SEDAR

Southeast Data, Assessment, and Review

SEDAR 73

South Atlantic Red Snapper

Stock Assessment Report

March 2021

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

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SEDAR

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Section I: Introduction

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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 73 addressed the stock assessment for South Atlantic Red Snapper. The assessment process consisted of a series of webinars held from July, 2020 to March 2021 and a workshop. Due to the 2020 pandemic the in-person workshop that was originally scheduled for December 2-3 in Beaufort, NC was rescheduled to be 4 four hour long webinars held December 1-4, 2020. The Stock Assessment Report is organized into 2 sections. Section I –Introduction contains a brief description of the SEDAR Process, Assessment and Management Histories for the species of interest, and the management specifications requested by the Cooperator. Section II is the Assessment Process report. This section details the assessment model, as well as documents any data recommendations that arise for new data sets presented during this assessment process, or changes to data sets used previously.

The final Stock Assessment Reports (SAR) for South Atlantic Red Snapper was disseminated to the public in March 2021. The Council's Scientific and Statistical Committee (SSC) will review the SAR for its stock. The SSCs are tasked with recommending whether the assessments represent Best Available Science, whether the results presented in the SARs are useful for providing management advice and developing fishing level recommendations for the Council. An SSC may request additional analyses be conducted or may use the information provided in the SAR as the basis for their Fishing Level Recommendations (e.g., Overfishing Limit and Acceptable Biological Catch). The South Atlantic Fishery Management Council's SSC will review the assessment at its April 2021 meeting, followed by the Council receiving that information at its June 2021 meeting. Documentation on SSC recommendations is not part of the SEDAR process and is handled through each Council.

2. Management Overview

2.1 Management Overview SAFMC Fishery Management Plan and Amendments

The following summary describes only those management actions that likely affect the red snapper portion of the snapper-grouper fishery.

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 1983, established 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° 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.

FMP Amendments Affecting Red Snapper

Description of Actions	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 black sea bass 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 limit for red snapper and a 10 snapper/person/day bag limit, excluding vermilion snapper, and allowing no more than 2 red snapper. Defined overfishing/overfished and established rebuilding timeframe: red snapper and groupers ≤ 15 years (year 1 = 1991).	Amendment 4	1/1/1992

Oculina Experimental Closed Area.	Amendment 6	6/27/1994
Limited entry program; transferable permits and 225 lbs non-transferable permits.	Amendment 8	12/14/1998
-Identified essential fish habitat (EFH) and established habitat areas of particular concern (HAPC) for species in the snapper grouper FMU.	Amendment 10 (included in Comprehensive Essential Fish Habitat Amendment)	7/4/2000
Approved definitions for overfished and overfishing. MSST = [(1-M) or 0.5 whichever is greater]*BMSY.	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 deep-water Type II marine protected areas to protect a portion of the population and habitat of long-lived deep-water snapper grouper species. Also protected known spawning areas of many snapper grouper species including red snapper.	Amendment 14	2/12/2009

Prohibited the sale of snapper-grouper harvested or possessed in the EEZ under the bag limits and prohibited the sale of snapper-grouper harvested or possessed under the bag limits by vessels with a Federal charter vessel/headboat permit for South Atlantic snapper-grouper regardless of where harvested	Amendment 15B	12/16/2009
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 and natural baits 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	red snapper closure effective 12/3/2010 circle hook requirement effective 3/3/2011

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 no minimum size limit for red snapper for either sector. The fishing seasons in 2013 for the commercial and recreational sectors were 44 and 3 days, respectively.	Amendment 28	8/23/2013
Revised red snapper commercial and recreational ACLs and noticed the red snapper commercial season opening date and the opening and closing dates for the recreational season in the South Atlantic for the 2018 fishing year. The commercial ACL was set at 124,815 lbs ww and the recreational ACL was set at 29,656 fish. The fishing seasons in 2018 for the commercial and recreational sectors were 116 and 6 days, respectively.	Amendment 43	7/26/2018

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 reefs off Georgia; revised boundaries of 7 existing SMZs off Georgia to meet CG permit specs; restricted fishing in new and revised SMZs.	Regulatory Amendment 8	11/15/2000
Eliminated closed area for snapper grouper species approved in Amendment 17A.	Regulatory Amendment 10	5/31/2011
Modified the definition of the overfished threshold (MSST) for red snapper, blueline tilefish, gag, black grouper, yellowtail snapper, vermilion snapper, red porgy, and greater amberjack. MSST changed from (1-M)*SSBMSY to MSST = 75%SSBMSY	Regulatory Amendment 21	11/6/2014
Required descending devices be *on board* and readily available for use on commercial, for-hire, and private recreational vessels while fishing for or possessing snapper-grouper species; required the use of *non-offset*, non-stainless steel circle hooks when fishing for snapper-grouper species with hook-and-line gear and natural baits north of 28º north latitude; required all hooks be non-stainless steel when fishing for snapper-grouper species with hook-and-line gear and natural baits south of 28º north latitude; and allowed the use of powerheads in federal waters off South Carolina.	Regulatory Amendment 29	7/15/2020

2.1.1 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 24 and six days, respectively.

Emergency Rule effective 11/2/2017: Modified the process used to set the red snapper ACL and announced the opening and closing dates of the 2017 recreational fishing season and the opening date for the 2017 commercial fishing season for red snapper. The 2017 commercial ACL was set at 124,815 lbs ww, and the 2017 recreational ACL was set at 29,656 fish. The commercial and recreational fishing seasons in 2017 were 60 days and 9 days, respectively.

<u>Secretarial Amendments (if any)</u>

None

<u>Control Date Notices (if any)</u>

Notice of Control Date effective 7/30/1991: 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 10/14/2005: 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 3/8/2007: The Council may consider measures to limit participation in the snapper grouper for-hire fishery.

Notice of Control Date effective 1/31/2011: 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.

Notice of Control Date effective 6/15/2016: Fishermen entering the federal for-hire recreational sector for the Snapper Grouper fishery after June 15, 2016, will not be assured of future access should a management regime that limits participation in the sector be prepared and implemented.

2.1.2 Management Program Specifications

General Management Information

Species	Red Snapper
Management Unit	South Atlantic
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 SERO: Rick DeVictor
Current stock exploitation status	Overfishing
Current stock biomass status	Overfished

2.1.3 Management Parameters

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 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)

Criteria	**Definition**	**Units**	**Estimate**	**Median**
F_{MSY}	[1]$F_{30\%}$	per year	0.15	0.15
F_{OY}	85% $F_{30\%}$	per year	0.12	0.13
F_{OY}	75% $F_{30\%}$	per year	0.11	0.11
F_{OY}	65% $F_{30\%}$	per year	0.10	0.10
F_{OY}	$F_{40\%}$	per year	0.11	0.11
B_{MSY}	Biomass at 30% SPR	metric tons	3,637	3,525
SSB_{MSY}	Spawning stock biomass at 30% SPR	eggs (1E8)	327,706	293,944
MSST	75%SSB_{MSY}	eggs (1E8)	245,779	220,458
R_{MSY}	recruits at 30% SPR	number	446,642	455,926
$F_{2012\text{-}2014}/F_{MSY}$	exploitation status	--	2.70	2.66
SSB_{2014}/MSST		--	0.20	0.21
SSB_{2014}/SSB_{MSY}	biomass status	--	0.15	0.16

[1] SAFMC defined $F_{MSY}=F_{30\%SPR}$ (or stated $F_{OY}=98\%_{F30\%SPR}$). SEFSC projections from SEDAR 24 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} following the SEDAR 24 assessment.

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.

2.1.4 General Projection Specifications

Requested Information	Value
First Year of Management	Assume management begins in 2022. 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 2021 fishing year.
Interim basis	ABC, if landings are within 10% of the ABC; average landings since 2018 (implementation of Amendment 43) otherwise.
Current Acceptable Biological Catch	??

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

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.

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

2.1.5 Quota Calculation Details

Amendment 43 implemented a total ACL for red snapper using the level of landings (commercial and recreational) in 2014. Landings of red snapper in 2014 were 42,510 fish. The total ACL was converted to pounds using 10.46 pounds as the average weight estimate (SEDAR 41 2017). This resulted in a total ACL of 444,655 pounds. Using 28.07% as the commercial allocation resulted in a commercial ACL of 124,815 pounds. To calculate the recreational ACL, the commercial ACL in pounds was converted back to numbers of fish using 9.71 pounds as the average weight (the average weight of red snapper caught in the commercial sector from 2012 to 2014, SEDAR 41 2017). This resulted in a commercial ACL of 12,854 fish, which was subtracted from the total ACL in numbers to obtain a recreational ACL of 29,656 fish. This corresponds to 71.93% of the total ACL, the established recreational allocation for red snapper in the South Atlantic.

Are there additional details of which the analysts should be aware to properly determine quotas for this stock?

2.2 Management and Regulatory Timeline

- See tables 2.2.1 and 2.2.2

. Closures Due to Meeting Commercial Quota or Commercial/Recreational ACL

- See tables 2.2.1 and 2.2.2

References

None provided.

Table 2.2.1 Red Snapper Commercial Regulatory History - Prepared by Myra Brouwer

Year	quota (units)	ACL (units)	days open	fishing season	reason for closure	season start date (first day implemented)	season end date (last day effective)	Size limit (units and length type, indicate maximum or natural length)	size limit start date	size limit end date	retention limit (units)	retention limit start date	retention limit end date
1983	NA	NA	122	open	NA	31-Aug	31-Dec	12 inches TL	31-Aug	31-Dec	NA	NA	NA
1984	NA	NA	366	open	NA	1-Jan	31-Dec	12 inches TL	1-Jan	31-Dec	NA	NA	NA
1985	NA	NA	365	open	NA	1-Jan	31-Dec	12 inches TL	1-Jan	31-Dec	NA	NA	NA
1986	NA	NA	365	open	NA	1-Jan	31-Dec	12 inches TL	1-Jan	31-Dec	NA	NA	NA
1987	NA	NA	365	open	NA	1-Jan	31-Dec	12 inches TL	1-Jan	31-Dec	NA	NA	NA
1988	NA	NA	366	open	NA	1-Jan	31-Dec	12 inches TL	1-Jan	31-Dec	NA	NA	NA
1989	NA	NA	365	open	NA	1-Jan	31-Dec	12 inches TL	1-Jan	31-Dec	NA	NA	NA
1990	NA	NA	365	open	NA	1-Jan	31-Dec	12 inches TL	1-Jan	31-Dec	NA	NA	NA
1991	NA	NA	365	open	NA	1-Jan	31-Dec	12 inches TL	1-Jan	31-Dec	NA	NA	NA
1992	NA	NA	366	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
1993	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
1994	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
1995	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
1996	NA	NA	366	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
1997	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
1998	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
1999	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
2000	NA	NA	366	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
2001	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
2002	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
2003	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
2004	NA	NA	366	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
2005	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
2006	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
2007	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
2008	NA	NA	366	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
2009	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	NA	NA	NA
2010	NA	NA	3	open	NA	1-Jan	3-Jan	20 inches TL	1-Jan	31-Dec	NA	NA	NA
	NA	NA	333	closed	interim rule[1]	4-Jan	2-Dec	None	NA	NA	NA	NA	NA
	NA	NA	29	closed	regulatory[2]	3-Dec	31-Dec	None	NA	NA	NA	NA	NA
2011	NA	NA	365	closed	regulatory	1-Jan	31-Dec	None	NA	NA	NA	NA	NA
2012	NA	NA	260	closed	regulatory	1-Jan	16-Sep	None	NA	NA	NA	NA	NA
		20,818 lbs gw[3]	8	open	emergency rule	17-Sep	24-Sep	None	NA	NA	50 lbs gw	17-Sep	24-Sep
		NA	49	closed	ACL projected to be met	25-Sep	12-Nov	None	NA	NA	NA	NA	NA
			8	open	NA	13-Nov	21-Nov	None	NA	NA	50 lbs gw	13-Nov	21-Nov
		NA	20	closed	ACL projected to be met	22-Nov	11-Dec	None	NA	NA	NA	NA	NA
			8	open	NA	12-Dec	19-Dec	None	NA	NA	50 lbs gw	12-Dec	19-Dec
		NA	12	closed	ACL met	20-Dec	31-Dec	None	NA	NA	NA	NA	NA
2013	NA	NA	237	closed	regulatory	1-Jan	25-Aug	None	NA	NA	NA	NA	NA
		21,447 lbs gw[4]	44	open	NA	26-Aug	8-Oct	None	NA	NA	75 lbs gw	26-Aug	8-Oct
		NA	84	closed	ACL met	9-Oct	31-Dec	None	NA	NA	NA	NA	NA
2014	NA	NA	194	closed	regulatory	1-Jan	13-Jul	None	NA	NA	NA	NA	NA
		50,994	58	open	NA	14-Jul	9-Sep	None	NA	NA	75 lbs gw	14-Sep	9-Sep
	NA	NA	113	closed	ACL met	10-Sep	31-Dec	None	NA	NA	NA	NA	NA
2015	NA	NA	365	closed	regulatory	1-Jan	31-Dec	None	NA	NA	NA	NA	NA
2016	NA	NA	366	closed	regulatory	1-Jan	31-Dec	None	NA	NA	NA	NA	NA
2017	NA	NA	305	closed	regulatory	1-Jan	1-Nov	None	NA	NA	NA	NA	NA
		124,815 lbs ww	60	open	NA	2-Nov	31-Dec	None	NA	NA	75 lbs gw	2-Nov	31-Dec
2018	NA	NA	206	closed	regulatory	1-Jan	25-Jul	None	NA	NA	NA	NA	NA
		124,815 lbs ww	105	open	NA	26-Jul	7-Nov	None	NA	NA	75 lbs gw	26-Jul	7-Nov
			27	closed	ACL projected to be met	8-Nov	4-Dec	None	NA	NA	NA	NA	NA
			11	open	NA	5-Dec	15-Dec	None	NA	NA	75 lbs gw	5-Dec	15-Dec
			16	closed	ACL met	16-Dec	31-Dec	None	NA	NA	NA	NA	NA
2019	NA	NA	188	closed	regulatory	1-Jan	7-Jul	None	NA	NA	NA	NA	NA
		124,815 lbs ww	53	open	NA	8-Jul	29-Aug	None	NA	NA	75 lbs gw	8-Jul	29-Aug
			124	closed	ACL met	30-Aug	31-Dec	None	NA	NA	NA	NA	NA

Notes:
1. Interim rule to reduce overfishing of red snapper. Prohibited harvest and posession (both sectors) while Amendment 17A was being developed
2. Amendment 17A prohibited harvest and posession of red snapper in the South Atlantic
3. Emergency rule estlablished red snapper commercial and recreational ACLs, seasons and management measures. Effective 8/28/2012
4. Amendment 28 implemented ACLs for 2013, management measures, and a process to allow for limited harvest in subsequent years

Table 2.2.2 Red Snapper Recreational Regulatory History - Prepared by Myra Brower

year	quota (units)	ACL (units)	days open	fishing season	reason for closure	season start date (first day implemented)	season end date (last day effective)	Size limit (units and length type, indicate maximum or natural length)	size limit start date	size limit end date	retention limit (units)	retention limit start date	retention limit end date	aggregate retentionlLimit (units)	aggregate retention limit start date	aggregate retention limit end date
1983	NA	NA	365	open	NA	1-Jan	31-Dec	12 inches TL	23-Aug	31-Dec	NA	NA	NA	NA	NA	NA
1984	NA	NA	366	open	NA	1-Jan	31-Dec	12 inches TL	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA
1985	NA	NA	365	open	NA	1-Jan	31-Dec	12 inches TL	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA
1986	NA	NA	365	open	NA	1-Jan	31-Dec	12 inches TL	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA
1987	NA	NA	365	open	NA	1-Jan	31-Dec	12 inches TL	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA
1988	NA	NA	366	open	NA	1-Jan	31-Dec	12 inches TL	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA
1989	NA	NA	365	open	NA	1-Jan	31-Dec	12 inches TL	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA
1990	NA	NA	365	open	NA	1-Jan	31-Dec	12 inches TL	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA
1991	NA	NA	365	open	NA	1-Jan	31-Dec	12 inches TL	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA
1992	NA	NA	366	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish[1]	1-Jan	31-Dec
1993	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish	1-Jan	31-Dec
1994	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish	1-Jan	31-Dec
1995	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish	1-Jan	31-Dec
1996	NA	NA	366	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish	1-Jan	31-Dec
1997	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish	1-Jan	31-Dec
1998	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish	1-Jan	31-Dec
1999	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish	1-Jan	31-Dec
2000	NA	NA	366	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish	1-Jan	31-Dec
2001	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish	1-Jan	31-Dec
2002	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish	1-Jan	31-Dec
2003	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish	1-Jan	31-Dec
2004	NA	NA	366	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish	1-Jan	31-Dec
2005	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish	1-Jan	31-Dec
2006	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish	1-Jan	31-Dec
2007	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish	1-Jan	31-Dec
2008	NA	NA	366	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish	1-Jan	31-Dec
2009	NA	NA	365	open	NA	1-Jan	31-Dec	20 inches TL	1-Jan	31-Dec	2 fish	1-Jan	31-Dec	10 fish	1-Jan	31-Dec
2010	NA	0	336	open	NA	1-Jan	2-Dec	20 inches TL	1-Jan	2-Dec	2 fish	1-Jan	2-Dec	10 fish	1-Jan	2-Dec
			29	closed	regulatory	3-Dec	31-Dec	NA	NA	NA	NA	NA	NA	NA	NA	NA
2011	NA	NA	365	closed	regulatory	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA	NA	NA	NA
2012	NA	NA	257	closed	regulatory	1-Jan	13-Sep	NA	NA	NA	NA	NA	NA	NA	NA	NA
		9,399 fish[2]	3	open	NA	14-Sep	16-Sep	None	NA	NA	1 fish	14-Sep	16-Sep	None	NA	NA
			4	closed	regulatory	17-Sep	20-Sep	NA	NA	NA	NA	NA	NA	NA	NA	NA
			3	open	NA	21-Sep	23-Sep	None	NA	NA	1 fish	21-Sep	23-Sep	None	NA	NA
			99	closed	regulatory	24-Sep	31-Dec	NA	NA	NA	NA	NA	NA	NA	NA	NA
2013	NA	9,585 fish[3]	234	closed	regulatory	1-Jan	22-Aug	NA	NA	NA	NA	NA	NA	NA	NA	NA
			3	open	NA	23-Aug	25-Aug	None	NA	NA	1 fish	23-Aug	25-Aug	None	NA	NA
			128	closed	regulatory	26-Aug	31-Dec	NA	NA	NA	NA	NA	NA	NA	NA	NA
2014	NA	NA	191	closed	regulatory	1-Jan	10-Jul	NA	NA	NA	NA	NA	NA	NA	NA	NA
		22,576 fish[4]	3	open	NA	11-Jul	13-Jul	None	NA	NA	1 fish	11-Jul	13-Jul	None	NA	NA
			4	closed	regulatory	14-Jul	17-Jul	NA	NA	NA	NA	NA	NA	NA	NA	NA
			3	open	NA	18-Jul	20-Jul	None	NA	NA	1 fish	18-Jul	20-Jul	None	NA	NA
			4	closed	regulatory	21-Jul	24-Jul	NA	NA	NA	NA	NA	NA	NA	NA	NA
			2	open	NA	25-Jul	26-Jul	None	NA	NA	1 fish	25-Jul	26-Jul	None	NA	NA
			158	closed	regulatory	27-Jul	31-Dec	NA	NA	NA	NA	NA	NA	NA	NA	NA
2015	NA	0	365	closed	regulatory	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA	NA	NA	NA
2016	NA	0	366	closed	regulatory	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA	NA	NA	NA
2017	NA	NA	306	closed	regulatory	1-Jan	2-Nov	NA	NA	NA	NA	NA	NA	NA	NA	NA
		29,656 fish[5]	3	open	NA	3-Nov	5-Nov	None	NA	NA	1 fish	3-Nov	5-Nov	None	NA	NA
			4	closed	regulatory	6-Nov	9-Nov	NA	NA	NA	NA	NA	NA	NA	NA	NA
			3	open	NA	10-Nov	12-Nov	None	NA	NA	1 fish	10-Nov	12-Nov	None	NA	NA
			25	closed	regulatory	13-Nov	7-Dec	NA	NA	NA	NA	NA	NA	NA	NA	NA
			3	open	NA	8-Dec	10-Dec	None	NA	NA	1 fish	8-Dec	10-Dec	None	NA	NA
			21	closed	regulatory	11-Dec	31-Dec	NA	NA	NA	NA	NA	NA	NA	NA	NA
2018	NA	NA	221	closed	regulatory	1-Jan	9-Aug	NA	NA	NA	NA	NA	NA	NA	NA	NA
		29,656 fish[6]	3	open	NA	10-Aug	12-Aug	None	NA	NA	1 fish	10-Aug	12-Aug	None	NA	NA
			4	closed	regulatory	13-Aug	16-Aug	NA	NA	NA	NA	NA	NA	NA	NA	NA
			3	open	NA	17-Aug	19-Aug	None	NA	NA	1 fish	17-Aug	19-Aug	None	NA	NA
			134	closed	regulatory	20-Aug	31-Dec	NA	NA	NA	NA	NA	NA	NA	NA	NA
2019	NA	NA	192	closed	regulatory	1-Jan	11-Jul	NA	NA	NA	NA	NA	NA	NA	NA	NA
		29,656 fish	3	open	NA	12-Jul	14-Jul	None	NA	NA	1 fish	12-Jul	14-Jul	None	NA	NA
			4	closed	regulatory	15-Jul	18-Jul	NA	NA	NA	NA	NA	NA	NA	NA	NA
			2	open	NA	19-Jul	20-Jul	NA	NA	NA	1 fish	19-Jul	20-Jul	None	NA	NA
			164	closed	regulatory	21-Jul	31-Dec	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:
1. Amendment 4 established a 10-snapper aggregate (excluding vermilion snapper) with a 2 fish/person/day bag limit for red snapper within the aggregate
2. Emergency rule effective 8/28/2012 established seasons and ACLs for 2012
3. Amendment 28 implemented the process to determine red snapper seasons and set ACLs for 2013. The amendment became effective on 8/23/2013.
4. Interim rule effective 7/11/2014 established seasons and ACLs for 2014
5. Interim rule effective 11/2/2017 modified the process to set red snapper ACLs and announced the seasons and ACLs for 2017
6. Amendment 43 became effective on 8/26/2018 and set red snapepr ACLs for 2018 and beyond

2.3 State Regulatory History

2.3.1 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.

2.3.2 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.

2.3.3 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.

2.3.4 Florida

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
1980	None	None	None		
1981	None	None	None		
1982	None	None	None		
1983	None	None	None		
1984	None	None	None		
1985	12 inches	None	None	Established a 12-inch minimum size limit.	July 29, 1985

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
986	12 inches	10 per person within the 10-fish snapper aggregate bag limit	None	Established a ten-fish daily recreational bag limit for snapper (excluded lane, vermilion, and yelloweye). Prohibited commercial harvest of snapper and grouper by longline gear and established a bycatch allowance of 5% for harvesters using longline gear to target other species. Prohibited use of stab nets (or sink nets) to harvest snapper and grouper in Atlantic state waters of Monroe County. Allowed 5% of snapper and grouper in possession of harvester to be smaller than the minimum size limit. Required snapper and grouper to be landed in whole condition (head and tail intact).	Dec. 11, 1986
1987	12 inches	10 per person within the 10-fish snapper aggregate bag limit	None		

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
1988	12 inches	10 per person within the 10-fish snapper aggregate bag limit	None		
1989	12 inches	10 per person within the 10-fish snapper aggregate bag limit	None		

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Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
1990	13 inches	2 per person within the 10-fish snapper aggregate bag limit	None	Designated all snapper and grouper "restricted species" and required commercial harvesters to possess a Restricted Species endorsement on their Saltwater Products License. Designated red snapper as protected species. Increased minimum size limit to 13 inches. Revised the daily recreational bag limit to be two per person within the ten-fish snapper aggregate. Set allowable gear as hook-and-line, black sea bass trap, spear, gig, or lance (except powerheads, bangsticks, or explosive devices) for snapper and grouper. Prohibited commercial harvest in state waters when harvest is prohibited in adjacent federal waters. Required snapper and grouper to be landed in whole condition.	Feb. 1, 1990

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
1991	13 inches	2 per person within the 10-fish snapper aggregate bag limit	None		
1992	20 inches	2 per person within the 10-fish snapper aggregate bag limit	None	Increased the minimum size limit to 20 inches.	Dec. 31, 1992
1993	20 inches	2 per person within the 10-fish snapper aggregate bag limit	None		
1994	20 inches	2 per person within the 10-fish snapper aggregate bag limit	None	Allowed a two-day possession limit for reef fish for persons aboard charter and headboats on trips exceeding 24 hours, provided the vessel is equipped with a permanent berth for each passenger, and each passenger has a receipt verifying the trip length. Modified rule language to provide the same state and federal definitions of Gulf of Mexico and Atlantic Ocean regions.	March 1, 1994

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
1995	20 inches	2 per person within the 10-fish snapper aggregate bag limit	None		
1996	20 inches	2 per person within the 10-fish snapper aggregate bag limit	None		
1997	20 inches	2 per person within the 10-fish snapper aggregate bag limit	None		
1998	20 inches	2 per person within the 10-fish snapper aggregate bag limit	None		
1999	20 inches	2 per person within the 10-fish snapper aggregate bag limit	None		
2000	20 inches	2 per person within the 10-fish snapper aggregate bag limit	None		

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
2001	20 inches	2 per person within the 10-fish snapper aggregate bag limit	None		
2002	20 inches	2 per person within the 10-fish snapper aggregate bag limit	None		
2003	20 inches	2 per person within the 10-fish snapper aggregate bag limit	None	Removed "protected species" designation for red snapper.	Jan. 1, 2003
2004	20 inches	2 per person within the 10-fish snapper aggregate bag limit	None		
2005	20 inches	2 per person within the 10-fish snapper aggregate bag limit	None		

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
2006	20 inches	2 per person within the 10-fish snapper aggregate bag limit	None	Specified that "total length" means the straight line distance from the most forward point of the head with the mouth closed, to the farthest tip of the tail with the tail compressed or squeezed, while the fish is lying on its side.	July 1, 2006
2007	20 inches	2 per person within the 10-fish snapper aggregate bag limit	Same as federal waters	Set commercial trip limits in the Atlantic to be the same as adjacent federal waters. Prohibited commercial fishermen from harvesting or possessing the recreational bag limit on commercial trips.	July 1, 2007
2008	20 inches	2 per person within the 10-fish snapper aggregate bag limit	Same as federal waters		
2009	20 inches	2 per person within the 10-fish snapper aggregate bag limit	Same as federal waters		
2010	20 inches	2 per person within the 10-fish snapper aggregate bag limit	Same as federal waters	Required dehooking tools be aboard commercial and recreational vessels for anglers to use as needed to remove hooks from Atlantic reef fish.	Jan. 9, 2010

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
2011	20 inches	2 per person within the 10-fish snapper aggregate bag limit	Same as federal waters		
2012	20 inches	2 per person within the 10-fish snapper aggregate bag limit	Same as federal waters		
2013	20 inches	2 per person within the 10-fish snapper aggregate bag limit	Same as federal waters		
2014	20 inches	2 per person within the 10-fish snapper aggregate bag limit	Same as federal waters		
2015	20 inches	2 per person within the 10-fish snapper aggregate bag limit	Same as federal waters		

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
2016	20 inches	2 per person within the 10-fish snapper aggregate bag limit	Same as federal waters	Created an exception allowing recreational anglers to land reef fish as fillets instead of as whole fish, provided the reef fish were recreationally harvested in The Bahamas and specific conditions are met.	Sept. 13, 2016
2017	20 inches	2 per person within the 10-fish snapper aggregate bag limit	Same as federal waters		
2018	20 inches	2 per person within the 10-fish snapper aggregate bag limit	Same as federal waters		
2019	20 inches	2 per person within the 10-fish snapper aggregate bag limit	Same as federal waters		
2020	20 inches	2 per person within the 10-fish snapper aggregate bag limit	Same as federal waters		

Florida Atlantic Red Snapper Regulation Changes by Chapter and Date

SNAPPER, GROUPER, AND SEA BASS, CH 46-14, FAC (Effective July 29, 1985)
- Established a minimum size limit of 12 inches for red snapper

REEF FISH, CH 46-14, FAC (Effective Dec. 11, 1986)
- Established a snapper bag limit of ten fish per recreational fisherman daily, with off-the-water possession limit of 20 per recreational fisherman, for any combination of snapper, excluding lane, vermillion, and yelloweye.
- Prohibited use of longline gear by commercial fishermen; bycatch allowance of 5% is permitted harvesters of other species using this gear.
- Prohibited use of stab nets (or sink nets) to take snapper or grouper in Atlantic waters of Monroe County.
- Allowed 5% of snapper and grouper in possession of harvester to be smaller than the minimum size limit.
- Required reef fish to be landed in whole condition (head and tail intact).

REEF FISH, CH 46-14, FAC (Effective Feb. 1, 1990)
- Designated all snapper and grouper as "restricted species."
- Designated red snapper and jewfish as protected species.
- Increased the red snapper minimum size limit to 13 inches.
- Revised the recreational bag limit for snappers to be 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).
- Set the allowable gear to be hook and line, black sea bass trap, spear, gig, or lance (except powerheads, bangsticks, or explosive devices) for snapper and grouper.
- Prohibited all commercial harvest of any species of snapper, grouper, and sea bass in state waters whenever harvest of that species is prohibited in adjacent federal waters.
- Required snapper and grouper to be landed in whole condition.

REEF FISH, CH 46-14, FAC (Effective Dec. 31, 1992)
- Increased the Atlantic state waters minimum size limit for red snapper to 20 inches.

REEF FISH, CH 46-14, FAC (Effective March 1, 1994)
- Allowed 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.
- Modified rule language to provide the same state and federal definitions of Gulf of Mexico and Atlantic Ocean regions.

REEF FISH, CH 68B-14, FAC (Effective January 1, 2003)
- Removed the "protected species" designation for red snapper and goliath grouper (formerly jewfish).

REEF FISH, CH 68B-14, FAC (Effective July 1, 2006)
- Provided that, for purposes of determining the legal size of reef fish species, "total length" means the straight line distance from the most forward point of the head with the mouth closed, to the farthest tip of the tail with the tail compressed or squeezed, while the fish is lying on its side.

REEF FISH, CH 68B-14, FAC (Effective July 1, 2007)
- Set commercial trip limits in the Atlantic that are the same as trip limits in federal waters.
- Prohibited commercial fishermen from harvesting or possessing the recreational bag limit of reef fish species on commercial trips.

REEF FISH, CH 68B-14, FAC (Effective Jan. 19, 2010)

- Required dehooking tools to be aboard commercial and recreational vessels for anglers to use as needed to remove hooks from Atlantic reef fish.

REEF FISH - BAHAMAS, 68B-14.006, FAC (Effective Sept. 13, 2016)

- Created an exception allowing recreational anglers to land reef fish as fillets instead of as whole fish, provided the reef fish were recreationally harvested in The Bahamas and specific conditions are met.

3. Assessment History

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 benchmark 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, this qualitative result of overfishing a depleted stock was 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).

SEDAR-24 (SEDAR-24, 2010) was a benchmark assessment using the Beaufort Assessment Model (BAM) with data through 2009. BAM is an integrated catch-age model, and is customizable to the multiple data sources available (Williams and Shertzer, 2015). A surplus production model implemented with the ASPIC software (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. In addition, this was the first red snapper assessment to include a Monte Carlo Bootstrap Ensemble (MCBE) approach to characterize uncertainty, in which 100% of the ensemble models were in qualitative agreement with the base run's status determinations.

SEDAR-41 (SEDAR-41, 2017) was a benchmark assessment using BAM with data through 2014. That was the first assessment to include fishery independent data from the then newly created SouthEast Reef Fish Survey (SERFS), including observations from underwater video gear. SERFS was launched in 2010, in large part because of the findings from SEDAR-24. In SEDAR-41, MSY-related benchmarks were based on $SPR_{30\%}$. The base model of SEDAR-41 estimated that the stock was not yet rebuilt ($SSB_{2014}/SSB_{F30\%} = 0.15$) and that overfishing was occurring ($F_{2012-2014}/F_{30\%} = 2.7$). Of the 27 sensitivity runs, all were in qualitative agreement (overfished and overfishing) with the base run, and 99.1% of the ensemble models were in agreement.

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://sedarweb.org/sedar-15-stock-assessment-report-south-atlantic-red-snapper

SEDAR. 2010. SEDAR 24 - Stock assessment report South Atlantic Red Snapper. 524 p. Available online at: http://sedarweb.org/sedar-24-stock-assessment-report-south-atlantic-red-snapper

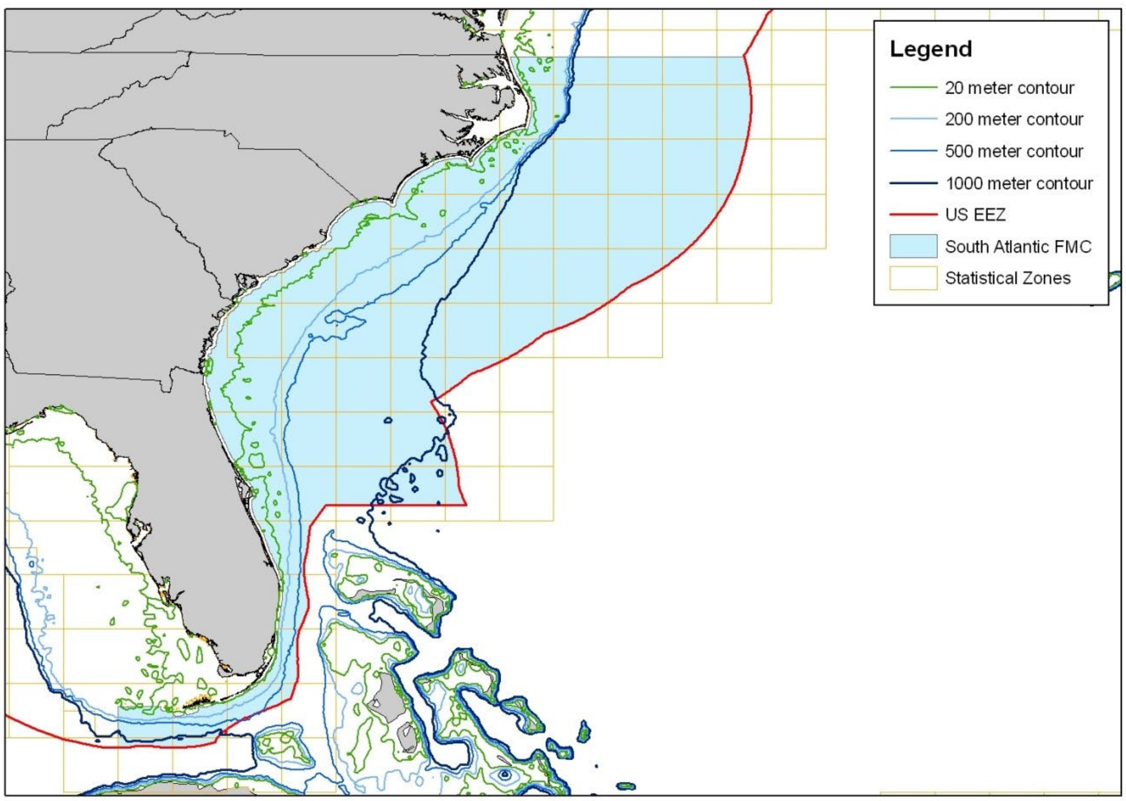
SEDAR. 2017. SEDAR 41 – South Atlantic Red Snapper Assessment Report – Revision 1. SEDAR, North Charleston SC, 805 pp. Available online at: http://sedarweb.org/sedar-41

Williams, E.H., K.W. Shertzer. 2015. Technical documentation of the Beaufort Assessment Model (BAM). U.S. Department of Commerce, NO"AA Technical Memorandum NMFS-SEFSC-671.

*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 3.1: South Atlantic Fishery Management Council and EEZ boundaries.



5. 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
ASPIC	a stock production model incorporating covariates
ASPM	age-structured production model
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)
MAFMC	Mid-Atlantic Fishery Management Council
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 73

South Atlantic Red Snapper

Section II: Assessment Report

March 2021

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

Document History

March, 2021 Original release.

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1. Introduction

1.1 Executive Summary

This operational assessment evaluated the stock of red snapper (Lutjanus campechanus) in the South Atlantic region of the southeastern United States, a stock currently under a rebuilding plan. The primary objectives were to update and improve the 2017 SEDAR41 benchmark assessment of red snapper and to conduct new stock projections. Using data through 2014, SEDAR41 had indicated that the stock was overfished and undergoing overfishing. For this SEDAR73 assessment, data compilation and assessment methods were guided by methodology of SEDAR41, as well as by current SEDAR practices. The assessment period is 1950–2019.

Available data on this stock included indices of abundance, landings, discards, and samples of annual length and age compositions from fishery dependent and fishery independent sources. Five indices of abundance were fitted by the model: one from the commercial logbooks, one from the recreational headboat logbooks, one from on-board observers of headboat discards, one from the SouthEast Reef Fish Survey (SERFS) chevron trap data, and one from SERFS video data. One sensitivity run included an index developed by FWRI from a (repetitive timed drop) hook and line survey, along with the corresponding ages observed by that survey. Data on landings and discards were modeled from three distinct fleets: commercial handline, recreational headboats, and general recreational (private and charter modes).

The primary model used in SEDAR41—and the one updated here—was the Beaufort Assessment Model (BAM), a state-of-the-art integrated statistical catch-age formulation. A base run of BAM was configured to provide point estimates of key management quantities, such as stock and fishery status. Uncertainty in estimates from the base run was evaluated through a mixed Monte Carlo/Bootstrap Ensemble (MCBE) procedure. Median values from the uncertainty analysis are also provided. In this assessment, as codified in the Fishery Management Plan, reference points were based on F¬30%, the F providing 30% SPR, as a proxy for FMSY.

The assessment estimated that spawning stock declined until about 1990, then increased slowly until about 2010, with more rapid increase since. The terminal (2019) base-run estimate of spawning stock was below the rebuilding criterion of SSBF30% (SSB2019/SSBF30% = 0.44), as was the median estimate from the MCBE (SSB2019/SSBF30% = 0.49). The estimated fishing rate has exceeded the maximum fishing mortality threshold (MFMT), represented by F¬30%, since about 1980. The terminal estimate, which is based on a three-year geometric mean, was above F¬30% in the base run (F2017–2019/ F¬30% = 2.20) and in the median of the MCBE (F2017–2019/ F¬30% = 1.95). Thus, this assessment indicated that the stock is not yet rebuilt and is experiencing overfishing.

The MCBE analysis illustrated that these estimates of stock and fishery status are robust. Of all MCBE runs, 97.8% were in agreement that the stock is not yet rebuilt, and 99.8% were in agreement that overfishing is occurring. Although qualitative results were robust, the primary source of uncertainty in quantitative results (i.e., degree of overfishing or overfished) was natural mortality.

The estimated trends of this operational assessment were quite similar to those from the SEDAR41 benchmark. However, the two assessments did show some differences in results, which was not surprising given several modifications made to both the data and the model (described throughout the report). Compared to SEDAR41, this assessment suggested lower levels of overfishing in terminal years and higher values of stock size relative to their benchmarks. The two assessments showed nearly identical stock status between 1990 and 2014, the terminal year of SEDAR41. Since then, SEDAR73 indicated that the red snapper stock has shown substantial progress toward rebuilding, and that the primary driver of overfishing is recreational discards.

1.2 Workshop Time and Place

The SEDAR 73 South Atlantic Red snapper assessment took place over a series of webinars held from July, 2020 to February 2021 and a workshop. Due to the 2020 pandemic the in-person workshop that was originally scheduled for December 2-3 in Beaufort, NC was rescheduled to be 4 four hour long webinars held December 1-4, 2020.

1.3 Terms of Reference

1. Update the approved South Atlantic Red Snapper SEDAR 41 model with data through 2019. Provide a model consistent with the previous assessment configuration and revised models as necessary to incorporate and evaluate any changes allowed for this update. Apply the current BAM configuration incorporating approved improvements developed since SEDAR 41.

2. Evaluate and document the following specific changes in input data or deviations from the benchmark model.
    - Include the revised MRIP recreational estimates.
    - Consider including as an estimate of recreational catch, the alternative (non-MRIP) estimates of catch during recent open seasons that are used to evaluate the Annual Catch Limit.
    - Include any new and updated information on discard mortality rate.
    - Calculate different F metrics (other than apical F) to evaluate the status of the stock (to address shifts in the age of apical F throughout the assessment time series).
    - Address SSC selectivity concerns
        1. Consider the results of the FLFWRI cooperative research 2018 study "First direct assessment of the size-selectivity of hook and line gear, Chevron traps, and underwater cameras for Red Snapper and other reef fishes in the U.S. South Atlantic" in upcoming assessments for Red Snapper.
        2. Re-evaluate if different selectivities can be used within the combined Chevron trap/video (CVID) index or whether the Chevron traps and the video should continue to be combined as a single CPUE index given the differences in selectivity found in the 2018 FL FWRI study.
        3. Re-evaluate the shape of the SERFS Chevron trap selectivity curve (flat-topped vs. dome-shaped).

3. Document any changes or corrections made to model and input datasets and provide updated input data tables. Provide commercial and recreational landings and discards in pounds and numbers.

4. Update model parameter estimates and their variances, model uncertainties, estimates of stock status and management benchmarks, and provide the probability of overfishing occurring at specified future harvest and exploitation levels.

5. Convene a working group including SSC representatives to meet via webinar or in-person, as needed to review model development relative to terms of reference 1 through 4.
   Outside of SEDAR, hold a workshop to focus on the selectivity issues regarding the Chevron trap and video indices. A report will be produced and will be reviewed at SEDAR workshop in December 2020.
6. Develop a stock assessment report to address these TORs and fully document the input data, methods, and results.

1.4 List of Participants

Appointee	Function	Affiliation
Kyle Shertzer	Lead Analyst	SEFSC Beaufort
Julie Defilippi-Simpson	Panelist	ACCSP
Mike Rinaldi	Panelist	ACCSP
Amanda Tong	Panelist	NCDMF
Bev Sauls	Panelist	FLFWC
Dawn Franco	Panelist	GADNR
Ted Switzer	Panelist	FLFWC
Dustin Addis	Panelist	FLFWC
Heather Christiansen	Panelist	FLFWC
Marcel Reichert	Panelist	SCDNR
Tracey Smart	Panelist	SCDNR
David Wyanski	Panelist	SCDNR
Wally Bubley	Panelist	SSC
Anne Lange	Panelist	SSC
Jeff Buckel	Panelist	SSC
George Sedberry	Panelist	SSC
Erik Williams	Analytical Team	SEFSC Beaufort
Kate Siegfried	Analytical Team	SEFSC Beaufort
Jennifer Potts	Analytical Team	SEFSC Beaufort
Ken Brennan	Analytical Team	SEFSC Beaufort
Beth Wrege	Analytical Team	SEFSC Miami
Refik Orhun	Analytical Team	SEFSC Miami
Andy Ostrowski	Analytical Team	SEFSC Beaufort
Rob Cheshire	Data Compiler	SEFSC Beaufort
Eric Fitzpatrick	Analytical Team	SEFSC Beaufort
Kelly Fitzpatrick	Analytical Team	SEFSC Beaufort
Vivian Matter	Analytical Team	SEFSC Miami
Nate Bacheler	Analytical Team	SEFSC Beaufort

Observers

Rusty Hudson	Observers	Snapper Grouper AP
Robert Lorenz	Observers	Snapper Grouper AP
Jimmy Hull	Observers	Snapper Grouper AP
Lawton Howard	Observers	Snapper Grouper AP

Data providers

Kevin McCarthy	Data Providers	SEFSC Miami
Larry Beerkircher	Data Providers	SEFSC Miami
Matt Nuttall	Data Providers	SEFSC Miami
John Carlson	Data Providers	SEFSC

Appointee	Function	Affiliation
Data providers Cont.		
Alyssa Mathers	Data Providers	SEFSC
Kevin Kolmos	Data Providers	SCDNR
Dominique Lazarre	Data Providers	FLFWC
Michelle Willis	Data Providers	SCDNR
Byron White	Data Providers	SCDNR
Jessica Carroll	Data Providers	FLFWC
Russ Brodie	Data Providers	FLFWC
Staff		
Michael Larkin	Observer	SERO
Myra Brower	Observer	SAFMC
Mike Errigo	Observer	SAFMC
Anna Beckwith	Council Rep	SAFMC
Chester Brewer	Council Rep	SAFMC
Chris Conklin	Council Rep	SAFMC
Tim Griner	Council Rep	SAFMC
Other		
Allie Iberle	Observer	SAFMC
Bebe Dalton Harrison	Observer	SAFMC
Julia Byrd	Observer	SAFMC
Mike Schmidke	Observer	SAFMC
Alan Lowther	Observer	NMFS
Alan Bianchi	Observer	NMFS
Amy Dukes	Observer	SCDNR
Andrew Cathey	Observer	NCDENR
Chip Collier	Observer	SAFMC
Christine Schobernd	Observer	NMFS
CJ Sweetmen	Observer	FLFWC
Dawn Glasgow	Observer	SCDNR
Derek Cox	Observer	FLFWC
Erika Burgess	Observer	FLFWC
Genny Nesslage	Observer	SSC/ UMCES
Hannah Hart	Observer	FLFWC
Homer Hiers	Observer	SCDNR
James Brooks	Observer	SCDNR
Joe Evans	Observer	SCDNR
John Carmichael	Observer	SAFMC
Julie Vecchio	Observer	FLFWC
Julie Neer	Observer	SEDAR
Kai Lorenzen	Observer	UFL
Keilin Gamboa-Salazar	Observer	SCDNR
Kellie Ralston	Observer	ASA Fishing
Kristin Foss	Observer	FLFWC
Kevan Gregalis	Observer	NOAA
Kevin Spanik	Observer	SCDNR

Appointee	Function	Affiliation
Other Continued		
Kim Iverson	Observer	SAFMC
Margaret Finch	Observer	SCDNR
Maria Liza Toring-Farquerabao	Observer	University of the Philippines
McLean Seward	Observer	NCDENR
Rebekah Ravago	Observer	SCDNR
Stephen Long	Observer	SCDNR
Steve Brown	Observer	FLFWC
Wiley Sinkus	Observer	SCDNR
Zach Gillum	Observer	NOAA
Cameron Rhodes	Observer	SAFMC

1.5 Document List

Document #	Title	Authors	Received
Documents Prepared for SEDAR 73			
SEDAR73-WP01	Red Snapper Fishery-Independent Index of Abundance and Age/Length Compositions in US South Atlantic Waters Based on a Chevron Video Trap Survey (2010-2019)	C. Michelle Willis, Dawn Glasgow, and Walter Bubley	11/9/2020
SEDAR73-WP02	Preliminary Report on Catch and Bycatch in the South Atlantic Reef fish Vertical Line Fishery, 2018 – 2020.	Alyssa N. Mathers, Heather E. Moncrief-Cox, and John K. Carlson	7/20/2020
SEDAR73-WP03	Summary of Red Snapper data collection from 2009 to 2019 in Georgia	Dawn Franco	11/16/2020
SEDAR73-WP04	Georgia Red Snapper Headboat Discard Lengths, 2010-2013	Dawn Franco and Capt. Steve Amick	11/16/2020 Revised: 12/2/2020
SEDAR73-WP05	Standardized video counts of Southeast U.S. Atlantic red snapper (Lutjanus campechanus) from the Southeast Reef Fish Survey	Rob Cheshire and Nathan Bachelor	10/29/2020
SEDAR73-WP06	Indices of abundance for Red Snapper (*Lutjanus campechanus*) from the FWC Fish and Wildlife Research Institute (FWRI) repetitive timed drop survey in the U.S. South	Heather M. Christiansen, Theodore S. Switzer , Russell B. Brodie, Justin J. Solomon, and Richard Paperno	10/16/2020
SEDAR73-WP07	Updated Estimates of Batch Fecundity vs. Total Length, Total Weight, and Calendar Age for South Atlantic Red Snapper	David M. Wyanski, Kathleen Howington, Keyaira Morgan, and Rebekah Ravago	11/19/2020
SEDAR 73-WP08	In search of the *Great South Atlantic Red Snapper Count*: Additional empirical data-based selectivity considerations for the SEDAR 73 Red Snapper model	Jimmy Hull and Dr. Barile	11/2/2020
SEDAR73-WP09	General Recreational Survey Data for Red Snapper in the South Atlantic	Nuttall and Matter	11/16/2020
SEDAR73- WP10	SEDAR 73 South Atlantic Red Snapper Mini-Season Ad-hoc Group Call	Red Snapper Mini-Season Ad-hoc Working Group	11/16/2020

SEDAR73-WP11	Summary of Length and Weight Data Collected from Harvested Red Snapper in Florida during S. Atlantic Recreational Seasons, 2012-2019	Beverly Sauls and Dominique Lazarre	11/4/2020
SEDAR73-WP12	Discard length frequency data	Dominique Lazarre	
SEDAR73-WP13	Size and age composition of Red Snapper, Lutjanus campechanus, collected in association with fishery-independent and fishery-dependent projects along Florida's Atlantic coast (2012 to 2019)	Justin J. Solomon, Jessica Carroll, Dominique Lazarre, Russell B. Brodie, Heather Christiansen, Beverly Sauls, Richard Paperno, and Theodore S. Switzer	11/13/2020
SEDAR73-WP14	Workgroup Report on the Selectivity of Red Snapper in the South Atlantic Region	South Atlantic Selectivity Workgroup	11/16/2020
SEDAR73-WP15	Utility and Usage of Descender Devices in the Red Snapper Recreational Fishery in the South Atlantic	Julie Vecchio, Dominique Lazarre, Beverly Sauls	11/16/2020 Revised: 12/4/2020
SEDAR73-WP16	My Fish Count Data for Red Snapper	Mike Errigo and Chip Collier	11/23/2020
SEDAR73-WP17	SEDAR 73 Public comment	SEDAR 73 Observers	3/8/2021
Final Assessment Report			
SEDAR73-SAR1	SEDAR 73 South Atlantic Red Snapper Stock assessment Report	Prepared by SEDAR 73 panel	4/7/2021
Reference Documents			
SEDAR73-RD01	2014 SEDAR 41 South Atlantic Red Snapper Assessment Report	2014 SEDAR 41	7/6/2020
SEDAR73-RD02	First direct assessment of the size-selectivity of hook and line gear, Chevron traps, and underwater cameras for Red Snapper and other reef fishes in the U.S. South Atlantic.	Florida Fish and Wildlife Conservation Commission	1/14/2020
SEDAR73-RD03	Characterization of the Southeastern US Atlantic Mid-shelf and Deepwater Reef Fish Fisheries	Michael P Enzenauer, Simon J.B. Gulak, Bethany M. Deacy, and John K. Carlson	7/16/2020
SEDAR73-RD04	Survey Methods for Estimating Red Snapper Landings in a High-Effort Recreational Fishery Managed with a Small Annual Catch Limit	Beverly J. Sauls, Richard P. Cody & Andrew J. Strelcheck	7/27/2020

SEDAR73-RD05	Recreational Effort, Catch and Biological Sampling in Florida During the 2018 South Atlantic Red Snapper Season	Beverly Sauls, Dominique Lazarre, Bridgette Cermak	7/27/2020
SEDAR73-RD06	Biological Sampling and Recreational Catch and Effort Estimation during the November 2017 South Atlantic Red Snapper Re-opening	Beverly Sauls and Dominique Lazarre	7/27/2020
SEDAR73-RD07	Recreational Effort, Catch and Biological Sampling in Florida During the 2019 South Atlantic Red Snapper Season	Beverly Sauls and Dominique Lazarre	7/27/2020
SEDAR73-RD08	Is there evidence of the size and age composition of U.S. South Atlantic Red Snapper expanding under an ongoing fishing moratorium	Cooperative Research Program (CRP) Final Report Grant# NA17NMF4540139	11/13/2020
SEDAR73-RD09	SEDAR 52 – WP09: Red Snapper Discard Mortality in Florida's Recreational Fisheries	B. Sauls, O. Ayala, R. Germeroth, J. Solomon, R. Brody	12/1/2020
SEDAR73-RD10	SEDAR 41 WP33: Size Distribution, Release Condition, and Estimated Discard Mortality of Red Snapper Observed in For-Hire Recreational Fisheries in the South Atlantic	Beverly Sauls, Alisha Gray, Chris Wilson, and Kelly Fitzpatrick	12/2/2020
SEDAR73-RD11	Representative Biological Sampling of Recreational Harvest on the East Coast of Florida to Improve Stock Assessments in the South Atlantic	Beverly Sauls	12/2/2020
SEDAR73-RD12	A Survey to Characterize Harvest and Regulatory Discards in the Offshore Recreational Charter Fishery off the Atlantic Coast of Florida	Beverly Sauls and Oscar Ayala	12/2/2020
SEDAR73-RD13	Evaluating the Efficacy of Descender Devices in Increasing the Survival of Deepwater Groupers Using Telemetry	BRENDAN J. RUNDE & JEFFREY A. BUCKEL	12/3/2020
SEDAR73-RD14	Snapper Grouper Advisory Panel Fishery Performance Report for Red Snapper November 2020	Snapper Grouper Advisory Panel	12/9/2020

1.6 Statements Addressing Each term of Reference

Note: Original ToRs are in normal font. Statements addressing ToRs are in italics.

1. Update the approved South Atlantic Red Snapper SEDAR 41 model with data through 2019. Provide a model consistent with the previous assessment configuration and revised models as necessary to incorporate and evaluate any changes allowed for this update. Apply the current BAM configuration incorporating approved improvements developed since SEDAR 41.

SEDAR73 applied the current BAM configuration. The assessment model structure and data sources were very similar to those used in SEDAR41. Important modifications, such as natural mortality and composition likelihoods, were investigated through sensitivity runs.

2. Evaluate and document the following specific changes in input data or deviations from the benchmark model.
   - Include the revised MRIP recreational estimates.
   - Consider including as an estimate of recreational catch, the alternative (non-MRIP) estimates of catch during recent open seasons that are used to evaluate the Annual Catch Limit.
   - Include any new and updated information on discard mortality rate.
   - Calculate different F metrics (other than apical F) to evaluate the status of the stock (to address shifts in the age of apical F throughout the assessment time series).
   - Address SSC selectivity concerns
     4. Consider the results of the FLFWRI cooperative research 2018 study "First direct assessment of the size-selectivity of hook and line gear, Chevron traps, and underwater cameras for Red Snapper and other reef fishes in the U.S. South Atlantic" in upcoming assessments for Red Snapper.
     5. Re-evaluate if different selectivities can be used within the combined Chevron trap/video (CVID) index or whether the Chevron traps and the video should continue to be combined as a single CPUE index given the differences in selectivity found in the 2018 FL FWRI study
     6. Re-evaluate the shape of the SERFS Chevron trap selectivity curve (flat-topped vs. dome-shaped).

All of above bullet points were addressed. Revised MRIP estimates were included, alternatives to MRIP were used to compute catches during mini-seasons (as in SEDAR41), and discard mortality information was reviewed and estimates revised. In addition to apical F, the assessment included two alternative measures of fishing intensity: SPR_F and exploitation rate. The SPR_F is the asymptotic spawning potential ratio conditional on the annual F and selectivity patterns. Exploitation rate is the total number of fish removed by fishing (landings and dead discards) divided by the total number in the population. A selectivity working group reviewed the FL FWRI stereo video data, as well as other relevant data sources. The working group recommended dome-shaped selectivity for the chevron trap index and flat-topped selectivity for the video index. Those recommendations were adopted in the assessment, and the two indices were input as separate time series (i.e., not combined, as was done in SEDAR41 under the assumption of same selectivities).

3. Document any changes or corrections made to model and input datasets and provide updated input data tables. Provide commercial and recreational landings and discards in pounds and numbers.

   Changes to data and model are documented in the report, along with tables of updated data input and removals in both pounds and numbers.

4. Update model parameter estimates and their variances, model uncertainties, estimates of stock status and management benchmarks, and provide the probability of overfishing occurring at specified future harvest and exploitation levels.

   All of these key estimates and outputs are documented in the report.

5. Convene a working group including SSC representatives to meet via webinar or in-person, as needed to review model development relative to terms of reference 1 through 4.

   Outside of SEDAR, hold a workshop to focus on the selectivity issues regarding the Chevron trap and video indices. A report will be produced and will be reviewed at SEDAR workshop in December 2020.

   The selectivity working group met via webinar from August through November, 2020. That group's recommendations, described in SEDAR73-WP14, were adopted in full by the SEDAR73 assessment panel. Selectivity of the chevron trap index was treated dome-shaped, and selectivity of the video index was treated as flat-topped.

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

   Please see this report.

2 Data Review and Update

The input data for this assessment are described below, with focus on modifications from the SEDAR41 benchmark assessment.

2.1 Data Review

In this operational assessment, the Beaufort assessment model (BAM) was fitted to data sources developed during the SEDAR73 process, evaluated during a four-day workshop (December 1–4, 2020) and post-workshop webinar (December 16, 2020). These data include updates to SEDAR41 data where appropriate, as well as several additional sources of information, which are highlighted below.

Model inputs used in SEDAR41 and SEDAR73

- Life history: Meristics, population growth, fishery dependent size at age, female maturity, proportion female, number of batches at age, size-dependent batch fecundity, age-dependent natural mortality
- Landings and discards: Commercial handline landings and discards, headboat landings and discards, general recreational landings and discards
- Indices of abundance: Commercial handline, headboat, headboat discards, SERFS[1] chevron trap, SERFS video
- Length compositions: Commercial landings, commercial discards, headboat discards
- Age compositions: Commercial landings, headboat landings, general recreational landings, SERFS chevron trap
- Other: Discard mortality

New data sources or updates in SEDAR73

- Life history: Size-dependent batch fecundity, age-dependent natural mortality
- Landings and discards: Recreational landings and discards
- Indices of abundance: SERFS indices (chevron trap and video), FWRI repetitive timed drop (RTD) survey
- Length compositions: Commercial discards, headboat discards, recreational discards
- Age compositions: FWRI RTD survey
- Discard mortality: Fleet-specific discard mortality (descender devices)

[1] Abbreviations and acronyms used in this report are defined in Appendix A

2.2 Data Update

2.2.1 Life History

Estimates of the von Bertalanffy growth parameters were provided by SEDAR41 for the population as a whole: ($L_\infty = 911$ mm, $K = 0.24$ yr^{-1}, and $t_0 = -0.33$ yr). As well, two alternative von Bertalanffy curves were utilized, one for all fleets when no size limit was in place, and another to represent the fish captured under a 20-inch size limit regulation (Table 1).

Age-specific natural mortality (M) was modified from the approach of SEDAR41, which used the Charnov estimator (Charnov et al. 2013) scaled to the age-invariant Then estimator of $M = 0.13$ (Then et al. 2014). The scaling provided the same cumulative survival between the two estimators for ages 4 through the maximum observed age of 51. For SEDAR73, M was based on the Lorenzen estimator (Lorenzen 1996; 2000), which had been updated and presented by Dr. Lorenzen to the SEDAR73 Assessment Panel. This estimator was also scaled to the age-invariant Then estimator (ages 4+), but only for Lutjanids ($M = 0.11$) rather than all fishes. The scaled Lorenzen estimator has been adopted in this and other SEDAR assessments as the most reliable approach to infer age-dependent natural mortality.

The batch fecundity relationship was updated with an additional 28 specimens in the data set (SEDAR73-WP07 2020). Whereas SEDAR41 used a two-parameter power function of size, SEDAR73 used a three-parameter function (addition of an intercept parameter) that better characterized fecundity of smaller fish. However, for the smallest fish ($<\sim 400$ mm), the updated function would predict negative fecundity, and therefore these values were replaced by the mean observed value (55,523 eggs) for this size range.

Life-history information is summarized in Table 2.

2.2.2 Landings and Discards

The fleet structure used in SEDAR73 was the same as that of SEDAR41, including commercial handline, headboats, and general recreational (private and charter modes). The relatively small amount of landings from commercial "other" gears were pooled with commercial handline. Recreational landings and discards were estimated using the current MRIP methodology. In SEDAR41, historical recreational landings were split between headboat and general recreational back to 1955. In SEDAR73, historical recreational landings were allotted entirely to the general recreational fleet, with headboat split starting in 1978. This change is inconsequential to model results, as the two fleets (headboat and general recreational) were assumed to share a selectivity pattern during the historical period, but was made in the interest of model parsimony, avoiding the need for annual (1955–1977) estimates of headboat fishing rates. Dead discards were modeled as separate fleets. Total removals as used in the assessment are in Table 3.

2.2.3 Indices of Abundance

SEDAR73 included five indices of abundance: commercial handline, headboat, headboat discards, SERFS chevron trap, and SERFS video. In SEDAR41, the SERFS chevron trap and video indices were combined as a means to account for the lack of independence between these two sampling gears (i.e. cameras mounted on the chevron traps). However, a key assumption underlying that approach is that the selectivities of the two gears are equivalent. In preparation for SEDAR73, a special working group was formed to evaluate that assumption, and they found that the assumption was untenable for red snapper (SEDAR73-WP14 2020). Examining length data from stereo-video cameras, the working group found that selectivity of chevron traps for red snapper was likely dome-shaped, but the degree of doming was uncertain. Their report recommended dome-shaped selectivity for chevron traps, and flat-topped selectivity for video gear. Therefore, the SEDAR73 panel decided to maintain the two SERFS indices as separate input for the assessment, but also to multiply each of their likelihoods by 0.5 (half weight) in the model fitting process as an *ad hoc* method to account for dependence of the sampling. This approach is novel and was therefore considered to be a source of uncertainty by the SEDAR73 panel; its influence on results was evaluated through sensitivity analyses that dropped one SERFS index or the other (i.e., full weight to one index, none to the other). All five indices and their corresponding CVs are shown in Table 4. Fishery dependent indices of abundance from landings were assumed to have CVs of 0.2, which is consistent with Francis (2003).

A sixth, fishery independent index was considered for SEDAR73 and included in a sensitivity run. This index was developed by analysts from the FWRI using hook gear in a repetitive timed drop (RTD) survey. Sampling and standardization methods of the RTD survey are described in SEDAR73-WP06 (2020).

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. For inclusion, length compositions in any given year had to meet the sample size criteria of $nfish > 30$ and $ntrips \geq 10$ (Table 5). As in SEDAR41, length compositions were excluded in years when age compositions were available, to avoid "double dipping" of individual fish that were both measured and aged and because age compositions provide more informative signals of year-class strength.

Several new data sources not in SEDAR41 were considered for SEDAR73. For lengths of commercial discards, specimens were included from the Shark Bottom Longline Observer Program. This program puts observers on handline vessels (as well as longline), and these data were pooled with those from the South Atlantic Fisheries Foundation' Reef Fish Observer Program (which was used in SEDAR41). For lengths of headboat discards, specimens collected by Captain Steve Amick (2010–2013) were pooled with those from the SRHS (SEDAR73-WP04 2020). These samples added 1,311 fish to the headboat discard length compositions, which were weighted by state. For lengths of general recreational discards, specimens were included from an FWRI MARFIN project (SEDAR73-WP12 2020), collected from charterboats during 2013–2015. In addition, lengths of discarded fish collected by MyFishCount (2017–2019) and representing the general recreational fleet were included in a sensitivity run (SEDAR73-WP16 2020).

2.2.5 Age Compositions

For age composition data, the upper range was pooled at 10 years old (headboat, general recreational, SERFS CVT) or 13 years old (commercial) because older fish comprised a small proportion of the data and to minimize observations of zero in the fitting process. 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.

Sample sizes of age compositions for the commercial and recreational landings differ between SEDAR73 and SEDAR41 for a few reasons. Following SEDAR41, the contributors of age data had more time to examine critically the age sampling methodologies, including routine dockside sampling, directed studies, and carcass collection programs. Also, new tools became available to reconcile (i.e., verify) old records. As a result, some records were omitted from

SEDAR73, because they were not collected randomly from fishery landings (not representative), and some previously omitted records were retained in SEDAR73 due to the data reconciliation process. Other additions to SEDAR73 data included samples that were not processed in time for SEDAR41. Notable omissions from SEDAR73 data were commercial ages collected between 1988 and 2000, primarily from landings in South Carolina. Notable additions included commercial ages collected in 2009 and 2014, general recreational ages collected from the charter mode in 2002 and 2003, and headboat ages collected in 2009. Minor changes to the number of age samples available for SEDAR73 compared to SEDAR41 occurred in many years, but averaged less than 6% change to the annual totals by fleet. These modifications had negligible effects on the age compositions fitted by the assessment model.

For the sensitivity run that added the FWRI RTD index, the corresponding RTD age compositions were included as well. This was considered important for representing the range of ages available to the survey, and it allowed the model to estimate selectivity of that index.

2.2.6 Discard mortality

Discard mortality was reviewed and revised for SEDAR73 (Table 6). Several changes to SEDAR41 were implemented, based on consensus of the SEDAR73 Assessment Panel and guided by SEDAR73-WP15 (2020), which synthesized information on usage and effects of descender devices. Whereas SEDAR41 used the same discard mortality values for headboat and general recreational fleets, SEDAR73 uses distinct estimates. SEDAR41 used two time blocks for discard mortality, to account for transition from J-hooks to circle hooks; SEDAR73 maintains those blocks and adds two more to account for increased use of descender devices. The first new block (Block 3, 2017–2020) assumes 25% usage of descender devices, and the second new block (Block 4, 2021–) assumes 75% usage of descender devices and was implemented in projections. Without direct estimates from the commercial sector (SEDAR73-WP15 (2020) focused on the recreational sector), the same proportional reductions in discard mortality from the charterboat fleet were assumed to apply to the commercial fleet. The same levels of uncertainty from SEDAR41 were assumed to apply in SEDAR73.

