age was assumed normal with a CV estimated by the assessment model for each growth curve.

3.8 Female maturity and sex ratio

Female maturity was modeled with a logistic function; parameters for this model and a vector of maturity at age were provided by the DW and treated as input to the assessment model (Table 2). The sex ratio was assumed to be 50:50, as recommended by the DW.

3.9 Spawning stock

Spawning biomass was modeled as population fecundity (number of eggs). For Red Snapper, peak spawning was considered to occur at the end of June. This included information on batch size as a function of age, as well as information on the number of annual batches as a function of age (SEDAR41-DW49 (2015) and Fitzhugh et al. (2012)).

3.10 Recruitment

Expected recruitment of age-1 fish was predicted from spawning biomass using the Beverton–Holt spawner-recruit model. Steepness, h, is a key parameter of this model, and unfortunately it is often difficult to estimate reliably (Conn et al. 2010). In this assessment, many initial attempts to estimate steepness resulted in a value near its upper bound of 1.0, indicating that the data were insufficient for estimation. Likelihood profiling showed that the value was likely above 0.92, and was unreliably estimated between 0.92 and 0.98. The AW Panel decided to assume an average annual recruitment while estimating lognormal deviations around that average. This was achieved by fixing steepness at $h = 0.99$.

3.11 Landings

Time series of landings from three fleets were modeled: commercial handline (1950–2014), general recreational (1955–2014), and headboat (1955–2014). Landings were modeled with the Baranov catch equation (Baranov 1918) and were fitted in either weight or numbers, depending on how the data were collected (1000 lb whole weight for commercial fleets, and 1000 fish for recreational). The DW provided observed landings back to the first assessment year (1950) for the commercial fleet and back to 1955 for the recreational fleets. However, sampling of headboats began in 1972 and other recreational sectors in 1981. Thus, historic landings of the recreational fleets were estimated indirectly by the DW using the FHWAR ratio method (SEDAR41 41dw17). Historic landings were considered (and treated) in this assessment as a primary source of uncertainty.

3.12 Discards

As with landings, discard mortalities (in units of 1000 fish) were modeled with the Baranov catch equation (Baranov 1918), which required estimates of discard selectivities and release mortality probabilities. Discards were assumed to have fleet-specific, year-specific mortality probabilities, as suggested by the DW. Until 2007, the rate for commercial handlines was 0.48, and 0.38 thereafter. Until 2011, the general recreational and headboat rate was 0.37, with 0.285 thereafter. Annual discard mortalities, as fit by the model, were computed by multiplying total discards (tabulated in the DW report) by the fleet-specific and year-specific discard mortality rate. For general recreational and headboat fleets, discard time series were assumed to begin in 1981; for the commercial handlines fleet, discards were modeled starting in 1992 corresponding to the implementation of the 20-inch size limit.

3.13 Fishing

For each time series of removals (landings and discards), the assessment model estimated a separate full fishing mortality rate (F). Age-specific rates were then computed as the product of full F and selectivity at age. The across-fleet annual F was represented by apical F, computed as the maximum of F at age summed across fleets.

3.14 Selectivities

Selectivity curves applied to landings were estimated using a parametric approach. This approach applies plausible structure on the shape of the curves, and achieves greater parsimony than occurs with unique parameters for each age. Flat-topped selectivities were modeled as a two-parameter logistic function. Dome-shaped selectivities were modeled by combining two logistic functions: a two-parameter logistic function to describe the ascending limb of the curve, and a two-parameter logistic function to describe the descending limb. To model landings, the AW Panel recommended flat-topped selectivity for commercial handlines and dome-shaped selectivity for headboat and the general recreational fleets.

The assessment panel devoted substantial discussion and exploration to the pattern (flat-topped or dome-shaped) of selectivity at age. Several working papers and scientific literature (SEDAR24-AW05, SEDAR24-AW09, SEDAR24-AW12, SEDAR31-AW04, SEDAR31-AW12, SEDAR41-DW50, SEDAR41-DW08, Patterson et al. (2012), Wells et al. (2008), and Mitchell et al. (2014)) helped guide the panel's decisions by providing insight into selectivity based on length and age compositions, depth distributions of fishing effort, skill levels of fishermen, and how circumstances contrasted between the Atlantic and Gulf of Mexico. The choice of flat-topped selectivity for commercial handlines landings and dome-shaped for all others was based on several criteria. Two related considerations were the fleet-specific depths of fishing effort and the distribution of age at depth. In general, the commercial handlines fleet fish

in deeper water than other fleets, and although there was only weak correlation between depth and age of older fish (5^+), younger fish (1–5) were more readily caught in shallower depths (SEDAR24-AW05, and Mitchell et al. (2014)). It was also suggested that commercial gear and fishermen can better handle larger fish (SEDAR24-AW12). Catch curve data were consistent with the hypothesis that older fish are more vulnerable to the commercial handlines fleet than to recreational fleets (SEDAR41-AW08 2015).

Selectivity of each fleet was fixed within each block of size-limit regulations, but was permitted to vary among blocks where possible or reasonable. Fisheries experienced four blocks of size-limit regulations (no limit prior to 1983, 12-inch limit during 1983–1991, 20-inch limit during 1992–2009, and no size limit during the moratorium/miniseasons 2010–2014). However, the panel combined blocks one and two after seeing that the 12-inch size limit had a negligible effect on the selectivity pattern. Age and length composition data are critical for estimating selectivity parameters, and ideally, a model would have sufficient composition data from each fleet over time to estimate distinct selectivities in each period of regulations. That was not the case here, and thus additional assumptions were applied to define selectivities, as follows. Because the general recreational fleet had little age or length composition data prior to 1998, this fleet mirrored the headboat fleet until the final time block. All domed-shaped selectivities meant to characterize landings were configured so as not to allow a selectivity of 0 at older ages, which was considered implausible. Size and age composition data show larger, older fish are caught by all fleets. However, the selectivity functions would reach zero before the plus group age of 20. Therefore, the panel examined the age composition data and used the information they contained to create a plus group for the selectivities. Headboat selectivities were fixed as constant after age 10 at the value estimated for age 10. For the general recreational fleet, the constant age at which we fixed selectivity was 13. These plus groups were consistent with how the age composition data were fitted.

Selectivities of discards were estimated in a similar fashion to the landings in that the general recreational fleet discards mirrored the headboat fleet discards. Both the commercial handline discards and the headboat discards had sufficient length composition to estimate selectivities.

Selectivities of fishery dependent indices were the same as those of the relevant fleet. The fishery independent CVID index selectivity was assumed logistic and informed by the SERFS chevron trap age compositions.

3.15 Indices of abundance

The model was fit to three fishery dependent indices of relative abundance (headboat 1976–2009; headboat discards 2005–2014; and commercial handlines 1993–2009), and one fishery independent index of abundance (SERFS combined video and trap, CVID). Predicted indices were conditional on selectivity of the corresponding fleet or survey, and were computed from abundance at the midpoint of the year or, in the case of commercial handlines, biomass. The headboat discard index tracks small fish (less than 20 inches) and was included as a measure of recruitment strength.

3.16 Catchability

In the BAM, catchability scales indices of relative abundance to the estimated population at large. For the base model, the AW Panel recommended a time-invariant catchability.

A sensitivity run adopted a time-varying catchability for the headboat index. In this formulation, catchability was estimated in two stanzas, pre- and post-1992. Choice of the year 1992 was based on the implementation of a fishery management plan that may have changed fishing behavior.

3.17 Biological reference points

Biological reference points (benchmarks) were calculated based on the fishing rate that would allow a stock to attain 30% of the maximum spawning potential which would have been obtained in the absence of fishing mortality. Computed benchmarks included the MSY proxy, fishing mortality rate at $F_{30\%}$, total biomass at $F_{30\%}$, and spawning stock at $F_{30\%}$ (Gabriel and Mace 1999). In this assessment, spawning stock measures total eggs of the mature stock. These benchmarks are conditional on the estimated selectivity functions and the relative contributions of each fleet's fishing mortality. The selectivity pattern used here was the effort-weighted selectivities at age, with effort from each fleet estimated as the full F averaged over the last three years of the assessment.

3.18 Fitting criterion

The fitting criterion was a penalized likelihood approach in which observed removals (landings and discards) were fit closely, and observed composition data and abundance indices were fit to the degree that they were compatible. Removals and index data were fit using lognormal likelihoods. Length and age composition data were fit using robust multinomial likelihoods (Francis 2011), and only from years that met minimum sample size criteria ($nfish > 30$ and $ntrips \geq 10$) for length compositions and ($nfish > 10$ and $ntrips \geq 10$) for age compositions. Commercial and headboat discard length composition minimum sample size threshold was set lower ($nfish > 10$) due to the fact that the discard composition data were the only information available to estimate selectivity.

The model includes the capability for each component of the likelihood to be weighted by user-supplied values. For data components, these weights were applied by either adjusting CVs (lognormal components) or adjusting effective sample sizes (multinomial components). In this application to Red Snapper, CVs of landings and discards (in arithmetic space) were assumed equal to 0.05, to achieve a close fit to these time series yet allowing some imprecision. In practice, the small CVs are a matter of computational convenience, as they help achieve the desired result of close fits to the landings, while avoiding having to solve the Baranov equation iteratively (which is complex when there are multiple fisheries). Weights on other data components (indices, age/length compositions) were adjusted iteratively, starting from initial weights as follows. The CVs of indices were set equal to the values estimated by the GLMs used for standardization or at the fixed value of 0.2 for the headboat and commercial handline indices. Effective sample sizes of the multinomial components were assumed equal to the number of trips sampled annually, rather than the number of fish measured, reflecting the belief that the basic sampling unit occurs at the level of trip. These initial weights were then adjusted until standard deviations of normalized residuals were near 1.0 (Francis 2011). In sensitivity runs, weights on the fishery dependent indices were adjusted upward to explore their effects (not because up-weighted runs were considered equally plausible).

For parameters defining selectivities, CV of size at age, and σ_R, normal priors were applied to maintain parameter estimates near reasonable values, and to prevent the optimization routine from drifting into parameter space with negligible gradient in the likelihood. For σ_R, the prior mean (0.6) and standard deviation (0.25) were based on Beddington and Cooke (1983) and Mertz and Myers (1996).

3.19 Configuration of a base run

The base run was configured as described above. This configuration does not necessarily represent reality better than all other possible configurations, and thus this assessment attempted to portray uncertainty in point estimates through sensitivity analyses and through a Monte-Carlo/bootstrap approach (described below).

3.20 Sensitivity analyses

Sensitivity runs were chosen to investigate issues that arose specifically with this benchmark assessment. They were intended to demonstrate directionality of results with changes in inputs or simply to explore model behavior, and not all were considered equally plausible. These model runs vary from the base run as follows:

- S1: Remove the 2008 and 2009 years from the handline and headboat indices
- S2: Upweight fishery independent index further than was explored in the Assessment Workshop (10X likelihood weight after the iterative reweighting)
- S3: Upweight handline and headboat indices (3X likelihood weight after iterative reweighting)
- S4: Fishery dependent indices only
- S5: High value of M
- S6: Low value of M
- S7: Low discard mortality probabilities (commercial handlines rate set to 0.38 or 0.28, all recreational set to 0.27 or 0.20)
- S8: High discard mortality probabilities (commercial handlines rate set to 0.58 or 0.48, all recreational set 0.45 or 0.36)
- S9: Longer combined chevron trap and video (CVID) index (2005-2014)
- S10: Reduced general recreational landings in 1984 and 1985 by taking the geometric mean of surrounding years
- S11: Steepness $h = 0.84$
- S12: Headboat discard index excluded after 2009
- S13: Ageing error matrix included
- S14: Low value for age-specific number of batches
- S15: High value for age-specific number of batches
- S16: Headboat discard index dropped
- S17: High landings
- S18: Low landings
- S19: High discards
- S20: Low discards
- S21: Dome-shaped selectivity for commercial handline fleet
- S22: Separate video and trap index rather than a single CVID index
- S23: Fishery independent index only
- S24: Continuity run: changes include SEDAR24 values such as M, steepness, maturity, and SSB
- S25: Two time blocks for Headboat logbook index catchability (pre- and post-1992)
- S26: Retrospective - 1 year of data
- S27: Retrospective - 2 years of data
- S28: Retrospective - 3 years of data
- S29: Retrospective - 4 years of data

- S30: Use 1978 as the starting year, applied a loose prior to the estimation of F_{init} that corresponds to the geometric mean of the fishing mortality for 1950-1977
- S31: Estimate selectivities without fixing a plus group (for the selectivity estimation)

Sensitivities 5, 6, 14, 15, and 17-20 used the 10th and 90th quantiles (as the low and the high respectively) from the bootstraps of the observed data described in the uncertainty analysis methods (Section 3.24).

3.21 Parameters Estimated

The model estimated annual fishing mortality rates of each fleet, selectivity parameters, catchability coefficients associated with indices, parameters of the spawner-recruit model (except steepness), annual recruitment deviations, and CV of size at age for each age and growth relationship.

3.22 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F, as were equilibrium landings and spawning biomass. Equilibrium landings and discards were also computed as functions of biomass B, which itself is a function of F. As in the computation of benchmarks (described in §3.23), per recruit and equilibrium analyses applied the most recent selectivity patterns averaged across fleets, weighted by each fleet's F from the last three years of the assessment (2012–2014).

3.23 Benchmark/Reference Point Methods

In this assessment of Red Snapper, the quantities $F_{30\%}$, $\mathrm{SSB}_{\mathrm{F30\%}}$, $B_{\mathrm{F30\%}}$, and $L_{\mathrm{F30\%}}$ were estimated as proxies for MSY-based reference points. Steepness was not reliably estimable, so the stock-recruit relationship was not used to identify a maximum yield. Instead, steepness was fixed at 0.99 in order to assume an average level of recruitment while estimating deviations around the mean. $F_{30\%}$ was used in the rebuilding plan for Red Snapper, therefore, it was used here to generate fishing benchmarks. However, because the stock-recruitment relationship was not estimated, assumptions about recruitment are required to generate biomass benchmarks. Here, equilibrium recruitment was assumed equal to expected recruitment (arithmetic average). On average, expected recruitment is higher than that estimated directly from the spawner-recruit curve, because of lognormal deviation in recruitment. Thus, in this assessment, the method of benchmark estimation accounted for lognormal deviation by including a bias correction in equilibrium recruitment. The bias correction (ς) was computed from the variance (σ_R^2) of recruitment deviation in log space: $\varsigma = \exp(\sigma_R^2/2)$. Then, equilibrium recruitment (R_{eq}) associated with any F is,

$$R_{eq} = \frac{R_0\left[\varsigma 0.8 h \Phi_F - 0.2(1-h)\right]}{(h-0.2)\Phi_F} \tag{1}$$

where R_0 is virgin recruitment, h is steepness which is fixed in this assessment, and $\Phi_F = \phi_F/\phi_0$ is spawning potential ratio given growth, maturity, and total mortality at age (including natural and fishing mortality rates). Because steepness is fixed at 0.99, R_{eq} as a function of F is approximately a straight line. The R_{eq} and mortality schedule imply an equilibrium age structure and an average sustainable yield (ASY). The estimate of $F_{30\%}$ is the F giving 30% of the SPR, and the estimate of $L_{\mathrm{F30\%}}$ is that ASY. The estimate of $\mathrm{SSB}_{\mathrm{F30\%}}$ follows from the corresponding equilibrium age structure, as does the estimate of discard mortalities $D_{F30\%\}}$, here separated from ASY (and consequently, $L_{\mathrm{F30\%}}$).

Estimates of $L_{\mathrm{F}30\%}$ and related benchmarks are conditional on selectivity pattern. The selectivity pattern used here was an average of terminal-year selectivities from each fleet, where each fleet-specific selectivity was weighted in proportion to its corresponding estimate of F averaged over the last three years (2012–2014). If the selectivities or relative fishing mortalities among fleets were to change, so would the estimates of $L_{\mathrm{F}30\%}$ and related benchmarks.

The maximum fishing mortality threshold (MFMT) is defined by the SAFMC as $F_{30\%}$, and the minimum stock size threshold (MSST) as 75%$\mathrm{SSB}_{\mathrm{F}30\%}$. Overfishing is defined as $F >$ MFMT and overfished as SSB $<$ MSST. However, because this stock is currently under a rebuilding plan, increased emphasis is given to SSB relative to $\mathrm{SSB}_{\mathrm{F}30\%}$ (rather than MSST), as $\mathrm{SSB}_{\mathrm{F}30\%}$ is the rebuilding target. Current status of the stock is represented by SSB in the latest assessment year (2014), and current status of the fishery is represented by the geometric mean of F from the latest three years (2012–2014). Recent SEDAR assessments have considered the mean over the terminal three years to be a more robust metric.

3.24 Uncertainty and Measures of Precision

As in SEDAR24, this assessment used a mixed Monte Carlo and bootstrap (MCB) approach to characterize uncertainty in results of the base run. Monte Carlo and bootstrap methods (Efron and Tibshirani 1993; Manly 1997) are often used to characterize uncertainty in ecological studies, and the mixed approach has been applied successfully in stock assessment, including Restrepo et al. (1992), Legault et al. (2001), SEDAR4 (2004), and many South Atlantic SEDAR assessments since SEDAR19 (2009). The approach is among those recommended for use in SEDAR assessments (SEDAR Procedural Guidance 2010).

The approach translates uncertainty in model input into uncertainty in model output, by fitting the model many times with different values of "observed" data and key input parameters. A chief advantage of the approach is that the results describe a range of possible outcomes, so that uncertainty is characterized more thoroughly than it could be by any single fit or handful of sensitivity runs. A minor disadvantage of the approach is that computational demands are relatively high.

In this assessment, the BAM was successively re-fit in $n = 4000$ trials that differed from the original inputs by bootstrapping on data sources, and by Monte Carlo sampling of several key input parameters. The value of $n = 4000$ was chosen because a minimum of 3000 runs were desired, and it was anticipated that not all runs would converge or otherwise be valid. Of the 4000 trials, approximately 0.88% were discarded, because the model did not properly converge (in most cases, an estimated quantity was at its upper bound). This left $n = 3965$ MCB trials used to characterize uncertainty, which was sufficient for convergence of standard errors in management quantities.

The MCB analysis should be interpreted as providing an approximation to the uncertainty associated with each output. The results are approximate for two related reasons. First, not all combinations of Monte Carlo parameter inputs are equally likely, as biological parameters might be correlated. Second, all runs are given equal weight in the results, yet some might provide better fits to data than others.

3.24.1 Bootstrap of observed data

To include uncertainty in the indices of abundance, multiplicative lognormal errors were applied through a parametric bootstrap. To implement this approach in the MCB trials, random variables ($x_{s,y}$) were drawn for each year y of time series s from a normal distribution with mean 0 and variance $\sigma^2_{s,y}$ [that is, $x_{s,y} \sim N(0, \sigma^2_{s,y})$]. Annual observations were then perturbed from their original values ($\hat{O}_{s,y}$),

$$O_{s,y} = \hat{O}_{s,y}[\exp(x_{s,y} - \sigma^2_{s,y}/2)] \tag{2}$$

The term $\sigma^2_{s,y}/2$ is a bias correction that centers the multiplicative error on the value of 1.0. Standard deviations in log space were computed from CVs in arithmetic space, $\sigma_{s,y} = \sqrt{\log(1.0 + CV^2_{s,y})}$. As used for fitting the base run, CVs of indices of abundance were those provided by, or modified from, the data providers (tabulated in Table 4 of this assessment report).

Uncertainty was modeled for historical commercial landings similarly to the indices, and by the CVs provided by the commercial working group at the DW. No commercial discard CVs, headboat landings CVs, or headboat discard CVs by year were provided, therefore the panel had to make some assumptions. We assumed a value of $CV = 0.20$ for commercial discards and headboat discards. For headboat landings, we used information from the headboat program to assume a decreasing CV by time blocks (i.e. $CV = 0.15$ 1981-1995, $CV = 0.1$ for 1996-2007, and $CV = 0.05$ thereafter). General recreational landings and discards had complementary CVs, and those were used as provided except in a few instances. A CV greater than 1 was capped at 1, which was sufficiently large to represent high uncertainty but not so high that bootstrapped values caused implausible time series. The panel thought the resulting draws sufficiently represented uncertainty in spite of the dampening of a few years' CVs (Table 6).

Uncertainty in age and length compositions were included by drawing new distributions for each year of each data source, following a multinomial sampling process. Ages (or lengths) of individual fish were drawn at random with replacement using the cell probabilities of the original data. For each year of each data source, the number of fish sampled was the same as in the original data.

3.24.2 Monte Carlo sampling

In each successive fit of the model, several parameters were fixed (i.e., not estimated) at values drawn at random from distributions described below.

3.25 Natural mortality

A vector of age-specific natural mortality was provided by the Life History Working Group. They used the Charnov et al. (2013) estimator scaled to the Then et al. (2014) max age asymptotic M, and then used the uncertainty around the determination of maximum age to provide an upper and lower bound to the M vector. The Assessment Panel thought the upper ($M = 0.14$) and lower ($M = 0.12$) bound were too similar to the base vector to represent the true uncertainty around M. Instead, the AW Panel wanted to carry the uncertainty forward in both maximum age and the parameters of the Then et al. (2014) estimator of asymptotic M:

$$M = aT^b_{max} \qquad (3)$$

To estimate uncertainty in a and b, we acquired the data of Then et al. (2014) and conducted a bootstrap of $n = 10,000$ iterations, drawing from the original data set with replacement. For each MCB iterations, one of the 10,000 fits was drawn at random, thus maintaining any correlation structure between a and b. We then drew T_{max} from a uniform distribution and calculated asymptotic M. For the age-dependent vector, we started with the Charnov age-dependent curve, and scaled it to the M estimate we calculated in the previous steps. A new M value was drawn and a new age-dependent vector was calculated for each MCB trial.

3.26 Discard mortality

The discard mortality working group provided an upper and lower bound for each time block (pre- and post-regulation) and fishery (commercial and recreational). Commercial rates before 2007 ranged from 38% to 58%, and 2007 to present ranged from 28% to 48%. Recreational rates before 2011 ranged from 27% to 45%, and 2011 on ranged from 20% to 36%. The rates decreased in response to the implementation of circle hooks, which are meant to cause fewer fatal bycatch events. We drew the rate for the earlier time period for each fleet from a truncated normal distribution with mean equal to the point estimate and a standard deviation devised to provide a 95% confidence interval similar to what the working group provided above. For the later time period for each fleet we also drew from a truncated normal distribution created similarly as in the previous step but with the upper bound fixed at the random draw from the earlier time period. The last step is meant to ensure that the second value is not larger than the first, so as to maintain the feature that discard mortality has decreased due to the circle hook regulation.

3.27 Batch Fecundity

Prior to the MCB analysis, a bootstrap procedure was run on the data set used to estimate batch fecundity at age for the base run. For each of 10000 bootstrap runs, the 69 paired observations of batch fecundity and fish length were sampled 69 times with replacement, the regression model refit, and the bootstrap parameters estimates saved to a data matrix. Once all bootstraps were run, the parameter matrix was trimmed by removing runs where either parameter value was outside of its 95% confidence interval. The parameters were found to be highly correlated, so during the MCB analysis, pairs of parameters were randomly drawn, with replacement, from the trimmed bootstrap parameter matrix. For each MCB run, predicted batch fecundity at age was calculated using a set of bootstrap parameters and a vector of length at age.

3.28 Batch number

Prior to the MCB analysis, a similar but separate bootstrap procedure was run on the data set used to estimate batch number at age for the base run. For each of 10000 bootstrap runs, the 1472 paired observations of spawning indicator presence, fish length, and day of the year were sampled 1472 times with replacement and the regression model refit. Predicted batch number at age was then calculated from the bootstrap parameter estimates and a vector of length at age, and the vectors saved to a data matrix. Once all bootstraps were run, the batch number at age matrix was trimmed by first summing batch number at age for each run, yielding lifetime batch number; runs where lifetime batch number was outside of the 95% confidence interval were trimmed. During the MCB analysis, a vector of batch number at age was randomly drawn, with replacement, from the trimmed bootstrap batch number at age matrix for each MCB run.

3.29 Projections

Projections were run to predict stock status in years after the assessment, 2015–2044. The year 2044 is the last year of the current rebuilding plan.

The structure of the projection model was the same as that of the assessment model, and parameter estimates were those from the assessment. Any time-varying quantities, such as recreational selectivity, were fixed to the most recent values of the assessment period. A single selectivity curve was applied to calculate removals, averaged across fleets using geometric mean Fs from the last three years of the assessment period, similar to computation of $L_{\mathrm{F30\%}}$ benchmarks (§3.23).

Expected values of SSB (time of peak spawning), F, recruits, and removals were represented by deterministic projections using parameter estimates from the base run. These projections were built on the spawner-recruit relationship with steepness fixed ($h = 0.99$) and with bias correction, and were thus consistent with estimated benchmarks in the sense that long-term fishing at $F_{30\%}$ would yield $L_{\mathrm{F30\%}}$ from a stock size at $\mathrm{SSB}_{\mathrm{F30\%}}$. Uncertainty in future time series was quantified through stochastic projections that extended the Monte Carlo/Bootstrap (MCB) fits of the stock assessment model.

3.29.1 Initialization of projections

Initial age structure at the start of 2015 was computed by the assessment model.

Fishing rates that define the projections were assumed to start in 2017. Because the assessment period ended in 2014, the projections required an initialization period (2015–2016). For 2015, a moratorium year, the landings selectivity was set to 0 and the discard selectivity was rescaled to peak at 1. Then, an optimization routine solved for the F that matched the current dead discards (mean of 2012-2014) in numbers. In 2016, a similar routine soved for the F that matched current landings (mean of 2012-2014), assuming a mini-season would occur.

3.29.2 Uncertainty of projections

To characterize uncertainty in future stock dynamics, stochasticity was included in replicate projections, each an extension of a single MCB assessment model fit. Thus, projections carried forward uncertainties in natural mortality, reproduction, landings, discards, and discard mortalities, as well as in estimated quantities such as selectivity curves, and in initial (start of 2015) abundance at age.

Initial and subsequent recruitment values were generated with stochasticity using a Monte Carlo procedure, in which the estimated Beverton–Holt model (i.e. R_0, σ_R estimated, and $h = 0.99$) of each MCB fit was used to compute mean annual recruitment values ($\bar{R}_y$). Variability was added to the mean values by choosing multiplicative deviations at random from a lognormal distribution,

$$R_y = \bar{R}_y \exp(\epsilon_y). \tag{4}$$

Here ϵ_y was drawn from a normal distribution with mean 0 and standard deviation σ_R, where σ_R is the standard deviation from the relevant MCB fit.

The procedure generated 20,000 replicate projections of MCB model fits drawn at random (with replacement) from the MCB runs. In cases where the same MCB run was drawn, projections would still differ as a result of stochasticity in projected recruitment streams. Central tendencies were represented by the deterministic projections of the base run, as well as by medians of the stochastic projections. Precision of projections was represented graphically by the 10^{th} and 90^{th} percentiles of the replicate projections.

3.30 Rebuilding time frame

Based on results from the previous SEDAR24 benchmark assessment, Red Snapper is currently under a rebuilding plan. In this plan, the terminal year is 2044, and rebuilding is defined by the criterion that projection replicates achieve stock recovery (i.e., $\mathrm{SSB}_{2044} \geq \mathrm{SSB}_{\mathrm{F30\%}}$) with probability of at least 50%. Here, the probability of stock recovery in each year of the rebuilding plan was computed as the proportion of stochastic projections where $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{F30\%}}$, with $\mathrm{SSB}_{\mathrm{F30\%}}$ taken to be iteration-specific (i.e., from that particular MCB run).

Projection scenarios Five projection scenarios were considered.

- Scenario 1: $F = 0$
- Scenario 2: $F = F_{\text{current}}$
- Scenario 3: $F = F_{30\%}$
- Scenario 4: $F_{target} = 98\% F_{30\%}$
- Scenario 5: $F = F_{\text{rebuild}}$, with rebuilding probability of 0.5 in 2044
- Scenario 6: Discards only

The F_{current} is represented by the geometric mean of fishing mortalities from 2012-2014. The F_{rebuild} is defined as the maximum F that achieves rebuilding in the allowable time frame. The discards only scenario treated the initialization year 2016 the same as 2015 (discards only), and then applied the mean F (from 2015-2016) forward starting in 2017.

3.31 Surplus Production Model

3.31.1 Overview

A logistic surplus production model, implemented in ASPIC (Version 7.03; Prager 2005), was used to estimate stock status of Red Snapper off the southeastern U.S. While primary assessment of the stock was performed using the age-structured BAM, the surplus production approach was intended as a complement, for additional comparison with the age-structured model's results. More specifically, this model focuses on the dynamics of the removals as they relate to the indices of abundance, while ignoring any age data or age-structure in the population.

3.31.2 Data Sources

Data sources supplied to a production model include a time series of removals (i.e. landings plus dead discards) and one or more indices of abundance (i.e. catch per unit of effort). These inputs should be in units of biomass (i.e. weight), therefore some of the data developed at the SEDAR41 DW required additional formatting. These changes are detailed below.

Removals

The available removals time series comprised commercial landings (1950-2014), recreational landings (1955-2014), commercial dead discards (1992-2014), and recreational dead discards (1981-2014), in pounds, summed by year.

Commercial Landings

The SEDAR41 DW reported commercial landings in pounds, thus these data did not need to be modified for the production model.

Recreational landings

During the SEDAR41 DW, recreational landings for the historical period (1955-1980) were estimated in numbers of individuals using the The National Survey of Fishing, Hunting, and Wildlife-Associated Recreation Survey (FHWAR) census method (see SEDAR41-DW17). For the contemporary period (1981-2014), the SEDAR-41 DW reported Southeast Region Headboat Survey (SRHS) and Marine Recreational Information Program (MRIP) recreational landings in numbers and weights. Recreational landings from this period did not need to be modified, but were used to convert historical landings to weight.

Following a similar approach used in SEDAR24, recreational landings in weight and numbers for all fleets were combined by year for the first three years of the contemporary period; dividing annual landings in weight by landings in numbers produced annual mean weight estimates. The average of these three mean weights (3.4 lb) was then multiplied by the historical landings in numbers to convert them to weight. The historical and combined contemporary recreational landings series were then joined to produce a single time series of recreational landings, in pounds.

Dead Discards

Discard estimates were generated in numbers at the SEDAR-41 DW. Since many discarded fish survive after release, discard mortality rates were applied to discards in numbers to calculate dead discards. For commercial discards, a discard mortality rate of 0.48 was applied prior to regulations in 2007, and a rate of 0.38 was applied from 2007 onward. For recreational discards, a discard mortality rate of 0.37 was applied prior to regulations in 2011, and a rate of 0.285 was applied from 2011 onward.

Mean weight of commercial discards was estimated by converting lengths of commercial discards to weights using data and a conversion equation supplied by the SEDAR-41 DW, and then calculating the average weight of these individuals. The data on lengths of commercial discards were divided into two time periods before (2007-2009) and after (2010-2013) the fishery was closed. The average estimated weights of commercial discards from each time period (before = 2.93 lb; after = 8.84 lb) were multiplied by discards in numbers, for years before and after the closure, respectively.

Mean weight of recreational discards was estimated by converting lengths of recreational headboat-at-sea observer discards to weights using data and a conversion equation supplied by the SEDAR-41 DW, and then calculating the average weight of these individuals. Year-specific mean weight estimates were multiplied by recreational discards in numbers for corresponding years when available (2005-2014). For years prior to 2005 where year-specific mean weights were not available, discards in numbers were multiplied by the average mean weight across the available years before the 2010 closure (1.96 lb).

Indices of Abundance

Five indices of abundance were produced by the SEDAR-41 DW for Red Snapper: commercial logbook handline index (hereafter commercial handline; units = lb kept per hook-hour), headboat (number of fish kept per angler), headboat-at-sea-observer (number of fish caught $<20''$ per angler), Southeast Reef Fish Survey (SERFS) chevron trap (number of fish caught per trap), and the SERFS video (number of fish observed per video). The commercial handline index was already in weight and did not need to be converted. The headboat index was converted to pounds by multiplying by year-specific mean weights, generated by dividing headboat landings in pounds by landings in numbers for each year. The headboat-at-sea-observer index was converted to pounds by multiplying by the same mean weights used to convert recreational discards to weight. The SERFS chevron trap and video indices were converted to weights by multiplying by year-specific mean weights calculated from combined recreational (headboat and MRIP) landings in weight divided by landings in numbers.

3.31.3 Model Configuration and Equations

Production modeling used the model formulation and ASPIC software (version 7.03) of Prager (1994; 2005). This is an observation-error estimator of the continuous-time form of the Schaefer (logistic) production model (Schaefer 1954; 1957). Estimation was conditioned on catch. The logistic model for population growth is the simplest form of a differential equation which satisfies a number of ecologically realistic constraints, such as a carrying capacity (a consequence of limited resources). When written in terms of stock biomass, this model specifies that

$$\frac{dB_t}{dt} = rB_t - \frac{r}{K}B_t^2 \tag{5}$$

where B_t is biomass in year t, r is the intrinsic rate of increase in absence of density dependence, and K is carrying capacity (Schaefer 1954; 1957). This equation may be rewritten to account for the effects of fishing by introducing an instantaneous fishing mortality term, F_t :

$$\frac{dB_t}{dt} = (r - F_t)B_t - \frac{r}{K}B_t^2 \tag{6}$$

By writing the term F_t as a function of catchability coefficients and effort expended by fishermen in different fisheries, Prager (1994) showed how to estimate model parameters from time series of yield and effort.

For Red Snapper, the model proved difficult to fit. It was configured using various combinations of removals, indices, starting dates, prior distributions and starting values, resulting in approximately 324 configurations. Many of these runs were completed during early model development but many others incorporated small changes to data inputs or model specifications suggested by AW panel members during the Assessment Workshop. As the BAM developed, most of these runs became obsolete and are not presented here. The run configured according to recommendations by the SEDAR41 AW panel is presented here. This model configuration (run 320) contained removals from 1950 to 2014 and the four indices used in the BAM (Comm, HB, HB-at-sea, CVID) from 1976 to 2014. Following the recommendations of the AW panel, the CVID index was upweighted by a factor of three (i.e. CVs divided by three), and the headboat-at-sea index was shifted forward by one year, since it indexes younger fish than the other indices.

Three other runs (318, 319, and 323) are also presented to relate the main run (320) to ASPIC results from the previous Red Snapper assessment (SEDAR 24). All three runs contain only the commercial and headboat indices, starting in 1993 and 1976 respectively, and removals starting in 1950. But in run 318 (the continuity run), the final year of removals and indices is 2009, as in SEDAR 24, while in run 319 (the updated continuity run) the final year of removals and indices is 2014, as in the BAM for the current assessment. Since both the commercial and headboat indices ended in 2009 the only difference between the continuity run and updated continuity run is the removals estimates from 2010-2014. Finally a run was completed (run 323; best configuration $\frac{B_1}{K}$ fixed) that is identical to the best configuration run, but with $\frac{B_1}{K}$ fixed at the estimate for the continuity run, for reasons described below.

To evaluate the uncertainty in the model fit and parameter estimates of the best configuration run, 1000 bootstrap runs were conducted. Percentile confidence intervals were also calculated for parameters.

4 Stock Assessment Results

4.1 Measures of Overall Model Fit

In general, the Beaufort assessment model (BAM) fit well to the available data. Predicted length compositions from the commercial handline and discards from the commercial and headboat fleets were reasonably close to observed data in most years, as were predicted age compositions (Figure 3). The model was configured to fit observed commercial and recreational removals closely (Figures 4–9). Fits to indices of abundance generally captured the observed trends but not all annual fluctuations (Figures 10–13).

4.2 Parameter Estimates

Estimates of all parameters from the catch-age model are shown in Appendix B. Estimates of management quantities and some key parameters are reported in sections below.

4.3 Stock Abundance and Recruitment

In general, estimated abundance at age showed truncation of the older ages through most of the assessment period, but with some signs of increase during the last decade (Figure 14; Table 7). Total estimated abundance was at its lowest value in the early 1990s, but near its highest levels at the end of the time series, comparable to those in the early 1970s, but with a more truncated age structure. The MCB results reflect the same patterns with their associated uncertainties for total abundance and abundance of age 2+ (Figure 18). Annual number of recruits is shown in Table 7 (age-1 column) and in Figure 15. The highest recruitment values were predicted to have occurred in the mid-1980s, 2006, and the terminal year of the model (2014).

4.4 Total and Spawning Biomass

Estimated biomass at age followed a similar pattern as abundance at age (Figure 16; Table 9). Total biomass and spawning biomass showed similar trends—general decline through to the early-1990s, and relatively stable or slowly increasing patterns since the mid-1990s (Figure 17; Table 10). Terminal year estimates are at levels not seen since the 1970s.

4.5 Selectivity

Selectivity of the SERFS index is shown in Figure 19, and selectivities of landings from commercial and recreational fleets are shown in Figures 20, 21, and 22. Selectivities of discards from commercial and recreational fleets are shown in Figures 23, 24, and 25. In the most recent years, full selection occurred near ages 2–4, depending on the fleet and time block.

Average selectivities of landings, dead discards, and the total weighted average of all selectivities were computed from F-weighted selectivities in the most recent three assessment years (Figure 26). This average selectivity was used in computation of point estimates of benchmarks, as well as in projections. All selectivities from each time block, including average selectivities, are tabulated in Tables 11, 12, and 13.

4.6 Fishing Mortality and Removals

Estimates of total F at age are shown in Table 15. In any given year, the maximum F at age (i.e., apical F) may be less than that year's sum of fully selected Fs across fleets. This inequality is due to the combination of two features of estimated selectivities: full selection occurs at different ages among gears and several sources of mortality have dome-shaped selectivity.

Estimated time series of landings and discards are shown in Tables 18, 19, 20, 21. Table 16 shows total landings at age in numbers, and Table 17 in weight. Landings have been dominated by the general recreational and commercial handline fleet until recent years when the general recreational fleet became the dominant source of removals (Tables 18 and 19). Also since 2010, total landings remained below the level at $L_{\mathrm{F30\%}}$ (Figure 29).

Estimated discard mortalities occurred on a smaller scale than landings until the implementation of regulations and the use of mini-seasons, and have been above the $D_{F_{30\%}}$ level for most of the moratorium years (Tables 20 and 21, and Figure 30).

4.7 Spawner-Recruitment Parameters

The Beverton–Holt spawner-recruit curve is shown in Figure 31, along with the effect of density dependence on recruitment, depicted graphically by recruits per spawner as a function of spawning stock (1E8 Eggs). Values of recruitment-related parameters were as follows: steepness $h = 0.99$ (fixed), unfished age-1 recruitment $\widehat{R_0} = 330503$, and standard deviation of recruitment residuals in log space $\widehat{\sigma}_R = 0.79$ (which resulted in bias correction of $\varsigma = 1.37$). Uncertainty in these quantities was estimated through the MCB analysis (Figure 32).

4.8 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F. These computations applied the most recent selectivity patterns averaged across fleets, weighted by F from the last three years (2012–2014) (Figures 33 and 34).

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of F (Figure 35). $F_{30\%}$ is used as a proxy for MSY, and the corresponding landings and spawning biomass are $L_{\mathrm{F30\%}}$ and $\mathrm{SSB}_{\mathrm{F30\%}}$.

4.9 Benchmarks / Reference Points

As described in §3.23, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the spawner-recruit curve with fixed steepness $h = 0.99$ (Figure 31). Reference points estimated were $F_{30\%}$, $L_{\mathrm{F30\%}}$, $B_{\mathrm{F30\%}}$ and $\mathrm{SSB}_{\mathrm{F30\%}}$. Based on $F_{30\%}$, three possible values of F at optimum yield (OY) were considered—$F_{\mathrm{OY}} = 65\% F_{30\%}$, $F_{\mathrm{OY}} = 75\% F_{30\%}$, and $F_{\mathrm{OY}} = 85\% F_{30\%}$—and for each, the corresponding yield was computed. Standard errors of benchmarks were approximated as those from MCB analysis (§3.24).

Maximum likelihood estimates (base run) of benchmarks, as well as median values from MCB analysis, are summarized in Table 22. Point estimates of $L_{\mathrm{F30\%}}$-related quantities were $F_{30\%} = 0$ (y^{-1}), $L_{\mathrm{F30\%}} = 459$ (1000 lb), $B_{\mathrm{F30\%}} = 3693$ (mt), and $\mathrm{SSB}_{\mathrm{F30\%}} = 329948$ (1E8 Eggs). Median estimates were $F_{30\%} = 0$ (y^{-1}), $L_{\mathrm{F30\%}} = 450$ (1000 lb), $B_{\mathrm{F30\%}} = 3628$ (mt), and $\mathrm{SSB}_{\mathrm{F30\%}} = 299651$ (1E8 Eggs). Distributions of these benchmarks from the MCB analysis are shown in Figure 36.

4.10 Status of the Stock and Fishery

Estimated time series of stock status $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{F30\%}}$ showed general decline throughout the beginning of the assessment period, a leveling off, and then a modest increase since 2010 (Figure 37, Table 10). Base-run estimates of spawning biomass have remained below the threshold (MSST) since the early-1970s. Current stock status was estimated in the base run to be $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{F30\%}} = 0$ (Table 22), indicating that the stock has not yet recovered to $\mathrm{SSB}_{\mathrm{F30\%}}$. Median values from the MCB analysis indicated similar results $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{F30\%}} = 0$. The uncertainty analysis suggested that the terminal estimate of stock status is robust (Figures 38, 39). Of the MCB runs, 100% indicated that the stock was below $\mathrm{SSB}_{\mathrm{F30\%}}$ in 2012. Age structure estimated by the base run generally showed fewer older fish than the (equilibrium) age structure expected at $L_{\mathrm{F30\%}}$, but it also showed increases since 2006.

The estimated time series of $F/F_{30\%}$ suggests that overfishing has occurred throughout most of the assessment period (Table 10, Figure 37). Current fishery status in the terminal year, with current F represented by the geometric mean from 2012–2014, was estimated by the base run to be $F/F_{30\%} = 3$ (Table 22). The fishery status was also robust (Figures 38, 39). Of the MCB runs, approximately 99.5% agreed with the base run that the stock is currently experiencing overfishing.

4.11 Sensitivity and Retrospective Analyses

Sensitivity runs, described in §3.3, were used for exploring data or model issues that arose during the assessment process, for evaluating implications of assumptions in the base assessment model, and for interpreting MCB results in terms of expected effects of input parameters. In some cases, sensitivity runs are simply a tool for better understanding model behavior, and therefore all runs are not considered equally plausible in the sense of alternative states of nature. Time series of $F/F_{30\%}$ and $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{F30\%}}$ are plotted to demonstrate sensitivity to the changing conditions in each run. The sensitivity of the base run to changes in natural mortality, steepness, dome-shaped selectivity for the commercial handline fleet, various index adjusts for both the fishery dependent indices and fishery independent index, the use of an ageing error matrix and high and low levels of landings and discards was explored (Figures 40–52). Sensitivity 24 is a version of a continuity run in that various assumptions made about parameters for SEDAR 24 were adopted for this sensitivity (e.g. higher discard mortalities, lower M, using gonad weight as a proxy for SSB, different female maturity and fecundity information, higher max age, lower steepness, different time of year for peak spawning, and fixed recruitment standard deviation). Time series of stock and fishery status estimated by this assessment are similar to those from the previous, SEDAR24 assessment (Figure 53). Trends in $F/F_{30\%}$ from the two assessments generally track each other, though the magnitude of the variations differ. Trends in $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{F30\%}}$ track each other, though there is divergence at the end of the time series where the current model estimates a more optimistic stock status.

None of the sensitivities show a recovered stock in 2014. A couple sensitivities suggest the stock is undergoing less overfishing than is estimated in the base. However, those runs eliminate the fishery independent index entirely, or upweight the fishery dependent indices to the point of swamping out any signal from the survey data. The vast majority of runs agree with the status indicated by the base run (Figure 54, Table 23). Results appeared to be most sensitive to natural mortality and steepness.

Retrospective analyses suggest a pattern of overestimating fishing mortality in the terminal year, however, the trend is less apparent for SSB (Figure 55).

4.12 Projections

Projections based on $F = 0$ allowed the spawning stock to grow such that the majority of replicate projections recovered to $\mathrm{SSB}_{\mathrm{F30\%}}$ by 2025 (Figure 56, Table 24), however the stock is already in a rebuilding plan so other projections were also requested in the TORs. This was not the case for projections based on $F = F_{\mathrm{current}}$ (Figure 57, Table 25), or if the fishing rate were reduced to $F_{30\%}$ (Figure 58, Table 26) or F_{target} (Figure 59, Table 27). By design, projections based on $F = F_{\mathrm{rebuild}}$ showed recovery with the desired probability in 2044 (Figure 60, Table 28). The projection with discard mortality only showed similar trajectories to the run assuming no other fishing mortality(Table 29 and Figure 61).

4.13 Surplus Production Model

4.13.1 Model Fit

For the best configuration run, model predictions underestimated observed values for the headboat index for the first ten years of the time series (1976-1985; Figure 62). They also underestimated the commercial index during the first five years of that series (1993-1997), while overestimating the headboat index for those same years. The model provided a very poor fit to the headboat-at-sea discard index (2006-2014) but produced a much better fit to the upweighted CVID index (2005-2014). The model did not fit high index values in 2008 and 2009 very closely, but predicted a slight decline from 2007-2009 followed by an increasing trend from 2010 to 2014.

4.13.2 Parameter Estimates and Uncertainty

The ASPIC model fits three main parameters ($\frac{B_1}{K}$, MSY, and F_{MSY}) as well as catchability coefficients (q_i) for each index i. Several other parameters can then be derived from these estimates: $r = 2F_{MSY}$, $K = \frac{2MSY}{F_{MSY}}$ and $B_{MSY} = \frac{K}{2}$. Recent status indicators $\frac{F}{F_{MSY}}$ and $\frac{B}{B_{MSY}}$ are calculated with the most recent estimates of F (2014) and B (2015). Estimates of the main parameters and recent status indicators for all four runs are presented in Table 30. Prior distributions and model estimates of the main parameters for the best configuration run are presented in Figure 63.

Across all runs, most of the main parameters varied very little (e.g. CV $MSY = 0.0027$; CV $F_{MSY} = 0.014$). By contrast $\frac{B_1}{K}$ varied widely (CV $\frac{B_1}{K} = 0.74$), due to variation in B_1 (CV $B_1 = 0.74$) rather than K (CV $K = 0.013$; Table 30). Among bootstrap runs based on the best configuration, distributions of $\frac{B_1}{K}$, MSY, and F_{MSY} were unimodal and relatively symmetrical (Figure 64).

4.13.3 Status of the Stock and Fishery

In the current best configuration run of the surplus production model, $\frac{B}{B_{MSY}}$ is greater than one, suggesting that the South Atlantic stock of Red Snapper is not overfished. The 95% bootstrap percentile confidence intervals for $\frac{B}{B_{MSY}}$ do not contain one (Figure 64). Since the surplus production model estimates that $\frac{F}{F_{MSY}}$ is less than one, the stock is considered to not be undergoing overfishing (Table 30; Figure 65). The 95% bootstrap percentile confidence intervals for $\frac{F}{F_{MSY}}$ do not contain one (Figure 64).

4.13.4 Interpretation

Status indicators in the continuity run (318), agree with the surplus production model from SEDAR 24 that South Atlantic Red Snapper were overfished and undergoing overfishing in 2009 (Table 30). However, in the updated continuity run (319), which is identical to the continuity run except for the 2010-2014 addition of landings data from 2010-2014, the surplus production model suggests that the stock is no longer overfished or undergoing overfishing. Despite several differences between the updated continuity run and the best configuration run (320), described above, most of the parameter estimates and status indicators are similar (Table 30). However the model estimate of $\frac{B_1}{K}$ is much lower in the best configuration run, driven by a lower estimate of B_1. After observing this difference, run 323 was configured by taking the best configuration run and fixing $\frac{B_1}{K}$ at the estimate from the continuity run to investigate potential influence. Fixing $\frac{B_1}{K}$ at this much lower value had little effect on status or most parameters, but caused the estimate of B_1 to go much lower.

As described above, the only data that go into a surplus production model are biomass of removals and abundance indices. Therefore such a model does not make use of many other sources of information such as sex, maturity, growth, fecundity, or population age and size structure. Because such data are available for Red Snapper, a model that uses them would be preferred for a detailed assessment on which to base management.

5 Discussion

5.1 Comments on the Assessment

Estimated benchmarks played a central role in this assessment. Values of $\text{SSB}_{\text{F30\%}}$ and $F_{30\%}$ were used to gauge the status of the stock and fishery to be consistent with established definitions of $MFMT$ and the existing rebuilding plan. The computation of the benchmarks was conditional on selectivity. If selectivity patterns change in the future, for example as a result of new size limits or different relative catch allocations among sectors, estimates of benchmarks would likely change as well.

The base run of the BAM indicated that the stock remains overfished $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{F30\%}}$ =0, and that overfishing is occurring $F/F_{30\%}$ =3, though at a lower rate than in 2009 (F/F_{MSY} =4.12 for SEDAR 24). Median values from the MCB analyses were in qualitative agreement with those results. This assessment estimates that, since 2010, the stock has been increasing at a modest rate and is now at levels not seen since the 1970s.

In addition to including the more recent years of data, this benchmark assessment contained several modifications to the previous data of SEDAR24, such as the use of APAIS-adjusted MRIP estimates instead of MRFSS, a new method for the reconstruction of historic recreational catch, the inclusion of a new fishery-independent survey, and the corresponding age composition data. Furthermore, life-history information was updated, including female maturity, sex ratio, growth, natural mortality, fecundity, and meristics. The assessment model itself was also modernized to the current version of BAM. The sum of these improvements should result in a more robust assessment.

In general, fishery dependent indices of abundance may not track actual abundance well, because of factors such as hyperdepletion or hyperstability. Furthermore, this issue can be exacerbated by management measures. In this assessment, the commercial handline and headboat indices generated from logbook data, were not extended beyond 2009 because of the moratorium on Red Snapper. In general, management measures in the southeast U.S. have made the continued utility of fishery dependent indices will be questionable. This situation amplifies the importance of fishery independent sampling and sampling programs conducted by the states.

Many assessed stocks in the southeast U.S. have shown histories of heavy exploitation. High rates of fishing mortality can lead to adaptive responses in life-history characteristics, such as growth and maturity schedules. Such adaptations can affect expected yield and stock recovery, and thus resource managers might wish to consider possible evolutionary effects of fishing in their management plans (Dunlop et al. 2009; Enberg et al. 2009). Indeed, Red Snapper have a very young age at maturity relative to their maximum lifespan, and some have hypothesized that this may be an adaptive response to exploitation.

Because steepness could not be estimated reliably in this assessment, its value in the base run was fixed at 0.99. Fixing steepness at its upper bound was not meant to imply that the stock has perfect compensation at any exploitation or stock level. Rather, it was a computational convenience to use the stock recruitment curve with $h = 0.99$ in order to treat recruitment as an average through time while estimating deviations around that average. Thus MSY-based management quantities are not appropriate, and the AW Panel provided the proxy of $F_{30\%}$ as was used for management subsequent to the last assessment.

The assessment start year was 1950, so as to include the period of largest landings. To initialize the model in 1950, the initial age structure was assumed to be in equilibrium, based on natural mortality at age and F_{init}. Average recruitment was assumed until the recruitment deviations could be estimated at the onset of the composition data (1978). These assumptions are common in assessment models, and they were tested with sensitivity runs where the start was 1978 and with different values of F_{init}. The end results were qualitatively similar, which indicates that the base run is not sensitive to these assumptions.

A complementary analysis was conducted using a surplus production model (ASPIC). ASPIC treats the stock as a pooled biomass and ignores the age structure in the population and the landings. It is unable to take into account that different ages are differentially vulnerable to fishing and therefore was not able to incorporate the (time-varying) selectivities used in the BAM. ASPIC is also not able to take into account that the reproductive contribution of this species increases with age or that there is variability in recruitment through time. ASPIC is useful in examining the relationship between removals and the indices. However, for a long-lived species with age-based data available, the catch-age model (BAM) provides the best illustration of the stock and is a better indicator of stock status, because it can account for the age structure of the population and landings and for year-class strength.

5.2 Comments on the Projections

Projections should be interpreted in light of the model assumptions and key aspects of the data. Some major considerations are the following:

- In general, projections of fish stocks are highly uncertain, particularly in the long term (e.g., beyond 5–10 years).
- Although projections included many major sources of uncertainty, they did not include structural (model) uncertainty. That is, projection results are conditional on one set of functional forms used to describe population dynamics, selectivity, recruitment, etc.
- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect projection results.
- The first five scenarios of projections assumed no change in the selectivity applied to discards. As stock increase generally begins with the smallest size classes, management action may be needed to meet that assumption.
- The projections assumed that the assumed spawner-recruit relationship applies in the future and that past deviations represent future uncertainty in recruitment. If future recruitment is characterized by runs of large or small year classes, possibly due to environmental or ecological conditions, stock projections may be affected.
- Projections apply the Baranov catch equation to relate F and landings using a one-year time step, as in the assessment. The catch equation implicitly assumes that mortality occurs throughout the year. This assumption is violated when seasonal closures or small intensive fishing seasons are in effect, introducing additional and unquantified uncertainty into the projection results.

5.3 Research Recommendations

- Increased fishery independent information, particularly maintaining reliable indices of abundance and composition data streams
- Red Snapper were modeled in this assessment as a unit stock off the southeastern U.S. For any stock, variation in exploitation and life-history characteristics might be expected at finer geographic scales. Modeling such sub-stock structure would require more data, such as information on the movements and migrations of adults and juveniles, as well as spatial patterns of larval dispersal and recruitment. In addition, it is unclear whether a spatial model would improve the assessment.
- More research to describe the juvenile life history of Red Snapper is needed, including more work to identify the location of juveniles before they recruit to the fishery.
- The effects of environmental variation on the changes in recruitment or survivorship.
- The Florida sampling program, during the miniseason in particular, provided invaluable data to this assessment. Programs such as these would be useful in all South Atlantic states, particularly if the management regulations continue to make established methods of index development or composition sampling from fleets less regular or possible.

6 References

Baranov, F. I. 1918. On the question of the biological basis of fisheries. Nauchnye Issledovaniya Ikhtiologicheskii Instituta Izvestiya **1**:81–128.

Beddington, J. R., and J. G. Cooke, 1983. The potential yield of fish stocks. FAO Fish. Tech. Pap. 242, 47 p.

Charnov, E. L., H. Gislason, and J. G. Pope. 2013. Evolutionary assembly rules for fish life histories. Fish and Fisheries **14(2)**:213–224.

Conn, P. B. 2010. Hierarchical analysis of multiple noisy abundance indices. Canadian Journal of Fisheries and Aquatic Sciences .

Conn, P. B., E. H. Williams, and K. W. Shertzer. 2010. When can we reliably estimate the productivity of fish stocks? Canadian Journal of Fisheries and Aquatic Sciences **67**:511–523.

Dunlop, E. S., K. Enberg, C. Jorgensen, and M. Heino. 2009. Toward Darwinian fisheries management. Evolutionary Applications **2**:245–259.

Efron, B., and R. Tibshirani. 1993. An Introduction to the Bootstrap. Chapman and Hall, London.

Enberg, K., C. Jorgensen, E. S. Dunlop, M. Heino, and U. Dieckmann. 2009. Implications of fisheries-induced evolution for stock rebuilding and recovery. Evolutionary Applications **2**:394–414.

Fitzhugh, G. R., K. W. Shertzer, G. T. Kellison, and D. M. Wyanski. 2012. Review of size- and age dependence in batch spawning: implications for stock assessment of fish species exhibiting indeterminate fecundity. Fishery Bulletin pages 413–425.

Fournier, D. A., H. J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optimization Methods and Software **27**:233–249.

Francis, R. 2003. Quantifying annual variation in catchability for commercial and research fishing. Fishery Bulletin **101**:293–304.

Francis, R. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences **68**:1124–1138.

Gabriel, W. L., and P. M. Mace, 1999. A review of biological reference points in the context of the precautionary approach. NOAA Technical Memorandum-F/SPO-40.

Legault, C. M., J. E. Powers, and V. R. Restrepo. 2001. Mixed Monte Carlo/bootstrap approach to assessing king and Spanish mackerel in the Atlantic and Gulf of Mexico: Its evolution and impact. Amercian Fisheries Society Symposium **24**:1–8.

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**:627–642.

Manly, B. F. J. 1997. Randomization, Bootstrap and Monte Carlo Methods in Biolog, 2nd edition. Chapman and Hall, London.

Mertz, G., and R. Myers. 1996. Influence of fecundity on recruitment variability of marine fish. Canadian Journal of Fisheries and Aquatic Sciences **53**:1618–1625.

Methot, R. D. 1989. Synthetic estimates of historical abundance and mortality for northern anchovy. American Fisheries Society Symposium **6**:66–82.

Methot, R. D., 2009. User Manual for Stock Synthesis, Model Version 3.04. NOAA Fisheries, Seattle, WA.

Mitchell, W. A., G. T. Kellison, N. M. Bacheler, J. C. Potts, C. M. Schobernd, and L. Hale. 2014. Depth-related distribution of postjuvenile Red Snapper in southeastern U.S. Atlantic Ocean waters: ontogenic patters and implications for management. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science **6**:142–155.

Patterson, W. F., C. E. Porch, J. H. Tarnecki, and A. J. Strelcheck. 2012. Effect of circle hook size on reef fish catch rates, species composition, and selectivity in the northern Gulf of Mexico recreational fishery. Bulletin of Marine Science **88**:647–665.

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

Prager, M. H., 2005. User's Manual for ASPIC: A Stock-Production Model Incorporating Covariates (ver. 5) And Auxiliary Programs. National Marine Fishery Service, Beaufort Laboratory Document BL-2004-01, Beaufort, NC.

Quinn, T. J., and R. B. Deriso. 1999. Quantitative Fish Dynamics. Oxford University Press, New York, New York.

Restrepo, V. R., J. M. Hoenig, J. E. Powers, J. W. Baird, and S. C. Turner. 1992. A simple simulation approach to risk and cost analysis, with applications to swordfish and cod fisheries. Fishery Bulletin **90**:736–748.

Schaefer, M. B. 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. Bulletin of the Inter-American Tropical Tuna Commission **1**:27–56.

Schaefer, M. B. 1957. A study of the dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. Bulletin of the Inter-American Tropical Tuna Commission **2**:247–268.

SEDAR Procedural Guidance, 2010. SEDAR Procedural Workshop IV: Characterizing and Presenting Assessment Uncertainty.

SEDAR19, 2009. SEDAR 19: South Atlantic Red Grouper. SEDAR, North Charleston, SC.

SEDAR24, 2010. SEDAR 24: South Atlantic Red Snapper. SEDAR, North Charleston, SC.

SEDAR4, 2004. SEDAR 4: Stock assessment of the deepwater snapper-grouper complex in the South Atlantic. SEDAR, North Charleston, SC.

SEDAR41-AW05, 2015. Commercial age and length composition weightings for Atlantic red snapper (Lutjanus campechanus).

SEDAR41-AW08, 2015. South Atlantic U.S. Atlantic red snapper (Lutjanus campechanus) catch curve analysis.

SEDAR41-DW49, 2015. Estimating annual fecundity of Red Snapper by size using nonlinear models. SEDAR41-DW49. SEDAR, North Charleston, SC.

Shertzer, K. W., M. H. Prager, D. S. Vaughan, and E. H. Williams, 2008. Fishery models. Pages 1582–1593 *in* S. E. Jorgensen and F. Fath, editors. Population Dynamics. Vol. [2] of Encyclopedia of Ecology, 5 vols. Elsevier, Oxford.

Then, A. Y., J. M. Hoenig, N. G. Hall, and D. A. Hewitt. 2014. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES Journal of Marine Science **72**:82–92.

Wells, R. D., K. M. Boswell, J. H. Cowan Jr., and W. F. Patterson. 2008. Size selectivity of sampling gears targeting red snapper in the northern Gulf of Mexico. Fisheries Research **89**:294–299.

Williams, E. H., and K. W. Shertzer, 2015. Technical documentation of the Beaufort Assessment Model (BAM). NOAA Technical Memorandum-NMFS-SEFSC-671.

7 Tables

Table 1. Life-history characteristics at age, including average body total length (TL) and weight (mid-year), proportion female, annual proportion females mature, and natural mortality at age. The CV of length was estimated by the assessment model; other values were treated as input.

Age	Avg. TL (mm)	Avg. TL (in)	CV length	Avg. Whole weight (kg)	Avg. Whole weight (lb)	Fem. maturity	Proportion Female	Nat. mortality
1	323.9	12.8	0.11	0.53	1.17	0.43	0.5	0.595
2	449.3	17.7	0.11	1.41	3.10	0.73	0.5	0.364
3	547.9	21.6	0.11	2.55	5.62	0.91	0.5	0.271
4	625.4	24.6	0.11	3.78	8.34	0.97	0.5	0.222
5	686.4	27.0	0.11	5.00	11.02	0.99	0.5	0.193
6	734.4	28.9	0.11	6.12	13.49	1.00	0.5	0.174
7	772.2	30.4	0.11	7.11	15.67	1.00	0.5	0.162
8	801.9	31.6	0.11	7.96	17.54	1.00	0.5	0.153
9	825.2	32.5	0.11	8.67	19.12	1.00	0.5	0.146
10	843.6	33.2	0.11	9.26	20.42	1.00	0.5	0.142
11	858.1	33.8	0.11	9.74	21.48	1.00	0.5	0.138
12	869.4	34.2	0.11	10.13	22.34	1.00	0.5	0.135
13	878.4	34.6	0.11	10.45	23.04	1.00	0.5	0.133
14	885.4	34.9	0.11	10.70	23.59	1.00	0.5	0.132
15	891.0	35.1	0.11	10.90	24.04	1.00	0.5	0.130
16	895.3	35.2	0.11	11.06	24.39	1.00	0.5	0.129
17	898.7	35.4	0.11	11.19	24.67	1.00	0.5	0.129
18	901.4	35.5	0.11	11.29	24.89	1.00	0.5	0.128
19	903.5	35.6	0.11	11.37	25.07	1.00	0.5	0.128
20	905.2	35.6	0.11	11.43	25.21	1.00	0.5	0.127

Table 2. Size (TL) in inches and weight in pounds (lb) at age as applied to the population (Pop), fishery–dependent portion of the population (FD), and fishery–dependent portion of the population during the 20 mm size limit (FD20). The CV of length was estimated by the assessment model; other values were treated as input through the von Bertalanffy growth parameters.

Age	Pop.TL	CV.Pop.TL	Pop.lb	FD.TL	CV.FD.TL	FD.lb	FD20.TL	CV.FD20.TL	FD20.lb
1	12.8	0.11	1.2	11.2	0.14	0.8	16.2	0.1	2.4
2	17.7	0.11	3.1	16.2	0.14	2.4	19.5	0.1	4.1
3	21.6	0.11	5.6	20.2	0.14	4.6	22.2	0.1	6.1
4	24.6	0.11	8.3	23.4	0.14	7.2	24.5	0.1	8.2
5	27.0	0.11	11.0	26.0	0.14	9.8	26.5	0.1	10.3
6	28.9	0.11	13.5	28.1	0.14	12.3	28.1	0.1	12.4
7	30.4	0.11	15.7	29.7	0.14	14.7	29.5	0.1	14.3
8	31.6	0.11	17.5	31.1	0.14	16.7	30.6	0.1	16.0
9	32.5	0.11	19.1	32.1	0.14	18.5	31.6	0.1	17.6
10	33.2	0.11	20.4	33.0	0.14	20.0	32.5	0.1	19.0
11	33.8	0.11	21.5	33.7	0.14	21.3	33.2	0.1	20.3
12	34.2	0.11	22.3	34.2	0.14	22.4	33.7	0.1	21.4
13	34.6	0.11	23.0	34.7	0.14	23.3	34.2	0.1	22.4
14	34.9	0.11	23.6	35.0	0.14	24.0	34.7	0.1	23.2
15	35.1	0.11	24.0	35.3	0.14	24.6	35.0	0.1	23.9
16	35.2	0.11	24.4	35.6	0.14	25.0	35.3	0.1	24.5
17	35.4	0.11	24.7	35.7	0.14	25.4	35.6	0.1	25.1
18	35.5	0.11	24.9	35.9	0.14	25.8	35.8	0.1	25.5
19	35.6	0.11	25.1	36.0	0.14	26.0	36.0	0.1	25.9
20	35.6	0.11	25.2	36.1	0.14	26.2	36.1	0.1	26.2

Table 3. Observed time series of landings(L) and discards(D) for commercial lines (cH), headboat (HB), and general recreational (GR). Commercial landings are in units of 1000 lb whole weight. Recreational landings and discards and commercial discards are in units of 1000 fish. Confidential data have been redacted.

Year	cH.L	HB.L	GR.L	cH.D	HB.D	GR.D
1950	368.657	.	.	.	.	.
1951	499.765	.	.	.	.	.
1952	385.930	.	.	.	.	.
1953	398.279	.	.	.	.	.
1954	593.207	.	.	.	.	.
1955	493.315	12.501	24.035	.	.	.
1956	483.907	13.652	26.248	.	.	.
1957	867.291	14.803	28.460	.	.	.
1958	612.508	15.953	30.673	.	.	.
1959	657.736	17.104	32.885	.	.	.
1960	671.075	18.255	35.098	.	.	.
1961	796.374	19.908	38.276	.	.	.
1962	645.983	21.561	41.454	.	.	.
1963	488.789	23.214	44.633	.	.	.
1964	537.589	24.867	47.811	.	.	.
1965	558.108	26.520	50.989	.	.	.
1966	554.506	26.676	51.288	.	.	.
1967	725.503	26.831	51.587	.	.	.
1968	865.520	26.986	51.885	.	.	.
1969	538.190	27.142	52.184	.	.	.
1970	513.023	27.297	52.483	.	.	.
1971	457.393	29.995	57.670	.	.	.
1972	406.641	32.693	62.857	.	.	.
1973	296.560	35.391	68.044	.	.	.
1974	478.352	38.088	73.231	.	.	.
1975	600.790	40.786	78.418	.	.	.
1976	571.504	41.246	79.303	.	.	.
1977	596.339	41.707	80.187	.	.	.
1978	594.356	42.167	81.072	.	.	.
1979	420.936	42.627	81.957	.	.	.
1980	385.485	43.087	82.842	.	.	.
1981	378.759	36.031	93.458	.	.	1.641
1982	308.445	19.553	36.294	.	.	1.641
1983	316.818	30.698	68.469	.	.	1.641
1984	253.431	31.146	212.547	.	0.026	22.875
1985	250.824	50.336	288.971	.	0.041	23.713
1986	219.440	16.625	100.736	.	0.014	23.713
1987	191.701	24.996	47.373	.	0.020	23.713
1988	173.689	36.527	80.821	.	0.030	18.601
1989	266.942	23.453	97.147	.	0.019	7.172
1990	226.542	20.919	12.092	.	0.017	7.172
1991	143.546	13.857	34.717	.	0.011	7.172
1992	104.374	5.301	51.908	9.409	0.929	10.358
1993	220.153	7.347	11.326	8.028	1.287	25.215
1994	195.319	8.225	18.313	10.144	1.441	24.620
1995	177.312	8.826	13.482	10.113	1.546	18.829
1996	138.671	5.543	9.342	9.949	0.971	7.565
1997	110.595	5.770	34.238	10.748	1.011	6.132
1998	89.602	4.741	13.015	7.762	0.830	9.912
1999	93.595	6.836	39.579	6.548	1.197	60.203
2000	104.165	8.437	45.347	6.985	1.478	91.981
2001	196.697	12.028	31.587	7.268	2.107	74.986
2002	187.967	12.931	35.062	14.327	2.265	45.644
2003	138.342	5.706	25.977	4.019	0.999	58.952
2004	172.083	10.842	28.914	1.164	6.952	73.866
2005	129.700	8.907	29.443	4.885	3.654	26.956
2006	86.382	5.945	26.769	2.312	6.376	44.302
2007	114.973	6.889	17.646	5.236	26.598	106.662
2008	252.146	18.943	81.638	4.770	27.235	189.434
2009	362.386	21.507	54.666	5.497	21.211	88.991
2010	6.448	0.477	0.062	6.626	14.224	51.237
2011	− − −	− − −	0.062	15.241	11.796	9.543
2012	8.142	2.127	15.628	7.301	13.333	40.744
2013	31.600	1.520	7.588	7.335	13.321	23.938
2014	65.443	5.904	28.186	10.263	13.284	81.499

Table 4. Observed indices of abundance and CVs from commercial line (cH), headboat (HB), combined chevon trap and video (CVID), and headboat discard (HB.D).

Year	cH	cH CV	HB	HB CV	CVID	CVID CV	HB.D	HB.D CV
1976	.	.	2.37	0.2	.	.	.	.
1977	.	.	2.16	0.2	.	.	.	.
1978	.	.	2.13	0.2	.	.	.	.
1979	.	.	2.23	0.2	.	.	.	.
1980	.	.	1.45	0.2	.	.	.	.
1981	.	.	2.95	0.2	.	.	.	.
1982	.	.	1.20	0.2	.	.	.	.
1983	.	.	1.64	0.2	.	.	.	.
1984	.	.	1.42	0.2	.	.	.	.
1985	.	.	2.07	0.2	.	.	.	.
1986	.	.	0.48	0.2	.	.	.	.
1987	.	.	0.58	0.2	.	.	.	.
1988	.	.	0.56	0.2	.	.	.	.
1989	.	.	0.90	0.2	.	.	.	.
1990	.	.	0.87	0.2	.	.	.	.
1991	.	.	0.69	0.2	.	.	.	.
1992	.	.	0.08	0.2	.	.	.	.
1993	1.09	0.2	0.16	0.2	.	.	.	.
1994	0.89	0.2	0.26	0.2	.	.	.	.
1995	0.89	0.2	0.28	0.2	.	.	.	.
1996	0.61	0.2	0.25	0.2	.	.	.	.
1997	0.59	0.2	0.27	0.2	.	.	.	.
1998	0.66	0.2	0.24	0.2	.	.	.	.
1999	0.80	0.2	0.29	0.2	.	.	.	.
2000	0.74	0.2	0.41	0.2	.	.	.	.
2001	1.27	0.2	0.76	0.2	.	.	.	.
2002	1.38	0.2	0.88	0.2	.	.	.	.
2003	1.04	0.2	0.52	0.2	.	.	.	.
2004	1.42	0.2	0.76	0.2	.	.	.	.
2005	1.19	0.2	0.76	0.2	.	.	0.56	0.30
2006	0.60	0.2	0.43	0.2	.	.	0.41	0.37
2007	0.67	0.2	0.44	0.2	.	.	2.02	0.17
2008	1.22	0.2	1.71	0.2	.	.	1.39	0.21
2009	1.94	0.2	1.81	0.2	.	.	0.63	0.27
2010	.	.	.	.	0.90	0.26	0.56	0.30
2011	.	.	.	.	0.66	0.23	0.41	0.37
2012	.	.	.	.	1.10	0.18	2.02	0.17
2013	.	.	.	.	0.87	0.20	1.39	0.21
2014	.	.	.	.	1.47	0.17	0.63	0.27

Table 5. Sample sizes (number of trips) of length compositions (len) or age compositions (age) by survey or fleet. Data sources are commercial lines (cH), headboat (HB), headboat discard (HB.D), general recreational (GR),and MARMAP chevron trap (CVT).

Year	len.cH	len.cH.D	len.HB.D	age.cH	age.HB	age.GR	age.CVT
1978	.	.	.	.	80	.	.
1979	.	.	.	.	31	.	.
1980	.	.	.	.	30	.	.
1981	.	.	.	.	141	.	.
1982	.	.	.	.	55	.	.
1983	.	.	.	.	167	.	.
1984	125	.	.	.	166	.	.
1985	139	.	.	.	160	.	.
1986	94	.	.	.	97	.	.
1987	89	.	.	.	60	.	.
1988	84	.	.	.	.	.	.
1989	88	.	.	.	.	.	.
1990	63	.	.	11	23	.	.
1991	106	.	.	.	13	.	.
1992	82	.	.	11	.	.	.
1993	.	.	.	.	.	.	.
1994	.	.	.	14	.	.	.
1995	.	.	.	.	.	.	.
1996	.	.	.	48	.	.	.
1997	.	.	.	45	.	.	.
1998	.	.	.	14	.	.	.
1999	.	.	.	15	.	.	.
2000	.	.	.	28	.	.	.
2001	.	.	.	23	.	15	.
2002	.	.	.	.	.	84	.
2003	.	.	.	10	.	91	.
2004	.	.	.	25	.	83	.
2005	.	.	37	53	22	78	.
2006	.	.	29	84	49	26	.
2007	.	.	64	132	34	.	.
2008	.	.	61	158	47	.	.
2009	.	13	56	263	241	58	.
2010	.	.	50	.	.	.	73
2011	.	.	48	.	.	.	70
2012	.	.	56	39	40	121	148
2013	.	13	60	109	35	139	139
2014	.	.	56	64	49	315	150

Table 6. Coefficients of variation used for the MCB bootstraps of landings and discards. Commercial handline landings (cv.L.cH), headboat landings (cv.L.HB), general recreational landings (cv.L.GR), commercial handline discards (cv.D.cH), headboat discards (cv.D.HB), and general recreational discards (cv.D.GR).

Year	CV.L.cH	CV.L.HB	CV.L.GR	CV.D.cH	CV.D.HB	CV.D.GR
1950	0.25	–	–	–	–	–
1951	0.25	–	–	–	–	–
1952	0.25	–	–	–	–	–
1953	0.25	–	–	–	–	–
1954	0.25	–	–	–	–	–
1955	0.25	0.59	0.59	–	–	–
1956	0.25	0.59	0.59	–	–	–
1957	0.25	0.59	0.59	–	–	–
1958	0.25	0.59	0.59	–	–	–
1959	0.25	0.59	0.59	–	–	–
1960	0.25	0.59	0.59	–	–	–
1961	0.25	0.59	0.59	–	–	–
1962	0.20	0.59	0.59	–	–	–
1963	0.20	0.59	0.59	–	–	–
1964	0.20	0.59	0.59	–	–	–
1965	0.20	0.59	0.59	–	–	–
1966	0.20	0.59	0.59	–	–	–
1967	0.20	0.59	0.59	–	–	–
1968	0.20	0.59	0.59	–	–	–
1969	0.20	0.59	0.59	–	–	–
1970	0.20	0.59	0.59	–	–	–
1971	0.20	0.59	0.59	–	–	–
1972	0.20	0.59	0.59	–	–	–
1973	0.20	0.59	0.59	–	–	–
1974	0.20	0.59	0.59	–	–	–
1975	0.20	0.59	0.59	–	–	–
1976	0.20	0.59	0.59	–	–	–
1977	0.20	0.59	0.59	–	–	–
1978	0.10	0.59	0.59	–	–	–
1979	0.10	0.59	0.59	–	–	–
1980	0.10	0.59	0.59	–	–	–
1981	0.10	0.15	0.27	–	–	1.00
1982	0.10	0.15	0.34	–	–	1.00
1983	0.10	0.15	0.18	–	–	1.00
1984	0.10	0.15	0.22	–	0.20	0.56
1985	0.10	0.15	0.20	–	0.20	1.34
1986	0.05	0.15	0.29	–	0.20	1.00
1987	0.05	0.15	0.20	–	0.20	1.00
1988	0.05	0.15	0.28	–	0.20	1.33
1989	0.05	0.15	0.21	–	0.20	1.18
1990	0.05	0.15	0.29	–	0.20	1.00
1991	0.05	0.15	0.31	–	0.20	1.00
1992	0.05	0.15	0.19	0.20	0.20	0.79
1993	0.05	0.15	0.22	0.20	0.20	0.68
1994	0.05	0.15	0.27	0.20	0.20	0.81
1995	0.05	0.15	0.29	0.20	0.20	0.53
1996	0.05	0.10	0.42	0.20	0.20	1.00
1997	0.05	0.10	0.52	0.20	0.20	0.54
1998	0.05	0.10	0.24	0.20	0.20	0.96
1999	0.05	0.10	0.23	0.20	0.20	0.47
2000	0.05	0.10	0.23	0.20	0.20	0.45
2001	0.05	0.10	0.18	0.20	0.20	0.42
2002	0.05	0.10	0.17	0.20	0.20	0.56
2003	0.05	0.10	0.20	0.20	0.20	0.47
2004	0.05	0.10	0.21	0.20	0.20	0.29
2005	0.05	0.10	0.24	0.20	0.20	0.23
2006	0.05	0.10	0.26	0.20	0.20	0.31
2007	0.05	0.10	0.24	0.20	0.20	0.26
2008	0.05	0.05	0.27	0.20	0.20	0.36
2009	0.05	0.05	0.25	0.20	0.20	0.38
2010	0.05	0.05	1.00	0.20	0.20	0.39
2011	0.05	0.05	1.00	0.20	0.20	0.34
2012	0.05	0.05	0.17	0.20	0.20	0.39
2013	0.05	0.05	0.18	0.20	0.20	0.31
2014	0.05	0.05	0.11	0.20	0.20	0.21

Table 7. Estimated total abundance at age (1000 fish) at start of year.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1950	451.38	248.86	170.37	126.19	98.12	78.54	64.07	52.90	44.07	36.97	31.14	26.34	22.34	18.99	16.15	13.77	11.75	10.03	8.57	50.48	1581.01
1951	451.38	248.85	170.29	126.08	98.03	78.47	64.01	52.85	44.03	36.94	31.11	26.31	22.32	18.97	16.14	13.76	11.74	10.02	8.56	50.43	1580.29
1952	451.37	248.81	169.34	124.65	96.86	77.53	63.25	52.22	43.51	36.50	30.74	26.00	22.05	18.74	15.95	13.59	11.60	9.90	8.46	49.83	1570.91
1953	451.36	248.84	170.10	125.09	96.66	77.32	63.08	52.08	43.39	36.40	30.66	25.93	21.99	18.69	15.90	13.56	11.57	9.87	8.43	49.69	1570.62
1954	451.36	248.83	170.03	125.52	96.89	77.07	62.84	51.88	43.22	36.26	30.54	25.83	21.91	18.62	15.84	13.51	11.52	9.83	8.40	49.50	1569.40
1955	451.34	248.77	168.58	123.39	95.59	75.96	61.58	50.82	42.33	35.52	29.92	25.30	21.46	18.24	15.52	13.23	11.29	9.63	8.23	48.49	1555.19
1956	451.31	248.00	162.02	115.41	89.26	71.88	58.84	48.78	40.97	34.60	29.28	24.76	21.00	17.85	15.19	12.95	11.05	9.43	8.05	47.46	1518.10
1957	451.27	247.88	160.50	109.83	82.74	66.61	55.34	46.39	39.19	33.40	28.47	24.19	20.52	17.44	14.84	12.65	10.79	9.21	7.87	46.36	1485.47
1958	451.18	247.59	156.19	103.58	75.00	58.90	49.00	41.76	35.72	30.65	26.38	22.58	19.24	16.36	13.91	11.86	10.12	8.64	7.38	43.48	1429.52
1959	451.08	247.49	156.52	101.76	71.50	54.06	43.95	37.56	32.71	28.45	24.68	21.33	18.31	15.63	13.30	11.34	9.68	8.26	7.05	41.56	1396.20
1960	450.98	247.29	154.75	100.09	69.01	50.70	39.74	33.25	29.07	25.77	22.67	19.75	17.12	14.72	12.58	10.73	9.15	7.81	6.67	39.32	1361.18
1961	450.85	247.08	153.06	97.31	66.81	48.24	36.81	29.74	25.49	22.71	20.38	18.00	15.72	13.66	11.76	10.07	8.59	7.33	6.26	36.91	1326.78
1962	450.68	246.75	149.73	92.74	62.66	45.15	33.94	26.76	22.20	19.41	17.53	15.79	13.99	12.25	10.65	9.19	7.88	6.72	5.74	33.83	1283.57
1963	450.50	246.52	148.88	90.35	59.58	42.35	31.86	24.80	20.12	17.06	15.14	13.72	12.40	11.01	9.64	8.40	7.26	6.22	5.31	31.31	1252.43
1964	450.33	246.31	148.60	90.05	58.29	40.52	30.14	23.53	18.89	15.68	13.50	12.03	10.94	9.90	8.80	7.73	6.74	5.82	4.99	29.42	1232.21
1965	450.14	245.99	146.09	87.47	56.61	38.72	28.24	21.85	17.62	14.50	12.24	10.58	9.46	8.61	7.81	6.95	6.11	5.33	4.61	27.26	1206.20
1966	449.92	245.65	143.53	83.70	53.61	36.76	26.45	20.12	16.12	13.35	11.18	9.48	8.22	7.36	6.71	6.09	5.43	4.77	4.17	24.95	1177.57
1967	449.65	245.41	142.16	81.09	50.62	34.38	24.83	18.66	14.71	12.12	10.22	8.59	7.30	6.35	5.69	5.20	4.73	4.21	3.70	22.62	1152.24
1968	449.27	245.00	138.04	76.19	46.53	30.85	22.11	16.70	13.02	10.56	8.86	7.51	6.33	5.39	4.69	4.21	3.85	3.50	3.13	19.55	1115.30
1969	448.68	244.44	132.99	69.30	40.98	26.64	18.68	14.03	11.02	8.85	7.33	6.17	5.24	4.43	3.78	3.29	2.96	2.71	2.46	15.96	1069.96
1970	448.12	244.22	135.93	70.17	39.25	24.74	17.03	12.53	9.80	7.94	6.51	5.41	4.57	3.89	3.29	2.81	2.45	2.20	2.02	13.75	1056.64
1971	447.62	243.87	135.37	71.31	39.52	23.57	15.74	11.38	8.72	7.04	5.82	4.79	3.99	3.38	2.88	2.44	2.09	1.82	1.64	11.73	1044.73
1972	447.12	243.32	133.31	69.65	39.51	23.44	14.87	10.48	7.92	6.27	5.18	4.30	3.55	2.96	2.51	2.14	1.82	1.56	1.36	9.98	1031.24
1973	446.63	242.73	130.94	67.09	37.85	23.09	14.64	9.85	7.28	5.70	4.63	3.84	3.20	2.65	2.21	1.88	1.60	1.36	1.17	8.50	1016.83
1974	446.21	242.22	129.99	65.83	36.55	22.28	14.60	9.86	6.98	5.37	4.32	3.52	2.93	2.44	2.02	1.70	1.44	1.23	1.05	7.44	1007.96
1975	445.47	241.26	121.77	58.45	32.19	19.42	12.80	8.99	6.43	4.76	3.77	3.05	2.49	2.08	1.73	1.44	1.21	1.03	0.88	6.05	975.25
1976	443.94	239.81	111.58	47.42	24.89	15.04	9.93	7.09	5.32	4.00	3.06	2.44	1.98	1.62	1.35	1.13	0.94	0.79	0.67	4.53	927.52
1977	441.43	238.18	104.58	39.38	18.40	10.69	7.13	5.14	3.95	3.14	2.45	1.89	1.51	1.22	1.00	0.84	0.70	0.58	0.49	3.23	885.94
1978	493.85	235.75	94.74	31.43	13.08	6.83	4.43	3.26	2.56	2.09	1.74	1.36	1.05	0.84	0.68	0.56	0.47	0.39	0.33	2.09	897.55
1979	367.80	262.12	82.82	22.90	8.46	3.99	2.36	1.71	1.39	1.17	1.00	0.84	0.66	0.51	0.41	0.33	0.27	0.23	0.19	1.18	760.33
1980	543.28	195.04	92.54	20.43	6.32	2.66	1.43	0.95	0.76	0.67	0.59	0.51	0.43	0.34	0.26	0.21	0.17	0.14	0.12	0.70	867.52
1981	194.01	285.97	60.81	18.59	4.65	1.67	0.82	0.50	0.38	0.33	0.31	0.27	0.24	0.20	0.16	0.12	0.10	0.08	0.07	0.38	569.64
1982	320.72	101.34	84.85	11.22	3.89	1.13	0.47	0.27	0.19	0.15	0.14	0.13	0.12	0.10	0.09	0.07	0.05	0.04	0.03	0.20	525.21
1983	886.15	169.97	36.12	20.54	2.99	1.15	0.37	0.17	0.10	0.08	0.07	0.06	0.06	0.05	0.05	0.04	0.03	0.02	0.02	0.10	1118.14
1984	1003.78	463.16	45.51	5.43	3.49	0.59	0.27	0.10	0.05	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.04	1522.60
1985	458.35	510.98	130.80	8.28	1.15	0.89	0.18	0.10	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	1110.93
1986	246.99	226.63	126.32	20.20	1.54	0.27	0.26	0.07	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.02	622.42
1987	758.45	122.13	86.53	38.92	7.05	0.61	0.12	0.13	0.04	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1014.07
1988	579.89	393.25	54.45	32.82	16.29	3.25	0.31	0.07	0.08	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1080.48
1989	192.10	303.67	184.92	22.67	15.06	8.23	1.80	0.18	0.04	0.05	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	728.78
1990	82.71	101.52	145.34	78.22	10.51	7.65	4.55	1.07	0.12	0.03	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	431.80
1991	70.98	43.25	57.72	82.11	47.48	6.73	5.11	3.15	0.76	0.09	0.02	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	317.46
1992	343.72	35.71	21.89	28.32	44.40	27.85	4.24	3.43	2.22	0.56	0.06	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.01	512.45
1993	124.40	175.94	22.16	9.80	8.54	15.02	11.41	2.09	1.98	1.43	0.39	0.05	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	373.25
1994	210.08	57.86	102.98	9.79	2.99	2.86	5.76	4.92	0.99	1.00	0.76	0.21	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	400.25
1995	99.53	97.79	33.82	47.09	3.15	1.05	1.14	2.57	2.41	0.52	0.55	0.42	0.12	0.01	0.00	0.00	0.00	0.00	0.00	0.00	290.19
1996	248.48	44.51	55.44	15.59	16.12	1.19	0.45	0.54	1.32	1.32	0.29	0.32	0.25	0.07	0.01	0.00	0.00	0.00	0.00	0.00	385.89
1997	180.06	126.71	28.20	29.60	6.50	7.18	0.58	0.24	0.30	0.78	0.79	0.18	0.19	0.15	0.04	0.01	0.00	0.00	0.00	0.00	381.53
1998	318.30	91.64	76.68	9.91	5.55	1.40	1.98	0.20	0.10	0.15	0.42	0.46	0.11	0.12	0.09	0.03	0.00	0.00	0.00	0.00	507.15
1999	423.89	165.69	59.12	41.70	4.22	2.53	0.70	1.09	0.12	0.06	0.10	0.28	0.30	0.07	0.08	0.06	0.02	0.00	0.00	0.00	700.03
2000	459.88	197.76	96.30	25.18	11.81	1.34	0.97	0.32	0.58	0.07	0.04	0.06	0.19	0.21	0.05	0.05	0.04	0.01	0.00	0.00	794.86
2001	324.84	202.68	110.01	39.81	6.94	3.67	0.50	0.44	0.17	0.34	0.04	0.03	0.04	0.13	0.14	0.03	0.04	0.03	0.01	0.00	689.88
2002	276.32	142.42	113.75	49.70	12.91	2.47	1.50	0.23	0.22	0.09	0.19	0.03	0.02	0.03	0.08	0.09	0.02	0.02	0.02	0.01	600.12
2003	346.33	125.01	81.57	53.14	17.26	4.94	1.08	0.74	0.13	0.13	0.06	0.12	0.02	0.01	0.02	0.05	0.06	0.01	0.01	0.02	630.71
2004	129.02	158.12	73.39	44.72	24.60	8.59	2.70	0.64	0.47	0.09	0.09	0.04	0.09	0.01	0.01	0.01	0.04	0.04	0.01	0.02	442.69
2005	57.11	45.66	76.10	33.76	17.01	10.41	4.12	1.45	0.38	0.30	0.06	0.06	0.03	0.06	0.01	0.00	0.01	0.02	0.03	0.02	246.59
2006	894.27	20.51	21.94	33.63	12.05	6.84	4.84	2.18	0.85	0.24	0.20	0.04	0.04	0.02	0.04	0.01	0.00	0.01	0.02	0.03	997.76
2007	636.29	454.43	12.82	10.10	10.65	4.25	2.86	2.38	1.23	0.53	0.16	0.14	0.03	0.03	0.01	0.03	0.00	0.00	0.00	0.04	1135.98
2008	656.59	288.19	261.18	5.52	2.97	3.49	1.63	1.26	1.18	0.66	0.30	0.09	0.08	0.02	0.02	0.01	0.02	0.00	0.00	0.03	1223.24
2009	204.65	254.88	144.37	90.41	1.13	0.70	1.02	0.58	0.54	0.57	0.35	0.16	0.05	0.05	0.01	0.01	0.00	0.01	0.00	0.02	699.49
2010	83.19	77.39	126.65	54.62	22.28	0.31	0.23	0.39	0.25	0.25	0.29	0.18	0.09	0.03	0.02	0.00	0.01	0.00	0.01	0.01	366.20
2011	268.39	37.95	42.07	71.43	31.60	13.50	0.20	0.16	0.28	0.19	0.20	0.22	0.14	0.07	0.02	0.02	0.00	0.00	0.00	0.01	466.47
2012	256.30	139.96	24.04	27.35	47.08	21.43	9.44	0.14	0.11	0.21	0.14	0.15	0.17	0.11	0.05	0.02	0.01	0.00	0.00	0.01	526.74
2013	457.91	124.67	81.45	14.00	14.90	25.17	11.88	5.47	0.09	0.07	0.13	0.09	0.10	0.11	0.07	0.03	0.01	0.01	0.00	0.01	736.17
2014	1146.50	237.07	78.73	52.68	8.76	9.31	16.14	7.83	3.69	0.06	0.05	0.09	0.06	0.07	0.08	0.05	0.02	0.01	0.01	0.01	1561.22
2015	432.79	582.88	144.14	45.74	25.89	3.98	4.31	7.72	3.86	1.87	0.03	0.03	0.05	0.03	0.04	0.04	0.03	0.01	0.00	0.01	1253.44

Table 8. Estimated biomass at age (mt) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1950	239.0	350.3	434.0	477.6	490.5	480.6	455.4	420.9	382.1	342.4	303.4	266.9	233.4	203.2	176.1	152.4	131.5	113.2	97.4	577.1	6327.6
1951	239.0	350.3	433.8	477.2	490.1	480.1	455.0	420.6	381.8	342.1	303.2	266.7	233.2	203.0	176.0	152.2	131.4	113.1	97.3	576.6	6322.7
1952	239.0	350.3	431.4	471.8	484.3	474.4	449.6	415.5	377.2	338.0	299.6	263.5	230.5	200.6	173.9	150.4	129.8	111.8	96.1	569.7	6257.3
1953	238.9	350.3	433.4	473.5	483.2	473.1	448.4	414.4	376.2	337.1	298.7	262.8	229.8	200.1	173.4	150.0	129.5	111.5	95.9	568.2	6248.3
1954	238.9	350.3	433.2	475.1	484.4	471.6	446.7	412.8	374.8	335.8	297.6	261.8	228.9	199.3	172.7	149.4	129.0	111.0	95.5	566.0	6234.8
1955	238.9	350.2	429.5	467.0	477.9	464.8	437.8	404.4	367.1	328.9	291.5	256.4	224.3	195.2	169.2	146.4	126.3	108.8	93.6	554.4	6132.4
1956	238.9	349.1	412.8	436.8	446.2	439.8	418.3	388.2	355.2	320.4	285.3	251.0	219.5	191.0	165.6	143.2	123.6	106.5	91.6	542.6	5925.7
1957	238.9	348.9	408.9	415.7	413.7	407.6	393.4	369.1	339.8	309.3	277.4	245.1	214.4	186.6	161.8	139.9	120.8	104.0	89.5	530.0	5714.9
1958	238.9	348.5	397.9	392.0	375.0	360.4	348.3	332.3	309.7	283.9	257.1	228.8	201.1	175.0	151.7	131.2	113.3	97.5	83.9	497.1	5323.7
1959	238.8	348.4	398.8	385.2	357.5	330.8	312.4	298.9	283.6	263.5	240.4	216.1	191.3	167.3	145.0	125.4	108.3	93.2	80.2	475.1	5060.2
1960	238.7	348.1	394.3	378.9	345.0	310.2	282.5	264.6	252.1	238.7	220.9	200.1	178.9	157.6	137.2	118.7	102.4	88.2	75.9	449.6	4782.4
1961	238.7	347.8	390.0	368.3	334.0	295.2	261.6	236.6	221.0	210.3	198.6	182.4	164.3	146.2	128.2	111.4	96.2	82.8	71.2	422.0	4506.8
1962	238.6	347.4	381.5	351.0	313.2	276.3	241.3	212.9	192.5	179.8	170.8	160.0	146.2	131.1	116.1	101.6	88.1	75.9	65.3	386.7	4176.2
1963	238.5	347.0	379.3	342.0	297.9	259.2	226.5	197.4	174.4	158.0	147.5	139.1	129.6	117.8	105.1	92.9	81.2	70.2	60.4	358.0	3921.9
1964	238.4	346.7	378.6	340.8	291.4	248.0	214.3	187.3	163.8	145.2	131.6	121.9	114.3	106.0	96.0	85.5	75.4	65.7	56.8	336.4	3743.9
1965	238.3	346.3	372.2	331.1	283.0	236.9	200.7	173.9	152.8	134.3	119.3	107.2	98.8	92.2	85.1	76.9	68.4	60.2	52.4	311.7	3541.7
1966	238.2	345.8	365.7	316.8	268.0	224.9	188.0	160.1	139.8	123.7	109.0	96.1	85.9	78.7	73.2	67.4	60.8	53.9	47.4	285.2	3328.5
1967	238.0	345.5	362.2	306.9	253.1	210.4	176.5	148.5	127.6	112.2	99.6	87.1	76.3	67.9	62.0	57.5	52.9	47.6	42.1	258.6	3132.4
1968	237.8	344.9	351.7	288.4	232.6	188.8	157.1	132.9	112.9	97.8	86.4	76.1	66.2	57.7	51.1	46.6	43.1	39.5	35.5	223.5	2870.7
1969	237.5	344.1	338.8	262.3	204.9	163.0	132.8	111.7	95.6	82.0	71.4	62.6	54.8	47.4	41.2	36.4	33.1	30.6	28.0	182.5	2560.6
1970	237.2	343.8	346.3	265.6	196.2	151.4	121.1	99.7	85.0	73.5	63.4	54.8	47.8	41.6	35.9	31.1	27.4	24.9	23.0	157.2	2427.0
1971	237.0	343.3	344.9	269.9	197.6	144.2	111.9	90.6	75.6	65.2	56.7	48.6	41.7	36.2	31.4	27.0	23.4	20.6	18.6	134.1	2318.4
1972	236.7	342.5	339.6	263.6	197.5	143.4	105.7	83.4	68.6	58.1	50.4	43.6	37.1	31.7	27.4	23.7	20.4	17.6	15.4	114.2	2220.7
1973	236.4	341.7	333.6	253.9	189.3	141.3	104.1	78.4	63.1	52.8	45.1	38.9	33.4	28.3	24.1	20.8	18.0	15.4	13.3	97.2	2129.0
1974	236.2	341.0	331.2	249.2	182.7	136.3	103.7	78.4	60.5	49.7	42.1	35.7	30.6	26.2	22.1	18.8	16.1	13.9	11.9	85.0	2071.3
1975	235.8	339.6	310.2	221.2	160.9	118.8	91.0	71.5	55.7	44.1	36.7	30.9	26.0	22.2	18.9	15.9	13.5	11.6	10.0	69.1	1903.8
1976	235.0	337.6	284.3	179.5	124.5	92.1	70.6	56.4	46.1	37.0	29.9	24.7	20.7	17.3	14.7	12.5	10.5	8.9	7.6	51.7	1661.5
1977	233.7	335.3	266.4	149.0	92.0	65.4	50.7	40.9	34.3	29.1	23.9	19.1	15.7	13.1	10.9	9.3	7.9	6.6	5.6	37.0	1445.8
1978	261.4	331.9	241.4	119.0	65.4	41.8	31.5	26.0	22.2	19.4	16.9	13.8	11.0	9.0	7.5	6.2	5.3	4.4	3.7	23.9	1261.7
1979	194.7	369.0	211.0	86.7	42.3	24.4	16.8	13.6	12.0	10.8	9.8	8.5	6.9	5.4	4.4	3.7	3.1	2.6	2.2	13.5	1041.3
1980	287.6	274.6	235.7	77.3	31.6	16.3	10.1	7.6	6.6	6.2	5.8	5.2	4.4	3.6	2.8	2.3	1.9	1.6	1.3	8.0	990.5
1981	102.7	402.6	154.9	70.4	23.2	10.2	5.8	4.0	3.3	3.1	3.0	2.8	2.5	2.1	1.7	1.3	1.1	0.9	0.7	4.4	800.7
1982	169.8	142.7	216.2	42.5	19.5	6.9	3.4	2.1	1.6	1.4	1.4	1.3	1.2	1.1	0.9	0.8	0.6	0.5	0.4	2.2	616.5
1983	469.1	239.3	92.0	77.7	14.9	7.1	2.6	1.4	0.9	0.7	0.6	0.6	0.6	0.6	0.5	0.4	0.3	0.3	0.2	1.2	911.1
1984	531.4	652.0	115.9	20.5	17.4	3.6	1.9	0.8	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.5	1346.5
1985	242.6	719.3	333.2	31.4	5.8	5.5	1.3	0.8	0.4	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	1341.8
1986	130.8	319.0	321.8	76.4	7.7	1.6	1.9	0.5	0.4	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.2	861.3
1987	401.5	171.9	220.5	147.3	35.3	3.7	0.9	1.0	0.3	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.2	983.3
1988	307.0	553.6	138.7	124.2	81.4	19.9	2.2	0.5	0.7	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1229.0
1989	101.7	427.5	471.1	85.8	75.3	50.3	12.8	1.5	0.4	0.5	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1227.4
1990	43.8	142.9	370.3	296.1	52.6	46.8	32.3	8.5	1.0	0.3	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	995.3
1991	37.6	60.9	147.1	310.8	237.4	41.2	36.3	25.0	6.6	0.8	0.2	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	904.4
1992	182.0	50.3	55.8	107.2	222.0	170.4	30.2	27.3	19.3	5.2	0.6	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	870.7
1993	65.9	247.7	56.5	37.1	42.7	91.9	81.1	16.7	17.1	13.3	3.8	0.5	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.1	674.6
1994	111.2	81.4	262.4	37.0	14.9	17.5	40.9	39.2	8.6	9.3	7.4	2.1	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	632.6
1995	52.7	137.7	86.2	178.2	15.8	6.4	8.1	20.5	20.9	4.8	5.3	4.3	1.2	0.2	0.0	0.1	0.0	0.0	0.0	0.0	542.4
1996	131.5	62.7	141.2	59.0	80.6	7.3	3.2	4.3	11.5	12.2	2.9	3.2	2.6	0.7	0.1	0.0	0.0	0.0	0.0	0.0	523.0
1997	95.3	178.4	71.8	112.0	32.5	43.9	4.1	1.9	2.6	7.2	7.7	1.8	2.0	1.6	0.5	0.1	0.0	0.0	0.0	0.0	563.7
1998	168.5	129.0	195.4	37.5	27.7	8.6	14.1	1.6	0.9	1.4	4.1	4.6	1.1	1.3	1.0	0.3	0.0	0.0	0.0	0.0	597.1
1999	224.4	233.2	150.6	157.8	21.1	15.5	5.0	8.6	1.0	0.6	0.9	2.8	3.2	0.8	0.9	0.7	0.2	0.0	0.0	0.0	827.4
2000	243.5	278.4	245.3	95.3	59.0	8.2	6.9	2.6	5.0	0.7	0.4	0.6	2.0	2.2	0.5	0.6	0.5	0.1	0.0	0.0	951.8
2001	172.0	285.3	280.3	150.7	34.7	22.5	3.6	3.5	1.5	3.1	0.4	0.3	0.4	1.4	1.5	0.4	0.4	0.3	0.1	0.0	962.3
2002	146.3	200.5	289.8	188.1	64.6	15.1	10.6	1.9	1.9	0.9	1.9	0.3	0.2	0.3	0.8	1.0	0.2	0.3	0.2	0.1	924.8
2003	183.3	176.0	207.8	201.1	86.3	30.2	7.7	5.9	1.1	1.2	0.6	1.2	0.2	0.1	0.2	0.6	0.6	0.1	0.2	0.2	904.7
2004	68.3	222.6	187.0	169.3	123.0	52.5	19.2	5.1	4.1	0.8	0.9	0.4	0.9	0.1	0.1	0.1	0.4	0.5	0.1	0.3	855.6
2005	30.2	64.3	193.9	127.8	85.1	63.7	29.3	11.5	3.3	2.7	0.5	0.6	0.3	0.6	0.1	0.1	0.1	0.3	0.3	0.2	614.9
2006	473.4	28.9	55.9	127.3	60.3	41.9	34.4	17.3	7.4	2.2	1.9	0.4	0.4	0.2	0.5	0.1	0.0	0.1	0.2	0.4	853.1
2007	336.8	639.7	32.7	38.2	53.2	26.0	20.3	19.0	10.6	4.9	1.5	1.4	0.3	0.3	0.1	0.3	0.0	0.0	0.0	0.4	1186.1
2008	347.6	405.7	665.4	20.9	14.9	21.4	11.6	10.1	10.2	6.1	2.9	0.9	0.8	0.2	0.2	0.1	0.2	0.0	0.0	0.3	1519.5
2009	108.3	358.8	367.8	342.2	5.6	4.3	7.2	4.6	4.7	5.3	3.4	1.7	0.5	0.5	0.1	0.1	0.1	0.1	0.0	0.2	1215.4
2010	44.0	108.9	322.7	206.7	111.4	1.9	1.6	3.1	2.2	2.4	2.8	1.8	0.9	0.3	0.3	0.1	0.1	0.0	0.1	0.1	811.3
2011	142.1	53.4	107.2	270.4	158.0	82.6	1.4	1.2	2.4	1.8	1.9	2.3	1.5	0.7	0.2	0.2	0.0	0.0	0.0	0.1	827.6
2012	135.7	197.0	61.3	103.5	235.4	131.1	67.1	1.1	1.0	1.9	1.4	1.5	1.8	1.1	0.6	0.2	0.2	0.0	0.0	0.1	942.1
2013	242.4	175.5	207.5	53.0	74.5	154.0	84.4	43.5	0.8	0.7	1.3	0.9	1.0	1.2	0.8	0.4	0.1	0.1	0.0	0.1	1042.2
2014	606.9	333.7	200.6	199.4	43.8	56.9	114.7	62.3	32.0	0.6	0.5	0.9	0.7	0.7	0.8	0.5	0.3	0.1	0.1	0.1	1655.7
2015	229.1	820.5	367.2	173.1	129.4	24.4	30.6	61.4	33.5	17.3	0.3	0.3	0.5	0.4	0.4	0.4	0.3	0.1	0.0	0.1	1889.4

Table 9. Estimated biomass at age (1000 lb) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1950	526.9	772.3	956.8	1052.9	1081.4	1059.5	1004.0	927.9	842.4	754.9	668.9	588.4	514.6	448.0	388.2	336.0	289.9	249.6	214.7	1272.3	13950.0
1951	526.9	772.3	956.4	1052.0	1080.5	1058.4	1003.1	927.3	841.7	754.2	668.4	588.0	514.1	447.5	388.0	335.5	289.7	249.3	214.5	1271.2	13939.2
1952	526.9	772.3	951.1	1040.1	1067.7	1045.9	991.2	916.0	831.6	745.2	660.5	580.9	508.2	442.2	383.4	331.6	286.2	246.5	211.9	1256.0	13795.0
1953	526.7	772.3	955.5	1043.9	1065.3	1043.0	988.6	913.6	829.4	743.2	658.5	579.4	506.6	441.1	382.3	330.7	285.5	245.8	211.4	1252.7	13775.1
1954	526.7	772.3	955.0	1047.4	1067.9	1039.7	984.8	910.1	826.3	740.3	656.1	577.2	504.6	439.4	380.7	329.4	284.4	244.7	210.5	1247.8	13745.4
1955	526.7	772.1	946.9	1029.6	1053.6	1024.7	965.2	891.5	809.3	725.1	642.6	565.3	494.5	430.3	373.0	322.8	278.4	239.9	206.4	1222.2	13519.6
1956	526.7	769.6	910.1	963.0	983.7	969.6	922.2	855.8	783.1	706.4	629.0	553.4	483.9	421.1	365.1	315.7	272.5	234.8	201.9	1196.2	13063.9
1957	526.7	769.2	901.5	916.5	912.1	898.6	867.3	813.7	749.1	681.9	611.6	540.4	472.7	411.4	356.7	308.4	266.3	229.3	197.3	1168.4	12599.2
1958	526.7	768.3	877.2	864.2	826.7	794.5	767.9	732.6	682.8	625.9	566.8	504.4	443.3	385.8	334.4	289.2	249.8	215.0	185.0	1095.9	11736.7
1959	526.5	768.1	879.2	849.2	788.2	729.3	688.7	659.0	625.2	580.9	530.0	476.4	421.7	368.8	319.7	276.5	238.8	205.5	176.8	1047.4	11155.8
1960	526.2	767.4	869.3	835.3	760.6	683.9	622.8	583.3	555.8	526.2	487.0	441.1	394.4	347.4	302.5	261.7	225.8	194.4	167.3	991.2	10543.4
1961	526.2	766.8	859.8	812.0	736.3	650.8	576.7	521.6	487.2	463.6	437.8	402.1	362.2	322.3	282.6	245.6	212.1	182.5	157.0	930.3	9935.8
1962	526.0	765.9	841.1	773.8	690.5	609.1	532.0	469.4	424.4	396.4	376.5	352.7	322.3	289.0	256.0	224.0	194.2	167.3	144.0	852.5	9206.9
1963	525.8	765.0	836.2	754.0	656.8	571.4	499.3	435.2	384.5	348.3	325.2	306.7	285.7	259.7	231.7	204.8	179.0	154.8	133.2	789.3	8646.3
1964	525.6	764.3	834.7	751.3	642.4	546.7	472.5	412.9	361.1	320.1	290.1	268.7	252.0	233.7	211.6	188.5	166.2	144.8	125.2	741.6	8253.9
1965	525.4	763.5	820.6	729.9	623.9	522.3	442.5	383.4	336.9	296.1	263.0	236.3	217.8	203.3	187.6	169.5	150.8	132.7	115.5	687.2	7808.1
1966	525.1	762.4	806.2	698.4	590.8	495.8	414.5	353.0	308.2	272.7	240.3	211.9	189.4	173.5	161.4	148.6	134.0	118.8	104.5	628.8	7338.1
1967	524.7	761.7	798.5	676.6	558.0	463.9	389.1	327.4	281.3	247.4	219.6	192.0	168.2	149.7	136.7	126.8	116.6	104.9	92.8	570.1	6905.8
1968	524.3	760.4	775.4	635.8	512.8	416.2	346.3	293.0	248.9	215.6	190.5	167.8	145.9	127.2	112.7	102.7	95.0	87.1	78.3	492.7	6328.8
1969	523.6	758.6	746.9	578.3	451.7	359.4	292.8	246.3	210.8	180.8	157.4	138.0	120.8	104.5	90.8	80.2	73.0	67.5	61.7	402.3	5645.1
1970	522.9	757.9	763.5	585.5	432.5	333.8	267.0	219.8	187.4	162.0	139.8	120.8	105.4	91.7	79.1	68.6	60.4	54.9	50.7	346.6	5350.6
1971	522.5	756.8	760.4	595.0	435.6	317.9	246.7	199.7	166.7	143.7	125.0	107.1	91.9	79.8	69.2	59.5	51.6	45.4	41.0	295.6	5111.2
1972	521.8	755.1	748.7	581.1	435.4	316.1	233.0	183.9	151.2	128.1	111.1	96.1	81.8	69.9	60.4	52.2	45.0	38.8	34.0	251.8	4895.8
1973	521.2	753.3	735.5	559.8	417.3	311.5	229.5	172.8	139.1	116.4	99.4	85.8	73.6	62.4	53.1	45.9	39.7	34.0	29.3	214.3	4693.6
1974	520.7	751.8	730.2	549.4	402.8	300.5	228.6	172.8	133.4	109.6	92.8	78.7	67.5	57.8	48.7	41.4	35.5	30.6	26.2	187.4	4566.4
1975	519.8	748.7	683.9	487.7	354.7	261.9	200.6	157.6	122.8	97.2	80.9	68.1	57.3	48.9	41.7	35.1	29.8	25.6	22.0	152.3	4197.2
1976	518.1	744.3	626.8	395.7	274.5	203.0	155.6	124.3	101.6	81.6	65.9	54.5	45.6	38.1	32.4	27.6	23.1	19.6	16.8	114.0	3663.0
1977	515.2	739.2	587.3	328.5	202.8	144.2	111.8	90.2	75.6	64.2	52.7	42.1	34.6	28.9	24.0	20.5	17.4	14.6	12.3	81.6	3187.4
1978	576.3	731.7	532.2	262.3	144.2	92.2	69.4	57.3	48.9	42.8	37.3	30.4	24.3	19.8	16.5	13.7	11.7	9.7	8.2	52.7	2781.6
1979	429.2	813.5	465.2	191.1	93.3	53.8	37.0	30.0	26.5	23.8	21.6	18.7	15.2	11.9	9.7	8.2	6.8	5.7	4.9	29.8	2295.7
1980	634.0	605.4	519.6	170.4	69.7	35.9	22.3	16.8	14.6	13.7	12.8	11.5	9.7	7.9	6.2	5.1	4.2	3.5	2.9	17.6	2183.7
1981	226.4	887.6	341.5	155.2	51.1	22.5	12.8	8.8	7.3	6.8	6.6	6.2	5.5	4.6	3.7	2.9	2.4	2.0	1.5	9.7	1765.2
1982	374.3	314.6	476.6	93.7	43.0	15.2	7.5	4.6	3.5	3.1	3.1	2.9	2.6	2.4	2.0	1.8	1.3	1.1	0.9	4.9	1359.1
1983	1034.2	527.6	202.8	171.3	32.8	15.7	5.7	3.1	2.0	1.5	1.3	1.3	1.3	1.3	1.1	0.9	0.7	0.7	0.4	2.6	2008.6
1984	1171.5	1437.4	255.5	45.2	38.4	7.9	4.2	1.8	0.9	0.7	0.7	0.4	0.4	0.4	0.4	0.4	0.2	0.2	0.2	1.1	2968.5
1985	534.8	1585.8	734.6	69.2	12.8	12.1	2.9	1.8	0.9	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.7	2958.2
1986	288.4	703.3	709.4	168.4	17.0	3.5	4.2	1.1	0.9	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.4	1898.8
1987	885.2	379.0	486.1	324.7	77.8	8.2	2.0	2.2	0.7	0.4	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.4	2167.8
1988	676.8	1220.5	305.8	273.8	179.5	43.9	4.9	1.1	1.5	0.4	0.4	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2709.5
1989	224.2	942.5	1038.6	189.2	166.0	110.9	28.2	3.3	0.9	1.1	0.4	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2706.0
1990	96.6	315.0	816.4	652.8	116.0	103.2	71.2	18.7	2.2	0.7	0.7	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2194.3
1991	82.9	134.3	324.3	685.2	523.4	90.8	80.0	55.1	14.6	1.8	0.4	0.7	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.2	1993.9
1992	401.2	110.9	123.0	236.3	489.4	375.7	66.6	60.2	42.5	11.5	1.3	0.4	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.2	1919.6
1993	145.3	546.1	124.6	81.8	94.1	202.6	178.8	36.8	37.7	29.3	8.4	1.1	0.2	0.4	0.2	0.0	0.0	0.0	0.0	0.2	1487.2
1994	245.2	179.5	578.5	81.6	32.8	38.6	90.2	86.4	19.0	20.5	16.3	4.6	0.7	0.2	0.2	0.0	0.0	0.0	0.0	0.0	1394.6
1995	116.2	303.6	190.0	392.9	34.8	14.1	17.9	45.2	46.1	10.6	11.7	9.5	2.6	0.4	0.0	0.2	0.0	0.0	0.0	0.0	1195.8
1996	289.9	138.2	311.3	130.1	177.7	16.1	7.1	9.5	25.4	26.9	6.4	7.1	5.7	1.5	0.2	0.0	0.0	0.0	0.0	0.0	1153.0
1997	210.1	393.3	158.3	246.9	71.7	96.8	9.0	4.2	5.7	15.9	17.0	4.0	4.4	3.5	1.1	0.2	0.0	0.0	0.0	0.0	1242.7
1998	371.5	284.4	430.8	82.7	61.1	19.0	31.1	3.5	2.0	3.1	9.0	10.1	2.4	2.9	2.2	0.7	0.0	0.0	0.0	0.0	1316.4
1999	494.7	514.1	332.0	347.9	46.5	34.2	11.0	19.0	2.2	1.3	2.0	6.2	7.1	1.8	2.0	1.5	0.4	0.0	0.0	0.0	1824.1
2000	536.8	613.8	540.8	210.1	130.1	18.1	15.2	5.7	11.0	1.5	0.9	1.3	4.4	4.9	1.1	1.3	1.1	0.2	0.0	0.0	2098.4
2001	379.2	629.0	618.0	332.2	76.5	49.6	7.9	7.7	3.3	6.8	0.9	0.7	0.9	3.1	3.3	0.9	0.9	0.7	0.2	0.0	2121.5
2002	322.5	442.0	638.9	414.7	142.4	33.3	23.4	4.2	4.2	2.0	4.2	0.7	0.4	0.7	1.8	2.2	0.4	0.7	0.4	0.2	2038.8
2003	404.1	388.0	458.1	443.3	190.3	66.6	17.0	13.0	2.4	2.6	1.3	2.6	0.4	0.2	0.4	1.3	1.3	0.2	0.4	0.4	1994.5
2004	150.6	490.7	412.3	373.2	271.2	115.7	42.3	11.2	9.0	1.8	2.0	0.9	2.0	0.2	0.2	0.2	0.9	1.1	0.2	0.7	1886.3
2005	66.6	141.8	427.5	281.8	187.6	140.4	64.6	25.4	7.3	6.0	1.1	1.3	0.7	1.3	0.2	0.2	0.2	0.7	0.7	0.4	1355.6
2006	1043.7	63.7	123.2	280.6	132.9	92.4	75.8	38.1	16.3	4.9	4.2	0.9	0.9	0.4	1.1	0.2	0.0	0.2	0.4	0.9	1880.8
2007	742.5	1410.3	72.1	84.2	117.3	57.3	44.8	41.9	23.4	10.8	3.3	3.1	0.7	0.7	0.2	0.7	0.0	0.0	0.0	0.9	2614.9
2008	766.3	894.4	1467.0	46.1	32.8	47.2	25.6	22.3	22.5	13.4	6.4	2.0	1.8	0.4	0.4	0.2	0.4	0.0	0.0	0.7	3349.9
2009	238.8	791.0	810.9	754.4	12.3	9.5	15.9	10.1	10.4	11.7	7.5	3.7	1.1	1.1	0.2	0.2	0.2	0.2	0.0	0.4	2679.5
2010	97.0	240.1	711.4	455.7	245.6	4.2	3.5	6.8	4.9	5.3	6.2	4.0	2.0	0.7	0.7	0.2	0.2	0.0	0.2	0.2	1788.6
2011	313.3	117.7	236.3	596.1	348.3	182.1	3.1	2.6	5.3	4.0	4.2	5.1	3.3	1.5	0.4	0.4	0.0	0.0	0.0	0.2	1824.5
2012	299.2	434.3	135.1	228.2	519.0	289.0	147.9	2.4	2.2	4.2	3.1	3.3	4.0	2.4	1.3	0.4	0.4	0.0	0.0	0.2	2077.0
2013	534.4	386.9	457.5	116.8	164.2	339.5	186.1	95.9	1.8	1.5	2.9	2.0	2.2	2.6	1.8	0.9	0.2	0.2	0.0	0.2	2297.7
2014	1338.0	735.7	442.2	439.6	96.6	125.4	252.9	137.3	70.5	1.3	1.1	2.0	1.5	1.5	1.8	1.1	0.7	0.2	0.2	0.2	3650.2
2015	505.1	1808.9	809.5	381.6	285.3	53.8	67.5	135.4	73.9	38.1	0.7	0.7	1.1	0.9	0.9	0.9	0.7	0.2	0.0	0.2	4165.4

Table 10. Estimated time series of status indicators, fishing mortality, and biomass. Fishing mortality rate is apical F. Total biomass (B, mt) is at the start of the year, and spawning biomass (SSB, 1E8 Eggs) at the time of peak spawning (mid-year). The $MSST_{\mathrm{F30}}$ is defined as $75\% SSB_{\mathrm{F30}}$, with constant $M = 0.134$.

Year	F	F/F_{30}	B	B/B_{unfished}	SSB	$SSB/SSBB_{\mathrm{F30}}$	$SSB/MSST_{\mathrm{F30}}$
1950	0.030	0.208	6328	0.786	780250	2.365	3.153
1951	0.042	0.284	6323	0.785	773414	2.344	3.125
1952	0.032	0.221	6257	0.777	769048	2.331	3.108
1953	0.033	0.228	6248	0.776	766696	2.324	3.098
1954	0.050	0.343	6235	0.774	755812	2.291	3.054
1955	0.108	0.736	6132	0.762	736224	2.231	2.975
1956	0.118	0.803	5926	0.736	711697	2.157	2.876
1957	0.167	1.139	5715	0.710	667321	2.023	2.697
1958	0.157	1.074	5324	0.661	623844	1.891	2.521
1959	0.176	1.201	5060	0.628	582561	1.766	2.354
1960	0.193	1.316	4782	0.594	539537	1.635	2.180
1961	0.230	1.570	4507	0.560	490901	1.488	1.984
1962	0.234	1.597	4176	0.519	446658	1.354	1.805
1963	0.232	1.581	3922	0.487	412811	1.251	1.668
1964	0.259	1.766	3744	0.465	380886	1.154	1.539
1965	0.286	1.951	3542	0.440	347909	1.054	1.406
1966	0.300	2.046	3328	0.413	316118	0.958	1.277
1967	0.353	2.406	3132	0.389	279545	0.847	1.130
1968	0.418	2.852	2871	0.357	236584	0.717	0.956
1969	0.368	2.513	2561	0.318	206348	0.625	0.834
1970	0.374	2.552	2427	0.301	185290	0.562	0.749
1971	0.394	2.684	2318	0.288	168164	0.510	0.680
1972	0.416	2.836	2221	0.276	153947	0.467	0.622
1973	0.417	2.842	2129	0.264	143809	0.436	0.581
1974	0.528	3.603	2071	0.257	128607	0.390	0.520
1975	0.672	4.584	1904	0.236	105348	0.319	0.426
1976	0.771	5.256	1662	0.206	81166	0.246	0.328
1977	0.931	6.351	1446	0.180	58018	0.176	0.234
1978	1.149	7.837	1262	0.157	37336	0.113	0.151
1979	1.129	7.700	1041	0.129	25314	0.077	0.102
1980	1.334	9.099	990	0.123	17080	0.052	0.069
1981	1.419	9.681	801	0.099	11929	0.036	0.048
1982	1.148	7.829	616	0.077	9209	0.028	0.037
1983	1.625	11.081	911	0.113	6799	0.021	0.027
1984	1.432	9.771	1347	0.167	8907	0.027	0.036
1985	1.597	10.895	1342	0.167	10528	0.032	0.043
1986	0.906	6.182	861	0.107	12382	0.038	0.050
1987	0.699	4.765	983	0.122	15116	0.046	0.061
1988	0.605	4.130	1229	0.153	20881	0.063	0.084
1989	0.589	4.020	1227	0.152	28619	0.087	0.116
1990	0.300	2.046	995	0.124	38649	0.117	0.156
1991	0.441	3.010	904	0.112	45004	0.136	0.182
1992	0.977	6.664	871	0.108	35087	0.106	0.142
1993	0.966	6.587	675	0.084	24738	0.075	0.100
1994	0.910	6.207	633	0.079	20691	0.063	0.084
1995	0.850	5.798	542	0.067	17843	0.054	0.072
1996	0.652	4.450	523	0.065	16811	0.051	0.068
1997	1.452	9.904	564	0.070	12872	0.039	0.052
1998	0.631	4.307	597	0.074	14323	0.043	0.058
1999	1.040	7.092	827	0.103	15832	0.048	0.064
2000	1.067	7.279	952	0.118	17266	0.052	0.070
2001	0.904	6.166	962	0.120	19909	0.060	0.080
2002	0.835	5.699	925	0.115	22166	0.067	0.090
2003	0.548	3.738	905	0.112	25713	0.078	0.104
2004	0.744	5.078	856	0.106	26400	0.080	0.107
2005	0.808	5.511	615	0.076	23391	0.071	0.095
2006	0.928	6.330	853	0.106	18520	0.056	0.075
2007	1.001	6.827	1186	0.147	19394	0.059	0.078
2008	1.365	9.310	1520	0.189	24276	0.074	0.098
2009	1.179	8.039	1215	0.151	23965	0.073	0.097
2010	0.325	2.218	811	0.101	29584	0.090	0.120
2011	0.195	1.334	828	0.103	38688	0.117	0.156
2012	0.433	2.954	942	0.117	41236	0.125	0.167
2013	0.278	1.896	1042	0.129	44587	0.135	0.180
2014	0.597	4.069	1656	0.206	44799	0.136	0.181
2015	.	.	1889	0.235	.	.	.

Table 11. Selectivity at age for SERFS combined trap and video index (CVID), commercial handlines (cH), headboat (HB), and general recreational (GR) landings (L) and discards (D). For time-varying selectivities, values shown are from selectivity block 1 (1950–1991).

Age	CVID	cH.L	HB.L	GR.L	cH.D	HB.D	GR.D
1	0.044	0.014	0.048	0.048	0.989	1.000	1.000
2	0.581	0.475	0.658	0.658	1.000	0.765	0.765
3	0.977	0.983	1.000	1.000	0.769	0.333	0.333
4	0.999	1.000	0.899	0.899	0.435	0.098	0.098
5	1.000	1.000	0.751	0.751	0.196	0.025	0.025
6	1.000	1.000	0.588	0.588	0.077	0.006	0.006
7	1.000	1.000	0.431	0.431	0.029	0.001	0.001
8	1.000	1.000	0.298	0.298	0.010	0.000	0.000
9	1.000	1.000	0.197	0.197	0.004	0.000	0.000
10	1.000	1.000	0.125	0.125	0.001	0.000	0.000
11	1.000	1.000	0.125	0.125	0.000	0.000	0.000
12	1.000	1.000	0.125	0.125	0.000	0.000	0.000
13	1.000	1.000	0.125	0.125	0.000	0.000	0.000
14	1.000	1.000	0.125	0.125	0.000	0.000	0.000
15	1.000	1.000	0.125	0.125	0.000	0.000	0.000
16	1.000	1.000	0.125	0.125	0.000	0.000	0.000
17	1.000	1.000	0.125	0.125	0.000	0.000	0.000
18	1.000	1.000	0.125	0.125	0.000	0.000	0.000
19	1.000	1.000	0.125	0.125	0.000	0.000	0.000
20	1.000	1.000	0.125	0.125	0.000	0.000	0.000

Table 12. Selectivity at age for SERFS combined trap and video index (CVID), commercial handlines (cH), headboat (HB), and general recreational (GR) landings (L) and discards (D). For time-varying selectivities, values shown are from selectivity block 2 (1992–2009).

Age	CVID	cH.L	HB.L	GR.L	cH.D	HB.D	GR.D
1	0.044	0.001	0.001	0.004	0.989	1.000	1.000
2	0.581	0.026	0.031	0.062	1.000	0.765	0.765
3	0.977	0.426	0.670	0.525	0.769	0.333	0.333
4	0.999	0.954	1.000	1.000	0.435	0.098	0.098
5	1.000	0.998	0.769	0.904	0.196	0.025	0.025
6	1.000	1.000	0.525	0.699	0.077	0.006	0.006
7	1.000	1.000	0.326	0.492	0.029	0.001	0.001
8	1.000	1.000	0.189	0.319	0.010	0.000	0.000
9	1.000	1.000	0.105	0.194	0.004	0.000	0.000
10	1.000	1.000	0.056	0.113	0.001	0.000	0.000
11	1.000	1.000	0.056	0.064	0.000	0.000	0.000
12	1.000	1.000	0.056	0.036	0.000	0.000	0.000
13	1.000	1.000	0.056	0.020	0.000	0.000	0.000
14	1.000	1.000	0.056	0.020	0.000	0.000	0.000
15	1.000	1.000	0.056	0.020	0.000	0.000	0.000
16	1.000	1.000	0.056	0.020	0.000	0.000	0.000
17	1.000	1.000	0.056	0.020	0.000	0.000	0.000
18	1.000	1.000	0.056	0.020	0.000	0.000	0.000
19	1.000	1.000	0.056	0.020	0.000	0.000	0.000
20	1.000	1.000	0.056	0.020	0.000	0.000	0.000

Table 13. Selectivity at age for SERFS combined trap and video index (CVID), commercial handlines (cH), headboat (HB), and general recreational (GR) landings (L) and discards (D). For time-varying selectivities, values shown are from selectivity block 3 (2010–2014).

Age	CVID	cH.L	HB.L	GR.L	cH.D	HB.D	GR.D
1	0.044	0.007	0.019	0.004	0.036	0.696	0.696
2	0.581	0.067	0.357	0.028	0.203	0.867	0.867
3	0.977	0.406	1.000	0.183	0.633	0.979	0.979
4	0.999	0.868	0.909	0.635	0.921	1.000	1.000
5	1.000	0.984	0.729	0.931	0.987	0.923	0.923
6	1.000	0.998	0.556	0.991	0.998	0.775	0.775
7	1.000	1.000	0.407	0.999	1.000	0.596	0.596
8	1.000	1.000	0.287	1.000	1.000	0.426	0.426
9	1.000	1.000	0.196	1.000	1.000	0.288	0.288
10	1.000	1.000	0.132	1.000	1.000	0.187	0.187
11	1.000	1.000	0.132	1.000	1.000	0.187	0.187
12	1.000	1.000	0.132	1.000	1.000	0.187	0.187
13	1.000	1.000	0.132	1.000	1.000	0.187	0.187
14	1.000	1.000	0.132	1.000	1.000	0.187	0.187
15	1.000	1.000	0.132	1.000	1.000	0.187	0.187
16	1.000	1.000	0.132	1.000	1.000	0.187	0.187
17	1.000	1.000	0.132	1.000	1.000	0.187	0.187
18	1.000	1.000	0.132	1.000	1.000	0.187	0.187
19	1.000	1.000	0.132	1.000	1.000	0.187	0.187
20	1.000	1.000	0.132	1.000	1.000	0.187	0.187

Table 14. Estimated time series of fully selected fishing mortality rates for commercial handlines (F.cH.L), headboat (F.HB.L), recreational (F.GR.L) landings (L) and discards (D). Also shown is Full F, the maximum F at age summed across fleets, which may not equal the sum of fully selected F's because of dome-shaped selectivities.

Year	F.cH.L	F.HB.L	F.GR.L	F.cH.D	F.HB.D	F.GR.D	Full F
1950	0.030	0.000	0.000	0.000	0.000	0.000	0.030
1951	0.042	0.000	0.000	0.000	0.000	0.000	0.042
1952	0.032	0.000	0.000	0.000	0.000	0.000	0.032
1953	0.033	0.000	0.000	0.000	0.000	0.000	0.033
1954	0.050	0.000	0.000	0.000	0.000	0.000	0.050
1955	0.043	0.022	0.043	0.000	0.000	0.000	0.108
1956	0.044	0.026	0.049	0.000	0.000	0.000	0.118
1957	0.083	0.029	0.056	0.000	0.000	0.000	0.167
1958	0.063	0.033	0.063	0.000	0.000	0.000	0.157
1959	0.072	0.036	0.069	0.000	0.000	0.000	0.176
1960	0.078	0.040	0.076	0.000	0.000	0.000	0.193
1961	0.101	0.045	0.086	0.000	0.000	0.000	0.230
1962	0.089	0.050	0.096	0.000	0.000	0.000	0.234
1963	0.072	0.055	0.106	0.000	0.000	0.000	0.232
1964	0.084	0.060	0.116	0.000	0.000	0.000	0.259
1965	0.094	0.066	0.127	0.000	0.000	0.000	0.286
1966	0.101	0.069	0.132	0.000	0.000	0.000	0.300
1967	0.144	0.072	0.138	0.000	0.000	0.000	0.353
1968	0.196	0.077	0.148	0.000	0.000	0.000	0.418
1969	0.136	0.080	0.154	0.000	0.000	0.000	0.368
1970	0.139	0.081	0.156	0.000	0.000	0.000	0.374
1971	0.132	0.090	0.173	0.000	0.000	0.000	0.394
1972	0.125	0.100	0.192	0.000	0.000	0.000	0.416
1973	0.096	0.110	0.212	0.000	0.000	0.000	0.417
1974	0.166	0.125	0.239	0.000	0.000	0.000	0.528
1975	0.244	0.148	0.284	0.000	0.000	0.000	0.672
1976	0.286	0.167	0.321	0.000	0.000	0.000	0.771
1977	0.381	0.190	0.365	0.000	0.000	0.000	0.931
1978	0.513	0.220	0.423	0.000	0.000	0.000	1.149
1979	0.456	0.232	0.447	0.000	0.000	0.000	1.129
1980	0.530	0.278	0.534	0.000	0.000	0.000	1.334
1981	0.598	0.230	0.597	0.000	0.000	0.006	1.419
1982	0.629	0.184	0.342	0.000	0.000	0.005	1.148
1983	0.809	0.256	0.571	0.000	0.000	0.002	1.625
1984	0.388	0.133	0.909	0.000	0.000	0.024	1.432
1985	0.285	0.193	1.109	0.000	0.000	0.043	1.597
1986	0.271	0.087	0.528	0.000	0.000	0.076	0.906
1987	0.251	0.152	0.287	0.000	0.000	0.037	0.699
1988	0.164	0.135	0.299	0.000	0.000	0.029	0.605
1989	0.183	0.078	0.324	0.000	0.000	0.021	0.589
1990	0.145	0.090	0.052	0.000	0.000	0.044	0.300
1991	0.101	0.091	0.227	0.000	0.000	0.075	0.441
1992	0.118	0.087	0.761	0.031	0.003	0.037	0.977
1993	0.442	0.226	0.292	0.034	0.007	0.129	0.966
1994	0.410	0.142	0.349	0.041	0.007	0.120	0.910
1995	0.378	0.179	0.272	0.058	0.011	0.139	0.850
1996	0.329	0.116	0.203	0.039	0.004	0.034	0.652
1997	0.335	0.170	0.941	0.043	0.005	0.029	1.452
1998	0.259	0.095	0.278	0.022	0.003	0.032	0.631
1999	0.216	0.121	0.693	0.014	0.003	0.147	1.040
2000	0.227	0.128	0.698	0.014	0.003	0.204	1.067
2001	0.350	0.146	0.399	0.016	0.006	0.205	0.904
2002	0.282	0.139	0.397	0.038	0.007	0.151	0.835
2003	0.186	0.062	0.288	0.010	0.003	0.175	0.548
2004	0.232	0.132	0.348	0.005	0.038	0.400	0.744
2005	0.200	0.127	0.436	0.041	0.046	0.341	0.808
2006	0.181	0.145	0.602	0.003	0.010	0.066	0.928
2007	0.355	0.231	0.412	0.007	0.038	0.151	1.001
2008	0.398	0.164	0.788	0.006	0.043	0.298	1.365
2009	0.468	0.189	0.505	0.014	0.070	0.292	1.179
2010	0.008	0.003	0.001	0.050	0.058	0.210	0.325
2011	0.001	0.011	0.001	0.120	0.041	0.033	0.195
2012	0.009	0.018	0.203	0.062	0.043	0.132	0.433
2013	0.034	0.011	0.109	0.056	0.031	0.056	0.278
2014	0.068	0.031	0.371	0.059	0.015	0.095	0.597

Table 15. Estimated instantaneous fishing mortality rate (per yr) at age.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1950	0.000	0.015	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
1951	0.001	0.021	0.041	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
1952	0.000	0.016	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
1953	0.000	0.017	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
1954	0.001	0.025	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
1955	0.004	0.065	0.108	0.102	0.092	0.081	0.071	0.062	0.056	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051
1956	0.004	0.071	0.118	0.111	0.100	0.088	0.076	0.066	0.058	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053
1957	0.005	0.098	0.167	0.159	0.147	0.133	0.120	0.108	0.100	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094
1958	0.006	0.095	0.157	0.149	0.134	0.119	0.104	0.091	0.082	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
1959	0.006	0.106	0.176	0.166	0.151	0.134	0.117	0.103	0.092	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085
1960	0.007	0.116	0.193	0.182	0.165	0.146	0.128	0.113	0.101	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093
1961	0.008	0.137	0.230	0.218	0.199	0.177	0.157	0.139	0.126	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117
1962	0.008	0.141	0.234	0.220	0.199	0.175	0.152	0.132	0.117	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107
1963	0.009	0.142	0.232	0.216	0.192	0.166	0.141	0.119	0.103	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092
1964	0.010	0.158	0.259	0.242	0.216	0.187	0.160	0.136	0.118	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106
1965	0.011	0.175	0.286	0.268	0.239	0.207	0.177	0.151	0.131	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118
1966	0.011	0.183	0.300	0.281	0.251	0.218	0.187	0.160	0.140	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
1967	0.012	0.211	0.353	0.333	0.302	0.268	0.235	0.207	0.185	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
1968	0.014	0.247	0.418	0.398	0.365	0.328	0.293	0.263	0.240	0.224	0.224	0.224	0.224	0.224	0.224	0.224	0.224	0.224	0.224	0.224
1969	0.013	0.223	0.368	0.347	0.312	0.274	0.237	0.206	0.182	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165
1970	0.013	0.226	0.374	0.352	0.317	0.278	0.241	0.210	0.186	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169
1971	0.015	0.240	0.394	0.369	0.330	0.287	0.245	0.210	0.184	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165
1972	0.016	0.256	0.416	0.388	0.344	0.296	0.250	0.211	0.182	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161
1973	0.017	0.261	0.417	0.385	0.337	0.285	0.234	0.191	0.158	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136
1974	0.020	0.324	0.528	0.494	0.439	0.380	0.323	0.274	0.237	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212
1975	0.024	0.407	0.672	0.632	0.568	0.497	0.429	0.372	0.328	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298
1976	0.028	0.466	0.771	0.725	0.652	0.573	0.496	0.431	0.381	0.347	0.347	0.347	0.347	0.347	0.347	0.347	0.347	0.347	0.347	0.347
1977	0.032	0.558	0.931	0.880	0.797	0.706	0.619	0.545	0.489	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
1978	0.038	0.682	1.149	1.091	0.995	0.890	0.789	0.704	0.639	0.593	0.593	0.593	0.593	0.593	0.593	0.593	0.593	0.593	0.593	0.593
1979	0.039	0.677	1.129	1.066	0.965	0.854	0.747	0.657	0.588	0.540	0.540	0.540	0.540	0.540	0.540	0.540	0.540	0.540	0.540	0.540
1980	0.047	0.802	1.334	1.259	1.138	1.006	0.878	0.770	0.688	0.631	0.631	0.631	0.631	0.631	0.631	0.631	0.631	0.631	0.631	0.631
1981	0.054	0.851	1.419	1.342	1.219	1.083	0.953	0.843	0.759	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701
1982	0.040	0.668	1.148	1.102	1.023	0.937	0.855	0.785	0.731	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694
1983	0.054	0.954	1.625	1.551	1.428	1.293	1.163	1.053	0.970	0.911	0.911	0.911	0.911	0.911	0.911	0.911	0.911	0.911	0.911	0.911
1984	0.080	0.900	1.432	1.326	1.169	0.999	0.835	0.696	0.591	0.517	0.517	0.517	0.517	0.517	0.517	0.517	0.517	0.517	0.517	0.517
1985	0.109	1.034	1.597	1.459	1.262	1.049	0.844	0.671	0.539	0.446	0.446	0.446	0.446	0.446	0.446	0.446	0.446	0.446	0.446	0.446
1986	0.109	0.599	0.906	0.830	0.733	0.631	0.535	0.453	0.390	0.347	0.347	0.347	0.347	0.347	0.347	0.347	0.347	0.347	0.347	0.347
1987	0.062	0.444	0.699	0.649	0.581	0.508	0.439	0.381	0.336	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305
1988	0.052	0.391	0.605	0.557	0.490	0.419	0.350	0.292	0.248	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217
1989	0.043	0.373	0.589	0.546	0.485	0.419	0.355	0.302	0.261	0.233	0.233	0.233	0.233	0.233	0.233	0.233	0.233	0.233	0.233	0.233
1990	0.053	0.201	0.300	0.277	0.253	0.229	0.206	0.187	0.173	0.163	0.163	0.163	0.163	0.163	0.163	0.163	0.163	0.163	0.163	0.163
1991	0.092	0.317	0.441	0.393	0.340	0.287	0.237	0.195	0.163	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
1992	0.075	0.113	0.533	0.977	0.891	0.718	0.545	0.399	0.291	0.221	0.180	0.156	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142
1993	0.170	0.172	0.546	0.966	0.899	0.785	0.678	0.594	0.534	0.496	0.480	0.471	0.466	0.466	0.466	0.466	0.466	0.466	0.466	0.466
1994	0.170	0.173	0.511	0.910	0.853	0.746	0.644	0.562	0.503	0.464	0.445	0.434	0.428	0.428	0.428	0.428	0.428	0.428	0.428	0.428
1995	0.210	0.204	0.504	0.850	0.784	0.681	0.587	0.512	0.459	0.426	0.411	0.402	0.397	0.397	0.397	0.397	0.397	0.397	0.397	0.397
1996	0.078	0.092	0.357	0.652	0.616	0.544	0.478	0.425	0.387	0.363	0.352	0.345	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342
1997	0.080	0.138	0.775	1.452	1.342	1.114	0.887	0.697	0.558	0.467	0.416	0.386	0.369	0.369	0.369	0.369	0.369	0.369	0.369	0.369
1998	0.058	0.074	0.338	0.631	0.594	0.515	0.439	0.376	0.331	0.301	0.286	0.277	0.272	0.272	0.272	0.272	0.272	0.272	0.272	0.272
1999	0.167	0.179	0.583	1.040	0.953	0.786	0.620	0.481	0.379	0.312	0.275	0.253	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241
2000	0.224	0.222	0.612	1.067	0.976	0.805	0.636	0.495	0.392	0.324	0.287	0.265	0.252	0.252	0.252	0.252	0.252	0.252	0.252	0.252
2001	0.230	0.214	0.524	0.904	0.839	0.722	0.611	0.519	0.453	0.410	0.389	0.377	0.369	0.369	0.369	0.369	0.369	0.369	0.369	0.369
2002	0.198	0.193	0.490	0.835	0.767	0.651	0.540	0.449	0.384	0.342	0.321	0.308	0.301	0.301	0.301	0.301	0.301	0.301	0.301	0.301
2003	0.189	0.169	0.330	0.548	0.505	0.431	0.358	0.299	0.255	0.227	0.211	0.202	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197
2004	0.444	0.367	0.505	0.744	0.667	0.561	0.462	0.381	0.324	0.286	0.267	0.256	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250
2005	0.429	0.369	0.546	0.808	0.718	0.592	0.474	0.379	0.309	0.264	0.241	0.227	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219
2006	0.082	0.106	0.504	0.928	0.851	0.698	0.547	0.420	0.328	0.268	0.236	0.217	0.206	0.206	0.206	0.206	0.206	0.206	0.206	0.206
2007	0.197	0.190	0.572	1.001	0.922	0.785	0.654	0.548	0.472	0.424	0.402	0.388	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381
2008	0.351	0.327	0.790	1.365	1.259	1.061	0.867	0.705	0.587	0.509	0.467	0.442	0.428	0.428	0.428	0.428	0.428	0.428	0.428	0.428
2009	0.377	0.335	0.701	1.179	1.092	0.942	0.800	0.684	0.600	0.546	0.519	0.503	0.493	0.493	0.493	0.493	0.493	0.493	0.493	0.493
2010	0.190	0.246	0.302	0.325	0.308	0.268	0.220	0.174	0.137	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
2011	0.056	0.092	0.159	0.195	0.195	0.184	0.169	0.156	0.145	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136
2012	0.126	0.177	0.270	0.385	0.433	0.416	0.384	0.352	0.327	0.308	0.308	0.308	0.308	0.308	0.308	0.308	0.308	0.308	0.308	0.308
2013	0.063	0.096	0.165	0.247	0.278	0.271	0.255	0.239	0.226	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217
2014	0.081	0.134	0.272	0.488	0.595	0.597	0.575	0.553	0.536	0.523	0.523	0.523	0.523	0.523	0.523	0.523	0.523	0.523	0.523	0.523

Table 16. Estimated total landings at age in numbers (1000 fish)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1950	0.15	3.18	4.42	3.40	2.68	2.17	1.78	1.47	1.23	1.04	0.87	0.74	0.63	0.53	0.46	0.39	0.33	0.28	0.24	1.42
1951	0.21	4.33	6.00	4.61	3.63	2.94	2.41	2.00	1.67	1.40	1.18	1.00	0.85	0.72	0.62	0.53	0.45	0.38	0.33	1.93
1952	0.16	3.37	4.66	3.56	2.80	2.27	1.86	1.54	1.29	1.08	0.91	0.77	0.66	0.56	0.48	0.41	0.35	0.30	0.25	1.49
1953	0.17	3.49	4.84	3.69	2.89	2.34	1.92	1.59	1.33	1.12	0.94	0.80	0.68	0.58	0.49	0.42	0.36	0.30	0.26	1.54
1954	0.25	5.23	7.22	5.53	4.33	3.47	2.85	2.36	1.97	1.66	1.40	1.19	1.01	0.86	0.73	0.62	0.53	0.45	0.39	2.28
1955	1.28	13.11	15.14	10.73	7.66	5.46	3.91	2.85	2.14	1.65	1.39	1.18	1.00	0.85	0.73	0.62	0.53	0.45	0.38	2.27
1956	1.43	14.31	15.81	10.88	7.71	5.53	3.97	2.89	2.16	1.67	1.41	1.20	1.02	0.86	0.74	0.63	0.54	0.46	0.39	2.30
1957	1.80	19.43	21.69	14.56	10.30	7.63	5.77	4.42	3.47	2.79	2.38	2.03	1.72	1.46	1.25	1.06	0.91	0.77	0.66	3.90
1958	1.87	18.78	20.00	12.86	8.60	6.07	4.47	3.38	2.61	2.06	1.78	1.52	1.30	1.11	0.94	0.80	0.68	0.58	0.50	2.94
1959	2.07	20.84	22.23	14.03	9.12	6.22	4.49	3.42	2.69	2.16	1.88	1.63	1.40	1.19	1.02	0.87	0.74	0.63	0.54	3.18
1960	2.27	22.72	23.89	15.01	9.58	6.34	4.42	3.29	2.60	2.13	1.88	1.64	1.42	1.22	1.05	0.89	0.76	0.65	0.56	3.27
1961	2.63	26.61	27.70	17.18	10.99	7.22	4.94	3.60	2.82	2.34	2.10	1.86	1.63	1.41	1.22	1.04	0.89	0.76	0.65	3.83
1962	2.82	27.36	27.52	16.52	10.30	6.66	4.42	3.08	2.29	1.84	1.66	1.50	1.33	1.16	1.01	0.87	0.75	0.64	0.55	3.22
1963	2.97	27.51	27.12	15.83	9.51	5.96	3.87	2.59	1.84	1.40	1.24	1.13	1.02	0.90	0.79	0.69	0.60	0.51	0.44	2.58
1964	3.27	30.37	29.87	17.45	10.33	6.37	4.11	2.78	1.96	1.47	1.27	1.13	1.03	0.93	0.83	0.73	0.64	0.55	0.47	2.78
1965	3.60	33.23	32.04	18.51	10.98	6.67	4.24	2.85	2.02	1.50	1.27	1.10	0.98	0.90	0.81	0.73	0.64	0.56	0.48	2.85
1966	3.75	34.62	32.80	18.48	10.87	6.64	4.17	2.77	1.96	1.47	1.23	1.05	0.91	0.81	0.74	0.67	0.60	0.53	0.46	2.77
1967	4.12	39.44	37.31	20.74	12.06	7.44	4.81	3.24	2.32	1.77	1.50	1.26	1.07	0.93	0.84	0.77	0.70	0.62	0.55	3.33
1968	4.60	45.27	41.71	22.60	13.00	7.95	5.20	3.59	2.59	1.98	1.66	1.41	1.19	1.02	0.88	0.79	0.73	0.66	0.59	3.69
1969	4.45	41.20	36.20	18.32	10.03	5.88	3.65	2.43	1.71	1.26	1.05	0.88	0.75	0.63	0.54	0.47	0.42	0.39	0.35	2.29
1970	4.50	41.71	37.47	18.79	9.74	5.54	3.38	2.20	1.55	1.15	0.95	0.79	0.67	0.57	0.48	0.41	0.36	0.32	0.29	2.01
1971	4.89	43.93	38.92	19.85	10.14	5.41	3.17	2.01	1.36	1.00	0.83	0.68	0.57	0.48	0.41	0.35	0.30	0.26	0.23	1.68
1972	5.32	46.36	40.09	20.22	10.52	5.54	3.05	1.86	1.23	0.87	0.72	0.60	0.50	0.41	0.35	0.30	0.25	0.22	0.19	1.40
1973	5.64	47.03	39.45	19.37	9.91	5.27	2.83	1.59	0.99	0.67	0.55	0.46	0.38	0.31	0.26	0.22	0.19	0.16	0.14	1.01
1974	6.64	56.69	47.28	23.21	11.90	6.50	3.73	2.20	1.38	0.96	0.77	0.63	0.52	0.44	0.36	0.30	0.26	0.22	0.19	1.33
1975	8.07	68.46	52.98	24.83	12.79	7.03	4.15	2.60	1.68	1.15	0.91	0.74	0.60	0.50	0.42	0.35	0.29	0.25	0.21	1.47
1976	9.14	75.92	53.42	22.22	10.96	6.07	3.61	2.31	1.58	1.10	0.84	0.67	0.54	0.45	0.37	0.31	0.26	0.22	0.18	1.25
1977	10.58	86.81	56.66	21.00	9.31	5.02	3.06	2.02	1.43	1.06	0.83	0.64	0.51	0.42	0.34	0.29	0.24	0.20	0.17	1.11
1978	14.05	99.72	58.13	19.09	7.62	3.74	2.26	1.54	1.13	0.88	0.73	0.57	0.44	0.35	0.29	0.24	0.20	0.17	0.14	0.88
1979	10.71	110.30	50.31	13.73	4.83	2.13	1.16	0.77	0.58	0.46	0.39	0.33	0.26	0.20	0.16	0.13	0.11	0.09	0.08	0.46
1980	18.74	92.31	61.46	13.42	3.97	1.57	0.78	0.48	0.36	0.29	0.26	0.22	0.19	0.15	0.11	0.09	0.08	0.06	0.05	0.31
1981	6.92	140.13	41.58	12.61	3.03	1.03	0.47	0.27	0.19	0.16	0.15	0.13	0.11	0.09	0.07	0.06	0.05	0.04	0.03	0.18
1982	8.19	41.94	51.95	6.85	2.30	0.64	0.25	0.14	0.09	0.07	0.07	0.06	0.06	0.05	0.04	0.03	0.03	0.02	0.02	0.09
1983	33.62	89.92	26.30	14.91	2.11	0.78	0.24	0.11	0.06	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.06
1984	40.69	231.80	31.13	3.65	2.23	0.35	0.14	0.05	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.02
1985	21.95	275.57	93.74	5.84	0.77	0.54	0.10	0.04	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
1986	5.94	78.76	65.45	10.28	0.74	0.12	0.10	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
1987	13.77	34.83	38.03	16.77	2.85	0.23	0.04	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	9.94	101.82	21.62	12.63	5.78	1.03	0.08	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	3.13	76.74	72.25	8.61	5.30	2.60	0.50	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	0.55	12.95	31.62	16.82	2.14	1.44	0.79	0.17	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	0.86	8.15	17.20	23.66	12.46	1.55	1.00	0.52	0.11	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	0.86	1.45	7.45	15.83	23.95	13.19	1.66	1.05	0.52	0.10	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	0.16	4.80	7.21	5.38	4.62	7.54	5.23	0.87	0.76	0.53	0.14	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1994	0.29	1.58	31.30	5.15	1.56	1.39	2.54	1.97	0.37	0.35	0.26	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	0.11	2.31	9.64	23.40	1.55	0.48	0.47	0.96	0.83	0.17	0.17	0.13	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	0.23	0.85	12.91	6.56	6.71	0.46	0.16	0.17	0.40	0.37	0.08	0.09	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00
1997	0.58	6.96	12.78	20.54	4.43	4.48	0.32	0.11	0.12	0.27	0.25	0.05	0.06	0.04	0.01	0.00	0.00	0.00	0.00	0.00
1998	0.35	1.92	17.79	4.12	2.26	0.52	0.65	0.06	0.03	0.04	0.10	0.10	0.02	0.03	0.02	0.01	0.00	0.00	0.00	0.00
1999	0.97	6.46	20.79	24.15	2.38	1.27	0.30	0.39	0.04	0.02	0.02	0.06	0.06	0.01	0.02	0.01	0.00	0.00	0.00	0.00
2000	1.03	7.68	34.15	14.73	6.74	0.69	0.42	0.12	0.17	0.02	0.01	0.01	0.04	0.04	0.01	0.01	0.01	0.00	0.00	0.00
2001	0.47	5.69	33.54	20.94	3.59	1.74	0.21	0.16	0.06	0.11	0.01	0.01	0.01	0.04	0.04	0.01	0.01	0.01	0.00	0.00
2002	0.39	3.82	32.55	24.65	6.27	1.09	0.58	0.08	0.07	0.03	0.05	0.01	0.00	0.01	0.02	0.02	0.00	0.01	0.00	0.00
2003	0.35	2.30	16.20	19.52	6.20	1.59	0.30	0.18	0.03	0.02	0.01	0.02	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
2004	0.14	3.43	18.32	20.09	10.83	3.40	0.93	0.19	0.12	0.02	0.02	0.01	0.02	0.00	0.00	0.00	0.01	0.01	0.00	0.00
2005	0.08	1.13	20.17	15.88	7.82	4.26	1.44	0.42	0.09	0.06	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00
2006	1.85	0.74	7.28	18.37	6.35	3.19	1.89	0.70	0.22	0.05	0.04	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01
2007	0.99	14.08	4.38	5.71	5.88	2.14	1.28	0.94	0.43	0.17	0.05	0.04	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.01
2008	1.64	12.91	108.42	3.68	1.96	2.12	0.88	0.60	0.49	0.25	0.11	0.03	0.03	0.01	0.01	0.00	0.01	0.00	0.00	0.01
2009	0.36	8.72	52.86	55.37	0.69	0.39	0.52	0.27	0.23	0.22	0.13	0.06	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.01
2010	0.01	0.09	0.61	0.44	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2011	0.04	0.12	0.38	0.62	0.24	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2012	0.21	1.38	1.10	3.15	7.38	3.56	1.59	0.02	0.02	0.04	0.02	0.03	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00
2013	0.29	0.91	2.95	1.22	1.70	3.01	1.43	0.66	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
2014	2.05	4.85	7.71	12.22	2.64	2.94	5.15	2.51	1.19	0.02	0.02	0.03	0.02	0.02	0.03	0.02	0.01	0.00	0.00	0.00

Table 17. Estimated landings at age in whole weight (1000 lb)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1950	0.23	10.91	25.93	28.87	29.74	29.30	27.94	26.00	23.77	21.43	19.11	16.90	14.85	12.98	11.29	9.80	8.48	7.32	6.31	37.46
1951	0.31	14.85	35.16	39.13	40.32	39.72	37.87	35.25	32.22	29.04	25.90	22.90	20.13	17.59	15.31	13.28	11.49	9.92	8.55	50.77
1952	0.24	11.56	27.30	30.21	31.11	30.65	29.22	27.20	24.86	22.41	19.98	17.67	15.53	13.57	11.81	10.25	8.87	7.66	6.60	39.17
1953	0.25	11.96	28.35	31.34	32.09	31.59	30.12	28.03	25.63	23.10	20.60	18.22	16.01	13.99	12.18	10.57	9.14	7.89	6.80	40.38
1954	0.37	17.92	42.31	46.94	48.01	47.00	44.79	41.68	38.10	34.35	30.63	27.09	23.80	20.80	18.10	15.71	13.59	11.73	10.11	60.04
1955	1.90	44.94	88.76	91.14	84.97	73.81	61.40	50.32	41.23	34.14	30.44	26.92	23.66	20.67	17.99	15.61	13.51	11.66	10.05	59.67
1956	2.12	49.06	92.67	92.35	85.57	74.88	62.41	50.92	41.70	34.49	30.90	27.33	24.01	20.98	18.26	15.85	13.71	11.84	10.20	60.57
1957	2.66	66.58	127.19	123.65	114.28	103.19	90.75	78.07	66.90	57.72	52.08	46.28	40.67	35.54	30.93	26.84	23.22	20.05	17.28	102.57
1958	2.76	64.35	117.27	109.24	95.40	82.12	70.30	59.64	50.28	42.65	38.86	34.78	30.71	26.83	23.35	20.27	17.53	15.14	13.04	77.45
1959	3.06	71.44	130.31	119.17	101.20	84.10	70.59	60.26	51.89	44.74	41.07	37.13	33.01	28.98	25.23	21.89	18.94	16.35	14.09	83.66
1960	3.36	77.88	140.07	127.46	106.24	85.83	69.47	58.06	50.20	44.09	41.07	37.40	33.59	29.70	25.97	22.54	19.50	16.83	14.51	86.13
1961	3.89	91.20	162.41	145.85	121.88	97.62	77.74	63.46	54.35	48.42	45.99	42.49	38.45	34.33	30.24	26.36	22.81	19.69	16.97	100.75
1962	4.17	93.79	161.32	140.27	114.23	90.09	69.48	54.30	44.18	38.03	36.35	34.24	31.43	28.28	25.16	22.09	19.20	16.58	14.29	84.82
1963	4.39	94.27	158.98	134.41	105.55	80.70	60.88	45.77	35.45	28.87	27.12	25.71	24.07	21.97	19.69	17.46	15.29	13.26	11.42	67.84
1964	4.84	104.11	175.10	148.17	114.63	86.16	64.68	49.10	37.90	30.41	27.72	25.83	24.33	22.65	20.59	18.40	16.27	14.21	12.30	73.05
1965	5.33	113.91	187.84	157.19	121.81	90.26	66.59	50.23	39.04	31.11	27.79	25.13	23.26	21.79	20.20	18.31	16.31	14.39	12.55	74.87
1966	5.55	118.65	192.33	156.94	120.58	89.79	65.56	48.79	37.80	30.41	26.96	23.89	21.46	19.76	18.43	17.04	15.40	13.69	12.06	72.73
1967	6.09	135.19	218.75	176.16	133.80	100.67	75.63	57.16	44.80	36.70	32.77	28.82	25.38	22.67	20.78	19.33	17.82	16.07	14.26	87.70
1968	6.81	155.17	244.56	191.90	144.27	107.59	81.70	63.31	50.00	40.98	36.40	32.24	28.17	24.66	21.94	20.06	18.61	17.11	15.40	97.05
1969	6.58	141.20	212.22	155.54	111.30	79.50	57.36	42.80	33.00	26.09	22.86	20.14	17.72	15.40	13.43	11.91	10.86	10.05	9.22	60.21
1970	6.66	142.95	219.69	159.57	108.05	74.89	53.11	38.87	29.87	23.83	20.68	17.97	15.74	13.77	11.92	10.36	9.16	8.33	7.70	52.83
1971	7.22	150.56	228.17	168.58	112.53	73.23	49.85	35.40	26.32	20.67	18.09	15.58	13.45	11.71	10.21	8.81	7.64	6.74	6.12	44.12
1972	7.86	158.91	235.04	171.67	116.70	74.97	47.99	32.76	23.68	18.04	15.75	13.68	11.70	10.05	8.71	7.57	6.51	5.63	4.96	36.74
1973	8.34	161.19	231.30	164.49	109.92	71.30	44.49	28.09	19.17	13.96	12.01	10.41	8.98	7.64	6.53	5.65	4.89	4.20	3.63	26.66
1974	9.82	194.31	277.19	197.05	132.05	87.90	58.69	38.82	26.56	19.79	16.86	14.39	12.38	10.62	9.00	7.68	6.62	5.72	4.90	35.09
1975	11.93	234.65	310.63	210.86	141.90	95.14	65.25	45.91	32.44	23.71	19.88	16.81	14.25	12.20	10.42	8.80	7.48	6.44	5.55	38.57
1976	13.51	260.20	313.18	188.70	121.59	82.11	56.71	40.81	30.41	22.71	18.41	15.31	12.86	10.84	9.24	7.87	6.63	5.63	4.83	32.88
1977	15.65	297.52	332.16	178.30	103.27	67.93	48.18	35.61	27.61	22.03	18.24	14.67	12.12	10.12	8.50	7.22	6.14	5.16	4.37	29.07
1978	20.78	341.77	340.79	162.10	84.51	50.65	35.48	27.23	21.84	18.20	15.97	13.11	10.48	8.61	7.16	6.00	5.08	4.31	3.61	23.26
1979	15.84	378.05	294.97	116.57	53.64	28.78	18.20	13.60	11.14	9.45	8.61	7.49	6.11	4.86	3.98	3.30	2.75	2.33	1.97	12.21
1980	27.72	316.40	360.32	113.92	44.09	21.22	12.24	8.43	6.86	6.05	5.68	5.13	4.44	3.60	2.85	2.32	1.92	1.60	1.35	8.17
1981	10.24	480.28	243.79	107.07	33.64	13.92	7.38	4.75	3.64	3.24	3.19	2.97	2.66	2.29	1.85	1.46	1.19	0.98	0.82	4.82
1982	12.11	143.75	304.56	58.16	25.55	8.67	4.00	2.40	1.75	1.48	1.47	1.43	1.32	1.18	1.01	0.82	0.64	0.52	0.43	2.45
1983	49.72	308.20	154.17	126.64	23.41	10.58	3.78	1.85	1.18	0.90	0.82	0.80	0.77	0.71	0.63	0.54	0.43	0.34	0.28	1.52
1984	60.17	794.47	182.49	31.03	24.69	4.69	2.21	0.82	0.41	0.27	0.22	0.20	0.20	0.19	0.17	0.15	0.13	0.10	0.08	0.43
1985	32.46	944.51	549.57	49.55	8.51	7.31	1.53	0.79	0.32	0.17	0.13	0.11	0.10	0.09	0.09	0.08	0.07	0.06	0.05	0.24
1986	8.78	269.96	383.70	87.30	8.16	1.58	1.59	0.40	0.25	0.12	0.08	0.06	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.13
1987	20.37	119.36	222.98	142.38	31.59	3.04	0.62	0.68	0.19	0.13	0.07	0.05	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.09
1988	14.70	349.00	126.73	107.28	64.09	13.89	1.33	0.27	0.30	0.08	0.06	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.05
1989	4.62	263.01	423.59	73.11	58.77	35.15	7.85	0.79	0.17	0.21	0.07	0.05	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.05
1990	0.81	44.38	185.36	142.80	23.71	19.47	12.35	3.01	0.34	0.08	0.11	0.03	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.03
1991	1.27	27.92	100.86	200.93	138.21	20.92	15.70	9.13	2.06	0.22	0.06	0.07	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.02
1992	2.78	7.42	53.44	146.99	272.27	175.94	25.12	17.69	9.63	2.04	0.21	0.05	0.06	0.02	0.01	0.01	0.00	0.00	0.00	0.02
1993	0.51	24.52	51.70	49.96	52.50	100.68	79.34	14.74	14.04	10.36	2.91	0.36	0.09	0.13	0.04	0.03	0.02	0.01	0.01	0.05
1994	0.94	8.09	224.49	47.87	17.73	18.54	38.57	33.28	6.73	6.86	5.34	1.52	0.19	0.05	0.07	0.02	0.02	0.01	0.01	0.03
1995	0.36	11.83	69.13	217.35	17.60	6.36	7.14	16.19	15.24	3.32	3.60	2.88	0.84	0.11	0.03	0.04	0.01	0.01	0.00	0.02
1996	0.73	4.35	92.61	60.94	76.26	6.11	2.39	2.93	7.28	7.38	1.71	1.89	1.53	0.45	0.06	0.01	0.02	0.01	0.00	0.01
1997	1.89	35.57	91.67	190.78	50.33	59.83	4.82	1.86	2.23	5.34	5.29	1.19	1.29	1.05	0.31	0.04	0.01	0.01	0.00	0.01
1998	1.13	9.84	127.57	38.29	25.70	6.93	9.90	1.00	0.49	0.72	2.05	2.27	0.55	0.62	0.51	0.15	0.02	0.00	0.01	0.01
1999	3.12	33.04	149.08	224.28	27.03	17.00	4.59	6.52	0.65	0.31	0.45	1.27	1.38	0.34	0.38	0.31	0.09	0.01	0.00	0.01
2000	3.34	39.26	244.93	136.85	76.62	9.16	6.43	1.97	3.21	0.36	0.19	0.30	0.89	1.03	0.25	0.28	0.23	0.07	0.01	0.01
2001	1.53	29.08	240.58	194.49	40.85	23.28	3.25	2.77	1.05	2.09	0.28	0.17	0.28	0.87	1.00	0.24	0.27	0.22	0.06	0.02
2002	1.27	19.50	233.47	228.92	71.29	14.53	8.80	1.32	1.22	0.49	1.04	0.14	0.09	0.15	0.46	0.52	0.13	0.14	0.11	0.04
2003	1.13	11.77	116.17	181.29	70.47	21.23	4.59	3.01	0.49	0.49	0.21	0.46	0.06	0.04	0.07	0.21	0.24	0.06	0.06	0.07
2004	0.47	17.53	131.36	186.59	123.04	45.30	14.07	3.21	2.24	0.39	0.41	0.19	0.41	0.06	0.04	0.06	0.19	0.22	0.05	0.12
2005	0.25	5.77	144.69	147.44	88.90	56.90	21.86	7.15	1.72	1.26	0.23	0.25	0.11	0.26	0.04	0.02	0.04	0.12	0.13	0.11
2006	5.99	3.76	52.22	170.65	72.14	42.50	28.76	11.74	4.08	1.04	0.81	0.15	0.17	0.08	0.18	0.03	0.02	0.03	0.08	0.16
2007	3.20	72.01	31.41	53.06	66.83	28.53	19.39	15.81	7.94	3.37	1.03	0.90	0.18	0.21	0.10	0.22	0.03	0.02	0.03	0.30
2008	5.30	65.99	777.58	34.16	22.28	28.34	13.37	10.08	9.02	4.88	2.20	0.68	0.60	0.12	0.14	0.07	0.15	0.02	0.01	0.22
2009	1.16	44.57	379.12	514.22	7.81	5.26	7.92	4.54	4.16	4.41	2.74	1.34	0.43	0.40	0.08	0.09	0.04	0.10	0.01	0.15
2010	0.01	0.31	3.59	3.70	2.16	0.04	0.03	0.06	0.04	0.04	0.05	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00
2011	0.06	0.40	2.21	5.29	2.63	1.11	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2012	0.31	4.74	6.44	26.75	81.86	48.10	24.99	0.43	0.38	0.75	0.54	0.59	0.69	0.45	0.22	0.07	0.07	0.01	0.02	0.05
2013	0.43	3.14	17.32	10.36	18.89	40.76	22.54	11.69	0.20	0.18	0.36	0.26	0.28	0.32	0.21	0.10	0.03	0.03	0.01	0.03
2014	3.03	16.62	45.20	103.79	29.28	39.74	80.99	44.37	23.01	0.40	0.35	0.69	0.50	0.54	0.62	0.40	0.20	0.06	0.06	0.07

Table 18. Estimated time series of landings in number (1000 fish) for commercial handlines (L.cH), headboat (L.HB), and recreational (L.GR).

Year	L.cH	L.HB	L.GR	Total
1950	27.42	0.00	0.00	27.42
1951	37.19	0.00	0.00	37.19
1952	28.76	0.00	0.00	28.76
1953	29.72	0.00	0.00	29.72
1954	44.33	0.00	0.00	44.33
1955	36.79	12.50	24.03	73.33
1956	36.00	13.65	26.24	75.90
1957	64.75	14.80	28.46	108.01
1958	46.24	15.95	30.67	92.86
1959	50.36	17.10	32.88	100.34
1960	52.26	18.25	35.09	105.60
1961	63.24	19.91	38.27	121.41
1962	52.51	21.56	41.44	115.51
1963	40.67	23.21	44.62	108.50
1964	45.69	24.86	47.79	118.35
1965	48.48	26.51	50.96	125.96
1966	49.37	26.67	51.26	127.30
1967	66.45	26.82	51.56	144.84
1968	82.30	26.98	51.85	161.13
1969	53.61	27.13	52.15	132.90
1970	53.13	27.29	52.45	132.87
1971	48.87	29.98	57.62	136.47
1972	44.52	32.68	62.80	139.99
1973	33.12	35.37	67.97	136.45
1974	54.33	38.06	73.13	165.52
1975	70.45	40.75	78.28	189.48
1976	71.02	41.21	79.18	191.42
1977	80.12	41.64	79.94	201.70
1978	89.01	42.15	81.01	212.17
1979	72.51	42.65	82.03	197.18
1980	68.92	43.10	82.88	194.90
1981	77.71	36.04	93.54	207.30
1982	56.95	19.57	36.36	112.89
1983	69.20	30.70	68.48	168.38
1984	65.98	31.16	213.00	310.14
1985	59.19	50.34	289.08	398.61
1986	44.17	16.62	100.66	161.45
1987	34.27	24.98	47.33	106.58
1988	35.76	36.50	80.69	152.95
1989	48.85	23.44	96.90	169.19
1990	33.49	20.91	12.09	66.49
1991	16.96	13.85	34.70	65.52
1992	9.02	5.30	51.76	66.08
1993	18.59	7.35	11.33	37.27
1994	20.28	8.23	18.34	46.85
1995	17.95	8.83	13.49	40.27
1996	14.20	5.54	9.34	29.08
1997	11.11	5.77	34.14	51.02
1998	10.26	4.74	13.02	28.02
1999	10.48	6.84	39.63	56.94
2000	12.11	8.44	45.35	65.90
2001	23.06	12.03	31.58	66.67
2002	21.54	12.94	35.16	69.64
2003	15.05	5.71	25.99	46.76
2004	17.84	10.84	28.86	57.54
2005	13.10	8.90	29.41	51.42
2006	8.09	5.94	26.69	40.71
2007	11.60	6.89	17.65	36.14
2008	32.31	18.96	81.86	133.14
2009	43.09	21.59	55.20	119.87
2010	0.82	0.48	0.06	1.36
2011	0.06	1.36	0.06	1.48
2012	0.79	2.13	15.65	18.56
2013	3.19	1.52	7.57	12.28
2014	7.34	5.91	28.17	41.43

Table 19. Estimated time series of landings in whole weight (1000 lb) for commercial handlines (L.cH), headboat (L.HB), and recreational (L.GR).

Year	L.cH	L.HB	L.GR	Total
1950	368.63	0.00	0.00	368.63
1951	499.70	0.00	0.00	499.70
1952	385.89	0.00	0.00	385.89
1953	398.23	0.00	0.00	398.23
1954	593.09	0.00	0.00	593.09
1955	493.22	105.93	203.67	802.82
1956	483.81	114.97	221.04	819.82
1957	866.94	123.01	236.48	1226.44
1958	612.32	129.91	249.76	991.98
1959	657.49	136.74	262.89	1057.12
1960	670.79	143.41	275.70	1089.90
1961	795.93	153.63	295.34	1244.90
1962	645.66	163.10	313.54	1122.29
1963	488.58	172.63	331.86	993.08
1964	537.31	182.43	350.69	1070.44
1965	557.78	191.69	368.47	1117.94
1966	554.15	189.47	364.19	1107.81
1967	724.84	186.75	358.97	1270.55
1968	864.48	182.55	350.89	1397.93
1969	537.75	177.84	341.82	1057.41
1970	512.58	175.69	337.69	1025.96
1971	457.01	190.97	367.03	1015.00
1972	406.30	206.25	396.37	1008.92
1973	296.36	221.28	425.20	942.84
1974	477.77	235.40	452.29	1165.46
1975	599.73	244.12	468.97	1312.82
1976	570.61	234.09	449.75	1254.45
1977	594.71	222.34	426.84	1243.89
1978	593.69	207.82	399.42	1200.93
1979	421.33	195.83	376.68	993.85
1980	385.74	194.51	374.06	954.31
1981	378.97	153.31	397.88	930.16
1982	309.36	92.50	171.84	573.70
1983	316.90	114.65	255.74	687.28
1984	253.57	108.41	741.15	1103.13
1985	250.84	199.46	1145.43	1595.74
1986	219.37	76.97	466.06	762.40
1987	191.52	121.00	229.22	541.74
1988	173.52	157.11	347.30	677.93
1989	266.49	117.07	483.99	867.55
1990	226.34	130.66	75.54	432.54
1991	143.49	106.70	267.24	517.43
1992	104.31	55.81	553.60	713.72
1993	220.05	71.74	110.20	402.00
1994	195.62	65.24	149.48	410.34
1995	177.50	76.95	117.61	372.05
1996	138.63	47.22	80.82	266.67
1997	110.45	50.34	292.73	453.52
1998	89.60	36.98	101.15	227.74
1999	93.62	56.30	319.94	469.86
2000	104.16	66.92	354.33	525.41
2001	196.59	95.95	249.84	542.38
2002	188.26	106.15	289.22	583.64
2003	138.39	49.06	224.67	412.12
2004	171.79	95.91	258.25	525.96
2005	129.55	78.86	268.85	477.26
2006	86.17	56.55	251.83	394.56
2007	114.62	57.01	132.92	304.55
2008	251.77	137.88	585.56	975.21
2009	364.50	173.55	440.50	978.54
2010	6.45	3.13	0.53	10.11
2011	0.57	10.61	0.61	11.79
2012	8.14	15.62	173.72	197.49
2013	31.59	9.97	85.58	127.13
2014	65.47	34.07	290.38	389.92

Table 20. Estimated time series of discard mortalities in numbers (1000 fish) for commercial handline (D.cH), headboat (D.HB), and recreational (D.GR).

Year	D.cH	D.HB	D.GR	Total
1950	.	.	.	.
1951	.	.	.	.
1952	.	.	.	.
1953	.	.	.	.
1954	.	.	.	.
1955	.	.	.	.
1956	.	.	.	.
1957	.	.	.	.
1958	.	.	.	.
1959	.	.	.	.
1960	.	.	.	.
1961	.	.	.	.
1962	.	.	.	.
1963	.	.	.	.
1964	.	.	.	.
1965	.	.	.	.
1966	.	.	.	.
1967	.	.	.	.
1968	.	.	.	.
1969	.	.	.	.
1970	.	.	.	.
1971	.	.	.	.
1972	.	.	.	.
1973	.	.	.	.
1974	.	.	.	.
1975	.	.	.	.
1976	.	.	.	.
1977	.	.	.	.
1978	.	.	.	.
1979	.	.	.	.
1980	.	.	.	.
1981	.	.	1.64	.
1982	.	.	1.64	.
1983	.	.	1.64	.
1984	.	0.03	22.88	.
1985	.	0.04	23.71	.
1986	.	0.01	23.71	.
1987	.	0.02	23.71	.
1988	.	0.03	18.60	.
1989	.	0.02	7.17	.
1990	.	0.02	7.17	.
1991	.	0.01	7.18	.
1992	9.41	0.93	10.36	20.70
1993	8.03	1.29	25.24	34.56
1994	10.15	1.44	24.64	36.23
1995	10.12	1.55	18.85	30.52
1996	9.95	0.97	7.57	18.49
1997	10.75	1.01	6.13	17.90
1998	7.76	0.83	9.91	18.51
1999	6.55	1.20	60.22	67.96
2000	6.98	1.48	91.96	100.42
2001	7.27	2.11	75.02	84.40
2002	14.33	2.27	45.67	62.27
2003	4.02	1.00	58.97	63.99
2004	1.16	6.95	74.04	82.16
2005	4.89	3.66	27.11	35.66
2006	2.31	6.38	44.32	53.01
2007	5.24	26.60	106.68	138.51
2008	4.77	27.24	189.49	221.50
2009	5.50	21.21	88.94	115.65
2010	6.63	14.24	51.39	72.26
2011	15.29	11.80	9.54	36.63
2012	7.30	13.34	40.79	61.43
2013	7.33	13.33	23.98	44.65
2014	10.27	13.29	81.60	105.15

Table 21. Estimated time series of discard mortalities in whole weight (1000 lb) for commercial handlines (D.cH), headboat (D.HB), and recreational (D.GR).

Year	D.cH	D.HB	D.GR	Total
1950	.	.	.	.
1951	.	.	.	.
1952	.	.	.	.
1953	.	.	.	.
1954	.	.	.	.
1955	.	.	.	.
1956	.	.	.	.
1957	.	.	.	.
1958	.	.	.	.
1959	.	.	.	.
1960	.	.	.	.
1961	.	.	.	.
1962	.	.	.	.
1963	.	.	.	.
1964	.	.	.	.
1965	.	.	.	.
1966	.	.	.	.
1967	.	.	.	.
1968	.	.	.	.
1969	.	.	.	.
1970	.	.	.	.
1971	.	.	.	.
1972	.	.	.	.
1973	.	.	.	.
1974	.	.	.	.
1975	.	.	.	.
1976	.	.	.	.
1977	.	.	.	.
1978	.	.	.	.
1979	.	.	.	.
1980	.	.	.	.
1981	.	.	3.64	.
1982	.	.	2.81	.
1983	.	.	2.30	.
1984	.	0.04	36.96	.
1985	.	0.08	48.66	.
1986	.	0.03	52.70	.
1987	.	0.03	35.92	.
1988	.	0.06	35.34	.
1989	.	0.05	18.90	.
1990	.	0.05	22.52	.
1991	.	0.03	20.20	.
1992	18.22	1.36	15.15	34.73
1993	21.41	3.00	58.84	83.25
1994	26.51	2.91	49.73	79.14
1995	30.59	3.68	44.84	79.11
1996	22.09	1.67	12.98	36.74
1997	25.86	2.04	12.40	40.30
1998	17.22	1.50	17.91	36.64
1999	14.24	2.17	108.94	125.35
2000	15.85	2.79	173.59	192.23
2001	19.08	4.50	160.28	183.87
2002	39.71	4.88	98.45	143.04
2003	10.15	1.94	114.26	126.35
2004	3.82	17.99	191.53	213.34
2005	19.50	10.73	79.57	109.79
2006	3.27	8.03	55.84	67.14
2007	11.00	51.00	204.53	266.53
2008	11.71	55.03	382.85	449.60
2009	17.64	55.16	231.34	304.14
2010	46.44	74.33	268.35	389.12
2011	127.64	53.36	43.17	224.17
2012	63.78	56.41	172.53	292.72
2013	58.36	45.05	81.02	184.43
2014	67.88	32.74	201.06	301.68

Table 22. Estimated status indicators, benchmarks, and related quantities from the base run of the Beaufort catch-age model, conditional on estimated current selectivities averaged across fleets. Also presented are median values and measures of precision (standard errors, SE) from the Monte Carlo/Bootstrap analysis. Rate estimates (F) are in units of y^{-1}*; status indicators are dimensionless; and biomass estimates are in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) is measured as population fecundity (number of eggs). L refers to landings and R to recruitment*

Quantity	Units	Estimate	Median	SE
$F_{30\%}$	y^{-1}	0.15	0.15	0.01
$85\%F_{30\%}$	y^{-1}	0.12	0.13	0.01
$75\%F_{30\%}$	y^{-1}	0.11	0.11	0.01
$65\%F_{30\%}$	y^{-1}	0.10	0.10	0.01
$F_{30\%}$	y^{-1}	0.15	0.15	0.01
$F_{40\%}$	y^{-1}	0.10	0.11	0.01
$B_{\mathrm{F30\%}}$	metric tons	3693	3628	599
$\mathrm{SSB}_{\mathrm{F30\%}}$	Eggs (1E8)	329948	299651	88001
MSST	Eggs (1E8)	247461	224739	66001
$L_{\mathrm{F30\%}}$	1000 lb whole	459	450	79
$R_{\mathrm{F30\%}}$	number fish	449774	467165	107594
$L_{85\%\mathrm{F30\%}}$	1000 lb whole	442	433	76
$L_{75\%\mathrm{F30\%}}$	1000 lb whole	425	417	73
$L_{65\%\mathrm{F30\%}}$	1000 lb whole	403	396	69
$F_{2012-2014}/F_{30\%}$	—	2.84	2.63	0.85
$\mathrm{SSB}_{2014}/\mathrm{MSST}$	—	0.18	0.20	0.11
$\mathrm{SSB}_{2014}/\mathrm{SSB}_{\mathrm{F30\%}}$	—	0.14	0.15	0.08

Table 23. Results from sensitivity runs of the Beaufort catch-age model. Current F represented by geometric mean of last three assessment years. Runs should not all be considered equally plausible.

Run	Description	$F_{30\%}$	$\mathrm{SSB}_{\mathrm{F30\%}}$ (1E8 Eggs)	$L_{\mathrm{F30\%}}$ (1000 lb)	$\mathrm{F}_{\mathrm{current}}/F_{30\%}$	$\mathrm{SSB}_{end}/\mathrm{SSB}_{\mathrm{F30\%}}$	R0(1000)	sigmaR	Finit
Base	—	0.147	329948	459	2.84	0.18	331	0.79	0.03
S1	remove 2008/9 from FD	0.147	329929	468	2.86	0.18	330	0.79	0.03
S2	upweight FI 10X	0.146	332402	438	2.07	0.28	325	0.82	0.03
S3	upweight FD 3X	0.146	344879	448	1.71	0.36	338	0.82	0.03
S4	FD only	0.145	332259	325	1.19	0.64	347	0.74	0.03
S5	M upper	0.169	246562	424	1.65	0.4	430	0.82	0.03
S6	M lower	0.133	406658	470	3.73	0.12	285	0.75	0.03
S7	Disc. M lower	0.147	328444	520	2.12	0.24	317	0.83	0.03
S8	Disc. M upper	0.146	335957	424	2.82	0.2	354	0.72	0.03
S9	Longer CVID index	0.147	334145	470	1.99	0.3	344	0.76	0.03
S10	Smooth 1984/5 MRIP peak	0.147	328483	462	2.53	0.22	327	0.8	0.03
S11	h=0.84	0.146	396289	525	3.56	0.11	497	0.6	0.03
S12	Truncated HB disc. index	0.147	331524	470	2.6	0.21	334	0.78	0.03
S13	Ageing error matrix	0.144	334881	409	1.63	0.39	319	0.85	0.03
S14	Batch number lower	0.154	220597	468	2.47	0.24	330	0.79	0.03
S15	Batch number upper	0.146	362022	465	2.63	0.21	333	0.78	0.03
S16	Drop HB disc. index	0.147	331560	470	2.59	0.21	334	0.78	0.03
S17	Higher landings	0.147	441258	654	1.94	0.25	406	0.89	0.03
S18	Lower landings	0.146	232011	298	3.36	0.18	258	0.64	0.03
S19	Higher discards	0.146	338021	500	2.6	0.19	362	0.7	0.03
S20	Lower discards	0.147	327352	561	1.89	0.26	306	0.87	0.03
S21	Dome-shaped selectivity for cH	0.15	355593	490	2.28	0.23	333	0.87	0.03
S22	Separate video and trap indices	0.143	331956	391	1.58	0.41	341	0.76	0.03
S23	FI index only	0.146	330170	436	2.75	0.18	342	0.75	0.03
S24	Continuity	0.102	817833	501	5.97	0.06	114	1.18	0.04
S25	Split q for HB CPUE	0.147	331168	466	2.61	0.2	333	0.79	0.03
S26	1978 start year	0.147	299224	418	2.93	0.19	320	0.7	0.2
S27	Estimate selex for all ages	0.148	328522	465	2.61	0.2	332	0.78	0.03

Table 24. Projection results with fishing mortality rate fixed at $F = 0$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{F30\%}}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	433	318	0.11	0.11	63179	62191	0	0	0	0	70	69	275	280	0.000
2016	438	319	0.22	0.22	95361	89833	28	28	238	240	64	60	321	309	0.002
2017	443	326	0.00	0.00	143309	131164	0	0	0	0	0	0	0	0	0.024
2018	446	326	0.00	0.00	206168	184119	0	0	0	0	0	0	0	0	0.115
2019	448	327	0.00	0.00	274970	242176	0	0	0	0	0	0	0	0	0.295
2020	449	327	0.00	0.00	345142	301374	0	0	0	0	0	0	0	0	0.524
2021	450	336	0.00	0.00	414438	358962	0	0	0	0	0	0	0	0	0.728
2022	450	331	0.00	0.00	482022	415322	0	0	0	0	0	0	0	0	0.867
2023	451	331	0.00	0.00	545065	468649	0	0	0	0	0	0	0	0	0.944
2024	451	329	0.00	0.00	604252	519617	0	0	0	0	0	0	0	0	0.980
2025	451	336	0.00	0.00	658370	567486	0	0	0	0	0	0	0	0	0.993
2026	451	335	0.00	0.00	707432	609743	0	0	0	0	0	0	0	0	0.997
2027	451	337	0.00	0.00	752572	650367	0	0	0	0	0	0	0	0	0.999
2028	451	332	0.00	0.00	792812	686122	0	0	0	0	0	0	0	0	1.000
2029	451	339	0.00	0.00	828614	718519	0	0	0	0	0	0	0	0	1.000
2030	451	332	0.00	0.00	861116	747989	0	0	0	0	0	0	0	0	1.000
2031	451	332	0.00	0.00	890065	774562	0	0	0	0	0	0	0	0	1.000
2032	452	333	0.00	0.00	915468	798510	0	0	0	0	0	0	0	0	1.000
2033	452	331	0.00	0.00	937967	818661	0	0	0	0	0	0	0	0	1.000
2034	452	331	0.00	0.00	957633	837215	0	0	0	0	0	0	0	0	1.000
2035	452	331	0.00	0.00	975027	851811	0	0	0	0	0	0	0	0	1.000
2036	452	332	0.00	0.00	990389	865858	0	0	0	0	0	0	0	0	1.000
2037	452	331	0.00	0.00	1003941	879543	0	0	0	0	0	0	0	0	1.000
2038	452	330	0.00	0.00	1015893	891407	0	0	0	0	0	0	0	0	1.000
2039	452	331	0.00	0.00	1026433	901818	0	0	0	0	0	0	0	0	1.000
2040	452	334	0.00	0.00	1035726	910888	0	0	0	0	0	0	0	0	1.000
2041	452	334	0.00	0.00	1043919	917917	0	0	0	0	0	0	0	0	1.000
2042	452	333	0.00	0.00	1051142	925184	0	0	0	0	0	0	0	0	1.000
2043	452	334	0.00	0.00	1057509	930483	0	0	0	0	0	0	0	0	1.000
2044	452	333	0.00	0.00	1063121	935301	0	0	0	0	0	0	0	0	1.000

Table 25. Projection results with fishing mortality rate fixed at $F = F_{\mathrm{current}}$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{F30\%}}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	433	318	0.11	0.11	63179	62191	0	0	0	0	70	69	275	280	0.000
2016	438	319	0.22	0.22	95361	89833	28	28	238	240	64	60	321	309	0.002
2017	443	326	0.42	0.40	113401	104810	67	58	630	554	117	98	664	568	0.012
2018	445	324	0.42	0.40	115947	106677	61	52	632	552	104	89	605	520	0.020
2019	445	324	0.42	0.40	112762	104136	53	46	575	503	97	83	545	474	0.026
2020	444	323	0.42	0.40	107612	99756	48	42	526	465	93	80	504	442	0.027
2021	444	330	0.42	0.40	102646	95823	45	40	493	438	92	79	480	423	0.026
2022	444	325	0.42	0.40	98614	92194	44	39	471	421	91	78	466	412	0.025
2023	443	325	0.42	0.40	95365	89455	43	38	457	409	90	78	459	407	0.023
2024	443	323	0.42	0.40	92923	87335	43	37	447	402	90	78	456	403	0.021
2025	443	328	0.42	0.40	91093	85712	42	37	441	396	90	78	453	401	0.019
2026	443	328	0.42	0.40	89770	84710	42	37	437	392	90	78	451	401	0.018
2027	442	329	0.42	0.40	88859	84008	42	37	434	391	90	78	450	400	0.017
2028	442	324	0.42	0.40	88218	83886	42	37	432	390	90	78	449	399	0.016
2029	442	330	0.42	0.40	87775	83543	42	37	430	388	89	78	449	398	0.016
2030	442	324	0.42	0.40	87477	83245	42	37	429	386	89	78	448	398	0.015
2031	442	324	0.42	0.40	87274	82990	42	37	429	385	89	77	448	397	0.016
2032	442	325	0.42	0.40	87134	82718	42	37	428	385	89	77	448	396	0.015
2033	442	324	0.42	0.40	87038	82568	42	37	428	386	89	77	448	395	0.014
2034	442	324	0.42	0.40	86973	82432	41	37	428	386	89	77	448	395	0.014
2035	442	323	0.42	0.40	86929	82550	41	37	427	385	89	77	448	395	0.014
2036	442	324	0.42	0.40	86899	82392	41	36	427	384	89	77	448	396	0.014
2037	442	323	0.42	0.40	86879	82185	41	36	427	382	89	77	448	395	0.015
2038	442	323	0.42	0.40	86865	82157	41	37	427	382	89	77	448	395	0.015
2039	442	323	0.42	0.40	86856	82381	41	37	427	382	89	77	448	395	0.015
2040	442	325	0.42	0.40	86849	82349	41	36	427	383	89	77	448	395	0.016
2041	442	326	0.42	0.40	86845	82326	41	36	427	382	89	77	448	394	0.015
2042	442	324	0.42	0.40	86842	82228	41	36	427	381	89	77	448	395	0.016
2043	442	326	0.42	0.40	86840	81916	41	36	427	381	89	78	448	397	0.015
2044	442	325	0.42	0.40	86838	81856	41	37	427	384	89	77	448	397	0.015

Table 26. Projection results with fishing mortality rate fixed at $F = F_{30\%}$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{F30\%}}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	433	318	0.11	0.11	63179	62191	0	0	0	0	70	69	275	280	0.000
2016	438	319	0.22	0.22	95361	89833	28	28	238	240	64	60	321	309	0.002
2017	443	326	0.15	0.15	131924	120312	26	25	248	238	44	41	257	242	0.013
2018	446	325	0.15	0.15	167969	149287	29	27	310	291	44	41	280	260	0.035
2019	447	326	0.15	0.15	199533	174399	30	27	342	316	44	40	289	266	0.066
2020	448	326	0.15	0.15	225598	194937	30	28	365	334	44	40	293	270	0.101
2021	448	335	0.15	0.15	246922	211288	31	28	384	350	44	40	296	272	0.138
2022	449	330	0.15	0.15	264596	225488	31	29	399	363	44	41	298	276	0.179
2023	449	330	0.15	0.15	278426	237594	32	29	412	374	44	41	301	279	0.216
2024	449	328	0.15	0.15	289565	247269	32	29	422	383	44	41	305	283	0.250
2025	449	335	0.15	0.15	298198	254920	33	30	430	391	44	41	307	285	0.281
2026	449	333	0.15	0.15	304895	261223	33	30	436	397	44	41	310	288	0.308
2027	450	335	0.15	0.15	310349	266014	33	30	441	402	44	41	311	290	0.330
2028	450	331	0.15	0.15	314532	270208	33	31	445	407	44	41	313	292	0.349
2029	450	337	0.15	0.15	317768	273495	33	31	448	411	44	41	314	293	0.368
2030	450	331	0.15	0.15	320416	275987	33	31	450	413	44	41	315	294	0.381
2031	450	331	0.15	0.15	322497	278522	33	31	452	415	44	41	315	294	0.393
2032	450	332	0.15	0.15	324086	280402	33	31	454	416	44	42	316	295	0.406
2033	450	330	0.15	0.15	325337	281499	34	31	455	418	44	41	316	295	0.414
2034	450	330	0.15	0.15	326297	282647	34	31	456	418	44	41	316	295	0.421
2035	450	330	0.15	0.15	327060	283723	34	31	456	420	45	41	317	296	0.426
2036	450	331	0.15	0.15	327664	283885	34	31	457	420	45	41	317	296	0.431
2037	450	330	0.15	0.15	328143	284982	34	31	457	420	45	41	317	297	0.432
2038	450	329	0.15	0.15	328521	285897	34	31	458	421	45	42	317	296	0.434
2039	450	330	0.15	0.15	328821	286158	34	31	458	421	45	41	317	296	0.438
2040	450	332	0.15	0.15	329058	286806	34	31	458	422	45	41	317	296	0.437
2041	450	333	0.15	0.15	329245	286990	34	31	458	422	45	42	317	296	0.437
2042	450	331	0.15	0.15	329392	286589	34	31	459	422	45	42	318	297	0.439
2043	450	332	0.15	0.15	329509	286831	34	31	459	422	45	42	318	297	0.437
2044	450	331	0.15	0.15	329601	286885	34	31	459	423	45	42	318	298	0.441

Table 27. Projection results with fishing mortality rate fixed at $F = 98\%F_{30\%}$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{F30\%}}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	433	318	0.11	0.11	63179	62191	0	0	0	0	70	69	275	280	0.000
2016	438	319	0.22	0.22	95361	89833	28	28	238	240	64	60	321	309	0.002
2017	443	326	0.14	0.15	132142	120531	26	24	243	234	43	40	253	237	0.013
2018	446	325	0.14	0.15	168656	149926	29	27	305	286	43	40	275	255	0.036
2019	447	326	0.14	0.15	200805	175527	29	27	337	312	43	40	285	262	0.068
2020	448	326	0.14	0.15	227494	196622	30	27	361	330	43	40	289	266	0.106
2021	449	335	0.14	0.15	249432	213487	31	28	380	346	43	40	292	269	0.146
2022	449	330	0.14	0.15	267688	228151	31	28	395	359	43	40	294	272	0.189
2023	449	330	0.14	0.15	282038	240783	32	29	408	371	43	40	297	275	0.231
2024	449	328	0.14	0.15	293642	250767	32	29	418	380	43	40	301	280	0.266
2025	449	335	0.14	0.15	302674	258727	32	29	427	388	43	40	304	282	0.299
2026	450	333	0.14	0.15	309711	265387	32	30	433	395	44	41	306	285	0.329
2027	450	335	0.14	0.15	315456	270490	33	30	438	400	44	41	308	287	0.353
2028	450	331	0.14	0.15	319881	274810	33	30	442	405	44	41	309	289	0.375
2029	450	337	0.14	0.15	323315	278357	33	30	445	408	44	41	311	290	0.395
2030	450	331	0.14	0.15	326130	280969	33	30	448	411	44	41	311	291	0.409
2031	450	331	0.14	0.15	328348	283573	33	30	450	413	44	41	312	291	0.423
2032	450	332	0.14	0.15	330049	285533	33	31	451	414	44	41	313	292	0.438
2033	450	330	0.14	0.15	331391	286798	33	31	453	416	44	41	313	292	0.444
2034	450	330	0.14	0.15	332423	287929	33	31	454	417	44	41	313	293	0.452
2035	450	330	0.14	0.15	333245	289119	33	31	454	418	44	41	314	293	0.459
2036	450	331	0.14	0.15	333898	289259	33	31	455	419	44	41	314	293	0.462
2037	450	330	0.14	0.15	334416	290483	33	31	455	418	44	41	314	294	0.464
2038	450	329	0.14	0.15	334827	291449	33	31	456	419	44	41	314	293	0.466
2039	450	330	0.14	0.15	335152	291671	33	31	456	420	44	41	314	294	0.468
2040	450	332	0.14	0.15	335410	292341	33	31	456	420	44	41	314	293	0.472
2041	450	333	0.14	0.15	335614	292681	33	31	457	420	44	41	314	294	0.471
2042	450	331	0.14	0.15	335776	292225	33	31	457	421	44	41	314	294	0.473
2043	450	332	0.14	0.15	335903	292374	33	31	457	420	44	41	314	294	0.474
2044	450	332	0.14	0.15	336005	292681	33	31	457	421	44	41	314	295	0.474

Table 28. Projection results with fishing mortality rate fixed at $F = F_{\mathrm{rebuild}}$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{F30\%}}$. The extension b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	433	318	0.11	0.11	63179	62191	0	0	0	0	70	69	275	280	0.000
2016	438	319	0.22	0.22	95361	89833	28	28	238	240	64	60	321	309	0.002
2017	443	326	0.14	0.14	132192	120903	26	24	242	227	43	39	251	230	0.015
2018	446	325	0.14	0.14	168813	150773	29	26	303	279	43	39	274	249	0.043
2019	447	326	0.14	0.14	201095	177328	29	26	336	305	43	39	284	257	0.084
2020	448	326	0.14	0.14	227929	199358	30	27	360	324	43	39	288	261	0.130
2021	449	335	0.14	0.14	250008	217453	30	27	379	341	43	39	291	265	0.179
2022	449	330	0.14	0.14	268398	232004	31	28	395	355	43	39	294	268	0.229
2023	449	330	0.14	0.14	282869	244493	31	28	407	367	43	39	296	272	0.272
2024	449	328	0.14	0.14	294580	255214	32	29	418	377	43	40	300	276	0.312
2025	449	335	0.14	0.14	303705	263434	32	29	426	385	43	40	303	278	0.349
2026	450	333	0.14	0.14	310821	270054	32	29	432	391	43	40	305	281	0.375
2027	450	335	0.14	0.14	316634	275260	33	30	437	396	43	40	307	283	0.400
2028	450	331	0.14	0.14	321115	279990	33	30	441	402	44	40	309	285	0.418
2029	450	337	0.14	0.14	324596	283568	33	30	445	406	44	40	310	286	0.438
2030	450	331	0.14	0.14	327450	286804	33	30	447	408	44	40	311	287	0.453
2031	450	331	0.14	0.14	329701	289246	33	30	449	411	44	40	311	288	0.463
2032	450	332	0.14	0.14	331428	290867	33	30	451	412	44	40	312	288	0.473
2033	450	330	0.14	0.14	332791	292379	33	30	452	413	44	40	312	288	0.482
2034	450	330	0.14	0.14	333840	293534	33	30	453	414	44	40	313	289	0.489
2035	450	330	0.14	0.14	334676	293969	33	30	454	415	44	40	313	289	0.492
2036	450	331	0.14	0.14	335341	294605	33	30	454	416	44	40	313	289	0.494
2037	450	330	0.14	0.14	335868	295473	33	30	455	416	44	40	313	290	0.499
2038	450	329	0.14	0.14	336286	295664	33	30	455	417	44	40	313	290	0.502
2039	450	330	0.14	0.14	336618	296527	33	30	456	417	44	40	314	289	0.502
2040	450	332	0.14	0.14	336880	297106	33	30	456	417	44	40	314	289	0.504
2041	450	333	0.14	0.14	337089	297412	33	30	456	417	44	40	314	290	0.508
2042	450	331	0.14	0.14	337253	297014	33	30	456	418	44	40	314	290	0.509
2043	450	332	0.14	0.14	337384	297057	33	30	456	418	44	40	314	290	0.509
2044	450	332	0.14	0.14	337487	297250	33	31	456	418	44	40	314	291	0.508

Table 29. Projection results with fishing mortality rate applied only to discards. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{F30\%}}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	433	318	0.11	0.11	63179	62191	0	0	0	0	70	69	275	280	0.000
2016	438	319	0.10	0.11	100608	94609	0	0	0	0	70	69	356	355	0.003
2017	444	327	0.10	0.11	144065	131070	0	0	0	0	75	70	446	430	0.024
2018	446	326	0.10	0.11	187212	165608	0	0	0	0	74	69	488	462	0.084
2019	448	327	0.10	0.11	227447	197122	0	0	0	0	73	69	507	474	0.174
2020	449	327	0.10	0.11	262938	224721	0	0	0	0	73	69	516	478	0.266
2021	449	335	0.10	0.11	294015	248495	0	0	0	0	73	69	522	484	0.348
2022	449	330	0.10	0.11	321514	269130	0	0	0	0	73	69	528	491	0.420
2023	450	330	0.10	0.11	344650	287029	0	0	0	0	73	70	535	498	0.480
2024	450	328	0.10	0.11	364487	301454	0	0	0	0	74	70	545	508	0.528
2025	450	335	0.10	0.11	380884	313969	0	0	0	0	74	71	553	517	0.565
2026	450	334	0.10	0.11	394436	323960	0	0	0	0	74	71	560	523	0.595
2027	450	336	0.10	0.11	406107	332409	0	0	0	0	74	72	566	530	0.620
2028	450	331	0.10	0.11	415654	339809	0	0	0	0	75	72	571	536	0.642
2029	450	337	0.10	0.11	423519	347017	0	0	0	0	75	72	575	540	0.660
2030	450	331	0.10	0.11	430322	352218	0	0	0	0	75	72	578	543	0.676
2031	450	331	0.10	0.11	436005	356899	0	0	0	0	75	72	581	546	0.687
2032	450	332	0.10	0.11	440632	360429	0	0	0	0	75	72	583	547	0.697
2033	450	330	0.10	0.11	444495	363434	0	0	0	0	75	72	585	549	0.704
2034	450	330	0.10	0.11	447648	365646	0	0	0	0	75	72	587	550	0.710
2035	451	330	0.10	0.11	450306	367705	0	0	0	0	75	72	588	551	0.715
2036	451	331	0.10	0.11	452546	369251	0	0	0	0	75	72	589	551	0.718
2037	451	330	0.10	0.11	454432	370451	0	0	0	0	75	72	590	552	0.722
2038	451	329	0.10	0.11	456019	371148	0	0	0	0	75	72	591	553	0.726
2039	451	330	0.10	0.11	457353	372734	0	0	0	0	76	72	592	555	0.728
2040	451	333	0.10	0.11	458476	373439	0	0	0	0	76	72	592	554	0.729
2041	451	333	0.10	0.11	459420	374145	0	0	0	0	76	73	593	555	0.732
2042	451	331	0.10	0.11	460214	374960	0	0	0	0	76	73	593	556	0.733
2043	451	332	0.10	0.11	460882	375981	0	0	0	0	76	73	594	557	0.734
2044	451	332	0.10	0.11	461443	376468	0	0	0	0	76	73	594	557	0.736

Table 30. Parameter estimates from selected ASPIC surplus production model runs 318 (continuity), 319 (updated continuity), 320 (best configuration), and 323 (best configuration with B_1/K fixed) All parameter values are rounded to 3 significant digits. MSY, B_1, and K are in units of 1000 pounds. Catchability parameters correspond to the commercial (q_1), headboat (q_2), headboat-at-sea (q_3), and CVID (q_4) indices.

