SEDAR

Southeast Data, Assessment, and Review

SEDAR 66

South Atlantic Tilefish

Stock Assessment Report

April 2021

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

Please cite this document as:

SEDAR. 2021. SEDAR 66 South Atlantic Tilefish Stock Assessment Report. SEDAR, North Charleston SC. 145 pp. available online at: http://sedarweb.org/sedar-66

Table of Contents

Each Section is Numbered Separately

SEDAR

Southeast Data, Assessment, and Review

SEDAR 66

South Atlantic Tilefish

Section I: Introduction

April 2021

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

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 66 addressed the stock assessment for South Atlantic Tilefish. The assessment process consisted of a series of webinars held from April 2020 to February, 2021 and a webinar workshop. Due to the 2020 Pandemic the in person workshop that was originally scheduled for November 17-19 in Beaufort, NC was rescheduled to be four 5 hour long webinars held November 16-19. 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 Tilefish was disseminated to the public in April 2021. The Council's Scientific and Statistical Committee (SSC) will review the SAR for its stock. The SSCs are tasked with recommending whether the assessments represent Best Available Science, whether the results presented in the SARs are useful for providing management advice and developing fishing level recommendations for the Council. An SSC may request additional analyses be conducted or may use the information provided in the SAR as the basis for their Fishing Level Recommendations (e.g., Overfishing Limit and Acceptable Biological Catch). The South Atlantic Fishery Management Council's SSC will review the assessment at its April 2021 meeting, followed by the Council receiving that information at its June 2021 meeting. Documentation on SSC recommendations is not part of the SEDAR process and is handled through each Council.

2. Management Overview

2.1 Fishery Management Plan and Amendments

The following summary describes only those management actions that likely affect golden tilefish fisheries and harvest.

Original Snapper Grouper FMP

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

Measures in the original FMP that affected golden tilefish include data reporting and research needs. No regulations specific to golden tilefish were included.

SAFMC FMP Amendments affecting golden tilefish

Description of Action	FMP/Amendment	Effective
-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
Prohibit fish traps, entanglement nets, and longline gear within 50 fathoms. Requirement to land with heads & fins attached. Permits - income requirement & required to exceed bag limits. Established 5 grouper aggregate.	Amendment 4	1/1/92
-Establish Total Allowable Catch (TAC) for golden tilefish and adjust the annual TAC downward by reserving a portion based on bycatch. Phase-in reduction over 3 years; year 1=1994 fishing year (calendar year). Logbook 1992 landings 1,777,772 lbs) used as base year: 1994 = 1,475,795 lbs gw 1995 = 1,238,818 lbs gw 1996 = 1,001,663 lbs gw -Establish a 5,000 pound (gutted weight) golden tilefish trip limit while the directed golden tilefish quota is open, then reduce to 300 pounds -Include all tilefish species in the current 5 grouper aggregate bag limit -Prohibited transfer at sea for snowy grouper and golden tilefish regardless of where the fish were caught (i.e., state vs. federal waters). -100% logbook coverage upon renewal of permit -Creation of the *Oculina* Experimental Closed Area -Data collection needs specified for evaluation of possible IFQ system	Amendment 6	6/27/94 trip limit effective 6/6/94
-Prohibit engaging in a directed fishery for tilefish in the EEZ north of Cape Canaveral, Florida, aboard a vessel that does not have a permit for snapper grouper -Bottom longline gear is allowed only north of St. Lucie Inlet, FL (27°10’N. latitude)	Amendment 7	1/23/95

-Limited entry program: transferable permits and 225-lb non-transferable permits.	Amendment 8	8/17/98
-Vessels with longline gear aboard may only possess snowy, warsaw, yellowedge, and misty grouper, and golden, blueline and sand tilefish. -Specify that within the 5-fish aggregate grouper bag limit (which currently includes tilefish and excludes goliath grouper and Nassau grouper), no more than 2 fish may be gag or black grouper (individually or in combination).	Amendment 9	2/24/99
-Maximum sustainable yield (MSY) proxy for sg species (other than Nassau and goliath) = 30% static SPR -OY: hermaphroditic groupers = 45% static SPR; all other species = 40% static SPR -Overfished/overfishing evaluations: Golden tilefish: overfished (couldn't update existing static SPR of 21% SPR). Council concluded measures in Amendments 7, 8 and 9 were sufficient to rebuild golden tilefish above the overfished level. -Defined overfishing level for sg species other than Nassau and goliath as F>F30% static SPR MSST = [(1-M) or 0.5 whichever is greater]* B_{MSY}. MFMT = F_{MSY}	Amendment 11	12/2/99
-Extended prohibition on bottom fishing for snapper grouper species in the Oculina Experimental Closed Area and on retaining such species in or from the area	Amendment 13A	4/26/04
-commercial quota for golden tilefish = 295,000 lbs gw -commercial trip limit for golden tilefish of 4,000 lbs gw until 75% of quota is taken then reduce to 300 lbs; do not adjust trip limit downwards unless 75% of quota is landed on or before September 1 -recreational bag limit of 1 golden tilefish/person/day and included within 5 grouper aggregate bag limit	Amendment 13C	10/23/06

-established eight deepwater marine protected areas (MPA) in which fishing for or possession of South Atlantic snapper grouper are prohibited	Amendment 14	2/12/09
1) -prohibited sale of bag-limit caught snapper grouper species, 2) reduced the effects of incidental hooking on sea turtles and smalltooth sawfish, 3) changed the commercial permit renewal period and transferability requirements, 4) implemented a plan to monitor and address bycatch, and 5) established management reference points, such as MSY and OY for golden tilefish. MSY equals the yield produced by F_{MSY}. MSY and F_{MSY} are defined by the most recent SEDAR. F_{MSY} = 0.043 = 336,425 lbs whole weight. If a stock is overfished, F_{OY} equals the fishing mortality rate specified by the rebuilding plan designed to rebuild the stock to SSB_{MSY} within the approved schedule. After the stock is rebuilt, F_{OY} = a fraction of F_{MSY}. Golden tilefish is not overfished. Therefore, F_{OY} = 75% F_{MSY} = 326,554 lbs whole weight. MSST equals SSB_{MSY}(0.75) =	Amendment 15B	12/16/09
-Reduced grouper aggregate (including tilefishes) from 5 to 3. -Required possession of dehooking tools when catching snapper grouper species to reduce recreational and commercial bycatch mortality.	Amendment 16	7/29/09
-Required use of non-stainless steel circle hooks when fishing for snapper grouper species with hook-and-line gear and natural bait north of 28 deg. N latitude in the South Atlantic EEZ	Amendment #17A	3/3/2011

1) Defined allocations for golden tilefish based upon landings from the ALS, MRFSS, and headboat databases. The allocation would be based on the following formula for each sector: Sector apportionment = (50% * average of long catch range (lbs) 1986-2008) + (50% * average of recent catch trend (lbs) 2006-2008). 97% com/3% rec. 2) Established the ACL at the F_{OY} level (Total ACL = 326,554 lbs whole weight or 291,566 lbs gutted weight). 3) The commercial ACL (282,819 lbs gutted weight) is based on the allocation alternative selected (97% commercial: 3% recreational). 4) The commercial AM for this stock is to prohibit harvest, possession, and retention when the quota is projected to be met. All purchase and sale is prohibited when the quota is projected to be met. 5) Specified a recreational ACL in numbers of fish (1,578 fish) based upon the allocation decision 6) Implemented accountability measures (AMs) for the recreational sector for golden tilefish. If the ACL is exceeded, the Regional Administrator shall publish a notice to reduce the length of the following fishing season by the amount necessary to ensure landings do not exceed the sector ACL for the following fishing season. Compare the recreational ACL with projected recreational landings over a range of years. For 2010, use only 2010 landings. For 2011, use the average landings of 2010 and 2011. For 2012 and beyond, use the most recent three-year running average. 7) Implemented a closure to commercial and recreational harvest of 6 deepwater species (snowy grouper, blueline tilefish, yellowedge grouper, misty grouper, queen snapper, and silk snapper) seaward of 240 feet (73 m) to curb bycatch of speckled hind and warsaw grouper	Amendment 17B	1/31/11
-Established a longline endorsement for the commercial component of the golden tilefish fishery, including eligibility and transferability requirements and appeals process -Allocated commercial ACL between gear groups: 75% to longline and 25% to hook-and-line -Established a commercial trip limit of 4,000 for longlines and 500 pounds for hook and line (longliners not eligible to fish under hook-and-line trip limit after	Amendment 18B	5/23/13

-Modified AMs for snapper grouper species, including golden tilefish	Amendment 34 (Generic Accountability Measures and Dolphin Allocation Amendment)	2/22/16
-Clarified regulations governing the use of Golden Tilefish Longline Endorsements.	Amendment 35	6/22/16

SAFMC Regulatory Amendments affecting golden tilefish

Description of Action	Regulatory Amendment	Effective Date
-Removed closure for deep water species (snowy grouper, blueline tilefish, yellowedge grouper, misty grouper, queen snapper, and silk snapper) beyond 240 ft (73 m) implemented through Amendment 17B	Regulatory Amendment 11	5/10/12
-Revised ABC based on projections from SEFSC (January 27, 2012) -Established ACL = yield at 75%Fmsy when stock is at equilibrium = 625,000 lbs ww (558,036 lbs gw) -Revised commercial and recreational ACLs based on existing allocations: Commercial ACL = 606,250 lbs ww (541,295 lbs gw) Recreational ACL = 3,019 fish -Revised rec ACT and AMs -Reopened commercial harvest under 300 lbs trip limit for 2012 fishing year	Regulatory Amendment 12	10/9/12
--Ended overfishing of golden tilefish by reducing the ACL based on the most recent stock assessment.	Regulatory Amendment 28	1/4/2019

2.2 Emergency and Interim Rules

Golden tilefish Interim Rule – effective 1/2/2018 through 7/1/2018 and 7/2/2018 through 1/3/2019 -- Reduced the golden tilefish total ACL, the commercial and recreational sector ACLs, and the quotas for the hook-and-line and longline components of the commercial sector.

2.3 Secretarial Amendments

SAFMC None.

2.4 Control Date Notices

1. Notice of Control Date (07/30/91 56 FR 36052) - Anyone entering **federal snapper grouper fishery (other than for wreckfish)** in the EEZ off S. Atlantic States after 07/30/91 was not assured of future access if limited entry program developed.
2. Notice of Control Date (10/14/05 70 FR 60058) - Anyone entering **federal snapper grouper fishery** off S. Atlantic states after 10/14/05 was not assured of future access if limited entry program developed.
3. Notice of Control Date (2/20/09 74 FR 7849) - Anyone entering **federal golden tilefish segment of the snapper grouper fishery** off S. Atlantic states after 12/4/08 was not assured of future access if limited entry program developed.
4. Notice of Control Date (01/31/11 76 FR 5325) - Anyone **entering federal snapper grouper fishery** off S. Atlantic states after 09/17/10 was not assured of future access if limited entry program developed.
5. Notice of Control Date (6/15/16 76 FR 66244) - Fishermen entering the **federal for-hire recreational sector for the Snapper Grouper fishery** after June 15, 2016, will not be assured of future access should a management regime that limits participation in the sector be prepared and implemented.

The net effect of these various control dates is that there are two control dates:

1. Federal Snapper Grouper Fishery – 1/31/2011
2. Federal Golden Tilefish Segment of the Snapper Grouper Fishery – 2/20/2009

2.5 Management Program Specifications

Table 2.5.1. General Management Information

South Atlantic

Species	Golden Tilefish
Management Unit	Southeastern US
Management Unit Definition	All waters within South Atlantic Fishery Management Council Boundaries (VA/NC boundary south to the SAMFC/GMFMC boundary)
Management Entity	South Atlantic Fishery Management Council
Management Contacts Council/SERO	Myra Brouwer / Rick DeVictor
Current stock exploitation status	Not Overfishing
Current stock biomass status	Not overfished

Table 2.5.2. Specific Management Criteria

Estimated status indicators, benchmarks, and related quantities from the Beaufort catch-age model, conditional on estimated current selectivities averaged across fisheries. Rate estimates (F) are in units of y-1; status indicators are dimensionless; and biomass estimates are in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) and minimum stock size threshold (MSST) are measured by total gonad weight of mature females.

Criteria	South Atlantic – Current (SEDAR 25 Update, 2016)	
	Definition	Value
MSST (metric tons)	75% SSB_{MSY}	16.45
MFMT (per year)	F_{MSY}	0.24
MSY (1000 pounds)	Yield at F_{MSY}	560
F_{MSY} (per year)	F_{MSY}	0.24
OY (1000 pounds)	Yield at F_{OY}	OY (65% F_{MSY})= 540 OY (75% F_{MSY})= 551 OY (85% F_{MSY})= 557
R_{MSY}	1000 age-1 fish	327
Yield at F_{TARGET} (equilibrium)	Landings and discards, pounds and numbers	
F_{OY}	F_{OY} = 65%,75%, 85% F_{MSY}	65% F_{MSY}= 0.15 75% F_{MSY}= 0.18 85% F_{MSY}= 0.20
M	Scalar of Lorenzen M	0.10
Terminal F	Exploitation (per year)	0.36
Terminal Biomass[1]	Biomass (metric tons)	18.65
Exploitation Status	$F_{CURRENT}/F_{MSY}$	1.22
Biomass Status[1]	$SSB_{2014}/MSST$[2]	1.13

Table 2.5.2. Continued Specific Management Criteria

Criteria	South Atlantic – Proposed (Values from SEDAR 66)		
	Definition	Base Run Values	Median of Base Run MCBs
MSST[1]	75% SSB_{MSY}		
MFMT	F_{MSY}		
MSY	Yield at F_{MSY}		
F_{MSY}	F_{MSY}		
OY	Yield at F_{OY}		
R_{MSY}	Recruits as MSY		
F Target			
Yield at F_{TARGET} (equilibrium)	Landings and discards, pounds and numbers		
F_{OY}	F_{OY} = 65%,75%, 85% F_{MSY}		
M	M		
Terminal F	Exploitation		
Terminal Biomass[1]	Biomass		
Exploitation Status	F/MFMT		
Biomass Status[1]	SSB/MSST SSB/SSB_{MSY}		
Generation Time			
$T_{REBUILD}$ (if appropriate)			

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

2. The SAFMC's definition of MSST for golden tilefish is (0.75*SSBmsy) which was established in Snapper Grouper Amendment 15B. The MSST value used in SEDAR 25 and the subsequent management actions was (1-M)*SSBmsy. Calculations for MSST in the 2015 update assessment used 0.75*SSBmsy.

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

N/A

Table 2.5.4. Stock projection information

South Atlantic

Requested Information	Value
First Year of Management	Assume management begins in 2022. However, if stock neither overfished or overfishing, a projection with the revised ABC and OFL should be provided assuming that landings limits are changed in the 2021 fishing year.
Interim basis	ACL, if landings are within 10% of the ACL; average landings otherwise.
Projection Outputs	
Landings	Pounds and numbers
Discards	Pounds and numbers
Exploitation	F & Probability F>MFMT
Biomass (total or SSB, as appropriate)	B & Probability B>MSST (and Prob. $B>B_{MSY}$ if under rebuilding plan)
Recruits	Number

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

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

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

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

Criteria		Overfished	Not overfished
Projection Span	Years	Interim + 5	Interim + 5
Probability Values	50%	Probability of stock rebuild	Probability of overfishing
	30%	Probability of stock rebuild	Probability of overfishing

Table 2.5.5. Quota Calculation Details

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

	Commercial ACL	Recreational ACL	Total ACL
Current Quota Value	331,740 lbs gw	2,316 fish	342,000 lbs gw)
Next Scheduled Quota Change	NA	NA	NA
Annual or averaged quota?	annual	annual	annual
If averaged, number of years to average	NA	NA	NA
Does the quota account for bycatch/discard?	No	No	No

How is the quota calculated - conditioned upon exploitation or average landings? Commercial ACL (331,740 lbs gutted weight) and Recreational ACL (2,316 fish) is based on yield at F_{OY} and assumes population biomass at equilibrium. Yield at F_{OY} is allocated to commercial and recreation sectors based on the following formula for each sector: Sector apportionment = (50% * average of long catch range (lbs) 1986-2008) + (50% * average of recent catch trend (lbs) 2006-2008). The allocation is 97% commercial and 3% recreational. This allocation was established in Amendment 17B (effective 1/31/11).

Does the quota include bycatch/discard estimates? If so, what is the source of the bycatch/discard values? What are the bycatch/discard allowances?
Commercial and Recreational ACLs do not require monitoring of discards and are based on landed catch. Assessment takes into consideration bycatch and provides estimates of yield at F_{MSY} and F_{OY} as landed catch rather than landed catch plus dead discards.

Are there additional details of which the analysts should be aware to properly determine quotas for this stock?
No.

2.6 Management and Regulatory Timeline

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

Table 2.6.1 South Atlantic Golden Tilefish Recreational Regulatory History prepared by: Myra Brouwer

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
1994	NA	NA	365	open		1-Jan	31-Dec	None	NA	NA	5/person/day [A]	27-Jun	31-Dec	5/person/day [A]	27-Jun	31-Dec
1995	NA	NA	365	open		1-Jan	31-Dec	None	NA	NA	5/person/day [A]	1-Jan	31-Dec	5/person/day [A]	1-Jan	31-Dec
1996	NA	NA	366	open		1-Jan	31-Dec	None	NA	NA	5/person/day [A]	1-Jan	31-Dec	5/person/day [A]	1-Jan	31-Dec
1997	NA	NA	365	open		1-Jan	31-Dec	None	NA	NA	5/person/day [A]	1-Jan	31-Dec	5/person/day [A]	1-Jan	31-Dec
1998	NA	NA	365	open		1-Jan	31-Dec	None	NA	NA	5/person/day [A]	1-Jan	31-Dec	5/person/day [A]	1-Jan	31-Dec
1999	NA	NA	365	open		1-Jan	31-Dec	None	NA	NA	5/person/day [A, B]	1-Jan	31-Dec	5/person/day [A, B]	1-Jan	31-Dec
2000	NA	NA	366	open		1-Jan	31-Dec	None	NA	NA	5/person/day [A, B]	1-Jan	31-Dec	5/person/day [A, B]	1-Jan	31-Dec
2001	NA	NA	365	open		1-Jan	31-Dec	None	NA	NA	5/person/day [A, B]	1-Jan	31-Dec	5/person/day [A, B]	1-Jan	31-Dec
2002	NA	NA	365	open		1-Jan	31-Dec	None	NA	NA	5/person/day [A, B]	1-Jan	31-Dec	5/person/day [A, B]	1-Jan	31-Dec
2003	NA	NA	365	open		1-Jan	31-Dec	None	NA	NA	5/person/day [A, B]	1-Jan	31-Dec	5/person/day [A, B]	1-Jan	31-Dec
2004	NA	NA	366	open		1-Jan	31-Dec	None	NA	NA	5/person/day [A, B]	1-Jan	31-Dec	5/person/day [A, B]	1-Jan	31-Dec
2005	NA	NA	365	open		1-Jan	31-Dec	None	NA	NA	5/person/day [A, B]	1-Jan	31-Dec	5/person/day [A, B]	1-Jan	31-Dec
2006	NA	NA	295	open		1-Jan	22-Oct	None		NA	5/person/day [A, B]	1-Jan	22-Oct	5/person/day [A, B]	1-Jan	22-Oct
			70	open		23-Oct	31-Dec				1/person/day [C, B]	23-Oct	31-Dec	5/person/day [C, B]	23-Oct	31-Dec
2007	NA	NA	365	open		1-Jan	31-Dec	None	NA	NA	1/person/day [C, B]	1-Jan	31-Dec	5/person/day [C, B]	1-Jan	31-Dec
2008	NA	NA	366	open		1-Jan	31-Dec	None	NA	NA	1/person/day [C, B]	1-Jan	31-Dec	5/person/day [C, B]	1-Jan	31-Dec
2009 [D]	NA	NA	1670	open		1-Jan	28-Jul	None	NA	NA	1/person/day [C, B]	1-Jan	28-Jul	5/person/day [C, B]	1-Jan	28-Jul
			156	open		29-Jul	31-Dec				1/person/day [E]	29-Jul	31-Dec	3/person/day [E]	29-Jul	31-Dec
2010 [D]	NA	NA	365	open		1-Jan	31-Dec	None	NA	NA	1/person/day [E]	1-Jan	31-Dec	3/person/day [E]	1-Jan	31-Dec
2011 [D, F, I]	See ACL	1,578 fish	278	open		1-Jan	5-Oct	None	NA	NA	1/person/day [E]	1-Jan	5-Oct	3/person/day [E, H]	1-Jan	5-Oct
			87	closed	quota met	6-Oct	31-Dec									
2012 [D, G, I, J]	See ACL	3,019 fish	159	open		1-Jan	7-Jun	None	NA	NA	1/person/day [E]	1-Jan	7-Jun	3/person/day [E, H, K]	1-Jan	7-Jun
			207	closed	quota met	8-Jun	31-Dec									
2013 [D, I]	See ACL	3,019 fish	153	open		1-Jan	2-Jun	None	NA	NA	1/person/day [E]	1-Jan	2-Jun	3/person/day [E, H, K]	1-Jan	2-Jun
			212	closed	quota met	3-Jun	31-Dec									
2014 [D, I, L]	See ACL	3,019 fish	157	open		1-Jan	6-Jun	None	NA	NA	1/person/day [E]	1-Jan	6-Jun	3/person/day [E, H, K]	1-Jan	6-Jun
			208	closed	quota met	7-Jun	31-Dec									
2015	See ACL	3,019 fish	222	open		1-Jan	10-Aug	None	N/A	N/A	1/person/day [E]	1-Jan	10-Aug	3/person/day [E, H, K]	1-Jan	10-Aug
			143	closed	quota met	11-Aug	31-Dec									
2016	See ACL	3,019 fish	239	open		1-Jan	26-Aug	None	N/A	N/A	1/person/day [E]	1-Jan	26-Aug	3/person/day [E, H, K]	1-Jan	26-Aug
			127	closed	quota met	27-Aug	31-Dec									
2017	See ACL	3,019 fish	365	open		1-Jan	31-Dec	None	N/A	N/A	1/person/day [E]	1-Jan	31-Dec	3/person/day [E, H, K]	1-Jan	31-Dec
2018	See ACL	2,187 fish[M]	238	open		2-Jan	27-Aug	None	N/A	N/A	1/person/day [E]	2-Jan	27-Aug	3/person/day [E, H, K]	2-Jan	27-Aug
			126	closed	quota met	28-Aug	31-Dec									
2019	See ACL	2,316 fish[N]	164	open		4-Jan	16-Jun	None	N/A	N/A	1/person/day [E]	4-Jan	16-Jun	3/person/day [E, H, K]	4-Jan	16-Jun
			198	closed	quota met	17-Jun	31-Dec									

Fishing year = Calendar Year
1 = Starting in 1994, the aggregate grouper bag limit included gag, scamp, red grouper, black grouper, speckled hind, snowy grouper, warsaw grouper, rock hind, red hind, coney, graysby, misty grouper, yellowedge grouper, yellowmouth grouper, yellowfin grouper, tiger grouper, golden tilefish, blueline tilefish, and sand tilefish. Unless otherwise noted below (see H and K) these species remain in the aggregate bag limit throughout the time series.
A = Aggregate grouper bag limit (includes gag, scamp, red grouper, black grouper, speckled hind, snowy grouper, warsaw grouper, rock hind, red hind, coney, graysby, misty grouper, yellowedge grouper, yellowmouth grouper, yellowfin grouper, tiger grouper, golden tilefish, blueline tilefish, and sand tilefish) of 5/person/day; specifies 1 speckled hind and 1 warsaw grouper in 5 grouper aggregate (Amendment 6; effective date 6/27/1994).
B = Aggregate grouper bag limit specifies no more than 2 can be gag or black grouper (Amendment 9; effective date 2/24/1999)
C = Limit possesstion to 1 golden tilefish in aggregate grouper bag limit of 5/person/day (Amendment 13C; effective date 10/23/2006)
D = Prohibited sale of bag-limit caught snapper grouper species, including golden tilefish (Amendment 15B; effective date:12/16/2009).
E = Limit possession to 1 golden tilefish in aggregate grouper bag limit of 3/person/day; no more than one fish in aggregate bag may be gag or black grouper; captain and crew may not retain bag limit (Amendment 16; effective date 07/29/2009)
F = Recreational ACL in numbers of fish (1,578 fish); Accountability Measure is if exceeded, Regional Administrator shall publish a notice to reduce the length of the following fishing season to ensure ACL is not exceeded.
G = Prohibits harvest of 6 deepwater species seaward of 240' (yellow edge grouper, misty grouper, snowy grouper, blueline tilefish, queen snapper, silk snapper; Amendment 17B; effective date: 1/31/11)
H = Harvest of speckled hind and warsaw grouper prohibited (e.g. removed from grouper aggregate bag limit; Amendment 17B; effective date: 1/31/11)
I = Recreational ACL in numbers of fish (3,019 fish); In-season closure if recreational ACL is met or projected to be met; if exceeded, monitor for persistence of increased landings and, if necessary, Regional Administrator shall publish a notice to reduce the length of the following fishing season to ensure ACL is not exceeded.
J = Deepwater closure eliminated (Regulatory Amendment 11; effective date 5/10/2012)
K = Tiger grouper removed from FMU (and therefore removed from aggregate bag limit; Comphrehensive ACL Amendment; effective date 4/16/2012)
L = Captain and crew on for-hire trips can retain bag limit of snapper grouper species (Amendment 27; effective date 1/27/2014)
M= interim rule adjsuted fishing levels temporarily. Was effective on 1/2/2018 and extended through 1/3/2019
N= Regulatory Amendment 28 implemented adjusted catch levels on 1/4/2019

Table 2.6.2 South Atlantic Golden Tilefish Commercial Regulatory History prepared by: Myra Brouwer & Julia Byrd

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
1994	1,475,795 (lbs gw)	NA	365	open		1-Jan	31-Dec	None	NA	NA	5,000 (lb gw) trip limit; allow retention of no more than 300 lbs when quota filled	6-Jun	31-Dec	None	NA	NA
1995	1,238,818 (lbs gw)	NA	365	open		1-Jan	31-Dec	None	NA	NA	5,000 (lb gw) trip limit; allow retention of no more than 300 lbs when quota filled	1-Jan	31-Dec	None	NA	NA
1996	1,001,663 (lbs gw)	NA	366	open		1-Jan	31-Dec	None	NA	NA	5,000 (lb gw) trip limit; allow retention of no more than 300 lbs when quota filled	1-Jan	31-Dec	None	NA	NA
1997	1,001,663 (lbs gw)	NA	365	open		1-Jan	31-Dec	None	NA	NA	5,000 (lb gw) trip limit; allow retention of no more than 300 lbs when quota filled	1-Jan	31-Dec	None	NA	NA
1998	1,001,663 (lbs gw)	NA	365	open		1-Jan	31-Dec	None	NA	NA	5,000 (lb gw) trip limit; allow retention of no more than 300 lbs when quota filled	1-Jan	31-Dec	None	NA	NA
1999	1,001,663 (lbs gw)	NA	365	open		1-Jan	31-Dec	None	NA	NA	5,000 (lb gw) trip limit; allow retention of no more than 300 lbs when quota filled	1-Jan	31-Dec	None	NA	NA
2000	1,001,663 (lbs gw)	NA	366	open		1-Jan	31-Dec	None	NA	NA	5,000 (lb gw) trip limit; allow retention of no more than 300 lbs when quota filled	1-Jan	31-Dec	None	NA	NA
2001	1,001,663 (lbs gw)	NA	365	open		1-Jan	31-Dec	None	NA	NA	5,000 (lb gw) trip limit; allow retention of no more than 300 lbs when quota filled	1-Jan	31-Dec	None	NA	NA
2002	1,001,663 (lbs gw)	NA	365	open		1-Jan	31-Dec	None	NA	NA	5,000 (lb gw) trip limit; allow retention of no more than 300 lbs when quota filled	1-Jan	31-Dec	None	NA	NA
2003	1,001,663 (lbs gw)	NA	365	open		1-Jan	31-Dec	None	NA	NA	5,000 (lb gw) trip limit; allow retention of no more than 300 lbs when quota filled	1-Jan	31-Dec	None	NA	NA
2004	1,001,663 (lbs gw)	NA	366	open		1-Jan	31-Dec	None	NA	NA	5,000 (lb gw) trip limit; allow retention of no more than 300 lbs when quota filled	1-Jan	31-Dec	None	NA	NA
2005	1,001,663 (lbs gw)	NA	365	open		1-Jan	31-Dec	None	NA	NA	5,000 (lb gw) trip limit; allow retention of no more than 300 lbs when quota filled	1-Jan	31-Dec	None	NA	NA
2006	295,000 (lbs gw)	NA	295	open		1-Jan	22-Oct	None	NA	NA	5,000 (lb gw) trip limit; allow retention of no more than 300 lbs when quota filled	1-Jan	22-Oct	None	NA	NA
				open							4,000 (lbs gw) [A]	23-Oct	31-Dec			
			70	closed	quota met	23-Oct	31-Dec									
2007	295,000 (lbs gw)	NA	136	open		1-Jan	16-May	None	NA	NA	4,000 (lbs gw) [A]	1-Jan	16-May	None	NA	NA
			139	open		17-May	2-Oct				300 (lbs gw) [A]	17-May	2-Oct			
			90	closed	quota met	3-Oct	31-Dec									
2008	295,000 (lbs gw)	NA	148	open		1-Jan	27-May	None	NA	NA	4,000 (lbs gw) [A]	1-Jan	27-May	None	NA	NA
			81	open		28-May	16-Aug				300 (lbs gw) [A]	28-May	16-Aug			
			137	closed	quota met	17-Aug	31-Dec									
2009	295,000 (lbs gw)	NA	110	open		1-Jan	20-Apr	None	NA	NA	4,000 (lbs gw) [A]	1-Jan	20-Apr	None	NA	NA
			85	open		21-Apr	14-Jul				300 (lbs gw) [A]	21-Apr	14-Jul			
			170	closed	quota met	15-Jul	31-Dec									
2010	295,000 (lbs gw)	NA	76	open		1-Jan	17-Mar	None	NA	NA	4,000 (lbs gw) [A]	1-Jan	17-Mar	None	NA	NA
			26	open		18-Mar	12-Apr				300 (lbs gw) [A]	18-Mar	12-Apr			
			264	closed	quota met	12-Apr	31-Dec									
2011	282,819 (lbs gw)	NA	67	open		1-Jan	8-Mar	None	NA	NA	4,000 (lbs gw) [A]	1-Jan	8-Mar	None	NA	NA
			298	closed	quota met	9-Mar	31-Dec									
2012	282,819 (lbs gw)	NA	47	open		1-Jan	16-Feb	None	NA	NA	4,000 (lbs gw) [A]	1-Jan	16-Feb	None	NA	NA
			235	closed	quota met	17-Feb	8-Oct									
	541,295 (lbs gw)	ACL = quota	84	open		9-Oct	31-Dec				300 (lbs gw) [B]	9-Oct	31-Dec			
2013	541,295 (lbs gw) [C]	ACL = quota	48	open		1-Jan	17-Feb	None	NA	NA	4,000 (lbs gw) [A]	1-Jan	17-Feb	None	NA	NA
			23	open		18-Feb	12-Mar				300 (lbs gw) [A]	18-Feb	12-Mar			
			9	open		13-Mar	21-Mar				4,000 (lbs gw) [A]	13-Mar	21-Mar			
			44	open		22-Mar	4-May				300 (lbs gw) [A]	22-Mar	4-May			
			241	closed	quota met	5-May	31-Dec									
2014	405,971 (lbs gw) [D,C]	ACL = quota	63	open		1-Jan	4-Mar	None	NA	NA	4,000 (lbs gw) [C]	1-Jan	4-Mar	None	NA	NA
			302	closed	quota met	5-Mar	31-Dec									
	135,324 (lbs gw) [E,C]		240	open		1-Jan	28-Aug				500 (lbs gw) [C]	1-Jan	28-Aug	None	NA	NA
			125	closed	quota met	29-Aug	31-Dec									
2015	405,971 (lbs gw) [C,D]	ACL=quota	49	open		1-Jan	18-Feb	None	N/A	N/A	4,000 (lbs gw) [C]	1-Jan	18-Feb	None	N/A	N/A
			316	closed	quota met	19-Feb	31-Dec									
	135,324 (lbs gw) [E,C]	ACL=quota	341	open		1-Jan	7-Dec	None	N/A	N/A	500 (lbs gw) [C]	1-Jan	7-Dec	None	N/A	N/A
			24	closed	quota met	8-Dec	31-Dec									
2016	405,971 (lbs gw) [C,D]	ACL=quota	74	open		1-Jan	14-Mar	None	N/A	N/A	4,000 (lbs gw) [C]	1-Jan	14-Mar	None	N/A	N/A
			292	closed	quota met	15-Mar	31-Dec									
	135,324 (lbs gw) [E,C]	ACL=quota	366	open		1-Jan	31-Dec	None	N/A	N/A	500 (lbs gw) [C]	1-Jan	31-Dec	None	N/A	N/A
2017	405,971 (lbs gw) [C,D]	ACL=quota	128	open		1-Jan	8-May	None	N/A	N/A	4,000 (lbs gw) [C]	1-Jan	8-May	None	N/A	N/A
			237	closed	quota met	9-May	31-Dec									
	135,324 (lbs gw) [E,C]	ACL=quota	332	open		1-Jan	28-Nov	None	N/A	N/A	500 (lbs gw) [C]	1-Jan	28-Nov	None	None	N/A
			33	closed	quota met	29-Nov	31-Dec					29-Nov	31-Dec			
2018	234,982 (lbs gw) [D,F]	ACL=quota	82	open		2-Jan	24-Mar	None	N/A	N/A	4,000 (lbs gw) [C]	2-Jan	24-Mar	None	None	N/A
			282	closed	quota met	25-Mar	31-Dec									
	78,328 (lbs gw) [E,F]	ACL=quota	224	open		2-Jan	13-Aug	None	N/A	N/A	500 (lbs gw) [C]	2-Jan	13-Aug	None	None	N/A
			140	closed	quota met	14-Aug	31-Dec									
2019	234,982 (lbs gw) [C,D,F]	ACL=quota	3	open		1-Jan	3-Jan	None	N/A	N/A	4,000 (lbs gw) [C]	1-Jan	3-Jan	None	None	N/A
	248,805 (lbs gw) [C,D,G]	ACL=quota	69	open	new regulations effective	4-Jan	13-Mar	None	N/A	N/A	4,000 (lbs gw) [C]	4-Jan	13-Mar			
			293	closed	quota met	14-Mar	31-Dec									
	78,328 (lbs gw) [E,F]	ACL=quota	3	open		1-Jan	3-Jan	None	N/A	N/A	500 (lbs gw) [C]	1-Jan	3-Jan	None	None	N/A
	82,935 (lbs gw) [C,E,G]	ACL=quota	200	open		4-Jan	22-Jul	None	N/A	N/A	500 (lbs gw) [C]	3-Jan	22-Jul	None	None	N/A
			162	closed		23-Jul	31-Dec									

[B] ACL increased due to results of SEDAR 25 assessment; season re-opened Oct 9, 2012 with 300 lb gw trip limit
[C] Snapper Grouper Amendment 18B (effective May 23, 2013) allocated commercial ACL between gear groups: 75% to longline and 25% to hook and line;establish 4000 lb gw trip limit for longliners and 500 lb gw trip limit for hook and line; longliners not eligible to fish under hook and line trip limit after longline quota is landed
[D] commercial golden tilefish longline quota
[E] commercial golden tilefish hook and line quota
[F] Interim rule ACL was effective on 1/2/2018 and was extended through 1/3/2019. ACL was temporarily reduced while permanent adjustments were made through Regulatory Amendment 28
[G] Fishing levels adjusted through implementation of Regulatory Amendment 28

Note: lbs = pounds; gw = gutted weight

2.7 Closures Due to Meeting Quota/ACL

Commercial:

- 2006 – October 23, 2006 through December 31, 2006.
- 2007 – October 3, 2007 through December 31, 2007.
- 2008 – August 17, 2008 through December 31, 2008.
- 2009 – July 15, 2009 through December 31, 2009.
- 2010 – April 12, 2010 through December 31, 2010.
- 2011 – March 9 2011 through December 31, 2011
- 2012 – February 17, 2012 through December 31, 2012
- 2013 – May 5, 2013 through December 31, 2013
- 2014 –
    - March 5, 2014 through December 31, 2014 – Longline
    - August 29, 2014 through December 31, 2014 – Hook-and-Line
- 2015 –
    - February 19 through December 31 – Longline
    - December 8 through December 31 – Hook-and-Line
- 2016 –
    - March 15 through December 31 – Longline
- 2017
    - May 9 through December 31 – Longline
    - November 29 through December 31 – Hook-and-Line
- 2018
    - March 25 through December 31 – Longline
    - August 14 through December 31 – Hook-and-Line

Recreational:

- 2011 – October 6, 2011 through December 31, 2011
- 2012 – June 8, 2012 through December 31, 2012
- 2013 – June 3, 2013 through December 31, 2013
- 2014 –June 7, 2014 through December 31, 2014
- 2015 – August 11 through December 31, 2015
- 2016 – August 27 through December 31, 2016
- 2017 – no closure
- 2018 – August 28 through December 31, 2018
- 2019 – June 17 through December 31, 2019

2.8 State Management Histories

2.8.1 North Carolina:

There are currently no North Carolina state-specific regulations for golden tilefish. North Carolina has complemented federal regulations for all snapper grouper species via proclamation authority since 1991. Between 1992 and 2005, species-specific regulations were added to the proclamation authority contained in rule 15A NCAC 03M .0506. Specific to golden tilefish, this rule was amended effective May 24, 1999 (following Amendment 9 to the SAFMC Snapper-Grouper FMP, eff. 2/24/99) to include the following Sub-item: (q) It is unlawful to possess any species of the Snapper-grouper complex except snowy, warsaw, yellowedge, and misty groupers; blueline, golden and sand tilefishes; while having longline gear aboard a vessel.

