SEDAR

Southeast Data, Assessment, and Review

SEDAR 68

South Atlantic Scamp

Stock Assessment Report

DECEMBER 2022

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

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Section I: Introduction

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I. Introduction

1. SEDAR Process Description

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

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

SEDAR 68OA addressed the stock assessment for South Atlantic Scamp. 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 Scamp was disseminated to the public in December 2022. 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 January 2023 meeting, followed by the Council receiving that information at its March 2023 meeting. Documentation on SSC recommendations is not part of the SEDAR process and is handled through each Council

2. Atlantic Scamp Management Overview - Updated in 2019

2.1 Fishery Management Plan and Amendments

The following summary describes only those management actions that likely affect Scamp and Yellowmouth Grouper 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, establishes a management regime for the fishery for snappers, groupers and related demersal species of the Continental Shelf of the southeastern United States in the exclusive economic zone (EEZ) under the area of authority of the South Atlantic Fishery Management Council (Council) and the territorial seas of the states, extending from the North Carolina/Virginia border through the Atlantic side of the Florida Keys to 83° W longitude. Regulations apply only to federal waters.

Note that this management overview focuses on management measures directly affecting scamp. There may be management of other species that indirectly affects scamp due to changes in the behavior of fishermen that cannot be reliably predicted.

SAFMC FMP Amendments affecting scamp

Description of Action	FMP/Amendment	Effective Date
-4" trawl mesh size -Gear limitations (poisons, explosives, fish traps, trawls) -Designated modified habitats or artificial reefs as Special Management Zones	Snapper Grouper FMP	8/31/1983
-Prohibit trawls to harvest snapper grouper species south of Cape Hatteras, NC and north of Cape Canaveral, FL -Defined directed fishery as vessel with trawl gear and at least 200 pounds of snapper grouper species on board	Amendment 1	1/12/1989
-Prohibited gear: fish traps except black sea bass pots north of Cape Canaveral, FL; entanglement nets; longlines inside 50 fathoms; powerheads in designated SMZs off SC -Required offloading of SG species with heads and fins intact -Scamp minimum size limit = 20 inches total length -Aggregate grouper bag limit (including scamp) = 5 per person per day -Allowance for multiple bag limits per trip on charter vessels and headboats for trips over 24 hours. -Defined overfishing/overfished and established rebuilding timeframe for overfished species. Groupers = 15 years (1991 is year 1). -Required permits (commercial and for-hire) and specified data collection regulations	Amendment 4	1/1/1992

-Required dealer, charter, and headboat federal permits -Restricted sale and purchase of SG species -Specified allowable gear -Modified criteria for possession of multi-day bag limits	Amendment 7	1/23/1995
-Established limited entry for commercial snapper grouper fishery	Amendment 8	12/14/1998
-Established MSY proxy for groupers = 30% static SPR -OY proxy for hermaphroditic groupers = 45% static SPR -Determined scamp no longer overfished (static SPR = 35%) Established overfishing level = F>F30% static SPR MSST = [(1-M) or 0.5, whichever is greater)*B_{MSY} MFMT=F_{MSY}	Amendment 11	12/02/1999
-Prohibited the sale of SG species harvested or possessed in the EEZ under the bag limit and by vessels with a federal charter/headboat permit for SG species, regardless of where harvested	Amendment 15B	12/16/2009
-Established recreational and commercial shallow-water grouper spawning closure annually from January through April -Reduced 5-fish aggregate to 3-fish -Captain and crew on for-hire trips cannot retain species within the 3-grouper aggregate	Amendment 16	7/29/2009
-Specified allocations and directed commercial quota for gag -Prohibited harvest and possession of gag and associated shallow-water groupers (including scamp) when the directed commercial quota of gag was reached		
-Required use of non-stainless-steel circle hooks when fishing for SG species with natural baits in the EEZ north of 28 degrees N Latitude.	Amendment 17A	3/3/2011
-Reorganized FMU into 6 complexes (deep-water, jacks, snappers, grunts, shallow-water groupers, porgies) -Established ABCs, ACLs, allocations, and AMs for SG species not undergoing overfishing. For scamp: commercial ACL = 341,636 lbs ww; recreational ACL = 150,936 lbs ww; allocations = 65.34% comm/34.66% rec For SASWG: commercial SASWG ACL = 49,488 lbs ww; recreational SASWG ACL = 48,329 lbs ww; Allocations (for Yellowmouth) = 1.35% commercial	Amendment 25 (Comprehensive ACL Amendment)	4/16/2012
-Limited harvest of SG species in SC SMZs to the bag limit	Amendment 23 (CE-BA2)	1/30/2012
-Removed restriction on retention of bag limit quantities of grouper aggregate species (including scamp and yellowmouth) by captain and crew on for-hire vessels	Amendment 27	1/27/2014

-Modified ABC Control Rule for SG species to incorporate ORCS methodology -Adjusted ABCs and fishing levels for 14 unassessed SG species. -For scamp: ACL = OY = 90%ABC and 0.5 risk tolerance scalar. New ABC = 373,049 lbs ww. Commercial ACL = 219,375 lbs ww Rec ACL = 116,369 lbs ww -For SASWG: ACL = OY = ABC. Commercial ACL = 55,542 lbs ww Rec ACL = 48,648 lbs ww	Amendment 29	7/1/2015
-Revised accountability measures for SG species (including scamp and yellowmouth)	Amendment 34	2/22/2016

SAFMC Regulatory Amendments affecting scamp

Description of Action	**Amendment**	**Effective Date**
-Adjusted ACLs in response to MRIP revisions. Scamp: Comm ACL =333,100 lbs ww; Rec ACL = 176,688 lbs ww Yellowmouth: Comm ACL = 49,776 lbs ww; Rec ACL = 46,656 lbs ww	Regulatory Amendment 13	7/17/2013
-Removed prohibition on harvest and possession of shallow-water groupers	Regulatory Amendment 15	9/12/2013
(including scamp and yellowmouth) when the gag commercial ACL is met or projected to be met.		

2.2 Emergency and Interim Rules
None affecting scamp or yellowmouth

2.3 Secretarial Amendments
None affecting scamp or yellowmouth

2.4 Control Date Notices
Notice of Control Date effective July 30, 1991: Anyone entering federal snapper grouper fishery (other than for wreckfish) in the EEZ off S. Atlantic states after 07/30/91 was not assured of future access if limited entry program developed.

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

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

Notice of Control Date effective January 31, 2011: Anyone entering federal snapper grouper fishery off S. Atlantic states after 09/17/10 was not assured of future access if limited entry program is developed.

Notice of Control Date effective June 15, 2016: Fishermen entering federal for-hire snapper grouper recreational fishery off S. Atlantic states after 06/15/16 is not assured of future access if limited entry program is developed.

2.5 Management Program Specifications Table
2.5.1. General Management Information

Atlantic

Species	Scamp (*Mycteroperca phenax*) Yellowmouth Grouper (*Mycteroperca interstitialis)*
Management Unit	Southeastern U.S.
Management Unit Definition	All waters within South Atlantic Fishery Management Council Boundaries
Management Entity	South Atlantic Fishery Management Council
Management Contacts SERO / Council	SAFMC: Myra Brouwer SERO: Rick DeVictor
Current stock exploitation status	Overfishing not occuring
Current stock biomass status	Unknown

Table 2.5.2. Management Parameters

As Scamp or Yellowmouth have never been formally assessed, most management parameters do not currently exist.

Criteria	Atlantic – Proposed (values from SEDAR 68)		
	Definition	Base Run Values	Median of Base Run MCBs
MSST[1]	(1-M) B_{MSY}		
	0.5 B_{MSY}		
MFMT	F_{MSY}, if available; $F_{30\% SPR}$ proxy [2]		
F_{MSY}	F_{MSY}		
MSY	Yield at F_{MSY}, landings and discards, pounds and numbers		
B_{MSY}[1]	Total or spawning stock, to be defined		
R_{MSY}	Recruits at MSY		
OY	Optimum Yield, landings and discards, pounds and numbers		
F_{OY}	F at OY		
F Target	75% F_{MSY}		
Yield at F_{TARGET} (equilibrium)	Landings and discards, pounds and numbers		
M	Natural mortality, average across ages or point estimate used to scale M at age		
Terminal F	Exploitation, geometric mean of the last 3 years		
Terminal Biomass[1]	Biomass		
Exploitation Status	F/MFMT		
Biomass Status[1]	B/MSST		
	B/B_{MSY}		
Generation Time			
$T_{REBUILD}$ (if appropriate)			

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

2. If an acceptable estimate of F_{MSY} is not provided by the assessment a proxy value may be considered. The current F_{MSY} proxy for this stock is 30% SPR; other values may be recommended by the assessment process for consideration by the SSC.

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

None

Table 2.5.4. General Projection Specifications

The projection information will be completed when the management history is updated for the Scamp Operational Assessment.

First Year of Management	
Interim basis	
Projection Outputs	
Landings	Pounds and numbers
dsscards	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.

The projection information will be completed when the management history is updated for the Scamp Operational Assessment.

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

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

Table 2.5.7. Quota Calculation Details

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

Scamp: Current Acceptable Biological Catch (ABC) and Total Annual Catch Level (ACL) Value for Scamp Yellowmouth ACL (part of SASWG complex):	ABC=373,049 lbs ww Total ACL = 335,744 lbs ww For SASWG: commercial SASWG ACL = 49,488 lbs ww; recreational SASWG ACL = 48,329 lbs ww
Commercial ACL for Scamp	219,375 lbs ww
Recreational ACL for Scamp	116,369 lbs ww
Commercial ACL allocation for yellowmouth	1.35% commercial
Recreational ACL allocation for yellowmouth	98.65% recreational
Next Scheduled Quota Change	upon completion of stock assessment
Annual or averaged quota?	annual
If averaged, number of years to average	N/A
Does the quota include bycatch/discard?	No

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

The ACL is set at 90% of the ABC, which was established under the Only Reliable Catch Stocks (ORCS) methodology incorporated in the ABC Control Rule in 2015. The methodology includes a catch statistic (highest landings between 1999 and 2007 =596,879 lbs ww), a risk of overexploitation scalar (1.25) and a risk tolerance scalar (0.5).

The sector allocations (65.34% comm/34.66% rec) were set using the formula (0.5 x average catch 1986-2008) + (0.5 x average catch 2006-2008).

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 include estimates of discards in it.

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

None

2.6 Federal Management and Regulatory Timeline

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

Table 2.6.1 South Atlantic Scamp and Yellowmouth Recreational Regulatory History prepared by: Myra Brouwer Notes: Regulatory Amendment 30 proposes extending the recreational seasonal closure ONLY OFF THE CAROLINAS AND FOR RED GROUPER ONLY. Regulations are expected to affect the 2020 fishing year

Year	Quota (# fish)	ACL (# fish)	Days Open	fishing season	reason for closure	season start date (first day implemented)	season end date (last day effective)	Size limit	size limit start date	size limit end date	Retention Limit (# fish)	Retention Limit Start Date	Retention Limit End Date	Aggregate Retention Limit[1] (# fish)	Aggregate Retention Limit Start Date	Aggregate Retention Limit End Date
1983	N/A	N/A	123	open	N/A	31-Aug	31-Dec	None	N/A	N/A	None	N/A	N/A	None	N/A	N/A
1984	N/A	N/A	366	open	N/A	1-Jan	31-Dec	None	N/A	N/A	None	N/A	N/A	None	N/A	N/A
1985	N/A	N/A	365	open	N/A	1-Jan	31-Dec	None	N/A	N/A	None	N/A	N/A	None	N/A	N/A
1986	N/A	N/A	365	open	N/A	1-Jan	31-Dec	None	N/A	N/A	None	N/A	N/A	None	N/A	N/A
1987	N/A	N/A	365	open	N/A	1-Jan	31-Dec	None	N/A	N/A	None	N/A	N/A	None	N/A	N/A
1988	N/A	N/A	366	open	N/A	1-Jan	31-Dec	None	N/A	N/A	None	N/A	N/A	None	N/A	N/A
1989	N/A	N/A	365	open	N/A	1-Jan	31-Dec	None	N/A	N/A	None	N/A	N/A	None	N/A	N/A
1990	N/A	N/A	365	open	N/A	1-Jan	31-Dec	None	N/A	N/A	None	N/A	N/A	None	N/A	N/A
1991	N/A	N/A	365	open	N/A	1-Jan	31-Dec	None	N/A	N/A	None	N/A	N/A	None	N/A	N/A
1992	N/A	N/A	366	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	31-Dec	5	1-Jan	31-Dec
1993	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	31-Dec	5	1-Jan	31-Dec
1994	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	31-Dec	5	1-Jan	31-Dec
1995	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	31-Dec	5	1-Jan	31-Dec
1996	N/A	N/A	366	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	31-Dec	5	1-Jan	31-Dec
1997	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	31-Dec	5	1-Jan	31-Dec
1998	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	31-Dec	5	1-Jan	31-Dec
1999	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	31-Dec	5	1-Jan	31-Dec
2000	N/A	N/A	366	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	31-Dec	5	1-Jan	31-Dec
2001	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	31-Dec	5	1-Jan	31-Dec
2002	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	31-Dec	5	1-Jan	31-Dec
2003	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	31-Dec	5	1-Jan	31-Dec
2004	N/A	N/A	366	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	31-Dec	5	1-Jan	31-Dec
2005	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	31-Dec	5	1-Jan	31-Dec
2006	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	31-Dec	5	1-Jan	31-Dec
2007	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	31-Dec	5	1-Jan	31-Dec
2008	N/A	N/A	366	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	31-Dec	5	1-Jan	31-Dec
2009	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	5	1-Jan	28-Jul	5	1-Jan	28-Jul
											3	29-Jul	31-Dec	3	29-Jul	31-Dec
2010	N/A	N/A	120	closed	Seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	3	1-May	31-Dec	3	1-May	31-Dec
			245	open	N/A	1-May	31-Dec									
2011	N/A	N/A	120	closed	Seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	3	1-May	31-Dec	3	1-May	31-Dec
			245	open	N/A	1-May	31-Dec									
2012	see ACL	150,936 lbs ww	121	closed	Seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	3	1-May	31-Dec	3	1-May	31-Dec
			245	open	N/A	1-May	31-Dec									
2013	see ACL	150,936 lbs ww	120	closed	Seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	3	1-May	31-Dec	3	1-May	31-Dec
			245	open	N/A	1-May	31-Dec									
2014	see ACL	150,936 lbs ww	120	closed	Seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	3	1-May	31-Dec	3	1-May	31-Dec
			245	open	N/A	1-May	31-Dec									
2015	see ACL	150,936 lbs ww	120	closed	Seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	3	1-May	31-Dec	3	1-May	31-Dec
			61	open	N/A	1-May	30-Jun									
		116,369 lbs ww	184	open	N/A	1-Jul	31-Dec									
2016	see ACL	116,369 lbs ww	121	closed	Seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	3	1-May	31-Dec	3	1-May	31-Dec
			245	open	N/A	1-May	31-Dec									
2017	see ACL	116,369 lbs ww	120	closed	Seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	3	1-May	31-Dec	3	1-May	31-Dec
			245	open	N/A	1-May	31-Dec									
2018	see ACL	116,369 lbs ww	120	closed	Seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	3	1-May	31-Dec	3	1-May	31-Dec
			245	open	N/A	1-May	31-Dec									

Table 2.6.2 South Atlantic Scamp and Yellowmouth Commercial Regulatory History prepared by: Myra Brouwer Notes: Regulatory Amendment 30 proposes extending the commercial seasonal closure ONLY OFF THE CAROLINAS AND FOR RED GROUPER ONLY. Regulations are expected to affect the 2020 fishing year.

Year	Quota (units)	ACL (units)	Days Open	fishing season	reason for closure	season start date (first day implemented)	season end date (last day effective)	Size limit (units and length type, indicate maximum or natural length)	size limit start date	size limit end date	Retention Limit (units)	Retention Limit Start Date	Retention Limit End Date	Aggregate Retention Limit (units)	Aggregate Retention Limit Start Date	Aggregate Retention Limit End Date
1983	N/A	N/A	365	open	N/A	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1984	N/A	N/A	366	open	N/A	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1985	N/A	N/A	365	open	N/A	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1986	N/A	N/A	365	open	N/A	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1987	N/A	N/A	365	open	N/A	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1988	N/A	N/A	366	open	N/A	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1989	N/A	N/A	365	open	N/A	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1990	N/A	N/A	365	open	N/A	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1991	N/A	N/A	365	open	N/A	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1992	N/A	N/A	366	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
1993	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
1994	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
1995	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
1996	N/A	N/A	366	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
1997	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
1998	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
1999	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
2000	N/A	N/A	366	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
2001	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
2002	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
2003	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
2004	N/A	N/A	366	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
2005	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
2006	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
2007	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
2008	N/A	N/A	366	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
2009	N/A	N/A	365	open	N/A	1-Jan	31-Dec	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
2010	N/A	N/A	120	closed	seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
2010	N/A	N/A	245	open	N/A	1-May	31-Dec									
2011	N/A	N/A	120	closed	seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
2011	N/A	N/A	245	open	N/A	1-May	31-Dec									
2012	N/A	N/A	121	closed	seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
	see ACL	341,636 lbs ww	173	open	N/A	1-May	20-Oct									
			23	closed	closure for gag	21-Oct	12-Nov									
			9	open	gag reopened	13-Nov	21-Nov									
			40	closed	closure for gag	22-Nov	31-Dec									
2013	see ACL	341,636 lbs ww	120	closed	seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
			78	open	N/A	1-May	17-Jul									
		333,100 lbs ww	167	open	N/A	18-Jul	31-Dec									
2014	see ACL	333,100 lbs ww	120	closed	seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
			245	open	N/A	1-May	31-Dec									
2015	see ACL	333,100 lbs ww	120	closed	seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
			62	open	N/A	1-May	1-Jul									
		219,375 lbs ww	183	open	N/A	2-Jul	31-Dec									
2016	see ACL	219,375 lbs ww	121	closed	seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
			245	open	N/A	1-May	31-Dec									
2017	see ACL	219,375 lbs ww	120	closed	seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
			245	open	N/A	1-May	31-Dec									
2018	see ACL	219,375 lbs ww	120	closed	seasonal	1-Jan	30-Apr	20 inches	1-Jan	31-Dec	N/A	N/A	N/A	N/A	N/A	N/A
			245	open	N/A	1-May	31-Dec									

2.7 Closures in the South Atlantic Due to Meeting Commercial Quota or Commercial/Recreational ACL

Commercial: 10/20/12; reopened 11/13/12 – 11/21/12

2.8 State Regulatory Information

2.8.1 North Carolina:

There are currently no North Carolina state-specific regulations for scamp. North Carolina has complemented federal regulations, including quota and/or annual catch limit closures, for all snapper grouper species via proclamation authority since January 1991, when rule 15A NCAC 03M .0506 was first implemented:

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/methods; and
(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 rule was modified slightly to remove the phrase "until September 1, 1991" effective September 1, 1991. The first proclamation (FF-19-94) pertaining to scamp was issued under the authority of this rule effective July 1, 1994 and established a 20-inch total length minimum size limit (both sectors) and included the species in a five-fish aggregate bag limit.

Rule 15A NCAC 03M .0506 remained unchanged until March 1, 1996 when species-specific regulations for all snapper grouper species were added to the proclamation authority contained in the rule. Specific to scamp, the rule was amended to include the minimum size limit initially established in FF-19-94:

15A NCAC 03M .0506 SNAPPER-GROUPER

(h) It is unlawful to possess scamp less than 20 inches total length.

(q) It is unlawful to possess more than five grouper taken in any one day unless fishing aboard a vessel holding a federal vessel permit for snapper-grouper authorizing the bag limit to be exceeded.

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.

In addition to the above change, rule 15A NCAC 03M .0512 was implemented effective March 1, 1996 and provided supplementary proclamation authority to the Fisheries Director to modify any existing size and harvest limits for species subject to interstate and federal management:

<u>15A NCAC 03M .0512 COMPLIANCE WITH FISHERY MANAGEMENT PLANS</u>

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; 143B-289.4; Eff. March 1, 1996.

Proclamation FF-20-99 was issued effective September 15, 1999 which prohibited all commercial and recreational harvest and possession, complementing the federal emergency closure of the fishery.

On January 1, 2002 rule 15A NCAC 03M .0506 was amended to remove the combined aggregate bag limit language for grouper. On May 1, 2004, the combined bag limit language was added back into rule. However, there was no regulatory change to the grouper bag limits as the combined bag limit language was consistently maintained in proclamation since Proclamation FF-20-99.

No further modifications to rule 15A NCAC 03M .0506 pertaining to scamp were implemented. In 2002, North Carolina adopted its Inter-Jurisdictional Fishery Management Plan (IJ FMP), which incorporates all Atlantic States Marine Fisheries Commission and council-managed species by reference and adopts all federal regulations as minimum standards for management, as appropriate. In 2007, the statutorily-mandated five-year review of the IJ FMP began, with final adoption of the updated plan in 2008. Changes to the FMP included removal of all species-specific regulations from rule 15A NCAC 03M .0506 effective October 1, 2008, and proclamation authority to implement changes for all species under federal or interstate management was moved to rule 15A NCAC 03M .0512.

Once the changes to rules 15A NCAC 03M .0506 and 03M .0512 described above were implemented, proclamation FF-66-2008 was issued effective October 1, 2008 and contained all relevant commercial and recreational regulations for all snapper grouper species. The portion of the proclamation specific to scamp is excerpted as follows:

III. Other Groupers

C. It is unlawful to possess scamp less than 20 inches total length.

IX. Combined Bag Limits

B. It is unlawful to possess more than five grouper without a valid Federal Commercial Snapper-Grouper permit of which:

1. no more than two may be a gag or black grouper (individually or in combination) per person per day;

2. no more than one per vessel per trip may be a speckled hind;

3. no more than one per vessel per trip may be a warsaw grouper;

4. no more than one per person per day may be a snowy grouper; and

5. no more than one per person per day may be a golden tilefish.

F. It is unlawful for persons in possession of a valid National Marine Fisheries Service Snapper-Grouper Permit for Charter Vessels to exceed the creel restrictions established in Sections (I), (V), (IX), and (X) of this proclamation when fishing with more than three persons (including the captain and mate) on board.

To comply with Amendment 16, Proclamation FF-48-2009 reduced the five-fish aggregate grouper limit to three fish and prohibited possession of “shallow water grouper” from January 1 to April 30. Later that year, Proclamation FF-66-2009 added the prohibition on sale of fish harvested under the recreational bag limit without a federal commercial snapper grouper permit (as per Amendment 15B) to the general regulations for the entire fishery.

An information update to the IJ FMP was completed and approved in November 2015 and contained no additional modifications to rules 15A NCAC 03M .0506 and 15A NCAC 03M .0512. The only procedural modifications that have occurred are starting in 2013, proclamations establishing the size limits, possession limits and seasons for the upcoming calendar year (“season-opening” proclamations) have been issued in December of the preceding year; and beginning in 2015, commercial and recreational regulations have been moved into separate proclamations for ease of use by the public. The most current Snapper Grouper proclamations, as well as previous versions from 2001 onward, can be found online using this link: http://portal.ncdenr.org/web/mf/proclamations. Proclamations issued prior to 2001 are contained in hard copy archives.

Tables 1 and 2 contain a summary of recreational and commercial regulations, respectively. Because many snapper grouper proclamations are issued throughout the year to complement federal management measures, only those proclamations that were issued which affect regulations for scamp in any one year are listed.

The current versions of rules 15A NCAC 03M .0506 and 15A NCAC 03M .0512 are below:

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.

Table 2.8.1.1. North Carolina recreational scamp regulations in state waters 1991-2019. (TL = total length)

Year	Season	Min. Size (TL)	Daily Possession Limit	Regulation(s)
1991	Year-round	n/a	n/a	15A NCAC 03M .0506
1992	Year-round	n/a	n/a	15A NCAC 03M .0506
1993	Year-round	n/a	n/a	15A NCAC 03M .0506
1994	Year-round	20 inches	n/a	15A NCAC 03M .0506/FF-19-94 (eff. 7/1/1994)
1995	Year-round	20 inches	n/a	15A NCAC 03M .0506/FF-19-94
1996	Year-round	20 inches	n/a	15A NCAC 03M .0506/03M .0512/FF-19-94
1997	Year-round	20 inches	n/a	15A NCAC 03M .0506/03M .0512
1998	Year-round	20 inches	n/a	15A NCAC 03M .0506/03M .0512
1999	Year-round	20 inches	5 fish/person	15A NCAC 03M .0506/03M .0512
2000	Year-round	20 inches	5 fish/person	15A NCAC 03M .0506/03M .0512
2001	Year-round	20 inches	5 fish/person	15A NCAC 03M .0506/03M .0512
2002	Year-round	20 inches	5 fish/person	15A NCAC 03M .0506/03M .0512
2003	Year-round	20 inches	5 fish/person	15A NCAC 03M .0506/03M .0512
2004	Year-round	20 inches	5 fish/person	15A NCAC 03M .0506/03M .0512
2005	Year-round	20 inches	5 fish/person	15A NCAC 03M .0506/03M .0512
2006	Year-round	20 inches	5 fish/person	15A NCAC 03M .0506/03M .0512
2007	Year-round	20 inches	5 fish/person	15A NCAC 03M .0506/03M .0512
2008	Year-round	20 inches	5 fish/person	15A NCAC 03M .0506/03M .0512/FF-66-2008
2009*	Closed January -April	20 inches	5 fish/person; 3 fish/person*	15A NCAC 03M .0506/03M .0512/FF-48-2009
2010	Closed January -April	20 inches	3 fish/person	15A NCAC 03M .0506/03M .0512
2011	Closed January -April	20 inches	3 fish/person	15A NCAC 03M .0506/03M .0512
2012	Closed January -April	20 inches	3 fish/person	15A NCAC 03M .0506/03M .0512
2013	Closed January -April	20 inches	3 fish/person	15A NCAC 03M .0506/03M .0512
2014	Closed January -April	20 inches	3 fish/person	15A NCAC 03M .0506/03M .0512
2015	Closed January -April	20 inches	3 fish/person	15A NCAC 03M .0506/03M .0512
2016	Closed January -April	20 inches	3 fish/person	15A NCAC 03M .0506/03M .0512
2017	Closed January -April	20 inches	3 fish/person	15A NCAC 03M .0506/03M .0512
2018	Closed January -April	20 inches	3 fish/person	15A NCAC 03M .0506/03M .0512
2019	Closed January -April	20 inches	3 fish/person	15A NCAC 03M .0506/03M .0512

*FF-48-2009 (effective July 29, 2009) established a January 1 to April 30 shallow water grouper spawning closure and reduced the aggregate grouper bag limit to three-fish

Table 2.8.1.2. North Carolina commercial scamp regulations in state waters 1991-2019. (TL = total length)

Year	Season	Min. Size (TL)	Trip Limit	Regulation(s)
1991	Year-round	n/a	n/a	15A NCAC 03M .0506
1992	Year-round	n/a	n/a	15A NCAC 03M .0506
1993	Year-round	n/a	n/a	15A NCAC 03M .0506
1994	Year-round	20 inches	n/a	15A NCAC 03M .0506/FF-19-94 (eff. 7/1/1994)
1995	Year-round	20 inches	n/a	15A NCAC 03M .0506/FF-19-94
1996	Year-round	20 inches	n/a	15A NCAC 03M .0506/03M .0512/FF-19-94
1997	Year-round	20 inches	n/a	15A NCAC 03M .0506/03M .0512
1998	Year-round	20 inches	n/a	15A NCAC 03M .0506/03M .0512
1999	Year-round	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2000	Year-round	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2001	Year-round	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2002	Year-round	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2003	Year-round	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2004	Year-round	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2005	Year-round	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2006	Year-round	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2007	Year-round	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2008	Year-round	20 inches	n/a	15A NCAC 03M .0506/03M .0512/FF-66-2008
2009*	Closed January -April	20 inches	n/a	15A NCAC 03M .0506/03M .0512/FF-48-2009
2010	Closed January -April	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2011	Closed January -April	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2012	Closed January -April	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2013	Closed January -April	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2014	Closed January -April	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2015	Closed January -April	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2016	Closed January -April	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2017	Closed January -April	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2018	Closed January -April	20 inches	n/a	15A NCAC 03M .0506/03M .0512
2019	Closed January -April	20 inches	n/a	15A NCAC 03M .0506/03M .0512

*FF-48-2009 (effective July 29, 2009) established a January 1 to April 30 shallow water grouper spawning closure

2.8.2 South Carolina:

1992: SC Code of Laws Section 50-17-510(C) adopted the federal minimum size limits automatically for all species managed under the Fishery Conservation and Management Act (PL94-265); and Section 50-17-510(F) adopted the federal catch and possession limits for a number of listed species managed under the Fishery Conservation and Management Act (PL94- 265) as the Law of the State of SC, with "all species of snapper grouper" specifically mentioned as being covered as well.

2000: SC Marine Fisheries-related Laws reorganized under SC Code of Laws Title 50 Chapter 5.

SC Code of Laws Section 50-5-2730 reads – "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 scamp–related regulation is pulled directly from the federal regulations as promulgated under Magnuson. No changes have been made to this approach in covering scamp since the Chapter 5 rewrite.

2.8.3 Georgia:

There are currently no GA state regulations for blueline tilefish. However, the authority rests with the GA Board of Natural Resources to regulate this species if deemed necessary in the future.

2.8.4 Florida East Coast:

Atlantic Scamp Regulation History

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
1980	None	None	None		
1981	None	None	None		
1982	None	None	None		
1983	None	None	None		
1984	None	None	None		
1985	None	None	None		
1986	None	5 per person per day within the 5- fish grouper	None	Established a recreational bag limit. Prohibited use of longline gear by	Dec. 11, 1986
		aggregate bag limit		commercial fishermen. Longline harvesters targeting other species have a bycatch allowance of 5%. Prohibited use of stab nets (or sink nets) to take grouper in Atlantic waters of Monroe County. Required fish to be landed in whole condition.	
1987	None	5 per person per day within the 5- fish grouper aggregate bag limit	None		
1988	None	5 per person per day within the 5- fish grouper aggregate bag limit	None		

1989	None	5 per person per day within the 5- fish grouper aggregate bag limit	None		
1990	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	None	Established a minimum size limit. Designated all grouper as “restricted species.” Designated allowable gear as hook and line, black sea bass trap, spear, gig, or lance (except powerheads, bangsticks, or explosive devices). Prohibited all commercial harvest in state waters when harvest for that species is prohibited in adjacent federal waters.	Feb. 1, 1990
1991	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	None		
1992	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	None		
1993	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	None	Allowed persons who possess either a Gulf of Mexico or South Atlantic federal reef fish permit to commercially harvest snappers and groupers (except red snapper) in all state waters until July 1, 1995.	Oct. 18, 1993

1994	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	None	Allowed a two-day possession limit for reef fish statewide for persons aboard charter and headboats on trips exceeding 24 hours provided the vessel is equipped with a permanent berth for each passenger aboard, and each passenger has a receipt verifying the trip length. Modified rule language to provide the same definitions of Gulf of Mexico and Atlantic Ocean regions.	March 1, 1994
1995	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	None	Continued the allowance for persons to possess either the proper South Atlantic or Gulf permit to harvest reef fish for commercial purposes through Dec. 31, 1995.	July 1, 1995
1996	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	None	(1) Continued the allowance for persons to possess either the proper South Atlantic or Gulf permit to harvest reef fish for commercial purposes through Dec. 31, 1996. (2) Continued the allowance for persons to possess either the proper South Atlantic or Gulf permit to harvest reef fish for commercial purposes through Dec. 31, 1997.	(1) Jan. 1, 1996 (2) Nov. 27, 1996

1997	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	None		
1998	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	None		
1999	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	None		
2000	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	None	Eliminated the 5-day commercial closure extension.	Jan. 1, 2000
2001	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	None		
2002	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	None		
2003	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	None		
2004	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	None		

2005	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	None		
2006	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	None	Provided that, for purposes of determining the legal size of reef fish species, "total length" means the straight-line distance from the most forward point of the head with the mouth closed, to the farthest tip of the tail with the tail compressed or squeezed, while the fish is lying on its side.	July 1, 2006
2007	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	Consistent with federal waters	Set commercial trip limits in the Atlantic that are the same as trip limits in federal waters.	July 1, 2007
				Prohibited commercial fishermen from harvesting or possessing the recreational bag limit of reef fish species on commercial trips.	
2008	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	Consistent with federal waters		
2009	20 inches TL	5 per person per day within the 5- fish grouper aggregate bag limit	Consistent with federal waters		

2010	20 inches TL	3 per person per day within the 3-fish grouper aggregate bag limit	Consistent with federal waters	Reduced the recreational bag limit. Prohibited the captain and crew of for-hire vessels from retaining any species in the aggregate grouper bag limit. Prohibited all harvest of shallow-water groupers from Jan. 1 – April 30 in Atlantic and Monroe County state waters. Required dehooking tools to be aboard commercial and recreational vessels for anglers to use as needed to remove hooks from Atlantic reef fish.	Jan. 19, 2010
2011	20 inches TL	3 per person per day within the 3-fish grouper aggregate bag limit	Consistent with federal waters		
2012	20 inches TL	3 per person per day within the 3-fish grouper aggregate bag limit	Consistent with federal waters		
2013	20 inches TL	3 per person per day within the 3-fish grouper aggregate bag limit	Consistent with federal waters		
2014	20 inches TL	3 per person per day within the 3-fish grouper aggregate bag limit	Consistent with federal waters	Eliminated language that prohibited captain and crew on for-hire vessels from retaining recreational bag limits of groupers on for-hire trips in state waters of the Atlantic (including Monroe County).	March 23, 2014

2015	20 inches TL	3 per person per day within the 3-fish grouper aggregate bag limit	Consistent with federal waters		
2016	20 inches TL	3 per person per day within the 3-fish grouper aggregate bag limit	Consistent with federal waters		
2017	20 inches TL	3 per person per day within the 3-fish grouper aggregate bag limit	Consistent with federal waters		
2018	20 inches TL	3 per person per day within the 3-fish grouper aggregate bag limit	Consistent with federal waters		
2019	20 inches TL	3 per person per day within the 3-fish grouper aggregate bag limit	Consistent with federal waters		

3. Scamp and Yellowmouth Grouper Assessment History

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

The first formal assessment of scamp in the U.S. Atlantic was conducted by Manooch et al. (1998). That assessment used separable Virtual Population Analysis, assuming four levels of natural mortality (M = 0.10, 0.15, 0.20, and 0.25). The authors believed then that M was likely in the range of 0.15-0.20 (similar to this SEDAR assessment's base level of M=0.155). For M=0.15, fishing mortality ranged from 0.11 to 0.29 for the entire assessment period, 1986-1996.

This stock of scamp was first assessed through the SEDAR process in 2021 (SEDAR-68, 2021). The SEDAR-68 Research Track assessment applied the Beaufort Assessment Model (Williams and Shertzer, 2015), using data over the time period 1968-2017. Because yellowmouth grouper can not be distinguished from scamp, the two species were combined in SEDAR-68 and assessed as a stock complex. The primary goals of the Research Track assessment were to develop the modeling methodology and data sources for use in the assessment. Estimation of status indicators and catch advice was left for the subsequent Operational Assessment.

References

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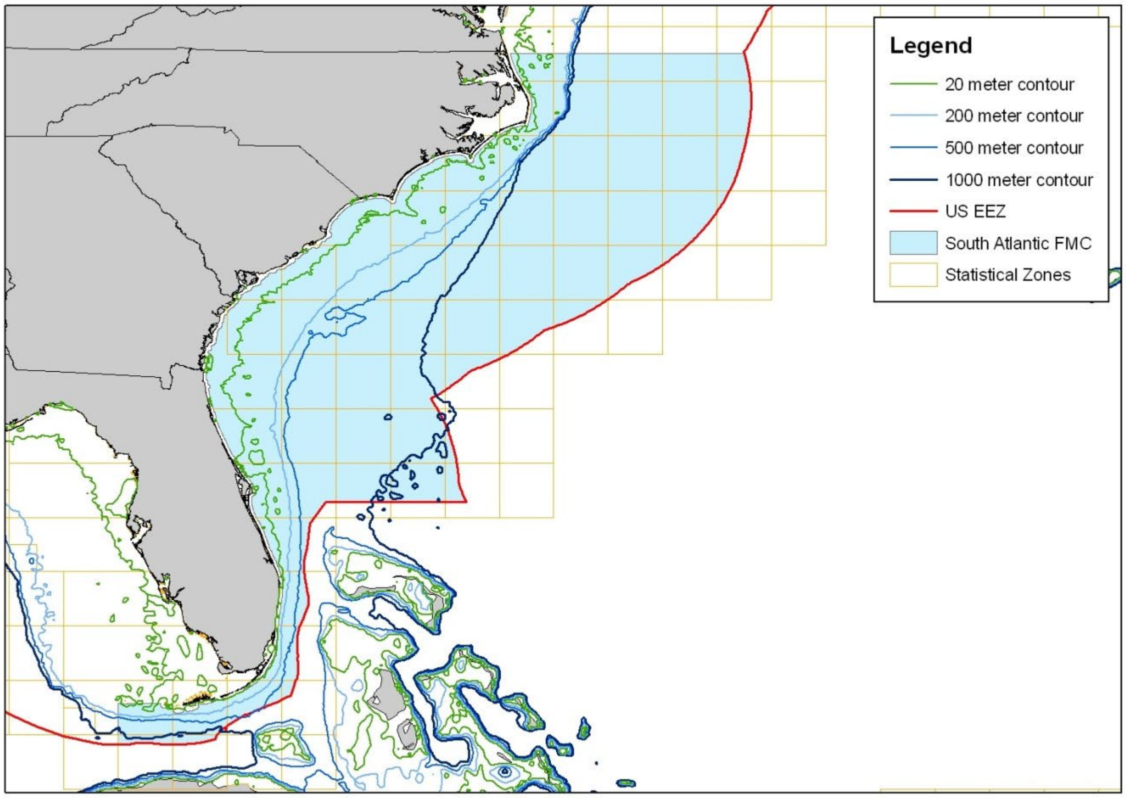
SEDAR. 2021. SEDAR 68 - Stock assessment report Atlantic Scamp Grouper. 397 p. Available online at: https://sedarweb.org/documents/sedar-68-atlantic-scamp-final-stock-assessment-report/

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

4. Regional Maps

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



5. Abbreviations

ABC	Acceptable Biological Catch
ACCSP	Atlantic Coastal Cooperative Statistics Program
ADMB	AD Model Builder software program
ALS	Accumulated Landings System; SEFSC fisheries data collection program
AMRD	Alabama Marine Resources Division
APAIS	Access Point Angler Intercept Survey
ASMFC	Atlantic States Marine Fisheries Commission
B	stock biomass level
BAM	Beaufort Assessment Model
B_{msy}	value of B capable of producing MSY on a continuing basis
BSIA	Best Scientific Information Available
CHTS	Coastal Household Telephone Survey
CFMC	Caribbean Fishery Management Council
CIE	Center for Independent Experts
CPUE	catch per unit of effort
EEZ	exclusive economic zone
F	fishing mortality (instantaneous)
FES	Fishing Effort Survey
FIN	Fisheries Information Network
F_{MSY}	fishing mortality to produce MSY under equilibrium conditions
F_{OY}	fishing mortality rate to produce Optimum Yield under equilibrium
$F_{XX\%\ SPR}$	fishing mortality rate that will result in retaining XX% of the maximum spawning production under equilibrium conditions
F_{max}	fishing mortality that maximizes the average weight yield per fish recruited to the fishery
F_o	a fishing mortality close to, but slightly less than, Fmax
FL FWCC	Florida Fish and Wildlife Conservation Commission
FWRI	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)
MARFIN	Marine Fisheries Initiative
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
MSA	Magnuson Stevens Act
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
OST NOAA	Fisheries Office of Science and Technology
OY	optimum yield
SAFMC	South Atlantic Fishery Management Council
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
SERFS	Southeast Reef Fish Survey
SERO	Fisheries Southeast Regional Office, National Marine Fisheries Service
SRFS	State Reef Fish Survey (Florida)
SRHS	Southeast Region Headboat Survey
SPR	spawning potential ratio, stock biomass relative to an unfished state of the stock
SSB	Spawning Stock Biomass
SS	Stock Synthesis
SSC	Science and Statistics Committee
TIP	Trip Incident Program; biological data collection program of the SEFSC and Southeast States.
TPWD	Texas Parks and Wildlife Department
Z	total mortality, the sum of M and F

SEDAR

Southeast Data, Assessment, and Review

SEDAR 68

South Atlantic Scamp

Section II: Assessment Report

December 2022

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

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1. Introduction

This operational assessment evaluated the stock of (*Mycteroperca phenax*) and yellowmouth grouper (*M. interstitialis*) off the southeastern United States. For this assessment, scamp and yellowmouth grouper were treated as a single complex[1]. The primary objectives were to update and improve the 2021 SEDAR68 Research Track assessment of scamp, to estimate stock and fishery status, and to conduct stock projections. Data compilation and assessment methods were guided by methodology of the SEDAR68 Research Track assessment, previous assessments, and SEDAR best practices. The assessment period is 1969–2021.

Available data on this stock included indices of abundance, landings, discards, and length and age compositions from fishery dependent and fishery independent sources. Three indices of abundance were fitted by the model: one from the recreational fleet, one from the commercial fleet, and one from the SouthEast Reef Fish Survey. Data on landings and discards were available from recreational and commercial fleets. For each fleet, dead discards were pooled with landings into a single time series of removals.

The primary model used here was the Beaufort Assessment Model (BAM), an integrated 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 an ensemble modeling approach, as well as with sensitivity and retrospective analyses. Reference points were based on $F_{40\%}$ as a proxy for F_{MSY}.

The estimated spawning stock biomass (SSB) has fluctuated throughout the time series, but has been declining since the mid-2000s. The terminal (2021) base-run estimate of spawning stock was near its lowest level of the time series and was well below the minimum stock size threshold (MSST) ($SSB_{2021}/MSST = 0.27$), as was the median estimate ($SSB_{2021}/MSST = 0.29$), indicating that the stock is overfished. The estimated fishing rate has fluctuated around the Maximum Fishing Mortality Threshold (MFMT, represented by $F_{40\%}$) throughout most of the assessment period, but has exceeded it only once since 2010. The terminal estimate, which is based on a three-year geometric mean, is below $F_{40\%}$ in the case of the base run ($F_{2019\text{-}2021}/F_{40\%} = 0.91$) and the median ($F_{2019\text{-}2021}/F_{40\%} = 0.81$). Thus, this assessment indicates that the stock is overfished, but is not experiencing overfishing.

The ensemble analysis indicates that these estimates of stock and fishery status are robust, but also reveals some uncertainty in the conclusions. Of all ensemble model runs, 100% were in qualitative agreement that the stock is overfished ($SSB_{2021}/MSST < 1.0$), and 69.5% that the stock is not experiencing overfishing ($F_{2019\text{-}2021}/F_{40\%} < 1.0$).

The term "overfished" as a description of stock status might be somewhat misleading in this assessment. The primary reason for the low stock size in terminal years of the assessment is not fishing, but rather low recruitment. Recruitment has been lower than average since the mid-2000s, and the lowest values for the

[1] Throughout the report, the words "stock" or "scamp" refer to the complex of both species, unless otherwise noted.

entire time series occur since 2010. Although there may be insufficient evidence to declare a productivity regime shift, it would be prudent for short-term projections to assume low recruitment for the purpose of catch advice.

Projections with F = 0 indicate that the stock could recover to its target of $SSB_{F40\%}$ within ten years, if recruitment returns to its long-term average. If recruitment remains low, so will stock abundance. Generation time for scamp is about 10 years.

1.1 Terms of Reference

1. Update the approved SEDAR 68 South Atlantic Scamp model with data through 2021 (provide any partial or preliminary 2021 data available at the time of data provision). Incorporate the latest BAM model configurations and updates to data calculation methodologies, detailing the changes made between the SEDAR 68 South Atlantic Scamp research track assessment model and the proposed SEDAR 68 Operational assessment model.

2. Consider updated information on life history, steepness, discard mortality, commercial and recreational landings and discards. Note any particular concerns or problems with any data collected since the completion of the research track. Document any changes or corrections made and provide updated input data tables. Provide commercial and recreational landings and discards in pounds and numbers.

3. Examine and describe impacts on model performance and estimates of the data limitations in any data collected since the completion of the research track.

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. Investigate potential changes to selectivity structure for Chevron trap data, using likelihood values to guide in determining best configuration. Consider sensitivities such as:
    a. Explore time-varying selectivity in the Chevron trap index
    b. Examine change over time in length and age comps
    c. Random walk on A50 selectivity parameter. Examine multispecies/targeting impact on selectivity.

6. Investigate influence of length and age composition data on stock assessment model. Consider the following:
    1. Dropping length comps from model.
    2. Excluding Chevron trap age comps.
    3. Address mismatch between length and age comps.

7. The SR curve overestimates R at low stock sizes and vice versa. Steepness may not be appropriately defined. Examine alternative way to estimate recruitment without SR curve.

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

1.2 Document List

Document #	Title	Authors	Received
Documents Prepared for SEDAR 68 OA			
SEDAR68OA-WP01	General Recreational Survey Data for Scamp and Yellowmouth Grouper in the South Atlantic	Mathew A. Nuttall	9/6/220
SEDAR68OA-WP02	Standardized video counts of southeast US Atlantic scamp (*Mycteroperca phenax*) and yellowmouth grouper (*Mycteroperca interstitialis*) from the Southeast Reef Fish Survey	Nathan Bacheler and Rob Cheshire	8/3/2022
SEDAR68OA-WP03	South Carolina Department of Natural Resources Fisheries Dependent Data Reconciliation Overview	Andy Ostrowski, Michelle Willis, Jennifer Potts and Tracy McCulloch	8/4/2022
SEDAR68OA-WP04	Commercial age and length composition weighting for Southeast U.S. scamp and yellowmouth grouper (Mycteroperca phenax and Mycteroperca interstitialis)	Sustainable Fisheries Branch, National Marine Fisheries Service Eric Fitzpatrick	8/25/22
SEDAR68OA-WP05	South Atlantic U.S. scamp (Mycteroperca phenax) age and length composition from the recreational fisheries	Sustainable Fisheries Branch, National Marine Fisheries Service Eric Fitzpatrick	8/25/22
SEDAR68OA-WP06	Diagnostics of the SEDAR68 Operational Assessment model of scamp/yellowmouth grouper	Sustainable Fisheries Branch, National Marine Fisheries Service Contact: Kyle Schertzer	12/21/2022
Final Assessment Report			
SEDAR68OA-SAR1	Stock Assessment Report of South Atlantic Scamp	To be prepared by SEFSC	Dec, 2022

1.3 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 approved SEDAR 68 South Atlantic Scamp model with data through 2021 (provide any partial or preliminary 2021 data available at the time of data provision). Incorporate the latest BAM model configurations and updates to data calculation methodologies, detailing the changes made between the SEDAR 68 South Atlantic Scamp research track assessment model and the proposed SEDAR 68 Operational assessment model.

-SEDAR68OA applied the current BAM configuration. The assessment model structure and data sources were very similar to those used in SEDAR68RT. Modifications are documented in the report.

2. Consider updated information on life history, steepness, discard mortality, commercial and recreational landings and discards. Note any particular concerns or problems with any data collected since the completion of the research track. Document any changes or corrections made and provide updated input data tables. Provide commercial and recreational landings and discards in pounds and numbers.

-The fishery-dependent growth function was updated for this Operational Assessment. Steepness was not reliably estimable, however the mean recruitment model, as used here, does not use that parameter. Modification to discard mortality, due to the potential increased use of descender devices, was considered in a sensitivity run. Commercial and recreational removals (landings plus dead discards) were updated and documented in the report in both pounds and numbers.

3. Examine and describe impacts on model performance and estimates of the data limitations in any data collected since the completion of the research track.

-The COVID19 pandemic limited data collections, particularly in 2020. There were no SERFS data in that year. BAM was modified to accommodate a gap year in the SERFS index. Limited age samples in the terminal years, combined with selectivity patterns (fewer younger fish observed), hindered annual estimation of recruitment in the last two years of the assessment (2020-2021). Instead, recruitment in those two years was assumed to be similar to recruitment in the years immediately prior, which is supported by the pattern of autocorrelation in the recruitment residuals.

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. Investigate potential changes to selectivity structure for Chervon trap data, using likelihood values to guide in determining best configuration. Consider sensitivities such as:
a. Explore time-varying selectivity in the Chevron trap index
b. Examine change over time in length and age comps
c. Random walk on A50 selectivity parameter. Examine multispecies/targeting impact on selectivity.

-Fits to the Chevron trap data did not raise any concerns in this assessment. Time-varying selectivity was considered in a sensitivity run.

6. Investigate influence of length and age composition data on stock assessment model. Consider the following:
1. Dropping length comps from model.
2. Excluding Chevron trap age comps.
3. Address mismatch between length and age comps.

-The base model dropped the SERFS length compositions in favor of the age compositions. Various combinations of dropping composition data (including chevron trap ages) were considered in sensitivity runs. The mismatch between length and age compositions appeared to largely be resolved by updating the fishery-dependent growth curve.

7. The SR curve overestimates R at low stock sizes and vice versa. Steepness may not be appropriately defined. Examine alternative way to estimate recruitment without SR curve.

-This assessment used the mean recruitment model, which does not rely on the steepness parameter.

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

-Please see this report.

2 Data Review and Update

The input data for this assessment[1] are described below, with focus on modifications from the SEDAR68 Research Track (SEDAR68RT) assessment. Data fitted by this assessment spanned 1969–2001 and are summarized in Figure 1.

2.1 Data Review

In this SEDAR68 Operational Assessment (SEDAR68OA), the Beaufort Assessment Model (BAM[2]) was fitted to data sources developed during the SEDAR68RT process. These data sources were updated to include additional years where appropriate and modifications were made as needed. The data sources and updates are highlighted below.

Data sources

- Life history: Meristics, population growth, fishery dependent size at age, female maturity, male maturity, proportion female at age, weight at age, age-dependent natural mortality
- Removals (pooled landings and dead discards): Commercial, recreational
- Indices of abundance: Commercial handline, headboat, CVID (SERFS combined chevron trap and video gear)
- Length compositions: Commercial, recreational, SERFS chevron trap
- Age compositions: Commercial, recreational, SERFS chevron trap
- Other: Discard mortality

Modifications in SEDAR68OA

- Life history: Fishery dependent size at age, Age-dependent natural mortality
- Removals: Commercial discards, recreational landings and discards, CVs of removals
- Length compositions: SERFS chevron trap
- Age compositions: Recreational

2.2 Data Update

2.2.1 Life History

Estimates of the von Bertalanffy growth parameters were provided by SEDAR68RT for the population as a whole ($L_\infty = 787.36$ mm, $K = 0.15$ yr^{-1}, and $t_0 = -1.84$ yr). In addition, a von Bertalanffy curve was used to model average size of fish captured under the 20-inch size limit regulation (Table 1). Parameters of this fishery dependent growth curve ($L_\infty = 919.06$ mm, $K = 0.08$ yr^{-1}, and $t_0 = -5.90$ yr) were re-estimated for this assessment for two reasons. First, one of the parameters in the SEDAR68RT fit was stuck at a bound, and second, the value of t_0 had been fixed at -0.66. However, the reason for using this fishery dependent curve is to represent mean length at age of fish landed under the size limit, and that representation is improved by not fixing any growth parameters. Allowing all

[1]Data providers are listed in Appendix A
[2]Abbreviations and acronyms used in this report are defined in Appendix B

three parameters to be freely estimated (external to the assessment model) resolved an apparent mismatch between length and age compositions.

Age-specific natural mortality (M) followed the approach of SEDAR68RT, which used the Lorenzen estimator (Lorenzen 1996; 2000; 2022; Lorenzen et al. 2022) scaled to the age-invariant Then estimator (Then et al. 2014), but only for Serranids ($M = 0.155$) rather than all fishes. The scaling provided the same cumulative survival between the two estimators for ages 6 through the maximum observed age of 34.

This operational assessment corrected two aspects of SEDAR68RT related to scaling natural mortality. First, the reference constant M survivability had been based on age 0^{+}, which was corrected here to be ages 6^{+}. Second, the conversion of length to weight, as used in the Lorenzen estimator, had been based on the TL–WW relationship, but had used measurements of fork length instead of total length; that was corrected here by using the FL-WW relationship. These corrections decreased natural mortality at age relative to the SEDAR68RT vector.

Life-history information is summarized in Table 2.

2.2.2 Landings and Discards

The fleet structure used in SEDAR68OA was the same as that of SEDAR68RT, in which removals were attributed to one of two fleets, commercial or recreational. All commercial gears were pooled into a single commercial fleet, and all recreational components were pooled into a single recreational fleet that included estimates of headboat removals from the SRHS and estimates from other recreational fishing modes from the MRIP. Dead discards were also pooled with landings for each fleet.