3 Stock Assessment Methods

3.1 Overview

This operational assessment updated the primary model applied in SEDAR41 (2017), a state-of-the-art integrated model implemented using the Beaufort Assessment Model (BAM) software (Williams and Shertzer 2015). BAM applies a statistical catch-age formulation, coded in AD Model Builder (Fournier et al. 2012). BAM is referred to as an integrated model because it uses multiple data sources relevant to population and fishery dynamics (e.g. removals, length and age compositions, and indices of abundance) in a single framework. 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 and Wetzel 2013) and other stock assessment models used in the United States (Dichmont et al. 2016; Li et al. In Press). Versions of BAM have been used in previous SEDAR assessments of reef fishes in the U.S. South Atlantic, such as Black Sea Bass, Blueline Tilefish, Gag, Greater Amberjack, Red Grouper, Red Porgy, Snowy Grouper, Tilefish, and Vermilion Snapper, as well as in the previous SEDAR assessments of red snapper (SEDAR24 2010; SEDAR41 2017).

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 two fishery independent indices of abundance (SERFS chevron trap and SERFS video index). Data used in the model are tabulated in §2 of this report.

3.3 Model Configuration

The assessment time period was 1950–2019. The initial year was the same as in SEDAR41, with the terminal year extended from 2014 to 2019. 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 mortality from fishing and natural sources. 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 SEDAR41 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 relationship (described below). 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 Lorenzen (1996; 2000), a change from SEDAR41 which based natural mortality on the findings of Charnov et al. (2013). The Lorenzen 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 $M = 0.11$. This approach using cumulative mortality allows that fraction at the oldest age to be consistent with the findings of Then et al. (2014), here constrained to lutjanids. The scaled Lorenzen estimator has become common in SEDAR assessments as the most reliable approach to infer age-dependent natural mortality.

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 1, Table 1). 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 SEDAR41 DW and treated as input to the assessment model (Table 1). The sex ratio was assumed to be 50:50, as in SEDAR41.

3.9 Spawning stock

Spawning biomass was modeled as population fecundity (number of eggs). For red snapper, peak spawning was considered to occur in the middle of summer. This included information on batch size as a function of age (SEDAR73-WP07 2020), 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 mean recruitment model. This is a slight modification from the approach of SEDAR41. That assessment used the Beverton–Holt spawner–recruit model, but because the steepness parameter (h) could not be estimated (went to its upper bound), the mean recruitment model was approximated by fixing steepness at $h = 0.99$. Instead, the SEDAR73 assessment applies the mean recruitment model directly, by estimating the average annual recruitment (here, $R0$). To include annual variability in recruitment, the model estimates lognormal deviations around that average.

This modification was made after initial model explorations, including likelihood profiling on h, found that steepness still could not be estimated. This result is not uncommon, as steepness is often difficult to estimate reliably (Conn et al. 2010). The underlying assumption of the mean recruitment model is that recruitment is independent of spawning biomass, which is known to be incorrect for extremely low values of spawning biomass (e.g., zero spawners, zero recruits), unless recruits derive from outside the system.

3.11 Landings

Time series of landings from three fleets were modeled: commercial handline (1950–2019), general recreational (1955–2019), and headboat (1978–2019). 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). Historic landings of the recreational fleets were estimated indirectly using the FHWAR ratio method (SEDAR41 2017; SEDAR41-DW17 2015). Although the FHWAR method is considered best practice (SEDAR Procedural Guidance 2015), these 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. Annual discard mortalities, as fit by the model, were computed by multiplying total discards by the fleet-specific and year-specific release 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 Discard mortality

Discard mortality (or, release mortality) was modeled as fleet-specific and decreased through time following three time blocks for the assessment period and a fourth for the projection period (Table 6). As described in §2.2.6, the decreases through time were primarily due to regulations, starting with the transition from J-hooks to circle hooks, followed by the increasing use of descender devices. Uncertainty in the point estimates of discard mortality (Table 6) were incorporated in the full uncertainty analysis of assessment results (§3.25).

3.14 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.

Two alternative metrics of fishing intensity were also computed. The first, SPR_{F}, measures equilibrium spawning potential ratio conditioned on the rate of fishing in a given year (similar to the metric of Cordue (2012)). The values range between zero and one, where lower values indicate higher levels of exploitation. They can be compared to some threshold level such as 30% SPR; values lower than the threshold would indicate overfishing. The second alternative metric was exploitation rate (E). Exploitation rate is computed as total fish killed in a year (landings plus dead discards) divided by standing abundance. Here, it was computed for ages 1+, because all ages in the model are subjected to exploitation. Similar to other metrics, E can be compared to threshold values, such as the exploitation rate expected when fishing at F_{MSY} or its proxy.

3.15 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, this assessment (as in SEDAR41) applied flat-topped selectivity for the commercial handline fleet and dome-shaped selectivity for headboat and the general recreational fleets.

The fishery has experienced four periods 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/mini-seasons of 2010–2019. However, the 12-inch size limit had a negligible effect on the selectivity pattern. Thus, the assessment used three selectivity blocks (prior to 1992, 1992–2009, and 2010–2019), in which selectivity of each fleet was fixed within blocks, but permitted to vary among blocks where possible or reasonable. Because the general recreational fleet had little age or length composition data prior to 1998, selectivity of this fleet mirrored that of the headboat fleet in the first block. Dome-shaped headboat and general recreational selectivities were fixed as constant after age 10 at the value estimated for age 10. These plus groups were consistent with how the age composition data were fitted.

Selectivities of discards were also estimated in time blocks. Both the commercial handline discards and the headboat discards had sufficient length composition to estimate selectivities. In SEDAR41, selectivity of general recreational discards mirrored that of the headboat. However, new data sources available for SEDAR73 (§2) provided information on general recreational discard lengths in the third (last) time block, allowing for separate estimation in this block.

Selectivities of fishery dependent indices were the same as those of the relevant fleet. The headboat discard index tracks small fish (less than 20 inches), and thus applies the selectivity of headboat discards from block 2. Selectivity of fishery independent sources followed recommendations of the Selectivity Workgroup (SEDAR73-WP14 2020). Selectivity of the chevron trap index was modeled as dome-shaped, with its estimation informed by the SERFS chevron trap age compositions. Selectivity of the video index was assumed flat-topped, with its ascending limb mirroring that of the chevron trap index until it reaches a value of 1.0 and then fixed at 1.0 thereafter. This approach is guided by the belief that the ascending limb of the trap selectivity is determined by availability to the gear (therefore also available to be seen on video), but that larger, older fish, when present, would be detectable by video but not necessarily enter the traps. The shape of selectivities (flat-topped or dome-shaped) for each fleet and survey are shown in Table 7.

3.16 Indices of abundance

The model was fit to three fishery dependent indices of relative abundance (headboat 1976–2009; headboat discards 2005–2019; and commercial handlines 1993–2009), and two fishery independent indices of abundance (SERFS chevron traps 2010–2019; and SERFS video 2011–2019). Predicted indices were conditional on selectivity of the corresponding fleet or survey, and were computed from abundance (numbers of fish) at the midpoint of the year or, in the case of commercial handlines, biomass.

3.17 Catchability

In the BAM, catchability scales indices of relative abundance to the estimated population at large, adjusted by selectivity of the fleet or survey. For SEDAR73, as in SEDAR41, catchability (q) of each index was assumed to be time-invariant, and these parameters (one q per index) were estimated within BAM.

3.18 Biological reference points

As codified in this stock's FMP, 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 $F_{30\%}$, exploitation 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.

3.19 Fitting criteria and data weighting

Model parameters were estimated using 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 the Dirichlet-multinomial likelihood, 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.

SEDAR41 fit composition data using the robust multinomial with iterative re-weighting (Francis 2011); for comparison, that approach was used here in a sensitivity run. Since Francis (2011), additional work on this topic has questioned the use of the multinomial distribution in stock assessment models (Francis 2014), and has recommended the Dirichlet-multinomial as an alternative (Francis 2017; Thorson et al. 2017). A chief advantage of the Dirichlet-multinomial is that it is self-weighting through estimation of an additional variance inflation parameter for each composition component, making iterative re-weighting unnecessary. Another advantage is that it can better account for overdispersion, or, larger variance in the data than would be expected by the multinomial. Overdispersion can result from intra-haul correlation, which results when fish caught in the same set are more alike in length or age than fish caught in a different set (Pennington and Volstad 1994). The Dirichlet-multinomial has been implemented in Stock Synthesis (Methot and Wetzel 2013; Thorson et al. 2017) and in the BAM, and since SEDAR41 has become the standard likelihood for fitting composition data in assessments of South Atlantic reef fishes.

Preliminary model fits to the SERFS video index were considered inadequate by the Assessment Panel, especially in the terminal years where the model was under-fitting (i.e., positive residuals). To help remedy this, the Panel increased the weight of this index to a value of 3. In effect, this divides annual CVs by 3 within the lognormal likelihood. This weighting was examined through sensitivity analyses, which applied weights of 2 (less weight), 4 (more weight), or 0 (index removed). In addition (as mentioned previously in §2), the total likelihood of each SERFS index was multiplied by 0.5 to account for correlation in the sampling.

For parameters defining selectivities, CV of size at age, F_{init}, Dirichlet-multinomial overdispersion parameters, and σ_R, normal priors were applied to maintain parameter estimates near reasonable values, and to prevent the gradient-based optimization routine from drifting into parameter space with negligible changes 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).

3.20 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 mixed Monte-Carlo and bootstrap ensemble (MCBE) approach (described below).

3.21 Sensitivity analyses

Sensitivity runs were chosen to investigate issues that arose specifically with this operational assessment. They were intended to demonstrate directionality of results with changes in inputs or simply to explore model behavior. These model runs vary from the base run as follows:

- S1: Included MyFishcount data on lengths of general recreational discards
- S2: Included FWC RTD index and corresponding age compositions
- S3: Drop SERFS CVT index
- S4: Drop SERFS VID index, with upweighting=3 on the CVT index
- S5: Drop headboat discard index
- S6: Increased weight=4 on the SERFS VID index
- S7: Decreased weight=2 on the SERFS VID index
- S8: High natural mortality (Lorenzen curve scaled to $M = 0.15$, which implies maximum age of 38)
- S9: Low natural mortality (Lorenzen curve scaled to $M = 0.07$, which implies maximum age of 87)
- S10: Charnov natural mortality curve scaled to $M = 0.13$, based on all fishes in Then et al. (2014), as in SEDAR41
- S11: Charnov natural mortality curve scaled to $M = 0.11$, based on lutjanids in Then et al. (2014)
- S12: Fit composition data with the robust multinomial, adjusted by iterative reweighting
- S13: Discards starting in 2010 adjusted downward to 10% of their observed values
- S14: Natural mortality adjusted upward until the stock is considered rebuilt

Sensitivities 13 and 14 are considered hypothetical "what if" scenarios. Sensitivity 13 was included to demonstrate the potential for stock rebuilding if discard mortality is substantially reduced. The value of 10% was chosen because it is roughly similar to the reduction in landings starting in 2010 from the general recreational fleet, the primary source of recent discards (ratio of average landings 2010–2019 to 2000–2009 is 0.07). Sensitivity 14 addressed the question of how high natural mortality would need to be for the stock to be considered rebuilt. For this analysis, the constant M used for scaling the Lorenzen estimator was increased until rebuilding was achieved in the terminal year of the assessment. Here, $M = 0.2$, which implies a maximum age of 28 (Then et al. 2014). For this stock of red snapper, the maximum age observed is 51.

3.22 Parameters Estimated

The model estimated annual fishing mortality rates of each fleet, selectivity parameters, catchability coefficients associated with indices, parameters of the mean recruitment model (R_0 and σ_R), annual recruitment deviations, Dirichlet-multinomial variance inflation factors, and CVs of size at age for each growth relationship. Estimated parameters are listed in Appendix B.

3.23 Per Recruit and Equilibrium Analyses

Equilibrium spawning potential ratio (SPR_{F}) of each year was computed as the asymptotic spawners (population fecundity) per recruit given that year's fishery-specific Fs and selectivities, divided by spawners per recruit that would be obtained in an unexploited stock. In this form, SPR_{F} ranges between zero and one, and it represents SPR that would be achieved under an equilibrium age structure given the year-specific F.

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 §3.24), 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 (2017–2019).

3.24 Benchmark/Reference Point Methods

The reference point for red snapper has been codified in the FMP to be $F_{30\%}$. Thus, in this assessment, the quantities $F_{30\%}$, $\mathrm{SSB}_{\mathrm{F30\%}}$, $E_{\mathrm{F30\%}}$, $B_{\mathrm{F30\%}}$, and $L_{\mathrm{F30\%}}$ were estimated as proxies for MSY-based reference points. The value of $F_{30\%}$ is the F that provides 30% SPR. To compute biomass benchmarks, equilibrium recruitment was assumed equal to expected recruitment in arithmetic space (mean unbiased). However, in BAM, spawner-recruit parameters correspond to median-unbiased recruitment. Thus, on average, expected recruitment is higher than that estimated directly from the spawner-recruit model (i.e., R_0, when using the mean recruitment model), because of lognormal deviation in recruitment. Therefore, 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,

$$R_{eq} = \varsigma R_0 \tag{1}$$

where R_0 is median-unbiased virgin recruitment. 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 estimates of $\mathrm{SSB}_{\mathrm{F30\%}}$ and $E_{\mathrm{F30\%}}$ follow 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 (2017–2019). 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 (2019), and current status of the fishery is represented by the geometric mean of F from the latest three years (2017–2019). Similarly, the two alternative fishing intensity metrics, (SPR_{F}) and exploitation rate, represent current fishery status with the geometric mean of the terminal three years. Generally, South Atlantic assessments have considered the mean over the terminal three years to be a more robust metric than that of a single, terminal year.

3.25 Uncertainty and Measures of Precision

As in SEDAR41, this assessment used a mixed Monte Carlo and bootstrap ensemble (MCBE) 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), and it is considered to be one of the more complete characterizations of uncertainty used in stock assessments across the United States.

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 main advantage of the approach is that the results describe a range of possible outcomes, so that the ensemble of models characterizes uncertainty in results more thoroughly than any single fit or handful of sensitivity runs (Scott et al. 2016; Jardim et al. 2021). A minor disadvantage of the approach is that computational demands are relatively high, but this can largely be mitigated through use of parallel processing.

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 8% were discarded, because the model did not properly converge (the Hessian was not positive definite or a parameter hit a bound). This left $n = 3677$ MCBE runs to characterize uncertainty, which was sufficient for convergence of standard errors in management quantities. All runs were given equal weight when forming the ensemble of results (Jardim et al. 2021).

The MCBE 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.

3.25.1 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 MCBE runs, 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 in landings and discards was similarly modeled with multiplicative lognormal error, using the CVs as described in (SEDAR41 2017). The values used in this assessment are tabulated in Table 8, treated as annual, independent errors.

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.

3.25.2 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.

3.26 Natural mortality

As in each model run, the vector of age-specific natural mortality (Lorenzen estimator) was scaled to the Then et al. (2014) age-invariant M as was done for the base run. The Then et al. (2014) estimator is,

$$M = aT_{max}^{b} \tag{3}$$

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 (lutjanids only) with replacement. For each MCBE iteration, 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, $T_{max} \sim U[48, 53]$. This provided a new M value in each MCBE iteration, used to generate a new (scaled Lorenzen) age-dependent vector.

3.27 Discard mortality

The Assessment Panel developed discard mortality and ranges of uncertainty by fleet and for different time periods Table (6). The rates decreased over time with implementation of circle hooks, and later with use of descender devices. To characterize uncertainty in these values, we drew the rate for the earliest time period for each fleet from a truncated normal distribution with mean equal to the point estimate and a standard deviation such that the range matched the 95% confidence interval. For subsequent time periods, 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 prior time period. Fixing the upper bound in this manner was designed to maintain the desired feature that discard mortality has decreased over time due to fishing practices (use of circle hooks and descender devices).

3.28 Batch Fecundity

Prior to the MCBE analysis, a bootstrap procedure was run on the data set used to estimate batch fecundity at length for the base run. For each of 10,000 bootstrap runs, the 97 paired observations of batch fecundity and fish length were sampled 97 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 any of the three parameter values was outside of its 95% confidence interval. Then, for each MCBE run, a set of parameters (a row) was drawn from the trimmed bootstrap parameter matrix, so as to maintain any correlation structure. That run's predicted batch fecundity at age was calculated using the set of bootstrap parameters and the vector of mean length at age.

3.29 Batch number

Prior to the MCBE 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 10,000 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. For each the MCBE run, a vector of batch number at age was randomly drawn, with replacement, from the trimmed bootstrap parameter matrix.

3.30 Historical recreational landings

Recreational landings (headboat and general recreational prior to 1981) were developed in SEDAR41 using the FHWAR method. Uncertainty in the scale of those landings was implemented by multiplying their values by a normal deviate with mean of 1.0 and CV=0.59 (Table 8), truncated to plus/minus one standard deviation. For each MCBE run, this multiplier shifted the entire time series of headboat and general recreational landings to values higher or lower than in the base run.

3.31 Projections

Projections were run to predict stock status in years after the assessment, 2020–2044. 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 landings, averaged across fleets using geometric mean Fs from the last three years of the assessment period, as in the computation of $L_{\mathrm{F30\%}}$ benchmarks (§3.24). Similarly, a single, average selectivity curve was applied to calculate dead discards.

Expected values of SSB (time of peak spawning), F, recruits, landings, and dead discards were represented by deterministic projections using parameter estimates from the base run. These projections applied mean recruit 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 ensemble (MCBE) fits of the stock assessment model.

3.31.1 Initialization of projections

Initial age structure at the start of 2020 was computed by the assessment model.

Fishing rates that define the projections were assumed to start in 2023. Because the assessment period ended in 2019, the projections required an initialization period (2020–2022). For this period, an optimization routine solved for the F that matched the current level of landings (arithmetic mean of 2017-2019).

3.31.2 Discard mortality in projections

The discard mortality rate was decreased in projections, starting in the year 2021 (Table 6). This decrease was intended to represent the more widespread use of descender devices. Because projections apply a fleet-averaged selectivity curve to discards, the reduction in discard mortality was treated in a similar fashion. First the proportion of each fleet's discard F of the total discard F was computed based on geometric means of the terminal three years (2017–2019), and these proportions were used to compute weighted mean discard mortality rates from Block 3 ($\hat{D}_3$) and Block 4 ($\hat{D}_4$). Then, the ratio of these weighted means provided the reduction in discard mortality, $D_R = \hat{D}_4/\hat{D}_3$, which scaled the forecast fishing rate (F) downward for computing discards, e.g., $F_D = D_R F$, where F_D is fishing rate applied to dead discards.

3.31.3 Benchmarks for projections

The reduction in discard mortality applied in projections modifies the relative contributions of dead discards and landings toward the overall selectivity pattern. In turn, this modification would affect the computation of benchmarks. Thus, for evaluating stock and fishery status in the projections, benchmarks were recomputed using the methods described above (§3.24) but with the lower discard mortality rate. This second set of benchmarks (e.g., $F_{30\%}$, $\mathrm{SSB}_{\mathrm{F30\%}}$) was used for projections, while the first set was used for the assessment period.

3.31.4 Uncertainty of projections

To characterize uncertainty in future stock dynamics, stochasticity was included in replicate projections, each an extension of a single MCBE assessment model fit. Thus, projections carried forward uncertainties of the ensemble in natural mortality, reproduction, landings, discards, and discard mortalities, as well as in estimated quantities such as selectivity curves, and in initial (start of 2020) abundance at age.

Initial and subsequent recruitment values were generated with stochasticity using a Monte Carlo procedure, in which the estimated recruitment parameters (i.e. R_0, σ_R) of each MCBE fit was used to compute mean annual recruitment values ($\bar{R}_y = R_0$). 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 MCBE fit.

The procedure generated 20,000 replicate projections of MCBE model fits drawn at random (with replacement) from the MCBE runs. In cases where the same MCBE 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 5^{th} and 95^{th} percentiles of the replicate projections.

3.32 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 was 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 0.5. In addition, the SSC's red snapper $P^{\star}$ Working Group (met 3 February 2021) applied their ABC Control Rule to recommend a rebuilding probability of 0.675. 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 MCBE run).

Projection scenarios Six projection scenarios were considered.

- Scenario 1: $F = F_{30\%}$
- Scenario 2: $F = F_{30\%}$ with higher than expected recruitment
- Scenario 3: $F = F_{\mathrm{rebuild}}$, with rebuilding probability of 0.5 in 2044

- Scenario 4: $F = F_{\text{rebuild}}$, with rebuilding probability of 0.5 in 2044 and higher than expected recruitment
- Scenario 5: $F = F_{\text{rebuild}}$, with rebuilding probability of 0.675 in 2044
- Scenario 6: $F = F_{\text{rebuild}}$, with rebuilding probability of 0.675 in 2044 and higher than expected recruitment

The F_{rebuild} is defined as the maximum F that achieves rebuilding in the allowable time frame. The high recruitment scenarios assume that higher than expected recruitment predicted in the last six years of the assessment period would continue into the future. Rather than applying mean recruitment from the full assessment time period, they apply the geometric mean recruitment from 2014–2019. For the deterministic projections, that geometric mean was applied directly; for the stochastic projections, it was adjusted to be median unbiased prior to applying lognormal deviations. All projections apply the second set of benchmarks (projection benchmarks) when applying $F_{30\%}$ or $\text{SSB}_{\text{F30\%}}$ for evaluating rebuilding probabilities.

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 were reasonably close to observed data in most years, as were predicted age compositions (Figure 2). The model was configured to fit observed commercial and recreational removals closely (Figures 3–8). Fits to indices of abundance generally captured the observed trends but not all annual fluctuations (Figures 9–13).

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 9). Total estimated abundance was at its lowest value in the early 1990s, but at its highest levels at the end of the time series, comparable to estimates in the 1950s and 1960s, but with a more truncated age structure. The MCBE results reflect the same patterns with their associated uncertainties for total abundance and abundance of age 2+ (Figure 15). Annual number of recruits is shown in Table 9 (age-1 column) and in Figure 16. The highest recruitment values were predicted to have occurred in the mid-1980s, 2006–2008, and the terminal six years of the assessment (2014–2019). It can be instructive to track those strong year-classes through time, e.g., the 2006–2008 recruits are ages 12–14 in the terminal year 2019 (Table 9).

4.4 Total and Spawning Biomass

Estimated biomass at age followed a similar pattern as abundance at age (Figure 17; Tables 10, 11), but the biomass recovery in recent years occurs to a lesser degree than the abundance recovery, because the age structure has shifted toward younger fish compared to the first several decades of the assessment period. Total biomass and spawning biomass showed similar trends—general decline through to the early-1990s, and relatively stable or increasing patterns since the mid-1990s (Figure 18; Table 12). The increase during 2013–2018 was notably rapid, although that increase appears to have subsided in the terminal year. Nonetheless, terminal year estimates are at levels not seen since around 1980, but with a younger age structure.

4.5 Selectivity

Selectivity of the SERFS indices are 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. Selectivities from each time block are tabulated in Tables 13, 14, 15. In the most recent selectivity block, full selection of landings or discards occurred near ages 2–5, depending on the fleet.

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, Table 16). These average selectivities were used in computation of point estimates of benchmarks, as well as in projections.

4.6 Fishing Mortality and Removals

Estimates of total F by fleet are shown in Figure 27 and Table 17, and estimates of F at age are shown in Table 18. 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. Since 2010, general recreational discards have been the dominant source of fishing mortality.

Alternative measures of fishing intensity have implications similar to those of apical F (Figure 28). The value of SPR_{F} has remained below 30% since the mid-1970s, with the single exception of 2013. Similarly, the exploitation rate has remained above that corresponding to $F_{30\%}$ since the late-1970s, with the exception of 2013. Since 2010, the exploitation rate has been dominated by dead discards, especially from the general recreational fleet.

Estimated time series of landings and discards are shown in Figures 29–31 and Tables 19–22. Table 23 shows total landings at age in numbers, and Table 24 in weight. Table 25 shows total discards at age in numbers, and Table 26 in weight. The general recreational fleet has been the dominant source of removals, for both landings and dead discards. Since 2010, total landings have remained near or below the level at $L_{\mathrm{F}30\%}$ (Figure 30), however discards have exceeded the $D_{F_{30\%}}$ level for most of these years (Figure 31).

4.7 Spawner-Recruitment Parameters

The mean recruit relationship and variability around that mean are shown in Figure 32. Values of recruitment-related parameters were as follows: unfished age-1 recruitment $\widehat{R_0} = 383121$, and standard deviation of recruitment residuals in log space $\widehat{\sigma}_R = 0.51$ (which resulted in bias correction of $\varsigma = 1.14$). Uncertainty in these quantities was estimated through the MCBE analysis (Figure 33).

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 (2017–2019) (Figures 34, 35).

As in per recruit analyses, equilibrium spawning biomass was computed as a function of F (Figure 36). Similarly, equilibrium biomass and removals are functions of F, allowing for their relationships to be depicted together (Figure 37).

4.9 Benchmarks / Reference Points

As described in §3.24, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the mean-unbiased recruitment (Figure 32). Reference points estimated were $F_{30\%}$, $L_{\mathrm{F30\%}}$, $B_{\mathrm{F30\%}}$, $\mathrm{SSB}_{\mathrm{F30\%}}$, and $E_{\mathrm{F30\%}}$. 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 MCBE analysis (§3.25).

Maximum likelihood estimates (base run) of benchmarks, as well as median values from MCBE analysis, are summarized in Table 27. Point estimates of $L_{\mathrm{F30\%}}$-related quantities were $F_{30\%} = 0.21$ (y^{-1}), $L_{\mathrm{F30\%}} = 405$ (1000 lb), $B_{\mathrm{F30\%}} = 6531$ (mt), and $\mathrm{SSB}_{\mathrm{F30\%}} = 635426$ (1E8 Eggs). Median estimates were $F_{30\%} = 0.21$ (y^{-1}), $L_{\mathrm{F30\%}} = 408$ (1000 lb), $B_{\mathrm{F30\%}} = 6484$ (mt), and $\mathrm{SSB}_{\mathrm{F30\%}} = 594630$ (1E8 Eggs). Distributions of these benchmarks from the MCBE analysis are shown in Figure 38.

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 increase since 2010 (Figure 39, Table 12). Base-run estimates of spawning biomass have remained below $\mathrm{SSB}_{\mathrm{F30\%}}$ since 1980. Current stock status was estimated in the base run to be $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{F30\%}} = 0.44$ (Table 27), indicating that, although increasing, the stock has not yet recovered to $\mathrm{SSB}_{\mathrm{F30\%}}$. Median values from the MCBE analysis indicated similar results $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{F30\%}} = 0.49$. The uncertainty analysis suggested that the terminal estimate of stock status is robust (Figures 40, 41). Of the MCBE runs, 97.8% indicated that the stock was below $\mathrm{SSB}_{\mathrm{F30\%}}$ in 2019. Age structure estimated by the base run showed fewer older fish in the last few decades than the (equilibrium) age structure expected at $F_{30\%}$ (Figure 42). However, there is improvement in the terminal year(2019), particularly for ages younger than fifteen.

The estimated time series of $F/F_{30\%}$ suggests that overfishing has occurred throughout most of the assessment period (Table 12, Figure 39). Current fishery status in the terminal year, with current F represented by the geometric mean from years 2017–2019, was estimated by the base run to be $F/F_{30\%} = 2.20$ (Table 27). The fishery status was also robust (Figures 40, 41). Of the MCBE runs, approximately 99.8% agreed with the base run that the stock is currently experiencing overfishing. Alternative fishing intensity metrics provided similar results about fishery status as did apical F (Figure 43).

Compared to SEDAR41, the qualitative results of stock and fishery status are similar (Figure 44). The SEDAR41 assessment estimated similar trends in overfishing, but at higher rates. It estimated an earlier decline in stock status, but nearly identical values since 1990. After the terminal year of SEDAR41 (2014), SEDAR73 estimates substantial improvement in stock status.

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 MCBE 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. This operational assessment explored sensitivity of the base run to changes in data input, natural mortality, and composition likelihood (Figures 45–51). Of these modifications, results were most sensitive to the scale of natural mortality. In the exploratory sensitivity run with hypothetically low discarding since 2010, overfishing was not occurring in the terminal years (Figure 52 but was more severe in years prior. This was due to a lower value of $F_{30\%}$ that emphasized landings than discards, as computed from the terminal three years. In the exploratory sensitivity run with hypothetically high natural mortality, the stock was not overfished in the terminal year, by definition (Figure 53). The scale of M that allowed for a rebuilt stock in 2019 was $M = 0.2$, and based on the Then et al. (2014) relationship, this value implied a maximum age of 28.

The hypothetical M sensitivity run was the only one that showed a rebuilt stock in 2019 (this run was configured to do so), and the hypothetical discard sensitivity run was the only one not showing overfishing in the terminal years (Table 28). Of the remaining runs, results appeared to be most sensitive to natural mortality.

Retrospective analyses suggest no concerning patterns of estimating F or SSB in the terminal year (Figure 54). However, terminal-year recruitment was underestimated in some (but not all) retrospective peels. In those cases, the model estimated recruitment near the overall mean value, rather than at the higher levels predicted by the base model.

4.12 Projections

For projections, going from discard block 3 to block 4 (Table 6), the fleet-weighted average reduction in discard mortality was about 12% in the base run, and about 13% (median) in the MCBE runs. Because of this reduction in discard mortality for projections, benchmarks were recomputed for evaluating projected stock status (Table 29).

Projections based on $F = F_{30\%}$ and mean recruitment allowed the spawning stock to continue its upward trend, although not to a level considered rebuilt by 2044 (Figures 55, 56; Table 30). However, if recruitment remains high, the spawning stock is projected to rebuild quickly, within about five years (Figures 57, 58; Table 31). The four F_{rebuild} scenarios allow for stock recover, by design (Figures 59–66, Tables 32–35). For the high recruitment scenarios, F_{rebuild} exceeds $F_{30\%}$.

5 Discussion

The base run of the BAM indicated that the stock remains overfished $\text{SSB}/\text{SSB}_{\text{F30\%}}$ =0.44, and that overfishing is occurring $F/F_{30\%}$ =2.20, though at a lower rate than in terminal years of previous red snapper assessments (Figure 44; F_{2006}/F_{MSY} =7.51 for SEDAR15, $F_{2007-2009}/F_{\text{MSY}}$ =4.12 for SEDAR24, $F_{2012-2014}/F_{\text{MSY}}$ =2.52 for SEDAR41). The primary driver of overfishing in recent years has been recreational discards. In the future, mortality of discards may be mitigated to some degree through increased use of descender devices. This assessment estimated that, since 2010, total abundance and spawning stock have been increasing at a relatively rapid rate, showing substantial progress toward rebuilding. Despite overfishing, this increase in abundance has been stimulated by higher than average recruitment.

The Monte Carlo/bootstrap ensemble analyses showed widespread agreement with the qualitative results of the base run. Of all MCBE runs, 97.8% showed that the stock is not yet rebuilt, and 99.8% showed that overfishing is occurring. These results are also in agreement with 12 sensitivity run configurations of this assessment (not including two runs that were developed as hypothetical), as well as with results from previous benchmark assessments of SEDAR15, SEDAR24, and SEDAR41 and all of their 100 sensitivity run configurations (31 in SEDAR15, 42 in SEDAR24, and 27 in SEDAR41).

5.1 Comments on the Assessment

Estimated benchmarks played a central role in this assessment. Values of $\mathrm{SSB}_{\mathrm{F}30\%}$ 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. In this assessment, the projections did use a different set of benchmarks than did the assessment period, to account for reduction in discard mortality. However, benchmarks would likely be modified further, if selectivity patterns change in the future, for example as a result of new size limits or different relative catch allocations among sectors.

In addition to including the more recent years of data, this operational assessment contained several modifications to the previous data of SEDAR41, such as the use of modern MRIP methodology, the separation of SERFS chevron trap and video indices, additional data sources on discard length compositions, and discard mortality. Furthermore, life-history information on fecundity and natural mortality was updated. A sensitivity run included the FRWI RTD index and the corresponding age composition data. 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 questionable. This situation amplifies the importance of fishery independent sampling, such as through SERFS, and sampling programs conducted by the states.

Two SERFS indices of abundance were included in this assessment, one developed from chevron trap data and one from video data. Because the video cameras are mounted on top of traps, sampling by these two gears is not independent. In previous SEDAR assessments, including SEDAR41, this non-independence was accounted for by combining the two indices into one prior to fitting the assessment model. However, that approach implicitly assumes that selectivities of the two gears are equivalent, which was not found to be the case by the selectivity working group (SEDAR73-WP14 2020). Instead, the working group found that, for red snapper, selectivity of chevron traps is dome-shaped relative to that of video cameras. This assessment fitted the two indices as separate time series to allow for different selectivities, but acknowledged their dependence by multiplying each likelihood by 0.5, such that their sum (rather than each component) would have full weight relative to other data sources. This weighting approach is novel, as this is the first SEDAR assessment for which these SERFS indices were fitted separately. Sensitivity to this choice of weights (i.e., [0.5,0.5]) was evaluated through model runs that gave full weight to one index or the other (i.e., [1,0] or [0,1]), and results were nearly identical regardless of weights (Figure 47).

Many assessed stocks in the southeast U.S. have shown histories of heavy exploitation. High rates of fishing mortality can lead to changes in life-history characteristics, such as growth and maturity schedules. Indeed, red snapper mature at a very young age relative to their maximum lifespan. This could in theory be explained by a density dependent response, in which more per capita resources available at low biomass allow for greater energetic investment in reproduction at younger ages. It could also be indicative of an adaptive response to exploitation. 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; Heino et al. 2013).

Because steepness could not be estimated reliably, this assessment used the mean recruitment model. SEDAR41 had approximated the mean model by fixing steepness at $h = 0.99$. In either approach, MSY-based management quantities are not appropriate, and a proxy is required. Here, as in SEDAR41, $F_{30\%}$ was used as a proxy for F_{MSY}.

Natural mortality plays a driving role in this assessment, as it does in most. The pattern of natural mortality at age affects multiple outputs, including annual fishing rates, benchmarks, and equilibrium age structure expected at MSY (or proxies and related quantities). Although this assessment estimates record-high abundance in recent years, the stock remains overfished while the age structure is still rebuilding. Nonetheless, progress on rebuilding the age structure is apparent, particularly for ages younger than fifteen (Figure 42). However, rebuilding to MSY levels can be a lengthy process for a fish that can live 50 years (current maximum observed age is 51). The natural mortality rate, on which the bar for rebuilding age structure is predicated, was estimated in this assessment using meta-analytical methods that are common in SEDAR. However, natural mortality of red snapper remains a source of uncertainty in the assessment, and the age structure associated with optimum yield may differ from MSY-related levels, depending on management objectives.

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 projections did, however, account for the reduction in discard mortality expected to result from increased use of descender devices.
- The projections assumed that the estimated 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

- Results of this assessment are sensitive to natural mortality. The scale and age dependence of natural mortality were estimated using meta-analytical methods, as is common in SEDAR assessments. While such methods describe relationships between M and other life-history characteristics (growth, maximum age) averaged across species, they may not describe well the natural mortality of any particular species. Research into natural mortality specific to red snapper in the South Atlantic region would benefit this assessment.
- This assessment used two indices of abundance from SERFS, one from chevron trap data and one from video data. In previous SEDAR assessments, indices from these gears were combined prior to fitting within the assessment, because the two gears do not sample independent (cameras housed on top of traps). However, this assessment includes these as separate indices because of new information suggesting that their selectivities differ for red snapper. To account for dependence of sampling, the likelihoods of the indices were multiplied

each by 0.5, such that the two combined received full weight. Research into statistical methodology for fitting indices derived from non-independent sampling, such as with a bivariate likelihood, might benefit this and other assessments.

- More research on discard mortality, particularly the use and effect of descender devices, would benefit stock assessments of South Atlantic reef fishes.

- More research on discard mortality, particularly the use and effect of descender devices, would benefit stock assessments of South Atlantic reef fishes.

5.4 Sampling Recommendations

- The selectivity of video gear was inferred for this assessment, based on sampling by FWRI and by SERFS (separately) using stereo cameras. Increased sampling with stereo video cameras would benefit this and other assessments of South Atlantic reef fishes, particularly for cases where selectivity of video cameras cannot reasonably be assumed to mirror that of chevron traps.

- Estimates of recreational landings and discards are critical for this assessment and for monitoring the stock. Thus, it remains important to continue estimation of recreational landings during mini-seasons and discards year-round, and any potential methodological or sampling improvements should be implemented if 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., 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.

Cordue, P. L. 2012. Fishing intensity metrics for use in overfishing determination. ICES Journal of Marine Science **69**:615–623.

Dichmont, C. M., R. A. Deng, A. E. Punt, J. Brodziak, Y. Chang, J. Cope, J. N. Ianelli, C. M. Legault, R. D. Methot Jr., C. E. Porch, M. H. Prager, and K. W. Shertzer. 2016. A review of stock assessment packages in the United States. Fisheries Research **183**:447–450.

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.

Francis, R. 2014. Replacing the multinomial in stock assessment models: A first step. Fisheries Research **151**:70–84.

Francis, R. 2017. Revisiting data weighting in fisheries stock assessment models. Fisheries Research **192**:5–14.

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.

Heino, M., L. Baulier, D. S. Boukal, B. Ernande, F. D. Johnston, et al. 2013. Con fisheries-induced evolution shift reference points for fisheries management? ICES Journal of Marine Science **70**:707–721.

Jardim, E., M. Azevedo, J. Brodziak, E. N. Brooks, K. F. Johnson, N. Klibansky, C. P. Millar, C. Minto, I. Mosqueira, R. D. M. Nash, P. Vasilakopoulos, and B. K. Wells. 2021. Operationalizing model ensembles for scientific advice to fisheries management. ICES Journal of Marine Science **https://doi.org/10.1093/icesjms/fsab010**.

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.

Li, B., K. W. Shertzer, P. D. Lynch, J. N. Ianelli, C. M. Legault, E. H. Williams, R. D. Methot Jr., E. N. Brooks, J. J. Deroba, A. M. Berger, S. R. Sagarese, J. K. T. Brodziak, I. G. Taylor, M. A. Karp, C. R. Wetzel, and M. Supernaw. In Press. A comparison of four primary age-structured stock assessment models used in the United States. Fishery Bulletin .

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.

Lorenzen, K. 2000. Allometry of natural morality as a basis for assessing optimal release size in fish-stocking programmes. Canadian Journal of Fisheries and Aquatic Sciences **57**:2374–2381.

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

Pennington, M., and J. H. Volstad. 1994. Assessing the effect of intra-haul correlation and variable density on estimates of population characteristics from marine surveys. Biometrics **50**:725–732.

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.

Scott, F., E. Jardim, C. Millar, and S. Cervino. 2016. An applied framework for incorporating multiple sources of uncertainty in fisheries stock assessments. PLOS ONE **11**:1–21.

SEDAR Procedural Guidance, 2010. SEDAR Procedural Workshop IV: Characterizing and Presenting Assessment Uncertainty.

SEDAR Procedural Guidance, 2015. SEDAR Procedural Workshop 7: Data Best Practices, SEDAR, North Charleston, SC.

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, 2017. SEDAR41 - South Atlantic Red Snapper Assessment Report – Revision 1, SEDAR, North Charleston, SC.

SEDAR41-DW17, 2015. Estimates of historic recreational landings of red snapper in the South Atlantic using the FHWAR census method.

SEDAR41-DW49, 2015. Estimating annual fecundity of Red Snapper by size using nonlinear models. SEDAR41-DW49. SEDAR, North Charleston, SC.

SEDAR73-WP04, 2020. Georgia red snapper headboat discard lengths, 2010–2013.

SEDAR73-WP06, 2020. Indices of abundance for Red Snapper (*Lutjanus campechanus* from the FWC Fish and Wildlife Research Institute (FWRI) repetive timed drop survey in the U.S. South Atlantic.

SEDAR73-WP07, 2020. Updated estimates of batch fecundity vs. total length, total weight, and calendar age for South Atlantic Red Snapper in support of the SEDAR73 operational assessment.

SEDAR73-WP12, 2020. Size and age composition of red snapper, *Lutjanus campechanus*, collected in association with fishery-independent and fishery-dependent projects along Florida's Atlantic coast, 2012 to 2019.

SEDAR73-WP14, 2020. Workgroup Report on the Selectivity of Red Snapper in the South Atlantic Region.

SEDAR73-WP15, 2020. Utility and usage of descender devices in the red snapper recreational fishery in the South Atlantic.

SEDAR73-WP16, 2020. My Fish Count data for red snapper.

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.

Thorson, J. T., K. F. Johnson, R. D. Methot, and I. G. Taylor. 2017. Model-based estimates of effective sample size in stock assessment models using the Dirichlet-multinomial distribution. Fisheries Research **192**:84–93.

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. 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-inch 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	0.13	1.2	13.8	0.1	1.5	17.9	0.1	3.2
2	17.7	0.13	3.1	18.3	0.1	3.4	20.9	0.1	5.1
3	21.6	0.13	5.6	21.9	0.1	5.9	23.4	0.1	7.2
4	24.6	0.13	8.3	24.8	0.1	8.5	25.5	0.1	9.3
5	27.0	0.13	11.0	27.1	0.1	11.1	27.3	0.1	11.4
6	28.9	0.13	13.5	28.9	0.1	13.5	28.8	0.1	13.3
7	30.4	0.13	15.7	30.4	0.1	15.7	30.1	0.1	15.2
8	31.6	0.13	17.5	31.6	0.1	17.6	31.1	0.1	16.9
9	32.5	0.13	19.1	32.6	0.1	19.3	32.1	0.1	18.4
10	33.2	0.13	20.4	33.4	0.1	20.7	32.8	0.1	19.7
11	33.8	0.13	21.5	34.0	0.1	21.9	33.5	0.1	20.9
12	34.2	0.13	22.3	34.5	0.1	22.8	34.0	0.1	21.9
13	34.6	0.13	23.0	34.9	0.1	23.6	34.5	0.1	22.8
14	34.9	0.13	23.6	35.2	0.1	24.3	34.8	0.1	23.6
15	35.1	0.13	24.0	35.5	0.1	24.8	35.2	0.1	24.2
16	35.2	0.13	24.4	35.7	0.1	25.2	35.4	0.1	24.8
17	35.4	0.13	24.7	35.8	0.1	25.6	35.7	0.1	25.3
18	35.5	0.13	24.9	36.0	0.1	25.9	35.9	0.1	25.7
19	35.6	0.13	25.1	36.1	0.1	26.1	36.0	0.1	26.1
20	35.6	0.13	25.2	36.1	0.1	26.3	36.2	0.1	26.4

Table 2. Average size (TL, in mm and in) and weight (Wgt, lb), proportion female (PropFem), Female maturity (FemMat), batch fecundity (BF, 1e3 eggs), Batches per year (BpYr), and natural mortality (M).

Age	Avg.TL(mm)	Avg.TL(in)	Avg.Wgt	PropFem	FemMat	BF	BpYr	M
1	323.9	12.8	1.2	0.5	0.43	55.5	22	0.29
2	449.3	17.7	3.1	0.5	0.73	165.4	45	0.21
3	547.9	21.6	5.6	0.5	0.91	480.7	63	0.17
4	625.4	24.6	8.3	0.5	0.97	809.6	77	0.15
5	686.4	27.0	11.0	0.5	0.99	1123.6	88	0.14
6	734.4	28.9	13.5	0.5	1.00	1407.4	97	0.13
7	772.2	30.4	15.7	0.5	1.00	1654.5	104	0.12
8	801.9	31.6	17.5	0.5	1.00	1864.3	109	0.12
9	825.2	32.5	19.1	0.5	1.00	2039.1	114	0.12
10	843.6	33.2	20.4	0.5	1.00	2182.9	117	0.11
11	858.1	33.8	21.5	0.5	1.00	2299.8	120	0.11
12	869.4	34.2	22.3	0.5	1.00	2394.3	122	0.11
13	878.4	34.6	23.0	0.5	1.00	2470.1	123	0.11
14	885.4	34.9	23.6	0.5	1.00	2530.7	125	0.11
15	891.0	35.1	24.0	0.5	1.00	2578.9	126	0.11
16	895.3	35.2	24.4	0.5	1.00	2617.2	126	0.11
17	898.7	35.4	24.7	0.5	1.00	2647.6	127	0.11
18	901.4	35.5	24.9	0.5	1.00	2671.7	128	0.11
19	903.5	35.6	25.1	0.5	1.00	2690.7	128	0.11
20	905.2	35.6	25.2	0.5	1.00	2705.7	128	0.11

Table 3. Observed time series of landings(L) and dead discards(D) for commercial lines (cH), headboat (HB), and general recreational (GR). Commercial landings values are in units of 1000 lb whole weight; all others are in units of 1000 fish.

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	.	36.536	.	.	.
1956	483.907	.	39.899	.	.	.
1957	867.291	.	43.263	.	.	.
1958	612.508	.	46.626	.	.	.
1959	657.736	.	49.989	.	.	.
1960	671.075	.	53.353	.	.	.
1961	796.374	.	58.184	.	.	.
1962	645.983	.	63.015	.	.	.
1963	488.789	.	67.847	.	.	.
1964	537.589	.	72.678	.	.	.
1965	558.108	.	77.510	.	.	.
1966	554.506	.	77.964	.	.	.
1967	725.503	.	78.418	.	.	.
1968	865.520	.	78.872	.	.	.
1969	538.190	.	79.326	.	.	.
1970	513.023	.	79.780	.	.	.
1971	457.393	.	87.665	.	.	.
1972	406.641	.	95.549	.	.	.
1973	296.560	.	103.434	.	.	.
1974	478.352	.	111.319	.	.	.
1975	600.790	.	119.204	.	.	.
1976	571.504	.	120.549	.	.	.
1977	596.339	.	121.894	.	.	.
1978	594.356	15.278	107.961	.	.	.
1979	420.936	15.445	109.140	.	.	.
1980	385.485	15.611	110.318	.	.	.
1981	378.759	36.031	380.314	.	.	2.699
1982	308.445	19.553	96.056	.	.	2.699
1983	316.818	30.698	115.439	.	.	2.699
1984	253.431	31.146	487.310	.	0.026	44.826
1985	250.824	50.336	557.006	.	0.041	37.208
1986	219.440	16.625	156.665	.	0.014	37.208
1987	191.701	24.996	122.532	.	0.020	37.208
1988	173.689	36.527	197.170	.	0.030	22.827
1989	266.942	23.453	251.295	.	0.019	12.675
1990	226.542	20.919	29.760	.	0.017	12.675
1991	143.546	13.857	72.485	.	0.011	12.675
1992	104.374	5.301	76.105	8.893	0.929	14.321
1993	220.153	7.347	30.167	7.721	1.287	65.865
1994	195.319	8.225	32.708	9.745	1.441	45.838
1995	177.312	8.826	17.240	9.720	1.546	32.510
1996	138.671	5.543	29.977	9.553	0.971	14.302
1997	110.595	5.770	16.734	10.314	1.011	6.256
1998	89.602	4.741	41.929	7.425	0.830	40.218
1999	93.595	6.836	99.202	6.266	1.197	120.165
2000	104.165	8.437	142.022	6.704	1.478	205.371
2001	196.697	12.028	135.065	6.972	2.107	198.061
2002	187.967	12.931	152.517	12.393	2.265	125.918
2003	138.342	5.706	60.691	3.966	0.999	149.751
2004	172.083	10.842	103.201	0.974	7.142	263.268
2005	129.700	8.907	53.373	4.776	3.690	48.039
2006	86.382	5.945	62.230	2.183	6.455	167.432
2007	114.973	6.889	60.086	4.997	27.158	356.523
2008	252.146	18.943	328.723	4.745	27.634	526.318
2009	362.386	21.507	421.979	5.380	21.425	355.531
2010	6.448	0.477	0.058	6.133	14.371	172.418
2011	0.568	1.359	0.058	14.724	10.915	70.348
2012	8.142	2.127	5.942	7.473	12.299	107.116
2013	31.600	1.520	0.058	6.260	12.152	59.018
2014	65.443	2.952	14.090	10.116	12.119	208.156
2015	4.723	0.750	2.035	11.417	14.145	366.453
2016	3.176	0.331	0.077	13.523	17.293	669.917
2017	90.349	2.724	19.422	7.561	10.325	420.756
2018	127.982	4.435	27.030	4.986	11.822	838.821
2019	120.410	4.055	30.648	4.549	12.140	511.036

Table 4. Observed indices of abundance and CVs from commercial line (cH), headboat (HB), headboat discard (HB.D), SERFS chevron traps (CVT), and SERFS video (VID).

Year	cH	cH CV	HB	HB CV	HB.D	HB.D CV	CVT	CVT CV	VID	VID 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	0.39	0.28	.	.	.	.
2006	0.60	0.2	0.43	0.2	0.45	0.32	.	.	.	.
2007	0.67	0.2	0.44	0.2	2.13	0.19	.	.	.	.
2008	1.22	0.2	1.71	0.2	1.72	0.24	.	.	.	.
2009	1.94	0.2	1.81	0.2	0.98	0.22	.	.	.	.
2010	.	.	.	.	0.47	0.22	0.31	0.20	.	.
2011	.	.	.	.	0.34	0.27	0.32	0.18	0.28	0.16
2012	.	.	.	.	0.65	0.27	0.56	0.14	0.54	0.13
2013	.	.	.	.	0.70	0.25	0.45	0.15	0.43	0.11
2014	.	.	.	.	0.92	0.23	0.76	0.13	0.63	0.18
2015	.	.	.	.	1.67	0.23	1.10	0.13	1.29	0.14
2016	.	.	.	.	1.21	0.29	1.42	0.11	1.10	0.12
2017	.	.	.	.	0.92	0.23	1.59	0.10	1.55	0.11
2018	.	.	.	.	1.10	0.25	2.02	0.10	1.60	0.10
2019	.	.	.	.	1.36	0.24	1.48	0.09	1.59	0.10

Table 5. Sample sizes (numbers 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 SERFS chevron traps (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	.	.	.	.	137	.	.
1982	.	.	.	.	55	.	.
1983	.	.	.	.	167	.	.
1984	125	.	.	.	176	.	.
1985	139	.	.	.	162	.	.
1986	94	.	.	.	99	.	.
1987	89	.	.	.	68	.	.
1988	84	.	.	.	18	.	.
1989	88	.	.	.	.	.	.
1990	63	.	.	.	24	.	.
1991	106	.	.	.	13	.	.
1992	82	.	.	.	.	.	.
1993	.	.	.	.	.	.	.
1994	.	.	.	.	.	.	.
1995	.	.	.	.	.	.	.
1996	.	.	.	37	.	.	.
1997	.	.	.	12	.	.	.
1998	.	.	.	16	.	.	.
1999	.	.	.	.	.	.	.
2000	.	.	.	.	.	.	.
2001	.	.	.	22	.	25	.
2002	.	.	.	.	.	100	.
2003	.	.	.	10	.	102	.
2004	.	.	.	22	10	88	.
2005	.	.	42	53	28	96	.
2006	.	.	30	80	69	45	.
2007	.	.	64	138	40	13	.
2008	.	13	61	157	52	.	.
2009	.	.	57	269	293	90	.
2010	.	.	121	.	.	.	73
2011	.	.	115	.	.	.	70
2012	.	.	99	39	54	420	148
2013	.	.	118	107	39	441	139
2014	.	.	58	101	63	1012	150
2015	.	52	59	.	.	.	164
2016	.	.	58	.	.	.	214
2017	.	.	61	94	28	227	242
2018	.	.	68	183	40	623	276
2019	.	.	66	56	.	642	290

Table 6. Discard mortality for commercial handlines (cH), headboat (HB), and general recreational (GR). For cH, Block 1 ends in 2006, and Block 2 is 2007–2016. For HB and GR, Block 1 ends in 2010, and Block 2 is 2011–2017. For all fleets, Block 3 is 2017–2020, and Block 4 is post-2020 (for projections). Shown in parentheses are the ranges used in uncertainty analyses.

Fleet	Block 1	Block 2	Block 3	Block 4
cH	0.48(0.38 − 0.58)	0.38(0.28 − 0.48)	0.36(0.26 − 0.46)	0.32(0.22 − 0.42)
HB	0.37(0.27 − 0.45)	0.26(0.18 − 0.34)	0.25(0.17 − 0.33)	0.22(0.14 − 0.30)
GR	0.37(0.27 − 0.45)	0.28(0.20 − 0.36)	0.26(0.18 − 0.34)	0.23(0.15 − 0.31)

Table 7. Selectivity blocks by fleet or survey, with shape of selectivity indicated (Flat for flat-topped, Dome for dome-shaped). Selectivities correspond to landings (L) or dead discards (D) from commercial handline (cH), headboat (HB), or general recreational (GR) fleets, to the headboat discard index (HBD), to the SERFS chevron trap index (CVT), or to the SERFS video index (VID). Selectivity of L.GR in Block 1 mirrored that of L.HB in Block 1, selectivity of D.HB and D.GR shared a single common curve in Blocks 1 and 2, and selectivity of HBD in Blocks 2 and 3 mirrored that of D.HB in Block 2.

Fleet/survey	Block 1 (1950–1991)	Block 2 (1992–2009)	Block 3 (2010–2019)
L.cH	Flat	Flat	Flat
L.HB	Dome	Dome	Dome
L.GR	Dome	Dome	Flat
D.cH	—	Dome	Flat
D.HB	Dome	Dome	Dome
D.GR	Dome	Dome	Dome
HBD	—	Dome	Dome
CVT	—	—	Dome
VID	—	—	Flat

Table 8. Coefficients of variation used in the MCBE analysis for landings (L) and discards (D) of commercial handline (cH), headboat (HB), and general recreational (GR) fleets.

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	.	.	.
1956	0.25	.	0.59	.	.	.
1957	0.25	.	0.59	.	.	.
1958	0.25	.	0.59	.	.	.
1959	0.25	.	0.59	.	.	.
1960	0.25	.	0.59	.	.	.
1961	0.25	.	0.59	.	.	.
1962	0.20	.	0.59	.	.	.
1963	0.20	.	0.59	.	.	.
1964	0.20	.	0.59	.	.	.
1965	0.20	.	0.59	.	.	.
1966	0.20	.	0.59	.	.	.
1967	0.20	.	0.59	.	.	.
1968	0.20	.	0.59	.	.	.
1969	0.20	.	0.59	.	.	.
1970	0.20	.	0.59	.	.	.
1971	0.20	.	0.59	.	.	.
1972	0.20	.	0.59	.	.	.
1973	0.20	.	0.59	.	.	.
1974	0.20	.	0.59	.	.	.
1975	0.20	.	0.59	.	.	.
1976	0.20	.	0.59	.	.	.
1977	0.20	.	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	0.40	.	.	1.00
1982	0.10	0.15	0.55	.	.	1.00
1983	0.10	0.15	0.37	.	.	0.71
1984	0.10	0.15	0.36	.	0.2	0.75
1985	0.10	0.15	0.46	.	0.2	0.74
1986	0.05	0.15	0.37	.	0.2	1.00
1987	0.05	0.15	0.25	.	0.2	0.83
1988	0.05	0.15	0.46	.	0.2	0.44
1989	0.05	0.15	0.32	.	0.2	0.52
1990	0.05	0.15	0.45	.	0.2	1.00
1991	0.05	0.15	0.40	.	0.2	0.53
1992	0.05	0.15	0.33	0.2	0.2	0.36
1993	0.05	0.15	0.35	0.2	0.2	0.69
1994	0.05	0.15	0.36	0.2	0.2	0.39
1995	0.05	0.15	0.39	0.2	0.2	0.40
1996	0.05	0.10	0.57	0.2	0.2	0.71
1997	0.05	0.10	0.45	0.2	0.2	0.39
1998	0.05	0.10	0.37	0.2	0.2	0.49
1999	0.05	0.10	0.23	0.2	0.2	0.23
2000	0.05	0.10	0.22	0.2	0.2	0.24
2001	0.05	0.10	0.27	0.2	0.2	0.29
2002	0.05	0.10	0.21	0.2	0.2	0.23
2003	0.05	0.10	0.24	0.2	0.2	0.34
2004	0.05	0.10	0.24	0.2	0.2	0.23
2005	0.05	0.10	0.26	0.2	0.2	0.23
2006	0.05	0.10	0.28	0.2	0.2	0.36
2007	0.05	0.10	0.33	0.2	0.2	0.24
2008	0.05	0.05	0.28	0.2	0.2	0.25
2009	0.05	0.05	0.27	0.2	0.2	0.25
2010	0.05	0.05	1.00	0.2	0.2	0.36
2011	0.05	0.05	1.00	0.2	0.2	0.47
2012	0.05	0.05	0.20	0.2	0.2	0.32
2013	0.05	0.05	0.20	0.2	0.2	0.32
2014	0.05	0.05	0.20	0.2	0.2	0.22
2015	0.05	0.05	0.73	0.2	0.2	0.36
2016	0.05	0.05	1.00	0.2	0.2	0.26
2017	0.05	0.05	0.69	0.2	0.2	0.26
2018	0.05	0.05	0.40	0.2	0.2	0.28
2019	0.05	0.05	0.26	0.2	0.2	0.24

Table 9. 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	436.87	325.50	255.12	207.11	171.70	144.21	122.09	104.09	89.10	76.50	65.87	56.84	49.09	42.44	36.73	31.79	27.54	23.86	20.69	135.09	2422.24
1951	436.87	326.91	260.43	211.53	175.36	147.28	124.69	106.31	91.00	78.13	67.28	58.05	50.14	43.35	37.52	32.47	28.13	24.37	21.13	137.97	2458.90
1952	436.87	326.59	260.34	214.89	178.25	149.71	126.74	108.06	92.50	79.41	68.38	59.01	50.96	44.06	38.13	33.00	28.59	24.77	21.48	140.25	2481.99
1953	436.87	326.90	261.26	215.82	181.92	152.87	129.43	110.34	94.45	81.09	69.83	60.25	52.04	45.00	38.94	33.70	29.20	25.29	21.93	143.21	2510.36
1954	436.87	326.88	261.45	216.53	182.67	155.99	132.14	112.66	96.43	82.79	71.30	61.52	53.13	45.94	39.76	34.41	29.81	25.82	22.39	146.22	2534.72
1955	436.87	326.42	259.68	215.20	182.01	155.55	133.90	114.22	97.77	83.94	72.29	62.37	53.87	46.58	40.31	34.89	30.22	26.18	22.71	148.25	2543.23
1956	436.87	325.45	253.66	208.46	176.88	152.03	131.40	114.27	98.17	84.52	72.95	62.95	54.37	47.01	40.68	35.21	30.50	26.42	22.91	149.61	2524.32
1957	436.87	325.34	252.27	203.05	170.90	147.42	128.18	111.96	98.10	84.78	73.41	63.49	54.84	47.41	41.03	35.51	30.76	26.65	23.11	150.90	2505.98
1958	436.87	324.23	247.90	198.36	163.57	140.01	122.22	107.44	94.58	83.40	72.51	62.90	54.46	47.08	40.75	35.27	30.55	26.47	22.95	149.86	2461.39
1959	436.87	324.69	248.48	196.02	160.74	134.84	116.86	103.18	91.44	81.04	71.90	62.64	54.39	47.14	40.80	35.31	30.59	26.50	22.98	150.03	2436.42
1960	436.87	324.41	247.57	195.41	158.03	131.88	112.05	98.25	87.49	78.09	69.65	61.92	54.00	46.94	40.72	35.24	30.53	26.45	22.93	149.74	2408.16
1961	436.87	324.20	246.37	193.84	156.89	129.17	109.22	93.93	83.10	74.54	66.98	59.86	53.27	46.50	40.46	35.10	30.41	26.34	22.84	149.16	2379.06
1962	436.87	323.62	243.79	190.87	154.07	127.02	106.02	90.79	78.82	70.27	63.49	57.16	51.14	45.56	39.81	34.64	30.08	26.06	22.60	147.53	2340.19
1963	436.87	323.77	243.54	188.95	151.84	124.91	104.46	88.35	76.41	66.89	60.09	54.40	49.03	43.91	39.15	34.21	29.80	25.87	22.44	146.50	2311.37
1964	436.87	323.97	244.04	188.99	150.56	123.37	103.00	87.34	74.64	65.12	57.46	51.73	46.87	42.29	37.91	33.80	29.57	25.75	22.38	146.15	2291.82
1965	436.87	323.60	242.54	187.99	149.56	121.55	101.14	85.67	73.43	63.34	55.73	49.27	44.40	40.27	36.37	32.60	29.10	25.45	22.19	145.24	2266.33
1966	436.87	323.28	240.81	185.60	147.86	120.07	99.16	83.75	71.75	62.11	54.05	47.65	42.17	38.04	34.54	31.19	27.99	24.98	21.87	143.87	2237.61
1967	436.87	323.20	240.21	183.97	145.75	118.53	97.82	82.01	70.08	60.64	52.96	46.18	40.75	36.10	32.59	29.59	26.75	24.01	21.45	142.31	2211.76
1968	436.87	322.58	237.85	181.69	143.05	115.72	95.66	80.15	68.00	58.69	51.24	44.84	39.14	34.57	30.66	27.68	25.16	22.74	20.43	139.35	2176.07
1969	436.87	321.99	235.21	178.18	139.94	112.53	92.54	77.69	65.88	56.46	49.18	43.03	37.69	32.93	29.12	25.82	23.34	21.21	19.19	134.85	2133.67
1970	436.87	322.91	237.90	178.58	139.12	111.61	91.25	76.22	64.77	55.50	48.01	41.90	36.69	32.17	28.14	24.88	22.09	19.96	18.16	131.89	2118.62
1971	436.87	322.93	238.60	180.63	139.45	110.97	90.52	75.18	63.57	54.59	47.21	40.92	35.75	31.34	27.51	24.06	21.29	18.90	17.10	128.55	2105.95
1972	436.87	322.75	237.44	180.13	140.34	110.77	89.72	74.41	62.62	53.54	46.44	40.24	34.92	30.54	26.80	23.52	20.59	18.22	16.19	124.77	2090.82
1973	436.87	322.53	236.01	178.12	139.17	110.97	89.23	73.55	61.87	52.69	45.54	39.57	34.33	29.82	26.10	22.90	20.12	17.62	15.61	120.73	2073.34
1974	436.87	322.52	235.24	176.44	137.26	109.86	89.33	73.17	61.22	52.16	44.94	38.92	33.85	29.40	25.56	22.37	19.65	17.27	15.13	117.10	2058.25
1975	436.87	321.45	230.92	172.42	133.43	106.43	86.97	72.12	60.03	50.92	43.92	37.91	32.87	28.62	24.88	21.63	18.95	16.65	14.64	112.12	2023.75
1976	436.87	320.47	226.12	166.06	128.05	101.74	82.96	69.22	58.40	49.34	42.41	36.65	31.67	27.48	23.95	20.82	18.12	15.88	13.96	106.32	1976.50
1977	436.87	320.29	224.50	161.84	122.81	97.28	79.05	65.86	55.94	47.93	41.05	35.35	30.58	26.45	22.98	20.03	17.43	15.17	13.30	100.76	1935.47
1978	160.49	319.92	222.86	159.51	118.87	92.70	75.14	62.42	52.97	45.70	39.71	34.07	29.38	25.44	22.02	19.13	16.69	14.52	12.65	95.16	1619.37
1979	162.12	117.36	220.53	156.72	116.05	88.96	71.06	58.95	49.91	43.06	37.71	32.83	28.20	24.34	21.10	18.26	15.88	13.86	12.07	89.58	1378.54
1980	423.81	118.19	78.91	150.72	111.19	85.03	67.05	55.04	46.72	40.37	35.45	31.11	27.11	23.31	20.14	17.46	15.13	13.15	11.49	84.28	1455.65
1981	143.59	307.47	76.90	51.98	103.40	79.09	62.48	50.84	42.87	37.27	32.88	28.93	25.41	22.16	19.08	16.48	14.30	12.39	10.79	78.54	1216.85
1982	320.45	94.32	105.63	24.95	18.78	41.77	35.71	31.49	28.36	26.18	24.61	21.76	19.17	16.85	14.71	12.66	10.95	9.50	8.24	59.41	925.52
1983	982.27	226.21	53.11	59.58	14.89	11.80	27.55	24.69	22.71	21.23	20.24	19.07	16.87	14.88	13.09	11.43	9.85	8.52	7.40	52.68	1618.07
1984	971.54	697.74	130.07	30.58	36.14	9.48	7.87	19.21	17.91	17.06	16.43	15.71	14.81	13.12	11.58	10.19	8.91	7.67	6.64	46.84	2089.49
1985	315.55	632.36	261.34	47.46	12.39	16.19	4.68	4.27	11.38	11.47	11.69	11.28	10.79	10.19	9.03	7.97	7.02	6.14	5.29	36.90	1433.41
1986	265.27	193.92	176.73	69.72	14.54	4.34	6.46	2.12	2.18	6.47	7.15	7.29	7.05	6.75	6.38	5.65	5.00	4.40	3.85	26.47	821.74
1987	511.88	169.50	87.02	82.41	35.87	8.05	2.56	4.06	1.41	1.53	4.72	5.23	5.35	5.17	4.96	4.68	4.16	3.67	3.24	22.31	967.79
1988	421.18	336.43	80.97	42.73	44.10	20.53	4.89	1.65	2.76	1.00	1.13	3.50	3.88	3.97	3.84	3.68	3.48	3.09	2.73	19.02	1004.56
1989	171.54	278.99	145.28	34.76	20.06	22.45	11.28	2.90	1.05	1.86	0.71	0.80	2.49	2.76	2.83	2.74	2.63	2.49	2.21	15.55	725.39
1990	153.11	108.90	90.74	45.55	12.20	7.86	9.78	5.46	1.54	0.61	1.16	0.45	0.50	1.57	1.74	1.78	1.73	1.66	1.57	11.19	459.07
1991	291.07	103.78	60.85	52.79	28.16	7.87	5.25	6.75	3.88	1.13	0.45	0.87	0.33	0.38	1.17	1.30	1.33	1.29	1.24	9.57	579.46
1992	252.83	196.79	52.09	30.98	28.88	16.36	4.83	3.40	4.58	2.75	0.83	0.33	0.64	0.25	0.28	0.87	0.96	0.99	0.96	8.00	607.58
1993	109.41	179.33	137.30	20.62	9.47	10.25	6.91	2.41	1.95	2.95	1.92	0.58	0.23	0.45	0.17	0.20	0.61	0.68	0.69	6.31	492.45
1994	191.52	64.47	105.87	71.81	10.44	5.22	6.06	4.35	1.60	1.35	2.10	1.37	0.41	0.17	0.32	0.12	0.14	0.44	0.48	5.01	473.23
1995	100.65	116.56	39.46	57.24	37.79	5.99	3.21	3.96	2.99	1.14	0.99	1.55	1.01	0.31	0.12	0.24	0.09	0.10	0.32	4.07	377.79
1996	175.67	62.17	72.83	22.36	32.25	23.07	3.87	2.18	2.80	2.18	0.85	0.74	1.16	0.76	0.23	0.09	0.18	0.07	0.08	3.31	406.85
1997	253.02	120.03	43.27	40.94	11.68	18.33	14.14	2.54	1.51	2.03	1.64	0.64	0.56	0.88	0.57	0.17	0.07	0.13	0.05	2.56	514.77
1998	484.96	181.87	89.77	27.59	24.77	7.51	12.44	10.07	1.88	1.16	1.59	1.28	0.50	0.44	0.69	0.45	0.14	0.06	0.11	2.06	849.34
1999	620.36	336.91	129.82	51.87	14.60	14.17	4.66	8.32	7.18	1.41	0.90	1.24	1.00	0.39	0.34	0.54	0.35	0.11	0.04	1.70	1195.93
2000	726.61	401.20	216.21	58.45	19.96	6.36	7.08	2.65	5.29	4.99	1.05	0.67	0.92	0.75	0.29	0.26	0.40	0.26	0.08	1.30	1454.79
2001	431.85	440.93	238.12	90.53	21.04	8.24	3.05	3.91	1.65	3.62	3.66	0.77	0.49	0.68	0.55	0.22	0.19	0.30	0.19	1.02	1251.01
2002	410.12	251.18	251.50	104.34	35.63	9.37	4.17	1.73	2.46	1.12	2.62	2.65	0.56	0.36	0.49	0.40	0.16	0.14	0.22	0.88	1080.10
2003	584.48	248.12	148.76	107.34	38.91	15.18	4.58	2.32	1.08	1.67	0.81	1.89	1.92	0.40	0.26	0.36	0.29	0.11	0.10	0.80	1159.38
2004	207.81	358.08	154.91	87.73	62.62	24.40	10.14	3.25	1.72	0.83	1.32	0.65	1.51	1.53	0.32	0.21	0.29	0.23	0.09	0.72	918.36
2005	83.22	87.58	142.70	63.62	38.06	31.14	13.58	6.24	2.17	1.23	0.63	1.00	0.49	1.14	1.16	0.24	0.16	0.22	0.18	0.61	475.36
2006	1797.50	47.58	50.18	77.99	35.04	22.93	20.21	9.41	4.57	1.66	0.97	0.50	0.79	0.39	0.90	0.92	0.19	0.12	0.17	0.63	2072.67
2007	1303.02	1202.06	32.44	27.49	38.86	19.06	13.71	13.22	6.64	3.43	1.30	0.77	0.39	0.62	0.30	0.71	0.72	0.15	0.10	0.63	2665.63
2008	1060.46	818.05	767.51	18.19	14.72	22.55	11.96	9.26	9.50	5.01	2.68	1.02	0.60	0.31	0.49	0.24	0.56	0.57	0.12	0.58	2744.37
2009	208.34	578.33	430.62	309.63	6.59	6.14	10.89	6.63	5.76	6.48	3.66	1.96	0.75	0.44	0.22	0.36	0.18	0.41	0.42	0.51	1578.32
2010	168.55	91.70	229.17	113.02	68.81	1.82	2.12	4.65	3.39	3.39	4.23	2.40	1.29	0.49	0.29	0.15	0.24	0.12	0.27	0.61	696.69
2011	253.98	101.80	49.72	117.72	62.74	44.11	1.33	1.70	3.90	2.91	2.95	3.69	2.09	1.12	0.43	0.25	0.13	0.21	0.10	0.77	651.63
2012	230.06	169.51	65.68	31.37	77.98	44.98	33.94	1.08	1.41	3.28	2.46	2.50	3.13	1.77	0.95	0.36	0.21	0.11	0.18	0.74	671.71
2013	444.85	145.48	99.53	36.75	18.46	51.07	32.67	26.45	0.87	1.16	2.73	2.06	2.09	2.62	1.49	0.80	0.31	0.18	0.09	0.77	870.42
2014	1078.01	307.32	100.83	68.54	26.31	14.02	40.90	27.13	22.40	0.75	1.00	2.36	1.78	1.81	2.27	1.29	0.69	0.26	0.16	0.75	1698.57
2015	1201.78	707.31	191.44	59.47	41.20	17.10	9.90	30.61	20.95	17.58	0.59	0.79	1.87	1.41	1.44	1.80	1.03	0.55	0.21	0.72	2307.77
2016	1046.63	775.86	431.13	112.80	37.06	28.50	13.04	8.07	25.82	17.98	15.22	0.51	0.69	1.63	1.23	1.25	1.57	0.89	0.48	0.81	2521.16
2017	1458.37	619.39	402.17	208.68	59.32	22.91	20.51	10.38	6.77	22.23	15.68	13.31	0.45	0.60	1.43	1.08	1.10	1.38	0.78	1.14	2867.66
2018	939.06	960.86	391.14	243.75	130.24	40.20	16.89	16.02	8.36	5.54	18.35	12.96	11.01	0.37	0.50	1.18	0.89	0.91	1.15	1.60	2800.99
2019	1212.59	540.22	470.23	172.47	114.06	71.98	26.27	12.36	12.44	6.68	4.49	14.90	10.54	8.97	0.30	0.41	0.97	0.73	0.75	2.24	2683.59
2020	436.87	764.14	313.85	256.04	97.04	71.38	50.31	19.81	9.70	9.96	5.41	3.64	12.10	8.57	7.29	0.25	0.33	0.79	0.59	2.43	2070.50