Run	F/F_{MSY}	B/B_{MSY}	B_1/K	MSY	F_{MSY}	q_1	q_2	q_3	q_4	B_1	K
318	2.15	0.53	0.467	805	0.313	9.35e-07	7.14e-07			2400	5140
319	0.614	1.3	1.94	802	0.314	9.42e-07	7.14e-07			9930	5110
320	0.531	1.48	0.91	805	0.322	8.69e-07	6.98e-07	2.98e-07	4.04e-07	4560	5010
323	0.53	1.47	0.467	807	0.321	8.74e-07	7e-07	2.99e-07	4.02e-07	2350	5030

8 Figures

Figure 1. Indices of abundance used in fitting the assessment model. HB indicates the headboat logbook index; Handline indicated the the commercial handline logbook index; HB Disc indicated the headboat discard observer index, CVT indicates the SERFS chevron trap index; VID indicates the SERFS video index, and CVID indicates the combined chevron trap and video index. The CVT and VID indices were only used during sensitivity runs.

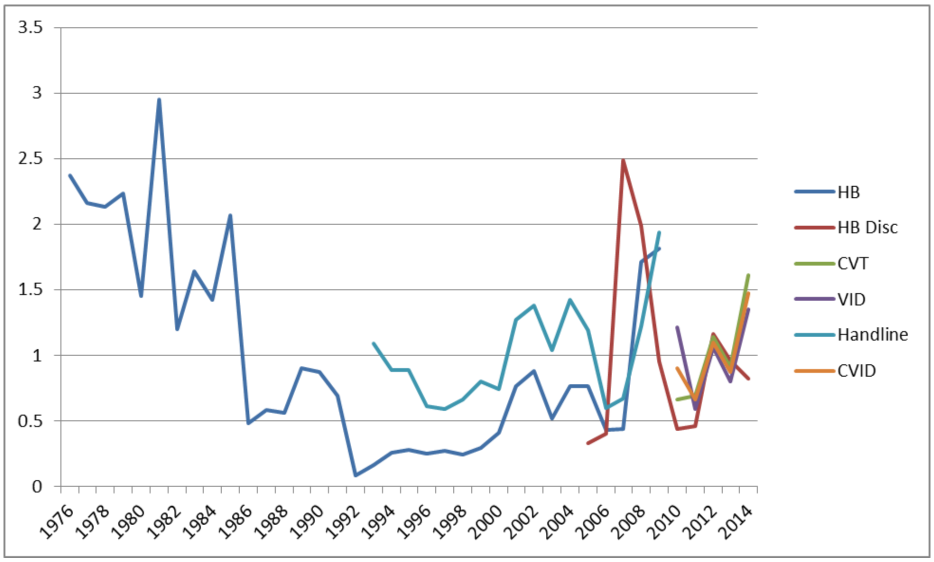


Figure 2. Mean total length at age (mm) and estimated upper and lower 95% confidence intervals of the population.

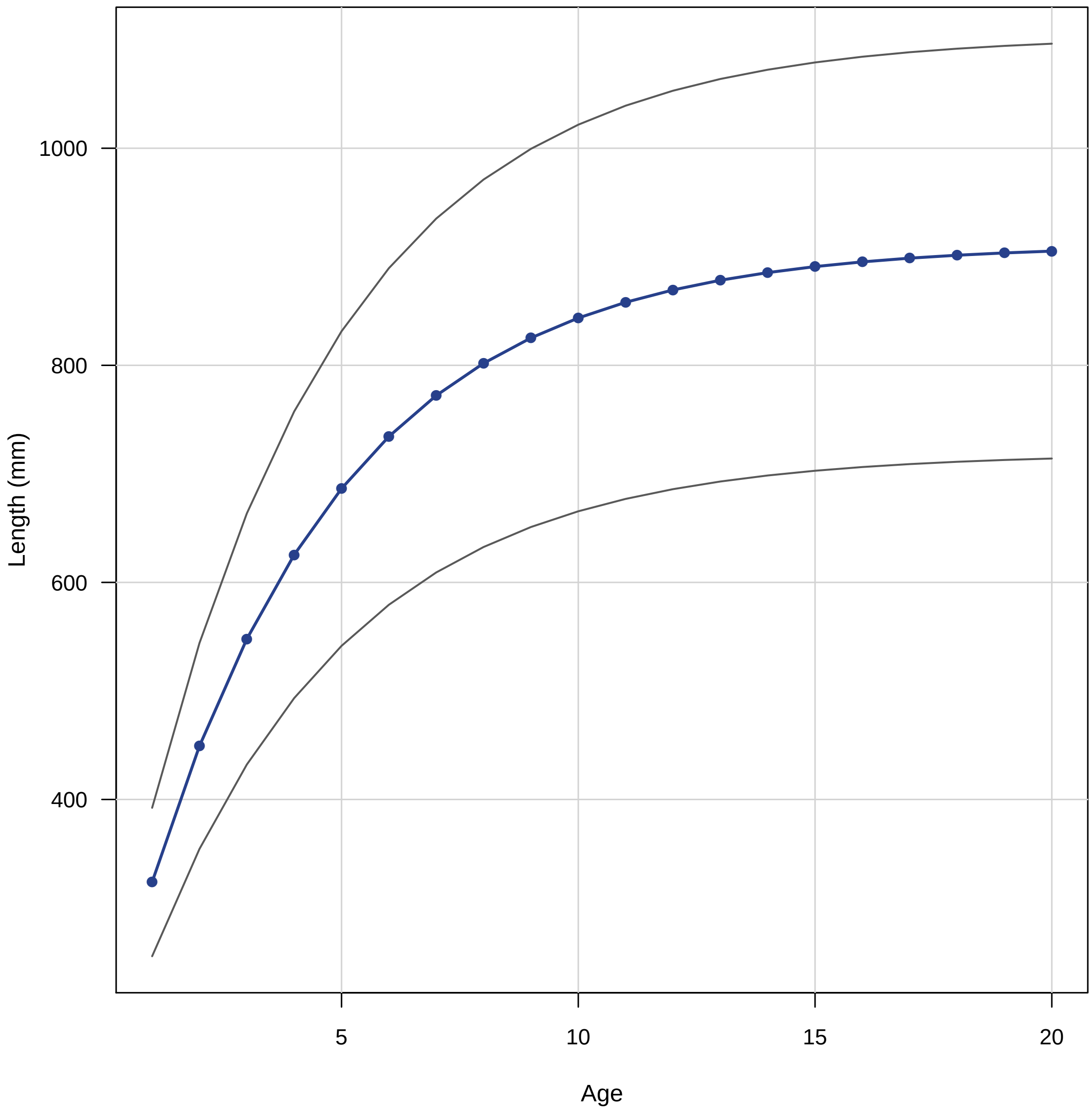


Figure 3. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, CVT to MARMAP chevron trap, cH to commercial handline, HB to headboat and GR to general recreational.

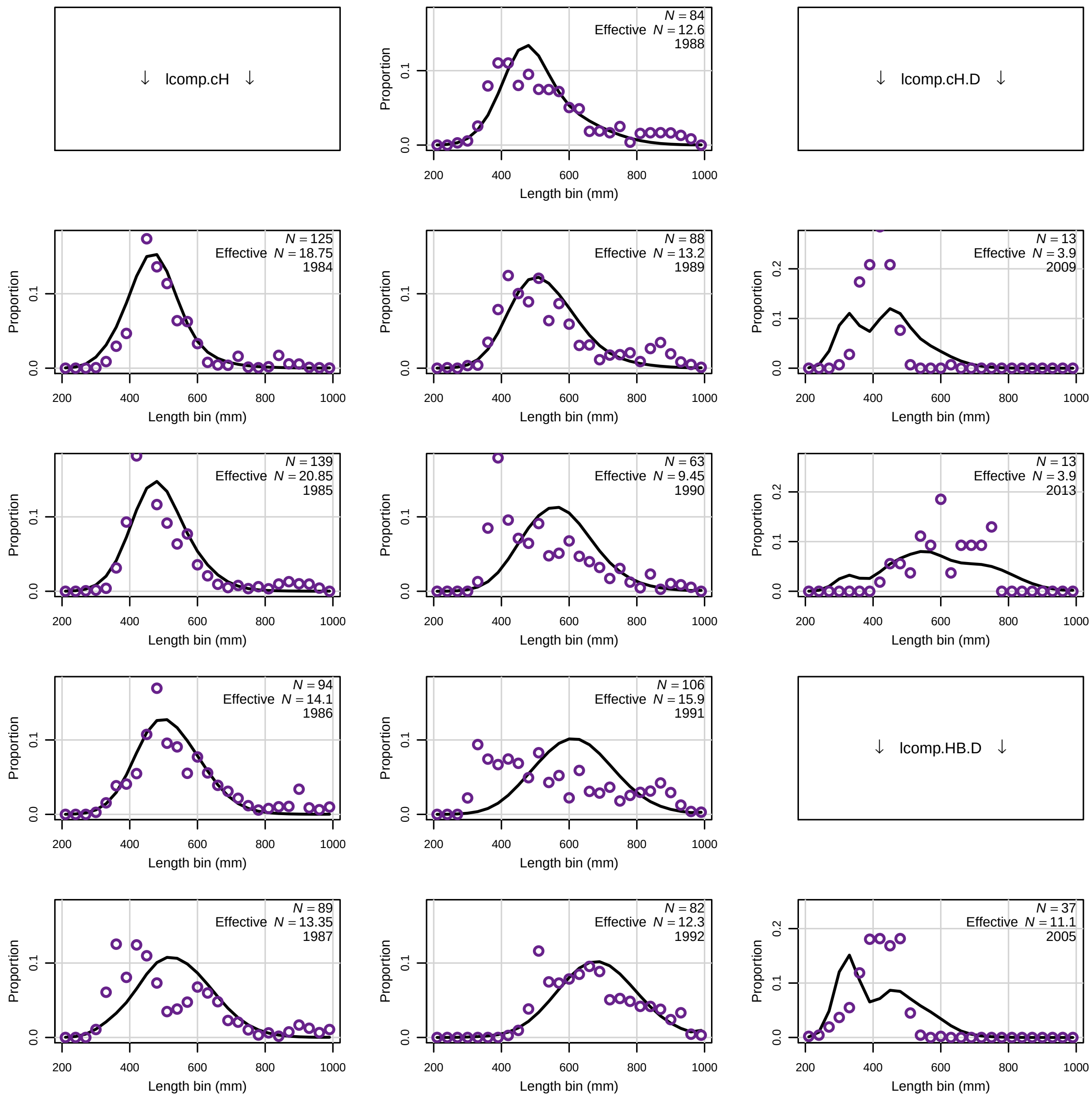


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

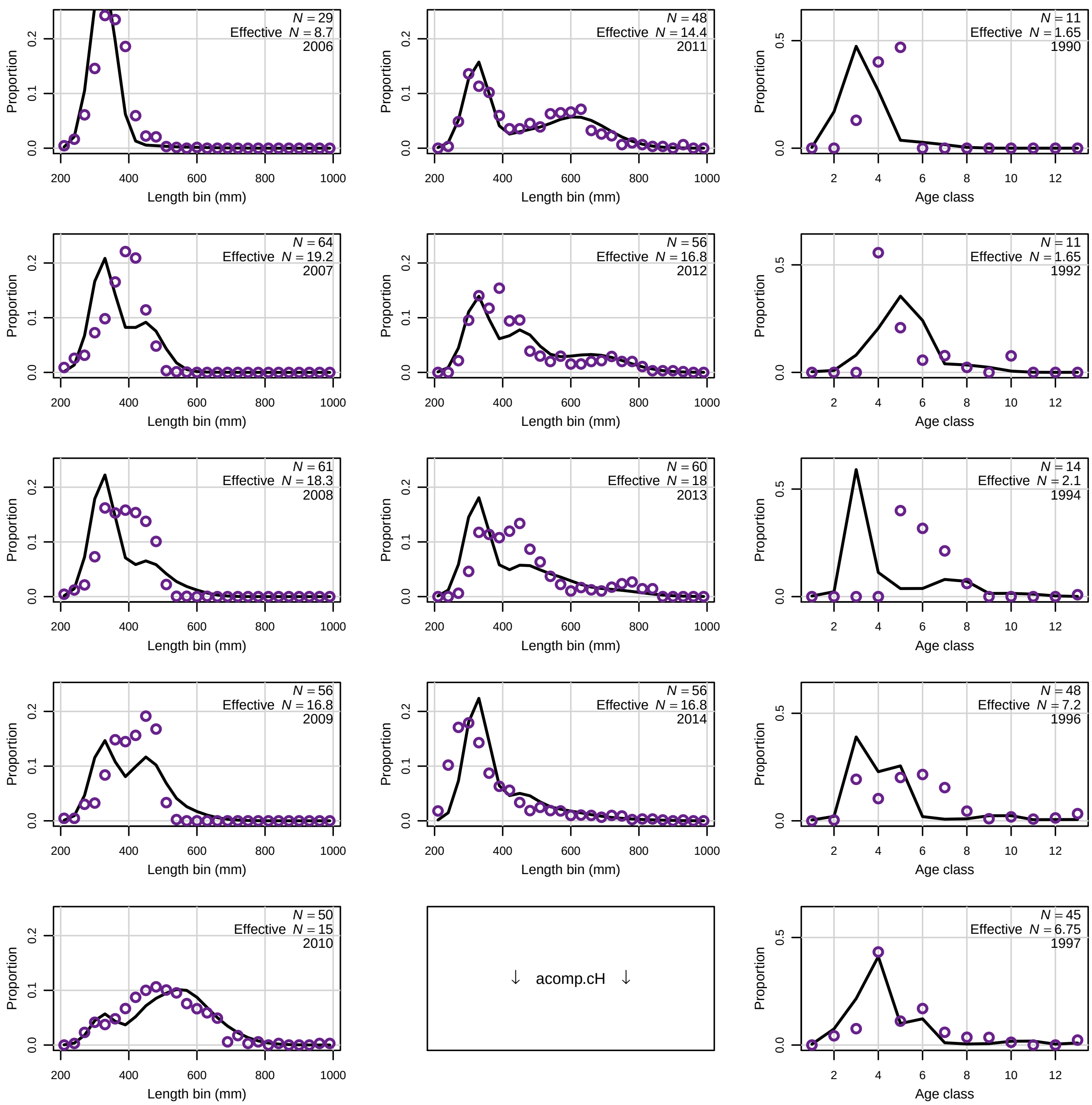


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

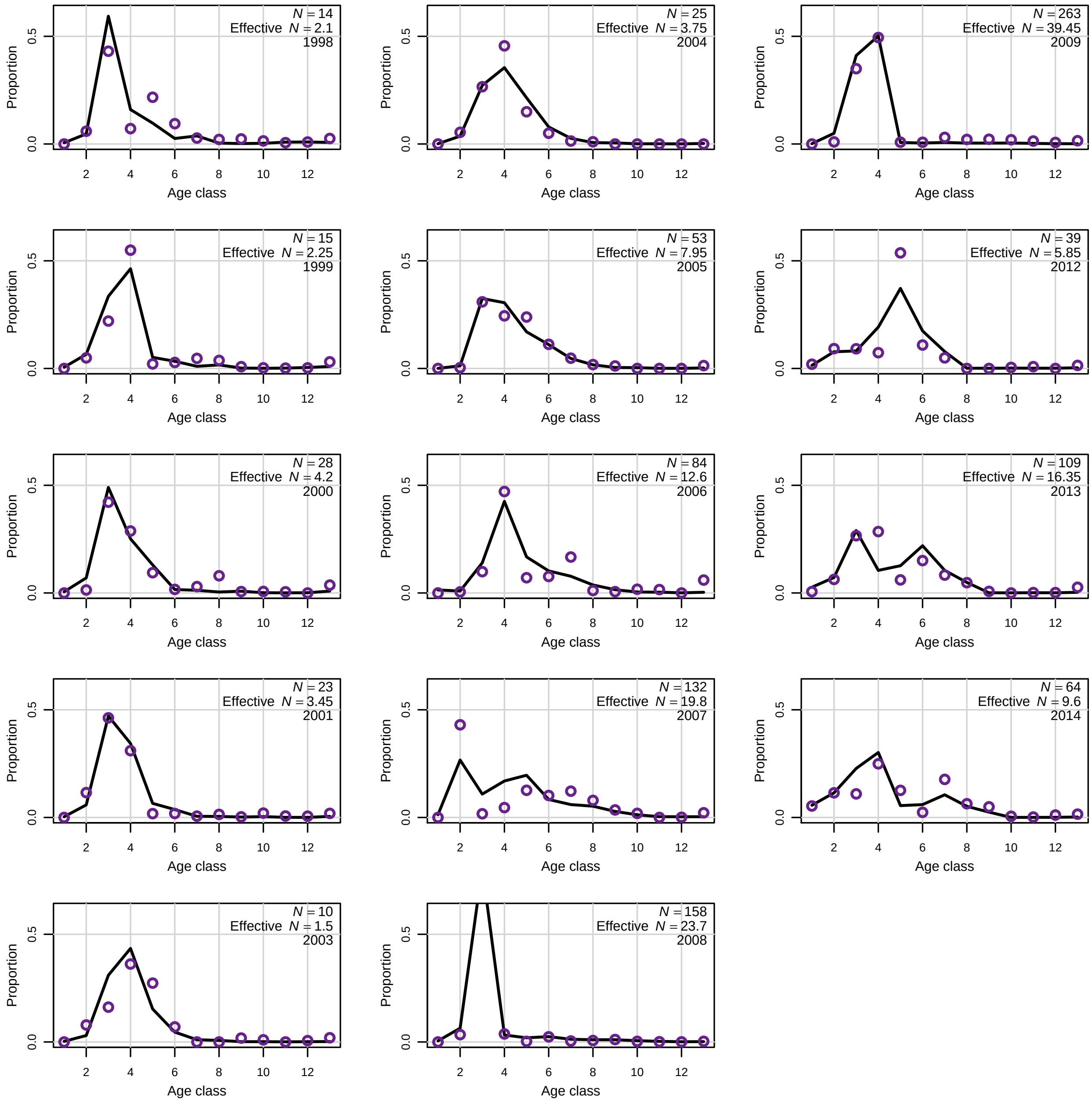


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

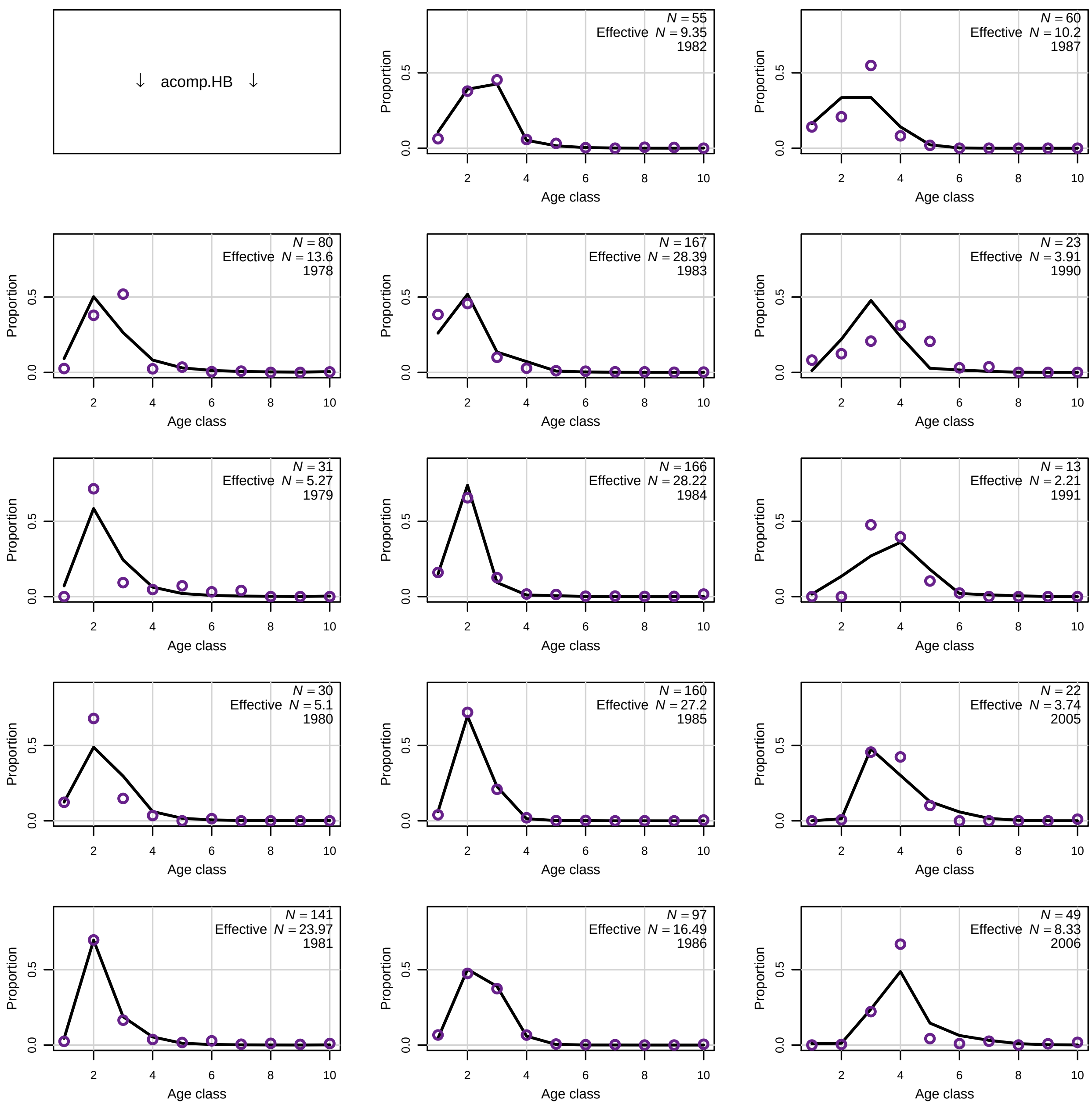


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

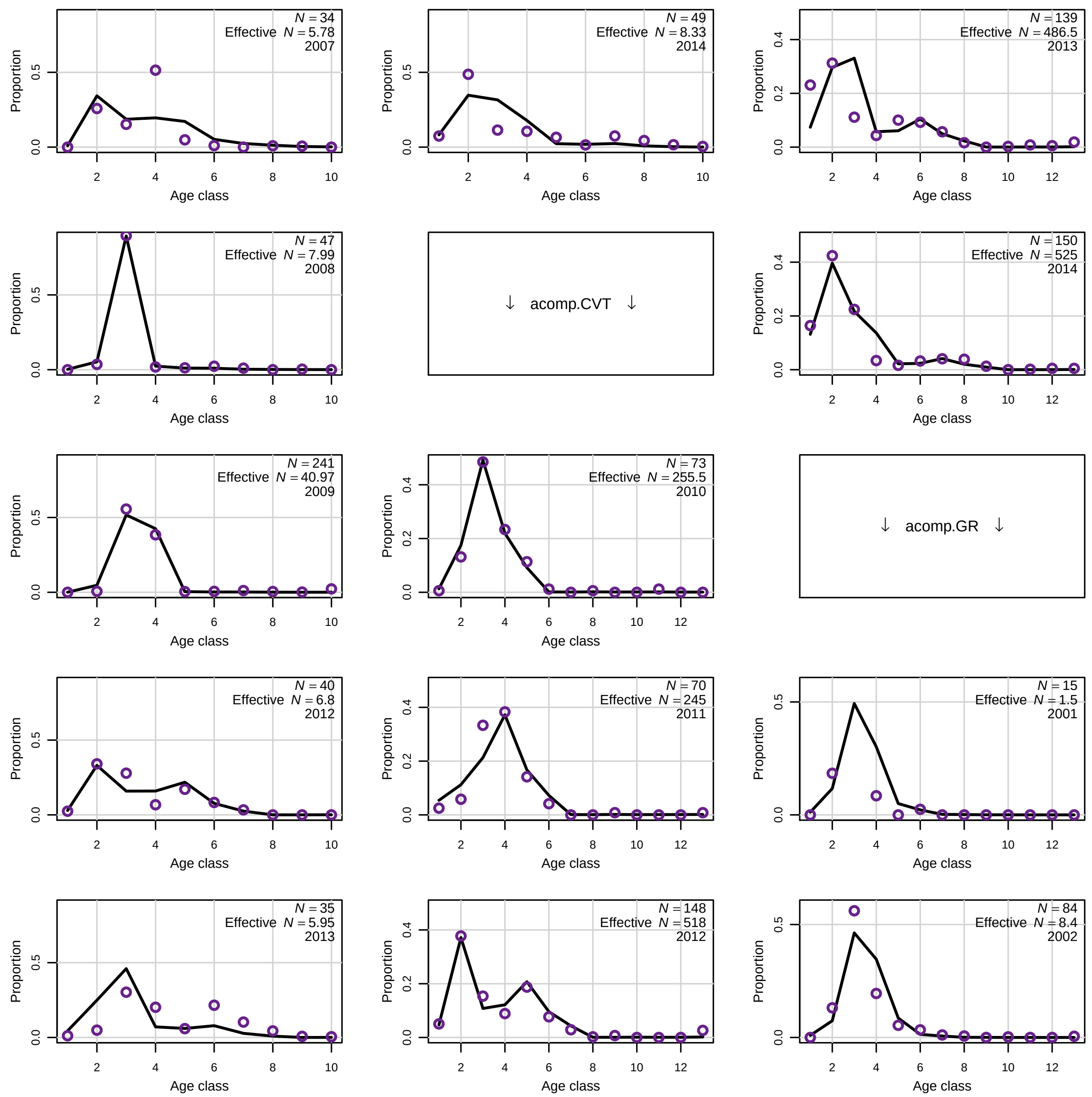


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

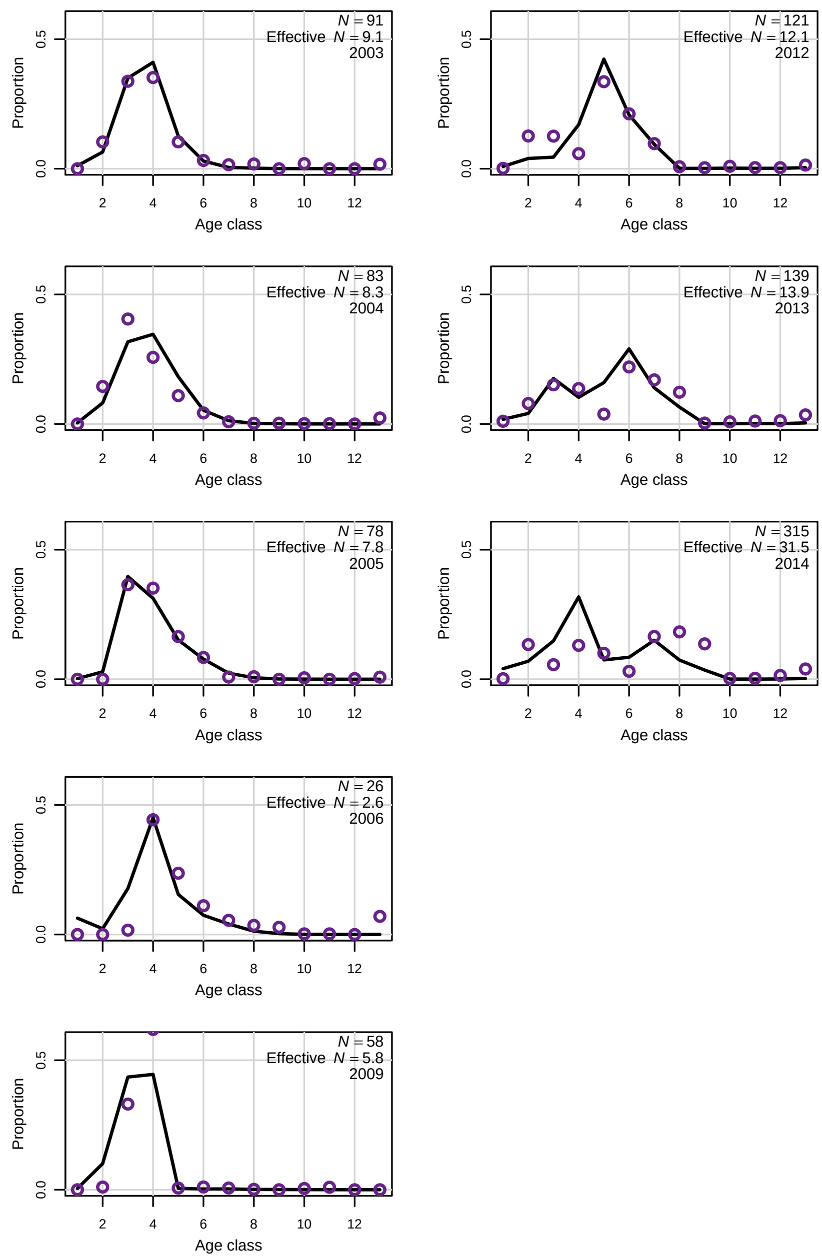


Figure 4. Observed (open circles) and estimated (solid line, circles) commercial handline landings in 1000 lb whole weight.

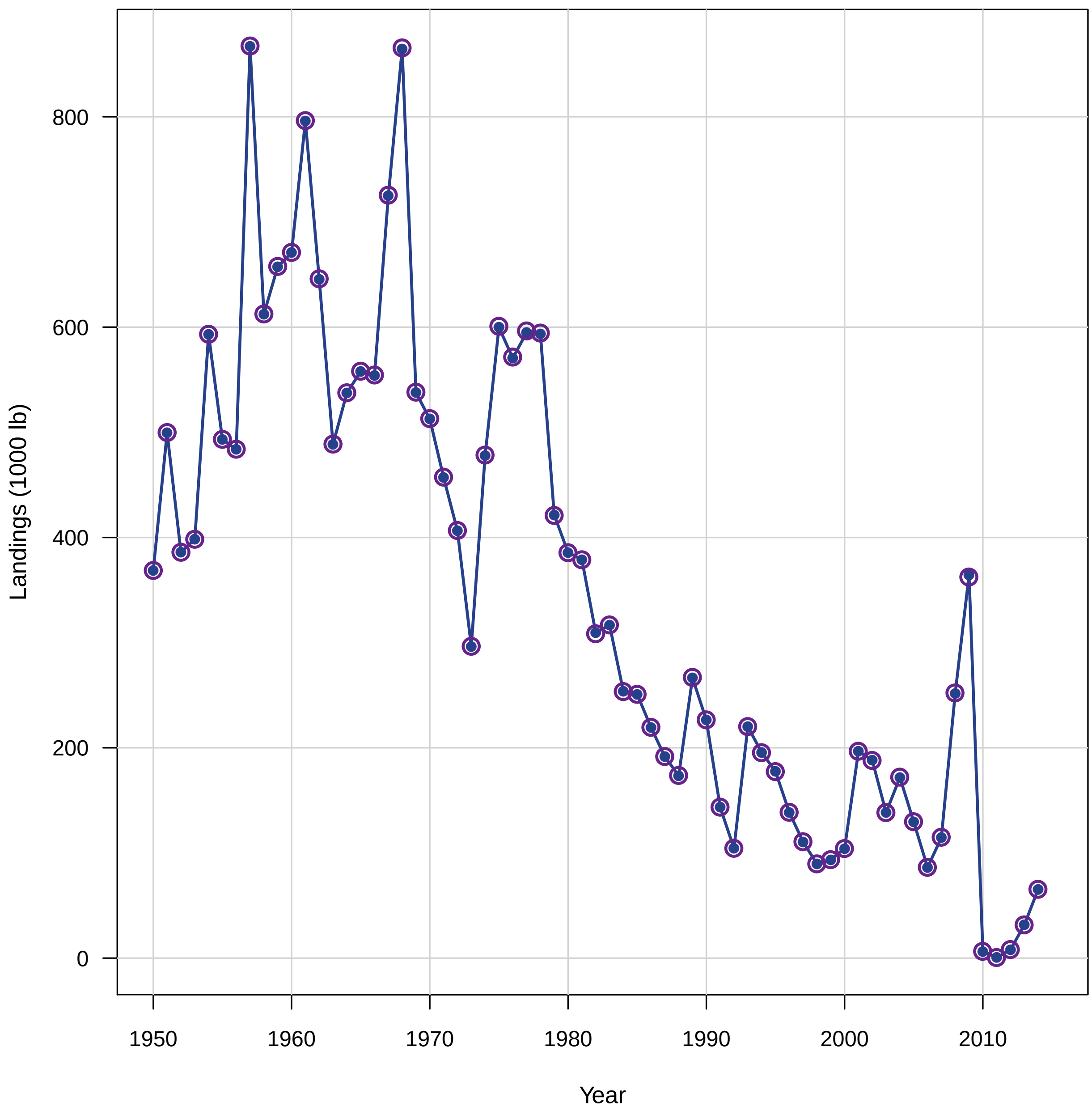


Figure 5. Observed (open circles) and estimated (solid line, circles) headboat landings in 1000s of fish.

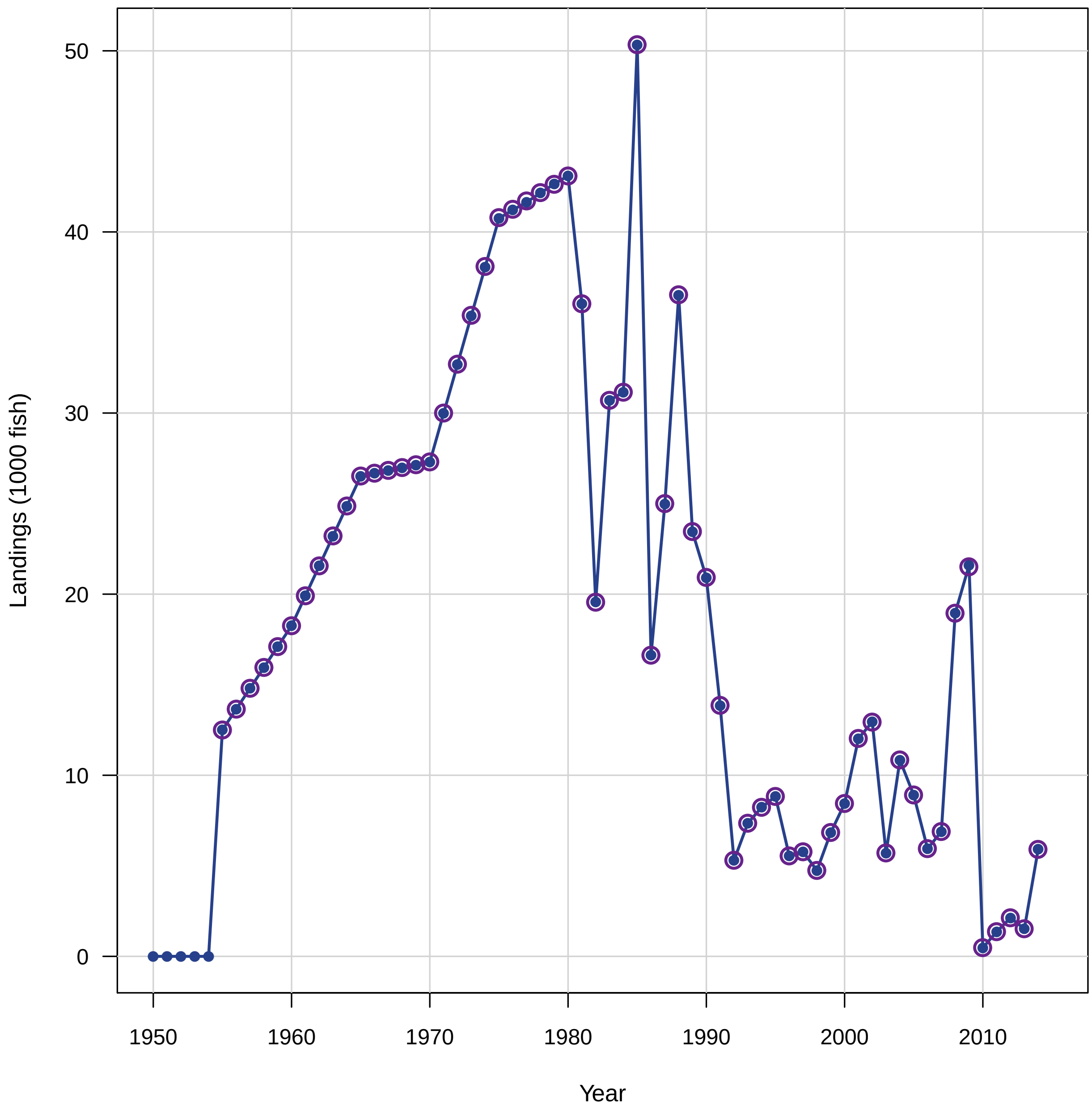


Figure 6. Observed (open circles) and estimated (solid line, circles) general recreational landings in 1000s of fish.

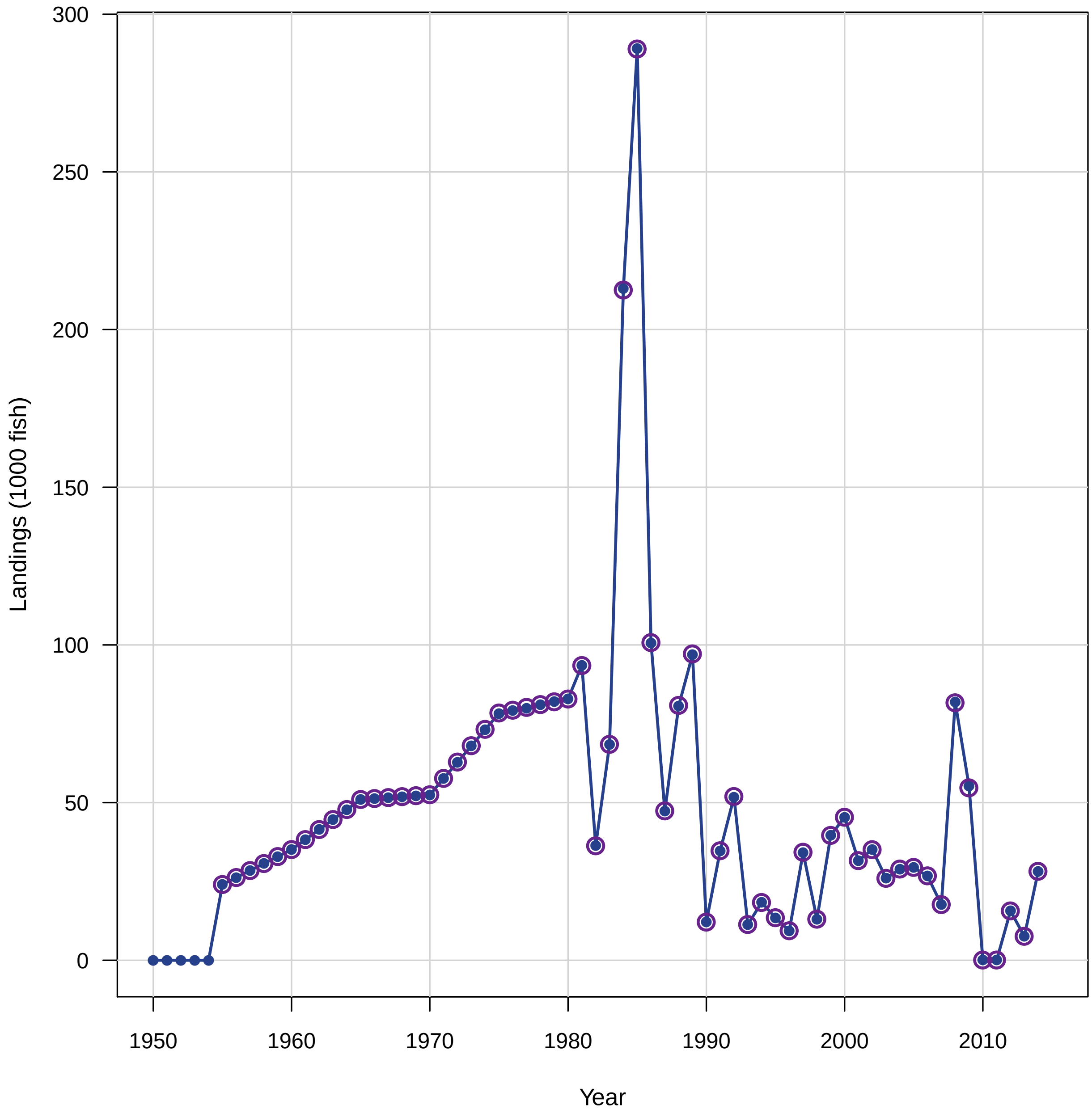


Figure 7. Observed (open circles) and estimated (solid line, circles) commercial handline discard mortalities.

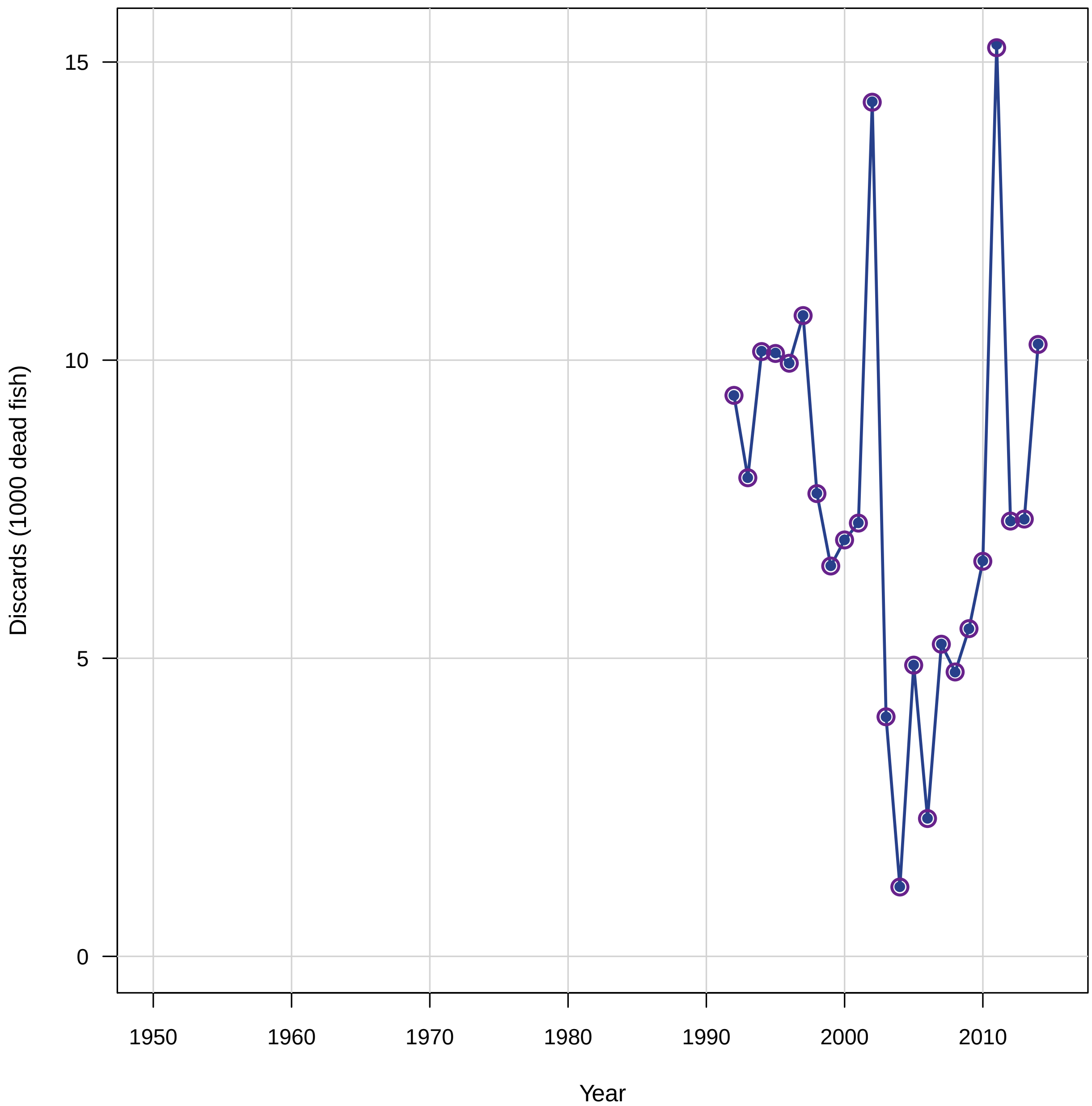


Figure 8. Observed (open circles) and estimated (solid line, circles) headboat discard mortalities.

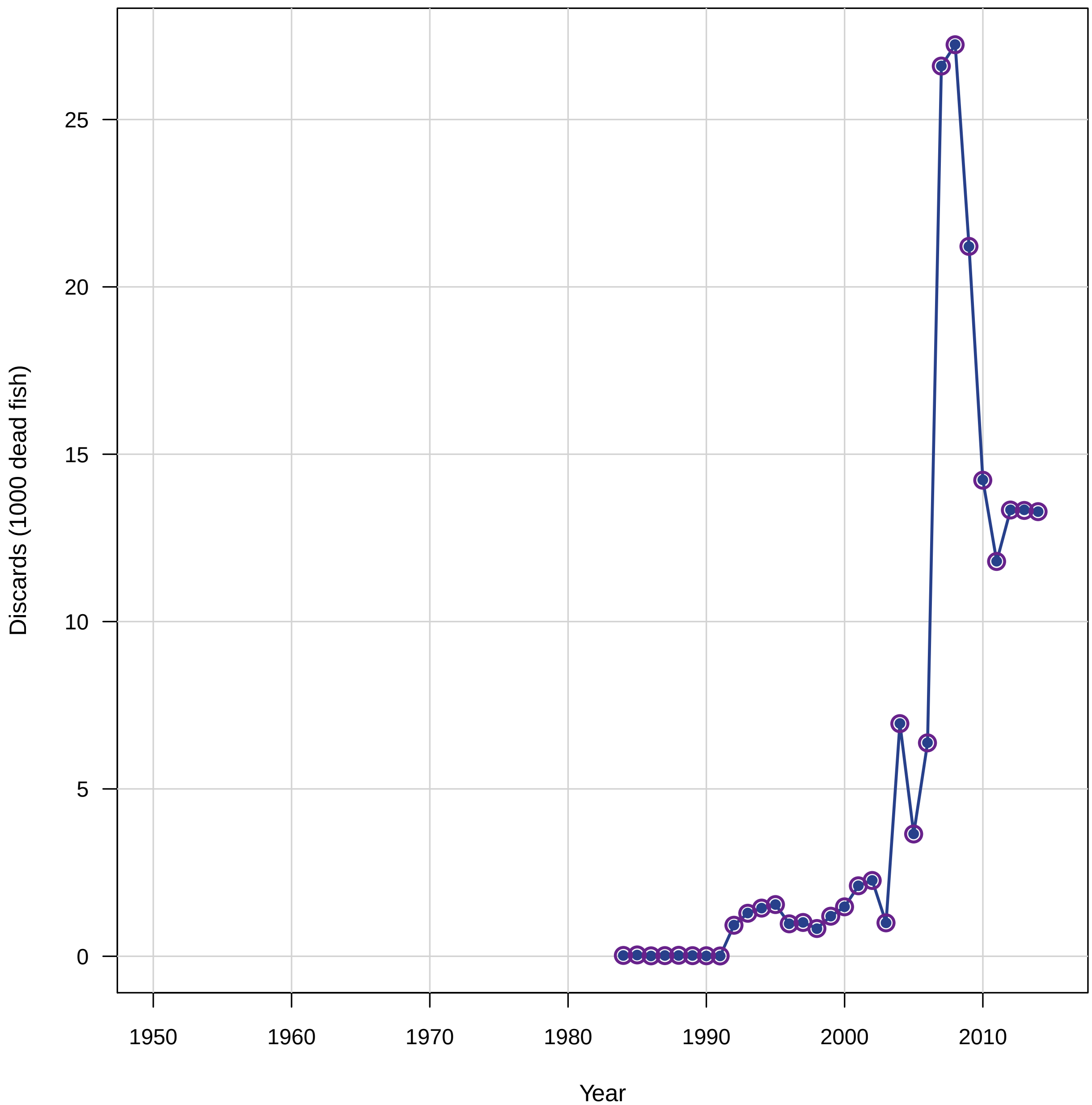


Figure 9. Observed (open circles) and estimated (solid line, circles) general recreational discard mortalities.

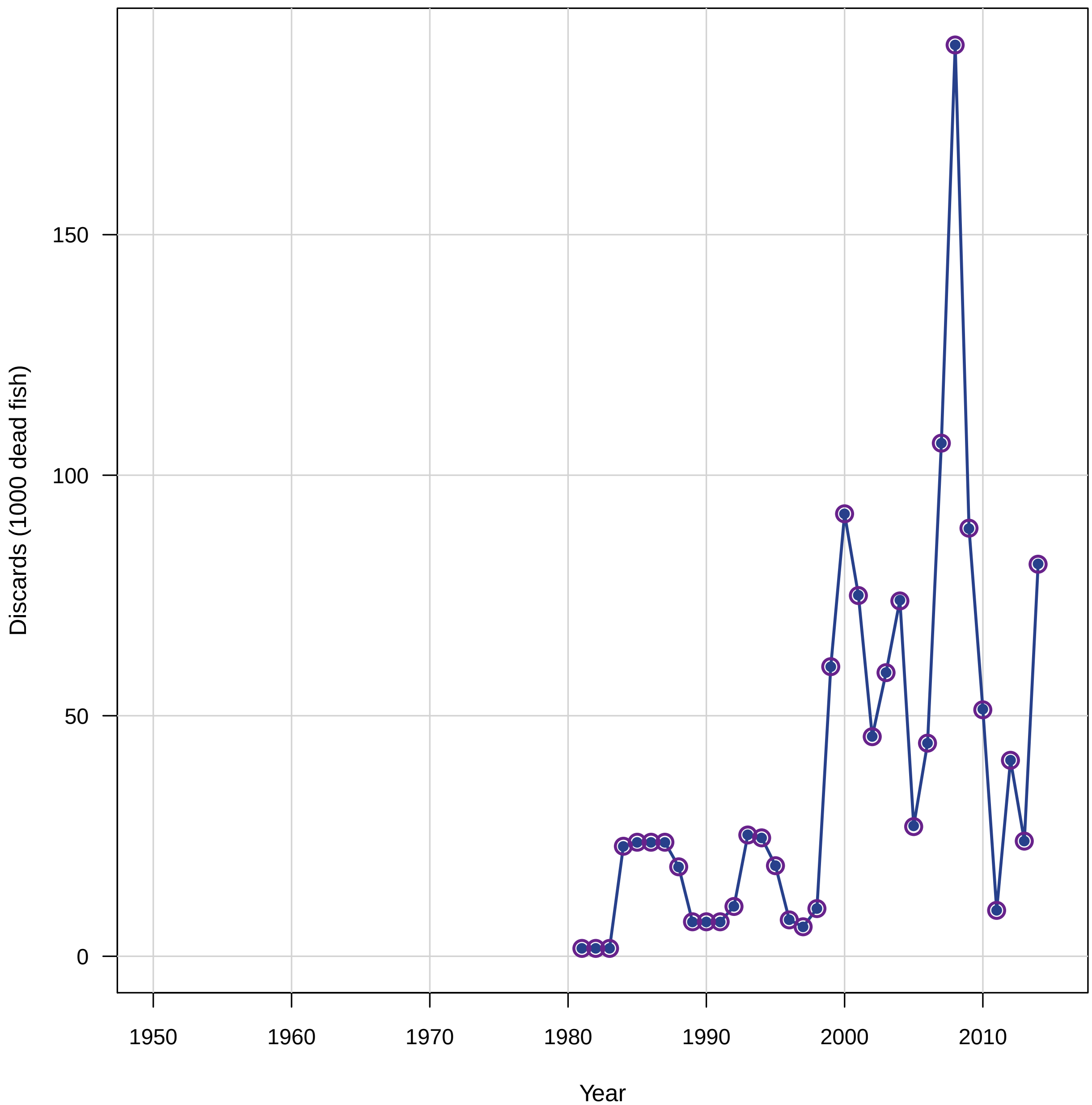


Figure 10. Observed (open circles) and estimated (solid line, circles) index of abundance from the SERFS combined trap and video index. The error bars represent the annual CV provided by the GLM standardization divided by the likelihood weight on the index.

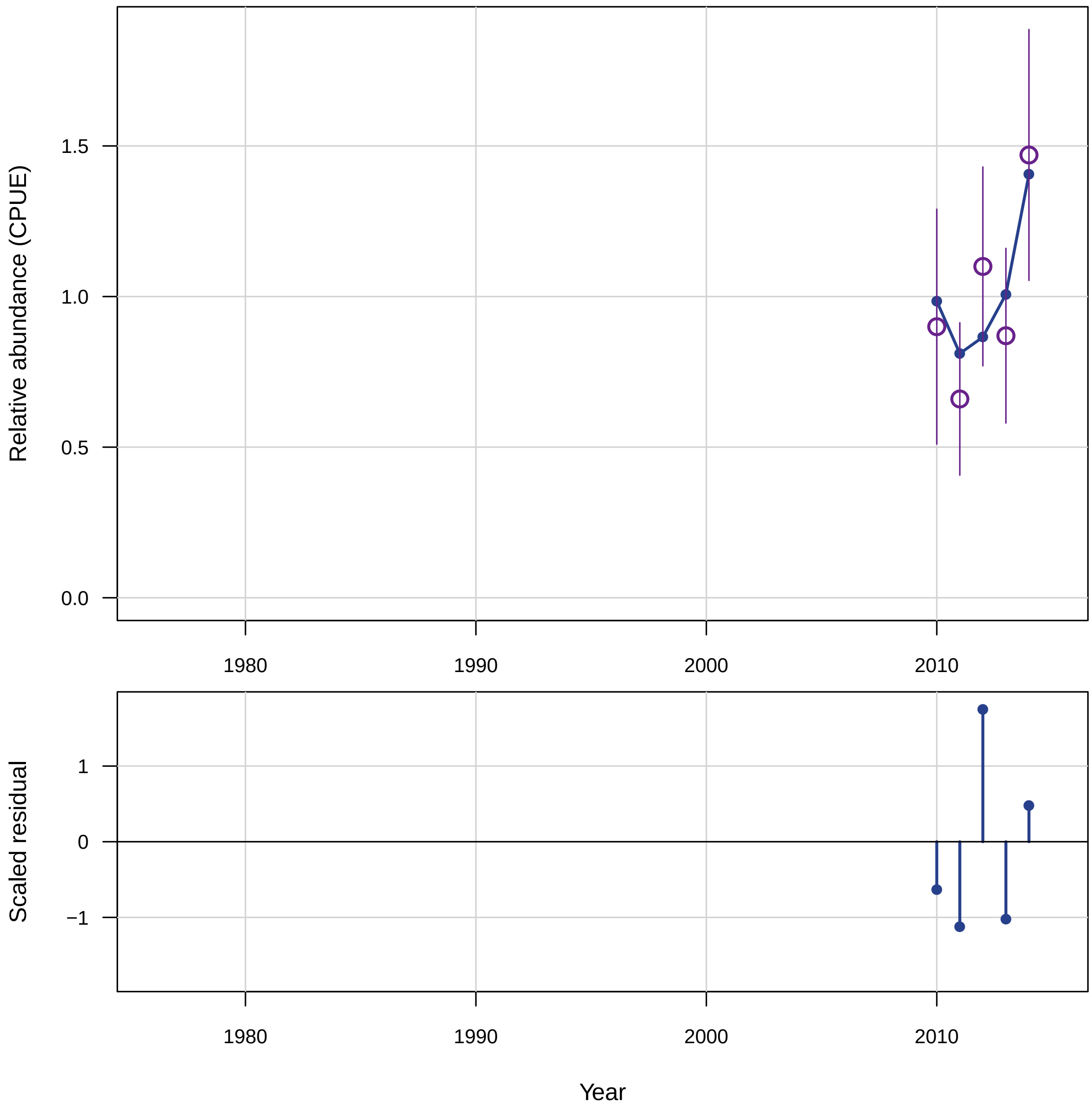


Figure 11. Observed (open circles) and estimated (solid line, circles) index of abundance from the commercial handline fleet. The error bars represent the annual CV of the index (0.2) divided by the likelihood weight on the index.

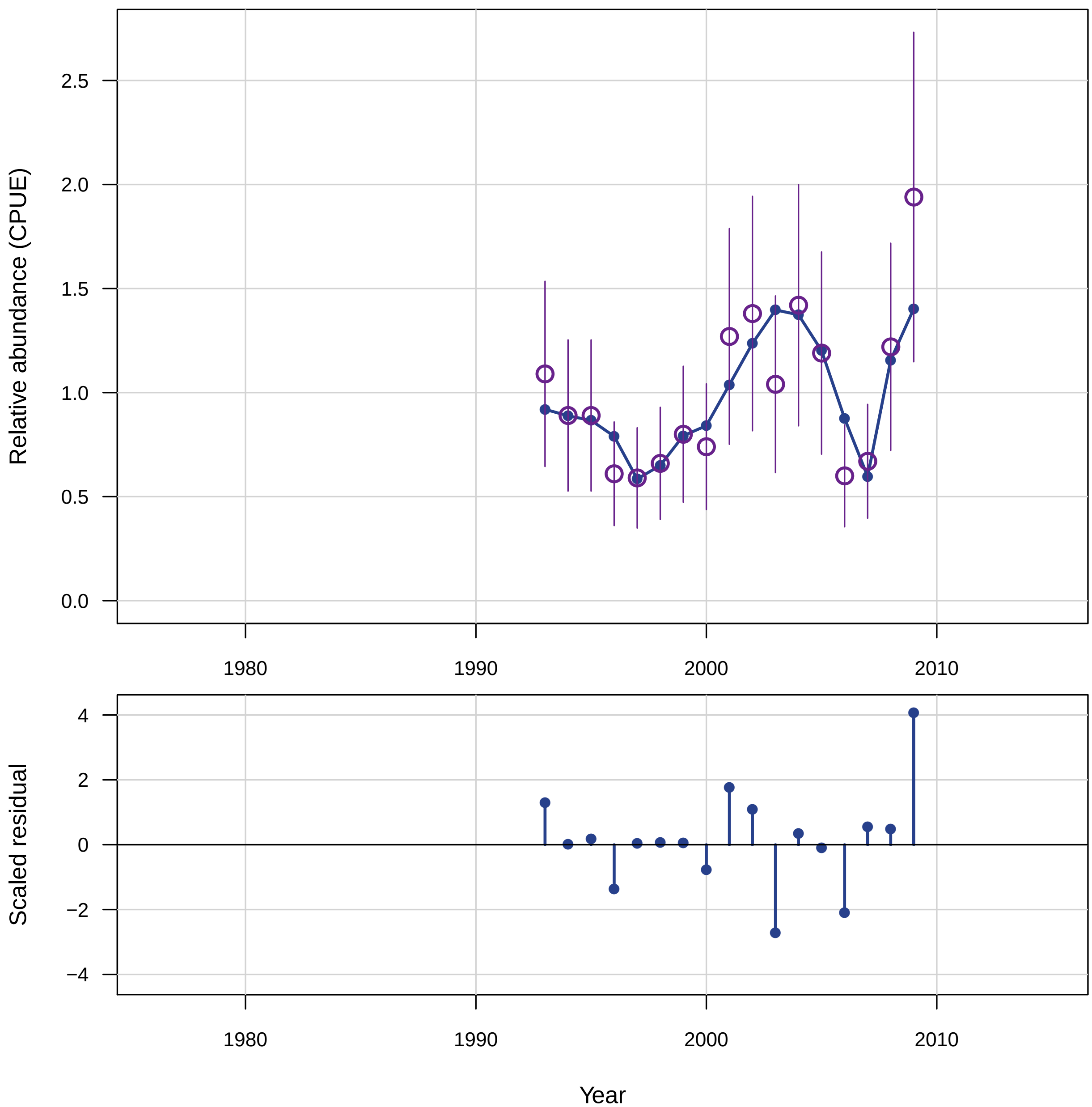


Figure 12. Observed (open circles) and estimated (solid line, circles) abundance from the headboat fleet. The error bars represent the annual CV of the index (0.2) divided by the likelihood weight on the index.

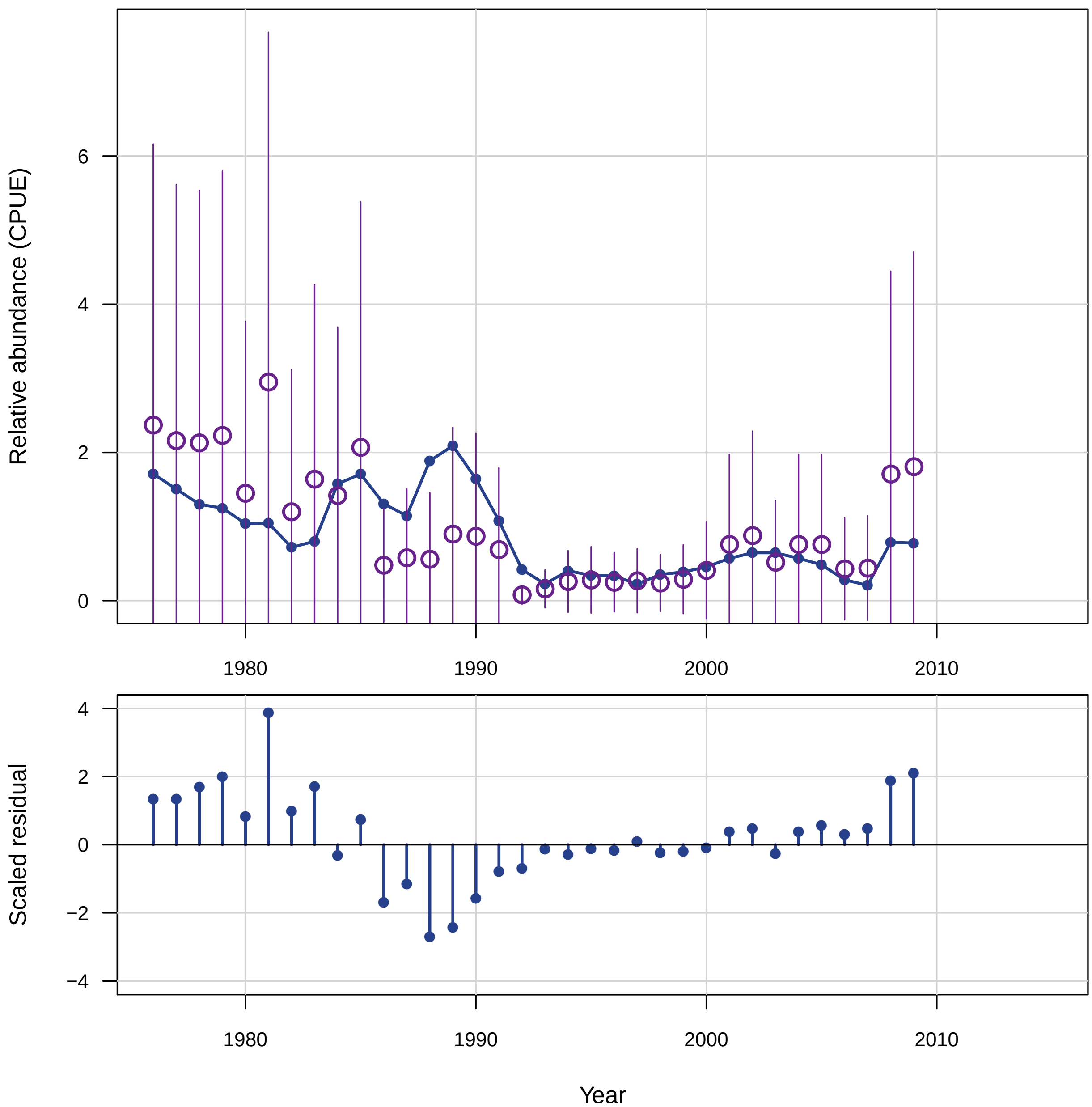


Figure 13. Observed (open circles) and estimated (solid line, circles) abundance from the headboat fleet (discards). The error bars represent the annual CV provided by the GLM standardization divided by the likelihood weight on the index.

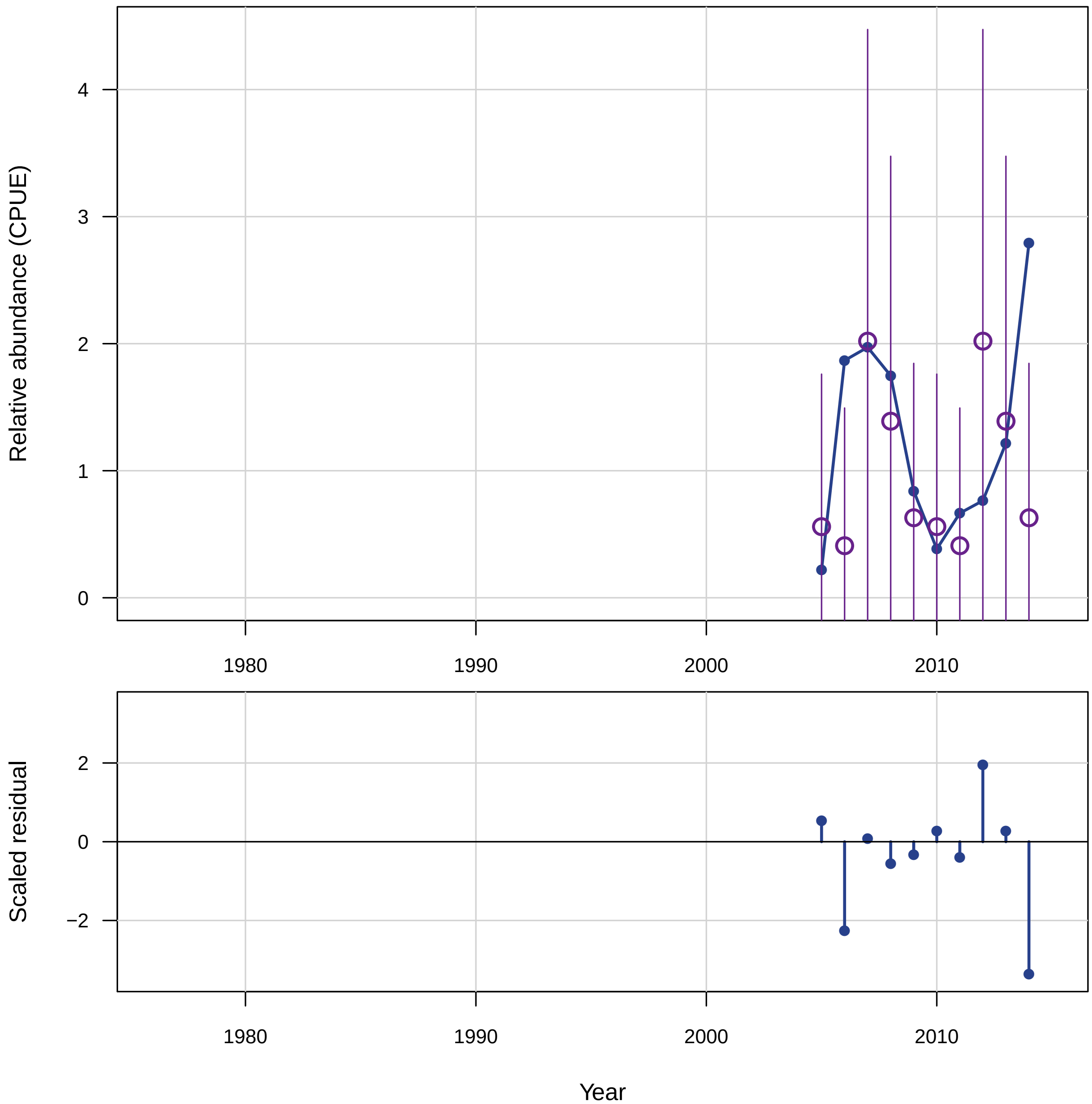


Figure 14. Estimated abundance at age at start of year.

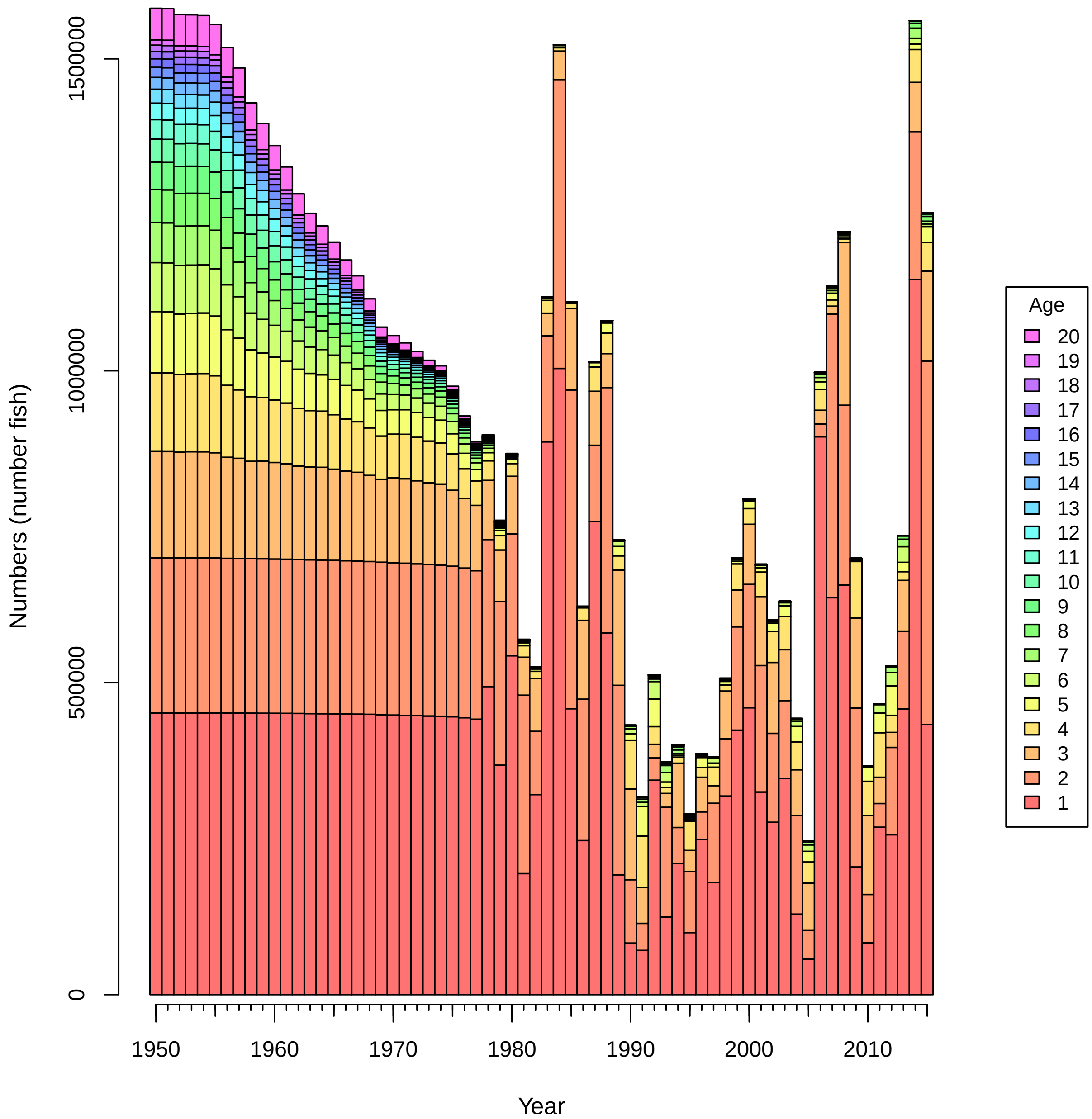


Figure 15. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates $R_{F30\%}$. Bottom panel: log recruitment residuals.

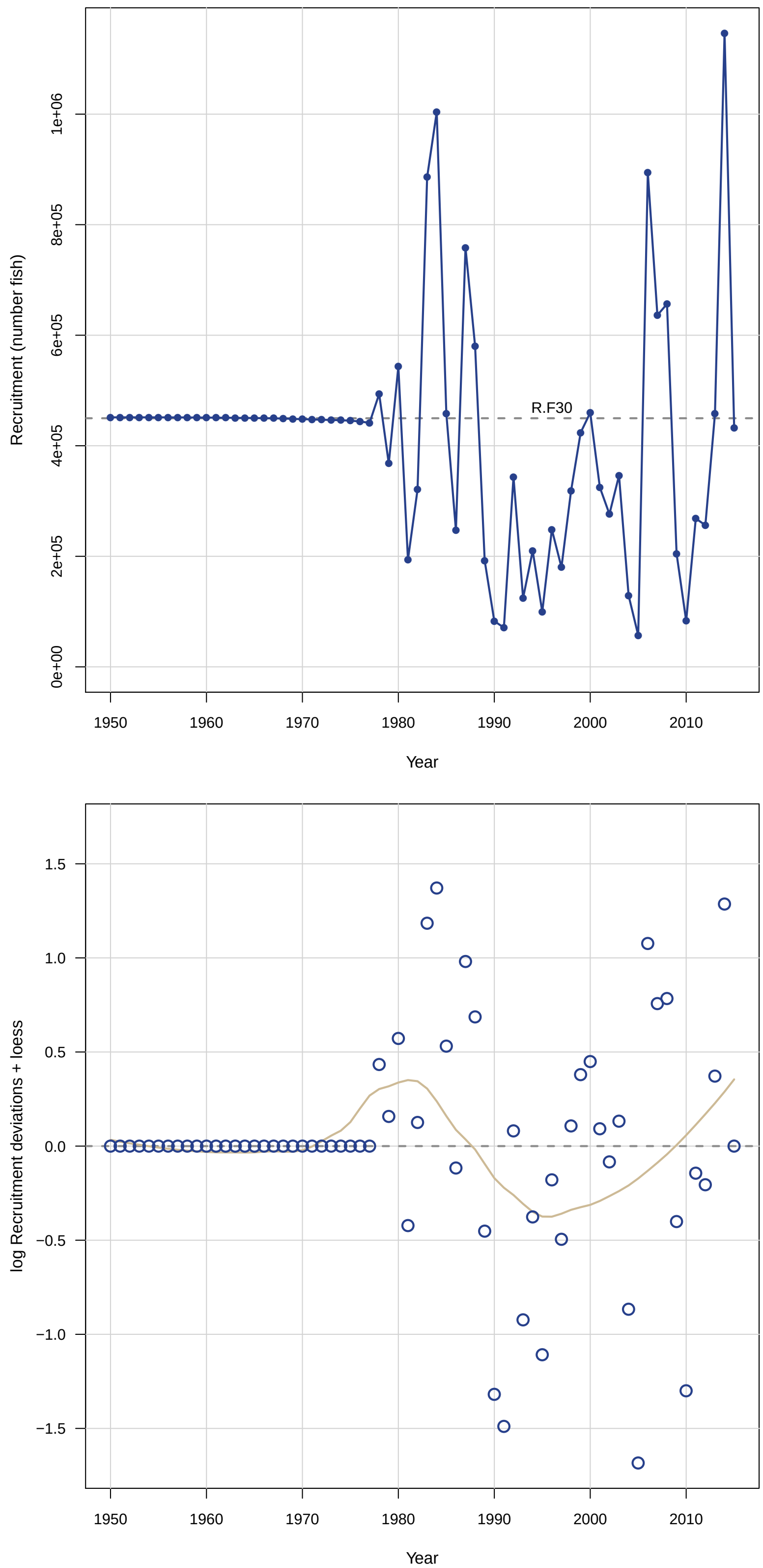


Figure 16. Estimated biomass at age at start of year.

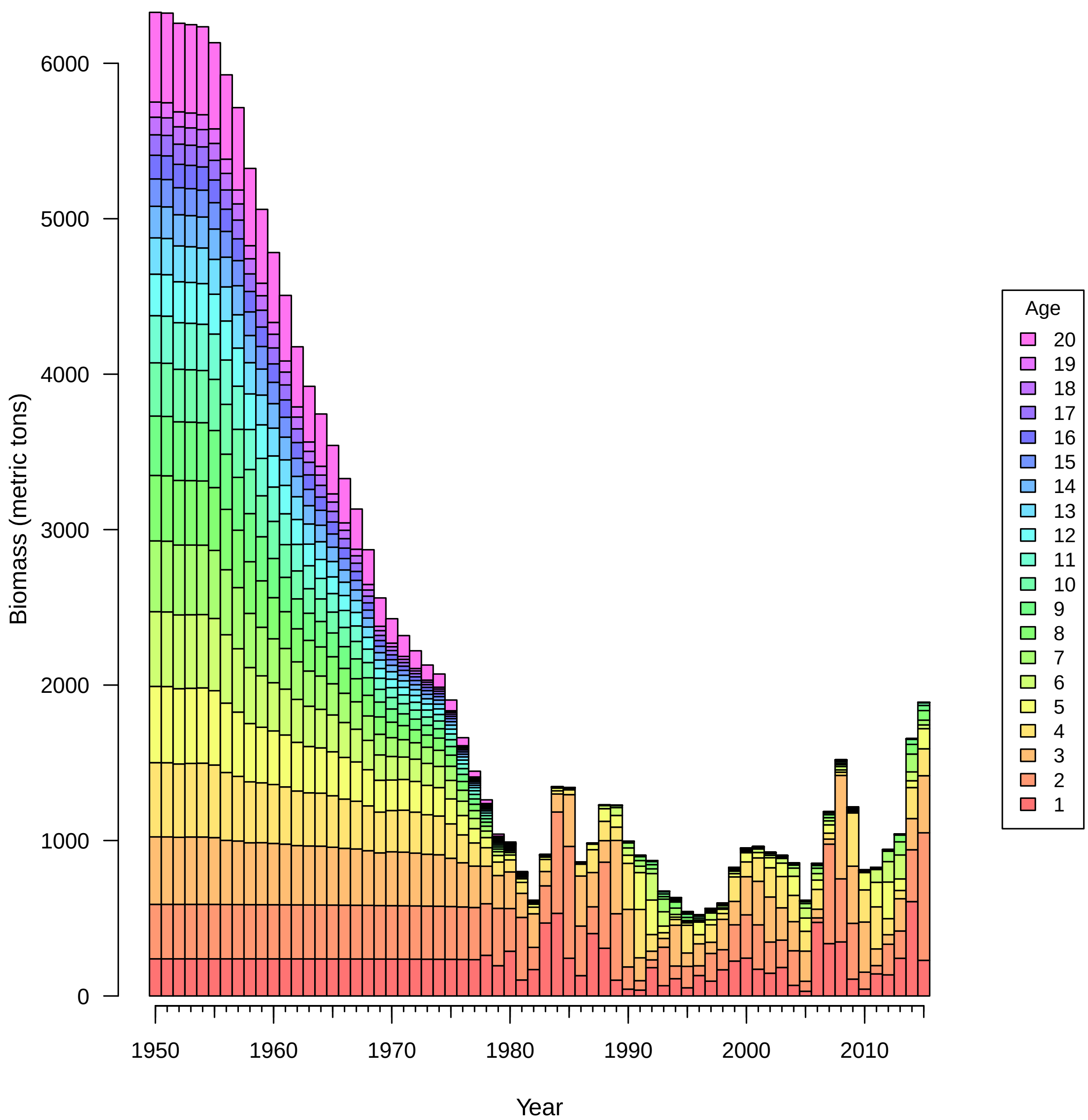


Figure 17. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates $B_{F30\%}$. Bottom panel: Estimated spawning stock (population fecundity) at time of peak spawning.

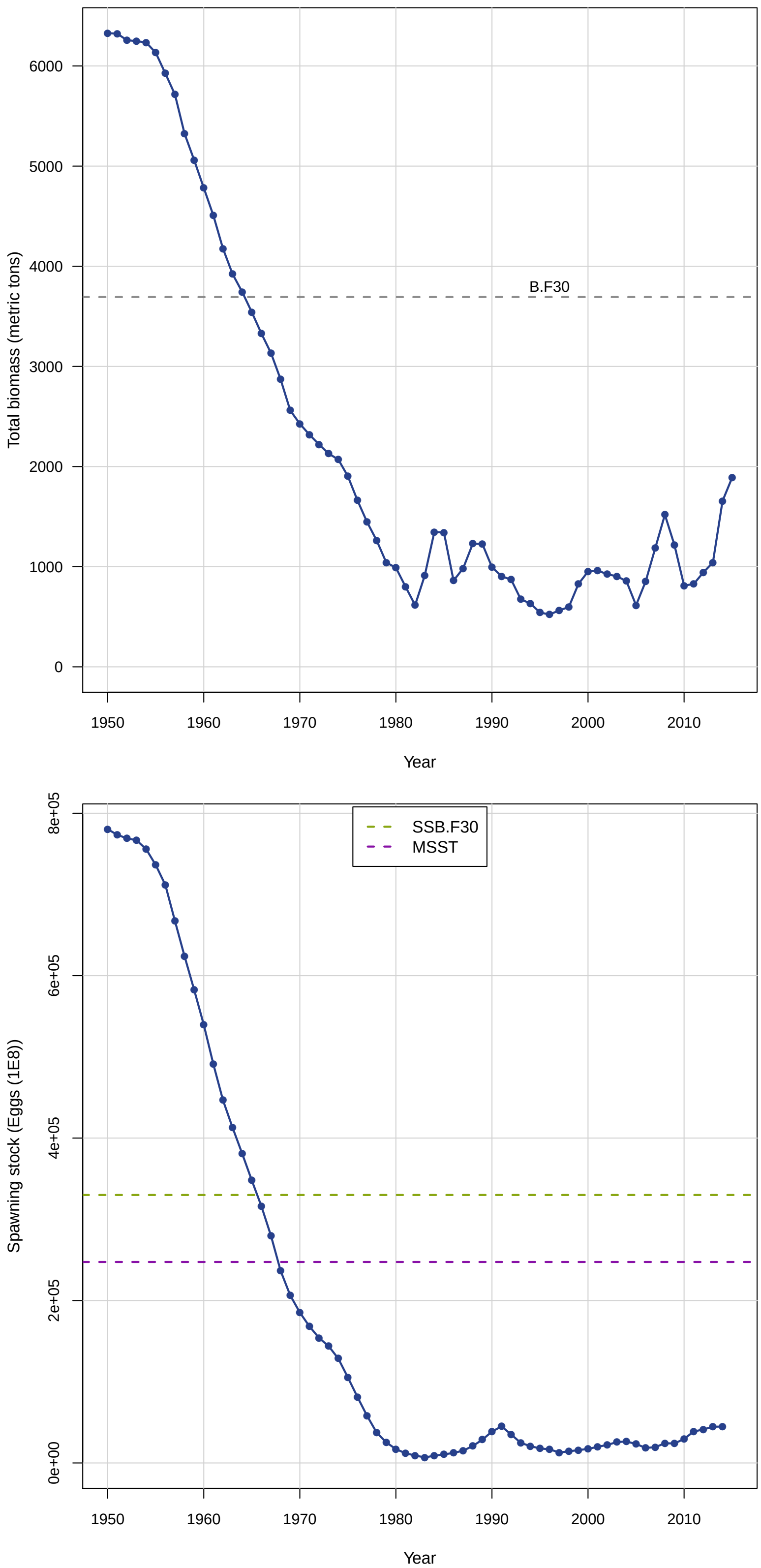


Figure 18. Monte Carlo Bootstrap estimates of population abundance. Top panel is all ages, and the bottom panel represents age 2+.

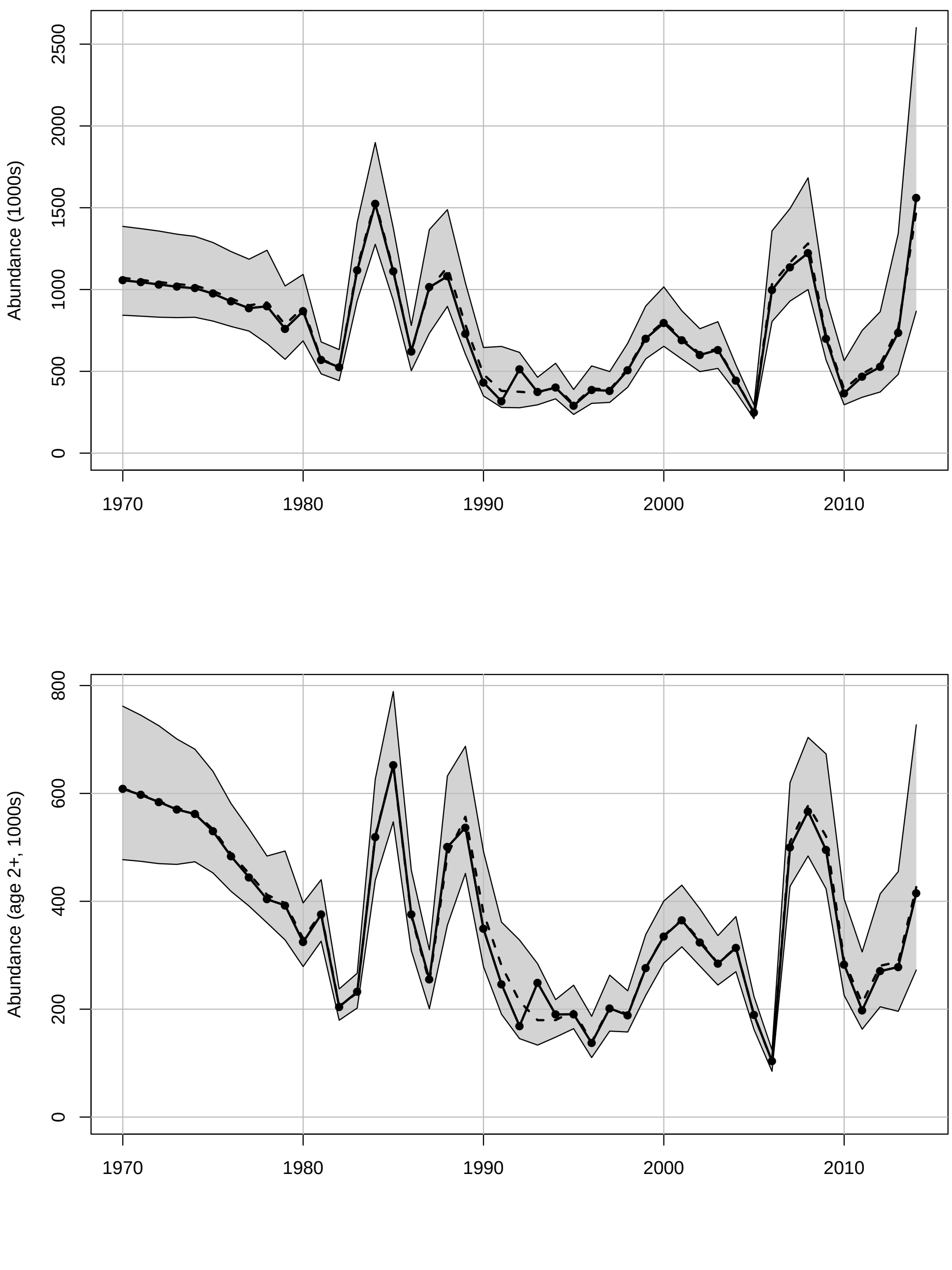


Figure 19. Selectivity of SERFS index.

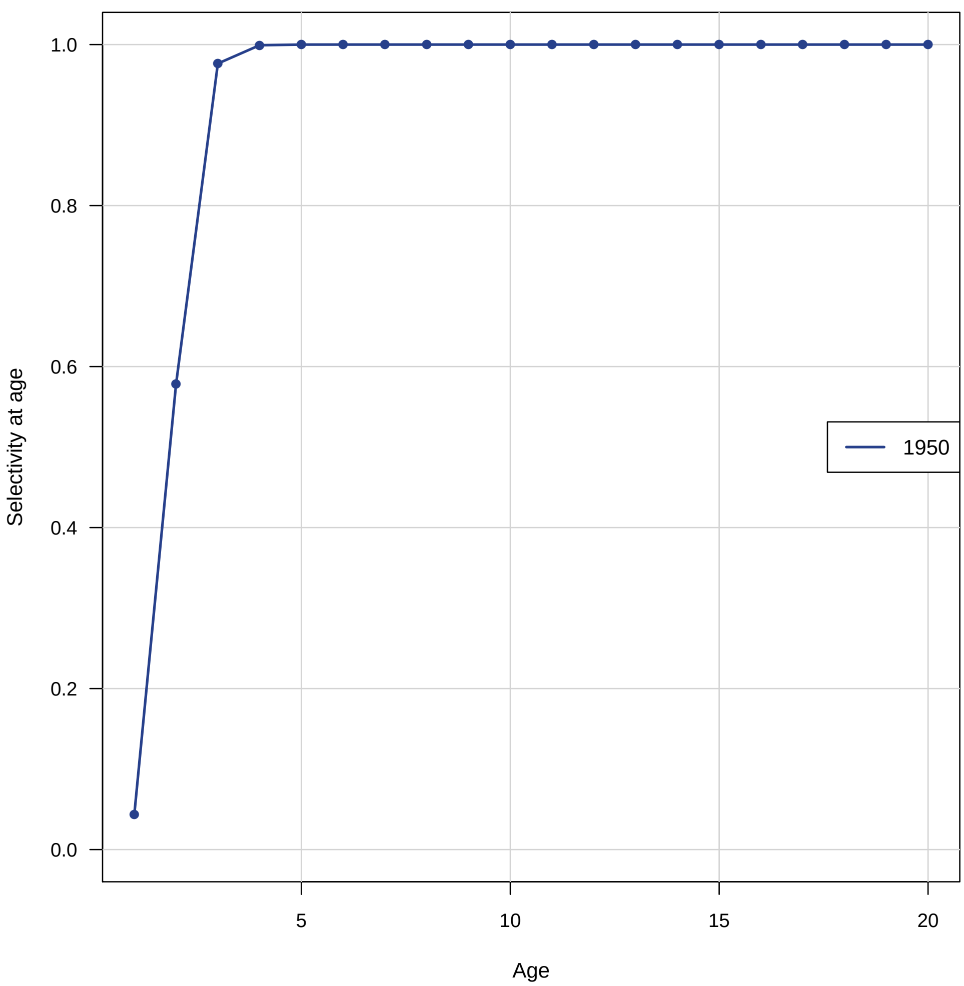


Figure 20. Selectivities of commercial handline landings. The legend indicates the first year each selectivity curve applies to the fleet.

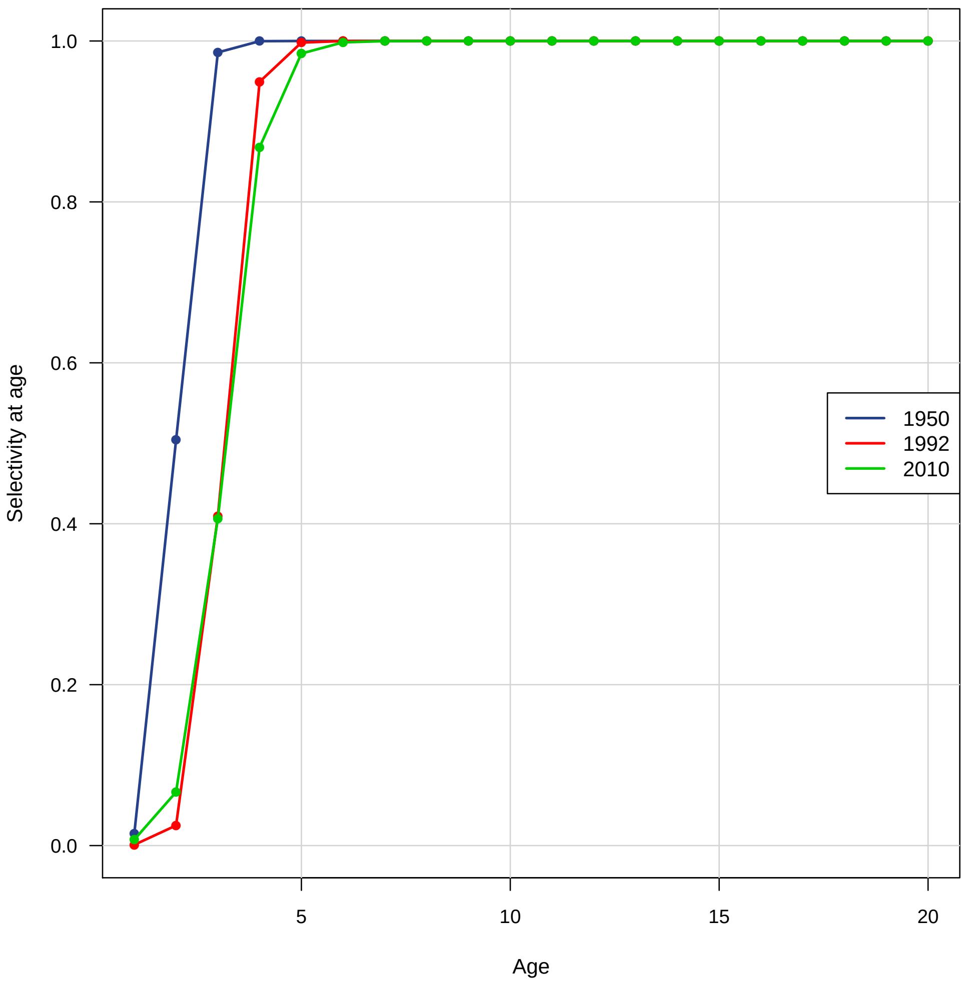


Figure 21. Selectivities of headboat landings. The legend indicates the first year each selectivity curve applies to the fleet.

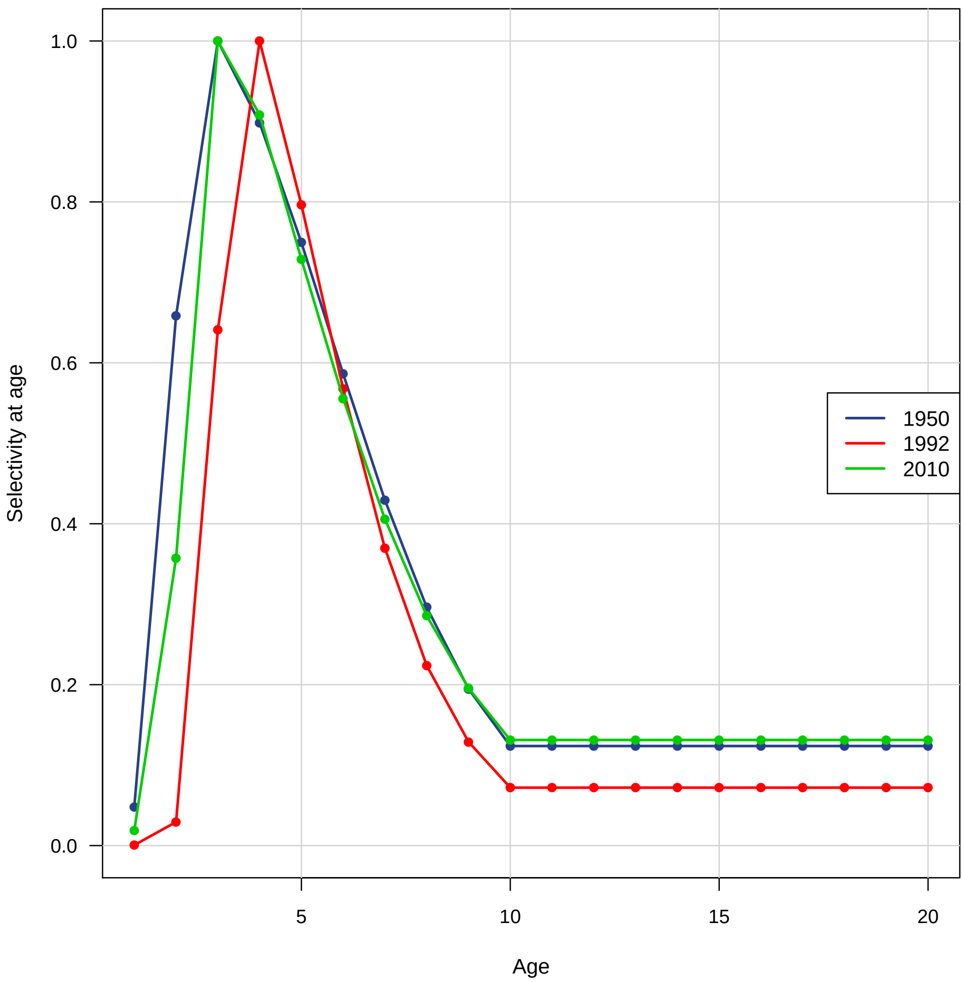


Figure 22. Selectivities of general recreational landings. The legend indicates the first year each selectivity curve applies to the fleet.

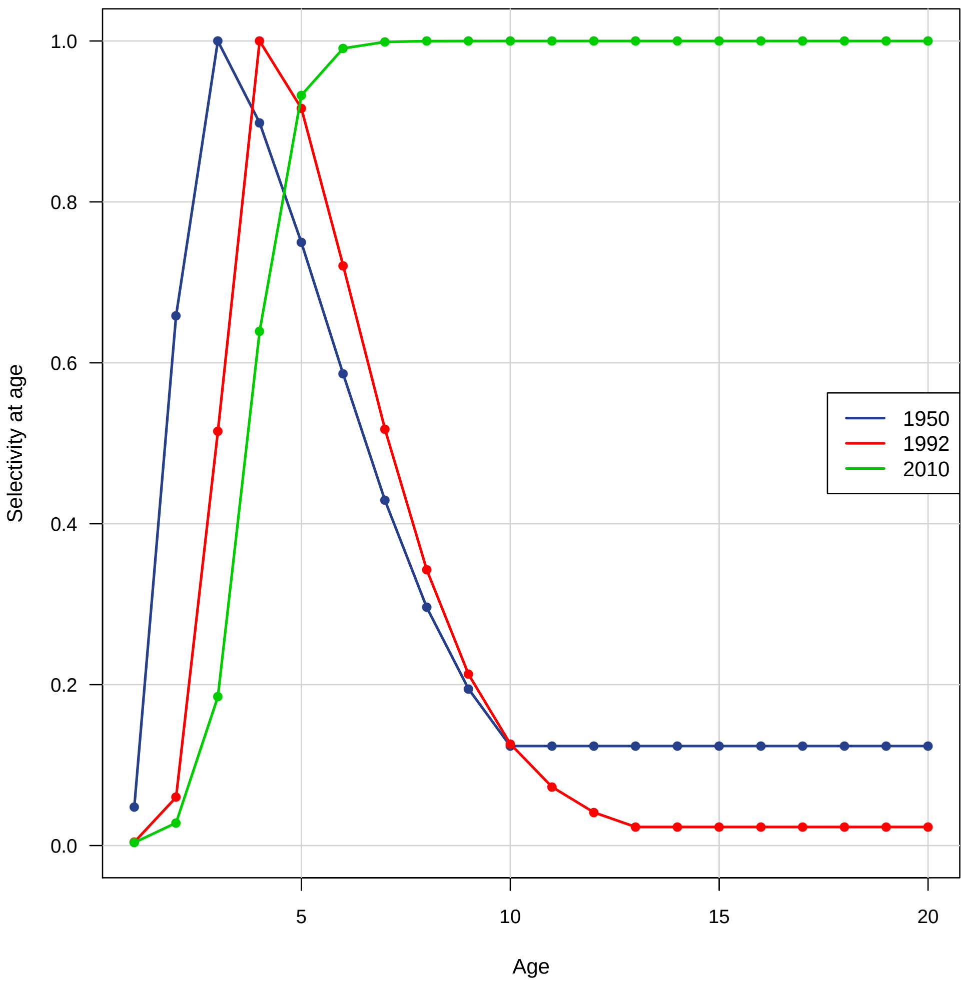


Figure 23. Selectivities of commercial handline discards. The legend indicates the first year each selectivity curve applies to the fleet.

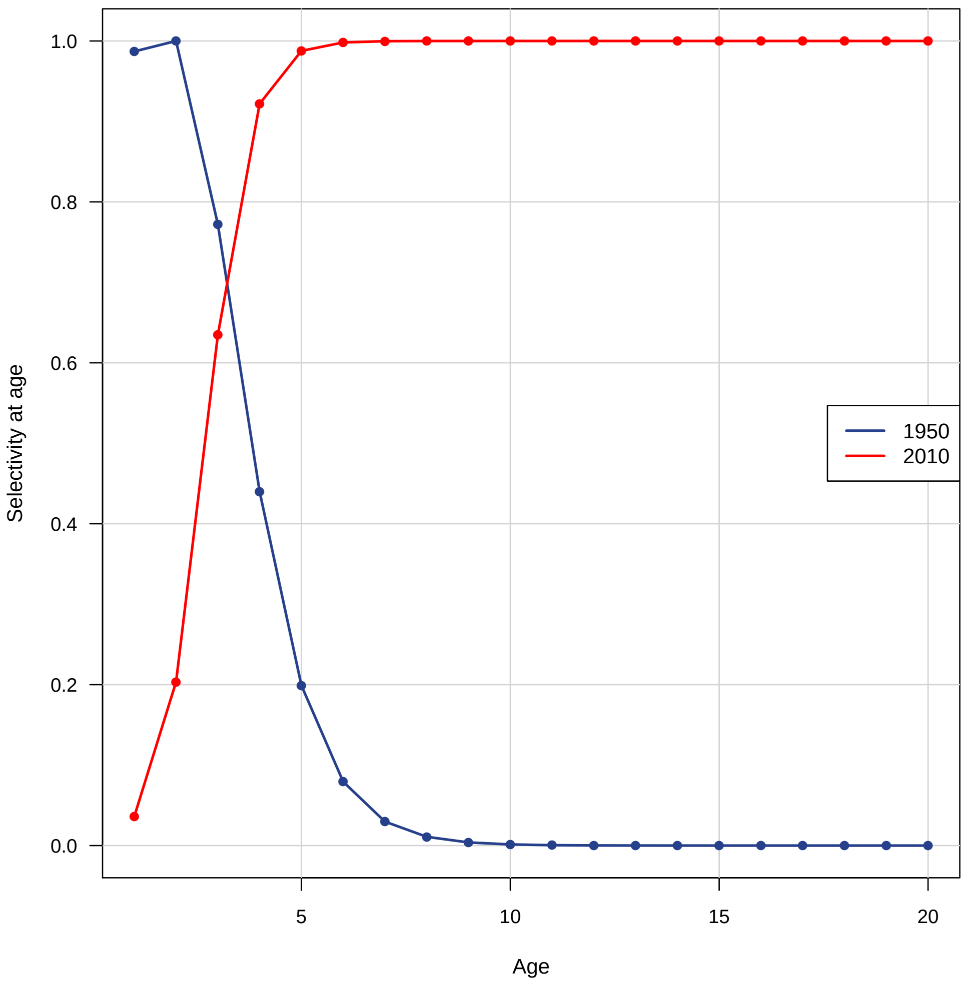


Figure 24. Selectivities of headboat discards. The legend indicates the first year each selectivity curve applies to the fleet.

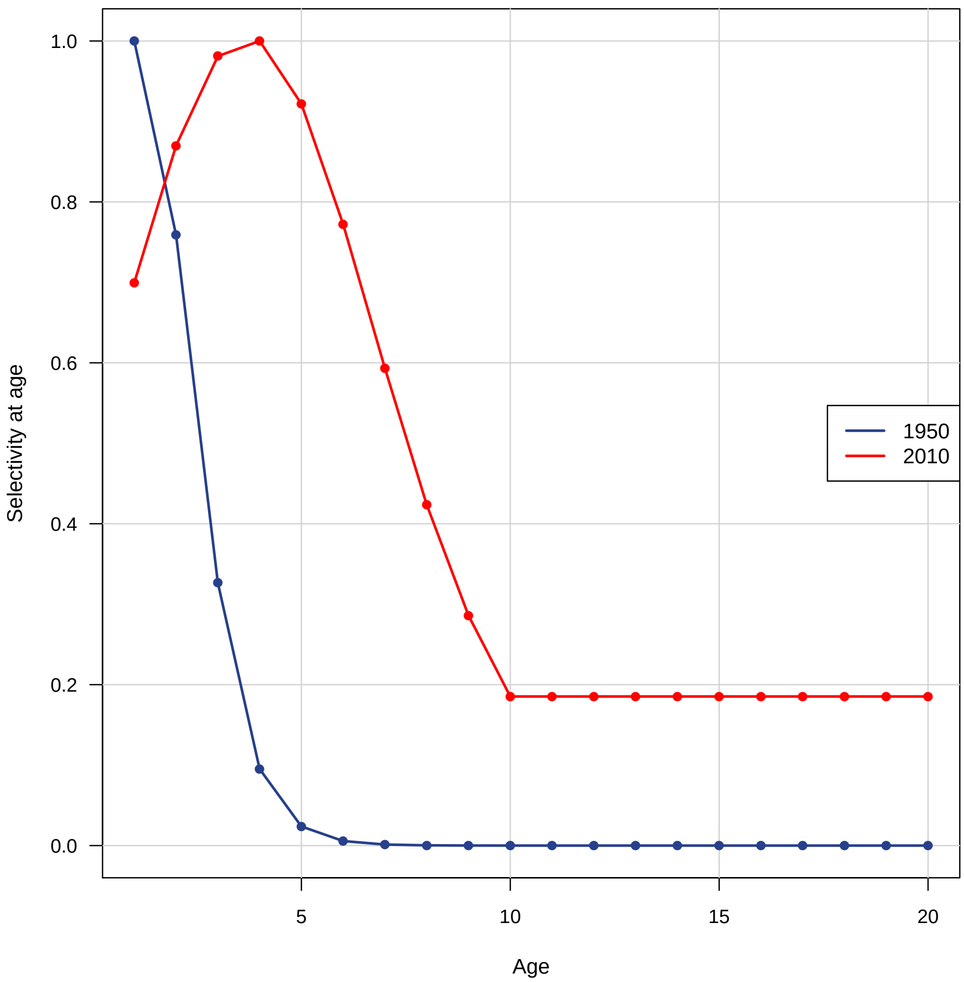


Figure 25. Selectivities of general recreational discards. The legend indicates the first year each selectivity curve applies to the fleet.

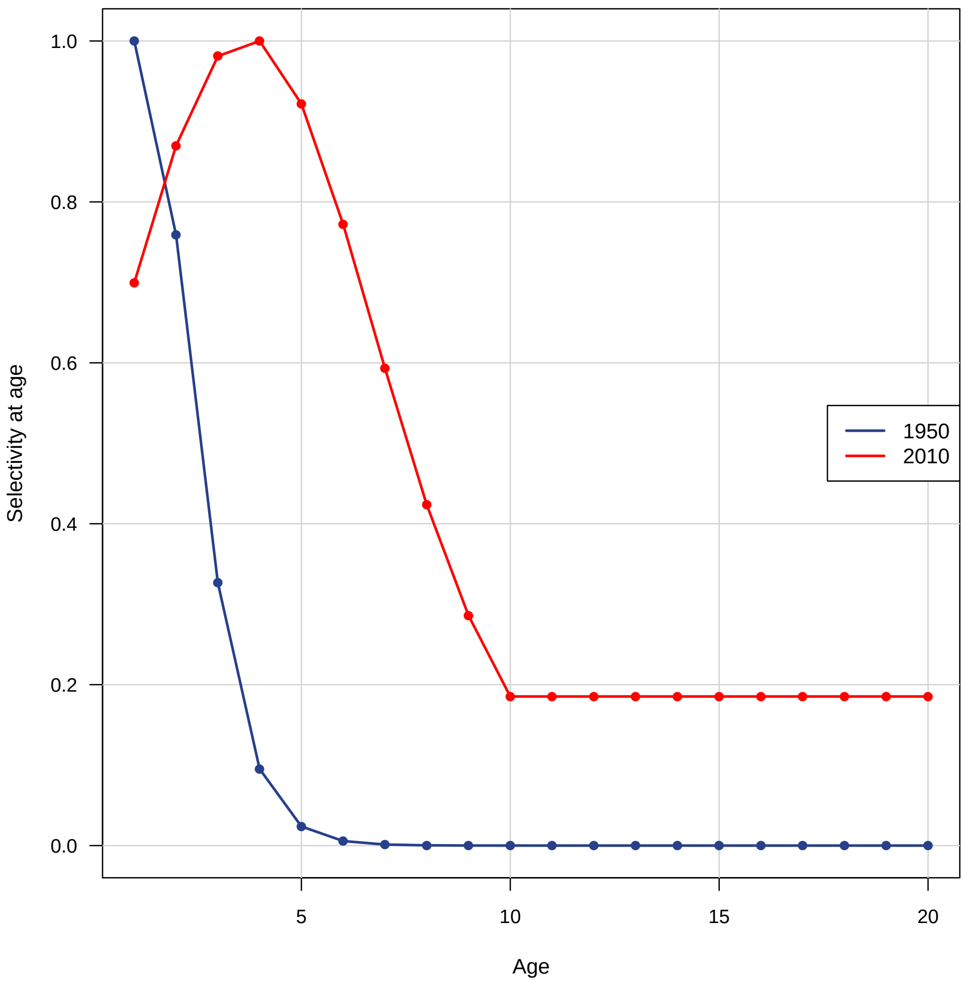


Figure 26. Average selectivity of discards(top left), landings (top right), and total weighted average (bottom) from the terminal assessment years, weighted by geometric mean F's from the last three assessment years, and used in computation of benchmarks and projections.

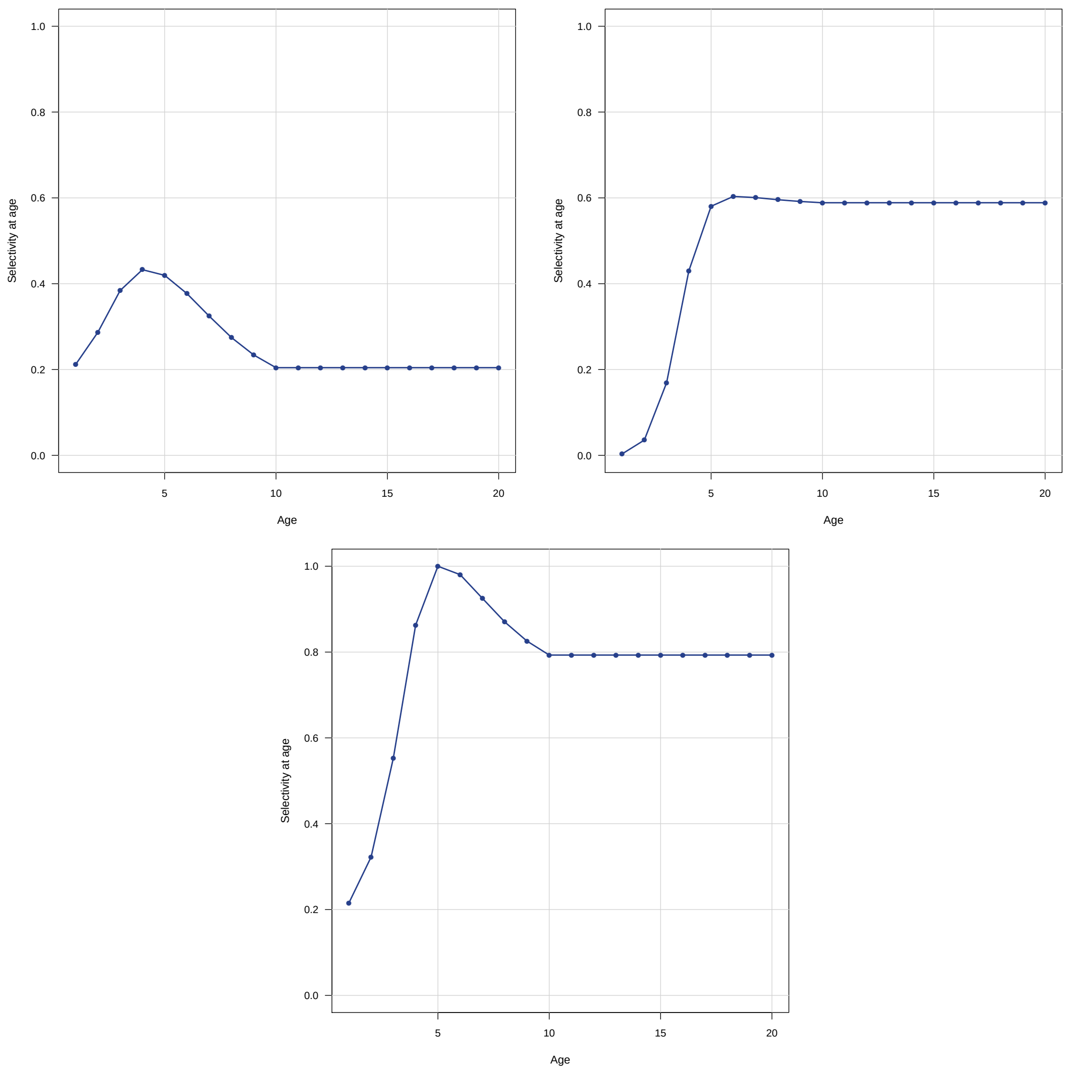


Figure 27. Estimated fully selected fishing mortality rate (per year) by fleet. cH refers to commercial handlines, HB to headboat, GR to general recreational, and D refers to discard mortality.

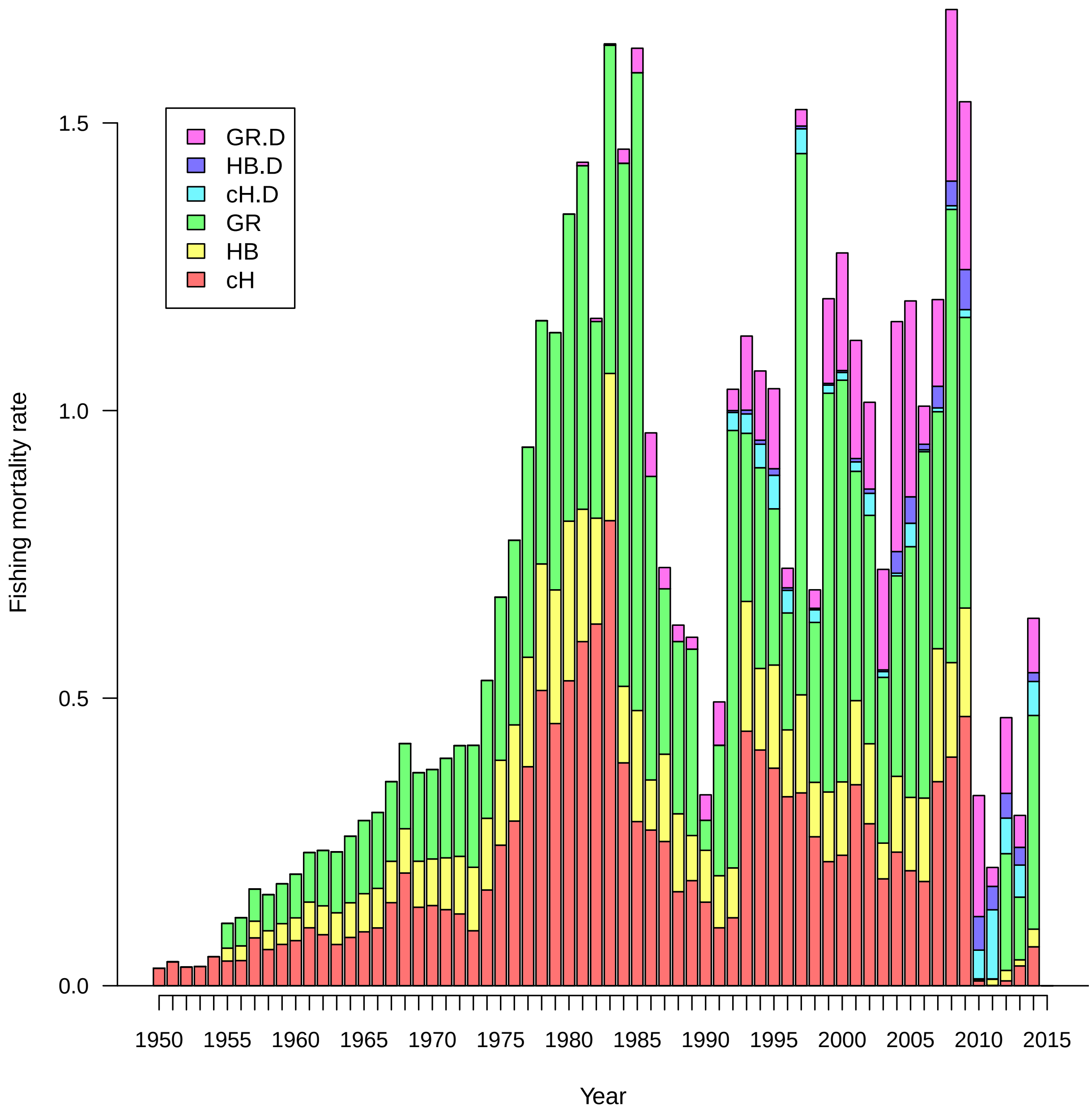


Figure 28. Estimated landings in numbers by fleet from the catch-age model. cH refers to commercial handlines, HB to headboat, and GR to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of $L_{\mathrm{F30\%}}$ in numbers.

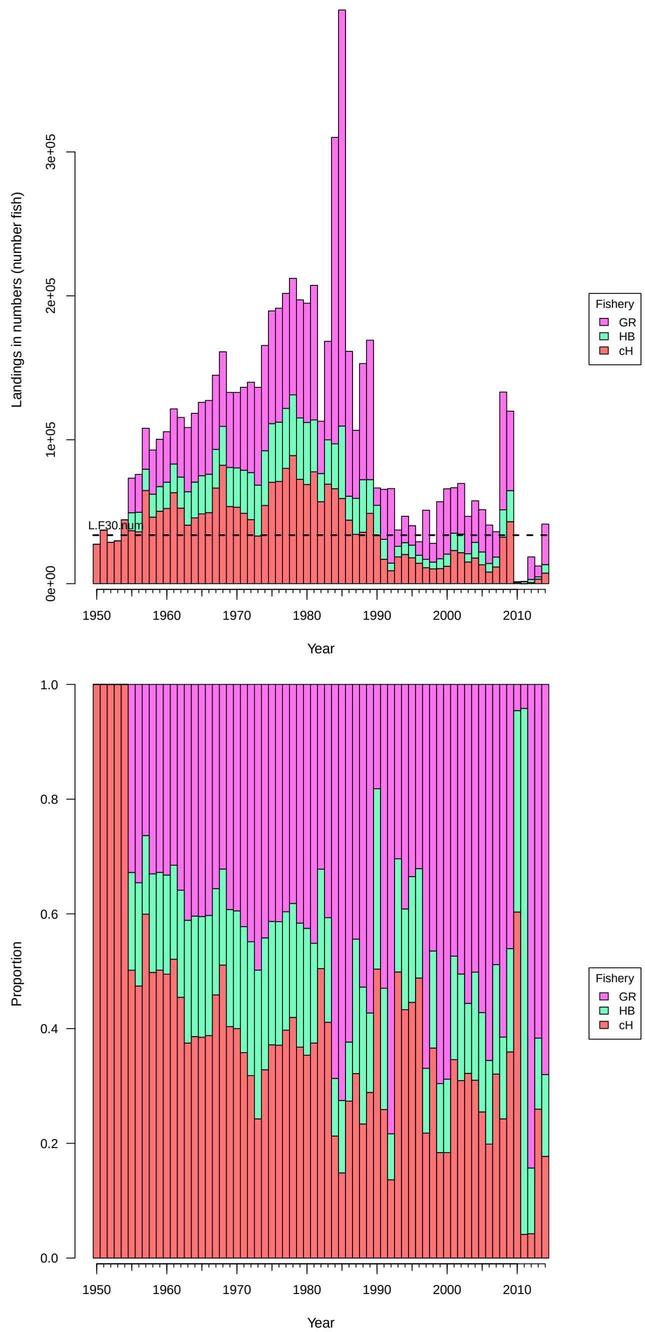


Figure 29. Estimated landings in whole weight by fleet from the catch-age model. cH refers to commercial handlines, HB to headboat, and GR to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of $L_{\mathrm{F30\%}}$ in weight.

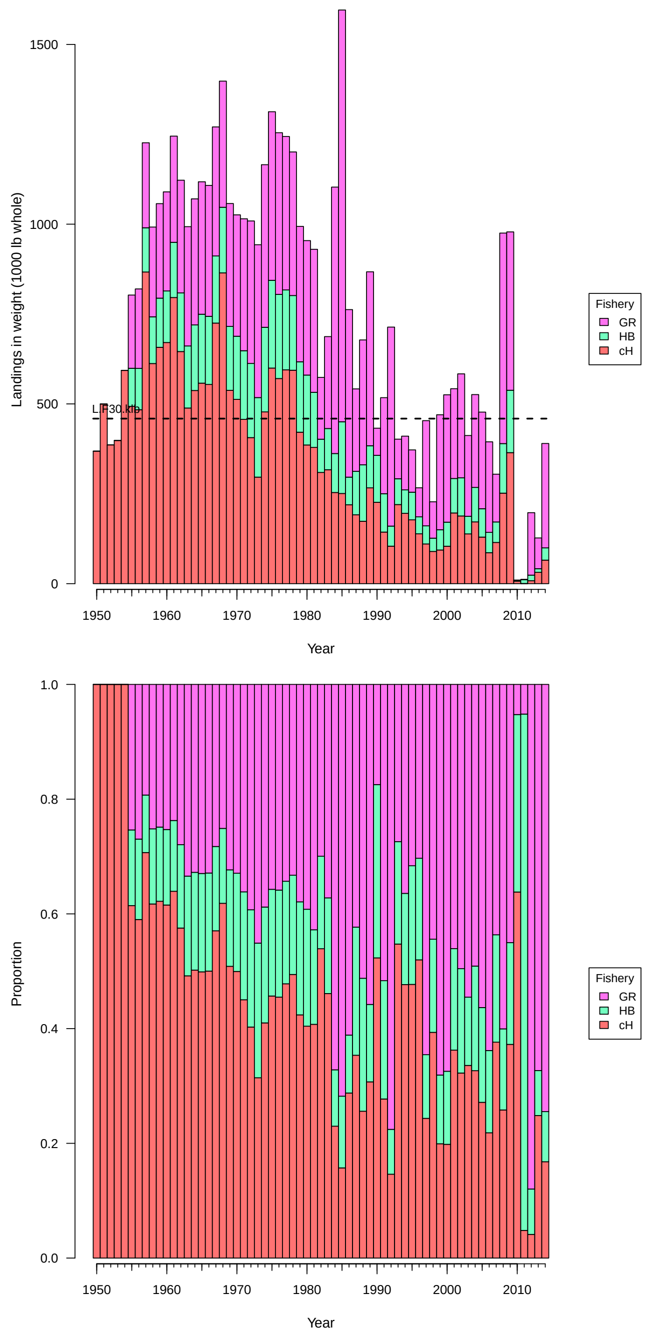


Figure 30. Estimated discard mortalities by fleet from the catch-age model. cH refers to commercial lines, hb to headboat, rec to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of $D_{F_{30\%}}$ *in numbers.*

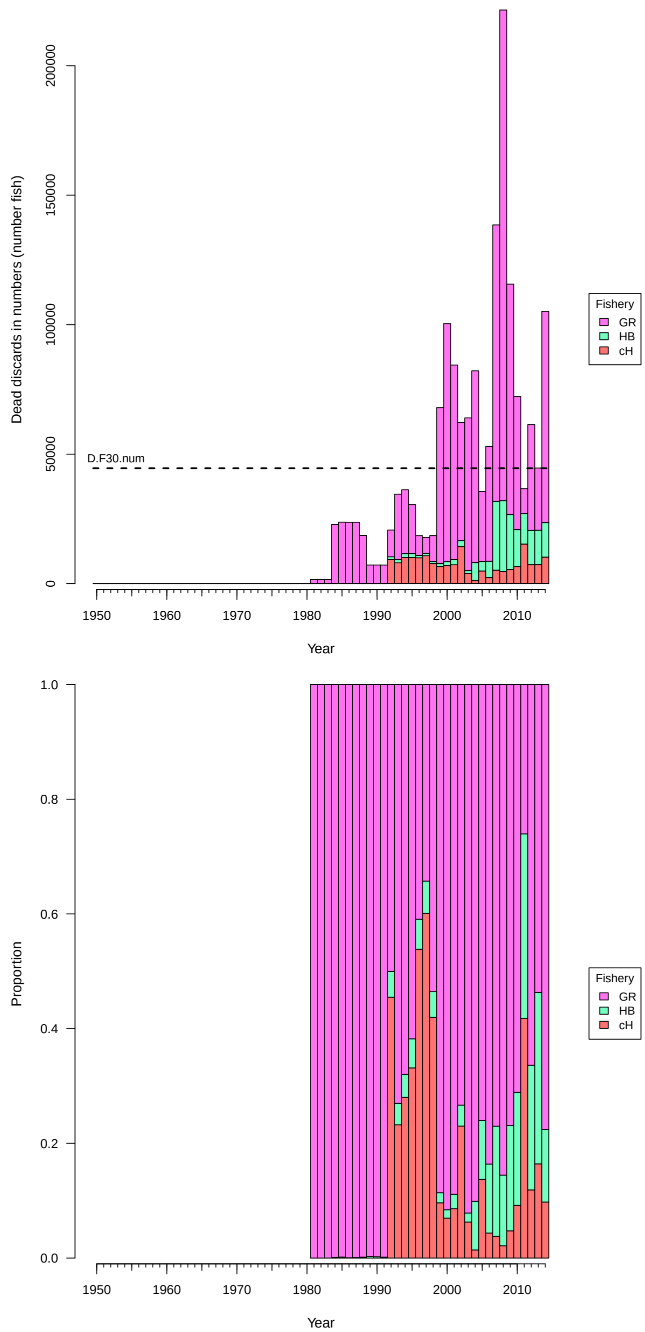
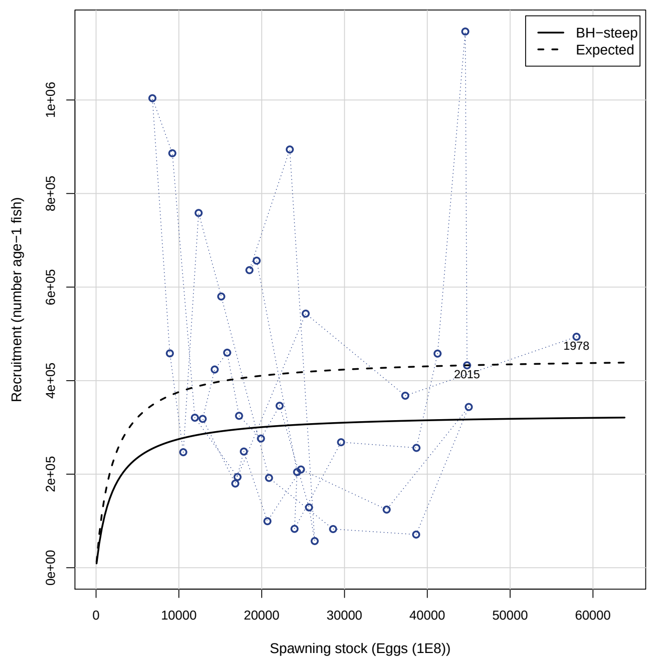


Figure 31. Top panel: Beverton–Holt spawner-recruit curves, with and without lognormal bias correction. The expected (upper) curve was used for computing management benchmarks. Bottom panel: log of recruits (number age-1 fish) per spawner as a function of spawners.



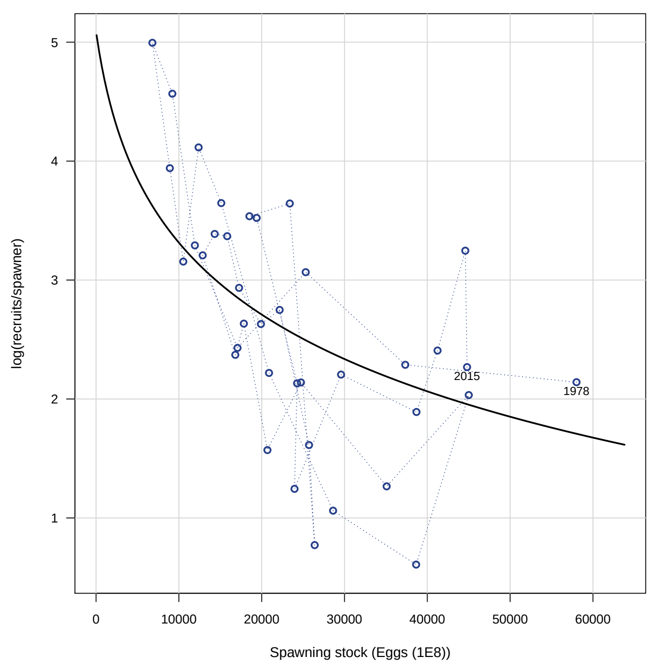


Figure 32. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-1 fish), steepness (fixed at 0.99), unfished spawners per recruit, and standard deviation of recruitment residuals in log space. Solid vertical lines represent point estimates or values from the base run of the Beaufort Assessment Model; dashed vertical lines represent medians from the MCB runs.

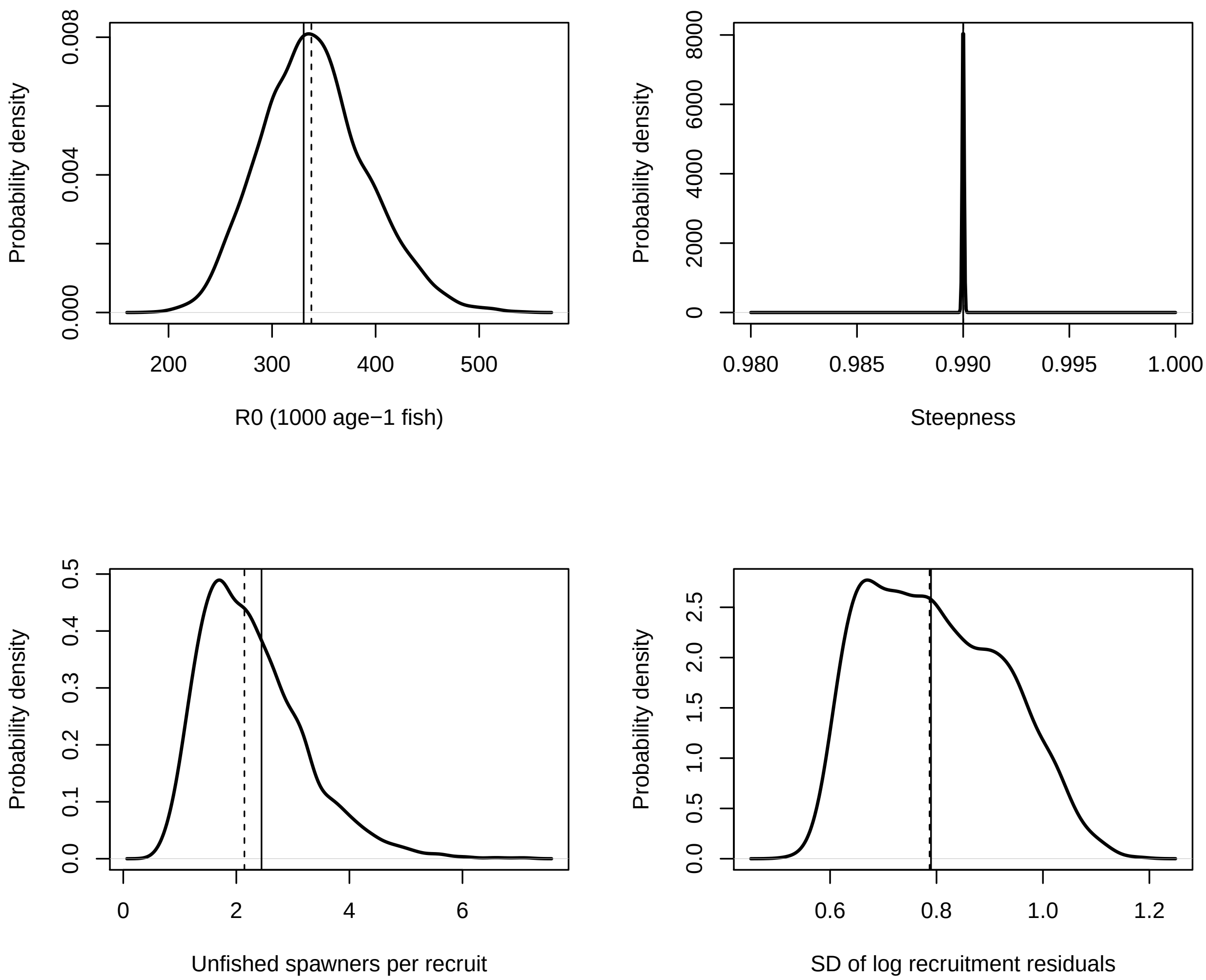


Figure 33. Yield per recruit based on average selectivity from the end of the assessment period.

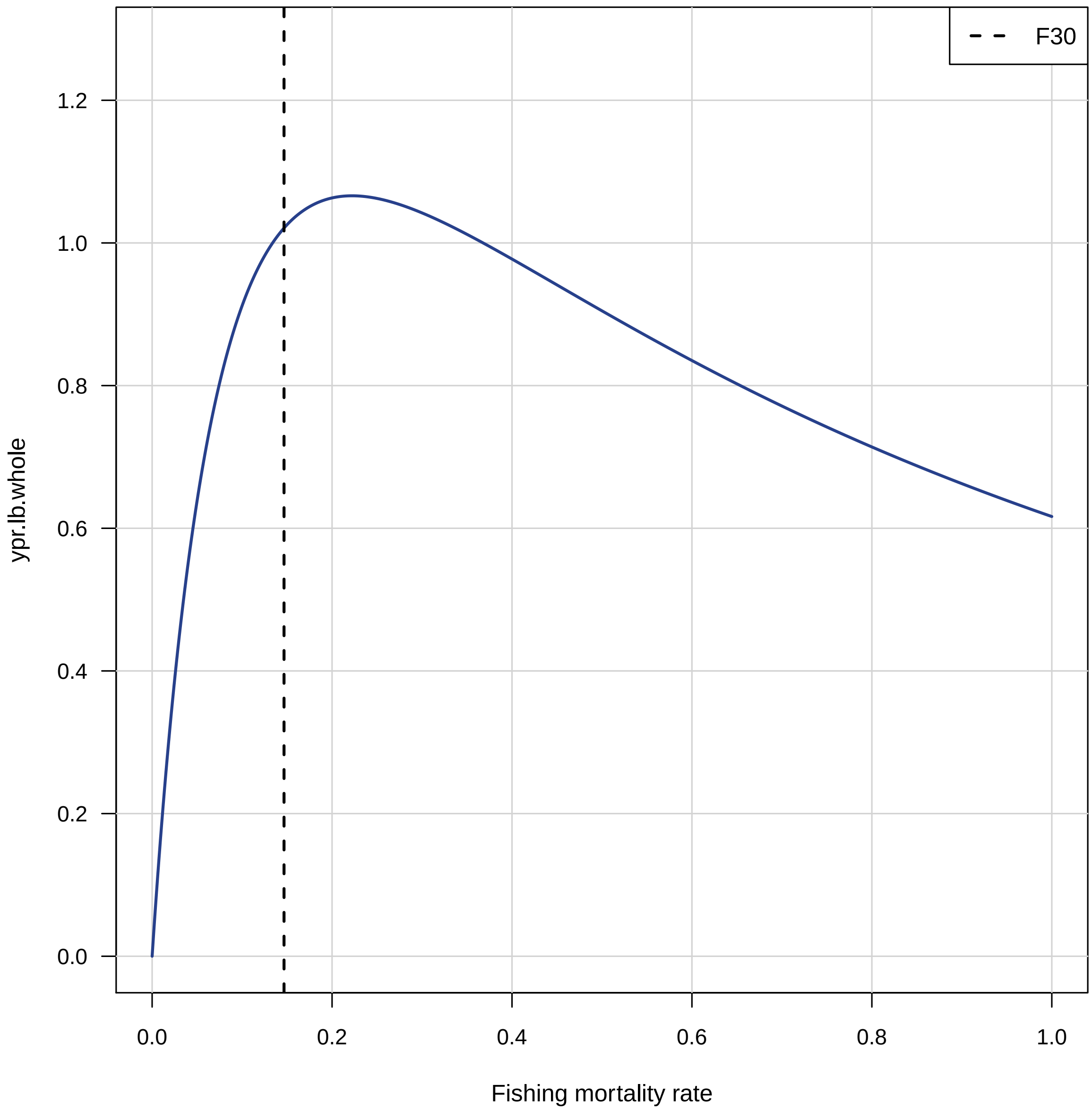


Figure 34. Spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the X% level of SPR provides $F_{X\%}$. SPR is based on average selectivity from the end of the assessment period.

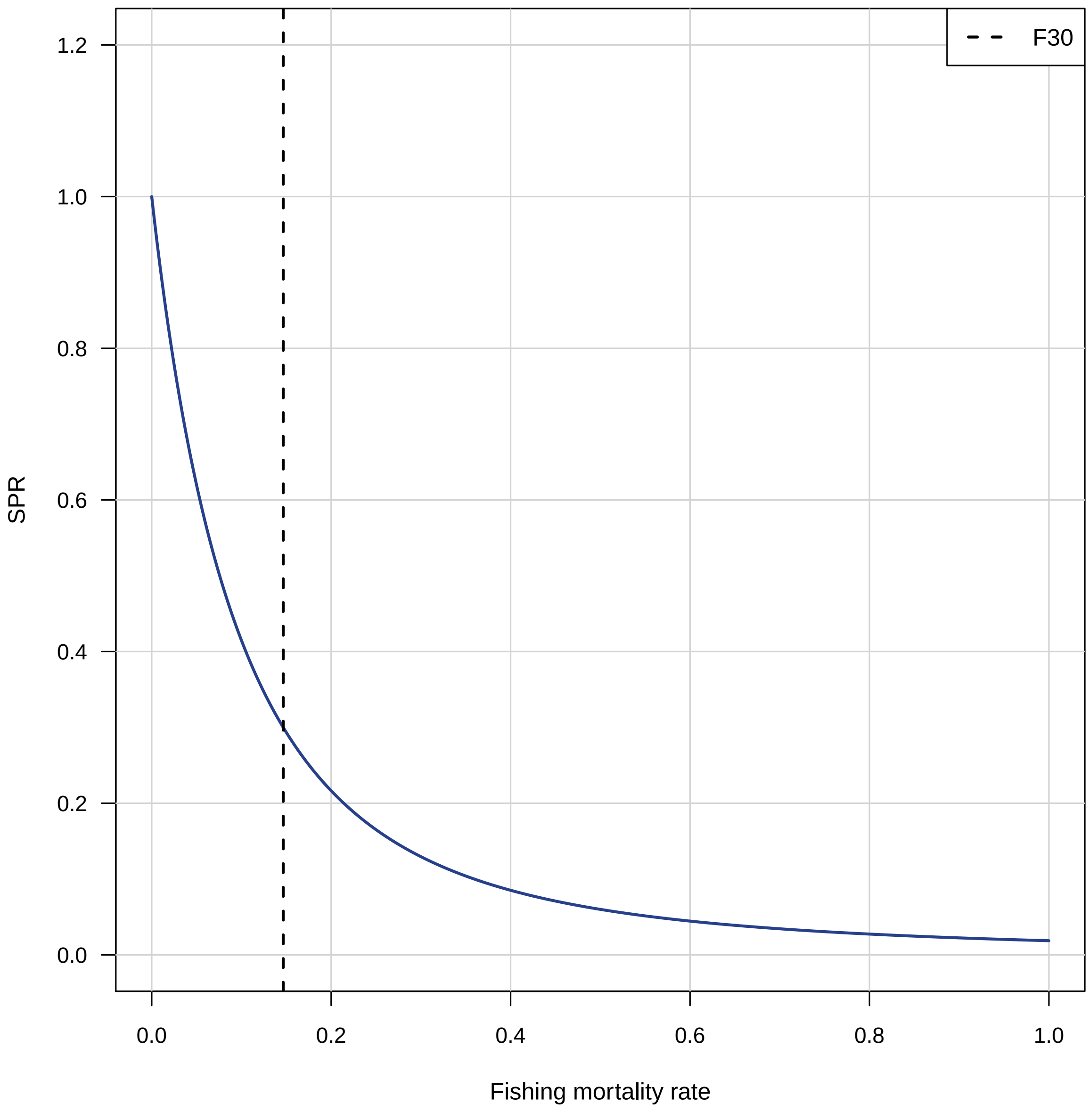


Figure 35. Equilibrium spawning biomass based on average selectivity from the end of the assessment period.

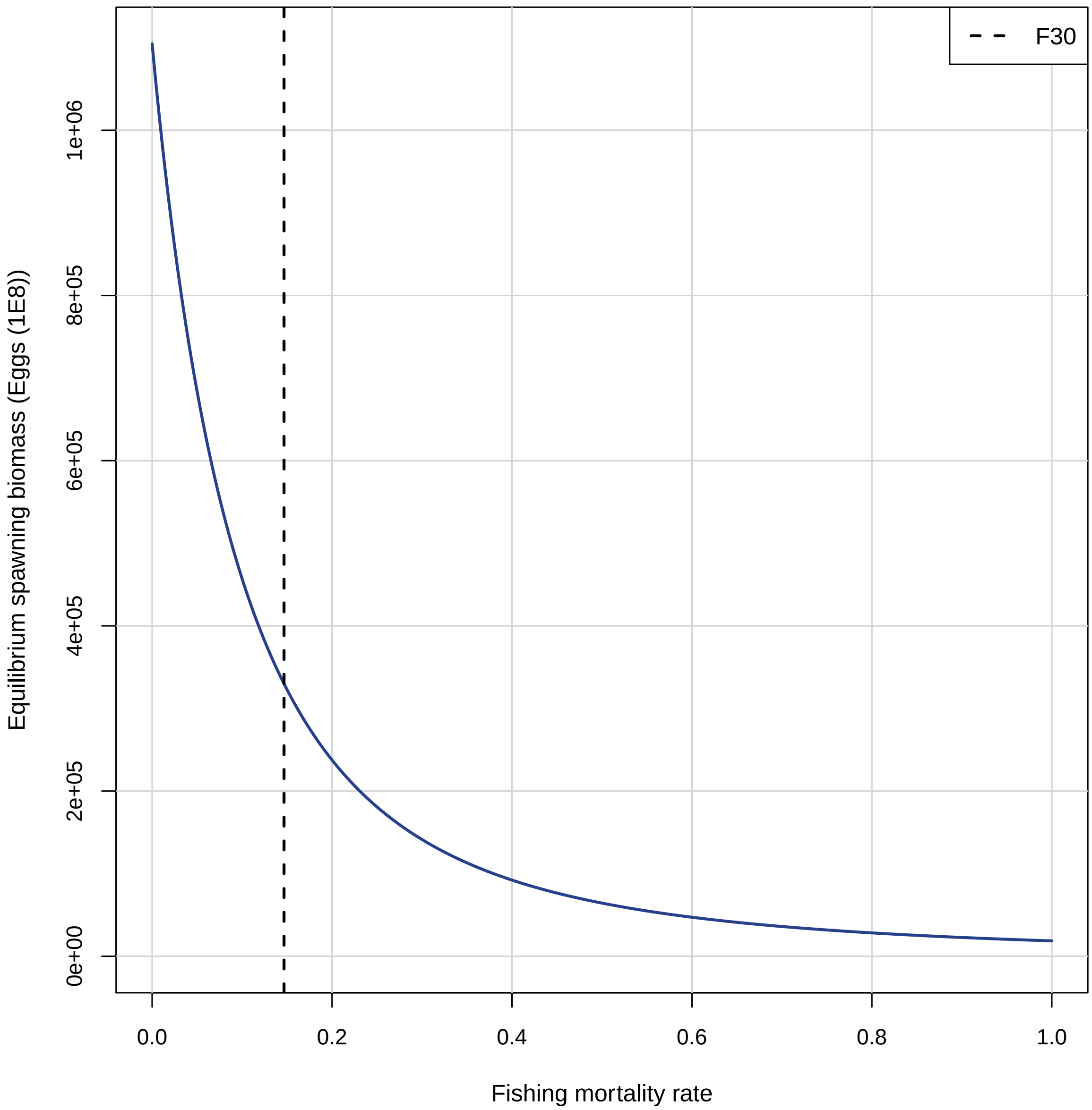


Figure 36. Probability densities of $F_{30\%}$-related benchmarks from MCB analysis of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.

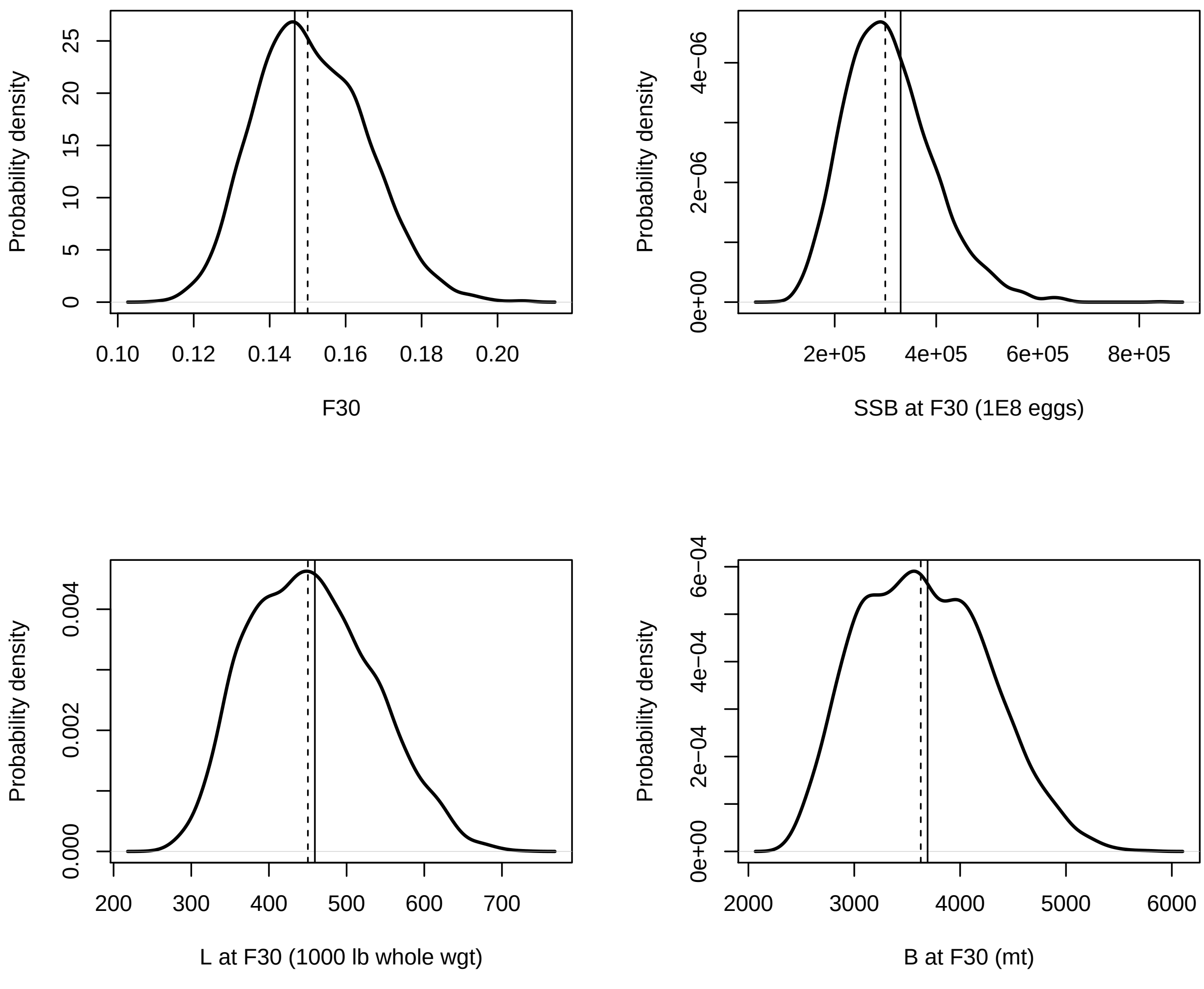


Figure 37. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; dashed lines represent median values; gray error bands indicate 5^{th} *and* 95^{th} *percentiles of the MCB trials. Top panel: spawning biomass relative to* $\mathrm{SSB}_{\mathrm{F30\%}}$*. Bottom panel: F relative to* $F_{30\%}$*.*

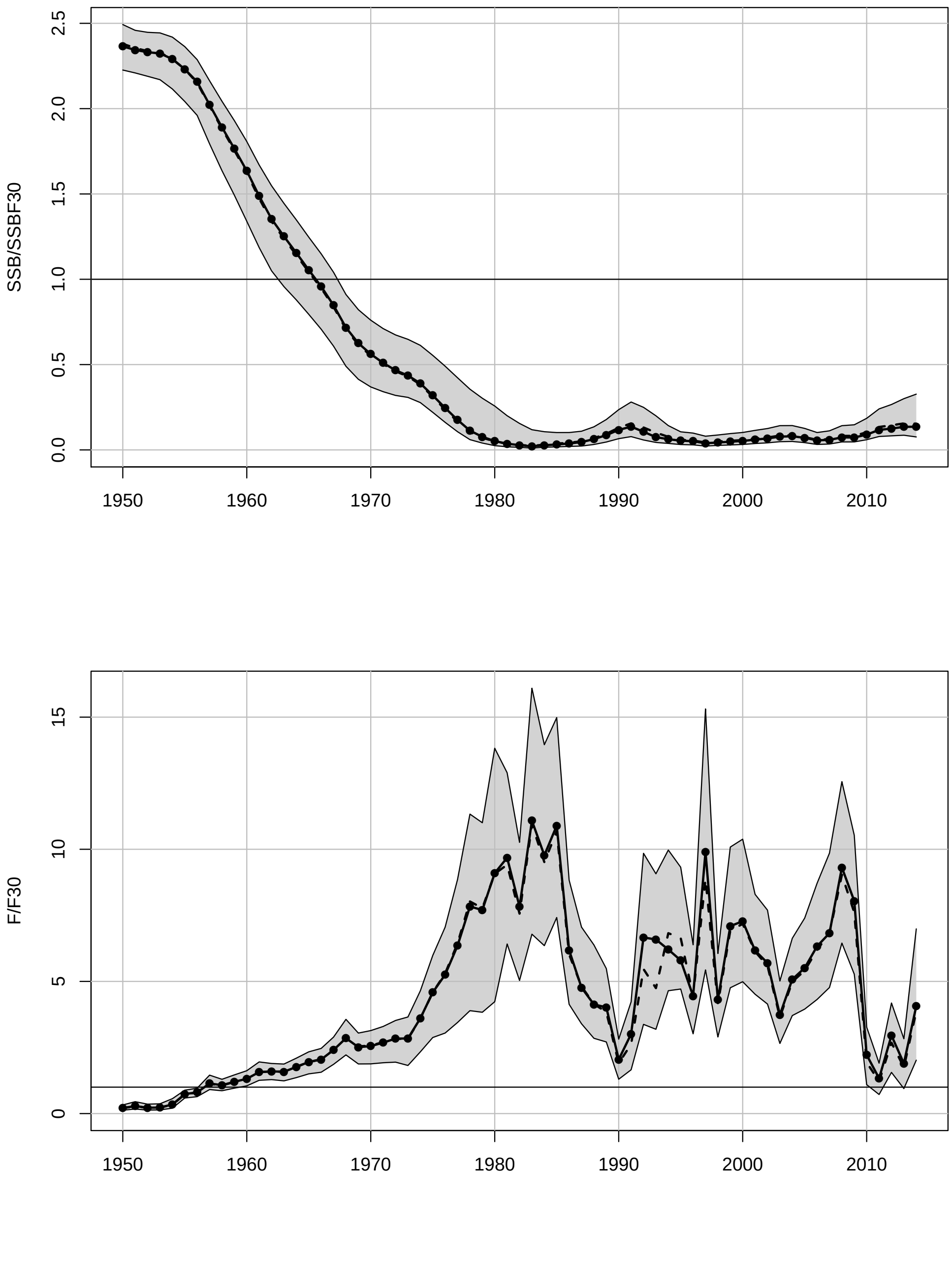


Figure 38. Probability densities of terminal status estimates from MCB analysis of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.

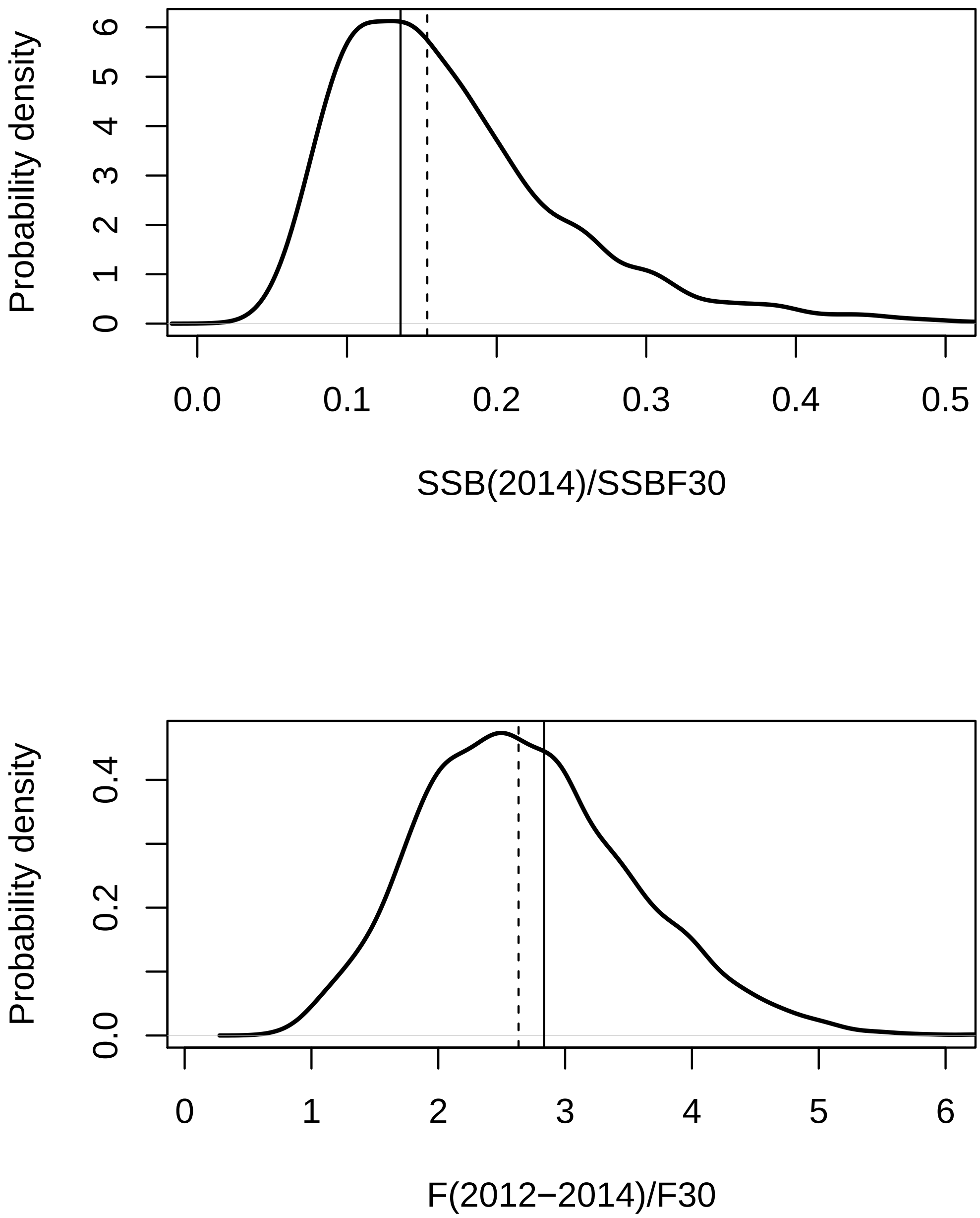


Figure 39. Phase plots of terminal status estimates from MCB analysis of the Beaufort Assessment Model. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by 5^{th} and 95^{th} percentiles. Proportion of runs falling in each quadrant indicated.

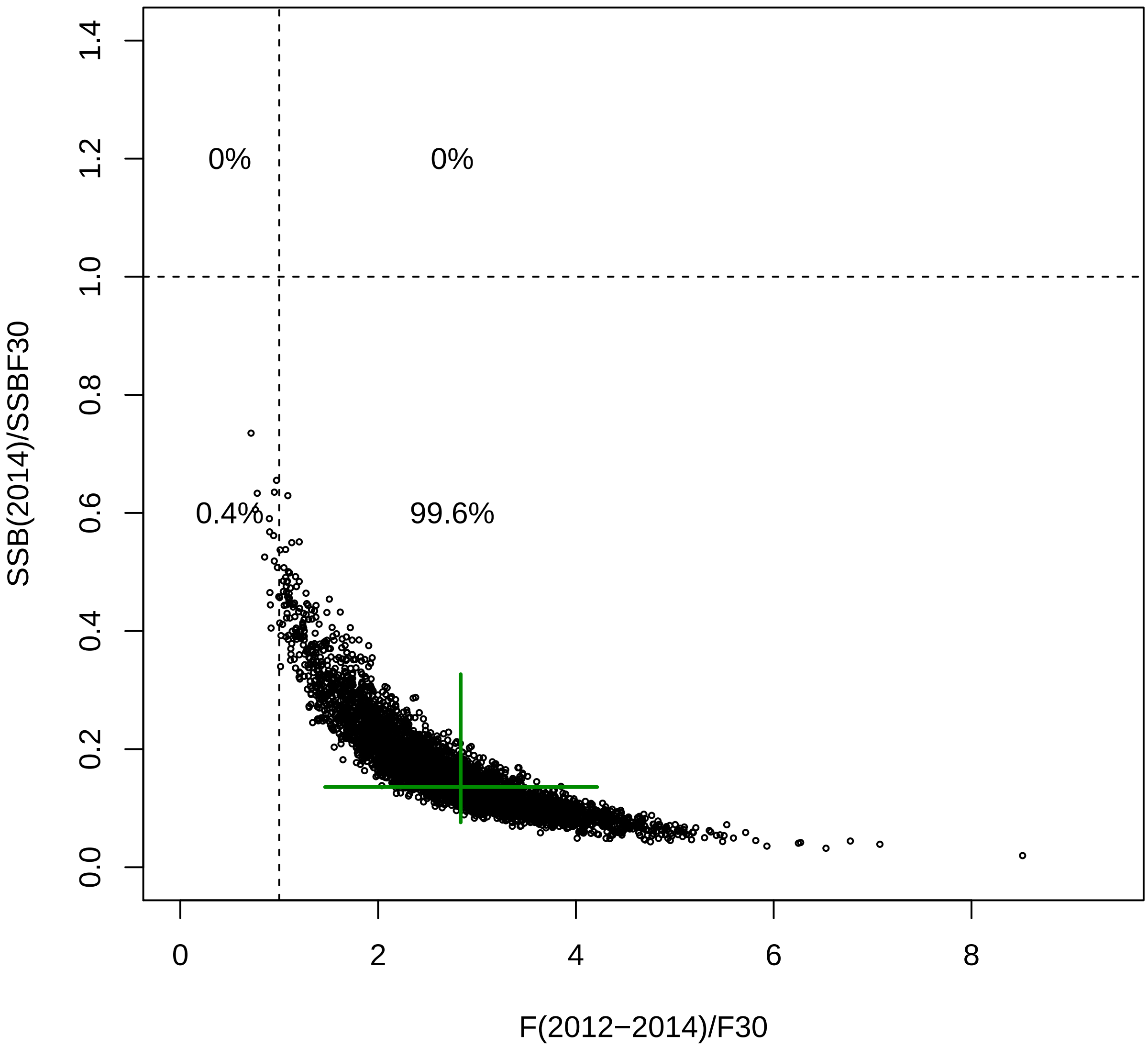


Figure 40. Sensitivity to changes in natural mortality (sensitivity runs S5 and S6). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

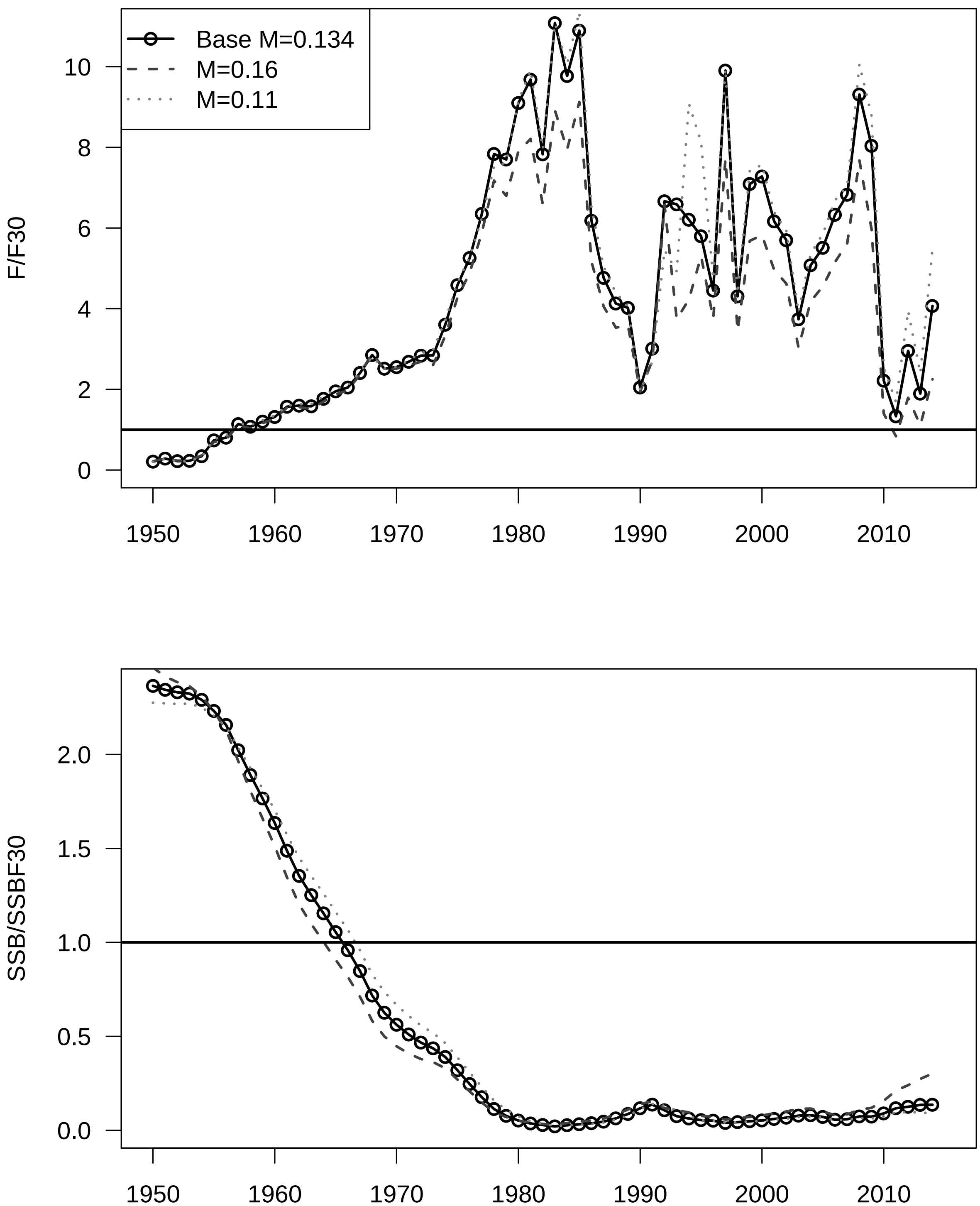
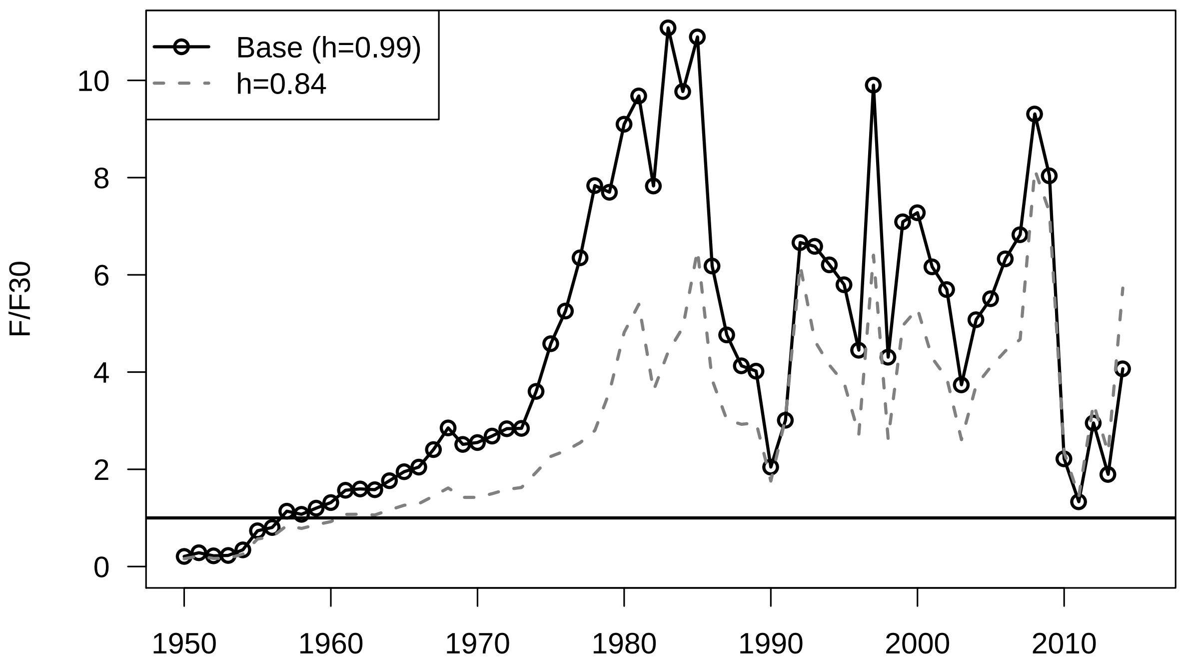


Figure 41. Sensitivity to steepness (sensitivity run S11). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $SSB_{F30\%}$.



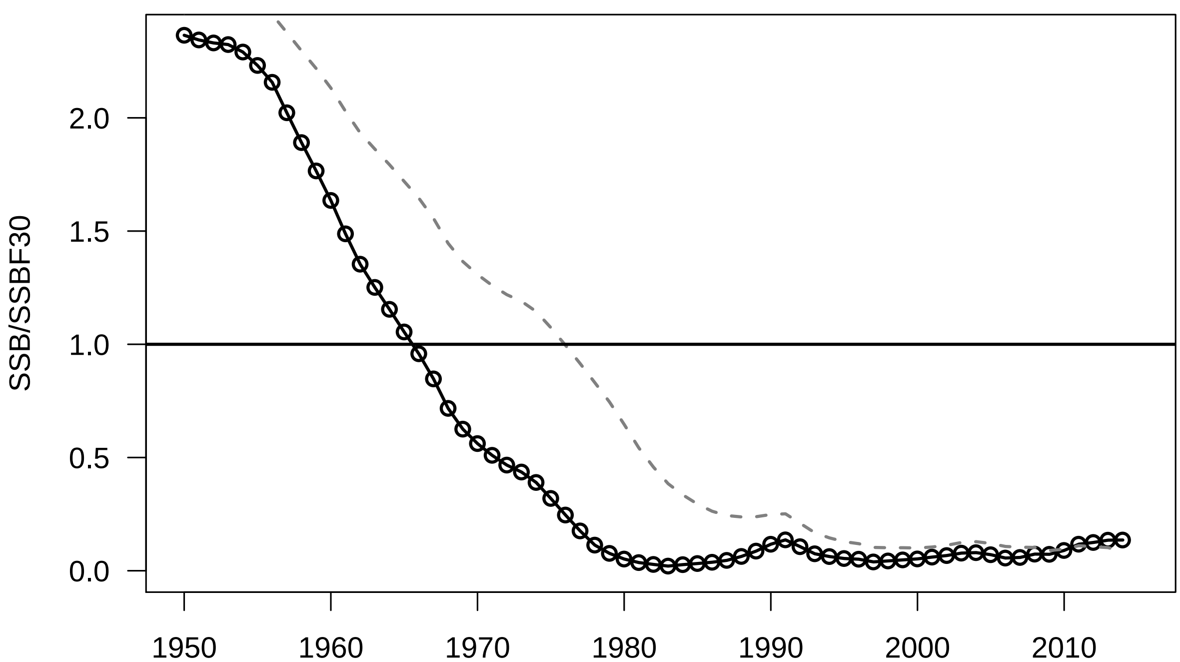
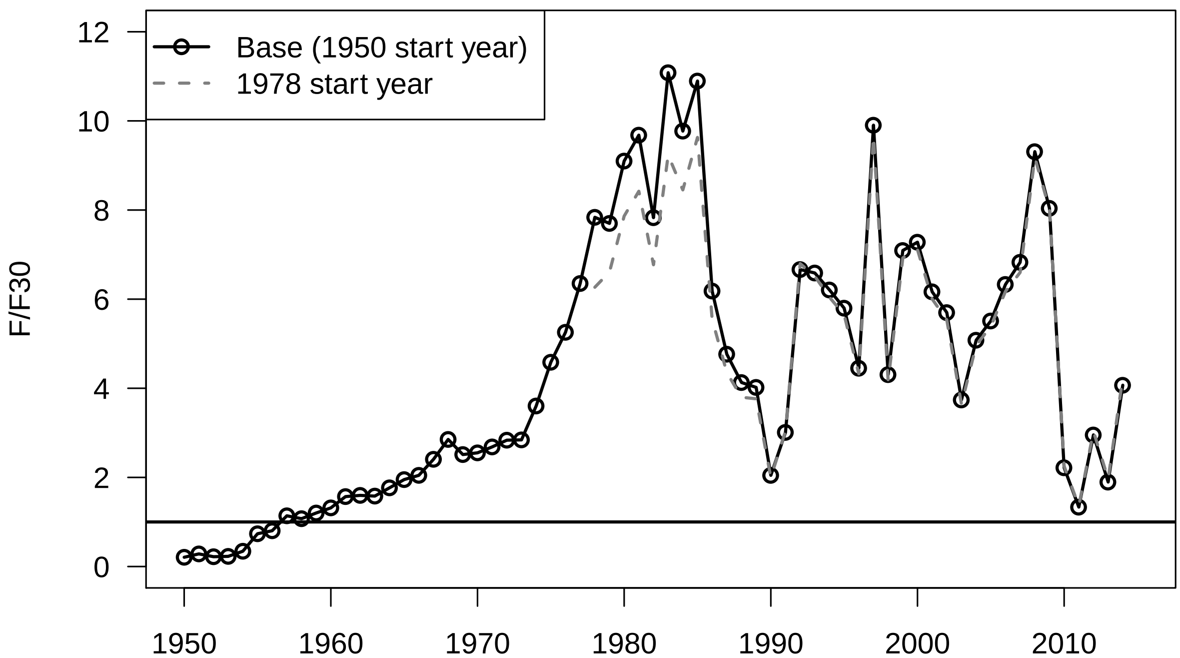


Figure 42. Sensitivity to start year (1978 compared to 1950) (sensitivity run S26). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.



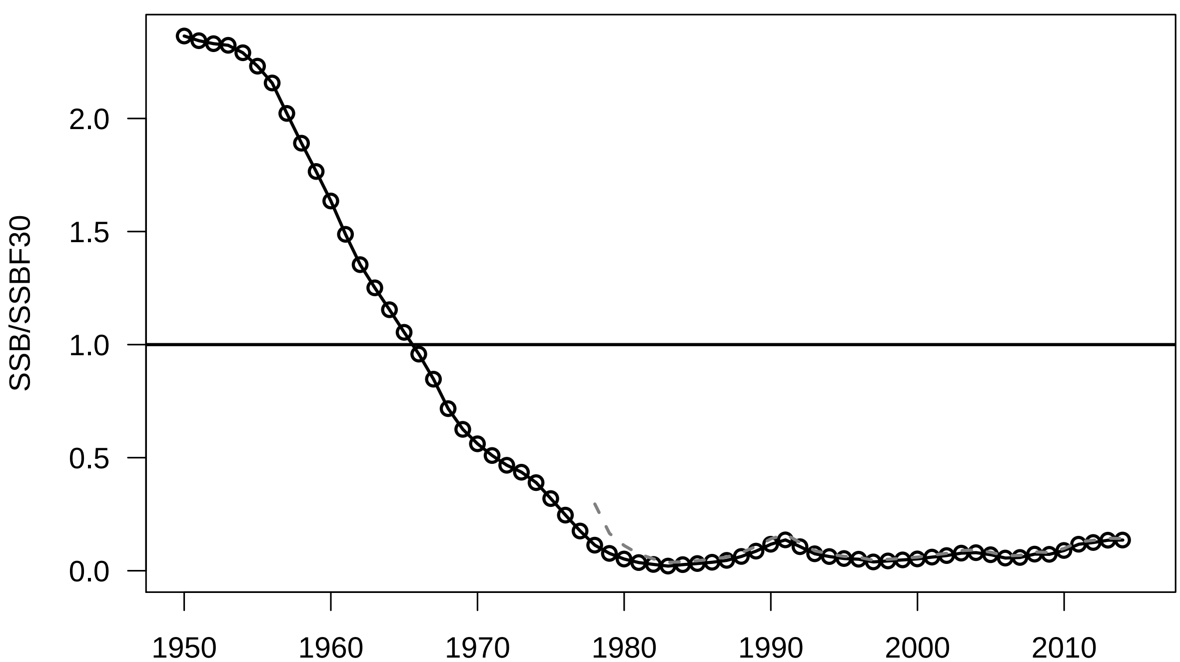


Figure 43. Sensitivity to aging error matrix (sensitivity run S13). Top panel: Ratio of F to $F_{30\%}$. *Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{F30\%}$.

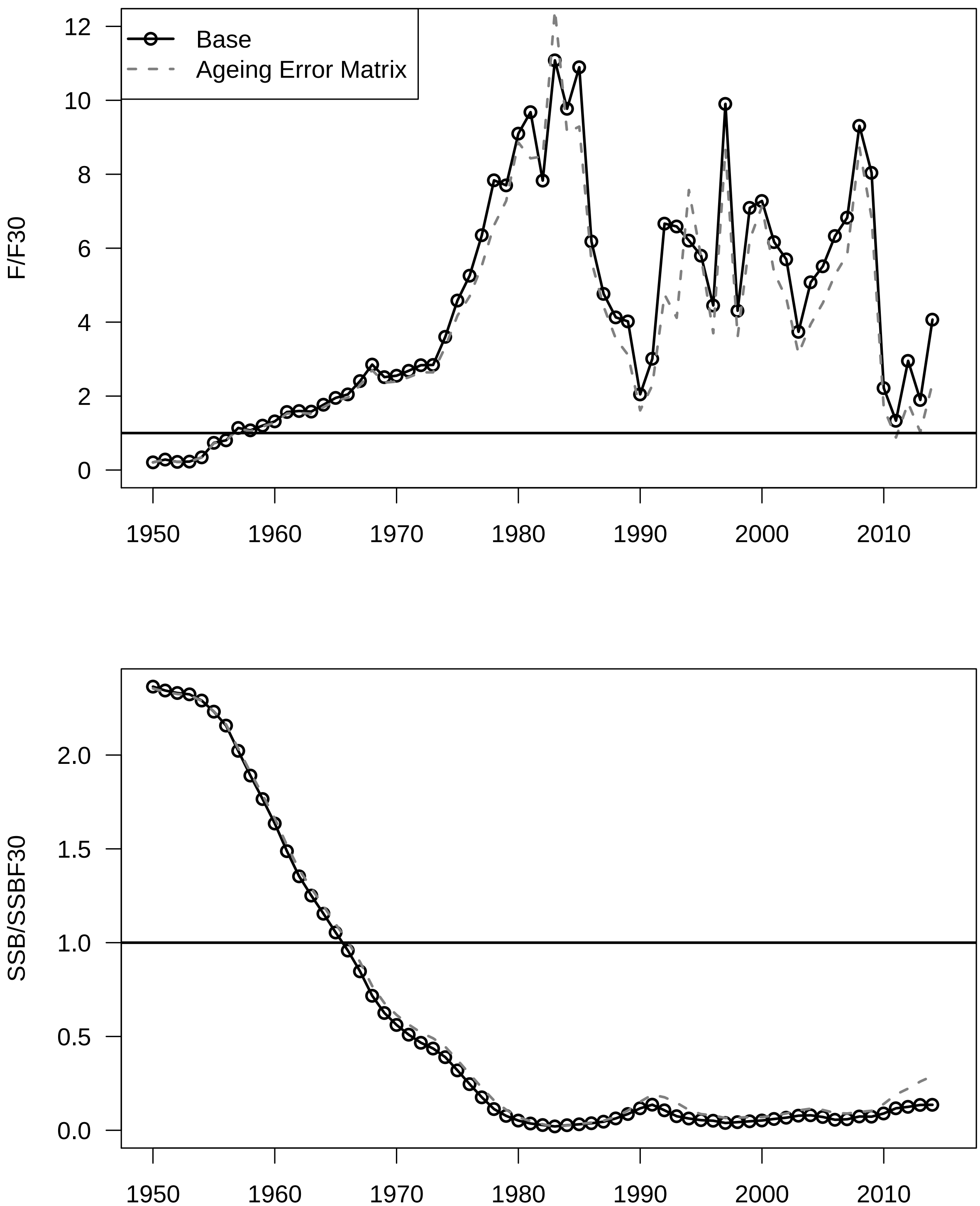
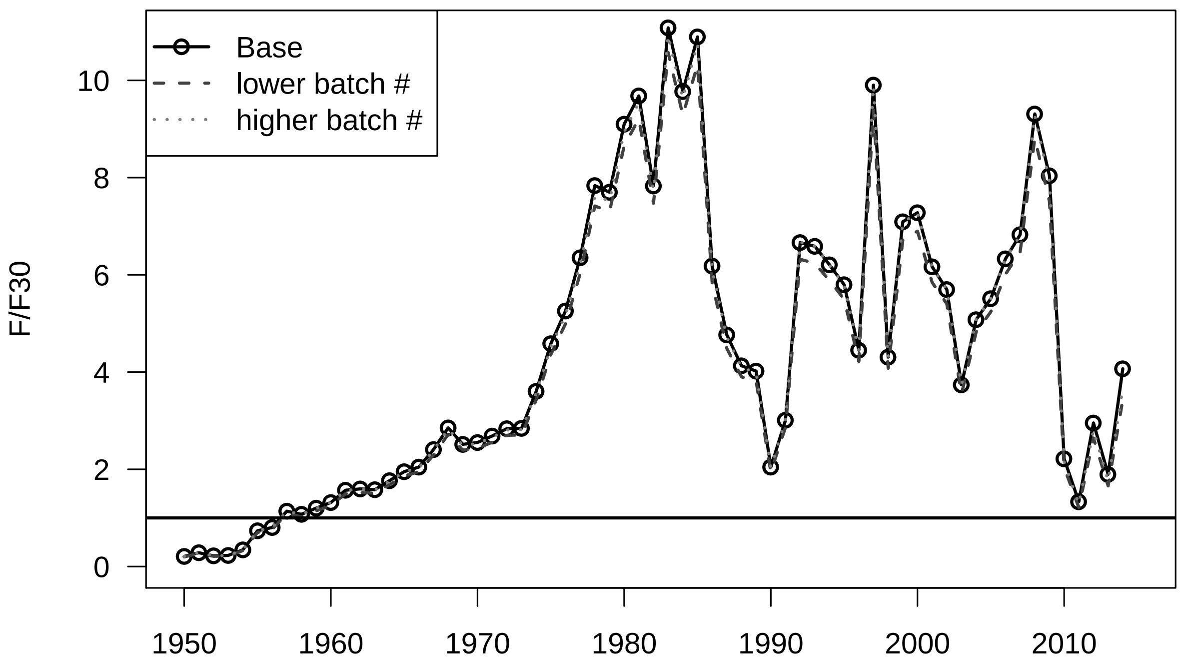


Figure 44. Sensitivity to batch number (sensitivity runs S14 and S15). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.



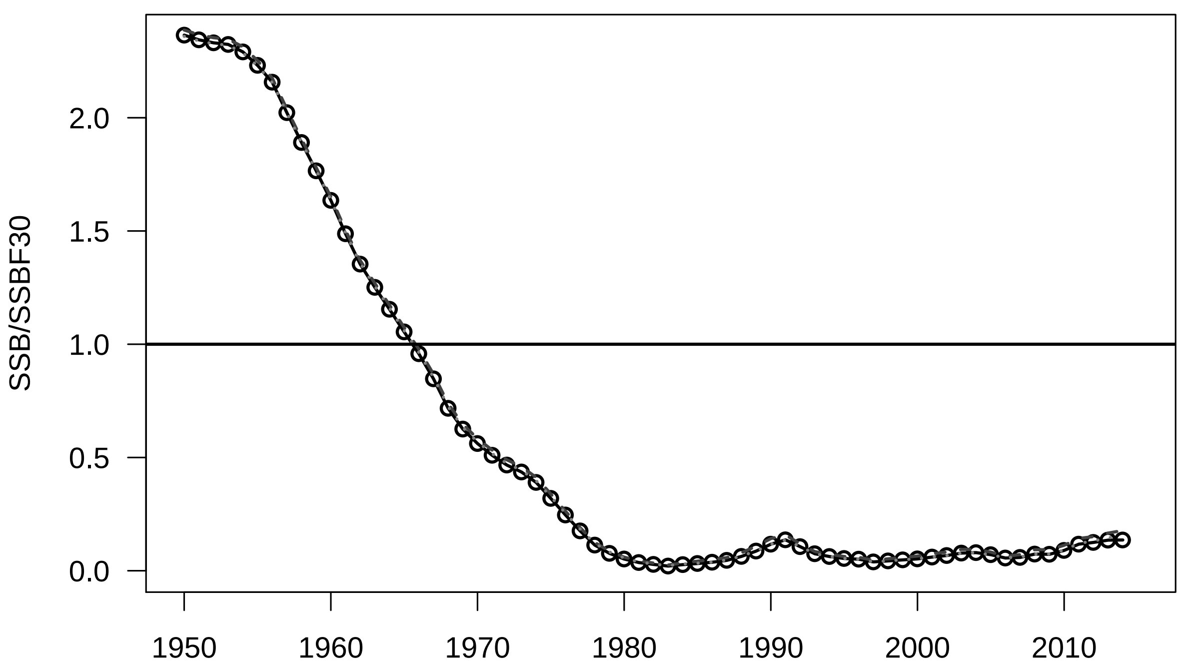
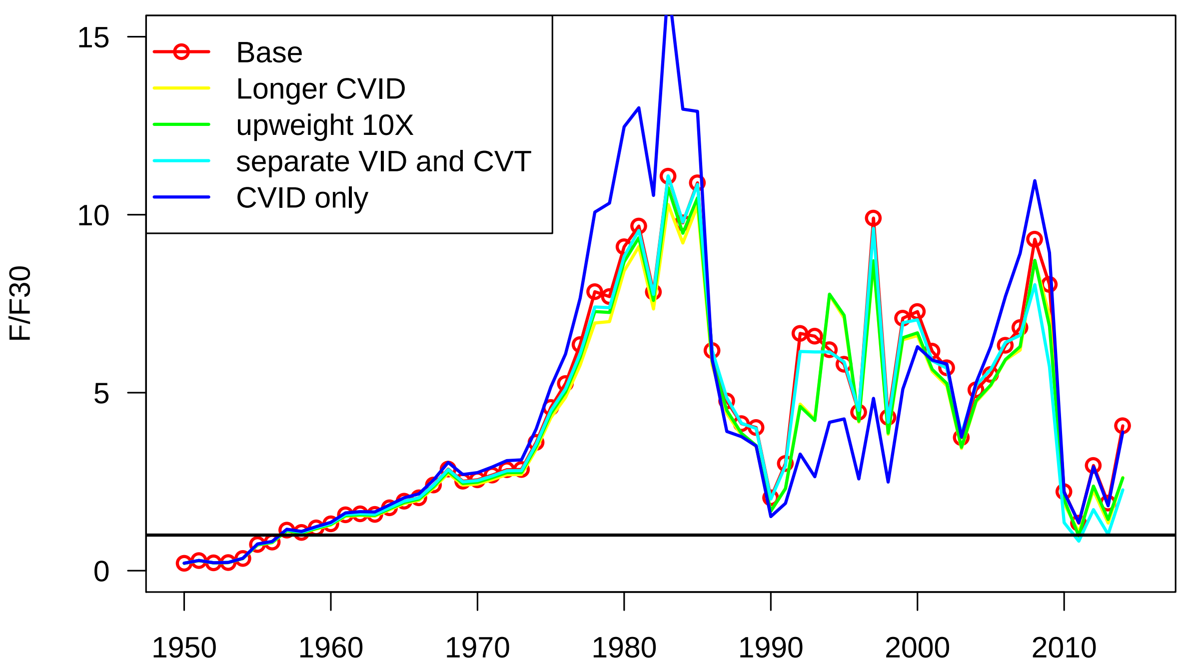


Figure 45. Sensitivity to various changes to SERFS video and trap indices (sensitivity runs S2, S9, S22 and S23). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.



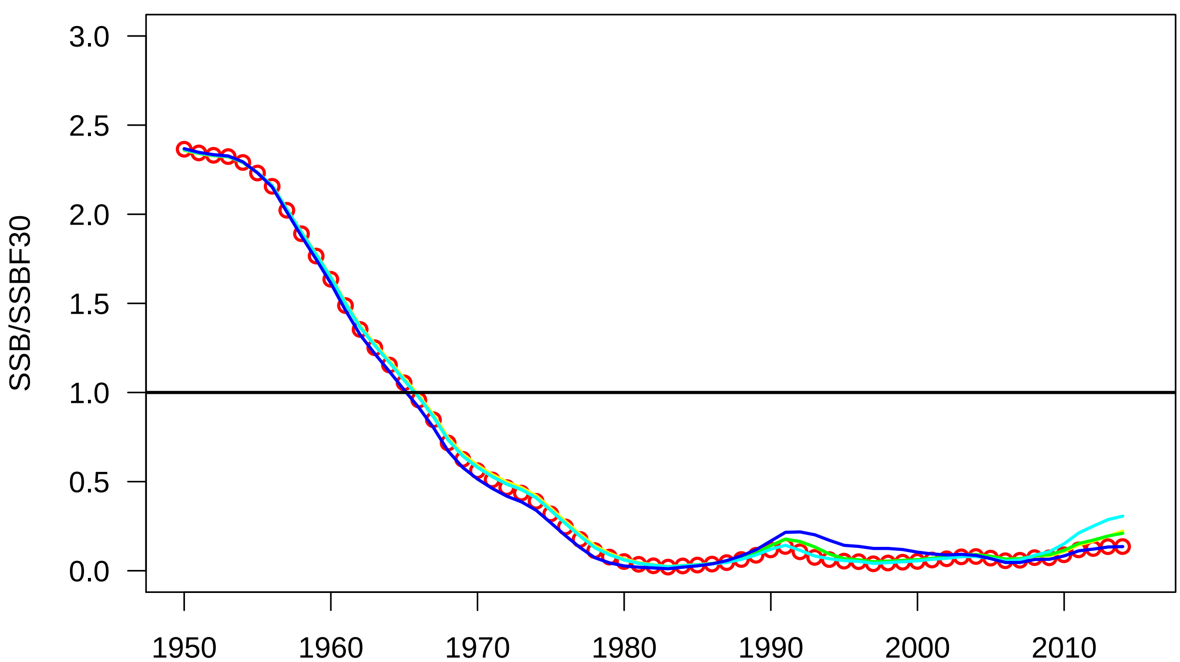


Figure 46. Sensitivity to discard mortality (sensitivity run S7 and S8). Top panel: Ratio of F to $F_{30\%}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{F30\%}$.

