SEDAR

Southeast Data, Assessment, and Review

SEDAR 76

South Atlantic Black Sea Bass

Stock Assessment Report

March 21, 2023

Revised: March 30, 2023

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

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Section I: Introduction

March 2023

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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 76 addressed the stock assessment for South Atlantic Black Sea Bass. The assessment process consisted of a series of webinars held from May 2022 – February 2023. 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 Black Sea Bass was disseminated to the public in March 2023. The Council’s Scientific and Statistical Committee (SSC) will review the SAR for its stock. The SSCs are tasked with recommending whether the assessments represent Best Available Science, whether the results presented in the SARs are useful for providing management advice and developing fishing level recommendations for the Council. An SSC may request additional analyses be conducted or may use the information provided in the SAR as the basis for their Fishing Level Recommendations (e.g., Overfishing Limit and Acceptable Biological Catch). The South Atlantic Fishery Management Council’s SSC will review the assessment at its April 2023 meeting, followed by the Council receiving that information at its June 2023 meeting. Documentation on SSC recommendations is not part of the SEDAR process and is handled through each Council.

2. Management Overview

2.1 Fishery Management Plan and Amendments

The following summary describes only those management actions that likely affect black sea bass fisheries and harvest.

Original SAMFC FMP

The Fishery Management Plan (FMP), Regulatory Impact Review, and Final Environmental Impact Statement for the Snapper Grouper Fishery of the South Atlantic Region, approved in 1983 and implemented in August of 1983, 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 under the area of authority of the South Atlantic Fishery Management 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 (black sea bass, bank sea bass, and rock sea bass), the fishery management unit/management regime applies only from Cape Hatteras, North Carolina south. Regulations apply only to federal waters.

Measures in the original FMP (effective 8/31/83) specified an 8-inch TL minimum size limit and a 4-inch trawl mesh size.

SAFMC FMP Amendments affecting black sea bass

FMP/Amendment	Description of Action	Effective Date
mendment 1	Prohibit trawls (roller rig trawls) from Cape Hatteras, NC to Cape Canaveral, FL.	1/12/89
Amendment 4	Established a 10-year rebuilding program for black sea bass; year 1=1991. Prohibited fish traps, entanglement nets, and longline gear within 50 fathoms; allowed BSB pots north of Cape Canaveral. Prohibited powerheads in SMZs off SC. Specified requirements for black sea bass pot permit, gear, vessel, and identification. Required that fish be landed with heads & fins attached. Permits - income requirement & required to exceed bag limits.	1/1/92
Amendment 7	Required dealer, charter and headboat federal permits.	3/1/95
Amendment 8	Established a limited entry program for the snapper grouper fishery: unlimited transferable permits and 225-lb non- transferable permits.	12/14/98
Amendment 9	10-inch TL minimum size limit recreational & commercial and 20 fish per person per day recreational bag limit; required escape vents and escape panels with degradable hinges and fasteners in black sea bass pots. Specified minimum dimensions of an escape vent opening (based on inside measurement): (1) 11⁄8 by 53⁄4 inches (2.9 by 14.6 cm) for a rectangular vent. (2) 1.75 by 1.75 inches (4.5 by 4.5 cm) for a square vent. (3) 2.0-inch (5.1-cm) diameter for a round vent.	2/24/99

Amendment 13C	1. Specified a **commercial** quota of 477,000 lbs gutted weight (563,000 lbs whole weight) in year 1; 423,000 lbs gutted weight (499,000 lbs whole weight) in year 2; and 309,000 lbs gutted weight (364,000 lbs whole weight) in year 3 onwards until modified. 2. The commercial quota & recreational allocation were based on a **Total Allowable Catch (TAC)** of 1,110,000 lbs gutted weight (1,310,000 lbs whole weight) in year 1; 983,000 lbs gutted weight (1,160,000 lbs whole weight) in year 2; and 718,000 lbs gutted weight (847,000 lbs whole weight) in year 3 onwards until modified. 3. After the commercial quota is met, all purchase and sale is prohibited and harvest and/or possession is limited to the bag limit. 4. Required use of at least 2” mesh for the entire back panel of black sea bass pots. This measure was effective 10/23/06. 5. Specified a **recreational** allocation of 633,000 lbs gutted weight (746,000 lbs whole weight) in year 1; 560,000 lbs gutted weight (661,000 lbs whole weight) in year 2; and 409,000 lbs gutted weight (483,000 lbs whole weight) in year 3 onwards until modified. 6. Limited recreational landings to approximate this harvest level by increasing the recreational minimum size limit from 10 inches total length (TL) to 11 inches TL in year 1 and to 12 inches TL in year 2 onwards until modified, and reduced the recreational bag limit from 20 to 15 black sea bass per person per day. 7. Changed the fishing year from the calendar year to June 1 through May 31. 8. Year 1 = 2006/07.	10/23/06

Amendment 15A	1) Updated management reference points for black sea bass. 2) Modified rebuilding strategies for black sea bass. 3) Defined rebuilding strategies for black sea bass. None of the measures included in Amendment 15A involved changes to existing regulations; therefore, no proposed or final rule was required. 4) Established 10-year rebuilding schedule for black sea bass where 2006 is year 1.	3/20/08
Amendment 15B	1) Prohibited the sale of bag-limit caught snapper grouper species. 2) Changed the commercial permit renewal period and transferability requirements. 3) Implemented a plan to monitor and address bycatch.	12/16/09
Amendment 17B	1) Commercial annual catch limit (ACL) = 309,000 lbs gw 2) Recreational ACL = 409,000 lbs gw 3) The commercial accountability measure (AM) for black sea bass is to prohibit harvest, possession, and retention when the ACL is projected to be met. 4) The recreational AM for black sea bass is to compare the recreational ACL with recreational landings over a range of years. For 2010, use only 2010 landings. For 2011, use the average landings of 2010 and 2011. For 2012 and beyond, use the most recent three-year running average. If black sea bass are *overfished* and the ACL is projected to be met, prohibit the harvest and retention of black sea bass. 5) If the recreational or commercial sector ACL is exceeded, independent of stock status, the Regional Administrator shall publish a notice to reduce the sector ACL in the following season by the amount of the overage. 4) Updated the framework procedure.	1/31/11
Amendment 17A	Required use of non-stainless steel circle hooks when fishing for snapper grouper species with hook-and-line gear and natural bait north of 28 deg. N latitude in the South Atlantic EEZ	3/3/11

Amendment 18A	1) Updated the following for black sea bass: • Rebuilding strategy: Defined a rebuilding strategy that holds catch constant in fishing years 2012/2013 and 2013/2014 and then changes to $F_{rebuild}$ in 2014/2015. ($F_{rebuild}$ is defined as a constant fishing mortality strategy that maintains the 66% probability of recovery rate throughout the remaining fishing seasons of the rebuilding timeframe.) After the 2015/2016 fishing season the fishing mortality rate would be held constant until modified. • Acceptable biological catch (ABC): ABC=ACL=OY= 847,000 lbs ww • ACLs: 409,000 lbs gw recreational 309,000 lbs gw commercial • Annual catch target (recreational only): 357,548 lbs gw 2) Established an endorsement program for the commercial black sea bass pot segment of the snapper grouper fishery. 3) Established an appeals process for the black sea bass pot endorsement program. 4) Modified commercial accountability measures. 5) Established a limit of 35 black sea bass pot tags issued to each endorsement holder each permit year. 6) Established a requirement to bring black sea bass pots back to shore at the end of each trip. 6) Specified a 1,000 pounds gw (1,180 pounds ww) commercial trip limit for the black sea bass commercial sector. 7) Increased the commercial minimum size limit for black sea bass from 10 inches TL to 11 inches TL. 8) Increased the recreational minimum size limit for black sea bass from 12 inches TL to 13 inches TL. 9) Modified recreational accountability measures. 10) Specified a requirement for selected for-hire vessels to report landings information electronically on a weekly or daily basis.	7/1/12 *The commercial fishing season for black sea bass in 2012 opened on July 1.

Amendment 42	Modification to sea turtle release gear and SG framework	1/8/2020
Amendment 39	Weekly electronic reporting for charter vessel operators with a federal for-hire permit; Reduce the time allowed for headboat operators to complete electronic reports; Requires location reporting by charter vessels with the same detail currently required for headboat vessels.	1/4/2021

SAFMC FMP Regulatory Amendments affecting black sea bass

FMP/Amendment	Description of Action	Effective Date
Regulatory Amendment 4	-For Black Sea Bass: -Modified definition of bsb pot; -Allowed multi-gear trips for bsb; -Allowed retention of incidentally-caught fish on bsb trips.	07/06/93
Regulatory Amendment 9	-Reduced recreational bag limit for black sea bass from 15 fish to 5 fish per person per day;	Bag limit: 6/22/11
Regulatory Amendment 19	-Specified ABC, and adjusted the ACL, recreational ACT and OY for black sea bass; -Implemented an annual closure on the use of black sea bass pots from November 1 to April 30.	ACL: 9/23/13 Pot closure: 10/23/13

Regulatory Amendment 14	-Changed the commercial and recreational fishing years for black sea bass from Jun 1 through May 31, to Jan 1 through Dec 31 for the commercial sector and Apr 1 through Mar 31 for the recreational sector. -established a trip limit of 300 lbs ww, for the hook-and-line component of the commercial sector from Jan 1 through Apr 30 when fishing with pots is prohibited. The trip limit for the remainder of the fishing year for both pots and hook-and-line remained at 1,180 lbs ww. -revised recreational AM to specify the length of the recreational fishing season for black sea bass, as determined by NMFS and announced annually in the Federal Register, prior to the April 1 recreational fishing season start date.	12/8/2014
Regulatory Amendment 25	-Increased the recreational bag limit for black sea bass from 5 fish to 7 fish per person per day	Effective 8/12/2016
Regulatory Amendment 16	-Revised the area where fishing with black sea bass pots from Nov.1-April 30 is prohibited. -Add additional gear marking requirements for black sea bass pot gear.	Prohibited area: 12/29/2016; Enhanced gear markings: 3/21/2017
Regulatory Amendment 25	-Revised the recreational bag limit for black sea bass	8/12/2016
Abbreviated Framework 2	-Modified commercial and recreational ACLs for black sea bass	5/9/2019
Regulatory Amendment 29	-Required descending devices on board and ready for use on vessels fishing for or possessing snapper grouper species -Modified the circle hook requirement -Removed the powerhead prohibition in federal waters off SC.	7/15/2020

2.2 Emergency and Interim Rules (if any)

SAFMC

Emergency Rule	For Black Sea Bass (bsb): -Modified definition of bsb pot; -Allowed multi-gear trips for bsb; -Allowed retention of incidentally-caught fish on bsb trips.	8/31/92
Emergency Rule Extension	For Black Sea Bass: -Modified definition of bsb pot; -Allowed multi-gear trips for bsb; -Allowed retention of incidentally-caught fish on bsb trips.	11/30/92
Emergency Action	-Reopened the Amendment 8 permit application process.	9/3/99

2.3 Secretarial Amendments (if any)

SAFMC None for black seabass

2.4 Control Date Notices (if any)

SAFMC:

1. Notice of Control Date (07/30/91 56 FR 36052) - Anyone entering **federal snapper grouper fishery (other than for wreckfish)** in the EEZ off S. Atlantic states after 07/30/91 was not assured of future access if limited entry program developed.
2. Notice of Control Date (04/23/97 62 FR 22995) - Anyone entering **federal black sea bass pot fishery** off S. Atlantic states after 04/23/97 was not assured of future access if limited entry program developed.
3. Notice of Control Date (10/14/05 70 FR 60058) - Anyone entering **federal snapper grouper fishery** off S. Atlantic states after 10/14/05 was not assured of future access if limited entry program developed.
4. Notice of Control Date (10/26/2007 72 FR 60794) - Considered measures to limit participation in the snapper grouper for-hire sector effective 3/8/07.
5. Notice of Control Date (02/20/09 74 FR 7849) - Anyone entering **federal black sea bass pot fishery** off S. Atlantic states after 12/04/08 was not assured of future access if limited entry program developed.
6. Notice of Control Date (01/31/11 76 FR 5325) - Anyone entering **federal snapper grouper fishery** off S. Atlantic states after 09/17/10 was not assured of future access if limited entry program developed.
7. Notice of Control Date (06/15/2016 81 FR 66244) - fishermen who enter 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.Management Program Specifications

Table 2.5.1. General Management Information

South Atlantic

Species	Black Sea Bass
Management Unit	Southeastern US
Management Unit Definition	Cape Hatteras, NC southward to the SAFMC/GMFMC boundary
Management Entity	South Atlantic Fishery Management Council
Management Contacts	SAFMC: Michael Schmidtke/Myra Brouwer SERO: Jack McGovern/Rick DeVictor
Current stock exploitation status	Not undergoing overfishing
Current stock biomass status	Not overfished

Table 2.5.2 Specific Management Criteria

Criteria	South Atlantic – Current (2018 SEDAR 56)		
	Definition	Base Run Values	Median of Base Run MCBs
MSST (1E10 eggs)	$(1\text{-}M)*SSB_{MSY}$	186	186
MFMT	F_{MSY}, if available	0.31	.34
F_{MSY}	F_{MSY}	0.31	.34
MSY (1000 lbs ww)	Yield at F_{MSY}, landings and discards, pounds and numbers	935	968
SSB_{MSY} (1E10 eggs)	Total or spawning stock, to be defined	300	304
R_{MSY} (1000 age-0 fish)	Recruits at MSY	36,400	36,919
F Target	75% F_{MSY}	0.23	0.26
Yield at F_{TARGET} (equilibrium) (1000 lbs ww)	Landings, pounds and numbers	701	943
M	Natural mortality, average across ages	0.38	0.38
Terminal F	Exploitation, $F_{2014\text{-}2016}$	0.20	0.20
Terminal SSB (1E10 eggs)	SSB_{2016}	214	214
Exploitation Status	$F_{2014\text{-}2016}$/MFMT	0.64	0.58
Biomass Status	SSB_{2016}/MSST	1.15	1.16
	SSB_{2016}/SSB_{MSY}	0.71	0.71
Generation Time		N/A	N/A
TREBUILD (if appropriate)		N/A	N/A

Criteria	South Atlantic – Proposed (2022 SEDAR 76)		
	Definition	Base Run Values	Median of Base Run MCBs
MSST[1] (1E10 eggs)	$(1\text{-}M)*SSB_{MSY}$		
MFMT	F_{MSY}, if available		
F_{MSY}	F_{MSY}		
MSY (1000 lbs ww)	Yield at F_{MSY}, landings and discards, pounds and numbers		
SSB_{MSY} (1E10 eggs)	Total or spawning stock, to be defined		
R_{MSY} (1000 age-0 fish)	Recruits at MSY		
F Target	75% F_{MSY}		
Yield at F_{TARGET} (equilibrium) (1000 lbs ww)	Landings, pounds and numbers		
M	Natural mortality, average across ages		
Terminal F	Exploitation, $F_{2014\text{-}2016}$		
Terminal SSB[1] (1E10 eggs)	SSB_{2016}		
Exploitation Status	$F_{2014\text{-}2016}$/MFMT		
Biomass Status[1]	SSB_{2016}/MSST		
	SSB_{2016}/SSB_{MSY}		
Generation Time			
TREBUILD (if appropriate)			

1. Biomass values reported for management parameters and status determinations should be based on the biomass metric recommended through the Assessment process and SSC. This may be total, spawning stock or some measure thereof, and should be applied consistently in this table.

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

Table 2.5.3. Stock Rebuilding Information
The black sea bass stock is not under rebuilding.

Table 2.5.4. Stock Projection Information
South Atlantic

First Year of Management	2019
Interim basis	SEDAR 56 ToR ask the Panel to provide guidance on appropriate assumptions to address harvest and mortality levels in interim years; recent SEDAR assessments have asked for ACL, if landings are within 10% of the ACL; average landings otherwise
Projection Outputs	
Landings	Pounds and numbers
Discards	Pounds and numbers
Exploitation	F & Probability F>MFMT
Biomass (total or SSB, as appropriate)	B & Probability B>MSST (and Prob. B>B_{MSY} if under rebuilding plan)
Recruits	Number

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

Criteria	Definition	If overfished	If overfishing	Neither overfished nor overfishing
Projection Span	Years	$T_{REBUILD}$	10	10
Projection Values	$F_{CURRENT}$	X	X	X
	F_{MSY}	X	X	X
	75% F_{MSY}	X	X	X
	$F_{REBUILD}$	X		
	F=0	X		

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

Table 2.5.6. P-star projections. Short term specifications for OFL and ABC recommendations. Additional P-star projections may be requested by the SSC once the ABC control rule is applied.

Basis	Value	Years to project	P* applies to
P*	50%	Interim + 5	Probability of overfishing
P*	40%	Interim + 5	Probability of overfishing
Exploitation	Fmsy	Interim + 5	NA
Exploitation	75% Fmsy	Interim + 5	NA

Table 2.5.7. Quota Calculation Details

Abbreviated Framework 2 implemented an ABC and total ACL of 760,000 lbs ww in 2019; 669,000 lbs ww in 2020; and 643,000 lbs ww for 2021 and future years until modified. Values below in lbs ww.

	Commercial	Recreational	Total Annual Catch Limit
Current Quota Value	276,490	366,510	643,000
Next Scheduled Quota Change	NA	NA	NA
Annual or averaged quota?	annual	annual	annual
If averaged, number of years to average	NA	NA	NA
Does the quota account for bycatch/discard?	No	No	No

How is the quota calculated - conditioned upon exploitation or average landings?

Allowable catch from the projection was allocated to recreational and commercial sectors based on sector allocation of 43% commercial and 57% recreational (established through Amendment 13C in 2006).

Does the quota include bycatch/discard estimates? If so, what is the source of the bycatch/discard values? What are the bycatch/discard allowances?

The quota does not require monitoring of discards and is based on landed catch. Assessment takes into consideration bycatch and provides estimate of yield at F_{MSY} and F_{OY} as landed catch rather than landed catch and dead discards.

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

No.

2.5 Management and Regulatory Timeline

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

Table 2.6.1 South Atlantic Black Sea Bass Federal Commercial Regulatory History

prepared by: Michael Schmidtke

Year	Quota (lbs ww)	ACL (lbs ww)	Days Open	Fishing Season	Reason for closure	Season Start Date (first day implemented)	Season End Date (last day effective)	Size Limit (in TL)	Size Limit Start Date	Size Limit End Date	Retention Limit (lbs ww)	Retention Limit Start Date	Retention Limit End Date
8/31/1983 [A]	NA	NA	365	open	NA	1-Jan	31-Dec	8	31-Aug	31-Dec	none	NA	NA
1984	NA	NA	365	open	NA	1-Jan	31-Dec	8	1-Jan	31-Dec	none	NA	NA
1985-1998	NA	NA	365	open	NA	1-Jan	31-Dec	8	1-Jan	31-Dec	none	NA	NA
1999 [B]	NA	NA	365	open	NA	1-Jan	31-Dec	8	1-Jan	23-Feb	none	NA	NA
								10	24-Feb	31-Dec	none	NA	NA
2000	NA	NA	365	open	NA	1-Jan	31-Dec	10	1-Jan	31-Dec	none	NA	NA
2001-2005	NA	NA	365	open	NA	1-Jan	31-Dec	10	1-Jan	31-Dec	none	NA	NA
2006	NA	NA	365	open	NA	1-Jan	22-Oct	10	1-Jan	22-Oct	none	1-Jan	22-Oct
2006/2007 [C]	563,000					23-Oct	31-May	10	23-Oct	31-May	none	23-Oct	31-May
2007/2008	499,000	NA	365	open	NA	1-Jun	31-May	10	1-Jun	31-May	none	NA	NA
2008/2009	364,000	NA	350	open	NA	1-Jun	15-May	10	1-Jun	31-May	none	NA	NA
				closed	quota met	16-May	31-May						
2009/2010	364,000	NA	192	open	NA	1-Jun	9-Dec	10	1-Jun	9-Dec	none	NA	NA
				closed	quota met	10-Dec	31-May						
2010/2011	364,000	NA	129	open	NA	1-Jun	6-Oct	10	1-Jun	6-Oct	none	NA	NA
				closed	quota met	7-Oct	30-Nov						
			16	open	NA	1-Dec	15-Dec	10	1-Dec	15-Dec	none	NA	NA
				closed	quota met	16-Dec	31-May						
2011/2012	NA	364,000	45	open	NA	1-Jun	14-Jul	10	1-Jun	14-Jul	none	NA	NA
				closed	ACL met	15-Jul	31-May						
2012/2013 [D]	NA	364,000	130	open	NA	7/1/2012 [D]	7-Oct	11	1-Jul	7-Oct	1,180	1-Jul	7-Oct
				closed	ACL met	8-Oct	31-May						
2013/2014	NA	364,000	H&L: 365 Pot: 184	open	NA	1-Jun	22-Sep	11	1-Jun	12-Sep	1,180	1-Jun	31-Oct
	NA	780020 [E]				23-Sep	H&L: 5/31/2014	11	13-Sep	H&L: 5/31/2014	1,180	13-Sep	H&L: 5/31/2014
				closed - pot only [F]	regulatory	1-Nov	30-Apr						
				open - pot and H&L		1-May	31-May	11	1-May	31-May	1,180	1-May	31-May
2014/2015	NA	780,020	H&L: 190 Pot: 153	open		1-Jun	H&L: 12/7/2014	11	1-Jun	H&L: 12/7/2014	1,180	1-Jun	H&L: 12/7/2014
				closed - pot only [F]	regulatory	1-Nov	7-Dec						
2014 [G]	NA	780,020	H&L: 24 Pot: 0	open - H&L	NA	8-Dec	31-Dec	11	8-Dec	31-Dec	1,180	8-Dec	31-Dec
				closed - pot only [F]	regulatory	8-Dec	31-Dec						
2015	NA	780,020	H&L: 365 Pot: 184	open - H&L only	NA	1-Jan	30-Apr	11	1-Jan	31-Dec	354 [G]	1-Jan	30-Apr
				closed - pot only	regulatory	1-Jan	30-Apr						
				open - H&L and pots		1-May	31-Oct	11	1-May	31-Oct	1,180	1-May	31-Oct
				open - H&L		1-Nov	31-Dec	11	1-Nov	31-Dec	1,180	1-Nov	31-Dec
				closed - pot only	regulatory	1-Nov	31-Dec						
2016 [H]	NA	780,020	H&L: 365 Pot: 184	open H&L only	NA	1-Jan	30-Apr	11	1-Jan	31-Oct	354	1-Jan	30-Apr
				closed - pot only	regulatory	1-Jan	30-Apr						
				open H&L and pots		1-May	31-Oct	11	1-May	31-Oct	1,180	1-May	31-Oct
				open - H&L		1-Nov	31-Dec	11	1-Nov	31-Dec	1,180	1-Nov	31-Dec
2017	NA	755,274	H&L: 365 Pot: 184	open H&L only	NA	1-Jan	30-Apr	11	1-Jan	31-Oct	354	1-Jan	30-Apr
				closed - pot only	regulatory	1-Jan	30-Apr						
				open H&L and pots		1-May	31-Oct	11	1-May	31-Oct	1,180	1-May	31-Oct
				open - H&L		1-Nov	31-Dec	11	1-Nov	31-Dec	1,180	1-Nov	31-Dec
2018	NA	755,274	H&L: 365 Pot: 184	open H&L only	NA	1-Jan	30-Apr	11	1-Jan	31-Oct	354	1-Jan	30-Apr
				closed - pot only	regulatory	1-Jan	30-Apr						
				open H&L and pots		1-May	31-Oct	11	1-May	31-Oct	1,180	1-May	31-Oct
				open - H&L		1-Nov	31-Dec	11	1-Nov	31-Dec	1,180	1-Nov	31-Dec
2019	NA	326,800	H&L: 365 Pot: 184	open H&L only	NA	1-Jan	30-Apr	11	1-Jan	31-Oct	354	1-Jan	30-Apr
				closed - pot only	regulatory	1-Jan	30-Apr						
				open H&L and pots		1-May	31-Oct	11	1-May	31-Oct	1,180	1-May	31-Oct
				open - H&L		1-Nov	31-Dec	11	1-Nov	31-Dec	1,180	1-Nov	31-Dec
2020	NA	287,670	H&L: 365 Pot: 184	open H&L only	NA	1-Jan	30-Apr	11	1-Jan	31-Oct	354	1-Jan	30-Apr
				closed - pot only	regulatory	1-Jan	30-Apr						
				open H&L and pots		1-May	31-Oct	11	1-May	31-Oct	1,180	1-May	31-Oct
				open - H&L		1-Nov	31-Dec	11	1-Nov	31-Dec	1,180	1-Nov	31-Dec

A: Original SAFMC FMP effective 8/31/1983.

B: Amendment 9 (effective 2/24/1999) established 10 inch TL minimum size limit; required escape vents and escape panels with degradable hinges in BSB pots and specified minimum dimensions of an escape vent opening

C: Amendment 13C (effective 10/23/2006) changed fishing year from calendar year to June 1-May 31; specified commercial quota as indicated in table; required use of at least 2" mesh for entire back panel of BSB pots

D: Amendment 18 A (effective 7/1/12) included the establishment of an endorsement program for the commercial BSB pot fishery - more details on the pot fishery endorsement program can be found in the PDF doc and in Amendment 18A; also included change in size limit and established trip limit as indicated in table; commercial fishery didn't open until July 1 in 2012 (remained closed June 2012)

E: ACL adjustment effective on 9/23/12 with implementation of Regulatory Amendment 19.

F: Regulatory Amendment 19 implemented annual closure for pot fishery Nov 30 through April 1 (effective date for pot closure 10/23/2013)

G: Regulatory Amendment 14 (effective 12/8/2014) changed the fishing year back to calendar year; added H&L 300 lb gw trip limit Jan 1 - Apr 30

H: Regulatory Amendment 16 (pot prohibition changes effective 12/29/2016; gear marking changes effective 3/21/2017) changed the size of the seasonal prohibited fishing areas and required pot markings

lbs = pounds
ww = whole weight
H&L = hook and line gear

2.6.2 South Atlantic Black Sea Bass Federal Recreational Regulatory History

prepared by: Michael Schmidtke

Year(s)	Quota (lbs ww)	ACL (lbs ww)	Days Open	Fishing Season	Reason for Closure	Season Start Date (first day implemented)	Season end date (last day effective)	Size Limit (in TL)	Size Limit Start Date	Size Limit End Date	Retention Limit (# fish)	Retention Limit Start Date	Retention Limit End Date
1983[A]	NA	NA	365	open		1-Jan	31-Dec	8	31-Aug	31-Dec	none	NA	NA
1984-1998	NA	NA	365	open		1-Jan	31-Dec	8	1-Jan	31-Dec	none	NA	NA
1999[B]	NA	NA	365	open		1-Jan	31-Dec	10	24-Feb	31-Dec	20/person/day	24-Feb	31-Dec
2000-2005	NA	NA	365	open		1-Jan	31-Dec	10	1-Jan	31-Dec	20/person/day	1-Jan	31-Dec
2006	NA	NA	365	open		1-Jan	22-Oct	10	1-Jan	22-Oct	20/person/day	1-Jan	22-Oct
2006/2007[C]	746,000	NA	365	open		23-Oct	31-May	11	23-Oct	31-May	15/person/day	23-Oct	31-May
2007/2008	661,000	NA	365	open		1-Jun	31-May	12	1-Jun	31-May	15/person/day	1-Jun	31-May
2008/2009	483,000	NA	365	open		1-Jun	31-May	12	1-Jun	31-May	15/person/day	1-Jun	31-May
2009/2010	483,000	NA	365	open		1-Jun	31-May	12	1-Jun	31-May	15/person/day	1-Jun	31-May
2010/2011	NA	483,000	257	open		1-Jun	12-Feb	12	1-Jun	12-Feb	15/person/day	1-Jun	12-Feb
				closed	ACL met	13-Feb	31-May						
2011/2012	NA	483,000	139	open		1-Jun	21-Jun	12	1-Jun	21-Jun	15/person/day	1-Jun	21-Jun
						22-Jun	17-Oct	12	22-Jun	17-Oct	5/person/day [D]	22-Jun	17-Oct
				closed	ACL met	18-Oct	31-May						
2012/2013		483,000	96	open		1-Jun	30-Jun	12	1-Jun	30-Jun	5/person/day	1-Jun	30-Jun
						1-Jul	4-Sep	13 [E]	1-Jul	4-Sep	5/person/day	1-Jul	4-Sep
				closed	ACL met	5-Sep	31-May						
2013/2014	NA	483,000	365	open		1-Jun	22-Sep	13	1-Jun	22-Sep	5/person/day	1-Jun	22-Sep
		1,033,980 [F]				23-Sep	31-May	13	23-Sep	31-May	5/person/day	23-Sep	31-May
2014/2015 [G]	NA	1,033,980	365	open		1-Jun	7-Dec	13	1-Jun	7-Dec	5/person/day	1-Jun	7-Dec
						8-Dec	31-Mar	13	8-Dec	31-Mar	5/person/day	8-Dec	31-Mar
2015/2016	NA	1,033,980	365	open		1-Apr	31-Mar	13	1-Apr	31-Mar	5/person/day	1-Apr	31-Mar
2016/2017	NA	1,001,177	365	open		1-Apr	11-Aug	13	1-Apr	11-Aug	5/person/day	1-Apr	11-Aug
						12-Aug	31-Mar	13	12-Aug	31-Mar	7/person/day [H]	12-Aug	31-Mar
2017/2018	NA	1,001,177	365	open		1-Apr	31-Mar	13	1-Apr	31-Mar	7/person/day	1-Apr	31-Mar
2018/2019	NA	1,001,177	365	open		1-Apr	31-Mar	13	1-Apr	31-Mar	7/person/day	1-Apr	31-Mar
2019/2020	NA	433,200	365	open		1-Apr	31-Mar	13	1-Apr	31-Mar	7/person/day	1-Apr	31-Mar
2020/2021	NA	366,510	365	open		1-Apr	31-Mar	13	1-Apr	31-Mar	7/person/day	1-Apr	31-Mar

A: Original SAFMC FMP effective 8/31/1983.

B: Amendment 9 (effective 2/24/1999) implemented 10inch TL size limit and 20 fish/person/day bag limit

C: Amendment 13C (effective 10/23/2006) changed the fishing year from the calendar year to June 1- May 31; also changed recreational quota, size limits, and bag limits as indicated in the table.

D: Regulatory Amendment 9 changed the bag limit to 5/person/day, effective 6/22/11

E: Amendment 18A (effective 7/1/2012) included changing the recreational size limit to 13 in. TL; see PDF document for additional regulatory changes in 18A

F: Regulatory Amendment 19 increased the ACL, effective 9/23/13

G: Regulatory Amendment 14 (effective 12/8/2014) changed the recreational fishing year from June 1-May 31 to **April 1-March 31**

H: Regulatory Amendment 25 revised the recreational bag limit to 7/person/day, effective 8/12/2016

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

Commercial:

- 2008/2009 – Commercial closure, May 15, 2009 through May 31, 2009.
- 2009/2010 – Commercial closure, December 9, 2009 through May 31, 2010.
- 2010/2011 – Commercial closure October 7, 2010. Because projected landings estimated the quota would be met by that time. However, it was later determined to not have been met. Therefore, the commercial sector for black sea bass in federal waters was reopened December 1, 2010, through December 15, 2010. The fishery is closed from December 16, 2010 through May 31, 2011. The overage will be deducted from the 2011/2012 fishing year.
- 2011/2012 – Commercial closure July 15, 2011 through May 31, 2012.
- 2012/2013 – Commercial closure October 8, 2012 through May 31, 2013.

Recreational

- 2010/2011 – Recreational closure February 12, 2011 through May 31, 2011. The overage will be deducted from the 2011/2012 fishing year.
- 2011/2012 – Recreational closure October 17, 2011 through May 31, 2012.
- 2012/2013 – Recreational closure September 4, 2012 through May 31, 2013.

2.7 . State Regulatory History

2.7.1 North Carolina:

North Carolina General Statute (N.C.G.S.) 143B-289.52(e) states: "the Commission [N.C. Marine Fisheries Commission] may adopt rules to implement or comply with a fishery management plan adopted by the Atlantic States Marine Fisheries Commission or adopted by the United States Secretary of Commerce pursuant to the Magnuson-Steven Fishery Conservation and management Act, 1601 U.S.C. §1801 et seq."

The N.C. Marine Fisheries Commission has used this authority to develop rules that allow it to complement federal management measures for all snapper grouper species managed by the SAFMC, including black sea bass, in state waters. The first rule regarding snapper grouper species was adopted in 1991:

15A NCAC 03M .0506 Snapper-Grouper

The Fisheries Director may, by proclamation, until September 1, 1991, impose any or all of the following restrictions in the fishery for 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:

1) Specify size;
2) Specify seasons;
3) Specify areas;

4) Specify quantity;
5) Specify means and methods;
6) Require submission of statistical and biological data.

History Note: Statutory authority G.S. 113-134; 113-182; 113-221; 143B-289.4 Eff. January 1, 1991.

The above rule was modified in September 1991 to remove the phrase "until September 1, 1991". Any changes to federal snapper grouper rules were put into proclamation. Eventually, because the Division has a policy of putting long-standing proclamations (5 years or more) that have not changed into rule, the components of the proclamation dealing with size and retention limits for snapper grouper species were put into rule 15A NCAC 03M .0506 above, modifying the rule as of March 1, 1996. Below are the relevant portions of this rule pertaining to black sea bass:

15A NCAC 03M .0506 SNAPPER-GROUPER

(a) The Fisheries Director may, by proclamation, impose any or all of the following restrictions in the fishery for 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:

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

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 is hereby incorporated by reference and copies are available at the Division of Marine Fisheries, P.O. Box 769, Morehead City, North Carolina 28557 at no cost.

(b) It is unlawful to possess black sea bass less than eight inches total length taken south of Cape Hatteras (35° 15' N, latitude).

…..

(s) Fish Traps/Pots:

(1) It is unlawful to use or have on board a vessel fish traps for taking snappers and groupers except sea bass pots as allowed in Subparagraph (2) of this Paragraph.

(2) Sea bass may be taken with pots that conform with federal rule requirements for mesh sizes and pot size as specified in 50 CFR Part 646.2 and openings and degradable fasteners specified in 50 CFR Part 646-22(c)(2)(i).

History Note: Statutory authority G.S. 113-134; 113-182; 113-221; 143B-289.4 Eff. January 1, 1991. Amended Eff. March 1, 1996; September 1, 1991.

At the same time (March 1996), the first version of rule 15A NCAC 03M .0512 was adopted to allow for the Fisheries Director to suspend existing rules in order to implement changes to comply with Atlantic States Marine Fisheries Commission FMPs or federal regulations as per below:

15A NCAC 03M .0512 COMPLIANCE WITH FISHERY MANAGEMENT PLANS
In order to comply with management requirements incorporated in Federal Fishery Management Council Management Plans or Atlantic States Marine Fisheries Commission Management Plans, the Fisheries director may, by proclamation, suspend the minimum size and harvest limits established by the Marine Fisheries Commission, and implement different minimum size and harvest limits. Proclamations issued under this Section 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 (e1).
History Note: Authority G.S. 113-134; 113-182; 113-221; 143B-289.4; Eff. March 1, 1996.

Rule 15A NCAC 03M .0506 was modified effective December 23, 1996 to incorporate changes to black sea bass management <u>north</u> of Cape Hatteras as well. It was amended again effective August 1, 1998 to allow for incorporation of changes pursuant to the ASMFC plan for black sea bass north of Hatteras. The next set of changes to this rule that pertain specifically to black sea bass south of Hatteras became effective May 24, 1999. These reflect the increase in commercial size limit to 10 inches TL, and a 20 fish recreational bag limit, as well escape vent requirements for pots:

15A NCAC 03M .0506 SNAPPER-GROUPER
(a) The Fisheries Director may, by proclamation, impose any or all of the following restrictions in the fisheries for species of the snapper-grouper complex and black sea bass in order to comply with the management requirements incorporated in the Fishery Management Plans for Snapper-Grouper and Sea Bass developed by the South Atlantic Fishery Management Council or Mid-Atlantic Fishery Management Council and the Atlantic States Marine Fisheries Commission:
(1) Specify size;
(2) Specify seasons;
(3) Specify areas;
(4) Specify quantity;
(5) Specify means/methods; and
(6) Require submission of statistical and biological data.
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 is hereby incorporated by reference and copies are available via the Federal Register posted on the Internet at www.access.gpo.gov and at the Division of Marine Fisheries, P.O. Box 769, Morehead City, North Carolina 28557 at no cost.
(b) Black sea bass:
(1) It is unlawful to possess black sea bass less than ten inches total length taken south of Cape Hatteras (35° 15' N, latitude).
(2) It is unlawful to take or possess more than 20 black sea bass per person per day south of Cape Hatteras without a valid Federal Commercial Snapper-Grouper permit.
…..
(s) Fish Traps/Pots:
(1) It is unlawful to use or have on board a vessel fish traps for taking snappers and groupers except sea bass pots as allowed in Subparagraph (2) of this Paragraph.
(2) Sea bass may be taken with pots that conform with federal rule requirements for mesh sizes and pot size as specified in 50 CFR Part 646.2, openings and degradable fasteners specified in 50 CFR Part 646-22(c)(2)(i), and escape vents and degradable materials as specified in 50 CFR Part 622.40 (b)(3)(i) and rules published in 50 CFR pertaining to sea bass north of Cape Hatteras (35° 15'N Latitude). Copies of these rules are available via the Federal Register posted on the Internet at wwww.access.gpo.gov and at the Division of Marine Fisheries, P.O. Box 769, Morehead City, North Carolina 28557 at no cost.
History Note: Statutory authority G.S. 113-134; 113-182; 113-221; 143B-289.4
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. May 24, 1999.

Beginning in January 2002, part (s) of rule 15A NCAC 03M .0512 was removed and presumably placed into proclamation due to changes in materials and construction. Part (s) was reincorporated into rule as noted above as of May 1, 2004.

In June 2008, the N.C. Marine Fisheries Commission approved the first version of the Interjurisdictional Fishery Management Plan (IJ FMP), which incorporated all existing federal council and ASMFC FMPs as minimum standards for North Carolina's fisheries. Management changes to several ASMFC and Council-managed species were occurring at a higher rate of frequency, and the IJ FMP allowed for such changes to be implemented more efficiently through proclamation, rather than rulemaking. Effective October 1, 2008 all size limits, bag limits, seasons, gear restrictions, etc. were removed from rule 15A NCAC 03M .0506 and implemented under the authority of rule 15A NCAC 03M .0512. Both rules have not changed since then and are in their current form here:

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.

In July 2012, the provisions of Snapper Grouper Amendment 18A (black sea bass pot endorsement program, modification to recreational size limit) were implemented via proclamation FF-37-2012:
http://portal.ncdenr.org/web/mf/proclamation-ff-37-2012

In October 2013, the provisions of Snapper Grouper Regulatory Amendment 19 (prohibition on use of black sea bass pots from November through April) were implemented via proclamation FF-52-2013:
http://portal.ncdenr.org/web/mf/proclamation-ff-52-2013
From October 2008 through 2014, all commercial and recreational snapper grouper regulations were contained in the same proclamation. Beginning with the 2015 fishing year, snapper grouper regulations (including seasonal ACL closures) were issued via separate proclamations for the commercial and recreational sectors.

In December 2016, the provisions of Snapper Grouper Regulatory Amendment 16 (modifications to seasonal prohibition on use of black sea bass pots were implemented via proclamation FF-67-2016, and revised via proclamations FF-67-2016 (revised):
FF-67-2016 (http://portal.ncdenr.org/c/document_library/get_file?uuid=02e22a2e-a7e5-46a3-853e-e1d8dac6fed7&groupId=38337)

FF-67-2016 (REVISED) (http://portal.ncdenr.org/c/document_library/get_file?uuid=76a5853f-0a6f-49ae-85b7-47b14157de95&groupId=38337)

2.7.2 South Carolina:

1987: SC Code of Laws Section 50-17-55 established 8 inch minimum size limit for Black Sea Bass. (Added through H2612 during the 85/86 session of the SCGA?)

1989: SC Code of Laws Section 50-17-510(3) adopted to include size limits for many Council Snapper Grouper species, including 8 inch minimum size limit for Black Sea Bass.

1992: SC Code of Laws Section 50-5-510(C) adopted the federal minimum size limits automatically for all species managed under the Fishery Conservation and Management Act (PL94-265); and Section 50-5-510(F) adopted the federal catch and possession limits for all snapper grouper species managed under the Fishery Conservation and Management Act (PL94-265) as the Law of the State of SC. (Changes came through S788 during the 91/92 session of the SCGA?)

1999: SC Code of Laws Section 50-17-510(D)(4) established a 10 inch minimum size limit for Black Sea Bass; 510(E) established a requirement for Black Sea Bass to be sold (wholesale and retail) with head and fins intact. (A product of S1135 and H4843 of the 97/98 SCGA?)

2000: SC Marine-related Laws reorganized under SC Code of Laws Title 50 Chapter 5. Section 50-5-1710(4) retained the 10 inch minimum size limit for Black Sea Bass. 1710(4) maintained a requirement that "Black Seabass sold or offered for sale must be processed,
marketed, and sold to the ultimate consumer with head and tail fins intact. A commercial retailer or restaurant may remove the head at the request of the ultimate consumer after completion of the transaction but before the transfer of the purchase or serving of the dish."

Added:

- SC Code of Laws Section 50-5-2730

'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, SC black sea bass regulations are pulled directly from the federal regulations as promulgated under Magnuson.

2007: SC General Assembly repealed the code section that established a 10 inch minimum size limit on Black Sea Bass

2013: SC Code of Laws Section 50-5-2730 amended as follows:
SECTION 50-5-2730. Federal fishing regulations declared to be law of State; exception for black sea bass.
(A) Unless otherwise provided by law, any regulations promulgated by the federal government under the Fishery Conservation and Management Act (PL 94-265) 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.
(B) This provision does not apply to black sea bass (*Centropristis striata*) whose lawful catch limit is five fish per person per day or the same as the federal limit for black sea bass, whichever is higher. The lawful minimum size is thirteen inches total length. Additionally, there is no closed season on the catching of black sea bass (Centropristis striata).

2.7.3 Georgia:

Georgia began regulating Black Sea Bass in 1989.

Georgia General Assembly - O.C.G.A. 27-4-130.1 became effective April 18, 1989. It set the parameters around which the Board of Natural Resources could manage Black Sea Bass. those parameters were:
No Closed Season - No Limit on max Daily Creel - 8-15 inches minimum size

GA Board of Natural Resources then adopted Rule 391-2-4-.04 Saltwater Finfishing which became effective on. Sept. 13, 1989 - The original rule stated - No Closed Season - No Creel Limit - 8 inch minimum size

Since then, the following has been amended:
Effective Nov. 17, 1999 - 20 fish creel limit - 10 inch minimum size limit Effective Dec. 8, 2006 - 15 fish creel limit - 11 inches minimum size limit Effective July 1, 2007 - 12 inch minimum size

Commercial limits follow federal permit restrictions.

In May 2012, Georgia Gov. Nathan Deal signed into law House Bill 869 which moved managed saltwater species from O.C.G.A. 27-4-130.1 to a more comprehensive section,
O.C.G.A. 27-4-10. This Code Section contains all fish species legislatively mandated for management and provided for greater flexibility by the Board of Natural Resources. The bill set the maximum daily creel at 15 and broadens the minimum size range from 0 to 15 inches. The bill also gave the commissioner of the Department of Natural Resources the ability to close the fishery for short durations, not to exceed six months. These changes will become effective January 1, 2013. Current management measures are 12 inches minimum size and a 15 fish creel limit in state waters.

2.7.4 Florida:

Black Sea Bass Regulation History (Atlantic only)

Year	Size Limit	Recreational Possession Limit	Regulation Changes
1980	None	None	Specified a 2x2x2 foot cube with a vertical throat of 5 inches high by 2 inches wide. Prohibited trap use below 27° latitude.
1981	None	None	
1982	None	None	
1983	None	None	

1984	None	None	
1985	8 in TL	None	
1986	8 in TL	None	
1987	8 in TL	None	
1988	8 in TL	None	
1989	8 in TL	None	
1990	8 in TL	None	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.
1991	8 in TL	None	
1992	8 in TL	None	
1993	8 in TL	None	
1994	8 in TL	None	
1995	8 in TL	None	Established degradability requirements for black sea bass traps.
1996	8 in TL	None	
1997	8 in TL	None	
1998	10 in TL	20 fish per person per day	Required escape vents on sea bass pots. Black sea bass designated as a “restricted species.” Required black sea bass to be landed in whole condition required.

1999	10 in TL	20 fish per person per day	Allowed the use of trap lid tie- down straps secured at one end by a loop composed of non-coated steel wire measuring 24 gauge or thinner, 2 X 3/8 inch non-treated pine dowels or squares to replace the hook on tie-down straps, a 3 X 6 inch panel attached to the trap opening with 24 gauge or less wire or single strand jute on black sea bass traps.
2000	10 in TL	20 fish per person per day	
2001	10 in TL	20 fish per person per day	
2002	10 in TL	20 fish per person per day	
2003	10 in TL	20 fish per person per day	
2004	10 in TL	20 fish per person per day	

2005	10 in TL	20 fish per person per day	Required each trap used for harvesting black sea bass to have the trap owner's Saltwater Products License (SPL) number permanently attached. Required a buoy or time-release buoy to be attached to each black sea bass trap or at each end of a weighted trap trotline. The buoy must be constructed of Styrofoam, cork, molded polyvinyl chloride, or molded polystyrene, be of sufficient strength and buoyancy to float, and be either white in color or the same color as the owner's blue crab or stone crab buoy colors. These buoys must be either spherical in shape with a diameter no smaller than six
2006	10 in TL	20 fish per person per day	inches, or some other shape that is no shorter than 10 inches in the longest dimension and the width at some point exceeds five inches. Required each buoy attached to these traps have the letter "B" and the owner's SPL number affixed to it in legible figures at least 1.5 inches high.

2007	Recreational: 11 inches TL Commercial: 10 inches TL	15 fish per person per day	Established a June 1 - May 31 harvest season. Required a minimum 2-inch mesh for the back panel of black sea bass traps in the Atlantic. Required removal of black sea bass traps in the Atlantic when the commercial quota is reached.
2008	Recreational: 12 inches TL Commercial: 10 inches TL	15 fish per person per day	Allowed the use of black sea bass traps to 8 cubic feet in volume.
2009	Recreational: 12 inches TL Commercial: 10 inches TL	15 fish per person per day	
2010	Recreational: 12 inches TL Commercial: 10 inches TL	15 fish per person per day	
2011	Recreational: 12 inches TL Commercial: 10 inches TL	15 fish per person per day	
2012	Recreational: 12 inches TL Commercial: 10 inches TL	15 fish per person per day	

2013	Recreational: 13 inches TL Commercial: 10 inches TL	5 fish per person per day	Required anyone fishing with black sea bass traps in Atlantic state waters to have a federal South Atlantic black sea bass pot endorsement and a commercial snapper grouper unlimited permit. Changed Atlantic state trap requirements to match federal trap specifications
2014	Recreational: 13 inches TL Commercial: 10 inches TL	5 fish per person per day	
2015	Recreational: 13 inches TL Commercial: 10 inches TL	5 fish per person per day	
2016	Recreational: 13 inches TL Commercial: 10 inches TL	5 fish per person per day	

[1980]

SNAPPER, GROUPER, AND SEA BASS, F.S.

- Eliminated finfish traps except for pinfish traps and black sea bass traps.
- Specified a 2x2x2 foot cube with a vertical throat of 5 inches high and 2 inches wide.
- Prohibited used below latitude of 27 degrees
- Federal rules prohibited all fish traps except black sea bass and pinfish

REEF FISH (formerly SNAPPER, GROUPER, AND SEA BASS), CH 46-14, F.A.C.
(Effective July 29, 1985)

Minimum size limits:
- Black and southern sea bass - 8 inches

REEF FISH, CH 46-14, F.A.C. (Effective February 1, 1990)
- Minimum size limits: Sea basses - 8 inches
- All commercial harvest of any species of snapper, grouper, and sea bass is prohibited in state waters whenever harvest of that species is prohibited in adjacent federal waters

REEF FISH - BLACK SEA BASS TRAPS, CH 46-14, F.A.C. (Effective October 4, 1995)
Establishes degradability requirements for black sea bass traps. Such traps are considered to have a legal degradable panel if:
- The trap lid tie-down strap is secured to the trap by a single loop of untreated jute twine, and the trap lid is secured so that when the jute degrades, the lid will no longer be securely closed, or
- The trap lid tie-down strap is secured to one end with a corrodible hook composed of non-coated steel wire measuring 24 gauge or thinner, and the trap lid is secured so that when the hook degrades, the lid will no longer be securely closed, or
- The trap contains at least one sidewall with a vertical rectangular opening no smaller in either dimension than 6 inches high and 3 inches wide, and the opening is laced, sewn, or otherwise obstructed by a single length of untreated jute twine knotted only at each end and not tied or looped more than once around a single mesh bar; the opening in the sidewall of the trap must no longer be obstructed when the jute degrades, or
- The trap contains at least one sidewall with a vertical rectangular opening no smaller in either dimension than 6 inches high by 3 inches wide, and the opening must be obstructed with an untreated pine slat or slats no thicker than 3/8 inch; the opening in the sidewall of the trap must no longer be obstructed when the slat degrades, or
- The trap contains at least one sidewall with a vertical rectangular opening no smaller in either dimension than 6 inches high by 3 inches wide, and the opening must be laced, sewn, or otherwise obstructed by non-coated steel wire measuring 24 gauge or thinner or be obstructed with a panel of ferrous single-dipped galvanized wire mesh made of 24 gauge or thinner wire.

REEF FISH, CH 46-14, F.A.C. (Effective December 31, 1998)

- Increases the minimum size limit on black sea bass from 8 to 10 inches total length statewide, establishes a 20 fish daily recreational aggregate bag limit on black sea bass in Atlantic state waters only, and requires escape vents on sea bass pots statewide.
- Requires that all reef fish species managed in Florida be landed in a whole condition, and designate all such species as "restricted species."

REEF FISH - BLACK SEA BASS TRAP SPECIFICATIONS, CH 46-14, F.A.C. (Effective June 1, 1999)

- Allows the use on black sea bass traps of trap lid tie-down straps secured at one end by a loop composed of non-coated steel wire measuring 24 gauge or thinner, 2 X 3/8 inch non-treated pine dowels or squares to replace the hook on tie-down straps, a 3 X 6 inch panel attached to the trap opening with 24 gauge or less wire or single strand jute

REEF FISH - SEA BASSES & RED PORGY, CH 68B-14, F.A.C. (Effective June 1, 2001)

- Withdraws federal permit requirements for the commercial harvest of sea basses and red porgy in the Gulf of Mexico.

REEF FISH - BLACK SEA BASS TRAPS, CH 68B-14, F.A.C. (Effective July 15, 2004)

- Establishes a September 20 through October 4 closure to use of black sea bass traps in all Gulf of Mexico state waters between three and nine miles from shore.

REEF FISH - BLACK SEA BASS TRAPS, CH 68B-14, F.A.C. (Effective July 17, 2005)

- Requires each trap used for harvesting black sea bass to have the trap owner's Saltwater Products License (SPL) number permanently attached
- Each buoy attached to these traps shall have the letter "B" and the owner's SPL number affixed to it in legible figures at least 1.5 inches high
- Requires a buoy or time-release buoy must be attached to each black sea bass trap or at each end of a weighted trap trotline. The buoy must be constructed of Styrofoam, cork, molded polyvinyl chloride, or molded polystyrene, be of sufficient strength and buoyancy to float, and be either white in color or the same color as the owner's blue crab or stone crab buoy colors. These buoys must be either spherical in shape with a diameter no smaller than six inches, or some other shape that is no shorter than 10 inches in the longest dimension and the width at some point exceeds five inches

REEF FISH, CH 68B-14, F.A.C. (Effective July 1, 2007)

- Increases the recreational minimum size limit for Atlantic black sea bass from 10 inches total length to 11 inches total length in 2007, and then to 12 inches total length in 2008, and establishes a June 1 - May 31 harvest season
- Requires a minimum 2-inch mesh for the back panel of black sea bass traps in the Atlantic, and requires removal of black sea bass traps in the Atlantic when the commercial quota is reached

REEF FISH - BLACK SEA BASS TRAPS, CH 68B-14, F.A.C. (Effective March 12, 2008)

- Allows the use of black sea bass traps to 8 cubic feet in volume.

REEF FISH – BLACK SEA BASS CH 68B- 14, F.A.C. (Effective February 1, 2013)

- Increase the minimum size limits for commercial and recreational harvest to 11 inches TL and 13 inches TL respectively in the Atlantic
- Decrease the recreational bag limit from 15 to five fish per person per day in the Atlantic
- Require anyone fishing with black sea bass traps in Atlantic state waters to have a federal South Atlantic black sea bass pot endorsement and a commercial snapper grouper unlimited permit
- Change Atlantic state trap requirements to match federal trap specifications and requirements (this would include trap construction requirements, requiring traps to be set in waters north of Cape Canaveral, and requiring traps to be removed from the water and brought back to shore at the conclusion of each trip)

References

None provided.

3. Assessment History

Prior to the inception of SEDAR, this stock of black sea bass was assessed using tuned VPA models (FADAPT). With data through 1990, Vaughan et al. (1995) concluded that overfishing was occurring during the 1980s. Subsequently, with data through 1995, Vaughan et al. (1996) estimated that the rate of overfishing had increased during the 1990s.

This stock was first assessed through the SEDAR process in 2002 (SEDAR-02). The 2002 assessment applied a statistical catch-age formulation as the primary model (BAM). It estimated that the rate of overfishing had increased through the 1990s and that the stock was overfished. That assessment was updated in 2005 with data through 2003 (SEDAR Update Process #1). The update assessment estimated that the rate of overfishing continued to increase into the 2000s and that the stock remained overfished.

Several notable improvements in data content occurred between the 2005 update assessment and the 2011 benchmark, SEDAR 25. Studies on black sea bass provided information on fecundity, as well as total discards and discard mortality rates. Additional processed otolith shed light on the age compositions of landings and surveys. Natural mortality was reexamined and revised such that estimates were larger than previously thought and depended on age. SEDAR 25 also found the stock was overfished and undergoing overfishing.

In 2013, the SEDAR 25 update assessment used two additional years of data and maintained all of the assumptions and structure of the SEDAR 25 BAM model. The results were that the stock was no longer overfished and overfishing was not occurring.

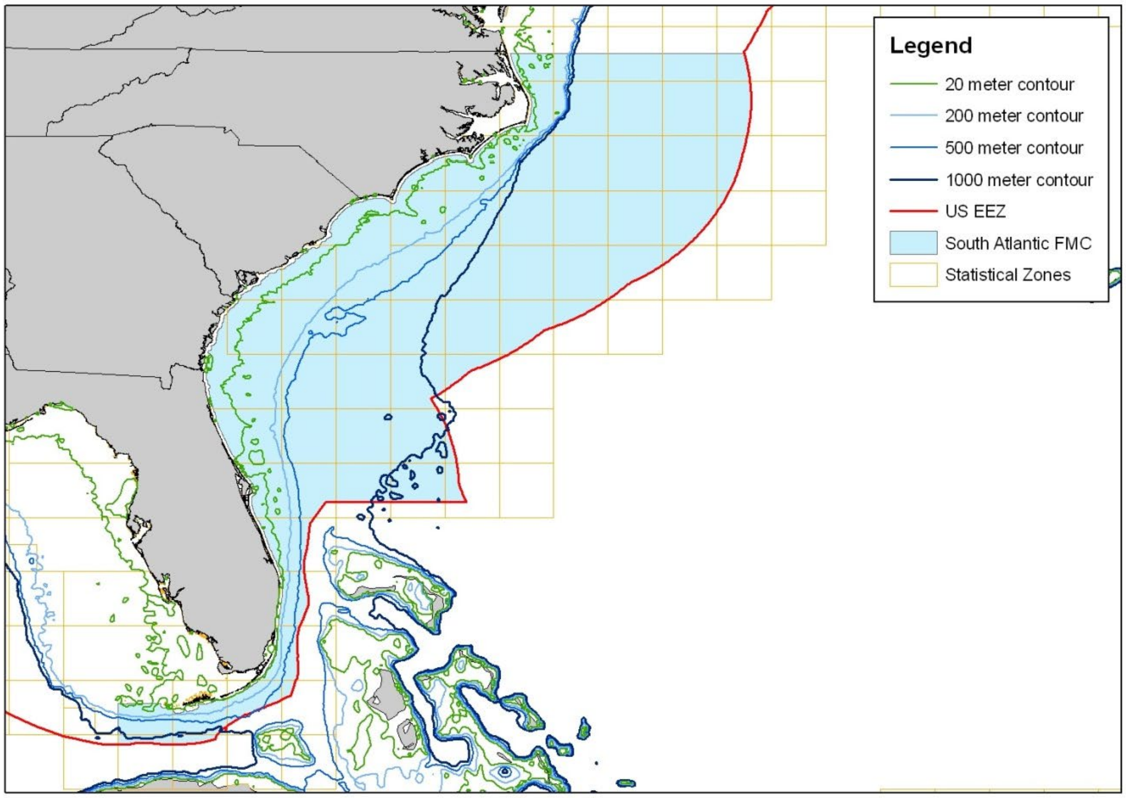
In 2018, the SEDAR 56 used an updated BAM model with data through 2016 to assess the stock in a SEDAR standard framework. Notable improvements were the addition of a SERFS video index and the availability of new studies to inform the discard mortality. The assessment results showed the stock was not undergoing overfishing, and, although the stock was below the SSBmsy threshold, it was not overfished.

In this assessment, SEDAR 76, used an updated version of BAM with data through 2021 to assess the status of the stock in an operational SEDAR framework. Changes to the model included natural mortality, discard mortality, correcting start dates for some selectivity time blocks, and domed shaped selectivity for the SERFS trap index. The assessment results showed that the stock is undergoing overfishing and is overfished.

- SEDAR. 2011. SEDAR 25 – South Atlantic Black Sea Bass Assessment Report. SEDAR, North Charleston SC. 480 pp.
- SEDAR. 2013. SEDAR Update Assessment – South Atlantic Black Sea Bass Assessment Report. SEDAR, North Charleston SC. 102 pp.
- SEDAR. 2018. SEDAR 56 – South Atlantic Black Seabass Assessment Report. SEDAR, North Charleston SC. 164 pp.
- Vaughan, DS, MR Collins, and DJ Schmidt. 1995. Population characteristics of the black sea bass *Centropristis striata* from the southeastern U.S. Bulletin of Marine Science 56:250−267.
- Vaughan, DS. 1996. Population characteristics of the black sea bass *Centropristis striata* from the U.S. southern Atlantic coast. Report to South Atlantic Fishery Management Council, Charleston, SC, 59 p.

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 76

South Atlantic Black Sea Bass

Section II: Assessment Report

March 2023

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

Document History

March 21, 2023 Original release

March 31, 2023 The BAM model in the original release included age and length composition in 2021 for the commercial lines fishery. The length composition in 2021 was removed and the model, MCBE, projections, and sensitivities were rerun. The results are qualitatively the same with minor changes to some values.

Contents

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1 Introduction

This operational assessment evaluated the stock of black sea bass, *Centropristis striata*, off the southeastern United States[1]. The primary objectives were to update and improve the 2018 SEDAR 56 assessment of black sea bass and to conduct new stock projections. Using data through 2016, SEDAR 56 had indicated that the stock was not overfished and not undergoing overfishing though this was only in the recent years. For this assessment, data compilation and assessment methods were guided by methodology of SEDAR 25 and SEDAR 56, as well as by current SEDAR practices. The assessment period is 1978–2021.

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. Four indices of abundance were fitted by the model: one from the recreational headboat fleet, one from the commercial lines fleet, one from the MARMAP blackfish/snapper trap survey, and one from the SERFS that combined chevron trap and video sampling. Data on landings and discards were available from recreational and commercial fleets.

The primary model used in the SEDAR 25 benchmark assessment and updated in this operational assessment was the Beaufort Assessment Model (BAM), a 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.

Results suggest that spawning stock declined until the early 1990s, increased gradually until the late-2000s, with a large increase in 2009 and 2010, and then declined precipitously. The base run estimate of terminal year (2021) spawning stock is below the MSST ($\mathrm{SSB}_{2021}/\mathrm{MSST} = 0.32$) indicating that the stock is overfished and the estimated fishing rate is above F_{MSY}. The terminal estimate, which is based on a three-year geometric mean, is above F_{MSY} in the base run ($F_{2019-2021}/F_{\mathrm{MSY}} = 2.18$). Thus, this assessment indicates that the stock is overfished and undergoing overfishing.

The MCBE analysis indicates that these estimates of stock and fishery status are robust, but with some uncertainty in the conclusions. All MCBE runs were in qualitative agreement that the stock is overfished ($\mathrm{SSB}_{2021}/\mathrm{MSST} < 1.0$), and 84.2% of all models show that the stock is undergoing overfishing ($F_{2019-2021}/F_{\mathrm{MSY}} > 1.0$).

The estimated population trends of this operational assessment are similar to those from SEDAR 56 and the SEDAR 25 benchmark and update. However, the three assessments did show some differences in results, which was not surprising given several modifications made to both the data and model (described throughout the report). Compared to the SEDAR 25 benchmark and SEDAR 56, this assessment suggests a lower value of MSY, and higher values of discard mortality, F_{MSY} and $\mathrm{SSB}_{\mathrm{MSY}}$.