In 2002, North Carolina adopted its Inter-Jurisdictional Fishery Management Plan (IJ FMP), which incorporates all ASMFC and council-managed species by reference, and adopts all federal regulations as minimum standards for management. In completing the 2008 update to the IJ FMP, all species-specific regulations were removed from rule 15A NCAC 03M .0506, and proclamation authority to implement changes in management was moved to rule 15A NCAC 03M .0512. Since this time, all snapper grouper regulations have been contained in a single proclamation, which is updated anytime an opening/closing of a particular species in the complex occurs, as well as any changes in allowable gear, required permits, etc. Beginning in 2015, commercial and recreational regulations are contained in separate proclamations. The most current Snapper Grouper proclamations (and all previous versions) can be found using this link: http://portal.ncdenr.org/web/mf/proclamations.

15A NCAC 03M .0506 SNAPPER-GROUPER COMPLEX

(a) In the Atlantic Ocean, it is unlawful for an individual fishing under a Recreational Commercial Gear License with seines, shrimp trawls, pots, trotlines or gill nets to take any species of the Snapper-Grouper complex.

(b) The species of the snapper-grouper complex listed in the South Atlantic Fishery Management Council Fishery Management Plan for the Snapper-Grouper Fishery of the South Atlantic Region are hereby incorporated by reference and copies are available via the Federal Register posted on the Internet at www.safmc.net and at the Division of Marine Fisheries, P.O. Box 769, Morehead City, North Carolina 28557 at no cost.

History Note: Authority G.S. 113-134; 113-182; 113-221; 143B-289.52;
Eff. January 1, 1991;
Amended Eff. April 1, 1997; March 1, 1996; September 1, 1991;
Temporary Amendment Eff. December 23, 1996;
Amended Eff. August 1, 1998; April 1, 1997;
Temporary Amendment Eff. January 1, 2002; August 29, 2000; January 1, 2000; May 24, 1999;
Amended Eff. October 1, 2008; May 1, 2004; July 1, 2003; April 1, 2003; August 1, 2002.

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

(a) In order to comply with management requirements incorporated in Federal Fishery Management Council Management Plans or Atlantic States Marine Fisheries Commission Management Plans or to

implement state management measures, the Fisheries Director may, by proclamation, take any or all of the following actions for species listed in the Interjurisdictional Fisheries Management Plan:
(1) Specify size;
(2) Specify seasons;
(3) Specify areas;
(4) Specify quantity;
(5) Specify means and methods; and
(6) Require submission of statistical and biological data.
(b) Proclamations issued under this Rule shall be subject to approval, cancellation, or modification by the Marine Fisheries Commission at its next regularly scheduled meeting or an emergency meeting held pursuant to G.S. 113-221.1.
History Note: Authority G.S. 113-134; 113-182; 113-221; 113-221.1; 143B-289.4;
Eff. March 1, 1996;
Amended Eff. October 1, 2008.

2.8.2 South Carolina

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

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

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

2.8.3 Georgia

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

2.8.4 Florida Regulatory History

Florida Atlantic and Monroe County Golden Tilefish 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	None	None		
1987	None	2 fish or 250 pounds per person, whichever is greater	None		
1988	None	2 fish or 250 pounds per person, whichever is greater	None		
1989	None	2 fish or 100 pounds per person, whichever is greater	None		

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
1990	None	2 fish or 100 pounds per person, whichever is greater	None		
1991	None	2 fish or 100 pounds per person, whichever is greater	None		
1992	None	2 fish or 100 pounds per person, whichever is greater	None		
1993	None	2 fish or 100 pounds per person, whichever is greater	None		
1994	None	2 fish or 100 pounds per person, whichever is greater	None		
1995	None	2 fish or 100 pounds per person, whichever is greater	None		

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
1996	None	2 fish or 100 pounds per person, whichever is greater	None		
1997	None	2 fish or 100 pounds per person, whichever is greater	None		
1998	None	2 fish or 100 pounds per person, whichever is greater	None		
1999	None	2 fish or 100 pounds per person, whichever is greater	None		
2000	None	2 fish or 100 pounds per person, whichever is greater	None		
2001	None	2 fish or 100 pounds per person, whichever is greater	None		

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
2002	None	2 fish or 100 pounds per person, whichever is greater	None		
2003	None	2 fish or 100 pounds per person, whichever is greater	None		
2004	None	2 fish or 100 pounds per person, whichever is greater	None		
2005	None	2 fish or 100 pounds per person, whichever is greater	None		
2006	None	2 fish or 100 pounds per person, whichever is greater	None		

2007	None	1 per person within the 5-fish grouper aggregate bag limit	Same as federal waters	Added Golden Tilefish to the Reef Fish rule, which established allowable gears (hook and line, black sea bass trap, and spear) and landing in whole condition requirement. Established a recreational bag limit of one Golden Tilefish within the five-fish daily aggregate grouper bag limit. Allowed a two-day possession limit for reef fish for persons aboard charter and headboats on trips exceeding 24 hours, provided the vessel is equipped with a permanent berth for each passenger, and each passenger has a receipt verifying the trip length. Designated Golden Tilefish as a “restricted species,” requiring commercial harvesters to possess a Restricted Species endorsement on their Saltwater Products License, as well as a federal South Atlantic Snapper Grouper commercial permit. Set commercial trip limits in the Atlantic that are the same as federal waters. Prohibited commercial harvest in state waters	July 1, 2007

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
				when federal waters are closed. Prohibited commercial fishermen from harvesting or possessing the recreational bag limit on commercial trips.	
2008	None	1 per person within the 5-fish grouper aggregate bag limit	Same as federal waters		
2009	None	1 per person within the 5-fish grouper aggregate bag limit	Same as federal waters		

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
2010	None	1 per person within the 3-fish grouper aggregate bag limit	Same as federal waters	Reduced the recreational grouper aggregate to three fish per day in Atlantic and Monroe County state waters (retained the Golden Tilefish limit of one fish within the aggregate). Prohibited the captain and crew of for-hire vessels from retaining any species in the aggregate grouper bag limit. Required dehooking tools be aboard commercial and recreational vessels for use as needed to remove hooks from Atlantic reef fish.	Jan. 19, 2010
2011	None	1 per person within the 3-fish grouper aggregate bag limit	Same as federal waters		
2012	None	1 per person within the 3-fish grouper aggregate bag limit	Same as federal waters		
2013	None	1 per person within the 3-fish grouper aggregate bag limit	Same as federal waters		

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
2014	None	1 per person within the 3-fish grouper aggregate bag limit	Same as federal waters	Eliminated prohibition on captain and crew of for-hire vessels from retaining recreational bag limits of Vermilion Snappers, groupers and Golden Tilefish on for-hire trips in state waters of the Atlantic (including Monroe County for grouper and Golden Tilefish).	March 13, 2014
2015	None	1 per person within the 3-fish grouper aggregate bag limit	Same as federal waters		
2016	None	1 per person within the 3-fish grouper aggregate bag limit	Same as federal waters	Created an exception allowing recreational anglers to land reef fish as fillets instead of as whole fish, provided the reef fish were recreationally harvested in The Bahamas and specific conditions are met.	Sept. 13, 2016
2017	None	1 per person within the 3-fish grouper aggregate bag limit	Same as federal waters		

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
2018	None	1 per person within the 3-fish grouper aggregate bag limit	Same as federal waters		
2019	None	1 per person within the 3-fish grouper aggregate bag limit	Same as federal waters		

Florida Atlantic and Monroe County Golden Tilefish Regulation Changes by Date

July 1, 2007

- Added Golden Tilefish to the Reef Fish chapter, which established the following regulations for Golden Tilefish:
  - Allowable gear: hook and line, black sea bass trap, and spear (except powerheads, bangsticks or explosive devices);
  - Commercial harvest prohibited when adjacent federal waters are closed to commercial harvest;
  - Fish must be landed in whole condition; and
  - Two-day possession limit allowed for persons aboard charter and headboats on trips exceeding 24 hours provided that the vessel is equipped with a permanent berth for each passenger aboard, and each passenger has a receipt verifying the trip length.
- Set the recreational harvest limit at one Golden Tilefish within the five-fish daily aggregate grouper bag limit for Atlantic and Monroe County state waters.
- Designated Golden Tilefish a “restricted species” and required commercial harvesters to possess a Restricted Species endorsement on their Saltwater Products License as well as a federal South Atlantic Snapper Grouper commercial permit to sell Golden Tilefish or harvest Golden Tilefish in excess of the recreational bag limit.
- Set commercial trip limits in the Atlantic that are the same as trip limits in adjacent federal waters.
- Prohibited commercial fishermen from harvesting or possessing the recreational bag limit of reef fish species on commercial trips.

January 19, 2010

- Reduced recreational aggregate grouper bag limit to 3 fish per person per day in all Atlantic and Monroe County state waters.
- Prohibited the captain and crew of for-hire vessels from retaining any species in the aggregate grouper bag limit.
- Required dehooking tools to be aboard commercial and recreational vessels for anglers to use as needed to remove hooks from Atlantic reef fish.

March 13, 2014

- Eliminated prohibition on captain and crew of for-hire vessels from retaining recreational bag limits of Vermilion Snappers, groupers and Golden Tilefish on for-hire trips in state waters of the Atlantic (including Monroe County for grouper and Golden Tilefish).

September 13, 2016

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

3. Assessment History

The benchmark assessment for Tilefish, SEDAR 04, was completed in 2004 with an assessment period 1961-2002 (SEDAR 04 2004). SEDAR 25 was a standard assessment completed in 2011 with an assessment period spanning 1962-2010 (SEDAR 25 2011). Several important changes were made during SEDAR 25 (e.g. M, h, SSB units) that make it somewhat difficult to compare SEDAR 04 with later assessments. Current management of South Atlantic Tilefish is based on an update assessment completed in 2016 with an assessment period of 1962-2014 (SEDAR 25 2016).

As of 2002, the stock was not overfished ($SSB_{2002}/MSST = 1.27$), but overfishing was occurring ($F_{2002}/F_{MSY} = 1.53$; SEDAR 04 2004). Terminal status estimates in SEDAR 25 found that the Tilefish stock was not overfished ($SSB_{2010}/MSST = 2.42$), and it was also not undergoing overfishing ($F_{2008\text{-}2010}/F_{MSY} = 0.36$; SEDAR 25 2011). Terminal status estimates in the SEDAR 25 showed the stock was not overfished ($SSB_{2014}/MSST = 1.13$), but overfishing was occurring ($F_{2008\text{-}2010}/F_{MSY} = 1.22$; SEDAR 25 2016).

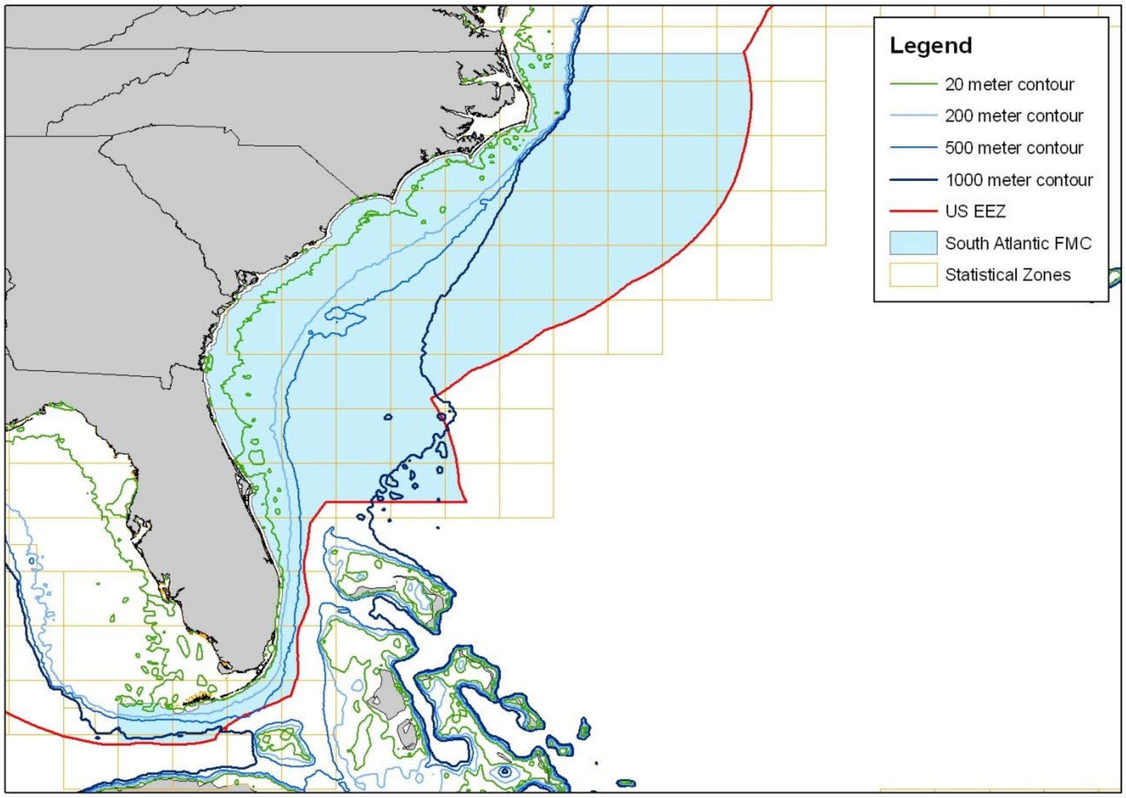
Values from the current SEDAR 66 assessment contrast with the stock status designation from SEDAR 04 ($SSB_{2002}/MSST = 0.96$) but concur with the unfished status from SEDAR 25 ($SSB_{2010}/MSST = 1.69$) and the SEDAR 25 ($SSB_{2014}/MSST = 1.49$). However, the current assessment results suggest that overfishing was not occurring at the ends of any of the previous South Atlantic Tilefish assessments ($F_{2002} / F_{MSY} = 0.7$, $F_{2008\text{-}2010}/F_{MSY} = 0.47$, $F_{2012\text{-}2014}/F_{MSY} = 0.78$).

The general pattern in time series of SSB/MSST in SEDAR 66 was similar to the SEDAR 25, but was shifted upwardso that it appears higher in all years. The trend and magnitude of SSB/MSST in SEDAR 25 were also similar up to 2003, but from 2004 to 2010 increased much more rapidly than what is reflected in the later assessments. The general pattern in the time series of F/F_{MSY} in SEDAR 66 was also similar to the SEDAR 25, but was shifted downward so that it appears lower in all years. This is particularly true of the period from approximately 1990-2005. The trend and magnitude of F/F_{MSY} in SEDAR 25 were quite similar to SEDAR 66.

Input values of constant M have been similar over the four Tilefish assessments (terminal years: 2002, 2010, 2014, 2018; M: 0.07, 0.1083, 0.1083, 0.1038), though M in SEDAR 04 was a little lower and was not used to scale age-varying M. Steepness has been fixed at similar values in all assessments (h: 0.72, 0.84, 0.84, 0.84) though again the value from SEDAR 04 was a little lower. The estimate of F_{MSY} in SEDAR 04 was considerably lower than in later assessments (F_{MSY}: 0.043, 0.185, 0.236, 0.3). The estimate of MSY was also much lower in SEDAR 04 than in later assessments (MSY, klb: 335, 638, 560, 518). In SEDAR 04 SSB was measured in units of female biomass (MSST,mt: 659) and thus was not comparable to later assessments which were in units of gonad weight (MSST, mt W_{gonad}:19.0, 16.4, 14).

4. Regional Maps

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



5. Abbreviations

APAIS	Access Point Angler Intercept Survey
ABC	Allowable Biological Catch
ACCSP	Atlantic Coastal Cooperative Statistics Program
ADMB	AD Model Builder software program
ALS	Accumulated Landings System; SEFSC fisheries data collection program
AMRD	Alabama Marine Resources Division
ASMFC	Atlantic States Marine Fisheries Commission
ASPIC	a stock production model incorporating covariates
ASPM	age-structured production model
B	stock biomass level
BAM	Beaufort Assessment Model
BMSY	value of B capable of producing MSY on a continuing basis
CFMC	Caribbean Fishery Management Council
CIE	Center for Independent Experts
CPUE	catch per unit of effort
EEZ	exclusive economic zone
F	fishing mortality (instantaneous)
FMSY	fishing mortality to produce MSY under equilibrium conditions
FOY	fishing mortality rate to produce Optimum Yield under equilibrium
FXX% SPR	fishing mortality rate that will result in retaining XX% of the maximum spawning production under equilibrium conditions
FMAX	fishing mortality that maximizes the average weight yield per fish recruited to the fishery
F0	a fishing mortality close to, but slightly less than, Fmax
FL FWCC	Florida Fish and Wildlife Conservation Commission
FWRI	(State of) Florida Fish and Wildlife Research Institute
GA DNR	Georgia Department of Natural Resources
GLM	general linear model
GMFMC	Gulf of Mexico Fishery Management Council
GSMFC	Gulf States Marine Fisheries Commission
GULF FIN	GSMFC Fisheries Information Network
HMS	Highly Migratory Species

LDWF	Louisiana Department of Wildlife and Fisheries
M	natural mortality (instantaneous)
MAFMC	Mid-Atlantic Fishery Management Council
MARMAP	Marine Resources Monitoring, Assessment, and Prediction
MDMR	Mississippi Department of Marine Resources
MFMT	maximum fishing mortality threshold, a value of F above which overfishing is deemed to be occurring
MRFSS	Marine Recreational Fisheries Statistics Survey; combines a telephone survey of households to estimate number of trips with creel surveys to estimate catch and effort per trip
MRIP	Marine Recreational Information Program
MSST	minimum stock size threshold, a value of B below which the stock is deemed to be overfished
MSY	maximum sustainable yield
NC DMF	North Carolina Division of Marine Fisheries
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
OY	optimum yield
SAFMC	South Atlantic Fishery Management Council
SAS	Statistical Analysis Software, SAS Corporation
SC DNR	South Carolina Department of Natural Resources
SEAMAP	Southeast Area Monitoring and Assessment Program
SEDAR	Southeast Data, Assessment and Review
SEFIS	Southeast Fishery-Independent Survey
SEFSC	Fisheries Southeast Fisheries Science Center, National Marine Fisheries Service
SERO	Fisheries Southeast Regional Office, National Marine Fisheries Service
SPR	spawning potential ratio, stock biomass relative to an unfished state of the stock
SSB	Spawning Stock Biomass
SSC	Science and Statistics Committee
TIP	Trip Incident Program; biological data collection program of the SEFSC and Southeast States.
TPWD	Texas Parks and Wildlife Department
Z	total mortality, the sum of M and F

SEDAR

Southeast Data, Assessment, and Review

SEDAR 66

South Atlantic Tilefish

Section II: Assessment Report

April 2021

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

Document History

April, 2021 Original release.

Contents

List of Tables

List of Figures

1 Introduction

1.1 Executive Summary

This operational assessment evaluated the status of Tilefish (*Lopholatilus chamaeleonticeps*; a.k.a. Golden Tilefish, Great Northern Tilefish) off the Southeastern United States (i.e. the US South Atlantic stock). The primary objectives of this assessment were to build on previous assessments [SEDAR 04, SEDAR 25, and the SEDAR 25 2016 Update (hereafter 2016 Update)] to provide recent estimates of benchmarks and conduct updated stock projections.

Data compilation and assessment methods were guided by methods used in previous Tilefish assessments and other recent SEDAR assessments. The benchmark assessment for Tilefish was completed in 2004 with an assessment period 1961-2002 (SEDAR 04 2004). SEDAR 25 was a standard assessment completed in 2011 with an assessment period spanning 1962-2010 (SEDAR 25 2011). Current management of South Atlantic Tilefish is based on an update assessment completed in 2016 with an assessment period of 1962-2014 (SEDAR 25 2016). This assessment was conducted by the Southeast Fisheries Science Center in cooperation with regional data providers, for the time period 1972-2018.

Available data on this stock included indices of abundance, landings, and samples of annual length compositions and age compositions from fishery-dependent and fishery-independent sources. Two indices of abundance were developed during the SEDAR process and fitted by the model: one fishery dependent index based on the commercial longline fleet logbooks and one fishery independent index based on the Marine Resources Monitoring, Assessment, and Prediction program 'long' bottom longline survey (MARMAP longline). Landings data were available from all significant recreational and commercial sources.

The model used in all previous assessments of this stock—and updated here—was the Beaufort Assessment Model (BAM), an integrated statistical catch-age formulation (Williams and Shertzer 2015). A base run of BAM was configured to provide estimates of key management quantities, such as stock and fishery status. Uncertainty in estimates from the base run was evaluated through a mixed Monte Carlo/Bootstrap Ensemble (MCBE) analysis.

Estimated time series of stock status (SSB/MSST) showed a rapid decline during the 1980s and a slower decline during the 1990s, to a minimum value in 1995. From 1995 to 2011 stock status improved, but has been in decline again since 2012.

Current stock status was estimated in the base run to be $\text{SSB}_{2018}/\text{MSST} = 1.294$, indicating that the stock is not overfished. Through its history, SSB has only dropped below MSST in a few years during the late 1990s and early 2000s. Results from the MCBE suggested that the estimate of SSB relative to SSB_{MSY} and the status relative to MSST is highly uncertain (Figures 26, 27). Only 58.3% of MCBE runs agreed with the stock status result from the assessment model.

The estimated time series of F/F_{MSY} from the assessment model suggests that although F has exceeded F_{MSY} sporadically for individual years during the assessment period, it has not been a consistent problem since the run of years of overfishing during 1990-1995. However, there is considerable uncertainty in F/F_{MSY} as demonstrated by the MCBE, especially toward the end of the assessment period. Current fishery status in the terminal year, with current F represented by the geometric mean from $2016-2018$ ($F_{\text{current}} = F_{2016-2018} = 0.2566$), was estimated by the base run to be $F_{2016-2018}/F_{\text{MSY}} = 0.86$. Thus, at the end of the assessment Tilefish was not undergoing overfishing. However, results from the MCBE show that there is a lot of uncertainty in the status of the fishery. Only 48.8% of MCBE runs agreed with the fishing status result from the model, and the median value of $F_{2016-2018}/F_{\text{MSY}}$ from the MCBE runs (1.029) suggests overfishing.

Compared to 2016 Update, stock status has improved and the stock is no longer undergoing overfishing as of 2018. The estimated trends from this operational assessment are similar to those from the SEDAR 04, SEDAR 25, and 2016 Update. However, this assessment did show some differences from previous assessments, which was not surprising, given modifications made to both the data and model (described throughout the report).

1.2 Workshop Time and Place

The SEDAR 66 South Atlantic Tilefish assessment took place over a series of webinars and a webinar workshop held from April, 2020 to February, 2021. Due to the 2020 Pandemic the in-person workshop that was originally scheduled for November 17-19 in Beaufort, NC was rescheduled to be four 5 hour long webinars held November 16-19.

1.3 Terms of Reference

1. Prepare a standard assessment, based on the approved 2016 SEDAR 25 South Atlantic Tilefish Update assessment with data through 2018. Provide commercial and recreational landings and discards in pounds and numbers.
2. Evaluate and document the following specific changes in input data or deviations from the update model. (List below each topic or new dataset that will be considered in this assessment.)
   - Incorporate the latest BAM model configurations and updates to data calculation methodologies, detailing the changes made between the 2016 SEDAR 25 South Atlantic Tilefish Update assessment model and the proposed SEDAR 66 model.
   - Examine evidence for changing selectivity in input data sources and consider implementing time blocks if warranted.
   - Re-consider error distributions for fitting age and length composition data.
   - Investigate the potential use of the following new data sources
     - CRP Cooperative Bottom Longline Survey to Augment Fishery Independent Reef Fish Data Collection in Deepwater Snapper Grouper
     - G. Nesslage FATE project
3. Document any changes or corrections made to the model and input datasets and provide updated input data tables. Fully document and describe the impacts (on population parameters and management benchmarks) of any changes to the model structure, methods, application or fitting procedures made between this assessment and the 2016 SEDAR 25 South Atlantic Tilefish Update assessment.
4. Update model parameter estimates and their variances, model uncertainties, and estimates of stock status and management benchmarks. Compare population parameter trends and management benchmarks estimated in this assessment with values from the previous assessment, and comment on the impacts of changes in data, assumptions or assessment methods on estimated population conditions and benchmarks.
5. Provide stock projections, including a probability density function (PDF) for biological reference point estimates and yield separated for landings and discards reported in pounds and numbers. Projection results are requested for 5 years from the start of the alternative fishing mortality levels. (The specific years for projections will be determined once the terminal year and schedule are known). The panel shall provide guidance on appropriate assumptions to address harvest and mortality levels in the interim years between the assessment terminal year (2018) and the first year of management (2020). Projection criteria:
   - To determine OFL: (1) P* = 50%; (2) F_{MSY}
   - To determine ABC: (1) P* = 30%; (2) 75%F_{MSY}
6. Review, evaluate, and report on the status and progress of all research recommendations listed in the last assessment, peer review reports, and SSC report concerning this stock.
7. Develop a stock assessment update report to address these TORS and fully document the input data, methods, and results of the stock assessment update.

1.4 List of Participants

Appointee	Function	Affiliation
ANALYTICAL TEAM		
Nikolai Klibansky	Lead Analyst	SEFSC Beaufort
Eric Fitzpatrick	Data Compiler	SEFSC Beaufort
Kyle Shertzer	Assessment Team	SEFSC Beaufort
Erik Williams	Assessment Team	SEFSC Beaufort
PANEL		
Ken Brennan	Assessment Team	SEFSC Beaufort
Wally Bubley	Panelist	SCDNR
Julie DeFilippi-Simpson	Panelist	ACCSP
Kelly Fitzpatrick	Assessment Team	SEFSC Beaufort
Churchill Grimes	Panelist	SAFMC SSC
Kevin Kolmos	Panelist	SCDNR
Vivian Matter	Assessment Team	SEFSC Miami
Genny Nesslage	Panelist	SAFMC SSC
Jennifer Potts	Assessment Team	SEFSC Beaufort
Walt Rogers	Assessment Team	SEFSC Beaufort
George Sedberry	Panelist	SAFMC SSC
Kevin Spanik	Panelist	SCDNR
Amanda Tong	Panelist	NCDMF
Beth Wrege	Assessment Team	SEFSC Miami
APPOINTED OBSERVERS		
Vincent Bonura	Fisherman	Snapper Grouper AP
Jim Freeman	Fisherman	Snapper Grouper AP
Rusty Hudson	Fisherman	Snapper Grouper AP
Andy Piland	Fisherman	Snapper Grouper AP
NON-PANEL DATA PROVIDERS		
Larry Beerkircher	Observer	SEFSC Miami
Steve Brown	Observer	FLFWCC
Julie Califf	Observer	GADNR
Andrew Cathey	Observer	NCDMF
Amy Dukes	Observer	SCDNR
Eric Hiltz	Observer	SCDNR
Dominique Lazarre	Observer	FLFWCC
Kevin McCarthy	Observer	SEFSC Miami
Refik Orhun	Observer	SEFSC Miami
STAFF		
Mike Errigo	SAFMC Lead	SAFMC
Kathleen Howington	Coordinator	SEDAR
Steve Poland	SAFMC Representative	SAFMC
Jeff Pulver	Observer	SERO

Appointee	Function	Affiliation
OTHER		
Nate Bacheler	Observer	SEFSC Beaufort
Julia Byrd	Observer	SAFMC
Rob Cheshire	Observer	SEFSC Beaufort
Chip Collier	Observer	SAFMC
Margaret Finch	Observer	SCDNR
Keilin Gamboa-Salazar	Observer	SCDNR
Dawn Glasgow	Observer	SCDNR
Homer Hiers	Observer	SCDNR
Ryan Lindh	Observer	Fisherman
Stephen Long	Observer	SCDNR
Alan Lowther	Observer	NMFS
Matthew Nuttall	Observer	NMFS
Andy Ostrowski	Observer	SEFSC Beaufort
Mike Rinaldi	Observer	ACCSP
Mike Schmidtke	Observer	SAFMC
McLean Seward	Observer	NCDENR
Wiley Sinkus	Observer	SCDNR
Tracy Smart	Observer	SCDNR
Laurie Stevens	Observer	SFA
Michelle Willis	Observer	SCDNR

1.5 Document List

Document number	Title	Authors	Date Received
	Documents Prepared for SEDAR 66		
SEDAR66-WP01	General Recreational Survey Data for Tilefish in the South Atlantic	Nuttall and Matter 2020	9/16/2020
SEDAR66-WP02	Golden Tilefish Fishery-Independent Index of Abundance in US South Atlantic Waters Based on a SCDNR Bottom Longline Survey (1996- 2016)	Bubley and Smart 2020	9/22/2020
SEDAR66-WP03	Standardized catch rates of tilefish (*Lopholatilus chamaeleonticeps*) in the southeast U.S. from commercial logbook data	Fitzpatrick 2020	12/4/2020
	Final Assessment Report		
SEDAR66-SAR1	SEDAR 66 Stock Assessment Report (*current document*)	Prepared by the SEDAR 66 panel	4/6/2021
	Reference Documents		
SEDAR66-RD01	Cooperative Bottom Longline Survey to Augment Fisheries Independent Reef Fish Data Collection in the Deep-Water Snapper-Grouper Fishery of the South Atlantic United States	Helies et al. 2016	5/5/2020
SEDAR66-RD02	Snapper Grouper Advisory Panel Golden Tilefish Fishery Performance Report	Snapper Grouper Advisory Panel 2018	7/17/2020

1.6 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. Prepare a standard assessment, based on the approved 2016 SEDAR 25 South Atlantic Tilefish Update assessment with data through 2018. Provide commercial and recreational landings and discards in pounds and numbers.

− *This report documents the preparation of an operational assessment, based on the approved 2016 Update assessment (SEDAR 25 2016) with data through 2018. Observed time series of landings are presented in Table 1, with associated CVs in Table 2. Estimated time series of landings are presented in numbers (Tables 16) and pounds (Table 17). Data providers have indicated that discarding has been negligible for this stock, thus discards have not been modeled in this past SEDAR assessments of South Atlantic Tilefish. We conferred with data providers for the current assessment and they confirmed that discarding remains minimal in recent years. Thus, discards have not been modeled in SEDAR 66 and are not provided in this report.*

2. Evaluate and document the following specific changes in input data or deviations from the update model. (List below each topic or new dataset that will be considered in this assessment.)

   - Incorporate the latest BAM model configurations and updates to data calculation methodologies, detailing the changes made between the 2016 SEDAR 25 South Atlantic Tilefish Update assessment model and the proposed SEDAR 66 model.

   − *The latest BAM model configurations and updates to data calculation methodologies have been considered and included in the SEDAR 66 base model.*

   - Examine evidence for changing selectivity in input data sources and consider implementing time blocks if warranted.

   − *Evidence for changing selectivity has been examined and discussed by the SEDAR 66 panel. Although past assessments for Tilefish did not include multiple time blocks for selectivity, the panel determined that both the commercial handline and commercial longline fleets should be modeled with two time blocks based on age composition data, due to the implementation of commercial fish seasons beginning in 2006 (see §I. Table 2.6.2). See Figs 13, 15 and 14 and Table 11 for estimated selectivities.*

   - Re-consider error distributions for fitting age and length composition data.

   − *Error distributions for fitting age and length composition data have been reconsidered. As in recent SEDAR assessments of other species (e.g. SEDAR 2017, SEDAR 60 2020) Dirichlet-Multinomial likelihoods were used for fitting age and length composition data for the SEDAR 66 assessment (Figure 3).*

   - Investigate the potential use of the following new data sources

     – CRP Cooperative Bottom Longline Survey to Augment Fishery Independent Reef Fish Data Collection in Deepwater Snapper Grouper

     − *We considered this early on in the assessment process and determined from speaking with the members of this project that these data were not appropriate for inclusion in SEDAR 66. This was due to the data collection of the survey occurring in 2019, as originally scheduled, but the terminal year of the assessment being 2018.*

     – G. Nesslage FATE project

     − *We considered this early on in the assessment process and determined from speaking with members of this project that new data sets would not be generated for use in this assessment.*

3. Document any changes or corrections made to the model and input datasets and provide updated input data tables. Fully document and describe the impacts (on population parameters and management benchmarks) of any changes to the model structure, methods, application or fitting procedures made between this assessment and the 2016 SEDAR 25 South Atlantic Tilefish Update assessment.

– *Changes made to the model and input datasets are documented throughout this report. Direct comparisons between the SEDAR 66 and the 2016 Update models are described in in §3.8 and 4.10*

4. Update model parameter estimates and their variances, model uncertainties, and estimates of stock status and management benchmarks. Compare population parameter trends and management benchmarks estimated in this assessment with values from the previous assessment, and comment on the impacts of changes in data, assumptions or assessment methods on estimated population conditions and benchmarks.

– *Estimates of all model paramaters are presented in Appendix A. Estimates of stock status and management benchmarks are presented in Table 18. Direct comparisons between the SEDAR 66 and the 2016 Update models are described in in §3.8 and 4.10*

5. Provide stock projections, including a probability density function (PDF) for biological reference point estimates and yield separated for landings and discards reported in pounds and numbers. Projection results are requested for 5 years from the start of the alternative fishing mortality levels. (The specific years for projections will be determined once the terminal year and schedule are known). The panel shall provide guidance on appropriate assumptions to address harvest and mortality levels in the interim years between the assessment terminal year (2018) and the first year of management (2020). Projection criteria:
   - To determine OFL: (1) P* = 50%; (2) F_{MSY}
   - To determine ABC: (1) P* = 30%; (2) 75%F_{MSY}

– *Projection results are described in §4.13. Relevant figures and tables are cited therein.*

6. Review, evaluate, and report on the status and progress of all research recommendations listed in the last assessment, peer review reports, and SSC report concerning this stock.

– *No research recommendations were made in the assessment report for the previous assessment (2016 Update; SEDAR 25 2016). This report did, however, contain a section (§5.2) entitled "Recommendations for the Next Benchmark Assessment". Note that SEDAR 66 is an operational assessment rather than a benchmark or research track assessment. I am not aware of research recommendations made in peer review reports or the SSC report associated with the 2016 Update.*

7. Develop a stock assessment update report to address these TORS and fully document the input data, methods, and results of the stock assessment update.

– *This SEDAR 66 Operational Assessment Report satisfies this ToR.*

2 Data Review and Update

The benchmark assessment for Tilefish (*Lopholatilus chamaeleonticeps*) off the Southeastern United States (i.e. the US South Atlantic stock), SEDAR 04, was completed in 2004 with an assessment period 1961-2002 (SEDAR 04 2004). SEDAR 25 was a standard assessment completed in 2011 with an assessment period spanning 1962-2010 (SEDAR 25 2011). Current management of South Atlantic Tilefish is based on an update assessment completed in 2016 with an assessment period of 1962-2014 (SEDAR 25 2016).

In the current SEDAR 66 assessment, data through 2018 were considered. For some data sources, the data were simply updated with the additional years of data (2015-2018) using the same methods as in the prior assessments. However, for some sources, it was necessary to update data prior to 2015 as well. The input data for this assessment are described below, with emphasis on the data that required modification beyond just the addition of years. A summary timeline of data sources fit to in this assessment is plotted in Fig. 1.

2.1 Data Review

In this operational assessment, the Beaufort assessment model (BAM) was fitted to many of the same data sources as in SEDAR 04 and the SEDAR 25 2016 Update (hereafter the 2016 Update).

- Landings: commercial handline, commercial longline, and general recreational
- Indices of abundance: commercial longline and Marine Resources Monitoring, Assessment, and Prediction program 'long' bottom longline survey (MARMAP longline)
- Length compositions of landings: general recreational
- Age compositions of landings: commercial handline, commercial longline, and MARMAP longline survey.

Contrasts to data used in the 2016 Update assessment include:

- The SEDAR 66 model time period was 1972-2018 in contrast to 1962-2014 for the 2016 Update. Thus, data during 1962-1971 were dropped in SEDAR 66 while data for the period 2015-2018 were added.
- The commercial longline index, redeveloped for SEDAR 66, included the period 1993-2006. By contrast, in the SEDAR 25, this index included the period 1993-2014. Years after 2006 were not included in SEDAR 66 based on the realization that reduced fishing seasons starting in 2006 and becoming shorter over subsequent years caused shifts in fleet behavior. Development of this index is detailed by Fitzpatrick (2020).
- The MARMAP longline index was also redeveloped for SEDAR 66 and includes individual discontinous years in the period 1996-2016 (i.e. 1996-2001, 2007, 2009-2011, 2015-2016). By contrast, in the SEDAR 25, this index included data from the period 1985-2010, averaged over five-year blocks and modeled at the midpoint of each of those blocks (i.e. 1985, 1998, 2002, 2006, 2010). Development of this index is detailed by Bubley and Smart (2020).
- While the SEDAR 25 had included ages 1-25 yr for all age compositions, the SEDAR 66 model included ages 1-20 yr for commercial and ages 1-16 yr for MARMAP longline survey age compositions. Few ages were available for the age classes that were excluded.
- Commercial handline and commercial longline length composition data were not used in SEDAR 66

2.2 Data Update

2.2.1 Life History

Life-history inputs from SEDAR 04 and subsequently the SEDAR 25 remained largely the same in SEDAR 66. All conversion equations (e.g. conversion from gutted weight to whole weight), time of peak spawning, growth model parameters, proportions female-at-age and maturity-at-age, were all identical to SEDAR 04. The exception being vectors-at-age were truncated to match the range of ages modeled in SEDAR 66 (1-20). Primary life-history information is summarized in Table 6. Maximum age (t_{max}) remained age $t_{max} = 40$, and constant natural mortality (M) used for scaling age-varying natural mortality (M_a) was still computed from the equation from Hoenig (1983, ; $M = \exp(1.46 - 1.01 \log t_{max})$) such that $M = 0.0138$. However, in SEDAR 04 and the SEDAR 25 the value of M was slightly different from this value at 0.0183, probably due to a typographical error where digits 3 and 8 were transposed during SEDAR 04. Thus, M_a was rescaled to reflect this change.