Estimates of commercial discards using the methodology of SEDAR68RT were provided for 1993–2020. For input to the assessment, the estimate in 2021 was assumed equal to the arithmetic mean of the nearest two values (i.e., 2019–2020).

Five years of landings estimates from MRIP had CVs that exceeded 0.5. In those cases, the estimates were deemed unreliable and were replaced with the arithmetic mean of the nearest two years. Three of those years (2005, 2014, 2017) occurred within the time series and thus the surrounding two years were used for replacement; two of those years (1981, 2021) were at the end points of the MRIP time series and thus the subsequent or preceding two years were used for replacement. For discard estimates from MRIP, the majority of years had CVs that exceeded 0.5. In an effort to obtain more reliable estimates by using information across years, a cubic regression spline was fitted to the MRIP observations using the mgcv package in R, and the smoothed estimates were used in the assessment model (Fig. 2). Smoothing in this case is a way to combine multiple estimates, some of which may have high CVs, into a combined estimate that has a lower level of variance. It is based on the premise that MRIP collects data using a nested stratified sampling design, such that higher (lower) level strata will have larger (smaller) sample sizes, which tend to result in lower (higher) CVs. Here, smoothing is an approach to combine higher-level strata (years) to reduce CVs. The tradeoff is a reduction in resolution. These modifications to MRIP estimates of landings and discards are a change from SEDAR68RT.

In the SEDAR68RT assessment, CVs of commercial removals were set equal to 0.05 for fitting the model and for bootstrapping in the uncertainty analysis. The CVs of recreational removals were set equal to those of MRIP landings for both fitting and for the uncertainty analysis. In this operational assessment, the CVs for fitting for both fleets were set equal to 0.05. This approach achieves a close fit to observed removals and avoids the potential for model instability when CVs are large (which was observed here during model development). However, for bootstrapping removals in the uncertainty analysis, CVs were larger. For the commercial removals, CVs decreased over time following the trend outlined by the SEDAR68 commercial working group for South Carolina, the state with the highest commercial landings and largest abundance based on SERFS sampling [SEDAR68 (2021); Table 3.4 therein]. For the recreational removals, annual CVs were those from MRIP landings (as in the SEDAR68RT), but capped at 0.5, as estimates where CV exceeded 0.5 were replaced as described above.

Table 3 shows total removals as used in the base assessment model and the CVs used in bootstrapping for uncertainty analysis.

2.2.3 Indices of Abundance

SEDAR68 included three indices of abundance: commercial, recreational, and SERFS combined chevron trap and video gears. The commercial index was developed from commercial logbooks using handline gear, and the recreational index was developed from headboat logbooks. Fishery dependent indices of abundance were assumed to have CVs centered on 0.2, which is consistent with Francis (2003). The SERFS index combined the separate trap and video indices using the method of Conn (Conn 2010), and the annual CVs were those estimated by that procedure. The three indices and their corresponding CVs are shown in Table 4.

The SEDAR68RT initially modeled the SERFS chevron trap and video indices as separate time series, to allow for possible dome-shaped selectivity in the trap index. However, due to the broad range of sizes and ages captured in the traps, the assessment model estimated flat-topped selectivity even when the parameterization allowed for doming (SEDAR68 2021). Thus SEDAR68 68 combined the two SERFS gears into a single index with flat-topped selectivity.

2.2.4 Length and Age Compositions

Length compositions for all data sources were developed in 3-cm bins over the range 20–89 cm (FL; labeled at bin center). All lengths below and above the minimum and maximum bins were pooled. For inclusion, length compositions in any given year had to meet the sample size criteria of $ntrips \geq 30$ (Table 5). Length compositions were generally excluded in years when age compositions were available, to avoid using the same individual fish twice if it were both measured and aged, and because age compositions provide more informative signals of year-class strength. However, the SEDAR68RT did include both length and age compositions from SERFS. Here, only the SERFS age compositions were included in the base scenario, and the consequences of this modification were explored through sensitivity analysis.

For age composition data, the upper range was pooled at 15 years old, because older fish comprised a small proportion of the data and to minimize observations of zero in the fitting process. The age compositions of fishery dependent samples were weighted by the length compositions in attempt to address bias in selection of fish to be aged. For inclusion, age compositions in any given year had to meet the sample size criteria of $ntrips \geq 10$ (Table 5). Age composition was preferred over length composition when both were available from a given fleet or survey in a given year. No ages were available for the terminal year of 2021.

Sample sizes of age compositions for the recreational fleet differ between SEDAR68RT and SEDAR68OA because of a data reconciliation project undertaken by the SCDNR and NMFS-Beaufort laboratories (Ostrowski et al. 2022). That project resulted in an increase of 409 age samples from the headboat fleet during the time period 1982–1992. Thus, recreational age compositions span a longer time period in this assessment, supplanting length compositions except for years 1978–1979.

2.2.5 Discard Mortality

The discard mortality working group of SEDAR68RT provided a commercial discard mortality of 0.39 (range: 0.33–0.45) and a recreational discard mortality rate of 0.26 (range: 0.16–0.40). Total discards were multiplied by the discard mortality rates to compute dead discards, and dead discards were added to landings to compute total removals, as used for fitting in the assessment model. The ranges were used in sensitivity runs and in uncertainty analysis, as described in the relevant sections below. In addition, a sensitivity run was developed to explore effects of a potential increase in descender device usage.

3 Stock Assessment Methods

3.1 Overview

This operational assessment updated the primary model applied in SEDAR68 (2021), which was developed using the Beaufort Assessment Model (BAM) software (Williams and Shertzer 2015). BAM applies a statistical catch-age formulation, coded in AD Model Builder (Fournier et al. 2012). BAM is referred to as an integrated model because it uses multiple data sources relevant to population and fishery dynamics (e.g. removals, length and age compositions, and indices of abundance) in a single framework. In essence, the catch-age model simulates a population forward in time while including fishing processes (Quinn and Deriso 1999; Shertzer et al. 2008). Quantities to be estimated are systematically varied until characteristics of the simulated population match available data on the real population. The model is similar in structure to Stock Synthesis (Methot and Wetzel 2013) and other stock assessment models used in the United States (Dichmont et al. 2016; Li et al. 2021). Versions of BAM have been used in previous SEDAR assessments of reef fishes in the U.S. South Atlantic, such as Black Sea Bass, Blueline Tilefish, Gag, Greater Amberjack, Red Grouper, Red Porgy, Red Snapper, Snowy Grouper, Tilefish, and Vermilion Snapper, as well as in the previous SEDAR assessment of Scamp (SEDAR68 2021).

This assessment is for the stock complex of scamp and yellowmouth grouper, although scamp are believed to be the more abundant species. The two are difficult to distinguish, and thus the SEDAR68RT assessment pooled the data for these species and assessed them as a unit (SEDAR68 2021). The use of “stock” or “scamp” in this report refers to the complex of both species, unless otherwise noted.

3.2 Data Sources

The catch-age model included data from two fleets that caught scamp in southeastern U.S. waters: commercial and recreational (including headboats). The model was fitted to data on annual removals (in numbers for the recreational fleet, in whole weight for the commercial fleet); annual length compositions of landings; annual age compositions of landings and surveys; two fishery dependent indices of abundance (commercial handlines, headboat); and one fishery independent index of abundance (SERFS combined chevron trap and video index). Time series of removals pooled dead discards with landings. Data used in the model are tabulated in §2 of this report.

3.3 Model Configuration

The assessment time period was 1969–2021. The initial year was the same as in SEDAR68RT, with the terminal year extended from 2017 to 2021. A general description of the assessment model follows.

3.4 Stock Dynamics

In the assessment model, new biomass was acquired through growth and recruitment, while abundance of existing cohorts experienced mortality from fishing and natural sources. Recruitment and fishing rates were considered to be time-varying quantities. The population was assumed closed to immigration and emigration, although there was no explicit assumption about the origin of new recruits. The model included age classes $1 - 20^+$, where the oldest age class 20^+ allowed for the accumulation of fish (i.e., plus group). Age compositions were fit to ages $1 - 15^+$.

3.5 Initialization

Initial (1969) numbers at age assumed the equilibrium age structure computed from expected recruitment and the initial, age-specific total mortality rate. That initial mortality was the sum of natural mortality and fishing mortality, where fishing mortality was the product of an initial fishing rate (F_{init}) and F-weighted average selectivity. The initial fishing rate was assumed equal to the geometric mean of estimated F for the period 1969–1971.

The initial recruitment in 1969 was assumed to be the expected value adjusted by an estimated multiplier, where the expected value came from the spawner-recruit relationship (described below). This constant level of recruitment was assumed for the remainder of the initialization period (1969–1979). Without sufficient age/length composition data prior to 1980, there is little information to estimate initialization-period recruitment deviations with accuracy.

3.6 Natural Mortality Rate

The natural mortality rate (M) was assumed constant over time, but decreasing with age. The form of M as a function of age was based on Lorenzen (1996; 2000), as in the SEDAR68RT. The Lorenzen approach inversely relates the natural mortality at age to somatic growth. As in previous SEDAR assessments, the age-dependent estimates of M_a were rescaled to provide the same fraction of fish surviving from age 6 through the oldest observed age (34 yr) as would occur with constant $M = 0.155$. This approach using cumulative mortality allows that fraction at the oldest age to be consistent with the findings of Then et al. (2014), here constrained to serranids. The scaled Lorenzen estimator has become common in SEDAR assessments as the most reliable approach to infer age-dependent natural mortality (Lorenzen 2022; Lorenzen et al. 2022).

3.7 Growth

Mean size at age of the population and fishery removals under a 20-inch size limit (total length, TL) were modeled with the von Bertalanffy equation, and weight at age (whole weight, WW) was modeled as a function of fork length (FL) (Figure 3, Table 1). Parameters of growth and conversions (FL-WW) were treated as input to the assessment model. For fitting length composition data, the distribution of size at age was assumed normal with a CV estimated by the assessment model for each growth curve. The estimated conversions between FL and TL (both in units of mm) were $FL = 19.72 + 0.89TL$ and $TL = -15.01 + 1.11FL$ (SEDAR68 2021).

3.8 Maturity and Sex Ratio

Female maturity was modeled with a logistic function, and the resulting vector of maturity at age was treated as input to the assessment model (Table 1). The age at 50% maturity was estimated to be 2.9 years and nearly all female fish were mature by age 5. All males were considered mature.

Because scamp are a protogynous hermaphrodite, the proportion female decreased with age, and this vector of proportion female at age was treated as input to the assessment model (Table 1). The age at 50:50 sex ratio was about 10 years and all fish transitioned to male by age 20.

3.9 Spawning Stock

Spawning biomass was modeled as the biomass of mature males and females (mt) measured at the time of peak spawning. For protogynous stocks, use of total mature biomass, rather than that of females or males only, has been found to provide more robust estimates of management quantities over a broad range of conditions (Brooks et al. 2008). For scamp, peak spawning was considered to be at the start of May.

3.10 Recruitment

Expected recruitment of age-1 fish was predicted from spawning biomass using the mean recruitment model. This is a modification from the approach of the SEDAR68RT assessment, which used the Beverton–Holt spawner–recruit model.

This modification was made for several reasons. First, it addresses TOR7, which stated, "Examine alternative way to estimate recruitment without SR curve." Second, because this is a stock complex of two species, predicting recruitment as a function of spawning biomass lacks a theoretical basis. For example, if each stock independently followed a Beverton–Holt spawner–recruit model, the resultant spawner–recruit relationship of the complex would not track a single curve but rather would vary depending on the relative proportions of the two stocks. Third, likelihood profiling of steepness (h) demonstrated that h was estimable in the sense of having a well-defined minimum in the composite negative log-likelihood; however, closer examination revealed that each data source pushed steepness toward its upper or lower bound, and the composite 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). Fourth, ongoing research has demonstrated the potential for a nontrivial amount of scamp recruitment originating from outside the South Atlantic, similar to results found for red snapper (Karnauskas et al. 2022). Such externally derived recruitment could obscure any spawner–recruit relationship that might exist within the South Atlantic. The underlying assumption of the mean recruitment model is that recruitment is independent of spawning biomass, which is known to be incorrect for extremely low values of spawning biomass (e.g., zero spawners, zero recruits), unless recruits derive from outside the system.

To include annual variability in recruitment, the model estimates lognormal deviations around the estimated mean for years 1980–2019. The start year of 1980 for recruitment deviations was chosen because it is the first year of age composition data; the terminal year of 2019 was chosen based on likelihood profiling, which showed that recruitment deviations in 2020-2021 were uninformed by data, but 2019 and earlier are estimable (SEDAR680A-WP06 2022). Prior to 1980 (1969–1979), recruitment was assumed constant at an estimated level, which was derived as an estimated multiplier of the mean recruitment. Likelihood profiling demonstrated that the multiplier was estimable (SEDAR680A-WP06 2022). Recruitment in 2020 and 2021 was assumed to be the arithmetic average of recruitment from 2010–2019. Without data to inform estimation of recruitment in 2020-2021, these estimates are, in essence, 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 of 2010–2019 was selected in part based on visual inspection of recruitment deviations and in part based on analyses of these deviations. Regression tree analysis (R library "tree") showed a breakpoint starting in 2009, and change point analysis (R library "strucchange") showed a breakpoint starting in 2010.

3.11 Landings and Discards

Time series of removals (landings plus dead discards) from two fleets were modeled: commercial and recreational (including headboat). Removals were modeled with the Baranov catch equation (Baranov 1918) and were fitted in either weight or numbers, depending on how the data were collected (1000 lb whole weight for commercial, and 1000 fish for recreational). Historic landings of the recreational fleets were estimated indirectly using the FHWAR census method (Brennan 2020). Although the FHWAR method is considered best practice (SEDAR Procedural Guidance 2015), these landings were treated in the assessment as an important source of uncertainty by assigning them relatively high CVs (Table 3). In addition, discard mortality was treated as a source of uncertainty in the Monte Carlo Bootstrap ensemble (MCBE) modeling, as described in §3.24.

3.12 Fishing

For each time series of removals, the assessment model estimated a separate full fishing mortality rate (F). Age-specific rates were then computed as the product of full F and selectivity at age. The across-fleet annual F was represented by apical F, computed as the maximum of F at age summed across fleets.

3.13 Selectivities

Selectivity curves applied to removals were estimated using a parametric approach. This approach applies plausible structure on the shape of the curves, and achieves greater parsimony than occurs with unique parameters for each age. Flat-topped selectivities were modeled as a two-parameter logistic function. As in SEDAR68RT, this assessment applied flat-topped selectivity for the commercial and recreational fleets, as well as for the SERFS index. Selectivities of the two fleets were permitted to vary across regulatory time blocks, to reflect potential changes associated with the 1992 implementation of the 20-inch size limit.

The SEDAR68RT assessment explored the use of dome-shaped selectivities for the two fleets, but this resulted in poor model convergence and poor fits to data, and thus the SEDAR Review Panel recommended flat-topped selectivities for both fleets (SEDAR68 2021). Similarly, the SEDAR68RT assessment considered maintaining separate SERFS indices (chevron trap and video gear), to potentially allow for dome-shaped selectivity of the trap gear. However, ultimately the Assessment Panel recommended flat-topped selectivity for the trap gear, which was also the justification for combining the two gears into a single index. The SEDAR68 assessment report stated:

"The lengths of scamp caught in Chevron traps ranged from 230 to 890 mm, indicating nearly the full size range of scamp modeled were available to the Chevron trap. A broad range of ages (Ages 1–27) were also captured in the Chevron traps. Previous SEDAR assessments have modeled the chevron selectivity as a double logistic due to concerns that the largest and oldest fish could not access the traps. However, the presence of older scamp in the traps indicated that larger fish were able to enter the traps. A double logistic selectivity was attempted, however the panel recommended that a logistic selectivity curve was more appropriate due to the presence of the older fish in the data. In initial model runs a double logistic selectivity curve was applied, however the model estimated a flat-topped selectivity. The descending limb parameter consistently hit a bound and the likelihood profile of that parameter did not exhibit a minimum."

3.14 Indices of Abundance

The model was fit to two fishery dependent indices of relative abundance: a recreational index developed from headboat logbooks (1981–2009) and a commercial index developed from commercial logbooks reporting handline gear (1993–2009). The model was also fit to a fishery independent index of abundance developed from survey data (SERFS combined chevron traps and video gears 1990–2021). The fishery independent index was missing 2020, because SERFS could not sample during the Covid19 pandemic. The model still predicted a value for 2020, but it did not enter the likelihood used for fitting data. Predicted indices were conditional on selectivity of the corresponding fleet or survey, and were computed from abundance (numbers of fish) at the midpoint of the year or, in the case of the commercial index, biomass.

3.15 Catchability

In the BAM, catchability scales indices of relative abundance to the estimated population at large, adjusted by selectivity of the fleet or survey. For this assessment, as in SEDAR68RT, catchability (q) of each index was assumed to be time-invariant, and these parameters (one q per index) were estimated within BAM.

3.16 Biological Reference Points

The SEDAR68RT assessment estimated MSY directly. However, this Operational Assessment found MSY to be poorly defined (i.e., no well-defined maximum of equilibrium landings as a function of F). Instead, this assessment used a proxy for MSY, based on $F_{40\%}$. That is, biological reference points (benchmarks) were calculated based on the fishing rate that would allow a stock to attain 40% of the maximum spawning potential which would have been obtained in the absence of fishing mortality. The value of $F_{40\%}$ was chosen here because of its commonality in fishery management and because it has been shown to be an effective proxy (e.g., Legault and Brooks (2013); Hartford et al. (2019)). The proxy of $F_{30\%}$ has been shown to be appropriate only for very resilient stocks (Brooks et al. 2010), and even $F_{40\%}$ might be an aggressive benchmark for some stocks (Clark 2002; Hartford et al. 2019; Zhou et al. 2020). Computed benchmarks included the MSY proxy, fishing mortality rate at $F_{40\%}$, total biomass at $F_{40\%}$, and spawning stock at $F_{40\%}$ (Gabriel and Mace 1999). In this assessment, spawning stock measures total biomass of the mature stock (males + 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 fleet estimated as the full F averaged over the last three years of the assessment.

3.17 Fitting Criteria and Data Weighting

Model parameters were estimated using a penalized likelihood approach in which observed removals (landings and dead discards) were fit closely, and observed composition data and abundance indices were fit to the degree that they were compatible. Removals and index data were fit using lognormal likelihoods. Length and age composition data were fit using the Dirichlet-multinomial likelihood, and only from years that met minimum sample size criteria for length compositions ($ntrips \geq 30$) and for age compositions ($ntrips \geq 10$). These cutoffs were used in SEDAR68RT and in other previous SEDAR assessments.

The assessment model fit composition data using the Dirichlet-multinomial distribution (Francis 2017; Thorson et al. 2017). This distribution is self-weighting through estimation of an additional variance inflation parameter for each composition component, making iterative re-weighting unnecessary. Another advantage is that it can better account for overdispersion, or, larger variance in the data than would be expected by the multinomial. Overdispersion can result from intra-haul correlation, which results when fish caught in the same set are more alike in length or age than fish caught in a different set (Pennington and Volstad 1994). The 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 been implemented in Stock Synthesis (Methot and Wetzel 2013; Thorson et al. 2017) and in the BAM, and since SEDAR41 has become the standard likelihood for fitting composition data in assessments of South Atlantic reef fishes.

Preliminary model fits to the SERFS index showed patterns of under-fitting (i.e., run of positive residuals) in the early part of the time series and over-fitting (run of negative residuals) in the terminal years, failing a statistical runs test. To help remedy this, the weight on the SERFS index was increased from 1.0 in increments of 0.25 until the fit passed the runs test. The resulting weight was 1.5, which was used in the base run. In effect, this divides annual CVs by 1.5 within the lognormal likelihood. This weighting puts the SERFS index CVs on a scale more similar to the CVs of the fishery dependent indices, which were scaled to have a mean of 0.2 (Table 4). The SERFS weight was included in the uncertainty analysis, as described below in §3.24.

For parameters defining selectivities, CV of size at age, Dirichlet-multinomial overdispersion parameters, and σ_R, normal penalties (priors) were applied to maintain parameter estimates near reasonable values, and to prevent the gradient-based optimization routine from drifting into parameter space with negligible changes in the likelihood. For σ_R, the prior mean (0.6) and standard deviation (0.15) were based on Beddington and Cooke (1983) and Mertz and Myers (1996).

3.18 Parameters Estimated

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

3.19 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F, as were equilibrium landings and spawning biomass. Equilibrium landings and discards were also computed as functions of biomass B, which itself is a function of F. As in the computation of benchmarks (described in §3.20), 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).

3.20 Benchmark/Reference Point Methods

The value of F_{MSY} was poorly defined in this assessment, necessitating a proxy. The quantities $F_{40\%}$, $\text{SSB}_{\text{F40\%}}$, $B_{\text{F40\%}}$, and $L_{\text{F40\%}}$ were estimated here and are recommended as proxies for MSY-based reference points. The value of $F_{40\%}$ is the F that provides 40% SPR. To compute biomass benchmarks, equilibrium recruitment was assumed equal to expected recruitment in arithmetic space (mean unbiased). However, in BAM, spawner-recruit parameters correspond to median-unbiased recruitment. Thus, on average, expected recruitment is higher than that estimated directly from the spawner-recruit model (i.e., R_0, when using the mean recruitment model), because of lognormal deviation in recruitment. Therefore, the method of benchmark estimation accounted for lognormal deviation by including a bias correction in equilibrium recruitment. The bias correction (ς) was computed from the variance (σ_R^2) of recruitment deviation in log space: $\varsigma = \exp(\sigma_R^2/2)$. Then, equilibrium recruitment (R_{eq}) associated with any F is,

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

where R_0 is median-unbiased virgin recruitment. The R_{eq} and mortality schedule imply an equilibrium age structure and an average sustainable yield (ASY). The estimate of $F_{40\%}$ is the F giving 40% of the SPR, and the estimate of $L_{\text{F40\%}}$ is that ASY. The estimates of $\text{SSB}_{\text{F40\%}}$ follows from the corresponding equilibrium age structure. In this assessment, because dead discards are pooled with landings, they are also included in the estimate of $L_{\text{F40\%}}$ (the proxy for MSY).

Estimates of $L_{\mathrm{F40\%}}$ 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 $L_{\mathrm{F40\%}}$ and related benchmarks.

The maximum fishing mortality threshold (MFMT) is defined here as $F_{40\%}$, and the minimum stock size threshold (MSST) as 75%$\mathrm{SSB}_{\mathrm{F40\%}}$. Overfishing is defined as $F >$ MFMT and overfished as SSB $<$ MSST. However, if the stock is overfished, the rebuilding target would be $\mathrm{SSB}_{\mathrm{F40\%}}$. 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.

3.21 Configuration of a Base Run

The base run was configured as described above. This configuration does not necessarily represent reality better than all other possible configurations, and thus this assessment attempted to portray uncertainty in point estimates through sensitivity analyses and through a mixed Monte-Carlo and bootstrap ensemble (MCBE) approach (described below).

3.22 Sensitivity Analyses

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

- S1: Low natural mortality (Lorenzen curve scaled to $M = 0.12$, which implies maximum age of 45)
- S2: High natural mortality (Lorenzen curve scaled to $M = 0.19$, which implies maximum age of 27)
- S3: Low discard mortality (0.16 for recreational, 0.33 for commercial)
- S4: High discard mortality (0.36 for recreational, 0.45 for commercial)
- S5: Increased use of descender devices reduces recreational discard mortality
- S6: SERFS CVID index weight=1
- S7: SERFS CVID index weight=2
- S8: Drop SERFS CVID index
- S9: Drop commercial index
- S10: Drop recreational index
- S11: Drop SERFS age compositions (SERFS selectivity fixed at base run values)
- S12: Drop commercial age compositions (Commercial selectivities fixed at base run values)
- S13: Drop recreational age compositions (Recreational selectivities fixed at base run values)
- S14: Drop all length compositions (Commercial selectivity in Block 1 fixed at base run values)
- S15: Include SERFS length compositions instead of age compositions
- S16: Time-varying SERFS selectivity (annual age at 50% selection)

For reference, the natural mortality rate in the base run was $M = 0.155$, computed from a maximum observed age of 34 (Then et al. 2014). Discard mortality rates in the base run were 0.26 for the recreational fleet and 0.39 for the commercial fleet. The SERFS index weight in the base run was 1.5. Sensitivity runs that dropped indices one at a time were conducted to examine the influence of those time series, not because the data sources themselves were suspect. Runs with various configurations of composition data or time-varying SERFS selectivity were conducted to satisfy TORs.

The descender device sensitivity run was developed as follows. Three key pieces of information were required to configure this run: 1) discard mortality rate when using descender devices, 2) current usage of descender devices, and 3) whether current usage is an increase in barotrauma mitigation or a shift from using other tools (in particular, venting). For groupers in deep water (including scamp), Runde and Buckel (2018) found a survival rate of 0.5 (95% confidence interval of 0.1–0.91) when using descender devices, which is consistent with the findings of Runde et al. (2020). Although low, it represents an increase from the ∼0% survival without descender devices (Runde and Buckel 2018; Runde et al. 2020), and from that perspective could be considered a reduction in discard mortality of ∼50%. Current use of descender devices is not well quantified, but a 2022 survey of recreational anglers from Florida and South Carolina found that 35% and 25% (FL and SC, respectively) have used descender devices (Responsive Management 2022). Here, we take the average as 30%. Of that 30%, it is unclear how much of that is new mitigation versus a shift from venting, so Sensitivity Run S5 assumes that half of it is new. Thus, a new discard mortality rate (D_{new}) can be computed as a weighted average of the old rate (D_{old}) and the "descender device" mortality rate (i.e., half of $D + old$): $D_{new} = 0.85 \times D_{old} + 0.15 \times 0.5 \times D_{old}$. For the recreational fleet ($D_{old} = 0.26$), this results in a new discard mortality rate of $D_{new} = 0.24$, which was used in Sensitivity Run S5 for the recreational fleet starting in 2020. For the commercial fleet, that run assumed no increased use of descender devices, whether as new mitigation or shift from venting.

3.23 Retrospective Analyses

Retrospective analyses were run by fitting the assessment model after dropping the terminal year. This was done iteratively going back six years to a terminal year of 2015. 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).

3.24 Uncertainty and Measures of Precision

As in the SEDAR68RT, this assessment used a mixed Monte Carlo and bootstrap ensemble (MCBE) approach to characterize uncertainty in results of the base run. Monte Carlo and bootstrap methods (Efron and Tibshirani 1993; Manly 1997) are often used to characterize uncertainty in ecological studies, and the mixed approach has been applied successfully in stock assessment (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), and it is considered to be one of the more complete characterizations of uncertainty used in stock assessments across the United States.

The approach translates uncertainty in model input into uncertainty in model output, by fitting the model many times with different values of "observed" data and key input parameters. A main advantage of the approach is that the results describe a range of possible outcomes, so that the ensemble of models characterizes uncertainty in results more thoroughly than any single fit or handful of sensitivity runs (Scott et al. 2016; Jardim et al. 2021; Ducharme-Barth and Vincent 2022). A minor disadvantage of the approach is that computational demands are relatively high, but this can largely be mitigated through use of parallel processing.

In this assessment, the BAM was successively re-fit in $n = 4000$ trials that differed from the original inputs by bootstrapping on data sources, and by Monte Carlo sampling of several key input parameters. The value of $n = 4000$ was chosen because a minimum of 3000 runs were desired, and it was anticipated that not all runs would converge or otherwise be valid. However, all 4000 runs demonstrated proper convergence (the Hessian was positive definite, the maximum gradient was not too large, and no parameters were stuck at bounds). Thus $n = 4000$ MCBE runs were used to characterize uncertainty, which was sufficient for convergence of standard errors in management quantities. All runs were given equal weight when forming the ensemble of results (Jardim et al. 2021).

The MCBE analysis should be interpreted as providing an approximation to the uncertainty associated with each output. The results are approximate for two related reasons. First, not all combinations of Monte Carlo parameter inputs are equally likely, as biological parameters might be correlated. Second, all runs are given equal weight in the results, yet some might provide better fits to data than others.

3.24.1 Bootstrap of Observed Data

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

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

The term $\sigma^2_{s,y}/2$ is a bias correction that centers the multiplicative error on the value of 1.0. Standard deviations in log space were computed from CVs in arithmetic space, $\sigma_{s,y} = \sqrt{\log(1.0 + CV^2_{s,y})}$. As used for fitting the base run, CVs of indices of abundance were those provided by, or modified from, the data providers (tabulated in Table 4 of this assessment report).

Uncertainty in removals (landings plus dead discards) was similarly modeled with multiplicative lognormal error, using the CVs shown in Table 3. These CVs were used to bootstrap new time series of removals, but the CV used in the estimation process remained CV= 0.05 to achieve a close fit to each series.

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

3.24.2 Monte Carlo Sampling

In each successive fit of the model, several inputs were fixed (i.e., not estimated) at values drawn at random from prescribed distributions. The inputs subjected to Monte Carlo sampling were natural mortality, discard mortality, and the SERFS CVID index weight.

3.24.2.1 Natural mortality

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

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

To estimate uncertainty in a and b, we acquired the data of Then et al. (2014) and conducted a bootstrap of $n = 10,000$ iterations, drawing from the original data set (serranids only) with replacement. For each MCBE iteration, one of the 10,000 fits was drawn at random, thus maintaining any correlation structure between a and b. We then drew T_{max} from a uniform distribution, $T_{max} \sim U[32, 36]$, which was the range given by the SEDAR68 68 DW. This provided a new M value in each MCBE iteration, used to generate a new (scaled Lorenzen) age-dependent vector.

The SEDAR68RT assessment also considered M in the MCBE, but only included uncertainty in the maximum age. Bootstrapping the Then et al. (2014) estimates of regression parameters a and b was done in SEDAR73, and provides a more complete accounting of the uncertainty in natural mortality.

3.24.2.2 Discard mortality

Discard mortality estimates and their ranges were provided by the SEDAR68 68 DW Discard Mortality Working Group (SEDAR68 2021). To characterize uncertainty in these values, a new value of commercial discard mortality was drawn for each MCBE iteration from a uniform distribution $x \sim U(0.33, 0.45)$ and a new value of recreational discard mortality was drawn from $x \sim U(0.16, 0.4)$. Because the assessment model is fitted to removals (landings plus dead discards), these discard mortality rates were applied to the total discards, then combined with landings to create the time series of observed removals.

3.24.2.3 SERFS CVID index weight

As described above, the base run applied a weight of $w = 1.5$ to the SERFS CVID index. In effect, this weight reduces the CV applied in the fitting process as CV/w. To include uncertainty in this weighting, each MCBE iteration applied a weight that was drawn from a uniform distribution, $w \sim U(1, 2)$.

3.25 Projections

Projections were not run as part of the Research Track process, but are here to forecast stock status for 15 years after the assessment, 2022–2036. Because this assessment found the stock to be overfished, these long-term projections were run using $F = 0$ to determine a rebuilding time frame. In addition, projections with $F = F_{\text{current}}$ were run under two different assumptions about recruitment.

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 curves, were fixed to the most recent values of the assessment period. A single selectivity curve was applied to calculate removals, averaged across fleets using geometric mean Fs from the last three years of the assessment period, as in the computation of $L_{\text{F40\%}}$ benchmarks (§3.20). As in the assessment, projected removals include landings and dead discards.

Expected values of SSB (time of peak spawning), F, recruits, removals, and the SERFS index were represented by deterministic projections using parameter estimates from the base run. These projections applied mean recruit with bias correction, and were thus consistent with estimated benchmarks in the sense that long-term fishing at $F_{40\%}$ would yield $L_{\text{F40\%}}$ from a stock size at $\text{SSB}_{\text{F40\%}}$. Uncertainty in future time series was quantified through stochastic projections that extended the ensemble (MCBE) fits of the stock assessment model.

3.25.1 Initialization and Recruitment in 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.

Fishing rates that define the projections were assumed to start in 2024. Because the assessment period ended in 2021, the projections required an initialization period (2022–2023). For this period, an optimization routine solved for the F that matched the current level of landings (arithmetic mean of 2019-2021). In addition, recruitment in 2022 was assumed equal to the recent average (lower than the long-term, expected recruitment). Starting in 2023, recruitment either returned to the long-term average or stayed at the recent average, depending on the scenario.

3.25.2 Benchmarks for Projections

The benchmark $\text{SSB}_{\text{F40\%}}$ was used as the target to gauge rebuilding. This benchmark was predicated on the long-term average recruitment. If or when this stock has been declared to have experienced a regime shift, the criterion for rebuilding could be based on a benchmark that assumes recent average recruitment.

3.25.3 Uncertainty of Projections

To characterize uncertainty in future stock dynamics, stochasticity was included in replicate projections, each an extension of a single MCBE assessment model fit. Thus, projections carried forward uncertainties of the ensemble in natural mortality, reproduction, landings, discards, and discard mortalities, as well as in estimated quantities such as selectivity curves, and in initial (start of 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 was added to the mean values by choosing multiplicative deviations at random from a lognormal distribution,

$$R_y = \bar{R}_y \exp(\epsilon_y). \tag{4}$$

Here ϵ_y was drawn from a normal distribution with mean 0 and standard deviation σ_R, where σ_R is the standard deviation from the relevant MCBE fit.

The procedure generated 20,000 replicate projections of MCBE model fits drawn at random (with replacement) from the MCBE runs. In cases where the same MCBE run was drawn, projections would still differ as a result of stochasticity in projected recruitment streams. Central tendencies were represented by the deterministic projections of the base run, as well as by medians of the stochastic projections. Precision of projections was represented graphically by the 5^{th} and 95^{th} percentiles of the replicate projections.

3.25.4 Rebuilding Time Frame and Generation Time

Based on the stock status estimated by this assessment, scamp 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 scamp and was found to be 10 yr.

3.25.5 Projection Scenarios

Three projection scenarios were considered for this report.

- Scenario 1: $F = 0$, with long-term average recruitment starting 2023
- Scenario 2: $F = F_{\text{current}}$, with long-term average recruitment starting 2023
- Scenario 3: $F = F_{\text{current}}$, 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 2010–2019, 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

In general, the Beaufort assessment model (BAM) fit well to the available data. Predicted length compositions were reasonably close to observed data in most years, as were predicted age compositions (Figures 4–14). The model was configured to fit observed commercial and recreational removals closely (Figures 15–16). Fits to indices of abundance generally captured the observed trends but not all annual fluctuations (Figures 17–19). Additional diagnostics applied to the base model or during model development are provided in SEDAR680A-WP06 (2022).

4.2 Parameter Estimates

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

4.3 Stock Abundance and Recruitment

Estimated abundance at age showed an increase in the late 1980s followed by a period of relatively high abundance through the mid-2000s, and then dropping to its lowest levels by the end of the assessment period (Figure 20; Table 6). Total estimated abundance of age 1+ and of age 2+ from the base run and MCBE follow that same trajectory through time (Figure 21), generally tracking the pattern of recruitment. Annual number of recruits is shown in Table 6 (age-1 column) and in Figure 22. Recruitment residuals demonstrated autocorrelation with a dominant lag of one year (Figure 23). The highest recruitment values were predicted to have occurred in the late-1980s, 1990s, and early 2000s. Lower-than-expected recruitment is predicted to have occurred since then, with the lowest values during the last decade of the assessment (2010 onward).

4.4 Total and Spawning Biomass

Estimated biomass at age followed a similar pattern as abundance at age (Figure 24; Tables 7, 8). Total biomass and spawning biomass showed similar trends—general decline through the mid-1980s, an increase until the early 2000s, and then a decreasing pattern since then (Figure 25; Table 9). The decrease during the last ∼15 years appears to have been driven by poor recruitment; terminal year estimates of total and spawning biomass were at the lowest levels of their time series.

4.5 Selectivity

Selectivity of the SERFS index is shown in Figure 26, and selectivities of landings from commercial and recreational fleets are shown in Figures 27–28. Selectivities from the latest time block is tabulated in Table 10. In the most recent selectivity block, full selection of removals for each fleet occurred near age 6.

Average selectivity of removals (landings + dead discards) was computed from the F-weighted selectivities in the most recent three assessment years (Figure 29, Table 10). This average selectivity was used in computation of point estimates of benchmarks, as well as in projections.

4.6 Fishing Mortality and Removals

Estimates of total F by fleet are shown in Figure 30 and Table 11, and estimates of F at age are shown in Table 12. In general, the commercial fleet has been the dominant source of fishing mortality, contributing about 50–75% of the total F, depending on the year.

Estimated time series of removals (landings + dead discards) are shown in Figures 31–32 and Table 13. Table 15 shows total removals at age in numbers, and Table 16 in weight. Total removals generally exceeded $L_{\mathrm{F40\%}}$ during the 1990s and 2000s, but since 2010, total removals have remained below the level at $L_{\mathrm{F40\%}}$ (Figure 32).

4.7 Spawner-Recruitment Parameters

The mean recruit relationship and variability around that mean are shown in Figure 33. Values of recruitment-related parameters were as follows: unfished age-1 recruitment $\widehat{R_0} = 226076$, and standard deviation of recruitment residuals in log space $\widehat{\sigma}_R = 0.71$ (which resulted in bias correction of $\varsigma = 1.29$). The early (1969–1979) recruitment multiplier was estimated to be 0.99, which scaled those recruitment estimates relative to the long-term mean (i.e., R_0 in the mean recruit model). Uncertainty in recruitment quantities were estimated through the MCBE analysis (Figure 34).

4.8 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were each computed as functions of F. These computations applied the most recent selectivity patterns averaged across fleets, weighted by F from the last three years (2019–2021) (Figures 35, 36).

As in per recruit analyses, equilibrium removals and equilibrium spawning biomass were each computed as a functions of F (Figure 37). The equilibrium removals curve (or else equilibrium landings if discards are separated) is the curve from which F_{MSY} is typically estimated, as the value of F for which removals (landings) are maximized. The curve here demonstrates why F_{MSY} in this assessment is poorly defined: 1) the curve is strictly increasing over the broad range of F considered and the curve is relatively flat. Thus, the peak occurs at the upper bound of $F = 2$, and there is little difference in equilibrium landings across the range of $F \in (0.5, 2.0)$. Poorly defined F_{MSY}, in addition to a poorly defined spawner-recruit curve (primarily steepness), are reasons why a proxy for F_{MSY} was used in this assessment.

4.9 Benchmarks/Reference Points

As described in §3.20, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the mean-unbiased recruitment (Figure 33). Reference points estimated were $F_{40\%}$, $L_{\text{F40\%}}$, $B_{\text{F40\%}}$, and $\text{SSB}_{\text{F40\%}}$. Based on $F_{40\%}$, three possible values of F at optimum yield (OY) were considered—$F_{\text{OY}} = 65\% F_{40\%}$, $F_{\text{OY}} = 75\% F_{40\%}$, and $F_{\text{OY}} = 85\% F_{40\%}$—and for each, the corresponding yield was computed. Standard errors of benchmarks were approximated as those from MCBE analysis (§3.24).

Maximum likelihood estimates (base run) of benchmarks, as well as median values from MCBE analysis, are summarized in Table 17. Point estimates of reference points were $F_{40\%} = 0.28$ (y^{-1}), $L_{\text{F40\%}} = 372.28$ (1000 lb), $B_{\text{F40\%}} = 1503.87$ (mt), and $\text{SSB}_{\text{F40\%}} = 1068.8$ (mt). Median estimates were $F_{40\%} = 0.3$ (y^{-1}), $L_{\text{F40\%}} = 381.39$ (1000 lb), $B_{\text{F40\%}} = 1540.65$ (mt), and $\text{SSB}_{\text{F40\%}} = 1068.19$ (mt). Note that the $L_{\text{F40\%}}$ values (proxies for MSY) comprise landings and dead discards. Distributions of these benchmarks from the MCBE analysis are shown in Figure 38.

4.10 Status of the Stock and Fishery

Estimated time series of stock status $\text{SSB}/\text{SSB}_{\text{F40\%}}$ showed general decline throughout the beginning of the assessment period, an increase starting in the mid-1980s, and then decline since the mid-2000s (Figure 39, Table 9). Base-run estimates of spawning biomass have remained below $\text{SSB}_{\text{F40\%}}$ since 2009. Current stock status relative to MSST was estimated in the base run to be $\text{SSB}/\text{MSST} = 0.36$ (Table 17), indicating that the stock is overfished relative to $\text{MSST} = 75\% \text{SSB}_{\text{F40\%}}$. Median values from the MCBE analysis indicated similar results of $\text{SSB}/\text{MSST} = 0.38$ in the terminal year. The uncertainty analysis suggested that the terminal estimate of stock status is robust (Figures 40, 41). Of the MCBE runs, 100% indicated that the stock was below MSST, as well as $\text{SSB}_{\text{F40\%}}$, in 2021. Age structure estimated by the base run showed fewer younger fish in the terminal years than the (equilibrium) age structure expected at $F_{40\%}$ (Figure 42). This was a result of lower-than-expected recruitment since the mid-2000s and particularly low since 2010.

The estimated time series of $F/F_{40\%}$ suggests that the fishing rate has fluctuated around its limit (here, $F_{40\%}$) since the 1980s, with overfishing in some years and not in other years (Table 9, Figure 39). Current fishery status in the terminal year, with current F represented by the geometric mean from years 2019–2021, was estimated by the base run to be $F/F_{40\%} = 0.91$ (Table 17). The fishery status was less certain than the stock status (Figures 40, 41). Of the MCBE runs, approximately 69.5% agreed with the base run that the stock is not currently experiencing overfishing.

4.11 Sensitivity and Retrospective Analyses

Sensitivity runs, described in §3.3, were used for multiple reasons: exploring data or model configurations, evaluating implications of assumptions in the base assessment model, interpreting MCBE results in terms of expected effects of input parameters, or satisfying TORs. In some cases, sensitivity runs are simply a tool for better understanding model behavior, and therefore all runs are not considered equally plausible in the sense of alternative states of nature. Time series of $F/F_{40\%}$ and SSB/SSB$_{F40\%}$ are plotted to demonstrate sensitivity to the changing conditions in each run. This operational assessment explored sensitivity of the base run to changes in natural mortality, discard mortality, data weighting, data sources, and SERFS selectivity (Figures 43–50, Table 18). Of these modifications, results were most sensitive to the scale of natural mortality and to inclusion of the SERFS index.

Retrospective analyses suggest no concerning patterns of estimating F or SSB in the terminal year (Figure 51). Terminal-year recruitment estimates are over-predicted for earlier peels, but converge on the base run for later peels. Values of Mohn's ρ (a measure of retrospective pattern) are 0.14, 0.80, and 0.05 for F, recruits, and SSB time-series, respectively (Carvalho et al. 2021). For SSB, Hurtado-Ferro et al. (2015) suggest a rule of thumb in which Mohn's ρ indicates an undesirable retrospective pattern if the value falls outside the range (-0.15, 0.20) for longer-lived species or (-0.22, 0.30) for shorter-lived species. In either case, the value here of 0.05 is not cause for concern.

4.12 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 2029 and greater than 90% chance by 2031 (Figures 52, 53; Table 19). 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 2024, the time frame of rebuilding would last until the end of 2033.

If the fishing rate remains at F_{current} and recruitment returns to its long-term average, the spawning stock is projected to rebuild by 2033 with a 51% chance (Figures 54 – 56; Table 20). However, if the fishing rate remains at F_{current} and recruitment remains low, rebuilding within 10 years appears to be unlikely (Figures 57 – 59; Table 21). Once a projection scenario is chosen for setting catch levels, comparison of the projected SERFS index (e.g., Figures 56, 59) to the actual, future SERFS index might aid in determining whether rebuilding is occurring faster than, slower than, or on pace with the expectation.

5 Discussion

The base run of the BAM indicated that the stock is overfished SSB/MSST =0.36, but that overfishing is not occurring $F/F_{40\%}$ =0.91. 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 69.5% showed that overfishing is not 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.

5.1 Comments on the Assessment

Estimated benchmarks played a central role in this assessment. Values of SSB$_{F40\%}$ and $F_{40\%}$ were used to gauge the status of the stock and fishery. Benchmarks would likely change in the future if selectivity patterns change, for example as a result of new size limits or different relative catch allocations among sectors.

Time series of commercial and recreational removals in the assessment included both landings and dead discards. Therefore, both types of mortality are included the benchmarks and in the projected removals.

In general, fishery dependent indices of abundance may not track actual abundance well, because of factors such as hyperdepletion or hyperstability. Furthermore, this issue can be exacerbated by management measures. In this assessment, the commercial and recreational (headboat) indices generated from logbook data, were not extended beyond 2009 because of regulatory effects associated with the red snapper moratorium. In general, management measures in the southeast U.S. have made the continued utility of fishery dependent indices questionable. This situation amplifies the importance of fishery independent sampling, such as through SERFS, and sampling programs conducted by the states.

Two SERFS indices of abundance were included in this assessment, one developed from chevron trap data and one from video data. Because the video cameras are mounted on top of traps, sampling by these two gears is not independent. To address this non-independence, the two gears were combined into a single index prior to model fitting. This was possible because both gears appeared to have flat-topped selectivities, which was a topic explored during the SEDAR68RT assessment. If future research were to find that the trap gear had dome-shaped selectivity, this could be accounted for in the assessment with a modest modification in the methods.

Many assessed reef-fish stocks in the southeast U.S. have shown histories of heavy exploitation, and protogynous hermaphrodites such as scamp 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 scamp or yellowmouth grouper, there is mounting evidence that these fishery effects are common and have potential to destabilize fisheries (Kuparinen et al. 2016). Life-history adaptations can affect expected yield and stock recovery, and thus resource managers might wish to consider possible evolutionary effects of fishing in their management plans (Dunlop et al. 2009; Enberg et al. 2009; Heino et al. 2013).

Because steepness could not be estimated reliably, and because the analysis is of a stock complex (two species), this assessment used the mean recruitment model. In addition, F_{MSY} was poorly defined. Thus, a proxy for MSY-based management quantities was used to estimate stock and fishery status. Here, $F_{40\%}$ is the proxy for F_{MSY}, and to translate that fishing rate into biomass reference points, long-term average recruitment (median unbiased) was assumed.

The low stock status at the end of the assessment does not appear to be caused by overfishing, but rather by poor recruitment. Recruitment was predicted to have been lower than expected since the mid-2000s, with the lowest values for the full time series occurring since 2010. Recruitment failure is consistent with the findings of Bacheler and Ballenger (2018), in which they discuss two potential hypotheses: recruitment overfishing and increased mortality on egg, larval, or juvenile stages. A third hypothesis would be reduction in egg production or fertilization, especially given the potential for sperm limitation in protogynous hermaphrodites (Robinson et al. 2017).

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 currently 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 10 years, and the recent, low recruitment has occurred for several years longer than that. The second category is “Understanding of assessment model input data,” for which this stock scored a 3 (“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 2 (“Modeled changes in key production parameters have been somewhat validated by investigation of alternative model structures and/or improved model behaviour such as the removal of retrospective patterns”). Sensitivity runs explored effects of data sources on estimated productivity parameters and recruitment time series, and no concerning retrospective patterns were revealed. The fourth category is “Explanatory hypothesis” for which this stock scored a 0 (“The mechanism is unknown”). For now, no plausible mechanism for a productivity shift has been identified. However, the notion that low recruitment has been demonstrated for multiple reef-fish stocks suggests the possibility of a common, external driver (Wade et al. 2023). Thus, the total score is 6, which does not meet the minimum required to support acceptance of a regime shift. In addition, identifying a plausible mechanism for a productivity shift would increase the total score by 1, but even then, declaring a regime shift would depend on the nature of that mechanism. For example, if a common driver of recruitment were identified, it would be critical to know whether that driver itself is expected to remain in its current state or return to a long-term average (e.g., as with an oscillatory oceanographic pattern).

5.3 Comments on the Projections

Projections should be interpreted in light of the model assumptions and key aspects of the data. Some major considerations are the following:

- In general, projections of fish stocks are highly uncertain, particularly in the long term (e.g., beyond 5 years).
- As in the assessment time period, removals in the projections included landings and dead discards.
- Although projections included many major sources of uncertainty, they did not include structural (model) uncertainty. That is, projection results are conditional on one set of functional forms used to describe population dynamics, selectivity, recruitment, etc.
- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect projection results.
- The projections assumed that the estimated spawner-recruit relationship applies in the future and that past deviations represent future uncertainty in recruitment. If future recruitment is characterized by runs of large or small year classes, possibly due to environmental or ecological conditions, stock projections may be affected.
- Projections apply the Baranov catch equation to relate F and landings using a one-year time step, as in the assessment. The catch equation implicitly assumes that mortality occurs throughout the year. This assumption is violated when seasonal closures or small intensive fishing seasons are in effect, introducing additional and unquantified uncertainty into the projection results.
- Projection output included forecasts of the SERFS index. These forecasts may be useful for tracking rebuilding progress, by comparing future observed values to the expected values. If observations are higher (or lower) than expected, rebuilding may be occurring more quickly (or more slowly) than expected.

5.4 Research Recommendations

- Results of this assessment are sensitive to natural mortality. The scale and age dependence of natural mortality were estimated using meta-analytical methods, as is common in SEDAR assessments. While such methods describe relationships between M and other life-history characteristics (growth, maximum age) averaged across species, they may not describe well the natural mortality of any particular species. Mark-recapture approaches (conventional, telemetry, close-kin) might make it possible to obtain direct estimates of natural mortality specific to scamp in the South Atlantic region.
- More research on the usage and effect of descender devices would benefit stock assessments of South Atlantic reef fishes.
- More research is needed on the cause(s) of low recruitment in several South Atlantic reef-fish stocks, including scamp. This topic is currently being investigated by the SEFSC.
- Better characterize reproductive parameters including age at maturity, sex transition, batch fecundity, spawning seasonality, and spawning frequency. Mature male and female biomass was the measure of reproductive potential in the assessment, to account for the importance of males in a protogynous hermaphrodite. However, this approach models the potential for sperm limitation implicitly, and more direct modeling approaches could be developed. Theoretical development would be desirable, but we note that for use in assessments, new modeling methods might also require the support of new data collections (e.g., to quantify sperm limitation as a function of sex ratio.)

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7 Tables

Table 1. Size (FL) in inches and weight in pounds (lb) at age as applied to the population (Pop) and fishery–dependent portion of the population during the 20-inch size limit (FD20). The CV of length was estimated by the assessment model; other values were treated as input through the von Bertalanffy growth parameters.

Age	Pop.FL	CV.Pop.FL	Pop.lb	FD20.FL	CV.FD20.FL	FD20.lb
1	12.2	0.12	1.1	15.6	0.09	2.1
2	14.8	0.12	1.9	17.1	0.09	2.8
3	17.0	0.12	2.7	18.5	0.09	3.4
4	19.0	0.12	3.7	19.8	0.09	4.1
5	20.6	0.12	4.7	21.0	0.09	4.9
6	22.1	0.12	5.6	22.1	0.09	5.6
7	23.3	0.12	6.5	23.1	0.09	6.4
8	24.4	0.12	7.4	24.1	0.09	7.1
9	25.3	0.12	8.2	25.0	0.09	7.9
10	26.1	0.12	8.9	25.8	0.09	8.6
11	26.8	0.12	9.5	26.5	0.09	9.3
12	27.3	0.12	10.1	27.2	0.09	10.0
13	27.8	0.12	10.6	27.9	0.09	10.7
14	28.3	0.12	11.1	28.5	0.09	11.3
15	28.7	0.12	11.5	29.1	0.09	12.0
16	29.0	0.12	11.9	29.6	0.09	12.6
17	29.3	0.12	12.2	30.1	0.09	13.1
18	29.5	0.12	12.5	30.5	0.09	13.7
19	29.7	0.12	12.7	30.9	0.09	14.2
20	29.9	0.12	12.9	31.3	0.09	14.7

Table 2. Average size (FL, in mm and in) and weight (Wgt, lb), proportion female (PropFem), female maturity (FemMat), reproductive value (Rep, kg per fish), and natural mortality (M). All males were considered mature.

Age	Avg.FL(mm)	Avg.FL(in)	Avg.Wgt	PropFem	FemMat	Rep	M
1	309.0	12.2	1.1	1.00	0.11	0.05	0.32
2	375.3	14.8	1.9	0.99	0.39	0.33	0.27
3	432.3	17.0	2.7	0.97	0.77	0.97	0.24
4	481.5	19.0	3.7	0.95	0.94	1.58	0.22
5	523.8	20.6	4.7	0.92	0.99	2.09	0.20
6	560.3	22.1	5.6	0.87	1.00	2.54	0.19
7	591.7	23.3	6.5	0.80	1.00	2.95	0.18
8	618.8	24.4	7.4	0.72	1.00	3.34	0.18
9	642.1	25.3	8.2	0.62	1.00	3.70	0.17
10	662.2	26.1	8.9	0.51	1.00	4.02	0.17
11	679.6	26.8	9.5	0.40	1.00	4.32	0.16
12	694.5	27.3	10.1	0.30	1.00	4.59	0.16
13	707.3	27.8	10.6	0.21	1.00	4.82	0.16
14	718.4	28.3	11.1	0.14	1.00	5.03	0.16
15	728.0	28.7	11.5	0.09	1.00	5.22	0.15
16	736.2	29.0	11.9	0.05	1.00	5.38	0.15
17	743.3	29.3	12.2	0.03	1.00	5.53	0.15
18	749.4	29.5	12.5	0.02	1.00	5.65	0.15
19	754.6	29.7	12.7	0.01	1.00	5.76	0.15
20	759.2	29.9	12.9	0.00	1.00	5.86	0.15

Table 3. Observed time series of removals (landings plus dead discards) for the commercial (Com) and recreational (Rec) fleets. Commercial removals are in units of 1000 lb whole weight, and recreational removals are in units of 1000 fish. The coefficients of variation (CV), as used in ensemble modeling, are also shown.