Projections with $F = 0$ indicate that the stock could recover to its target of $\mathrm{SSB}_{\mathrm{MSY}}$ within ten years, if recruitment returns to its long-term average. If recruitment remains low, so will stock abundance and the stock will not achieve $\mathrm{SSB}_{\mathrm{MSY}}$. Generation time for black sea bass is about 6 years.

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

1.1 Workshop Time and Place

The SEDAR 76 South Atlantic Black Sea Bass operational assessment took place over a series of webinars held from May 2022 to February 2023.

1.2 Terms of Reference

1. Update the South Atlantic Black Sea Bass SEDAR 56 assessment from a terminal year of 2015 with data through 2020. 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 56.
2. Evaluate and document the following specific changes in input data or deviations from the benchmark model.
   - Include any newly available information on steepness for similar species.
   - Include any new and updated information on discard mortality and life history.
   - Calculate different F metrics (in addition to apical F) (to address shifts in the age of apical F towards the end of the assessment time series).
   - Consider sensitivity analyses to address SSC concerns with selectivity differences between Chevron traps and cameras used to create the CVID index addressed at the selectivity workshop .
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, as needed to review model development relative to terms of reference 1 through 4

1.3 List of Participants

Appointee	Function	Affiliation
Panel		
Matt Vincent	Lead Analyst	Beaufort, NC
Erik Williams	Assessment	Support Beaufort, NC
Kyle Shertzer	Assessment	Support Beaufort, NC
Jennifer Potts	Analytical team	Beaufort, NC
Walt Rogers	Analytical team	Beaufort, NC
Matthew Nuttal	Analytical team	FSD-Miami
Eric Fitzpatrick	Data Compiler	Beaufort, NC
Mike Rinaldi	Panelist	ACCSP
Alan Bianchi	Panelist	NCDMF
Kevin Spanik	Panelist	SCDNR
Joseph Evans	Panelist	SCDNR
Kevin Kolmos	Panelist	SCDNR
Dawn Franco	Panelist	GADNR
Fred Serchuk	Panelist	SSC
Alexie Sharov	Panelist	SSC
Matt Damiano	Panelist	NCSU
APPOINTED OBSERVERS		
Robert Lorenz	Industry Rep	SGAP
APPOINTED COUNCIL MEMBERS		
Tim Griner	Council Rep	SAFMC
STAFF		
Kathleen Howington	Coordinator	SEDAR
Mike Schmidke	Observer	SAFMC
Judd Curtis	Council Staff Rep	SAFMC
Mike Larkin	SERO Staff Rep	SERO
Chip Collier	Observer	SAFMC
NON-PANEL DATA PROVIDERS		
Amy Dukes	Data Provider	SCDNR
Dominique Lazarre	Data Provider	FLFWC
Steve Brown	Data Provider	FLFWC
Michelle Willis	Data Provider	SCDNR
Marcel Reichert	Data Provider	SCDNR
David Wyanski	Data Provider	SCDNR
Ken Brennan	Data Provider	FSD-RFMB
Nate Bachelor	Data Provider	FSD-Miami
Kevin McCarthy	Data Provider	FSD-Miami
Larry Beerkircher	Data Provider	FSD-Miami
Eric Hiltz	Data Provider	SCDNR

Appointee	Function	Affiliation
Other		
Mclean Seward	Observer	NCDNR
Tracey Smart	Observer	SCDNR
Elizabeth Gooding	Observer	SCDNR
Homer Hiers	Observer	SCDNR
Margaret Finch	Observer	SCDNR
Julie Vecchio	Observer	SCDNR
Laura Lee	Observer	NCDNR
Marisa Ponte	Observer	
Rob Cheshire	Observer	NMFS
Wiley Sinkus	Observer	SCDNR
Willow Patten	Observer	DNDNR

1.4 Document List

Document #	Title	Authors	Received
	Documents Prepared for SEDAR 76		
SEDAR76-WP01	General Recreational Survey Data for Black Sea Bass in the South Atlantic	Matthew Nuttall	9/16/22
SEDAR76-WP02	Standardized video counts of southeast US Atlantic black sea bass (Centropristis striata) from the Southeast Reef Fish Survey	Nathan Bacheler and Rob Cheshire	8/3/22
SEDAR76-WP03	Black Sea Bass Fishery-Independent Index of Abundance and Age//Length Compositions in US South Atlantic Waters Based on a Chevron Trap Survey (1990-2021)	Walter J. Bubley and C. Michelle Willis	9/9/2022
SEDAR76-WP04	Length and age distributions of Southeast U.S.Atlantic black sea bass (Centropristis striata)from commercial fisheries	Sustainable Fisheries Branch, National Marine Fisheries Service, Southeast Fisheries Science Contact Eric Fitzpatrick	8/25/22
SEDAR76-WP05	South Atlantic U.S. black sea bass (Centropristis striata) age and length composition from the recreational fisheries	Sustainable Fisheries Branch, National Marine Fisheries Service, Southeast Fisheries Science Contact: Eric Fitzpatrick	8/25/22
SEDAR76-WP06	Black Seabass Length Frequencies and Condition of Released Fish from At-Sea Headboat Observer Surveys, 2005 to 2020.	Ellie Corbett, Beverly Sauls and Andrew Cathey	9/9/22
SEDAR76-WP07	Diagnostics of the SEDAR 76 Assessment Model of Black Sea Bass	National Marine Fisheries Service Southeast Fisheries Science Center Sustainable Fisheries Division Atlantic Fisheries Branch Contact: Matt Vincent	3/20/2023
	Final Assessment Report		
SEDAR76-SAR1	Stock Assessment report of South Atlantic Black Sea Bass	To be prepared by SEDAR 76 Panel	March 2023
	Reference Documents		
SEDAR76-RD01	Black Sea Bass Stakeholder Engagement Meeting Summary	Mid Atlantic Council Black Sea Bass Working Group	7/6/2022
SEDAR76-RD02	South Atlantic Fishery Management Council Snapper Grouper Advisory Panel Black Sea Bass Fishery Performance Report Update April 2022	SAFMC Snapper Grouper Advisory Panel	7/12/22
SEDAR76-RD03	Swim Bladder Deflation In Black Sea Bass And Vermilion Snapper: Potential For Increasing Post Release Survival	Mark R. Collins, John C. Mcgovern, George R. Sedberry, H. Scott Meister, And Renee Pardieck	9/20/2022

Document #	Title	Authors	Received
SEDAR76-RD04	Discard Composition And Release Fate In The Snapper And Grouper Commercial Hook-And-Line Fishery In North Carolina, USA	P . J . Rudershausen, J. A. Buckel and E . H . Williams	9/20/2022
SEDAR76-RD05	Estimating Reef Fish Discard Mortality Using Surface And Bottom Tagging: Effects Of Hook Injury And Barotrauma	P.J. Rudershausen, J.A. Buckel, And J.E. Hightower	9/20/2022
SEDAR76-RD06	Effect Of Catch-And-Release Angling On The Survival Of Black Sea Bass	Karen Bugley And Gary Shepherd	9/20/2022
SEDAR76-RD07	Impairment Indicators For Predicting Delayed Mortality In Black Sea Bass (Centropristis Striata) Discards Within The Commercial Trap Fishery	Cara C. Schweitzer, Andrij Z. Horodysky, Andre L. Price And Bradley G. Stevens	9/20/2022
SEDAR76-RD08	Commercial catch composition with discard and immediate release mortality proportions off the southeastern coast of the United States	Jessica A. Stephen, Patrick J. Harris	9/20/2022
SEDAR76-RD09	Discard mortality of black sea bass (Centropristis striata) in a deepwater recreational fishery off New Jersey: role of swim bladder venting in reducing mortality	Douglas R. Zemeckis, Jeff Kneebone, Connor W. Capizzano, Eleanor A. Bochenek, William S. Hoffman, Thomas M. Grothues, John W. Mandelman, Olaf P. Jensen,	9/20/2022
SEDAR76-RD10	Relating trap capture to abundance: a hierarchical state-space model applied to black sea bass (Centropristis striata)	Kyle W. Shertzer, Nathan M. Bacheler, Lewis G. Coggins Jr, and John Fieberg	9/26/22
SEDAR76-RD11	Effectiveness of Venting and Descender Devices at Increasing Rates of Postrelease Survival of Black Sea Bass	P. J. Rudershausen, B. J. Runde, and J. A. Buckel	9/26/22
SEDAR76-RD12	Assessing the size selectivity of capture gears for reef fishes using paired stereo-baited remote underwater video	Heather M. Christiansen, Justin J. Solomon, Theodore S. Switzer, Russell B. Brodie	9/27/22
SEDAR76-RD13	Size- and age-dependent natural mortality in fish populations: Biology, models, implications, and a generalized length-inverse mortality paradigm	Kai Lorenzen	11/21/22
SEDAR76-RD14	Natural mortality and body size in fish populations	Kai Lorenzen, Edward V. Camp, Taryn M. Garlock	11/21/22
SEDAR76-RD15	Development and considerations for application of a longevity-based prior for the natural mortality rate	Owen S. Hamel and Jason M. Cope	11/21/22

1.5 Statements Addressing Each Term of Reference

Note: Original ToRs are in normal font. Statements addressing ToRs are in italics and preceded by a dash (–).

1) Update the South Atlantic Black Sea Bass SEDAR 56 assessment from a terminal year of 2016 with data through 2020. 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 56.

   – SEDAR 76 applied the current BAM configuration and updated data through 2021 where available. The changes and modifications to the data and assessment model are documented in the report.

2) Evaluate and document the following specific changes in input data or deviations from the benchmark model.

   - Include any newly available information on steepness for similar species.

     – No new information on steepness were available for similar species. Instead the Beverton-Holt stock recruitment relationship was removed and a mean recruit model with estimated deviates was used.

   - Include any new and updated information on discard mortality and life history.

     – New studies on discard mortality were discussed by the Assessment Panel but were not ultimate incorporated into the base model. Instead the uncertainty in the discard mortality rates was expanded to include these new studies and were incorporated into the Monte-Carlo Bootstrap Ensemble (MCBE). The growth curve was updated using available age and length data. Natural mortality at age was changed in two ways. First, the mean value of natural mortality (0.375) was determined by averaging the estimate from Hamel and Cope (2022, 0.49) and the estimate from within BAM (0.26). The uncertainty around mean M was expanded to include this uncertainty. Second, the M at age was determined by the inverse length (Lorenzen 2022) rescaled by the survival of ages 3 through 11.

   - Calculate different F metrics (in addition to apical F) (to address shifts in the age of apical F towards the end of the assessment time series).

     – A plot of fishing mortality at age was created and presented to show how changes in the selectivity over time have changed fishing mortality on each age class. These figures show the apparent change in fishing mortality at age following changes in minimum size limits.

   - Consider sensitivity analyses to address SSC concerns with selectivity differences between Chevron traps and cameras used to create the CVID index addressed at the selectivity workshop.

     – A variety of different modeling assumptions regarding the use of the chevron trap index and video index were explored including assumptions about selectivity. These model sensitivities resulted in estimates very similar to the base model.

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 the model and input datasets are provided in the working papers and assessment report. Model inputs and outputs are provided in the desired units within this report.

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 quantities are provided in the report, with a minor modification to one of them. Because the stock was found to be overfished, projections explored the probability of rebuilding rather than the probability of overfishing.

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

   – A total of 5 webinars were conducted with the working group that included SSC representatives to review the model development relative to these terms of reference.

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

In the SEDAR 25 benchmark assessment, the assessment period was 1978–2010, and for SEDAR 56, the assessment period was 1978–2016. In this assessment, the terminal year was extended to 2021. Data sources from SEDAR 25 were considered here; however, all data were updated, including data prior to 2010, using current methodologies. The input data for this assessment are described below, with focus on modifications from SEDAR 56.

2.1 Data Review

In this operational assessment, the Beaufort assessment model (BAM) was fitted to data sources similar to those used in the SEDAR 25 benchmark and SEDAR 56 with some modifications and additions.

- Landings: Commercial lines; Commercial trawl, Commercial pots, Headboat, General recreational (charterboat and private boats)
- Discards: Commercial (lines and pots), Headboat, General recreational
- Indices of abundance: MARMAP blackfish/snapper trap, Combined SERFS chevron trap and video survey, Commercial lines, Headboat
- Length compositions of surveys or landings: MARMAP blackfish/snapper trap, Commercial lines, Commercial pots, Headboat, General recreational
- Length compositions of discards: Headboat
- Age compositions of surveys or landings: MARMAP blackfish/snapper trap, SERFS chevron trap, Commercial lines, Commercial pots, Headboat

In addition to data fitted by the model, this assessment utilized life-history information that was treated as input. Many inputs remained the same for this assessment as were used in the SEDAR 25 benchmark and SEDAR 56, including fecundity at age, female maturity at age, and sex ratio by age. However, there were changes to some vital rates such as somatic growth, natural mortality, and discard mortality.

2.2 Data Update

The following is a summarization of the data differences between this assessment and the SEDAR 25 benchmark and SEDAR 56. Data available for this assessment are summarized in Tables 3 to 7 and Figure 1.

- Discards: Commercial lines and pot discards for both open and closed seasons were updated through 2021. Headboat and recreational discards were updated through 2021. The estimates for commercial and recreational discards are either model- or ratio-based, therefore the entire time series of new estimates was replaced.
- Indices of abundance: The SERFS chevron trap index was updated through 2021 and the SERFS video index was standardized and provided for consideration. The SERFS indices were combined to form one index (CVID). Because of changing regulations since 2009, the commercial lines and headboat indices were not updated. The headboat at-sea discards index was not used.

- Size/age compositions of surveys or landings: SERFS chevron trap age compositions were updated through 2021 and corrected for previous years. Headboat age compositions were corrected and updated through 2019, and length composition were available for 2020. Commercial pots age compositions were available through 2020 and length compositions were available for 2021. Commercial lines and general recreational composition data were corrected and updated through 2021, the terminal year of the assessment, though general recreational age compositions were not used. All of the updated composition data are subject to the same minimum sample size (n=10 trips for lengths and n=10 trips for ages or for lengths from the MARMAP blackfish/snapper trap survey).
- The iterative reweighting method used in SEDAR 25 was not used for composition data, as the Dirichlet multinomial distribution was used. The Dirichlet multinomial is a self-weighting distribution, thus removing the need for weights on the composition data. The same weight of 2.5 was applied to the four indices, which is consistent with SEDAR 25 and SEDAR 56.

In several cases, the SEDAR 25 benchmark and SEDAR 56 data did not require updating: landings from commercial trawl (1978–1990), MARMAP blackfish/snapper index values (1981–1987), and the headboat index values were all unchanged.

2.2.1 Discard Mortality

The discard mortalities for all the fleets were revisited due to the availability of new studies on black sea bass (Zemeckis et al. 2020; Schweitzer et al. 2020; Rudershausen et al. 2020). Discard mortality rates used in SEDAR 56 were derived from Rudershausen et al. (2014) and Rudershausen et al. (2008) and applied the following discard mortalities to the data: 14% for commercial pot discard mortality prior to 2007 (when 1.5 inch mesh pots were used), 48.3% of the 1.5" mesh pot mortality for 2007 to present (when the 2 inch back panel is required), 19% for commercial lines, 13.7% for the general recreational fleet, and 15.2% for the headboat fleet. Estimates from Rudershausen et al. (2014) were thought to be potentially too low due to the tagging procedure of the study, which caused the "release of gas from the abdominal cavity during tagging of black sea bass." The rates of discard mortality for black sea bass from a recreational headboat experiment in 45 to 67 m were estimated at 50.4% off the Atlantic coast of New Jersey (Zemeckis et al. 2020). These estimates were obtained from acoustic transmitters and this study also estimated the mortality rate for vented fish to be 21.9%. This was consistent with Rudershausen et al. (2020) which found that survival rates (i.e., 1 - discard mortality rates) for vented fish (and fish brought to the bottom by descender devices) were 1.5 times higher than fish that were not vented. A study on discard mortality in the pot fishery off the coast of Delaware and Maryland in 25 to 30 m deep estimated a discard mortality rate of 47.1%. These recent studies all suggest a higher rate of discard mortality than was previously used in SEDAR 56. However, the Assessment Panel and industry experts had concerns that these studies were conducted outside of the southeast and under different fishing conditions than occur within the region, particularly depth. Consequently, the Assessment Panel decided to retain the estimates of discard mortality used in the SEDAR 56 but expanded the bounds of uncertainty used in the Monte-Carlo Bootstrap Ensemble (MCBE).

2.2.2 Recreational Landings and Discards

The landings and discards from the general recreational fleet were provided for SEDAR 25 using MRFSS , whereas SEDAR 56 were provided through MRIP. Here, estimates were available from MRIP (FES) and were used to update the landings and discards data for the general recreational fleet through 2021. Headboat landings were updated through 2021, and headboat discards were recalculated for the entire time series, as it is a model-based approach (Table 4).

2.2.3 Commercial Landings and Discards

The commercial discards were revised for the entire time series, as it is a model-based approach, and provided through 2021. It was noted that commercial discards for the pot fishery during the closed season had increased significantly since 2017 and this was not believed to be reliable. The pot fishery had a spatially restricted closure starting in 2017 and thus estimates of the pot fishery closed season discards for 2013 - 2021 were treated as open season discards. Commercial landings were updated through 2021 (Table 4).

2.2.4 Indices of Abundance

Following SEDAR 56 the standardized SERFS video index was added and merged with the chevron trap index using the Conn method (Conn 2010) to form the CVID index (Table 6). The video cameras are mounted to the traps, and likely observe a similar portion of the population as the trap. Combining the indices using the Conn method better represents the observation and process error in the system. The effects of the video data on the base model results were examined with sensitivity runs that excluded video data, used only video data after 2010, fit both video and trap indexes separately, assumed a logistic selectivity curve, and weighted the selectivity curve as logistic for the video and dome shaped for the trap.

The headboat index was not updated for this assessment due to intermittent closures for the recreational season since 2011 as well as new bag limits and size limits since SEDAR 25, which likely invalidates catch per effort as a meaningful index of abundance. The terminal year of the commercial index was 2010 as used in SEDAR 56 and SEDAR 25.

As in SEDAR 56, the headboat at-sea observer index was removed because the size composition data clearly overlapped with the chevron trap survey. The chevron trap survey data are available further back in time, fishery-independent data are considered better than fishery-dependent data for constructing an index of abundance, and it is not necessary to include an additional index.

Following the precedent of SEDAR 56 and the advice provided by Francis (2003) the CVs of the fishery dependent indices and the MARMAP blackfish/snapper trap index was set to the largest estimate from the CVID index (0.27). Prior to 1984, the CVs of the headboat index were assumed to be double that (0.54) of the more modern time period, which is consistent with the assumptions made in the SEDAR 25 benchmark and SEDAR 56.

2.2.5 Length Compositions

Length compositions were corrected and updated through 2021 (Table 7). The length compositions were used in years with no age composition data, or when the age data were sparse. However, length compositions were not included during years of adequate age composition data (i.e. multiple consecutive years with greater than 10 trips). For the MARMAP blackfish/snapper trap index, length compositions were used from 1981–1987, except in 1983. For the commercial lines fleet, length compositions were used from 1984–2002. For the commercial pots fleet, length compositions were used from 1984–2003 and 2021. For the headboat fleet, length compositions were used from 1978–2002 and 2020. For the general recreational fleet, length compositions were used from 1981-2021. For discards from the headboat fleet, length compositions were used from 2005–2020. This is similar to the treatment of length compositions in SEDAR 56.

2.2.6 Age Compositions

Age composition data were included for the most recent year available for the respective fishery or survey (Table 7). Age composition were available for the MARMAP blackfish/snapper trap index in 1983. The model included age composition data collected by the SERFS chevron trap survey from 1990–2021, excluding 2020. The age compositions used for the CVID index are only from the SERFS chevron trap survey, as no size or age data are collected for the video survey. Commercial lines age composition were used from 2002–2021, while commercial pots were available for 1999 and 2005–2020. For the headboat fleet, age compositions were used for 1991, 1992, 2003–2020. As in SEDAR 56 the general recreational age compositions were not used because they were not representative of the fleet.

3 Stock Assessment Methods

This assessment updates the primary model applied during the SEDAR 25 benchmark and SEDAR 56 for South Atlantic black sea bass. The methods are reviewed below, and any changes since the SEDAR 25 benchmark or SEDAR 56 are flagged.

3.1 Overview

This assessment used the Beaufort Assessment Model (BAM, Williams and Shertzer 2015), which applies a statistical catch-age formulation, implemented with the AD Model Builder software (Fournier et al. 2012). In essence, the 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 match available data on the real population. The model is similar in structure to Stock Synthesis (Methot and Wetzel 2013) and other common assessment packages used in the United States (Li et al. 2021). Versions of BAM have been used in previous SEDAR assessments of reef fishes in the U.S. South Atlantic, such as red porgy, tilefish, blueline tilefish, gag, greater amberjack, snowy grouper, vermilion snapper, and red snapper, as well as in previous SEDAR assessments of black sea bass (SEDAR25 2011; SEDAR56 2018).

3.2 Data Sources

The catch-age model included data from fishery independent surveys and from five fleets that caught black sea bass in southeastern U.S. waters: commercial lines (primarily handlines), commercial pots, commercial trawls, recreational headboats, and general recreational. The model was fitted to data on annual landings (in units of 1000 lb whole weight), annual discard mortalities (in units of 1000 fish), annual length compositions of landings, annual age compositions of landings, annual length compositions of discards, two fishery-independent indices of abundance (MARMAP blackfish/snapper traps and SERFS combined chevron traps and videos), and two fishery-dependent indices (commercial lines and headboat). Data used in the model are tabulated in §2 of this report.

3.3 Model Configuration

Model structure and equations of the BAM are detailed in Williams and Shertzer (2015). The assessment time period was 1978–2021. A general description of the assessment model follows.

3.3.1 Stock dynamics

In the assessment model, new biomass was acquired through growth and recruitment, while abundance of existing cohorts experienced exponential decay from fishing and natural mortality. The population was assumed closed to immigration and emigration. The model included age classes $0 - 11^+$, where the oldest age class 11^+ allowed for the accumulation of fish (i.e., plus group).

3.3.2 Initialization

Initial (1978) abundance at age was estimated in the model as follows. First, the equilibrium age structure was computed for ages 1–11 based on natural and fishing mortality (F), where F was set equal to the geometric mean fishing mortality from the first three assessment years (1978-1980). Second, lognormal deviations around that equilibrium age structure were estimated. The deviations were lightly penalized, such that the initial abundance of each age could vary from equilibrium if suggested by early composition data, but remain estimable if data were uninformative. Given the initial abundance of ages 1–11, initial (1978) abundance of age-0 fish was computed using the same methods as for recruits in other years (described below).

3.3.3 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 2022). The Lorenzen (2022) approach inversely relates the natural mortality at age to mean length at age (L_a) by the power function $M_a = \alpha L_a^{-1}$, where α is a scale parameter. As in previous SEDAR assessments, the Lorenzen estimates of M_a were rescaled to provide the same fraction of fish surviving across a range of ages as would occur with a constant M. The constant rate of natural mortality ($M = 0.375$) was determined by averaging the values determined by Hamel and Cope (2022, 0.49) and the natural mortality rate when estimated as a parameter within BAM (0.26). This rate was similar to the $M = 0.38$ from the SEDAR 25 DW that was determined from Hewitt and Hoenig (2005). Estimates of M from Hamel and Cope (2022) and Hewitt and Hoenig (2005) were determined primarily across ages that were fully selected to the fishery. Therefore, we determined the fully selected age to the fishery as age-3 and rescaled the M_a to have survival across ages 3 through the oldest observed age (11 years) to be consistent with what would occur with a constant $M = 0.375$ (Table 3).

3.3.4 Growth

Mean size at age of the population (total length, TL) was modeled with the von Bertalanffy equation (Figure 2), and weight at age (whole weight, WW) was modeled as a function of total length (Table 3). Parameters of TL-WW conversions were estimated by the SEDAR 25 DW and were treated as input to the assessment model. The von Bertalanffy parameter estimates used in this assessment were updated from available length-age data as $L_\infty = 480.2$, $K = 0.183$, and $t_0 = -0.94$. For fitting length composition data, the distribution of size at age was assumed normal with coefficient of variation (CV) estimated by the assessment model. A constant CV, rather than constant standard deviation, was suggested by the size at age data.

3.3.5 Sex transition

Black sea bass is a protogynous hermaphrodite. Proportion female at age was modeled with a logistic function, estimated by the SEDAR 25 DW. The age at 50% transition to male was estimated to be 3.83 years.

3.3.6 Female maturity and fecundity

Female maturity was modeled with a logistic function; the age at 50% female maturity was estimated to be ~ 1 year. Annual egg production by mature females was computed as eggs spawned per batch, a function of body weight, multiplied by the number of batches per year. Maturity and fecundity parameters were provided by the SEDAR 25 DW and treated as input to the assessment model.

3.3.7 Spawning stock

Spawning stock was modeled as population fecundity of mature females (i.e., total annual egg production) measured at the time of peak spawning. For black sea bass, peak spawning was considered to occur at the end of March.

3.3.8 Recruitment

Expected recruitment of age-0 fish was predicted using the mean recruitment model, which was a modification from the approach of SEDAR 56. Annual variation in recruitment was assumed to occur with lognormal deviations for years 1978–2019, when composition data could provide information on year-class strength. The terminal year of 2019 was chosen based on likelihood profiling, which showed that recruitment deviations in 2020-2021 were informed poorly by the data, but 2019 and earlier are estimable (SEDAR76-WP07 2023). Recruitment in 2020 and 2021 was assumed to be the arithmetic average of recruitment from 2014–2019. Without data to inform estimation of recruitment in 2020-2021, these estimates are essentially forecasts. Using estimates nearest in time to forecast these values is consistent with analysis of autocorrelation in recruitment (Wade et al. 2023) and with the SAFMC SSC's report of April, 2022 titled "SSC Catch Level Projections Workgroup". The time period 2014–2019 was selected by a change point analysis that showed a break-point in 2014.

The modification from the Beverton-Holt stock recruitment relationship used in SEDAR 56 was made for a few reasons. First, the likelihood profile of steepness revealed that there was little change in likelihood over a wide range of values of steepness, indicating that the parameter was poorly informed by the data. Additionally, investigation of individual components of the profile showed that each data source was best fit at either the highest or lowest and the estimated minimum was not supported by any data source. This result is not surprising, as steepness is often difficult to estimate reliably (Conn et al. 2010). Second, the recommendation for the CAPAM best practices workshop suggested that the best method for estimating recruitment was to use a mean model when there was no strong proof of a stock recruitment relationship. Third, the Assessment Panel was concerned that the recent low recruitment would be overly influencing the estimate of steepness because there was only estimates of recruitment from small SSB in recent years. Additionally, these estimates of recruitment in recent years were all below the expected curve indicating that steepness is poorly estimated and may be due to other factors not related to the spawning stock biomass estimates. Finally, the terms of reference state "include any newly available information on steepness for similar species", but no new information are available. Recent SEDAR assessments such as red snapper (SEDAR 73) and scamp (SEDAR 68) have used a constant recruitment model in the absence of strong evidence to support a stock recruitment relationship.

3.3.9 Landings

The model included time series of landings from five fleets: commercial lines, commercial pots, commercial trawls, headboat, and general recreational (charterboat and private boats combined). The commercial trawl time series was used through 1990. Trawling was banned in January, 1989 within federal waters of the SAFMC's jurisdiction, but appears to have continued for another two years.

Landings were modeled with the Baranov catch equation (Baranov 1918) and were fitted in units of weight (1000 lb whole weight). Observed landings were provided back to the first assessment year (1978) for each fleet except general recreational, because the MRIP started in 1981. Thus for years 1978–1980, general recreational landings were predicted in the assessment model (but not fitted to data), by applying the geometric mean recreational F from the years 1981–1983.

3.3.10 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 discard mortality probabilities. Discards were assumed to have gear-specific mortality probabilities, as suggested by the Assessment panel described in §2.2.1. Annual discard mortalities, as fitted by the model, were computed by multiplying total discards by the gear-specific discard mortality probability.

For the commercial fleets, open and closed season discards from line and pot gears were combined, and were modeled starting in 1984 with implementation of the 8-inch size limit (TL). Commercial discards prior to 1984 were considered negligible and not modeled. Data on commercial discards were available starting in 1993. Thus for years 1984–1992, commercial discards were predicted in the assessment model (but not fitted to data), by applying the geometric mean commercial discard F from the years 1993–1998 (the 10-inch limit began in 1999). Closed season discards from the commercial pot gear from 2013–2021 were treated as open season discards.

For headboat and general recreational fleets, discard time series were assumed to begin in 1978, as observations from MRIP indicated the occurrence of recreational discards prior to implementation of the 8-inch size limit. Headboat discard estimates were separated from MRIP beginning in 1986, and were combined for 1978–1985. Because MRIP began in 1981, the 1978–1980 general recreational (plus headboat) discards were predicted in the assessment model (but not fitted to data), by applying the geometric mean recreational discard F from the years 1981–1983.

3.3.11 Fishing

For each time series of landings and discard mortalities, 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. Apical F was computed as the maximum of F at age summed across fleets.

3.3.12 Selectivities

Selectivity curves applied to landings, MARMAP, SERFS survey gears, and the last two periods of recreational discards were estimated using a parametric approach. This approach applies plausible structure on the shape of the selectivity curves, and achieves greater parsimony than occurs with unique parameters for each age. Selectivities of landings from all fleets were modeled as flat-topped, using a two-parameter logistic function, as was selectivity of MARMAP trap gears. The selectivity for the SERFS trap gear was fit by a four-parameter double logistic that resulted in a dome shape relative to the commercial fishery. The dome-shaped selectivity was chosen by the Assessment Panel because it resulted in a large improvement in the fit to the data, the parameter estimates were supported by likelihood profiles, and the resulting biomass estimates were not significantly altered. The Assessment Panel had extensive discussion about the difference between availability and contact selectivity, differences in fishing methods (e.g., soak time and gear configuration) between the commercial pots fleet and survey, and behavioral differences that could potentially cause a domed-shaped selectivity, but decided to choose this curve based on statistical principles of better model fit.

Selectivity of each fleet was fixed within each block of size-limit (in TL) regulations, but was permitted to vary among blocks where possible or reasonable. Commercial fisheries experienced four blocks of size-limit regulations: no limit prior to 1984, 8-inch limit during 1984–1998, 10-inch limit during 1999–2012, and 11-inch limit during 2013-2021. Recreational fisheries experience five blocks of size-limit regulations, which were the same as those of the commercial fisheries until 2007 with a 12-inch size limit implemented until 2012. From 2012-2021, a 13-inch size limit was in effect for the recreational fisheries.

Age and length composition data are critical for estimating selectivity parameters, and ideally, a model would have sufficient composition data from each fleet over time to estimate distinct selectivities in each period of regulations. That was not the case here, and thus additional assumptions were applied to define selectivities as follows. Because no age and very few length composition data were available from commercial trawls, selectivity of this fleet was assumed equal to the commercial pots. With no composition data from commercial fleets prior to regulations, commercial line selectivities in the first and second regulatory blocks were set equal, as were commercial pot selectivities, consistent with the SEDAR 25 DW recommendation that the 8-inch size limit had little effect on commercial fishing. Length and age composition data from both the headboat and general recreational fleets were sufficient to estimate selectivities in each time block.

Selectivities of commercial discards were assumed to be dome-shaped. They were partially estimated, assuming that discards consisted primarily of undersized fish, as implied by observed length compositions of discards. The general approach taken was that age-specific values for ages 0–2 were estimated, age 3 was assumed to have full selection, and selectivity for each age 4^+ was set equal to the age-specific probability of being below the size limit, given the estimated normal distribution of size at age. In this way, the descending limb of discard selectivities would change with modification in the size limit. The exception to the above approach was in years 2009–2013, when the commercial quota was exceeded resulting in a closure. For those years, commercial discard selectivity included fish larger than the size limit that were released during the closed season. The commercial discard selectivity for these years was computed as the combined selectivities of sublegal-sized fish and landed fish from commercial lines and pots, weighted by the mean of fleet-specific observed discards or landings.

Similarly, selectivities of recreational discards were assumed to be dome-shaped. They were partially estimated, assuming that discards consisted primarily of undersized fish, as implied by observed length compositions of discards. The general approach taken for the first two time blocks was that age-specific values for ages 0–2 were estimated, age 3 was assumed to have full selection, and selectivity for each age 4^+ was set equal to the age-specific probability of being below the size limit, given the estimated normal distribution of size at age. In this way, the descending limb of discard selectivities would change with modification in the size limit. In the third and fourth time block, there were sufficient length compositions to estimate a logistic exponential, dome-shaped selectivity with age 3 fully selected.

3.3.13 Indices of abundance

The model was fit to two fishery independent indices of relative abundance (MARMAP blackfish/snapper traps (1981–1987) and SERFS CVID (1990–2021)) and two fishery dependent indices (headboat 1979–2010 and commercial lines 1993–2009) (Figure 3). Predicted indices were conditional on selectivity of the corresponding fleet or survey and were computed from abundance or biomass (as appropriate) at the midpoint of the year. All indices were significantly positively correlated.

3.3.14 Catchability

In the BAM, catchability scales indices of relative abundance to estimated population abundance at large. Several options for time-varying catchability were implemented in the BAM following recommendations of the 2009 SEDAR procedural workshop on catchability (SEDAR Procedural Guidance 2009). In particular, the BAM allows for density dependence, linear trends, and random walk, as well as time-invariant catchability. Parameters for these models could be estimated or fixed based on *a priori* considerations. Catchability of the two fishery dependent indices varied over time, and was modeled with a random walk (Wilberg and Bence 2006; SEDAR Procedural Guidance 2009; Wilberg et al. 2010). This was consistent with SEDAR 56, but was a modification from the SEDAR 25 benchmark, which assumed constant catchability for all indices.

3.3.15 Biological reference points

Biological reference points (benchmarks) were calculated based on maximum sustainable yield (MSY) estimates from the mean recruitment model with bias correction (expected values in arithmetic space). Computed benchmarks included MSY, fishing mortality rate at MSY (F_{MSY}), and spawning stock at MSY (SSB_{MSY}). In this assessment, spawning stock measures population fecundity of mature females. 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 fishery (including discard mortalities) estimated as the full F averaged over the last three years of the assessment.

3.3.16 Fitting criterion

The fitting criterion was a penalized likelihood approach in which observed landings and discards were fit closely, and observed composition data and abundance indices were fit to the degree that they were compatible. Landings, discards, and index data were fitted using lognormal likelihoods. Length and age composition data were fitted using the Dirichlet-multinomial distribution, with sample size represented by the annual number of trips, adjusted by an estimated variance inflation factor.

The SEDAR 25 benchmark and update fit composition data using the multinomial distribution, and many SEDAR assessments since then have applied a robust version of the multinomial likelihood, as recommended by Francis (2011). More recent work has questioned use of the multinomial distribution in stock assessment models (Francis 2014), and of the alternative distributions, two appear most promising, the Dirichlet-multinomial and logistic-normal (Francis 2017; Thorson et al. 2017). Both are self-weighting and therefore iterative re-weighting (e.g., Francis 2011) is unnecessary, and both better account for intra-haul correlations (i.e., fish caught in the same set are more alike in length or age than fish caught in a different set). The effectiveness of the Dirichlet-multinomial distribution for composition data has been demonstrated through simulation studies and applications (Fisch et al. 2021; 2022). The Dirichlet-multinomial has become the standard likelihood for fitting composition data in assessments of South

Atlantic reef fishes since SEDAR 41 and is implemented in Stock Synthesis (Methot and Wetzel 2013; Thorson et al. 2017) and in the BAM. This assessment used the Dirichlet-multinomial distribution in the base run as in SEDAR 56.

The model includes the capability for each component of the likelihood to be weighted by user-supplied values. When applied to landings and indices, these weights modified the effect of the input CVs. In this application to black sea bass, CVs of landings and discards (in arithmetic space) were assumed equal to 0.05 to achieve a close fit to these data while allowing some imprecision. In practice, the small CVs are a matter of computational convenience, as they help achieve a close fit to the landings, while avoiding having to solve the Baranov equation iteratively (which is complex when there are multiple fisheries). Weights on other data components (indices) were adjusted iteratively, starting from initial weights as follows. These initial weights were then adjusted in an attempt to achieve standard deviations of normalized residuals (SDNRs) near 1.0. This iterative reweighting failed to converge to reasonable estimates and resulted in unreasonable fits to some data sources. Consequently, to remain consistent with the SEDAR 25 benchmark and SEDAR 56 a weight of 2.5 was applied to all four indices, in accordance with the principle that abundance data should be given primacy (Francis 2011).

In addition, a lognormal likelihood was applied to the spawner-recruit relationship. The compound objective function also included several penalties or prior distributions, applied to CV of growth (based on the empirical estimate), and selectivity parameters. Penalties or priors were applied to maintain parameter estimates near reasonable values, and to prevent the optimization routine from drifting into parameter space with negligible gradient in the likelihood.

3.3.17 Configuration of base run

The base run was configured as described above. However, the base run configuration was not considered to represent all uncertainty. Sensitivities, retrospective analysis, and a MCBE analysis was conducted to better characterize the uncertainty in base run point estimates.

3.3.18 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, and not all were considered equally plausible. Sensitivity runs vary from the base run as follows.

- M High: High natural mortality $M = 0.60$ used to scale the Lorenzen (2022) age-based estimator.
- M Low: Low natural mortality $M = 0.22$ used to scale the Lorenzen (2022) age-based estimator.
- Trap Only: The chevron trap index rather than the CVID index.
- Trap then Vid: The chevron trap index for 1990–2010 and then the SERFS video index for 2011–2021.
- Trap & Vid: The SERFS chevron trap and video index trap fit separately each with half the weight of the base model.
- Weighted Sel: CVID selectivity determined by average of logistic video and domed chevron trap weighted by the inverse of the process error estimated by the Conn method.
- Logistic Sel: Assumed logistic selectivity for the CVID index.
- Continuity: Continuity configuration using SEDAR 56 configurations including selectivity time blocks, logistic CVID selectivity, and Beverton-Holt stock recruitment.
- Discard High: High rates of discard mortality three times the base level for all fisheries.
- Discard Low: Low rates of discard mortality half the base level for all fisheries.

3.4 Retrospective Analysis

A retrospective analysis was run by incrementally dropping one year at a time for five iterations making the terminal years 2020, 2019, 2018, 2017, and 2016. Going further back in time was not possible due to using the average recruitment for 2014 to the terminal year as the recruitment in the last 2 model years. The purpose of these runs is to examine whether there is serial over- or under-prediction in the terminal year estimate, as compared to the full time series (i.e., through 2021). Note that there was no SERFS index for 2020 so the first peel did not have an index for the terminal year.

3.5 Parameters Estimated

The model estimated annual fishing mortality rates of each fleet, selectivity parameters, Dirichlet-multinomial variance inflation factors, catchability coefficients associated with indices, parameters of the spawner-recruit model, annual recruitment deviations, and CV of size at age.

3.6 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F, as were equilibrium landings, discards, and spawning biomass. Equilibrium landings and discards were also computed as functions of biomass B, which itself is a function of F. As in computation of MSY-related benchmarks (described in §3.7), 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 (2019–2021).

3.7 Benchmark/Reference Point Methods

In this assessment of black sea bass, the quantities F_{MSY}, $\mathrm{SSB}_{\mathrm{MSY}}$, B_{MSY}, and MSY were estimated by the method of Shepherd (1982). In that method, the point of maximum yield is identified from the spawner-recruit curve and parameters describing growth, natural mortality, maturity, and selectivity. The value of F_{MSY} is the F that maximizes equilibrium landings.

On average, expected recruitment is higher than that estimated directly from the spawner-recruit curve, because of lognormal deviation in recruitment. Thus, in this assessment, the method of benchmark estimation accounted for lognormal deviation by including a bias correction in equilibrium recruitment. The bias correction (ς) was computed from the variance (σ_R^2) of recruitment deviation in log space: $\varsigma = \exp(\sigma_R^2/2)$. Then, equilibrium recruitment (R_{eq}) associated with any F is,

$$R_{eq} = \varsigma R_0 \quad (1)$$

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_{MSY} is the F giving the highest ASY (excluding discards), and the estimate of MSY is that ASY. The estimate of $\mathrm{SSB}_{\mathrm{MSY}}$ follows from the corresponding equilibrium age structure, as does the estimate of discard mortalities (D_{MSY}), here separated from ASY (and consequently, MSY).

Estimates of MSY 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 (2019–2021). If the selectivities or relative fishing mortalities among fleets were to change, so would the estimates of MSY and related benchmarks.

The maximum fishing mortality threshold (MFMT) is defined by the SAFMC as F_{MSY}, and the minimum stock size threshold (MSST) as MSST $= (1 - M)\text{SSB}_{\text{MSY}}$ (Restrepo et al. 1998), with constant M in the base model equated to 0.375. Overfishing is defined as $F >$ MFMT and overfished as SSB $<$ MSST. However, if the stock is overfished, the rebuilding target would be SSB_{MSY}. Current status of the stock is represented by SSB in the latest assessment year (2021), and current status of the fishery is represented by the geometric mean of F from the latest three years (2019–2021). 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.

3.8 Uncertainty and Measures of Precision

For the base run of the catch-age model (BAM), uncertainty in results and precision of estimates was computed more thoroughly through a mixed Monte-Carlo Bootstrap Ensemble (MCBE) approach. 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 (Restrepo et al. 1992; Legault et al. 2001) and many South Atlantic SEDAR assessments since SEDAR4 (2004). The approach is among those recommended for use in SEDAR assessments (SEDAR Procedural Guidance 2010).

The approach translates uncertainty in model input into uncertainty in model output, by fitting the model many times with different values of "observed" data and key input parameters. A chief advantage of the approach is that the results describe a range of possible outcomes, so that uncertainty is characterized more thoroughly than it could be by any single fit or handful of sensitivity runs (Scott et al. 2016; Jardim et al. 2021; Ducharme-Barth and Vincent 2022). A minor disadvantage of the approach is that computational demands are relatively high, though parallel computing can somewhat mitigate those demands.

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 at least 3000 runs were desired, and it was anticipated that not all runs would be valid. Of the 4000 trials, approximately 1.85% were discarded, based on a non-positive definite hessian, a large maximum gradient, or parameter estimates close to the bounds. This left $n = 3926$ trials used to characterize uncertainty, which was sufficient for convergence of standard errors in management quantities.

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.

3.8.1 Bootstrap of observed data

To include uncertainty in time series of observed landings, discards, and indices of abundance, multiplicative lognormal errors were applied through a parametric bootstrap. To implement this approach in the MCBE trials, random variables ($x_{s,y}$) were drawn for each year y of time series s from a normal distribution with mean 0 and variance $\sigma^2_{s,y}$ [that is, $x_{s,y} \sim N(0, \sigma^2_{s,y})$]. Annual observations were then perturbed from their original values ($\hat{O}_{s,y}$),

$$O_{s,y} = \hat{O}_{s,y}[\exp(x_{s,y} - \sigma^2_{s,y}/2)] \tag{2}$$

The term $\sigma^2_{s,y}/2$ is a bias correction that centers the multiplicative error on the value of 1.0. Standard deviations in log space were computed from CVs in arithmetic space, $\sigma_{s,y} = \sqrt{\log(1.0 + CV^2_{s,y})}$. As used for fitting the base run, CVs of commercial landings were assumed to be 0.05. The CVs for recreational landings and both commercial and recreational discards were those provided by the data providers or from Assessment Panel consensus (see Table 5). The CVs of indices of abundance were those provided by, or modified from, the data providers (see Table 6).

Uncertainty in age and length compositions were included by drawing new distributions for each year of each data source, following a multinomial sampling process. Ages (or lengths) of individual fish were drawn at random with replacement using the cell probabilities of the original data. For each year of each data source, the number of individuals sampled was the same as in the original data (number of fish), and the effective sample sizes used for fitting (number of trips) was unmodified.

3.8.2 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.

3.8.2.1 Natural mortality

In each model run, the vector of age-specific natural mortality (Lorenzen estimator) was scaled to an age-invariant M, as was done for the base run. Two sources of natural mortality estimates were used to determine the range values that created the final distribution in the MCBE analysis. The first source of estimates were from Hamel and Cope (2022) that estimated M as

$$log(M) = a * log(T_{max}) \tag{3}$$

To estimate uncertainty in a, we acquired the data of Then et al. (2014) and conducted a bootstrap of $n = 4,000$ iterations, drawing from the original data set with replacement. For each iteration, one of the 4,000 fits was used as the value of a and T_{max} was drawn from a normal distribution with a mean of 11 and a standard deviation of 1. This resulted in an upper 95$^{\text{th}}$ quantile of 0.6 which was used as the upper bound of the uniform distribution in the MCBE. The second source of M values were estimated from an MCBE analysis that estimated natural mortality within the BAM that was scaled to M at age. Models that estimated M with BAM were considered to be plausible, but were not considered to be a sufficient base model because the estimates of M were not informed to a large degree by the age composition. These estimates of M were lower than those obtained from Hamel and Cope (2022) and the lower 5$^{\text{th}}$ quantile from this distribution of 0.22 was used as the lower bound in the final MCBE. Thus, for the 4000 iterations of the MCBE analysis a single value of natural mortality was drawn from a uniform distribution, $M \sim U[0.22, 0.6]$, which was then scaled by the inverse length to provide the natural mortality at age vector.

3.8.2.2 Discard mortalities

Similarly, discard mortalities δ were subjected to Monte-Carlo variation as follows. Based on discussion with the Assessment panel the 5$^{\text{th}}$ and 95$^{\text{th}}$ percentiles of the discard mortality rates were determined to be half and three times the rate used in SEDAR 56 for each fishery, respectively. These quantiles were then fit to a gamma distribution to determine the parameters that best matched these assumptions. A new value for the discard mortalities for all fishing gears except the pots with 2" mesh were drawn for each MCBE trial from truncated gamma distributions where the lower bound was 0.45 times the base estimate and the upper bound was 3.3 times the base estimate. The estimate for the 2" mesh pot gear was calculated as 0.483 times the value drawn for the 1.5" mesh (Rudershausen et al. 2008).

3.8.2.3 Weighting of indices

In the base run, external weights applied to four indices (commercial, headboat, MARMAP blackfish/snapper, and SERFS CVID) were adjusted upward to a value of $\omega = 2.5$. In MCBE trials, that weight was drawn from a uniform distribution with bounds at $\pm 25\%$ of 2.5.

3.8.2.4 **Recreational Landings and Discards CVs** The recreational landings and all discards were allowed to vary based on the CV provided. If no CV was provided, fleet experts were consulted to determine a CV appropriate for the fleet and year. For example, the headboat program coordinator provided assumed CVs for the headboat landings and discards data. The 5% and 95% confidence intervals were used to calculate the lower and upper bound for each distribution.

3.9 Projections—Probabilistic Analysis

Projections were run to predict stock status in years after the assessment as requested in the TORs. Because this assessment found the stock to be overfished, these long-term projections were run using $F = 0$ to determine a rebuilding time frame.

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 selectivity, were fixed to the most recent values of the assessment period. A single selectivity curve was applied to calculate landings, and one applied to calculate dead discards, each computed by averaging selectivities across fleets using geometric mean Fs from the last three years of the assessment period, similar to the computation of MSY benchmarks (§3.7).

Expected values of SSB (time of peak spawning), F, recruits, landings, and discards were represented by deterministic projections using parameter estimates from the base run. These projections applied long-term average or recent average recruitment with bias correction, depending on the scenario. Only the long-term average would be consistent with estimated benchmarks in the sense that long-term fishing at F_{MSY} would yield MSY from a stock size at $\mathrm{SSB}_{\mathrm{MSY}}$. Uncertainty in future time series was quantified through stochastic projections that extended the Monte-Carlo Bootstrap Ensemble (MCBE) fits of the stock assessment model.

3.9.1 Initialization of projections

Initial age structure at the start of 2022 was computed by applying the 2021 age-dependent mortality (Z_a) to the 2021 abundance at age N_a, where both Z_a and N_a in 2021 were estimated by the assessment. The recent mean recruitment from each MCBE iteration were retained as the recruitment values for 2020 and 2021 and carried forward to initialize the 2022 abundance at age using the estimated mortality.

Fishing rates that define the projections were assumed to start in 2025. Because the assessment period ended in 2021, the projections required an initialization period (2022–2024). For this period, an optimization routine solved for the F that matched the current level of landings (arithmetic mean of 2019-2021), but was set a maximum fishing mortality rate of 10 if the estimates were larger than this threshold. In addition, recruitment in 2022 was assumed equal to the recent average (lower than the long-term, expected recruitment). The recent average recruitment in 2022 was assumed because recruitment estimates are often autocorrelated and best predicted in the short-term by using recent estimates of recruitment deviates (Van Beveren et al. 2021; Wade et al. 2023). Starting in 2023, recruitment either returned to the long-term average or stayed at the recent average, depending on the scenario. Projections with the long-term average recruitment make the assumptions that the recruitment process will return to the long-term average condition within a few years. Conversely, projections using the recent average recruitment make the assumption that the recruitment processes with continue at the recent low levels indefinitely, which implicitly assumes a regime shift.

3.9.2 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 in natural mortality, indices, landings, discards, and discard mortality, as well as in estimated quantities such as mean recruitment, selectivity curves, and initial (start of 2022) 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 is 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 is 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.

3.9.3 Rebuilding Time Frame and Generation Time

Based on the overfished stock status estimated by this assessment, black sea bass would enter a rebuilding plan. The projections with $F = 0$ are intended to help determine an appropriate rebuilding time-frame. In addition, the generation time was computed given the life-history characteristics of black sea bass and was found to be 6 years.

3.9.4 Projection Scenarios

Four projection scenarios were considered for this report.

- Scenario 1: $F = 0$, with long-term average recruitment starting 2023
- Scenario 2: $F = 0$, with recent average recruitment
- Scenario 3: $F = F_{\text{current}}$, with recent average recruitment
- Scenario 4: $F = F_{\text{MSY}}$, with recent average recruitment

The F_{current} is defined as the recent (2019–2021) average F estimated by the assessment. The long-term average recruitment scenarios assume that recruitment will return to the long-term average starting in 2023. The recent average recruitment scenarios use the arithmetic average recruitment from 2014–2019, which was also assumed in the assessment for 2020–2021. For the deterministic projections, that arithmetic mean was applied directly; for the stochastic projections, it was adjusted to be median unbiased prior to applying lognormal deviations.

4 Stock Assessment Results

4.1 Measures of Overall Model Fit

The Beaufort assessment model (BAM) fit well to the available data. Predicted length compositions from each fishery were reasonably close to observed data in most years (Figures 4 to 9), as were predicted age compositions (Figures 10 to 14). There was some over estimation of fish below the size limit in the last year of length comps. However, these years had small sample sizes that were overpowered by the age composition data and numerous other models attempting to better fit the length composition data performed worse. The model was configured to fit observed commercial and recreational landings closely (Figures 15 to 19), as well as observed discards (Figures 20 to 22). Fits to indices of abundance generally captured the observed trends but not all annual fluctuations (Figures 23 to 26).

4.2 Parameter Estimates

Estimates of all parameters from the catch-age model are shown in §B. Estimates of management quantities and some key parameters are reported in sections below.

4.3 Stock Abundance and Recruitment

Estimated abundance at age shows a decline until 1992, a leveling off through the mid-2000s, and an increase due to high recruitment in 2008 through 2010 (Figure 27 and Table 8). Total estimated abundance at the end of the assessment period showed a sharp decline since 2010. Annual number of recruits is shown in Table 8 (age-0 column) and in Figure 28. In the most recent two decades, a notably strong year class (age-0 fish) was predicted to have occurred in 2009, but since 2012 recruitment was lower than average with the final eight years being the lowest predicted for the whole assessment time period.

4.4 Total and Spawning Biomass

Estimated biomass at age followed a similar pattern as abundance at age (Figure 29 and Table 9). Total biomass and spawning biomass showed similar trends—general decline from early 1980s until the mid-1990s, a relatively stable period from 1993–2006, an increase from 2007–2011 followed by a precipitous decline (Figure 30 and Table 10).

4.5 Selectivity

Estimated selectivities of the two fishery-independent gears were both fully selected at age 3 but selectivity for the SERFS index declined after this age (Figures 31 and 32). Selectivities of landings from commercial and recreational fleets are shown in Figures 33 and 34. In general, selectivities shift toward older ages with increased size limits. In the most recent years, full selection occurred near age-6 for most gears, and age-8 for the general recreational fleet.

Selectivity of discard mortalities from commercial fleets was mostly on age-2 and age-3 fish, with relatively low selection of age-1 and age-4 fish (Figure 35). In 2009–2013, commercial discard selectivities included more older fish (fish of legal size), accounting for black sea bass caught during closed seasons, mostly from lines. Selectivity of discard mortalities from the headboat and general recreational fleets was mostly of age-2 and age-3 fish. However, since 2007 selectivity on headboat discard mortality included more older fish with the increasing size limits (Figure 35).

Average selectivities of landings and of discard mortalities were computed from F-weighted selectivities in the most recent period of regulations (Figure 36). These average selectivities were used to compute benchmarks. All selectivities from the most recent period, including average selectivities, are tabulated in Table 11.

4.6 Fishing Mortality, Landings, and Discards

The estimated fishing mortality rates (F) increased until the mid 1980s, were stable through the 1990s and generally increased starting in 2004 reaching a peak in 2014 (Figure 37). Since then, the fishing mortality due to landings have remained above 1 with variability. The general recreational fleet has been the largest contributor to total F with large contributions from discard mortality in the last 7 years (Table 12). Fishing mortality for age 6 and older has increased since 2012, while fishing mortality on age 5 has decreased slightly. The introduction of larger size limits in 1999, 2006, and 2012 resulted in a decrease in fishing mortality on one age class but an increase for all other ages (Figure 38).

Estimates of total F at age are shown in Table 13. 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 a result of full selection occurring at different ages among gears.

Table 14 shows total landings at age in numbers, and Table 15 in weight. In general, the majority of estimated landings were from the recreational sector, i.e., headboat and general recreational fleets (Figures 39 and 40 and Tables 16 and 17). Estimated discard mortalities were on the same scale in terms of weight but was more than double in terms of numbers of fish in recent years (Figure 44 and Tables 18 and 19)

4.7 Spawner-Recruitment Parameters

The mean recruit relationship and variability around that mean are shown in Figure 45. Values of recruitment-related parameters were as follows: unfished age-0 recruitment $\widehat{R_0} = 70,839,380$, and standard deviation of recruitment residuals in log space $\widehat{\sigma_R} = 0.54$ (which resulted in bias correction of $\varsigma = 1.15$). Uncertainty in these quantities was estimated through the Monte-Carlo Bootstrap Ensemble (MCBE) analysis (Figure 46).

4.8 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F (Figure 47). As in computation of MSY-related benchmarks, per recruit analyses applied the most recent selectivity patterns averaged across fleets, weighted by F from the last three years (2019–2021).

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of F (Figure 48). By definition, the F that maximizes equilibrium landings is F_{MSY}, and the corresponding landings and spawning biomass are MSY and $\mathrm{SSB}_{\mathrm{MSY}}$.

4.9 Benchmarks / Reference Points

As described in §3.7, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the mean-unbiased recruitment (Figure 45). Reference points estimated were F_{MSY}, MSY, B_{MSY} and $\mathrm{SSB}_{\mathrm{MSY}}$. Based on F_{MSY}, an optimum yield (OY) of $F_{\mathrm{OY}} = 75\% F_{\mathrm{MSY}}$, and the corresponding yield was computed. Standard errors of benchmarks were approximated as those from MCBE analysis (§3.8).

Maximum likelihood estimates (base run) of benchmarks, as well as median values from MCBE analysis, are summarized in Table 20. Point estimates of MSY-related quantities were $F_{\mathrm{MSY}} = 0.43$ (y^{-1}), MSY = 959.85 (1000 lb), $B_{\mathrm{MSY}} = 22193.12$ (1000 lb), and $\mathrm{SSB}_{\mathrm{MSY}} = 407.61$ (1E10 eggs). Median estimates were $F_{\mathrm{MSY}} = 0.37$ (y^{-1}), MSY = 911.56 (1000 lb), $B_{\mathrm{MSY}} = 27725.96$ (1000 lb), and $\mathrm{SSB}_{\mathrm{MSY}} = 480.84$ (1E10 eggs). Distributions of these benchmarks from the MCBE analysis are shown in Figure 50.

4.9.1 Status of the Stock and Fishery

Estimated time series of stock status (SSB/MSST and SSB/$\mathrm{SSB_{MSY}}$) showed general decline until the mid-1990s, followed by a marginal increase until 2011 and since then decreased to below 1 (Figure 51 and Table 10). The increase in stock status appears to have been initiated by strong year classes in 2008 to 2010. The decline in stock status since appears to be due to decreased recruitment but coincides with changes in management regulations. Base-run estimates of spawning biomass have remained near MSST and below $\mathrm{SSB_{MSY}}$ since the early 1990s, increased substantially from 2008 to 2011, and then decreased again in the last ten years. Current stock status was estimated in the base run to be $\mathrm{SSB_{2021}/MSST} = 0.32$ and $\mathrm{SSB_{2021}/SSB_{MSY}} = 0.2$ (Table 20), indicating that the stock is overfished. Uncertainty from the MCBE analysis suggested that the estimate of SSB relative to $\mathrm{SSB_{MSY}}$ is robust and that the status relative to MSST is also certain (Figures 52 and 53). More specifically, 100% of MCBE runs indicate the stock is below $\mathrm{SSB_{MSY}}$ and MSST indicating an overfished status. Age structure estimated by the base run showed fewer fish of all ages in the last year than the (equilibrium) age structure expected at MSY (Figure 54).

The estimated time series of F/F_{MSY} suggests that overfishing has been occurring throughout most of the assessment period (Table 10), but with much uncertainty demonstrated by the MCBE analysis (Figure 51). However, the fishery benchmark is based on the last three years of selectivity and fishing mortality, and may not be appropriate to compare to earlier years as the selectivity and the proportional contributions of the fleets to the total fishing mortality have changed through time. Current fishery status in the terminal year, with current F represented by the geometric mean from 2019–2021, was estimated by the base run to be $F_{2019-2021}/F_{\mathrm{MSY}} = 2.18$ (Table 20), and 84.2% of MCBE trials indicated that overfishing is occurring (Figures 52 and 53).

4.9.2 Comparison to previous assessment

Estimates from this assessment are compared to estimates from the previous four assessments for black sea bass (Figure 55). The declines in SSB/MSST during the 1990s seen in the previous assessments are absent from the current assessment. Additionally, the increase in SSB/MSST around 2010 is not as sudden as seen in the previous 2 assessments, but is a more gradual increase. The estimates of F/F_{MSY} from this assessment were lower than SEDAR 56 for most of the time series until 2012. This difference in the time series may be due to differences in the selectivities in the terminal year which would impact the F_{MSY} reference point.

4.10 Sensitivity and Retrospective Analysis

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. Sensitivity runs are a tool for better understanding model behavior, and therefore should not be used as the basis for management. All runs are not considered equally plausible in the sense of alternative states of nature. Time series of F/F_{MSY} and SSB/$\mathrm{SSB_{MSY}}$ demonstrate sensitivity to natural mortality (Figure 56), SEDAR 56 configuration (Figure 57), the CVT index (Figure 58), and discard mortality rate (Figure 59). The majority of these runs agreed with the status indicated by the base run (Figure 60 and Table 21). Results appeared to be most sensitive to natural mortality and discard mortality.

The retrospective analysis did not suggest any patterns of substantial over- or underestimation in terminal-year estimates of biomass, SSB or Apical F starting in 2021 (Figure 61). However, the analysis did reveal a pattern of overestimated recruitment in the terminal year despite being fixed at the recent average recruitment. Values of Mohn's ρ (a measure of retrospective pattern) are -0.27, 0.84, and 0.28 for F, recruits, and SSB time-series, respectively (Carvalho et al. 2021). The Mohn's ρ for SSB falls within the suggested a rule of thumb range (-0.22, 0.30) for shorter-lived species, which does not indicate an undesirable retrospective pattern.

4.11 Projections

Projections based on $F = 0$ and long-term, average recruitment allowed the spawning stock to increase quickly, achieving greater than 50% chance of recovery by 2028 and greater than 75% chance by 2031 (Figures 62 and 63 and Table 22). Thus, given that the stock can recover (probabilistically) within 10 years under $F = 0$, the rebuilding time-frame would equal 10 years. Assuming that the start year of a recovery plan would be 2025, the time frame of rebuilding would last until the end of 2034. However, based on $F = 0$ and recent average recruitment the spawning stock is never able to rebuild (Figures 64 and 65 and Table 23).

If the fishing rate remains at F_{current} and recruitment remains at recent average recruitment the spawning stock stays at low levels with no probability of rebuilding (Figure 66 and Table 24). Similarly, fishing at F_{MSY} with recent average recruitment also results in a 0% probability of rebuilding (Figure 67 and Table 25).

5 Discussion

The base run of the BAM indicated that the stock is overfished SSB/MSST = 0.32 and that overfishing is occurring $F/F_{\text{MSY}} = 2.18$. The MCBE analyses showed general agreement with the qualitative results of the base run. Of all MCBE runs, 100% showed that the stock is overfished, and 84.2% showed that overfishing is occurring. These results are also in agreement with most of the sensitivity runs. The uncertainty in the overfishing status appears to be driven primarily by uncertainty in natural mortality and discard mortality.