Table 10. 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	231	458	650	784	858	882	868	828	773	708	642	576	513	454	401	352	308	269	235	1545	12336
1951	231	460	663	801	877	901	886	846	789	724	656	588	524	464	409	359	315	275	240	1578	12586
1952	231	460	663	813	891	916	901	860	802	735	666	598	533	472	416	365	320	280	244	1603	12770
1953	231	460	666	817	910	935	920	878	819	751	680	611	544	482	425	373	327	286	249	1637	13000
1954	231	460	666	820	913	955	939	896	836	767	695	623	555	492	433	381	334	292	255	1672	13214
1955	231	460	662	815	910	952	952	909	848	777	704	632	563	498	440	386	338	296	258	1695	13325
1956	231	458	646	789	884	930	934	909	851	783	711	638	568	503	444	390	341	298	261	1711	13280
1957	231	458	643	769	854	902	911	891	851	785	715	643	573	507	447	393	344	301	263	1725	13207
1958	231	456	632	751	818	857	869	855	820	772	706	637	569	504	444	390	342	299	261	1713	12927
1959	231	457	633	742	804	825	831	821	793	750	701	635	568	504	445	391	342	299	261	1715	12749
1960	231	457	631	740	790	807	797	782	759	723	679	628	564	502	444	390	342	299	261	1712	12535
1961	231	456	628	734	784	790	776	747	721	690	653	607	557	498	441	388	340	297	260	1705	12304
1962	231	456	621	722	770	777	754	722	683	651	619	579	534	488	434	383	337	294	257	1687	12000
1963	231	456	620	715	759	764	743	703	663	619	585	551	512	470	427	378	333	292	255	1675	11754
1964	231	456	622	715	753	755	732	695	647	603	560	524	490	453	413	374	331	291	255	1671	11570
1965	231	456	618	712	748	744	719	682	637	587	543	499	464	431	397	361	326	287	252	1661	11352
1966	231	455	614	703	739	735	705	666	622	575	527	483	441	407	377	345	313	282	249	1645	11113
1967	231	455	612	696	729	725	695	653	608	562	516	468	426	386	355	327	299	271	244	1627	10886
1968	231	454	606	688	715	708	680	638	590	544	499	454	409	370	334	306	282	257	232	1593	10590
1969	231	453	599	674	700	689	658	618	571	523	479	436	394	352	317	286	261	239	218	1542	10242
1970	231	455	606	676	696	683	649	607	562	514	468	425	383	344	307	275	247	225	207	1508	10066
1971	231	455	608	684	697	679	643	598	551	506	460	415	374	335	300	266	238	213	194	1470	9918
1972	231	454	605	682	702	678	638	592	543	496	452	408	365	327	292	260	230	206	184	1427	9772
1973	231	454	601	674	696	679	634	585	536	488	444	401	359	319	285	253	225	199	177	1380	9622
1974	231	454	599	668	686	672	635	582	531	483	438	394	354	315	279	248	220	195	172	1339	9495
1975	231	453	588	653	667	651	618	574	521	472	428	384	343	306	271	239	212	188	166	1282	9248
1976	231	451	576	629	640	623	590	551	506	457	413	371	331	294	261	230	203	179	159	1216	8911
1977	231	451	572	613	614	595	562	524	485	444	400	358	320	283	251	222	195	171	151	1152	8593
1978	85	450	568	604	594	567	534	497	459	423	387	345	307	272	240	212	187	164	144	1088	8128
1979	86	165	562	593	580	544	505	469	433	399	367	333	295	260	230	202	178	156	137	1024	7519
1980	224	166	201	570	556	520	477	438	405	374	345	315	283	249	220	193	169	149	131	964	6950
1981	76	433	196	197	517	484	444	405	372	345	320	293	266	237	208	182	160	140	123	898	6295
1982	170	133	269	94	94	256	254	251	246	242	240	221	200	180	160	140	123	107	94	679	4153
1983	520	318	135	225	74	72	196	197	197	197	197	193	176	159	143	126	110	96	84	602	4020
1984	514	982	331	116	181	58	56	153	155	158	160	159	155	140	126	113	100	87	76	536	4355
1985	167	890	666	180	62	99	33	34	99	106	114	114	113	109	98	88	79	69	60	422	3603
1986	140	273	450	264	73	27	46	17	19	60	70	74	74	72	70	63	56	50	44	303	2242
1987	271	239	222	312	179	49	18	32	12	14	46	53	56	55	54	52	47	41	37	255	2045
1988	223	474	206	162	220	126	35	13	24	9	11	35	41	42	42	41	39	35	31	217	2026
1989	91	393	370	132	100	137	80	23	9	17	7	8	26	30	31	30	29	28	25	178	1745
1990	81	153	231	172	61	48	70	43	13	6	11	5	5	17	19	20	19	19	18	128	1139
1991	154	146	155	200	141	48	37	54	34	10	4	9	3	4	13	14	15	15	14	109	1180
1992	134	277	133	117	144	100	34	27	40	25	8	3	7	3	3	10	11	11	11	91	1189
1993	58	252	350	78	47	63	49	19	17	27	19	6	2	5	2	2	7	8	8	72	1091
1994	101	91	270	272	52	32	43	35	14	12	20	14	4	2	3	1	2	5	6	57	1036
1995	53	164	101	217	189	37	23	31	26	11	10	16	11	3	1	3	1	1	4	47	946
1996	93	88	186	85	161	141	28	17	24	20	8	8	12	8	3	1	2	1	1	38	923
1997	134	169	110	155	58	112	101	20	13	19	16	7	6	9	6	2	1	2	1	29	969
1998	257	256	229	104	124	46	88	80	16	11	15	13	5	5	8	5	2	1	1	24	1289
1999	328	474	331	196	73	87	33	66	62	13	9	13	10	4	4	6	4	1	0	19	1735
2000	385	565	551	221	100	39	50	21	46	46	10	7	10	8	3	3	4	3	1	15	2088
2001	229	621	607	343	105	50	22	31	14	34	36	8	5	7	6	2	2	3	2	12	2139
2002	217	354	641	395	178	57	30	14	21	10	25	27	6	4	5	4	2	2	2	10	2005
2003	309	349	379	406	195	93	33	18	9	15	8	19	20	4	3	4	3	1	1	9	1880
2004	110	504	395	332	313	149	72	26	15	8	13	7	16	16	4	2	3	3	1	8	1996
2005	44	123	364	241	190	191	97	50	19	11	6	10	5	12	13	3	2	2	2	7	1391
2006	952	67	128	295	175	140	144	75	40	15	9	5	8	4	10	10	2	1	2	7	2090
2007	690	1692	83	104	194	117	97	105	58	32	13	8	4	7	3	8	8	2	1	7	3232
2008	561	1152	1955	69	74	138	85	74	82	46	26	10	6	3	5	3	6	6	1	7	4311
2009	110	814	1097	1172	33	38	77	53	50	60	36	20	8	5	2	4	2	5	5	6	3596
2010	89	129	584	428	344	11	15	37	29	31	41	24	13	5	3	2	3	1	3	7	1801
2011	134	143	127	446	314	270	9	14	34	27	29	37	22	12	5	3	1	2	1	9	1638
2012	122	239	167	119	390	275	241	9	12	30	24	25	33	19	10	4	2	1	2	9	1734
2013	236	205	254	139	92	313	232	210	8	11	27	21	22	28	16	9	3	2	1	9	1836
2014	571	433	257	259	132	86	291	216	194	7	10	24	19	19	25	14	8	3	2	9	2576
2015	636	996	488	225	206	105	70	244	182	163	6	8	20	15	16	20	11	6	2	8	3426
2016	554	1092	1098	427	185	174	93	64	224	166	148	5	7	17	13	14	18	10	5	9	4326
2017	772	872	1025	790	297	140	146	83	59	206	153	135	5	6	16	12	12	16	9	13	4764
2018	497	1353	996	923	651	246	120	127	73	51	179	131	115	4	5	13	10	10	13	18	5537
2019	642	760	1198	653	570	440	187	98	108	62	44	151	110	96	3	5	11	8	8	26	5181
2020	231	1076	800	969	485	437	358	158	84	92	53	37	126	92	79	3	4	9	7	28	5126

Table 11. 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	509	1010	1433	1728	1892	1944	1914	1825	1704	1561	1415	1270	1131	1001	884	776	679	593	518	3406	27196
1951	509	1014	1462	1766	1933	1986	1953	1865	1739	1596	1446	1296	1155	1023	902	791	694	606	529	3479	27747
1952	509	1014	1462	1792	1964	2019	1986	1896	1768	1620	1468	1318	1175	1041	917	805	705	617	538	3534	28153
1953	509	1014	1468	1801	2006	2061	2028	1936	1806	1656	1499	1347	1199	1063	937	822	721	631	549	3609	28660
1954	509	1014	1468	1808	2013	2105	2070	1975	1843	1691	1532	1373	1224	1085	955	840	736	644	562	3686	29132
1955	509	1014	1459	1797	2006	2099	2099	2004	1870	1713	1552	1393	1241	1098	970	851	745	653	569	3737	29377
1956	509	1010	1424	1739	1949	2050	2059	2004	1876	1726	1567	1407	1252	1109	979	860	752	657	575	3772	29277
1957	509	1010	1418	1695	1883	1989	2008	1964	1876	1731	1576	1418	1263	1118	985	866	758	664	580	3803	29116
1958	509	1005	1393	1656	1803	1889	1916	1885	1808	1702	1556	1404	1254	1111	979	860	754	659	575	3777	28499
1959	509	1008	1396	1636	1773	1819	1832	1810	1748	1653	1545	1400	1252	1111	981	862	754	659	575	3781	28107
1960	509	1008	1391	1631	1742	1779	1757	1724	1673	1594	1497	1385	1243	1107	979	860	754	659	575	3774	27635
1961	509	1005	1385	1618	1728	1742	1711	1647	1590	1521	1440	1338	1228	1098	972	855	750	655	573	3759	27126
1962	509	1005	1369	1592	1698	1713	1662	1592	1506	1435	1365	1276	1177	1076	957	844	743	648	567	3719	26455
1963	509	1005	1367	1576	1673	1684	1638	1550	1462	1365	1290	1215	1129	1036	941	833	734	644	562	3693	25913
1964	509	1005	1371	1576	1660	1664	1614	1532	1426	1329	1235	1155	1080	999	911	825	730	642	562	3684	25507
1965	509	1005	1362	1570	1649	1640	1585	1504	1404	1294	1197	1100	1023	950	875	796	719	633	556	3662	25027
1966	509	1003	1354	1550	1629	1620	1554	1468	1371	1268	1162	1065	972	897	831	761	690	622	549	3627	24500
1967	509	1003	1349	1534	1607	1598	1532	1440	1340	1239	1138	1032	939	851	783	721	659	597	538	3587	23999
1968	509	1001	1336	1517	1576	1561	1499	1407	1301	1199	1100	1001	902	816	736	675	622	567	511	3512	23347
1969	509	999	1321	1486	1543	1519	1451	1362	1259	1153	1056	961	869	776	699	631	575	527	481	3400	22580
1970	509	1003	1336	1490	1534	1506	1431	1338	1239	1133	1032	937	844	758	677	606	545	496	456	3325	22192
1971	509	1003	1340	1508	1537	1497	1418	1318	1215	1116	1014	915	825	739	661	586	525	470	428	3241	21865
1972	509	1001	1334	1504	1548	1495	1407	1305	1197	1093	996	899	805	721	644	573	507	454	406	3146	21544
1973	509	1001	1325	1486	1534	1497	1398	1290	1182	1076	979	884	791	703	628	558	496	439	390	3042	21213
1974	509	1001	1321	1473	1512	1482	1400	1283	1171	1065	966	869	780	694	615	547	485	430	379	2952	20933
1975	509	999	1296	1440	1470	1435	1362	1265	1149	1041	944	847	756	675	597	527	467	414	366	2826	20388
1976	509	994	1270	1387	1411	1373	1301	1215	1116	1008	911	818	730	648	575	507	448	395	351	2681	19645
1977	509	994	1261	1351	1354	1312	1239	1155	1069	979	882	789	705	624	553	489	430	377	333	2540	18944
1978	187	992	1252	1332	1310	1250	1177	1096	1012	933	853	761	677	600	529	467	412	362	317	2399	17919
1979	190	364	1239	1307	1279	1199	1113	1034	955	880	809	734	650	573	507	445	392	344	302	2258	16577
1980	494	366	443	1257	1226	1146	1052	966	893	825	761	694	624	549	485	425	373	328	289	2125	15322
1981	168	955	432	434	1140	1067	979	893	820	761	705	646	586	522	459	401	353	309	271	1980	13878
1982	375	293	593	207	207	564	560	553	542	534	529	487	441	397	353	309	271	236	207	1497	9156
1983	1146	701	298	496	163	159	432	434	434	434	434	425	388	351	315	278	243	212	185	1327	8863
1984	1133	2165	730	256	399	128	123	337	342	348	353	351	342	309	278	249	220	192	168	1182	9601
1985	368	1962	1468	397	137	218	73	75	218	234	251	251	249	240	216	194	174	152	132	930	7943
1986	309	602	992	582	161	60	101	37	42	132	154	163	163	159	154	139	123	110	97	668	4943
1987	597	527	489	688	395	108	40	71	26	31	101	117	123	121	119	115	104	90	82	562	4508
1988	492	1045	454	357	485	278	77	29	53	20	24	77	90	93	93	90	86	77	68	478	4467
1989	201	866	816	291	220	302	176	51	20	37	15	18	57	66	68	66	64	62	55	392	3847
1990	179	337	509	379	134	106	154	95	29	13	24	11	11	37	42	44	42	42	40	282	2511
1991	340	322	342	441	311	106	82	119	75	22	9	20	7	9	29	31	33	33	31	240	2601
1992	295	611	293	258	317	220	75	60	88	55	18	7	15	7	7	22	24	24	24	201	2621
1993	128	556	772	172	104	139	108	42	37	60	42	13	4	11	4	4	15	18	18	159	2405
1994	223	201	595	600	115	71	95	77	31	26	44	31	9	4	7	2	4	11	13	126	2284
1995	117	362	223	478	417	82	51	68	57	24	22	35	24	7	2	7	2	2	9	104	2086
1996	205	194	410	187	355	311	62	37	53	44	18	18	26	18	7	2	4	2	2	84	2035
1997	295	373	243	342	128	247	223	44	29	42	35	15	13	20	13	4	2	4	2	64	2136
1998	567	564	505	229	273	101	194	176	35	24	33	29	11	11	18	11	4	2	2	53	2842
1999	723	1045	730	432	161	192	73	146	137	29	20	29	22	9	9	13	9	2	0	42	3825
2000	849	1246	1215	487	220	86	110	46	101	101	22	15	22	18	7	7	9	7	2	33	4603
2001	505	1369	1338	756	231	110	49	68	31	75	79	18	11	15	13	4	4	7	4	26	4716
2002	478	780	1413	871	392	126	66	31	46	22	55	60	13	9	11	9	4	4	4	22	4420
2003	681	769	836	895	430	205	73	40	20	33	18	42	44	9	7	9	7	2	2	20	4145
2004	243	1111	871	732	690	328	159	57	33	18	29	15	35	35	9	4	7	7	2	18	4400
2005	97	271	802	531	419	421	214	110	42	24	13	22	11	26	29	7	4	4	4	15	3067
2006	2099	148	282	650	386	309	317	165	88	33	20	11	18	9	22	22	4	2	4	15	4608
2007	1521	3730	183	229	428	258	214	231	128	71	29	18	9	15	7	18	18	4	2	15	7125
2008	1237	2540	4310	152	163	304	187	163	181	101	57	22	13	7	11	7	13	13	2	15	9504
2009	243	1795	2418	2584	73	84	170	117	110	132	79	44	18	11	4	9	4	11	11	13	7928
2010	196	284	1287	944	758	24	33	82	64	68	90	53	29	11	7	4	7	2	7	15	3971
2011	295	315	280	983	692	595	20	31	75	60	64	82	49	26	11	7	2	4	2	20	3611
2012	269	527	368	262	860	606	531	20	26	66	53	55	73	42	22	9	4	2	4	20	3823
2013	520	452	560	306	203	690	511	463	18	24	60	46	49	62	35	20	7	4	2	20	4048
2014	1259	955	567	571	291	190	642	476	428	15	22	53	42	42	55	31	18	7	4	20	5679
2015	1402	2196	1076	496	454	231	154	538	401	359	13	18	44	33	35	44	24	13	4	18	7553
2016	1221	2407	2421	941	408	384	205	141	494	366	326	11	15	37	29	31	40	22	11	20	9537
2017	1702	1922	2260	1742	655	309	322	183	130	454	337	298	11	13	35	26	26	35	20	29	10503
2018	1096	2983	2196	2035	1435	542	265	280	161	112	395	289	254	9	11	29	22	22	29	40	12207
2019	1415	1676	2641	1440	1257	970	412	216	238	137	97	333	243	212	7	11	24	18	18	57	11422
2020	509	2372	1764	2136	1069	963	789	348	185	203	117	82	278	203	174	7	9	20	15	62	11301

Table 12. 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 $75\%SSB_{\mathrm{F30}}$. Exploitation rate (E) is based on numbers, and SPR_{F} is equilibrium spawners per recruit conditioned on annual F.

Year	F	F/F_{30}	B	B/B_{unfished}	SSB	SSB/SSB_{F30}	$SSB/MSST_{\mathrm{F30}}$	E	E/E_{F30}	SPR_{F}
1950	0.014	0.070	12336	0.689	1342193	2.112	2.816	0.011	0.135	0.821
1951	0.019	0.093	12586	0.703	1385555	2.181	2.907	0.015	0.179	0.772
1952	0.015	0.071	12770	0.713	1411962	2.222	2.963	0.012	0.136	0.820
1953	0.015	0.072	13000	0.726	1439897	2.266	3.021	0.012	0.138	0.818
1954	0.022	0.106	13214	0.738	1460083	2.298	3.064	0.017	0.203	0.748
1955	0.047	0.227	13325	0.744	1467068	2.309	3.078	0.029	0.297	0.645
1956	0.050	0.241	13280	0.741	1465606	2.306	3.075	0.030	0.308	0.634
1957	0.067	0.328	13207	0.737	1445523	2.275	3.033	0.042	0.453	0.524
1958	0.062	0.300	12927	0.722	1423240	2.240	2.986	0.037	0.385	0.568
1959	0.067	0.327	12749	0.712	1400476	2.204	2.939	0.040	0.419	0.542
1960	0.072	0.348	12535	0.700	1373821	2.162	2.883	0.042	0.442	0.525
1961	0.082	0.400	12304	0.687	1339895	2.109	2.812	0.049	0.514	0.478
1962	0.082	0.398	12000	0.670	1306867	2.057	2.742	0.047	0.488	0.491
1963	0.081	0.392	11754	0.656	1280430	2.015	2.687	0.045	0.455	0.510
1964	0.088	0.428	11570	0.646	1253648	1.973	2.631	0.049	0.500	0.480
1965	0.095	0.460	11352	0.634	1223917	1.926	2.568	0.053	0.536	0.458
1966	0.096	0.468	11113	0.620	1193998	1.879	2.505	0.054	0.546	0.452
1967	0.106	0.516	10886	0.608	1158940	1.824	2.432	0.061	0.629	0.409
1968	0.116	0.563	10590	0.591	1116844	1.758	2.344	0.067	0.706	0.373
1969	0.102	0.498	10242	0.572	1085340	1.708	2.277	0.057	0.584	0.432
1970	0.102	0.498	10066	0.562	1062370	1.672	2.229	0.057	0.582	0.434
1971	0.108	0.526	9918	0.554	1041577	1.639	2.186	0.059	0.599	0.423
1972	0.114	0.557	9772	0.545	1021670	1.608	2.144	0.062	0.619	0.410
1973	0.118	0.573	9622	0.537	1004122	1.580	2.107	0.062	0.612	0.412
1974	0.138	0.669	9495	0.530	979202	1.541	2.055	0.074	0.744	0.349
1975	0.157	0.762	9248	0.516	943256	1.484	1.979	0.084	0.861	0.302
1976	0.161	0.785	8911	0.497	904512	1.423	1.898	0.086	0.880	0.295
1977	0.169	0.820	8593	0.480	865359	1.362	1.816	0.090	0.926	0.279
1978	0.179	0.871	8128	0.454	824730	1.298	1.731	0.107	0.992	0.262
1979	0.208	1.009	7519	0.420	778784	1.226	1.634	0.114	1.062	0.230
1980	0.244	1.188	6950	0.388	716889	1.128	1.504	0.107	1.161	0.187
1981	0.953	4.631	6295	0.351	537910	0.847	1.129	0.385	3.502	0.012
1982	0.400	1.943	4153	0.232	420446	0.662	0.882	0.154	1.663	0.083
1983	0.379	1.843	4020	0.224	356826	0.562	0.749	0.112	1.570	0.091
1984	0.835	4.060	4355	0.243	282714	0.445	0.593	0.292	3.363	0.016
1985	1.148	5.583	3603	0.201	201570	0.317	0.423	0.478	4.778	0.007
1986	0.592	2.879	2242	0.125	159164	0.250	0.334	0.288	2.905	0.034
1987	0.538	2.616	2045	0.114	136813	0.215	0.287	0.215	2.616	0.043
1988	0.673	3.270	2026	0.113	115136	0.181	0.242	0.277	3.322	0.026
1989	0.987	4.798	1745	0.097	86384	0.136	0.181	0.439	4.770	0.010
1990	0.373	1.813	1139	0.064	74998	0.118	0.157	0.203	2.298	0.081
1991	0.502	2.441	1180	0.066	70109	0.110	0.147	0.205	2.712	0.049
1992	1.033	5.022	1189	0.066	56824	0.089	0.119	0.186	3.500	0.025
1993	0.529	2.571	1091	0.061	54568	0.086	0.115	0.270	3.144	0.044
1994	0.490	2.383	1036	0.058	55812	0.088	0.117	0.246	3.078	0.055
1995	0.422	2.051	946	0.053	55545	0.087	0.117	0.227	2.647	0.070
1996	0.498	2.420	923	0.052	54349	0.086	0.114	0.178	2.660	0.074
1997	0.350	1.702	969	0.054	55793	0.088	0.117	0.097	1.733	0.138
1998	0.485	2.356	1289	0.072	60313	0.095	0.127	0.121	2.118	0.086
1999	0.803	3.903	1735	0.097	62780	0.099	0.132	0.201	3.215	0.031
2000	0.870	4.229	2088	0.117	66639	0.105	0.140	0.255	3.777	0.024
2001	0.781	3.795	2139	0.119	72170	0.114	0.151	0.298	4.012	0.025
2002	0.834	4.056	2005	0.112	72969	0.115	0.153	0.302	4.345	0.025
2003	0.387	1.881	1880	0.105	82255	0.129	0.173	0.202	2.538	0.089
2004	0.717	3.485	1996	0.111	83420	0.131	0.175	0.435	4.469	0.015
2005	0.444	2.160	1391	0.078	82824	0.130	0.174	0.277	2.945	0.063
2006	0.545	2.648	2090	0.117	81109	0.128	0.170	0.122	2.151	0.068
2007	0.473	2.299	3232	0.180	95712	0.151	0.201	0.173	2.096	0.070
2008	0.864	4.200	4311	0.241	127120	0.200	0.267	0.336	4.420	0.018
2009	1.352	6.573	3596	0.201	101906	0.160	0.214	0.545	6.569	0.006
2010	0.493	2.398	1801	0.101	98391	0.155	0.206	0.279	2.761	0.108
2011	0.288	1.398	1638	0.091	110317	0.174	0.231	0.148	1.561	0.206
2012	0.407	1.981	1734	0.097	117822	0.185	0.247	0.199	1.933	0.114
2013	0.200	0.972	1836	0.103	130718	0.206	0.274	0.094	0.927	0.327
2014	0.357	1.735	2576	0.144	142001	0.223	0.298	0.148	1.740	0.109
2015	0.356	1.731	3426	0.191	166277	0.262	0.349	0.168	1.677	0.181
2016	0.553	2.686	4326	0.241	201299	0.317	0.422	0.268	2.655	0.088
2017	0.328	1.593	4764	0.266	240380	0.378	0.504	0.160	1.832	0.147
2018	0.646	3.140	5537	0.309	260567	0.410	0.547	0.314	3.230	0.041
2019	0.435	2.114	5181	0.289	279191	0.439	0.586	0.213	2.338	0.088
2020	.	.	5126	0.286	.	.	.	.	.	.

Table 13. Selectivity at age in selectivity block 1 (1950–1991) for commercial handlines (cH), headboat (HB), and general recreational (GR) landings (L) and discards (D).

Age	cH.L	HB.L	GR.L	cH.D	HB.D	GR.D
1	0.205	0.130	0.130	0.566	0.869	0.869
2	0.975	0.894	0.894	0.908	1.000	1.000
3	1.000	1.000	1.000	1.000	0.432	0.432
4	1.000	0.909	0.909	0.524	0.099	0.099
5	1.000	0.801	0.801	0.107	0.019	0.019
6	1.000	0.688	0.688	0.015	0.003	0.003
7	1.000	0.575	0.575	0.002	0.001	0.001
8	1.000	0.469	0.469	0.000	0.000	0.000
9	1.000	0.373	0.373	0.000	0.000	0.000
10	1.000	0.290	0.290	0.000	0.000	0.000
11	1.000	0.290	0.290	0.000	0.000	0.000
12	1.000	0.290	0.290	0.000	0.000	0.000
13	1.000	0.290	0.290	0.000	0.000	0.000
14	1.000	0.290	0.290	0.000	0.000	0.000
15	1.000	0.290	0.290	0.000	0.000	0.000
16	1.000	0.290	0.290	0.000	0.000	0.000
17	1.000	0.290	0.290	0.000	0.000	0.000
18	1.000	0.290	0.290	0.000	0.000	0.000
19	1.000	0.290	0.290	0.000	0.000	0.000
20	1.000	0.290	0.290	0.000	0.000	0.000

Table 14. Selectivity at age in selectivity block 2 (1992–2009) for commercial handlines (cH), headboat (HB), and general recreational (GR) landings (L) and discards (D).

Age	cH.L	HB.L	GR.L	cH.D	HB.D	GR.D
1	0.002	0.001	0.005	0.566	0.869	0.869
2	0.052	0.048	0.088	0.908	1.000	1.000
3	0.628	0.775	0.698	1.000	0.432	0.432
4	0.981	1.000	1.000	0.524	0.099	0.099
5	0.999	0.858	0.869	0.107	0.019	0.019
6	1.000	0.694	0.693	0.015	0.003	0.003
7	1.000	0.532	0.521	0.002	0.001	0.001
8	1.000	0.388	0.373	0.000	0.000	0.000
9	1.000	0.272	0.255	0.000	0.000	0.000
10	1.000	0.184	0.169	0.000	0.000	0.000
11	1.000	0.184	0.169	0.000	0.000	0.000
12	1.000	0.184	0.169	0.000	0.000	0.000
13	1.000	0.184	0.169	0.000	0.000	0.000
14	1.000	0.184	0.169	0.000	0.000	0.000
15	1.000	0.184	0.169	0.000	0.000	0.000
16	1.000	0.184	0.169	0.000	0.000	0.000
17	1.000	0.184	0.169	0.000	0.000	0.000
18	1.000	0.184	0.169	0.000	0.000	0.000
19	1.000	0.184	0.169	0.000	0.000	0.000
20	1.000	0.184	0.169	0.000	0.000	0.000

Table 15. Selectivity at age in selectivity block 3 (2010–2019) for SERFS chevron traps (CVT), SERFS video (VID), commercial handlines (cH), headboat (HB), and general recreational (GR) landings (L) and discards (D).

Age	CVT	VID	cH.L	HB.L	GR.L	cH.D	HB.D	GR.D
1	0.107	0.107	0.027	0.035	0.009	0.119	0.716	0.432
2	0.621	0.621	0.201	0.350	0.055	0.595	1.000	0.812
3	1.000	1.000	0.693	0.950	0.271	0.941	0.976	1.000
4	0.964	1.000	0.953	1.000	0.703	0.994	0.752	0.885
5	0.861	1.000	0.995	0.914	0.938	0.999	0.497	0.608
6	0.750	1.000	0.999	0.820	0.990	1.000	0.298	0.339
7	0.642	1.000	1.000	0.728	0.998	1.000	0.167	0.164
8	0.539	1.000	1.000	0.640	1.000	1.000	0.090	0.073
9	0.445	1.000	1.000	0.558	1.000	1.000	0.048	0.031
10	0.362	1.000	1.000	0.483	1.000	1.000	0.025	0.013
11	0.362	1.000	1.000	0.483	1.000	1.000	0.025	0.013
12	0.362	1.000	1.000	0.483	1.000	1.000	0.025	0.013
13	0.362	1.000	1.000	0.483	1.000	1.000	0.025	0.013
14	0.362	1.000	1.000	0.483	1.000	1.000	0.025	0.013
15	0.362	1.000	1.000	0.483	1.000	1.000	0.025	0.013
16	0.362	1.000	1.000	0.483	1.000	1.000	0.025	0.013
17	0.362	1.000	1.000	0.483	1.000	1.000	0.025	0.013
18	0.362	1.000	1.000	0.483	1.000	1.000	0.025	0.013
19	0.362	1.000	1.000	0.483	1.000	1.000	0.025	0.013
20	0.362	1.000	1.000	0.483	1.000	1.000	0.025	0.013

Table 16. Selectivity of removals averaged (avg) across fleets in the terminal three years of the assessment (2017–2019) for landings (L), discards (D) and total (Tot), as used in computation of benchmarks and projections.

Age	L.avg	D.avg	Tot.avg
1	0.003	0.402	0.404
2	0.019	0.754	0.773
3	0.073	0.927	1.000
4	0.140	0.821	0.961
5	0.171	0.567	0.738
6	0.177	0.322	0.499
7	0.177	0.162	0.339
8	0.177	0.079	0.255
9	0.176	0.040	0.216
10	0.175	0.024	0.199
11	0.175	0.024	0.199
12	0.175	0.024	0.199
13	0.175	0.024	0.199
14	0.175	0.024	0.199
15	0.175	0.024	0.199
16	0.175	0.024	0.199
17	0.175	0.024	0.199
18	0.175	0.024	0.199
19	0.175	0.024	0.199
20	0.175	0.024	0.199

Table 17. 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	0.014	0.000	0.000	0.000	0.000	0.000	0.014
1951	0.019	0.000	0.000	0.000	0.000	0.000	0.019
1952	0.015	0.000	0.000	0.000	0.000	0.000	0.015
1953	0.015	0.000	0.000	0.000	0.000	0.000	0.015
1954	0.022	0.000	0.000	0.000	0.000	0.000	0.022
1955	0.018	0.000	0.029	0.000	0.000	0.000	0.047
1956	0.018	0.000	0.032	0.000	0.000	0.000	0.050
1957	0.032	0.000	0.035	0.000	0.000	0.000	0.067
1958	0.023	0.000	0.039	0.000	0.000	0.000	0.062
1959	0.025	0.000	0.042	0.000	0.000	0.000	0.067
1960	0.026	0.000	0.045	0.000	0.000	0.000	0.072
1961	0.032	0.000	0.050	0.000	0.000	0.000	0.082
1962	0.026	0.000	0.055	0.000	0.000	0.000	0.082
1963	0.020	0.000	0.060	0.000	0.000	0.000	0.081
1964	0.023	0.000	0.065	0.000	0.000	0.000	0.088
1965	0.024	0.000	0.070	0.000	0.000	0.000	0.095
1966	0.025	0.000	0.072	0.000	0.000	0.000	0.096
1967	0.033	0.000	0.073	0.000	0.000	0.000	0.106
1968	0.041	0.000	0.075	0.000	0.000	0.000	0.116
1969	0.026	0.000	0.076	0.000	0.000	0.000	0.102
1970	0.025	0.000	0.077	0.000	0.000	0.000	0.102
1971	0.023	0.000	0.085	0.000	0.000	0.000	0.108
1972	0.021	0.000	0.094	0.000	0.000	0.000	0.114
1973	0.015	0.000	0.103	0.000	0.000	0.000	0.118
1974	0.025	0.000	0.112	0.000	0.000	0.000	0.138
1975	0.033	0.000	0.124	0.000	0.000	0.000	0.157
1976	0.033	0.000	0.129	0.000	0.000	0.000	0.161
1977	0.035	0.000	0.133	0.000	0.000	0.000	0.169
1978	0.037	0.017	0.125	0.000	0.000	0.000	0.179
1979	0.028	0.022	0.157	0.000	0.000	0.000	0.208
1980	0.029	0.026	0.189	0.000	0.000	0.000	0.244
1981	0.036	0.076	0.838	0.000	0.000	0.009	0.953
1982	0.040	0.060	0.297	0.000	0.000	0.008	0.400
1983	0.045	0.069	0.263	0.000	0.000	0.003	0.379
1984	0.037	0.046	0.736	0.000	0.000	0.038	0.835
1985	0.047	0.088	0.988	0.000	0.000	0.058	1.148
1986	0.058	0.047	0.443	0.000	0.000	0.098	0.592
1987	0.058	0.077	0.373	0.000	0.000	0.072	0.538
1988	0.054	0.095	0.505	0.000	0.000	0.041	0.673
1989	0.103	0.076	0.791	0.000	0.000	0.039	0.987
1990	0.113	0.095	0.136	0.000	0.000	0.056	0.373
1991	0.076	0.066	0.343	0.000	0.000	0.041	0.502
1992	0.085	0.064	0.866	0.028	0.003	0.039	1.033
1993	0.173	0.062	0.258	0.027	0.005	0.254	0.529
1994	0.138	0.062	0.251	0.041	0.006	0.206	0.490
1995	0.135	0.084	0.160	0.052	0.009	0.180	0.422
1996	0.110	0.055	0.302	0.048	0.005	0.070	0.498
1997	0.090	0.063	0.177	0.038	0.003	0.020	0.350
1998	0.067	0.042	0.361	0.016	0.002	0.074	0.485
1999	0.064	0.049	0.670	0.010	0.002	0.159	0.803
2000	0.062	0.045	0.736	0.009	0.002	0.233	0.870
2001	0.101	0.054	0.594	0.010	0.003	0.280	0.781
2002	0.090	0.055	0.657	0.022	0.004	0.226	0.834
2003	0.065	0.026	0.272	0.007	0.002	0.226	0.387
2004	0.079	0.052	0.487	0.002	0.018	0.642	0.717
2005	0.063	0.048	0.295	0.021	0.021	0.276	0.444
2006	0.047	0.043	0.442	0.002	0.005	0.124	0.545
2007	0.066	0.050	0.337	0.003	0.014	0.187	0.473
2008	0.072	0.041	0.715	0.003	0.018	0.343	0.864
2009	0.111	0.057	1.123	0.007	0.035	0.568	1.352
2010	0.003	0.001	0.000	0.016	0.034	0.441	0.493
2011	0.000	0.005	0.000	0.046	0.028	0.211	0.288
2012	0.003	0.009	0.032	0.023	0.032	0.335	0.407
2013	0.012	0.006	0.000	0.018	0.023	0.147	0.200
2014	0.022	0.009	0.069	0.020	0.012	0.282	0.357
2015	0.001	0.001	0.008	0.015	0.010	0.328	0.356
2016	0.001	0.000	0.000	0.014	0.011	0.527	0.553
2017	0.016	0.003	0.049	0.007	0.006	0.288	0.328
2018	0.020	0.005	0.060	0.004	0.007	0.599	0.646
2019	0.019	0.005	0.067	0.004	0.007	0.388	0.435

Table 18. 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	0.003	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
1951	0.004	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
1952	0.003	0.014	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
1953	0.003	0.014	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
1954	0.004	0.021	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022
1955	0.007	0.043	0.047	0.044	0.041	0.038	0.035	0.031	0.029	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026
1956	0.008	0.046	0.050	0.047	0.043	0.040	0.036	0.033	0.030	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027
1957	0.011	0.063	0.067	0.064	0.060	0.056	0.052	0.049	0.045	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
1958	0.010	0.057	0.062	0.058	0.054	0.050	0.045	0.041	0.038	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
1959	0.011	0.062	0.067	0.063	0.059	0.054	0.049	0.045	0.041	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037
1960	0.011	0.066	0.072	0.068	0.063	0.058	0.052	0.048	0.043	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
1961	0.013	0.076	0.082	0.078	0.072	0.067	0.061	0.055	0.051	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046
1962	0.013	0.075	0.082	0.077	0.071	0.065	0.058	0.052	0.047	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
1963	0.012	0.074	0.081	0.075	0.069	0.062	0.055	0.049	0.043	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038
1964	0.013	0.080	0.088	0.082	0.075	0.068	0.060	0.053	0.047	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
1965	0.014	0.086	0.095	0.088	0.081	0.073	0.065	0.057	0.050	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
1966	0.014	0.088	0.096	0.090	0.082	0.074	0.066	0.058	0.051	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
1967	0.016	0.098	0.106	0.100	0.092	0.083	0.075	0.067	0.060	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054
1968	0.018	0.107	0.116	0.109	0.101	0.093	0.084	0.076	0.069	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063
1969	0.015	0.094	0.102	0.095	0.087	0.079	0.070	0.062	0.055	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048
1970	0.015	0.094	0.102	0.095	0.087	0.078	0.070	0.061	0.054	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048
1971	0.016	0.099	0.108	0.100	0.091	0.082	0.072	0.063	0.055	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048
1972	0.016	0.104	0.114	0.106	0.096	0.085	0.075	0.065	0.056	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048
1973	0.016	0.107	0.118	0.109	0.098	0.086	0.074	0.063	0.054	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
1974	0.020	0.125	0.138	0.127	0.115	0.103	0.090	0.078	0.067	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058
1975	0.023	0.143	0.157	0.145	0.132	0.118	0.104	0.091	0.079	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069
1976	0.023	0.147	0.161	0.150	0.136	0.121	0.107	0.093	0.081	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
1977	0.025	0.154	0.169	0.157	0.142	0.127	0.112	0.098	0.085	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074
1978	0.026	0.163	0.179	0.166	0.151	0.135	0.119	0.104	0.090	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078
1979	0.029	0.188	0.208	0.191	0.172	0.152	0.132	0.112	0.095	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
1980	0.034	0.221	0.244	0.225	0.202	0.177	0.153	0.130	0.109	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091
1981	0.133	0.859	0.953	0.866	0.768	0.664	0.561	0.464	0.376	0.301	0.301	0.301	0.301	0.301	0.301	0.301	0.301	0.301	0.301	0.301
1982	0.061	0.365	0.400	0.365	0.326	0.285	0.245	0.207	0.173	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143
1983	0.055	0.344	0.379	0.348	0.312	0.274	0.237	0.201	0.169	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142
1984	0.142	0.773	0.835	0.751	0.664	0.575	0.487	0.404	0.329	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264
1985	0.200	1.066	1.148	1.031	0.910	0.788	0.666	0.551	0.448	0.359	0.359	0.359	0.359	0.359	0.359	0.359	0.359	0.359	0.359	0.359
1986	0.161	0.592	0.590	0.512	0.452	0.395	0.340	0.287	0.240	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1987	0.133	0.530	0.538	0.473	0.419	0.367	0.316	0.268	0.225	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188
1988	0.125	0.631	0.673	0.604	0.536	0.468	0.400	0.336	0.278	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229
1989	0.167	0.914	0.987	0.895	0.799	0.700	0.602	0.510	0.427	0.355	0.355	0.355	0.355	0.355	0.355	0.355	0.355	0.355	0.355	0.355
1990	0.102	0.373	0.369	0.329	0.300	0.273	0.246	0.222	0.200	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180
1991	0.104	0.480	0.502	0.451	0.404	0.357	0.311	0.267	0.228	0.194	0.194	0.194	0.194	0.194	0.194	0.194	0.194	0.194	0.194	0.194
1992	0.056	0.151	0.754	1.033	0.897	0.730	0.571	0.433	0.324	0.243	0.243	0.243	0.243	0.243	0.243	0.243	0.243	0.243	0.243	0.243
1993	0.242	0.318	0.475	0.529	0.457	0.396	0.340	0.293	0.255	0.228	0.228	0.228	0.228	0.228	0.228	0.228	0.228	0.228	0.228	0.228
1994	0.210	0.282	0.442	0.490	0.417	0.356	0.302	0.255	0.219	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192
1995	0.195	0.261	0.395	0.422	0.354	0.305	0.263	0.227	0.198	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177
1996	0.094	0.153	0.403	0.498	0.426	0.358	0.297	0.244	0.202	0.171	0.171	0.171	0.171	0.171	0.171	0.171	0.171	0.171	0.171	0.171
1997	0.043	0.081	0.277	0.350	0.302	0.257	0.216	0.180	0.152	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132
1998	0.077	0.128	0.376	0.485	0.420	0.347	0.277	0.218	0.170	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136
1999	0.149	0.235	0.625	0.803	0.692	0.563	0.439	0.333	0.248	0.186	0.186	0.186	0.186	0.186	0.186	0.186	0.186	0.186	0.186	0.186
2000	0.213	0.313	0.698	0.870	0.746	0.604	0.470	0.354	0.262	0.195	0.195	0.195	0.195	0.195	0.195	0.195	0.195	0.195	0.195	0.195
2001	0.255	0.352	0.652	0.781	0.670	0.551	0.440	0.344	0.268	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212
2002	0.216	0.315	0.678	0.834	0.714	0.584	0.462	0.357	0.273	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212
2003	0.203	0.262	0.355	0.387	0.328	0.272	0.220	0.176	0.141	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116
2004	0.577	0.711	0.717	0.683	0.559	0.455	0.361	0.281	0.218	0.171	0.171	0.171	0.171	0.171	0.171	0.171	0.171	0.171	0.171	0.171
2005	0.272	0.348	0.431	0.444	0.368	0.302	0.242	0.191	0.151	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122
2006	0.115	0.174	0.429	0.545	0.470	0.383	0.300	0.228	0.171	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130
2007	0.179	0.240	0.405	0.473	0.405	0.335	0.268	0.211	0.165	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132
2008	0.319	0.433	0.735	0.864	0.735	0.597	0.467	0.354	0.266	0.201	0.201	0.201	0.201	0.201	0.201	0.201	0.201	0.201	0.201	0.201
2009	0.534	0.717	1.165	1.352	1.147	0.931	0.727	0.552	0.413	0.312	0.312	0.312	0.312	0.312	0.312	0.312	0.312	0.312	0.312	0.312
2010	0.217	0.403	0.493	0.437	0.306	0.180	0.098	0.055	0.035	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027
2011	0.117	0.229	0.288	0.260	0.194	0.131	0.090	0.068	0.057	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053
2012	0.171	0.324	0.407	0.378	0.284	0.189	0.125	0.092	0.076	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
2013	0.083	0.158	0.200	0.182	0.136	0.091	0.062	0.046	0.038	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
2014	0.134	0.264	0.355	0.357	0.292	0.217	0.166	0.138	0.125	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119
2015	0.151	0.286	0.356	0.321	0.230	0.140	0.081	0.050	0.036	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
2016	0.238	0.448	0.553	0.491	0.342	0.198	0.104	0.055	0.033	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023
2017	0.130	0.251	0.328	0.319	0.250	0.174	0.123	0.096	0.084	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078
2018	0.266	0.506	0.646	0.607	0.454	0.294	0.188	0.133	0.107	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096
2019	0.175	0.334	0.435	0.423	0.330	0.227	0.158	0.122	0.105	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098

Table 19. 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	27.46	0.00	0.00	27.46
1951	37.14	0.00	0.00	37.14
1952	28.57	0.00	0.00	28.57
1953	29.35	0.00	0.00	29.35
1954	43.51	0.00	0.00	43.51
1955	35.95	0.00	36.57	72.52
1956	35.07	0.00	39.95	75.02
1957	62.73	0.00	43.33	106.05
1958	44.28	0.00	46.71	90.98
1959	47.64	0.00	50.09	97.73
1960	48.76	0.00	53.48	102.24
1961	58.13	0.00	58.35	116.49
1962	47.39	0.00	63.23	110.62
1963	36.05	0.00	68.12	104.17
1964	39.88	0.00	73.03	112.91
1965	41.65	0.00	77.95	119.60
1966	41.66	0.00	78.45	120.11
1967	54.98	0.00	78.96	133.94
1968	66.26	0.00	79.47	145.73
1969	41.52	0.00	79.99	121.51
1970	39.95	0.00	80.52	120.47
1971	35.88	0.00	88.66	124.54
1972	32.08	0.00	96.86	128.94
1973	23.49	0.00	105.12	128.62
1974	38.17	0.00	113.45	151.62
1975	48.33	0.00	121.83	170.16
1976	46.38	0.00	123.40	169.78
1977	48.95	0.00	124.73	173.68
1978	47.82	15.32	110.20	173.33
1979	30.77	15.49	111.46	157.72
1980	27.70	15.65	112.35	155.70
1981	27.56	36.21	401.69	465.46
1982	22.02	19.62	97.81	139.46
1983	31.01	30.79	116.82	178.63
1984	33.78	31.20	501.08	566.06
1985	33.22	50.40	565.01	648.63
1986	25.68	16.63	156.85	199.16
1987	24.36	24.94	121.28	170.58
1988	25.76	36.39	193.16	255.31
1989	38.06	23.39	244.19	305.64
1990	29.91	20.90	29.71	80.52
1991	20.01	13.86	72.48	106.35
1992	8.58	5.30	75.29	89.17
1993	21.14	7.33	29.90	58.37
1994	18.90	8.21	32.40	59.50
1995	15.95	8.81	17.17	41.93
1996	12.39	5.54	29.83	47.76
1997	9.72	5.76	16.68	32.16
1998	8.35	4.74	41.58	54.67
1999	9.36	6.83	97.35	113.54
2000	11.27	8.43	139.02	158.72
2001	21.77	12.01	133.39	167.18
2002	20.60	12.93	152.97	186.50
2003	14.46	5.71	60.75	80.91
2004	17.22	10.84	102.87	130.93
2005	12.49	8.91	53.59	74.99
2006	7.63	5.95	62.84	76.42
2007	11.12	6.89	59.96	77.97
2008	30.30	18.92	323.00	372.22
2009	40.25	21.50	420.63	482.38
2010	0.76	0.48	0.06	1.29
2011	0.06	1.36	0.06	1.47
2012	0.75	2.13	5.93	8.81
2013	2.93	1.52	0.06	4.51
2014	6.60	2.95	14.03	23.58
2015	0.55	0.75	2.03	3.34
2016	0.39	0.33	0.08	0.79
2017	10.75	2.72	19.36	32.83
2018	14.78	4.43	26.94	46.15
2019	13.41	4.05	30.61	48.07

Table 20. 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	368.85	0.00	0.00	368.85
1951	500.15	0.00	0.00	500.15
1952	386.18	0.00	0.00	386.18
1953	398.57	0.00	0.00	398.57
1954	593.91	0.00	0.00	593.91
1955	493.85	0.00	383.75	877.60
1956	484.47	0.00	420.75	905.22
1957	869.27	0.00	456.53	1325.80
1958	613.59	0.00	490.57	1104.17
1959	659.11	0.00	523.80	1182.91
1960	672.65	0.00	556.46	1229.12
1961	798.82	0.00	603.91	1402.73
1962	647.76	0.00	650.36	1298.12
1963	489.91	0.00	696.33	1186.24
1964	539.09	0.00	742.34	1281.43
1965	559.89	0.00	788.04	1347.93
1966	556.45	0.00	788.27	1344.72
1967	729.19	0.00	788.01	1517.20
1968	871.34	0.00	786.73	1658.07
1969	540.68	0.00	784.38	1325.06
1970	515.53	0.00	783.22	1298.75
1971	459.61	0.00	857.32	1316.92
1972	408.58	0.00	932.52	1341.11
1973	297.70	0.00	1008.18	1305.88
1974	481.60	0.00	1083.92	1565.52
1975	606.38	0.00	1157.28	1763.66
1976	576.96	0.00	1161.34	1738.30
1977	602.40	0.00	1160.16	1762.57
1978	600.42	144.86	1041.85	1787.13
1979	423.80	164.21	1181.56	1769.57
1980	387.74	171.21	1229.06	1788.02
1981	380.99	371.81	4124.67	4877.47
1982	310.29	203.00	1011.80	1525.09
1983	318.61	224.41	851.32	1394.34
1984	254.32	169.95	2729.43	3153.70
1985	251.33	283.53	3178.49	3713.35
1986	219.60	108.10	1019.74	1347.44
1987	191.34	157.27	764.66	1113.27
1988	173.18	201.03	1067.20	1441.41
1989	265.57	134.98	1409.24	1809.79
1990	225.89	132.67	188.66	547.22
1991	143.42	86.68	453.37	683.47
1992	104.16	51.79	706.93	862.88
1993	218.31	61.99	249.18	529.48
1994	193.99	72.63	285.80	552.42
1995	176.43	85.65	164.49	426.58
1996	138.26	53.42	286.30	477.97
1997	110.31	56.56	159.95	326.81
1998	89.39	43.33	370.53	503.24
1999	93.33	58.77	809.40	961.50
2000	103.84	68.66	1102.16	1274.66
2001	195.80	98.07	1066.12	1359.98
2002	187.70	108.19	1267.34	1563.23
2003	138.27	50.37	528.97	717.61
2004	171.91	99.10	927.29	1198.30
2005	129.78	83.10	500.36	713.25
2006	86.46	60.42	618.58	765.47
2007	114.93	61.84	478.98	655.75
2008	251.57	143.21	2398.75	2793.53
2009	362.18	178.48	3452.22	3992.89
2010	6.45	3.63	0.57	10.66
2011	0.57	12.16	0.65	13.38
2012	8.14	19.62	73.24	101.00
2013	31.58	13.57	0.74	45.89
2014	65.36	23.18	174.48	263.02
2015	4.72	4.97	23.33	33.02
2016	3.18	2.19	0.83	6.20
2017	90.21	18.92	203.43	312.57
2018	127.82	31.70	288.71	448.23
2019	120.37	30.47	337.73	488.57

Table 21. 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	.	.	2.70	.
1982	.	.	2.70	.
1983	.	.	2.70	.
1984	.	0.03	44.79	.
1985	.	0.04	37.17	.
1986	.	0.01	37.14	.
1987	.	0.02	37.14	.
1988	.	0.03	22.80	.
1989	.	0.02	12.67	.
1990	.	0.02	12.68	.
1991	.	0.01	12.67	.
1992	8.89	0.93	14.31	24.13
1993	7.71	1.29	65.57	74.57
1994	9.74	1.44	45.73	56.91
1995	9.72	1.55	32.47	43.73
1996	9.55	0.97	14.29	24.81
1997	10.31	1.01	6.25	17.57
1998	7.42	0.83	40.14	48.39
1999	6.26	1.20	119.58	127.04
2000	6.70	1.48	203.80	211.98
2001	6.97	2.11	196.86	205.93
2002	12.39	2.26	125.38	140.03
2003	3.97	1.00	148.73	153.70
2004	0.97	7.14	260.61	268.73
2005	4.78	3.69	48.15	56.62
2006	2.18	6.45	166.78	175.42
2007	5.00	27.13	352.32	384.45
2008	4.74	27.61	518.86	551.22
2009	5.38	21.41	351.54	378.33
2010	6.14	14.37	172.55	193.06
2011	14.68	10.89	69.43	95.01
2012	7.46	12.28	105.37	125.11
2013	6.26	12.16	59.20	77.62
2014	10.10	12.11	206.03	228.24
2015	11.41	14.13	359.06	384.60
2016	13.51	17.28	645.16	675.95
2017	7.56	10.32	409.47	427.35
2018	4.98	11.82	816.57	833.37
2019	4.55	12.14	507.33	524.02

Table 22. 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	.	.	7.37	.
1982	.	.	5.60	.
1983	.	.	4.47	.
1984	.	0.05	92.01	.
1985	.	0.11	100.99	.
1986	.	0.04	95.83	.
1987	.	0.04	72.12	.
1988	.	0.07	50.17	.
1989	.	0.05	34.47	.
1990	.	0.04	32.80	.
1991	.	0.02	25.60	.
1992	25.27	2.10	32.33	59.70
1993	29.62	3.87	197.35	230.84
1994	37.80	3.56	113.15	154.51
1995	37.15	4.16	87.34	128.64
1996	31.95	2.19	32.30	66.44
1997	30.09	2.14	13.23	45.46
1998	19.77	1.66	80.30	101.74
1999	17.24	2.55	254.89	274.68
2000	19.48	3.26	449.85	472.60
2001	23.82	5.48	512.29	541.60
2002	44.48	5.72	316.75	366.95
2003	12.57	2.18	325.03	339.79
2004	3.72	20.67	754.42	778.81
2005	22.22	12.28	160.25	194.75
2006	3.66	8.46	218.72	230.84
2007	12.20	59.61	773.98	845.79
2008	16.10	71.41	1341.86	1429.37
2009	23.09	69.98	1148.94	1242.01
2010	45.67	72.14	973.32	1091.13
2011	125.07	48.98	379.43	553.48
2012	64.99	51.21	525.48	641.68
2013	52.44	40.48	238.58	331.51
2014	69.66	30.80	629.92	730.39
2015	66.91	38.71	1134.71	1240.33
2016	82.43	56.00	2400.76	2539.19
2017	47.75	32.67	1541.00	1621.41
2018	32.75	43.06	3438.80	3514.61
2019	31.87	42.70	2121.18	2195.75