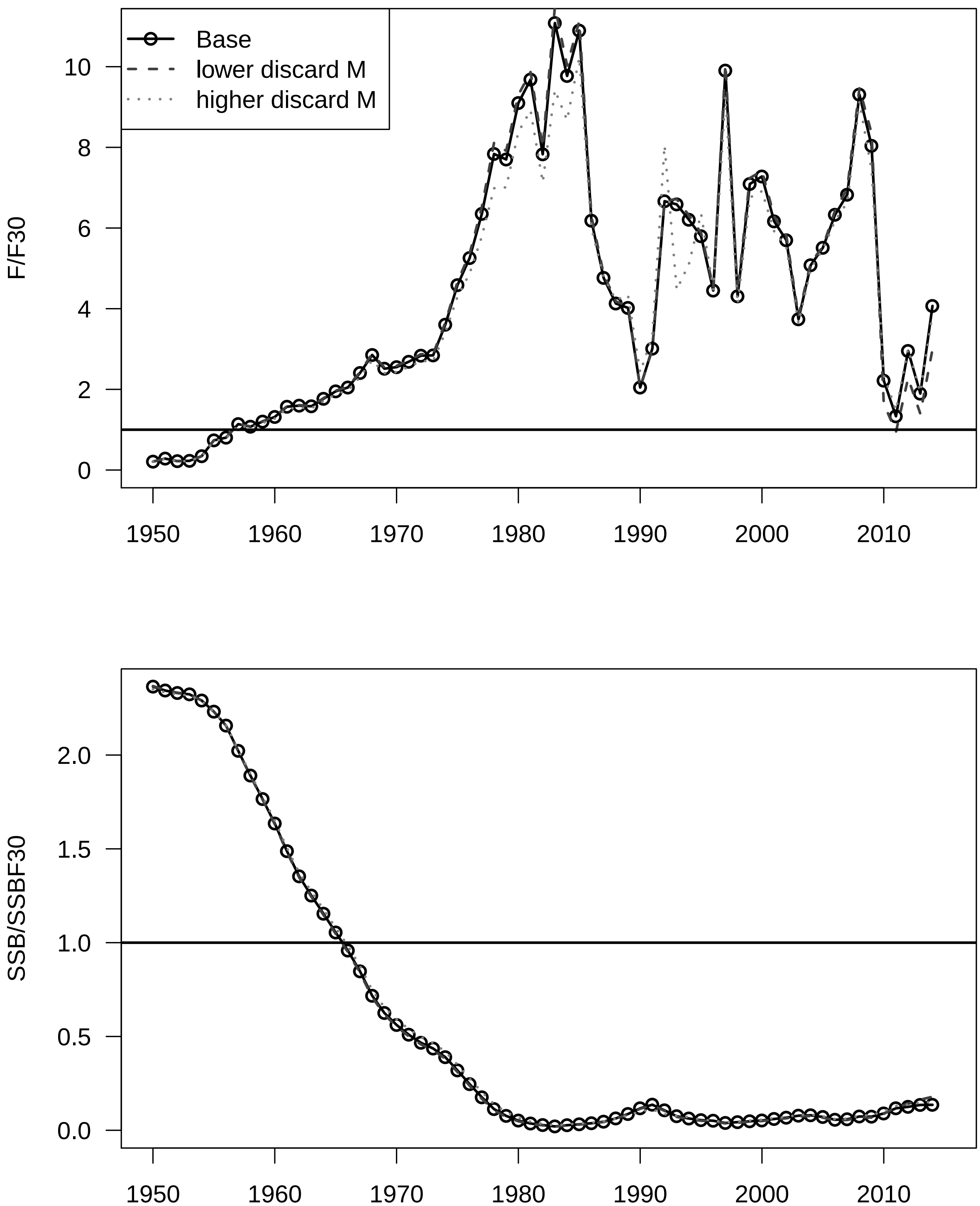


Figure 47. Sensitivity to dome-shaped selectivity for commercial handline (sensitivity run S21). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

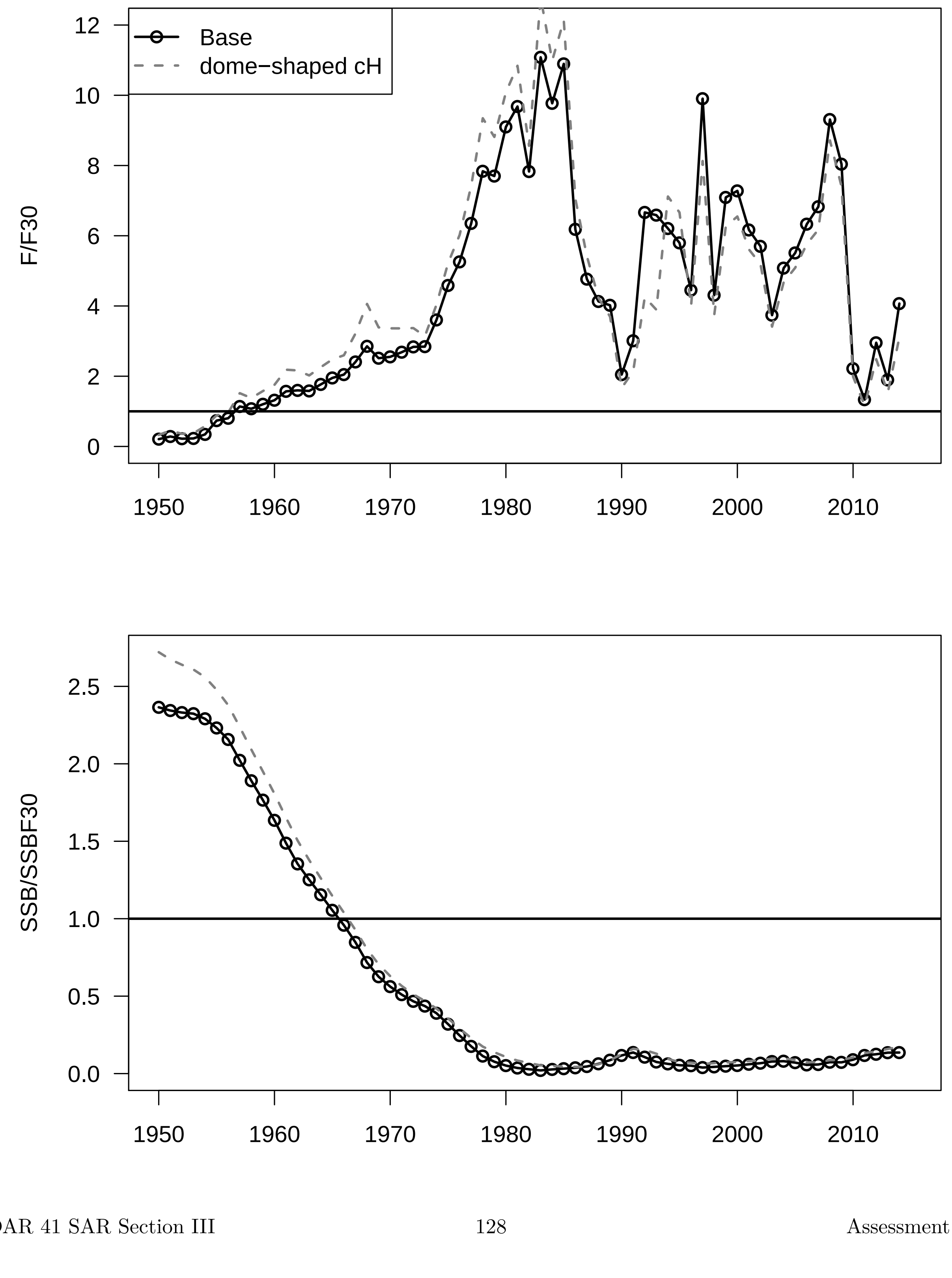


Figure 48. Sensitivity to various changes to fishery dependent indices (sensitivity runs S1, S3, S4, and S25). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

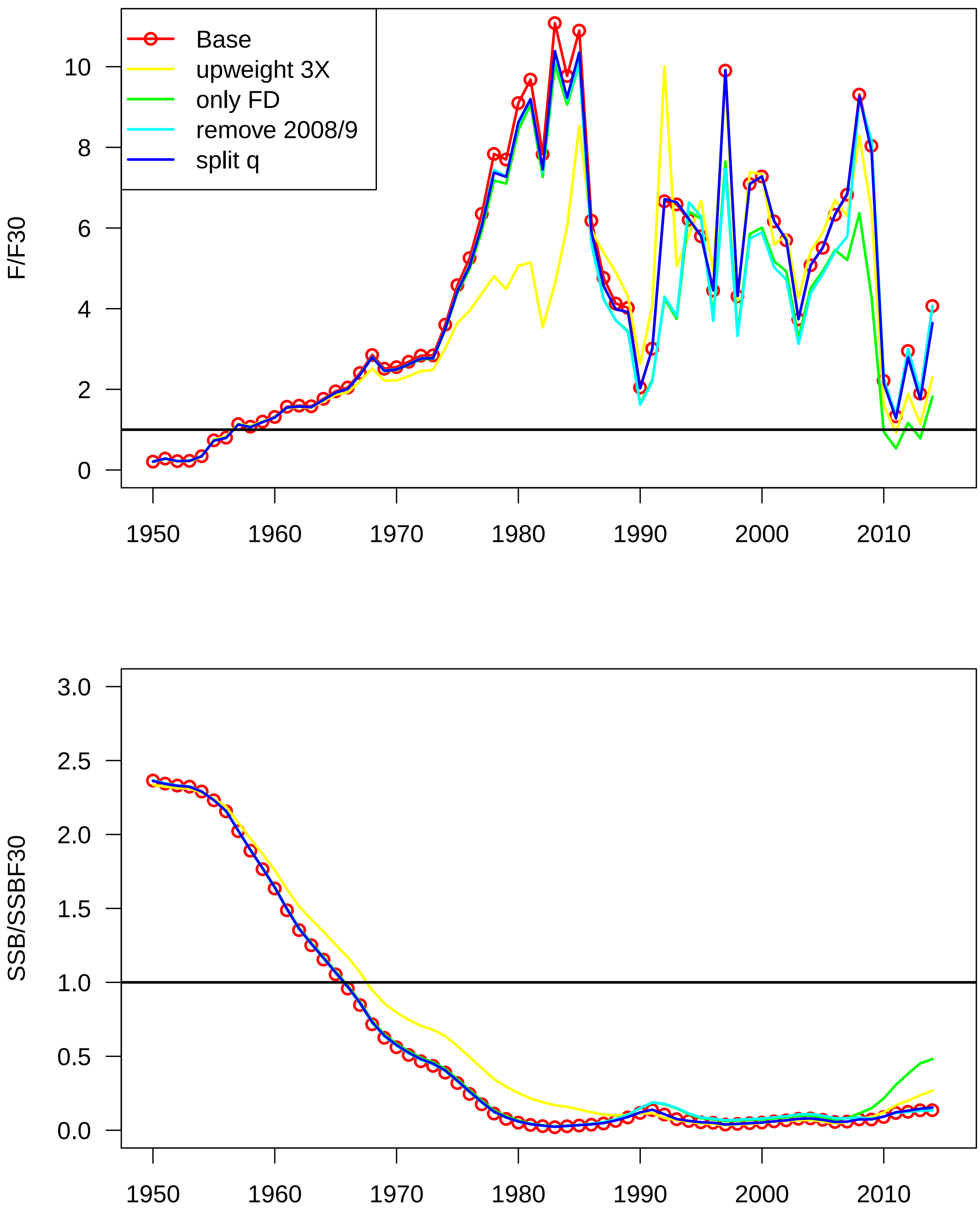


Figure 49. Sensitivity to not fixing selectivities (sensitivity run S27). Top panel: Ratio of F to $F_{30\%}$. *Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

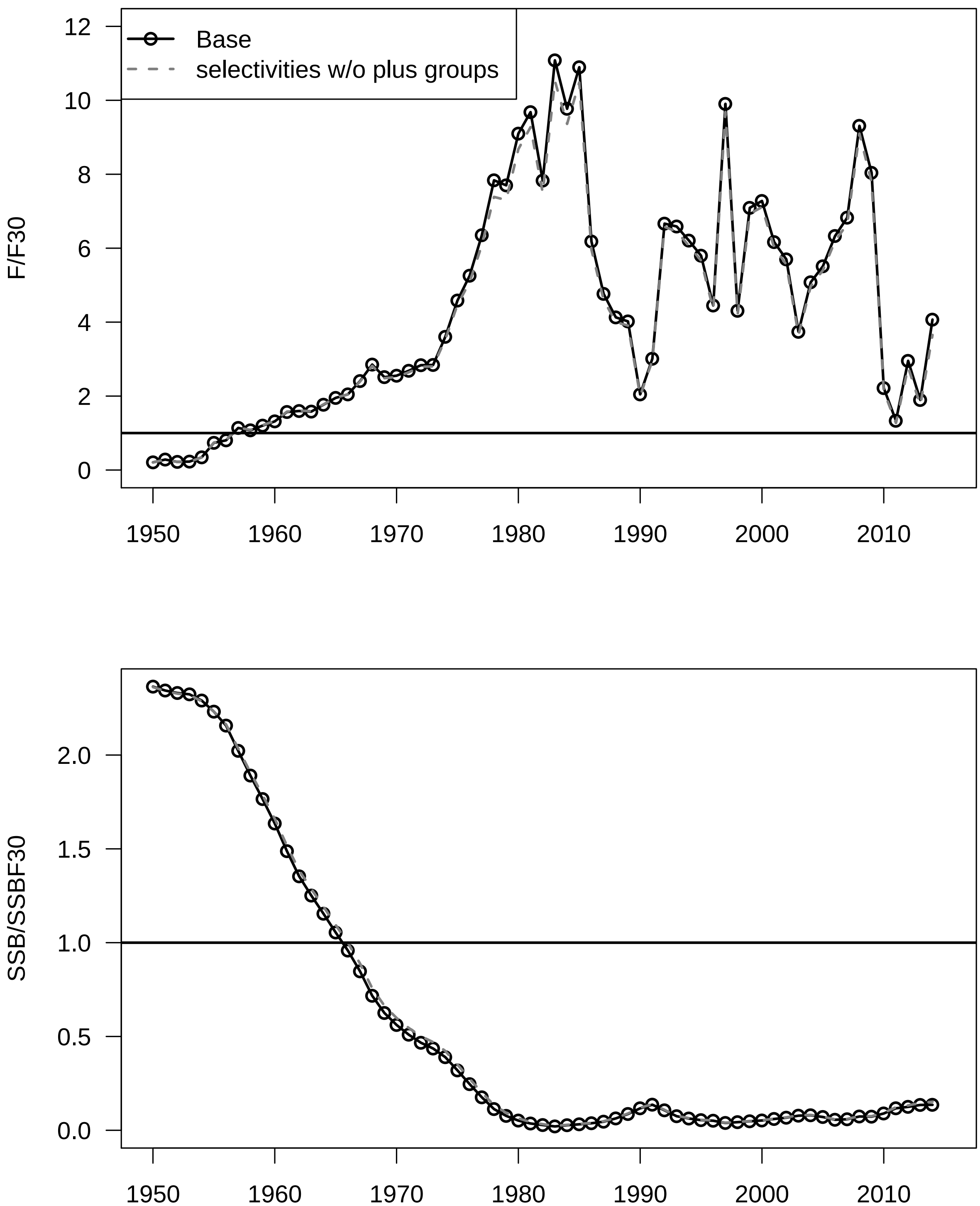


Figure 50. Sensitivity to dropping or truncating headboat discard index (sensitivity runs S12 and S16). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

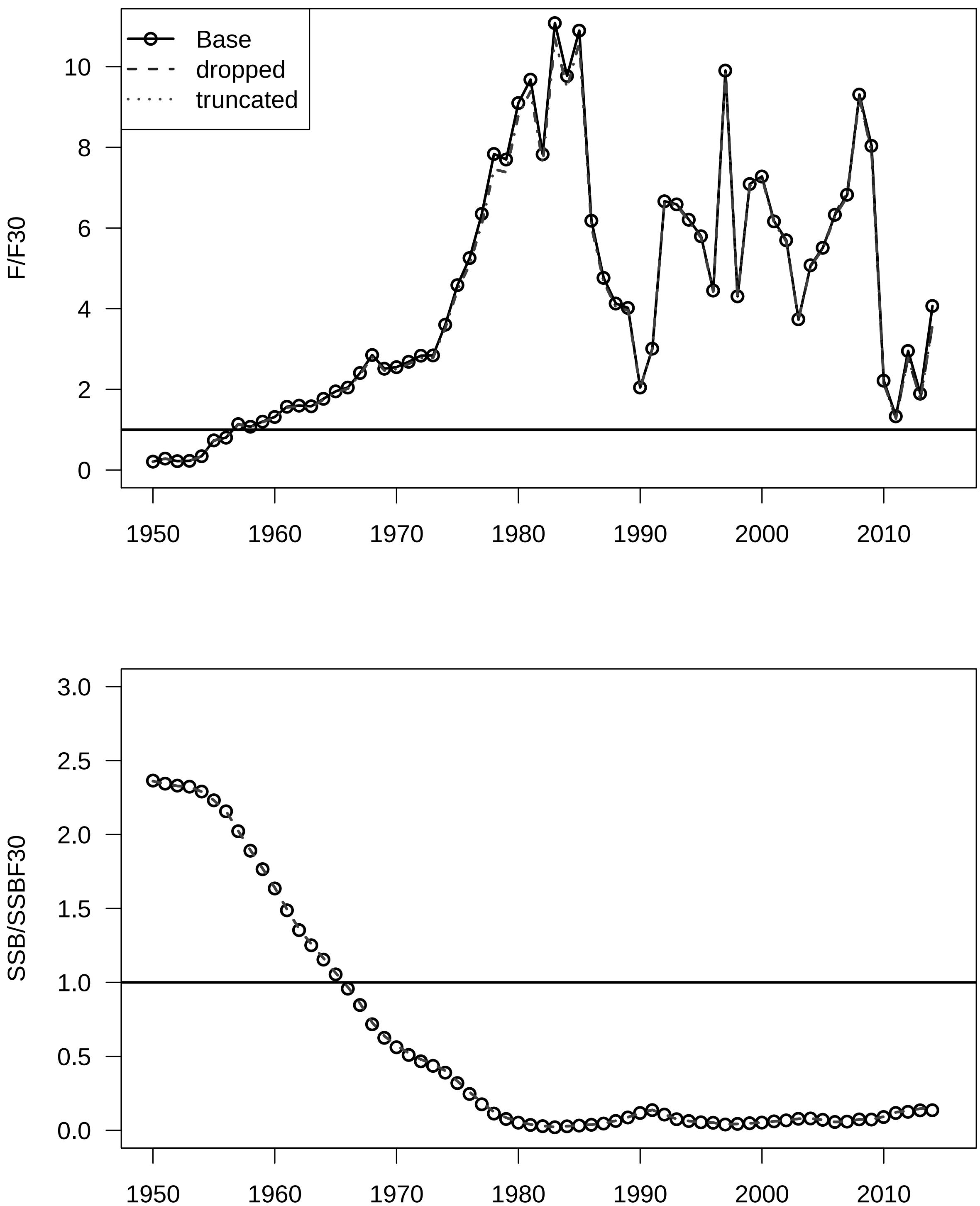
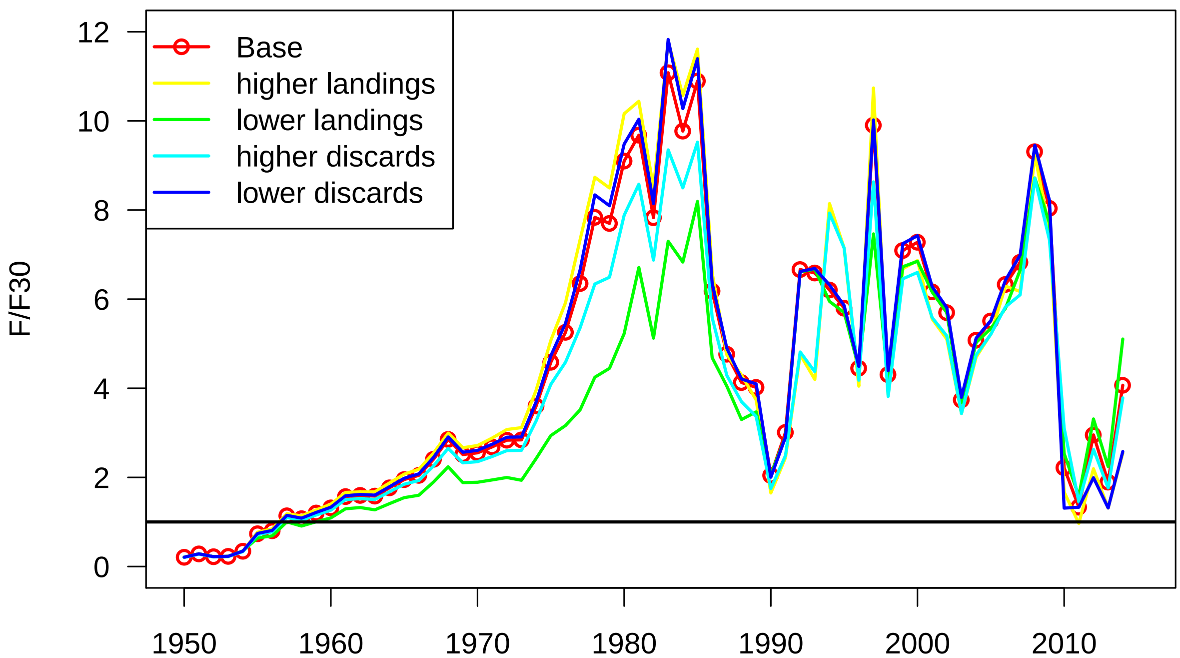


Figure 51. Sensitivity to higher or lower estimates of landings and discards (sensitivity runs S17–S20). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB_{F30\%}}$.



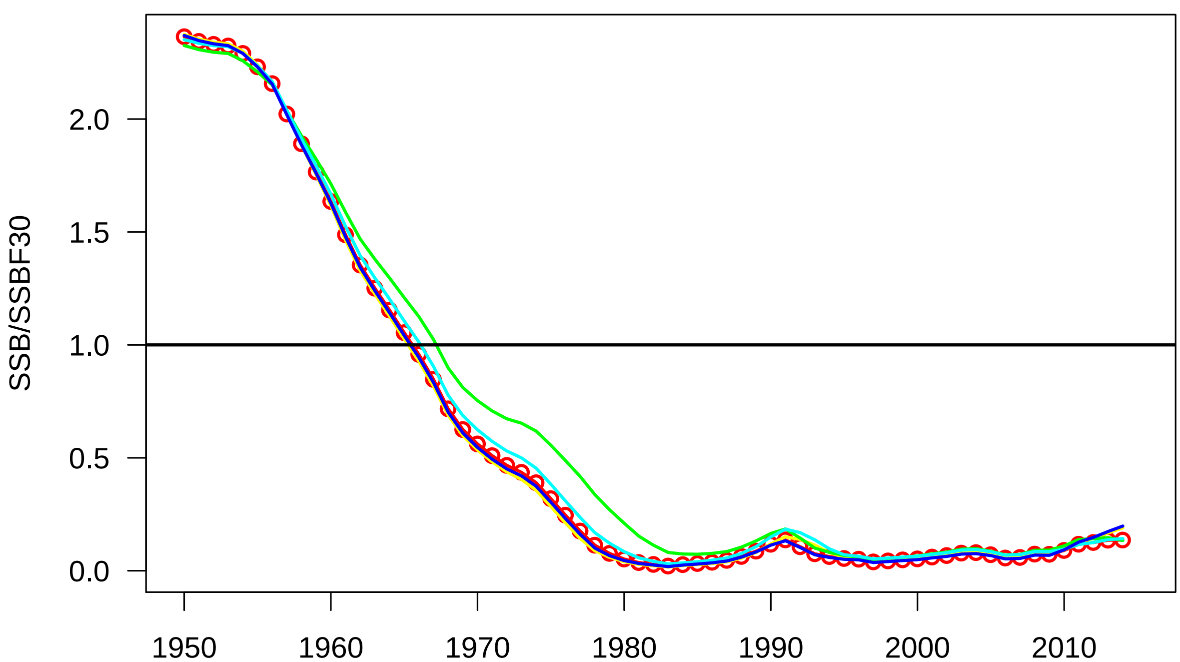


Figure 52. Sensitivity to smoothed 1984 and 1985 MRIP landings (sensitivity run S10). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F}30\%}$.

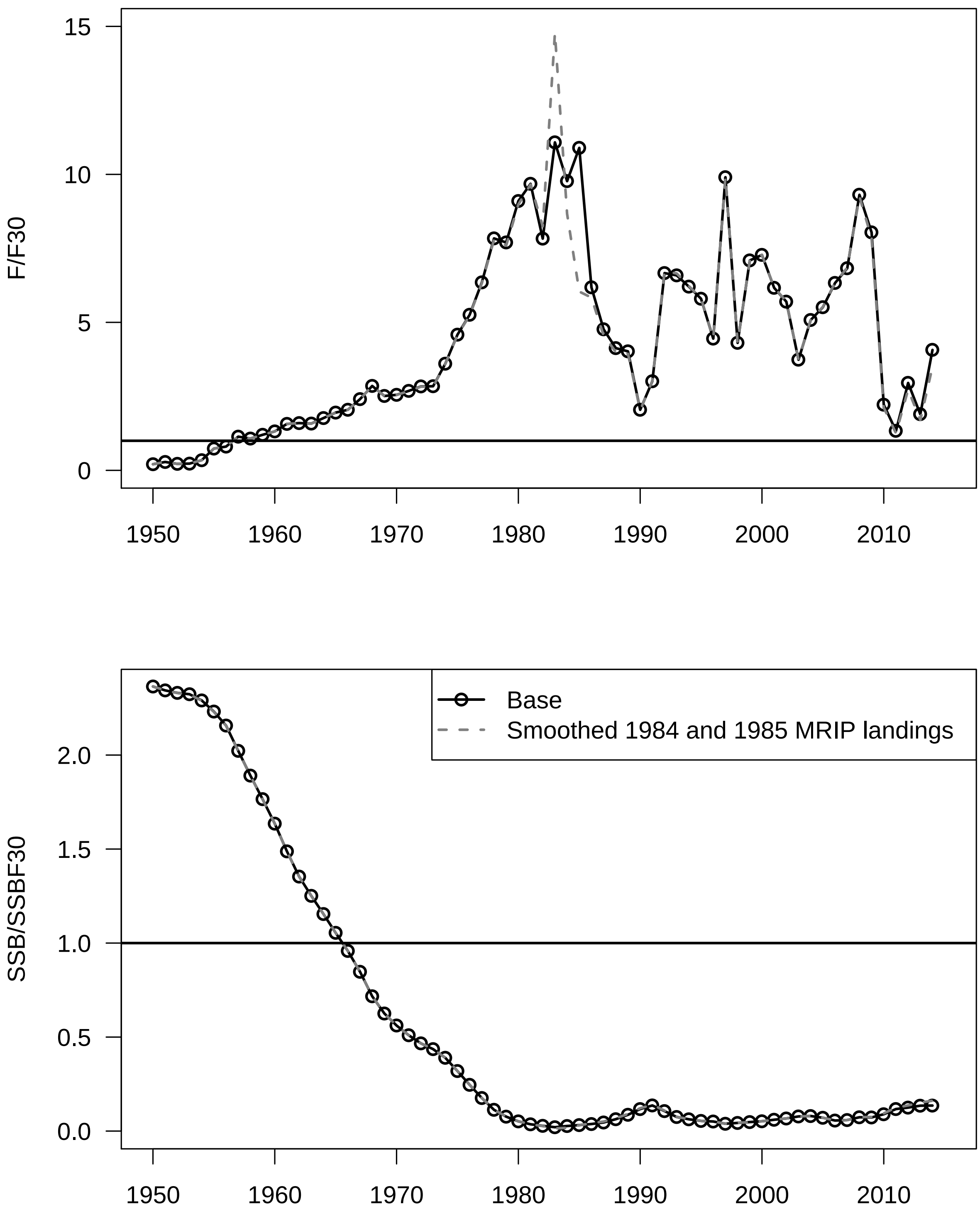


Figure 53. Sensitivity to continuity assumptions from SEDAR 24 (sensitivity run S24). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

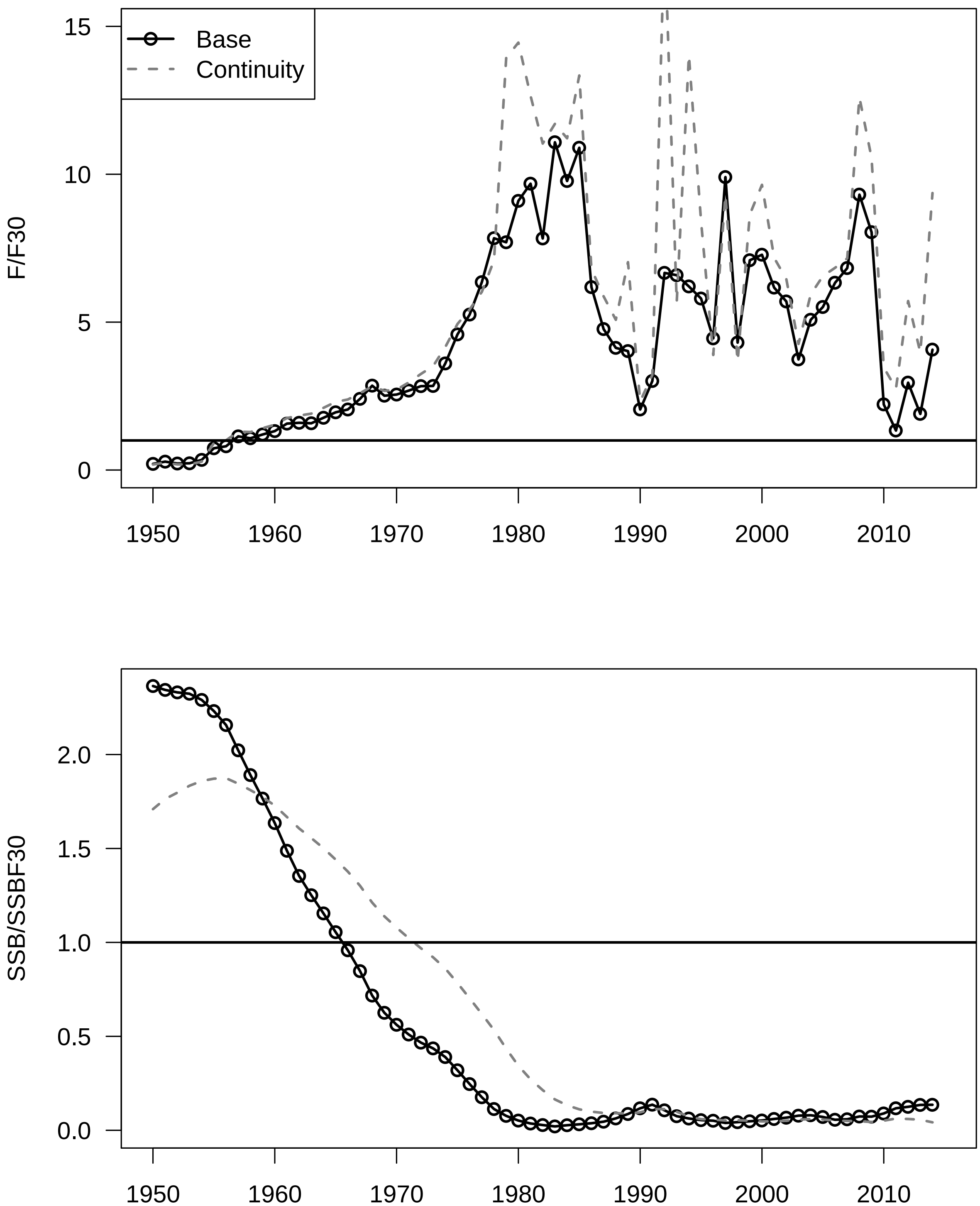


Figure 54. Phase plot of terminal status indicators from sensitivity runs of the Beaufort Assessment Model.

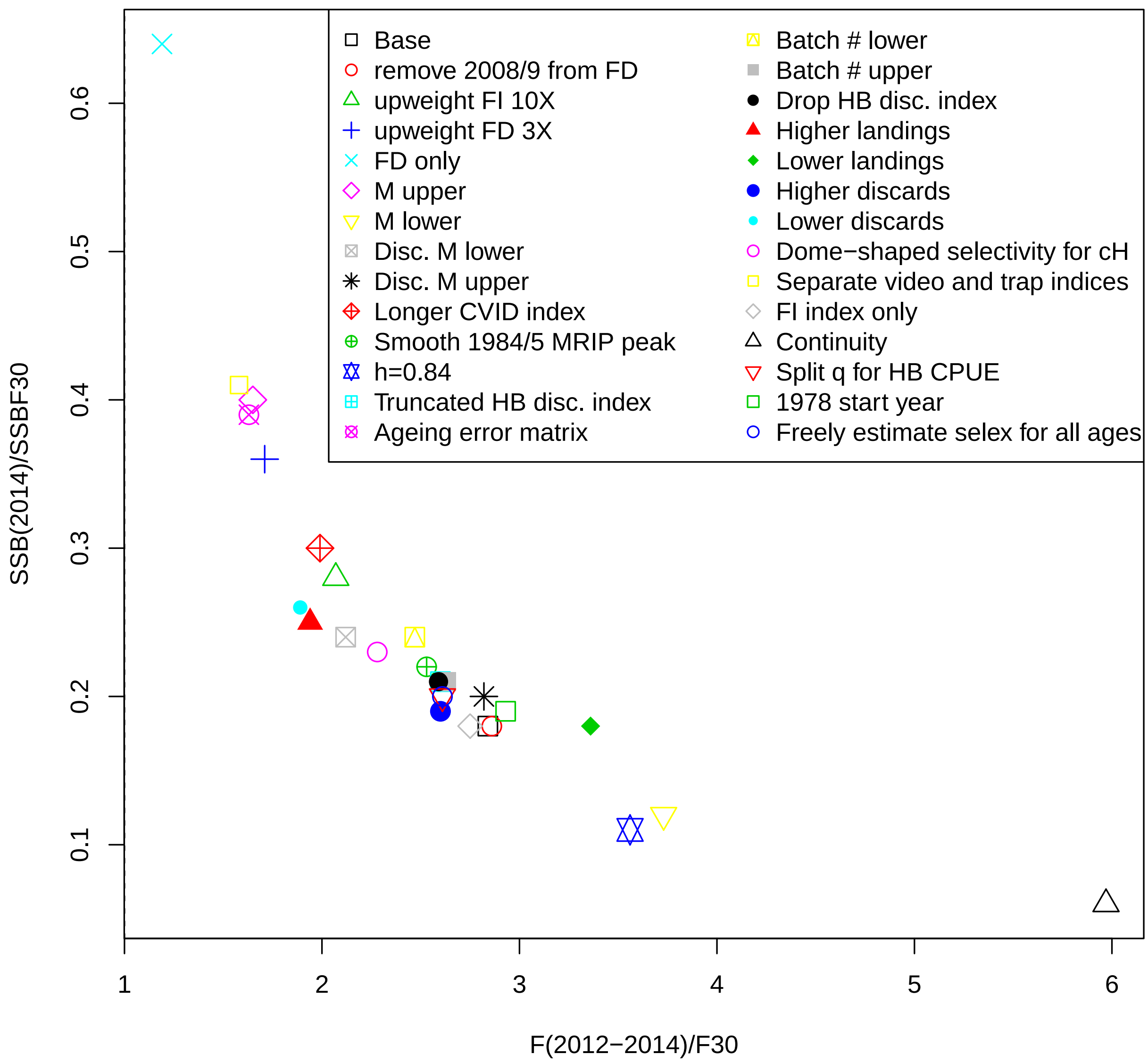


Figure 55. Retrospective analyses. Sensitivity to terminal year of data. Top panel: Fishing mortality rates. Middle panel: Recruits. Bottom panel: Spawning biomass. Closed circles show terminal-year estimates. Imperceptible lines overlap results of the base run.

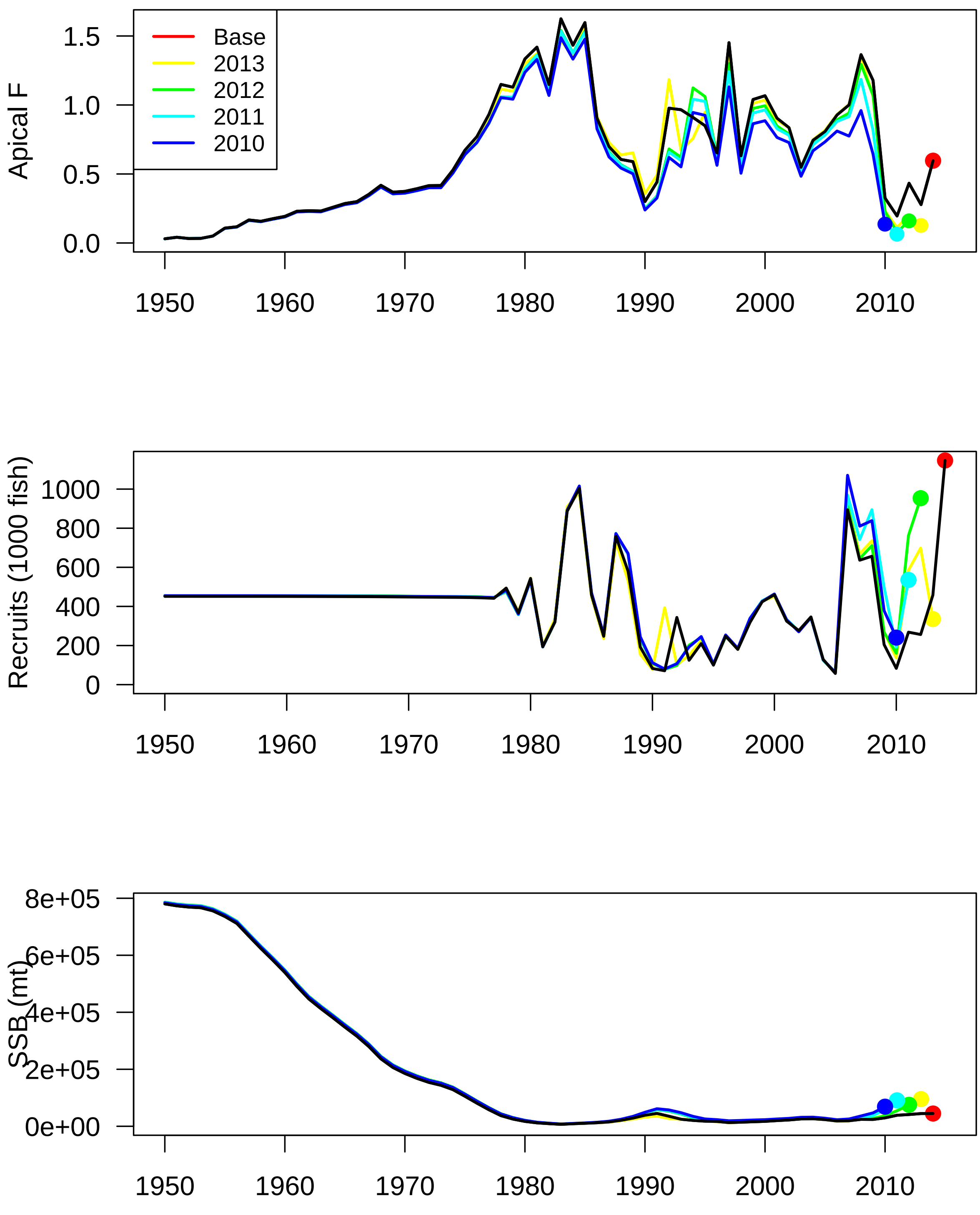


Figure 56. Projection results under scenario 1—fishing mortality rate at $F = 0$. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{F30\%}}$.

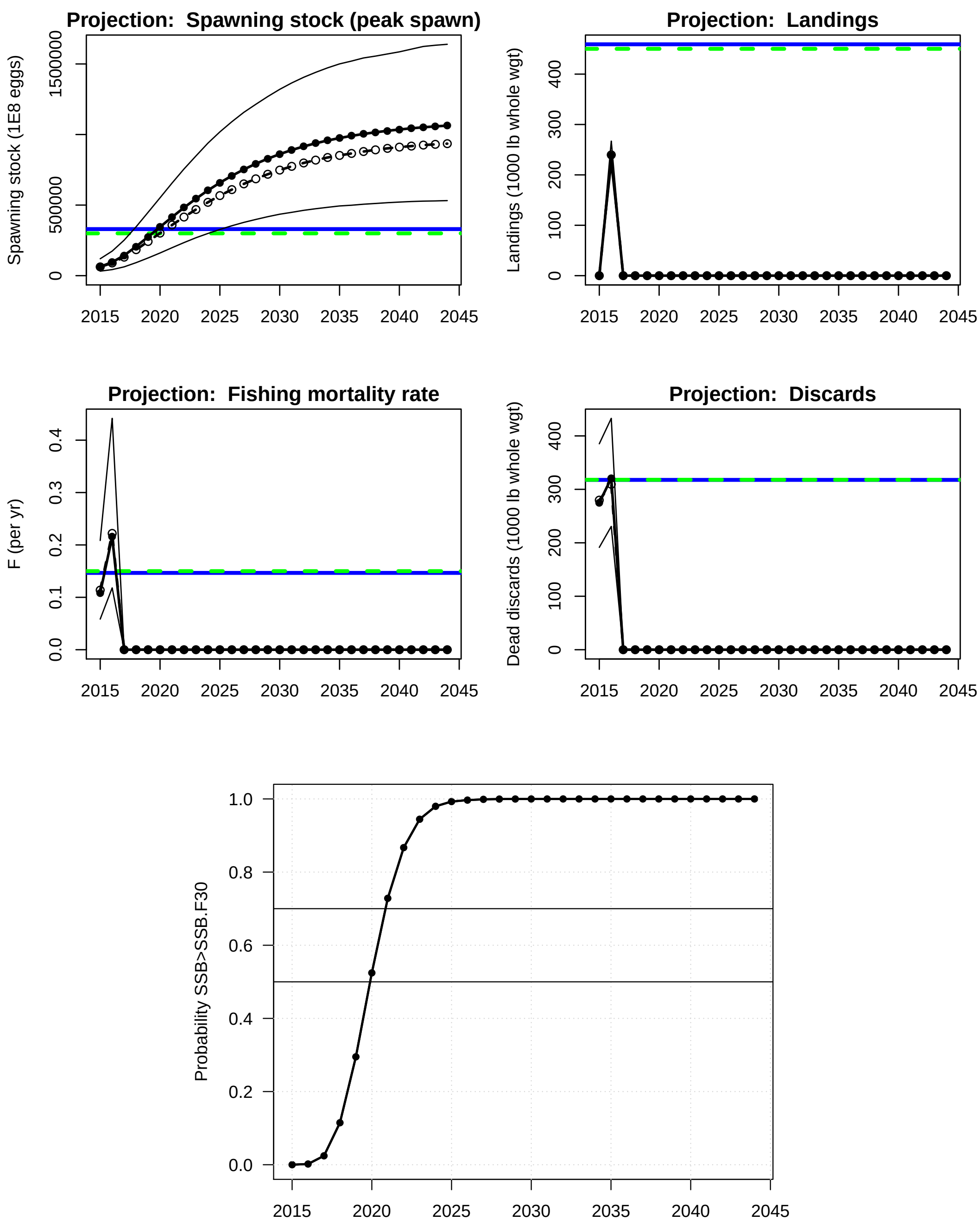


Figure 57. Projection results under scenario 2—fishing mortality rate at $F = F_{\mathrm{current}}$. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{F30\%}}$.

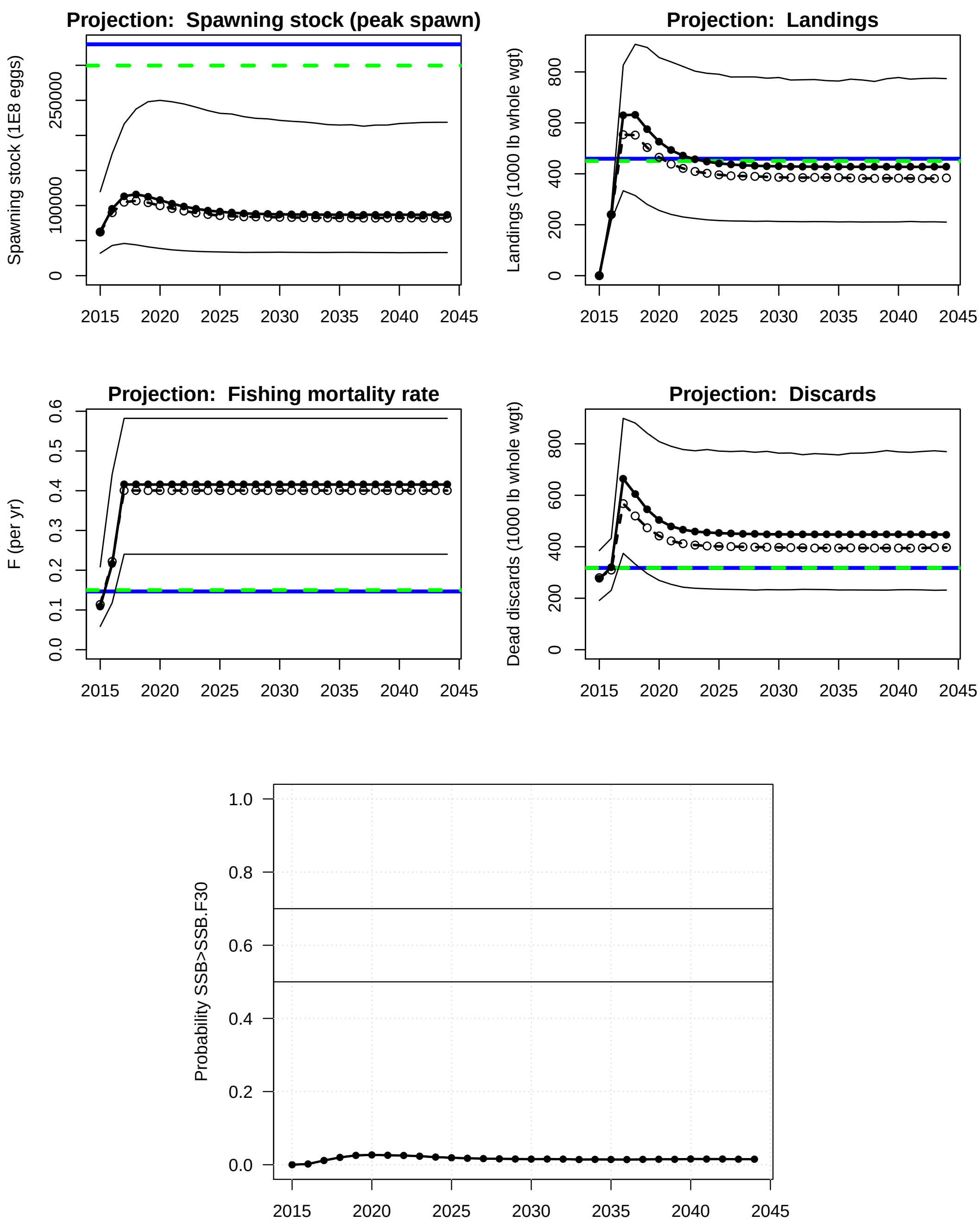


Figure 58. Projection results under scenario 3—fishing mortality rate at $F = F_{30\%}$. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{F30\%}}$.

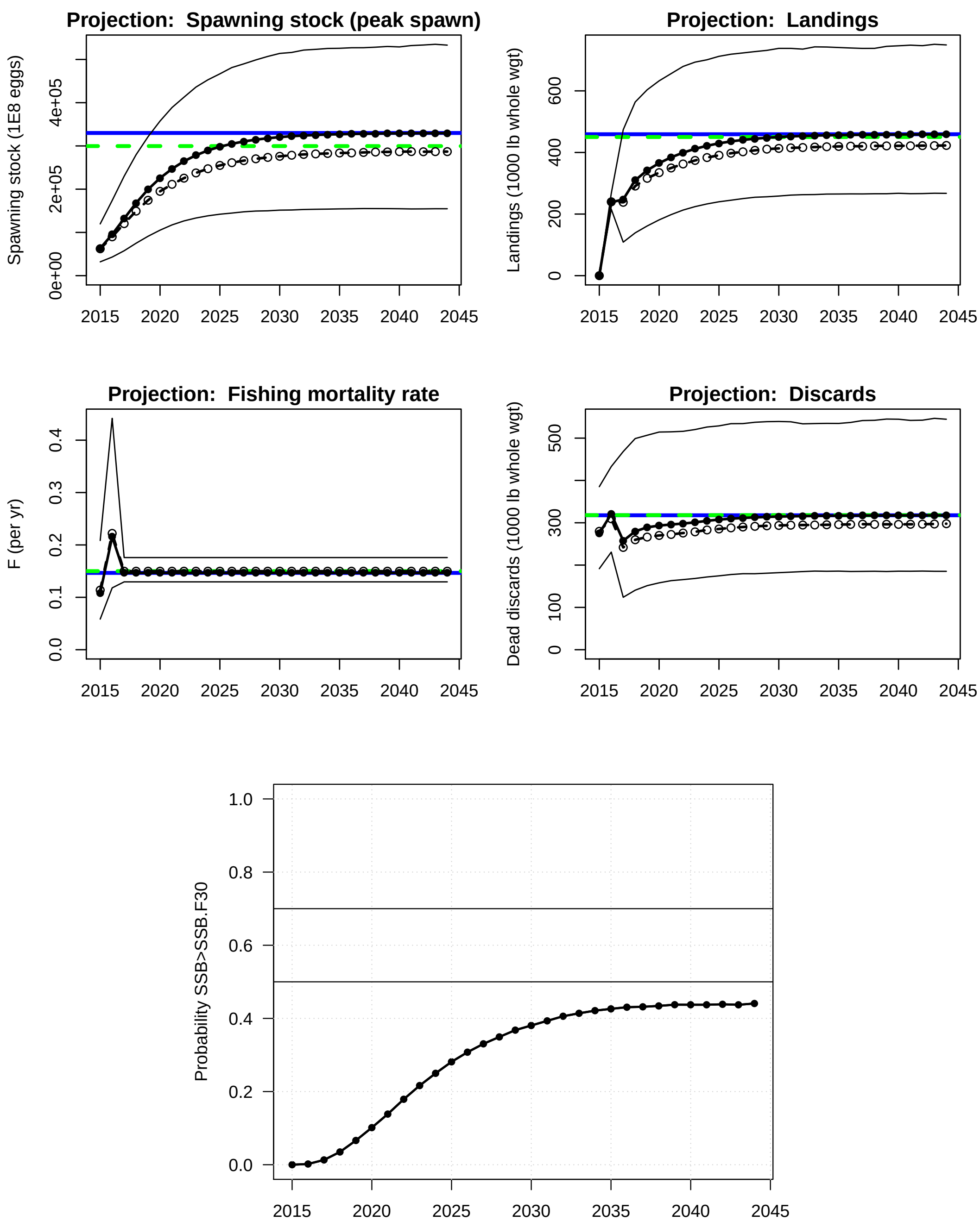


Figure 59. Projection results under scenario 4—fishing mortality rate at $F = 98\%F_{30\%}$*. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to* 5^{th} *and* 95^{th} *percentiles of replicate projections. Solid horizontal lines mark* $F_{30\%}$*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{F30\%}}$*.*

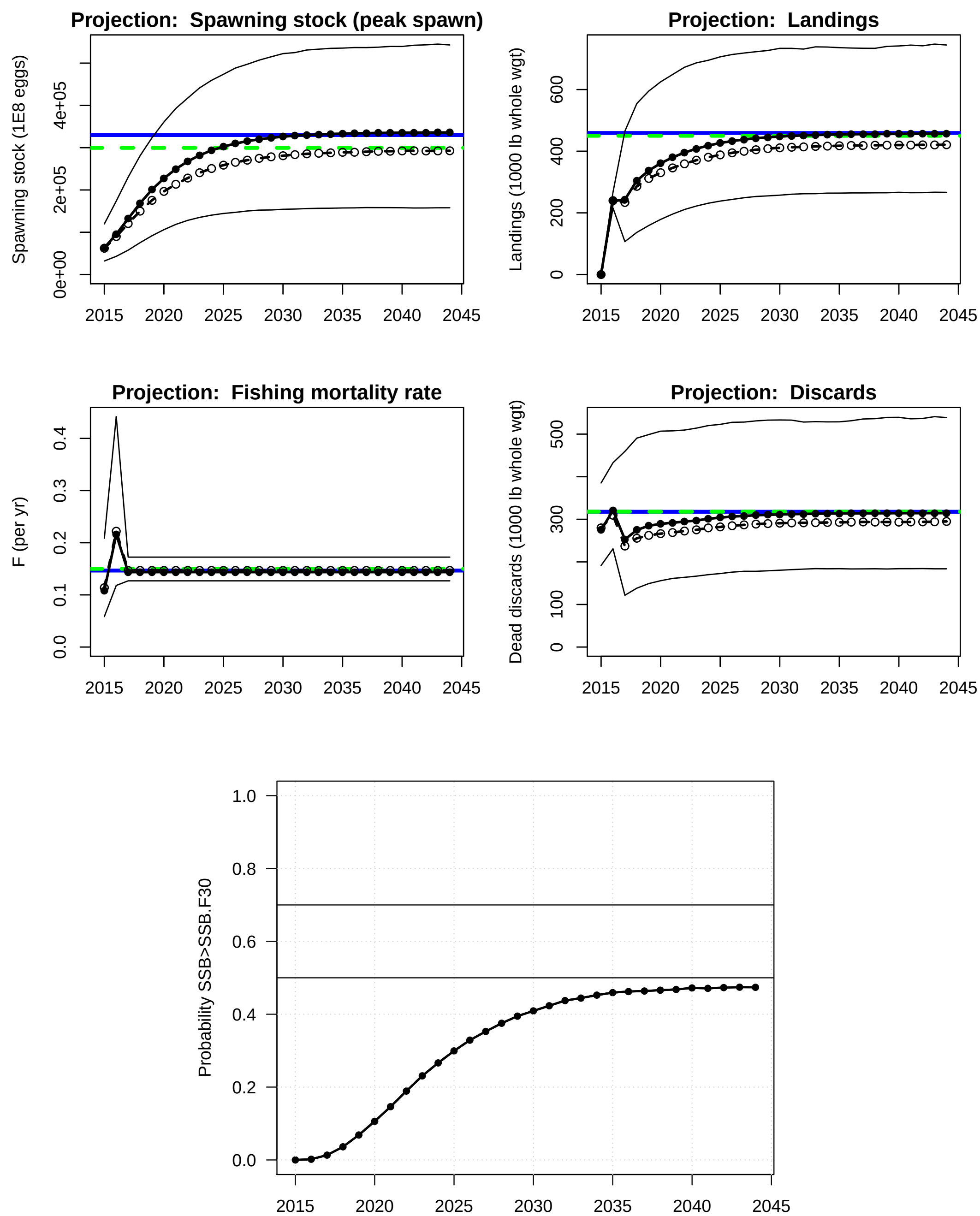


Figure 60. Projection results under scenario 5—fishing mortality rate at $F = F_{\mathrm{rebuild}}$, with rebuilding probability of 0.5 in 2044. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{F30\%}}$.

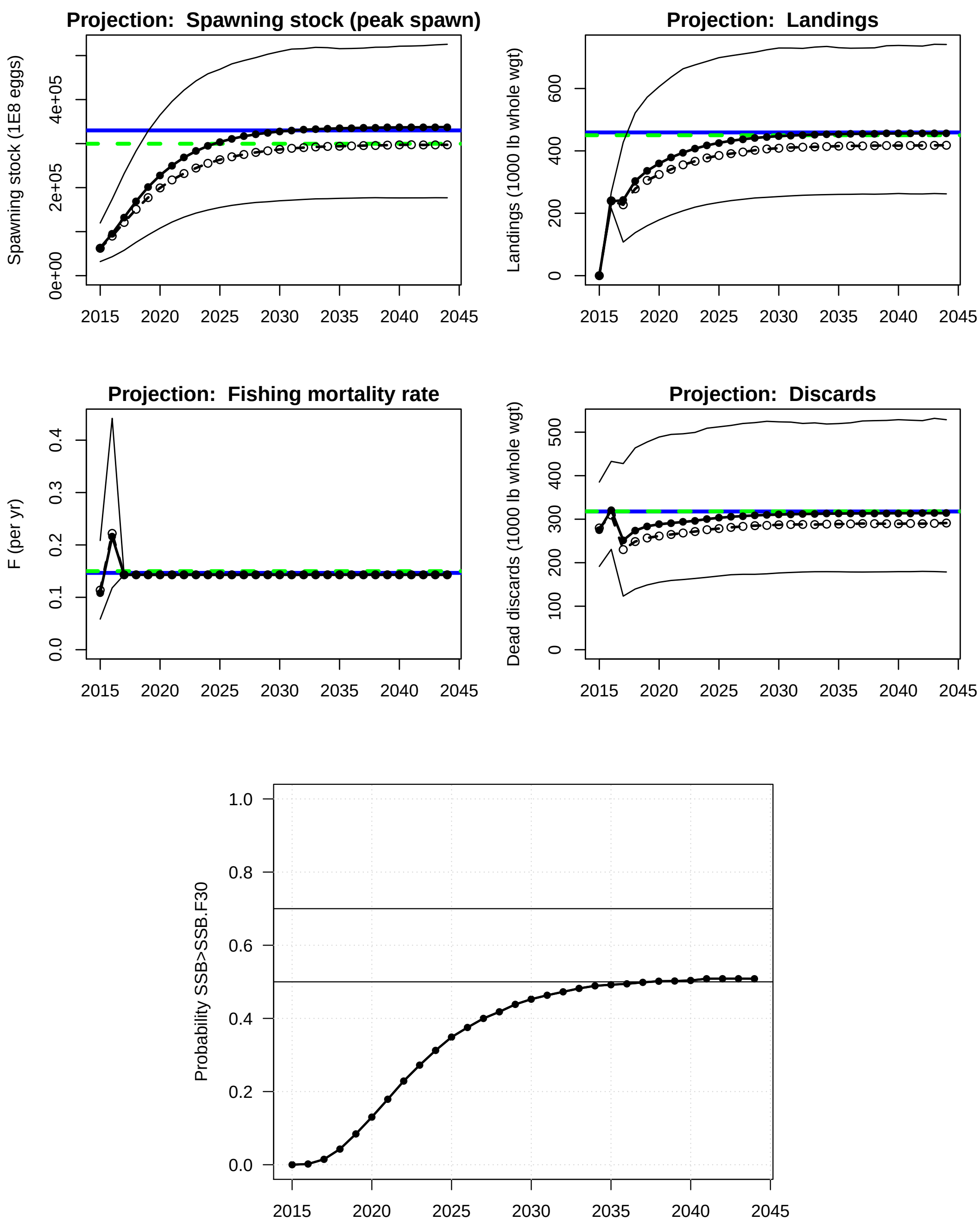


Figure 61. Projection results under scenario 6—fishing mortality rate set to average discard mortality rate only. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{F30\%}}$.

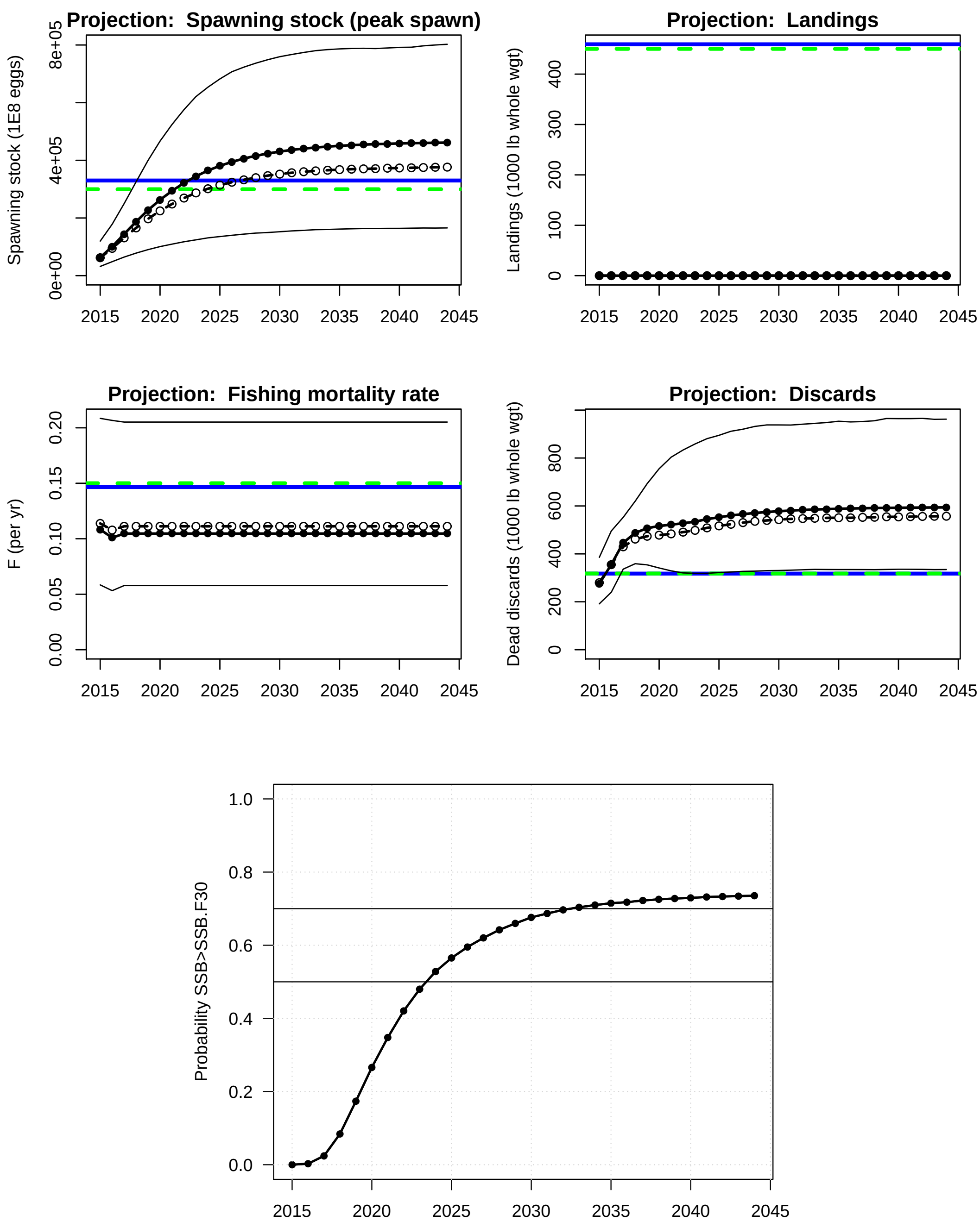


Figure 62. Abundance indices observed (obs.) and predicted (pred.) by the ASPIC surplus production model, and observed total removals (100,000 lbs) for South Atlantic red snapper. Comm = commercial, HB = headboat, HB.at.sea = headboat at sea discards, CVID = combined chevron trap-video index.

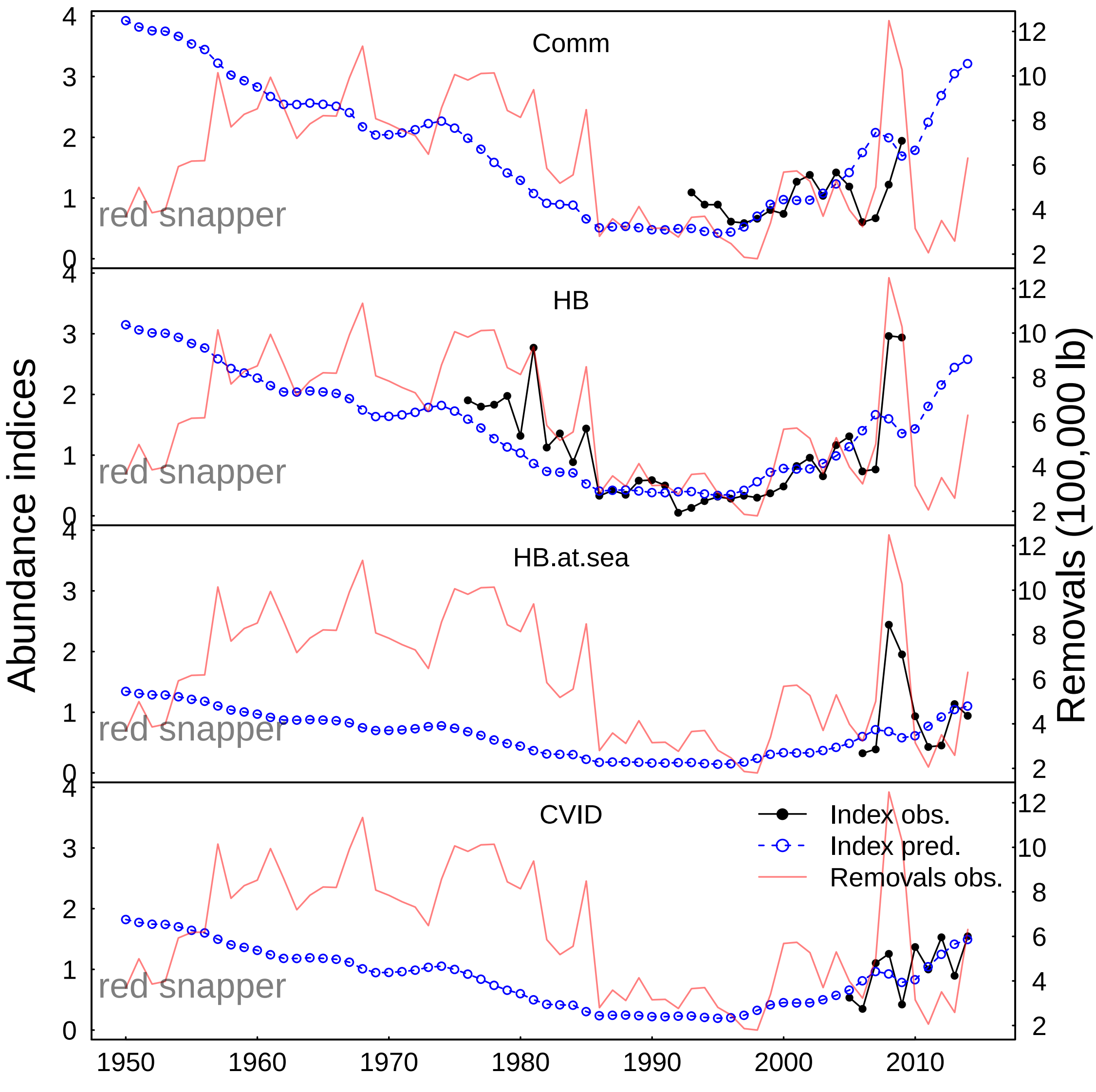


Figure 63. Prior distributions (blue shapes) and estimated parameter values (vertical black lines) for the South Atlantic red snapper ASPIC surplus production model.

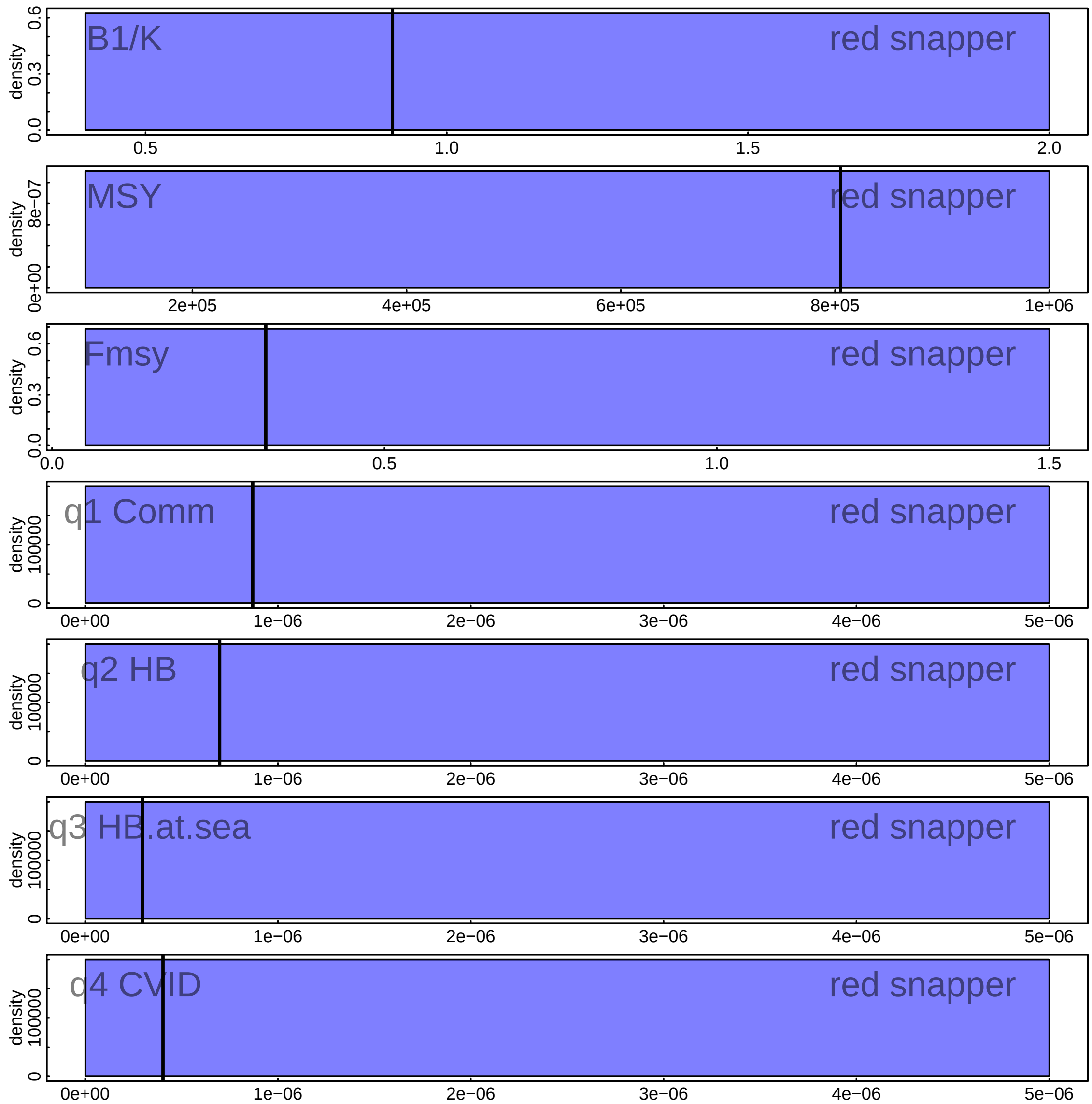


Figure 64. Bootstrap parameter values from ASPIC surplus production model run 320. Thick vertical lines represent ASPIC parameter estimates (solid) and 95% bootstrap percentile confidence intervals (dashed). Thin solid vertical lines are drawn at one in plots of F/F_{MSY} and B/B_{MSY} for reference.

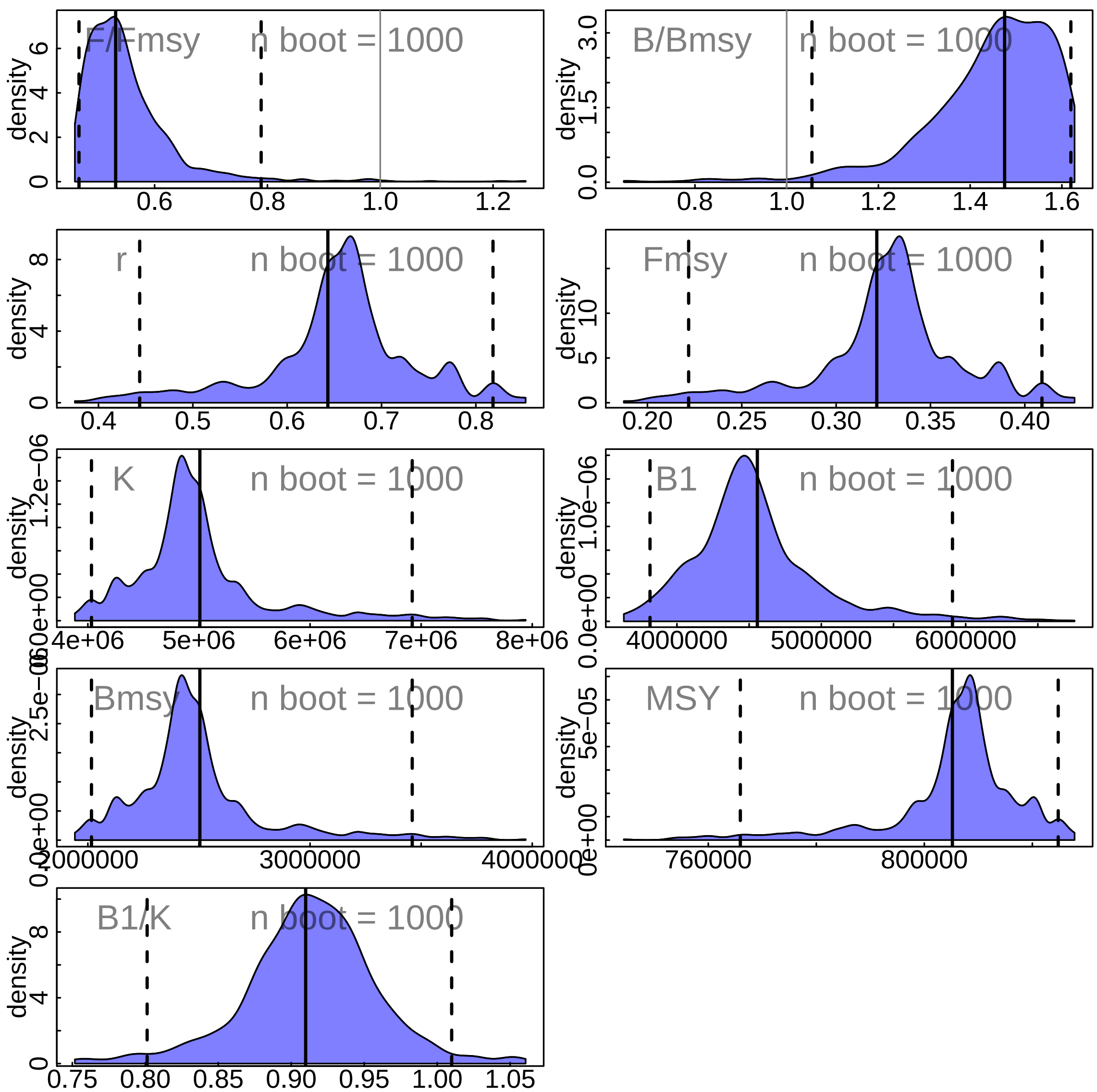
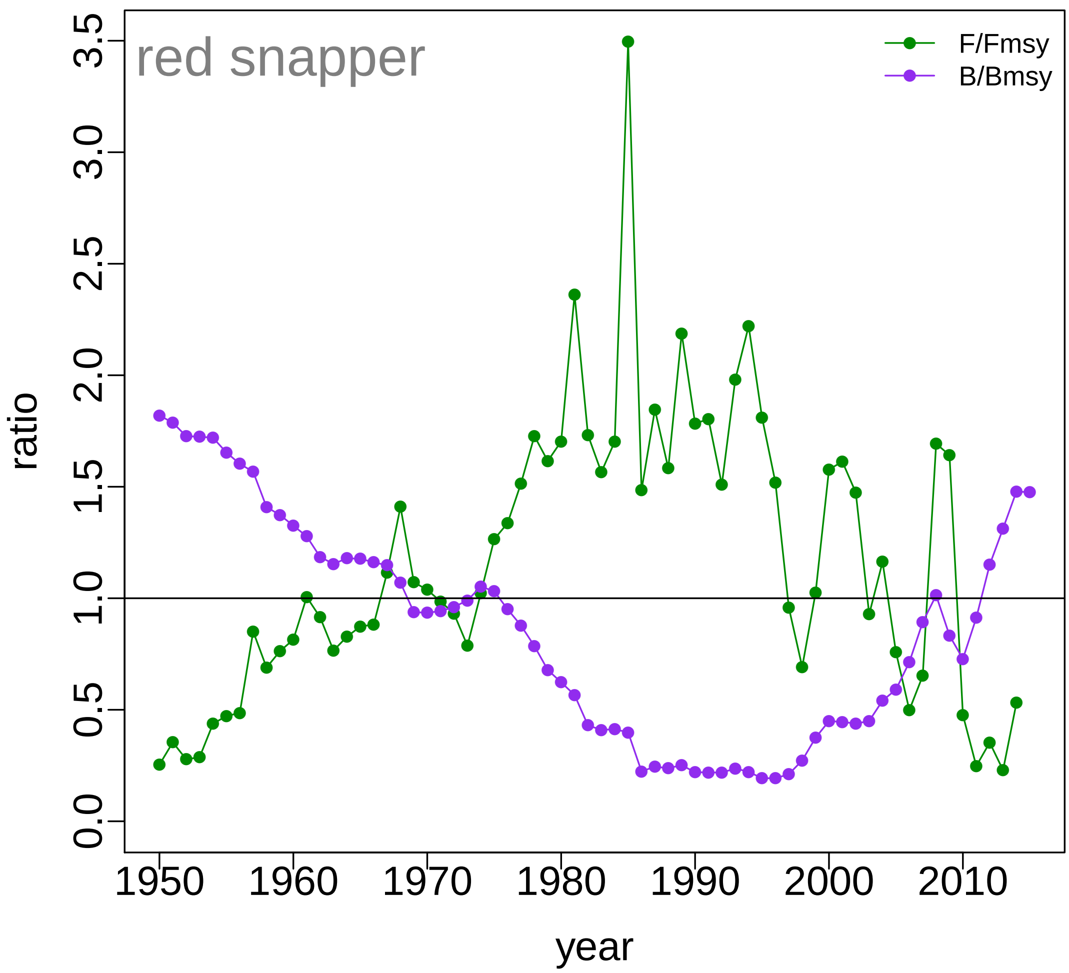


Figure 65. ASPIC surplus production model estimates of relative fishing rate (F/F_{MSY}) and biomass (B/B_{MSY}).



Appendix A Abbreviations and symbols

Table 31. Acronyms and abbreviations used in this report

Symbol	Meaning
ABC	Acceptable Biological Catch
AW	Assessment Workshop (here, for red snapper)
ASY	Average Sustainable Yield
B	Total biomass of stock, conventionally on January 1
BAM	Beaufort Assessment Model (a statistical catch-age formulation)
CPUE	Catch per unit effort; used after adjustment as an index of abundance
CV	Coefficient of variation
CVID	SERFS combined chevron trap and video survey
DW	Data Workshop (here, for red snapper)
F	Instantaneous rate of fishing mortality
$F_{30\%}$	Fishing mortality rate at which $F_{30\%}$ can be attained
F_{MSY}	Fishing mortality rate at which MSY can be attained
FL	State of Florida
FHWAR	The National Survey of Fishing, Hunting, and Wildlife-Associated Recreation Survey
GA	State of Georgia
GLM	Generalized linear model
K	Average size of stock when not exploited by man; carrying capacity
kg	Kilogram(s); 1 kg is about 2.2 lb.
klb	Thousand pounds; thousands of pounds
lb	Pound(s); 1 lb is about 0.454 kg
m	Meter(s); 1 m is about 3.28 feet.
M	Instantaneous rate of natural (non-fishing) mortality
MARMAP	Marine Resources Monitoring, Assessment, and Prediction Program, a fishery-independent data collection program of SCDNR
MCB	Monte Carlo/Bootstrap, an approach to quantifying uncertainty in model results
MFMT	Maximum fishing-mortality threshold; a limit reference point used in U.S. fishery management; often based on F_{MSY}
mm	Millimeter(s); 1 inch = 25.4 mm
MRFSS	Marine Recreational Fisheries Statistics Survey, a data-collection program of NMFS, predecessor of MRIP
MRIP	Marine Recreational Information Program, a data-collection program of NMFS, descended from MRFSS
MSST	Minimum stock-size threshold; a limit reference point used in U.S. fishery management. The SAFMC has defined MSST for red snapper as $(1 - M)\mathrm{SSB}_{\mathrm{MSY}} = 0.7\mathrm{SSB}_{\mathrm{MSY}}$.
MSY	Maximum sustainable yield (per year)
mt	Metric ton(s). One mt is 1000 kg, or about 2205 lb.
N	Number of fish in a stock, conventionally on January 1
NC	State of North Carolina
NMFS	National Marine Fisheries Service, same as "NOAA Fisheries Service"
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
OY	Optimum yield; SFA specifies that OY $\leq$ MSY.
PSE	Proportional standard error
R	Recruitment
SAFMC	South Atlantic Fishery Management Council (also, Council)
SC	State of South Carolina
SCDNR	Department of Natural Resources of SC
SDNR	Standard deviation of normalized residuals
SEDAR	SouthEast Data Assessment and Review process
SERFS	Southeast Regional Fishery-independent Sampling
SFA	Sustainable Fisheries Act; the Magnuson–Stevens Act, as amended
SL	Standard length (of a fish)
SRHS	Southeast Region Headboat Survey, conducted by NMFS-Beaufort laboratory
SPR	Spawning potential ratio
SSB	Spawning stock biomass; mature biomass of males and females
$\mathrm{SSB}_{\mathrm{MSY}}$	Level of SSB at which MSY can be attained
$\mathrm{SSB}_{\mathrm{F30\%}}$	Level of SSB at which $F_{30\%}$ can be attained
TIP	Trip Interview Program, a fishery-dependent biodata collection program of NMFS
TL	Total length (of a fish), as opposed to FL (fork length) or SL (standard length)
VPA	Virtual population analysis, an age-structured assessment
WW	Whole weight, as opposed to GW (gutted weight)
yr	Year(s)

Appendix B Parameter estimates from the Beaufort Assessment Model

```
# Number of parameters = 366  Objective function value = -1956.14  Maximum gradient component = 5.96937e-005
# Linf:
911.360000000
# K:
0.240000000000
# t0:
-0.330000000000
# len_cv_val:
0.107710207376
# Linf_L:
927.000000000
# K_L:
0.220000000000
# t0_L:
-0.660000000000
# len_cv_val_L:
0.138554456778
# Linf_20:
938.000000000
# K_20:
0.170000000000
# t0_20:
-2.41000000000
# len_cv_val_20:
0.100000029485
# log_Nage_dev:
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000
# log_R0:
12.7083722877
# steep:
0.990000000000
# rec_sigma:
0.789660384622
# R_autocorr:
0.00000000000
# log_rec_dev:
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 -0.116188568848 0.981085231489 0.686667445781 -0.451643590208 -1.31878122068 -1.48911312114 0.0811371437489
 -0.922992309386 -0.376167909813 -1.10841151212 -0.179202090276 -0.494969822897 0.107396220451 0.379878264774
 0.449377221761 0.0921864288671 -0.0837258040958 0.132548488808 -0.866607533977 -1.68351876147 1.07673003520
 0.757318324702 0.784222329636 -0.400893545137 -1.30002703800 -0.143801874907 -0.205256786125 0.371955484101 1.28619711286
# selpar_A50_cH1:
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# selpar_slope_cH1:
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# selpar_A50_cH2:
3.11132259576
# selpar_slope_cH2:
3.29722528688
# selpar_A50_cH3:
3.16773149230
# selpar_slope_cH3:
2.26236442631
# selpar_A50_HB1:
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# selpar_slope_HB1:
3.53054368964
# selpar_A502_HB1:
3.80005950304
# selpar_slope2_HB1:
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# selpar_A50_HB2:
2.96232318521
# selpar_slope_HB2:
3.93119690694
# selpar_A502_HB2:
2.25027736370
# selpar_slope2_HB2:
0.623141401382
# selpar_A50_HB3:
2.26872846556
# selpar_slope_HB3:
3.35767716522
# selpar_A502_HB3:
2.18384991290
# selpar_slope2_HB3:
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# selpar_A50_GR2:
3.11131983608
# selpar_slope_GR2:
2.71842181046
# selpar_A502_GR2:
2.97495905159
# selpar_slope2_GR2:
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# selpar_A50_GR3:
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```

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# selpar_slope_GR3:
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# selpar_A50_HB2_D:
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# selpar_slope_HB2_D:
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# selpar_A502_HB2_D:
1.23869212362
# selpar_slope2_HB2_D:
1.49507820428
# selpar_A50_HB3_D:
1.58012985774
# selpar_slope_HB3_D:
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# selpar_A502_HB3_D:
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# selpar_slope2_HB3_D:
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# selpar_A50_cH2_D:
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# selpar_slope_cH2_D:
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# selpar_A502_cH2_D:
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# selpar_slope2_cH2_D:
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# selpar_A50_cH3_D:
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# selpar_slope_cH3_D:
1.91711364986
# selpar_A50_CVT:
1.90730549321
# selpar_slope_CVT:
3.40818432774
# log_q_cH:
-6.25844174272
# log_q_HB:
-11.8453332840
# log_q_HB_D:
-12.7700652995
# log_q_CVT:
-12.1646316437
# M_constant:
0.134000000000
# log_avg_F_cH:
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# log_F_dev_cH:
 -1.50640443619 -1.19606666129 -1.44779804593 -1.41419831960 -1.00552018315 -1.16337121283 -1.14440240712
 -0.502111212050 -0.780960903034 -0.648434784587 -0.561311694188 -0.311131629420 -0.437655809103 -0.650106776150
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 0.676887588441 0.600817043938 0.172933692896 0.284213531392 0.0552230838463 -0.311689646371 -0.151579848805
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 0.947680107534 1.06128618693 1.22472756668 -2.80995484932 -5.47691169818 -2.78283576102 -1.38423640564 -0.708873090477
# log_avg_F_HB:
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# log_F_dev_HB:
 -1.34716469082 -1.21795523634 -1.08860726618 -0.972042851347 -0.873657741108 -0.779381477338 -0.656277435174
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 -0.0748011913017 -0.0632384700369 0.0431176191044 0.149563624258 0.246508551309 0.368190750885 0.537236484677
 0.661712395070 0.791476042563 0.936442804895 0.991328649085 1.16873523320 0.981619425524 0.758050799224
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 0.0439287036212 0.0487781883903 0.00470594165115 0.961918734776 0.497089398881 0.731754552306 0.297891330481
 0.681478883611 0.0927081289701 0.339350804695 0.391214325591 0.527670309816 0.477499713349 -0.327838468814
 0.423821917999 0.390563878751 0.519614539358 0.985941504161 0.644212206360 0.782283643821 -3.42347033019 -2.09076149162
 -1.55576844436 -2.09687352859 -1.03254040721
# log_avg_F_GR:
-1.57640711663
# log_F_dev_GR:
 -1.56766279383 -1.43846127465 -1.30915764440 -1.19253871293 -1.09419809168 -0.999935392212 -0.876854428914
 -0.762895287374 -0.669008856282 -0.579203674346 -0.484410823768 -0.447718030445 -0.401093643883 -0.334328839436
 -0.295558319401 -0.283999521379 -0.177710329929 -0.0713434319796 0.0255017203914 0.147092735903 0.315971480922
 0.440545044930 0.569523398454 0.715623993134 0.771313514093 0.948535472682 1.06116075246 0.503257392687 1.01569096953
 1.48147444378 1.67974724108 0.937110843678 0.329739748713 0.370480455580 0.449522531037 -1.37817128845 0.0927475607962
 1.30270808844 0.346328084582 0.523710915901 0.272923172864 -0.0165978450950 1.51563969896 0.296162200291 1.21003604027
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 1.33812486224 0.893754437193 -5.37375787731 -5.61379561482 -0.0184348910426 -0.640272823186 0.586184086417
# log_avg_F_cH_D:
-3.73353664537
# log_F_dev_cH_D:
 0.266588335516 0.343374502893 0.536899448846 0.891800778558 0.498394351227 0.588495779628 -0.0837877271924
 -0.523731278719 -0.569880122668 -0.375438654243 0.470982344992 -0.867713112224 -1.62483732369 0.533077355969
 -1.95064679219 -1.28747200456 -1.32824320794 -0.567093445156 0.735814373727 1.61352129256 0.949591879322
 0.846759620716 0.903543604624
# log_avg_F_HB_D:
-5.79644061647
# log_F_dev_HB_D:
 -4.71391630350 -3.71970901904 -4.24142341991 -4.56012299479 -4.20180378046 -4.00481204664 -3.36454338245 -3.26224582130
  0.0901217913932 0.770686051314 0.839774983440 1.32324787838 0.361352389058 0.442727954169 -0.124655874267
  -0.0370543321215 0.0780347286159 0.641015729367 0.901150739278 -0.0256535397639 2.51436057142 2.71597771725
   1.14292945111 2.51505782970 2.64689926556 3.13112075694 2.95417502377 2.59545904401 2.65113555734 2.31820752654
   1.62250552559
# log_avg_F_GR_D:
```