In addition, the upper and lower bounds of M used in the MCBE analysis were recomputed by applying the Hoenig (1983) equation to lower and upper estimates of $t_{max} = 50, 30$ resulting in a range of M from 0.08 to 0.14. This method is similar to the approach used in other recent assessments (SEDAR 50 2017; SEDAR 60 2020) and was preferred by the SEDAR 66 panel. The SEDAR 04 had computed range of 0.03-0.21 based on 13 estimates of M using 12 different meta-analysis regression methods. However, most of the estimates included in the SEDAR 04 approach are no longer considered for use in recent SEDAR assessments, and the resulting range seemed unreasonably wide and used estimates that are not considered realistic. The approach of using the range from multiple M estimates was in fact used in assessments as recent as SEDAR 60 (2020) which used a range from six M values based on two methods and three estimates of t_{max}. However, it is not helpful to include estimates that are not considered realistic for the stock.

2.2.2 Landings

Landings estimates were combined into three fleets: commercial handline, commercial longline, and general recreational (Table 1). Commercial landings of Tilefish were compiled from 1950 through 2018 for the entire U.S. Atlantic Coast, in gutted weight (GW). Only landings from 1972 to 2018 were included in this assessment as landings prior to 1972 were minimal. Sources for landings in the U.S. South Atlantic (Florida through North Carolina) included the Florida Trip Ticket program (FTT), South Carolina Department of Natural Resources (SCDNR), North Carolina Division of Marine Fisheries (NCDMF), and the Atlantic Coastal Cooperative Statistics Program (ACCSP). Commercial handline landings included gear types such as hook and line, bandit reels, and similar hook gear. Landings from gear types other than handline and longline were negligible and were not included in the assessment. Commercial landings include data from the North Carolina-Virginia border to the Florida Keys in Monroe County, Florida along US Highway 1. Landings in Monroe County were apportioned by data providers to exclude landings north of the Florida Keys, which are considered part of the Gulf of Mexico.

For this assessment, estimates of recreational landings from the private and charter modes were based on current Marine Recreational Information Program (MRIP) methodology. This included landings from 1981 to 2019, from North Carolina to Florida, including the Florida Keys. The inclusion of the Keys is a slight deviation from methods used in SEDAR 04. Estimates account for changes in the Fishing Effort Survey, the redesigned Access Point Angler Intercept Survey, and the For Hire Survey. A large value of recreational landings in 1981 (226,989 fish) was associated with one trip which reported 12 Tilefish (Nuttall and Matter 2020). In contrast with previous Tilefish assessments, the 2005 estimate was not replaced with an average of values from other years (SEDAR 25 2016), since it is not anomolous in the current time series of recreational landings.

The Southeast Region Headboat Survey (SRHS) also provided landings, but they were negligible and were not included in the recreational landings (E. Fitzpatrick, pers. comm.). Recreational landings were provided in whole weight (WW) but were converted to GW outside of the assessment using Eq. 3 so that all landings would be in the same units (Table 1).

In years where no recreational landings were estimated (1982, 1989, 1993, and 1995), these zeros were replaced with the minimum non-zero value from the recreational landings time series (0.039 klb WW from 2008) by the lead analyst. This is similar to what was done in SEDAR 04, where zeroes were replaced with a small value of 0.02 klb WW (SEDAR 25 2016).

2.3 Discards

As in the SEDAR 04, SEDAR 25, and the SEDAR 25, no discard estimates were included in the model as discards appear to be negligible in all sectors of the Tilefish fishery. For SEDAR 66, discards for recent years were shown to be minimal for commercial fisheries (Kevin McCarthy, unpublished data), the recreational headboat fishery (Dominique Lazarre, pers. comm.), and from the recreational private and charter fisheries (Nuttall and Matter 2020).

2.4 Indices of abundance

The indices of abundance used in SEDAR 25 included the fishery-independent MARMAP longline index and the fishery dependent longline logbook index (Table 5). Both indices were updated for this assessment. See Bubley and Smart (2020) and Fitzpatrick (2020) for detailed descriptions of index development

2.5 Length Composition

Length compositions were developed from the commercial handline, commercial longline, and recreational sampling data. Sample sizes by year and fleet are reported in Tables 3 (trips) and 4. Following the methodology of SEDAR 25, the contribution of each length was weighted by the landings associated by state, gear, and year.

2.6 Age Composition

Age data were available from the commercial handline, commercial longline, and MARMAP longline sampling programs. For commercial data, ages greater than 20 yr were pooled to age-20 creating a plus group. For the MARMAP age compositions, there were few ages > 16 yr, so ages ≥ 16 yr were pooled as a plus group. Sample sizes by year and fleet are reported in Tables 3 (trips) and 4.

3 Stock Assessment Methods

This assessment updates the primary model applied during the SEDAR 04 and the 2016 Update for Tilefish (*Lopholatilus chamaeleonticeps*) off the Southeastern United States (hereafter South Atlantic Tilefish). The methods are reviewed below, and any changes since the 2016 Update are emphasized.

3.1 Overview

The primary model in this assessment was the Beaufort Assessment Model (BAM), which applies a statistical catch-age formulation (Williams and Shertzer 2015). The model was implemented with the AD Model Builder software (Fournier et al. 2012). In essence, the model simulates a population forward in time while including fishing processes (Quinn and Deriso 1999; Shertzer et al. 2008). Quantities to be estimated are systematically varied until characteristics of the simulated populations match available data on the real population. Statistical catch-age models share many attributes with ADAPT-style tuned and untuned Virtual Population Analysis (VPA).

The method of forward projection has a long history in fishery models. It was introduced by Pella and Tomlinson (1969) for fitting production models and then, among many applications, used by Fournier and Archibald (1982), by Deriso et al. (1985) in their CAGEAN model, and by Methot (1989; 2009) in his Stock Synthesis model. The catch-age model of this assessment is similar in structure to the CAGEAN and Stock Synthesis models. Versions of this model have been used in previous SEDAR assessments in the U.S. South Atlantic, including those for Tilefish (SEDAR 04 2004; SEDAR 25 2011; 2016) and other reef fishes such as Vermilion Snapper, Black Sea Bass, Snowy Grouper, Gag Grouper, Greater Amberjack, Spanish Mackerel, Red Grouper, and Red Snapper.

3.2 Data Sources

The catch-age model included data from the fishery dependent SRHS survey, the fishery independent MARMAP longline survey, and three fleets that caught South Atlantic Tilefish: commercial handline, commercial longline, and the recreational fishery. The model was fitted to annual landings (GW; Table 1). Data providers also provided coefficients of variation (CVs) associated with landings (Table 2), which were used to generate bootstrap data sets during the MCBE model analysis. The model was also fitted to annual length compositions of recreational landings and annual age compositions from commercial handline and commercial longline landings and from the MARMAP longline survey. Samples sizes associated with composition data are provided in numbers of trips (Table 3) and numbers of fish (Table 4). The model was also fitted to the fishery dependent SRHS survey and the fishery independent MARMAP longline survey index of abundance (Table 5). Data used in the model are described in §2 of this report and in previous reports of South Atlantic Tilefish.

3.3 Model Configuration and Equations

Model structure and equations of the BAM are detailed in Williams and Shertzer (2015). The assessment time period for this assessment was 1972-2018. A general description of the assessment model follows.

Stock dynamics In the assessment model, new biomass was acquired through growth and recruitment, while abundance of existing cohorts experienced mortality from fishing and natural sources. The population was assumed closed to immigration and emigration. The model included age classes $1-20^{+}$, where the oldest age class 20^{+} allowed for the accumulation of fish (i.e., plus group).

Initialization Initial (1972) abundance at age was estimated in the model as follows. The equilibrium age structure was computed for ages 1–20 based on natural and fishing mortality (F_{init}), where F_{init} was set equal to a value that resulted in the 1972 biomass level equaling 90% of the unfished level. This was done in SEDAR 25 and the SEDAR 25 based on the assumption by the SEDAR 25 workshop panel that the stock was lightly exploited prior to the 1960's. In SEDAR 66, landings data showed minimal exploitation prior to 1972, and the same method was followed. Lognormal deviations around that equilibrium age structure were found not to deviate from zero during model development and thus were fixed at zero.

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). As in previous SEDAR assessments, the age-dependent estimates of M_a were rescaled to provide the same fraction of fish surviving from age-1 through the oldest observed age (40 yr) as would occur with constant $M = 0.1038$. This approach using cumulative mortality is consistent with the findings of Hoenig (1983) and Hewitt and Hoenig (2005). For the MCBE analysis, M was randomly drawn from a uniform distribution from $0.08 - 0.14$.

Growth Mean length in the population [l_a; total length (TL) in millimeters, (mm)] was modeled with the von Bertalanffy function of age (a)

$$l_a = L_\infty(1 - exp[-K(a - t_0 + \tau)]) \tag{1}$$

where $L_\infty = 825.1$, $K = 0.189$, and $t_0 = -0.47$, are parameters estimated external to the assessment model during the SEDAR 25 process and $\tau = 0.5$, representing a fraction of the year. Here, l_a is being computed at midyear. All parameters in Eq. 1 were treated as fixed input to the assessment model. For fitting length composition data, the distribution of size at age was assumed normal with coefficient of variation estimated by the assessment model ($CV_l = 0.1445$). A constant CV, rather than constant standard deviation, was suggested by the size at age data.

Weight at age [w_a; WW in kilograms (kg)] was modeled as a power function of l_a

$$w_a = \theta_1 l_a^{\theta_2} \tag{2}$$

where $\theta_1 = 4.04e-12$ and $\theta_2 = 3.155$ are parameters estimated external to the assessment model during the SEDAR 25 process and treated as fixed input to the assessment model (Table 6, Figure 2). Where necessary (e.g. converting recreational landings to GW), WW was converted to gutted weight (GW) with the equation

$$GW = \frac{WW}{a} \tag{3}$$

where $a = 1.05893$.

Spawning stock Spawning stock was modeled using mature female gonad weight measured at the time of peak spawning. In cases when reliable estimates of fecundity are unavailable, spawning biomass, and in this case, female gonad weight, is commonly used as a proxy for population fecundity. For Tilefish, peak spawning was considered to occur at the end of May (May 31^{st}; $spawn\_time\_frac = 5/12 = 0.42$. Gonad weight ($W_{\text{gonad}}$; g) was computed from whole fish weight (WW; g) with the equation

$$W_{\text{gonad}} = aWW^b \tag{4}$$

where $a = -9.16802$, $b = 1.70498$, and weights are in grams (g).

Recruitment Expected annual recruitment ($\bar{R}_y$) of age-1 fish (i.e. recruits) was predicted from spawning stock in year y (S_y) using the Beverton–Holt spawner-recruit model

$$\bar{R}_{y+1} = \frac{0.8R_0hS_y}{0.2R_0\phi_0(1-h) + S_y(h-0.2)} \tag{5}$$

where R_0 is virgin recruitment, h is steepness, and ϕ_0 is the unfished spawners per recruit (Williams and Shertzer 2015). In SEDAR 66, R_0 was estimated while h was fixed at 0.84 from a meta-analysis by Shertzer and Conn 2012, as in SEDAR 25 and the SEDAR 25. When attempts were made to estimate h during the assessment process, it tended toward the upper bound. Likelihood profiles for h showed that most data sources favored maximizing steepness, which also supported fixing it. For years where data were considered useful for providing information on year-class strength, annual recruitment deviations (r_y) were estimated, assuming a lognormal distribution with standard deviation (σ_R)

$$N_{1,y} = \bar{R}_y exp(r_y) \tag{6}$$

In early runs of the model, σ_R had a tendency to be estimated at the lower bound and thus was fixed at a value of 0.6 from a meta-analysis.

Annual variation in recruitment was assumed to occur with lognormal deviations for years $1982 - 2011$ only. The start of recruitment residuals in 1982 was based on examination of a series of different starting years and the start of the age composition data that have information on year class strength. The first year of age composition data was 1992 from the commercial longline landings. In those early age compositions, the number of fish diminishes beyond age-10 (Fig. 3) which is the approximate age at full selection (Fig. 14). Thus, 1982 seemed to be about the earliest year that the composition data could reliably provide information on year class strength (i.e. estimate a recruitment residual). The ending year of estimated recruitment residuals (2011) was based on commercial longline age composition data, which had large sample sizes up until 2018 (Tables 3 and 4). The age at 50% selection for commercial longline toward the end of the assessment was at approximately age-8, so 2011 was the latest year for which recruitment could be informed by the age composition data. Tilefish from the 2011 year class are represented in commercial longline age composition data from 2015 to 2018, though are in fairly small numbers during 2015 and 2016.

Landings The model included time series of landings from three fleets: commercial longlines ($1972 - 2018$), commercial handlines ($1972 - 2018$), and general recreational ($1981 - 2018$). Landings were modeled with the Baranov catch equation (Baranov 1918) and were fitted in units of weight (1000 lb WW).

Discards As noted above, observed discards are negligible for South Atlantic Tilefish, thus discards were not modeled in this assessment.

Fishing Mortality For each time series of landings, the assessment model estimated a separate full fishing mortality rate (F). Age-specific rates were then computed as the product of full F and selectivity at age. Apical F was computed as the maximum of F at age summed across fleets.

Selectivities As in the SEDAR 25, selectivity at age was estimated using a two-parameter, flat-topped, logistic model in all cases. This parametric approach reduces the number of estimated parameters and imposes theoretical structure on selectivity. Age and size composition data are critical for estimating selectivity functions.

As in the SEDAR 25, seperate selectivity functions were estimated for commercial handline, commercial longline, and general recreational fleets, as well as for the MARMAP longline index. But in contrast to the SEDAR 25, selectivity functions for both the commercial handline and commercial longline fleets were estimated for two time blocks (1972-2008, 2009-2018). Though there have been no size-limits on South Atlantic Tilefish, decreases in the fishing season began taking place in 2006 and have continued in the years since. Age composition data for the commercial longline fleet suggest a shift in selectivity beginning in 2009. During the SEDAR 66 workshop multiple fishermen (appointed observers) confirmed that decreases in the fishing season affected behavior of the commercial fleet in ways that might cause a change in selectivity.

No selectivity parameters are fixed in SEDAR 66, but a normal prior distribution was applied to the slope parameter for the general recreational fleet selectivity which was not well estimated. Likelihood profiling showed that this parameter was poorly informed by the data. Thus, the mean value of the prior was set at the minimum of the likelihood profile, and the prior CV was set fairly tightly at -0.15.

During the SEDAR 66 process, dome-shaped (i.e. double-logistic) selectivity was investigated for the commercial handline and recreational fleets. However, likelihood profiling showed that the data contained little information for estimating parameters of the descending limb of a double-logistic function. When attempting to estimate dome-shaped selectivity for these fleets within the assessment model, the function tended toward a logistic (i.e. flat-top) shape. Thus, selectivity for these fleets remained logistic in the base model.

Indices of abundance The model was fit to two indices of relative abundance: commercial longline (1993-2006) and MARMAP longline survey (discontinuous years from 1996to 2016; Table 5). Predicted indices were conditional on selectivity of the corresponding fleet or survey and were computed from abundance (MARMAP) or biomass (commercial) at the midpoint of the year.

In this assessment, commercial CPUE units within the model code were converted from GW to WW to better match the population units of WW. This conversion does not affect model results, as the predicted index is ultimately scaled by the catchability parameter.

Catchability In the BAM, catchability scales indices of relative abundance to the estimated vulnerable population at large. As in prior assessments, catchability coefficients of both indices were assumed constant through time.

Fitting criterion The fitting criterion was a penalized likelihood approach in which observed landings were fit closely, and observed composition data and abundance indices were fit to the degree that they were compatible. Landings and index data were fitted using lognormal likelihoods. Length and age composition data were fit using the Dirichlet-multinomial distribution, with sample size represented by the annual number of trips (Table 5), adjusted by an estimated variance inflation factor (i.e. one additional parameter for each fleet's composition data).

The 2016 Update fit composition data using the robust multinomial with iterative re-weighting (Francis 2011). Since Francis (2011), additional work on this topic has questioned the use of the multinomial distribution in stock assessment models (Francis 2014), and has recommended the Dirichlet-multinomial as an alternative (Francis 2017; Thorson et al. 2017). A chief advantage of the Dirichlet-multinomial is that it is self-weighting through estimation of an additional variance inflation parameter for each composition component, making iterative re-weighting unnecessary. Another advantage is that it can better account for overdispersion, or, larger variance in the data than would be expected by the multinomial. Overdispersion can result from intra-haul correlation, which results when fish caught in the same set are more alike in length or age than fish caught in a different set (Pennington and Volstad 1994). The Dirichlet-multinomial has been implemented in Stock Synthesis (Methot and Wetzel 2013; Thorson et al. 2017) and in the BAM, and since the 2016 Update has become the standard likelihood for fitting composition data in assessments of South Atlantic reef fishes.

The model includes the capability for each component of the likelihood to be weighted by user-supplied values. When applied to landings and indices, these weights modify the effect of the input CVs. In this application to Tilefish, CVs of landings (in arithmetic space) were assumed equal to 0.05 to achieve a close fit to these data while allowing some imprecision. In practice, the small CVs are a matter of computational convenience, as they help achieve a close fit to the landings, while avoiding having to solve the Baranov equation iteratively (which is complex when there are multiple fisheries). In contrast to the SEDAR 25, iterative re-weighting was not conducted here, in part because the composition likelihoods were self-weighting. Thus, data weights were all equal in the base model.

In addition, the compound objective function included several prior distributions, applied to the Dirichlet-multinomial variance inflation factor parameters associated with each set of composition data and the slope parameter for the selectivity function of the general recreational fleet. Priors were applied to maintain parameter estimates near reasonable values, and to prevent the optimization routine from drifting into parameter space with negligible gradient in the likelihood which can result in a non-positive definite Hessian matrix (an indication of incomplete or incorrect parameter solutions).

Parameters Estimated The model estimated a total of 185 parameters including average fishing mortality rates (3 parameters) and annual fishing mortality rates (132 parameters) for each fleet, selectivity parameters (12 parameters), Dirichlet-multinomial variance inflation factors (4 parameters), a catchability coefficient associated with each index (2 parameters), coefficient of variation of length at age (CV_l; 1 parameter), virgin recruitment (R_0; 1 parameter), and annual recruitment deviations (30 parameters).

Biological reference points Biological reference points (benchmarks) were calculated based on maximum sustainable yield (MSY) estimates in gutted pounds from the Beverton–Holt spawner-recruit model with bias correction (expected values in arithmetic space). Computed benchmarks included MSY, fishing mortality rate at MSY (F_{MSY}), and spawning stock at MSY ($\mathrm{SSB}_{\mathrm{MSY}}$) by the method of Shepherd (1982). In this assessment spawning stock measures total gonad weight of mature females. These benchmarks are conditional on the estimated selectivity functions and the relative contributions of each fleet's fishing mortality. The selectivity pattern used here was the effort-weighted selectivities at age, with effort from each fishery estimated as the full F averaged over the last three years of the assessment (2016-2018).

Configuration of base run The base run was configured as described above. However, the base run configuration was not considered to represent all uncertainty. Sensitivity analyses, retrospective analyses, and ensemble modeling was conducted to better characterize the uncertainty in base run point estimates.

3.4 Sensitivity Analysis

Sensitivity of results to some key model inputs and assumptions was examined through sensitivity analyses. Sensitivity runs were chosen to address specific questions that arose during the SEDAR 66 assessment process. 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-S2: Low/high values of natural mortality ($M = 0.08, 0.14$)
- S3-S4: Low/high values of steepness ($h = 0.74, 0.94$)
- S5-S6: Higher values of initial F ($F_{init} = 0.053, 0.106$). Values associated with minimum of likelihood profile (lkmin) and half that value (0.5lkmin).
- S7-S8: Down/upweight MARMAP longline index: 1/10×, 10×
- S9: Use alternate recruitment estimates for years at the end of the assessment (2012-2018) where recruitment deviations were not estimated, based on geometric mean recruitment deviation from the last six years where recruitment deviations were estimated (2006-2011)

3.5 Retrospective Analysis

Retrospective analyses were run by reducing the terminal year of the model from 2018 to 2010-2017, thereby trimming all time series accordingly, and rerunning the assessment model. This analysis facilitates investigation of patterns in model results, particularly terminal status estimates, that may occur when recent data are excluded.

Retrospective analyses should be interpreted with caution because several data sources are not continuous between 2010 and 2018 (Fig. 1). These include the MARMAP longline index and age compositions, commercial handline age compositions, and recreational length compositions. The final year of recruitment deviations in each retrospective run was set to the terminal year minus seven years to mirror the base run model configuration.

3.6 Per Recruit and Equilibrium Analysis

Yield per recruit and spawning potential ratio were computed as functions of F, as were equilibrium landings and spawning biomass. Equilibrium landings were also computed as functions of biomass B, which itself is a function of F. As in computation of MSY-related benchmarks (described in §3.7), per recruit and equilibrium analyses applied the most recent selectivity patterns averaged across fleets, weighted by each fleet's F from the last three years (2016–2018) of the assessment.

3.7 Benchmarks and Reference Points

In this assessment of Tilefish, the quantities F_{MSY}, SSB_{MSY}, B_{MSY}, and MSY were estimated by the method of Shepherd (1982). In that method, the point of maximum yield is calculated from the spawner-recruit curve and parameters describing growth, natural mortality, maturity, and selectivity. The value of F_{MSY} is the F that maximizes equilibrium landings.

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

$$R_{eq} = \frac{R_0 \left[\varsigma 0.8 h \Phi_F - 0.2(1-h)\right]}{(h-0.2)\Phi_F} \tag{7}$$

where R_0 is virgin recruitment, h is steepness, and Φ_F is spawning potential ratio given growth, maturity, and total mortality at age. In BAM, the calculation of total mortality includes natural, fishing mortality rates, and discard mortality rates (though recall that SEDAR 66 does not model discards). The R_{eq} and mortality schedule imply an equilibrium age structure and an average sustainable yield (ASY). The estimate of F_{MSY} is the F giving the highest ASY,and the estimate of MSY is that ASY. The estimate of SSB_{MSY} follows from the corresponding equilibrium age structure.

Estimates of MSY and related benchmarks are conditional on selectivity pattern. The selectivity pattern used here was an average of terminal-year selectivities from each fleet, where each fleet-specific selectivity was weighted in proportion to its corresponding estimate of F averaged over the last three years (2016–2018) of the assessment. If the selectivities or relative fishing mortalities among fleets were to change, so would the estimates of MSY and related benchmarks.

The maximum fishing mortality threshold (MFMT) is defined by the SAFMC as F_{MSY}, and the minimum stock size threshold (MSST) as $75\%\text{SSB}_{\text{MSY}}$ (Restrepo et al. 1998). Overfishing is defined as $F >$ MFMT and overfished as SSB $<$ MSST. Current stock size is represented as SSB in the last assessment year (2018), and current fishing mortality (F_{current}) is represented by the geometric mean of F from the last three years of the assessment (2016-2018). Thus, $F_{\text{current}} = F_{2016-2018}$.

In addition to the MSY-related benchmarks, the assessment considered proxies based on per recruit analyses (e.g., $F_{40\%}$). The values of $F_{X\%}$ are defined as those Fs corresponding to X% spawning potential ratio, i.e., spawners (spawning biomass) per recruit relative to that at the unfished level. These quantities may serve as proxies for F_{MSY}, if the spawner-recruit relationship cannot be estimated reliably. Mace (1994) recommended $F_{40\%}$ as a proxy; however, later studies have found that $F_{40\%}$ is too high of a fishing rate across many life-history strategies (Williams and Shertzer 2003; Brooks et al. 2009) and can lead to undesirably low levels of biomass and recruitment (Clark 2002).

3.8 Comparison to Previous Assessments

This SEDAR 66 operational assessment builds upon the 2016 Update with an additional 4 years of data, substantial improvements to the structure of the BAM, and minor changes to the configuration of the model. No new data sources were included. See §2 for changes to data included in SEDAR 66 compared with the SEDAR 25.

Changes to the life history information used in the model included:

1. Made a minor correction to the estimate of constant natural mortality, now $M = 0.1038$, which had been incorrectly included as 0.0183 in previous assessments.
2. Less uncertainty in M incorporated into MCBE in SEDAR 66 ($0.08 - 0.14$) than in the SEDAR 25 (0.03-0.21).

Changes to model configuration include:

1. The start year of the model was 1972 instead of 1962.
2. Ages 1-20 were modeled in the population and used for fitting most age compositions. Ages 1-16 yr were used to fit the MARMAP longline survey age compositions. The 2016 Update modeled ages 1-25 yr.
3. Length and age compositions were fit using Dirichlet multinomial likelihoods, compared with robust multinomial likelihoods used in the 2016 Update.
4. Selectivity of commercial longline and handline included two time blocks, as opposed to one.
5. Selectivity slope parameters were fit without priors, except for the slope of recreational selectivity.
6. Data sources being fitted were not re-weighted by user-supplied weights. In the 2016 Update assessment, data weights were treated as inputs and varied across data sources.
7. The standard deviation of recruitment deviations (σ_R) was fixed as opposed to being estimated with a strong prior as in the SEDAR 25.
8. The coefficient of variation of length at age CV_l was estimated without a prior distribution.

3.9 Monte Carlo/Bootstrap Ensemble (MCBE) Analysis

For the base run of the catch-age model (BAM), uncertainty in results and precision of estimates was computed thoroughly through an ensemble modeling approach (Scott et al. 2016; Jardim et al. 2021) using a mixed Monte Carlo and bootstrap framework (Efron and Tibshirani 1993; Manly 1997). Monte Carlo and bootstrap methods 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; SEDAR4 2004; SEDAR19 2009; SEDAR24 2010). The approach is among those recommended for use in SEDAR assessments (SEDAR Procedural Guidance 2010).

The approach translates uncertainty in model input into uncertainty in model output, by fitting the model many times with different values of "observed" data and key input parameters. A chief advantage of the approach is that the results describe a range of possible outcomes, so that uncertainty is characterized more thoroughly than it could be by any single fit or small set of sensitivity runs. A minor disadvantage of the approach is that computation times can be long, though current parallel computing techniques largely mitigate those demands (i.e. computing results many times as fast as a single processor).

In this assessment, the BAM was re-fit in $n = 4200$ trials that differed from the original inputs by bootstrapping on data sources, and by Monte Carlo sampling of several key input parameters. Of the 4200 trials, 4050 were ultimately retained in the uncertainty analysis. The remaining runs were discarded because of poor model convergence (maximum gradient ≥ 0.01) or unrealistic values of $F_{2016-2018}/F_{\text{MSY}}$ (≥ 6) or σ_R ((≥ 1). This filtering procedure was also done in 2016 Update, though the gradient limit was not as strict (≥ 1000). A check was also run to see if any estimated parameters were near bounds (within 1% of the range between bounds from either bound) in each run, to see if they should be removed from the ensemble. Based on this criterion, 0 runs had parameters near bounds.

The MCBE 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.

3.9.1 Bootstrapping of Observed Data

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

$$O_{s,y} = \hat{O}_{s,y}[\exp(x_{s,y} - \sigma^2_{s,y}/2)] \tag{8}$$

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, $\sigma_{s,y} = \sqrt{\log(1.0 + CV^2_{s,y})}$. The CVs used to generate bootstrap data sets of landingswere supplied by the data providers (Table 2). Note that these values are different and generally higher than the CVs used to estimate landings when fitting the assessment model (i.e. 0.05 for all years and fleets). The CVs used to generate bootstrap data sets of indices of abundance were the same as those used when fitting the assessment model (Table 5).

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 (Table 4) 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 (Table 5).

3.9.2 Monte Carlo Sampling

In each successive fit of the model, several parameters were fixed (i.e., not estimated) at values drawn at random from distributions described below.

Natural mortality The point estimate of natural mortality ($M = 0.1038$) was provided by the SEDAR 66 Workshop Panel with some uncertainty. To carry forward this source of uncertainty, Monte Carlo sampling was used to generate deviations from the point estimate. A new M value was drawn for each MCBE trial from a uniform distribution between 0.08 and 0.14. In each run of the ensemble, a drawn value of constant M was then used to rescale natural mortality at age, as described for the base model above.

Beverton-Holt steepness parameter The steepness parameter (h) of the Beverton-Holt stock-recruit function was fixed in the base model at 0.84. For each MCBE trial, a new value of h was drawn from a truncated beta distribution defined by shape parameters ($shape_1 = 5.94$, $shape_2 = 1.97$, truncated to 0.32 to 0.99 (Shertzer and Conn 2012).

Standard deviation of recruitment deviations (σ_R) In the base model, the standard deviation of recruitment deviations (σ_R) was fixed at 0.6. For each MCBE trial, a new value of σ_R was drawn from a truncated normal distribution defined by $\mu = 0.6$ and $\sigma = 0.15$ truncated to 0.3 to 1.0.

3.10 Projection Analysis

Projections were run to determine the overfishing limit (OFL) and evaluate the existing rebuilding plan as requested in the TORs. The structure of the projection model was the same as that of the assessment model, and parameter estimates were those from the assessment. Any time-varying quantities, such as selectivity, were fixed to the most recent values of the assessment period. A single selectivity curve was applied to calculate landings computed by averaging selectivities across fleets using geometric mean Fs from the last three years of the assessment period, similar to computation of MSY benchmarks (§3.7).

Expected values of SSB (time of peak spawning), F, recruits, and landings were represented by deterministic projections using parameter estimates from the base run. These projections were built on the estimated spawner-recruit relationship with bias correction, and were thus consistent with estimated benchmarks in the sense that long-term fishing at F_{MSY} would yield MSY from a stock size at $\mathrm{SSB}_{\mathrm{MSY}}$. Uncertainty in future time series was quantified through stochastic projections that extended the ensemble model fits of the stock assessment model.

3.10.1 Initialization of Projections

Although the terminal year of the assessment is 2018, the assessment model computes abundance at age (N_a) at the start of 2019. For projections, those estimates were used to initialize N_a. However, the assessment has no information to inform the strength of 2019 recruitment, and thus it computes 2019 recruits (N_1) as the expected value, that is, without deviation from the spawner-recruit curve, and corrected to be unbiased in arithmetic space. In the stochastic projections, lognormal stochasticity was applied to these abundances after adjusting them to be unbiased in log space, with variability based on the estimate of σ_R. Thus, the initial abundance in year one of projections (2019) included this variability in N_1. The deterministic projections were not adjusted in this manner, because deterministic recruitment follows Beverton-Holt expectation.

Fishing rates that define the projections were assumed to start in 2022. Because the assessment period ended in 2018, the projections required an interim period (2019–2021). Fishing mortality during this interim period was set at the estimate of F_{current} the assessment model.

3.10.2 Uncertainty of Projections

To characterize uncertainty in future stock dynamics stochasticity was included in replicate projections, each an extension of a single assessment fit from the ensemble. Thus, projections carried forward uncertainties in natural mortality as well as in estimated quantities such as spawner-recruit parameters (R_0 and σ_R), selectivity curves, and in initial (start of 2019) abundance at age.

Initial and subsequent recruitment values were generated with stochasticity using a Monte Carlo procedure in which the estimated recruitment of each model within the ensemble is used to compute expected annual recruitment values ($\bar{R}_y$). Variability is added to the mean values by choosing multiplicative deviations at random from a lognormal distribution,

$$R_y = \bar{R}_y \exp(\epsilon_y). \tag{9}$$

Here ϵ_y is drawn from a normal distribution with mean 0 and standard deviation σ_R, where σ_R is the standard deviation from the relevant ensemble model run.

The procedure generated 20,000 replicate projections of models within the ensemble drawn at random (with replacement). In cases where the same model 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.

3.10.3 Projection Scenarios

Projections were run to determine the overfishing limit (OFL) and evaluate the existing rebuilding plan as requested in the TORs. In the projections, management started in 2022, the earliest year possible. Projections were carried forward to 2027. Scenarios 1 and 2 were considered to determine the OFL and scenarios 3 and 4 were considered to determine the ABC. In all scenarios $F = F_{\text{current}}$ from 2019 to 2021:

- Scenario 1: $F = F_{\text{P}^*_{50\%}}$ from 2022 to 2027
- Scenario 2: $F = F_{\text{MSY}}$ from 2022 to 2027
- Scenario 3: $F = F_{\text{P}^*_{30\%}}$ from 2022 to 2027
- Scenario 4: $F = 75\% F_{\text{MSY}}$ from 2022 to 2027

4 Stock Assessment Results

4.1 Measures of Overall Model Fit

The Beaufort assessment model (BAM) generally fit well to the available data. Predicted age compositions from each fishery were reasonably close to observed data in most years. Fits to length compositions for the recreational fleet were not quite as good, but the data were also very variable, probably due to small sample sizes (often < 50 fish per year; Figure 3; Tables 3 and 4). The model was configured to fit observed commercial and recreational landings closely (Figures 4, 5, and 6). The fit to the commercial longline index captured the general trend well but not all annual fluctuations (Figure 7). The fit to the MARMAP longline survey index (Figure 8) did not capture the general trend very well due in part to the large CVs associated with the index (Table 5). This is largely why sensitivity runs S7 and S8 were developed, investigating the effect of downweighting or upweighting the MARMAP longline index (see §3.4).

4.2 Parameter Estimates

Estimates of all parameters from the catch-age model are shown in Appendix A. No parameters were hitting bounds. Estimates of management quantities and some key parameters, such as those of the spawner-recruit model, are reported in sections below.

4.3 Total Abundance, Spawning Biomass and Recruitment

Total abundance shows a decline in the early 1980s (Figure 9; Table 7) concurrent with large increase in landings, especially in the commercial longline fleet (Figures 18 and 19; Tables 16 and 17). Since then, abundance has fluctuated between approximately 1-1.5 million fish with peaks in the late 1980s, mid 2000s, and an increase through the end of the assessment. Truncation of the older ages also began in the 1980s, declined through the mid 1990s and then expanded after the early 2000s (Figure 9; Table 7). Spawning stock biomass (SSB) declined in the early 1980s and continued to decline to a low point in 1996, despite relatively large numbers of fish in the late 1980s. Since 1996, SSB has generally increased but has decreased gradually since 2012 (Figures 10 and 12; Table 8). Recruitment has fluctuated during the period when deviations were estimated (1982-2011) ranging from 169,472 to 387,502 fish with peaks in 1987 and 1998, but with little evidence of a long term trend (Figure 11 upper panel; Table 10). Similarly, recruitment deviations showed fluctuations over this same period with no evidence of a longterm trend. Although thelast few years of recruitment deviations are below average, they are are all within the range of values exhibited during the lower periods during the 1980s and 1990s (Figure 11 lower panel).

4.4 Selectivity

Selectivity of the MARMAP longline survey is shown in Figure 13, selectivities of landings from commercial and recreational fleets are shown in Figures 14 and 15. In the most recent years, full selection occurred near age-5 in the recreational fleet, age-9 in the commercial handline fleet, age-10 in the MARMAP longline survey, and age-12 in the commercial longline fleet. Logistic selectivity functions were used for all fleets. As noted in §3, dome-shaped (i.e. double-logistic) selectivity was investigated for the commercial handline and recreational fleets, but likelihood profiling suggested that logistic selectivity functions were more appropriate.

Average selectivities of landings were computed from F-weighted selectivities in the most recent period of regulations (Figure 16). These average selectivities were used to compute point estimates of benchmarks. All selectivities from the most recent period, including average selectivities, are tabulated in Table 11. In the average selectivity, full selection occurred near age-12, like the commercial longline fleet which is responsible for $> 80\%$ of the total F in most years (Figure 17).

4.5 Landings, Fishing Mortality, Quotas, and Biomass

From 1972 to 1980, total landings were low (< 200 klb; Figures 18, 19; Tables 16, 17) and estimated fishing mortality rate (F) was very low (≤ 0.02; Figure 17, Table 12), with stock biomass still near virgin (B_0). Since this early period of low exploitation, landings and F have occurred in about five main periods of exploitation, each lasting 5-10 years. The first period from 1981 to 1986 represents a set of years with the highest landings in the South Atlantic Tilefish stock, all of which were near or above 1000 klb, with peak landings in 1982 over 2600 klb. During this period F increased to range between 0.1 to nearly 0.4. Estimated biomass during this first period dropped dramatically, from 91 to 45% of B_0. The second period begins in 1987 with landings dropping sharply down below 300 klb, but quickly increasing again to a range of 600 to 900 klb for most years through 1995. Due to the decline in biomass during the first period, this second period exhibits lower landings but higher F than the first period, with most values of F 0.3 to nearly 0.6. During the second period, biomass continued to decline to 26% of B_0. In the third period, from 1996 to 2002, landings decreased sharply again, remaining between 300-400 klb in most years through 2002. Total F also declined but remained within a range similar to the first period (0.2-0.44). Biomass in 1996 was the lowest in the history of the stock, but increased slightly over the period. In 2003 landings dropped to just over 200 klb, the lowest level in the history of the stock since 1980. This fourth period from 2003 to 2011 was characterized by a gradual increase back up to the mid-300 klb range, as F remained low (0.1-0.17). This fourth period marks a period of recovery from 29 to 36% of B_0. In 2006 the commercial quota was substantially reduced from 1,001 klb to 295 klb, and was met, reducing the fishing season from 365 to 295 days in 2006 (see §I. Table 2.6.2). The quota remained at this level through 2010, and was reduced slightly in 2011 (282 klb) resulting in the commercial fishery being open for only 67 days. In 2012, the commercial quota increased to 541 klb following results of SEDAR 25, and remained at this level through 2017. An increase in landings followed as the commercial fleets repeatedly reached the quota, and total landings remained in the 400-650 klb range again through 2017, until dropping back below 300 klb in 2018 when the quota was again reduced to 313 klb. Values of F increased during this period (0.19-0.33) while biomass was again in decline.