Table 23. Estimated total removals (landings and dead 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	1.12	4.10	3.35	2.75	2.29	1.93	1.64	1.40	1.20	1.03	0.89	0.77	0.66	0.58	0.50	0.43	0.37	0.32	0.28	1.83
1951	1.49	5.47	4.54	3.73	3.11	2.62	2.23	1.90	1.63	1.40	1.21	1.04	0.90	0.78	0.68	0.58	0.51	0.44	0.38	2.49
1952	1.13	4.15	3.46	2.88	2.41	2.03	1.72	1.47	1.26	1.09	0.94	0.81	0.70	0.60	0.52	0.45	0.39	0.34	0.29	1.92
1953	1.15	4.21	3.52	2.93	2.49	2.10	1.78	1.52	1.31	1.12	0.97	0.84	0.72	0.62	0.54	0.47	0.41	0.35	0.30	1.99
1954	1.69	6.18	5.16	4.31	3.66	3.14	2.67	2.28	1.95	1.68	1.45	1.25	1.08	0.93	0.81	0.70	0.61	0.53	0.46	2.98
1955	2.81	12.46	10.89	8.62	6.83	5.40	4.27	3.33	2.61	2.06	1.78	1.53	1.33	1.15	0.99	0.86	0.74	0.65	0.56	3.65
1956	2.94	13.14	11.27	8.82	6.99	5.54	4.37	3.46	2.70	2.12	1.84	1.58	1.37	1.18	1.03	0.89	0.77	0.67	0.58	3.77
1957	4.22	17.90	15.11	11.72	9.36	7.59	6.16	5.02	4.10	3.33	2.88	2.50	2.16	1.87	1.61	1.40	1.21	1.05	0.91	5.94
1958	3.69	16.26	13.66	10.43	8.05	6.37	5.10	4.09	3.29	2.66	2.32	2.01	1.74	1.51	1.30	1.13	0.98	0.85	0.74	4.80
1959	4.02	17.68	14.86	11.18	8.59	6.67	5.30	4.27	3.46	2.82	2.50	2.18	1.89	1.64	1.42	1.23	1.07	0.92	0.80	5.23
1960	4.26	18.77	15.74	11.85	8.97	6.91	5.38	4.30	3.49	2.85	2.55	2.27	1.98	1.72	1.49	1.29	1.12	0.97	0.84	5.49
1961	4.93	21.45	17.88	13.44	10.21	7.80	6.07	4.78	3.87	3.20	2.88	2.57	2.29	2.00	1.74	1.51	1.31	1.14	0.98	6.43
1962	4.76	21.20	17.61	13.10	9.84	7.45	5.65	4.37	3.42	2.77	2.50	2.25	2.02	1.80	1.57	1.37	1.19	1.03	0.89	5.83
1963	4.53	20.78	17.34	12.69	9.41	7.02	5.26	3.95	3.03	2.35	2.11	1.91	1.73	1.55	1.38	1.21	1.05	0.91	0.79	5.17
1964	4.96	22.63	18.89	13.82	10.17	7.57	5.67	4.28	3.24	2.52	2.22	2.00	1.82	1.64	1.47	1.31	1.15	1.00	0.87	5.67
1965	5.32	24.23	20.12	14.73	10.82	7.99	5.96	4.49	3.41	2.62	2.30	2.04	1.84	1.67	1.51	1.35	1.21	1.05	0.92	6.02
1966	5.41	24.62	20.32	14.79	10.88	8.03	5.95	4.47	3.39	2.61	2.27	2.00	1.77	1.60	1.45	1.31	1.18	1.05	0.92	6.06
1967	6.14	27.18	22.26	16.19	11.94	8.90	6.67	5.04	3.88	3.03	2.65	2.31	2.04	1.81	1.63	1.48	1.34	1.21	1.08	7.14
1968	6.82	29.56	23.94	17.43	12.84	9.59	7.26	5.54	4.27	3.37	2.95	2.58	2.25	1.99	1.77	1.59	1.45	1.31	1.18	8.03
1969	5.75	26.02	21.06	15.07	10.93	7.98	5.89	4.40	3.30	2.51	2.19	1.92	1.68	1.47	1.30	1.15	1.04	0.95	0.86	6.03
1970	5.73	26.07	21.29	15.09	10.84	7.89	5.78	4.28	3.22	2.44	2.12	1.85	1.62	1.42	1.24	1.10	0.98	0.88	0.80	5.83
1971	5.94	27.39	22.50	16.02	11.36	8.16	5.92	4.32	3.20	2.40	2.08	1.80	1.58	1.38	1.21	1.06	0.94	0.84	0.76	5.68
1972	6.19	28.82	23.63	16.82	11.99	8.49	6.08	4.39	3.20	2.37	2.06	1.78	1.55	1.36	1.19	1.04	0.91	0.81	0.72	5.54
1973	6.20	29.49	24.15	17.02	12.09	8.57	6.02	4.26	3.05	2.20	1.90	1.65	1.43	1.25	1.09	0.96	0.84	0.74	0.65	5.05
1974	7.44	34.30	27.84	19.61	13.98	10.06	7.24	5.18	3.76	2.78	2.39	2.08	1.81	1.57	1.36	1.19	1.05	0.92	0.81	6.26
1975	8.58	38.69	30.84	21.69	15.45	11.13	8.10	5.92	4.31	3.21	2.77	2.39	2.07	1.81	1.57	1.37	1.20	1.05	0.93	7.09
1976	8.79	39.62	31.03	21.46	15.21	10.91	7.91	5.80	4.27	3.16	2.72	2.35	2.03	1.76	1.54	1.34	1.16	1.02	0.90	6.82
1977	9.22	41.29	32.09	21.80	15.23	10.91	7.90	5.80	4.31	3.24	2.78	2.39	2.07	1.79	1.56	1.36	1.18	1.03	0.90	6.83
1978	3.59	43.56	33.64	22.70	15.57	10.97	7.92	5.80	4.31	3.25	2.83	2.43	2.10	1.82	1.57	1.37	1.19	1.04	0.90	6.80
1979	4.04	18.20	38.08	25.37	17.15	11.76	8.25	5.91	4.28	3.15	2.76	2.40	2.06	1.78	1.55	1.34	1.16	1.02	0.89	6.57
1980	12.29	21.21	15.77	28.22	19.00	12.97	8.95	6.32	4.56	3.33	2.93	2.57	2.24	1.93	1.67	1.45	1.25	1.09	0.95	6.98
1981	14.76	160.74	43.79	28.22	52.17	36.23	25.38	17.86	12.73	9.17	8.10	7.13	6.27	5.47	4.71	4.07	3.53	3.06	2.66	19.40
1982	14.73	25.65	31.87	7.09	4.89	9.74	7.31	5.56	4.25	3.31	3.11	2.75	2.43	2.13	1.86	1.60	1.39	1.20	1.04	7.53
1983	43.65	59.32	15.42	16.30	3.74	2.66	5.47	4.25	3.34	2.66	2.54	2.39	2.12	1.87	1.64	1.43	1.24	1.07	0.93	6.61
1984	86.17	326.48	67.08	15.05	16.48	3.91	2.87	6.03	4.75	3.75	3.62	3.46	3.26	2.89	2.55	2.25	1.96	1.69	1.47	10.34
1985	37.32	360.15	162.89	28.53	6.98	8.34	2.16	1.72	3.90	3.28	3.35	3.23	3.10	2.92	2.59	2.29	2.02	1.76	1.52	10.60
1986	16.12	65.90	67.69	25.61	4.94	1.33	1.75	0.50	0.44	1.11	1.23	1.25	1.21	1.16	1.10	0.97	0.86	0.76	0.66	4.55
1987	29.34	54.87	31.58	28.56	11.49	2.33	0.66	0.90	0.27	0.25	0.77	0.85	0.87	0.84	0.81	0.76	0.68	0.60	0.53	3.63
1988	30.76	134.21	35.78	17.99	17.17	7.22	1.52	0.45	0.63	0.19	0.22	0.68	0.75	0.77	0.75	0.71	0.68	0.60	0.53	3.69
1989	18.43	146.73	83.42	19.20	10.39	10.67	4.83	1.10	0.34	0.53	0.20	0.23	0.71	0.79	0.80	0.78	0.75	0.71	0.63	4.42
1990	6.75	26.17	24.13	11.69	2.95	1.76	2.01	1.02	0.26	0.09	0.18	0.07	0.08	0.25	0.27	0.28	0.27	0.26	0.25	1.75
1991	16.52	32.92	21.43	17.72	8.76	2.22	1.32	1.50	0.75	0.19	0.08	0.15	0.06	0.06	0.20	0.22	0.22	0.22	0.21	1.61
1992	0.98	13.90	24.04	18.41	16.06	8.00	1.99	1.13	1.20	0.56	0.17	0.07	0.13	0.05	0.06	0.18	0.20	0.20	0.20	1.64
1993	0.14	4.84	33.98	7.31	3.21	3.14	1.88	0.58	0.42	0.57	0.37	0.11	0.05	0.09	0.03	0.04	0.12	0.13	0.13	1.22
1994	0.24	1.65	24.47	23.73	3.27	1.46	1.49	0.93	0.30	0.22	0.35	0.23	0.07	0.03	0.05	0.02	0.02	0.07	0.08	0.83
1995	0.09	2.34	7.86	16.37	10.30	1.47	0.70	0.76	0.51	0.18	0.15	0.24	0.16	0.05	0.02	0.04	0.01	0.02	0.05	0.63
1996	0.26	1.83	17.85	7.65	10.34	6.52	0.94	0.45	0.48	0.32	0.13	0.11	0.17	0.11	0.03	0.01	0.03	0.01	0.01	0.50
1997	0.24	2.43	7.96	10.55	2.81	3.89	2.59	0.40	0.20	0.24	0.19	0.08	0.07	0.10	0.07	0.02	0.01	0.02	0.01	0.30
1998	0.81	5.78	22.55	9.56	7.90	2.07	2.84	1.86	0.28	0.14	0.19	0.15	0.06	0.05	0.08	0.05	0.02	0.01	0.01	0.25
1999	1.79	17.67	48.81	26.12	6.82	5.74	1.57	2.23	1.49	0.23	0.14	0.20	0.16	0.06	0.06	0.09	0.06	0.02	0.01	0.27
2000	2.22	22.04	84.85	30.84	9.81	2.72	2.51	0.75	1.15	0.84	0.18	0.11	0.15	0.13	0.05	0.04	0.07	0.04	0.01	0.22
2001	1.08	20.37	84.29	43.99	9.57	3.29	1.02	1.08	0.37	0.66	0.66	0.14	0.09	0.12	0.10	0.04	0.03	0.05	0.04	0.19
2002	1.14	12.79	94.38	53.08	16.96	3.90	1.46	0.49	0.56	0.20	0.47	0.48	0.10	0.06	0.09	0.07	0.03	0.02	0.04	0.16
2003	0.70	5.67	28.92	29.96	10.04	3.38	0.85	0.35	0.13	0.17	0.08	0.20	0.20	0.04	0.03	0.04	0.03	0.01	0.01	0.08
2004	0.37	11.64	44.11	36.69	24.65	8.36	2.90	0.75	0.32	0.12	0.20	0.10	0.23	0.23	0.05	0.03	0.04	0.03	0.01	0.11
2005	0.11	2.12	30.22	19.37	10.75	7.59	2.75	1.03	0.29	0.13	0.07	0.11	0.05	0.12	0.13	0.03	0.02	0.02	0.02	0.07
2006	3.50	1.72	13.99	29.81	12.27	6.86	4.94	1.81	0.68	0.19	0.11	0.06	0.09	0.04	0.10	0.11	0.02	0.01	0.02	0.07
2007	1.95	34.49	7.76	9.23	12.02	5.09	3.04	2.37	0.96	0.40	0.15	0.09	0.05	0.07	0.04	0.08	0.08	0.02	0.01	0.07
2008	3.01	41.62	290.44	9.44	7.14	9.54	4.22	2.61	2.10	0.86	0.46	0.18	0.10	0.05	0.08	0.04	0.10	0.10	0.02	0.10
2009	0.84	40.66	213.07	206.34	4.21	3.51	5.33	2.66	1.85	1.64	0.93	0.50	0.19	0.11	0.06	0.09	0.04	0.10	0.11	0.13
2010	0.02	0.07	0.54	0.35	0.23	0.01	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	0.00
2011	0.04	0.15	0.21	0.54	0.28	0.19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2012	0.13	0.72	0.96	0.84	2.63	1.62	1.25	0.04	0.05	0.12	0.09	0.09	0.11	0.06	0.03	0.01	0.01	0.00	0.01	0.03
2013	0.19	0.53	1.13	0.53	0.28	0.76	0.48	0.38	0.01	0.02	0.04	0.03	0.03	0.04	0.02	0.01	0.00	0.00	0.00	0.01
2014	1.35	2.77	3.31	4.20	2.02	1.15	3.45	2.31	1.91	0.06	0.09	0.20	0.15	0.15	0.19	0.11	0.06	0.02	0.01	0.06
2015	0.16	0.69	0.68	0.41	0.36	0.16	0.10	0.30	0.20	0.17	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.00	0.01
2016	0.03	0.18	0.30	0.11	0.04	0.03	0.01	0.01	0.03	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2017	1.20	3.55	8.78	8.88	3.21	1.33	1.23	0.63	0.41	1.35	0.96	0.81	0.03	0.04	0.09	0.07	0.07	0.08	0.05	0.07
2018	0.93	6.36	9.47	11.46	8.02	2.76	1.22	1.19	0.63	0.42	1.38	0.98	0.83	0.03	0.04	0.09	0.07	0.07	0.09	0.12
2019	1.25	3.81	12.59	9.16	7.82	5.39	2.04	0.97	0.99	0.53	0.36	1.18	0.84	0.71	0.02	0.03	0.08	0.06	0.06	0.18

Table 24. 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	1.65	14.04	19.64	23.34	25.43	26.15	25.82	24.75	23.20	21.40	19.48	17.57	15.71	13.97	12.35	10.88	9.56	8.38	7.33	48.19
1951	2.20	18.73	26.64	31.67	34.51	35.49	35.04	33.59	31.49	29.03	26.44	23.84	21.32	18.95	16.76	14.77	12.97	11.37	9.95	65.39
1952	1.67	14.24	20.26	24.48	26.69	27.45	27.10	25.98	24.35	22.46	20.45	18.44	16.49	14.66	12.96	11.42	10.03	8.79	7.69	50.58
1953	1.70	14.45	20.61	24.92	27.61	28.41	28.05	26.89	25.21	23.24	21.16	19.08	17.07	15.17	13.42	11.82	10.38	9.10	7.96	52.35
1954	2.49	21.17	30.23	36.64	40.63	42.48	41.96	40.23	37.71	34.77	31.67	28.55	25.53	22.70	20.08	17.69	15.54	13.61	11.91	78.32
1955	4.15	42.72	63.84	73.16	75.76	73.11	67.19	58.82	50.37	42.66	38.85	35.02	31.32	27.84	24.63	21.70	19.06	16.70	14.61	96.08
1956	4.34	45.02	66.06	74.88	77.53	74.92	68.78	61.03	52.12	43.96	40.13	36.18	32.36	28.76	25.44	22.41	19.69	17.25	15.09	99.25
1957	6.24	61.37	88.61	99.53	103.84	102.62	96.91	88.53	79.19	68.89	63.07	57.00	50.97	45.31	40.08	35.31	31.01	27.18	23.78	156.36
1958	5.46	55.73	80.07	88.54	89.32	86.21	80.23	72.25	63.50	55.11	50.67	45.93	41.17	36.60	32.37	28.52	25.05	21.95	19.21	126.29
1959	5.94	60.59	87.10	94.97	95.31	90.19	83.36	75.42	66.77	58.26	54.66	49.75	44.74	39.86	35.26	31.06	27.28	23.91	20.92	137.55
1960	6.30	64.33	92.29	100.61	99.47	93.52	84.60	75.88	67.35	59.06	55.71	51.74	46.72	41.76	37.02	32.62	28.65	25.11	21.97	144.43
1961	7.29	73.53	104.80	114.15	113.29	105.48	95.38	84.31	74.75	66.23	62.94	58.77	54.16	48.61	43.22	38.17	33.53	29.38	25.71	169.03
1962	7.04	72.67	103.24	111.22	109.20	100.78	88.87	77.13	66.07	57.25	54.70	51.46	47.67	43.66	38.99	34.53	30.41	26.65	23.31	153.29
1963	6.70	71.22	101.64	107.79	104.40	95.03	82.76	69.75	58.38	48.64	46.21	43.70	40.79	37.56	34.22	30.44	26.88	23.62	20.66	135.85
1964	7.33	77.58	110.77	117.35	112.81	102.42	89.22	75.52	62.60	52.11	48.63	45.74	42.91	39.81	36.47	33.10	29.36	25.87	22.68	149.15
1965	7.86	83.04	117.98	125.09	120.05	108.08	93.78	79.25	65.85	54.14	50.37	46.53	43.42	40.49	37.37	34.10	30.86	27.31	24.02	158.32
1966	8.00	84.39	119.14	125.62	120.72	108.60	93.52	78.80	65.43	53.98	49.68	45.76	41.94	38.89	36.09	33.17	30.18	27.25	24.07	159.48
1967	9.07	93.14	130.53	137.51	132.42	120.44	104.87	88.95	74.83	62.78	57.98	52.82	48.27	43.96	40.56	37.49	34.37	31.20	28.12	187.89
1968	10.09	101.32	140.34	148.05	142.47	129.78	114.12	97.67	82.44	69.76	64.41	58.90	53.23	48.35	43.81	40.27	37.11	33.94	30.75	211.26
1969	8.51	89.19	123.47	127.96	121.25	108.00	92.61	77.56	63.73	52.04	47.94	43.82	39.75	35.70	32.27	29.13	26.69	24.54	22.40	158.51
1970	8.47	89.35	124.84	128.11	120.28	106.76	90.87	75.58	62.09	50.58	46.26	42.19	38.26	34.49	30.83	27.75	24.97	22.83	20.96	153.28
1971	8.79	93.87	131.89	136.07	126.05	110.34	93.03	76.24	61.67	49.73	45.49	41.19	37.26	33.59	30.13	26.82	24.07	21.62	19.73	149.35
1972	9.15	98.78	138.51	142.81	133.01	114.90	95.54	77.55	61.79	49.05	44.99	40.73	36.60	32.91	29.51	26.37	23.40	20.96	18.79	145.77
1973	9.17	101.08	141.56	144.53	134.10	115.97	94.63	75.20	58.80	45.47	41.57	37.74	33.90	30.27	27.08	24.19	21.55	19.09	17.06	132.90
1974	11.00	117.55	163.20	166.55	155.09	136.05	113.77	91.37	72.53	57.47	52.36	47.38	42.67	38.10	33.85	30.17	26.87	23.88	21.11	164.55
1975	12.68	132.61	180.78	184.21	171.35	150.62	127.41	104.41	83.24	66.38	60.54	54.60	49.01	43.88	38.98	34.50	30.65	27.24	24.17	186.39
1976	13.00	135.80	181.92	182.21	168.74	147.54	124.36	102.34	82.48	65.31	59.37	53.61	47.96	42.79	38.12	33.73	29.76	26.38	23.40	179.48
1977	13.64	141.51	188.13	185.16	168.95	147.54	124.16	102.28	83.23	67.04	60.72	54.64	48.95	43.53	38.64	34.28	30.25	26.63	23.56	179.75
1978	5.30	149.29	197.22	192.72	172.69	148.44	124.58	102.26	83.07	67.33	61.86	55.47	49.52	44.09	39.01	34.49	30.51	26.86	23.60	178.80
1979	5.98	62.37	223.25	215.43	190.31	159.07	129.68	104.32	82.62	65.13	60.31	54.85	48.79	43.29	38.35	33.80	29.80	26.30	23.11	172.78
1980	18.17	72.70	92.46	239.67	210.73	175.42	140.77	111.59	88.08	69.00	64.08	58.74	53.00	46.86	41.37	36.51	32.08	28.22	24.86	183.69
1981	21.82	550.93	256.74	239.65	578.81	490.18	399.03	315.10	245.62	189.85	177.11	162.84	148.09	132.80	116.82	102.73	90.38	79.23	69.58	510.17
1982	21.79	87.90	186.86	60.20	54.23	131.81	115.01	98.06	82.04	68.44	68.04	62.84	57.32	51.81	46.23	40.51	35.52	31.17	27.28	198.05
1983	64.55	203.31	90.43	138.38	41.45	35.99	86.06	74.98	64.50	54.95	55.43	54.55	49.98	45.31	40.75	36.22	31.64	27.68	24.26	173.92
1984	127.43	1118.99	393.29	127.77	182.83	52.91	45.07	106.48	91.63	77.62	79.09	78.97	77.10	70.22	63.34	56.74	50.28	43.82	38.27	271.84
1985	55.18	1234.38	955.03	242.23	77.42	112.84	33.89	30.27	75.17	67.95	73.21	73.85	73.15	70.98	64.32	57.79	51.61	45.63	39.71	278.75
1986	23.85	225.87	396.86	217.47	54.84	18.02	27.59	8.84	8.51	22.95	26.81	28.60	28.62	28.18	27.21	24.55	22.00	19.60	17.30	119.78
1987	43.38	188.08	185.16	242.52	127.43	31.49	10.31	15.94	5.20	5.13	16.78	19.42	20.55	20.44	20.02	19.25	17.33	15.48	13.78	95.58
1988	45.48	460.00	209.78	152.75	190.48	97.71	23.95	7.86	12.22	4.02	4.78	15.49	17.78	18.69	18.50	18.05	17.31	15.54	13.87	97.15
1989	27.26	502.89	489.06	163.04	115.25	144.37	75.93	19.34	6.64	10.88	4.42	5.20	16.72	19.07	19.95	19.67	19.13	18.31	16.41	116.27
1990	9.99	89.71	141.49	99.29	32.72	23.82	31.65	18.08	5.10	1.97	3.97	1.60	1.86	5.95	6.76	7.04	6.92	6.72	6.42	46.15
1991	24.43	112.85	125.64	150.49	97.19	30.07	20.80	26.41	14.44	3.90	1.66	3.32	1.32	1.53	4.88	5.51	5.73	5.62	5.44	42.25
1992	3.18	71.07	172.40	170.94	182.54	106.81	30.18	19.04	22.03	11.07	3.53	1.50	2.99	1.19	1.38	4.40	4.99	5.20	5.12	43.31
1993	0.46	24.77	243.70	67.93	36.46	41.94	28.55	9.75	7.65	11.21	7.74	2.45	1.03	2.04	0.81	0.94	2.98	3.37	3.50	32.19
1994	0.77	8.42	175.49	220.38	37.19	19.54	22.58	15.60	5.44	4.38	7.24	4.96	1.56	0.65	1.29	0.51	0.59	1.85	2.09	21.90
1995	0.29	11.97	56.37	152.03	117.08	19.65	10.60	12.78	9.32	3.45	3.18	5.21	3.54	1.11	0.46	0.91	0.36	0.41	1.30	16.56
1996	0.84	9.35	128.05	71.03	117.49	87.02	14.24	7.51	8.89	6.40	2.65	2.43	3.95	2.67	0.83	0.34	0.67	0.26	0.30	13.05
1997	0.78	12.43	57.11	97.99	31.92	51.92	39.25	6.67	3.71	4.67	3.99	1.64	1.49	2.41	1.62	0.50	0.21	0.41	0.16	7.92
1998	2.61	29.53	161.74	88.82	89.84	27.58	43.13	31.34	5.11	2.73	3.99	3.38	1.38	1.25	2.01	1.34	0.41	0.17	0.33	6.54
1999	5.78	90.35	350.05	242.62	77.53	76.65	23.76	37.52	27.40	4.47	3.02	4.38	3.68	1.50	1.34	2.15	1.44	0.44	0.18	7.23
2000	7.18	112.67	608.54	286.41	111.48	36.25	38.08	12.60	21.20	16.45	3.66	2.46	3.53	2.95	1.19	1.07	1.71	1.14	0.35	5.76
2001	3.49	104.15	604.52	408.60	108.78	43.86	15.56	18.12	6.74	12.90	13.83	3.05	2.03	2.90	2.42	0.97	0.87	1.38	0.92	4.88
2002	3.69	65.38	676.91	492.97	192.80	52.10	22.11	8.29	10.21	4.00	9.88	10.50	2.30	1.52	2.17	1.80	0.72	0.64	1.02	4.22
2003	2.27	28.98	207.44	278.27	114.12	45.16	12.95	5.95	2.46	3.38	1.75	4.28	4.52	0.98	0.65	0.92	0.76	0.30	0.27	2.18
2004	1.20	59.49	316.35	340.75	280.14	111.54	44.03	12.66	5.85	2.44	4.12	2.11	5.13	5.39	1.17	0.77	1.08	0.89	0.36	2.84
2005	0.34	10.86	216.74	179.91	122.14	101.31	41.79	17.31	5.30	2.64	1.42	2.37	1.21	2.92	3.05	0.66	0.43	0.61	0.50	1.76
2006	11.30	8.80	100.34	276.89	139.46	91.57	75.03	30.59	12.50	3.77	2.34	1.25	2.08	1.05	2.53	2.63	0.57	0.37	0.52	1.91
2007	6.30	176.30	55.68	85.70	136.66	67.86	46.13	39.96	17.56	7.89	3.18	1.96	1.04	1.72	0.87	2.07	2.15	0.46	0.30	1.95
2008	9.74	212.79	2083.01	87.70	81.19	127.31	63.99	44.05	38.48	16.98	9.63	3.85	2.36	1.24	2.04	1.02	2.45	2.53	0.54	2.62
2009	2.73	207.88	1528.09	1916.47	47.83	46.86	80.88	44.87	33.94	32.38	19.39	10.91	4.33	2.64	1.38	2.26	1.13	2.69	2.78	3.43
2010	0.02	0.24	3.15	2.96	2.55	0.09	0.12	0.29	0.22	0.23	0.31	0.18	0.10	0.04	0.02	0.01	0.02	0.01	0.02	0.05
2011	0.06	0.53	1.21	4.60	3.11	2.51	0.08	0.11	0.24	0.17	0.18	0.24	0.14	0.08	0.03	0.02	0.01	0.01	0.01	0.06
2012	0.19	2.46	5.61	7.11	29.16	21.98	19.69	0.70	1.00	2.45	1.95	2.07	2.68	1.56	0.86	0.33	0.20	0.10	0.17	0.71
2013	0.29	1.83	6.65	4.54	3.07	10.34	7.58	6.74	0.24	0.33	0.82	0.64	0.68	0.87	0.51	0.28	0.11	0.06	0.03	0.28
2014	2.00	9.48	19.41	35.68	22.42	15.61	54.25	40.70	36.77	1.31	1.86	4.57	3.57	3.73	4.79	2.76	1.51	0.58	0.35	1.68
2015	0.24	2.37	3.99	3.47	4.02	2.19	1.51	5.28	3.94	3.52	0.13	0.18	0.43	0.33	0.35	0.44	0.26	0.14	0.05	0.18
2016	0.05	0.62	1.78	0.92	0.44	0.43	0.23	0.16	0.55	0.40	0.36	0.01	0.02	0.04	0.03	0.03	0.04	0.03	0.01	0.02
2017	1.78	12.18	51.49	75.38	35.57	18.04	19.33	11.11	7.95	28.00	20.88	18.52	0.65	0.90	2.16	1.66	1.72	2.18	1.25	1.83
2018	1.37	21.79	55.54	97.34	89.02	37.39	19.26	21.00	12.09	8.61	30.16	22.27	19.59	0.68	0.94	2.25	1.73	1.78	2.26	3.17
2019	1.85	13.07	73.79	77.76	86.80	72.87	32.09	17.20	19.04	10.98	7.80	27.05	19.81	17.32	0.60	0.82	1.97	1.50	1.55	4.69

Table 25. 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	0.87	1.62	0.17	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	0.00
1982	1.85	0.56	0.27	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	2.12	0.51	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	26.33	17.04	1.36	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	0.00
1985	12.62	20.77	3.64	0.16	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
1986	18.27	13.11	5.25	0.50	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
1987	26.13	8.62	1.93	0.44	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
1988	12.35	9.36	0.97	0.12	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
1989	4.65	6.50	1.44	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	0.00
1990	6.17	4.62	1.69	0.20	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	8.63	3.09	0.79	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	0.00	0.00	0.00	0.00
1992	11.10	11.05	1.56	0.34	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
1993	20.41	39.48	14.02	0.60	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
1994	31.39	12.72	10.48	2.24	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
1995	15.47	21.96	4.03	2.01	0.27	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
1996	13.46	6.17	4.46	0.54	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	0.00	0.00	0.00
1997	9.06	6.06	1.68	0.72	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
1998	30.59	14.02	3.40	0.33	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
1999	73.05	46.16	7.08	0.70	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
2000	119.32	75.71	15.86	1.01	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
2001	83.90	98.54	21.44	1.96	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
2002	68.34	48.77	20.49	2.27	0.16	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	93.09	46.19	12.11	2.15	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
2004	79.92	154.82	29.43	3.95	0.56	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
2005	17.23	21.24	15.96	1.93	0.23	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	167.22	5.16	2.18	0.78	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
2007	184.03	197.63	2.22	0.44	0.12	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
2008	250.90	219.62	80.18	0.43	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
2009	75.01	229.66	63.46	10.14	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
2010	28.74	27.58	81.97	36.95	16.75	0.28	0.18	0.22	0.10	0.07	0.09	0.05	0.03	0.01	0.01	0.00	0.01	0.00	0.01	0.01
2011	24.47	18.74	11.25	24.52	10.06	4.90	0.10	0.10	0.19	0.13	0.13	0.17	0.10	0.05	0.02	0.01	0.01	0.01	0.00	0.04
2012	31.49	41.80	19.35	8.37	15.45	5.64	2.51	0.05	0.05	0.09	0.06	0.07	0.08	0.05	0.02	0.01	0.01	0.00	0.00	0.02
2013	30.61	18.65	15.48	5.16	1.91	3.41	1.36	0.74	0.02	0.02	0.05	0.04	0.04	0.05	0.03	0.01	0.01	0.00	0.00	0.01
2014	116.88	61.94	24.50	14.97	4.22	1.42	2.43	1.00	0.59	0.02	0.02	0.05	0.04	0.04	0.05	0.03	0.01	0.01	0.00	0.02
2015	146.42	158.89	52.25	14.80	7.55	1.93	0.63	1.12	0.50	0.32	0.01	0.01	0.03	0.03	0.03	0.03	0.02	0.01	0.00	0.01
2016	193.47	254.65	169.11	40.72	10.02	4.78	1.20	0.40	0.75	0.36	0.31	0.01	0.01	0.03	0.02	0.03	0.03	0.02	0.01	0.02
2017	154.10	120.92	94.90	44.27	9.08	2.10	1.01	0.27	0.10	0.22	0.16	0.13	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2018	190.88	340.77	163.00	92.27	36.58	6.87	1.51	0.69	0.18	0.06	0.21	0.15	0.12	0.00	0.01	0.01	0.01	0.01	0.01	0.02
2019	168.47	135.44	140.65	46.33	22.20	8.36	1.58	0.37	0.19	0.06	0.04	0.13	0.09	0.08	0.00	0.00	0.01	0.01	0.01	0.02

Table 26. 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	1.02	5.02	0.96	0.23	0.12	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
1982	2.15	1.75	1.53	0.13	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
1983	2.48	1.58	0.29	0.11	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
1984	30.73	52.88	7.62	0.64	0.20	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
1985	14.73	64.47	20.44	1.33	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
1986	21.33	40.70	29.47	4.13	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
1987	30.50	26.74	10.86	3.64	0.41	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
1988	14.41	29.06	5.45	1.02	0.27	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
1989	5.43	20.18	8.09	0.69	0.10	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
1990	7.20	14.33	9.51	1.67	0.11	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	10.07	9.59	4.42	1.35	0.18	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
1992	12.96	34.30	8.76	2.85	0.75	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
1993	23.82	122.53	78.76	4.97	0.61	0.14	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
1994	36.64	39.47	58.85	18.72	0.73	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
1995	18.05	68.15	22.61	16.74	2.99	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
1996	15.70	19.16	25.05	4.50	1.78	0.24	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	10.57	18.80	9.46	6.00	0.47	0.13	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
1998	35.70	43.50	19.08	2.74	0.66	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
1999	85.26	143.24	39.78	5.86	0.44	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
2000	139.26	234.97	89.07	8.47	0.77	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
2001	97.92	305.81	120.42	16.34	1.01	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
2002	79.76	151.37	115.06	18.91	1.74	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	0.00
2003	108.64	143.34	68.01	17.96	1.69	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
2004	93.28	480.46	165.31	32.94	6.21	0.56	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
2005	20.11	65.91	89.64	16.07	2.54	0.44	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
2006	195.16	16.02	12.24	6.52	0.76	0.11	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
2007	214.78	613.33	12.47	3.69	1.35	0.15	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
2008	292.83	681.57	450.34	3.56	0.76	0.27	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
2009	87.54	712.75	356.43	84.63	0.49	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
2010	33.55	85.60	460.39	308.32	184.61	3.72	2.82	3.86	1.91	1.48	1.95	1.15	0.63	0.25	0.15	0.08	0.12	0.06	0.15	0.33
2011	28.56	58.16	63.18	204.64	110.93	66.05	1.61	1.74	3.69	2.71	2.89	3.76	2.20	1.21	0.47	0.28	0.15	0.23	0.12	0.89
2012	36.75	129.72	108.66	69.85	170.24	76.12	39.39	0.86	0.87	1.75	1.38	1.46	1.89	1.10	0.60	0.23	0.14	0.07	0.12	0.49
2013	35.73	57.89	86.94	43.06	21.09	45.98	21.31	13.02	0.36	0.44	1.10	0.86	0.90	1.16	0.67	0.37	0.14	0.08	0.04	0.36
2014	136.41	192.24	137.62	124.96	46.55	19.09	38.10	17.57	11.25	0.33	0.46	1.14	0.88	0.92	1.18	0.68	0.37	0.14	0.08	0.41
2015	170.89	493.12	293.44	123.52	83.22	26.08	9.87	19.64	9.53	6.51	0.23	0.32	0.78	0.61	0.63	0.80	0.46	0.25	0.10	0.33
2016	225.80	790.30	949.81	339.80	110.39	64.42	18.77	7.01	14.41	7.41	6.61	0.23	0.32	0.78	0.60	0.62	0.79	0.45	0.24	0.42
2017	179.85	375.26	533.01	369.40	100.13	28.37	15.76	4.71	1.93	4.59	3.41	3.01	0.10	0.14	0.35	0.27	0.27	0.35	0.20	0.29
2018	222.78	1057.57	915.52	769.90	403.18	92.74	23.64	12.16	3.38	1.28	4.46	3.28	2.87	0.10	0.14	0.33	0.25	0.26	0.33	0.46
2019	196.62	420.33	789.95	386.57	244.69	112.76	24.81	6.42	3.58	1.18	0.83	2.88	2.10	1.83	0.06	0.09	0.21	0.16	0.16	0.49

Table 27. 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 ensemble analysis. Rate estimates (F) are in units of y^{-1}*; exploitation rate (E) and status indicators are dimensionless; biomass estimates are in units of metric tons or pounds, as indicated; and recruits are in number of age-1 fish. Spawning stock biomass (SSB) is measured as population fecundity (number of eggs).*

Quantity	Units	Estimate	Median	SE
$F_{30\%}$	y^{-1}	0.21	0.21	0.02
$85\%F_{30\%}$	y^{-1}	0.17	0.17	0.02
$75\%F_{30\%}$	y^{-1}	0.15	0.15	0.02
$65\%F_{30\%}$	y^{-1}	0.13	0.13	0.01
$F_{40\%}$	y^{-1}	0.15	0.15	0.02
$E_{\mathrm{F30\%}}$	—	0.10	0.10	0.01
$B_{\mathrm{F30\%}}$	metric tons	6530.71	6483.54	1475.32
$\mathrm{SSB}_{\mathrm{F30\%}}$	eggs (1E8)	635426.40	594630.20	233432.64
MSST	eggs (1E8)	476569.80	445972.60	175074.48
$L_{\mathrm{F30\%}}$	1000 lb whole	404.70	407.78	99.69
$R_{\mathrm{F30\%}}$	number fish	436868.50	439823.20	89925.13
$L_{85\%\mathrm{F30\%}}$	1000 lb whole	404.85	407.88	98.99
$L_{75\%\mathrm{F30\%}}$	1000 lb whole	398.97	401.84	97.18
$L_{65\%\mathrm{F30\%}}$	1000 lb whole	386.75	389.45	93.96
$F_{2017-2019}/F_{30\%}$	—	2.20	1.95	0.45
$E_{2017-2019}/E_{\mathrm{F30\%}}$	—	2.20	1.97	0.53
$\mathrm{SSB}_{2019}/\mathrm{MSST}$	—	0.59	0.66	0.27
$\mathrm{SSB}_{2019}/\mathrm{SSB}_{\mathrm{F30\%}}$	—	0.44	0.49	0.20

Table 28. Results from sensitivity runs of the Beaufort Assessment Model. Current F represented by geometric mean of last three assessment years. Runs should not all be considered equally plausible.

Run	Description	$F_{30\%}$	$SSB_{F30\%}$ (1e8 eggs)	$L_{F30\%}$ (1000 lb)	$F_{current}/F_{30\%}$	$SSB_{2019}/SSB_{F30\%}$	R0 (1000)
Base	—	0.206	635426	405	2.2	0.44	383
S1	MyFishcount	0.203	634734	405	2.2	0.44	383
S2	RTD index = ages	0.206	637013	410	2.18	0.44	384
S3	No CVT index	0.205	639502	411	2.07	0.47	385
S4	No VID index	0.2	641304	390	1.96	0.54	387
S5	No HB.D index	0.204	633982	410	2.22	0.43	382
S6	VID wgt=4	0.205	639419	408	2.07	0.47	385
S7	VID wgt=2	0.205	630558	395	2.39	0.4	381
S8	High M	0.229	415636	325	1.73	0.73	497
S9	Low M	0.172	1113050	543	2.93	0.23	283
S10	Charnov M=0.13 (S41)	0.219	431049	330	1.76	0.71	647
S11	Charnov M=0.11	0.203	570315	383	2.07	0.5	517
S12	Robust Multinomial	0.27	443544	314	2.62	0.42	229
S13	Hypothetical Low Discards	0.162	515579	780	0.76	0.7	309
S14	Hypothetical M	0.255	301691	279	1.33	1.14	664

Table 29. Estimated benchmarks for projections, computed using the same methods as for the assessment benchmarks, but with reduced discard mortality rate due to use of descender devices. Also presented are median values and measures of precision (standard errors, SE) from the Monte Carlo/Bootstrap ensemble analysis. Rate estimates (F) are in units of y^{-1}; exploitation rate (E) is dimensionless; biomass estimates are in units of metric tons or pounds, as indicated; and recruits are in number of age-1 fish. Spawning stock biomass (SSB) is measured as population fecundity (number of eggs).

Quantity	Units	Estimate	Median	SE
$F_{30\%}$	y^{-1}	0.22	0.23	0.03
$E_{\mathrm{F30\%}}$	—	0.10	0.10	0.01
$B_{\mathrm{F30\%}}$	metric tons	6556	6522	1480
$\mathrm{SSB}_{\mathrm{F30\%}}$	eggs (1E8)	635583	594795	233436
$L_{\mathrm{F30\%}}$	1000 lb whole	442	456	112
$R_{\mathrm{F30\%}}$	number fish	436869	439823	89925

Table 30. Projection results with fishing mortality rate fixed at $F = F_{30\%}$ starting in 2023 and long-term, average recruitment. 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 $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$. 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
2020	437	380	0.39	0.34	306993	324501	40	39	416	409	408	378	1980	1874	0.052
2021	437	380	0.35	0.31	342360	367864	38	37	420	413	272	240	1499	1369	0.107
2022	437	381	0.33	0.28	369131	401377	35	35	419	412	213	185	1219	1108	0.168
2023	437	380	0.22	0.23	398103	431220	24	28	302	353	136	136	752	793	0.210
2024	437	381	0.22	0.23	429163	458171	24	27	318	368	135	131	723	730	0.244
2025	437	381	0.22	0.23	457019	480318	25	27	333	379	136	129	718	705	0.272
2026	437	377	0.22	0.23	481357	499146	25	28	348	390	136	129	721	696	0.293
2027	437	382	0.22	0.23	503100	514885	26	28	361	399	137	129	726	696	0.308
2028	437	381	0.22	0.23	521476	526457	26	28	372	407	137	129	730	696	0.322
2029	437	380	0.22	0.23	537402	536710	26	28	382	413	137	129	733	699	0.333
2030	437	378	0.22	0.23	551144	543529	27	28	390	418	137	130	734	701	0.339
2031	437	378	0.22	0.23	562901	550883	27	28	397	423	137	130	735	703	0.346
2032	437	380	0.22	0.23	573246	556824	27	29	404	426	137	130	736	705	0.352
2033	437	380	0.22	0.23	582035	562116	27	29	409	430	137	130	737	707	0.356
2034	437	381	0.22	0.23	589522	566207	28	29	414	433	137	130	737	706	0.365
2035	437	380	0.22	0.23	596094	570590	28	29	418	435	137	130	737	706	0.371
2036	437	379	0.22	0.23	601727	573432	28	29	421	437	137	130	738	707	0.377
2037	437	380	0.22	0.23	606443	576438	28	29	424	440	137	130	738	708	0.385
2038	437	381	0.22	0.23	610514	579022	28	29	426	442	137	131	739	709	0.392
2039	437	379	0.22	0.23	613991	581361	28	29	429	444	137	130	739	712	0.400
2040	437	381	0.22	0.23	617005	583259	28	29	430	445	137	130	739	711	0.407
2041	437	385	0.22	0.23	619606	584483	28	29	432	446	137	130	739	710	0.414
2042	437	381	0.22	0.23	621844	585966	28	29	433	447	137	130	739	710	0.420
2043	437	382	0.22	0.23	623769	587483	28	30	435	448	138	130	739	709	0.426
2044	437	380	0.22	0.23	625424	588026	28	30	436	449	138	130	740	709	0.433

Table 31. Projection results with fishing mortality rate fixed at $F = F_{30\%}$ starting in 2023 and recent average recruitment. 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 $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$. 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
2020	1145	980	0.39	0.34	308482	326178	40	40	416	409	496	447	2079	1961	0.054
2021	1145	982	0.34	0.30	354122	379262	40	39	420	413	421	356	1813	1615	0.129
2022	1145	984	0.29	0.25	416135	448412	40	39	419	412	387	325	1739	1523	0.252
2023	1145	984	0.22	0.23	497494	527371	36	40	383	439	319	307	1499	1491	0.386
2024	1145	983	0.22	0.23	592020	613831	41	45	456	510	339	321	1660	1607	0.530
2025	1145	985	0.22	0.23	690331	701264	46	50	530	581	349	327	1769	1688	0.673
2026	1145	975	0.22	0.23	787833	786625	51	53	600	645	355	330	1833	1735	0.795
2027	1145	986	0.22	0.23	882353	866607	54	57	666	705	357	331	1867	1757	0.884
2028	1145	985	0.22	0.23	971484	942264	57	59	725	760	358	334	1885	1771	0.941
2029	1145	987	0.22	0.23	1054133	1011250	60	62	779	807	359	334	1895	1783	0.972
2030	1145	974	0.22	0.23	1129813	1074781	62	64	827	853	359	334	1902	1788	0.989
2031	1145	977	0.22	0.23	1197981	1132538	64	65	870	891	359	334	1907	1794	0.996
2032	1145	984	0.22	0.23	1258871	1183522	66	67	908	926	359	335	1911	1799	0.999
2033	1145	981	0.22	0.23	1312855	1227167	67	68	942	958	359	335	1915	1807	1.000
2034	1145	987	0.22	0.23	1360287	1265945	68	69	971	985	360	336	1918	1813	1.000
2035	1145	984	0.22	0.23	1401799	1300445	69	70	996	1008	360	336	1921	1817	1.000
2036	1145	981	0.22	0.23	1438041	1331793	70	71	1019	1028	360	337	1924	1822	1.000
2037	1145	987	0.22	0.23	1469513	1358375	71	72	1038	1047	360	338	1926	1827	1.000
2038	1145	984	0.22	0.23	1496803	1379877	71	72	1054	1064	360	338	1928	1832	1.000
2039	1145	982	0.22	0.23	1520378	1400793	72	73	1069	1078	360	337	1930	1832	1.000
2040	1145	985	0.22	0.23	1540703	1418726	72	73	1081	1089	360	336	1931	1832	1.000
2041	1145	990	0.22	0.23	1558198	1431597	73	74	1092	1098	360	336	1932	1831	1.000
2042	1145	982	0.22	0.23	1573246	1443670	73	74	1101	1110	360	337	1933	1832	1.000
2043	1145	989	0.22	0.23	1586186	1454091	73	75	1109	1118	360	337	1934	1832	1.000
2044	1145	983	0.22	0.23	1597313	1464902	74	75	1116	1124	360	337	1935	1832	1.000

Table 32. Projection results with fishing mortality rate fixed at $F = F_{\text{rebuild}}$ (P=0.5) starting in 2023 and long-term, average recruitment. 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 $\text{SSB} \geq \text{SSB}_{\text{MSY}}$. 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
2020	437	380	0.39	0.34	306993	324501	40	39	416	409	408	378	1980	1874	0.052
2021	437	380	0.35	0.31	342360	367864	38	37	420	413	272	240	1499	1369	0.107
2022	437	381	0.33	0.28	369131	401377	35	35	419	412	213	185	1219	1108	0.168
2023	437	380	0.22	0.22	398610	431801	23	27	296	346	133	133	738	778	0.211
2024	437	381	0.22	0.22	430561	459717	24	27	312	362	133	129	712	719	0.247
2025	437	381	0.22	0.22	459395	482866	24	27	328	374	134	127	708	695	0.277
2026	437	377	0.22	0.22	484754	502549	25	27	343	385	134	127	712	687	0.302
2027	437	382	0.22	0.22	507530	519328	25	28	357	395	135	127	718	688	0.320
2028	437	381	0.22	0.22	526910	531966	26	28	368	403	135	127	722	689	0.338
2029	437	380	0.22	0.22	543798	542940	26	28	379	409	135	128	725	692	0.352
2030	437	378	0.22	0.22	558439	550611	27	28	387	415	135	128	726	694	0.365
2031	437	378	0.22	0.22	571024	558782	27	28	395	420	135	128	727	696	0.374
2032	437	380	0.22	0.22	582125	565559	27	28	402	424	135	128	728	697	0.385
2033	437	380	0.22	0.22	591593	571155	27	29	407	428	135	128	729	699	0.394
2034	437	381	0.22	0.22	599686	576077	28	29	412	432	135	128	729	698	0.405
2035	437	380	0.22	0.22	606797	580821	28	29	416	434	136	128	730	698	0.416
2036	437	379	0.22	0.22	612907	583952	28	29	420	436	136	128	730	699	0.425
2037	437	380	0.22	0.22	618040	587443	28	29	423	439	136	128	731	701	0.433
2038	437	381	0.22	0.22	622478	590483	28	29	426	441	136	129	731	702	0.444
2039	437	379	0.22	0.22	626274	592779	28	29	428	443	136	128	731	705	0.455
2040	437	381	0.22	0.22	629568	594990	28	29	430	445	136	128	731	704	0.464
2041	437	385	0.22	0.22	632412	596449	28	29	432	446	136	128	732	702	0.472
2042	437	381	0.22	0.22	634862	598117	28	29	433	447	136	128	732	703	0.482
2043	437	382	0.22	0.22	636971	599956	28	29	434	448	136	128	732	702	0.491
2044	437	380	0.22	0.22	638786	600537	28	29	436	449	136	129	732	702	0.498

Table 33. Projection results with fishing mortality rate fixed at $F = F_{\mathrm{rebuild}}$ (P=0.5) starting in 2023 and recent average recruitment. 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 $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$. 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
2020	1145	980	0.39	0.34	308482	326178	40	40	416	409	496	447	2079	1961	0.054
2021	1145	982	0.34	0.30	354122	379262	40	39	420	413	421	356	1813	1615	0.129
2022	1145	984	0.29	0.25	416135	448412	40	39	419	412	387	325	1739	1523	0.252
2023	1145	984	0.43	0.43	465234	493777	64	72	691	795	569	547	2657	2646	0.325
2024	1145	983	0.43	0.43	497755	518102	65	72	734	825	551	523	2587	2514	0.354
2025	1145	985	0.43	0.43	524199	535478	66	71	764	845	539	505	2513	2410	0.378
2026	1145	975	0.43	0.43	545916	549697	66	70	787	856	534	496	2464	2341	0.397
2027	1145	986	0.43	0.43	564370	559689	66	70	806	865	532	493	2441	2303	0.411
2028	1145	985	0.43	0.43	579562	567432	67	70	822	871	531	494	2431	2292	0.422
2029	1145	987	0.43	0.43	591943	573021	67	70	835	876	531	494	2428	2290	0.434
2030	1145	974	0.43	0.43	602056	578873	67	70	846	881	531	495	2428	2288	0.441
2031	1145	977	0.43	0.43	610109	582618	68	70	855	886	531	494	2429	2294	0.449
2032	1145	984	0.43	0.43	616597	584424	68	70	862	889	531	495	2430	2292	0.455
2033	1145	981	0.43	0.43	621859	586777	68	70	868	893	531	495	2431	2297	0.458
2034	1145	987	0.43	0.43	626074	587104	68	70	873	894	531	496	2431	2303	0.466
2035	1145	984	0.43	0.43	629480	589123	68	70	877	894	531	495	2432	2300	0.467
2036	1145	981	0.43	0.43	632268	589800	69	70	880	897	531	496	2432	2303	0.473
2037	1145	987	0.43	0.43	634523	590534	69	71	883	899	531	497	2432	2311	0.476
2038	1145	984	0.43	0.43	636360	591833	69	71	885	902	531	496	2433	2309	0.484
2039	1145	982	0.43	0.43	637845	592481	69	71	887	902	531	496	2433	2310	0.489
2040	1145	985	0.43	0.43	639055	592295	69	71	888	903	531	496	2433	2306	0.490
2041	1145	990	0.43	0.43	640049	592269	69	71	889	905	531	496	2433	2304	0.495
2042	1145	982	0.43	0.43	640868	593256	69	71	890	906	531	496	2433	2305	0.497
2043	1145	989	0.43	0.43	641545	594306	69	71	891	907	531	497	2433	2302	0.501
2044	1145	983	0.43	0.43	642105	594782	69	71	892	908	531	495	2433	2306	0.502

Table 34. Projection results with fishing mortality rate fixed at $F = F_{\mathrm{rebuild}}$ (P=0.675) starting in 2023 and long-term, average recruitment. 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 $\mathrm{SSB} \geq \mathrm{SSB_{MSY}}$. 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
2020	437	380	0.39	0.34	306993	324501	40	39	416	409	408	378	1980	1874	0.052
2021	437	380	0.35	0.31	342360	367864	38	37	420	413	272	240	1499	1369	0.107
2022	437	381	0.33	0.28	369131	401377	35	35	419	412	213	185	1219	1108	0.168
2023	437	380	0.21	0.21	400085	433465	22	26	279	327	126	126	698	735	0.215
2024	437	381	0.21	0.21	434647	464134	22	26	297	343	126	123	678	684	0.256
2025	437	381	0.21	0.21	466375	490157	23	26	314	357	127	122	679	666	0.293
2026	437	377	0.21	0.21	494778	512937	24	26	330	370	128	122	686	662	0.326
2027	437	382	0.21	0.21	520646	532326	25	27	344	381	129	122	693	663	0.356
2028	437	381	0.21	0.21	543054	547922	25	27	357	390	129	122	697	665	0.383
2029	437	380	0.21	0.21	562848	561743	26	27	369	399	130	122	701	668	0.410
2030	437	378	0.21	0.21	580221	572076	26	27	379	405	130	123	702	671	0.433
2031	437	378	0.21	0.21	595329	582301	26	28	387	411	130	122	704	672	0.460
2032	437	380	0.21	0.21	608742	591054	27	28	395	417	130	123	704	674	0.482
2033	437	380	0.21	0.21	620292	598873	27	28	401	422	130	123	705	677	0.505
2034	437	381	0.21	0.21	630247	605272	27	28	407	426	130	123	706	676	0.525
2035	437	380	0.21	0.21	639023	611412	27	28	412	429	130	123	706	676	0.546
2036	437	379	0.21	0.21	646607	616002	27	28	416	432	130	123	707	677	0.566
2037	437	380	0.21	0.21	653035	620116	28	29	420	435	130	123	707	678	0.585
2038	437	381	0.21	0.21	658612	624417	28	29	423	438	130	124	708	679	0.600
2039	437	379	0.21	0.21	663408	628110	28	29	426	440	130	123	708	682	0.613
2040	437	381	0.21	0.21	667577	630823	28	29	428	442	130	123	708	681	0.628
2041	437	385	0.21	0.21	671185	632568	28	29	430	444	130	123	708	680	0.642
2042	437	381	0.21	0.21	674301	634816	28	29	432	445	130	123	709	680	0.657
2043	437	382	0.21	0.21	676990	637421	28	29	433	447	130	123	709	680	0.667
2044	437	380	0.21	0.21	679310	638047	28	29	435	448	130	123	709	680	0.677

Table 35. Projection results with fishing mortality rate fixed at $F = F_{\text{rebuild}}$ (P=0.675) starting in 2023 and recent average recruitment. 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 $\text{SSB} \geq \text{SSB}_{\text{MSY}}$. 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
2020	1145	980	0.39	0.34	308482	326178	40	40	416	409	496	447	2079	1961	0.054
2021	1145	982	0.34	0.30	354122	379262	40	39	420	413	421	356	1813	1615	0.129
2022	1145	984	0.29	0.25	416135	448412	40	39	419	412	387	325	1739	1523	0.252
2023	1145	984	0.41	0.41	468024	496608	61	69	665	764	548	527	2560	2548	0.330
2024	1145	983	0.41	0.41	505427	525943	63	70	713	801	535	507	2520	2448	0.370
2025	1145	985	0.41	0.41	536977	548193	64	70	749	828	526	492	2468	2366	0.406
2026	1145	975	0.41	0.41	563629	566870	65	69	778	845	522	484	2431	2308	0.439
2027	1145	986	0.41	0.41	586708	581399	66	70	802	860	520	482	2413	2274	0.471
2028	1145	985	0.41	0.41	606157	593091	67	70	823	871	519	483	2405	2266	0.497
2029	1145	987	0.41	0.41	622400	601949	67	70	840	880	519	483	2404	2265	0.523
2030	1145	974	0.41	0.41	635969	610792	68	70	855	890	519	484	2404	2265	0.547
2031	1145	977	0.41	0.41	647069	617334	68	70	867	897	519	483	2406	2271	0.566
2032	1145	984	0.41	0.41	656212	621566	69	71	877	904	519	484	2407	2270	0.582
2033	1145	981	0.41	0.41	663767	625693	69	71	885	909	519	484	2408	2275	0.598
2034	1145	987	0.41	0.41	669943	627813	69	71	892	912	519	484	2408	2282	0.610
2035	1145	984	0.41	0.41	675017	631221	69	71	898	915	519	484	2409	2279	0.620
2036	1145	981	0.41	0.41	679221	633207	69	71	902	918	519	485	2410	2282	0.632
2037	1145	987	0.41	0.41	682670	634966	70	71	906	922	519	485	2410	2290	0.642
2038	1145	984	0.41	0.41	685512	636991	70	71	909	926	519	485	2410	2288	0.648
2039	1145	982	0.41	0.41	687839	638503	70	72	912	928	519	485	2411	2289	0.655
2040	1145	985	0.41	0.41	689754	638449	70	72	914	929	519	485	2411	2286	0.660
2041	1145	990	0.41	0.41	691336	638980	70	72	916	931	519	485	2411	2283	0.664
2042	1145	982	0.41	0.41	692646	640312	70	72	917	933	519	485	2411	2286	0.668
2043	1145	989	0.41	0.41	693733	641355	70	72	919	934	519	486	2411	2283	0.673
2044	1145	983	0.41	0.41	694635	642512	70	72	920	936	519	484	2412	2287	0.675

8 Figures

Figure 1. Mean total length at age (mm) and estimated upper and lower 95% confidence intervals of the population.

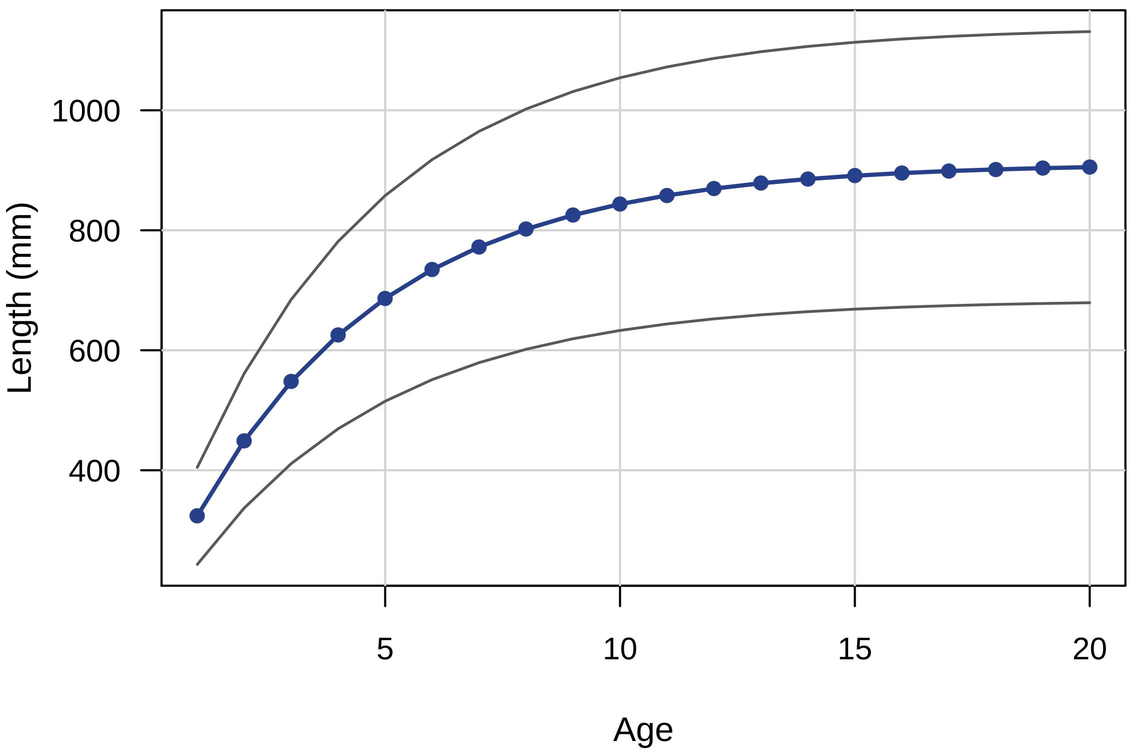


Figure 2. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, CVT to SERFS chevron trap, cH to commercial handline, HB to headboat, and GR to general recreational.