Year	Com	Rec	CV.Com	CV.Rec
1969	33.70	10.70	0.20	0.47
1970	44.67	10.76	0.20	0.47
1971	49.98	11.83	0.20	0.47
1972	36.54	12.89	0.20	0.47
1973	48.40	13.96	0.20	0.47
1974	66.55	15.02	0.20	0.47
1975	67.25	16.08	0.20	0.47
1976	85.71	16.27	0.20	0.47
1977	125.52	16.45	0.20	0.47
1978	277.94	16.63	0.10	0.47
1979	262.80	16.81	0.10	0.47
1980	252.56	16.99	0.10	0.47
1981	244.28	14.02	0.10	0.50
1982	378.56	18.47	0.10	0.41
1983	322.83	9.56	0.10	0.07
1984	320.17	17.97	0.10	0.29
1985	255.34	14.77	0.10	0.35
1986	286.40	11.15	0.10	0.15
1987	328.42	16.40	0.10	0.05
1988	348.05	34.37	0.10	0.21
1989	376.67	32.63	0.10	0.21
1990	484.32	45.37	0.10	0.23
1991	394.16	35.38	0.10	0.12
1992	285.89	30.76	0.10	0.20
1993	313.94	31.79	0.10	0.24
1994	313.29	48.82	0.10	0.22
1995	347.37	20.04	0.10	0.01
1996	289.46	20.35	0.10	0.26
1997	292.15	21.73	0.10	0.15
1998	268.86	24.77	0.10	0.07
1999	385.94	31.22	0.10	0.12
2000	301.52	48.22	0.10	0.26
2001	229.48	30.67	0.10	0.18
2002	241.02	64.45	0.10	0.21
2003	266.35	51.66	0.10	0.30
2004	262.47	47.69	0.05	0.26
2005	279.34	53.33	0.05	0.50
2006	324.43	59.09	0.05	0.41
2007	346.48	65.95	0.05	0.22
2008	260.02	37.73	0.05	0.29
2009	263.12	23.51	0.05	0.40
2010	186.16	15.98	0.05	0.32
2011	160.95	10.70	0.05	0.35
2012	163.68	12.16	0.05	0.36
2013	143.10	13.00	0.05	0.34
2014	166.38	10.98	0.05	0.50
2015	129.72	9.02	0.05	0.42
2016	112.93	9.77	0.05	0.40
2017	111.82	7.19	0.05	0.50
2018	98.14	4.75	0.05	0.35
2019	121.59	6.21	0.05	0.35
2020	64.00	4.77	0.05	0.34
2021	51.71	5.48	0.05	0.50

Table 4. Observed indices of abundance and CVs from commercial (Com), recreational (Rec), and SERFS combined chevron trap and video gears (CVID).

Year	Com	Com CV	Rec	Rec CV	CVID	CVID CV
1981	.	.	0.55	0.26	.	.
1982	.	.	0.64	0.20	.	.
1983	.	.	0.55	0.20	.	.
1984	.	.	0.58	0.22	.	.
1985	.	.	0.74	0.19	.	.
1986	.	.	0.68	0.18	.	.
1987	.	.	0.86	0.16	.	.
1988	.	.	0.78	0.17	.	.
1989	.	.	0.79	0.26	.	.
1990	.	.	1.23	0.19	1.44	0.34
1991	.	.	1.29	0.24	1.24	0.35
1992	.	.	0.95	0.21	1.45	0.35
1993	0.90	0.22	0.77	0.21	1.52	0.34
1994	0.78	0.22	0.95	0.19	1.62	0.31
1995	0.96	0.18	1.16	0.20	2.12	0.32
1996	0.87	0.19	0.85	0.20	1.35	0.35
1997	0.94	0.18	1.30	0.17	2.28	0.31
1998	0.96	0.21	1.36	0.16	2.05	0.32
1999	1.12	0.20	1.61	0.14	1.38	0.36
2000	1.17	0.19	1.38	0.17	1.34	0.33
2001	0.94	0.19	1.09	0.18	1.15	0.36
2002	0.94	0.19	1.25	0.19	1.00	0.37
2003	1.08	0.20	1.35	0.23	1.59	0.36
2004	0.92	0.22	1.33	0.20	1.47	0.34
2005	1.09	0.21	1.20	0.19	1.29	0.35
2006	1.28	0.20	1.19	0.23	0.47	0.47
2007	1.22	0.18	1.29	0.18	1.09	0.35
2008	0.96	0.20	0.76	0.26	0.40	0.47
2009	0.87	0.22	0.53	0.23	0.45	0.46
2010	.	.	.	.	0.79	0.38
2011	.	.	.	.	0.51	0.28
2012	.	.	.	.	0.52	0.24
2013	.	.	.	.	0.46	0.24
2014	.	.	.	.	0.41	0.23
2015	.	.	.	.	0.40	0.24
2016	.	.	.	.	0.32	0.27
2017	.	.	.	.	0.33	0.25
2018	.	.	.	.	0.21	0.25
2019	.	.	.	.	0.17	0.32
2020	.	.	.	.	.	.
2021	.	.	.	.	0.18	0.31

Table 5. Sample sizes (numbers of trips) of length compositions (len) or age compositions (age) by survey or fleet. Data sources are commercial (Com), recreational (Rec), and SERFS chevron traps (CVT).

Year	len.Com	len.Rec	age.Com	age.Rec	age.CVT
1978	.	112	.	.	.
1979	.	84	.	.	.
1980	.	.	.	24	.
1981	.	.	.	35	.
1982	.	.	.	21	.
1983	.	.	.	42	.
1984	119	.	.	42	.
1985	178	.	.	40	.
1986	127	.	.	17	.
1987	171	.	.	.	.
1988	153	.	.	.	.
1989	138	.	.	40	.
1990	122	.	.	12	13
1991	178	.	.	25	33
1992	.	.	.	11	31
1993	.	.	.	.	43
1994	.	.	.	.	69
1995	.	.	.	.	50
1996	.	.	.	51	68
1997	.	.	.	.	87
1998	.	.	.	.	53
1999	.	.	.	.	32
2000	.	.	.	.	44
2001	.	.	.	.	38
2002	.	.	.	25	33
2003	.	.	.	34	27
2004	.	.	46	45	40
2005	.	.	110	53	33
2006	.	.	263	50	11
2007	.	.	368	49	40
2008	.	.	345	23	11
2009	.	.	260	40	12
2010	.	.	201	32	36
2011	.	.	226	.	31
2012	.	.	187	24	46
2013	.	.	130	35	53
2014	.	.	124	27	55
2015	.	.	100	17	57
2016	.	.	115	31	43
2017	.	.	81	20	57
2018	.	.	98	21	33
2019	.	.	106	.	16
2020	.	.	53	.	.
2021	89	.	.	.	.

Table 6. Estimated total abundance at age (1000 fish) at start of year.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1969	224.67	163.45	124.43	96.96	76.11	60.00	47.65	38.14	30.73	24.89	20.25	16.53	13.54	11.11	9.14	7.53	6.22	5.13	4.25	20.49	1001.20
1970	224.67	163.46	124.45	97.02	76.27	60.19	47.83	38.28	30.84	24.98	20.32	16.59	13.59	11.15	9.17	7.56	6.24	5.15	4.26	20.57	1002.61
1971	224.67	163.45	124.45	96.98	76.17	60.12	47.80	38.28	30.84	24.98	20.32	16.59	13.59	11.15	9.17	7.56	6.24	5.15	4.26	20.57	1002.34
1972	224.67	163.44	124.40	96.87	75.95	59.82	47.54	38.10	30.70	24.87	20.23	16.52	13.53	11.10	9.13	7.53	6.21	5.13	4.24	20.48	1000.47
1973	224.67	163.43	124.38	96.83	75.92	59.75	47.41	37.97	30.62	24.82	20.19	16.48	13.50	11.08	9.11	7.51	6.20	5.12	4.23	20.43	999.67
1974	224.67	163.42	124.32	96.67	75.60	59.39	47.05	37.62	30.32	24.59	20.01	16.34	13.38	10.98	9.03	7.44	6.14	5.08	4.20	20.25	996.51
1975	224.67	163.40	124.25	96.46	75.10	58.66	46.34	36.99	29.76	24.12	19.64	16.04	13.14	10.79	8.87	7.31	6.03	4.98	4.12	19.89	990.57
1976	224.67	163.38	124.20	96.30	74.76	58.09	45.62	36.31	29.16	23.59	19.20	15.70	12.86	10.56	8.68	7.15	5.90	4.88	4.03	19.47	984.52
1977	224.67	163.37	124.15	96.13	74.32	57.42	44.82	35.45	28.39	22.93	18.63	15.22	12.47	10.24	8.43	6.94	5.73	4.73	3.92	18.89	976.85
1978	224.67	163.36	124.07	95.83	73.53	56.24	43.56	34.23	27.25	21.94	17.79	14.51	11.89	9.77	8.04	6.62	5.47	4.52	3.74	18.02	965.03
1979	224.67	163.29	123.80	94.80	70.83	52.52	39.97	31.12	24.60	19.69	15.92	12.96	10.60	8.70	7.17	5.91	4.88	4.03	3.33	16.08	934.86
1980	150.85	163.28	123.70	94.45	69.80	50.30	37.08	28.36	22.22	17.66	14.19	11.51	9.40	7.71	6.34	5.23	4.32	3.57	2.95	14.24	837.16
1981	251.85	109.62	123.63	94.20	69.22	49.21	35.23	26.10	20.08	15.82	12.62	10.18	8.29	6.78	5.57	4.59	3.79	3.14	2.59	12.52	865.04
1982	218.13	183.04	83.04	94.27	69.16	48.88	34.52	24.83	18.51	14.32	11.32	9.07	7.34	5.99	4.91	4.04	3.34	2.76	2.28	11.02	850.76
1983	233.70	158.38	138.05	62.13	65.34	44.46	30.84	21.84	15.80	11.84	9.20	7.30	5.86	4.75	3.89	3.19	2.63	2.18	1.80	8.70	831.87
1984	266.99	169.82	119.80	104.21	43.88	43.11	28.87	20.09	14.31	10.41	7.83	6.10	4.86	3.91	3.18	2.60	2.14	1.77	1.46	7.07	862.42
1985	246.12	193.80	127.90	89.16	71.14	27.54	26.48	17.77	12.43	8.90	6.50	4.91	3.84	3.06	2.47	2.01	1.65	1.36	1.12	5.43	853.59
1986	484.79	178.73	146.25	95.94	62.25	46.28	17.61	16.98	11.46	8.06	5.79	4.25	3.22	2.52	2.02	1.63	1.33	1.09	0.90	4.34	1095.43
1987	497.25	352.15	134.97	109.67	66.45	39.80	29.01	11.07	10.73	7.28	5.14	3.71	2.73	2.07	1.63	1.30	1.05	0.86	0.71	3.41	1280.98
1988	708.86	360.94	265.11	99.99	73.40	40.23	23.47	17.12	6.57	6.40	4.36	3.09	2.24	1.65	1.25	0.99	0.79	0.64	0.52	2.51	1620.12
1989	556.44	513.66	269.96	192.24	63.67	41.33	21.89	12.75	9.35	3.60	3.53	2.41	1.72	1.24	0.92	0.70	0.55	0.44	0.36	1.70	1698.47
1990	301.32	403.43	384.90	196.72	123.36	36.16	22.69	12.01	7.03	5.18	2.01	1.97	1.35	0.96	0.70	0.52	0.40	0.31	0.25	1.17	1502.43
1991	628.85	218.26	301.17	276.47	121.34	65.83	18.51	11.59	6.16	3.63	2.68	1.04	1.03	0.71	0.50	0.37	0.27	0.21	0.16	0.75	1659.53
1992	270.69	456.21	164.03	222.27	184.51	73.50	38.87	10.94	6.88	3.68	2.17	1.61	0.63	0.62	0.43	0.31	0.22	0.17	0.13	0.56	1438.41
1993	386.68	197.05	347.76	127.47	166.09	122.23	44.80	23.34	6.59	4.17	2.24	1.33	0.99	0.39	0.38	0.26	0.19	0.14	0.10	0.42	1432.61
1994	572.18	281.48	150.22	270.39	95.54	111.14	75.70	27.38	14.31	4.06	2.58	1.39	0.83	0.62	0.24	0.24	0.17	0.12	0.09	0.33	1609.01
1995	578.02	416.50	214.50	116.43	199.25	61.81	66.39	44.63	16.19	8.51	2.42	1.54	0.83	0.50	0.37	0.15	0.14	0.10	0.07	0.25	1728.63
1996	467.45	420.79	317.63	167.22	88.54	137.43	39.63	42.03	28.34	10.34	5.45	1.56	1.00	0.54	0.32	0.24	0.09	0.09	0.07	0.21	1728.97
1997	335.57	340.30	320.95	247.88	128.00	62.60	91.78	26.24	27.94	18.94	6.94	3.67	1.05	0.67	0.37	0.22	0.16	0.06	0.06	0.19	1613.59
1998	404.75	244.29	259.57	250.55	190.10	91.02	42.17	61.36	17.62	18.85	12.83	4.72	2.50	0.72	0.46	0.25	0.15	0.11	0.04	0.18	1602.23
1999	359.83	294.66	186.36	202.79	193.01	137.43	63.02	29.06	42.47	12.26	13.17	9.00	3.32	1.77	0.51	0.33	0.18	0.11	0.08	0.16	1549.49
2000	324.28	261.96	224.72	145.33	154.58	135.19	90.75	41.25	19.09	28.05	8.13	8.77	6.01	2.22	1.18	0.34	0.22	0.12	0.07	0.16	1452.42
2001	507.04	236.07	199.74	174.90	109.63	106.96	89.02	59.42	27.13	12.62	18.62	5.42	5.86	4.02	1.49	0.80	0.23	0.15	0.08	0.16	1559.35
2002	492.56	369.14	180.08	155.99	134.51	79.59	75.06	62.34	41.83	19.19	8.97	13.28	3.87	4.20	2.89	1.07	0.57	0.17	0.11	0.17	1645.59
2003	452.39	358.55	281.36	139.74	115.81	90.47	51.05	47.93	40.00	26.98	12.43	5.83	8.66	2.53	2.75	1.90	0.70	0.38	0.11	0.18	1639.76
2004	307.99	329.32	273.33	218.56	104.33	78.43	58.15	32.62	30.77	25.81	17.48	8.08	3.80	5.66	1.66	1.81	1.25	0.46	0.25	0.19	1499.94
2005	209.88	224.21	251.06	212.44	163.68	71.02	50.64	37.31	21.02	19.93	16.79	11.41	5.29	2.50	3.72	1.09	1.19	0.82	0.31	0.29	1304.61
2006	172.34	152.78	170.90	194.96	158.27	109.94	45.04	31.88	23.59	13.36	12.72	10.75	7.33	3.41	1.61	2.41	0.71	0.77	0.53	0.39	1113.68
2007	182.31	125.45	116.43	132.47	143.73	103.37	67.05	27.19	19.32	14.37	8.17	7.81	6.62	4.52	2.11	1.00	1.49	0.44	0.48	0.58	964.91
2008	193.87	132.70	95.56	89.93	95.75	89.47	59.22	37.91	15.42	11.01	8.23	4.69	4.50	3.82	2.62	1.22	0.58	0.87	0.26	0.62	848.25
2009	147.87	141.13	101.15	74.19	66.92	63.84	55.94	36.68	23.57	9.64	6.91	5.18	2.97	2.85	2.43	1.66	0.78	0.37	0.55	0.56	745.19
2010	83.62	107.65	107.60	78.69	55.79	45.39	40.46	35.07	23.08	14.91	6.12	4.41	3.31	1.90	1.83	1.56	1.07	0.50	0.24	0.72	613.92
2011	73.49	60.88	82.10	83.93	60.08	39.45	30.51	27.02	23.53	15.56	10.09	4.16	3.00	2.26	1.30	1.26	1.07	0.74	0.35	0.66	521.44
2012	99.47	53.50	46.44	64.16	64.76	43.57	27.41	21.09	18.77	16.42	10.91	7.10	2.94	2.12	1.60	0.92	0.89	0.76	0.53	0.72	484.09
2013	110.27	72.42	40.81	36.26	49.25	46.38	29.77	18.62	14.39	12.87	11.31	7.54	4.92	2.04	1.48	1.12	0.65	0.62	0.53	0.87	462.14
2014	88.07	80.28	55.23	31.84	27.73	35.06	31.55	20.15	12.66	9.84	8.84	7.79	5.21	3.41	1.42	1.03	0.78	0.45	0.44	0.98	422.76
2015	51.27	64.11	61.22	43.04	24.18	19.25	22.91	20.42	13.09	8.27	6.45	5.82	5.14	3.45	2.26	0.94	0.68	0.52	0.30	0.95	354.28
2016	61.81	37.32	48.90	47.74	32.80	16.97	12.78	15.09	13.51	8.70	5.52	4.32	3.91	3.47	2.33	1.53	0.64	0.46	0.35	0.85	319.00
2017	36.01	45.00	28.46	38.09	36.20	22.79	11.14	8.33	9.87	8.88	5.75	3.66	2.87	2.60	2.31	1.56	1.02	0.43	0.31	0.81	266.08
2018	55.67	26.22	34.32	22.19	29.02	25.31	15.01	7.27	5.45	6.50	5.87	3.81	2.43	1.92	1.74	1.55	1.04	0.69	0.29	0.75	247.05
2019	101.41	40.53	20.00	26.80	17.04	20.67	17.06	10.04	4.88	3.68	4.40	3.99	2.60	1.66	1.31	1.20	1.07	0.72	0.47	0.72	280.27
2020	76.11	73.83	30.90	15.55	20.13	11.39	12.70	10.32	6.09	2.98	2.25	2.71	2.46	1.61	1.03	0.81	0.74	0.66	0.45	0.74	273.46
2021	76.11	55.41	56.31	24.10	11.88	14.25	7.66	8.49	6.93	4.11	2.02	1.53	1.84	1.68	1.10	0.71	0.56	0.51	0.46	0.82	276.48

Table 7. Estimated biomass at age (mt) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1969	111	138	155	162	161	152	141	127	114	100	87	76	65	56	48	41	34	29	24	120	1942
1970	111	138	155	163	161	153	141	128	114	101	88	76	66	56	48	41	34	29	25	121	1947
1971	111	138	155	162	161	153	141	128	114	101	88	76	66	56	48	41	34	29	25	121	1947
1972	111	138	155	162	160	152	140	127	114	100	87	76	65	56	48	41	34	29	24	120	1940
1973	111	138	155	162	160	152	140	127	113	100	87	76	65	56	48	40	34	29	24	120	1938
1974	111	138	155	162	160	151	139	126	112	99	86	75	65	55	47	40	34	29	24	119	1926
1975	111	138	155	162	159	149	137	124	110	97	85	74	63	54	46	39	33	28	24	117	1904
1976	111	138	155	161	158	148	135	121	108	95	83	72	62	53	45	39	33	28	23	114	1881
1977	111	138	155	161	157	146	132	118	105	92	80	70	60	52	44	37	32	27	23	111	1851
1978	111	138	155	160	155	143	129	114	101	88	77	67	57	49	42	36	30	26	22	106	1805
1979	111	138	154	159	150	133	118	104	91	79	69	59	51	44	37	32	27	23	19	94	1693
1980	75	138	154	158	147	128	109	95	82	71	61	53	45	39	33	28	24	20	17	83	1562
1981	125	93	154	158	146	125	104	87	74	64	55	47	40	34	29	25	21	18	15	73	1485
1982	108	154	103	158	146	124	102	83	68	58	49	42	35	30	26	22	18	16	13	65	1420
1983	116	134	172	104	138	113	91	73	58	48	40	33	28	24	20	17	15	12	10	51	1298
1984	132	143	149	175	93	110	85	67	53	42	34	28	23	20	17	14	12	10	8	41	1256
1985	122	164	159	149	150	70	78	59	46	36	28	23	19	15	13	11	9	8	6	32	1197
1986	240	151	182	161	131	118	52	57	42	32	25	19	16	13	11	9	7	6	5	25	1302
1987	246	297	168	184	140	101	86	37	40	29	22	17	13	10	8	7	6	5	4	20	1441
1988	351	305	330	167	155	102	69	57	24	26	19	14	11	8	7	5	4	4	3	15	1677
1989	275	434	336	322	134	105	65	43	35	15	15	11	8	6	5	4	3	3	2	10	1830
1990	149	341	479	329	261	92	67	40	26	21	9	9	7	5	4	3	2	2	1	7	1853
1991	311	184	375	463	256	167	55	39	23	15	12	5	5	4	3	2	2	1	1	4	1925
1992	134	385	204	372	390	187	115	37	25	15	9	7	3	3	2	2	1	1	1	3	1897
1993	191	166	433	213	351	311	132	78	24	17	10	6	5	2	2	1	1	1	1	2	1948
1994	283	238	187	453	202	282	224	91	53	16	11	6	4	3	1	1	1	1	1	2	2060
1995	286	352	267	195	421	157	196	149	60	34	10	7	4	3	2	1	1	1	0	1	2147
1996	231	355	396	280	187	349	117	140	105	42	24	7	5	3	2	1	1	1	0	1	2246
1997	166	287	400	415	270	159	271	88	103	76	30	17	5	3	2	1	1	0	0	1	2297
1998	200	206	323	420	401	231	125	205	65	76	55	22	12	4	2	1	1	1	0	1	2352
1999	178	249	232	340	408	349	186	97	157	49	57	41	16	9	3	2	1	1	0	1	2375
2000	160	221	280	243	326	344	268	138	71	113	35	40	29	11	6	2	1	1	0	1	2291
2001	251	199	249	293	232	272	263	198	100	51	80	25	28	20	8	4	1	1	0	1	2277
2002	244	312	224	261	284	202	222	208	155	77	39	61	19	21	15	6	3	1	1	1	2355
2003	224	303	350	234	245	230	151	160	148	109	54	27	42	13	14	10	4	2	1	1	2320
2004	152	278	340	366	220	199	172	109	114	104	76	37	18	29	9	10	7	3	1	1	2245
2005	104	189	313	356	346	180	150	125	78	80	73	52	26	13	19	6	7	5	2	2	2123
2006	85	129	213	327	334	279	133	106	87	54	55	49	35	17	8	13	4	4	3	2	1940
2007	90	106	145	222	304	263	198	91	71	58	35	36	32	23	11	5	8	2	3	3	1706
2008	96	112	119	151	202	227	175	127	57	44	36	22	22	19	14	7	3	5	1	4	1442
2009	73	119	126	124	141	162	165	123	87	39	30	24	14	14	13	9	4	2	3	3	1277
2010	41	91	134	132	118	115	119	117	85	60	26	20	16	10	10	8	6	3	1	4	1118
2011	36	51	102	141	127	100	90	90	87	63	44	19	14	11	7	7	6	4	2	4	1006
2012	49	45	58	107	137	111	81	70	69	66	47	33	14	11	8	5	5	4	3	4	928
2013	55	61	51	61	104	118	88	62	53	52	49	35	24	10	8	6	4	4	3	5	851
2014	44	68	69	53	59	89	93	67	47	40	38	36	25	17	7	6	4	3	3	6	772
2015	25	54	76	72	51	49	68	68	48	33	28	27	25	17	12	5	4	3	2	6	673
2016	31	32	61	80	69	43	38	50	50	35	24	20	19	17	12	8	4	3	2	5	602
2017	18	38	35	64	76	58	33	28	36	36	25	17	14	13	12	8	6	2	2	5	526
2018	28	22	43	37	61	64	44	24	20	26	25	17	12	10	9	8	6	4	2	4	468
2019	50	34	25	45	36	53	50	34	18	15	19	18	13	8	7	6	6	4	3	4	448
2020	38	62	38	26	43	29	37	34	23	12	10	12	12	8	5	4	4	4	3	4	409
2021	38	47	70	40	25	36	23	28	26	17	9	7	9	8	6	4	3	3	3	5	405

Table 8. Estimated biomass at age (1000 lb) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1969	245	304	342	357	355	335	311	280	251	220	192	168	143	123	106	90	75	64	53	265	4281
1970	245	304	342	359	355	337	311	282	251	223	194	168	146	123	106	90	75	64	55	267	4292
1971	245	304	342	357	355	337	311	282	251	223	194	168	146	123	106	90	75	64	55	267	4292
1972	245	304	342	357	353	335	309	280	251	220	192	168	143	123	106	90	75	64	53	265	4277
1973	245	304	342	357	353	335	309	280	249	220	192	168	143	123	106	88	75	64	53	265	4273
1974	245	304	342	357	353	333	306	278	247	218	190	165	143	121	104	88	75	64	53	262	4246
1975	245	304	342	357	351	328	302	273	243	214	187	163	139	119	101	86	73	62	53	258	4198
1976	245	304	342	355	348	326	298	267	238	209	183	159	137	117	99	86	73	62	51	251	4147
1977	245	304	342	355	346	322	291	260	231	203	176	154	132	115	97	82	71	60	51	245	4081
1978	245	304	342	353	342	315	284	251	223	194	170	148	126	108	93	79	66	57	49	234	3979
1979	245	304	340	351	331	293	260	229	201	174	152	130	112	97	82	71	60	51	42	207	3732
1980	165	304	340	348	324	282	240	209	181	157	134	117	99	86	73	62	53	44	37	183	3444
1981	276	205	340	348	322	276	229	192	163	141	121	104	88	75	64	55	46	40	33	161	3274
1982	238	340	227	348	322	273	225	183	150	128	108	93	77	66	57	49	40	35	29	143	3131
1983	256	295	379	229	304	249	201	161	128	106	88	73	62	53	44	37	33	26	22	112	2862
1984	291	315	328	386	205	243	187	148	117	93	75	62	51	44	37	31	26	22	18	90	2769
1985	269	362	351	328	331	154	172	130	101	79	62	51	42	33	29	24	20	18	13	71	2639
1986	529	333	401	355	289	260	115	126	93	71	55	42	35	29	24	20	15	13	11	55	2870
1987	542	655	370	406	309	223	190	82	88	64	49	37	29	22	18	15	13	11	9	44	3177
1988	774	672	728	368	342	225	152	126	53	57	42	31	24	18	15	11	9	9	7	33	3697
1989	606	957	741	710	295	231	143	95	77	33	33	24	18	13	11	9	7	7	4	22	4034
1990	328	752	1056	725	575	203	148	88	57	46	20	20	15	11	9	7	4	4	2	15	4085
1991	686	406	827	1021	564	368	121	86	51	33	26	11	11	9	7	4	4	2	2	9	4244
1992	295	849	450	820	860	412	254	82	55	33	20	15	7	7	4	4	2	2	2	7	4182
1993	421	366	955	470	774	686	291	172	53	37	22	13	11	4	4	2	2	2	2	4	4295
1994	624	525	412	999	445	622	494	201	117	35	24	13	9	7	2	2	2	2	2	4	4542
1995	631	776	589	430	928	346	432	328	132	75	22	15	9	7	4	2	2	2	0	2	4733
1996	509	783	873	617	412	769	258	309	231	93	53	15	11	7	4	2	2	2	0	2	4952
1997	366	633	882	915	595	351	597	194	227	168	66	37	11	7	4	2	2	0	0	2	5064
1998	441	454	712	926	884	509	276	452	143	168	121	49	26	9	4	2	2	2	0	2	5185
1999	392	549	511	750	899	769	410	214	346	108	126	90	35	20	7	4	2	2	0	2	5236
2000	353	487	617	536	719	758	591	304	157	249	77	88	64	24	13	4	2	2	0	2	5051
2001	553	439	549	646	511	600	580	437	220	112	176	55	62	44	18	9	2	2	0	2	5020
2002	538	688	494	575	626	445	489	459	342	170	86	134	42	46	33	13	7	2	2	2	5192
2003	494	668	772	516	540	507	333	353	326	240	119	60	93	29	31	22	9	4	2	2	5115
2004	335	613	750	807	485	439	379	240	251	229	168	82	40	64	20	22	15	7	2	2	4949
2005	229	417	690	785	763	397	331	276	172	176	161	115	57	29	42	13	15	11	4	4	4680
2006	187	284	470	721	736	615	293	234	192	119	121	108	77	37	18	29	9	9	7	4	4277
2007	198	234	320	489	670	580	437	201	157	128	77	79	71	51	24	11	18	4	7	7	3761
2008	212	247	262	333	445	500	386	280	126	97	79	49	49	42	31	15	7	11	2	9	3179
2009	161	262	278	273	311	357	364	271	192	86	66	53	31	31	29	20	9	4	7	7	2815
2010	90	201	295	291	260	254	262	258	187	132	57	44	35	22	22	18	13	7	2	9	2465
2011	79	112	225	311	280	220	198	198	192	139	97	42	31	24	15	15	13	9	4	9	2218
2012	108	99	128	236	302	245	179	154	152	146	104	73	31	24	18	11	11	9	7	9	2046
2013	121	134	112	134	229	260	194	137	117	115	108	77	53	22	18	13	9	9	7	11	1876
2014	97	150	152	117	130	196	205	148	104	88	84	79	55	37	15	13	9	7	7	13	1702
2015	55	119	168	159	112	108	150	150	106	73	62	60	55	37	26	11	9	7	4	13	1484
2016	68	71	134	176	152	95	84	110	110	77	53	44	42	37	26	18	9	7	4	11	1327
2017	40	84	77	141	168	128	73	62	79	79	55	37	31	29	26	18	13	4	4	11	1160
2018	62	49	95	82	134	141	97	53	44	57	55	37	26	22	20	18	13	9	4	9	1032
2019	110	75	55	99	79	117	110	75	40	33	42	40	29	18	15	13	13	9	7	9	988
2020	84	137	84	57	95	64	82	75	51	26	22	26	26	18	11	9	9	9	7	9	902
2021	84	104	154	88	55	79	51	62	57	37	20	15	20	18	13	9	7	7	7	11	893

Table 9. Estimated time series of status indicators, fishing mortality, and biomass. Fishing mortality rate is apical F. Total biomass (B, mt) is at the start of the year, and spawning biomass (SSB, mt) at the time of peak spawning (May 1). The $MSST_{\mathrm{F40}}$ is defined by $75\% SSB_{\mathrm{F40}}$. Also shown is the proportion male (prop.m) in the population.

Year	F	F/F_{40}	B	B/B_{unfished}	SSB	SSB/SSB_{F40}	$SSB/MSST_{\mathrm{F40}}$	prop.m
1969	0.035	0.126	1942	0.620	1595	1.492	1.989	0.163
1970	0.039	0.140	1947	0.622	1599	1.496	1.995	0.164
1971	0.043	0.156	1947	0.622	1597	1.494	1.992	0.164
1972	0.041	0.148	1940	0.620	1592	1.489	1.986	0.163
1973	0.048	0.172	1938	0.619	1586	1.484	1.979	0.163
1974	0.057	0.205	1926	0.615	1571	1.470	1.960	0.162
1975	0.061	0.218	1904	0.608	1550	1.450	1.933	0.160
1976	0.069	0.248	1881	0.601	1525	1.426	1.902	0.159
1977	0.086	0.310	1851	0.591	1489	1.394	1.858	0.156
1978	0.153	0.552	1805	0.576	1421	1.329	1.772	0.152
1979	0.160	0.576	1693	0.541	1318	1.233	1.644	0.142
1980	0.168	0.605	1562	0.499	1226	1.148	1.530	0.144
1981	0.167	0.600	1485	0.474	1143	1.070	1.426	0.127
1982	0.275	0.991	1420	0.454	1044	0.976	1.302	0.118
1983	0.246	0.885	1298	0.414	940	0.880	1.173	0.102
1984	0.303	1.091	1256	0.401	876	0.819	1.092	0.087
1985	0.262	0.942	1197	0.382	830	0.776	1.035	0.077
1986	0.282	1.015	1302	0.416	829	0.776	1.035	0.055
1987	0.345	1.242	1441	0.460	861	0.805	1.074	0.046
1988	0.428	1.541	1677	0.535	939	0.879	1.172	0.035
1989	0.419	1.507	1830	0.584	1061	0.992	1.323	0.034
1990	0.491	1.766	1853	0.592	1181	1.105	1.473	0.040
1991	0.344	1.238	1925	0.615	1240	1.160	1.546	0.036
1992	0.330	1.189	1897	0.606	1302	1.219	1.625	0.045
1993	0.313	1.125	1948	0.622	1381	1.292	1.722	0.051
1994	0.349	1.255	2060	0.658	1394	1.304	1.738	0.048
1995	0.277	0.998	2147	0.686	1422	1.331	1.775	0.047
1996	0.231	0.833	2246	0.717	1538	1.439	1.919	0.052
1997	0.222	0.798	2297	0.734	1669	1.562	2.082	0.061
1998	0.191	0.688	2352	0.751	1755	1.642	2.190	0.066
1999	0.243	0.875	2375	0.759	1770	1.656	2.208	0.074
2000	0.242	0.872	2291	0.732	1714	1.604	2.138	0.080
2001	0.174	0.627	2277	0.727	1673	1.565	2.087	0.075
2002	0.267	0.961	2355	0.752	1657	1.550	2.067	0.074
2003	0.267	0.959	2320	0.741	1629	1.524	2.032	0.072
2004	0.262	0.945	2245	0.717	1633	1.528	2.037	0.077
2005	0.282	1.014	2123	0.678	1608	1.505	2.006	0.086
2006	0.324	1.166	1940	0.619	1496	1.399	1.866	0.096
2007	0.390	1.405	1706	0.545	1293	1.210	1.613	0.101
2008	0.298	1.074	1442	0.460	1091	1.020	1.360	0.097
2009	0.286	1.031	1277	0.408	965	0.903	1.204	0.101
2010	0.222	0.801	1118	0.357	878	0.822	1.096	0.113
2011	0.188	0.676	1006	0.321	817	0.764	1.019	0.126
2012	0.205	0.739	928	0.297	746	0.698	0.931	0.131
2013	0.209	0.752	851	0.272	666	0.623	0.831	0.129
2014	0.254	0.916	772	0.247	593	0.554	0.739	0.130
2015	0.237	0.852	673	0.215	528	0.494	0.659	0.138
2016	0.248	0.892	602	0.192	475	0.444	0.592	0.136
2017	0.246	0.886	526	0.168	420	0.393	0.524	0.144
2018	0.221	0.796	468	0.149	371	0.347	0.462	0.137
2019	0.323	1.164	448	0.143	324	0.303	0.404	0.109
2020	0.222	0.799	409	0.131	291	0.273	0.363	0.094
2021	0.224	0.805	405	0.129	290	0.272	0.362	0.087

Table 10. Selectivity at age for SERFS index (CVID). Selectivity at age in block 2 (1992–2021) for commercial (COM) and recreational fleets (REC). Selectivity of removals averaged (Sel.avg) across fleets in the terminal three years of the assessment (2019–2021), as used in computation of benchmarks and projections.

Age	CVID	COM	REC	Sel.avg
1	0.016	0.001	0.001	0.001
2	0.074	0.004	0.009	0.005
3	0.283	0.025	0.073	0.039
4	0.660	0.148	0.404	0.226
5	0.905	0.542	0.853	0.637
6	0.979	0.890	0.980	0.918
7	0.996	0.982	0.998	0.987
8	0.999	0.997	1.000	0.998
9	1.000	1.000	1.000	1.000
10	1.000	1.000	1.000	1.000
11	1.000	1.000	1.000	1.000
12	1.000	1.000	1.000	1.000
13	1.000	1.000	1.000	1.000
14	1.000	1.000	1.000	1.000
15	1.000	1.000	1.000	1.000
16	1.000	1.000	1.000	1.000
17	1.000	1.000	1.000	1.000
18	1.000	1.000	1.000	1.000
19	1.000	1.000	1.000	1.000
20	1.000	1.000	1.000	1.000

Table 11. Estimated time series of fully selected fishing mortality rates (landings + dead discards) for commercial (F.COM) and recreational (F.REC) fleets. Also shown is Full F, the maximum F at age summed across fleets, which may not equal the sum of fully selected F's if dome-shaped selectivities are utilized.

Year	F.COM	F.REC	Full F
1969	0.012	0.023	0.035
1970	0.015	0.024	0.039
1971	0.017	0.026	0.043
1972	0.013	0.028	0.041
1973	0.017	0.031	0.048
1974	0.023	0.034	0.057
1975	0.024	0.036	0.061
1976	0.031	0.037	0.069
1977	0.047	0.039	0.086
1978	0.112	0.041	0.153
1979	0.116	0.044	0.160
1980	0.121	0.048	0.168
1981	0.125	0.041	0.167
1982	0.216	0.060	0.275
1983	0.212	0.034	0.246
1984	0.236	0.067	0.303
1985	0.205	0.056	0.262
1986	0.241	0.041	0.282
1987	0.287	0.058	0.345
1988	0.318	0.110	0.428
1989	0.328	0.091	0.419
1990	0.378	0.113	0.491
1991	0.264	0.080	0.344
1992	0.237	0.093	0.330
1993	0.221	0.091	0.313
1994	0.212	0.137	0.349
1995	0.222	0.055	0.277
1996	0.175	0.056	0.231
1997	0.168	0.054	0.222
1998	0.137	0.054	0.191
1999	0.178	0.066	0.243
2000	0.136	0.107	0.242
2001	0.104	0.071	0.174
2002	0.112	0.155	0.267
2003	0.133	0.133	0.267
2004	0.139	0.124	0.262
2005	0.149	0.133	0.282
2006	0.175	0.149	0.324
2007	0.202	0.188	0.390
2008	0.170	0.128	0.298
2009	0.193	0.093	0.286
2010	0.151	0.071	0.222
2011	0.138	0.050	0.188
2012	0.145	0.060	0.205
2013	0.136	0.073	0.209
2014	0.181	0.074	0.254
2015	0.166	0.071	0.237
2016	0.165	0.083	0.248
2017	0.180	0.066	0.246
2018	0.172	0.049	0.221
2019	0.247	0.076	0.323
2020	0.153	0.069	0.222
2021	0.139	0.085	0.224

Table 12. Estimated instantaneous fishing mortality rate (per yr) at age.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1969	0.001	0.003	0.009	0.021	0.031	0.034	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
1970	0.001	0.003	0.010	0.023	0.034	0.038	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
1971	0.001	0.003	0.011	0.026	0.038	0.042	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
1972	0.001	0.003	0.011	0.025	0.036	0.040	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
1973	0.001	0.004	0.012	0.029	0.042	0.046	0.047	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048
1974	0.001	0.004	0.014	0.034	0.050	0.055	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
1975	0.001	0.005	0.015	0.036	0.053	0.059	0.060	0.060	0.060	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
1976	0.001	0.005	0.017	0.040	0.060	0.067	0.068	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069
1977	0.001	0.006	0.019	0.049	0.075	0.084	0.085	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086
1978	0.002	0.008	0.030	0.083	0.133	0.149	0.152	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153
1979	0.002	0.008	0.031	0.087	0.138	0.155	0.159	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160
1980	0.002	0.008	0.033	0.092	0.146	0.163	0.167	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168
1981	0.002	0.008	0.032	0.090	0.144	0.162	0.166	0.166	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167
1982	0.003	0.012	0.051	0.148	0.238	0.268	0.274	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275
1983	0.002	0.009	0.042	0.129	0.212	0.239	0.245	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246
1984	0.003	0.014	0.056	0.163	0.262	0.295	0.301	0.303	0.303	0.303	0.303	0.303	0.303	0.303	0.303	0.303	0.303	0.303	0.303	0.303
1985	0.003	0.012	0.048	0.140	0.226	0.254	0.260	0.261	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262
1986	0.002	0.011	0.048	0.148	0.243	0.274	0.281	0.282	0.282	0.282	0.282	0.282	0.282	0.282	0.282	0.282	0.282	0.282	0.282	0.282
1987	0.003	0.014	0.060	0.183	0.298	0.336	0.343	0.345	0.345	0.345	0.345	0.345	0.345	0.345	0.345	0.345	0.345	0.345	0.345	0.345
1988	0.005	0.021	0.082	0.233	0.370	0.416	0.426	0.428	0.428	0.428	0.428	0.428	0.428	0.428	0.428	0.428	0.428	0.428	0.428	0.428
1989	0.004	0.019	0.077	0.225	0.362	0.407	0.416	0.418	0.418	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419
1990	0.005	0.023	0.091	0.264	0.424	0.477	0.488	0.490	0.490	0.490	0.491	0.491	0.491	0.491	0.491	0.491	0.491	0.491	0.491	0.491
1991	0.004	0.016	0.064	0.186	0.297	0.334	0.342	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344
1992	0.000	0.002	0.013	0.073	0.208	0.302	0.326	0.330	0.330	0.330	0.330	0.330	0.330	0.330	0.330	0.330	0.330	0.330	0.330	0.330
1993	0.000	0.002	0.012	0.070	0.198	0.286	0.308	0.312	0.312	0.312	0.312	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313
1994	0.000	0.002	0.015	0.087	0.232	0.323	0.344	0.348	0.348	0.349	0.349	0.349	0.349	0.349	0.349	0.349	0.349	0.349	0.349	0.349
1995	0.000	0.001	0.010	0.055	0.168	0.252	0.273	0.277	0.277	0.277	0.277	0.277	0.277	0.277	0.277	0.277	0.277	0.277	0.277	0.277
1996	0.000	0.001	0.008	0.048	0.143	0.211	0.228	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231
1997	0.000	0.001	0.008	0.047	0.137	0.202	0.219	0.221	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222
1998	0.000	0.001	0.007	0.042	0.120	0.175	0.188	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191
1999	0.000	0.001	0.009	0.053	0.152	0.222	0.240	0.243	0.243	0.243	0.243	0.243	0.243	0.243	0.243	0.243	0.243	0.243	0.243	0.243
2000	0.000	0.001	0.011	0.063	0.164	0.225	0.239	0.242	0.242	0.242	0.242	0.242	0.242	0.242	0.242	0.242	0.242	0.242	0.242	0.242
2001	0.000	0.001	0.008	0.044	0.116	0.161	0.172	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.174
2002	0.000	0.002	0.014	0.079	0.193	0.251	0.264	0.266	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.267
2003	0.000	0.002	0.013	0.073	0.186	0.249	0.264	0.266	0.266	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.267
2004	0.000	0.002	0.012	0.070	0.181	0.245	0.260	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262
2005	0.000	0.002	0.013	0.076	0.194	0.263	0.279	0.281	0.282	0.282	0.282	0.282	0.282	0.282	0.282	0.282	0.282	0.282	0.282	0.282
2006	0.000	0.002	0.015	0.086	0.222	0.302	0.321	0.323	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324
2007	0.000	0.002	0.019	0.106	0.270	0.364	0.386	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.390
2008	0.000	0.002	0.014	0.077	0.201	0.277	0.295	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298
2009	0.000	0.002	0.012	0.066	0.184	0.263	0.283	0.286	0.286	0.286	0.286	0.286	0.286	0.286	0.286	0.286	0.286	0.286	0.286	0.286
2010	0.000	0.001	0.009	0.051	0.143	0.204	0.220	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222
2011	0.000	0.001	0.007	0.040	0.117	0.172	0.185	0.187	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188
2012	0.000	0.001	0.008	0.046	0.130	0.188	0.203	0.205	0.205	0.205	0.205	0.205	0.205	0.205	0.205	0.205	0.205	0.205	0.205	0.205
2013	0.000	0.001	0.009	0.049	0.136	0.192	0.206	0.208	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209
2014	0.000	0.001	0.010	0.056	0.161	0.233	0.251	0.254	0.254	0.254	0.254	0.254	0.254	0.254	0.254	0.254	0.254	0.254	0.254	0.254
2015	0.000	0.001	0.009	0.053	0.150	0.217	0.233	0.236	0.236	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237
2016	0.000	0.001	0.010	0.058	0.160	0.228	0.245	0.247	0.248	0.248	0.248	0.248	0.248	0.248	0.248	0.248	0.248	0.248	0.248	0.248
2017	0.000	0.001	0.009	0.053	0.154	0.225	0.243	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246
2018	0.000	0.001	0.008	0.045	0.135	0.201	0.218	0.221	0.221	0.221	0.221	0.221	0.221	0.221	0.221	0.221	0.221	0.221	0.221	0.221
2019	0.000	0.002	0.012	0.067	0.199	0.295	0.319	0.323	0.323	0.323	0.323	0.323	0.323	0.323	0.323	0.323	0.323	0.323	0.323	0.323
2020	0.000	0.001	0.009	0.050	0.142	0.204	0.219	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222
2021	0.000	0.001	0.010	0.055	0.148	0.207	0.221	0.223	0.224	0.224	0.224	0.224	0.224	0.224	0.224	0.224	0.224	0.224	0.224	0.224

Table 13. Estimated time series of removals (landings + dead discards) in number (1000 fish) for commercial (COM) and recreational (REC) fleets.

Year	COM	REC	Total
1969	4.72	10.71	15.44
1970	6.26	10.78	17.03
1971	7.00	11.85	18.85
1972	5.12	12.90	18.02
1973	6.79	13.98	20.76
1974	9.35	15.04	24.39
1975	9.47	16.11	25.58
1976	12.11	16.31	28.42
1977	17.85	16.49	34.34
1978	40.01	16.66	56.67
1979	38.29	16.82	55.12
1980	37.35	16.99	54.34
1981	36.68	14.00	50.68
1982	57.42	18.42	75.84
1983	50.00	9.54	59.55
1984	51.64	17.90	69.54
1985	43.18	14.73	57.91
1986	50.40	11.13	61.53
1987	60.51	16.37	76.88
1988	68.62	34.28	102.91
1989	80.13	32.57	112.70
1990	106.78	45.29	152.07
1991	86.78	35.35	122.13
1992	52.07	30.75	82.81
1993	55.78	31.82	87.60
1994	54.29	48.94	103.23
1995	59.78	20.09	79.87
1996	48.69	20.42	69.11
1997	48.74	21.80	70.54
1998	45.06	24.87	69.93
1999	64.28	31.37	95.65
2000	48.84	48.53	97.37
2001	36.00	30.73	66.73
2002	37.04	64.39	101.43
2003	40.60	51.55	92.15
2004	40.32	47.65	87.96
2005	43.94	53.42	97.36
2006	51.90	59.29	111.20
2007	55.52	66.36	121.87
2008	40.86	37.87	78.73
2009	40.03	23.51	63.53
2010	27.65	15.96	43.61
2011	23.66	10.69	34.35
2012	23.91	12.14	36.05
2013	20.55	12.98	33.53
2014	23.16	10.96	34.12
2015	17.72	9.00	26.71
2016	15.56	9.75	25.31
2017	15.72	7.19	22.91
2018	13.85	4.75	18.60
2019	16.93	6.20	23.13
2020	8.90	4.77	13.67
2021	7.22	5.48	12.70

Table 14. Estimated time series of removals (landings + dead discards) in whole weight (1000 lb) for commercial (COM) and recreational (REC) fleets.