5.1 Comments on the Assessment

Estimated benchmarks played a central role in this assessment. Values of SSB_{MSY} and F_{MSY} were used to gauge the status of the stock and fishery. Computation of benchmarks was conditional on selectivity. If selectivity patterns change in the future, for example as a result of new size limits or different relative catch allocations among sectors, estimates of benchmarks would likely change as well.

The decreasing trend for biomass is dependent on what appears to be below average recruitment since 2014. The stock has been declining over the last several years of the assessment, and this decline will likely continue if recruitment remains low. These years of low recruitment followed shortly after the change in the minimum size limit for the commercial fishery to 11 inches and for the recreational fishery to 13 inches. In 2014 there was the highest level of discards for the time series, which was increasing since 2004. Additionally, the number of trips reported by the commercial fishery log books with no discards of any species has increased in recent years and has reached approximately 70% of all trip records. This resulted in a decrease in the estimated number of fish discarded from the commercial lines for the entire time series compared to the values used in SEDAR 56. A lack of reported discards from the commercial fisheries could appear as recruitment failure in the assessment model because these dead fish would not be recorded at all within the model. Similarly, if the discard mortality rates assumed within the assessment are an underestimate, as studies from other regions suggest (Zemeckis et al. 2020; Schweitzer et al. 2020; Rudershausen et al. 2020), then the model would treat a large portion of discarded fish as alive to be able to be caught in the future and would underestimate the fishing mortality due to this mortality source as seen in the sensitivities (Figure 59). There is also an apparent gap in selectivity for ages 4 through 6 for the general recreational discard during the most recent period. However, there could truly be a decrease in recruitment since 2014 that could be due to environmental causes not related to a decline in spawning stock. The recent low recruitment may or may not continue into the future. No mechanism for the recent low recruitment has been identified, but the duration (since 2014) has exceeded a single generation time. The possibility of sperm limitation was not accounted for, which could be exacerbated by focusing the fishing mortality from the recreational sector on the largest and oldest individuals most likely to be male. Determining the cause of this apparent decline in recruitment in the assessment will be critical for management decisions.

In general, most scientific studies of discard mortality are performed under ideal conditions and often focus on one-off experimental designs meant to isolate certain conditions. In practice there are many more and complicating factors that are likely to increase the final realized discard mortality for black sea bass and any other fish caught by hook gear. For example, studies conducted to determine the effectiveness of venting are done by biologist that have intimate knowledge of fish physiology, which may not be representative of the venting procedures conducted by commercial or recreational fishers. Furthermore, some discard mortality studies are limited to studies of short-term post-release time periods. Manifestation of the final discard mortality rate in practice may take months and is often beyond the scope of some studies. All of these factors suggests that discard mortality estimates have a potential to be biased low and thus underestimated.

In addition to more years of data, this operational assessment included several modifications to previous data and model assumptions. All composition data were updated and any needed corrections were made including the sample size of age and length compositions particularly the headboat discard length composition. Updated growth curves were influential on the fit to the length composition data and influenced natural mortality at age which was scaled by the inverse length at age. This model made the assumption of a domed shaped selectivity of the SERFS chevron trap index due to the better fit, which is likely due to behavioral and/or availability differences compared to the fisheries and not contact selectivity of the gear.

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, fishery dependent indices were not extended beyond 2010, because of the implementation of restrictive bag, trip, or size limits, along with seasonal closures. Such regulations change fisher behavior, thus altering the portion of the population or habitat represented by the logbook data that would be used to create an index of abundance. As such management measures become more common in the southeast U.S., the continued utility of fishery dependent indices in SEDAR stock assessments will be questionable. This situation amplifies the importance of fishery independent sampling.

Many assessed reef-fish stocks in the southeast U.S. have shown histories of heavy exploitation, and protogynous hermaphrodites such as black sea bass can be particularly vulnerable to overfishing (Coleman et al. 1999). High rates of fishing mortality can lead to changes in behavioral traits that affect natural mortality, such as boldness, or life-history characteristics, such as growth and maturity schedules (Devine et al. 2012; Claireaux et al. 2018). Although we have no direct evidence of such adaptations for black sea bass, there is mounting evidence that these fishery effects are common and have potential to destabilize fisheries (Kuparinen et al. 2016). 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).

Steepness could not be estimated reliably in this assessment, thus this assessment used a mean recruitment model. The MSY-based management quantities from the base model are conditional on the selectivity, maturity, fecundity, and proportion female (i.e., protogynous transition to males). If selectivity or proportion discard mortality to landing mortality were to change, then the MSY metrics would also change. An alternative approach would be to choose a proxy for F_{MSY}, most likely $F_{X\%}$ (such as $F_{40\%}$). However, such proxies do not provide biomass-based benchmarks. If managers wish to gauge stock status, assumptions about equilibrium recruitment levels would be necessary. When modeling recruitment with the Beverton-Holt model the choice of X% implies an underlying steepness (Brooks et al. 2010), thus, choosing a proxy equates to choosing the steepness.

5.2 Regime Shift

The pattern of low recruitment at the end of the time series raises the question of whether there has been a regime shift. The answer is important because a regime shift designation would imply that benchmarks should be based on the recent average recruitment rather than the long-term average, which would lower the target for rebuilding as well as lower the Acceptable Biological Catch. On the other hand, lack of a regime shift designation indicates that stock productivity should eventually return to its long-term average. In either case, short-term catch advice is likely to be more accurate if based on recent levels of recruitment (Van Beveren et al. 2021).

This assessment used the long-term average recruitment to define biomass benchmarks, after considering the possibility of a regime shift and concluding that there is insufficient evidence to support such a declaration. This conclusion was based on the criteria put forward by Klaer et al. (2015). Klaer et al. (2015) provided a scoring rubric with four categories, each receiving a score in the range of 0–4, in which higher scores are more consistent with productivity regime shifts than lower scores. They suggested that a total score of at least 7 supports acceptance of a regime shift.

The first category of Klaer et al. (2015) is "Observed change in a productivity indicator." For that category, this stock scored a 1 ("More than one generation"). The generation time is estimated to be about 6 years, and the recent low recruitment has occurred for one year longer. The second category is "Understanding of assessment model input data," for which this stock scored a 2 ("Uncertain model inputs have been characterised and plausible ranges for those uncertainties have been investigated"). The MCBE analysis incorporates uncertainties in model inputs. The third category is "Understanding of assessment model structural assumptions," for which this stock scored a 0 ("Key population parameters affect have not been identified"). Alternative models that fit a Beverton-Holt stock recruitment model also showed a trend of negative log deviates in recent years, though the magnitude of this negative trend was slightly less. Therefore, no model parameters were identified that would correct for this trend in the recruitment. The fourth category is "Explanatory hypothesis" for which this stock scored a 0 ("The mechanism is unknown"). Currently, no plausible mechanism for a productivity shift has been identified and the occurrence of these low recruits following directly after the most recent change in fishing regulations for the commercial and recreational fisheries is intriguing. Low recruitment has been demonstrated for multiple reef-fish stocks suggests the possibility of a common external driver (Wade et al. 2023). The total score of 3 does not meet the minimum required to support acceptance of a regime shift. Identifying a plausible mechanism for a productivity shift would likely allow for changes in the model structure to account for changes in key parameters and would be critical for declaring a regime shift. Determining whether a driver of poor recruitment is expected to remain in its current state or return to a long-term average (e.g., as with an oscillatory oceanographic pattern) would greatly aid the management decision making process.

5.3 Comments on the Projections

As usual, 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 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.
- Landings and discarding rates were assumed to continue at their estimated current proportions of total fishing mortality, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect projection results.

- The projections assumed no change in the selectivity applied to discards. As stock increase generally begins with the smallest size classes, management action may be needed to meet that assumption.
- The projections assumed that the 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 are in effect, introducing additional and unquantified uncertainty into the projection results.

5.4 Research Recommendations

- Results of this assessment are sensitive to natural mortality because it is highly correlated with the scale of the population (i.e., the R0 parameter). For this assessment, the range and age-dependence of natural mortality was estimated by an indirect method (Hamel and Cope 2022) and within BAM. Mark-recapture approaches (conventional, telemetry, close-kin) might make it possible to obtain direct estimates of natural mortality specific to black sea bass in the South Atlantic region. Some tag-recapture studies have demonstrated relatively high tag return rates for black sea bass, at least compared to those of other reef fishes of the southeast U.S.
- Further research on best methods and approaches to combine multiple estimates of discard mortality into a single population wide value would be beneficial. Additional experiments to estimate discard mortality in greater ranges of depths, locations, angler experience related to barotrauma mitigation techniques (venting and descender devices), and times of year to match fishing within the South Atlantic would better characterize the uncertainty in this critical parameter.
- More research is needed on the cause(s) of low recruitment in several South Atlantic reef-fish stocks, including black sea bass. This topic is currently being investigated by the SEFSC.
- The number of fish discarded by the commercial sector appears to be highly uncertain as seen by the shift in scale of estimates from SEDAR 56. Direct observation of fishing practices by observers or video are needed to determine reliable estimates of these sources of mortality to fish in the Southeast Atlantic Ocean.
- Establish a more comprehensive sampling program for ages and lengths of fish captured by the recreational fleet in all regions of the South Atlantic.
- Investigate the potential impact of sampling of age composition data from commercial catch by size class (small, medium, or large) on compositions used within the assessment model and if methods are needed to correct these data.
- Gather more depth data and discarding behavior (venting or descending device) from private boat anglers.
- The following are from SEDAR 56, and are still needed:

  The assessment panel recommended increasing the number of age samples collected from the general recreational sector.

  Black sea bass in the southeast U.S. were modeled in this assessment as a unit stock, as recommended by the DW and supported by genetic analysis (SEDAR 76-RD42). For any stock, variation in exploitation and life-history characteristics might be expected at finer geographic scales. Modeling such sub-stock structure would require more data, such as information on the movements and migrations of adults and juveniles, as well as spatial patterns of recruitment. Even when fine-scale spatial structure exists, incorporating it into a model may or may not lead to better assessment results (e.g., greater precision, less bias). Spatial structure in a black sea bass assessment model might range from the very broad (e.g., a single Atlantic stock) to the very narrow (e.g., a connected network of meta-populations living on individual reefs). What is the optimal level of spatial structure to model in an assessment of snapper-grouper species such as black sea bass?

Protogynous life history: 1) Investigate possible effects of hermaphroditism on the [recent low recruitment]; 2) Investigate the sexual transition for temporal patterns, considering possible mechanistic explanations if any patterns are identified; 3) Investigate methods for incorporating the dynamics of sexual transition in assessment models.

In this assessment, the number of spawning events per mature female per year assumed a constant value of $X = 31$. That number was computed from the estimated spawning frequency and spawning season duration. If either of those characteristics depends on age or size, X would likely also depend on age or size. For black sea bass, does spawning frequency or spawning season duration (and therefore X) depend on age or size? Such dependence would have implications for estimating spawning potential as it relates to age structure in the stock assessment.

For this assessment, the age-dependent natural mortality rate was estimated by indirect methods. More direct methods, e.g. tag-recapture, might prove useful. Some tag-recapture studies have demonstrated relatively high tag return rates for black sea bass, at least compared to those of other reef fishes of the southeast U.S.

6 References

Baranov, F. I. 1918. On the question of the biological basis of fisheries. Nauchnye Issledovaniya Ikhtiologicheskii Instituta Izvestiya **1**:81–128.

Brooks, E. N., J. E. Powers, and E. Cortes. 2010. Analytical reference points for age-structured models: application to data-poor fisheries. ICES Journal of Marine Science **67**:165–175.

Carvalho, F., H. Winker, D. Courtney, M. Kapur, L. Kell, M. Cardinale, M. Schirripa, T. Kitakado, D. Yemane, K. Piner, M. Maunder, I. Taylor, C. Wetzel, K. Doering, K. Johnson, and R. Methot. 2021. A cookbook for using model diagnostics in integrated stock assessments. Fisheries Research **240**:105959.

Claireaux, M., C. Jorgensen, and K. Enberg. 2018. Evolutionary effects of fishing gear on foraging behavior and life-history traits. Ecology and Evolution **8**:10711–10721.

Coleman, F. C., C. C. Koenig, A. Eklund, and C. B. Grimes. 1999. Management and conservation of temperate reef fishes in the grouper-snapper complex of the Southeastern United States. American Fisheries Society Symposium **23**:233–242.

Conn, P. B. 2010. Hierarchical analysis of multiple noisy abundance indices. Canadian Journal of Fisheries and Aquatic Sciences **67**:108–120.

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.

Devine, J. A., P. J. Wright, H. E. Pardoe, and M. Heino. 2012. Comparing rates of contemporary evolution in life-history traits for exploited fish stocks. Canadian Journal of Fisheries and Aquatic Sciences **69**:1105–1120.

Ducharme-Barth, N. D., and M. T. Vincent. 2022. Focusing on the front end: A framework for incorporating uncertainty in biological parameters in model ensembles of integrated stock assessments. Fisheries Research **255**:106452.

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.

Fisch, N., R. Ahrens, K. Shertzer, and E. Camp. 2022. An emprical comparison of alternative likelihood formualations for composition data, with application to cobia and Pacific hake. Canadian Journal of Fisheries and Aquatic Sciences **79**:1745–1764.

Fisch, N., E. Camp, K. Shertzer, and R. Ahrens. 2021. Assessing likelihoods for fitting composition data within stock assessments, with emphasis on different degrees of process and observation error. Fisheries Research **243**:106069.

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.

Hamel, O. S., and J. M. Cope. 2022. Development and considerations for application of a longevity-based prior for the natural mortality rate. Fisheries Research **256**:106477.

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

Hewitt, D. A., and J. M. Hoenig. 2005. Comparison of two approaches for estimating natural mortality based on longevity. Fishery Bulletin **103**:433–437.

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**.

Klaer, N. L., R. N. O'Boyle, J. J. Deroba, S. E. Wayte, L. R. Little, L. A. Alade, and P. J. Rago. 2015. How much evidence is required for acceptance of productivity regimeshifts in fish stock assessments: Are we letting managers off the hook? Fisheries Research **168**:49–55.

Kuparinen, A., A. Boit, F. S. Valdovinos, H. Lassaux, and N. D. Martinez. 2016. Fishing-induced life-history changes degrade and destabilize harvested ecosystems. Scientific Reports **6**:srep22245.

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. 2021. A comparison of four primary age-structured stock assessment models used in the United States. Fishery Bulletin **119**:149–167.

Lorenzen, K. 2022. Size- and age-dependent natural mortality in fish populations: Biology, models, implications, and a generalized legnth-inverse mortality paradigm. Fisheries Research **106454**.

Manly, B. F. J. 1997. Randomization, Bootstrap and Monte Carlo Methods in Biolog, 2nd edition. Chapman and Hall, London.

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.

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.

Restrepo, V. R., G. G. Thompson, P. M. Mace, L. L. Gabriel, L. L. Wow, A. D. MacCall, R. D. Methot, J. E. Powers, B. L. Taylor, P. R. Wade, and J. F. Witzig, 1998. Technical guidance on the use of precautionary approahces to implementing Natinoal Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum-F/SPO-31.

Rudershausen, P., M. Baker Jr., and J. Buckel. 2008. Catch rates and selectivity among three trap types in the U.S. South Atlantic Black Sea Bass commercial trap fishery. North American Journal of Fisheries Management **28**:1099–1107.

Rudershausen, P., J. Buckel, and J. Hightower. 2014. Estimating reef fish discard mortality using surface and bottom tagging: Effects of hook injury and barotrauma. Canadian Journal of Fisheries and Aquatic Sciences **71**:514–520.

Rudershausen, P. J., B. J. Runde, and J. A. Buckel. 2020. Effectiveness of Venting and Descender Devices at Increasing Rates of Postrelease Survival of Black Sea Bass. North American Journal of Fisheries Management **40**:125–132.

Schweitzer, C. C., A. Z. Horodysky, A. L. Price, and B. G. Stevens. 2020. Impairment indicators for predicting delayed mortality in black sea bass (*Centropristis striata*) discards within the commercial trap fishery. Conservation Physiology **8**:coaa068;.

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, 2009. SEDAR Procedural Guidance Document 2: Addressing Time-Varying Catchability.

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

SEDAR25, 2011. SEDAR 25: South Atlantic Black Sea Bass. SEDAR, North Charleston, SC.

SEDAR4, 2004. SEDAR 4: Stock assessment of the deepwater snapper-grouper complex in the South Atlantic. SEDAR, North Charleston, SC.

SEDAR56, 2018. South Atlantic Black Seabass Assessment Report. SEDAR, North Charleston SC.

SEDAR76-WP07, 2023. Diagnostics of the SEDAR76 Assessment model of black sea bass. SEDAR, North Charleston, SC.

Shepherd, J. G. 1982. A versatile new stock-recruitment relationship for fisheries, and the construction of sustainable yield curves. Journal du Conseil pour l'Exploration de la Mer **40**:67–75.

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.

Van Beveren, E., H. P. Benoit, and D. E. Duplisea. 2021. Forecasting fish recruitment in age-structured population models. Fish and Fisheries **22**:941–954.

Wade, K. J., K. W. Shertzer, J. K. Craig, and E. H. Williams. 2023. Correlations in recruitment patterns of Atlantic reef fishes off the southeastern United States based on multi-decadal estimates from stock assessments. Regional Studies in Marine Science **57**:102736.

Wilberg, M. J., and J. R. Bence. 2006. Performance of time-varying catchability estimators in statistical catch-at-age analysis. Canadian Journal of Fisheries and Aquatic Science **63**:2275–2285.

Wilberg, M. J., J. T. Thorson, B. C. Linton, and J. Berkson. 2010. Incorporating Time-Varying Catchability into Population Dynamic Stock Assessment Models. Reviews in Fisheries Science **18**:7–24.

Williams, E. H., and K. W. Shertzer, 2015. Technical documentation of the Beaufort Assessment Model (BAM). NOAA Technical Memorandum-NMFS-SEFSC-671.

Zemeckis, D. R., J. Kneebone, C. W. Capizzano, E. A. Bochenek, W. S. Hoffman, T. M. Grothues, J. W. Mandelman, and O. P. Jensen. 2020. Discard mortality of black sea bass (*Centropristis striata*) in a deepwater recreational fishery off New Jersey: role of swim bladder venting in reducing mortality. Fishery Bulletin **118**:105–119.

7 Tables

Table 3. Life-history characteristics at age, including average body length and weight (mid-year), annual fecundity per mature female (number batches X eggs per batch), proportion females mature, and natural mortality at age. The CV of length was estimated by the assessment model; other values were treated as input.

Age	Total length (mm)	Total length (in)	CV length	Whole wgt (kg)	Whole wgt (lb)	Fecundity (million eggs)	Fem. mat.	prop. fem.	M
0	111.2	4.4	0.09	0.02	0.05	0.08	0.00	0.963	1.205
1	172.9	6.8	0.09	0.08	0.17	0.10	0.52	0.918	0.775
2	224.3	8.8	0.09	0.16	0.36	0.16	0.90	0.827	0.598
3	267.1	10.5	0.09	0.26	0.58	0.28	0.98	0.671	0.502
4	302.8	11.9	0.09	0.37	0.83	0.49	1.00	0.465	0.443
5	332.4	13.1	0.09	0.49	1.07	0.89	1.00	0.270	0.403
6	357.1	14.1	0.09	0.59	1.30	1.56	1.00	0.136	0.375
7	377.7	14.9	0.09	0.69	1.52	2.65	1.00	0.063	0.355
8	394.9	15.5	0.09	0.78	1.72	4.27	1.00	0.028	0.340
9	409.1	16.1	0.09	0.86	1.90	6.56	1.00	0.012	0.328
10	421.0	16.6	0.09	0.93	2.06	9.56	1.00	0.005	0.318
11	430.9	17.0	0.09	1.00	2.19	13.29	1.00	0.002	0.311

Table 4. Observed time series of landings (L) and discards (D) for commercial lines (cl), commercial pots (cp), commercial historic trawl (ct), recreational headboat (hb), and general recreational (mrip). Landings are in units of 1000 lb whole weight, and discards are in units of 1000 fish. Discards include all released fish, live or dead.

Year	L.cl	L.cp	L.ct	L.hb	L.mrip	D.cl	D.cp	D.hb	D.mrip
1978	118.675	134.350	31.817	532.207	.	.	.	.	.
1979	140.539	676.696	27.327	571.238	.	.	.	.	.
1980	107.927	888.174	25.393	617.798	.	.	.	.	.
1981	163.821	1028.197	32.221	678.256	2083.662	.	.	.	2799.189
1982	150.879	788.173	20.623	701.364	3412.899	.	.	.	2116.559
1983	145.746	484.284	8.527	690.327	728.813	.	.	.	808.738
1984	194.532	410.419	17.778	661.070	3207.680	.	.	.	1748.292
1985	164.100	395.772	23.826	568.099	2242.316	.	.	.	1994.148
1986	163.256	502.508	22.346	536.798	1387.070	.	.	128.267	2591.027
1987	149.296	403.407	7.474	616.517	1294.955	.	.	648.190	1723.912
1988	236.629	513.731	21.177	635.222	981.124	.	.	1127.045	1665.745
1989	248.538	517.738	13.484	478.030	1590.486	.	.	81.276	1874.018
1990	258.736	684.587	13.576	379.573	799.444	.	.	5.087	1250.932
1991	267.179	616.552	.	286.239	1031.540	.	.	552.651	1630.799
1992	226.570	546.323	.	215.877	973.385	.	.	78.207	1418.359
1993	188.927	508.023	.	143.026	801.769	6.556	110.922	57.997	1558.912
1994	213.869	531.041	.	132.441	1042.036	8.183	153.908	233.270	2496.537
1995	141.466	413.274	.	127.625	601.636	8.075	143.233	112.271	1312.713
1996	128.008	511.790	.	146.543	1111.013	7.787	151.935	207.455	1578.402
1997	162.325	540.959	.	147.742	822.420	7.509	156.018	207.901	2021.473
1998	221.095	450.850	.	142.504	543.354	6.201	137.171	68.413	1670.236
1999	187.538	501.350	.	192.569	593.243	5.028	124.561	184.994	3215.790
2000	92.849	407.650	.	144.590	895.610	5.298	99.015	200.345	4518.202
2001	88.663	492.746	.	172.025	1442.772	5.849	112.426	273.389	4325.698
2002	97.985	419.811	.	123.275	809.604	9.858	68.883	147.872	3239.568
2003	91.588	484.243	.	134.111	859.599	2.224	159.078	140.682	3267.764
2004	107.121	626.498	.	237.586	2100.013	3.927	95.588	83.372	6004.849
2005	66.911	384.384	.	179.660	1501.321	5.248	87.289	52.788	5123.593
2006	62.169	483.272	.	174.066	1172.795	10.235	176.208	124.684	5696.108
2007	54.915	351.913	.	162.070	984.906	2.276	46.075	117.444	5733.885
2008	57.594	360.016	.	99.311	912.851	1.557	48.677	167.385	5859.493
2009	87.707	564.614	.	158.279	729.380	6.628	74.162	238.967	5127.075
2010	71.207	408.269	.	282.706	1467.502	3.781	26.643	334.806	6826.082
2011	46.373	342.497	.	226.260	1035.731	1.135	9.059	545.689	9931.153
2012	106.971	269.160	.	122.858	799.878	8.154	49.814	675.410	11244.270
2013	195.304	274.330	.	113.416	759.744	15.584	44.698	500.845	7113.257
2014	295.891	181.308	.	100.681	1712.894	16.630	38.167	470.873	15435.070
2015	152.330	171.621	.	76.446	982.490	6.806	26.877	462.935	11160.650
2016	160.266	103.900	.	64.533	791.531	7.202	11.078	444.760	10042.940
2017	141.014	194.797	.	52.780	1018.522	2.465	13.405	333.690	11379.210
2018	92.063	156.739	.	56.249	439.471	9.334	13.451	301.047	5870.268
2019	70.079	128.571	.	43.470	530.539	1.942	7.657	358.095	7737.630
2020	31.019	49.691	.	30.424	299.361	1.773	0.771	225.191	5974.116
2021	34.481	22.701	.	23.805	349.935	1.446	1.609	338.951	5554.083

Table 5. CVs used in the MCBE analysis for Headboat (HB) and general recreational (GR) landings and discards.

Year	HB Landings CVs	GR Landings CVs	HB Discards CVs	GR Discards CVs
1978	0.59	.	.	.
1979	0.59	.	.	.
1980	0.59	.	.	.
1981	0.15	0.35	.	0.41
1982	0.15	0.31	.	0.28
1983	0.15	0.27	.	0.31
1984	0.15	0.40	.	0.28
1985	0.15	0.35	.	0.17
1986	0.15	0.28	0.2	0.41
1987	0.15	0.28	0.2	0.22
1988	0.15	0.23	0.2	0.27
1989	0.15	0.24	0.2	0.19
1990	0.15	0.31	0.2	0.20
1991	0.15	0.32	0.2	0.24
1992	0.15	0.22	0.2	0.19
1993	0.15	0.24	0.2	0.22
1994	0.15	0.26	0.2	0.17
1995	0.15	0.23	0.2	0.15
1996	0.10	0.34	0.2	0.22
1997	0.10	0.26	0.2	0.15
1998	0.10	0.26	0.2	0.13
1999	0.10	0.37	0.2	0.15
2000	0.10	0.21	0.2	0.11
2001	0.10	0.19	0.2	0.11
2002	0.10	0.21	0.2	0.11
2003	0.10	0.18	0.2	0.11
2004	0.10	0.27	0.2	0.13
2005	0.10	0.24	0.2	0.10
2006	0.10	0.24	0.2	0.10
2007	0.10	0.20	0.2	0.11
2008	0.10	0.24	0.2	0.13
2009	0.10	0.22	0.2	0.11
2010	0.10	0.32	0.2	0.11
2011	0.10	0.26	0.2	0.09
2012	0.10	0.24	0.2	0.13
2013	0.10	0.38	0.2	0.10
2014	0.10	0.21	0.2	0.13
2015	0.10	0.25	0.2	0.12
2016	0.10	0.31	0.2	0.11
2017	0.10	0.30	0.2	0.10
2018	0.10	0.25	0.2	0.13
2019	0.10	0.27	0.2	0.13
2020	0.10	0.22	0.2	0.13
2021	0.10	0.30	0.2	0.11

Table 6. Observed indices of abundance and CVs from MARMAP blackfish trap (Mbft), SERFS combined chevron trap and videos (CVID), commercial lines (cl), and headboats (hb).

Year	Mbft	Mbft CV	CVID	CVID CV	cl	cl CV	hb	hb CV
1979	.	.	.	.	.	.	2.17	0.54
1980	.	.	.	.	.	.	1.85	0.54
1981	1.07	0.27	.	.	.	.	2.13	0.54
1982	1.21	0.27	.	.	.	.	2.19	0.54
1983	1.10	0.27	.	.	.	.	1.98	0.54
1984	0.94	0.27	.	.	.	.	1.84	0.27
1985	1.09	0.27	.	.	.	.	1.99	0.27
1986	0.78	0.27	.	.	.	.	1.63	0.27
1987	0.81	0.27	.	.	.	.	1.56	0.27
1988	.	.	.	.	.	.	1.50	0.27
1989	.	.	.	.	.	.	1.23	0.27
1990	.	.	1.18	0.18	.	.	1.22	0.27
1991	.	.	1.05	0.19	.	.	1.01	0.27
1992	.	.	0.93	0.20	.	.	0.69	0.27
1993	.	.	0.67	0.20	1.15	0.27	0.44	0.27
1994	.	.	0.84	0.20	1.07	0.27	0.49	0.27
1995	.	.	0.63	0.20	0.67	0.27	0.50	0.27
1996	.	.	0.74	0.20	0.69	0.27	0.52	0.27
1997	.	.	0.93	0.20	0.88	0.27	0.57	0.27
1998	.	.	0.96	0.19	1.21	0.27	0.50	0.27
1999	.	.	1.82	0.21	1.26	0.27	0.56	0.27
2000	.	.	1.11	0.20	0.86	0.27	0.41	0.27
2001	.	.	1.43	0.21	0.93	0.27	0.43	0.27
2002	.	.	0.75	0.22	0.86	0.27	0.42	0.27
2003	.	.	0.66	0.22	1.10	0.27	0.48	0.27
2004	.	.	1.33	0.22	1.55	0.27	0.66	0.27
2005	.	.	0.95	0.21	1.11	0.27	0.58	0.27
2006	.	.	1.00	0.21	0.99	0.27	0.62	0.27
2007	.	.	0.72	0.22	0.60	0.27	0.38	0.27
2008	.	.	0.86	0.21	0.80	0.27	0.30	0.27
2009	.	.	0.58	0.21	1.27	0.27	0.46	0.27
2010	.	.	1.55	0.20	.	.	0.73	0.27
2011	.	.	2.32	0.18	.	.	.	.
2012	.	.	1.71	0.17	.	.	.	.
2013	.	.	1.57	0.17	.	.	.	.
2014	.	.	1.26	0.16	.	.	.	.
2015	.	.	0.89	0.16	.	.	.	.
2016	.	.	0.64	0.19	.	.	.	.
2017	.	.	0.54	0.17	.	.	.	.
2018	.	.	0.46	0.18	.	.	.	.
2019	.	.	0.34	0.17	.	.	.	.
2020	.	.	.	1.00	.	.	.	.
2021	.	.	0.16	0.18	.	.	.	.

Table 7. Sample sizes (number of trips) of length compositions (len) or age compositions (age) by survey or fleet, including those of discards (D). Data sources are SERFS/MARMAP chevron trap (Mcvt), MARMAP blackfish/snapper trap (Mbft), commercial lines (cl), commercial pots(cp), headboats (hb), and general recreational (mrip).

Year	len.Mbft	len.cl	len.cp	len.hb	len.mrip	len.hbd	age.Mbft	age.Mcvt	age.cl	age.cp	age.hb
1978	.	.	.	327	.	.	.	.	.	.	.
1979	.	.	.	201	.	.	.	.	.	.	.
1980	.	.	.	277	.	.	.	.	.	.	.
1981	108	.	.	387	53	.	.	.	.	.	.
1982	120	.	.	439	123	.	.	.	.	.	.
1983	.	.	.	624	47	.	453	.	.	.	.
1984	62	77	12	695	107	.	.	.	.	.	.
1985	25	64	.	638	137	.	.	.	.	.	.
1986	26	68	.	683	210	.	.	.	.	.	.
1987	16	74	.	787	290	.	.	.	.	.	.
1988	.	61	20	545	122	.	.	.	.	.	.
1989	.	31	.	427	399	.	.	.	.	.	.
1990	.	54	17	481	232	.	.	363	.	.	.
1991	.	87	30	.	210	.	.	268	.	.	39
1992	.	73	19	.	320	.	.	322	.	.	26
1993	.	72	20	387	229	.	.	351	.	.	.
1994	.	55	33	350	233	.	.	341	.	.	.
1995	.	66	29	283	188	.	.	251	.	.	.
1996	.	60	20	276	227	.	.	461	.	.	.
1997	.	72	17	375	193	.	.	357	.	.	.
1998	.	100	.	460	206	.	.	369	.	.	.
1999	.	98	0	403	242	.	.	247	.	120	.
2000	.	100	.	333	227	.	.	288	.	.	.
2001	.	121	.	329	313	.	.	245	.	.	.
2002	.	92	611	305	218	.	.	240	67	.	.
2003	.	0	1043	0	275	.	.	215	95	.	29
2004	.	0	0	0	377	.	.	274	115	.	54
2005	.	0	0	0	330	100	.	379	126	21	110
2006	.	0	0	0	309	94	.	331	102	34	249
2007	.	0	0	0	229	109	.	302	113	83	231
2008	.	0	0	0	200	112	.	106	111	101	161
2009	.	0	0	0	209	97	.	126	102	108	226
2010	.	0	0	0	298	116	.	274	85	74	344
2011	.	0	0	0	143	120	.	327	46	49	131
2012	.	0	0	0	236	114	.	459	115	40	89
2013	.	0	0	0	158	101	.	458	155	34	246
2014	.	0	0	0	199	110	.	395	174	26	208
2015	.	0	0	0	188	90	.	493	173	32	158
2016	.	0	0	0	183	92	.	399	97	18	261
2017	.	0	0	0	134	94	.	388	117	25	211
2018	.	0	0	0	131	77	.	411	99	26	238
2019	.	0	0	0	127	67	.	350	69	17	112
2020	.	0	0	27	170	0	.	.	28	10	0
2021	.	0	15	.	141	.	.	247	25	.	.

Table 8. Estimated total abundance at age (1000 fish) at start of year.

Year	0	1	2	3	4	5	6	7	8	9	10	11	Total
1978	125091.60	40914.41	12842.17	7134.40	4234.47	2834.45	949.33	1733.10	302.26	153.06	79.28	156.50	196425.02
1979	137427.10	37435.75	18075.32	6039.54	3600.09	2270.66	1576.70	542.85	1011.48	179.15	91.80	143.42	208393.86
1980	141683.60	41127.21	16533.95	8399.91	2895.07	1826.80	1194.21	852.35	299.52	566.74	101.57	135.20	215616.13
1981	102583.50	42400.88	18159.07	7622.88	3926.69	1433.38	937.90	630.25	459.11	163.84	313.70	132.83	178764.05
1982	97660.94	30693.30	18620.11	8165.81	3410.45	1858.35	701.98	472.04	323.74	239.49	86.48	238.42	162471.11
1983	98285.84	29194.35	13056.14	7581.57	3335.32	1469.92	828.67	321.69	220.78	153.76	115.11	158.45	154721.60
1984	105637.60	29432.69	13157.35	6386.70	3839.11	1771.99	807.92	468.07	185.45	129.25	91.09	164.26	162071.47
1985	113490.00	31634.78	13373.10	5801.92	2385.83	1482.85	705.92	330.67	195.51	78.66	55.48	111.15	169645.87
1986	86519.61	33987.42	14390.31	6027.06	2268.40	966.74	619.39	302.91	144.81	86.95	35.40	76.05	145425.05
1987	93997.96	25911.27	15486.20	6742.63	2553.43	1001.55	439.60	289.31	144.40	70.10	42.59	55.38	146734.42
1988	96305.55	28152.58	11819.86	7347.11	2978.47	1178.50	476.56	214.89	144.33	73.15	35.94	50.90	148777.85
1989	74843.56	28842.38	12839.74	5659.88	3302.94	1393.26	566.11	235.07	108.17	73.78	37.84	45.53	127948.26
1990	81081.05	22415.44	13148.08	6028.12	2386.22	1432.71	620.28	258.79	109.66	51.25	35.37	40.50	127607.46
1991	55310.41	24288.33	10260.18	6499.82	2780.69	1128.46	694.79	308.83	131.49	56.59	26.76	40.14	101526.49
1992	53689.19	16565.24	11081.46	5009.99	2951.90	1304.62	542.84	343.14	155.65	67.30	29.31	35.12	91775.76
1993	77555.07	16081.14	7568.40	5479.55	2330.58	1421.36	645.60	275.87	177.96	81.98	35.87	34.80	111688.17
1994	70251.86	23228.71	7345.51	3788.40	2629.79	1168.32	733.74	342.33	149.28	97.80	45.59	39.80	109821.13
1995	63339.55	21035.10	10558.37	3545.80	1686.21	1229.42	561.41	362.09	172.40	76.35	50.61	44.76	102662.07
1996	67057.08	18972.54	9621.81	5344.43	1742.19	866.46	651.51	305.64	201.18	97.28	43.59	55.15	104958.87
1997	93006.12	20083.28	8653.15	4690.16	2407.65	821.54	421.53	325.63	155.91	104.22	50.99	52.45	130772.63
1998	70914.39	27853.28	9155.98	4257.84	2161.03	1162.59	408.42	215.24	169.70	82.51	55.81	56.12	116492.90
1999	88182.55	21240.92	12736.94	4632.46	2083.32	1093.52	603.58	217.71	117.09	93.75	46.12	63.38	131111.34
2000	83088.96	26410.21	9708.54	6802.06	2324.69	947.47	508.30	288.05	106.03	57.91	46.92	55.55	130344.70
2001	80798.15	24880.25	12039.52	5139.41	3397.48	1060.59	445.44	245.56	142.03	53.09	29.34	52.61	128283.47
2002	75807.02	24194.73	11345.05	6373.70	2397.32	1328.54	426.97	184.28	103.69	60.90	23.04	36.06	122281.30
2003	90601.32	22704.54	11063.86	6071.91	3257.34	1120.15	639.40	211.15	93.01	53.14	31.59	31.08	135878.48
2004	67646.47	27134.76	10378.24	5913.61	3112.08	1541.12	546.70	320.70	108.09	48.35	27.96	33.39	116811.47
2005	80924.46	20251.76	12330.58	5424.10	2555.49	1057.43	538.05	196.13	117.42	40.19	18.19	23.39	123477.20
2006	82757.95	24230.14	9221.06	6493.88	2482.99	972.40	414.64	216.84	80.67	49.05	16.99	17.81	126954.41
2007	89345.11	24775.42	11008.39	4820.91	3032.42	1007.84	407.19	178.46	95.25	35.99	22.14	15.92	134745.04
2008	96722.65	26762.23	11346.57	5791.56	2554.66	1452.98	343.63	127.31	56.62	30.69	11.73	12.56	145213.20
2009	132004.90	28972.64	12260.10	5984.42	3102.64	1267.48	541.95	119.54	44.99	20.32	11.15	8.94	184339.08
2010	100280.90	39543.55	13284.34	6507.48	3179.35	1509.77	502.74	205.74	46.17	17.65	8.07	8.07	165093.83
2011	71906.71	30038.35	18113.76	6997.04	3425.38	1453.78	446.23	132.23	54.79	12.48	4.83	4.47	132590.05
2012	67431.97	21536.75	13737.58	9431.20	3671.55	1665.78	525.37	150.04	45.19	19.02	4.39	3.31	118222.13
2013	60920.13	20194.80	9837.10	7090.63	4975.82	1906.21	729.00	222.87	64.91	19.86	8.46	3.47	105973.26
2014	40547.63	18244.52	9235.56	5147.19	3884.90	2785.66	965.57	272.57	74.31	21.60	6.68	4.05	81190.24
2015	28734.48	12132.30	8248.63	4464.48	2466.73	1992.79	1151.15	199.44	42.72	11.38	3.33	1.68	59449.12
2016	28603.55	8599.31	5498.36	4053.98	2206.40	1321.84	980.92	393.90	59.20	12.61	3.39	1.51	51734.98
2017	23554.25	8558.68	3888.88	2662.78	1958.29	1180.27	678.04	382.68	138.18	20.74	4.46	1.75	43029.00
2018	15295.15	7041.96	3829.92	1750.49	1128.89	943.02	517.37	184.38	85.89	30.63	4.64	1.41	30813.75
2019	11118.55	4576.16	3180.94	1840.04	827.91	578.42	466.47	201.92	65.68	30.62	11.03	2.20	22899.96
2020	24642.27	3323.58	2043.75	1412.70	761.06	391.35	261.10	146.11	54.60	17.64	8.30	3.63	33066.09
2021	24642.27	7365.78	1483.53	904.28	585.62	375.90	195.71	99.93	50.18	18.72	6.11	4.18	35732.21

Table 9. Estimated biomass at age (1000 lb) at start of year

Year	0	1	2	3	4	5	6	7	8	9	10	11	Total
1978	6448.1	7159.9	4619.7	4162.5	3495.0	3031.1	1238.3	2640.1	520.7	290.9	163.1	343.4	34112.8
1979	7083.9	6551.2	6502.2	3523.7	2971.4	2428.2	2056.6	826.9	1742.3	340.5	188.9	314.7	34530.6
1980	7303.4	7197.2	5947.8	4900.9	2389.5	1953.5	1557.7	1298.4	515.9	1077.1	209.0	296.7	34647.0
1981	5287.9	7420.1	6532.4	4447.5	3240.9	1532.8	1223.4	960.1	790.9	311.4	645.4	291.5	32684.2
1982	5034.1	5371.3	6698.2	4764.3	2814.9	1987.3	915.6	719.1	557.7	455.2	177.9	523.2	30018.7
1983	5066.3	5108.9	4696.7	4423.4	2752.8	1571.9	1080.9	490.0	380.3	292.2	236.8	347.7	26448.1
1984	5445.3	5150.7	4733.1	3726.3	3168.7	1894.9	1053.8	713.0	319.4	245.7	187.4	360.4	26998.7
1985	5850.1	5536.0	4810.7	3385.1	1969.2	1585.7	920.8	503.7	336.8	149.5	114.1	243.9	25405.6
1986	4459.8	5947.7	5176.6	3516.5	1872.2	1033.8	807.9	461.4	249.4	165.3	72.8	166.9	23930.5
1987	4845.3	4534.4	5570.9	3934.0	2107.5	1071.0	573.4	440.7	248.7	133.2	87.6	121.5	23668.3
1988	4964.3	4926.6	4252.0	4286.6	2458.3	1260.3	621.6	327.3	248.6	139.0	73.9	111.7	23670.3
1989	3858.0	5047.4	4618.8	3302.2	2726.1	1489.9	738.4	358.1	186.3	140.2	77.9	99.9	22643.3
1990	4179.5	3922.7	4729.8	3517.1	1969.5	1532.1	809.1	394.2	188.9	97.4	72.8	88.9	21501.8
1991	2851.1	4250.4	3690.9	3792.3	2295.1	1206.8	906.3	470.4	226.5	107.5	55.1	88.1	19940.4
1992	2767.5	2898.9	3986.3	2923.1	2436.4	1395.1	708.1	522.7	268.1	127.9	60.3	77.1	18171.5
1993	3997.7	2814.2	2722.6	3197.0	1923.6	1520.0	842.1	420.2	306.6	155.8	73.8	76.4	18049.9
1994	3621.3	4065.0	2642.4	2210.3	2170.5	1249.4	957.1	521.5	257.2	185.9	93.8	87.3	18061.6
1995	3265.0	3681.1	3798.2	2068.8	1391.7	1314.7	732.3	551.6	297.0	145.1	104.1	98.2	17447.7
1996	3456.6	3320.2	3461.3	3118.2	1437.9	926.6	849.8	465.6	346.5	184.9	89.7	121.0	17778.2
1997	4794.2	3514.5	3112.8	2736.4	1987.2	878.5	549.8	496.0	268.6	198.1	104.9	115.1	18756.2
1998	3655.4	4874.3	3293.7	2484.2	1783.6	1243.2	532.7	327.9	292.3	156.8	114.8	123.1	18882.2
1999	4545.5	3717.1	4581.9	2702.8	1719.5	1169.4	787.3	331.6	201.7	178.2	94.9	139.1	20169.0
2000	4283.0	4621.7	3492.5	3968.6	1918.7	1013.2	663.0	438.8	182.6	110.1	96.5	121.9	20910.7
2001	4164.9	4354.0	4331.0	2998.6	2804.2	1134.2	581.0	374.1	244.7	100.9	60.4	115.4	21263.2
2002	3907.6	4234.0	4081.2	3718.7	1978.7	1420.7	556.9	280.7	178.6	115.7	47.4	79.1	20599.4
2003	4670.2	3973.2	3980.0	3542.6	2688.5	1197.9	834.0	321.6	160.2	101.0	65.0	68.2	21602.5
2004	3487.0	4748.5	3733.4	3450.3	2568.6	1648.0	713.1	488.5	186.2	91.9	57.5	73.3	21246.3
2005	4171.4	3544.0	4435.7	3164.7	2109.2	1130.8	701.8	298.8	202.3	76.4	37.4	51.3	19923.8
2006	4265.9	4240.2	3317.1	3788.8	2049.4	1039.9	540.8	330.3	139.0	93.2	35.0	39.1	19878.7
2007	4605.5	4335.6	3960.1	2812.7	2502.8	1077.8	531.1	271.9	164.1	68.4	45.6	34.9	20410.4
2008	4985.8	4683.3	4081.7	3379.1	2108.5	1553.8	448.2	193.9	97.5	58.3	24.1	27.6	21641.9
2009	6804.4	5070.1	4410.3	3491.6	2560.8	1355.4	706.9	182.1	77.5	38.6	22.9	19.6	24740.4
2010	5169.2	6920.0	4778.8	3796.8	2624.1	1614.5	655.8	313.4	79.5	33.5	16.6	17.7	26019.9
2011	3706.6	5256.6	6516.1	4082.4	2827.2	1554.6	582.0	201.4	94.4	23.7	9.9	9.8	24864.8
2012	3475.9	3768.9	4941.8	5502.6	3030.4	1781.4	685.3	228.6	77.8	36.1	9.0	7.3	23545.0
2013	3140.2	3534.0	3538.7	4137.0	4106.9	2038.5	950.9	339.5	111.8	37.8	17.4	7.6	21960.3
2014	2090.1	3192.8	3322.3	3003.1	3206.5	2978.9	1259.4	415.2	128.0	41.0	13.7	8.9	19660.0
2015	1481.2	2123.1	2967.3	2604.8	2036.0	2131.1	1501.5	303.8	73.6	21.6	6.9	3.7	15254.4
2016	1474.4	1504.9	1977.9	2365.3	1821.1	1413.6	1279.5	600.0	102.0	24.0	7.0	3.3	12572.9
2017	1214.1	1497.8	1398.9	1553.6	1616.3	1262.2	884.4	583.0	238.0	39.4	9.2	3.9	10300.7
2018	788.4	1232.3	1377.7	1021.3	931.7	1008.5	674.8	280.9	147.9	58.2	9.5	3.1	7534.5
2019	573.1	800.8	1144.3	1073.6	683.3	618.5	608.4	307.6	113.1	58.2	22.7	4.8	6008.6
2020	1270.2	581.6	735.2	824.2	628.1	418.5	340.6	222.6	94.0	33.5	17.1	8.0	5173.7
2021	1270.2	1289.0	533.7	527.6	483.3	402.0	255.3	152.2	86.4	35.6	12.6	9.2	5057.1

Table 10. Estimated time series and status indicators. Fishing mortality rate is apical F, which includes discard mortalities. Total biomass (B, 1000 lb) is at the start of the year, and spawning biomass (SSB, population fecundity, 1E10 eggs) at the time of peak spawning (end of March). The MSST *is defined by* $\mathrm{MSST} = (1 - M)\mathrm{SSB}_{\mathrm{MSY}}$, *with constant* $M = 0.375$. *Prop.fem is proportion of age-*2^+ *population that is female.*

Year	F	F/F_{MSY}	B	B/B_{unfished}	SSB	$\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$	SSB/MSST	Prop.fem
1978	0.184	0.428	34113	1.091	588.5	1.444	2.310	0.605
1979	0.240	0.559	34531	1.105	585.8	1.437	2.299	0.643
1980	0.264	0.615	34647	1.108	589.4	1.446	2.314	0.652
1981	0.311	0.726	32684	1.045	598.4	1.468	2.349	0.667
1982	0.405	0.944	30019	0.960	543.6	1.334	2.134	0.677
1983	0.196	0.457	26448	0.846	485.2	1.190	1.905	0.660
1984	0.518	1.208	26999	0.864	465.1	1.141	1.826	0.651
1985	0.471	1.097	25406	0.813	434.7	1.066	1.706	0.676
1986	0.386	0.900	23930	0.765	447.7	1.098	1.758	0.697
1987	0.340	0.794	23668	0.757	441.4	1.083	1.733	0.704
1988	0.331	0.773	23670	0.757	435.3	1.068	1.709	0.678
1989	0.408	0.950	22643	0.724	431.0	1.057	1.692	0.677
1990	0.322	0.751	21502	0.688	404.0	0.991	1.586	0.685
1991	0.330	0.770	19940	0.638	392.4	0.963	1.540	0.664
1992	0.302	0.703	18171	0.581	353.3	0.867	1.387	0.667
1993	0.259	0.604	18050	0.577	316.8	0.777	1.244	0.638
1994	0.331	0.772	18062	0.578	317.3	0.779	1.246	0.629
1995	0.233	0.543	17448	0.558	322.0	0.790	1.264	0.674
1996	0.318	0.742	17778	0.569	322.4	0.791	1.266	0.671
1997	0.297	0.692	18756	0.600	316.0	0.775	1.240	0.663
1998	0.254	0.592	18882	0.604	349.0	0.856	1.370	0.667
1999	0.364	0.850	20169	0.645	364.2	0.894	1.430	0.692
2000	0.352	0.821	20911	0.669	387.9	0.952	1.523	0.673
2001	0.507	1.182	21263	0.680	395.9	0.971	1.554	0.679
2002	0.329	0.767	20599	0.659	396.4	0.973	1.556	0.683
2003	0.315	0.734	21603	0.691	399.4	0.980	1.568	0.671
2004	0.650	1.515	21246	0.680	400.5	0.983	1.572	0.659
2005	0.533	1.243	19924	0.637	368.5	0.904	1.446	0.691
2006	0.468	1.090	19879	0.636	365.4	0.897	1.434	0.675
2007	0.793	1.849	20410	0.653	374.0	0.917	1.468	0.683
2008	0.685	1.597	21642	0.692	399.1	0.979	1.567	0.686
2009	0.596	1.390	24740	0.791	430.8	1.057	1.691	0.686
2010	0.968	2.257	26020	0.832	494.3	1.213	1.940	0.685
2011	0.719	1.675	24865	0.795	516.7	1.268	2.028	0.709
2012	0.483	1.126	23545	0.753	489.0	1.200	1.919	0.681
2013	0.763	1.778	21960	0.702	446.4	1.095	1.752	0.637
2014	1.541	3.592	19660	0.629	390.5	0.958	1.533	0.616
2015	0.883	2.059	15254	0.488	310.1	0.761	1.217	0.628
2016	0.711	1.657	12573	0.402	243.7	0.598	0.956	0.606
2017	1.170	2.727	10301	0.329	188.4	0.462	0.740	0.582
2018	0.694	1.617	7535	0.241	146.1	0.358	0.573	0.614
2019	0.977	2.278	6009	0.192	114.2	0.280	0.448	0.622
2020	0.733	1.708	5174	0.165	83.4	0.205	0.328	0.616
2021	1.144	2.667	5057	0.162	80.4	0.197	0.315	0.602

Table 11. Selectivity at age for MARMAP blackfish/snapper traps (Mbft), SERFS chevron traps (CVID), commercial lines (cl), commercial pots (cp), headboat (hb), general recreational (GR), commercial discard mortalities (D.comm), headboat discard mortalities (D.hb), selectivity of landings averaged across fisheries (L.avg), and selectivity of discard mortalities averaged across fisheries (D.avg). Selectivity from the commercial trawl fleet (1978–1990) mirrored that of the commercial pot fleet. TL is total length. For time-varying selectivities, values shown are from the terminal assessment year.

Age	TL(mm)	TL(in)	Mbft	CVID	cl	cp	hb	GR	D.comm	D.hb	L.avg	D.avg	L.avg+D.avg
0	111.2	4.4	0.000	0.001	0.000	0.000	0.000	0.000	0.019	0.007	0.000	0.003	0.003
1	172.9	6.8	0.029	0.034	0.001	0.001	0.001	0.000	0.279	0.086	0.000	0.035	0.035
2	224.3	8.8	0.921	0.523	0.010	0.018	0.010	0.000	0.971	0.596	0.002	0.242	0.244
3	267.1	10.5	1.000	1.000	0.090	0.190	0.131	0.003	1.000	1.000	0.020	0.406	0.426
4	302.8	11.9	1.000	0.953	0.502	0.753	0.693	0.029	0.197	0.493	0.105	0.200	0.305
5	332.4	13.1	1.000	0.856	0.912	0.975	0.971	0.235	0.040	0.128	0.323	0.052	0.374
6	357.1	14.1	1.000	0.747	0.991	0.998	0.998	0.757	0.008	0.017	0.787	0.007	0.794
7	377.7	14.9	1.000	0.632	0.999	1.000	1.000	0.970	0.002	0.001	0.973	0.001	0.974
8	394.9	15.5	1.000	0.519	1.000	1.000	1.000	0.997	0.001	0.000	0.997	0.000	0.997
9	409.1	16.1	1.000	0.413	1.000	1.000	1.000	1.000	0.000	0.000	1.000	0.000	1.000
10	421.0	16.6	1.000	0.320	1.000	1.000	1.000	1.000	0.000	0.000	1.000	0.000	1.000
11	430.9	17.0	1.000	0.242	1.000	1.000	1.000	1.000	0.000	0.000	1.000	0.000	1.000

Table 12. Estimated time series of fully selected fishing mortality rates for commercial lines (F.cl), commercial pots (F.cp), commercial trawl (F.ct), headboat (F.hb), general recreational (F.rec), commercial discard mortalities (F.comm.D), headboat discard mortalities (F.hb.D), general recreational discard mortalities (F.rec.D). Also shown is apical 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.cl	F.cp	F.ct	F.hb	F.rec	F.comm.D	F.hb.D	F.rec.D	Apical F
1978	0.013	0.011	0.003	0.036	0.121	0.000	0.000	0.010	0.184
1979	0.017	0.060	0.002	0.039	0.121	0.000	0.000	0.010	0.240
1980	0.015	0.081	0.002	0.044	0.121	0.000	0.000	0.010	0.264
1981	0.025	0.100	0.003	0.051	0.133	0.000	0.000	0.014	0.311
1982	0.026	0.083	0.002	0.056	0.238	0.000	0.000	0.012	0.405
1983	0.026	0.053	0.001	0.060	0.056	0.000	0.000	0.005	0.196
1984	0.037	0.051	0.002	0.067	0.361	0.001	0.000	0.012	0.518
1985	0.040	0.060	0.004	0.068	0.300	0.001	0.000	0.014	0.471
1986	0.045	0.080	0.004	0.065	0.193	0.001	0.001	0.017	0.386
1987	0.041	0.060	0.001	0.070	0.169	0.001	0.005	0.011	0.340
1988	0.059	0.072	0.003	0.072	0.125	0.001	0.009	0.012	0.331
1989	0.061	0.077	0.002	0.056	0.211	0.001	0.001	0.014	0.408
1990	0.066	0.103	0.002	0.045	0.107	0.001	0.000	0.009	0.322
1991	0.066	0.090	0.000	0.035	0.139	0.001	0.005	0.013	0.330
1992	0.056	0.084	0.000	0.027	0.135	0.001	0.001	0.013	0.302
1993	0.046	0.078	0.000	0.019	0.115	0.001	0.001	0.016	0.259
1994	0.055	0.092	0.000	0.020	0.165	0.002	0.003	0.026	0.331
1995	0.040	0.076	0.000	0.019	0.098	0.001	0.001	0.012	0.233
1996	0.037	0.089	0.000	0.021	0.172	0.002	0.002	0.015	0.318
1997	0.047	0.096	0.000	0.022	0.132	0.002	0.002	0.019	0.297
1998	0.064	0.081	0.000	0.021	0.088	0.001	0.001	0.015	0.254
1999	0.059	0.121	0.000	0.038	0.147	0.001	0.002	0.025	0.364
2000	0.029	0.091	0.000	0.025	0.208	0.001	0.002	0.035	0.352
2001	0.027	0.111	0.000	0.031	0.339	0.001	0.002	0.033	0.507
2002	0.030	0.093	0.000	0.021	0.185	0.001	0.001	0.024	0.329
2003	0.025	0.096	0.000	0.021	0.173	0.001	0.001	0.025	0.315
2004	0.031	0.133	0.000	0.041	0.446	0.001	0.001	0.047	0.650
2005	0.023	0.096	0.000	0.035	0.380	0.001	0.000	0.040	0.533
2006	0.022	0.119	0.000	0.032	0.295	0.002	0.001	0.047	0.468
2007	0.019	0.087	0.000	0.043	0.644	0.000	0.002	0.067	0.793
2008	0.020	0.085	0.000	0.026	0.555	0.000	0.002	0.063	0.685
2009	0.027	0.121	0.000	0.038	0.411	0.000	0.003	0.051	0.596
2010	0.022	0.086	0.000	0.066	0.794	0.000	0.003	0.062	0.968
2011	0.014	0.069	0.000	0.050	0.585	0.000	0.005	0.080	0.719
2012	0.026	0.045	0.000	0.023	0.388	0.001	0.006	0.094	0.483
2013	0.048	0.052	0.000	0.023	0.640	0.000	0.006	0.075	0.763
2014	0.073	0.036	0.000	0.021	1.411	0.000	0.007	0.206	1.541
2015	0.044	0.041	0.000	0.019	0.779	0.000	0.008	0.178	0.883
2016	0.053	0.029	0.000	0.019	0.611	0.000	0.010	0.201	0.711
2017	0.059	0.068	0.000	0.019	1.024	0.000	0.011	0.322	1.170
2018	0.051	0.074	0.000	0.028	0.541	0.001	0.012	0.211	0.694
2019	0.052	0.082	0.000	0.029	0.814	0.001	0.017	0.337	0.977
2020	0.031	0.042	0.000	0.027	0.633	0.000	0.014	0.348	0.733
2021	0.046	0.025	0.000	0.028	1.045	0.000	0.026	0.391	1.144

Table 13. Estimated instantaneous fishing mortality rate (per yr) at age, including discard mortality

Year	0	1	2	3	4	5	6	7	8	9	10	11
1978	0.001	0.042	0.157	0.182	0.180	0.183	0.184	0.184	0.184	0.184	0.184	0.184
1979	0.001	0.042	0.169	0.233	0.236	0.239	0.240	0.240	0.240	0.240	0.240	0.240
1980	0.001	0.042	0.177	0.259	0.260	0.263	0.264	0.264	0.264	0.264	0.264	0.264
1981	0.002	0.048	0.202	0.302	0.305	0.311	0.311	0.311	0.311	0.311	0.311	0.311
1982	0.002	0.080	0.301	0.394	0.399	0.404	0.405	0.405	0.405	0.405	0.405	0.405
1983	0.001	0.022	0.117	0.179	0.190	0.195	0.196	0.196	0.196	0.196	0.196	0.196
1984	0.001	0.014	0.221	0.483	0.508	0.517	0.518	0.518	0.518	0.518	0.518	0.518
1985	0.001	0.013	0.199	0.437	0.461	0.470	0.471	0.471	0.471	0.471	0.471	0.471
1986	0.001	0.011	0.160	0.357	0.375	0.385	0.386	0.386	0.386	0.386	0.386	0.386
1987	0.001	0.010	0.148	0.315	0.330	0.339	0.340	0.340	0.340	0.340	0.340	0.340
1988	0.001	0.010	0.139	0.298	0.317	0.330	0.331	0.331	0.331	0.331	0.331	0.331
1989	0.001	0.010	0.158	0.362	0.392	0.406	0.407	0.408	0.408	0.408	0.408	0.408
1990	0.000	0.006	0.107	0.272	0.306	0.320	0.322	0.322	0.322	0.322	0.322	0.322
1991	0.001	0.010	0.119	0.287	0.314	0.329	0.330	0.330	0.330	0.330	0.330	0.330
1992	0.000	0.008	0.107	0.263	0.288	0.300	0.302	0.302	0.302	0.302	0.302	0.302
1993	0.000	0.008	0.094	0.232	0.248	0.258	0.259	0.259	0.259	0.259	0.259	0.259
1994	0.001	0.013	0.131	0.308	0.318	0.330	0.331	0.331	0.331	0.331	0.331	0.331
1995	0.000	0.007	0.083	0.209	0.223	0.232	0.233	0.233	0.233	0.233	0.233	0.233
1996	0.001	0.010	0.121	0.296	0.309	0.317	0.318	0.318	0.318	0.318	0.318	0.318
1997	0.001	0.010	0.112	0.273	0.285	0.296	0.297	0.297	0.297	0.297	0.297	0.297
1998	0.000	0.007	0.084	0.213	0.238	0.252	0.254	0.254	0.254	0.254	0.254	0.254
1999	0.001	0.008	0.030	0.188	0.345	0.363	0.364	0.364	0.364	0.364	0.364	0.364
2000	0.001	0.010	0.038	0.192	0.342	0.351	0.352	0.352	0.352	0.352	0.352	0.352
2001	0.001	0.010	0.038	0.261	0.496	0.507	0.507	0.507	0.507	0.507	0.507	0.507
2002	0.000	0.007	0.027	0.169	0.318	0.328	0.329	0.329	0.329	0.329	0.329	0.329
2003	0.001	0.008	0.029	0.166	0.306	0.314	0.315	0.315	0.315	0.315	0.315	0.315
2004	0.001	0.014	0.051	0.337	0.637	0.649	0.650	0.650	0.650	0.650	0.650	0.650
2005	0.001	0.012	0.044	0.280	0.523	0.533	0.533	0.533	0.533	0.533	0.533	0.533
2006	0.001	0.014	0.051	0.260	0.459	0.467	0.468	0.468	0.468	0.468	0.468	0.468
2007	0.000	0.006	0.045	0.133	0.293	0.673	0.787	0.793	0.793	0.793	0.793	0.793
2008	0.000	0.005	0.042	0.122	0.258	0.583	0.681	0.685	0.685	0.685	0.685	0.685
2009	0.000	0.005	0.036	0.131	0.277	0.521	0.593	0.596	0.596	0.596	0.596	0.596
2010	0.000	0.006	0.043	0.140	0.340	0.816	0.960	0.968	0.968	0.968	0.968	0.968
2011	0.000	0.007	0.055	0.143	0.278	0.615	0.715	0.719	0.719	0.719	0.719	0.719
2012	0.001	0.008	0.064	0.138	0.213	0.423	0.482	0.483	0.482	0.482	0.482	0.482
2013	0.001	0.007	0.050	0.100	0.137	0.277	0.608	0.743	0.761	0.763	0.763	0.763
2014	0.001	0.019	0.129	0.234	0.225	0.480	1.202	1.498	1.537	1.541	1.541	1.541
2015	0.001	0.016	0.113	0.203	0.181	0.306	0.697	0.860	0.881	0.883	0.883	0.883
2016	0.001	0.018	0.127	0.226	0.183	0.264	0.566	0.693	0.709	0.711	0.711	0.711
2017	0.002	0.029	0.201	0.356	0.288	0.421	0.927	1.139	1.167	1.170	1.170	1.170
2018	0.002	0.020	0.135	0.247	0.226	0.301	0.565	0.677	0.692	0.693	0.694	0.694
2019	0.002	0.031	0.214	0.381	0.306	0.392	0.785	0.953	0.975	0.977	0.977	0.977
2020	0.002	0.031	0.218	0.379	0.263	0.290	0.585	0.714	0.731	0.733	0.733	0.733
2021	0.003	0.036	0.251	0.433	0.297	0.392	0.897	1.113	1.141	1.144	1.144	1.144