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-2.71035756204
# log_F_dev_GR_D:
 -2.42503054076 -2.50099432141 -3.38722052527 -1.00203912450 -0.447369409911 0.129573824294 -0.585607931015 -0.844764777417
 -1.16994513942 -0.406879027687 0.123321112551 -0.584026154680 0.660802503276 0.592823729801 0.738070257363 -0.671535139188
 -0.840415497560 -0.730881501787 0.794714817227 1.12276860438 1.12756166661 0.818937371024 0.965919231288 1.79365010697
 1.63318630174 -0.00432480925527 0.817903500109 1.50061375511 1.47865474555 1.15184581026 -0.702657019111 0.682903492790
  -0.180988960775 0.351429049406
# F_init:
0.0296007209743
```

9. South Atlantic and Gulf of Mexico Comparison (TOR #10)

This section addresses AW ToR 10: Compare and contrast productivity measures and assessment assumptions between the Gulf of Mexico and South Atlantic stocks. Comparisons are presented in Table 31.

A template of Table 31 was prepared by the SEDAR41 Assessment Panel, with guidance from SAFMC Council members attending the Assessment Workshop. Input for the South Atlantic stock was based on this (SEDAR41) assessment. Input for the Gulf of Mexico stock was based on the most recent (SEDAR31 update) assessment of that stock, and values were provided or reviewed by assessment scientists from the NMFS-Miami laboratory.

Table 31. Productivity measures and assessment assumptions from the South Atlantic (SA, SEDAR41) and Gulf of Mexico (GoM, SEDAR31 update) stocks of red snapper.

Productivity measure/assumption	SA	GoM	Comments
Reproductive output	Fecundity (eggs/female)	Fecundity (eggs/female)	SA units = $1X10^8$ eggs/female
Age at 50% maturity	1.2	NA	GoM: Age at 50% maturity was not used in the stock assessment model. Instead, a fixed vector of fecundity (eggs) at age was used.
Natural mortality	M=0.13	M=0.09	SA max age = 51. SA age dependent M was based on a scaled version of the Charnov estimator. GoM max age = 48. GoM age dependent M (ages 2+; age 0 and 1 M fixed) was based on a scaled version of the Lorenzen estimator.
Assessment model type	Statistical catch at age	Statistical catch at age	SA software = BAM (implemented in AD Model Builder) GoM software = Stock Synthesis (implemented in AD Model Builder; two areas modeled E and W of the Mississippi River; Single S/R relationship.
Assessment time frame	1950–2014	1872–2013	GoM: terminal year of data = 2013

			except for landings for which provisional 2014 estimates were available
Spawner-recruit model	Beverton-Holt	Beverton-Holt	SA: fixed steepness = 0.99 to model recruitment as variable around an average value. GoM: To fix projected recruitments at "recent" levels, steepness and σ_R were fixed.
Spawner-recruit model parameter values	h=0.99 log(R0)=12.71 σ_R=0.79	h=0.99 log(R0)=12.04 σ_R=0.3	SA: steepness fixed, R0 and σ_R estimated. R0 in number age-1 fish. GoM: There is evidence that observed recruitments have generally increased in recent years. Therefore, R0 was estimated for two time blocks (pre 1984 and 1984-present). Ln(R0) = 12.04 from recent time period. R0 in 1000s age-0 fish.
Modeled population recruitment age	Age=1	Age=0	GOM: Age 0 included in because of shrimp bycatch mortality.
Growth model	von Bertalanffy	von Bertalanffy	
Growth model parameter values	Linf=911.36mm (TL)	Linf=85.6374cm (Max TL) K=0.19	SA: Fixed in the assessment,

	K=0.24 t0=–0.33	t0=–0.39	estimated external to the model. Separate growth model applied to landings during the period of the 20-inch size limit. GoM: Fixed in the assessment; Parameters determined using a censored-regression approach to account for the effect of size limits (available data are generally from fishery dependent sources).
Scale of total removals over assessment time frame	Mean=0.82 mp Min=0.24 Max=1.64	Mean = 6.7 mp Min=0.52 mp Max = 18.45 mp	Total Removals (landings + dead discards) in millions of lb (mp)
MSY (or proxy)	0.46 mp	12.9 mp	SA: F30 proxy assuming average recruitment GoM: Equilibrium *Retained* Yield at $SSB_{SPR26\%}$
Fmsy (or proxy)	0.147	0.0494	SA: proxy=F30 GoM: $F_{SPR26\%}$ used as proxy
Bmsy (or proxy)	3692 mt	220.9 mp	SA: Total biomass (all ages 1+) at F30 GOM: Total biomass (all ages 0+) at $SSB_{SPR26\%}$
SSBmsy (or proxy)	3.3E+13 eggs	1.28E+12 eggs	SA: F30 proxy assuming average recruitment GoM: In units of

			1000s. Equilibirum SSB @ $F_{SPR26\%}$
F SPR values	$F_{SPR30\%}$=0.147	$F_{SPR26\%}$ = 0.0494	GOM: $F_{SPR26\%}$
Fleets/Indices modeled (selectivity assumptions)	Commercial handline (flat-topped), trap/video survey (flat-topped), headboat (domed), general recreational (domed, flat-topped since 2010)	**FLEETS:** COM_VL_E: ***RW*** COM_VL_W: ***RW*** COM_LL_E: ***RW*** COM_LL_W: ***RW*** MRIP(PB,CB)_E: ***RW*** MRIP(PB,CB)_W: ***RW*** HB_E: ***RW*** HB_W: ***RW*** COM_CLOSED SEASON_E: ***RW*** COM_CLOSED SEASON_W: ***RW*** REC_CLOSED SEASON_E: ***MIRROR MRIP(PB,CB)_E*** REC_CLOSED SEASON_W: ***MIRROR MRIP(PB,CB)_W*** SHRIMP BYCATCH_E: ***RW*** SHRIMP BYCATCH_W: ***RW*** **INDICES:** SEAMAP VIDEO_E: ***RW*** SEAMAP VIDEO_W: ***RW*** SEAMAP LARVAL_E: ***SSB*** SEAMAP LARVAL_W: ***SSB*** SUMMER GROUNDFISH_E: ***RW*** SUMMER GROUNDFISH_W: ***RW*** FALL GROUNDFISH_E: ***RW***	GOM: ***RW*** = Random Walk, Each age as random walk from previous age – can be dome shaped; ***MIRROR***: Use selectivity from another fleet; ***SSB:*** Sets expected survey selectivity such that abundance indexes spawning biomass; ***LOG***: Logistic or “Flat-topped”.

		FALL GROUNDFISH_W: ***RW*** NMFS BOTTOM LL_E: ***MIRROR NMFS BOTTOM LL_W*** NMFS BOTTOM LL_W: ***LOG*** REM_OPER_VEHICLE_E: ***RW*** NMFS BOTTOM LL_E: ***RW*** COM_HL_E: ***MIRROR COM_HL_E Fleet*** COM_HL_W: ***MIRROR MRIP(PB,CB)_E Fleet*** MRIP(PB,CB)_E: ***MIRROR MRIP(PB,CB)_W Fleet*** MRIP(PB,CB)_W: ***MIRROR MRIP(PB,CB)_W Fleet*** HB_E: ***MIRROR HB_E Fleet*** HB_W: ***MIRROR HB_W Fleet***	
Fleet Modeled Retention Assumption	NA	Logistic: As a function of size.	SA: Dead discards modeled as having their own selectivities and fishing rates. GOM: For each fishery, retention was modeled using a logistic function. "Retained" fish are "landed." Fish that were not retained were discarded. Dead

			discards were estimated by applying the relevant discard mortality rate. Retention does not apply to surveys.
Time varying catchability?	Y	N	SA: Explored in sensitivity analysis
Time varying selectivity?	Y	Y	SA: Three time blocks based on regulatory periods – 1950–1991, 1992–2009, 2010–current. GOM: 2007-2014; A new selectivity function was estimated for change in commercial selectivity with implementation of IFQ. GOM: 2008-2010 and 2011-2014; New selectivity functions were estimated for the recreational fisheries due to implementation of circle hooks and other regulatory effects (on fishing behavior).
Time varying retention?	NA	Y	GOM: Retention functions for recreational and commercial fisheries were re-estimated at all changes in size-limits. For the

			commercial fisheries, the asymptote (retention at sizes larger than the minimum size limit) was allowed to be <100% after the imposition of IFQ to account for regulatory discards not due to minimum size.

SEDAR

Southeast Data, Assessment, and Review

SEDAR 41

South Atlantic Red Snapper

SECTION IV: Research Recommendations

April 2016

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

Contents

IV. Research Recommendations

1. Data Workshop

1.1 Life History

Red Snapper Mini Season

If this program, along with continued closure of the fishery, is to extend into future seasons, an exploration of methods to further incentivize angler participation would be useful. After brief interviews with participants from the recreational fishers group at SEDAR 41, the following suggestions were provided to increase angler participation:

- Free fish cleaning at donation site.
- As people may be tired after being out on the water all day and with busy boat ramps, short questionnaire from a biologist on-site could be used instead of the anglers filling the forms out or requiring fishermen to fill out a survey online after they return home.
- Advertise data collection at local bait & tackle shops.
- Use NOAA's announcement system on weather radio channel where they also announce season closures, etc. Since fishermen are frequently monitoring this channel for weather updates, it could be an effective communication route to announce the collection information (drop locations, reward information, etc.).
- Dry storage areas are a good place to sample; many people store boats there instead of trailering home.

Life History Research

- More research on red snapper movements and migrations in Atlantic waters is needed. Available data and the results of studies in the Gulf of Mexico indicate high site fidelity, but that tropical storms may cause greater than normal movement that might help dispersal to depleted areas. This needs to be confirmed in the South Atlantic. Additional acoustic and traditional tagging is needed on known spawning locations to document spawning migrations or aggregations, and return of fish to non-spawning areas.
- Evaluate more thoroughly the data/sample collection during the mini-season to improve utility for assessments. This should include what samples should be collected (e.g. reproductive information).
- Possible changes in life history parameters, in particular relative to reproduction, need to be further investigated.
- Much is unknown about the early life history of Red Snapper, in particular relative to spawning areas, larval and juvenile stages, including habitat and dispersal.
- Alternative methods of reproductive output. The methods described in Klibansky's SEDAR41-DW49 may provide a more accurate estimate of reproductive output than

previously used. Further investigation into this modeling effort and use for future assessments should be investigated.
- Duration of spawning indicators. The definition of spawning indicators has received significant discussion recently. As this has significant implications for the estimates of reproductive output, further research is needed to define consistent criteria for spawning indicators in finfish.
- Continuing the age reading comparisons and calibrations between labs on a reference collection of known age fish would be beneficial for determining a more accurate aging error matrix and would provide accuracy to the age composition data.

1.2 Commercial Statistics

Landings

- Improve gear and effort data for each trip.
- Standardize methodology for developing average proportions to parse out unclassified landings.

Discards

- Investigate the validity and magnitude of “no discard” trips. This may include fisher interviews throughout the region.
- Examine potential impacts of “no discard” trips on estimated discards.
- Improve discard logbook data collections via program expansion or more detailed reporting (i.e. electronic logbooks, etc.)
- Establish an observer program that is representative of the fisheries in the South Atlantic

Biosampling

- Establish an observer program that is representative of the fisheries in the South Atlantic.
- Angler education with regards to recording depths on paper logbooks (i.e. standardized units); validation of additions to the logbook form still needed.
- Standardize TIP sampling protocol to get representative samples at the species level.
- Standardize TIP data extraction.

1.3 Recreational Statistics

- Complete analysis of available historic photos for trends in CPUE and mean size of landed Red Snapper and Gray Triggerfish for pre-1981 time period. (Ultimately all species).
- Formally archive data and photos for all other SEDAR target species.
- For Hire Survey (FHS) should collect additional variables (e.g. depth fished).
- Increasing sample sizes for at-sea headboat observers (i.e. number of trips sampled).

- Compute variance estimate for headboat landings.
- Mandatory logbooks for all federally permitted for-hire vessels.

1.4 Indices

- Compare existing methods and/or develop new methods to define effective effort in fishery dependent data.
- Estimate selectivity of video gear in the SERFS.
    - Tagging, stereo cameras
- For video reading, evaluate methods to score water clarity and habitat.
- Evaluate effect of (non) independence between chevron traps and videos, including methods to combine the indices.
- Continue exploring the use of continuous predictor variables (e.g., splines or polynomials) for ZIP and ZINB standardization models.
- Headboat at-sea observer program needs depth data from all states (not just FL) and increased coverage overall.
- SCDNR charterboat logbook program should be replicated by other states.
- Develop fishery independent hook-gear index (S41-DW08).

2. Assessment Workshop

- Increased fishery independent information, in particular reliable indices of abundance and age compositions.
- Red Snapper were modeled in this assessment as a unit stock off the southeastern U.S. For any stock, variation in exploitation and life-history characteristics might be expected at finer geographic scales. Modeling such sub-stock structure would require more data, such as information on the movements and migrations of adults and juveniles, as well as spatial patterns of larval dispersal and recruitment. In addition, it is unknown whether a spatial model would improve the assessment.
- More research to describe the life history of Red Snapper is needed, including more work to identify the location of juveniles before they recruit to the fishery.
- The effects on environmental variation on the changes in recruitment or survivorship.
- The Florida sampling program, during the mini-season in particular, provided invaluable data to this assessment. Programs such as these would be useful in all South Atlantic states, particularly if the management regulations continue to make established methods of index development or composition sampling from fleets less regular or possible.

3. Review Workshop

The Review Panel considers the first three of the following bullets to be the highest priority for assessment improvement.

- Increased fishery independent information, particularly maintaining reliable indices of abundance and composition data streams.
- Improve the reliability of discard data as an abundance index by improving knowledge of private recreational fisherman behavior.
- Research to determine the spatial distribution (horizontal and vertical) of large adult Red Snapper using tracking and telemetry.
- The Review Panel reiterates various research recommendations focused on Red Snapper population structure in the South Atlantic. Red Snapper were modeled in this assessment as a unit stock off the southeastern U.S. For any stock, variation in exploitation and life-history characteristics might be expected at finer geographic scales. Modeling such sub-stock structure would require more data, such as information on the movements and migrations of adults and juveniles, as well as spatial patterns of larval dispersal and recruitment, and spatially-explicit data of all types used in the assessment model. It is unclear whether a spatially-explicit model would improve the assessment. Given the robust ocean circulation in the South Atlantic Bight conditions creating population sub-structure. The research effort necessary to support such an effort would be extensive and probably unjustified on stock assessment improvement grounds, however, it would be needed to support MPA placement, performance evaluation, etc.
- More research to describe the juvenile life history of Red Snapper is needed, including more work to identify the location of juveniles before they recruit to the fishery.
- The effects of environmental variation on the changes in recruitment or survivorship.
- Investigate possible historical changes in sexual maturity. The current estimate of age of sexual maturity is low and unusual for other Lutjanids. Is it right or a compensatory response to heavy exploitation?
- Continue conducting studies to develop a time series of batch fecundity to obtain information on the inter-annual variation in reproductive output.

SEDAR

Southeast Data, Assessment, and Review

SEDAR 41

South Atlantic Red Snapper

SECTION V: Review Workshop Report

April 2016

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

Table of Contents

1. Introduction

1.1 Workshop Time and Place

The SEDAR 41 Review Workshop for South Atlantic Red Snapper (*Lutjanus campechanus*) was held March 15-18, 2016 in North Charleston, SC. Review Panel members were presented all information generated throughout the Data (DW) and Assessment (AW) Workshops and webinars, and the Review Workshop (RW) Panel then developed a consensus review and analysis of the stock assessment model and inputs according to a number of SEDAR Terms of Reference.

1.2 Terms of Reference

1. Evaluate the data used in the assessment, including discussion of the strengths and weaknesses of data sources and decisions, and consider the following:
    a) Are data decisions made by the DW and AW sound and robust?
    b) Are data uncertainties acknowledged, reported, and within the normal or expected levels?
    c) Are data properly applied within the assessment model?
    d) Are data input series reliable and sufficient to support the assessment approach and findings?

2. Evaluate and discuss the strengths and weaknesses of the methods used to assess the stock, taking into account the available data, and consider the following:
    a) Are methods scientifically sound and robust?
    b) Are assessment models configured properly and used consistent with standard practices?
    c) Are the methods appropriate for the available data?

3. Evaluate the assessment findings and consider the following:
    a) Are abundance, exploitation, and biomass estimates reliable, consistent with input data and population biological characteristics, and useful to support status inferences?
    b) Is the stock overfished? What information helps you to reach this conclusion?
    c) Is the stock undergoing overfishing? What information helps you reach this conclusion?
    d) Is there an informative stock recruitment relationship? Is the stock recruitment curve reliable and useful for evaluation of productivity and future stock conditions?
    e) Are the quantitative estimates of the status determination criteria for this stock reliable? If not, are there other indicators that may be used to inform managers about stock trends and conditions?

4. Evaluate the stock projections, including discussing the strengths and weaknesses, and consider the following:
    a) Are the methods consistent with accepted practices and available data?
    b) Are the methods appropriate for the assessment model and outputs?
    c) Are the results informative and robust, and are they useful to support inferences of probably future conditions?
    d) Are key uncertainties acknowledged, discussed, and reflected in the projection results?

5. Consider how uncertainties in the assessment, and their potential consequences, are addressed.
    a) Comment on the degree to which methods used to evaluate uncertainty reflect and capture the significant sources of uncertainty in the population, data sources, and assessment methods.
    b) Ensure that the implications of uncertainty in technical conclusions are clearly stated.

6. Consider the research recommendations provided by the Data and Assessment workshops and make any additional recommendations or prioritizations warranted.
    a) Clearly denote research and monitoring that could improve the reliability of, and information provided by, future assessments.
    b) Provide recommendations on possible ways to improve the SEDAR process.

7. Consider whether the stock assessment constitutes the best scientific information available using the following criteria as appropriate: relevance, inclusiveness, objectivity, transparency, timeliness, verification, validation, and peer review of fishery management information.

8. Compare and contrast assessment uncertainties between the Gulf of Mexico and South Atlantic stocks.

9. Provide guidance on key improvements in data or modeling approaches which should be considered when scheduling the next assessment.

10. Prepare a Peer Review Summary summarizing the Panel's evaluation of the stock assessment and addressing each Term of Reference. Develop a list of tasks to be completed following the workshop. Complete and submit the Peer Review Summary Report in accordance with the project guidelines.

1.3 List of Participants

REVIEW WORKSHOP PANELISTS

Luiz Barbieri	Review Panel Chair	SAFMC SSC
Mike Armstrong	Reviewer	CIE
Jon Helge Vølstad	Reviewer	CIE
Stephen Smith	Reviewer	CIE
Steve Cadrin	Reviewer	SAFMC SSC
Churchill Grimes	Reviewer	SAFMC SSC

ANALYTICAL REPRESENTATIVES

Kevin Craig	Lead Analyst, GTF	SEFSC Beaufort
Kate Siegfried	Lead Analyst, RS	SEFSC Beaufort
Kyle Shertzer	Assessment Team	SEFSC Beaufort
Erik Williams	Assessment Team	SEFSC Beaufort
Rob Cheshire*	Assessment Team	SEFSC Beaufort
Eric Fitzpatrick*	Assessment Team	SEFSC Beaufort

APPOINTED OBSERVERS

Rusty Hudson	Recreational/Commercial	FL / SFA
Robert Johnson	For-Hire	FL

APPOINTED COUNCIL REPRESENTATIVES

Zack Bowen	Council Member	SAFMC
Mark Brown	Council Member	SAFMC
Chris Conklin	Council Member	SAFMC

COUNCIL AND AGENCY STAFF

Julia Byrd	Coordinator	SEDAR
Julie O'Dell	Admin	SEDAR / SAFMC
Chip Collier	Fishery Biologist	SAMFC
Mike Errigo	Fishery Biologist	SAFMC
Nick Farmer	Fishery Biologist	SERO

WORKSHOP ATTENDEES

Joey Ballenger, SCDNR
Peter Barile, SFA
Myra Brouwer, SAFMC
John Carmichael, SAFMC
Brian Cheuvront, SAFMC
Lora Clarke, PEW

Amy Dukes, SCDNR
Jimmy Hull, FL fisherman
Julie Neer, SAFMC
Adam Nelson, FL fisherman
David Nelson, FL fisherman
Michael Nelson, FL fisherman
Paul Nelson, FL fisherman
Marcel Reichert, SCDNR
Tracey Smart, SCDNR

*Appointees marked with a * were appointed to the workshop panel but did not attend the workshop.

1.4 Document List

SEDAR 41 review workshop working papers and reference documents.

Document #	Title	Authors
Documents Prepared for the Review Workshop		
SEDAR41-RW01	Addendum to SEDAR41-DW16: Report on Life History of South Atlantic Gray Triggerfish, *Balistes capriscus*, from Fishery-Independent Sources: UPDATE on analyses of maturity, spawning fraction, and sex ratio	Kolmos et al. 2016
SEDAR41-RW02	Age structured production model (ASPM) for U.S. South Atlantic Red Snapper (*Lutjanus campechanus*)	SFB-NMFS 2016
SEDAR41-RW03	Age structured production model (ASPM) for U.S. South Atlantic Gray Triggerfish (*Balistes capriscus*)	SFB-NMFS 2016
SEDAR41-RW04	Red Snapper: Additional BAM diagnostics, analyses, and code	SFB-NMFS 2016
SEDAR41-RW05	Model Diagnostics and Source Code for SEDAR 41 Gray Triggerfish (*Balistes capriscus*) Benchmark Stock Assessment	SFB-NMFS 2016
Reference Documents		
SEDAR41-RD01	List of documents and working papers for SEDAR 32 (South Atlantic Blueline Tilefish and Gray Triggerfish) – all documents available on the SEDAR website.	SEDAR 32
SEDAR41-RD02	List of documents and working papers for SEDAR 9 (Gulf of Mexico Gray Triggerfish, Greater Amberjack, and Vermilion Snapper) – all documents available on the SEDAR website.	SEDAR 9
SEDAR41-RD03	2011 Gulf of Mexico Gray Triggerfish Update Assessment	SEDAR 2011
SEDAR41-RD04	List of documents and working papers for SEDAR 24 (South Atlantic Red Snapper) – all documents available on the SEDAR website.	SEDAR 24
SEDAR41-RD05	List of documents and working papers for SEDAR 31 (Gulf of Mexico Red Snapper) – all documents available on the SEDAR website.	SEDAR 31

SEDAR41-RD06	List of documents and working papers for SEDAR 15 (South Atlantic Red Snapper and greater amberjack) – all documents available on the SEDAR website.	SEDAR 15
SEDAR41-RD07	2009 Gulf of Mexico Red Snapper update assessment	SEDAR 2009
SEDAR41-RD08	List of documents and working papers for SEDAR 7 (Gulf of Mexico Red Snapper) – all documents available on the SEDAR website.	SEDAR 7
SEDAR41-RD09	SEDAR 24 South Atlantic Red Snapper: management quantities and projections requested by the SSC and SERO	NMFS - Sustainable Fisheries Branch 2010
SEDAR41-RD10	Total removals of Red Snapper (*Lutjanus campechanus*) in 2012 from the US South Atlantic	NMFS - Sustainable Fisheries Branch 2013
SEDAR41-RD11	Amendment 17A to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region	SAFMC 2010
SEDAR41-RD12	Amendment 28 to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region	SAFMC 2013
SEDAR41-RD13	Total removals of Red Snapper (*Lutjanus campechanus*) in 2013 from the U.S. South Atlantic	NMFS - Sustainable Fisheries Branch 2014
SEDAR41-RD14	South Atlantic Red Snapper (*Lutjanus campechanus*) monitoring in Florida for the 2012 season	Sauls et al. 2013
SEDAR41-RD15	South Atlantic Red Snapper (*Lutjanus campechanus*) monitoring in Florida for the 2013 season	Sauls et al. 2014
SEDAR41-RD16	A directed study of the recreational Red Snapper fisheries in the Gulf of Mexico along the West Florida shelf	Sauls et al. 2014
SEDAR41-RD17	Using generalized linear models to estimate selectivity from short-term recoveries of tagged red drum *Sciaenops ocellatus*: Effects of gear, fate, and regulation period	Bacheler et al. 2009
SEDAR41-RD18	Direct estimates of gear selectivity from multiple tagging experiments	Myers and Hoenig 1997

SEDAR41-RD19	Examining the utility of alternative video monitoring metrics for indexing reef fish abundance	Schobernd et al. 2014
SEDAR41-RD20	An evaluation and power analysis of fishery independent reef fish sampling in the Gulf of Mexico and U.S. South Atlantic	Conn 2011
SEDAR41-RD21	Consultant's Report: Summary of the MRFSS/MRIP Calibration Workshop	Boreman 2012
SEDAR41-RD22	2013 South Atlantic Red Snapper Annual Catch Limit and Season Length Projections	SERO 2013
SEDAR41-RD23	Southeast Reef Fish Survey Video Index Development Workshop	Bacheler and Carmichael 2014
SEDAR41-RD24	Observer Coverage of the 2010-2011 Gulf of Mexico Reef Fish Fishery	Scott-Denton and Williams
SEDAR41-RD25	Circle Hook Requirements in the Gulf of Mexico: Application in Recreational Fisheries and Effectiveness for Conservation of Reef Fishes	Sauls and Ayala 2012
SEDAR41-RD26	GADNR Marine Sportfish Carcass Recovery Project	Harrell 2013
SEDAR41-RD27	Catch Characterization and Discards within the Snapper Grouper Vertical Hook-and-Line Fishery of the South Atlantic United States	Gulf and South Atlantic Fisheries Foundation 2008
SEDAR41-RD28	A Continuation of Catch Characterization and Discards within the Snapper Grouper Vertical Hook-and-Line Fishery of the South Atlantic United States	Gulf and South Atlantic Fisheries Foundation 2010
SEDAR41-RD29	Continuation of Catch Characterization and Discards within the Snapper Grouper Vertical Hook-and-Line Fishery of the South Atlantic United States	Gulf and South Atlantic Fisheries Foundation 2013
SEDAR41-RD30	Amendment 1 and Environmental Assessment and Regulatory Impact Review to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region	SAFMC 1988
SEDAR41-RD31	Final Rule for Amendment 1 to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region	Federal Register 1989
SEDAR41-RD32	Population Structure and Genetic Diversity of Red Snapper (Lutjanus campechanus) in the U.S.	Gold and Portnoy 2013

	South Atlantic and Connectivity with Red Snapper in the Gulf of Mexico	
SEDAR41-RD33	Oogenesis and fecundity type of Gulf of Mexico gray triggerfish reflects warm water environmental and parental care	Lang and Fitzhugh 2014
SEDAR41-RD34	Depth-related Distribution of Postjuvenile Red Snapper in Southeastern U.S. Atlantic Ocean Waters: Ontogenetic Patterns and Implications for Management	Mitchell et al. 2014
SEDAR41-RD35	Gray Triggerfish Age Workshop	Potts 2013
SEDAR41-RD36	Age, Growth, and Reproduction of Gray Triggerfish *Balistes capriscus* Off the Southeastern U.S. Atlantic Coast	Kelly 2014
SEDAR41-RD37	Assessment of Genetic Stock Structure of Gray Triggerfish (*Balistes capriscus*) in U.S. Waters of the Gulf of Mexico and South Atlantic Regions	Saillant and Antoni 2014
SEDAR41-RD38	Genetic Variation of Gray Triggerfish in U.S. Waters of the Gulf of Mexico and Western Atlantic Ocean as Inferred from Mitochondrial DNA Sequences	Antoni et al. 2011
SEDAR41-RD39	Characterization of the U.S. Gulf of Mexico and South Atlantic Penaeid and Rock Shrimp Fisheries Based on Observer Data	Scott-Denton et al. 2012
SEDAR41-RD40	Does hook type influence the catch rate, size, and injury of grouper in a North Carolina commercial fishery	Bacheler and Buckel 2004
SEDAR41-RD41	Fishes associated with North Carolina shelf-edge hardbottoms and initial assessment of a proposed marine protected area	Quattrini and Ross 2006
SEDAR41-RD42	Growth of grey triggerfish, *Balistes capriscus*, based on growth checks of the dorsal spine	Ofori-Danson 1989
SEDAR41-RD43	Age Validation and Growth of Gray Triggerfish, *Balistes capriscus*, In the Northern Gulf of Mexico	Fioramonti 2012
SEDAR41-RD44	A review of the biology and fishery for Gray Triggerfish, *Balistes capriscus*, in the Gulf of Mexico	Harper and McClellan 1997

SEDAR41-RD45	Stock structure of gray triggerfish, *Balistes capriscus*, on multiple spatial scales in the Gulf of Mexico	Ingram 2001
SEDAR41-RD46	Evaluation of the Efficacy of the Current Minimum Size Regulation for Selected Reef Fish Based on Release Mortality and Fish Physiology	Burns and Brown-Peterson 2008
SEDAR41-RD47	Population Structure of Red Snapper from the Gulf of Mexico as Inferred from Analysis of Mitochondrial DNA	Gold et al. 1997
SEDAR41-RD48	Successful Discrimination Using Otolith Microchemistry Among Samples of Red Snapper *Lutjanus campechanus* from Artificial Reefs and Samples of *L.campechanus* Taken from Nearby Oil and Gas Platforms	Nowling et al. 2011
SEDAR41-RD49	Population Structure and Variation in Red Snapper (Lutjanus campechanus) from the Gulf of Mexico and Atlantic Coast of Florida as Determined from Mitochondrial DNA Control Region Sequence	Garber et al. 2003
SEDAR41-RD50	Population assessment of the Red Snapper from the southeastern United States	Manooch et al. 1998
SEDAR41-RD51	Otolith Microchemical Fingerprints of Age-0 Red Snapper, *Lutjanus campechanus*, from the Northern Gulf of Mexico	Patterson et al. 1998
SEDAR41-RD52	Implications of reef fish movement from unreported artificial reef sites in the northern Gulf of Mexico	Addis et al. 2013
SEDAR41-RD53	Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species	Then et al. 2014
SEDAR41-RD54	Length selectivity of commercial fish traps assessed from in situ comparisons with stereo-video: Is there evidence of sampling bias?	Langlois et al. 2015
SEDAR41-RD55	MRIP Calibration Workshop II – Final Report	Carmichael and Van Vorhees (eds.) 2015
SEDAR41-RD56	Total Removals of Red Snapper (*Lutjanus campechanus*) in 2014 from the U.S. South Atlantic	SEFSC 2015
SEDAR41-RD57	Assessing reproductive resilience: an example with South Atlantic Red Snapper *Lutjanus campechanus*	Lowerre-Barbiere et al. 2015

SEDAR41-RD58	Overview of sampling gears and standard protocols used by the Southeast Reef Fish Survey and its partners	Smart et al. 2014
SEDAR41-RD59	MRIP Transition Plan for the Fishing Effort Survey	Atlantic and Gulf Subgroup of the MRIP Transition Team 2015
SEDAR41-RD60	Technical documentation of the Beaufort Assessment Model (BAM)	Williams and Shertzer 2015
SEDAR41-RD61	Stock Assessment of Red Snapper in the Gulf of Mexico 1872-2013, with Provisional 2014 Landings: SEDAR Update Assessment	Cass-Calay et al. 2015
SEDAR41-RD62	Excerpt from the December 2013 SAFMC SEDAR Committee Minutes (pages 11-21 where SEDAR 41 ToR were discussed)	SAFMC SEDAR Committee
SEDAR41-RD63	Population structure of Red Snapper (*Lutjanus campechanus)* in U.S. waters of the western Atlantic Ocean and the northeastern Gulf of Mexico	Hollenbeck et al. 2015
SEDAR41-RD64	SEDAR31-AW04: The Effect of Hook Type on Red Snapper Catch	Saul and Walter 2013
SEDAR41-RD65	SEDAR31-AW12: Estimation of hook selectivity on Red Snapper (*Lutjanus campechanus*) during a fishery independent survey of natural reefs in the Gulf of Mexico	Pollack et al. 2013
SEDAR41-RD66	Effect of Circle Hook Size on Reef Fish Catch Rates, Species Composition, and Selectivity in the Northern Gulf of Mexico Recreational Fishery	Patterson et al. 2012
SEDAR41-RD67	Effect of trawling on juvenile Red Snapper (*Lutjanus campechanus*) habitat selection and life history parameters	Wells et al. 2008
SEDAR41-RD68	SEDAR24-AW05: Selectivity of Red Snapper in the southeast U.S. Atlantic: dome-shaped or flat topped?	SFB-SEFSC 2010
SEDAR41-RD69	Hierarchical analysis of multiple noisy abundance indices	Conn 2010
SEDAR41-RD70	Data weighting in statistical fisheries stock assessment models	Francis 2011
SEDAR41-RD71	Corrigendum to Francis 2011 paper	Francis

SEDAR41-RD72	Quantifying annual variation in catchability for commercial and research fishing	Francis et al. 2003
SEDAR41-RD73	Evolutionary assembly rules for fish life histories	Charnov et al. 2012
SEDAR41-RD74	User's Guide for ASPIC Suite, version 7: A Stock-Production Model Incorporating Covariates and auxiliary programs	Prager 2015
SEDAR41-RD75	Standing and Special Reef Fish SSC, September 2015 Meeting Summary (see pages 4-7 for SEDAR 43 review)	Gulf of Mexico Standing and Special Reef Fish SSC
SEDAR41-RD76	Standing and Special Reef Fish SSC, January 2016 Meeting Summary (see pages 2-7 for SEDAR 43 review)	Gulf of Mexico Standing and Special Reef Fish SSC
SEDAR41-RD77	SEDAR 43 Gulf of Mexico Gray Triggerfish Stock Assessment Report	SEDAR 43
SEDAR41-RD78	Review of 2014 SEDAR 31 Gulf of Mexico Red Snapper Update Assessment	Gulf of Mexico Standing and Special Reef Fish SSC
SEDAR41-RD79	Influence of soak time and fish accumulation on catches of reef fishes in a multispecies trap survey	Bacheler et al. 2013

2. Review Panel Report

Executive Summary

The Review Workshop (RW) Panel was presented outputs and results of the SEDAR 41 South Atlantic Red Snapper stock assessment. The primary assessment model used was the Beaufort Assessment Model (BAM), a software package that implements a statistical catch-at-age framework. The formulation is an age-structured population model that is fit using standard statistical methods to data available from surveys and fishing fleets, such as landings, discards, indices of abundance, age compositions, and length compositions. The modeling framework is nearly identical to other common assessment packages, such Age Structure Assessment Program (ASAP) and Stock Synthesis (SS), and the programming language (AD Model Builder) is the same across all three. A secondary, surplus-production model (Stock Production Model Incorporating Covariates, ASPIC) provided a comparison of model results. The Review Panel concluded that the data used in the assessment were generally sound and robust. Likewise, data generally were applied properly and uncertainty in data inputs was appropriately acknowledged. Numerous sensitivity analyses and exploration of alternative scenarios were also presented during the RW, all of which agreed with the base model run conclusions of stock status. Note that a follow-up webinar on 8 April 2016 was necessary to continue discussion of projections and finalize the SEDAR 41 RW process. Based on these results the Review Panel concluded that the stock is overfished and overfishing is occurring. The current level of spawning stock biomass (SSB_{2014}) is estimated to be about 22% of MSST (SSB_{2014}/MSST= 0.22), and the current level of fishing mortality is about 2 ½ times $F_{30\%SPR}$ ($F_{2012\text{-}2014}/F_{30\%SPR}$= 2.52). Although the Review Panel concluded that assessment results represent the best available science, there were significant areas of uncertainty identified in both the data and in components to the model. The most significant sources of this uncertainty include: the stock-recruitment relationship, the composition and magnitude of recreational discards, potential changes in CPUE catchability, and the selectivities for the different fishery fleets. The Review Panel recognized that the perception of current selectivity used to derive reference points and projections is conditional on poorly-informed assumptions regarding recent fishing behavior. During the most recent years of the stock assessment series (i.e., the 2010-2014 moratorium), recreational discards are one of the most important and most uncertain sources of information. Also, a strong retrospective pattern in apical F indicates the base BAM model is very sensitive to terminal year of data and suggests higher uncertainty in exploitation status.

2.1 Statements Addressing Each ToR

1. Evaluate the data used in the assessment, including discussion of the strengths and weaknesses of data sources and decisions, and consider the following:
    e) Are data decisions made by the DW and AW sound and robust?

f) Are data uncertainties acknowledged, reported, and within the normal or expected levels?
g) Are data properly applied within the assessment model?
h) Are data input series reliable and sufficient to support the assessment approach and findings?

General comments

Data decisions made by the DW and AW were sound and robust. The Review Panel acknowledges the considerable efforts of the DW and AW to compile the data and evaluate their strengths and weaknesses. The development of input data and parameters for the BAM and ASPIC models required an extremely thorough compilation and evaluation of all available data at the DW. Modifications made subsequently by the AW were fully explained.

Data uncertainties were acknowledged, reported, and were within the normal or expected levels. Where this could be ascertained from information provided to the RW. Data on fishery catches and length/age compositions, and fishery-dependent and independent relative abundance indices, varied widely in coverage and quality. Complex manipulations and standardisation methods were often required to try and develop coherent time series from diverse data sources of differing designs, coverage and accuracy, and the combined data will have biases that in some cases are poorly understood especially in earlier years of the time series. All decisions made by the DW and AW in compiling data were explained and justified in detail. Data quality metrics were provided by the DW in terms of numbers of samples, CVs, or alternative plausible data series or biological parameter values. These were used by the AW to weight data series in the assessment model, estimate the uncertainty in the assessment results using the Monte Carlo/bootstrap method, or to explore the sensitivity of the assessment to data decisions and uncertainty. The sensitivity analyses were carried out altering one input at a time, and did not explore the impact of combinations of adjustments.

The data were properly applied within the assessment model. Any issues with application of the data such as time periods for fitting, use of length and age data from the same sampling schemes, or weighting of data according to data quality metrics, were explored at the SEDAR-41 RW if not previously evaluated by the DW and AW.

Data input series were applied if considered reliable and sufficient to support the assessment approach and findings. Reliability and sufficiency was evaluated based on a-priori criteria where possible, supported by data quality metrics such as numbers of samples or CVs and by model fits. The assessment is supported primarily by a wide range of fishery-dependent data covering landings and discards, and therefore is heavily driven by these data and assumptions related to their reliability and use. An additional fishery-independent trap survey data set unfortunately covers only the period since 2010 due to very low incidence of Red Snapper catches prior to the recent increase in abundance due to strong year classes.

An evaluation of the strengths and weaknesses of the data sources and decisions is given below for each type of data used.

Life history parameters

Life history data and assumptions used in the Red Snapper assessment include stock structure, reproductive biology and natural mortality. The assessment was sensitive to estimates of natural mortality (M) as is generally the case, although sensitivity to trends in M could not be evaluated as there is no information on this. An age-dependent, year-invariant estimate of M was determined by a meta-analysis approach using growth parameters and maximum observed age. Reproductive biology was included in the model by computing total annual egg production at age based on maturity, length, number of batches and batch fecundity, thus allowing the effect of age structure on reproductive output to be reflected in setting SSB reference points and stock status. This represents a significant change from previous assessments. Interannual variation in fecundity, a possible source of uncertainty, was not able to be included as historical information was not available. The low estimate of age at first maturity in females (43% at age 1) was considered by the RW to be unusual for snappers, and it was speculated if it has declined as a compensatory response to heavy exploitation. Annual maturity data from the SERFS chevron trap survey could not be used to test this because sample collections have been from different areas in different time periods.

Fishery removals

Reconstruction of a historical series of commercial and recreational fishery removals (landings and dead discards) was made back to 1950 to allow a sufficient burn-in period for the BAM model as well as to establish a period of stable age structure and low fishing mortality. Creation of a series of removals estimates since 1950 required a large number of decisions to infer historical values from more recent data or to calibrate data series where design has changed. This included calibration factors to adjust NMFS Marine Recreational Fisheries Statistics Survey (MRFSS) surveys catch estimates from 1981 to 2003 to be consistent with catches from the Marine Recreational Information Programme (MRIP: 2004 to present), and to develop combined recreational landings back to 1955 using effort data from the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation Survey (FHWAR: SEDAR41-DW17) combined with average MRFSS and SRHS CPUE data for 1981-83.

The recording of landings of the commercial handline fleets have improved in accuracy over time, and the DW proposed CVs that could be used for MCB uncertainty analysis in the assessment. Recreational landings of headboats are estimated from the Southeast Region Headboat Survey (SRHS) logbook scheme which has improved in quality over time due to introduction of mandatory reporting in 1996 and improved logbook supply from 2008 onwards. Private boat and charter boat landings since early 1980s were estimated from MRFSS/MRIP, which has a robust and peer-reviewed statistical design that has substantially reduced bias and improved precision over time, and for which CVs are estimated directly based on efficient estimators.

Discards estimates are inherently less reliable than landings for both the commercial and recreational fleets, and for the commercial handline fleet involved extrapolating observations for 2002-2009 to other years back to 1992, with zero discards assumed prior to that due to low minimum landing size. Similarly, headboat discard estimates are available from logbooks and some at-sea observation since 2004 but had to be extrapolated back in time based on changes in length frequencies recorded by dockside sampling before and after changes in minimum landing sizes, with zero discards assumed pre-1984. All these data manipulations introduce additional error in the time series. Discards estimates from MRFSS/MRIP are self-reported by anglers intercepted at landing sites and are not verified.

Sample sizes and allocation in MRIP have not been sufficient to provide reliable estimates of Red Snapper landings or discards for the very brief mini-seasons since 2012, and alternative data sources from State surveys were also used for these periods, based on collaboration between MRIP staff and State laboratories which the Review Panel was advised is continuing to develop options for future sampling, which the Review Panel encourages.

Discarding of Red Snapper has increased over time due to changes in minimum landing size to 20 inches in 1992 and increases in abundance of young fish from above-average year classes in some recent years. The introduction of the moratorium in 2010 and 2011, and the small commercial catch limits and recreational bag limits in the mini seasons for 2012 onwards, have resulted in most of the catch now being discarded. Estimates of discards are of poorer quality than for landings, and are often self-reported with no verification although some data are available from at-sea observations. The Review Panel notes that under the current management regime the quality of total fishery removals estimates may therefore have deteriorated significantly. The BAM model has estimated a very strong 2013 year class, based mainly on recreational discards data and CVID Chevron trap survey data. Preliminary 2015 CVID data shown to the Review Panel confirmed this by showing increased numbers of 2-year-olds. The accuracy of future BAM estimates for this year class, and projections of its contribution to future biomass and fishery catches will depend on quality of discard estimates to quantify the fishery removals. The Review Panel supports any initiatives to improve quality of discards estimates particularly as the BAM model requires these and any landings estimates to be treated as precise.

Length and age compositions

The AW used age composition data in preference to length composition data in BAM where both data exist, and length composition data were fitted only for commercial handline from 1984 to 1992, commercial discards in 2009 and 2013, and headboat discards from 2005 to 2014. Age compositions were fitted for commercial handline landings from 1990 onwards, for headboat landings in two widely separated blocks in the 1980s and 2000s, for general recreational landings since 2001, and for the CVID survey from 2010. The CVID age data were found towards the end of the Review Workshop to have not been converted to calendar ages, and revised data were provided along with some preliminary assessment results which indicated some relatively small changes to the overall assessment results and stock status.

The Review Panel heard testimony from recreational and commercial fishermen, documented also in SEDAR 41-RW6, expressing concern that the BAM assessment underestimates the numbers of large, older Red Snappers. In their experience these fish occur more frequently in midwater than is the case for smaller snappers, which are strongly benthic and therefore are less likely to enter traps, and also have behaviour and distribution that makes them less probable to be caught by commercial handline, suggesting that all fisheries have domed selectivity. The scientific sampling of fishery catches shows that the incidence of large snappers is lowest in headboats operating inshore, highest in commercial lines operating in deeper water on average, and intermediate in recreational private and charter boats which typically operate in intermediate depths. The age composition of Red Snappers caught in the Chevron trap survey, which extends across a wide depth range, is closer to the composition of commercial handline. Broad spatial coverage of the commercial fishery and survey has been used by the DW and AW to justify asymptotic selectivity for these catches. The relative selectivity of the different fisheries is shown clearly by the size and age compositions in samples collected over time, but it is more difficult to prove that the commercial fishery and Chevron trap survey have asymptotic selectivity based purely on model diagnostics or spatial fishery distribution. The Review Panel did not see any empirical data from independent studies to confirm the selection pattern for commercial handline or chevron traps. Studies are needed to provide independent data showing how Red Snapper behaviour and depth distribution affects the probability of encounter with a fishing operation or trap, and the probability of being caught when encountering the gear, to help define selectivity patterns and resolve the different perspectives on abundance of large snappers during the rebuilding period. The Review Panel suggests some approaches later in this report.

Relative abundance indices

The Review Panel considers the rationale for including abundance indices from the fisheries-independent combined CVID trap/video survey (2010-2014) and data from three fisheries-dependent CPUE series in the BAM stock assessment model to be reasonable. The combination of trap/video survey indices of abundance for the years 2010-2014 is clearly supported since the video camera is mounted on the traps, and thus cannot be considered independent observations. The three fishery dependent indices of relative abundance consisted of data from headboat logbooks (1976–2009), headboat discards (2005–2014), and commercial handline logbooks (1993–2009). The CPUE series were standardized to account for potential biases related to spatial and temporal coverage, and trip type, among other factors. The application of the method of Stephens and MacCall (2004), which takes into account other species than Red Snapper to subset trips in Red Snapper habitats, seems reasonable. The CPUE series had data gaps that required imputations to fill in the missing data points. The pragmatic method of indexing recreational catches against commercial landings and then applying a multiplier to back calculate historic landings, and the imputed values for years with zero discards based on averaging across the current and two adjacent years were considered to be reasonable. The CPUE values from commercial handline and headboat fisheries are likely to be biased indices of abundance for the stock since relatively more fishing effort will be spent in areas with high catch rates (before the 2010 moratorium) , and since the spatial coverage cannot be controlled like in a fishery-independent survey. HB CPUE series cover shallower waters where younger and smaller Red Snapper occur disproportionately more than in the deeper water where the commercial handline fishery spends more effort. A combination of the CPUE series external to the model based on their spatial/depth coverage is an alternative that might be explored in future assessments.

The various sources of systematic errors (e.g., spatial coverage, selectivity) and random errors (e.g., sample sizes) in each individual relative abundance series are well documented. There is some indication of lower discards in the HB fishery immediately following the moratorium (Figure 1; SEDAR41-DW14), which could suggest changes in fishing patterns to avoid snapper catches. The Review Panel is of the opinion that changes in management actions such as the moratorium, mini-season and reductions in bag limits that are expected to alter fishing behavior and hence catchability in fishery-dependent indices should inform decisions on inclusion of data or periods of data in assessments. A member of the SAFMC stated on record that the behavior of anglers has changed substantially since the moratorium, to avoid catching and discarding Red Snapper. The Review Panel, therefore, considers the fishery CPUE series to be applicable only to 2009, the year before the moratorium. CPUE series are also likely to be affected by technology creep in catchability due to improvements in fishing gear, positioning (GPS) and communication systems, and also by rising fuel costs in recent years.

The application of the data in the model follows common practice and appears sound. However, since the CPUE indices of abundance partly cover different depths/areas it should be noted that they do not individually cover the entire stock. Of particular concern is that the age and length composition of data from the headboat fishery likely differ from the data from the commercial fishery that tends to operate in deeper waters. Also, the precision of the CPUE series differs depending on survey design and sample sizes. The results of the stock assessment modeling depend on the relative weights assigned to different data sets. However, there is no consensus amongst practitioners as to the best approach to data weighting. This stock assessment follows the common practice of weighting compositional catch data and abundance indices in two stages. The input data are first assigned relative weights before the model is run, and then iteratively weighted during a model run to improve model fit. Ideally, stage 1 weighting would use information about sample sizes (primary sampling units, and lower level sample sizes) and the way in which the data were collected (i.e., multi-stage survey designs), through calculated precision and effective sample sizes (Francis 2011; Pennington and Vølstad 1994). In particular, abundance indices by cohorts are likely to have different precision due to differences in the number of primary sampling units (e.g., trips, or trap-sets) where the cohorts are caught (Aanes and Vølstad 2015). In general, the multi-stage sampling can introduce complex correlation structures among cohorts, and drastically reduce the effective sample sizes for estimating compositions, and indices of cohorts (Aanes and Vølstad 2015). This would allow different weighting to each data point. The current assessment appears to largely apply ad-hoc weighting of input data. In particular weighting of the fishery-independent abundance indices (across cohorts) in the base model is poorly justified. The inclusion of CPUE indices with fixed CVs (relative standard error) of 0.2 (i.e., equal weights) follows Francis (2003), based on the argument that the CVs of the fishery dependent indices do not reflect true variation in abundance. However, since sample sizes vary over the years, a fixed CV could cause bias. An estimate of the variance of CPUE indices based only on the between-trip variability in CPUE may indeed underestimate the true variance of the CPUE abundance indices if catchability varies over time, which is likely. Pennington and Godø (1995) estimated the actual variance of survey abundance indices by cross-calibrating independent VPA estimates and survey catch per tow indices. For the current BAM assessment, the fishery-independent trap data could potentially be used for cross-calibration of CPUE indices, but since the fishery-independent index only is considered to be from 2010 onwards this is problematic. A pragmatic alternative to the fixed CV of 0.2 for the CPUE series could be to apply this value for an average sample size (number of trips) for each series, and then adjust the CV for actual sample sizes every year.

The input data series appears adequate to support the assessment results and findings. However, the CPUE series are likely to have large uncertainties as measures of abundance, and the trap/video index only covers the recent years. In particular, the fishery-dependent CPUE abundance indices after 2010 are based on discards, and may be biased downwards if the HB and commercial fishery successfully avoids areas with high abundance of snappers.

2. Evaluate and discuss the strengths and weaknesses of the methods used to assess the stock, taking into account the available data, and consider the following:
   d) Are methods scientifically sound and robust?
   e) Are assessment models configured properly and used consistent with standard practices?
   f) Are the methods appropriate for the available data?

The Review Panel agrees with the DW and AW decisions and confirms that the methods are sound and relatively robust. Many stock assessment decisions are somewhat subjective, but alternative decisions were considered and the final decisions were generally well justified. Sensitivity analyses explored a wide range of data decisions, model assumptions and model configurations to examine the robustness of stock status determination. The Monte Carlo Bootstrap procedure also explored many combinations of alternative data and model assumptions.

The Review Panel concluded that the assessment models were reasonably configured and are consistent with standard practices. The BAM is the approved assessment method for many stocks in the South Atlantic Snapper-Grouper complex and is well suited to the fishery-dependent and fishery-independent information available (e.g., life history information, commercial landings and discards, recreational landings and discards, standardized CPUE indices, trap survey indices, length and age sampling). The model has many assumptions and many estimated parameters, but the base model configuration appears to have reasonable assumptions and parameter estimates. The ASPIC model and an Age-Structured Production Model were also applied to aggregate catch and stock biomass indices to provide alternative perspectives on stock status. However, the age-aggregate models do not consider length and age composition data. Although the interpretation of length and age composition data are conditional on assumed forms of selectivity and estimates of selectivity at age, the Review Panel agrees with the AW that length and age composition information is an important source of information. Catch curves of age composition data were provided as exploratory information on trends in maturity, but results are not considered to be a valid basis for status determination, because estimates are imprecise and the implicit assumption of constant mortality rate at age do not appear to be valid. The BAM base configuration is considered to be the most appropriate basis for status determination, because it fully considers important information on demographic structure, including regulated changes in selectivity, age-based maturity and fecundity, and variable recruitment of new age classes. The base configuration of BAM from the AW ('base') was revised with corrected age compositions of the Chevron Trap survey. Results and diagnostics from the AW base model and the corrected base model ('newbase') were similar. The review of methods was based on the Assessment Workshop report and the corrected base model, but conclusions from the RW were confirmed with corrected results.

During the most recent years of the stock assessment series (i.e., the 2010-2014 moratorium), recreational discards are one of the most important sources of information for the assessment. Unfortunately, recreational discards are also one of the most uncertain sources of information. Despite the imprecision in estimates of recreational catch, the BAM base configuration is conditional on catch estimates (e.g., the input CV for catch was 0.05). Exploratory analyses that allow error in landings could not produce a solution, but the Review Panel requested an exploratory analysis that allowed error in the estimates of recreational discards, assuming the MRIP estimates of CV. Exploratory assessment models with more or less catch had similar estimates for the last 30 years (BAM runs S17–S20).

Fishery CPUE indices suggest a greater recent increase in stock biomass and lower mortality (BAM run S4). However, the Review Panel agrees that the fishery-independent index is informative and should be included in the assessment model. Considering the Chevron Trap Survey and Video Survey as separate indices (BAM run S22) also estimates a greater recent increase in stock biomass and lower mortality, but the Review Panel agrees that the two series are not independent and should not be considered as separate indicators of stock trends. An alternative model configuration that included the entire series of Chevron Trap Survey provided similar estimates as the base model.

Accurate interpretation of length and age composition data relies on accurate assumptions about the form of selectivity and estimates of selectivity at age in the fisheries and the survey. The commercial fishery is assumed to be asymptotic (i.e., ‘flat topped’), and the model estimated that all Red Snapper older than age-4 have been fully vulnerable to the commercial fishery since the minimum legal size regulation in 1992. The Review Panel agrees that the flat-topped selectivity assumption for the commercial fishery is justified, because the commercial fishery covers the entire resource area and targets large fish. Assuming ‘dome-shaped’ selectivity (i.e., oldest ages are not full vulnerable) for the commercial fishery (BAM run S21) produced similar results as the base model.

Selectivity of the headboat fleet was assumed to be dome-shaped, and the model estimated full selectivity at ages 3-4 and low selectivity of ages 10+. Selectivity of the general recreational fleet was also assumed to be dome shaped until 2010, with full selectivity at ages 3-4 and low selectivity of ages 10+. Results were not sensitive to how selectivity was estimated for ages 10+ (BAM run S31).

Since 2010 (during the moratorium, mini-seasons and 1-fish bag limit), selectivity of the general recreational fleet was assumed to be flat-topped, with full selection at ages 6+. The Review Panel could not agree on whether the flat-topped assumption is well-justified. The Review Panel requested a sensitivity analysis in which selectivity of the recent general recreational fleet was assumed to be the same as the recent headboat fleet.

Results suggest that the model does not fit age composition data well, underestimating catch at older ages, and estimates are not sensitive to the selectivity assumption of the recent general recreational fleet (Appendix A).

The Review Panel recognizes that the perception of current selectivity used to derive reference points and projections is conditional on poorly-informed assumptions regarding recent fishing behavior, and projections of alternative management scenarios should consider alternative selectivity assumptions that are consistent with each scenario. For example, alternatives that do not allow recreational landings (e.g., moratoria with no mini-seasons) should not assume the *status quo* composite selectivity that includes a flat-topped selectivity for general recreational landings.

The form of selectivity of the Chevron Trap Survey was assumed to be flat topped, and the model estimated that all Red Snapper older than age-3 are fully vulnerable to the trap survey. Public comment suggested that traps may not catch large Red Snapper as efficiently as small Red Snapper. However, some of the largest and oldest samples available are from the trap survey, and efforts to estimate lower selectivity of older ages produced estimates near full selectivity.

The flat-topped selectivity assumption for the Chevron Trap survey implies that relative abundance of old fish is represented by the survey. The assumed shift from dome-shaped selectivity to flat-topped selectivity of the general recreational fishery implies that the recent increase in catch of larger and older fish reflects a shift in selectivity, rather than a proportional increase in the abundance of older fish in the population. Alternative interpretations would require evidence that larger, older Red Snapper are not fully vulnerable to the fishery or the survey.

Attempts to sample larger and older Red Snapper than sampled in the fisheries or trap survey have not been successful. Mitchell et al. (2014 Marine and Coastal Fisheries 6: 142-155 and SEDAR41-RD34) investigated length-specific depth distributions of Red Snapper in the South Atlantic region from two fishery-independent surveys targeting hard-bottom habitats, and reported "*no evidence of a positive relationship between depth and age or length. Additionally, age and length distributions of Red Snapper ≥ 50 cm FL did not differ between fishery-independent surveys and the commercial hook-and-line fishery. These results provide no support for assertions of greater abundances of older and larger Red Snapper in deeper SE USA waters*."

The information available on size selectivity of Red Snapper by survey traps is equivocal on the form of selectivity. Wells et al. (2008, Fisheries Research 89: 294–299 and SEDAR31-RD36) compared catch rates of trawls, small fish traps, chevron traps, and underwater video for sampling Red Snapper in the Gulf of Mexico. They concluded that "*the chevron trap is most effective for sampling adults, while trawls were the most effective gear for sampling age-0 fish*." DeVries et al. (2012, SEDAR31-DW28) compared size samples of Red Snapper from traps and cameras and found that "*the traps* *do select against most Red Snapper >650 mm TL, although fish that large appear to be uncommon in the survey area based on the few stereo measurements obtained*" and "*distributions of the trap fish and that from the stereo images, like in 2011, were very similar*." Therefore, there is insufficient evidence to reject the selectivity assumptions in the assessment. However, the assumptions of asymptotic selectivity of the trap survey and recent recreational fishery should be investigated further in future assessments.

3. Evaluate the assessment findings and consider the following:
    a) Are abundance, exploitation, and biomass estimates reliable, consistent with input data and population biological characteristics, and useful to support status inferences?

The Review panel accepted the new base model with the corrected age compositions for the CVID survey index as the best available model to provide advice for the South Atlantic red snapper fishery. However, the review panel did have concerns such as those discussed below.

The recent Red Snapper fishery comprises two periods of distinct exploitation patterns where the period up to and including 2009 consist of commercial and recreational fisheries with a moratorium on fishing from 2010 to the present. Since 2010 removals albeit reduced have continued through mini-seasons and discard mortality from the headboat and general recreational fishery. This change in the fishery has complicated the monitoring of the fishery because the fishery dependent indices (catch rates from the commercial handline, general recreational and headboat fleets) end in 2009. The SERFS combined video and trap survey index, CVID was introduced in this assessment to cover the moratorium period from 2010 to the present. The annual Red Snapper discard rate from the headboat fleet for 2005 to the present is used to link the fishery dependent indices in the earlier period with the CVID during the moratorium period.

The reliability of model estimates of abundance, biomass and exploitation depend on how well the monitoring indices included in the model track the population trends over time. In this assessment fishery dependent catch rates were used for the pre-moratorium period and were replaced by the CVID survey index for 2010 to the present. The MRIP annual red snapper discard rate from the headboat fleet for 2005 to the present was the only index that spanned the two time periods.

The consistency of the stock status determinations for this combination of monitoring indices was evaluated through a series of sensitivity runs. These runs indicated that the determination of stock status was actually fairly insensitive to changes such as using the longer time series for the CVID (S9), removing the CVID (S4), up-weighting the fishery dependent indices (S3), dropping the headboat discard index for 2010 to the present (S12), dropping the headboat discard index altogether (S16) or only using the CVID

(S23). All indices were well fit by the data, except for the headboat discard rate in the most recent years (Figure 13 of document).

All of these results suggest that the population trends in the model results probably have as much or more to do with the very close fit of the model to the landings, discard data, and associated age compositions as they do with the trends in the monitoring data. CVs were set to 0.05 for the landings and discards, which seems unreasonably low for the MRIP estimates of the latter but a higher CV of 0.20 for discards was investigated in MCB study and the results did not indicate a change in stock status from the base case.

b) Is the stock overfished? What information helps you reach this conclusion?

The estimated abundance for 2014 was at levels not seen in the model since the mid-1960s (Fig. 14 in the assessment report) however the 2014 population mainly consisted of ages 1-4 years (96% by number). Despite these high abundance levels the stock is overfished as $SSB_{2014}/SSB_{F30\%}=0.16$ due to the lack of older fish in the population.

c) Is the stock undergoing overfishing? What information helps you reach this conclusion?

The review panel could not find any evidence against the overfishing determination in the assessment but did have a number serious concerns that are discussed below. The panel also reflected on issues with using <u>apical fishing mortality</u> to monitor the impact of the fishery on the stock over time (*see item e below*)

The determination of overfishing in the assessment relies on the geometric mean of apical F summed across fleets each year over 2012–2014 period. Currently, $F_{2012-2104}/F_{30\%}=2.52$. The retrospective analysis indicated that there was a substantial increase in apical F for 2010 to 2013 with the addition of the 2014 data (Figure 55 in the assessment report). The individual results for the different runs were not presented and it is not known whether the ages at which the apical F's occurred changed with the addition of 2014 data.

Given the retrospective pattern, it is likely that had the red snapper assessment been done a year ago, evidence for overfishing would have been much weaker than presented here. The main change between 2013 and 2014 was that landings and discards by the general recreational fleet were much higher in 2014 vs. 2013 by about 3.7 times for numbers landed and 3.4 times for discard numbers. Estimated increase in weight landed by the general recreational fleet was 3.4 times the 2013 landings. Fishing mortalities associated with general recreational landings and discards make up 78% of the 2014 apical F estimate (Table 14 in the assessment report). The mini-season in 2014 was longer than in previous years and recruits in 2014 were the highest in the time series.

The current determination that overfishing is occurring while the fishery is under moratorium generated much discussion during the panel review. The moratorium has not resulted in a complete closure as there have been landings from mini-seasons in 2011–2014 and removals due to discards during these seasons and throughout the year for recreational fisheries. The estimated fishing mortalities (Figure 27, in the assessment report) reflect the large decrease expected with the introduction of the moratorium in 2010. However since 2010 fishing mortalities have increased from this low point mainly due to discard mortalities and catches from the general recreational fishery. A comparison of mean Fs at ages 1, 2, 3, 4, and 5+ indicates that while fishing mortality was greatly reduced on all age groups in 2010, fishing mortality greatly increased on the older age 4 and 5+ group by 2014 while the Fs for the younger group ages level continued to be lower. The moratorium appears to have been a benefit to the younger fish but not so for fish 4 years and older as interpreted by the selectivity curves used for the moratorium years.

The panel asked for a sensitivity run to investigate the impact of the flat topped selectivity curve assumed for the general recreational fishery by substituting the domed curve used for headboats for 2010–2014. The domed selectivity did not result in any substantial change in stock status from the base case. The fishing mortalities-at-age were not presented by gear so it was not possible to see which age corresponded to apical F for the general recreational landings or discards for either selectivity curve.

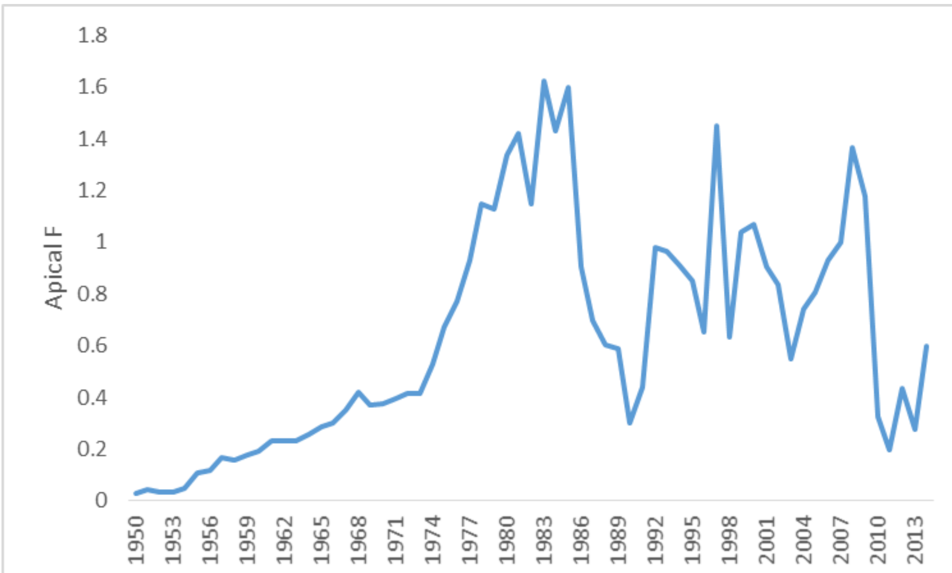
d) Is there an informative stock recruitment relationship? Is the stock recruitment curve reliable and useful for evaluation of productivity and future stock conditions?

The stock recruitment curve was not informative and inference was based on setting steepness to 0.99 and assuming average recruitment. Mean annual recruitment was assumed and lognormal deviations around that mean were estimated in the model.

Recruitment is typically not well estimated in the last year of stock assessments, because there is little information to inform the estimate. The estimate of strong recruitment in the last year of the assessment is supported by the high CVID index as well as the length composition of the headboat fleet. Review Workshop participants reported continued signals of strong recruitment in 2015 fishery and survey data. The Review Panel recognizes that projections are largely dependent on the estimate of recent recruitment, but the estimates of abundance at age from the base model is the most reliable basis for stock status determination and projection.

e) Are the quantitative estimates of the status determination criteria for this stock reliable? If not, are there other indicators that may be used to inform managers about stock trends and conditions?

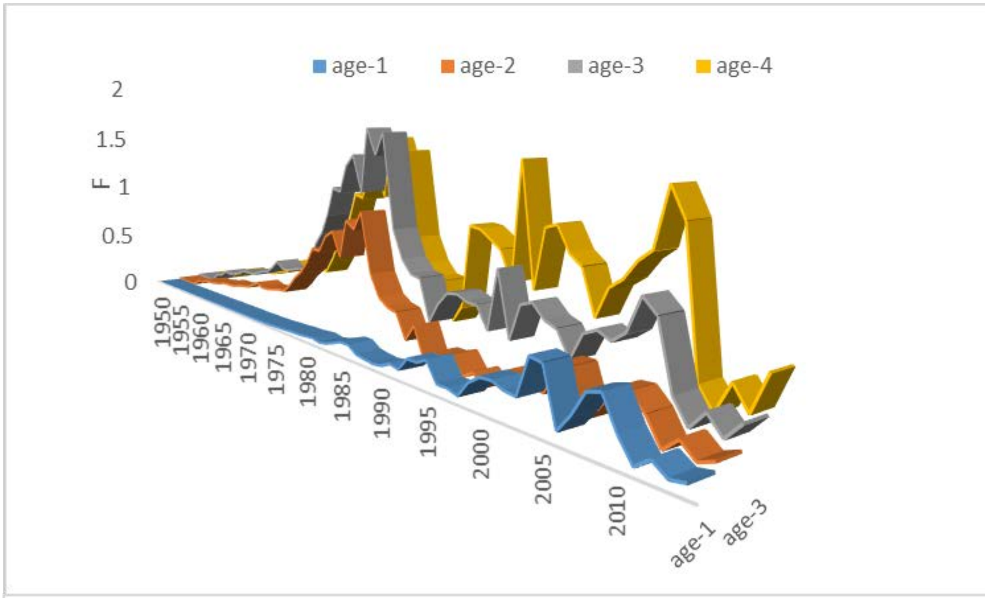
Evaluating trends in F over time requires a metric that is comparable among years and reflects exploitation across a range of ages. Apical F (maximum F at age, Figure 1) is based on a different range of ages among years, because of changing fleet contributions and fleet selectivities. Apical F also does not reflect F for partially selected ages.

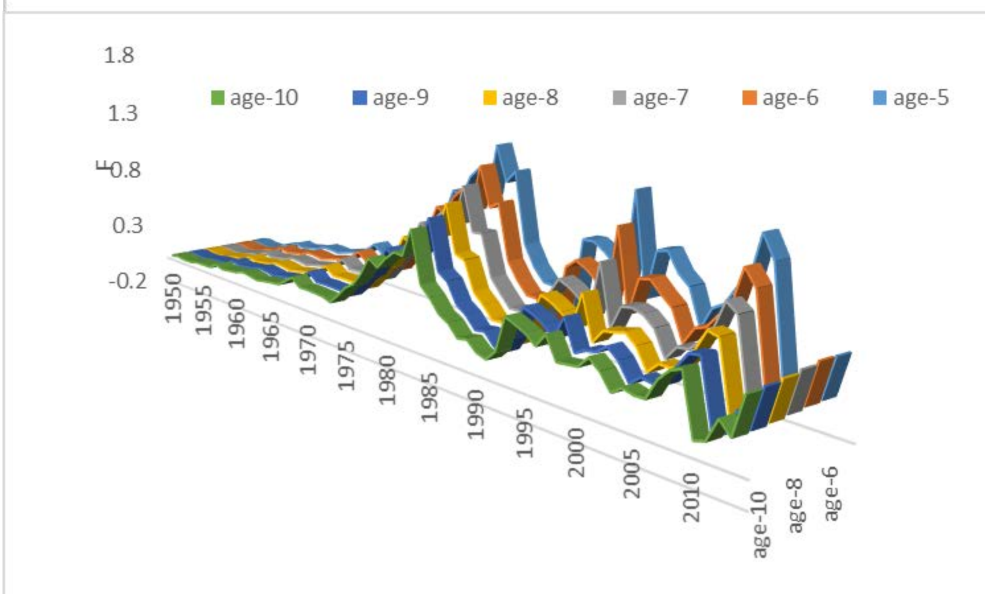


Deciding on a more appropriate metric of F for Red Snapper is challenging because of the complexity of patterns in estimated F at age:

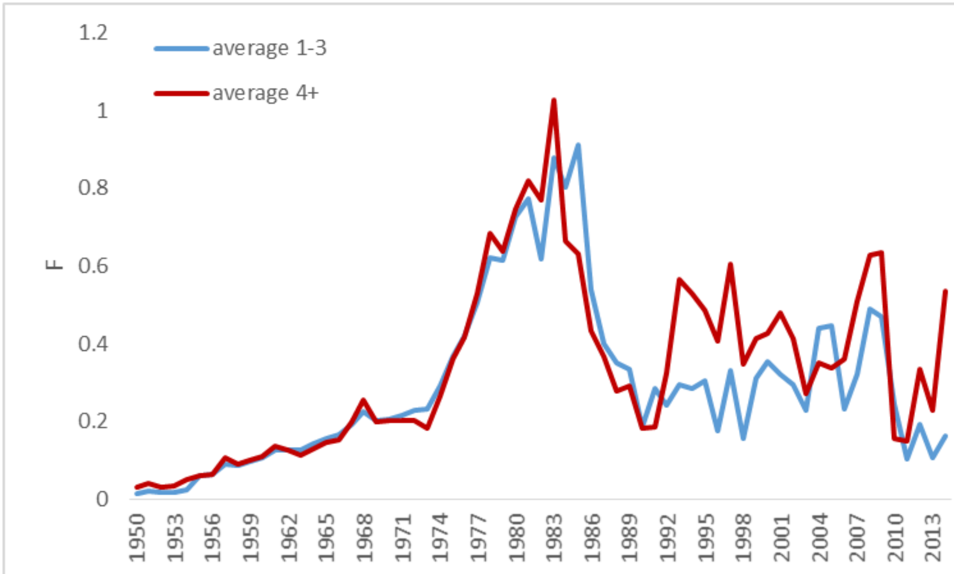
- Age-1 F has one peak in 2004. F was negligible until the mid-1990s, peaked at 0.4 in 2004, then decreased to ~0.1 since 2010.
- Age-2 F had one peak at 1.0 in 1985. F decreased to ~0.1 in the late 1990s, increased to 0.2-0.3 from 1999 to 2010, then decreased to ~0.1 since 2010.
- Age-3 F also had a major peak at 1.6 in the early 1980s, decreased to 0.3-0.5 in the early 1990s, increased to a minor peak of 0.8 in 2008 and decreased to 0.2-0.3 since 2010.
- Age-4 F had three peaks at >1.0 in the early 1980s, 1.5 in 1997 and 1.4 in 2008, then increasing from 0.2 in 2010 to 0.5 in 2014.
- Ages 5 and older have similar patterns in F (three peaks in the early 1980s, 1997 and 2008-2009, then increasing from 2010 to 2014). For most of the time series F

decreases with age, but since 2010, F at ages 5+ is similar, increasing from ~0.2 in 2010 to ~0.5 in 2014.

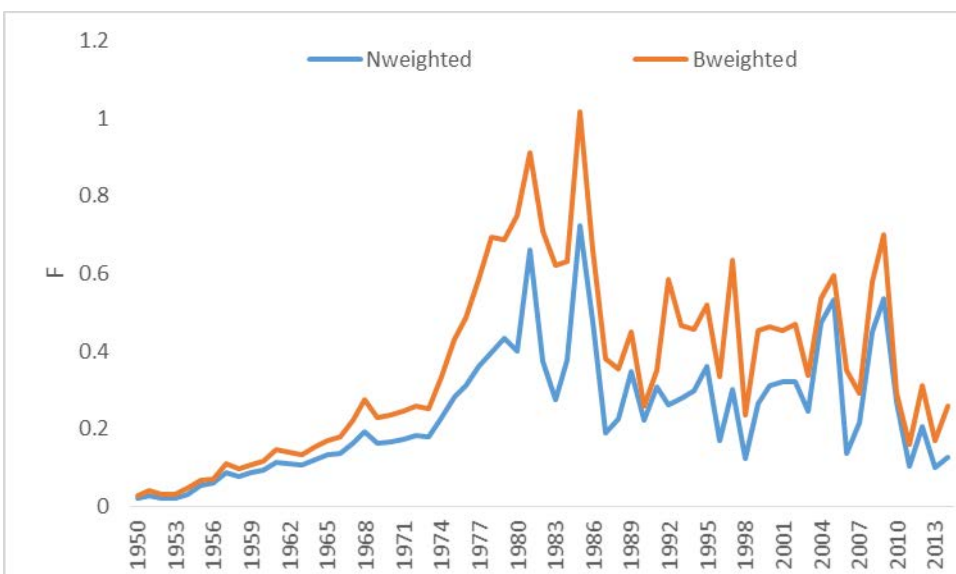




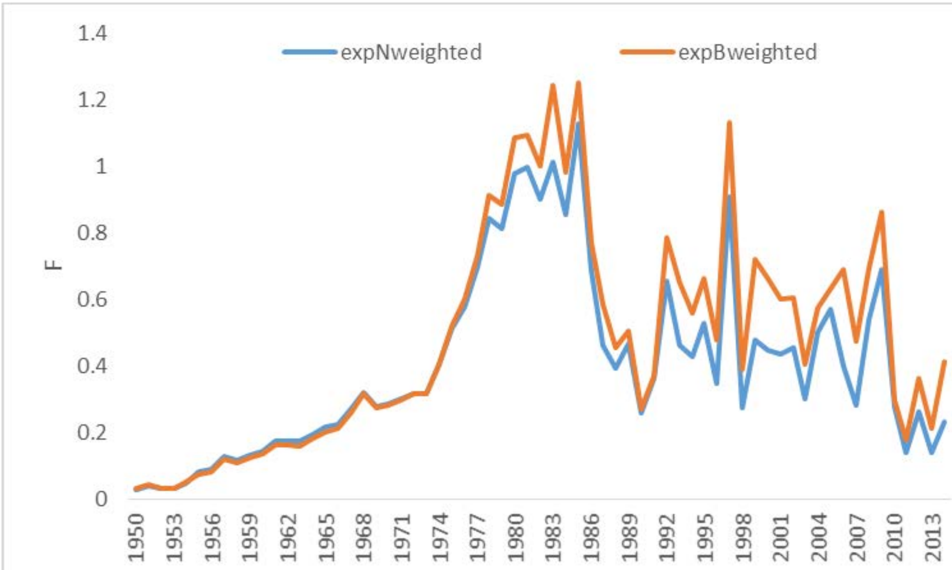
Alternative metrics of F will reflect these patterns differently. Simple average F at age can reflect trends for similar ages (e.g., ages 2-3, ages 4+), and show different recent trends. During the moratorium, F remained low for ages 1-3, but more than tripled for ages 4+.



Average F can be weighted by abundance at age or biomass at age to measure the average F exerted on the entire stock. With young ages typically having greater abundance, abundance weighted average F reflects patterns of F at young ages. Biomass peaks at different ages over the assessment time series (age-20 in 1950, age-2 in 2014), so biomass weighted average F reflects a varying age range.



Average F can also be weighted by exploitable abundance (the product of abundance at age and selectivity at age) or exploitable biomass (the product of biomass at age and selectivity at age) to measure the average F exerted on the exploitable stock. The two exploitable stock average F's are similar, but the exploitable biomass weighted F reflects older ages (e.g., more than doubles during the moratorium) and the exploitable abundance weighted F reflects younger ages (e.g., remains low during the moratorium.



The overfishing limit ($F_{30\%SPR}$) can be expressed in the same currency as the measure of F from the stock assessment. $F_{30\%}$ is currently expressed as Apical F, assuming the average selectivity for the last three years of the stock assessment, which peaks at age-5 (e.g., $F_{30\%}$ expressed as age-5 F is 0.15). All forms of $F_{30\%SPR}$ expressed as an average F are less than age-5 F, because they include some partially recruited ages. According to all of the alternative F metrics considered, overfishing is occurring, but to varying degrees.

Metric	2012-2014 Geo.Mean	F30%	F/F30%
F(age-5)	0.43	0.15	2.8
F(ages 1-3)	0.15	0.06	2.7
F(age-4+)	0.35	0.12	2.8
F(Nwtd)	0.14	0.08	1.8
F(Bwtd)	0.24	0.11	2.1
F(expNwtd)	0.20	0.10	2.0
F(expBwtd)	0.31	0.12	2.5

In conclusion, despite the Review Panel's concurrence that the base BAM configuration can be used for stock status determination the Panel has clearly expressed caveats on some key aspects such as selectivity changes, given the number of parameters being fitted vs. data quality. All the assessment runs clearly show a stock that is abundant at younger ages but overfished in terms of egg production and very slowly recovering. However it is of some concern that the retrospective analysis indicates a substantial upward adjustment of recent F's with addition of 2014 data. Remove 2014 data and the recent Fs are down to around the $F_{30\%}$ reference point (apical values). SSB's are correspondingly adjusted down. The recent strong year classes (age 1 in 2006-2008) appear more stable, but these are feeding progressively into the 5+ age groups from 2010 onwards, the period for which the model sees more adult fish and "wants" to estimate asymptotic selectivity for the general recreational fishery. The Panel expressed concerns that no diagnostics (e.g. parameter correlation tables) were provided to evaluate whether the model has an issue estimating fully selected F's in 2014 vs. recruitment estimates for the strong year classes. There is a potential large uncertainty in the F estimates from the assessment including 2014 data. Some of the age composition data are very well fitted in 2014 – the CVID comps are fitted extremely closely (perhaps too closely!) in 2012 and 2014 and close in 2013, whilst the general recreational age comps are fitted very poorly in 2014 despite a very large sample size and may be an indication of problems with the data for this fishery in 2014. Further, the retrospective analysis indicated that there was a substantial increase in apical F for 2010 to 2013 with the addition of the 2014 data. It is likely that had the red snapper assessment been done up to and including 2013 data, that evidence for overfishing would have been very much weaker than presented here.

4. Evaluate the stock projections, including discussing the strengths and weaknesses, and consider the following:
    e) Are the methods consistent with accepted practices and available data?
    f) Are the methods appropriate for the assessment model and outputs?
    g) Are the results informative and robust, and are they useful to support inferences of probably future conditions?
    h) Are key uncertainties acknowledged, discussed, and reflected in the projection results?

Projections were run to predict stock status in years after the assessment, 2015–2044. The structure of the projection model was the same as that of the assessment model, and parameter estimates were those from the assessment. A single selectivity curve was applied to calculate landings and one for discards, averaged across fleets using geometric mean F's from the last three years of the assessment period, similar to computation of $LF_{30\%}$ benchmarks (§3.22). Expected values of SSB (time of peak spawning), F, recruits, and removals were represented by deterministic projections using parameter estimates from the base run. These projections were built on the spawner-recruit relationship (*h* =

0.99) with bias correction, and were thus consistent with estimated benchmarks in the sense that long-term fishing at $F_{30\%}$ would yield $LF_{30\%}$ from a stock size at $SSB_{30\%}$. Uncertainty in future time series was quantified through stochastic projections that extended the Monte Carlo/Bootstrap (MCB) fits of the stock assessment model.

The projection method is consistent with those used widely in SEDAR assessments based on statistical models such as BAM and Stock Synthesis, and is consistent with the available data. The method used stochastic projections that extended the Monte Carlo/ Bootstrap (MCB) fits of the assessment model with added stochasticity in recruitment, and hence the propagation of uncertainty from the assessment into the projection period is internally consistent.

The Review Panel concluded that the Red Snapper stock projections provided for SEDAR 41 are appropriate for the BAM assessment model and outputs. The results of the projections are informative and robust, and are useful to support inferences of probable future conditions. The projections provide the information needed to develop management advice, showing projections for F=0; $F=F_{CURRENT}$ (geometric mean of the last 3 years); $F=F_{30\%}$; $F=F_{TARGET}$; $F=F_{REBUILD}$ (max exploitation that rebuilds in greatest allowed time (2044). An additional projection was carried out with F from discards only. Each projection shows the 10th and 90th percentiles of the replicate projections allowing an evaluation of the probability of overfishing occurring, or the stock being overfished, for each year in the rebuilding time frame up to 2044. The projections are robust in terms of propagating realistic levels of uncertainty from the accepted base model run.

Key uncertainties in the projections are acknowledged, discussed, and reflected in the projection results. The MCB runs included ranges of values of natural mortality, discard mortality and fecundity at age agreed by the AW, together with bootstrap selection of data using well-justified error distributions and additional random process error in recruitment conditional on the fitted stock recruit pattern with steepness fixed at 0.99. Initial age structure at the start of 2015 was computed by the assessment model, and fishing rates for the projection started in 2017 following an initialization period in 2015-2016 where fishing mortality rates were derived to represent the management measures in place.

5. Consider how uncertainties in the assessment, and their potential consequences, are addressed.
    c) Comment on the degree to which methods used to evaluate uncertainty reflect and capture the significant sources of uncertainty in the population, data sources, and assessment methods.
    d) Ensure that the implications of uncertainty in technical conclusions are clearly stated.

The Review Panel is concerned that many of the reported uncertainties on quantities of interest are a consequence of the assumed (and fixed) observation variance parameters. No clear evidence of the appropriateness of these assumed values has been presented.

Because of the large number of parameters in BAM a thorough evaluation of convergence and model sensitivity is necessary, but difficult. Uncertainties in the assessment were explored through (1) a mixed Monte Carlo and bootstrap (MCB) analysis to quantify random errors in the assessment output; (2) sensitivity analysis around the base BAM run; and (3) the use of alternative assessment models. The Monte Carlo Bootstrap procedure also explored many combinations of alternative data and model assumptions. In the bootstrapping of observed data on landings, information from the headboat program was used to specify a decreasing CV by time blocks (i.e. CV = 0.15 for 1981-1995, CV = 0.1 for 1996-2007, and CV = 0.05 thereafter). These CVs reflect random errors. However, landings from the headboat fishery are monitored through mandatory logbooks, and thus should in principle have zero sampling errors for the vessels in the sampling frame. The CVs may reasonably reflect random errors in reporting. However, various sources of systematic errors (bias) are not reflected through these CVs. It is known that under-reporting of trips does occur, that catch data may not always be 100% accurate (for example due to recall bias if logbooks are not filled in immediately after each trip), and that other variations in reporting likely occur. Because the distribution of such systematic errors is unknown, it is not possible to quantify the magnitude of the resulting uncertainty in the landings.

The input data on catch composition and abundance indices by cohort are obtained from multi-stage sampling programs where fishing trips typically are the primary sampling units (PSUs) for fisheries data, and locations/standardizes trap catches (90 min soak time) are the PSUs for the chevron trap. Substantial correlations can be expected in age or length composition data sets that are constructed from samples/sub-samples from multiple catches (whether from fisheries-independent surveys or fisheries) (e.g., Aanes and Vølstad 2015). The BAM model itself and the MCB is not likely to realistically account for complex error structure in data weighting without prior estimates of the actual variance-covariance matrices for the input data. The robust multinomial approach with number of PSU's as proxy effective sample sizes employed in the uncertainty evaluation of the BAM can only partly reflect the complex error structure. Ideally, it would be possible to run bootstrap resampling on the PSU's to create replicated BAM runs that reflect the complexity in input data, but given the complexity and configuration of BAM this is not possible. The Review Panel therefore considers the uncertainty in the assessment to be appropriately addressed given these restrictions.

The sensitivity analyses were used to explore a wide range of data decisions, model assumptions and model configurations to examine the robustness of stock status determination. The model was run for a plausible range of values for each factor. The

Review Panel noted that the sensitivity testing by alternating one factor at a time, although commonly done, may not fully reflect the uncertainty in model outputs from a complex model such as BAM with a large number of parameters where many are likely to be correlated (e.g., Saltelli and Annoni (2010). Global sensitivity analysis (Saltelli et al. 2008) may be used to untangle the contribution of single factors/parameters and interactions between parameters to the overall variability in model output. Anderson et al. (2011) provide an excellent overview of the literature, and many examples of applications of global sensitivity analysis to Integrated Assessment Models in climate research, and some of these are likely to be applicable to the BAM model. The following is a description of each of the model runs provided to the reviewers during the course of the RW:

S12: (based on the old base model) The headboat discard index was truncated to only include years 2005-2009.

S16: (based on the old base model) The headboat discard index was dropped entirely.

S32: (based on the old base model) The general recreational fleet was set to have the same selectivity as headboat in the last time block (dome-shaped, 2010-2014).

DroppedHBdiscindex: same as S16, except starting with the new base model (corrected chevron trap age compositions).

TruncatedHBdiscindex: same as S12, except starting with the new base model (corrected chevron trap age compositions).

Model uncertainty was mainly explored by running ASPIC (Version 7.03, 2005) that relies on length-age aggregated catch and CPUE indices, with no compositional catch being included. The ASPIC runs resulted in biomass estimates above B_{MSY} and estimates of F below F_{MSY}, and hence do not place the stock in the "overfished-overfishing" category. The difference between the ASPIC and the BAM results can however be explained by the fact that ASPIC does not take into account the age-structure of the catches and the stock. Thus, a biomass made up largely by recruits can result in a stock status of not overfished-overfishing. In addition to ASPIC, a simple catch curve analysis was performed that tended to support the Z values estimated from the BAM. Therefore, despite the many uncertainties and the concerns expressed above the BAM base configuration is therefore considered to provide the most appropriate basis for status determination, despite many sources of uncertainty.

6. Consider the research recommendations provided by the Data and Assessment workshops and make any additional recommendations or prioritizations warranted.
    a) Clearly denote research and monitoring that could improve the reliability of, and information provided by, future assessments.
    b) Provide recommendations on possible ways to improve the SEDAR process.

The Review Panel considers the first three of the following bullets to be the highest priority for assessment improvement.

- Increased fishery independent information, particularly maintaining reliable indices of abundance and composition data streams.
- Improve the reliability of discard data as an abundance index by improving knowledge of private recreational fisherman behavior.
- Research to determine the spatial distribution (horizontal and vertical) of large adult Red Snapper using tracking and telemetry.
- The Review Panel reiterates various research recommendations focused on Red Snapper population structure in the South Atlantic. Red Snapper were modeled in this assessment as a unit stock off the southeastern U.S. For any stock, variation in exploitation and life-history characteristics might be expected at finer geographic scales. Modeling such sub-stock structure would require more data, such as information on the movements and migrations of adults and juveniles, as well as spatial patterns of larval dispersal and recruitment, and spatially-explicit data of all types used in the assessment model. It is unclear whether a spatially-explicit model would improve the assessment. Given the robust ocean circulation in the South Atlantic Bight conditions creating population sub-structure. The research effort necessary to support such an effort would be extensive and probably unjustified on stock assessment improvement grounds, however, it would be needed to support MPA placement, performance evaluation, etc.
- More research to describe the juvenile life history of Red Snapper is needed, including more work to identify the location of juveniles before they recruit to the fishery.
- The effects of environmental variation on the changes in recruitment or survivorship.
- Investigate possible historical changes in sexual maturity. The current estimate of age of sexual maturity is low and unusual for other Lutjanids. Is it right or a compensatory response to heavy exploitation?
- Continue conducting studies to develop a time series of batch fecundity to obtain information on the inter-annual variation in reproductive output.

7. Consider whether the stock assessment constitutes the best scientific information available using the following criteria as appropriate: relevance, inclusiveness, objectivity, transparency, timeliness, verification, validation, and peer review of fishery management information.

The Review Panel considers that the BAM assessment for Red Snapper constitutes the best scientific information available, and fulfils the following criteria:

Relevance: The SEDAR 41 assessment is highly relevant as the Red Snapper stock is depleted and undergoing rebuilding under a moratorium with limited landings permitted and most catches being discarded. The data and assessment provide the best means of establishing the rate of recovery of the stock, determining if measures are preventing overfishing, and providing information that can be used to adjust management actions where appropriate.

Inclusiveness: The SEDAR 41 assessment includes all data that have been quality assured and proved adequate for use in the assessment. This includes data from State as well as Federal sampling schemes where needed, for example to estimate discards during the mini-season where MRIP sampling is too limited for such a short season length.

Objectivity: The SEDAR 41 BAM model is a highly objective procedure based on well-tested statistical modeling principles, and using data sets and assumptions that have been rigorously documented and reviewed through the SEDAR data, assessment and peer-review process. Where fully objective decisions are difficult to make, such as some decisions on scenarios for historic catches where evidence is lacking, the uncertainties around the decisions made have been explored and included in sensitivity analyses and the Monte Carlo Bootstrap evaluation of assessment uncertainty.

Transparency: All outputs of the data, assessment and review workshops in SEDAR 41 are fully documented and publicly available. The discussions at the review workshop are also recorded for record. All data sets are thoroughly explored and the quality of data on which the assessment is based is documented and transparent, as are all decisions related to the choice of assessment model, how it is implemented, and the results of the base run and sensitivity and uncertainty analyses.

Timeliness: The SEDAR process in general is arranged to provide timely fishery management advice where it is needed, and to ensure that assessments are benchmarked and reviewed at appropriate intervals.

Verification: The SEDAR 41 assessment process and deliverables comply with legal requirements under the Magnuson Stevens Act (2007) for developing and monitoring of fishery management plans and providing information on stock status.

Validation: The SEDAR 41 process is designed to meet the needs of fishery managers for peer-reviewed stock assessments and associated advice on stock status and future catches, and the process is open and fully transparent to the fishery managers and to stakeholders from commercial and recreational fisheries, conservation groups or others with a stake in the outcomes and who have opportunity to give their views on record.

Peer review: The SEDAR 41 process includes full peer-review by experts appointed by the Center for Independent Experts (CIE, University of Miami) and by reviewers from the SAFMC SSC. The review panel report and the independent CIE reviews are publicly available

8. Compare and contrast assessment uncertainties between the Gulf of Mexico and South Atlantic stocks.

   Both the South Atlantic and Gulf of Mexico Red Snapper stock assessments have multiple uncertainties. The table below summarizes the significant sources of assessment uncertainty in the population, data sources, and assessment methods for both stocks.

Sources of Uncertainty	**South Atlantic (SEDAR 41)**	**Gulf of Mexico (SEDAR 31)**
Population	• Juvenile life history, including the location of juveniles before they recruit to the fishery • Spatial distribution (horizontal and vertical) of large adult Red Snapper • Variability in batch fecundity and spawning frequency with size and age • Effects of environmental variation on changes in recruitment • Density-dependent changes in growth, reproduction, and natural mortality	• Population structure and connectivity between eastern and western Gulf (for both adults and juveniles) • The use and effect of artificial reef structures on red snapper population abundance, age and length composition, and spatial distribution Effects of environmental variation on changes in recruitment • Density-dependent changes in growth, reproduction, and natural mortality
	• Limited fishery independent indices of abundance • No fishery independent index of abundance for early juveniles	• Limited fishery independent index of abundance for early juveniles • Limited information on the magnitude, size, and age composition of discards

Data Sources	• Changes in selectivity, catch, and discard data due to changes in fisher behavior within and outside the mini-season • Poor information on the magnitude, size, and age composition of discards • Poorly-informed selectivity functions for most fleets	• Poorly-informed selectivity functions for most fleets
Assessment Methods	• Uninformative Stock-Recruitment relationship (had to use proxy reference points) • Uncertainty for certain parameters and data inputs was fixed to chosen values that could be considered arbitrary (e.g., CV for landings and discards set = 0.05) • Model uncertainty was mainly explored by running an alternative Stock Production Model	• Uninformative Stock-Recruitment relationship (had to use proxy reference points) • Uncertainty for certain parameters and data inputs was fixed to chosen values that could be considered arbitrary (e.g., CV for landings set = 0.05 and for discards = 0.5) • Model uncertainty was not explicitly explored by the use of different models

9. Provide guidance on key improvements in data or modeling approaches which should be considered when scheduling the next assessment.

   The RW Panel recommends that given the data and model complexities inherently associated with stock assessment of South Atlantic Red Snapper, more realistic timelines be considered for the next assessment.

   Additionally, given that the input data on catch-at-age and abundance indices by cohort are likely to be cluster-correlated (Nelson 2014), and therefore have low effective sample sizes, it is problematic that the BAM model has a very large number of parameters. It would therefore make sense to provide alternative runs using more parsimonious models to get a wider evaluation of the robustness of the assessment. One recommended candidate is a statistical assessment model (XSAM) (Sondre Aanes, Norwegian Computing Center) recently applied in the ICES Benchmark Assessment for Norwegian Spring Spawning Herring, and approved as the standard assessment model. This model template is based on a state-space model and structural time series models for fish stock assessment (inspired by Gudmundsson 1994), and includes the DTU Aqua SAM model (Nielsen and Berg 2014) that is widely used in ICES as a special case. The main advantage of this XSAM model template is that it can utilize the sampling distributions derived from analysis of sample survey data (estimated catch-at-age, and abundance indices at age) by giving appropriate weights to input-data points. It is coded in TMB (R library) which is efficient for nonlinear models with latent variables.

Another important point in addressing future assessments of South Atlantic Red Snapper is that it would be extremely useful for the Review Panel to see direct estimates of total removals by age-class across fleets (each fleet is essentially a stratum when it comes to estimating the age-composition of removals). This would allow the Panel to see how well cohorts are tracked in the fisheries data. The selectivity by fleet is only relevant when trying to use the fishery-dependent data as indices of abundance. However, selectivity in this context is muddled by the spatial coverage of each fleet. For example, two fleets using same gear (with same selectivity) would end up with different age-compositions if they operate in different areas (depths), if in fact the population by age-class differs by area (depths), which seems to the case for Red Snapper. Therefore, the Review Panel has struggled to understand how multiple abundance indices from fisheries-dependent data that each only covers portions of the stock can be pooled within the BAM model to yield representative indices for the entire stock. In the suggestions made above regarding the use of alternative assessment models (Gudmundsson 1994, and refinements by Aanes), input data from fisheries are total estimates across fleets of yearly removals by age-class and have an associated variance-covariance matrix that reflects the complex cluster sampling.

Another recommendation from the Review Panel concerns the process used for standardization of the CVID index of abundance. The CVID index was derived from fitting a Zero-Inflated Negative Binomial (ZINB) generalized linear model to individual catches with polynomials (degree) of depth (3), temperature (2) and Latitude (7) fit to catches greater than zero and polynomials (degree) of depth (3) and Latitude (4) fit to the zero-inflation portion of the model. Standardized index for each year was based on converting each covariate (all continuous except year) to a sequence of a small number of evenly space values over the range of each covariate over all the years. These converted covariates were used to predict catches over all years with the effect added and then averaged within each year to give annual indices. The variances of these indices were estimated by bootstrapping observed catches and associated covariates and running each bootstrap through the above process. This standardization approach amounts to predicting the catch expected for the mean of the converted covariates. Bootstrapping the individual Chevron trap sets implicitly assumes that the covariates are a random sample from a population of potential covariate values. In this case, the range of covariate values will vary over bootstrap samples and so will mean of the converted covariates. This may be appropriate in a case of a one-off analysis of the survey data for any one year but the focus of standardization is to have a fixed set of covariate variables. In addition, changes in the range of the covariates in the bootstrap samples may not support the original fitted model, especially for coefficients of high degree polynomials.

As an alternative, bootstrapping of the residuals from the original model fit to the data may be more appropriately estimate the variance of the standardized survey index. In this case the residuals (in the appropriate scale) are randomly combined with the predicted values to give new observations that are then used to fit the ZINB model. The range of the covariates and mean of the converted covariates will stay the same over all of the bootstrap replications and the variances of the annual indices will be a function of the variability of the residuals from the fitted model.

10. Prepare a Peer Review Summary summarizing the Panel's evaluation of the stock assessment and addressing each Term of Reference. Develop a list of tasks to be completed following the workshop. Complete and submit the Peer Review Summary Report in accordance with the project guidelines.

    This report constitutes the Review Panel's summary evaluation of the stock assessment and discussion of the Terms of Reference. The Review Panel will complete edits to its report and submit a final document to the SEDAR program for inclusion in the full set of documents associated with SEDAR 41.

References

Aanes, S., and Vølstad, J. H. 2015. Efficient statistical estimators and sampling strategies for estimating the age composition of fish. Canadian Journal of Fisheries and Aquatic Sciences, 72(6): 938-953.

Anderson, B., Emanuele Borgonovo, Marzio Galeotti and Roberto Roson. 2012. Uncertainty in Integrated Assessment Modelling: Can Global Sensitivity Analysis Be of Help? Working Paper Series. Working Paper 52. ISSN 1973-0381. IEFE - The Center for Research on Energy and Environmental Economics and Policy at Bocconi University. This paper can be downloaded at www.iefe.unibocconi.it

Francis, Chris RIC, Rosemary J. Hurst, and James A. Renwick. 2003. Quantifying annual variation in catchability for commercial and research fishing. Fishery Bulletin 101: 293-304.

Francis, RIC Chris. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68: 1124-1138.

Gudmundsson, G., 1994. Time series analysis of catch-at-age observations. Journal of the Royal Statistical Society: Series C (Applied Statistics) 43: 117–126.

Mitchell, W. A., Kellison, G. T., Bacheler, N. M., Potts, J. C., Schobernd, C. M., & Hale, L. F. 2014. Depth-related distribution of post-juvenile Red Snapper in southeastern US Atlantic Ocean waters: ontogenetic patterns and implications for management. Marine and Coastal Fisheries, 6(1): 142-155.

Nelson, G.A. 2014. Cluster Sampling: a pervasive, yet little recognized survey design in fisheries research. Trans. Am. Fish. Soc. 143: 926–938.

Nielsen, A., and Berg, C.W. 2014. Estimation of time-varying selectivity in stock assessments using state-space models. Fish. Res. 158: 96–101.

Pennington, Michael, and Olav Rune Godø. 1995. Measuring the effect of changes in catchability on the variance of marine survey abundance indices. Fisheries research 23: 301-310.

Pennington, M., and Vølstad, J. H. 1994. Assessing the effect of intra-haul correlation and variable density on estimates of population characteristics from marine surveys. Biometrics, 725-732.

Saltelli, A., and P. Annoni (2010), 'How to Avoid a Perfunctory Sensitivity Analysis', Environmental Modelling & Software 25, 1508-1517.

Saltelli, A., S. Tarantola, F. Campolongo, and M. Ratto (2004), Sensitivity Analysis in Practice - A Guide to Assessing Scientific Models (Chichester: John Wiley & Sons).

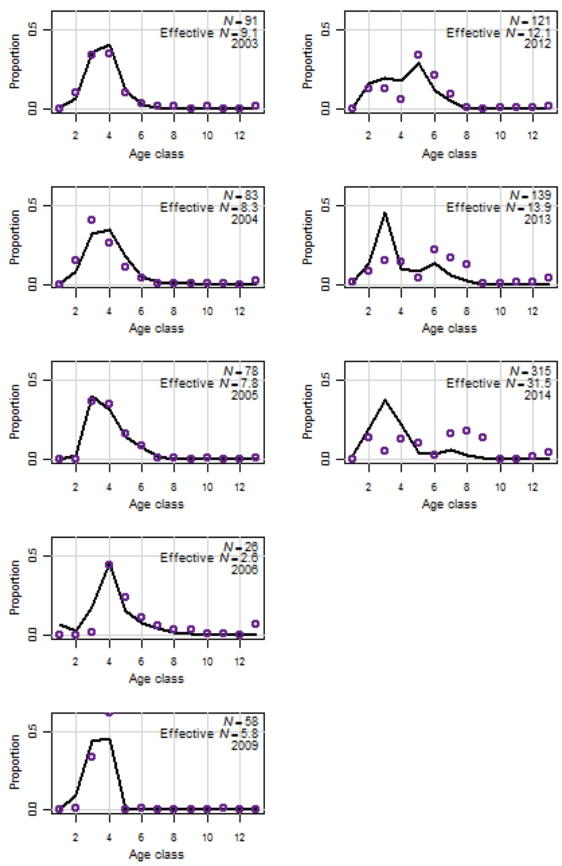
Saltelli, A., M. Ratto, T. Andres, F. Campolongo, J. Cariboni, D. Gatelli, M. Saisana, and S. Tarantola. 2008. Global Sensitivity Analysis - The Primer. John Wiley & Sons. Chichester.

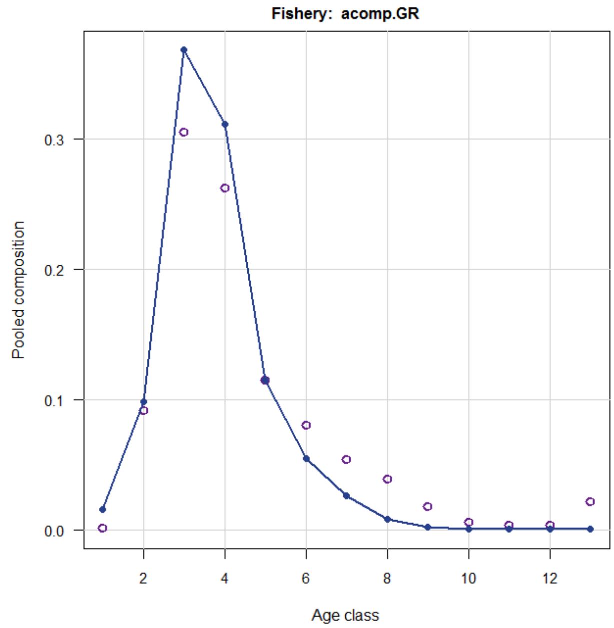
Stephens, A., and MacCall, A. 2004. A multispecies approach to sub-setting logbook data for purposes of estimating CPUE. Fisheries Research, 70: 299-310.

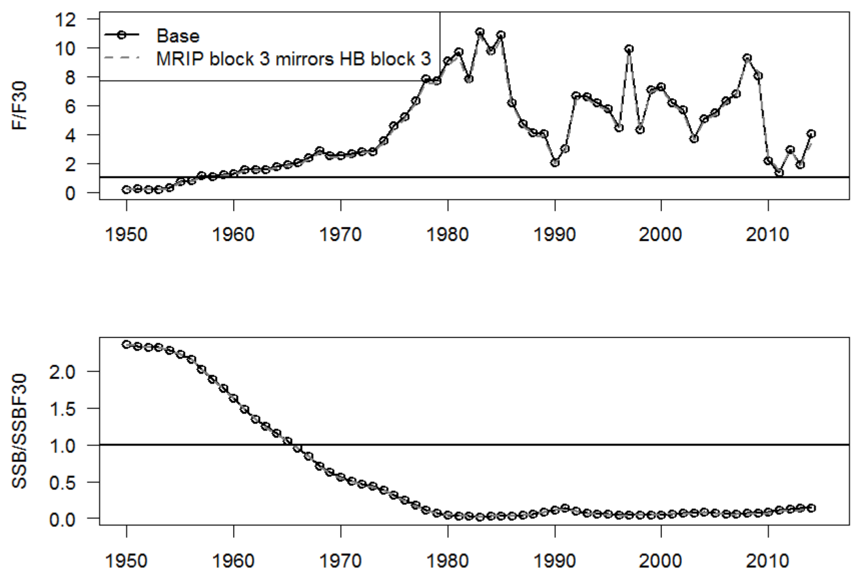
2.2 Summary Results of Analytical Requests

Additional analyses were provided to the Review Panel for consideration at the Panel's request. These materials are provided in Appendix A to the Review Workshop Report.

Appendix A. BAM sensitivity run assuming that selectivity of the general recreational fleet 2010-2014 is the same as the headboat fleet (block 3).




Fishery: acomp.GR
Pooled composition
Age class
0.0
0.1
0.2
0.3
2
4
6
8
10
12


Base
MRIP block 3 mirrors HB block 3
F/F30
SSB/SSBF30
1950
1960
1970
1980
1990
2000
2010

SEDAR

Southeast Data, Assessment, and Review

SEDAR 41

South Atlantic Red Snapper

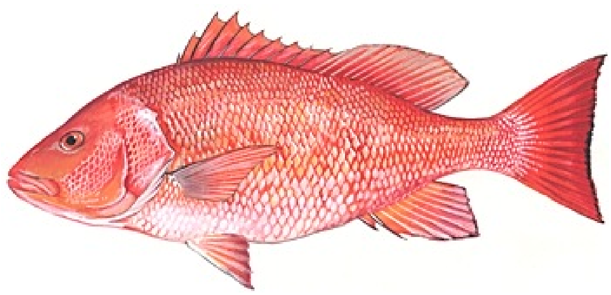
SECTION VI: Addenda 1

April 2016

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

Stock Assessment of Red Snapper off the Southeastern United States

SEDAR Benchmark Assessment



Southeast Fisheries Science Center

National Marine Fisheries Service

Last revision: April, 2016

Document History

February, 2016 Original release.

March, 2016 This release incorporates some of the corrections made during the Review Workshop, including corrected age composition data from the MARMAP program.

April, 2016 This release incorporates all of the corrections made during the Review Workshop, including corrected chevron trap age composition data. The corrections resulted in a new base run, for which iterative reweighting of the likelihood components and the starting value analysis were re-run. The new base run results, including updated uncertainty analyses and projections are included. The sensitivities and retrospectives, however, are unchanged. The Reviewers did not request that sensitivities or retrospectives be re-run because the base run changes were relatively small.

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2 Data Review and Update

The input data for this assessment are described below, with focus on modifications from the SEDAR41 DW.

2.1 Data Review

In this benchmark assessment, the Beaufort assessment model (BAM) was fitted to data sources developed during the SEDAR 41 DW with some modifications and additions.

Model input compiled during the DW

- Life history: Life history meristics, population growth, female maturity, proportion female, number of batches at age, size-dependent batch fecundity, and discard mortality
- Landings and discards: Commercial handline landings and discards, Headboat landings and discards, Recreational landings and discards
- Indices of abundance: Commercial handline, Headboat, Headboat discards, SERFS chevron trap, SERFS video

Model input modified or developed after the DW

- Life history: Fishery-dependent growth estimates, Growth estimates during the 20 inch size regulation, Age–specific natural mortality
- Landings and discards: changes to the recreational discards
- Indices of abundance: Fishery–independent indices combined (Chevron trap and Video)
- Length compositions: Commercial handline, Headboat, Recreational
- Age compositions: Commercial handline, Headboat, Recreational, Chevron trap

2.2 Data Update

2.2.1 Life History

Estimates of the von Bertalanffy growth parameters were provided by the DW for the population as a whole: (911mm, 0.24yr^{-1}, and -0.33yr). Two alternative von Bertalanffy curves were generated: one for all fisheries when no size limit was in place, and another to represent the fish captured by all fisheries under a 20 inch size limit regulation. Age-specific mortality was updated due to an error in the original calculation which forced the t_0 value to 0. Life-history information is summarized in Tables 1 and 2.

2.2.2 Landings and Discards

The fleet structure to be modeled was decided after the DW. The general recreational fleet comprises the charterboat and private boat fleets, while the headboat fleet stands alone. The decision was made to separate headboat from all other recreational fishing modes because length compositions diverge later in the time series. The general recreational fleet discards contained some zeros (years 1982, 1986, and 1990) that the panel considered unlikely to be accurate due to the magnitude of the surrounding years' values. The decision was made by the panel to fill in the zeros with the lowest observed discards in the regulatory time block of the zero value. Total removals as used in the assessment are in Table 3.

2.2.3 Indices of Abundance

The DW provided a SERFS chevron trap and video index separately. However, because the data are collected from the same sampling platforms (i.e. cameras mounted on the chevron traps), the two indices are not independent measures of abundance. Therefore, the panel decided to combine the two using the Conn (2010) method for combining indices. All indices and their corresponding CVs are shown in Table 4, and Figure 1 shows the indices as recommended by the data workshop plotted with the new CVID index for comparison. Fishery dependent indices of abundance were assumed to have CVs of 0.2, which is consistent with Francis (2003).

2.2.4 Length Compositions

Length compositions for all data sources were developed in 3-cm bins over the range 21–99 cm (labeled at bin center). All lengths below and above the minimum and maximum bins were pooled. The commercial handline, general recreational and headboat lengths were weighted by the region and landings (SEDAR41-AW05 2015). For inclusion, length compositions in any given year had to meet the sample size criteria of $nfish > 30$ and $ntrips \geq 10$ (Table 5). Furthermore, the AW panel decided to eliminate length comps where age comps were available. There were conflicts between the length compositions and age compositions, and the panel thought, given the relative ease of ageing this species and the fact the model is age-structured, the age compositions would provide more informative signals of year-class strength and better represent the catch in each fleet or survey.

2.2.5 Age Compositions

For age composition data, the upper range was pooled at 13 years old because a very small proportion of the data exist past age 13. The age compositions were weighted by the length compositions in attempt to address bias in selection of fish to be aged. For inclusion, age compositions in any given year had to meet the sample size criteria of $nfish > 10$ and $ntrips \geq 10$ (Table 5). Age composition was preferred over length composition when both were available from a given fleet in a given year. Age compositions were further corrected at the Review Workshop (SEDAR41-RW07 2016).

2.2.6 Additional Data Considerations

Size limits were in place beginning in 1983 (12 inch minimum size limit TL), and changed in 1992 (20 inch minimum size limit TL). A moratorium was put in place for Red Snapper in 2010, and three subsequent mini-seasons were allowed (2011-2014) with no size limit. The panel examined size composition data and determined that three time blocks should be used to account for size limits, or the lack thereof: 1950-1991, 1992-2009, and 2010-2014. Data available for this assessment are summarized in Tables 1–5.

3 Stock Assessment Methods

3.1 Overview

The primary model discussed during the Assessment Workshop (AW) was a statistical catch-age model implemented using the Beaufort Assessment Model (BAM) software (Williams and Shertzer 2015). BAM applies a statistical catch-age formulation, coded using AD Model Builder (Fournier et al. 2012). BAM is referred to as an integrated analysis because it uses all population dynamics-relevant data (e.g. removals, length and age compositions, and indices of abundance) in a single modeling framework. In contrast, production models (e.g. ASPIC or ASPM) or catch curve analyses only use subsets of the available data and often require simplifying assumptions. In essence, the catch-age model simulates a population forward in time while including fishing processes (Quinn and Deriso 1999; Shertzer et al. 2008). Quantities to be estimated are systematically varied until characteristics of the simulated population matches available data on the real population. The model is similar in structure to Stock Synthesis (Methot 1989; 2009). Versions of BAM have been used in previous SEDAR assessments of reef fishes in the U.S. South Atlantic, such as Red Porgy, Black Sea Bass, Tilefish, Blueline Tilefish, Gag, Greater Amberjack, Red Grouper, Snowy Grouper, and Vermilion Snapper, as well as in the previous SEDAR assessments of Red Snapper (SEDAR24 2010). In addition, a surplus production model implemented using ASPIC and a catch curve analysis (SEDAR41-AW08 2015) were used to provide supplementary information.

3.2 Data Sources

The catch-age model included data from three fleets that caught Red Snapper in southeastern U.S. waters: general recreational (charter and private boat), commercial handlines (hook-and-line), and recreational headboats. The model was fitted to data on annual landings (in numbers for the recreational fleets, in whole weight for commercial fleet); annual discards (in numbers for all fleets), annual length compositions of removals; annual age compositions of landings and surveys; three fishery dependent indices of abundance (commercial handlines, headboat, and headboat discards); and one fishery independent index of abundance (combined SERFS chevron trap and SERFS video index). Removals included landings and dead discards, assuming the mortality rates provided by the Data Workshop. Data used in the model are tabulated in §2 of this report.

3.3 Model Configuration

The assessment time period was 1950–2014. A general description of the assessment model follows.

3.4 Stock dynamics

In the assessment model, new biomass was acquired through growth and recruitment, while abundance of existing cohorts experienced exponential decay from fishing and natural mortality. The population was assumed closed to immigration and emigration. The model included age classes $1 - 20^+$, where the oldest age class 20^+ allowed for the accumulation of fish (i.e., plus group).

3.5 Initialization

Initial (1950) numbers at age assumed the stable age structure computed from expected recruitment and the initial, age-specific total mortality rate. That initial mortality was the sum of natural mortality and fishing mortality, where fishing mortality was the product of an initial fishing rate (F_{init}) and F-weighted average selectivity. The initial fishing rate was estimated using a prior centered around $F_{\text{init}} = 0.03$. The assumption matches what was used for SEDAR24 with the justification that the value should be small given the relatively low volume of landings prior to the assessment period. The initial recruitment in 1950 was assumed to be the expected value from the spawner-recruit curve. For the remainder of the initialization period (1950–1977), recruitment was assumed equal to expected values. Without sufficient age/length composition data prior to 1978, there is little information to estimate those historic recruitment deviations with accuracy.

3.6 Natural mortality rate

The natural mortality rate (M) was assumed constant over time, but decreasing with age. The form of M as a function of age was based on Charnov et al. (2013), a change from SEDAR24 which based natural mortality on the findings of Lorenzen (1996). The Charnov et al. (2013) approach inversely relates the natural mortality at age to somatic growth. As in previous SEDAR assessments, the age-dependent estimates of M_a were rescaled to provide the same fraction of fish surviving from age 4 through the oldest observed age (51 yr) as would occur with constant $M = 0.134$. This approach using cumulative mortality allows that fraction at the oldest age to be consistent with the findings of Then et al. (2014).

3.7 Growth

Mean size at age of the population, fishery removals under no size limit, and fishery removals under a 20 inch size limit (total length, TL) were modeled with the von Bertalanffy equation, and weight at age (whole weight, WW) was modeled as a function of total length (Figure 2, Table 2). Parameters of growth and conversions (TL-WW) were treated as input to the assessment model. For fitting length composition data, the distribution of size at age was assumed normal with a CV estimated by the assessment model for each growth curve.

3.8 Female maturity and sex ratio

Female maturity was modeled with a logistic function; parameters for this model and a vector of maturity at age were provided by the DW and treated as input to the assessment model (Table 2). The sex ratio was assumed to be 50:50, as recommended by the DW.

3.9 Spawning stock

Spawning biomass was modeled as population fecundity (number of eggs). For Red Snapper, peak spawning was considered to occur at the end of June. This included information on batch size as a function of age, as well as information on the number of annual batches as a function of age (SEDAR41-DW49 (2015) and Fitzhugh et al. (2012)).

3.10 Recruitment

Expected recruitment of age-1 fish was predicted from spawning biomass using the Beverton–Holt spawner-recruit model. Steepness, h, is a key parameter of this model, and unfortunately it is often difficult to estimate reliably (Conn et al. 2010). In this assessment, many initial attempts to estimate steepness resulted in a value near its upper bound of 1.0, indicating that the data were insufficient for estimation. Likelihood profiling showed that the value was likely above 0.92, and was unreliably estimated between 0.92 and 0.98. The AW Panel decided to assume an average annual recruitment while estimating lognormal deviations around that average. This was achieved by fixing steepness at $h = 0.99$.

3.11 Landings

Time series of landings from three fleets were modeled: commercial handline (1950–2014), general recreational (1955–2014), and headboat (1955–2014). Landings were modeled with the Baranov catch equation (Baranov 1918) and were fitted in either weight or numbers, depending on how the data were collected (1000 lb whole weight for commercial fleets, and 1000 fish for recreational). The DW provided observed landings back to the first assessment year (1950) for the commercial fleet and back to 1955 for the recreational fleets. However, sampling of headboats began in 1972 and other recreational sectors in 1981. Thus, historic landings of the recreational fleets were estimated indirectly by the DW using the FHWAR ratio method (SEDAR41 41dw17). Historic landings were considered (and treated) in this assessment as a primary source of uncertainty.

3.12 Discards

As with landings, discard mortalities (in units of 1000 fish) were modeled with the Baranov catch equation (Baranov 1918), which required estimates of discard selectivities and release mortality probabilities. Discards were assumed to have fleet-specific, year-specific mortality probabilities, as suggested by the DW. Until 2007, the rate for commercial handlines was 0.48, and 0.38 thereafter. Until 2011, the general recreational and headboat rate was 0.37, with 0.285 thereafter. Annual discard mortalities, as fit by the model, were computed by multiplying total discards (tabulated in the DW report) by the fleet-specific and year-specific discard mortality rate. For general recreational and headboat fleets, discard time series were assumed to begin in 1981; for the commercial handlines fleet, discards were modeled starting in 1992 corresponding to the implementation of the 20-inch size limit.

3.13 Fishing

For each time series of removals (landings and discards), the assessment model estimated a separate full fishing mortality rate (F). Age-specific rates were then computed as the product of full F and selectivity at age. The across-fleet annual F was represented by apical F, computed as the maximum of F at age summed across fleets.

3.14 Selectivities

Selectivity curves applied to landings were estimated using a parametric approach. This approach applies plausible structure on the shape of the curves, and achieves greater parsimony than occurs with unique parameters for each age. Flat-topped selectivities were modeled as a two-parameter logistic function. Dome-shaped selectivities were modeled by combining two logistic functions: a two-parameter logistic function to describe the ascending limb of the curve, and a two-parameter logistic function to describe the descending limb. To model landings, the AW Panel recommended flat-topped selectivity for commercial handlines and dome-shaped selectivity for headboat and the general recreational fleets.

The assessment panel devoted substantial discussion and exploration to the pattern (flat-topped or dome-shaped) of selectivity at age. Several working papers and scientific literature (SEDAR24-AW05, SEDAR24-AW09, SEDAR24-AW12, SEDAR31-AW04, SEDAR31-AW12, SEDAR41-DW50, SEDAR41-DW08, Patterson et al. (2012), Wells et al. (2008), and Mitchell et al. (2014)) helped guide the panel's decisions by providing insight into selectivity based on length and age compositions, depth distributions of fishing effort, skill levels of fishermen, and how circumstances contrasted between the Atlantic and Gulf of Mexico. The choice of flat-topped selectivity for commercial handlines landings and dome-shaped for all others was based on several criteria. Two related considerations were the fleet-specific depths of fishing effort and the distribution of age at depth. In general, the commercial handlines fleet fish

in deeper water than other fleets, and although there was only weak correlation between depth and age of older fish (5^+), younger fish (1–5) were more readily caught in shallower depths (SEDAR24-AW05, and Mitchell et al. (2014)). It was also suggested that commercial gear and fishermen can better handle larger fish (SEDAR24-AW12). Catch curve data were consistent with the hypothesis that older fish are more vulnerable to the commercial handlines fleet than to recreational fleets (SEDAR41-AW08 2015).

Selectivity of each fleet was fixed within each block of size-limit regulations, but was permitted to vary among blocks where possible or reasonable. Fisheries experienced four blocks of size-limit regulations (no limit prior to 1983, 12-inch limit during 1983–1991, 20-inch limit during 1992–2009, and no size limit during the moratorium/miniseasons 2010–2014). However, the panel combined blocks one and two after seeing that the 12-inch size limit had a negligible effect on the selectivity pattern. Age and length composition data are critical for estimating selectivity parameters, and ideally, a model would have sufficient composition data from each fleet over time to estimate distinct selectivities in each period of regulations. That was not the case here, and thus additional assumptions were applied to define selectivities, as follows. Because the general recreational fleet had little age or length composition data prior to 1998, this fleet mirrored the headboat fleet until the final time block. All domed-shaped selectivities meant to characterize landings were configured so as not to allow a selectivity of 0 at older ages, which was considered implausible. Size and age composition data show larger, older fish are caught by all fleets. However, the selectivity functions would reach zero before the plus group age of 20. Therefore, the panel examined the age composition data and used the information they contained to create a plus group for the selectivities. Headboat selectivities were fixed as constant after age 10 at the value estimated for age 10. For the general recreational fleet, the constant age at which we fixed selectivity was 13. These plus groups were consistent with how the age composition data were fitted.

Selectivities of discards were estimated in a similar fashion to the landings in that the general recreational fleet discards mirrored the headboat fleet discards. Both the commercial handline discards and the headboat discards had sufficient length composition to estimate selectivities.

Selectivities of fishery dependent indices were the same as those of the relevant fleet. The fishery independent CVID index selectivity was assumed logistic and informed by the SERFS chevron trap age compositions.

3.15 Indices of abundance

The model was fit to three fishery dependent indices of relative abundance (headboat 1976–2009; headboat discards 2005–2014; and commercial handlines 1993–2009), and one fishery independent index of abundance (SERFS combined video and trap, CVID). Predicted indices were conditional on selectivity of the corresponding fleet or survey, and were computed from abundance at the midpoint of the year or, in the case of commercial handlines, biomass. The headboat discard index tracks small fish (less than 20 inches) and was included as a measure of recruitment strength.

3.16 Catchability

In the BAM, catchability scales indices of relative abundance to the estimated population at large. For the base model, the AW Panel recommended a time-invariant catchability.

A sensitivity run adopted a time-varying catchability for the headboat index. In this formulation, catchability was estimated in two stanzas, pre- and post-1992. Choice of the year 1992 was based on the implementation of a fishery management plan that may have changed fishing behavior.

3.17 Biological reference points

Biological reference points (benchmarks) were calculated based on the fishing rate that would allow a stock to attain 30% of the maximum spawning potential which would have been obtained in the absence of fishing mortality. Computed benchmarks included the MSY proxy, fishing mortality rate at $F_{30\%}$, total biomass at $F_{30\%}$, and spawning stock at $F_{30\%}$ (Gabriel and Mace 1999). In this assessment, spawning stock measures total eggs of the mature stock. These benchmarks are conditional on the estimated selectivity functions and the relative contributions of each fleet's fishing mortality. The selectivity pattern used here was the effort-weighted selectivities at age, with effort from each fleet estimated as the full F averaged over the last three years of the assessment.

3.18 Fitting criterion

The fitting criterion was a penalized likelihood approach in which observed removals (landings and discards) were fit closely, and observed composition data and abundance indices were fit to the degree that they were compatible. Removals and index data were fit using lognormal likelihoods. Length and age composition data were fit using robust multinomial likelihoods (Francis 2011), and only from years that met minimum sample size criteria ($nfish > 30$ and $ntrips \geq 10$) for length compositions and ($nfish > 10$ and $ntrips \geq 10$) for age compositions. Commercial and headboat discard length composition minimum sample size threshold was set lower ($nfish > 10$) due to the fact that the discard composition data were the only information available to estimate selectivity.

The model includes the capability for each component of the likelihood to be weighted by user-supplied values. For data components, these weights were applied by either adjusting CVs (lognormal components) or adjusting effective sample sizes (multinomial components). In this application to Red Snapper, CVs of landings and discards (in arithmetic space) were assumed equal to 0.05, to achieve a close fit to these time series yet allowing some imprecision. In practice, the small CVs are a matter of computational convenience, as they help achieve the desired result of close fits to the landings, while avoiding having to solve the Baranov equation iteratively (which is complex when there are multiple fisheries). Weights on other data components (indices, age/length compositions) were adjusted iteratively, starting from initial weights as follows. The CVs of indices were set equal to the values estimated by the GLMs used for standardization or at the fixed value of 0.2 for the headboat and commercial handline indices. Effective sample sizes of the multinomial components were assumed equal to the number of trips sampled annually, rather than the number of fish measured, reflecting the belief that the basic sampling unit occurs at the level of trip. These initial weights were then adjusted until standard deviations of normalized residuals were near 1.0 (Francis 2011). In sensitivity runs, weights on the fishery dependent indices were adjusted upward to explore their effects (not because up-weighted runs were considered equally plausible).

For parameters defining selectivities, CV of size at age, and σ_R, normal priors were applied to maintain parameter estimates near reasonable values, and to prevent the optimization routine from drifting into parameter space with negligible gradient in the likelihood. For σ_R, the prior mean (0.6) and standard deviation (0.25) were based on Beddington and Cooke (1983) and Mertz and Myers (1996).

3.19 Configuration of a base run

The base run was configured as described above. This configuration does not necessarily represent reality better than all other possible configurations, and thus this assessment attempted to portray uncertainty in point estimates through sensitivity analyses and through a Monte-Carlo/bootstrap approach (described below).

3.20 Sensitivity analyses

Sensitivity runs were chosen to investigate issues that arose specifically with this benchmark assessment. They were intended to demonstrate directionality of results with changes in inputs or simply to explore model behavior, and not all were considered equally plausible. These model runs vary from the base run as follows:

- S1: Remove the 2008 and 2009 years from the handline and headboat indices
- S2: Upweight fishery independent index further than was explored in the Assessment Workshop (10X likelihood weight after the iterative reweighting)
- S3: Upweight handline and headboat indices (3X likelihood weight after iterative reweighting)
- S4: Fishery dependent indices only
- S5: High value of M
- S6: Low value of M
- S7: Low discard mortality probabilities (commercial handlines rate set to 0.38 or 0.28, all recreational set to 0.27 or 0.20)
- S8: High discard mortality probabilities (commercial handlines rate set to 0.58 or 0.48, all recreational set 0.45 or 0.36)
- S9: Longer combined chevron trap and video (CVID) index (2005-2014)
- S10: Reduced general recreational landings in 1984 and 1985 by taking the geometric mean of surrounding years
- S11: Steepness $h = 0.84$
- S12: Headboat discard index excluded after 2009
- S13: Ageing error matrix included
- S14: Low value for age-specific number of batches
- S15: High value for age-specific number of batches
- S16: Headboat discard index dropped
- S17: High landings
- S18: Low landings
- S19: High discards
- S20: Low discards
- S21: Dome-shaped selectivity for commercial handline fleet
- S22: Separate video and trap index rather than a single CVID index
- S23: Fishery independent index only
- S24: Continuity run: changes include SEDAR24 values such as M, steepness, maturity, and SSB
- S25: Two time blocks for Headboat logbook index catchability (pre- and post-1992)
- S26: Retrospective - 1 year of data
- S27: Retrospective - 2 years of data
- S28: Retrospective - 3 years of data
- S29: Retrospective - 4 years of data

- S30: Use 1978 as the starting year, applied a loose prior to the estimation of F_{init} that corresponds to the geometric mean of the fishing mortality for 1950-1977
- S31: Estimate selectivities without fixing a plus group (for the selectivity estimation)

Sensitivities 5, 6, 14, 15, and 17-20 used the 10th and 90th quantiles (as the low and the high respectively) from the bootstraps of the observed data described in the uncertainty analysis methods (Section 3.24).

3.21 Parameters Estimated

The model estimated annual fishing mortality rates of each fleet, selectivity parameters, catchability coefficients associated with indices, parameters of the spawner-recruit model (except steepness), annual recruitment deviations, and CV of size at age for each age and growth relationship.

3.22 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F, as were equilibrium landings and spawning biomass. Equilibrium landings and discards were also computed as functions of biomass B, which itself is a function of F. As in the computation of benchmarks (described in §3.23), per recruit and equilibrium analyses applied the most recent selectivity patterns averaged across fleets, weighted by each fleet's F from the last three years of the assessment (2012–2014).

3.23 Benchmark/Reference Point Methods

In this assessment of Red Snapper, the quantities $F_{30\%}$, $\mathrm{SSB}_{\mathrm{F30\%}}$, $B_{\mathrm{F30\%}}$, and $L_{\mathrm{F30\%}}$ were estimated as proxies for MSY-based reference points. Steepness was not reliably estimable, so the stock-recruit relationship was not used to identify a maximum yield. Instead, steepness was fixed at 0.99 in order to assume an average level of recruitment while estimating deviations around the mean. $F_{30\%}$ was used in the rebuilding plan for Red Snapper, therefore, it was used here to generate fishing benchmarks. However, because the stock-recruitment relationship was not estimated, assumptions about recruitment are required to generate biomass benchmarks. Here, equilibrium recruitment was assumed equal to expected recruitment (arithmetic average). On average, expected recruitment is higher than that estimated directly from the spawner-recruit curve, because of lognormal deviation in recruitment. Thus, in this assessment, the method of benchmark estimation accounted for lognormal deviation by including a bias correction in equilibrium recruitment. The bias correction (ς) was computed from the variance (σ_R^2) of recruitment deviation in log space: $\varsigma = \exp(\sigma_R^2/2)$. Then, equilibrium recruitment (R_{eq}) associated with any F is,

$$R_{eq} = \frac{R_0 \left[\varsigma 0.8h\Phi_F - 0.2(1-h)\right]}{(h-0.2)\Phi_F} \tag{1}$$

where R_0 is virgin recruitment, h is steepness which is fixed in this assessment, and $\Phi_F = \phi_F/\phi_0$ is spawning potential ratio given growth, maturity, and total mortality at age (including natural and fishing mortality rates). Because steepness is fixed at 0.99, R_{eq} as a function of F is approximately a straight line. The R_{eq} and mortality schedule imply an equilibrium age structure and an average sustainable yield (ASY). The estimate of $F_{30\%}$ is the F giving 30% of the SPR, and the estimate of $L_{\mathrm{F30\%}}$ is that ASY. The estimate of $\mathrm{SSB}_{\mathrm{F30\%}}$ follows from the corresponding equilibrium age structure, as does the estimate of discard mortalities $D_{F30\%\}}$, here separated from ASY (and consequently, $L_{\mathrm{F30\%}}$).

Estimates of $L_{\mathrm{F30\%}}$ and related benchmarks are conditional on selectivity pattern. The selectivity pattern used here was an average of terminal-year selectivities from each fleet, where each fleet-specific selectivity was weighted in proportion to its corresponding estimate of F averaged over the last three years (2012–2014). If the selectivities or relative fishing mortalities among fleets were to change, so would the estimates of $L_{\mathrm{F30\%}}$ and related benchmarks.

The maximum fishing mortality threshold (MFMT) is defined by the SAFMC as $F_{30\%}$, and the minimum stock size threshold (MSST) as 75%$\mathrm{SSB}_{\mathrm{F30\%}}$. Overfishing is defined as $F >$ MFMT and overfished as SSB $<$ MSST. However, because this stock is currently under a rebuilding plan, increased emphasis is given to SSB relative to $\mathrm{SSB}_{\mathrm{F30\%}}$ (rather than MSST), as $\mathrm{SSB}_{\mathrm{F30\%}}$ is the rebuilding target. Current status of the stock is represented by SSB in the latest assessment year (2014), and current status of the fishery is represented by the geometric mean of F from the latest three years (2012–2014). Recent SEDAR assessments have considered the mean over the terminal three years to be a more robust metric.

3.24 Uncertainty and Measures of Precision

As in SEDAR24, this assessment used a mixed Monte Carlo and bootstrap (MCB) approach to characterize uncertainty in results of the base run. Monte Carlo and bootstrap methods (Efron and Tibshirani 1993; Manly 1997) are often used to characterize uncertainty in ecological studies, and the mixed approach has been applied successfully in stock assessment, including Restrepo et al. (1992), Legault et al. (2001), SEDAR4 (2004), and many South Atlantic SEDAR assessments since SEDAR19 (2009). The approach is among those recommended for use in SEDAR assessments (SEDAR Procedural Guidance 2010).

The approach translates uncertainty in model input into uncertainty in model output, by fitting the model many times with different values of "observed" data and key input parameters. A chief advantage of the approach is that the results describe a range of possible outcomes, so that uncertainty is characterized more thoroughly than it could be by any single fit or handful of sensitivity runs. A minor disadvantage of the approach is that computational demands are relatively high.

In this assessment, the BAM was successively re-fit in $n = 4000$ trials that differed from the original inputs by bootstrapping on data sources, and by Monte Carlo sampling of several key input parameters. The value of $n = 4000$ was chosen because a minimum of 3000 runs were desired, and it was anticipated that not all runs would converge or otherwise be valid. Of the 4000 trials, approximately 5.2% were discarded, because the model did not properly converge (in most cases, an estimated quantity was at its upper bound). This left $n = 3791$ MCB trials used to characterize uncertainty, which was sufficient for convergence of standard errors in management quantities.

The MCB analysis should be interpreted as providing an approximation to the uncertainty associated with each output. The results are approximate for two related reasons. First, not all combinations of Monte Carlo parameter inputs are equally likely, as biological parameters might be correlated. Second, all runs are given equal weight in the results, yet some might provide better fits to data than others.

3.24.1 Bootstrap of observed data

To include uncertainty in the indices of abundance, multiplicative lognormal errors were applied through a parametric bootstrap. To implement this approach in the MCB trials, random variables ($x_{s,y}$) were drawn for each year y of time series s from a normal distribution with mean 0 and variance $\sigma^2_{s,y}$ [that is, $x_{s,y} \sim N(0, \sigma^2_{s,y})$]. Annual observations were then perturbed from their original values ($\hat{O}_{s,y}$),

$$O_{s,y} = \hat{O}_{s,y}[\exp(x_{s,y} - \sigma^2_{s,y}/2)] \tag{2}$$

The term $\sigma^2_{s,y}/2$ is a bias correction that centers the multiplicative error on the value of 1.0. Standard deviations in log space were computed from CVs in arithmetic space, $\sigma_{s,y} = \sqrt{\log(1.0 + CV^2_{s,y})}$. As used for fitting the base run, CVs of indices of abundance were those provided by, or modified from, the data providers (tabulated in Table 4 of this assessment report).

Uncertainty was modeled for historical commercial landings similarly to the indices, and by the CVs provided by the commercial working group at the DW. No commercial discard CVs, headboat landings CVs, or headboat discard CVs by year were provided, therefore the panel had to make some assumptions. We assumed a value of $CV = 0.20$ for commercial discards and headboat discards. For headboat landings, we used information from the headboat program to assume a decreasing CV by time blocks (i.e. $CV = 0.15$ 1981-1995, $CV = 0.1$ for 1996-2007, and $CV = 0.05$ thereafter). General recreational landings and discards had complementary CVs, and those were used as provided except in a few instances. A CV greater than 1 was capped at 1, which was sufficiently large to represent high uncertainty but not so high that bootstrapped values caused implausible time series. The panel thought the resulting draws sufficiently represented uncertainty in spite of the dampening of a few years' CVs (Table 6).

Uncertainty in age and length compositions were included by drawing new distributions for each year of each data source, following a multinomial sampling process. Ages (or lengths) of individual fish were drawn at random with replacement using the cell probabilities of the original data. For each year of each data source, the number of fish sampled was the same as in the original data.

3.24.2 Monte Carlo sampling

In each successive fit of the model, several parameters were fixed (i.e., not estimated) at values drawn at random from distributions described below.

3.25 Natural mortality

A vector of age-specific natural mortality was provided by the Life History Working Group. They used the Charnov et al. (2013) estimator scaled to the Then et al. (2014) max age asymptotic M, and then used the uncertainty around the determination of maximum age to provide an upper and lower bound to the M vector. The Assessment Panel thought the upper ($M = 0.14$) and lower ($M = 0.12$) bound were too similar to the base vector to represent the true uncertainty around M. Instead, the AW Panel wanted to carry the uncertainty forward in both maximum age and the parameters of the Then et al. (2014) estimator of asymptotic M:

$$M = aT^b_{max} \tag{3}$$

To estimate uncertainty in a and b, we acquired the data of Then et al. (2014) and conducted a bootstrap of $n = 10,000$ iterations, drawing from the original data set with replacement. For each MCB iterations, one of the 10,000 fits was drawn at random, thus maintaining any correlation structure between a and b. We then drew T_{max} from a uniform distribution and calculated asymptotic M. For the age-dependent vector, we started with the Charnov age-dependent curve, and scaled it to the M estimate we calculated in the previous steps. A new M value was drawn and a new age-dependent vector was calculated for each MCB trial.

3.26 Discard mortality

The discard mortality working group provided an upper and lower bound for each time block (pre- and post-regulation) and fishery (commercial and recreational). Commercial rates before 2007 ranged from 38% to 58%, and 2007 to present ranged from 28% to 48%. Recreational rates before 2011 ranged from 27% to 45%, and 2011 on ranged from 20% to 36%. The rates decreased in response to the implementation of circle hooks, which are meant to cause fewer fatal bycatch events. We drew the rate for the earlier time period for each fleet from a truncated normal distribution with mean equal to the point estimate and a standard deviation devised to provide a 95% confidence interval similar to what the working group provided above. For the later time period for each fleet we also drew from a truncated normal distribution created similarly as in the previous step but with the upper bound fixed at the random draw from the earlier time period. The last step is meant to ensure that the second value is not larger than the first, so as to maintain the feature that discard mortality has decreased due to the circle hook regulation.

3.27 Batch Fecundity

Prior to the MCB analysis, a bootstrap procedure was run on the data set used to estimate batch fecundity at age for the base run. For each of 10000 bootstrap runs, the 69 paired observations of batch fecundity and fish length were sampled 69 times with replacement, the regression model refit, and the bootstrap parameters estimates saved to a data matrix. Once all bootstraps were run, the parameter matrix was trimmed by removing runs where either parameter value was outside of its 95% confidence interval. The parameters were found to be highly correlated, so during the MCB analysis, pairs of parameters were randomly drawn, with replacement, from the trimmed bootstrap parameter matrix. For each MCB run, predicted batch fecundity at age was calculated using a set of bootstrap parameters and a vector of length at age.

3.28 Batch number

Prior to the MCB analysis, a similar but separate bootstrap procedure was run on the data set used to estimate batch number at age for the base run. For each of 10000 bootstrap runs, the 1472 paired observations of spawning indicator presence, fish length, and day of the year were sampled 1472 times with replacement and the regression model refit. Predicted batch number at age was then calculated from the bootstrap parameter estimates and a vector of length at age, and the vectors saved to a data matrix. Once all bootstraps were run, the batch number at age matrix was trimmed by first summing batch number at age for each run, yielding lifetime batch number; runs where lifetime batch number was outside of the 95% confidence interval were trimmed. During the MCB analysis, a vector of batch number at age was randomly drawn, with replacement, from the trimmed bootstrap batch number at age matrix for each MCB run.

3.29 Projections

Projections were run to predict stock status in years after the assessment, 2015–2044. The year 2044 is the last year of the current rebuilding plan.

The structure of the projection model was the same as that of the assessment model, and parameter estimates were those from the assessment. Any time-varying quantities, such as recreational selectivity, were fixed to the most recent values of the assessment period. A single selectivity curve was applied to calculate removals, averaged across fleets using geometric mean Fs from the last three years of the assessment period, similar to computation of $L_{\mathrm{F}30\%}$ benchmarks (§3.23).

Expected values of SSB (time of peak spawning), F, recruits, and removals were represented by deterministic projections using parameter estimates from the base run. These projections were built on the spawner-recruit relationship with steepness fixed ($h = 0.99$) and with bias correction, and were thus consistent with estimated benchmarks in the sense that long-term fishing at $F_{30\%}$ would yield $L_{\mathrm{F30\%}}$ from a stock size at $\mathrm{SSB}_{\mathrm{F30\%}}$. Uncertainty in future time series was quantified through stochastic projections that extended the Monte Carlo/Bootstrap (MCB) fits of the stock assessment model.

3.29.1 Initialization of projections

Initial age structure at the start of 2015 was computed by the assessment model.

Fishing rates that define the projections were assumed to start in 2017. Because the assessment period ended in 2014, the projections required an initialization period (2015–2016). For 2015, a moratorium year, the landings selectivity was set to 0 and the discard selectivity was rescaled to peak at 1. Then, an optimization routine solved for the F that matched the current dead discards (mean of 2012-2014) in numbers. In 2016, a similar routine soved for the F that matched current landings (mean of 2012-2014), assuming a mini-season would occur.

3.29.2 Uncertainty of projections

To characterize uncertainty in future stock dynamics, stochasticity was included in replicate projections, each an extension of a single MCB assessment model fit. Thus, projections carried forward uncertainties in natural mortality, reproduction, landings, discards, and discard mortalities, as well as in estimated quantities such as selectivity curves, and in initial (start of 2015) abundance at age.

Initial and subsequent recruitment values were generated with stochasticity using a Monte Carlo procedure, in which the estimated Beverton–Holt model (i.e. R_0, σ_R estimated, and $h = 0.99$) of each MCB fit was used to compute mean annual recruitment values ($\bar{R}_y$). Variability was added to the mean values by choosing multiplicative deviations at random from a lognormal distribution,

$$R_y = \bar{R}_y \exp(\epsilon_y). \tag{4}$$

Here ϵ_y was drawn from a normal distribution with mean 0 and standard deviation σ_R, where σ_R is the standard deviation from the relevant MCB fit.

The procedure generated 20,000 replicate projections of MCB model fits drawn at random (with replacement) from the MCB runs. In cases where the same MCB run was drawn, projections would still differ as a result of stochasticity in projected recruitment streams. Central tendencies were represented by the deterministic projections of the base run, as well as by medians of the stochastic projections. Precision of projections was represented graphically by the 10^{th} and 90^{th} percentiles of the replicate projections.

3.30 Rebuilding time frame

Based on results from the previous SEDAR24 benchmark assessment, Red Snapper is currently under a rebuilding plan. In this plan, the terminal year is 2044, and rebuilding is defined by the criterion that projection replicates achieve stock recovery (i.e., $\mathrm{SSB}_{2044} \geq \mathrm{SSB}_{\mathrm{F30\%}}$) with probability of at least 50%. Here, the probability of stock recovery in each year of the rebuilding plan was computed as the proportion of stochastic projections where $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{F30\%}}$, with $\mathrm{SSB}_{\mathrm{F30\%}}$ taken to be iteration-specific (i.e., from that particular MCB run).

Projection scenarios Five projection scenarios were considered.

- Scenario 1: $F = 0$
- Scenario 2: $F = F_{\text{current}}$
- Scenario 3: $F = F_{30\%}$
- Scenario 4: $F_{target} = 98\% F_{30\%}$
- Scenario 5: $F = F_{\text{rebuild}}$, with rebuilding probability of 0.5 in 2044
- Scenario 6: Discards only

The F_{current} is represented by the geometric mean of fishing mortalities from 2012-2014. The F_{rebuild} is defined as the maximum F that achieves rebuilding in the allowable time frame. The discards only scenario treated the initialization year 2016 the same as 2015 (discards only), and then applied the mean F (from 2015-2016) forward starting in 2017.

3.31 Surplus Production Model

3.31.1 Overview

A logistic surplus production model, implemented in ASPIC (Version 7.03; Prager 2005), was used to estimate stock status of Red Snapper off the southeastern U.S. While primary assessment of the stock was performed using the age-structured BAM, the surplus production approach was intended as a complement, for additional comparison with the age-structured model's results. More specifically, this model focuses on the dynamics of the removals as they relate to the indices of abundance, while ignoring any age data or age-structure in the population.

3.31.2 Data Sources

Data sources supplied to a production model include a time series of removals (i.e. landings plus dead discards) and one or more indices of abundance (i.e. catch per unit of effort). These inputs should be in units of biomass (i.e. weight), therefore some of the data developed at the SEDAR41 DW required additional formatting. These changes are detailed below.

Removals

The available removals time series comprised commercial landings (1950-2014), recreational landings (1955-2014), commercial dead discards (1992-2014), and recreational dead discards (1981-2014), in pounds, summed by year.

Commercial Landings

The SEDAR41 DW reported commercial landings in pounds, thus these data did not need to be modified for the production model.

Recreational landings

During the SEDAR41 DW, recreational landings for the historical period (1955-1980) were estimated in numbers of individuals using the The National Survey of Fishing, Hunting, and Wildlife-Associated Recreation Survey (FHWAR) census method (see SEDAR41-DW17). For the contemporary period (1981-2014), the SEDAR-41 DW reported Southeast Region Headboat Survey (SRHS) and Marine Recreational Information Program (MRIP) recreational landings in numbers and weights. Recreational landings from this period did not need to be modified, but were used to convert historical landings to weight.

Following a similar approach used in SEDAR24, recreational landings in weight and numbers for all fleets were combined by year for the first three years of the contemporary period; dividing annual landings in weight by landings in numbers produced annual mean weight estimates. The average of these three mean weights (3.4 lb) was then multiplied by the historical landings in numbers to convert them to weight. The historical and combined contemporary recreational landings series were then joined to produce a single time series of recreational landings, in pounds.

Dead Discards

Discard estimates were generated in numbers at the SEDAR-41 DW. Since many discarded fish survive after release, discard mortality rates were applied to discards in numbers to calculate dead discards. For commercial discards, a discard mortality rate of 0.48 was applied prior to regulations in 2007, and a rate of 0.38 was applied from 2007 onward. For recreational discards, a discard mortality rate of 0.37 was applied prior to regulations in 2011, and a rate of 0.285 was applied from 2011 onward.

Mean weight of commercial discards was estimated by converting lengths of commercial discards to weights using data and a conversion equation supplied by the SEDAR-41 DW, and then calculating the average weight of these individuals. The data on lengths of commercial discards were divided into two time periods before (2007-2009) and after (2010-2013) the fishery was closed. The average estimated weights of commercial discards from each time period (before = 2.93 lb; after = 8.84 lb) were multiplied by discards in numbers, for years before and after the closure, respectively.

Mean weight of recreational discards was estimated by converting lengths of recreational headboat-at-sea observer discards to weights using data and a conversion equation supplied by the SEDAR-41 DW, and then calculating the average weight of these individuals. Year-specific mean weight estimates were multiplied by recreational discards in numbers for corresponding years when available (2005-2014). For years prior to 2005 where year-specific mean weights were not available, discards in numbers were multiplied by the average mean weight across the available years before the 2010 closure (1.96 lb).

Indices of Abundance

Five indices of abundance were produced by the SEDAR-41 DW for Red Snapper: commercial logbook handline index (hereafter commercial handline; units = lb kept per hook-hour), headboat (number of fish kept per angler), headboat-at-sea-observer (number of fish caught $<20''$ per angler), Southeast Reef Fish Survey (SERFS) chevron trap (number of fish caught per trap), and the SERFS video (number of fish observed per video). The commercial handline index was already in weight and did not need to be converted. The headboat index was converted to pounds by multiplying by year-specific mean weights, generated by dividing headboat landings in pounds by landings in numbers for each year. The headboat-at-sea-observer index was converted to pounds by multiplying by the same mean weights used to convert recreational discards to weight. The SERFS chevron trap and video indices were converted to weights by multiplying by year-specific mean weights calculated from combined recreational (headboat and MRIP) landings in weight divided by landings in numbers.

3.31.3 Model Configuration and Equations

Production modeling used the model formulation and ASPIC software (version 7.03) of Prager (1994; 2005). This is an observation-error estimator of the continuous-time form of the Schaefer (logistic) production model (Schaefer 1954; 1957). Estimation was conditioned on catch. The logistic model for population growth is the simplest form of a differential equation which satisfies a number of ecologically realistic constraints, such as a carrying capacity (a consequence of limited resources). When written in terms of stock biomass, this model specifies that

$$\frac{dB_t}{dt} = rB_t - \frac{r}{K}B_t^2 \tag{5}$$

where B_t is biomass in year t, r is the intrinsic rate of increase in absence of density dependence, and K is carrying capacity (Schaefer 1954; 1957). This equation may be rewritten to account for the effects of fishing by introducing an instantaneous fishing mortality term, F_t :

$$\frac{dB_t}{dt} = (r - F_t)B_t - \frac{r}{K}B_t^2 \tag{6}$$

By writing the term F_t as a function of catchability coefficients and effort expended by fishermen in different fisheries, Prager (1994) showed how to estimate model parameters from time series of yield and effort.

For Red Snapper, the model proved difficult to fit. It was configured using various combinations of removals, indices, starting dates, prior distributions and starting values, resulting in approximately 324 configurations. Many of these runs were completed during early model development but many others incorporated small changes to data inputs or model specifications suggested by AW panel members during the Assessment Workshop. As the BAM developed, most of these runs became obsolete and are not presented here. The run configured according to recommendations by the SEDAR41 AW panel is presented here. This model configuration (run 320) contained removals from 1950 to 2014 and the four indices used in the BAM (Comm, HB, HB-at-sea, CVID) from 1976 to 2014. Following the recommendations of the AW panel, the CVID index was upweighted by a factor of three (i.e. CVs divided by three), and the headboat-at-sea index was shifted forward by one year, since it indexes younger fish than the other indices.

Three other runs (318, 319, and 323) are also presented to relate the main run (320) to ASPIC results from the previous Red Snapper assessment (SEDAR 24). All three runs contain only the commercial and headboat indices, starting in 1993 and 1976 respectively, and removals starting in 1950. But in run 318 (the continuity run), the final year of removals and indices is 2009, as in SEDAR 24, while in run 319 (the updated continuity run) the final year of removals and indices is 2014, as in the BAM for the current assessment. Since both the commercial and headboat indices ended in 2009 the only difference between the continuity run and updated continuity run is the removals estimates from 2010-2014. Finally a run was completed (run 323; best configuration $\frac{B_1}{K}$ fixed) that is identical to the best configuration run, but with $\frac{B_1}{K}$ fixed at the estimate for the continuity run, for reasons described below.

To evaluate the uncertainty in the model fit and parameter estimates of the best configuration run, 1000 bootstrap runs were conducted. Percentile confidence intervals were also calculated for parameters.

4 Stock Assessment Results

4.1 Measures of Overall Model Fit

In general, the Beaufort assessment model (BAM) fit well to the available data. Predicted length compositions from the commercial handline and discards from the commercial and headboat fleets were reasonably close to observed data in most years, as were predicted age compositions (Figure 3). The model was configured to fit observed commercial and recreational removals closely (Figures 4–9). Fits to indices of abundance generally captured the observed trends but not all annual fluctuations (Figures 10–13).

4.2 Parameter Estimates

Estimates of all parameters from the catch-age model are shown in Appendix B. Estimates of management quantities and some key parameters are reported in sections below.

4.3 Stock Abundance and Recruitment

In general, estimated abundance at age showed truncation of the older ages through most of the assessment period, but with some signs of increase during the last decade (Figure 14; Table 7). Total estimated abundance was at its lowest value in the early 1990s, but near its highest levels at the end of the time series, comparable to those in the early 1970s, but with a more truncated age structure. The MCB results reflect the same patterns with their associated uncertainties for total abundance and abundance of age 2+ (Figure 18). Annual number of recruits is shown in Table 7 (age-1 column) and in Figure 15. The highest recruitment values were predicted to have occurred in the mid-1980s, 2006, and the terminal year of the model (2014).

4.4 Total and Spawning Biomass

Estimated biomass at age followed a similar pattern as abundance at age (Figure 16; Table 9). Total biomass and spawning biomass showed similar trends—general decline through to the early-1990s, and relatively stable or slowly increasing patterns since the mid-1990s (Figure 17; Table 10). Terminal year estimates are at levels not seen since the 1970s.

4.5 Selectivity

Selectivity of the SERFS index is shown in Figure 19, and selectivities of landings from commercial and recreational fleets are shown in Figures 20, 21, and 22. Selectivities of discards from commercial and recreational fleets are shown in Figures 23, 24, and 25. In the most recent years, full selection occurred near ages 2–4, depending on the fleet and time block.

Average selectivities of landings, dead discards, and the total weighted average of all selectivities were computed from F-weighted selectivities in the most recent three assessment years (Figure 26). This average selectivity was used in computation of point estimates of benchmarks, as well as in projections. All selectivities from each time block, including average selectivities, are tabulated in Tables 11, 12, and 13.

4.6 Fishing Mortality and Removals

Estimates of total F at age are shown in Table 15. In any given year, the maximum F at age (i.e., apical F) may be less than that year's sum of fully selected Fs across fleets. This inequality is due to the combination of two features of estimated selectivities: full selection occurs at different ages among gears and several sources of mortality have dome-shaped selectivity.

Estimated time series of landings and discards are shown in Tables 16, 17, 18, 19. Table 20 shows total landings at age in numbers, and Table 21 in weight. Table 22 shows total discards at age in numbers, and Table 23 in weight. Landings have been dominated by the general recreational and commercial handline fleet until recent years when the general recreational fleet became the dominant source of removals (Tables 16 and 17). Also since 2010, total landings remained below the level at $L_{\mathrm{F30\%}}$ (Figure 29).

Estimated discard mortalities occurred on a smaller scale than landings until the implementation of regulations and the use of mini-seasons, and have been above the $D_{F_{30\%}}$ level for most of the moratorium years (Tables 18 and 19, and Figure 30).

4.7 Spawner-Recruitment Parameters

The Beverton–Holt spawner-recruit curve is shown in Figure 31, along with the effect of density dependence on recruitment, depicted graphically by recruits per spawner as a function of spawning stock (1E8 Eggs). Values of recruitment-related parameters were as follows: steepness $h = 0.99$ (fixed), unfished age-1 recruitment $\widehat{R_0} = 330503$, and standard deviation of recruitment residuals in log space $\widehat{\sigma}_R = 0.79$ (which resulted in bias correction of $\varsigma = 1.37$). Uncertainty in these quantities was estimated through the MCB analysis (Figure 32).

4.8 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F. These computations applied the most recent selectivity patterns averaged across fleets, weighted by F from the last three years (2012–2014) (Figures 33 and 34).

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of F (Figure 35). $F_{30\%}$ is used as a proxy for MSY, and the corresponding landings and spawning biomass are $L_{\mathrm{F30\%}}$ and $\mathrm{SSB}_{\mathrm{F30\%}}$.

4.9 Benchmarks / Reference Points

As described in §3.23, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the spawner-recruit curve with fixed steepness $h = 0.99$ (Figure 31). Reference points estimated were $F_{30\%}$, $L_{\mathrm{F30\%}}$, $B_{\mathrm{F30\%}}$ and $\mathrm{SSB}_{\mathrm{F30\%}}$. Based on $F_{30\%}$, three possible values of F at optimum yield (OY) were considered—$F_{\mathrm{OY}} = 65\% F_{30\%}$, $F_{\mathrm{OY}} = 75\% F_{30\%}$, and $F_{\mathrm{OY}} = 85\% F_{30\%}$—and for each, the corresponding yield was computed. Standard errors of benchmarks were approximated as those from MCB analysis (§3.24).

Maximum likelihood estimates (base run) of benchmarks, as well as median values from MCB analysis, are summarized in Table 24. Point estimates of $L_{\mathrm{F30\%}}$-related quantities were $F_{30\%} = 0.15$ (y^{-1}), $L_{\mathrm{F30\%}} = 430$ (1000 lb), $B_{\mathrm{F30\%}} = 3647$ (mt), and $\mathrm{SSB}_{\mathrm{F30\%}} = 328552$ (1E8 Eggs). Median estimates were $F_{30\%} = 0.15$ (y^{-1}), $L_{\mathrm{F30\%}} = 419$ (1000 lb), $B_{\mathrm{F30\%}} = 3534$ (mt), and $\mathrm{SSB}_{\mathrm{F30\%}} = 294166$ (1E8 Eggs). Distributions of these benchmarks from the MCB analysis are shown in Figure 36.

4.10 Status of the Stock and Fishery

Estimated time series of stock status $SSB/SSB_{F30\%}$ showed general decline throughout the beginning of the assessment period, a leveling off, and then a modest increase since 2010 (Figure 37, Table 10). Base-run estimates of spawning biomass have remained below the threshold (MSST) since the early-1970s. Current stock status was estimated in the base run to be $SSB/SSB_{F30\%} = 0.16$ (Table 24), indicating that the stock has not yet recovered to $SSB_{F30\%}$. Median values from the MCB analysis indicated similar results $SSB/SSB_{F30\%}$ =0.17. The uncertainty analysis suggested that the terminal estimate of stock status is robust (Figures 38, 39). Of the MCB runs, 100% indicated that the stock was below $SSB_{F30\%}$ in 2014. Age structure estimated by the base run showed fewer older fish in the last few decades than the (equilibrium) age structure expected at $L_{F30\%}$ (Figure 40). However, there is improvement in the terminal year(2014), particularly for ages younger than ten.

The estimated time series of $F/F_{30\%}$ suggests that overfishing has occurred throughout most of the assessment period (Table 10, Figure 37). Current fishery status in the terminal year, with current F represented by the geometric mean from 2012–2014, was estimated by the base run to be $F/F_{30\%} = 2.52$ (Table 24). The fishery status was also robust (Figures 38, 39). Of the MCB runs, approximately 98.7% agreed with the base run that the stock is currently experiencing overfishing.

4.11 Sensitivity and Retrospective Analyses

Sensitivity runs, described in §3.3, were used for exploring data or model issues that arose during the assessment process, for evaluating implications of assumptions in the base assessment model, and for interpreting MCB results in terms of expected effects of input parameters. In some cases, sensitivity runs are simply a tool for better understanding model behavior, and therefore all runs are not considered equally plausible in the sense of alternative states of nature. Time series of $F/F_{30\%}$ and $SSB/SSB_{F30\%}$ are plotted to demonstrate sensitivity to the changing conditions in each run. The sensitivity of the base run to changes in natural mortality, steepness, dome-shaped selectivity for the commercial handline fleet, various index adjusts for both the fishery dependent indices and fishery independent index, the use of an ageing error matrix and high and low levels of landings and discards was explored (Figures 41–53). Sensitivity 24 is a version of a continuity run in that various assumptions made about parameters for SEDAR 24 were adopted for this sensitivity (e.g. higher discard mortalities, lower M, using gonad weight as a proxy for SSB, different female maturity and fecundity information, higher max age, lower steepness, different time of year for peak spawning, and fixed recruitment standard deviation). Time series of stock and fishery status estimated by this assessment are similar to those from the previous, SEDAR24 assessment (Figure 54). Trends in $F/F_{30\%}$ from the two assessments generally track each other, though the magnitude of the variations differ. Trends in $SSB/SSB_{F30\%}$ track each other, though there is divergence at the end of the time series where the current model estimates a more optimistic stock status.

None of the sensitivities show a recovered stock in 2014. A couple sensitivities suggest the stock is undergoing less overfishing than is estimated in the base. However, those runs eliminate the fishery independent index entirely, or upweight the fishery dependent indices to the point of swamping out any signal from the survey data. The vast majority of runs agree with the status indicated by the base run (Figure 55, Table 25). Results appeared to be most sensitive to natural mortality and steepness.

Retrospective analyses suggest a pattern of overestimating fishing mortality in the terminal year, however, the trend is less apparent for SSB (Figure 56).

4.12 Projections

Projections based on $F = 0$ allowed the spawning stock to grow such that the majority of replicate projections recovered to $\mathrm{SSB}_{\mathrm{F30\%}}$ by 2025 (Figure 57, Table 26), however the stock is already in a rebuilding plan so other projections were also requested in the TORs. This was not the case for projections based on $F = F_{\mathrm{current}}$ (Figure 58, Table 27), or if the fishing rate were reduced to $F_{30\%}$ (Figure 59, Table 28) or F_{target} (Figure 60, Table 29). By design, projections based on $F = F_{\mathrm{rebuild}}$ showed recovery with the desired probability in 2044 (Figure 61, Table 30). The projection with discard mortality only showed similar trajectories to the run assuming no other fishing mortality(Table 31 and Figure 62).

4.13 Surplus Production Model

4.13.1 Model Fit

For the best configuration run, model predictions underestimated observed values for the headboat index for the first ten years of the time series (1976-1985; Figure 63). They also underestimated the commercial index during the first five years of that series (1993-1997), while overestimating the headboat index for those same years. The model provided a very poor fit to the headboat-at-sea discard index (2006-2014) but produced a much better fit to the upweighted CVID index (2005-2014). The model did not fit high index values in 2008 and 2009 very closely, but predicted a slight decline from 2007-2009 followed by an increasing trend from 2010 to 2014.

4.13.2 Parameter Estimates and Uncertainty

The ASPIC model fits three main parameters ($\frac{B_1}{K}$, MSY, and F_{MSY}) as well as catchability coefficients (q_i) for each index i. Several other parameters can then be derived from these estimates: $r = 2F_{MSY}$, $K = \frac{2MSY}{F_{MSY}}$ and $B_{MSY} = \frac{K}{2}$. Recent status indicators $\frac{F}{F_{MSY}}$ and $\frac{B}{B_{MSY}}$ are calculated with the most recent estimates of F (2014) and B (2015). Estimates of the main parameters and recent status indicators for all four runs are presented in Table 32. Prior distributions and model estimates of the main parameters for the best configuration run are presented in Figure 64.

Across all runs, most of the main parameters varied very little (e.g. CV $MSY = 0.0027$; CV $F_{MSY} = 0.014$). By contrast $\frac{B_1}{K}$ varied widely (CV $\frac{B_1}{K} = 0.74$), due to variation in B_1 (CV $B_1 = 0.74$) rather than K (CV $K = 0.013$; Table 32). Among bootstrap runs based on the best configuration, distributions of $\frac{B_1}{K}$, MSY, and F_{MSY} were unimodal and relatively symmetrical (Figure 65).

4.13.3 Status of the Stock and Fishery

In the current best configuration run of the surplus production model, $\frac{B}{B_{MSY}}$ is greater than one, suggesting that the South Atlantic stock of Red Snapper is not overfished. The 95% bootstrap percentile confidence intervals for $\frac{B}{B_{MSY}}$ do not contain one (Figure 65). Since the surplus production model estimates that $\frac{F}{F_{MSY}}$ is less than one, the stock is considered to not be undergoing overfishing (Table 32; Figure 66). The 95% bootstrap percentile confidence intervals for $\frac{F}{F_{MSY}}$ do not contain one (Figure 65).

4.13.4 Interpretation

Status indicators in the continuity run (318), agree with the surplus production model from SEDAR 24 that South Atlantic Red Snapper were overfished and undergoing overfishing in 2009 (Table 32). However, in the updated continuity run (319), which is identical to the continuity run except for the 2010-2014 addition of landings data from 2010-2014, the surplus production model suggests that the stock is no longer overfished or undergoing overfishing. Despite several differences between the updated continuity run and the best configuration run (320), described above, most of the parameter estimates and status indicators are similar (Table 32). However the model estimate of $\frac{B_1}{K}$ is much lower in the best configuration run, driven by a lower estimate of B_1. After observing this difference, run 323 was configured by taking the best configuration run and fixing $\frac{B_1}{K}$ at the estimate from the continuity run to investigate potential influence. Fixing $\frac{B_1}{K}$ at this much lower value had little effect on status or most parameters, but caused the estimate of B_1 to go much lower.

As described above, the only data that go into a surplus production model are biomass of removals and abundance indices. Therefore such a model does not make use of many other sources of information such as sex, maturity, growth, fecundity, or population age and size structure. Because such data are available for Red Snapper, a model that uses them would be preferred for a detailed assessment on which to base management.

5 Discussion

5.1 Comments on the Assessment

Estimated benchmarks played a central role in this assessment. Values of $\text{SSB}_{\text{F30\%}}$ and $F_{30\%}$ were used to gauge the status of the stock and fishery to be consistent with established definitions of $MFMT$ and the existing rebuilding plan. The computation of the benchmarks was conditional on selectivity. If selectivity patterns change in the future, for example as a result of new size limits or different relative catch allocations among sectors, estimates of benchmarks would likely change as well.

The base run of the BAM indicated that the stock remains overfished $\text{SSB}/\text{SSB}_{\text{F30\%}}$ =0.16, and that overfishing is occurring $F/F_{30\%}$ =2.52, though at a lower rate than in 2009 (F/F_{MSY} =4.12 for SEDAR 24). Median values from the MCB analyses were in qualitative agreement with those results. This assessment estimates that, since 2010, the stock has been increasing at a modest rate and is now at levels not seen since the 1970s.

In addition to including the more recent years of data, this benchmark assessment contained several modifications to the previous data of SEDAR24, such as the use of APAIS-adjusted MRIP estimates instead of MRFSS, a new method for the reconstruction of historic recreational catch, the inclusion of a new fishery-independent survey, and the corresponding age composition data. Furthermore, life-history information was updated, including female maturity, sex ratio, growth, natural mortality, fecundity, and meristics. The assessment model itself was also modernized to the current version of BAM. The sum of these improvements should result in a more robust assessment.

In general, fishery dependent indices of abundance may not track actual abundance well, because of factors such as hyperdepletion or hyperstability. Furthermore, this issue can be exacerbated by management measures. In this assessment, the commercial handline and headboat indices generated from logbook data, were not extended beyond 2009 because of the moratorium on Red Snapper. In general, management measures in the southeast U.S. have made the continued utility of fishery dependent indices will be questionable. This situation amplifies the importance of fishery independent sampling and sampling programs conducted by the states.

Many assessed stocks in the southeast U.S. have shown histories of heavy exploitation. High rates of fishing mortality can lead to adaptive responses in life-history characteristics, such as growth and maturity schedules. Such adaptations can affect expected yield and stock recovery, and thus resource managers might wish to consider possible evolutionary effects of fishing in their management plans (Dunlop et al. 2009; Enberg et al. 2009). Indeed, Red Snapper have a very young age at maturity relative to their maximum lifespan, and some have hypothesized that this may be an adaptive response to exploitation.

Because steepness could not be estimated reliably in this assessment, its value in the base run was fixed at 0.99. Fixing steepness at its upper bound was not meant to imply that the stock has perfect compensation at any exploitation or stock level. Rather, it was a computational convenience to use the stock recruitment curve with $h = 0.99$ in order to treat recruitment as an average through time while estimating deviations around that average. Thus MSY-based management quantities are not appropriate, and the AW Panel provided the proxy of $F_{30\%}$ as was used for management subsequent to the last assessment.

The assessment start year was 1950, so as to include the period of largest landings. To initialize the model in 1950, the initial age structure was assumed to be in equilibrium, based on natural mortality at age and F_{init}. Average recruitment was assumed until the recruitment deviations could be estimated at the onset of the composition data (1978). These assumptions are common in assessment models, and they were tested with sensitivity runs where the start was 1978 and with different values of F_{init}. The end results were qualitatively similar, which indicates that the base run is not sensitive to these assumptions.

A complementary analysis was conducted using a surplus production model (ASPIC). ASPIC treats the stock as a pooled biomass and ignores the age structure in the population and the landings. It is unable to take into account that different ages are differentially vulnerable to fishing and therefore was not able to incorporate the (time-varying) selectivities used in the BAM. ASPIC is also not able to take into account that the reproductive contribution of this species increases with age or that there is variability in recruitment through time. ASPIC is useful in examining the relationship between removals and the indices. However, for a long-lived species with age-based data available, the catch-age model (BAM) provides the best illustration of the stock and is a better indicator of stock status, because it can account for the age structure of the population and landings and for year-class strength.

5.2 Comments on the Projections

Projections should be interpreted in light of the model assumptions and key aspects of the data. Some major considerations are the following:

- In general, projections of fish stocks are highly uncertain, particularly in the long term (e.g., beyond 5–10 years).
- Although projections included many major sources of uncertainty, they did not include structural (model) uncertainty. That is, projection results are conditional on one set of functional forms used to describe population dynamics, selectivity, recruitment, etc.
- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect projection results.
- The first five scenarios of projections assumed no change in the selectivity applied to discards. As stock increase generally begins with the smallest size classes, management action may be needed to meet that assumption.
- The projections assumed that the assumed spawner-recruit relationship applies in the future and that past deviations represent future uncertainty in recruitment. If future recruitment is characterized by runs of large or small year classes, possibly due to environmental or ecological conditions, stock projections may be affected.

- Projections apply the Baranov catch equation to relate F and landings using a one-year time step, as in the assessment. The catch equation implicitly assumes that mortality occurs throughout the year. This assumption is violated when seasonal closures or small intensive fishing seasons are in effect, introducing additional and unquantified uncertainty into the projection results.

5.3 Research Recommendations

- Increased fishery independent information, particularly maintaining reliable indices of abundance and composition data streams
- Red Snapper were modeled in this assessment as a unit stock off the southeastern U.S. For any stock, variation in exploitation and life-history characteristics might be expected at finer geographic scales. Modeling such sub-stock structure would require more data, such as information on the movements and migrations of adults and juveniles, as well as spatial patterns of larval dispersal and recruitment. In addition, it is unclear whether a spatial model would improve the assessment.
- More research to describe the juvenile life history of Red Snapper is needed, including more work to identify the location of juveniles before they recruit to the fishery.
- The effects of environmental variation on the changes in recruitment or survivorship.
- The Florida sampling program, during the miniseason in particular, provided invaluable data to this assessment. Programs such as these would be useful in all South Atlantic states, particularly if the management regulations continue to make established methods of index development or composition sampling from fleets less regular or possible.

6 References

Baranov, F. I. 1918. On the question of the biological basis of fisheries. Nauchnye Issledovaniya Ikhtiologicheskii Instituta Izvestiya **1**:81–128.

Beddington, J. R., and J. G. Cooke, 1983. The potential yield of fish stocks. FAO Fish. Tech. Pap. 242, 47 p.

Charnov, E. L., H. Gislason, and J. G. Pope. 2013. Evolutionary assembly rules for fish life histories. Fish and Fisheries **14(2)**:213–224.

Conn, P. B. 2010. Hierarchical analysis of multiple noisy abundance indices. Canadian Journal of Fisheries and Aquatic Sciences .

Conn, P. B., E. H. Williams, and K. W. Shertzer. 2010. When can we reliably estimate the productivity of fish stocks? Canadian Journal of Fisheries and Aquatic Sciences **67**:511–523.

Dunlop, E. S., K. Enberg, C. Jorgensen, and M. Heino. 2009. Toward Darwinian fisheries management. Evolutionary Applications **2**:245–259.

Efron, B., and R. Tibshirani. 1993. An Introduction to the Bootstrap. Chapman and Hall, London.

Enberg, K., C. Jorgensen, E. S. Dunlop, M. Heino, and U. Dieckmann. 2009. Implications of fisheries-induced evolution for stock rebuilding and recovery. Evolutionary Applications **2**:394–414.

Fitzhugh, G. R., K. W. Shertzer, G. T. Kellison, and D. M. Wyanski. 2012. Review of size- and age dependence in batch spawning: implications for stock assessment of fish species exhibiting indeterminate fecundity. Fishery Bulletin pages 413–425.

Fournier, D. A., H. J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optimization Methods and Software **27**:233–249.

Francis, R. 2003. Quantifying annual variation in catchability for commercial and research fishing. Fishery Bulletin **101**:293–304.

Francis, R. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences **68**:1124–1138.

Gabriel, W. L., and P. M. Mace, 1999. A review of biological reference points in the context of the precautionary approach. NOAA Technical Memorandum-F/SPO-40.

Legault, C. M., J. E. Powers, and V. R. Restrepo. 2001. Mixed Monte Carlo/bootstrap approach to assessing king and Spanish mackerel in the Atlantic and Gulf of Mexico: Its evolution and impact. Amercian Fisheries Society Symposium **24**:1–8.

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**:627–642.

Manly, B. F. J. 1997. Randomization, Bootstrap and Monte Carlo Methods in Biolog, 2nd edition. Chapman and Hall, London.

Mertz, G., and R. Myers. 1996. Influence of fecundity on recruitment variability of marine fish. Canadian Journal of Fisheries and Aquatic Sciences **53**:1618–1625.

Methot, R. D. 1989. Synthetic estimates of historical abundance and mortality for northern anchovy. American Fisheries Society Symposium **6**:66–82.

Methot, R. D., 2009. User Manual for Stock Synthesis, Model Version 3.04. NOAA Fisheries, Seattle, WA.

Mitchell, W. A., G. T. Kellison, N. M. Bacheler, J. C. Potts, C. M. Schobernd, and L. Hale. 2014. Depth-related distribution of postjuvenile Red Snapper in southeastern U.S. Atlantic Ocean waters: ontogenic patters and implications for management. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science **6**:142–155.

Patterson, W. F., C. E. Porch, J. H. Tarnecki, and A. J. Strelcheck. 2012. Effect of circle hook size on reef fish catch rates, species composition, and selectivity in the northern Gulf of Mexico recreational fishery. Bulletin of Marine Science **88**:647–665.

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

Prager, M. H., 2005. User's Manual for ASPIC: A Stock-Production Model Incorporating Covariates (ver. 5) And Auxiliary Programs. National Marine Fishery Service, Beaufort Laboratory Document BL-2004-01, Beaufort, NC.

Quinn, T. J., and R. B. Deriso. 1999. Quantitative Fish Dynamics. Oxford University Press, New York, New York.

Restrepo, V. R., J. M. Hoenig, J. E. Powers, J. W. Baird, and S. C. Turner. 1992. A simple simulation approach to risk and cost analysis, with applications to swordfish and cod fisheries. Fishery Bulletin **90**:736–748.

Schaefer, M. B. 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. Bulletin of the Inter-American Tropical Tuna Commission **1**:27–56.

Schaefer, M. B. 1957. A study of the dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. Bulletin of the Inter-American Tropical Tuna Commission **2**:247–268.

SEDAR Procedural Guidance, 2010. SEDAR Procedural Workshop IV: Characterizing and Presenting Assessment Uncertainty.

SEDAR19, 2009. SEDAR 19: South Atlantic Red Grouper. SEDAR, North Charleston, SC.

SEDAR24, 2010. SEDAR 24: South Atlantic Red Snapper. SEDAR, North Charleston, SC.

SEDAR4, 2004. SEDAR 4: Stock assessment of the deepwater snapper-grouper complex in the South Atlantic. SEDAR, North Charleston, SC.

SEDAR41-AW05, 2015. Commercial age and length composition weightings for Atlantic red snapper (Lutjanus campechanus).

SEDAR41-AW08, 2015. South Atlantic U.S. Atlantic red snapper (Lutjanus campechanus) catch curve analysis.

SEDAR41-DW49, 2015. Estimating annual fecundity of Red Snapper by size using nonlinear models. SEDAR41-DW49. SEDAR, North Charleston, SC.

SEDAR41-RW07, 2016. Modifications to the Southeast Reef Fish Survey Chevron Trap Age Compositions for Red Snapper and Gray Triggerfish.

Shertzer, K. W., M. H. Prager, D. S. Vaughan, and E. H. Williams, 2008. Fishery models. Pages 1582–1593 *in* S. E. Jorgensen and F. Fath, editors. Population Dynamics. Vol. [2] of Encyclopedia of Ecology, 5 vols. Elsevier, Oxford.

Then, A. Y., J. M. Hoenig, N. G. Hall, and D. A. Hewitt. 2014. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES Journal of Marine Science **72**:82–92.

Wells, R. D., K. M. Boswell, J. H. Cowan Jr., and W. F. Patterson. 2008. Size selectivity of sampling gears targeting red snapper in the northern Gulf of Mexico. Fisheries Research **89**:294–299.

Williams, E. H., and K. W. Shertzer, 2015. Technical documentation of the Beaufort Assessment Model (BAM). NOAA Technical Memorandum-NMFS-SEFSC-671.

7 Tables

Table 1. Life-history characteristics at age, including average body total length (TL) and weight (mid-year), proportion female, annual proportion females mature, and natural mortality at age. The CV of length was estimated by the assessment model; other values were treated as input.

Age	Avg. TL (mm)	Avg. TL (in)	CV length	Avg. Whole weight (kg)	Avg. Whole weight (lb)	Fem. maturity	Proportion Female	Nat. mortality
1	323.9	12.8	0.11	0.53	1.17	0.43	0.5	0.595
2	449.3	17.7	0.11	1.41	3.10	0.73	0.5	0.364
3	547.9	21.6	0.11	2.55	5.62	0.91	0.5	0.271
4	625.4	24.6	0.11	3.78	8.34	0.97	0.5	0.222
5	686.4	27.0	0.11	5.00	11.02	0.99	0.5	0.193
6	734.4	28.9	0.11	6.12	13.49	1.00	0.5	0.174
7	772.2	30.4	0.11	7.11	15.67	1.00	0.5	0.162
8	801.9	31.6	0.11	7.96	17.54	1.00	0.5	0.153
9	825.2	32.5	0.11	8.67	19.12	1.00	0.5	0.146
10	843.6	33.2	0.11	9.26	20.42	1.00	0.5	0.142
11	858.1	33.8	0.11	9.74	21.48	1.00	0.5	0.138
12	869.4	34.2	0.11	10.13	22.34	1.00	0.5	0.135
13	878.4	34.6	0.11	10.45	23.04	1.00	0.5	0.133
14	885.4	34.9	0.11	10.70	23.59	1.00	0.5	0.132
15	891.0	35.1	0.11	10.90	24.04	1.00	0.5	0.130
16	895.3	35.2	0.11	11.06	24.39	1.00	0.5	0.129
17	898.7	35.4	0.11	11.19	24.67	1.00	0.5	0.129
18	901.4	35.5	0.11	11.29	24.89	1.00	0.5	0.128
19	903.5	35.6	0.11	11.37	25.07	1.00	0.5	0.128
20	905.2	35.6	0.11	11.43	25.21	1.00	0.5	0.127

Table 2. Size (TL) in inches and weight in pounds (lb) at age as applied to the population (Pop), fishery–dependent portion of the population (FD), and fishery–dependent portion of the population during the 20 mm size limit (FD20). The CV of length was estimated by the assessment model; other values were treated as input through the von Bertalanffy growth parameters.

Age	Pop.TL	CV.Pop.TL	Pop.lb	FD.TL	CV.FD.TL	FD.lb	FD20.TL	CV.FD20.TL	FD20.lb
1	12.8	0.11	1.2	11.2	0.14	0.8	16.2	0.1	2.4
2	17.7	0.11	3.1	16.2	0.14	2.4	19.5	0.1	4.1
3	21.6	0.11	5.6	20.2	0.14	4.6	22.2	0.1	6.1
4	24.6	0.11	8.3	23.4	0.14	7.2	24.5	0.1	8.2
5	27.0	0.11	11.0	26.0	0.14	9.8	26.5	0.1	10.3
6	28.9	0.11	13.5	28.1	0.14	12.3	28.1	0.1	12.4
7	30.4	0.11	15.7	29.7	0.14	14.7	29.5	0.1	14.3
8	31.6	0.11	17.5	31.1	0.14	16.7	30.6	0.1	16.0
9	32.5	0.11	19.1	32.1	0.14	18.5	31.6	0.1	17.6
10	33.2	0.11	20.4	33.0	0.14	20.0	32.5	0.1	19.0
11	33.8	0.11	21.5	33.7	0.14	21.3	33.2	0.1	20.3
12	34.2	0.11	22.3	34.2	0.14	22.4	33.7	0.1	21.4
13	34.6	0.11	23.0	34.7	0.14	23.3	34.2	0.1	22.4
14	34.9	0.11	23.6	35.0	0.14	24.0	34.7	0.1	23.2
15	35.1	0.11	24.0	35.3	0.14	24.6	35.0	0.1	23.9
16	35.2	0.11	24.4	35.6	0.14	25.0	35.3	0.1	24.5
17	35.4	0.11	24.7	35.7	0.14	25.4	35.6	0.1	25.1
18	35.5	0.11	24.9	35.9	0.14	25.8	35.8	0.1	25.5
19	35.6	0.11	25.1	36.0	0.14	26.0	36.0	0.1	25.9
20	35.6	0.11	25.2	36.1	0.14	26.2	36.1	0.1	26.2

Table 3. Observed time series of landings(L) and discards(D) for commercial lines (cH), headboat (HB), and general recreational (GR). Commercial landings are in units of 1000 lb whole weight. Recreational landings and discards and commercial discards are in units of 1000 fish. Confidential data have been redacted.

Year	cH.L	HB.L	GR.L	cH.D	HB.D	GR.D
1950	368.657	.	.	.	.	.
1951	499.765	.	.	.	.	.
1952	385.930	.	.	.	.	.
1953	398.279	.	.	.	.	.
1954	593.207	.	.	.	.	.
1955	493.315	12.501	24.035	.	.	.
1956	483.907	13.652	26.248	.	.	.
1957	867.291	14.803	28.460	.	.	.
1958	612.508	15.953	30.673	.	.	.
1959	657.736	17.104	32.885	.	.	.
1960	671.075	18.255	35.098	.	.	.
1961	796.374	19.908	38.276	.	.	.
1962	645.983	21.561	41.454	.	.	.
1963	488.789	23.214	44.633	.	.	.
1964	537.589	24.867	47.811	.	.	.
1965	558.108	26.520	50.989	.	.	.
1966	554.506	26.676	51.288	.	.	.
1967	725.503	26.831	51.587	.	.	.
1968	865.520	26.986	51.885	.	.	.
1969	538.190	27.142	52.184	.	.	.
1970	513.023	27.297	52.483	.	.	.
1971	457.393	29.995	57.670	.	.	.
1972	406.641	32.693	62.857	.	.	.
1973	296.560	35.391	68.044	.	.	.
1974	478.352	38.088	73.231	.	.	.
1975	600.790	40.786	78.418	.	.	.
1976	571.504	41.246	79.303	.	.	.
1977	596.339	41.707	80.187	.	.	.
1978	594.356	42.167	81.072	.	.	.
1979	420.936	42.627	81.957	.	.	.
1980	385.485	43.087	82.842	.	.	.
1981	378.759	36.031	93.458	.	.	4.435
1982	308.445	19.553	36.294	.	.	4.435
1983	316.818	30.698	68.469	.	.	4.435
1984	253.431	31.146	212.547	.	0.069	61.825
1985	250.824	50.336	288.971	.	0.111	64.088
1986	219.440	16.625	100.736	.	0.037	64.088
1987	191.701	24.996	47.373	.	0.055	64.088
1988	173.689	36.527	80.821	.	0.08	50.274
1989	266.942	23.453	97.147	.	0.052	19.383
1990	226.542	20.919	12.092	.	0.046	19.383
1991	143.546	13.857	34.717	.	0.03	19.383
1992	104.374	5.301	51.908	19.603	2.51	27.994
1993	220.153	7.347	11.326	16.725	3.478	68.149
1994	195.319	8.225	18.313	21.134	3.894	66.54
1995	177.312	8.826	13.482	21.068	4.178	50.89
1996	138.671	5.543	9.342	20.727	2.624	20.445
1997	110.595	5.770	34.238	22.392	2.732	16.574
1998	89.602	4.741	13.015	16.171	2.244	26.789
1999	93.595	6.836	39.579	13.641	3.236	162.71
2000	104.165	8.437	45.347	14.552	3.994	248.597
2001	196.697	12.028	31.587	15.141	5.694	202.665
2002	187.967	12.931	35.062	29.848	6.122	123.362
2003	138.342	5.706	25.977	8.372	2.701	159.329
2004	172.083	10.842	28.914	2.425	18.79	199.638
2005	129.700	8.907	29.443	10.177	9.876	72.855
2006	86.382	5.945	26.769	4.817	17.233	119.735
2007	114.973	6.889	17.646	13.778	71.886	288.276
2008	252.146	18.943	81.638	12.553	73.609	511.984
2009	362.386	21.507	54.666	14.466	57.327	240.516
2010	6.448	0.477	0.062	17.438	38.443	138.478
2011	− − −	− − −	0.062	40.107	41.391	33.484
2012	8.142	2.127	15.628	19.214	46.782	142.961
2013	31.600	1.520	7.588	19.302	46.74	83.992
2014	65.443	5.904	28.186	27.008	46.612	285.962

Table 4. Observed indices of abundance and CVs from commercial line (cH), headboat (HB), combined chevon trap and video (CVID), and headboat discard (HB.D).

Year	cH	cH CV	HB	HB CV	CVID	CVID CV	HB.D	HB.D CV
1976	.	.	2.37	0.2	.	.	.	.
1977	.	.	2.16	0.2	.	.	.	.
1978	.	.	2.13	0.2	.	.	.	.
1979	.	.	2.23	0.2	.	.	.	.
1980	.	.	1.45	0.2	.	.	.	.
1981	.	.	2.95	0.2	.	.	.	.
1982	.	.	1.20	0.2	.	.	.	.
1983	.	.	1.64	0.2	.	.	.	.
1984	.	.	1.42	0.2	.	.	.	.
1985	.	.	2.07	0.2	.	.	.	.
1986	.	.	0.48	0.2	.	.	.	.
1987	.	.	0.58	0.2	.	.	.	.
1988	.	.	0.56	0.2	.	.	.	.
1989	.	.	0.90	0.2	.	.	.	.
1990	.	.	0.87	0.2	.	.	.	.
1991	.	.	0.69	0.2	.	.	.	.
1992	.	.	0.08	0.2	.	.	.	.
1993	1.09	0.2	0.16	0.2	.	.	.	.
1994	0.89	0.2	0.26	0.2	.	.	.	.
1995	0.89	0.2	0.28	0.2	.	.	.	.
1996	0.61	0.2	0.25	0.2	.	.	.	.
1997	0.59	0.2	0.27	0.2	.	.	.	.
1998	0.66	0.2	0.24	0.2	.	.	.	.
1999	0.80	0.2	0.29	0.2	.	.	.	.
2000	0.74	0.2	0.41	0.2	.	.	.	.
2001	1.27	0.2	0.76	0.2	.	.	.	.
2002	1.38	0.2	0.88	0.2	.	.	.	.
2003	1.04	0.2	0.52	0.2	.	.	.	.
2004	1.42	0.2	0.76	0.2	.	.	.	.
2005	1.19	0.2	0.76	0.2	.	.	0.56	0.30
2006	0.60	0.2	0.43	0.2	.	.	0.41	0.37
2007	0.67	0.2	0.44	0.2	.	.	2.02	0.17
2008	1.22	0.2	1.71	0.2	.	.	1.39	0.21
2009	1.94	0.2	1.81	0.2	.	.	0.63	0.27
2010	.	.	.	.	0.90	0.26	0.56	0.30
2011	.	.	.	.	0.66	0.23	0.41	0.37
2012	.	.	.	.	1.10	0.18	2.02	0.17
2013	.	.	.	.	0.87	0.20	1.39	0.21
2014	.	.	.	.	1.47	0.17	0.63	0.27

Table 5. Sample sizes (number of trips) of length compositions (len) or age compositions (age) by survey or fleet. Data sources are commercial lines (cH), headboat (HB), headboat discard (HB.D), general recreational (GR),and MARMAP chevron trap (CVT).

Year	len.cH	len.cH.D	len.HB.D	age.cH	age.HB	age.GR	age.CVT
1978	.	.	.	.	80	.	.
1979	.	.	.	.	31	.	.
1980	.	.	.	.	30	.	.
1981	.	.	.	.	141	.	.
1982	.	.	.	.	55	.	.
1983	.	.	.	.	167	.	.
1984	125	.	.	.	166	.	.
1985	139	.	.	.	160	.	.
1986	94	.	.	.	97	.	.
1987	89	.	.	.	60	.	.
1988	84	.	.	.	.	.	.
1989	88	.	.	.	.	.	.
1990	63	.	.	11	23	.	.
1991	106	.	.	.	13	.	.
1992	82	.	.	11	.	.	.
1993	.	.	.	.	.	.	.
1994	.	.	.	14	.	.	.
1995	.	.	.	.	.	.	.
1996	.	.	.	48	.	.	.
1997	.	.	.	45	.	.	.
1998	.	.	.	14	.	.	.
1999	.	.	.	15	.	.	.
2000	.	.	.	28	.	.	.
2001	.	.	.	23	.	15	.
2002	.	.	.	.	.	84	.
2003	.	.	.	10	.	91	.
2004	.	.	.	25	.	83	.
2005	.	.	37	53	22	78	.
2006	.	.	29	84	49	26	.
2007	.	.	64	132	34	.	.
2008	.	.	61	158	47	.	.
2009	.	13	56	263	241	58	.
2010	.	.	50	.	.	.	73
2011	.	.	48	.	.	.	70
2012	.	.	56	39	40	121	148
2013	.	13	60	109	35	139	139
2014	.	.	56	64	49	315	150

Table 6. Coefficients of variation used for the MCB bootstraps of landings and discards. Commercial handline landings (cv.L.cH), headboat landings (cv.L.HB), general recreational landings (cv.L.GR), commercial handline discards (cv.D.cH), headboat discards (cv.D.HB), and general recreational discards (cv.D.GR).

Year	CV.L.cH	CV.L.HB	CV.L.GR	CV.D.cH	CV.D.HB	CV.D.GR
1950	0.25	–	–	–	–	–
1951	0.25	–	–	–	–	–
1952	0.25	–	–	–	–	–
1953	0.25	–	–	–	–	–
1954	0.25	–	–	–	–	–
1955	0.25	0.59	0.59	–	–	–
1956	0.25	0.59	0.59	–	–	–
1957	0.25	0.59	0.59	–	–	–
1958	0.25	0.59	0.59	–	–	–
1959	0.25	0.59	0.59	–	–	–
1960	0.25	0.59	0.59	–	–	–
1961	0.25	0.59	0.59	–	–	–
1962	0.20	0.59	0.59	–	–	–
1963	0.20	0.59	0.59	–	–	–
1964	0.20	0.59	0.59	–	–	–
1965	0.20	0.59	0.59	–	–	–
1966	0.20	0.59	0.59	–	–	–
1967	0.20	0.59	0.59	–	–	–
1968	0.20	0.59	0.59	–	–	–
1969	0.20	0.59	0.59	–	–	–
1970	0.20	0.59	0.59	–	–	–
1971	0.20	0.59	0.59	–	–	–
1972	0.20	0.59	0.59	–	–	–
1973	0.20	0.59	0.59	–	–	–
1974	0.20	0.59	0.59	–	–	–
1975	0.20	0.59	0.59	–	–	–
1976	0.20	0.59	0.59	–	–	–
1977	0.20	0.59	0.59	–	–	–
1978	0.10	0.59	0.59	–	–	–
1979	0.10	0.59	0.59	–	–	–
1980	0.10	0.59	0.59	–	–	–
1981	0.10	0.15	0.27	–	–	1.00
1982	0.10	0.15	0.34	–	–	1.00
1983	0.10	0.15	0.18	–	–	1.00
1984	0.10	0.15	0.22	–	0.20	0.56
1985	0.10	0.15	0.20	–	0.20	1.34
1986	0.05	0.15	0.29	–	0.20	1.00
1987	0.05	0.15	0.20	–	0.20	1.00
1988	0.05	0.15	0.28	–	0.20	1.33
1989	0.05	0.15	0.21	–	0.20	1.18
1990	0.05	0.15	0.29	–	0.20	1.00
1991	0.05	0.15	0.31	–	0.20	1.00
1992	0.05	0.15	0.19	0.20	0.20	0.79
1993	0.05	0.15	0.22	0.20	0.20	0.68
1994	0.05	0.15	0.27	0.20	0.20	0.81
1995	0.05	0.15	0.29	0.20	0.20	0.53
1996	0.05	0.10	0.42	0.20	0.20	1.00
1997	0.05	0.10	0.52	0.20	0.20	0.54
1998	0.05	0.10	0.24	0.20	0.20	0.96
1999	0.05	0.10	0.23	0.20	0.20	0.47
2000	0.05	0.10	0.23	0.20	0.20	0.45
2001	0.05	0.10	0.18	0.20	0.20	0.42
2002	0.05	0.10	0.17	0.20	0.20	0.56
2003	0.05	0.10	0.20	0.20	0.20	0.47
2004	0.05	0.10	0.21	0.20	0.20	0.29
2005	0.05	0.10	0.24	0.20	0.20	0.23
2006	0.05	0.10	0.26	0.20	0.20	0.31
2007	0.05	0.10	0.24	0.20	0.20	0.26
2008	0.05	0.05	0.27	0.20	0.20	0.36
2009	0.05	0.05	0.25	0.20	0.20	0.38
2010	0.05	0.05	1.00	0.20	0.20	0.39
2011	0.05	0.05	1.00	0.20	0.20	0.34
2012	0.05	0.05	0.17	0.20	0.20	0.39
2013	0.05	0.05	0.18	0.20	0.20	0.31
2014	0.05	0.05	0.11	0.20	0.20	0.21

Table 7. Estimated total abundance at age (1000 fish) at start of year.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1950	449.22	247.68	170.03	125.98	97.96	78.41	63.97	52.81	44.00	36.91	31.09	26.29	22.30	18.96	16.13	13.75	11.73	10.01	8.55	50.39	1576.19
1951	449.22	247.68	169.95	125.84	97.85	78.32	63.89	52.75	43.95	36.87	31.06	26.26	22.28	18.93	16.11	13.73	11.72	10.00	8.54	50.33	1575.30
1952	449.21	247.64	169.17	124.42	96.65	77.36	63.11	52.11	43.41	36.42	30.68	25.94	22.00	18.70	15.91	13.56	11.57	9.88	8.44	49.72	1565.90
1953	449.21	247.67	169.80	124.98	96.45	77.13	62.92	51.95	43.28	36.31	30.58	25.86	21.94	18.65	15.86	13.52	11.54	9.85	8.41	49.57	1565.46
1954	449.20	247.66	169.73	125.30	96.78	76.89	62.66	51.73	43.10	36.16	30.46	25.76	21.85	18.57	15.80	13.47	11.49	9.81	8.38	49.36	1564.14
1955	449.18	247.60	168.55	123.19	95.39	75.84	61.41	50.65	42.20	35.40	29.82	25.22	21.39	18.18	15.47	13.19	11.25	9.60	8.20	48.33	1550.05
1956	449.15	246.82	161.79	115.43	89.10	71.71	58.73	48.62	40.82	34.47	29.17	24.67	20.93	17.79	15.13	12.90	11.01	9.39	8.02	47.28	1512.93
1957	449.11	246.69	160.25	109.72	82.74	66.48	55.19	46.28	39.04	33.26	28.35	24.09	20.43	17.36	14.77	12.59	10.75	9.17	7.83	46.16	1480.29
1958	449.02	246.42	156.50	103.47	74.89	58.87	48.87	41.61	35.60	30.51	26.25	22.46	19.14	16.27	13.84	11.80	10.07	8.59	7.34	43.25	1424.79
1959	448.93	246.31	156.55	102.01	71.41	53.96	43.90	37.44	32.57	28.34	24.54	21.20	18.20	15.54	13.22	11.27	9.62	8.21	7.01	41.31	1391.54
1960	448.83	246.12	154.88	100.16	69.16	50.62	39.65	33.19	28.96	25.64	22.56	19.62	17.00	14.62	12.50	10.65	9.09	7.76	6.63	39.05	1356.67
1961	448.70	245.91	153.27	97.44	66.83	48.32	36.72	29.64	25.42	22.60	20.25	17.89	15.61	13.55	11.67	9.99	8.53	7.28	6.21	36.62	1322.46
1962	448.54	245.59	150.21	92.92	62.71	45.14	33.97	26.67	22.09	19.33	17.42	15.67	13.89	12.14	10.55	9.10	7.80	6.66	5.69	33.51	1279.61
1963	448.35	245.35	149.19	90.72	59.69	42.37	31.83	24.80	20.03	16.96	15.05	13.62	12.29	10.91	9.55	8.31	7.18	6.15	5.26	30.98	1248.59
1964	448.19	245.13	148.67	90.32	58.52	40.59	30.14	23.49	18.87	15.59	13.41	11.95	10.84	9.81	8.72	7.64	6.66	5.75	4.94	29.08	1228.30
1965	448.00	244.82	146.30	87.59	56.77	38.86	28.26	21.83	17.57	14.47	12.15	10.49	9.38	8.53	7.72	6.88	6.03	5.26	4.55	26.91	1202.38
1966	447.78	244.48	143.83	83.89	53.67	36.85	26.52	20.12	16.08	13.29	11.14	9.40	8.14	7.29	6.63	6.02	5.36	4.71	4.11	24.59	1173.89
1967	447.52	244.25	142.54	81.34	50.72	34.40	24.87	18.69	14.69	12.07	10.16	8.54	7.23	6.27	5.62	5.13	4.66	4.15	3.65	22.25	1148.74
1968	447.14	243.86	138.94	76.45	46.63	30.87	22.08	16.69	13.01	10.52	8.81	7.44	6.28	5.32	4.62	4.15	3.79	3.44	3.07	19.18	1112.31
1969	446.56	243.33	134.48	69.80	41.05	26.64	18.64	13.97	10.97	8.81	7.27	6.11	5.18	4.38	3.71	3.23	2.91	2.65	2.41	15.60	1067.71
1970	446.00	243.09	136.78	71.05	39.52	24.76	17.00	12.48	9.74	7.88	6.46	5.35	4.51	3.83	3.24	2.76	2.40	2.16	1.97	13.41	1054.40
1971	445.51	242.75	136.22	71.85	40.00	23.71	15.73	11.34	8.67	6.97	5.76	4.74	3.94	3.33	2.83	2.40	2.04	1.78	1.60	11.41	1042.55
1972	445.02	242.19	134.05	70.19	39.79	23.70	14.94	10.45	7.87	6.22	5.11	4.24	3.50	2.91	2.46	2.10	1.78	1.52	1.32	9.69	1029.05
1973	444.53	241.60	131.55	67.58	38.16	23.25	14.79	9.87	7.24	5.65	4.58	3.78	3.15	2.60	2.17	1.84	1.57	1.33	1.13	8.23	1014.59
1974	444.13	241.07	130.24	66.28	36.86	22.46	14.69	9.94	6.99	5.33	4.27	3.47	2.88	2.40	1.99	1.66	1.41	1.20	1.02	7.18	1005.47
1975	443.41	240.15	122.70	58.66	32.39	19.56	12.88	9.02	6.46	4.74	3.73	3.00	2.45	2.03	1.70	1.41	1.17	1.00	0.85	5.82	973.13
1976	441.88	238.74	113.20	47.87	24.95	15.11	9.96	7.10	5.31	4.00	3.04	2.39	1.93	1.58	1.31	1.10	0.91	0.76	0.65	4.34	926.13
1977	439.39	237.15	106.54	40.05	18.55	10.68	7.13	5.13	3.93	3.11	2.43	1.85	1.47	1.19	0.97	0.81	0.68	0.56	0.47	3.08	885.17
1978	490.53	234.78	97.34	32.10	13.27	6.85	4.40	3.23	2.52	2.06	1.70	1.33	1.02	0.81	0.65	0.54	0.45	0.37	0.31	1.97	896.22
1979	364.63	260.57	86.07	23.54	8.57	4.00	2.33	1.67	1.35	1.13	0.97	0.80	0.63	0.48	0.38	0.31	0.26	0.21	0.18	1.09	759.17
1980	539.16	193.50	95.37	21.16	6.43	2.66	1.41	0.92	0.73	0.63	0.56	0.48	0.40	0.31	0.24	0.19	0.16	0.13	0.11	0.63	865.15
1981	188.64	284.03	62.99	19.16	4.77	1.68	0.80	0.49	0.36	0.31	0.28	0.25	0.22	0.18	0.14	0.11	0.09	0.07	0.06	0.34	564.97
1982	310.46	98.55	87.42	11.30	3.86	1.12	0.46	0.25	0.17	0.14	0.13	0.12	0.10	0.09	0.07	0.06	0.05	0.04	0.03	0.16	514.58
1983	881.10	164.58	36.72	20.79	2.93	1.11	0.36	0.16	0.10	0.07	0.06	0.05	0.05	0.04	0.04	0.03	0.03	0.02	0.02	0.08	1108.34
1984	1003.36	460.16	45.09	5.03	3.18	0.52	0.23	0.09	0.04	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.03	1517.89
1985	460.99	510.01	130.11	7.76	1.00	0.76	0.15	0.08	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.02	1111.02
1986	239.59	227.42	126.82	19.69	1.41	0.23	0.22	0.05	0.03	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	615.54
1987	777.07	117.93	88.26	38.83	6.79	0.55	0.10	0.11	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1029.73
1988	582.89	403.01	53.57	33.38	16.14	3.11	0.28	0.05	0.06	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1092.54
1989	205.82	305.21	192.51	22.39	15.32	8.13	1.71	0.16	0.03	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	751.35
1990	74.19	108.79	149.15	82.42	10.47	7.82	4.50	1.02	0.10	0.02	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	438.55
1991	64.46	38.66	62.94	85.31	50.50	6.76	5.26	3.13	0.73	0.08	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	317.88
1992	340.40	32.10	19.84	31.51	46.94	30.06	4.31	3.56	2.23	0.54	0.06	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	511.60
1993	121.03	173.87	19.93	9.01	10.26	17.14	13.10	2.23	2.12	1.47	0.38	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	370.63
1994	211.20	55.67	101.85	8.95	2.97	3.75	7.11	6.07	1.12	1.14	0.82	0.22	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	400.93
1995	95.70	97.71	32.66	47.33	3.09	1.12	1.60	3.37	3.14	0.62	0.65	0.48	0.13	0.01	0.00	0.00	0.00	0.00	0.00	0.00	287.63
1996	254.92	42.19	55.32	15.13	17.00	1.23	0.50	0.79	1.81	1.78	0.36	0.39	0.29	0.08	0.01	0.00	0.00	0.00	0.00	0.00	391.80
1997	175.72	129.95	26.80	29.72	6.58	7.93	0.62	0.28	0.46	1.09	1.10	0.23	0.25	0.19	0.05	0.01	0.00	0.00	0.00	0.00	380.98
1998	322.87	89.20	78.53	9.48	6.09	1.56	2.37	0.23	0.12	0.24	0.62	0.66	0.14	0.15	0.12	0.03	0.00	0.00	0.00	0.00	512.43
1999	431.59	167.93	57.66	43.21	4.25	2.93	0.82	1.36	0.14	0.08	0.16	0.42	0.45	0.10	0.11	0.08	0.02	0.00	0.00	0.00	711.30
2000	451.11	201.06	98.26	24.93	13.14	1.45	1.19	0.39	0.75	0.09	0.05	0.11	0.29	0.31	0.07	0.07	0.06	0.02	0.00	0.00	793.35
2001	325.68	197.11	112.51	41.74	7.54	4.48	0.59	0.57	0.22	0.45	0.06	0.03	0.07	0.20	0.22	0.05	0.05	0.04	0.01	0.00	691.61
2002	267.02	141.35	111.28	52.27	14.75	2.93	1.97	0.29	0.31	0.12	0.27	0.03	0.02	0.05	0.13	0.14	0.03	0.03	0.02	0.01	593.01
2003	346.59	119.25	80.97	52.75	19.33	6.02	1.36	1.02	0.17	0.19	0.08	0.18	0.02	0.01	0.03	0.08	0.09	0.02	0.02	0.02	628.22
2004	127.74	156.98	70.30	44.78	25.23	9.94	3.38	0.83	0.66	0.11	0.13	0.06	0.13	0.02	0.01	0.02	0.06	0.07	0.01	0.03	440.49
2005	52.24	43.69	75.59	32.70	17.68	11.07	4.92	1.86	0.49	0.42	0.07	0.09	0.04	0.09	0.01	0.01	0.02	0.04	0.05	0.03	241.14
2006	943.19	17.60	20.48	33.34	12.08	7.37	5.31	2.67	1.12	0.32	0.29	0.05	0.06	0.03	0.06	0.01	0.01	0.01	0.03	0.06	1044.08
2007	660.20	480.92	11.04	9.33	10.82	4.38	3.17	2.67	1.53	0.71	0.21	0.20	0.04	0.05	0.02	0.05	0.01	0.00	0.01	0.06	1185.42
2008	741.35	300.00	280.11	4.83	2.94	3.82	1.79	1.48	1.39	0.86	0.41	0.13	0.12	0.02	0.03	0.01	0.03	0.00	0.00	0.04	1339.38
2009	115.07	295.70	156.90	106.44	1.21	0.84	1.31	0.73	0.70	0.73	0.48	0.24	0.08	0.07	0.01	0.02	0.01	0.02	0.00	0.03	680.57
2010	148.33	40.21	142.83	64.82	33.03	0.42	0.33	0.59	0.37	0.37	0.41	0.28	0.14	0.05	0.04	0.01	0.01	0.00	0.01	0.02	432.28
2011	220.73	69.37	22.60	84.06	39.43	21.06	0.28	0.24	0.44	0.28	0.30	0.33	0.22	0.11	0.04	0.04	0.01	0.01	0.00	0.02	459.57
2012	241.50	115.17	44.07	14.82	56.34	27.27	15.03	0.21	0.18	0.34	0.22	0.23	0.25	0.17	0.09	0.03	0.03	0.01	0.01	0.02	515.98
2013	547.75	117.10	66.89	25.69	8.24	31.47	15.89	9.17	0.13	0.12	0.23	0.15	0.16	0.17	0.12	0.06	0.02	0.02	0.00	0.02	823.39
2014	941.88	285.09	74.50	43.72	16.48	5.35	21.02	10.91	6.44	0.09	0.08	0.16	0.11	0.11	0.13	0.09	0.04	0.01	0.01	0.02	1406.27
2015	434.25	475.21	171.85	42.81	21.87	7.94	2.65	10.81	5.79	3.51	0.05	0.05	0.09	0.06	0.06	0.07	0.05	0.02	0.01	0.02	1177.17

Table 8. Estimated biomass at age (mt) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1950	237.8	348.7	433.2	476.8	489.8	479.8	454.7	420.3	381.5	341.8	302.9	266.5	233.1	202.9	175.8	152.1	131.3	113.0	97.2	576.1	6315.3
1951	237.8	348.7	433.0	476.3	489.2	479.2	454.2	419.8	381.1	341.5	302.6	266.2	232.8	202.6	175.6	151.9	131.1	112.9	97.1	575.5	6309.1
1952	237.8	348.6	431.0	470.9	483.2	473.4	448.6	414.6	376.4	337.3	298.9	262.9	229.9	200.1	173.5	150.1	129.5	111.5	95.9	568.4	6242.6
1953	237.8	348.6	432.6	473.0	482.2	472.0	447.3	413.4	375.3	336.2	298.0	262.1	229.2	199.5	173.0	149.6	129.1	111.2	95.6	566.7	6232.5
1954	237.8	348.6	432.4	474.3	483.8	470.5	445.4	411.7	373.7	334.9	296.8	261.0	228.3	198.7	172.2	149.0	128.6	110.7	95.2	564.4	6218.1
1955	237.8	348.6	429.4	466.3	476.9	464.1	436.5	403.1	365.9	327.8	290.5	255.6	223.5	194.6	168.6	145.9	125.9	108.4	93.3	552.5	6115.0
1956	237.8	347.5	412.2	436.9	445.5	438.8	417.5	386.9	353.9	319.2	284.2	250.0	218.7	190.3	165.0	142.7	123.2	106.1	91.2	540.5	5908.0
1957	237.8	347.3	408.3	415.3	413.7	406.8	392.3	368.3	338.5	308.0	276.2	244.1	213.5	185.8	161.1	139.3	120.3	103.5	89.1	527.8	5696.9
1958	237.7	346.9	398.7	391.6	374.4	360.2	347.4	331.1	308.7	282.5	255.8	227.7	200.0	174.1	150.9	130.6	112.7	97.0	83.5	494.5	5306.1
1959	237.7	346.7	398.8	386.1	357.0	330.2	312.1	297.9	282.4	262.4	239.1	214.9	190.2	166.3	144.2	124.7	107.6	92.7	79.7	472.3	5043.0
1960	237.6	346.5	394.6	379.1	345.8	309.7	281.8	264.1	251.1	237.4	219.8	198.9	177.7	156.5	136.3	117.9	101.7	87.6	75.4	446.5	4765.8
1961	237.5	346.2	390.5	368.8	334.1	295.7	261.0	235.9	220.4	209.3	197.3	181.4	163.1	145.0	127.2	110.5	95.4	82.2	70.7	418.7	4490.9
1962	237.5	345.7	382.7	351.7	313.5	276.2	241.5	212.2	191.6	179.1	169.7	158.8	145.1	129.9	115.0	100.7	87.3	75.2	64.7	383.2	4161.2
1963	237.4	345.4	380.1	343.4	298.4	259.3	226.2	197.3	173.6	157.0	146.7	138.0	128.4	116.8	104.1	92.0	80.3	69.5	59.8	354.2	3907.9
1964	237.3	345.1	378.8	341.9	292.6	248.4	214.2	186.9	163.6	144.4	130.7	121.1	113.3	104.9	95.0	84.5	74.5	64.9	56.1	332.5	3730.7
1965	237.2	344.6	372.7	331.5	283.8	237.8	200.9	173.7	152.4	134.0	118.4	106.3	98.0	91.3	84.2	76.1	67.5	59.4	51.7	307.7	3529.2
1966	237.1	344.2	366.4	317.5	268.3	225.5	188.5	160.1	139.5	123.1	108.5	95.2	85.0	78.0	72.3	66.6	60.0	53.1	46.7	281.1	3316.8
1967	236.9	343.8	363.1	307.9	253.6	210.5	176.8	148.7	127.3	111.7	99.0	86.6	75.5	67.1	61.3	56.7	52.1	46.9	41.5	254.4	3121.6
1968	236.7	343.3	354.0	289.4	233.1	188.9	157.0	132.8	112.8	97.4	85.8	75.4	65.6	57.0	50.4	46.0	42.4	38.9	34.9	219.3	2861.0
1969	236.4	342.5	342.6	264.2	205.3	163.0	132.5	111.2	95.2	81.6	70.8	61.9	54.1	46.8	40.5	35.8	32.5	30.0	27.4	178.4	2552.7
1970	236.1	342.2	348.5	268.9	197.6	151.5	120.9	99.3	84.4	73.0	63.0	54.2	47.1	41.0	35.3	30.5	26.9	24.4	22.4	153.3	2420.6
1971	235.8	341.7	347.0	271.9	200.0	145.1	111.8	90.2	75.1	64.5	56.1	48.0	41.1	35.6	30.8	26.5	22.8	20.1	18.2	130.4	2313.1
1972	235.6	340.9	341.5	265.7	199.0	145.0	106.2	83.1	68.2	57.6	49.8	43.0	36.6	31.2	26.9	23.2	19.9	17.1	15.0	110.7	2216.3
1973	235.3	340.1	335.2	255.8	190.8	142.2	105.2	78.6	62.8	52.3	44.6	38.3	32.9	27.9	23.6	20.3	17.5	15.0	12.9	94.1	2125.3
1974	235.1	339.4	331.8	250.9	184.3	137.4	104.4	79.1	60.6	49.3	41.6	35.2	30.1	25.7	21.7	18.3	15.7	13.5	11.6	82.1	2067.9
1975	234.7	338.1	312.6	222.0	162.0	119.7	91.6	71.8	56.0	43.9	36.3	30.4	25.6	21.7	18.5	15.6	13.1	11.3	9.7	66.6	1901.1
1976	233.9	336.1	288.4	181.2	124.7	92.4	70.8	56.5	46.0	37.0	29.6	24.3	20.2	16.9	14.3	12.2	10.2	8.6	7.4	49.6	1660.2
1977	232.6	333.8	271.4	151.6	92.7	65.4	50.7	40.8	34.1	28.8	23.7	18.8	15.3	12.7	10.6	8.9	7.6	6.3	5.3	35.2	1446.4
1978	259.7	330.5	248.0	121.5	66.3	41.9	31.3	25.7	21.9	19.0	16.5	13.5	10.7	8.7	7.1	5.9	5.0	4.2	3.5	22.5	1263.5
1979	193.0	366.8	219.3	89.1	42.9	24.5	16.6	13.3	11.7	10.4	9.4	8.1	6.6	5.2	4.2	3.4	2.9	2.4	2.0	12.4	1044.2
1980	285.4	272.4	243.0	80.1	32.1	16.3	10.0	7.3	6.3	5.8	5.4	4.8	4.1	3.4	2.6	2.1	1.7	1.4	1.2	7.2	992.9
1981	99.9	399.8	160.5	72.5	23.9	10.3	5.7	3.9	3.1	2.9	2.8	2.5	2.3	1.9	1.6	1.2	1.0	0.8	0.7	3.9	800.9
1982	164.4	138.7	222.7	42.8	19.3	6.8	3.2	2.0	1.5	1.3	1.2	1.2	1.1	1.0	0.8	0.7	0.5	0.4	0.3	1.9	611.7
1983	466.4	231.7	93.5	78.7	14.7	6.8	2.5	1.3	0.8	0.6	0.6	0.5	0.5	0.5	0.4	0.3	0.3	0.2	0.2	0.9	901.6
1984	531.2	647.8	114.9	19.0	15.9	3.2	1.6	0.7	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.4	1336.6
1985	244.0	717.9	331.5	29.4	5.0	4.7	1.1	0.6	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.2	1335.7
1986	126.8	320.1	323.1	74.5	7.0	1.4	1.5	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	856.1
1987	411.4	166.0	224.9	147.0	34.0	3.4	0.7	0.8	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	989.0
1988	308.6	567.3	136.5	126.4	80.7	19.0	2.0	0.4	0.5	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1241.9
1989	109.0	429.6	490.4	84.7	76.6	49.7	12.1	1.3	0.3	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1254.7
1990	39.3	153.1	380.0	312.0	52.3	47.9	32.0	8.1	0.9	0.2	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1026.4
1991	34.1	54.4	160.4	322.9	252.5	41.3	37.4	24.9	6.3	0.7	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	935.5
1992	180.2	45.2	50.5	119.2	234.7	184.0	30.6	28.4	19.3	5.0	0.6	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	898.2
1993	64.1	244.8	50.8	34.1	51.3	104.9	93.1	17.7	18.4	13.6	3.7	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	697.3
1994	111.8	78.4	259.5	33.9	14.9	22.9	50.6	48.3	9.8	10.5	8.0	2.2	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	651.2
1995	50.7	137.5	83.2	179.1	15.5	6.9	11.3	26.8	27.2	5.7	6.3	4.9	1.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	556.8
1996	135.0	59.4	140.9	57.3	85.0	7.5	3.6	6.3	15.7	16.4	3.5	3.9	3.0	0.8	0.1	0.0	0.0	0.0	0.0	0.0	538.5
1997	93.0	182.9	68.3	112.5	32.9	48.5	4.4	2.2	4.0	10.1	10.8	2.3	2.6	2.0	0.5	0.1	0.0	0.0	0.0	0.0	577.2
1998	170.9	125.6	200.1	35.9	30.5	9.5	16.9	1.9	1.1	2.2	6.0	6.7	1.5	1.7	1.3	0.3	0.0	0.0	0.0	0.0	611.9
1999	228.5	236.4	146.9	163.5	21.3	17.9	5.8	10.8	1.2	0.7	1.5	4.2	4.7	1.0	1.2	0.9	0.2	0.0	0.0	0.0	846.9
2000	238.8	283.0	250.3	94.4	65.7	8.9	8.5	3.1	6.5	0.8	0.5	1.1	3.0	3.4	0.7	0.8	0.6	0.2	0.0	0.0	970.4
2001	172.4	277.5	286.6	158.0	37.7	27.4	4.2	4.5	1.9	4.2	0.5	0.4	0.8	2.1	2.4	0.5	0.6	0.4	0.1	0.0	982.2
2002	141.4	199.0	283.5	197.8	73.7	17.9	14.0	2.3	2.7	1.1	2.6	0.3	0.2	0.5	1.4	1.5	0.3	0.4	0.3	0.1	941.1
2003	183.5	167.9	206.3	199.7	96.7	36.8	9.6	8.1	1.4	1.7	0.8	1.8	0.2	0.2	0.3	0.9	1.0	0.2	0.3	0.3	917.7
2004	67.6	221.0	179.1	169.5	126.1	60.8	24.1	6.6	5.8	1.0	1.3	0.6	1.3	0.2	0.1	0.2	0.7	0.8	0.2	0.4	867.3
2005	27.7	61.5	192.6	123.8	88.4	67.8	35.0	14.8	4.3	3.9	0.7	0.9	0.4	0.9	0.1	0.1	0.2	0.5	0.5	0.4	624.5
2006	499.3	24.8	52.2	126.2	60.4	45.1	37.7	21.2	9.7	3.0	2.8	0.5	0.7	0.3	0.7	0.1	0.1	0.1	0.4	0.7	885.8
2007	349.5	677.0	28.1	35.3	54.1	26.8	22.5	21.3	13.3	6.5	2.1	2.0	0.4	0.5	0.2	0.5	0.1	0.0	0.1	0.7	1241.1
2008	392.5	422.3	713.6	18.3	14.7	23.4	12.7	11.8	12.0	7.9	4.0	1.3	1.3	0.2	0.3	0.1	0.3	0.0	0.0	0.5	1637.4
2009	60.9	416.3	399.7	402.9	6.1	5.1	9.3	5.8	6.0	6.7	4.7	2.5	0.8	0.8	0.2	0.2	0.1	0.2	0.0	0.3	1328.5
2010	78.5	56.6	363.9	245.3	165.1	2.6	2.4	4.7	3.2	3.5	4.0	2.8	1.5	0.5	0.5	0.1	0.1	0.1	0.1	0.2	935.6
2011	116.9	97.7	57.6	318.2	197.1	128.9	2.0	1.9	3.8	2.6	2.9	3.3	2.3	1.2	0.4	0.4	0.1	0.1	0.0	0.3	937.6
2012	127.8	162.1	112.3	56.1	281.7	166.9	106.8	1.7	1.5	3.1	2.1	2.3	2.7	1.9	1.0	0.3	0.3	0.1	0.1	0.2	1031.0
2013	290.0	164.8	170.4	97.2	41.2	192.6	113.0	73.0	1.1	1.1	2.2	1.5	1.6	1.8	1.3	0.7	0.2	0.2	0.0	0.2	1154.2
2014	498.6	401.3	189.8	165.5	82.4	32.7	149.4	86.8	55.9	0.9	0.8	1.7	1.1	1.2	1.4	1.0	0.5	0.2	0.2	0.2	1671.5
2015	229.9	669.0	437.8	162.0	109.3	48.6	18.9	86.0	50.2	32.5	0.5	0.5	1.0	0.6	0.7	0.8	0.5	0.3	0.1	0.2	1849.3

Table 9. Estimated biomass at age (1000 lb) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1950	524.3	768.8	955.0	1051.2	1079.8	1057.8	1002.4	926.6	841.1	753.5	667.8	587.5	513.9	447.3	387.6	335.3	289.5	249.1	214.3	1270.1	13922.8
1951	524.3	768.8	954.6	1050.1	1078.5	1056.5	1001.3	925.5	840.2	752.9	667.1	586.9	513.2	446.7	387.1	334.9	289.0	248.9	214.1	1268.8	13909.2
1952	524.3	768.5	950.2	1038.2	1065.3	1043.7	989.0	914.0	829.8	743.6	659.0	579.6	506.8	441.1	382.5	330.9	285.5	245.8	211.4	1253.1	13762.6
1953	524.3	768.5	953.7	1042.8	1063.1	1040.6	986.1	911.4	827.4	741.2	657.0	577.8	505.3	439.8	381.4	329.8	284.6	245.2	210.8	1249.4	13740.3
1954	524.3	768.5	953.3	1045.7	1066.6	1037.3	981.9	907.6	823.9	738.3	654.3	575.4	503.3	438.1	379.6	328.5	283.5	244.1	209.9	1244.3	13708.5
1955	524.3	768.5	946.7	1028.0	1051.4	1023.2	962.3	888.7	806.7	722.7	640.4	563.5	492.7	429.0	371.7	321.7	277.6	239.0	205.7	1218.1	13481.3
1956	524.3	766.1	908.7	963.2	982.2	967.4	920.4	853.0	780.2	703.7	626.6	551.2	482.2	419.5	363.8	314.6	271.6	233.9	201.1	1191.6	13024.9
1957	524.3	765.7	900.1	915.6	912.1	896.8	864.9	812.0	746.3	679.0	608.9	538.1	470.7	409.6	355.2	307.1	265.2	228.2	196.4	1163.6	12559.5
1958	524.0	764.8	879.0	863.3	825.4	794.1	765.9	729.9	680.6	622.8	563.9	502.0	440.9	383.8	332.7	287.9	248.5	213.8	184.1	1090.2	11697.9
1959	524.0	764.3	879.2	851.2	787.0	728.0	688.1	656.8	622.6	578.5	527.1	473.8	419.3	366.6	317.9	274.9	237.2	204.4	175.7	1041.2	11117.9
1960	523.8	763.9	869.9	835.8	762.4	682.8	621.3	582.2	553.6	523.4	484.6	438.5	391.8	345.0	300.5	259.9	224.2	193.1	166.2	984.4	10506.8
1961	523.6	763.2	860.9	813.1	736.6	651.9	575.4	520.1	485.9	461.4	435.0	399.9	359.6	319.7	280.4	243.6	210.3	181.2	155.9	923.1	9900.7
1962	523.6	762.1	843.7	775.4	691.1	608.9	532.4	467.8	422.4	394.8	374.1	350.1	319.9	286.4	253.5	222.0	192.5	165.8	142.6	844.8	9173.9
1963	523.4	761.5	838.0	757.1	657.9	571.7	498.7	435.0	382.7	346.1	323.4	304.2	283.1	257.5	229.5	202.8	177.0	153.2	131.8	780.9	8615.4
1964	523.2	760.8	835.1	753.8	645.1	547.6	472.2	412.0	360.7	318.3	288.1	267.0	249.8	231.3	209.4	186.3	164.2	143.1	123.7	733.0	8224.8
1965	522.9	759.7	821.7	730.8	625.7	524.3	442.9	382.9	336.0	295.4	261.0	234.4	216.1	201.3	185.6	167.8	148.8	131.0	114.0	678.4	7780.5
1966	522.7	758.8	807.8	700.0	591.5	497.1	415.6	353.0	307.5	271.4	239.2	209.9	187.4	172.0	159.4	146.8	132.3	117.1	103.0	619.7	7312.3
1967	522.3	757.9	800.5	678.8	559.1	464.1	389.8	327.8	280.6	246.3	218.3	190.9	166.4	147.9	135.1	125.0	114.9	103.4	91.5	560.9	6881.9
1968	521.8	756.8	780.4	638.0	513.9	416.5	346.1	292.8	248.7	214.7	189.2	166.2	144.6	125.7	111.1	101.4	93.5	85.8	76.9	483.5	6307.4
1969	521.2	755.1	755.3	582.5	452.6	359.4	292.1	245.2	209.9	179.9	156.1	136.5	119.3	103.2	89.3	78.9	71.7	66.1	60.4	393.3	5627.7
1970	520.5	754.4	768.3	592.8	435.6	334.0	266.5	218.9	186.1	160.9	138.9	119.5	103.8	90.4	77.8	67.2	59.3	53.8	49.4	338.0	5336.5
1971	519.8	753.3	765.0	599.4	440.9	319.9	246.5	198.9	165.6	142.2	123.7	105.8	90.6	78.5	67.9	58.4	50.3	44.3	40.1	287.5	5099.5
1972	519.4	751.6	752.9	585.8	438.7	319.7	234.1	183.2	150.4	127.0	109.8	94.8	80.7	68.8	59.3	51.1	43.9	37.7	33.1	244.1	4886.1
1973	518.7	749.8	739.0	563.9	420.6	313.5	231.9	173.3	138.5	115.3	98.3	84.4	72.5	61.5	52.0	44.8	38.6	33.1	28.4	207.5	4685.5
1974	518.3	748.2	731.5	553.1	406.3	302.9	230.2	174.4	133.6	108.7	91.7	77.6	66.4	56.7	47.8	40.3	34.6	29.8	25.6	181.0	4558.9
1975	517.4	745.4	689.2	489.4	357.1	263.9	201.9	158.3	123.5	96.8	80.0	67.0	56.4	47.8	40.8	34.4	28.9	24.9	21.4	146.8	4191.2
1976	515.7	741.0	635.8	399.5	274.9	203.7	156.1	124.6	101.4	81.6	65.3	53.6	44.5	37.3	31.5	26.9	22.5	19.0	16.3	109.3	3660.1
1977	512.8	735.9	598.3	334.2	204.4	144.2	111.8	89.9	75.2	63.5	52.2	41.4	33.7	28.0	23.4	19.6	16.8	13.9	11.7	77.6	3188.8
1978	572.5	728.6	546.7	267.9	146.2	92.4	69.0	56.7	48.3	41.9	36.4	29.8	23.6	19.2	15.7	13.0	11.0	9.3	7.7	49.6	2785.5
1979	425.5	808.7	483.5	196.4	94.6	54.0	36.6	29.3	25.8	22.9	20.7	17.9	14.6	11.5	9.3	7.5	6.4	5.3	4.4	27.3	2302.1
1980	629.2	600.5	535.7	176.6	70.8	35.9	22.0	16.1	13.9	12.8	11.9	10.6	9.0	7.5	5.7	4.6	3.7	3.1	2.6	15.9	2189.0
1981	220.2	881.4	353.8	159.8	52.7	22.7	12.6	8.6	6.8	6.4	6.2	5.5	5.1	4.2	3.5	2.6	2.2	1.8	1.5	8.6	1765.7
1982	362.4	305.8	491.0	94.4	42.5	15.0	7.1	4.4	3.3	2.9	2.6	2.6	2.4	2.2	1.8	1.5	1.1	0.9	0.7	4.2	1348.6
1983	1028.2	510.8	206.1	173.5	32.4	15.0	5.5	2.9	1.8	1.3	1.3	1.1	1.1	1.1	0.9	0.7	0.7	0.4	0.4	2.0	1987.7
1984	1171.1	1428.2	253.3	41.9	35.1	7.1	3.5	1.5	0.9	0.7	0.4	0.4	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.9	2946.7
1985	537.9	1582.7	730.8	64.8	11.0	10.4	2.4	1.3	0.7	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.4	2944.7
1986	279.5	705.7	712.3	164.2	15.4	3.1	3.3	0.9	0.7	0.4	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.2	1887.4
1987	907.0	366.0	495.8	324.1	75.0	7.5	1.5	1.8	0.4	0.4	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2180.4
1988	680.3	1250.7	300.9	278.7	177.9	41.9	4.4	0.9	1.1	0.4	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2737.9
1989	240.3	947.1	1081.1	186.7	168.9	109.6	26.7	2.9	0.7	0.9	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2766.1
1990	86.6	337.5	837.8	687.8	115.3	105.6	70.5	17.9	2.0	0.4	0.7	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2262.8
1991	75.2	119.9	353.6	711.9	556.7	91.1	82.5	54.9	13.9	1.5	0.4	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2062.4
1992	397.3	99.6	111.3	262.8	517.4	405.7	67.5	62.6	42.5	11.0	1.3	0.2	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1980.2
1993	141.3	539.7	112.0	75.2	113.1	231.3	205.3	39.0	40.6	30.0	8.2	0.9	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1537.3
1994	246.5	172.8	572.1	74.7	32.8	50.5	111.6	106.5	21.6	23.1	17.6	4.9	0.7	0.2	0.2	0.0	0.0	0.0	0.0	0.0	1435.6
1995	111.8	303.1	183.4	394.8	34.2	15.2	24.9	59.1	60.0	12.6	13.9	10.8	2.9	0.4	0.0	0.0	0.0	0.0	0.0	0.0	1227.5
1996	297.6	131.0	310.6	126.3	187.4	16.5	7.9	13.9	34.6	36.2	7.7	8.6	6.6	1.8	0.2	0.0	0.0	0.0	0.0	0.0	1187.2
1997	205.0	403.2	150.6	248.0	72.5	106.9	9.7	4.9	8.8	22.3	23.8	5.1	5.7	4.4	1.1	0.2	0.0	0.0	0.0	0.0	1272.5
1998	376.8	276.9	441.1	79.1	67.2	20.9	37.3	4.2	2.4	4.9	13.2	14.8	3.3	3.7	2.9	0.7	0.0	0.0	0.0	0.0	1349.0
1999	503.8	521.2	323.9	360.5	47.0	39.5	12.8	23.8	2.6	1.5	3.3	9.3	10.4	2.2	2.6	2.0	0.4	0.0	0.0	0.0	1867.1
2000	526.5	623.9	551.8	208.1	144.8	19.6	18.7	6.8	14.3	1.8	1.1	2.4	6.6	7.5	1.5	1.8	1.3	0.4	0.0	0.0	2139.4
2001	380.1	611.8	631.8	348.3	83.1	60.4	9.3	9.9	4.2	9.3	1.1	0.9	1.8	4.6	5.3	1.1	1.3	0.9	0.2	0.0	2165.4
2002	311.7	438.7	625.0	436.1	162.5	39.5	30.9	5.1	6.0	2.4	5.7	0.7	0.4	1.1	3.1	3.3	0.7	0.9	0.7	0.2	2074.8
2003	404.5	370.2	454.8	440.3	213.2	81.1	21.2	17.9	3.1	3.7	1.8	4.0	0.4	0.4	0.7	2.0	2.2	0.4	0.7	0.7	2023.2
2004	149.0	487.2	394.8	373.7	278.0	134.0	53.1	14.6	12.8	2.2	2.9	1.3	2.9	0.4	0.2	0.4	1.5	1.8	0.4	0.9	1912.1
2005	61.1	135.6	424.6	272.9	194.9	149.5	77.2	32.6	9.5	8.6	1.5	2.0	0.9	2.0	0.2	0.2	0.4	1.1	1.1	0.9	1376.8
2006	1100.8	54.7	115.1	278.2	133.2	99.4	83.1	46.7	21.4	6.6	6.2	1.1	1.5	0.7	1.5	0.2	0.2	0.2	0.9	1.5	1952.9
2007	770.5	1492.5	61.9	77.8	119.3	59.1	49.6	47.0	29.3	14.3	4.6	4.4	0.9	1.1	0.4	1.1	0.2	0.0	0.2	1.5	2736.2
2008	865.3	931.0	1573.2	40.3	32.4	51.6	28.0	26.0	26.5	17.4	8.8	2.9	2.9	0.4	0.7	0.2	0.7	0.0	0.0	1.1	3609.8
2009	134.3	917.8	881.2	888.2	13.4	11.2	20.5	12.8	13.2	14.8	10.4	5.5	1.8	1.8	0.4	0.4	0.2	0.4	0.0	0.7	2928.8
2010	173.1	124.8	802.3	540.8	364.0	5.7	5.3	10.4	7.1	7.7	8.8	6.2	3.3	1.1	1.1	0.2	0.2	0.2	0.2	0.4	2062.6
2011	257.7	215.4	127.0	701.5	434.5	284.2	4.4	4.2	8.4	5.7	6.4	7.3	5.1	2.6	0.9	0.9	0.2	0.2	0.0	0.7	2067.1
2012	281.8	357.4	247.6	123.7	621.0	368.0	235.5	3.7	3.3	6.8	4.6	5.1	6.0	4.2	2.2	0.7	0.7	0.2	0.2	0.4	2273.0
2013	639.3	363.3	375.7	214.3	90.8	424.6	249.1	160.9	2.4	2.4	4.9	3.3	3.5	4.0	2.9	1.5	0.4	0.4	0.0	0.4	2544.6
2014	1099.2	884.7	418.4	364.9	181.7	72.1	329.4	191.4	123.2	2.0	1.8	3.7	2.4	2.6	3.1	2.2	1.1	0.4	0.4	0.4	3685.0
2015	506.8	1474.9	965.2	357.1	241.0	107.1	41.7	189.6	110.7	71.7	1.1	1.1	2.2	1.3	1.5	1.8	1.1	0.7	0.2	0.4	4077.0

Table 10. Estimated time series of status indicators, fishing mortality, and biomass. Fishing mortality rate is apical F. Total biomass (B, mt) is at the start of the year, and spawning biomass (SSB, 1E8 eggs) at the time of peak spawning (mid-year). The $MSST_{\mathrm{F30}}$ is defined by $\mathrm{MSST} = (1 - M)SSB_{\mathrm{F30}}$*, with constant* $M = 0.134$.

Year	F	F/F_{30}	B	B/B_{unfished}	SSB	$SSB/SSBB_{\mathrm{F30}}$	$SSB/MSST_{\mathrm{F30}}$
1950	0.031	0.210	6315	0.788	778960	2.371	3.161
1951	0.042	0.287	6309	0.787	771773	2.349	3.132
1952	0.033	0.223	6243	0.779	767209	2.335	3.113
1953	0.034	0.231	6233	0.778	764680	2.327	3.103
1954	0.051	0.347	6218	0.776	753582	2.294	3.058
1955	0.108	0.736	6115	0.763	733829	2.234	2.978
1956	0.117	0.803	5908	0.737	709192	2.159	2.878
1957	0.166	1.139	5697	0.711	664637	2.023	2.697
1958	0.157	1.074	5306	0.662	621070	1.890	2.520
1959	0.176	1.201	5043	0.629	579755	1.765	2.353
1960	0.192	1.316	4766	0.595	536726	1.634	2.178
1961	0.229	1.569	4491	0.560	488083	1.486	1.981
1962	0.233	1.596	4161	0.519	443907	1.351	1.801
1963	0.231	1.579	3908	0.488	410213	1.249	1.665
1964	0.258	1.765	3731	0.466	378434	1.152	1.536
1965	0.285	1.950	3529	0.440	345580	1.052	1.402
1966	0.299	2.046	3317	0.414	313902	0.955	1.274
1967	0.352	2.408	3122	0.390	277381	0.844	1.126
1968	0.418	2.856	2861	0.357	234431	0.714	0.951
1969	0.367	2.510	2553	0.319	204371	0.622	0.829
1970	0.373	2.550	2421	0.302	183530	0.559	0.745
1971	0.392	2.682	2313	0.289	166624	0.507	0.676
1972	0.414	2.831	2216	0.277	152622	0.465	0.619
1973	0.415	2.835	2125	0.265	142706	0.434	0.579
1974	0.527	3.602	2068	0.258	127612	0.388	0.518
1975	0.670	4.585	1901	0.237	104381	0.318	0.424
1976	0.768	5.253	1660	0.207	80264	0.244	0.326
1977	0.929	6.353	1446	0.181	57202	0.174	0.232
1978	1.149	7.857	1263	0.158	36637	0.112	0.149
1979	1.132	7.742	1044	0.130	24769	0.075	0.101
1980	1.334	9.124	993	0.124	16724	0.051	0.068
1981	1.447	9.900	801	0.100	11596	0.035	0.047
1982	1.165	7.969	612	0.076	8961	0.027	0.036
1983	1.717	11.745	902	0.113	6393	0.019	0.026
1984	1.489	10.185	1337	0.167	8512	0.026	0.035
1985	1.617	11.063	1336	0.167	10233	0.031	0.042
1986	0.913	6.242	856	0.107	12176	0.037	0.049
1987	0.701	4.796	989	0.123	14948	0.045	0.061
1988	0.601	4.113	1242	0.155	20904	0.064	0.085
1989	0.577	3.949	1255	0.157	29141	0.089	0.118
1990	0.288	1.968	1026	0.128	39978	0.122	0.162
1991	0.421	2.880	936	0.117	47267	0.144	0.192
1992	0.900	6.157	898	0.112	38229	0.116	0.155
1993	0.887	6.066	697	0.087	27957	0.085	0.113
1994	0.840	5.747	651	0.081	23471	0.071	0.095
1995	0.802	5.483	557	0.069	20207	0.062	0.082
1996	0.610	4.176	539	0.067	18883	0.057	0.077
1997	1.363	9.320	577	0.072	14722	0.045	0.060
1998	0.580	3.965	612	0.076	16002	0.049	0.065
1999	0.968	6.622	847	0.106	17548	0.053	0.071
2000	0.974	6.663	970	0.121	19194	0.058	0.078
2001	0.818	5.598	982	0.123	22085	0.067	0.090
2002	0.773	5.284	941	0.117	24413	0.074	0.099
2003	0.516	3.526	918	0.115	27949	0.085	0.113
2004	0.707	4.836	867	0.108	28594	0.087	0.116
2005	0.774	5.294	624	0.078	25432	0.077	0.103
2006	0.903	6.176	886	0.111	20275	0.062	0.082
2007	0.932	6.372	1241	0.155	21429	0.065	0.087
2008	1.161	7.944	1637	0.204	28100	0.086	0.114
2009	0.948	6.485	1328	0.166	30379	0.092	0.123
2010	0.275	1.881	936	0.117	37902	0.115	0.154
2011	0.178	1.218	938	0.117	48791	0.149	0.198
2012	0.389	2.663	1031	0.129	51799	0.158	0.210
2013	0.239	1.637	1154	0.144	55022	0.167	0.223
2014	0.538	3.680	1672	0.209	54037	0.164	0.219
2015	.	.	1849	0.231	.	.	.

Table 11. Selectivity at age for MARMAP chevron traps (CVT), commercial handlines (cH), headboat (HB), and general recreational (GR) landings (L) and discards (D). For time-varying selectivities, values shown are from selectivity block 1 (1950–1991).

Age	CVT	cH.L	HB.L	GR.L	cH.D	HB.D	GR.D
1	0.065	0.013	0.049	0.049	1.000	1.000	1.000
2	0.634	0.410	0.670	0.670	0.990	0.701	0.701
3	0.977	0.974	1.000	1.000	0.734	0.269	0.269
4	0.999	1.000	0.897	0.897	0.398	0.071	0.071
5	1.000	1.000	0.749	0.749	0.172	0.017	0.017
6	1.000	1.000	0.587	0.587	0.066	0.004	0.004
7	1.000	1.000	0.430	0.430	0.024	0.001	0.001
8	1.000	1.000	0.298	0.298	0.009	0.000	0.000
9	1.000	1.000	0.196	0.196	0.003	0.000	0.000
10	1.000	1.000	0.125	0.125	0.001	0.000	0.000
11	1.000	1.000	0.125	0.125	0.000	0.000	0.000
12	1.000	1.000	0.125	0.125	0.000	0.000	0.000
13	1.000	1.000	0.125	0.125	0.000	0.000	0.000
14	1.000	1.000	0.125	0.125	0.000	0.000	0.000
15	1.000	1.000	0.125	0.125	0.000	0.000	0.000
16	1.000	1.000	0.125	0.125	0.000	0.000	0.000
17	1.000	1.000	0.125	0.125	0.000	0.000	0.000
18	1.000	1.000	0.125	0.125	0.000	0.000	0.000
19	1.000	1.000	0.125	0.125	0.000	0.000	0.000
20	1.000	1.000	0.125	0.125	0.000	0.000	0.000

Table 12. Selectivity at age for MARMAP chevron traps (CVT), commercial handlines (cH), headboat (HB), and general recreational (GR) landings (L) and discards (D). For time-varying selectivities, values shown are from selectivity block 2 (1992–2009).

Age	CVT	cH.L	HB.L	GR.L	cH.D	HB.D	GR.D
1	0.065	0.001	0.001	0.005	1.000	1.000	1.000
2	0.634	0.026	0.031	0.067	0.990	0.701	0.701
3	0.977	0.431	0.689	0.544	0.734	0.269	0.269
4	0.999	0.956	1.000	1.000	0.398	0.071	0.071
5	1.000	0.998	0.772	0.911	0.172	0.017	0.017
6	1.000	1.000	0.532	0.719	0.066	0.004	0.004
7	1.000	1.000	0.334	0.519	0.024	0.001	0.001
8	1.000	1.000	0.195	0.345	0.009	0.000	0.000
9	1.000	1.000	0.109	0.216	0.003	0.000	0.000
10	1.000	1.000	0.059	0.129	0.001	0.000	0.000
11	1.000	1.000	0.059	0.075	0.000	0.000	0.000
12	1.000	1.000	0.059	0.043	0.000	0.000	0.000
13	1.000	1.000	0.059	0.024	0.000	0.000	0.000
14	1.000	1.000	0.059	0.024	0.000	0.000	0.000
15	1.000	1.000	0.059	0.024	0.000	0.000	0.000
16	1.000	1.000	0.059	0.024	0.000	0.000	0.000
17	1.000	1.000	0.059	0.024	0.000	0.000	0.000
18	1.000	1.000	0.059	0.024	0.000	0.000	0.000
19	1.000	1.000	0.059	0.024	0.000	0.000	0.000
20	1.000	1.000	0.059	0.024	0.000	0.000	0.000

Table 13. Selectivity at age for MARMAP chevron traps (CVT), commercial handlines (cH), headboat (HB), and general recreational (GR) landings (L) and discards (D). For time-varying selectivities, values shown are from selectivity block 3 (2010–2014).

Age	CVT	cH.L	HB.L	GR.L	cH.D	HB.D	GR.D
1	0.065	0.006	0.017	0.005	0.038	0.715	0.715
2	0.634	0.066	0.334	0.036	0.222	0.885	0.885
3	0.977	0.447	1.000	0.233	0.672	0.991	0.991
4	0.999	0.902	0.914	0.711	0.937	1.000	1.000
5	1.000	0.991	0.734	0.952	0.991	0.911	0.911
6	1.000	0.999	0.560	0.994	0.999	0.752	0.752
7	1.000	1.000	0.409	0.999	1.000	0.569	0.569
8	1.000	1.000	0.288	1.000	1.000	0.401	0.401
9	1.000	1.000	0.198	1.000	1.000	0.267	0.267
10	1.000	1.000	0.133	1.000	1.000	0.171	0.171
11	1.000	1.000	0.133	1.000	1.000	0.171	0.171
12	1.000	1.000	0.133	1.000	1.000	0.171	0.171
13	1.000	1.000	0.133	1.000	1.000	0.171	0.171
14	1.000	1.000	0.133	1.000	1.000	0.171	0.171
15	1.000	1.000	0.133	1.000	1.000	0.171	0.171
16	1.000	1.000	0.133	1.000	1.000	0.171	0.171
17	1.000	1.000	0.133	1.000	1.000	0.171	0.171
18	1.000	1.000	0.133	1.000	1.000	0.171	0.171
19	1.000	1.000	0.133	1.000	1.000	0.171	0.171
20	1.000	1.000	0.133	1.000	1.000	0.171	0.171

Table 14. Estimated time series of fully selected fishing mortality rates for commercial handlines (F.cH.L), headboat (F.HB.L), recreational (F.GR.L) landings (L) and discards (D). Also shown is Full F, the maximum F at age summed across fleets, which may not equal the sum of fully selected F's because of dome-shaped selectivities.

Year	F.cH.L	F.HB.L	F.GR.L	F.cH.D	F.HB.D	F.GR.D	Full F
1950	0.031	0.000	0.000	0.000	0.000	0.000	0.031
1951	0.042	0.000	0.000	0.000	0.000	0.000	0.042
1952	0.033	0.000	0.000	0.000	0.000	0.000	0.033
1953	0.034	0.000	0.000	0.000	0.000	0.000	0.034
1954	0.051	0.000	0.000	0.000	0.000	0.000	0.051
1955	0.043	0.022	0.043	0.000	0.000	0.000	0.108
1956	0.044	0.025	0.049	0.000	0.000	0.000	0.117
1957	0.084	0.029	0.056	0.000	0.000	0.000	0.166
1958	0.064	0.032	0.062	0.000	0.000	0.000	0.157
1959	0.073	0.036	0.069	0.000	0.000	0.000	0.176
1960	0.079	0.039	0.076	0.000	0.000	0.000	0.192
1961	0.102	0.044	0.086	0.000	0.000	0.000	0.229
1962	0.090	0.050	0.096	0.000	0.000	0.000	0.233
1963	0.073	0.055	0.105	0.000	0.000	0.000	0.231
1964	0.085	0.060	0.115	0.000	0.000	0.000	0.258
1965	0.095	0.066	0.127	0.000	0.000	0.000	0.285
1966	0.102	0.068	0.131	0.000	0.000	0.000	0.299
1967	0.147	0.071	0.137	0.000	0.000	0.000	0.352
1968	0.200	0.076	0.147	0.000	0.000	0.000	0.418
1969	0.139	0.079	0.152	0.000	0.000	0.000	0.367
1970	0.143	0.080	0.154	0.000	0.000	0.000	0.373
1971	0.135	0.089	0.171	0.000	0.000	0.000	0.392
1972	0.128	0.099	0.190	0.000	0.000	0.000	0.414
1973	0.098	0.109	0.210	0.000	0.000	0.000	0.415
1974	0.171	0.123	0.237	0.000	0.000	0.000	0.527
1975	0.251	0.146	0.280	0.000	0.000	0.000	0.670
1976	0.295	0.164	0.316	0.000	0.000	0.000	0.768
1977	0.395	0.186	0.358	0.000	0.000	0.000	0.929
1978	0.536	0.215	0.412	0.000	0.000	0.000	1.149
1979	0.482	0.226	0.435	0.000	0.000	0.000	1.132
1980	0.558	0.271	0.520	0.000	0.000	0.000	1.334
1981	0.653	0.225	0.584	0.000	0.000	0.006	1.447
1982	0.660	0.182	0.338	0.000	0.000	0.006	1.165
1983	0.910	0.257	0.573	0.000	0.000	0.002	1.717
1984	0.458	0.132	0.904	0.000	0.000	0.025	1.489
1985	0.323	0.191	1.099	0.000	0.000	0.044	1.617
1986	0.291	0.086	0.522	0.000	0.000	0.080	0.913
1987	0.263	0.150	0.285	0.000	0.000	0.037	0.701
1988	0.178	0.131	0.290	0.000	0.000	0.029	0.601
1989	0.188	0.076	0.313	0.000	0.000	0.021	0.577
1990	0.143	0.086	0.050	0.000	0.000	0.048	0.288
1991	0.097	0.087	0.217	0.000	0.000	0.086	0.421
1992	0.108	0.082	0.699	0.032	0.003	0.038	0.900
1993	0.394	0.218	0.268	0.035	0.007	0.138	0.887
1994	0.368	0.134	0.328	0.041	0.007	0.125	0.840
1995	0.347	0.174	0.260	0.060	0.012	0.150	0.802
1996	0.301	0.111	0.193	0.039	0.004	0.034	0.610
1997	0.305	0.164	0.887	0.043	0.005	0.030	1.363
1998	0.234	0.087	0.258	0.022	0.003	0.033	0.580
1999	0.198	0.114	0.648	0.014	0.003	0.149	0.968
2000	0.205	0.117	0.640	0.014	0.003	0.213	0.974
2001	0.313	0.133	0.363	0.017	0.006	0.215	0.818
2002	0.256	0.130	0.370	0.039	0.008	0.161	0.773
2003	0.173	0.059	0.274	0.010	0.003	0.182	0.516
2004	0.218	0.128	0.335	0.005	0.040	0.431	0.707
2005	0.188	0.124	0.421	0.044	0.053	0.394	0.774
2006	0.171	0.145	0.588	0.003	0.009	0.063	0.903
2007	0.329	0.226	0.375	0.006	0.037	0.148	0.932
2008	0.341	0.139	0.672	0.006	0.040	0.275	1.161
2009	0.370	0.151	0.405	0.014	0.085	0.355	0.948
2010	0.006	0.003	0.001	0.041	0.050	0.179	0.275
2011	0.000	0.010	0.001	0.103	0.040	0.032	0.178
2012	0.007	0.017	0.165	0.054	0.043	0.132	0.389
2013	0.028	0.011	0.087	0.050	0.028	0.050	0.239
2014	0.058	0.031	0.311	0.055	0.017	0.102	0.538

Table 15. Estimated instantaneous fishing mortality rate (per yr) at age.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1950	0.000	0.013	0.030	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031
1951	0.001	0.017	0.041	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
1952	0.000	0.013	0.032	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
1953	0.000	0.014	0.033	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
1954	0.001	0.021	0.049	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051
1955	0.004	0.062	0.108	0.102	0.092	0.082	0.071	0.063	0.056	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052
1956	0.004	0.068	0.117	0.111	0.100	0.088	0.076	0.066	0.059	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054
1957	0.005	0.091	0.166	0.160	0.147	0.134	0.120	0.109	0.101	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095
1958	0.005	0.090	0.157	0.149	0.135	0.119	0.105	0.092	0.082	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076
1959	0.006	0.100	0.176	0.167	0.151	0.134	0.118	0.104	0.093	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086
1960	0.007	0.110	0.192	0.183	0.166	0.147	0.129	0.114	0.102	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094
1961	0.008	0.129	0.229	0.219	0.199	0.178	0.158	0.141	0.128	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118
1962	0.008	0.134	0.233	0.221	0.199	0.175	0.153	0.133	0.119	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108
1963	0.009	0.137	0.231	0.216	0.193	0.167	0.142	0.120	0.104	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093
1964	0.010	0.152	0.258	0.242	0.216	0.188	0.161	0.137	0.120	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107
1965	0.011	0.168	0.285	0.268	0.239	0.208	0.178	0.152	0.133	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119
1966	0.011	0.176	0.299	0.281	0.252	0.219	0.188	0.162	0.141	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127
1967	0.012	0.200	0.352	0.334	0.303	0.269	0.237	0.209	0.188	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173
1968	0.013	0.231	0.418	0.400	0.367	0.331	0.296	0.266	0.244	0.228	0.228	0.228	0.228	0.228	0.228	0.228	0.228	0.228	0.228	0.228
1969	0.013	0.212	0.367	0.347	0.313	0.275	0.239	0.208	0.185	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168
1970	0.013	0.215	0.373	0.352	0.318	0.280	0.243	0.212	0.188	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172
1971	0.015	0.230	0.392	0.369	0.330	0.288	0.247	0.213	0.186	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168
1972	0.016	0.246	0.414	0.387	0.345	0.298	0.252	0.214	0.185	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164
1973	0.017	0.254	0.415	0.384	0.337	0.285	0.235	0.193	0.160	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
1974	0.020	0.311	0.527	0.494	0.441	0.382	0.326	0.278	0.241	0.216	0.216	0.216	0.216	0.216	0.216	0.216	0.216	0.216	0.216	0.216
1975	0.024	0.388	0.670	0.633	0.570	0.501	0.434	0.378	0.335	0.304	0.304	0.304	0.304	0.304	0.304	0.304	0.304	0.304	0.304	0.304
1976	0.027	0.443	0.768	0.726	0.655	0.577	0.502	0.438	0.389	0.355	0.355	0.355	0.355	0.355	0.355	0.355	0.355	0.355	0.355	0.355
1977	0.032	0.526	0.929	0.883	0.802	0.714	0.629	0.557	0.501	0.463	0.463	0.463	0.463	0.463	0.463	0.463	0.463	0.463	0.463	0.463
1978	0.038	0.640	1.149	1.098	1.005	0.903	0.805	0.722	0.659	0.614	0.614	0.614	0.614	0.614	0.614	0.614	0.614	0.614	0.614	0.614
1979	0.039	0.641	1.132	1.076	0.978	0.871	0.767	0.679	0.612	0.565	0.565	0.565	0.565	0.565	0.565	0.565	0.565	0.565	0.565	0.565
1980	0.046	0.758	1.334	1.267	1.150	1.021	0.898	0.793	0.713	0.656	0.656	0.656	0.656	0.656	0.656	0.656	0.656	0.656	0.656	0.656
1981	0.054	0.814	1.447	1.380	1.260	1.128	1.001	0.894	0.812	0.754	0.754	0.754	0.754	0.754	0.754	0.754	0.754	0.754	0.754	0.754
1982	0.040	0.623	1.165	1.127	1.050	0.965	0.884	0.815	0.762	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
1983	0.055	0.931	1.717	1.655	1.532	1.397	1.267	1.157	1.073	1.014	1.014	1.014	1.014	1.014	1.014	1.014	1.014	1.014	1.014	1.014
1984	0.082	0.899	1.489	1.390	1.235	1.066	0.904	0.766	0.662	0.588	0.588	0.588	0.588	0.588	0.588	0.588	0.588	0.588	0.588	0.588
1985	0.112	1.028	1.617	1.485	1.291	1.081	0.879	0.707	0.577	0.485	0.485	0.485	0.485	0.485	0.485	0.485	0.485	0.485	0.485	0.485
1986	0.114	0.583	0.913	0.842	0.747	0.648	0.552	0.472	0.410	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367
1987	0.062	0.425	0.701	0.656	0.589	0.518	0.450	0.392	0.348	0.317	0.317	0.317	0.317	0.317	0.317	0.317	0.317	0.317	0.317	0.317
1988	0.052	0.375	0.601	0.557	0.493	0.424	0.358	0.303	0.260	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
1989	0.043	0.352	0.577	0.538	0.479	0.416	0.355	0.304	0.264	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237
1990	0.057	0.183	0.288	0.268	0.245	0.223	0.201	0.183	0.169	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160
1991	0.102	0.303	0.421	0.375	0.326	0.275	0.227	0.187	0.156	0.135	0.135	0.135	0.135	0.135	0.135	0.135	0.135	0.135	0.135	0.135
1992	0.077	0.113	0.518	0.900	0.815	0.657	0.499	0.366	0.268	0.203	0.166	0.143	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130
1993	0.182	0.171	0.530	0.887	0.814	0.705	0.607	0.530	0.476	0.442	0.427	0.418	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413
1994	0.176	0.169	0.495	0.840	0.780	0.679	0.584	0.508	0.454	0.419	0.401	0.390	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384
1995	0.224	0.205	0.499	0.802	0.731	0.631	0.542	0.472	0.423	0.391	0.377	0.369	0.364	0.364	0.364	0.364	0.364	0.364	0.364	0.364
1996	0.079	0.090	0.350	0.610	0.570	0.502	0.439	0.390	0.355	0.333	0.322	0.316	0.312	0.312	0.312	0.312	0.312	0.312	0.312	0.312
1997	0.083	0.140	0.768	1.363	1.247	1.033	0.821	0.644	0.515	0.429	0.381	0.353	0.336	0.336	0.336	0.336	0.336	0.336	0.336	0.336
1998	0.059	0.072	0.326	0.580	0.540	0.467	0.397	0.340	0.299	0.272	0.258	0.250	0.245	0.245	0.245	0.245	0.245	0.245	0.245	0.245
1999	0.169	0.172	0.567	0.968	0.881	0.726	0.573	0.444	0.350	0.288	0.253	0.232	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220
2000	0.233	0.217	0.585	0.974	0.884	0.729	0.577	0.449	0.356	0.295	0.260	0.240	0.228	0.228	0.228	0.228	0.228	0.228	0.228	0.228
2001	0.240	0.208	0.496	0.818	0.753	0.647	0.547	0.465	0.406	0.368	0.349	0.337	0.330	0.330	0.330	0.330	0.330	0.330	0.330	0.330
2002	0.211	0.193	0.475	0.773	0.703	0.594	0.493	0.410	0.351	0.312	0.292	0.280	0.273	0.273	0.273	0.273	0.273	0.273	0.273	0.273
2003	0.197	0.165	0.321	0.516	0.473	0.402	0.335	0.279	0.238	0.212	0.197	0.188	0.183	0.183	0.183	0.183	0.183	0.183	0.183	0.183
2004	0.478	0.367	0.494	0.707	0.630	0.529	0.435	0.359	0.304	0.269	0.251	0.240	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234
2005	0.493	0.394	0.548	0.774	0.682	0.561	0.449	0.358	0.293	0.250	0.227	0.213	0.206	0.205	0.205	0.205	0.205	0.205	0.205	0.205
2006	0.079	0.102	0.515	0.903	0.820	0.671	0.524	0.402	0.314	0.255	0.224	0.205	0.194	0.194	0.194	0.194	0.194	0.194	0.194	0.194
2007	0.194	0.177	0.556	0.932	0.849	0.720	0.600	0.503	0.435	0.391	0.371	0.359	0.352	0.352	0.352	0.352	0.352	0.352	0.352	0.352
2008	0.324	0.284	0.697	1.161	1.066	0.899	0.736	0.600	0.501	0.436	0.399	0.378	0.365	0.365	0.365	0.365	0.365	0.365	0.365	0.365
2009	0.456	0.364	0.613	0.948	0.866	0.745	0.632	0.540	0.475	0.432	0.410	0.397	0.389	0.389	0.389	0.389	0.389	0.389	0.389	0.389
2010	0.165	0.212	0.259	0.275	0.257	0.221	0.179	0.140	0.109	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087
2011	0.056	0.090	0.151	0.178	0.176	0.163	0.149	0.136	0.125	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118
2012	0.129	0.179	0.268	0.365	0.389	0.366	0.332	0.301	0.276	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.258
2013	0.058	0.088	0.154	0.222	0.239	0.229	0.214	0.200	0.188	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180
2014	0.089	0.142	0.283	0.471	0.538	0.528	0.503	0.480	0.461	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448

Table 16. Estimated time series of landings in number (1000 fish) for commercial handlines (L.cH), headboat (L.HB), and recreational (L.GR).

Year	L.cH	L.HB	L.GR	Total
1950	26.93	0.00	0.00	26.93
1951	36.52	0.00	0.00	36.52
1952	28.24	0.00	0.00	28.24
1953	29.18	0.00	0.00	29.18
1954	43.53	0.00	0.00	43.53
1955	36.13	12.50	24.03	72.67
1956	35.34	13.65	26.24	75.23
1957	63.51	14.80	28.46	106.77
1958	45.33	15.95	30.67	91.95
1959	49.33	17.10	32.88	99.31
1960	51.16	18.25	35.09	104.50
1961	61.87	19.91	38.27	120.05
1962	51.34	21.56	41.44	114.33
1963	39.73	23.21	44.62	107.56
1964	44.60	24.86	47.79	117.26
1965	47.29	26.51	50.96	124.77
1966	48.12	26.67	51.26	126.05
1967	64.73	26.82	51.56	143.11
1968	80.12	26.98	51.85	158.95
1969	52.14	27.13	52.15	131.43
1970	51.64	27.29	52.45	131.38
1971	47.47	29.98	57.62	135.07
1972	43.21	32.68	62.80	138.68
1973	32.11	35.37	67.96	135.44
1974	52.63	38.06	73.12	163.81
1975	68.18	40.75	78.27	187.20
1976	68.63	41.21	79.17	189.01
1977	77.38	41.63	79.91	198.93
1978	85.92	42.15	81.02	209.09
1979	69.90	42.65	82.05	194.60
1980	66.74	43.10	82.89	192.73
1981	75.05	36.05	93.56	204.66
1982	55.53	19.57	36.37	111.47
1983	66.97	30.70	68.48	166.15
1984	65.07	31.16	213.09	309.32
1985	57.93	50.34	289.25	397.52
1986	43.14	16.62	100.67	160.43
1987	33.32	24.98	47.33	105.63
1988	34.58	36.50	80.68	151.75
1989	47.48	23.44	96.89	167.81
1990	33.05	20.91	12.09	66.04
1991	16.72	13.85	34.69	65.27
1992	9.02	5.30	51.74	66.05
1993	18.25	7.35	11.33	36.93
1994	19.73	8.23	18.34	46.30
1995	17.51	8.83	13.49	39.84
1996	13.89	5.54	9.34	28.76
1997	10.82	5.77	34.09	50.68
1998	10.05	4.74	13.02	27.81
1999	10.30	6.84	39.63	56.77
2000	11.94	8.44	45.34	65.72
2001	22.75	12.03	31.58	66.36
2002	21.22	12.95	35.19	69.36
2003	14.84	5.71	26.00	46.55
2004	17.57	10.84	28.86	57.27
2005	12.92	8.91	29.45	51.28
2006	7.93	5.95	26.72	40.59
2007	11.37	6.89	17.65	35.91
2008	32.18	18.97	81.92	133.07
2009	42.54	21.56	55.03	119.13
2010	0.79	0.48	0.06	1.33
2011	0.06	1.36	0.06	1.48
2012	0.76	2.13	15.62	18.51
2013	3.00	1.52	7.58	12.11
2014	6.85	5.90	28.20	40.95

Table 17. Estimated time series of landings in whole weight (1000 lb) for commercial handlines (L.cH), headboat (L.HB), and recreational (L.GR).

Year	L.cH	L.HB	L.GR	Total
1950	368.63	0.00	0.00	368.63
1951	499.70	0.00	0.00	499.70
1952	385.89	0.00	0.00	385.89
1953	398.23	0.00	0.00	398.23
1954	593.09	0.00	0.00	593.09
1955	493.22	105.73	203.28	802.24
1956	483.81	114.76	220.62	819.19
1957	866.94	122.74	235.96	1225.64
1958	612.31	129.58	249.13	991.03
1959	657.49	136.40	262.23	1056.12
1960	670.79	143.04	274.98	1088.81
1961	795.93	153.19	294.49	1243.61
1962	645.66	162.61	312.60	1120.87
1963	488.58	172.16	330.95	991.69
1964	537.31	181.96	349.77	1069.04
1965	557.78	191.15	367.44	1116.37
1966	554.15	188.90	363.10	1106.15
1967	724.83	186.10	357.71	1268.65
1968	864.47	181.77	349.38	1395.63
1969	537.74	177.12	340.44	1055.30
1970	512.58	175.11	336.56	1024.25
1971	457.00	190.40	365.94	1013.34
1972	406.30	205.69	395.28	1007.27
1973	296.36	220.76	424.19	941.31
1974	477.76	234.74	451.01	1163.51
1975	599.71	243.15	467.08	1309.94
1976	570.55	233.05	447.72	1251.32
1977	594.84	221.32	424.81	1240.97
1978	593.57	206.97	397.81	1198.35
1979	421.45	195.51	376.09	993.05
1980	385.86	194.35	373.78	953.99
1981	379.01	153.11	397.42	929.54
1982	309.48	92.58	172.00	574.06
1983	317.00	113.71	253.63	684.34
1984	253.57	107.60	735.87	1097.04
1985	250.87	198.23	1138.94	1588.04
1986	219.41	76.54	463.49	759.44
1987	191.52	120.33	227.94	539.79
1988	173.51	155.72	344.23	673.46
1989	266.44	116.72	482.48	865.64
1990	226.33	130.06	75.19	431.58
1991	143.47	107.59	269.42	520.47
1992	104.30	55.74	554.98	715.02
1993	220.07	72.66	112.36	405.09
1994	195.69	65.33	151.62	412.64
1995	177.57	77.01	118.32	372.91
1996	138.63	47.09	81.06	266.78
1997	110.39	50.36	292.70	453.45
1998	89.59	36.90	101.25	227.73
1999	93.61	56.35	319.96	469.91
2000	104.14	66.82	354.14	525.10
2001	196.55	96.04	250.68	543.27
2002	188.39	106.65	291.53	586.57
2003	138.42	49.13	225.90	413.45
2004	171.81	96.00	259.47	527.28
2005	129.64	78.63	270.48	478.76
2006	86.21	56.67	252.86	395.73
2007	114.58	56.26	130.36	301.20
2008	251.86	137.53	584.16	973.55
2009	363.61	174.09	441.65	979.35
2010	6.45	3.30	0.54	10.29
2011	0.57	11.11	0.62	12.30
2012	8.14	16.69	177.80	202.63
2013	31.60	10.70	87.43	129.73
2014	65.45	34.90	300.79	401.13

Table 18. Estimated time series of discard mortalities in numbers (1000 fish) for commercial handlines (D.cH), headboat (D.HB), and recreational (D.GR).

Year	D.cH	D.HB	D.GR	Total
1981	.	.	1.64	.
1982	.	.	1.64	.
1983	.	.	1.64	.
1984	.	0.03	22.88	.
1985	.	0.04	23.71	.
1986	.	0.01	23.71	.
1987	.	0.02	23.71	.
1988	.	0.03	18.60	.
1989	.	0.02	7.17	.
1990	.	0.02	7.17	.
1991	.	0.01	7.18	.
1992	9.41	0.93	10.36	20.70
1993	8.03	1.29	25.24	34.56
1994	10.15	1.44	24.64	36.23
1995	10.12	1.55	18.85	30.52
1996	9.95	0.97	7.57	18.49
1997	10.75	1.01	6.13	17.90
1998	7.76	0.83	9.91	18.51
1999	6.55	1.20	60.21	67.96
2000	6.98	1.48	91.96	100.42
2001	7.27	2.11	75.03	84.40
2002	14.33	2.27	45.67	62.27
2003	4.02	1.00	58.97	63.98
2004	1.16	6.95	74.05	82.16
2005	4.89	3.66	27.12	35.67
2006	2.31	6.38	44.31	53.00
2007	5.24	26.60	106.66	138.50
2008	4.77	27.23	189.33	221.33
2009	5.50	21.22	89.08	115.79
2010	6.63	14.24	51.39	72.25
2011	15.28	11.80	9.55	36.62
2012	7.30	13.34	40.83	61.47
2013	7.34	13.33	23.98	44.65
2014	10.26	13.29	81.59	105.14

Table 19. Estimated time series of discard mortalities in whole weight (1000 lb) for commercial handlines (D.cH), headboat (D.HB), and recreational (D.GR).

Year	D.cH	D.HB	D.GR	Total
1981	.	.	3.58	.
1982	.	.	2.74	.
1983	.	.	2.26	.
1984	.	0.04	36.20	.
1985	.	0.08	47.25	.
1986	.	0.03	51.32	.
1987	.	0.03	34.75	.
1988	.	0.06	34.58	.
1989	.	0.05	18.06	.
1990	.	0.05	22.14	.
1991	.	0.03	19.72	.
1992	17.83	1.31	14.63	33.78
1993	21.23	2.94	57.58	81.74
1994	25.87	2.76	47.13	75.75
1995	30.29	3.57	43.56	77.42
1996	21.36	1.58	12.34	35.28
1997	25.68	2.00	12.16	39.84
1998	16.91	1.44	17.21	35.56
1999	13.99	2.10	105.42	121.51
2000	15.83	2.73	169.97	188.53
2001	18.92	4.34	154.59	177.85
2002	39.51	4.72	95.20	139.43
2003	9.92	1.85	108.97	120.73
2004	3.75	17.33	184.56	205.65
2005	19.56	10.44	77.41	107.41
2006	3.18	7.88	54.74	65.79
2007	10.93	50.16	201.15	262.24
2008	11.40	52.20	362.92	426.52
2009	19.76	62.13	260.85	342.73
2010	48.44	74.12	267.57	390.12
2011	133.73	59.28	47.95	240.96
2012	67.07	61.67	188.74	317.48
2013	61.91	43.61	78.43	183.96
2014	71.86	35.54	218.23	325.63

Table 20. Estimated total landings at age in numbers (1000 fish)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1950	0.13	2.60	4.40	3.42	2.70	2.18	1.79	1.48	1.24	1.04	0.88	0.75	0.63	0.54	0.46	0.39	0.33	0.28	0.24	1.43
1951	0.18	3.55	5.97	4.64	3.66	2.95	2.42	2.01	1.68	1.41	1.19	1.01	0.86	0.73	0.62	0.53	0.45	0.39	0.33	1.94
1952	0.14	2.76	4.64	3.58	2.82	2.28	1.87	1.55	1.30	1.09	0.92	0.78	0.66	0.56	0.48	0.41	0.35	0.30	0.25	1.50
1953	0.14	2.86	4.81	3.72	2.91	2.35	1.93	1.60	1.34	1.12	0.95	0.80	0.68	0.58	0.49	0.42	0.36	0.31	0.26	1.54
1954	0.22	4.28	7.19	5.57	4.36	3.50	2.87	2.38	1.99	1.67	1.41	1.19	1.01	0.86	0.73	0.63	0.53	0.46	0.39	2.30
1955	1.27	12.41	15.09	10.73	7.66	5.47	3.91	2.86	2.15	1.66	1.40	1.19	1.01	0.86	0.73	0.62	0.53	0.45	0.39	2.28
1956	1.42	13.61	15.74	10.89	7.72	5.54	3.98	2.90	2.17	1.68	1.42	1.20	1.02	0.87	0.74	0.63	0.54	0.46	0.39	2.31
1957	1.76	18.06	21.61	14.59	10.34	7.65	5.79	4.45	3.48	2.80	2.39	2.04	1.73	1.47	1.25	1.07	0.91	0.78	0.66	3.92
1958	1.85	17.77	19.98	12.87	8.61	6.09	4.48	3.39	2.62	2.07	1.79	1.53	1.31	1.11	0.95	0.81	0.69	0.59	0.50	2.96
1959	2.05	19.70	22.17	14.09	9.13	6.23	4.51	3.43	2.70	2.18	1.89	1.63	1.40	1.20	1.02	0.87	0.74	0.63	0.54	3.19
1960	2.25	21.49	23.85	15.04	9.62	6.36	4.43	3.31	2.62	2.14	1.89	1.65	1.43	1.23	1.05	0.90	0.76	0.65	0.56	3.29
1961	2.59	25.03	27.67	17.23	11.03	7.26	4.97	3.62	2.84	2.35	2.11	1.87	1.63	1.42	1.22	1.05	0.89	0.76	0.65	3.84
1962	2.79	26.00	27.52	16.57	10.33	6.68	4.45	3.09	2.30	1.85	1.67	1.51	1.34	1.17	1.02	0.88	0.75	0.64	0.55	3.23
1963	2.96	26.43	27.08	15.89	9.54	5.98	3.89	2.61	1.85	1.40	1.25	1.13	1.02	0.91	0.79	0.69	0.60	0.51	0.44	2.58
1964	3.26	29.14	29.79	17.51	10.39	6.40	4.14	2.80	1.98	1.48	1.27	1.14	1.03	0.93	0.83	0.73	0.64	0.55	0.47	2.78
1965	3.58	31.87	32.00	18.55	11.03	6.72	4.26	2.87	2.04	1.52	1.28	1.11	0.99	0.90	0.82	0.73	0.64	0.56	0.48	2.85
1966	3.73	33.16	32.79	18.54	10.90	6.68	4.21	2.79	1.98	1.48	1.24	1.05	0.91	0.82	0.74	0.68	0.60	0.53	0.46	2.76
1967	4.07	37.36	37.34	20.86	12.13	7.49	4.86	3.28	2.35	1.79	1.51	1.27	1.08	0.94	0.84	0.77	0.70	0.62	0.55	3.33
1968	4.52	42.49	41.93	22.76	13.10	8.01	5.24	3.63	2.62	2.00	1.68	1.42	1.20	1.02	0.89	0.80	0.73	0.66	0.59	3.68
1969	4.39	39.22	36.49	18.46	10.07	5.90	3.67	2.44	1.73	1.28	1.05	0.89	0.75	0.64	0.54	0.47	0.42	0.39	0.35	2.27
1970	4.45	39.70	37.60	19.05	9.83	5.57	3.40	2.22	1.56	1.16	0.95	0.79	0.67	0.57	0.48	0.41	0.36	0.32	0.29	1.99
1971	4.84	42.06	39.04	20.01	10.29	5.47	3.19	2.02	1.37	1.01	0.83	0.69	0.57	0.48	0.41	0.35	0.30	0.26	0.23	1.66
1972	5.28	44.65	40.17	20.37	10.61	5.62	3.09	1.87	1.24	0.88	0.72	0.60	0.50	0.41	0.35	0.30	0.25	0.22	0.19	1.38
1973	5.63	45.75	39.47	19.47	9.98	5.31	2.87	1.61	1.00	0.68	0.55	0.46	0.38	0.31	0.26	0.22	0.19	0.16	0.14	1.00
1974	6.59	54.57	47.26	23.38	12.03	6.58	3.79	2.24	1.40	0.97	0.78	0.63	0.52	0.44	0.36	0.30	0.26	0.22	0.19	1.31
1975	7.97	65.50	53.29	24.96	12.91	7.12	4.21	2.64	1.72	1.16	0.92	0.74	0.60	0.50	0.42	0.35	0.29	0.25	0.21	1.44
1976	9.00	72.56	54.07	22.46	11.02	6.13	3.65	2.35	1.60	1.12	0.85	0.67	0.54	0.44	0.37	0.31	0.26	0.21	0.18	1.22
1977	10.37	82.66	57.63	21.41	9.43	5.06	3.10	2.04	1.45	1.08	0.85	0.65	0.51	0.41	0.34	0.28	0.24	0.20	0.16	1.08
1978	13.67	94.77	59.72	19.56	7.77	3.79	2.27	1.56	1.14	0.89	0.73	0.58	0.44	0.35	0.28	0.23	0.19	0.16	0.13	0.85
1979	10.44	105.38	52.37	14.18	4.94	2.16	1.17	0.77	0.58	0.46	0.39	0.33	0.26	0.20	0.16	0.13	0.10	0.09	0.07	0.44
1980	18.28	88.18	63.34	13.94	4.07	1.58	0.78	0.47	0.35	0.29	0.25	0.22	0.18	0.14	0.11	0.09	0.07	0.06	0.05	0.29
1981	6.67	135.14	43.49	13.17	3.17	1.06	0.48	0.27	0.19	0.15	0.14	0.13	0.11	0.09	0.07	0.05	0.04	0.04	0.03	0.17
1982	7.80	38.79	53.99	6.99	2.32	0.64	0.25	0.13	0.09	0.07	0.06	0.06	0.05	0.04	0.04	0.03	0.02	0.02	0.01	0.08
1983	33.89	85.75	27.36	15.53	2.14	0.78	0.24	0.10	0.06	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.05
1984	41.36	230.37	31.44	3.47	2.09	0.32	0.13	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01
1985	22.33	274.48	93.89	5.51	0.67	0.47	0.08	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
1986	5.76	77.38	66.24	10.13	0.68	0.10	0.09	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	14.09	32.57	39.02	16.88	2.78	0.21	0.03	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	9.84	100.98	21.21	12.87	5.75	0.99	0.08	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	3.27	73.50	74.19	8.42	5.34	2.55	0.47	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	0.46	12.51	31.39	17.23	2.07	1.44	0.76	0.16	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	0.75	6.86	18.08	23.71	12.77	1.50	0.99	0.50	0.10	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	0.88	1.33	6.63	16.75	23.91	13.36	1.57	1.02	0.49	0.09	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	0.15	4.69	6.38	4.70	5.21	8.01	5.54	0.85	0.75	0.49	0.12	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	0.30	1.53	30.55	4.49	1.46	1.70	2.92	2.26	0.38	0.36	0.25	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	0.11	2.36	9.36	22.70	1.45	0.48	0.62	1.18	1.01	0.19	0.19	0.14	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	0.24	0.82	12.82	6.08	6.69	0.45	0.17	0.24	0.50	0.47	0.09	0.10	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00
1997	0.60	7.37	12.12	20.02	4.32	4.74	0.33	0.12	0.17	0.36	0.33	0.06	0.07	0.05	0.01	0.00	0.00	0.00	0.00	0.00
1998	0.36	1.87	17.79	3.71	2.31	0.54	0.72	0.06	0.03	0.05	0.13	0.14	0.03	0.03	0.02	0.01	0.00	0.00	0.00	0.00
1999	1.03	6.76	20.16	24.04	2.28	1.40	0.33	0.45	0.04	0.02	0.03	0.08	0.08	0.02	0.02	0.01	0.00	0.00	0.00	0.00
2000	1.03	7.88	34.14	13.86	7.07	0.70	0.48	0.13	0.21	0.02	0.01	0.02	0.06	0.06	0.01	0.01	0.01	0.00	0.00	0.00
2001	0.47	5.47	33.33	20.65	3.64	1.97	0.23	0.20	0.07	0.13	0.02	0.01	0.02	0.05	0.06	0.01	0.01	0.01	0.00	0.00
2002	0.39	3.83	31.44	24.66	6.75	1.21	0.71	0.09	0.08	0.03	0.06	0.01	0.00	0.01	0.03	0.03	0.01	0.01	0.01	0.00
2003	0.37	2.28	16.14	18.59	6.60	1.84	0.36	0.23	0.03	0.03	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
2004	0.15	3.56	17.89	19.58	10.69	3.76	1.11	0.23	0.16	0.02	0.03	0.01	0.02	0.00	0.00	0.00	0.01	0.01	0.00	0.01
2005	0.07	1.13	20.40	15.00	7.86	4.36	1.65	0.52	0.12	0.09	0.01	0.02	0.01	0.02	0.00	0.00	0.00	0.01	0.01	0.01
2006	2.13	0.68	7.00	17.94	6.21	3.34	2.01	0.82	0.28	0.07	0.05	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.01
2007	1.03	15.05	3.77	5.07	5.68	2.08	1.33	0.99	0.51	0.21	0.06	0.06	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.02
2008	1.78	12.80	109.11	2.97	1.77	2.10	0.87	0.62	0.51	0.28	0.13	0.04	0.03	0.01	0.01	0.00	0.01	0.00	0.00	0.01
2009	0.17	8.68	50.44	57.15	0.64	0.41	0.57	0.28	0.25	0.24	0.15	0.07	0.02	0.02	0.00	0.01	0.00	0.01	0.00	0.01
2010	0.01	0.04	0.61	0.43	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2011	0.03	0.19	0.19	0.68	0.27	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2012	0.19	1.07	1.99	1.56	7.53	3.80	2.12	0.03	0.03	0.05	0.03	0.03	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00
2013	0.31	0.82	2.39	2.03	0.80	3.14	1.59	0.92	0.01	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00
2014	1.57	5.66	7.38	9.51	4.40	1.48	5.85	3.05	1.81	0.03	0.02	0.05	0.03	0.03	0.04	0.02	0.01	0.00	0.00	0.00

Table 21. Estimated landings at age in whole weight (1000 lb)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1950	0.19	8.93	25.79	29.05	29.94	29.50	28.13	26.17	23.93	21.57	19.23	17.01	14.95	13.06	11.37	9.86	8.54	7.37	6.35	37.70
1951	0.27	12.15	34.98	39.38	40.58	39.98	38.12	35.48	32.43	29.23	26.07	23.05	20.26	17.70	15.41	13.37	11.57	9.99	8.61	51.09
1952	0.21	9.46	27.20	30.41	31.31	30.84	29.41	27.37	25.02	22.56	20.11	17.79	15.63	13.66	11.89	10.32	8.93	7.70	6.64	39.42
1953	0.21	9.79	28.22	31.58	32.30	31.79	30.32	28.21	25.79	23.25	20.73	18.33	16.11	14.08	12.25	10.63	9.20	7.94	6.84	40.63
1954	0.32	14.69	42.13	47.27	48.39	47.31	45.07	41.94	38.34	34.56	30.82	27.26	23.95	20.93	18.22	15.81	13.68	11.81	10.17	60.41
1955	1.88	42.53	88.50	91.12	84.98	73.96	61.55	50.49	41.43	34.33	30.61	27.07	23.79	20.79	18.09	15.70	13.58	11.73	10.11	60.00
1956	2.10	46.65	92.28	92.45	85.60	74.95	62.61	51.10	41.89	34.67	31.06	27.47	24.14	21.10	18.36	15.93	13.78	11.90	10.25	60.88
1957	2.61	61.90	126.69	123.86	114.71	103.51	91.09	78.49	67.24	58.03	52.36	46.52	40.88	35.72	31.09	26.98	23.34	20.15	17.37	103.11
1958	2.73	60.89	117.16	109.26	95.48	82.38	70.50	59.86	50.56	42.87	39.04	34.94	30.85	26.96	23.46	20.36	17.62	15.21	13.10	77.80
1959	3.03	67.52	129.97	119.63	101.33	84.28	70.92	60.53	52.15	45.01	41.27	37.29	33.16	29.11	25.33	21.98	19.02	16.42	14.15	84.01
1960	3.32	73.64	139.81	127.73	106.76	86.04	69.72	58.41	50.47	44.34	41.30	37.56	33.72	29.81	26.07	22.62	19.57	16.90	14.56	86.45
1961	3.83	85.80	162.22	146.35	122.32	98.25	78.07	63.79	54.75	48.72	46.22	42.71	38.59	34.45	30.34	26.45	22.89	19.76	17.02	101.08
1962	4.13	89.11	161.36	140.67	114.58	90.41	69.95	54.56	44.43	38.31	36.53	34.38	31.56	28.36	25.21	22.14	19.25	16.61	14.32	85.00
1963	4.37	90.60	158.79	134.92	105.84	80.95	61.12	46.10	35.63	29.03	27.28	25.80	24.13	22.03	19.71	17.48	15.30	13.27	11.44	67.90
1964	4.82	99.86	174.68	148.66	115.28	86.58	65.04	49.41	38.25	30.61	27.86	25.97	24.41	22.69	20.64	18.41	16.27	14.22	12.31	73.08
1965	5.30	109.25	187.59	157.48	122.38	90.92	67.05	50.60	39.35	31.42	27.95	25.23	23.37	21.84	20.23	18.34	16.31	14.39	12.55	74.83
1966	5.51	113.66	192.23	157.41	120.96	90.36	66.17	49.21	38.14	30.68	27.21	24.00	21.53	19.83	18.46	17.04	15.41	13.68	12.04	72.62
1967	6.01	128.05	218.94	177.10	134.57	101.31	76.36	57.86	45.29	37.07	33.03	29.06	25.47	22.73	20.84	19.34	17.81	16.06	14.23	87.51
1968	6.68	145.63	245.84	193.23	145.30	108.42	82.38	64.02	50.65	41.43	36.71	32.45	28.36	24.72	21.97	20.09	18.59	17.08	15.37	96.71
1969	6.50	134.42	213.93	156.77	111.76	79.86	57.68	43.07	33.31	26.39	23.03	20.24	17.78	15.45	13.41	11.88	10.84	10.00	9.17	59.80
1970	6.58	136.08	220.46	161.76	109.10	75.34	53.46	39.15	30.09	24.05	20.87	18.07	15.78	13.78	11.93	10.33	9.12	8.30	7.65	52.37
1971	7.16	144.17	228.91	169.90	114.11	73.97	50.18	35.65	26.51	20.81	18.21	15.67	13.48	11.71	10.18	8.79	7.59	6.69	6.07	43.60
1972	7.81	153.02	235.54	172.93	117.68	76.07	48.51	33.00	23.85	18.16	15.81	13.72	11.73	10.04	8.68	7.53	6.48	5.58	4.91	36.22
1973	8.32	156.82	231.40	165.34	110.72	71.89	45.14	28.39	19.31	14.05	12.05	10.40	8.97	7.63	6.50	5.61	4.85	4.16	3.58	26.19
1974	9.75	187.04	277.08	198.53	133.43	89.03	59.51	39.60	26.97	19.98	16.97	14.43	12.38	10.61	8.99	7.64	6.57	5.67	4.86	34.49
1975	11.78	224.50	312.41	211.94	143.28	96.36	66.24	46.64	33.13	24.09	20.03	16.87	14.25	12.16	10.38	8.77	7.43	6.37	5.49	37.84
1976	13.31	248.68	317.01	190.70	122.24	82.91	57.44	41.42	30.87	23.15	18.61	15.35	12.84	10.79	9.17	7.81	6.57	5.56	4.76	32.13
1977	15.33	283.30	337.91	181.77	104.57	68.40	48.71	36.07	27.99	22.32	18.49	14.74	12.08	10.05	8.41	7.13	6.05	5.08	4.29	28.28
1978	20.21	324.82	350.11	166.14	86.21	51.28	35.68	27.45	22.02	18.34	16.01	13.16	10.42	8.49	7.04	5.87	4.96	4.20	3.52	22.42
1979	15.43	361.18	307.01	120.45	54.82	29.25	18.33	13.60	11.16	9.46	8.57	7.42	6.06	4.77	3.88	3.20	2.66	2.24	1.90	11.64
1980	27.04	302.22	371.35	118.41	45.11	21.43	12.26	8.34	6.71	5.90	5.51	4.95	4.26	3.46	2.71	2.20	1.81	1.50	1.26	7.57
1981	9.86	463.20	254.97	111.86	35.18	14.31	7.48	4.77	3.61	3.18	3.10	2.87	2.56	2.19	1.77	1.39	1.12	0.92	0.76	4.45
1982	11.53	132.94	316.51	59.34	25.75	8.71	3.93	2.32	1.66	1.38	1.34	1.29	1.19	1.06	0.90	0.73	0.57	0.46	0.37	2.10
1983	50.12	293.89	160.40	131.84	23.73	10.62	3.79	1.82	1.14	0.86	0.76	0.73	0.70	0.64	0.57	0.48	0.39	0.30	0.24	1.31
1984	61.16	789.58	184.36	29.43	23.21	4.32	2.02	0.76	0.38	0.24	0.20	0.17	0.17	0.16	0.14	0.13	0.11	0.09	0.07	0.34
1985	33.02	940.75	550.47	46.81	7.49	6.36	1.30	0.67	0.27	0.14	0.11	0.09	0.08	0.07	0.07	0.06	0.05	0.05	0.04	0.17
1986	8.52	265.21	388.36	86.04	7.55	1.36	1.35	0.33	0.20	0.10	0.06	0.05	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.09
1987	20.83	111.63	228.76	143.36	30.79	2.78	0.53	0.57	0.15	0.10	0.06	0.04	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.06
1988	14.55	346.10	124.36	109.26	63.81	13.42	1.21	0.23	0.25	0.07	0.05	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.04
1989	4.83	251.92	434.95	71.46	59.28	34.54	7.45	0.70	0.14	0.17	0.05	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.03
1990	0.68	42.89	184.03	146.30	22.98	19.42	11.95	2.80	0.29	0.07	0.09	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.02
1991	1.11	23.50	105.98	201.37	141.71	20.23	15.57	8.76	1.89	0.18	0.04	0.06	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.01
1992	2.84	6.80	47.56	155.57	271.80	178.34	23.86	17.14	8.99	1.82	0.17	0.04	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.01
1993	0.49	23.96	45.79	43.65	59.22	106.90	84.06	14.39	13.79	9.71	2.59	0.30	0.07	0.09	0.03	0.02	0.01	0.01	0.01	0.03
1994	0.96	7.85	219.08	41.69	16.65	22.72	44.38	38.03	7.05	7.18	5.32	1.44	0.17	0.04	0.05	0.02	0.01	0.01	0.00	0.02
1995	0.36	12.08	67.12	210.80	16.48	6.46	9.40	19.92	18.55	3.69	4.00	3.04	0.84	0.10	0.02	0.03	0.01	0.01	0.00	0.01
1996	0.77	4.18	91.97	56.48	76.06	5.94	2.51	4.00	9.26	9.26	1.95	2.16	1.67	0.46	0.05	0.01	0.02	0.00	0.00	0.01
1997	1.93	37.69	86.89	185.97	49.12	63.28	4.95	2.06	3.17	7.05	6.86	1.40	1.51	1.17	0.33	0.04	0.01	0.01	0.00	0.01
1998	1.16	9.58	127.60	34.44	26.30	7.15	10.94	1.06	0.55	1.04	2.75	2.99	0.65	0.75	0.58	0.16	0.02	0.00	0.01	0.01
1999	3.32	34.54	144.59	223.31	25.97	18.67	5.05	7.64	0.72	0.37	0.68	1.77	1.89	0.42	0.48	0.37	0.10	0.01	0.00	0.01
2000	3.34	40.31	244.82	128.76	80.34	9.29	7.36	2.24	3.84	0.41	0.23	0.46	1.25	1.41	0.31	0.35	0.27	0.07	0.01	0.01
2001	1.52	27.99	239.04	191.81	41.37	26.28	3.50	3.32	1.24	2.56	0.32	0.20	0.44	1.25	1.40	0.31	0.35	0.27	0.07	0.02
2002	1.25	19.58	225.46	229.06	76.76	16.11	10.78	1.53	1.55	0.61	1.34	0.17	0.11	0.24	0.69	0.77	0.17	0.19	0.15	0.05
2003	1.18	11.64	115.73	172.67	75.05	24.49	5.43	3.90	0.60	0.65	0.27	0.62	0.08	0.05	0.12	0.33	0.37	0.08	0.09	0.09
2004	0.48	18.20	128.33	181.88	121.51	50.18	16.81	3.91	2.99	0.49	0.57	0.25	0.57	0.08	0.05	0.11	0.31	0.34	0.07	0.17
2005	0.24	5.77	146.28	139.34	89.34	58.24	25.02	8.79	2.15	1.72	0.30	0.35	0.15	0.36	0.05	0.03	0.07	0.19	0.21	0.15
2006	6.88	3.47	50.19	166.66	70.63	44.54	30.58	13.90	5.16	1.32	1.12	0.20	0.24	0.11	0.25	0.03	0.02	0.05	0.13	0.25
2007	3.34	76.96	27.02	47.11	64.57	27.81	20.16	16.62	9.28	4.21	1.30	1.24	0.23	0.30	0.13	0.32	0.04	0.03	0.06	0.47
2008	5.74	65.46	782.49	27.62	20.17	28.04	13.21	10.50	9.39	5.58	2.67	0.83	0.80	0.15	0.19	0.09	0.21	0.03	0.02	0.34
2009	0.55	44.37	361.78	530.80	7.27	5.42	8.63	4.80	4.52	4.70	3.17	1.63	0.53	0.53	0.10	0.13	0.06	0.13	0.02	0.23
2010	0.01	0.13	3.55	3.65	2.56	0.04	0.04	0.07	0.05	0.05	0.06	0.04	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00
2011	0.04	0.64	1.10	5.79	3.02	1.59	0.02	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
2012	0.28	3.68	11.67	13.23	83.52	51.39	33.30	0.52	0.49	1.00	0.69	0.76	0.86	0.61	0.32	0.10	0.10	0.02	0.02	0.08
2013	0.45	2.80	14.03	17.20	8.85	42.48	25.01	16.20	0.25	0.24	0.49	0.34	0.37	0.42	0.29	0.15	0.05	0.05	0.01	0.05
2014	2.32	19.41	43.25	80.72	48.79	19.98	92.04	53.90	34.95	0.55	0.52	1.06	0.72	0.78	0.88	0.62	0.32	0.11	0.10	0.12

Table 22. Estimated discards at age in numbers (1000 fish)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1950	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1951	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1952	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1953	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1954	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1955	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1956	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1976	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.86	0.73	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	1.32	0.25	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	1.48	0.15	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1984	18.19	4.57	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	14.55	8.49	0.69	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	13.78	8.27	1.60	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	21.00	2.11	0.56	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	12.49	5.81	0.28	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	3.21	3.22	0.74	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	2.64	2.84	1.48	0.22	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	3.99	1.70	1.05	0.39	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	18.16	1.54	0.47	0.29	0.18	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	15.13	18.32	0.88	0.13	0.05	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	25.59	5.77	4.69	0.14	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	14.52	12.91	2.00	1.05	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	14.38	2.22	1.61	0.19	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	9.99	6.88	0.69	0.29	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	13.55	3.35	1.51	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	49.94	15.60	1.99	0.41	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	70.44	25.14	4.49	0.30	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	52.46	25.71	5.62	0.58	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	38.30	17.10	5.84	0.92	0.09	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	46.80	12.96	3.50	0.65	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	37.28	37.29	6.39	1.04	0.15	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	15.63	10.93	7.87	1.02	0.18	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2006	51.79	0.76	0.31	0.13	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2007	87.45	50.52	0.41	0.09	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2008	155.39	49.94	15.93	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2009	32.33	67.72	13.41	2.33	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	17.13	6.45	28.12	13.62	6.61	0.07	0.05	0.07	0.03	0.03	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2011	8.98	4.82	2.59	11.66	5.52	2.80	0.03	0.03	0.05	0.03	0.03	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
2012	21.95	14.87	7.15	2.53	9.10	3.91	1.82	0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00
2013	23.03	7.49	6.01	2.58	0.80	2.80	1.25	0.63	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
2014	59.22	26.15	8.81	5.35	1.89	0.55	1.87	0.82	0.42	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00

Table 23. Estimated discards at age in whole weight (1000 lb)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1950	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1951	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1952	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1953	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1954	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1955	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1956	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1976	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	1.00	2.25	0.28	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	1.54	0.78	0.40	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	1.73	0.46	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1984	21.23	14.17	0.80	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	16.99	26.36	3.88	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	16.08	25.67	9.01	0.58	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	24.50	6.54	3.14	0.57	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	14.57	18.03	1.57	0.40	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	3.74	9.99	4.13	0.20	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	3.08	8.81	8.34	1.88	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	4.66	5.27	5.89	3.29	0.62	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	21.19	4.79	2.65	2.46	2.00	0.62	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	17.66	56.84	4.96	1.10	0.60	0.44	0.14	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	29.86	17.91	26.36	1.19	0.20	0.11	0.09	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	16.95	40.05	11.23	8.78	0.29	0.05	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	16.78	6.90	9.02	1.56	0.96	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	11.66	21.36	3.86	2.46	0.31	0.19	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	15.81	10.41	8.48	0.61	0.21	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	58.29	48.41	11.17	3.45	0.14	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	82.21	78.02	25.22	2.53	0.53	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	61.22	79.78	31.57	4.84	0.35	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	44.70	53.08	32.81	7.68	1.03	0.09	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	54.62	40.23	19.66	5.38	0.75	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	43.51	115.73	35.90	8.65	1.64	0.20	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	18.24	33.92	44.18	8.54	1.95	0.48	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2006	60.44	2.35	1.73	1.07	0.15	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2007	102.06	156.79	2.29	0.73	0.31	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2008	181.35	154.98	89.47	0.54	0.11	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2009	37.73	210.15	75.30	19.43	0.08	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	20.00	20.02	157.95	113.65	72.85	1.00	0.76	1.19	0.63	0.55	0.63	0.45	0.23	0.08	0.08	0.01	0.02	0.01	0.02	0.03
2011	10.48	14.96	14.54	97.29	60.87	37.83	0.55	0.48	0.90	0.59	0.65	0.74	0.52	0.27	0.09	0.09	0.02	0.02	0.01	0.06
2012	25.62	46.14	40.18	21.13	100.31	52.78	28.54	0.36	0.28	0.47	0.32	0.36	0.40	0.28	0.15	0.05	0.05	0.01	0.01	0.04
2013	26.88	23.25	33.74	21.51	8.85	37.78	19.52	10.98	0.15	0.13	0.26	0.18	0.19	0.22	0.15	0.08	0.03	0.03	0.00	0.03
2014	69.11	81.15	49.49	44.63	20.88	7.45	29.36	14.47	7.95	0.11	0.10	0.21	0.14	0.15	0.17	0.12	0.06	0.02	0.02	0.02

Table 24. Estimated status indicators, benchmarks, and related quantities from the base run of the Beaufort catch-age model, conditional on estimated current selectivities averaged across fleets. Also presented are median values and measures of precision (standard errors, SE) from the Monte Carlo/Bootstrap analysis. Rate estimates (F) are in units of y^{-1}*; status indicators are dimensionless; and biomass estimates are in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) is measured as population fecundity (number of eggs)*

Quantity	Units	Estimate	Median	SE
$F_{30\%}$	y^{-1}	0.15	0.15	0.01
$85\%F_{30\%}$	y^{-1}	0.12	0.13	0.01
$75\%F_{30\%}$	y^{-1}	0.11	0.11	0.01
$65\%F_{30\%}$	y^{-1}	0.10	0.10	0.01
$F_{30\%}$	y^{-1}	0.15	0.15	0.01
$F_{40\%}$	y^{-1}	0.11	0.11	0.01
$B_{\mathrm{F30\%}}$	metric tons	3647	3534	606
$\mathrm{SSB}_{\mathrm{F30\%}}$	Eggs (1E8)	328552	294166	91553
MSST	Eggs (1E8)	246414	220624	68665
$L_{\mathrm{F30\%}}$	1000 lb whole	430	419	77
$R_{\mathrm{F30\%}}$	number fish	447646	456646	110298
$L_{85\%\mathrm{F30\%}}$	1000 lb whole	414	403	74
$L_{75\%\mathrm{F30\%}}$	1000 lb whole	398	387	71
$L_{65\%\mathrm{F30\%}}$	1000 lb whole	378	368	67
$F_{2012-2014}/F_{30\%}$	—	2.52	2.49	0.88
$\mathrm{SSB}_{2014}/\mathrm{MSST}$	—	0.22	0.23	0.13
$\mathrm{SSB}_{2014}/\mathrm{SSB}_{\mathrm{F30\%}}$	—	0.16	0.17	0.10

Table 25. Results from sensitivity runs of the Beaufort catch-age model. Current F represented by geometric mean of last three assessment years. Runs should not all be considered equally plausible.

Run	Description	$F_{30\%}$	$\mathrm{SSB}_{\mathrm{F30\%}}$ (1E8 Eggs)	$L_{\mathrm{F30\%}}$ (1000 lb)	$\mathrm{F}_{\mathrm{current}}/F_{30\%}$	$\mathrm{SSB}_{end}/\mathrm{SSB}_{\mathrm{F30\%}}$	R0(1000)	sigmaR	Finit
Base	—	0.147	329948	459	2.84	0.18	331	0.79	0.03
S1	remove 2008/9 from FD	0.147	329929	468	2.86	0.18	330	0.79	0.03
S2	upweight FI 10X	0.146	332402	438	2.07	0.28	325	0.82	0.03
S3	upweight FD 3X	0.146	344879	448	1.71	0.36	338	0.82	0.03
S4	FD only	0.145	332259	325	1.19	0.64	347	0.74	0.03
S5	M upper	0.169	246562	424	1.65	0.4	430	0.82	0.03
S6	M lower	0.133	406658	470	3.73	0.12	285	0.75	0.03
S7	Disc. M lower	0.147	328444	520	2.12	0.24	317	0.83	0.03
S8	Disc. M upper	0.146	335957	424	2.82	0.2	354	0.72	0.03
S9	Longer CVID index	0.147	334145	470	1.99	0.3	344	0.76	0.03
S10	Smooth 1984/5 MRIP peak	0.147	328483	462	2.53	0.22	327	0.8	0.03
S11	h=0.84	0.146	396289	525	3.56	0.11	497	0.6	0.03
S12	Truncated HB disc. index	0.147	331524	470	2.6	0.21	334	0.78	0.03
S13	Ageing error matrix	0.144	334881	409	1.63	0.39	319	0.85	0.03
S14	Batch number lower	0.154	220597	468	2.47	0.24	330	0.79	0.03
S15	Batch number upper	0.146	362022	465	2.63	0.21	333	0.78	0.03
S16	Drop HB disc. index	0.147	331560	470	2.59	0.21	334	0.78	0.03
S17	Higher landings	0.147	441258	654	1.94	0.25	406	0.89	0.03
S18	Lower landings	0.146	232011	298	3.36	0.18	258	0.64	0.03
S19	Higher discards	0.146	338021	500	2.6	0.19	362	0.7	0.03
S20	Lower discards	0.147	327352	561	1.89	0.26	306	0.87	0.03
S21	Dome-shaped selectivity for cH	0.15	355593	490	2.28	0.23	333	0.87	0.03
S22	Separate video and trap indices	0.143	331956	391	1.58	0.41	341	0.76	0.03
S23	FI index only	0.146	330170	436	2.75	0.18	342	0.75	0.03
S24	Continuity	0.102	817833	501	5.97	0.06	114	1.18	0.04
S25	Split q for HB CPUE	0.147	331168	466	2.61	0.2	333	0.79	0.03
S26	1978 start year	0.147	299224	418	2.93	0.19	320	0.7	0.2
S27	Estimate selex for all ages	0.148	328522	465	2.61	0.2	332	0.78	0.03

Table 26. Projection results with fishing mortality rate fixed at $F = 0$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{F30\%}}$. The extension b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	434	313	0.11	0.12	70861	64644	0	0	0	0	70	69	284	284	0.001
2016	438	314	0.21	0.23	99227	88895	28	28	244	243	67	62	332	318	0.006
2017	441	318	0.00	0.00	142378	125245	0	0	0	0	0	0	0	0	0.028
2018	444	318	0.00	0.00	200495	174381	0	0	0	0	0	0	0	0	0.110
2019	446	320	0.00	0.00	264749	227588	0	0	0	0	0	0	0	0	0.269
2020	447	319	0.00	0.00	331385	284074	0	0	0	0	0	0	0	0	0.482
2021	448	327	0.00	0.00	398356	340017	0	0	0	0	0	0	0	0	0.682
2022	448	322	0.00	0.00	464175	394134	0	0	0	0	0	0	0	0	0.829
2023	448	323	0.00	0.00	526601	447189	0	0	0	0	0	0	0	0	0.920
2024	449	321	0.00	0.00	585590	497486	0	0	0	0	0	0	0	0	0.965
2025	449	327	0.00	0.00	639992	544455	0	0	0	0	0	0	0	0	0.986
2026	449	324	0.00	0.00	689814	587517	0	0	0	0	0	0	0	0	0.995
2027	449	329	0.00	0.00	735620	628715	0	0	0	0	0	0	0	0	0.998
2028	449	323	0.00	0.00	776696	665729	0	0	0	0	0	0	0	0	0.999
2029	449	328	0.00	0.00	813530	698995	0	0	0	0	0	0	0	0	1.000
2030	449	325	0.00	0.00	846902	728549	0	0	0	0	0	0	0	0	1.000
2031	449	326	0.00	0.00	876659	754214	0	0	0	0	0	0	0	0	1.000
2032	449	323	0.00	0.00	902924	778370	0	0	0	0	0	0	0	0	1.000
2033	449	323	0.00	0.00	926190	799735	0	0	0	0	0	0	0	0	1.000
2034	449	323	0.00	0.00	946624	816889	0	0	0	0	0	0	0	0	1.000
2035	449	323	0.00	0.00	964695	832702	0	0	0	0	0	0	0	0	1.000
2036	449	326	0.00	0.00	980653	847133	0	0	0	0	0	0	0	0	1.000
2037	449	324	0.00	0.00	994731	860374	0	0	0	0	0	0	0	0	1.000
2038	449	323	0.00	0.00	1007148	872161	0	0	0	0	0	0	0	0	1.000
2039	449	322	0.00	0.00	1018096	882631	0	0	0	0	0	0	0	0	1.000
2040	449	325	0.00	0.00	1027750	892432	0	0	0	0	0	0	0	0	1.000
2041	450	325	0.00	0.00	1036261	899851	0	0	0	0	0	0	0	0	1.000
2042	450	326	0.00	0.00	1043764	906517	0	0	0	0	0	0	0	0	1.000
2043	450	326	0.00	0.00	1050377	913518	0	0	0	0	0	0	0	0	1.000
2044	450	325	0.00	0.00	1056207	919348	0	0	0	0	0	0	0	0	1.000

Table 27. Projection results with fishing mortality rate fixed at $F = F_{\text{current}}$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\text{SSB} \geq \text{SSB}_{\text{F30\%}}$. The extension b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	434	313	0.11	0.12	70861	64644	0	0	0	0	70	69	284	284	0.001
2016	438	314	0.21	0.23	99227	88895	28	28	244	243	67	62	332	318	0.006
2017	441	318	0.37	0.37	115357	101306	57	50	541	480	110	93	610	523	0.015
2018	443	317	0.37	0.37	119647	103892	52	45	539	471	101	86	570	487	0.025
2019	443	317	0.37	0.37	119197	102804	47	41	506	439	95	82	527	452	0.031
2020	443	315	0.37	0.37	116562	100566	44	38	477	415	93	79	497	427	0.035
2021	443	322	0.37	0.37	113492	97995	42	36	456	397	91	79	479	413	0.036
2022	443	316	0.37	0.37	110676	95397	41	36	443	386	91	79	468	406	0.036
2023	442	317	0.37	0.37	108184	93542	40	35	433	378	90	78	463	403	0.035
2024	442	314	0.37	0.37	106154	92101	40	35	426	373	90	78	460	400	0.033
2025	442	320	0.37	0.37	104514	91016	40	35	422	369	90	77	458	399	0.032
2026	442	317	0.37	0.37	103258	89757	40	35	418	367	90	78	457	398	0.030
2027	442	322	0.37	0.37	102345	88639	40	34	416	364	90	78	456	397	0.030
2028	442	316	0.37	0.37	101667	88070	39	34	414	363	90	77	455	396	0.028
2029	442	321	0.37	0.37	101178	87571	39	34	413	363	90	78	455	396	0.028
2030	442	317	0.37	0.37	100837	87479	39	34	412	362	90	78	454	395	0.028
2031	442	318	0.37	0.37	100593	87044	39	34	411	361	90	77	454	395	0.029
2032	442	316	0.37	0.37	100419	87033	39	34	411	361	90	77	454	395	0.028
2033	442	315	0.37	0.37	100296	86809	39	34	411	360	90	77	454	395	0.028
2034	442	316	0.37	0.37	100208	86883	39	34	410	361	90	77	453	393	0.027
2035	442	316	0.37	0.37	100148	86965	39	34	410	360	90	77	453	393	0.027
2036	442	318	0.37	0.37	100105	86806	39	34	410	360	90	77	453	393	0.027
2037	442	317	0.37	0.37	100075	86509	39	34	410	360	90	78	453	393	0.027
2038	442	316	0.37	0.37	100055	86749	39	34	410	359	90	77	453	393	0.027
2039	442	314	0.37	0.37	100040	86632	39	34	410	360	90	77	453	393	0.027
2040	442	317	0.37	0.37	100030	86477	39	34	410	360	90	77	453	393	0.028
2041	442	317	0.37	0.37	100022	86663	39	34	410	360	90	77	453	393	0.028
2042	442	318	0.37	0.37	100017	86687	39	34	410	360	90	77	453	394	0.028
2043	442	318	0.37	0.37	100014	86580	39	34	410	358	90	78	453	394	0.028
2044	442	317	0.37	0.37	100011	86656	39	34	410	360	90	77	453	395	0.028

Table 28. Projection results with fishing mortality rate fixed at $F = F_{30\%}$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{F30\%}}$. The extension b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	434	313	0.11	0.12	70861	64644	0	0	0	0	70	69	284	284	0.001
2016	438	314	0.21	0.23	99227	88895	28	28	244	243	67	62	332	318	0.006
2017	441	318	0.15	0.15	130959	114906	25	23	235	221	46	41	262	237	0.016
2018	444	318	0.15	0.15	163158	141018	27	24	281	260	47	42	284	256	0.035
2019	445	319	0.15	0.15	192082	163844	27	25	310	283	47	42	295	265	0.063
2020	446	318	0.15	0.15	216811	183808	28	26	332	301	47	42	301	269	0.093
2021	446	326	0.15	0.15	237794	200505	29	26	351	317	47	42	306	274	0.128
2022	447	321	0.15	0.15	255516	214980	30	27	366	331	47	42	309	278	0.163
2023	447	322	0.15	0.15	269916	226991	30	27	379	341	47	42	313	282	0.199
2024	447	320	0.15	0.15	281741	236878	31	28	389	351	47	43	317	286	0.232
2025	447	325	0.15	0.15	291154	245312	31	28	398	360	48	43	321	289	0.263
2026	447	323	0.15	0.15	298684	252669	31	28	404	366	48	43	323	291	0.289
2027	447	328	0.15	0.15	304844	258556	31	29	409	371	48	43	325	295	0.314
2028	447	322	0.15	0.15	309677	262641	31	29	414	375	48	43	327	296	0.337
2029	447	326	0.15	0.15	313515	267181	32	29	417	380	48	43	328	297	0.355
2030	448	323	0.15	0.15	316655	270533	32	29	420	383	48	44	329	299	0.370
2031	448	324	0.15	0.15	319147	273096	32	29	422	384	48	44	330	300	0.383
2032	448	322	0.15	0.15	321094	275224	32	29	424	386	48	43	330	300	0.396
2033	448	321	0.15	0.15	322637	276256	32	29	425	388	48	43	331	300	0.407
2034	448	322	0.15	0.15	323843	277230	32	29	426	389	48	43	331	300	0.413
2035	448	322	0.15	0.15	324806	277461	32	29	427	390	48	43	332	300	0.418
2036	448	324	0.15	0.15	325573	278447	32	29	427	391	48	43	332	301	0.424
2037	448	323	0.15	0.15	326184	279294	32	29	428	392	48	43	332	302	0.425
2038	448	322	0.15	0.15	326670	280728	32	29	428	392	48	43	332	302	0.428
2039	448	320	0.15	0.15	327056	281441	32	29	429	393	48	43	332	301	0.433
2040	448	324	0.15	0.15	327363	281134	32	29	429	393	48	43	333	302	0.433
2041	448	323	0.15	0.15	327608	281482	32	29	429	394	48	43	333	302	0.434
2042	448	324	0.15	0.15	327802	282269	32	29	429	394	48	44	333	302	0.436
2043	448	325	0.15	0.15	327956	282718	32	29	430	394	48	44	333	303	0.436
2044	448	324	0.15	0.15	328078	282284	32	30	430	394	48	44	333	303	0.440

Table 29. Projection results with fishing mortality rate fixed at $F = 98\%F_{30\%}$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{F30\%}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	434	313	0.11	0.12	70861	64644	0	0	0	0	70	69	284	284	0.001
2016	438	314	0.21	0.23	99227	88895	28	28	244	243	67	62	332	318	0.006
2017	441	318	0.14	0.15	131178	115118	24	23	230	217	45	41	257	233	0.017
2018	444	318	0.14	0.15	163829	141629	26	24	277	256	46	41	279	251	0.036
2019	445	319	0.14	0.15	193308	164882	27	25	305	279	46	41	291	261	0.065
2020	446	318	0.14	0.15	218633	185412	28	25	328	297	46	41	297	265	0.098
2021	446	326	0.14	0.15	240210	202548	29	26	347	313	46	42	302	270	0.134
2022	447	321	0.14	0.15	258500	217491	29	26	363	327	46	42	305	274	0.172
2023	447	322	0.14	0.15	273418	229903	30	27	376	338	46	42	309	279	0.211
2024	447	320	0.14	0.15	285711	240313	30	27	386	348	47	42	314	283	0.249
2025	447	325	0.14	0.15	295533	249099	31	28	395	357	47	42	317	286	0.281
2026	447	323	0.14	0.15	303416	256851	31	28	401	363	47	43	320	288	0.310
2027	447	328	0.14	0.15	309881	262963	31	28	407	368	47	43	322	291	0.336
2028	447	322	0.14	0.15	314971	267225	31	29	411	373	47	43	323	293	0.363
2029	448	326	0.14	0.15	319024	271916	31	29	415	378	47	43	325	294	0.382
2030	448	323	0.14	0.15	322345	275417	31	29	417	381	47	43	326	295	0.398
2031	448	324	0.14	0.15	324987	278129	32	29	420	382	47	43	326	297	0.413
2032	448	322	0.14	0.15	327059	280450	32	29	421	384	47	43	327	297	0.427
2033	448	321	0.14	0.15	328703	281529	32	29	423	387	47	43	328	297	0.436
2034	448	322	0.14	0.15	329992	282607	32	29	424	387	47	43	328	298	0.445
2035	448	322	0.14	0.15	331023	282838	32	29	425	388	47	43	328	297	0.450
2036	448	324	0.14	0.15	331846	283777	32	29	426	389	47	43	329	298	0.456
2037	448	323	0.14	0.15	332503	284779	32	29	426	390	47	43	329	299	0.458
2038	448	322	0.14	0.15	333026	286185	32	29	427	391	47	43	329	299	0.463
2039	448	320	0.14	0.15	333443	286855	32	29	427	392	47	43	329	299	0.465
2040	448	324	0.14	0.15	333775	286659	32	29	427	392	47	43	329	299	0.466
2041	448	323	0.14	0.15	334039	286968	32	29	427	393	47	43	329	299	0.467
2042	448	324	0.14	0.15	334250	287860	32	29	428	392	47	43	329	300	0.469
2043	448	325	0.14	0.15	334417	288294	32	29	428	392	47	43	330	300	0.471
2044	448	324	0.14	0.15	334551	287938	32	29	428	392	47	43	330	300	0.473

Table 30. Projection results with fishing mortality rate fixed at $F = F_{\text{rebuild}}$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{F30\%}}$*. The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	434	313	0.11	0.12	70861	64644	0	0	0	0	70	69	284	284	0.001
2016	438	314	0.21	0.23	99227	88895	28	28	244	243	67	62	332	318	0.006
2017	441	318	0.14	0.14	131198	115490	24	22	230	212	45	40	257	227	0.018
2018	444	318	0.14	0.14	163892	142614	26	23	276	250	46	40	279	245	0.043
2019	445	319	0.14	0.14	193424	166688	27	24	305	273	46	40	290	255	0.077
2020	446	318	0.14	0.14	218805	188063	28	25	328	292	46	40	297	261	0.116
2021	446	326	0.14	0.14	240439	205874	29	26	347	309	46	41	301	266	0.161
2022	447	321	0.14	0.14	258784	220741	29	26	362	323	46	41	305	270	0.206
2023	447	322	0.14	0.14	273751	233843	30	27	375	334	46	41	309	275	0.251
2024	447	320	0.14	0.14	286089	244677	30	27	386	346	47	41	313	280	0.289
2025	447	325	0.14	0.14	295950	254012	31	28	394	355	47	42	317	283	0.325
2026	447	323	0.14	0.14	303867	261422	31	28	401	361	47	42	319	286	0.353
2027	447	328	0.14	0.14	310362	267854	31	28	407	367	47	42	321	288	0.379
2028	447	322	0.14	0.14	315476	272516	31	28	411	371	47	42	323	289	0.402
2029	448	326	0.14	0.14	319550	276187	31	28	414	375	47	42	324	291	0.422
2030	448	323	0.14	0.14	322888	280048	31	28	417	378	47	42	325	292	0.437
2031	448	324	0.14	0.14	325546	282707	32	29	419	380	47	42	326	293	0.450
2032	448	322	0.14	0.14	327629	284895	32	29	421	382	47	42	327	293	0.462
2033	448	321	0.14	0.14	329283	286318	32	29	423	385	47	42	327	294	0.471
2034	448	322	0.14	0.14	330580	287505	32	29	424	385	47	42	328	294	0.481
2035	448	322	0.14	0.14	331618	288052	32	29	425	386	47	42	328	294	0.486
2036	448	324	0.14	0.14	332447	289099	32	29	425	387	47	42	328	295	0.487
2037	448	323	0.14	0.14	333107	290492	32	29	426	387	47	42	329	296	0.491
2038	448	322	0.14	0.14	333634	291081	32	29	426	388	47	42	329	295	0.495
2039	448	320	0.14	0.14	334054	291632	32	29	427	389	47	42	329	295	0.496
2040	448	324	0.14	0.14	334388	291260	32	29	427	389	47	42	329	296	0.498
2041	448	323	0.14	0.14	334655	291695	32	29	427	390	47	42	329	295	0.498
2042	448	324	0.14	0.14	334867	292066	32	29	427	389	47	42	329	296	0.500
2043	448	325	0.14	0.14	335036	292552	32	29	428	390	47	42	329	297	0.500
2044	448	324	0.14	0.14	335171	292995	32	29	428	390	47	42	329	296	0.501

Table 31. Projection results with fishing mortality rate applied only to discards. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* SSB $\geq$ $\mathrm{SSB_{F30\%}}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	434	313	0.11	0.12	70861	64644	0	0	0	0	70	69	284	284	0.001
2016	438	314	0.10	0.11	105033	94082	0	0	0	0	70	69	355	353	0.006
2017	442	318	0.11	0.12	144176	126495	0	0	0	0	75	70	435	418	0.027
2018	444	318	0.11	0.12	183389	157600	0	0	0	0	75	69	474	445	0.084
2019	446	320	0.11	0.12	220330	186110	0	0	0	0	74	69	493	457	0.161
2020	446	318	0.11	0.12	253560	211337	0	0	0	0	74	70	504	463	0.245
2021	447	326	0.11	0.12	283302	233991	0	0	0	0	74	70	512	470	0.324
2022	447	321	0.11	0.12	309795	253779	0	0	0	0	75	71	519	479	0.392
2023	447	322	0.11	0.12	332590	271031	0	0	0	0	75	71	528	489	0.449
2024	448	320	0.11	0.12	352312	284690	0	0	0	0	75	72	538	498	0.491
2025	448	326	0.11	0.12	368864	296476	0	0	0	0	76	72	546	505	0.527
2026	448	323	0.11	0.12	382827	307651	0	0	0	0	76	72	553	512	0.557
2027	448	328	0.11	0.12	394845	316094	0	0	0	0	76	73	559	518	0.583
2028	448	322	0.11	0.12	404805	323518	0	0	0	0	77	73	564	523	0.604
2029	448	327	0.11	0.12	413161	329865	0	0	0	0	77	73	568	527	0.623
2030	448	324	0.11	0.12	420369	334422	0	0	0	0	77	73	571	530	0.637
2031	448	324	0.11	0.12	426415	338421	0	0	0	0	77	73	574	533	0.651
2032	448	322	0.11	0.12	431412	341926	0	0	0	0	77	73	577	535	0.660
2033	448	321	0.11	0.12	435590	345467	0	0	0	0	77	73	579	536	0.669
2034	448	322	0.11	0.12	439044	348333	0	0	0	0	77	73	581	537	0.675
2035	448	322	0.11	0.12	441960	350054	0	0	0	0	77	73	582	538	0.682
2036	448	324	0.11	0.12	444419	352140	0	0	0	0	77	73	583	539	0.686
2037	448	323	0.11	0.12	446493	354157	0	0	0	0	77	73	584	539	0.689
2038	448	322	0.11	0.12	448241	354692	0	0	0	0	77	74	585	541	0.692
2039	448	320	0.11	0.12	449715	356590	0	0	0	0	77	73	586	541	0.694
2040	448	324	0.11	0.12	450956	356646	0	0	0	0	77	74	587	542	0.698
2041	448	323	0.11	0.12	452001	356525	0	0	0	0	77	74	587	542	0.700
2042	448	325	0.11	0.12	452882	357632	0	0	0	0	77	74	588	544	0.702
2043	448	325	0.11	0.12	453624	358288	0	0	0	0	78	74	588	544	0.704
2044	448	324	0.11	0.12	454249	358585	0	0	0	0	78	74	588	545	0.705

Table 32. Parameter estimates from selected ASPIC surplus production model runs 318 (continuity), 319 (updated continuity), 320 (best configuration), and 323 (best configuration with B_1/K fixed) All parameter values are rounded to 3 significant digits. MSY, B_1, and K are in units of 1000 pounds. Catchability parameters correspond to the commercial (q_1), headboat (q_2), headboat-at-sea (q_3), and CVID (q_4) indices.

Run	F/F_{MSY}	B/B_{MSY}	B_1/K	MSY	F_{MSY}	q_1	q_2	q_3	q_4	B_1	K
318	2.15	0.53	0.467	805	0.313	9.35e-07	7.14e-07			2400	5140
319	0.614	1.3	1.94	802	0.314	9.42e-07	7.14e-07			9930	5110
320	0.531	1.48	0.91	805	0.322	8.69e-07	6.98e-07	2.98e-07	4.04e-07	4560	5010
323	0.53	1.47	0.467	807	0.321	8.74e-07	7e-07	2.99e-07	4.02e-07	2350	5030

8 Figures

Figure 1. Indices of abundance used in fitting the assessment model. HB indicates the headboat logbook index; Handline indicated the the commercial handline logbook index; HB Disc indicated the headboat discard observer index, CVT indicates the SERFS chevron trap index; VID indicates the SERFS video index, and CVID indicates the combined chevron trap and video index. The CVT and VID indices were only used during sensitivity runs.

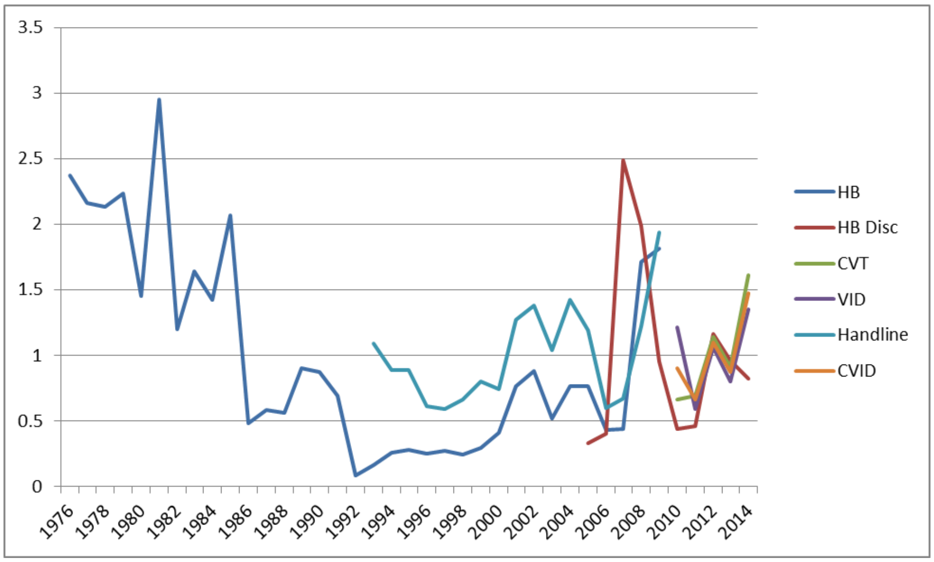


Figure 2. Mean total length at age (mm) and estimated upper and lower 95% confidence intervals of the population.

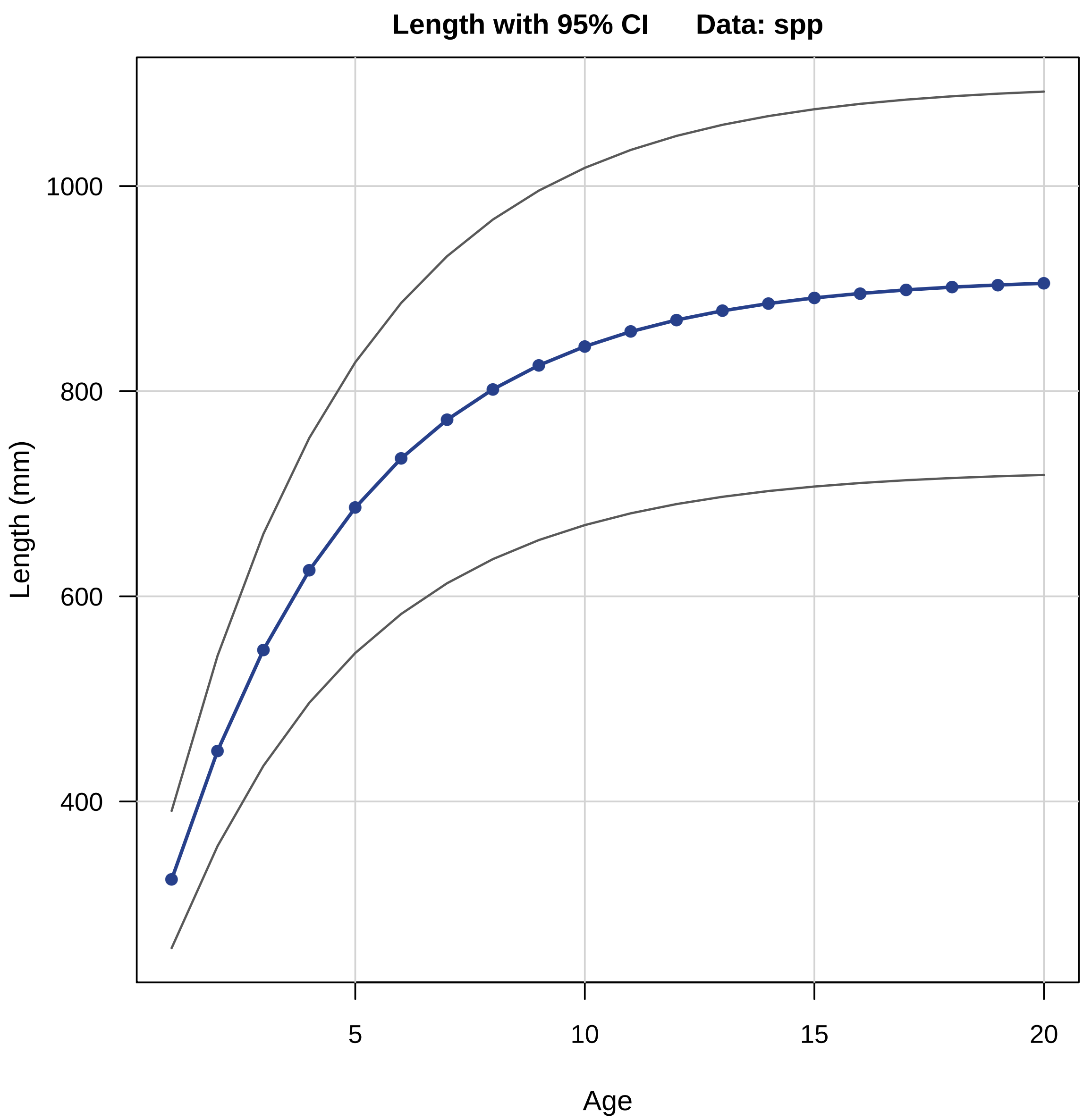


Figure 3. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, CVT to MARMAP chevron trap, cH to commercial handline, HB to headboat and GR to general recreational.

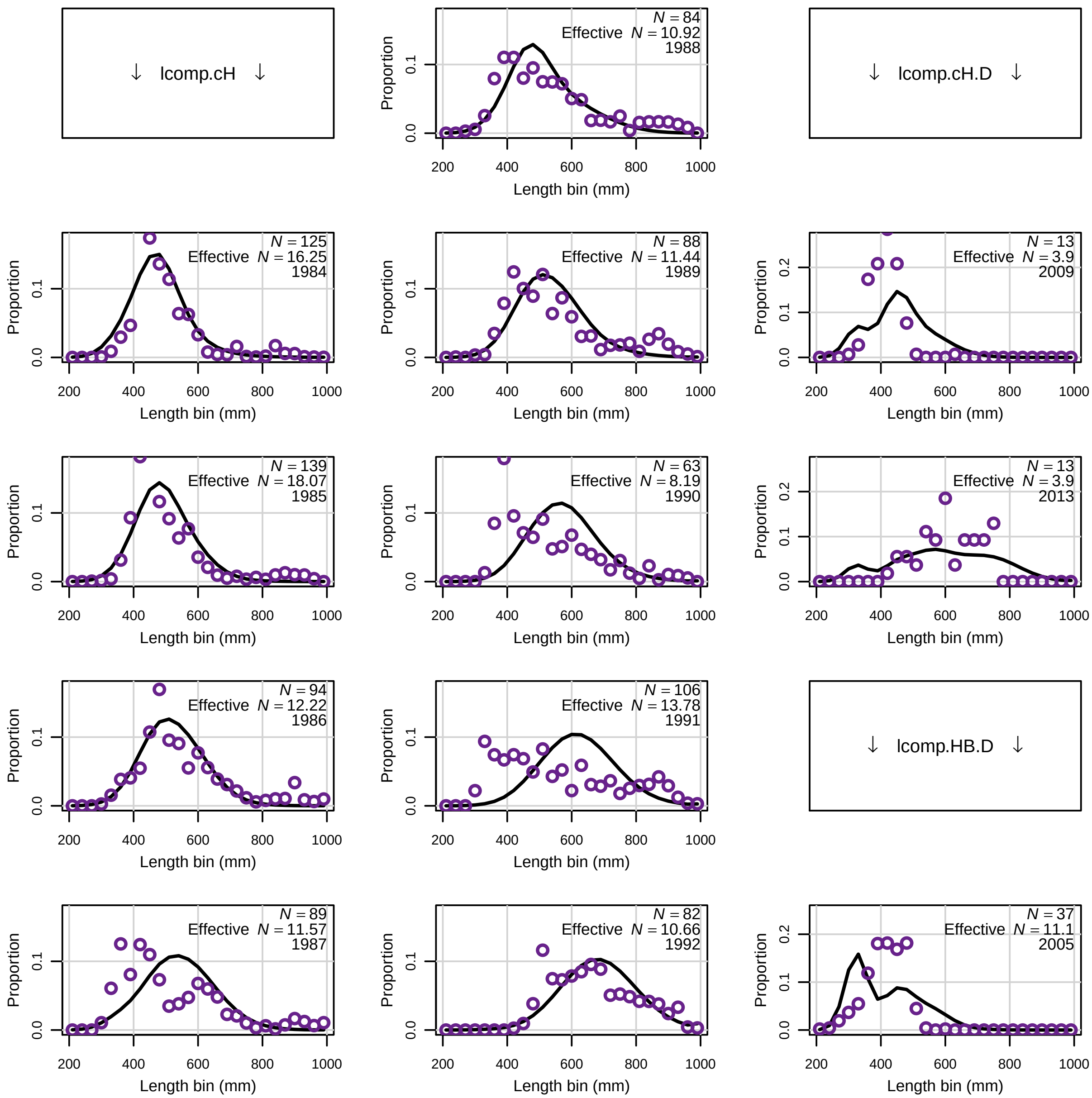


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

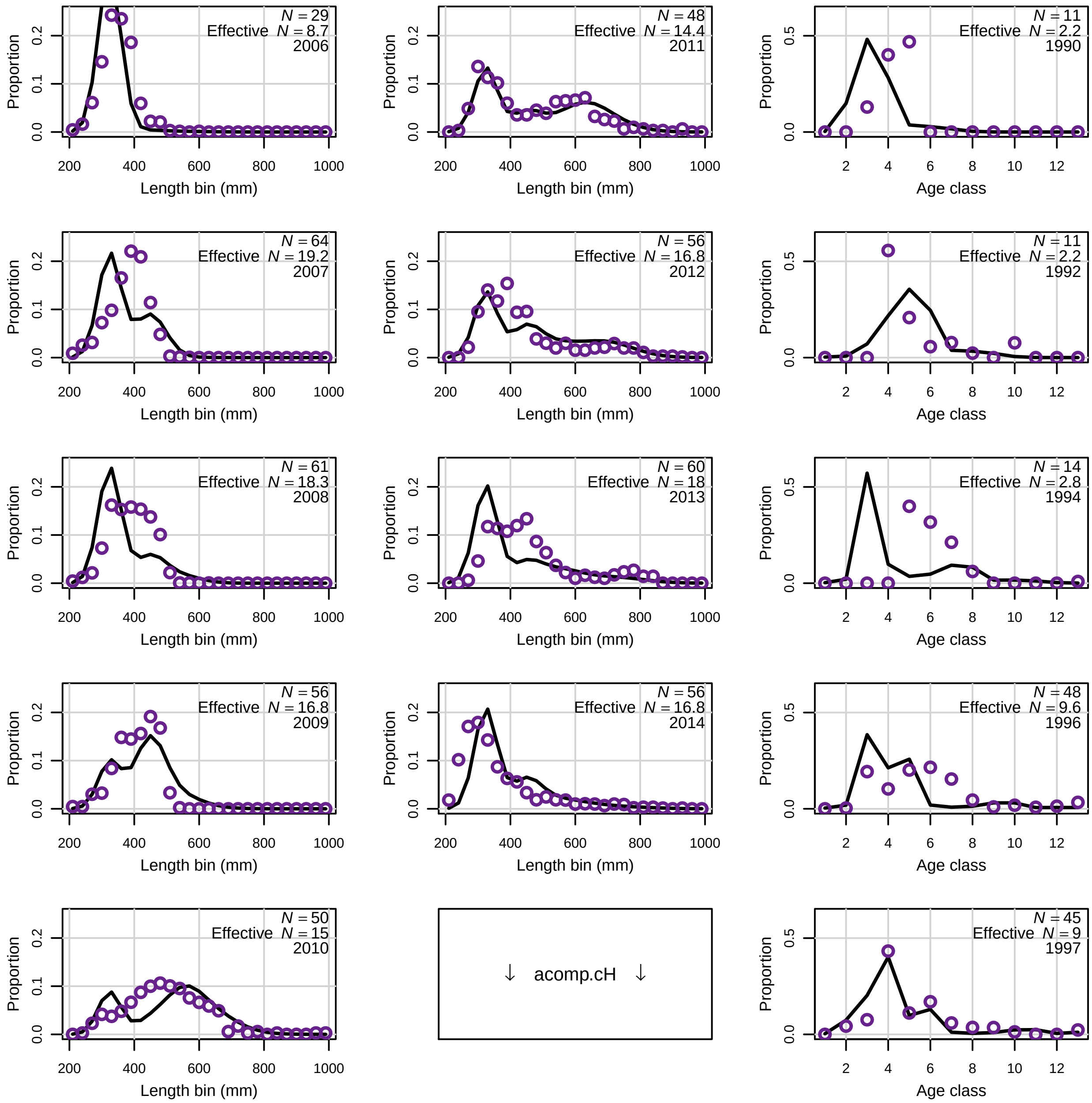


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

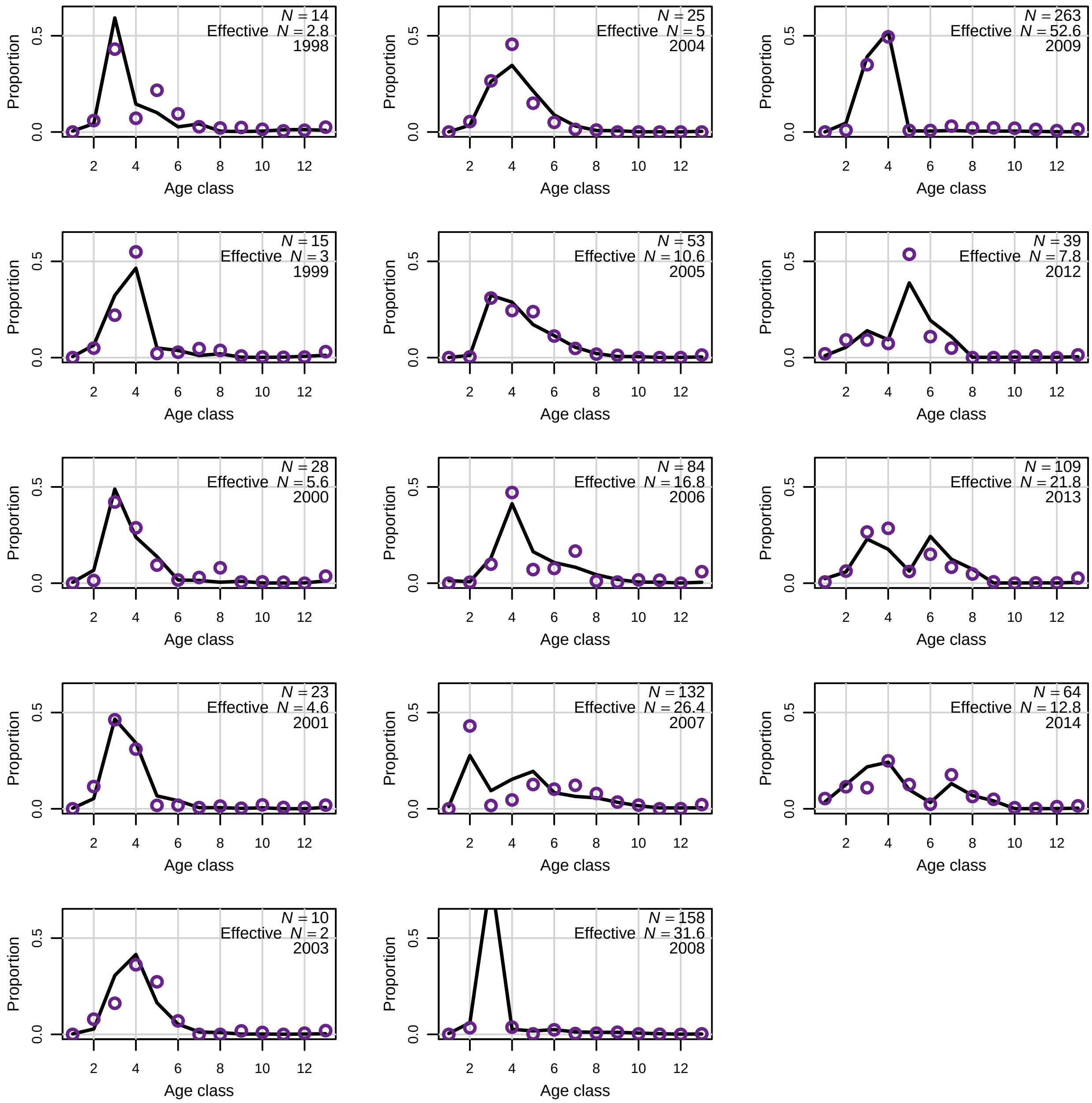


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

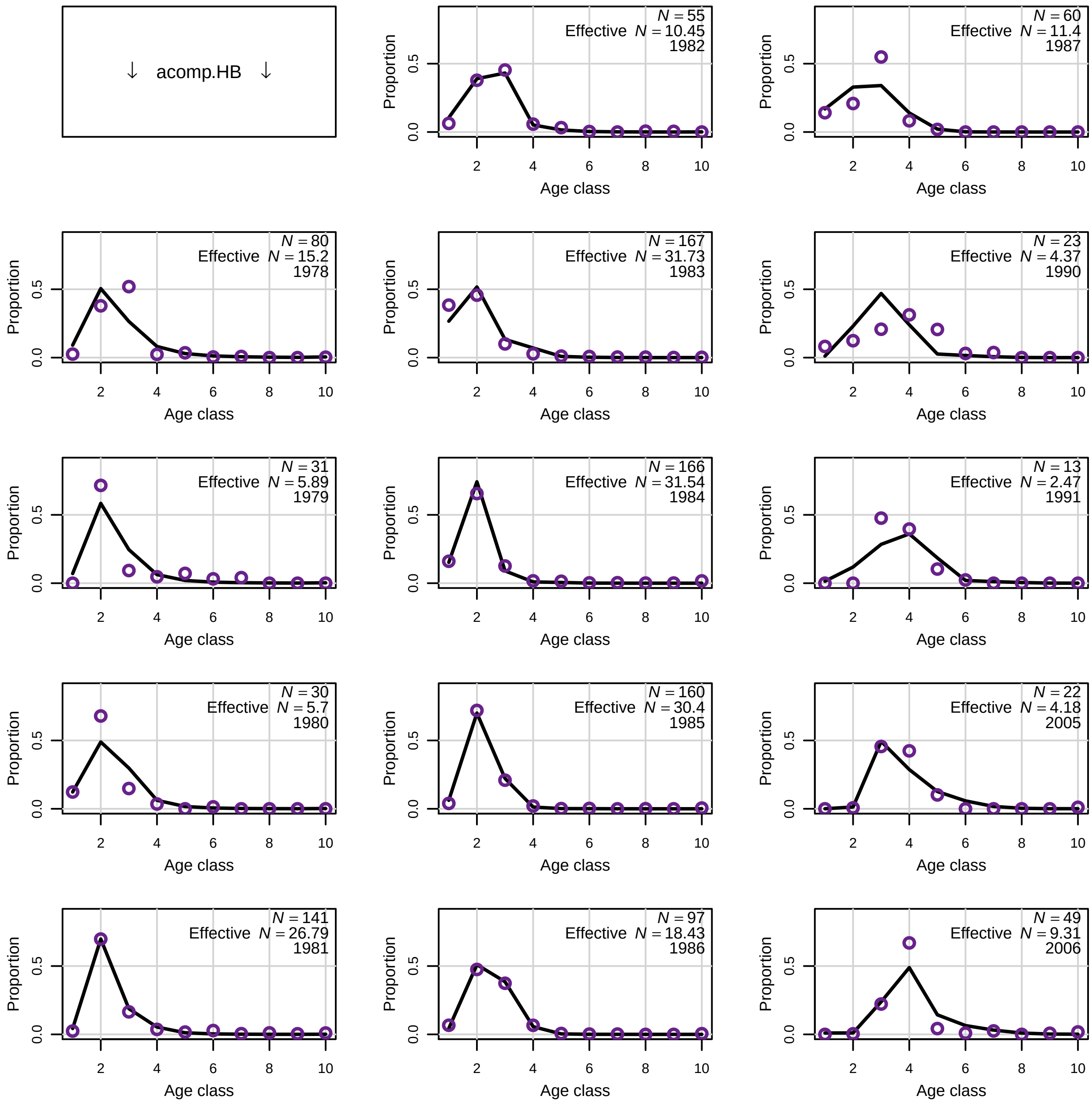


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

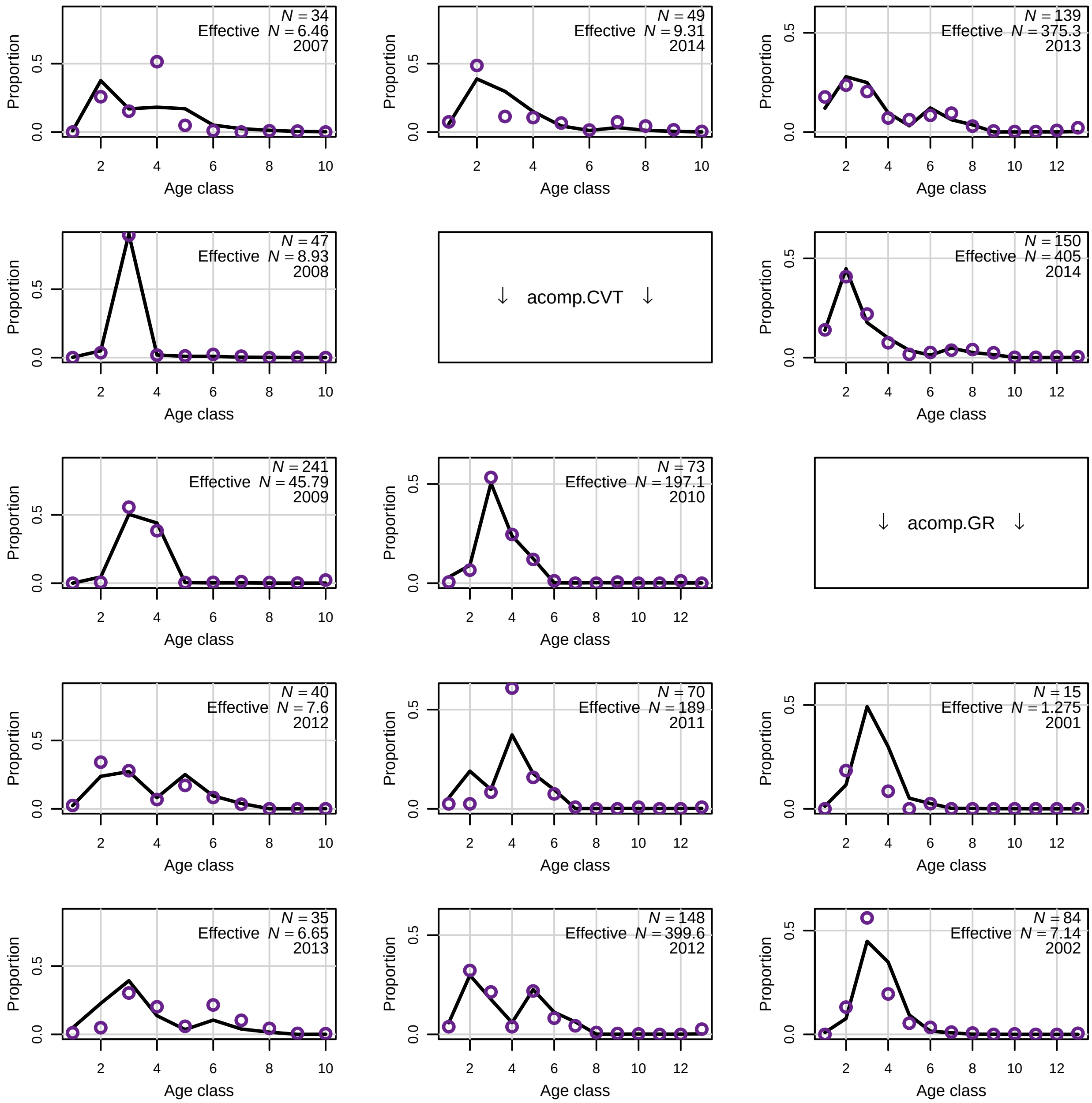


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

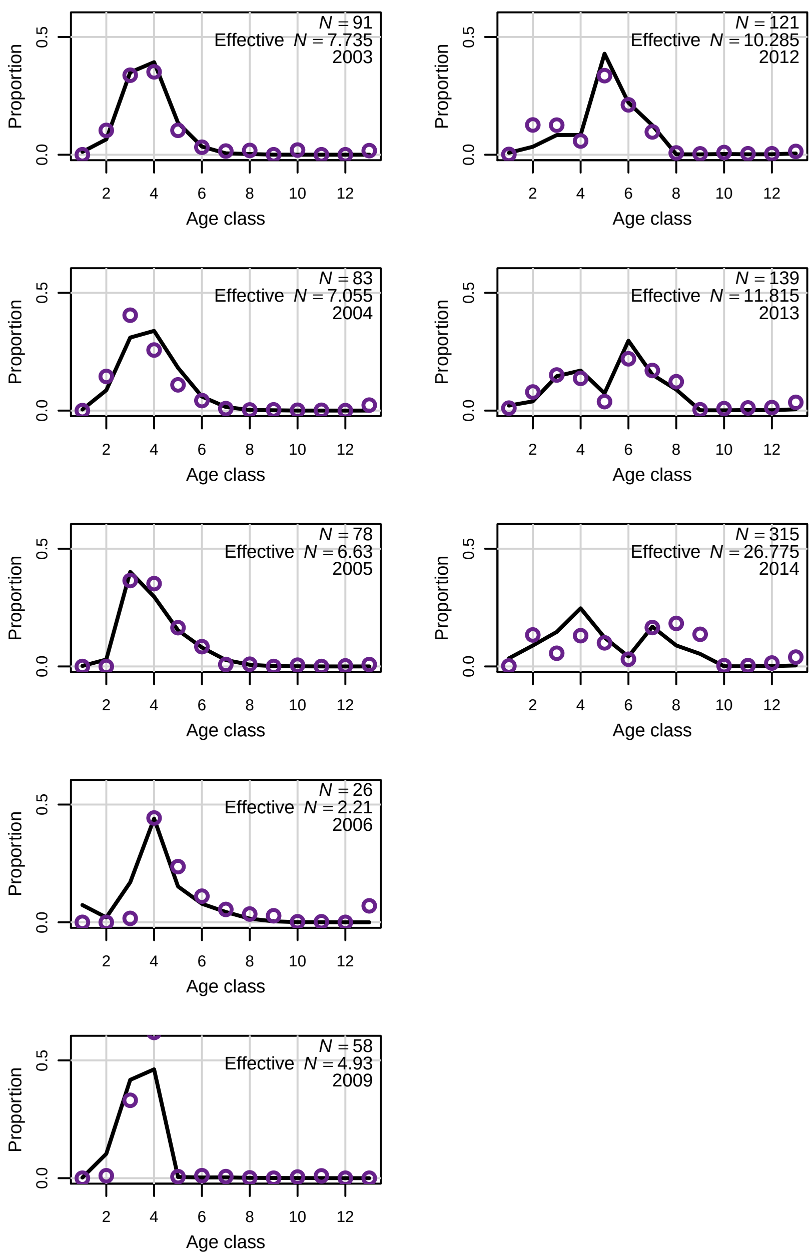


Figure 4. Observed (open circles) and estimated (solid line, circles) commercial handline landings in 1000 lb whole weight.

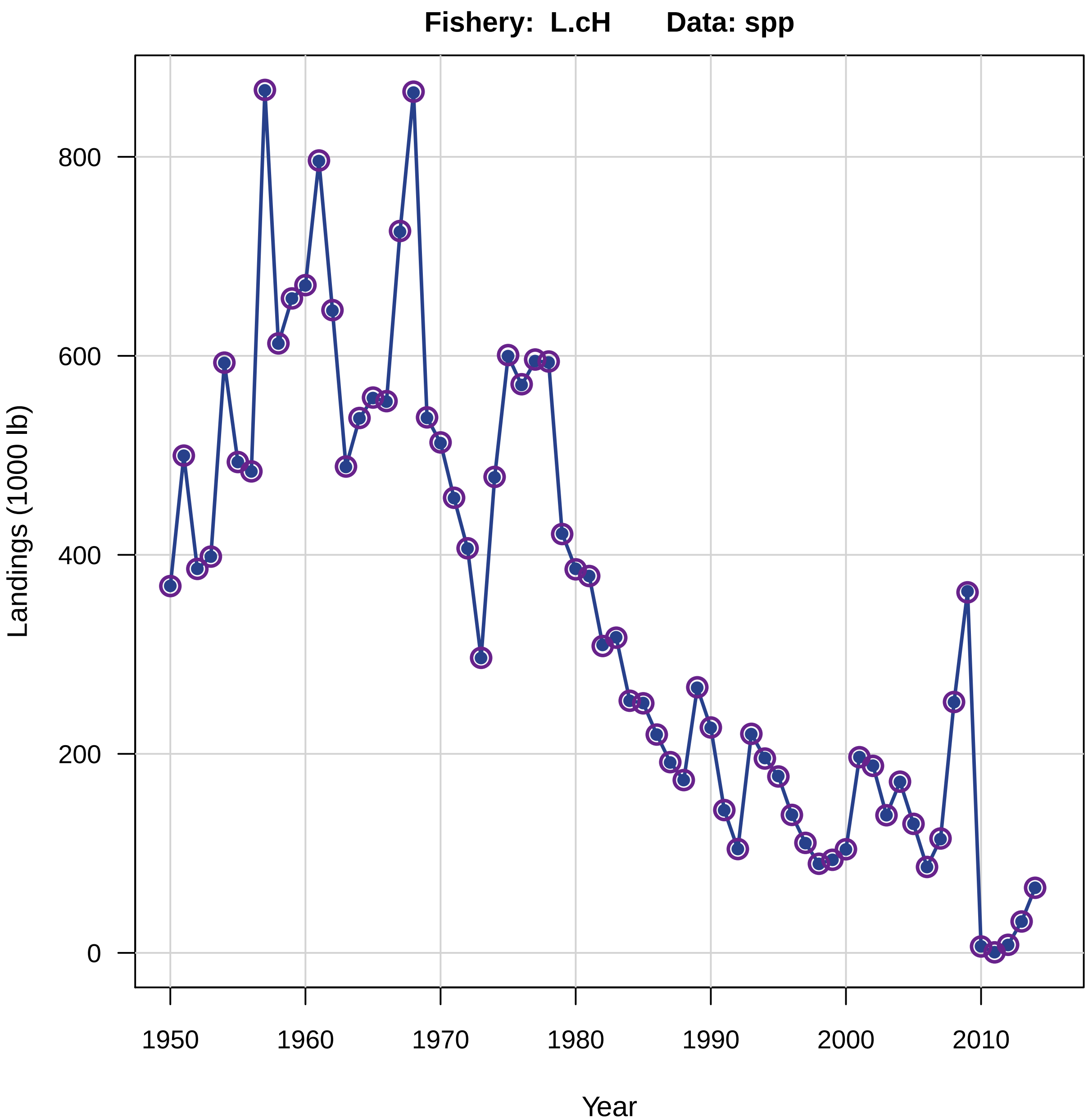


Figure 5. Observed (open circles) and estimated (solid line, circles) headboat landings in 1000s of fish.

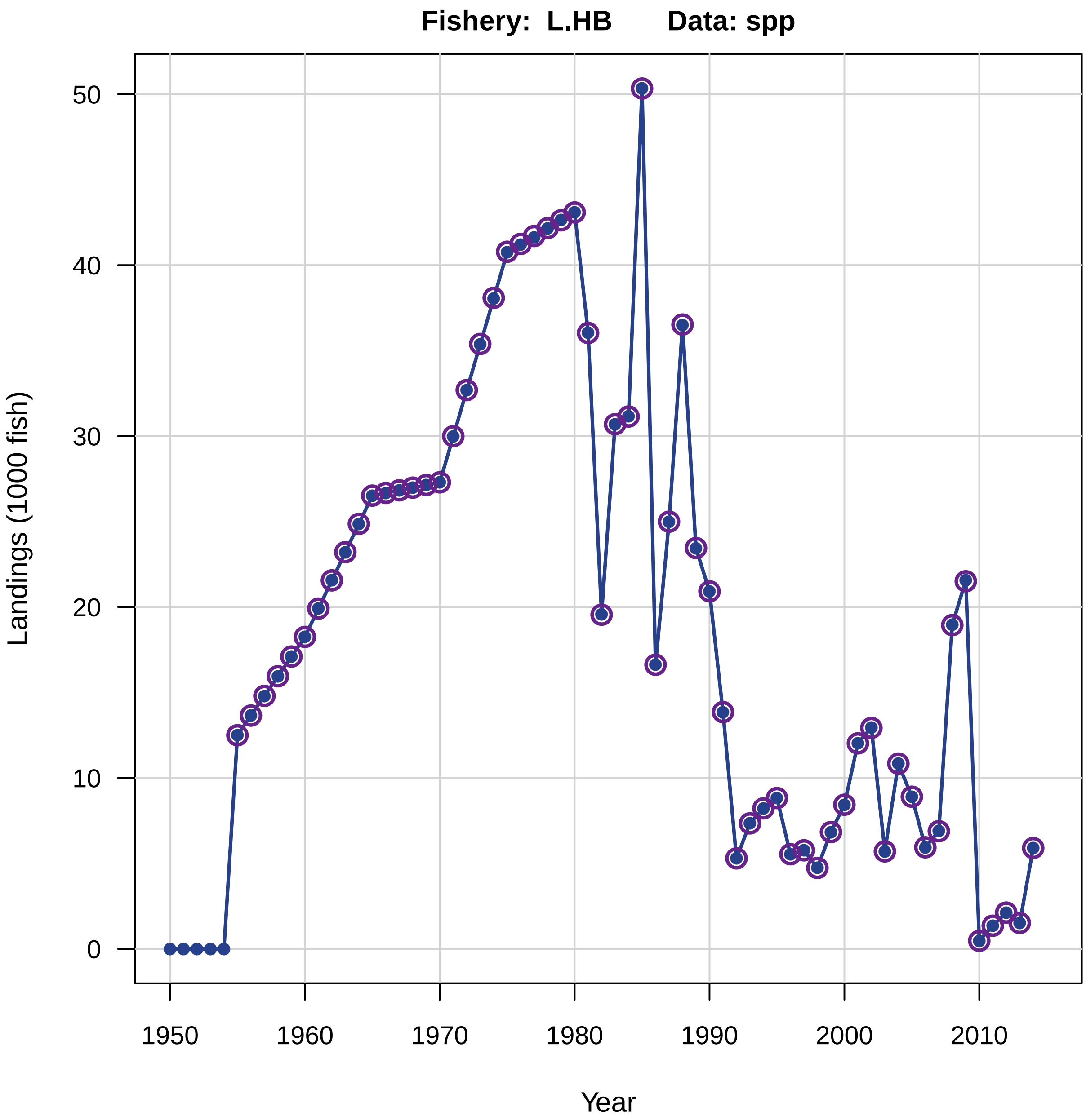


Figure 6. Observed (open circles) and estimated (solid line, circles) general recreational landings in 1000s of fish.

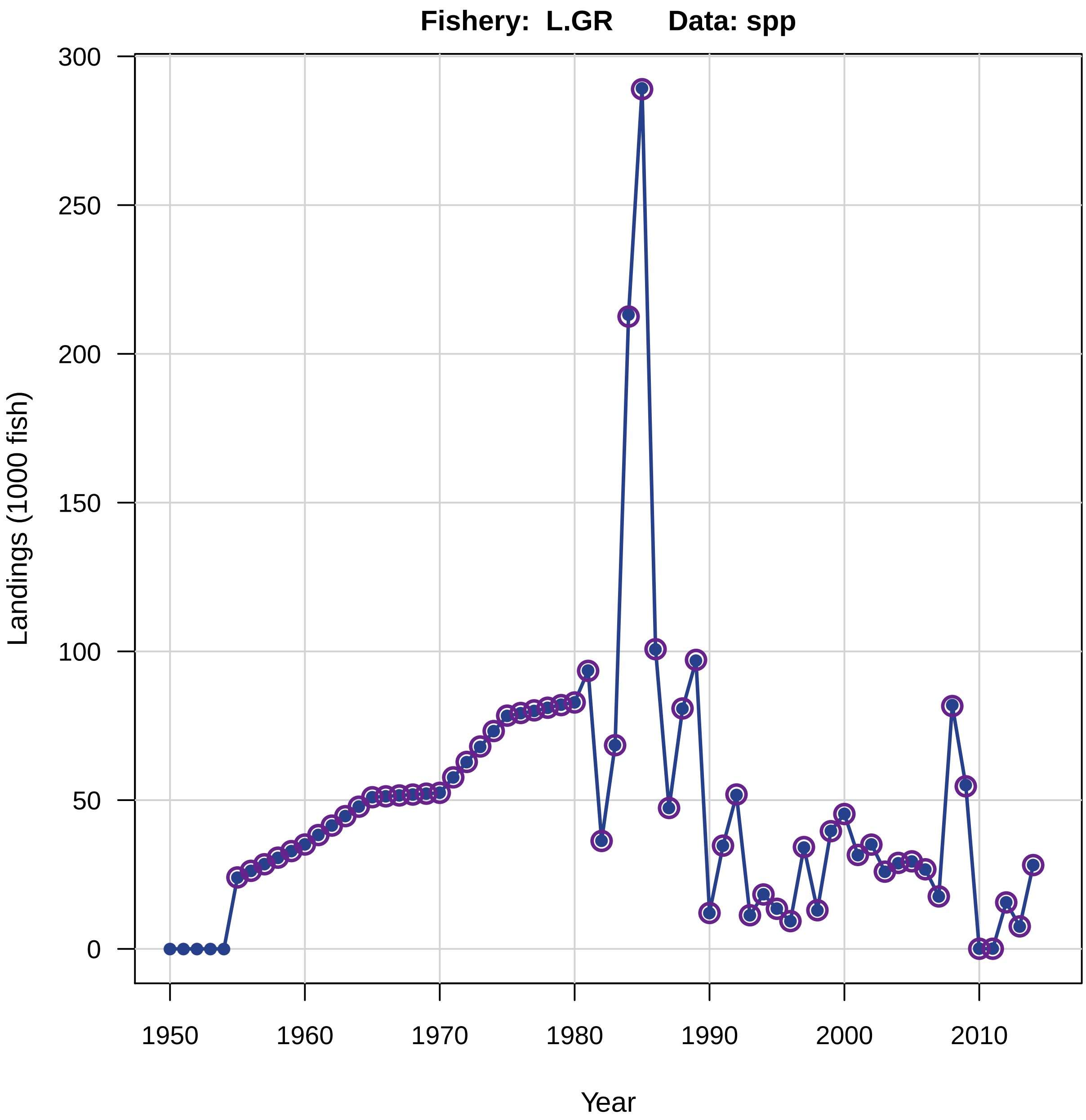


Figure 7. Observed (open circles) and estimated (solid line, circles) commercial handline discard mortalities.

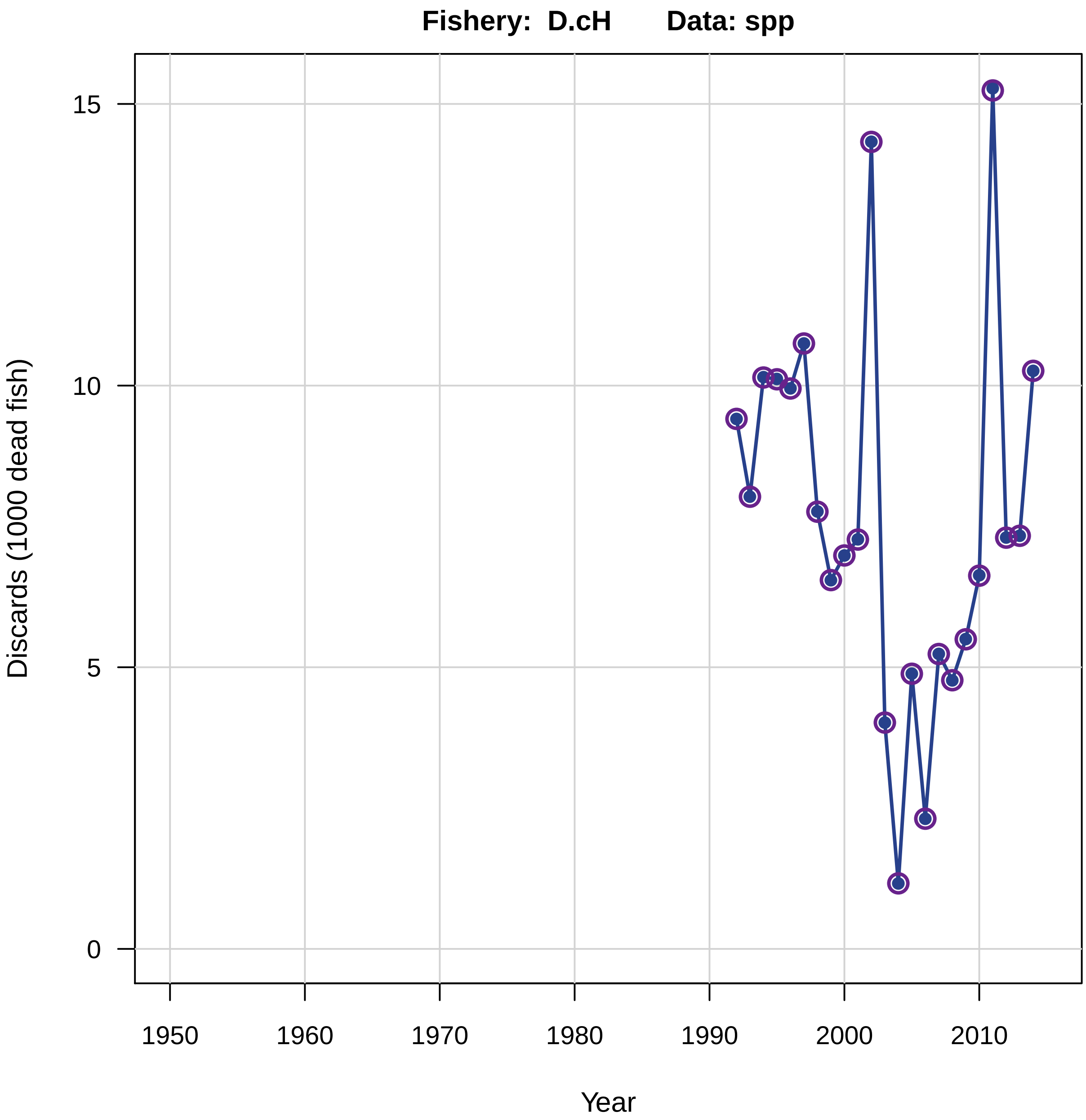


Figure 8. Observed (open circles) and estimated (solid line, circles) headboat discard mortalities.

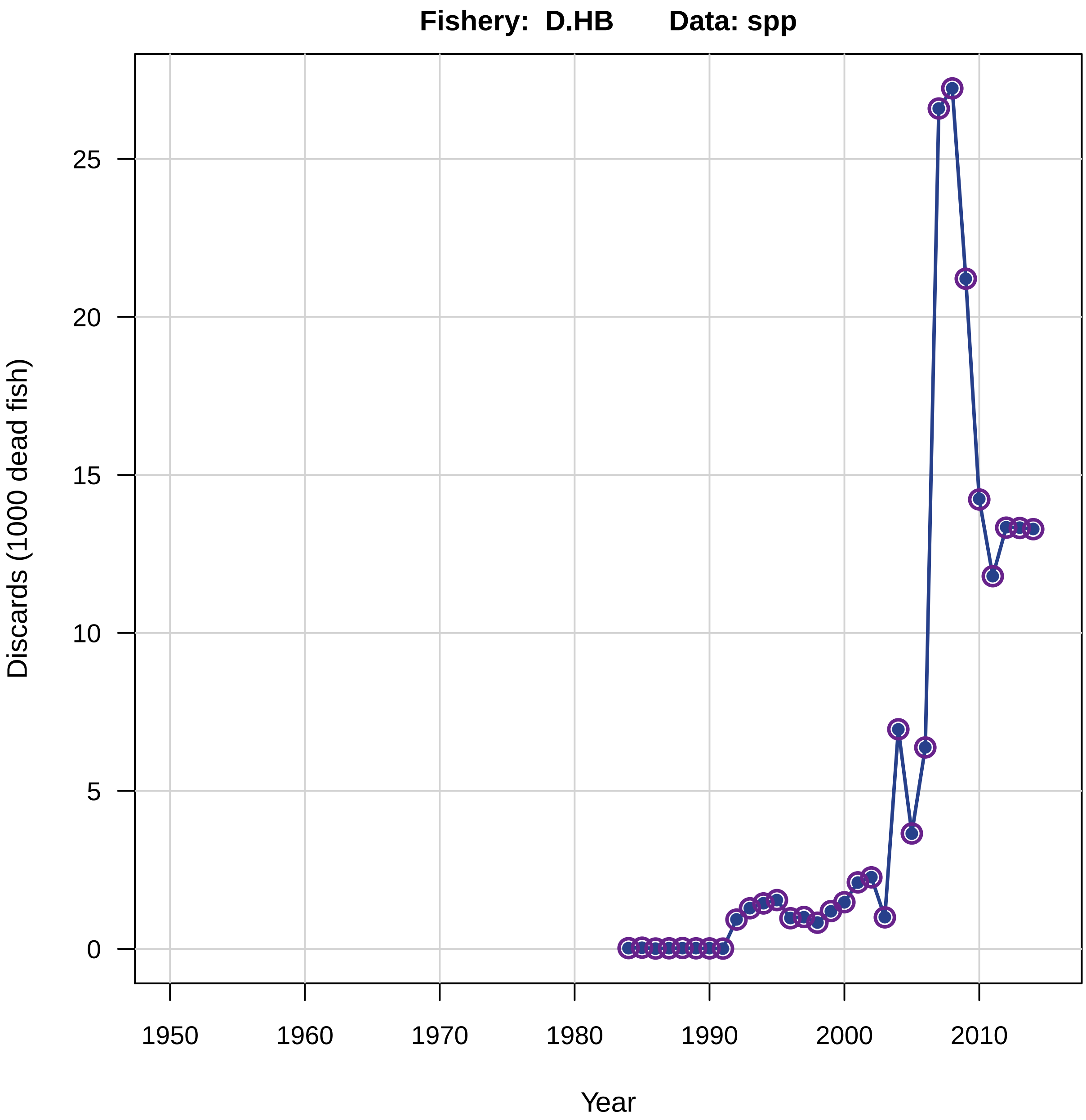


Figure 9. Observed (open circles) and estimated (solid line, circles) general recreational discard mortalities.

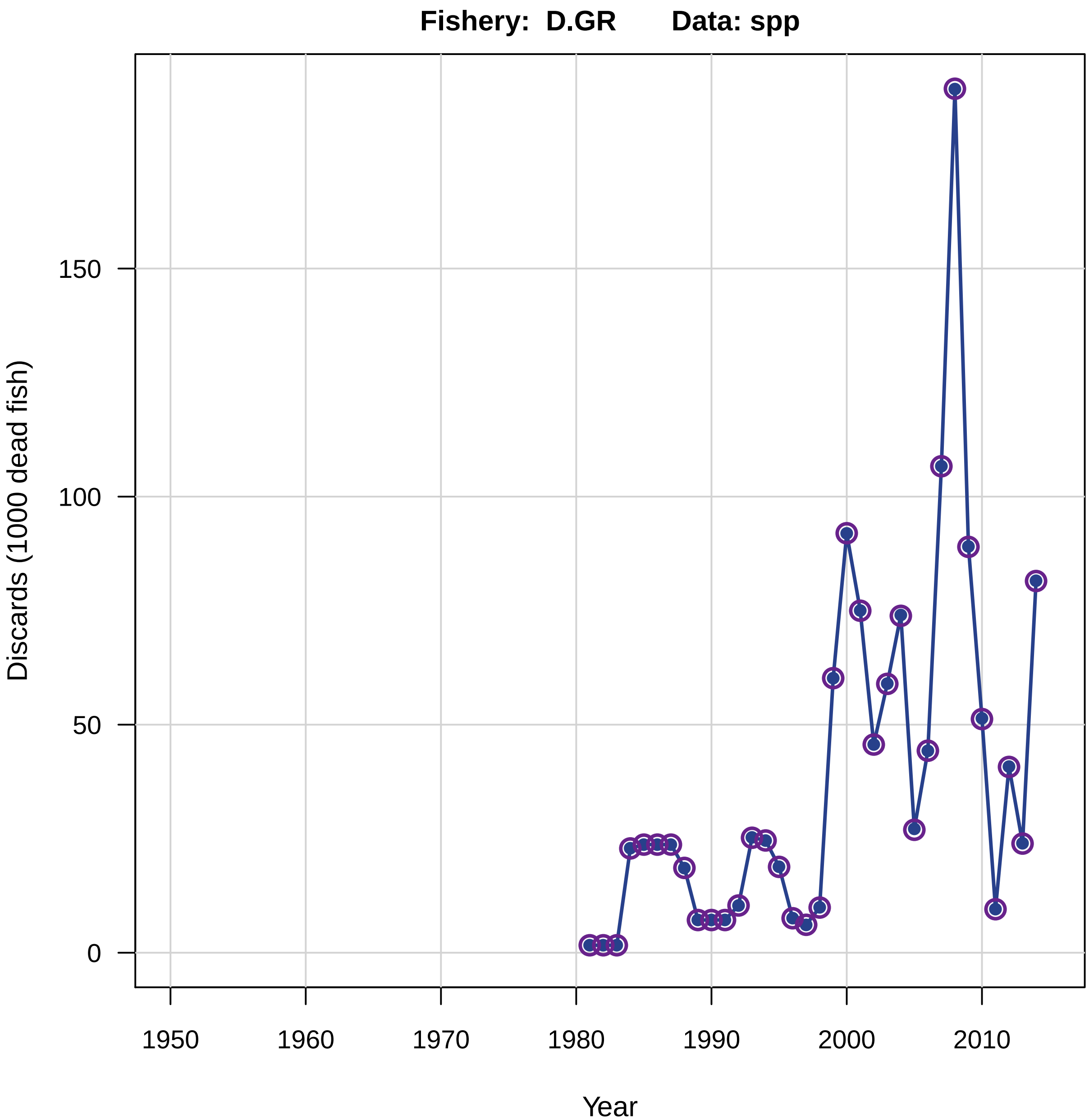


Figure 10. Observed (open circles) and estimated (solid line, circles) index of abundance from the SERFS combined trap and video index. The error bars represent the annual CV provided by the GLM standardization divided by the likelihood weight on the index.

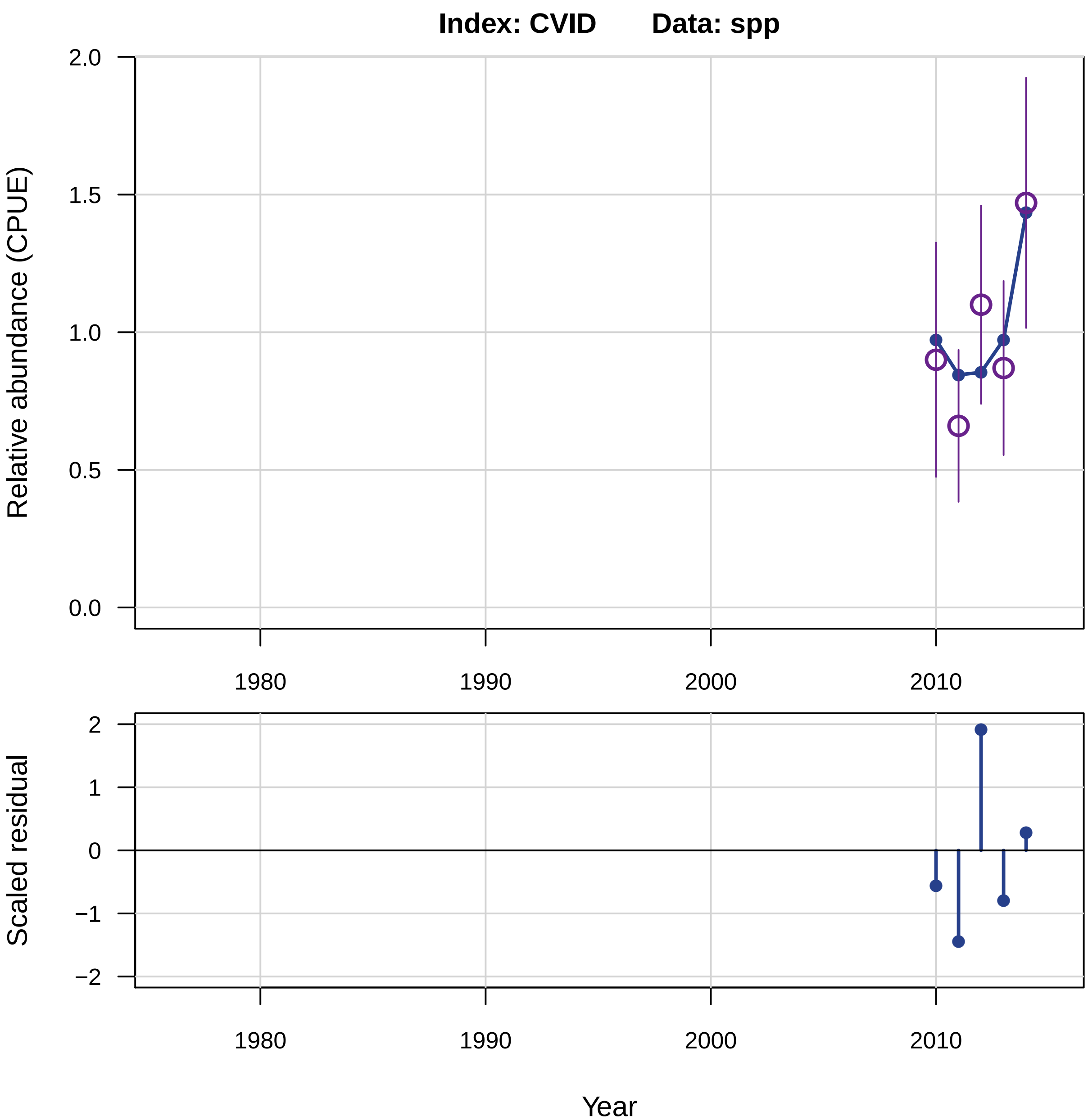


Figure 11. Observed (open circles) and estimated (solid line, circles) index of abundance from the commercial handline fleet. The error bars represent the annual CV of the index (0.2) divided by the likelihood weight on the index.

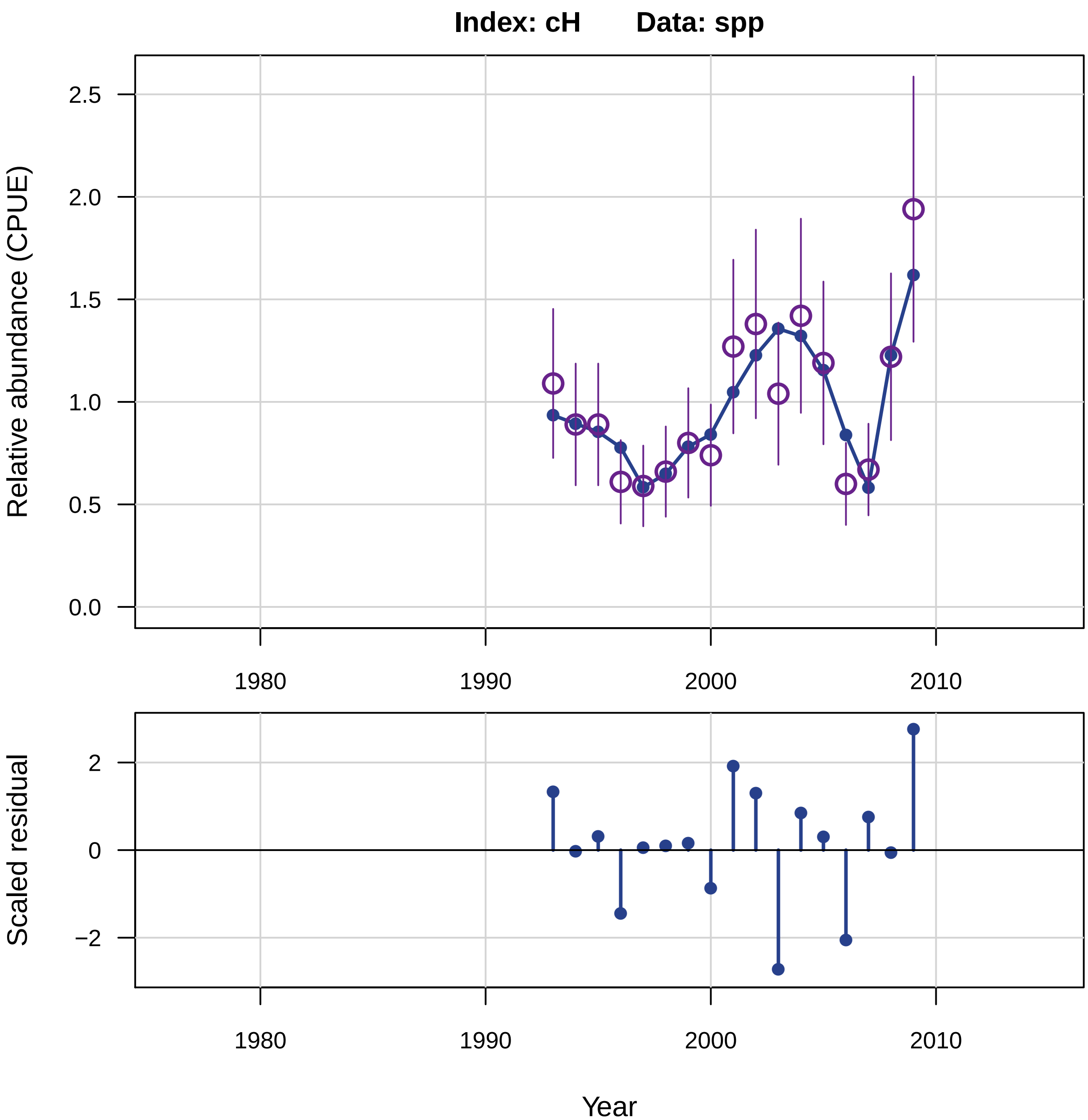


Figure 12. Observed (open circles) and estimated (solid line, circles) abundance from the headboat fleet. The error bars represent the annual CV of the index (0.2) divided by the likelihood weight on the index.

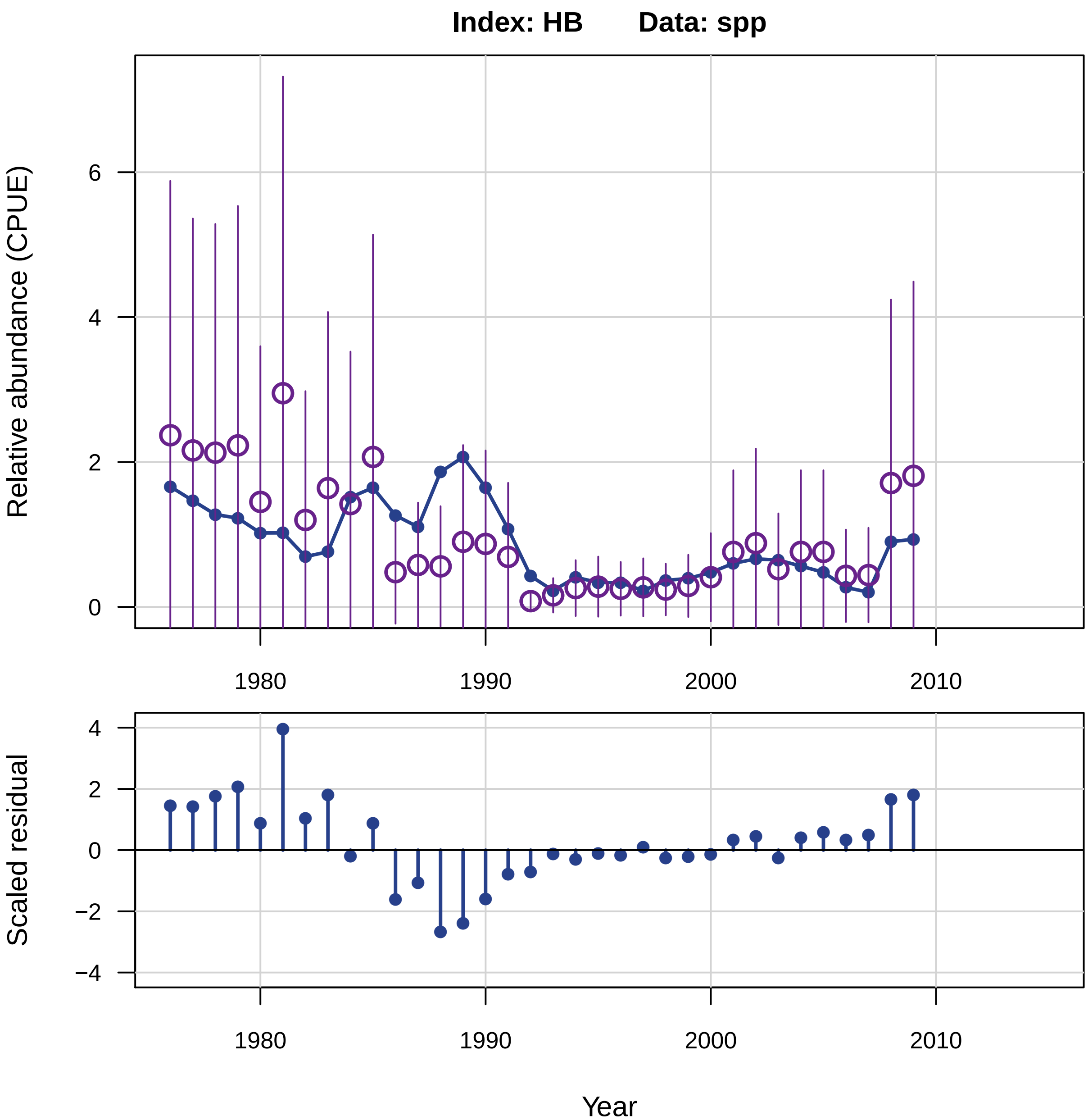


Figure 13. Observed (open circles) and estimated (solid line, circles) abundance from the headboat fleet (discards). The error bars represent the annual CV provided by the GLM standardization divided by the likelihood weight on the index.

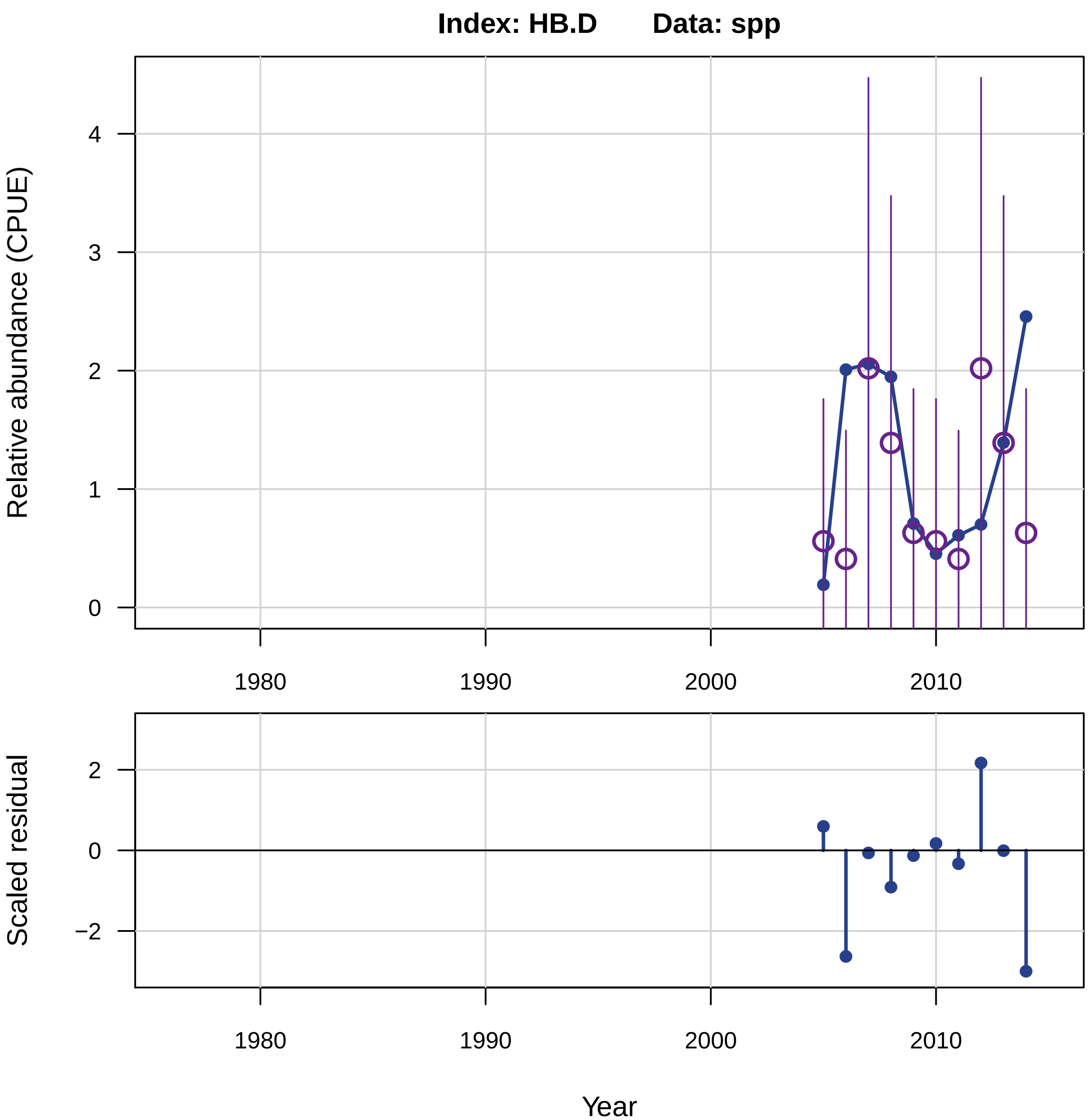


Figure 14. Estimated abundance at age at start of year.

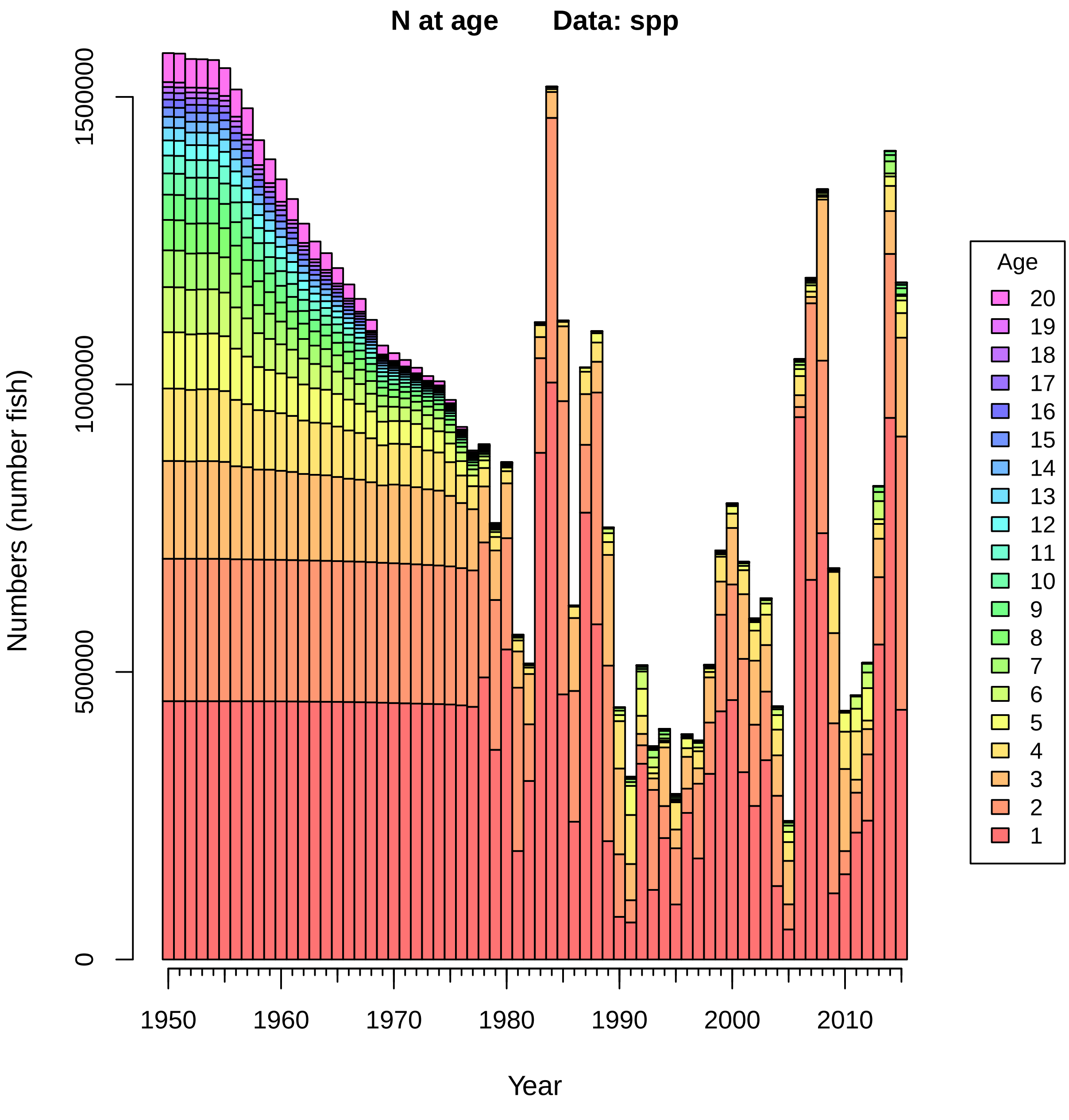


Figure 15. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates $R_{F30\%}$. Bottom panel: log recruitment residuals.

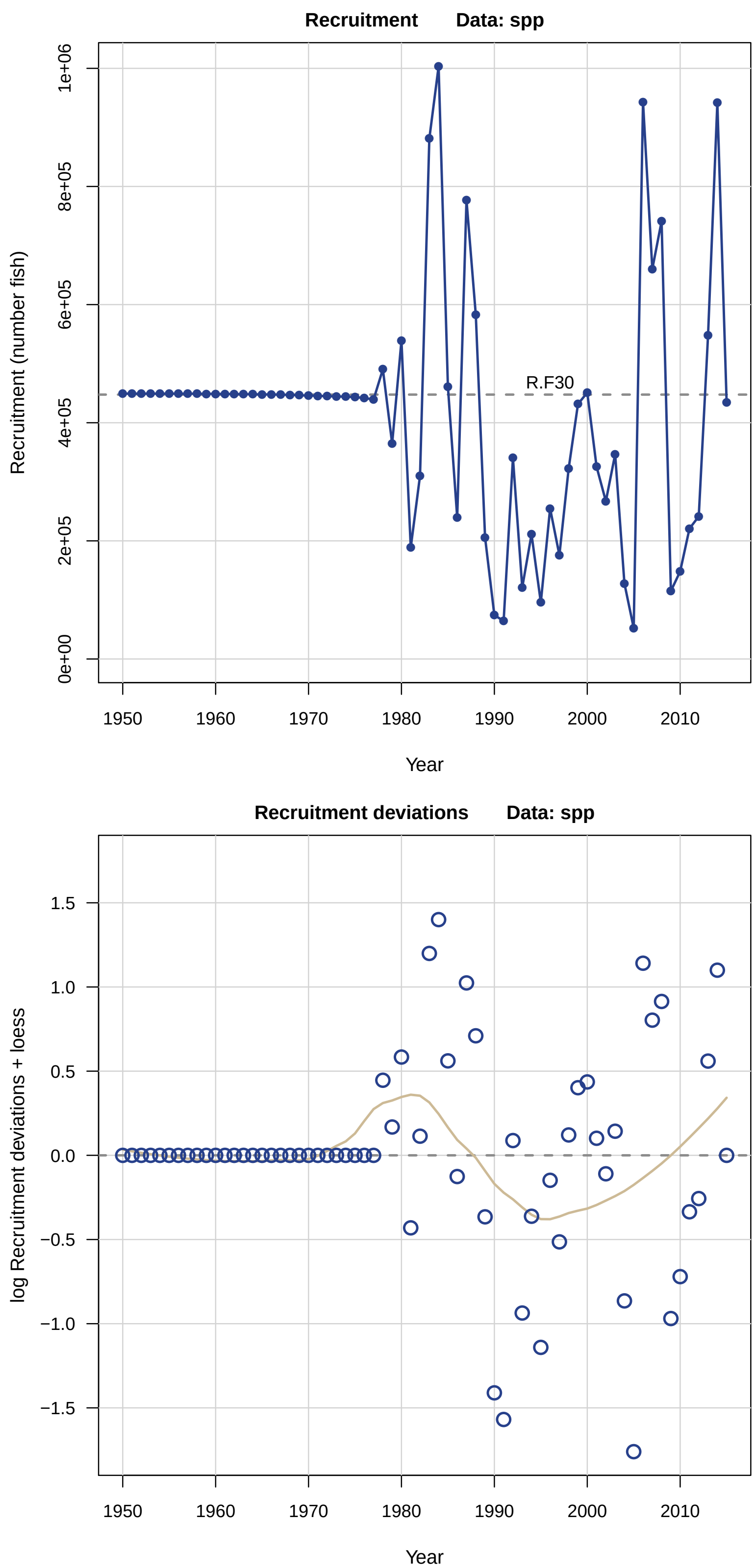


Figure 16. Estimated biomass at age at start of year.

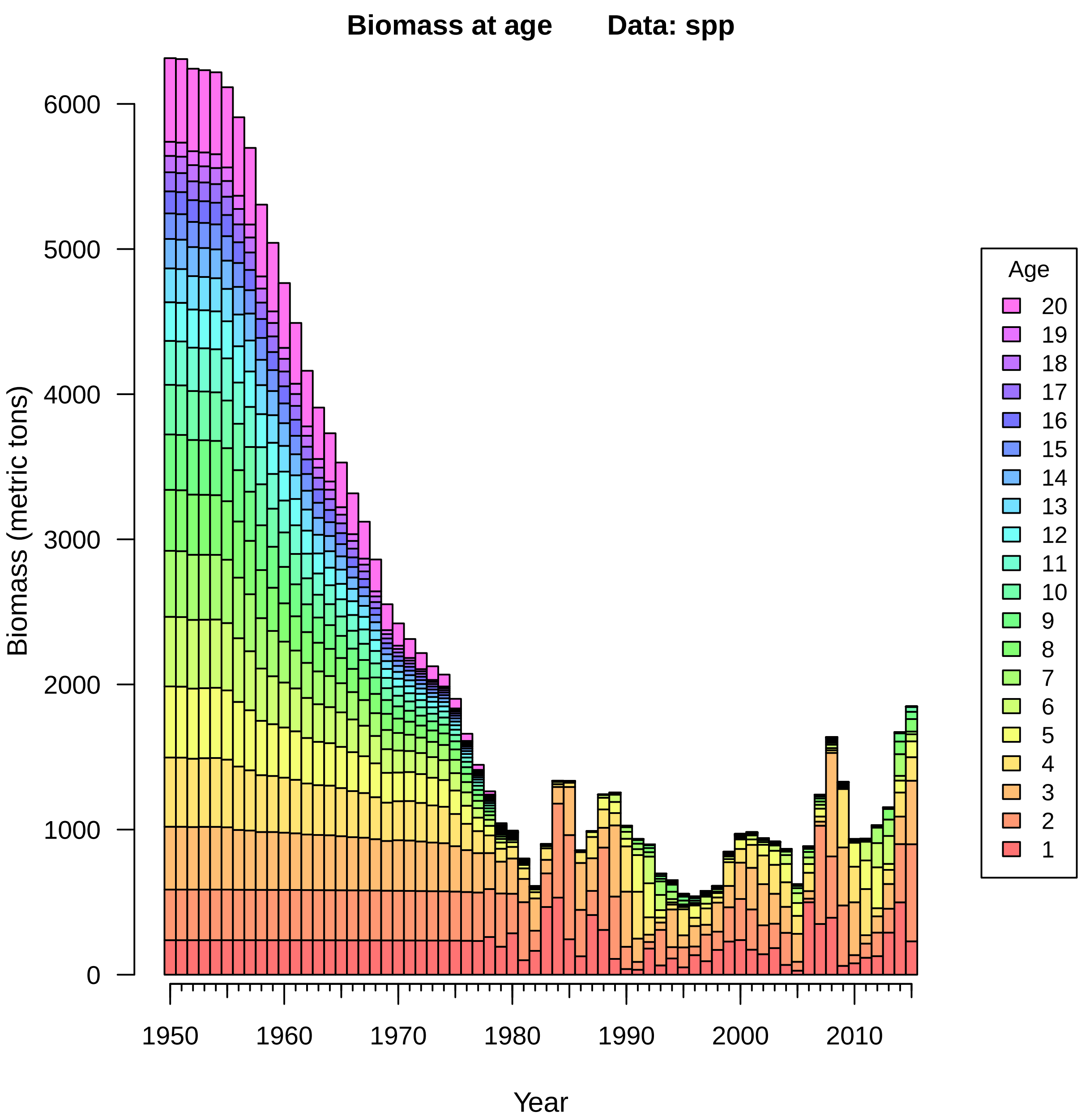
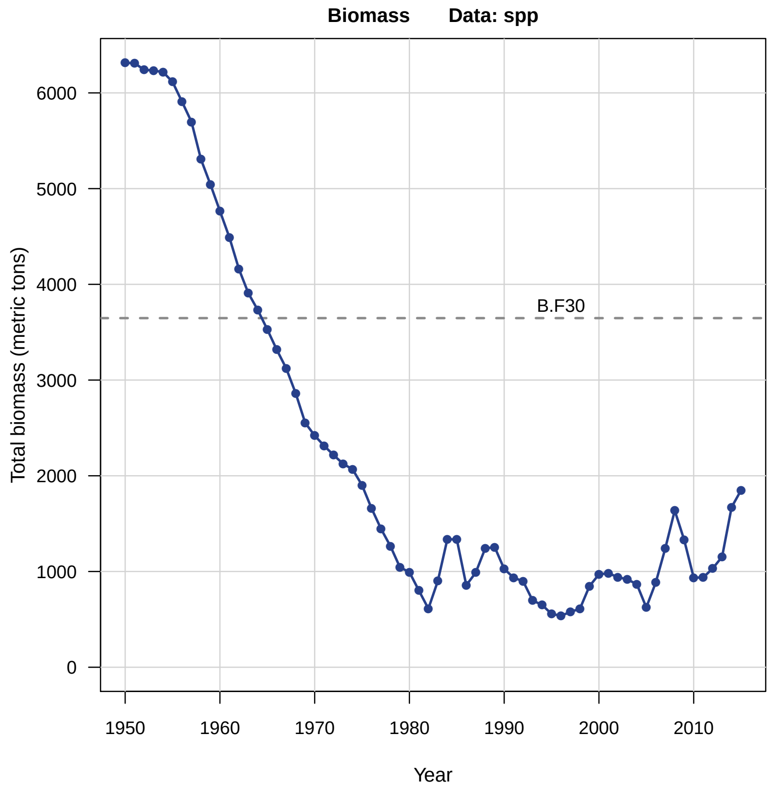


Figure 17. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates $B_{F30\%}$. Bottom panel: Estimated spawning stock (population fecundity) at time of peak spawning.



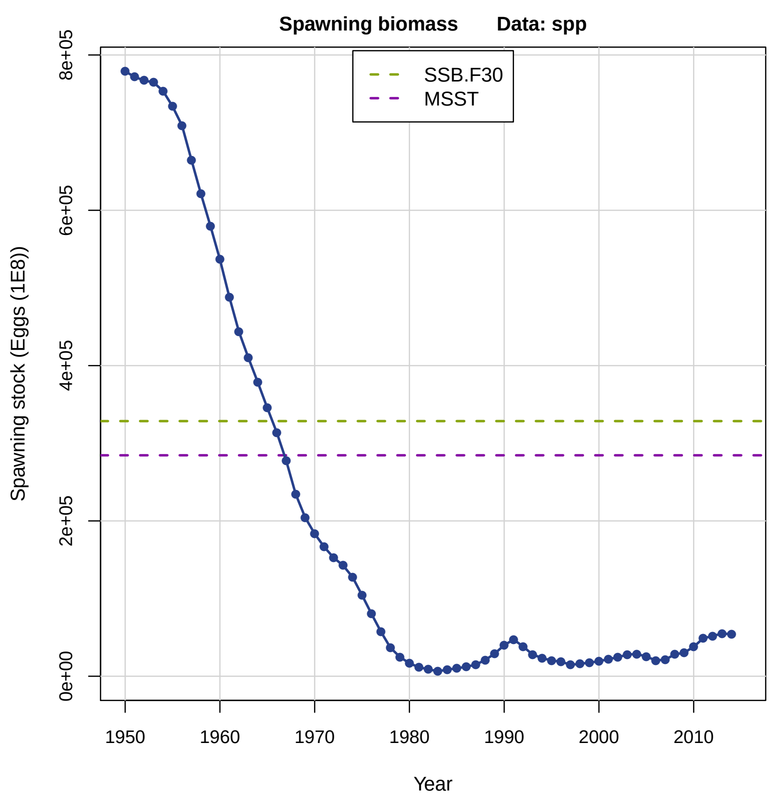


Figure 18. Monte Carlo Bootstrap estimates of population abundance. Top panel is all ages, and the bottom panel represents age 2+.

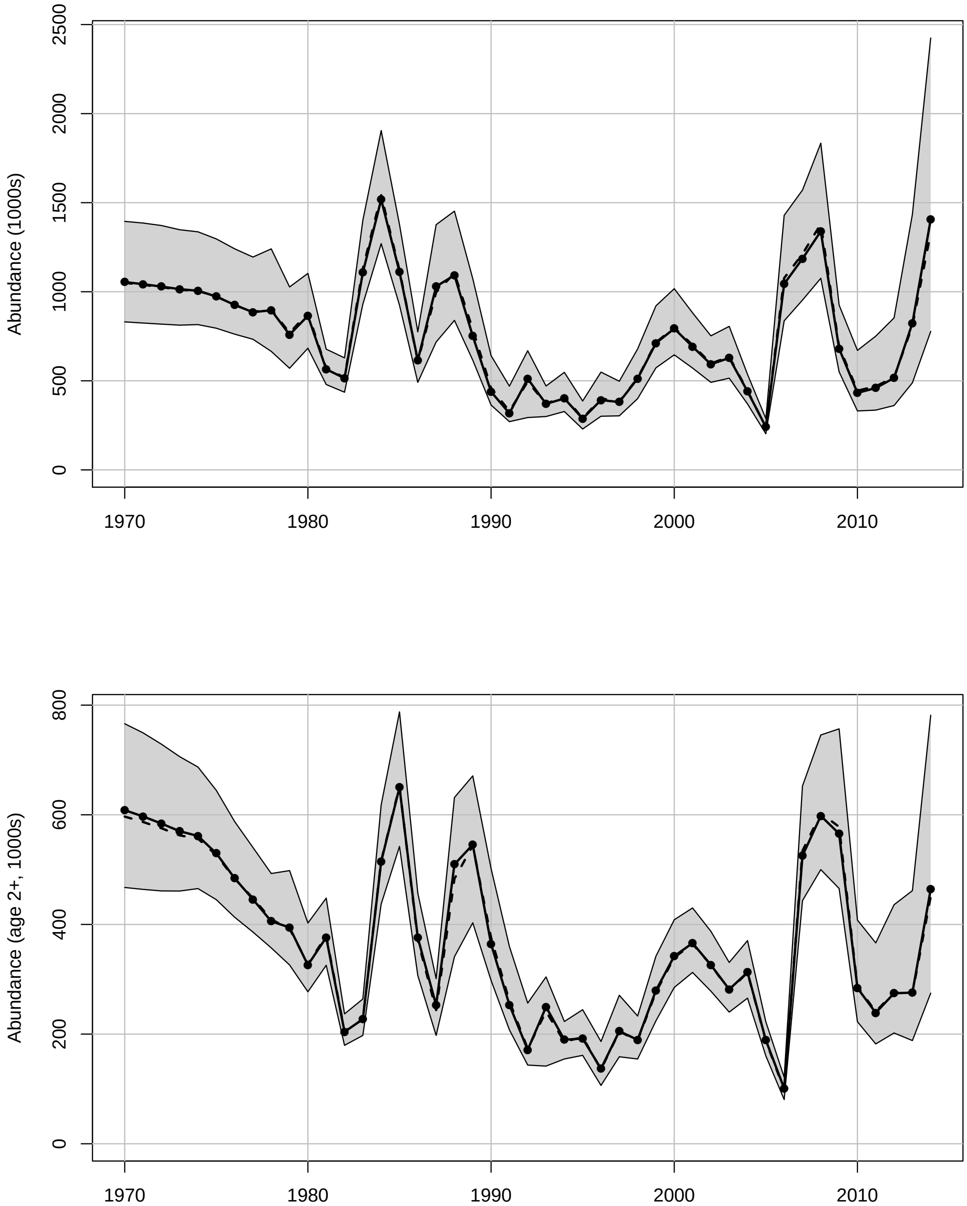


Figure 19. Selectivity of SERFS index.

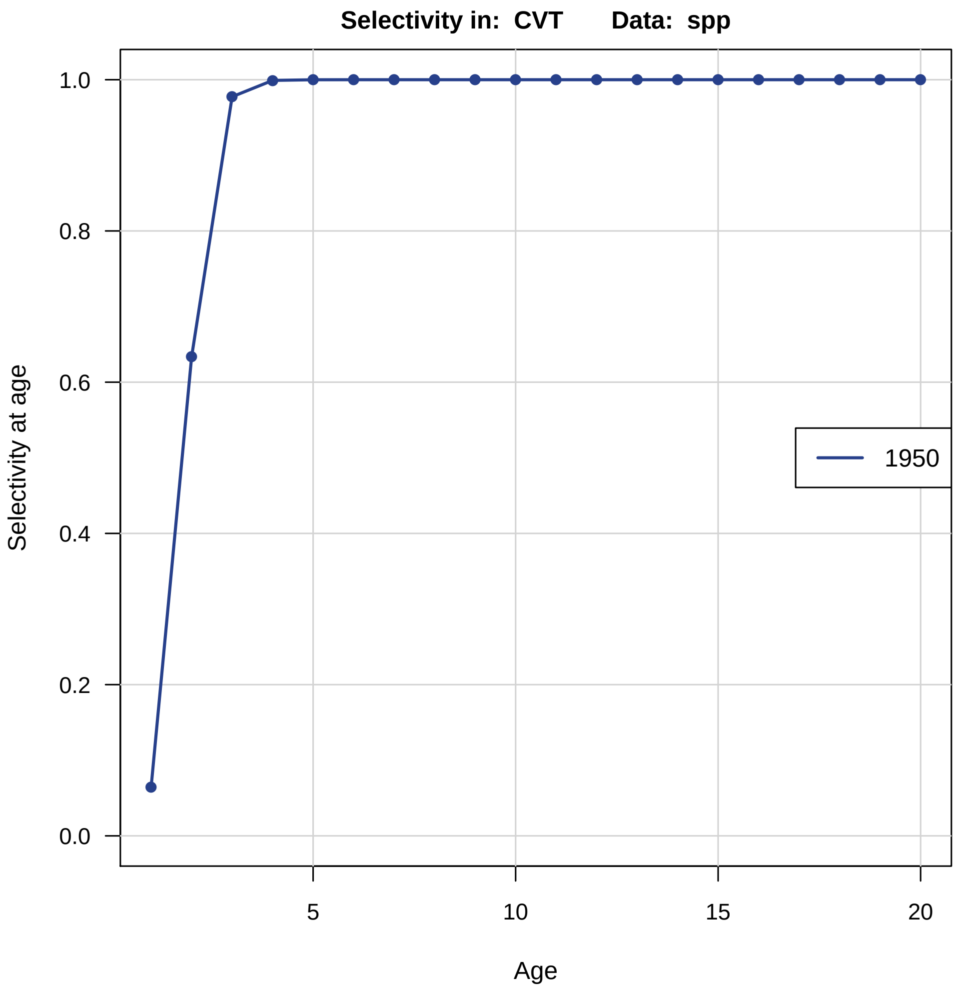


Figure 20. Selectivities of commercial handline landings. The legend indicates the first year each selectivity curve applies to the fleet.

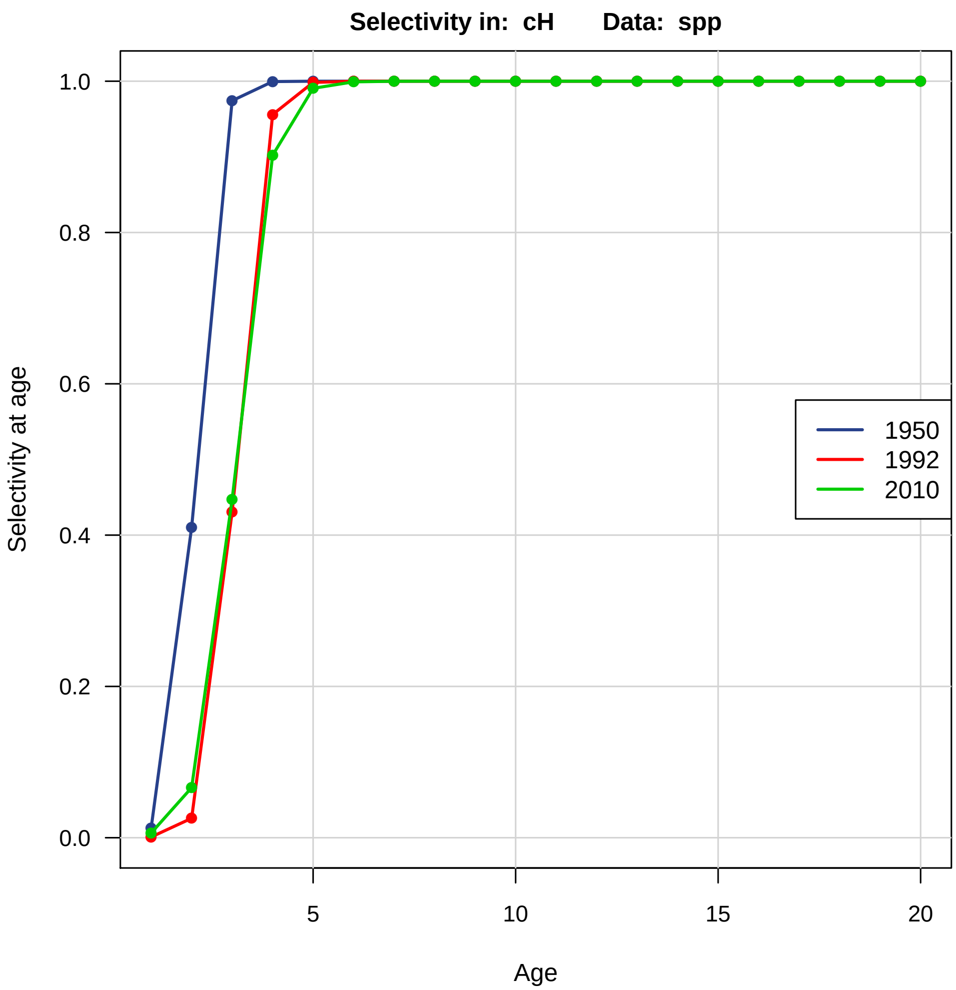


Figure 21. Selectivities of headboat landings. The legend indicates the first year each selectivity curve applies to the fleet.

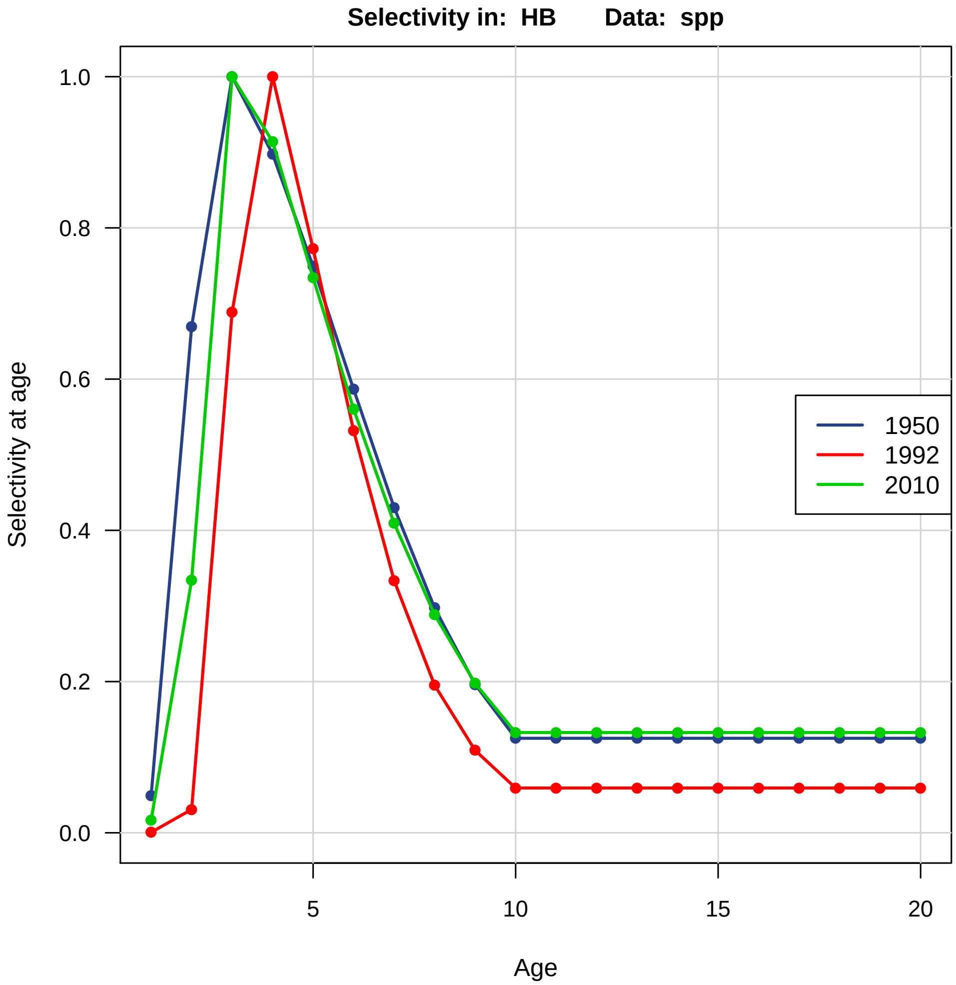


Figure 22. Selectivities of general recreational landings. The legend indicates the first year each selectivity curve applies to the fleet.

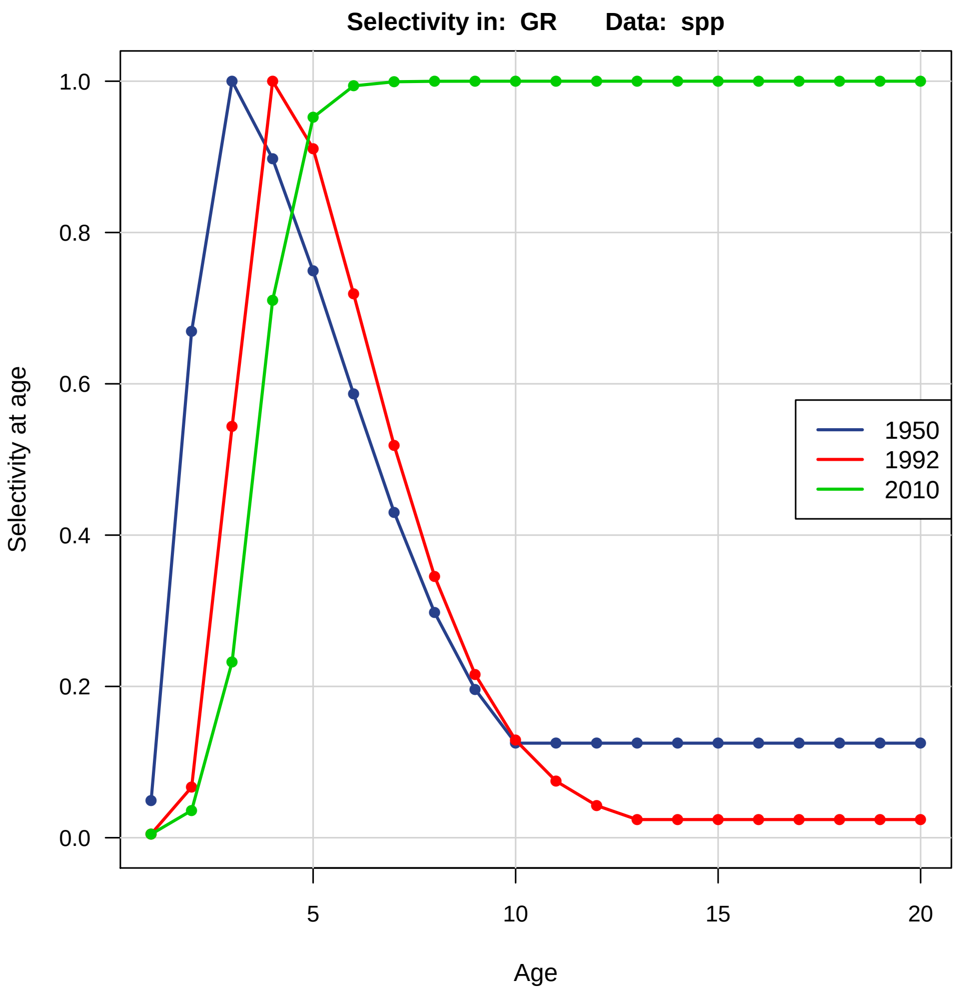


Figure 23. Selectivities of commercial handline discards. The legend indicates the first year each selectivity curve applies to the fleet.

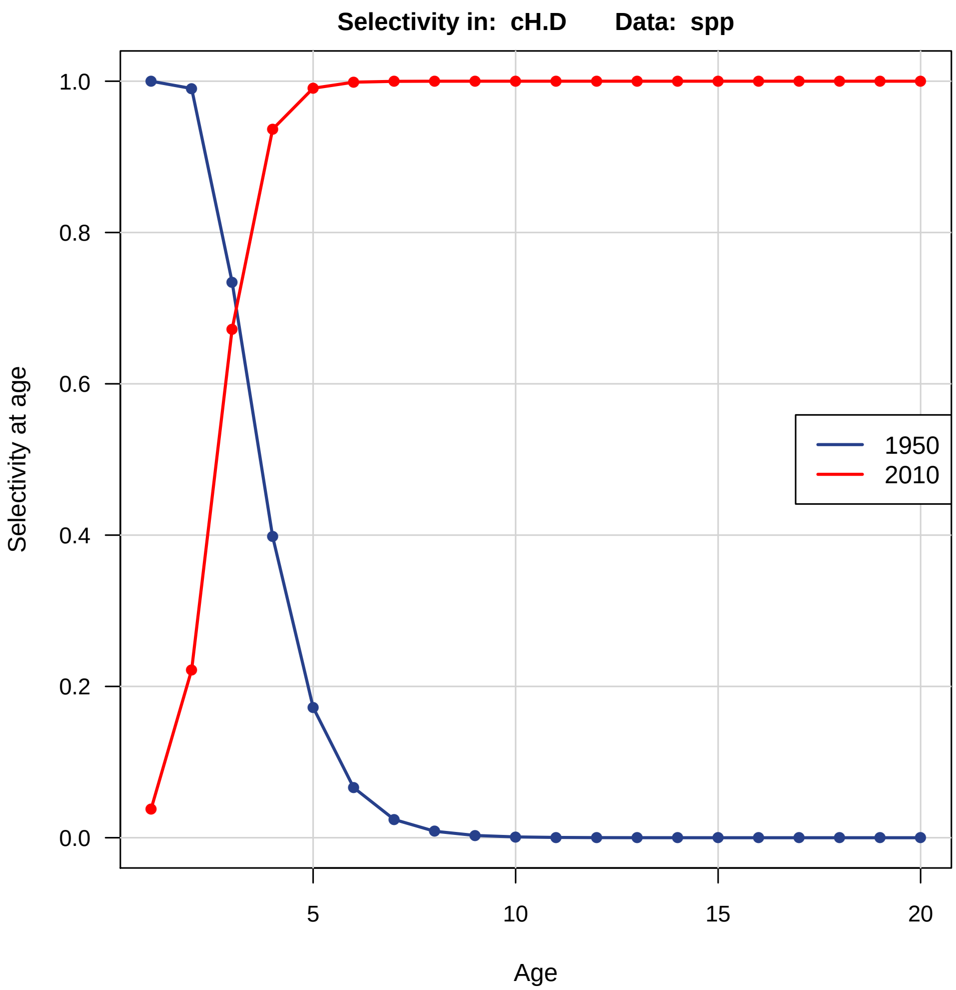


Figure 24. Selectivities of headboat discards. The legend indicates the first year each selectivity curve applies to the fleet.

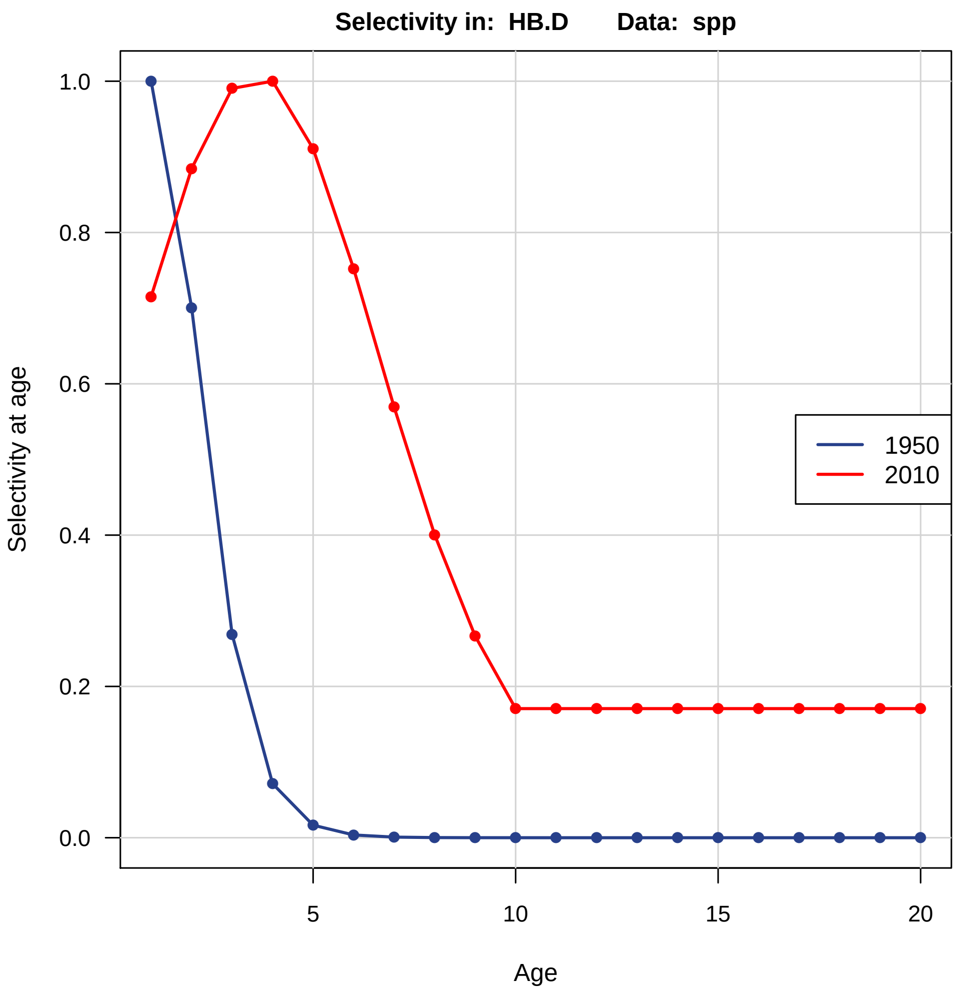


Figure 25. Selectivities of general recreational discards. The legend indicates the first year each selectivity curve applies to the fleet.

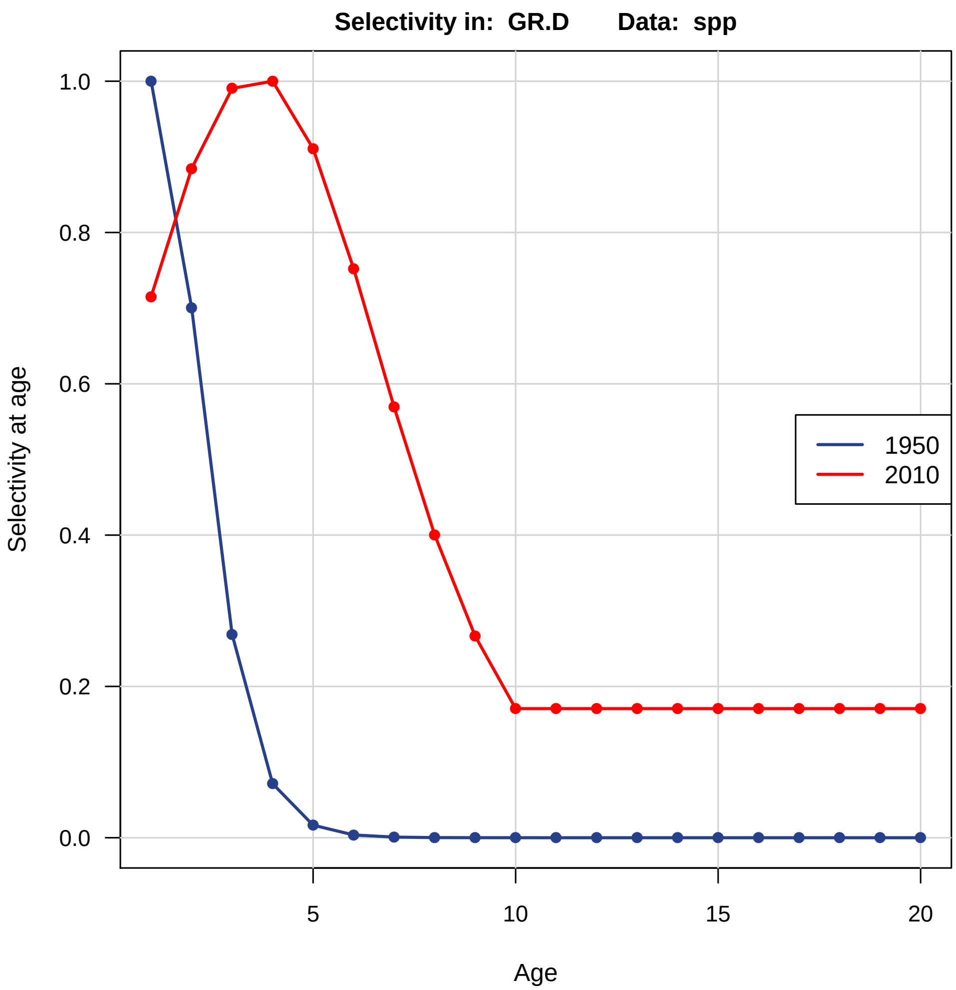


Figure 26. Average selectivity of discards(top left), landings (top right), and total weighted average (bottom) from the terminal assessment years, weighted by geometric mean F's from the last three assessment years, and used in computation of benchmarks and projections.

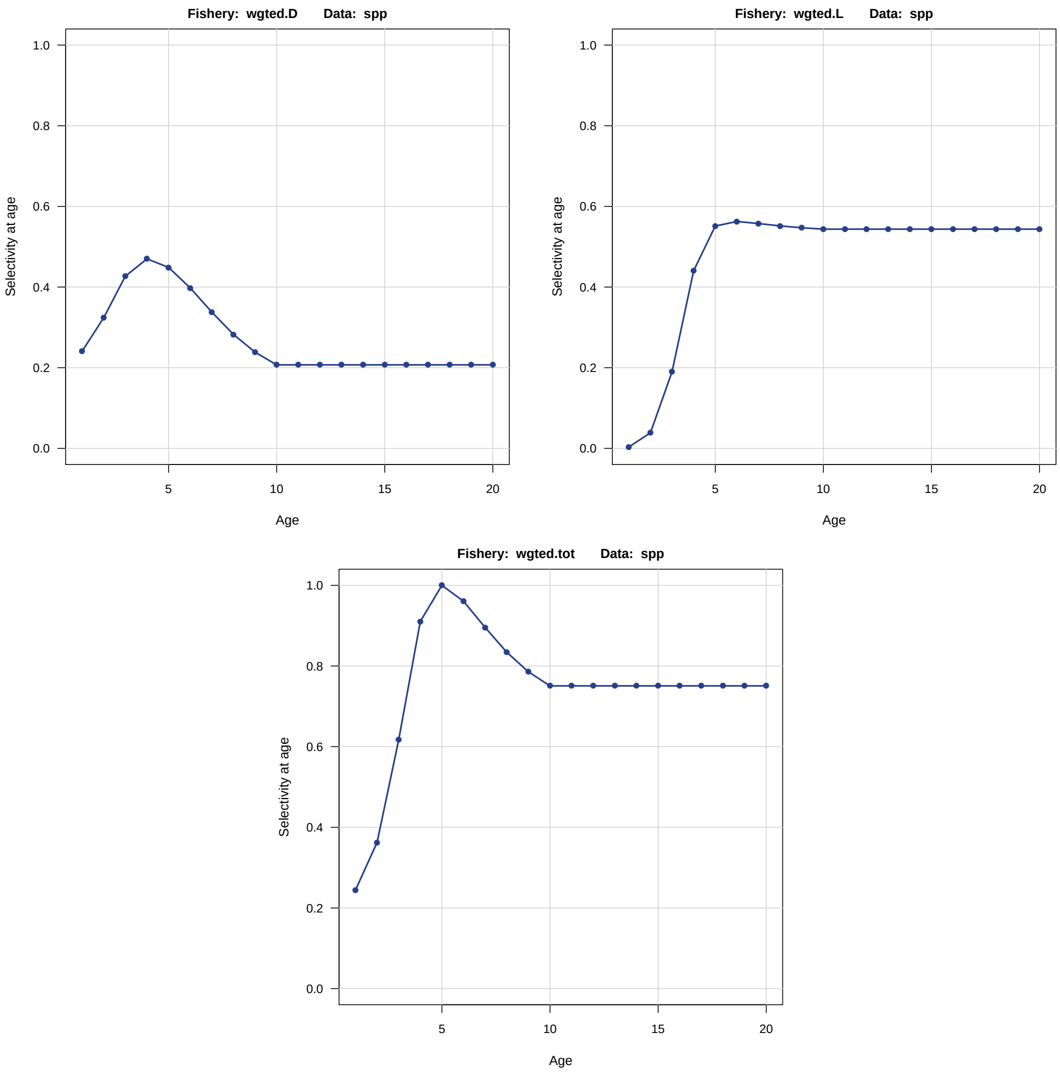


Figure 27. Estimated fully selected fishing mortality rate (per year) by fleet. cH refers to commercial handlines, HB to headboat, GR to general recreational, and D refers to discard mortality.

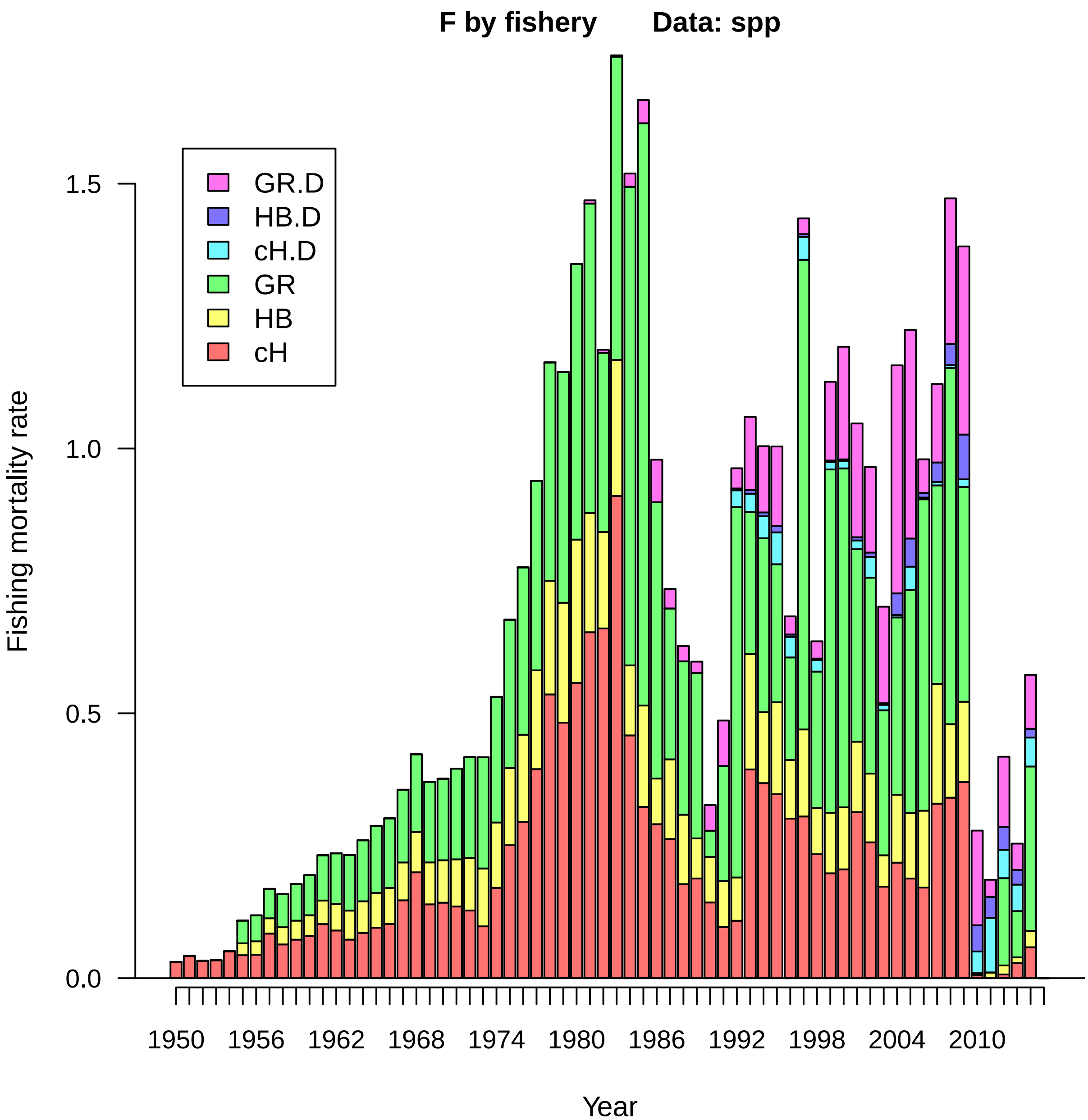


Figure 28. Estimated landings in numbers by fleet from the catch-age model. cH refers to commercial handlines, HB to headboat, and GR to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of $L_{\mathrm{F30\%}}$ in numbers.

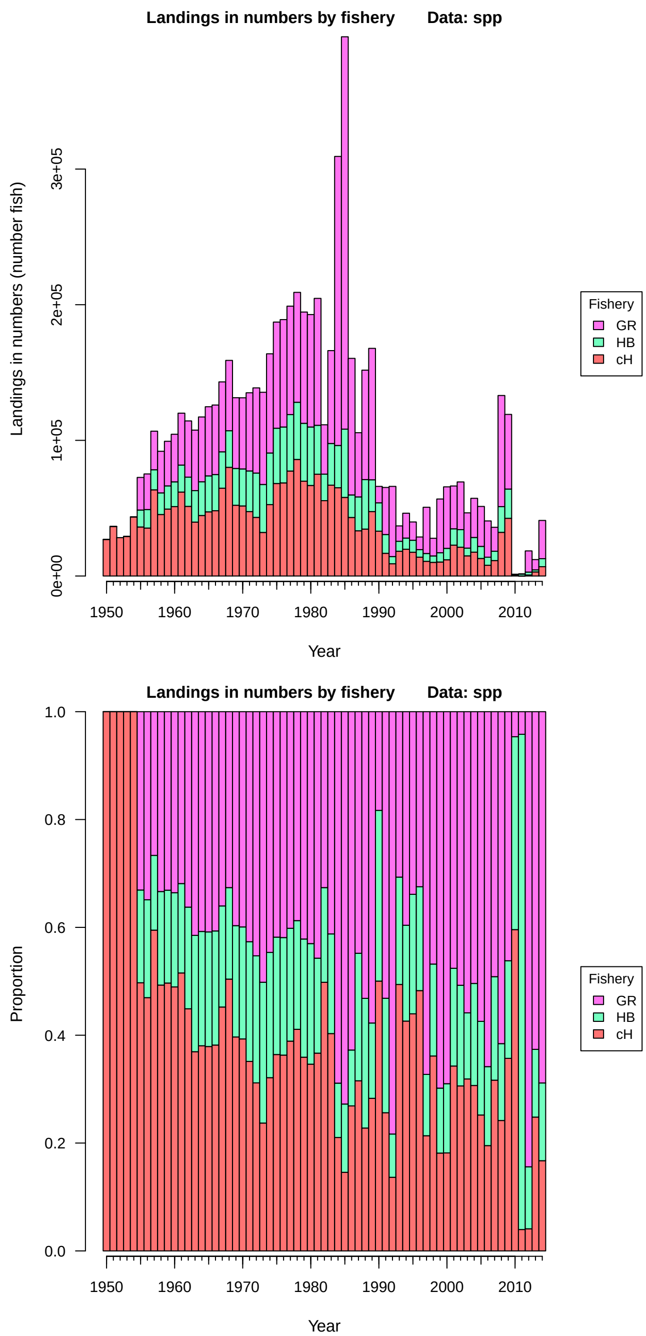
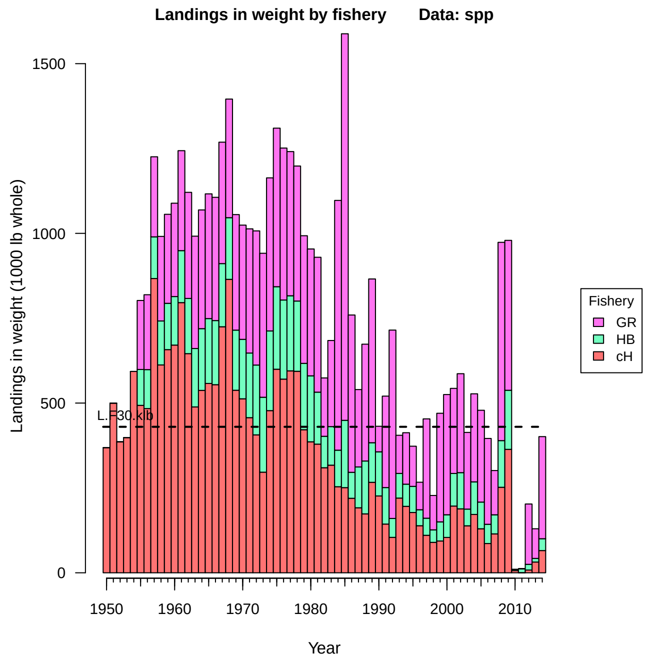


Figure 29. Estimated landings in whole weight by fleet from the catch-age model. cH refers to commercial handlines, HB to headboat, and GR to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of $L_{\mathrm{F30\%}}$ in weight.



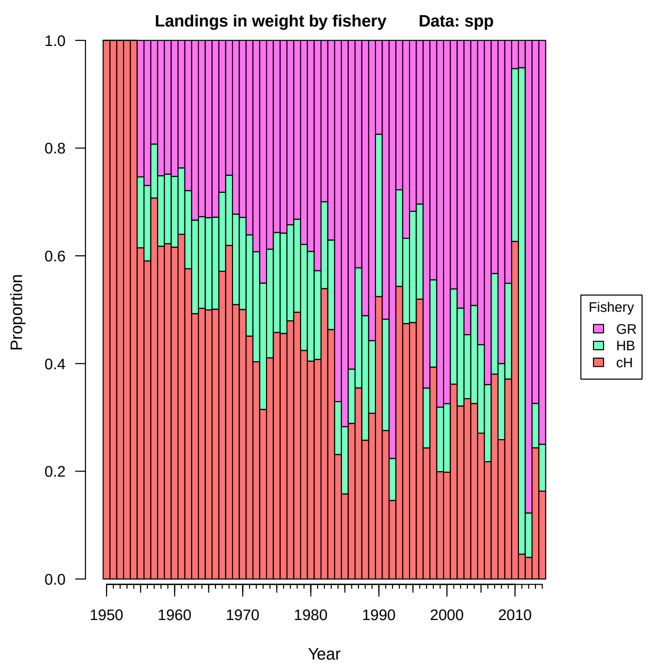


Figure 30. Estimated discard mortalities by fleet from the catch-age model. cH refers to commercial lines, hb to headboat, rec to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of $D_{F_{30\%}}$ in numbers.

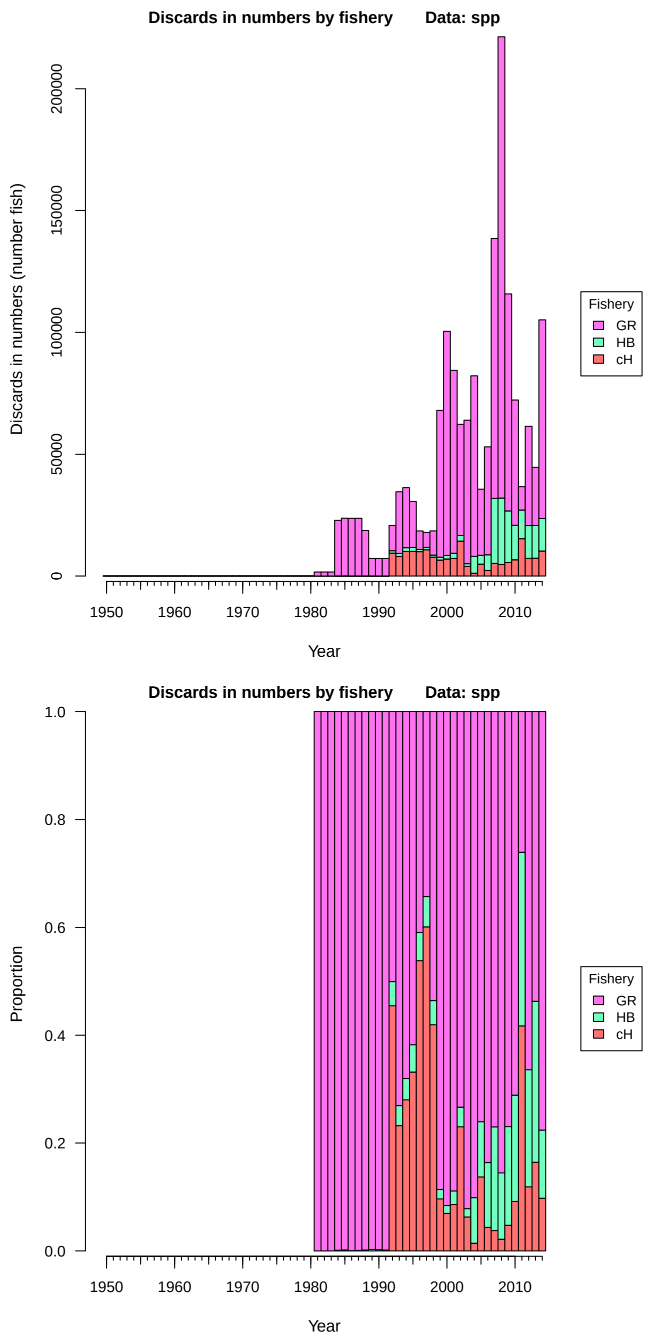


Figure 31. Top panel: Beverton–Holt spawner-recruit curves, with and without lognormal bias correction. The expected (upper) curve was used for computing management benchmarks. Bottom panel: log of recruits (number age-1 fish) per spawner as a function of spawners.

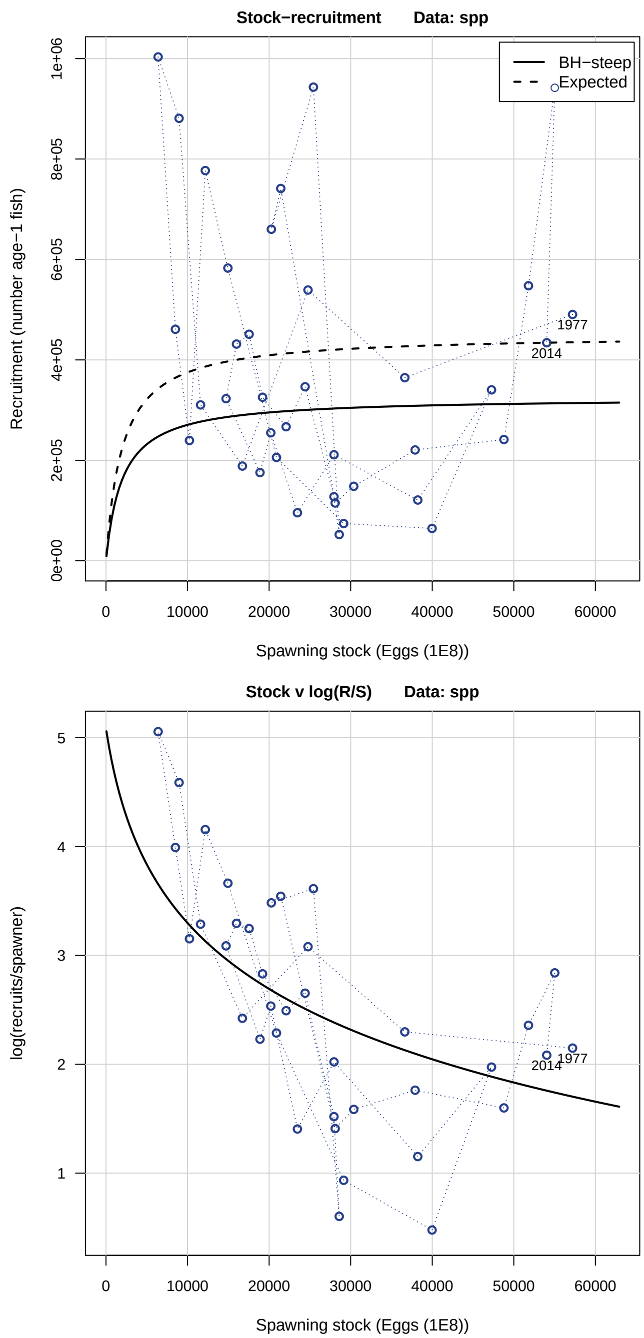


Figure 32. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-1 fish), steepness (fixed at 0.99), unfished spawners per recruit, and standard deviation of recruitment residuals in log space. Solid vertical lines represent point estimates or values from the base run of the Beaufort Assessment Model; dashed vertical lines represent medians from the MCB runs.

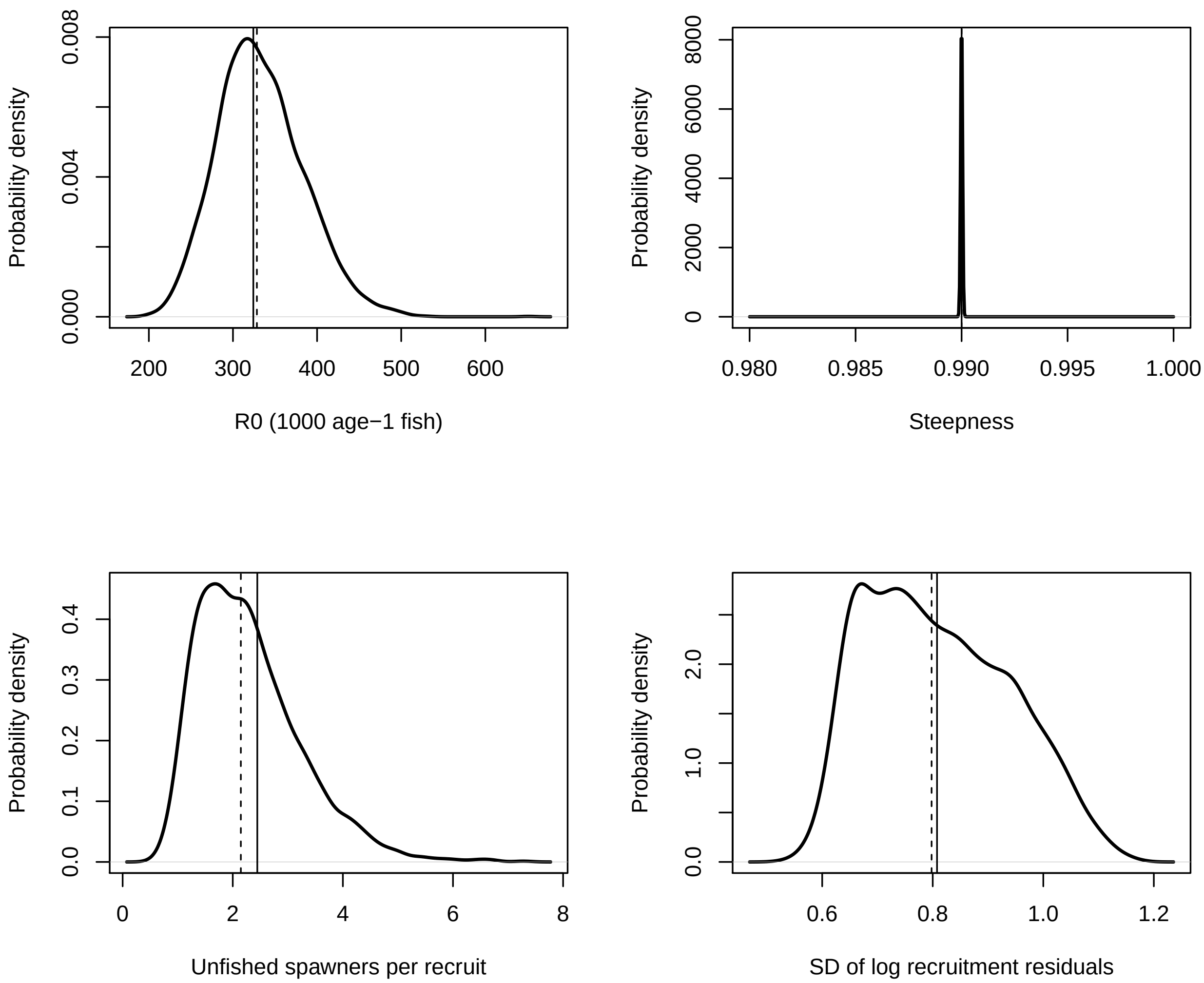


Figure 33. Yield per recruit based on average selectivity from the end of the assessment period.

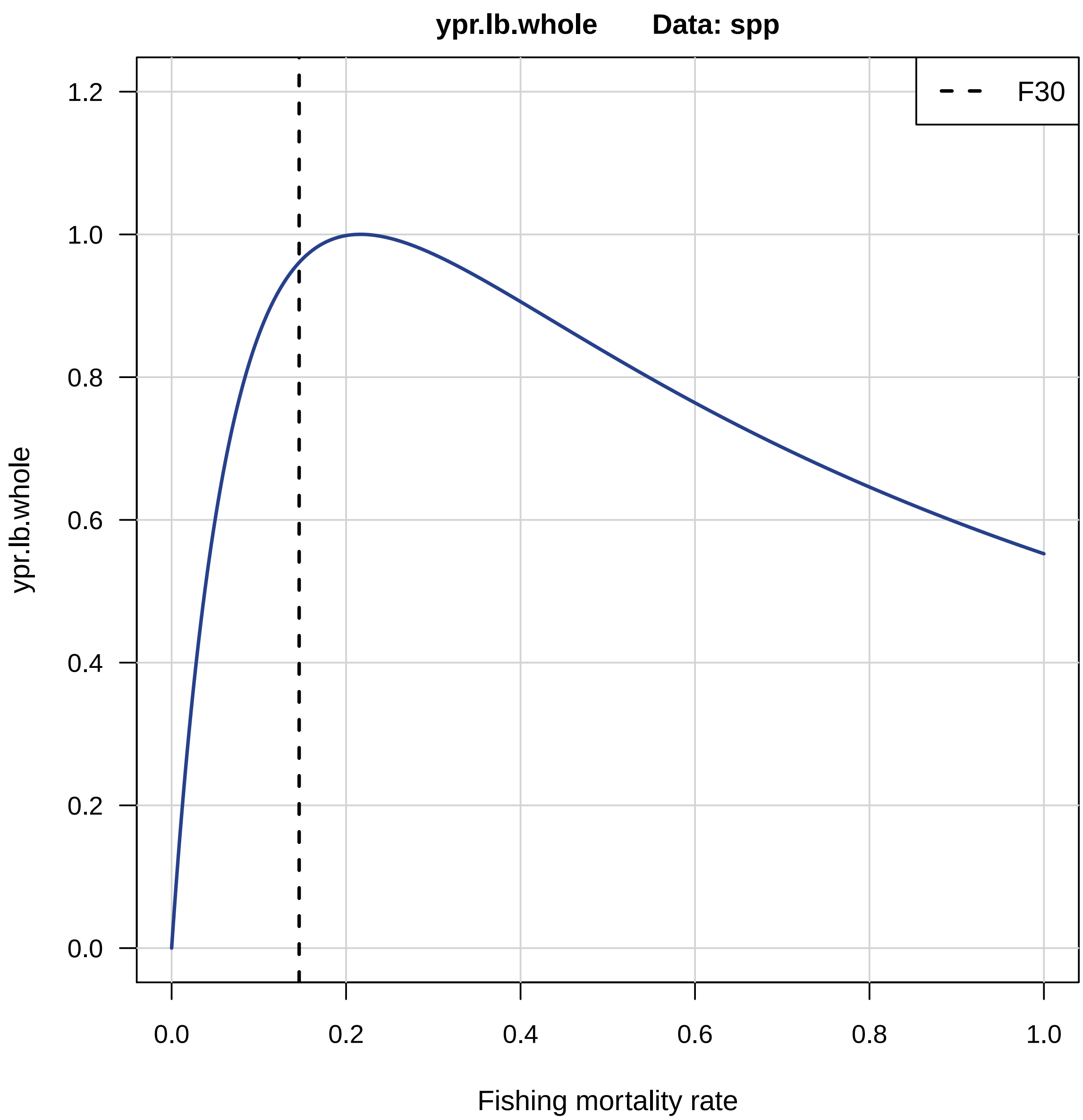


Figure 34. Spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the X% level of SPR provides $F_{X\%}$. SPR is based on average selectivity from the end of the assessment period.

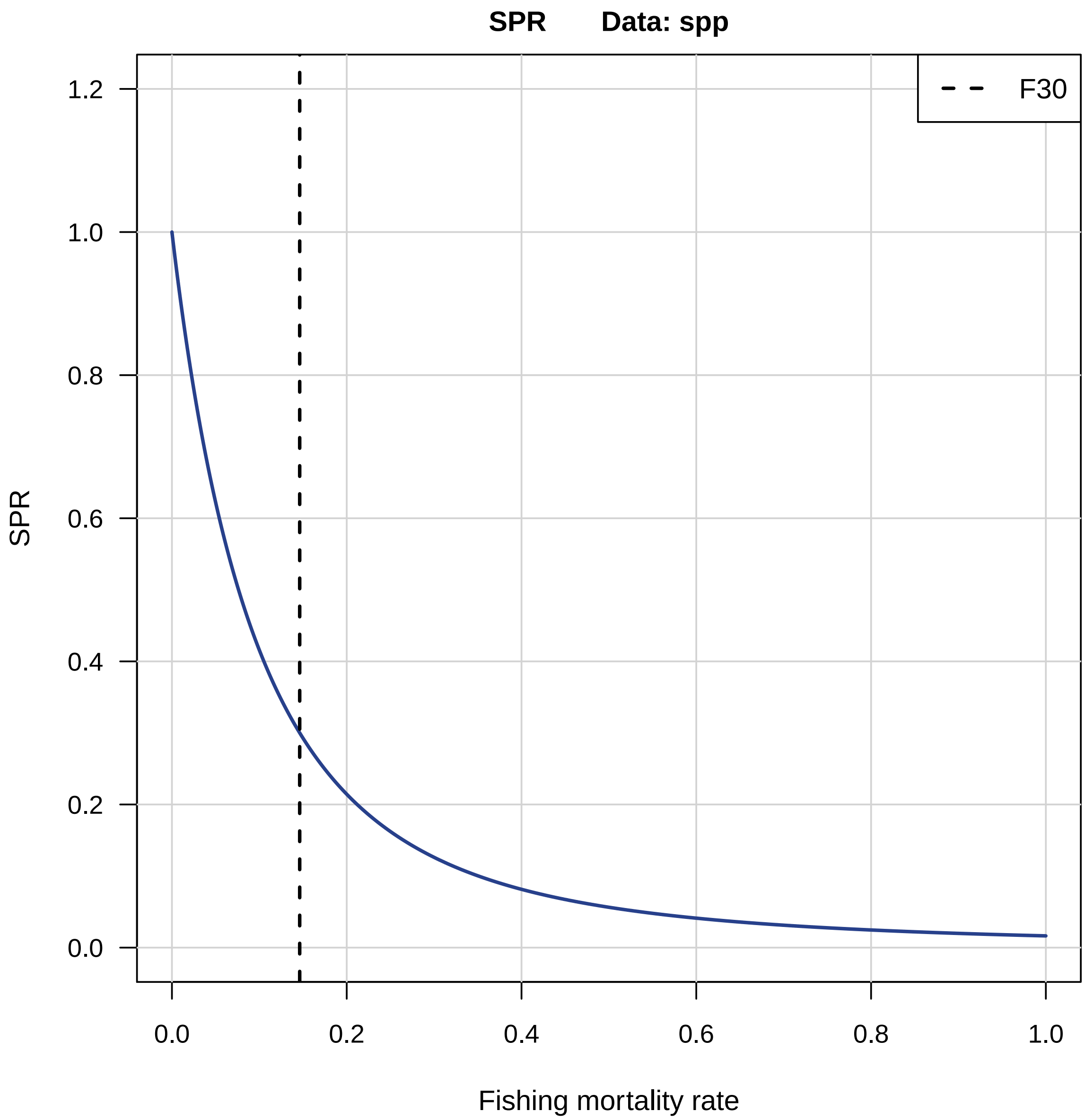


Figure 35. Equilibrium spawning biomass based on average selectivity from the end of the assessment period.

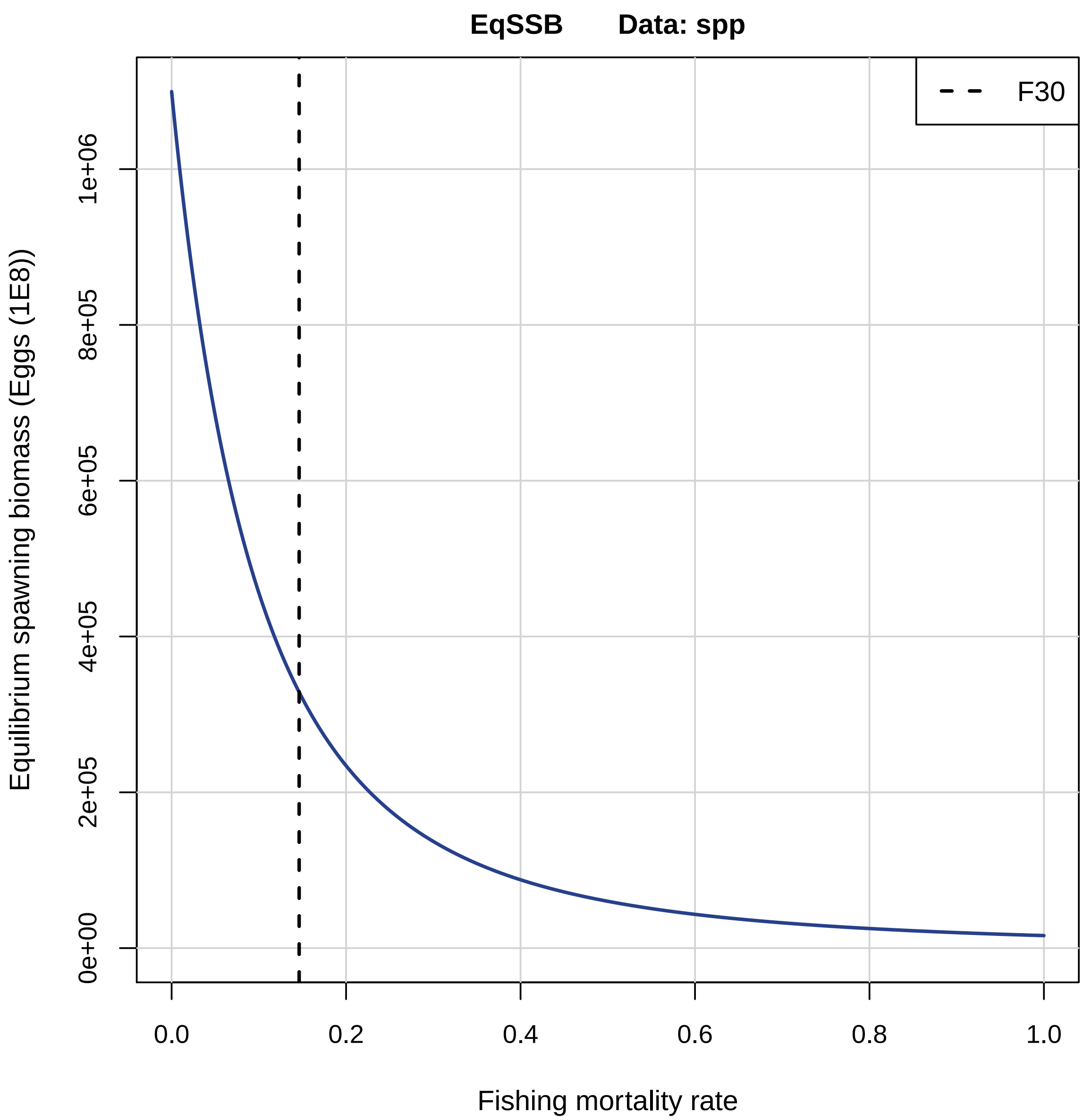


Figure 36. Probability densities of $F_{30\%}$-related benchmarks from MCB analysis of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.

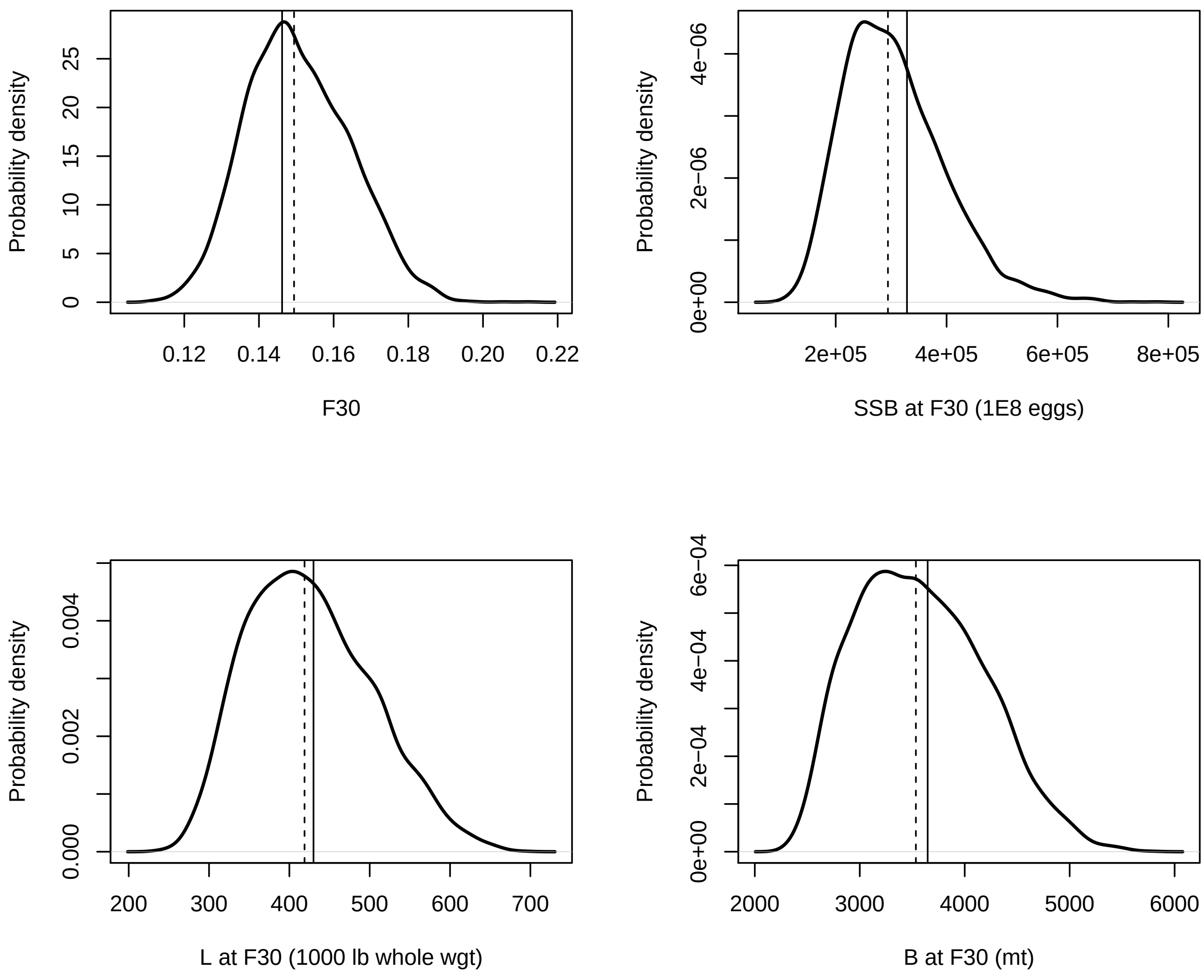
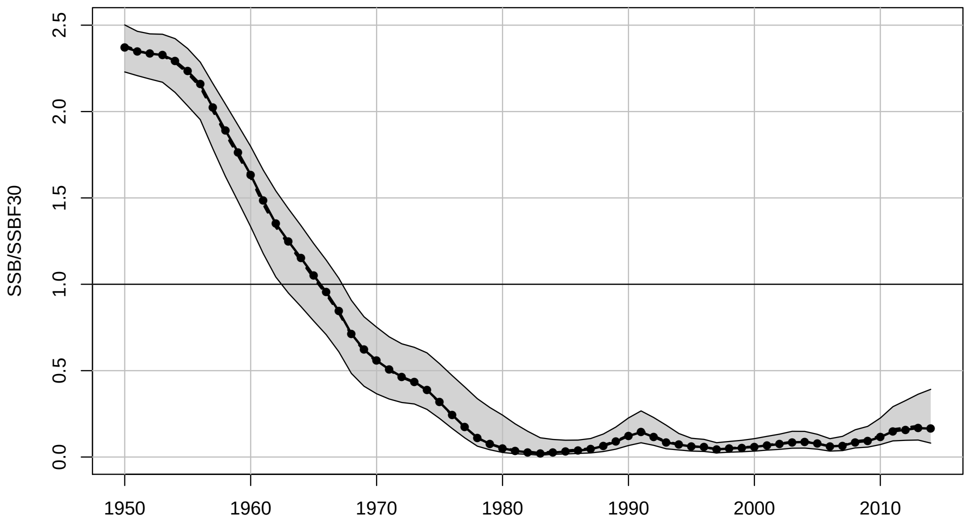


Figure 37. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; dashed lines represent median values; gray error bands indicate 5^{th} and 95^{th} percentiles of the MCB trials. Top panel: spawning biomass relative to $\mathrm{SSB}_{\mathrm{F30\%}}$. *Bottom panel: F relative to* $F_{30\%}$.



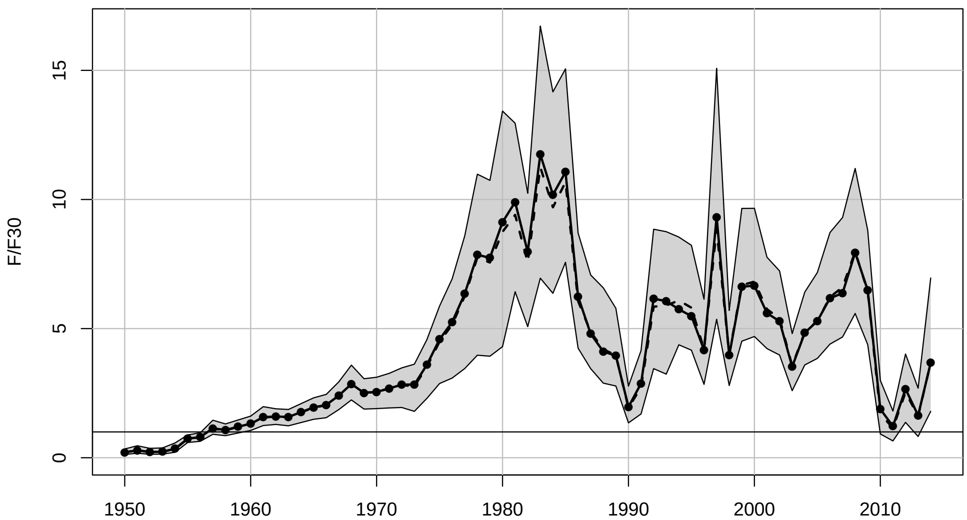
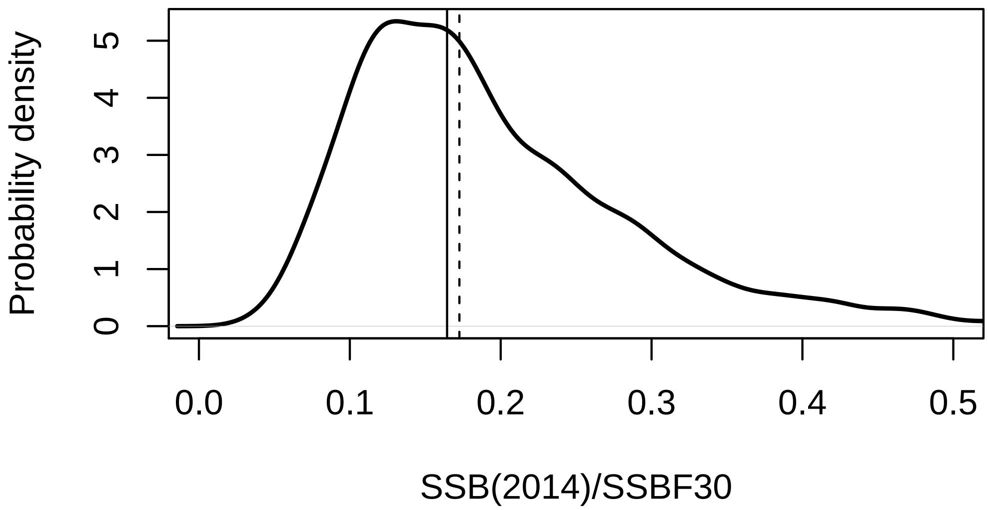


Figure 38. Probability densities of terminal status estimates from MCB analysis of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.



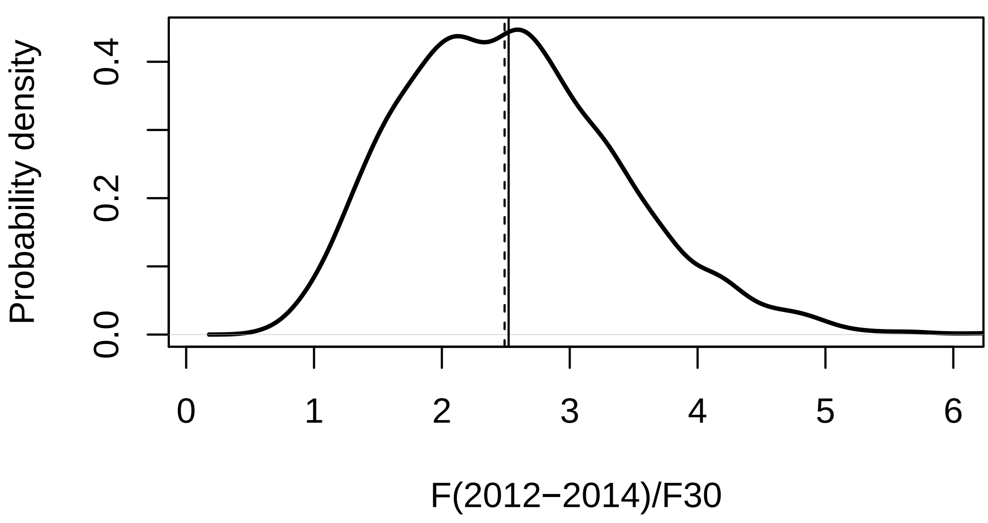


Figure 39. Phase plots of terminal status estimates from MCB analysis of the Beaufort Assessment Model. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by 5^{th} and 95^{th} percentiles. Proportion of runs falling in each quadrant indicated.

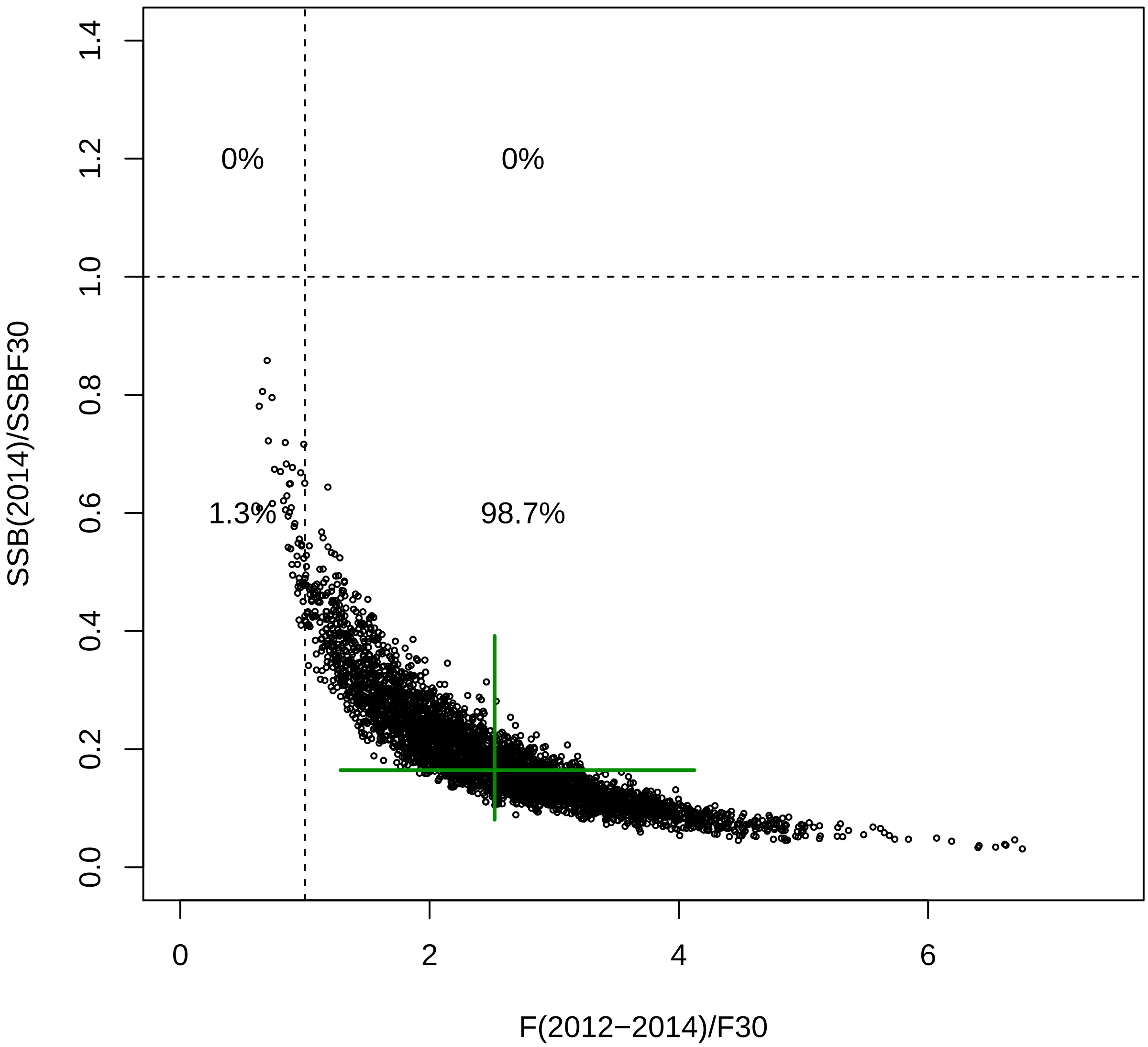


Figure 40. Age structure relative to the equilibrium expected at $F_{30\%}$.

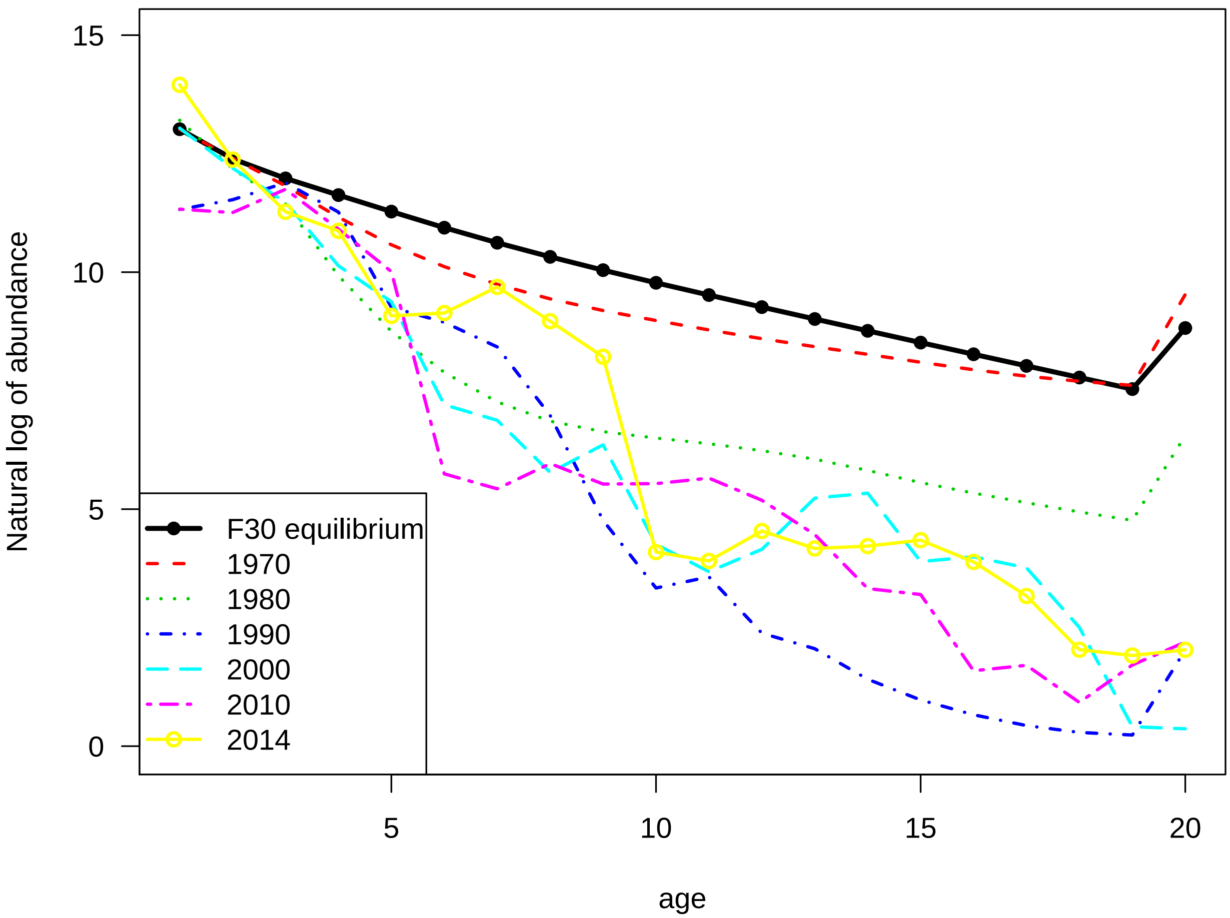


Figure 41. Sensitivity to changes in natural mortality (sensitivity runs S5 and S6). Top panel: Ratio of F to $F_{30\%}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{F30\%}$.

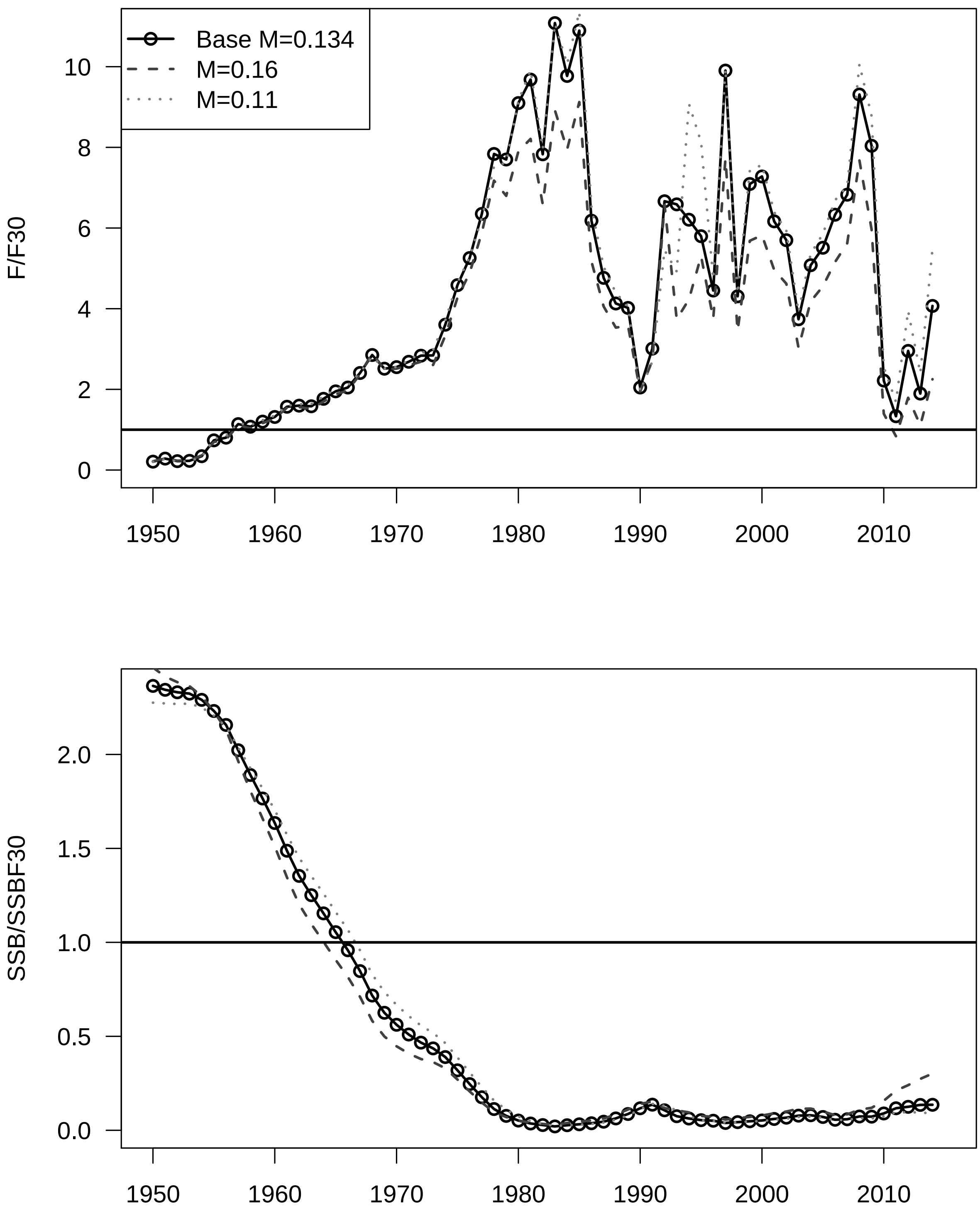
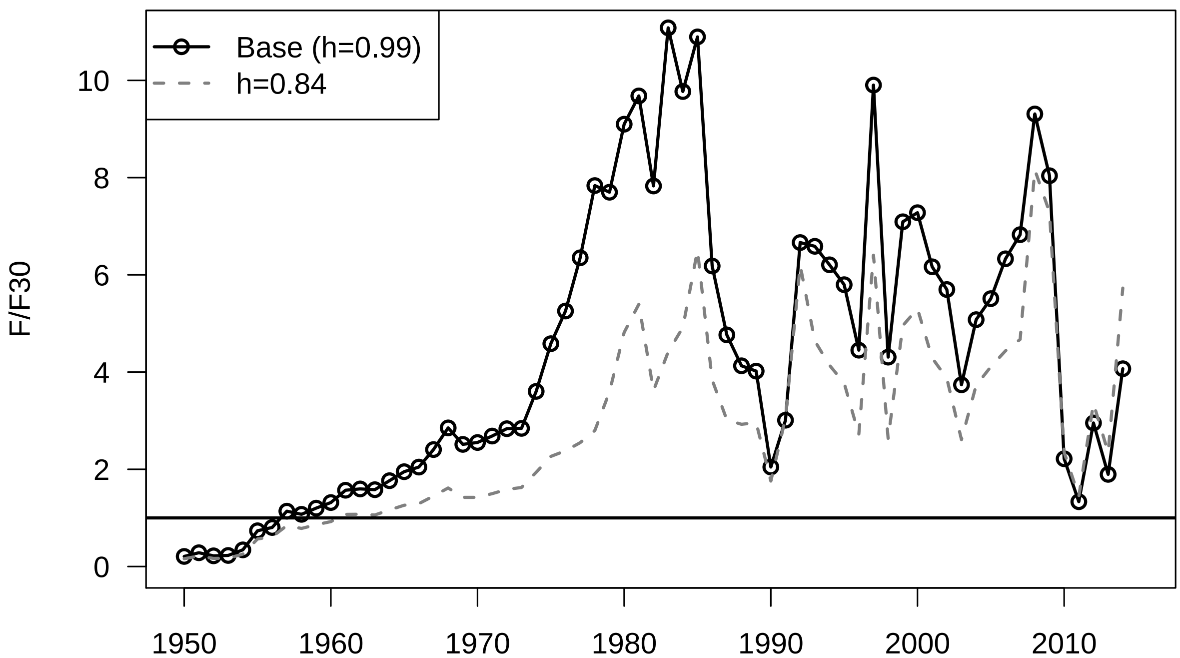


Figure 42. Sensitivity to steepness (sensitivity run S11). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.



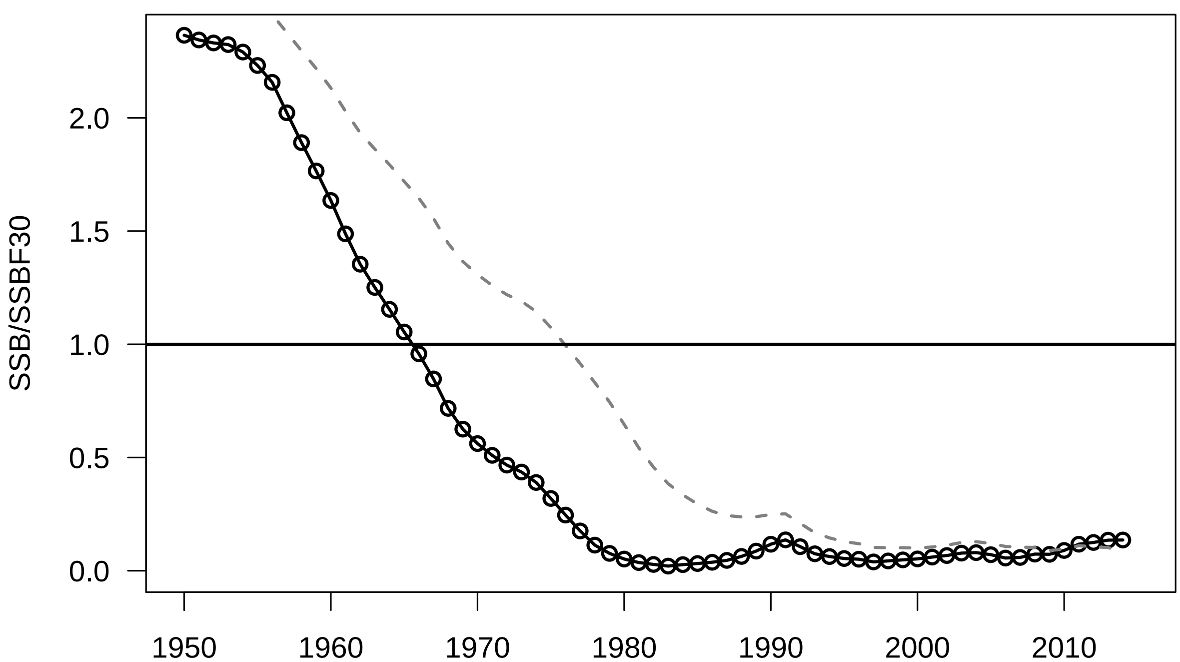
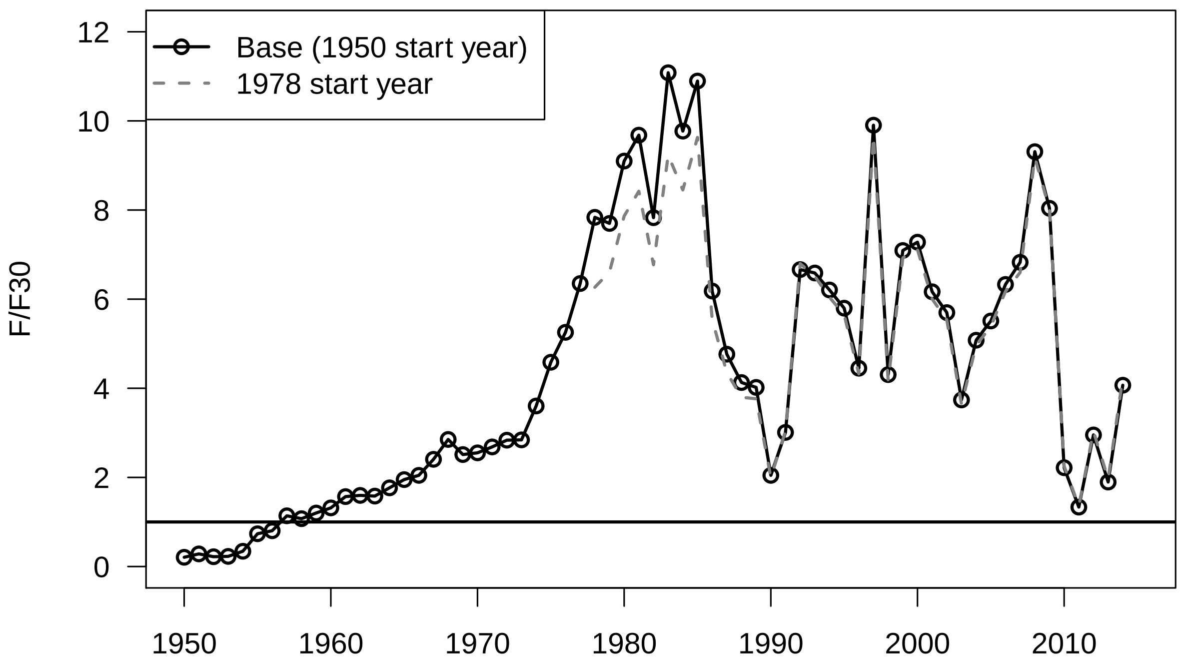


Figure 43. Sensitivity to start year (1978 compared to 1950) (sensitivity run S26). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.



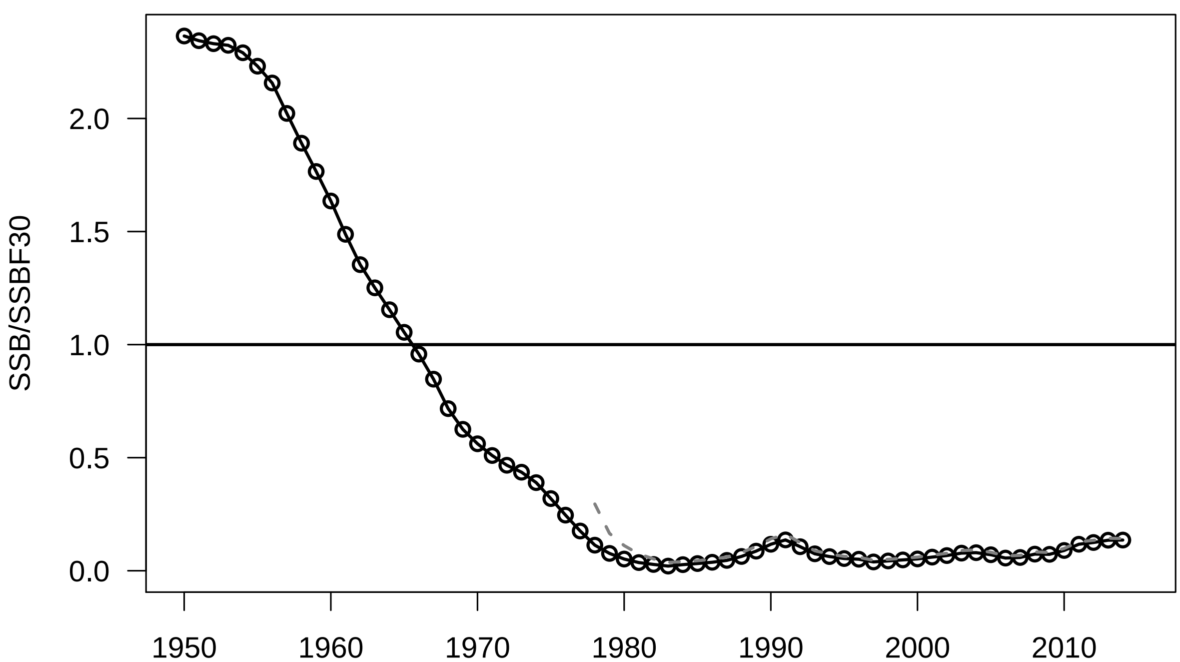


Figure 44. Sensitivity to aging error matrix (sensitivity run S13). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

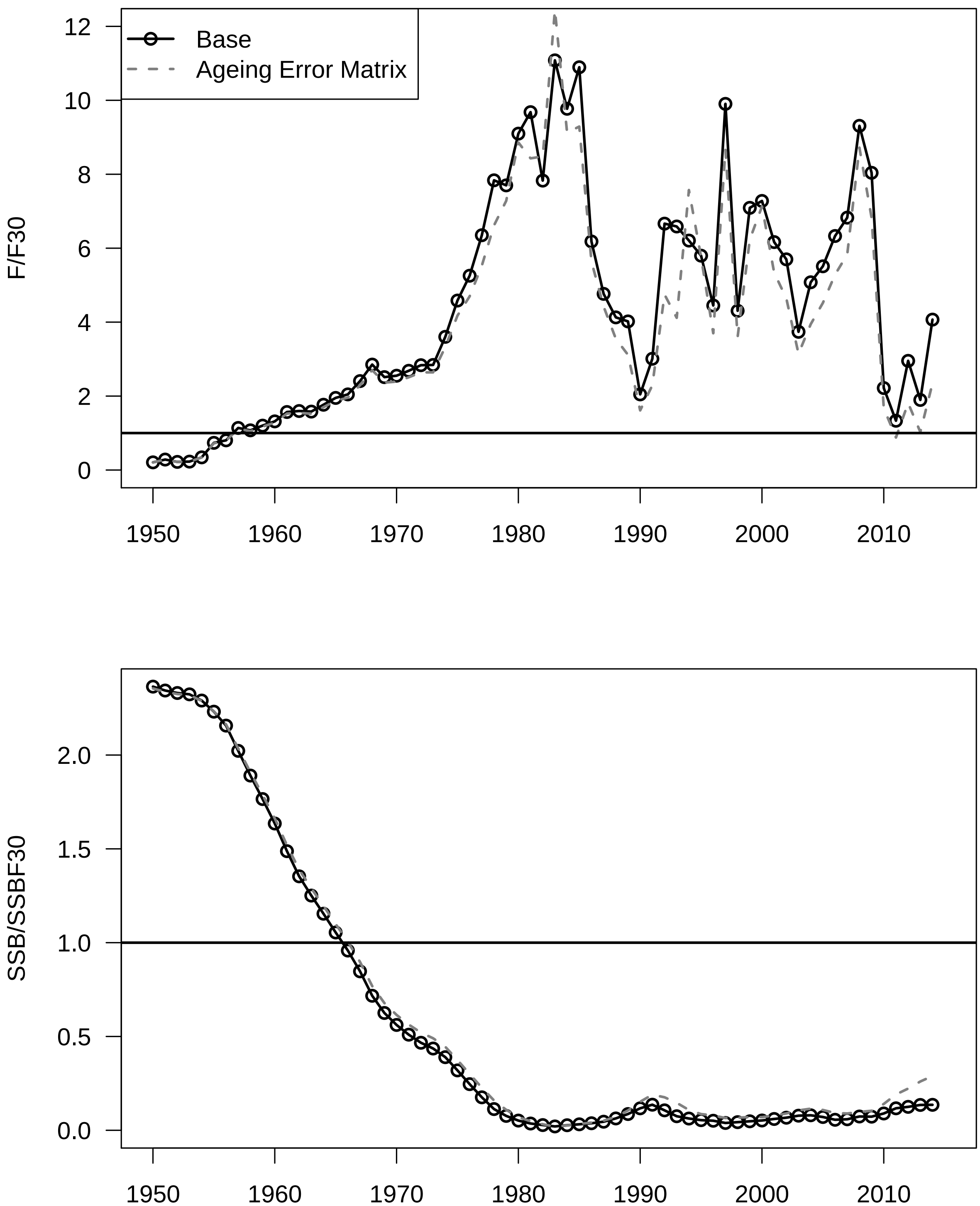


Figure 45. Sensitivity to batch number (sensitivity runs S14 and S15). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

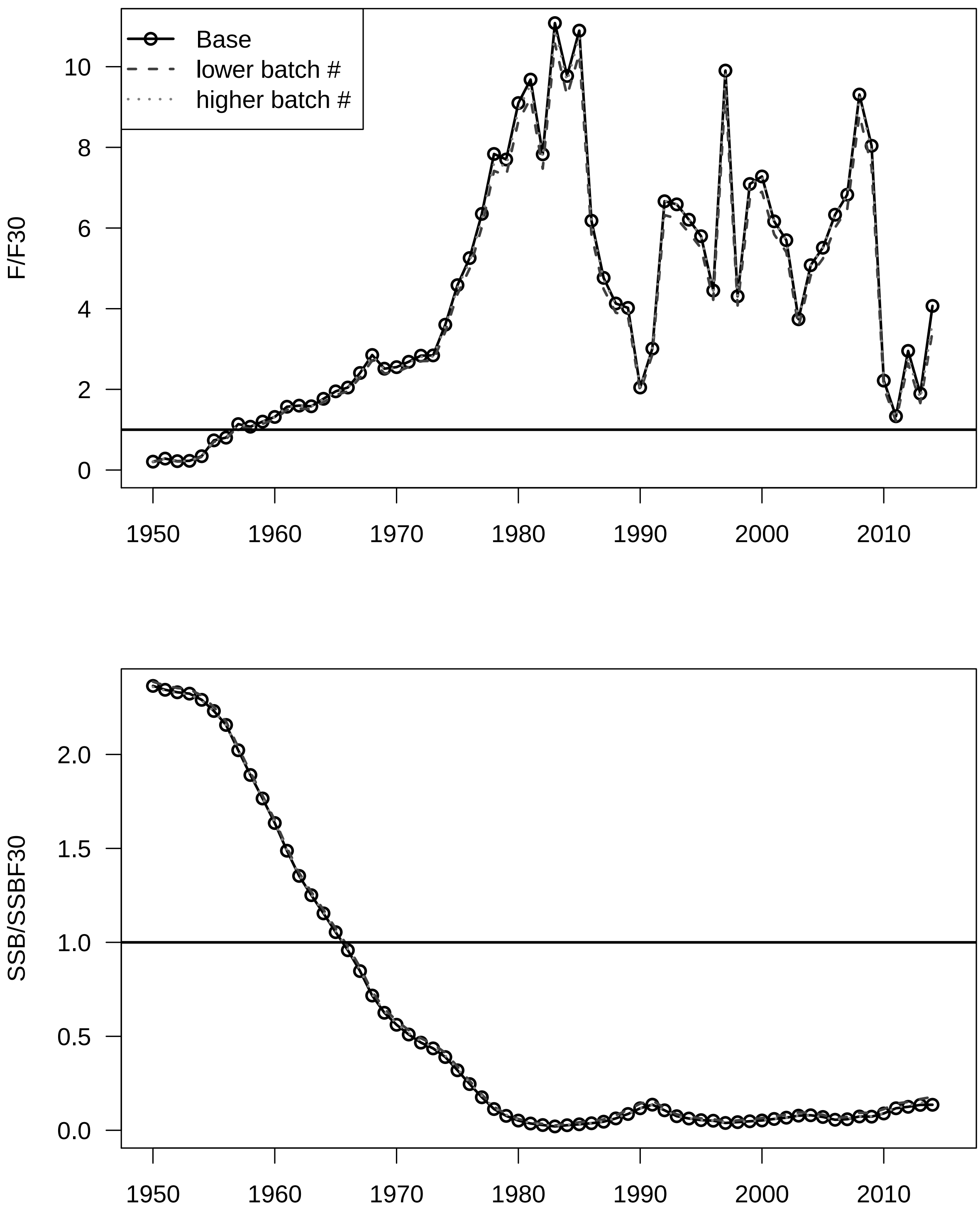
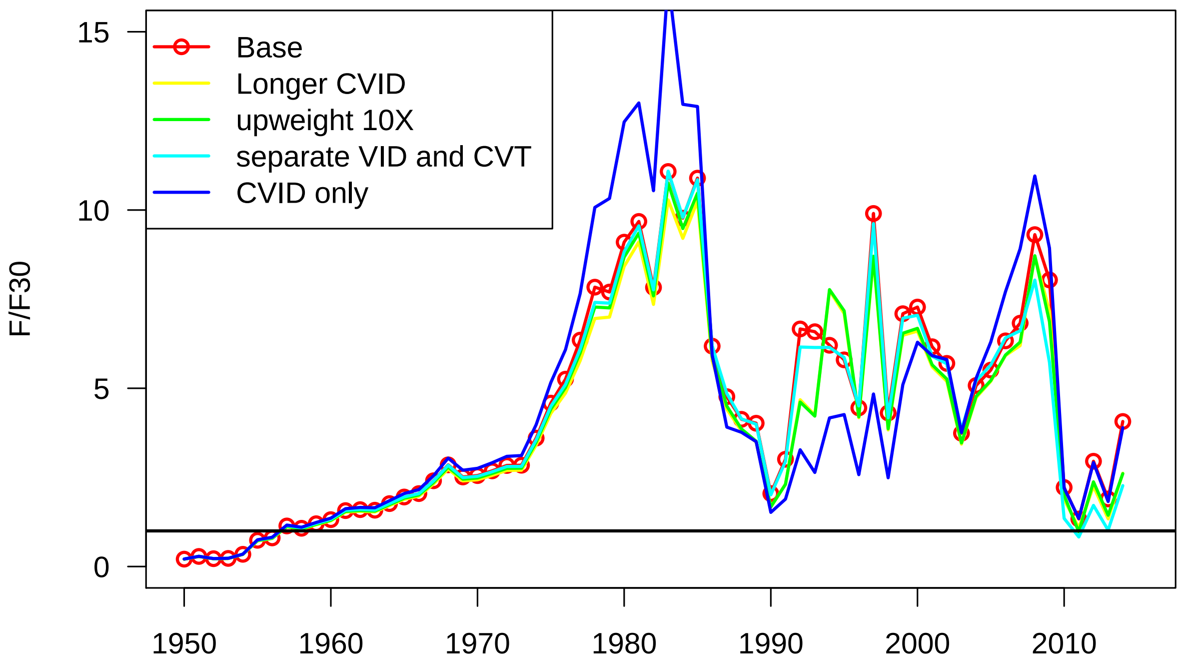


Figure 46. Sensitivity to various changes to SERFS video and trap indices (sensitivity runs S2, S9, S22 and S23). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.



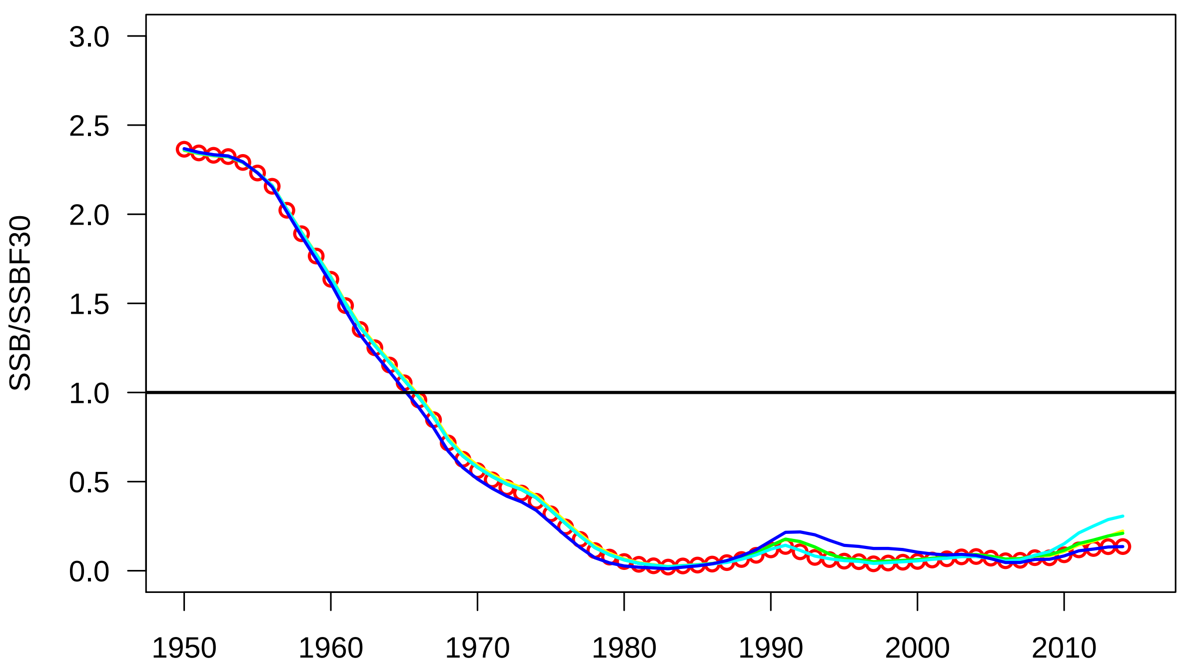
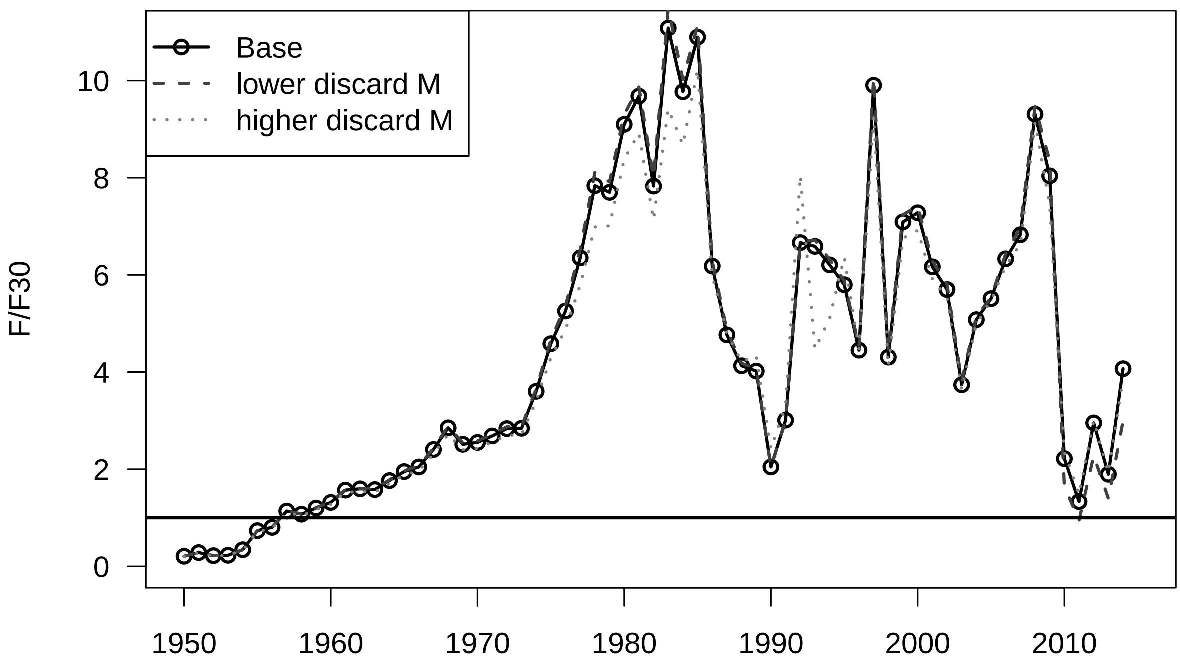


Figure 47. Sensitivity to discard mortality (sensitivity run S7 and S8). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.



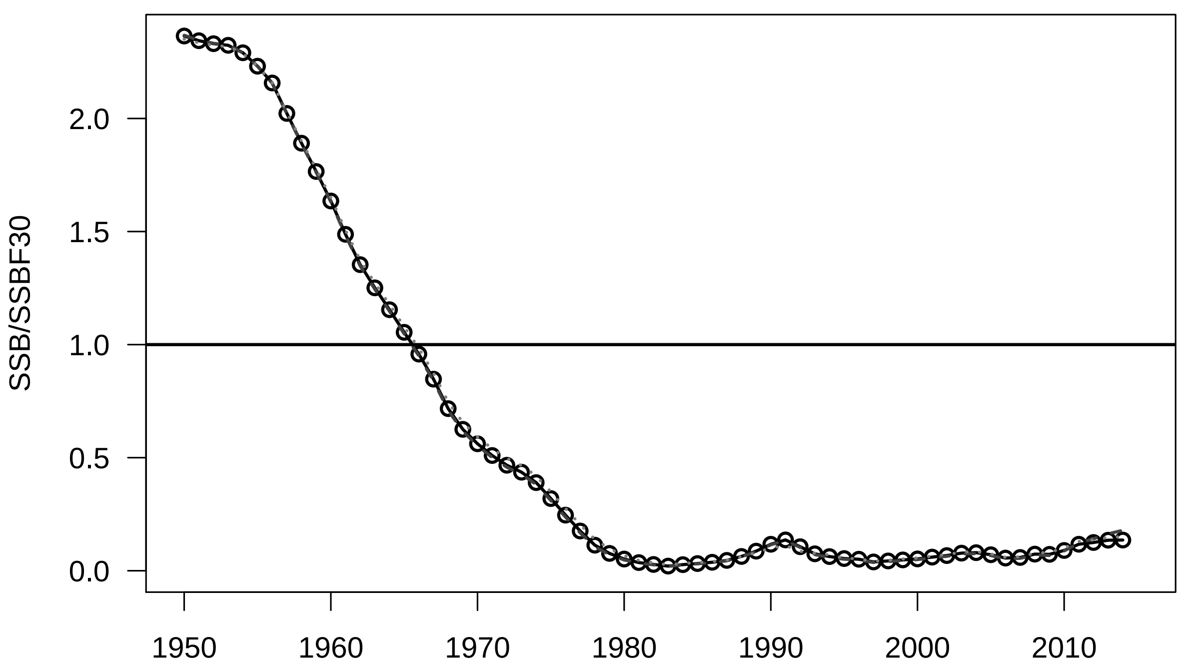
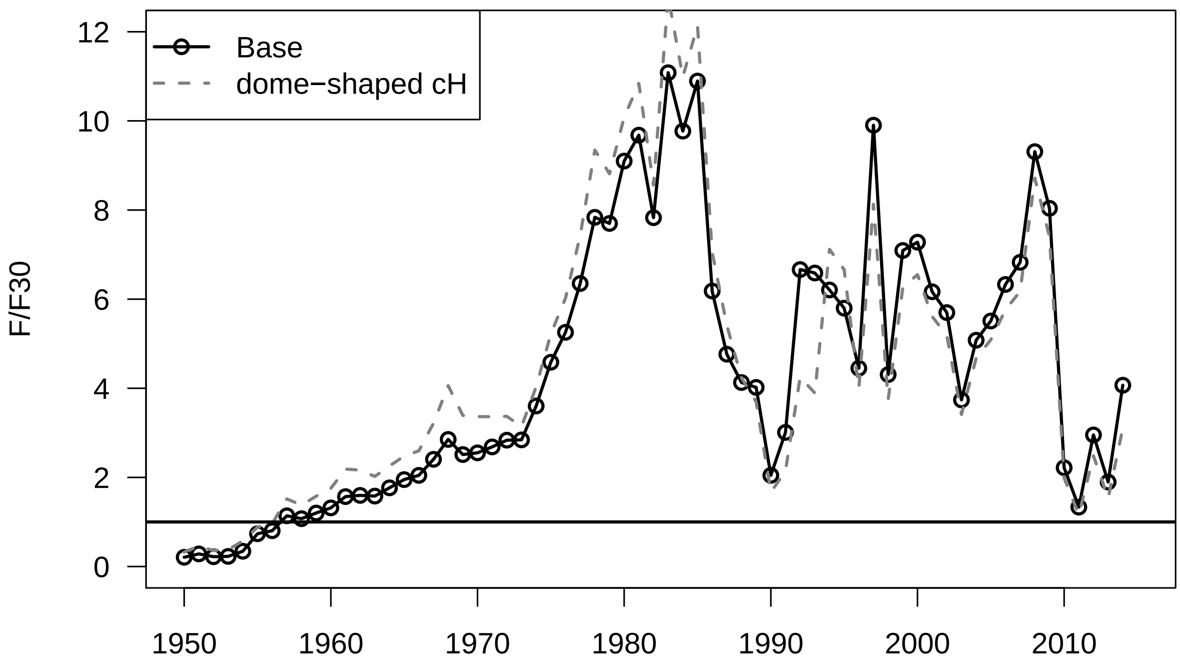


Figure 48. Sensitivity to dome-shaped selectivity for commercial handline (sensitivity run S21). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.



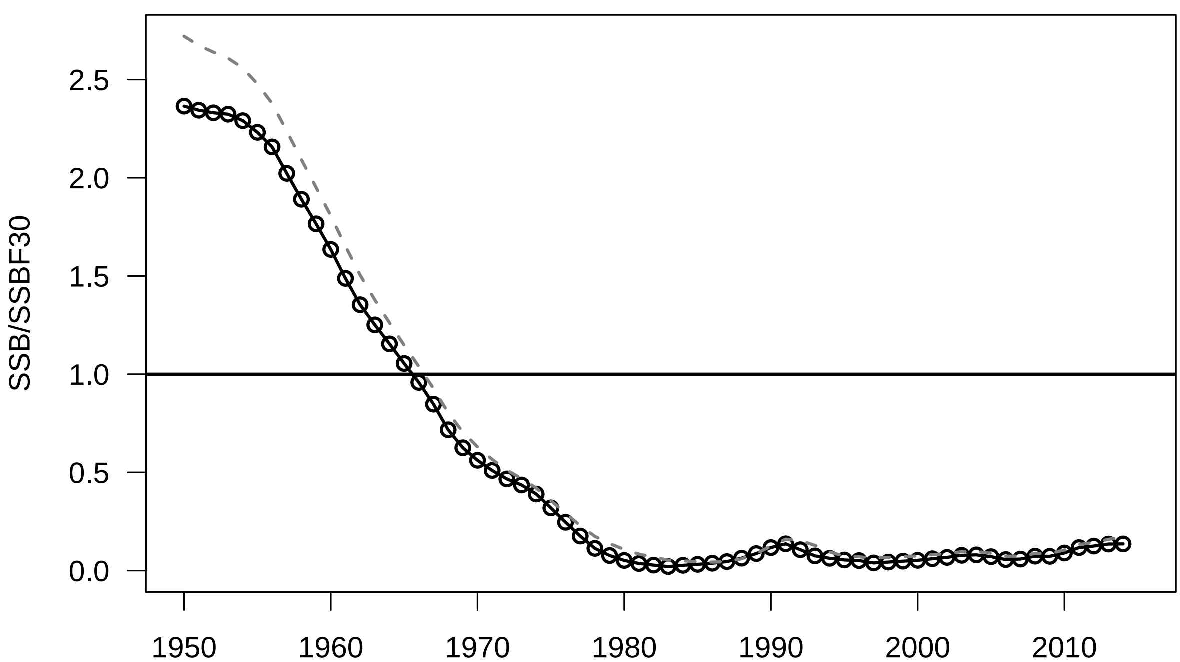


Figure 49. Sensitivity to various changes to fishery dependent indices (sensitivity runs S1, S3, S4, and S25). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

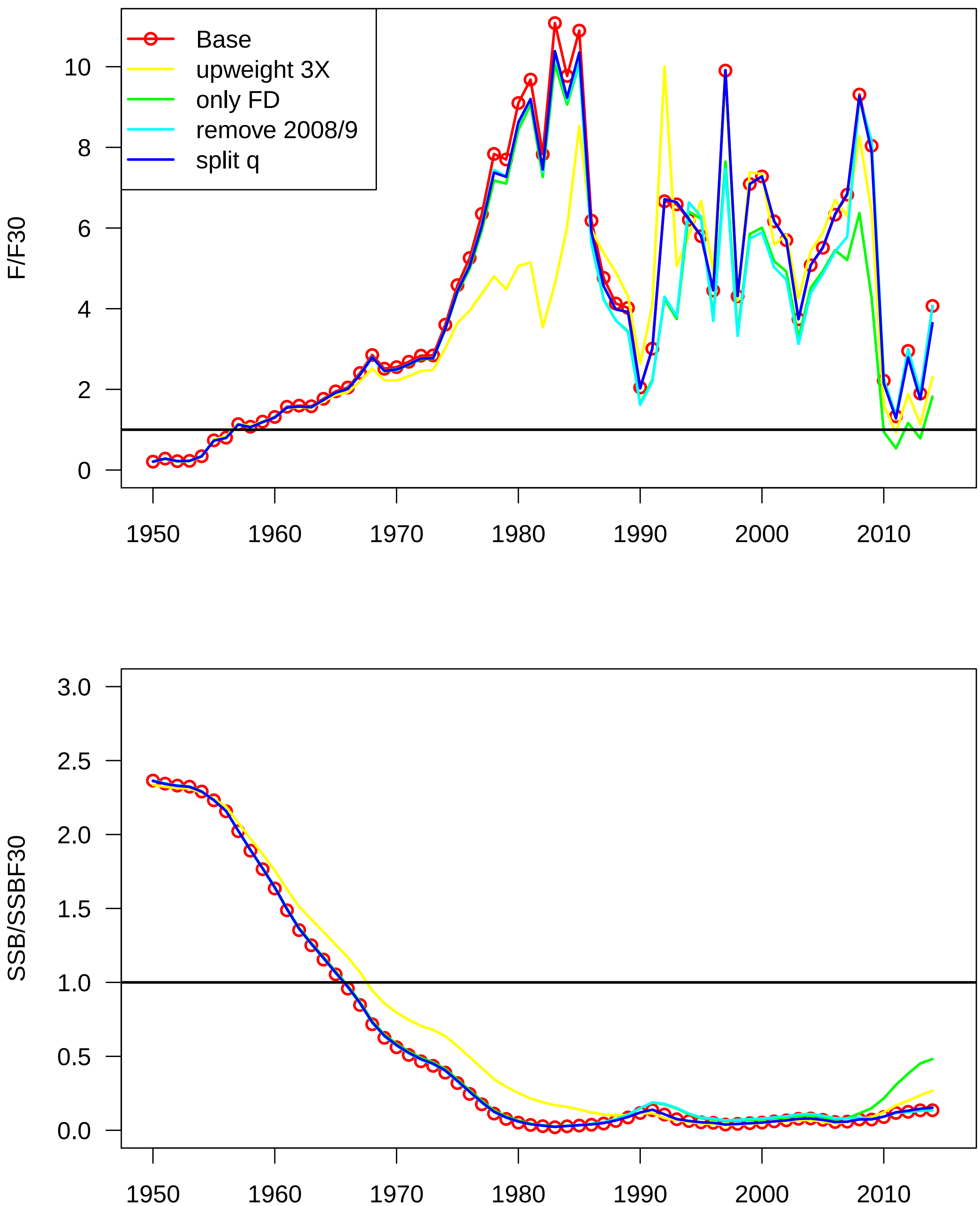


Figure 50. Sensitivity to not fixing selectivities (sensitivity run S27). Top panel: Ratio of F to $F_{30\%}$*. Bottom panel: Ratio of* SSB *to* $SSB_{F30\%}$.

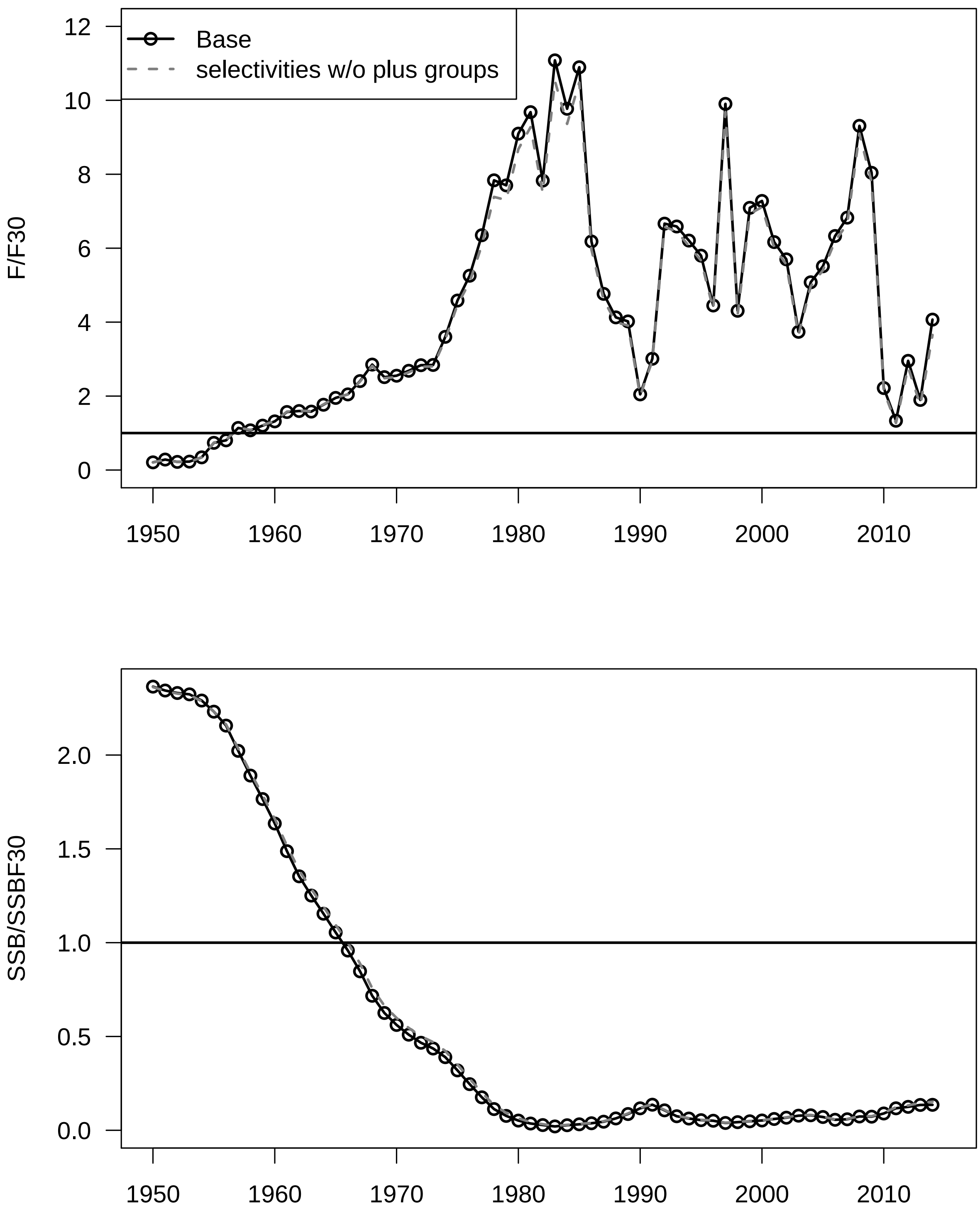


Figure 51. Sensitivity to dropping or truncating headboat discard index (sensitivity runs S12 and S16). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

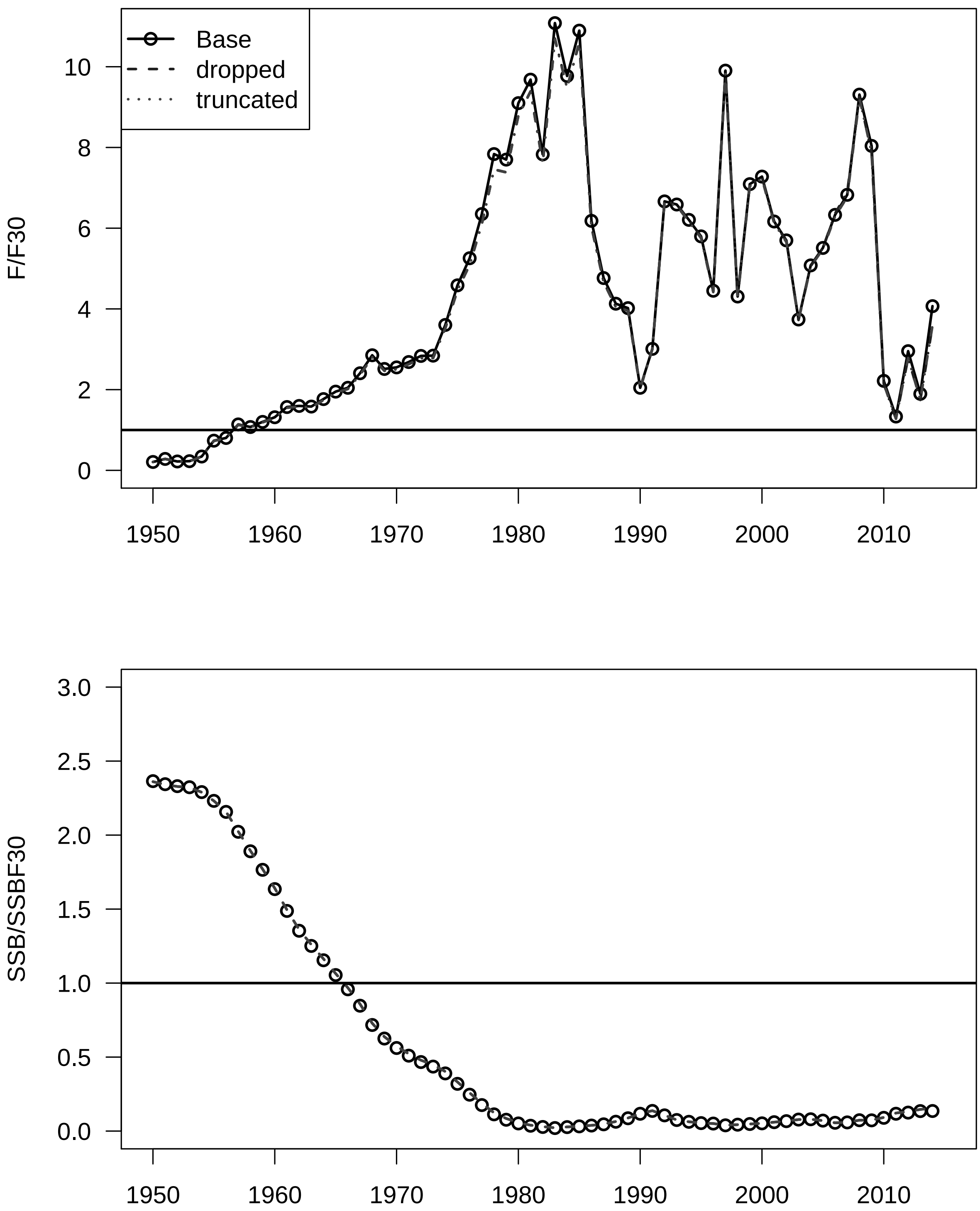


Figure 52. Sensitivity to higher or lower estimates of landings and discards (sensitivity runs S17–S20). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

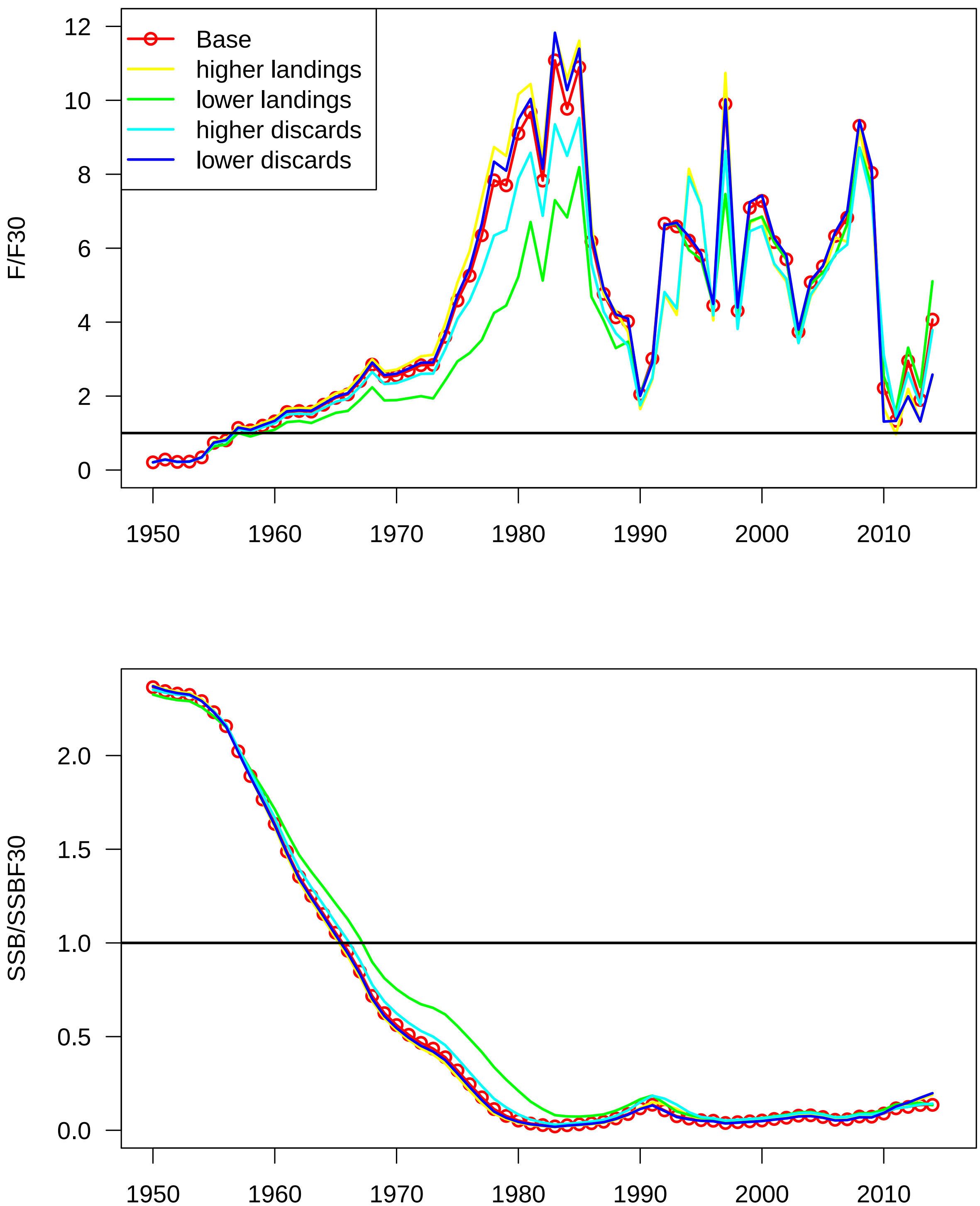


Figure 53. Sensitivity to smoothed 1984 and 1985 MRIP landings (sensitivity run S10). Top panel: Ratio of F to $F_{30\%}$. *Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

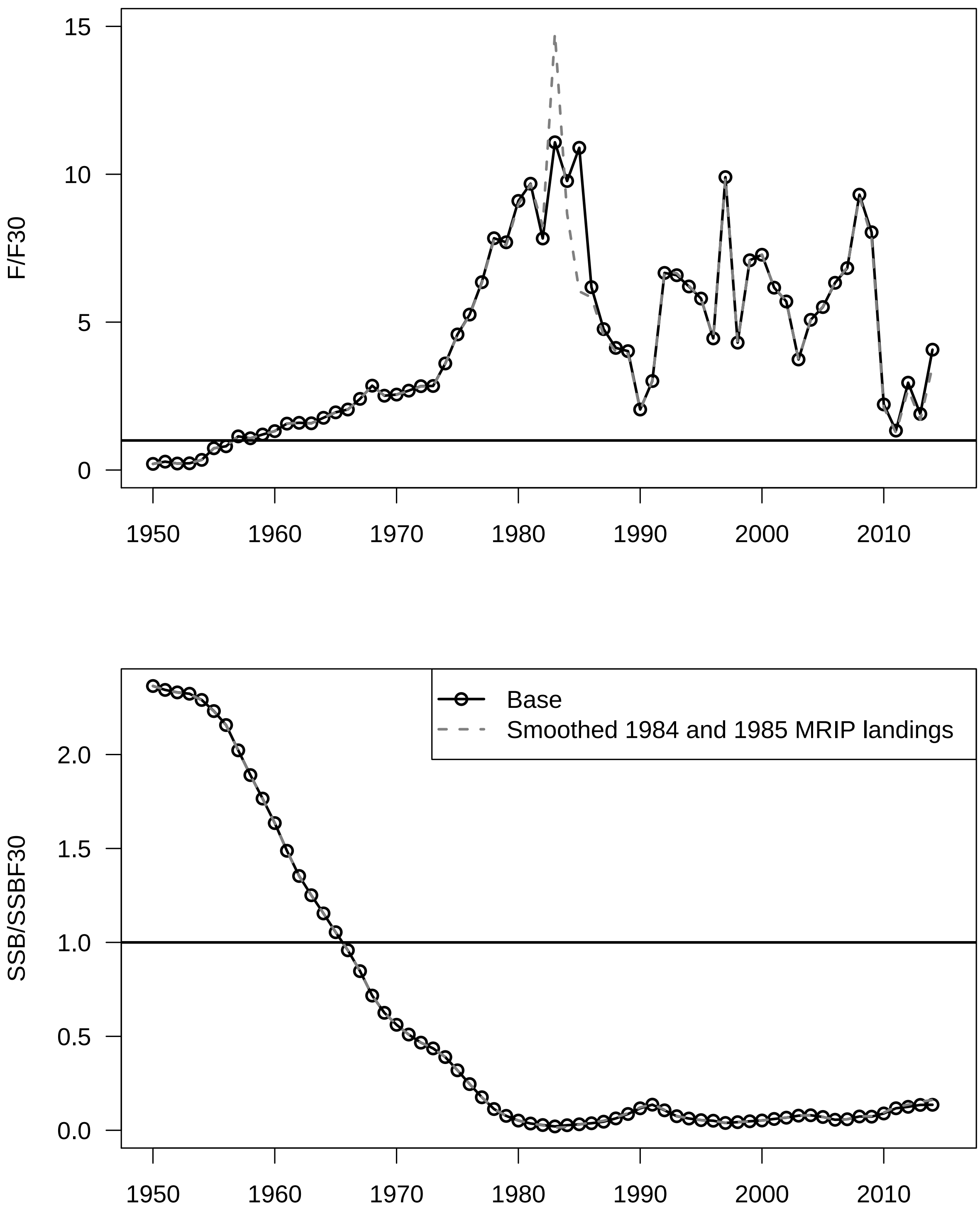


Figure 54. Sensitivity to continuity assumptions from SEDAR 24 (sensitivity run S24). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

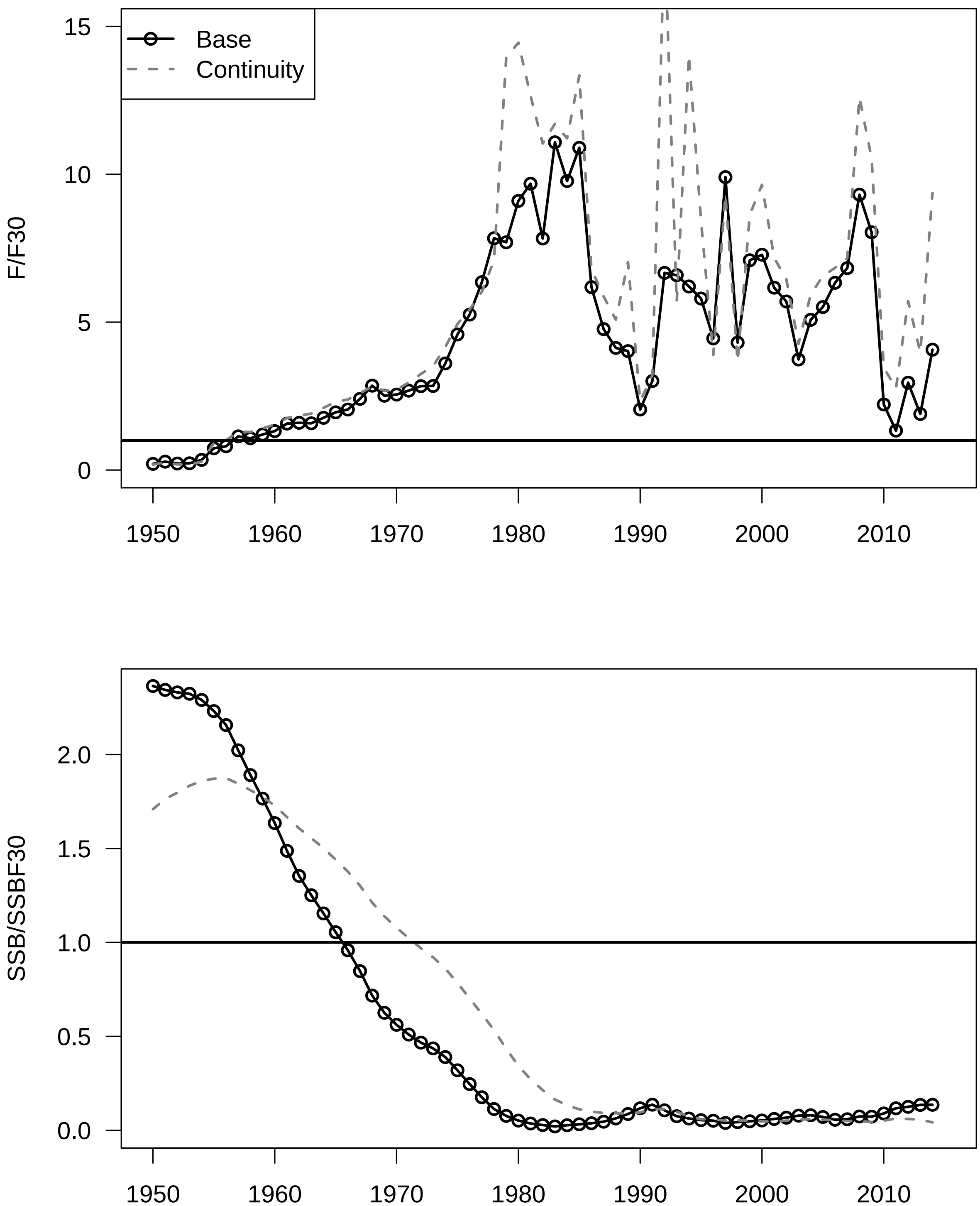


Figure 55. Phase plot of terminal status indicators from sensitivity runs of the Beaufort Assessment Model.

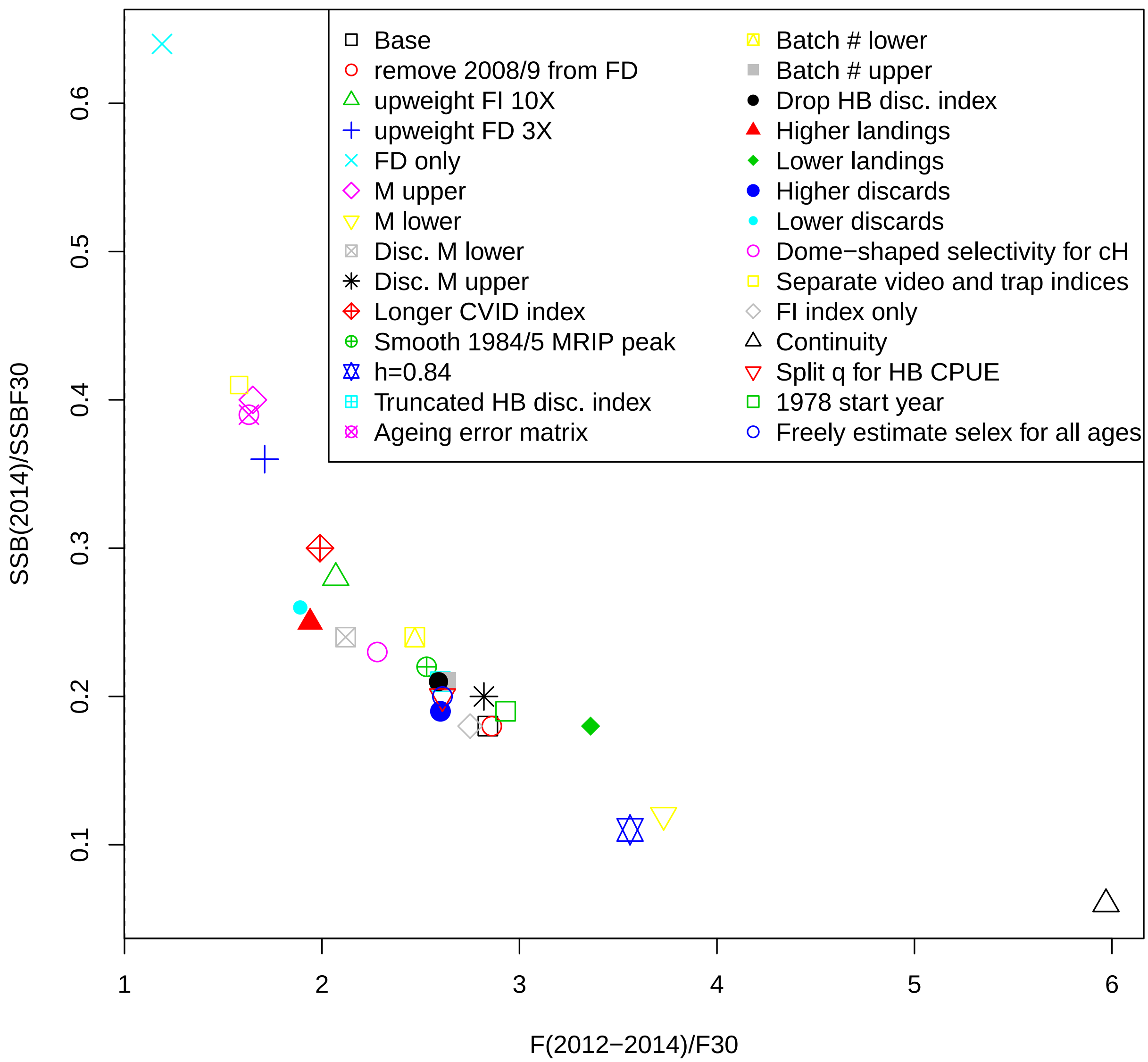


Figure 56. Retrospective analyses. Sensitivity to terminal year of data. Top panel: Fishing mortality rates. Middle panel: Recruits. Bottom panel: Spawning biomass. Closed circles show terminal-year estimates. Imperceptible lines overlap results of the base run.

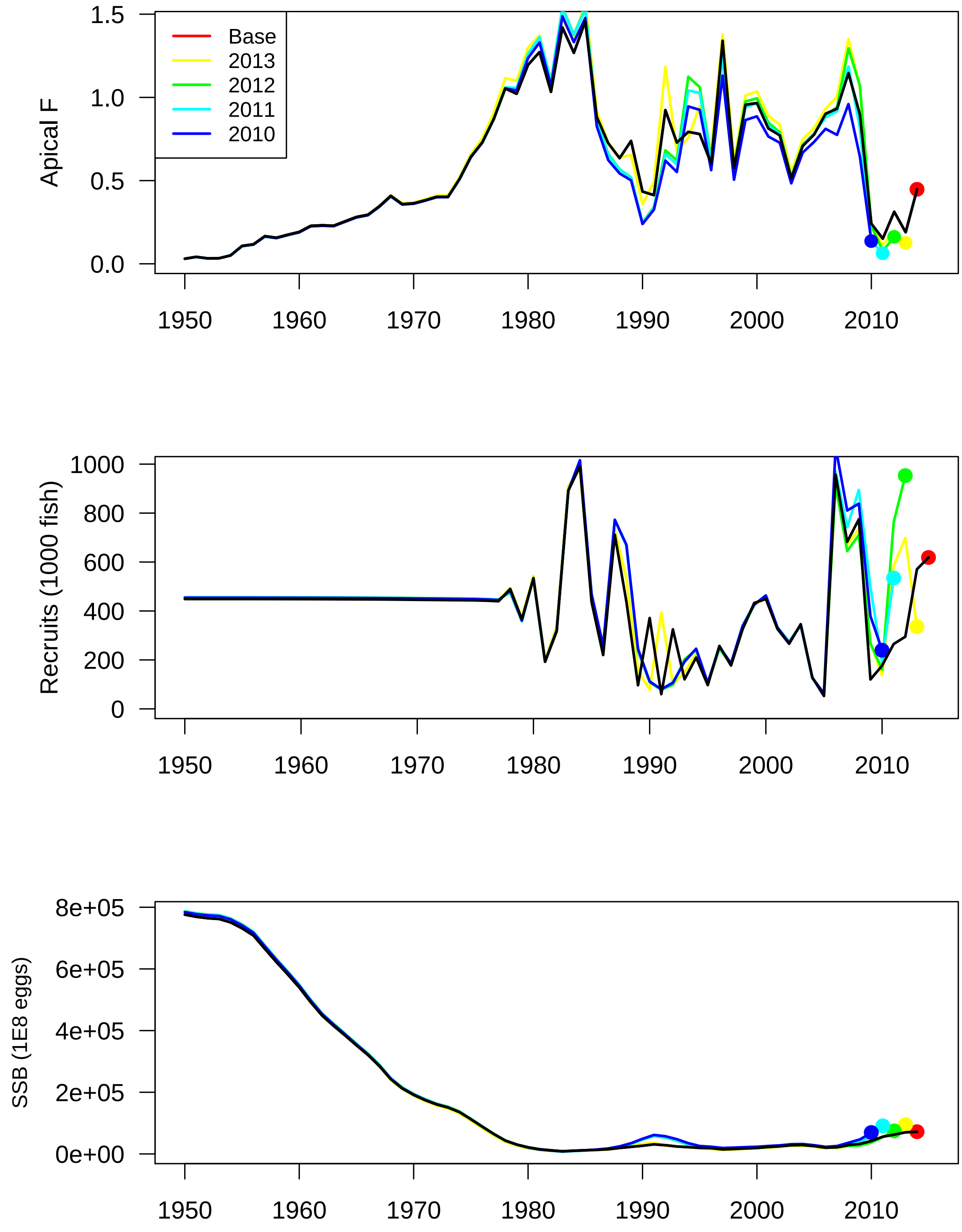


Figure 57. Projection results under scenario 1—fishing mortality rate at $F = 0$. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{F30\%}}$.

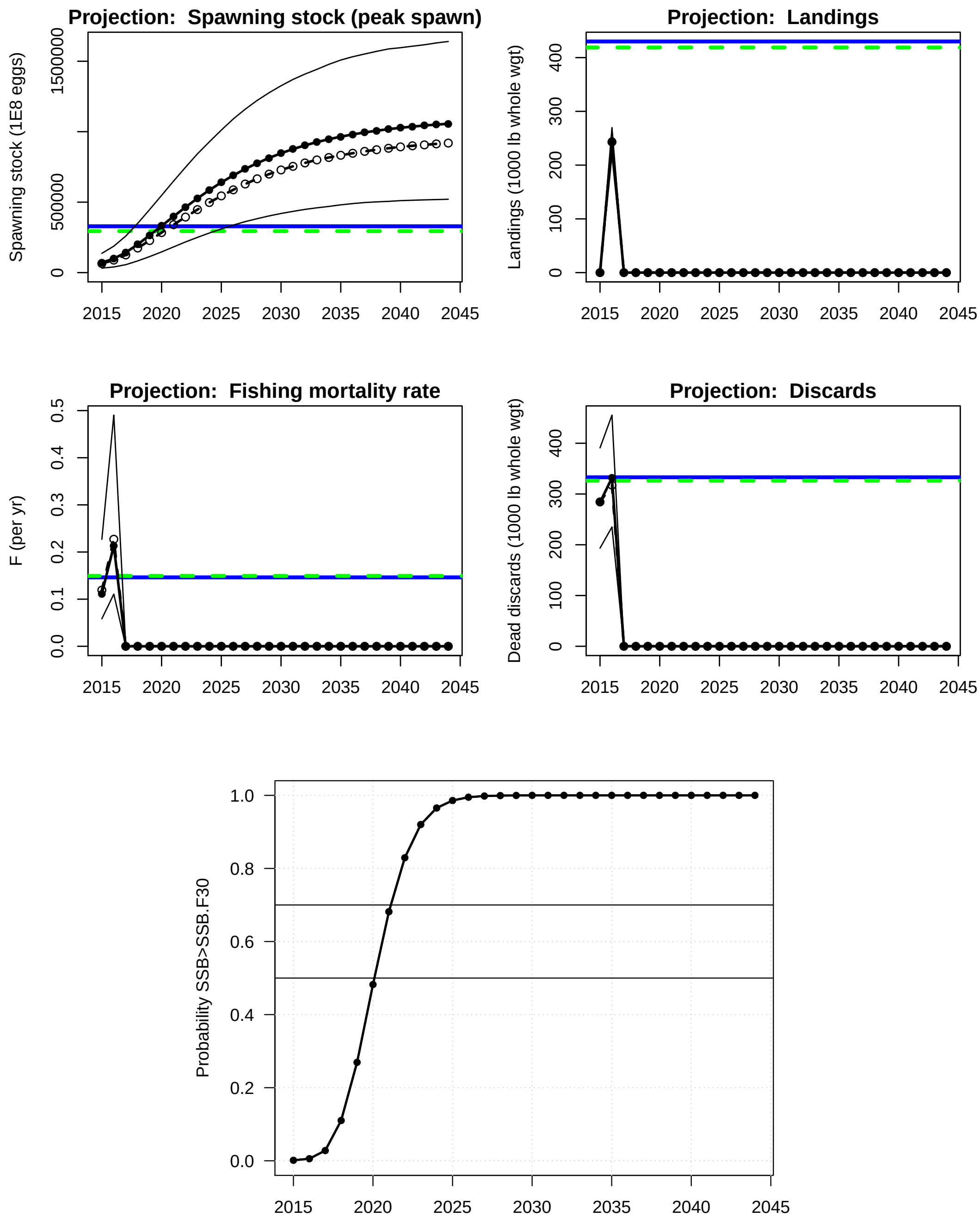


Figure 58. Projection results under scenario 2—fishing mortality rate at $F = F_{\mathrm{current}}$. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{F30\%}}$.

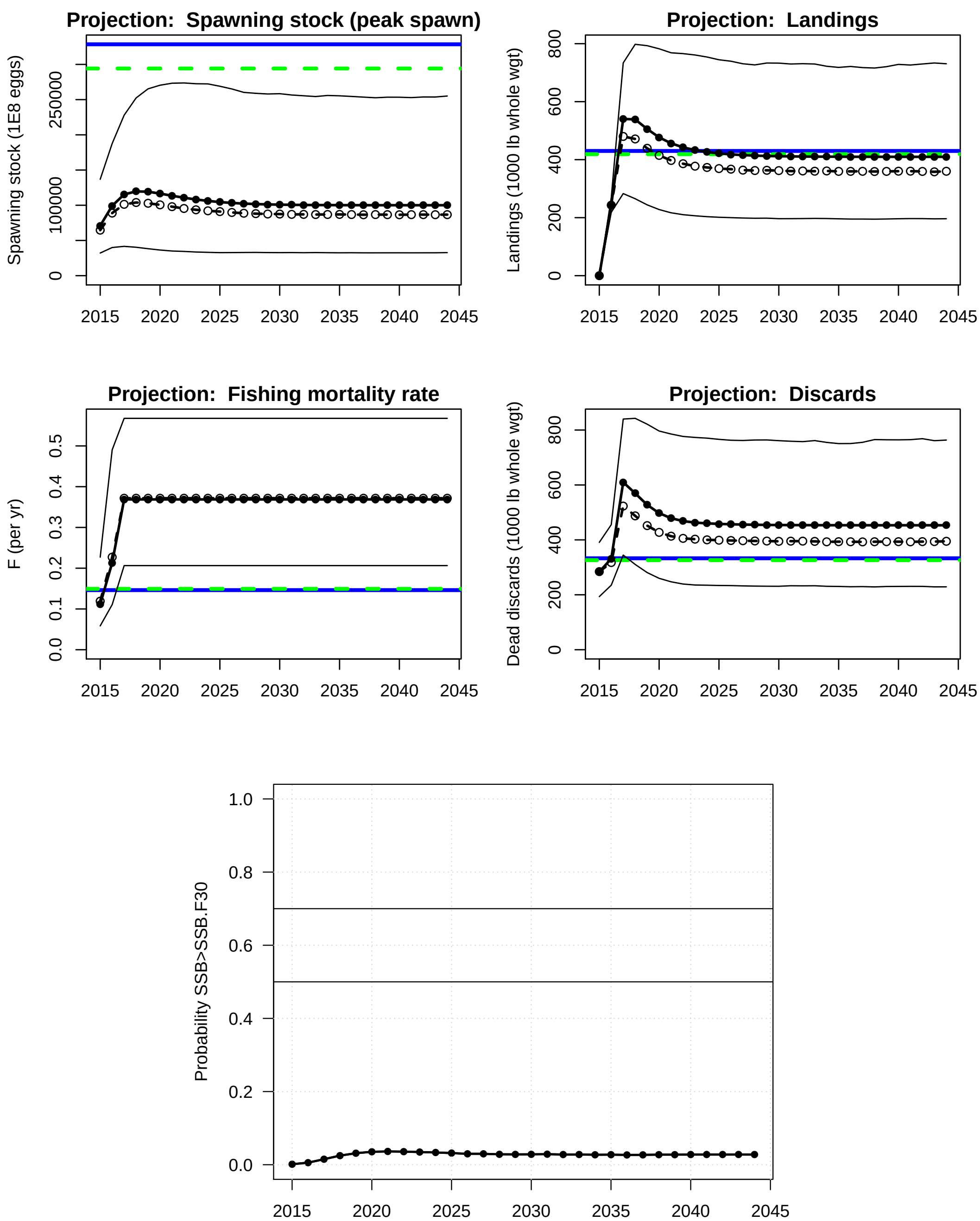


Figure 59. Projection results under scenario 3—fishing mortality rate at $F = F_{30\%}$. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{F30\%}}$.

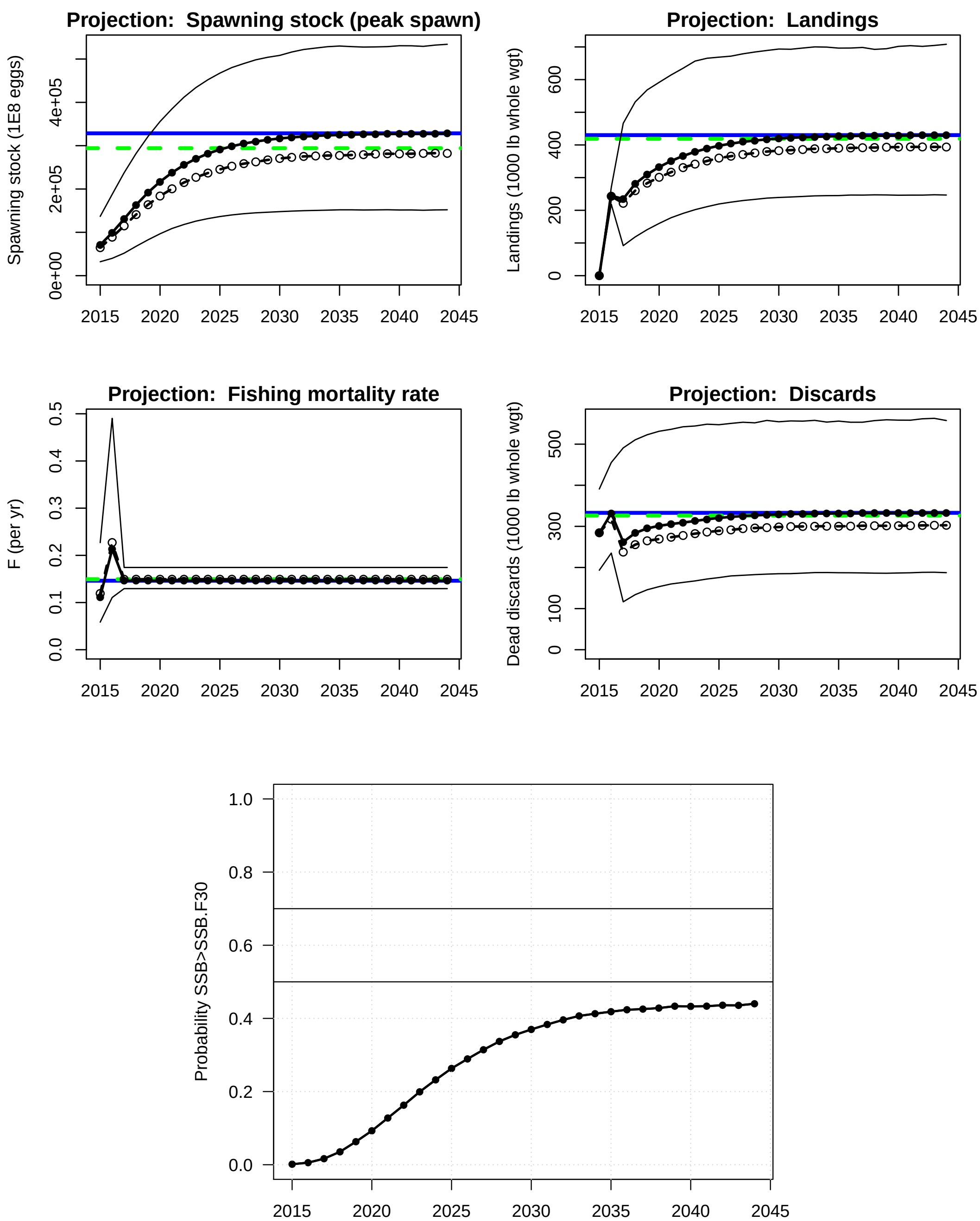
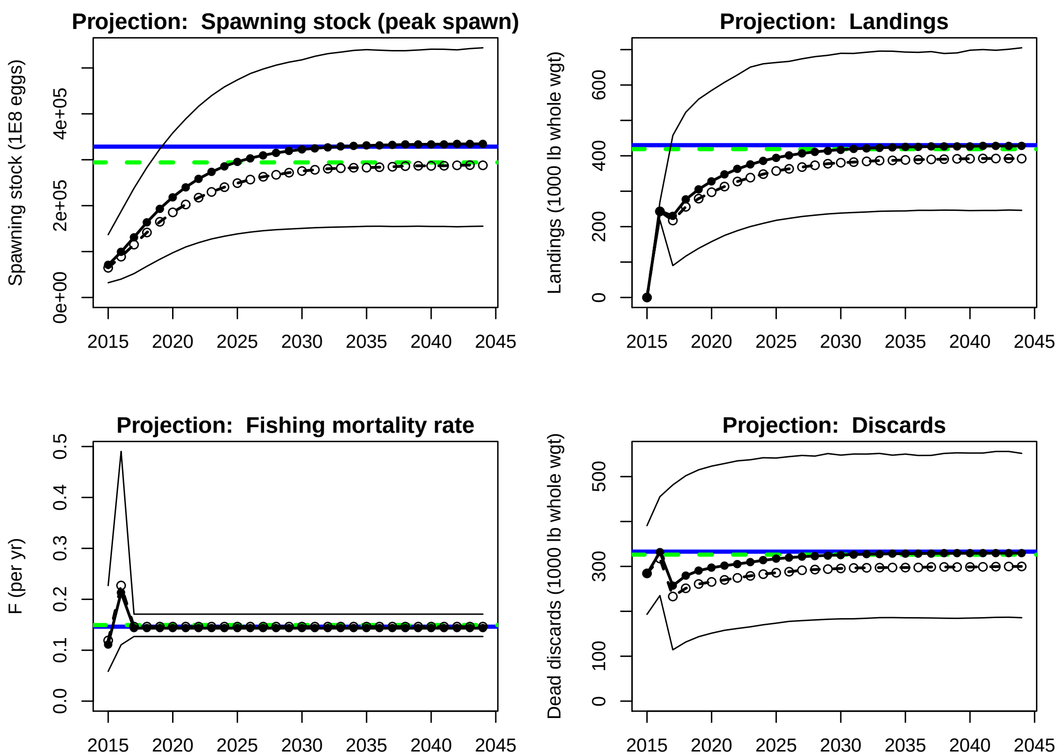


Figure 60. Projection results under scenario 4—fishing mortality rate at $F = 98\% F_{30\%}$. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB_{F30\%}}$.



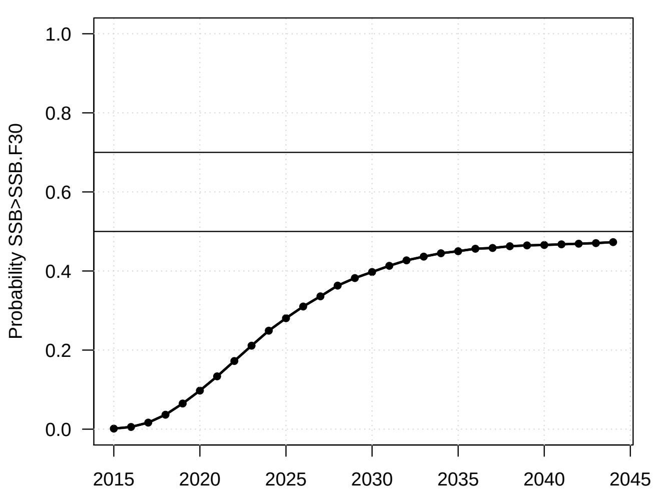


Figure 61. Projection results under scenario 5—fishing mortality rate at $F = F_{\text{rebuild}}$, with rebuilding probability of 0.5 in 2044. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\text{SSB}_{\text{F30\%}}$.

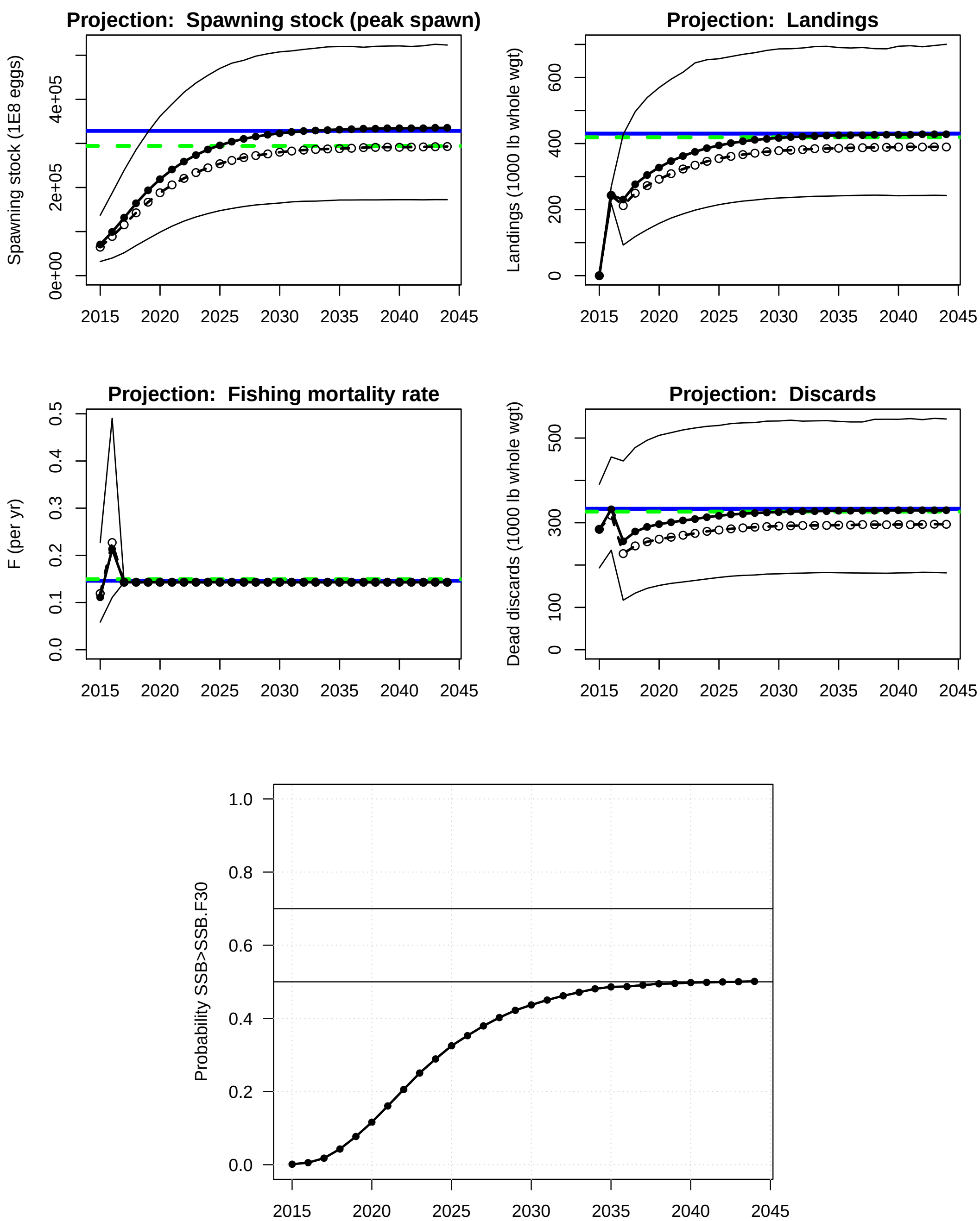


Figure 62. Projection results under scenario 6—fishing mortality rate set to average discard mortality rate only. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{F30\%}}$.

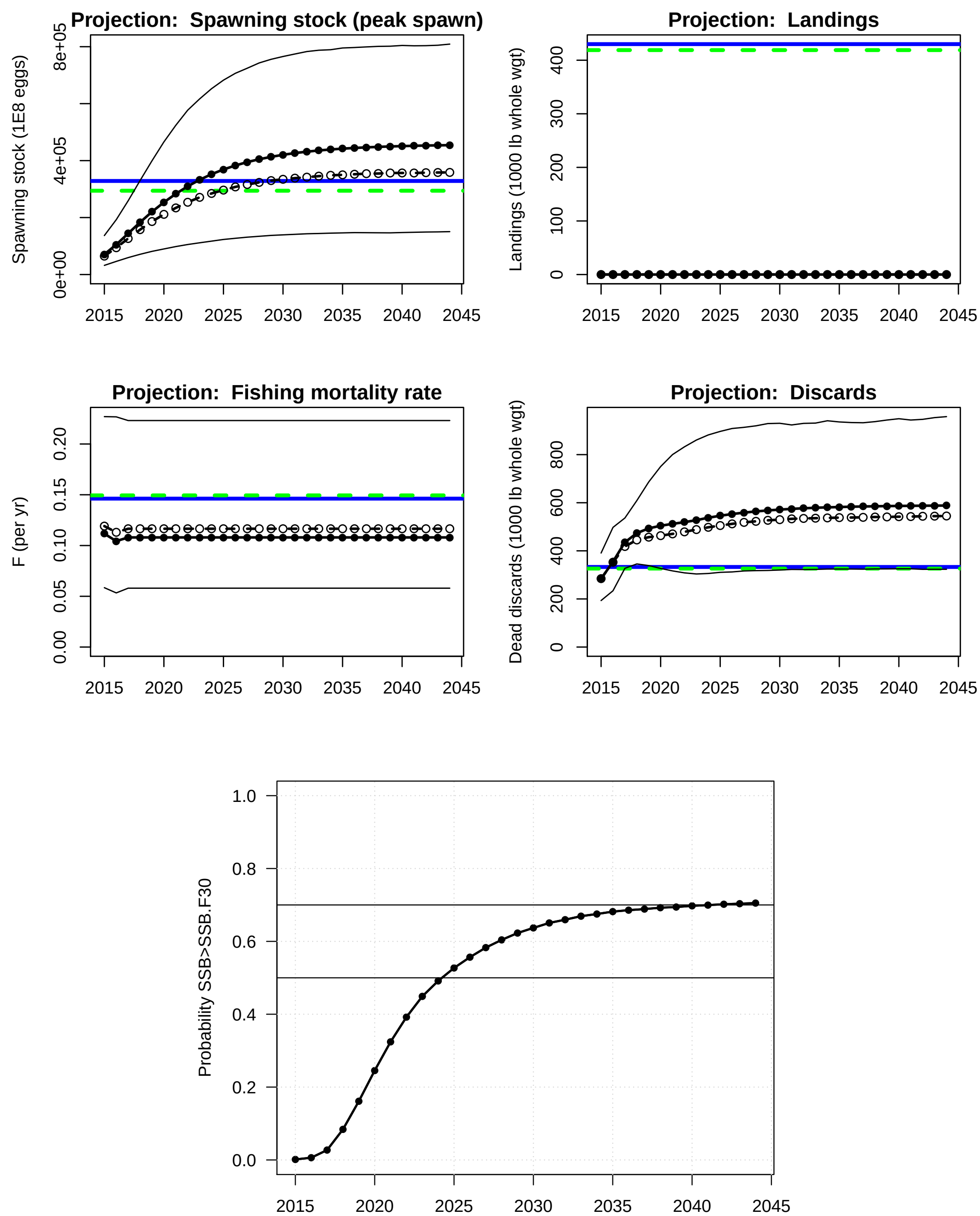


Figure 63. Abundance indices observed (obs.) and predicted (pred.) by the ASPIC surplus production model, and observed total removals (100,000 lbs) for South Atlantic red snapper. Comm = commercial, HB = headboat, HB.at.sea = headboat at sea discards, CVID = combined chevron trap-video index.

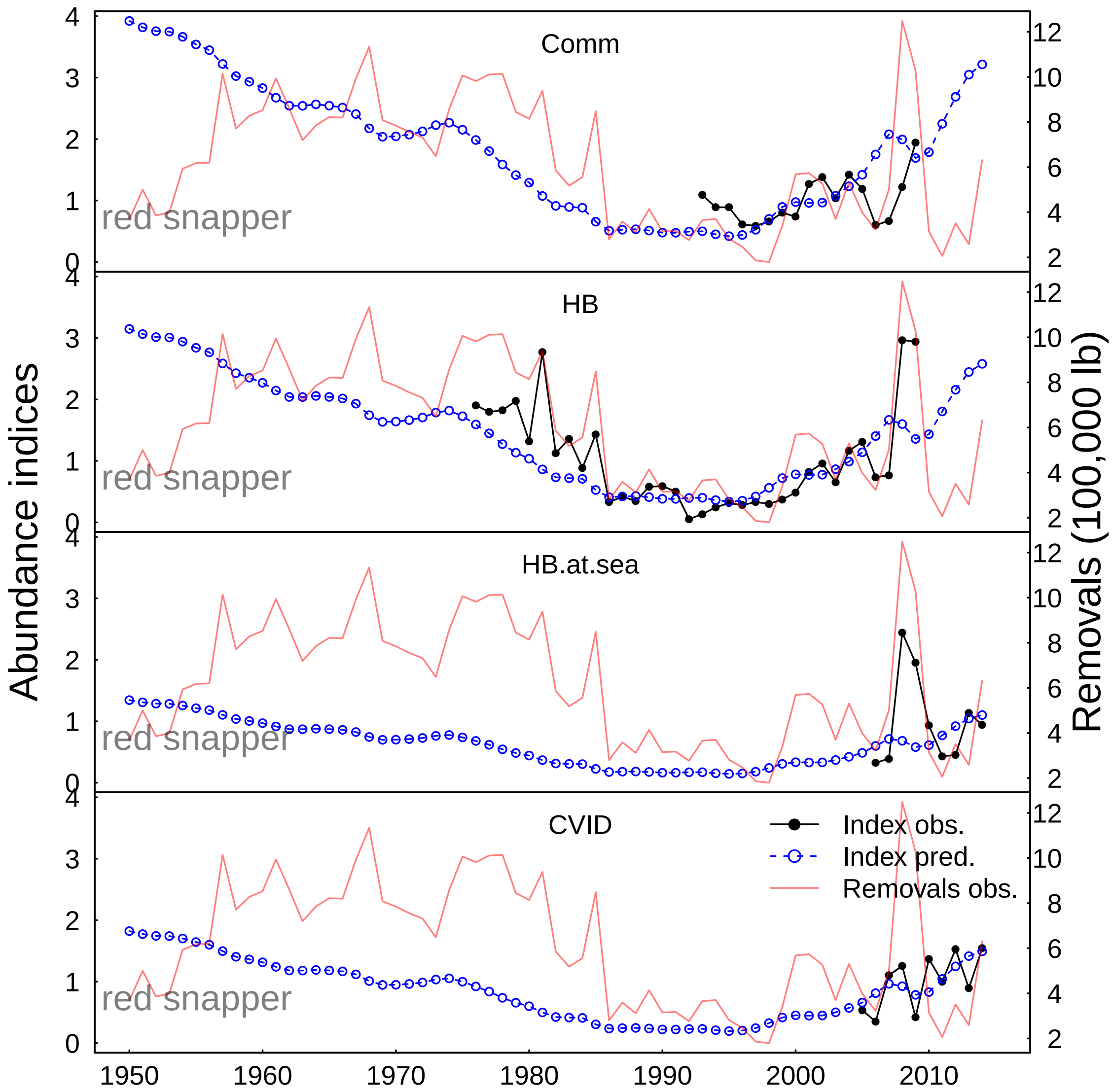


Figure 64. Prior distributions (blue shapes) and estimated parameter values (vertical black lines) for the South Atlantic red snapper ASPIC surplus production model.

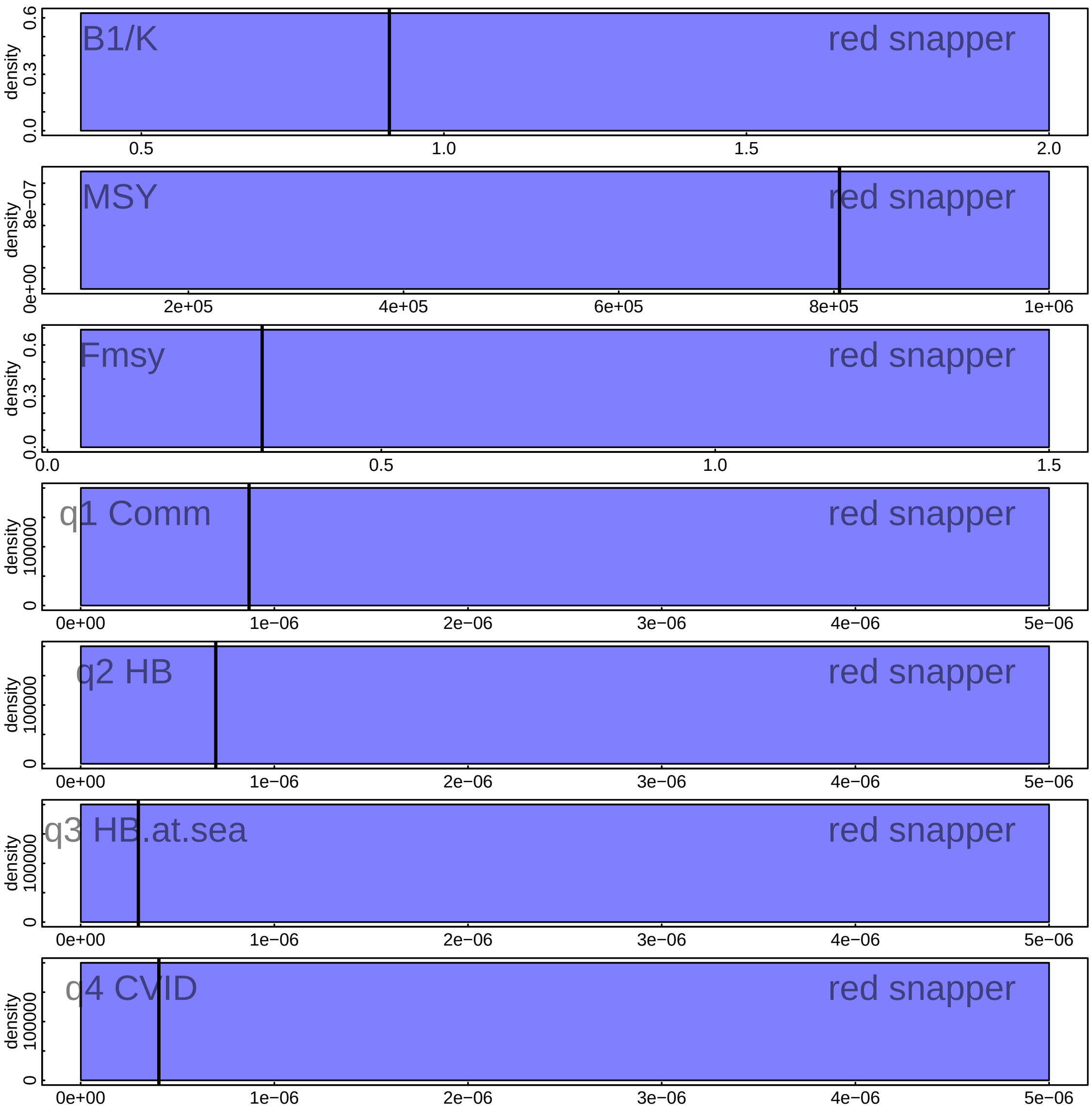


Figure 65. Bootstrap parameter values from ASPIC surplus production model run 320. Thick vertical lines represent ASPIC parameter estimates (solid) and 95% bootstrap percentile confidence intervals (dashed). Thin solid vertical lines are drawn at one in plots of F/F_{MSY} and B/B_{MSY} for reference.

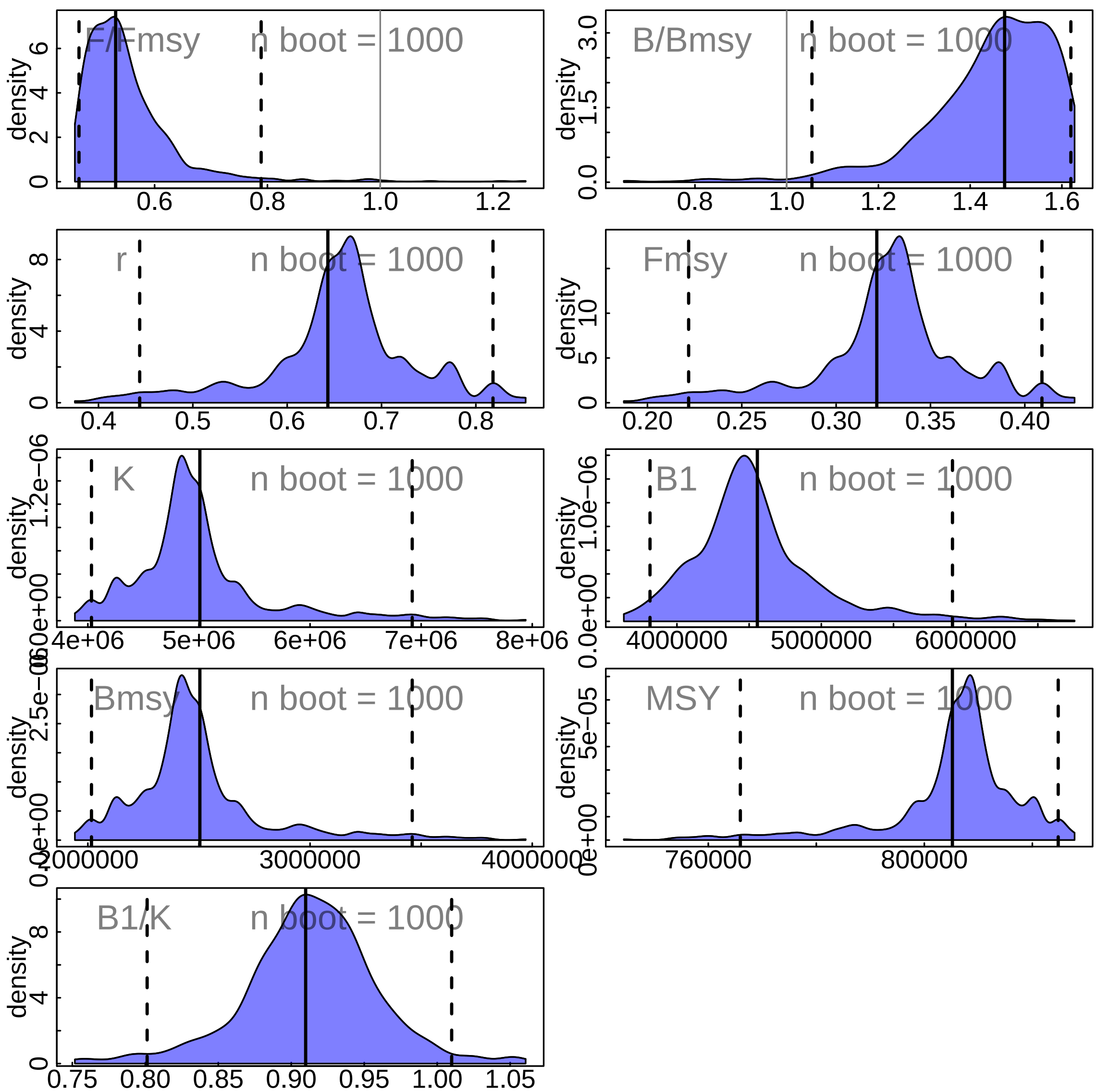
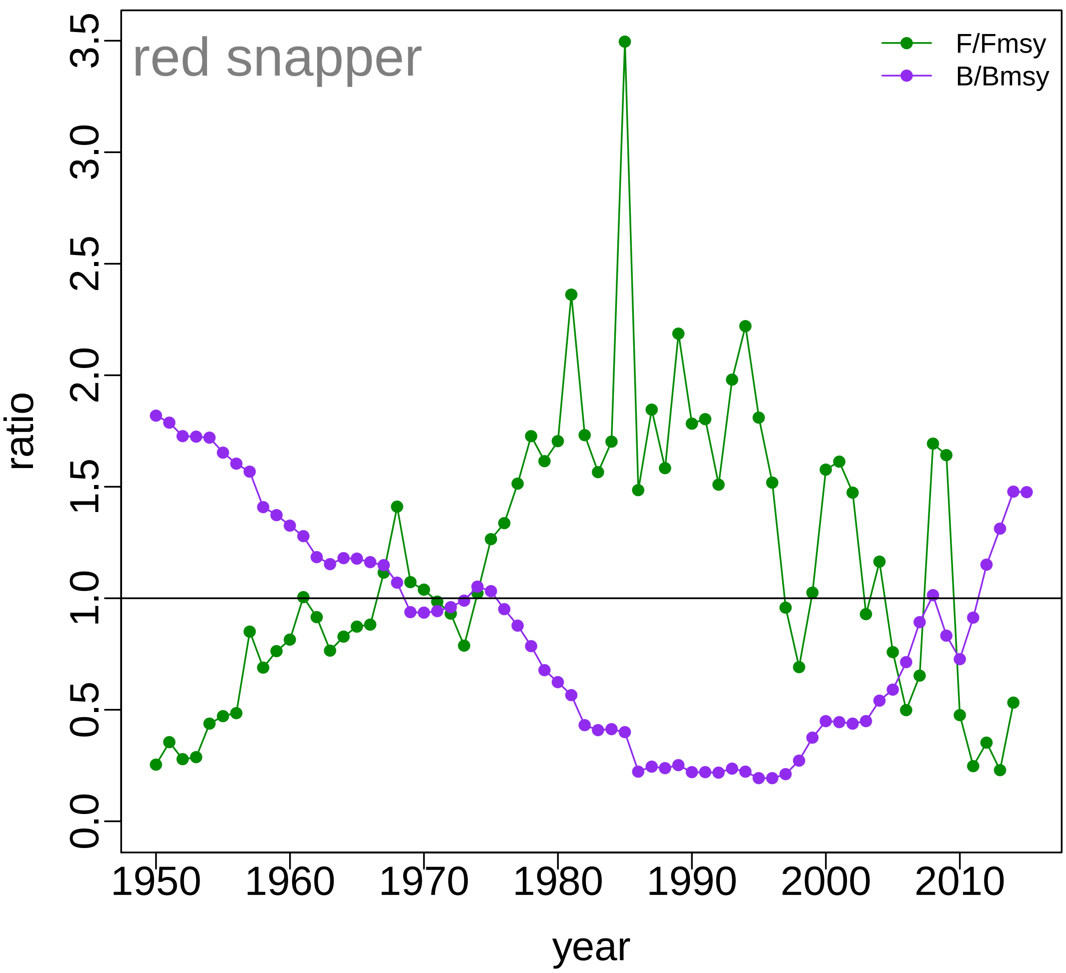


Figure 66. ASPIC surplus production model estimates of relative fishing rate (F/F_{MSY}) and biomass (B/B_{MSY}).



Appendix A Abbreviations and symbols

Table 33. Acronyms and abbreviations used in this report

Symbol	Meaning
ABC	Acceptable Biological Catch
AW	Assessment Workshop (here, for red snapper)
ASY	Average Sustainable Yield
B	Total biomass of stock, conventionally on January 1
BAM	Beaufort Assessment Model (a statistical catch-age formulation)
CPUE	Catch per unit effort; used after adjustment as an index of abundance
CV	Coefficient of variation
CVID	SERFS combined chevron trap and video survey
DW	Data Workshop (here, for red snapper)
F	Instantaneous rate of fishing mortality
$F_{30\%}$	Fishing mortality rate at which $F_{30\%}$ can be attained
F_{MSY}	Fishing mortality rate at which MSY can be attained
FL	State of Florida
FHWAR	The National Survey of Fishing, Hunting, and Wildlife-Associated Recreation Survey
GA	State of Georgia
GLM	Generalized linear model
K	Average size of stock when not exploited by man; carrying capacity
kg	Kilogram(s); 1 kg is about 2.2 lb.
klb	Thousand pounds; thousands of pounds
lb	Pound(s); 1 lb is about 0.454 kg
m	Meter(s); 1 m is about 3.28 feet.
M	Instantaneous rate of natural (non-fishing) mortality
MARMAP	Marine Resources Monitoring, Assessment, and Prediction Program, a fishery-independent data collection program of SCDNR
MCB	Monte Carlo/Bootstrap, an approach to quantifying uncertainty in model results
MFMT	Maximum fishing-mortality threshold; a limit reference point used in U.S. fishery management; often based on F_{MSY}
mm	Millimeter(s); 1 inch = 25.4 mm
MRFSS	Marine Recreational Fisheries Statistics Survey, a data-collection program of NMFS, predecessor of MRIP
MRIP	Marine Recreational Information Program, a data-collection program of NMFS, descended from MRFSS
MSST	Minimum stock-size threshold; a limit reference point used in U.S. fishery management. The SAFMC has defined MSST for red snapper as $(1-M)\mathrm{SSB}_{\mathrm{MSY}} = 0.7\mathrm{SSB}_{\mathrm{MSY}}$.
MSY	Maximum sustainable yield (per year)
mt	Metric ton(s). One mt is 1000 kg, or about 2205 lb.
N	Number of fish in a stock, conventionally on January 1
NC	State of North Carolina
NMFS	National Marine Fisheries Service, same as “NOAA Fisheries Service”
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
OY	Optimum yield; SFA specifies that OY $\leq$ MSY.
PSE	Proportional standard error
R	Recruitment
SAFMC	South Atlantic Fishery Management Council (also, Council)
SC	State of South Carolina
SCDNR	Department of Natural Resources of SC
SDNR	Standard deviation of normalized residuals
SEDAR	SouthEast Data Assessment and Review process
SERFS	Southeast Regional Fishery-independent Sampling
SFA	Sustainable Fisheries Act; the Magnuson–Stevens Act, as amended
SL	Standard length (of a fish)
SRHS	Southeast Region Headboat Survey, conducted by NMFS-Beaufort laboratory
SPR	Spawning potential ratio
SSB	Spawning stock biomass; mature biomass of males and females
$\mathrm{SSB}_{\mathrm{MSY}}$	Level of SSB at which MSY can be attained
$\mathrm{SSB}_{\mathrm{F30\%}}$	Level of SSB at which $F_{30\%}$ can be attained
TIP	Trip Interview Program, a fishery-dependent biodata collection program of NMFS
TL	Total length (of a fish), as opposed to FL (fork length) or SL (standard length)
VPA	Virtual population analysis, an age-structured assessment
WW	Whole weight, as opposed to GW (gutted weight)
yr	Year(s)

Appendix B Parameter estimates from the Beaufort Assessment Model