4.6 Spawner-Recruitment Parameters

The estimated Beverton–Holt spawner-recruit curve is shown in Figure 20, along with the effect of density dependence on recruitment, depicted graphically by recruits per spawner as a function of spawners (spawning biomass). Values of recruitment-related parameters were as follows: steepness $h = 0.84$ (fixed), unfished age-1 recruitment $R_0 = 283,300$, unfished spawning biomass (mt) per recruit $\phi_0 = 0.00027$, and standard deviation of recruitment residuals in log space $\widehat{\sigma}_R = 0.6$ (fixed; which resulted in bias correction of $\varsigma = 1.2$). Uncertainty in these quantities was estimated from the MCBE (Figure 21).

4.7 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F (Figure 22). As in computation of MSY-related benchmarks, per recruit analyses applied the most recent selectivity patterns averaged across fisheries, weighted by F from the last three years ($2016 - 2018$). The F that provides 40% SPR is $F_{40\%} = 0.129$, 30% is $F_{30\%} = 0.204$, and 20% is $F_{20\%} = 0.381$.

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of F (Figure 23). By definition, the F that maximizes equilibrium landings is F_{MSY}, and the corresponding landings and spawning biomass are MSY and $\mathrm{SSB}_{\mathrm{MSY}}$.

4.8 Benchmarks / Reference Points

As described in §3.7, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the expected spawner-recruit curve (Figure 20). These benchmarks are conditional on the estimated selectivity functions and the relative contributions of each fleet's fishing mortality. Furthermore the selectivity pattern used here was the effort-weighted selectivities at age, with effort from each fishery estimated as the full F averaged over the last three years of the assessment (2016-2018).

Reference points estimated were F_{MSY}, MSY, B_{MSY} and $\mathrm{SSB}_{\mathrm{MSY}}$. Based on F_{MSY}, three possible values of F at optimum yield (OY) were considered—$F_{\mathrm{OY}} = 65\% F_{\mathrm{MSY}}$, $F_{\mathrm{OY}} = 75\% F_{\mathrm{MSY}}$, and $F_{\mathrm{OY}} = 85\% F_{\mathrm{MSY}}$—and for each, the corresponding yield was computed. Estimates of benchmarks are summarized in Table 18. Standard errors of benchmarks were approximated as those from the MCBE (§3.9) .

Maximum likelihood estimates (base run) of benchmarks, as well as median values from MCBE, are summarized in Table 18. Point estimates of MSY-related quantities were $F_{\mathrm{MSY}} = 0.3$ (y^{-1}), MSY = 518 (1000 lb GW), $B_{\mathrm{MSY}} = 2282$ (mt), MSST = 14 (mt), and $\mathrm{SSB}_{\mathrm{MSY}} = 19$ (mt). The estimate of $\mathrm{SSB}_{\mathrm{MSY}}$ is about 25% of the unfished spawning biomass. Median estimates were $F_{\mathrm{MSY}} = 0.26$ (y^{-1}), MSY = 507 (1000 lb GW), $B_{\mathrm{MSY}} = 2492$ (mt), MSST = 16 (mt W_{gonad}), and $\mathrm{SSB}_{\mathrm{MSY}} = 21$ (mt W_{gonad}). Distributions of these benchmarks from the MCBE are shown in Figure 24.

4.9 Status of the Stock and Fishery

Estimated time series of stock status (SSB/MSST) showed a rapid decline during the 1980s and a slower decline during the 1990s, to a minimum value in 1995. From 1995 through 2011 stock status improved, but has been in decline again since 2012 (Figure 25, Table 10).

Current stock status was estimated in the base run to be $\mathrm{SSB}_{2018}/\mathrm{MSST} = 1.294$ (Table 18), indicating that the stock is not overfished. Throughout its history, the stock has only dropped below MSST in a few years during the late 1990s and early 2000s. Results from the MCBE suggested that the estimate of SSB relative to $\mathrm{SSB}_{\mathrm{MSY}}$ and the status relative to MSST is highly uncertain (Figures 26, 27). Only 58.3% of MCBE runs agreed with the stock status result from the base model.

Age structure estimated by the base run during 2018 shows numbers of fish at all age classes declined over the assessment period but especially older age classes. Numbers of Tilefish age-13 reached their lowest point in the early 2000s. During the recovery of the stock in the 2000s numbers of older fish increased substantially back above the predicted numbers at F_{MSY} equilibrium by 2012. At the end of the assessment, the oldest age classes remain near 2012 levels but numbers of fish 8-12 years old have declined (Figure 28).

The estimated time series of F/F_{MSY} from the base model suggests that although F has exceeded F_{MSY} sporadically for individual years during the assessment period, it has not been a consistent problem since the run of years of overfishing from 1990 to 1995 (Figure 25; Table 10). However, there is considerable uncertainty in F/F_{MSY} as demonstrated by the MCBE, especially toward the end of the assessment period (Figure 25). Current fishery status in the terminal year, with current F represented by the geometric mean from 2016to 2018($F_{\text{current}} = F_{2016-2018} = 0.2566$), was estimated by the base run to be $F_{2016-2018}/F_{\text{MSY}} = 0.86$ (Table 18). Thus, at the end of the assessment Tilefish was not undergoing overfishing. However, results from the MCBE show that there is a lot of uncertainty in the status of the fishery (Figures 26, 27). Only 48.8% of MCBE runs agreed with the fishing status result from the base model. Note that F_{MSY} is based on average F's from last three years of the assessment and thus it is not the technically correct denominator for all years going back in time. Thus, caution should be applied when interpreting F status back in time.

4.10 Comparison to Previous Assessments

The benchmark assessment for Tilefish, SEDAR 04, was completed in 2004 with an assessment period 1961-2002 (SEDAR 04 2004). SEDAR 25 was a standard assessment completed in 2011 with an assessment period spanning 1962-2010 (SEDAR 25 2011). Several important changes were made during SEDAR 25 (e.g. M, h, SSB units) that make it somewhat difficult to compare SEDAR 04 with later assessments. Current management of South Atlantic Tilefish is based on an update assessment completed in 2016 with an assessment period of 1962-2014 (SEDAR 25 2016).

As of 2002, the stock was not overfished ($\text{SSB}_{2002}/\text{MSST} = 1.27$), but overfishing was occurring ($F_{2002}/F_{\text{MSY}} = 1.53$; SEDAR 04 2004). Terminal status estimates in SEDAR 25 found that the Tilefish stock was not overfished ($\text{SSB}_{2010}/\text{MSST} = 2.42$), and it was also not undergoing overfishing ($F_{2008-2010}/F_{\text{MSY}} = 0.36$; SEDAR 25 2011). Terminal status estimates in the SEDAR 25 showed the stock was not overfished ($\text{SSB}_{2014}/\text{MSST} = 1.13$), but overfishing was occurring ($F_{2008-2010}/F_{\text{MSY}} = 1.22$; SEDAR 25 2016).

Values from the current SEDAR 66 assessment contrast with the stock status designation from SEDAR 04 ($\text{SSB}_{2002}/\text{MSST} = 0.96$) but concur with the unfished status from SEDAR 25 ($\text{SSB}_{2010}/\text{MSST} = 1.69$) and the SEDAR 25 ($\text{SSB}_{2014}/\text{MSST} = 1.49$; Table 10). However, the current assessement results suggest that overfishing was not occurring at the ends of any of the previous South Atlantic Tilefish assessments ($F_{2002}/F_{\text{MSY}} = 0.7$, $F_{2008-2010}/F_{\text{MSY}} = 0.47$, $F_{2012-2014}/F_{\text{MSY}} = 0.78$).

The general pattern in time series of SSB/MSST in SEDAR 66 was similar to the SEDAR 25, but was shifted upward so that it appears higher in all years. The trend and magnitude of SSB/MSST in SEDAR 25 were also similar up to 2003, but from 2004 to 2010 increased much more rapidly than what is reflected in the later assessments. The general pattern in the time series of F/F_{MSY} in SEDAR 66 was also similar to the SEDAR 25, but was shifted downward so that it appears lower in all years. This is particularly true of the period from approximately 1990-2005. The trend and magnitude of F/F_{MSY} in SEDAR 25 were quite similar to SEDAR 66.

Input values of constant M have been similar over the four Tilefish assessments (terminal years: 2002, 2010, 2014, 2018; M: 0.07, 0.1083, 0.1083, 0.1038), though M in SEDAR 04 was a little lower and was not used to scale age-varying M. Steepness has been fixed at similar values in all assessments (h: 0.72, 0.84, 0.84, 0.84) though again the value from SEDAR 04 was a little lower. The estimate of F_{MSY} in SEDAR 04 was considerably lower than in later assessments (F_{MSY}: 0.043, 0.185, 0.236, 0.3). The estimate of MSY was also much lower in SEDAR 04 than in later assessments (MSY, klb: 335, 638, 560, 518). In SEDAR 04 SSB was measured in units of female biomass (MSST, mt: 659) and thus was not comparable to later assessments which were in units of gonad weight (MSST, mt W_{gonad}: 19.0, 16.4, 14).

4.11 Sensitivity Analyses

Sensitivity runs, described in §3.3, may be useful for evaluating implications of assumptions in the base model, and for interpreting MCBE results in terms of expected effects from input parameters. Time series of F/F_{MSY}, SSB/MSST, B, and recruitment ($\bar{R}_y$) are plotted to demonstrate sensitivity to natural mortality (Figure 29), the steepness of the stock-recruit relationship (Figure 30), higher values of initial F (F_{init}; Figure 31), weight of the MARMAP longline index (Figure 32), and using alternate recruitment estimates for years at the end of the assessment (Figure 33).

The qualitative results on terminal stock and fishing status were the same for five of the sensitivity runs (S2: high M, S4: high h, S5-S6: higher F_{init}, and S7: downweight MARMAP longline index by 1/10×; Figure 34, Table 19). However, the other four sensitivity runs disagreed, and suggested that the stock was overfished ($\text{SSB}_{2018} < \text{MSST}$) and undergoing overfishing ($F_{2016-2018} > F_{\text{MSY}}$. These exceptions were runs S1 (low M), S3 (low h), S8 (upweight MARMAP longline index by 10×), and S9 (alternate recruitment). Sensitivity analyses were in general agreement with those of the MCBE that there is considerable uncertainty in the stock and fishing status of South Atlantic Tilefish.

4.12 Retrospective Analyses

Retrospective analyses did not suggest any patterns of substantial over- or underestimation in terminal-year estimates of F/F_{MSY}, SSB/MSST, or B (Figure 35). Recruitment plots emphasizing the final year of freely estimated recruitment deviations show that estimates of recruitment in those years tended to underestimate values from the base model when the terminal year of the assessment was reduced to 2013 or earlier. There is no data set that is completely eliminated by that point, but it does substantially reduce the commercial handline age and recreational length composition data. And the remaining data for these data sets is mostly from earlier periods that are discontinuous from later data (Fig. 1).

4.13 Projections

Projection results for Tilefish are shown in Figures 36, 37, 38, and 39, and Tables 20, 21, 22, and 23. Among all scenarios considered, the probability that SSB_{MSY} exceeds MSST [$P(>\text{MSST})$] is at least 0.6 in all years of all projections. Thus, under no management prescription considered in the projections thus far is the South Atlantic Tilefish stock predicted to be overfished.

5 Discussion

5.1 Comments on Assessment Results

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

The base run of the BAM indicated that the stock is not overfished ($\text{SSB}_{2018}/\text{MSST} = 1.294$), and that overfishing is not occurring ($F_{2016-2018}/F_{\text{MSY}} = 0.86$). Sensitivity runs and MCBE analyses show that that there is a lot of uncertainty in these qualitative results, with considerably more uncertainty in the overfishing status than in the stock status. Notably, the median value of $F_{2016-2018}/F_{\text{MSY}}$ from the MCBE does suggest that overfishing is occurring. There was also much uncertainty in status in the SEDAR 25. This is partly a statistical phenomenon that occurs when status indicators are near the cutoff values we compare them with (i.e. relative values near 1). But a lot of the uncertainty in benchmarks is due to uncertainty in data inputs, especially h and M. Despite the uncertainty in M, likelihood profiles conducted during the assessment process favored a value of $M \approx 0.12$, which is close to the value of M used in the base model ($M = 0.1038$). Table 18 shows that 25% of MCBE runs result in $\mathrm{SSB}_{2018}/\mathrm{MSST} \leq 0.729$ and another 25% of MCBE runs (possibly overlapping) result in $F_{2016-2018}/F_{\mathrm{MSY}} \geq 1.869$.

As an overall metric of sensitivity of the model in terms of stock and fishery status, one can measure δ_{status}, the absolute linear distance in status space $[(x, y) = (F/F_{\mathrm{MSY}}, \mathrm{SSB/MSST})]$ between results of each sensitivity run and base model result. Based on this metric, the model was least sensitive ($\delta_{status} < 0.5$) to higher values of F_{init} (S5 and S6) and downweighting the MARMAP longline index (S7), moderately sensitive ($0.5 \leq \delta_{status} < 1.0$) to lower and higher values of steepness (S3 and S4) and alternative recruitment (S9), and most sensitive ($\delta_{status} \geq 1.0$) to lower and higher values of M (S1 and S2) and upweighting the MARMAP longline index (S8). This can be observed visually in the senstivity plots shown in Figures 29-34.

5.2 Comments on Projections

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

- In general, projections of fish stocks are highly uncertain, particularly in the long term (e.g., beyond 5–10 years).
- Although projections included many major sources of uncertainty, they did not include structural (model) uncertainty. That is, projection results are conditional on one set of functional forms used to describe population dynamics, selectivity, recruitment, etc.
- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. Benchmarks (e.g. MSY) are conditional on the estimated selectivity functions and the relative contributions of each fleet's fishing mortality. New management regulations that reallocate harvest in a way that alters proportions of F by fleet or selectivity patterns would likely affect projection results.
- The projections assumed that the estimated spawner-recruit relationship applies in the future and that past residuals 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 trajectories may be affected.
- Projections apply the Baranov catch equation to relate F and landings using a one-year time step, as in the assessment. The catch equation implicitly assumes that mortality occurs throughout the year. This assumption is violated when seasonal closures are in effect, introducing additional and unquantified uncertainty into the projection results.

6 Research Recommendations

1. From the previous assessment (2016 Update)
   (a) Re-examine the quantity and quality of biological samples collected by "Other" commercial gears. If adequate, consider methods for inclusion.
   (b) Monitor the quantity of commercial and recreational discards and consider methods for inclusion if deemed necessary.
   (c) More closely examine historical length composition data used in the assessment and consider alternate methods for incorporating this information in the model.

2. From the current assessment (SEDAR 66)
   (a) Explore alternative distributional assumptions for natural mortality M for MCBE uncertainty analysis.
   (b) Consider incorporation of new fishery independent abundance data and/or life history data from: CRP Coop Bottom longline survey data, deepwater survey data, SCDNR vertical longline survey, SA Deepwater longline Survey
   (c) Reconsider evidence for stock structure (i.e. potential for a north/south split)
   (d) Increase age sampling to improve composition data
   (e) Investigate effects of weather/oceanographic patterns on catchability. Due to the derby style nature of the fishery, the fleet tends to operate in less than ideal conditions which may affect catchability and fishery-dependent CPUE.

7 References

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

Brooks, E. N., J. E. Powers, and E. Cortes. 2009. Analytical reference points for age-structured models: application to data-poor fisheries. ICES Journal of Marine Science **67**:165–175.

Bubley, W. J., and T. I. Smart. 2020. Golden Tilefish Fishery-Independent Index of Abundance in US South Atlantic Waters Based on a SCDNR Bottom Longline Survey (1996-2016). SEDAR66-WP02. SEDAR, North Charleston, SC. pages 1–19.

Clark, W. G. 2002. $F_{35\%}$ revisited ten years later. North American Journal of Fisheries Management **22**:251–257.

Deriso, R. B., T. J. Quinn, and P. R. Neal. 1985. Catch-age analysis with auxiliary information. Canadian Journal of Fisheries and Aquatic Sciences **42**:815–824.

Efron, B., and R. Tibshirani. 1993. An Introduction to the Bootstrap. Chapman and Hall, London.

Fitzpatrick, E. 2020. Standardized catch rates of tilefish (Lopholatilus chamaeleonticeps) in the southeast U.S. from commercial logbook data. SEDAR66-WP03. SEDAR, North Charleston, SC. pages 1–27.

Fournier, D., and C. P. Archibald. 1982. A general theory for analyzing catch at age data. Canadian Journal of Fisheries and Aquatic Sciences **39**:1195–1207.

Fournier, D. A., H. J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optimization Methods and Software **27**:233–249.

Francis, R. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences **68**:1124–1138.

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

Francis, R. 2017. Revisiting data weighting in fisheries stock assessment models. Fisheries Research **192**:5–15.

Helies, F. C., J. L. Jamison, P. Barile, and K. Carpenter. 2016. Cooperative Bottom Longline Survey to Augment Fisheries Independent Reef Fish Data Collection in the Deep-Water Snapper-Grouper Fishery of the South Atlantic United States. NOAA/NMFS Final Report pages 1–40.

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

Hoenig, J. M. 1983. Empirical use of longevity data to estimate mortality rates. Fishery Bulletin **81**:898–903.

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

Legault, C. M., J. E. Powers, and V. R. Restrepo. 2001. Mixed Monte Carlo/bootstrap approach to assessing king and Spanish mackerel in the Atlantic and Gulf of Mexico: Its evolution and impact. Amercian Fisheries Society Symposium **24**:1–8.

Lorenzen, K. 1996. The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural ecosystems and aquaculture. Journal of Fish Biology **49**:627–642.

Mace, P. M. 1994. Relationships between common biological reference points used as thresholds and targets of fisheries management strategies. Canadian Journal of Fisheries and Aquatic Sciences **51**:110–122.

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

Methot, R. D. 1989. Synthetic estimates of historical abundance and mortality for northern anchovy. American Fisheries Society Symposium **6**:66–82.

Methot, R. D., 2009. User Manual for Stock Synthesis, Model Version 3.04. NOAA Fisheries, Seattle, WA.

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

Nuttall, M. A., and V. M. Matter. 2020. Recreational Survey Data for Tilefish in the South Atlantic. SEDAR66-WP01. SEDAR, North Charleston, SC. pages 1–25.

Pella, J. J., and P. K. Tomlinson. 1969. A generalized stock production model. Bulletin of the Inter-American Tropical Tuna Commission **13**:419–496.

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

Quinn, T. J., and R. B. Deriso. 1999. Quantitative Fish Dynamics. Oxford University Press, New York, New York.

Restrepo, V. R., J. M. Hoenig, J. E. Powers, J. W. Baird, and S. C. Turner. 1992. A simple simulation approach to risk and cost analysis, with applications to swordfish and cod fisheries. Fishery Bulletin **90**:736–748.

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

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

SEDAR. 2017. SEDAR 53 – South Atlantic Red Grouper Assessment Report. SEDAR, North Charleston SC page 159. URL http://sedarweb.org/sedar-53.

SEDAR 04, 2004. SEDAR4 Stock Assessment Report 1 SECTION III.B Assessment of Tilefish, Lopholatilus chamaeleonticeps, in the South Atlantic Fishery Management Council Management Area. SEDAR, North Charleston, SC.

SEDAR 25, 2011. SEDAR 25: South Atlantic Tilefish. SEDAR, North Charleston, SC.

SEDAR 25, 2016. SEDAR 25: Stock Assessment of Golden Tilefish off the Southeastern United States, 2016 SEDAR Update Assessment. SEDAR, North Charleston, SC.

SEDAR 50, 2017. SEDAR 50: Atlantic Blueline Tilefish Assessment Report. SEDAR, North Charleston, SC.

SEDAR 60, 2020. SEDAR 60 South Atlantic Red Porgy Stock Assessment Report. SEDAR, North Charleston SC.

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

SEDAR19, 2009. SEDAR 19: South Atlantic Red Grouper. SEDAR, North Charleston, SC.

SEDAR24, 2010. SEDAR 24: South Atlantic Red Snapper. SEDAR, North Charleston, SC.

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

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

Shertzer, K. W., and P. B. Conn. 2012. Spawner-recruit relationships of demersal marine fishes: Prior distribution of steepness. Bulletin of Marine Science **88**:39–50.

Shertzer, K. W., M. H. Prager, D. S. Vaughan, and E. H. Williams, 2008. Fishery models. Pages 1582–1593 *in* S. E. Jorgensen and F. Fath, editors. Population Dynamics. Vol. [2] of Encyclopedia of Ecology, 5 vols. Elsevier, Oxford.

Snapper Grouper Advisory Panel . 2018. Snapper Grouper Advisory Panel Golden Tilefish Fishery Performance Report. SEDAR, North Charleston, SC. pages 1–5.

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

Williams, E. H., and K. W. Shertzer. 2003. Implications of life-history invariants for biological reference points used in fishery management. Canadian Journal of Fisheries and Aquatic Science **60**:710–720.

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

8 Tables

Table 1. Observed time series of landings (L) for commercial handline (cH), commercial longline (cL), and recreational (rA). All landings are in units of 1000 lb gutted weight.

Year	L.cH	L.cL	L.rA
1972	0.40	4.74	.
1973	2.17	25.82	.
1974	5.25	62.60	.
1975	8.98	106.29	.
1976	9.42	107.21	.
1977	8.82	40.63	.
1978	23.06	55.85	.
1979	16.61	85.14	.
1980	49.69	148.01	.
1981	117.47	665.27	214.36
1982	242.81	2421.11	0.04
1983	99.42	1392.88	0.37
1984	69.48	925.96	7.30
1985	64.64	855.30	38.04
1986	60.22	941.26	0.06
1987	20.52	248.92	1.93
1988	33.13	431.67	0.46
1989	51.64	686.17	0.04
1990	51.98	699.76	0.41
1991	53.41	706.62	0.13
1992	48.98	787.80	2.48
1993	12.75	880.07	0.04
1994	99.53	636.97	1.89
1995	79.33	539.95	0.04
1996	38.42	273.95	1.27
1997	42.47	296.92	10.50
1998	35.31	301.50	0.33
1999	28.45	443.52	1.10
2000	40.47	620.99	3.10
2001	118.73	237.43	3.78
2002	120.96	198.50	1.89
2003	70.69	133.01	7.45
2004	37.40	209.49	12.92
2005	35.35	207.51	33.69
2006	36.47	337.16	7.12
2007	37.73	232.54	1.57
2008	19.63	262.33	0.04
2009	12.61	282.57	23.98
2010	23.21	306.42	5.88
2011	9.44	317.10	10.03
2012	49.15	419.16	5.34
2013	39.71	455.23	4.53
2014	120.69	523.08	3.99
2015	124.43	361.88	7.85
2016	99.25	389.03	14.55
2017	102.59	435.29	3.50
2018	50.49	235.64	9.00

Table 2. Observed time series of CVs used in the Monte Carlo/Bootstrap Ensemble (MCBE) associated with landings (L) for commercial handline (cH), commercial longline (cL), and recreational (rA). These CVs were used to generate bootstrap data sets in the ensemble model analysis only. When fitting the assessment model, CVs of 0.05 were used for estimating landings.

Year	L.cH	L.cL	L.rA
1972	0.05	0.05	.
1973	0.05	0.05	.
1974	0.05	0.05	.
1975	0.05	0.05	.
1976	0.05	0.05	.
1977	0.05	0.05	.
1978	0.05	0.05	.
1979	0.05	0.05	.
1980	0.05	0.05	.
1981	0.05	0.05	1.00
1982	0.05	0.05	0.00
1983	0.05	0.05	1.00
1984	0.05	0.05	1.00
1985	0.05	0.05	0.99
1986	0.05	0.05	1.00
1987	0.05	0.05	0.98
1988	0.05	0.05	1.00
1989	0.05	0.05	0.00
1990	0.05	0.05	1.00
1991	0.05	0.05	1.00
1992	0.05	0.05	0.69
1993	0.05	0.05	0.00
1994	0.05	0.05	0.94
1995	0.05	0.05	0.00
1996	0.05	0.05	0.98
1997	0.05	0.05	0.70
1998	0.05	0.05	1.00
1999	0.05	0.05	0.94
2000	0.05	0.05	0.67
2001	0.05	0.05	0.47
2002	0.05	0.05	0.70
2003	0.05	0.05	0.57
2004	0.05	0.05	0.74
2005	0.05	0.05	0.57
2006	0.05	0.05	0.56
2007	0.05	0.05	0.69
2008	0.05	0.05	1.00
2009	0.05	0.05	0.83
2010	0.05	0.05	0.59
2011	0.05	0.05	0.73
2012	0.05	0.05	0.51
2013	0.05	0.05	0.53
2014	0.05	0.05	0.56
2015	0.05	0.05	0.51
2016	0.05	0.05	0.41
2017	0.05	0.05	0.57
2018	0.05	0.05	0.65

Table 3. Sample sizes (number of trips) of length compositions (lcomp) or age compositions (acomp) by survey or fleet. Data sources are recreational (rA), commercial handline (cH), commercial longline (cL), and the MARMAP longline survey (sM).

Year	lcomp.rA	acomp.cH	acomp.cL	acomp.sM
1972	.	.	.	.
1973	.	.	.	.
1974	.	.	.	.
1975	.	.	.	.
1976	.	.	.	.
1977	.	.	.	.
1978	.	.	.	.
1979	.	.	.	.
1980	.	.	.	.
1981	.	.	.	.
1982	.	.	.	.
1983	.	.	.	.
1984	.	.	.	.
1985	.	.	.	.
1986	.	.	.	.
1987	.	.	.	.
1988	.	.	.	.
1989	.	.	.	.
1990	.	.	.	.
1991	.	.	.	.
1992	.	.	7	.
1993	.	.	15	.
1994	.	.	.	.
1995	.	.	25	.
1996	.	.	.	.
1997	.	5	7	11
1998	.	5	.	.
1999	.	5	.	19
2000	.	11	16	.
2001	.	5	11	8
2002	6	20	.	.
2003	7	.	10	.
2004	.	9	5	.
2005	11	10	6	.
2006	.	6	39	.
2007	.	12	46	5
2008	.	.	27	.
2009	.	.	26	21
2010	.	.	30	24
2011	.	.	22	17
2012	.	21	48	.
2013	8	18	25	.
2014	.	35	16	.
2015	19	25	21	.
2016	14	39	31	9
2017	.	21	35	.
2018	16	.	35	.

Table 4. Sample sizes (number of fish) of length compositions (lcomp) or age compositions (acomp) by survey or fleet. Data sources are recreational (rA), commercial handline (cH), commercial longline (cL), and the MARMAP longline survey (sM).

Year	lcomp.rA	acomp.cH	acomp.cL	acomp.sM
1972	.	.	.	.
1973	.	.	.	.
1974	.	.	.	.
1975	.	.	.	.
1976	.	.	.	.
1977	.	.	.	.
1978	.	.	.	.
1979	.	.	.	.
1980	.	.	.	.
1981	.	.	.	.
1982	.	.	.	.
1983	.	.	.	.
1984	.	.	.	.
1985	.	.	.	.
1986	.	.	.	.
1987	.	.	.	.
1988	.	.	.	.
1989	.	.	.	.
1990	.	.	.	.
1991	.	.	.	.
1992	.	.	100	.
1993	.	.	186	.
1994	.	.	.	.
1995	.	.	374	.
1996	.	.	.	.
1997	.	102	186	120
1998	.	39	.	.
1999	.	34	.	156
2000	.	237	270	.
2001	.	44	223	48
2002	28	195	.	.
2003	64	.	148	.
2004	.	241	119	.
2005	132	255	110	.
2006	.	196	796	.
2007	.	272	1115	33
2008	.	.	681	.
2009	.	.	749	206
2010	.	.	863	128
2011	.	.	528	130
2012	.	454	1264	.
2013	27	262	531	.
2014	.	462	387	.
2015	39	177	446	.
2016	30	197	656	25
2017	.	115	591	.
2018	27	.	651	.

Table 5. Observed indices of abundance and CVs from commercial longline (cL) and the MARMAP longline survey (sM).

Year	cL	sM	cv.cL	cv.sM
1972	.	.	.	.
1973	.	.	.	.
1974	.	.	.	.
1975	.	.	.	.
1976	.	.	.	.
1977	.	.	.	.
1978	.	.	.	.
1979	.	.	.	.
1980	.	.	.	.
1981	.	.	.	.
1982	.	.	.	.
1983	.	.	.	.
1984	.	.	.	.
1985	.	.	.	.
1986	.	.	.	.
1987	.	.	.	.
1988	.	.	.	.
1989	.	.	.	.
1990	.	.	.	.
1991	.	.	.	.
1992	.	.	.	.
1993	0.888	.	0.053	.
1994	0.850	.	0.069	.
1995	0.829	.	0.072	.
1996	0.571	0.62	0.062	0.57
1997	0.810	1.69	0.060	0.39
1998	0.963	1.11	0.076	0.57
1999	1.011	1.94	0.079	0.32
2000	1.159	0.76	0.078	0.38
2001	0.847	1.54	0.065	0.36
2002	0.880	.	0.117	.
2003	0.711	.	0.089	.
2004	0.904	.	0.085	.
2005	1.720	.	0.104	.
2006	1.858	.	0.093	.
2007	.	0.29	.	0.40
2008	.	.	.	.
2009	.	2.06	.	0.23
2010	.	0.61	.	0.24
2011	.	1.04	.	0.36
2012	.	.	.	.
2013	.	.	.	.
2014	.	.	.	.
2015	.	0.12	.	0.56
2016	.	0.20	.	0.52
2017	.	.	.	.
2018	.	.	.	.

Table 6. Life-history characteristics at age. Variables include total length (TL) in millimeters (mm) and inches (in) and weight (mid-year), and inches (in), the coefficient of variation (CV) of TL, whole weight (WW) in kilograms (kg) and pounds (lb), gutted weight (GW) in pounds (lb), proportion female [P(fem.)] and proportion of females mature [P(fem. mat.)], gonad weight of females (kg), spawning stock biomass (SSB; sum product of the proportion of females mature and gonad weight), and natural mortality. All values were fixed model input.

Age	TL (mm)	TL (in)	TL CV	WW (kg)	WW (lb)	GW (lb)	P(fem.)	P(fem. mat.)	W_{gonad} (kg)	SSB (kg)	M
1	257	10.1	0.14	0.16	0.36	0.34	0.50	0.10	0.00	0.00	0.30
2	354	14.0	0.14	0.45	0.99	0.93	0.50	0.25	0.00	0.00	0.22
3	435	17.1	0.14	0.86	1.89	1.78	0.50	0.50	0.01	0.00	0.18
4	503	19.8	0.14	1.34	2.96	2.80	0.50	1.00	0.01	0.01	0.16
5	558	22.0	0.14	1.87	4.13	3.90	0.50	1.00	0.02	0.01	0.14
6	604	23.8	0.14	2.40	5.30	5.00	0.50	1.00	0.04	0.02	0.13
7	642	25.3	0.14	2.91	6.42	6.07	0.50	1.00	0.05	0.03	0.12
8	674	26.5	0.14	3.39	7.47	7.06	0.50	1.00	0.07	0.04	0.12
9	700	27.5	0.14	3.82	8.42	7.95	0.50	1.00	0.09	0.05	0.11
10	721	28.4	0.14	4.21	9.27	8.76	0.50	1.00	0.11	0.06	0.11
11	739	29.1	0.14	4.54	10.02	9.46	0.50	1.00	0.13	0.07	0.11
12	754	29.7	0.14	4.84	10.66	10.07	0.50	1.00	0.15	0.07	0.11
13	766	30.2	0.14	5.09	11.22	10.59	0.50	1.00	0.17	0.08	0.10
14	776	30.6	0.14	5.30	11.69	11.04	0.50	1.00	0.18	0.09	0.10
15	785	30.9	0.14	5.49	12.10	11.42	0.50	1.00	0.19	0.10	0.10
16	792	31.2	0.14	5.64	12.44	11.74	0.50	1.00	0.21	0.10	0.10
17	797	31.4	0.14	5.77	12.72	12.02	0.50	1.00	0.22	0.11	0.10
18	802	31.6	0.14	5.88	12.96	12.24	0.50	1.00	0.23	0.11	0.10
19	806	31.7	0.14	5.97	13.17	12.43	0.50	1.00	0.24	0.12	0.10
20	809	31.9	0.14	6.05	13.34	12.59	0.50	1.00	0.24	0.12	0.10