Year	COM	REC	Total
1969	33.72	71.21	104.93
1970	44.71	71.64	116.34
1971	50.02	78.76	128.79
1972	36.55	85.72	122.27
1973	48.43	92.80	141.22
1974	66.61	99.70	166.31
1975	67.33	106.46	173.78
1976	85.86	107.30	193.16
1977	125.90	107.83	233.73
1978	279.74	107.69	387.43
1979	263.74	106.62	370.36
1980	252.66	105.70	358.36
1981	243.54	85.49	329.03
1982	374.91	110.08	484.99
1983	319.14	54.85	373.99
1984	315.91	97.80	413.70
1985	252.88	76.78	329.65
1986	283.83	54.98	338.80
1987	325.68	75.73	401.41
1988	345.74	144.93	490.67
1989	374.31	129.58	503.89
1990	481.76	179.44	661.20
1991	392.90	144.01	536.91
1992	285.27	157.89	443.16
1993	314.20	169.19	483.39
1994	314.16	263.93	578.09
1995	350.14	110.73	460.87
1996	292.45	114.68	407.12
1997	294.98	121.65	416.63
1998	271.49	138.95	410.44
1999	391.09	179.04	570.13
2000	304.21	285.29	589.50
2001	230.36	184.64	415.00
2002	241.03	392.07	633.10
2003	265.96	314.31	580.27
2004	262.23	284.46	546.68
2005	279.37	312.27	591.64
2006	325.80	345.79	671.58
2007	349.76	392.74	742.51
2008	262.25	229.92	492.17
2009	263.77	146.38	410.14
2010	185.80	100.59	286.40
2011	160.46	67.64	228.10
2012	163.14	77.83	240.97
2013	142.72	85.61	228.33
2014	165.47	74.37	239.85
2015	128.83	61.21	190.04
2016	112.32	65.09	177.42
2017	111.51	47.39	158.90
2018	97.93	31.60	129.52
2019	120.97	41.70	162.66
2020	63.82	32.06	95.89
2021	51.68	36.21	87.89

Table 15. Estimated total removals (landings + dead discards) at age in numbers (1000 fish)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1969	0.15	0.41	1.03	1.83	2.08	1.83	1.49	1.20	0.97	0.79	0.64	0.53	0.43	0.36	0.29	0.24	0.20	0.16	0.14	0.66
1970	0.15	0.43	1.09	2.00	2.31	2.03	1.66	1.34	1.08	0.88	0.72	0.59	0.48	0.40	0.33	0.27	0.22	0.18	0.15	0.73
1971	0.17	0.47	1.20	2.21	2.56	2.25	1.84	1.48	1.20	0.97	0.79	0.65	0.53	0.44	0.36	0.30	0.25	0.20	0.17	0.81
1972	0.18	0.49	1.22	2.15	2.42	2.12	1.73	1.40	1.13	0.92	0.75	0.61	0.50	0.41	0.34	0.28	0.23	0.19	0.16	0.77
1973	0.19	0.55	1.37	2.46	2.81	2.46	2.01	1.62	1.31	1.07	0.87	0.71	0.58	0.48	0.39	0.32	0.27	0.22	0.18	0.89
1974	0.22	0.61	1.57	2.89	3.32	2.91	2.37	1.91	1.54	1.26	1.02	0.84	0.69	0.56	0.46	0.38	0.32	0.26	0.22	1.04
1975	0.23	0.66	1.68	3.06	3.50	3.04	2.47	1.99	1.61	1.31	1.06	0.87	0.71	0.59	0.48	0.40	0.33	0.27	0.22	1.09
1976	0.24	0.70	1.83	3.42	3.94	3.41	2.75	2.21	1.78	1.45	1.18	0.96	0.79	0.65	0.54	0.44	0.36	0.30	0.25	1.20
1977	0.27	0.79	2.12	4.15	4.85	4.19	3.36	2.68	2.15	1.74	1.42	1.16	0.95	0.78	0.64	0.53	0.44	0.36	0.30	1.45
1978	0.34	1.08	3.22	6.90	8.28	7.09	5.64	4.46	3.56	2.88	2.34	1.91	1.56	1.29	1.06	0.87	0.72	0.60	0.49	2.38
1979	0.36	1.14	3.38	7.13	8.30	6.89	5.38	4.22	3.35	2.68	2.17	1.77	1.45	1.19	0.98	0.81	0.67	0.55	0.46	2.21
1980	0.26	1.21	3.56	7.46	8.57	6.91	5.23	4.03	3.17	2.52	2.03	1.65	1.35	1.11	0.91	0.75	0.62	0.51	0.43	2.05
1981	0.39	0.76	3.42	7.31	8.42	6.71	4.93	3.68	2.84	2.24	1.79	1.45	1.18	0.97	0.79	0.65	0.54	0.45	0.37	1.79
1982	0.52	1.98	3.65	11.67	13.30	10.48	7.58	5.49	4.11	3.18	2.52	2.02	1.64	1.34	1.10	0.90	0.75	0.62	0.51	2.47
1983	0.40	1.31	5.02	6.77	11.33	8.63	6.13	4.37	3.17	2.38	1.85	1.47	1.19	0.96	0.79	0.65	0.53	0.44	0.37	1.77
1984	0.71	2.03	5.80	14.11	9.19	10.05	6.89	4.83	3.45	2.52	1.90	1.48	1.18	0.95	0.77	0.63	0.52	0.43	0.36	1.72
1985	0.56	1.99	5.34	10.52	13.08	5.65	5.56	3.76	2.64	1.89	1.39	1.05	0.82	0.66	0.53	0.43	0.35	0.29	0.24	1.16
1986	0.98	1.73	6.14	11.92	12.21	10.14	3.95	3.84	2.60	1.83	1.32	0.97	0.73	0.58	0.46	0.37	0.30	0.25	0.21	0.99
1987	1.31	4.35	7.05	16.51	15.56	10.38	7.74	2.97	2.89	1.97	1.39	1.00	0.74	0.56	0.44	0.35	0.29	0.23	0.19	0.93
1988	2.91	6.49	18.57	18.71	20.68	12.54	7.48	5.49	2.11	2.06	1.41	1.00	0.72	0.53	0.41	0.32	0.26	0.21	0.17	0.82
1989	2.03	8.42	17.82	34.90	17.59	12.65	6.85	4.02	2.96	1.14	1.12	0.77	0.55	0.40	0.29	0.22	0.18	0.14	0.11	0.54
1990	1.33	7.92	29.94	41.25	38.85	12.57	8.06	4.29	2.52	1.86	0.72	0.71	0.49	0.35	0.25	0.19	0.14	0.11	0.09	0.42
1991	1.96	3.03	16.70	42.20	28.38	17.11	4.93	3.10	1.66	0.98	0.72	0.28	0.28	0.19	0.14	0.10	0.07	0.06	0.04	0.20
1992	0.05	0.69	1.84	13.98	31.44	17.53	9.92	2.83	1.79	0.96	0.57	0.42	0.16	0.16	0.11	0.08	0.06	0.04	0.03	0.15
1993	0.07	0.28	3.74	7.70	27.06	27.81	10.91	5.76	1.63	1.03	0.56	0.33	0.25	0.10	0.10	0.07	0.05	0.03	0.03	0.11
1994	0.13	0.50	2.02	20.16	17.94	28.02	20.26	7.41	3.89	1.11	0.70	0.38	0.23	0.17	0.07	0.07	0.05	0.03	0.02	0.09
1995	0.09	0.48	1.81	5.61	27.88	12.57	14.56	9.92	3.62	1.90	0.54	0.35	0.19	0.11	0.08	0.03	0.03	0.02	0.02	0.06
1996	0.06	0.43	2.37	7.11	10.69	23.86	7.41	7.97	5.40	1.97	1.04	0.30	0.19	0.10	0.06	0.05	0.02	0.02	0.01	0.04
1997	0.04	0.33	2.31	10.15	14.87	10.46	16.52	4.79	5.12	3.48	1.28	0.68	0.19	0.12	0.07	0.04	0.03	0.01	0.01	0.04
1998	0.05	0.21	1.69	9.29	19.56	13.32	6.64	9.79	2.82	3.03	2.06	0.76	0.40	0.12	0.07	0.04	0.02	0.02	0.01	0.03
1999	0.05	0.32	1.52	9.35	24.71	25.01	12.32	5.76	8.45	2.44	2.63	1.80	0.66	0.35	0.10	0.07	0.04	0.02	0.02	0.03
2000	0.05	0.34	2.22	7.98	21.26	24.88	17.72	8.15	3.78	5.57	1.62	1.75	1.20	0.44	0.24	0.07	0.04	0.02	0.01	0.03
2001	0.06	0.21	1.37	6.73	10.92	14.54	12.89	8.71	3.99	1.86	2.75	0.80	0.87	0.60	0.22	0.12	0.03	0.02	0.01	0.02
2002	0.10	0.59	2.24	10.66	21.40	16.16	16.00	13.42	9.03	4.15	1.94	2.88	0.84	0.91	0.63	0.23	0.13	0.04	0.02	0.04
2003	0.08	0.54	3.25	8.90	17.83	18.23	10.86	10.30	8.63	5.83	2.69	1.26	1.88	0.55	0.60	0.41	0.15	0.08	0.02	0.04
2004	0.05	0.47	3.02	13.36	15.65	15.55	12.20	6.92	6.55	5.50	3.73	1.73	0.81	1.21	0.36	0.39	0.27	0.10	0.05	0.04
2005	0.04	0.35	2.98	13.91	26.20	14.99	11.30	8.42	4.76	4.52	3.82	2.60	1.21	0.57	0.85	0.25	0.27	0.19	0.07	0.07
2006	0.04	0.27	2.30	14.46	28.62	26.18	11.34	8.11	6.02	3.42	3.26	2.76	1.88	0.88	0.41	0.62	0.18	0.20	0.14	0.10
2007	0.05	0.27	1.93	11.96	30.91	28.88	19.74	8.09	5.77	4.30	2.45	2.34	1.99	1.36	0.63	0.30	0.45	0.13	0.14	0.17
2008	0.04	0.21	1.15	5.98	15.86	19.78	13.88	8.99	3.67	2.63	1.96	1.12	1.08	0.92	0.63	0.29	0.14	0.21	0.06	0.15
2009	0.03	0.19	1.04	4.27	10.22	13.50	12.64	8.39	5.42	2.22	1.59	1.20	0.69	0.66	0.56	0.39	0.18	0.09	0.13	0.13
2010	0.01	0.11	0.85	3.52	6.73	7.66	7.31	6.42	4.24	2.75	1.13	0.81	0.61	0.35	0.34	0.29	0.20	0.09	0.04	0.13
2011	0.01	0.05	0.51	2.99	6.03	5.67	4.72	4.24	3.71	2.46	1.60	0.66	0.48	0.36	0.21	0.20	0.17	0.12	0.06	0.11
2012	0.01	0.05	0.33	2.57	7.15	6.82	4.60	3.59	3.21	2.81	1.87	1.22	0.51	0.37	0.28	0.16	0.15	0.13	0.09	0.12
2013	0.01	0.07	0.31	1.57	5.67	7.41	5.08	3.22	2.50	2.24	1.97	1.32	0.86	0.36	0.26	0.20	0.11	0.11	0.09	0.15
2014	0.01	0.09	0.48	1.57	3.74	6.66	6.42	4.16	2.62	2.04	1.84	1.62	1.09	0.71	0.30	0.21	0.16	0.09	0.09	0.21
2015	0.01	0.07	0.50	2.00	3.06	3.43	4.37	3.95	2.54	1.61	1.26	1.14	1.01	0.67	0.44	0.18	0.13	0.10	0.06	0.19
2016	0.01	0.04	0.44	2.41	4.40	3.16	2.54	3.04	2.73	1.77	1.12	0.88	0.80	0.71	0.47	0.31	0.13	0.09	0.07	0.17
2017	0.01	0.05	0.23	1.78	4.69	4.19	2.20	1.67	1.98	1.79	1.16	0.74	0.58	0.53	0.47	0.32	0.21	0.09	0.06	0.16
2018	0.01	0.02	0.24	0.88	3.33	4.21	2.69	1.32	1.00	1.19	1.08	0.70	0.45	0.35	0.32	0.29	0.19	0.13	0.05	0.14
2019	0.02	0.06	0.21	1.57	2.79	4.82	4.28	2.55	1.25	0.94	1.13	1.02	0.67	0.43	0.34	0.31	0.27	0.19	0.12	0.18
2020	0.01	0.08	0.24	0.69	2.41	1.92	2.29	1.89	1.12	0.55	0.41	0.50	0.45	0.30	0.19	0.15	0.14	0.12	0.08	0.14
2021	0.01	0.06	0.48	1.16	1.48	2.43	1.39	1.56	1.28	0.76	0.37	0.28	0.34	0.31	0.20	0.13	0.10	0.10	0.09	0.15

Table 16. Estimated removals (landings + dead discards) at age in whole weight (1000 lb)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1969	0.16	0.77	2.82	6.76	9.70	10.24	9.72	8.87	7.94	7.02	6.14	5.33	4.60	3.94	3.37	2.86	2.43	2.05	1.73	8.49
1970	0.16	0.80	2.99	7.39	10.76	11.39	10.81	9.87	8.84	7.81	6.83	5.93	5.11	4.39	3.74	3.18	2.70	2.28	1.92	9.44
1971	0.18	0.88	3.31	8.17	11.90	12.60	11.96	10.93	9.78	8.65	7.57	6.57	5.66	4.86	4.15	3.53	2.99	2.53	2.13	10.46
1972	0.19	0.91	3.34	7.92	11.29	11.89	11.29	10.33	9.25	8.18	7.15	6.21	5.35	4.59	3.92	3.33	2.83	2.39	2.01	9.89
1973	0.21	1.02	3.76	9.09	13.07	13.78	13.06	11.93	10.70	9.46	8.27	7.18	6.19	5.31	4.53	3.86	3.27	2.76	2.33	11.44
1974	0.23	1.14	4.31	10.66	15.47	16.29	15.42	14.06	12.59	11.14	9.75	8.46	7.30	6.26	5.34	4.54	3.85	3.26	2.75	13.48
1975	0.25	1.23	4.61	11.31	16.29	17.05	16.09	14.64	13.10	11.58	10.14	8.81	7.59	6.51	5.56	4.73	4.01	3.39	2.86	14.03
1976	0.27	1.31	5.02	12.63	18.34	19.13	17.93	16.27	14.53	12.82	11.23	9.75	8.41	7.22	6.16	5.24	4.44	3.75	3.17	15.54
1977	0.29	1.46	5.83	15.32	22.59	23.48	21.87	19.72	17.55	15.46	13.51	11.73	10.13	8.69	7.42	6.31	5.35	4.52	3.81	18.71
1978	0.37	2.00	8.84	25.48	38.54	39.74	36.69	32.85	29.05	25.51	22.25	19.29	16.64	14.29	12.20	10.38	8.80	7.44	6.27	30.78
1979	0.39	2.12	9.27	26.33	38.66	38.62	35.03	31.08	27.29	23.82	20.72	17.93	15.44	13.25	11.32	9.63	8.16	6.90	5.82	28.57
1980	0.28	2.25	9.79	27.56	39.92	38.73	34.03	29.66	25.81	22.37	19.34	16.68	14.34	12.28	10.49	8.93	7.57	6.40	5.40	26.51
1981	0.43	1.41	9.39	27.01	39.22	37.59	32.07	27.06	23.13	19.87	17.06	14.63	12.54	10.72	9.14	7.78	6.60	5.58	4.71	23.10
1982	0.57	3.68	10.02	43.08	61.93	58.73	49.38	40.45	33.49	28.26	24.03	20.46	17.43	14.86	12.65	10.74	9.11	7.71	6.51	31.92
1983	0.44	2.44	13.78	25.01	52.75	48.36	39.94	32.20	25.87	21.14	17.66	14.90	12.61	10.68	9.06	7.68	6.51	5.50	4.65	22.81
1984	0.78	3.78	15.93	52.11	42.78	56.32	44.88	35.57	28.14	22.32	18.06	14.97	12.55	10.56	8.90	7.52	6.36	5.37	4.53	22.27
1985	0.61	3.70	14.67	38.85	60.89	31.65	36.23	27.69	21.52	16.80	13.20	10.59	8.72	7.27	6.09	5.12	4.31	3.63	3.06	15.05
1986	1.07	3.22	16.87	44.03	56.85	56.82	25.73	28.25	21.17	16.24	12.56	9.79	7.80	6.39	5.30	4.42	3.71	3.11	2.62	12.85
1987	1.43	8.10	19.36	60.98	72.47	58.14	50.39	21.88	23.57	17.44	13.25	10.16	7.87	6.24	5.09	4.20	3.50	2.92	2.45	11.98
1988	3.18	12.08	50.99	69.10	96.29	70.24	48.70	40.45	17.23	18.32	13.42	10.11	7.70	5.93	4.68	3.80	3.13	2.60	2.17	10.54
1989	2.21	15.67	48.94	128.88	81.90	70.86	44.60	29.59	24.09	10.13	10.66	7.75	5.80	4.40	3.37	2.65	2.14	1.76	1.46	7.02
1990	1.45	14.73	82.23	152.30	180.88	70.42	52.48	31.61	20.56	16.52	6.88	7.18	5.18	3.86	2.91	2.22	1.74	1.41	1.15	5.47
1991	2.14	5.64	45.85	155.83	132.15	95.86	32.07	22.86	13.50	8.66	6.89	2.85	2.95	2.12	1.57	1.18	0.90	0.70	0.57	2.62
1992	0.11	1.91	6.32	57.96	153.29	98.49	63.21	20.15	14.06	8.23	5.28	4.22	1.76	1.84	1.34	1.01	0.77	0.59	0.47	2.15
1993	0.16	0.79	12.85	31.90	131.90	156.32	69.52	41.02	12.84	8.90	5.18	3.31	2.63	1.09	1.14	0.83	0.62	0.47	0.36	1.56
1994	0.28	1.39	6.96	83.56	87.43	157.48	129.07	52.80	30.60	9.51	6.55	3.80	2.42	1.92	0.79	0.82	0.60	0.45	0.34	1.34
1995	0.19	1.34	6.22	23.24	135.91	70.63	92.77	70.70	28.46	16.38	5.06	3.47	2.01	1.27	1.00	0.41	0.43	0.31	0.23	0.84
1996	0.13	1.18	8.16	29.48	52.11	134.12	47.23	56.77	42.46	16.97	9.71	2.99	2.04	1.17	0.74	0.58	0.24	0.25	0.18	0.60
1997	0.09	0.92	7.93	42.06	72.49	58.80	105.27	34.12	40.29	29.92	11.89	6.78	2.08	1.41	0.81	0.51	0.40	0.16	0.17	0.52
1998	0.10	0.59	5.82	38.51	95.35	74.88	42.28	69.72	22.20	26.03	19.23	7.61	4.32	1.32	0.89	0.51	0.32	0.25	0.10	0.42
1999	0.11	0.90	5.21	38.76	120.47	140.54	78.49	41.01	66.48	21.02	24.51	18.02	7.10	4.01	1.22	0.83	0.47	0.29	0.23	0.46
2000	0.11	0.94	7.63	33.08	103.62	139.81	112.89	58.02	29.78	47.93	15.07	17.50	12.81	5.03	2.83	0.86	0.58	0.33	0.21	0.47
2001	0.12	0.59	4.71	27.91	53.21	81.69	82.16	62.06	31.42	16.02	25.64	8.03	9.28	6.77	2.65	1.49	0.45	0.30	0.17	0.34
2002	0.21	1.64	7.72	44.18	104.33	90.83	101.94	95.58	71.08	35.73	18.12	28.88	9.00	10.37	7.53	2.94	1.64	0.50	0.33	0.55
2003	0.18	1.49	11.17	36.89	86.92	102.44	69.18	73.41	67.91	50.17	25.09	12.67	20.10	6.24	7.16	5.19	2.02	1.13	0.34	0.59
2004	0.12	1.31	10.38	55.35	76.28	87.38	77.72	49.28	51.53	47.35	34.80	17.33	8.71	13.77	4.26	4.87	3.52	1.36	0.76	0.61
2005	0.09	0.96	10.24	57.66	127.72	84.24	72.01	59.97	37.46	38.90	35.56	26.02	12.90	6.46	10.17	3.14	3.58	2.58	1.00	0.98
2006	0.08	0.75	7.92	59.94	139.51	147.14	72.24	57.79	47.40	29.41	30.38	27.64	20.14	9.95	4.96	7.79	2.40	2.72	1.96	1.48
2007	0.10	0.75	6.63	49.59	150.69	162.31	125.79	57.62	45.38	36.97	22.82	23.46	21.26	15.43	7.59	3.78	5.91	1.81	2.06	2.55
2008	0.08	0.58	3.94	24.77	77.31	111.17	88.44	64.01	28.88	22.59	18.31	11.25	11.52	10.40	7.52	3.69	1.83	2.85	0.87	2.17
2009	0.06	0.54	3.57	17.71	49.83	75.89	80.55	59.80	42.61	19.09	14.86	11.98	7.33	7.48	6.73	4.85	2.37	1.17	1.83	1.90
2010	0.02	0.32	2.93	14.59	32.80	43.03	46.58	45.73	33.38	23.62	10.53	8.15	6.55	3.99	4.06	3.64	2.61	1.28	0.63	1.96
2011	0.02	0.14	1.77	12.41	29.39	31.89	30.11	30.22	29.18	21.15	14.89	6.60	5.09	4.08	2.48	2.51	2.24	1.61	0.78	1.54
2012	0.03	0.14	1.13	10.67	34.87	38.31	29.33	25.58	25.24	24.20	17.45	12.22	5.40	4.15	3.31	2.00	2.02	1.80	1.29	1.82
2013	0.03	0.21	1.08	6.52	27.65	41.63	32.40	22.94	19.67	19.27	18.38	13.19	9.20	4.05	3.10	2.46	1.49	1.50	1.33	2.25
2014	0.03	0.26	1.66	6.51	18.22	37.41	40.93	29.61	20.63	17.56	17.12	16.25	11.61	8.07	3.54	2.70	2.14	1.29	1.29	3.02
2015	0.02	0.20	1.73	8.28	14.91	19.26	27.86	28.13	20.00	13.84	11.72	11.37	10.75	7.65	5.30	2.32	1.76	1.39	0.84	2.73
2016	0.02	0.12	1.51	10.00	21.47	17.76	16.21	21.67	21.51	15.19	10.45	8.81	8.51	8.01	5.68	3.92	1.71	1.30	1.02	2.55
2017	0.01	0.14	0.81	7.36	22.85	23.57	14.03	11.88	15.62	15.40	10.81	7.41	6.22	5.98	5.61	3.97	2.73	1.19	0.90	2.41
2018	0.01	0.07	0.82	3.66	16.22	23.67	17.17	9.43	7.85	10.24	10.05	7.02	4.79	4.01	3.84	3.59	2.53	1.74	0.75	2.04
2019	0.04	0.16	0.71	6.49	13.61	27.11	27.25	18.16	9.80	8.09	10.51	10.26	7.14	4.85	4.04	3.86	3.60	2.53	1.73	2.72
2020	0.02	0.21	0.83	2.84	11.75	10.77	14.59	13.43	8.79	4.71	3.87	5.00	4.86	3.37	2.28	1.89	1.81	1.68	1.18	2.02
2021	0.02	0.17	1.65	4.79	7.21	13.65	8.87	11.12	10.07	6.54	3.48	2.85	3.67	3.55	2.45	1.66	1.37	1.30	1.21	2.25

Table 17. 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 metric tons or pounds, as indicated; and recruits are in number of age-1 fish. Spawning stock biomass (SSB) is measured as total (males + females) mature biomass (mt). The values of* $L_{F40\%}$ *and* $L_{current}$ *include landings and dead discards.*

Quantity	Units	Estimate	Median	SE
$F_{40\%}$	y^{-1}	0.28	0.30	0.09
$75\% F_{40\%}$	y^{-1}	0.21	0.22	0.07
$B_{F40\%}$	metric tons	1503.87	1540.65	61.90
$SSB_{F40\%}$	metric tons	1068.80	1068.19	78.95
MSST	metric tons	801.60	801.14	59.22
$L_{F40\%}$	1000 lb whole	372.28	381.39	35.90
$L_{75\%F40\%}$	1000 lb whole	344.83	353.68	34.47
$L_{current}$	1000 lb whole	115.48	114.80	9.55
$R_{F40\%}$	number fish	290882.80	305247.70	74569.47
$F_{2019-2021}/F_{40\%}$	—	0.91	0.81	0.36
$SSB_{2021}/MSST$	—	0.36	0.38	0.10
$SSB_{2021}/SSB_{F40\%}$	—	0.27	0.29	0.07

Table 18. Results from sensitivity runs of the Beaufort Assessment Model. Current F represented by geometric mean of last three assessment years. Values of $L_{F40\%}$ include landings and dead discards. For reference, recent landings (mean of last three yr) in the base case was $L_{current} = 115.48$ (1000 lb). Runs should not all be considered equally plausible.

Run	Description	$F_{40\%}$	$SSB_{F40\%}$ (mt)	$L_{F40\%}$ (1000 lb)	$F_{current}/F_{40\%}$	$SSB_{2021}/SSB_{F40\%}$	R0 (1000)
Base	—	0.278	1069	372	0.91	0.27	226
S1	Low M	0.176	1263	340	1.61	0.2	156
S2	High M	0.444	1002	438	0.5	0.35	333
S3	Low Mdisc	0.278	1048	365	0.91	0.27	222
S4	High Mdisc	0.277	1090	380	0.9	0.27	231
S5	Descender dev	0.278	1069	372	0.91	0.27	226
S6	SERFS wgt=1	0.278	1092	380	0.63	0.39	241
S7	SERFS wgt=2	0.278	1066	371	1.04	0.24	222
S8	Drop SERFS index	0.282	1433	500	0.11	1.57	370
S9	Drop comm index	0.28	1071	373	0.91	0.27	227
S10	Drop rec index	0.283	1061	370	0.91	0.27	225
S11	Drop SERFS acomps	0.289	1053	367	0.93	0.26	225
S12	Drop comm acomps	0.278	1068	372	0.91	0.27	226
S13	Drop rec acomps	0.276	1077	375	0.89	0.27	228
S14	Drop all lcomps	0.281	1072	374	1.08	0.27	229
S15	SERFS lcomps replace acomps	0.281	1050	366	0.91	0.26	222
S16	SERFS variable selex	0.281	1074	374	0.75	0.34	234

Table 19. Projection results with fishing mortality rate fixed at $F = 0$ starting in 2024 and long-term, average recruitment starting in 2023. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*), pr.reb = proportion of stochastic projection replicates with* $SSB \geq SSB_{MSY}$*. Here, landings include dead discards. 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)	pr.reb
2022	76	83	0.32	0.30	289	311	17	17	115	115	0.000
2023	291	240	0.33	0.31	291	318	18	18	115	115	0.000
2024	291	241	0.00	0.00	350	381	0	0	0	0	0.000
2025	291	242	0.00	0.00	499	524	0	0	0	0	0.015
2026	291	240	0.00	0.00	677	692	0	0	0	0	0.091
2027	291	238	0.00	0.00	862	870	0	0	0	0	0.254
2028	291	239	0.00	0.00	1042	1047	0	0	0	0	0.468
2029	291	240	0.00	0.00	1214	1214	0	0	0	0	0.666
2030	291	241	0.00	0.00	1375	1373	0	0	0	0	0.816
2031	291	241	0.00	0.00	1523	1518	0	0	0	0	0.907
2032	291	242	0.00	0.00	1658	1654	0	0	0	0	0.957
2033	291	238	0.00	0.00	1781	1774	0	0	0	0	0.983
2034	291	240	0.00	0.00	1891	1883	0	0	0	0	0.993
2035	291	240	0.00	0.00	1989	1980	0	0	0	0	0.997
2036	291	240	0.00	0.00	2077	2067	0	0	0	0	0.999

Table 20. Projection results with fishing mortality rate fixed at $F = F_{\text{current}}$ starting in 2024 and long-term, average recruitment starting in 2023. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*), pr.reb = proportion of stochastic projection replicates with* SSB $\geq$ SSB_{MSY}*. Here, landings include dead discards. 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)	pr.reb
2022	76	83	0.32	0.30	289	311	17	17	115	115	0.000
2023	291	240	0.33	0.31	291	318	18	18	115	115	0.000
2024	291	241	0.25	0.24	336	366	15	15	89	90	0.000
2025	291	242	0.25	0.24	446	469	16	16	94	96	0.011
2026	291	240	0.25	0.24	583	595	21	20	115	114	0.053
2027	291	238	0.25	0.24	716	723	30	28	162	152	0.134
2028	291	239	0.25	0.24	826	831	40	36	215	198	0.228
2029	291	240	0.25	0.24	909	913	46	42	257	237	0.319
2030	291	241	0.25	0.24	970	975	51	46	287	266	0.386
2031	291	241	0.25	0.24	1014	1022	54	49	309	287	0.441
2032	291	242	0.25	0.24	1045	1057	55	51	325	303	0.482
2033	291	238	0.25	0.24	1068	1081	57	52	337	314	0.510
2034	291	240	0.25	0.24	1083	1096	57	53	345	322	0.530
2035	291	240	0.25	0.24	1094	1110	58	54	350	329	0.543
2036	291	240	0.25	0.24	1101	1119	58	54	354	333	0.554

Table 21. Projection results with fishing mortality rate fixed at $F = F_{\text{current}}$ starting in 2024 and recent, average recruitment throughout. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*), pr.reb = proportion of stochastic projection replicates with* $\text{SSB} \geq \text{SSB}_{\text{MSY}}$*. Here, landings include dead discards. 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)	pr.reb
2022	76	83	0.32	0.30	289	311	17	17	115	115	0
2023	76	65	0.33	0.31	281	307	18	18	115	115	0
2024	76	65	0.25	0.24	278	309	14	14	88	89	0
2025	76	66	0.25	0.24	282	314	15	15	90	92	0
2026	76	65	0.25	0.24	285	315	15	15	91	94	0
2027	76	64	0.25	0.24	287	315	15	15	92	95	0
2028	76	65	0.25	0.24	288	314	15	15	93	95	0
2029	76	65	0.25	0.24	290	312	15	15	94	94	0
2030	76	66	0.25	0.24	291	311	15	15	94	94	0
2031	76	65	0.25	0.24	291	310	15	15	94	94	0
2032	76	65	0.25	0.24	292	310	15	15	95	94	0
2033	76	65	0.25	0.24	292	309	15	15	95	93	0
2034	76	65	0.25	0.24	292	309	15	15	95	93	0
2035	76	65	0.25	0.24	292	308	15	15	95	93	0
2036	76	65	0.25	0.24	292	309	15	15	95	93	0

8 Figures

Figure 1. Data availability by source and year. COM indicates commercial, REC indicates recreational, and CVT indicates SERFS chevron trap data for compositions or combined trap and video gear for abundance indices.

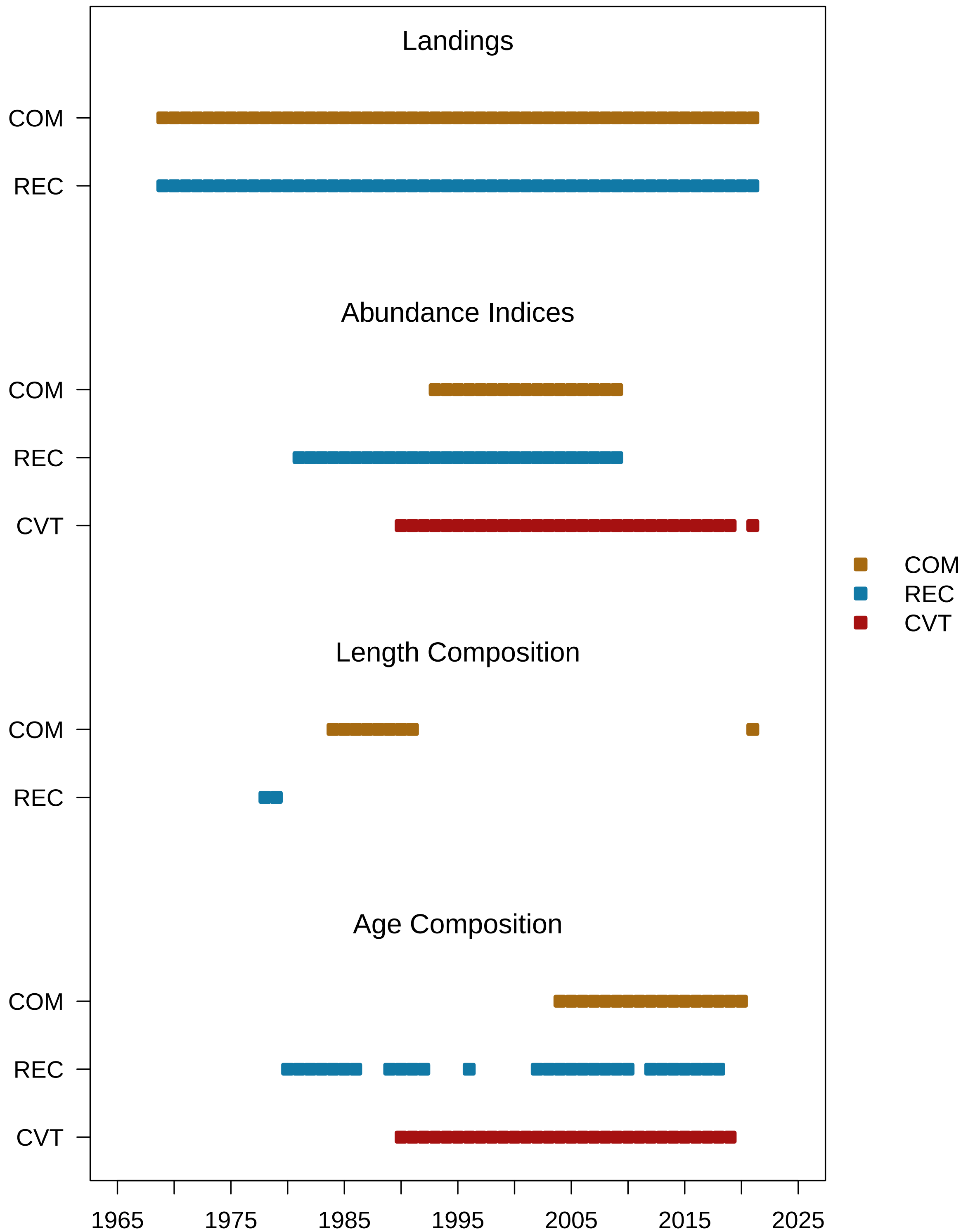


Figure 2. MRIP discard estimates (number fish) smoothed by a cubic regression spline.

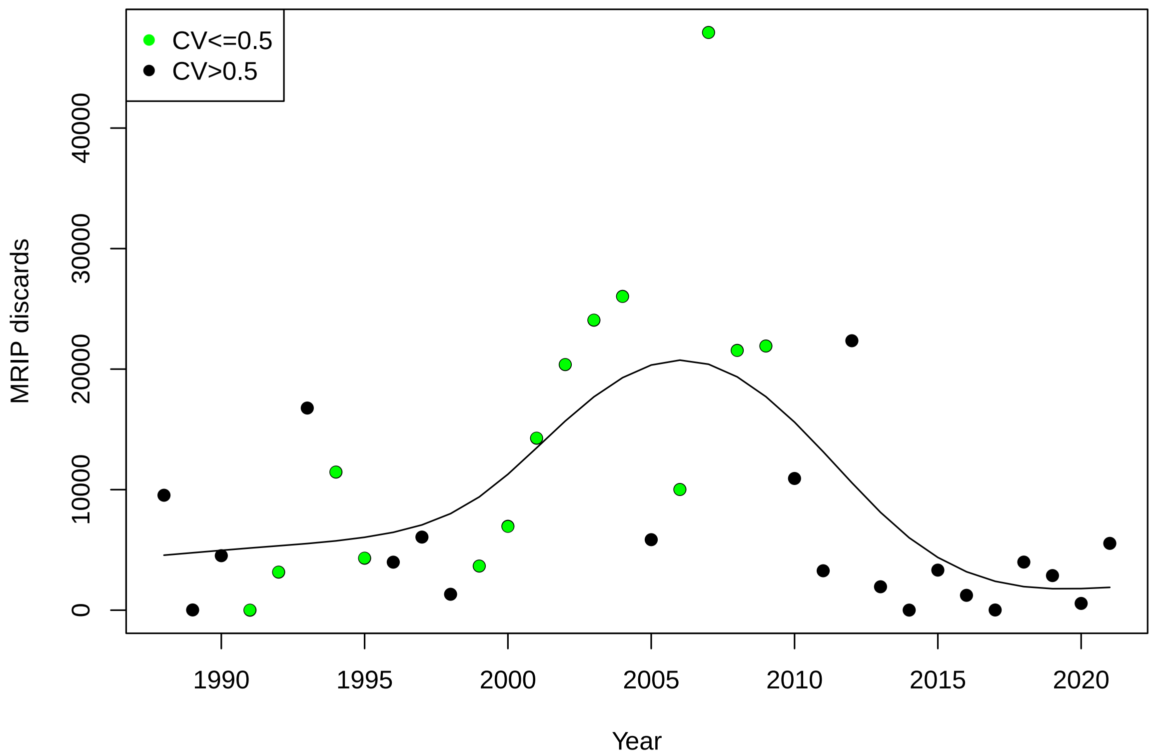


Figure 3. Mean fork length at age (mm) and estimated upper and lower 95% confidence intervals of the population (solid, blue). Mean fork length at age (mm) of the fishery dependent landings under the 20-inch size limit (dashed, green).

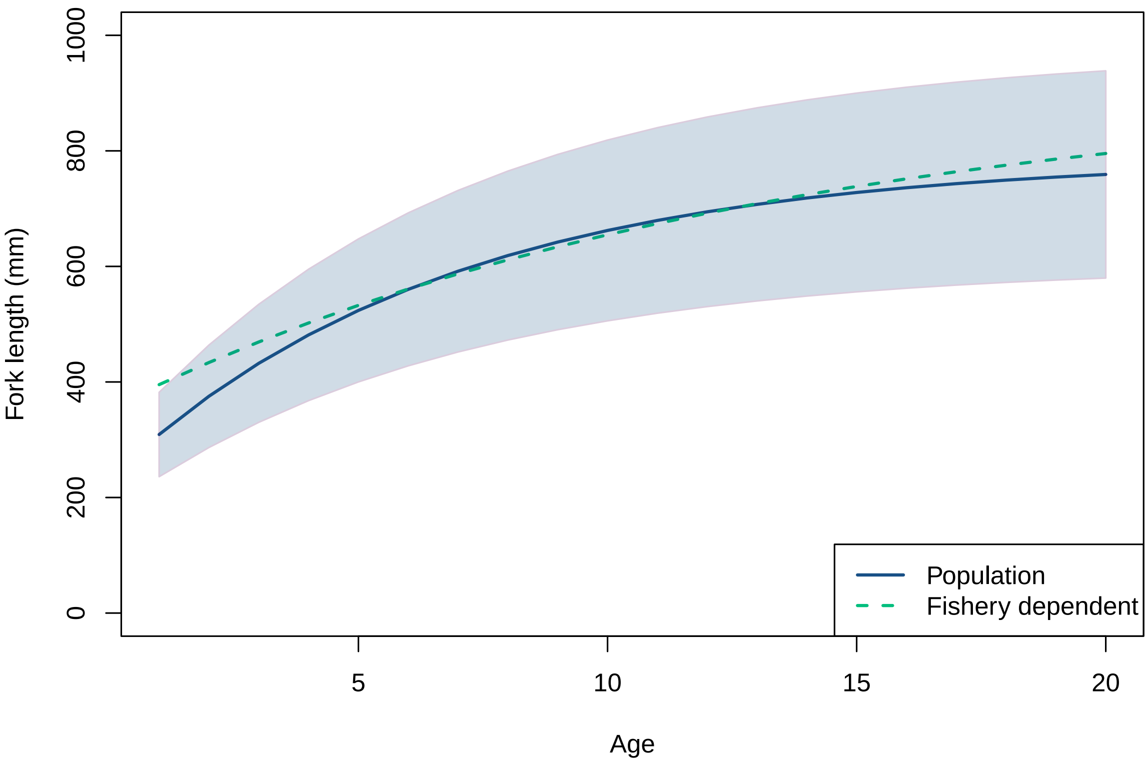


Figure 4. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, CVT to SERFS chevron trap, COM to commercial, and REC to recreational.

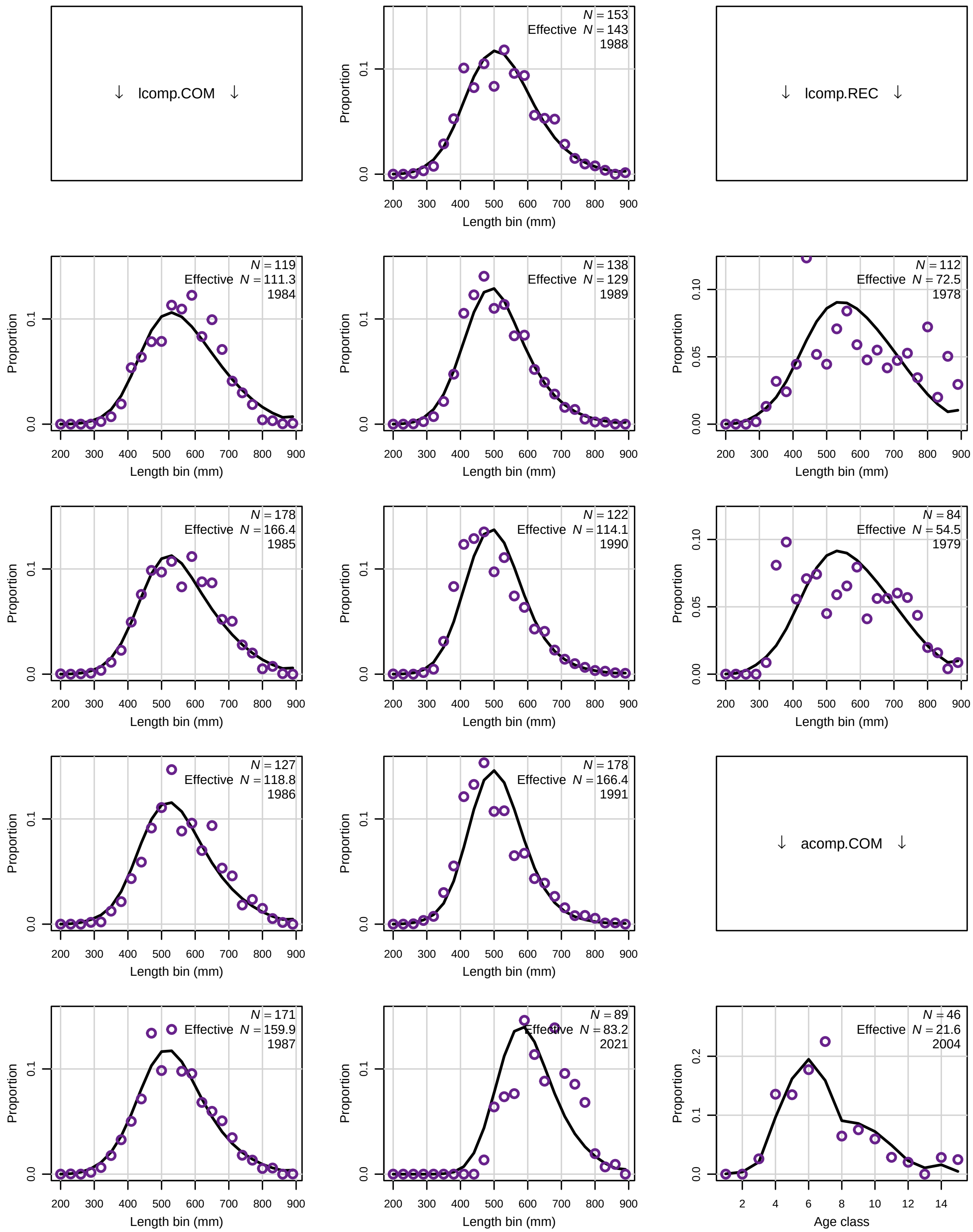


Figure 4. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

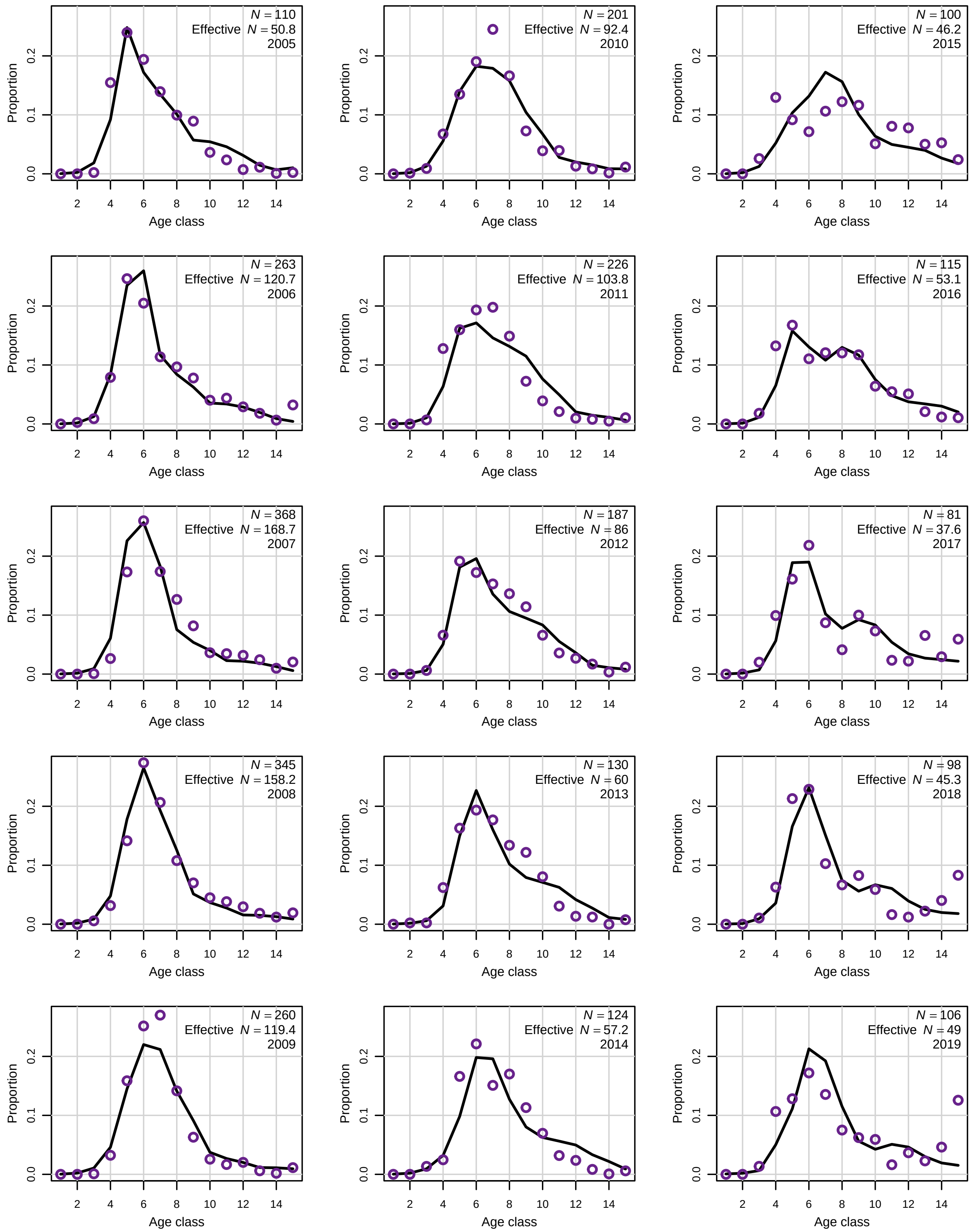


Figure 4. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

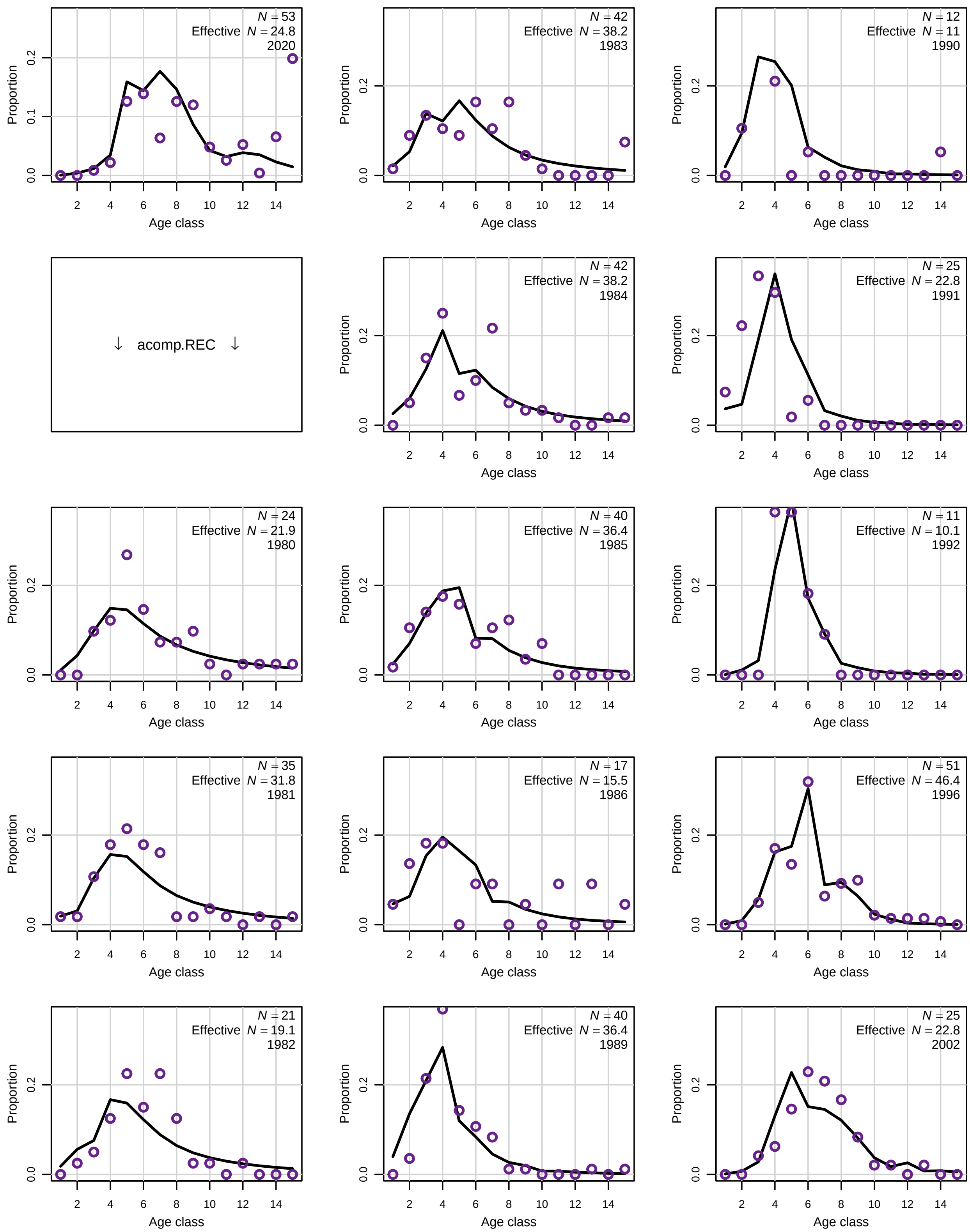


Figure 4. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

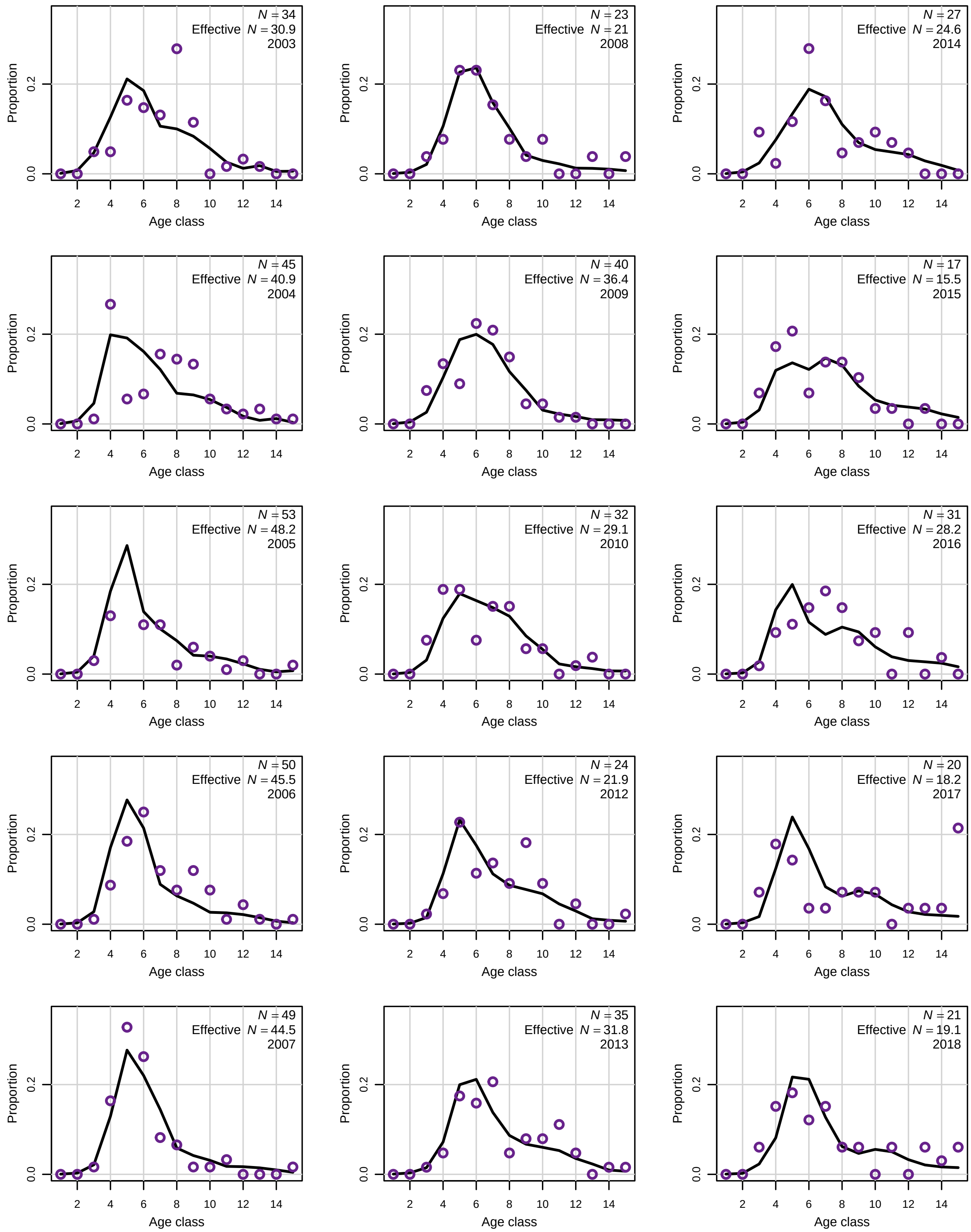


Figure 4. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

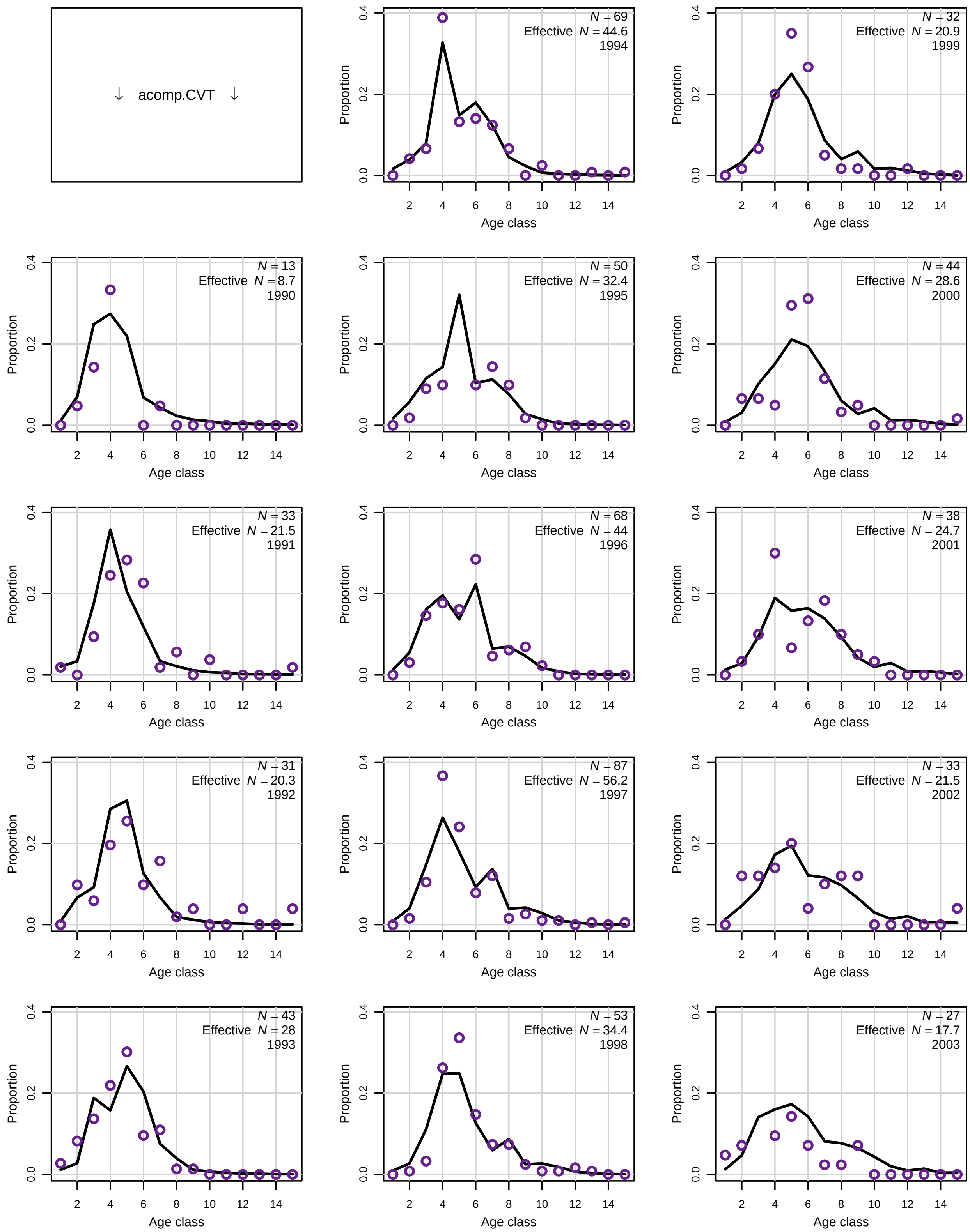


Figure 4. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

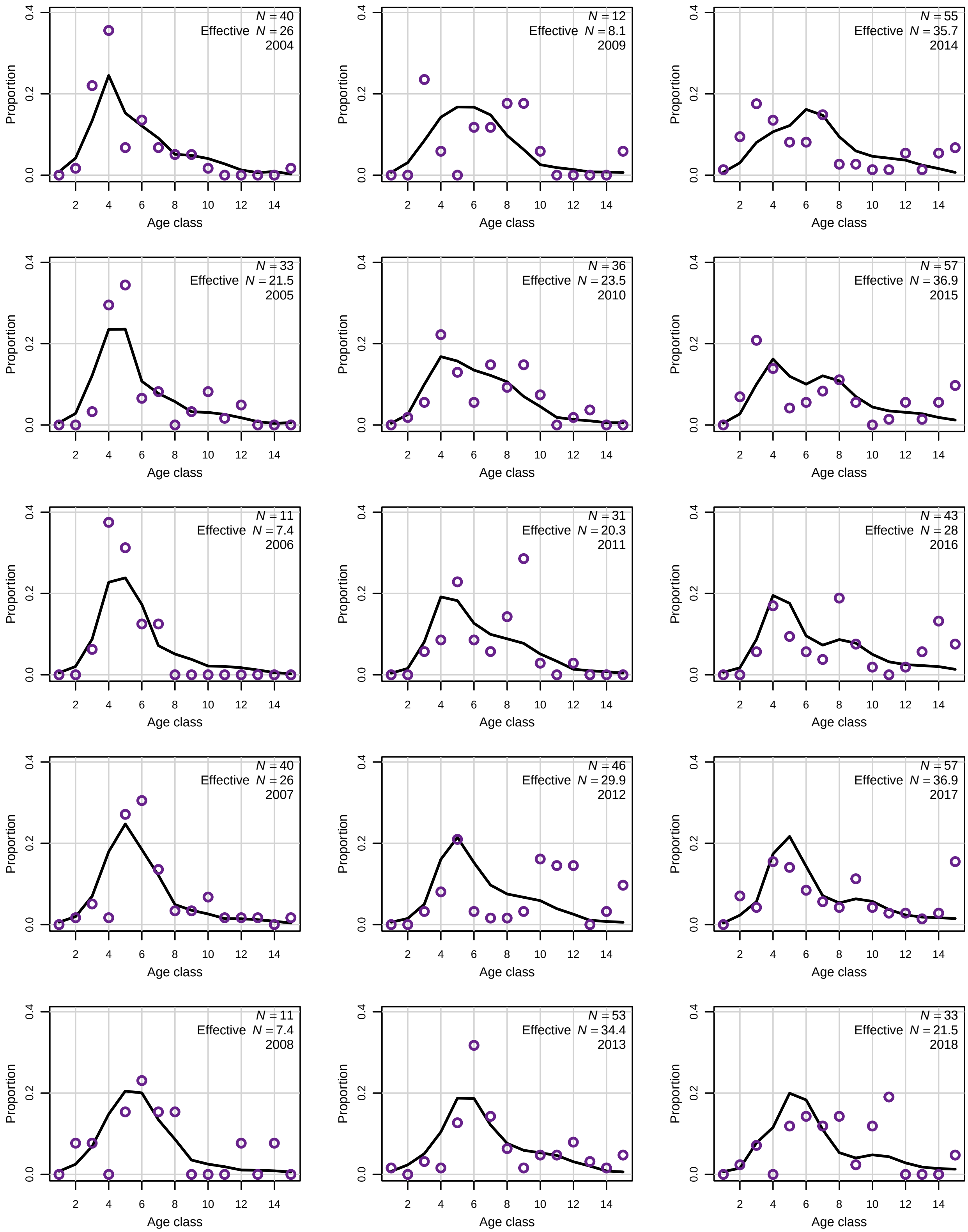


Figure 4. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

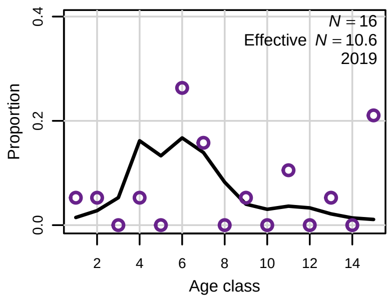


Figure 5. Observed (open circles) and estimated (solid line) commercial length compositions pooled across years. Years shown indicate the first year of data fitted within a selectivity block.