Table 14. Estimated total landings at age in numbers (1000 fish)

Year	0	1	2	3	4	5	6	7	8	9	10	11
1978	80.37	1092.22	1329.21	890.96	568.42	392.93	133.48	246.00	43.21	22.00	11.44	22.66
1979	88.60	1006.27	2011.64	956.93	615.81	400.88	282.30	98.10	184.07	32.78	16.87	26.44
1980	91.62	1113.50	1925.07	1464.03	540.95	351.19	232.73	167.65	59.32	112.85	20.31	27.12
1981	73.15	1263.76	2345.64	1508.35	844.08	318.23	211.16	143.21	105.04	37.68	72.45	30.78
1982	122.92	1573.64	3553.54	2058.15	919.55	515.51	197.35	133.91	92.46	68.76	24.93	68.95
1983	31.10	409.86	1048.08	953.58	468.79	215.93	123.63	48.45	33.49	23.45	17.63	24.35
1984	22.47	200.92	1867.44	1905.99	1259.43	598.94	276.72	161.74	64.51	45.19	31.97	57.84
1985	20.19	182.01	1702.38	1588.26	723.49	464.58	224.20	105.96	63.07	25.51	18.06	36.30
1986	10.07	130.75	1432.38	1366.62	580.66	257.38	167.31	82.58	39.75	23.99	9.81	21.14
1987	9.60	88.19	1432.91	1372.44	587.50	239.92	106.87	70.98	35.67	17.41	10.62	13.86
1988	7.57	74.91	983.68	1395.13	661.31	275.56	113.23	51.53	34.85	17.76	8.76	12.45
1989	9.62	120.20	1290.43	1311.81	878.71	387.76	159.95	67.03	31.05	21.29	10.96	13.24
1990	5.59	51.43	910.11	1095.84	514.02	326.72	143.81	60.57	25.84	12.14	8.41	9.67
1991	4.82	68.32	733.19	1203.52	612.39	262.89	164.54	73.83	31.65	13.69	6.50	9.79
1992	4.52	44.87	730.64	868.98	603.18	281.22	118.92	75.89	34.66	15.07	6.59	7.92
1993	5.56	36.97	419.34	830.93	416.97	268.23	123.83	53.42	34.70	16.07	7.06	6.87
1994	7.11	74.78	524.90	718.27	584.83	272.94	174.12	82.00	36.00	23.71	11.10	9.72
1995	3.87	41.68	527.35	492.19	274.56	210.88	97.87	63.73	30.56	13.60	9.06	8.04
1996	6.94	62.96	708.08	1020.92	378.32	195.91	149.49	70.79	46.91	22.80	10.26	13.02
1997	7.58	52.80	550.84	814.81	487.75	174.74	91.08	71.02	34.24	23.01	11.30	11.67
1998	4.08	51.31	449.04	597.36	373.56	215.10	76.92	40.93	32.50	15.88	10.79	10.89
1999	0.20	0.98	27.57	535.72	495.97	277.05	155.41	56.58	30.64	24.66	12.18	16.80
2000	0.10	0.72	17.51	761.19	548.52	233.67	127.17	72.73	26.95	14.80	12.04	14.30
2001	0.09	0.75	29.54	807.49	1090.16	352.66	150.08	83.47	48.60	18.26	10.13	18.22
2002	0.09	0.67	19.34	665.85	532.22	309.00	100.76	43.89	24.87	14.68	5.58	8.76
2003	0.09	0.55	18.02	615.87	698.35	250.95	145.32	48.43	21.48	12.34	7.36	7.27
2004	0.09	0.99	32.18	1155.43	1208.24	618.44	222.19	131.47	44.60	20.05	11.64	13.94
2005	0.08	0.57	31.27	896.29	854.98	365.76	188.52	69.33	41.78	14.37	6.53	8.42
2006	0.08	0.64	21.12	956.28	747.59	303.20	131.00	69.12	25.89	15.82	5.50	5.79
2007	0.24	1.55	18.23	230.24	540.20	405.55	188.60	84.11	45.21	17.16	10.60	7.64
2008	0.21	1.29	15.01	245.27	401.78	524.65	143.66	54.19	24.27	13.22	5.07	5.45
2009	0.34	1.71	20.87	339.10	541.47	420.78	204.78	45.94	17.42	7.91	4.35	3.50
2010	0.35	3.31	28.14	355.83	661.65	698.36	265.32	110.38	24.94	9.58	4.39	4.41
2011	0.18	1.85	28.74	295.86	552.79	542.47	192.84	58.19	24.28	5.56	2.16	2.01
2012	0.14	0.95	14.15	255.44	408.98	453.06	168.00	48.94	14.85	6.28	1.45	1.10
2013	0.45	2.09	12.87	100.98	367.93	368.31	281.49	100.50	29.94	9.22	3.94	1.62
2014	0.36	2.17	12.80	74.03	339.45	838.37	581.99	185.80	51.54	15.06	4.67	2.84
2015	0.19	1.11	9.24	53.18	163.98	402.28	489.91	99.23	21.73	5.83	1.71	0.86
2016	0.17	0.70	5.34	41.40	129.17	228.92	357.34	169.02	26.01	5.58	1.51	0.67
2017	0.22	1.12	6.03	42.45	172.61	304.70	349.17	226.21	83.30	12.58	2.72	1.07
2018	0.13	0.89	6.02	29.30	95.64	184.30	188.30	77.85	37.08	13.31	2.02	0.62
2019	0.11	0.64	5.38	32.33	76.94	138.42	215.07	107.30	35.63	16.71	6.04	1.21
2020	0.15	0.28	2.06	15.06	45.86	68.73	97.12	64.04	24.50	7.97	3.77	1.65
2021	0.16	0.63	1.46	9.16	37.96	87.77	98.54	58.28	29.87	11.21	3.67	2.52

Table 15. Estimated total landings at age in whole weight (1000 lb)

Year	0	1	2	3	4	5	6	7	8	9	10	11
1978	4.14	191.14	478.16	519.83	469.15	420.19	174.11	374.73	74.42	41.81	23.54	49.73
1979	4.57	176.10	723.65	558.32	508.26	428.69	368.21	149.45	317.08	62.30	34.70	58.01
1980	4.72	194.86	692.50	854.18	446.48	375.55	303.56	255.39	102.19	214.48	41.79	59.52
1981	3.77	221.16	843.80	880.04	696.67	340.31	275.42	218.15	180.94	71.62	149.07	67.54
1982	6.34	275.38	1278.32	1200.82	758.97	551.28	257.41	203.99	159.27	130.68	51.29	151.30
1983	1.60	71.72	377.02	556.36	386.92	230.91	161.25	73.81	57.68	44.57	36.27	53.43
1984	1.18	35.16	671.77	1112.04	1039.49	640.50	360.94	246.39	111.10	85.83	65.67	126.41
1985	1.06	31.85	612.40	926.66	597.14	496.82	292.44	161.42	108.64	48.45	37.10	79.34
1986	0.53	22.88	515.27	797.34	479.26	275.23	218.23	125.79	68.45	45.57	20.14	46.20
1987	0.50	15.43	515.46	800.74	484.90	256.57	139.39	108.13	61.44	33.07	21.81	30.28
1988	0.40	13.11	353.86	813.98	545.82	294.68	147.69	78.50	60.03	33.73	17.99	27.21
1989	0.50	21.04	464.21	765.37	725.26	414.66	208.63	102.11	53.49	40.44	22.52	28.93
1990	0.29	9.00	327.39	639.36	424.25	349.39	187.57	92.26	44.51	23.06	17.28	21.13
1991	0.25	11.96	263.75	702.19	505.44	281.14	214.62	112.46	54.51	26.01	13.35	21.39
1992	0.24	7.85	262.83	507.00	497.84	300.74	155.12	115.60	59.70	28.62	13.53	17.31
1993	0.29	6.47	150.85	484.80	344.15	286.85	161.52	81.37	59.77	30.53	14.50	15.02
1994	0.37	13.09	188.82	419.07	482.70	291.88	227.12	124.91	62.01	45.04	22.79	21.25
1995	0.20	7.29	189.70	287.17	226.61	225.52	127.66	97.08	52.63	25.84	18.60	17.56
1996	0.36	11.02	254.72	595.65	312.25	209.50	194.99	107.83	80.80	43.32	21.07	28.46
1997	0.40	9.24	198.15	475.40	402.57	186.86	118.80	108.19	58.97	43.70	23.22	25.50
1998	0.21	8.98	161.53	348.53	308.32	230.02	100.33	62.35	55.97	30.17	22.16	23.79
1999	0.01	0.17	9.92	312.56	409.36	296.27	202.71	86.19	52.77	46.84	25.02	36.71
2000	0.01	0.13	6.30	444.11	452.73	249.88	165.87	110.79	46.43	28.11	24.73	31.26
2001	0.00	0.13	10.63	471.13	899.78	377.12	195.75	127.15	83.70	34.68	20.81	39.83
2002	0.00	0.12	6.96	388.49	439.27	330.43	131.43	66.86	42.83	27.89	11.45	19.14
2003	0.00	0.10	6.48	359.33	576.40	268.36	189.54	73.78	37.00	23.44	15.12	15.89
2004	0.00	0.17	11.57	674.13	997.23	661.35	289.81	200.26	76.81	38.08	23.90	30.47
2005	0.00	0.10	11.25	522.94	705.66	391.14	245.90	105.61	71.96	27.30	13.42	18.41
2006	0.00	0.11	7.60	557.94	617.03	324.24	170.88	105.29	44.59	30.05	11.30	12.65
2007	0.01	0.27	6.56	134.33	445.86	433.69	246.00	128.12	77.86	32.60	21.77	16.70
2008	0.01	0.23	5.40	143.10	331.62	561.05	187.38	82.54	41.80	25.11	10.42	11.91
2009	0.02	0.30	7.51	197.85	446.91	449.98	267.10	69.99	30.00	15.02	8.94	7.66
2010	0.02	0.58	10.12	207.61	546.10	746.82	346.08	168.14	42.95	18.19	9.02	9.64
2011	0.01	0.32	10.34	172.62	456.25	580.11	251.54	88.64	41.82	10.56	4.43	4.38
2012	0.01	0.17	5.09	149.04	337.56	484.49	219.13	74.55	25.58	11.93	2.99	2.41
2013	0.02	0.37	4.63	58.92	303.68	393.87	367.16	153.09	51.57	17.51	8.10	3.54
2014	0.02	0.38	4.60	43.20	280.17	896.54	759.13	283.03	88.77	28.61	9.59	6.21
2015	0.01	0.20	3.32	31.02	135.34	430.19	639.01	151.16	37.43	11.07	3.52	1.89
2016	0.01	0.12	1.92	24.15	106.61	244.80	466.09	257.47	44.79	10.59	3.09	1.47
2017	0.01	0.20	2.17	24.77	142.46	325.84	455.44	344.59	143.48	23.89	5.58	2.34
2018	0.01	0.16	2.17	17.10	78.93	197.08	245.61	118.60	63.86	25.28	4.16	1.34
2019	0.01	0.11	1.93	18.86	63.50	148.02	280.53	163.45	61.36	31.74	12.41	2.64
2020	0.01	0.05	0.74	8.79	37.85	73.50	126.68	97.55	42.19	15.14	7.73	3.61
2021	0.01	0.11	0.52	5.34	31.33	93.86	128.53	88.78	51.45	21.29	7.54	5.51

Table 16. Estimated time series of landings in numbers (1000 fish) for commercial lines (L.cl), commercial pots (L.cp), commercial trawl (L.ct), headboat (L.hb), and general recreational (L.rec)

Year	L.cl	L.cp	L.ct	L.hb	L.rec	Total
1978	111.90	157.61	37.38	781.99	3744.02	4832.90
1979	129.83	802.75	32.48	896.56	3859.06	5720.67
1980	101.40	1103.16	31.63	994.77	3875.39	6106.35
1981	159.31	1310.41	41.25	1136.91	4305.65	6953.53
1982	150.72	1040.17	27.28	1198.05	6913.47	9329.68
1983	148.57	638.68	11.24	1143.13	1456.71	3398.33
1984	197.53	531.54	23.02	1026.92	4714.14	6493.16
1985	168.07	532.72	32.09	935.25	3485.89	5154.02
1986	173.49	710.55	31.61	930.76	2276.01	4122.42
1987	164.06	584.46	10.85	1086.23	2140.37	3985.96
1988	261.81	728.07	30.03	1058.45	1558.38	3636.73
1989	269.72	715.28	18.64	795.66	2502.77	4302.07
1990	277.60	957.36	18.99	641.38	1268.80	3164.14
1991	286.69	849.09	0.00	461.88	1587.49	3185.14
1992	238.69	734.83	0.00	347.73	1471.21	2792.46
1993	194.60	662.10	0.00	215.89	1147.38	2219.96
1994	213.94	659.57	0.00	195.46	1450.52	2519.50
1995	139.47	532.90	0.00	205.06	895.97	1773.39
1996	129.59	679.66	0.00	235.23	1641.93	2686.42
1997	167.91	713.57	0.00	233.56	1215.79	2330.83
1998	229.02	597.80	0.00	227.72	823.81	1878.36
1999	187.45	557.55	0.00	236.82	651.94	1633.76
2000	96.61	483.92	0.00	189.80	1059.35	1829.69
2001	93.75	578.08	0.00	218.82	1718.80	2609.45
2002	103.97	500.52	0.00	161.61	959.59	1725.70
2003	96.90	565.55	0.00	171.95	991.63	1826.03
2004	111.77	717.23	0.00	300.31	2329.93	3459.25
2005	70.96	450.61	0.00	232.54	1723.81	2477.92
2006	67.40	585.18	0.00	232.86	1396.60	2282.04
2007	60.61	422.44	0.00	193.20	873.09	1549.33
2008	64.11	436.93	0.00	120.01	813.02	1434.07
2009	97.64	674.05	0.00	190.23	646.25	1608.17
2010	80.14	496.37	0.00	342.17	1248.00	2166.67
2011	53.24	427.75	0.00	281.16	944.78	1706.93
2012	122.13	340.95	0.00	152.64	757.64	1373.36
2013	207.94	310.81	0.00	124.12	636.48	1279.34
2014	304.02	195.94	0.00	105.59	1503.53	2109.08
2015	150.45	180.00	0.00	77.48	841.31	1249.25
2016	154.18	106.37	0.00	63.97	641.31	965.83
2017	134.27	197.02	0.00	51.82	819.08	1202.19
2018	85.84	155.04	0.00	54.03	340.54	635.46
2019	64.72	127.39	0.00	41.56	402.11	635.78
2020	29.09	50.03	0.00	29.61	222.46	331.19
2021	32.62	22.88	0.00	23.24	262.48	341.22

Table 17. Estimated time series of landings in whole weight (1000 lb) for commercial lines (L.cl), commercial pots (L.cp), commercial trawl (L.ct), headboat (L.hb), and general recreational (L.rec)

Year	L.cl	L.cp	L.ct	L.hb	L.rec	Total
1978	118.61	134.14	31.81	530.80	2005.60	2820.95
1979	140.49	675.38	27.32	569.81	1976.32	3389.32
1980	107.87	885.41	25.39	615.96	1910.61	3545.24
1981	163.69	1023.40	32.22	676.65	2052.54	3948.49
1982	150.75	786.30	20.62	700.61	3366.77	5025.05
1983	145.71	484.47	8.53	690.52	722.32	2051.56
1984	194.48	410.45	17.78	661.40	3212.37	4496.48
1985	163.87	395.49	23.82	568.58	2241.53	3393.30
1986	162.87	502.36	22.35	537.77	1389.56	2614.89
1987	148.85	402.74	7.47	616.75	1291.91	2467.73
1988	235.78	513.48	21.18	635.63	980.92	2386.99
1989	248.04	517.51	13.48	478.16	1589.96	2847.15
1990	257.99	684.28	13.58	379.86	799.79	2135.50
1991	266.61	617.96	0.00	286.64	1035.86	2207.07
1992	226.35	547.45	0.00	216.03	976.55	1966.38
1993	188.63	506.61	0.00	142.90	797.98	1636.12
1994	212.96	526.72	0.00	132.22	1027.15	1899.05
1995	141.06	410.89	0.00	127.39	596.52	1275.86
1996	127.58	505.05	0.00	146.02	1081.34	1859.98
1997	161.67	534.51	0.00	147.24	807.57	1650.99
1998	220.99	448.97	0.00	142.24	540.17	1352.37
1999	187.88	502.72	0.00	192.60	595.32	1478.52
2000	92.98	410.92	0.00	145.07	911.35	1560.32
2001	88.85	499.09	0.00	172.70	1500.08	2260.72
2002	98.13	422.71	0.00	123.52	820.51	1464.88
2003	91.56	483.24	0.00	133.98	856.65	1565.43
2004	107.01	620.81	0.00	236.57	2039.42	3003.81
2005	66.89	383.25	0.00	179.42	1484.14	2113.70
2006	62.15	481.76	0.00	173.86	1163.91	1881.68
2007	54.88	350.70	0.00	161.79	976.41	1543.78
2008	57.50	356.54	0.00	99.04	887.49	1400.58
2009	87.36	551.54	0.00	157.21	705.16	1501.26
2010	70.97	401.80	0.00	279.45	1353.04	2105.26
2011	46.35	342.17	0.00	226.02	1006.49	1621.03
2012	107.23	270.75	0.00	123.19	811.77	1312.94
2013	196.39	276.37	0.00	113.77	775.91	1362.45
2014	298.92	182.38	0.00	101.02	1817.91	2400.24
2015	153.34	172.82	0.00	76.69	1041.31	1444.16
2016	161.33	104.30	0.00	64.69	830.81	1161.13
2017	141.50	195.39	0.00	52.83	1081.05	1470.78
2018	92.16	156.91	0.00	56.27	448.94	754.29
2019	70.16	128.84	0.00	43.50	542.08	784.58
2020	31.04	49.75	0.00	30.45	302.60	413.84
2021	34.50	22.71	0.00	23.81	353.24	434.27

Table 18. Estimated time series of dead discards in numbers (1000 fish) for commercial (D.comm), headboat (D.hb), and general recreational (D.rec). D.rec and D.hb are combined under D.rec prior to 1986.

Year	D.comm	D.hb	D.rec	Total
1978	0.00	0.00	223.22	223.22
1979	0.00	0.00	243.36	243.36
1980	0.00	0.00	255.65	255.65
1981	0.00	0.00	383.26	383.26
1982	0.00	0.00	289.90	289.90
1983	0.00	0.00	110.76	110.76
1984	29.27	0.00	239.56	268.83
1985	29.93	0.00	273.46	303.39
1986	31.85	19.50	355.63	406.98
1987	31.69	98.57	236.46	366.73
1988	29.35	171.44	228.44	429.24
1989	28.24	12.35	256.89	297.49
1990	27.73	0.77	171.50	200.00
1991	25.22	84.04	223.67	332.93
1992	22.40	11.89	194.43	228.71
1993	16.78	8.82	213.48	239.07
1994	23.11	35.46	341.95	400.51
1995	21.59	17.06	179.75	218.41
1996	22.75	31.53	215.91	270.18
1997	23.27	31.59	276.47	331.33
1998	20.38	10.40	228.43	259.21
1999	18.39	28.12	440.50	487.01
2000	14.87	30.46	621.06	666.39
2001	16.85	41.56	593.19	651.60
2002	11.52	22.48	444.13	478.13
2003	22.69	21.38	446.61	490.69
2004	14.13	12.67	819.70	846.50
2005	13.22	8.02	701.70	722.94
2006	26.61	18.95	780.93	826.49
2007	3.57	17.85	784.54	805.96
2008	3.61	25.44	798.07	827.11
2009	8.18	36.31	697.43	741.92
2010	5.62	50.88	930.02	986.51
2011	7.86	82.97	1366.92	1457.75
2012	11.44	102.72	1554.73	1668.90
2013	8.36	76.16	980.24	1064.76
2014	5.76	71.62	2152.60	2229.98
2015	3.16	70.39	1540.65	1614.20
2016	2.13	67.57	1363.69	1433.40
2017	2.36	50.70	1536.51	1589.57
2018	3.45	45.76	805.76	854.98
2019	3.03	54.46	1070.22	1127.70
2020	0.94	34.24	826.29	861.47
2021	0.40	51.54	764.89	816.83

Table 19. Estimated time series of dead discards in whole weight (1000 lb) for commercial (D.comm), headboat (D.hb), and general recreational (D.rec). D.rec and D.hb are combined under D.rec prior to 1986.

Year	D.comm	D.hb	D.rec	Total
1978	0.00	0.00	73.45	73.45
1979	0.00	0.00	79.55	79.55
1980	0.00	0.00	86.05	86.05
1981	0.00	0.00	128.28	128.28
1982	0.00	0.00	102.04	102.04
1983	0.00	0.00	39.11	39.11
1984	9.79	0.00	80.10	89.89
1985	9.77	0.00	89.23	98.99
1986	10.56	6.47	117.92	134.95
1987	11.08	34.47	82.69	128.24
1988	10.26	59.93	79.86	150.05
1989	9.51	4.16	86.51	100.18
1990	9.77	0.27	60.43	70.47
1991	9.00	29.99	79.81	118.80
1992	8.07	4.28	70.06	82.42
1993	6.07	3.19	77.30	86.56
1994	7.44	11.42	110.17	129.04
1995	7.18	5.68	59.80	72.66
1996	8.06	11.17	76.49	95.72
1997	7.88	10.69	93.57	112.14
1998	6.61	3.37	74.07	84.06
1999	6.32	9.67	151.47	167.46
2000	5.27	10.79	220.11	236.17
2001	5.77	14.22	203.01	223.00
2002	4.11	8.03	158.57	170.71
2003	8.06	7.59	158.57	174.22
2004	4.87	4.37	282.52	291.76
2005	4.66	2.83	247.49	254.98
2006	9.42	6.71	276.49	292.62
2007	1.21	8.20	360.34	369.75
2008	1.24	11.70	366.99	379.93
2009	3.32	16.61	318.97	338.90
2010	2.21	22.85	417.64	442.70
2011	3.24	37.74	621.74	662.72
2012	5.25	50.81	769.00	825.06
2013	4.08	38.38	493.90	536.35
2014	2.21	35.30	1061.04	1098.55
2015	1.24	34.35	751.72	787.31
2016	0.87	34.17	689.56	724.59
2017	0.91	25.40	769.91	796.23
2018	1.29	21.67	381.51	404.46
2019	1.19	26.17	514.37	541.73
2020	0.36	16.61	400.75	417.71
2021	0.12	22.27	330.44	352.83

Table 20. Estimated status indicators, benchmarks, and related quantities from the base run of the BAM, 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}; status indicators are dimensionless; biomass estimates are in units of thousands of pounds, as indicated; and recruits are in millions of age-0 fish. Spawning stock biomass (SSB) is measured as fecundity of mature females (1E10 eggs). L_{current} and D_{current} are the average landings and discards from 2019–2021, respectively. Estimates of yield do not include discards; D_{MSY} represents discard mortalities expected when fishing at F_{MSY}.

Quantity	Units	Estimate	Median	SE
F_{MSY}	y^{-1}	0.48	0.37	0.13
$75\%F_{\mathrm{MSY}}$	y^{-1}	0.36	0.28	0.10
B_{MSY}	1000 lb	53481.22	27725.96	22013.58
$\mathrm{SSB}_{\mathrm{MSY}}$	1E10 eggs	752.58	480.84	228.19
MSST	1E10 eggs	254.75	284.71	63.20
MSY	1000 lb	959.85	911.56	184.75
$L_{75\%\mathrm{MSY}}$	1000 lb	937.39	888.39	181.78
L_{current}	1000 lb	544.23	536.40	65.80
D_{MSY}	1000 dead fish	931.45	2694.03	1600.53
$D_{75\%\mathrm{MSY}}$	1000 dead fish	1586.27	2094.29	1251.13
D_{current}	1000 dead fish	437.42	1242.30	530.60
R_{MSY}	millions fish	390.60	127.32	232.69
$F_{2019-2021}/F_{\mathrm{MSY}}$	—	2.18	2.07	1.42
$\mathrm{SSB}_{2021}/\mathrm{MSST}$	—	0.32	0.37	0.13
$\mathrm{SSB}_{2021}/\mathrm{SSB}_{\mathrm{MSY}}$	—	0.20	0.21	0.04

Table 21. Results from sensitivity runs of the Beaufort Assessment Model. Current F represented by geometric mean of last three assessment years. For reference, recent landings (mean of last three yr) in the base case was $L_{\mathrm{current}} = 544.23$ *(1000 lb). Runs should not all be considered equally plausible.*

Run	Description	F_{MSY}	$\mathrm{SSB}_{\mathrm{MSY}}$ (1E10 eggs)	MSY (1000 lb)	$F_{\mathrm{current}}/F_{\mathrm{MSY}}$	$\mathrm{SSB}_{2021}/\mathrm{SSB}_{\mathrm{MSY}}$	R0 (millions)
Base	—	0.429	408	960	2.18	0.2	70.84
S1	Low M	0.283	311	1378	4.54	0.15	17.2
S2	High M	0.6	1114	955	0.63	0.23	768.57
S3	Low Mdisc	0.577	389	1087	1.35	0.2	65.95
S4	High Mdisc	0.299	480	895	4.12	0.22	88.83
S5	Trap Only	0.333	408	834	2.04	0.19	70.6
S6	Trap Then Video	0.49	410	1048	3.17	0.13	69.17
S7	Trap And Video	0.47	408	1008	2.42	0.18	70.41
S8	CVID wgt Sels	0.47	408	1008	2.42	0.18	70.41
S9	CVID Logistic	0.455	406	980	2.31	0.19	70.17
S10	Continuity	0.412	338	830	2.96	0.16	65.66

Table 22. Projection results with fishing mortality rate fixed at $F = 0$ starting in 2025 and long-term, average recruitment starting in 2023. R = number of age-0 recruits (in millions), F = fishing mortality rate (per year), S = spawning stock (1E10 eggs), L = landings and D = 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	S.med	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
2022	25	116	3.255	2.558	76	99	465	419	544	508	2603	3791	953	1236	0.000
2023	82	115	10.000	10.000	50	143	219	281	205	261	5892	8975	1621	2167	0.012
2024	82	117	10.000	10.000	103	160	53	86	18	27	8244	14957	1668	3743	0.023
2025	82	115	0.000	0.000	178	223	0	0	0	0	0	0	0	0	0.049
2026	82	116	0.000	0.000	282	347	0	0	0	0	0	0	0	0	0.161
2027	82	114	0.000	0.000	367	444	0	0	0	0	0	0	0	0	0.336
2028	82	116	0.000	0.000	427	509	0	0	0	0	0	0	0	0	0.516
2029	82	115	0.000	0.000	466	549	0	0	0	0	0	0	0	0	0.654
2030	82	115	0.000	0.000	488	575	0	0	0	0	0	0	0	0	0.731
2031	82	116	0.000	0.000	499	588	0	0	0	0	0	0	0	0	0.765
2032	82	116	0.000	0.000	505	594	0	0	0	0	0	0	0	0	0.781
2033	82	114	0.000	0.000	507	595	0	0	0	0	0	0	0	0	0.787
2034	82	115	0.000	0.000	508	595	0	0	0	0	0	0	0	0	0.788
2035	82	114	0.000	0.000	509	595	0	0	0	0	0	0	0	0	0.786
2036	82	115	0.000	0.000	509	595	0	0	0	0	0	0	0	0	0.787
2037	82	115	0.000	0.000	510	596	0	0	0	0	0	0	0	0	0.789
2038	82	114	0.000	0.000	510	597	0	0	0	0	0	0	0	0	0.794
2039	82	115	0.000	0.000	510	597	0	0	0	0	0	0	0	0	0.794

Table 23. Projection results with fishing mortality rate fixed at $F = 0$ starting in 2025 and recent average recruitment starting in 2023. R = number of age-0 recruits (in millions), F = fishing mortality rate (per year), S = spawning stock (1E10 eggs), L = landings and D = 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	S.med	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
2022	25	116	3.255	2.558	76	99	465	419	544	508	2603	3791	953	1236	0.000
2023	25	38	10.000	10.000	50	143	215	275	205	261	4980	8117	1573	2126	0.012
2024	25	38	10.000	10.000	41	85	33	63	15	24	3829	9586	1007	2935	0.001
2025	25	38	0.000	0.000	55	78	0	0	0	0	0	0	0	0	0.000
2026	25	38	0.000	0.000	86	119	0	0	0	0	0	0	0	0	0.000
2027	25	38	0.000	0.000	111	150	0	0	0	0	0	0	0	0	0.000
2028	25	38	0.000	0.000	129	172	0	0	0	0	0	0	0	0	0.000
2029	25	38	0.000	0.000	141	187	0	0	0	0	0	0	0	0	0.000
2030	25	38	0.000	0.000	147	195	0	0	0	0	0	0	0	0	0.000
2031	25	38	0.000	0.000	150	199	0	0	0	0	0	0	0	0	0.000
2032	25	38	0.000	0.000	152	201	0	0	0	0	0	0	0	0	0.000
2033	25	37	0.000	0.000	153	202	0	0	0	0	0	0	0	0	0.000
2034	25	38	0.000	0.000	153	202	0	0	0	0	0	0	0	0	0.000
2035	25	38	0.000	0.000	153	202	0	0	0	0	0	0	0	0	0.000
2036	25	38	0.000	0.000	153	203	0	0	0	0	0	0	0	0	0.000
2037	25	38	0.000	0.000	154	203	0	0	0	0	0	0	0	0	0.000
2038	25	38	0.000	0.000	154	203	0	0	0	0	0	0	0	0	0.000
2039	25	38	0.000	0.000	154	203	0	0	0	0	0	0	0	0	0.000

Table 24. Projection results with fishing mortality rate fixed at $F = F_{\text{current}}$ starting in 2025 and long-term, average recruitment starting in 2023. R = number of age-0 recruits (in millions), F = fishing mortality rate (per year), S = spawning stock (1e10 eggs), L = landings and D= 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	S.med	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
2022	25	115	3.255	2.558	76	99	465	419	544	508	2603	3784	953	1238	0.000
2023	25	38	10.000	10.000	50	142	215	276	205	261	4980	8123	1573	2115	0.012
2024	25	38	10.000	10.000	41	85	33	62	15	24	3829	9515	1007	2912	0.001
2025	25	38	0.936	0.801	53	74	5	6	2	3	586	831	176	260	0.000
2026	25	37	0.936	0.801	77	103	20	22	12	13	958	1237	363	469	0.000
2027	25	38	0.936	0.801	90	118	55	56	40	41	1116	1429	464	584	0.000
2028	25	38	0.936	0.801	98	126	109	103	96	91	1152	1468	493	618	0.000
2029	25	37	0.936	0.801	101	128	165	147	165	146	1157	1474	498	626	0.000

Table 25. Projection results with fishing mortality rate fixed at $F = F_{\mathrm{MSY}}$ starting in 2025 and recent average recruitment starting in 2023. R = number of age-0 recruits (in millions), F = fishing mortality rate (per year), S = spawning stock (1E10 eggs), L = landings and D = 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	S.med	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
2022	25	115	3.255	2.558	76	99	465	419	544	508	2603	3784	953	1238	0.000
2023	25	38	10.000	10.000	50	142	215	276	205	261	4980	8123	1573	2115	0.012
2024	25	38	10.000	10.000	41	85	33	62	15	24	3829	9515	1007	2912	0.001
2025	25	38	0.429	0.375	54	76	2	3	1	1	280	412	85	129	0.000
2026	25	37	0.429	0.375	81	110	11	13	7	8	486	685	190	267	0.000
2027	25	38	0.429	0.375	100	134	36	38	27	29	586	830	255	356	0.000
2028	25	38	0.429	0.375	112	148	79	83	73	76	611	870	276	387	0.000
2029	25	37	0.429	0.375	119	156	137	138	145	145	616	883	280	397	0.000

8 Figures

Figure 1. Data availability by source and year. cl refers to commercial lines, cp to commercial pots, ct to commercial trawl, hb to headboat, mrip to general recreational, comm to commercial discard, Mbft to MARMAP blackfish/snapper trap survey, hb.D to headboat discards, Mcvt indicates SERFS chevron trap data for compositions and CVID to combined trap and video gear abundance index.

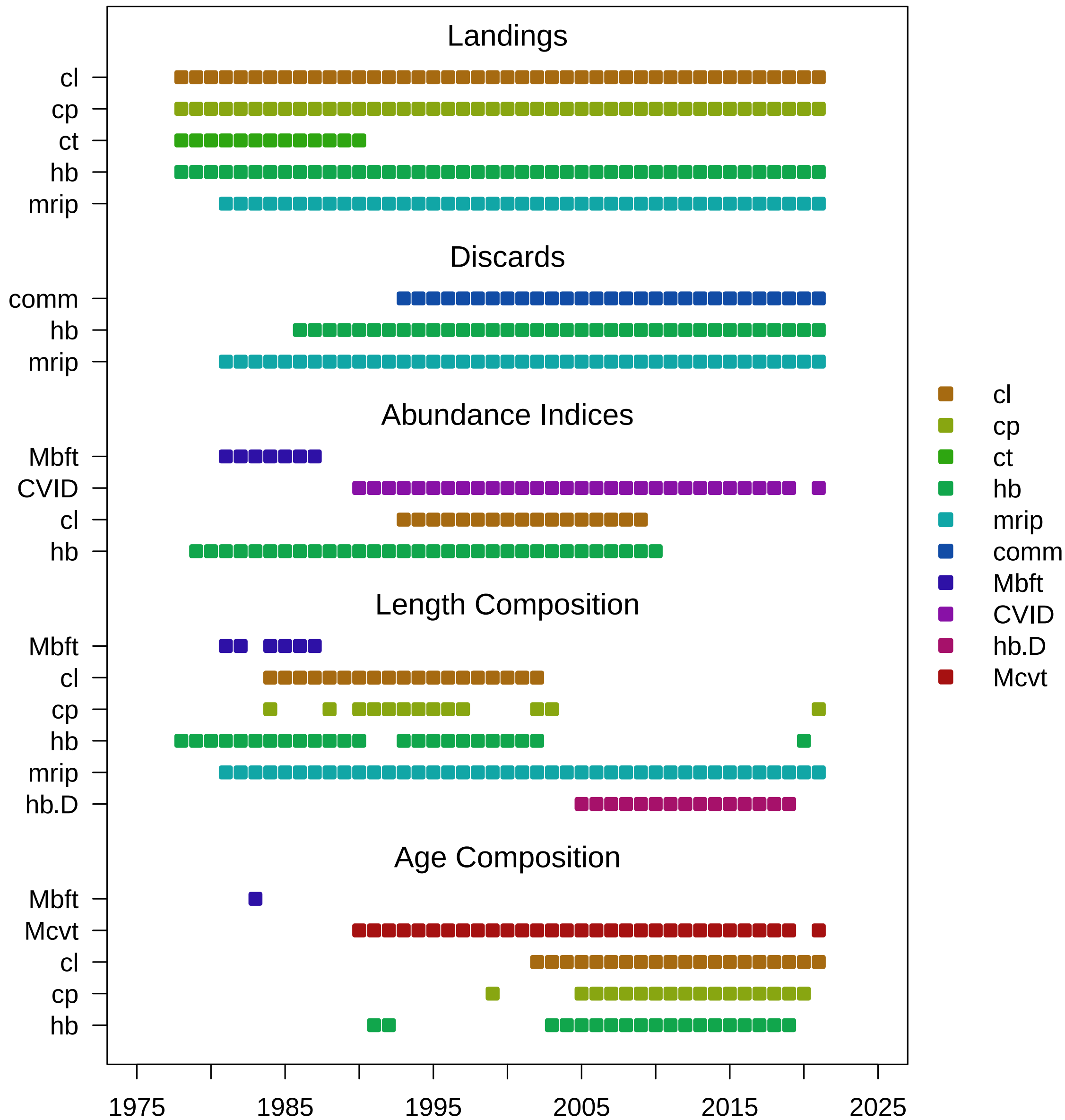


Figure 2. Mean length at age (mm) and estimated upper and lower 95% confidence intervals of the population.

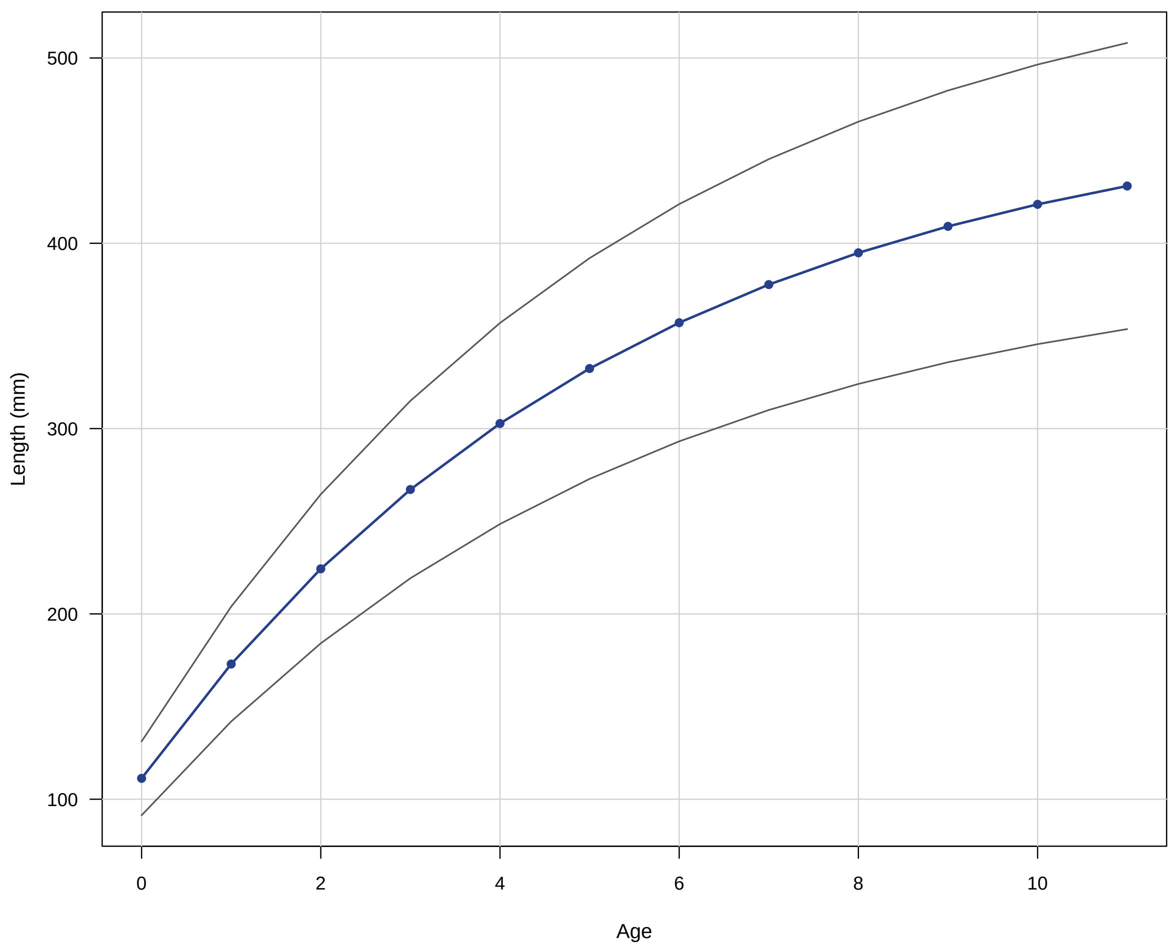


Figure 3. Indices of abundance used in fitting the assessment model in standardized Catch per unit effort (CPUE). U.MBFT indicates the Marine Resources Monitoring, Assessment, and Prediction Program blackfish/snapper trap survey; U.CVID indicates the SouthEast Reef Fish Survey chevron trap/video survey; U.HB is the headboat logbook data; and U.cH the commercial lines logbook data.

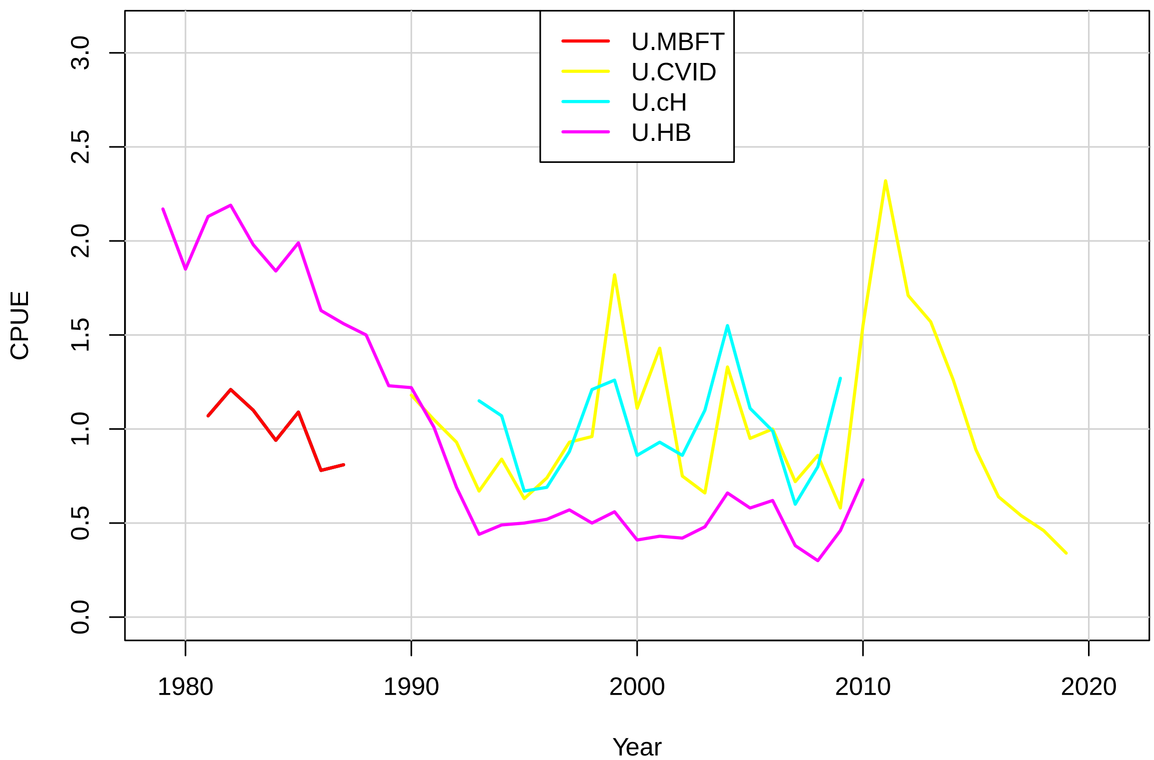


Figure 4. Observed (open circles) and estimated (solid line) pooled length compositions for the commercial lines fishery weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot.

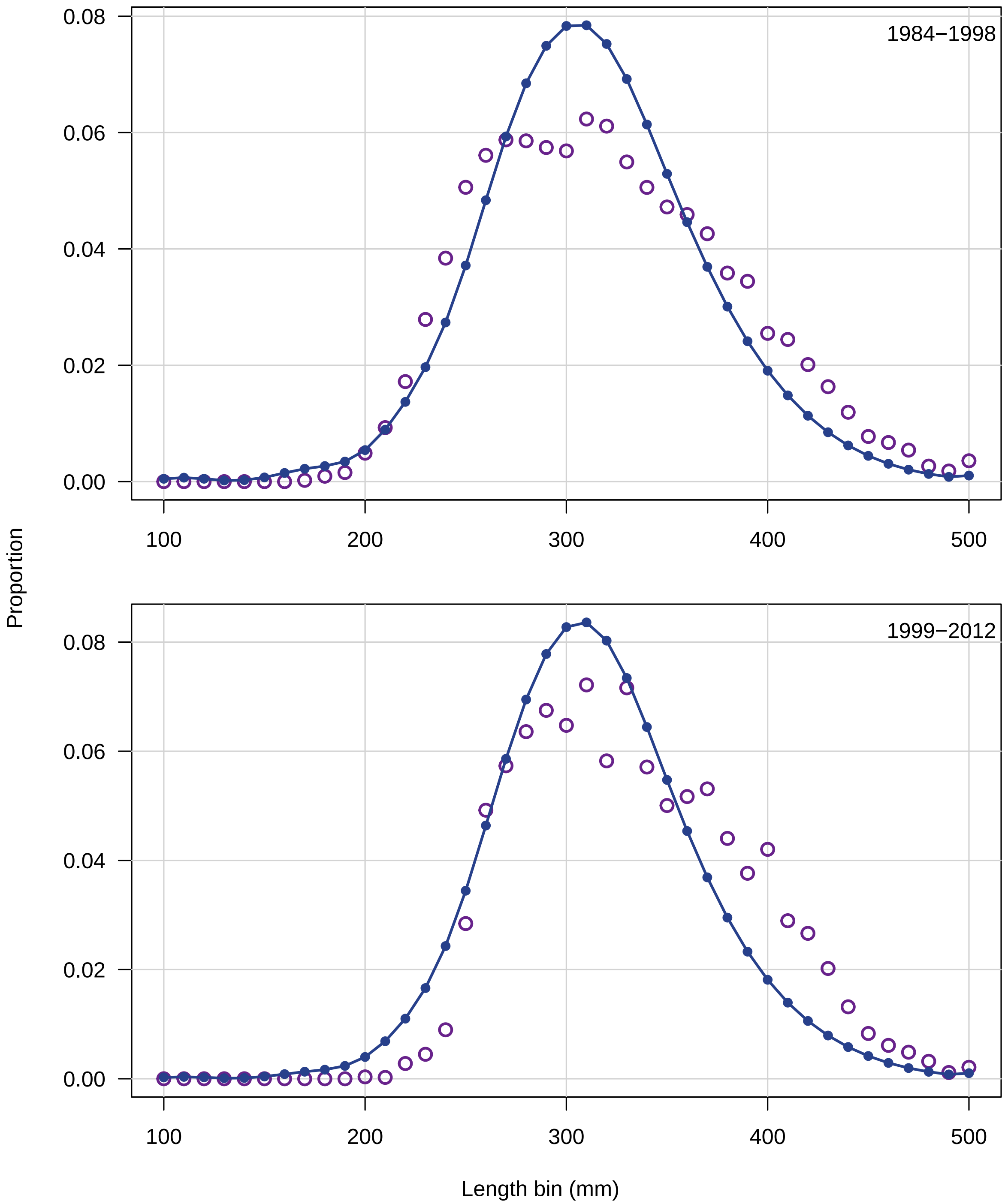


Figure 5. Observed (open circles) and estimated (solid line) pooled length compositions for the commercial pots fishery weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot. Note that the time block 2013-2021 only has data for the year 2021.

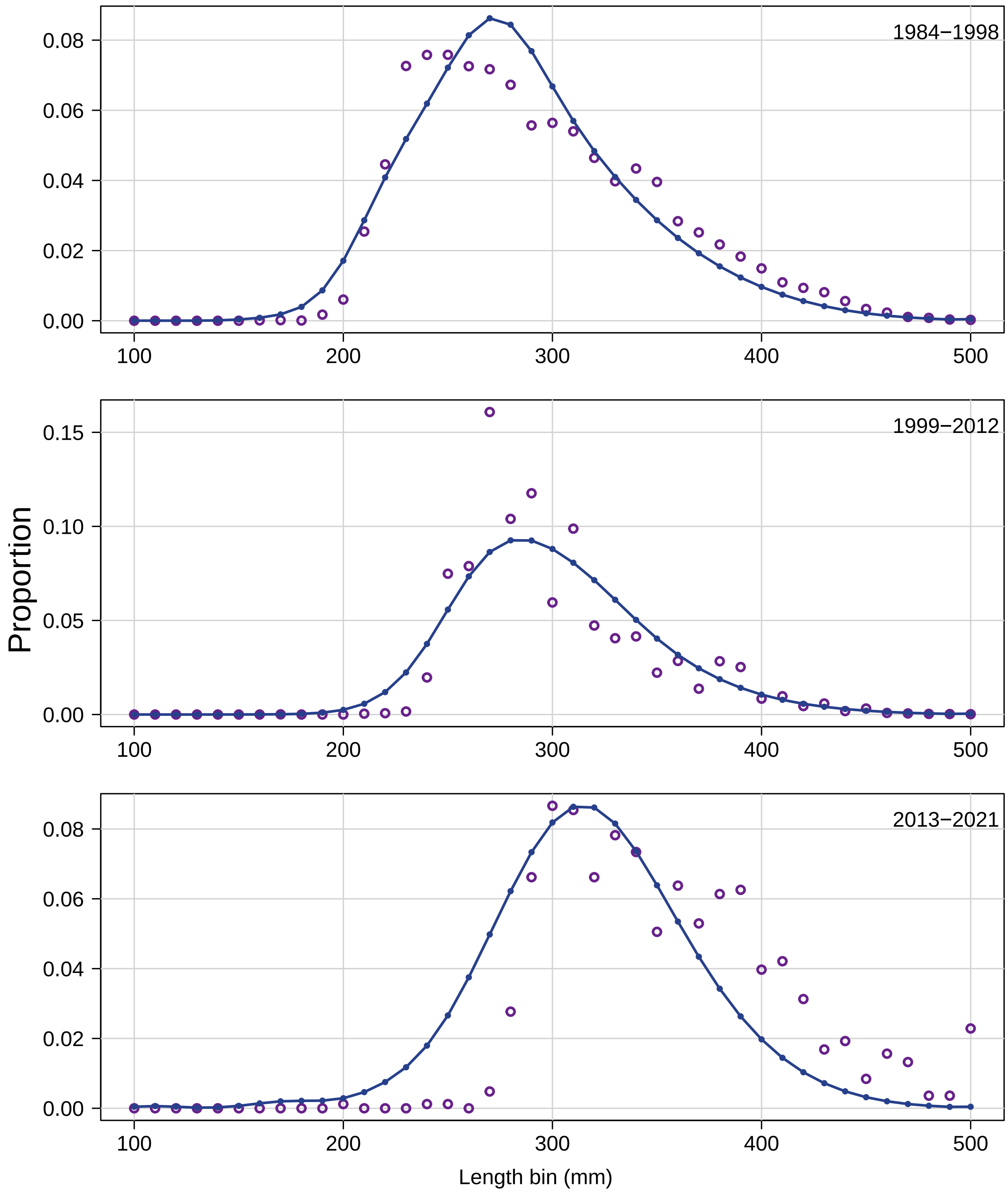


Figure 6. Observed (open circles) and estimated (solid line) pooled length compositions for the headboat fishery weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot. Note that the time block 2013-2020 only has data for the year 2020.

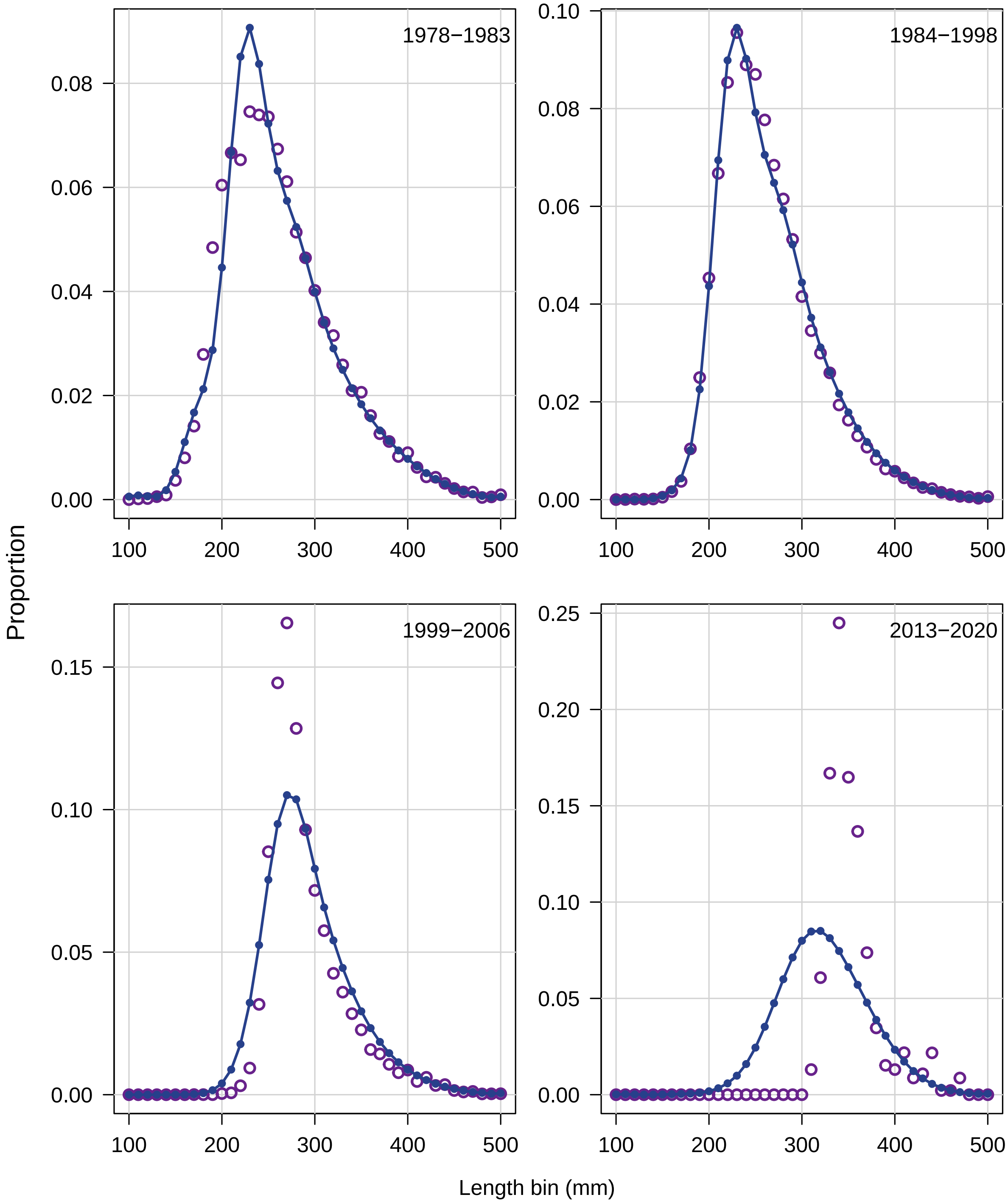


Figure 7. Observed (open circles) and estimated (solid line) pooled length compositions for the headboat discard fishery weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot.

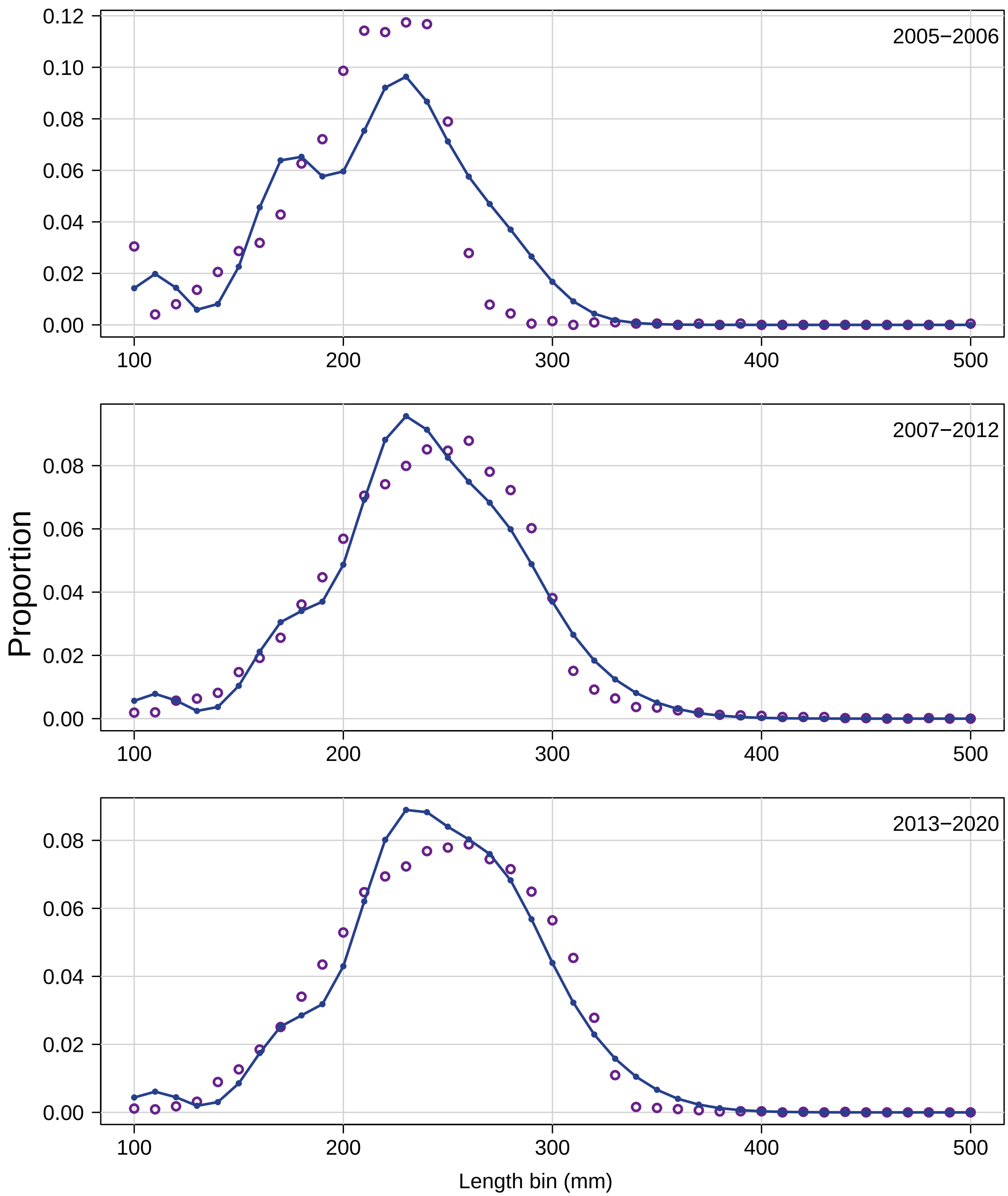


Figure 8. Observed (open circles) and estimated (solid line) pooled length compositions for the MARMAP blackfish/snapper trap survey weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot.

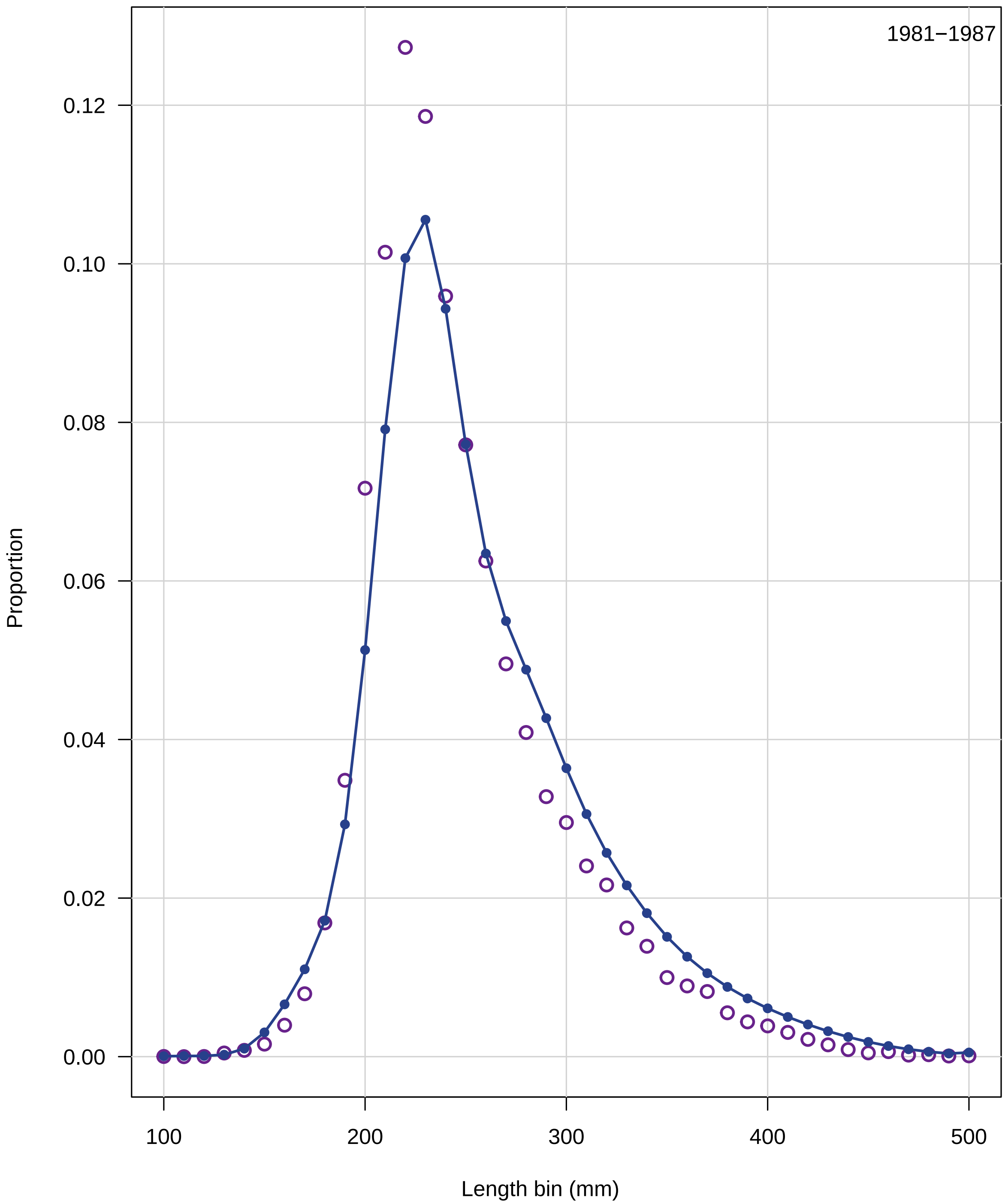


Figure 9. Observed (open circles) and estimated (solid line) pooled length compositions for the general recreational fishery weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot.