```
# Number of parameters = 366  Objective function value = -1956.14  Maximum gradient component = 5.96937e-005
# Linf:
911.360000000
# K:
0.240000000000
# t0:
-0.330000000000
# len_cv_val:
0.107710207376
# Linf_L:
927.000000000
# K_L:
0.220000000000
# t0_L:
-0.660000000000
# len_cv_val_L:
0.138554456778
# Linf_20:
938.000000000
# K_20:
0.170000000000
# t0_20:
-2.41000000000
# len_cv_val_20:
0.100000029485
# log_Nage_dev:
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000
# log_R0:
12.7083722877
# steep:
0.990000000000
# rec_sigma:
0.789660384622
# R_autocorr:
0.00000000000
# log_rec_dev:
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 -0.116188568848 0.981085231489 0.686667445781 -0.451643590208 -1.31878122068 -1.48911312114 0.0811371437489
 -0.922992309386 -0.376167909813 -1.10841151212 -0.179202090276 -0.494969822897 0.107396220451 0.379878264774
 0.449377221761 0.0921864288671 -0.0837258040958 0.132548488808 -0.866607533977 -1.68351876147 1.07673003520
 0.757318324702 0.784222329636 -0.400893545137 -1.30002703800 -0.143801874907 -0.205256786125 0.371955484101 1.28619711286
# selpar_A50_cH1:
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# selpar_slope_cH1:
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# selpar_A50_cH2:
3.11132259576
# selpar_slope_cH2:
3.29722528688
# selpar_A50_cH3:
3.16773149230
# selpar_slope_cH3:
2.26236442631
# selpar_A50_HB1:
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# selpar_slope_HB1:
3.53054368964
# selpar_A502_HB1:
3.80005950304
# selpar_slope2_HB1:
0.517452712579
# selpar_A50_HB2:
2.96232318521
# selpar_slope_HB2:
3.93119690694
# selpar_A502_HB2:
2.25027736370
# selpar_slope2_HB2:
0.623141401382
# selpar_A50_HB3:
2.26872846556
# selpar_slope_HB3:
3.35767716522
# selpar_A502_HB3:
2.18384991290
# selpar_slope2_HB3:
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# selpar_A50_GR2:
3.11131983608
# selpar_slope_GR2:
2.71842181046
# selpar_A502_GR2:
2.97495905159
# selpar_slope2_GR2:
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# selpar_A50_GR3:
3.72167063151
```