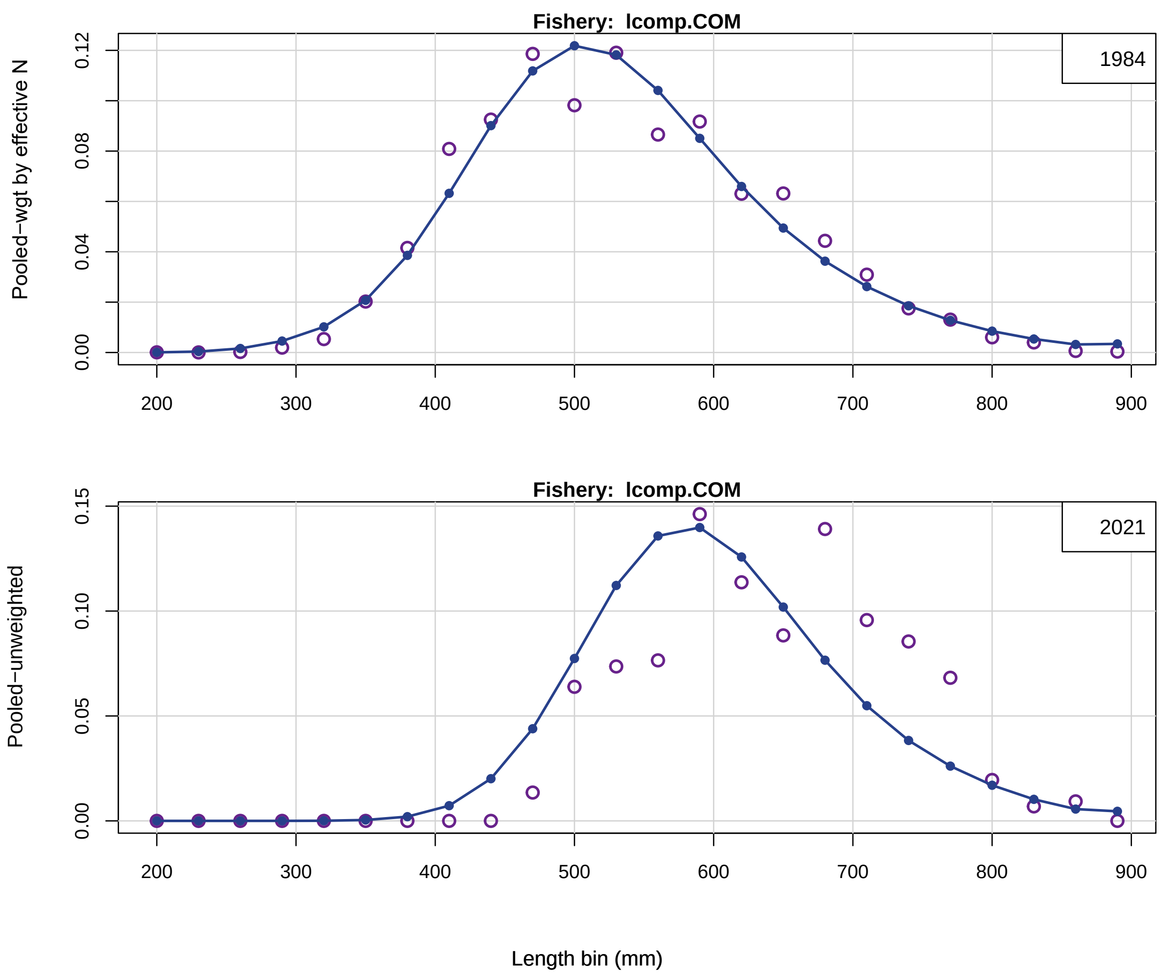


Figure 6. Observed (open circles) and estimated (solid line) recreational length composition pooled across years. Year shown indicates the first year of data fitted within a selectivity block.

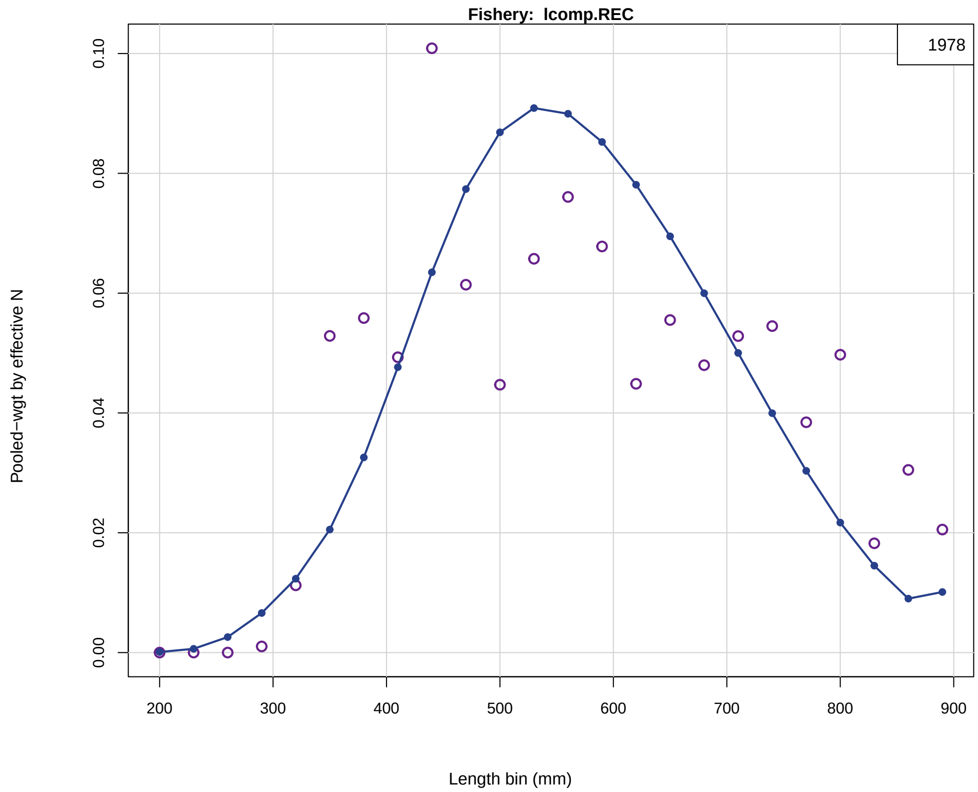


Figure 7. Observed (open circles) and estimated (solid line) commercial age composition pooled across years. Year shown indicates the first year of data fitted within a selectivity block.

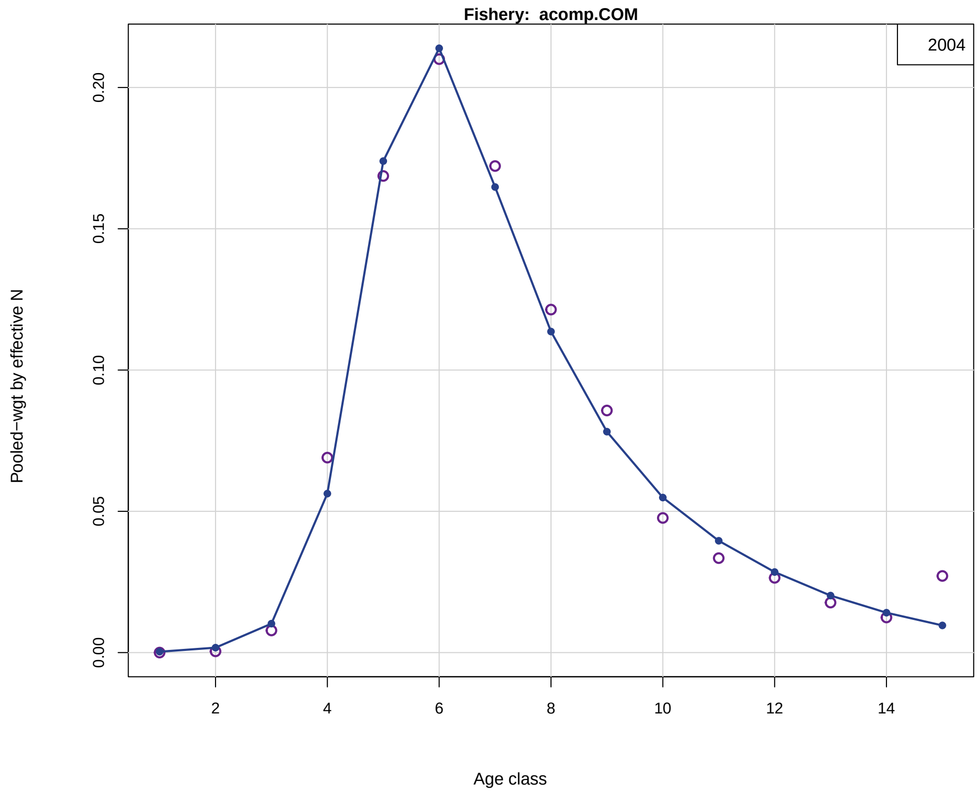


Figure 8. Observed (open circles) and estimated (solid line) recreational age compositions pooled across years. Years shown indicate the first year of data fitted within a selectivity block.

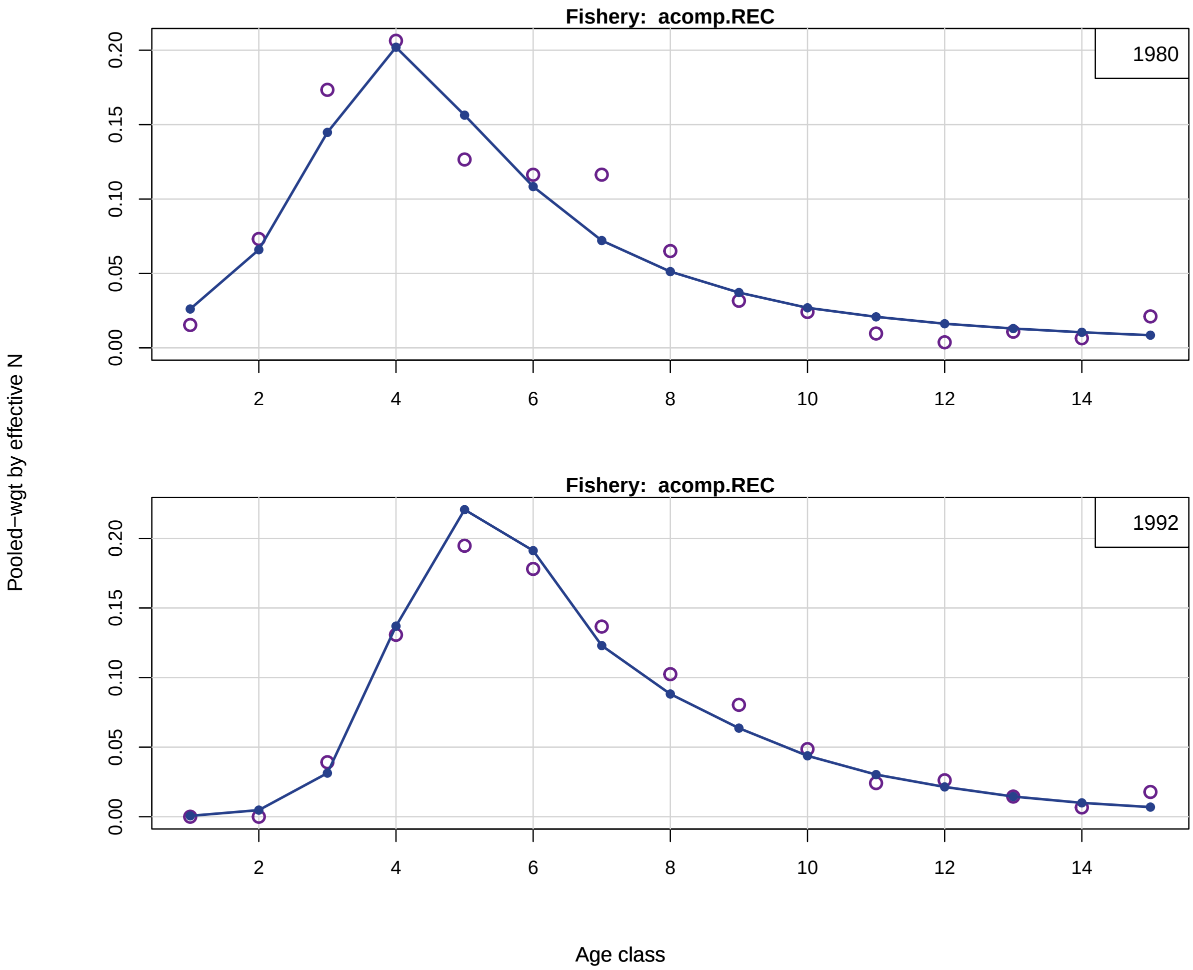


Figure 9. Observed (open circles) and estimated (solid line) SERFS chevron trap age composition pooled across years. Year shown indicates the first year of data fitted within a selectivity block.

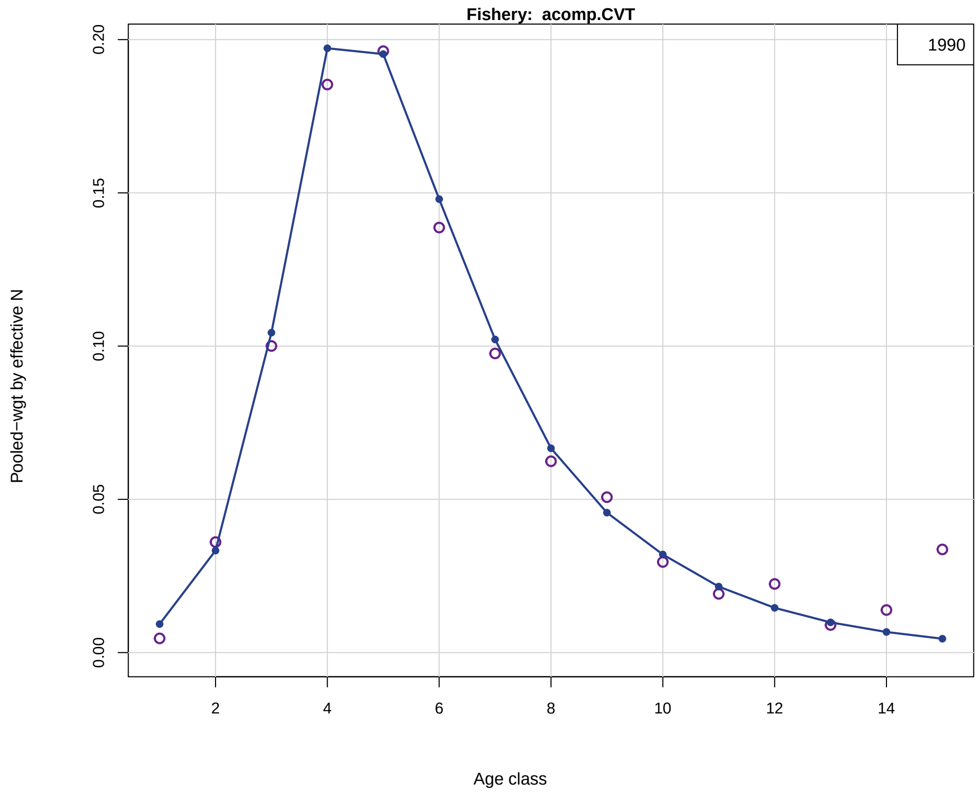


Figure 10. Top Panel: deviance residuals of estimated commercial length compositions. Orange indicates an underestimate. Bottom Panel: correlations between vectors of estimated and observed values.

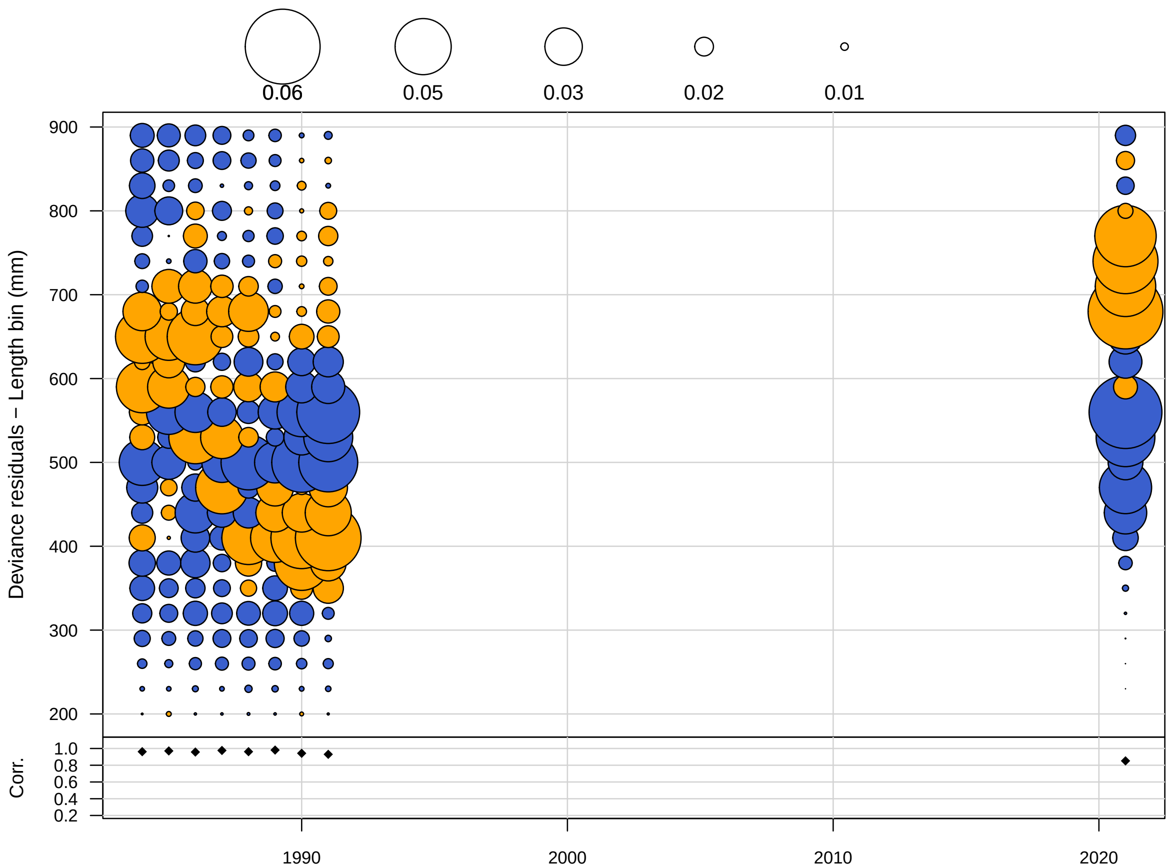


Figure 11. Top Panel: deviance residuals of estimated recreational length compositions. Orange indicates an underestimate. Bottom Panel: correlations between vectors of estimated and observed values.

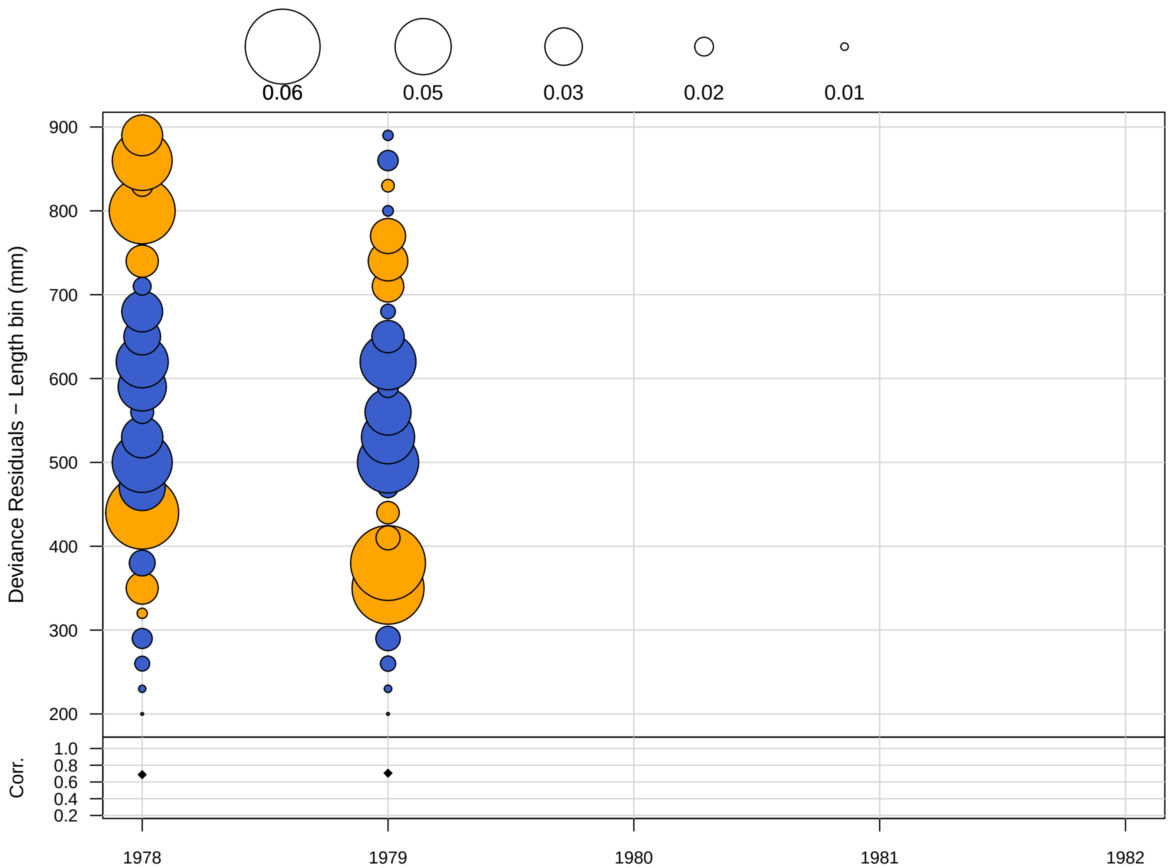


Figure 12. Top Panel: deviance residuals of estimated commercial age compositions. Orange indicates an underestimate. Bottom Panel: correlations between vectors of estimated and observed values.

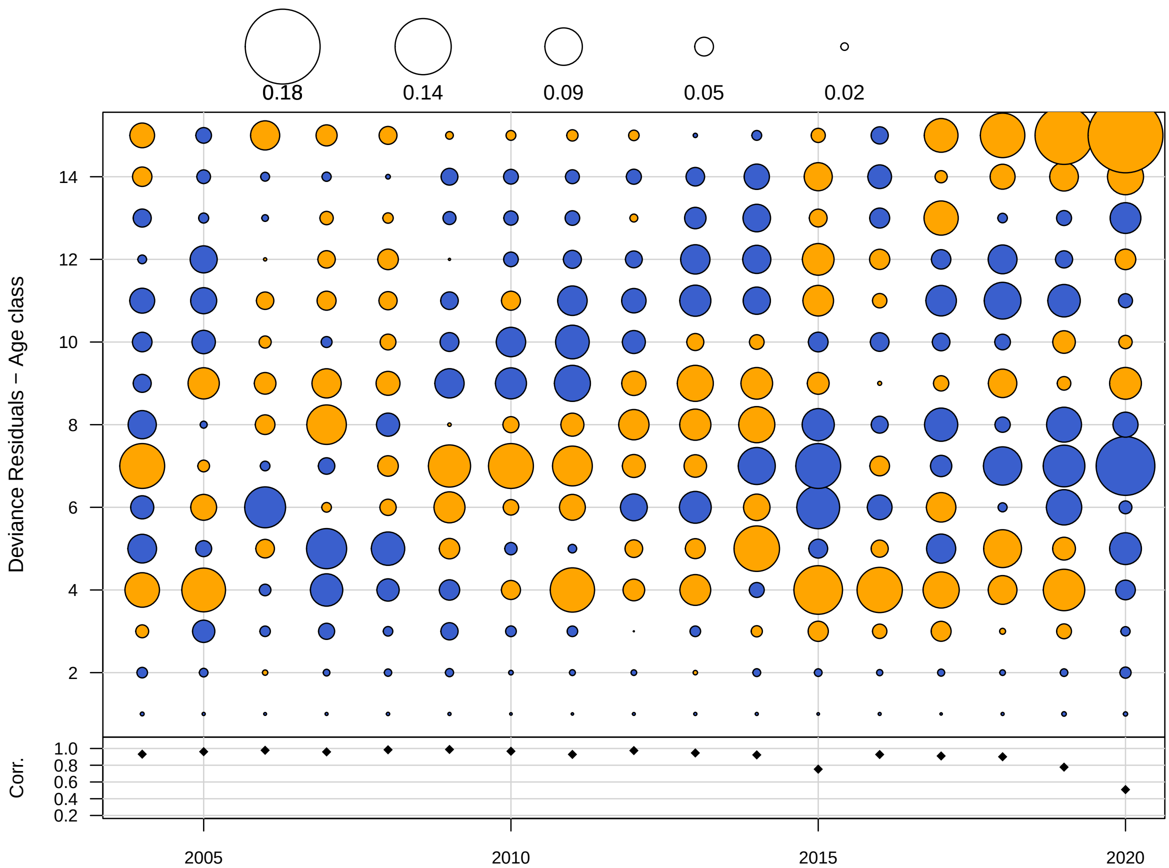


Figure 13. Top Panel: deviance residuals of estimated recreational age compositions. Orange indicates an underestimate. Bottom Panel: correlations between vectors of estimated and observed values.

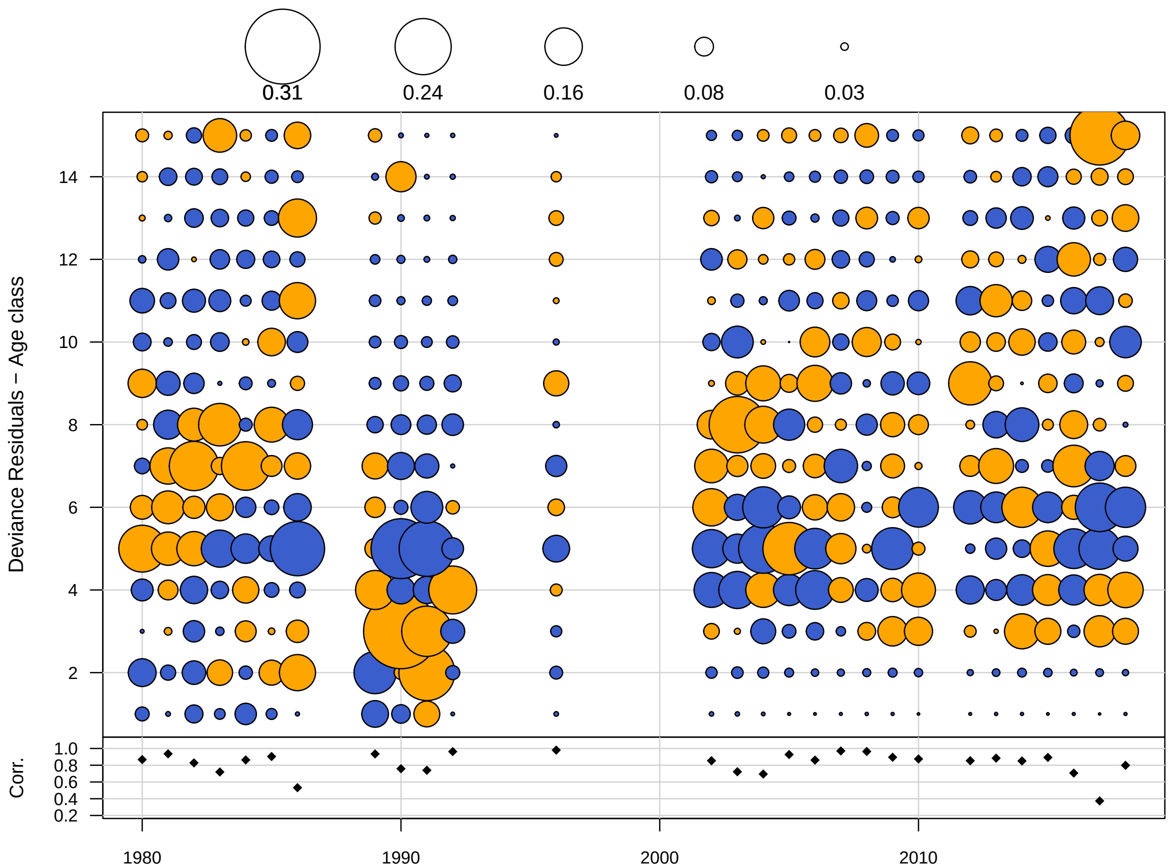


Figure 14. Top Panel: deviance residuals of estimated SERFS chevron trap age compositions. Orange indicates an underestimate. Bottom Panel: correlations between vectors of estimated and observed values.

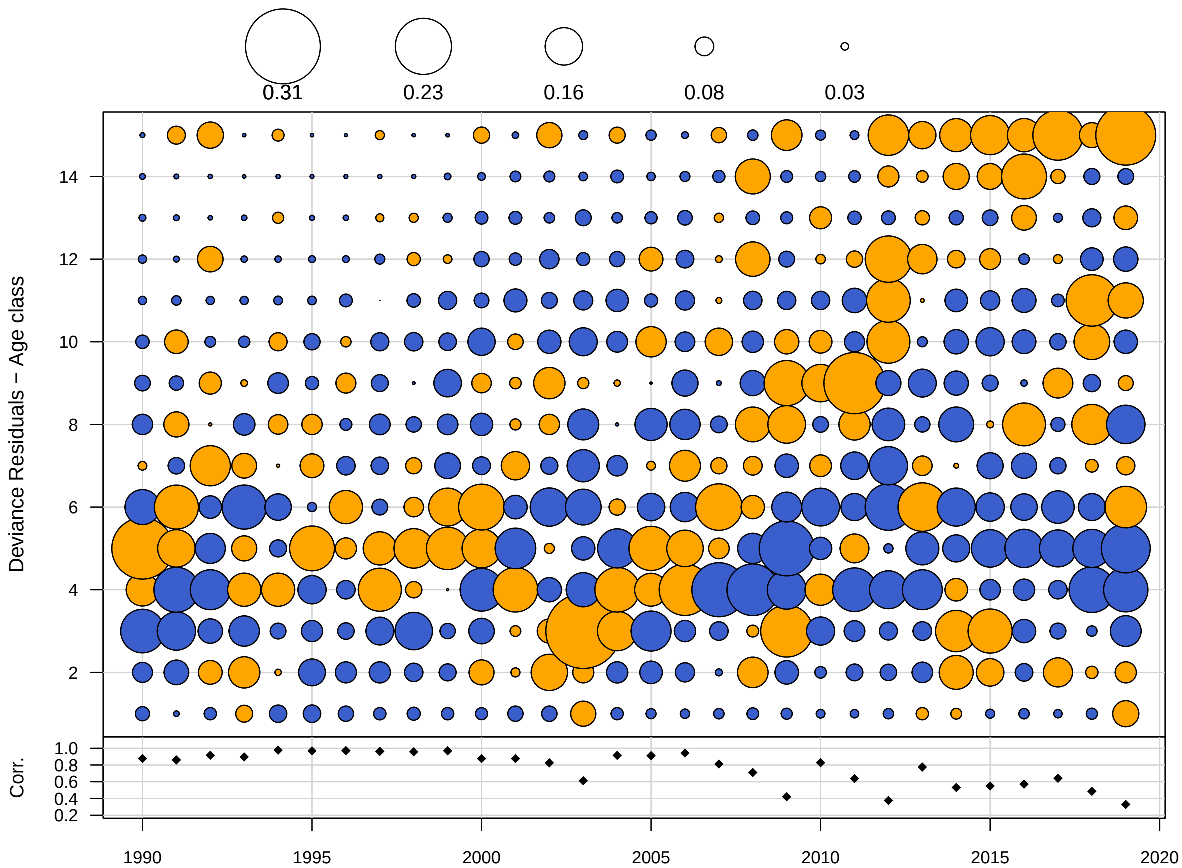


Figure 15. Observed (open circles) and estimated (solid line, circles) commercial removals (landings + dead discards) in 1000 lb whole weight.

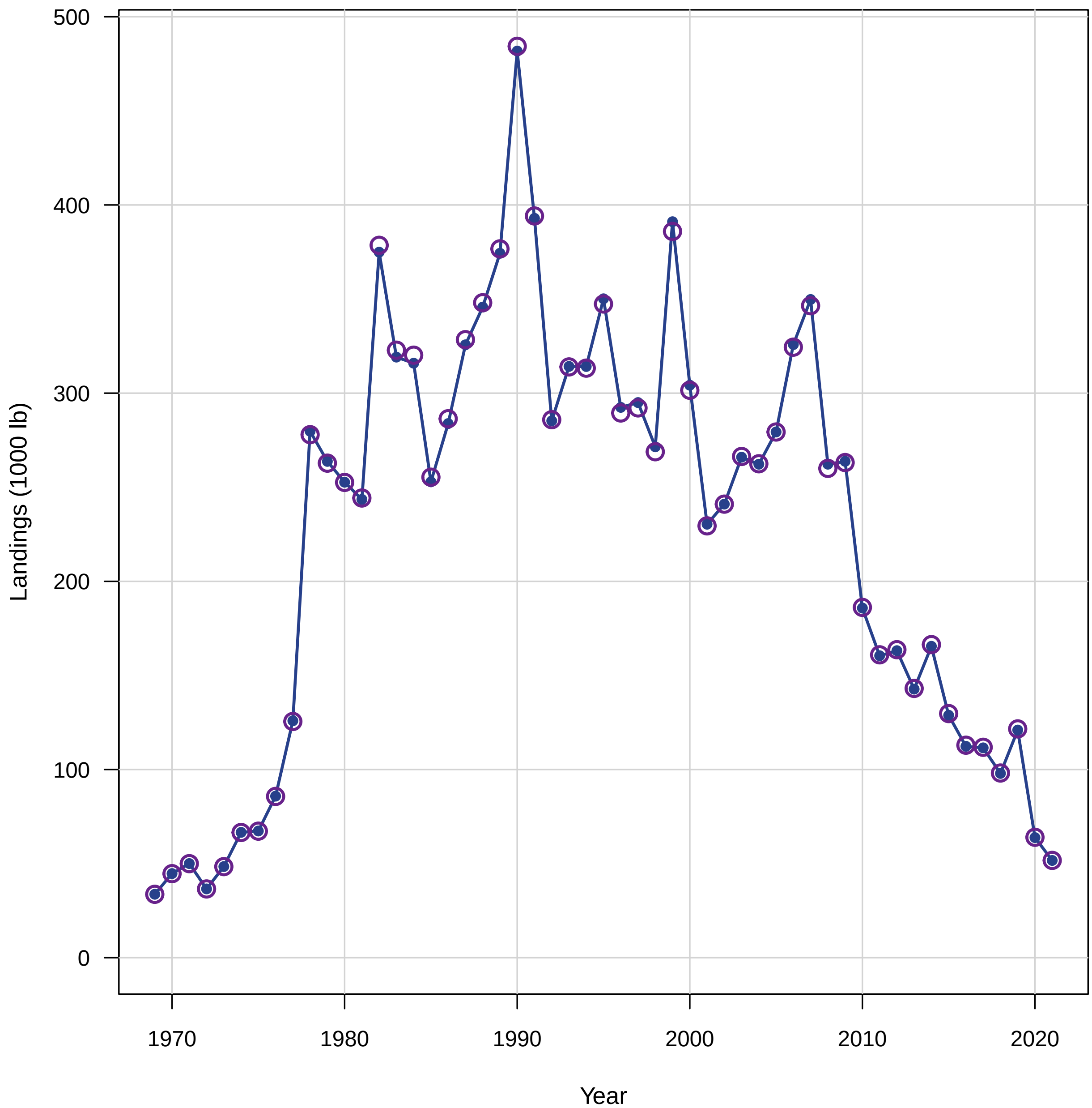


Figure 16. Observed (open circles) and estimated (solid line, circles) recreational removals (landings + dead discards) in 1000s of fish.

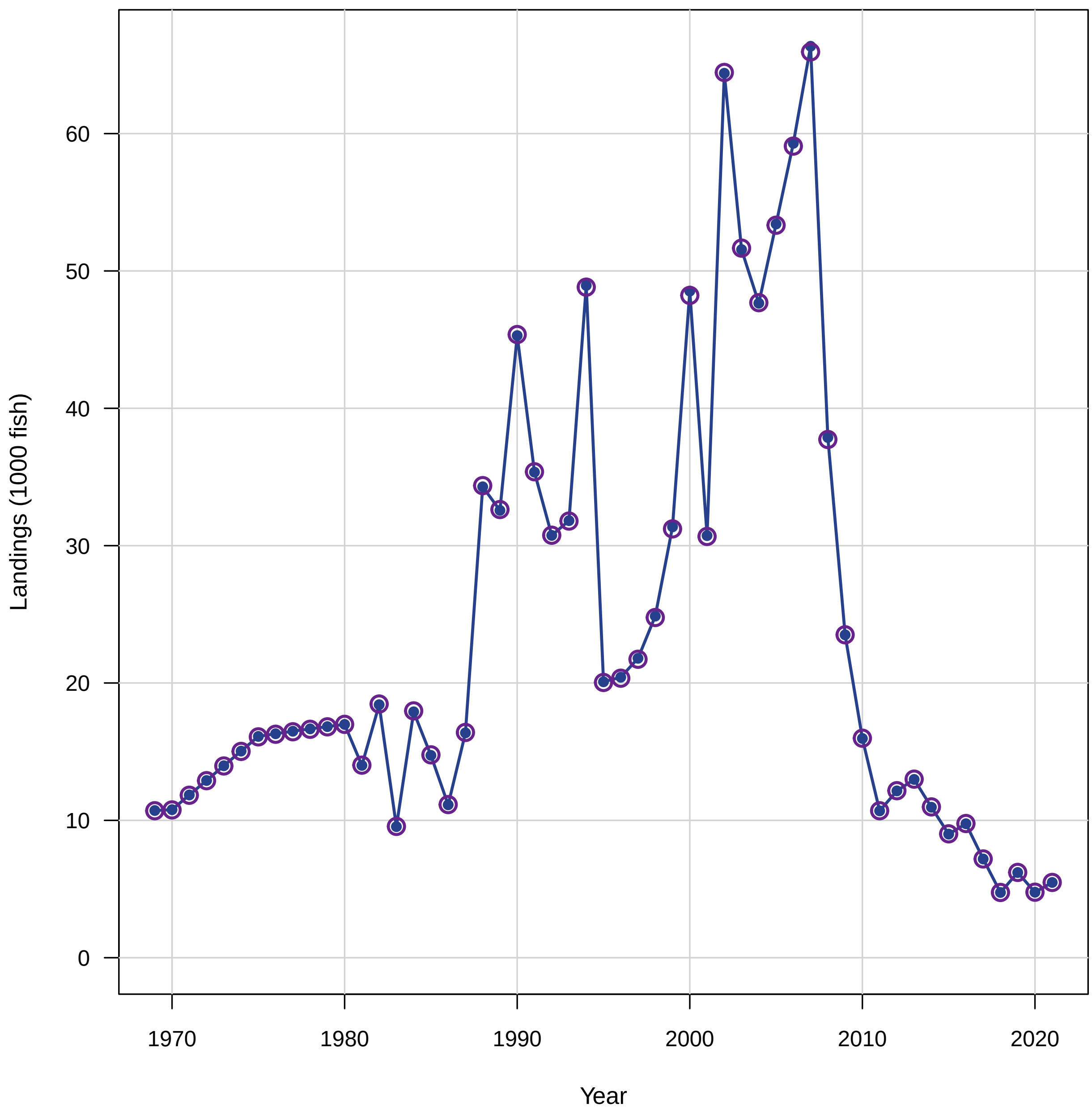


Figure 17. Observed (open circles) and estimated (solid line, circles) index of abundance from the SERFS combined chevron trap and video gear index. The error bars represent plus/minus two standard errors, based on the annual CVs. Residuals are observed minus predicted values, then scaled by the mean residual for plotting.

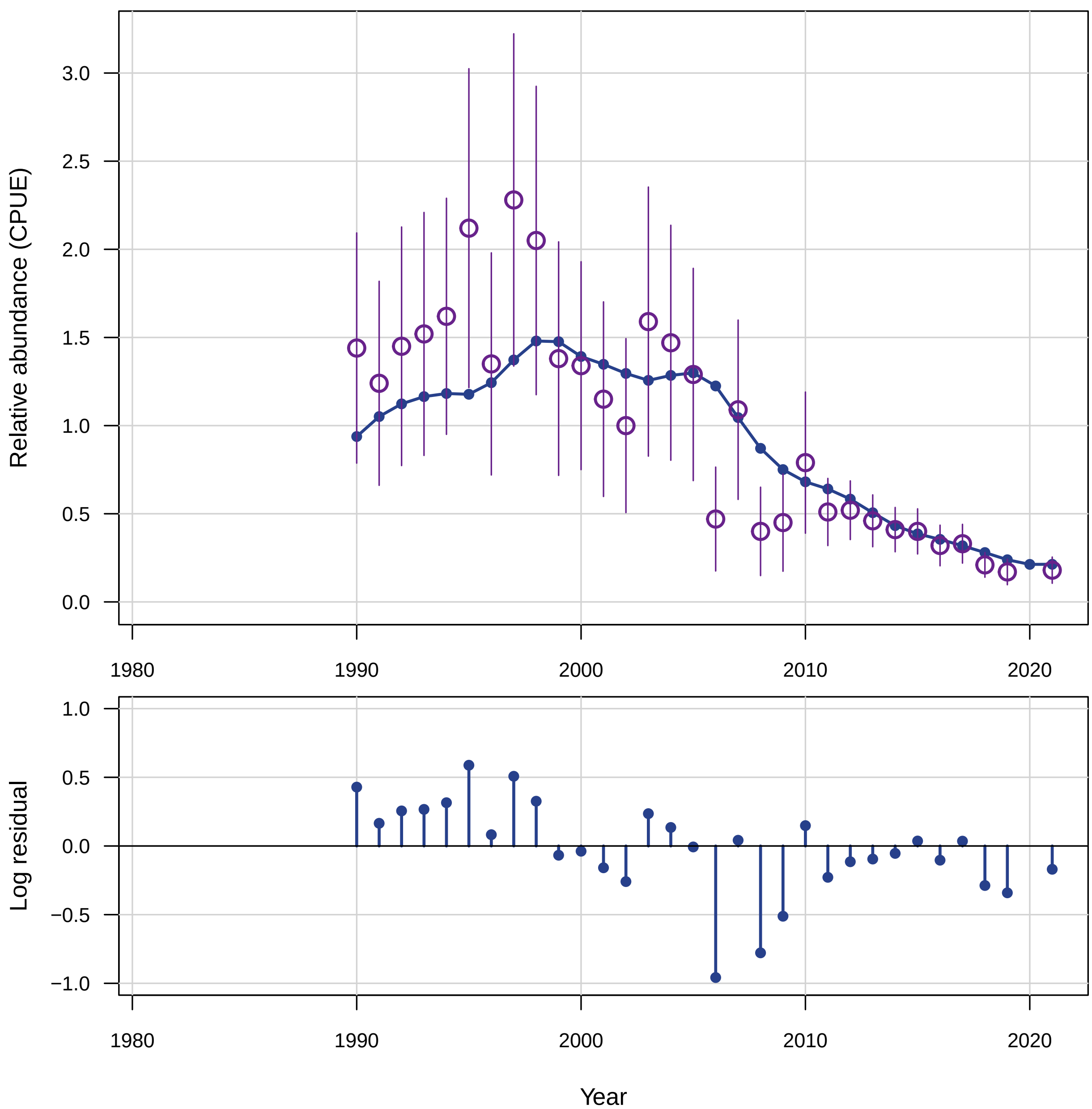


Figure 18. Observed (open circles) and estimated (solid line, circles) index of abundance from the commercial fleet (handline gear). The error bars represent plus/minus two standard errors, based on the annual CVs. Residuals are observed minus predicted values, then scaled by the mean residual for plotting.

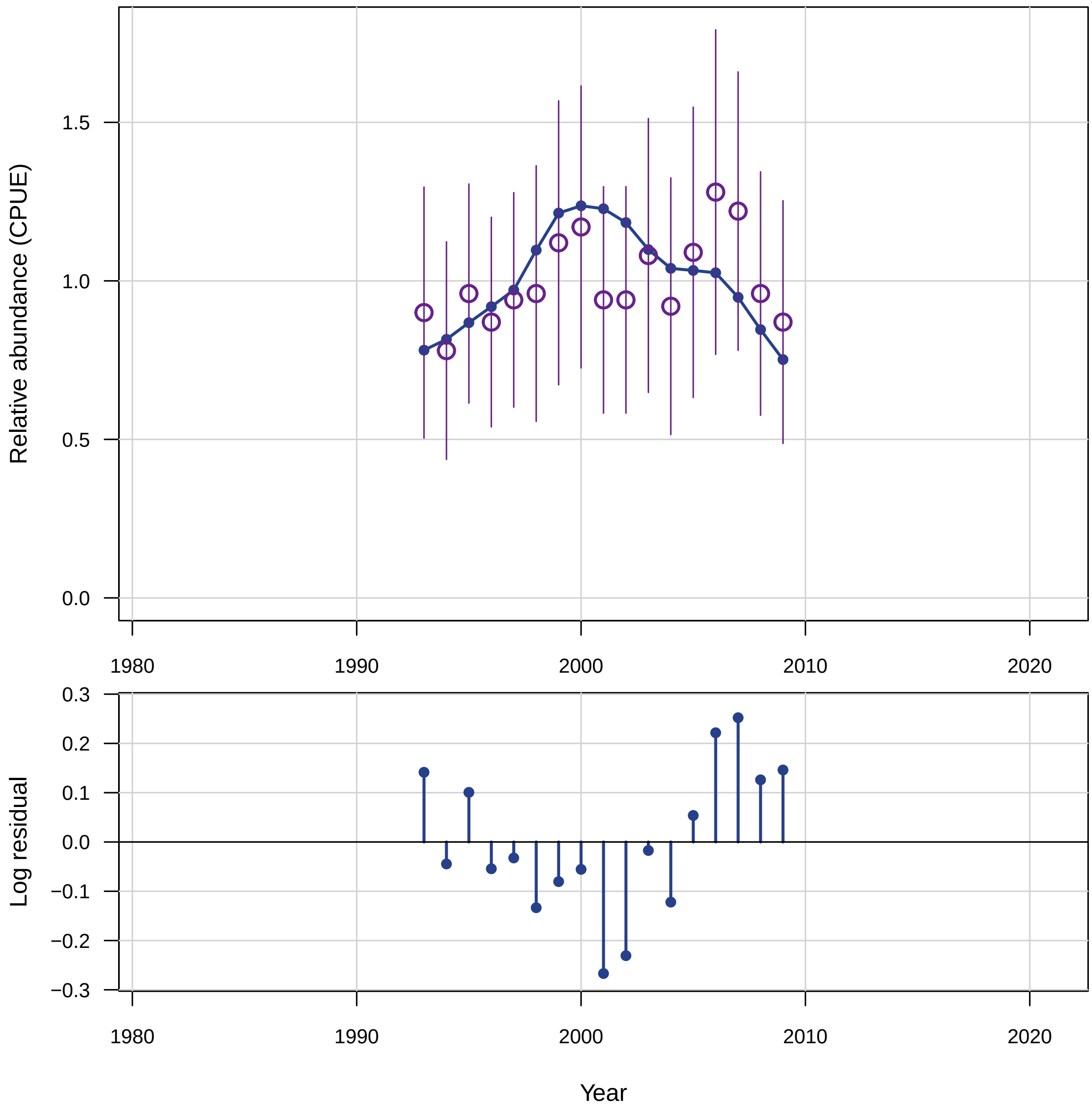


Figure 19. Observed (open circles) and estimated (solid line, circles) abundance from the recreational fleet (headboats). The error bars represent plus/minus two standard errors, based on the annual CVs. Residuals are observed minus predicted values, then scaled by the mean residual for plotting.