Table 7. Estimated total abundance at age (1000 fish) at start of year.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1972	340.22	252.88	203.49	170.25	145.75	126.61	110.96	97.64	86.12	76.18	67.59	60.13	53.59	47.84	42.76	38.27	34.27	30.71	27.54	240.91	2253.71
1973	340.22	252.88	203.49	170.26	145.76	126.65	111.15	98.12	86.81	76.88	68.23	60.70	54.10	48.29	43.17	38.63	34.59	31.00	27.80	243.20	2261.94
1974	340.39	252.88	203.49	170.25	145.76	126.65	111.13	98.15	87.06	77.32	68.69	61.12	54.48	48.64	43.47	38.90	34.84	31.22	28.00	244.92	2267.37
1975	340.45	253.00	203.49	170.25	145.75	126.61	111.03	97.92	86.78	77.23	68.80	61.28	54.63	48.77	43.60	39.01	34.94	31.31	28.08	245.62	2268.55
1976	340.45	253.05	203.59	170.25	145.74	126.57	110.88	97.55	86.19	76.61	68.38	61.07	54.50	48.67	43.50	38.93	34.86	31.25	28.02	245.10	2265.14
1977	340.41	253.04	203.62	170.33	145.74	126.55	110.83	97.41	85.86	76.08	67.81	60.68	54.30	48.54	43.40	38.84	34.78	31.17	27.95	244.54	2261.90
1978	340.40	253.01	203.62	170.37	145.82	126.59	110.96	97.73	86.26	76.31	67.83	60.61	54.35	48.71	43.60	39.03	34.95	31.32	28.09	245.72	2265.27
1979	340.44	253.01	203.59	170.36	145.83	126.60	110.86	97.65	86.31	76.44	67.83	60.44	54.12	48.60	43.62	39.09	35.01	31.38	28.14	246.17	2265.48
1980	340.43	253.03	203.59	170.34	145.82	126.61	110.85	97.45	86.06	76.30	67.77	60.29	53.84	48.28	43.42	39.01	34.98	31.36	28.12	246.01	2263.57
1981	340.35	253.03	203.61	170.32	145.76	126.45	110.48	96.81	85.12	75.34	66.98	59.65	53.17	47.55	42.70	38.44	34.56	31.02	27.82	243.39	2252.54
1982	190.08	252.96	203.59	170.12	142.98	123.30	106.48	91.08	78.27	68.49	60.68	54.07	48.24	43.07	38.57	34.67	31.24	28.11	25.24	220.86	2012.12
1983	187.21	141.28	203.51	170.16	144.88	121.38	99.81	76.76	59.07	48.95	42.57	37.74	33.68	30.10	26.91	24.12	21.70	19.56	17.61	154.35	1661.35
1984	209.67	139.14	113.67	170.16	145.17	123.96	100.70	76.11	54.13	40.56	33.49	29.15	25.89	23.14	20.71	18.53	16.63	14.97	13.50	118.78	1488.05
1985	215.77	155.83	111.95	95.04	145.13	124.46	103.91	79.07	56.23	39.19	29.30	24.23	21.13	18.79	16.82	15.07	13.49	12.11	10.91	96.52	1384.98
1986	288.36	160.37	125.38	93.58	80.64	123.64	103.50	80.63	57.52	40.04	27.83	20.84	17.26	15.07	13.43	12.03	10.78	9.66	8.68	77.05	1366.28
1987	387.50	214.32	129.03	104.83	79.84	68.99	102.41	78.42	56.22	38.99	27.03	18.81	14.10	11.70	10.23	9.12	8.18	7.34	6.58	58.42	1432.07
1988	358.22	288.02	172.45	107.93	89.62	69.02	59.51	86.60	65.05	46.40	32.22	22.38	15.60	11.72	9.73	8.52	7.61	6.82	6.13	54.30	1517.88
1989	254.69	266.25	231.75	144.23	92.23	77.24	58.82	48.71	68.23	50.65	36.12	25.12	17.48	12.21	9.18	7.63	6.69	5.97	5.36	47.53	1466.09
1990	237.47	189.30	214.22	193.77	123.09	79.00	64.36	45.38	34.98	47.85	35.40	25.28	17.61	12.28	8.58	6.46	5.38	4.72	4.21	37.34	1386.69
1991	304.31	176.50	152.30	179.10	165.25	105.15	65.16	48.32	31.22	23.37	31.81	23.56	16.85	11.76	8.21	5.74	4.33	3.60	3.16	27.89	1387.59
1992	295.46	226.18	142.00	127.31	152.64	140.73	85.69	47.36	31.57	19.67	14.63	19.93	14.78	10.59	7.40	5.17	3.62	2.73	2.28	19.62	1369.36
1993	297.31	219.60	181.96	118.68	108.33	129.30	112.35	58.71	28.14	17.85	11.02	8.20	11.18	8.31	5.96	4.17	2.91	2.04	1.54	12.36	1339.94
1994	249.86	220.97	176.67	152.08	101.05	91.71	101.76	72.57	31.47	14.12	8.84	5.45	4.06	5.55	4.13	2.96	2.07	1.45	1.02	6.94	1254.73
1995	186.71	185.70	177.75	147.56	129.03	84.61	71.12	66.40	40.50	16.63	7.38	4.62	2.86	2.13	2.91	2.17	1.56	1.09	0.76	4.19	1135.70
1996	169.47	138.77	149.38	148.49	125.35	108.39	66.14	47.11	37.84	21.91	8.91	3.95	2.48	1.53	1.15	1.57	1.17	0.84	0.59	2.68	1037.70
1997	217.81	125.96	111.65	124.89	126.59	107.09	89.83	50.65	33.56	26.32	15.18	6.18	2.75	1.73	1.07	0.80	1.10	0.82	0.59	2.29	1046.85
1998	354.36	161.88	101.34	93.32	106.16	107.85	88.67	69.05	36.37	23.56	18.42	10.64	4.34	1.93	1.22	0.75	0.56	0.77	0.58	2.03	1183.83
1999	327.06	263.38	130.25	84.74	79.65	91.02	90.31	69.53	50.96	26.31	17.01	13.32	7.71	3.15	1.40	0.88	0.55	0.41	0.56	1.90	1260.09
2000	262.66	243.09	211.91	108.90	72.28	68.13	75.36	68.29	48.31	34.40	17.68	11.44	8.97	5.20	2.13	0.95	0.60	0.37	0.28	1.67	1242.60
2001	290.83	195.21	195.57	177.10	92.65	61.27	54.67	52.50	41.72	28.19	19.91	10.24	6.63	5.21	3.02	1.24	0.55	0.35	0.22	1.14	1238.22
2002	307.93	216.15	157.04	163.38	150.39	78.22	49.77	41.52	37.75	29.49	19.89	14.07	7.25	4.70	3.70	2.15	0.88	0.39	0.25	0.97	1285.89
2003	280.16	228.86	173.89	131.21	138.90	127.28	63.99	38.48	30.68	27.51	21.47	14.51	10.28	5.30	3.45	2.71	1.58	0.65	0.29	0.89	1302.10
2004	260.66	208.23	184.13	145.37	111.70	118.75	107.26	52.31	30.67	24.29	21.80	17.04	11.54	8.19	4.23	2.75	2.17	1.26	0.52	0.95	1313.82
2005	233.39	193.74	167.54	153.96	123.74	95.76	100.61	87.58	41.28	23.96	18.98	17.06	13.37	9.06	6.44	3.33	2.17	1.71	1.00	1.16	1295.84
2006	216.46	173.47	155.89	140.06	130.44	105.64	81.05	82.59	69.89	32.68	18.98	15.06	13.56	10.64	7.23	5.14	2.66	1.73	1.37	1.72	1266.26
2007	176.55	160.89	139.57	130.35	119.43	111.99	89.32	65.33	63.67	53.13	24.82	14.44	11.48	10.35	8.13	5.53	3.94	2.04	1.33	2.37	1194.66
2008	213.82	131.22	129.45	116.73	111.36	102.93	95.76	74.18	52.82	51.08	42.65	19.96	11.63	9.26	8.37	6.58	4.48	3.19	1.65	3.00	1190.15
2009	228.56	158.92	105.59	108.28	99.81	96.19	88.38	79.88	60.18	42.51	41.13	34.41	16.14	9.42	7.51	6.79	5.35	3.64	2.59	3.79	1199.05
2010	206.55	169.88	127.87	88.29	92.11	85.92	83.06	75.48	66.22	48.28	33.53	32.30	27.02	12.68	7.41	5.91	5.35	4.22	2.87	5.04	1179.99
2011	227.59	153.52	136.68	106.94	75.39	79.58	74.38	71.02	62.55	53.03	38.00	26.27	25.30	21.18	9.95	5.82	4.65	4.21	3.32	6.23	1185.59
2012	306.79	169.15	123.52	114.31	91.26	65.13	68.98	63.75	59.03	50.26	41.88	29.86	20.64	19.90	16.68	7.85	4.59	3.67	3.33	7.55	1268.11
2013	306.32	228.01	136.09	103.27	97.52	78.60	55.96	58.07	51.35	45.37	37.70	31.19	22.22	15.37	14.83	12.45	5.86	3.43	2.75	8.14	1314.51
2014	304.42	227.67	183.44	113.78	88.11	84.01	67.52	46.96	46.31	38.78	33.31	27.44	22.67	16.16	11.19	10.81	9.08	4.28	2.51	7.96	1346.42
2015	301.09	226.24	183.11	153.22	96.78	75.22	70.68	54.64	35.42	32.50	26.22	22.25	18.29	15.11	10.78	7.47	7.23	6.07	2.86	7.01	1352.20
2016	297.69	223.76	181.96	152.93	130.17	82.50	63.27	57.55	42.09	25.81	23.01	18.40	15.59	12.82	10.61	7.58	5.26	5.08	4.27	6.95	1367.31
2017	295.82	221.24	179.98	151.98	129.76	110.91	69.41	51.40	43.87	30.06	17.81	15.71	12.54	10.63	8.75	7.25	5.18	3.60	3.48	7.69	1377.08
2018	293.91	219.84	177.94	150.33	129.26	110.73	93.15	55.85	38.23	30.10	19.77	11.56	10.17	8.11	6.89	5.67	4.70	3.36	2.34	7.26	1379.19

Table 8. Estimated total abundance 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
1972	54.81	112.99	174.12	228.96	272.85	304.25	323.35	330.93	329.04	320.38	307.07	290.76	272.66	253.71	234.61	215.86	197.78	180.61	164.48	1457.26	6026.49
1973	54.81	112.99	174.12	228.97	272.87	304.37	323.89	332.57	331.69	323.31	309.97	293.52	275.25	256.12	236.84	217.91	199.66	182.32	166.04	1471.10	6068.31
1974	54.83	112.99	174.12	228.97	272.86	304.34	323.84	332.68	332.64	325.15	312.06	295.58	277.20	257.93	238.51	219.45	201.07	183.61	167.22	1481.50	6096.56
1975	54.84	113.04	174.12	228.96	272.85	304.26	323.53	331.87	331.56	324.77	312.54	296.34	277.97	258.67	239.20	220.08	201.65	184.14	167.70	1485.75	6103.83
1976	54.84	113.06	174.21	228.96	272.82	304.15	323.09	330.64	329.34	322.16	310.62	295.31	277.30	258.10	238.68	219.61	201.22	183.75	167.34	1482.59	6087.79
1977	54.83	113.06	174.24	229.07	272.82	304.12	322.96	330.15	328.06	319.94	308.07	293.45	276.29	257.43	238.12	219.10	200.75	183.32	166.95	1479.17	6071.91
1978	54.83	113.05	174.24	229.12	272.97	304.21	323.35	331.26	329.57	320.91	308.12	293.11	276.51	258.33	239.20	220.15	201.72	184.21	167.76	1486.32	6088.92
1979	54.84	113.05	174.22	229.11	272.99	304.22	323.04	330.95	329.77	321.44	308.13	292.29	275.37	257.76	239.31	220.48	202.08	184.55	168.07	1489.05	6090.73
1980	54.84	113.06	174.21	229.08	272.98	304.27	323.01	330.29	328.81	320.87	307.89	291.58	273.92	256.07	238.20	220.04	201.89	184.41	167.96	1488.08	6081.45
1981	54.83	113.05	174.23	229.06	272.86	303.87	321.94	328.12	325.23	316.82	304.29	288.44	270.52	252.17	234.27	216.83	199.47	182.40	166.16	1472.26	6026.83
1982	30.62	113.03	174.22	228.79	267.65	296.31	310.27	308.72	299.07	288.01	275.68	261.48	245.45	228.42	211.60	195.59	180.28	165.29	150.73	1335.97	5567.19
1983	30.16	63.12	174.15	228.84	271.21	291.69	290.85	260.18	225.69	205.85	193.37	182.52	171.38	159.62	147.62	136.06	125.25	115.06	105.20	933.64	4311.44
1984	33.77	62.17	97.26	228.84	271.76	297.89	293.44	257.97	206.80	170.59	152.12	140.98	131.74	122.74	113.60	104.54	95.95	88.03	80.65	718.47	3669.31
1985	34.76	69.63	95.80	127.82	271.67	299.09	302.80	268.01	214.85	164.82	133.12	117.15	107.50	99.67	92.29	84.99	77.88	71.24	65.18	583.85	3282.13
1986	46.45	71.66	107.29	125.85	150.95	297.11	301.59	273.28	219.77	168.37	126.43	100.77	87.80	79.94	73.66	67.86	62.23	56.83	51.85	466.07	2935.75
1987	62.42	95.76	110.41	140.99	149.46	165.78	298.43	265.80	214.80	163.97	122.77	90.94	71.76	62.04	56.13	51.46	47.21	43.15	39.30	353.40	2606.01
1988	57.70	128.69	147.57	145.15	167.77	165.87	173.42	293.53	248.53	195.14	146.37	108.23	79.39	62.16	53.40	48.08	43.89	40.13	36.58	328.48	2670.11
1989	41.03	118.96	198.30	193.97	172.65	185.61	171.39	165.08	260.70	213.00	164.07	121.49	88.95	64.75	50.38	43.06	38.61	35.13	32.03	287.51	2646.68
1990	38.25	84.58	183.31	260.59	230.42	189.86	187.54	153.81	133.67	201.23	160.84	122.24	89.62	65.11	47.09	36.46	31.04	27.73	25.17	225.85	2494.41
1991	49.02	78.86	130.32	240.86	309.35	252.69	189.88	163.77	119.29	98.26	144.52	113.94	85.73	62.36	45.02	32.40	24.98	21.20	18.89	168.68	2350.04
1992	47.59	101.06	121.51	171.22	285.74	338.20	249.71	160.51	120.64	82.72	66.46	96.38	75.22	56.16	40.60	29.16	20.90	16.06	13.59	118.65	2212.07
1993	47.89	98.12	155.71	159.60	202.80	310.73	327.40	199.01	107.53	75.08	50.06	39.63	56.89	44.06	32.69	23.51	16.82	12.01	9.21	74.79	2043.52
1994	40.25	98.73	151.18	204.52	189.17	220.40	296.54	245.95	120.23	59.37	40.16	26.36	20.66	29.42	22.64	16.71	11.97	8.54	6.08	41.95	1850.83
1995	30.08	82.97	152.10	198.44	241.54	203.34	207.25	225.05	154.75	69.94	33.55	22.35	14.53	11.29	15.98	12.24	9.00	6.42	4.57	25.37	1720.75
1996	27.30	62.00	127.83	199.69	234.65	260.48	192.72	159.67	144.60	92.12	40.46	19.12	12.61	8.13	6.28	8.85	6.75	4.94	3.52	16.19	1627.91
1997	35.09	56.28	95.54	167.96	236.98	257.36	261.77	171.69	128.24	110.68	68.98	29.89	13.99	9.15	5.87	4.51	6.32	4.80	3.51	13.83	1682.42
1998	57.08	72.33	86.72	125.51	198.74	259.19	258.39	234.03	138.97	99.08	83.68	51.46	22.08	10.25	6.67	4.25	3.25	4.55	3.45	12.29	1731.96
1999	52.68	117.68	111.45	113.96	149.10	218.72	263.16	235.67	194.71	110.66	77.26	64.39	39.21	16.69	7.70	4.98	3.16	2.41	3.36	11.50	1798.47
2000	42.31	108.61	181.33	146.46	135.30	163.72	219.59	231.46	184.57	144.66	80.34	55.33	45.65	27.58	11.67	5.36	3.45	2.18	1.66	10.11	1801.34
2001	46.85	87.22	167.35	238.18	173.44	147.24	159.30	177.94	159.40	118.55	90.44	49.51	33.75	27.63	16.59	6.98	3.19	2.05	1.29	6.89	1713.78
2002	49.60	96.58	134.38	219.73	281.54	187.96	145.03	140.74	144.24	123.99	90.35	68.03	36.87	24.94	20.29	12.12	5.08	2.32	1.48	5.84	1791.12
2003	45.13	102.26	148.80	176.46	260.01	305.88	186.47	130.41	117.24	115.71	97.53	70.16	52.31	28.13	18.91	15.31	9.11	3.80	1.73	5.40	1890.75
2004	41.99	93.04	157.56	195.50	209.11	285.36	312.56	177.28	117.18	102.16	99.02	82.42	58.71	43.43	23.21	15.53	12.52	7.42	3.09	5.73	2042.82
2005	37.60	86.56	143.37	207.05	231.64	230.13	293.17	296.84	157.74	100.77	86.22	82.51	68.01	48.07	35.34	18.79	12.52	10.06	5.95	6.99	2159.31
2006	34.87	77.51	133.39	188.36	244.18	253.86	236.19	279.92	267.05	137.43	86.20	72.83	69.02	56.44	39.65	29.00	15.36	10.19	8.17	10.42	2250.04
2007	28.44	71.88	119.43	175.31	223.57	269.12	260.27	221.43	243.27	223.44	112.75	69.81	58.40	54.91	44.63	31.19	22.72	11.99	7.94	14.34	2264.85
2008	34.44	58.63	110.77	156.99	208.46	247.35	279.06	251.43	201.81	214.82	193.75	96.54	59.19	49.13	45.91	37.13	25.84	18.76	9.87	18.16	2318.04
2009	36.82	71.01	90.35	145.62	186.84	231.14	257.54	270.73	229.94	178.76	186.85	166.39	82.10	49.95	41.20	38.31	30.85	21.40	15.49	22.91	2354.20
2010	33.27	75.90	109.42	118.74	172.44	206.47	242.04	255.84	253.00	203.01	152.33	156.19	137.46	67.26	40.66	33.37	30.89	24.80	17.15	30.49	2360.73
2011	36.66	68.59	116.96	143.82	141.12	191.23	216.73	240.71	239.00	223.01	172.61	127.03	128.71	112.32	54.61	32.84	26.84	24.77	19.83	37.71	2355.09
2012	49.42	75.58	105.70	153.74	170.84	156.52	201.00	216.06	225.53	211.35	190.24	144.42	105.02	105.52	91.50	44.26	26.51	21.59	19.87	45.67	2360.31
2013	49.34	101.88	116.45	138.88	182.55	188.90	163.08	196.83	196.21	190.80	171.28	150.84	113.07	81.52	81.38	70.20	33.82	20.18	16.40	49.24	2312.84
2014	49.04	101.72	156.97	153.01	164.95	201.90	196.75	159.17	176.94	163.10	151.33	132.72	115.36	85.72	61.40	60.98	52.39	25.15	14.97	48.12	2271.70
2015	48.50	101.08	156.69	206.06	181.17	180.76	205.97	185.18	135.34	136.67	119.09	107.60	93.05	80.16	59.17	42.17	41.70	35.71	17.10	42.39	2175.56
2016	47.95	99.98	155.70	205.67	243.68	198.26	184.37	195.07	160.83	108.52	104.52	88.96	79.33	68.01	58.20	42.74	30.33	29.90	25.53	42.06	2169.61
2017	47.65	98.85	154.01	204.39	242.92	266.54	202.27	174.22	167.63	126.40	80.92	75.99	63.80	56.39	48.02	40.89	29.90	21.15	20.79	46.53	2169.26
2018	47.34	98.23	152.26	202.17	241.98	266.10	271.45	189.29	146.08	126.59	89.81	55.89	51.72	43.03	37.78	32.01	27.14	19.78	13.96	43.94	2156.57

Table 9. Estimated total abundance 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
1972	120.80	249.10	383.90	504.80	601.50	670.70	712.90	729.60	725.40	706.30	677.00	641.00	601.10	559.30	517.20	475.90	436.00	398.20	362.60	3212.70	13286.00
1973	120.80	249.10	383.90	504.80	601.60	671.00	714.00	733.20	731.20	712.80	683.40	647.10	606.80	564.60	522.10	480.40	440.20	401.90	366.10	3243.20	13378.20
1974	120.90	249.10	383.90	504.80	601.50	670.90	713.90	733.40	733.30	716.80	688.00	651.60	611.10	568.60	525.80	483.80	443.30	404.80	368.70	3266.10	13440.50
1975	120.90	249.20	383.90	504.80	601.50	670.80	713.30	731.60	731.00	716.00	689.00	653.30	612.80	570.30	527.30	485.20	444.60	406.00	369.70	3275.50	13456.50
1976	120.90	249.30	384.10	504.80	601.50	670.50	712.30	728.90	726.10	710.20	684.80	651.00	611.30	569.00	526.20	484.20	443.60	405.10	368.90	3268.50	13421.10
1977	120.90	249.30	384.10	505.00	601.50	670.50	712.00	727.80	723.20	705.30	679.20	646.90	609.10	567.50	525.00	483.00	442.60	404.10	368.10	3261.00	13386.10
1978	120.90	249.20	384.10	505.10	601.80	670.70	712.90	730.30	726.60	707.50	679.30	646.20	609.60	569.50	527.30	485.30	444.70	406.10	369.80	3276.70	13423.60
1979	120.90	249.20	384.10	505.10	601.80	670.70	712.20	729.60	727.00	708.60	679.30	644.40	607.10	568.30	527.60	486.10	445.50	406.90	370.50	3282.80	13427.60
1980	120.90	249.30	384.10	505.00	601.80	670.80	712.10	728.20	724.90	707.40	678.80	642.80	603.90	564.50	525.10	485.10	445.10	406.60	370.30	3280.60	13407.20
1981	120.90	249.20	384.10	505.00	601.50	669.90	709.70	723.40	717.00	698.50	670.80	635.90	596.40	555.90	516.50	478.00	439.80	402.10	366.30	3245.70	13286.70
1982	67.50	249.20	384.10	504.40	590.10	653.20	684.00	680.60	659.30	634.90	607.80	576.50	541.10	503.60	466.50	431.20	397.40	364.40	332.30	2945.30	12273.40
1983	66.50	139.20	383.90	504.50	597.90	643.10	641.20	573.60	497.60	453.80	426.30	402.40	377.80	351.90	325.40	300.00	276.10	253.70	231.90	2058.30	9505.00
1984	74.40	137.10	214.40	504.50	599.10	656.70	646.90	568.70	455.90	376.10	335.40	310.80	290.40	270.60	250.40	230.50	211.50	194.10	177.80	1583.90	8089.40
1985	76.60	153.50	211.20	281.80	598.90	659.40	667.60	590.90	473.70	363.40	293.50	258.30	237.00	219.70	203.50	187.40	171.70	157.10	143.70	1287.20	7235.80
1986	102.40	158.00	236.50	277.40	332.80	655.00	664.90	602.50	484.50	371.20	278.70	222.20	193.60	176.20	162.40	149.60	137.20	125.30	114.30	1027.50	6472.20
1987	137.60	211.10	243.40	310.80	329.50	365.50	657.90	586.00	473.50	361.50	270.70	200.50	158.20	136.80	123.70	113.40	104.10	95.10	86.60	779.10	5745.20
1988	127.20	283.70	325.30	320.00	369.90	365.70	382.30	647.10	547.90	430.20	322.70	238.60	175.00	137.00	117.70	106.00	96.80	88.50	80.60	724.20	5886.50
1989	90.50	262.30	437.20	427.60	380.60	409.20	377.80	363.90	574.70	469.60	361.70	267.80	196.10	142.70	111.10	94.90	85.10	77.40	70.60	633.80	5834.90
1990	84.30	186.50	404.10	574.50	508.00	418.60	413.50	339.10	294.70	443.60	354.60	269.50	197.60	143.50	103.80	80.40	68.40	61.10	55.50	497.90	5499.20
1991	108.10	173.90	287.30	531.00	682.00	557.10	418.60	361.00	263.00	216.60	318.60	251.20	189.00	137.50	99.30	71.40	55.10	46.70	41.60	371.90	5180.90
1992	104.90	222.80	267.90	377.50	629.90	745.60	550.50	353.90	266.00	182.40	146.50	212.50	165.80	123.80	89.50	64.30	46.10	35.40	30.00	261.60	4876.70
1993	105.60	216.30	343.30	351.90	447.10	685.00	721.80	438.70	237.10	165.50	110.40	87.40	125.40	97.10	72.10	51.80	37.10	26.50	20.30	164.90	4505.10
1994	88.70	217.70	333.30	450.90	417.00	485.90	653.80	542.20	265.10	130.90	88.50	58.10	45.50	64.90	49.90	36.80	26.40	18.80	13.40	92.50	4080.30
1995	66.30	182.90	335.30	437.50	532.50	448.30	456.90	496.10	341.20	154.20	74.00	49.30	32.00	24.90	35.20	27.00	19.80	14.20	10.10	55.90	3793.60
1996	60.20	136.70	281.80	440.20	517.30	574.30	424.90	352.00	318.80	203.10	89.20	42.20	27.80	17.90	13.80	19.50	14.90	10.90	7.80	35.70	3588.90
1997	77.40	124.10	210.60	370.30	522.40	567.40	577.10	378.50	282.70	244.00	152.10	65.90	30.80	20.20	12.90	9.90	13.90	10.60	7.70	30.50	3709.10
1998	125.80	159.50	191.20	276.70	438.10	571.40	569.60	515.90	306.40	218.40	184.50	113.40	48.70	22.60	14.70	9.40	7.20	10.00	7.60	27.10	3818.30
1999	116.10	259.40	245.70	251.20	328.70	482.20	580.20	519.60	429.30	244.00	170.30	142.00	86.40	36.80	17.00	11.00	7.00	5.30	7.40	25.40	3964.90
2000	93.30	239.40	399.80	322.90	298.30	360.90	484.10	510.30	406.90	318.90	177.10	122.00	100.60	60.80	25.70	11.80	7.60	4.80	3.70	22.30	3971.20
2001	103.30	192.30	368.90	525.10	382.40	324.60	351.20	392.30	351.40	261.40	199.40	109.10	74.40	60.90	36.60	15.40	7.00	4.50	2.80	15.20	3778.20
2002	109.30	212.90	296.30	484.40	620.70	414.40	319.70	310.30	318.00	273.30	199.20	150.00	81.30	55.00	44.70	26.70	11.20	5.10	3.30	12.90	3948.70
2003	99.50	225.40	328.00	389.00	573.20	674.30	411.10	287.50	258.50	255.10	215.00	154.70	115.30	62.00	41.70	33.80	20.10	8.40	3.80	11.90	4168.30
2004	92.60	205.10	347.40	431.00	461.00	629.10	689.10	390.80	258.30	225.20	218.30	181.70	129.40	95.70	51.20	34.20	27.60	16.40	6.80	12.60	4503.60
2005	82.90	190.80	316.10	456.50	510.70	507.30	646.30	654.40	347.80	222.20	190.10	181.90	149.90	106.00	77.90	41.40	27.60	22.20	13.10	15.40	4760.40
2006	76.90	170.90	294.10	415.30	538.30	559.70	520.70	617.10	588.70	303.00	190.00	160.60	152.20	124.40	87.40	63.90	33.90	22.50	18.00	23.00	4960.40
2007	62.70	158.50	263.30	386.50	492.90	593.30	573.80	488.20	536.30	492.60	248.60	153.90	128.70	121.10	98.40	68.80	50.10	26.40	17.50	31.60	4993.10
2008	75.90	129.30	244.20	346.10	459.60	545.30	615.20	554.30	444.90	473.60	427.10	212.80	130.50	108.30	101.20	81.90	57.00	41.40	21.80	40.00	5110.40
2009	81.20	156.50	199.20	321.00	411.90	509.60	567.80	596.90	506.90	394.10	411.90	366.80	181.00	110.10	90.80	84.50	68.00	47.20	34.10	50.50	5190.10
2010	73.30	167.30	241.20	261.80	380.20	455.20	533.60	564.00	557.80	447.60	335.80	344.30	303.00	148.30	89.60	73.60	68.10	54.70	37.80	67.20	5204.50
2011	80.80	151.20	257.90	317.10	311.10	421.60	477.80	530.70	526.90	491.60	380.50	280.10	283.80	247.60	120.40	72.40	59.20	54.60	43.70	83.10	5192.00
2012	109.00	166.60	233.00	338.90	376.60	345.10	443.10	476.30	497.20	465.90	419.40	318.40	231.50	232.60	201.70	97.60	58.40	47.60	43.80	100.70	5203.50
2013	108.80	224.60	256.70	306.20	402.40	416.40	359.50	433.90	432.60	420.60	377.60	332.50	249.30	179.70	179.40	154.80	74.60	44.50	36.20	108.60	5098.90
2014	108.10	224.30	346.10	337.30	363.60	445.10	433.80	350.90	390.10	359.60	333.60	292.60	254.30	189.00	135.40	134.40	115.50	55.40	33.00	106.10	5008.20
2015	106.90	222.80	345.40	454.30	399.40	398.50	454.10	408.20	298.40	301.30	262.50	237.20	205.10	176.70	130.40	93.00	91.90	78.70	37.70	93.50	4796.20
2016	105.70	220.40	343.30	453.40	537.20	437.10	406.50	430.10	354.60	239.20	230.40	196.10	174.90	149.90	128.30	94.20	66.90	65.90	56.30	92.70	4783.10
2017	105.00	217.90	339.50	450.60	535.50	587.60	445.90	384.10	369.60	278.70	178.40	167.50	140.70	124.30	105.90	90.10	65.90	46.60	45.80	102.60	4782.40
2018	104.40	216.60	335.70	445.70	533.50	586.60	598.40	417.30	322.00	279.10	198.00	123.20	114.00	94.90	83.30	70.60	59.80	43.60	30.80	96.90	4754.40

Table 10. Estimated time series of status indicators. Fishing mortality rate is apical F (F_{apical}). Total and spawning stock biomass (B and SSB, mt) are at the start of the year. The MSST *is defined by* $\mathrm{MSST} = (1 - M)\mathrm{SSB}_{\mathrm{MSY}}$*, with constant* $M = 0.1038$*. SPR is static spawning potential ratio and* R_y *is expected annual recruitment.*

Year	F_{apical}	F/F_{MSY}	B	B/B_{unfished}	SSB	$\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$	SSB/MSST	SPR	R_y
1972	0.001	0.002	6026	0.915	82	4.359	5.812	0.993	340224
1973	0.003	0.010	6068	0.921	83	4.407	5.877	0.965	340224
1974	0.007	0.024	6097	0.926	83	4.426	5.901	0.920	340390
1975	0.012	0.041	6104	0.927	83	4.425	5.900	0.870	340453
1976	0.012	0.041	6088	0.924	83	4.412	5.883	0.868	340450
1977	0.005	0.017	6072	0.922	83	4.411	5.882	0.940	340406
1978	0.008	0.027	6089	0.924	83	4.421	5.895	0.907	340403
1979	0.011	0.036	6091	0.925	83	4.419	5.892	0.883	340437
1980	0.021	0.070	6081	0.923	83	4.394	5.859	0.792	340430
1981	0.107	0.361	6027	0.915	79	4.202	5.603	0.387	340346
1982	0.368	1.240	5567	0.845	66	3.485	4.647	0.173	190082
1983	0.272	0.915	4311	0.655	50	2.673	3.565	0.218	187207
1984	0.217	0.730	3669	0.557	42	2.247	2.995	0.256	209666
1985	0.234	0.789	3282	0.498	37	1.949	2.598	0.238	215772
1986	0.285	0.960	2936	0.446	31	1.663	2.218	0.211	288355
1987	0.082	0.275	2606	0.396	28	1.510	2.013	0.484	387502
1988	0.142	0.478	2670	0.405	28	1.482	1.976	0.346	358221
1989	0.250	0.842	2647	0.402	26	1.376	1.835	0.232	254687
1990	0.301	1.012	2494	0.379	23	1.228	1.638	0.202	237474
1991	0.361	1.216	2350	0.357	21	1.091	1.454	0.177	304312
1992	0.473	1.593	2212	0.336	18	0.949	1.266	0.147	295461
1993	0.597	2.012	2044	0.310	15	0.802	1.069	0.129	297314
1994	0.542	1.824	1851	0.281	13	0.693	0.924	0.131	249863
1995	0.518	1.745	1721	0.261	12	0.631	0.842	0.136	186709
1996	0.258	0.870	1628	0.247	12	0.636	0.849	0.224	169472
1997	0.249	0.837	1682	0.255	13	0.687	0.916	0.228	217807
1998	0.218	0.733	1732	0.263	14	0.729	0.971	0.255	354361
1999	0.290	0.975	1798	0.273	14	0.745	0.993	0.209	327059
2000	0.440	1.482	1801	0.273	13	0.703	0.937	0.154	262655
2001	0.240	0.809	1714	0.260	13	0.682	0.909	0.224	290830
2002	0.209	0.702	1791	0.272	14	0.723	0.964	0.249	307927
2003	0.124	0.417	1891	0.287	15	0.791	1.055	0.364	280161
2004	0.138	0.465	2043	0.310	17	0.883	1.178	0.346	260661
2005	0.124	0.419	2159	0.328	18	0.972	1.295	0.365	233390
2006	0.167	0.561	2250	0.342	20	1.041	1.387	0.308	216461
2007	0.111	0.373	2265	0.344	21	1.100	1.467	0.403	176552
2008	0.108	0.363	2318	0.352	22	1.171	1.561	0.414	213820
2009	0.138	0.463	2354	0.357	23	1.222	1.630	0.388	228563
2010	0.140	0.472	2361	0.358	24	1.250	1.666	0.389	206548
2011	0.137	0.461	2355	0.358	24	1.266	1.688	0.395	227585
2012	0.192	0.645	2360	0.358	24	1.252	1.670	0.319	306785
2013	0.215	0.725	2313	0.351	23	1.199	1.599	0.299	306323
2014	0.303	1.019	2272	0.345	21	1.114	1.485	0.232	304422
2015	0.252	0.848	2176	0.330	20	1.037	1.383	0.255	301094
2016	0.280	0.942	2170	0.329	19	0.999	1.332	0.241	297691
2017	0.332	1.119	2169	0.329	18	0.962	1.282	0.220	295817
2018	0.182	0.612	2157	0.327	18	0.970	1.294	0.325	293907

Table 11. Selectivity at age for landings from commercial handline (cH), commercial longline (cL), and recreational (rA) fleets, selectivity for the MARMAP longline (sM) survey, selectivity of landings averaged across fisheries (L.avg), and selectivity of total removals (Total = L.avg). For time-varying selectivities, values shown are from the first year of each constant selectivity time period.

Age	TL (mm)	TL (in)	cH-1972	cH-2009	cL-1972	cL-2009	rA	sM	L.avg	Total
1	257	10.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	354	13.95	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
3	435	17.14	0.02	0.03	0.00	0.00	0.05	0.01	0.01	0.01
4	503	19.79	0.08	0.09	0.01	0.01	0.90	0.05	0.02	0.02
5	558	21.97	0.31	0.27	0.04	0.02	1.00	0.17	0.06	0.06
6	604	23.78	0.69	0.56	0.18	0.07	1.00	0.43	0.14	0.14
7	642	25.28	0.92	0.82	0.52	0.20	1.00	0.74	0.29	0.29
8	674	26.52	0.98	0.94	0.85	0.48	1.00	0.91	0.54	0.54
9	700	27.55	1.00	0.98	0.97	0.77	1.00	0.97	0.80	0.80
10	721	28.40	1.00	0.99	0.99	0.92	1.00	0.99	0.93	0.93
11	739	29.10	1.00	1.00	1.00	0.98	1.00	1.00	0.98	0.98
12	754	29.68	1.00	1.00	1.00	0.99	1.00	1.00	0.99	0.99
13	766	30.17	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
14	776	30.57	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15	785	30.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
16	792	31.17	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
17	797	31.40	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
18	802	31.58	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
19	806	31.74	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	809	31.87	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 12. Estimated time series of fully selected fishing mortality rates for commercial handline (F_{cH}), commercial longline (F_{cL}), and recreational (F_{rA}). Also shown is apical F (F_{apical}), the maximum F at age summed across fleets.

Year	F_{cH}	F_{cL}	F_{rA}	F_{apical}
1972	0.000	0.001	0.000	0.001
1973	0.000	0.003	0.000	0.003
1974	0.001	0.007	0.000	0.007
1975	0.001	0.011	0.000	0.012
1976	0.001	0.011	0.000	0.012
1977	0.001	0.004	0.000	0.005
1978	0.002	0.006	0.000	0.008
1979	0.002	0.009	0.000	0.011
1980	0.005	0.016	0.000	0.021
1981	0.012	0.075	0.020	0.107
1982	0.030	0.338	0.000	0.368
1983	0.016	0.256	0.000	0.272
1984	0.013	0.203	0.001	0.217
1985	0.014	0.214	0.007	0.234
1986	0.014	0.271	0.000	0.285
1987	0.005	0.076	0.000	0.082
1988	0.009	0.133	0.000	0.142
1989	0.015	0.235	0.000	0.250
1990	0.017	0.283	0.000	0.301
1991	0.020	0.341	0.000	0.361
1992	0.020	0.452	0.001	0.473
1993	0.006	0.592	0.000	0.597
1994	0.052	0.489	0.001	0.542
1995	0.047	0.472	0.000	0.518
1996	0.022	0.236	0.000	0.258
1997	0.022	0.223	0.004	0.249
1998	0.017	0.201	0.000	0.218
1999	0.013	0.276	0.000	0.290
2000	0.021	0.418	0.001	0.440
2001	0.065	0.174	0.001	0.240
2002	0.064	0.144	0.001	0.209
2003	0.033	0.089	0.002	0.124
2004	0.015	0.119	0.004	0.138
2005	0.013	0.102	0.009	0.124
2006	0.013	0.152	0.002	0.167
2007	0.012	0.098	0.000	0.111
2008	0.006	0.102	0.000	0.108
2009	0.004	0.128	0.006	0.138
2010	0.007	0.132	0.001	0.140
2011	0.003	0.132	0.003	0.137
2012	0.015	0.175	0.001	0.192
2013	0.013	0.201	0.001	0.215
2014	0.043	0.258	0.001	0.303
2015	0.048	0.201	0.002	0.252
2016	0.040	0.235	0.004	0.280
2017	0.043	0.288	0.001	0.332
2018	0.020	0.159	0.003	0.182

Table 13. Estimated instantaneous fishing mortality rate F (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
1972	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1973	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
1974	0.000	0.000	0.000	0.000	0.000	0.002	0.004	0.006	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
1975	0.000	0.000	0.000	0.000	0.001	0.003	0.007	0.010	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
1976	0.000	0.000	0.000	0.000	0.001	0.003	0.007	0.011	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
1977	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.004	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
1978	0.000	0.000	0.000	0.000	0.001	0.003	0.005	0.007	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
1979	0.000	0.000	0.000	0.000	0.001	0.003	0.006	0.009	0.010	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
1980	0.000	0.000	0.000	0.001	0.002	0.006	0.013	0.018	0.020	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021
1981	0.000	0.000	0.001	0.020	0.027	0.042	0.070	0.095	0.105	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107
1982	0.000	0.000	0.001	0.005	0.023	0.081	0.204	0.316	0.356	0.366	0.368	0.368	0.368	0.368	0.368	0.368	0.368	0.368	0.368	0.368
1983	0.000	0.000	0.001	0.004	0.016	0.057	0.148	0.232	0.263	0.270	0.271	0.272	0.272	0.272	0.272	0.272	0.272	0.272	0.272	0.272
1984	0.000	0.000	0.001	0.004	0.014	0.046	0.119	0.186	0.210	0.215	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217
1985	0.000	0.000	0.001	0.009	0.020	0.054	0.131	0.201	0.227	0.233	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234
1986	0.000	0.000	0.001	0.003	0.016	0.058	0.155	0.244	0.276	0.283	0.285	0.285	0.285	0.285	0.285	0.285	0.285	0.285	0.285	0.285
1987	0.000	0.000	0.000	0.001	0.005	0.018	0.045	0.070	0.079	0.081	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082
1988	0.000	0.000	0.000	0.002	0.008	0.030	0.078	0.121	0.137	0.141	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142
1989	0.000	0.000	0.001	0.003	0.014	0.052	0.137	0.214	0.242	0.248	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250
1990	0.000	0.000	0.001	0.004	0.017	0.063	0.164	0.257	0.291	0.299	0.300	0.300	0.301	0.301	0.301	0.301	0.301	0.301	0.301	0.301
1991	0.000	0.000	0.001	0.005	0.020	0.075	0.196	0.308	0.349	0.359	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361
1992	0.000	0.000	0.001	0.006	0.026	0.095	0.255	0.403	0.457	0.470	0.472	0.473	0.473	0.473	0.473	0.473	0.473	0.473	0.473	0.473
1993	0.000	0.000	0.001	0.005	0.026	0.109	0.314	0.507	0.577	0.593	0.597	0.597	0.597	0.597	0.597	0.597	0.597	0.597	0.597	0.597
1994	0.000	0.000	0.002	0.009	0.037	0.124	0.304	0.466	0.525	0.538	0.541	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542
1995	0.000	0.000	0.002	0.008	0.034	0.116	0.289	0.445	0.502	0.515	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518
1996	0.000	0.000	0.001	0.004	0.017	0.058	0.144	0.222	0.250	0.257	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.258
1997	0.000	0.000	0.001	0.007	0.020	0.059	0.140	0.214	0.241	0.247	0.248	0.249	0.249	0.249	0.249	0.249	0.249	0.249	0.249	0.249
1998	0.000	0.000	0.001	0.003	0.014	0.047	0.120	0.187	0.211	0.216	0.217	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218
1999	0.000	0.000	0.001	0.004	0.016	0.059	0.157	0.247	0.280	0.288	0.289	0.290	0.290	0.290	0.290	0.290	0.290	0.290	0.290	0.290
2000	0.000	0.000	0.001	0.006	0.025	0.090	0.239	0.376	0.426	0.437	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440
2001	0.000	0.000	0.002	0.008	0.029	0.078	0.152	0.213	0.234	0.239	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240
2002	0.000	0.000	0.001	0.007	0.026	0.071	0.135	0.185	0.203	0.208	0.208	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209
2003	0.000	0.000	0.001	0.006	0.016	0.041	0.079	0.110	0.121	0.123	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124
2004	0.000	0.000	0.001	0.006	0.014	0.036	0.080	0.120	0.134	0.137	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
2005	0.000	0.000	0.001	0.010	0.018	0.037	0.075	0.109	0.121	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124
2006	0.000	0.000	0.001	0.004	0.012	0.038	0.093	0.143	0.161	0.165	0.166	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167
2007	0.000	0.000	0.000	0.002	0.008	0.026	0.063	0.096	0.107	0.110	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
2008	0.000	0.000	0.000	0.001	0.006	0.022	0.059	0.092	0.104	0.107	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108
2009	0.000	0.000	0.001	0.006	0.009	0.017	0.035	0.070	0.108	0.127	0.135	0.137	0.137	0.138	0.138	0.138	0.138	0.138	0.138	0.138
2010	0.000	0.000	0.000	0.003	0.006	0.014	0.034	0.071	0.109	0.130	0.137	0.139	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
2011	0.000	0.000	0.000	0.003	0.006	0.013	0.032	0.068	0.106	0.126	0.134	0.136	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137
2012	0.000	0.000	0.001	0.004	0.009	0.022	0.049	0.099	0.150	0.178	0.187	0.190	0.191	0.192	0.192	0.192	0.192	0.192	0.192	0.192
2013	0.000	0.000	0.001	0.003	0.009	0.022	0.053	0.109	0.168	0.199	0.210	0.214	0.215	0.215	0.215	0.215	0.215	0.215	0.215	0.215
2014	0.000	0.000	0.002	0.007	0.018	0.043	0.089	0.165	0.241	0.282	0.296	0.301	0.302	0.302	0.303	0.303	0.303	0.303	0.303	0.303
2015	0.000	0.000	0.002	0.008	0.019	0.043	0.083	0.144	0.204	0.236	0.247	0.251	0.252	0.252	0.252	0.252	0.252	0.252	0.252	0.252
2016	0.000	0.000	0.002	0.009	0.020	0.043	0.085	0.154	0.224	0.261	0.274	0.278	0.279	0.280	0.280	0.280	0.280	0.280	0.280	0.280
2017	0.000	0.000	0.002	0.007	0.018	0.044	0.095	0.179	0.264	0.309	0.325	0.330	0.332	0.332	0.332	0.332	0.332	0.332	0.332	0.332
2018	0.000	0.000	0.001	0.005	0.011	0.025	0.052	0.097	0.144	0.169	0.178	0.181	0.181	0.182	0.182	0.182	0.182	0.182	0.182	0.182