```
# selpar_slope_GR3:
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# selpar_slope_HB2_D:
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# selpar_A502_HB2_D:
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# selpar_slope2_HB2_D:
1.49507820428
# selpar_A50_HB3_D:
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# selpar_slope_HB3_D:
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# selpar_A502_HB3_D:
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# selpar_slope2_HB3_D:
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# selpar_A50_cH2_D:
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# selpar_slope_cH2_D:
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# selpar_A502_cH2_D:
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# selpar_slope2_cH2_D:
1.03489131779
# selpar_A50_cH3_D:
2.71203348201
# selpar_slope_cH3_D:
1.91711364986
# selpar_A50_CVT:
1.90730549321
# selpar_slope_CVT:
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# log_q_cH:
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# log_q_HB:
-11.8453332840
# log_q_HB_D:
-12.7700652995
# log_q_CVT:
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# M_constant:
0.134000000000
# log_avg_F_cH:
-1.98381803602
# log_F_dev_cH:
 -1.50640443619 -1.19606666129 -1.44779804593 -1.41419831960 -1.00552018315 -1.16337121283 -1.14440240712
 -0.502111212050 -0.780960903034 -0.648434784587 -0.561311694188 -0.311131629420 -0.437655809103 -0.650106776150
 -0.492830411543 -0.383282298421 -0.313110376106 0.0486587829093 0.354139697066 -0.00766574024572 0.0139446490799
 -0.0387686996753 -0.0969873687998 -0.363586238903 0.190944332318 0.574817113965 0.733215705057 1.01835913030
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 0.676887588441 0.600817043938 0.172933692896 0.284213531392 0.0552230838463 -0.311689646371 -0.151579848805
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 0.500384533551 0.932614621671 0.716786005286 0.300996123848 0.524106797328 0.374376210489 0.275972078585
 0.947680107534 1.06128618693 1.22472756668 -2.80995484932 -5.47691169818 -2.78283576102 -1.38423640564 -0.708873090477
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# log_F_dev_HB:
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 -0.0748011913017 -0.0632384700369 0.0431176191044 0.149563624258 0.246508551309 0.368190750885 0.537236484677
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 0.0439287036212 0.0487781883903 0.00470594165115 0.961918734776 0.497089398881 0.731754552306 0.297891330481
 0.681478883611 0.0927081289701 0.339350804695 0.391214325591 0.527670309816 0.477499713349 -0.327838468814
 0.423821917999 0.390563878751 0.519614539358 0.985941504161 0.644212206360 0.782283643821 -3.42347033019 -2.09076149162
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# log_F_dev_GR:
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 -0.295558319401 -0.283999521379 -0.177710329929 -0.0713434319796 0.0255017203914 0.147092735903 0.315971480922
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 1.48147444378 1.67974724108 0.937110843678 0.329739748713 0.370480455580 0.449522531037 -1.37817128845 0.0927475607962
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 1.33812486224 0.893754437193 -5.37375787731 -5.61379561482 -0.0184348910426 -0.640272823186 0.586184086417
# log_avg_F_cH_D:
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# log_F_dev_cH_D:
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 0.846759620716 0.903543604624
# log_avg_F_HB_D:
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# log_F_dev_HB_D:
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  0.0901217913932 0.770686051314 0.839774983440 1.32324787838 0.361352389058 0.442727954169 -0.124655874267
  -0.0370543321215 0.0780347286159 0.641015729367 0.901150739278 -0.0256535397639 2.51436057142 2.71597771725
   1.14292945111 2.51505782970 2.64689926556 3.13112075694 2.95417502377 2.59545904401 2.65113555734 2.31820752654
   1.62250552559
# log_avg_F_GR_D:
```

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-2.71035756204
# log_F_dev_GR_D:
 -2.42503054076 -2.50099432141 -3.38722052527 -1.00203912450 -0.447369409911 0.129573824294 -0.585607931015 -0.844764777417
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 1.63318630174 -0.00432480925527 0.817903500109 1.50061375511 1.47865474555 1.15184581026 -0.702657019111 0.682903492790
  -0.180988960775 0.351429049406
# F_init:
0.0296007209743
```

SEDAR

Southeast Data, Assessment, and Review

SEDAR 41

South Atlantic Red Snapper

SECTION VII: Addenda 2

April 2017

SEDAR
4055 Faber Place Drive, Suite 201
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UNITED STATES DEPARTMENT OF COMMERCE
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April 19, 2017

Memorandum To: Gregg Waugh, Executive Director, SAFMC

From: Bonnie J. Ponwith, Ph.D BRAINERD.THEOPHIL US.R.DR.1365819285 Digitally signed by BRAINERD.THEOPHILUS.R.DR.1365819285 Date: 2017.04.19 13:02:33 -04'00'
Science and Research Director

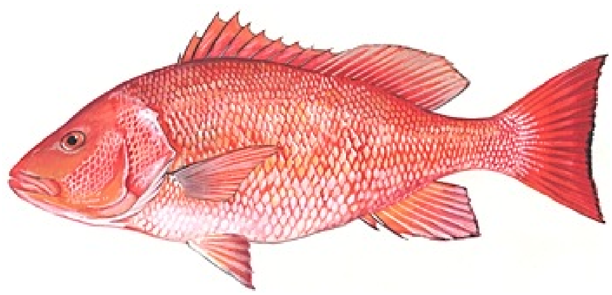
Subject: Red Snapper Assessment Errata

Southeast Fisheries Science Center Analysis discovered an error in the Red Snapper Assessment in the Headboat Discard Index input to the model. The input data were corrected and the model was rerun. The difference between the original run and corrected run is negligible. Monte Carlo Bootstrap uncertainty analysis shows almost no change. The attached report contains the corrected base run.

This information will be discussed at the upcoming SSC meeting.

Stock Assessment of Red Snapper off the Southeastern United States

SEDAR Benchmark Assessment



Southeast Fisheries Science Center

National Marine Fisheries Service

Last revision: April, 2017

Document History

February, 2016 Original release.

March, 2016 This release incorporates some of the corrections made during the Review Workshop, including corrected age composition data from the MARMAP program.

April, 2016 This release incorporates all of the corrections made during the Review Workshop, including corrected chevron trap age composition data. The corrections resulted in a new base run, for which iterative reweighting of the likelihood components and the starting value analysis were re-run. The new base run results, including updated uncertainty analyses and projections are included. The sensitivities and retrospectives, however, are unchanged. The Reviewers did not request that sensitivities or retrospectives be re-run because the base run changes were relatively small.

April, 2017 This release corrects the data used for the Headboat at-sea discard index. The correction resulted in a new base run, for which iterative reweighting of the likelihood components was conducted. The new base run results, including updated uncertainty analyses and projections are included. The sensitivities and retrospectives, however, are unchanged.

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2 Data Review and Update

The input data for this assessment are described below, with focus on modifications from the SEDAR41 DW.

2.1 Data Review

In this benchmark assessment, the Beaufort assessment model (BAM) was fitted to data sources developed during the SEDAR 41 DW with some modifications and additions.

Model input compiled during the DW

- Life history: Life history meristics, population growth, female maturity, proportion female, number of batches at age, size-dependent batch fecundity, and discard mortality
- Landings and discards: Commercial handline landings and discards, Headboat landings and discards, Recreational landings and discards
- Indices of abundance: Commercial handline, Headboat, Headboat discards, SERFS chevron trap, SERFS video

Model input modified or developed after the DW

- Life history: Fishery-dependent growth estimates, Growth estimates during the 20 inch size regulation, Age–specific natural mortality
- Landings and discards: changes to the recreational discards
- Indices of abundance: Fishery–independent indices combined (Chevron trap and Video)
- Length compositions: Commercial handline, Headboat, Recreational
- Age compositions: Commercial handline, Headboat, Recreational, Chevron trap

2.2 Data Update

2.2.1 Life History

Estimates of the von Bertalanffy growth parameters were provided by the DW for the population as a whole: (911.36mm, 0.24yr^{-1}, and -0.33yr). Two alternative von Bertalanffy curves were generated: one for all fisheries when no size limit was in place, and another to represent the fish captured by all fisheries under a 20 inch size limit regulation. Age-specific mortality was updated due to an error in the original calculation which forced the t_0 value to 0. Life-history information is summarized in Tables 1 and 2.

2.2.2 Landings and Discards

The fleet structure to be modeled was decided after the DW. The general recreational fleet comprises the charterboat and private boat fleets, while the headboat fleet stands alone. The decision was made to separate headboat from all other recreational fishing modes because length compositions diverge later in the time series. The general recreational fleet discards contained some zeros (years 1982, 1986, and 1990) that the panel considered unlikely to be accurate due to the magnitude of the surrounding years' values. The decision was made by the panel to fill in the zeros with the lowest observed discards in the regulatory time block of the zero value. Total removals as used in the assessment are in Table 3.

2.2.3 Indices of Abundance

The DW provided a SERFS chevron trap and video index separately. However, because the data are collected from the same sampling platforms (i.e. cameras mounted on the chevron traps), the two indices are not independent measures of abundance. Therefore, the panel decided to combine the two using the Conn (2010) method for combining indices. All indices and their corresponding CVs are shown in Table 4, and Figure 1 shows the indices as recommended by the data workshop plotted with the new CVID index for comparison. Fishery dependent indices of abundance were assumed to have CVs of 0.2, which is consistent with Francis (2003).

2.2.4 Length Compositions

Length compositions for all data sources were developed in 3-cm bins over the range 21–99 cm (labeled at bin center). All lengths below and above the minimum and maximum bins were pooled. The commercial handline, general recreational and headboat lengths were weighted by the region and landings (SEDAR41-AW05 2015). For inclusion, length compositions in any given year had to meet the sample size criteria of $nfish > 30$ and $ntrips \geq 10$ (Table 5). Furthermore, the AW panel decided to eliminate length comps where age comps were available. There were conflicts between the length compositions and age compositions, and the panel thought, given the relative ease of ageing this species and the fact the model is age-structured, the age compositions would provide more informative signals of year-class strength and better represent the catch in each fleet or survey.

2.2.5 Age Compositions

For age composition data, the upper range was pooled at 13 years old because a very small proportion of the data exist past age 13. The age compositions were weighted by the length compositions in attempt to address bias in selection of fish to be aged. For inclusion, age compositions in any given year had to meet the sample size criteria of $nfish > 10$ and $ntrips \geq 10$ (Table 5). Age composition was preferred over length composition when both were available from a given fleet in a given year. Age compositions were further corrected at the Review Workshop (SEDAR41-RW07 2016).

2.2.6 Additional Data Considerations

Size limits were in place beginning in 1983 (12 inch minimum size limit TL), and changed in 1992 (20 inch minimum size limit TL). A moratorium was put in place for Red Snapper in 2010, and three subsequent mini-seasons were allowed (2011-2014) with no size limit. The panel examined size composition data and determined that three time blocks should be used to account for size limits, or the lack thereof: 1950-1991, 1992-2009, and 2010-2014. Data available for this assessment are summarized in Tables 1–5.

3 Stock Assessment Methods

3.1 Overview

The primary model discussed during the Assessment Workshop (AW) was a statistical catch-age model implemented using the Beaufort Assessment Model (BAM) software (Williams and Shertzer 2015). BAM applies a statistical catch-age formulation, coded using AD Model Builder (Fournier et al. 2012). BAM is referred to as an integrated analysis because it uses all population dynamics-relevant data (e.g. removals, length and age compositions, and indices of abundance) in a single modeling framework. In contrast, production models (e.g. ASPIC or ASPM) or catch curve analyses only use subsets of the available data and often require simplifying assumptions. In essence, the catch-age model simulates a population forward in time while including fishing processes (Quinn and Deriso 1999; Shertzer et al. 2008). Quantities to be estimated are systematically varied until characteristics of the simulated population matches available data on the real population. The model is similar in structure to Stock Synthesis (Methot 1989; 2009). Versions of BAM have been used in previous SEDAR assessments of reef fishes in the U.S. South Atlantic, such as Red Porgy, Black Sea Bass, Tilefish, Blueline Tilefish, Gag, Greater Amberjack, Red Grouper, Snowy Grouper, and Vermilion Snapper, as well as in the previous SEDAR assessments of Red Snapper (SEDAR24 2010). In addition, a surplus production model implemented using ASPIC and a catch curve analysis (SEDAR41-AW08 2015) were used to provide supplementary information.

3.2 Data Sources

The catch-age model included data from three fleets that caught Red Snapper in southeastern U.S. waters: general recreational (charter and private boat), commercial handlines (hook-and-line), and recreational headboats. The model was fitted to data on annual landings (in numbers for the recreational fleets, in whole weight for commercial fleet); annual discards (in numbers for all fleets), annual length compositions of removals; annual age compositions of landings and surveys; three fishery dependent indices of abundance (commercial handlines, headboat, and headboat discards); and one fishery independent index of abundance (combined SERFS chevron trap and SERFS video index). Removals included landings and dead discards, assuming the mortality rates provided by the Data Workshop. Data used in the model are tabulated in §2 of this report.

3.3 Model Configuration

The assessment time period was 1950–2014. A general description of the assessment model follows.

3.4 Stock dynamics

In the assessment model, new biomass was acquired through growth and recruitment, while abundance of existing cohorts experienced exponential decay from fishing and natural mortality. The population was assumed closed to immigration and emigration. The model included age classes $1 - 20^+$, where the oldest age class 20^+ allowed for the accumulation of fish (i.e., plus group).

3.5 Initialization

Initial (1950) numbers at age assumed the stable age structure computed from expected recruitment and the initial, age-specific total mortality rate. That initial mortality was the sum of natural mortality and fishing mortality, where fishing mortality was the product of an initial fishing rate (F_{init}) and F-weighted average selectivity. The initial fishing rate was estimated using a prior centered around $F_{\text{init}} = 0.03$. The assumption matches what was used for SEDAR24 with the justification that the value should be small given the relatively low volume of landings prior to the assessment period. The initial recruitment in 1950 was assumed to be the expected value from the spawner-recruit curve. For the remainder of the initialization period (1950–1977), recruitment was assumed equal to expected values. Without sufficient age/length composition data prior to 1978, there is little information to estimate those historic recruitment deviations with accuracy.

3.6 Natural mortality rate

The natural mortality rate (M) was assumed constant over time, but decreasing with age. The form of M as a function of age was based on Charnov et al. (2013), a change from SEDAR24 which based natural mortality on the findings of Lorenzen (1996). The Charnov et al. (2013) approach inversely relates the natural mortality at age to somatic growth. As in previous SEDAR assessments, the age-dependent estimates of M_a were rescaled to provide the same fraction of fish surviving from age 4 through the oldest observed age (51 yr) as would occur with constant $M = 0.134$. This approach using cumulative mortality allows that fraction at the oldest age to be consistent with the findings of Then et al. (2014).

3.7 Growth

Mean size at age of the population, fishery removals under no size limit, and fishery removals under a 20 inch size limit (total length, TL) were modeled with the von Bertalanffy equation, and weight at age (whole weight, WW) was modeled as a function of total length (Figure 2, Table 2). Parameters of growth and conversions (TL-WW) were treated as input to the assessment model. For fitting length composition data, the distribution of size at age was assumed normal with a CV estimated by the assessment model for each growth curve.

3.8 Female maturity and sex ratio

Female maturity was modeled with a logistic function; parameters for this model and a vector of maturity at age were provided by the DW and treated as input to the assessment model (Table 2). The sex ratio was assumed to be 50:50, as recommended by the DW.

3.9 Spawning stock

Spawning biomass was modeled as population fecundity (number of eggs). For Red Snapper, peak spawning was considered to occur at the end of June. This included information on batch size as a function of age, as well as information on the number of annual batches as a function of age (SEDAR41-DW49 (2015) and Fitzhugh et al. (2012)).

3.10 Recruitment

Expected recruitment of age-1 fish was predicted from spawning biomass using the Beverton–Holt spawner-recruit model. Steepness, h, is a key parameter of this model, and unfortunately it is often difficult to estimate reliably (Conn et al. 2010). In this assessment, many initial attempts to estimate steepness resulted in a value near its upper bound of 1.0, indicating that the data were insufficient for estimation. Likelihood profiling showed that the value was likely above 0.92, and was unreliably estimated between 0.92 and 0.98. The AW Panel decided to assume an average annual recruitment while estimating lognormal deviations around that average. This was achieved by fixing steepness at $h = 0.99$.

3.11 Landings

Time series of landings from three fleets were modeled: commercial handline (1950–2014), general recreational (1955–2014), and headboat (1955–2014). Landings were modeled with the Baranov catch equation (Baranov 1918) and were fitted in either weight or numbers, depending on how the data were collected (1000 lb whole weight for commercial fleets, and 1000 fish for recreational). The DW provided observed landings back to the first assessment year (1950) for the commercial fleet and back to 1955 for the recreational fleets. However, sampling of headboats began in 1972 and other recreational sectors in 1981. Thus, historic landings of the recreational fleets were estimated indirectly by the DW using the FHWAR ratio method (SEDAR41-DW17). Historic landings were considered (and treated) in this assessment as a primary source of uncertainty.

3.12 Discards

As with landings, discard mortalities (in units of 1000 fish) were modeled with the Baranov catch equation (Baranov 1918), which required estimates of discard selectivities and release mortality probabilities. Discards were assumed to have fleet-specific, year-specific mortality probabilities, as suggested by the DW. Until 2007, the rate for commercial handlines was 0.48, and 0.38 thereafter. Until 2011, the general recreational and headboat rate was 0.37, with 0.285 thereafter. Annual discard mortalities, as fit by the model, were computed by multiplying total discards (tabulated in the DW report) by the fleet-specific and year-specific discard mortality rate. For general recreational and headboat fleets, discard time series were assumed to begin in 1981; for the commercial handlines fleet, discards were modeled starting in 1992 corresponding to the implementation of the 20-inch size limit.

3.13 Fishing

For each time series of removals (landings and discards), the assessment model estimated a separate full fishing mortality rate (F). Age-specific rates were then computed as the product of full F and selectivity at age. The across-fleet annual F was represented by apical F, computed as the maximum of F at age summed across fleets.

3.14 Selectivities

Selectivity curves applied to landings were estimated using a parametric approach. This approach applies plausible structure on the shape of the curves, and achieves greater parsimony than occurs with unique parameters for each age. Flat-topped selectivities were modeled as a two-parameter logistic function. Dome-shaped selectivities were modeled by combining two logistic functions: a two-parameter logistic function to describe the ascending limb of the curve, and a two-parameter logistic function to describe the descending limb. To model landings, the AW Panel recommended flat-topped selectivity for commercial handlines and dome-shaped selectivity for headboat and the general recreational fleets.

The assessment panel devoted substantial discussion and exploration to the pattern (flat-topped or dome-shaped) of selectivity at age. Several working papers and scientific literature (SEDAR24-AW05, SEDAR24-AW09, SEDAR24-AW12, SEDAR31-AW04, SEDAR31-AW12, SEDAR41-DW50, SEDAR41-DW08, Patterson et al. (2012), Wells et al. (2008), and Mitchell et al. (2014)) helped guide the panel's decisions by providing insight into selectivity based on length and age compositions, depth distributions of fishing effort, skill levels of fishermen, and how circumstances contrasted between the Atlantic and Gulf of Mexico. The choice of flat-topped selectivity for commercial handlines landings and dome-shaped for all others was based on several criteria. Two related considerations were the fleet-specific depths of fishing effort and the distribution of age at depth. In general, the commercial handlines fleet fish

in deeper water than other fleets, and although there was only weak correlation between depth and age of older fish (5^+), younger fish (1–5) were more readily caught in shallower depths (SEDAR24-AW05, and Mitchell et al. (2014)). It was also suggested that commercial gear and fishermen can better handle larger fish (SEDAR24-AW12). Catch curve data were consistent with the hypothesis that older fish are more vulnerable to the commercial handlines fleet than to recreational fleets (SEDAR41-AW08 2015).

Selectivity of each fleet was fixed within each block of size-limit regulations, but was permitted to vary among blocks where possible or reasonable. Fisheries experienced four blocks of size-limit regulations (no limit prior to 1983, 12-inch limit during 1983–1991, 20-inch limit during 1992–2009, and no size limit during the moratorium/miniseasons 2010–2014). However, the panel combined blocks one and two after seeing that the 12-inch size limit had a negligible effect on the selectivity pattern. Age and length composition data are critical for estimating selectivity parameters, and ideally, a model would have sufficient composition data from each fleet over time to estimate distinct selectivities in each period of regulations. That was not the case here, and thus additional assumptions were applied to define selectivities, as follows. Because the general recreational fleet had little age or length composition data prior to 1998, this fleet mirrored the headboat fleet until the final time block. All domed-shaped selectivities meant to characterize landings were configured so as not to allow a selectivity of 0 at older ages, which was considered implausible. Size and age composition data show larger, older fish are caught by all fleets. However, the selectivity functions would reach zero before the plus group age of 20. Therefore, the panel examined the age composition data and used the information they contained to create a plus group for the selectivities. Headboat selectivities were fixed as constant after age 10 at the value estimated for age 10. For the general recreational fleet, the constant age at which we fixed selectivity was 13. These plus groups were consistent with how the age composition data were fitted.

Selectivities of discards were estimated in a similar fashion to the landings in that the general recreational fleet discards mirrored the headboat fleet discards. Both the commercial handline discards and the headboat discards had sufficient length composition to estimate selectivities.

Selectivities of fishery dependent indices were the same as those of the relevant fleet. The fishery independent CVID index selectivity was assumed logistic and informed by the SERFS chevron trap age compositions.

3.15 Indices of abundance

The model was fit to three fishery dependent indices of relative abundance (headboat 1976–2009; headboat discards 2005–2014; and commercial handlines 1993–2009), and one fishery independent index of abundance (SERFS combined video and trap, CVID). Predicted indices were conditional on selectivity of the corresponding fleet or survey, and were computed from abundance at the midpoint of the year or, in the case of commercial handlines, biomass. The headboat discard index tracks small fish (less than 20 inches) and was included as a measure of recruitment strength.

3.16 Catchability

In the BAM, catchability scales indices of relative abundance to the estimated population at large. For the base model, the AW Panel recommended a time-invariant catchability.

A sensitivity run adopted a time-varying catchability for the headboat index. In this formulation, catchability was estimated in two stanzas, pre- and post-1992. Choice of the year 1992 was based on the implementation of a fishery management plan that may have changed fishing behavior.

3.17 Biological reference points

Biological reference points (benchmarks) were calculated based on the fishing rate that would allow a stock to attain 30% of the maximum spawning potential which would have been obtained in the absence of fishing mortality. Computed benchmarks included the MSY proxy, fishing mortality rate at $F_{30\%}$, total biomass at $F_{30\%}$, and spawning stock at $F_{30\%}$ (Gabriel and Mace 1999). In this assessment, spawning stock measures total eggs of the mature stock. These benchmarks are conditional on the estimated selectivity functions and the relative contributions of each fleet's fishing mortality. The selectivity pattern used here was the effort-weighted selectivities at age, with effort from each fleet estimated as the full F averaged over the last three years of the assessment.

3.18 Fitting criterion

The fitting criterion was a penalized likelihood approach in which observed removals (landings and discards) were fit closely, and observed composition data and abundance indices were fit to the degree that they were compatible. Removals and index data were fit using lognormal likelihoods. Length and age composition data were fit using robust multinomial likelihoods (Francis 2011), and only from years that met minimum sample size criteria ($nfish > 30$ and $ntrips \geq 10$) for length compositions and ($nfish > 10$ and $ntrips \geq 10$) for age compositions. Commercial and headboat discard length composition minimum sample size threshold was set lower ($nfish > 10$) due to the fact that the discard composition data were the only information available to estimate selectivity.

The model includes the capability for each component of the likelihood to be weighted by user-supplied values. For data components, these weights were applied by either adjusting CVs (lognormal components) or adjusting effective sample sizes (multinomial components). In this application to Red Snapper, CVs of landings and discards (in arithmetic space) were assumed equal to 0.05, to achieve a close fit to these time series yet allowing some imprecision. In practice, the small CVs are a matter of computational convenience, as they help achieve the desired result of close fits to the landings, while avoiding having to solve the Baranov equation iteratively (which is complex when there are multiple fisheries). Weights on other data components (indices, age/length compositions) were adjusted iteratively, starting from initial weights as follows. The CVs of indices were set equal to the values estimated by the GLMs used for standardization or at the fixed value of 0.2 for the headboat and commercial handline indices. Effective sample sizes of the multinomial components were assumed equal to the number of trips sampled annually, rather than the number of fish measured, reflecting the belief that the basic sampling unit occurs at the level of trip. These initial weights were then adjusted until standard deviations of normalized residuals were near 1.0 (Francis 2011). In sensitivity runs, weights on the fishery dependent indices were adjusted upward to explore their effects (not because up-weighted runs were considered equally plausible).

For parameters defining selectivities, CV of size at age, and σ_R, normal priors were applied to maintain parameter estimates near reasonable values, and to prevent the optimization routine from drifting into parameter space with negligible gradient in the likelihood. For σ_R, the prior mean (0.6) and standard deviation (0.25) were based on Beddington and Cooke (1983) and Mertz and Myers (1996).

3.19 Configuration of a base run

The base run was configured as described above. This configuration does not necessarily represent reality better than all other possible configurations, and thus this assessment attempted to portray uncertainty in point estimates through sensitivity analyses and through a Monte-Carlo/bootstrap approach (described below).

3.20 Sensitivity analyses

Sensitivity runs were chosen to investigate issues that arose specifically with this benchmark assessment. They were intended to demonstrate directionality of results with changes in inputs or simply to explore model behavior, and not all were considered equally plausible. These model runs vary from the base run as follows:

- S1: Remove the 2008 and 2009 years from the handline and headboat indices
- S2: Upweight fishery independent index further than was explored in the Assessment Workshop (10X likelihood weight after the iterative reweighting)
- S3: Upweight handline and headboat indices (3X likelihood weight after iterative reweighting)
- S4: Fishery dependent indices only
- S5: High value of M
- S6: Low value of M
- S7: Low discard mortality probabilities (commercial handlines rate set to 0.38 or 0.28, all recreational set to 0.27 or 0.20)
- S8: High discard mortality probabilities (commercial handlines rate set to 0.58 or 0.48, all recreational set 0.45 or 0.36)
- S9: Longer combined chevron trap and video (CVID) index (2005-2014)
- S10: Reduced general recreational landings in 1984 and 1985 by taking the geometric mean of surrounding years
- S11: Steepness $h = 0.84$
- S12: Headboat discard index excluded after 2009
- S13: Ageing error matrix included
- S14: Low value for age-specific number of batches
- S15: High value for age-specific number of batches
- S16: Headboat discard index dropped
- S17: High landings
- S18: Low landings
- S19: High discards
- S20: Low discards
- S21: Dome-shaped selectivity for commercial handline fleet
- S22: Separate video and trap index rather than a single CVID index
- S23: Fishery independent index only
- S24: Continuity run: changes include SEDAR24 values such as M, steepness, maturity, and SSB
- S25: Two time blocks for Headboat logbook index catchability (pre- and post-1992)
- S26: Retrospective - 1 year of data
- S27: Retrospective - 2 years of data
- S28: Retrospective - 3 years of data
- S29: Retrospective - 4 years of data

- S30: Use 1978 as the starting year, applied a loose prior to the estimation of F_{init} that corresponds to the geometric mean of the fishing mortality for 1950-1977
- S31: Estimate selectivities without fixing a plus group (for the selectivity estimation)

Sensitivities 5, 6, 14, 15, and 17-20 used the 10th and 90th quantiles (as the low and the high respectively) from the bootstraps of the observed data described in the uncertainty analysis methods (Section 3.24).

3.21 Parameters Estimated

The model estimated annual fishing mortality rates of each fleet, selectivity parameters, catchability coefficients associated with indices, parameters of the spawner-recruit model (except steepness), annual recruitment deviations, and CV of size at age for each age and growth relationship.

3.22 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F, as were equilibrium landings and spawning biomass. Equilibrium landings and discards were also computed as functions of biomass B, which itself is a function of F. As in the computation of benchmarks (described in §3.23), per recruit and equilibrium analyses applied the most recent selectivity patterns averaged across fleets, weighted by each fleet's F from the last three years of the assessment (2012–2014).

3.23 Benchmark/Reference Point Methods

In this assessment of Red Snapper, the quantities $F_{30\%}$, $\mathrm{SSB}_{\mathrm{F30\%}}$, $B_{\mathrm{F30\%}}$, and $L_{\mathrm{F30\%}}$ were estimated as proxies for MSY-based reference points. Steepness was not reliably estimable, so the stock-recruit relationship was not used to identify a maximum yield. Instead, steepness was fixed at 0.99 in order to assume an average level of recruitment while estimating deviations around the mean. $F_{30\%}$ was used in the rebuilding plan for Red Snapper, therefore, it was used here to generate fishing benchmarks. However, because the stock-recruitment relationship was not estimated, assumptions about recruitment are required to generate biomass benchmarks. Here, equilibrium recruitment was assumed equal to expected recruitment (arithmetic average). On average, expected recruitment is higher than that estimated directly from the spawner-recruit curve, because of lognormal deviation in recruitment. Thus, in this assessment, the method of benchmark estimation accounted for lognormal deviation by including a bias correction in equilibrium recruitment. The bias correction (ς) was computed from the variance (σ_R^2) of recruitment deviation in log space: $\varsigma = \exp(\sigma_R^2/2)$. Then, equilibrium recruitment (R_{eq}) associated with any F is,

$$R_{eq} = \frac{R_0 \left[\varsigma 0.8 h \Phi_F - 0.2(1-h)\right]}{(h-0.2)\Phi_F} \tag{1}$$

where R_0 is virgin recruitment, h is steepness which is fixed in this assessment, and $\Phi_F = \phi_F/\phi_0$ is spawning potential ratio given growth, maturity, and total mortality at age (including natural and fishing mortality rates). Because steepness is fixed at 0.99, R_{eq} as a function of F is approximately a straight line. The R_{eq} and mortality schedule imply an equilibrium age structure and an average sustainable yield (ASY). The estimate of $F_{30\%}$ is the F giving 30% of the SPR, and the estimate of $L_{\mathrm{F30\%}}$ is that ASY. The estimate of $\mathrm{SSB}_{\mathrm{F30\%}}$ follows from the corresponding equilibrium age structure, as does the estimate of discard mortalities $D_{F30\%\}}$, here separated from ASY (and consequently, $L_{\mathrm{F30\%}}$).

Estimates of $L_{\mathrm{F30\%}}$ and related benchmarks are conditional on selectivity pattern. The selectivity pattern used here was an average of terminal-year selectivities from each fleet, where each fleet-specific selectivity was weighted in proportion to its corresponding estimate of F averaged over the last three years (2012–2014). If the selectivities or relative fishing mortalities among fleets were to change, so would the estimates of $L_{\mathrm{F30\%}}$ and related benchmarks.

The maximum fishing mortality threshold (MFMT) is defined by the SAFMC as $F_{30\%}$, and the minimum stock size threshold (MSST) as $75\%\mathrm{SSB}_{\mathrm{F30\%}}$. Overfishing is defined as $F > \mathrm{MFMT}$ and overfished as $\mathrm{SSB} < \mathrm{MSST}$. However, because this stock is currently under a rebuilding plan, increased emphasis is given to SSB relative to $\mathrm{SSB}_{\mathrm{F30\%}}$ (rather than MSST), as $\mathrm{SSB}_{\mathrm{F30\%}}$ is the rebuilding target. Current status of the stock is represented by SSB in the latest assessment year (2014), and current status of the fishery is represented by the geometric mean of F from the latest three years (2012–2014). Recent SEDAR assessments have considered the mean over the terminal three years to be a more robust metric.

3.24 Uncertainty and Measures of Precision

As in SEDAR24, this assessment used a mixed Monte Carlo and bootstrap (MCB) approach to characterize uncertainty in results of the base run. Monte Carlo and bootstrap methods (Efron and Tibshirani 1993; Manly 1997) are often used to characterize uncertainty in ecological studies, and the mixed approach has been applied successfully in stock assessment, including Restrepo et al. (1992), Legault et al. (2001), SEDAR4 (2004), and many South Atlantic SEDAR assessments since SEDAR19 (2009). The approach is among those recommended for use in SEDAR assessments (SEDAR Procedural Guidance 2010).

The approach translates uncertainty in model input into uncertainty in model output, by fitting the model many times with different values of "observed" data and key input parameters. A chief advantage of the approach is that the results describe a range of possible outcomes, so that uncertainty is characterized more thoroughly than it could be by any single fit or handful of sensitivity runs. A minor disadvantage of the approach is that computational demands are relatively high.

In this assessment, the BAM was successively re-fit in $n = 4000$ trials that differed from the original inputs by bootstrapping on data sources, and by Monte Carlo sampling of several key input parameters. The value of $n = 4000$ was chosen because a minimum of 3000 runs were desired, and it was anticipated that not all runs would converge or otherwise be valid. Of the 4000 trials, approximately 1.9% were discarded, because the model did not properly converge (in most cases, an estimated quantity was at its upper bound). This left $n = 3926$ MCB trials used to characterize uncertainty, which was sufficient for convergence of standard errors in management quantities.

The MCB analysis should be interpreted as providing an approximation to the uncertainty associated with each output. The results are approximate for two related reasons. First, not all combinations of Monte Carlo parameter inputs are equally likely, as biological parameters might be correlated. Second, all runs are given equal weight in the results, yet some might provide better fits to data than others.

3.24.1 Bootstrap of observed data

To include uncertainty in the indices of abundance, multiplicative lognormal errors were applied through a parametric bootstrap. To implement this approach in the MCB trials, random variables ($x_{s,y}$) were drawn for each year y of time series s from a normal distribution with mean 0 and variance $\sigma^2_{s,y}$ [that is, $x_{s,y} \sim N(0, \sigma^2_{s,y})$]. Annual observations were then perturbed from their original values ($\hat{O}_{s,y}$),

$$O_{s,y} = \hat{O}_{s,y}[\exp(x_{s,y} - \sigma^2_{s,y}/2)] \qquad (2)$$

The term $\sigma^2_{s,y}/2$ is a bias correction that centers the multiplicative error on the value of 1.0. Standard deviations in log space were computed from CVs in arithmetic space, $\sigma_{s,y} = \sqrt{\log(1.0 + CV^2_{s,y})}$. As used for fitting the base run, CVs of indices of abundance were those provided by, or modified from, the data providers (tabulated in Table 4 of this assessment report).

Uncertainty was modeled for historical commercial landings similarly to the indices, and by the CVs provided by the commercial working group at the DW. No commercial discard CVs, headboat landings CVs, or headboat discard CVs by year were provided, therefore the panel had to make some assumptions. We assumed a value of $CV = 0.20$ for commercial discards and headboat discards. For headboat landings, we used information from the headboat program to assume a decreasing CV by time blocks (i.e. $CV = 0.15$ 1981-1995, $CV = 0.1$ for 1996-2007, and $CV = 0.05$ thereafter). General recreational landings and discards had complementary CVs, and those were used as provided except in a few instances. A CV greater than 1 was capped at 1, which was sufficiently large to represent high uncertainty but not so high that bootstrapped values caused implausible time series. The panel thought the resulting draws sufficiently represented uncertainty in spite of the dampening of a few years' CVs (Table 6).

Uncertainty in age and length compositions were included by drawing new distributions for each year of each data source, following a multinomial sampling process. Ages (or lengths) of individual fish were drawn at random with replacement using the cell probabilities of the original data. For each year of each data source, the number of fish sampled was the same as in the original data.

3.24.2 Monte Carlo sampling

In each successive fit of the model, several parameters were fixed (i.e., not estimated) at values drawn at random from distributions described below.

3.25 Natural mortality

A vector of age-specific natural mortality was provided by the Life History Working Group. They used the Charnov et al. (2013) estimator scaled to the Then et al. (2014) max age asymptotic M, and then used the uncertainty around the determination of maximum age to provide an upper and lower bound to the M vector. The Assessment Panel thought the upper ($M = 0.14$) and lower ($M = 0.12$) bound were too similar to the base vector to represent the true uncertainty around M. Instead, the AW Panel wanted to carry the uncertainty forward in both maximum age and the parameters of the Then et al. (2014) estimator of asymptotic M:

$$M = aT^b_{max} \tag{3}$$

To estimate uncertainty in a and b, we acquired the data of Then et al. (2014) and conducted a bootstrap of $n = 10,000$ iterations, drawing from the original data set with replacement. For each MCB iterations, one of the 10,000 fits was drawn at random, thus maintaining any correlation structure between a and b. We then drew T_{max} from a uniform distribution and calculated asymptotic M. For the age-dependent vector, we started with the Charnov age-dependent curve, and scaled it to the M estimate we calculated in the previous steps. A new M value was drawn and a new age-dependent vector was calculated for each MCB trial.

3.26 Discard mortality

The discard mortality working group provided an upper and lower bound for each time block (pre- and post-regulation) and fishery (commercial and recreational). Commercial rates before 2007 ranged from 38% to 58%, and 2007 to present ranged from 28% to 48%. Recreational rates before 2011 ranged from 27% to 45%, and 2011 on ranged from 20% to 36%. The rates decreased in response to the implementation of circle hooks, which are meant to cause fewer fatal bycatch events. We drew the rate for the earlier time period for each fleet from a truncated normal distribution with mean equal to the point estimate and a standard deviation devised to provide a 95% confidence interval similar to what the working group provided above. For the later time period for each fleet we also drew from a truncated normal distribution created similarly as in the previous step but with the upper bound fixed at the random draw from the earlier time period. The last step is meant to ensure that the second value is not larger than the first, so as to maintain the feature that discard mortality has decreased due to the circle hook regulation.

3.27 Batch Fecundity

Prior to the MCB analysis, a bootstrap procedure was run on the data set used to estimate batch fecundity at age for the base run. For each of 10000 bootstrap runs, the 69 paired observations of batch fecundity and fish length were sampled 69 times with replacement, the regression model refit, and the bootstrap parameters estimates saved to a data matrix. Once all bootstraps were run, the parameter matrix was trimmed by removing runs where either parameter value was outside of its 95% confidence interval. The parameters were found to be highly correlated, so during the MCB analysis, pairs of parameters were randomly drawn, with replacement, from the trimmed bootstrap parameter matrix. For each MCB run, predicted batch fecundity at age was calculated using a set of bootstrap parameters and a vector of length at age.

3.28 Batch number

Prior to the MCB analysis, a similar but separate bootstrap procedure was run on the data set used to estimate batch number at age for the base run. For each of 10000 bootstrap runs, the 1472 paired observations of spawning indicator presence, fish length, and day of the year were sampled 1472 times with replacement and the regression model refit. Predicted batch number at age was then calculated from the bootstrap parameter estimates and a vector of length at age, and the vectors saved to a data matrix. Once all bootstraps were run, the batch number at age matrix was trimmed by first summing batch number at age for each run, yielding lifetime batch number; runs where lifetime batch number was outside of the 95% confidence interval were trimmed. During the MCB analysis, a vector of batch number at age was randomly drawn, with replacement, from the trimmed bootstrap batch number at age matrix for each MCB run.

3.29 Projections

Projections were run to predict stock status in years after the assessment, 2015–2044. The year 2044 is the last year of the current rebuilding plan.

The structure of the projection model was the same as that of the assessment model, and parameter estimates were those from the assessment. Any time-varying quantities, such as recreational selectivity, were fixed to the most recent values of the assessment period. A single selectivity curve was applied to calculate removals, averaged across fleets using geometric mean Fs from the last three years of the assessment period, similar to computation of $L_{\mathrm{F30\%}}$ benchmarks (§3.23).

Expected values of SSB (time of peak spawning), F, recruits, and removals were represented by deterministic projections using parameter estimates from the base run. These projections were built on the spawner-recruit relationship with steepness fixed ($h = 0.99$) and with bias correction, and were thus consistent with estimated benchmarks in the sense that long-term fishing at $F_{30\%}$ would yield $L_{\mathrm{F30\%}}$ from a stock size at $\mathrm{SSB}_{\mathrm{F30\%}}$. Uncertainty in future time series was quantified through stochastic projections that extended the Monte Carlo/Bootstrap (MCB) fits of the stock assessment model.

3.29.1 Initialization of projections

Initial age structure at the start of 2015 was computed by the assessment model.

Fishing rates that define the projections were assumed to start in 2017. Because the assessment period ended in 2014, the projections required an initialization period (2015–2016). For 2015, a moratorium year, the landings selectivity was set to 0 and the discard selectivity was rescaled to peak at 1. Then, an optimization routine solved for the F that matched the current dead discards (mean of 2012-2014) in numbers. In 2016, a similar routine soved for the F that matched current landings (mean of 2012-2014), assuming a mini-season would occur.

3.29.2 Uncertainty of projections

To characterize uncertainty in future stock dynamics, stochasticity was included in replicate projections, each an extension of a single MCB assessment model fit. Thus, projections carried forward uncertainties in natural mortality, reproduction, landings, discards, and discard mortalities, as well as in estimated quantities such as selectivity curves, and in initial (start of 2015) abundance at age.

Initial and subsequent recruitment values were generated with stochasticity using a Monte Carlo procedure, in which the estimated Beverton–Holt model (i.e. R_0, σ_R estimated, and $h = 0.99$) of each MCB fit was used to compute mean annual recruitment values ($\bar{R}_y$). Variability was added to the mean values by choosing multiplicative deviations at random from a lognormal distribution,

$$R_y = \bar{R}_y \exp(\epsilon_y). \tag{4}$$

Here ϵ_y was drawn from a normal distribution with mean 0 and standard deviation σ_R, where σ_R is the standard deviation from the relevant MCB fit.

The procedure generated 20,000 replicate projections of MCB model fits drawn at random (with replacement) from the MCB runs. In cases where the same MCB run was drawn, projections would still differ as a result of stochasticity in projected recruitment streams. Central tendencies were represented by the deterministic projections of the base run, as well as by medians of the stochastic projections. Precision of projections was represented graphically by the 10^{th} and 90^{th} percentiles of the replicate projections.

3.30 Rebuilding time frame

Based on results from the previous SEDAR24 benchmark assessment, Red Snapper is currently under a rebuilding plan. In this plan, the terminal year is 2044, and rebuilding is defined by the criterion that projection replicates achieve stock recovery (i.e., $\mathrm{SSB}_{2044} \geq \mathrm{SSB}_{\mathrm{F30\%}}$) with probability of at least 50%. Here, the probability of stock recovery in each year of the rebuilding plan was computed as the proportion of stochastic projections where $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{F30\%}}$, with $\mathrm{SSB}_{\mathrm{F30\%}}$ taken to be iteration-specific (i.e., from that particular MCB run).

Projection scenarios Five projection scenarios were considered.

- Scenario 1: $F = 0$
- Scenario 2: $F = F_{\text{current}}$
- Scenario 3: $F = F_{30\%}$
- Scenario 4: $F_{target} = 98\% F_{30\%}$
- Scenario 5: $F = F_{\text{rebuild}}$, with rebuilding probability of 0.5 in 2044
- Scenario 6: Discards only

The F_{current} is represented by the geometric mean of fishing mortalities from 2012-2014. The F_{rebuild} is defined as the maximum F that achieves rebuilding in the allowable time frame. The discards only scenario treated the initialization year 2016 the same as 2015 (discards only), and then applied the mean F (from 2015-2016) forward starting in 2017.

3.31 Surplus Production Model

3.31.1 Overview

A logistic surplus production model, implemented in ASPIC (Version 7.03; Prager 2005), was used to estimate stock status of Red Snapper off the southeastern U.S. While primary assessment of the stock was performed using the age-structured BAM, the surplus production approach was intended as a complement, for additional comparison with the age-structured model's results. More specifically, this model focuses on the dynamics of the removals as they relate to the indices of abundance, while ignoring any age data or age-structure in the population.

3.31.2 Data Sources

Data sources supplied to a production model include a time series of removals (i.e. landings plus dead discards) and one or more indices of abundance (i.e. catch per unit of effort). These inputs should be in units of biomass (i.e. weight), therefore some of the data developed at the SEDAR41 DW required additional formatting. These changes are detailed below.

Removals

The available removals time series comprised commercial landings (1950-2014), recreational landings (1955-2014), commercial dead discards (1992-2014), and recreational dead discards (1981-2014), in pounds, summed by year.

Commercial Landings

The SEDAR41 DW reported commercial landings in pounds, thus these data did not need to be modified for the production model.

Recreational landings

During the SEDAR41 DW, recreational landings for the historical period (1955-1980) were estimated in numbers of individuals using the The National Survey of Fishing, Hunting, and Wildlife-Associated Recreation Survey (FHWAR) census method (see SEDAR41-DW17). For the contemporary period (1981-2014), the SEDAR-41 DW reported Southeast Region Headboat Survey (SRHS) and Marine Recreational Information Program (MRIP) recreational landings in numbers and weights. Recreational landings from this period did not need to be modified, but were used to convert historical landings to weight.

Following a similar approach used in SEDAR24, recreational landings in weight and numbers for all fleets were combined by year for the first three years of the contemporary period; dividing annual landings in weight by landings in numbers produced annual mean weight estimates. The average of these three mean weights (3.4 lb) was then multiplied by the historical landings in numbers to convert them to weight. The historical and combined contemporary recreational landings series were then joined to produce a single time series of recreational landings, in pounds.

Dead Discards

Discard estimates were generated in numbers at the SEDAR-41 DW. Since many discarded fish survive after release, discard mortality rates were applied to discards in numbers to calculate dead discards. For commercial discards, a discard mortality rate of 0.48 was applied prior to regulations in 2007, and a rate of 0.38 was applied from 2007 onward. For recreational discards, a discard mortality rate of 0.37 was applied prior to regulations in 2011, and a rate of 0.285 was applied from 2011 onward.

Mean weight of commercial discards was estimated by converting lengths of commercial discards to weights using data and a conversion equation supplied by the SEDAR-41 DW, and then calculating the average weight of these individuals. The data on lengths of commercial discards were divided into two time periods before (2007-2009) and after (2010-2013) the fishery was closed. The average estimated weights of commercial discards from each time period (before = 2.93 lb; after = 8.84 lb) were multiplied by discards in numbers, for years before and after the closure, respectively.

Mean weight of recreational discards was estimated by converting lengths of recreational headboat-at-sea observer discards to weights using data and a conversion equation supplied by the SEDAR-41 DW, and then calculating the average weight of these individuals. Year-specific mean weight estimates were multiplied by recreational discards in numbers for corresponding years when available (2005-2014). For years prior to 2005 where year-specific mean weights were not available, discards in numbers were multiplied by the average mean weight across the available years before the 2010 closure (1.96 lb).

Indices of Abundance

Five indices of abundance were produced by the SEDAR-41 DW for Red Snapper: commercial logbook handline index (hereafter commercial handline; units = lb kept per hook-hour), headboat (number of fish kept per angler), headboat-at-sea-observer (number of fish caught $<20''$ per angler), Southeast Reef Fish Survey (SERFS) chevron trap (number of fish caught per trap), and the SERFS video (number of fish observed per video). The commercial handline index was already in weight and did not need to be converted. The headboat index was converted to pounds by multiplying by year-specific mean weights, generated by dividing headboat landings in pounds by landings in numbers for each year. The headboat-at-sea-observer index was converted to pounds by multiplying by the same mean weights used to convert recreational discards to weight. The SERFS chevron trap and video indices were converted to weights by multiplying by year-specific mean weights calculated from combined recreational (headboat and MRIP) landings in weight divided by landings in numbers.

3.31.3 Model Configuration and Equations

Production modeling used the model formulation and ASPIC software (version 7.03) of Prager (1994; 2005). This is an observation-error estimator of the continuous-time form of the Schaefer (logistic) production model (Schaefer 1954; 1957). Estimation was conditioned on catch. The logistic model for population growth is the simplest form of a differential equation which satisfies a number of ecologically realistic constraints, such as a carrying capacity (a consequence of limited resources). When written in terms of stock biomass, this model specifies that

$$\frac{dB_t}{dt} = rB_t - \frac{r}{K}B_t^2 \tag{5}$$

where B_t is biomass in year t, r is the intrinsic rate of increase in absence of density dependence, and K is carrying capacity (Schaefer 1954; 1957). This equation may be rewritten to account for the effects of fishing by introducing an instantaneous fishing mortality term, F_t :

$$\frac{dB_t}{dt} = (r - F_t)B_t - \frac{r}{K}B_t^2 \tag{6}$$

By writing the term F_t as a function of catchability coefficients and effort expended by fishermen in different fisheries, Prager (1994) showed how to estimate model parameters from time series of yield and effort.

For Red Snapper, the model proved difficult to fit. It was configured using various combinations of removals, indices, starting dates, prior distributions and starting values, resulting in approximately 324 configurations. Many of these runs were completed during early model development but many others incorporated small changes to data inputs or model specifications suggested by AW panel members during the Assessment Workshop. As the BAM developed, most of these runs became obsolete and are not presented here. The run configured according to recommendations by the SEDAR41 AW panel is presented here. This model configuration (run 320) contained removals from 1950 to 2014 and the four indices used in the BAM (Comm, HB, HB-at-sea, CVID) from 1976 to 2014. Following the recommendations of the AW panel, the CVID index was upweighted by a factor of three (i.e. CVs divided by three), and the headboat-at-sea index was shifted forward by one year, since it indexes younger fish than the other indices.

Three other runs (318, 319, and 323) are also presented to relate the main run (320) to ASPIC results from the previous Red Snapper assessment (SEDAR 24). All three runs contain only the commercial and headboat indices, starting in 1993 and 1976 respectively, and removals starting in 1950. But in run 318 (the continuity run), the final year of removals and indices is 2009, as in SEDAR 24, while in run 319 (the updated continuity run) the final year of removals and indices is 2014, as in the BAM for the current assessment. Since both the commercial and headboat indices ended in 2009 the only difference between the continuity run and updated continuity run is the removals estimates from 2010-2014. Finally a run was completed (run 323; best configuration $\frac{B_1}{K}$ fixed) that is identical to the best configuration run, but with $\frac{B_1}{K}$ fixed at the estimate for the continuity run, for reasons described below.

To evaluate the uncertainty in the model fit and parameter estimates of the best configuration run, 1000 bootstrap runs were conducted. Percentile confidence intervals were also calculated for parameters.

4 Stock Assessment Results

4.1 Measures of Overall Model Fit

In general, the Beaufort assessment model (BAM) fit well to the available data. Predicted length compositions from the commercial handline and discards from the commercial and headboat fleets were reasonably close to observed data in most years, as were predicted age compositions (Figure 3). The model was configured to fit observed commercial and recreational removals closely (Figures 4–9). Fits to indices of abundance generally captured the observed trends but not all annual fluctuations (Figures 10–13).

4.2 Parameter Estimates

Estimates of all parameters from the catch-age model are shown in Appendix B. Estimates of management quantities and some key parameters are reported in sections below.

4.3 Stock Abundance and Recruitment

In general, estimated abundance at age showed truncation of the older ages through most of the assessment period, but with some signs of increase during the last decade (Figure 14; Table 7). Total estimated abundance was at its lowest value in the early 1990s, but near its highest levels at the end of the time series, comparable to those in the early 1970s, but with a more truncated age structure. The MCB results reflect the same patterns with their associated uncertainties for total abundance and abundance of age 2+ (Figure 18). Annual number of recruits is shown in Table 7 (age-1 column) and in Figure 15. The highest recruitment values were predicted to have occurred in the mid-1980s, 2006, and the terminal year of the model (2014).

4.4 Total and Spawning Biomass

Estimated biomass at age followed a similar pattern as abundance at age (Figure 16; Table 9). Total biomass and spawning biomass showed similar trends—general decline through to the early-1990s, and relatively stable or slowly increasing patterns since the mid-1990s (Figure 17; Table 10). Terminal year estimates are at levels not seen since the 1970s.

4.5 Selectivity

Selectivity of the SERFS index is shown in Figure 19, and selectivities of landings from commercial and recreational fleets are shown in Figures 20, 21, and 22. Selectivities of discards from commercial and recreational fleets are shown in Figures 23, 24, and 25. In the most recent years, full selection occurred near ages 2–4, depending on the fleet and time block.

Average selectivities of landings, dead discards, and the total weighted average of all selectivities were computed from F-weighted selectivities in the most recent three assessment years (Figure 26). This average selectivity was used in computation of point estimates of benchmarks, as well as in projections. All selectivities from each time block, including average selectivities, are tabulated in Tables 11, 12, and 13.

4.6 Fishing Mortality and Removals

Estimates of total F at age are shown in Table 15. In any given year, the maximum F at age (i.e., apical F) may be less than that year's sum of fully selected Fs across fleets. This inequality is due to the combination of two features of estimated selectivities: full selection occurs at different ages among gears and several sources of mortality have dome-shaped selectivity.

Estimated time series of landings and discards are shown in Tables 16, 17, 18, 19. Table 20 shows total landings at age in numbers, and Table 21 in weight. Table 22 shows total discards at age in numbers, and Table 23 in weight. Landings have been dominated by the general recreational and commercial handline fleet until recent years when the general recreational fleet became the dominant source of removals (Tables 16 and 17). Also since 2010, total landings remained below the level at $L_{\mathrm{F30\%}}$ (Figure 29).

Estimated discard mortalities occurred on a smaller scale than landings until the implementation of regulations and the use of mini-seasons, and have been above the $D_{F_{30\%}}$ level for most of the moratorium years (Tables 18 and 19, and Figure 30).

4.7 Spawner-Recruitment Parameters

The Beverton–Holt spawner-recruit curve is shown in Figure 31, along with the effect of density dependence on recruitment, depicted graphically by recruits per spawner as a function of spawning stock (1E8 Eggs). Values of recruitment-related parameters were as follows: steepness $h = 0.99$ (fixed), unfished age-1 recruitment $\widehat{R_0} = 320738$, and standard deviation of recruitment residuals in log space $\widehat{\sigma}_R = 0.81$ (which resulted in bias correction of $\varsigma = 1.40$). Uncertainty in these quantities was estimated through the MCB analysis (Figure 32).

4.8 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F. These computations applied the most recent selectivity patterns averaged across fleets, weighted by F from the last three years (2012–2014) (Figures 33 and 34).

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of F (Figure 35). $F_{30\%}$ is used as a proxy for MSY, and the corresponding landings and spawning biomass are $L_{\mathrm{F30\%}}$ and $\mathrm{SSB}_{\mathrm{F30\%}}$.

4.9 Benchmarks / Reference Points

As described in §3.23, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the spawner-recruit curve with fixed steepness $h = 0.99$ (Figure 31). Reference points estimated were $F_{30\%}$, $L_{\mathrm{F30\%}}$, $B_{\mathrm{F30\%}}$ and $\mathrm{SSB}_{\mathrm{F30\%}}$. Based on $F_{30\%}$, three possible values of F at optimum yield (OY) were considered—$F_{\mathrm{OY}} = 65\%F_{30\%}$, $F_{\mathrm{OY}} = 75\%F_{30\%}$, and $F_{\mathrm{OY}} = 85\%F_{30\%}$—and for each, the corresponding yield was computed. Standard errors of benchmarks were approximated as those from MCB analysis (§3.24).

Maximum likelihood estimates (base run) of benchmarks, as well as median values from MCB analysis, are summarized in Table 24. Point estimates of $L_{\mathrm{F30\%}}$-related quantities were $F_{30\%} = 0.15$ (y^{-1}), $L_{\mathrm{F30\%}} = 427.01$ (1000 lb), $B_{\mathrm{F30\%}} = 3637.2$ (mt), and $\mathrm{SSB}_{\mathrm{F30\%}} = 327705.9$ (1E8 Eggs). Median estimates were $F_{30\%} = 0.15$ (y^{-1}), $L_{\mathrm{F30\%}} = 415.17$ (1000 lb), $B_{\mathrm{F30\%}} = 3524.9$ (mt), and $\mathrm{SSB}_{\mathrm{F30\%}} = 293943.5$ (1E8 Eggs). Distributions of these benchmarks from the MCB analysis are shown in Figure 36.

4.10 Status of the Stock and Fishery

Estimated time series of stock status SSB/$\mathrm{SSB_{F30\%}}$ showed general decline throughout the beginning of the assessment period, a leveling off, and then a modest increase since 2010 (Figure 37, Table 10). Base-run estimates of spawning biomass have remained below the threshold (MSST) since the early-1970s. Current stock status was estimated in the base run to be SSB/$\mathrm{SSB_{F30\%}}$ = 0.15 (Table 24), indicating that the stock has not yet recovered to $\mathrm{SSB_{F30\%}}$. Median values from the MCB analysis indicated similar results SSB/$\mathrm{SSB_{F30\%}}$ =0.16. The uncertainty analysis suggested that the terminal estimate of stock status is robust (Figures 38, 39). Of the MCB runs, 100% indicated that the stock was below $\mathrm{SSB_{F30\%}}$ in 2014. Age structure estimated by the base run showed fewer older fish in the last few decades than the (equilibrium) age structure expected at $L_{\mathrm{F30\%}}$ (Figure 40). However, there is improvement in the terminal year(2014), particularly for ages younger than ten.

The estimated time series of $F/F_{30\%}$ suggests that overfishing has occurred throughout most of the assessment period (Table 10, Figure 37). Current fishery status in the terminal year, with current F represented by the geometric mean from 2012–2014, was estimated by the base run to be $F/F_{30\%}$ = 2.7 (Table 24). The fishery status was also robust (Figures 38, 39). Of the MCB runs, approximately 99.1% agreed with the base run that the stock is currently experiencing overfishing.

4.11 Sensitivity and Retrospective Analyses

Sensitivity runs, described in §3.3, were used for exploring data or model issues that arose during the assessment process, for evaluating implications of assumptions in the base assessment model, and for interpreting MCB results in terms of expected effects of input parameters. In some cases, sensitivity runs are simply a tool for better understanding model behavior, and therefore all runs are not considered equally plausible in the sense of alternative states of nature. Time series of $F/F_{30\%}$ and SSB/$\mathrm{SSB_{F30\%}}$ are plotted to demonstrate sensitivity to the changing conditions in each run. The sensitivity of the base run to changes in natural mortality, steepness, dome-shaped selectivity for the commercial handline fleet, various index adjusts for both the fishery dependent indices and fishery independent index, the use of an ageing error matrix and high and low levels of landings and discards was explored (Figures 41–53). Sensitivity 24 is a version of a continuity run in that various assumptions made about parameters for SEDAR 24 were adopted for this sensitivity (e.g. higher discard mortalities, lower M, using gonad weight as a proxy for SSB, different female maturity and fecundity information, higher max age, lower steepness, different time of year for peak spawning, and fixed recruitment standard deviation). Time series of stock and fishery status estimated by this assessment are similar to those from the previous, SEDAR24 assessment (Figure 54). Trends in $F/F_{30\%}$ from the two assessments generally track each other, though the magnitude of the variations differ. Trends in SSB/$\mathrm{SSB_{F30\%}}$ track each other, though there is divergence at the end of the time series where the current model estimates a more optimistic stock status.

None of the sensitivities show a recovered stock in 2014. A couple sensitivities suggest the stock is undergoing less overfishing than is estimated in the base. However, those runs eliminate the fishery independent index entirely, or upweight the fishery dependent indices to the point of swamping out any signal from the survey data. The vast majority of runs agree with the status indicated by the base run (Figure 55, Table 25). Results appeared to be most sensitive to natural mortality and steepness.

Retrospective analyses suggest a pattern of overestimating fishing mortality in the terminal year, however, the trend is less apparent for SSB (Figure 56).

4.12 Projections

Projections based on $F = 0$ allowed the spawning stock to grow such that the majority of replicate projections recovered to $\mathrm{SSB}_{\mathrm{F30\%}}$ by 2025 (Figure 57, Table 26), however the stock is already in a rebuilding plan so other projections were also requested in the TORs. This was not the case for projections based on $F = F_{\mathrm{current}}$ (Figure 58, Table 27), or if the fishing rate were reduced to $F_{30\%}$ (Figure 59, Table 28) or F_{target} (Figure 60, Table 29). By design, projections based on $F = F_{\mathrm{rebuild}}$ showed recovery with the desired probability in 2044 (Figure 61, Table 30). The projection with discard mortality only showed similar trajectories to the run assuming no other fishing mortality(Table 31 and Figure 62).

4.13 Surplus Production Model

4.13.1 Model Fit

For the best configuration run, model predictions underestimated observed values for the headboat index for the first ten years of the time series (1976-1985; Figure 63). They also underestimated the commercial index during the first five years of that series (1993-1997), while overestimating the headboat index for those same years. The model provided a very poor fit to the headboat-at-sea discard index (2006-2014) but produced a much better fit to the upweighted CVID index (2005-2014). The model did not fit high index values in 2008 and 2009 very closely, but predicted a slight decline from 2007-2009 followed by an increasing trend from 2010 to 2014.

4.13.2 Parameter Estimates and Uncertainty

The ASPIC model fits three main parameters ($\frac{B_1}{K}$, MSY, and F_{MSY}) as well as catchability coefficients (q_i) for each index i. Several other parameters can then be derived from these estimates: $r = 2F_{MSY}$, $K = \frac{2MSY}{F_{MSY}}$ and $B_{MSY} = \frac{K}{2}$. Recent status indicators $\frac{F}{F_{MSY}}$ and $\frac{B}{B_{MSY}}$ are calculated with the most recent estimates of F (2014) and B (2015). Estimates of the main parameters and recent status indicators for all four runs are presented in Table 32. Prior distributions and model estimates of the main parameters for the best configuration run are presented in Figure 64.

Across all runs, most of the main parameters varied very little (e.g. CV $MSY = 0.0027$; CV $F_{MSY} = 0.014$). By contrast $\frac{B_1}{K}$ varied widely (CV $\frac{B_1}{K} = 0.74$), due to variation in B_1 (CV $B_1 = 0.74$) rather than K (CV $K = 0.013$; Table 32). Among bootstrap runs based on the best configuration, distributions of $\frac{B_1}{K}$, MSY, and F_{MSY} were unimodal and relatively symmetrical (Figure 65).

4.13.3 Status of the Stock and Fishery

In the current best configuration run of the surplus production model, $\frac{B}{B_{MSY}}$ is greater than one, suggesting that the South Atlantic stock of Red Snapper is not overfished. The 95% bootstrap percentile confidence intervals for $\frac{B}{B_{MSY}}$ do not contain one (Figure 65). Since the surplus production model estimates that $\frac{F}{F_{MSY}}$ is less than one, the stock is considered to not be undergoing overfishing (Table 32; Figure 66). The 95% bootstrap percentile confidence intervals for $\frac{F}{F_{MSY}}$ do not contain one (Figure 65).

4.13.4 Interpretation

Status indicators in the continuity run (318), agree with the surplus production model from SEDAR 24 that South Atlantic Red Snapper were overfished and undergoing overfishing in 2009 (Table 32). However, in the updated continuity run (319), which is identical to the continuity run except for the 2010-2014 addition of landings data from 2010-2014, the surplus production model suggests that the stock is no longer overfished or undergoing overfishing. Despite several differences between the updated continuity run and the best configuration run (320), described above, most of the parameter estimates and status indicators are similar (Table 32). However the model estimate of $\frac{B_1}{K}$ is much lower in the best configuration run, driven by a lower estimate of B_1. After observing this difference, run 323 was configured by taking the best configuration run and fixing $\frac{B_1}{K}$ at the estimate from the continuity run to investigate potential influence. Fixing $\frac{B_1}{K}$ at this much lower value had little effect on status or most parameters, but caused the estimate of B_1 to go much lower.

As described above, the only data that go into a surplus production model are biomass of removals and abundance indices. Therefore such a model does not make use of many other sources of information such as sex, maturity, growth, fecundity, or population age and size structure. Because such data are available for Red Snapper, a model that uses them would be preferred for a detailed assessment on which to base management.

5 Discussion

5.1 Comments on the Assessment

Estimated benchmarks played a central role in this assessment. Values of $\mathrm{SSB}_{\mathrm{F30\%}}$ and $F_{30\%}$ were used to gauge the status of the stock and fishery to be consistent with established definitions of $MFMT$ and the existing rebuilding plan. The computation of the benchmarks was conditional on selectivity. If selectivity patterns change in the future, for example as a result of new size limits or different relative catch allocations among sectors, estimates of benchmarks would likely change as well.

The base run of the BAM indicated that the stock remains overfished $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{F30\%}}$ =0.15, and that overfishing is occurring $F/F_{30\%}$ =2.7, though at a lower rate than in 2009 (F/F_{MSY} =4.12 for SEDAR 24). Median values from the MCB analyses were in qualitative agreement with those results. This assessment estimates that, since 2010, the stock has been increasing at a modest rate and is now at levels not seen since the 1970s.

In addition to including the more recent years of data, this benchmark assessment contained several modifications to the previous data of SEDAR24, such as the use of APAIS-adjusted MRIP estimates instead of MRFSS, a new method for the reconstruction of historic recreational catch, the inclusion of a new fishery-independent survey, and the corresponding age composition data. Furthermore, life-history information was updated, including female maturity, sex ratio, growth, natural mortality, fecundity, and meristics. The assessment model itself was also modernized to the current version of BAM. The sum of these improvements should result in a more robust assessment.

In general, fishery dependent indices of abundance may not track actual abundance well, because of factors such as hyperdepletion or hyperstability. Furthermore, this issue can be exacerbated by management measures. In this assessment, the commercial handline and headboat indices generated from logbook data, were not extended beyond 2009 because of the moratorium on Red Snapper. In general, management measures in the southeast U.S. have made the continued utility of fishery dependent indices will be questionable. This situation amplifies the importance of fishery independent sampling and sampling programs conducted by the states.

Many assessed stocks in the southeast U.S. have shown histories of heavy exploitation. High rates of fishing mortality can lead to adaptive responses in life-history characteristics, such as growth and maturity schedules. Such adaptations can affect expected yield and stock recovery, and thus resource managers might wish to consider possible evolutionary effects of fishing in their management plans (Dunlop et al. 2009; Enberg et al. 2009). Indeed, Red Snapper have a very young age at maturity relative to their maximum lifespan, and some have hypothesized that this may be an adaptive response to exploitation.

Because steepness could not be estimated reliably in this assessment, its value in the base run was fixed at 0.99. Fixing steepness at its upper bound was not meant to imply that the stock has perfect compensation at any exploitation or stock level. Rather, it was a computational convenience to use the stock recruitment curve with $h = 0.99$ in order to treat recruitment as an average through time while estimating deviations around that average. Thus MSY-based management quantities are not appropriate, and the AW Panel provided the proxy of $F_{30\%}$ as was used for management subsequent to the last assessment.

The assessment start year was 1950, so as to include the period of largest landings. To initialize the model in 1950, the initial age structure was assumed to be in equilibrium, based on natural mortality at age and F_{init}. Average recruitment was assumed until the recruitment deviations could be estimated at the onset of the composition data (1978). These assumptions are common in assessment models, and they were tested with sensitivity runs where the start was 1978 and with different values of F_{init}. The end results were qualitatively similar, which indicates that the base run is not sensitive to these assumptions.

A complementary analysis was conducted using a surplus production model (ASPIC). ASPIC treats the stock as a pooled biomass and ignores the age structure in the population and the landings. It is unable to take into account that different ages are differentially vulnerable to fishing and therefore was not able to incorporate the (time-varying) selectivities used in the BAM. ASPIC is also not able to take into account that the reproductive contribution of this species increases with age or that there is variability in recruitment through time. ASPIC is useful in examining the relationship between removals and the indices. However, for a long-lived species with age-based data available, the catch-age model (BAM) provides the best illustration of the stock and is a better indicator of stock status, because it can account for the age structure of the population and landings and for year-class strength.

5.2 Comments on the Projections

Projections should be interpreted in light of the model assumptions and key aspects of the data. Some major considerations are the following:

- In general, projections of fish stocks are highly uncertain, particularly in the long term (e.g., beyond 5–10 years).
- Although projections included many major sources of uncertainty, they did not include structural (model) uncertainty. That is, projection results are conditional on one set of functional forms used to describe population dynamics, selectivity, recruitment, etc.
- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect projection results.
- The first five scenarios of projections assumed no change in the selectivity applied to discards. As stock increase generally begins with the smallest size classes, management action may be needed to meet that assumption.
- The projections assumed that the assumed spawner-recruit relationship applies in the future and that past deviations represent future uncertainty in recruitment. If future recruitment is characterized by runs of large or small year classes, possibly due to environmental or ecological conditions, stock projections may be affected.

- Projections apply the Baranov catch equation to relate F and landings using a one-year time step, as in the assessment. The catch equation implicitly assumes that mortality occurs throughout the year. This assumption is violated when seasonal closures or small intensive fishing seasons are in effect, introducing additional and unquantified uncertainty into the projection results.

5.3 Research Recommendations

- Increased fishery independent information, particularly maintaining reliable indices of abundance and composition data streams
- Red Snapper were modeled in this assessment as a unit stock off the southeastern U.S. For any stock, variation in exploitation and life-history characteristics might be expected at finer geographic scales. Modeling such sub-stock structure would require more data, such as information on the movements and migrations of adults and juveniles, as well as spatial patterns of larval dispersal and recruitment. In addition, it is unclear whether a spatial model would improve the assessment.
- More research to describe the juvenile life history of Red Snapper is needed, including more work to identify the location of juveniles before they recruit to the fishery.
- The effects of environmental variation on the changes in recruitment or survivorship.
- The Florida sampling program, during the miniseason in particular, provided invaluable data to this assessment. Programs such as these would be useful in all South Atlantic states, particularly if the management regulations continue to make established methods of index development or composition sampling from fleets less regular or possible.

6 References

Baranov, F. I. 1918. On the question of the biological basis of fisheries. Nauchnye Issledovaniya Ikhtiologicheskii Instituta Izvestiya **1**:81–128.

Beddington, J. R., and J. G. Cooke, 1983. The potential yield of fish stocks. FAO Fish. Tech. Pap. 242, 47 p.

Charnov, E. L., H. Gislason, and J. G. Pope. 2013. Evolutionary assembly rules for fish life histories. Fish and Fisheries **14(2)**:213–224.

Conn, P. B. 2010. Hierarchical analysis of multiple noisy abundance indices. Canadian Journal of Fisheries and Aquatic Sciences .

Conn, P. B., E. H. Williams, and K. W. Shertzer. 2010. When can we reliably estimate the productivity of fish stocks? Canadian Journal of Fisheries and Aquatic Sciences **67**:511–523.

Dunlop, E. S., K. Enberg, C. Jorgensen, and M. Heino. 2009. Toward Darwinian fisheries management. Evolutionary Applications **2**:245–259.

Efron, B., and R. Tibshirani. 1993. An Introduction to the Bootstrap. Chapman and Hall, London.

Enberg, K., C. Jorgensen, E. S. Dunlop, M. Heino, and U. Dieckmann. 2009. Implications of fisheries-induced evolution for stock rebuilding and recovery. Evolutionary Applications **2**:394–414.

Fitzhugh, G. R., K. W. Shertzer, G. T. Kellison, and D. M. Wyanski. 2012. Review of size- and age dependence in batch spawning: implications for stock assessment of fish species exhibiting indeterminate fecundity. Fishery Bulletin pages 413–425.

Fournier, D. A., H. J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optimization Methods and Software **27**:233–249.

Francis, R. 2003. Quantifying annual variation in catchability for commercial and research fishing. Fishery Bulletin **101**:293–304.

Francis, R. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences **68**:1124–1138.

Gabriel, W. L., and P. M. Mace, 1999. A review of biological reference points in the context of the precautionary approach. NOAA Technical Memorandum-F/SPO-40.

Legault, C. M., J. E. Powers, and V. R. Restrepo. 2001. Mixed Monte Carlo/bootstrap approach to assessing king and Spanish mackerel in the Atlantic and Gulf of Mexico: Its evolution and impact. Amercian Fisheries Society Symposium **24**:1–8.

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**:627–642.

Manly, B. F. J. 1997. Randomization, Bootstrap and Monte Carlo Methods in Biolog, 2nd edition. Chapman and Hall, London.

Mertz, G., and R. Myers. 1996. Influence of fecundity on recruitment variability of marine fish. Canadian Journal of Fisheries and Aquatic Sciences **53**:1618–1625.

Methot, R. D. 1989. Synthetic estimates of historical abundance and mortality for northern anchovy. American Fisheries Society Symposium **6**:66–82.

Methot, R. D., 2009. User Manual for Stock Synthesis, Model Version 3.04. NOAA Fisheries, Seattle, WA.

Mitchell, W. A., G. T. Kellison, N. M. Bacheler, J. C. Potts, C. M. Schobernd, and L. Hale. 2014. Depth-related distribution of postjuvenile Red Snapper in southeastern U.S. Atlantic Ocean waters: ontogenic patters and implications for management. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science **6**:142–155.

Patterson, W. F., C. E. Porch, J. H. Tarnecki, and A. J. Strelcheck. 2012. Effect of circle hook size on reef fish catch rates, species composition, and selectivity in the northern Gulf of Mexico recreational fishery. Bulletin of Marine Science **88**:647–665.

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

Prager, M. H., 2005. User's Manual for ASPIC: A Stock-Production Model Incorporating Covariates (ver. 5) And Auxiliary Programs. National Marine Fishery Service, Beaufort Laboratory Document BL-2004-01, Beaufort, NC.

Quinn, T. J., and R. B. Deriso. 1999. Quantitative Fish Dynamics. Oxford University Press, New York, New York.

Restrepo, V. R., J. M. Hoenig, J. E. Powers, J. W. Baird, and S. C. Turner. 1992. A simple simulation approach to risk and cost analysis, with applications to swordfish and cod fisheries. Fishery Bulletin **90**:736–748.

Schaefer, M. B. 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. Bulletin of the Inter-American Tropical Tuna Commission **1**:27–56.

Schaefer, M. B. 1957. A study of the dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. Bulletin of the Inter-American Tropical Tuna Commission **2**:247–268.

SEDAR Procedural Guidance, 2010. SEDAR Procedural Workshop IV: Characterizing and Presenting Assessment Uncertainty.

SEDAR19, 2009. SEDAR 19: South Atlantic Red Grouper. SEDAR, North Charleston, SC.

SEDAR24, 2010. SEDAR 24: South Atlantic Red Snapper. SEDAR, North Charleston, SC.

SEDAR4, 2004. SEDAR 4: Stock assessment of the deepwater snapper-grouper complex in the South Atlantic. SEDAR, North Charleston, SC.

SEDAR41-AW05, 2015. Commercial age and length composition weightings for Atlantic red snapper (Lutjanus campechanus).

SEDAR41-AW08, 2015. South Atlantic U.S. Atlantic red snapper (Lutjanus campechanus) catch curve analysis.

SEDAR41-DW49, 2015. Estimating annual fecundity of Red Snapper by size using nonlinear models. SEDAR41-DW49. SEDAR, North Charleston, SC.

SEDAR41-RW07, 2016. Modifications to the Southeast Reef Fish Survey Chevron Trap Age Compositions for Red Snapper and Gray Triggerfish.

Shertzer, K. W., M. H. Prager, D. S. Vaughan, and E. H. Williams, 2008. Fishery models. Pages 1582–1593 *in* S. E. Jorgensen and F. Fath, editors. Population Dynamics. Vol. [2] of Encyclopedia of Ecology, 5 vols. Elsevier, Oxford.

Then, A. Y., J. M. Hoenig, N. G. Hall, and D. A. Hewitt. 2014. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES Journal of Marine Science **72**:82–92.

Wells, R. D., K. M. Boswell, J. H. Cowan Jr., and W. F. Patterson. 2008. Size selectivity of sampling gears targeting red snapper in the northern Gulf of Mexico. Fisheries Research **89**:294–299.

Williams, E. H., and K. W. Shertzer, 2015. Technical documentation of the Beaufort Assessment Model (BAM). NOAA Technical Memorandum-NMFS-SEFSC-671.

7 Tables

Table 1. Life-history characteristics at age, including average body total length (TL) and weight (mid-year), proportion female, annual proportion females mature, and natural mortality at age. The CV of length was estimated by the assessment model; other values were treated as input.

Age	Avg. TL (mm)	Avg. TL (in)	CV length	Avg. Whole weight (kg)	Avg. Whole weight (lb)	Fem. maturity	Proportion Female	Nat. mortality
1	323.9	12.8	0.1	0.53	1.17	0.43	0.5	0.595
2	449.3	17.7	0.1	1.41	3.10	0.73	0.5	0.364
3	547.9	21.6	0.1	2.55	5.62	0.91	0.5	0.271
4	625.4	24.6	0.1	3.78	8.34	0.97	0.5	0.222
5	686.4	27.0	0.1	5.00	11.02	0.99	0.5	0.193
6	734.4	28.9	0.1	6.12	13.49	1.00	0.5	0.174
7	772.2	30.4	0.1	7.11	15.67	1.00	0.5	0.162
8	801.9	31.6	0.1	7.96	17.54	1.00	0.5	0.153
9	825.2	32.5	0.1	8.67	19.12	1.00	0.5	0.146
10	843.6	33.2	0.1	9.26	20.42	1.00	0.5	0.142
11	858.1	33.8	0.1	9.74	21.48	1.00	0.5	0.138
12	869.4	34.2	0.1	10.13	22.34	1.00	0.5	0.135
13	878.4	34.6	0.1	10.45	23.04	1.00	0.5	0.133
14	885.4	34.9	0.1	10.70	23.59	1.00	0.5	0.132
15	891.0	35.1	0.1	10.90	24.04	1.00	0.5	0.130
16	895.3	35.2	0.1	11.06	24.39	1.00	0.5	0.129
17	898.7	35.4	0.1	11.19	24.67	1.00	0.5	0.129
18	901.4	35.5	0.1	11.29	24.89	1.00	0.5	0.128
19	903.5	35.6	0.1	11.37	25.07	1.00	0.5	0.128
20	905.2	35.6	0.1	11.43	25.21	1.00	0.5	0.127

Table 2. Size (TL) in inches and weight in pounds (lb) at age as applied to the population (Pop), fishery–dependent portion of the population (FD), and fishery–dependent portion of the population during the 20 mm size limit (FD20). The CV of length was estimated by the assessment model; other values were treated as input through the von Bertalanffy growth parameters.

Age	Pop.TL	CV.Pop.TL	Pop.lb	FD.TL	CV.FD.TL	FD.lb	FD20.TL	CV.FD20.TL	FD20.lb
1	12.8	0.1	1.2	11.2	0.14	0.8	16.2	0.1	2.4
2	17.7	0.1	3.1	16.2	0.14	2.4	19.5	0.1	4.1
3	21.6	0.1	5.6	20.2	0.14	4.6	22.2	0.1	6.1
4	24.6	0.1	8.3	23.4	0.14	7.2	24.5	0.1	8.2
5	27.0	0.1	11.0	26.0	0.14	9.8	26.5	0.1	10.3
6	28.9	0.1	13.5	28.1	0.14	12.3	28.1	0.1	12.4
7	30.4	0.1	15.7	29.7	0.14	14.7	29.5	0.1	14.3
8	31.6	0.1	17.5	31.1	0.14	16.7	30.6	0.1	16.0
9	32.5	0.1	19.1	32.1	0.14	18.5	31.6	0.1	17.6
10	33.2	0.1	20.4	33.0	0.14	20.0	32.5	0.1	19.0
11	33.8	0.1	21.5	33.7	0.14	21.3	33.2	0.1	20.3
12	34.2	0.1	22.3	34.2	0.14	22.4	33.7	0.1	21.4
13	34.6	0.1	23.0	34.7	0.14	23.3	34.2	0.1	22.4
14	34.9	0.1	23.6	35.0	0.14	24.0	34.7	0.1	23.2
15	35.1	0.1	24.0	35.3	0.14	24.6	35.0	0.1	23.9
16	35.2	0.1	24.4	35.6	0.14	25.0	35.3	0.1	24.5
17	35.4	0.1	24.7	35.7	0.14	25.4	35.6	0.1	25.1
18	35.5	0.1	24.9	35.9	0.14	25.8	35.8	0.1	25.5
19	35.6	0.1	25.1	36.0	0.14	26.0	36.0	0.1	25.9
20	35.6	0.1	25.2	36.1	0.14	26.2	36.1	0.1	26.2

Table 3. Observed time series of landings(L) and discards(D) for commercial lines (cH), headboat (HB), and general recreational (GR). Commercial landings are in units of 1000 lb whole weight. Recreational landings and discards and commercial discards are in units of 1000 fish. Confidential data have been redacted.

Year	cH.L	HB.L	GR.L	cH.D	HB.D	GR.D
1950	368.657	.	.	.	.	.
1951	499.765	.	.	.	.	.
1952	385.930	.	.	.	.	.
1953	398.279	.	.	.	.	.
1954	593.207	.	.	.	.	.
1955	493.315	12.501	24.035	.	.	.
1956	483.907	13.652	26.248	.	.	.
1957	867.291	14.803	28.460	.	.	.
1958	612.508	15.953	30.673	.	.	.
1959	657.736	17.104	32.885	.	.	.
1960	671.075	18.255	35.098	.	.	.
1961	796.374	19.908	38.276	.	.	.
1962	645.983	21.561	41.454	.	.	.
1963	488.789	23.214	44.633	.	.	.
1964	537.589	24.867	47.811	.	.	.
1965	558.108	26.520	50.989	.	.	.
1966	554.506	26.676	51.288	.	.	.
1967	725.503	26.831	51.587	.	.	.
1968	865.520	26.986	51.885	.	.	.
1969	538.190	27.142	52.184	.	.	.
1970	513.023	27.297	52.483	.	.	.
1971	457.393	29.995	57.670	.	.	.
1972	406.641	32.693	62.857	.	.	.
1973	296.560	35.391	68.044	.	.	.
1974	478.352	38.088	73.231	.	.	.
1975	600.790	40.786	78.418	.	.	.
1976	571.504	41.246	79.303	.	.	.
1977	596.339	41.707	80.187	.	.	.
1978	594.356	42.167	81.072	.	.	.
1979	420.936	42.627	81.957	.	.	.
1980	385.485	43.087	82.842	.	.	.
1981	378.759	36.031	93.458	.	.	4.435
1982	308.445	19.553	36.294	.	.	4.435
1983	316.818	30.698	68.469	.	.	4.435
1984	253.431	31.146	212.547	.	0.069	61.825
1985	250.824	50.336	288.971	.	0.111	64.088
1986	219.440	16.625	100.736	.	0.037	64.088
1987	191.701	24.996	47.373	.	0.055	64.088
1988	173.689	36.527	80.821	.	0.08	50.274
1989	266.942	23.453	97.147	.	0.052	19.383
1990	226.542	20.919	12.092	.	0.046	19.383
1991	143.546	13.857	34.717	.	0.03	19.383
1992	104.374	5.301	51.908	19.603	2.51	27.994
1993	220.153	7.347	11.326	16.725	3.478	68.149
1994	195.319	8.225	18.313	21.134	3.894	66.54
1995	177.312	8.826	13.482	21.068	4.178	50.89
1996	138.671	5.543	9.342	20.727	2.624	20.445
1997	110.595	5.770	34.238	22.392	2.732	16.574
1998	89.602	4.741	13.015	16.171	2.244	26.789
1999	93.595	6.836	39.579	13.641	3.236	162.71
2000	104.165	8.437	45.347	14.552	3.994	248.597
2001	196.697	12.028	31.587	15.141	5.694	202.665
2002	187.967	12.931	35.062	29.848	6.122	123.362
2003	138.342	5.706	25.977	8.372	2.701	159.329
2004	172.083	10.842	28.914	2.425	18.79	199.638
2005	129.700	8.907	29.443	10.177	9.876	72.855
2006	86.382	5.945	26.769	4.817	17.233	119.735
2007	114.973	6.889	17.646	13.778	71.886	288.276
2008	252.146	18.943	81.638	12.553	73.609	511.984
2009	362.386	21.507	54.666	14.466	57.327	240.516
2010	6.448	0.477	0.062	17.438	38.443	138.478
2011	− − −	− − −	0.062	40.107	41.391	33.484
2012	8.142	2.127	15.628	19.214	46.782	142.961
2013	31.600	1.520	7.588	19.302	46.74	83.992
2014	65.443	5.904	28.186	27.008	46.612	285.962

Table 4. Observed indices of abundance and CVs from commercial line (cH), headboat (HB), combined chevon trap and video (CVID), and headboat discard (HB.D).

Year	cH	cH CV	HB	HB CV	CVID	CVID CV	HB.D	HB.D CV
1976	.	.	2.37	0.2	.	.	.	.
1977	.	.	2.16	0.2	.	.	.	.
1978	.	.	2.13	0.2	.	.	.	.
1979	.	.	2.23	0.2	.	.	.	.
1980	.	.	1.45	0.2	.	.	.	.
1981	.	.	2.95	0.2	.	.	.	.
1982	.	.	1.20	0.2	.	.	.	.
1983	.	.	1.64	0.2	.	.	.	.
1984	.	.	1.42	0.2	.	.	.	.
1985	.	.	2.07	0.2	.	.	.	.
1986	.	.	0.48	0.2	.	.	.	.
1987	.	.	0.58	0.2	.	.	.	.
1988	.	.	0.56	0.2	.	.	.	.
1989	.	.	0.90	0.2	.	.	.	.
1990	.	.	0.87	0.2	.	.	.	.
1991	.	.	0.69	0.2	.	.	.	.
1992	.	.	0.08	0.2	.	.	.	.
1993	1.09	0.2	0.16	0.2	.	.	.	.
1994	0.89	0.2	0.26	0.2	.	.	.	.
1995	0.89	0.2	0.28	0.2	.	.	.	.
1996	0.61	0.2	0.25	0.2	.	.	.	.
1997	0.59	0.2	0.27	0.2	.	.	.	.
1998	0.66	0.2	0.24	0.2	.	.	.	.
1999	0.80	0.2	0.29	0.2	.	.	.	.
2000	0.74	0.2	0.41	0.2	.	.	.	.
2001	1.27	0.2	0.76	0.2	.	.	.	.
2002	1.38	0.2	0.88	0.2	.	.	.	.
2003	1.04	0.2	0.52	0.2	.	.	.	.
2004	1.42	0.2	0.76	0.2	.	.	.	.
2005	1.19	0.2	0.76	0.2	.	.	0.33	0.34
2006	0.60	0.2	0.43	0.2	.	.	0.4	0.4
2007	0.67	0.2	0.44	0.2	.	.	2.49	0.19
2008	1.22	0.2	1.71	0.2	.	.	1.99	0.29
2009	1.94	0.2	1.81	0.2	.	.	0.95	0.26
2010	.	.	.	.	0.90	0.26	0.44	0.29
2011	.	.	.	.	0.66	0.23	0.46	0.34
2012	.	.	.	.	1.10	0.18	1.16	0.25
2013	.	.	.	.	0.87	0.20	0.96	0.27
2014	.	.	.	.	1.47	0.17	0.82	0.28

Table 5. Sample sizes (number of trips) of length compositions (len) or age compositions (age) by survey or fleet. Data sources are commercial lines (cH), headboat (HB), headboat discard (HB.D), general recreational (GR),and MARMAP chevron trap (CVT).

Year	len.cH	len.cH.D	len.HB.D	age.cH	age.HB	age.GR	age.CVT
1978	.	.	.	.	80	.	.
1979	.	.	.	.	31	.	.
1980	.	.	.	.	30	.	.
1981	.	.	.	.	141	.	.
1982	.	.	.	.	55	.	.
1983	.	.	.	.	167	.	.
1984	125	.	.	.	166	.	.
1985	139	.	.	.	160	.	.
1986	94	.	.	.	97	.	.
1987	89	.	.	.	60	.	.
1988	84	.	.	.	.	.	.
1989	88	.	.	.	.	.	.
1990	63	.	.	11	23	.	.
1991	106	.	.	.	13	.	.
1992	82	.	.	11	.	.	.
1993	.	.	.	.	.	.	.
1994	.	.	.	14	.	.	.
1995	.	.	.	.	.	.	.
1996	.	.	.	48	.	.	.
1997	.	.	.	45	.	.	.
1998	.	.	.	14	.	.	.
1999	.	.	.	15	.	.	.
2000	.	.	.	28	.	.	.
2001	.	.	.	23	.	15	.
2002	.	.	.	.	.	84	.
2003	.	.	.	10	.	91	.
2004	.	.	.	25	.	83	.
2005	.	.	37	53	22	78	.
2006	.	.	29	84	49	26	.
2007	.	.	64	132	34	.	.
2008	.	.	61	158	47	.	.
2009	.	13	56	263	241	58	.
2010	.	.	50	.	.	.	73
2011	.	.	48	.	.	.	70
2012	.	.	56	39	40	121	148
2013	.	13	60	109	35	139	139
2014	.	.	56	64	49	315	150

Table 6. Coefficients of variation used for the MCB bootstraps of landings and discards. Commercial handline landings (cv.L.cH), headboat landings (cv.L.HB), general recreational landings (cv.L.GR), commercial handline discards (cv.D.cH), headboat discards (cv.D.HB), and general recreational discards (cv.D.GR).