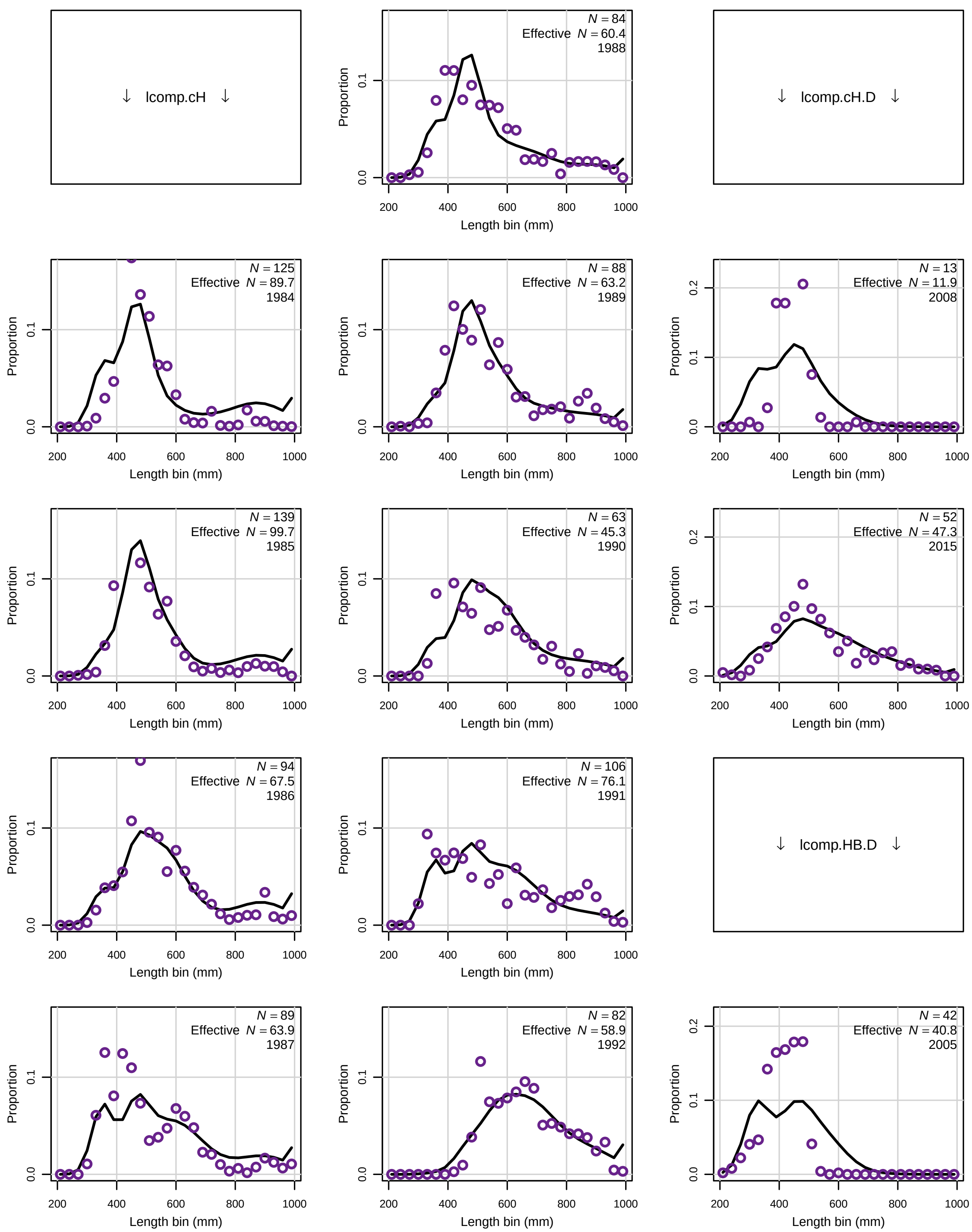


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

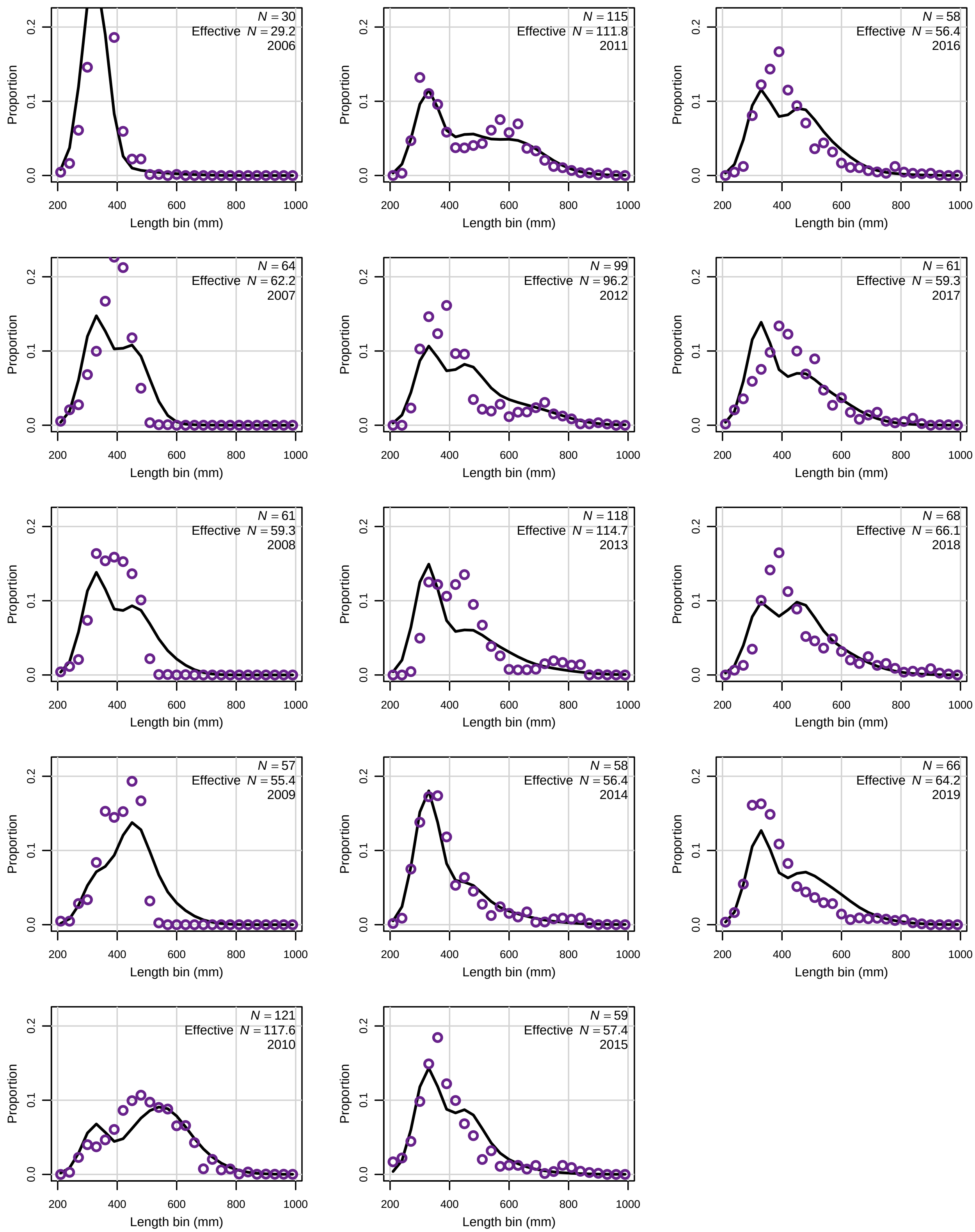


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

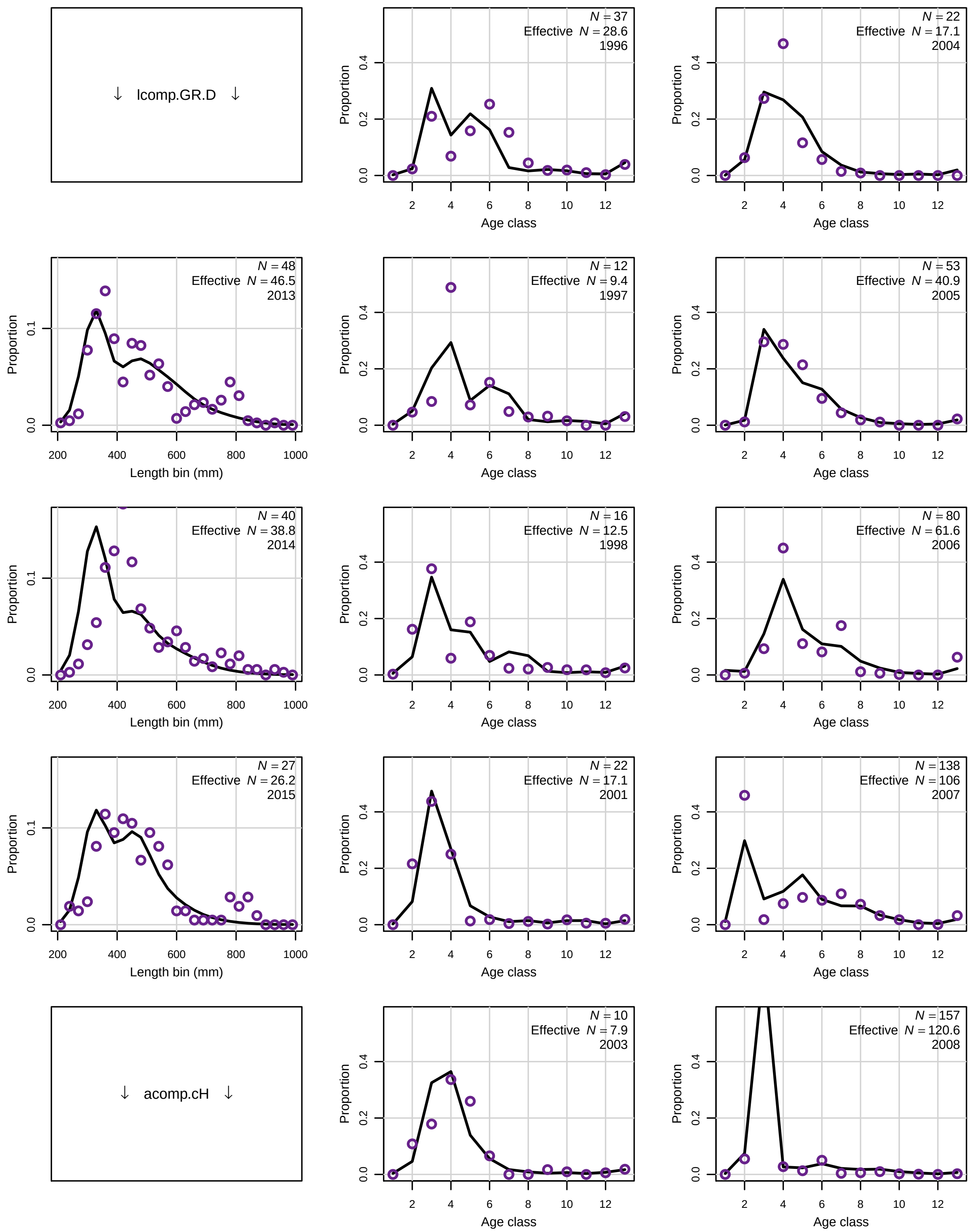


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

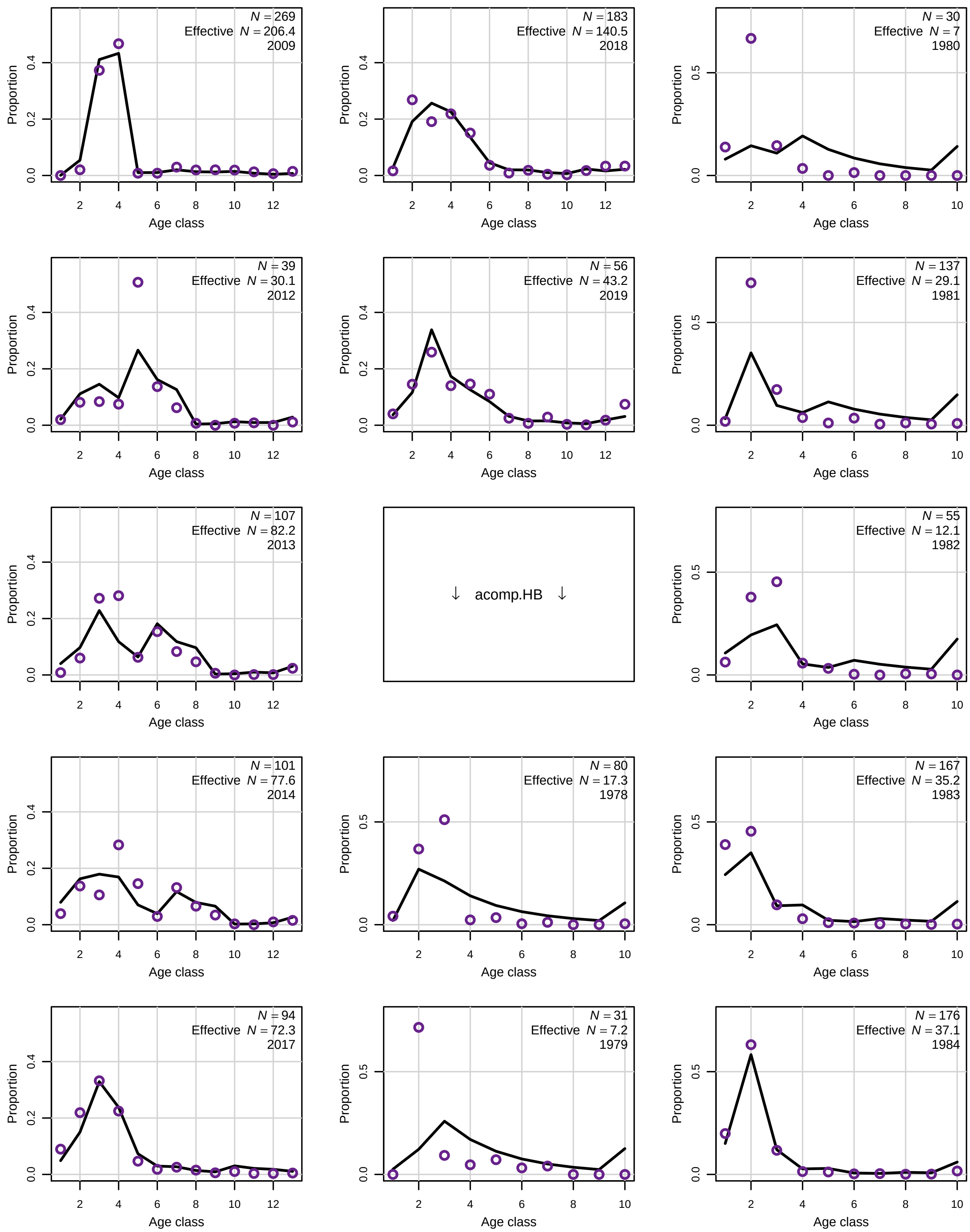


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

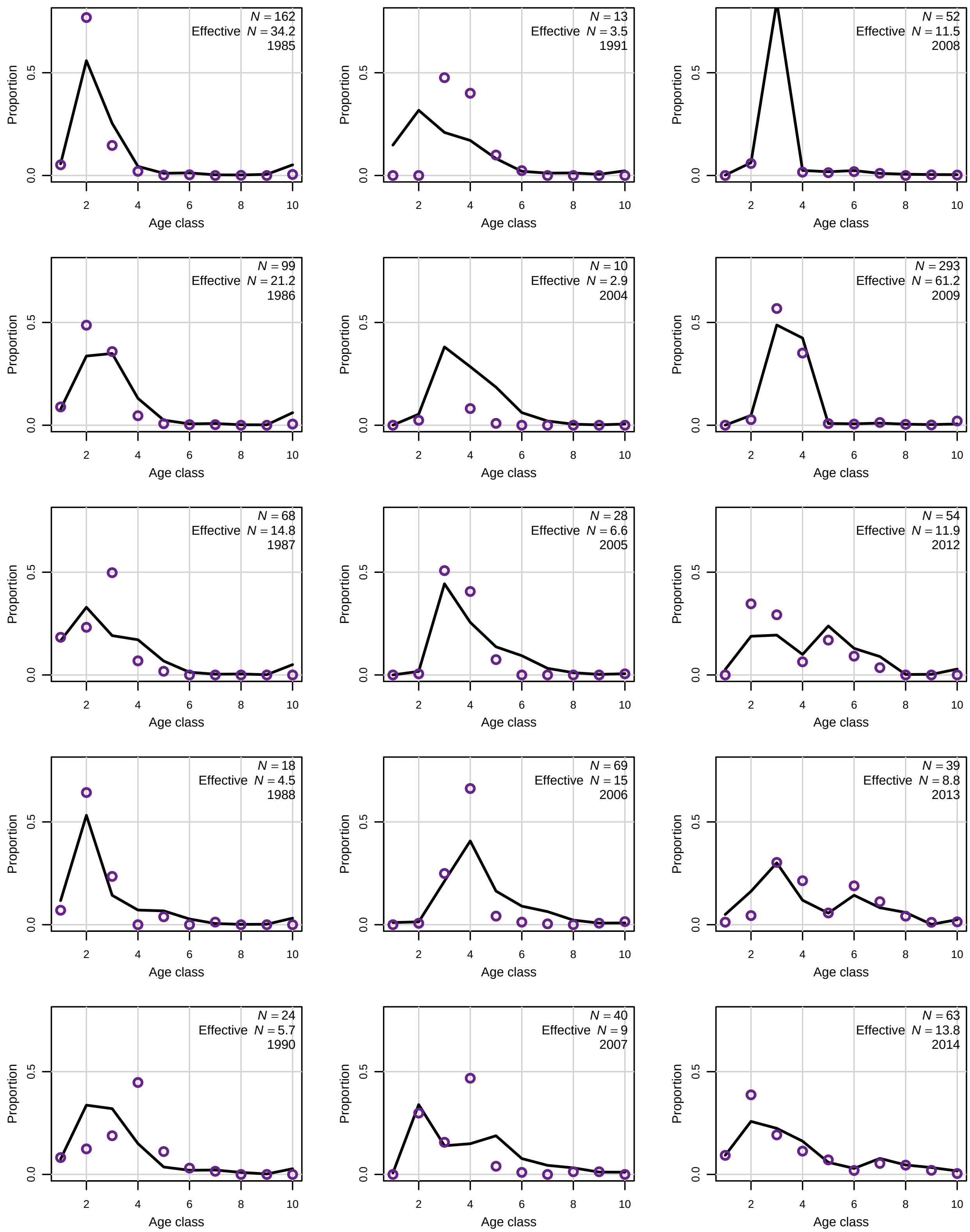


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

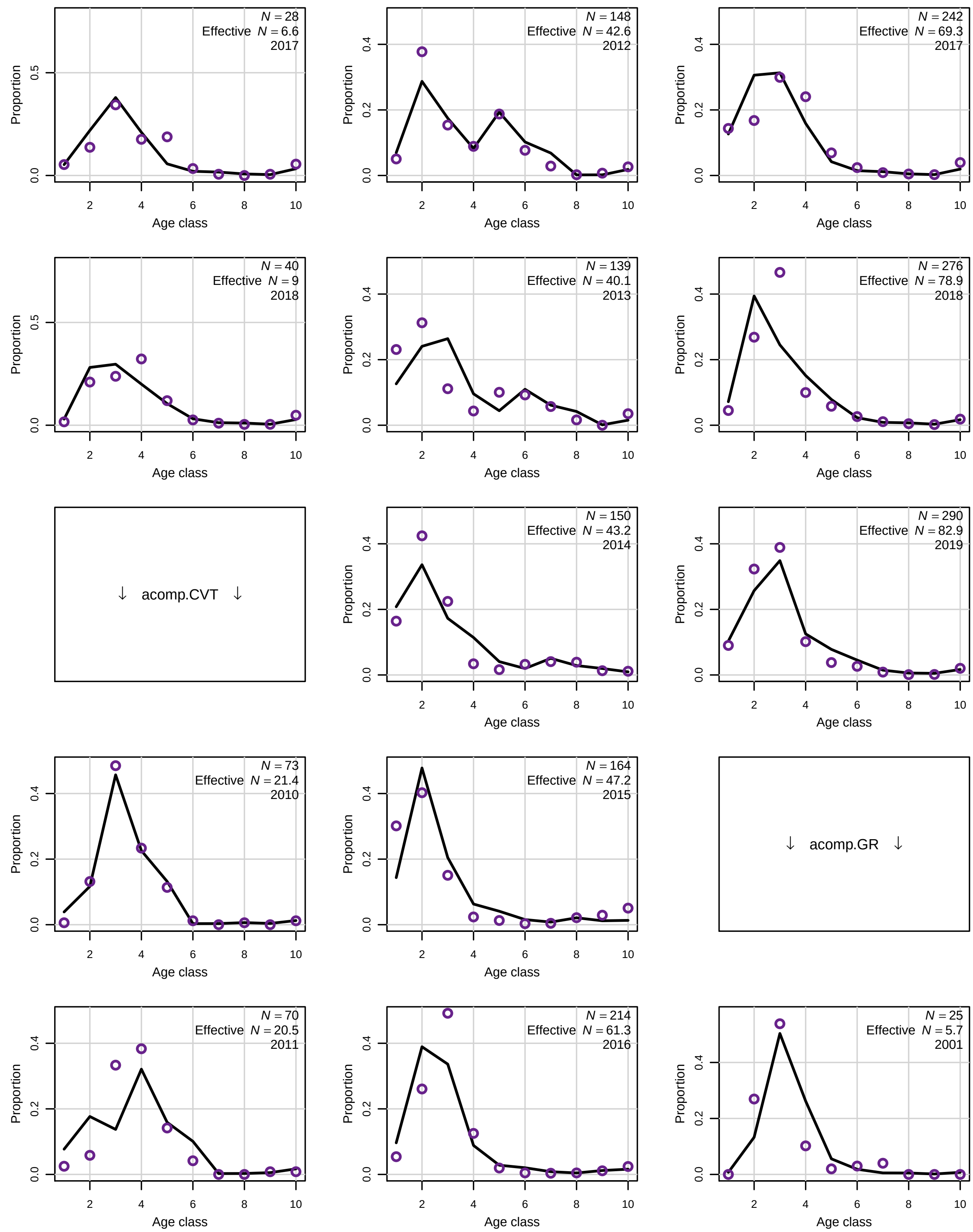


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

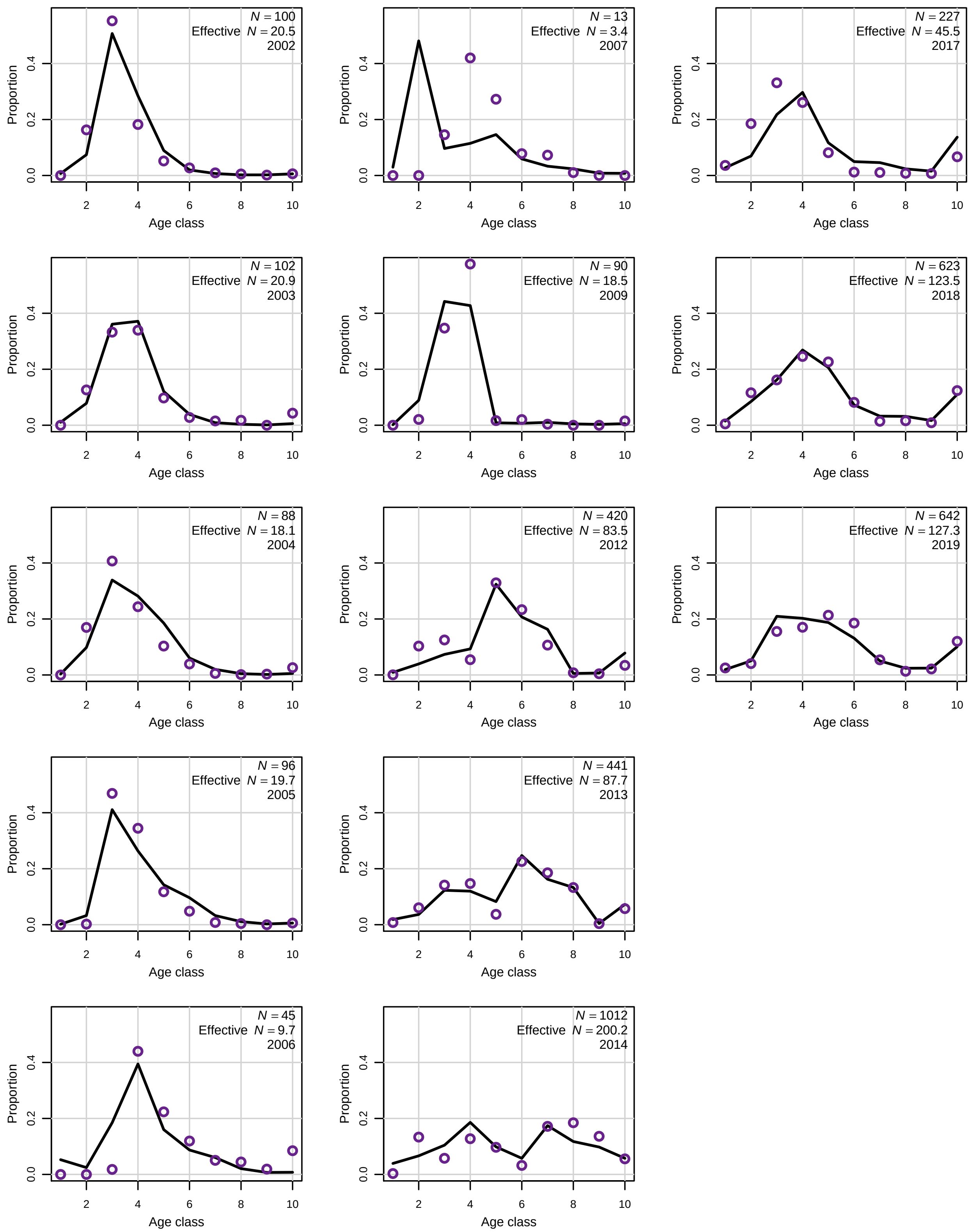


Figure 3. Observed (open circles) and estimated (solid line, circles) commercial handline landings in 1000 lb whole weight.

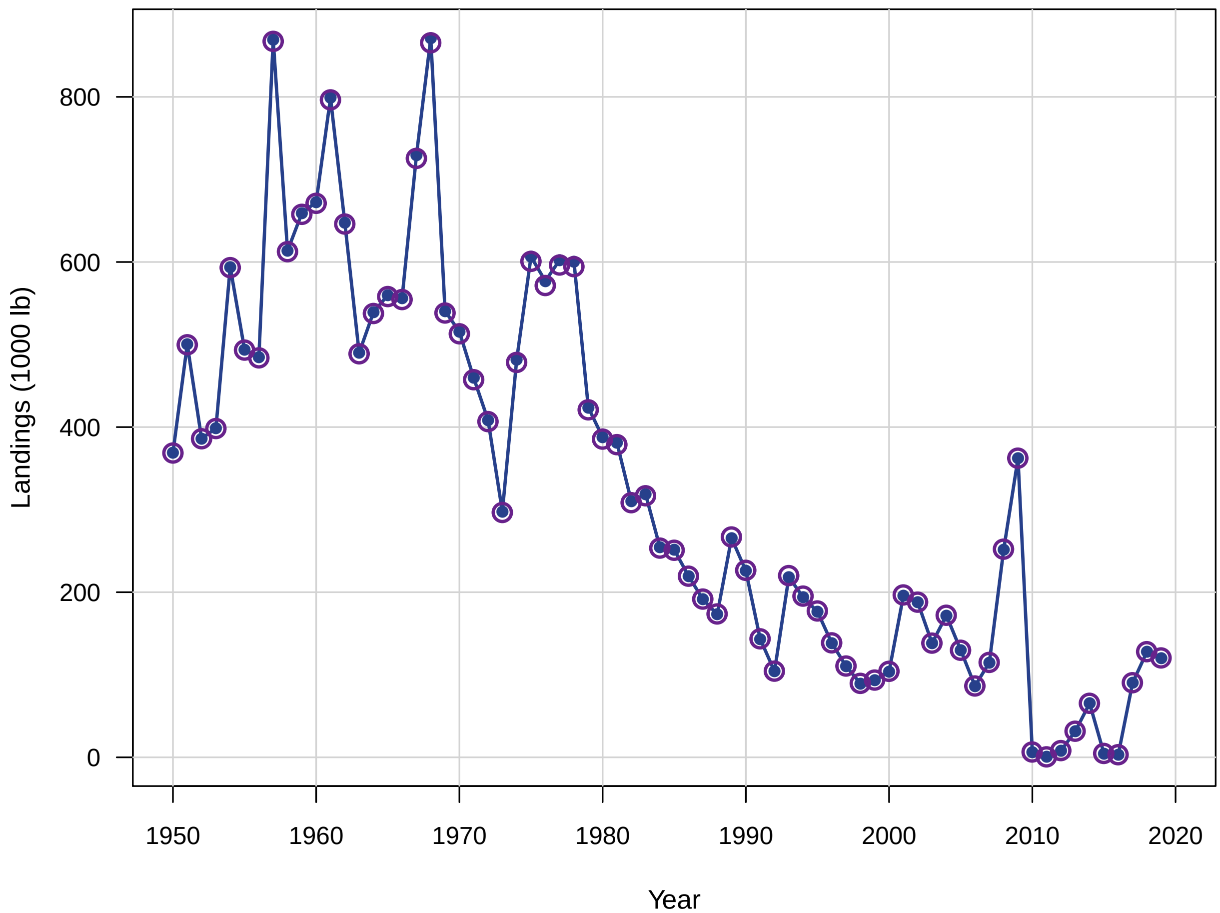


Figure 4. Observed (open circles) and estimated (solid line, circles) headboat landings in 1000s of fish.

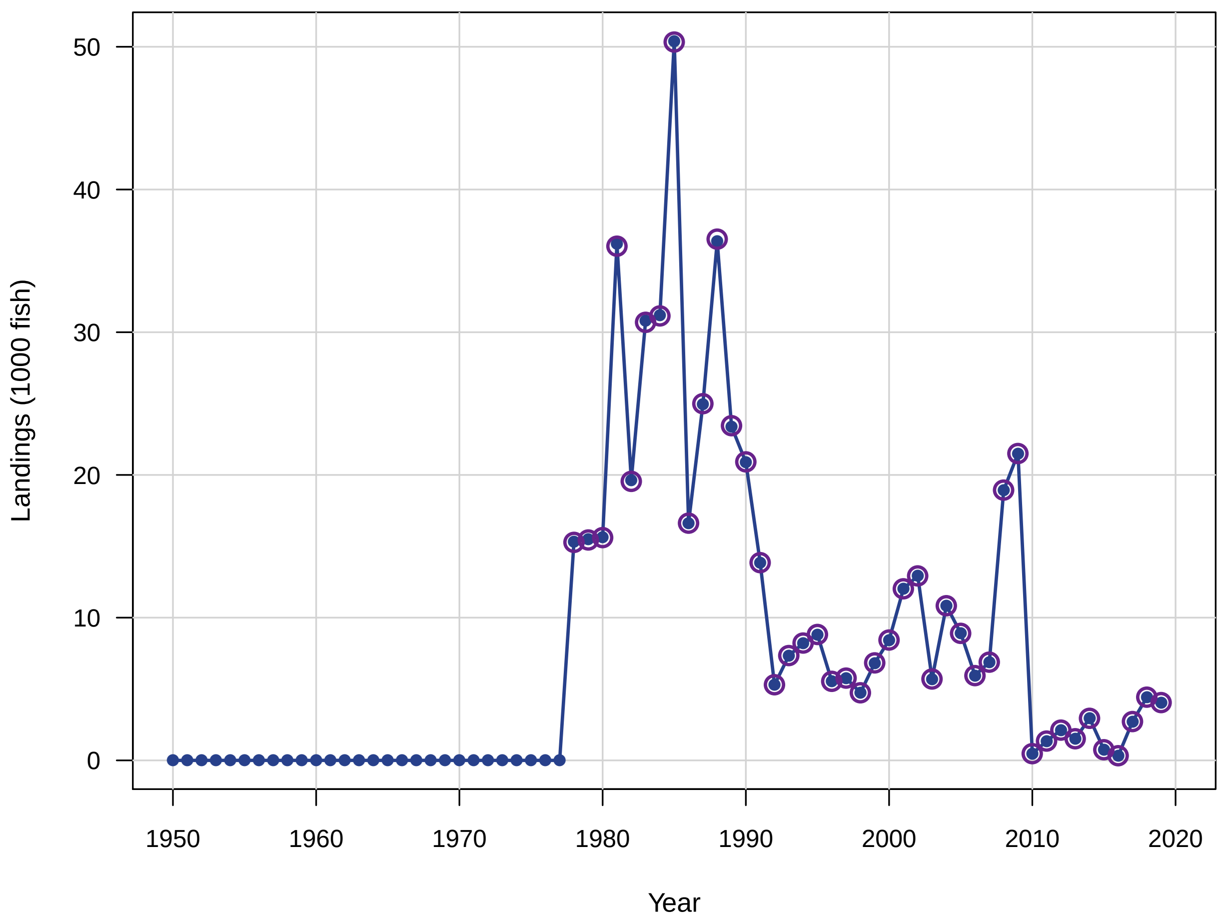


Figure 5. Observed (open circles) and estimated (solid line, circles) general recreational landings in 1000s of fish.

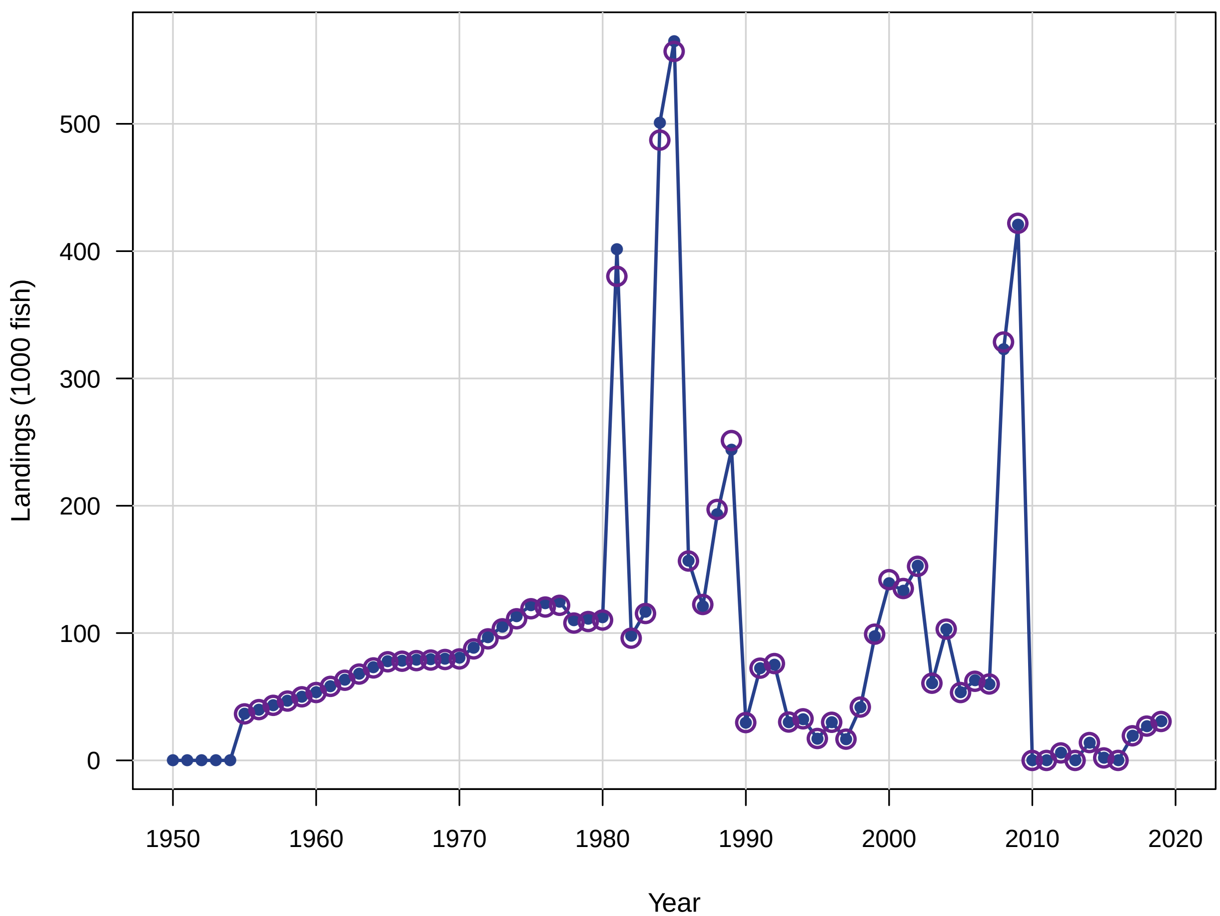


Figure 6. Observed (open circles) and estimated (solid line, circles) commercial handline discard mortalities.

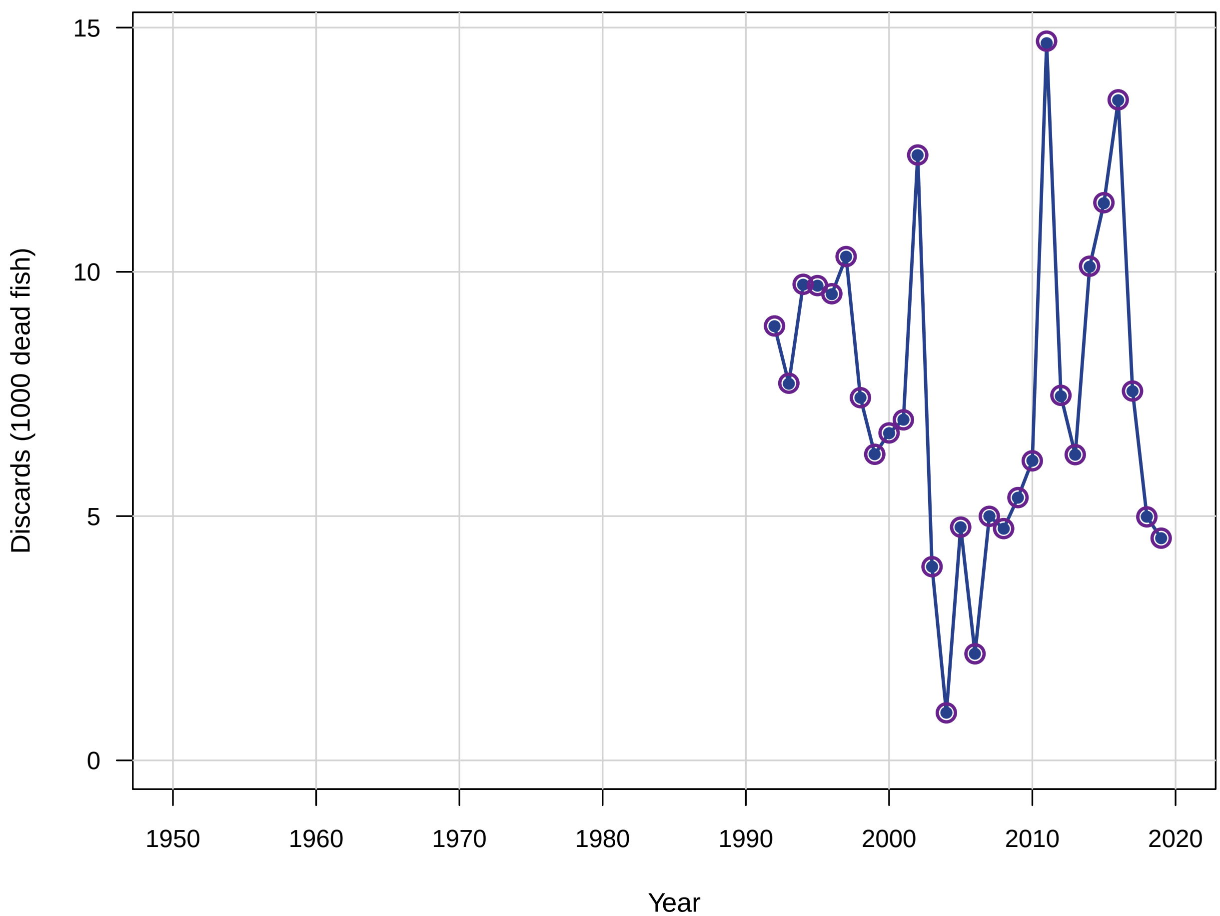


Figure 7. Observed (open circles) and estimated (solid line, circles) headboat discard mortalities.

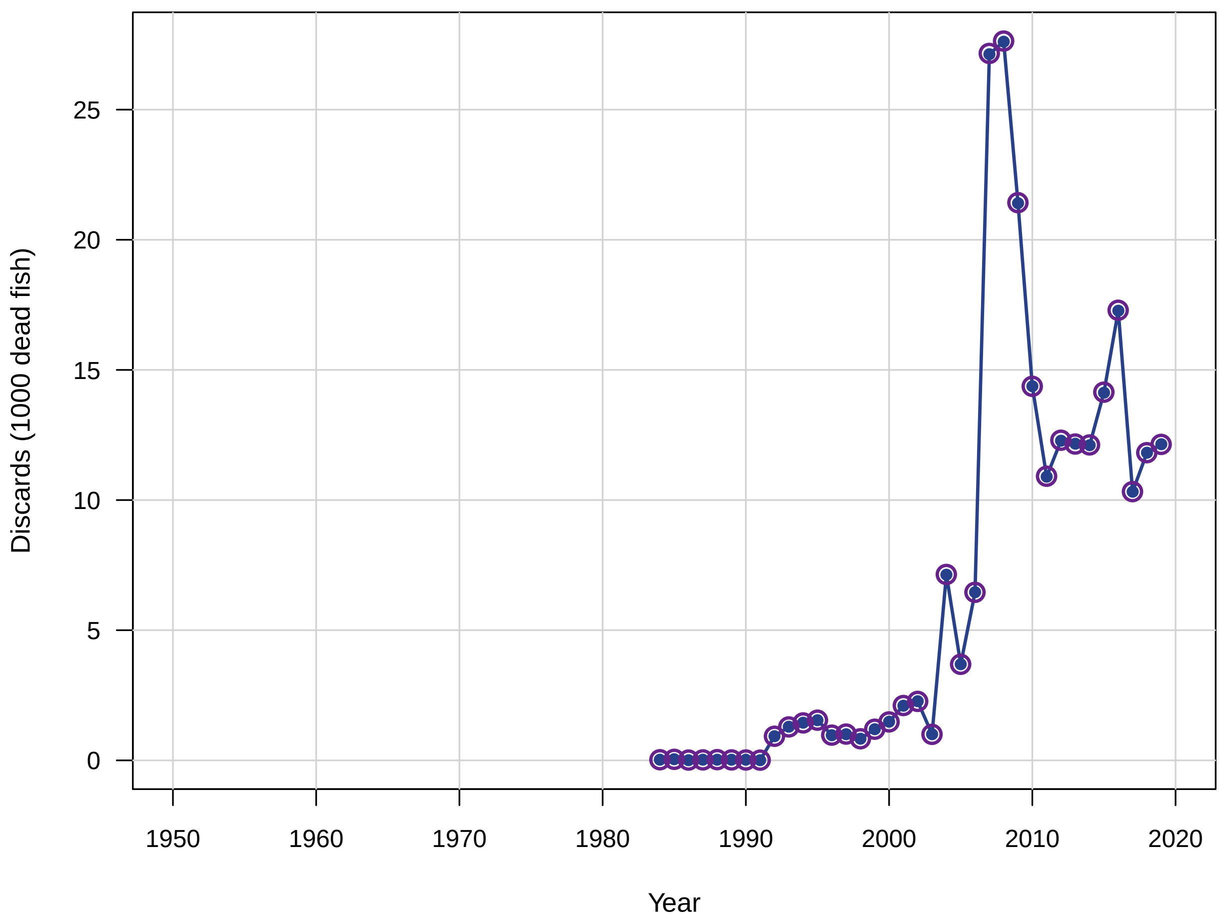


Figure 8. Observed (open circles) and estimated (solid line, circles) general recreational discard mortalities.

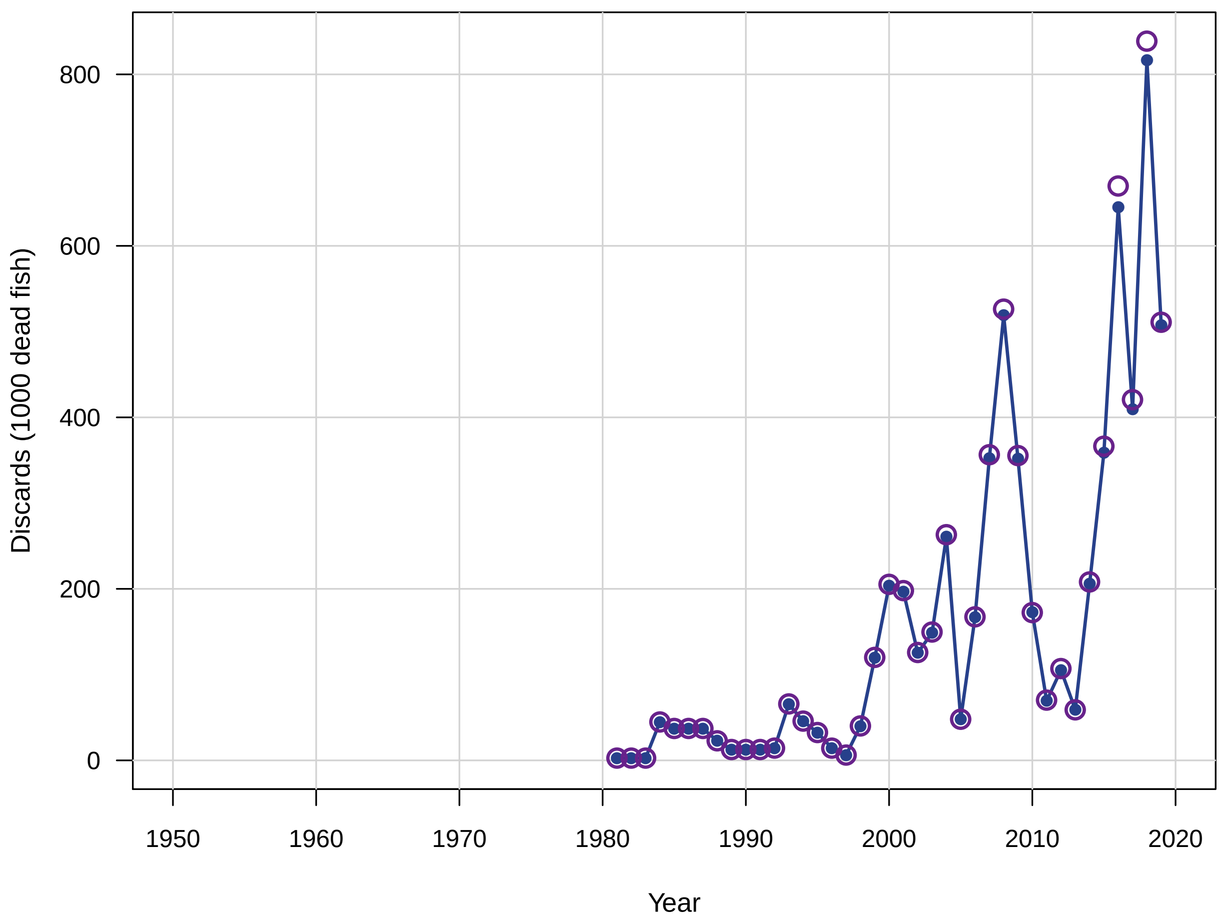


Figure 9. Observed (open circles) and estimated (solid line, circles) index of abundance from the SERFS chevron trap. The error bars represent plus/minus two standard errors, based on the annual CVs. Residuals are observed minus predicted values, then scaled by the mean residual for plotting.

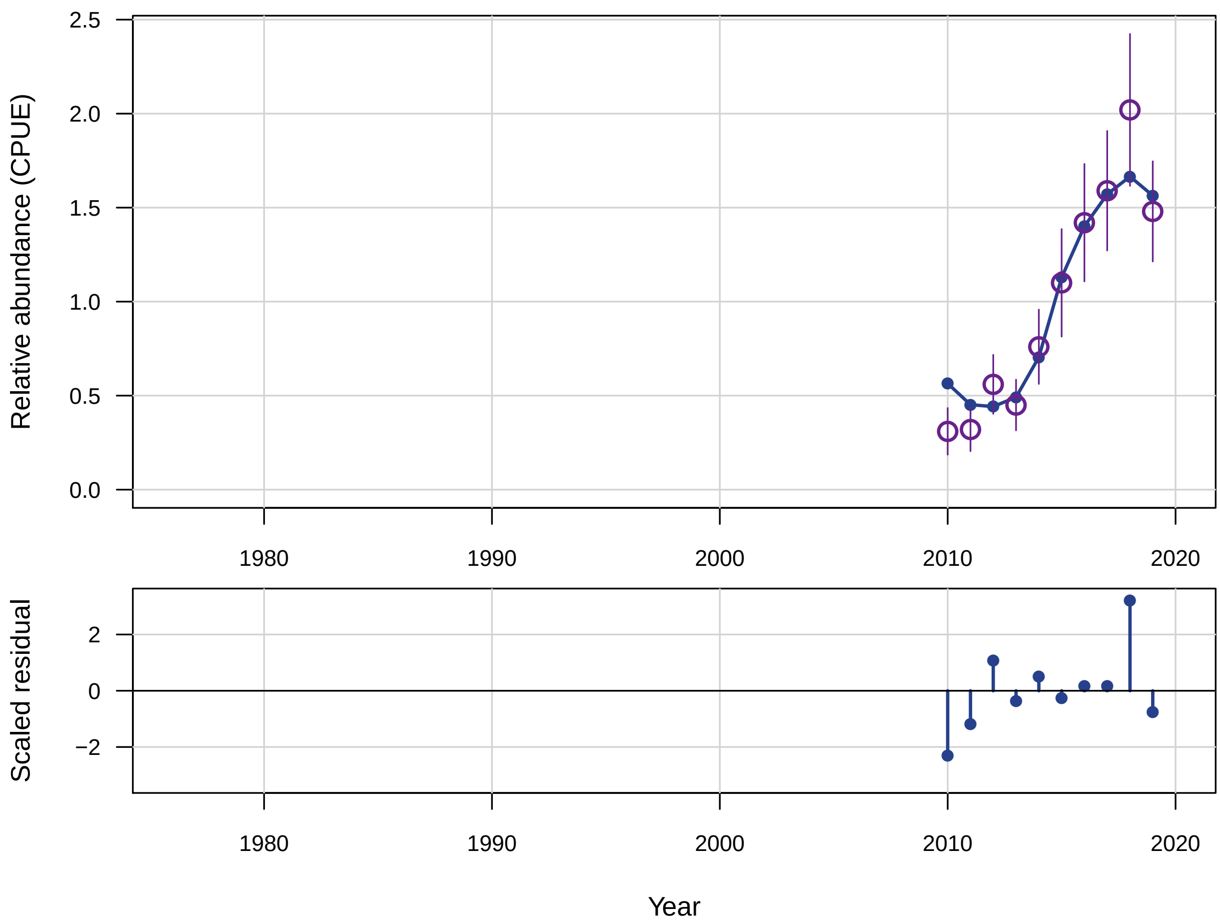


Figure 10. Observed (open circles) and estimated (solid line, circles) index of abundance from the SERFS video. The error bars represent plus/minus two standard errors, based on the annual CVs divided by the likelihood weight on the index. Residuals are observed minus predicted values, then scaled by the mean residual for plotting.

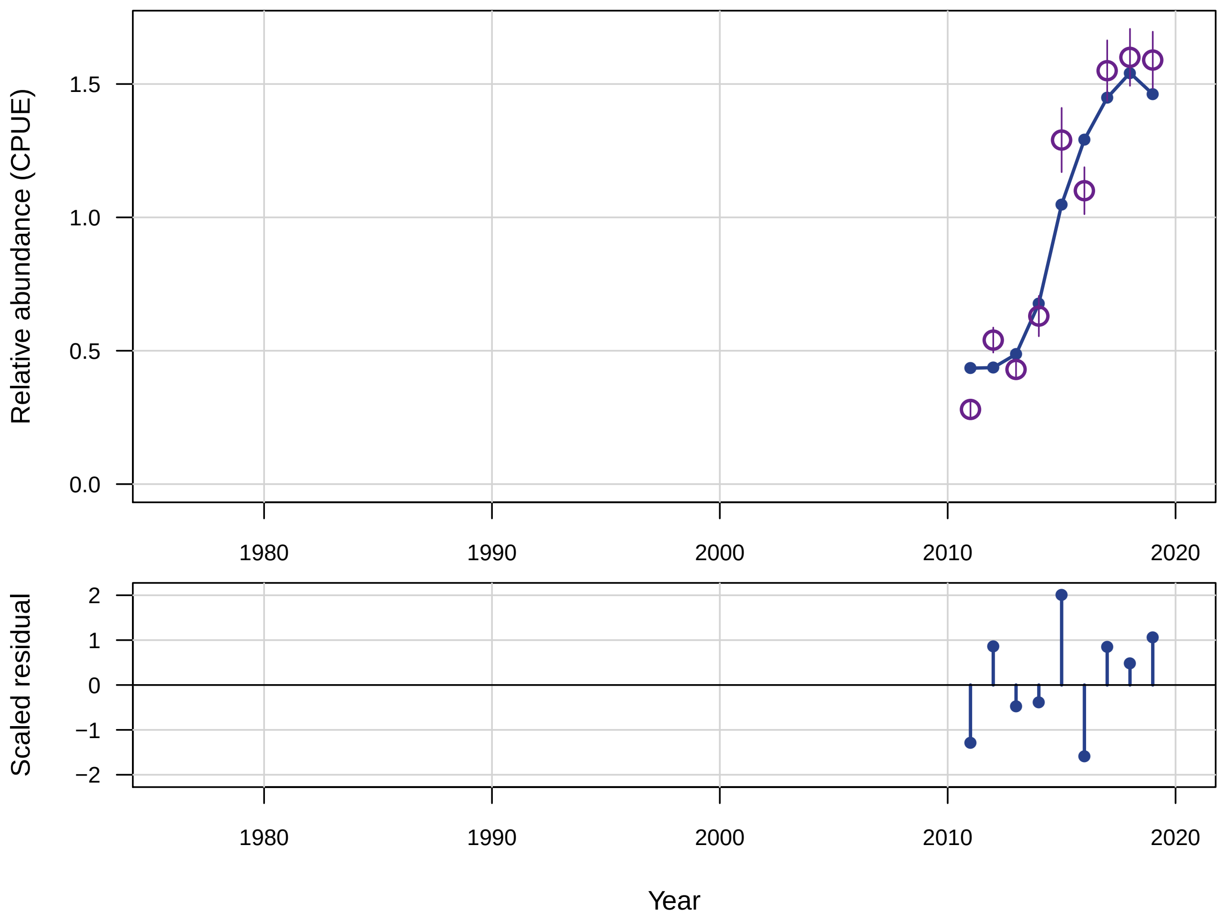


Figure 11. Observed (open circles) and estimated (solid line, circles) index of abundance from the commercial handline fleet. The error bars represent plus/minus two standard errors, based on the annual CVs. Residuals are observed minus predicted values, then scaled by the mean residual for plotting.

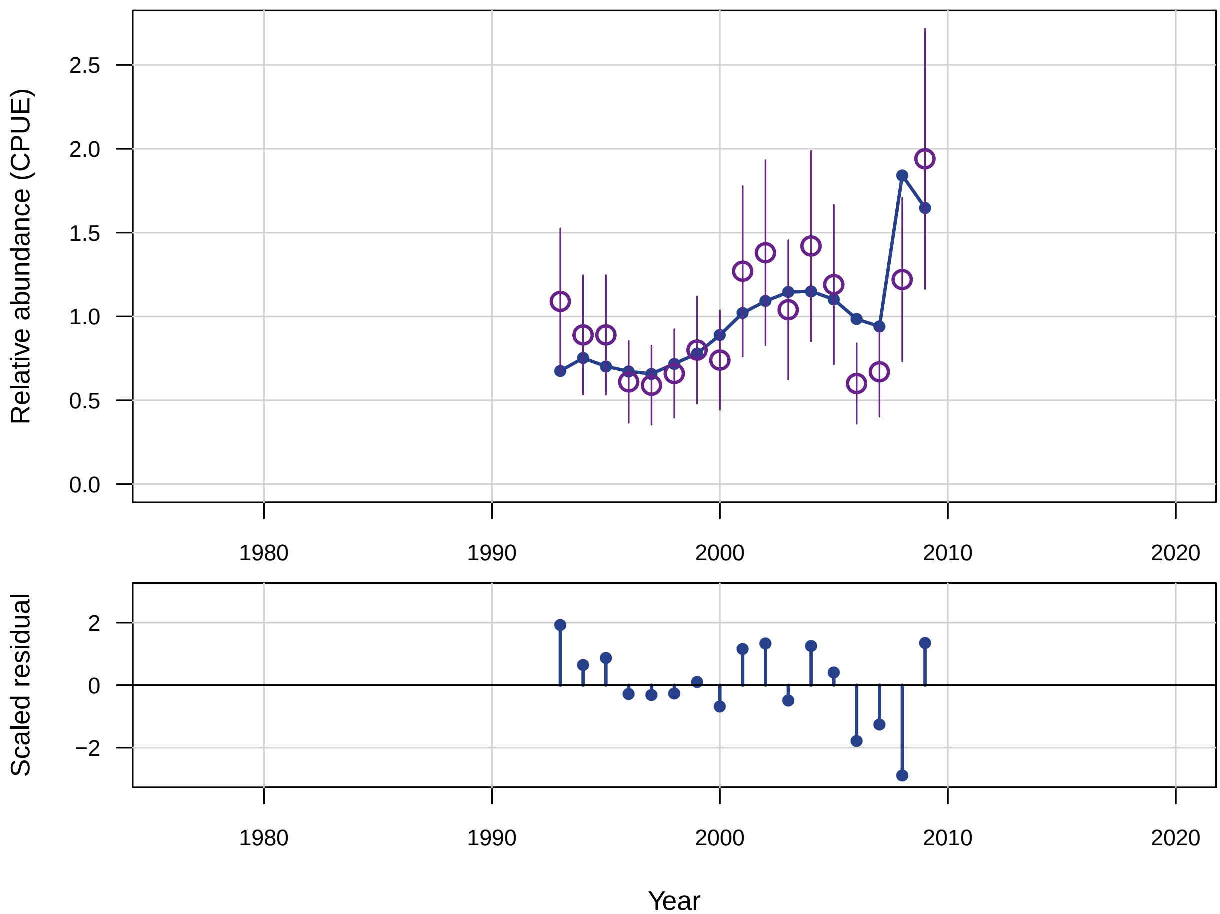


Figure 12. Observed (open circles) and estimated (solid line, circles) abundance from the headboat fleet. The error bars represent plus/minus two standard errors, based on the annual CVs. Residuals are observed minus predicted values, then scaled by the mean residual for plotting.

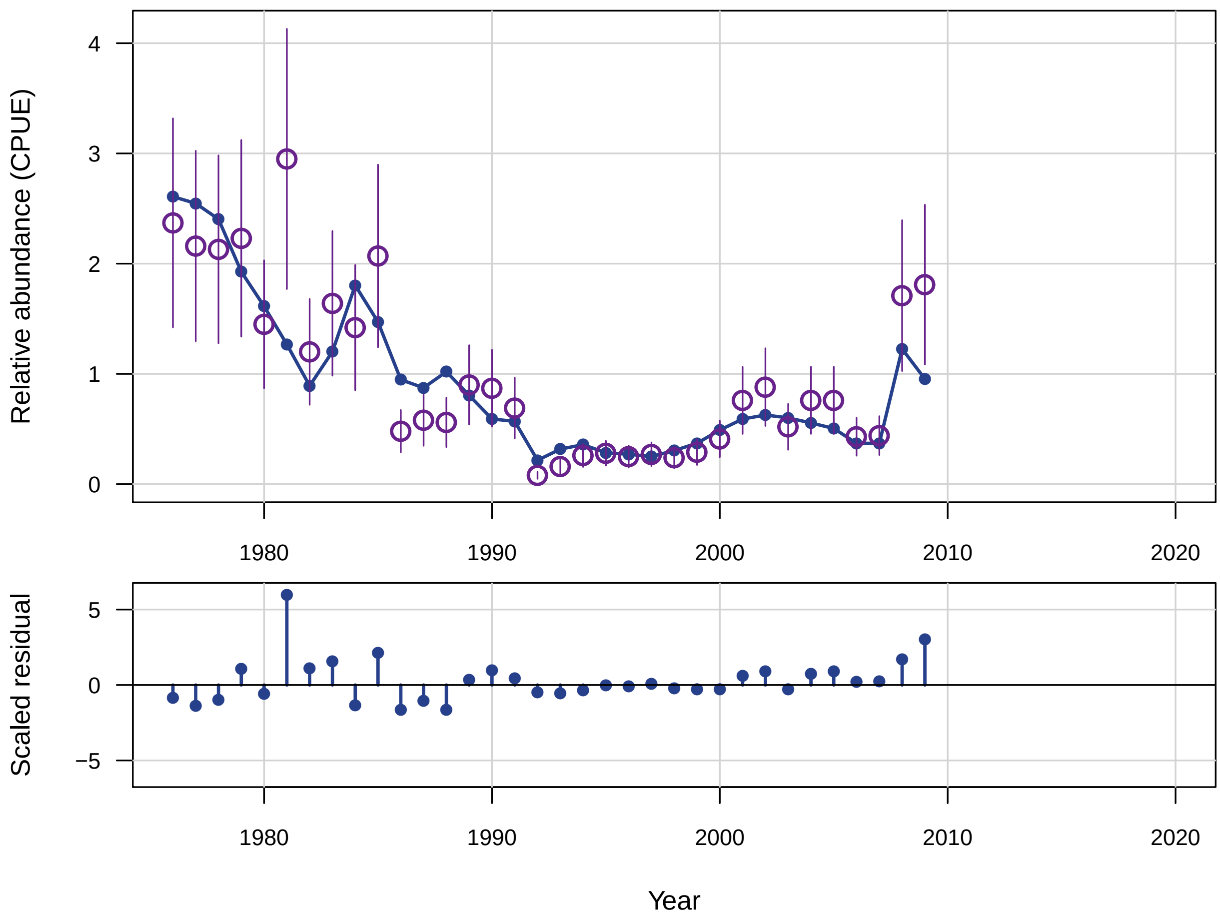


Figure 13. Observed (open circles) and estimated (solid line, circles) abundance from the headboat fleet (discards). The error bars represent plus/minus two standard errors, based on the annual CVs. Residuals are observed minus predicted values, then scaled by the mean residual for plotting.

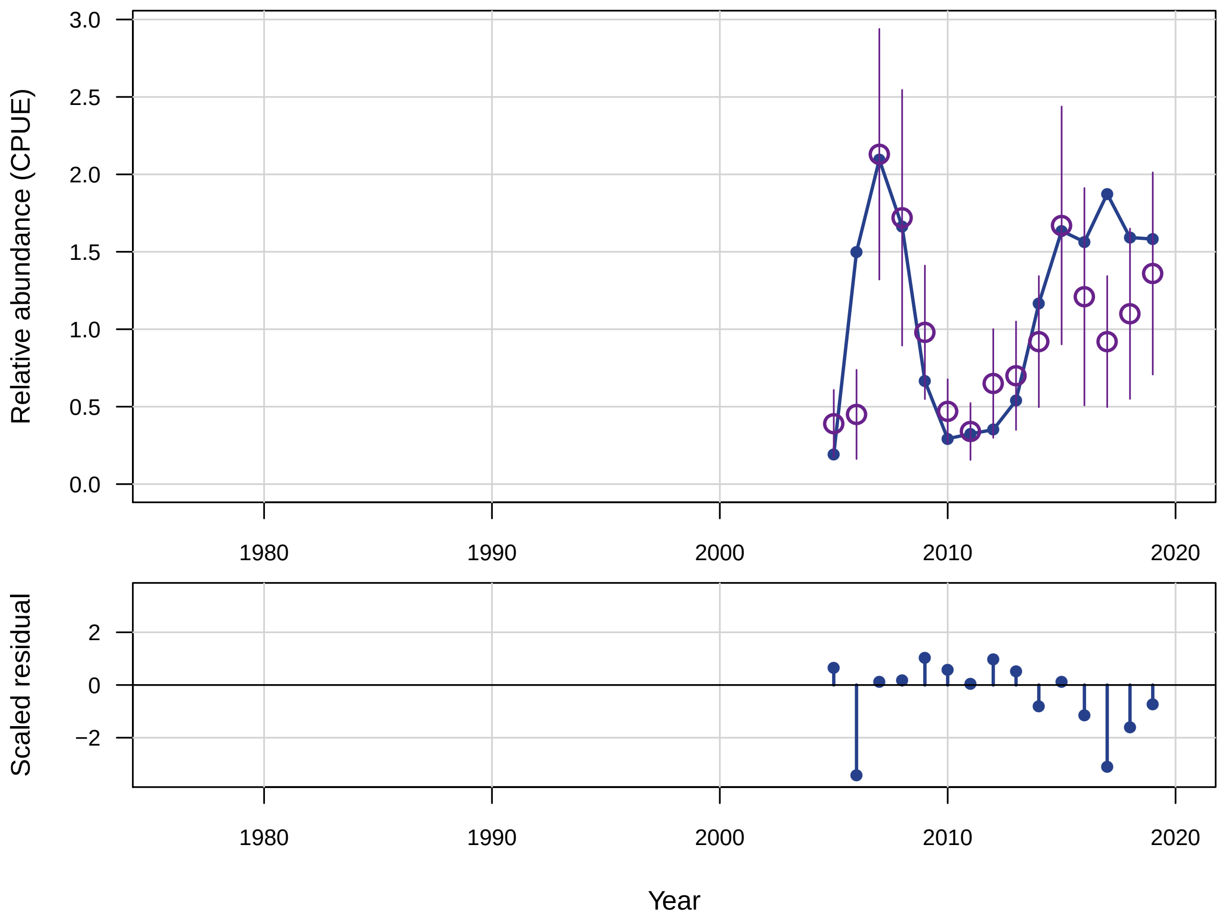


Figure 14. Estimated abundance at age at start of year.

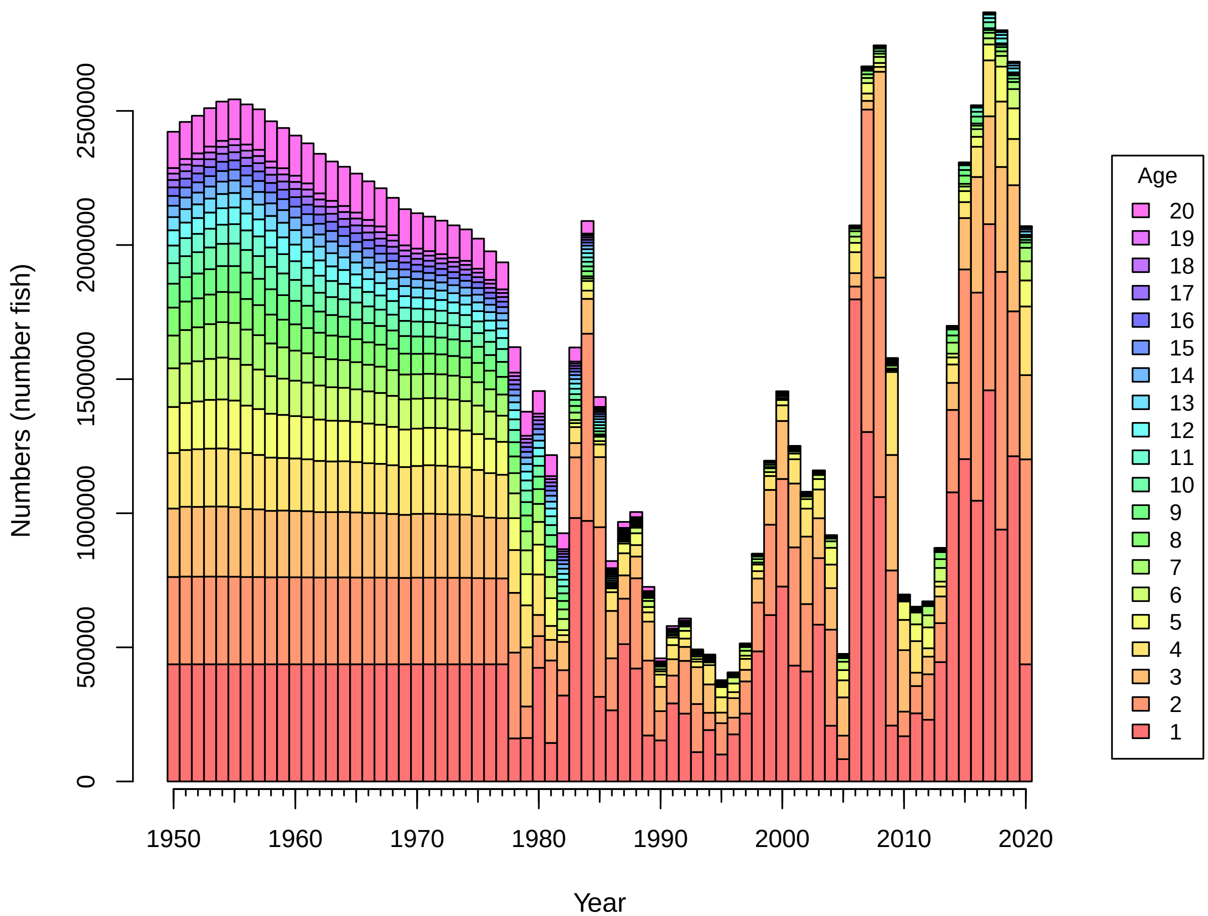


Figure 15. MCBE estimates of population abundance. Top panel shows all ages 1+, and the bottom panel shows ages 2+.

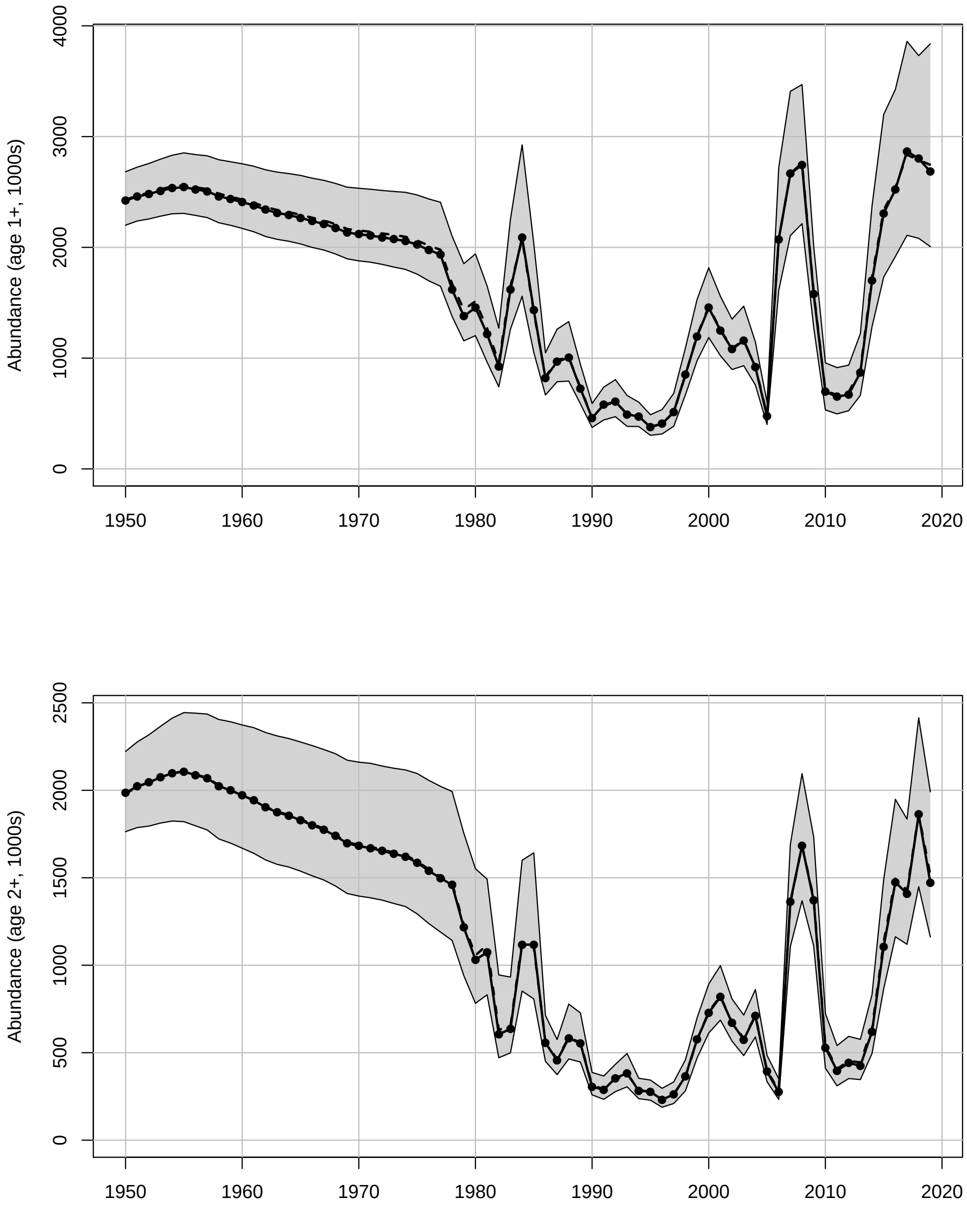


Figure 16. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates $R_{F30\%}$. Bottom panel: log recruitment residuals.

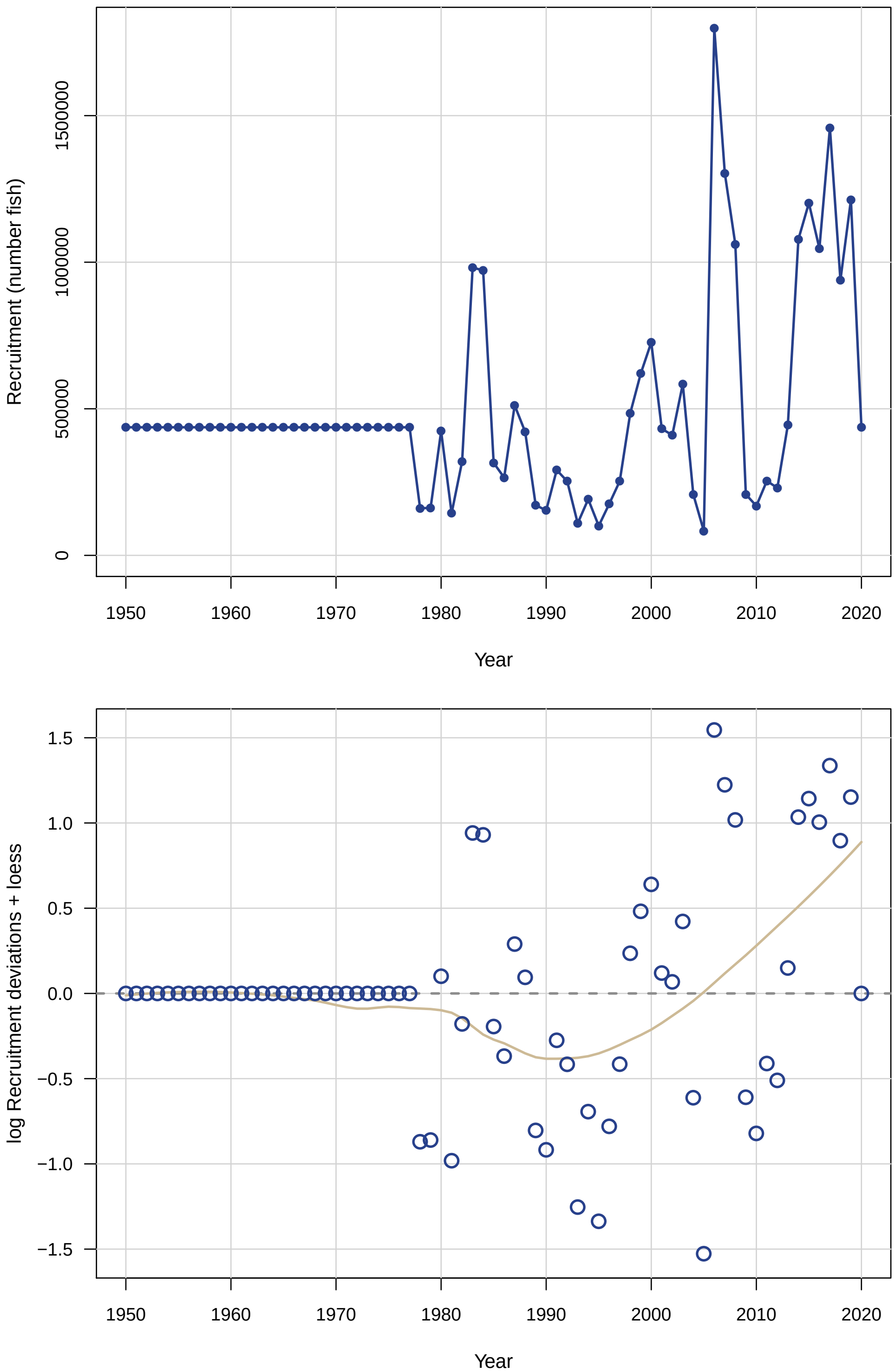


Figure 17. Estimated biomass at age at start of year.