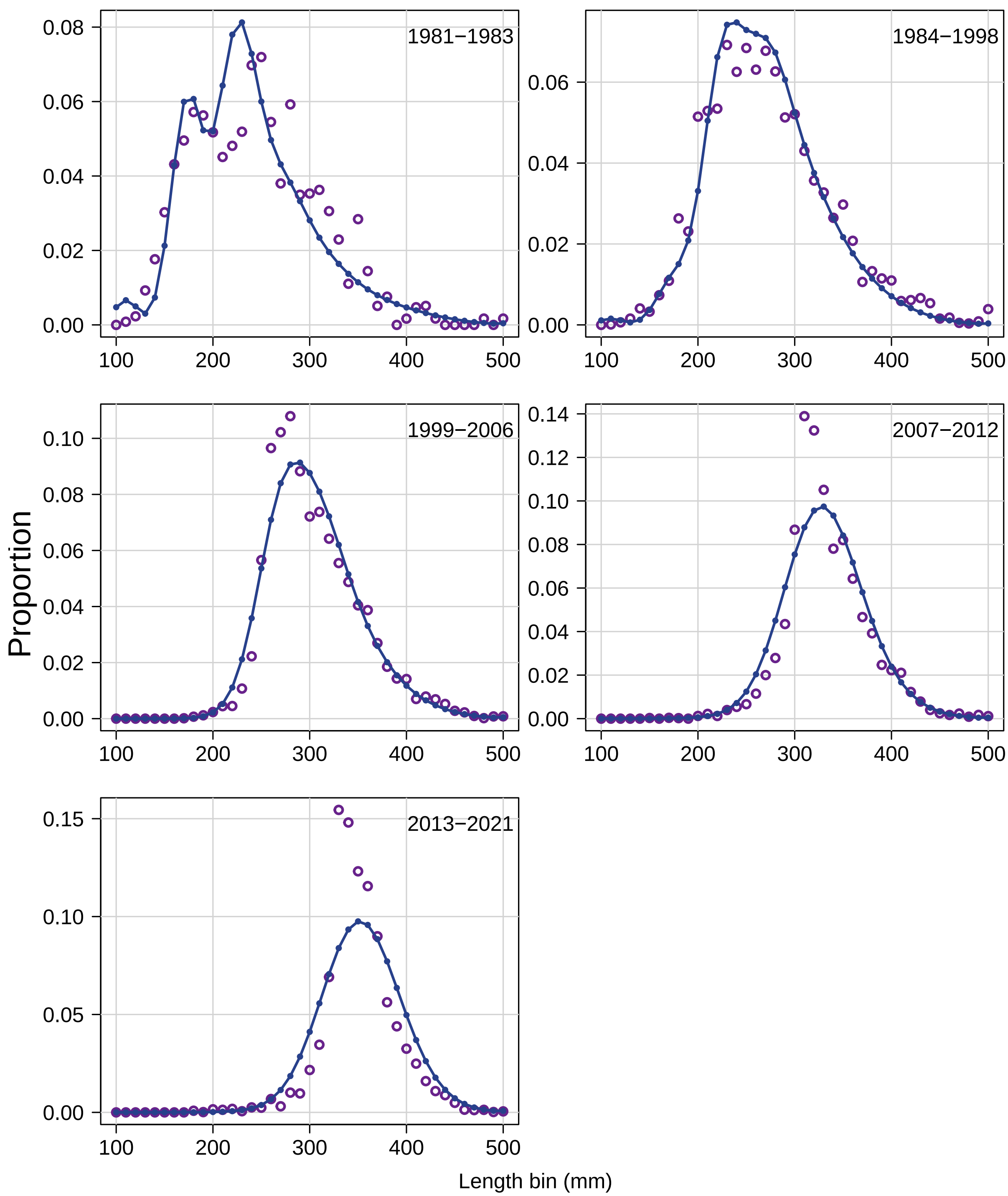


Figure 10. Observed (open circles) and estimated (solid line) pooled age compositions for the commercial lines fishery weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot.

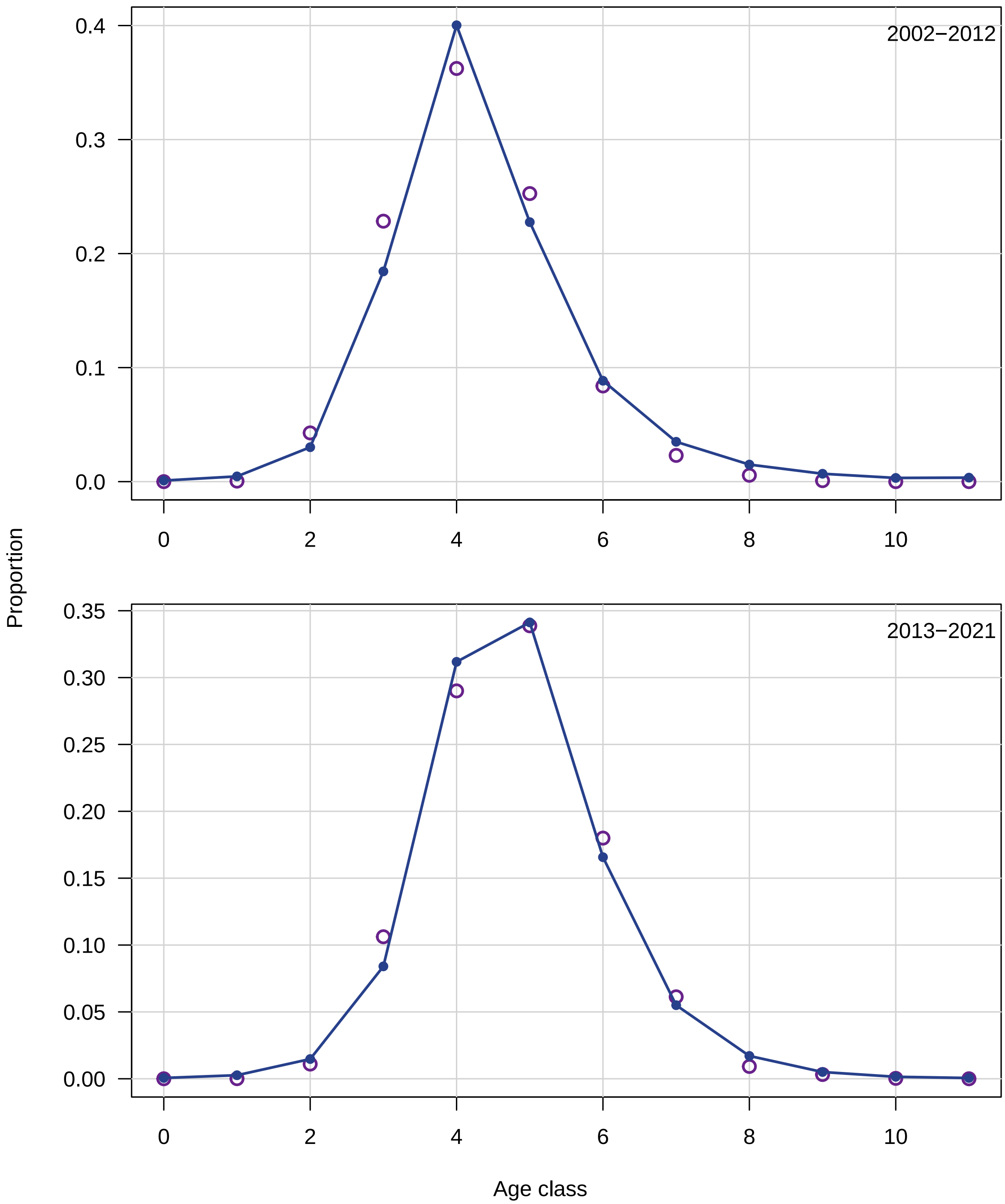


Figure 11. Observed (open circles) and estimated (solid line) pooled age compositions for the commerical pots fishery weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot.

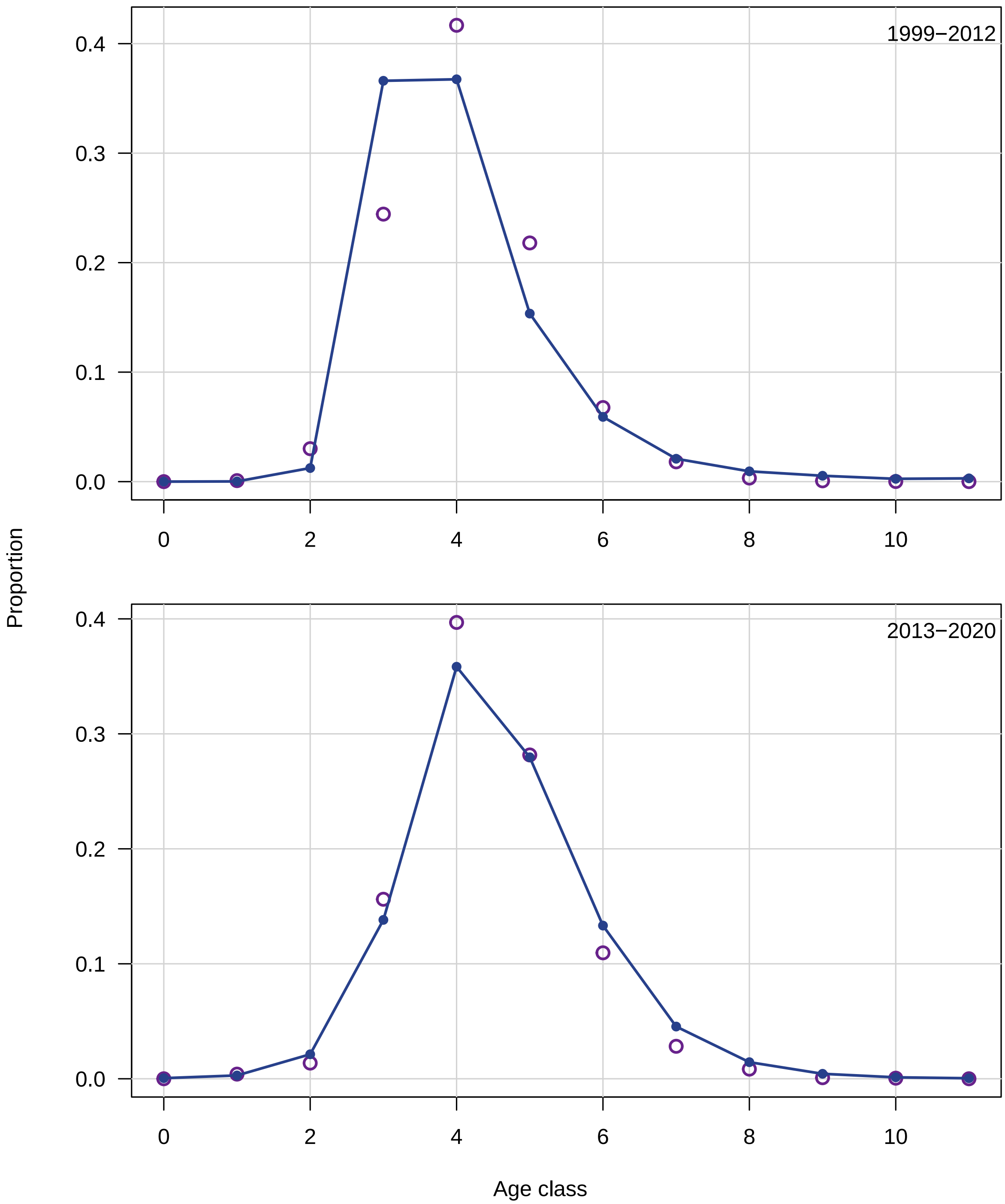


Figure 12. Observed (open circles) and estimated (solid line) pooled age compositions for the headboat fishery weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot.

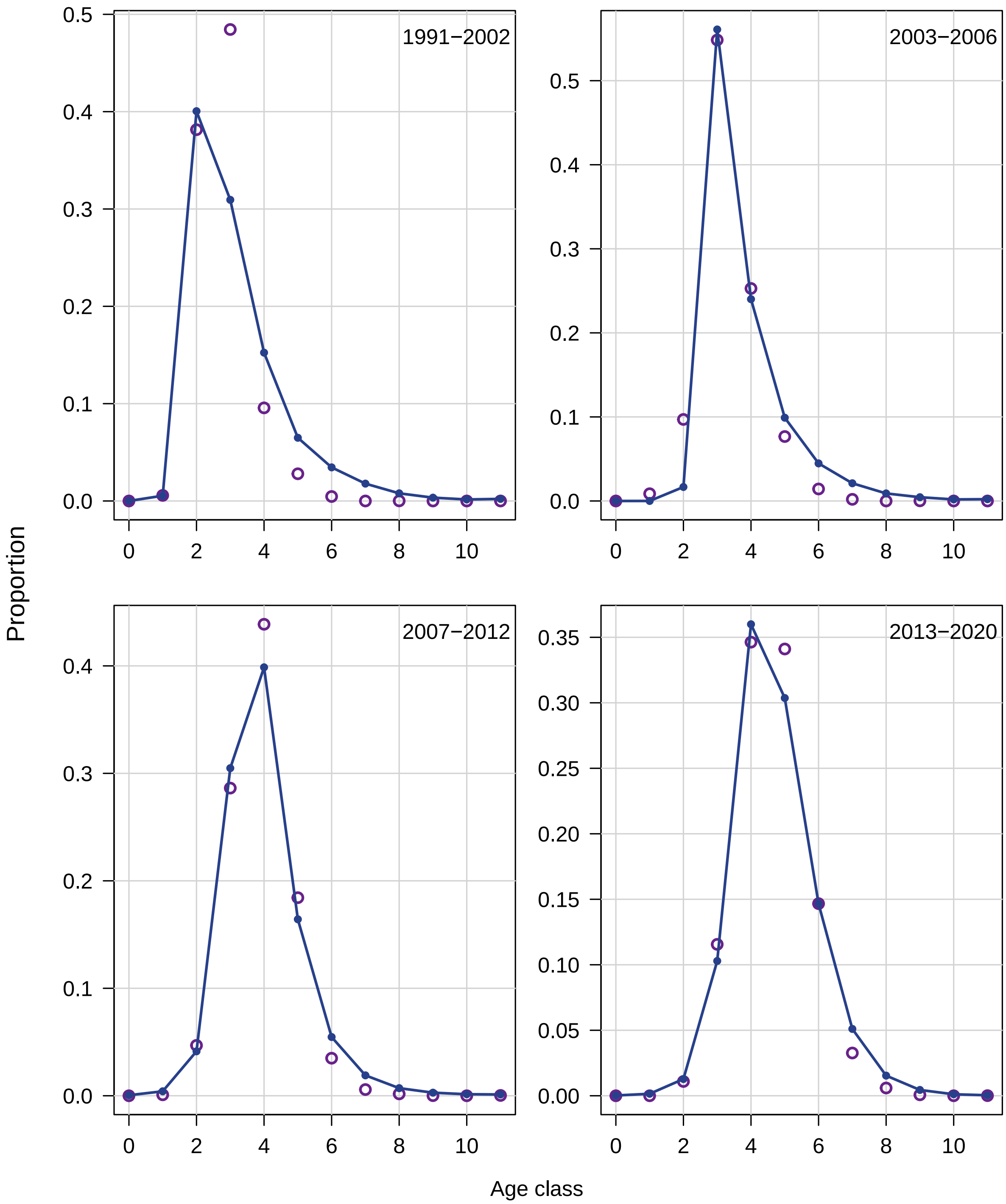


Figure 13. Observed (open circles) and estimated (solid line) age compositions in 1983 for the MARMAP blackfish/snapper trap survey from the base run.

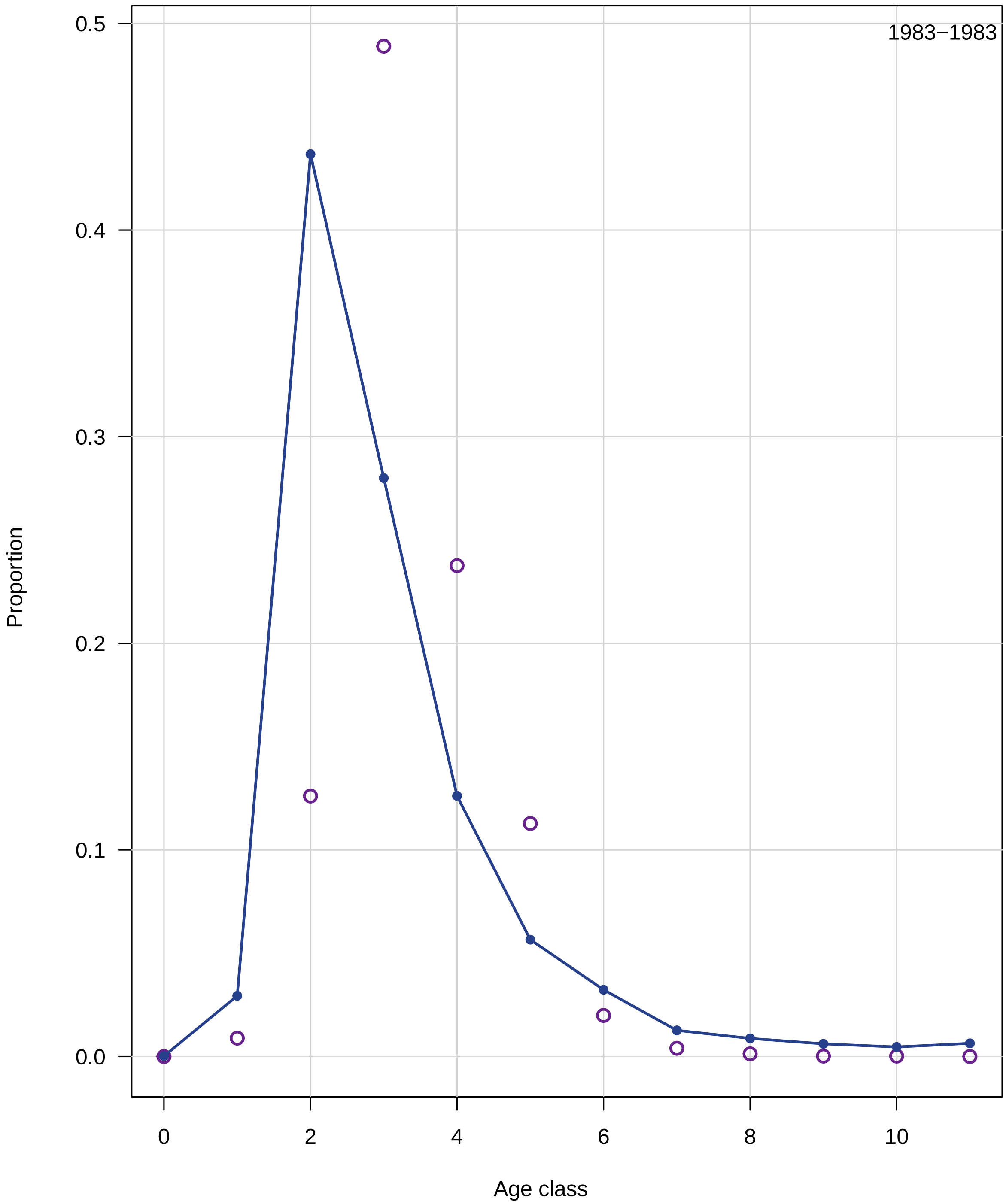


Figure 14. Observed (open circles) and estimated (solid line) pooled age compositions for the SERFS chevron trap survey weighted by the effective sample size from the base run.

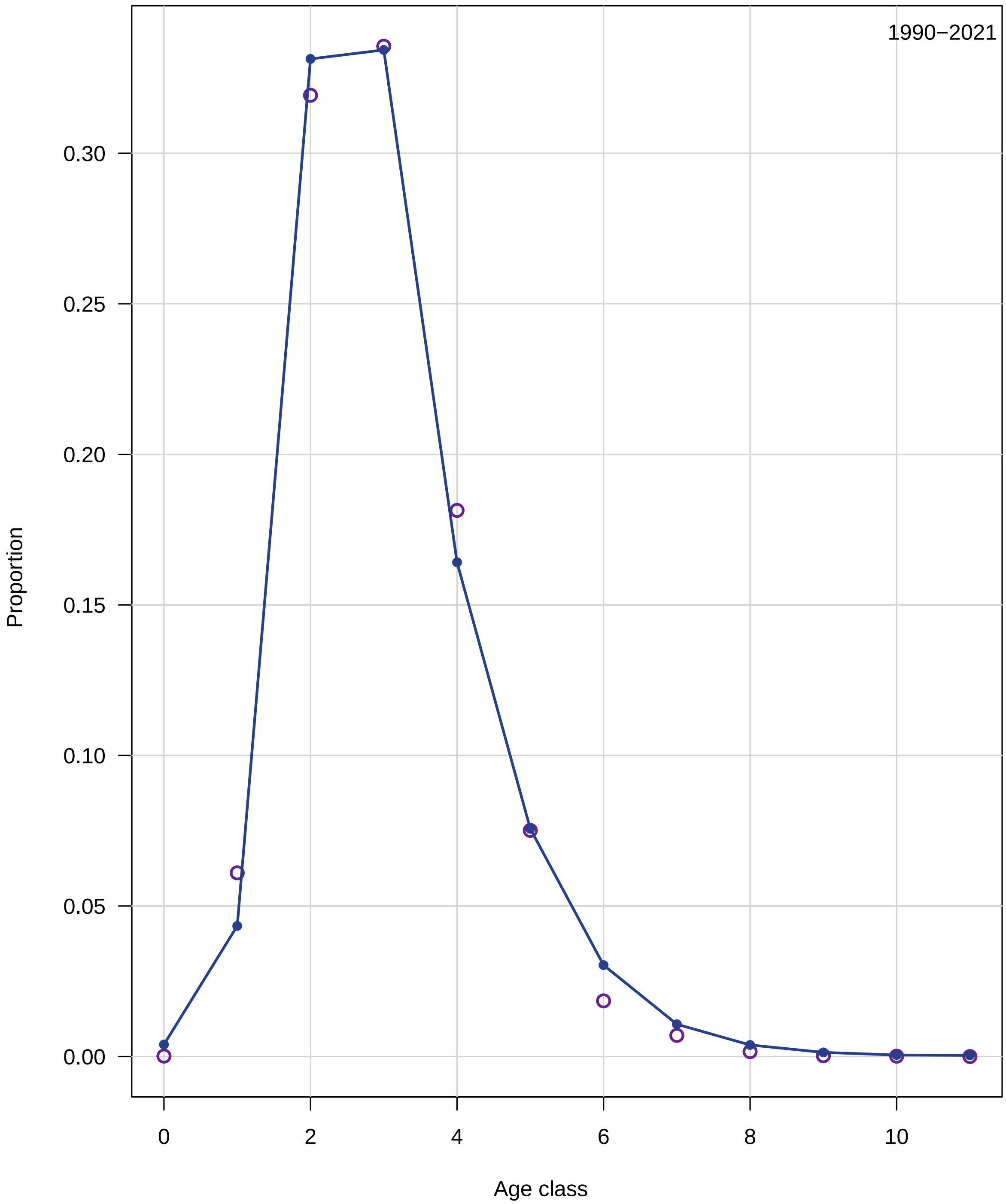


Figure 15. Observed (open circles) and estimated (line, solid circles) commercial lines landings (1000 lb whole weight).

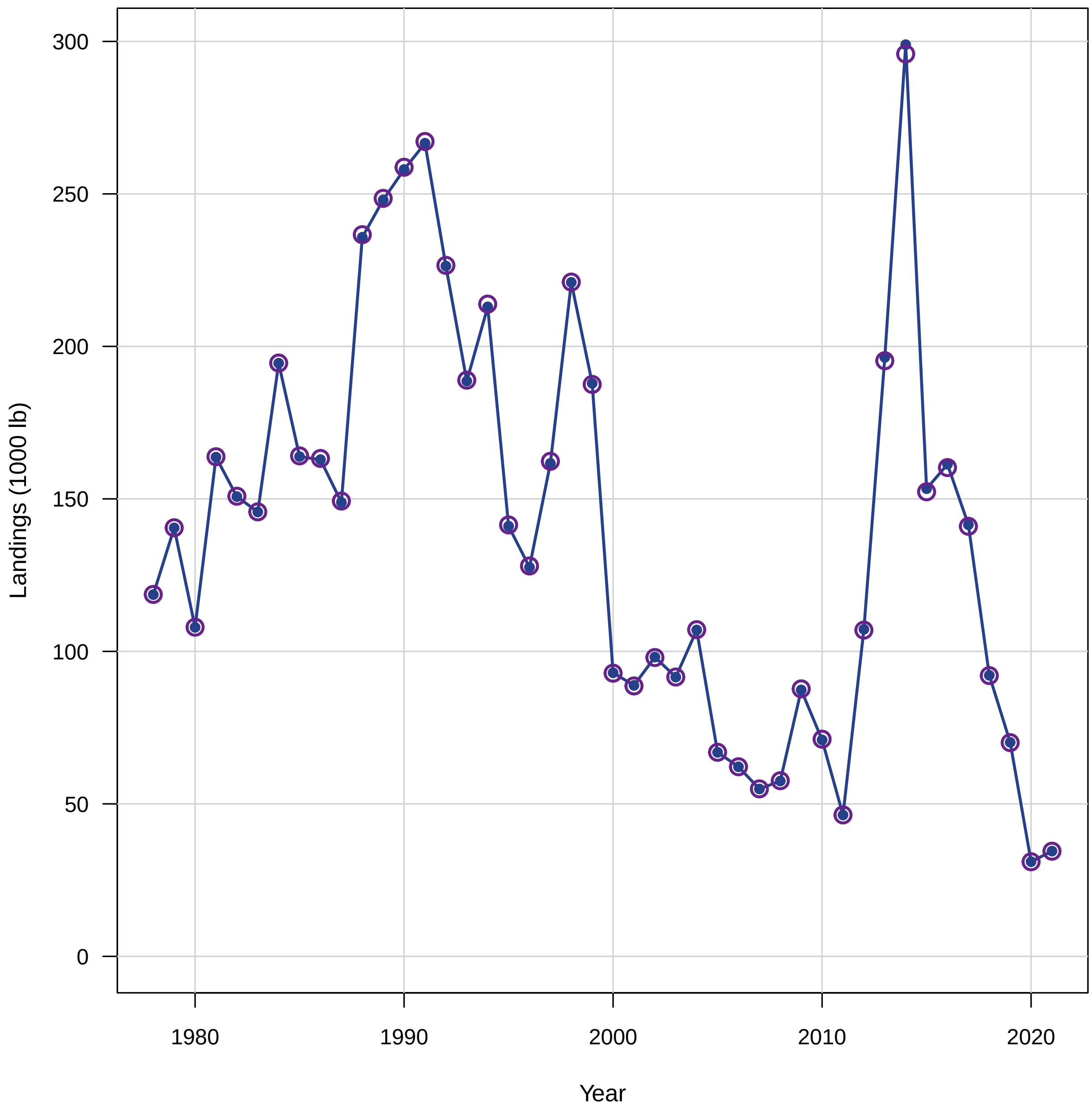


Figure 16. Observed (open circles) and estimated (line, solid circles) commercial pot landings (1000 lb whole weight).

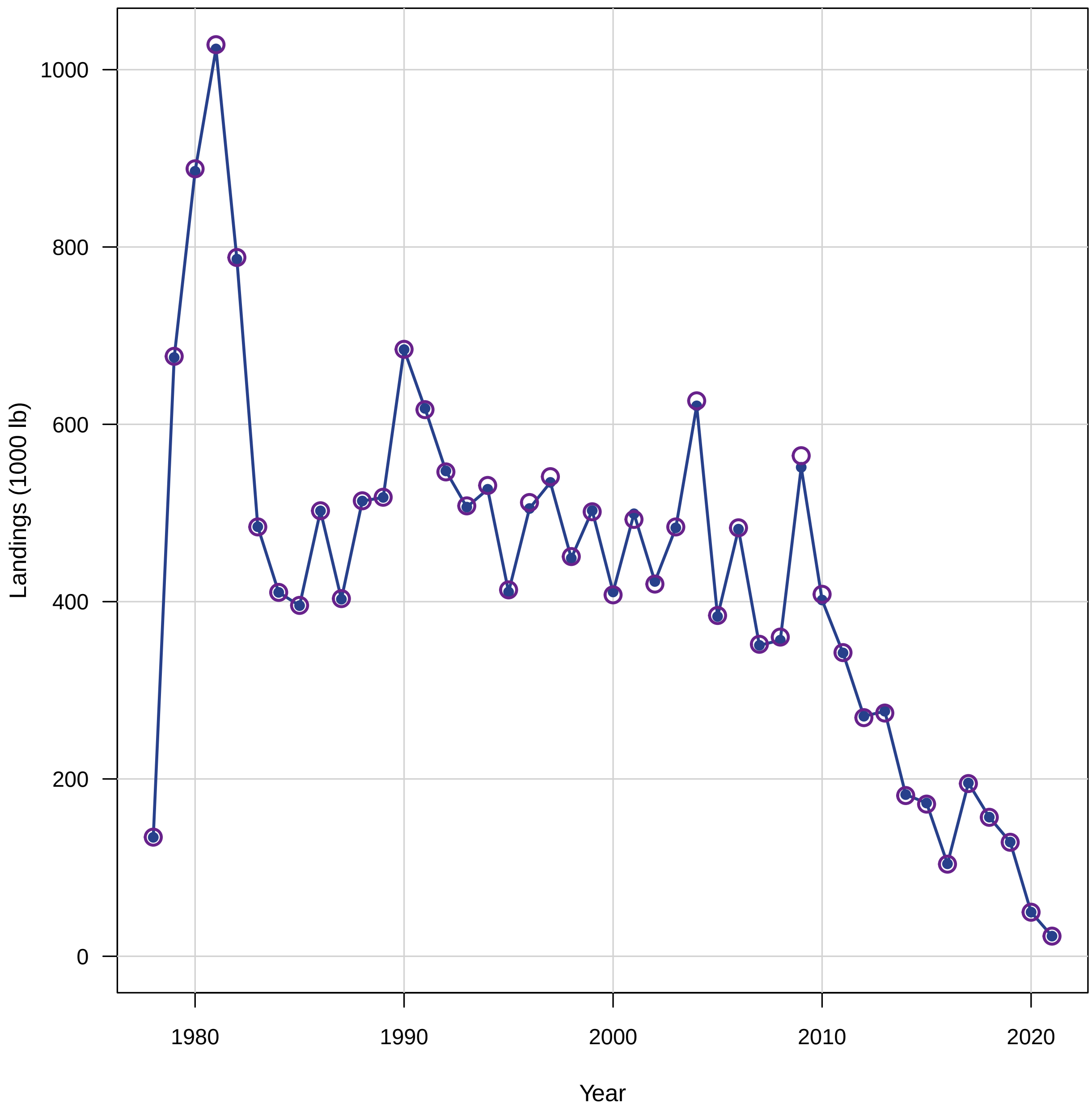


Figure 17. Observed (open circles) and estimated (line, solid circles) commercial trawl landings (1000 lb whole weight).

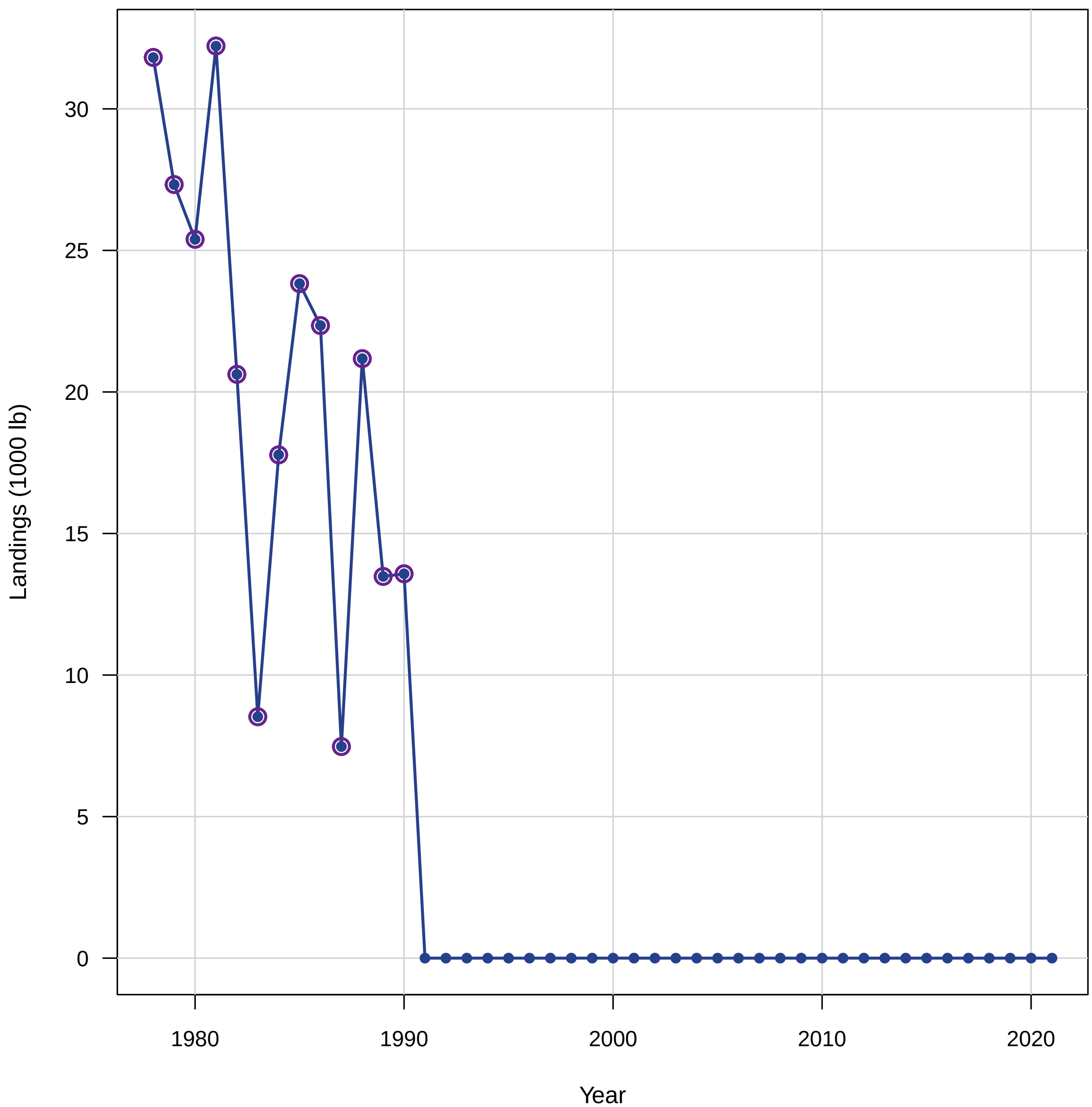


Figure 18. Observed (open circles) and estimated (line, solid circles) headboat landings (1000 lb whole weight).

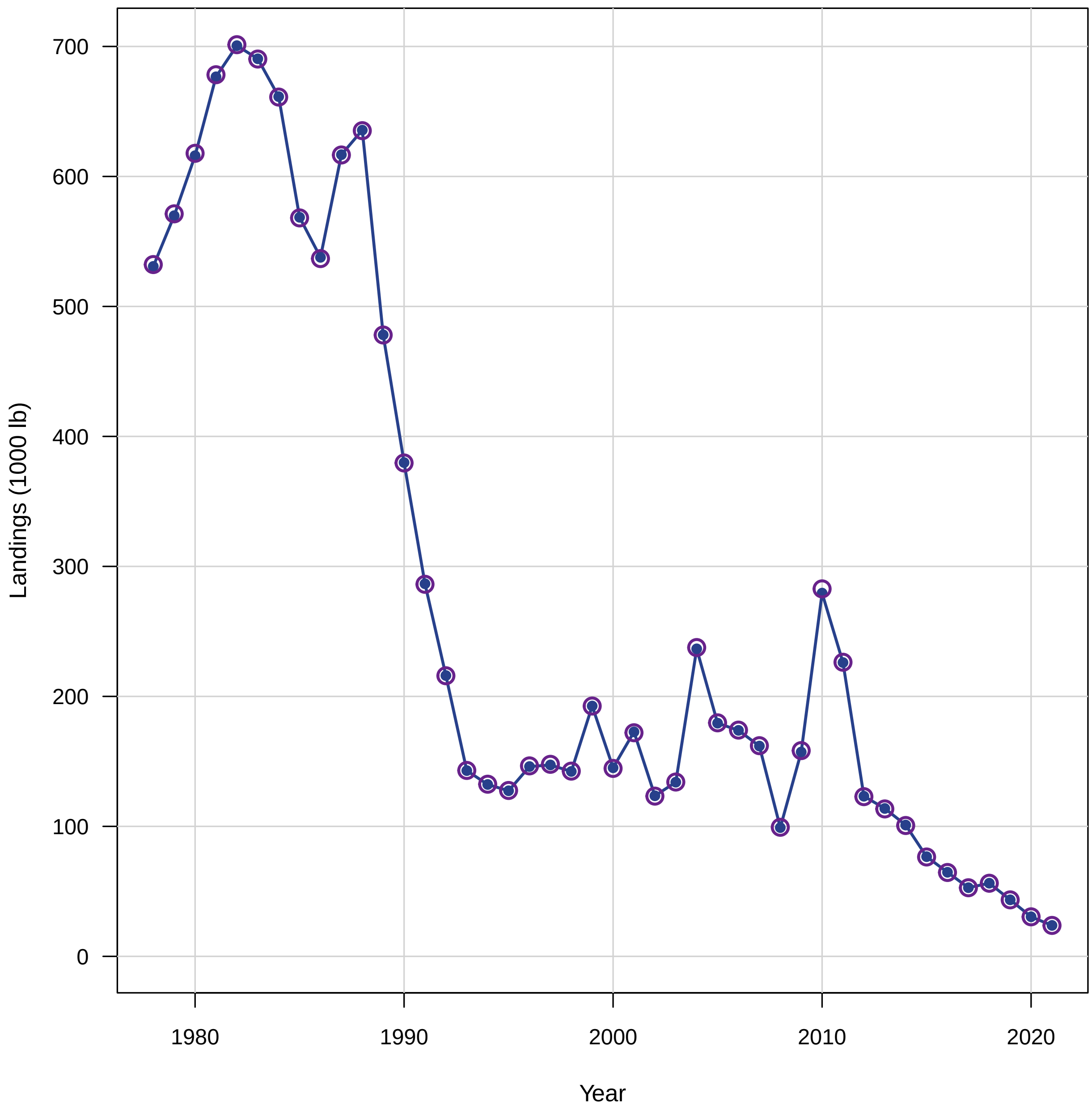


Figure 19. Observed (open circles) and estimated (line, solid circles) general recreational landings (1000 lb whole weight). In years without observations (1978–1980), values were predicted using average F (see §3.3 for details).

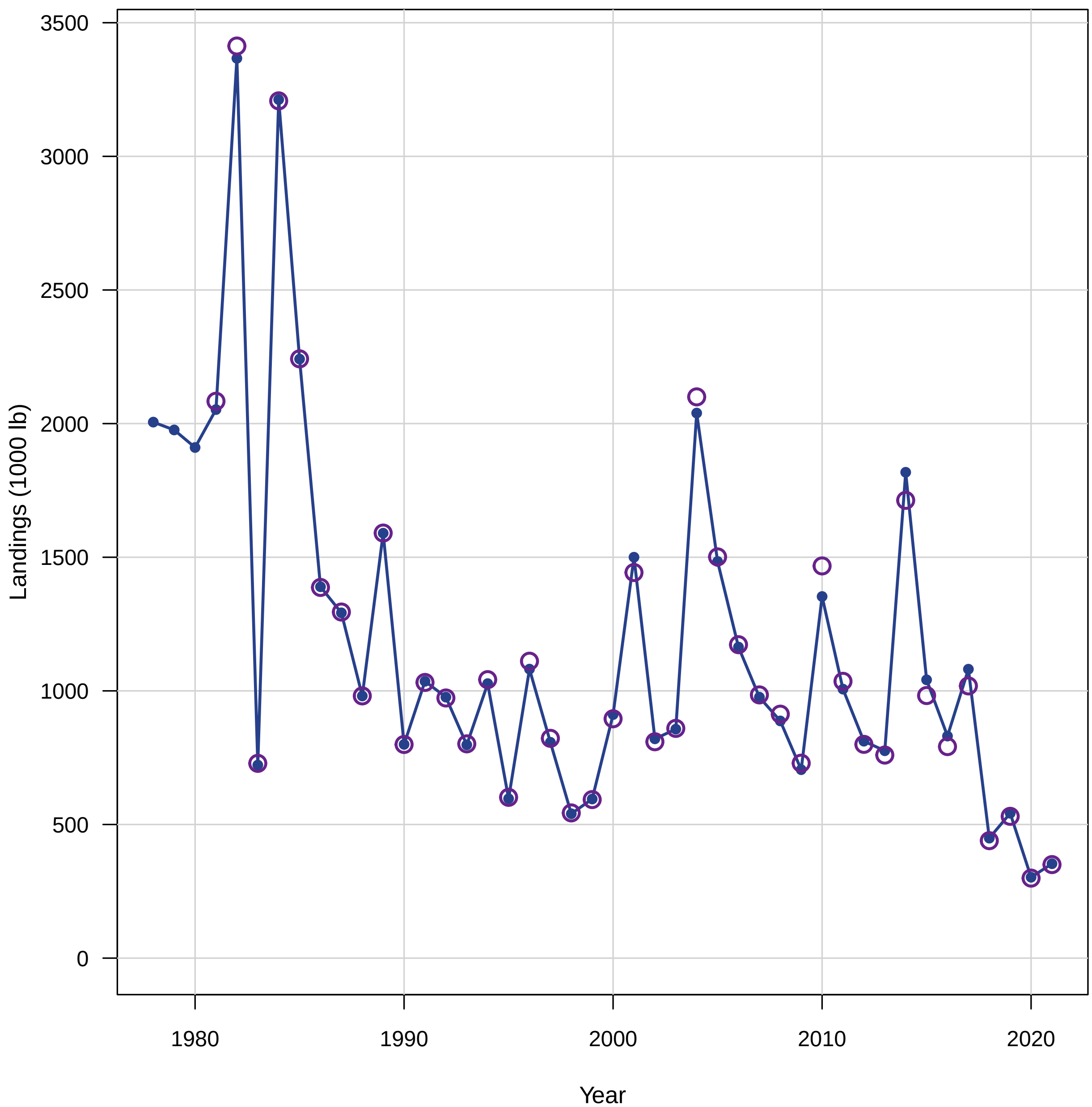


Figure 20. Observed (open circles) and estimated (line, solid circles) commercial (lines + pots) discard mortalities (1000 dead fish). In years without observations (1984–1992), values were predicted using average F (see §3.3 for details). Commercial discards were modeled starting in 1984 with implementation of the 8-inch size limit.

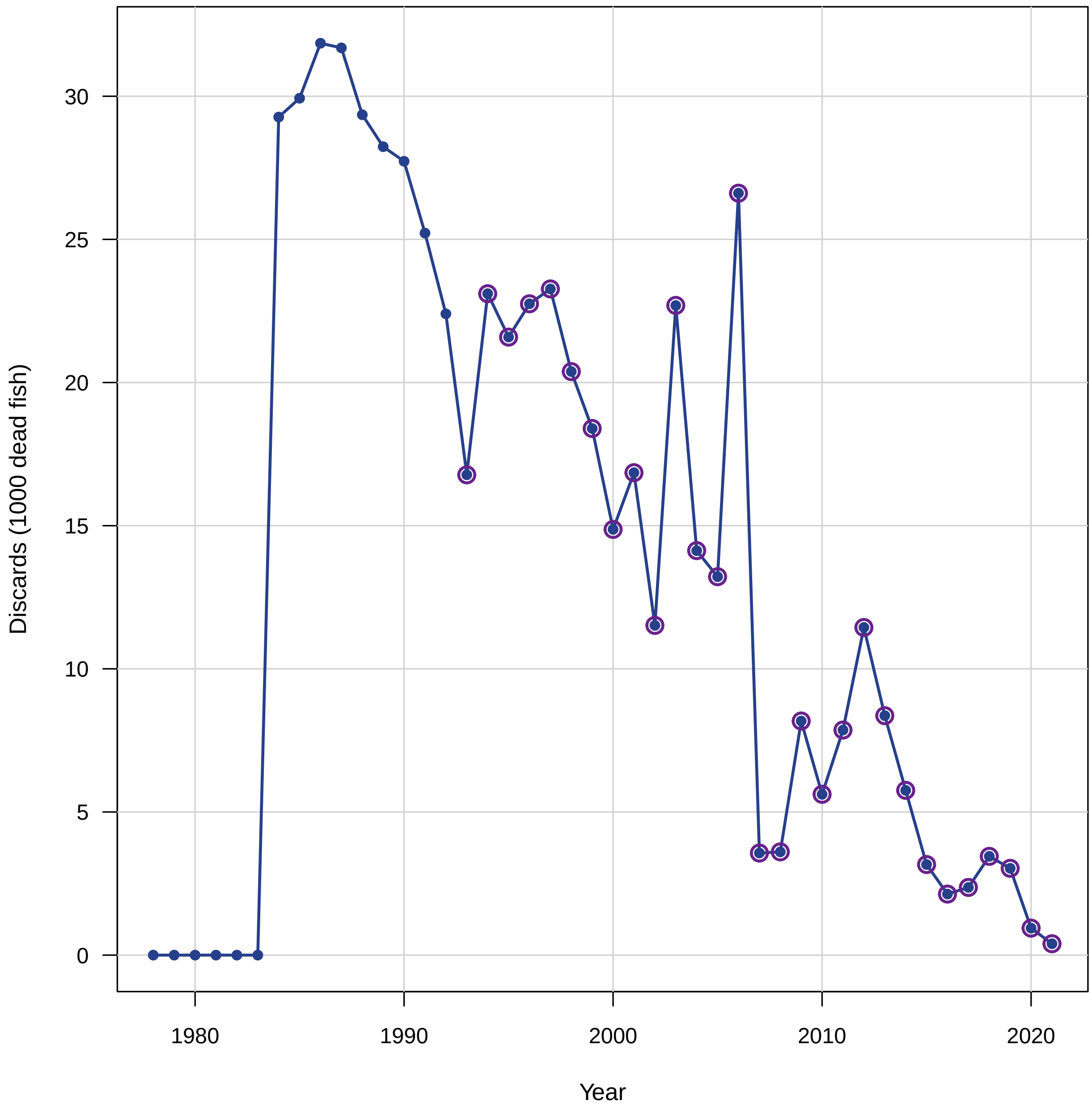


Figure 21. Observed (open circles) and estimated (line, solid circles) headboat discard mortalities (1000 dead fish). Estimates prior to 1986 were combined with the general recreational discards.

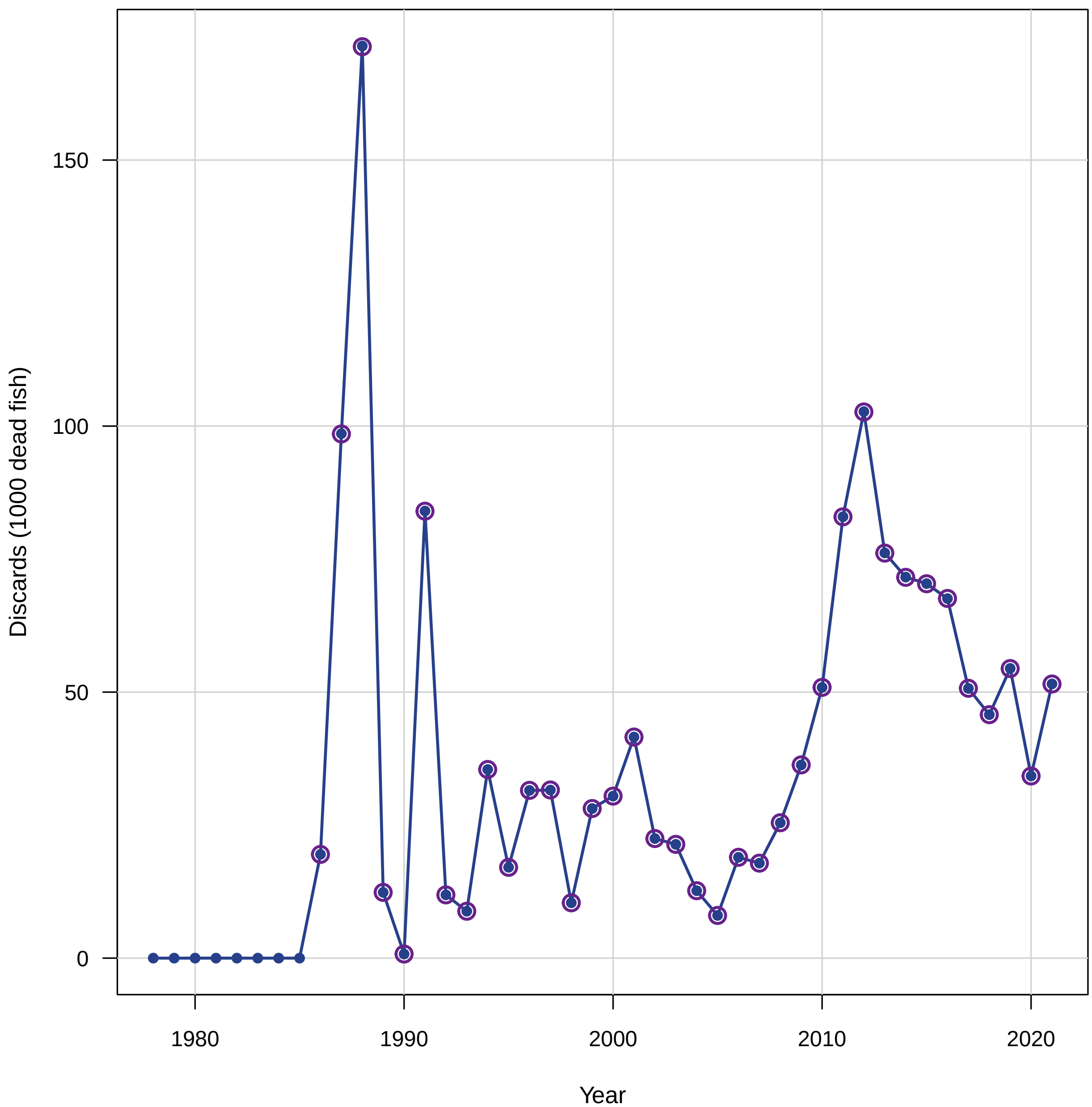


Figure 22. Observed (open circles) and estimated (line, solid circles) general recreational discard mortalities (1000 dead fish). Estimates prior to 1986 include headboat discard mortalities. In years without observations (1978–1980), values were predicted using average F (see §3.3 for details).

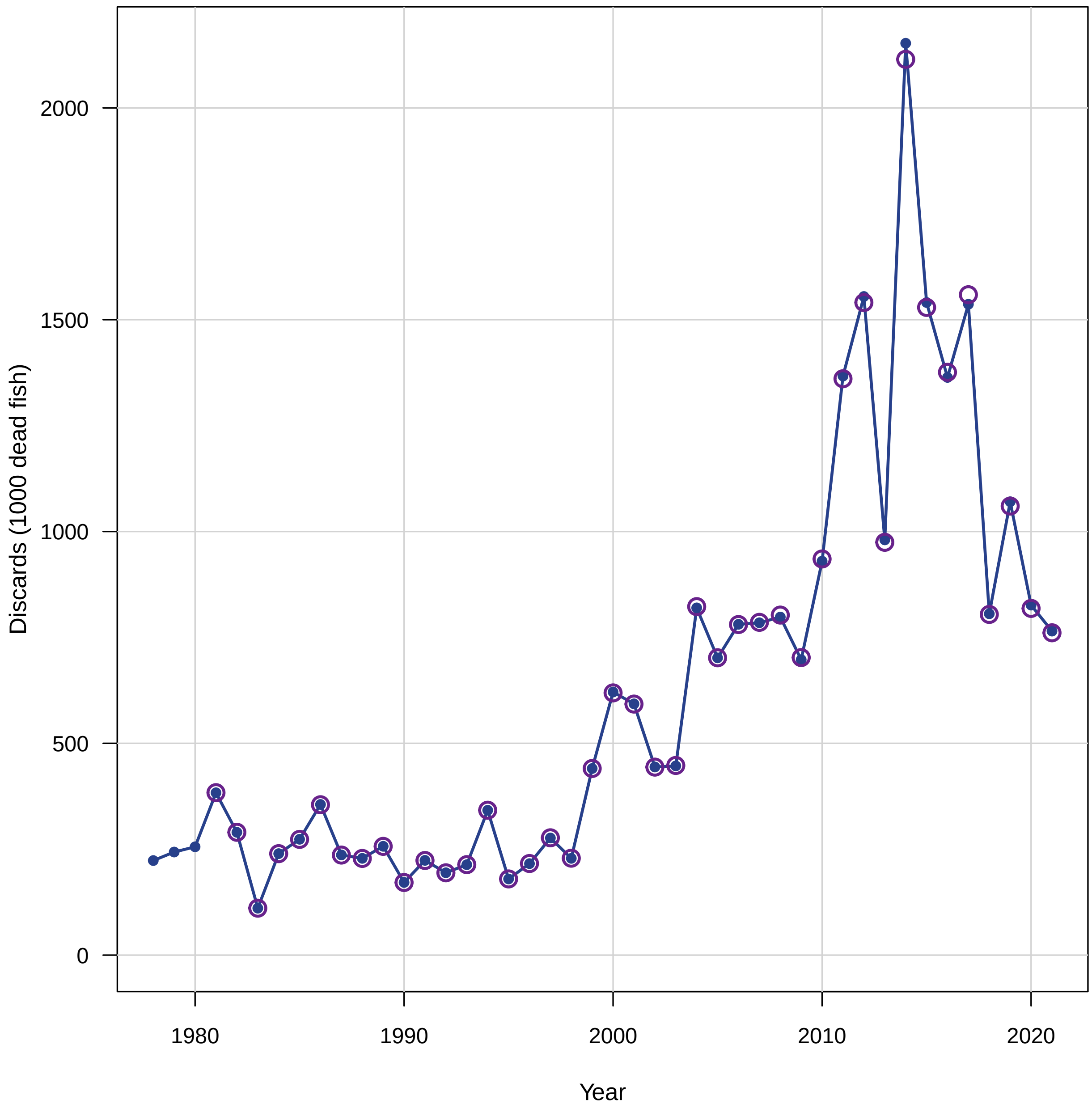


Figure 23. Observed (open circles) and estimated (line, solid circles) index of abundance from MARMAP blackfish/snapper traps. The bottom panel are the log residuals of the fit to the index and the color of the box indicates the p-value of the runs test (green > 0.05, orange ≤ 0.05 and >0.01, red < 0.01) and the width of the box is 3 times the standard error. Points that fall outside 3 standard errors are plotted in red.

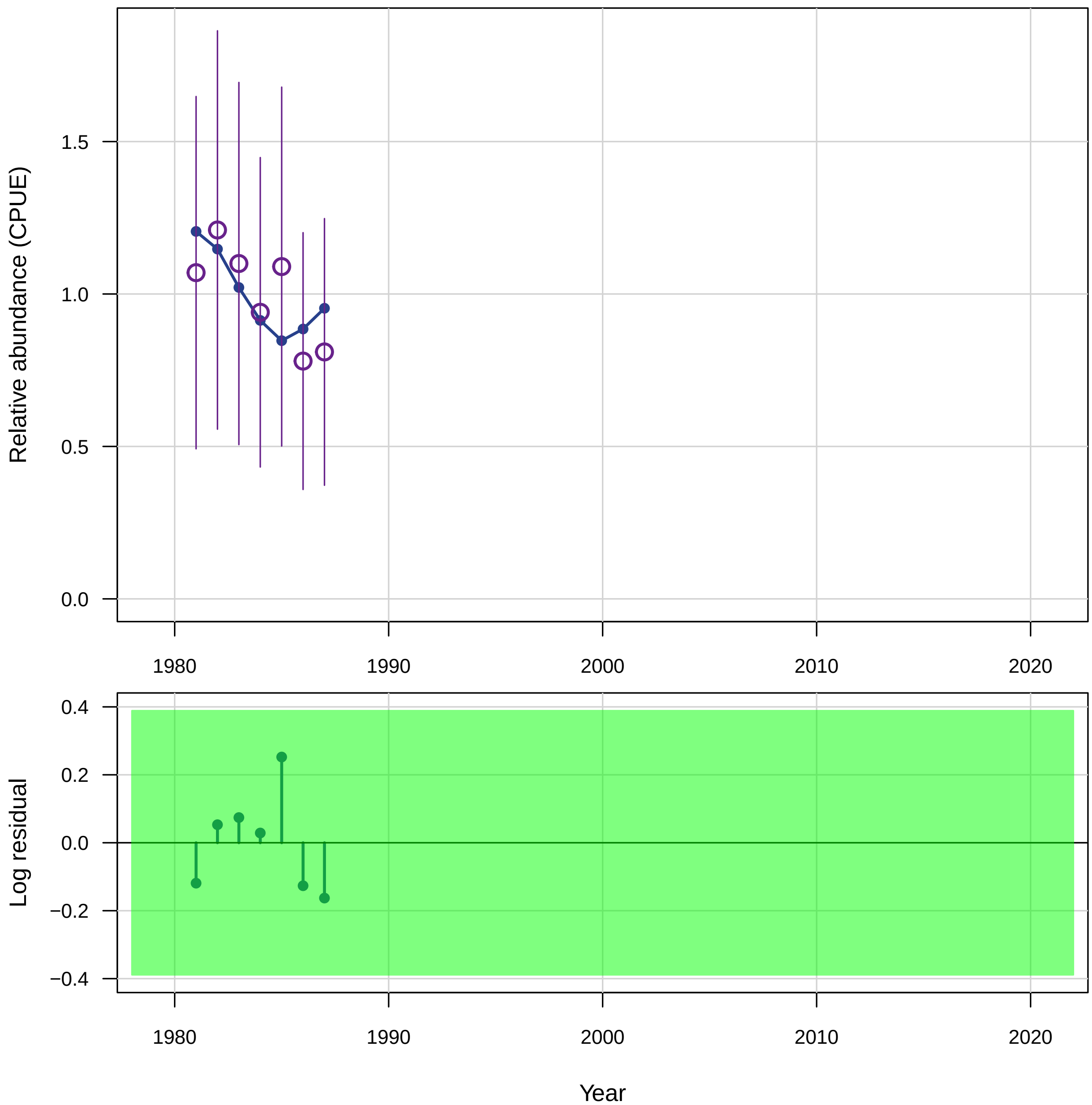


Figure 24. Observed (open circles) and estimated (line, solid circles) index of abundance from SERFS chevron trap index and SERFS Video index combined (CVID). The bottom panel are the log residuals of the fit to the index and the color of the box indicates the p-value of the runs test (green > 0.05, orange ≤ 0.05 and >0.01, red ≤ 0.01) and the width of the box is 3 times the standard error. Points that fall outside 3 standard errors are plotted in red.