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1972	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.13
1973	0.00	0.00	0.00	0.01	0.02	0.08	0.17	0.23	0.23	0.21	0.19	0.17	0.15	0.14	0.12	0.11	0.10	0.09	0.08	0.68
1974	0.00	0.00	0.00	0.02	0.06	0.18	0.41	0.56	0.57	0.52	0.46	0.41	0.37	0.33	0.29	0.26	0.24	0.21	0.19	1.66
1975	0.00	0.00	0.01	0.03	0.10	0.31	0.70	0.96	0.96	0.88	0.79	0.70	0.63	0.56	0.50	0.45	0.40	0.36	0.32	2.82
1976	0.00	0.00	0.01	0.03	0.10	0.32	0.71	0.97	0.97	0.88	0.79	0.71	0.63	0.57	0.51	0.45	0.41	0.36	0.33	2.86
1977	0.00	0.00	0.00	0.02	0.06	0.16	0.32	0.41	0.41	0.37	0.33	0.30	0.27	0.24	0.21	0.19	0.17	0.15	0.14	1.20
1978	0.00	0.00	0.01	0.04	0.13	0.31	0.54	0.66	0.65	0.58	0.52	0.47	0.42	0.38	0.34	0.30	0.27	0.24	0.22	1.90
1979	0.00	0.00	0.01	0.03	0.12	0.32	0.65	0.85	0.84	0.76	0.68	0.61	0.54	0.49	0.44	0.39	0.35	0.32	0.28	2.48
1980	0.00	0.01	0.02	0.08	0.29	0.73	1.32	1.66	1.62	1.47	1.31	1.17	1.05	0.94	0.85	0.76	0.68	0.61	0.55	4.80
1981	0.00	0.02	0.26	3.08	3.61	4.86	7.07	8.32	7.99	7.22	6.45	5.76	5.14	4.60	4.13	3.72	3.35	3.00	2.69	23.57
1982	0.01	0.05	0.20	0.84	3.08	9.03	18.57	23.36	22.27	19.94	17.77	15.86	14.16	12.65	11.34	10.20	9.19	8.27	7.43	65.00
1983	0.00	0.02	0.13	0.55	2.08	6.28	12.97	15.05	12.94	11.00	9.62	8.54	7.63	6.82	6.10	5.47	4.93	4.44	4.00	35.07
1984	0.00	0.01	0.07	0.60	1.82	5.26	10.65	12.19	9.71	7.46	6.20	5.41	4.81	4.30	3.85	3.44	3.09	2.78	2.51	22.10
1985	0.00	0.02	0.10	0.80	2.66	6.17	12.02	13.63	10.81	7.72	5.81	4.81	4.20	3.74	3.35	3.00	2.69	2.41	2.17	19.23
1986	0.01	0.02	0.08	0.30	1.17	6.56	13.99	16.48	13.15	9.38	6.56	4.92	4.08	3.56	3.18	2.85	2.55	2.29	2.06	18.26
1987	0.00	0.01	0.03	0.14	0.39	1.13	4.24	5.00	4.04	2.88	2.01	1.40	1.05	0.87	0.76	0.68	0.61	0.55	0.49	4.36
1988	0.00	0.02	0.06	0.19	0.69	1.91	4.19	9.35	7.90	5.79	4.04	2.81	1.96	1.48	1.23	1.07	0.96	0.86	0.77	6.85
1989	0.01	0.03	0.14	0.43	1.23	3.69	7.08	8.87	13.89	10.57	7.59	5.29	3.68	2.57	1.94	1.61	1.41	1.26	1.13	10.04
1990	0.01	0.03	0.15	0.70	1.95	4.49	9.17	9.73	8.37	11.73	8.73	6.24	4.35	3.04	2.12	1.60	1.33	1.17	1.04	9.25
1991	0.01	0.03	0.13	0.75	3.09	7.09	10.96	12.14	8.73	6.69	9.16	6.80	4.87	3.40	2.37	1.66	1.25	1.04	0.92	8.07
1992	0.01	0.04	0.15	0.72	3.59	11.98	18.22	14.89	11.00	7.01	5.24	7.16	5.31	3.81	2.66	1.86	1.30	0.98	0.82	7.07
1993	0.01	0.04	0.18	0.60	2.61	12.58	28.62	22.13	11.73	7.61	4.72	3.52	4.80	3.57	2.56	1.79	1.25	0.88	0.66	5.32
1994	0.01	0.07	0.29	1.27	3.44	10.05	25.20	25.63	12.21	5.59	3.52	2.17	1.62	2.22	1.65	1.18	0.83	0.58	0.41	2.78
1995	0.01	0.05	0.26	1.06	4.01	8.72	16.86	22.61	15.18	6.37	2.84	1.78	1.10	0.82	1.13	0.84	0.60	0.42	0.30	1.62
1996	0.00	0.02	0.11	0.58	1.97	5.70	8.36	8.87	7.94	4.71	1.93	0.86	0.54	0.33	0.25	0.34	0.25	0.18	0.13	0.58
1997	0.01	0.02	0.10	0.82	2.31	5.73	11.09	9.23	6.81	5.47	3.17	1.29	0.58	0.36	0.22	0.17	0.23	0.17	0.12	0.48
1998	0.01	0.02	0.06	0.27	1.33	4.69	9.48	11.12	6.55	4.35	3.42	1.98	0.81	0.36	0.23	0.14	0.11	0.14	0.11	0.38
1999	0.01	0.03	0.09	0.30	1.17	4.87	12.35	14.40	11.80	6.25	4.06	3.19	1.85	0.75	0.34	0.21	0.13	0.10	0.14	0.46
2000	0.01	0.05	0.22	0.64	1.65	5.50	15.10	20.26	15.90	11.58	5.99	3.88	3.05	1.77	0.72	0.32	0.20	0.13	0.09	0.57
2001	0.01	0.05	0.27	1.33	2.47	4.30	7.28	9.51	8.25	5.69	4.04	2.08	1.35	1.06	0.62	0.25	0.11	0.07	0.04	0.23
2002	0.01	0.05	0.20	1.07	3.66	5.01	5.91	6.64	6.58	5.24	3.55	2.52	1.30	0.84	0.66	0.39	0.16	0.07	0.04	0.17
2003	0.01	0.03	0.14	0.69	2.10	4.80	4.57	3.78	3.30	3.02	2.37	1.61	1.14	0.59	0.38	0.30	0.18	0.07	0.03	0.10
2004	0.00	0.02	0.11	0.78	1.40	3.90	7.77	5.57	3.64	2.95	2.67	2.09	1.41	1.00	0.52	0.34	0.27	0.16	0.06	0.12
2005	0.00	0.01	0.14	1.49	2.03	3.23	6.82	8.51	4.45	2.64	2.10	1.90	1.49	1.01	0.72	0.37	0.24	0.19	0.11	0.13
2006	0.00	0.01	0.08	0.52	1.46	3.67	6.78	10.40	9.86	4.73	2.76	2.20	1.98	1.55	1.06	0.75	0.39	0.25	0.20	0.25
2007	0.00	0.01	0.05	0.27	0.92	2.74	5.13	5.62	6.13	5.25	2.47	1.44	1.14	1.03	0.81	0.55	0.39	0.20	0.13	0.24
2008	0.00	0.01	0.03	0.15	0.63	2.13	5.14	6.16	4.95	4.92	4.13	1.94	1.13	0.90	0.81	0.64	0.44	0.31	0.16	0.29
2009	0.00	0.01	0.06	0.64	0.88	1.48	2.86	5.13	5.81	4.82	4.92	4.18	1.97	1.15	0.92	0.83	0.65	0.45	0.32	0.46
2010	0.01	0.02	0.06	0.22	0.51	1.13	2.61	4.87	6.48	5.57	4.08	3.99	3.36	1.58	0.92	0.74	0.67	0.53	0.36	0.63
2011	0.00	0.01	0.05	0.32	0.41	0.95	2.17	4.40	5.95	5.97	4.52	3.17	3.07	2.58	1.21	0.71	0.57	0.51	0.40	0.76
2012	0.02	0.03	0.09	0.38	0.75	1.30	3.13	5.68	7.80	7.76	6.80	4.92	3.42	3.30	2.77	1.30	0.76	0.61	0.55	1.26
2013	0.01	0.04	0.09	0.33	0.78	1.60	2.70	5.68	7.51	7.78	6.80	5.71	4.09	2.83	2.74	2.30	1.08	0.63	0.51	1.50
2014	0.04	0.10	0.29	0.69	1.45	3.29	5.42	6.75	9.41	9.05	8.13	6.79	5.63	4.02	2.79	2.69	2.26	1.07	0.62	1.98
2015	0.04	0.10	0.31	1.10	1.72	2.96	5.29	6.91	6.19	6.48	5.46	4.69	3.87	3.21	2.29	1.59	1.53	1.29	0.61	1.49
2016	0.03	0.09	0.29	1.27	2.37	3.23	4.86	7.78	8.00	5.63	5.25	4.25	3.62	2.98	2.47	1.76	1.22	1.18	1.00	1.62
2017	0.04	0.10	0.29	0.92	2.18	4.52	5.91	7.96	9.64	7.59	4.71	4.21	3.37	2.86	2.36	1.96	1.40	0.97	0.94	2.08
2018	0.02	0.05	0.16	0.71	1.34	2.53	4.41	4.90	4.86	4.44	3.06	1.82	1.60	1.28	1.09	0.90	0.74	0.53	0.37	1.15

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1972	0.00	0.00	0.00	0.00	0.02	0.07	0.19	0.30	0.34	0.34	0.33	0.31	0.29	0.27	0.25	0.23	0.21	0.20	0.18	1.58
1973	0.00	0.00	0.00	0.02	0.09	0.38	1.03	1.65	1.86	1.87	1.80	1.71	1.61	1.50	1.38	1.27	1.17	1.07	0.97	8.61
1974	0.00	0.00	0.01	0.04	0.23	0.91	2.49	3.98	4.51	4.53	4.37	4.15	3.90	3.63	3.36	3.09	2.83	2.59	2.36	20.88
1975	0.00	0.00	0.01	0.07	0.39	1.55	4.22	6.74	7.62	7.67	7.43	7.06	6.63	6.17	5.71	5.26	4.82	4.40	4.01	35.53
1976	0.00	0.00	0.01	0.08	0.40	1.58	4.29	6.82	7.68	7.72	7.49	7.14	6.71	6.25	5.78	5.32	4.88	4.46	4.06	35.97
1977	0.00	0.00	0.01	0.05	0.24	0.81	1.92	2.91	3.24	3.24	3.14	2.99	2.82	2.63	2.43	2.24	2.05	1.88	1.71	15.14
1978	0.00	0.00	0.02	0.10	0.50	1.55	3.26	4.68	5.14	5.12	4.94	4.71	4.45	4.16	3.85	3.55	3.25	2.97	2.71	23.97
1979	0.00	0.00	0.01	0.09	0.46	1.62	3.92	5.98	6.68	6.68	6.44	6.12	5.77	5.41	5.02	4.63	4.24	3.88	3.53	31.29
1980	0.00	0.00	0.04	0.24	1.15	3.67	8.01	11.69	12.90	12.88	12.43	11.80	11.09	10.38	9.66	8.92	8.19	7.48	6.82	60.41
1981	0.00	0.02	0.46	8.63	14.07	24.31	42.89	58.73	63.59	63.23	61.04	57.96	54.41	50.75	47.17	43.68	40.19	36.76	33.50	296.87
1982	0.00	0.05	0.36	2.35	12.01	45.20	112.66	164.83	177.15	174.59	168.05	159.68	150.03	139.71	129.49	119.73	110.40	101.25	92.35	818.62
1983	0.00	0.02	0.24	1.55	8.12	31.40	78.70	106.21	102.97	96.27	90.97	86.03	80.86	75.35	69.72	64.29	59.20	54.40	49.75	441.59
1984	0.00	0.01	0.12	1.68	7.10	26.32	64.60	86.02	77.22	65.33	58.61	54.42	50.90	47.46	43.95	40.45	37.14	34.09	31.23	278.31
1985	0.00	0.02	0.17	2.23	10.37	30.89	72.95	96.15	86.00	67.61	54.93	48.43	44.48	41.27	38.23	35.22	32.28	29.54	27.03	242.19
1986	0.00	0.02	0.14	0.84	4.55	32.84	84.86	116.31	104.57	82.13	62.04	49.53	43.20	39.36	36.28	33.44	30.68	28.02	25.57	229.90
1987	0.00	0.01	0.05	0.40	1.51	5.66	25.71	35.28	32.13	25.20	18.99	14.09	11.13	9.63	8.72	7.99	7.34	6.71	6.11	54.96
1988	0.00	0.02	0.11	0.54	2.70	9.54	25.42	65.99	62.83	50.65	38.23	28.32	20.80	16.29	14.00	12.61	11.52	10.54	9.61	86.26
1989	0.00	0.03	0.25	1.21	4.78	18.49	42.95	62.56	110.52	92.58	71.74	53.22	39.01	28.41	22.12	18.91	16.96	15.44	14.08	126.39
1990	0.00	0.02	0.27	1.96	7.60	22.48	55.65	68.63	66.57	102.69	82.56	62.86	46.13	33.54	24.27	18.80	16.01	14.31	12.98	116.55
1991	0.00	0.03	0.23	2.10	12.03	35.45	66.50	85.64	69.44	58.58	86.64	68.43	51.54	37.52	27.10	19.51	15.05	12.77	11.38	101.66
1992	0.00	0.04	0.27	2.01	14.00	59.96	110.55	105.07	87.53	61.40	49.60	72.06	56.30	42.05	30.42	21.86	15.67	12.04	10.19	89.01
1993	0.00	0.04	0.33	1.68	10.18	62.94	173.63	156.18	93.30	66.60	44.64	35.40	50.87	39.41	29.26	21.05	15.06	10.76	8.25	67.03
1994	0.00	0.06	0.51	3.56	13.40	50.31	152.89	180.83	97.12	48.97	33.29	21.89	17.17	24.47	18.84	13.91	9.97	7.11	5.06	34.95
1995	0.00	0.05	0.46	2.98	15.63	43.64	102.28	159.53	120.76	55.75	26.88	17.94	11.67	9.08	12.86	9.85	7.24	5.17	3.68	20.43
1996	0.00	0.02	0.20	1.63	7.69	28.54	50.71	62.57	63.17	41.24	18.22	8.63	5.69	3.67	2.84	4.00	3.05	2.24	1.59	7.33
1997	0.00	0.02	0.17	2.30	9.02	28.65	67.28	65.16	54.18	47.90	30.02	13.03	6.10	4.00	2.56	1.97	2.76	2.10	1.54	6.05
1998	0.00	0.02	0.10	0.77	5.20	23.47	57.51	78.44	52.09	38.08	32.35	19.93	8.56	3.98	2.59	1.65	1.26	1.77	1.34	4.78
1999	0.00	0.03	0.15	0.83	4.55	24.36	74.93	101.63	93.89	54.70	38.42	32.08	19.55	8.33	3.84	2.49	1.58	1.21	1.68	5.75
2000	0.00	0.04	0.39	1.78	6.45	27.53	91.59	142.94	126.46	101.42	56.64	39.07	32.27	19.51	8.26	3.79	2.44	1.55	1.18	7.17
2001	0.00	0.05	0.48	3.74	9.61	21.53	44.16	67.12	65.66	49.83	38.20	20.95	14.29	11.71	7.03	2.96	1.35	0.87	0.55	2.92
2002	0.00	0.05	0.36	2.99	14.27	25.04	35.85	46.88	52.36	45.91	33.62	25.36	13.76	9.31	7.58	4.53	1.90	0.87	0.55	2.18
2003	0.00	0.03	0.24	1.93	8.18	24.03	27.75	26.65	26.27	26.48	22.43	16.17	12.06	6.49	4.37	3.54	2.10	0.88	0.40	1.25
2004	0.00	0.02	0.20	2.18	5.47	19.52	47.13	39.29	28.94	25.85	25.21	21.02	14.99	11.09	5.93	3.97	3.20	1.90	0.79	1.47
2005	0.00	0.01	0.24	4.17	7.91	16.18	41.36	60.03	35.37	23.13	19.90	19.08	15.74	11.13	8.19	4.36	2.90	2.33	1.38	1.62
2006	0.00	0.01	0.15	1.47	5.70	18.37	41.12	73.41	78.42	41.40	26.12	22.11	20.97	17.16	12.06	8.83	4.68	3.10	2.49	3.17
2007	0.00	0.01	0.09	0.74	3.58	13.70	31.14	39.67	48.79	45.97	23.34	14.48	12.12	11.41	9.28	6.48	4.73	2.49	1.65	2.98
2008	0.00	0.01	0.06	0.41	2.45	10.66	31.19	43.49	39.36	43.04	39.07	19.51	11.97	9.94	9.30	7.52	5.24	3.80	2.00	3.68
2009	0.00	0.01	0.11	1.79	3.41	7.43	17.37	36.22	46.19	42.24	46.51	42.08	20.87	12.72	10.50	9.77	7.87	5.46	3.95	5.85
2010	0.00	0.02	0.10	0.62	1.97	5.67	15.83	34.39	51.54	48.76	38.57	40.19	35.54	17.42	10.54	8.65	8.02	6.44	4.45	7.92
2011	0.00	0.01	0.09	0.90	1.59	4.76	13.18	31.04	47.33	52.29	42.72	31.96	32.54	28.45	13.84	8.33	6.81	6.29	5.03	9.57
2012	0.01	0.03	0.16	1.08	2.93	6.53	18.99	40.10	62.03	67.96	64.32	49.57	36.22	36.46	31.64	15.31	9.17	7.47	6.88	15.82
2013	0.00	0.04	0.17	0.92	3.05	8.00	16.41	40.07	59.76	68.09	64.31	57.50	43.31	31.28	31.25	26.98	13.00	7.76	6.31	18.94
2014	0.01	0.09	0.51	1.92	5.65	16.48	32.86	47.62	74.82	79.22	76.85	68.32	59.64	44.39	31.82	31.62	27.17	13.05	7.77	24.98
2015	0.01	0.09	0.54	3.07	6.69	14.83	32.09	48.78	49.22	56.72	51.60	47.23	41.02	35.39	26.14	18.64	18.44	15.79	7.56	18.76
2016	0.01	0.08	0.52	3.55	9.23	16.16	29.48	54.88	63.63	49.27	49.61	42.80	38.33	32.91	28.19	20.71	14.70	14.50	12.38	20.40
2017	0.01	0.09	0.51	2.59	8.50	22.61	35.86	56.16	76.72	66.49	44.51	42.37	35.73	31.63	26.96	22.96	16.80	11.88	11.69	26.16
2018	0.01	0.04	0.28	2.00	5.22	12.66	26.74	34.57	38.64	38.89	28.95	18.28	17.00	14.17	12.45	10.55	8.95	6.53	4.60	14.50

Table 16. Estimated time series of landings in numbers (1000 fish) for commercial handline (cH), commercial longline (cL), and recreational (rA)

Year	L.cH	L.cL	L.rA
1972	0.04	0.47	0.00
1973	0.23	2.55	0.00
1974	0.56	6.18	0.00
1975	0.96	10.49	0.00
1976	1.01	10.58	0.00
1977	0.94	4.01	0.00
1978	2.47	5.51	0.00
1979	1.78	8.40	0.00
1980	5.32	14.60	0.00
1981	12.63	65.81	26.40
1982	26.63	242.59	0.00
1983	11.35	142.26	0.05
1984	8.24	96.98	1.04
1985	7.89	92.04	5.42
1986	7.47	103.96	0.01
1987	2.54	27.82	0.28
1988	4.07	48.00	0.07
1989	6.43	76.02	0.01
1990	6.75	78.40	0.07
1991	7.39	81.73	0.02
1992	7.20	96.21	0.45
1993	1.95	113.24	0.01
1994	15.50	84.86	0.37
1995	12.64	73.94	0.01
1996	6.18	37.22	0.25
1997	6.71	39.67	2.01
1998	5.42	40.06	0.06
1999	4.23	58.06	0.19
2000	5.94	81.14	0.55
2001	17.66	30.64	0.73
2002	18.35	25.37	0.37
2003	10.78	17.03	1.40
2004	5.61	26.81	2.36
2005	5.18	26.39	6.01
2006	5.24	42.44	1.24
2007	5.33	28.94	0.27
2008	2.71	32.15	0.01
2009	1.68	32.09	3.79
2010	3.03	34.39	0.90
2011	1.21	35.03	1.52
2012	6.24	45.60	0.81
2013	5.06	48.97	0.69
2014	15.64	56.17	0.63
2015	16.55	39.24	1.31
2016	13.60	42.76	2.53
2017	14.55	48.82	0.62
2018	7.29	27.06	1.61

Table 17. Estimated time series of landings in gutted weight (1000 lb) for commercial handline (cH), commercial longline (cL), and recreational (rA)

Year	L.cH	L.cL	L.rA
1972	0.40	4.74	0.00
1973	2.17	25.83	0.00
1974	5.25	62.60	0.00
1975	8.98	106.31	0.00
1976	9.42	107.23	0.00
1977	8.82	40.63	0.00
1978	23.07	55.86	0.00
1979	16.61	85.15	0.00
1980	49.70	148.05	0.00
1981	117.50	666.28	214.46
1982	242.95	2435.52	0.04
1983	99.44	1397.83	0.37
1984	69.50	928.19	7.30
1985	64.66	857.30	38.04
1986	60.23	944.01	0.06
1987	20.52	249.14	1.93
1988	33.14	432.39	0.46
1989	51.65	687.96	0.04
1990	51.99	701.48	0.41
1991	53.42	708.04	0.13
1992	48.98	788.58	2.48
1993	12.75	873.82	0.04
1994	99.47	632.97	1.89
1995	79.44	546.39	0.04
1996	38.40	273.34	1.27
1997	42.39	291.92	10.50
1998	35.28	298.27	0.33
1999	28.44	440.46	1.10
2000	40.49	626.89	3.10
2001	119.25	239.99	3.78
2002	121.37	200.11	1.89
2003	70.69	133.12	7.45
2004	37.36	207.88	12.91
2005	35.32	206.06	33.66
2006	36.47	337.15	7.12
2007	37.75	233.33	1.57
2008	19.64	263.03	0.04
2009	12.61	283.75	23.99
2010	23.21	307.55	5.88
2011	9.44	317.30	10.03
2012	49.13	418.17	5.34
2013	39.70	452.90	4.53
2014	120.61	520.18	3.99
2015	124.35	360.43	7.85
2016	99.20	387.60	14.55
2017	102.55	434.16	3.50
2018	50.49	235.54	9.00

Table 18. Estimated status indicators, benchmarks, and related quantities from the base run of the Beaufort catch-age model, conditional on estimated current selectivities averaged across fleets. Also presented are median values and measures of precision (standard errors, SE), 25th and 75th percentiles from the Monte Carlo Bootstrap Ensemble (MCBE). Rate estimates (F) are in units of y^{-1}*; status indicators are dimensionless; and biomass estimates are in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) is measured in gonad wgt (mt)*

			MCBE			
Quantity	Units	Estimate	Median	SE	25%	75%
F_{MSY}	y^{-1}	0.297	0.261	0.188	0.18	0.384
$85\%F_{\mathrm{MSY}}$	y^{-1}	0.252	0.222	0.159	0.153	0.326
$75\%F_{\mathrm{MSY}}$	y^{-1}	0.223	0.196	0.141	0.135	0.288
$65\%F_{\mathrm{MSY}}$	y^{-1}	0.193	0.17	0.122	0.117	0.25
$F_{20\%}$	y^{-1}	0.381	0.432	0.136	0.336	0.558
$F_{30\%}$	y^{-1}	0.204	0.228	0.055	0.186	0.276
$F_{40\%}$	y^{-1}	0.129	0.141	0.03	0.117	0.168
B_{MSY}	metric tons	2282	2491.7	411.8	2256.8	2799.9
$\mathrm{SSB}_{\mathrm{MSY}}$	gonad wgt (mt)	18.8	20.9	6.5	17	25.9
MSST	gonad wgt (mt)	14.1	15.7	4.8	12.8	19.4
MSY	1000 lb gutted	518.4	506.9	73.9	461.6	561.2
R_{MSY}	1000 fish	295.9	337.1	105.2	257.7	434.4
$L_{85\%\mathrm{MSY}}$	1000 lb gutted	516.2	504.3	74.6	458.4	559.2
$L_{75\%\mathrm{MSY}}$	1000 lb gutted	511.5	499.5	76	452	554.8
$L_{65\%\mathrm{MSY}}$	1000 lb gutted	502.8	490	78.1	440.8	546.6
$F_{2016-2018}/F_{\mathrm{MSY}}$	—	0.864	1.029	1.123	0.602	1.779
$\mathrm{SSB}_{2018}/\mathrm{MSST}$	—	1.294	1.135	0.622	0.756	1.616
$\mathrm{SSB}_{2018}/\mathrm{SSB}_{\mathrm{MSY}}$	—	0.97	0.851	0.466	0.567	1.212

Table 19. Results from sensitivity runs of the Beaufort catch-age model. Current F represented by geometric mean of last three assessment years ($F/F_{\mathrm{MSY}} = F_{2016-2018}/F_{\mathrm{MSY}}$). MSY *is in 1000 lb gutted weight. Stock and rebuild status based on terminal year* ($\mathrm{SSB/MSST} = \mathrm{SSB}_{2018}/\mathrm{MSST}$; $\mathrm{SSB/SSB}_{\mathrm{MSY}} = \mathrm{SSB}_{2018}/\mathrm{SSB}_{\mathrm{MSY}}$). h *= Beverton-Holt steepness.* δ_{status} *is the absolute linear distance in status space* $[(x, y) = (F/F_{\mathrm{MSY}}, \mathrm{SSB/MSST})]$ *between sensitivity results and base model results, as an overall metric of sensitivity. See text for full description of sensitivity runs.*

Description	F_{MSY}	$\mathrm{SSB}_{\mathrm{MSY}}$ (mt)	B_{MSY} (mt)	MSY (1000 lb)	F/F_{MSY}	SSB/MSST	$\mathrm{SSB/SSB}_{\mathrm{MSY}}$	h	R_0 (1000 $fish$)	δ_{status}
Base	0.297	19	2282	518	0.86	1.29	0.97	0.84	283	0.00
S1 set M constant lo	0.204	22	2238	457	1.72	0.78	0.58	0.84	182	1.00
S2 set M constant up	0.552	16	2453	619	0.35	2.18	1.63	0.84	526	1.02
S3 set steep lo	0.210	23	2565	483	1.40	0.91	0.68	0.74	296	0.66
S4 set steep up	0.480	14	1984	559	0.48	1.90	1.42	0.94	272	0.72
S5 set F init 0.5lkmin	0.297	20	2409	548	0.79	1.35	1.01	0.84	299	0.09
S6 set F init lkmin	0.297	21	2517	572	0.73	1.39	1.04	0.84	313	0.17
S7 set w cpue sM lo	0.288	20	2366	536	0.63	1.65	1.24	0.84	294	0.42
S8 set w cpue sM up	0.456	16	1930	442	2.13	0.96	0.72	0.84	235	1.31
S9 rec alt 06to11	0.288	18	2193	497	1.28	0.79	0.59	0.84	273	0.65

Table 20. Projection results with fishing mortality rate fixed at $F = F_{\mathrm{P}^*_{50\%}}$ *starting in 2022 and projecting forward to 2027. From 2019 to 2021 the fishing mortality rate was fixed at* $F_{\mathrm{current}} = 0.2566$*.* 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 gutted weight (GW, in 1000* lb*),* $P(>\mathrm{MSST})$*= proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{MSST}$*. 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 (mt)	S_{med} (mt)	L_b (n)	L_{med} (n)	L_b (GW)	L_{med} (GW)	$P(>\mathrm{MSST})$
2019	294	0	0.26	0.27	19	18	54	52	440	428	0.611
2020	297	246	0.26	0.27	19	18	57	54	457	437	0.614
2021	297	250	0.26	0.27	20	18	58	55	472	446	0.610
2022	298	247	0.30	0.26	20	18	68	56	552	463	0.599
2023	298	248	0.30	0.26	20	17	67	56	546	458	0.593
2024	298	246	0.30	0.26	19	16	67	54	539	449	0.571
2025	297	246	0.30	0.26	19	15	66	51	533	426	0.546
2026	297	247	0.30	0.26	19	15	65	48	529	394	0.540
2027	297	248	0.30	0.26	19	16	65	47	526	380	0.555

Table 21. Projection results with fishing mortality rate fixed at $F = F_{\mathrm{MSY}}$ starting in 2022 and projecting forward to 2027. From 2019 to 2021 the fishing mortality rate was fixed at $F_{\mathrm{current}} = 0.2566$. 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 gutted weight (GW, in 1000 lb*), $P(>\mathrm{MSST})$= proportion of stochastic projection replicates with* SSB $\geq$ MSST. *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 (mt)	S_{med} (mt)	L_b (n)	L_{med} (n)	L_b (GW)	L_{med} (GW)	$P(>\mathrm{MSST})$
2019	294	0	0.26	0.27	19	18	54	52	440	427	0.596
2020	297	246	0.26	0.27	19	18	57	54	457	436	0.598
2021	297	250	0.26	0.27	20	18	58	55	472	445	0.596
2022	298	244	0.30	0.26	20	17	68	55	552	449	0.585
2023	298	244	0.30	0.26	20	16	67	55	546	451	0.579
2024	298	246	0.30	0.26	19	16	67	53	539	442	0.561
2025	297	243	0.30	0.26	19	15	66	51	533	422	0.539
2026	297	244	0.30	0.26	19	15	65	48	529	391	0.531
2027	297	246	0.30	0.26	19	16	65	47	526	377	0.548

Table 22. Projection results with fishing mortality rate fixed at $F = F_{\mathrm{P}^*_{30\%}}$ *starting in 2022 and projecting forward to 2027. From 2019 to 2021 the fishing mortality rate was fixed at* $F_{\mathrm{current}} = 0.2566$. 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 gutted weight (GW, in 1000 lb),* $P(>\mathrm{MSST})$*= proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{MSST}$*. 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 (mt)	S_{med} (mt)	L_b (n)	L_{med} (n)	L_b (GW)	L_{med} (GW)	$P(>\mathrm{MSST})$
2019	294	0	0.26	0.27	19	18	54	52	440	428	0.605
2020	297	249	0.26	0.27	19	18	57	54	457	437	0.608
2021	297	247	0.26	0.27	20	18	58	55	472	445	0.604
2022	298	244	0.20	0.17	20	18	47	38	383	312	0.601
2023	300	249	0.20	0.17	21	18	49	40	404	333	0.628
2024	301	249	0.20	0.17	22	18	51	41	422	346	0.652
2025	303	255	0.20	0.17	22	18	52	41	436	349	0.676
2026	304	256	0.20	0.17	23	18	53	40	447	340	0.700
2027	305	255	0.20	0.17	23	19	54	39	455	335	0.727

Table 23. Projection results with fishing mortality rate fixed at $F = 0.75F_{\mathrm{MSY}}$ starting in 2022 and projecting forward to 2027. From 2019 to 2021 the fishing mortality rate was fixed at $F_{\mathrm{current}} = 0.2566$. 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 gutted weight (GW, in 1000 lb), $P(>\mathrm{MSST})$= proportion of stochastic projection replicates with SSB $\geq$ MSST. 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 (mt)	S_{med} (mt)	L_b (n)	L_{med} (n)	L_b (GW)	L_{med} (GW)	$P(>\mathrm{MSST})$
2019	294	0	0.26	0.27	19	18	54	52	440	428	0.602
2020	297	249	0.26	0.27	19	18	57	54	457	436	0.605
2021	297	248	0.26	0.27	20	18	58	55	472	445	0.603
2022	298	246	0.22	0.20	20	18	52	43	425	350	0.598
2023	299	248	0.22	0.20	21	18	54	44	442	366	0.617
2024	301	251	0.22	0.20	21	17	55	44	455	373	0.635
2025	302	250	0.22	0.20	22	17	56	44	465	371	0.649
2026	302	251	0.22	0.20	22	18	57	42	472	356	0.668
2027	303	254	0.22	0.20	22	18	57	42	478	348	0.693

9 Figures

Figure 1. Timeline of data fit to in this assessment. Date types include landings (L), indices of abundance (index; CPUE), age compositions (ageComp; acomp), and length compositions (lengthComp; lcomp). Data sources include the commercial (com) handline (cH), commercial longline (cL), and general recreational (rec all; rA) fleets, and the MARMAP longline survey.

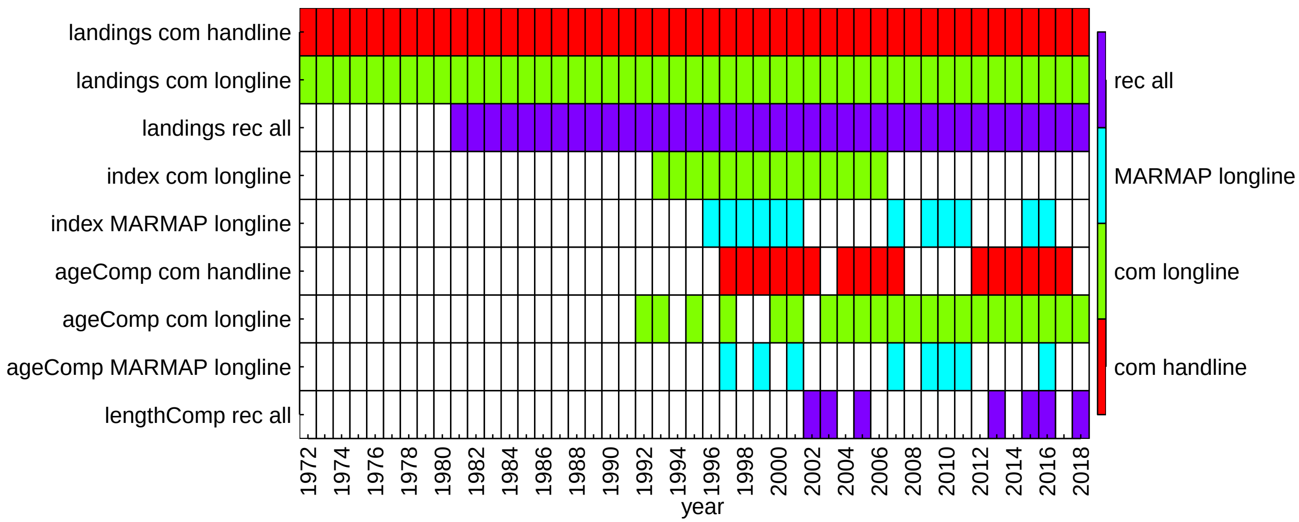


Figure 2. Length, female maturity, and reproductive output at age. Top panel: Mean length at age (mm) and estimated 95% confidence interval of the population. Middle panel: Female maturity by age. Bottom panel: Reproductive output (mt W_{gonad}) by age.