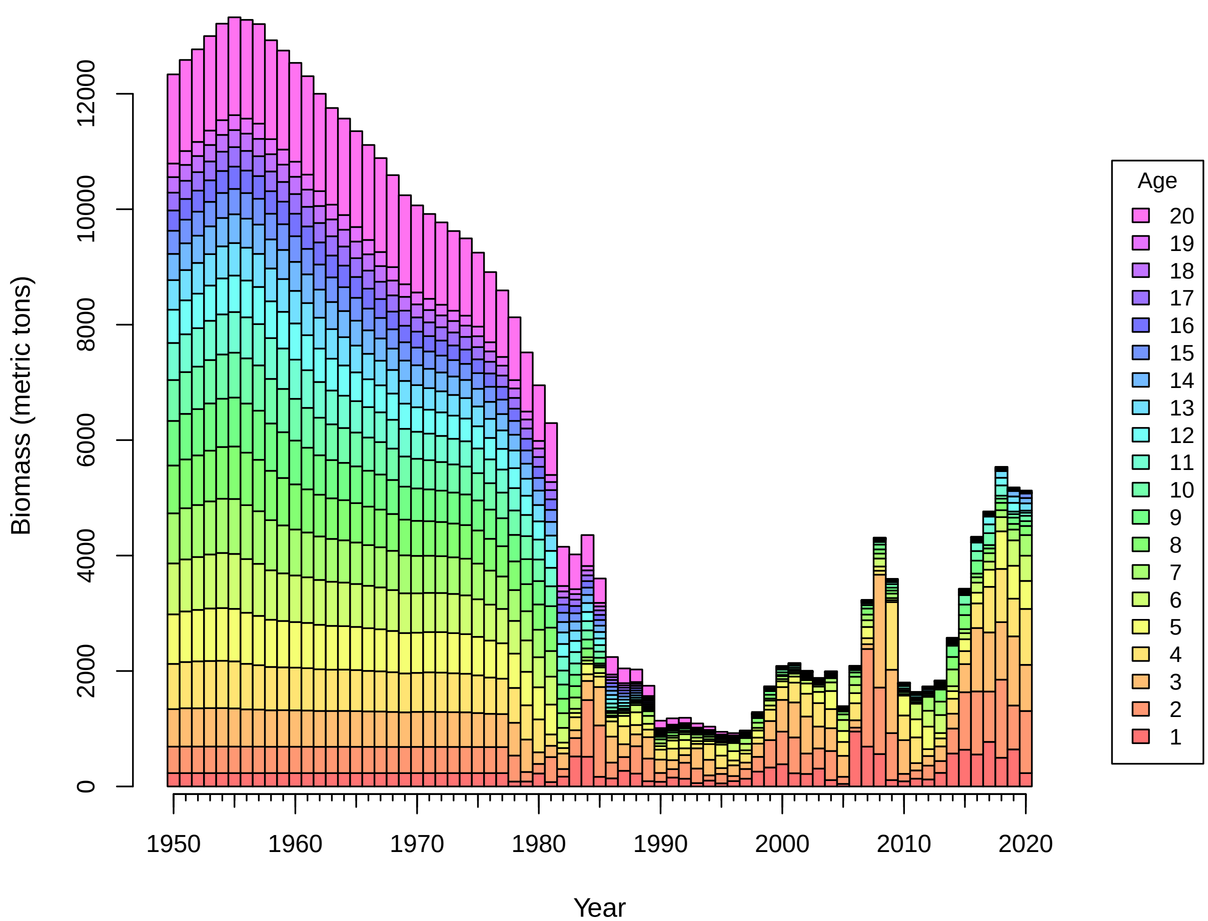
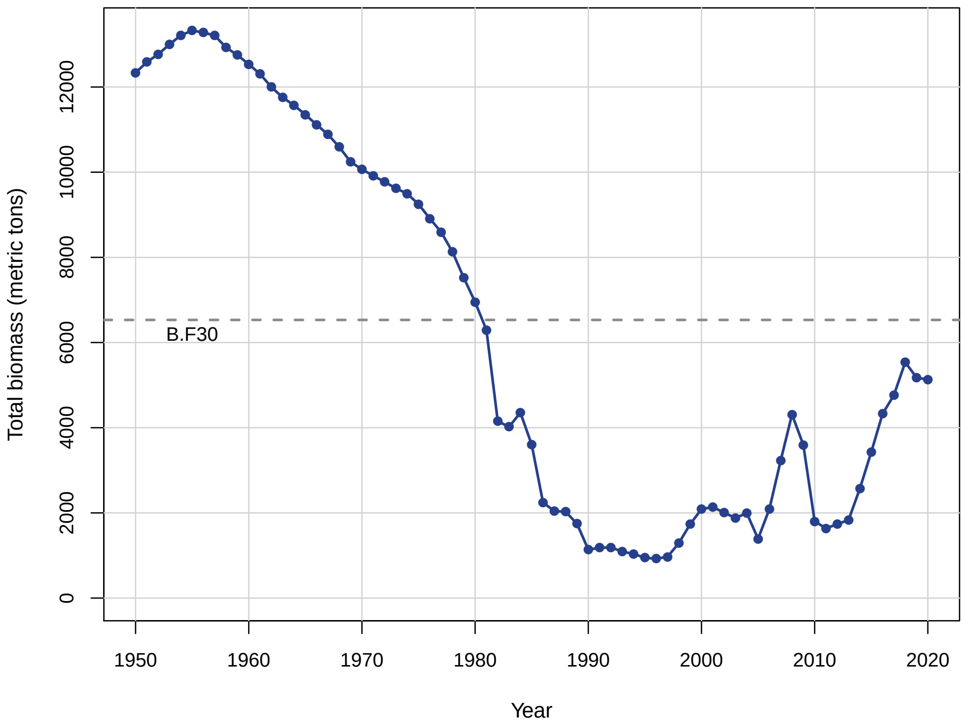


Figure 18. Top panel: Estimated total biomass (metric tons) at start of year. Bottom panel: Estimated spawning stock (population fecundity) at time of peak spawning. Horizontal dashed lines indicate $F_{30\%}$ reference points.



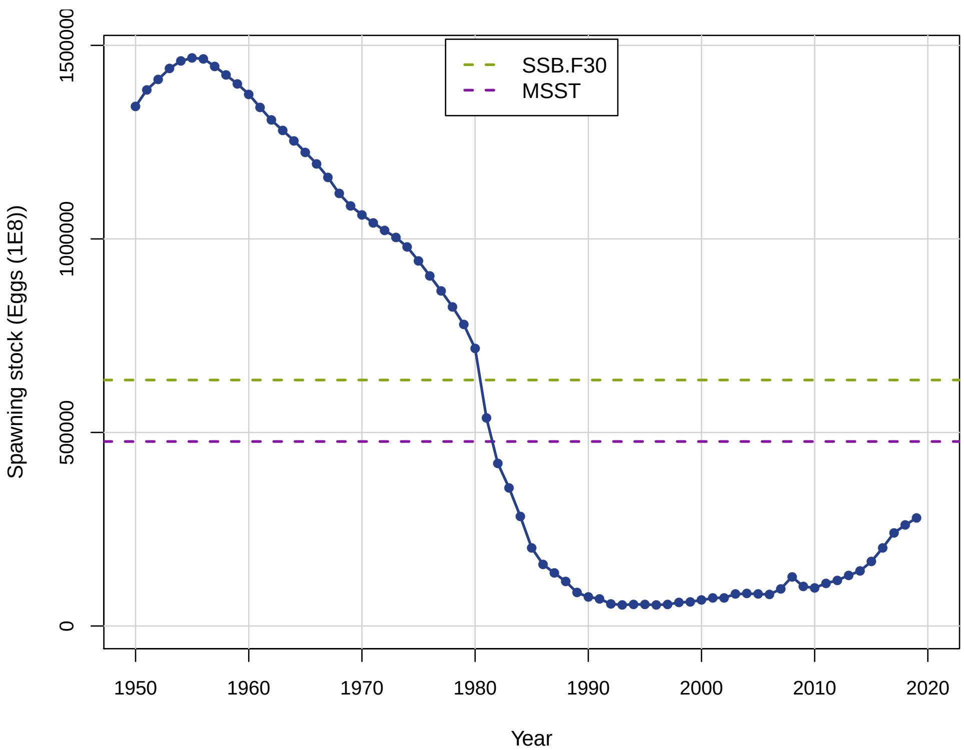


Figure 19. Selectivities of SERFS chevron trap index (top) and video index (bottom).

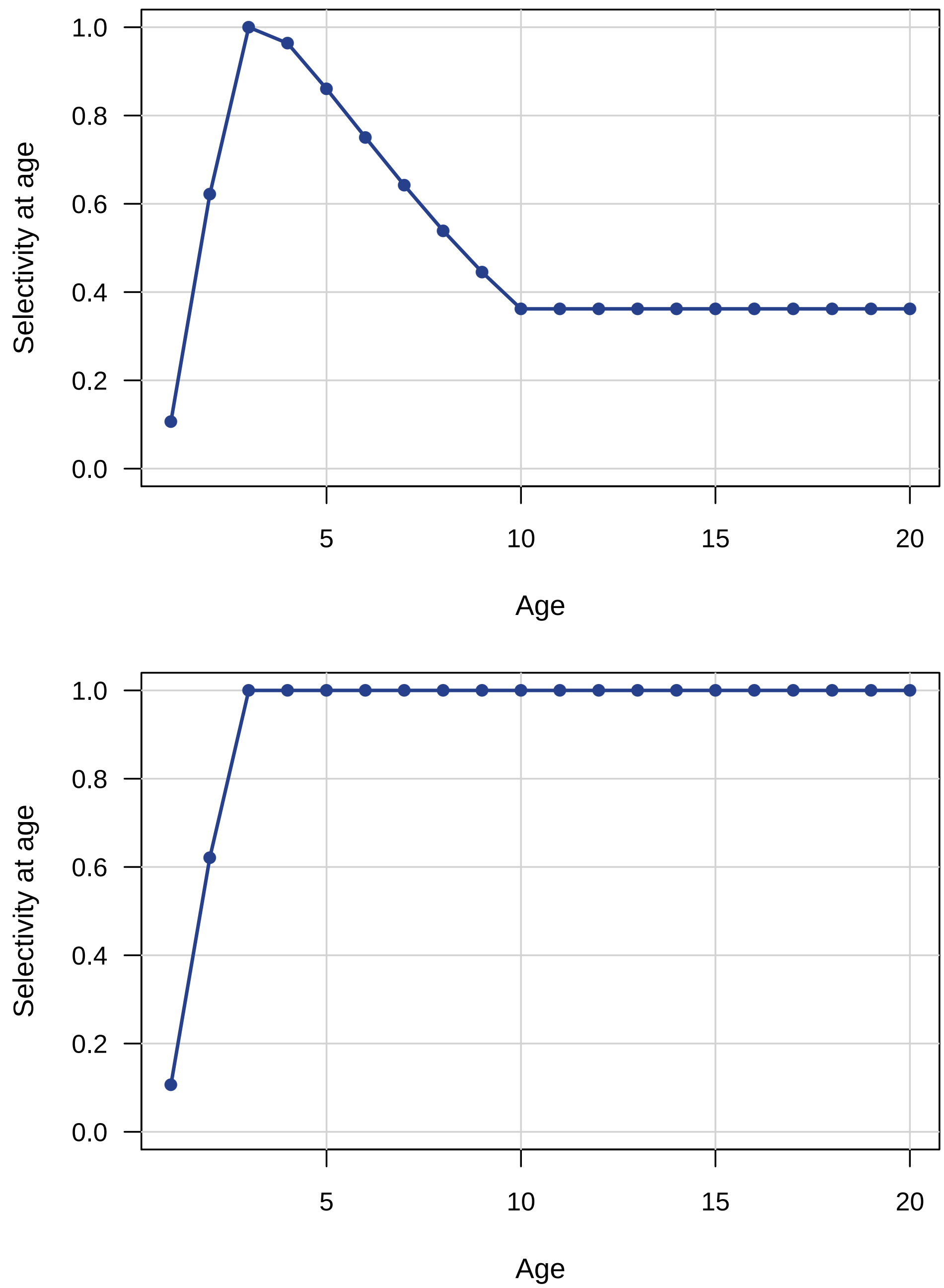


Figure 20. Selectivities of commercial handline landings. The legend indicates the first year each selectivity block.

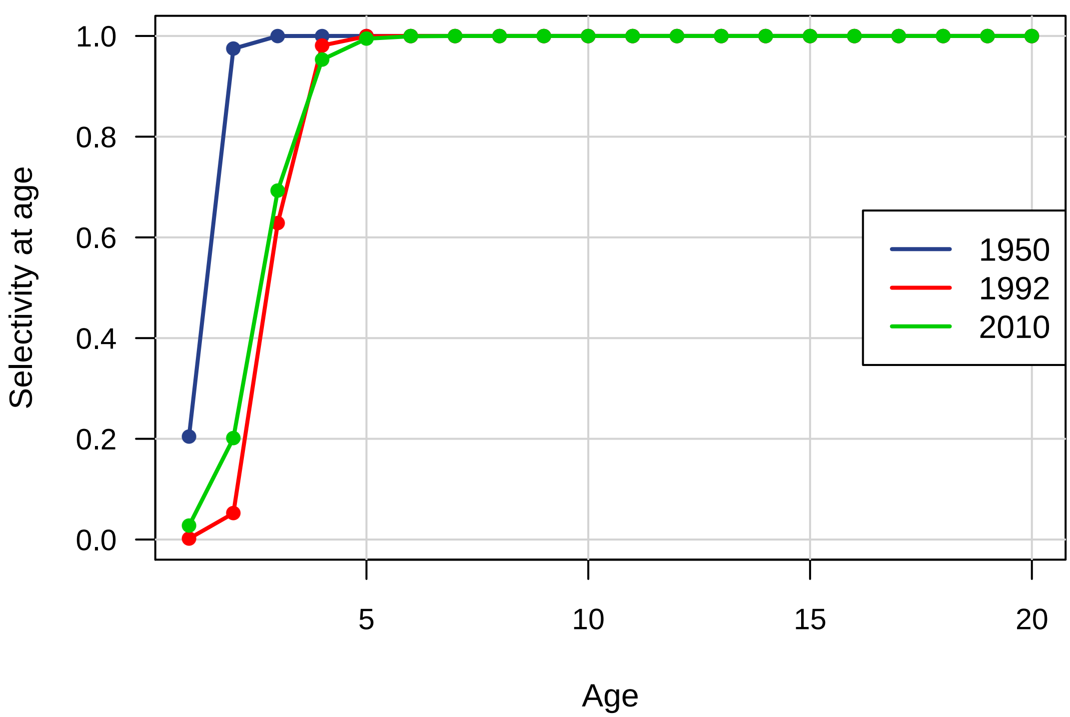


Figure 21. Selectivities of headboat landings. The legend indicates the first year each selectivity block.

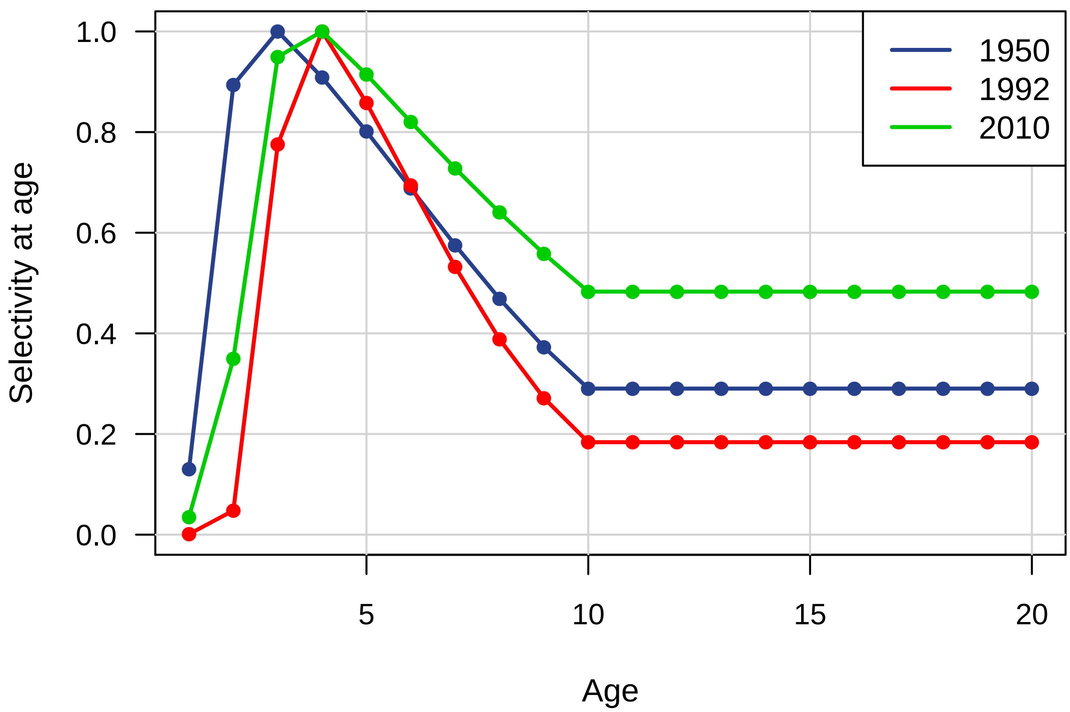


Figure 22. Selectivities of general recreational landings. The legend indicates the first year each selectivity block.

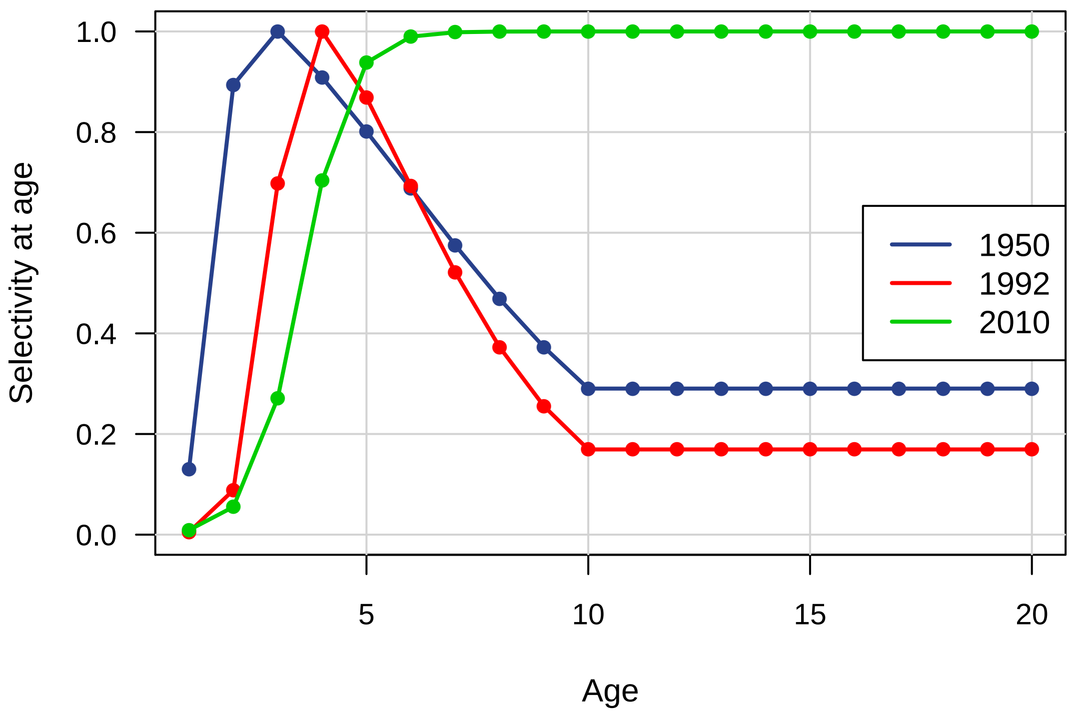


Figure 23. Selectivities of commercial handline discards. The legend indicates the first year each selectivity block.

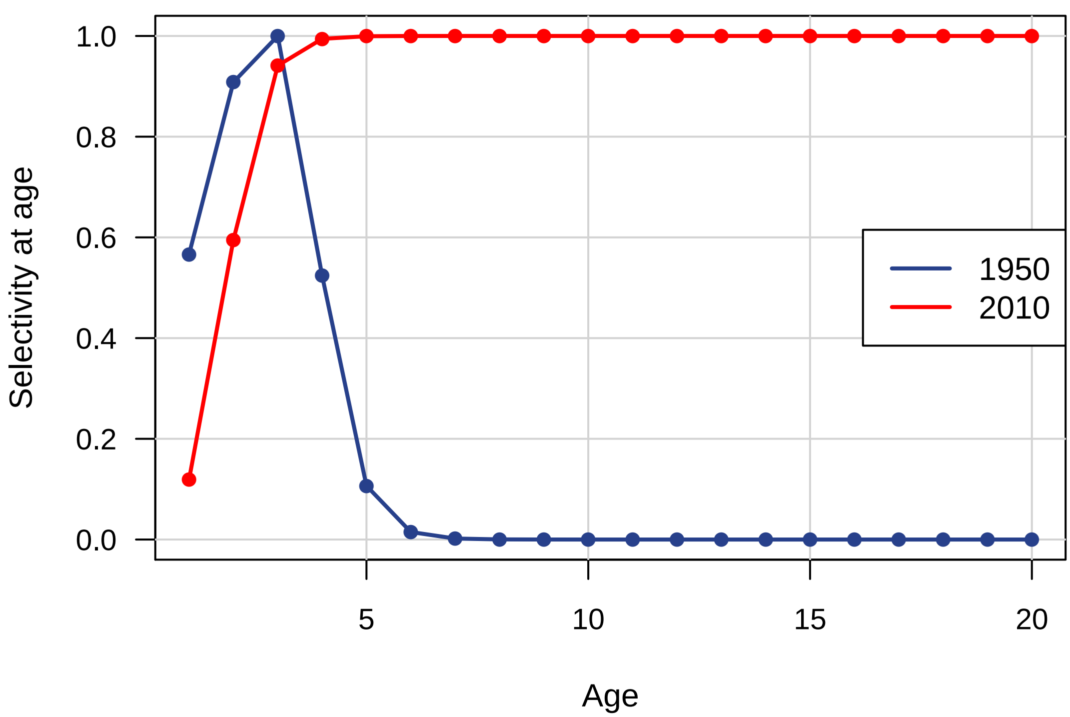


Figure 24. Selectivities of headboat discards. The legend indicates the first year each selectivity block.

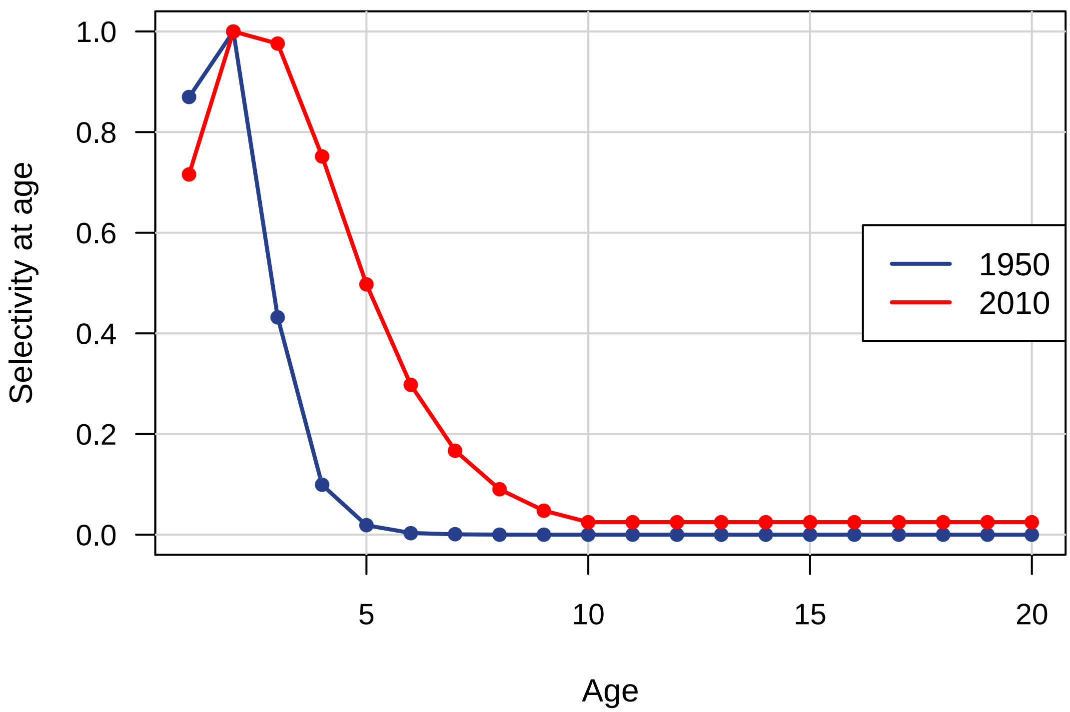


Figure 25. Selectivities of general recreational discards. The legend indicates the first year each selectivity block.

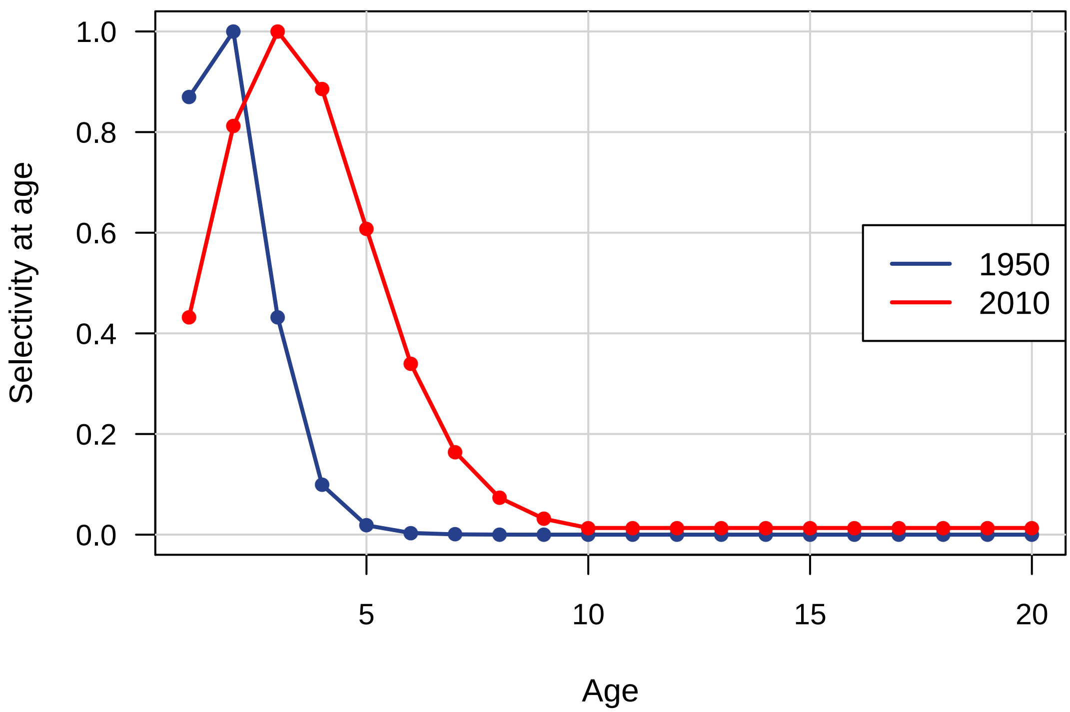


Figure 26. Average selectivity of discards (top), landings (middle), and total weighted average (bottom) from the terminal assessment years, weighted by geometric mean Fs from the last three assessment years, and used in computation of benchmarks and projections.

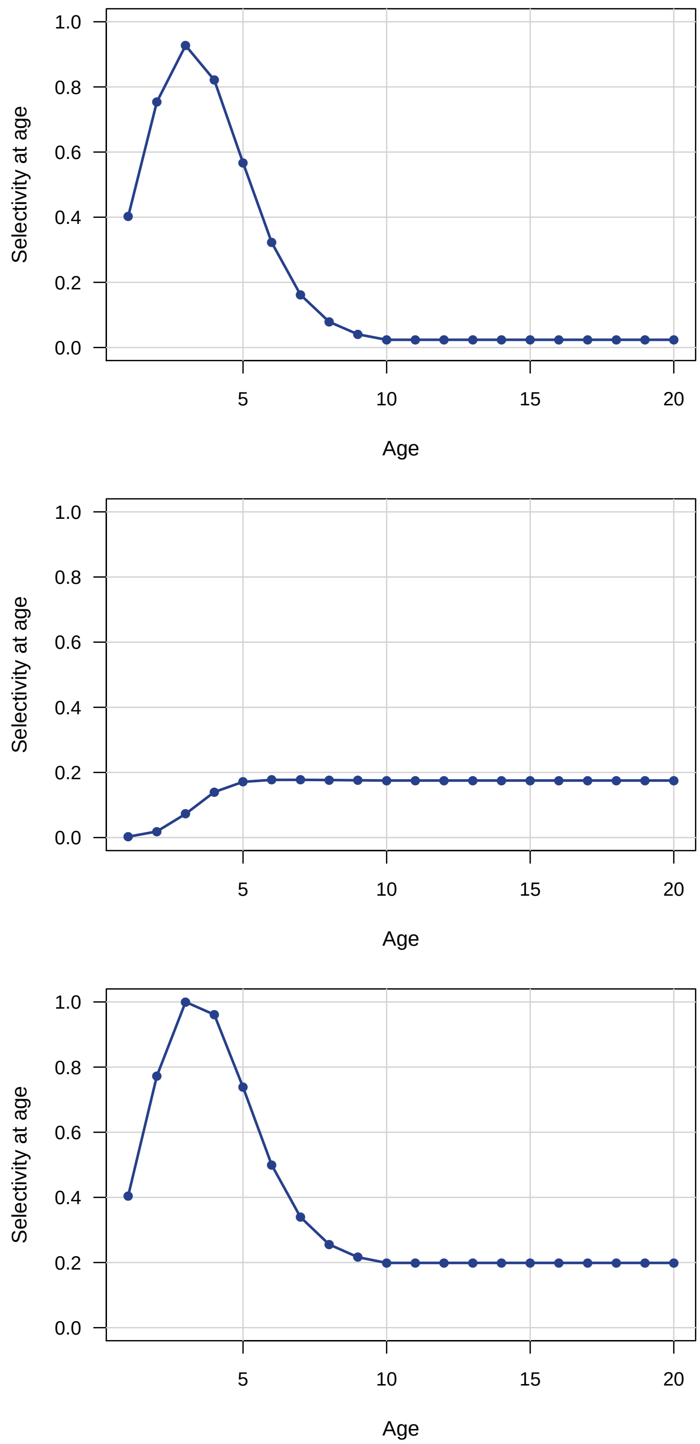


Figure 27. Estimated fully selected fishing mortality rate (per year) by fleet. cH refers to commercial handlines, HB to headboat, GR to general recreational, and D refers to discard mortality.

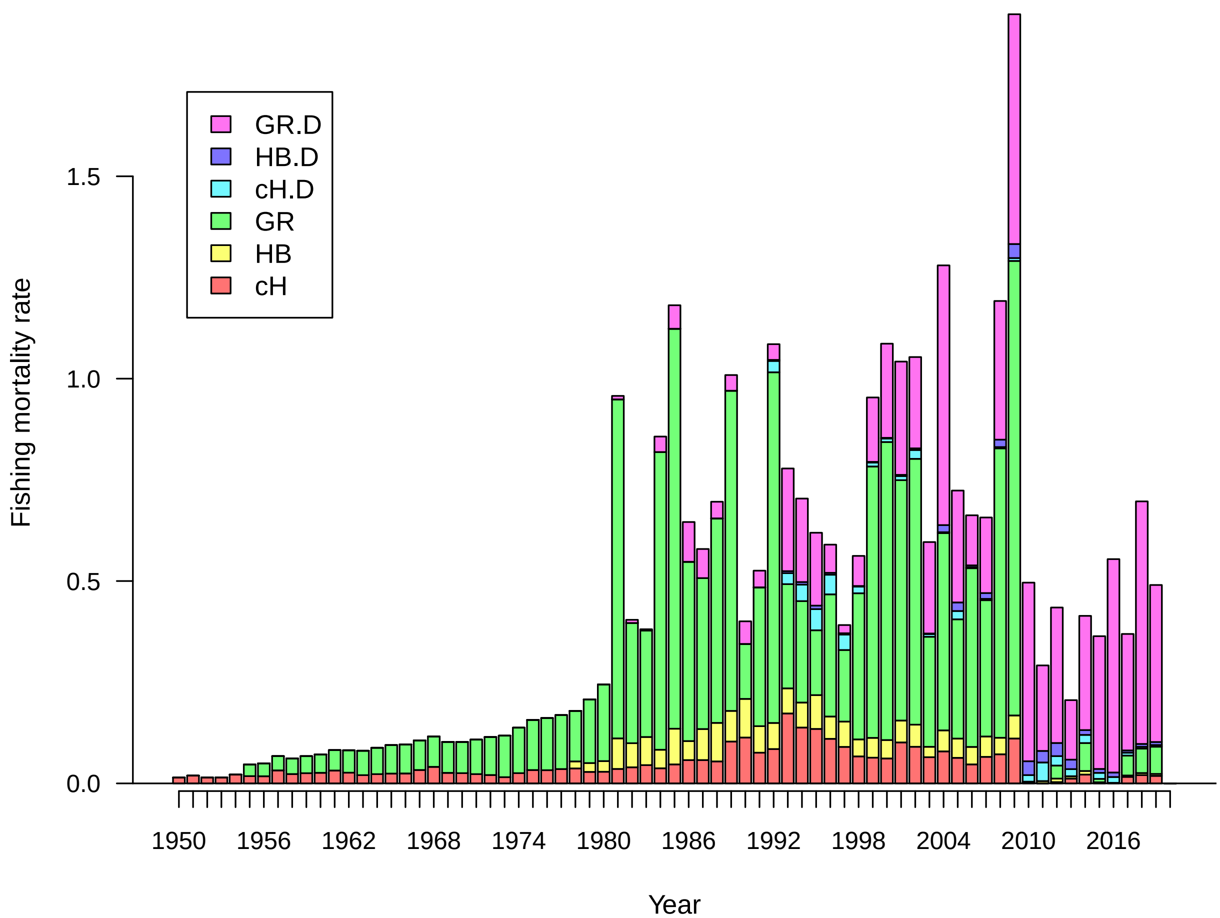
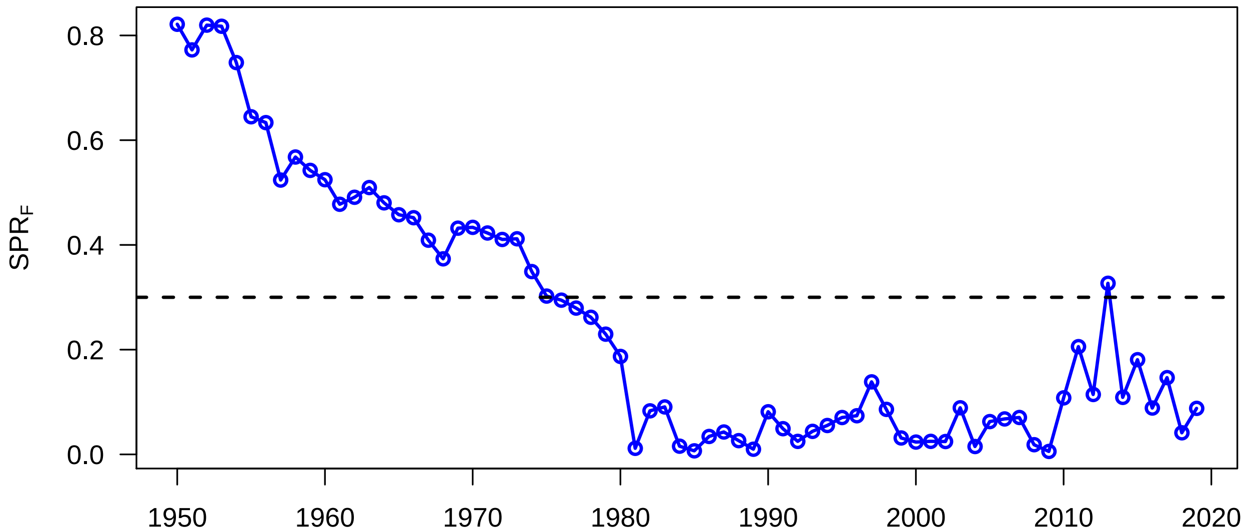


Figure 28. Alternative measures of fishing intensity. Top panel shows equilibrium SPR conditional on annual F, with a reference line at 0.3 (or, 30%). Bottom panel shows exploitation rate (E) computed as number killed divided total abundance (thick black curve), which can be divided into its components of landings (thin green curve) and dead discards (thin blue curve).



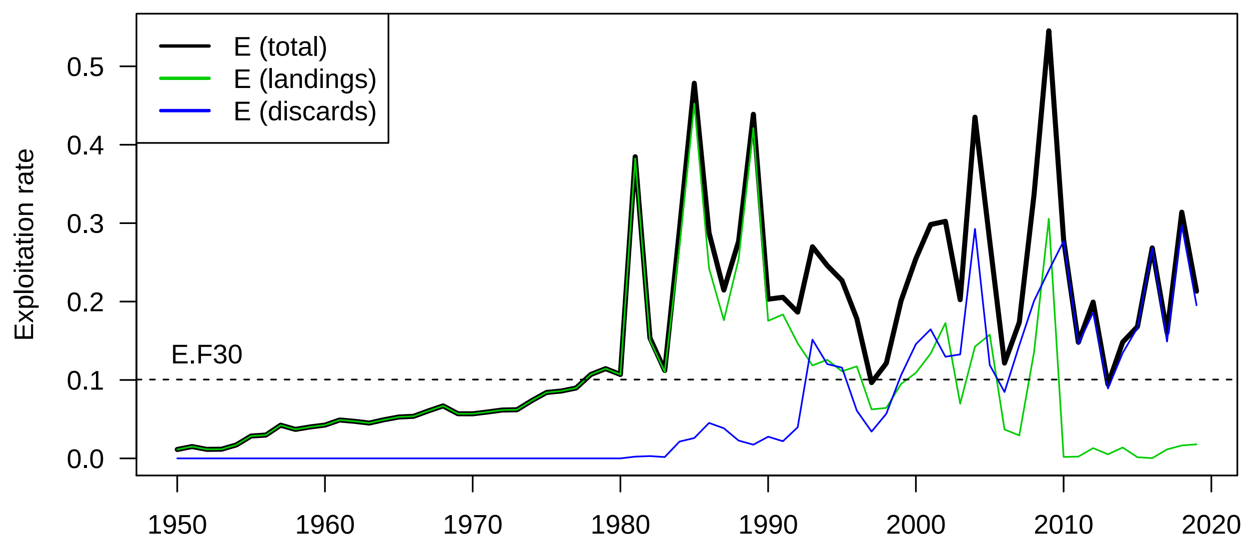


Figure 29. Estimated landings in numbers by fleet from the catch-age model. cH refers to commercial handlines, HB to headboat, and GR to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of $L_{F30\%}$ in numbers.

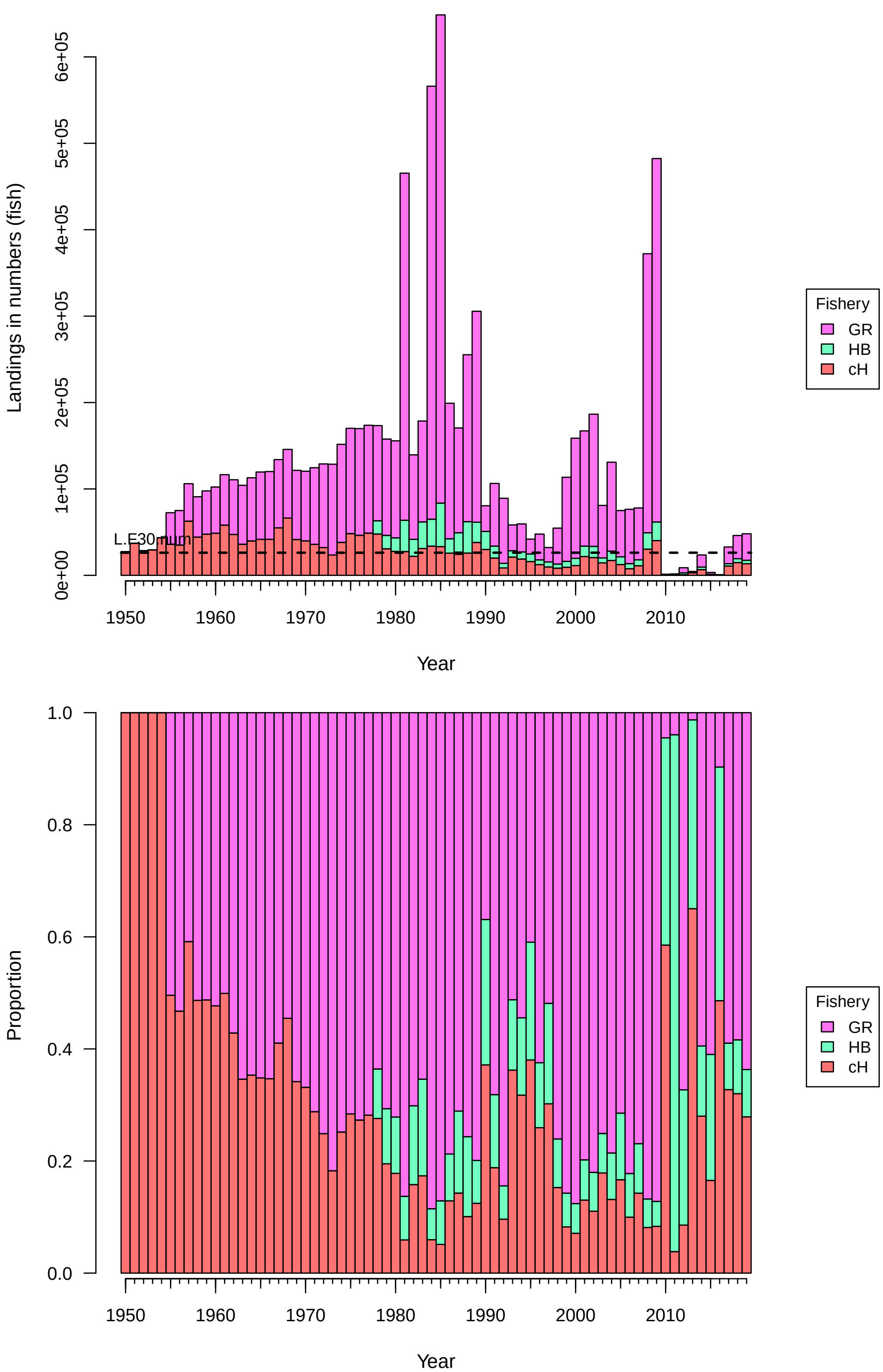


Figure 30. Estimated landings in whole weight by fleet from the catch-age model. cH refers to commercial handlines, HB to headboat, and GR to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of $L_{F30\%}$ in weight.

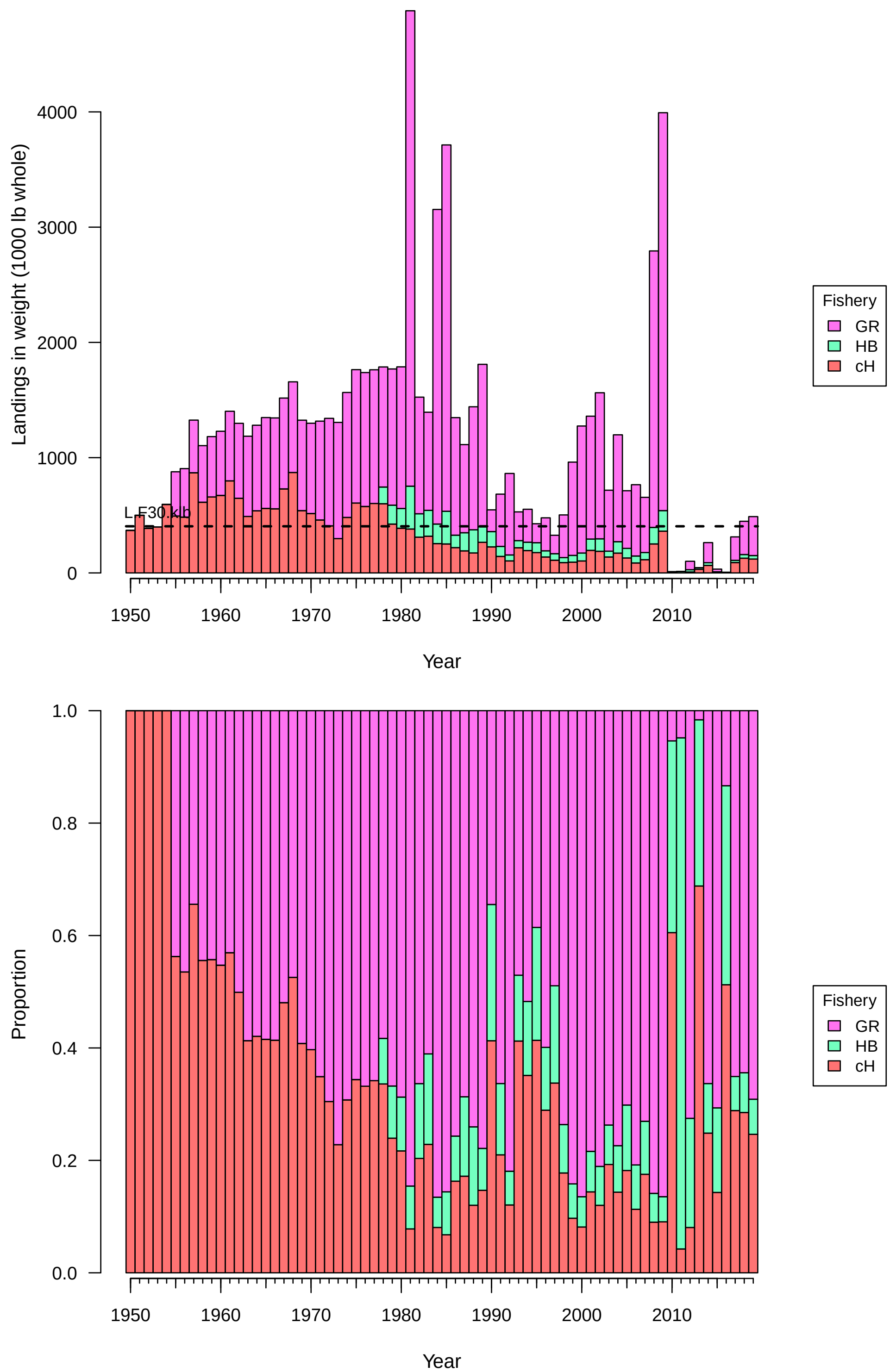


Figure 31. Estimated discard mortalities by fleet from the catch-age model. cH refers to commercial lines, hb to headboat, rec to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of $D_{F_{30\%}}$ *in numbers.*

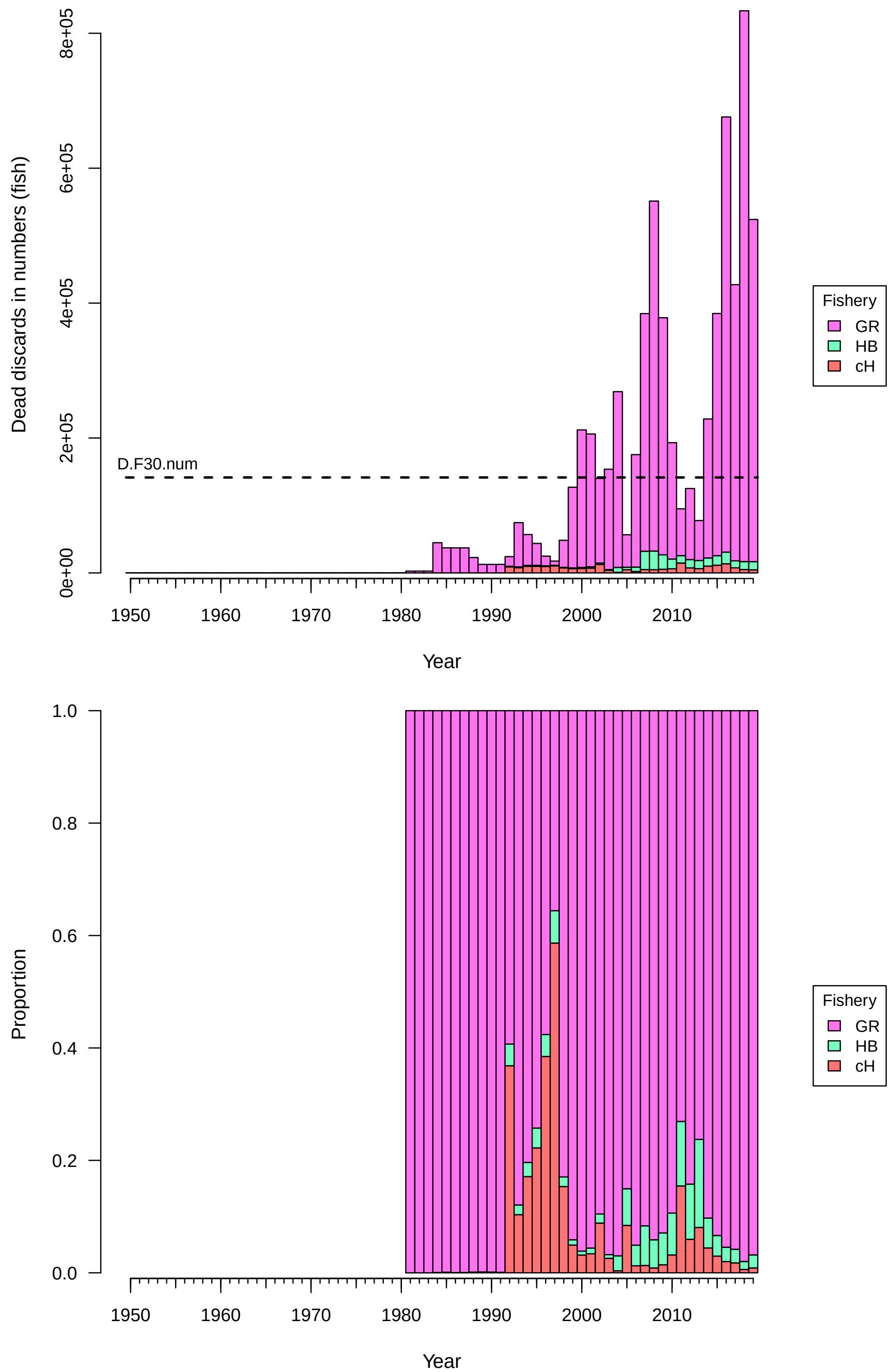


Figure 32. Top panel: Spawner-recruit relationship, with and without lognormal bias correction. The expected (mean-unbiased) curve was used for computing management benchmarks.

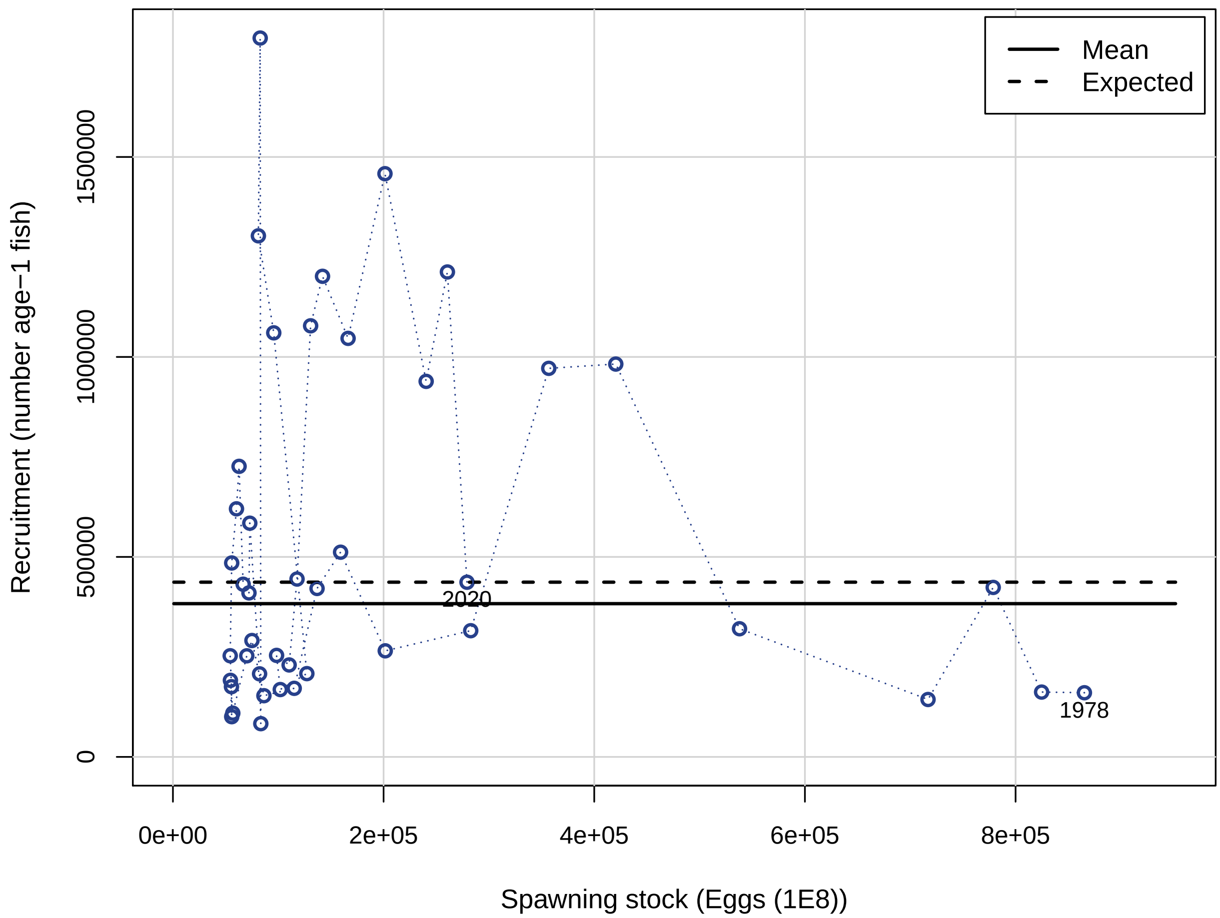


Figure 33. Probability densities of spawner-recruit quantities: Mean recruits (R0, age-1 fish), median recruits, unfished spawners per recruit, and standard deviation of recruitment residuals in log space. Solid vertical lines represent point estimates or values from the base run of the Beaufort Assessment Model; dashed vertical lines represent medians from the MCBE runs.

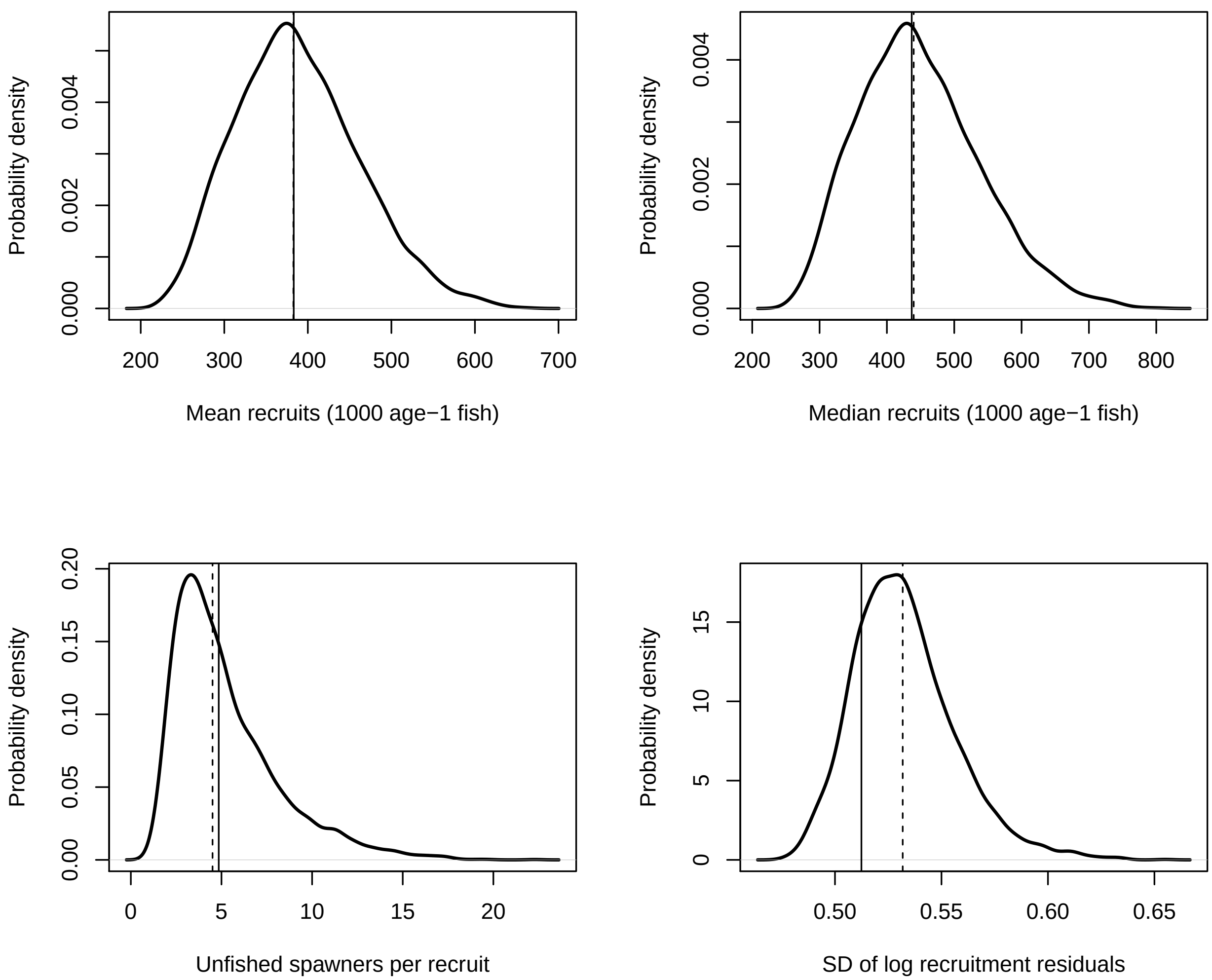


Figure 34. Yield (lb whole weight) per recruit based on average selectivity from the end of the assessment period.

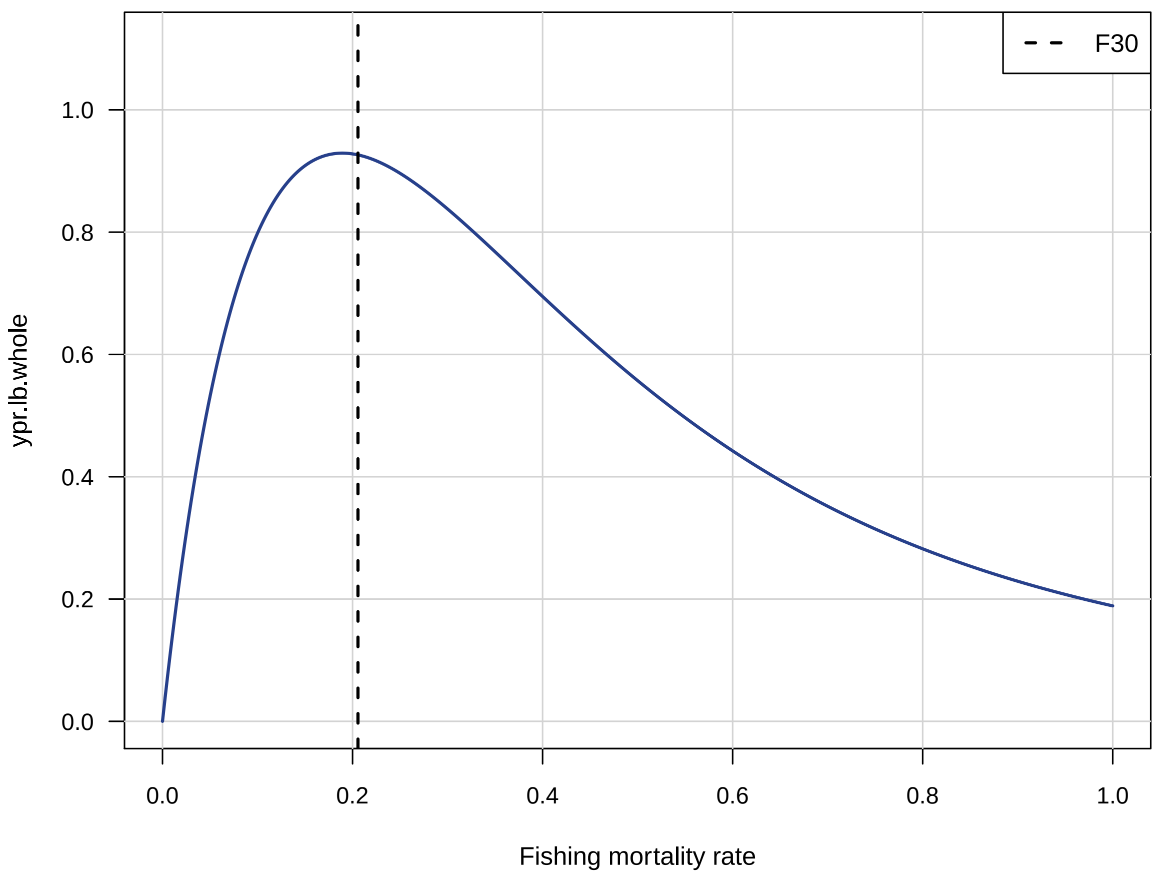


Figure 35. Spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the X% level of SPR provides $F_{X\%}$. SPR is based on average selectivity from the end of the assessment period.

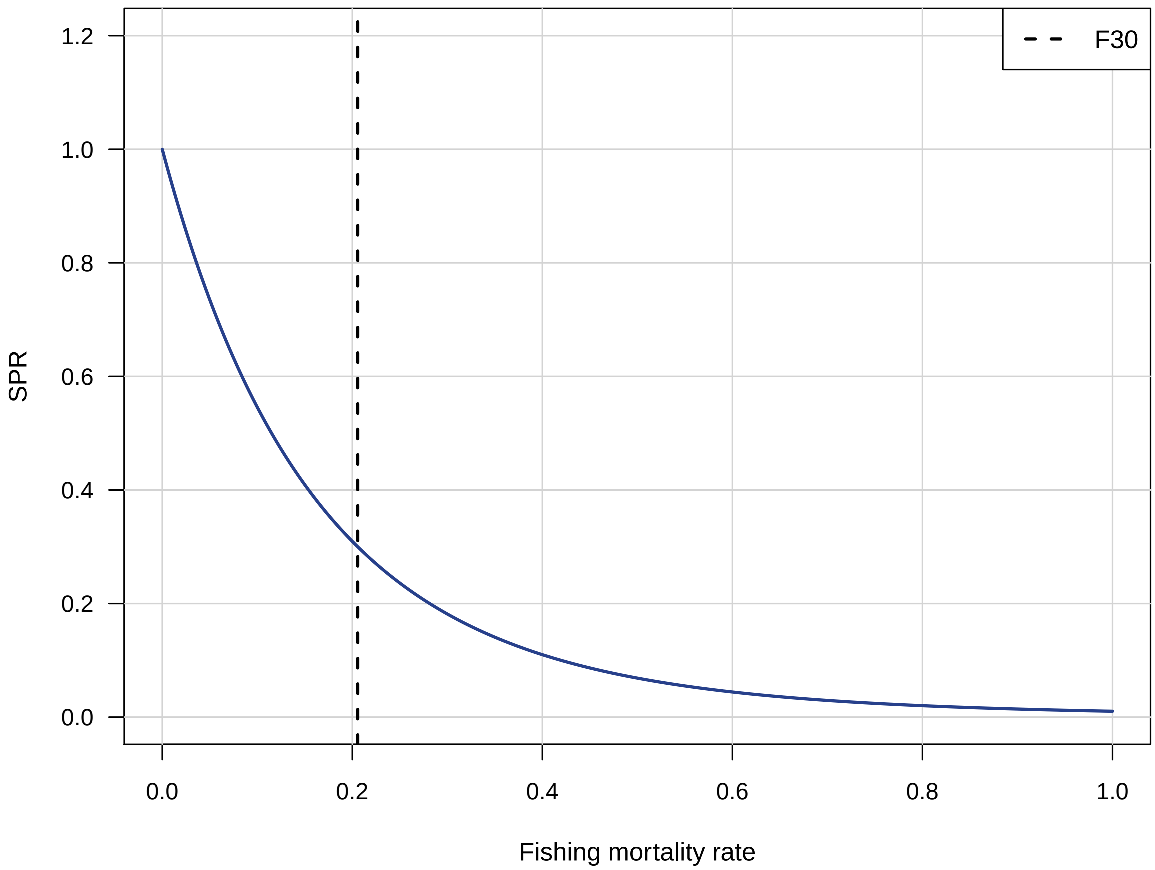


Figure 36. Equilibrium spawning biomass based on average selectivity from the end of the assessment period.