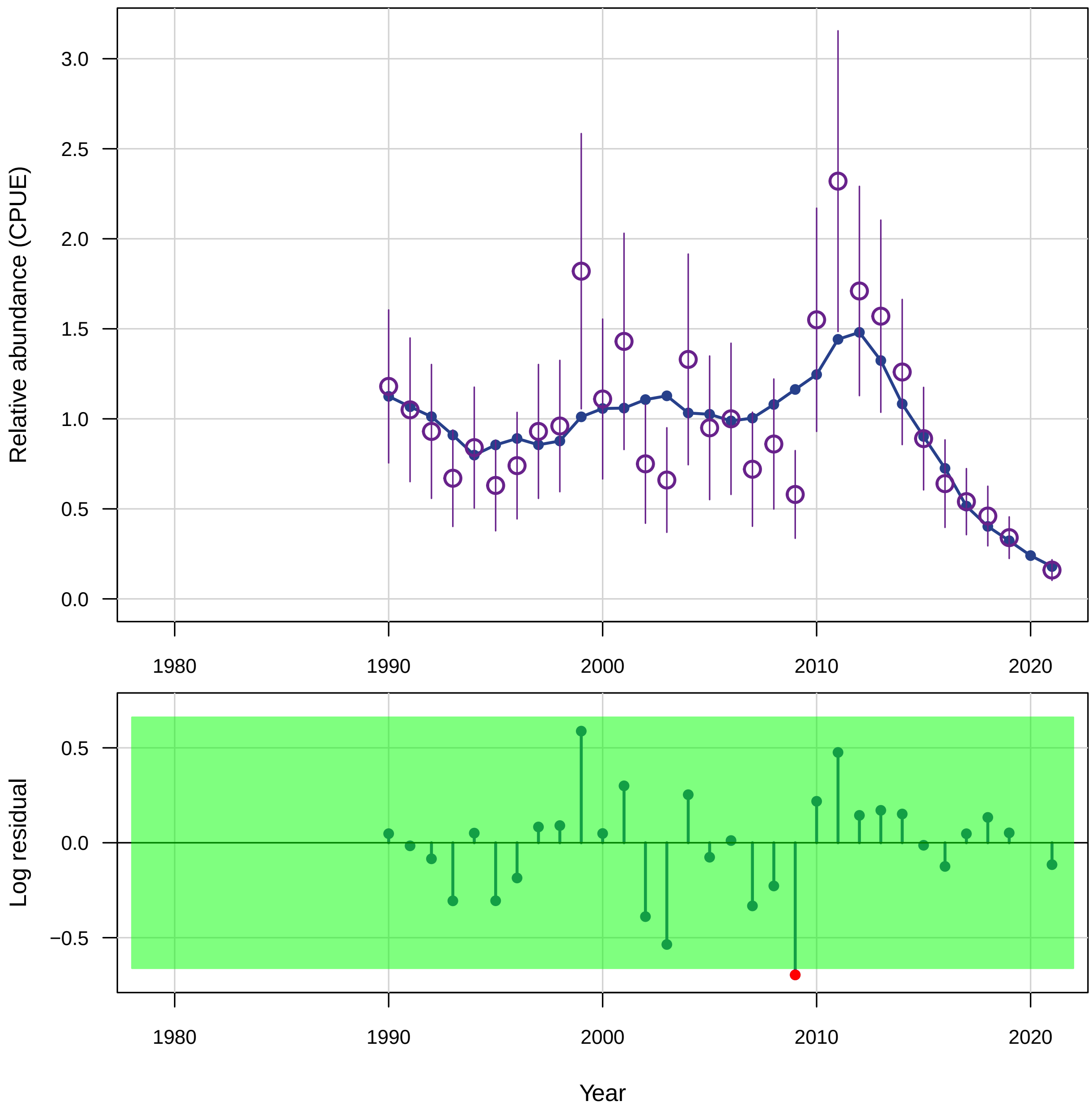


Figure 25. Observed (open circles) and estimated (line, solid circles) index of abundance from commercial lines. The bottom panel are the log residuals of the fit to the index and the color of the box indicates the p-value of the runs test (green > 0.05, orange ≤ 0.05 and >0.01, red ≤ 0.01) and the width of the box is 3 times the standard error. Points that fall outside 3 standard errors are plotted in red.

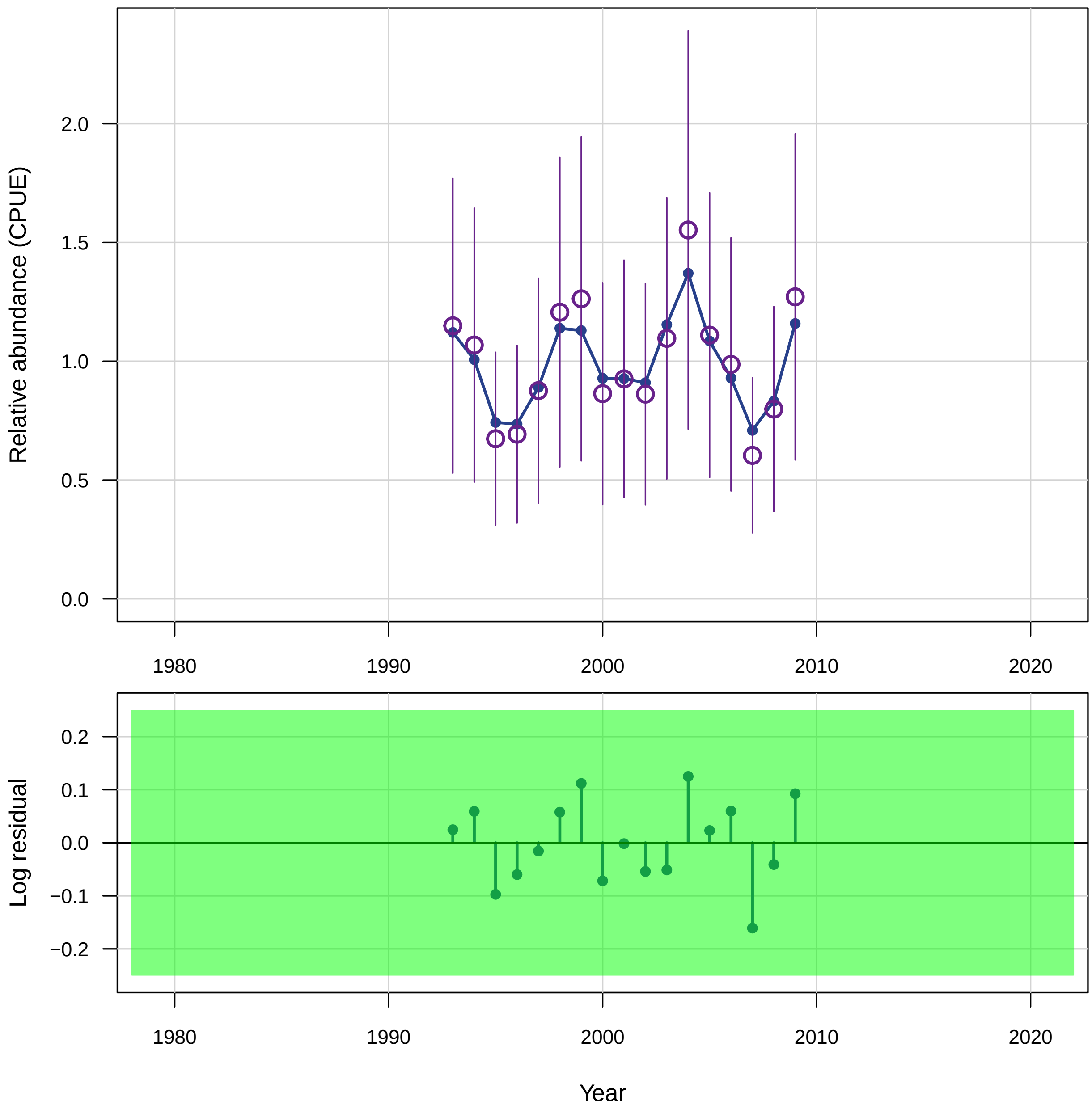


Figure 26. Observed (open circles) and estimated (line, solid circles) index of abundance from the headboat fleet. The bottom panel are the log residuals of the fit to the index and the color of the box indicates the p-value of the runs test (green > 0.05, orange ≤ 0.05 and >0.01, red ≤ 0.01) and the width of the box is 3 times the standard error. Points that fall outside 3 standard errors are plotted in red.

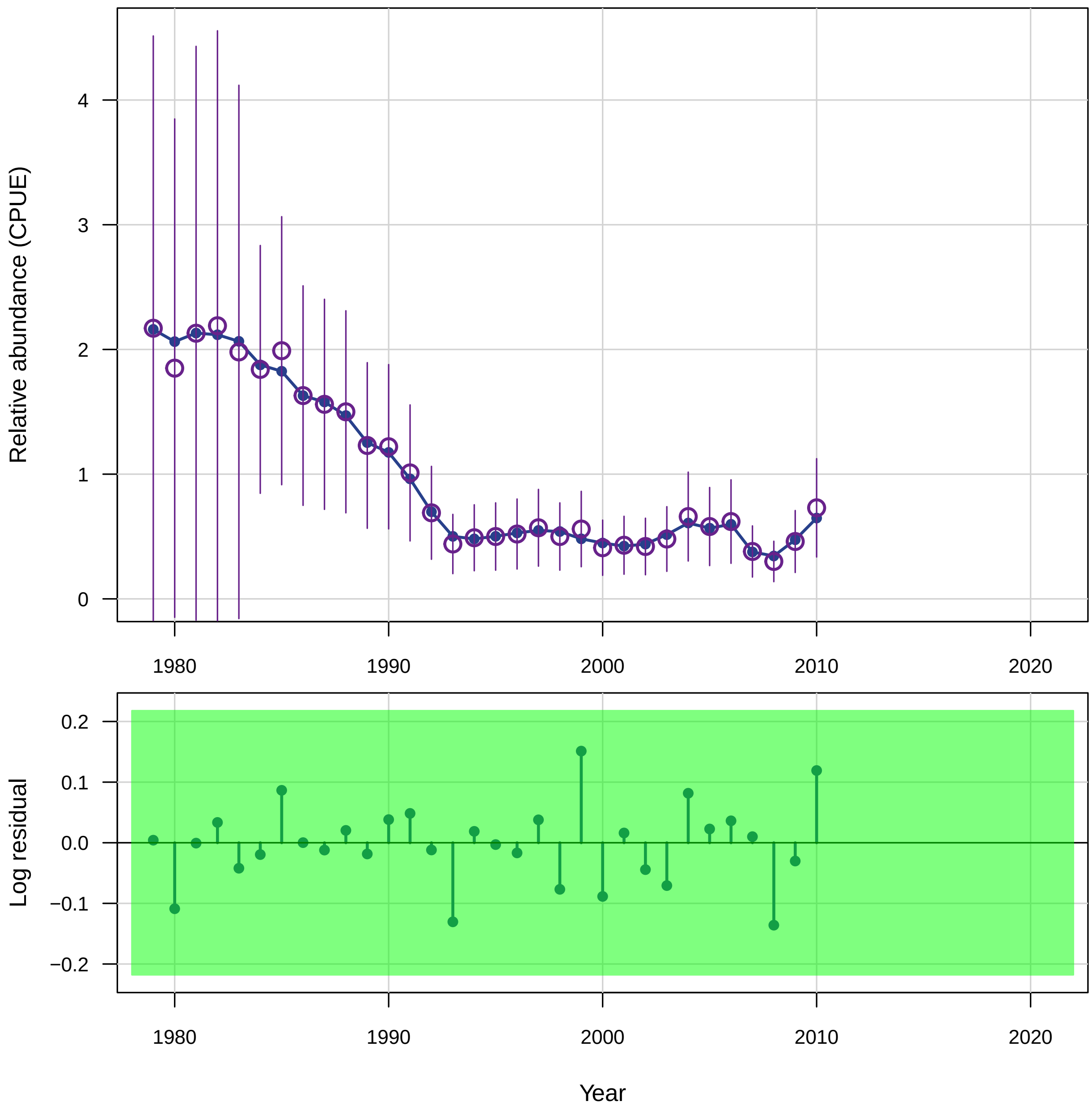


Figure 27. Estimated abundance at age at start of year.

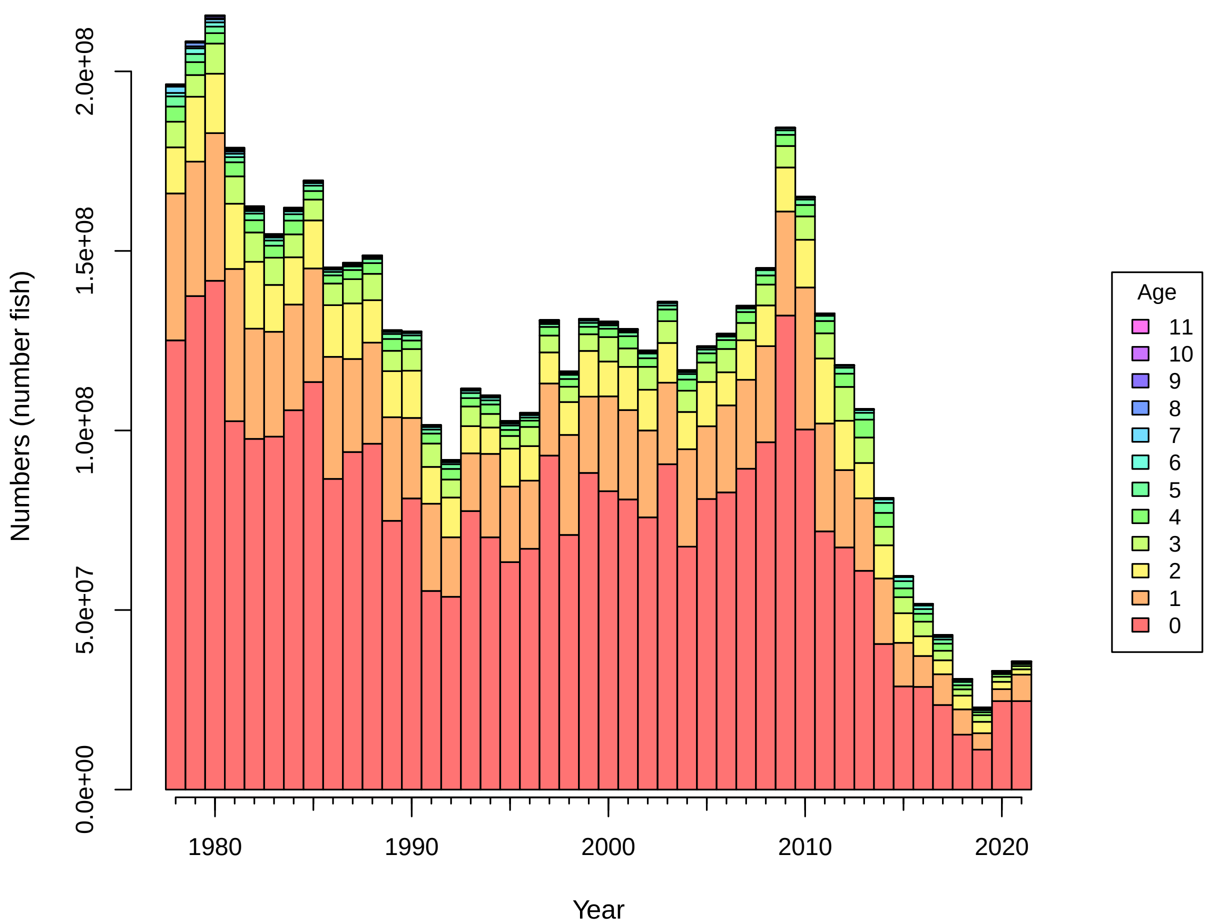


Figure 28. Top panel: Estimated recruitment of age-0 fish. Horizontal dashed line indicates R_{MSY}. Bottom panel: log recruitment residuals where recruitment in 2020 and 2021 were set at the average of 2014–2019.

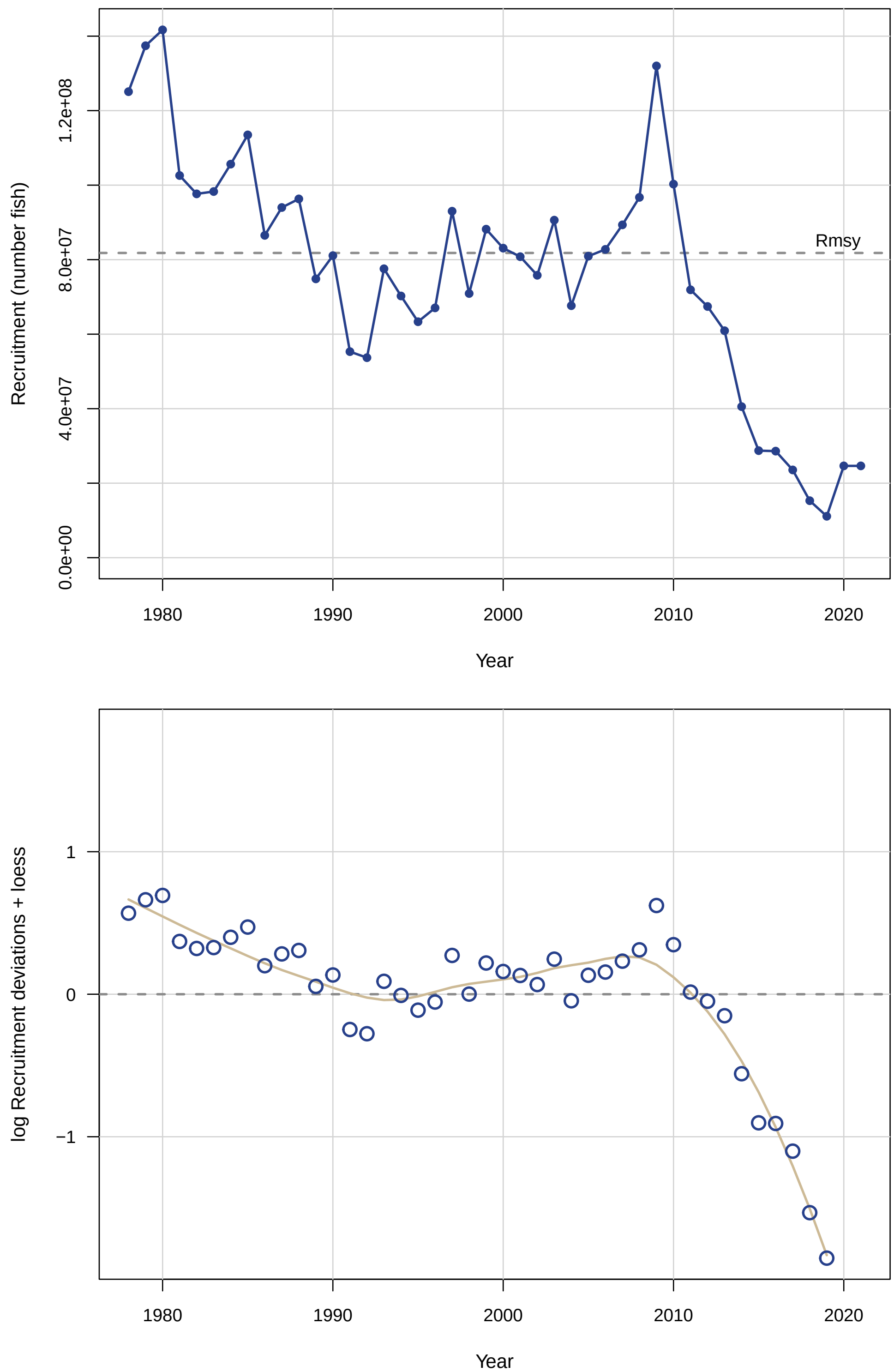


Figure 29. Estimated biomass at age at start of year.

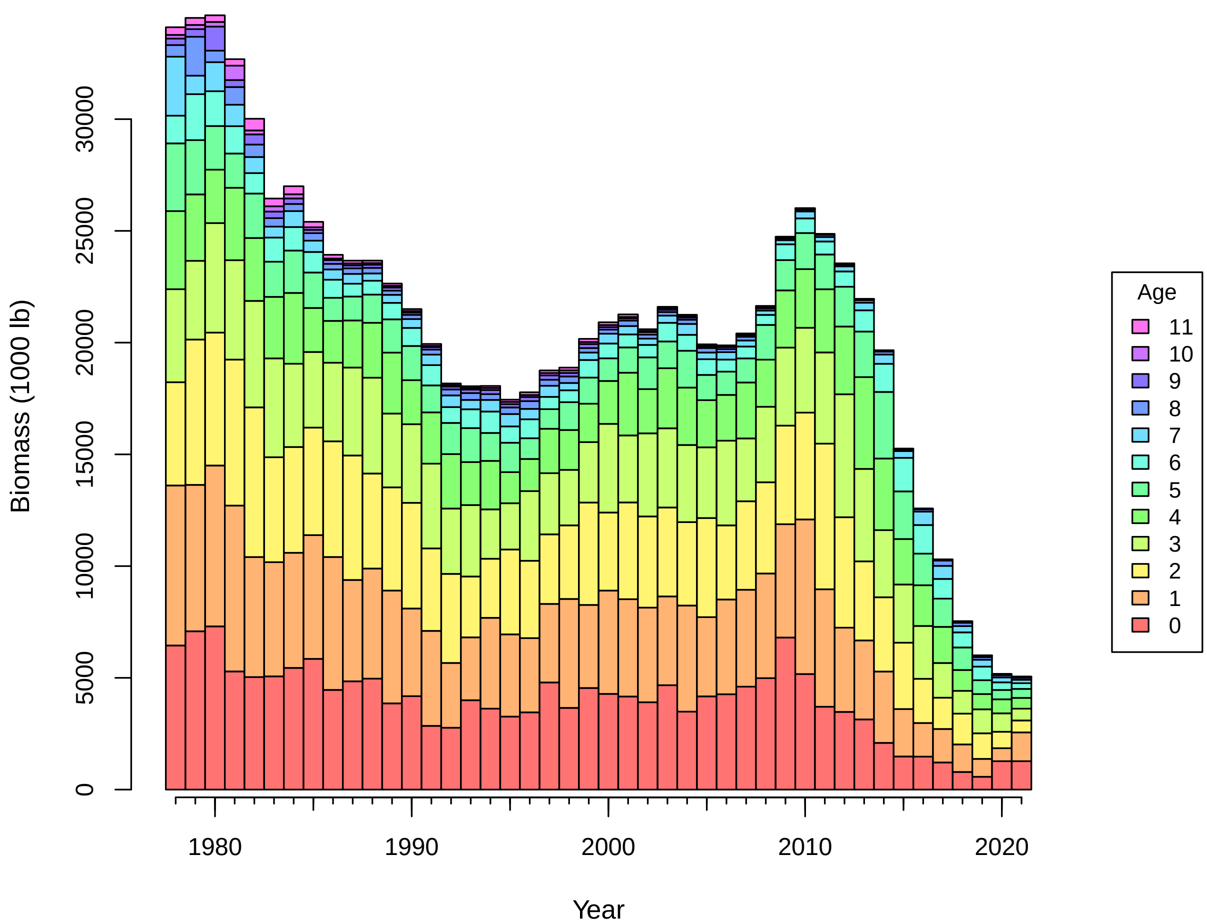


Figure 30. Top panel: Estimated total biomass (1000 lb) at start of year. Horizontal dashed line indicates B_{MSY}. *Bottom panel: Estimated spawning stock (population fecundity) at time of peak spawning.*

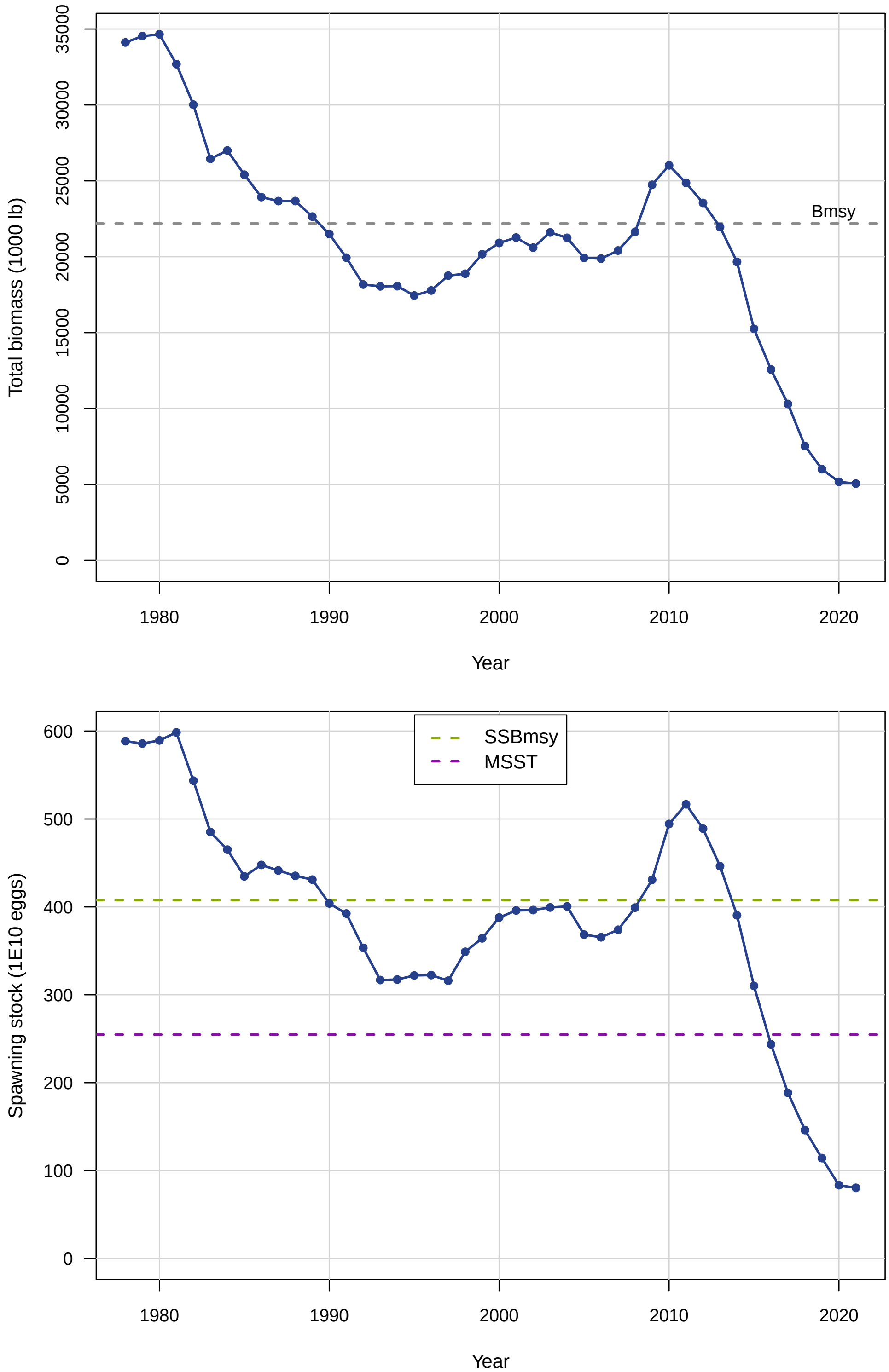


Figure 31. Selectivity (time-invariant) of SERFS chevron trap/video gear.

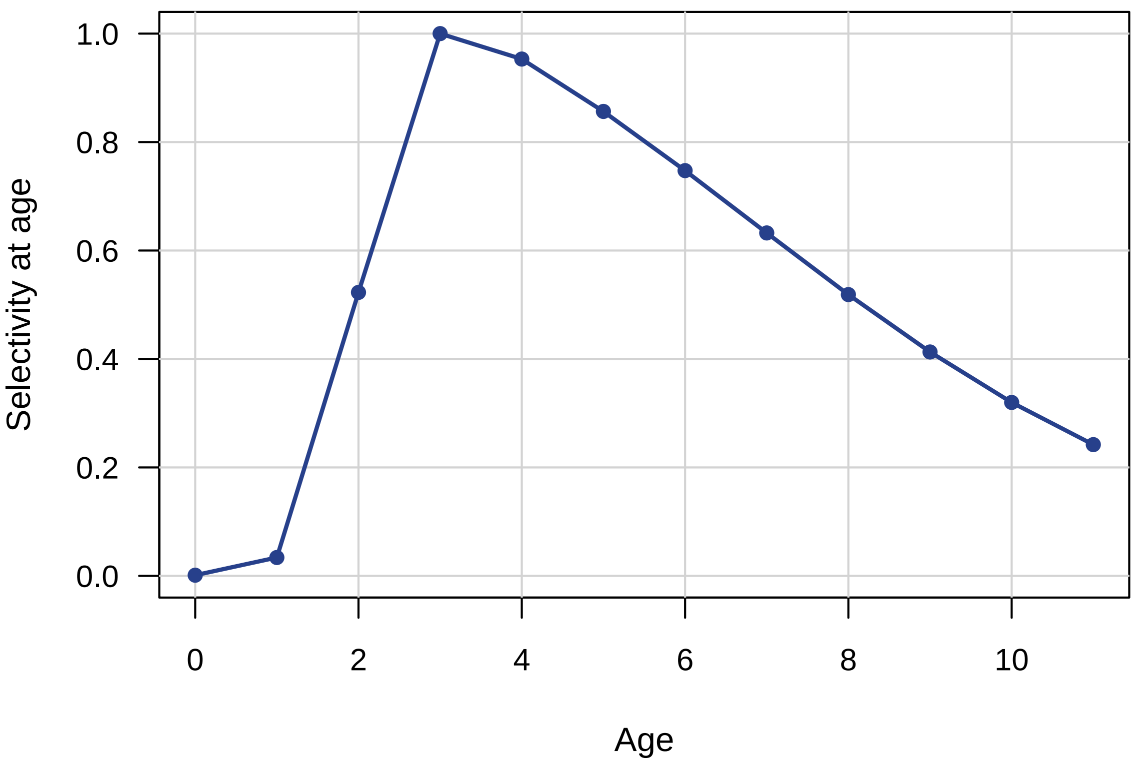


Figure 32. Selectivity (time-invariant) of MARMAP blackfish trap gear.

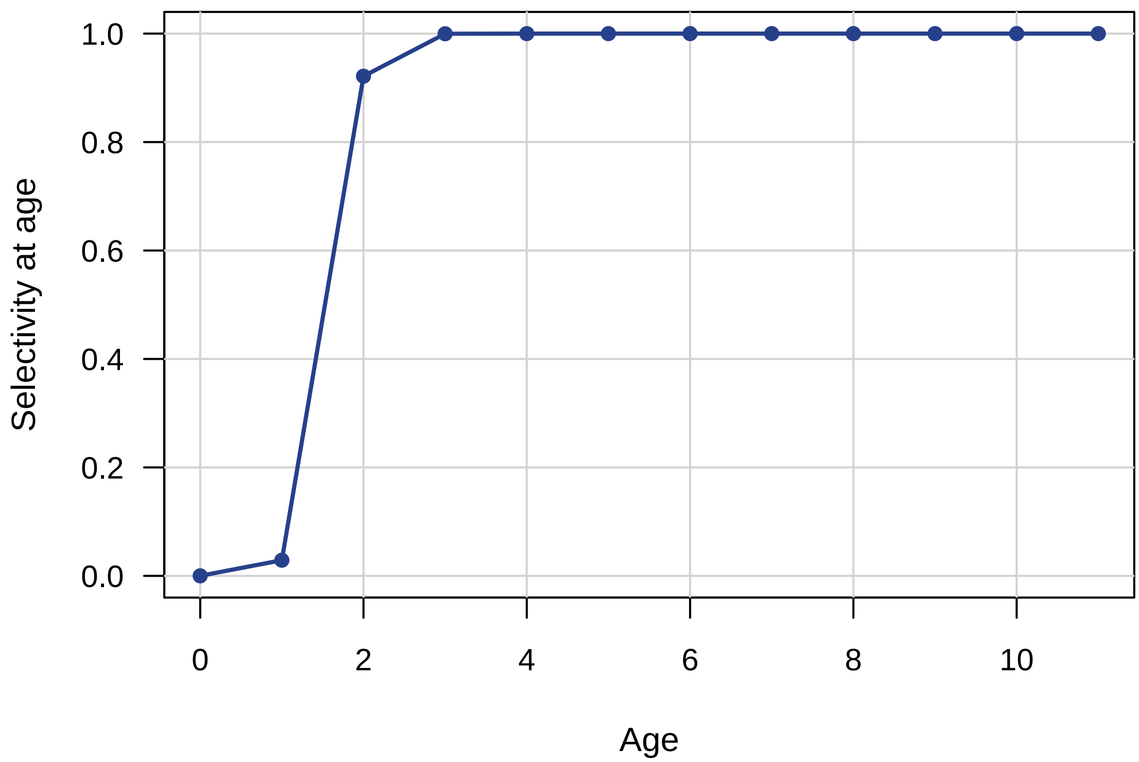


Figure 33. Estimated selectivities of commercial fleets. Commercial trawl fleet selectivity mirrors the pot fleet. Years indicated on panels signify the first year of a time block. Top panel: commercial lines. Bottom panel: commercial pots.

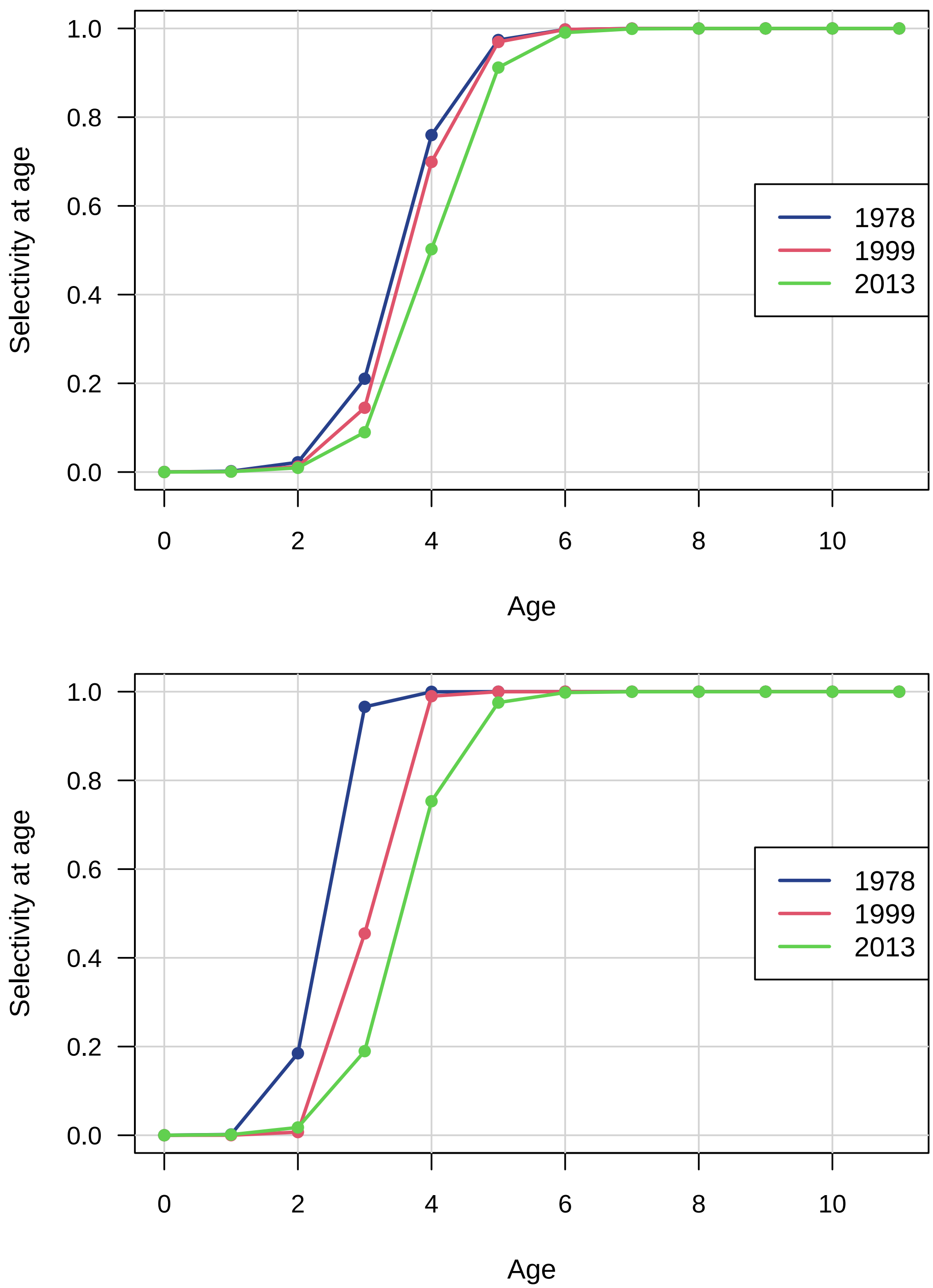


Figure 34. Estimated selectivities of headboat and general recreational fleets. Years indicated on panels signify the first year of a time block. Top panel: headboat. Bottom panel: general recreational.

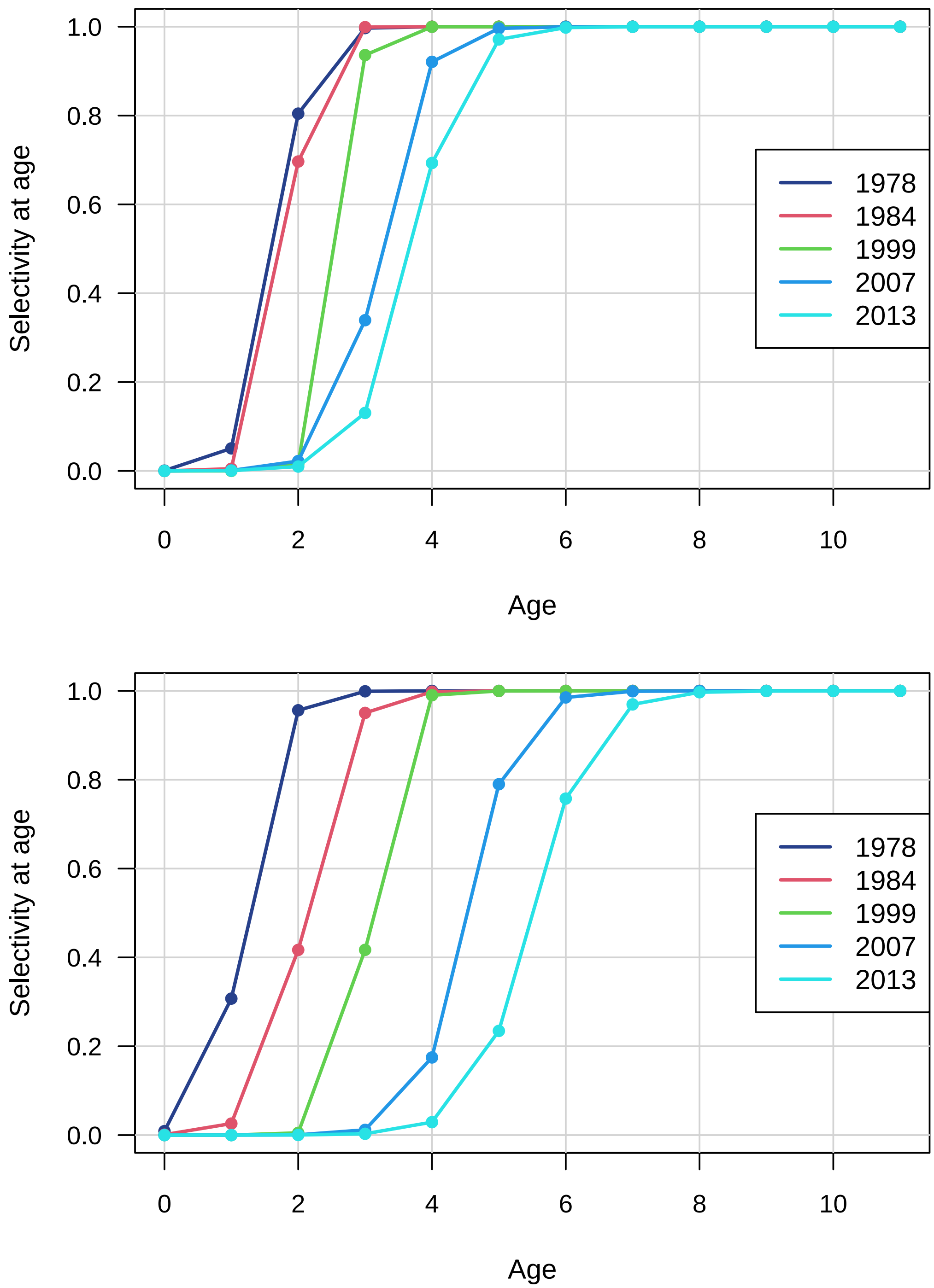


Figure 35. Estimated selectivity of discard mortalities from commercial lines (top panel) and headboat (bottom panel). The general recreational fleet mirrors the headboat fleet. Years indicated on panels signify the first year of a time block.

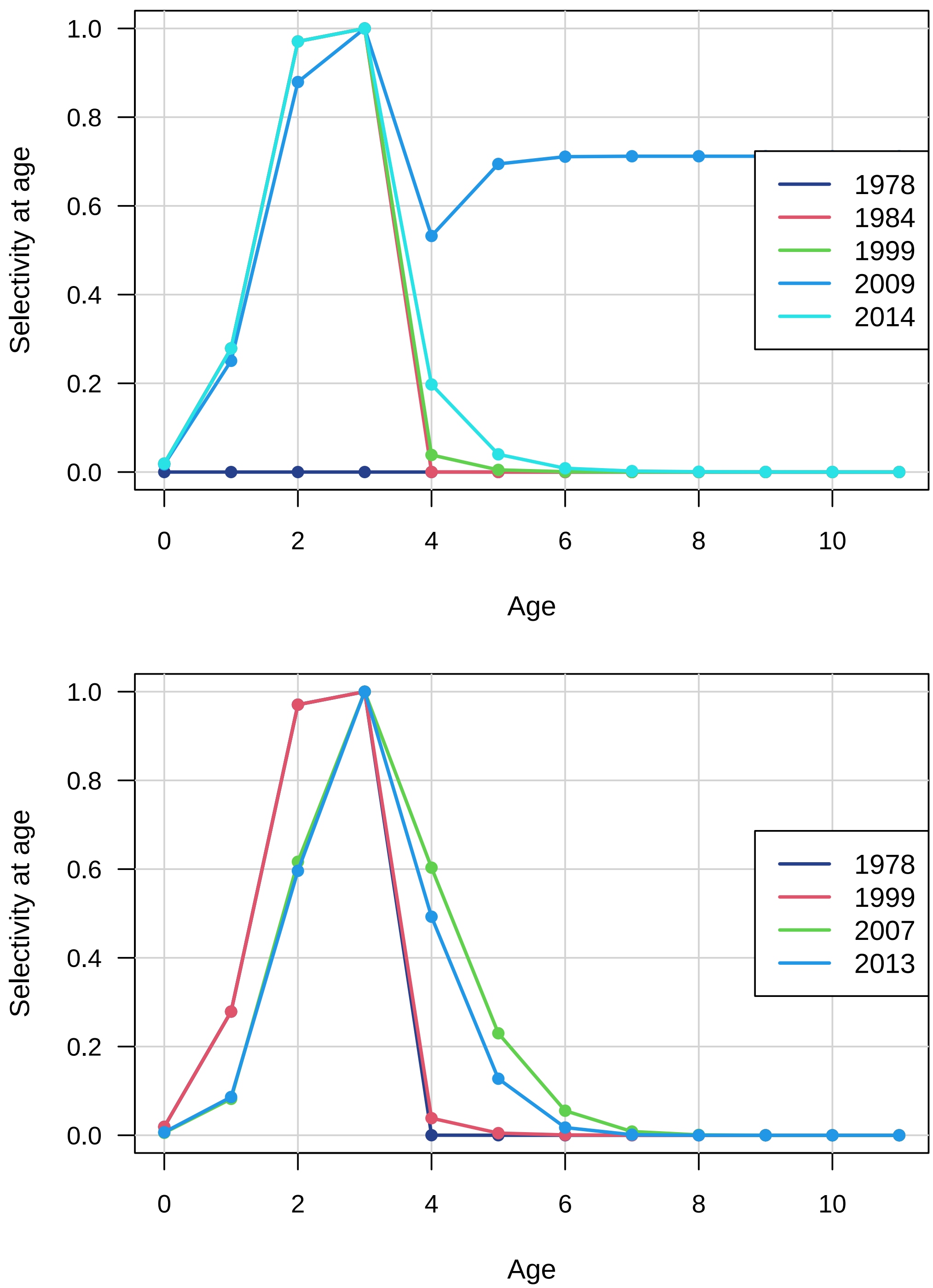


Figure 36. Average selectivities from the terminal assessment years, weighted by geometric mean Fs from the last three assessment years, and used in computation of benchmarks and projections. Top panel: average selectivity applied to landings. Middle panel: average selectivity applied to discard mortalities. Bottom panel: total average selectivity.

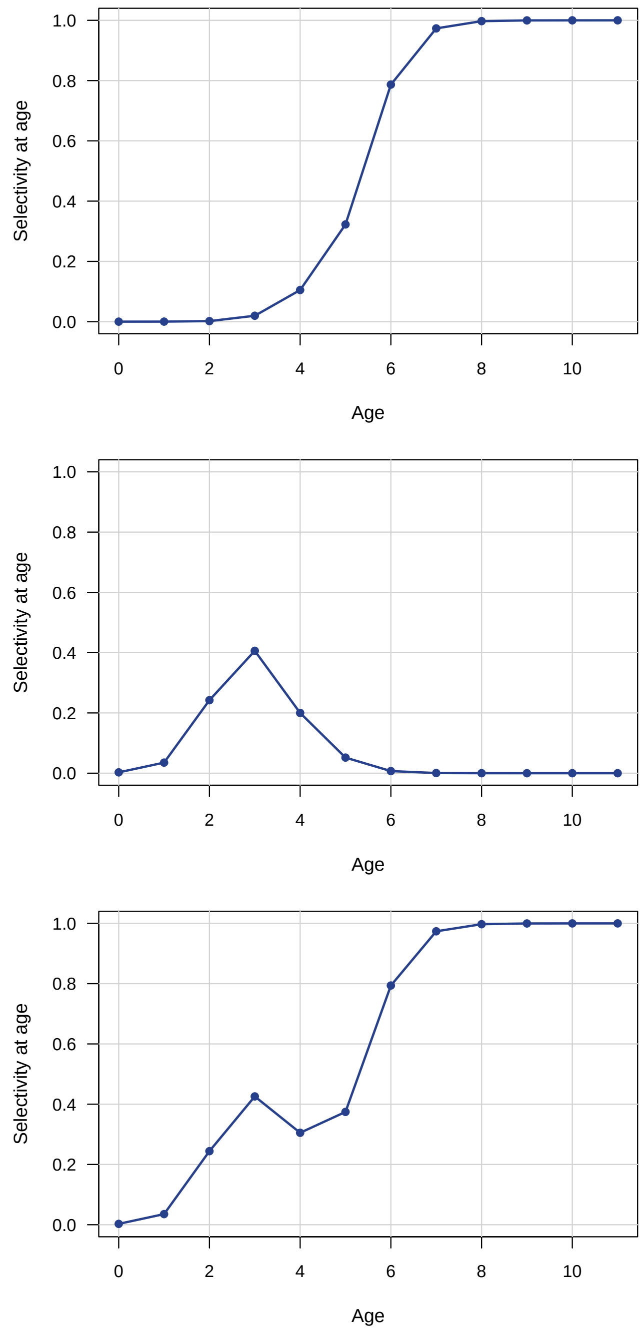


Figure 37. Estimated fully selected fishing mortality rate (per year) by fishery. cl refers to commercial lines, cp to commercial pots, ct to commercial trawl, hb to headboat, mrip to general recreational, comm.D to commercial discard mortalities, hb.D to headboat discard mortalities, and mrip.D to general recreational discard mortalities.

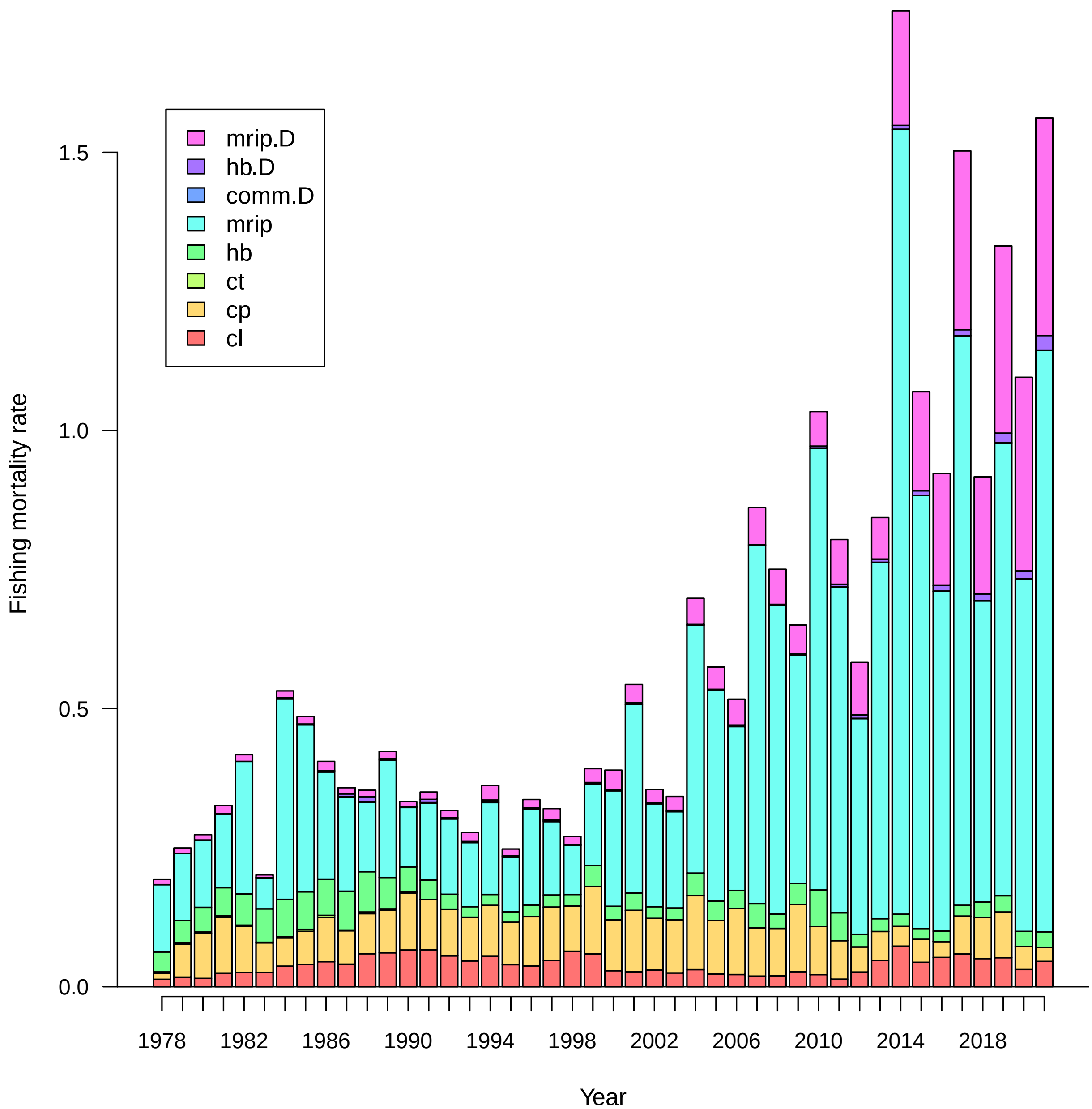


Figure 38. Estimated fishing mortality rate (per year) by age summed across fisheries.

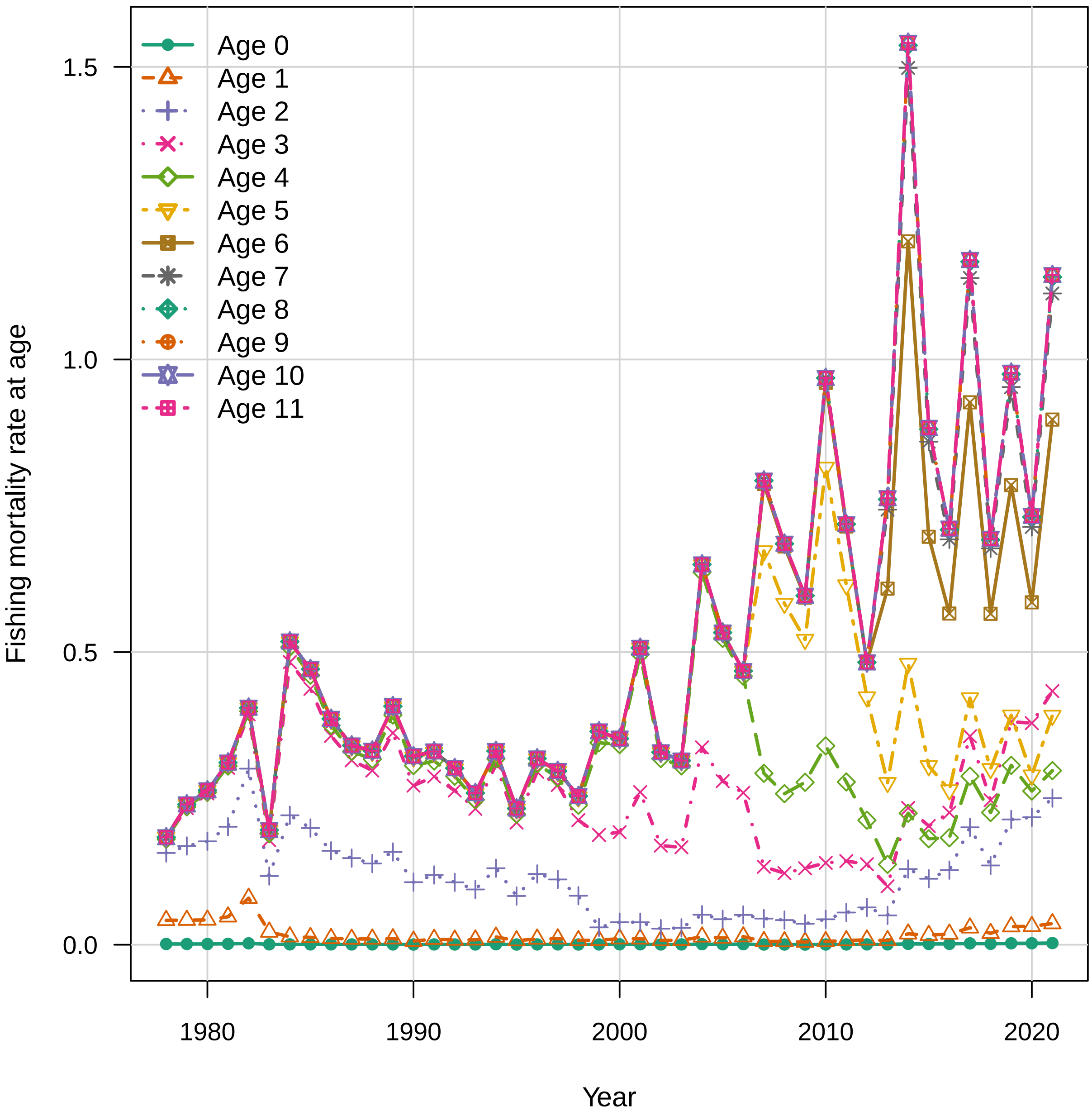


Figure 39. Estimated landings in numbers by fishery from the catch-age model. cl refers to commercial lines, cp to commercial pots, ct to commercial trawl, hb to headboat, mrip to general recreational.

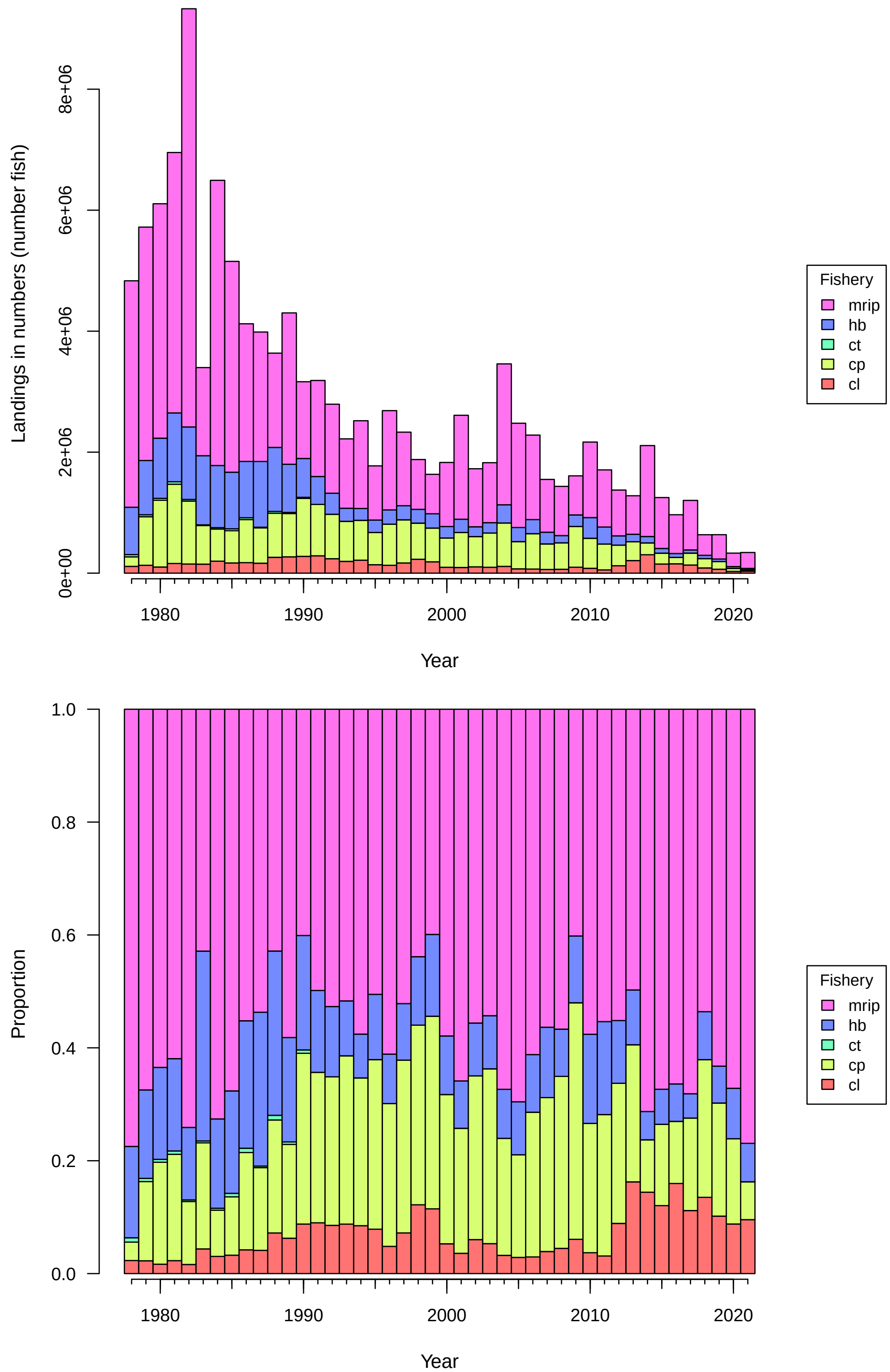


Figure 40. Estimated landings in whole weight by fishery from the catch-age model. cl refers to commercial lines, cp to commercial pots, ct to commercial trawl, hb to headboat, mrip to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of MSY.

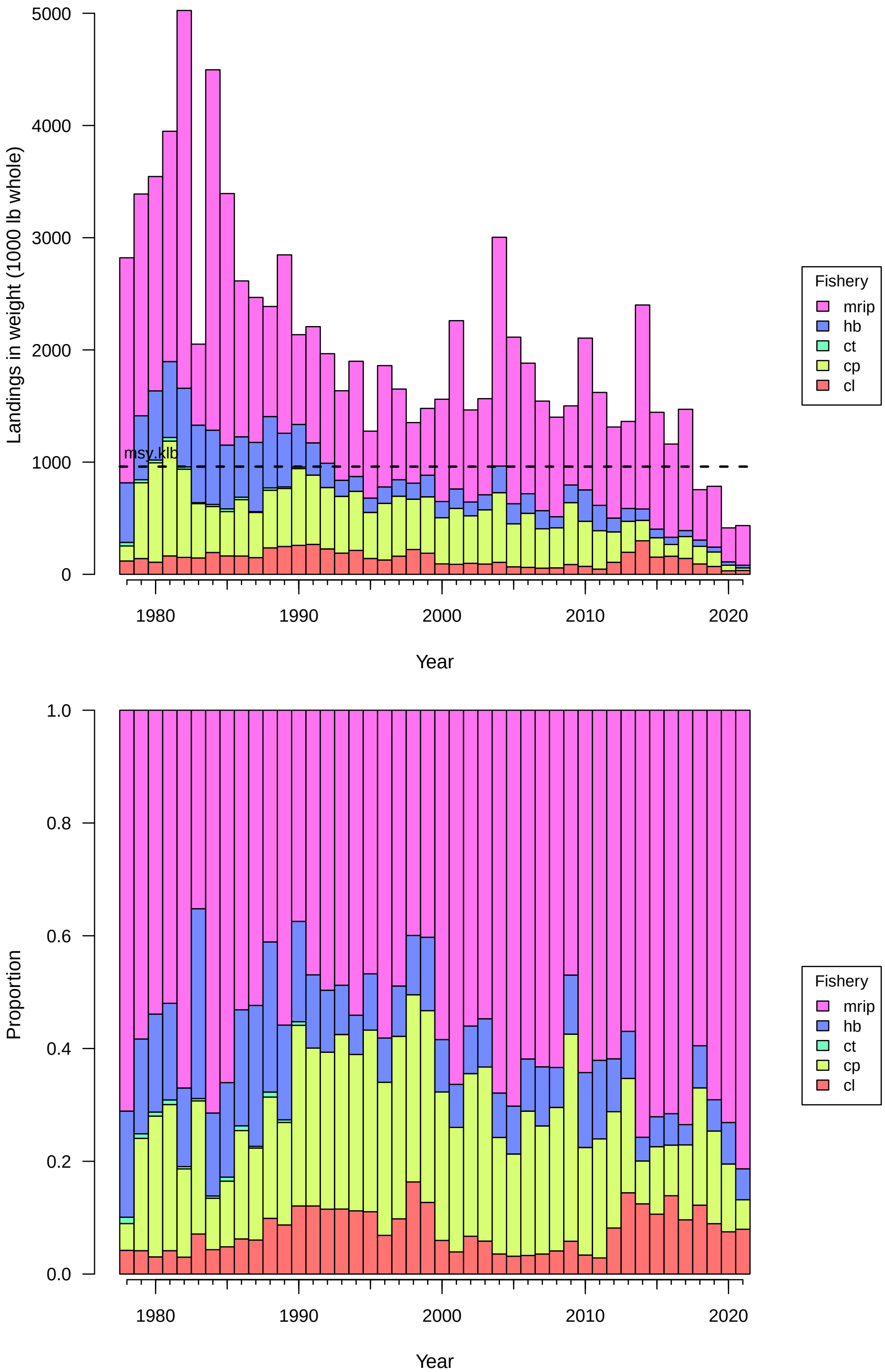


Figure 41. Estimated discard mortalities in numbers by fishery from the catch-age model. comm refers to commercial (lines and pots combined), hb to headboat, mrip to general recreational. Discards from hb were included with mrip prior to 1986.