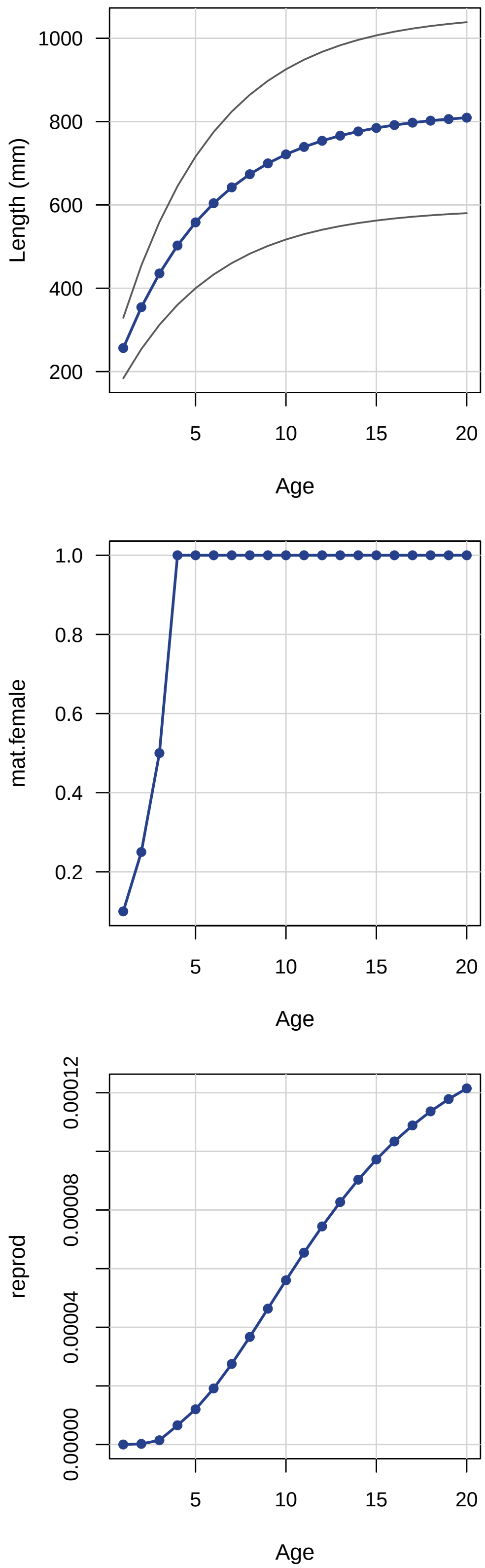


Figure 3. Observed (open circles) and estimated (solid line) annual and and length compositions by fleet. In panels indicating the data set: acomp = age compositions, lcomp = length compositions, cH = commercial handline, cL = commercial longline, sM = MARMAP longline survey, rA = general recreational. N indicates the number of trips from which individual fish samples were taken. The four digit number in upper right corner of each panel indicates year of sampling (e.g. 1997, 1998).

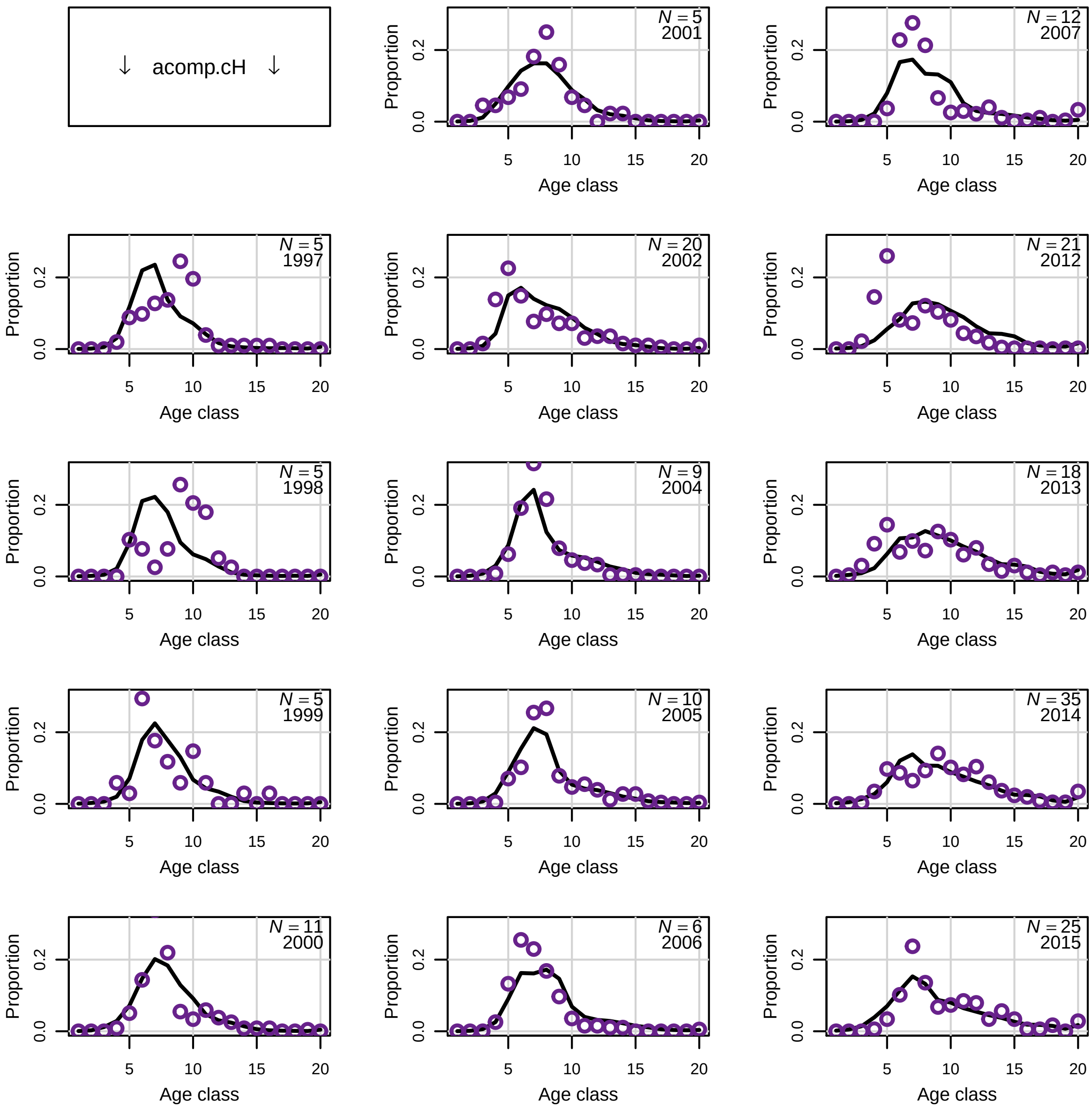


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual age and length compositions by fleet.

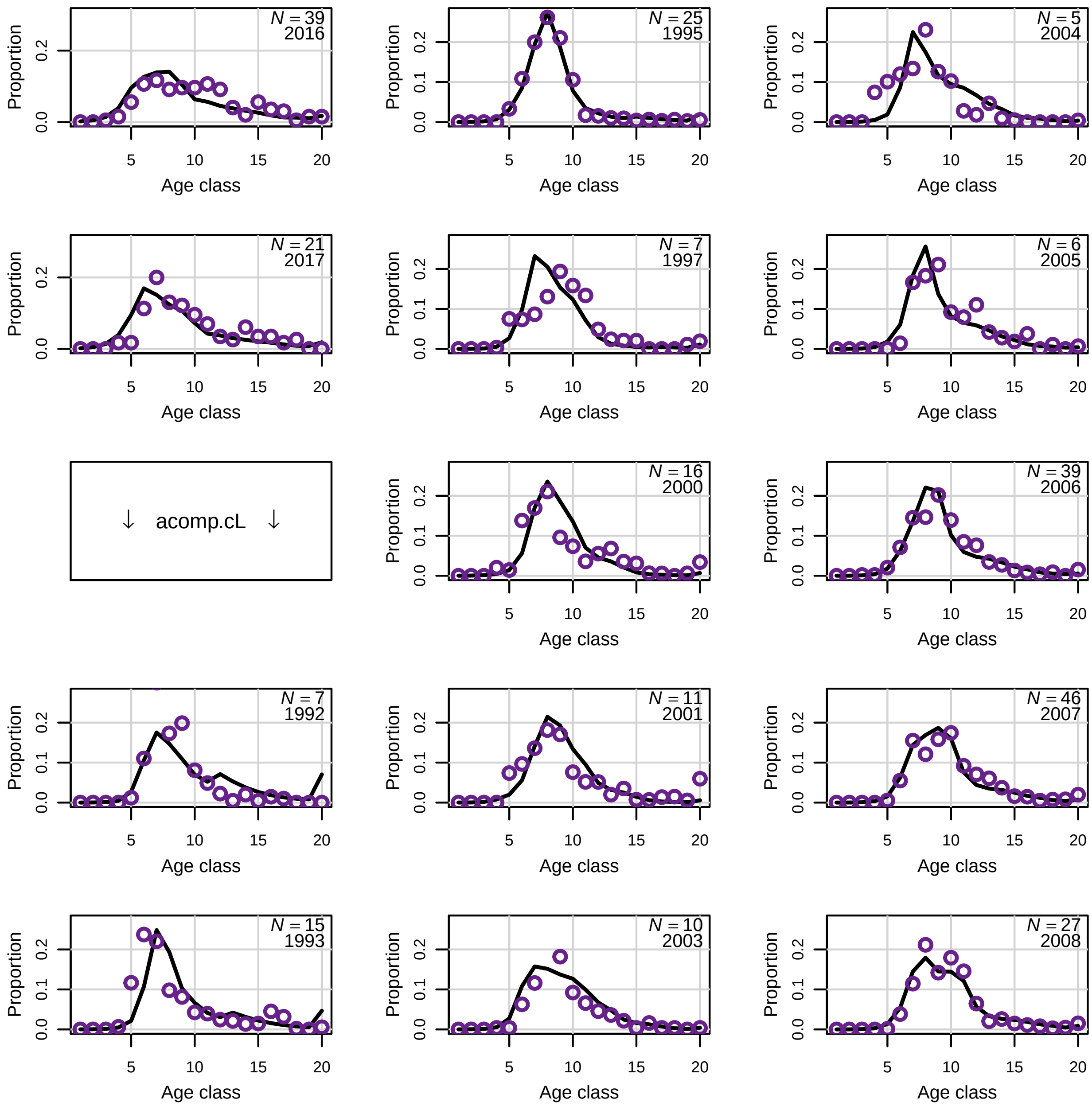


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual age and length compositions by fleet.

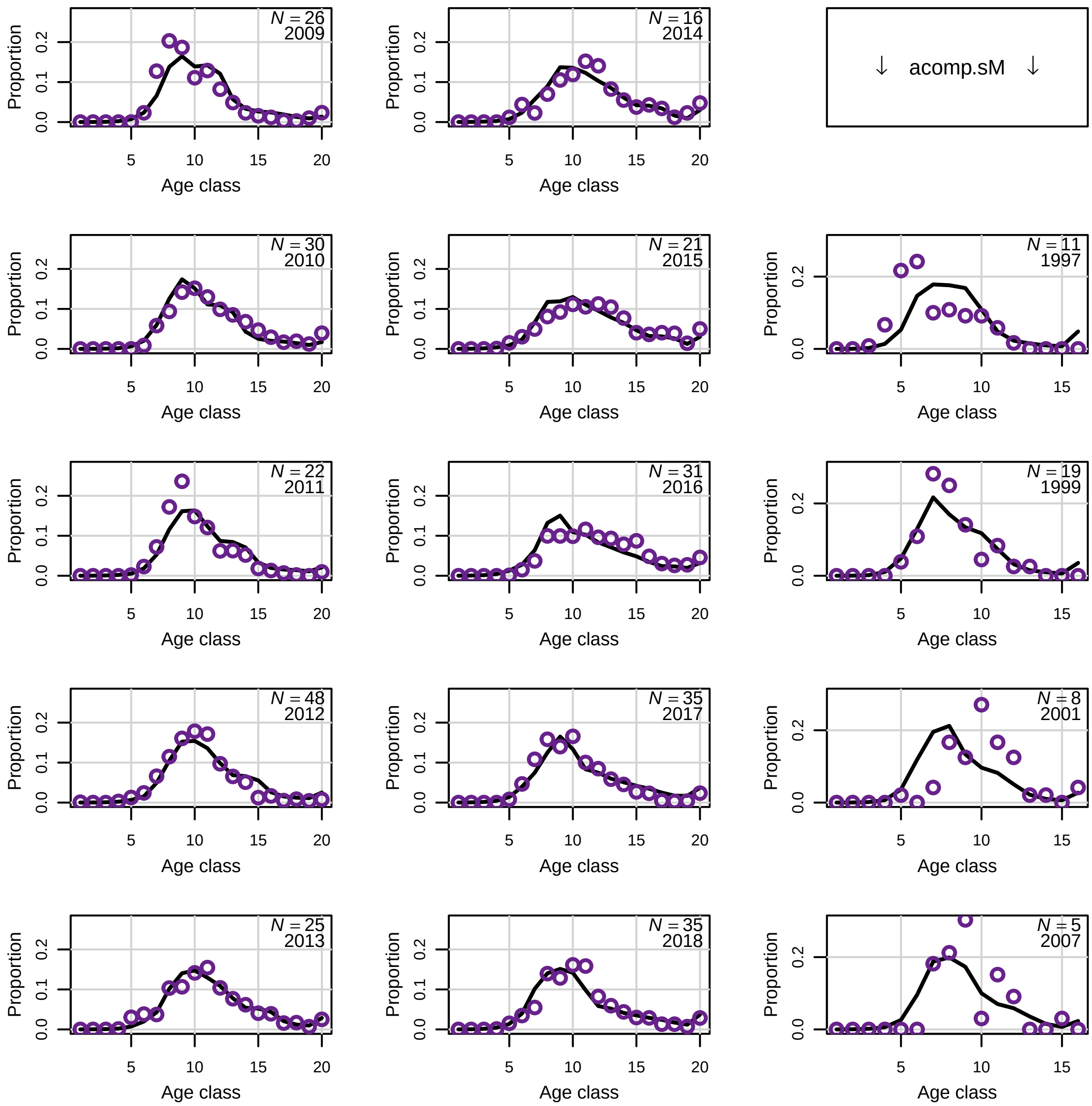


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual age and length compositions by fleet.

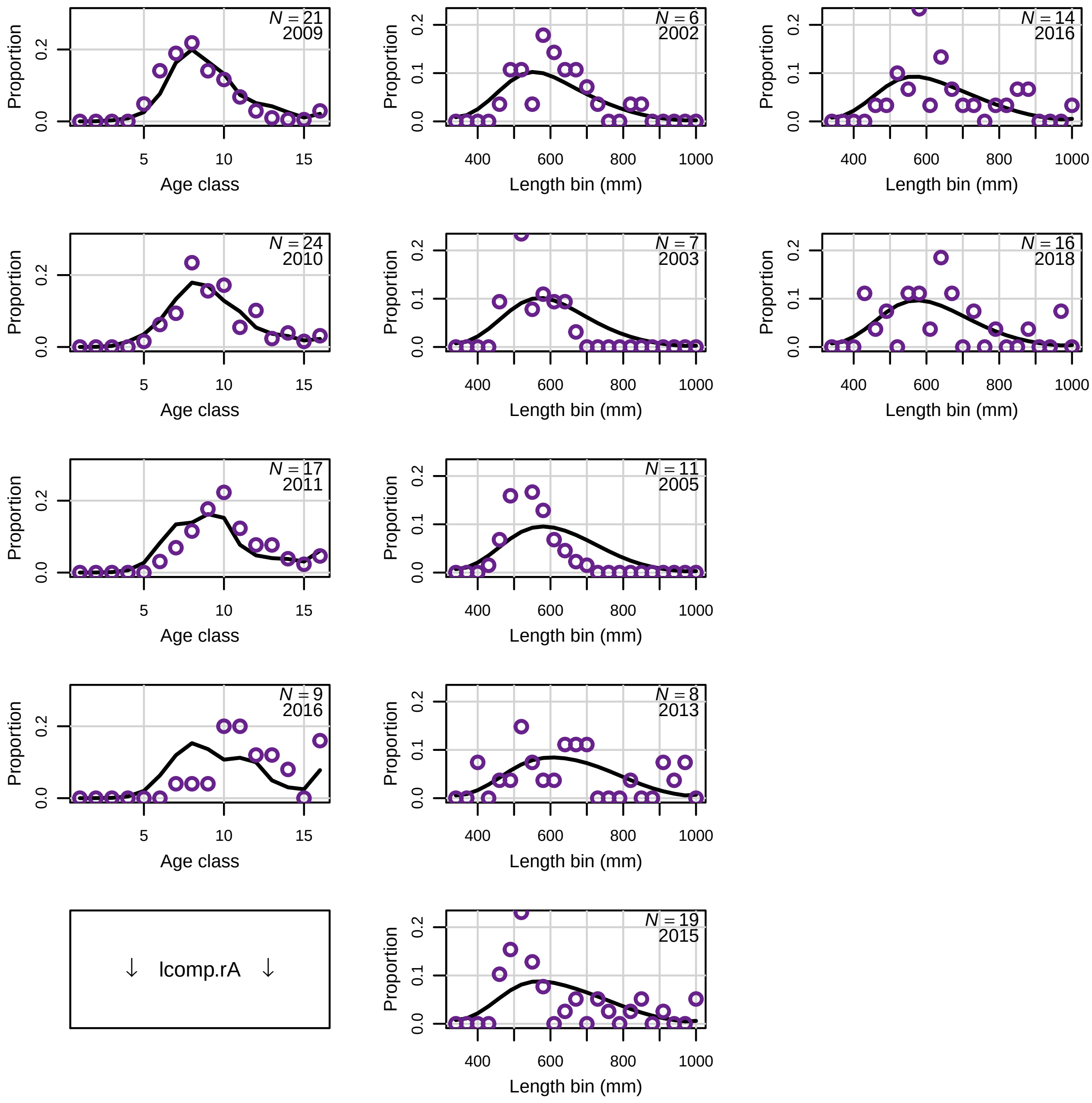


Figure 4. Observed (open circles) and estimated (line, solid circles) commercial handline landings (1000 lb gutted weight).

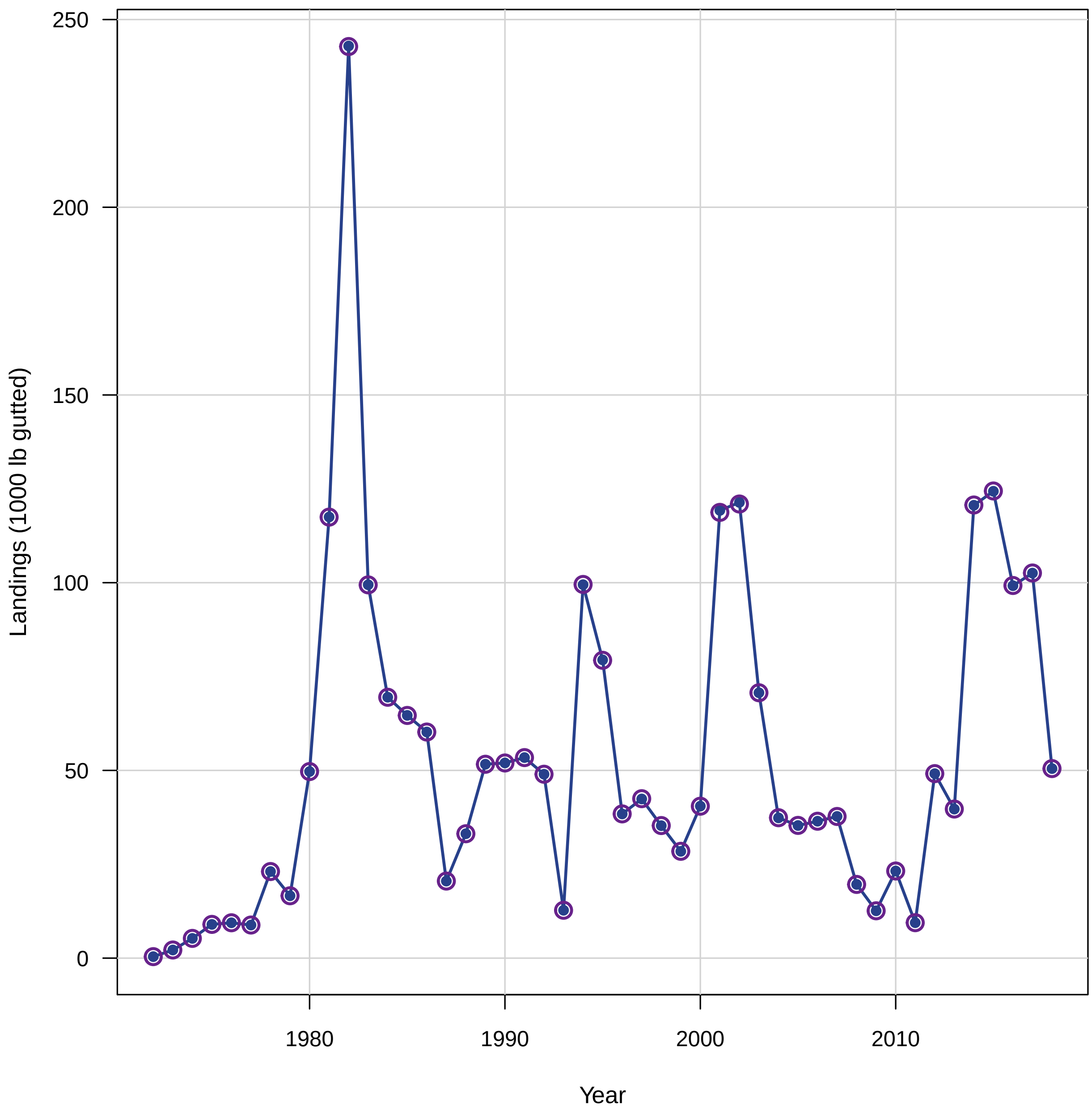


Figure 5. Observed (open circles) and estimated (line, solid circles) commercial longline landings (1000 lb gutted weight).

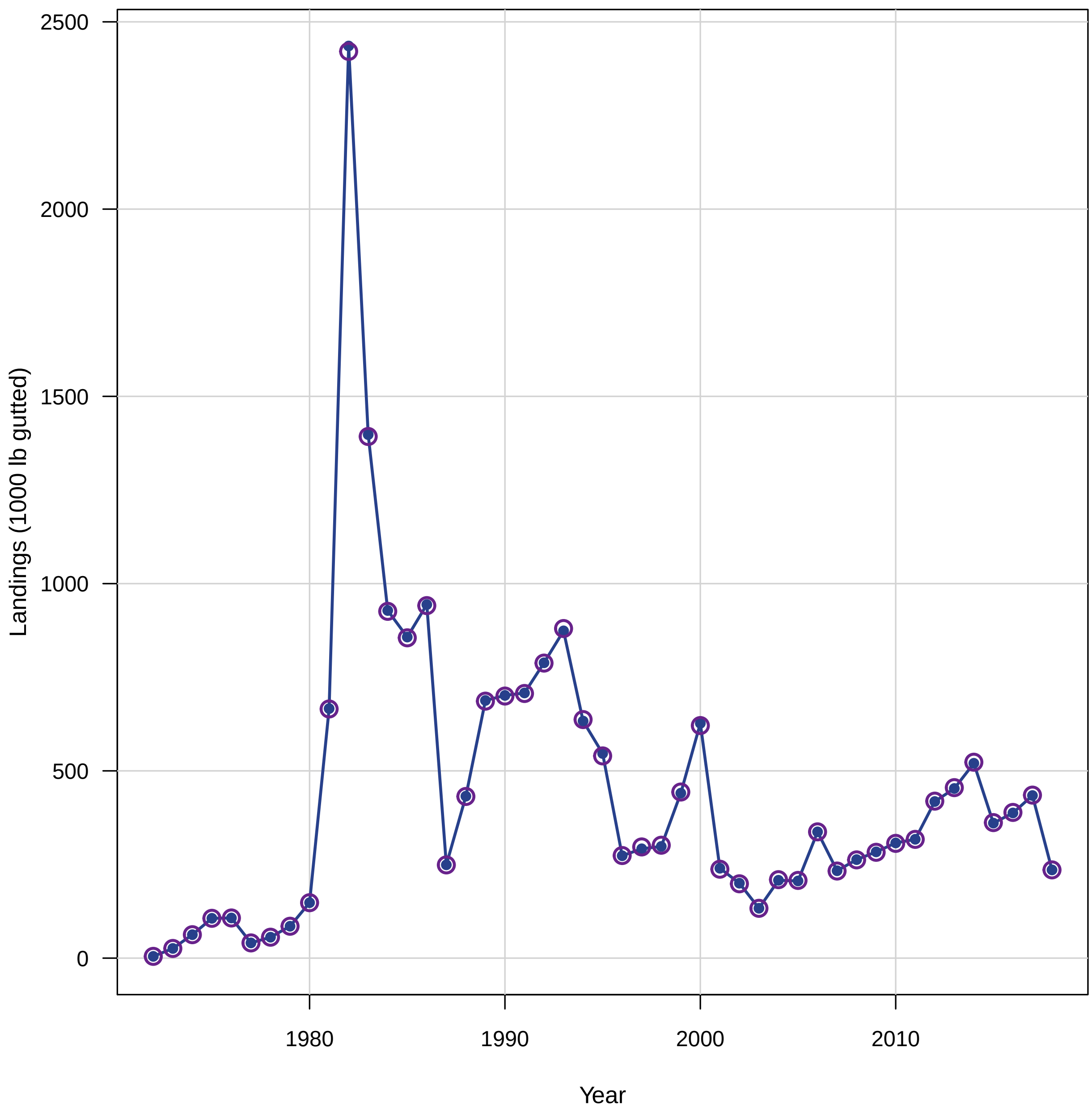


Figure 6. Observed (open circles) and estimated (line, solid circles) recreational landings (1000 lb gutted weight).

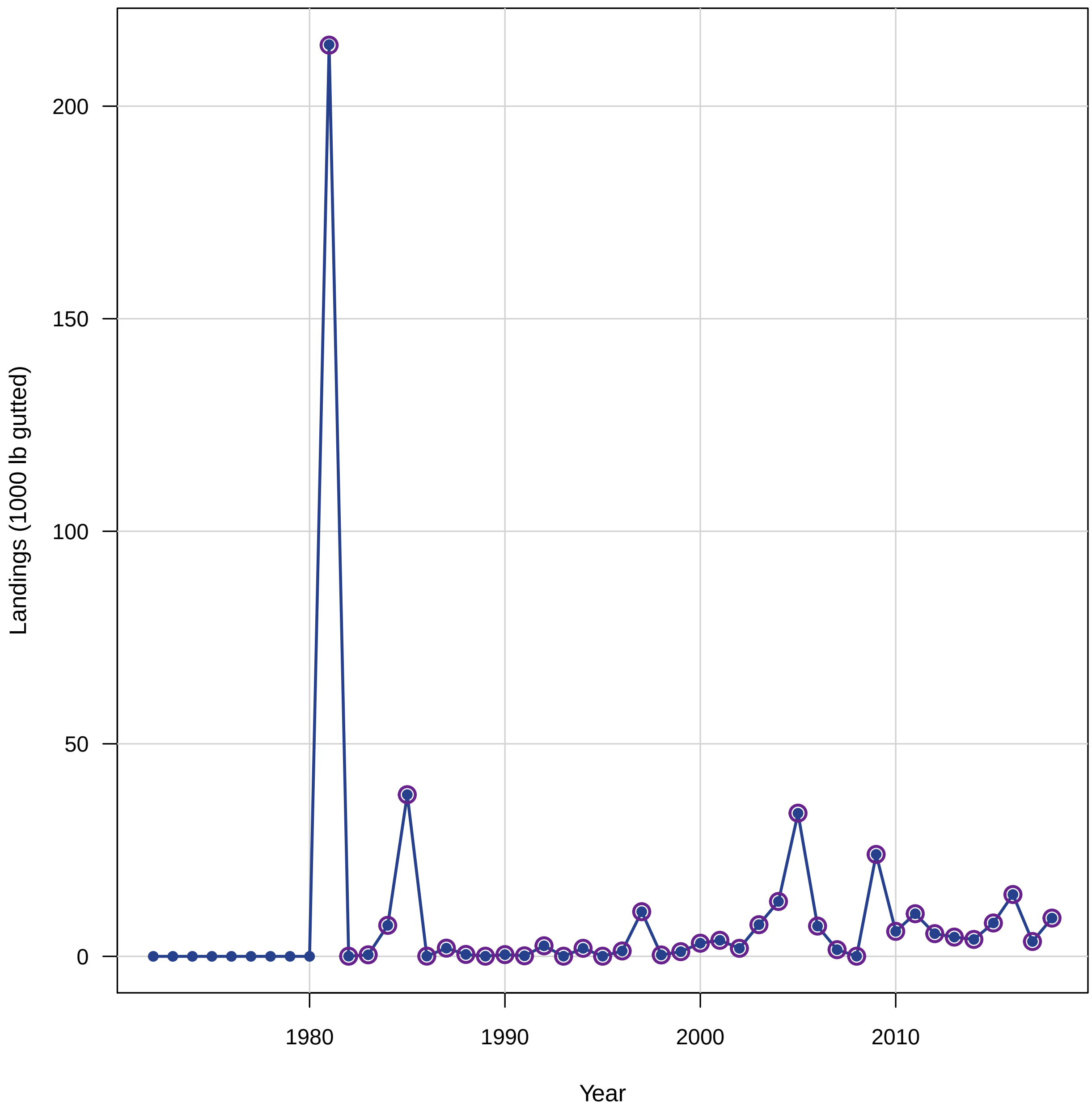


Figure 7. Observed (open circles) and estimated (line, solid circles) commercial longline index of abundance . In the upper panel, error bars indicate ±2 standard errors of the observed index (U_{ob}). In the lower panel, scaled residuals are computed $(U_{ob} - U_{pr})/mean(abs(U_{ob} - U_{pr}))$.

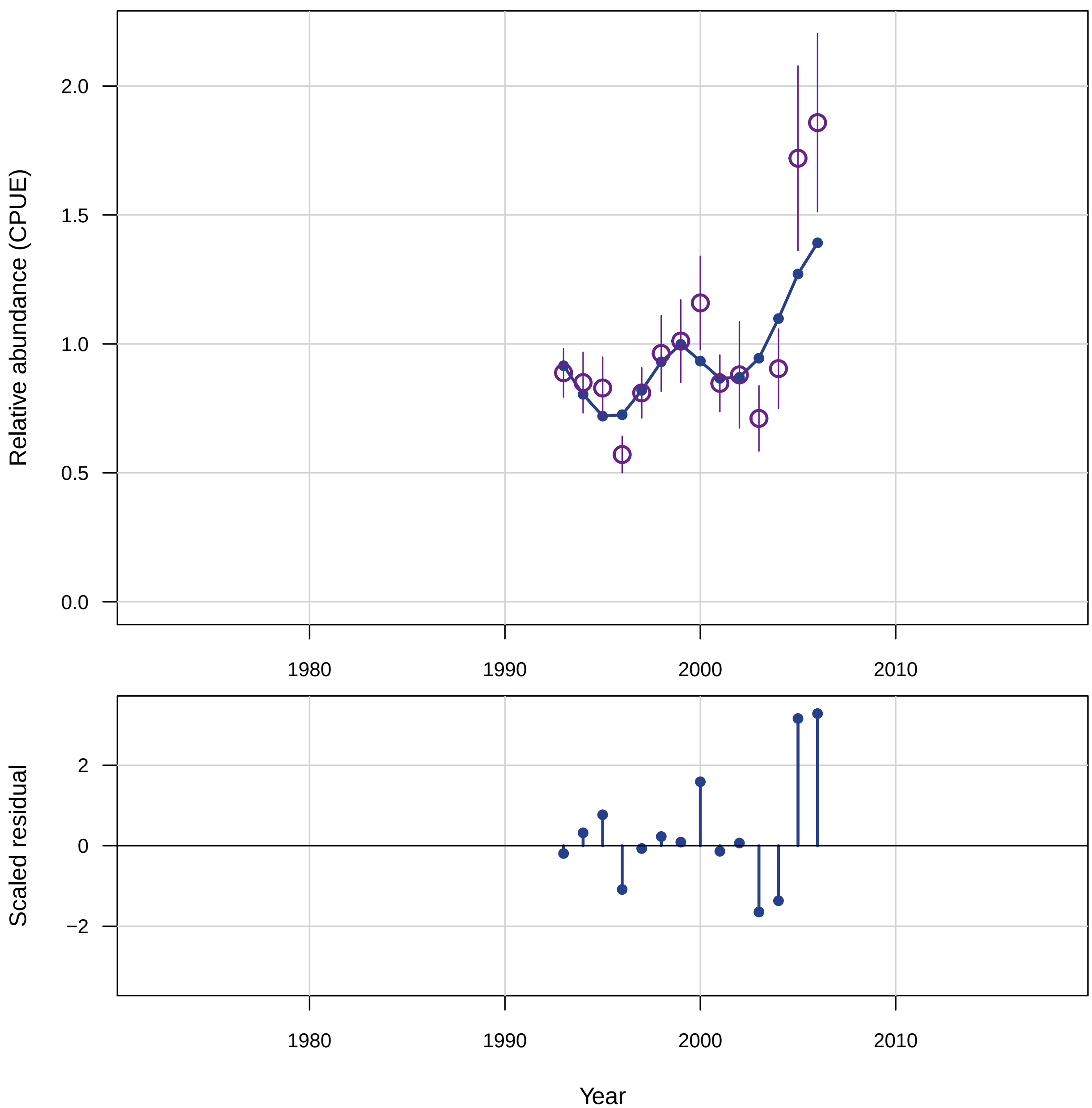


Figure 8. Observed (open circles) and estimated (line, solid circles) MARMAP longline survey index of abundance . In the upper panel, error bars indicate ±2 standard errors of the observed index (U_{ob}). In the lower panel, scaled residuals are computed $(U_{ob} - U_{pr})/mean(abs(U_{ob} - U_{pr}))$.

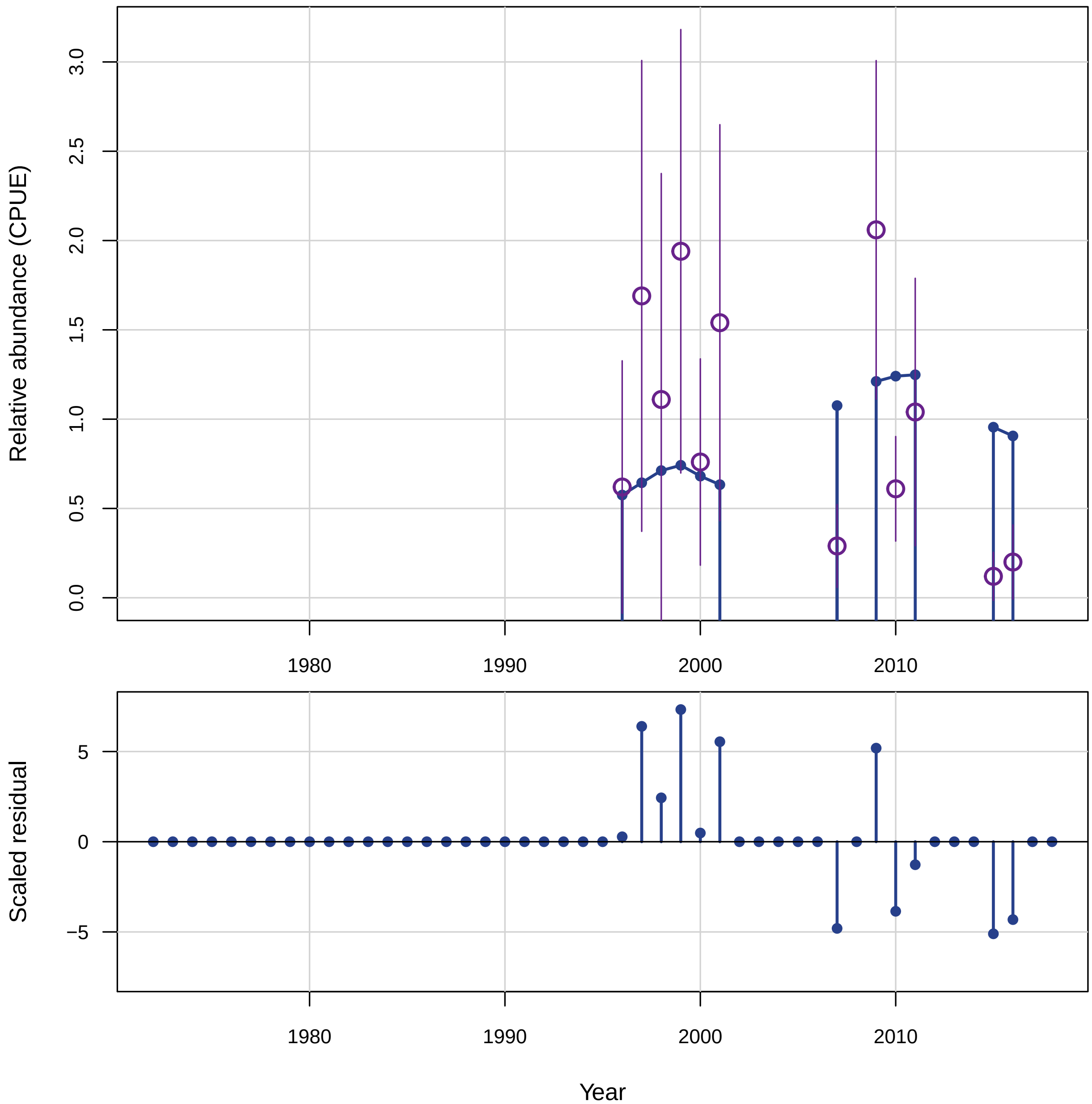


Figure 9. Estimated abundance at age at start of year

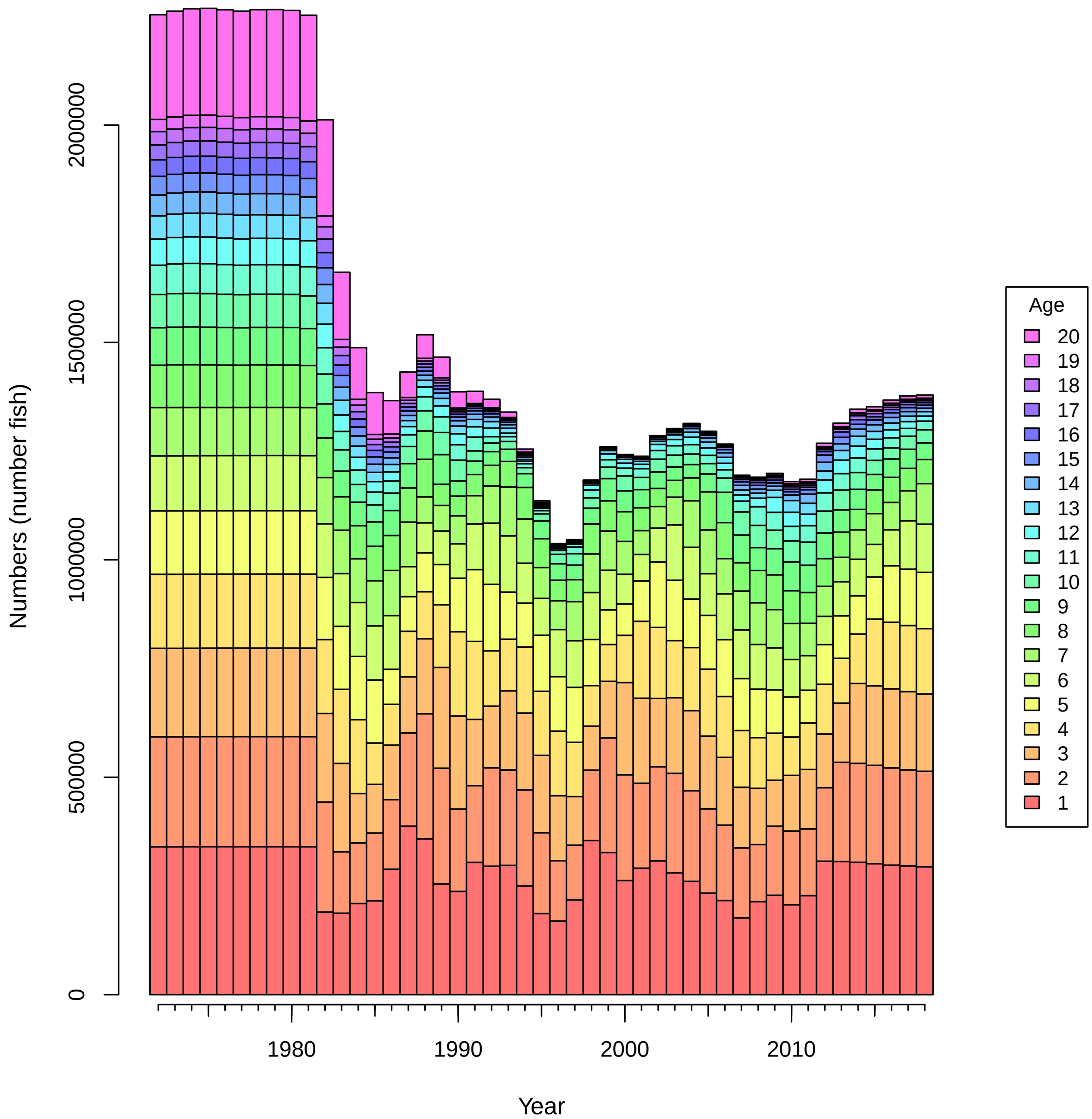


Figure 10. Estimated biomass at age at start of year.