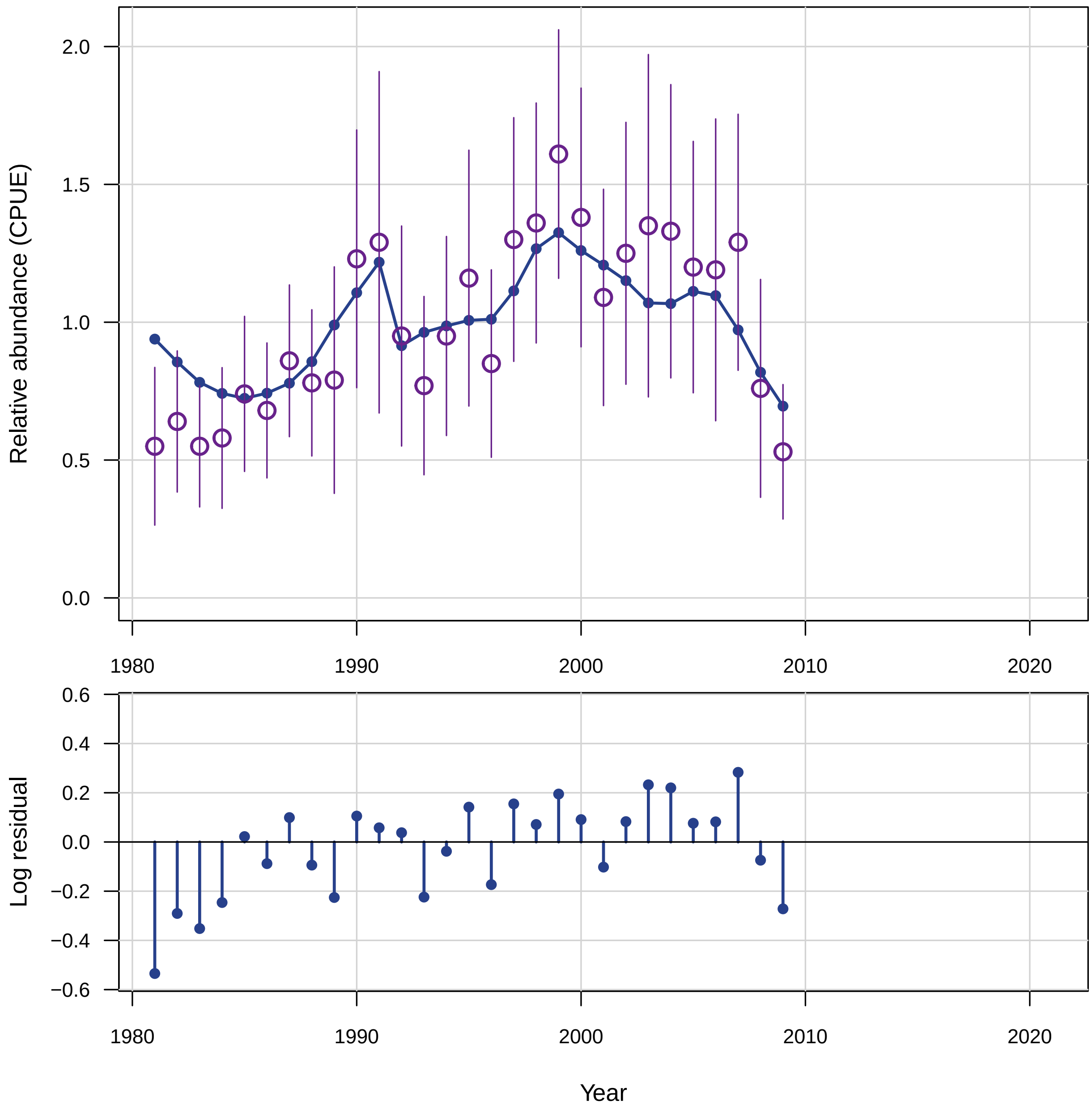


Figure 20. Estimated abundance at age at start of year.

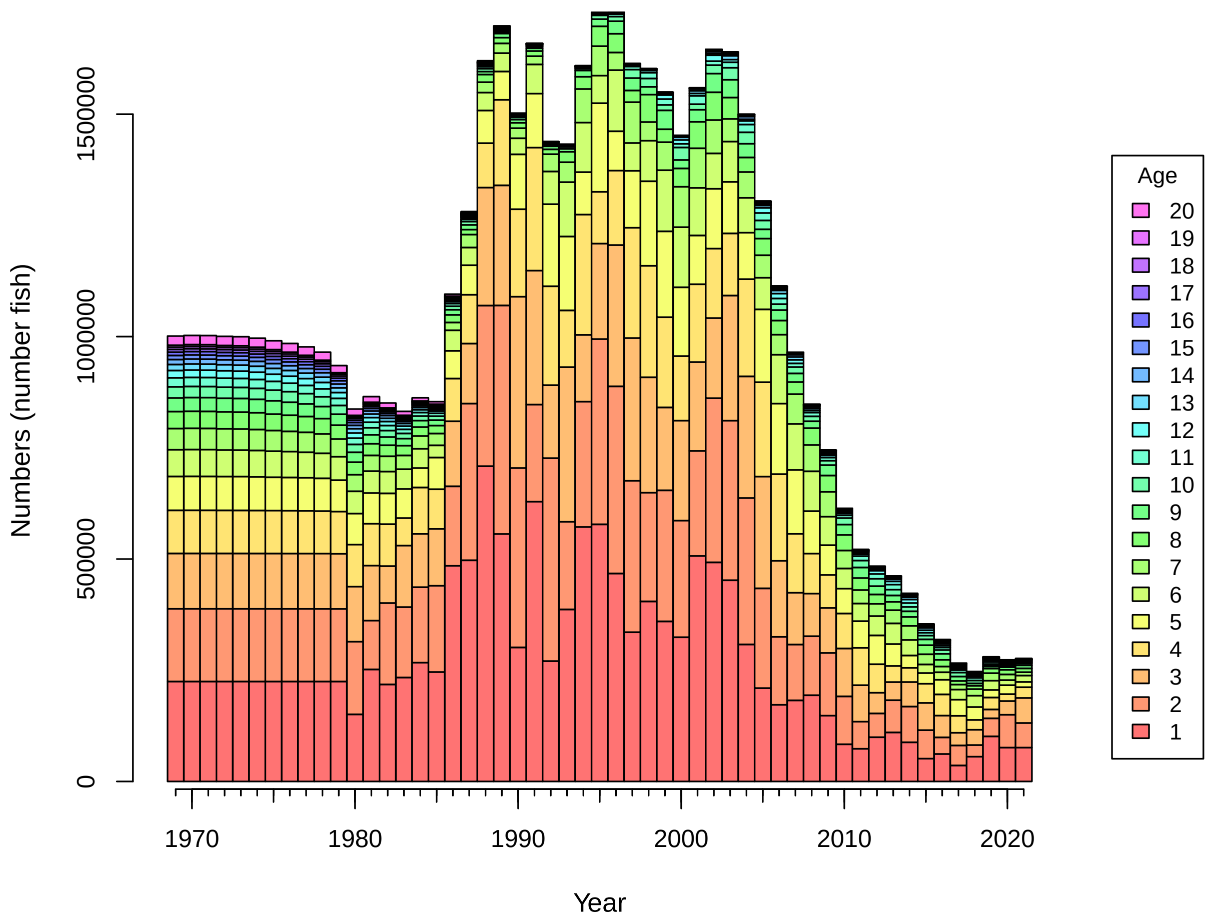


Figure 21. MCBE estimates of population abundance. Solid line indicates estimates from base run of the BAM; dashed lines represent median values; gray error bands indicate 5^{th} and 95^{th} percentiles of the MCBE. Top panel shows all ages 1+, and the bottom panel shows ages 2+.

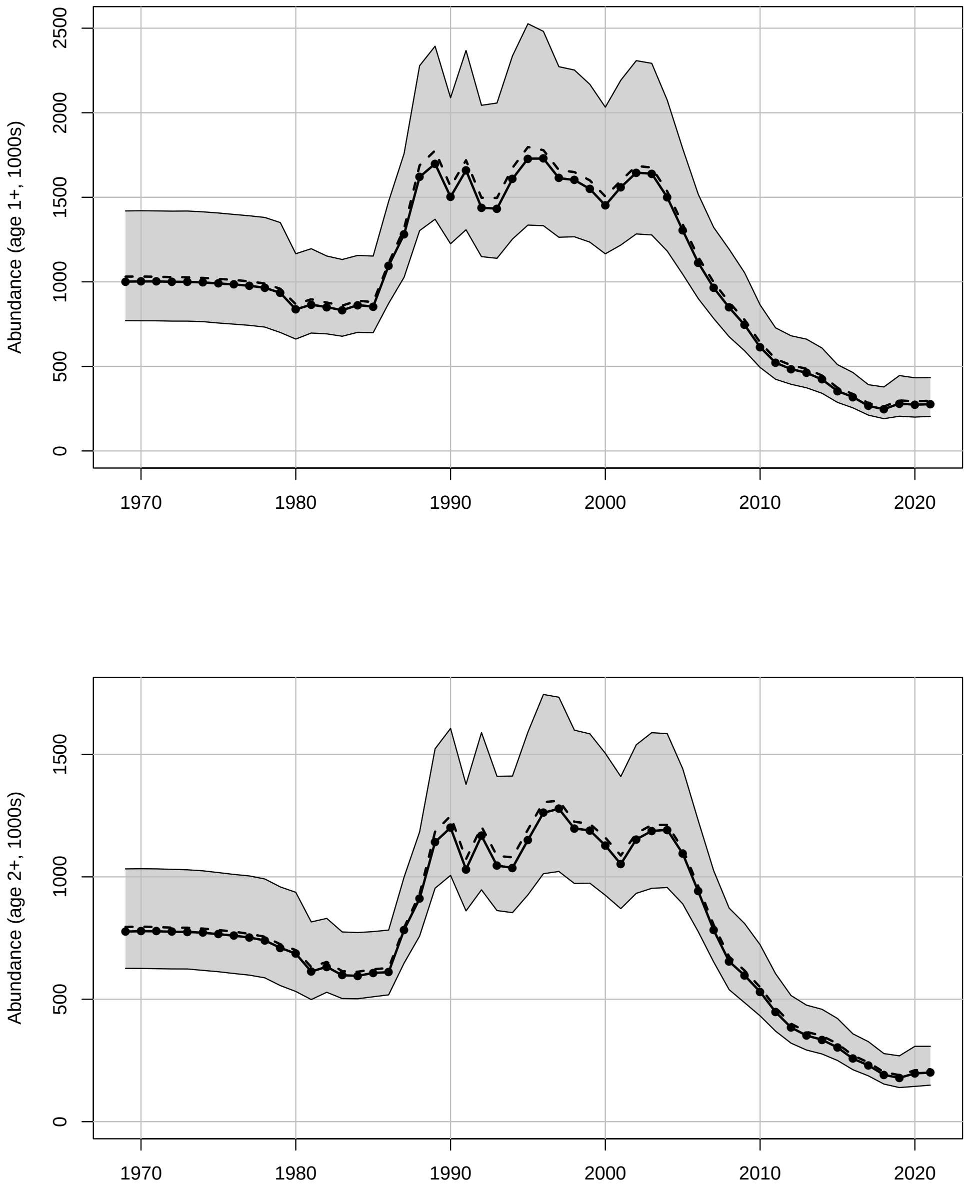


Figure 22. Top panel: Estimated recruitment of age-1 fish. Bottom panel: log recruitment residuals. Zero values (1969–1979, 2020–2021) were not estimated and not used in the assessment model.

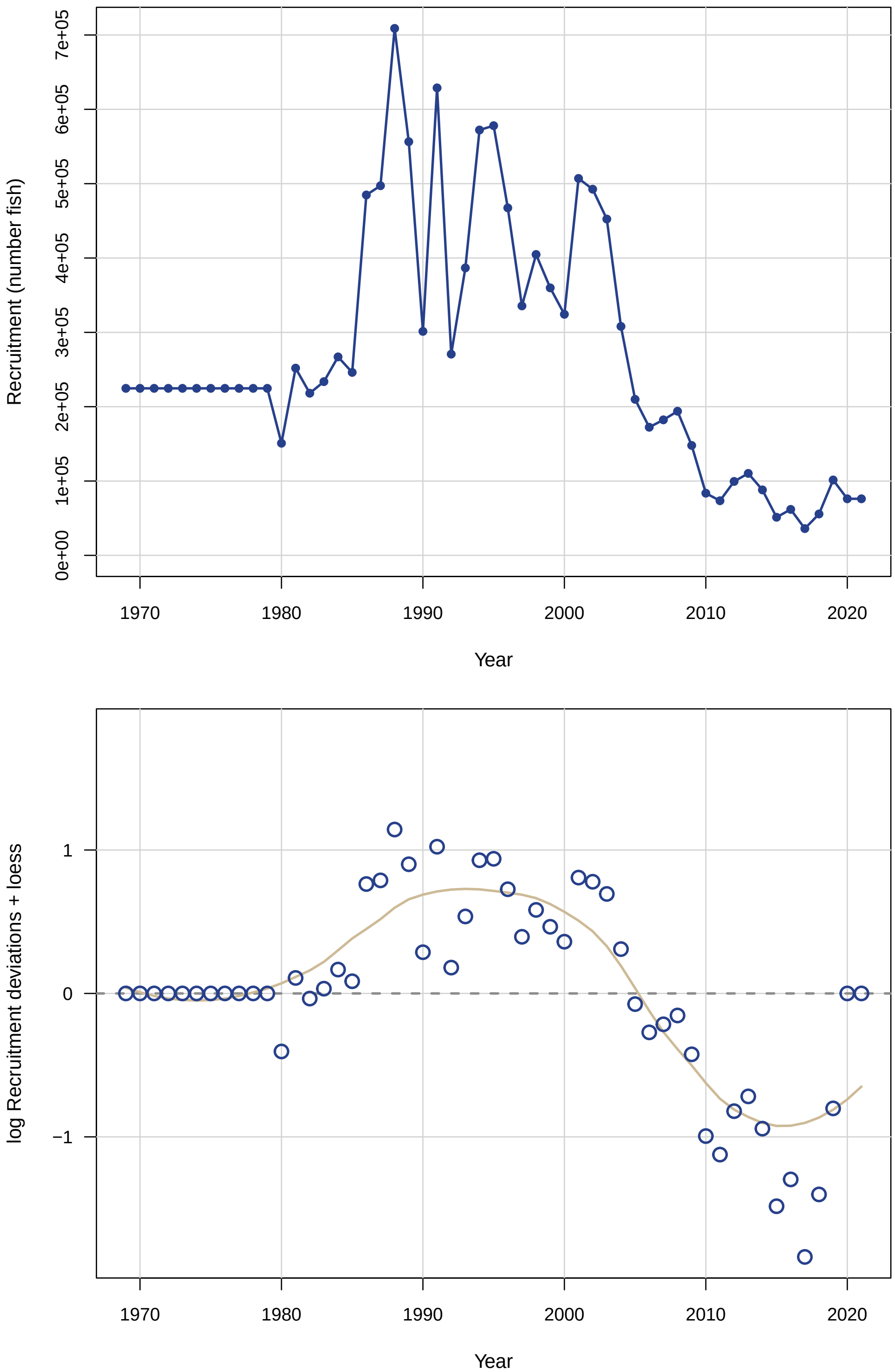


Figure 23. Top panel: Autocorrelation (ACF) of estimated (1980–2019) log recruitment residuals. Bottom panel: Partial autocorrelation of estimated (1980–2019) log recruitment residuals..

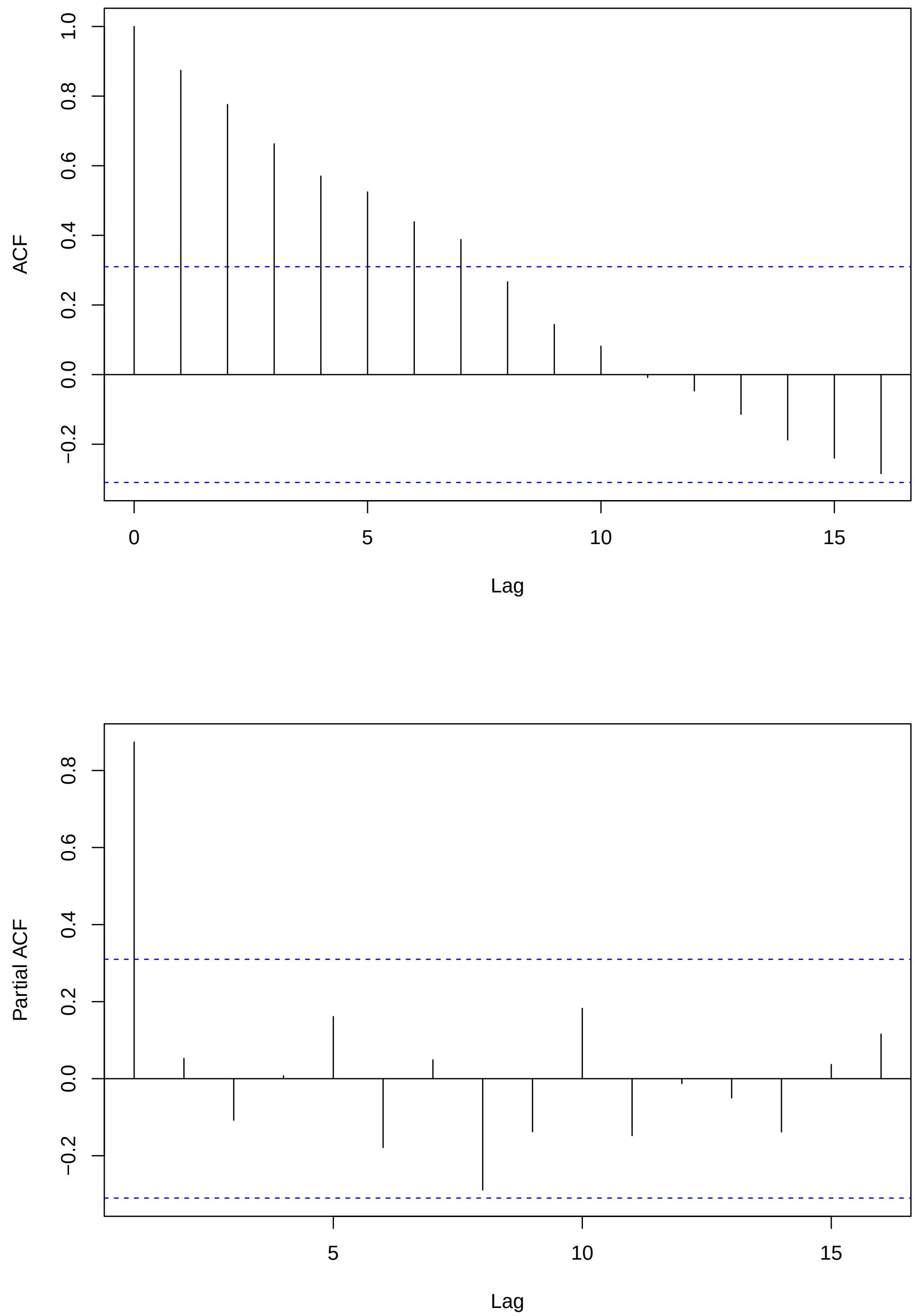


Figure 24. Estimated biomass at age at start of year.

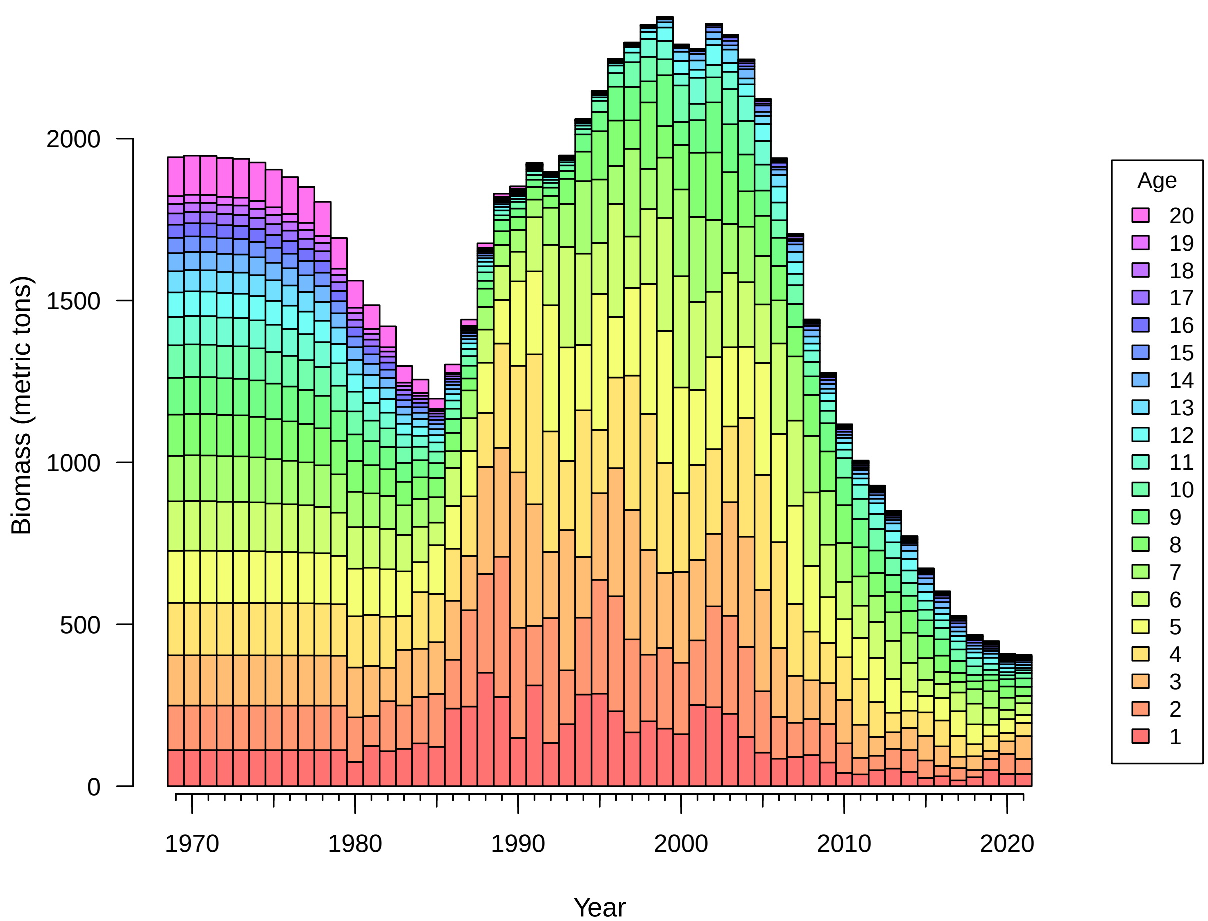
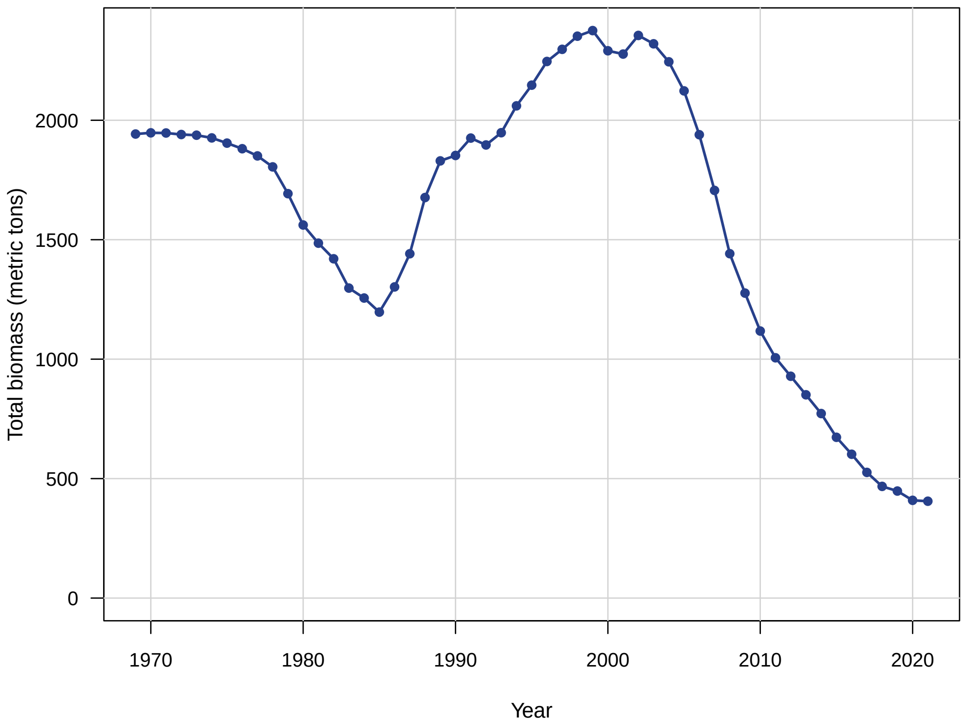


Figure 25. Top panel: Estimated total biomass (mt) at start of year. Bottom panel: Estimated spawning stock (mt) at time of peak spawning.



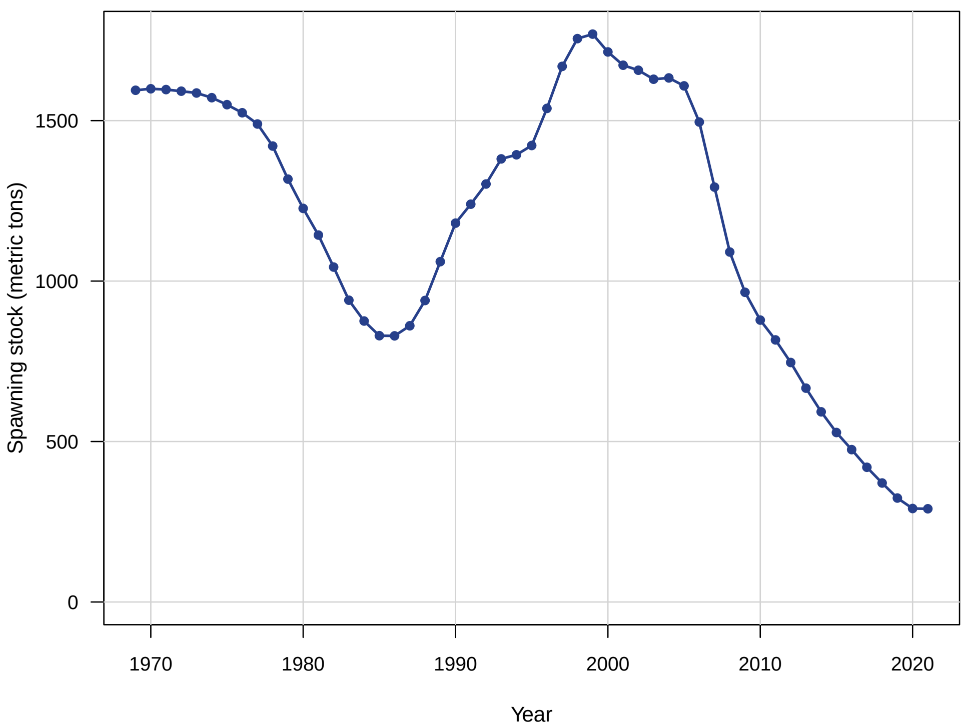


Figure 26. Selectivity of SERFS chevron trap and video index. The legend indicates the first year of each selectivity block.

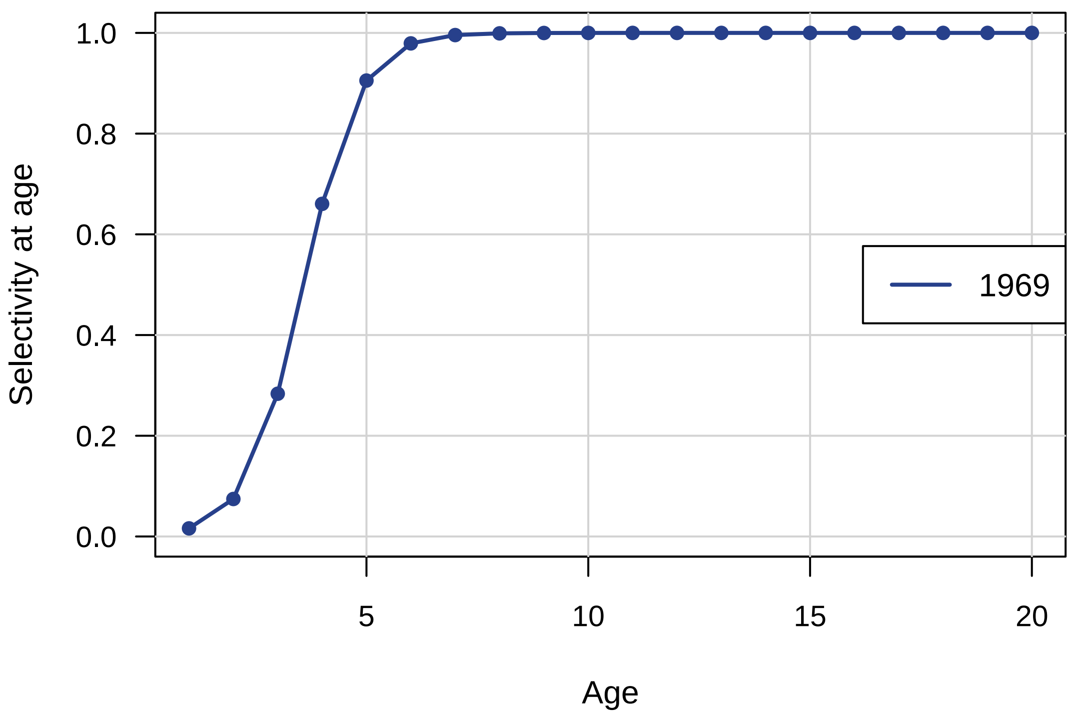


Figure 27. Selectivities of commercial removals (landings + dead discards). The legend indicates the first year of each selectivity block.

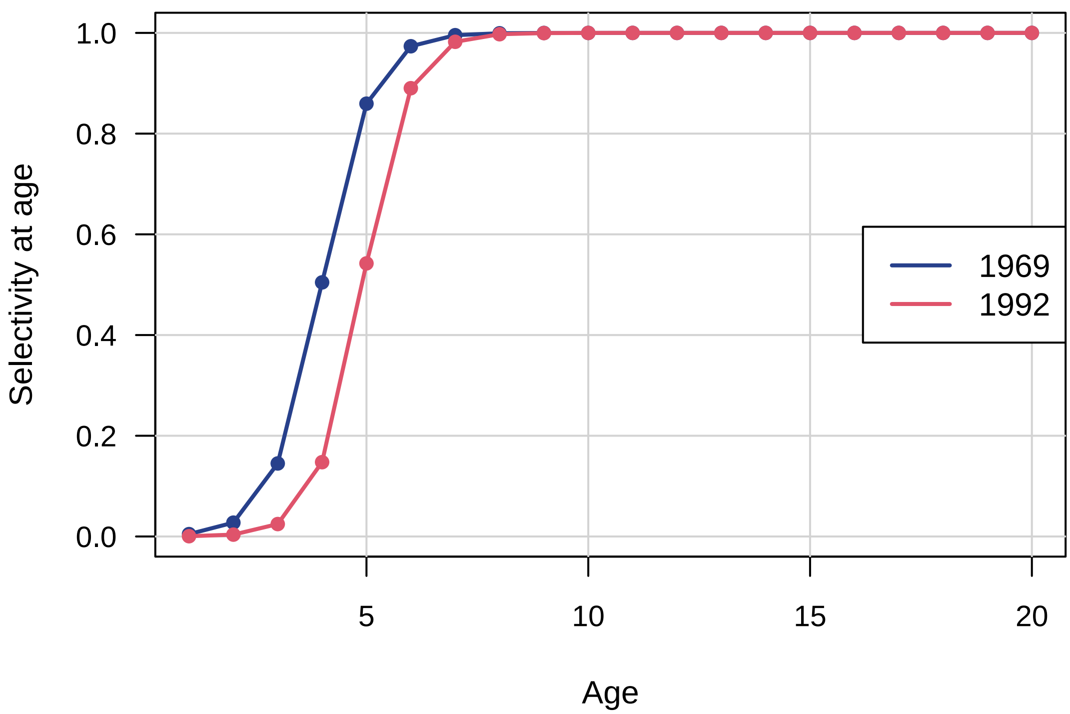


Figure 28. Selectivities of recreational removals (landings + dead discards). The legend indicates the first year of each selectivity block, although the SERFS index did not vary across blocks.

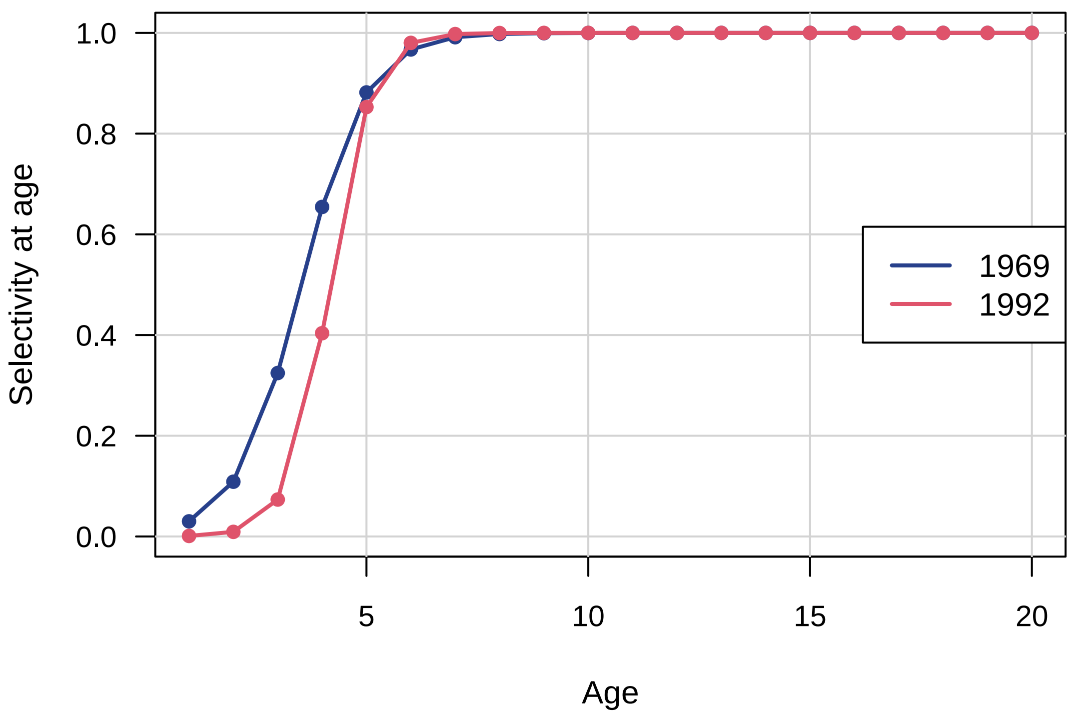


Figure 29. Average selectivity of removals (landings + dead discards) from the terminal assessment years, weighted by geometric mean Fs from the last three assessment years, and used in computation of benchmarks and projections.

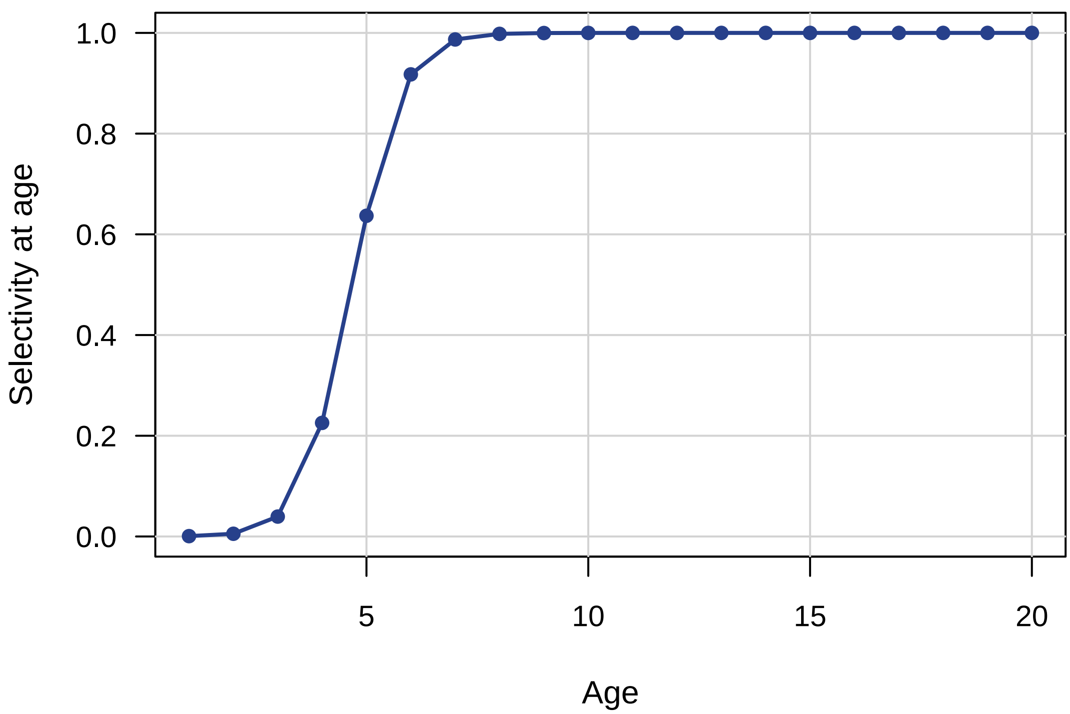


Figure 30. Estimated fully selected fishing mortality rate (per year) by fleet. COM refers to commercial and REC to recreational.

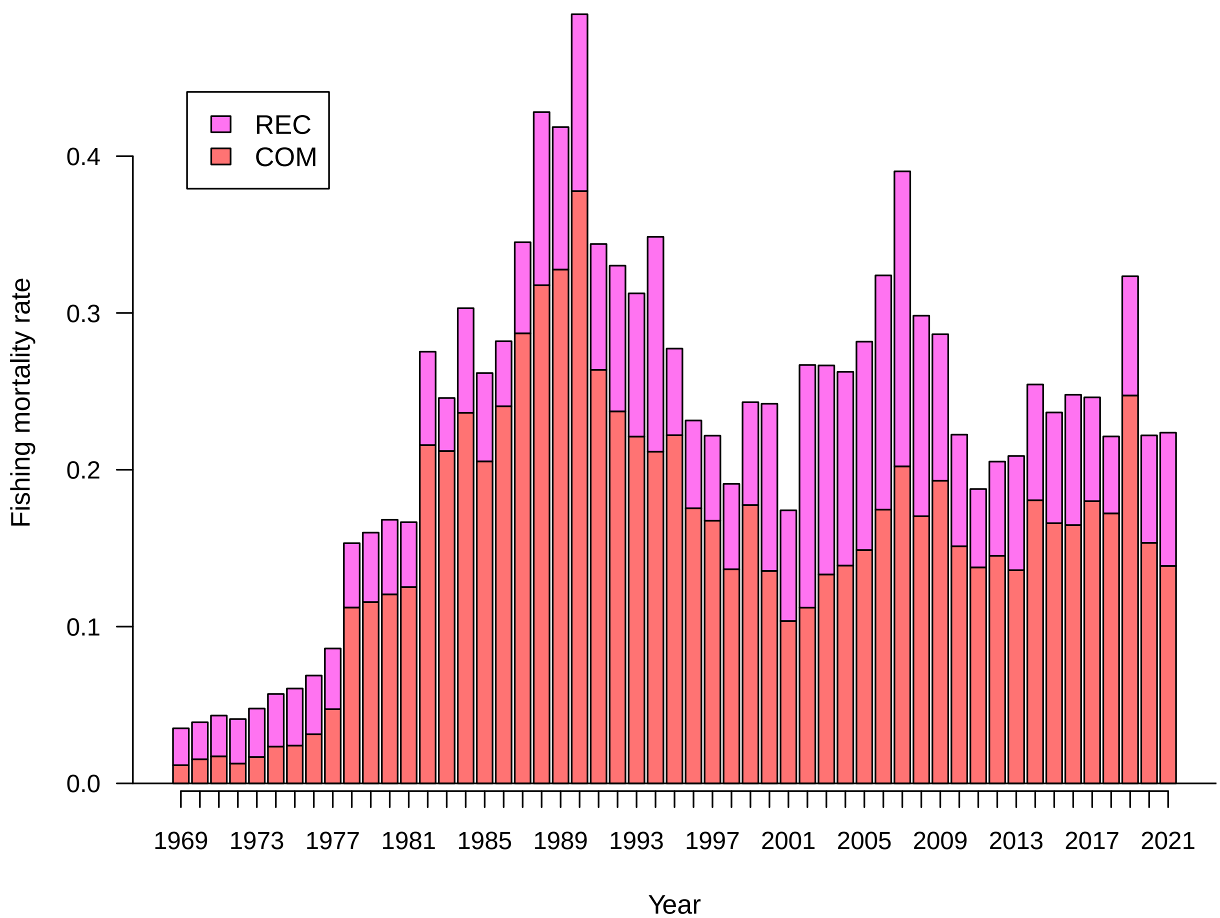


Figure 31. Estimated removals (landings + dead discards) in numbers by fleet from the catch-age model. COM refers to commercial and REC to recreational. For reference, the point estimate of $L_{F40\%}$ in numbers is 61.39 *(1000 fish).*

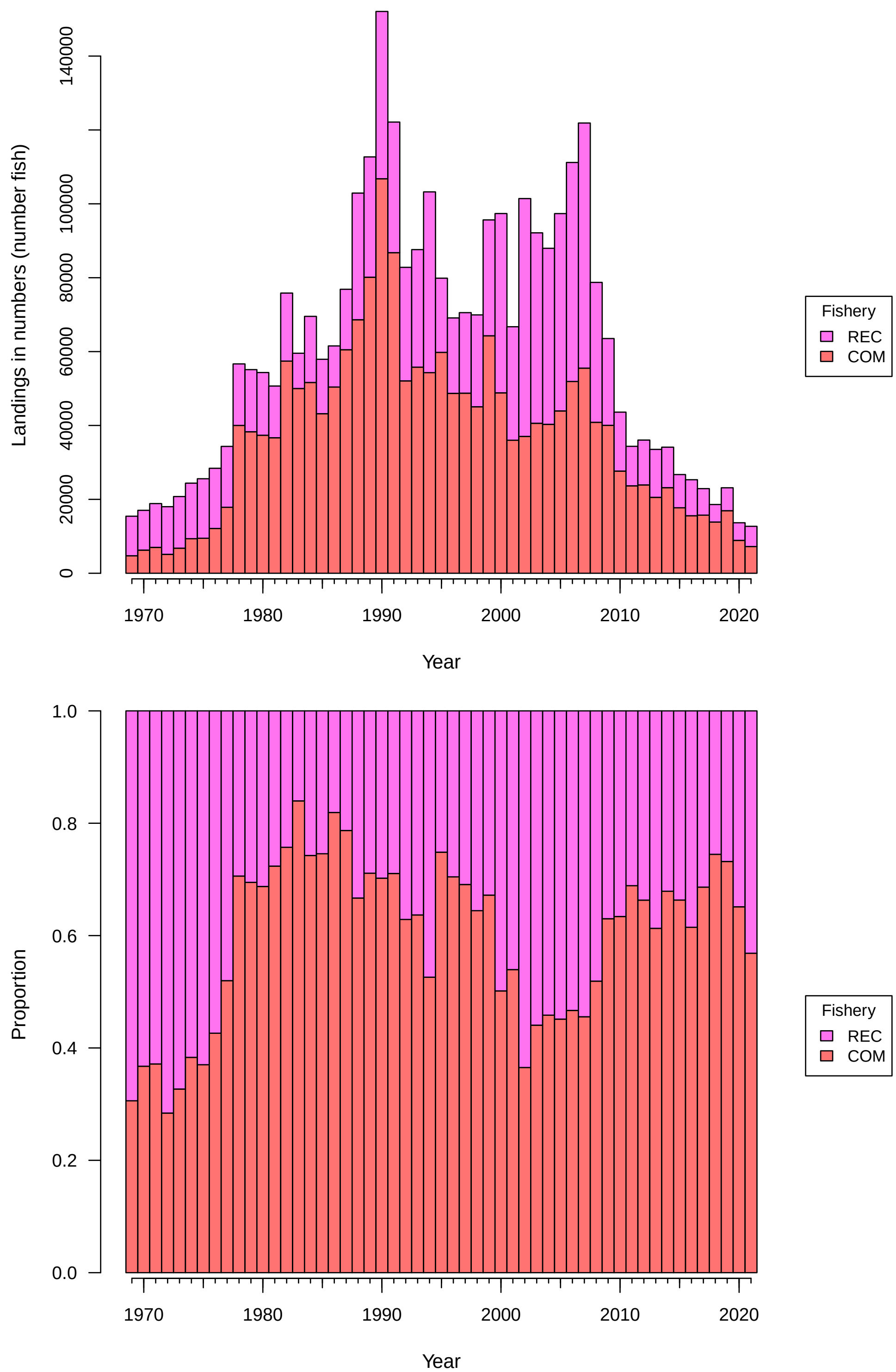


Figure 32. Estimated removals (landings + dead discards) in whole weight by fleet from the catch-age model. COM refers to commercia and REC to recreational. Horizontal dashed line in the top panel corresponds to the point estimate of $L_{\mathrm{F40\%}}$ in weight.

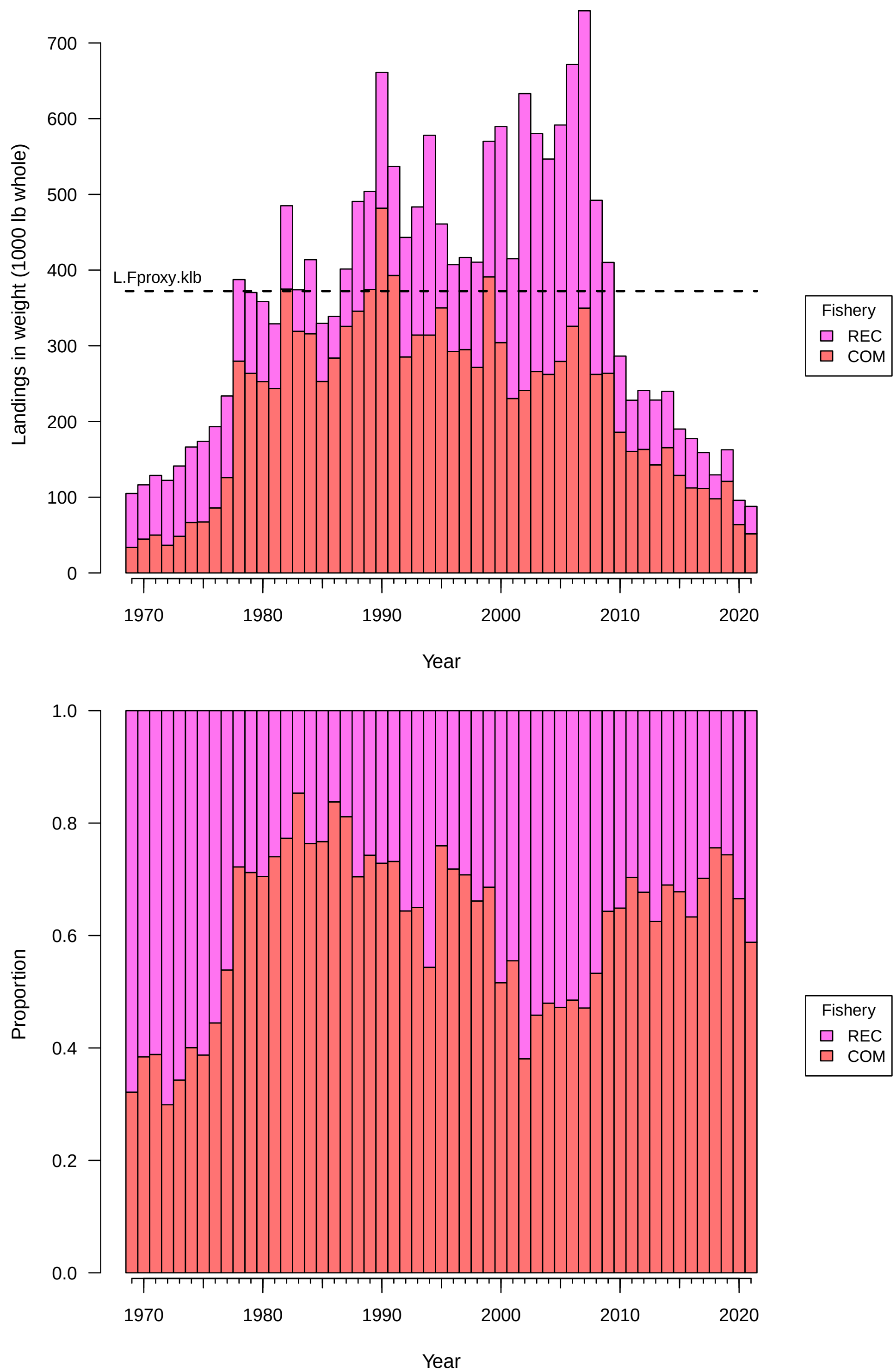


Figure 33. Spawner-recruit relationship, with and without lognormal bias correction. The expected (mean-unbiased) curve was used for computing management benchmarks.

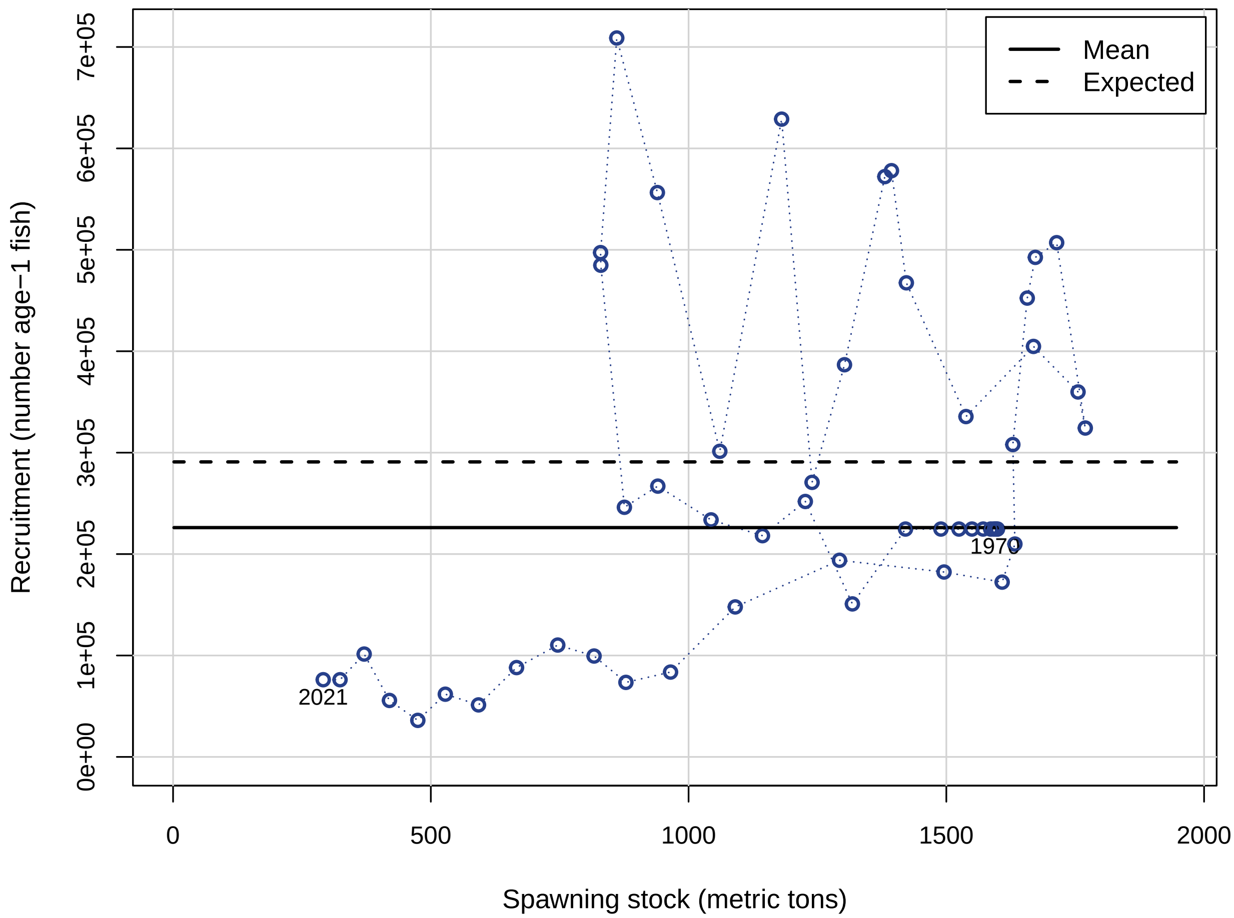


Figure 34. Probability densities of spawner-recruit quantities: Mean recruits (R0, age-1 fish), median recruits, unfished spawners per recruit, and standard deviation of recruitment residuals in log space. Solid vertical lines represent point estimates or values from the base run of the BAM; dashed vertical lines represent medians from the MCBE runs.