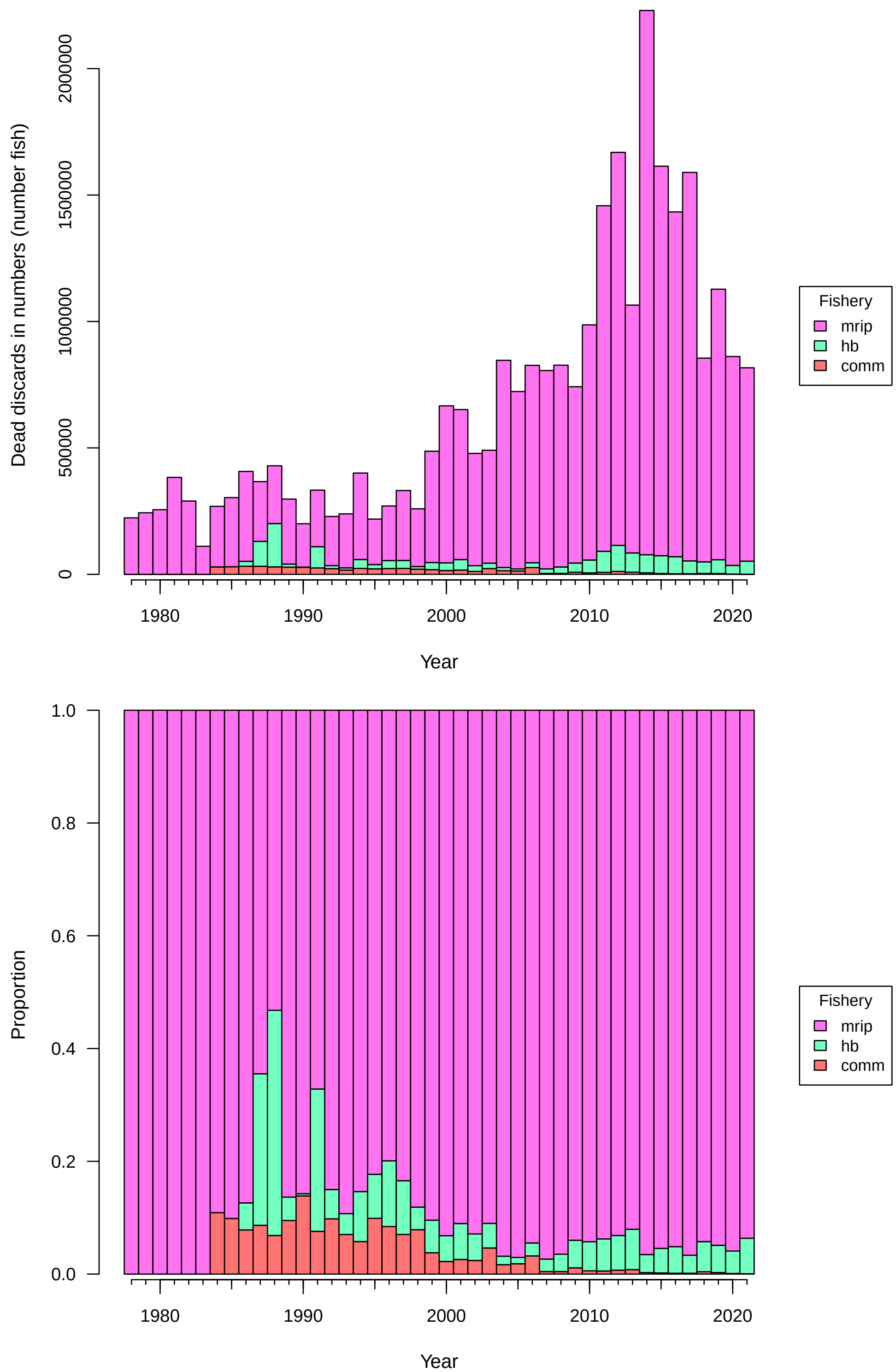


Figure 42. Estimated discard mortalities in whole weight by fishery from the catch-age model. comm refers to commercial (lines and pots combined), hb to headboat, mrip to general recreational. Discards from hb were included with mrip prior to 1986.

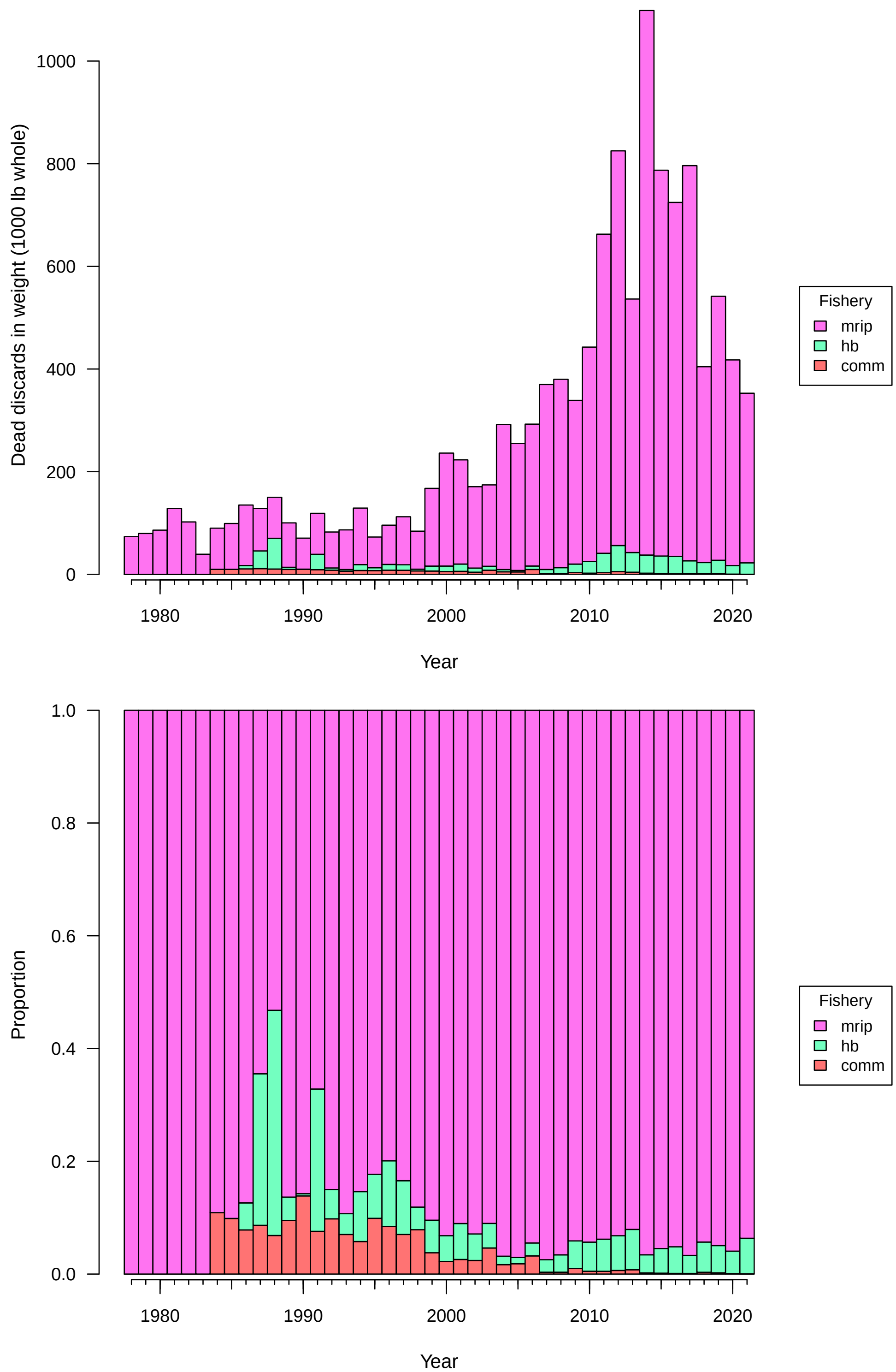


Figure 43. Estimated landings and dead discards in numbers by fishery from the catch-age model. An L. prefix refers to landings, while a D. prefix refers to discards, cl refers to commercial lines, cp to commercial pots, ct to commercial trawl, hb to headboat, mrip to general recreational, comm refers to commercial (lines and pots combined). Discards from hb were included with mrip prior to 1986.

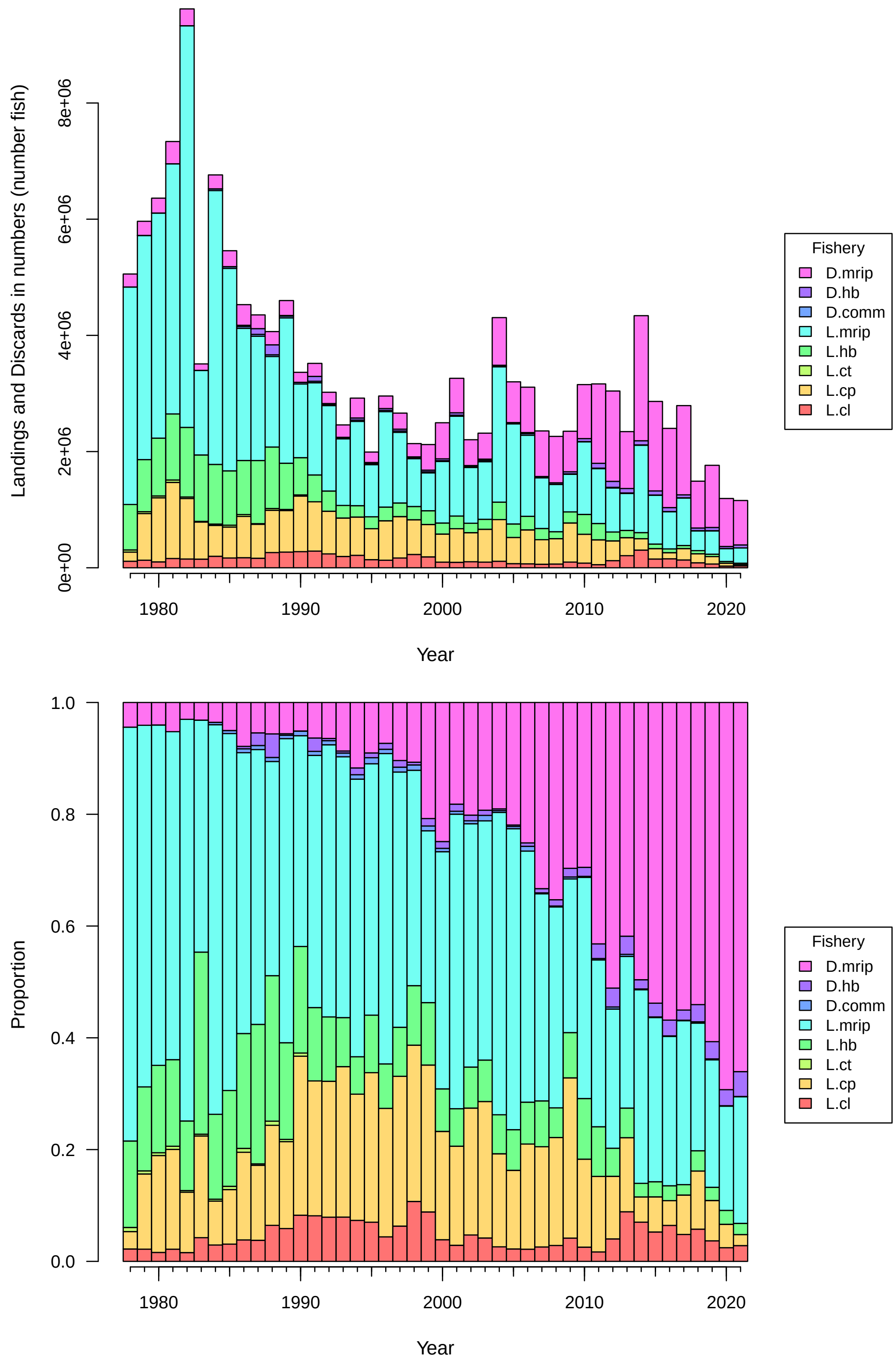


Figure 44. Estimated landings and dead discards in whole weight by fishery from the catch-age model. An L. prefix refers to landings, while a D. prefix refers to discards, cl refers to commercial lines, cp to commercial pots, ct to commercial trawl, hb to headboat, mrip to general recreational, comm refers to commercial (lines and pots combined)l. Discards from hb were included with mrip prior to 1986.

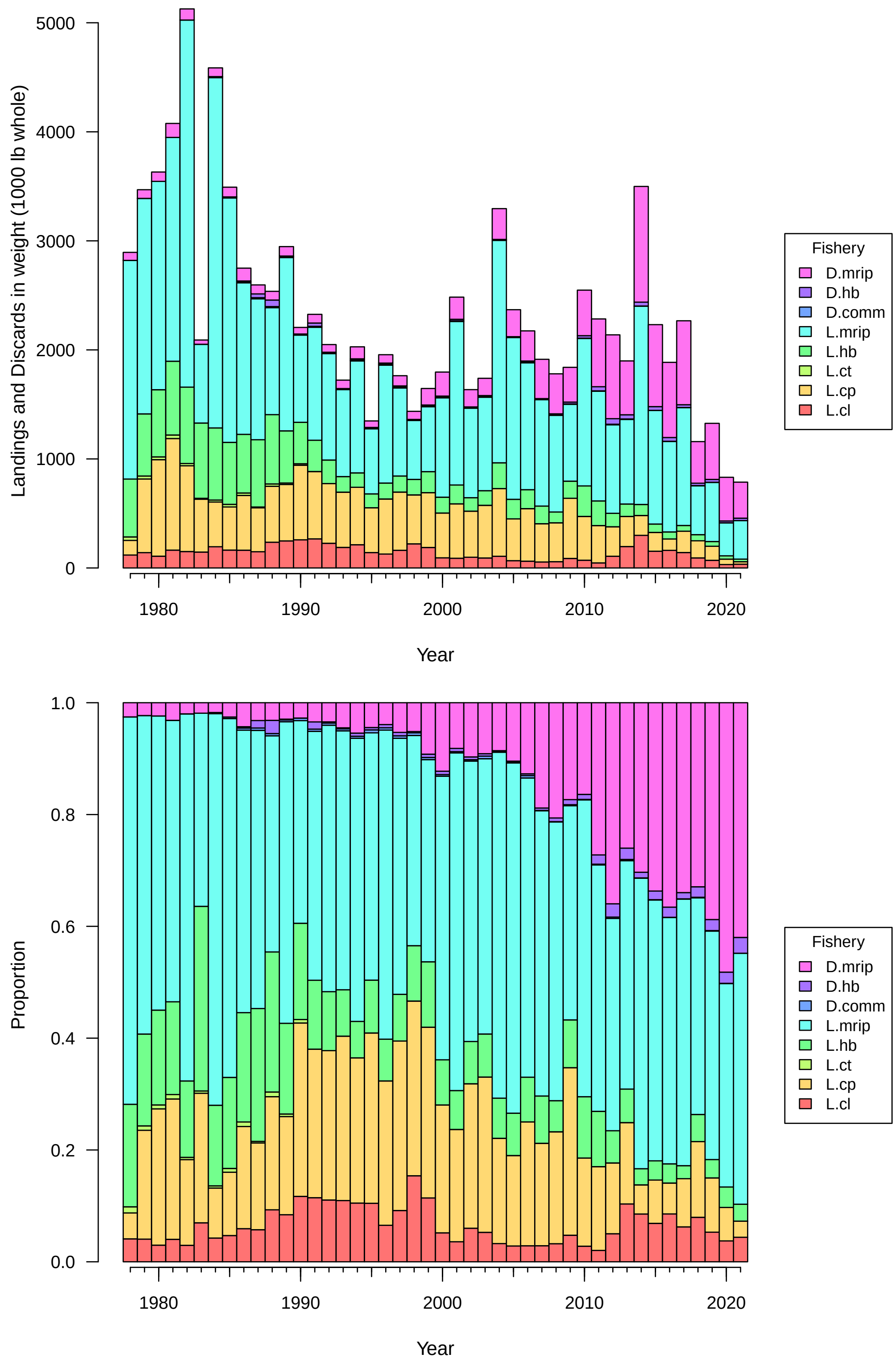


Figure 45. Spawner-recruit relationship, with and without lognormal bias correction. The expected (mean-unbiased) curve was used for computing management benchmarks.

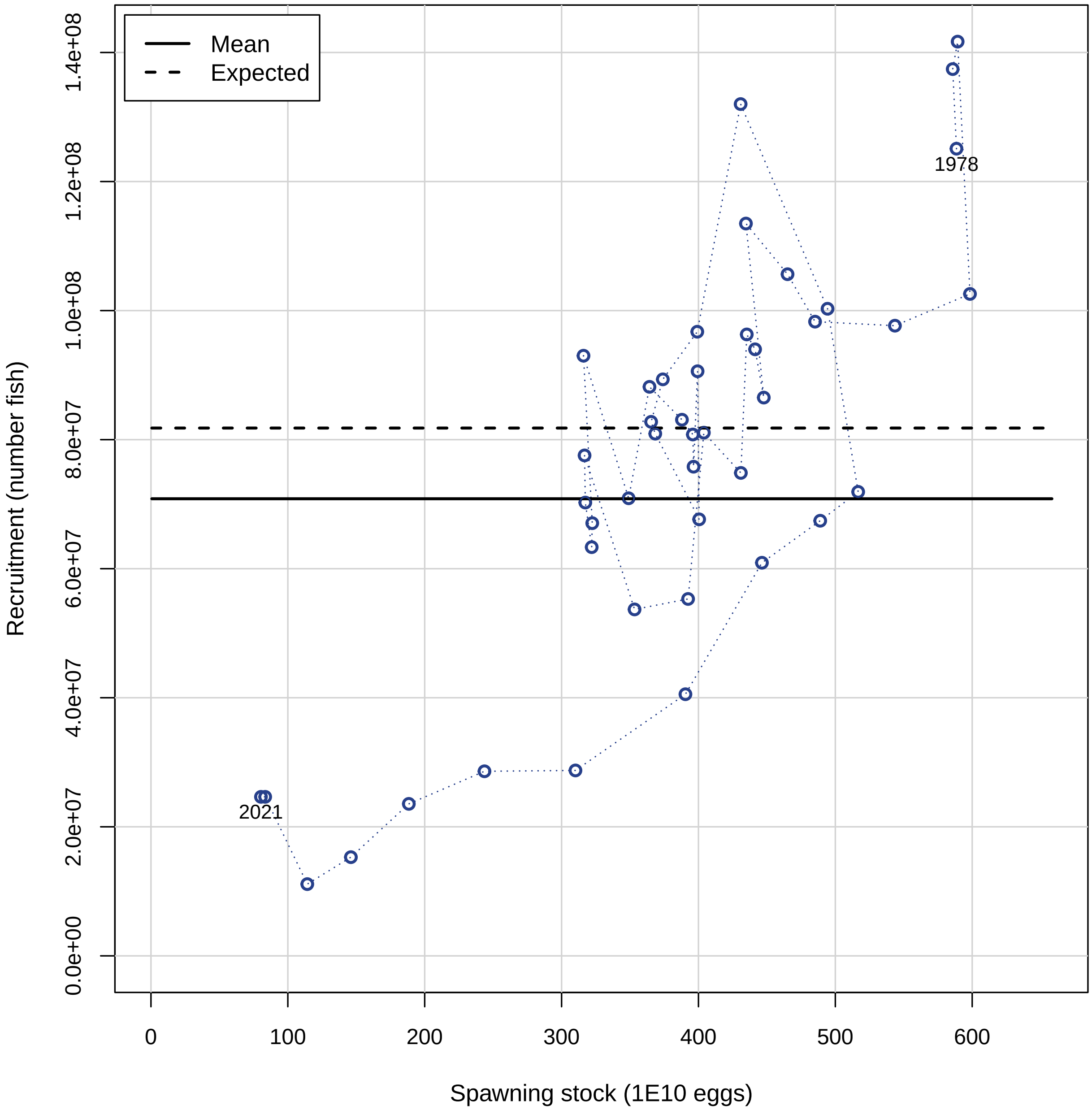


Figure 46. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-0 fish), unfished spawners per recruit and standard deviation of recruitment residuals. Solid vertical line represent point estimates from the base run and the dashed vertical line represent the median of the MCBE distribution.

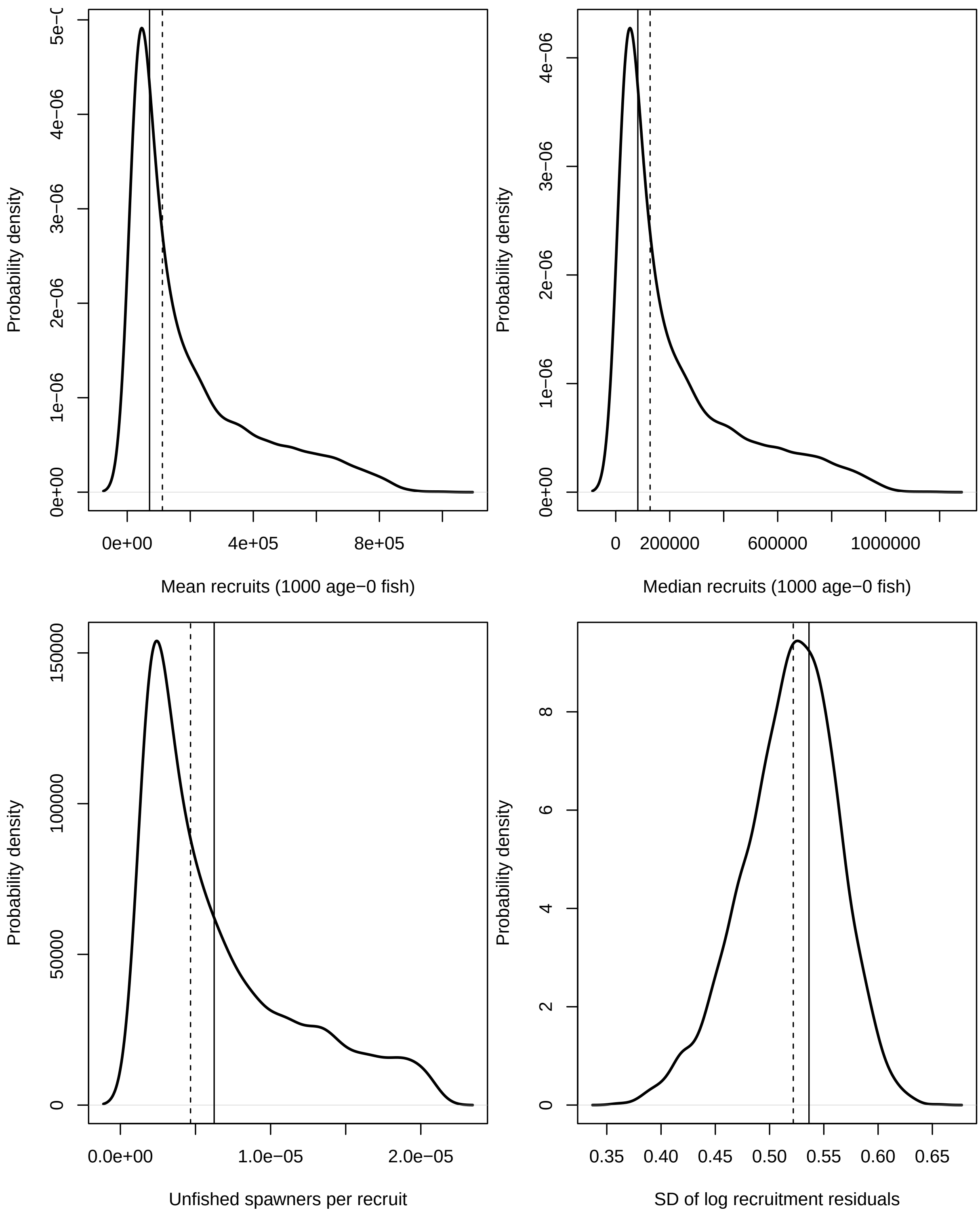


Figure 47. Top panel: yield per recruit in pounds. Bottom panel: spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the X% level of SPR provides $F_{X\%}$. Both curves are based on average selectivity from the end of the assessment period.

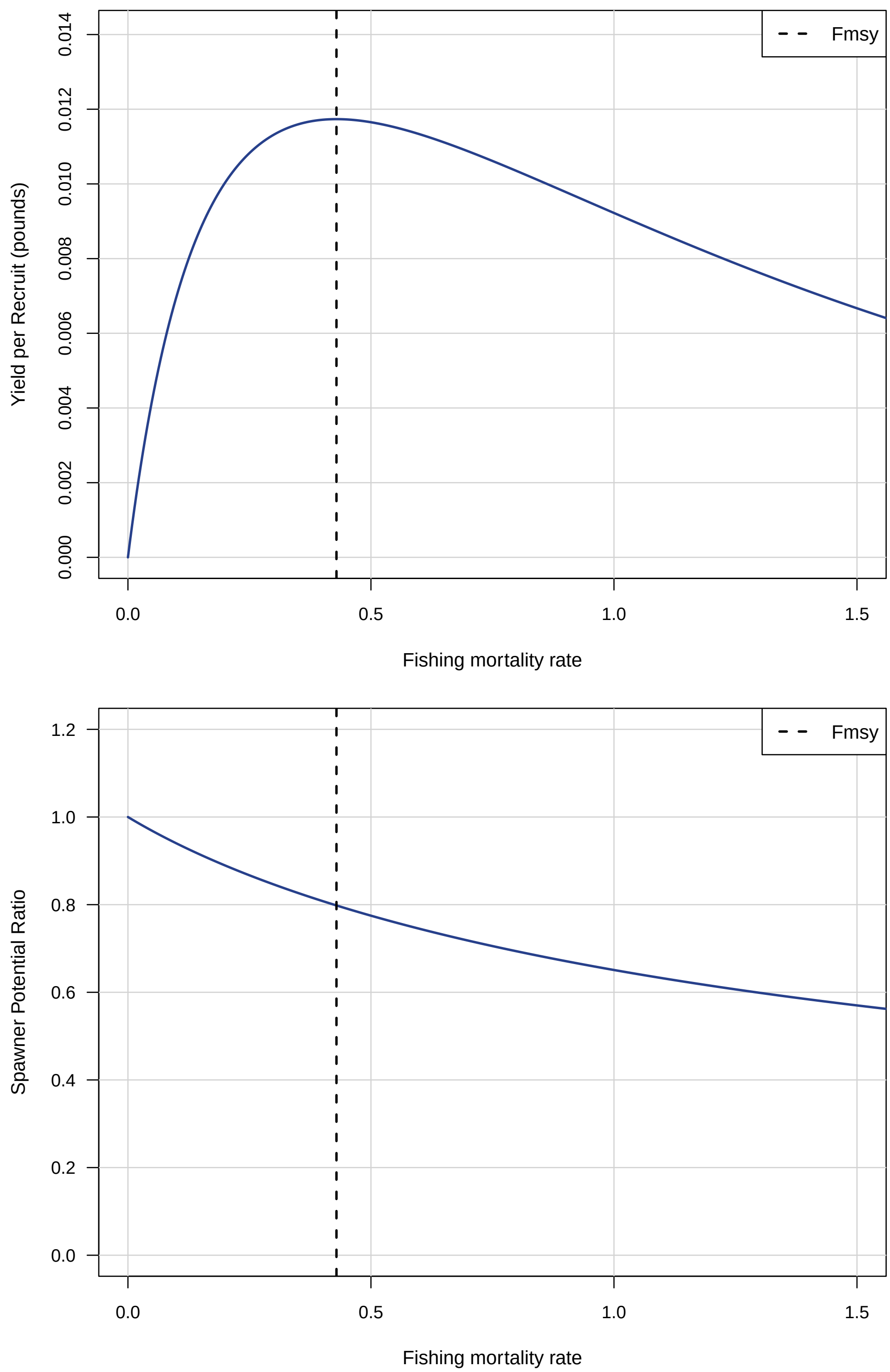


Figure 48. Top panel: equilibrium landings. The peak occurs where fishing rate is $F_{\mathrm{MSY}} = 0.43$ *and equilibrium landings are* MSY = 959.85 *(klb). Middle panel: equilibrium spawning biomass. Bottom panel: equilibrium dead discards in number of fish. All curves are based on average selectivity from the end of the assessment period.*

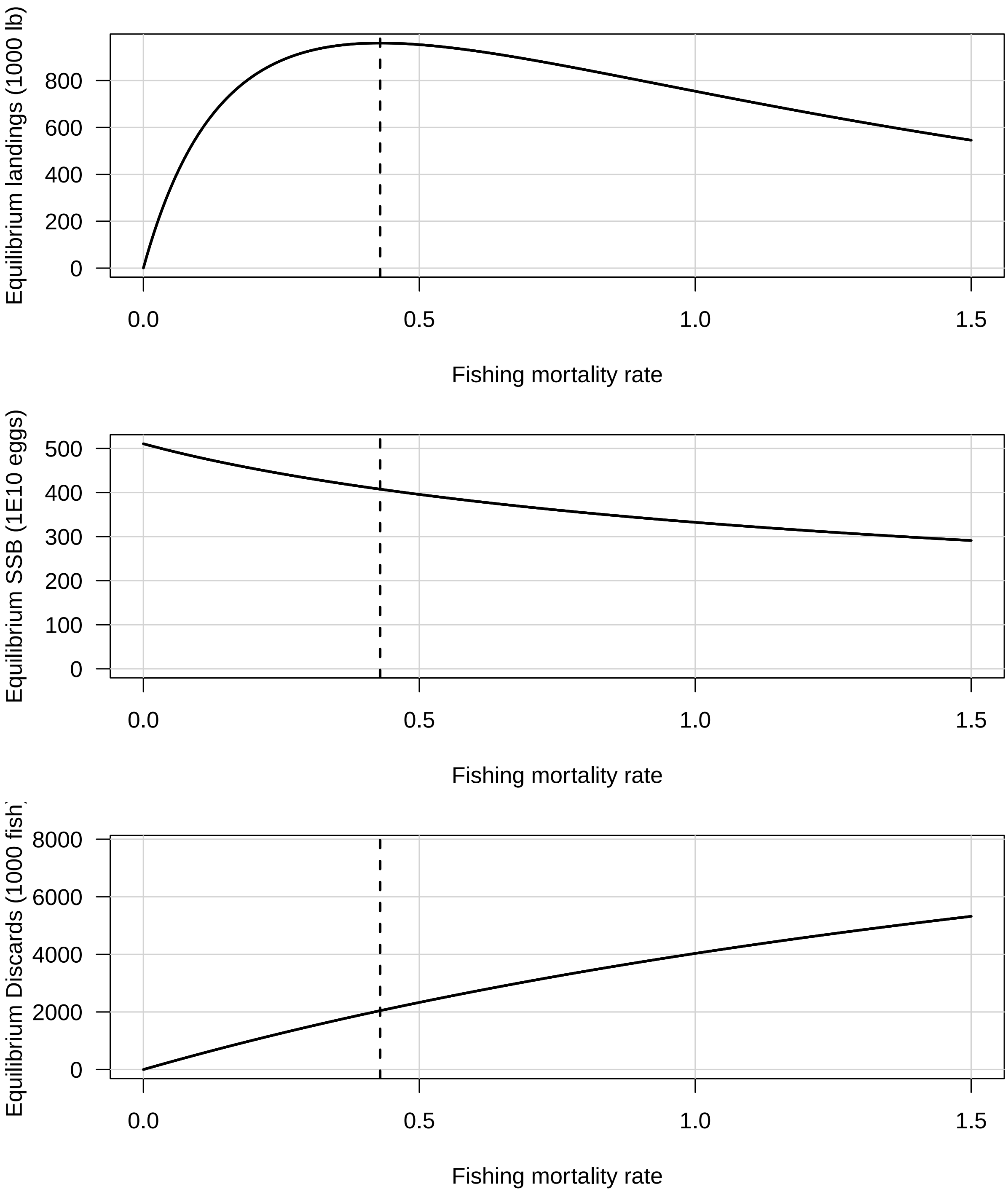


Figure 49. Top panel: equilibrium landings as a function of equilibrium biomass, which itself is a function of fishing mortality rate. The peak occurs where equilibrium biomass is $B_{\mathrm{MSY}} = 22193.12$ *klb and equilibrium landings are* $\mathrm{MSY} = 959.85$ *(klb). Bottom panel: equilibrium discard mortalities as a function of equilibrium biomass.*

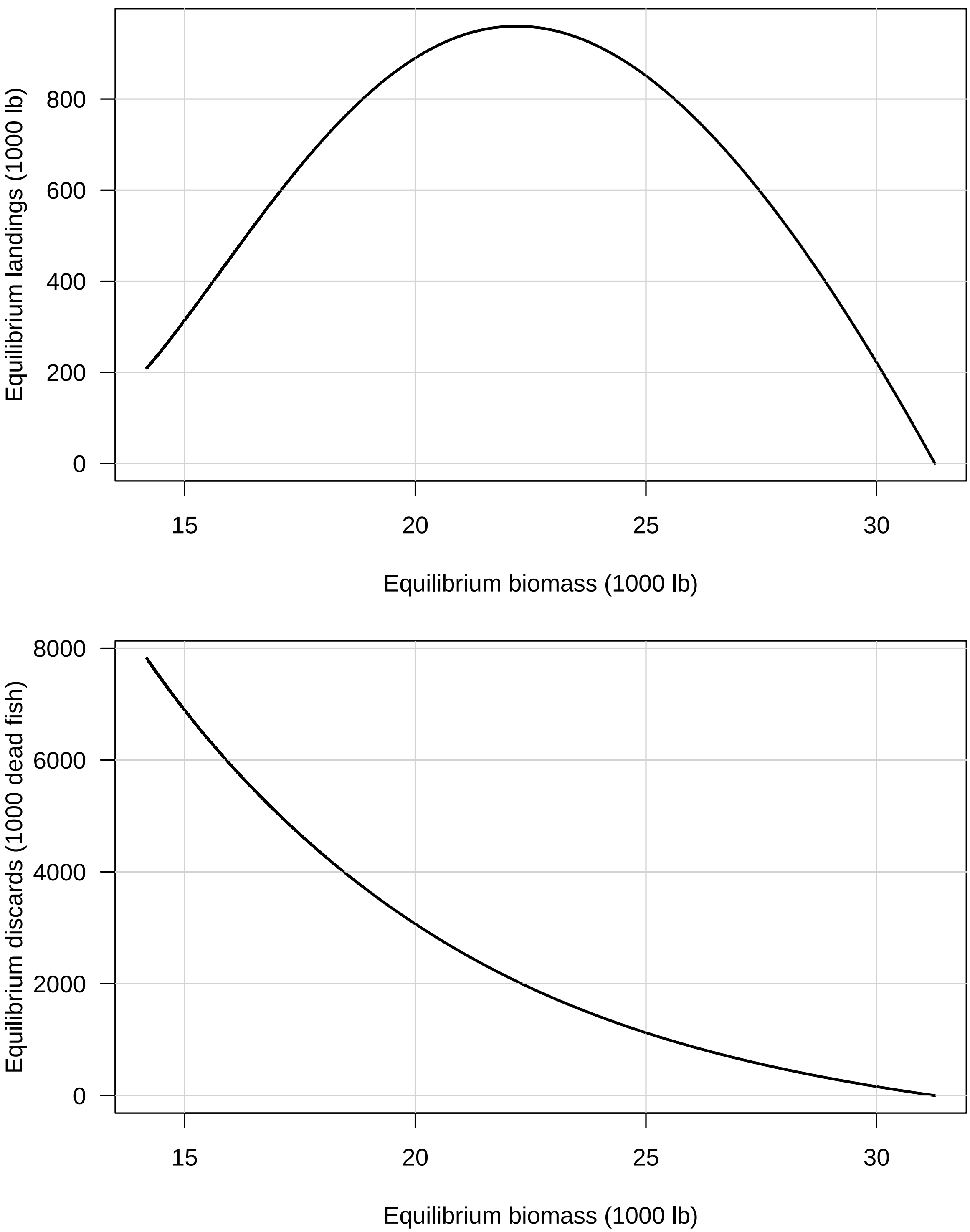


Figure 50. Probability densities of MSY*-related benchmarks from the MCBE of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run and dashed vertical lines represent medians from the MCBE.*

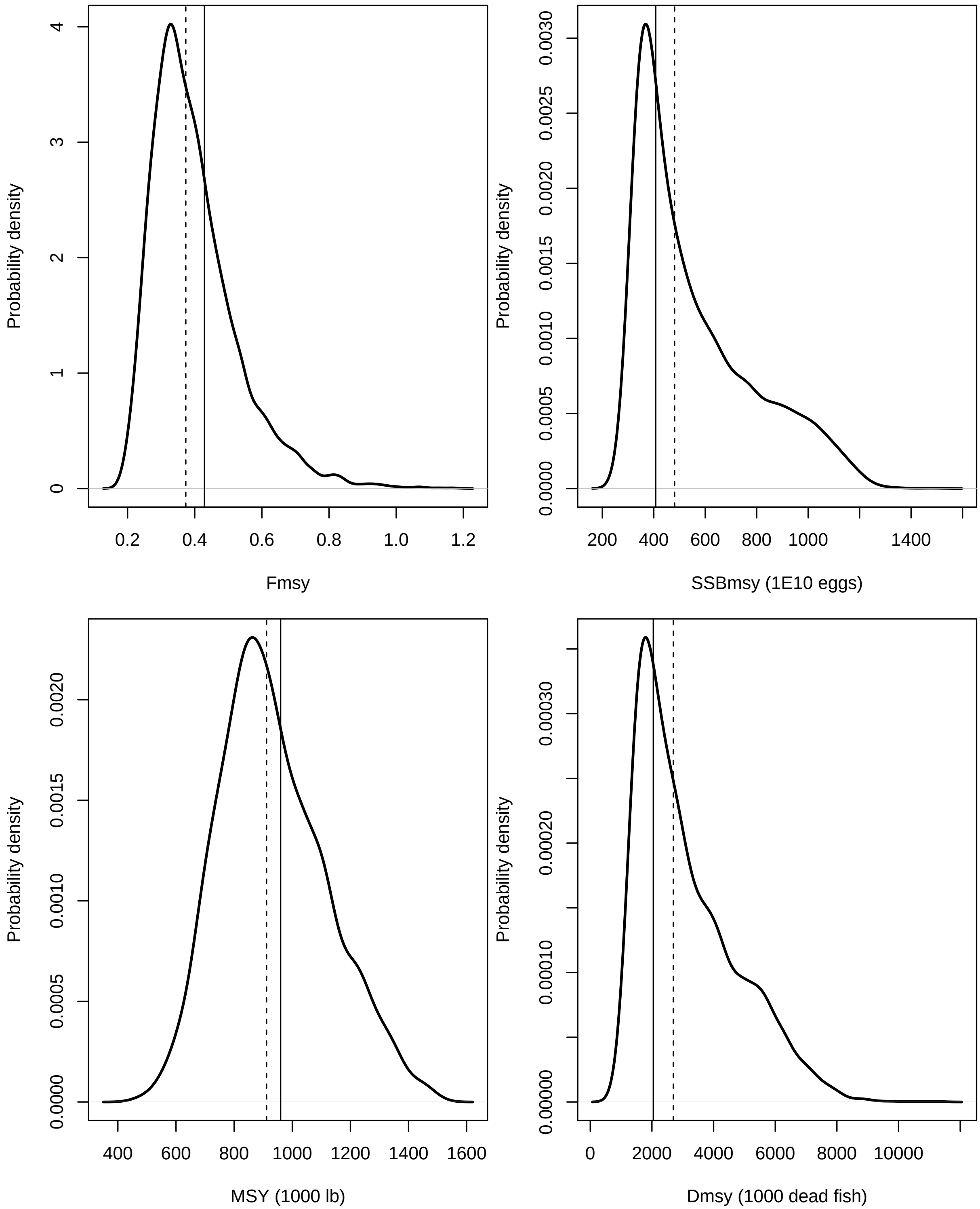


Figure 51. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model and dashed vertical lines represent medians from the MCBE; gray error bands indicate 5^{th} *and* 95^{th} *percentiles of the MCBE. Top panel: spawning biomass relative to the minimum stock size threshold (*MSST*). Middle panel: spawning biomass relative to* $\mathrm{SSB_{MSY}}$*. Bottom panel:* F *relative to* F_{MSY}*.*

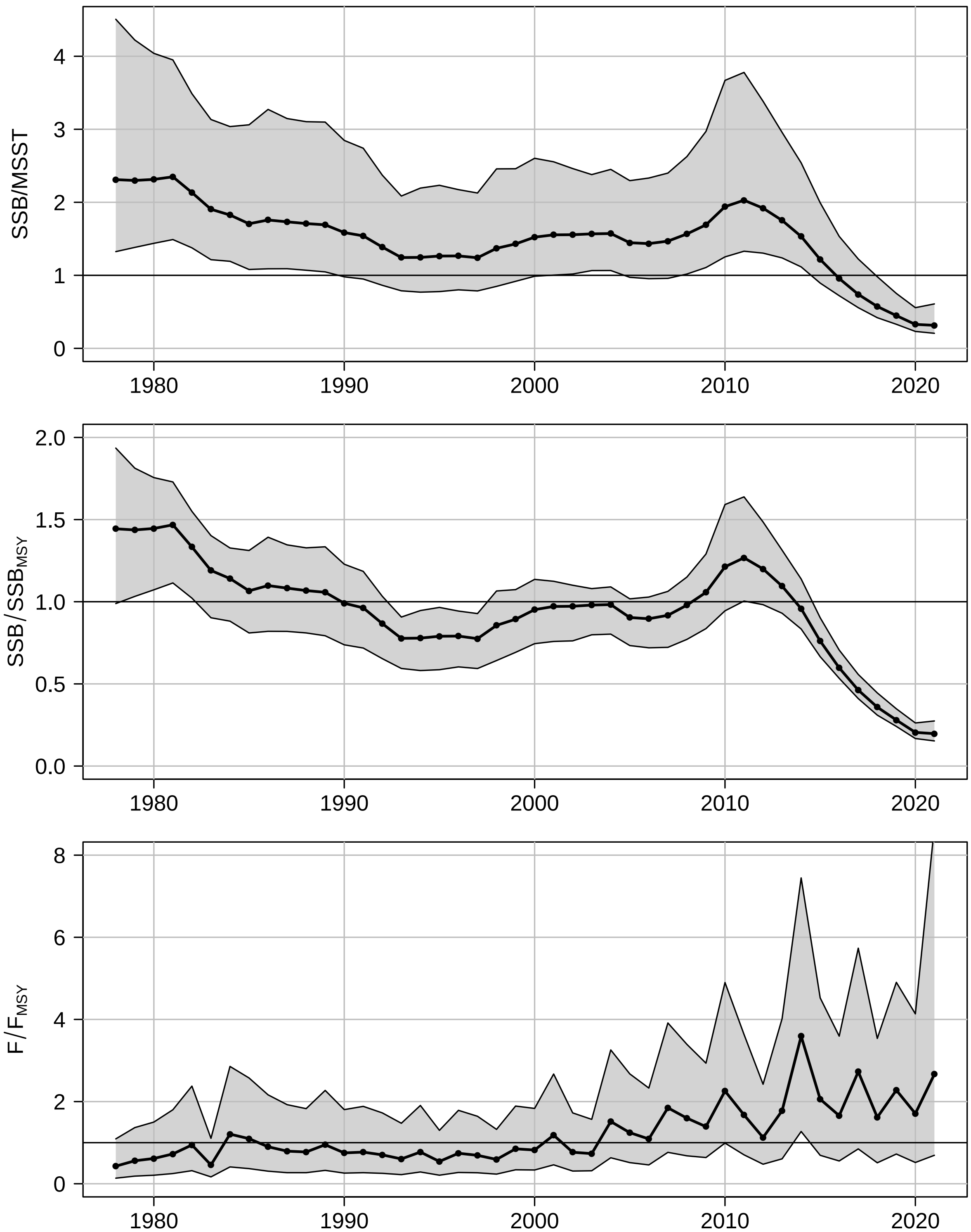


Figure 52. Probability densities of terminal status estimates from the MCBE of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run and dashed vertical lines represent medians from the MCBE.

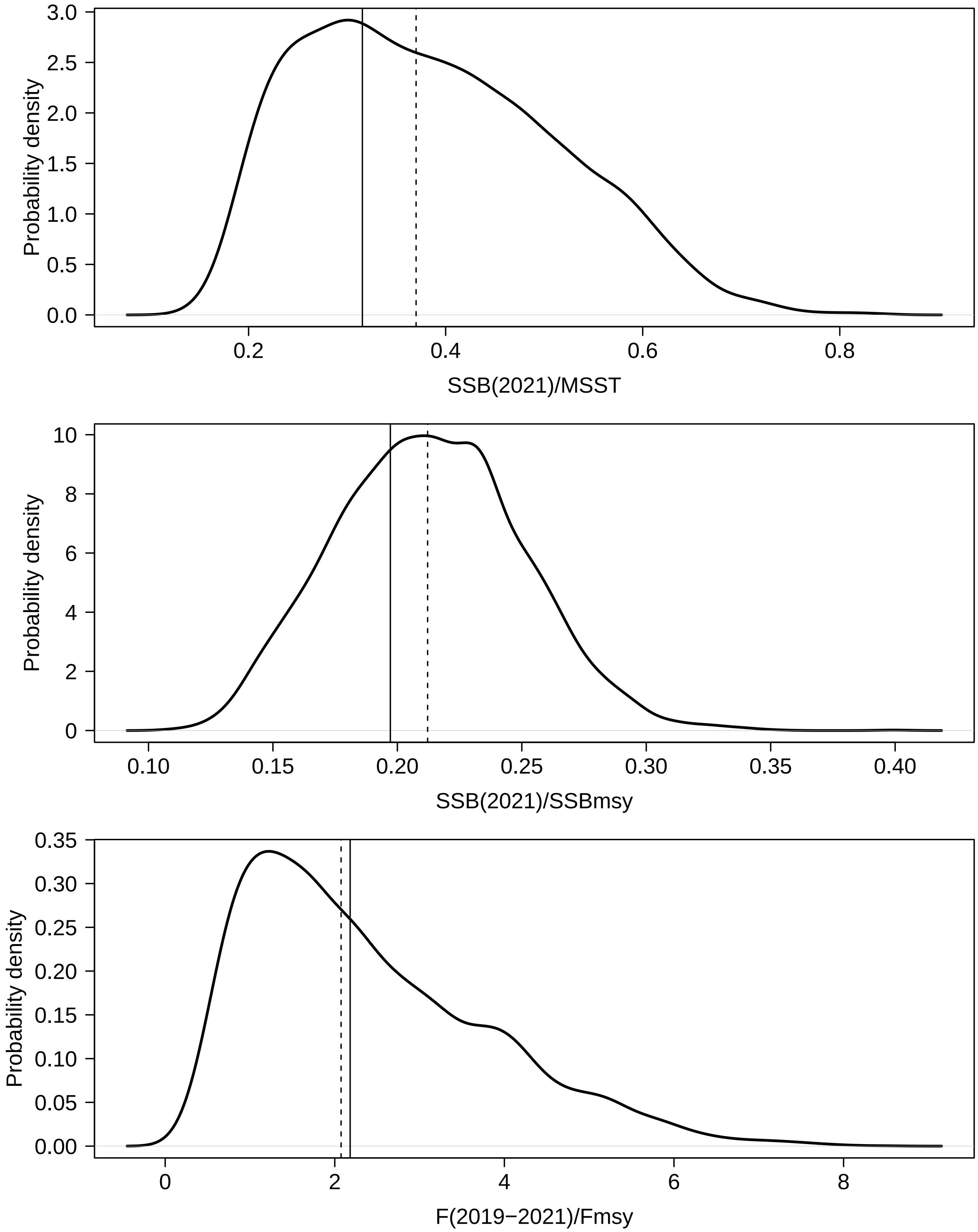


Figure 53. Phase plots of terminal status estimates from the MCBE of the Beaufort Assessment Model. Top panel is status relative to MSST*, and the bottom panel is status relative to* MSY*. The filled black dot indicates the estimate from the base run; the grey points indicate estimates from the MCBE runs and the shaded region is the* 90^{th} *percentile of the two parameters.*

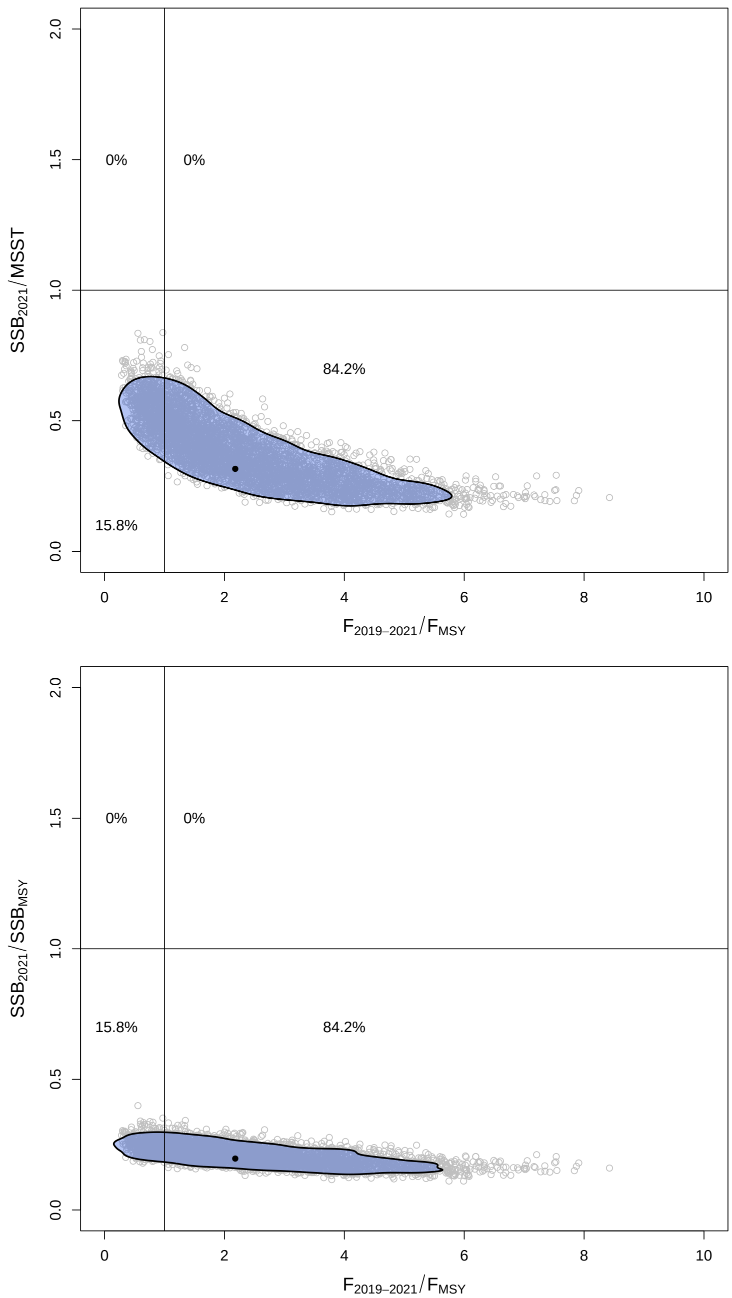


Figure 54. Age structure relative to the equilibrium expected at MSY.

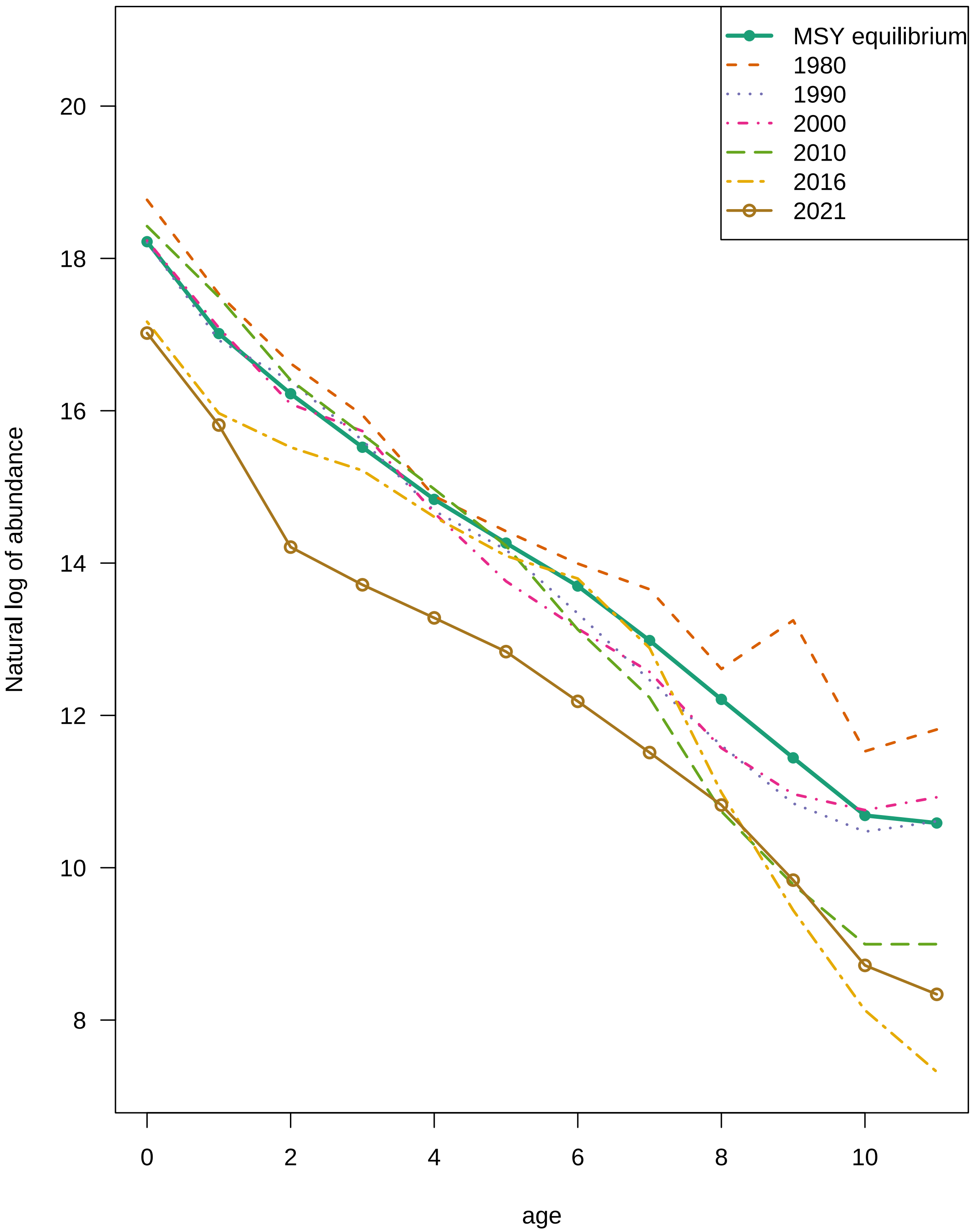


*Figure 55. Comparison of results from this operational assessment to the previous assessments: SEDAR 56, SEDAR 25 Update, and SEDAR 25. Top panel: spawning biomass relative to the minimum stock size threshold (*MSST*). Bottom panel: F relative to* F_{MSY}.