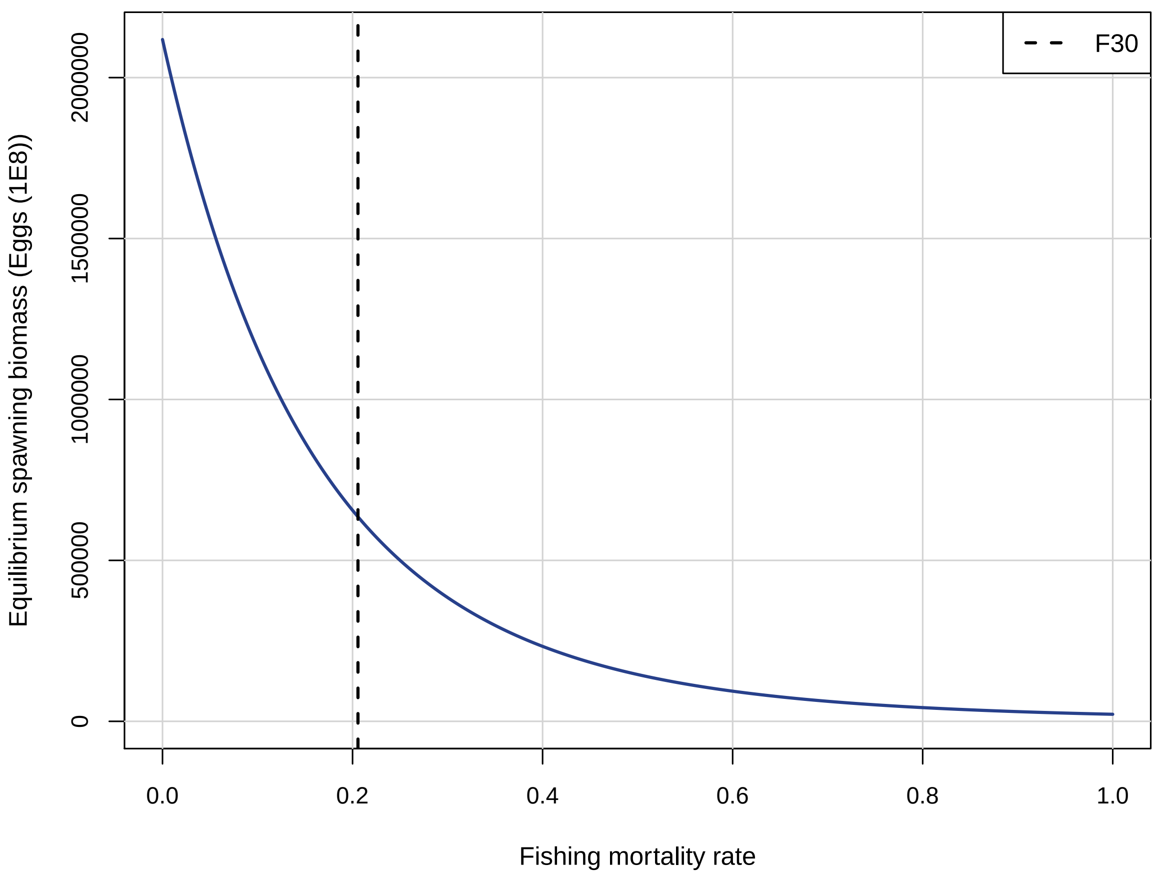


Figure 37. Equilibrium removals as a function of equilibrium biomass, which itself is a function of fishing mortality rate. Top panel: landings. Bottom panel: discards.

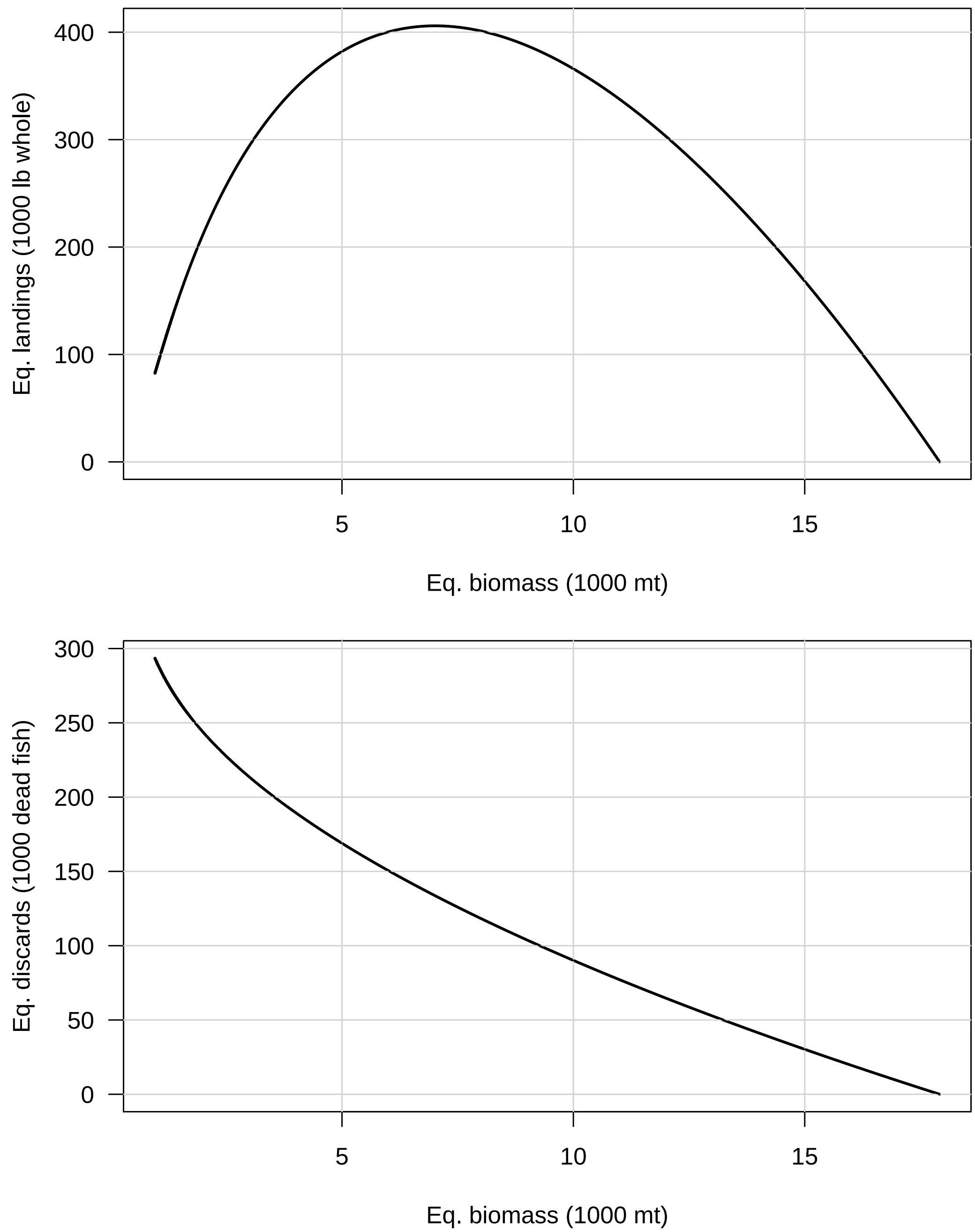


Figure 38. Probability densities of $F_{30\%}$-related benchmarks from MCBE analysis. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.

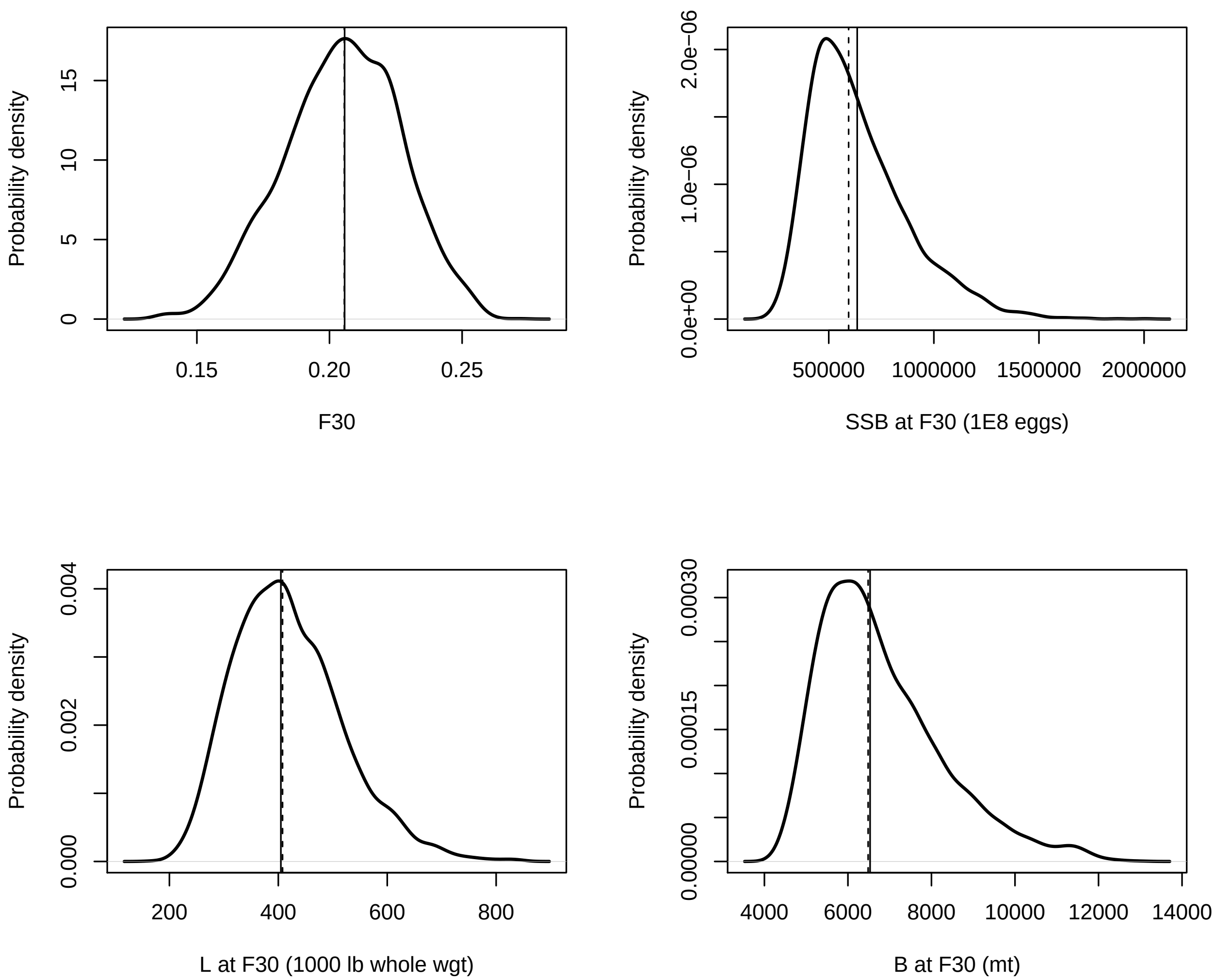


Figure 39. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; dashed lines represent median values; gray error bands indicate 5^{th} *and* 95^{th} *percentiles of the MCBE. Top panel: spawning biomass relative to* $\mathrm{SSB}_{\mathrm{F30\%}}$*. Bottom panel: F relative to* $F_{30\%}$*.*

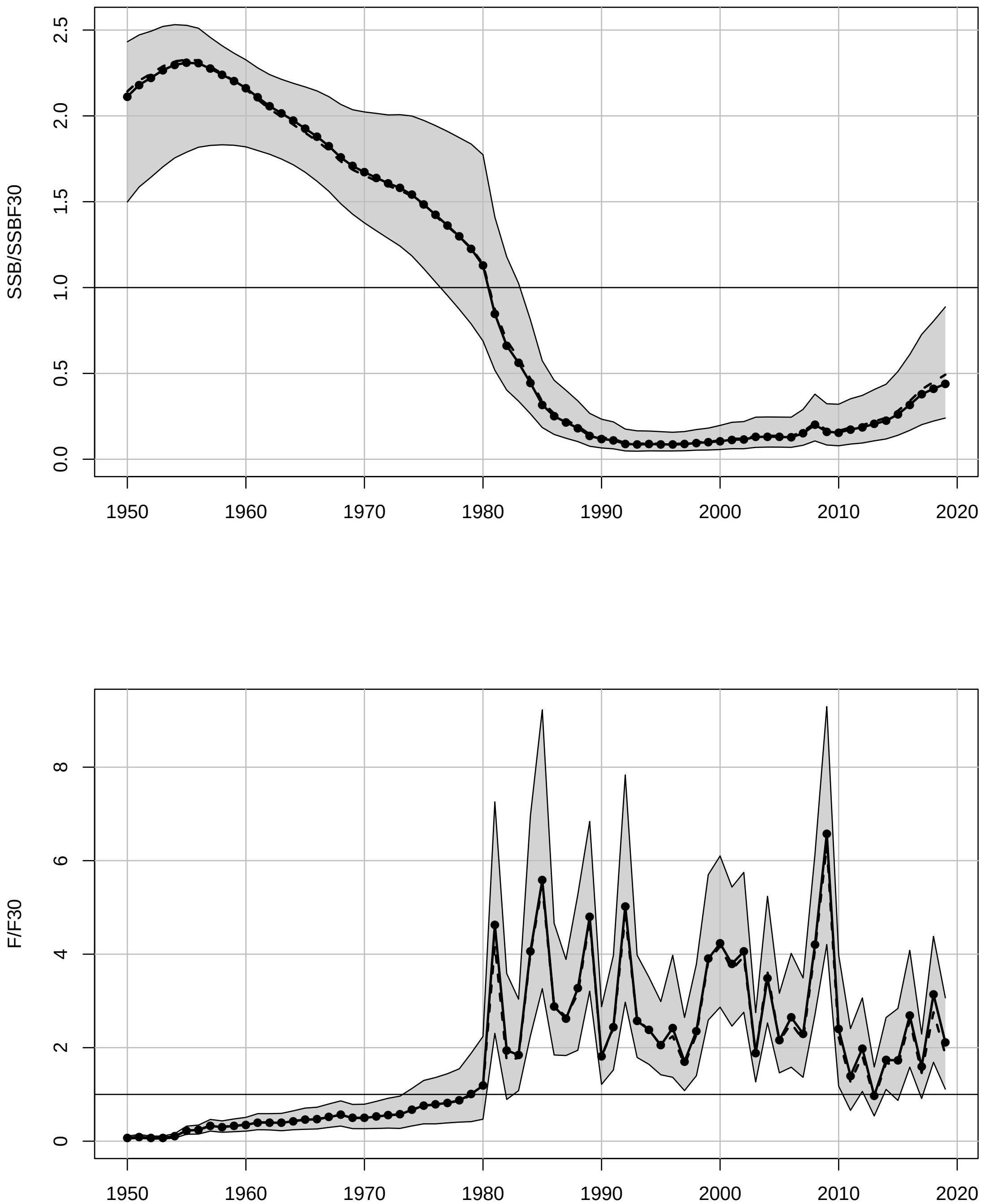
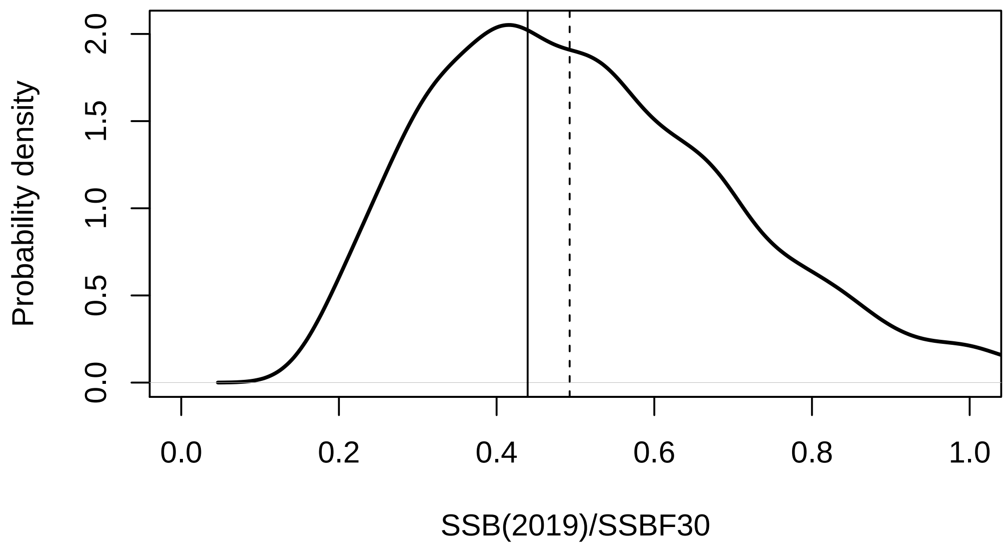


Figure 40. Probability densities of terminal status estimates from MCBE analysis. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.



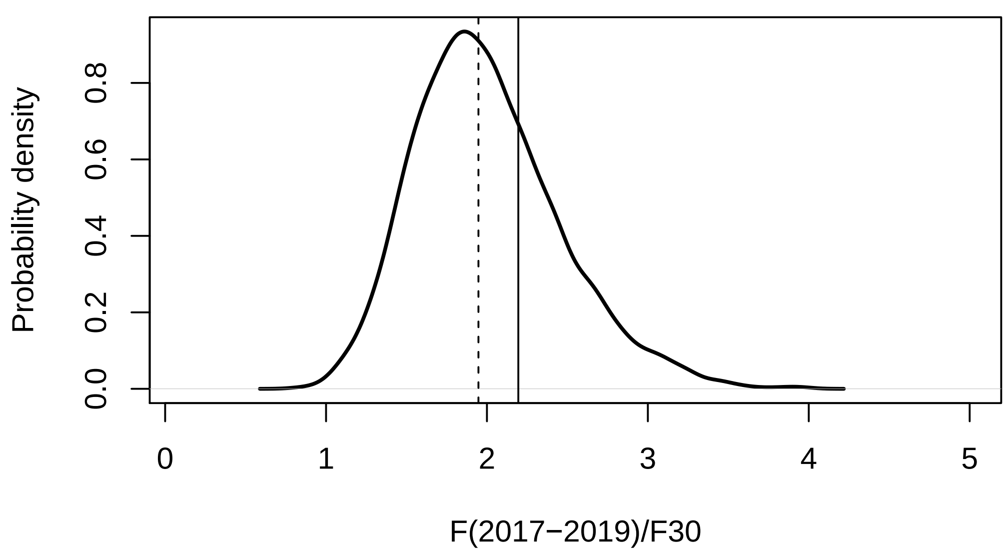


Figure 41. Phase plots of terminal status estimates from MCBE analysis. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by 5^{th} *and* 95^{th} *percentiles. Proportion of runs falling in each quadrant indicated.*

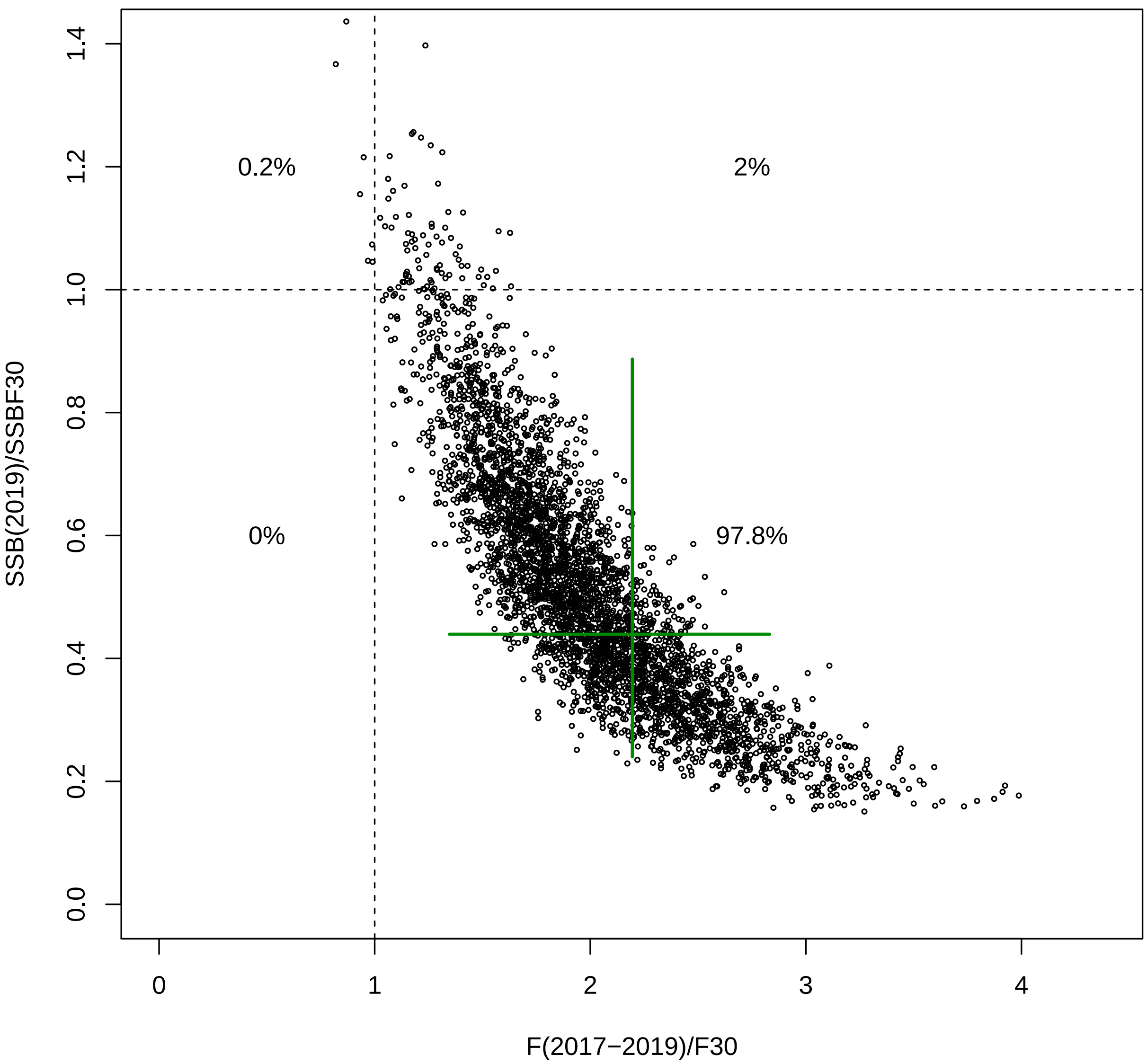


Figure 42. Age structure relative to the equilibrium expected at $F_{30\%}$.

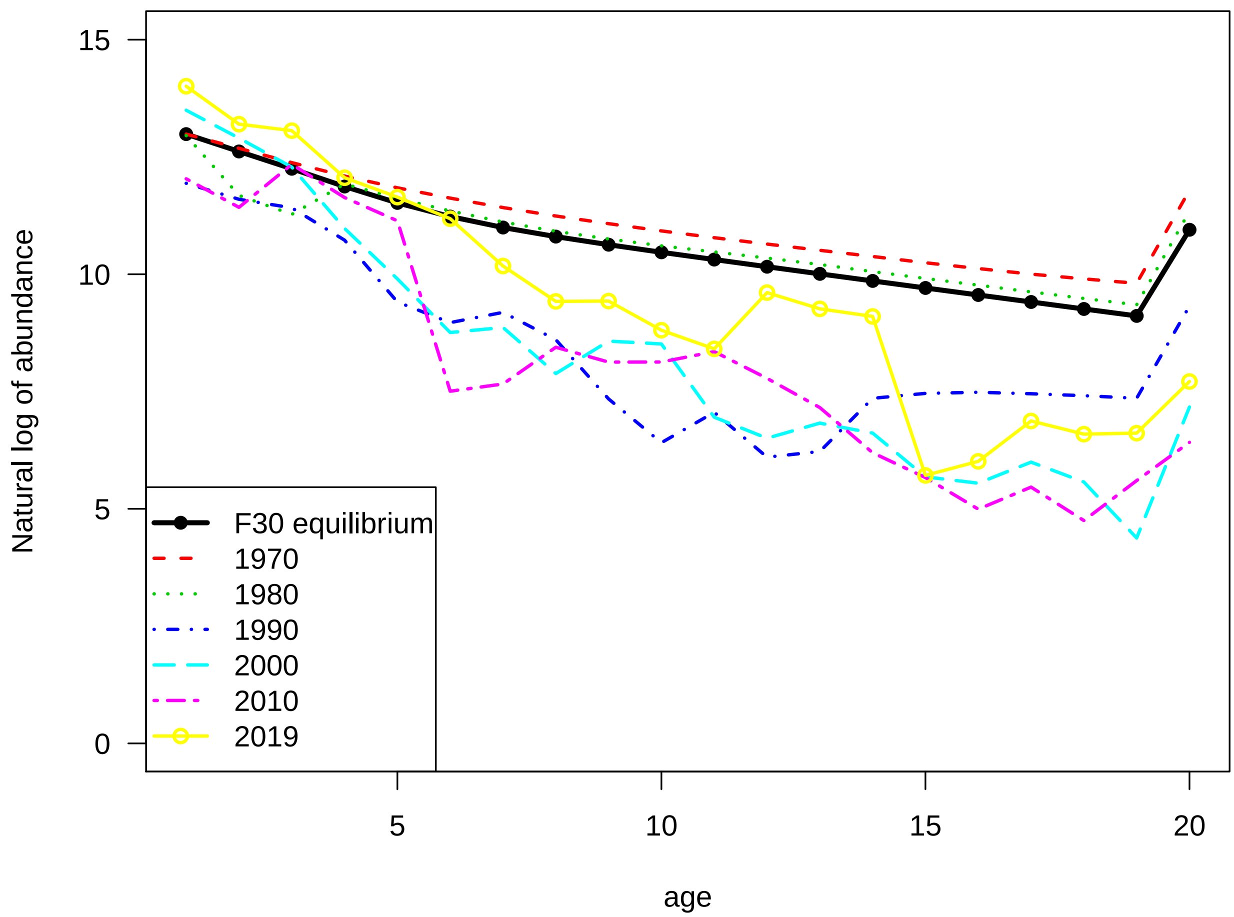
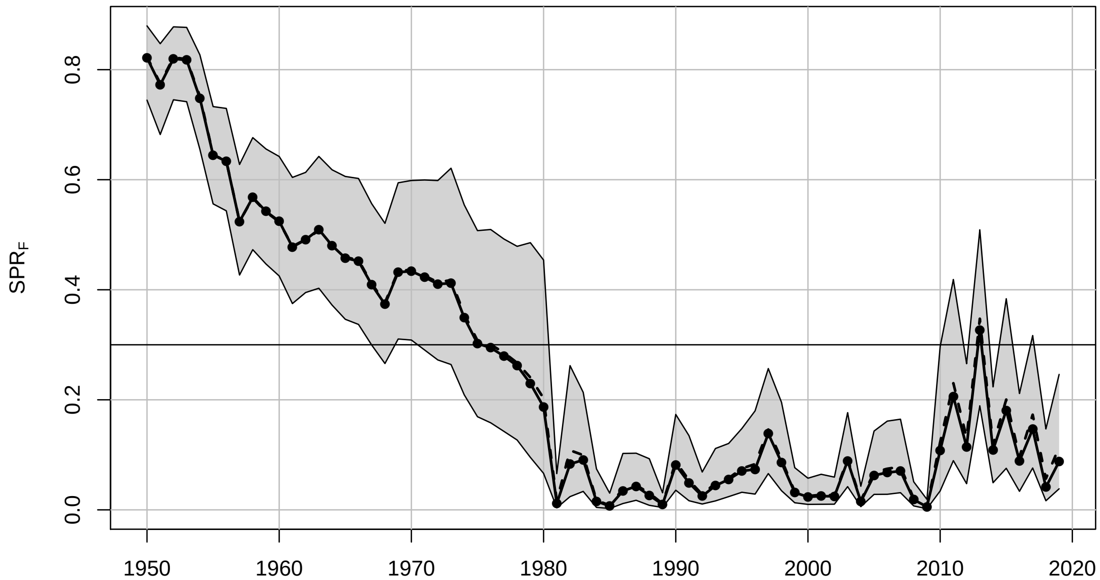


Figure 43. Estimated time series of alternative fishing intensity metrics relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; dashed lines represent median values; gray error bands indicate 5^{th} and 95^{th} percentiles of the MCBE. Top panel: SPR_{F} with a reference line at 0.30 (i.e., 30% SPR). Bottom panel: E relative to $E_{\mathrm{F30\%}}$, computed from numbers of fish.



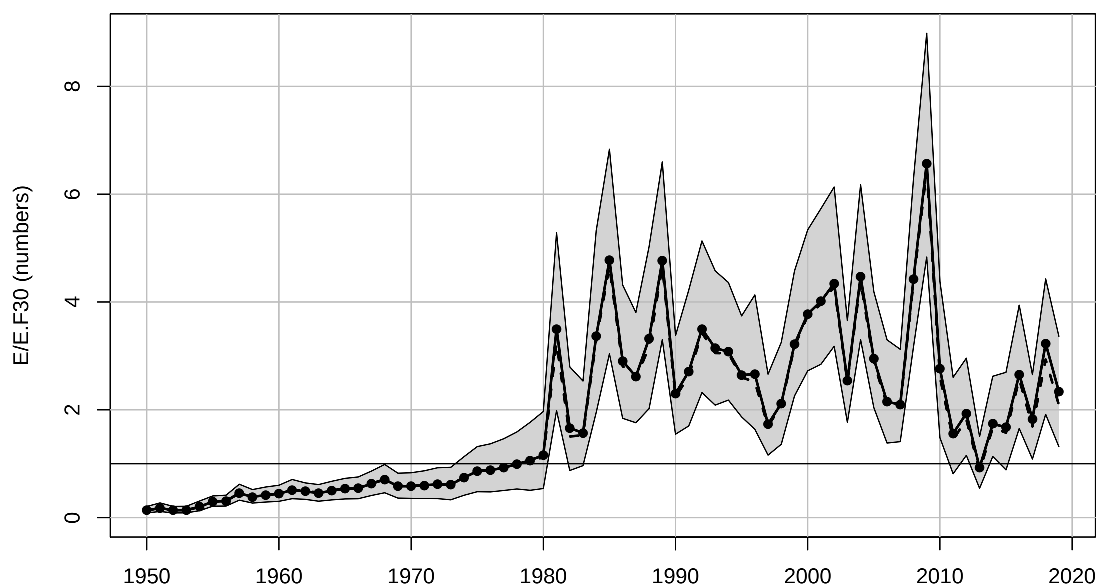
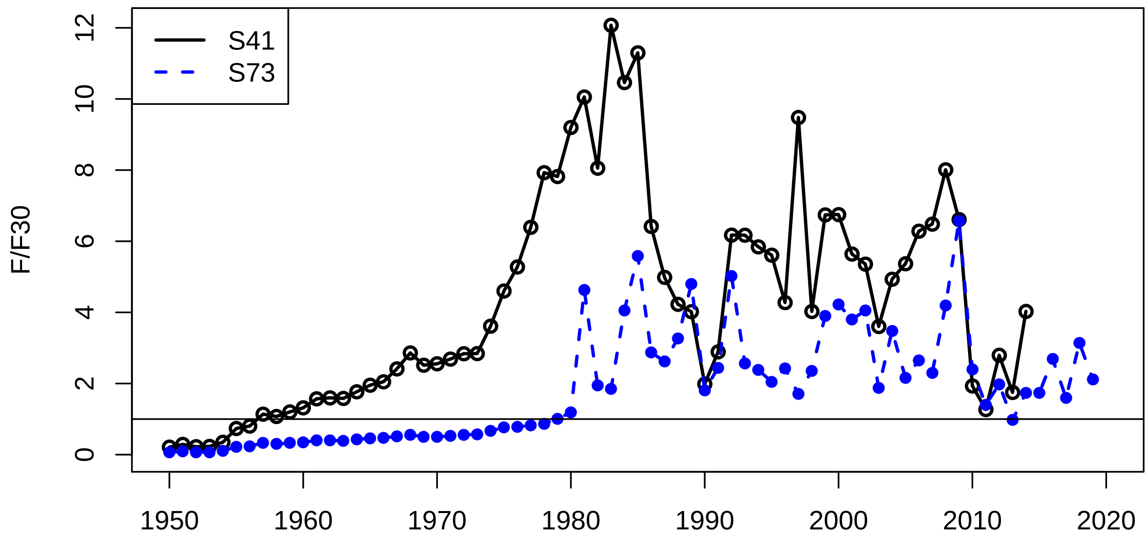


Figure 44. Comparison between SEDAR41 (S41) and SEDAR73 (S73) status indicators. Top panel: F relative to $F_{30\%}$. Bottom panel: spawning biomass relative to $\mathrm{SSB}_{\mathrm{F30\%}}$.



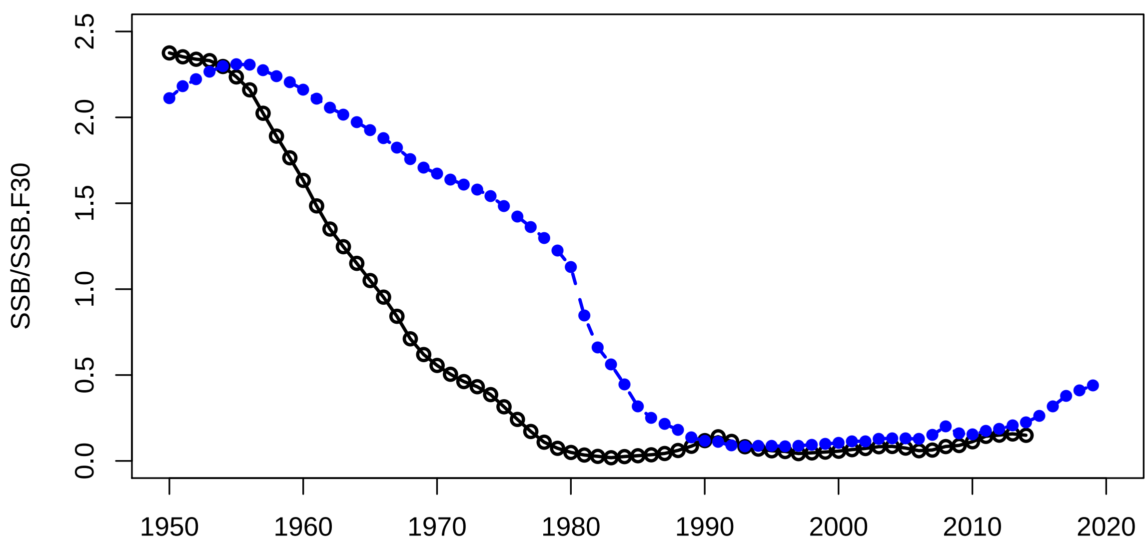
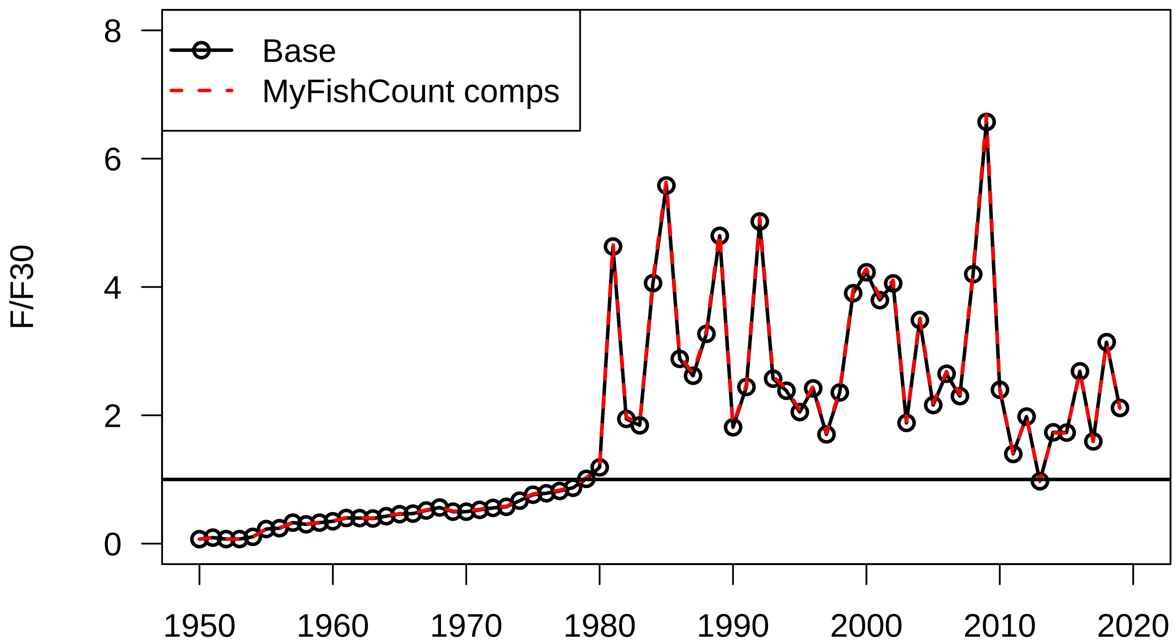


Figure 45. Sensitivity to including MyFishCount data on lengths of general recreational discards (sensitivity run S1). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB_{F30\%}}$.



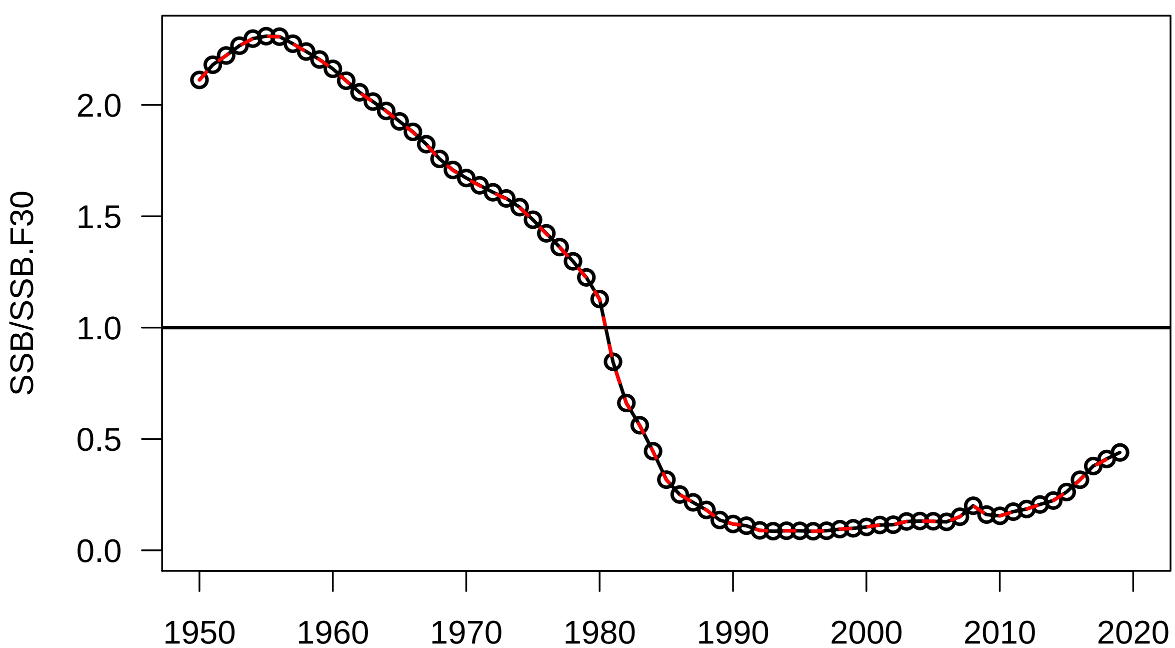


Figure 46. Sensitivity to including FWC RTD index and age compositions (sensitivity run S2). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

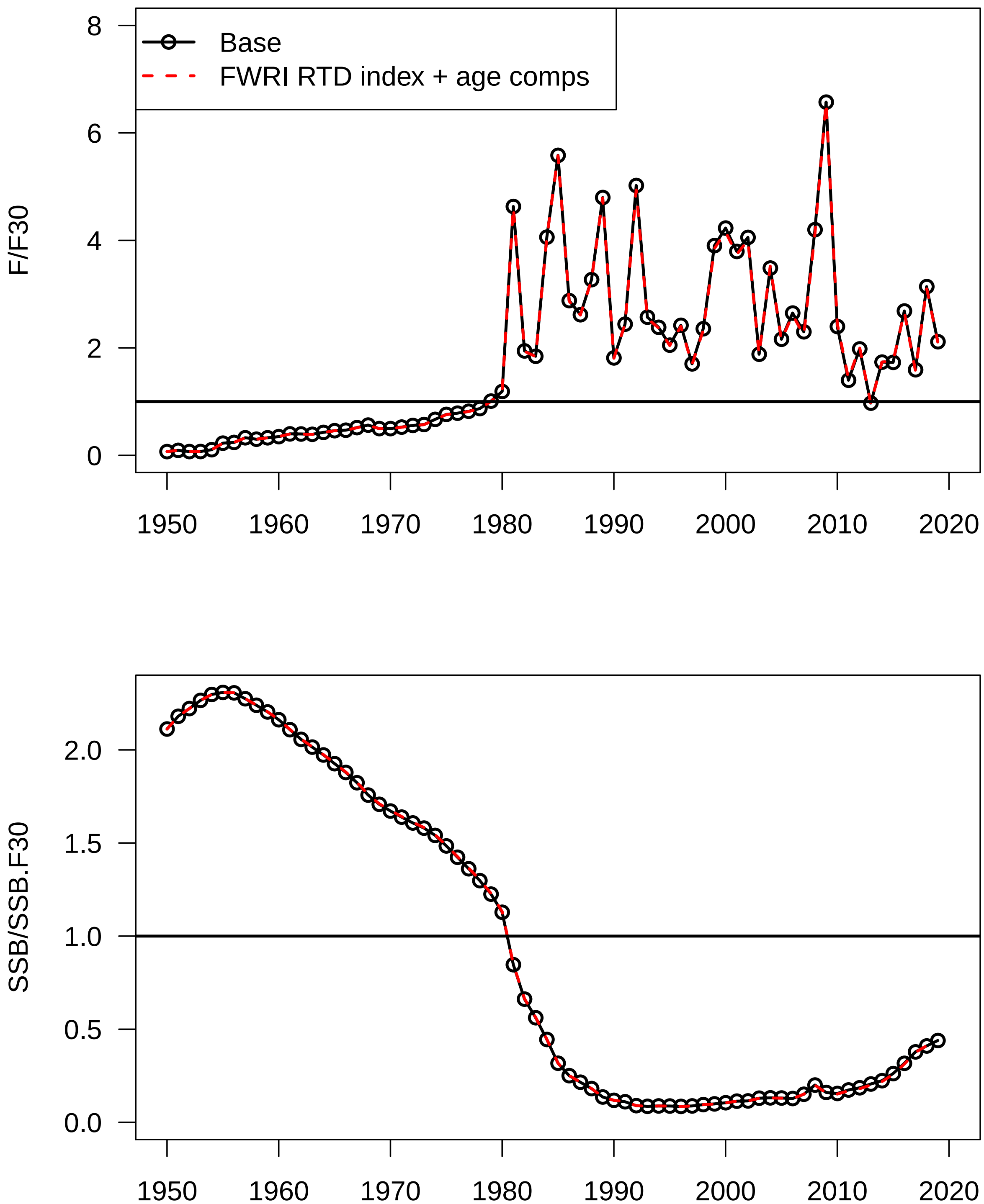


Figure 47. Sensitivity to dropping indices (sensitivity runs S3–S5). Top panel: Ratio of F to $F_{30\%}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

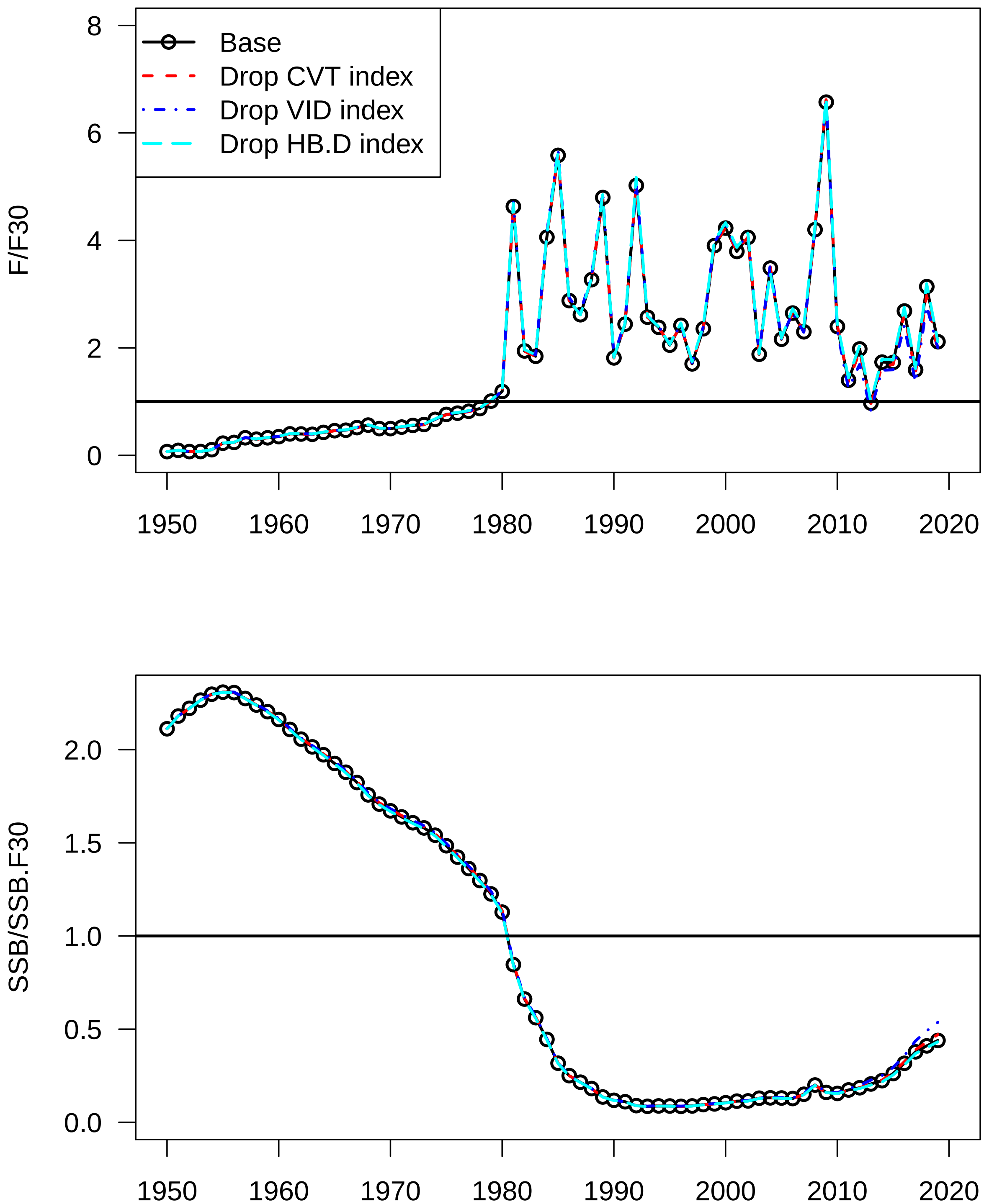


Figure 48. Sensitivity to weight of SERFS video index (sensitivity runs S6,S7). Top panel: Ratio of F to $F_{30\%}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$*.*

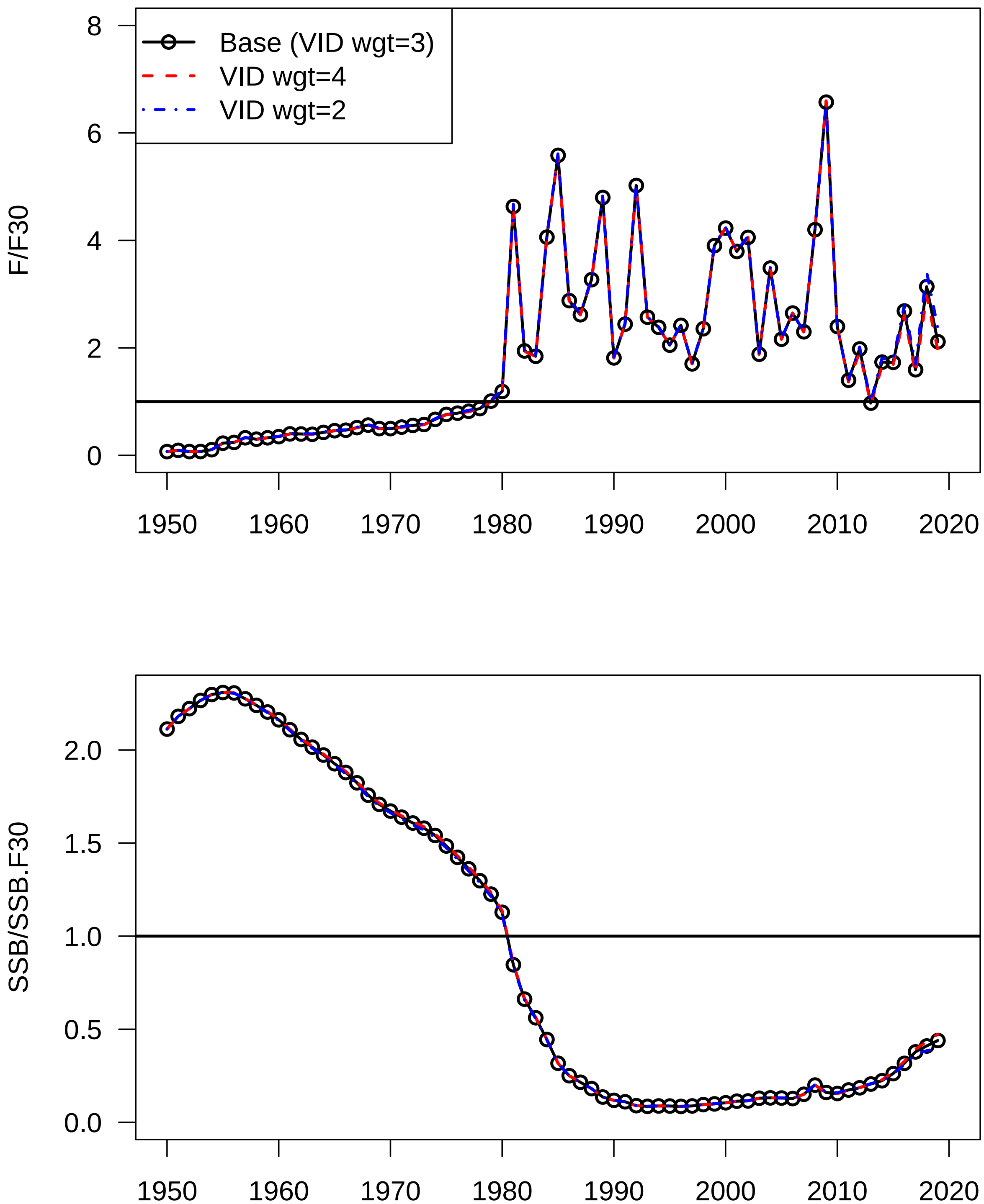
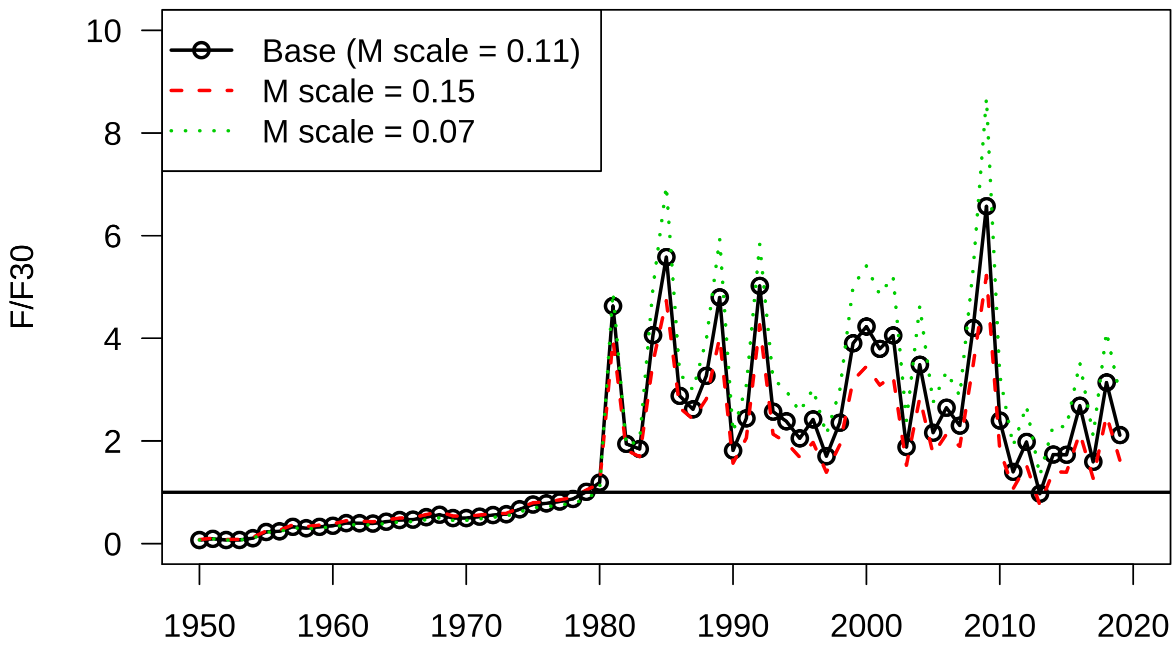


Figure 49. Sensitivity to scale of natural mortality (sensitivity runs S8, S9). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.



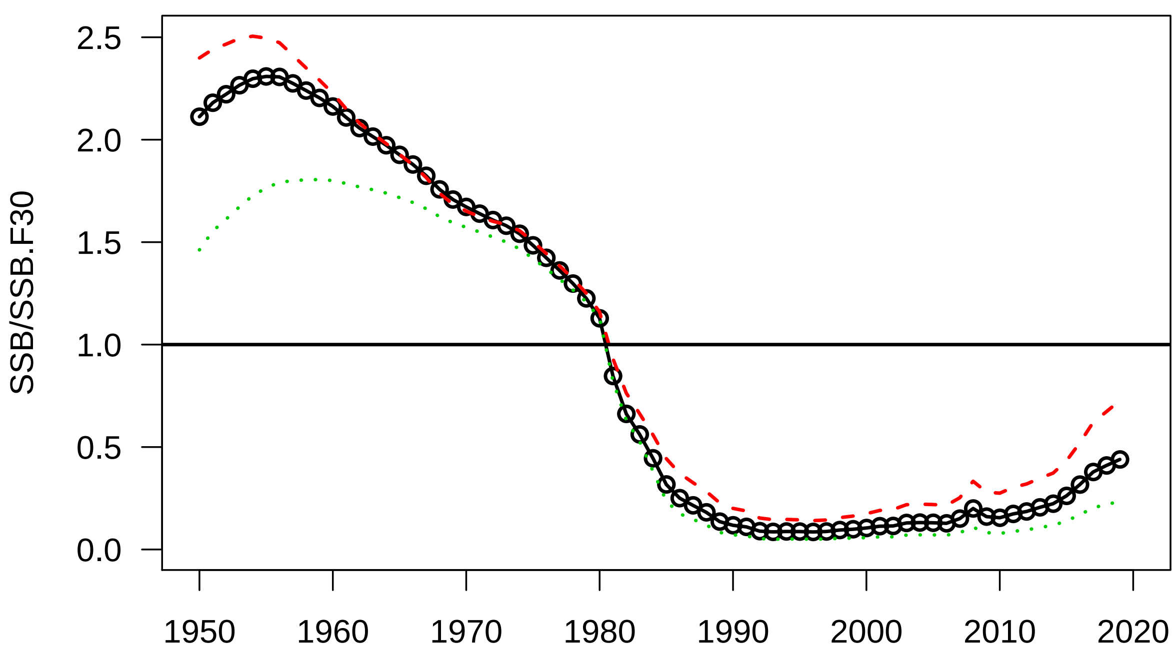


Figure 50. Sensitivity to shape of natural mortality vector, using the Charnov estimator (sensitivity runs S10, S11). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

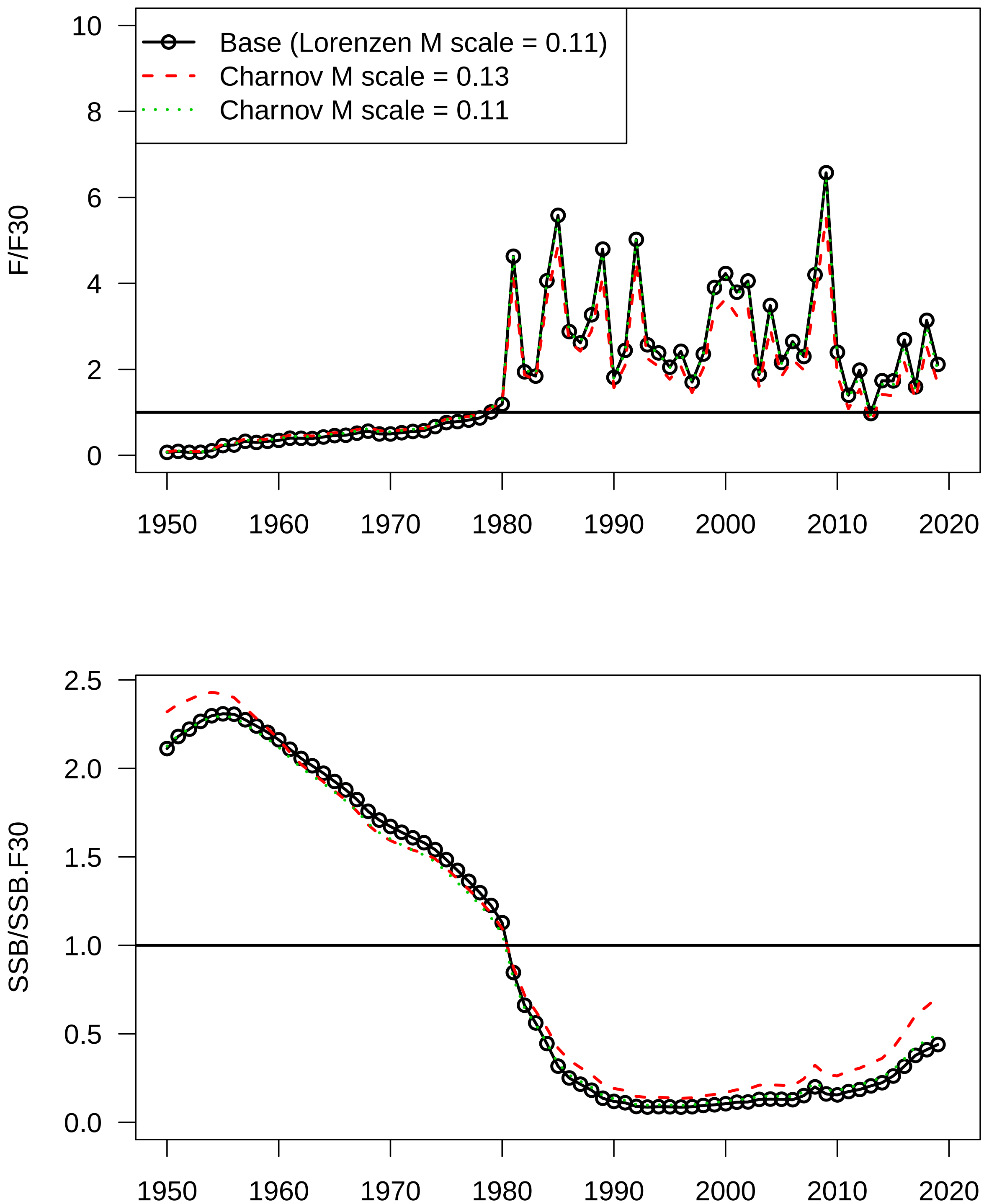


Figure 51. Sensitivity to composition likelihood, using the iteratively reweighted robust multinomial (sensitivity run S12). Top panel: Ratio of F to $F_{30\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

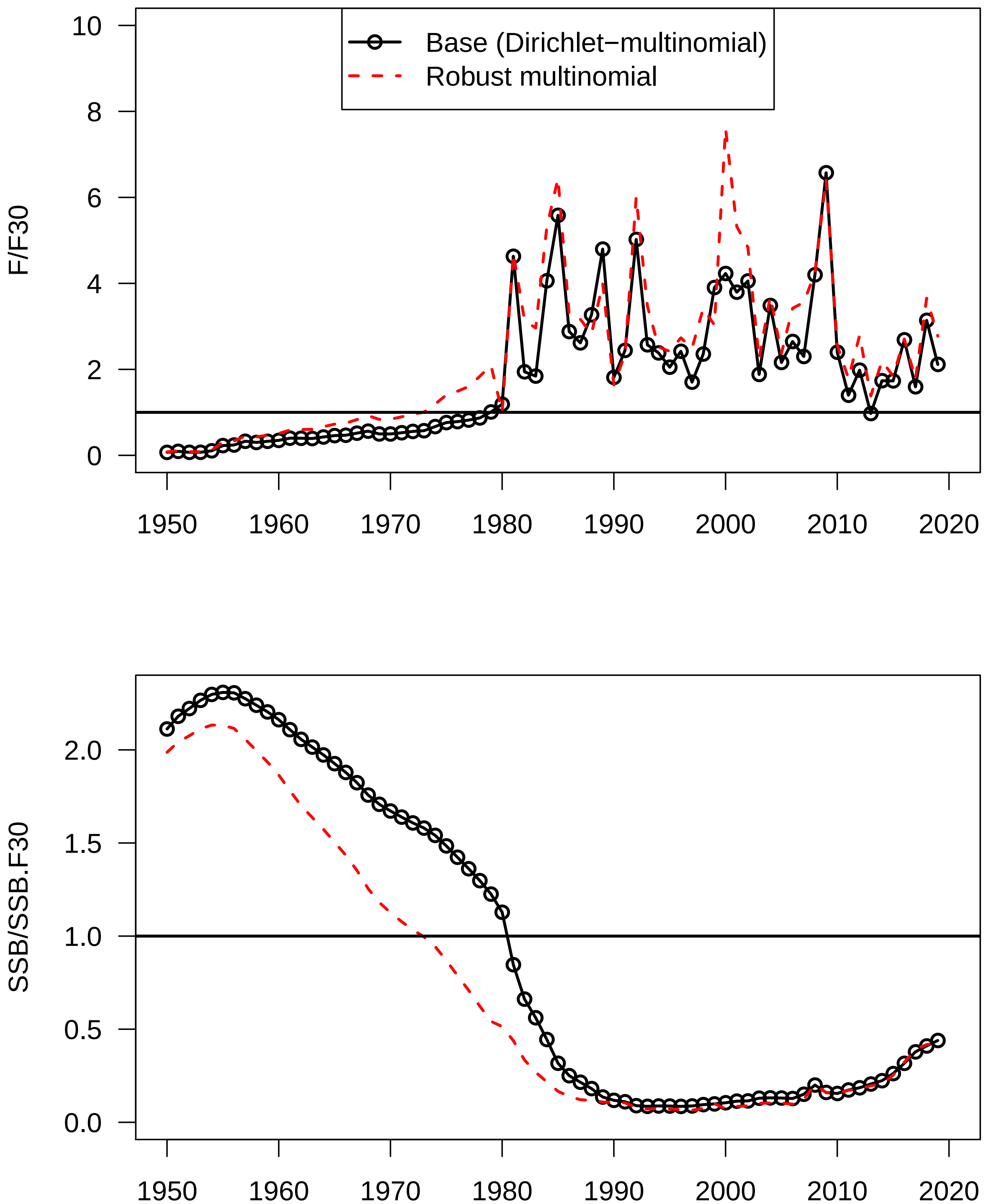
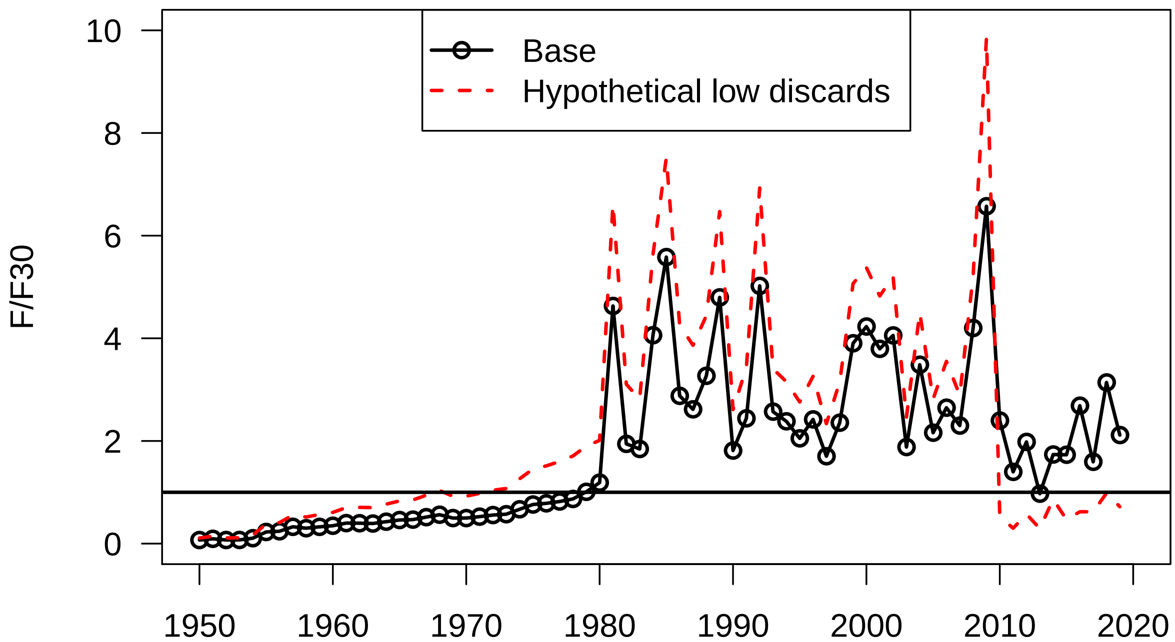


Figure 52. Sensitivity to hypothetically low discards starting in 2010 (sensitivity run S13). Top panel: Ratio of F to $F_{30\%}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$*.*



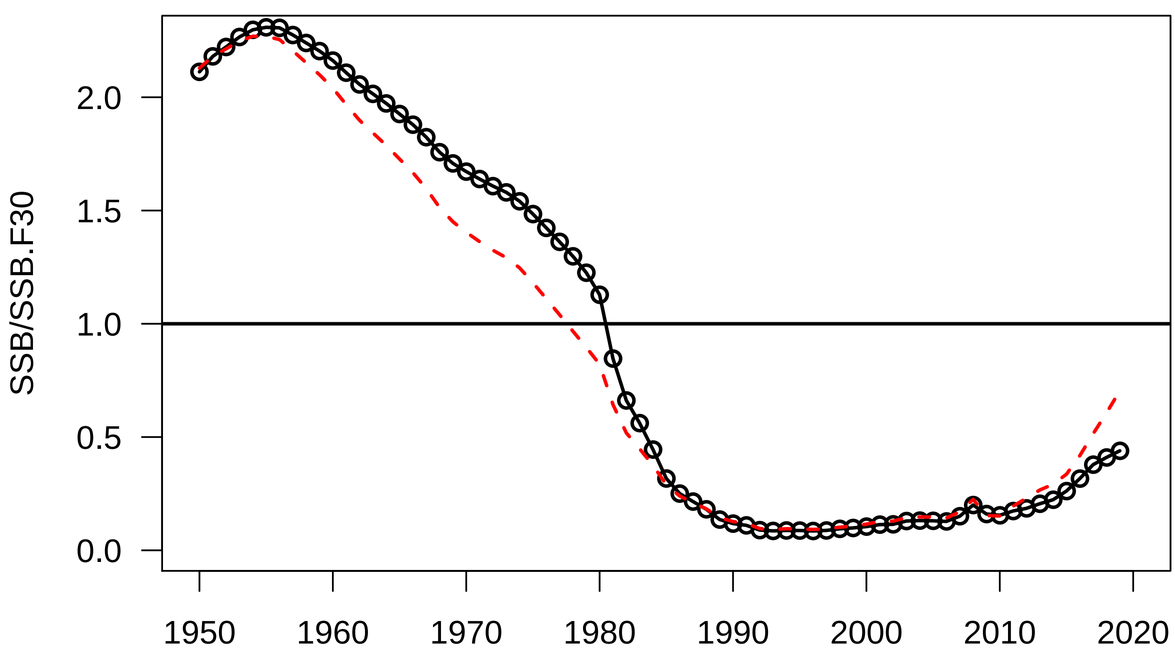


Figure 53. Sensitivity to hypothetically high natural mortality (sensitivity run S14). Top panel: Ratio of F to $F_{30\%}$. *Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F30\%}}$.