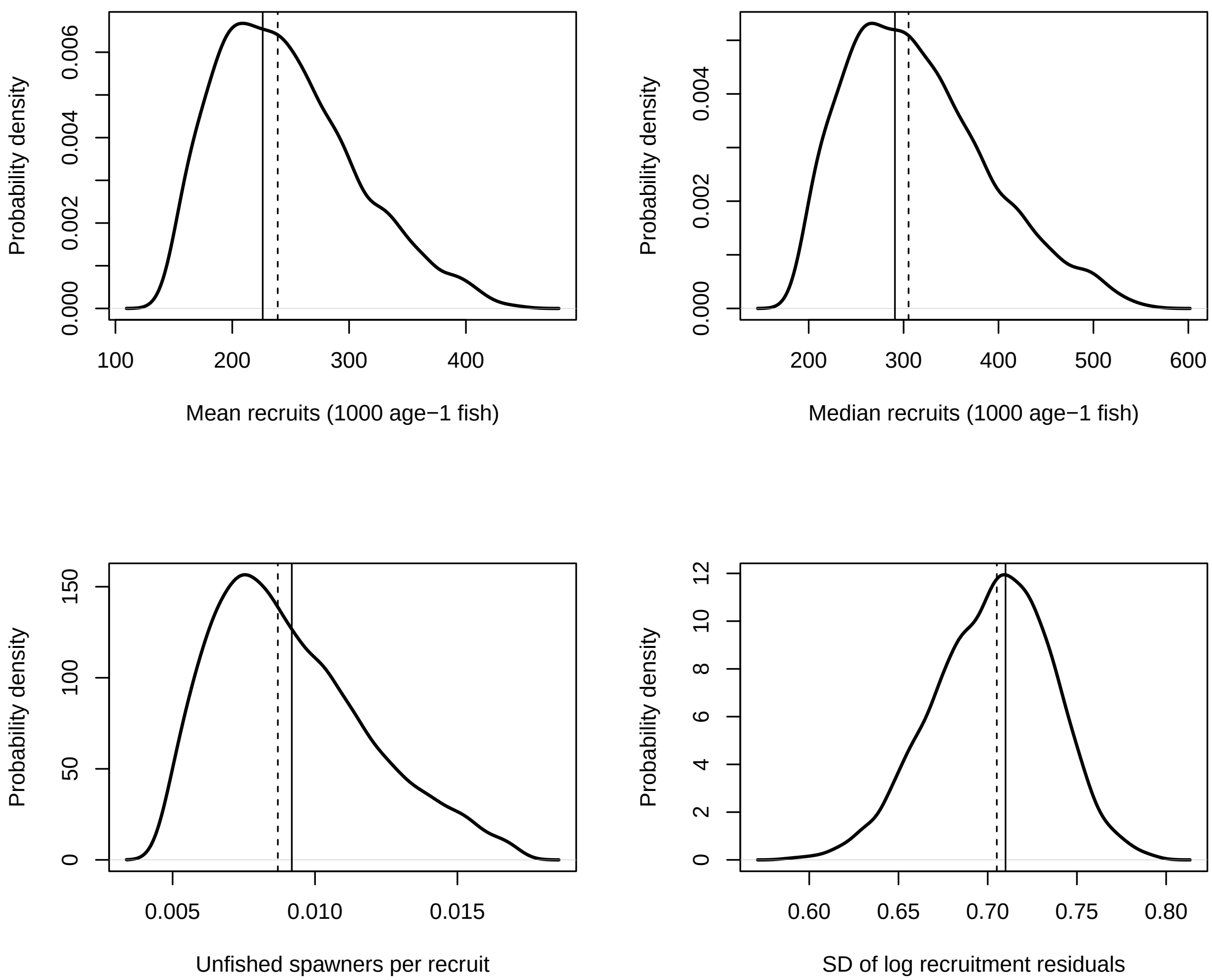


Figure 35. Yield (lb whole weight) per recruit based on average selectivity from the end of the assessment period. The dashed line indicates $F_{40\%}$.

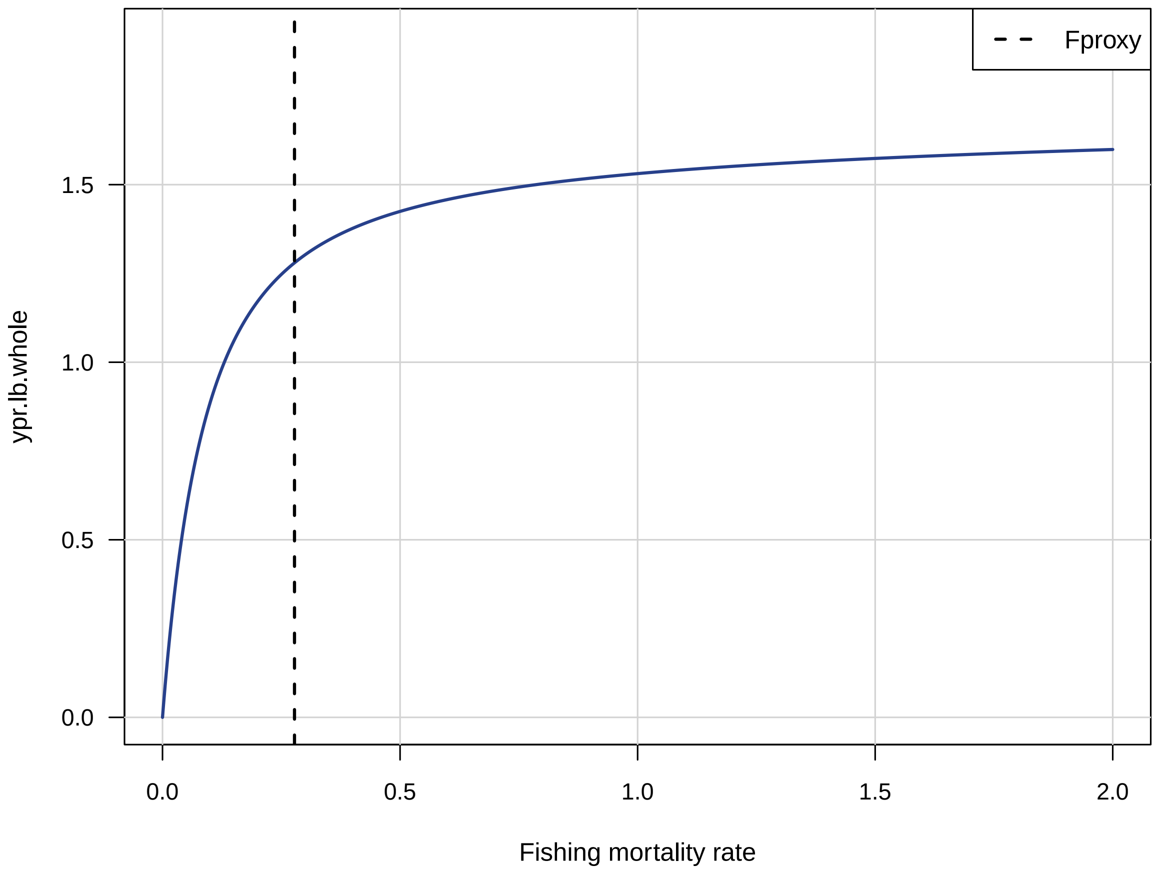


Figure 36. Spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the X% level of SPR provides $F_{X\%}$. The dashed line indicates $F_{40\%}$. SPR is based on average selectivity from the end of the assessment period.

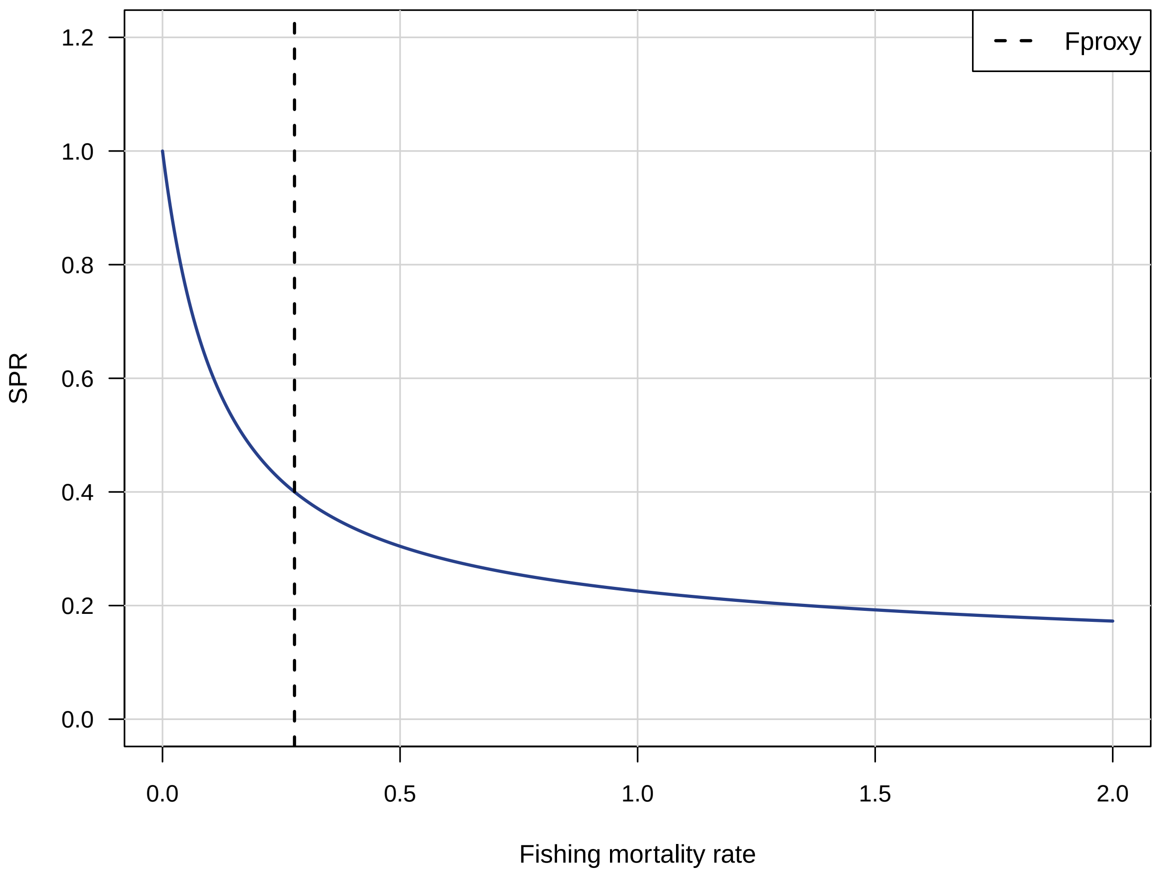


Figure 37. Top panel: equilibrium removals (landings + dead discards) as a function of fishing rate. Bottom panel: equilibrium spawning biomass as a function of fishing rate. Both functions are based on average selectivity from the end of the assessment period. The dashed line indicates $F_{40\%}$*.*

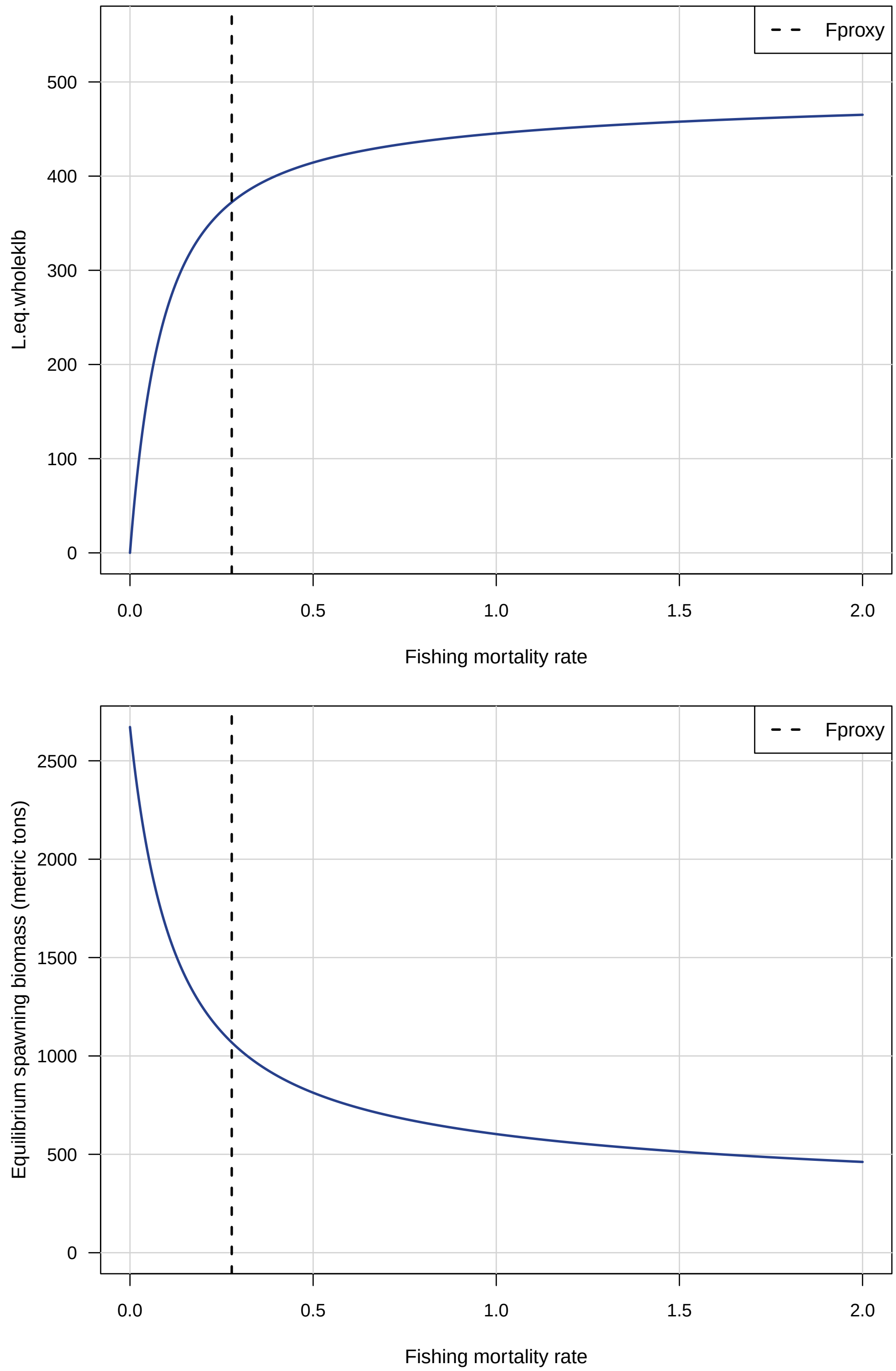


Figure 38. Probability densities of $F_{40\%}$-related benchmarks from the MCBE analysis. L at $F_{40\%}$ is the proxy for MSY *and represents landings and dead discards. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.*

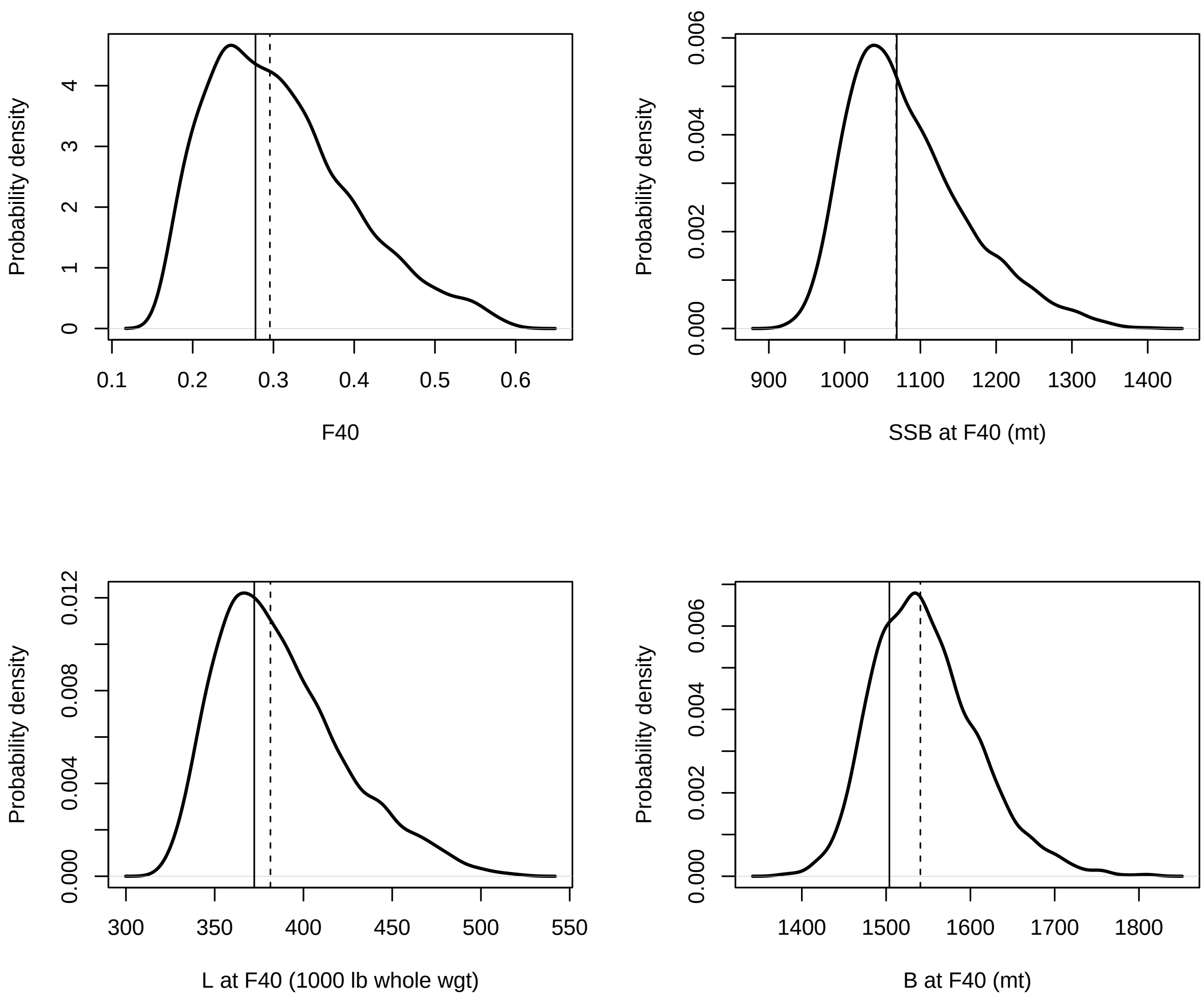


Figure 39. Estimated time series relative to benchmarks. Solid line indicates estimates from the base run; dashed lines represent median values of the MCBE analysis; gray error bands indicate 5^{th} *and* 95^{th} *percentiles of the MCBE. Top panel: spawning biomass relative to* $\mathrm{SSB}_{\mathrm{F40\%}}$*. Bottom panel: F relative to* $F_{40\%}$*.*

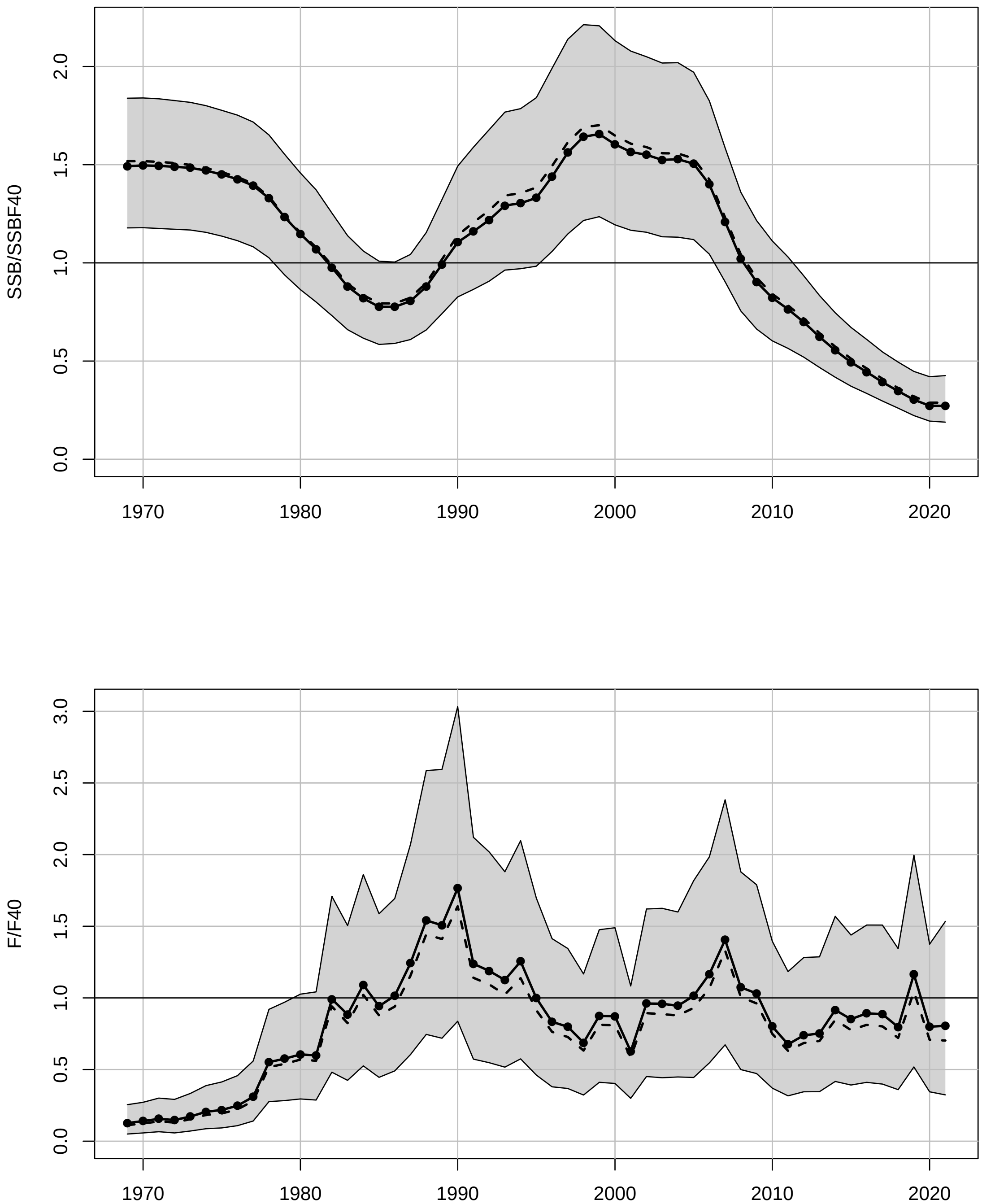


Figure 40. Probability densities of terminal status estimates from the MCBE analysis. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.

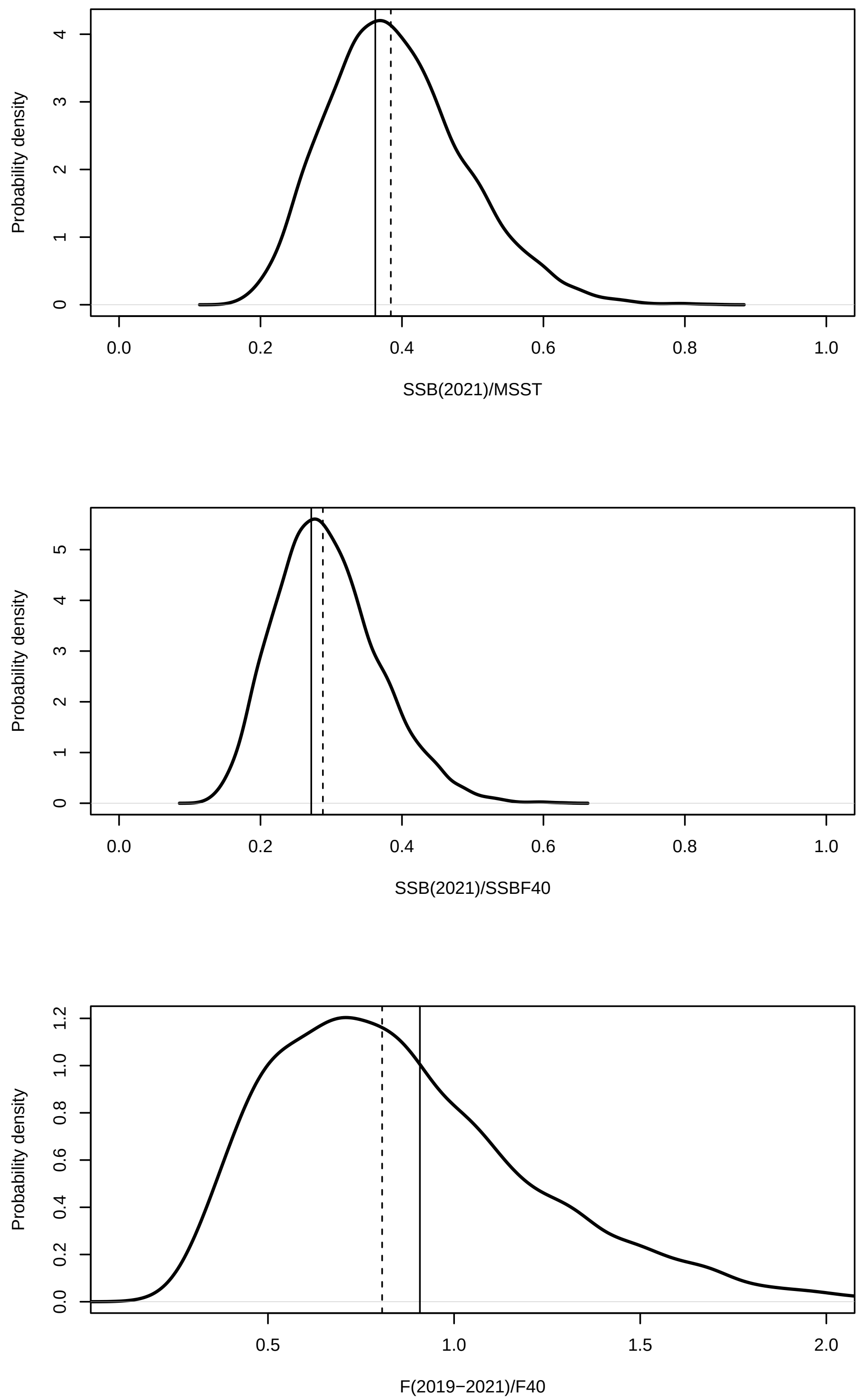


Figure 41. Phase plots of terminal status estimates from MCBE analysis. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by 5^{th} and 95^{th} percentiles. Proportion of runs falling in each quadrant indicated.

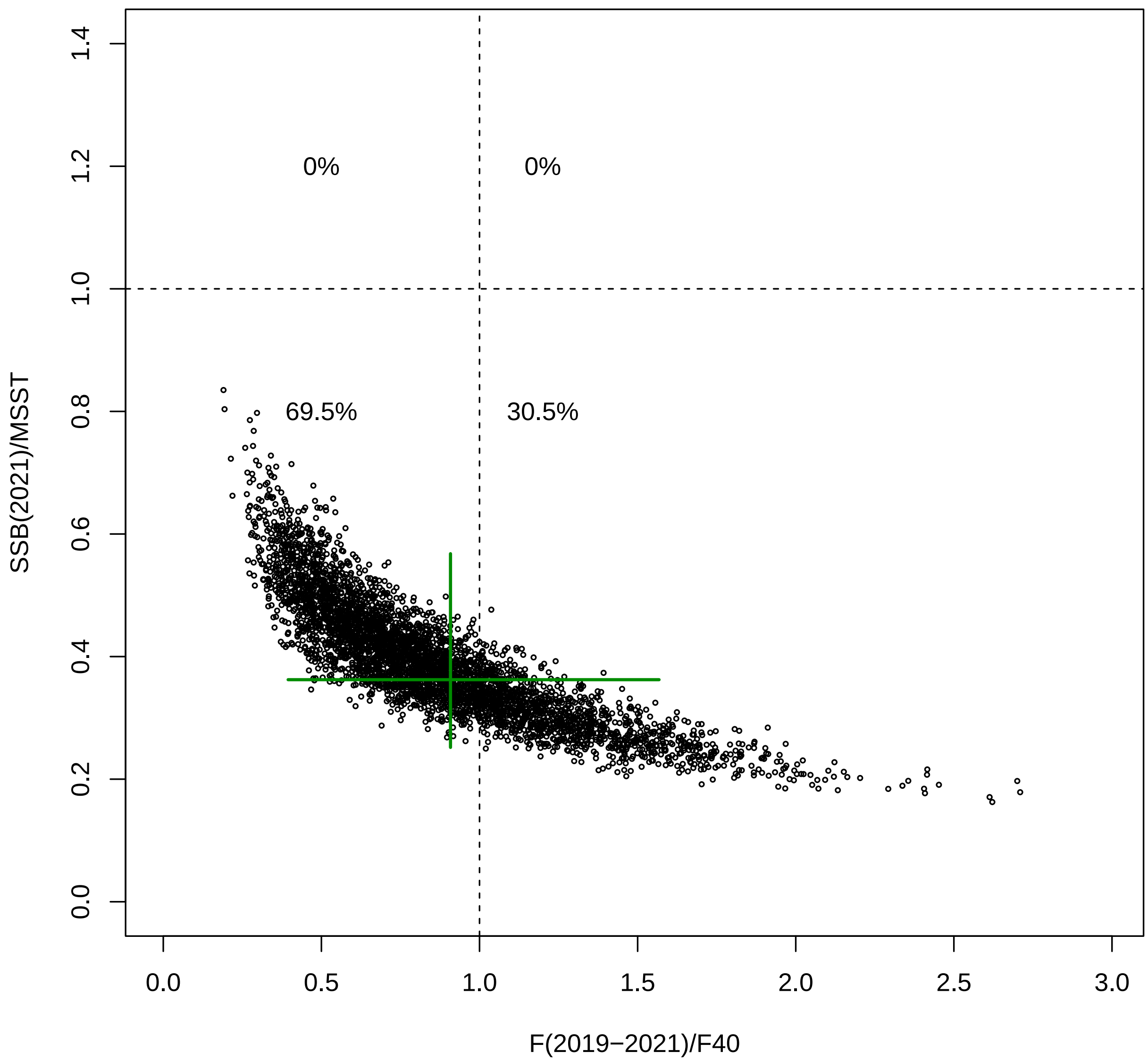


Figure 42. Age structure relative to the equilibrium expected at $F_{40\%}$.

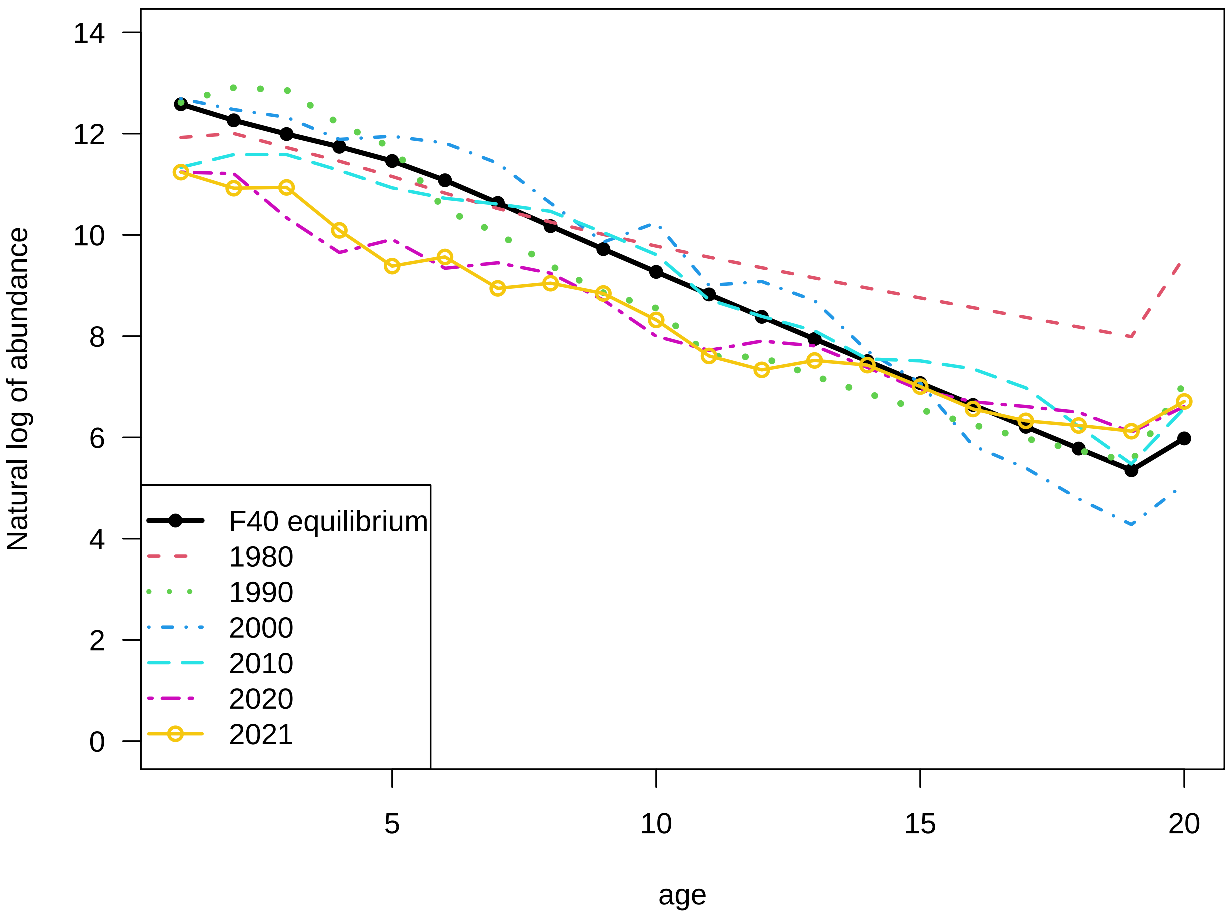


Figure 43. Sensitivity to natural mortality rate (sensitivity runs S1–S2). Top panel: Ratio of F to $F_{40\%}$. Bottom panel: Ratio of SSB *to* $SSB_{F40\%}$.

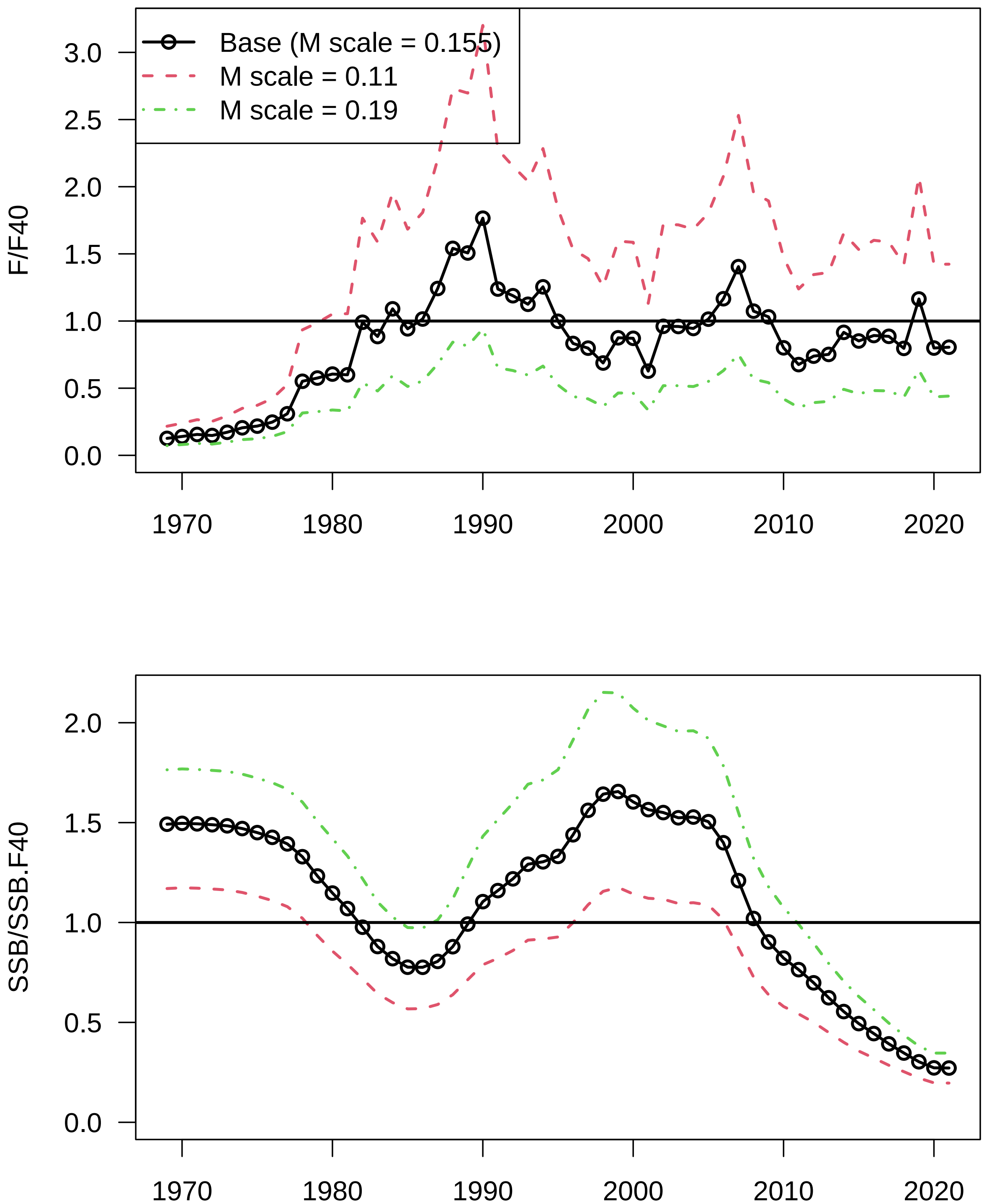


Figure 44. Sensitivity to discard mortality rate(sensitivity runs S3–S5). Top panel: Ratio of F to $F_{40\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{F40\%}}$.

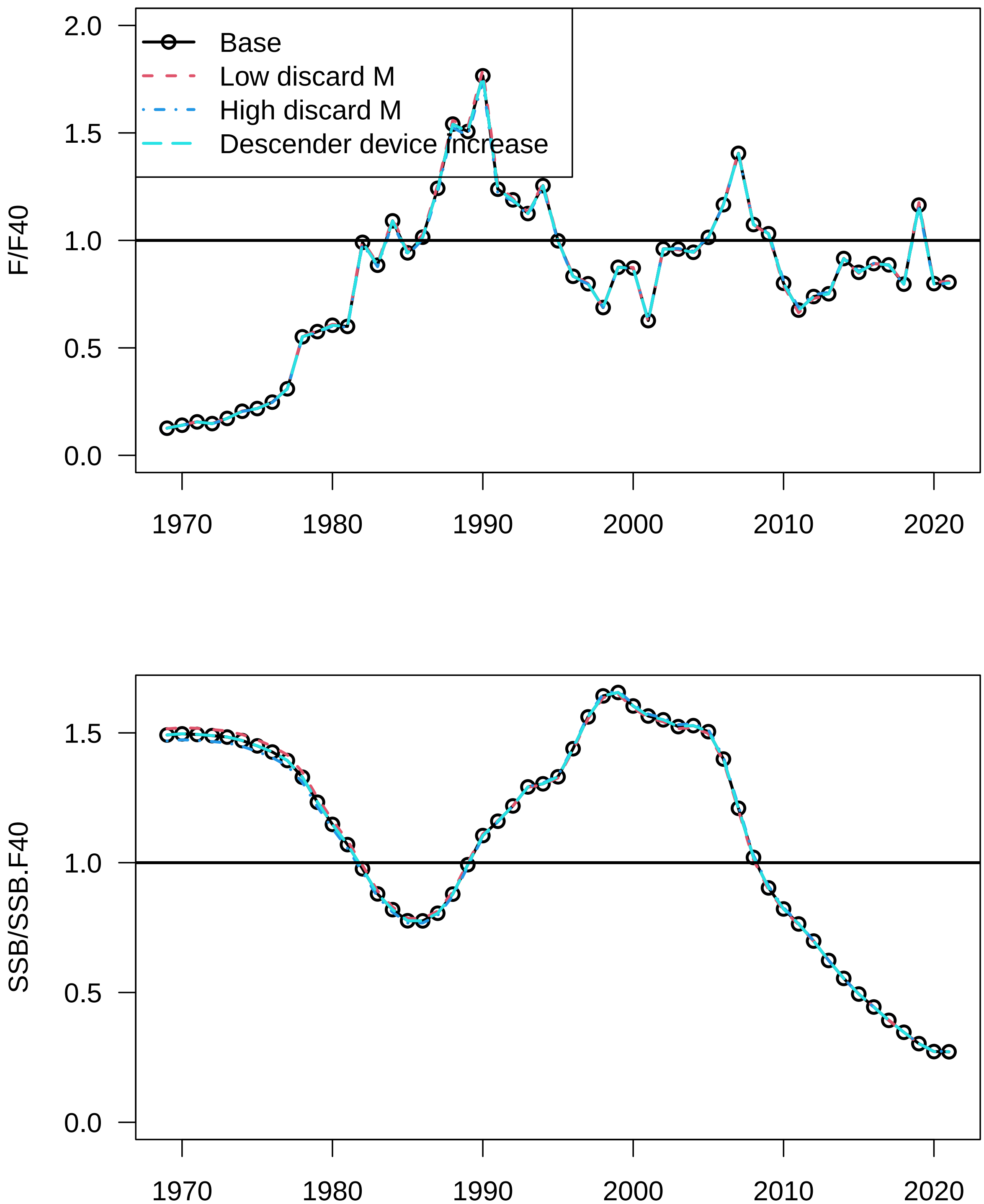


Figure 45. Sensitivity to weight of SERFS index (sensitivity runs S6–S7). Top panel: Ratio of F to $F_{40\%}$. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{F40\%}$.

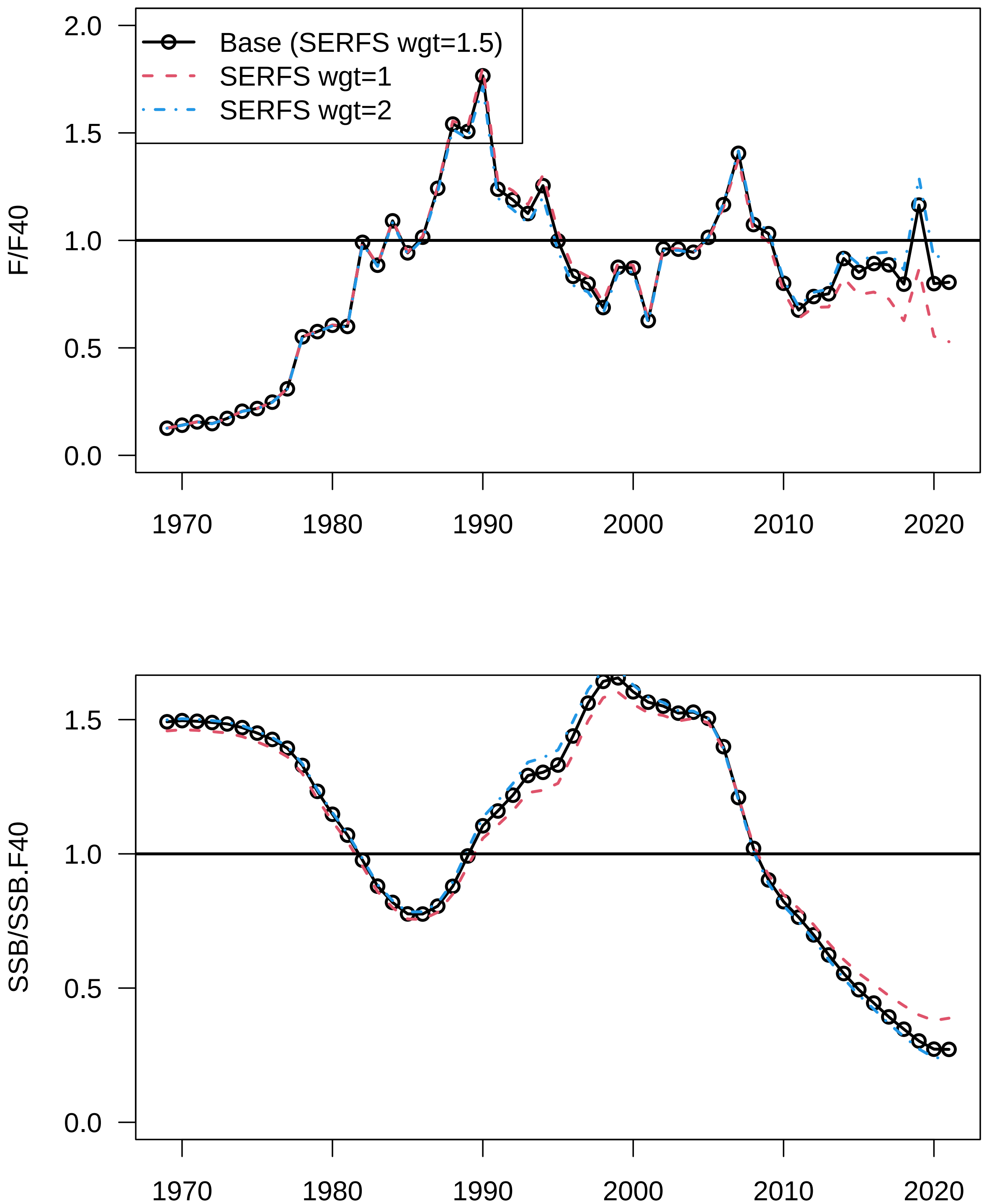


Figure 46. Sensitivity to dropping indices (sensitivity runs S8–S10). Top panel: Ratio of F to $F_{40\%}$*. Bottom panel: Ratio of* SSB *to* $SSB_{F40\%}$.

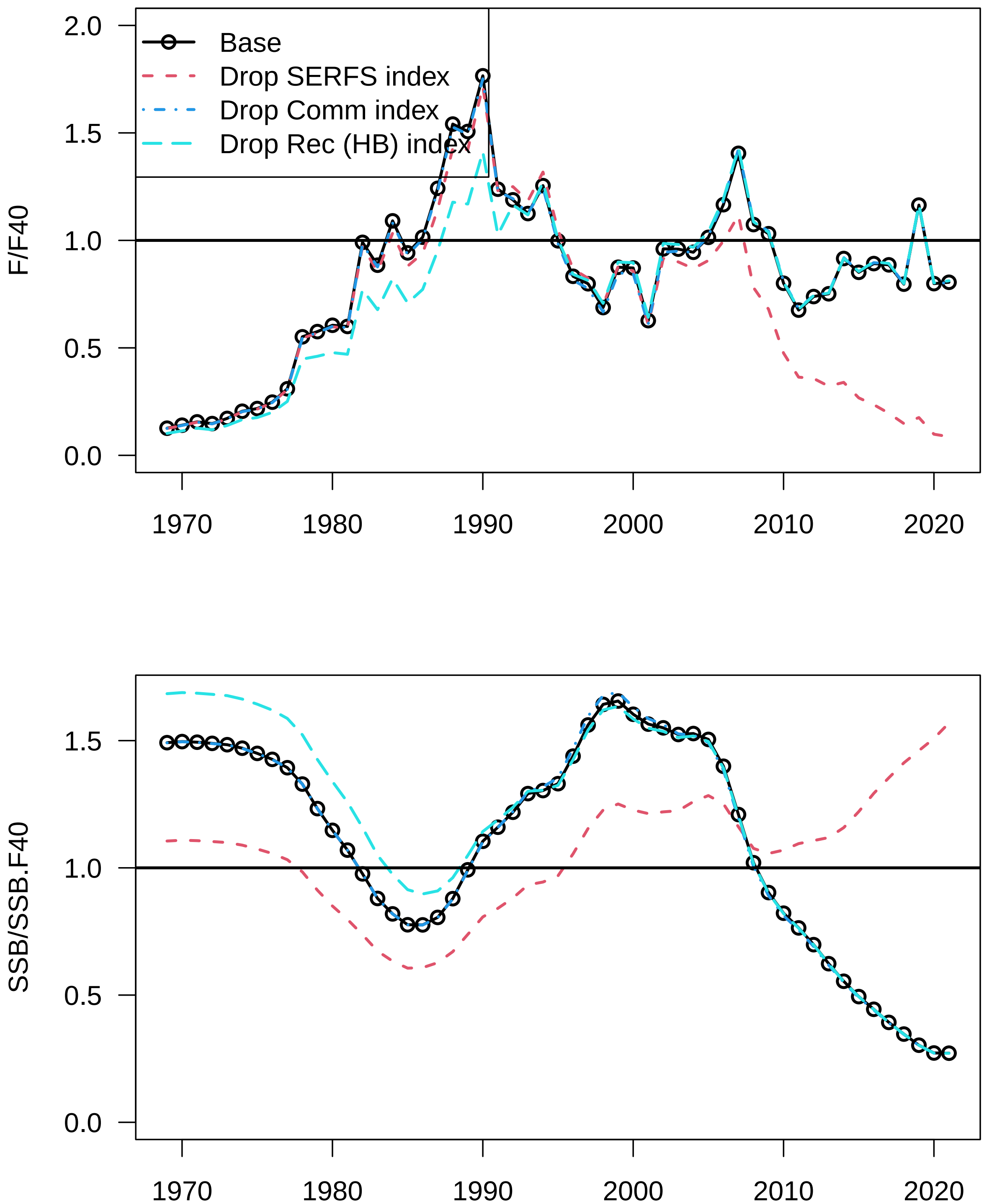


Figure 47. Sensitivity to dropping age compositions (sensitivity runs S11–S13). Top panel: Ratio of F to $F_{40\%}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F40\%}}$.

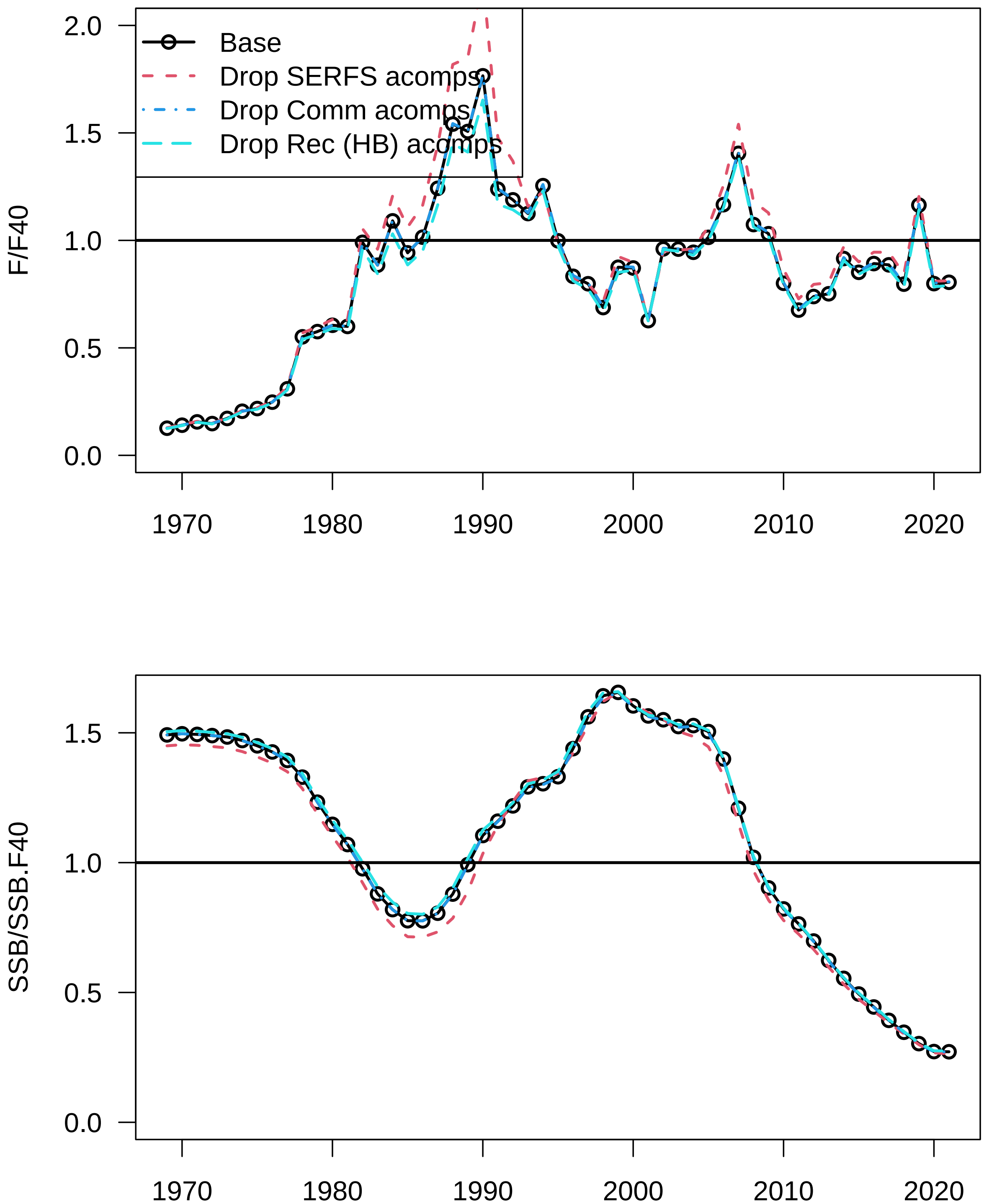


Figure 48. Sensitivity to dropping length compositions (sensitivity run S14). Top panel: Ratio of F to $F_{40\%}$. Bottom panel: Ratio of SSB *to* $SSB_{F40\%}$.