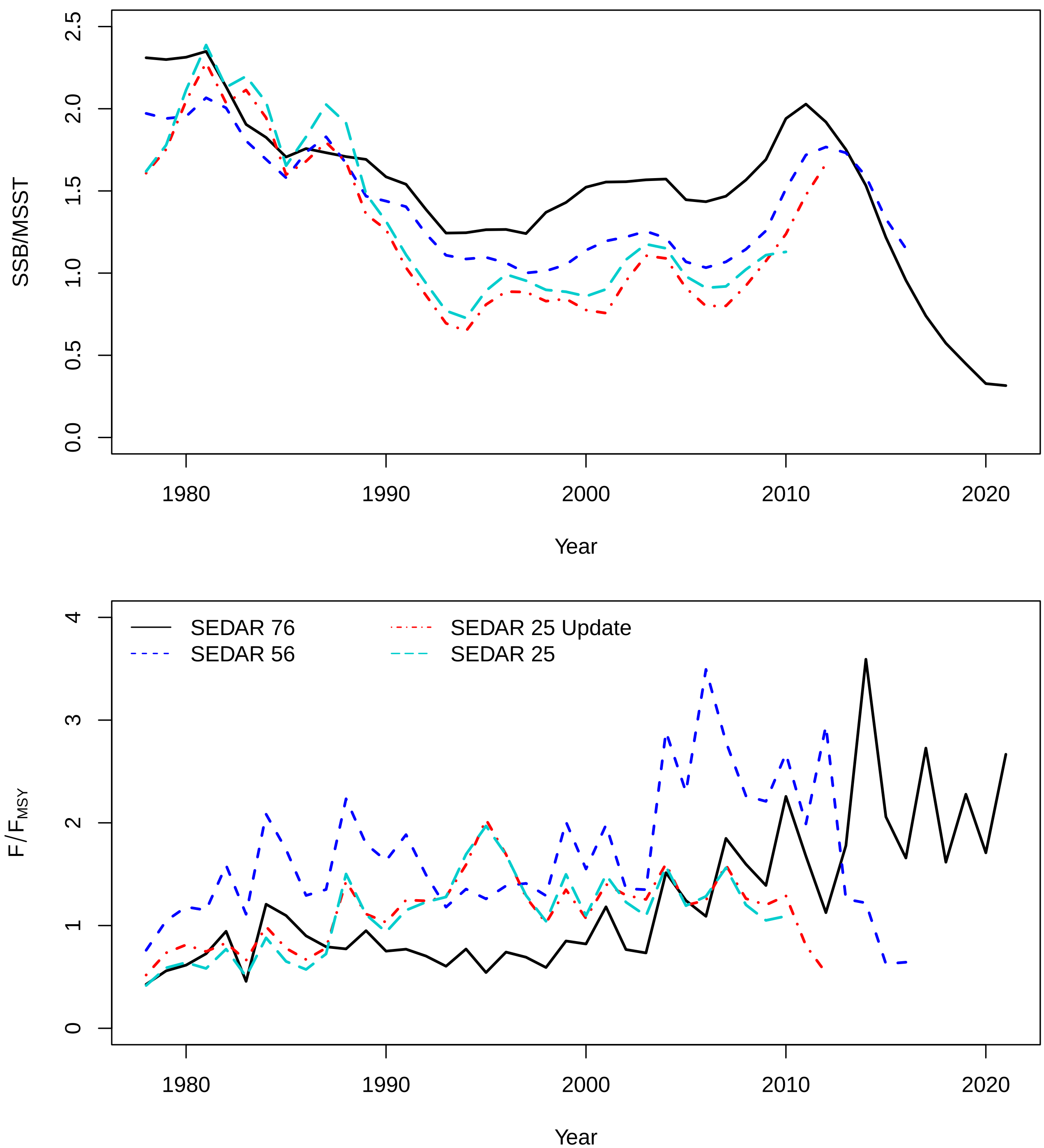
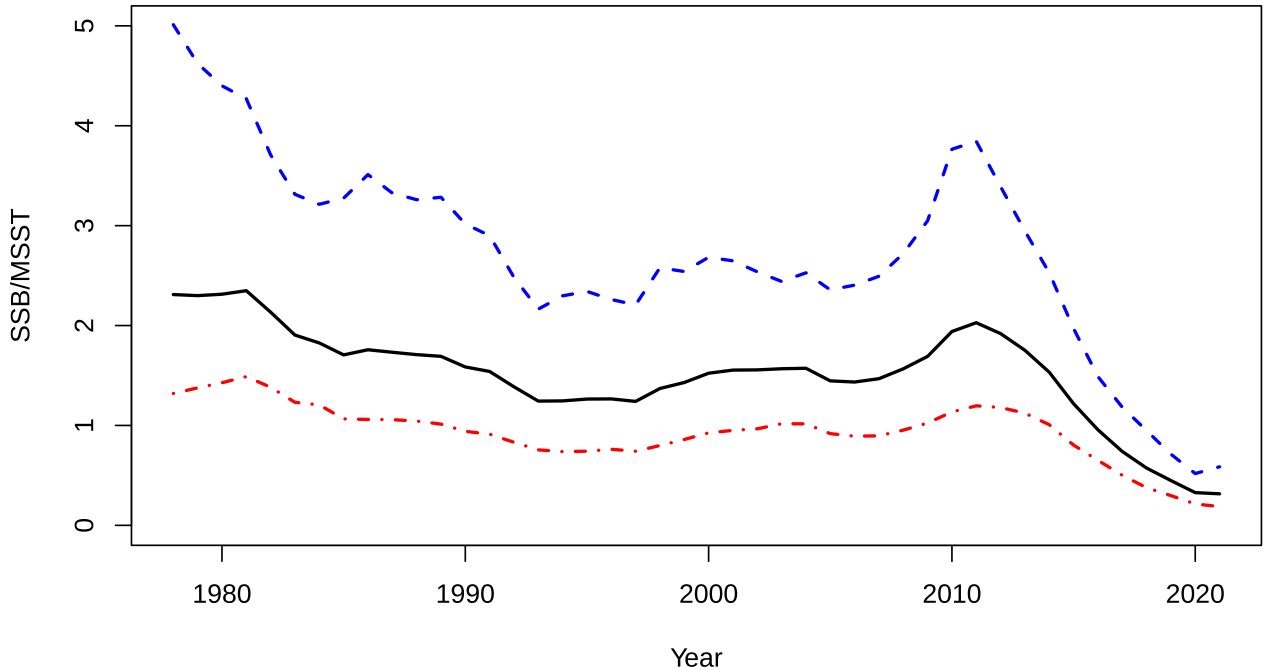


Figure 56. Sensitivity to changes in natural mortality (sensitivity runs M High and M Low). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$*.*



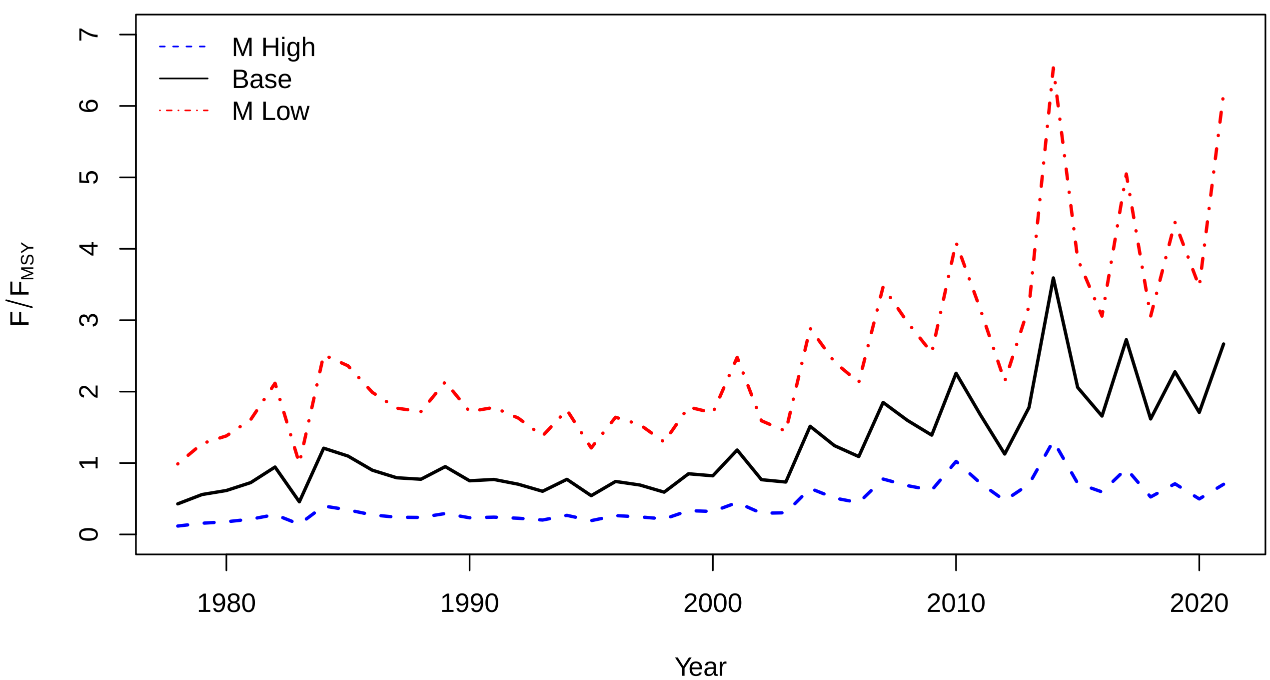


Figure 57. Comparison to continuity assumptions (sensitivity run Continuity). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

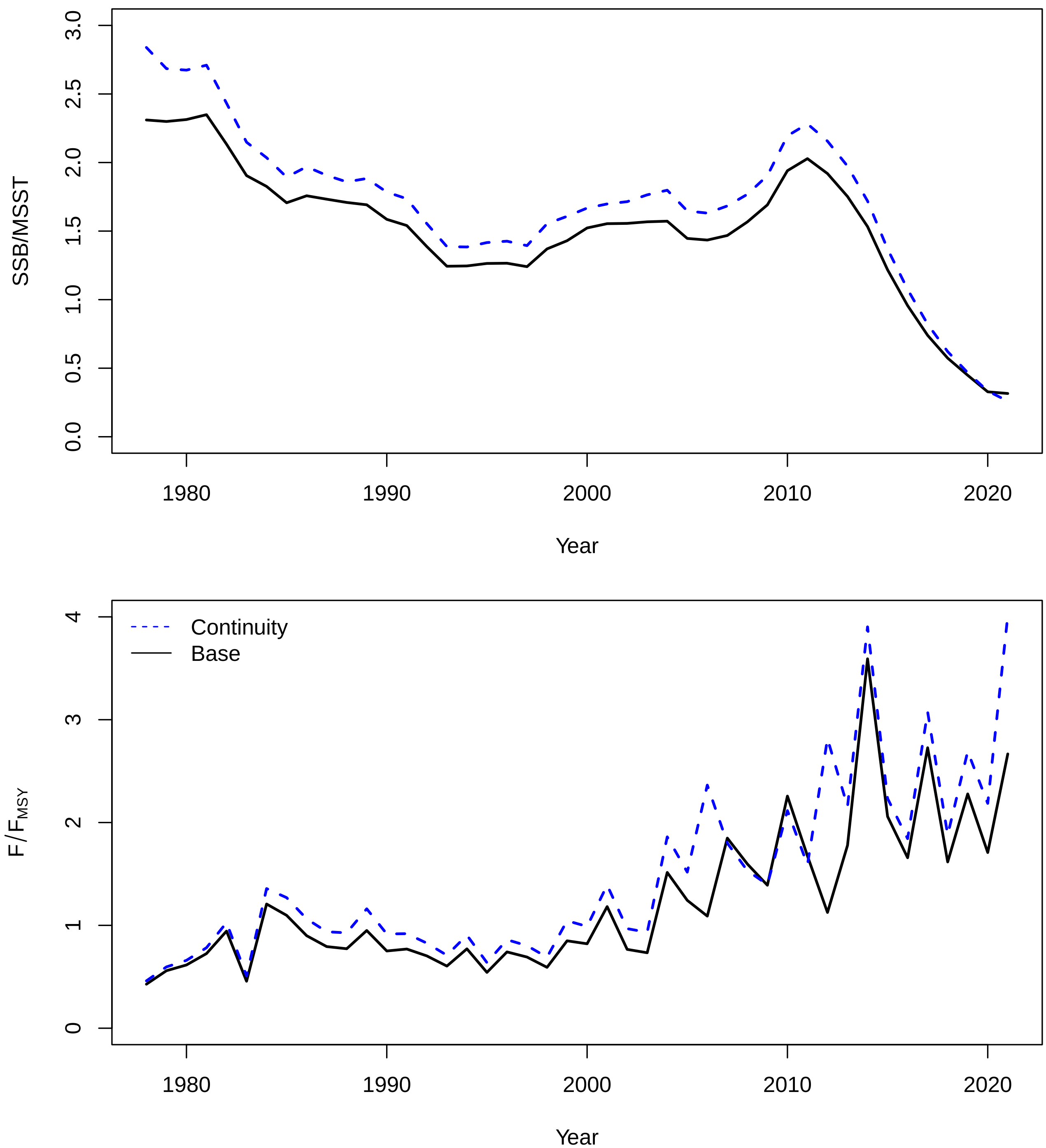


Figure 58. Sensitivity assumptions of the SERFS chevron trap index where Trap Only is the SERFS trap only index, Base fits the combined trap and video index (CVID), Trap then Vid is the chevron trap until 2010 and then the video index after, Trap & Vid is fit to both the trap and video index separately, Weighted Sel combined a domed trap selectivity for the trap with a logistic selectivity for the video weighted by the inverse process error of the indices, and Logistic assumes a logistic selectivity for the CVID index. Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$*. Any lines not visible overlap results of the base run.*

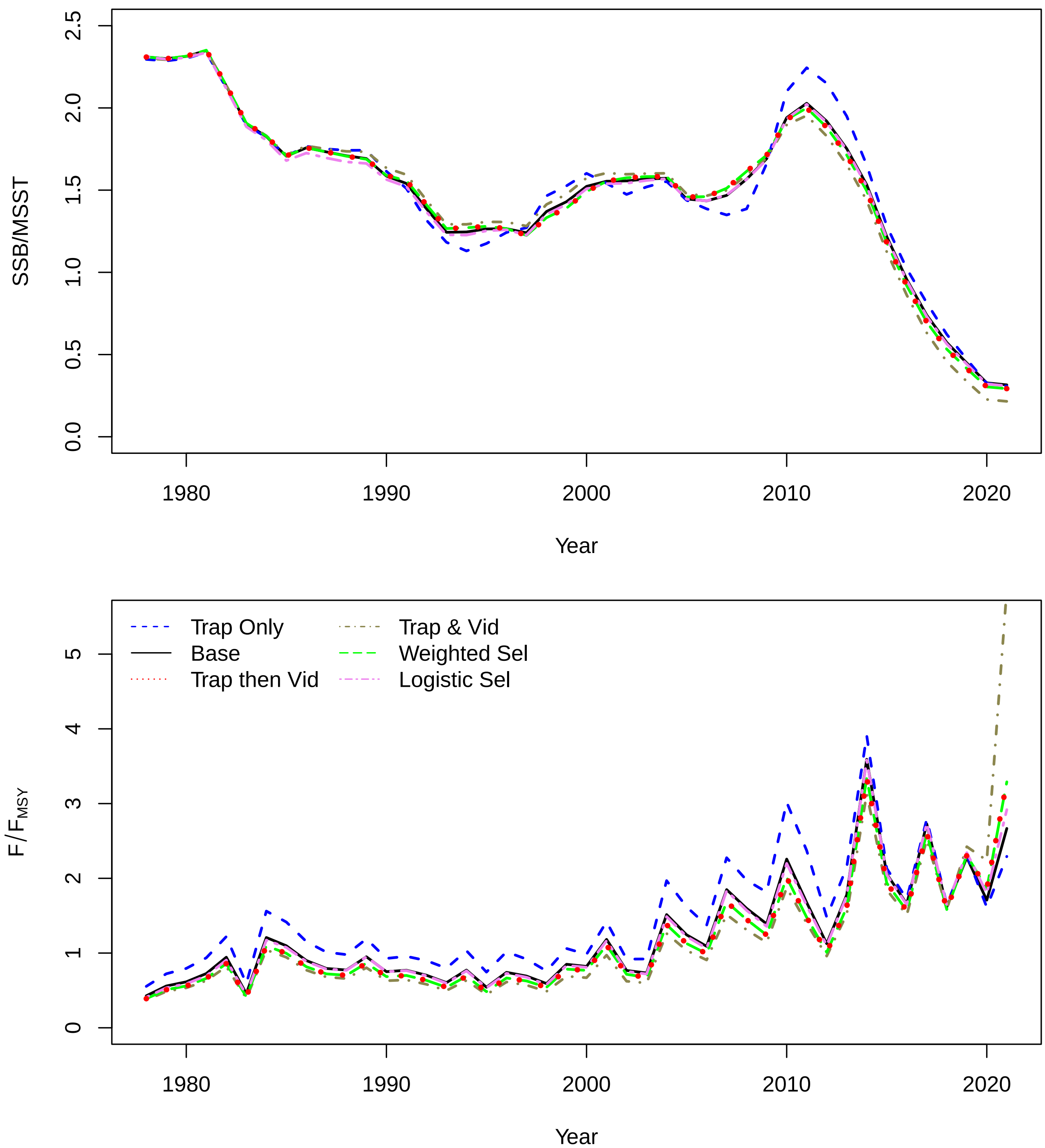


Figure 59. Sensitivity to higher and lower discard mortalities (sensitivity runs Discard high and Discard Low). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$*. Any lines not visible overlap results of the base run.*

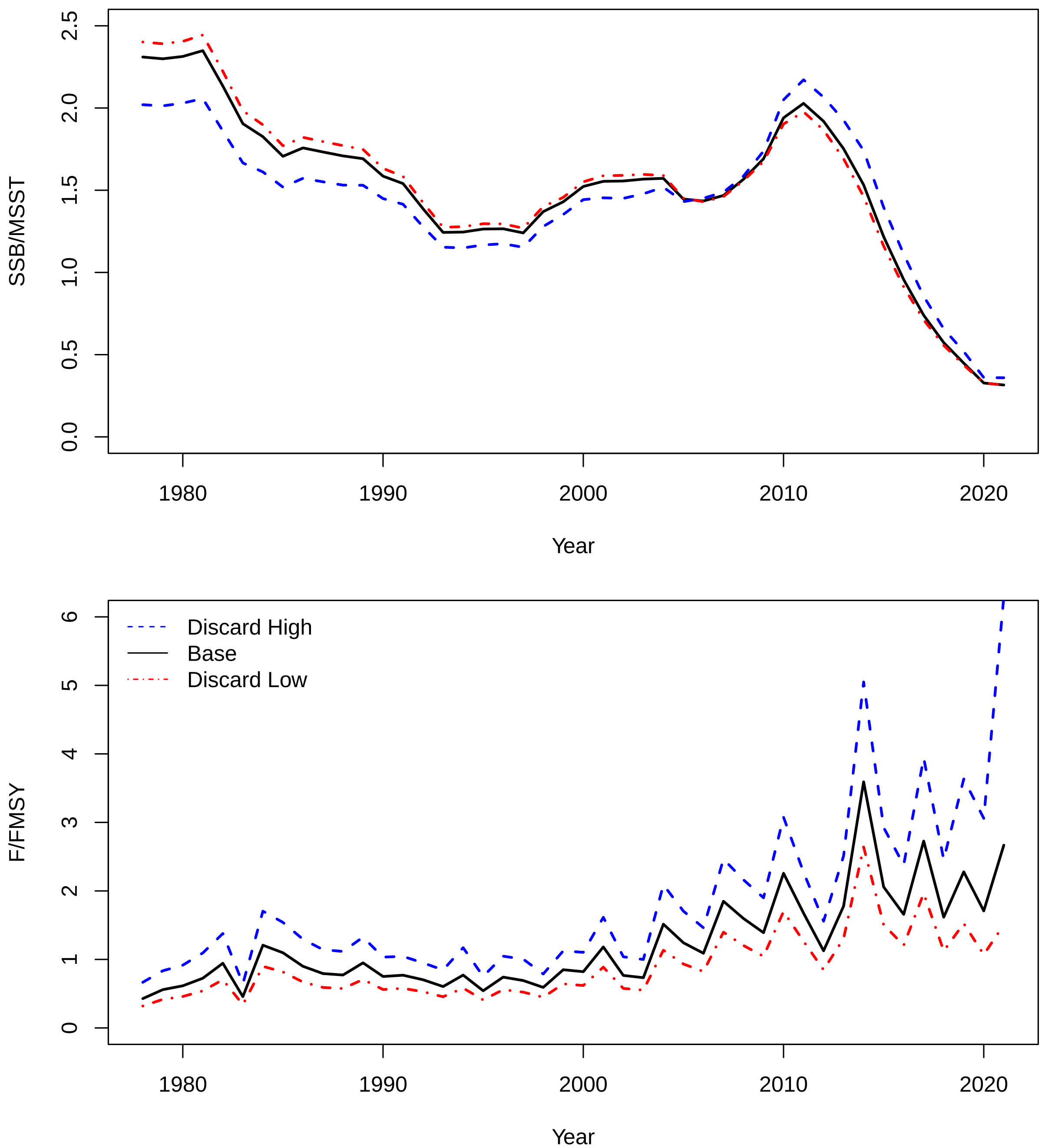


Figure 60. Phase plot of terminal status estimates from sensitivity runs of the Beaufort Assessment Model. Note that not all models are considered equally plausible and proportions of points in the quadrants should not be interpreted as probability statements about stock or fishery status.

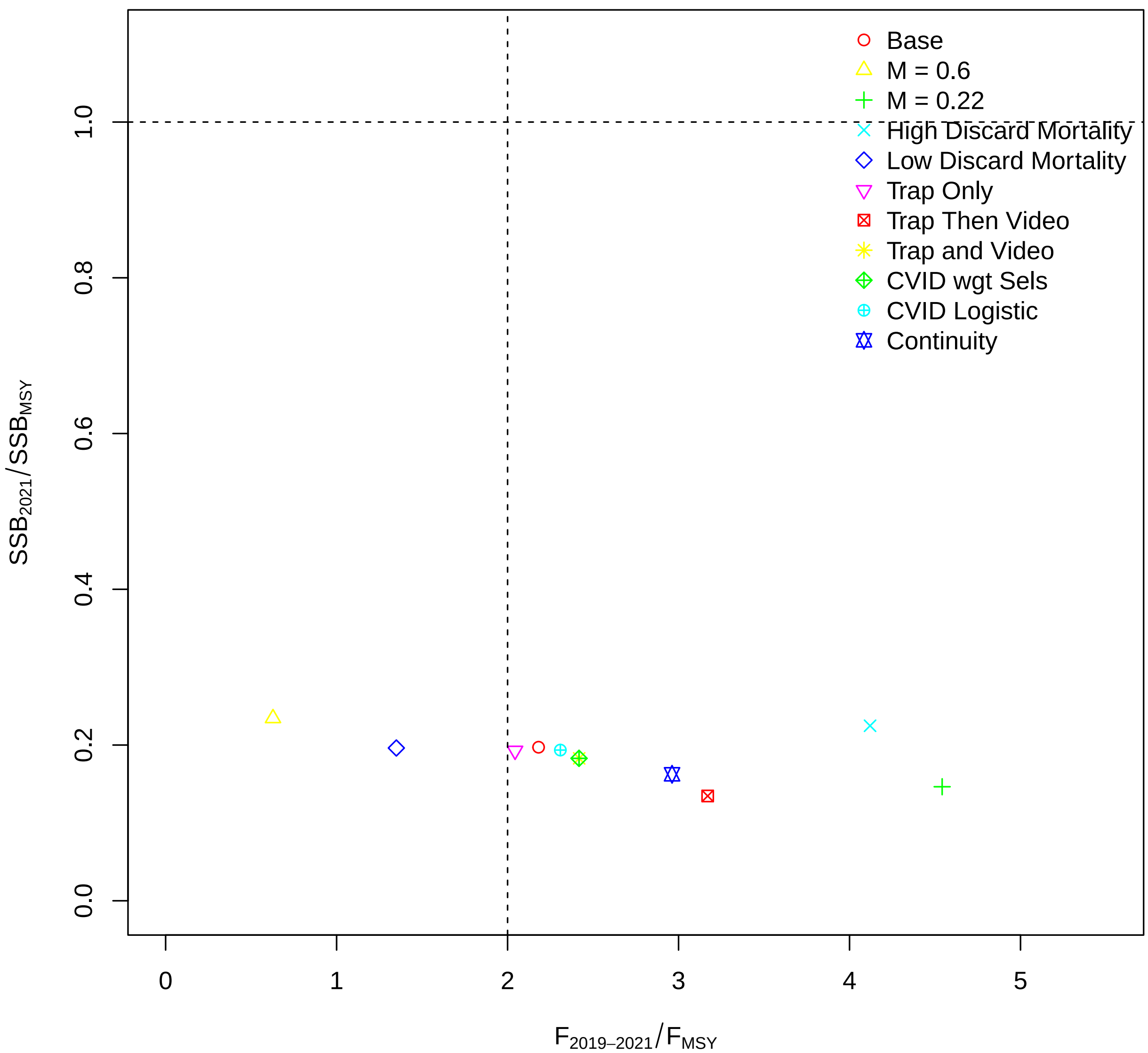


Figure 61. Retrospective analysis. Sensitivity to terminal year of data (2020-2016). Top left panel: Spawning Stock Biomass. Top right panel: Recruits. Bottom left panel: Biomass. Bottom right: Fishing mortality rates. Closed circles show terminal-year estimates. Imperceptible lines overlap results of the base run.

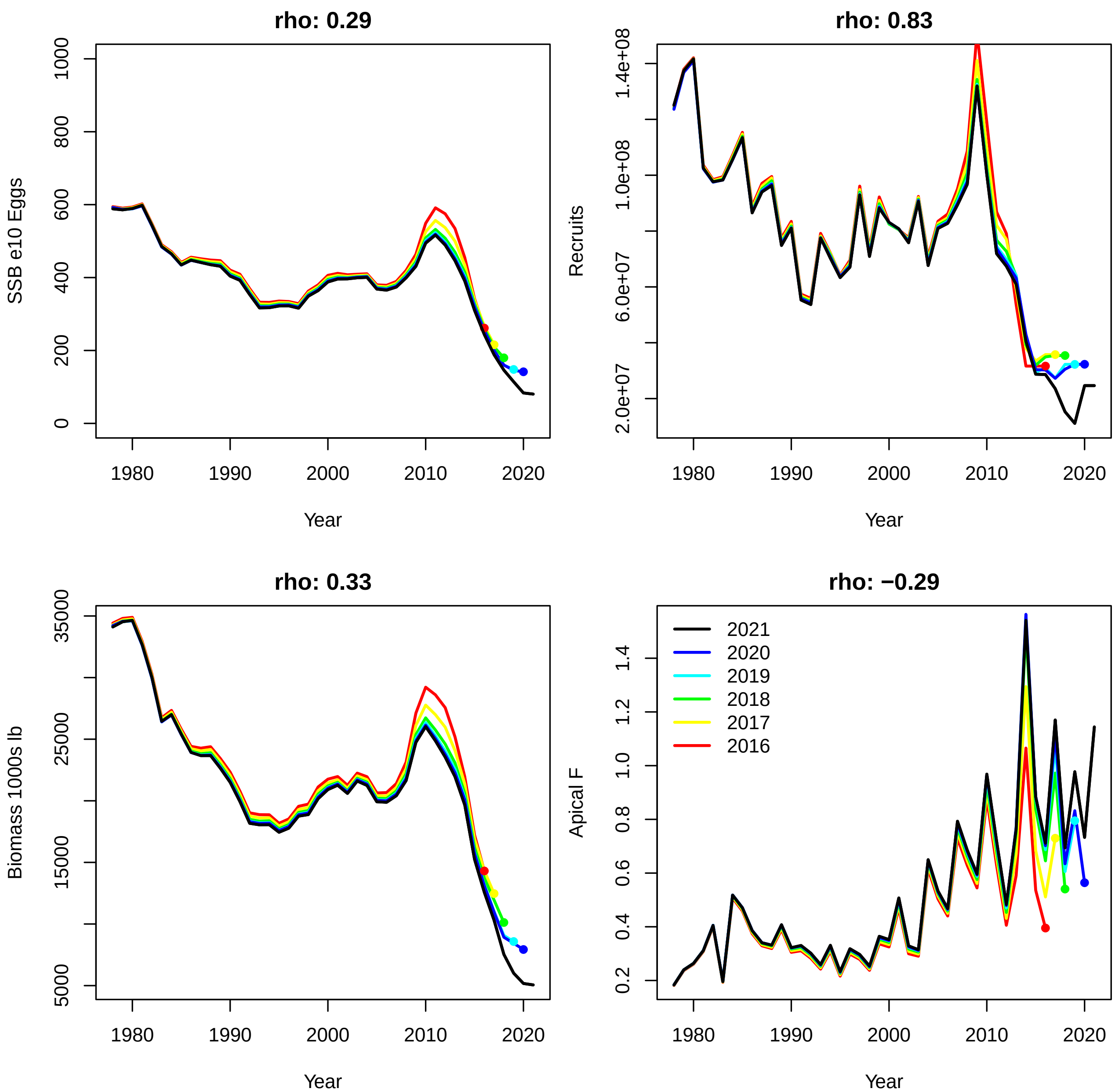


Figure 62. Projected time series under scenario 1—fishing mortality rate at F = 0 and long-term average recruitment. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Solid horizontal lines mark F_{MSY}-related benchmarks from the base model; dashed horizontal lines represent corresponding medians from the MCBE. Spawning stock (SSB) is at time of peak spawning.

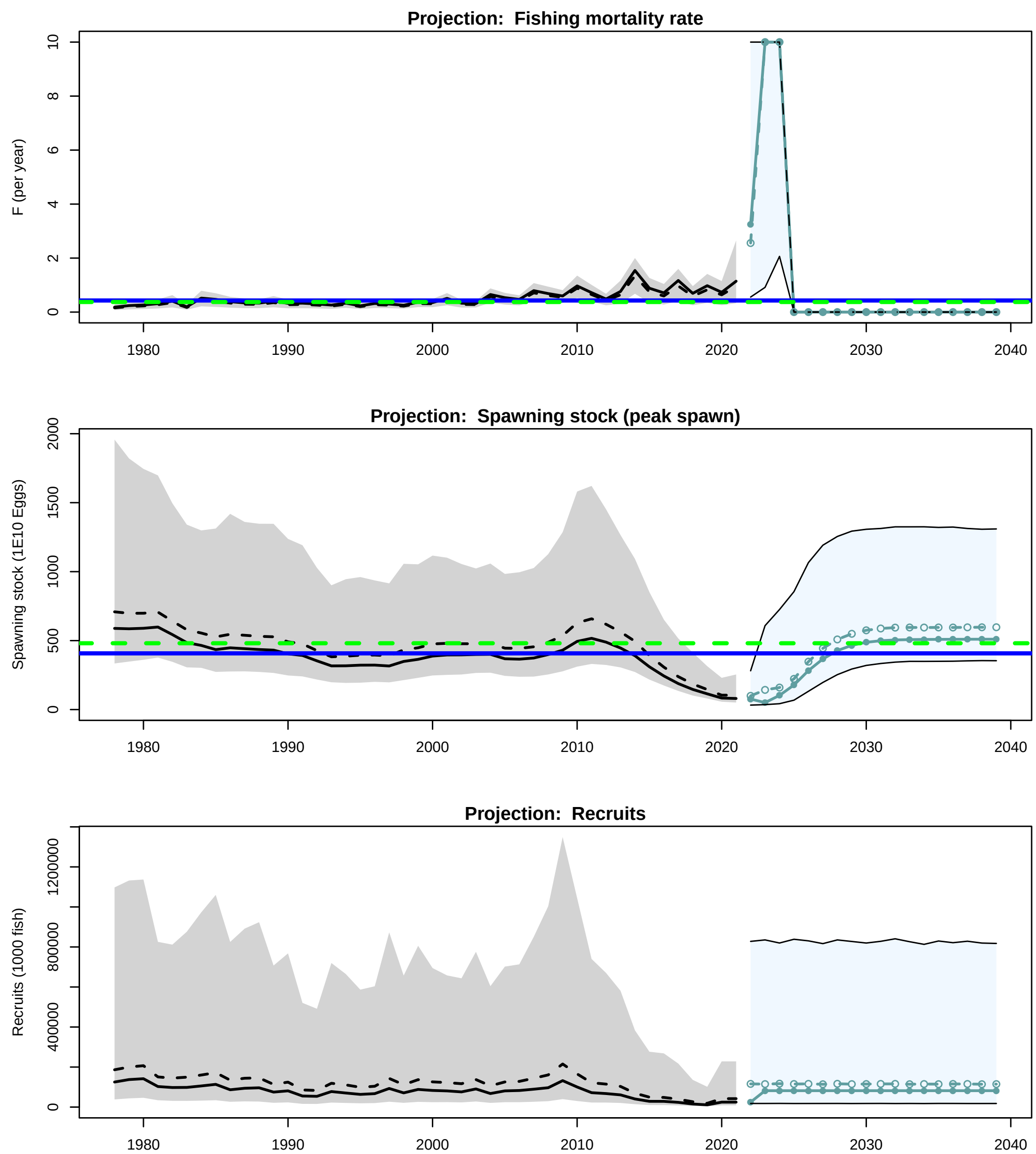


Figure 63. Projected probability of rebuilding under scenario 1—fishing mortality rate at F = 0 and long-term average recruitment. The curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB_{MSY}}$*, with reference lines at 0.5 and 0.7.*

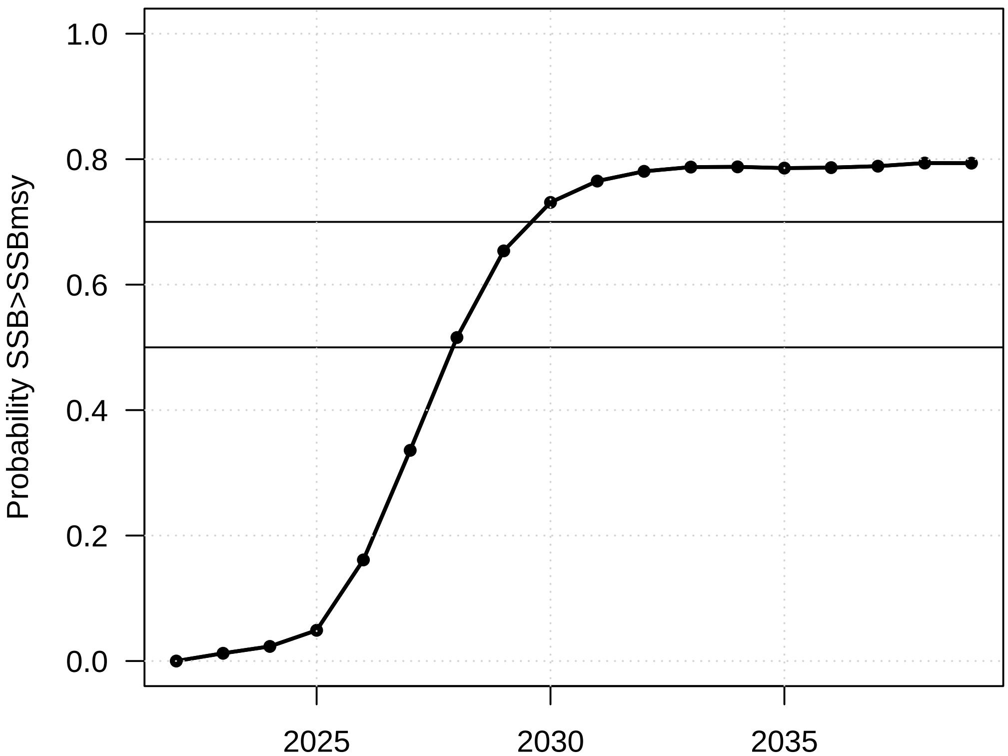


Figure 64. Projected time series under scenario 2—fishing mortality rate at F = 0 and recent average recruitment. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Solid horizontal lines mark F_{MSY}-related benchmarks from the base model; dashed horizontal lines represent corresponding medians from the MCBE. Spawning stock (SSB) is at time of peak spawning.

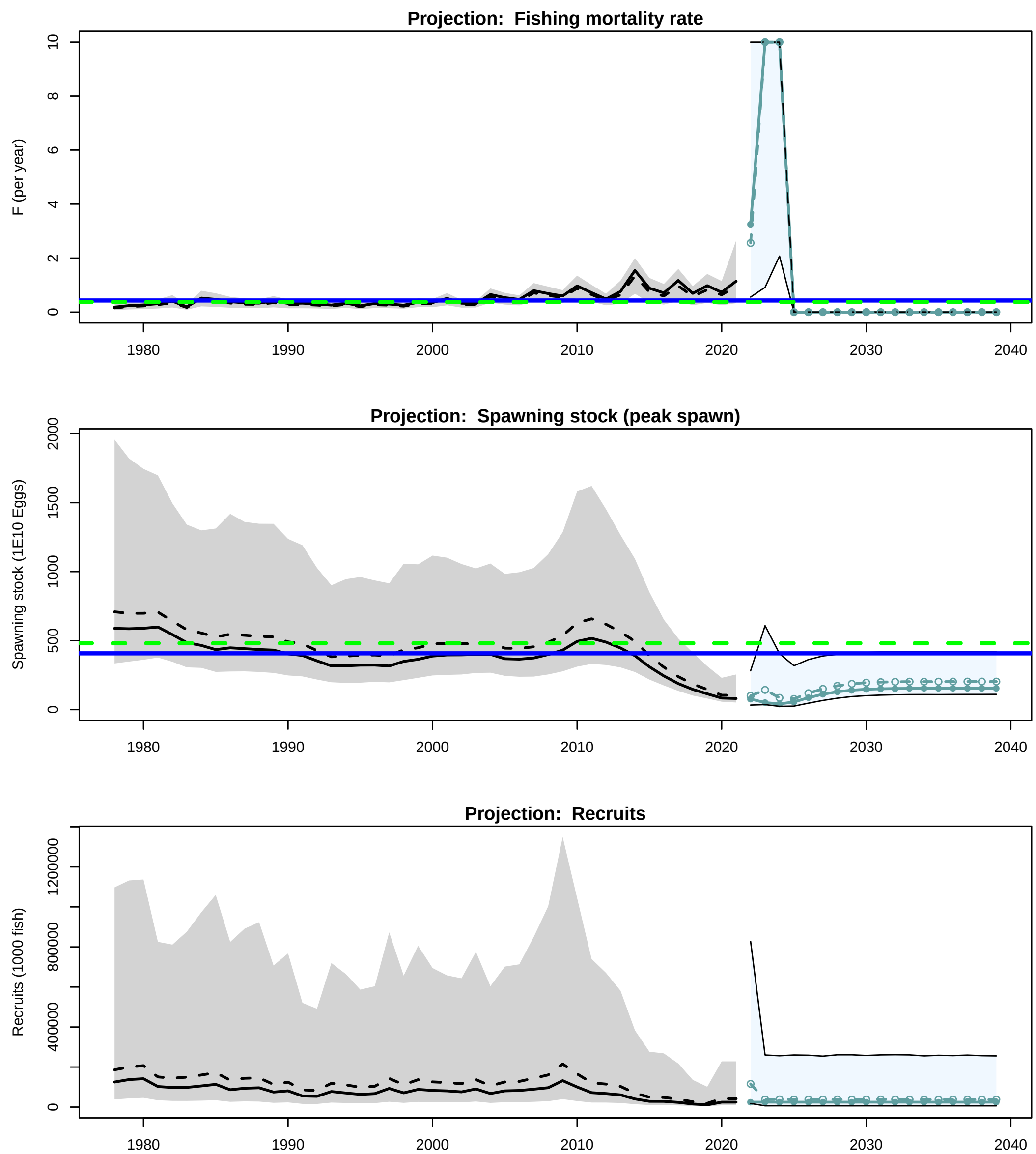


Figure 65. Projected probability of rebuilding under scenario 2—fishing mortality rate at F = 0 and recent average recruitment. The curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{MSY}}$*, with reference lines at 0.5 and 0.7.*

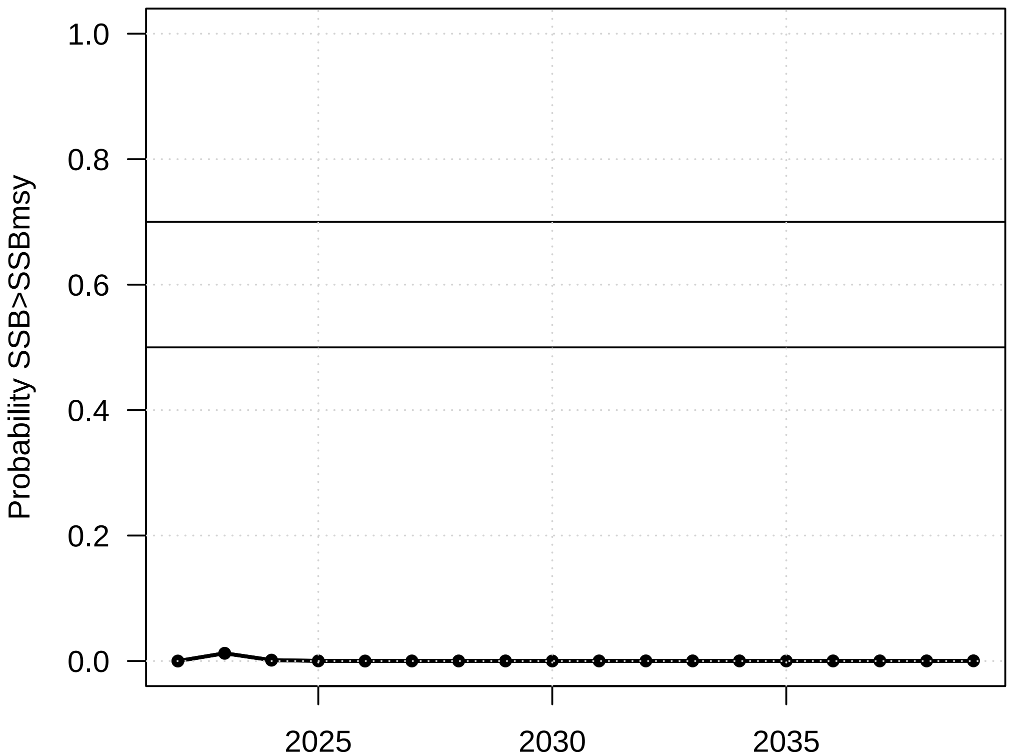


Figure 66. Projected time series under scenario 3—fishing mortality rate at $F = F_{\text{current}}$ and recent average recruitment. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Solid horizontal lines mark F_{MSY}-related benchmarks from the base model; dashed horizontal lines represent corresponding medians from the MCBE. Spawning stock (SSB) is at time of peak spawning.

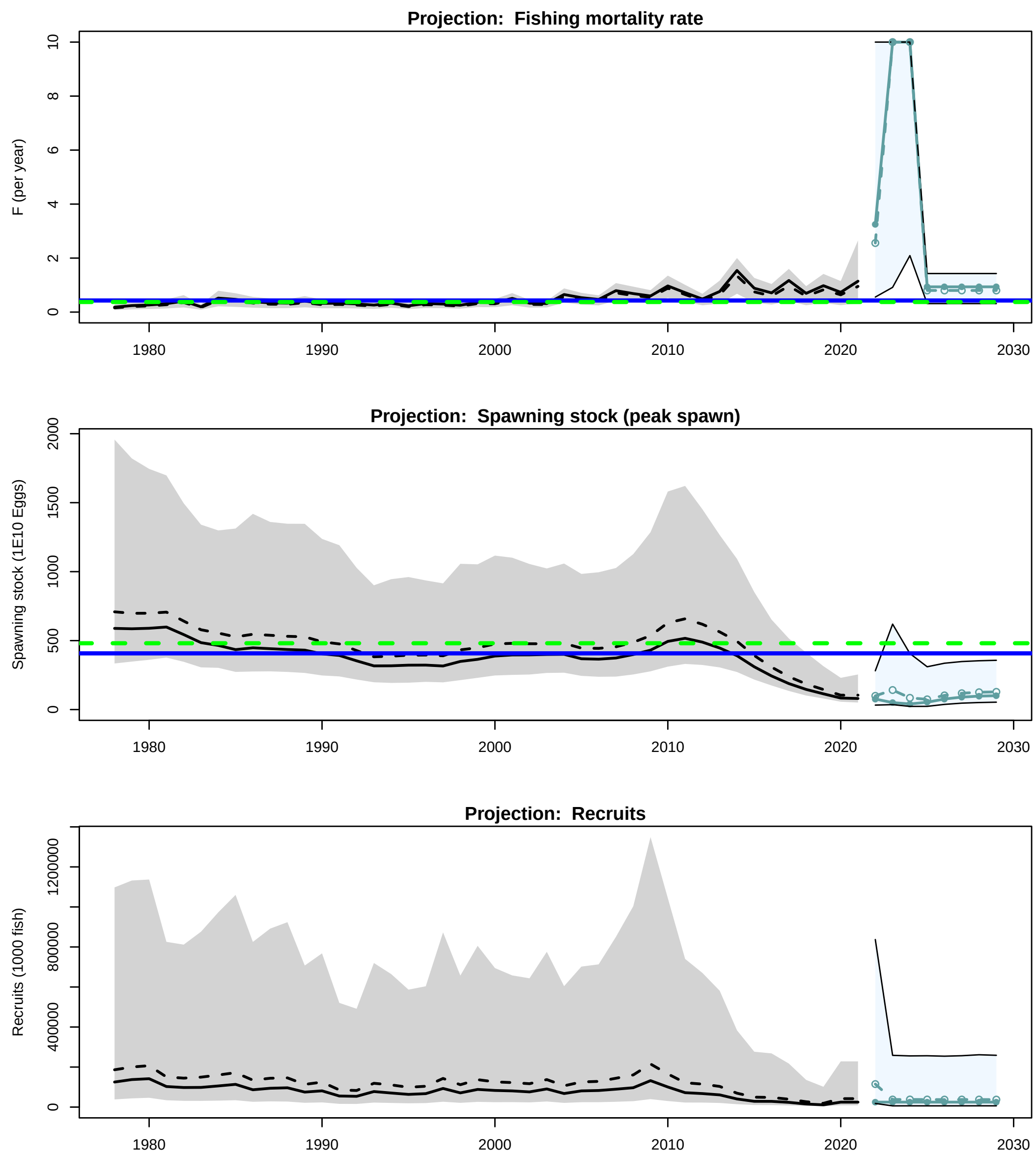
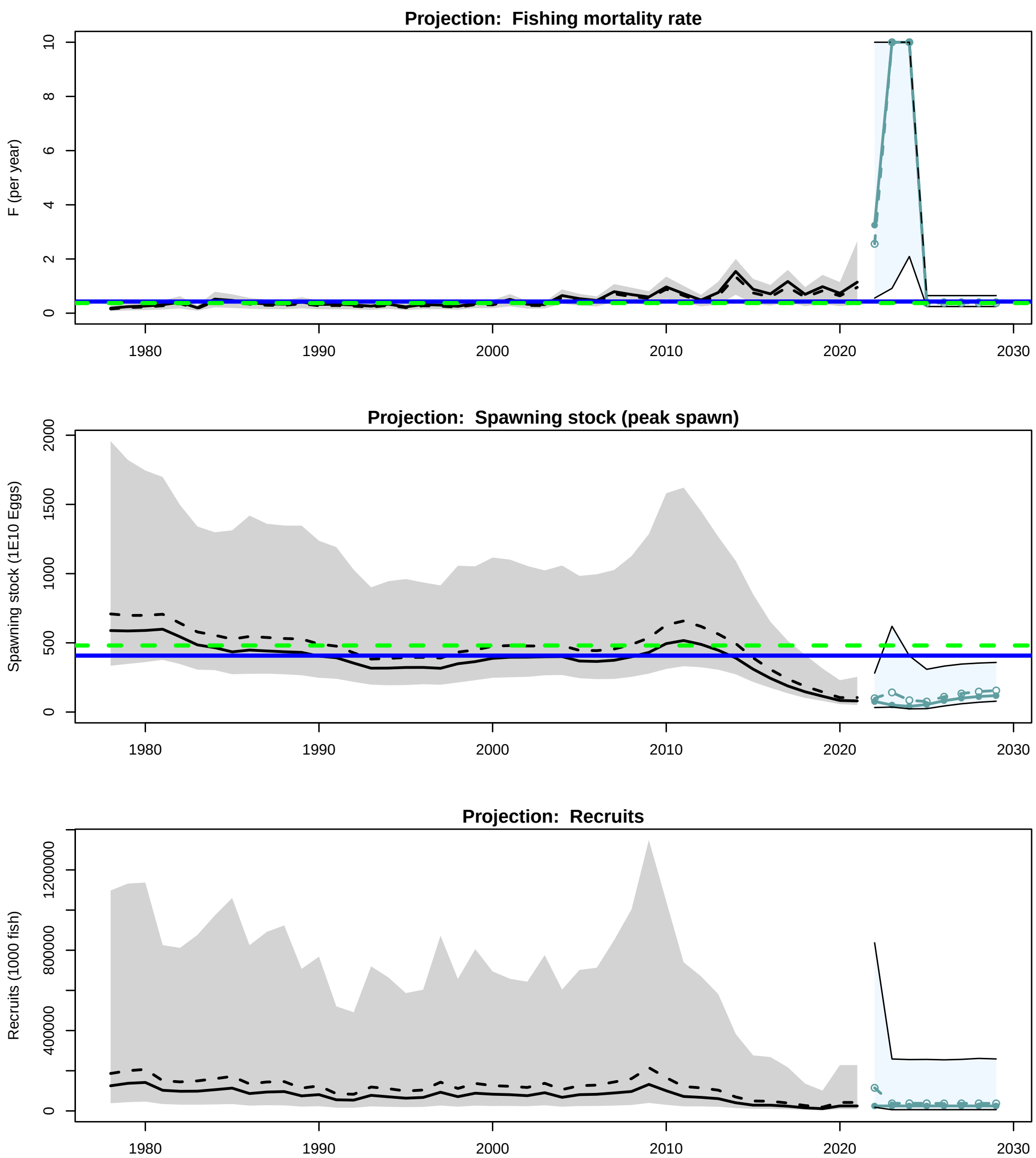


Figure 67. Projected time series under scenario 4—fishing mortality rate at $F = F_{\mathrm{MSY}}$ and recent average recruitment. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Solid horizontal lines mark F_{MSY}-related benchmarks from the base model; dashed horizontal lines represent corresponding medians from the MCBE. Spawning stock (SSB) is at time of peak spawning.



Appendix A Abbreviations and symbols

Table 26. Acronyms and abbreviations used in this report

Symbol	Meaning
ABC	Acceptable Biological Catch
AW	Assessment Workshop (here, for black sea bass)
ASY	Average Sustainable Yield
B	Total biomass of stock, conventionally on January 1
BAM	Beaufort Assessment Model (a statistical catch-age formulation)
CPUE	Catch per unit effort; used after adjustment as an index of abundance
CV	Coefficient of variation
CI	Confidence Interval
CVID	SERFS index combining sampling from chevron traps and video gear
DW	Data Workshop (here, for black sea bass)
F	Instantaneous rate of fishing mortality
F_{MSY}	Fishing mortality rate at which MSY can be attained
FL	State of Florida
GA	State of Georgia
GLM	Generalized linear model
K	Average size of stock when not exploited by man; carrying capacity
kg	Kilogram(s); 1 kg is about 2.2 lb.
klb	Thousand pounds; thousands of pounds
lb	Pound(s); 1 lb is about 0.454 kg
m	Meter(s); 1 m is about 3.28 feet.
M	Instantaneous rate of natural (non-fishing) mortality
MARMAP	Marine Resources Monitoring, Assessment, and Prediction Program, a fishery-independent data collection program of SCDNR
MCBE	Monte Carlo/Bootstrap ensemble, an approach to quantifying uncertainty in model results
MFMT	Maximum fishing-mortality threshold; a limit reference point used in U.S. fishery management; often based on F_{MSY}
mm	Millimeter(s); 1 inch = 25.4 mm
MRFSS	Marine Recreational Fisheries Statistics Survey, a data-collection program of NMFS, predecessor of MRIP
MRIP	Marine Recreational Information Program, a data-collection program of NMFS, descended from MRFSS
MSST	Minimum stock-size threshold; a limit reference point used in U.S. fishery management. The SAFMC has defined MSST for black sea bass as $(1 - M)\mathrm{SSB}_{\mathrm{MSY}} = 0.7\mathrm{SSB}_{\mathrm{MSY}}$.
MSY	Maximum sustainable yield (per year)
mt	Metric ton(s). One mt is 1000 kg, or about 2205 lb.
N	Number of fish in a stock, conventionally on January 1
NC	State of North Carolina
NMFS	National Marine Fisheries Service, same as “NOAA Fisheries Service”
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
OY	Optimum yield; SFA specifies that OY $\leq$ MSY.
PSE	Proportional standard error
R	Recruitment
SAFMC	South Atlantic Fishery Management Council (also, Council)
SC	State of South Carolina
SCDNR	Department of Natural Resources of SC
SDNR	Standard deviation of normalized residuals
SEDAR	SouthEast Data Assessment and Review process
SEFIS	SouthEast Fishery-Independent Survey
SERFS	SouthEast Reef Fish Survey
SFA	Sustainable Fisheries Act; the Magnuson–Stevens Act, as amended
SL	Standard length (of a fish)
SPR	Spawning potential ratio
SSB	Spawning stock biomass; mature biomass of males and females
$\mathrm{SSB}_{\mathrm{MSY}}$	Level of SSB at which MSY can be attained
TIP	Trip Interview Program, a fishery-dependent biodata collection program of NMFS
TL	Total length (of a fish), as opposed to FL (fork length) or SL (standard length)
VPA	Virtual population analysis, an age-structured assessment
WW	Whole weight, as opposed to GW (gutted weight)
yr	Year(s)

Appendix B Parameter estimates from the Beaufort Assessment Model

```
# Number of parameters = 465 Objective function value = 95194.5256574269  Maximum gradient component = 0.00290535931240813
# len_cv_val:
0.0914328556212
# log_Nage_dev:
 0.657490638510 0.315926015554 0.490567386762 0.682630730323 0.936071041760 0.460794650440 1.65372421590 0.477945348039 0.352667727733 0.238185562393 0.559558137779
# log_R0:
18.0759256725
# rec_sigma:
0.536319577667
# log_rec_dev:
 0.568631102806 0.662678779060 0.693181431971 0.370261766518 0.321086558563 0.327464840549 0.399598867915 0.471299309674 0.199956030386 0.282858009477 0.307110884784
 0.0549849791056 0.135034200463 -0.247454055582 -0.277203438790 0.0905731492523 -0.00832834312386 -0.111905195994 -0.0548709812026 0.272250224791 0.00105824077504 0.218993963583
 0.159496743529 0.131538958968 0.0677757483408 0.246053687813 -0.0461199762185 0.133100977517 0.155505026508 0.232091366233 0.311432460601 0.622424128633 0.347560525606
 0.0149544395932 -0.0492959345655 -0.150851488311 -0.557937781735 -0.902317223341 -0.906884180543 -1.10110882787 -1.53287911936 -1.85179985638
# log_dm_Mbft_lc:
3.72874546435
# log_dm_cL_lc:
4.65287655163
# log_dm_cP_lc:
3.61086322874
# log_dm_HB_lc:
3.70881873006
# log_dm_HB_D_lc:
5.79291689080
# log_dm_mrip_lc:
0.347660284767
# log_dm_Mbft_ac:
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# log_dm_Mcvt_ac:
-1.22110833776
# log_dm_cL_ac:
1.08625952131
# log_dm_cP_ac:
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# log_dm_HB_ac:
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# selpar_A50_Mbft:
1.58804698942
# selpar_slope_Mbft:
5.97759857373
# selpar_A50_Mcvt:
2.03164737363
# selpar_slope_Mcvt:
3.39452975374
# selpar_A502_Mcvt:
4.79919609270
# selpar_slope2_Mcvt:
0.354661753127
# selpar_A50_cL2:
3.53475340172
# selpar_slope_cL2:
2.47333558237
# selpar_A50_cL3:
3.67807244508
# selpar_slope_cL3:
2.61755527182
# selpar_A50_cL4:
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# selpar_slope_cL4:
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# selpar_A50_cP2:
2.30754361001
# selpar_slope_cP2:
4.82551176975
# selpar_A50_cP3:
3.03802737374
# selpar_slope_cP3:
4.75701772104
# selpar_A50_cP4:
3.56581982208
# selpar_slope_cP4:
2.56752427534
# selpar_A50_HB1:
1.67447277082
# selpar_slope_HB1:
4.34274861417
# selpar_A50_HB2:
1.86494562908
# selpar_slope_HB2:
6.14987260397
# selpar_A50_HB3:
2.60690964040
# selpar_slope_HB3:
6.82962759848
# selpar_A50_HB4:
3.21354366585
# selpar_slope_HB4:
3.12113829631
# selpar_A50_HB5:
```

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3.69937286442
# selpar_slope_HB5:
2.71087983887
# selpar_A50_HBD4:
1.90196210387
# selpar_slope_HBD4:
2.77672290677
# selpar_A502_HBD4:
2.08639703493
# selpar_A50_HBD5:
1.95253792789
# selpar_slope_HBD5:
2.61066276453
# selpar_A502_HBD5:
1.76277006365
# selpar_Age0_HB_D_logit:
-3.94339256105
# selpar_Age1_HB_D_logit:
-0.950458033841
# selpar_Age2_HB_D_logit:
3.49945516887
# selpar_A50_mrip1:
1.20853605056
# selpar_slope_mrip1:
3.89843449064
# selpar_A50_mrip2:
2.10205213249
# selpar_slope_mrip2:
3.28881450049
# selpar_A50_mrip3:
3.06776262538
# selpar_slope_mrip3:
4.94405702187
# selpar_A50_mrip4:
4.53960046019
# selpar_slope_mrip4:
2.87627545784
# selpar_A50_mrip5:
5.50949978759
# selpar_slope_mrip5:
2.32174106445
# log_q_Mbft:
-16.7526744398
# log_q_Mcvt:
-16.2177239414
# log_q_cL:
-8.17647554959
# log_q_HB:
-8.78818389913
# q_RW_log_dev_cL:
 -0.0637470370485 -0.216695834639 0.0346270386193 0.189751843203 0.230064597626 0.0807908960460 -0.208523335428 -0.0226209789091 -0.0183628076601 0.121753895251 0.254356264480
 -0.0688874952393 -0.128481604625 -0.282897084665 0.133069840920 0.239271867872
# q_RW_log_dev_HB:
 -0.00278295625394 0.0688127915574 0.0692146370436 0.0471777971352 0.0748215202201 0.125216789782 -0.0985480758726 -0.0990820057707 -0.0678756966896 -0.120669444369 -0.0728755563011
 -0.171599767362 -0.296826467559 -0.266022499251 0.0713189599387 0.0226697742357 0.0304731103361 0.0737819832044 -0.0240383521759 0.174703970579 -0.216371157146 0.0126345743634
 -0.0290578903829 0.0855214757417 0.268216810800 0.0569737405198 -0.00182233296125 -0.0954297473403 -0.121369194172 0.230268319741 0.308241594422
# log_avg_F_cL:
-3.34728289917
# log_F_dev_cL:
 -0.975665079099 -0.712420869262 -0.855866123726 -0.356154393197 -0.318806273290 -0.307987488518 0.0500936967959 0.127276067757 0.248714698005 0.143372243939 0.522968941331
 0.551823285140 0.629711765169 0.636517370720 0.456244070093 0.277969975286 0.439262232418 0.120625611391 0.0591867698248 0.296480132864 0.595300623156 0.516891992659
 -0.198551386724 -0.275848831588 -0.164530892435 -0.349454098042 -0.133221428179 -0.429484239326 -0.472759130326 -0.613703428183 -0.590001849759 -0.261182724295 -0.476243421460
 -0.952182451332 -0.288594480428 0.301026673672 0.729453536625 0.221853930034 0.403656545596 0.513950921169 0.363681150230 0.396598970873 -0.128468922134 0.258466306556
# log_avg_F_cP:
-2.65254199509
# log_F_dev_cP:
 -1.87695298096 -0.167752759554 0.138933697816 0.347227607105 0.162433156704 -0.283521317532 -0.329708550656 -0.168072110618 0.121946922278 -0.160275921803 0.0217785350674
 0.0873086754935 0.375301769239 0.249868557691 0.173977906106 0.107688799523 0.263852314672 0.0783210099716 0.228235991512 0.308049824584 0.141901086720 0.543463885386
 0.258293044167 0.450912409676 0.277659104827 0.305453386137 0.634430094898 0.307211357191 0.521969128613 0.207136971647 0.190720842379 0.539061068936 0.203306069716
 -0.0163591534056 -0.444346532150 -0.309423953632 -0.667836852924 -0.533237094743 -0.903796663997 -0.0325497214285 0.0486473600500 0.152440708851 -0.527428485364 -1.02626918819
# log_avg_F_cT:
-6.10430963121
# log_F_dev_cT:
 0.135830784449 0.0765063827845 0.0389864850511 0.340581185089 -0.0267906884310 -0.871566761496 -0.0172415069624 0.474305995409 0.461032908902 -0.695407470957 0.285233659017
 -0.108464237751 -0.0930067351045
# log_avg_F_HB:
-3.40308035671
# log_F_dev_HB:
 0.0763199611654 0.170106362678 0.290253943133 0.417707895954 0.521595450848 0.592058585821 0.702928007492 0.707777611347 0.671530481548 0.743112035647 0.777694206436
 0.528455042766 0.295217698012 0.0403467197700 -0.216979000477 -0.563031076923 -0.531308396708 -0.582868855651 -0.473389509610 -0.427410711304 -0.466973133650 0.122161658723
 -0.305115755765 -0.0699178272737 -0.461013967094 -0.453796654007 0.197865077555 0.0561910472688 -0.0266181958008 0.266037807954 -0.252118490527 0.120326536319 0.679493914098
 0.407317407926 -0.381127458559 -0.369043608470 -0.448205110869 -0.539944300371 -0.575653908137 -0.539117588461 -0.180844010642 -0.131133779117 -0.212283842758 -0.176602270285
# log_avg_F_mrip:
-1.24470322037
# log_F_dev_mrip:
 -0.770990888664 -0.189522882731 -1.63979716465 0.225856172529 0.0411757849529 -0.402582675561 -0.534450504396 -0.836927088682 -0.310626004257 -0.991925627454 -0.731105656088
 -0.754160982911 -0.915817799375 -0.556355900239 -1.07523575977 -0.517624135123 -0.780756621672 -1.18542417593 -0.675662010663 -0.327538264407 0.162687368392 -0.442794695435
 -0.509191231642 0.436235424909 0.275903184394 0.0224779714049 0.804452272907 0.655026777302 0.354622252335 1.01445454672 0.709281901749 0.297312002146 0.798957856891
 1.58880681339 0.994318410915 0.752243424843 1.26805656316 0.630741592032 1.03868731172 0.788001184961 1.28919125200
# log_avg_F_comm_D:
-7.43682575199
# log_F_dev_comm_D:
 0.772720092375 1.11055066615 0.910731247638 0.962379019589 1.02395039151 0.792844695976 0.569145751613 0.340223651174 0.461514963964 0.0596477787400 0.766669430769
 0.316600639391 0.250187061872 0.990084283265 -1.05148546237 -1.12048469189 -0.407850977070 -0.897616453332 -0.628144309286 -0.159967788449 -0.304501786410 -0.402609652743
 -0.805535331337 -0.912836957459 -0.496913848685 0.0477017474968 0.140986070295 -0.731004199014 -1.59698603378
```

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# log_avg_F_HB_D:
-5.99267960580
# log_F_dev_HB_D:
 -1.00600772152 0.619548135188 1.24955558750 -1.34191619353 -4.09486152738 0.688433491839 -1.14878865408 -1.31492685717 0.0946435927280 -0.768607647267 -0.155534838527
 -0.114352150713 -1.32435732410 -0.450571912321 -0.386932472357 -0.0799773927797 -0.715801708673 -0.736920112404 -1.23629182722 -1.69309529612 -0.793589888428 -0.494699560641
 -0.215866952557 0.0631574806028 0.308292050173 0.670358984052 0.912967108020 0.842268440547 1.01019503581 1.18034899522 1.38431581218 1.44662942757 1.56614726789
 1.92587982770 1.75355924662 2.35679955416
# log_avg_F_mrip_D:
-3.28015022560
# log_F_dev_mrip_D:
 -0.958446508902 -1.14236770076 -1.97661677345 -1.12565815257 -1.01552819327 -0.814981118756 -1.21800895392 -1.17594481981 -1.01978705975 -1.40560114998 -1.04519679282
 -1.06679019697 -0.840418866069 -0.351518268780 -1.12653828062 -0.944031765423 -0.657770361443 -0.947266819981 -0.411634071021 -0.0843662269707 -0.134082275542 -0.444715670910
 -0.410268240771 0.220739864292 0.0654777131302 0.212436253244 0.575810278047 0.517560731455 0.305953493046 0.501594327525 0.759685368356 0.917441798952 0.684655924277
 1.70079346005 1.55371804907 1.67651988895 2.14550626624 1.72190696031 2.19155807942 2.22450501847 2.34167479365
```