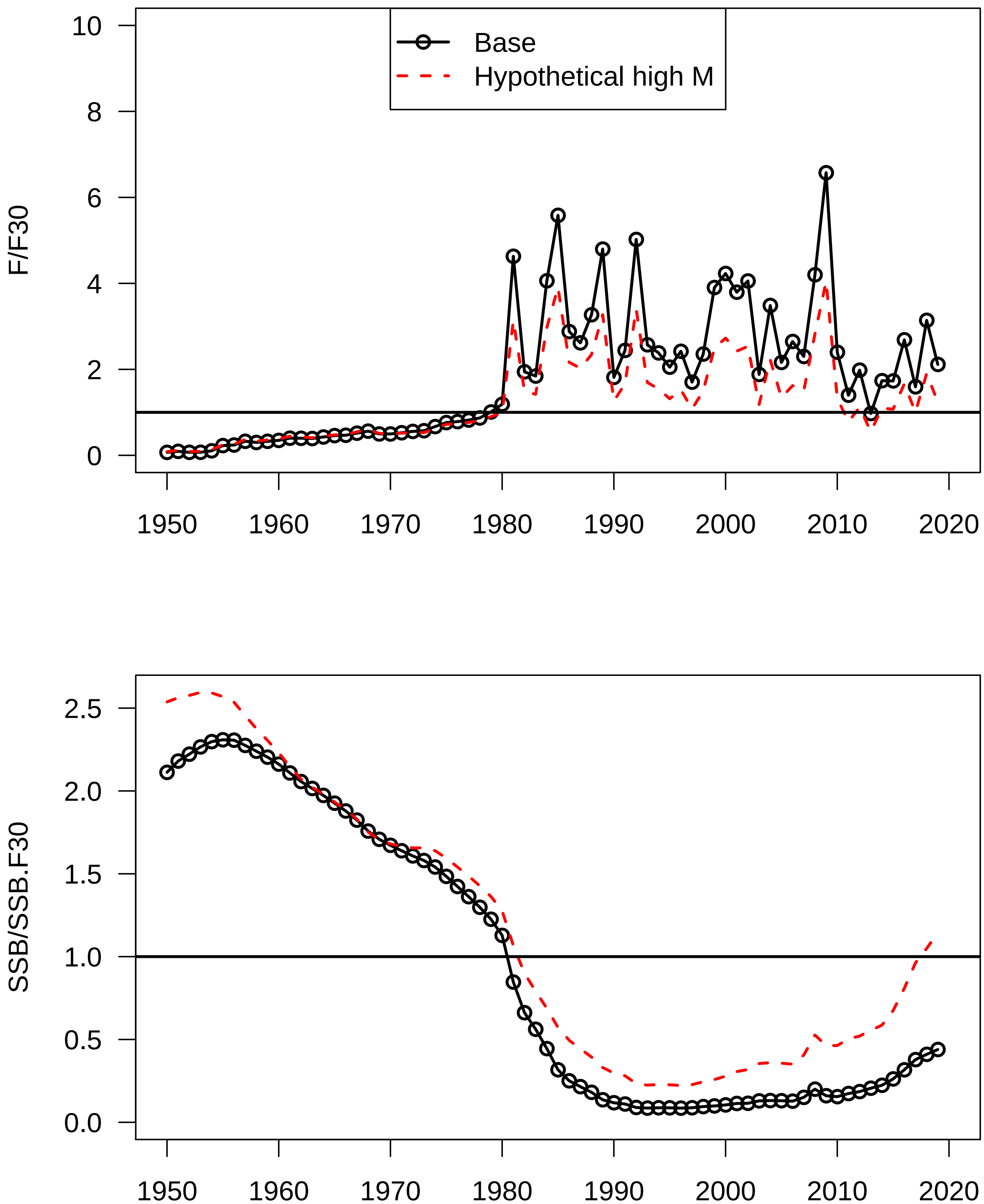


Figure 54. Retrospective analyses. Sensitivity to terminal year of data. Top panel: Fishing mortality rates. Middle panel: Recruits. Bottom panel: Spawning biomass. Closed circles show terminal-year estimates. Imperceptible lines overlap results of the base run.

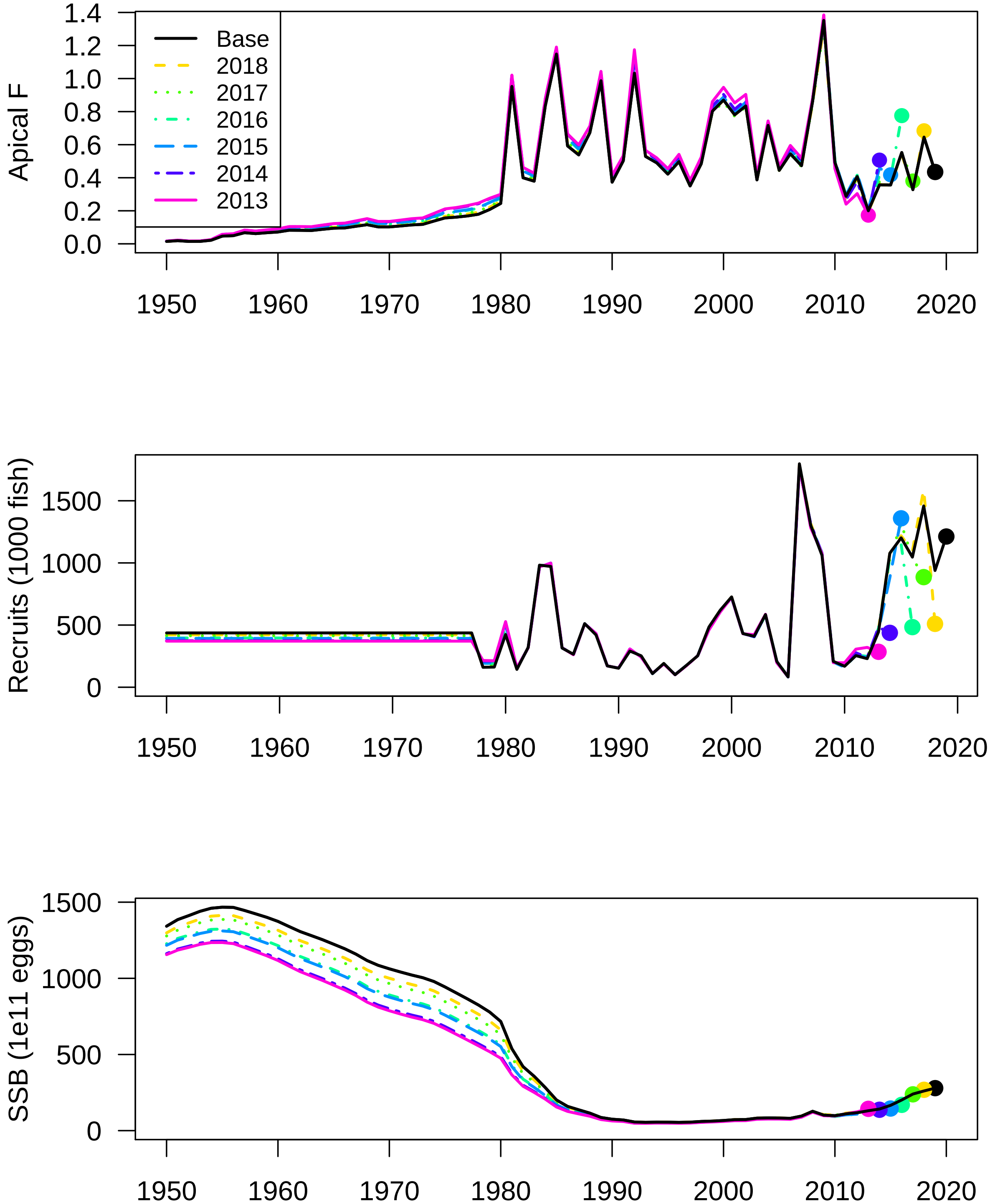


Figure 55. Projected time series under scenario 1—fishing mortality rate at $F = F_{30\%}$. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities (projection benchmarks); dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning.

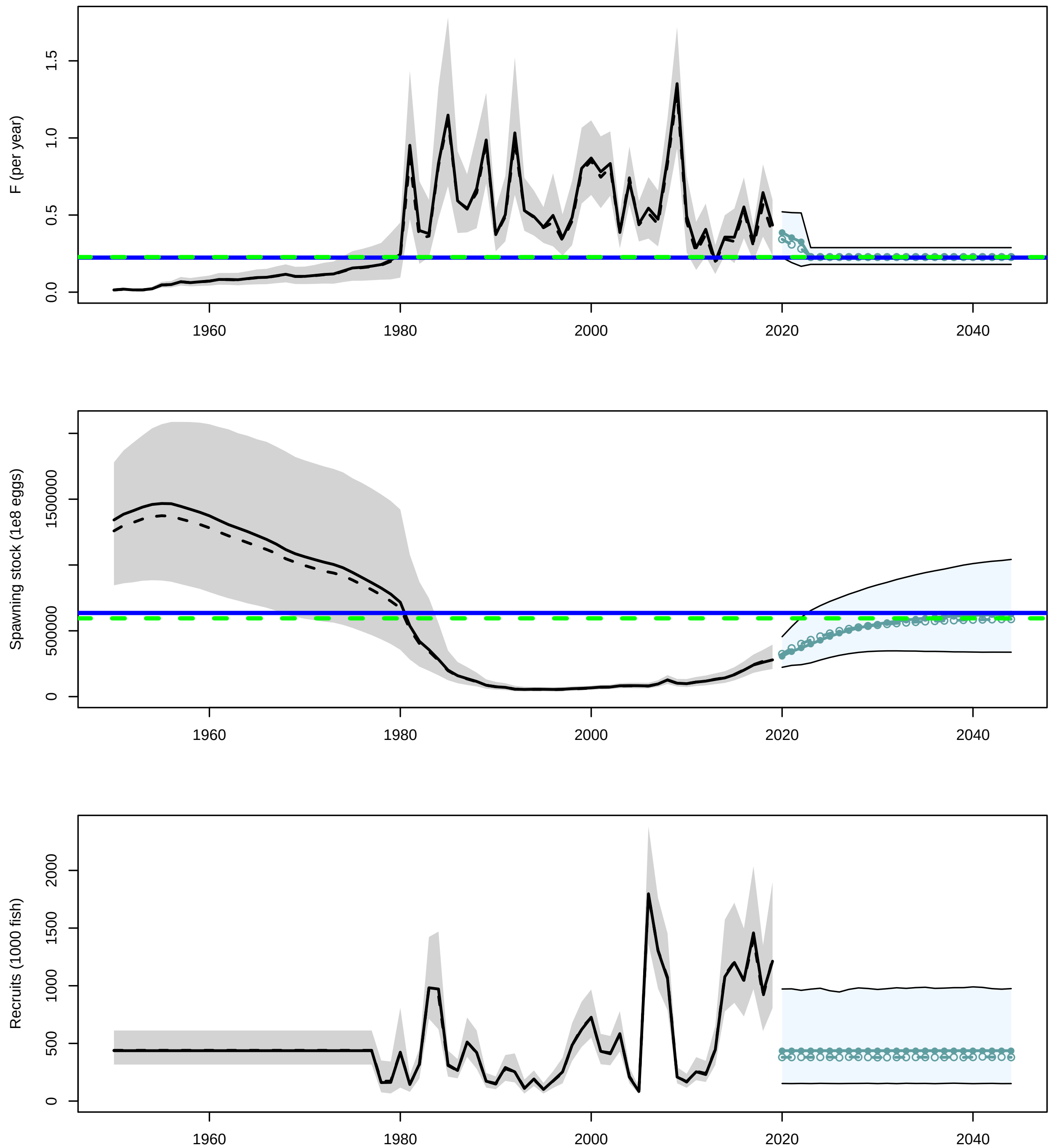


Figure 56. Projected probability of rebuilding under scenario 1—fishing mortality rate at $F = F_{30\%}$. The curve represents the proportion of projection replicates for which SSB *has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{F30\%}}$*, with reference lines at 0.5 and 0.675.*

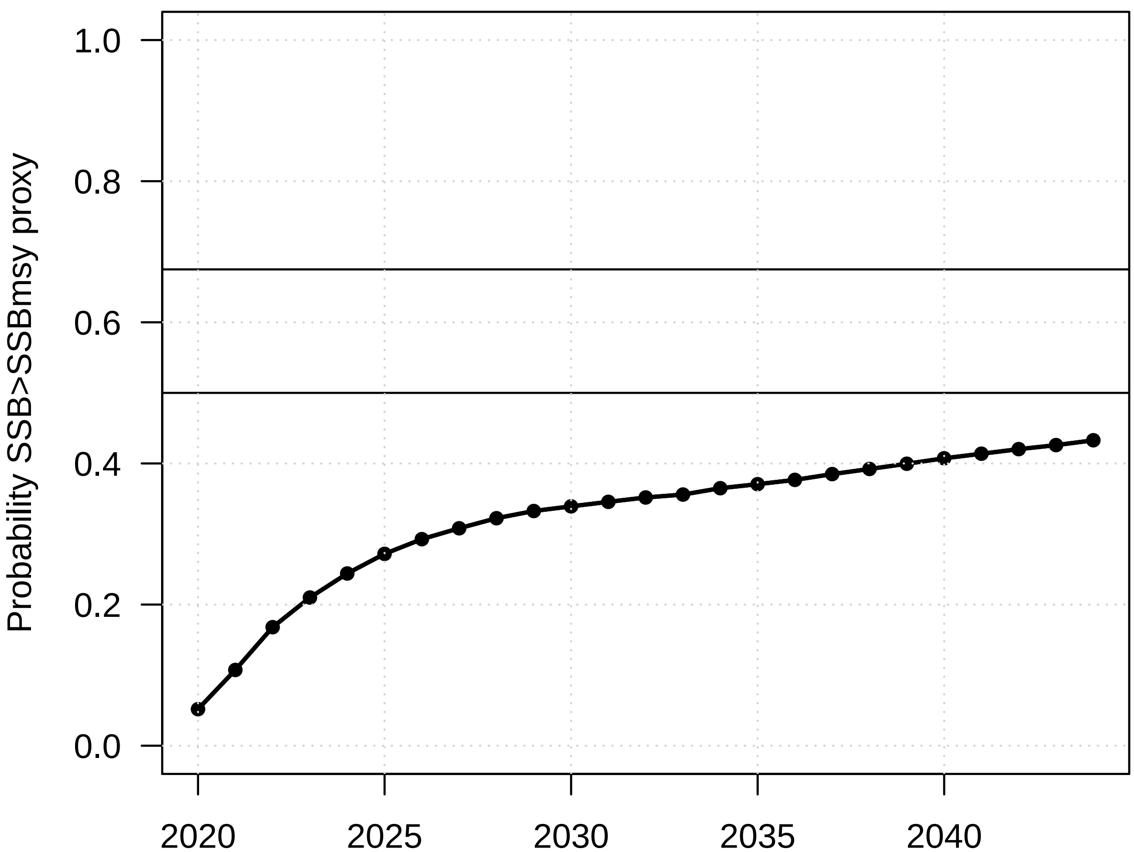


Figure 57. Projected time series under scenario 2—fishing mortality rate at $F = F_{30\%}$ and higher than expected recruitment. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities (projection benchmarks); dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning.

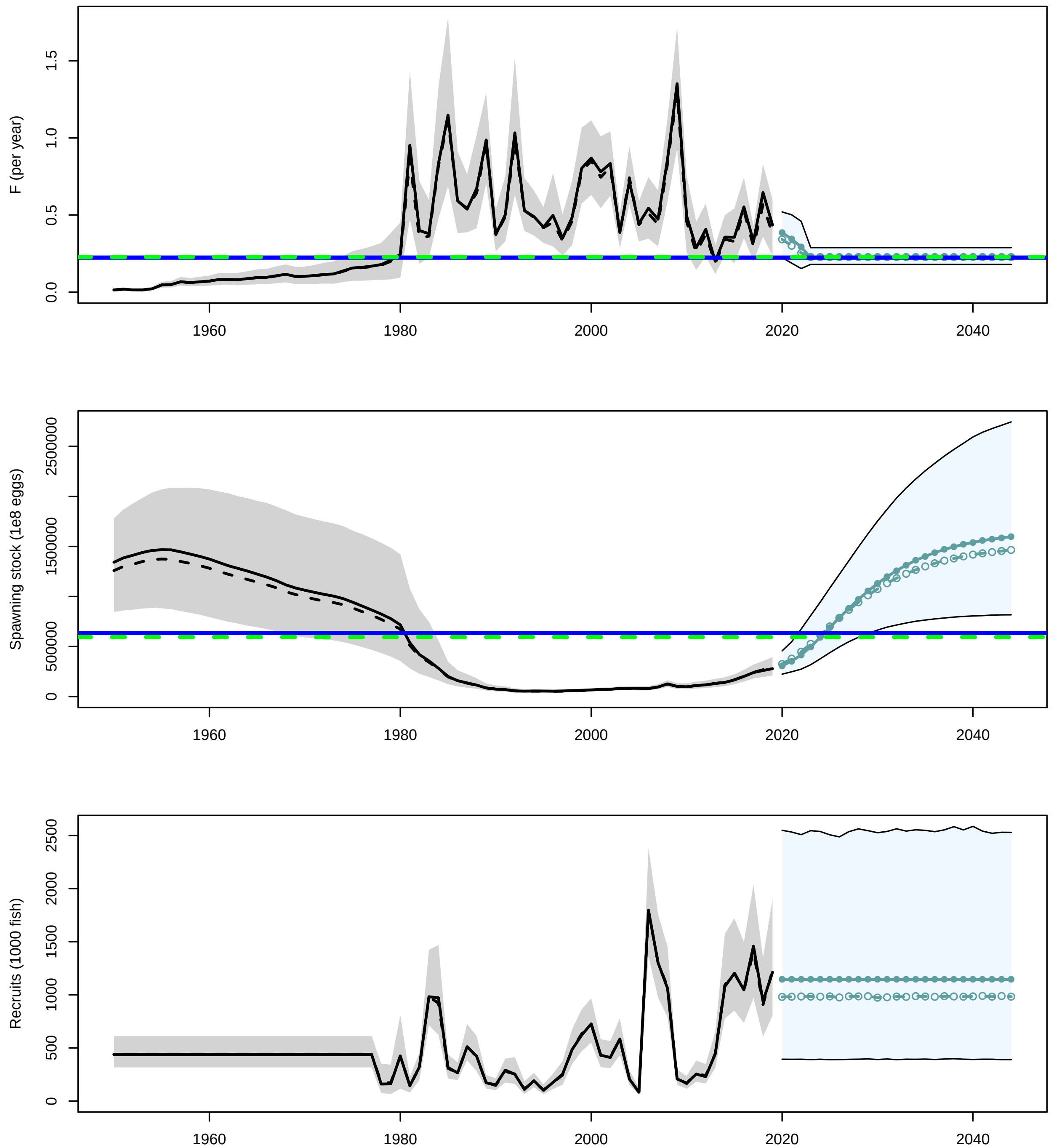


Figure 58. Projected probability of rebuilding under scenario 2—fishing mortality rate at $F = F_{30\%}$ and higher than expected recruitment. The curve represents the proportion of projection replicates for which SSB *has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{F30\%}}$*, with reference lines at 0.5 and 0.675.*

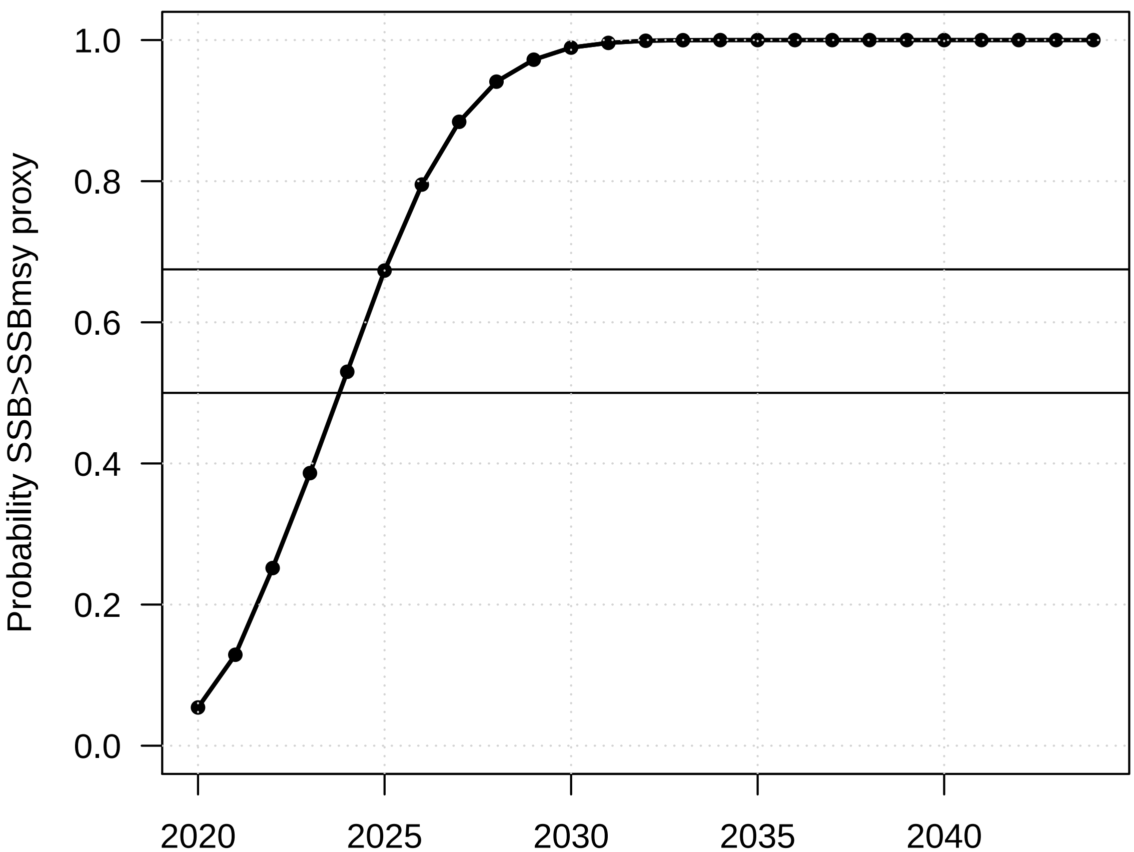


Figure 59. Projected time series under scenario 3—fishing mortality rate at $F = F_{\text{rebuild}}$ with 0.5 probability. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities (projection benchmarks); dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning.

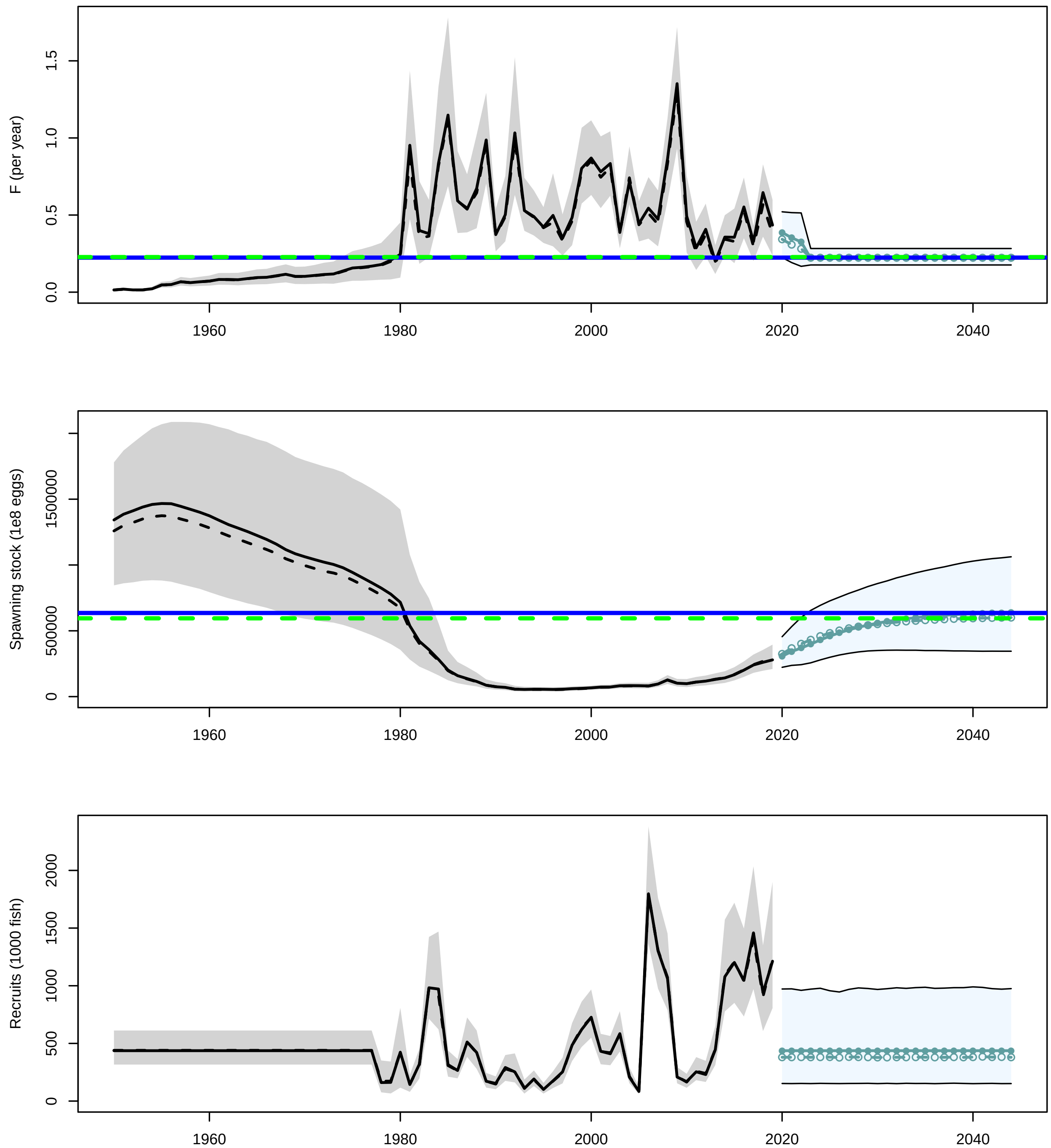


Figure 60. Projected probability of rebuilding under scenario 3—fishing mortality rate at $F = F_{\mathrm{rebuild}}$ with 0.5 probability. The curve represents the proportion of projection replicates for which SSB *has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{F30\%}}$*, with reference lines at 0.5 and 0.675.*

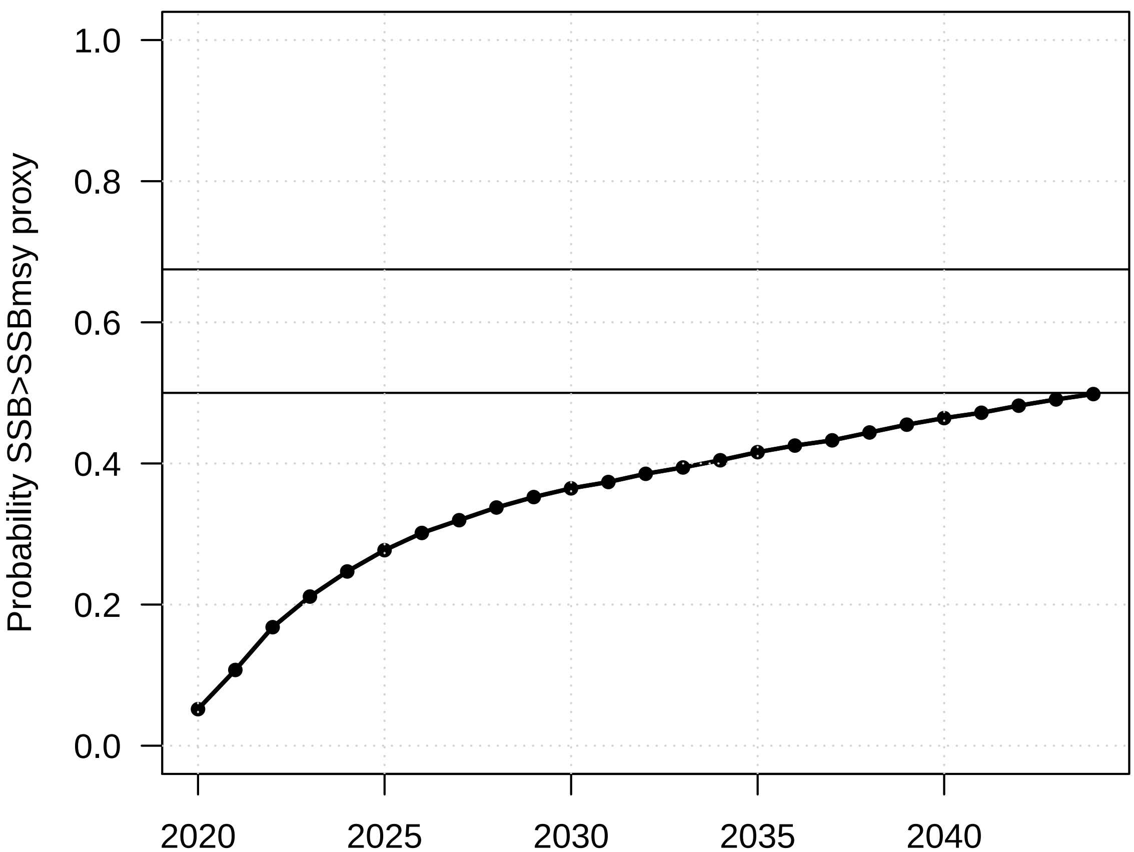
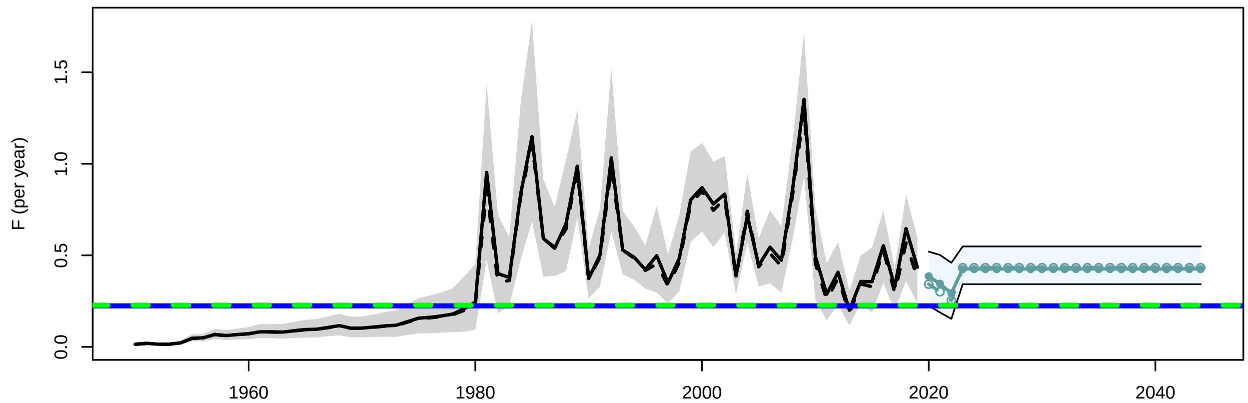
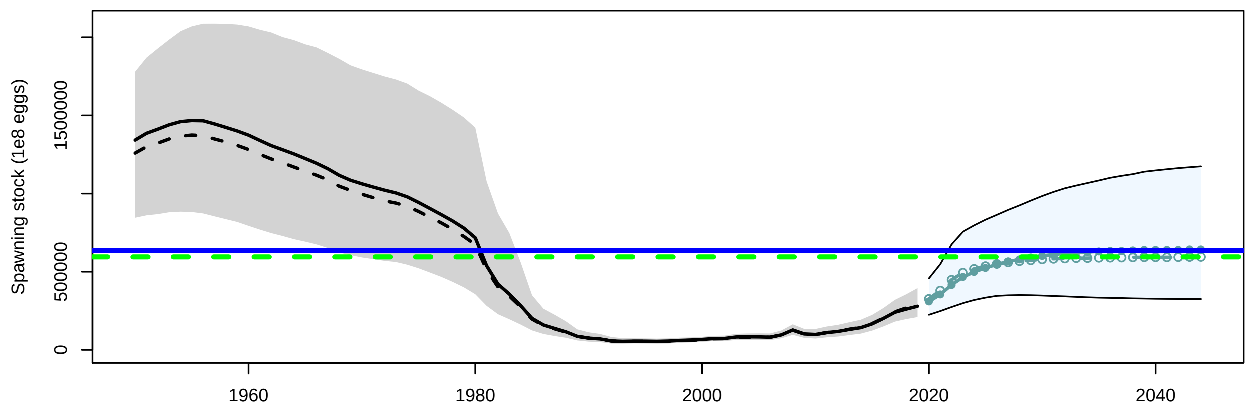


Figure 61. Projected time series under scenario 4—fishing mortality rate at $F = F_{\mathrm{rebuild}}$ with 0.5 probability and higher than expected recruitment. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities (projection benchmarks); dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning.





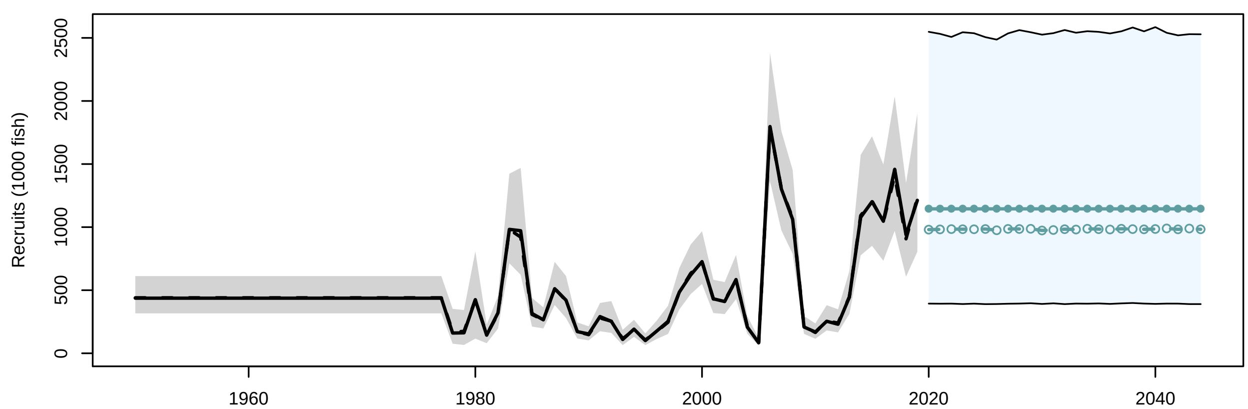


Figure 62. Projected probability of rebuilding under scenario 4—fishing mortality rate at $F = F_{\mathrm{rebuild}}$ with 0.5 probability and higher than expected recruitment. The curve represents the proportion of projection replicates for which SSB *has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{F30\%}}$, *with reference lines at 0.5 and 0.675.*

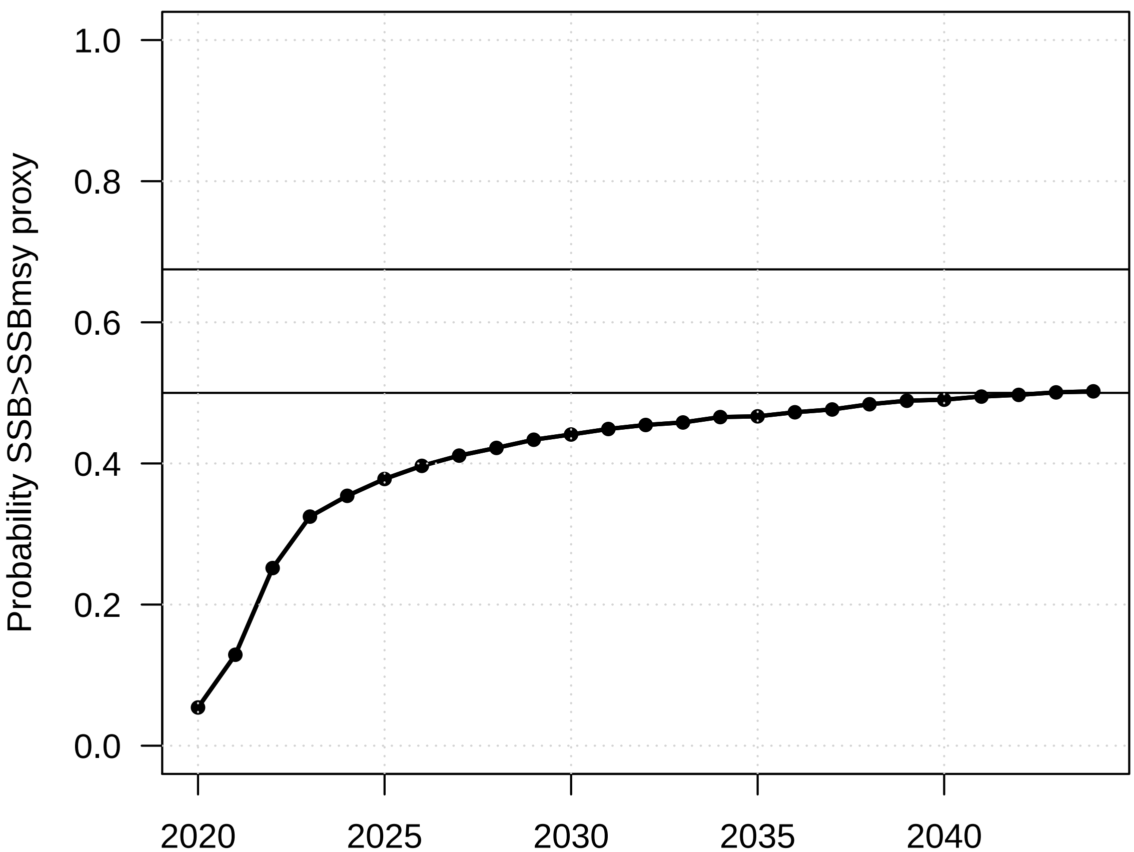


Figure 63. Projected time series under scenario 5—fishing mortality rate at $F = F_{\text{rebuild}}$ with 0.675 probability. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities (projection benchmarks); dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning.

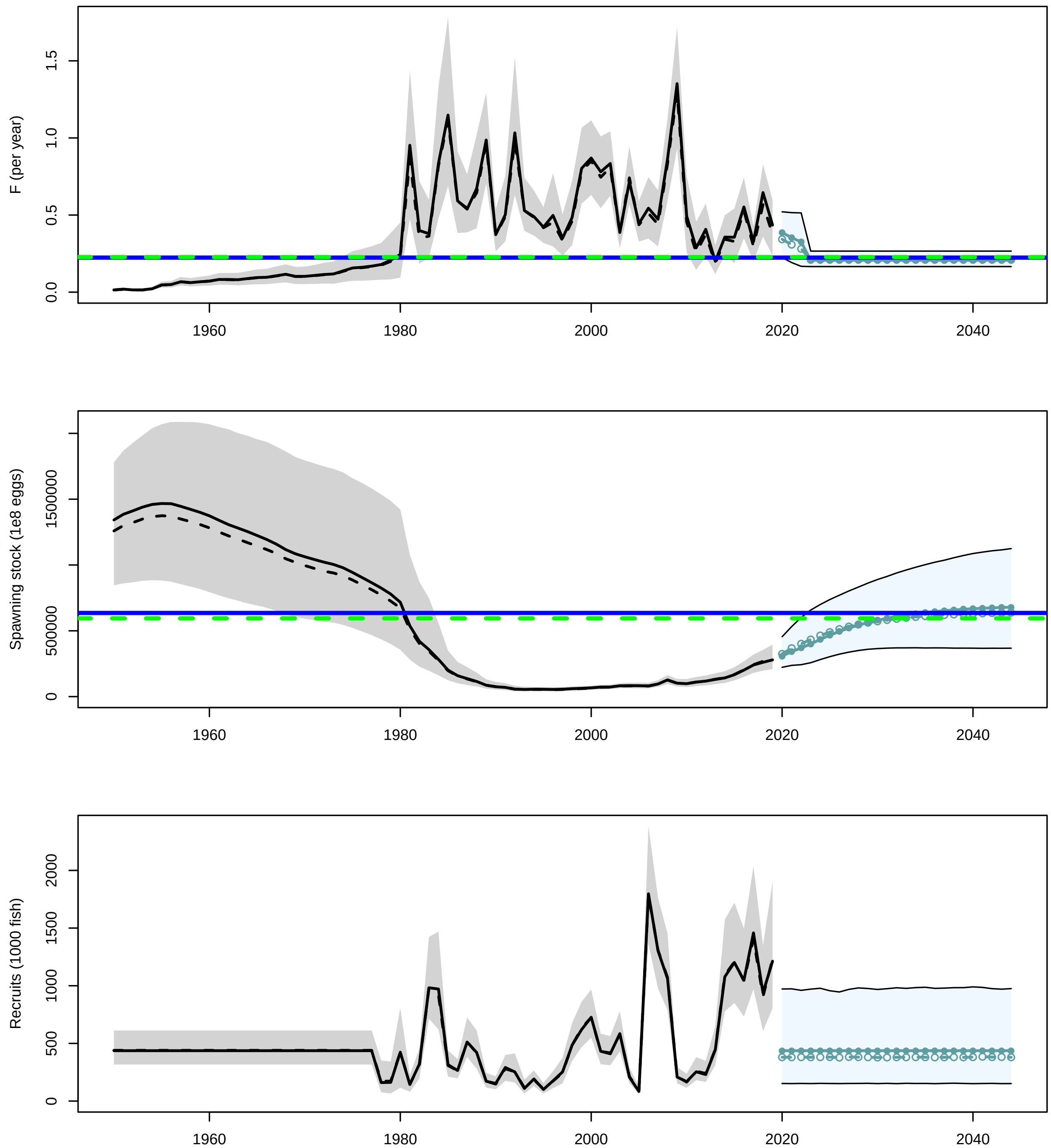


Figure 64. Projected probability of rebuilding under scenario 5—fishing mortality rate at $F = F_{\mathrm{rebuild}}$ with 0.675 probability. The curve represents the proportion of projection replicates for which SSB *has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{F30\%}}$*, with reference lines at 0.5 and 0.675.*

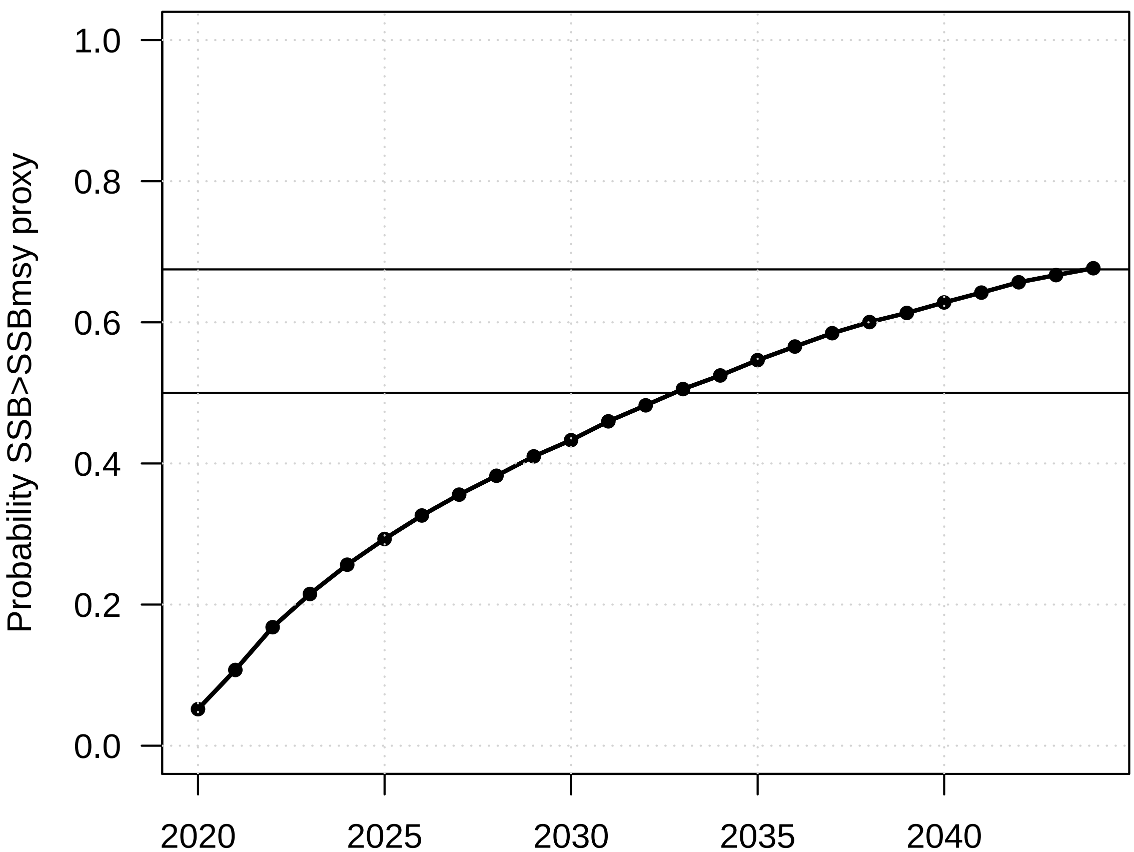


Figure 65. Projected time series under scenario 6—fishing mortality rate at $F = F_{\text{rebuild}}$ with 0.675 probability and higher than expected recruitment. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{30\%}$-related quantities (projection benchmarks); dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning.

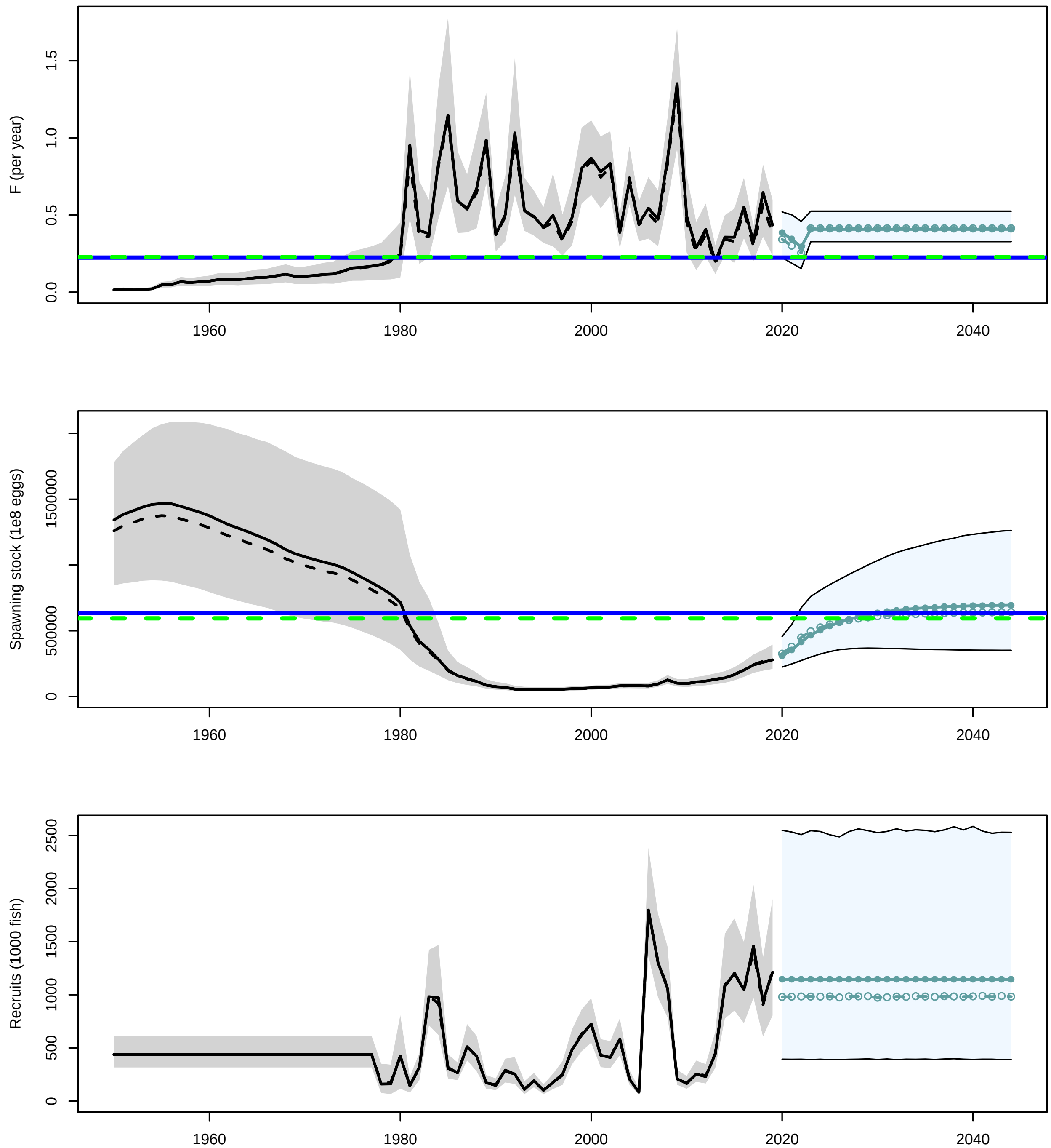
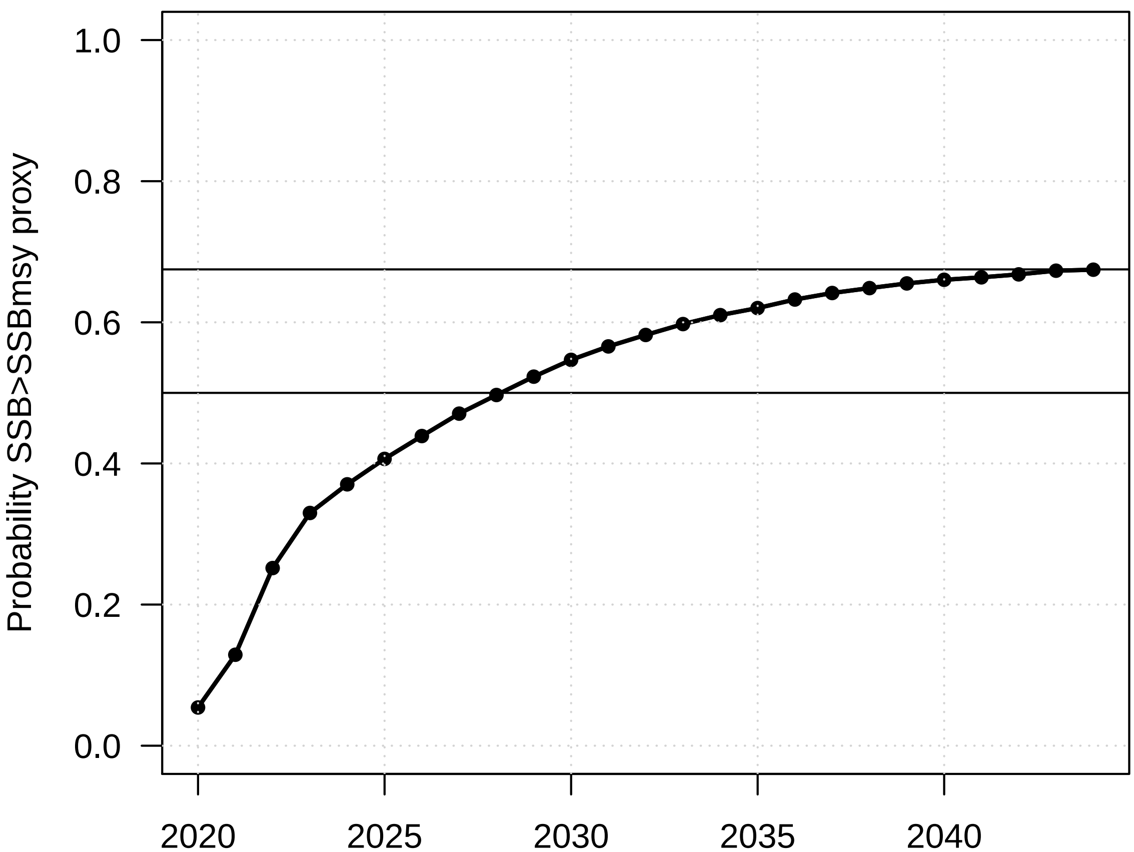


Figure 66. Projected probability of rebuilding under scenario 6—fishing mortality rate at $F = F_{\text{rebuild}}$ with 0.675 probability and higher than expected recruitment. The curve represents the proportion of projection replicates for which SSB *has reached the replicate-specific* $\text{SSB}_{\text{F30\%}}$*, with reference lines at 0.5 and 0.675.*



Appendix A Abbreviations and symbols

Table 36. 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
BAM	Beaufort Assessment Model (an integrated, statistical catch-age formulation)
CPUE	Catch per unit effort; used after adjustment as an index of abundance
CV	Coefficient of variation
CVT	SERFS chevron trap gear
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
FHWAR	The National Survey of Fishing, Hunting, and Wildlife-Associated Recreation Survey
FL	State of Florida
FWRI	Fish and Wildlife Research Institute (Florida)
GA	State of Georgia
GLM	Generalized linear model
GW	Gutted weight of a fish
K	Average size of stock when not exploited by man (carrying capacity); or, Brody growth coefficient of the von Bertalanffy equation
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
MCBE	Monte Carlo/Bootstrap Ensemble approach, another name for MCB
MFMT	Maximum fishing-mortality threshold; a limit reference point used in U.S. fishery management; typically based on F_{MSY} or its proxy
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.
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
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 Reef Fish Survey
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)
VID	SERFS video gear
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 = 393 (not including FIXED parameters)  Objective function value = 21109.1  Maximum gradient component = 0.000383712
# Linf (FIXED):
911.360000000
# K (FIXED):
0.240000000000
# t0 (FIXED):
-0.330000000000
# len_cv_val:
0.127373652035
# Linf_L (FIXED):
927.000000000
# K_L (FIXED):
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# t0_L (FIXED):
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# len_cv_val_L:
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# Linf_20 (FIXED):
938.000000000
# K_20 (FIXED):
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# t0_20 (FIXED):
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# len_cv_val_20:
0.100000031002
# log_Nage_dev (FIXED):
 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:
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# rec_sigma:
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# R_autocorr (FIXED):
0.00000000000
# log_rec_dev:
 -0.870102143375 -0.860003459693 0.100938946830 -0.981360010837 -0.178617411216 0.941513708107 0.930529080847 -0.194028640683 -0.367619235277
 0.289730604101 0.0946979545239 -0.803506183678 -0.917178325723 -0.274803650978 -0.415624232717 -1.25326182248 -0.693380949511 -1.33666824961
 -0.779743515850 -0.414895504106 0.235716521327 0.481945016587 0.640043268966 0.119721309762 0.0681092969316 0.422372625482 -0.611738990366
 -1.52689810695 1.54580023381 1.22408817546 1.01810410120 -0.609158989541 -0.821121900197 -0.411076815408 -0.510019379084 0.149386437643
 1.03451527160 1.14320683452 1.00497871357 1.33671994005 0.896529946570 1.15215952941
# log_dm_cH_lc:
0.920727536422
# log_dm_cH_D_lc:
2.28297352207
# log_dm_HB_D_lc:
3.53407311742
# log_dm_GR_D_lc:
3.43220527421
# log_dm_cH_ac:
1.18846401473
# log_dm_HB_ac:
-1.34726557723
# log_dm_CVT_ac:
-0.928340765106
# log_dm_GR_ac:
-1.40521571967
# selpar_A50_cH1:
1.27078906659
# selpar_slope_cH1:
5.00825754922
# selpar_A50_cH2:
2.84708735984
# selpar_slope_cH2:
3.42371294334
# selpar_A50_cH3:
2.62875335738
# selpar_slope_cH3:
2.19332652401
# selpar_A50_HB1:
1.57745054844
# selpar_slope_HB1:
3.58638971308
# selpar_A502_HB1:
4.36976500361
# selpar_slope2_HB1:
0.328314970976
# selpar_A50_HB2:
2.80569263703
# selpar_slope_HB2:
3.97653076761
# selpar_A502_HB2:
3.05544354073
# selpar_slope2_HB2:
0.463433300240
# selpar_A50_HB3:
2.33051727640
# selpar_slope_HB3:
2.68689393314
# selpar_A502_HB3:
```

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2.07504332464
# selpar_slope2_HB3:
0.197935622163
# selpar_A50_GR2:
2.87014438720
# selpar_slope_GR2:
2.98534134949
# selpar_A502_GR2:
2.82491480464
# selpar_slope2_GR2:
0.477878961621
# selpar_A50_GR3:
3.53372655587
# selpar_slope_GR3:
1.85237309686
# selpar_A50_HB2_D:
1.22814950013
# selpar_slope_HB2_D:
1.31651104166
# selpar_A502_HB2_D:
0.993286939229
# selpar_slope2_HB2_D:
1.72718594091
# selpar_A50_HB3_D:
1.13065435836
# selpar_slope_HB3_D:
1.20460961168
# selpar_A502_HB3_D:
2.37682763192
# selpar_slope2_HB3_D:
0.661331678933
# selpar_A50_GR3_D:
1.64377054273
# selpar_slope_GR3_D:
1.25922324098
# selpar_A502_GR3_D:
2.99638050122
# selpar_slope2_GR3_D:
0.875603094722
# selpar_A50_cH2_D:
1.37596421467
# selpar_slope_cH2_D:
1.05574247881
# selpar_A502_cH2_D:
2.41472708976
# selpar_slope2_cH2_D:
2.05194353507
# selpar_A50_cH3_D:
1.83935299794
# selpar_slope_cH3_D:
2.38849332415
# selpar_A50_CVT:
1.94640250507
# selpar_slope_CVT:
2.50204499522
# selpar_A502_CVT:
3.58342028680
# selpar_slope2_CVT:
0.275937912957
# log_q_cH:
-7.52129257408
# log_q_HB:
-12.8104189987
# log_q_HB_D:
-13.7024218149
# log_q_CVT:
-13.3636424830
# log_q_VID:
-13.5091571829
# M_constant (FIXED):
0.110000000000
# log_avg_F_cH:
-3.50861208575
# log_F_dev_cH:
 -0.731706847380 -0.445208796916 -0.720747592158 -0.707199185233 -0.321590213299 -0.509667842312 -0.525127678774 0.0725504768487 -0.257931006460
 -0.170743652154 -0.132178204409 0.0622951091290 -0.123381690203 -0.383453592856 -0.269458464229 -0.210279360958 -0.194154446472 0.101753728735
 0.312219213629 -0.137533651601 -0.167443774065 -0.265993328450 -0.367237665162 -0.668319303860 -0.166332363687 0.0974628067192 0.0867397851573
 0.169564893239 0.212531010613 -0.0527047693633 -0.0404387092505 0.176437684067 0.283875393209 0.412450517591 0.220566222748 0.449767744099
 0.654394667482 0.654857775036 0.596161128652 1.23946508433 1.33118666583 0.929463922397 1.04216396868 1.75303637691 1.52831683657 1.50297944587
 1.30225860656 1.10308680145 0.801851763615 0.752059894101 0.721757002612 1.21873784298 1.10617707410 0.771476830239 0.971746306524 0.745974225672
 0.449990801803 0.784254623086 0.876220713131 1.30991650784 -2.45410514518 -4.89877346904 -2.24408191897 -0.944951378911 -0.317238682641
 -3.12328923699 -3.77941437667 -0.618348175833 -0.379518623511 -0.477196304258
# log_avg_F_HB:
-3.59554859235
# log_F_dev_HB:
 -0.459214573376 -0.227225150431 -0.0398410674768 1.01197136896 0.775160801264 0.927811456174 0.512035468361 1.16678512979 0.537013782825
 1.02750056966 1.24353390995 1.01537543755 1.24631766363 0.870903285111 0.854075669005 0.815347138143 0.810523078129 1.11348072048 0.697894603746
 0.823392446931 0.425001754014 0.579586475868 0.505415101620 0.677675836857 0.688243553266 -0.0673916862284 0.637159315213 0.550629783697
 0.452954200404 0.606764200962 0.397132338132 0.730013519847 -2.96453675198 -1.66430566936 -1.14750166626 -1.55520281862 -1.12667984173 -2.92574335003
 -4.05297264154 -2.07728606226 -1.66509104066 -1.72670628964
# log_avg_F_GR:
-2.22218005580
# log_F_dev_GR:
 -1.32778036739 -1.22479603429 -1.12403925189 -1.03021471896 -0.947360635944 -0.868995510382 -0.766573192257 -0.671664557706 -0.588026355878
 -0.509768696215 -0.432740379728 -0.414383642747 -0.393902043835 -0.368525626973 -0.350283863576 -0.340827402952 -0.240453445399 -0.144913309843
```

```
 -0.0550544655473 0.0357911574024 0.132755734172 0.172660539877 0.206880672543 0.140414248716 0.372872485227 0.557890207129 2.04496733198
 1.00807489411 0.887775703299 1.91501362631 2.21027023029 1.40789531758 1.23559869190 1.53951934503 1.98771866785 0.224978980633 1.15205246757
 2.07876975474 0.865476749926 0.838398314087 0.390809278731 1.02433278581 0.489466065176 1.20343823745 1.82244196976 1.91610849141 1.70108630877
 1.80174635740 0.919792521594 1.50338960700 1.00028957162 1.40462663727 1.13354573066 1.88691503956 2.33812912677 -5.85072295181 -5.88994432351
 -1.21293086118 -5.83626827210 -0.451337685372 -2.56060897392 -6.09311890271 -0.791592976480 -0.586391360846 -0.478673039903
# log_avg_F_cH_D:
-4.36381530561
# log_F_dev_cH_D:
 0.790244884327 0.756305144605 1.16108681933 1.41250347749 1.33695969047 1.09971422869 0.253931737454 -0.262796786296 -0.383824931784 -0.230907108000
 0.540705261639 -0.662003585998 -1.72702318671 0.477051138359 -1.70597032558 -1.34635707925 -1.39923836681 -0.566754040516 0.243313718411
 1.28466289756 0.604835944217 0.322198049188 0.459034413914 0.156151572735 0.118679020490 -0.576635454613 -1.06113780331 -1.09472933003
# log_avg_F_HB_D:
-6.02414783838
# log_F_dev_HB_D:
 -4.70757956268 -3.63000631179 -4.20164207025 -4.11805292818 -3.81473007496 -3.71658231161 -3.47359352143 -4.20623569513 0.0417193317179 0.721260898891
 0.987815374722 1.26502086131 0.670546254075 0.298410149208 -0.453391802937 -0.417765149039 -0.360766094329 0.213381859432 0.521108498933 -0.466197615172
 1.98311243900 2.16963191198 0.682196752913 1.78188268486 2.01978263198 2.65962537891 2.64901103072 2.46624069318 2.59481270247 2.26501245086 1.59575897207
 1.38491188281 1.53405734623 0.851798854895 1.08170580918 1.12773836717
# log_avg_F_GR_D:
-2.09970920348
# log_F_dev_GR_D:
 -2.66146493104 -2.74825633933 -3.73122249259 -1.16213337205 -0.746582697445 -0.220376684262 -0.533198690621 -1.09245657605 -1.15113198941 -0.784929752549
 -1.09032251492 -1.14766032127 0.727874692103 0.521004249760 0.385448046087 -0.564644876748 -1.80349283520 -0.499380750482 0.261717854317 0.641438923343
 0.826320602107 0.610425437261 0.612195930595 1.65603387246 0.813870801261 0.00969279647409 0.421219464558 1.02869698816 1.53362980809 1.28166465160
 0.544986592402 1.00525108494 0.182833263136 0.834399212797 0.984934530241 1.45949286493 0.853849733940 1.58768345134 1.15258997206
# F_init:
0.0355045784678
```