Year	CV.L.cH	CV.L.HB	CV.L.GR	CV.D.cH	CV.D.HB	CV.D.GR
1950	0.25	–	–	–	–	–
1951	0.25	–	–	–	–	–
1952	0.25	–	–	–	–	–
1953	0.25	–	–	–	–	–
1954	0.25	–	–	–	–	–
1955	0.25	0.59	0.59	–	–	–
1956	0.25	0.59	0.59	–	–	–
1957	0.25	0.59	0.59	–	–	–
1958	0.25	0.59	0.59	–	–	–
1959	0.25	0.59	0.59	–	–	–
1960	0.25	0.59	0.59	–	–	–
1961	0.25	0.59	0.59	–	–	–
1962	0.20	0.59	0.59	–	–	–
1963	0.20	0.59	0.59	–	–	–
1964	0.20	0.59	0.59	–	–	–
1965	0.20	0.59	0.59	–	–	–
1966	0.20	0.59	0.59	–	–	–
1967	0.20	0.59	0.59	–	–	–
1968	0.20	0.59	0.59	–	–	–
1969	0.20	0.59	0.59	–	–	–
1970	0.20	0.59	0.59	–	–	–
1971	0.20	0.59	0.59	–	–	–
1972	0.20	0.59	0.59	–	–	–
1973	0.20	0.59	0.59	–	–	–
1974	0.20	0.59	0.59	–	–	–
1975	0.20	0.59	0.59	–	–	–
1976	0.20	0.59	0.59	–	–	–
1977	0.20	0.59	0.59	–	–	–
1978	0.10	0.59	0.59	–	–	–
1979	0.10	0.59	0.59	–	–	–
1980	0.10	0.59	0.59	–	–	–
1981	0.10	0.15	0.27	–	–	1.00
1982	0.10	0.15	0.34	–	–	1.00
1983	0.10	0.15	0.18	–	–	1.00
1984	0.10	0.15	0.22	–	0.20	0.56
1985	0.10	0.15	0.20	–	0.20	1.34
1986	0.05	0.15	0.29	–	0.20	1.00
1987	0.05	0.15	0.20	–	0.20	1.00
1988	0.05	0.15	0.28	–	0.20	1.33
1989	0.05	0.15	0.21	–	0.20	1.18
1990	0.05	0.15	0.29	–	0.20	1.00
1991	0.05	0.15	0.31	–	0.20	1.00
1992	0.05	0.15	0.19	0.20	0.20	0.79
1993	0.05	0.15	0.22	0.20	0.20	0.68
1994	0.05	0.15	0.27	0.20	0.20	0.81
1995	0.05	0.15	0.29	0.20	0.20	0.53
1996	0.05	0.10	0.42	0.20	0.20	1.00
1997	0.05	0.10	0.52	0.20	0.20	0.54
1998	0.05	0.10	0.24	0.20	0.20	0.96
1999	0.05	0.10	0.23	0.20	0.20	0.47
2000	0.05	0.10	0.23	0.20	0.20	0.45
2001	0.05	0.10	0.18	0.20	0.20	0.42
2002	0.05	0.10	0.17	0.20	0.20	0.56
2003	0.05	0.10	0.20	0.20	0.20	0.47
2004	0.05	0.10	0.21	0.20	0.20	0.29
2005	0.05	0.10	0.24	0.20	0.20	0.23
2006	0.05	0.10	0.26	0.20	0.20	0.31
2007	0.05	0.10	0.24	0.20	0.20	0.26
2008	0.05	0.05	0.27	0.20	0.20	0.36
2009	0.05	0.05	0.25	0.20	0.20	0.38
2010	0.05	0.05	1.00	0.20	0.20	0.39
2011	0.05	0.05	1.00	0.20	0.20	0.34
2012	0.05	0.05	0.17	0.20	0.20	0.39
2013	0.05	0.05	0.18	0.20	0.20	0.31
2014	0.05	0.05	0.11	0.20	0.20	0.21

Table 7. Estimated total abundance at age (1000 fish) at start of year.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1950	448.20	247.12	169.84	125.87	97.87	78.34	63.91	52.77	43.96	36.88	31.07	26.27	22.29	18.94	16.12	13.74	11.72	10.00	8.55	50.37	1573.85
1951	448.20	247.12	169.75	125.71	97.75	78.24	63.83	52.70	43.91	36.84	31.03	26.24	22.26	18.92	16.10	13.72	11.71	9.99	8.54	50.30	1572.86
1952	448.19	247.09	169.04	124.30	96.54	77.27	63.04	52.05	43.36	36.38	30.64	25.91	21.98	18.68	15.90	13.55	11.56	9.87	8.43	49.68	1563.45
1953	448.19	247.11	169.61	124.90	96.34	77.03	62.84	51.88	43.22	36.26	30.55	25.83	21.91	18.62	15.85	13.51	11.53	9.84	8.40	49.52	1562.94
1954	448.18	247.10	169.55	125.18	96.70	76.79	62.57	51.66	43.04	36.11	30.41	25.72	21.82	18.54	15.78	13.45	11.48	9.79	8.37	49.31	1561.56
1955	448.17	247.05	168.47	123.08	95.28	75.76	61.32	50.57	42.13	35.34	29.77	25.18	21.36	18.15	15.44	13.17	11.23	9.59	8.19	48.26	1547.50
1956	448.13	246.27	161.68	115.37	88.99	71.61	58.66	48.54	40.74	34.41	29.12	24.63	20.89	17.75	15.10	12.88	10.99	9.38	8.01	47.21	1510.35
1957	448.09	246.14	160.15	109.64	82.67	66.38	55.10	46.21	38.97	33.19	28.29	24.04	20.39	17.33	14.74	12.57	10.73	9.15	7.82	46.08	1477.69
1958	448.01	245.87	156.61	103.41	74.79	58.79	48.77	41.52	35.54	30.44	26.19	22.41	19.10	16.23	13.81	11.77	10.05	8.57	7.32	43.16	1422.36
1959	447.91	245.76	156.56	102.08	71.33	53.86	43.82	37.35	32.49	28.27	24.48	21.14	18.15	15.50	13.18	11.24	9.59	8.19	6.99	41.21	1389.12
1960	447.81	245.57	154.94	100.16	69.17	50.53	39.56	33.11	28.88	25.57	22.50	19.56	16.95	14.58	12.46	10.62	9.06	7.73	6.61	38.94	1354.30
1961	447.69	245.37	153.37	97.47	66.79	48.29	36.64	29.56	25.35	22.52	20.19	17.84	15.55	13.50	11.62	9.96	8.50	7.25	6.19	36.50	1320.15
1962	447.52	245.05	150.43	92.97	62.68	45.07	33.93	26.59	22.02	19.27	17.35	15.61	13.84	12.09	10.50	9.06	7.77	6.63	5.66	33.38	1277.43
1963	447.34	244.81	149.35	90.83	59.67	42.32	31.76	24.75	19.96	16.89	15.00	13.56	12.23	10.87	9.50	8.27	7.14	6.12	5.23	30.83	1246.44
1964	447.18	244.59	148.74	90.39	58.55	40.55	30.08	23.43	18.82	15.53	13.35	11.90	10.79	9.76	8.67	7.60	6.62	5.72	4.91	28.93	1226.11
1965	446.99	244.28	146.42	87.60	56.77	38.85	28.22	21.77	17.51	14.42	12.10	10.44	9.33	8.48	7.68	6.84	6.00	5.23	4.52	26.75	1200.20
1966	446.77	243.94	144.01	83.93	53.62	36.81	26.49	20.07	16.03	13.24	11.10	9.35	8.09	7.25	6.59	5.98	5.33	4.68	4.08	24.42	1171.76
1967	446.51	243.71	142.75	81.39	50.68	34.33	24.82	18.65	14.64	12.02	10.11	8.51	7.19	6.23	5.59	5.09	4.62	4.12	3.62	22.08	1146.66
1968	446.14	243.33	139.35	76.51	46.59	30.80	22.00	16.63	12.97	10.47	8.76	7.40	6.24	5.28	4.59	4.12	3.76	3.41	3.05	19.01	1110.41
1969	445.55	242.80	135.12	69.95	41.00	26.56	18.56	13.89	10.91	8.77	7.22	6.06	5.14	4.34	3.68	3.20	2.88	2.63	2.39	15.44	1066.07
1970	444.99	242.56	137.16	71.34	39.54	24.69	16.93	12.41	9.67	7.83	6.42	5.31	4.47	3.79	3.21	2.73	2.37	2.14	1.95	13.24	1052.74
1971	444.50	242.22	136.61	71.99	40.09	23.68	15.66	11.27	8.60	6.91	5.71	4.70	3.90	3.29	2.80	2.37	2.01	1.75	1.58	11.25	1040.89
1972	444.02	241.66	134.40	70.33	39.80	23.72	14.90	10.38	7.81	6.16	5.06	4.20	3.47	2.88	2.43	2.07	1.76	1.50	1.30	9.54	1027.37
1973	443.53	241.07	131.86	67.68	38.16	23.21	14.78	9.83	7.18	5.60	4.53	3.74	3.11	2.57	2.14	1.81	1.54	1.31	1.11	8.09	1012.86
1974	443.13	240.54	130.42	66.37	36.85	22.43	14.64	9.92	6.95	5.28	4.23	3.43	2.84	2.37	1.96	1.63	1.39	1.18	1.00	7.05	1003.62
1975	442.41	239.62	123.15	58.64	32.34	19.50	12.83	8.97	6.43	4.70	3.68	2.96	2.41	2.00	1.67	1.38	1.16	0.98	0.84	5.71	971.39
1976	440.88	238.23	113.91	47.92	24.83	15.02	9.89	7.04	5.26	3.96	3.00	2.36	1.90	1.55	1.29	1.08	0.89	0.75	0.63	4.23	924.61
1977	438.36	236.64	107.35	40.16	18.46	10.57	7.05	5.07	3.88	3.06	2.40	1.82	1.44	1.16	0.95	0.79	0.66	0.55	0.46	2.99	883.81
1978	490.78	234.27	98.35	32.15	13.18	6.76	4.31	3.17	2.47	2.01	1.66	1.30	0.99	0.78	0.63	0.52	0.43	0.36	0.30	1.89	896.34
1979	363.96	260.76	87.23	23.53	8.46	3.92	2.27	1.62	1.30	1.09	0.93	0.77	0.61	0.46	0.37	0.30	0.24	0.20	0.17	1.03	759.23
1980	539.19	193.18	96.76	21.20	6.32	2.58	1.36	0.88	0.69	0.60	0.53	0.45	0.38	0.30	0.23	0.18	0.15	0.12	0.10	0.59	865.79
1981	186.41	284.13	63.96	19.23	4.71	1.63	0.77	0.46	0.34	0.29	0.27	0.23	0.20	0.17	0.13	0.10	0.08	0.07	0.05	0.31	563.53
1982	307.89	97.40	88.82	11.21	3.77	1.07	0.43	0.23	0.16	0.13	0.11	0.11	0.09	0.08	0.07	0.05	0.04	0.03	0.03	0.15	511.87
1983	878.93	163.24	36.96	20.86	2.86	1.07	0.34	0.15	0.09	0.06	0.05	0.05	0.04	0.04	0.03	0.03	0.02	0.02	0.01	0.07	1104.92
1984	999.37	458.86	45.27	4.82	3.02	0.48	0.21	0.08	0.04	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	1512.31
1985	458.06	507.73	129.72	7.48	0.92	0.69	0.13	0.07	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	1104.93
1986	228.35	225.81	125.77	18.96	1.31	0.20	0.19	0.05	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	600.73
1987	784.38	112.09	87.32	37.54	6.38	0.50	0.09	0.09	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1028.46
1988	576.82	406.58	50.66	32.13	15.16	2.84	0.24	0.05	0.05	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1084.58
1989	215.42	301.94	194.02	20.83	14.48	7.51	1.54	0.14	0.03	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	755.97
1990	69.98	113.91	147.92	82.21	9.63	7.31	4.12	0.91	0.09	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	436.13
1991	63.82	36.48	66.17	84.38	50.19	6.19	4.90	2.86	0.65	0.07	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	315.75
1992	338.34	31.78	18.77	33.07	46.35	29.83	3.94	3.32	2.03	0.48	0.05	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	507.98
1993	118.87	172.64	19.71	8.50	10.74	16.91	13.01	2.04	1.98	1.34	0.34	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	366.14
1994	210.63	54.54	100.84	8.76	2.76	3.87	6.95	5.98	1.02	1.05	0.74	0.19	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	397.38
1995	97.19	97.24	31.92	46.52	2.99	1.03	1.63	3.26	3.05	0.55	0.59	0.43	0.11	0.01	0.00	0.00	0.00	0.00	0.00	0.00	286.55
1996	253.91	42.82	54.98	14.64	16.41	1.17	0.45	0.80	1.72	1.71	0.32	0.35	0.26	0.07	0.01	0.00	0.00	0.00	0.00	0.00	389.61
1997	172.65	129.31	27.19	29.34	6.28	7.54	0.58	0.25	0.46	1.03	1.05	0.20	0.22	0.16	0.04	0.00	0.00	0.00	0.00	0.00	376.30
1998	322.66	87.46	77.95	9.48	5.88	1.46	2.22	0.22	0.11	0.23	0.58	0.62	0.12	0.14	0.10	0.03	0.00	0.00	0.00	0.00	509.24
1999	436.64	167.71	56.50	42.70	4.21	2.80	0.76	1.26	0.13	0.07	0.15	0.38	0.42	0.08	0.09	0.07	0.02	0.00	0.00	0.00	714.00
2000	442.42	203.70	98.01	24.16	12.76	1.42	1.13	0.36	0.69	0.08	0.04	0.10	0.26	0.29	0.06	0.06	0.05	0.01	0.00	0.00	785.62
2001	323.07	192.88	113.53	41.23	7.21	4.30	0.57	0.53	0.20	0.41	0.05	0.03	0.07	0.18	0.20	0.04	0.05	0.03	0.01	0.00	684.60
2002	268.67	139.89	108.50	52.48	14.48	2.78	1.88	0.28	0.29	0.11	0.25	0.03	0.02	0.04	0.11	0.13	0.03	0.03	0.02	0.01	590.04
2003	346.83	119.88	79.98	51.09	19.20	5.86	1.28	0.97	0.16	0.17	0.07	0.16	0.02	0.01	0.03	0.08	0.08	0.02	0.02	0.02	625.93
2004	128.50	157.16	70.55	43.92	24.16	9.77	3.26	0.77	0.63	0.11	0.12	0.05	0.12	0.01	0.01	0.02	0.06	0.06	0.01	0.03	439.31
2005	52.34	44.17	75.58	32.50	17.10	10.48	4.79	1.78	0.46	0.40	0.07	0.08	0.03	0.08	0.01	0.01	0.01	0.04	0.04	0.03	240.01
2006	942.72	17.68	20.67	33.07	11.87	7.06	4.99	2.59	1.06	0.30	0.27	0.05	0.06	0.02	0.06	0.01	0.00	0.01	0.03	0.05	1042.56
2007	653.29	480.63	11.07	9.31	10.57	4.26	3.01	2.49	1.48	0.67	0.20	0.19	0.03	0.04	0.02	0.04	0.01	0.00	0.01	0.06	1177.37
2008	736.26	296.64	279.22	4.79	2.89	3.68	1.72	1.39	1.28	0.82	0.39	0.12	0.11	0.02	0.03	0.01	0.02	0.00	0.00	0.04	1329.44
2009	113.51	293.11	154.42	105.26	1.19	0.81	1.25	0.70	0.65	0.67	0.46	0.23	0.07	0.07	0.01	0.02	0.01	0.02	0.00	0.02	672.46
2010	144.25	39.53	140.62	62.97	32.07	0.41	0.32	0.56	0.35	0.35	0.37	0.26	0.13	0.04	0.04	0.01	0.01	0.00	0.01	0.02	422.31
2011	212.06	67.20	22.10	82.13	38.03	20.31	0.27	0.23	0.42	0.27	0.28	0.30	0.21	0.10	0.03	0.03	0.01	0.01	0.00	0.02	443.99
2012	227.48	110.51	42.57	14.38	54.64	26.14	14.42	0.20	0.17	0.32	0.21	0.21	0.23	0.16	0.08	0.03	0.02	0.00	0.01	0.02	491.78
2013	506.39	109.61	63.60	24.45	7.85	29.93	14.96	8.65	0.12	0.11	0.21	0.14	0.14	0.15	0.11	0.05	0.02	0.02	0.00	0.02	766.53
2014	859.61	262.50	69.29	41.06	15.43	5.01	19.69	10.12	6.00	0.09	0.08	0.15	0.10	0.10	0.11	0.08	0.04	0.01	0.01	0.01	1289.51
2015	431.84	430.16	156.09	38.69	19.63	7.06	2.36	9.65	5.14	3.13	0.05	0.04	0.08	0.05	0.06	0.06	0.04	0.02	0.01	0.01	1104.18

Table 8. Estimated biomass at age (mt) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1950	237.3	347.9	432.7	476.4	489.3	479.4	454.3	419.9	381.2	341.6	302.7	266.3	232.9	202.7	175.7	152.0	131.2	113.0	97.2	575.9	6309.5
1951	237.3	347.9	432.5	475.8	488.7	478.8	453.7	419.4	380.7	341.1	302.3	265.9	232.6	202.5	175.5	151.8	131.0	112.8	97.1	575.1	6302.5
1952	237.3	347.8	430.7	470.5	482.6	472.8	448.1	414.2	376.0	336.9	298.6	262.6	229.7	199.9	173.3	149.9	129.4	111.4	95.8	568.0	6235.5
1953	237.3	347.9	432.1	472.7	481.7	471.3	446.7	412.8	374.8	335.8	297.6	261.8	229.0	199.3	172.8	149.4	129.0	111.1	95.5	566.2	6224.8
1954	237.3	347.8	432.0	473.8	483.5	469.9	444.8	411.1	373.2	334.4	296.3	260.7	228.0	198.5	172.0	148.8	128.4	110.6	95.1	563.8	6209.9
1955	237.3	347.8	429.2	465.9	476.3	463.6	435.9	402.4	365.3	327.3	290.1	255.2	223.2	194.3	168.4	145.7	125.7	108.2	93.1	551.8	6106.4
1956	237.2	346.7	411.9	436.7	444.9	438.2	417.0	386.2	353.3	318.7	283.7	249.6	218.3	190.0	164.7	142.5	123.0	105.9	91.1	539.7	5899.1
1957	237.2	346.5	408.0	415.0	413.3	406.2	391.7	367.7	337.9	307.4	275.7	243.6	213.1	185.5	160.8	139.1	120.0	103.4	88.9	526.9	5687.7
1958	237.2	346.1	399.0	391.4	373.9	359.7	346.7	330.4	308.1	281.9	255.1	227.1	199.6	173.7	150.6	130.2	112.4	96.8	83.3	493.4	5296.7
1959	237.1	346.0	398.9	386.4	356.6	329.6	311.5	297.2	281.7	261.8	238.5	214.3	189.6	165.9	143.8	124.4	107.3	92.4	79.5	471.1	5033.6
1960	237.1	345.7	394.7	379.1	345.8	309.2	281.2	263.5	250.4	236.8	219.3	198.3	177.1	156.0	135.8	117.5	101.4	87.3	75.1	445.2	4756.4
1961	237.0	345.4	390.7	368.9	333.9	295.5	260.5	235.2	219.8	208.6	196.7	180.8	162.5	144.5	126.7	110.1	95.1	81.9	70.4	417.3	4481.6
1962	236.9	345.0	383.2	351.9	313.4	275.8	241.2	211.6	190.9	178.5	169.1	158.2	144.6	129.4	114.5	100.3	86.9	74.9	64.4	381.6	4152.2
1963	236.8	344.6	380.5	343.8	298.3	258.9	225.8	197.0	173.0	156.4	146.1	137.4	127.8	116.3	103.6	91.5	79.9	69.2	59.5	352.5	3899.1
1964	236.7	344.3	378.9	342.1	292.7	248.1	213.8	186.4	163.2	143.8	130.1	120.6	112.7	104.4	94.6	84.1	74.1	64.6	55.8	330.8	3722.0
1965	236.6	343.9	373.0	331.6	283.8	237.7	200.6	173.3	151.9	133.6	117.9	105.8	97.5	90.7	83.7	75.7	67.1	59.0	51.4	305.9	3520.6
1966	236.5	343.4	366.9	317.7	268.1	225.2	188.3	159.7	139.0	122.6	108.1	94.7	84.5	77.6	71.9	66.1	59.7	52.8	46.4	279.2	3308.4
1967	236.4	343.1	363.7	308.1	253.4	210.1	176.4	148.4	126.9	111.3	98.5	86.2	75.1	66.7	60.9	56.3	51.7	46.5	41.2	252.5	3113.3
1968	236.2	342.5	355.0	289.6	232.9	188.5	156.4	132.3	112.4	96.9	85.3	74.9	65.2	56.5	50.0	45.6	42.1	38.5	34.6	217.3	2853.1
1969	235.9	341.8	344.2	264.7	205.0	162.5	131.9	110.6	94.6	81.2	70.3	61.4	53.7	46.5	40.1	35.4	32.2	29.6	27.1	176.5	2545.4
1970	235.6	341.5	349.4	270.0	197.7	151.1	120.3	98.8	83.8	72.5	62.5	53.8	46.7	40.6	35.0	30.2	26.6	24.1	22.2	151.4	2413.7
1971	235.3	341.0	348.0	272.5	200.4	144.9	111.3	89.7	74.6	64.0	55.6	47.6	40.7	35.2	30.5	26.2	22.5	19.8	18.0	128.6	2306.5
1972	235.1	340.2	342.4	266.2	199.0	145.1	105.9	82.6	67.7	57.0	49.3	42.6	36.2	30.8	26.5	22.9	19.7	16.9	14.8	109.0	2209.9
1973	234.8	339.4	335.9	256.2	190.8	142.0	105.0	78.2	62.3	51.9	44.1	37.9	32.5	27.5	23.3	20.0	17.3	14.8	12.7	92.5	2119.0
1974	234.6	338.6	332.3	251.2	184.2	137.2	104.1	78.9	60.2	48.9	41.2	34.8	29.7	25.4	21.4	18.1	15.5	13.3	11.4	80.7	2061.7
1975	234.2	337.3	313.7	222.0	161.7	119.3	91.2	71.4	55.8	43.6	35.9	30.0	25.2	21.4	18.2	15.3	12.9	11.1	9.5	65.2	1894.9
1976	233.4	335.4	290.2	181.4	124.1	91.9	70.3	56.0	45.6	36.7	29.2	23.9	19.9	16.6	14.0	11.9	10.0	8.4	7.2	48.4	1654.6
1977	232.1	333.1	273.5	152.0	92.3	64.7	50.1	40.3	33.6	28.3	23.4	18.5	15.0	12.4	10.3	8.7	7.4	6.2	5.2	34.2	1441.3
1978	259.8	329.8	250.6	121.7	65.9	41.4	30.7	25.2	21.4	18.6	16.1	13.2	10.4	8.4	6.9	5.7	4.8	4.1	3.4	21.6	1259.9
1979	192.7	367.1	222.2	89.1	42.3	24.0	16.1	12.9	11.3	10.1	9.1	7.8	6.3	5.0	4.0	3.3	2.7	2.3	1.9	11.8	1041.9
1980	285.4	271.9	246.5	80.2	31.6	15.8	9.6	7.0	6.0	5.6	5.1	4.6	3.9	3.2	2.5	2.0	1.6	1.4	1.1	6.8	992.0
1981	98.7	400.0	163.0	72.8	23.5	9.9	5.5	3.7	2.9	2.7	2.6	2.4	2.1	1.8	1.4	1.1	0.9	0.7	0.6	3.5	799.8
1982	163.0	137.1	226.3	42.4	18.8	6.6	3.1	1.9	1.4	1.2	1.1	1.1	1.0	0.9	0.7	0.6	0.5	0.4	0.3	1.7	609.8
1983	465.3	229.8	94.2	79.0	14.3	6.5	2.4	1.2	0.8	0.6	0.5	0.5	0.5	0.4	0.4	0.3	0.2	0.2	0.2	0.8	897.9
1984	529.1	645.9	115.3	18.3	15.1	3.0	1.5	0.6	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	1330.7
1985	242.5	714.7	330.5	28.3	4.6	4.3	1.0	0.6	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.2	1327.6
1986	120.9	317.9	320.4	71.8	6.6	1.2	1.4	0.4	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	841.4
1987	415.2	157.8	222.5	142.1	31.9	3.1	0.6	0.7	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	974.6
1988	305.4	572.3	129.1	121.6	75.8	17.4	1.7	0.4	0.5	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1224.6
1989	114.0	425.0	494.3	78.8	72.4	45.9	10.9	1.1	0.3	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1243.5
1990	37.0	160.3	376.8	311.2	48.1	44.7	29.3	7.2	0.8	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1016.2
1991	33.8	51.4	168.6	319.4	250.9	37.9	34.8	22.7	5.6	0.6	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	926.2
1992	179.1	44.7	47.8	125.2	231.7	182.6	28.0	26.4	17.6	4.4	0.5	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	888.4
1993	62.9	243.0	50.2	32.2	53.7	103.5	92.4	16.2	17.1	12.4	3.3	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	687.7
1994	111.5	76.8	256.9	33.2	13.8	23.7	49.4	47.6	8.9	9.7	7.2	1.9	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	641.0
1995	51.5	136.9	81.3	176.1	14.9	6.3	11.6	25.9	26.5	5.1	5.8	4.3	1.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	547.6
1996	134.4	60.3	140.1	55.4	82.0	7.1	3.2	6.3	14.9	15.8	3.1	3.6	2.7	0.7	0.1	0.0	0.0	0.0	0.0	0.0	529.9
1997	91.4	182.0	69.3	111.1	31.4	46.1	4.2	2.0	4.0	9.5	10.2	2.0	2.3	1.7	0.5	0.1	0.0	0.0	0.0	0.0	567.7
1998	170.8	123.1	198.6	35.9	29.4	8.9	15.8	1.7	0.9	2.2	5.6	6.3	1.3	1.5	1.1	0.3	0.0	0.0	0.0	0.0	603.3
1999	231.2	236.1	143.9	161.6	21.1	17.1	5.4	10.0	1.1	0.6	1.5	3.9	4.4	0.9	1.0	0.8	0.2	0.0	0.0	0.0	840.8
2000	234.2	286.7	249.7	91.4	63.8	8.7	8.0	2.9	6.0	0.7	0.4	1.0	2.8	3.1	0.6	0.7	0.5	0.1	0.0	0.0	961.6
2001	171.0	271.5	289.2	156.1	36.1	26.3	4.1	4.3	1.7	3.8	0.5	0.3	0.7	2.0	2.2	0.4	0.5	0.4	0.1	0.0	971.2
2002	142.2	196.9	276.4	198.6	72.4	17.0	13.4	2.2	2.5	1.0	2.4	0.3	0.2	0.5	1.3	1.4	0.3	0.3	0.2	0.1	929.7
2003	183.6	168.8	203.8	193.4	96.0	35.8	9.1	7.7	1.4	1.6	0.7	1.6	0.2	0.1	0.3	0.8	0.9	0.2	0.2	0.2	906.6
2004	68.0	221.2	179.7	166.2	120.8	59.8	23.2	6.2	5.4	1.0	1.2	0.5	1.2	0.2	0.1	0.2	0.6	0.7	0.1	0.3	856.7
2005	27.7	62.2	192.6	123.0	85.5	64.1	34.1	14.2	4.0	3.7	0.7	0.8	0.4	0.8	0.1	0.1	0.2	0.4	0.5	0.3	615.3
2006	499.1	24.9	52.7	125.2	59.4	43.2	35.5	20.6	9.2	2.7	2.6	0.5	0.6	0.3	0.6	0.1	0.0	0.1	0.3	0.6	878.1
2007	345.8	676.6	28.2	35.3	52.8	26.1	21.4	19.9	12.8	6.2	1.9	1.9	0.4	0.4	0.2	0.4	0.1	0.0	0.1	0.6	1231.1
2008	389.8	417.6	711.4	18.1	14.5	22.5	12.3	11.1	11.1	7.6	3.8	1.2	1.2	0.2	0.3	0.1	0.3	0.0	0.0	0.4	1623.4
2009	60.1	412.6	393.4	398.4	5.9	5.0	8.9	5.6	5.7	6.2	4.4	2.3	0.7	0.7	0.1	0.2	0.1	0.2	0.0	0.3	1310.8
2010	76.4	55.6	358.3	238.3	160.3	2.5	2.3	4.5	3.0	3.2	3.6	2.6	1.4	0.4	0.4	0.1	0.1	0.0	0.1	0.2	913.4
2011	112.3	94.6	56.3	310.9	190.1	124.3	1.9	1.8	3.6	2.5	2.7	3.0	2.2	1.1	0.4	0.4	0.1	0.1	0.0	0.2	908.3
2012	120.4	155.6	108.4	54.4	273.2	160.0	102.5	1.6	1.5	2.9	2.0	2.2	2.4	1.7	0.9	0.3	0.3	0.1	0.1	0.2	990.5
2013	268.1	154.3	162.0	92.5	39.2	183.2	106.4	68.9	1.1	1.0	2.0	1.4	1.5	1.6	1.2	0.6	0.2	0.2	0.0	0.2	1085.6
2014	455.1	369.5	176.5	155.4	77.2	30.7	139.9	80.6	52.0	0.8	0.8	1.5	1.0	1.1	1.2	0.9	0.4	0.1	0.1	0.2	1545.1
2015	228.6	605.5	397.7	146.4	98.1	43.2	16.8	76.8	44.6	29.0	0.5	0.4	0.8	0.6	0.6	0.7	0.5	0.2	0.1	0.2	1691.2

Table 9. Estimated biomass at age (1000 lb) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1950	523.2	767.0	953.9	1050.3	1078.7	1056.9	1001.6	925.7	840.4	753.1	667.3	587.1	513.5	446.9	387.4	335.1	289.2	249.1	214.3	1269.6	13910.0
1951	523.2	767.0	953.5	1049.0	1077.4	1055.6	1000.2	924.6	839.3	752.0	666.5	586.2	512.8	446.4	386.9	334.7	288.8	248.7	214.1	1267.9	13894.6
1952	523.2	766.8	949.5	1037.3	1063.9	1042.3	987.9	913.2	828.9	742.7	658.3	578.9	506.4	440.7	382.1	330.5	285.3	245.6	211.2	1252.2	13746.9
1953	523.2	767.0	952.6	1042.1	1062.0	1039.0	984.8	910.1	826.3	740.3	656.1	577.2	504.9	439.4	381.0	329.4	284.4	244.9	210.5	1248.3	13723.3
1954	523.2	766.8	952.4	1044.5	1065.9	1036.0	980.6	906.3	822.8	737.2	653.2	574.7	502.7	437.6	379.2	328.0	283.1	243.8	209.7	1243.0	13690.5
1955	523.2	766.8	946.2	1027.1	1050.1	1022.1	961.0	887.1	805.3	721.6	639.6	562.6	492.1	428.4	371.3	321.2	277.1	238.5	205.3	1216.5	13462.3
1956	522.9	764.3	908.1	962.8	980.8	966.1	919.3	851.4	778.9	702.6	625.5	550.3	481.3	418.9	363.1	314.2	271.2	233.5	200.8	1189.8	13005.3
1957	522.9	763.9	899.5	914.9	911.2	895.5	863.5	810.6	744.9	677.7	607.8	537.0	469.8	409.0	354.5	306.7	264.6	228.0	196.0	1161.6	12539.2
1958	522.9	763.0	879.6	862.9	824.3	793.0	764.3	728.4	679.2	621.5	562.4	500.7	440.0	382.9	332.0	287.0	247.8	213.4	183.6	1087.8	11677.2
1959	522.7	762.8	879.4	851.9	786.2	726.6	686.7	655.2	621.0	577.2	525.8	472.5	418.0	365.7	317.0	274.3	236.6	203.7	175.3	1038.6	11097.2
1960	522.7	762.1	870.2	835.8	762.4	681.7	619.9	580.9	552.0	522.1	483.5	437.2	390.4	343.9	299.4	259.0	223.5	192.5	165.6	981.5	10486.1
1961	522.5	761.5	861.3	813.3	736.1	651.5	574.3	518.5	484.6	459.9	433.6	398.6	358.3	318.6	279.3	242.7	209.7	180.6	155.2	920.0	9880.2
1962	522.3	760.6	844.8	775.8	690.9	608.0	531.8	466.5	420.9	393.5	372.8	348.8	318.8	285.3	252.4	221.1	191.6	165.1	142.0	841.3	9154.0
1963	522.1	759.7	838.9	757.9	657.6	570.8	497.8	434.3	381.4	344.8	322.1	302.9	281.8	256.4	228.4	201.7	176.1	152.6	131.2	777.1	8596.0
1964	521.8	759.1	835.3	754.2	645.3	547.0	471.3	410.9	359.8	317.0	286.8	265.9	248.5	230.2	208.6	185.4	163.4	142.4	123.0	729.3	8205.6
1965	521.6	758.2	822.3	731.1	625.7	524.0	442.2	382.1	334.9	294.5	259.9	233.2	215.0	200.0	184.5	166.9	147.9	130.1	113.3	674.4	7761.6
1966	521.4	757.1	808.9	700.4	591.1	496.5	415.1	352.1	306.4	270.3	238.3	208.8	186.3	171.1	158.5	145.7	131.6	116.4	102.3	615.5	7293.8
1967	521.2	756.4	801.8	679.2	558.7	463.2	388.9	327.2	279.8	245.4	217.2	190.0	165.6	147.0	134.3	124.1	114.0	102.5	90.8	556.7	6863.6
1968	520.7	755.1	782.6	638.5	513.5	415.6	344.8	291.7	247.8	213.6	188.1	165.1	143.7	124.6	110.2	100.5	92.8	84.9	76.3	479.1	6290.0
1969	520.1	753.5	758.8	583.6	451.9	358.3	290.8	243.8	208.6	179.0	155.0	135.4	118.4	102.5	88.4	78.0	71.0	65.3	59.7	389.1	5611.6
1970	519.4	752.9	770.3	595.2	435.9	333.1	265.2	217.8	184.7	159.8	137.8	118.6	103.0	89.5	77.2	66.6	58.6	53.1	48.9	333.8	5321.3
1971	518.7	751.8	767.2	600.8	441.8	319.4	245.4	197.8	164.5	141.1	122.6	104.9	89.7	77.6	67.2	57.8	49.6	43.7	39.7	283.5	5085.0
1972	518.3	750.0	754.9	586.9	438.7	319.9	233.5	182.1	149.3	125.7	108.7	93.9	79.8	67.9	58.4	50.5	43.4	37.3	32.6	240.3	4872.0
1973	517.6	748.2	740.5	564.8	420.6	313.1	231.5	172.4	137.3	114.4	97.2	83.6	71.7	60.6	51.4	44.1	38.1	32.6	28.0	203.9	4671.6
1974	517.2	746.5	732.6	553.8	406.1	302.5	229.5	173.9	132.7	107.8	90.8	76.7	65.5	56.0	47.2	39.9	34.2	29.3	25.1	177.9	4545.3
1975	516.3	743.6	691.6	489.4	356.5	263.0	201.1	157.4	123.0	96.1	79.1	66.1	55.6	47.2	40.1	33.7	28.4	24.5	20.9	143.7	4177.5
1976	514.6	739.4	639.8	399.9	273.6	202.6	155.0	123.5	100.5	80.9	64.4	52.7	43.9	36.6	30.9	26.2	22.0	18.5	15.9	106.7	3647.8
1977	511.7	734.4	603.0	335.1	203.5	142.6	110.5	88.8	74.1	62.4	51.6	40.8	33.1	27.3	22.7	19.2	16.3	13.7	11.5	75.4	3177.5
1978	572.8	727.1	552.5	268.3	145.3	91.3	67.7	55.6	47.2	41.0	35.5	29.1	22.9	18.5	15.2	12.6	10.6	9.0	7.5	47.6	2777.6
1979	424.8	809.3	489.9	196.4	93.3	52.9	35.5	28.4	24.9	22.3	20.1	17.2	13.9	11.0	8.8	7.3	6.0	5.1	4.2	26.0	2297.0
1980	629.2	599.4	543.4	176.8	69.7	34.8	21.2	15.4	13.2	12.3	11.2	10.1	8.6	7.1	5.5	4.4	3.5	3.1	2.4	15.0	2187.0
1981	217.6	881.8	359.4	160.5	51.8	21.8	12.1	8.2	6.4	6.0	5.7	5.3	4.6	4.0	3.1	2.4	2.0	1.5	1.3	7.7	1763.3
1982	359.4	302.3	498.9	93.5	41.4	14.6	6.8	4.2	3.1	2.6	2.4	2.4	2.2	2.0	1.5	1.3	1.1	0.9	0.7	3.7	1344.4
1983	1025.8	506.6	207.7	174.2	31.5	14.3	5.3	2.6	1.8	1.3	1.1	1.1	1.1	0.9	0.9	0.7	0.4	0.4	0.4	1.8	1979.5
1984	1166.5	1424.0	254.2	40.3	33.3	6.6	3.3	1.3	0.7	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.7	2933.7
1985	534.6	1575.6	728.6	62.4	10.1	9.5	2.2	1.3	0.7	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.4	2926.9
1986	266.5	700.8	706.4	158.3	14.6	2.6	3.1	0.9	0.4	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1855.0
1987	915.4	347.9	490.5	313.3	70.3	6.8	1.3	1.5	0.4	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2148.6
1988	673.3	1261.7	284.6	268.1	167.1	38.4	3.7	0.9	1.1	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2699.8
1989	251.3	937.0	1089.7	173.7	159.6	101.2	24.0	2.4	0.7	0.7	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2741.4
1990	81.6	353.4	830.7	686.1	106.0	98.5	64.6	15.9	1.8	0.4	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2240.3
1991	74.5	113.3	371.7	704.2	553.1	83.6	76.7	50.0	12.3	1.3	0.2	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2041.9
1992	394.8	98.5	105.4	276.0	510.8	402.6	61.7	58.2	38.8	9.7	1.1	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1958.6
1993	138.7	535.7	110.7	71.0	118.4	228.2	203.7	35.7	37.7	27.3	7.3	0.9	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1516.1
1994	245.8	169.3	566.4	73.2	30.4	52.2	108.9	104.9	19.6	21.4	15.9	4.2	0.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0	1413.2
1995	113.5	301.8	179.2	388.2	32.8	13.9	25.6	57.1	58.4	11.2	12.8	9.5	2.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1207.2
1996	296.3	132.9	308.9	122.1	180.8	15.7	7.1	13.9	32.8	34.8	6.8	7.9	6.0	1.5	0.2	0.0	0.0	0.0	0.0	0.0	1168.2
1997	201.5	401.2	152.8	244.9	69.2	101.6	9.3	4.4	8.8	20.9	22.5	4.4	5.1	3.7	1.1	0.2	0.0	0.0	0.0	0.0	1251.6
1998	376.5	271.4	437.8	79.1	64.8	19.6	34.8	3.7	2.0	4.9	12.3	13.9	2.9	3.3	2.4	0.7	0.0	0.0	0.0	0.0	1330.0
1999	509.7	520.5	317.2	356.3	46.5	37.7	11.9	22.0	2.4	1.3	3.3	8.6	9.7	2.0	2.2	1.8	0.4	0.0	0.0	0.0	1853.6
2000	516.3	632.1	550.5	201.5	140.7	19.2	17.6	6.4	13.2	1.5	0.9	2.2	6.2	6.8	1.3	1.5	1.1	0.2	0.0	0.0	2120.0
2001	377.0	598.6	637.6	344.1	79.6	58.0	9.0	9.5	3.7	8.4	1.1	0.7	1.5	4.4	4.9	0.9	1.1	0.9	0.2	0.0	2141.1
2002	313.5	434.1	609.4	437.8	159.6	37.5	29.5	4.9	5.5	2.2	5.3	0.7	0.4	1.1	2.9	3.1	0.7	0.7	0.4	0.2	2049.6
2003	404.8	372.1	449.3	426.4	211.6	78.9	20.1	17.0	3.1	3.5	1.5	3.5	0.4	0.2	0.7	1.8	2.0	0.4	0.4	0.4	1998.7
2004	149.9	487.7	396.2	366.4	266.3	131.8	51.1	13.7	11.9	2.2	2.6	1.1	2.6	0.4	0.2	0.4	1.3	1.5	0.2	0.7	1888.7
2005	61.1	137.1	424.6	271.2	188.5	141.3	75.2	31.3	8.8	8.2	1.5	1.8	0.9	1.8	0.2	0.2	0.4	0.9	1.1	0.7	1356.5
2006	1100.3	54.9	116.2	276.0	131.0	95.2	78.3	45.4	20.3	6.0	5.7	1.1	1.3	0.7	1.3	0.2	0.0	0.2	0.7	1.3	1935.9
2007	762.4	1491.6	62.2	77.8	116.4	57.5	47.2	43.9	28.2	13.7	4.2	4.2	0.9	0.9	0.4	0.9	0.2	0.0	0.2	1.3	2714.1
2008	859.4	920.6	1568.4	39.9	32.0	49.6	27.1	24.5	24.5	16.8	8.4	2.6	2.6	0.4	0.7	0.2	0.7	0.0	0.0	0.9	3579.0
2009	132.5	909.6	867.3	878.3	13.0	11.0	19.6	12.3	12.6	13.7	9.7	5.1	1.5	1.5	0.2	0.4	0.2	0.4	0.0	0.7	2889.8
2010	168.4	122.6	789.9	525.4	353.4	5.5	5.1	9.9	6.6	7.1	7.9	5.7	3.1	0.9	0.9	0.2	0.2	0.0	0.2	0.4	2013.7
2011	247.6	208.6	124.1	685.4	419.1	274.0	4.2	4.0	7.9	5.5	6.0	6.6	4.9	2.4	0.9	0.9	0.2	0.2	0.0	0.4	2002.5
2012	265.4	343.0	239.0	119.9	602.3	352.7	226.0	3.5	3.3	6.4	4.4	4.9	5.3	3.7	2.0	0.7	0.7	0.2	0.2	0.4	2183.7
2013	591.1	340.2	357.1	203.9	86.4	403.9	234.6	151.9	2.4	2.2	4.4	3.1	3.3	3.5	2.6	1.3	0.4	0.4	0.0	0.4	2393.3
2014	1003.3	814.6	389.1	342.6	170.2	67.7	308.4	177.7	114.6	1.8	1.8	3.3	2.2	2.4	2.6	2.0	0.9	0.2	0.2	0.4	3406.4
2015	504.0	1334.9	876.8	322.8	216.3	95.2	37.0	169.3	98.3	63.9	1.1	0.9	1.8	1.3	1.3	1.5	1.1	0.4	0.2	0.4	3728.5

Table 10. Estimated time series of status indicators, fishing mortality, and biomass. Fishing mortality rate is apical F. Total biomass (B, mt) is at the start of the year, and spawning biomass (SSB, 1E8 eggs) at the time of peak spawning (mid-year). The $MSST_{\mathrm{F30}}$ is defined by $\mathrm{MSST} = (1-M)SSB_{\mathrm{F30}}$, *with constant* $M = 0.134$.

Year	F	F/F_{30}	B	B/B_{unfished}	SSB	$SSB/SSBB_{\mathrm{F30}}$	$SSB/MSST_{\mathrm{F30}}$
1950	0.031	0.211	6309	0.789	778399	2.375	3.167
1951	0.042	0.288	6303	0.788	771030	2.353	3.137
1952	0.033	0.224	6235	0.780	766363	2.339	3.118
1953	0.034	0.232	6225	0.779	763741	2.331	3.107
1954	0.051	0.349	6210	0.777	752534	2.296	3.062
1955	0.108	0.736	6106	0.764	732688	2.236	2.981
1956	0.117	0.803	5899	0.738	707974	2.160	2.881
1957	0.166	1.139	5688	0.711	663309	2.024	2.699
1958	0.157	1.074	5297	0.663	619670	1.891	2.521
1959	0.176	1.201	5034	0.630	578307	1.765	2.353
1960	0.192	1.317	4756	0.595	535242	1.633	2.178
1961	0.230	1.570	4482	0.561	486562	1.485	1.980
1962	0.233	1.597	4152	0.519	442383	1.350	1.800
1963	0.231	1.581	3899	0.488	408720	1.247	1.663
1964	0.258	1.768	3722	0.466	376971	1.150	1.534
1965	0.286	1.953	3521	0.440	344137	1.050	1.400
1966	0.300	2.049	3308	0.414	312478	0.954	1.271
1967	0.353	2.412	3113	0.389	275954	0.842	1.123
1968	0.418	2.861	2853	0.357	232992	0.711	0.948
1969	0.368	2.515	2545	0.318	202988	0.619	0.826
1970	0.374	2.556	2414	0.302	182221	0.556	0.741
1971	0.393	2.688	2307	0.289	165389	0.505	0.673
1972	0.415	2.839	2210	0.276	151460	0.462	0.616
1973	0.416	2.843	2119	0.265	141616	0.432	0.576
1974	0.528	3.614	2062	0.258	126555	0.386	0.515
1975	0.673	4.602	1895	0.237	103334	0.315	0.420
1976	0.772	5.277	1655	0.207	79258	0.242	0.322
1977	0.935	6.393	1441	0.180	56261	0.172	0.229
1978	1.159	7.929	1260	0.158	35804	0.109	0.146
1979	1.144	7.821	1042	0.130	24108	0.074	0.098
1980	1.345	9.200	992	0.124	16265	0.050	0.066
1981	1.470	10.056	800	0.100	11267	0.034	0.046
1982	1.178	8.055	610	0.076	8746	0.027	0.036
1983	1.765	12.074	898	0.112	6173	0.019	0.025
1984	1.530	10.462	1331	0.166	8305	0.025	0.034
1985	1.652	11.299	1328	0.166	9969	0.030	0.041
1986	0.938	6.416	841	0.105	11769	0.036	0.048
1987	0.729	4.986	975	0.122	14235	0.043	0.058
1988	0.618	4.227	1225	0.153	19963	0.061	0.081
1989	0.588	4.020	1244	0.156	28089	0.086	0.114
1990	0.290	1.985	1016	0.127	38849	0.119	0.158
1991	0.423	2.891	926	0.116	46176	0.141	0.188
1992	0.903	6.173	888	0.111	37334	0.114	0.152
1993	0.902	6.172	688	0.086	27160	0.083	0.111
1994	0.854	5.844	641	0.080	22693	0.069	0.092
1995	0.820	5.611	548	0.068	19406	0.059	0.079
1996	0.625	4.278	530	0.066	18083	0.055	0.074
1997	1.386	9.482	568	0.071	14062	0.043	0.057
1998	0.589	4.027	603	0.075	15399	0.047	0.063
1999	0.986	6.741	841	0.105	16923	0.052	0.069
2000	0.987	6.751	962	0.120	18635	0.057	0.076
2001	0.825	5.641	971	0.121	21573	0.066	0.088
2002	0.783	5.358	930	0.116	23781	0.073	0.097
2003	0.527	3.605	907	0.113	27137	0.083	0.110
2004	0.721	4.934	857	0.107	27692	0.085	0.113
2005	0.785	5.369	615	0.077	24579	0.075	0.100
2006	0.919	6.284	878	0.110	19523	0.060	0.079
2007	0.948	6.483	1231	0.154	20795	0.063	0.085
2008	1.171	8.010	1623	0.203	27476	0.084	0.112
2009	0.967	6.612	1311	0.164	29515	0.090	0.120
2010	0.282	1.932	913	0.114	36650	0.112	0.149
2011	0.186	1.269	908	0.114	46989	0.143	0.191
2012	0.409	2.796	990	0.124	49264	0.150	0.200
2013	0.256	1.750	1086	0.136	51560	0.157	0.210
2014	0.589	4.028	1545	0.193	48993	0.150	0.199
2015	.	.	1691	0.212	.	.	.

Table 11. Selectivity at age for combined chevon trap and video (CVID), commercial handlines (cH), headboat (HB), and general recreational (GR) landings (L) and discards (D). For time-varying selectivities, values shown are from selectivity block 1 (1950–1991).

Age	CVID	cH.L	HB.L	GR.L	cH.D	HB.D	GR.D
1	0.065	0.012	0.049	0.049	1.000	1.000	1.000
2	0.637	0.374	0.667	0.667	0.956	0.709	0.709
3	0.978	0.967	1.000	1.000	0.663	0.275	0.275
4	0.999	0.999	0.897	0.897	0.331	0.073	0.073
5	1.000	1.000	0.749	0.749	0.133	0.017	0.017
6	1.000	1.000	0.586	0.586	0.048	0.004	0.004
7	1.000	1.000	0.429	0.429	0.017	0.001	0.001
8	1.000	1.000	0.297	0.297	0.006	0.000	0.000
9	1.000	1.000	0.196	0.196	0.002	0.000	0.000
10	1.000	1.000	0.125	0.125	0.001	0.000	0.000
11	1.000	1.000	0.125	0.125	0.000	0.000	0.000
12	1.000	1.000	0.125	0.125	0.000	0.000	0.000
13	1.000	1.000	0.125	0.125	0.000	0.000	0.000
14	1.000	1.000	0.125	0.125	0.000	0.000	0.000
15	1.000	1.000	0.125	0.125	0.000	0.000	0.000
16	1.000	1.000	0.125	0.125	0.000	0.000	0.000
17	1.000	1.000	0.125	0.125	0.000	0.000	0.000
18	1.000	1.000	0.125	0.125	0.000	0.000	0.000
19	1.000	1.000	0.125	0.125	0.000	0.000	0.000
20	1.000	1.000	0.125	0.125	0.000	0.000	0.000

Table 12. Selectivity at age for combined chevon trap and video (CVID), commercial handlines (cH), headboat (HB), and general recreational (GR) landings (L) and discards (D). For time-varying selectivities, values shown are from selectivity block 2 (1992–2009).

Age	CVID	cH.L	HB.L	GR.L	cH.D	HB.D	GR.D
1	0.065	0.001	0.001	0.005	1.000	1.000	1.000
2	0.637	0.026	0.030	0.068	0.956	0.709	0.709
3	0.978	0.425	0.697	0.547	0.663	0.275	0.275
4	0.999	0.954	1.000	1.000	0.331	0.073	0.073
5	1.000	0.998	0.763	0.909	0.133	0.017	0.017
6	1.000	1.000	0.518	0.716	0.048	0.004	0.004
7	1.000	1.000	0.320	0.515	0.017	0.001	0.001
8	1.000	1.000	0.185	0.342	0.006	0.000	0.000
9	1.000	1.000	0.102	0.213	0.002	0.000	0.000
10	1.000	1.000	0.055	0.127	0.001	0.000	0.000
11	1.000	1.000	0.055	0.074	0.000	0.000	0.000
12	1.000	1.000	0.055	0.042	0.000	0.000	0.000
13	1.000	1.000	0.055	0.024	0.000	0.000	0.000
14	1.000	1.000	0.055	0.024	0.000	0.000	0.000
15	1.000	1.000	0.055	0.024	0.000	0.000	0.000
16	1.000	1.000	0.055	0.024	0.000	0.000	0.000
17	1.000	1.000	0.055	0.024	0.000	0.000	0.000
18	1.000	1.000	0.055	0.024	0.000	0.000	0.000
19	1.000	1.000	0.055	0.024	0.000	0.000	0.000
20	1.000	1.000	0.055	0.024	0.000	0.000	0.000

Table 13. Selectivity at age for combined chevon trap and video (CVID), commercial handlines (cH), headboat (HB), and general recreational (GR) landings (L) and discards (D). For time-varying selectivities, values shown are from selectivity block 3 (2010–2014).

Age	CVID	cH.L	HB.L	GR.L	cH.D	HB.D	GR.D
1	0.065	0.006	0.017	0.005	0.032	0.714	0.714
2	0.637	0.067	0.336	0.036	0.219	0.883	0.883
3	0.978	0.446	1.000	0.232	0.704	0.990	0.990
4	0.999	0.901	0.916	0.710	0.953	1.000	1.000
5	1.000	0.990	0.738	0.952	0.994	0.911	0.911
6	1.000	0.999	0.566	0.994	0.999	0.753	0.753
7	1.000	1.000	0.416	0.999	1.000	0.570	0.570
8	1.000	1.000	0.295	1.000	1.000	0.401	0.401
9	1.000	1.000	0.203	1.000	1.000	0.267	0.267
10	1.000	1.000	0.137	1.000	1.000	0.171	0.171
11	1.000	1.000	0.137	1.000	1.000	0.171	0.171
12	1.000	1.000	0.137	1.000	1.000	0.171	0.171
13	1.000	1.000	0.137	1.000	1.000	0.171	0.171
14	1.000	1.000	0.137	1.000	1.000	0.171	0.171
15	1.000	1.000	0.137	1.000	1.000	0.171	0.171
16	1.000	1.000	0.137	1.000	1.000	0.171	0.171
17	1.000	1.000	0.137	1.000	1.000	0.171	0.171
18	1.000	1.000	0.137	1.000	1.000	0.171	0.171
19	1.000	1.000	0.137	1.000	1.000	0.171	0.171
20	1.000	1.000	0.137	1.000	1.000	0.171	0.171

Table 14. Estimated time series of fully selected fishing mortality rates for commercial handlines (F.cH.L), headboat (F.HB.L), recreational (F.GR.L) landings (L) and discards (D). Also shown is Full F, the maximum F at age summed across fleets, which may not equal the sum of fully selected F's because of dome-shaped selectivities.

Year	F.cH.L	F.HB.L	F.GR.L	F.cH.D	F.HB.D	F.GR.D	Full F
1950	0.031	0.000	0.000	0.000	0.000	0.000	0.031
1951	0.042	0.000	0.000	0.000	0.000	0.000	0.042
1952	0.033	0.000	0.000	0.000	0.000	0.000	0.033
1953	0.034	0.000	0.000	0.000	0.000	0.000	0.034
1954	0.051	0.000	0.000	0.000	0.000	0.000	0.051
1955	0.044	0.022	0.043	0.000	0.000	0.000	0.108
1956	0.044	0.025	0.049	0.000	0.000	0.000	0.117
1957	0.085	0.029	0.056	0.000	0.000	0.000	0.166
1958	0.064	0.033	0.063	0.000	0.000	0.000	0.157
1959	0.073	0.036	0.069	0.000	0.000	0.000	0.176
1960	0.080	0.039	0.076	0.000	0.000	0.000	0.192
1961	0.103	0.045	0.086	0.000	0.000	0.000	0.230
1962	0.091	0.050	0.096	0.000	0.000	0.000	0.233
1963	0.073	0.055	0.105	0.000	0.000	0.000	0.231
1964	0.086	0.060	0.115	0.000	0.000	0.000	0.258
1965	0.096	0.066	0.127	0.000	0.000	0.000	0.286
1966	0.103	0.068	0.131	0.000	0.000	0.000	0.300
1967	0.148	0.072	0.138	0.000	0.000	0.000	0.353
1968	0.202	0.076	0.147	0.000	0.000	0.000	0.418
1969	0.141	0.079	0.152	0.000	0.000	0.000	0.368
1970	0.144	0.080	0.154	0.000	0.000	0.000	0.374
1971	0.137	0.089	0.171	0.000	0.000	0.000	0.393
1972	0.129	0.099	0.191	0.000	0.000	0.000	0.415
1973	0.099	0.109	0.210	0.000	0.000	0.000	0.416
1974	0.173	0.124	0.238	0.000	0.000	0.000	0.528
1975	0.255	0.146	0.280	0.000	0.000	0.000	0.673
1976	0.301	0.165	0.316	0.000	0.000	0.000	0.772
1977	0.404	0.187	0.358	0.000	0.000	0.000	0.935
1978	0.551	0.214	0.412	0.000	0.000	0.000	1.159
1979	0.500	0.226	0.435	0.000	0.000	0.000	1.144
1980	0.575	0.270	0.519	0.000	0.000	0.000	1.345
1981	0.683	0.225	0.584	0.000	0.000	0.006	1.470
1982	0.678	0.182	0.339	0.000	0.000	0.006	1.178
1983	0.960	0.259	0.578	0.000	0.000	0.002	1.765
1984	0.494	0.133	0.912	0.000	0.000	0.025	1.530
1985	0.345	0.194	1.113	0.000	0.000	0.044	1.652
1986	0.306	0.088	0.532	0.000	0.000	0.082	0.938
1987	0.278	0.156	0.295	0.000	0.000	0.037	0.729
1988	0.191	0.133	0.293	0.000	0.000	0.029	0.618
1989	0.196	0.076	0.316	0.000	0.000	0.021	0.588
1990	0.147	0.086	0.050	0.000	0.000	0.048	0.290
1991	0.098	0.087	0.217	0.000	0.000	0.086	0.423
1992	0.110	0.083	0.701	0.032	0.003	0.038	0.903
1993	0.403	0.223	0.272	0.036	0.007	0.139	0.902
1994	0.380	0.135	0.333	0.043	0.007	0.125	0.854
1995	0.360	0.178	0.266	0.063	0.012	0.148	0.820
1996	0.314	0.113	0.197	0.040	0.004	0.034	0.625
1997	0.317	0.167	0.899	0.045	0.005	0.030	1.386
1998	0.242	0.088	0.260	0.022	0.003	0.033	0.589
1999	0.205	0.116	0.658	0.014	0.003	0.147	0.986
2000	0.212	0.118	0.646	0.014	0.003	0.214	0.987
2001	0.320	0.133	0.365	0.017	0.006	0.216	0.825
2002	0.263	0.132	0.375	0.041	0.008	0.161	0.783
2003	0.178	0.061	0.279	0.011	0.003	0.181	0.527
2004	0.225	0.130	0.341	0.005	0.040	0.426	0.721
2005	0.194	0.125	0.427	0.047	0.052	0.389	0.785
2006	0.176	0.148	0.596	0.003	0.009	0.063	0.919
2007	0.340	0.231	0.376	0.006	0.037	0.149	0.948
2008	0.350	0.139	0.674	0.006	0.040	0.277	1.171
2009	0.381	0.154	0.412	0.015	0.085	0.357	0.967
2010	0.006	0.003	0.001	0.041	0.051	0.184	0.282
2011	0.000	0.010	0.001	0.106	0.041	0.033	0.186
2012	0.007	0.018	0.172	0.056	0.046	0.140	0.409
2013	0.030	0.012	0.093	0.053	0.030	0.054	0.256
2014	0.064	0.033	0.339	0.060	0.018	0.112	0.589

Table 15. Estimated instantaneous fishing mortality rate (per yr) at age.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1950	0.000	0.012	0.030	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031
1951	0.001	0.016	0.041	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
1952	0.000	0.012	0.032	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
1953	0.000	0.013	0.033	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
1954	0.001	0.019	0.049	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051
1955	0.004	0.060	0.108	0.102	0.093	0.082	0.072	0.063	0.056	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052
1956	0.004	0.066	0.117	0.111	0.100	0.088	0.076	0.067	0.059	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054
1957	0.005	0.088	0.166	0.161	0.148	0.134	0.121	0.110	0.101	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095
1958	0.005	0.087	0.157	0.149	0.135	0.120	0.105	0.092	0.083	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076
1959	0.006	0.097	0.176	0.167	0.152	0.135	0.118	0.104	0.094	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086
1960	0.007	0.107	0.192	0.183	0.166	0.147	0.129	0.114	0.102	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094
1961	0.008	0.125	0.230	0.220	0.200	0.179	0.159	0.141	0.128	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119
1962	0.008	0.131	0.233	0.221	0.200	0.176	0.153	0.134	0.119	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
1963	0.009	0.134	0.231	0.217	0.193	0.167	0.142	0.121	0.105	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093
1964	0.010	0.149	0.258	0.243	0.217	0.189	0.161	0.138	0.120	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108
1965	0.011	0.164	0.286	0.269	0.240	0.209	0.179	0.153	0.134	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120
1966	0.011	0.172	0.300	0.282	0.253	0.220	0.189	0.162	0.142	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128
1967	0.012	0.195	0.353	0.336	0.305	0.271	0.238	0.210	0.189	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.174
1968	0.013	0.224	0.418	0.402	0.369	0.333	0.298	0.268	0.246	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
1969	0.013	0.207	0.368	0.349	0.314	0.277	0.240	0.210	0.186	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
1970	0.013	0.210	0.374	0.354	0.320	0.281	0.245	0.214	0.190	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173
1971	0.014	0.225	0.393	0.371	0.332	0.290	0.249	0.214	0.188	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169
1972	0.016	0.242	0.415	0.389	0.346	0.299	0.254	0.215	0.186	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165
1973	0.017	0.250	0.416	0.386	0.338	0.286	0.236	0.194	0.162	0.139	0.139	0.139	0.139	0.139	0.139	0.139	0.139	0.139	0.139	0.139
1974	0.020	0.306	0.528	0.497	0.443	0.384	0.328	0.280	0.244	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218
1975	0.024	0.380	0.673	0.637	0.574	0.505	0.438	0.382	0.338	0.308	0.308	0.308	0.308	0.308	0.308	0.308	0.308	0.308	0.308	0.308
1976	0.027	0.433	0.772	0.732	0.661	0.582	0.507	0.443	0.395	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361
1977	0.032	0.514	0.935	0.892	0.811	0.723	0.637	0.565	0.510	0.472	0.472	0.472	0.472	0.472	0.472	0.472	0.472	0.472	0.472	0.472
1978	0.037	0.624	1.159	1.113	1.020	0.918	0.820	0.737	0.674	0.629	0.629	0.629	0.629	0.629	0.629	0.629	0.629	0.629	0.629	0.629
1979	0.038	0.627	1.144	1.092	0.994	0.886	0.783	0.696	0.629	0.582	0.582	0.582	0.582	0.582	0.582	0.582	0.582	0.582	0.582	0.582
1980	0.046	0.741	1.345	1.283	1.166	1.037	0.914	0.809	0.730	0.674	0.674	0.674	0.674	0.674	0.674	0.674	0.674	0.674	0.674	0.674
1981	0.054	0.799	1.470	1.408	1.288	1.157	1.030	0.923	0.841	0.784	0.784	0.784	0.784	0.784	0.784	0.784	0.784	0.784	0.784	0.784
1982	0.040	0.605	1.178	1.145	1.068	0.983	0.901	0.832	0.780	0.743	0.743	0.743	0.743	0.743	0.743	0.743	0.743	0.743	0.743	0.743
1983	0.055	0.919	1.765	1.710	1.586	1.450	1.319	1.208	1.124	1.064	1.064	1.064	1.064	1.064	1.064	1.064	1.064	1.064	1.064	1.064
1984	0.082	0.899	1.530	1.433	1.277	1.106	0.943	0.805	0.699	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625
1985	0.112	1.032	1.652	1.520	1.324	1.110	0.906	0.733	0.601	0.508	0.508	0.508	0.508	0.508	0.508	0.508	0.508	0.508	0.508	0.508
1986	0.117	0.586	0.938	0.868	0.771	0.669	0.572	0.490	0.427	0.383	0.383	0.383	0.383	0.383	0.383	0.383	0.383	0.383	0.383	0.383
1987	0.062	0.430	0.729	0.684	0.616	0.542	0.471	0.412	0.366	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334
1988	0.052	0.376	0.618	0.575	0.510	0.440	0.374	0.317	0.274	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244
1989	0.042	0.350	0.588	0.550	0.490	0.426	0.365	0.313	0.273	0.245	0.245	0.245	0.245	0.245	0.245	0.245	0.245	0.245	0.245	0.245
1990	0.056	0.179	0.290	0.271	0.249	0.226	0.205	0.187	0.173	0.163	0.163	0.163	0.163	0.163	0.163	0.163	0.163	0.163	0.163	0.163
1991	0.102	0.301	0.423	0.377	0.327	0.276	0.229	0.188	0.157	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136
1992	0.078	0.113	0.521	0.903	0.815	0.656	0.498	0.365	0.268	0.204	0.166	0.144	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131
1993	0.184	0.174	0.540	0.902	0.827	0.716	0.615	0.538	0.484	0.450	0.436	0.427	0.422	0.422	0.422	0.422	0.422	0.422	0.422	0.422
1994	0.178	0.172	0.503	0.854	0.793	0.691	0.596	0.519	0.465	0.430	0.412	0.401	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395
1995	0.225	0.206	0.508	0.820	0.748	0.646	0.555	0.484	0.435	0.404	0.389	0.381	0.376	0.376	0.376	0.376	0.376	0.376	0.376	0.376
1996	0.080	0.090	0.357	0.625	0.585	0.515	0.452	0.402	0.367	0.345	0.334	0.328	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324
1997	0.085	0.142	0.782	1.386	1.268	1.049	0.834	0.656	0.526	0.440	0.392	0.364	0.347	0.347	0.347	0.347	0.347	0.347	0.347	0.347
1998	0.059	0.073	0.331	0.589	0.549	0.475	0.405	0.347	0.307	0.280	0.266	0.258	0.253	0.253	0.253	0.253	0.253	0.253	0.253	0.253
1999	0.167	0.173	0.579	0.986	0.896	0.737	0.581	0.452	0.357	0.295	0.260	0.239	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227
2000	0.235	0.221	0.595	0.987	0.895	0.737	0.583	0.455	0.362	0.301	0.266	0.246	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234
2001	0.242	0.211	0.501	0.825	0.758	0.651	0.551	0.470	0.411	0.374	0.354	0.343	0.336	0.336	0.336	0.336	0.336	0.336	0.336	0.336
2002	0.212	0.195	0.482	0.783	0.712	0.602	0.499	0.416	0.356	0.318	0.298	0.286	0.279	0.279	0.279	0.279	0.279	0.279	0.279	0.279
2003	0.197	0.166	0.328	0.527	0.483	0.411	0.342	0.285	0.244	0.217	0.202	0.193	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188
2004	0.473	0.368	0.504	0.721	0.642	0.538	0.443	0.366	0.311	0.275	0.257	0.246	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240
2005	0.490	0.395	0.555	0.785	0.691	0.568	0.455	0.363	0.298	0.255	0.232	0.219	0.211	0.211	0.211	0.211	0.211	0.211	0.211	0.211
2006	0.079	0.104	0.526	0.919	0.833	0.680	0.531	0.408	0.319	0.260	0.228	0.209	0.198	0.198	0.198	0.198	0.198	0.198	0.198	0.198
2007	0.195	0.179	0.567	0.948	0.862	0.730	0.608	0.512	0.444	0.401	0.381	0.369	0.362	0.362	0.362	0.362	0.362	0.362	0.362	0.362
2008	0.326	0.289	0.705	1.171	1.073	0.905	0.741	0.606	0.507	0.443	0.407	0.385	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373
2009	0.460	0.370	0.626	0.967	0.882	0.758	0.643	0.551	0.485	0.442	0.420	0.407	0.399	0.399	0.399	0.399	0.399	0.399	0.399	0.399
2010	0.169	0.218	0.267	0.282	0.264	0.226	0.183	0.143	0.111	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089
2011	0.057	0.092	0.159	0.186	0.182	0.169	0.154	0.140	0.129	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121
2012	0.135	0.188	0.284	0.384	0.409	0.384	0.348	0.315	0.289	0.270	0.270	0.270	0.270	0.270	0.270	0.270	0.270	0.270	0.270	0.270
2013	0.062	0.095	0.167	0.238	0.256	0.245	0.229	0.213	0.201	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192
2014	0.097	0.156	0.312	0.516	0.589	0.578	0.551	0.525	0.505	0.490	0.490	0.490	0.490	0.490	0.490	0.490	0.490	0.490	0.490	0.490

Table 16. Estimated time series of landings in number (1000 fish) for commercial handlines (L.cH), headboat (L.HB), and recreational (L.GR).

Year	L.cH	L.HB	L.GR	Total
1950	26.72	0.00	0.00	26.72
1951	36.24	0.00	0.00	36.24
1952	28.03	0.00	0.00	28.03
1953	28.96	0.00	0.00	28.96
1954	43.21	0.00	0.00	43.21
1955	35.86	12.50	24.03	72.40
1956	35.07	13.65	26.24	74.96
1957	63.01	14.80	28.46	106.27
1958	44.96	15.95	30.67	91.58
1959	48.92	17.10	32.88	98.90
1960	50.72	18.25	35.09	104.06
1961	61.33	19.91	38.27	119.50
1962	50.87	21.56	41.44	113.87
1963	39.36	23.21	44.62	107.18
1964	44.17	24.86	47.79	116.83
1965	46.83	26.51	50.96	124.30
1966	47.63	26.67	51.26	125.56
1967	64.06	26.82	51.56	142.44
1968	79.27	26.98	51.85	158.10
1969	51.58	27.13	52.15	130.87
1970	51.08	27.29	52.44	130.81
1971	46.95	29.98	57.62	134.55
1972	42.73	32.68	62.79	138.19
1973	31.74	35.37	67.96	135.07
1974	52.01	38.06	73.12	163.19
1975	67.36	40.74	78.26	186.37
1976	67.80	41.21	79.16	188.17
1977	76.47	41.63	79.89	197.98
1978	84.98	42.15	81.02	208.15
1979	69.21	42.66	82.06	193.94
1980	66.23	43.10	82.90	192.24
1981	74.29	36.05	93.58	203.92
1982	55.18	19.58	36.38	111.13
1983	66.37	30.70	68.48	165.55
1984	64.77	31.16	213.19	309.12
1985	57.44	50.35	289.40	397.20
1986	42.79	16.62	100.67	160.09
1987	33.05	24.98	47.32	105.35
1988	34.45	36.50	80.66	151.61
1989	47.25	23.44	96.85	167.54
1990	33.10	20.91	12.09	66.10
1991	16.78	13.85	34.68	65.31
1992	9.05	5.30	51.69	66.04
1993	18.28	7.35	11.33	36.96
1994	19.78	8.23	18.34	46.35
1995	17.56	8.83	13.49	39.89
1996	13.95	5.54	9.34	28.83
1997	10.90	5.77	34.06	50.73
1998	10.12	4.74	13.02	27.87
1999	10.34	6.84	39.64	56.81
2000	12.00	8.44	45.33	65.77
2001	22.84	12.03	31.58	66.44
2002	21.23	12.95	35.21	69.39
2003	14.86	5.71	26.00	46.57
2004	17.62	10.84	28.85	57.30
2005	12.98	8.91	29.45	51.34
2006	7.97	5.94	26.71	40.62
2007	11.46	6.89	17.64	35.99
2008	32.29	18.97	81.94	133.19
2009	42.58	21.56	55.04	119.18
2010	0.80	0.48	0.06	1.34
2011	0.06	1.36	0.06	1.48
2012	0.76	2.13	15.63	18.52
2013	3.01	1.52	7.58	12.11
2014	6.86	5.90	28.19	40.96

Table 17. Estimated time series of landings in whole weight (1000 lb) for commercial handlines (L.cH), headboat (L.HB), and recreational (L.GR).

Year	L.cH	L.HB	L.GR	Total
1950	368.62	0.00	0.00	368.62
1951	499.70	0.00	0.00	499.70
1952	385.89	0.00	0.00	385.89
1953	398.23	0.00	0.00	398.23
1954	593.08	0.00	0.00	593.08
1955	493.22	105.75	203.31	802.28
1956	483.80	114.78	220.66	819.24
1957	866.92	122.74	235.97	1225.63
1958	612.30	129.58	249.12	991.00
1959	657.47	136.40	262.22	1056.09
1960	670.77	143.03	274.96	1088.76
1961	795.90	153.17	294.44	1243.51
1962	645.64	162.58	312.54	1120.76
1963	488.57	172.14	330.92	991.63
1964	537.30	181.95	349.75	1068.99
1965	557.76	191.13	367.39	1116.28
1966	554.13	188.87	363.02	1106.02
1967	724.79	186.03	357.57	1268.39
1968	864.41	181.64	349.13	1395.18
1969	537.72	177.02	340.23	1054.96
1970	512.55	175.05	336.44	1024.04
1971	456.98	190.36	365.84	1013.18
1972	406.28	205.65	395.20	1007.13
1973	296.34	220.73	424.13	941.21
1974	477.72	234.66	450.83	1163.20
1975	599.63	242.92	466.60	1309.14
1976	570.47	232.73	447.08	1250.28
1977	594.82	220.92	423.98	1239.72
1978	593.46	206.52	396.94	1196.93
1979	421.56	195.11	375.36	992.03
1980	385.97	194.12	373.36	953.44
1981	379.07	152.91	396.94	928.92
1982	309.64	92.64	172.14	574.42
1983	317.08	113.40	252.95	683.43
1984	253.59	107.39	734.77	1095.75
1985	250.90	197.92	1137.61	1586.42
1986	219.44	76.40	462.69	758.53
1987	191.49	119.79	226.91	538.19
1988	173.48	154.01	340.42	667.91
1989	266.36	116.12	479.86	862.34
1990	226.27	128.96	74.56	429.79
1991	143.44	107.22	268.45	519.11
1992	104.28	55.54	552.83	712.65
1993	219.96	72.37	111.99	404.32
1994	195.68	65.04	151.15	411.87
1995	177.58	76.82	117.98	372.38
1996	138.61	46.80	80.59	265.99
1997	110.34	50.02	290.38	450.75
1998	89.59	36.77	100.84	227.20
1999	93.62	56.24	318.87	468.74
2000	104.14	66.54	352.23	522.91
2001	196.53	95.73	249.85	542.11
2002	188.45	106.61	291.45	586.52
2003	138.42	48.99	225.26	412.67
2004	171.75	95.44	258.03	525.22
2005	129.65	78.12	269.04	476.81
2006	86.18	56.31	251.10	393.59
2007	114.51	55.91	129.07	299.49
2008	251.87	137.40	583.25	972.53
2009	363.67	173.98	441.18	978.83
2010	6.45	3.30	0.54	10.28
2011	0.57	11.10	0.62	12.29
2012	8.14	16.71	177.71	202.56
2013	31.60	10.73	87.37	129.70
2014	65.44	34.94	300.40	400.78

Table 18. Estimated time series of discard mortalities in numbers (1000 fish) for commercial handlines (D.cH), headboat (D.HB), and recreational (D.GR).

Year	D.cH	D.HB	D.GR	Total
1981	.	.	1.64	.
1982	.	.	1.64	.
1983	.	.	1.64	.
1984	.	0.03	22.88	.
1985	.	0.04	23.71	.
1986	.	0.01	23.71	.
1987	.	0.02	23.71	.
1988	.	0.03	18.60	.
1989	.	0.02	7.17	.
1990	.	0.02	7.17	.
1991	.	0.01	7.18	.
1992	9.41	0.93	10.36	20.70
1993	8.03	1.29	25.24	34.56
1994	10.15	1.44	24.64	36.23
1995	10.12	1.55	18.85	30.52
1996	9.95	0.97	7.57	18.49
1997	10.75	1.01	6.13	17.90
1998	7.76	0.83	9.91	18.51
1999	6.55	1.20	60.22	67.96
2000	6.98	1.48	91.96	100.42
2001	7.27	2.11	75.03	84.41
2002	14.33	2.27	45.68	62.27
2003	4.02	1.00	58.97	63.98
2004	1.16	6.95	74.05	82.16
2005	4.89	3.66	27.12	35.66
2006	2.31	6.38	44.31	53.00
2007	5.24	26.60	106.67	138.51
2008	4.77	27.24	189.47	221.48
2009	5.50	21.22	89.22	115.94
2010	6.63	14.24	51.45	72.32
2011	15.29	11.80	9.55	36.64
2012	7.30	13.34	40.83	61.48
2013	7.34	13.33	23.98	44.65
2014	10.26	13.29	81.59	105.14

Table 19. Estimated time series of discard mortalities in whole weight (1000 lb) for commercial handlines (D.cH), headboat (D.HB), and recreational (D.GR).

Year	D.cH	D.HB	D.GR	Total
1981	.	.	3.60	.
1982	.	.	2.76	.
1983	.	.	2.26	.
1984	.	0.04	36.31	.
1985	.	0.08	47.41	.
1986	.	0.03	52.04	.
1987	.	0.03	34.54	.
1988	.	0.06	34.77	.
1989	.	0.05	17.92	.
1990	.	0.05	22.49	.
1991	.	0.03	20.02	.
1992	16.93	1.31	14.66	32.90
1993	20.82	2.95	57.87	81.64
1994	24.91	2.76	47.22	74.88
1995	29.00	3.56	43.42	75.98
1996	20.52	1.59	12.40	34.51
1997	25.11	2.02	12.24	39.37
1998	16.37	1.44	17.22	35.03
1999	13.52	2.09	105.29	120.90
2000	15.50	2.76	171.76	190.03
2001	18.39	4.36	155.23	177.98
2002	37.87	4.71	95.05	137.64
2003	9.49	1.85	109.24	120.58
2004	3.61	17.36	184.84	205.81
2005	18.73	10.48	77.71	106.92
2006	3.11	7.88	54.79	65.79
2007	10.82	50.42	202.22	263.47
2008	11.11	52.43	364.70	428.24
2009	19.25	62.33	262.02	343.60
2010	48.30	74.13	267.83	390.25
2011	134.28	59.46	48.10	241.84
2012	67.40	62.09	190.03	319.52
2013	62.72	44.02	79.16	185.90
2014	73.25	35.67	219.04	327.97

Table 20. Estimated landings at age in numbers (1000 fish)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1950	0.13	2.38	4.37	3.43	2.71	2.19	1.79	1.49	1.24	1.05	0.88	0.75	0.63	0.54	0.46	0.39	0.33	0.29	0.24	1.44
1951	0.17	3.24	5.94	4.65	3.67	2.96	2.43	2.02	1.69	1.42	1.20	1.01	0.86	0.73	0.62	0.53	0.45	0.39	0.33	1.95
1952	0.13	2.52	4.62	3.59	2.83	2.29	1.88	1.56	1.30	1.09	0.92	0.78	0.66	0.56	0.48	0.41	0.35	0.30	0.25	1.50
1953	0.14	2.61	4.79	3.73	2.92	2.36	1.93	1.60	1.34	1.13	0.95	0.81	0.68	0.58	0.50	0.42	0.36	0.31	0.26	1.55
1954	0.21	3.91	7.15	5.58	4.38	3.51	2.87	2.38	1.99	1.67	1.41	1.20	1.02	0.86	0.74	0.63	0.54	0.46	0.39	2.30
1955	1.26	12.07	15.09	10.75	7.67	5.48	3.92	2.87	2.15	1.66	1.40	1.19	1.01	0.86	0.73	0.62	0.53	0.45	0.39	2.29
1956	1.41	13.27	15.74	10.92	7.73	5.55	3.99	2.90	2.17	1.68	1.42	1.21	1.02	0.87	0.74	0.63	0.54	0.46	0.39	2.32
1957	1.75	17.45	21.59	14.62	10.37	7.66	5.80	4.46	3.49	2.81	2.40	2.04	1.73	1.47	1.26	1.07	0.91	0.78	0.67	3.93
1958	1.83	17.29	20.01	12.90	8.62	6.10	4.49	3.40	2.63	2.08	1.79	1.53	1.31	1.11	0.95	0.81	0.69	0.59	0.50	2.96
1959	2.03	19.16	22.18	14.14	9.15	6.24	4.52	3.44	2.71	2.18	1.89	1.64	1.41	1.20	1.02	0.87	0.74	0.64	0.54	3.20
1960	2.23	20.91	23.87	15.09	9.66	6.37	4.44	3.32	2.62	2.15	1.89	1.65	1.43	1.23	1.05	0.90	0.77	0.65	0.56	3.29
1961	2.57	24.31	27.70	17.30	11.06	7.28	4.97	3.62	2.84	2.36	2.12	1.87	1.64	1.42	1.22	1.05	0.90	0.76	0.65	3.85
1962	2.77	25.35	27.58	16.63	10.36	6.70	4.46	3.10	2.31	1.85	1.67	1.51	1.34	1.17	1.02	0.88	0.75	0.64	0.55	3.24
1963	2.94	25.89	27.14	15.96	9.57	5.99	3.89	2.62	1.85	1.40	1.25	1.13	1.02	0.91	0.79	0.69	0.60	0.51	0.44	2.58
1964	3.23	28.52	29.84	17.58	10.43	6.42	4.14	2.81	1.99	1.48	1.28	1.14	1.03	0.94	0.83	0.73	0.64	0.55	0.47	2.78
1965	3.56	31.20	32.06	18.61	11.07	6.74	4.27	2.87	2.04	1.52	1.28	1.11	0.99	0.90	0.82	0.73	0.64	0.56	0.48	2.85
1966	3.70	32.45	32.87	18.61	10.93	6.70	4.22	2.80	1.98	1.49	1.25	1.05	0.91	0.82	0.74	0.67	0.60	0.53	0.46	2.76
1967	4.03	36.40	37.45	20.96	12.17	7.51	4.87	3.29	2.35	1.80	1.51	1.28	1.08	0.94	0.84	0.77	0.70	0.62	0.54	3.33
1968	4.47	41.25	42.12	22.88	13.15	8.04	5.25	3.64	2.64	2.01	1.68	1.42	1.20	1.02	0.89	0.80	0.73	0.66	0.59	3.67
1969	4.36	38.30	36.72	18.58	10.10	5.91	3.67	2.44	1.73	1.28	1.05	0.89	0.75	0.64	0.54	0.47	0.42	0.39	0.35	2.27
1970	4.41	38.78	37.78	19.21	9.89	5.58	3.40	2.22	1.56	1.16	0.96	0.79	0.67	0.57	0.48	0.41	0.36	0.32	0.29	1.98
1971	4.80	41.19	39.23	20.13	10.36	5.49	3.19	2.02	1.37	1.01	0.83	0.69	0.57	0.48	0.41	0.35	0.30	0.26	0.23	1.65
1972	5.24	43.82	40.36	20.49	10.66	5.65	3.09	1.87	1.24	0.88	0.72	0.60	0.50	0.41	0.35	0.30	0.25	0.21	0.19	1.37
1973	5.60	45.09	39.65	19.57	10.02	5.33	2.88	1.61	1.00	0.68	0.55	0.45	0.38	0.31	0.26	0.22	0.19	0.16	0.14	0.99
1974	6.55	53.57	47.44	23.52	12.09	6.61	3.80	2.26	1.40	0.97	0.78	0.63	0.52	0.44	0.36	0.30	0.26	0.22	0.18	1.30
1975	7.91	64.19	53.63	25.08	12.97	7.15	4.23	2.65	1.73	1.17	0.92	0.74	0.60	0.50	0.42	0.35	0.29	0.24	0.21	1.43
1976	8.93	71.11	54.58	22.60	11.03	6.13	3.66	2.35	1.60	1.12	0.85	0.67	0.54	0.44	0.37	0.31	0.26	0.21	0.18	1.21
1977	10.29	80.96	58.30	21.60	9.45	5.05	3.09	2.04	1.45	1.08	0.85	0.64	0.51	0.41	0.34	0.28	0.23	0.19	0.16	1.06
1978	13.60	92.86	60.64	19.75	7.79	3.78	2.25	1.55	1.14	0.88	0.73	0.57	0.44	0.35	0.28	0.23	0.19	0.16	0.13	0.84
1979	10.36	103.78	53.38	14.30	4.92	2.14	1.15	0.76	0.57	0.45	0.39	0.32	0.25	0.19	0.15	0.12	0.10	0.08	0.07	0.43
1980	18.18	86.66	64.53	14.06	4.03	1.55	0.76	0.46	0.34	0.28	0.24	0.21	0.17	0.14	0.11	0.08	0.07	0.06	0.05	0.27
1981	6.57	133.43	44.49	13.35	3.16	1.04	0.46	0.26	0.18	0.15	0.14	0.12	0.10	0.09	0.07	0.05	0.04	0.03	0.03	0.16
1982	7.70	37.48	55.17	7.00	2.29	0.62	0.24	0.12	0.08	0.06	0.06	0.05	0.05	0.04	0.03	0.03	0.02	0.02	0.01	0.07
1983	34.04	84.34	27.85	15.79	2.12	0.77	0.23	0.10	0.06	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.04
1984	41.53	229.69	31.96	3.38	2.02	0.30	0.12	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01
1985	22.39	273.77	94.45	5.37	0.63	0.43	0.07	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
1986	5.57	76.91	66.80	9.95	0.65	0.09	0.08	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	14.62	31.26	39.68	16.83	2.69	0.19	0.03	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	9.84	102.03	20.47	12.68	5.55	0.93	0.07	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	3.44	72.31	75.79	7.96	5.14	2.41	0.44	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	0.43	12.75	31.36	17.39	1.93	1.36	0.71	0.14	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	0.74	6.38	19.04	23.54	12.74	1.38	0.93	0.46	0.09	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	0.89	1.33	6.32	17.65	23.66	13.27	1.44	0.94	0.45	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	0.15	4.74	6.42	4.49	5.52	7.99	5.56	0.79	0.71	0.46	0.11	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	0.30	1.54	30.73	4.46	1.38	1.78	2.90	2.26	0.36	0.34	0.24	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	0.12	2.42	9.37	22.76	1.43	0.45	0.64	1.17	1.01	0.17	0.18	0.13	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	0.25	0.85	13.06	6.02	6.60	0.43	0.15	0.25	0.49	0.47	0.09	0.09	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00
1997	0.61	7.52	12.49	19.97	4.16	4.55	0.31	0.11	0.17	0.34	0.32	0.06	0.06	0.04	0.01	0.00	0.00	0.00	0.00	0.00
1998	0.37	1.88	17.94	3.76	2.26	0.51	0.68	0.06	0.03	0.05	0.13	0.13	0.03	0.03	0.02	0.01	0.00	0.00	0.00	0.00
1999	1.07	6.92	20.10	24.05	2.29	1.35	0.31	0.43	0.04	0.02	0.03	0.08	0.08	0.02	0.02	0.01	0.00	0.00	0.00	0.00
2000	1.04	8.14	34.48	13.54	6.92	0.68	0.46	0.12	0.20	0.02	0.01	0.02	0.05	0.06	0.01	0.01	0.01	0.00	0.00	0.00
2001	0.48	5.41	33.86	20.52	3.50	1.90	0.22	0.19	0.06	0.12	0.01	0.01	0.02	0.05	0.05	0.01	0.01	0.01	0.00	0.00
2002	0.40	3.87	31.14	25.07	6.70	1.16	0.69	0.09	0.08	0.03	0.06	0.01	0.00	0.01	0.03	0.03	0.01	0.01	0.00	0.00
2003	0.38	2.36	16.29	18.34	6.68	1.82	0.34	0.22	0.03	0.03	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
2004	0.16	3.65	18.30	19.49	10.38	3.75	1.08	0.22	0.16	0.02	0.03	0.01	0.02	0.00	0.00	0.00	0.01	0.01	0.00	0.01
2005	0.08	1.17	20.74	15.10	7.69	4.17	1.62	0.51	0.11	0.08	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.00
2006	2.19	0.70	7.18	18.00	6.17	3.23	1.91	0.81	0.27	0.06	0.05	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01
2007	1.04	15.27	3.84	5.12	5.60	2.04	1.27	0.93	0.50	0.21	0.06	0.05	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.02
2008	1.80	12.81	109.43	2.96	1.75	2.03	0.84	0.59	0.48	0.27	0.12	0.04	0.03	0.01	0.01	0.00	0.01	0.00	0.00	0.01
2009	0.17	8.78	50.40	57.22	0.64	0.40	0.55	0.28	0.23	0.22	0.15	0.07	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.01
2010	0.01	0.04	0.61	0.43	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2011	0.03	0.19	0.19	0.68	0.27	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2012	0.18	1.07	1.99	1.57	7.57	3.78	2.11	0.03	0.03	0.05	0.03	0.03	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00
2013	0.30	0.81	2.40	2.03	0.80	3.15	1.58	0.92	0.01	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00
2014	1.57	5.66	7.38	9.54	4.39	1.48	5.86	3.03	1.81	0.03	0.02	0.05	0.03	0.03	0.03	0.02	0.01	0.00	0.00	0.00

Table 21. Estimated landings at age in whole weight (1000 lb)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1950	0.19	8.14	25.65	29.12	30.02	29.57	28.20	26.25	23.99	21.63	19.29	17.06	14.99	13.10	11.40	9.89	8.56	7.39	6.37	37.82
1951	0.26	11.09	34.80	39.47	40.69	40.08	38.22	35.57	32.52	29.31	26.14	23.12	20.31	17.75	15.45	13.41	11.60	10.01	8.63	51.25
1952	0.20	8.64	27.07	30.49	31.39	30.93	29.49	27.45	25.09	22.62	20.17	17.84	15.67	13.70	11.92	10.35	8.95	7.73	6.66	39.54
1953	0.21	8.94	28.08	31.68	32.39	31.88	30.40	28.29	25.86	23.31	20.79	18.38	16.16	14.12	12.29	10.66	9.23	7.96	6.86	40.76
1954	0.31	13.41	41.93	47.41	48.55	47.44	45.19	42.05	38.44	34.65	30.90	27.33	24.02	20.99	18.27	15.85	13.71	11.84	10.20	60.59
1955	1.86	41.38	88.47	91.31	85.13	74.09	61.63	50.56	41.50	34.40	30.67	27.13	23.84	20.83	18.13	15.73	13.61	11.75	10.13	60.14
1956	2.09	45.48	92.26	92.69	85.74	75.06	62.71	51.17	41.95	34.74	31.12	27.52	24.19	21.14	18.40	15.96	13.81	11.92	10.28	61.02
1957	2.58	59.81	126.59	124.17	114.99	103.69	91.24	78.66	67.37	58.15	52.46	46.62	40.97	35.80	31.16	27.04	23.39	20.20	17.40	103.35
1958	2.71	59.26	117.29	109.54	95.64	82.52	70.59	59.94	50.66	42.95	39.11	35.00	30.90	27.01	23.50	20.40	17.65	15.23	13.13	77.96
1959	3.00	65.68	130.04	120.10	101.55	84.41	71.04	60.61	52.24	45.12	41.35	37.35	33.21	29.16	25.38	22.02	19.05	16.45	14.18	84.17
1960	3.29	71.65	139.93	128.15	107.12	86.19	69.81	58.51	50.55	44.42	41.39	37.63	33.77	29.86	26.11	22.66	19.60	16.92	14.58	86.60
1961	3.79	83.32	162.40	146.90	122.67	98.56	78.20	63.89	54.86	48.81	46.30	42.80	38.65	34.50	30.38	26.49	22.92	19.78	17.05	101.25
1962	4.10	86.89	161.71	141.21	114.90	90.59	70.13	54.63	44.49	38.38	36.58	34.42	31.61	28.39	25.24	22.16	19.26	16.63	14.33	85.10
1963	4.34	88.74	159.12	135.51	106.14	81.11	61.21	46.20	35.67	29.07	27.32	25.83	24.15	22.05	19.73	17.48	15.31	13.28	11.44	67.94
1964	4.78	97.76	174.97	149.28	115.73	86.80	65.16	49.50	38.35	30.66	27.89	26.00	24.42	22.71	20.65	18.42	16.28	14.22	12.31	73.11
1965	5.26	106.95	187.99	158.06	122.80	91.22	67.21	50.71	39.43	31.52	27.98	25.26	23.39	21.85	20.23	18.35	16.32	14.38	12.54	74.84
1966	5.47	111.24	192.74	158.06	121.30	90.61	66.37	49.34	38.23	30.75	27.28	24.03	21.54	19.84	18.46	17.04	15.41	13.67	12.03	72.60
1967	5.97	124.77	219.57	177.96	135.05	101.57	76.59	58.07	45.43	37.18	33.11	29.14	25.50	22.74	20.85	19.34	17.81	16.06	14.23	87.47
1968	6.62	141.40	246.94	194.29	145.87	108.74	82.57	64.22	50.85	41.56	36.80	32.50	28.42	24.73	21.96	20.09	18.58	17.06	15.37	96.61
1969	6.44	131.28	215.27	157.76	112.09	80.00	57.74	43.11	33.38	26.46	23.06	20.26	17.78	15.46	13.40	11.86	10.82	9.98	9.15	59.65
1970	6.52	132.92	221.47	163.13	109.66	75.50	53.53	39.19	30.12	24.10	20.91	18.08	15.77	13.77	11.92	10.30	9.10	8.28	7.62	52.18
1971	7.10	141.16	230.00	170.96	114.88	74.24	50.23	35.66	26.52	20.81	18.21	15.67	13.47	11.69	10.16	8.77	7.56	6.66	6.05	43.38
1972	7.75	150.18	236.63	173.98	118.21	76.47	48.64	33.01	23.85	18.16	15.79	13.70	11.72	10.01	8.65	7.50	6.46	5.55	4.88	35.99
1973	8.28	154.53	232.44	166.22	111.14	72.07	45.30	28.43	19.29	14.04	12.02	10.37	8.94	7.60	6.47	5.58	4.82	4.14	3.55	25.97
1974	9.69	183.62	278.16	199.71	134.07	89.38	59.71	39.80	27.05	20.00	16.95	14.40	12.34	10.58	8.96	7.60	6.53	5.63	4.83	34.20
1975	11.70	219.99	314.42	212.94	143.83	96.68	66.45	46.79	33.30	24.16	20.02	16.83	14.20	12.10	10.34	8.73	7.38	6.33	5.45	37.50
1976	13.21	243.73	319.98	191.94	122.39	83.00	57.52	41.49	30.93	23.24	18.62	15.31	12.79	10.73	9.11	7.76	6.53	5.51	4.72	31.77
1977	15.21	277.49	341.79	183.42	104.82	68.26	48.64	36.05	27.99	22.32	18.50	14.70	12.01	9.98	8.34	7.06	5.99	5.03	4.24	27.88
1978	20.12	318.26	355.52	167.71	86.42	51.10	35.42	27.29	21.92	18.25	15.91	13.09	10.33	8.39	6.94	5.79	4.88	4.14	3.47	21.98
1979	15.33	355.70	312.97	121.44	54.63	28.98	18.08	13.37	10.99	9.33	8.44	7.30	5.96	4.68	3.79	3.12	2.60	2.19	1.85	11.29
1980	26.88	297.02	378.36	119.39	44.73	21.01	11.95	8.09	6.49	5.71	5.32	4.78	4.10	3.34	2.61	2.10	1.73	1.43	1.21	7.20
1981	9.71	457.32	260.84	113.36	35.10	14.06	7.28	4.62	3.48	3.05	2.97	2.74	2.45	2.09	1.69	1.32	1.06	0.87	0.72	4.19
1982	11.38	128.45	323.47	59.41	25.35	8.44	3.75	2.18	1.55	1.28	1.23	1.19	1.09	0.97	0.83	0.67	0.52	0.42	0.34	1.91
1983	50.34	289.06	163.29	134.07	23.49	10.35	3.64	1.73	1.07	0.80	0.70	0.67	0.64	0.59	0.52	0.44	0.35	0.27	0.22	1.18
1984	61.41	787.25	187.39	28.66	22.42	4.07	1.89	0.70	0.35	0.22	0.18	0.16	0.15	0.14	0.13	0.11	0.10	0.08	0.06	0.30
1985	33.11	938.32	553.74	45.61	6.96	5.88	1.17	0.60	0.24	0.13	0.09	0.07	0.06	0.06	0.06	0.05	0.05	0.04	0.03	0.15
1986	8.23	263.59	391.65	84.52	7.18	1.24	1.23	0.29	0.18	0.09	0.06	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.07
1987	21.62	107.14	232.65	142.89	29.83	2.61	0.48	0.51	0.13	0.09	0.05	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.05
1988	14.55	349.71	120.03	107.67	61.55	12.64	1.11	0.21	0.23	0.06	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.03
1989	5.09	247.82	444.36	67.56	57.04	32.55	6.85	0.63	0.12	0.15	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.02
1990	0.64	43.71	183.88	147.65	21.40	18.42	11.10	2.54	0.26	0.06	0.07	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.01
1991	1.09	21.88	111.62	199.91	141.39	18.61	14.58	8.03	1.69	0.16	0.04	0.05	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01
1992	2.88	6.82	45.36	163.90	268.90	177.03	21.81	15.93	8.17	1.62	0.15	0.03	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.01
1993	0.49	24.22	46.06	41.71	62.74	106.60	84.36	13.33	13.02	8.97	2.34	0.26	0.06	0.08	0.02	0.02	0.01	0.01	0.00	0.02
1994	0.98	7.85	220.37	41.39	15.67	23.80	43.97	38.06	6.52	6.78	4.91	1.29	0.15	0.03	0.04	0.01	0.01	0.00	0.00	0.01
1995	0.38	12.37	67.22	211.42	16.22	6.03	9.79	19.64	18.48	3.40	3.75	2.79	0.75	0.09	0.02	0.03	0.01	0.01	0.00	0.01
1996	0.79	4.36	93.65	55.89	74.99	5.77	2.32	4.14	9.08	9.18	1.79	2.01	1.52	0.41	0.05	0.01	0.01	0.00	0.00	0.01
1997	1.96	38.42	89.55	185.51	47.30	60.77	4.68	1.86	3.21	6.78	6.67	1.26	1.39	1.05	0.28	0.03	0.01	0.01	0.00	0.01
1998	1.19	9.59	128.65	34.91	25.71	6.77	10.39	0.99	0.49	1.05	2.63	2.88	0.58	0.68	0.51	0.14	0.02	0.00	0.00	0.00
1999	3.46	35.38	144.18	223.34	26.02	18.04	4.73	7.19	0.67	0.33	0.68	1.68	1.81	0.37	0.43	0.32	0.09	0.01	0.00	0.01
2000	3.36	41.59	247.26	125.80	78.63	9.13	7.02	2.08	3.58	0.38	0.21	0.46	1.18	1.34	0.27	0.32	0.24	0.06	0.01	0.01
2001	1.54	27.67	242.83	190.58	39.78	25.39	3.41	3.15	1.14	2.38	0.30	0.18	0.43	1.16	1.31	0.27	0.31	0.23	0.06	0.01
2002	1.29	19.78	223.36	232.87	76.19	15.49	10.43	1.49	1.47	0.57	1.24	0.16	0.10	0.24	0.64	0.72	0.15	0.17	0.13	0.04
2003	1.22	12.04	116.81	170.33	75.87	24.23	5.22	3.79	0.59	0.62	0.25	0.58	0.07	0.05	0.11	0.30	0.34	0.07	0.08	0.08
2004	0.50	18.67	131.22	181.04	117.96	50.01	16.43	3.72	2.88	0.48	0.54	0.23	0.53	0.07	0.04	0.11	0.28	0.32	0.06	0.14
2005	0.24	5.96	148.72	140.23	87.38	55.70	24.64	8.52	2.03	1.65	0.29	0.33	0.14	0.33	0.04	0.03	0.07	0.18	0.20	0.13
2006	7.08	3.56	51.50	167.17	70.13	43.08	29.00	13.60	4.97	1.25	1.07	0.19	0.22	0.10	0.23	0.03	0.02	0.05	0.12	0.22
2007	3.37	78.06	27.51	47.53	63.69	27.26	19.35	15.72	9.09	4.07	1.23	1.18	0.22	0.28	0.12	0.29	0.04	0.02	0.06	0.42
2008	5.81	65.47	784.82	27.51	19.89	27.14	12.77	9.96	8.78	5.40	2.54	0.77	0.75	0.15	0.18	0.08	0.18	0.02	0.01	0.30
2009	0.56	44.90	361.43	531.43	7.23	5.34	8.38	4.65	4.30	4.40	3.06	1.55	0.49	0.49	0.10	0.12	0.05	0.12	0.02	0.20
2010	0.01	0.14	3.58	3.63	2.55	0.04	0.04	0.07	0.05	0.05	0.05	0.04	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00
2011	0.04	0.64	1.10	5.81	3.00	1.58	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
2012	0.27	3.68	11.68	13.29	83.95	51.12	33.18	0.52	0.49	0.98	0.67	0.73	0.81	0.59	0.30	0.10	0.10	0.02	0.02	0.07
2013	0.45	2.79	14.07	17.24	8.89	42.63	24.86	16.15	0.25	0.24	0.49	0.33	0.36	0.40	0.29	0.15	0.05	0.05	0.01	0.04
2014	2.32	19.42	43.26	80.99	48.74	19.98	92.12	53.50	34.84	0.55	0.52	1.04	0.71	0.75	0.84	0.60	0.31	0.10	0.10	0.11

Table 22. Estimated discards at age in numbers (1000 fish)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1950	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1951	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1952	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1953	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1954	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1955	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1956	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1976	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.85	0.74	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	1.31	0.25	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	1.48	0.15	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1984	18.14	4.62	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	14.48	8.56	0.70	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	13.47	8.53	1.65	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	21.09	2.01	0.56	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	12.37	5.94	0.27	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	3.28	3.15	0.74	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	2.47	2.99	1.49	0.23	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	3.97	1.63	1.13	0.40	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	18.28	1.53	0.43	0.27	0.15	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	15.05	18.45	0.87	0.12	0.05	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	25.79	5.71	4.57	0.13	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	14.79	12.87	1.90	0.94	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	14.49	2.25	1.51	0.16	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	10.04	6.90	0.66	0.26	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	13.69	3.30	1.44	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	50.09	15.54	1.92	0.39	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	69.66	25.89	4.53	0.29	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	52.49	25.58	5.75	0.56	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	38.69	17.03	5.61	0.86	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	46.72	13.11	3.47	0.61	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	37.18	37.36	6.45	1.02	0.14	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	15.59	11.07	7.83	0.98	0.16	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2006	51.78	0.77	0.31	0.13	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2007	86.83	51.15	0.41	0.09	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2008	155.08	50.12	16.20	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2009	32.07	68.13	13.42	2.31	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	17.03	6.48	28.41	13.54	6.56	0.07	0.05	0.07	0.03	0.03	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2011	8.82	4.80	2.66	11.83	5.49	2.79	0.03	0.03	0.05	0.03	0.03	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
2012	21.63	14.93	7.28	2.57	9.21	3.91	1.82	0.02	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00
2013	22.73	7.50	6.19	2.63	0.82	2.84	1.25	0.63	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
2014	58.80	26.23	8.99	5.45	1.91	0.56	1.89	0.83	0.42	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00

Table 23. Estimated discards at age in whole weight (1000 lb)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1950	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1951	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1952	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1953	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1954	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1955	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1956	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1976	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.99	2.29	0.29	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	1.53	0.79	0.42	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	1.73	0.46	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1984	21.17	14.33	0.81	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	16.90	26.57	3.92	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	15.73	26.46	9.29	0.58	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	24.62	6.25	3.13	0.55	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	14.44	18.42	1.51	0.39	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	3.83	9.78	4.14	0.18	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	2.88	9.29	8.39	1.90	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	4.63	5.06	6.36	3.35	0.63	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	21.34	4.76	2.40	2.28	1.62	0.47	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	17.56	57.26	4.86	0.96	0.54	0.35	0.10	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	30.10	17.74	25.64	1.07	0.15	0.09	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	17.26	39.93	10.66	7.82	0.24	0.03	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	16.91	7.00	8.50	1.32	0.75	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	11.72	21.41	3.73	2.13	0.24	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	15.97	10.23	8.09	0.54	0.16	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	58.46	48.24	10.81	3.24	0.13	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	81.30	80.35	25.46	2.41	0.48	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	61.26	79.38	32.27	4.70	0.31	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	45.15	52.86	31.50	7.16	0.87	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	54.53	40.69	19.48	5.10	0.70	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	43.40	115.94	36.22	8.49	1.55	0.19	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	18.19	34.36	44.01	8.17	1.72	0.39	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2006	60.43	2.38	1.76	1.05	0.14	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2007	101.34	158.74	2.33	0.72	0.29	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2008	180.99	155.54	91.00	0.54	0.11	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2009	37.43	211.44	75.38	19.25	0.08	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	19.87	20.12	159.56	112.98	72.27	0.98	0.74	1.15	0.60	0.51	0.58	0.42	0.22	0.07	0.07	0.01	0.02	0.01	0.02	0.03
2011	10.29	14.91	14.96	98.75	60.56	37.58	0.54	0.47	0.87	0.57	0.62	0.69	0.50	0.26	0.08	0.08	0.02	0.02	0.01	0.05
2012	25.24	46.33	40.86	21.46	101.54	52.81	28.58	0.36	0.28	0.46	0.32	0.34	0.38	0.28	0.14	0.05	0.04	0.01	0.01	0.03
2013	26.52	23.29	34.75	21.96	9.00	38.33	19.60	11.05	0.15	0.13	0.26	0.18	0.19	0.21	0.15	0.08	0.02	0.02	0.00	0.02
2014	68.63	81.41	50.52	45.46	21.08	7.52	29.69	14.52	8.02	0.11	0.10	0.21	0.14	0.15	0.16	0.12	0.06	0.02	0.02	0.02

Table 24. Estimated status indicators, benchmarks, and related quantities from the base run of the Beaufort catch-age model, conditional on estimated current selectivities averaged across fleets. Also presented are median values and measures of precision (standard errors, SE) from the Monte Carlo/Bootstrap analysis. Rate estimates (F) are in units of y^{-1}*; status indicators are dimensionless; and biomass estimates are in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) is measured as population fecundity (number of eggs)*

Quantity	Units	Estimate	Median	SE
$F_{30\%}$	y^{-1}	0.15	0.15	0.01
$85\%F_{30\%}$	y^{-1}	0.12	0.13	0.01
$75\%F_{30\%}$	y^{-1}	0.11	0.11	0.01
$65\%F_{30\%}$	y^{-1}	0.10	0.10	0.01
$F_{30\%}$	y^{-1}	0.15	0.15	0.01
$F_{40\%}$	y^{-1}	0.11	0.11	0.01
$B_{\mathrm{F30\%}}$	metric tons	3637	3525	6052
$\mathrm{SSB}_{\mathrm{F30\%}}$	Eggs (1E8)	327706	293944	91136
MSST	Eggs (1E8)	245779	220458	68352
$L_{\mathrm{F30\%}}$	1000 lb whole	427	415	77
$R_{\mathrm{F30\%}}$	number fish	446642	455926	110006
$L_{85\%\mathrm{F30\%}}$	1000 lb whole	411	399	74
$L_{75\%\mathrm{F30\%}}$	1000 lb whole	395	384	71
$L_{65\%\mathrm{F30\%}}$	1000 lb whole	375	365	67
$F_{2012-2014}/F_{30\%}$	—	2.70	2.66	0.90
$\mathrm{SSB}_{2014}/\mathrm{MSST}$	—	0.20	0.21	0.12
$\mathrm{SSB}_{2014}/\mathrm{SSB}_{\mathrm{F30\%}}$	—	0.15	0.16	0.09

Table 25. Results from sensitivity runs of the Beaufort catch-age model. Current F represented by geometric mean of last three assessment years. Runs should not all be considered equally plausible.

Run	Description	$F_{30\%}$	$\mathrm{SSB}_{\mathrm{F30\%}}$ (1E8 Eggs)	$L_{\mathrm{F30\%}}$ (1000 lb)	$\mathrm{F}_{\mathrm{current}}/F_{30\%}$	$\mathrm{SSB}_{end}/\mathrm{SSB}_{\mathrm{F30\%}}$	R0(1000)	sigmaR	Finit
Base	—	0.147	329948	459	2.84	0.18	331	0.79	0.03
S1	remove 2008/9 from FD	0.147	329929	468	2.86	0.18	330	0.79	0.03
S2	upweight FI 10X	0.146	332402	438	2.07	0.28	325	0.82	0.03
S3	upweight FD 3X	0.146	344879	448	1.71	0.36	338	0.82	0.03
S4	FD only	0.145	332259	325	1.19	0.64	347	0.74	0.03
S5	M upper	0.169	246562	424	1.65	0.4	430	0.82	0.03
S6	M lower	0.133	406658	470	3.73	0.12	285	0.75	0.03
S7	Disc. M lower	0.147	328444	520	2.12	0.24	317	0.83	0.03
S8	Disc. M upper	0.146	335957	424	2.82	0.2	354	0.72	0.03
S9	Longer CVID index	0.147	334145	470	1.99	0.3	344	0.76	0.03
S10	Smooth 1984/5 MRIP peak	0.147	328483	462	2.53	0.22	327	0.8	0.03
S11	h=0.84	0.146	396289	525	3.56	0.11	497	0.6	0.03
S12	Truncated HB disc. index	0.147	331524	470	2.6	0.21	334	0.78	0.03
S13	Ageing error matrix	0.144	334881	409	1.63	0.39	319	0.85	0.03
S14	Batch number lower	0.154	220597	468	2.47	0.24	330	0.79	0.03
S15	Batch number upper	0.146	362022	465	2.63	0.21	333	0.78	0.03
S16	Drop HB disc. index	0.147	331560	470	2.59	0.21	334	0.78	0.03
S17	Higher landings	0.147	441258	654	1.94	0.25	406	0.89	0.03
S18	Lower landings	0.146	232011	298	3.36	0.18	258	0.64	0.03
S19	Higher discards	0.146	338021	500	2.6	0.19	362	0.7	0.03
S20	Lower discards	0.147	327352	561	1.89	0.26	306	0.87	0.03
S21	Dome-shaped selectivity for cH	0.15	355593	490	2.28	0.23	333	0.87	0.03
S22	Separate video and trap indices	0.143	331956	391	1.58	0.41	341	0.76	0.03
S23	FI index only	0.146	330170	436	2.75	0.18	342	0.75	0.03
S24	Continuity	0.102	817833	501	5.97	0.06	114	1.18	0.04
S25	Split q for HB CPUE	0.147	331168	466	2.61	0.2	333	0.79	0.03
S26	1978 start year	0.147	299224	418	2.93	0.19	320	0.7	0.2
S27	Estimate selex for all ages	0.148	328522	465	2.61	0.2	332	0.78	0.03

Table 26. Projection results with fishing mortality rate fixed at $F = 0$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $SSB \geq SSB_{F30\%}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	432	310	0.12	0.13	63370	58040	0	0	0	0	70	69	279	281	0.001
2016	436	308	0.24	0.26	87803	78457	28	28	244	243	71	66	343	329	0.004
2017	439	314	0.00	0.00	126462	111544	0	0	0	0	0	0	0	0	0.015
2018	442	314	0.00	0.00	180342	157052	0	0	0	0	0	0	0	0	0.067
2019	444	318	0.00	0.00	241177	207405	0	0	0	0	0	0	0	0	0.192
2020	446	316	0.00	0.00	305554	261097	0	0	0	0	0	0	0	0	0.390
2021	446	325	0.00	0.00	371340	315588	0	0	0	0	0	0	0	0	0.605
2022	447	319	0.00	0.00	436842	369565	0	0	0	0	0	0	0	0	0.776
2023	447	320	0.00	0.00	499775	422387	0	0	0	0	0	0	0	0	0.892
2024	448	318	0.00	0.00	559749	473142	0	0	0	0	0	0	0	0	0.953
2025	448	325	0.00	0.00	615542	521524	0	0	0	0	0	0	0	0	0.983
2026	448	322	0.00	0.00	666967	565810	0	0	0	0	0	0	0	0	0.993
2027	448	327	0.00	0.00	714392	606683	0	0	0	0	0	0	0	0	0.997
2028	448	321	0.00	0.00	757163	644437	0	0	0	0	0	0	0	0	0.999
2029	448	324	0.00	0.00	795659	680658	0	0	0	0	0	0	0	0	1.000
2030	448	321	0.00	0.00	830549	711124	0	0	0	0	0	0	0	0	1.000
2031	448	322	0.00	0.00	861736	739593	0	0	0	0	0	0	0	0	1.000
2032	448	320	0.00	0.00	889361	764257	0	0	0	0	0	0	0	0	1.000
2033	448	320	0.00	0.00	913872	786749	0	0	0	0	0	0	0	0	1.000
2034	448	319	0.00	0.00	935454	806215	0	0	0	0	0	0	0	0	1.000
2035	448	321	0.00	0.00	954544	824197	0	0	0	0	0	0	0	0	1.000
2036	448	323	0.00	0.00	971405	839359	0	0	0	0	0	0	0	0	1.000
2037	448	322	0.00	0.00	986280	853107	0	0	0	0	0	0	0	0	1.000
2038	448	319	0.00	0.00	999400	865349	0	0	0	0	0	0	0	0	1.000
2039	448	319	0.00	0.00	1010969	876882	0	0	0	0	0	0	0	0	1.000
2040	448	322	0.00	0.00	1021170	885872	0	0	0	0	0	0	0	0	1.000
2041	448	320	0.00	0.00	1030164	891838	0	0	0	0	0	0	0	0	1.000
2042	448	322	0.00	0.00	1038093	899554	0	0	0	0	0	0	0	0	1.000
2043	448	320	0.00	0.00	1045082	903786	0	0	0	0	0	0	0	0	1.000
2044	448	321	0.00	0.00	1051243	910470	0	0	0	0	0	0	0	0	1.000

Table 27. Projection results with fishing mortality rate fixed at $F = F_{\text{current}}$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\text{SSB} \geq \text{SSB}_{F30\%}$. The extension b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	432	310	0.12	0.13	63370	58040	0	0	0	0	70	69	279	281	0.001
2016	436	308	0.24	0.26	87803	78457	28	28	244	243	71	66	343	329	0.004
2017	439	314	0.39	0.40	101048	88970	54	47	506	447	111	94	596	507	0.009
2018	441	313	0.39	0.40	104221	90788	50	43	504	438	103	87	559	475	0.014
2019	441	314	0.39	0.40	103601	89616	45	39	475	411	98	84	522	447	0.018
2020	441	311	0.39	0.40	101372	87427	43	37	451	390	96	82	496	426	0.021
2021	441	319	0.39	0.40	98928	85355	41	35	433	376	95	82	481	414	0.023
2022	441	313	0.39	0.40	96768	83444	40	35	422	367	94	81	472	410	0.024
2023	440	313	0.39	0.40	94914	82528	40	35	415	362	94	81	468	405	0.024
2024	440	311	0.39	0.40	93436	81291	40	34	409	358	94	81	466	404	0.025
2025	440	318	0.39	0.40	92263	80530	39	34	406	355	94	81	464	405	0.023
2026	440	314	0.39	0.40	91381	79593	39	34	403	354	94	81	463	404	0.023
2027	440	319	0.39	0.40	90750	79116	39	34	401	352	94	81	462	404	0.023
2028	440	313	0.39	0.40	90288	78840	39	34	400	352	93	81	462	402	0.022
2029	440	316	0.39	0.40	89959	78457	39	34	399	351	93	81	461	400	0.022
2030	440	313	0.39	0.40	89733	78412	39	34	398	349	93	81	461	402	0.022
2031	440	314	0.39	0.40	89574	78504	39	34	398	348	93	81	461	403	0.021
2032	440	312	0.39	0.40	89461	78546	39	34	398	349	93	81	461	402	0.021
2033	440	312	0.39	0.40	89383	78488	39	34	398	349	93	80	461	400	0.019
2034	440	311	0.39	0.40	89328	78699	39	34	397	348	93	80	460	400	0.019
2035	440	312	0.39	0.40	89290	78393	39	34	397	347	93	80	460	400	0.018
2036	440	315	0.39	0.40	89263	78314	39	34	397	348	93	80	460	398	0.018
2037	440	314	0.39	0.40	89245	77966	39	34	397	348	93	80	460	398	0.017
2038	440	311	0.39	0.40	89232	77935	39	34	397	348	93	80	460	399	0.017
2039	440	310	0.39	0.40	89224	78213	39	34	397	348	93	80	460	399	0.018
2040	440	314	0.39	0.40	89217	78131	39	34	397	348	93	80	460	399	0.019
2041	440	312	0.39	0.40	89213	78267	39	34	397	348	93	81	460	399	0.020
2042	440	313	0.39	0.40	89210	78063	39	34	397	348	93	81	460	400	0.020
2043	440	312	0.39	0.40	89208	78081	39	34	397	346	93	81	460	401	0.019
2044	440	313	0.39	0.40	89207	78117	39	34	397	348	93	80	460	401	0.020

Table 28. Projection results with fishing mortality rate fixed at $F = F_{30\%}$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{F30\%}}$*. The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	432	310	0.12	0.13	63370	58040	0	0	0	0	70	69	279	281	0.001
2016	436	308	0.24	0.26	87803	78457	28	28	244	243	71	66	343	329	0.004
2017	439	314	0.15	0.15	116361	102522	22	20	207	195	44	39	241	218	0.009
2018	442	314	0.15	0.15	146966	127331	24	22	253	233	45	40	266	239	0.021
2019	443	317	0.15	0.15	175465	149920	26	23	285	258	46	41	281	252	0.040
2020	444	315	0.15	0.15	200733	169768	27	24	310	279	46	41	291	261	0.064
2021	445	323	0.15	0.15	222841	187374	28	25	332	298	47	42	299	267	0.096
2022	445	318	0.15	0.15	241979	202838	29	26	350	313	47	42	304	273	0.133
2023	446	319	0.15	0.15	257965	216120	29	27	365	327	47	42	310	279	0.167
2024	446	317	0.15	0.15	271354	227528	30	27	377	339	47	43	315	284	0.203
2025	446	324	0.15	0.15	282261	237107	30	27	387	349	48	43	319	288	0.234
2026	446	320	0.15	0.15	291141	244945	31	28	395	357	48	43	322	292	0.265
2027	446	325	0.15	0.15	298461	252233	31	28	401	364	48	43	324	295	0.293
2028	446	320	0.15	0.15	304304	258346	31	28	407	370	48	43	326	297	0.319
2029	446	323	0.15	0.15	308994	262872	31	29	411	375	48	44	328	298	0.340
2030	446	320	0.15	0.15	312828	266655	31	29	414	378	48	44	329	300	0.357
2031	447	320	0.15	0.15	315895	269863	31	29	417	380	48	44	330	301	0.373
2032	447	318	0.15	0.15	318319	271942	32	29	419	382	48	44	331	303	0.387
2033	447	319	0.15	0.15	320248	273385	32	29	421	384	48	44	332	302	0.398
2034	447	317	0.15	0.15	321769	275170	32	29	422	385	48	44	332	302	0.406
2035	447	319	0.15	0.15	322982	276801	32	29	423	386	48	44	332	303	0.413
2036	447	322	0.15	0.15	323949	277909	32	29	424	387	48	43	333	302	0.420
2037	447	321	0.15	0.15	324719	278086	32	29	424	387	48	44	333	303	0.422
2038	447	318	0.15	0.15	325331	278898	32	29	425	387	48	44	333	303	0.426
2039	447	317	0.15	0.15	325818	279526	32	29	425	389	48	44	333	304	0.429
2040	447	321	0.15	0.15	326206	279292	32	29	426	388	48	43	334	303	0.431
2041	447	318	0.15	0.15	326513	279646	32	29	426	388	48	44	334	304	0.433
2042	447	320	0.15	0.15	326758	280069	32	29	426	389	48	44	334	303	0.434
2043	447	319	0.15	0.15	326953	280511	32	29	426	389	48	44	334	304	0.436
2044	447	320	0.15	0.15	327107	281317	32	29	426	389	48	44	334	305	0.438

Table 29. Projection results with fishing mortality rate fixed at $F = 98\%F_{30\%}$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{F}30\%}$. The extension b indicates expected values (deterministic) from the base run; the extension med indicates median values from the stochastic projections.

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	432	310	0.12	0.13	63370	58040	0	0	0	0	70	69	279	281	0.001
2016	436	308	0.24	0.26	87803	78457	28	28	244	243	71	66	343	329	0.004
2017	439	314	0.14	0.15	116554	102701	22	20	204	191	43	39	236	214	0.009
2018	442	314	0.14	0.15	147566	127869	24	22	249	229	44	40	261	235	0.021
2019	443	317	0.14	0.15	176574	150930	25	23	280	255	45	40	277	248	0.041
2020	444	315	0.14	0.15	202402	171207	27	24	306	276	45	40	287	257	0.068
2021	445	323	0.14	0.15	225080	189241	28	25	328	294	46	41	295	263	0.101
2022	445	318	0.14	0.15	244772	205267	28	26	346	310	46	41	301	270	0.140
2023	446	319	0.14	0.15	261274	218931	29	26	362	324	46	42	306	276	0.177
2024	446	317	0.14	0.15	275135	230819	30	27	374	336	47	42	311	281	0.216
2025	446	324	0.14	0.15	286462	240644	30	27	384	346	47	42	315	285	0.250
2026	446	320	0.14	0.15	295709	248731	30	28	392	354	47	43	318	289	0.283
2027	446	325	0.14	0.15	303348	256468	31	28	399	362	47	43	321	292	0.314
2028	446	320	0.14	0.15	309463	262888	31	28	404	367	47	43	323	294	0.340
2029	446	323	0.14	0.15	314383	267501	31	28	408	373	47	43	324	295	0.366
2030	447	320	0.14	0.15	318413	271419	31	28	412	376	47	43	326	297	0.384
2031	447	320	0.14	0.15	321643	274734	31	28	415	378	47	43	327	298	0.401
2032	447	318	0.14	0.15	324202	277080	31	29	417	380	47	43	328	300	0.419
2033	447	319	0.14	0.15	326244	278482	31	29	418	382	47	43	328	299	0.429
2034	447	317	0.14	0.15	327857	280438	31	29	420	383	47	43	329	299	0.437
2035	447	319	0.14	0.15	329147	282062	31	29	421	385	47	43	329	300	0.445
2036	447	322	0.14	0.15	330176	283369	31	29	422	386	47	43	330	300	0.451
2037	447	321	0.14	0.15	330997	283572	32	29	423	385	47	43	330	300	0.454
2038	447	318	0.14	0.15	331652	284239	32	29	423	386	47	43	330	300	0.457
2039	447	318	0.14	0.15	332173	284986	32	29	424	387	47	43	330	301	0.461
2040	447	321	0.14	0.15	332589	284754	32	29	424	387	47	43	330	300	0.463
2041	447	318	0.14	0.15	332920	285289	32	29	424	387	47	43	330	301	0.466
2042	447	320	0.14	0.15	333184	285527	32	29	424	387	47	43	331	300	0.468
2043	447	319	0.14	0.15	333393	286147	32	29	425	387	47	43	331	301	0.469
2044	447	320	0.14	0.15	333561	286879	32	29	425	388	47	43	331	302	0.473

Table 30. Projection results with fishing mortality rate fixed at $F = F_{\text{rebuild}}$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\text{SSB} \geq \text{SSB}_{\text{F30\%}}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	432	310	0.12	0.13	63370	58040	0	0	0	0	70	69	279	281	0.001
2016	436	308	0.24	0.26	87803	78457	28	28	244	243	71	66	343	329	0.004
2017	439	314	0.14	0.14	116573	102855	21	20	203	186	43	38	236	209	0.010
2018	442	314	0.14	0.14	147623	128689	24	21	249	224	44	39	261	230	0.025
2019	443	317	0.14	0.14	176680	152227	25	22	280	250	45	39	277	244	0.049
2020	444	315	0.14	0.14	202560	173676	26	23	306	272	45	40	287	253	0.083
2021	445	323	0.14	0.14	225292	192272	28	24	328	291	46	40	294	259	0.124
2022	445	318	0.14	0.14	245038	208432	28	25	346	306	46	41	300	266	0.168
2023	446	319	0.14	0.14	261589	222291	29	26	361	321	46	41	306	273	0.210
2024	446	317	0.14	0.14	275495	235178	30	27	374	334	47	41	311	278	0.251
2025	446	324	0.14	0.14	286862	245047	30	27	384	344	47	42	315	282	0.288
2026	446	320	0.14	0.14	296144	253406	30	27	392	352	47	42	318	285	0.323
2027	446	325	0.14	0.14	303815	260726	31	28	399	360	47	42	320	288	0.355
2028	446	320	0.14	0.14	309955	266702	31	28	404	366	47	42	322	290	0.380
2029	446	323	0.14	0.14	314897	271842	31	28	408	371	47	42	324	292	0.403
2030	447	320	0.14	0.14	318946	276078	31	28	412	374	47	42	325	293	0.421
2031	447	320	0.14	0.14	322193	278737	31	28	414	376	47	42	326	295	0.436
2032	447	318	0.14	0.14	324765	281639	31	28	417	378	47	42	327	296	0.452
2033	447	319	0.14	0.14	326817	283858	31	28	418	380	47	43	328	296	0.462
2034	447	317	0.14	0.14	328439	285560	31	28	420	382	47	42	328	296	0.471
2035	447	319	0.14	0.14	329736	286369	31	29	421	382	47	42	329	297	0.477
2036	447	322	0.14	0.14	330772	287263	31	29	422	383	47	42	329	296	0.482
2037	447	321	0.14	0.14	331598	288575	32	29	422	383	47	42	329	296	0.485
2038	447	318	0.14	0.14	332257	289369	32	29	423	383	47	42	330	297	0.490
2039	447	317	0.14	0.14	332782	290043	32	29	423	384	47	42	330	298	0.495
2040	447	321	0.14	0.14	333200	290214	32	29	424	384	47	42	330	297	0.497
2041	447	319	0.14	0.14	333533	290371	32	29	424	385	47	42	330	297	0.496
2042	447	320	0.14	0.14	333799	290884	32	29	424	385	47	43	330	297	0.496
2043	447	319	0.14	0.14	334010	291259	32	29	424	386	47	43	330	298	0.495
2044	447	320	0.14	0.14	334179	291227	32	29	425	385	47	43	330	298	0.496

Table 31. Projection results with fishing mortality rate applied only to discards. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1E8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{F}30\%}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1E8)	S.med(1E8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2015	432	306	0.12	0.13	63370	58033	0	0	0	0	70	69	279	282	0.001
2016	436	311	0.11	0.12	93943	84171	0	0	0	0	70	69	346	345	0.004
2017	440	312	0.12	0.13	129264	113133	0	0	0	0	76	71	430	414	0.016
2018	443	316	0.12	0.13	165018	141286	0	0	0	0	77	71	472	443	0.052
2019	444	314	0.12	0.13	199126	167365	0	0	0	0	77	72	496	459	0.110
2020	445	322	0.12	0.13	230244	191136	0	0	0	0	77	73	511	470	0.181
2021	446	317	0.12	0.13	258437	212321	0	0	0	0	78	73	522	480	0.251
2022	446	318	0.12	0.13	283795	231043	0	0	0	0	78	74	531	489	0.313
2023	446	319	0.12	0.13	305879	246463	0	0	0	0	79	74	541	498	0.366
2024	446	324	0.12	0.13	325137	260140	0	0	0	0	79	75	552	509	0.414
2025	447	320	0.12	0.13	341463	272140	0	0	0	0	79	76	561	517	0.452
2026	447	325	0.12	0.13	355334	282256	0	0	0	0	80	76	569	527	0.484
2027	447	319	0.12	0.13	367293	291101	0	0	0	0	80	76	575	533	0.512
2028	447	323	0.12	0.13	377276	298167	0	0	0	0	80	77	581	539	0.535
2029	447	320	0.12	0.13	385681	304830	0	0	0	0	80	77	585	543	0.554
2030	447	320	0.12	0.13	392908	310205	0	0	0	0	81	77	589	547	0.567
2031	447	320	0.12	0.13	398981	315115	0	0	0	0	81	77	592	549	0.581
2032	447	320	0.12	0.13	404020	319257	0	0	0	0	81	77	595	552	0.592
2033	447	319	0.12	0.13	408235	322070	0	0	0	0	81	77	597	552	0.601
2034	447	319	0.12	0.13	411727	324568	0	0	0	0	81	77	599	554	0.609
2035	447	323	0.12	0.13	414665	326003	0	0	0	0	81	77	601	554	0.614
2036	447	321	0.12	0.13	417136	327593	0	0	0	0	81	77	602	556	0.620
2037	447	318	0.12	0.13	419213	328401	0	0	0	0	81	77	603	557	0.625
2038	447	318	0.12	0.13	420958	330168	0	0	0	0	81	78	604	558	0.628
2039	447	323	0.12	0.13	422424	331400	0	0	0	0	81	77	605	559	0.631
2040	447	318	0.12	0.13	423655	332671	0	0	0	0	81	78	606	559	0.632
2041	447	320	0.12	0.13	424689	332754	0	0	0	0	81	78	606	560	0.634
2042	447	321	0.12	0.13	425557	333040	0	0	0	0	81	78	607	563	0.638
2043	447	321	0.12	0.13	426286	333165	0	0	0	0	81	78	607	562	0.639
2044	447	320	0.12	0.13	426898	334378	0	0	0	0	81	78	607	562	0.640

Table 32. Parameter estimates from selected ASPIC surplus production model runs 318 (continuity), 319 (updated continuity), 320 (best configuration), and 323 (best configuration with B_1/K fixed) All parameter values are rounded to 3 significant digits. MSY, B_1, and K are in units of 1000 pounds. Catchability parameters correspond to the commercial (q_1), headboat (q_2), headboat-at-sea (q_3), and CVID (q_4) indices.

Run	F/F_{MSY}	B/B_{MSY}	B_1/K	MSY	F_{MSY}	q_1	q_2	q_3	q_4	B_1	K
318	2.15	0.53	0.467	805	0.313	9.35e-07	7.14e-07			2400	5140
319	0.614	1.3	1.94	802	0.314	9.42e-07	7.14e-07			9930	5110
320	0.531	1.48	0.91	805	0.322	8.69e-07	6.98e-07	2.98e-07	4.04e-07	4560	5010
323	0.53	1.47	0.467	807	0.321	8.74e-07	7e-07	2.99e-07	4.02e-07	2350	5030

8 Figures

Figure 1. Indices of abundance used in fitting the assessment model. HB indicates the headboat logbook index; Handline indicated the the commercial handline logbook index; HB Disc indicated the headboat discard observer index, CVT indicates the SERFS chevron trap index; VID indicates the SERFS video index, and CVID indicates the combined chevron trap and video index. The CVT and VID indices were only used during sensitivity runs.

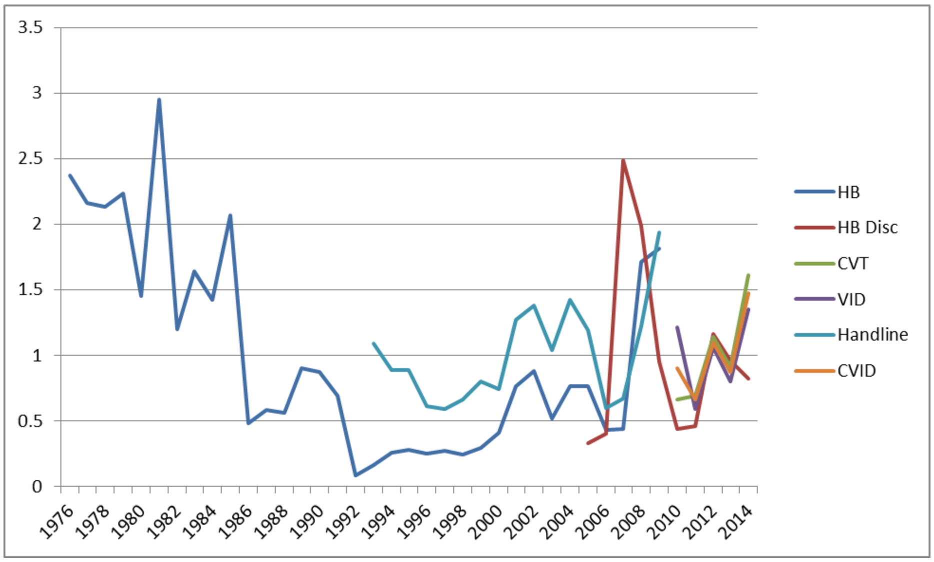


Figure 2. Mean total length at age (mm) and estimated upper and lower 95% confidence intervals of the population.

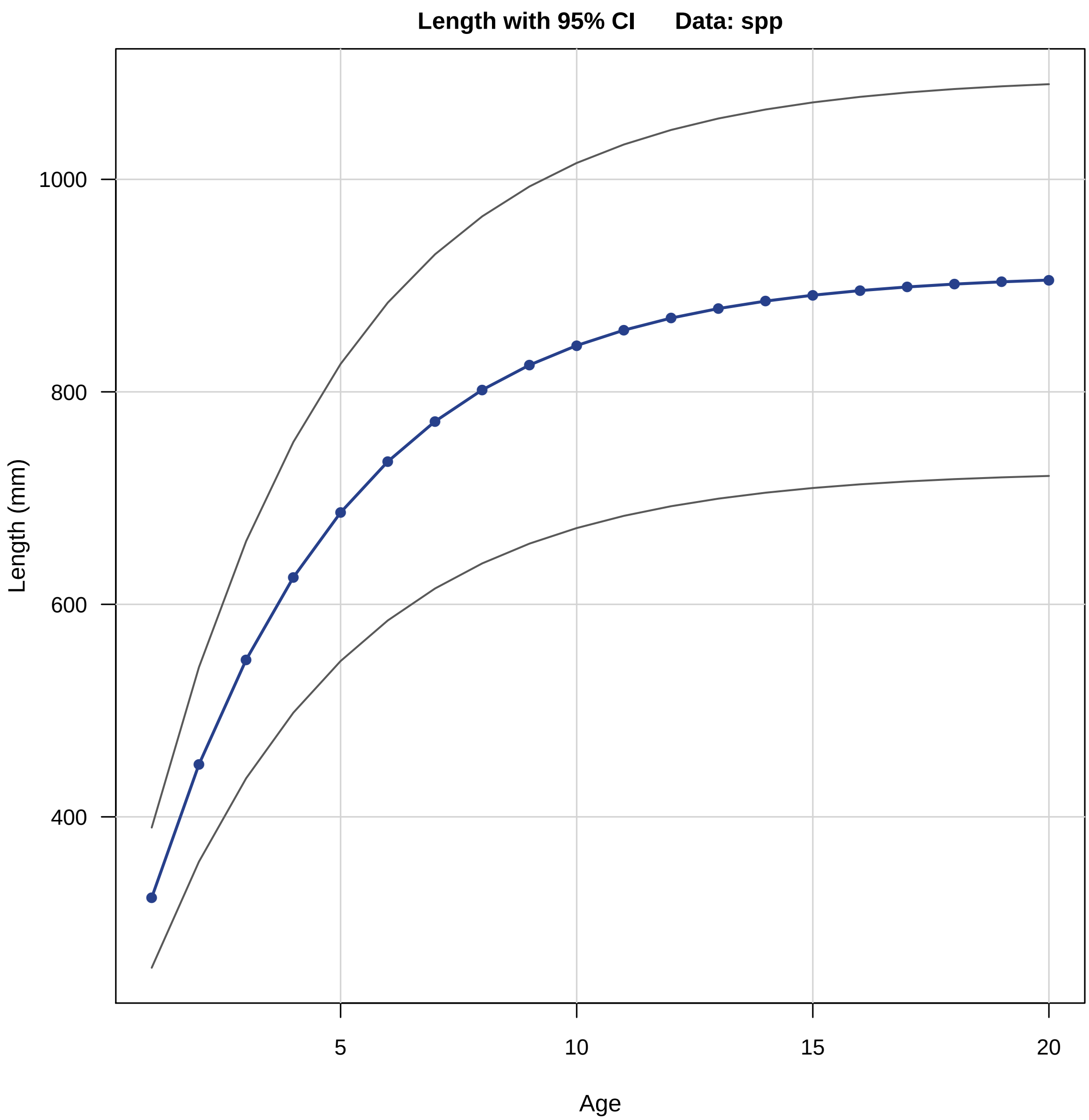


Figure 3. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, CVT to MARMAP chevron trap, cH to commercial handline, HB to headboat and GR to general recreational.

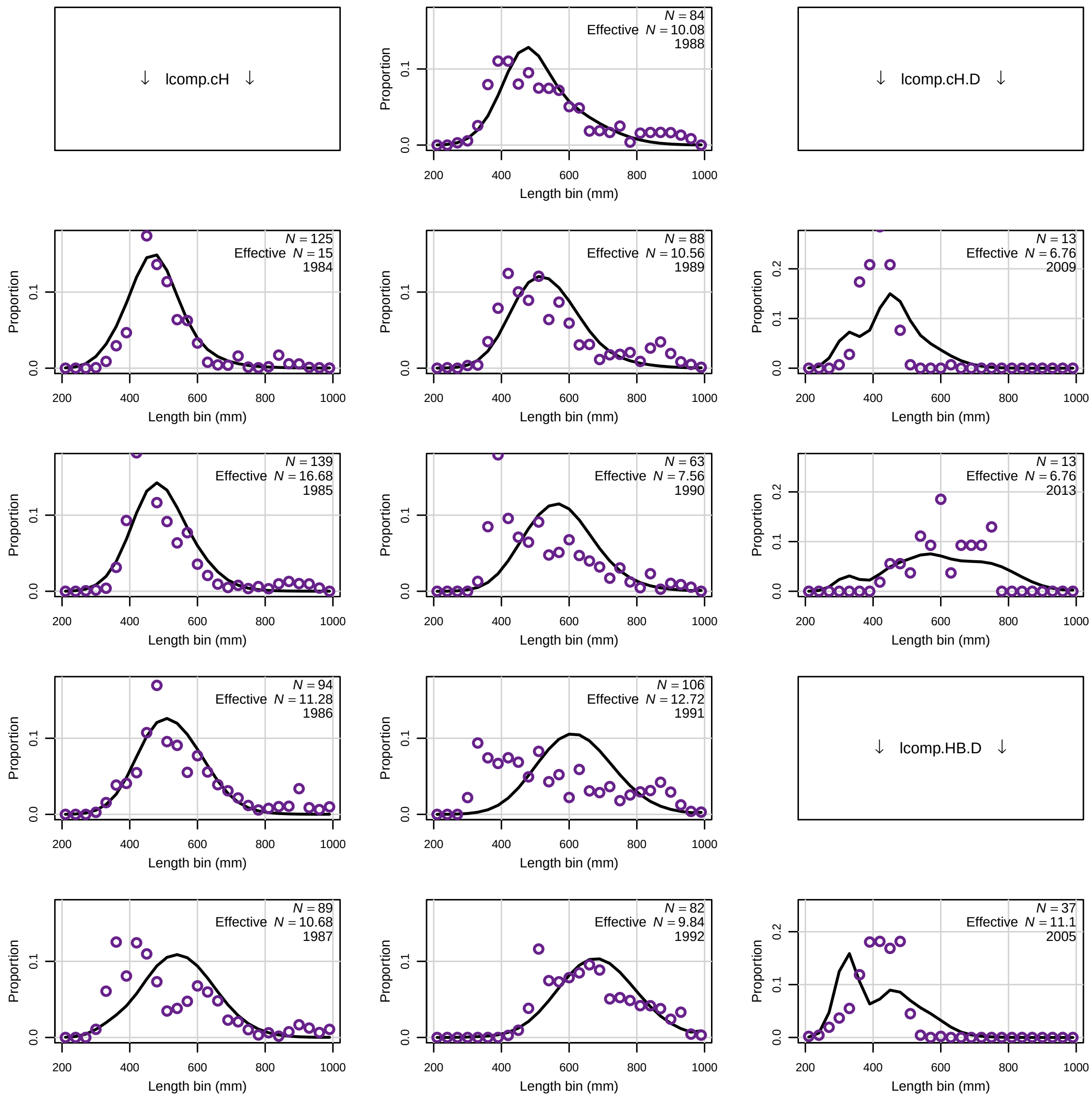


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

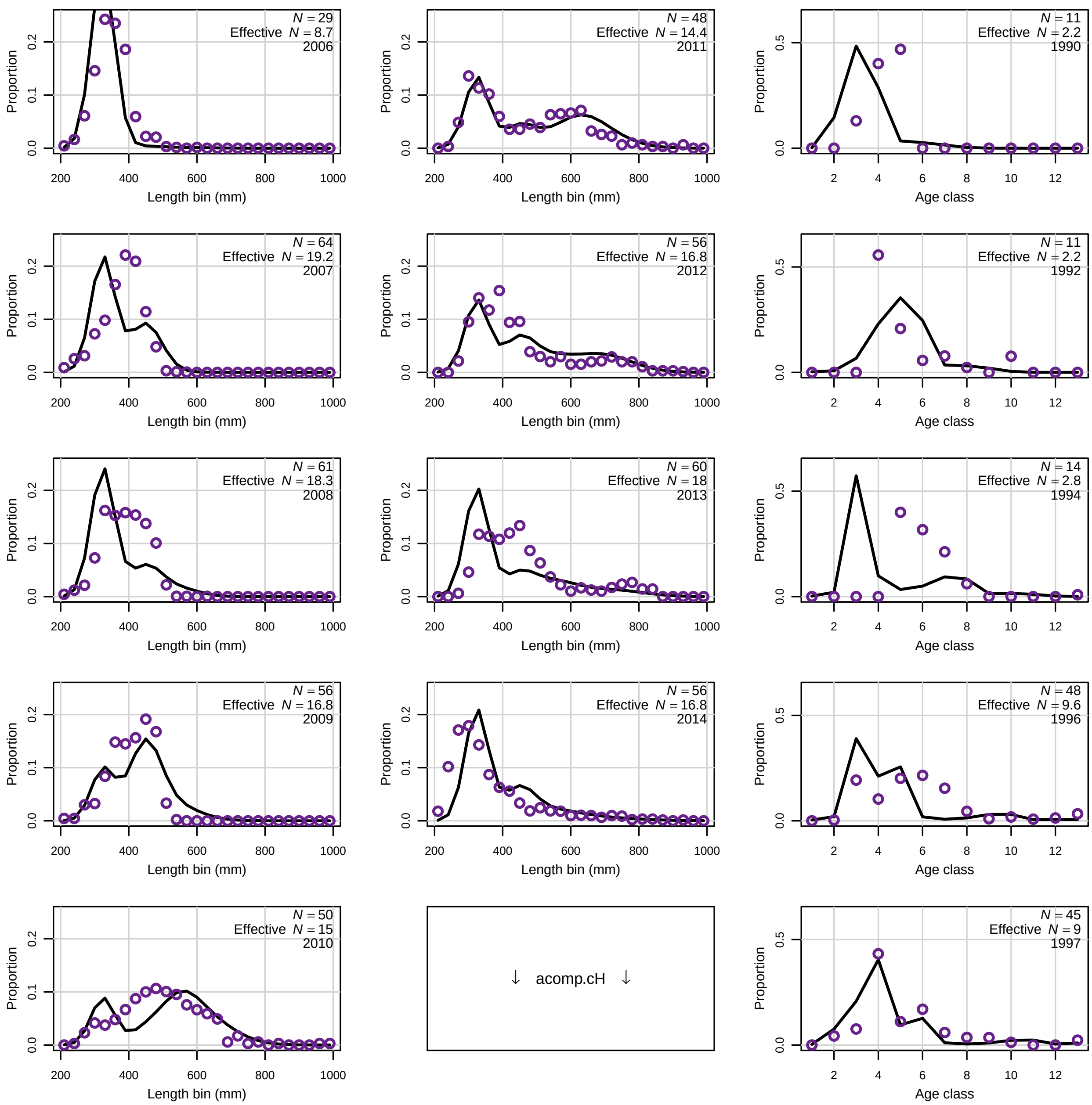


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

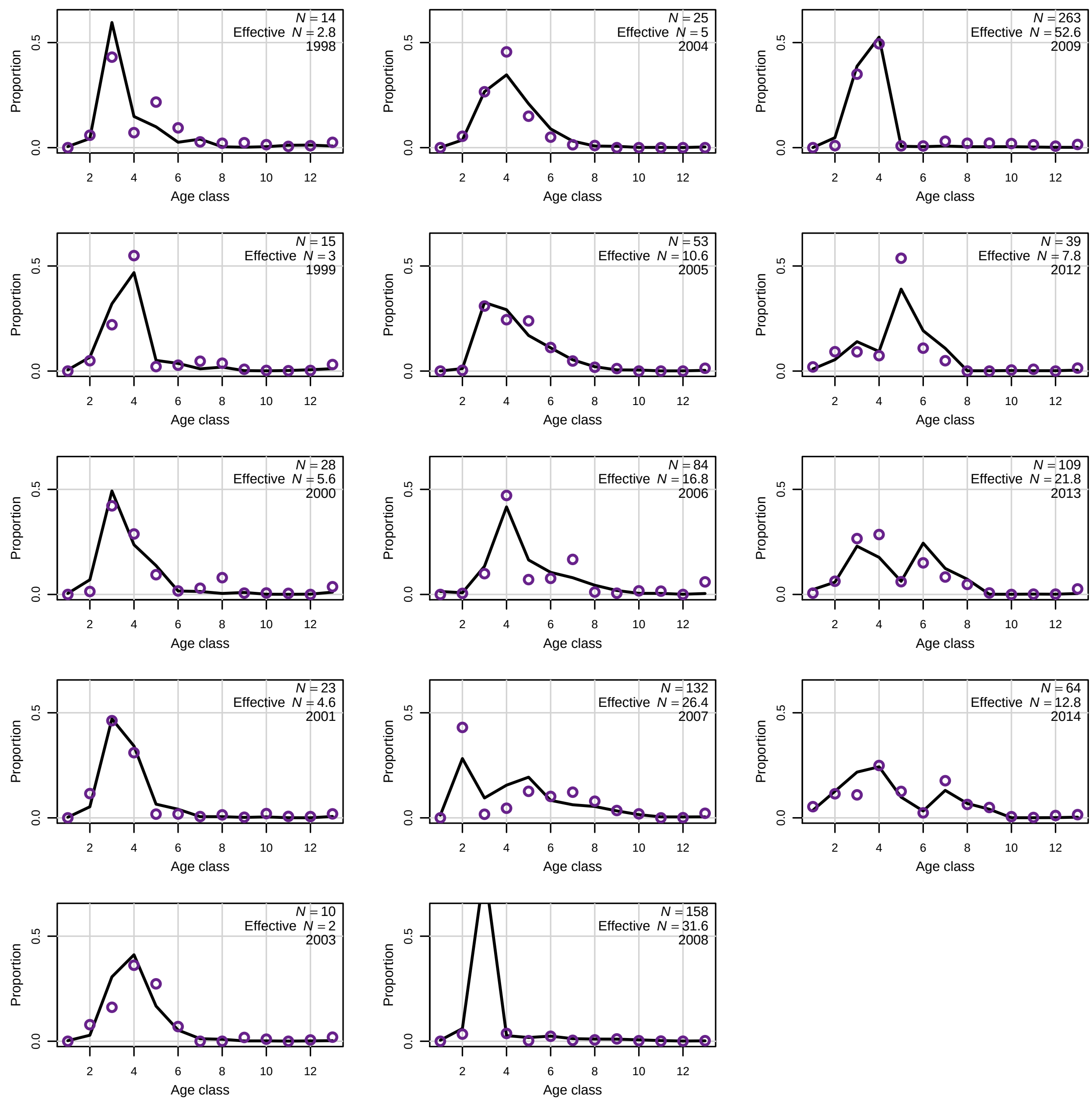


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

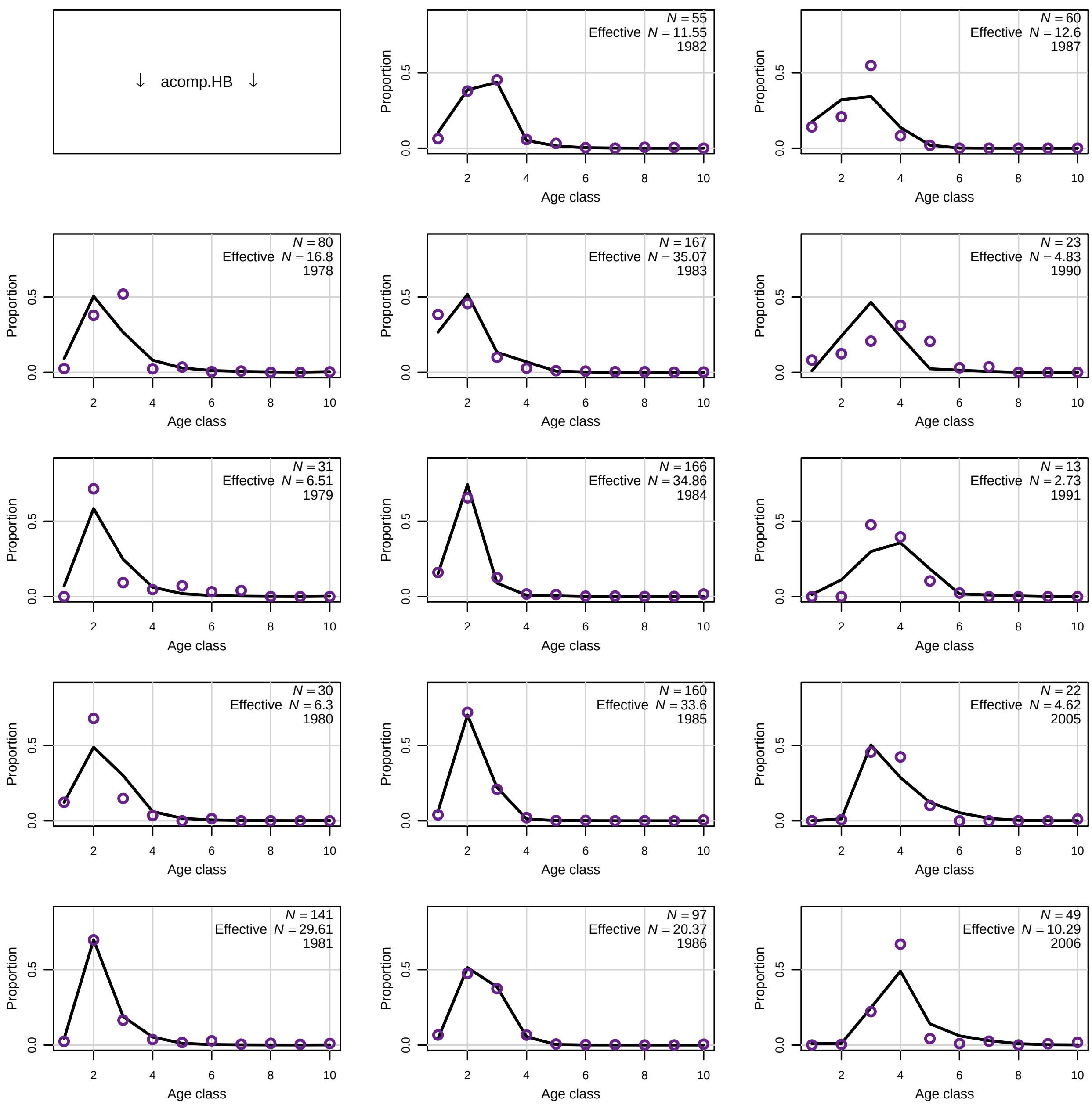


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

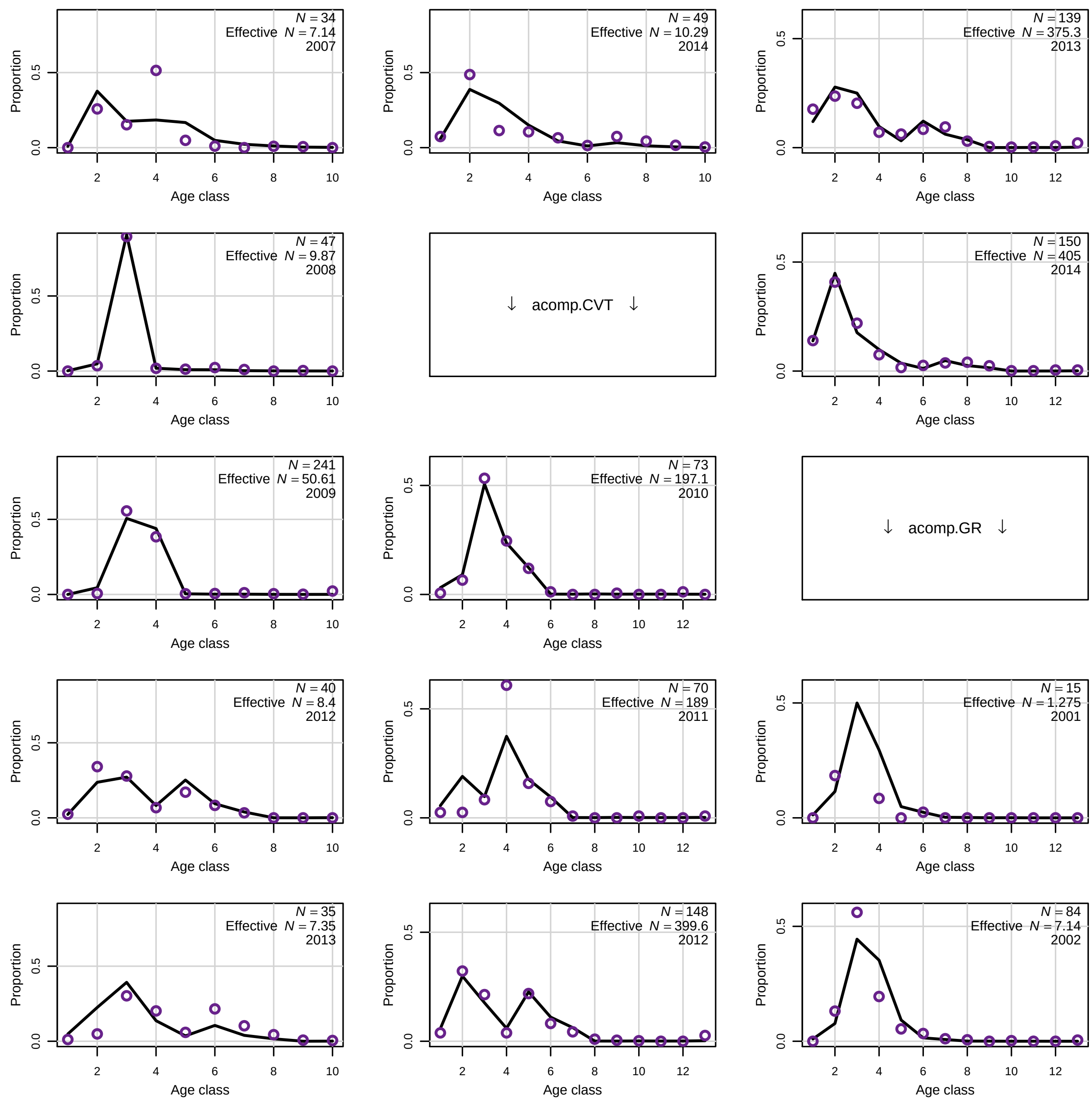


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

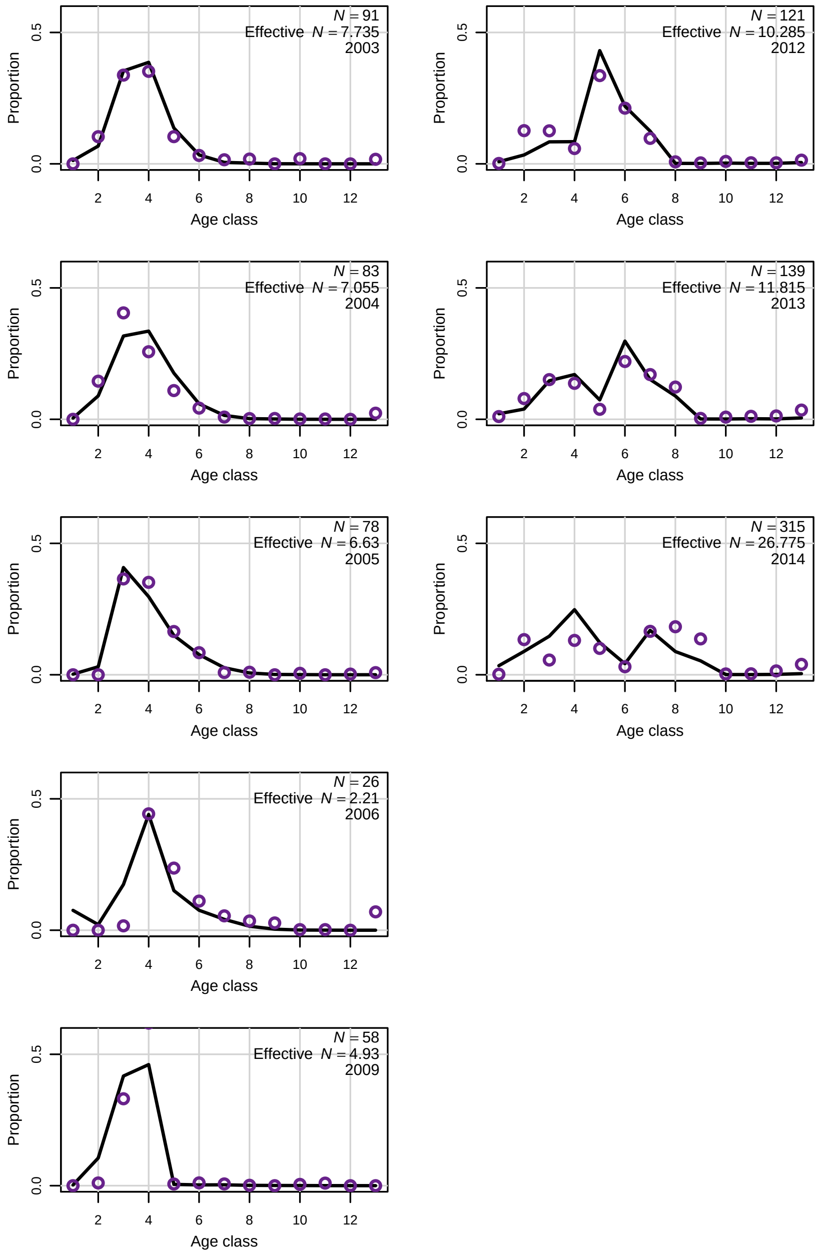


Figure 4. Observed (open circles) and estimated (solid line, circles) commercial handline landings in 1000 lb whole weight.

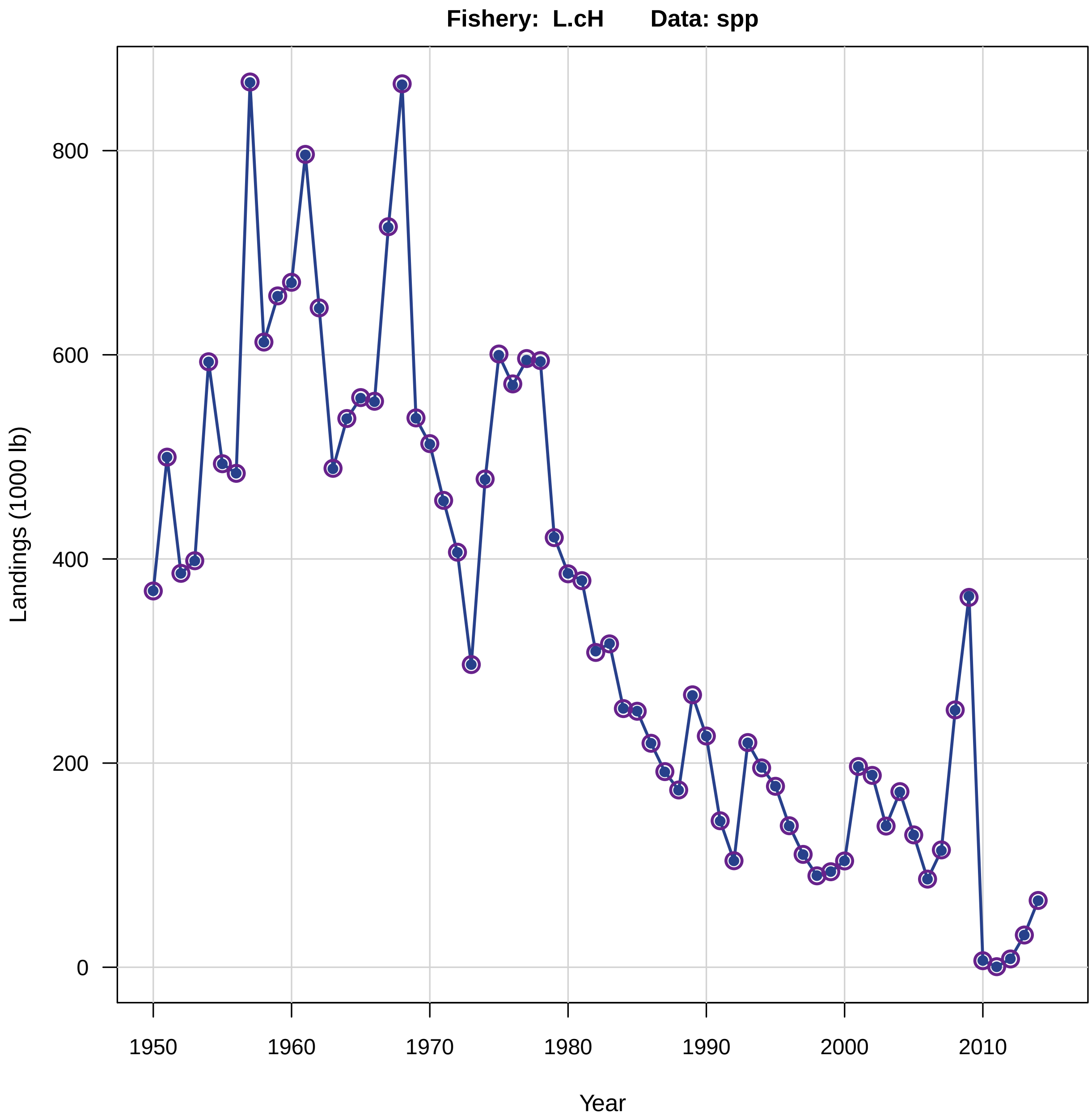


Figure 5. Observed (open circles) and estimated (solid line, circles) headboat landings in 1000s of fish.

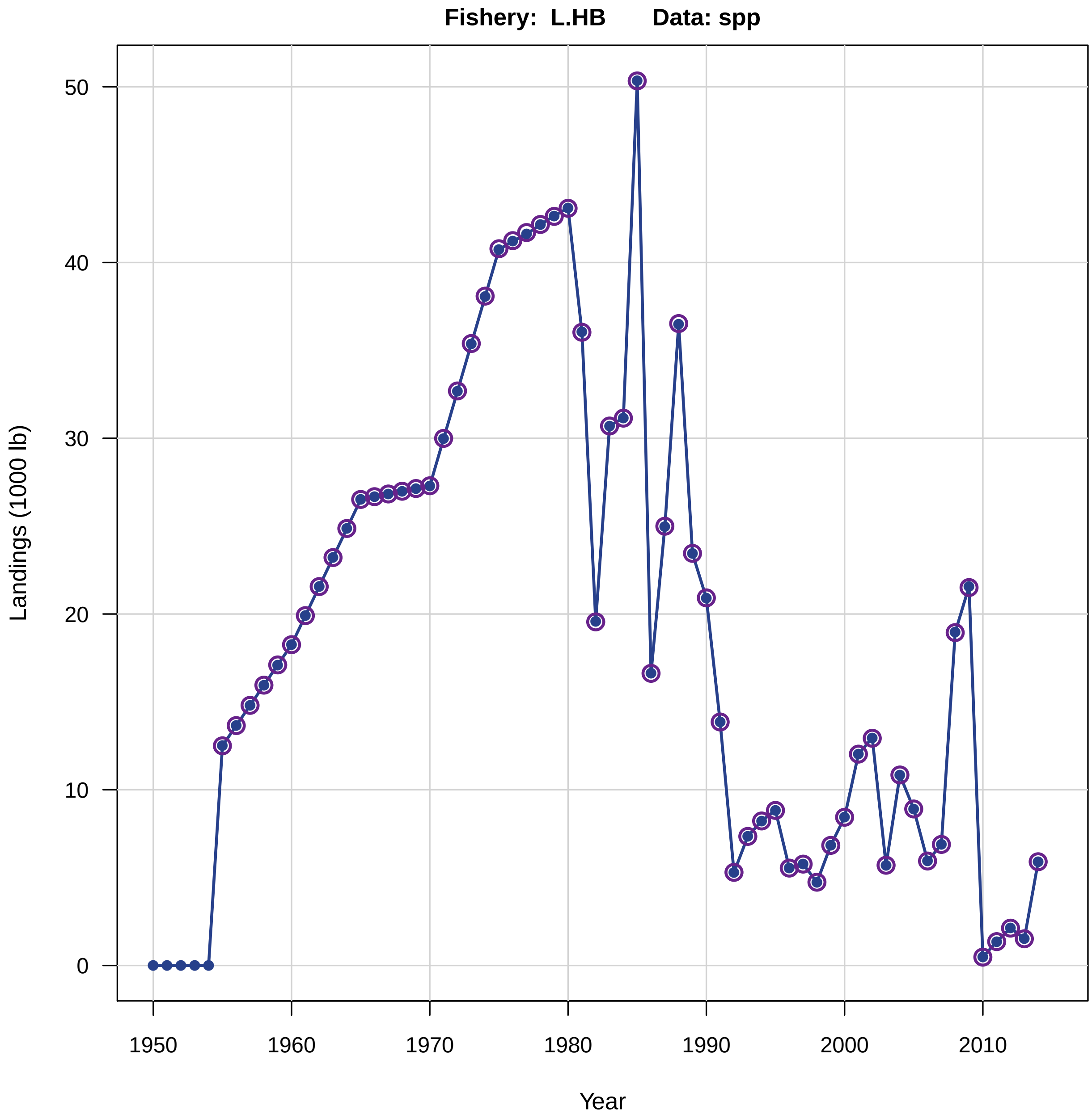


Figure 6. Observed (open circles) and estimated (solid line, circles) general recreational landings in 1000s of fish.

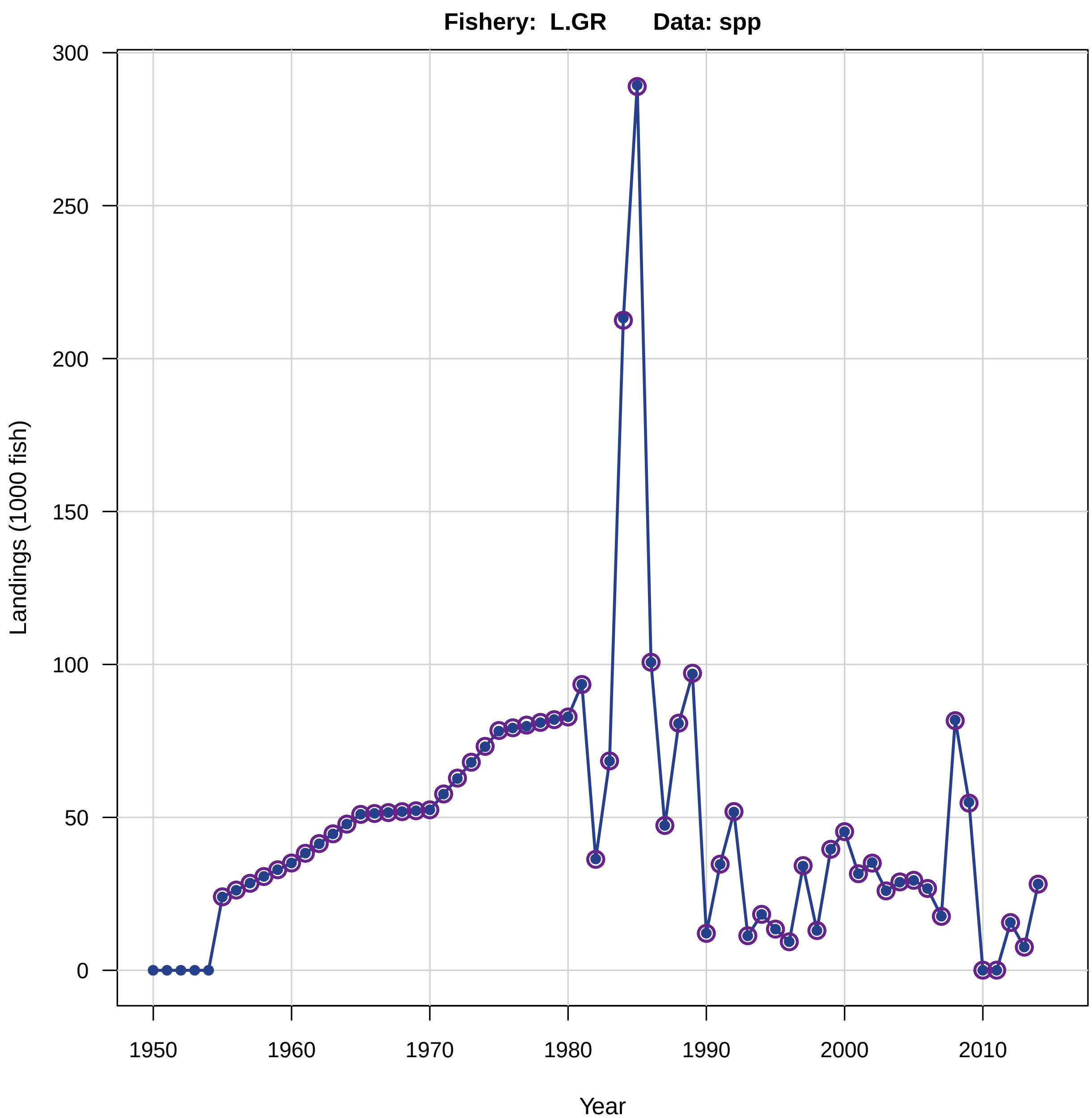


Figure 7. Observed (open circles) and estimated (solid line, circles) commercial handline discard mortalities.

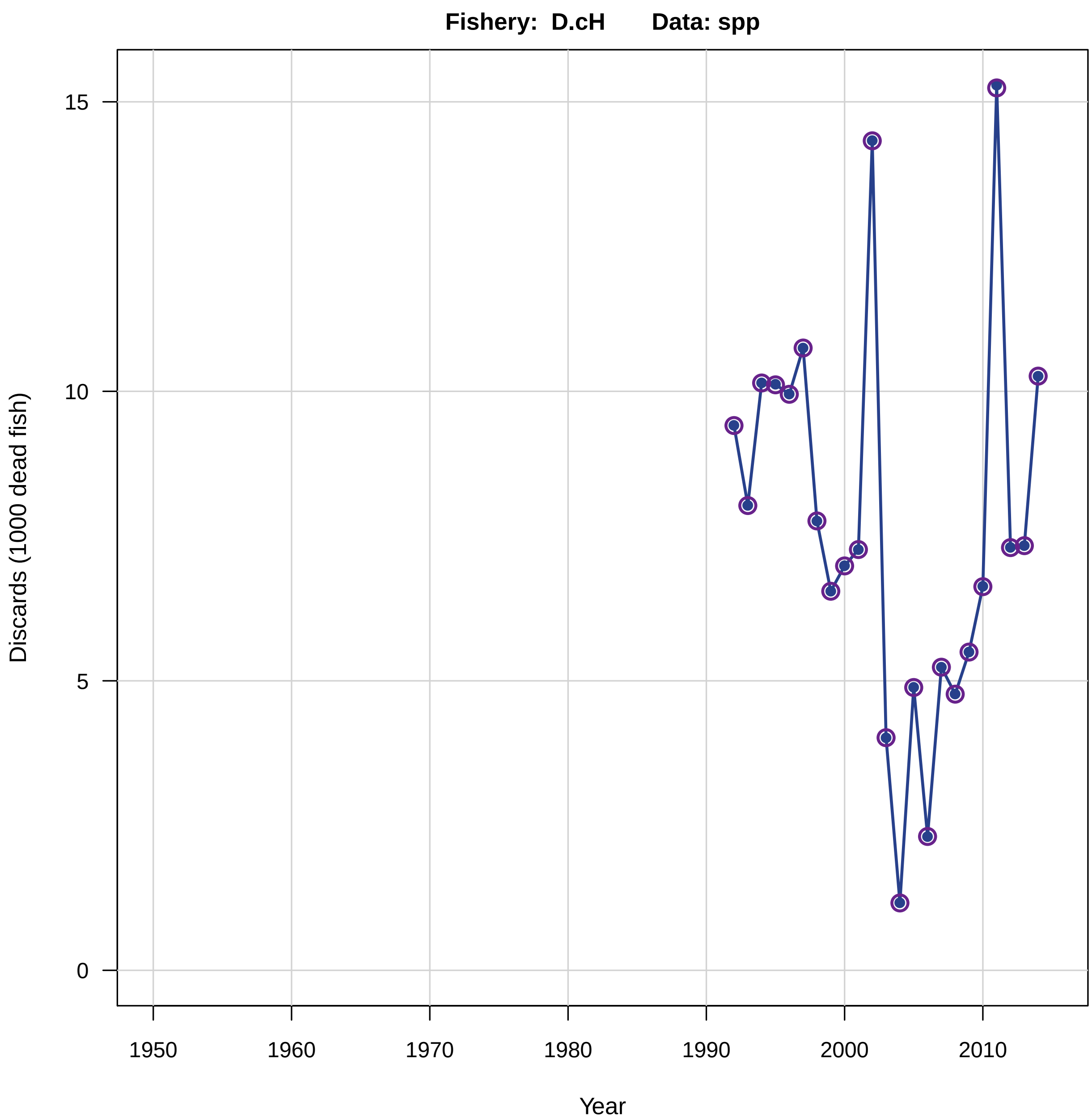


Figure 8. Observed (open circles) and estimated (solid line, circles) headboat discard mortalities.

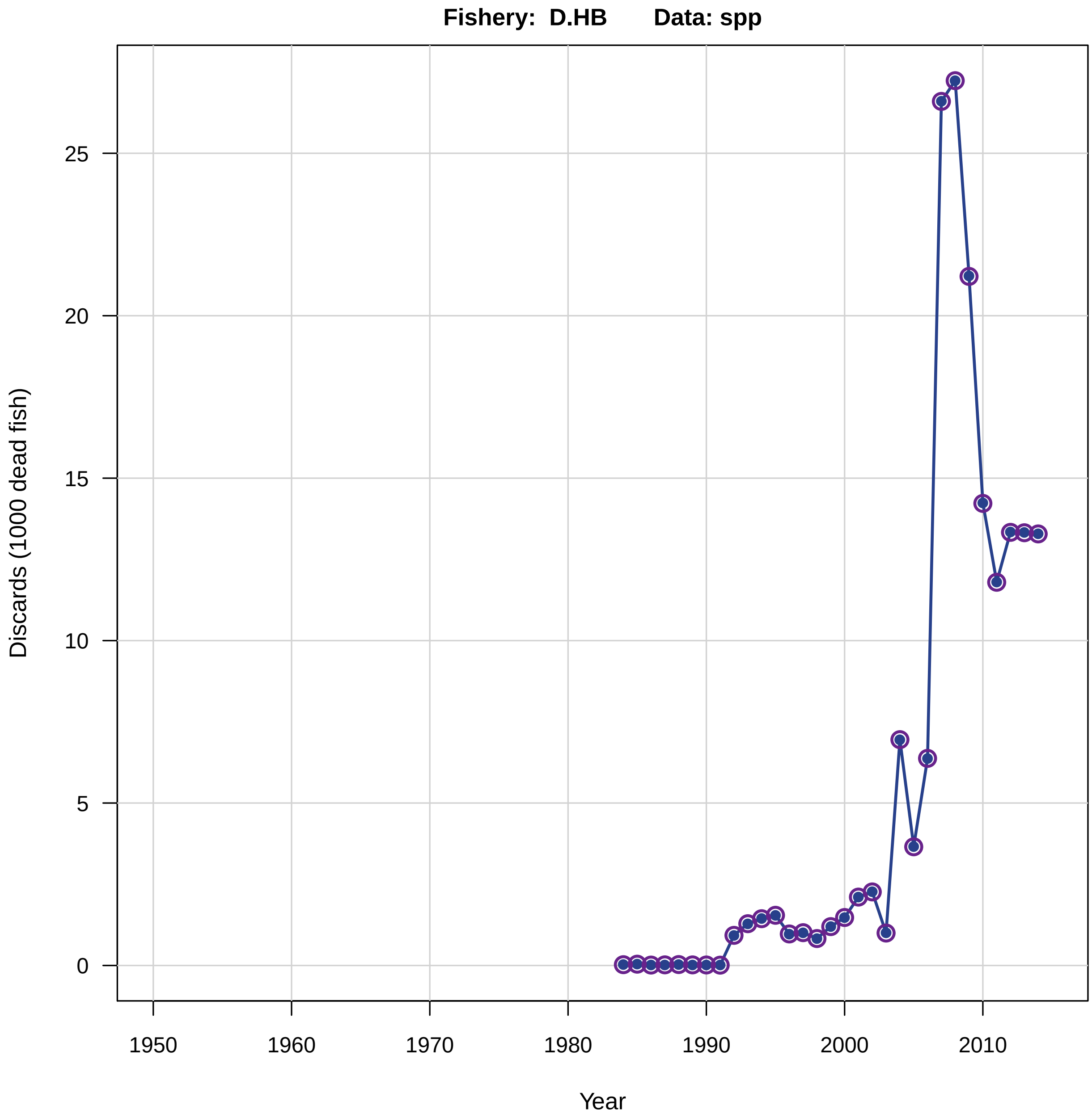


Figure 9. Observed (open circles) and estimated (solid line, circles) general recreational discard mortalities.

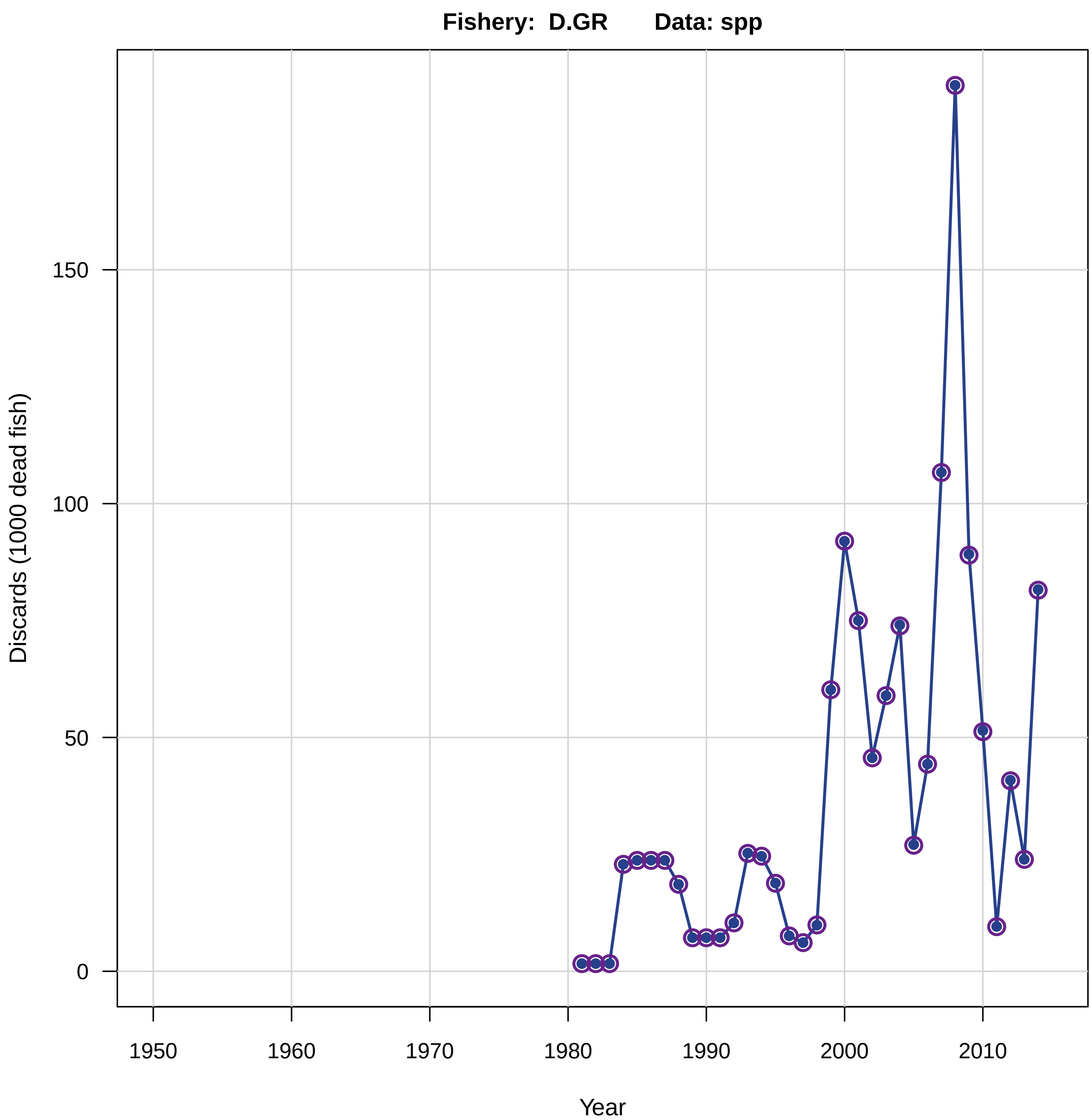


Figure 10. Observed (open circles) and estimated (solid line, circles) index of abundance from the SERFS combined trap and video index. The error bars represent the annual CV provided by the GLM standardization divided by the likelihood weight on the index.

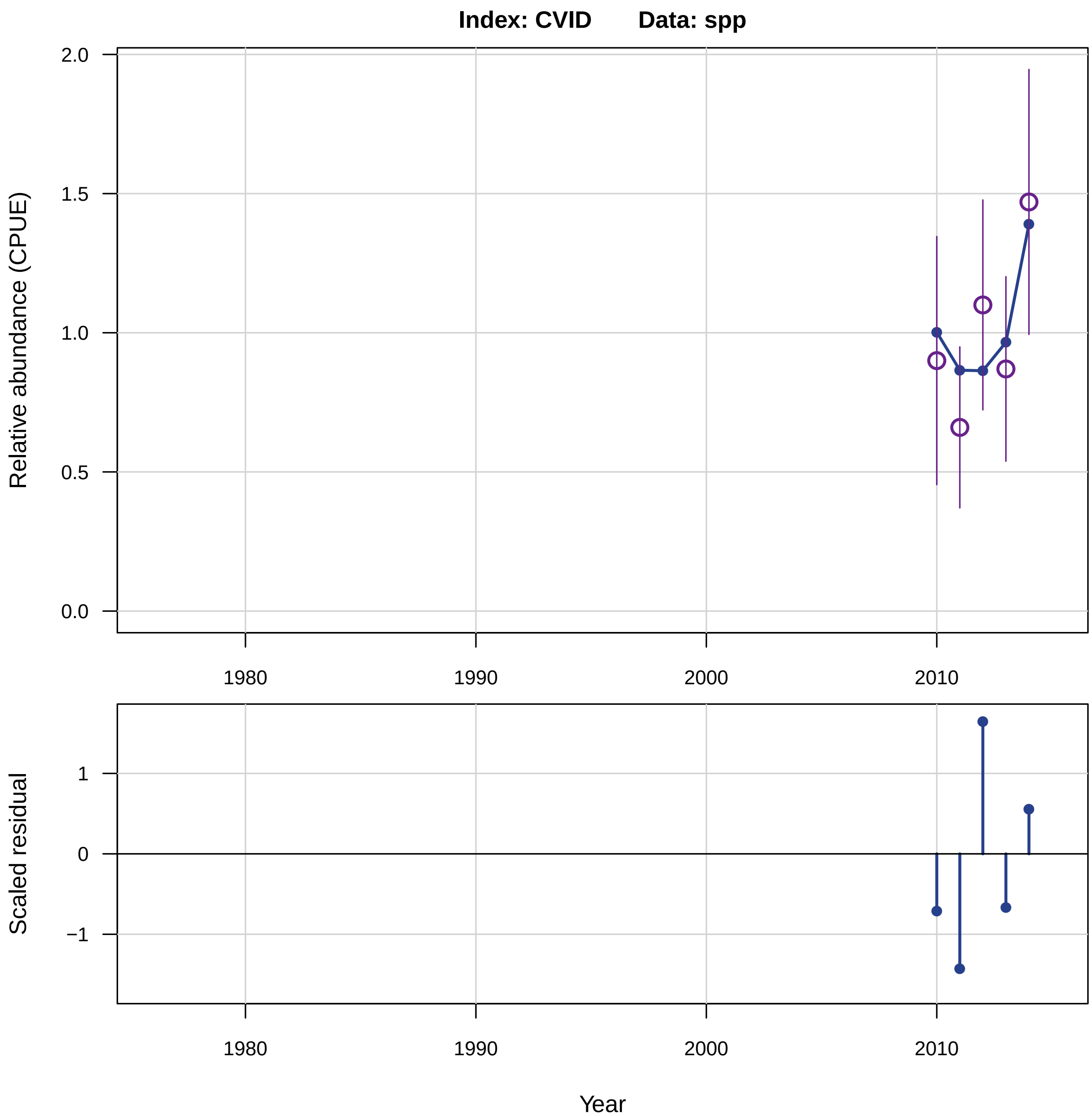


Figure 11. Observed (open circles) and estimated (solid line, circles) index of abundance from the commercial handline fleet. The error bars represent the annual CV of the index (0.2) divided by the likelihood weight on the index.

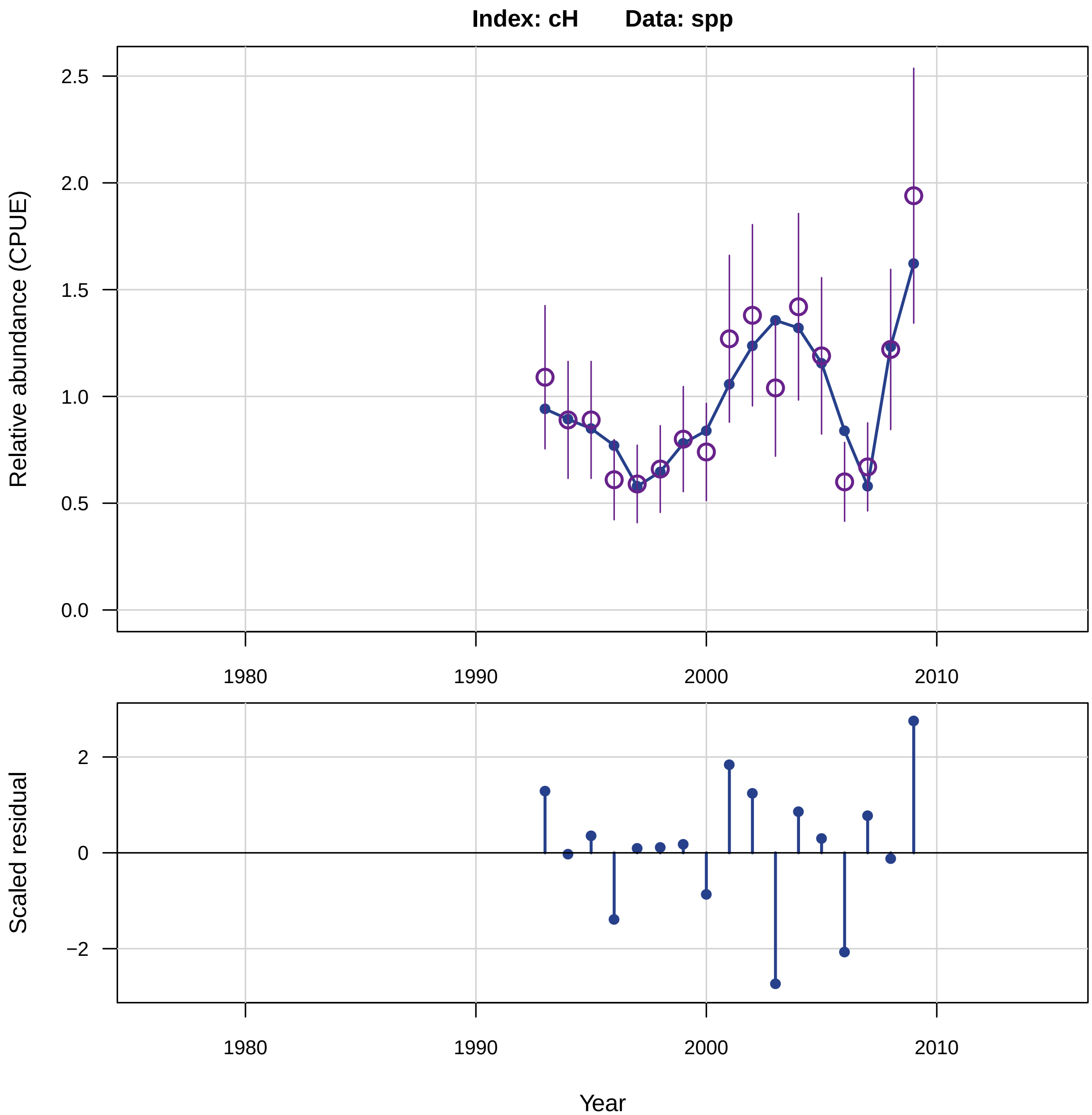


Figure 12. Observed (open circles) and estimated (solid line, circles) abundance from the headboat fleet. The error bars represent the annual CV of the index (0.2) divided by the likelihood weight on the index.

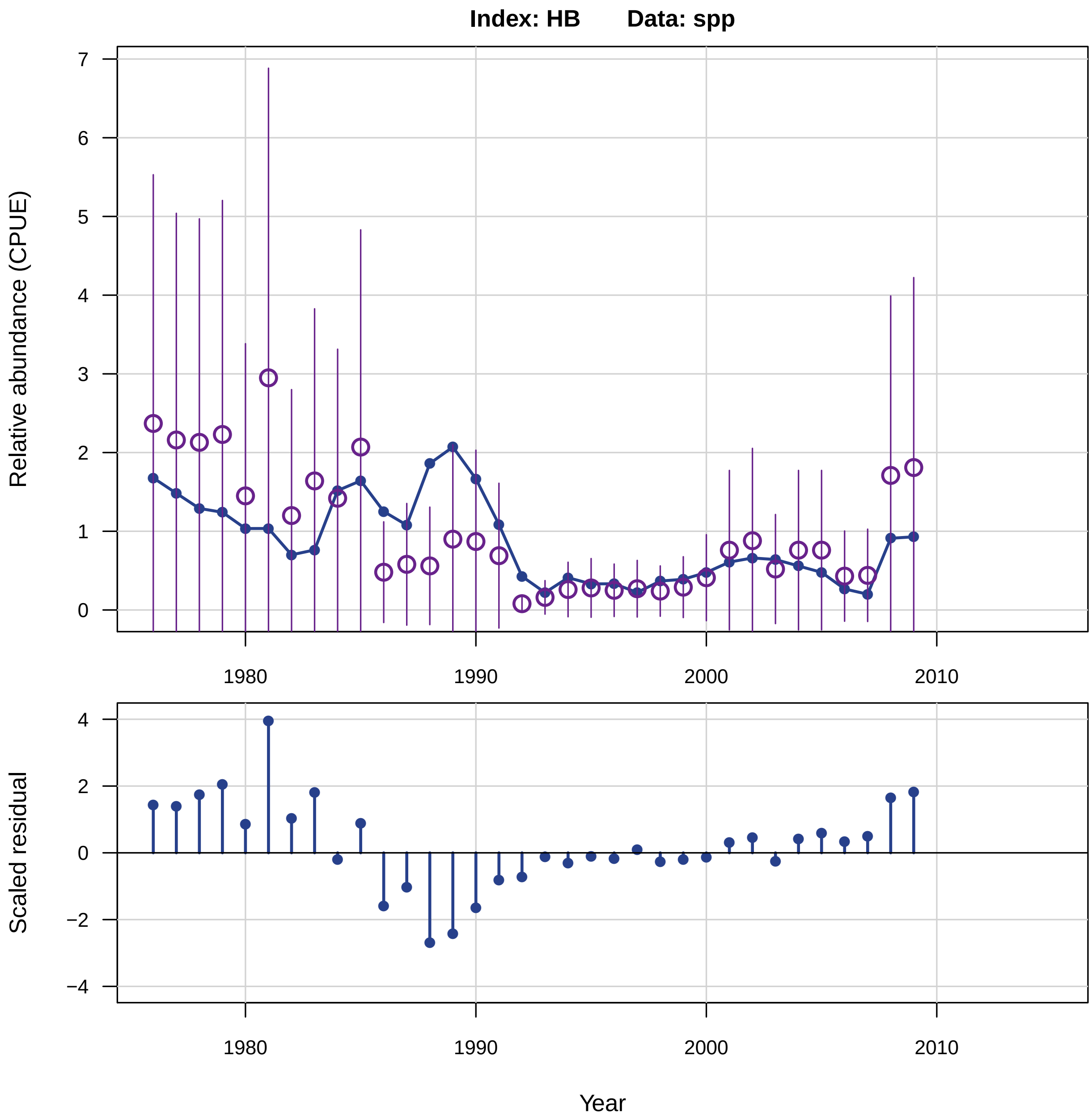


Figure 13. Observed (open circles) and estimated (solid line, circles) abundance from the headboat fleet (discards). The error bars represent the annual CV provided by the GLM standardization divided by the likelihood weight on the index.

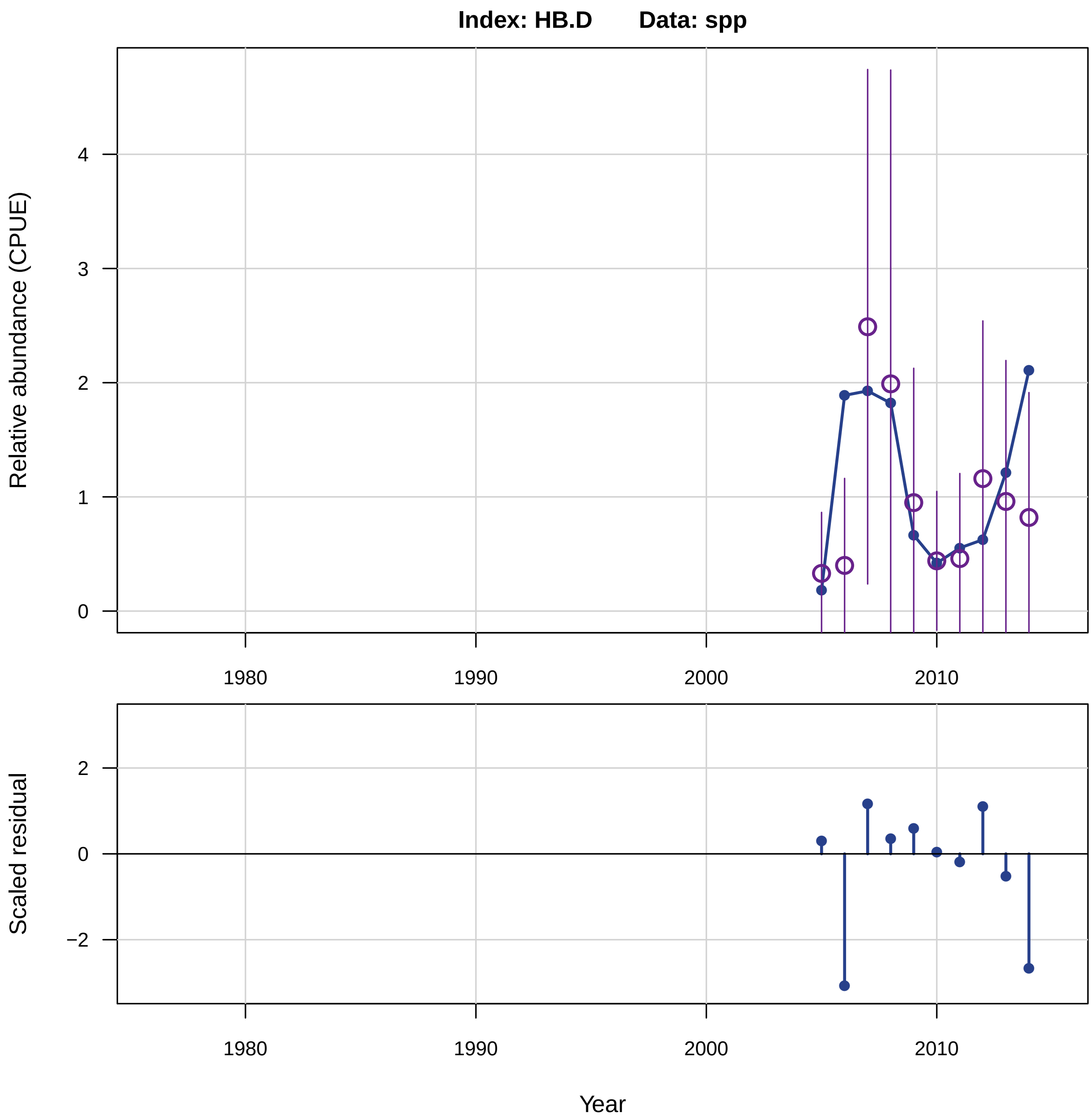


Figure 14. Estimated abundance at age at start of year.

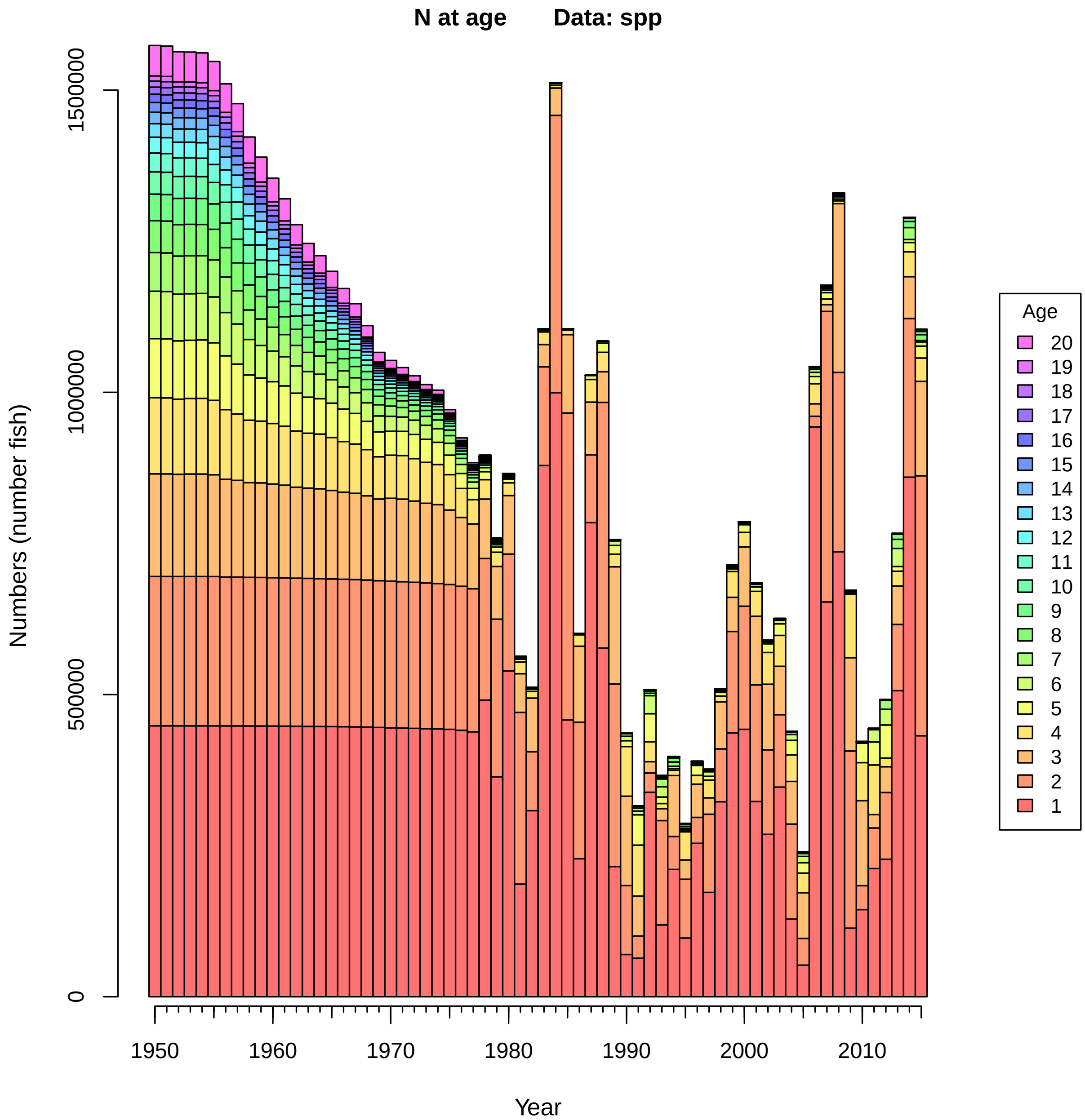


Figure 15. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates $R_{\mathrm{F30\%}}$. *Bottom panel: log recruitment residuals.*

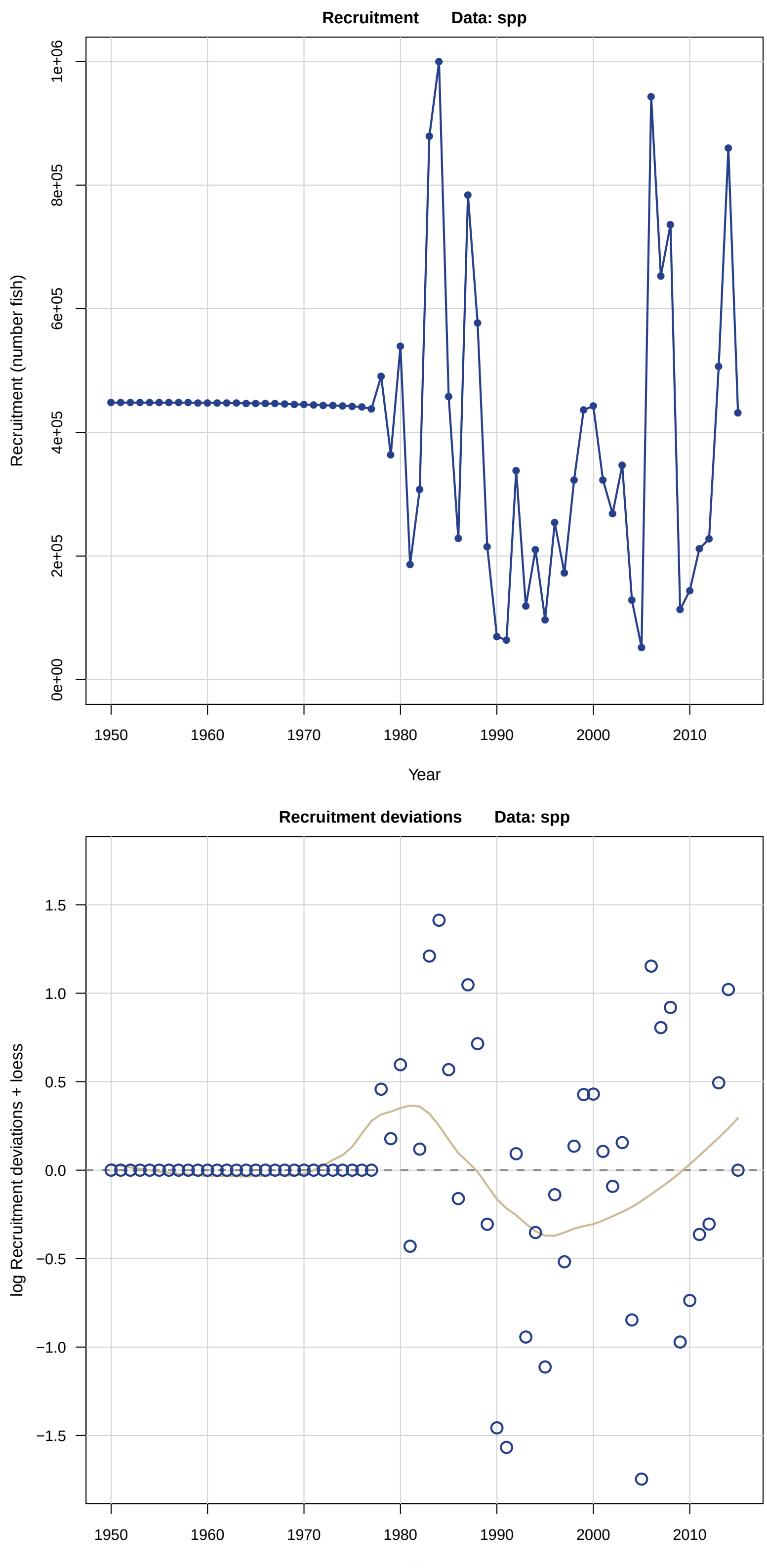


Figure 16. Estimated biomass at age at start of year.

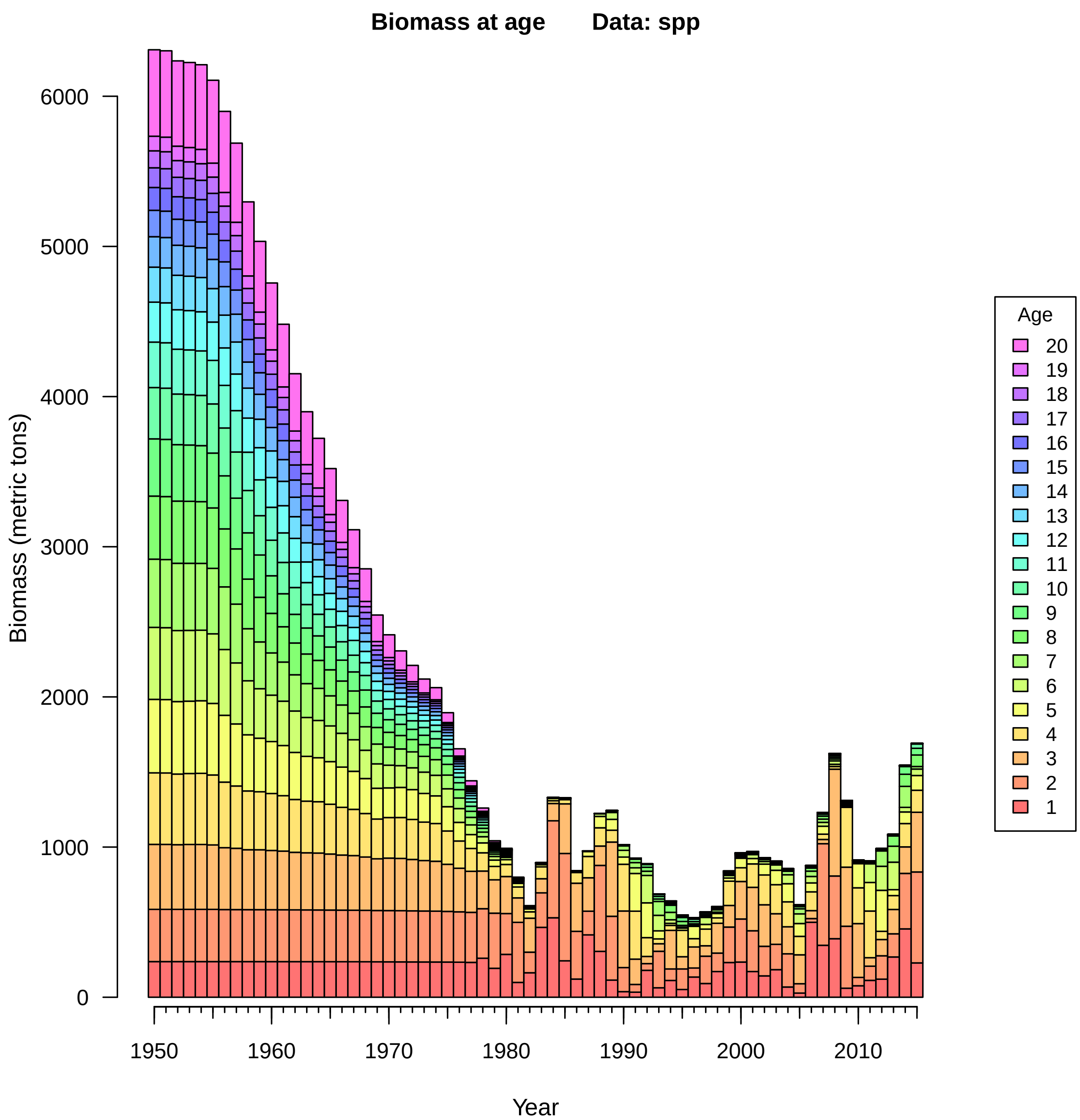


Figure 17. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates $B_{F30\%}$. Bottom panel: Estimated spawning stock (population fecundity) at time of peak spawning.

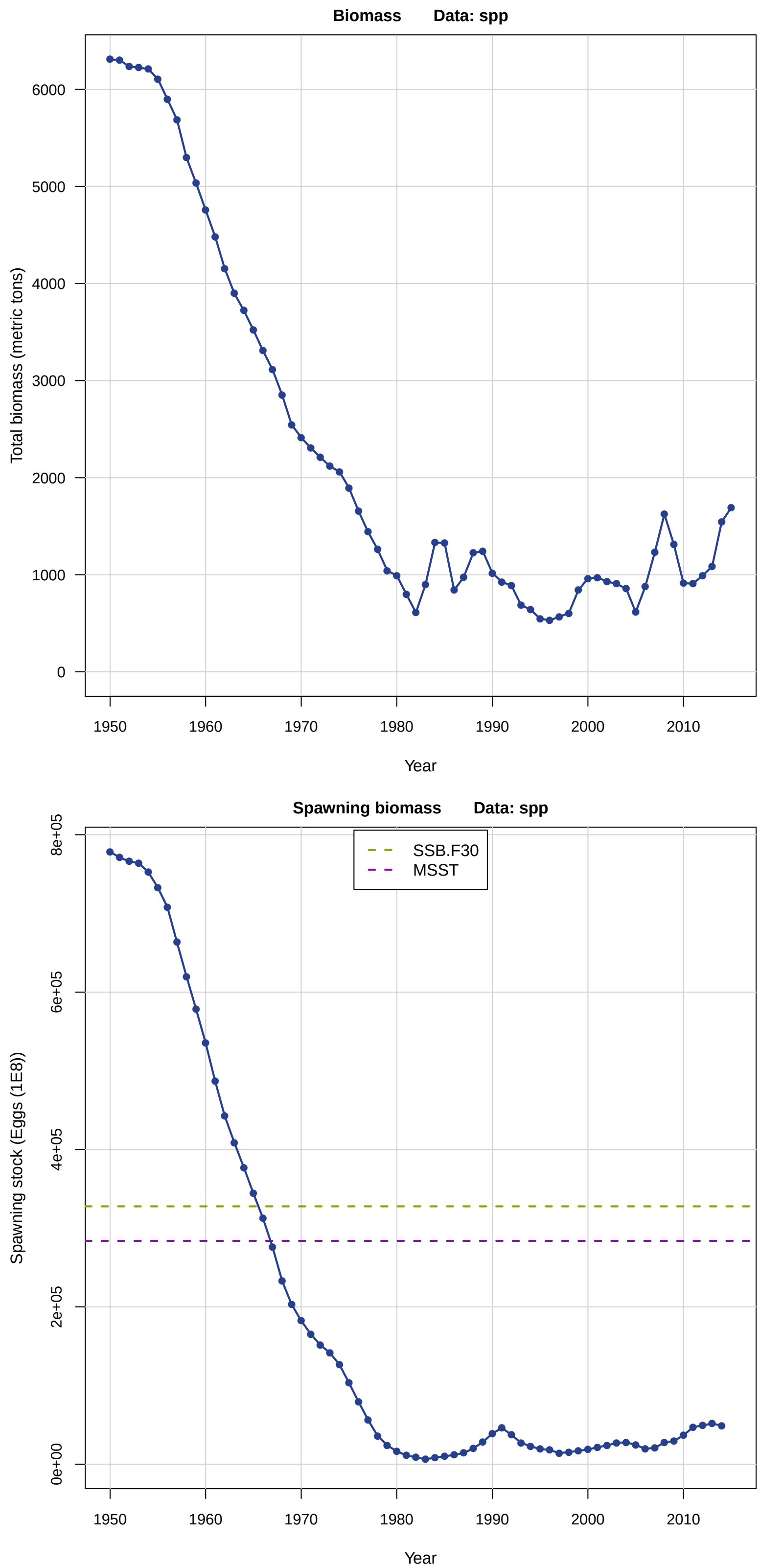


Figure 18. Monte Carlo Bootstrap estimates of population abundance. Top panel is all ages, and the bottom panel represents age 2+.