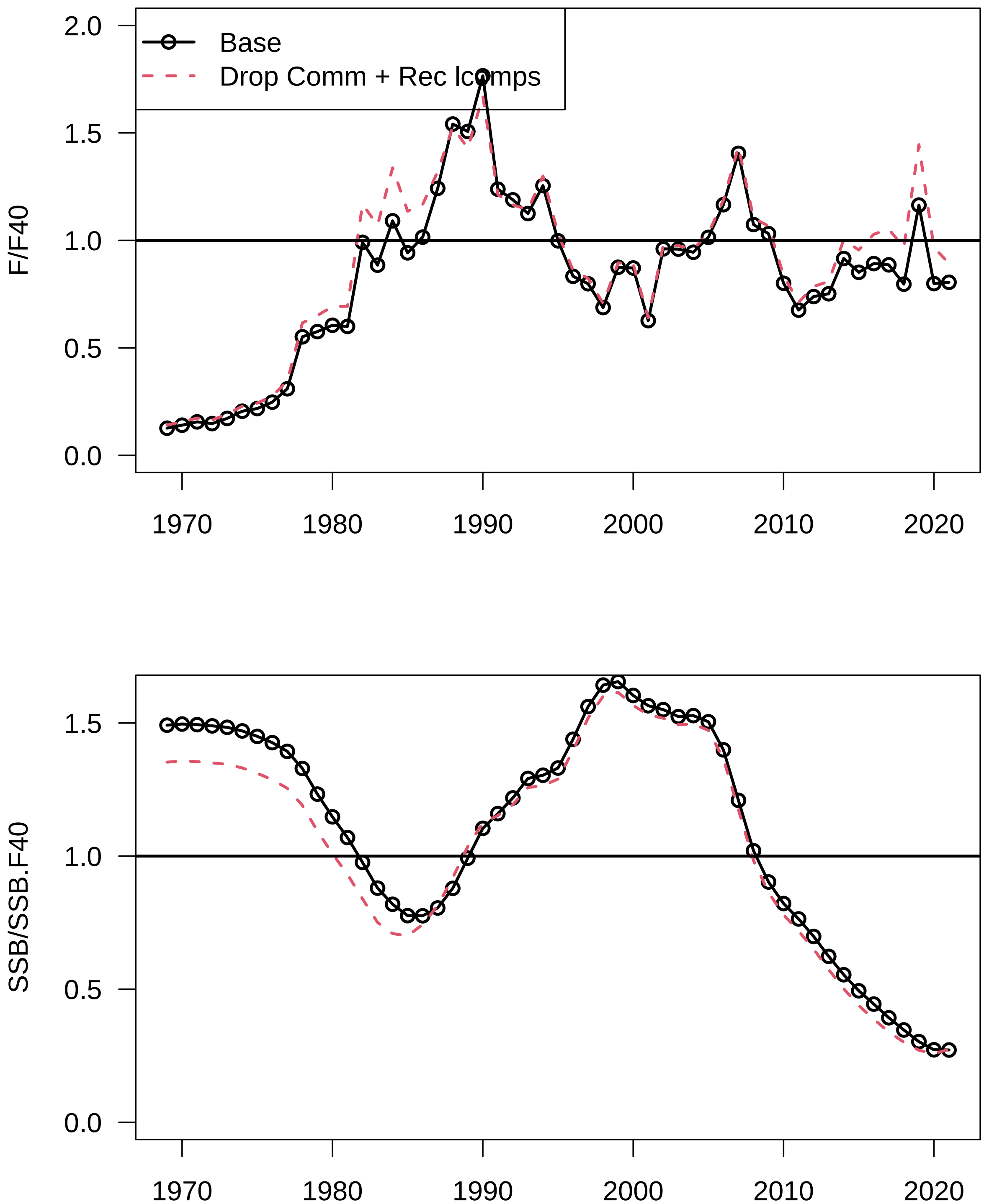


Figure 49. Sensitivity to using SERFS length instead of age compositions (sensitivity run S15). Top panel: Ratio of F to $F_{40\%}$. Bottom panel: Ratio of SSB *to* $\text{SSB}_{\text{F40\%}}$.

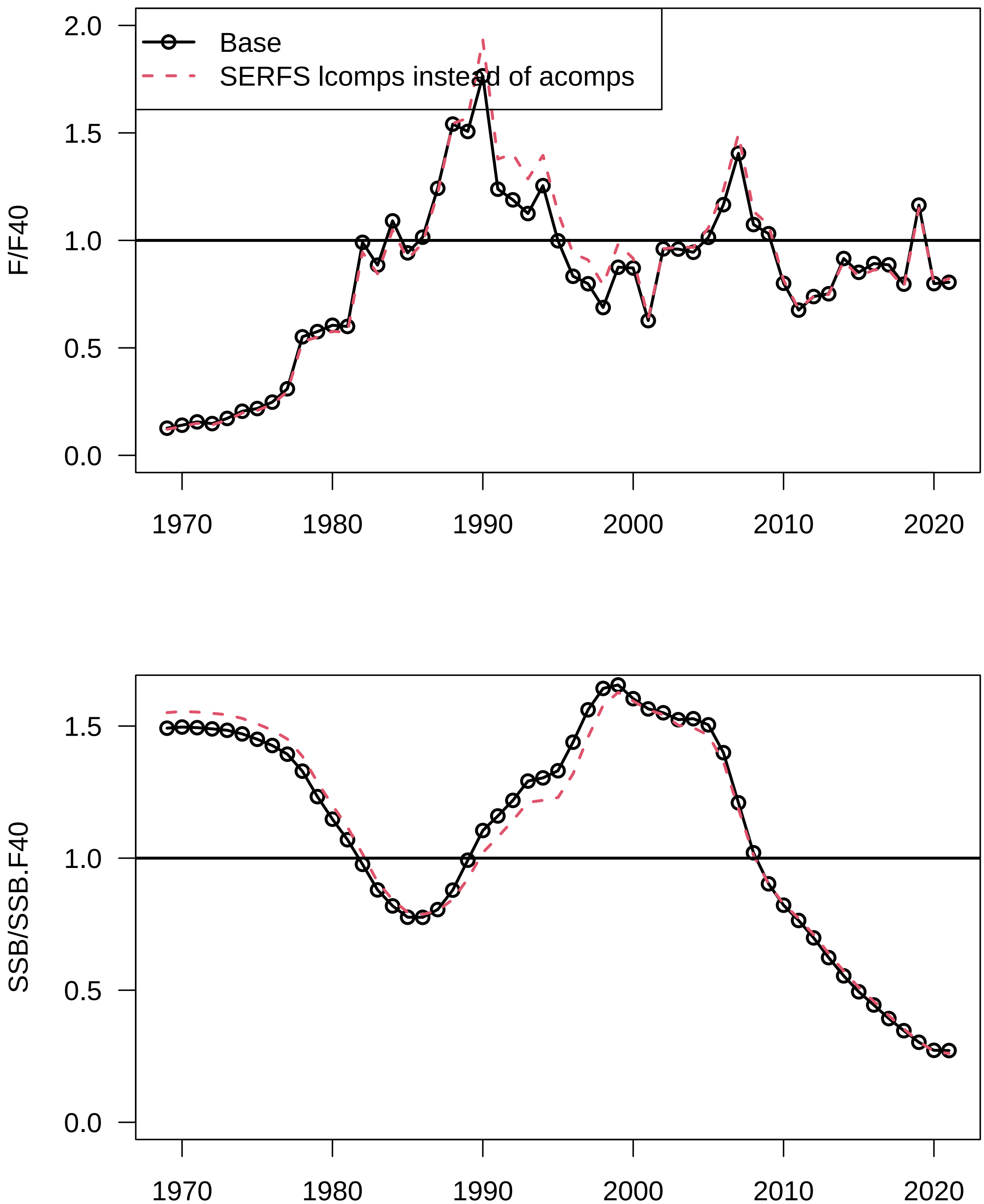


Figure 50. Sensitivity to time-varying SERFS selectivity (sensitivity run S16). Top panel: Ratio of F to $F_{40\%}$. Bottom panel: Ratio of SSB *to* $SSB_{F40\%}$.

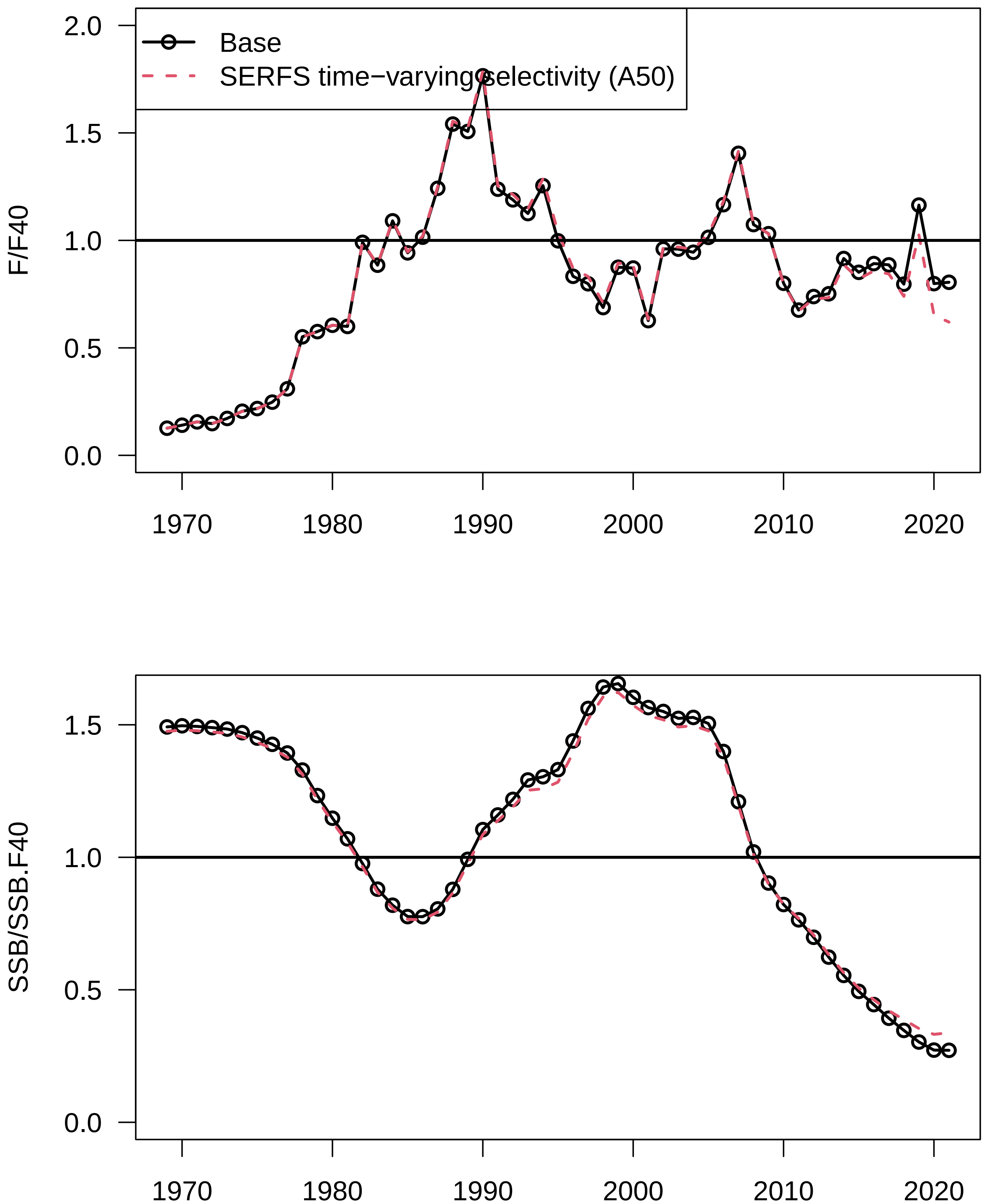


Figure 51. Retrospective analyses. Sensitivity to terminal year of data. Top panel: Fishing mortality rates. Middle panel: Recruits. Bottom panel: Spawning biomass. Closed circles show terminal-year estimates. Imperceptible lines overlap results of the base run.

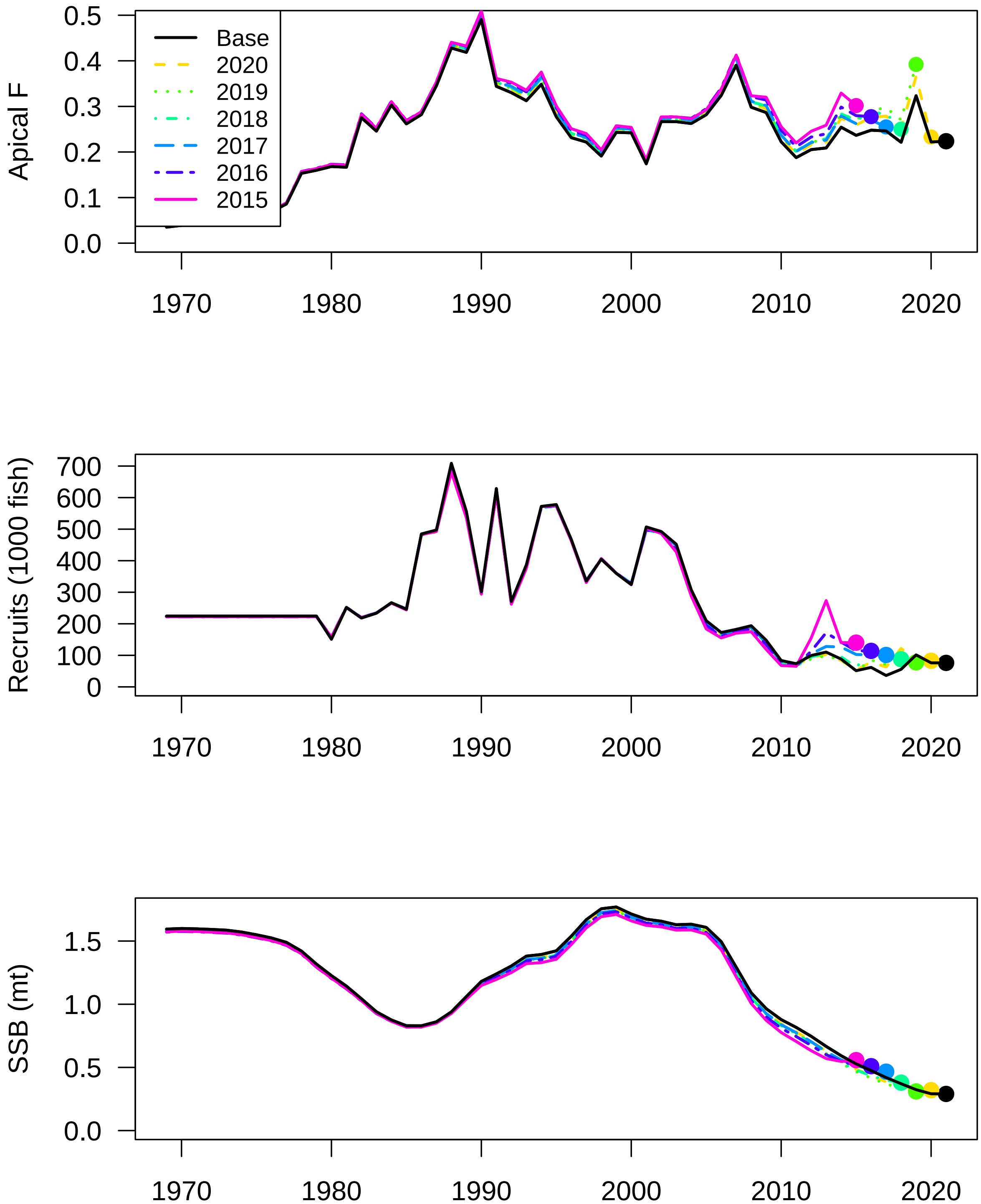


Figure 52. Projected time series under scenario 1—fishing mortality rate at $F = 0$ and long-term average recruitment. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{40\%}$-related quantities benchmarks; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning.

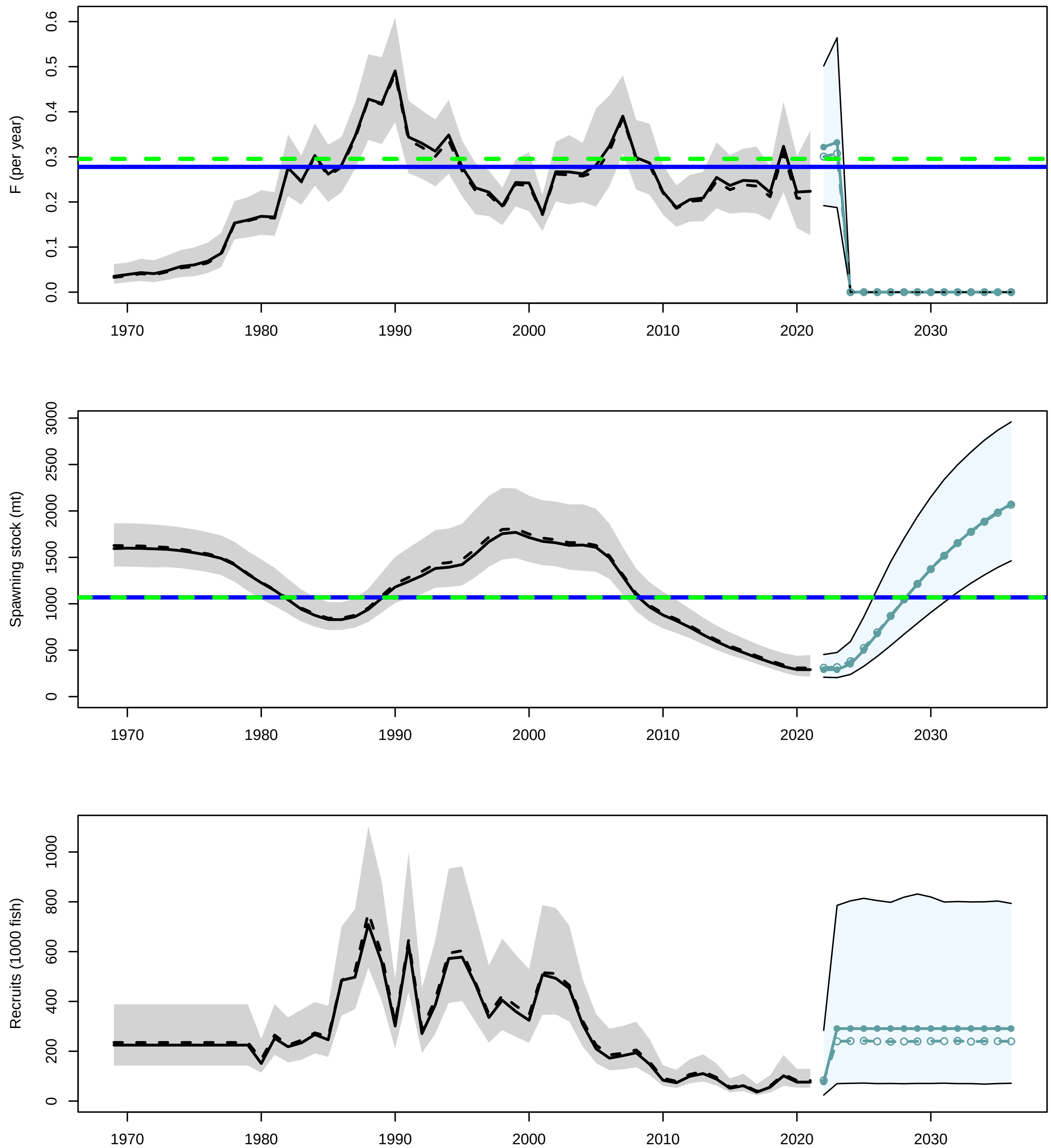


Figure 53. Projected probability of rebuilding under scenario 1—fishing mortality rate at $F = 0$ and long-term average recruitment. The curve represents the proportion of projection replicates for which SSB *has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{F40\%}}$*, with reference lines at 0.5 and 0.7.*

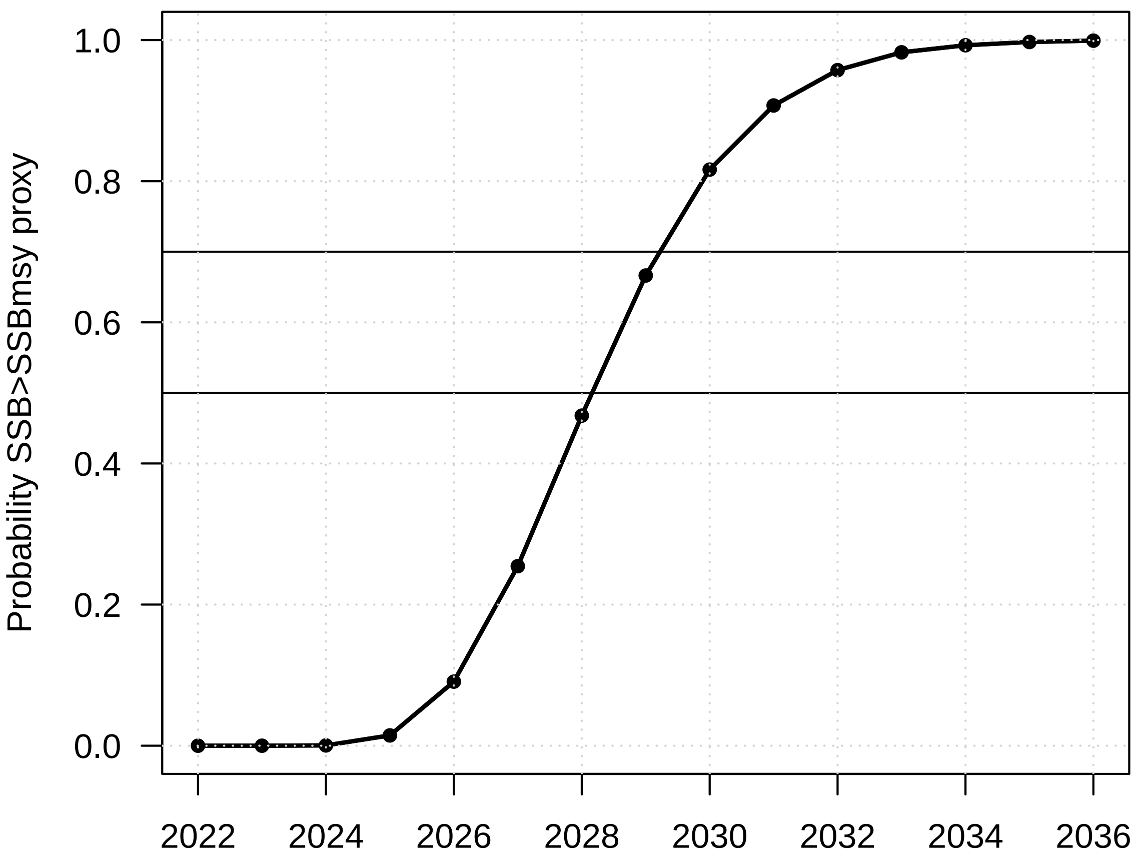


Figure 54. Projected time series under scenario 2—fishing mortality rate at $F = F_{\mathrm{current}}$ and long-term average recruitment. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{40\%}$-related benchmarks; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning.

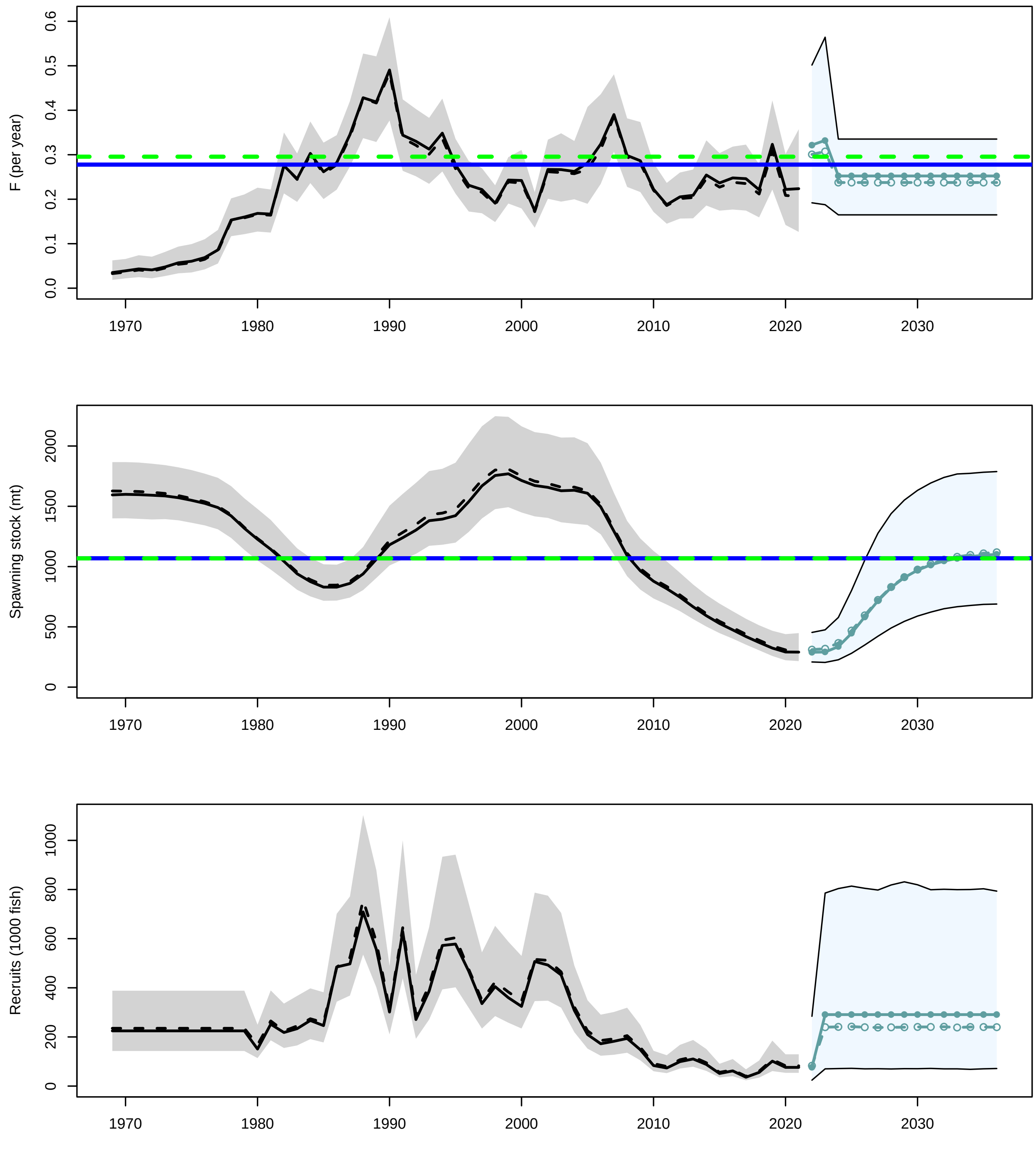


Figure 55. Projected probability of rebuilding under scenario 2—fishing mortality rate at $F = F_{\text{current}}$ and long-term average recruitment. The curve represents the proportion of projection replicates for which SSB *has reached the replicate-specific* $\text{SSB}_{\text{F40\%}}$*, with reference lines at 0.5 and 0.7.*

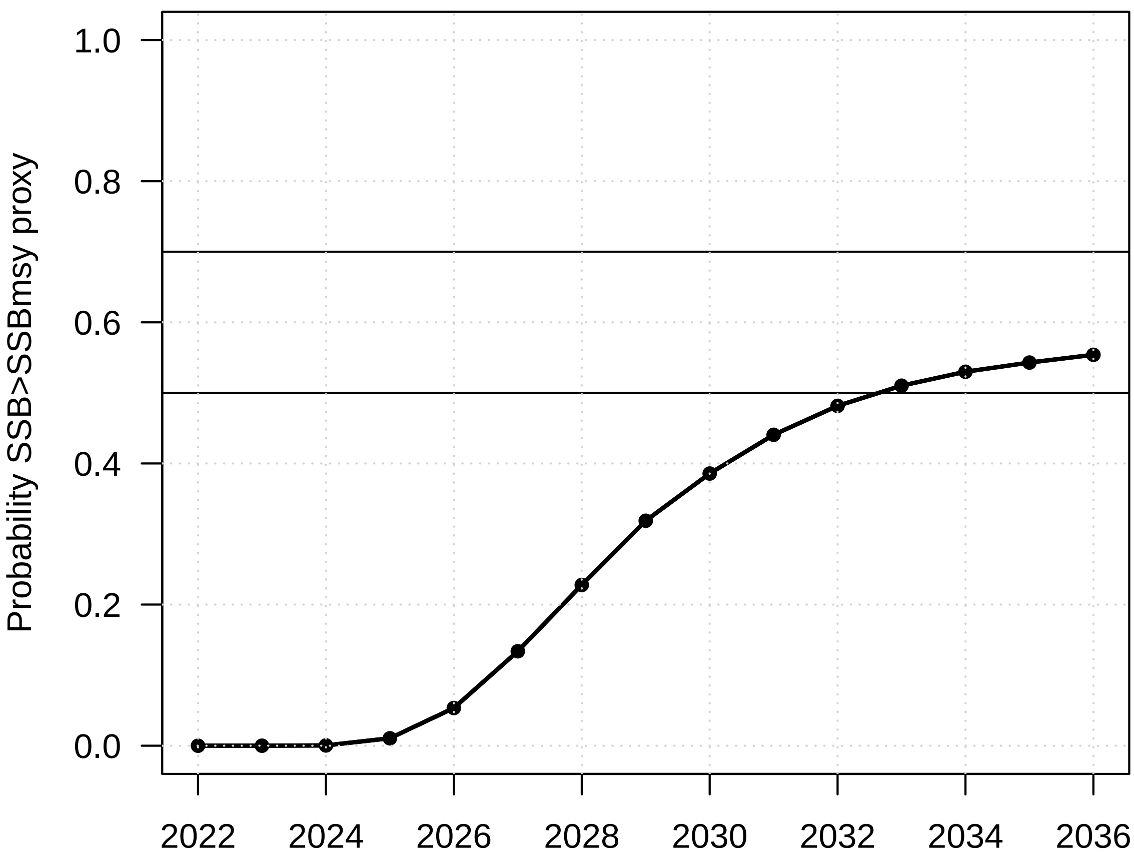


Figure 56. Projected SERFS index under scenario 2—fishing mortality rate at $F = F_{\text{current}}$ and long-term average recruitment. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections.

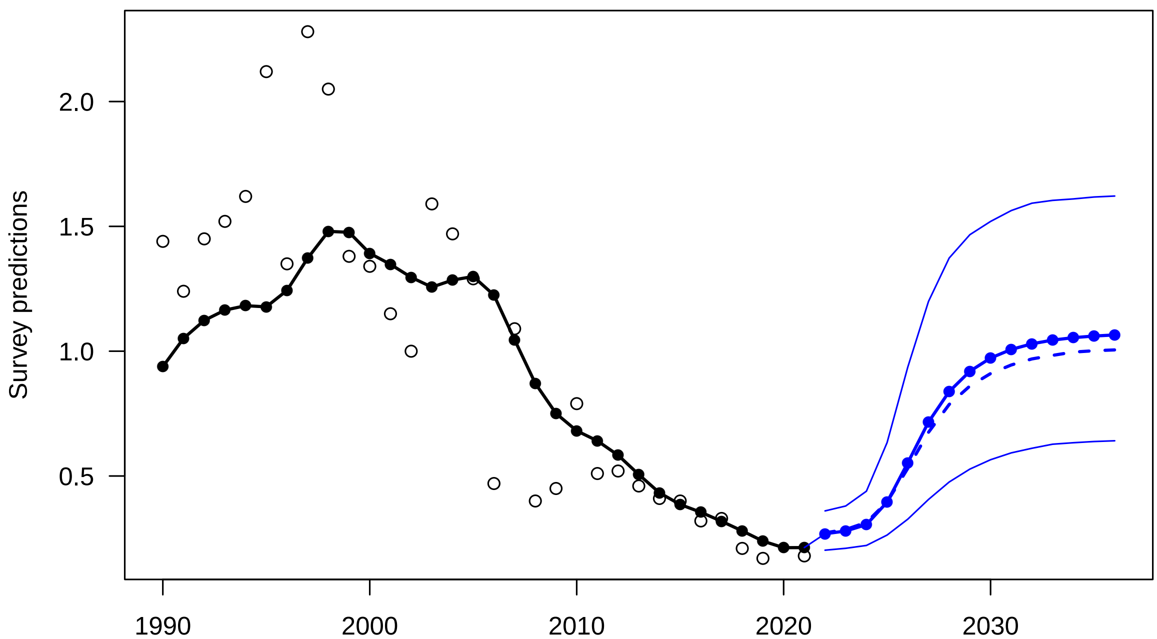


Figure 57. Projected time series under scenario 3—fishing mortality rate at $F = F_{\mathrm{current}}$ and recent average recruitment. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark $F_{40\%}$-related benchmarks; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning.

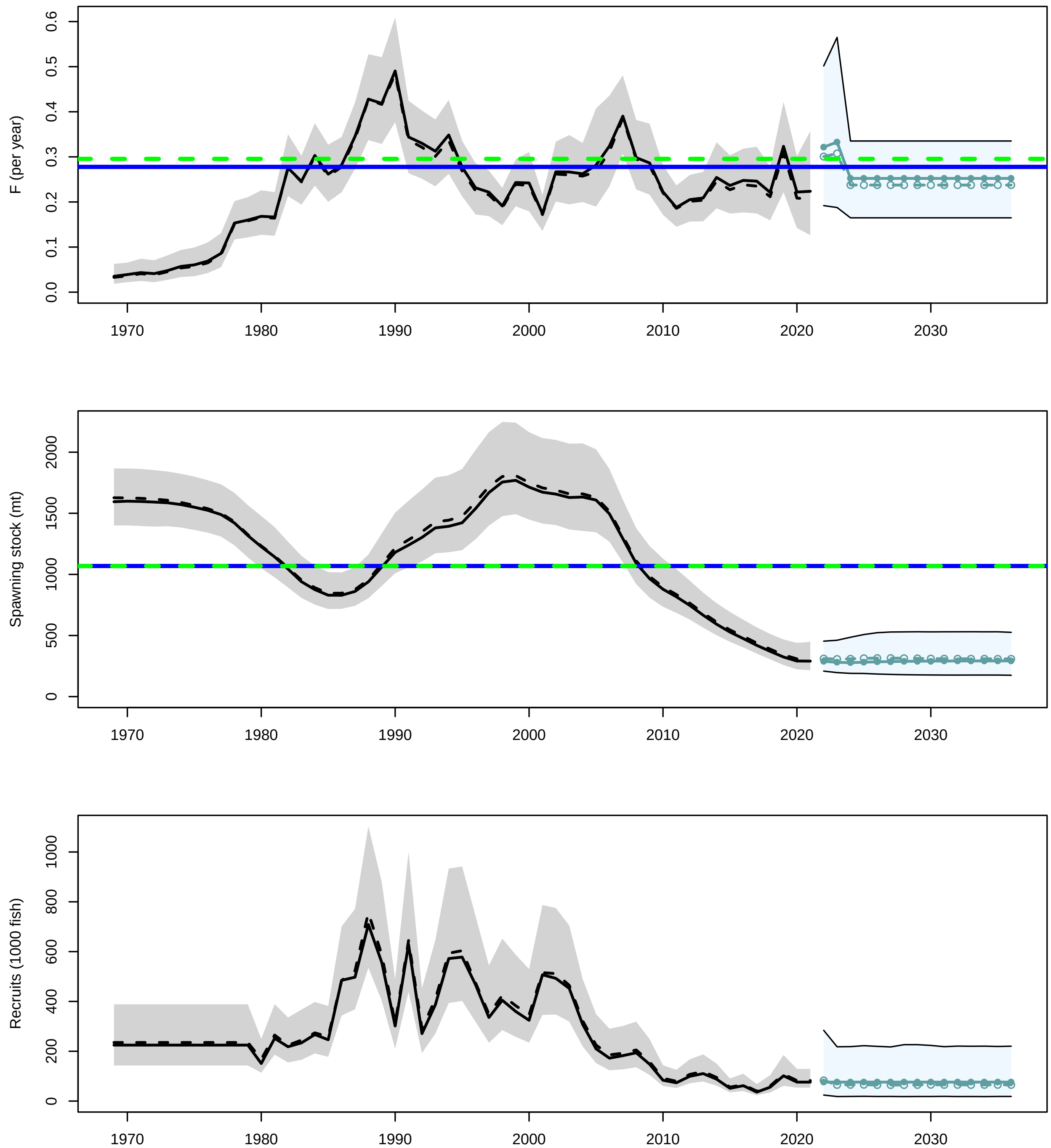


Figure 58. Projected probability of rebuilding under scenario 3—fishing mortality rate at $F = F_{\text{current}}$ and recent average recruitment. The curve represents the proportion of projection replicates for which SSB *has reached the replicate-specific* $\text{SSB}_{\text{F40\%}}$*, with reference lines at 0.5 and 0.7.*

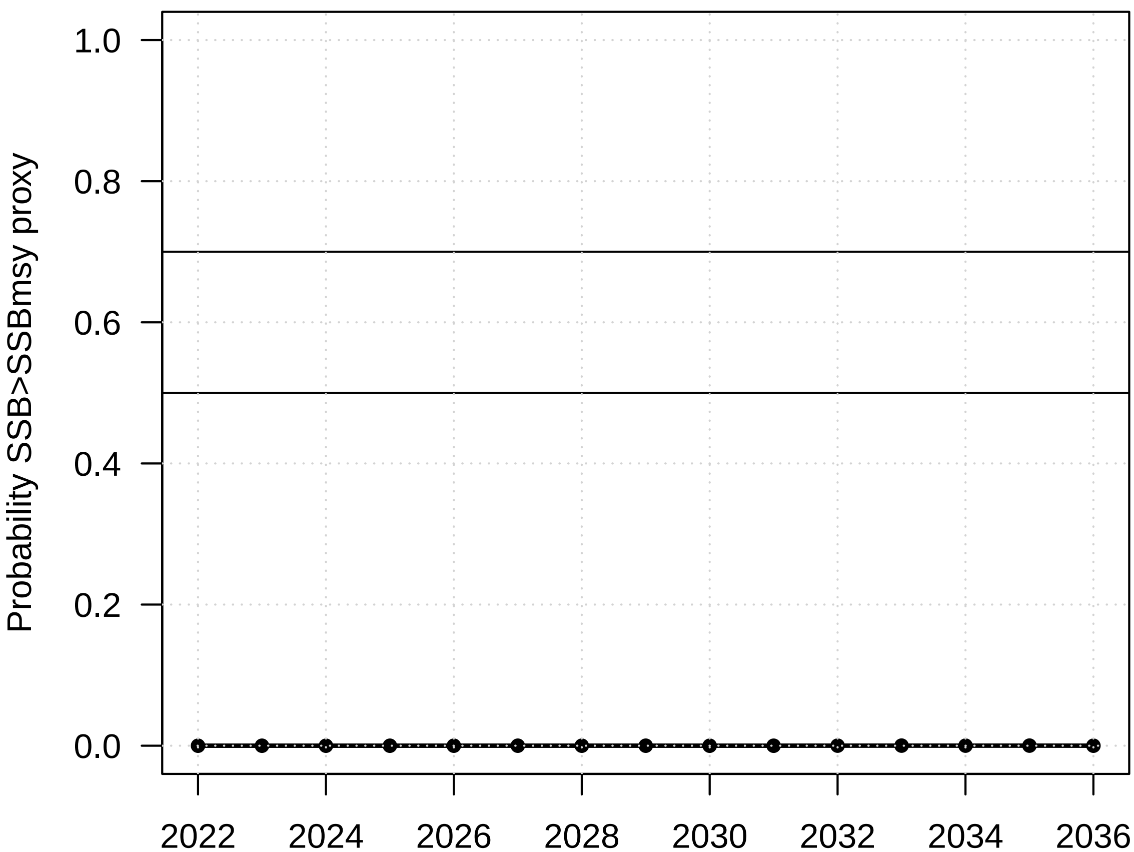
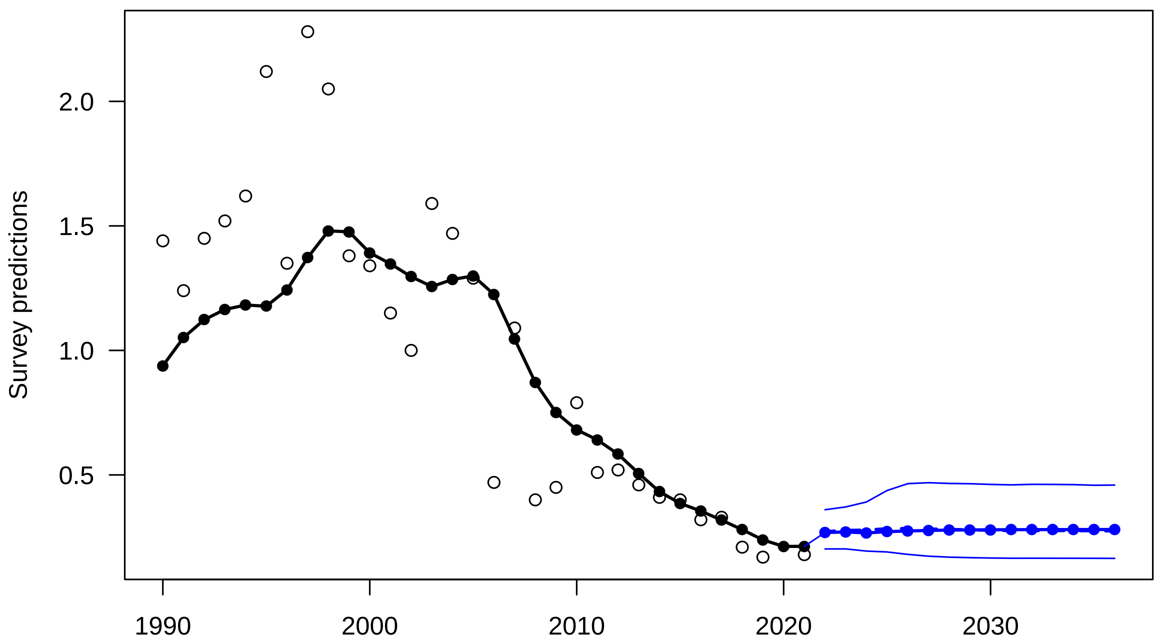


Figure 59. Projected SERFS index under scenario 3—fishing mortality rate at $F = F_{\text{current}}$ and recent average recruitment. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections.



Appendix A Data Providers

Table 22. Data Providers for this Operational Assessment

Data Type	Data Source	Contributor	Point of Contact
Landings and Discards	Headboat landings and discards	SEFSC-FSD-RFMB	Ken Brennan
	MRIP landings and discards	SEFSC-SFD-DAAS	Matt Nuttall
	Commercial landings	ACCSP	Mike Rinaldi
Indices	Commercial handline	Not updated	NA
	Headboat	Not updated	NA
	SERFS chevron trap	SCDNR	Tracey Smart
	SERFS video gear	SEFSC-PEMD-ACRFB	Nate Bacheler
	SERFS combined trap and video	SEFSC-SFB-AFB	Kyle Shertzer
Life History	FI and FD data	SCDNR	Tracey Smart
	FI data	FWRI	Meagan Schrandt
	FD data from FWRI	GSMFC/GulfFin	Gregg Bray
Length Comps	Raw commercial	SEFSC-FSD-CVB	Larry Beerkircher
	Raw headboat	SEFSC-FSD-RFMB	Ken Brennan
	Raw MRIP	SEFSC-SFD-DAAS	Matt Nuttall
	Processed commercial, headboat, MRIP	SEFSC-SFD-DAAS	Eric Fitzpatrick
	SERFS chevron traps	SCDNR	Tracey Smart
Age Comps	Raw commercial	SEFSC-FATES-BLH	Andy Ostrowski
	Raw headboat	SEFSC-FATES-BLH	Andy Ostrowski
	Raw MRIP	SEFSC-FATES-BLH	Andy Ostrowski
	Processed commercial, headboat, MRIP	SEFSC-SFD-DAAS	Eric Fitzpatrick
	SERFS chevron traps	SCDNR	Tracey Smart

Appendix B Abbreviations and symbols

Table 23. Acronyms and abbreviations used in this report

Symbol	Meaning
ABC	Acceptable Biological Catch
AW	Assessment Workshop (here, for scamp)
ASY	Average Sustainable Yield
B	Total biomass of stock
BAM	Beaufort Assessment Model (an integrated, statistical catch-age formulation)
CPUE	Catch per unit effort; used after adjustment as an index of abundance
CV	Coefficient of variation
CVID	SERFS index combining sampling from chevron traps and video gear
CVT	SERFS chevron trap gear
DW	Data Workshop (here, for scamp)
F	Instantaneous rate of fishing mortality
$F_{40\%}$	Fishing mortality rate at which $F_{40\%}$ can be attained
F_{MSY}	Fishing mortality rate at which MSY can be attained
FHWAR	The National Survey of Fishing, Hunting, and Wildlife-Associated Recreation Survey
FL	State of Florida; or, fork length (of fish)
FWRI	Fish and Wildlife Research Institute (Florida)
GA	State of Georgia
GLM	Generalized linear model
GW	Gutted weight of a fish
K	Average size of stock when not exploited by man (carrying capacity); or, Brody growth coefficient of the von Bertalanffy equation
kg	Kilogram(s); 1 kg is about 2.2 lb.
klb	Thousand pounds; thousands of pounds
lb	Pound(s); 1 lb is about 0.454 kg
m	Meter(s); 1 m is about 3.28 feet.
M	Instantaneous rate of natural (non-fishing) mortality
MARMAP	Marine Resources Monitoring, Assessment, and Prediction Program, a fishery-independent data collection program of SCDNR
MCB	Monte Carlo/Bootstrap, an approach to quantifying uncertainty in model results
MCBE	Monte Carlo/Bootstrap Ensemble approach, another name for MCB
MFMT	Maximum fishing-mortality threshold; a limit reference point used in U.S. fishery management; typically based on F_{MSY} or its proxy
mm	Millimeter(s); 1 inch = 25.4 mm
MRFSS	Marine Recreational Fisheries Statistics Survey, a data-collection program of NMFS, predecessor of MRIP
MRIP	Marine Recreational Information Program, a data-collection program of NMFS, descended from MRFSS
MSST	Minimum stock-size threshold; a limit reference point used in U.S. fishery management.
MSY	Maximum sustainable yield (per year)
mt	Metric ton(s). One mt is 1000 kg, or about 2205 lb.
N	Number of fish in a stock
NC	State of North Carolina
NMFS	National Marine Fisheries Service, same as "NOAA Fisheries Service"
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
OY	Optimum yield; SFA specifies that OY $\leq$ MSY.
PSE	Proportional standard error
R	Recruitment
SAFMC	South Atlantic Fishery Management Council (also, Council)
SC	State of South Carolina
SCDNR	Department of Natural Resources of SC
SDNR	Standard deviation of normalized residuals
SEDAR	SouthEast Data Assessment and Review process
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)
SRHS	Southeast Region Headboat Survey, conducted by NMFS-Beaufort laboratory
SPR	Spawning potential ratio
SSB	Spawning stock biomass; mature biomass of males and females
$\mathrm{SSB_{MSY}}$	Level of SSB at which MSY can be attained
$\mathrm{SSB_{F40\%}}$	Level of SSB at which $F_{40\%}$ can be attained
TIP	Trip Interview Program, a fishery-dependent biodata collection program of NMFS
TL	Total length (of a fish), as opposed to FL (fork length) or SL (standard length)
VID	SERFS video gear
VPA	Virtual population analysis, an age-structured assessment
WW	Whole weight, as opposed to GW (gutted weight)
yr	Year(s)

Appendix C Parameter estimates from the Beaufort Assessment Model

```
# Number of parameters = 171 Objective function value = 14822.3122169807  Maximum gradient component = 0.000515085500617071
# len_cv_val:
0.120539267014
# len_cv_val_L:
0.0884500679820
# log_R0:
12.3286262909
# rec_sigma:
0.709998981381
# log_rec_dev:
 -0.404566251918 0.107967836541 -0.0357674009952 0.0331473278109 0.166355168787 0.0849508217693 0.762850043112 0.788222714716
 1.14278592872 0.900693731312 0.287290120828 1.02301730226 0.180105531916 0.536714574546 0.928587406083 0.938741475432 0.726419845224
 0.394949864264 0.582391519170 0.464774198935 0.360738209713 0.807723461098 0.778736084356 0.693675185075 0.309202574088 -0.0743157264366
 -0.271408163836 -0.215173490285 -0.153673722150 -0.424512277632 -0.994560334357 -1.12374532010 -0.821011747794 -0.717900227133
 -0.942739833844 -1.48380413794 -1.29672838949 -1.83706875038 -1.40141080950 -0.801654341961
# log_dm_COM_lc:
2.65852364716
# log_dm_REC_lc:
0.593516522656
# log_dm_COM_ac:
-0.172296045120
# log_dm_REC_ac:
2.28059818867
# log_dm_CVT_ac:
0.582693265823
# selpar_A50_COM1:
3.98983517983
# selpar_slope_COM1:
1.79255586297
# selpar_A50_COM2:
4.91185777123
# selpar_slope_COM2:
1.92337304085
# selpar_A50_REC1:
3.53445945714
# selpar_slope_REC1:
1.37102114899
# selpar_A50_REC2:
4.18183404868
# selpar_slope_REC2:
2.14641195329
# selpar_A50_CVT:
3.58217022390
# selpar_slope_CVT:
1.59280825343
# log_q_COM:
-7.49710224876
# log_q_REC:
-12.7911624207
# log_q_CVT:
-12.8906817078
# log_avg_F_COM:
-2.09819555480
# log_F_dev_COM:
 -2.35570668922 -2.07536047887 -1.96062324365 -2.27119733480 -1.98493412801 -1.65426734178 -1.62701427206 -1.36367376160
 -0.951584363402 -0.0895828911322 -0.0588011701108 -0.0173615882533 0.0206711203023 0.564670513172 0.546958975273 0.655771191893
 0.515318317544 0.673265749452 0.850046811776 0.951609678514 0.982570203703 1.12468667445 0.765435489625 0.659641405715
 0.589385738929 0.544820660687 0.593496154919 0.357962089877 0.311549567742 0.107340609183 0.369689891365 0.0994276103423
 -0.169231064704 -0.0904364897351 0.0826630957051 0.124313912265 0.193422734924 0.352857331485 0.499637313105 0.328629812753
 0.453232511945 0.209317777334 0.115963222427 0.168246373933 0.103098401195 0.386624932685 0.302200280926 0.295020828269
 0.383484921026 0.339104556583 0.701396055662 0.223583025982 0.122659274653
# log_avg_F_REC:
-2.74224395734
# log_F_dev_REC:
 -1.00891529695 -1.00441614652 -0.907335971420 -0.819580688887 -0.735439309847 -0.652299803596 -0.570837039165 -0.543630197683
 -0.510534626579 -0.450797938094 -0.375396373759 -0.303540219407 -0.443158194177 -0.0791242741493 -0.645672202410
 0.0349063178917 -0.134508275630 -0.440394955744 -0.103574985391 0.538604538434 0.343734731215 0.559779894171 0.219520014889
 0.366384088106 0.348943433006 0.754596631673 -0.154358161751 -0.141059317037 -0.171973248829 -0.168478192827 0.0173454943261
 0.503658465159 0.0911638487520 0.876382412828 0.726940752572 0.651043968728 0.723887104113 0.841006760394 1.07158610272
 0.685524678622 0.371617707090 0.0996318476224 -0.254126892679 -0.0700611871055 0.122435411627 0.135982889318 0.0913288335118
 0.254171391103 0.0267804022292 -0.272409555119 0.165852412018 0.0618291459568 0.276983776680
# logit_earlyrec_mult:
-0.0124760369263
```