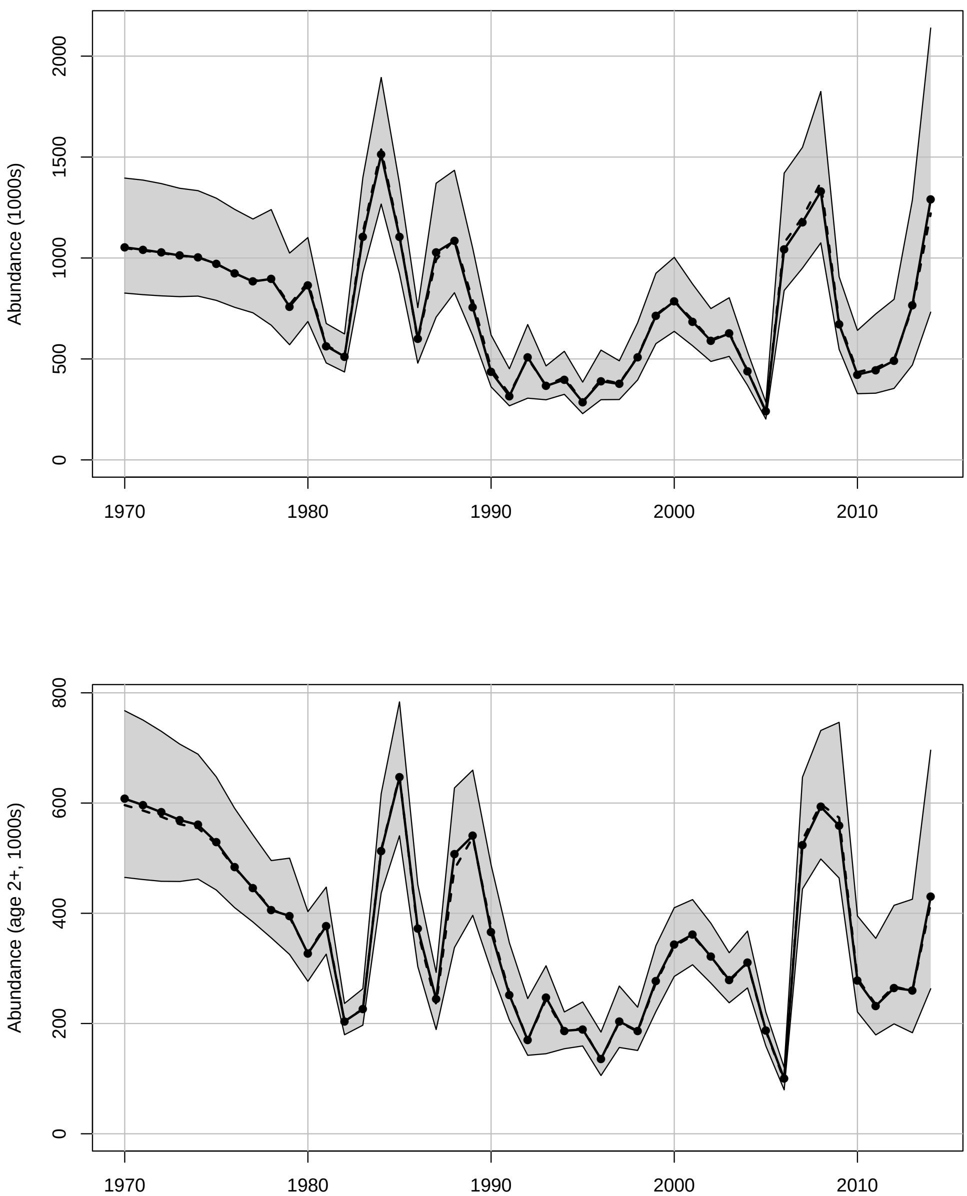


Figure 19. Selectivity of SERFS index.

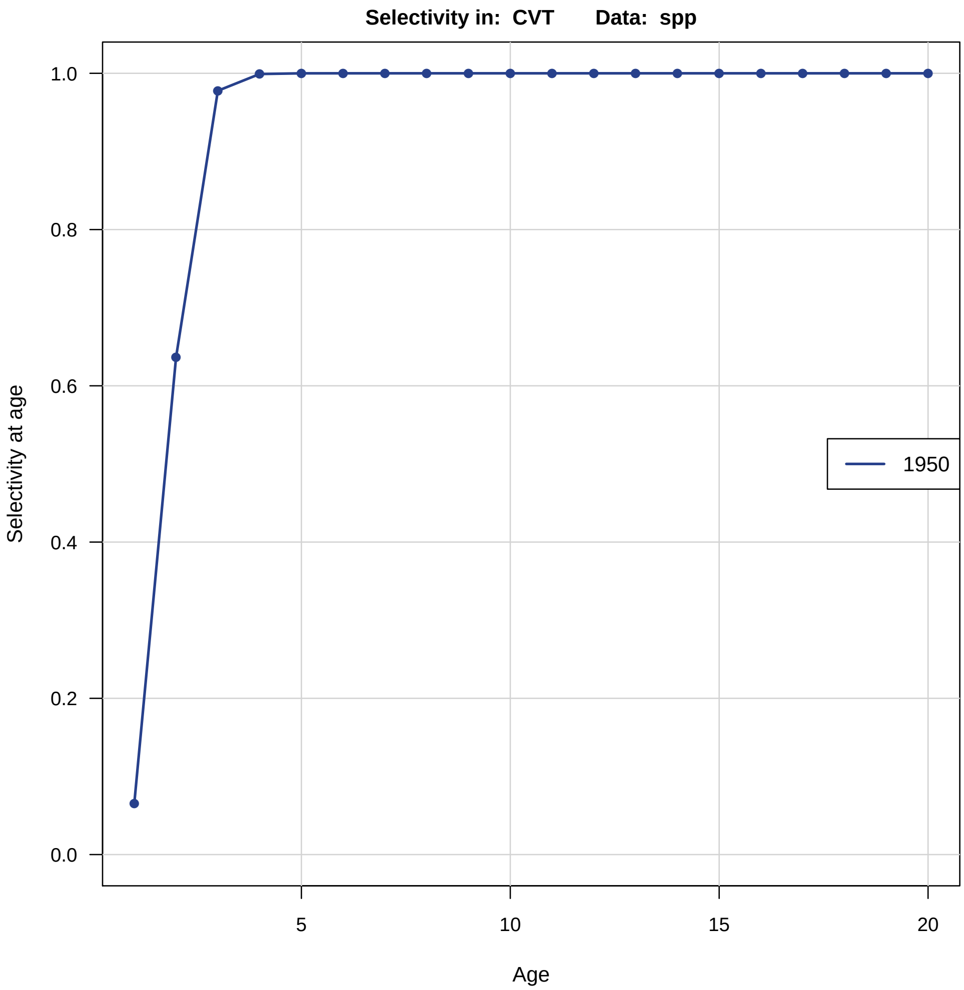


Figure 20. Selectivities of commercial handline landings. The legend indicates the first year each selectivity curve applies to the fleet.

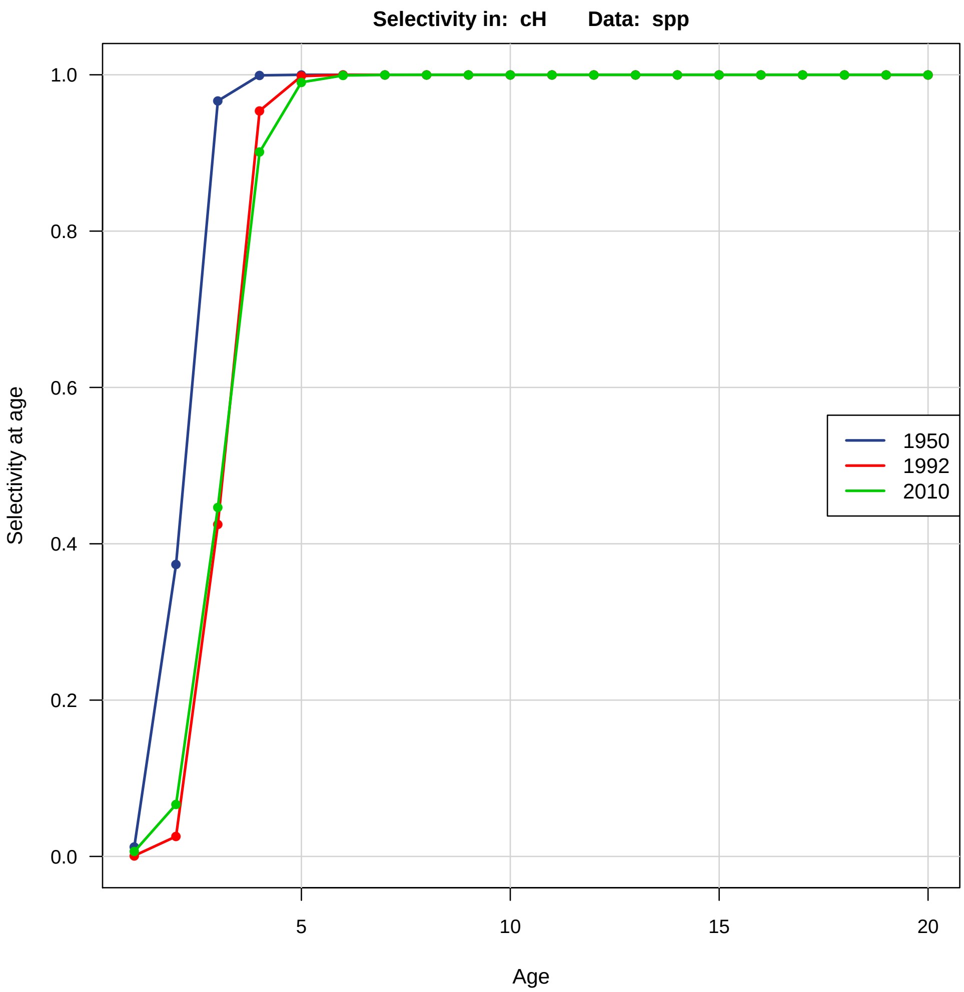


Figure 21. Selectivities of headboat landings. The legend indicates the first year each selectivity curve applies to the fleet.

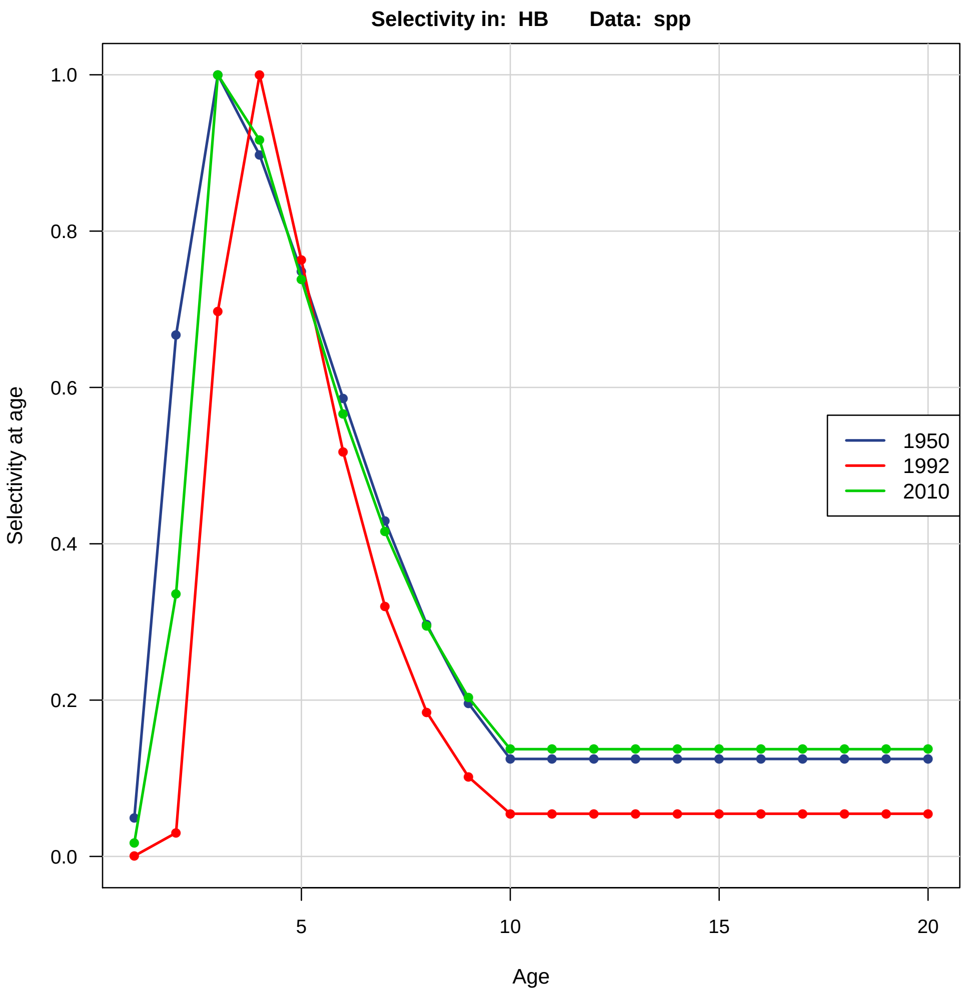


Figure 22. Selectivities of general recreational landings. The legend indicates the first year each selectivity curve applies to the fleet.

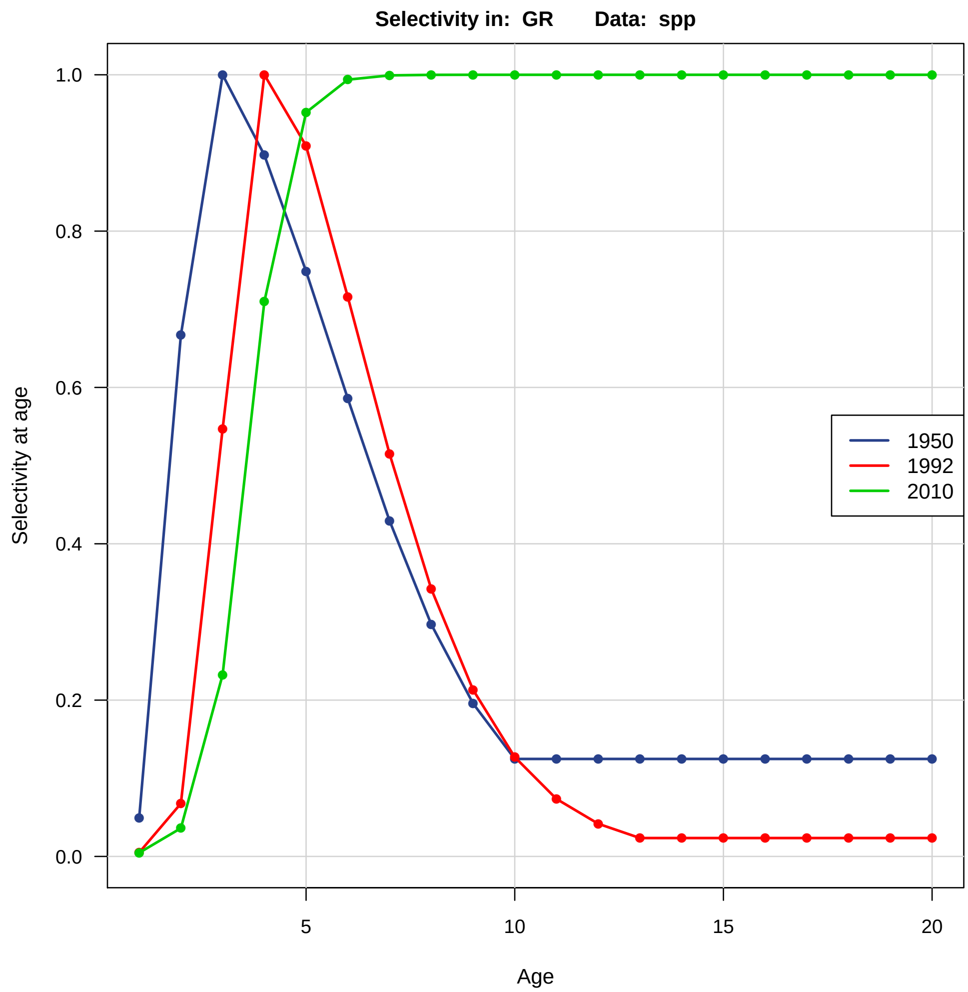


Figure 23. Selectivities of commercial handline discards. The legend indicates the first year each selectivity curve applies to the fleet.

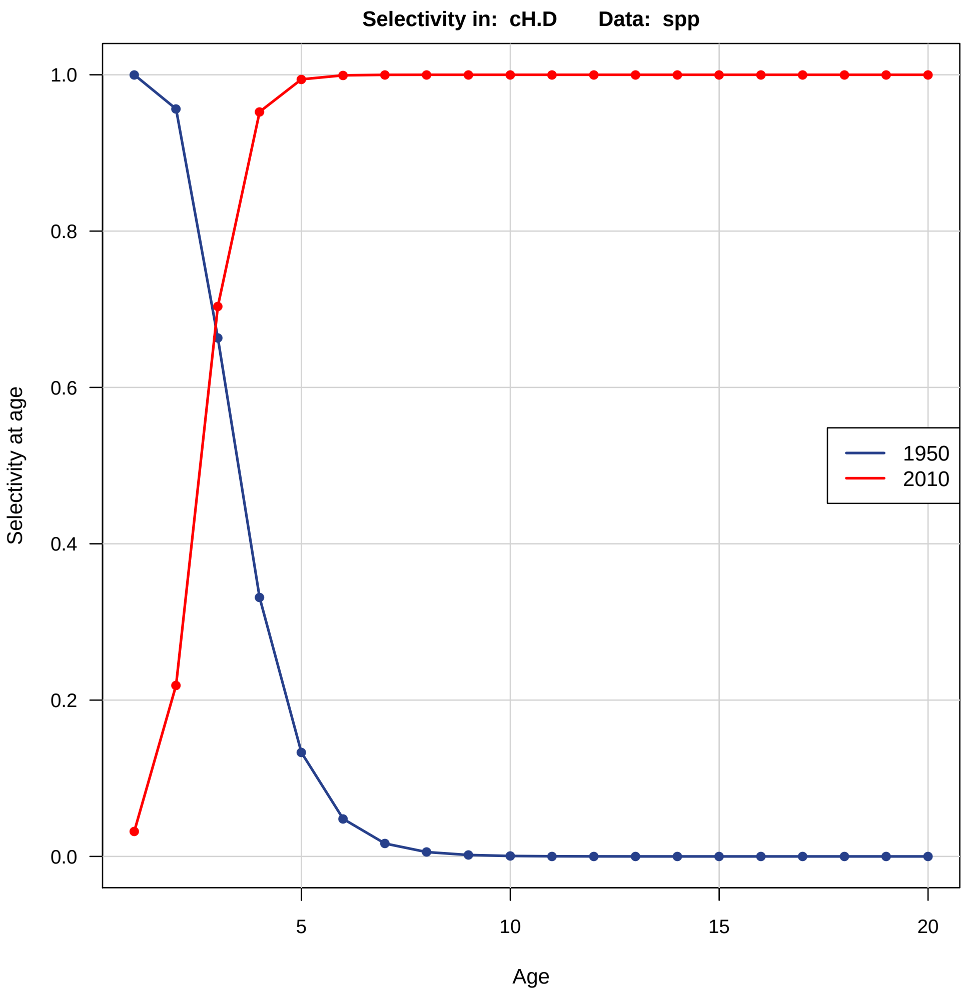


Figure 24. Selectivities of headboat discards. The legend indicates the first year each selectivity curve applies to the fleet.

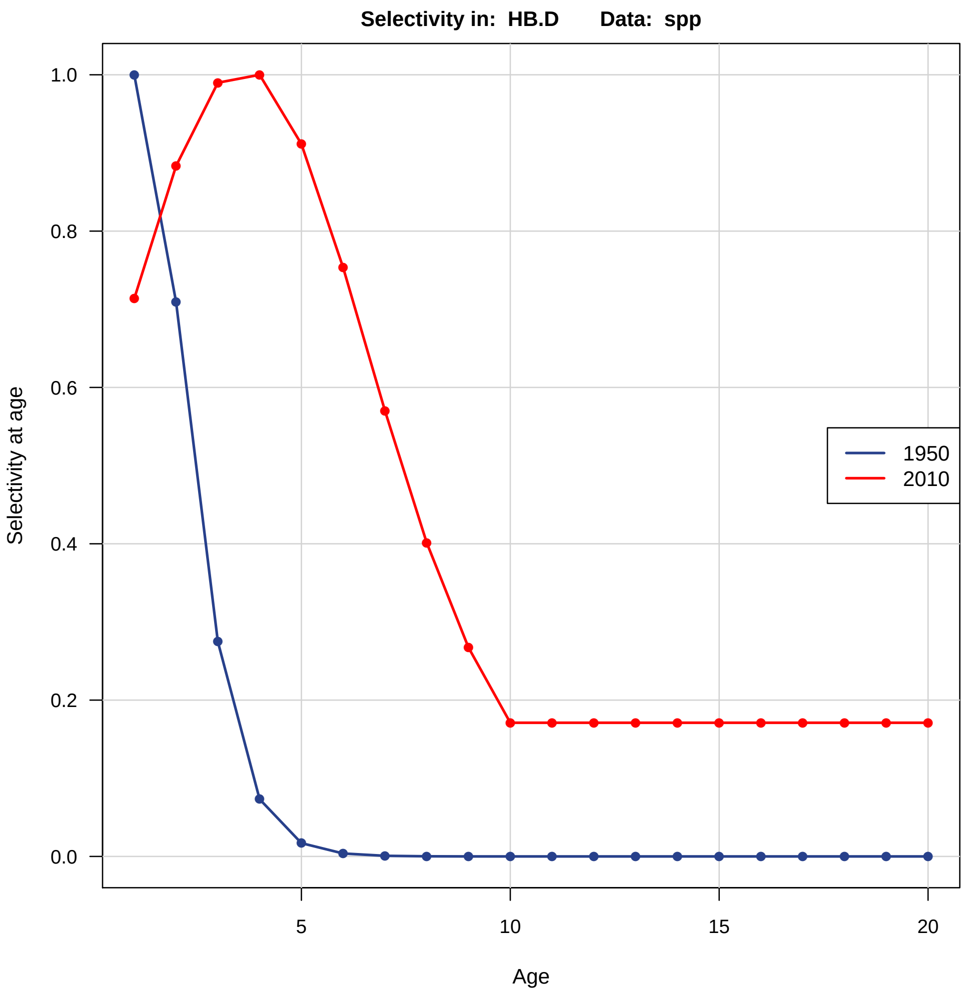


Figure 25. Selectivities of general recreational discards. The legend indicates the first year each selectivity curve applies to the fleet.

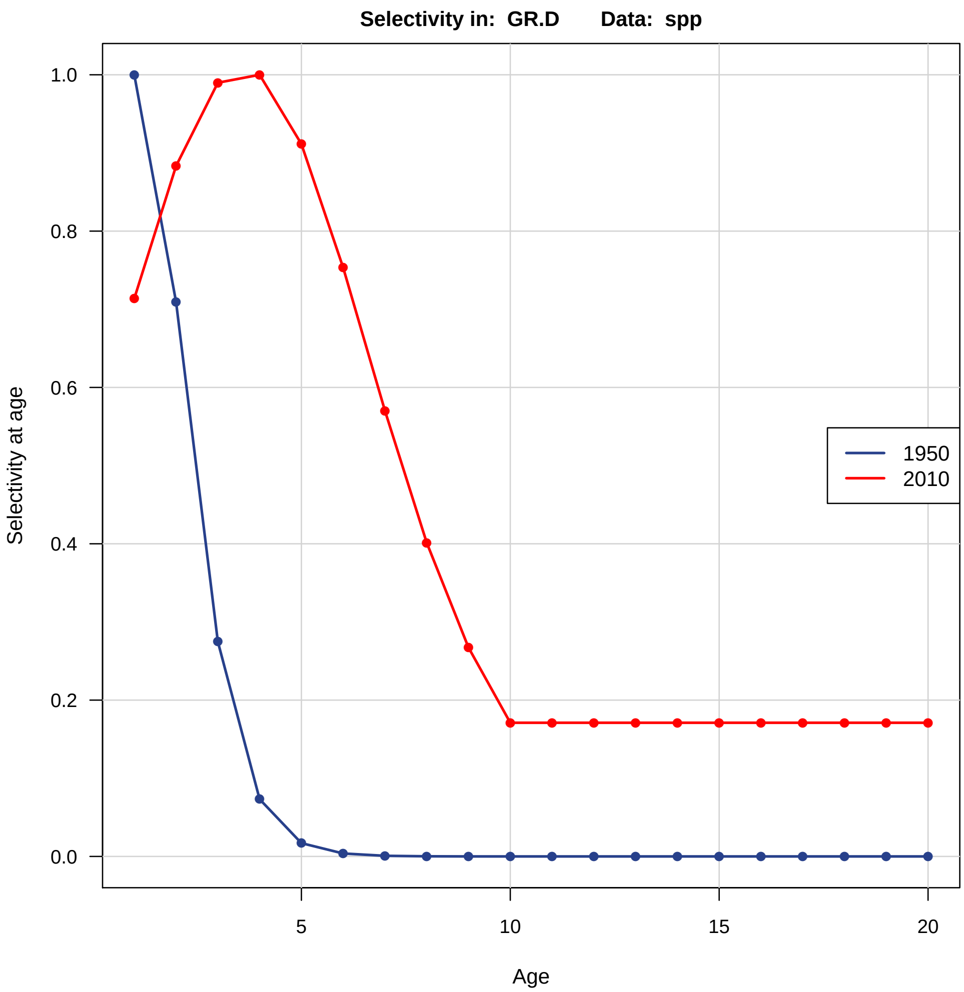


Figure 26. Average selectivity of discards(top left), landings (top right), and total weighted average (bottom) from the terminal assessment years, weighted by geometric mean F's from the last three assessment years, and used in computation of benchmarks and projections.

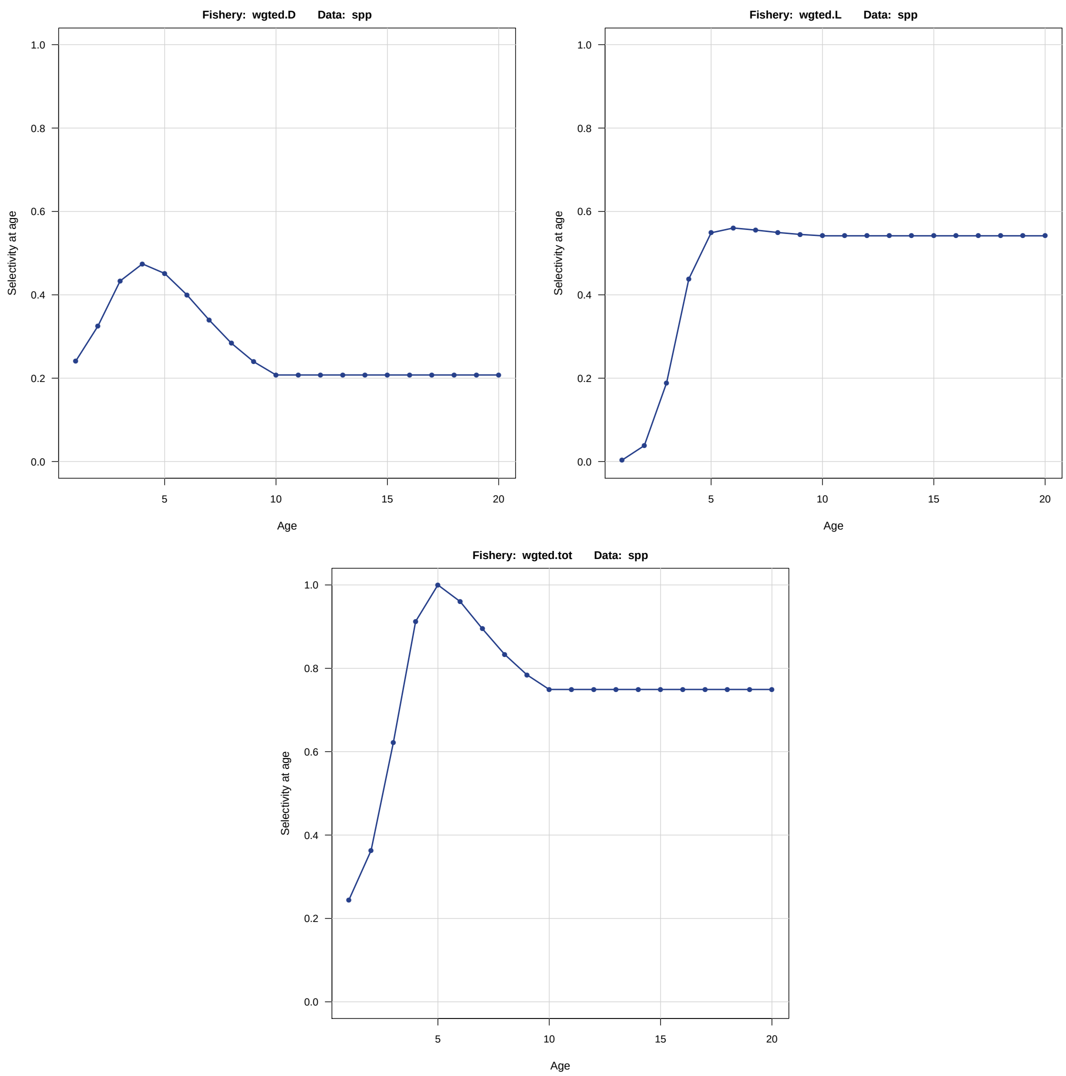


Figure 27. Estimated fully selected fishing mortality rate (per year) by fleet. cH refers to commercial handlines, HB to headboat, GR to general recreational, and D refers to discard mortality.

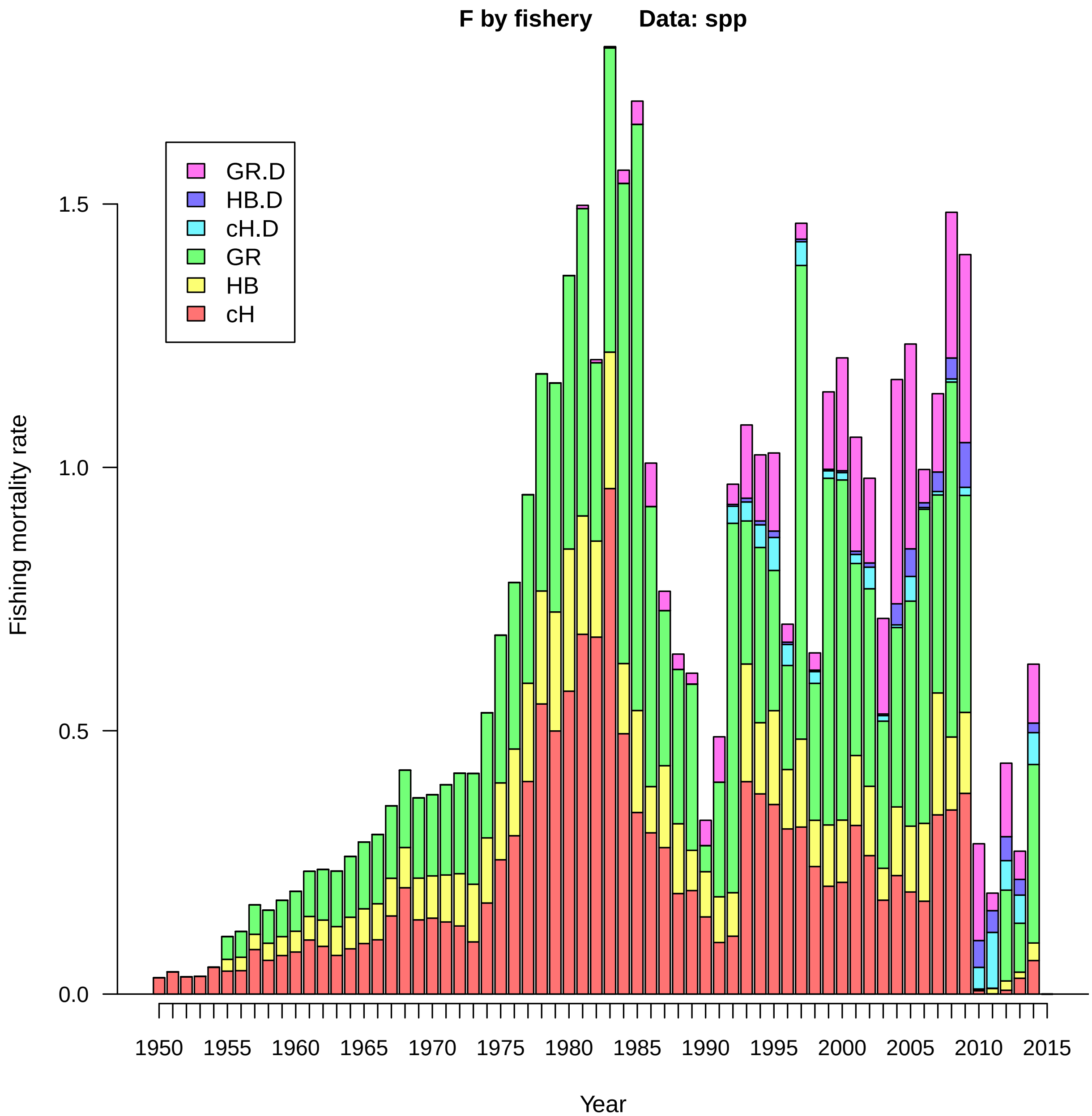
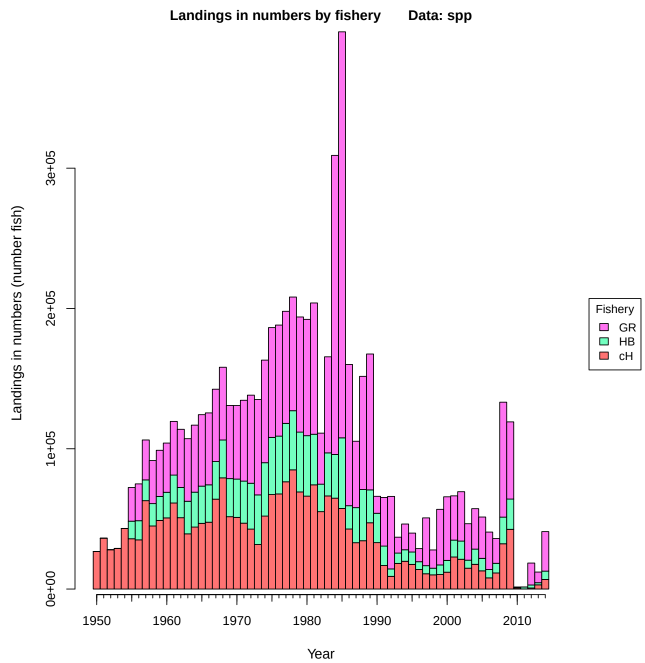


Figure 28. Estimated landings in numbers by fleet from the catch-age model. cH refers to commercial handlines, HB to headboat, and GR to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of $L_{F30\%}$ in numbers.



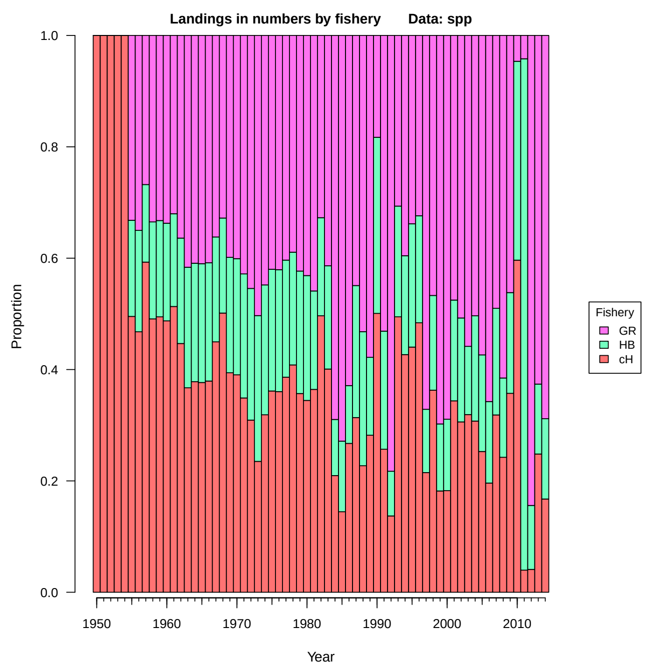


Figure 29. Estimated landings in whole weight by fleet from the catch-age model. cH refers to commercial handlines, HB to headboat, and GR to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of $L_{\mathrm{F30\%}}$ in weight.

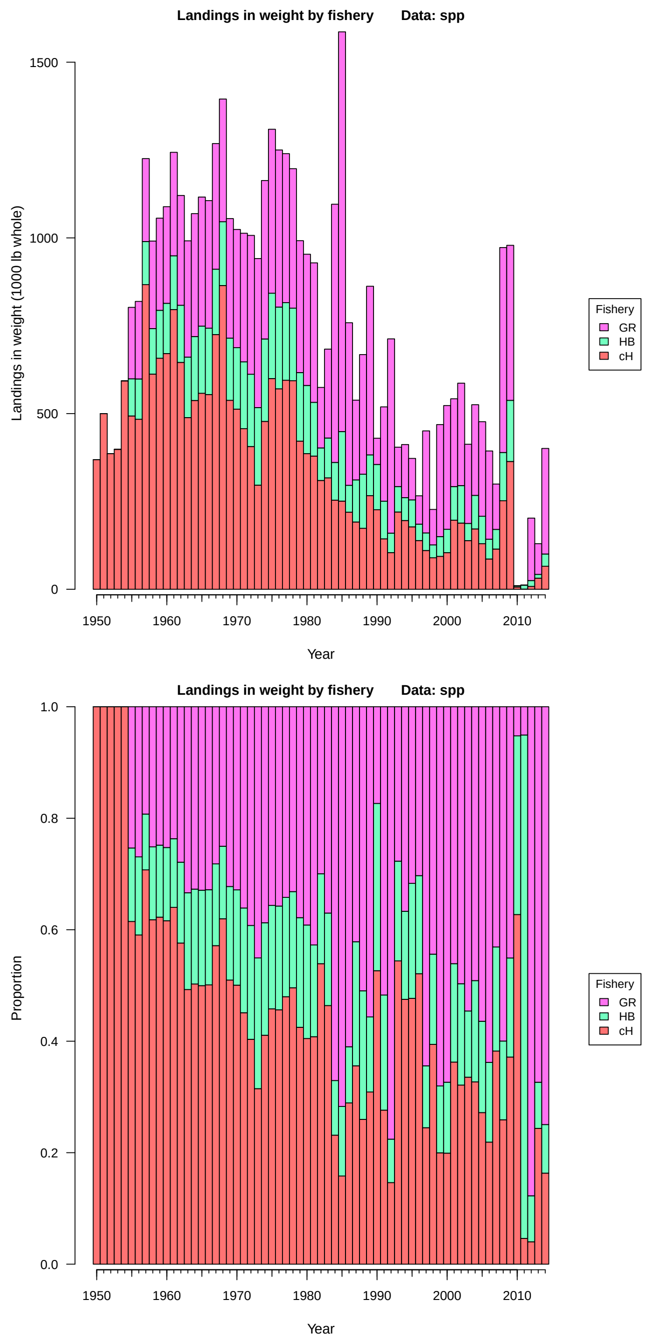


Figure 30. Estimated discard mortalities by fleet from the catch-age model. cH refers to commercial lines, hb to headboat, rec to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of $D_{F_{30\%}}$ *in numbers.*

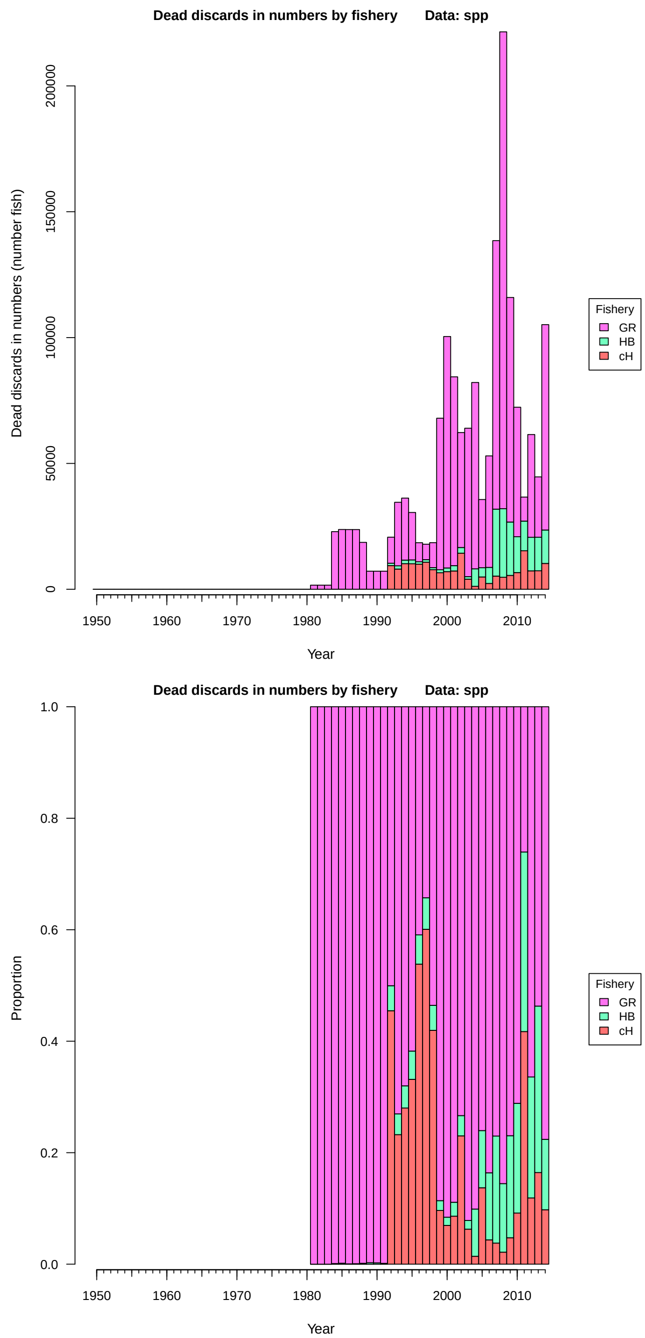


Figure 31. Top panel: Beverton–Holt spawner-recruit curves, with and without lognormal bias correction. The expected (upper) curve was used for computing management benchmarks. Bottom panel: log of recruits (number age-1 fish) per spawner as a function of spawners.

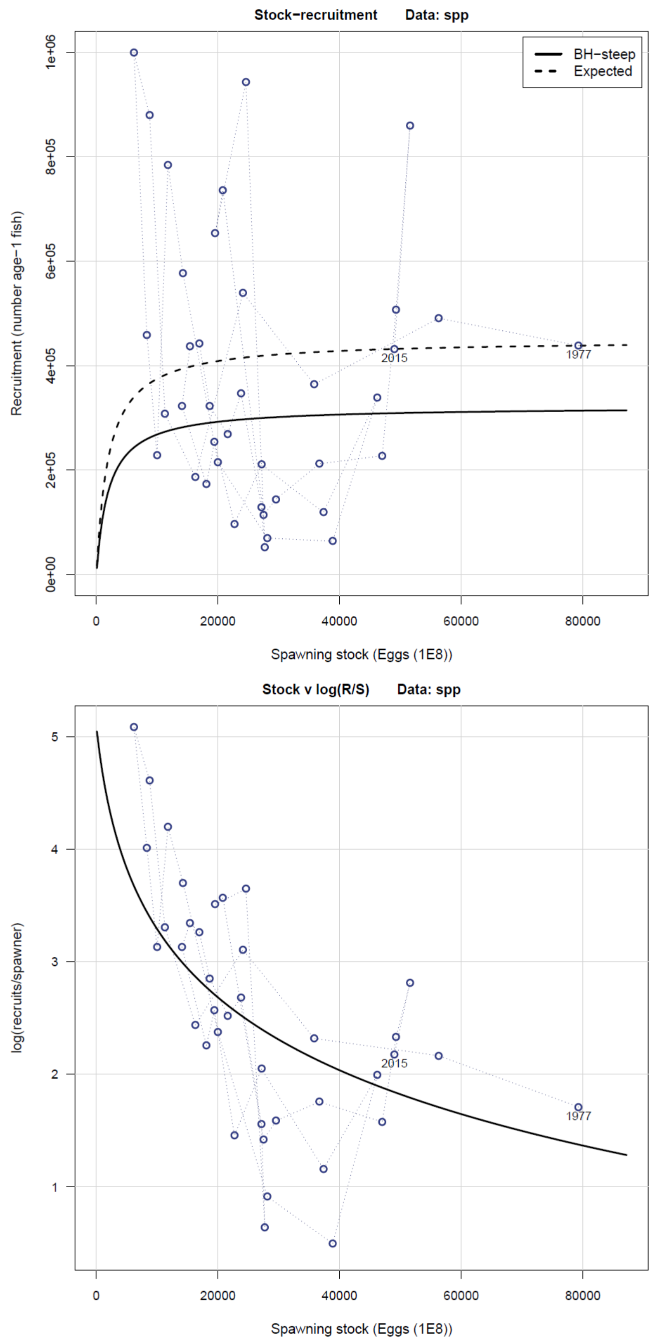


Figure 32. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-1 fish), steepness (fixed at 0.99), unfished spawners per recruit, and standard deviation of recruitment residuals in log space. Solid vertical lines represent point estimates or values from the base run of the Beaufort Assessment Model; dashed vertical lines represent medians from the MCB runs.

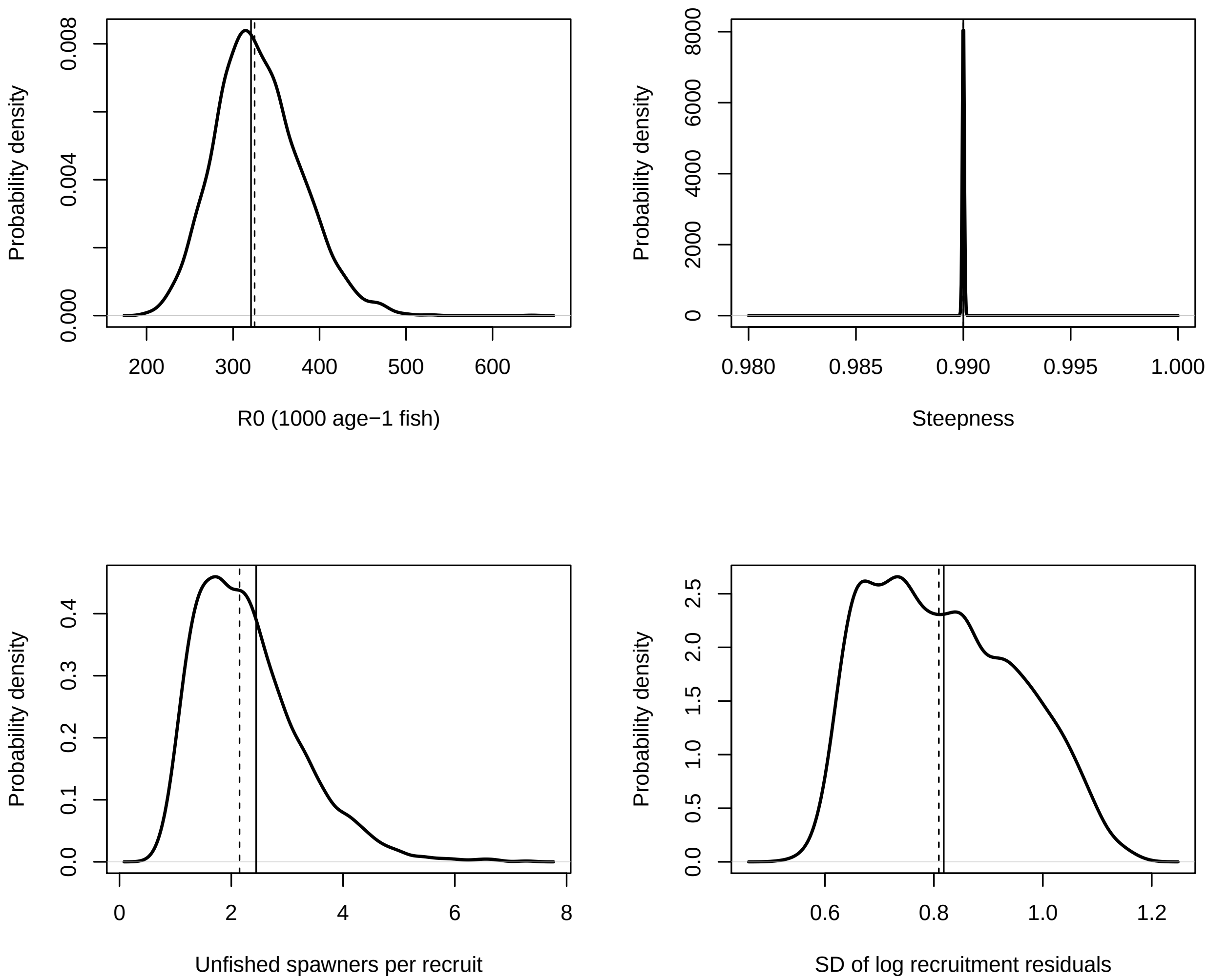


Figure 33. Yield per recruit based on average selectivity from the end of the assessment period.

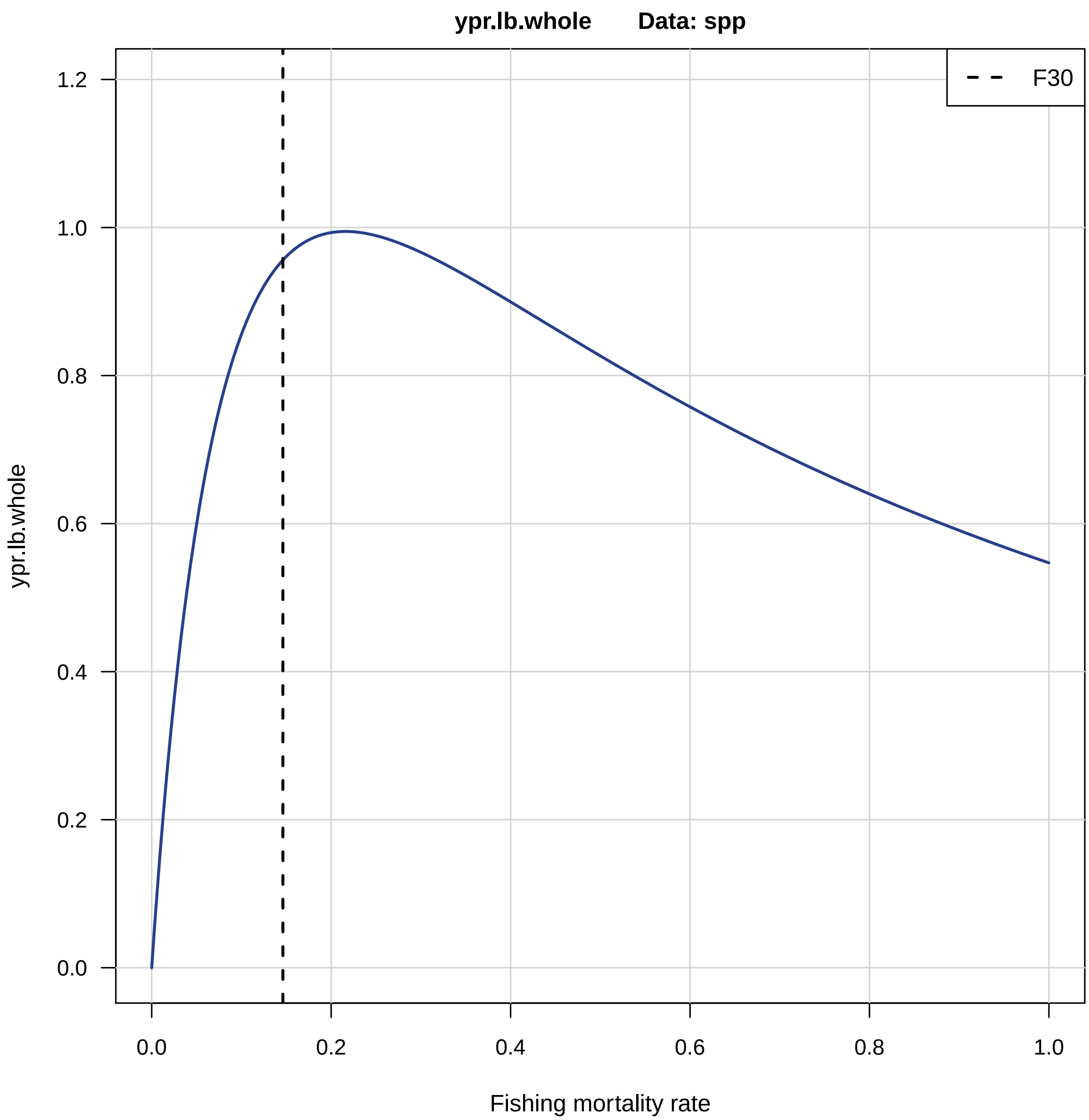


Figure 34. Spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the X% level of SPR provides $F_{X\%}$. SPR is based on average selectivity from the end of the assessment period.

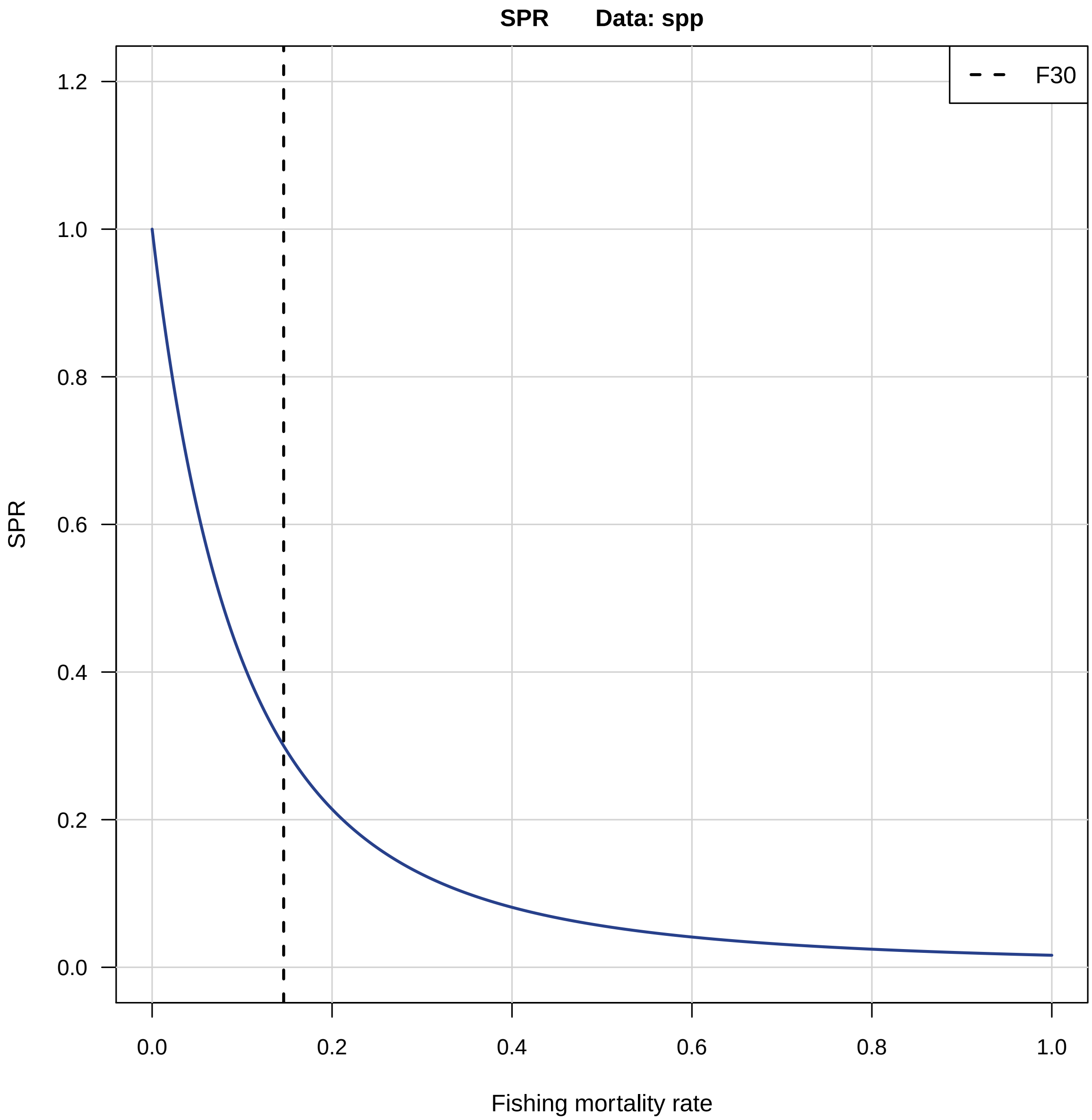


Figure 35. Equilibrium spawning biomass based on average selectivity from the end of the assessment period.

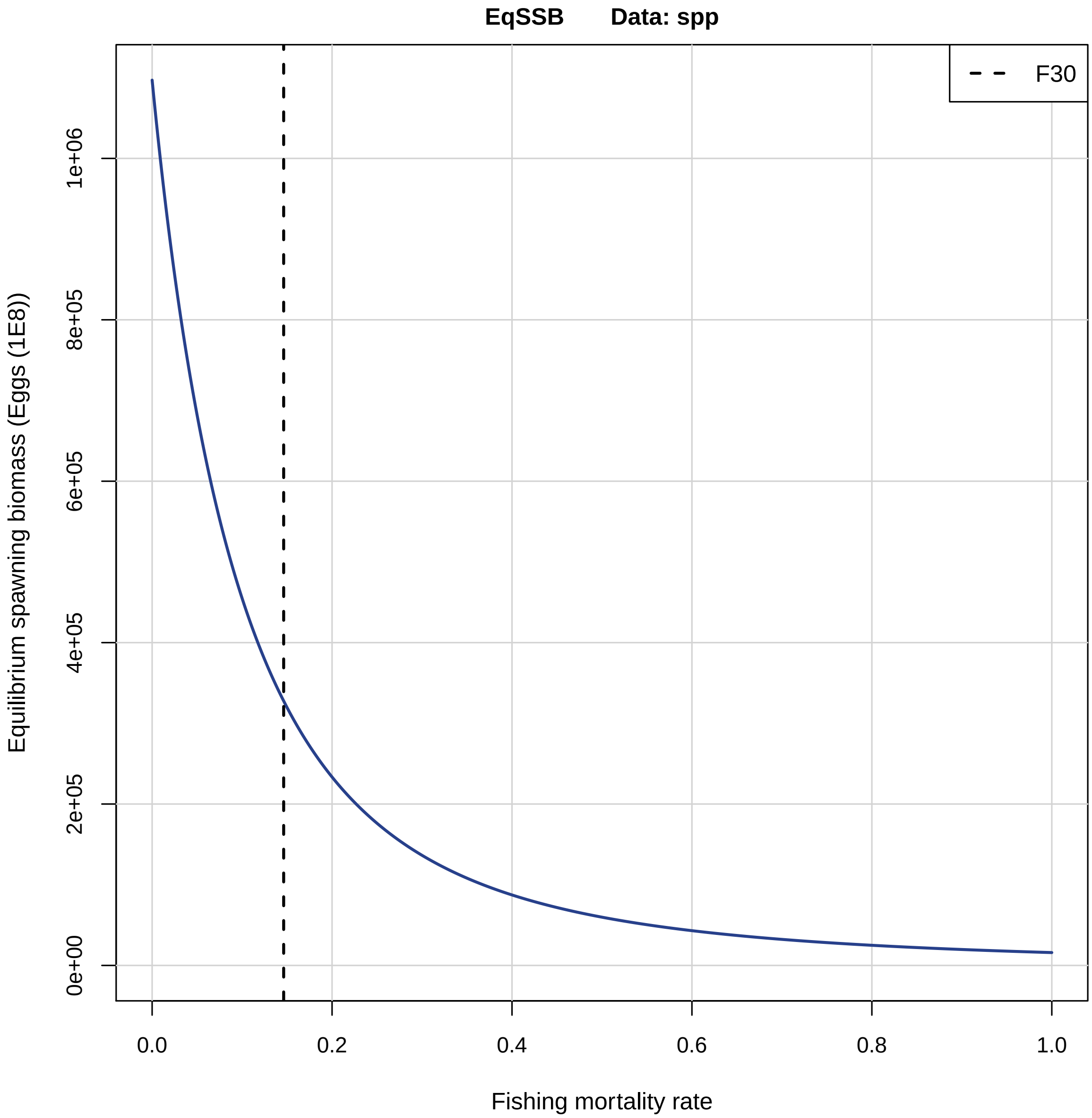


Figure 36. Probability densities of $F_{30\%}$-related benchmarks from MCB analysis of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.

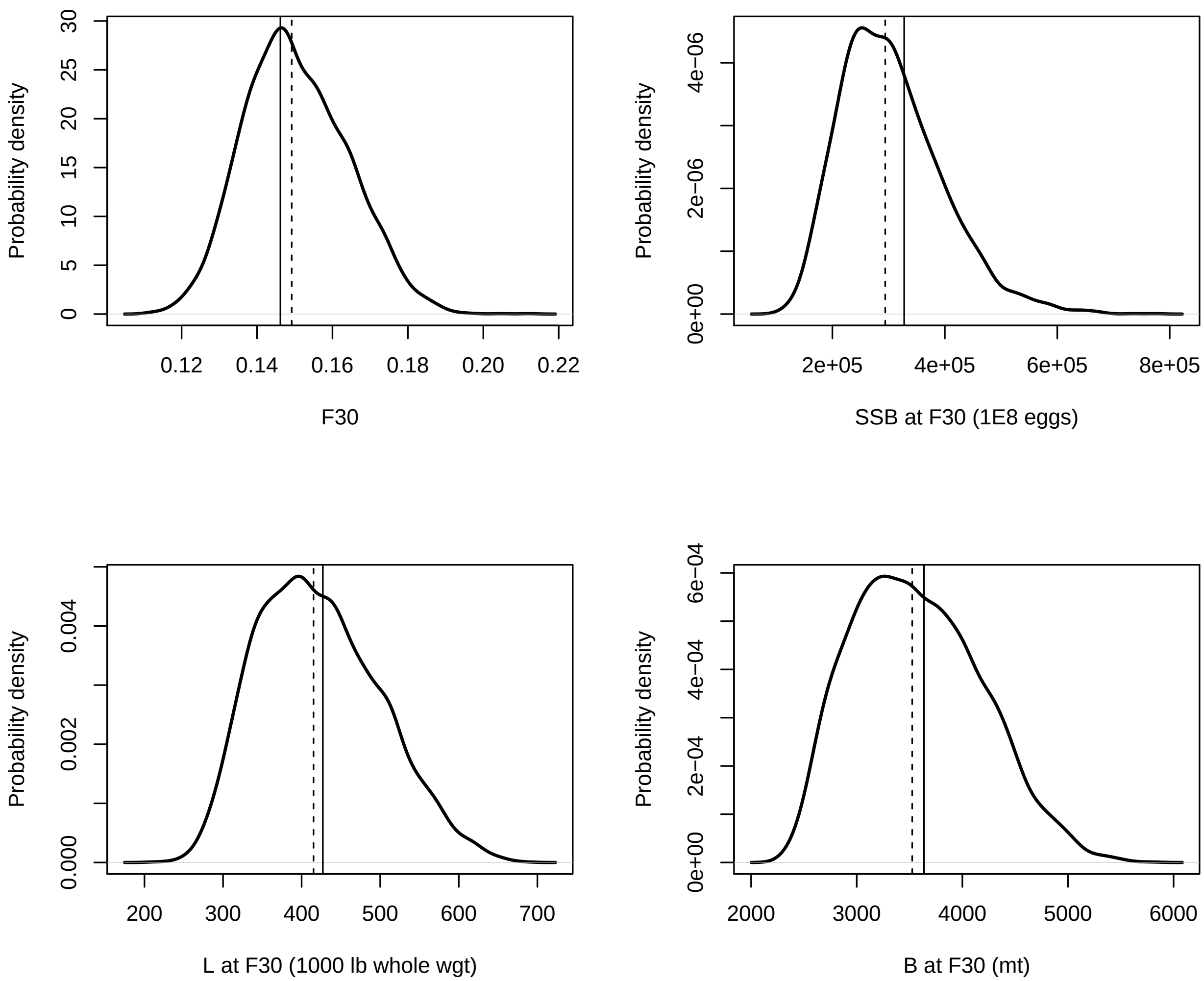


Figure 37. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; dashed lines represent median values; gray error bands indicate 5^{th} *and* 95^{th} *percentiles of the MCB trials. Top panel: spawning biomass relative to* $\mathrm{SSB_{F30\%}}$*. Bottom panel: F relative to* $F_{30\%}$*.*

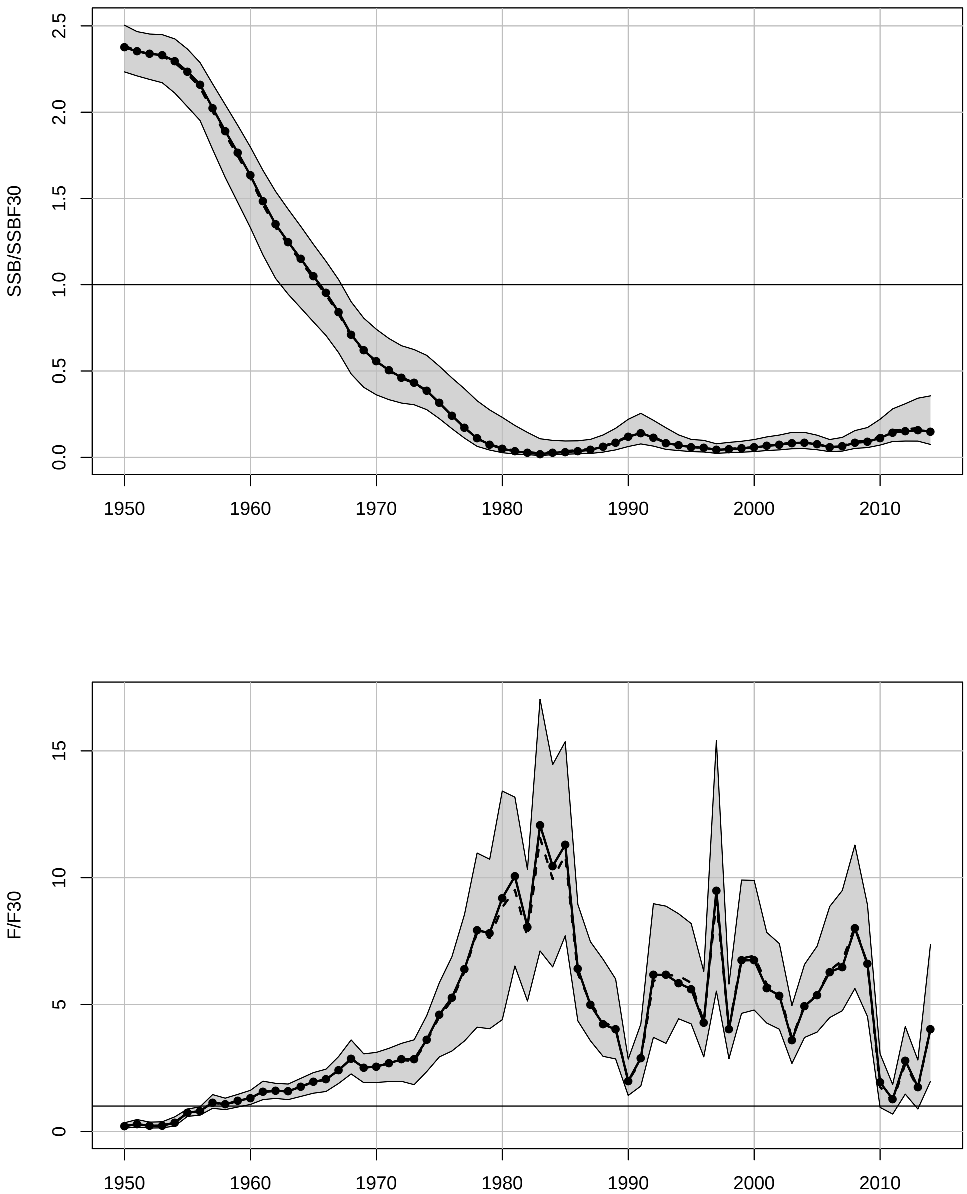
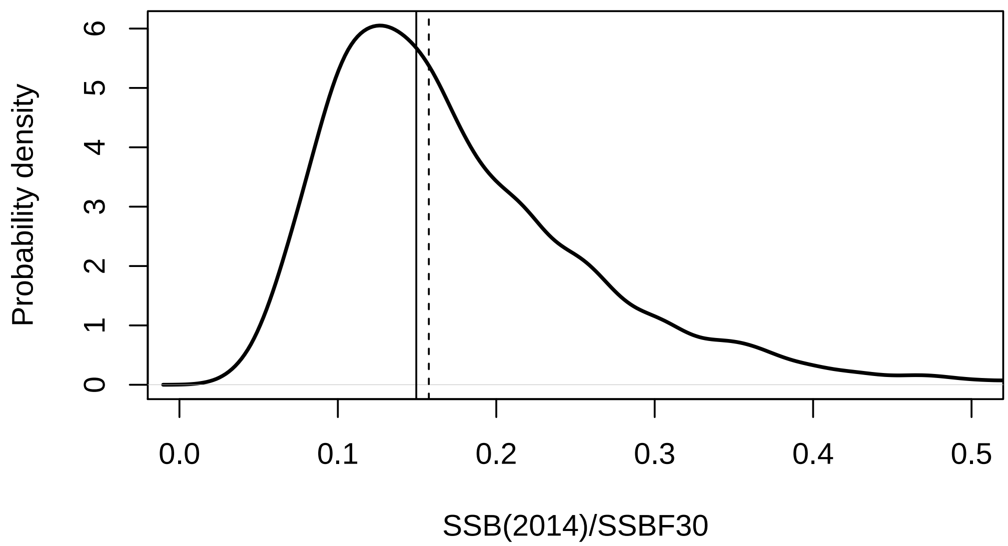


Figure 38. Probability densities of terminal status estimates from MCB analysis of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.



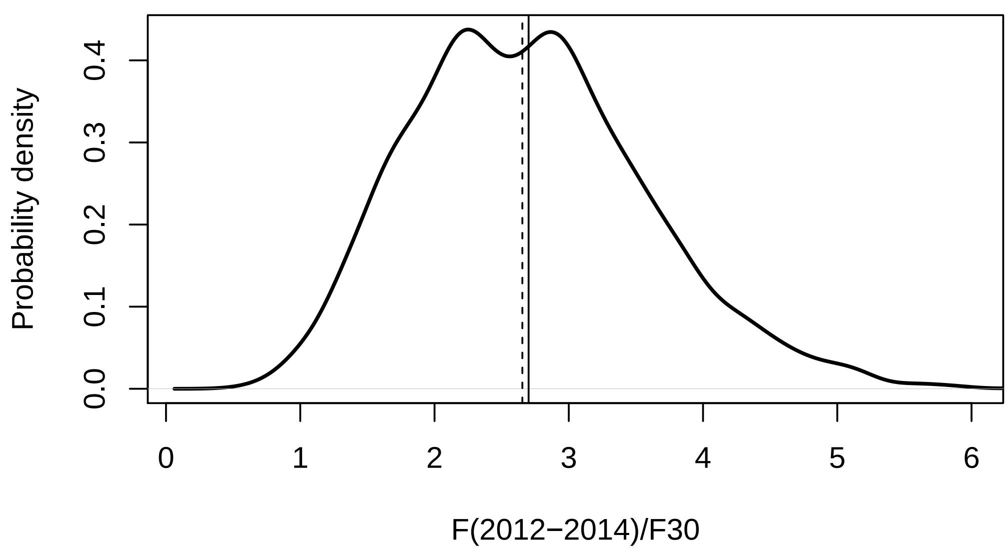


Figure 39. Phase plots of terminal status estimates from MCB analysis of the Beaufort Assessment Model. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by 5^{th} and 95^{th} percentiles. Proportion of runs falling in each quadrant indicated.

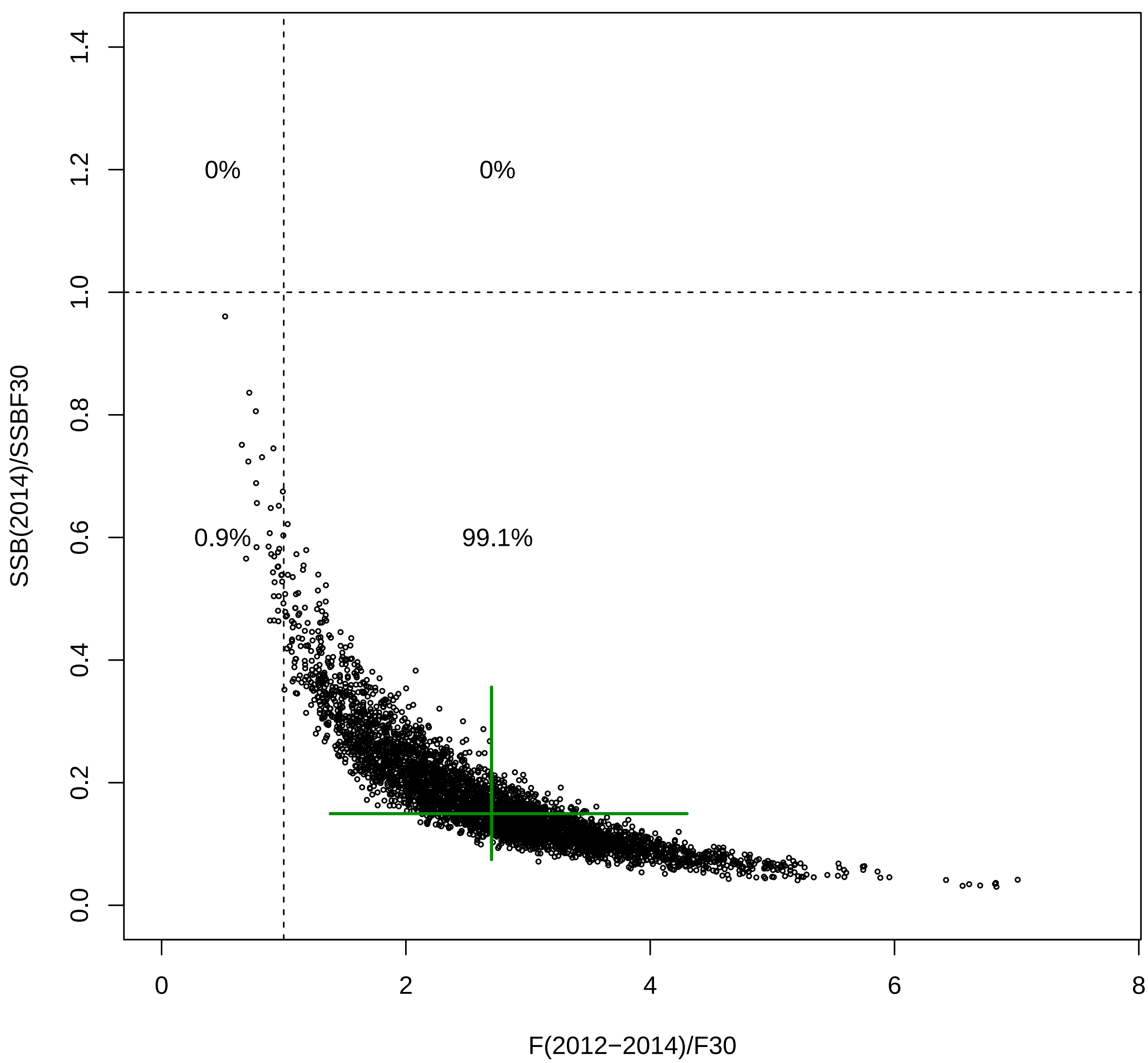


Figure 40. Age structure relative to the equilibrium expected at $F_{30\%}$.

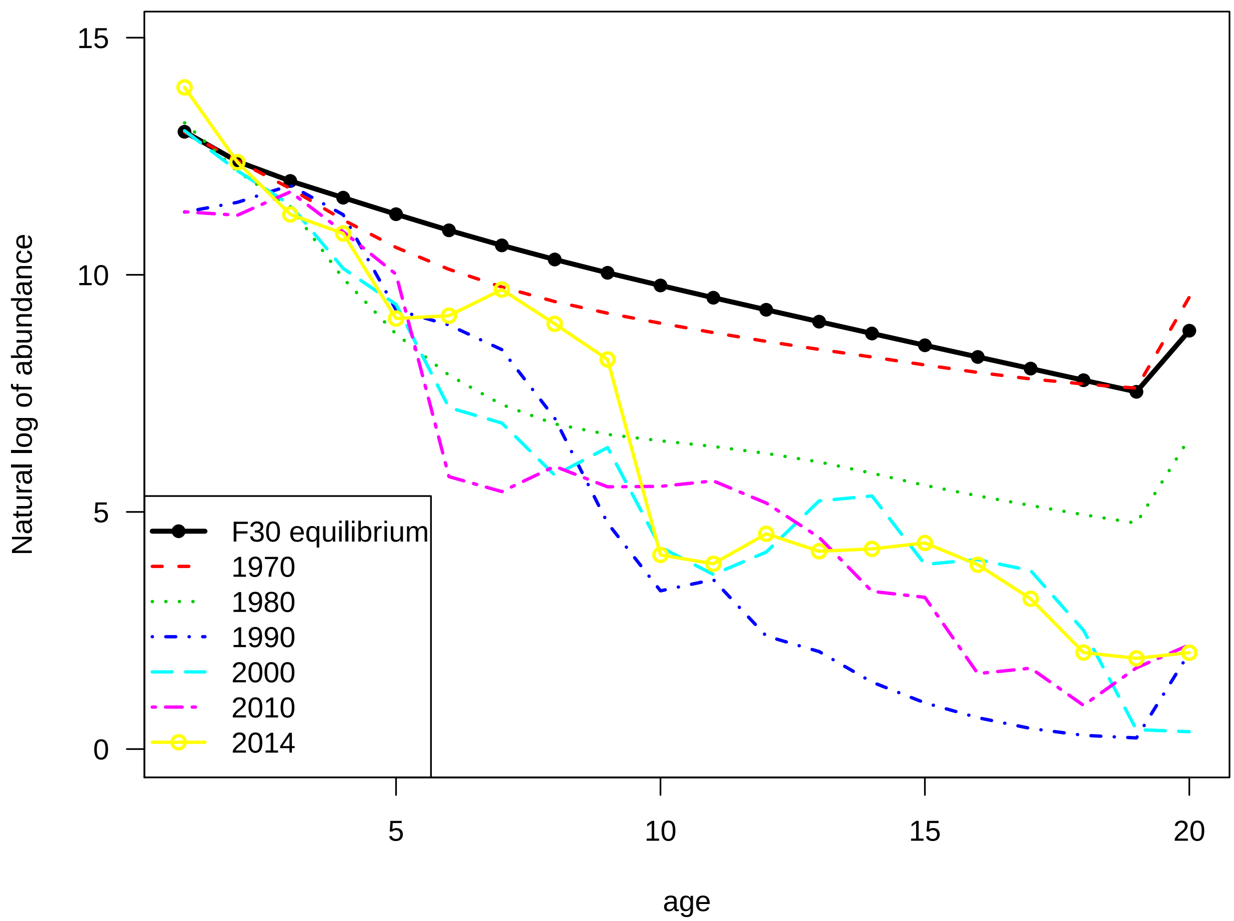


Figure 41. Sensitivity to changes in natural mortality (sensitivity runs S5 and S6). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

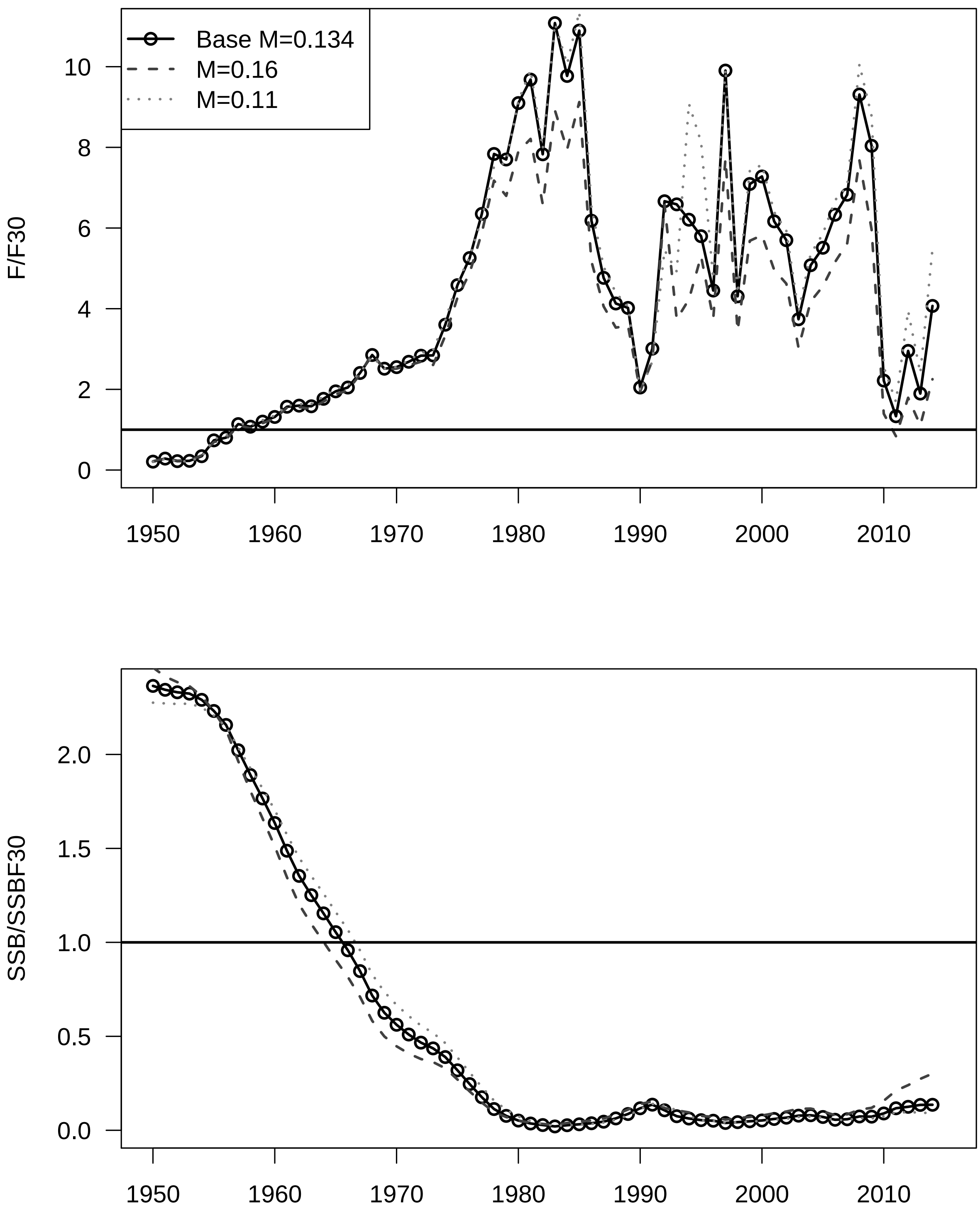


Figure 42. Sensitivity to steepness (sensitivity run S11). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

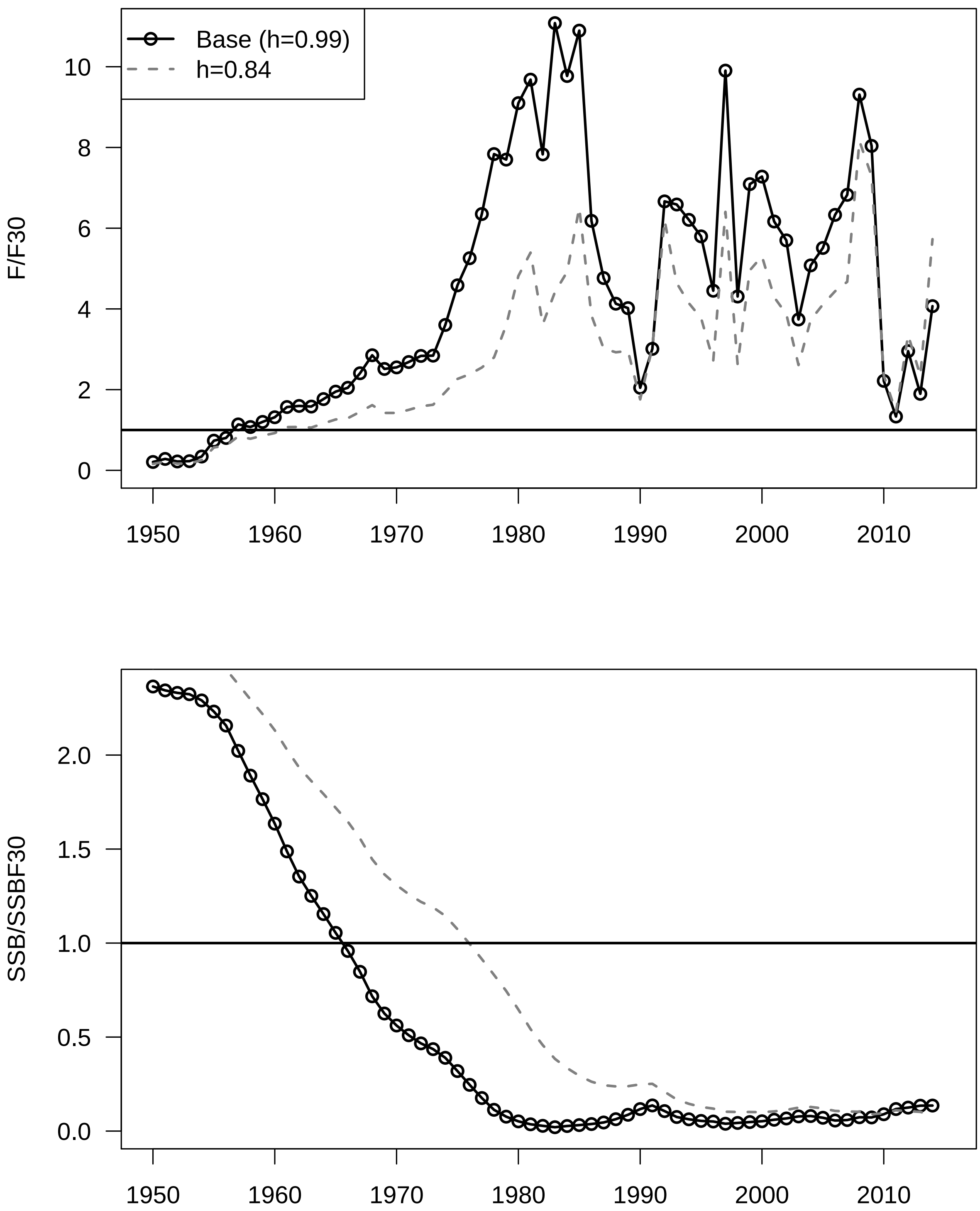


Figure 43. Sensitivity to start year (1978 compared to 1950) (sensitivity run S26). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

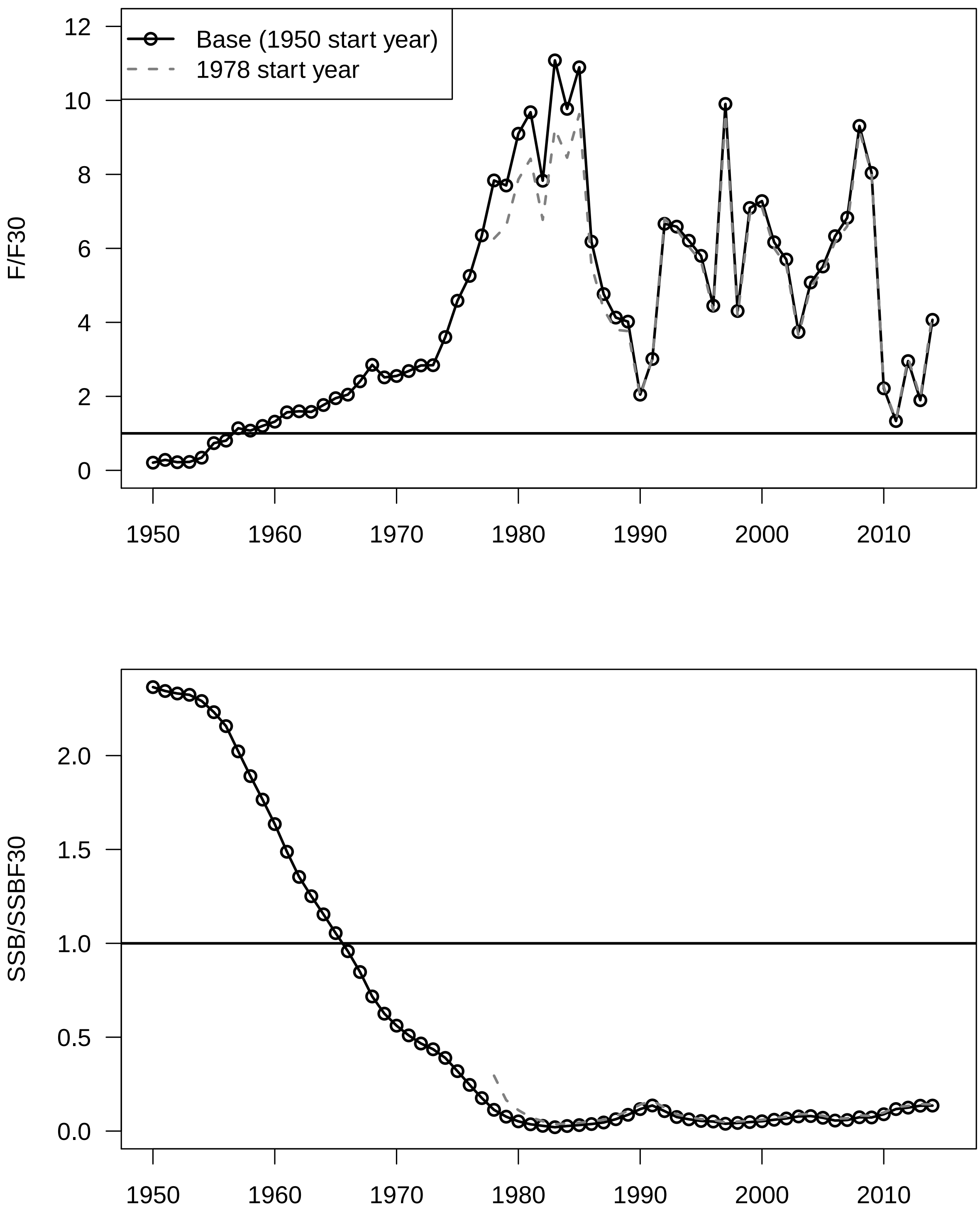


Figure 44. Sensitivity to aging error matrix (sensitivity run S13). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

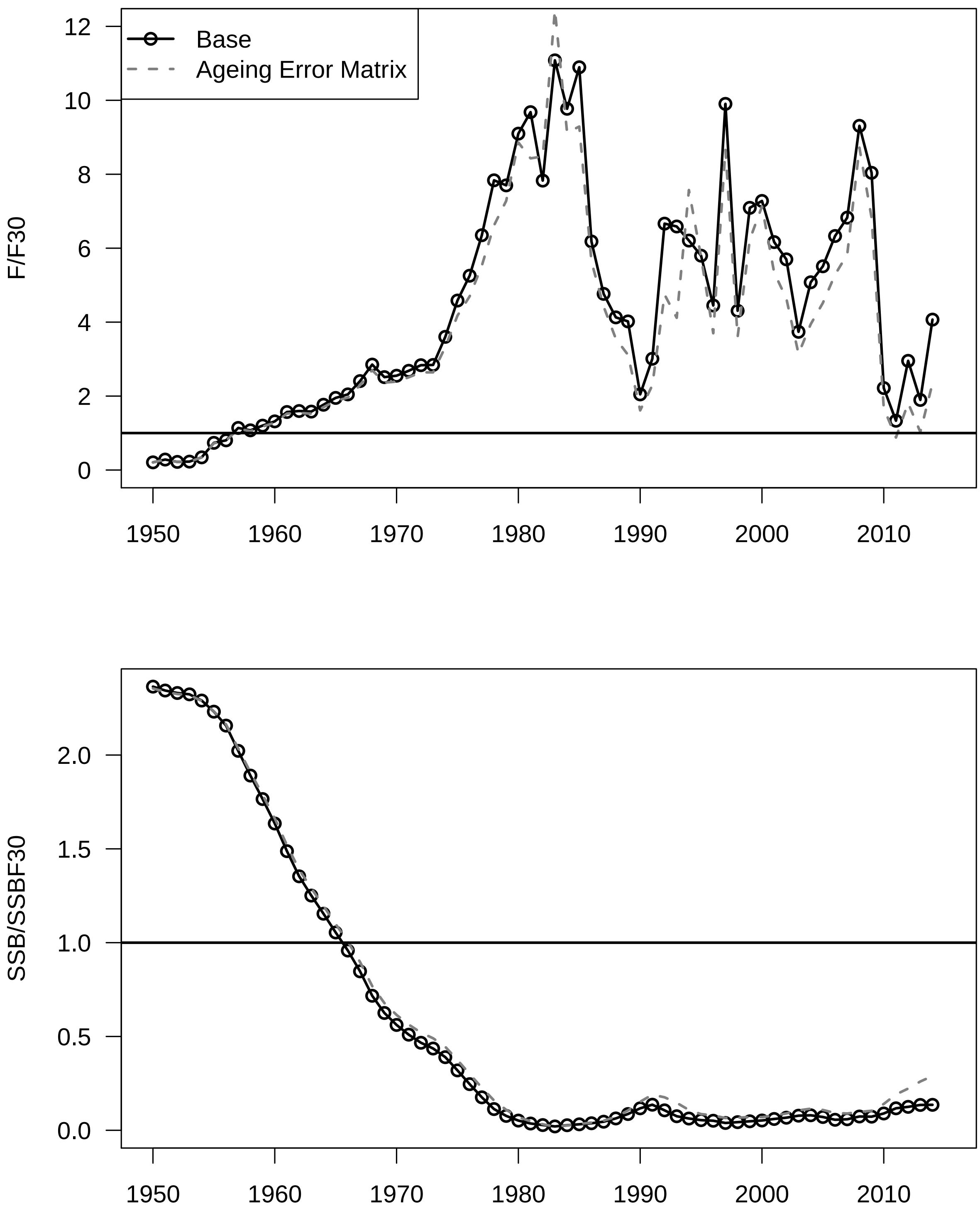


Figure 45. Sensitivity to batch number (sensitivity runs S14 and S15). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

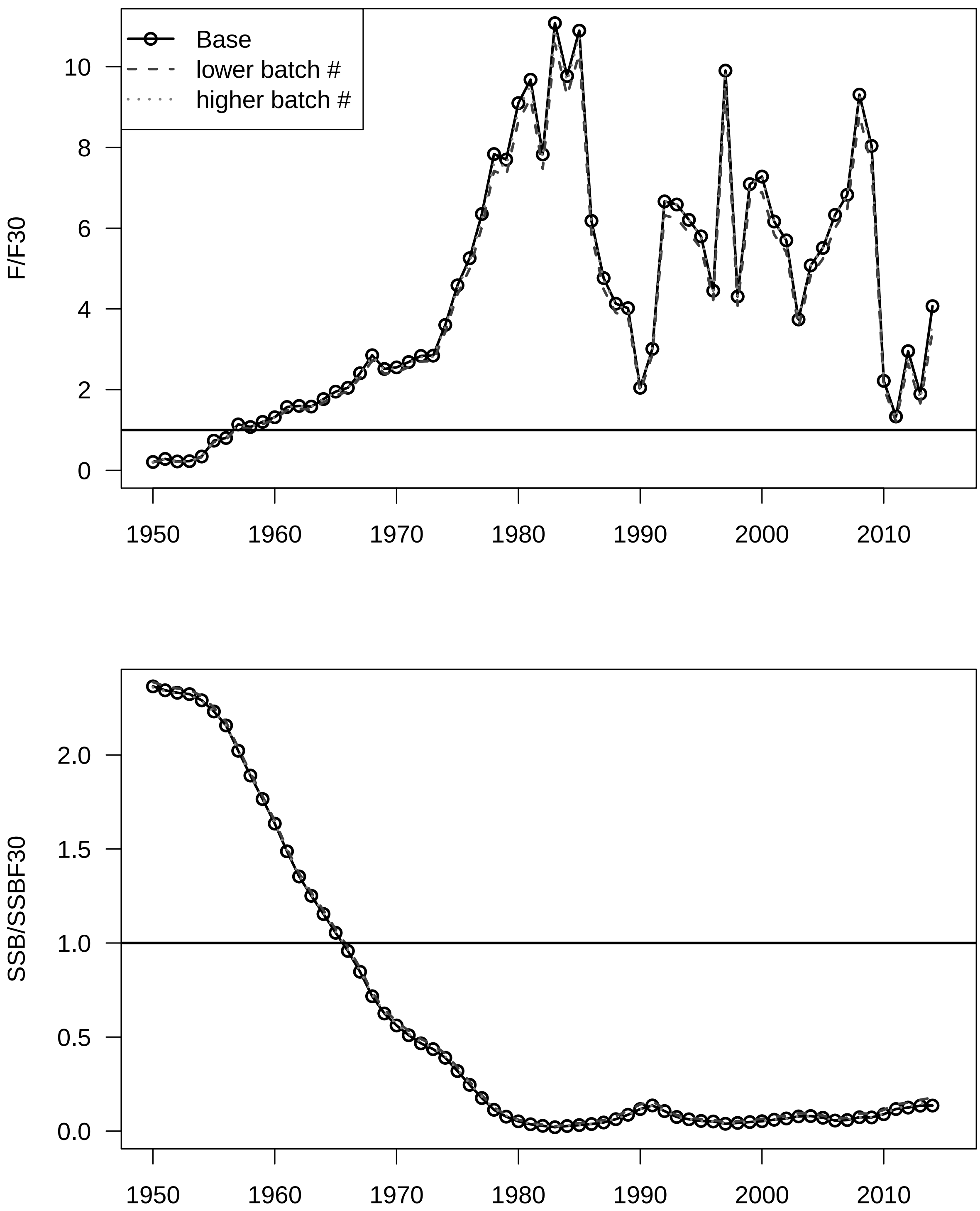
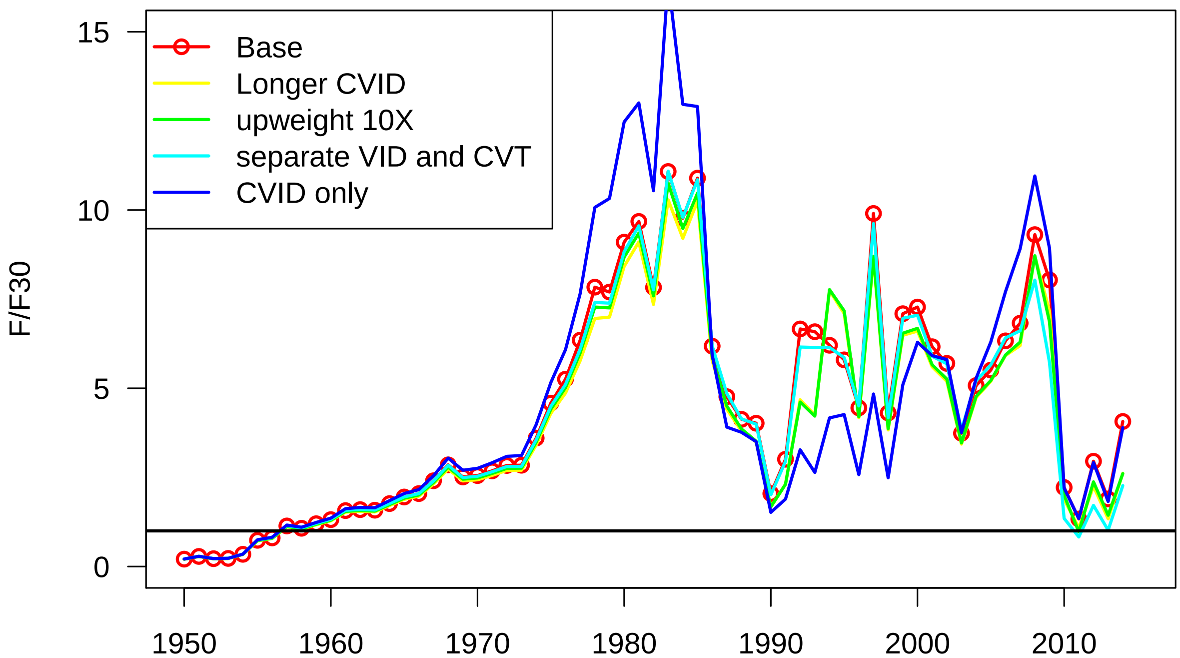


Figure 46. Sensitivity to various changes to SERFS video and trap indices (sensitivity runs S2, S9, S22 and S23). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.



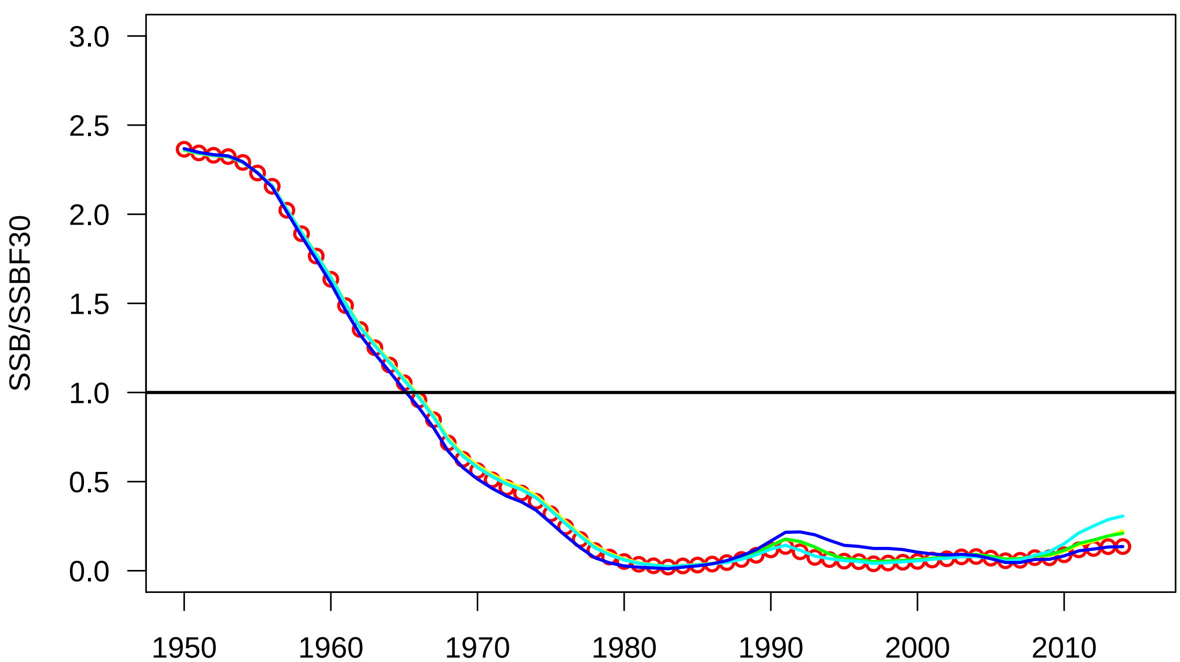


Figure 47. Sensitivity to discard mortality (sensitivity run S7 and S8). Top panel: Ratio of F to $F_{30\%}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

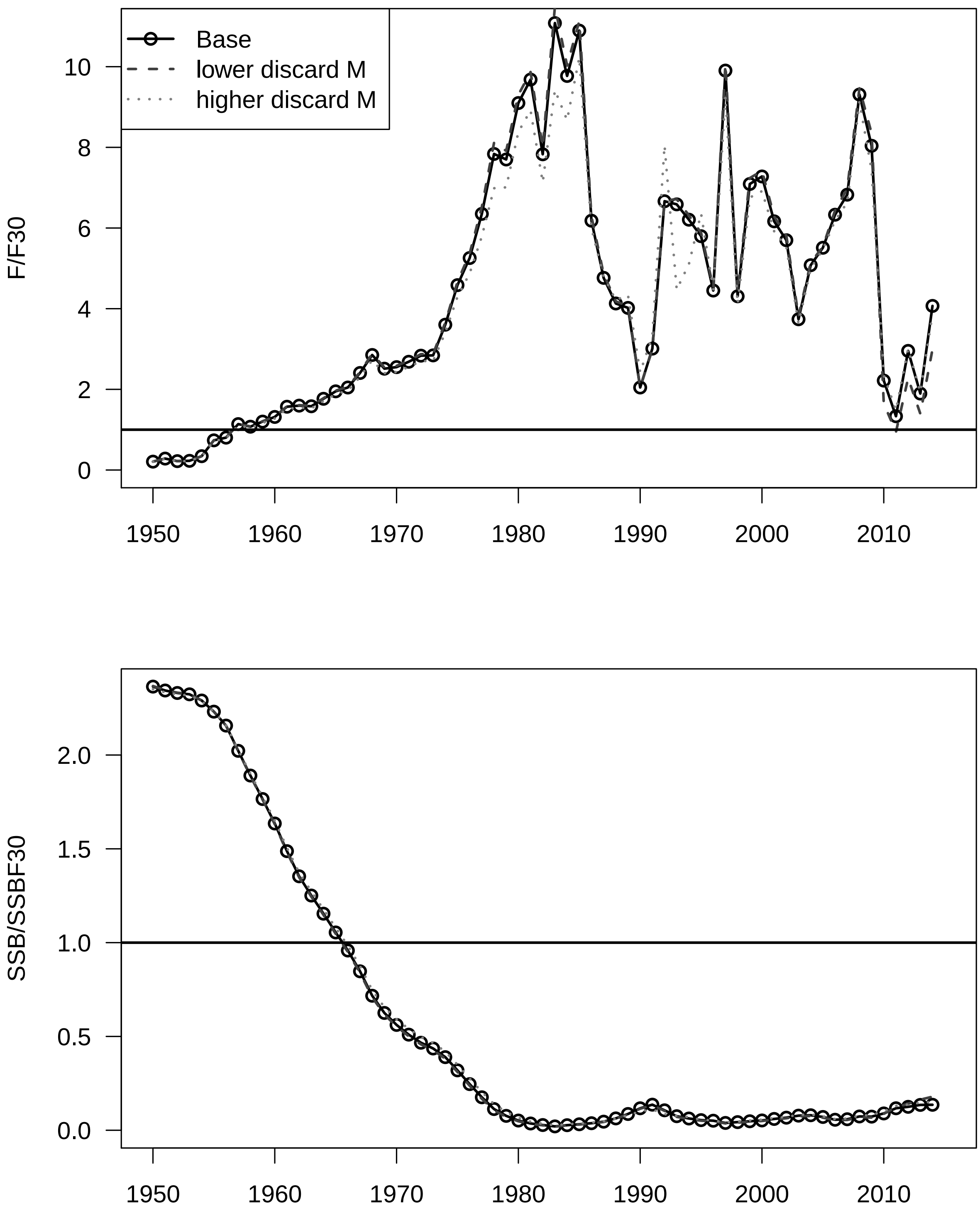
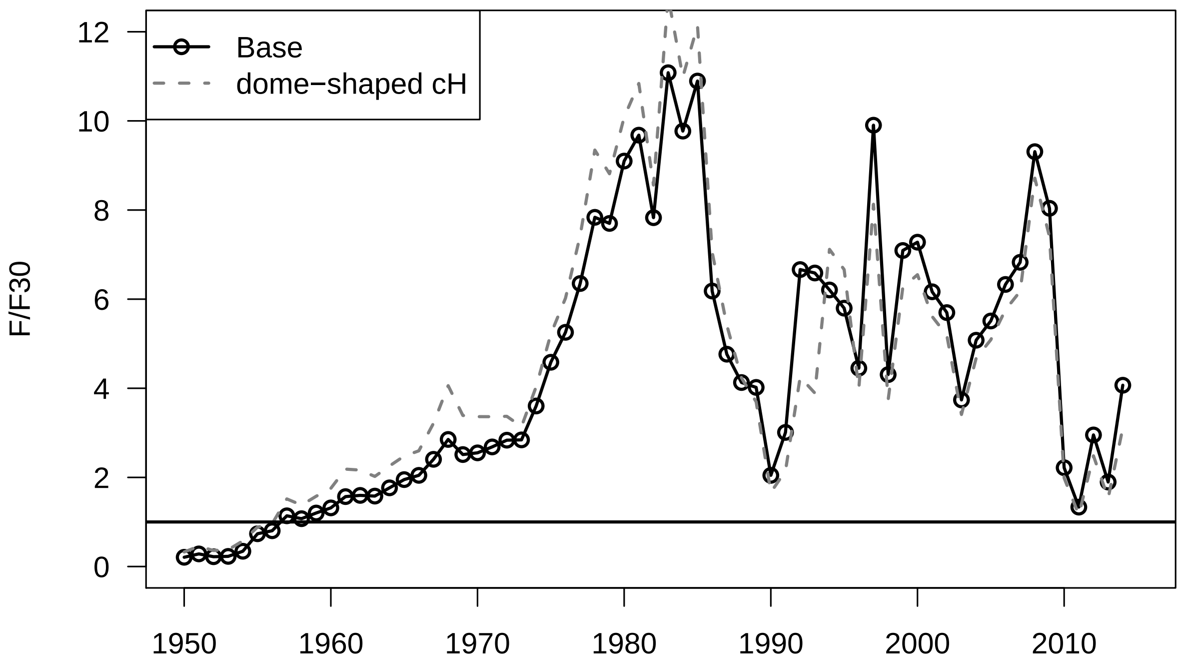


Figure 48. Sensitivity to dome-shaped selectivity for commercial handline (sensitivity run S21). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.



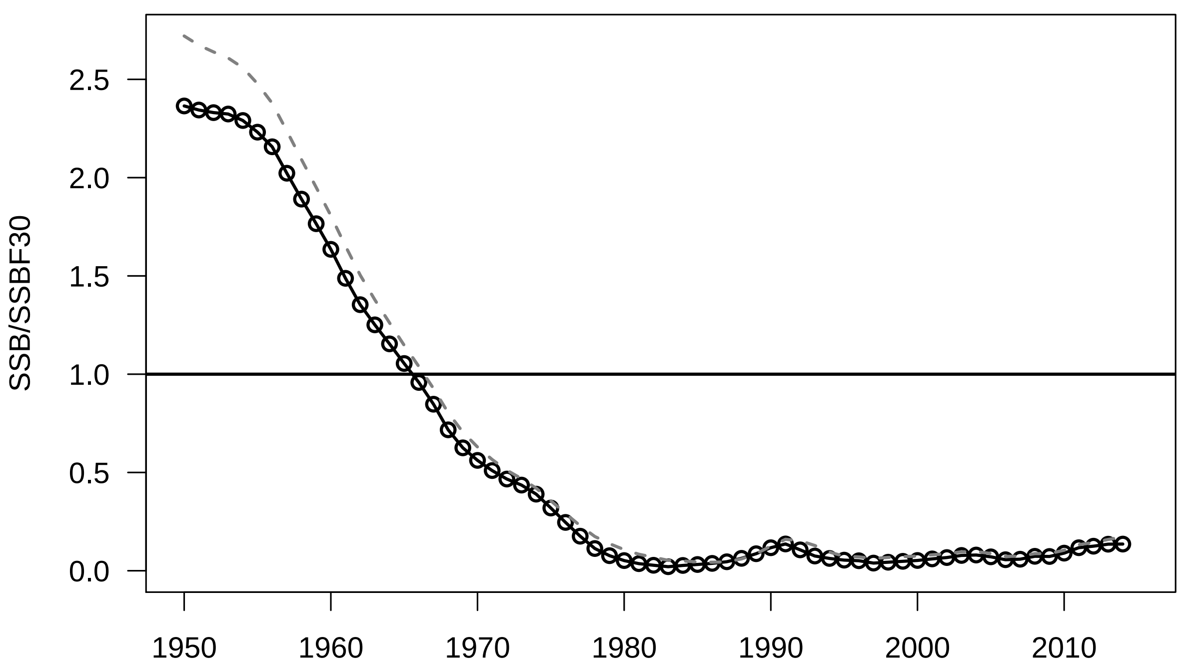


Figure 49. Sensitivity to various changes to fishery dependent indices (sensitivity runs S1, S3, S4, and S25). Top panel: Ratio of F *to* $F_{30\%}$. *Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

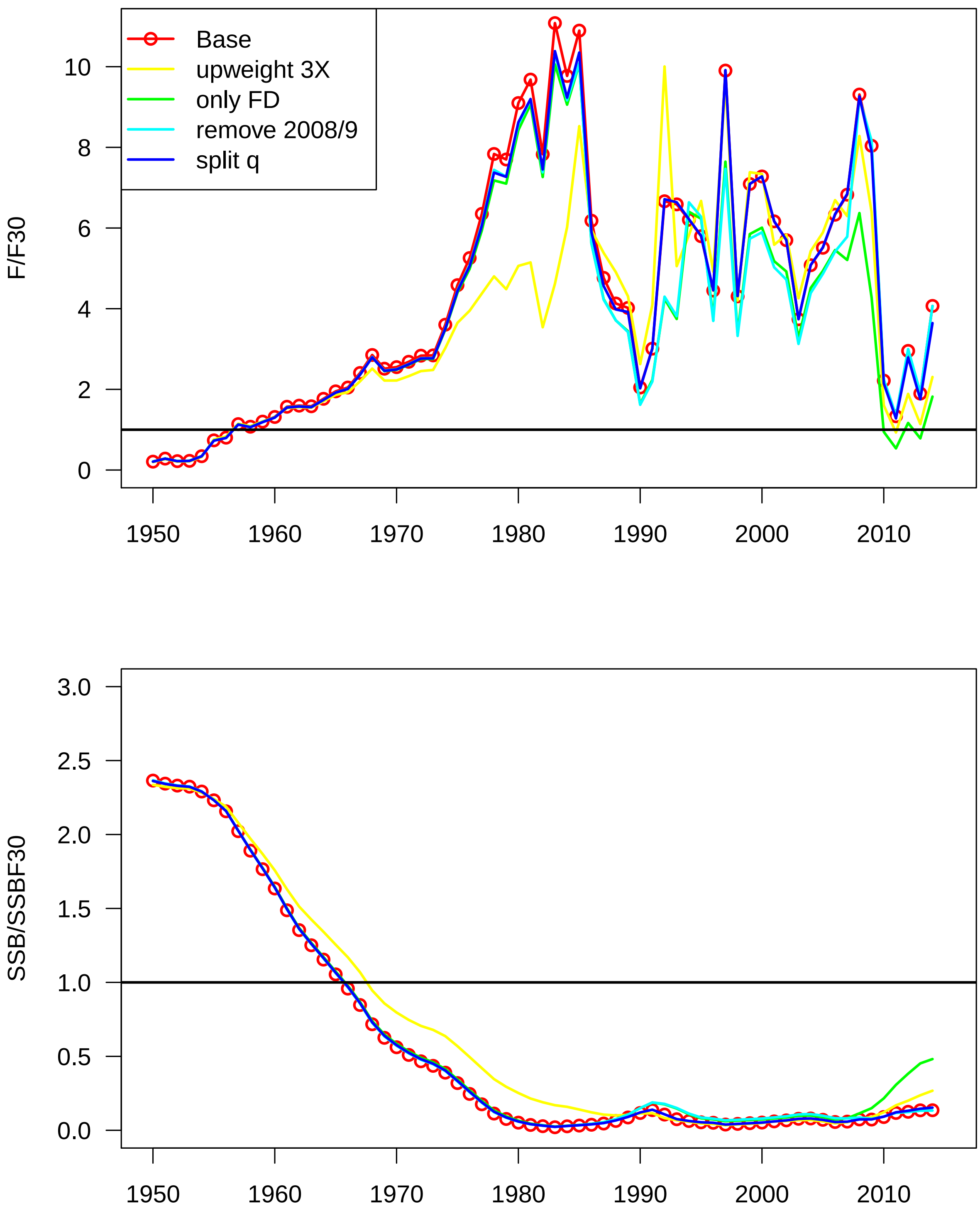
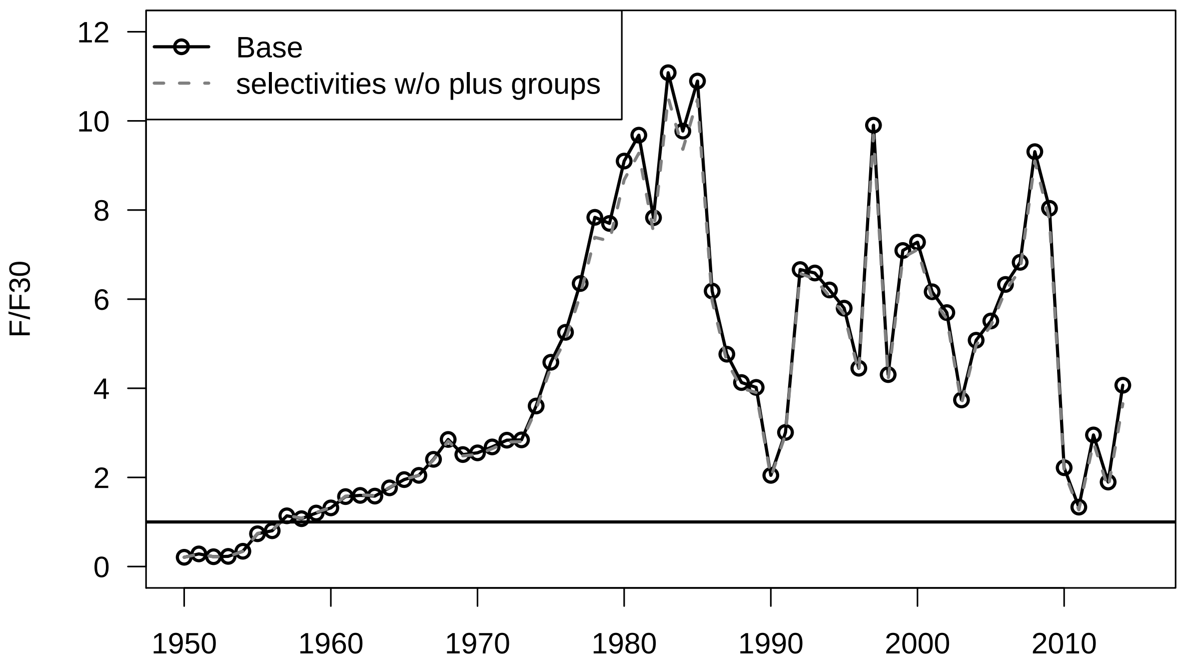


Figure 50. Sensitivity to not fixing selectivities (sensitivity run S27). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.



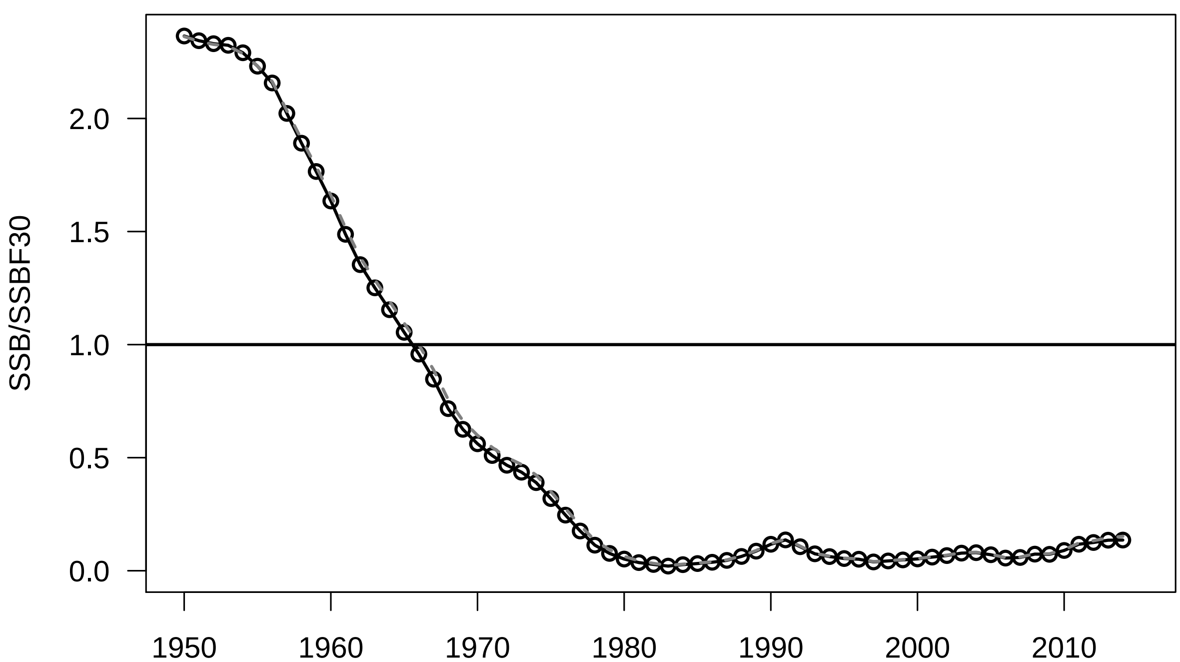
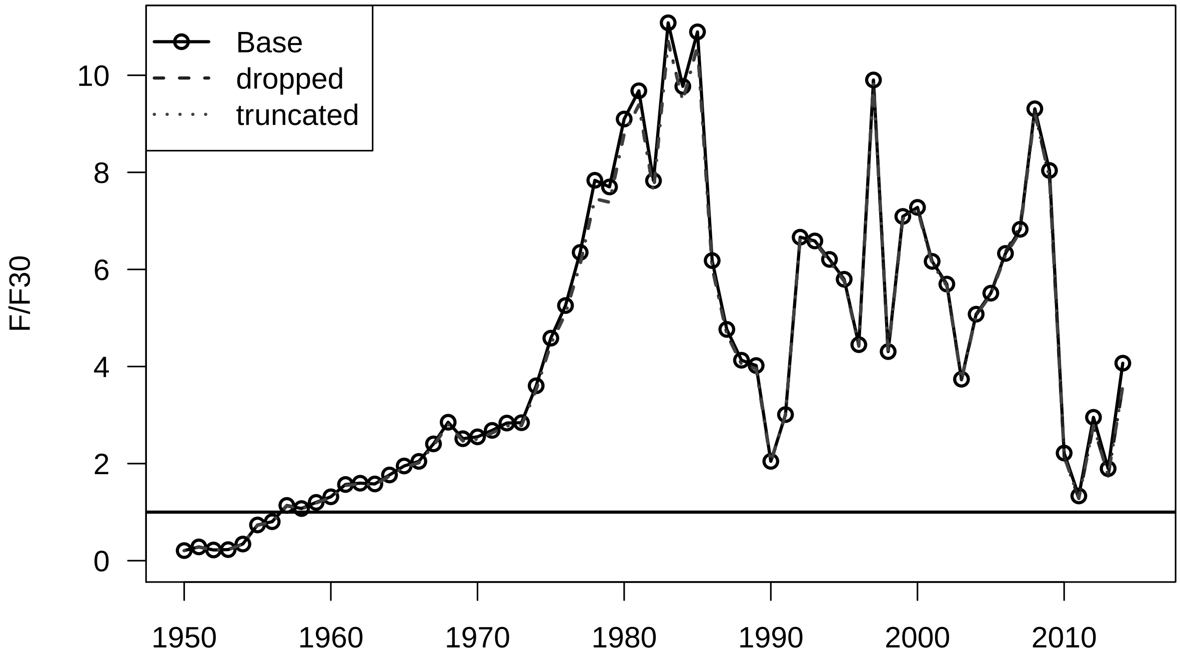


Figure 51. Sensitivity to dropping or truncating headboat discard index (sensitivity runs S12 and S16). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.



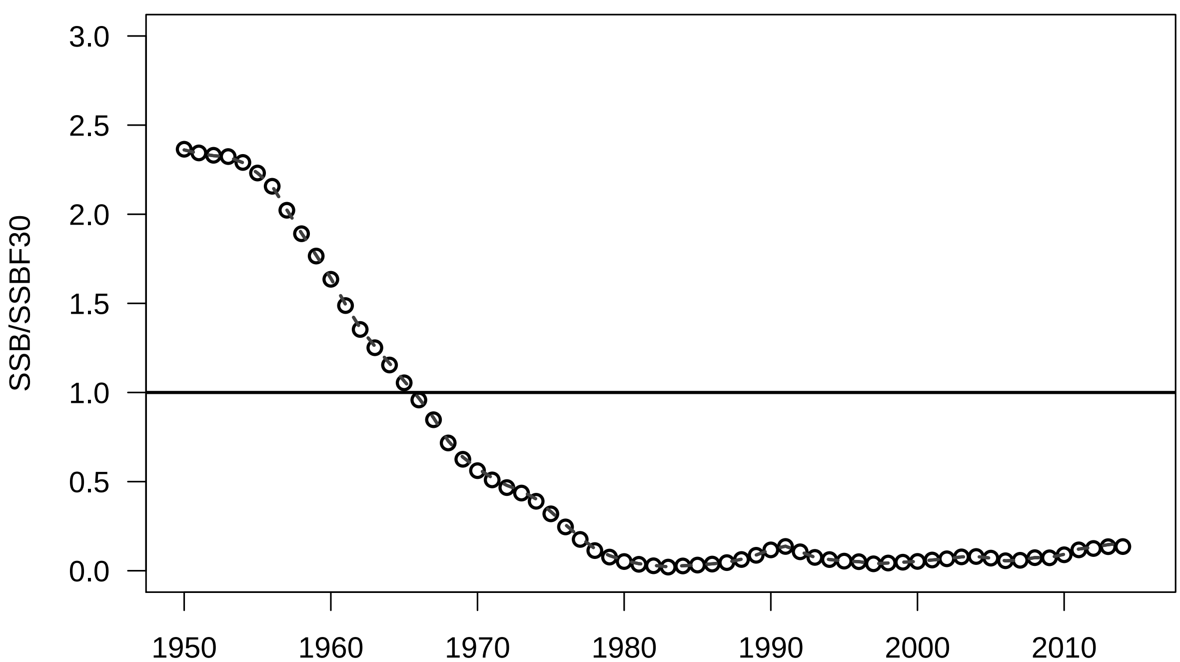


Figure 52. Sensitivity to higher or lower estimates of landings and discards (sensitivity runs S17–S20). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\text{SSB}_{\text{F30\%}}$.

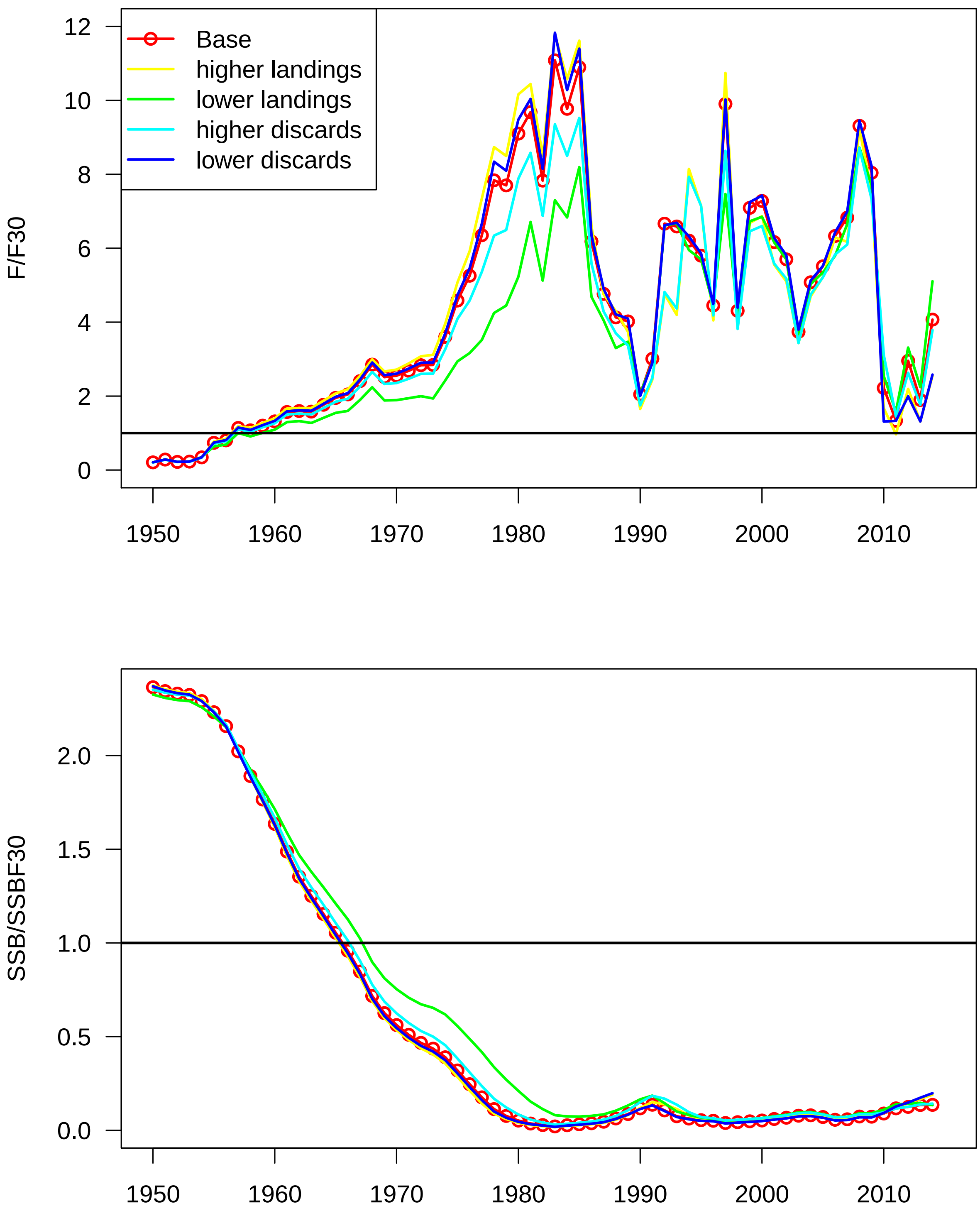


Figure 53. Sensitivity to smoothed 1984 and 1985 MRIP landings (sensitivity run S10). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

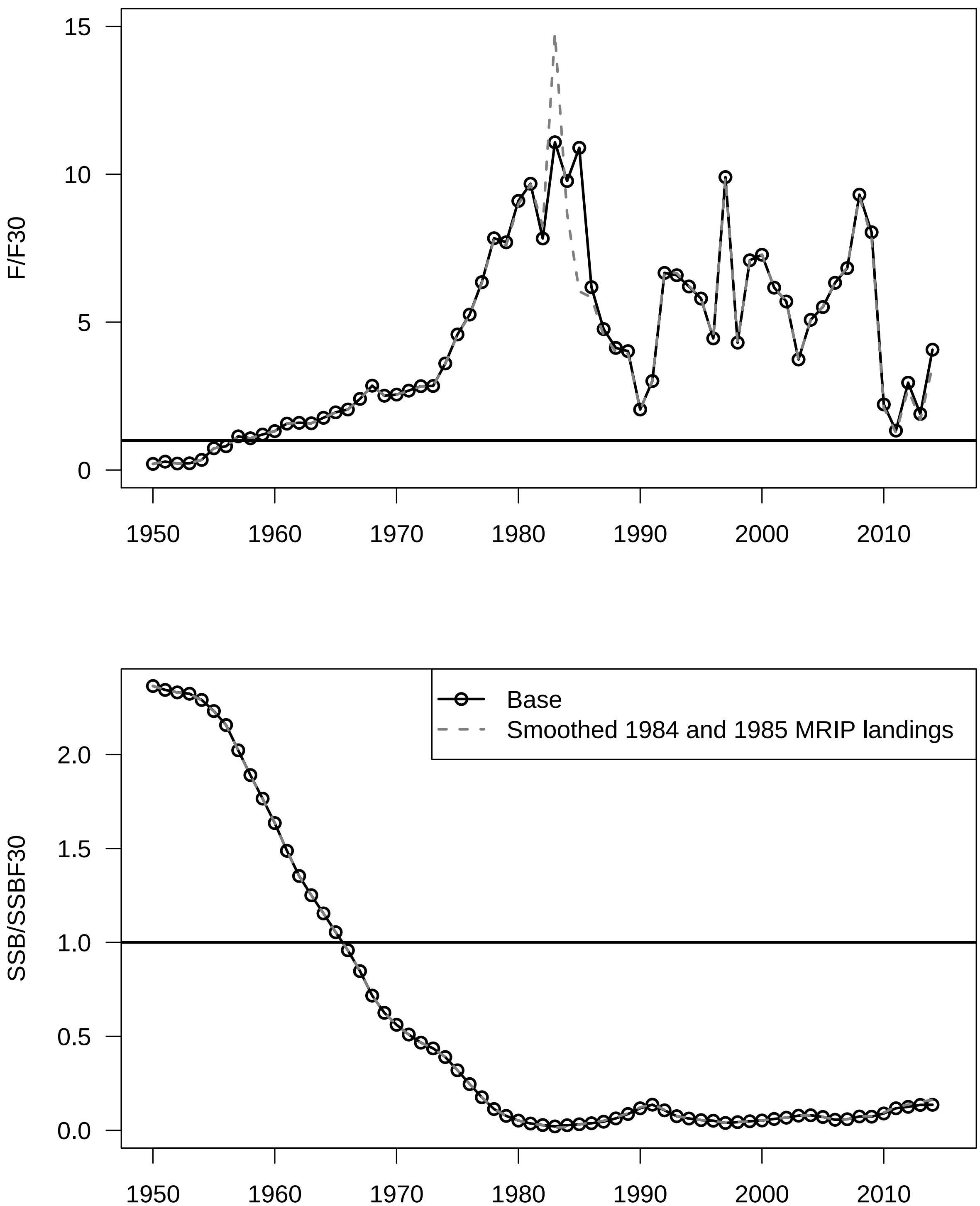


Figure 54. Sensitivity to continuity assumptions from SEDAR 24 (sensitivity run S24). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

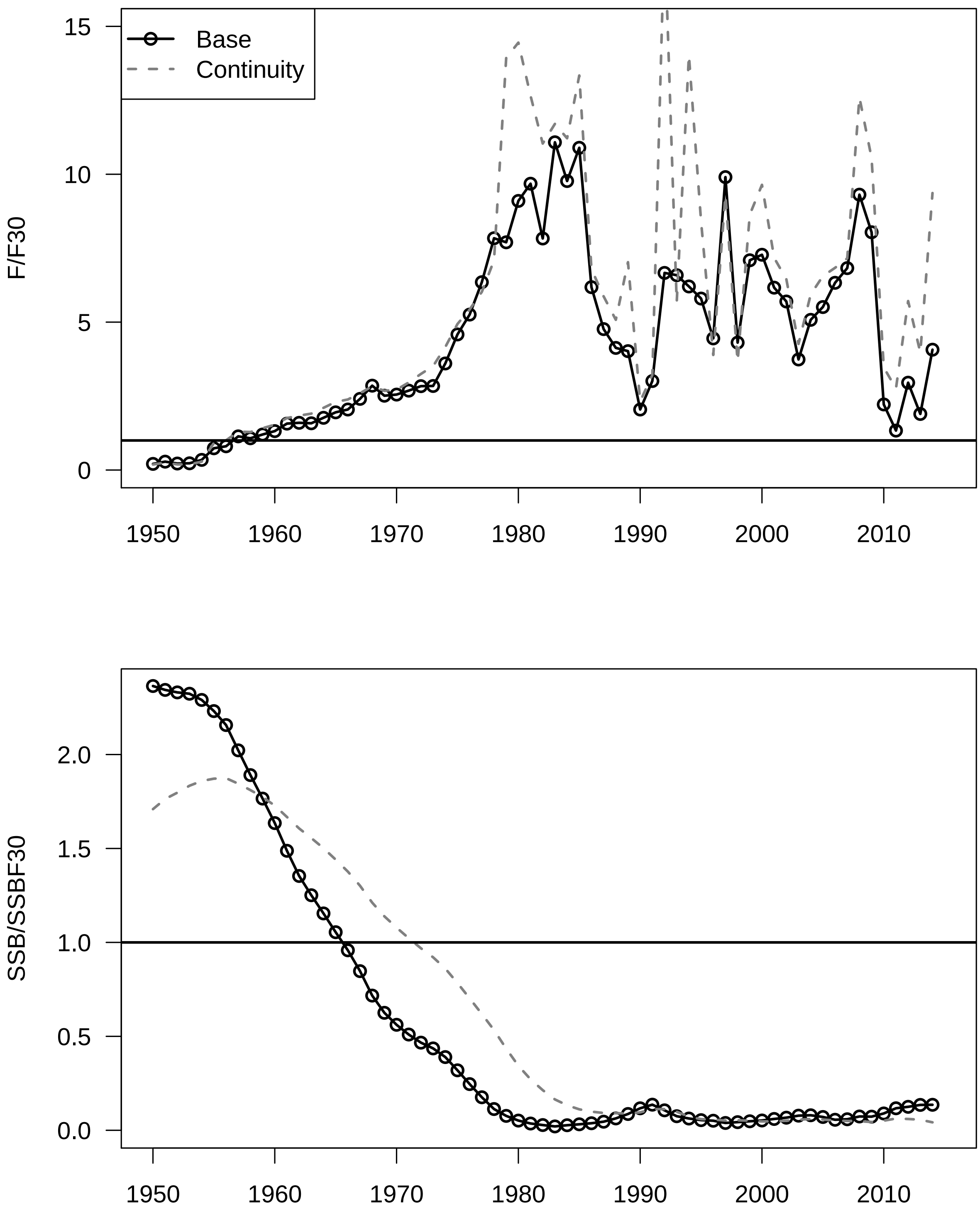


Figure 55. Phase plot of terminal status indicators from sensitivity runs of the Beaufort Assessment Model.

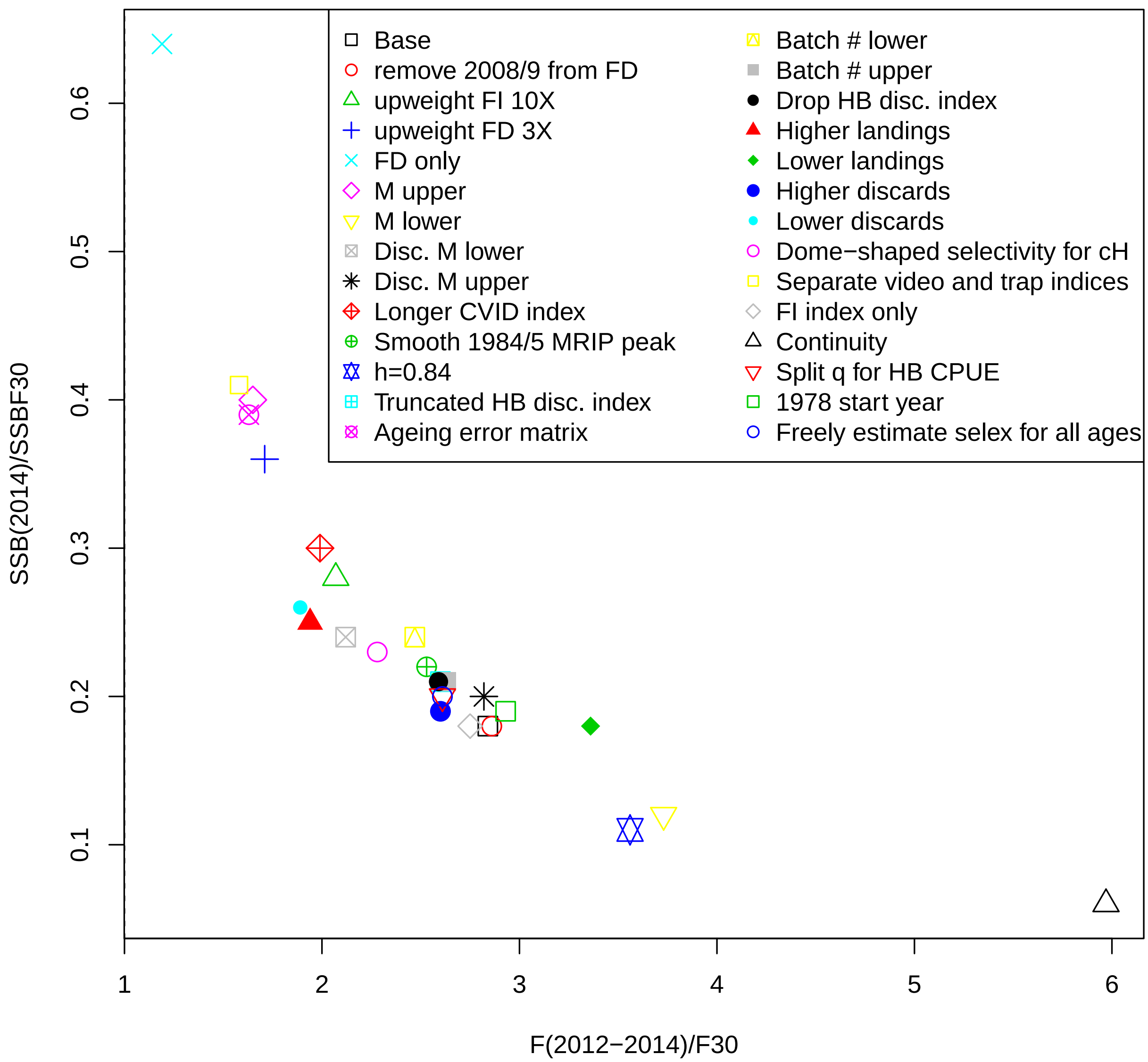


Figure 56. Retrospective analyses. Sensitivity to terminal year of data. Top panel: Fishing mortality rates. Middle panel: Recruits. Bottom panel: Spawning biomass. Closed circles show terminal-year estimates. Imperceptible lines overlap results of the base run.

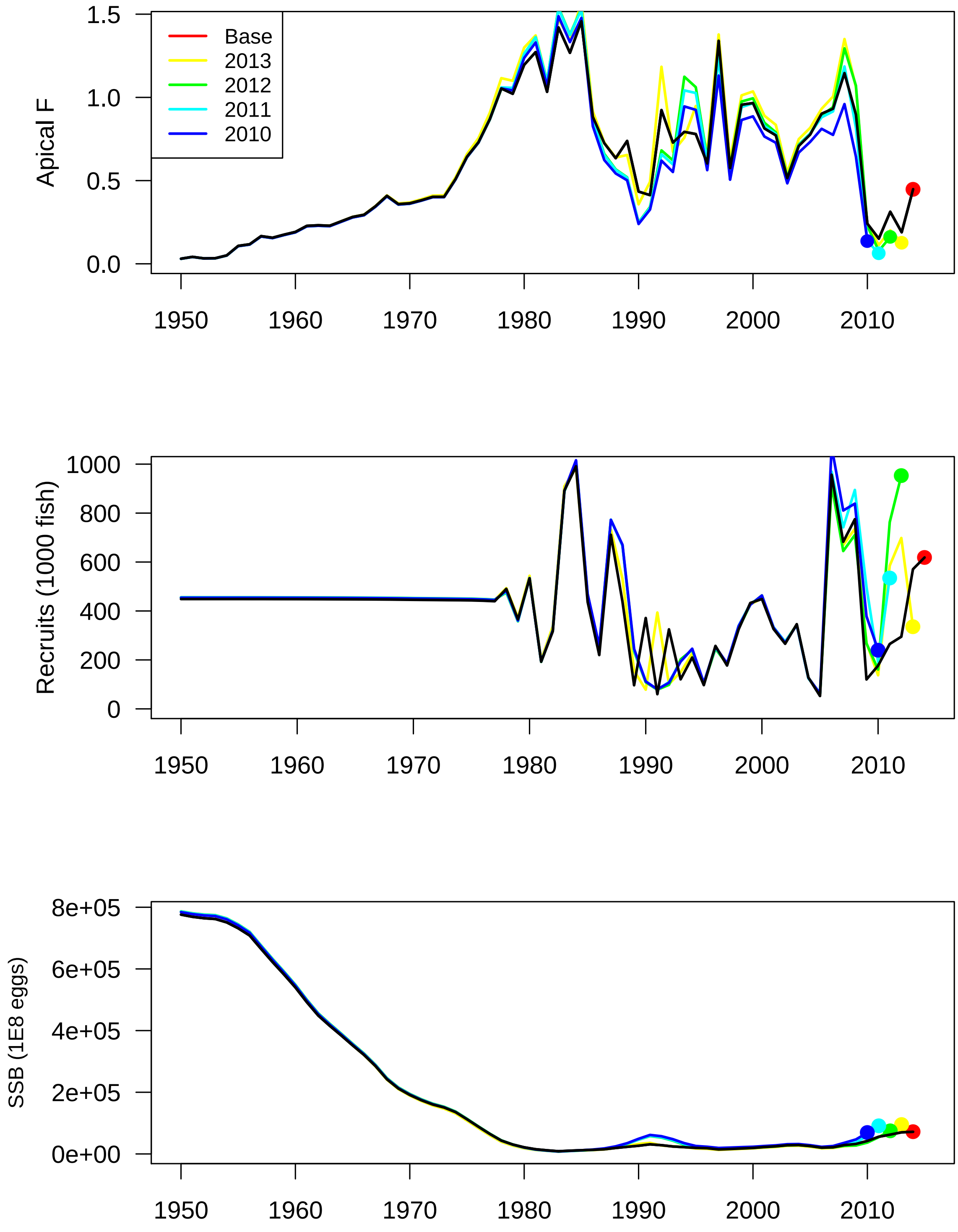


Figure 57. Projection results under scenario 1—fishing mortality rate at $F = 0$. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB_{F30\%}}$.

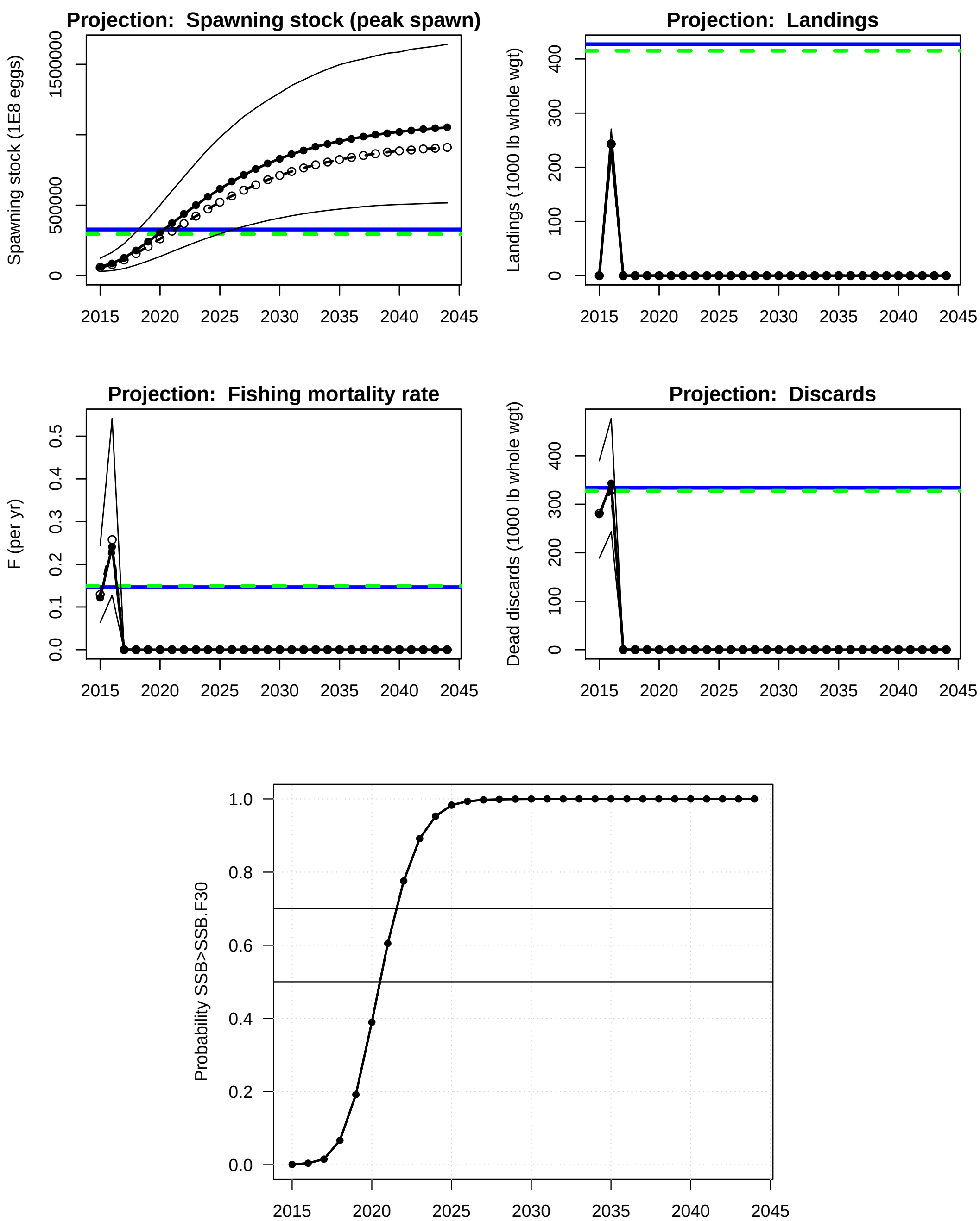


Figure 58. Projection results under scenario 2—fishing mortality rate at $F = F_{\mathrm{current}}$. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{F30\%}}$.

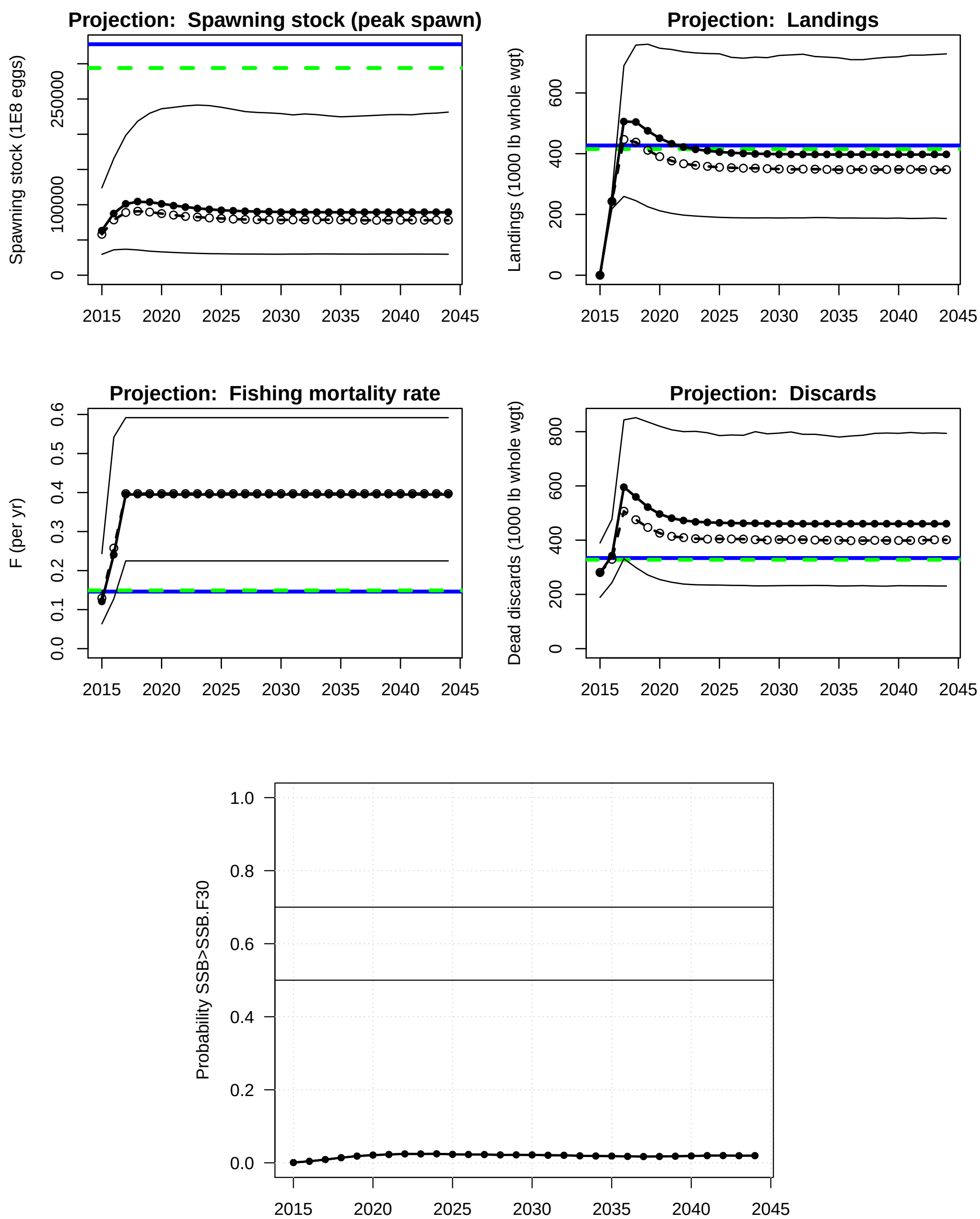


Figure 59. Projection results under scenario 3—fishing mortality rate at $F = F_{30\%}$. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{F30\%}}$.

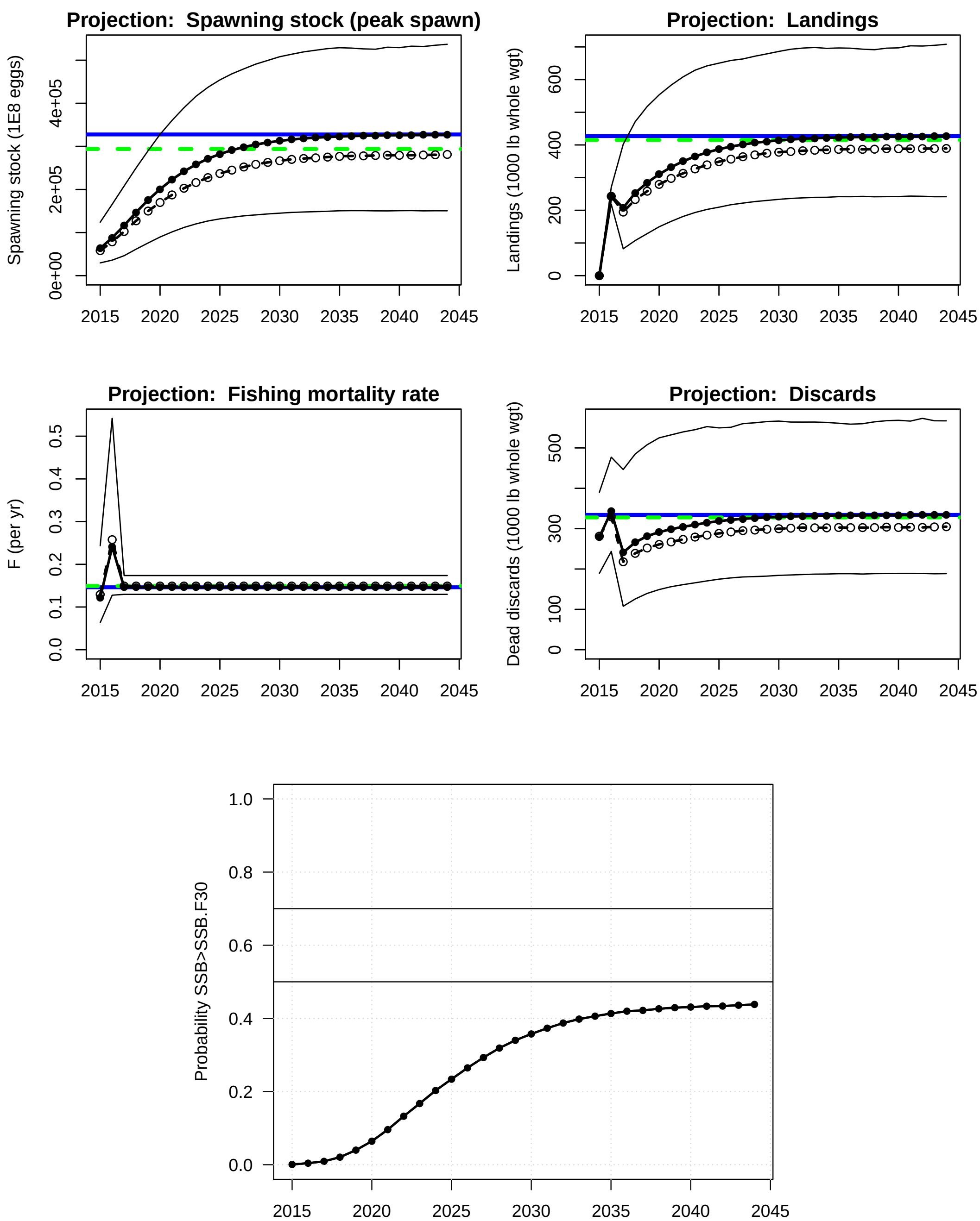


Figure 60. Projection results under scenario 4—fishing mortality rate at $F = 98\% F_{30\%}$. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{F30\%}}$.

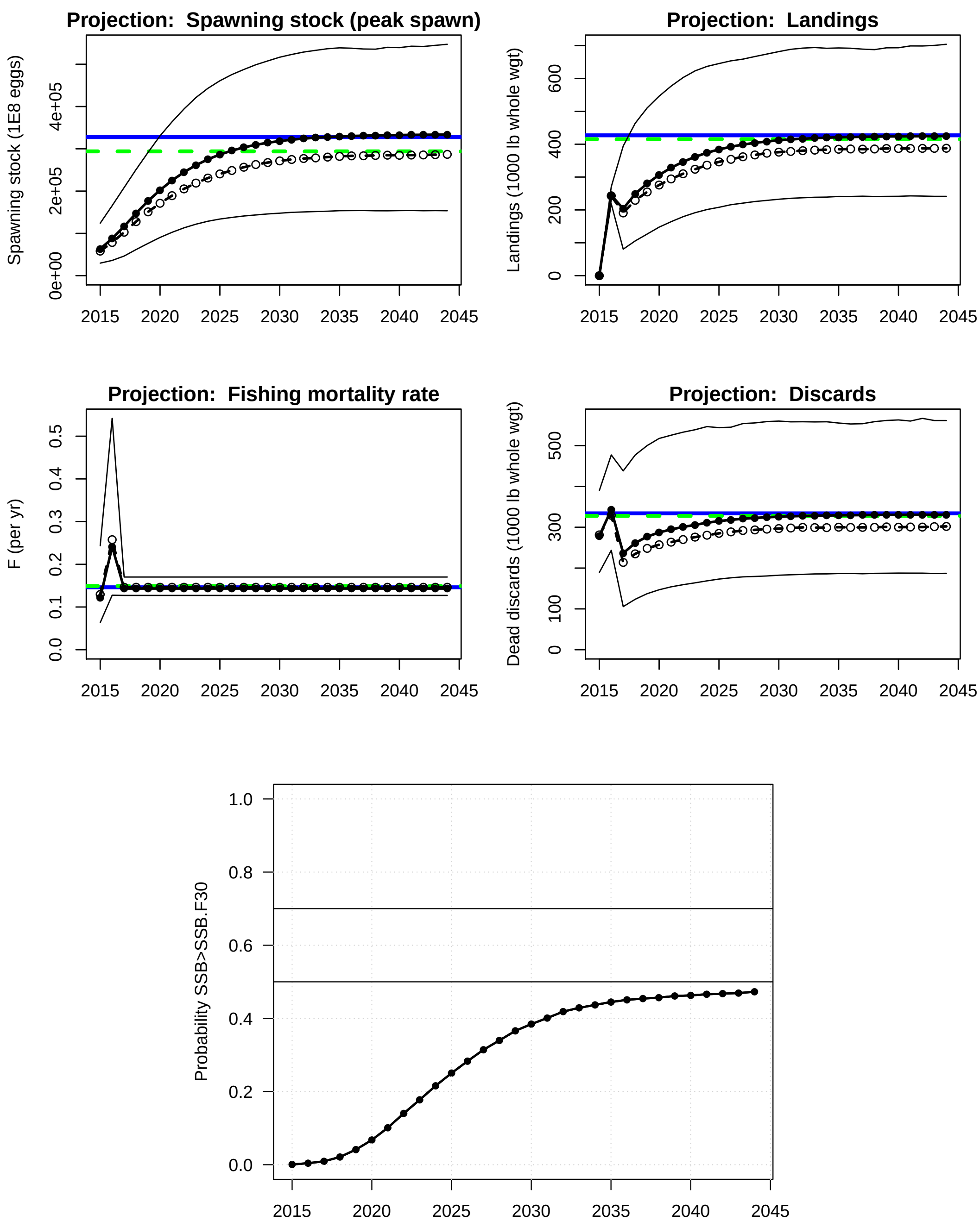


Figure 61. Projection results under scenario 5—fishing mortality rate at $F = F_{\mathrm{rebuild}}$, with rebuilding probability of 0.5 in 2044. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{F30\%}}$.

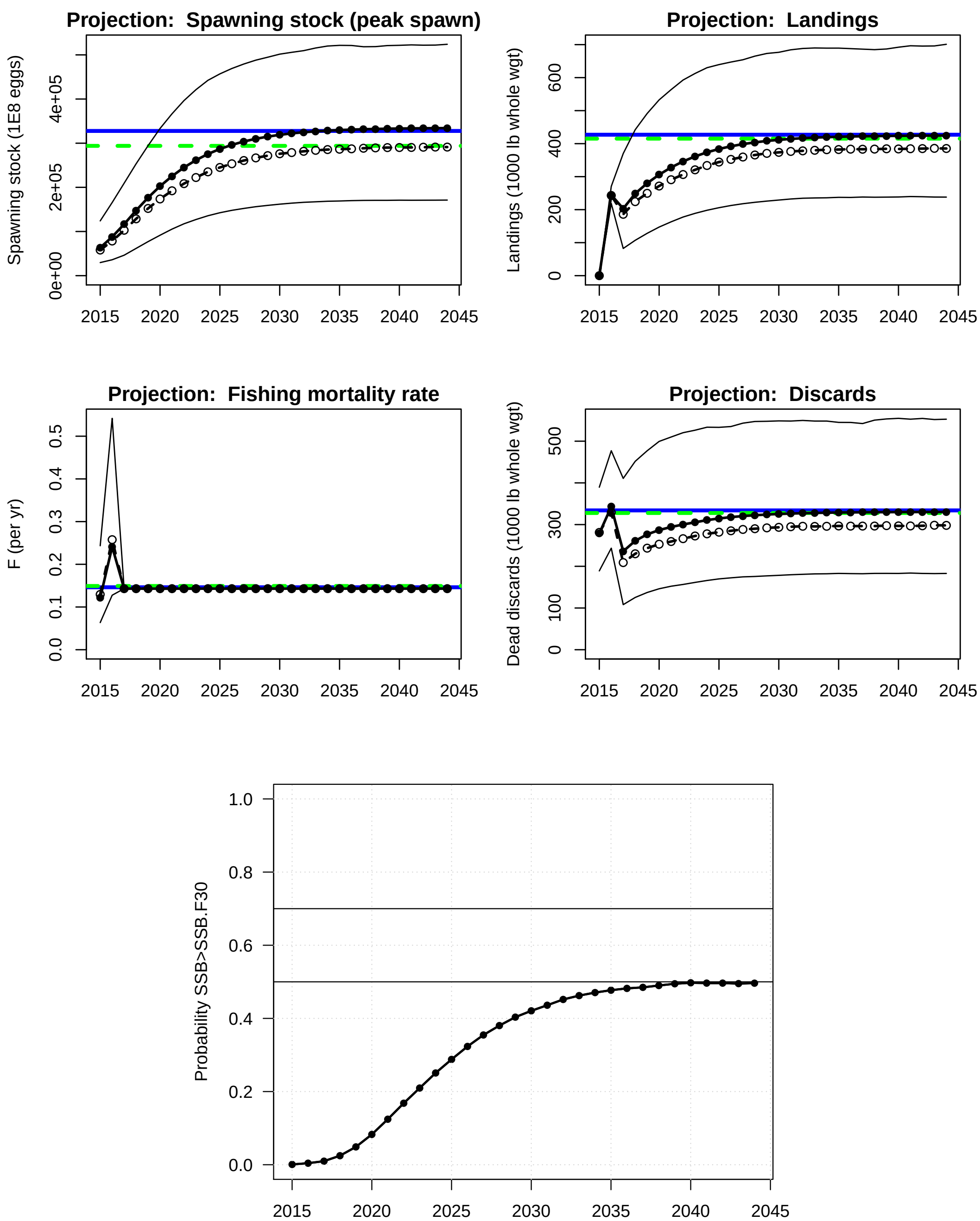


Figure 62. Projection results under scenario 6—fishing mortality rate set to average discard mortality rate only. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} *and* 95^{th} *percentiles of replicate projections. Solid horizontal lines mark* $F_{30\%}$*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{F30\%}}$.

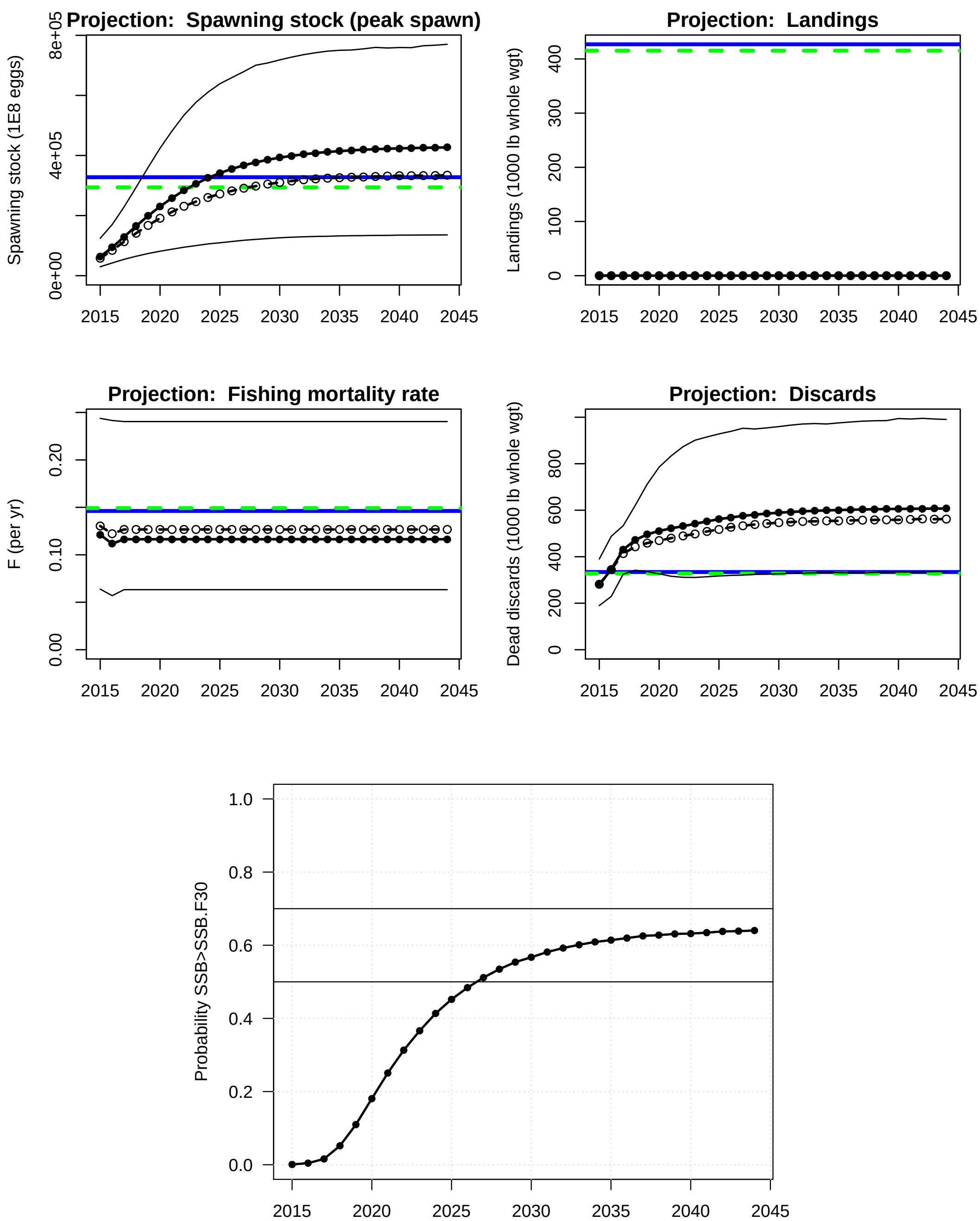


Figure 63. Abundance indices observed (obs.) and predicted (pred.) by the ASPIC surplus production model, and observed total removals (100,000 lbs) for South Atlantic red snapper. Comm = commercial, HB = headboat, HB.at.sea = headboat at sea discards, CVID = combined chevron trap-video index.

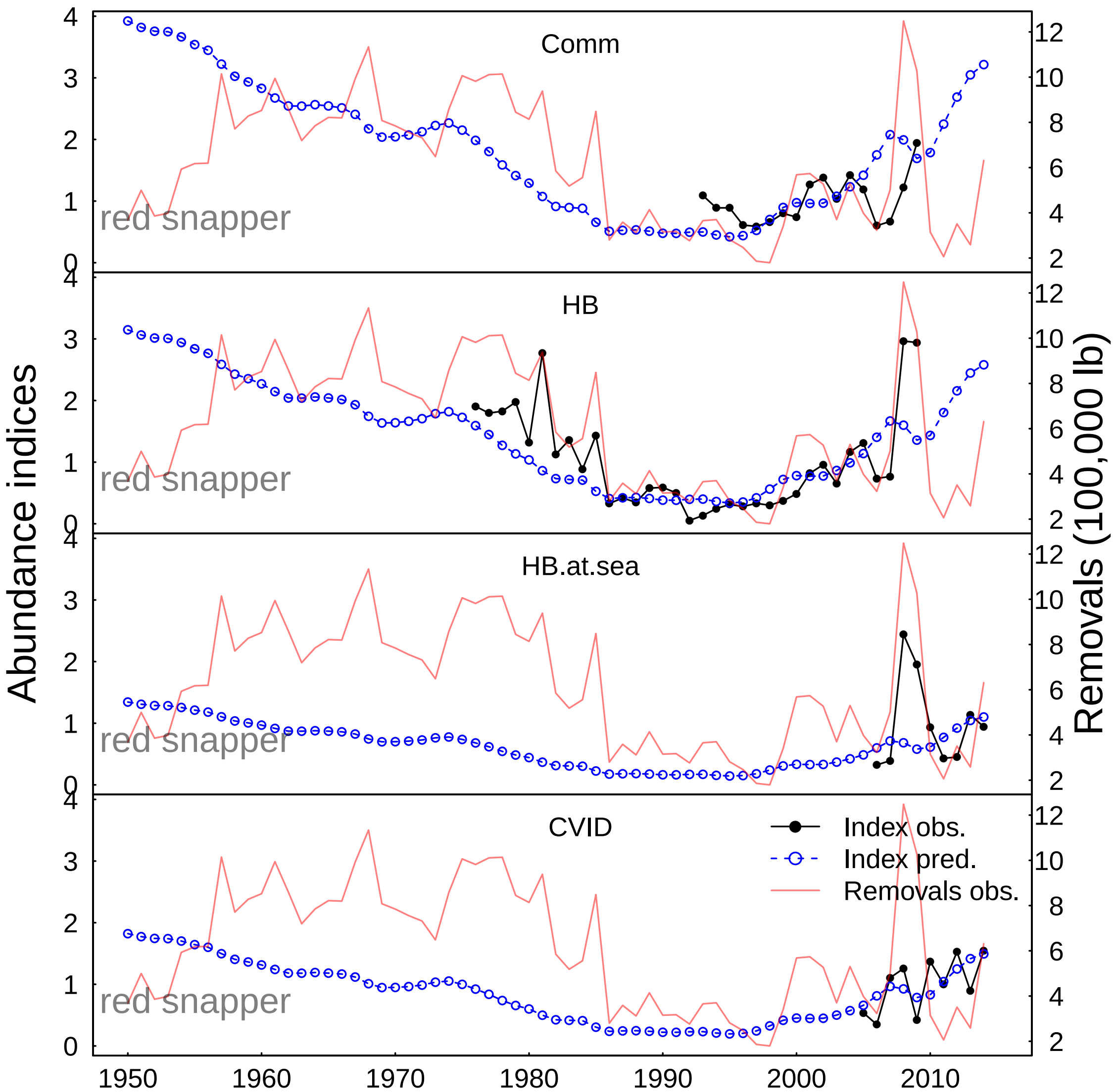


Figure 64. Prior distributions (blue shapes) and estimated parameter values (vertical black lines) for the South Atlantic red snapper ASPIC surplus production model.

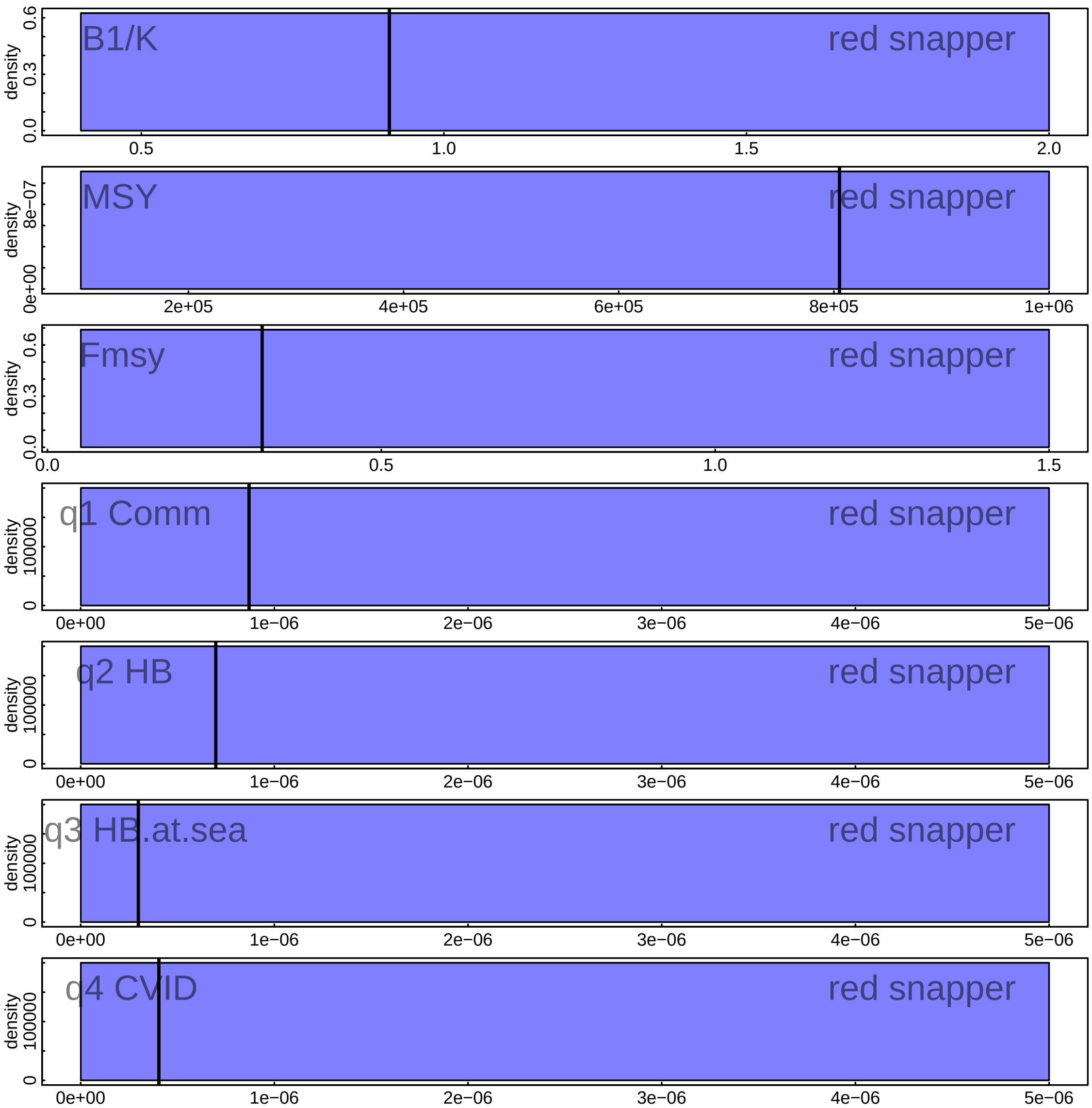


Figure 65. Bootstrap parameter values from ASPIC surplus production model run 320. Thick vertical lines represent ASPIC parameter estimates (solid) and 95% bootstrap percentile confidence intervals (dashed). Thin solid vertical lines are drawn at one in plots of F/F_{MSY} and B/B_{MSY} for reference.

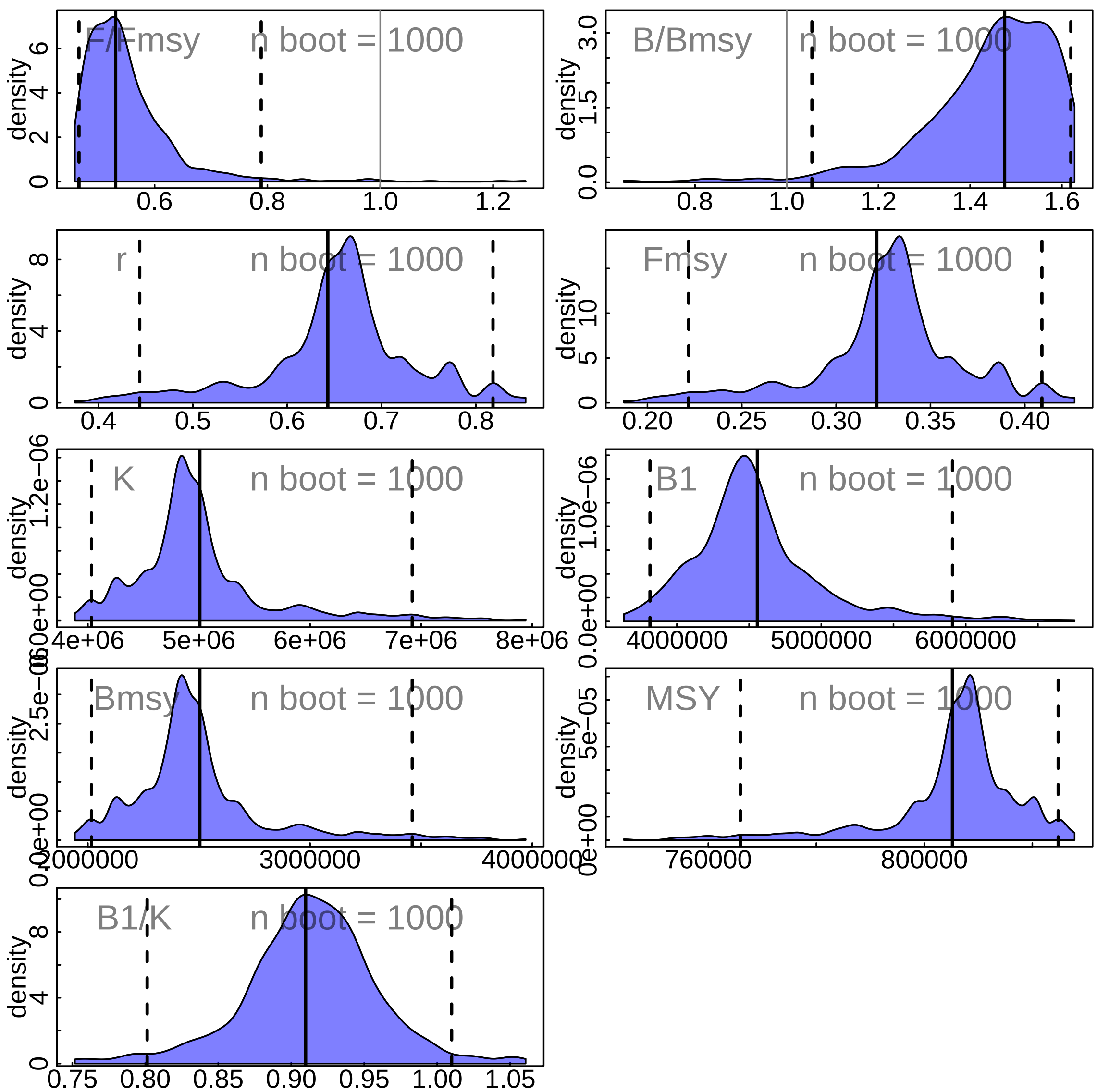
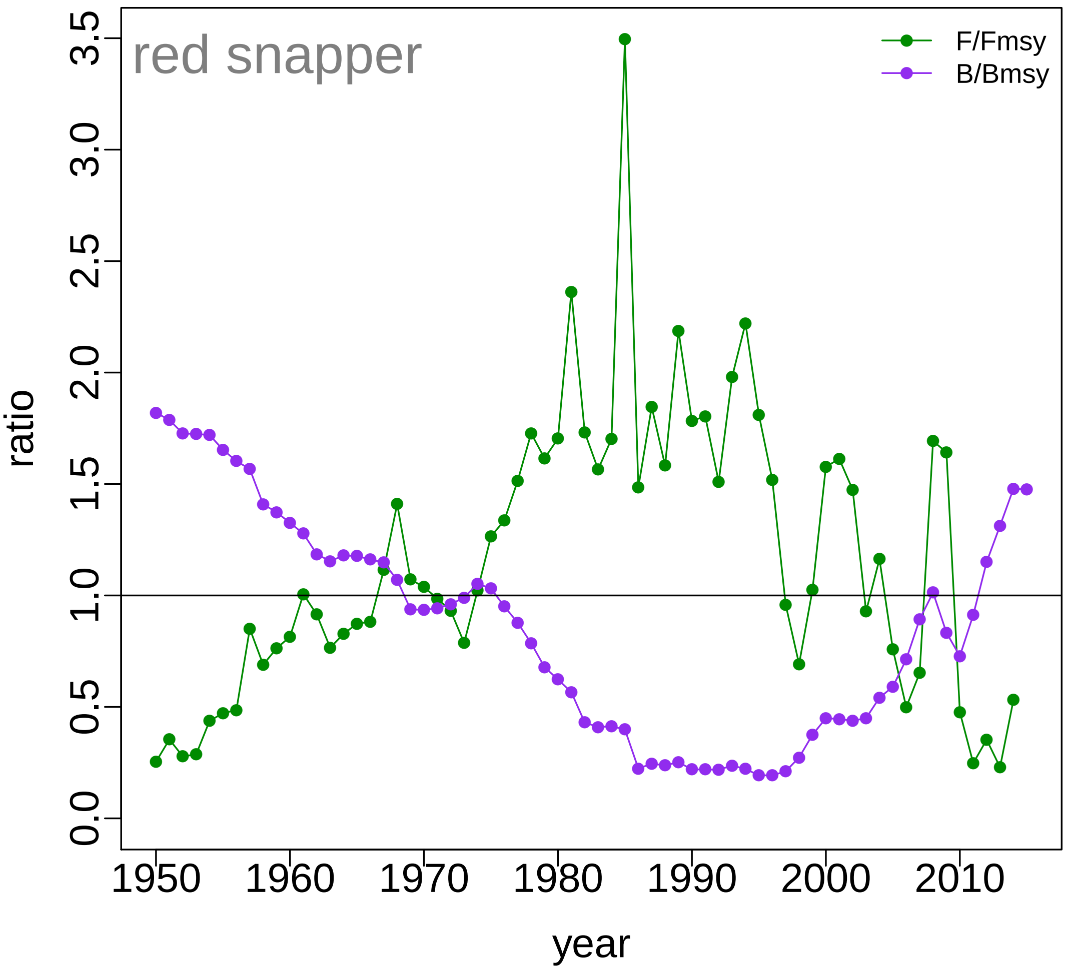


Figure 66. ASPIC surplus production model estimates of relative fishing rate (F/F_{MSY}) and biomass (B/B_{MSY}).



Appendix A Abbreviations and symbols

Table 33. Acronyms and abbreviations used in this report

Symbol	Meaning
ABC	Acceptable Biological Catch
AW	Assessment Workshop (here, for red snapper)
ASY	Average Sustainable Yield
B	Total biomass of stock, conventionally on January 1
BAM	Beaufort Assessment Model (a statistical catch-age formulation)
CPUE	Catch per unit effort; used after adjustment as an index of abundance
CV	Coefficient of variation
CVID	SERFS combined chevron trap and video survey
DW	Data Workshop (here, for red snapper)
F	Instantaneous rate of fishing mortality
$F_{30\%}$	Fishing mortality rate at which $F_{30\%}$ can be attained
F_{MSY}	Fishing mortality rate at which MSY can be attained
FL	State of Florida
FHWAR	The National Survey of Fishing, Hunting, and Wildlife-Associated Recreation Survey
GA	State of Georgia
GLM	Generalized linear model
K	Average size of stock when not exploited by man; carrying capacity
kg	Kilogram(s); 1 kg is about 2.2 lb.
klb	Thousand pounds; thousands of pounds
lb	Pound(s); 1 lb is about 0.454 kg
m	Meter(s); 1 m is about 3.28 feet.
M	Instantaneous rate of natural (non-fishing) mortality
MARMAP	Marine Resources Monitoring, Assessment, and Prediction Program, a fishery-independent data collection program of SCDNR
MCB	Monte Carlo/Bootstrap, an approach to quantifying uncertainty in model results
MFMT	Maximum fishing-mortality threshold; a limit reference point used in U.S. fishery management; often based on F_{MSY}
mm	Millimeter(s); 1 inch = 25.4 mm
MRFSS	Marine Recreational Fisheries Statistics Survey, a data-collection program of NMFS, predecessor of MRIP
MRIP	Marine Recreational Information Program, a data-collection program of NMFS, descended from MRFSS
MSST	Minimum stock-size threshold; a limit reference point used in U.S. fishery management. The SAFMC has defined MSST for red snapper as $(1 - M)\text{SSB}_{\text{MSY}} = 0.7\text{SSB}_{\text{MSY}}$.
MSY	Maximum sustainable yield (per year)
mt	Metric ton(s). One mt is 1000 kg, or about 2205 lb.
N	Number of fish in a stock, conventionally on January 1
NC	State of North Carolina
NMFS	National Marine Fisheries Service, same as "NOAA Fisheries Service"
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
OY	Optimum yield; SFA specifies that OY $\leq$ MSY.
PSE	Proportional standard error
R	Recruitment
SAFMC	South Atlantic Fishery Management Council (also, Council)
SC	State of South Carolina
SCDNR	Department of Natural Resources of SC
SDNR	Standard deviation of normalized residuals
SEDAR	SouthEast Data Assessment and Review process
SERFS	Southeast Regional Fishery-independent Sampling
SFA	Sustainable Fisheries Act; the Magnuson–Stevens Act, as amended
SL	Standard length (of a fish)
SRHS	Southeast Region Headboat Survey, conducted by NMFS-Beaufort laboratory
SPR	Spawning potential ratio
SSB	Spawning stock biomass; mature biomass of males and females
SSB_{MSY}	Level of SSB at which MSY can be attained
$\text{SSB}_{\text{F30\%}}$	Level of SSB at which $F_{30\%}$ can be attained
TIP	Trip Interview Program, a fishery-dependent biodata collection program of NMFS
TL	Total length (of a fish), as opposed to FL (fork length) or SL (standard length)
VPA	Virtual population analysis, an age-structured assessment
WW	Whole weight, as opposed to GW (gutted weight)
yr	Year(s)

Appendix B Parameter estimates from the Beaufort Assessment Model

```
# Number of parameters = 366  Objective function value = -1951.20  Maximum gradient component = 3.74112e-005
# Linf:
911.360000000
# K:
0.240000000000
# t0:
-0.330000000000
# len_cv_val:
0.103911613704
# Linf_L:
927.000000000
# K_L:
0.220000000000
# t0_L:
-0.660000000000
# len_cv_val_L:
0.139090983676
# Linf_20:
938.000000000
# K_20:
0.170000000000
# t0_20:
-2.41000000000
# len_cv_val_20:
0.100000029668
# log_Nage_dev:
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
# log_R0:
12.6783793044
# steep:
0.990000000000
# rec_sigma:
0.818102531385
# R_autocorr:
0.00000000000
# log_rec_dev:
 0.457537558478 0.177887516656 0.596081349239 -0.430026388392 0.118926982008 1.21016744625 1.41291313014 0.568249030814 -0.160622680087 1.04766572397 0.714977120708 -0.305747974534 -1.45660939739 -1.56722307051
# selpar_A50_cH1:
2.13297154796
# selpar_slope_cH1:
3.88062143991
# selpar_A50_cH2:
3.09105863848
# selpar_slope_cH2:
3.33473916537
# selpar_A50_cH3:
3.08891050864
# selpar_slope_cH3:
2.42510949883
# selpar_A50_HB1:
1.88378267082
# selpar_slope_HB1:
3.54246021238
# selpar_A502_HB1:
3.79838916550
# selpar_slope2_HB1:
0.514619758261
# selpar_A50_HB2:
2.92961195540
# selpar_slope_HB2:
4.07669904945
# selpar_A502_HB2:
1.98351604776
# selpar_slope2_HB2:
0.653233646931
# selpar_A50_HB3:
2.29407884707
# selpar_slope_HB3:
3.37817174161
# selpar_A502_HB3:
2.19260024802
# selpar_slope2_HB3:
0.436836800807
# selpar_A50_GR2:
3.06592361767
# selpar_slope_GR2:
2.70676736368
# selpar_A502_GR2:
3.02073139942
# selpar_slope2_GR2:
0.588080290001
# selpar_A50_GR3:
3.57180467300
# selpar_slope_GR3:
2.08907291585
# selpar_A50_HB2_D:
0.766113358942
# selpar_slope_HB2_D:
0.484983160191
```

```
# selpar_A502_HB2_D:
1.15344665739
# selpar_slope2_HB2_D:
1.55677128989
# selpar_A50_HB3_D:
1.55070623873
# selpar_slope_HB3_D:
0.529401014875
# selpar_A502_HB3_D:
4.08062361079
# selpar_slope2_HB3_D:
0.516121290879
# selpar_A50_cH2_D:
0.912667864468
# selpar_slope_cH2_D:
0.488972548711
# selpar_A502_cH2_D:
1.70477627954
# selpar_slope2_cH2_D:
1.11106174907
# selpar_A50_cH3_D:
2.59513853167
# selpar_slope_cH3_D:
2.13645024460
# selpar_A50_CVT:
1.82586340241
# selpar_slope_CVT:
3.21899177029
# log_q_cH:
-6.33120989517
# log_q_HB:
-11.8810905835
# log_q_HB_D:
-12.8060356742
# log_q_CVT:
-12.2394582969
# M_constant:
0.134000000000
# log_avg_F_cH:
-1.98147518192
# log_F_dev_cH:
 -1.49687584191 -1.18611810279 -1.43746548361 -1.40355079721 -0.994476899346 -1.15200499920 -1.13248446861 -0.489280249664 -0.767142009048 -0.633713965540 -0.545597710092 -0.294220576158 -0.419521117751 -0.63101
# log_avg_F_HB:
-2.47173956726
# log_F_dev_HB:
 -1.32661816356 -1.19747207806 -1.06867014027 -0.953120143952 -0.855016377799 -0.761175117217 -0.638778346766 -0.525604485812 -0.431669732036 -0.341505724094 -0.246872928729 -0.210585614455 -0.164994735575 -0.10
# log_avg_F_GR:
-1.61803667431
# log_F_dev_GR:
 -1.52666935698 -1.39753187965 -1.26877505002 -1.15317139303 -1.05511310010 -0.961286518369 -0.838914340222 -0.725767285047 -0.631839134719 -0.541707815486 -0.447109690682 -0.410859004909 -0.365267028399 -0.3009
# log_avg_F_cH_D:
-3.72256331837
# log_F_dev_cH_D:
 0.292811823207 0.400833551825 0.576381470652 0.950509229335 0.500771663677 0.621339569425 -0.0750482116686 -0.537094562241 -0.542953545333 -0.336159205679 0.527801866279 -0.833215659609 -1.56395787905 0.6616494
# log_avg_F_HB_D:
-5.75855003085
# log_F_dev_HB_D:
 -4.73020931752 -3.72289661565 -4.19441528381 -4.60824727639 -4.22209722560 -4.04857749218 -3.32397085361 -3.16474888643 0.0869964083602 0.809321470525 0.843678532847 1.34886481821 0.329935038360 0.456159709437
# log_avg_F_GR_D:
-2.67216775093
# log_F_dev_GR_D:
 -2.41347222131 -2.48708991382 -3.40703651572 -1.01858950327 -0.450826242458 0.176279486394 -0.634044616253 -0.865374339250 -1.21402434434 -0.366618049618 0.220573093966 -0.587460476786 0.699171684388 0.59639720
# F_init:
0.0295838913167
```