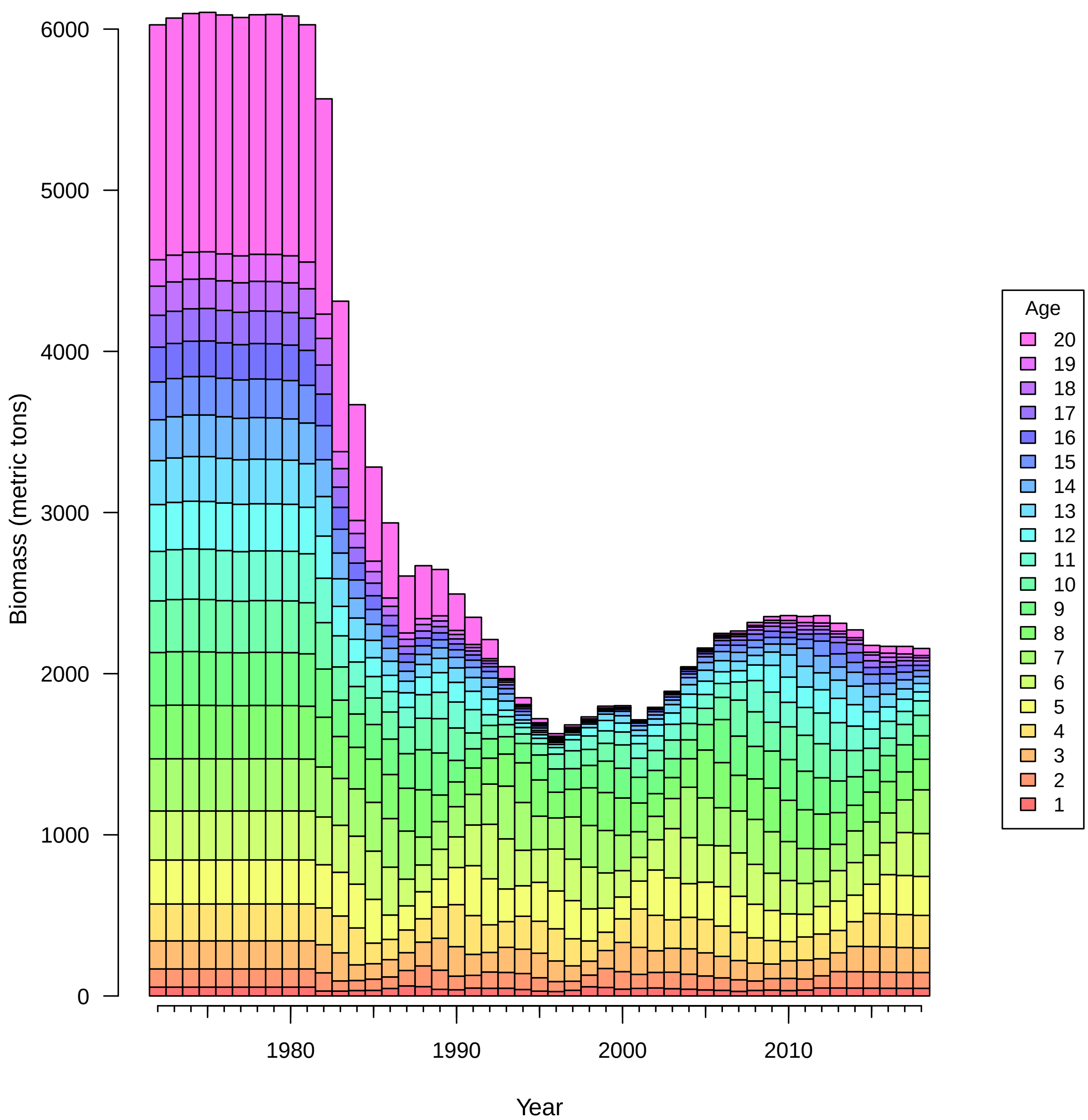


Figure 11. Estimated recruitment time series. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates R_{MSY}. Bottom panel: log recruitment residuals (open circles). These are annual recruitment deviations (r_y) estimated within the model. The solid tan line is a lowess smoother fit to the residuals.

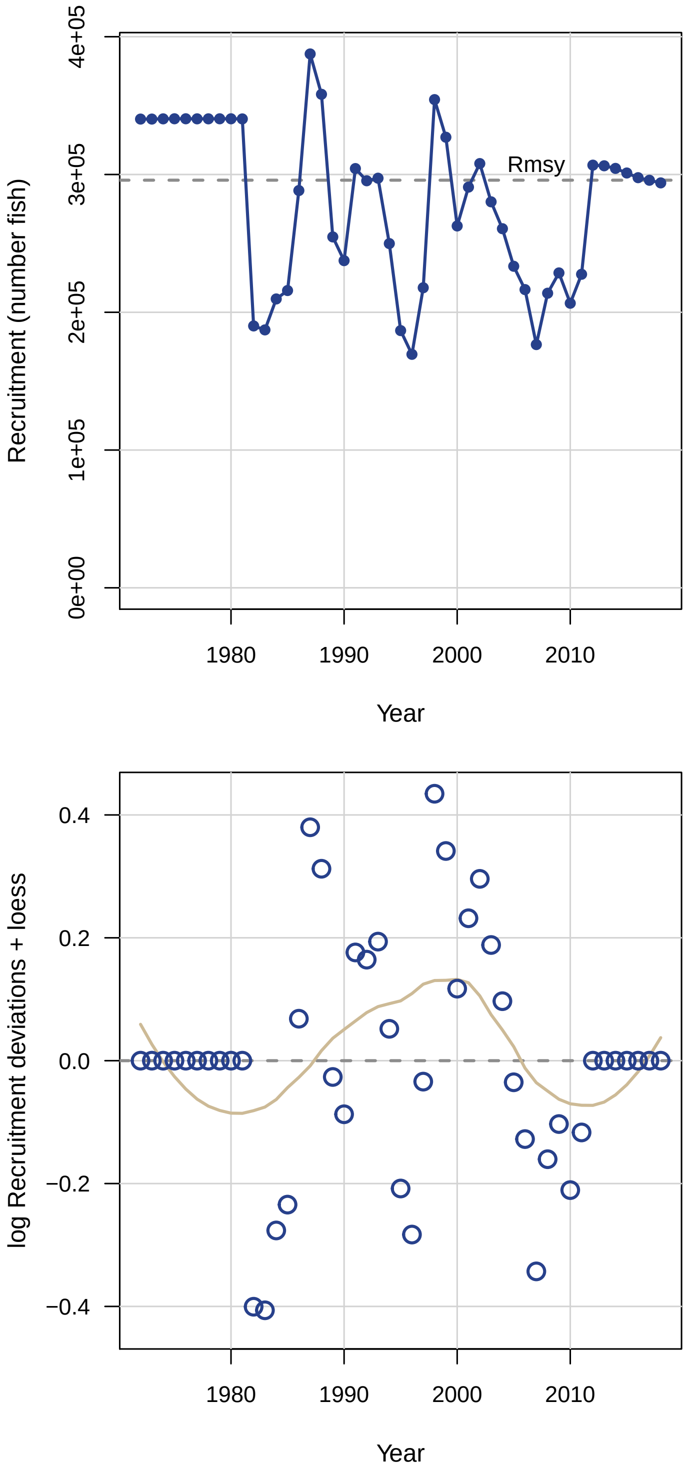


Figure 12. Estimated total biomass and spawning stock time series. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates B_{MSY}. Bottom panel: Estimated spawning stock (mt) at time of peak spawning (May 31^{st}; 0.42 yr).

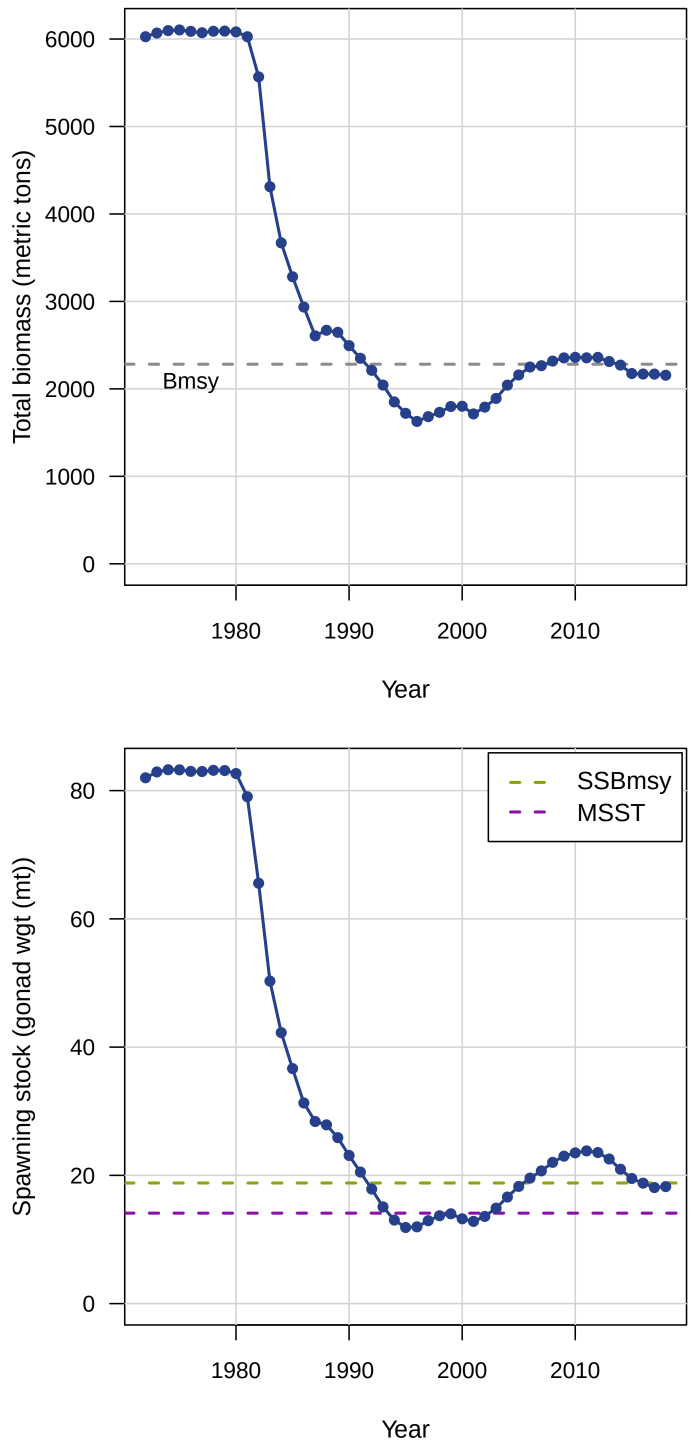


Figure 13. Selectivity of MARMAP longline index. Different colored lines indicate different selectivity blocks. The first year of each selectivity block is indicated in the legend. In this case, there was only one selectivity block.

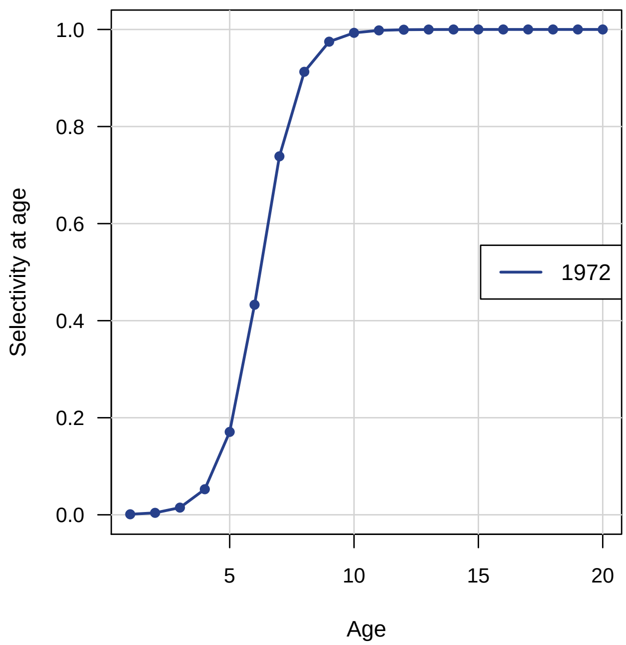


Figure 14. Selectivities of commercial handline landings (top) and commercial longline landings (bottom). Different colored lines indicate different selectivity blocks. The first year of each selectivity block is indicated in the legend.

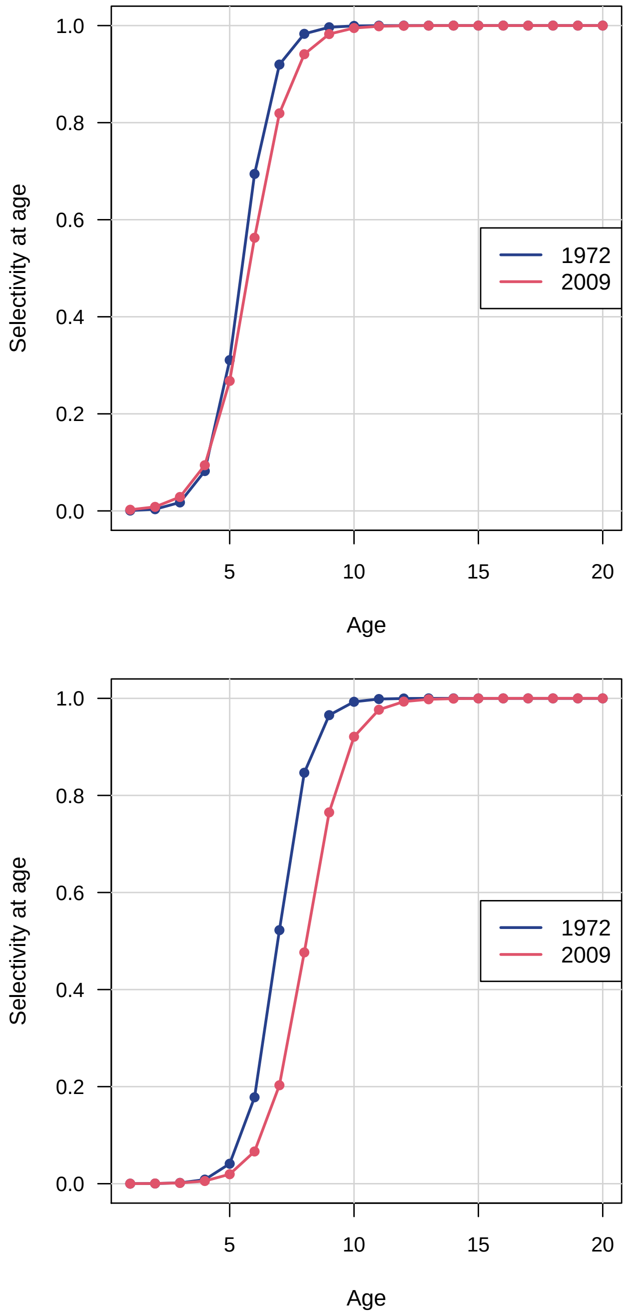


Figure 15. Selectivity of recreational landings. Different colored lines indicate different selectivity blocks. The first year of each selectivity block is indicated in the legend. In this case, there was only one selectivity block.

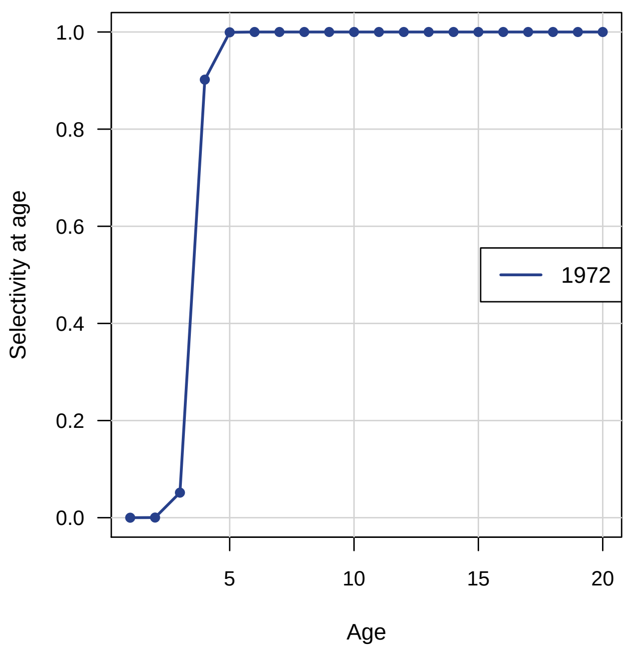


Figure 16. Average selectivity from the terminal assessment year weighted by geometric mean Fs from the last three assessment years, for landings. This selectivity is used in computation of benchmarks and central-tendency projections.

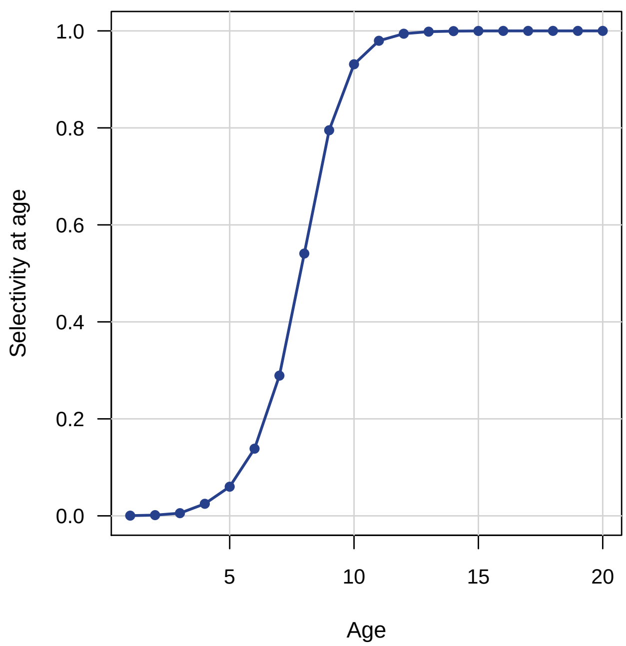


Figure 17. Estimated fully selected fishing mortality rate (per year) by fleet. rA = recreational, cL = commercial longline, and cH = commercial handline landings.

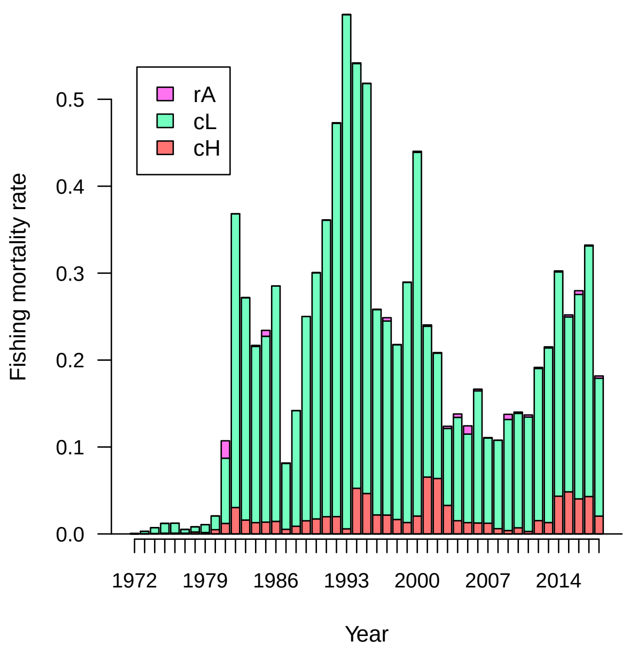
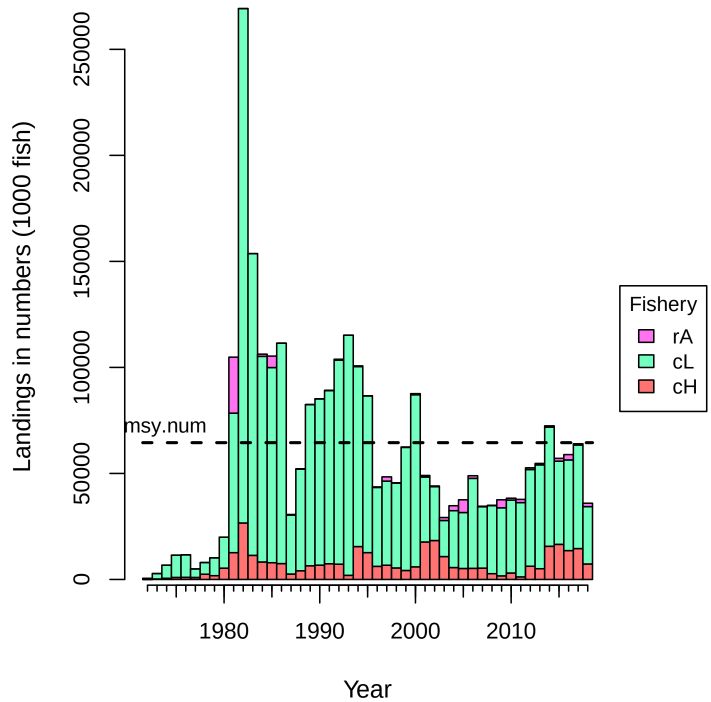


Figure 18. Estimated landings in absolute numbers (top) and proportion of total numbers (bottom) by fleet from the catch-at-age model. rA = recreational landings, cL = commercial longline landings, and cH = commercial handline landings



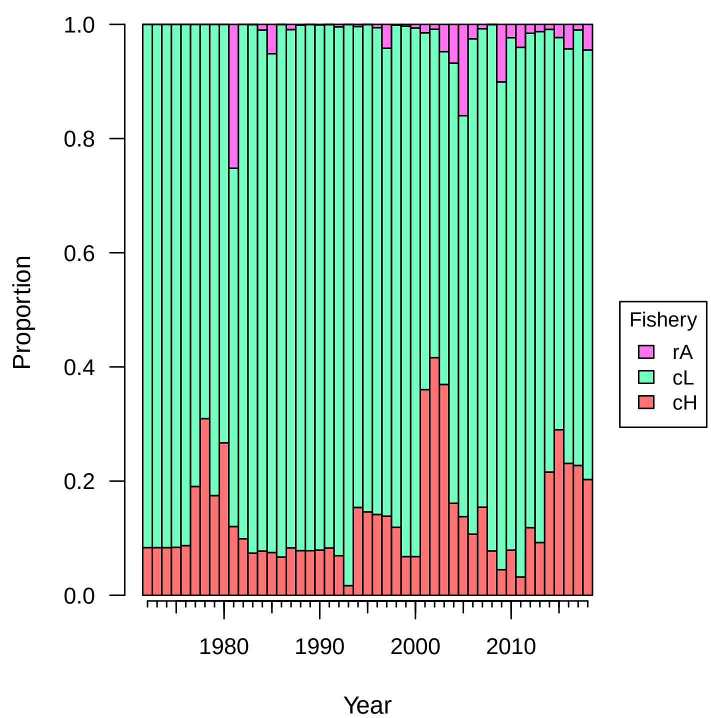


Figure 19. Estimated landings in absolute weight (top) and proportion of total weight (bottom) by fleet from the catch-at-age model. rA = recreational landings, cL = commercial longline landings, and cH = commercial handline landings

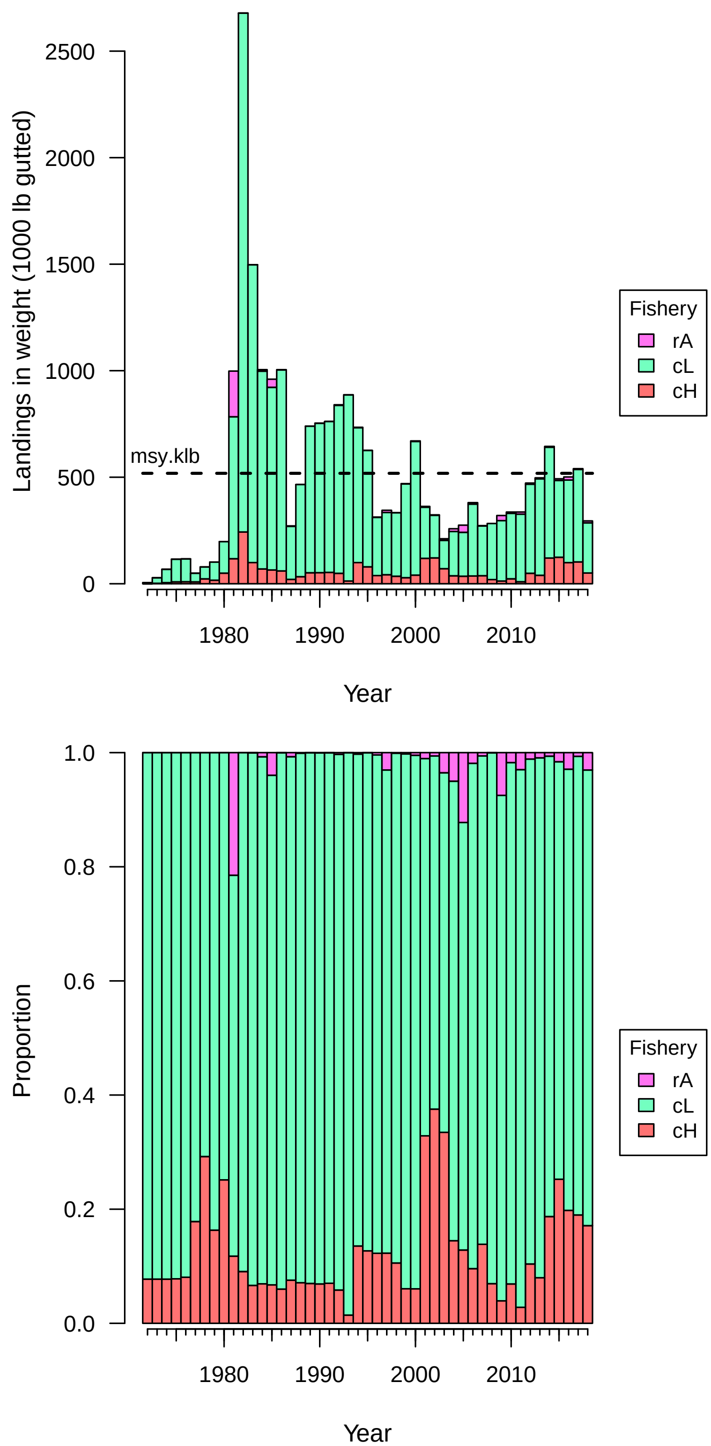


Figure 20. Beverton–Holt spawner-recruit curve (top) with and without lognormal bias correction. The expected (upper) curve was used for computing management benchmarks. Years within panel indicate year of recruitment generated from spawning biomass. Natural log of recruits (number of age-1 fish) per spawner is also plotted as function of the spawning stock (lower).

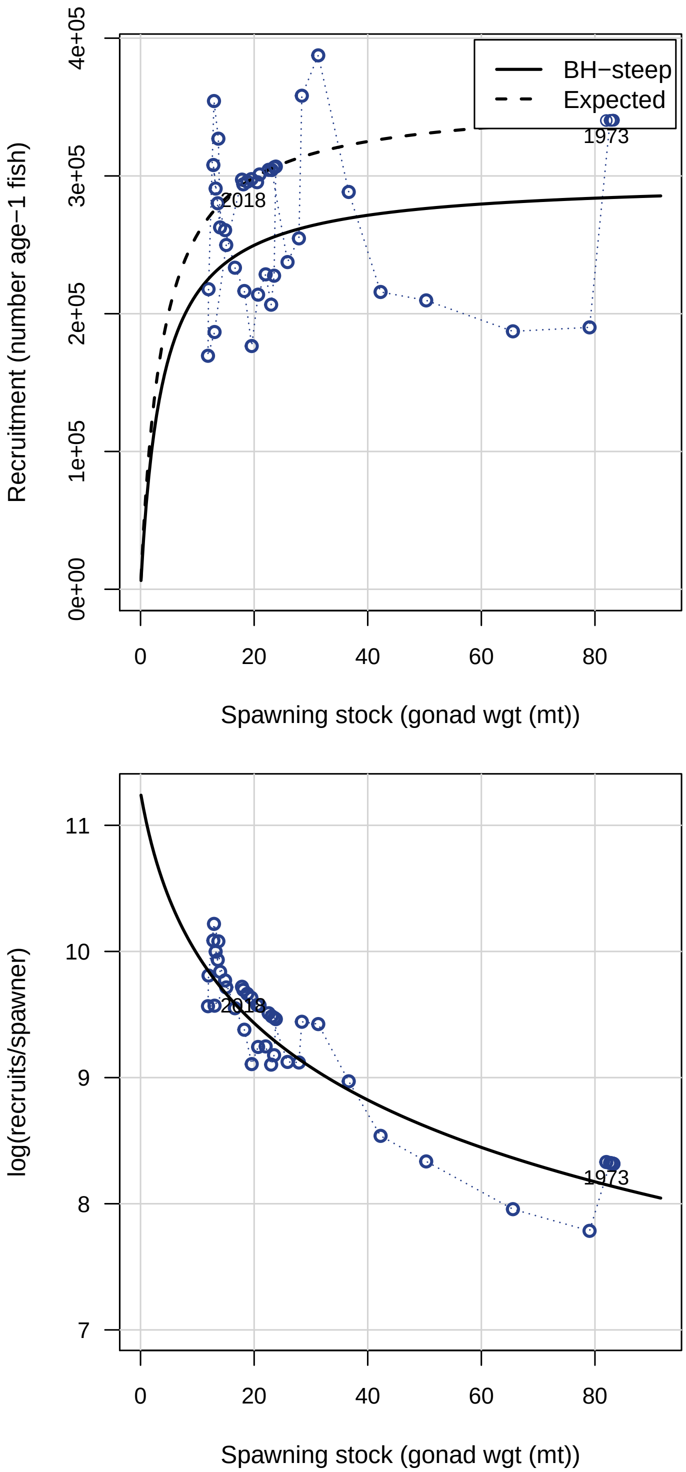


Figure 21. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-1 fish), steepness, unfished spawners per recruit, and standard deviation of recruitment residuals in log space. Solid vertical lines represent point estimates or values from the BAM base run; dashed vertical lines represent medians from the MCBE runs ($n = 4050$*).*

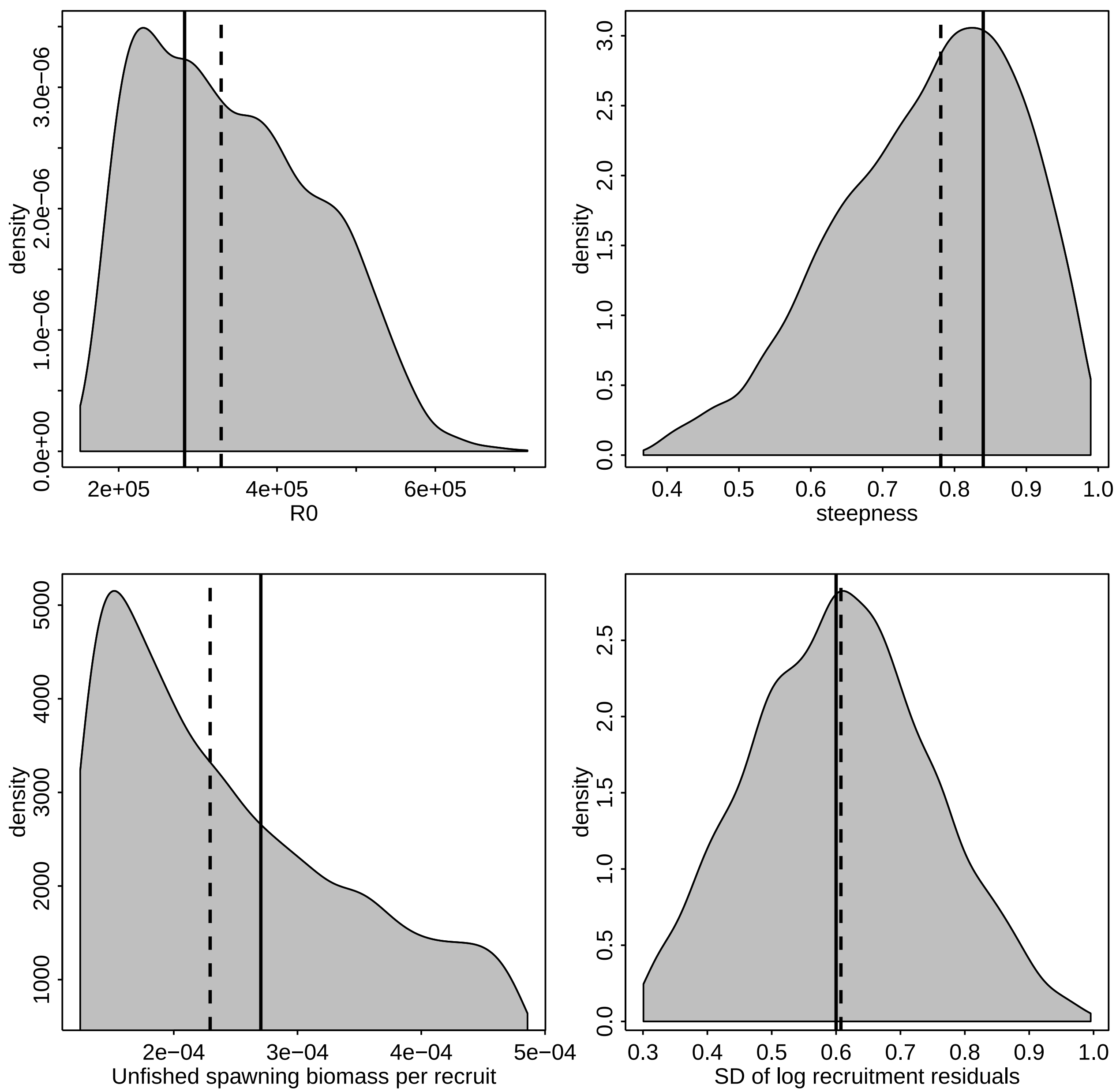


Figure 22. Yield per recruit (top; lb GW) and spawning potential ratio (bottom; spawning biomass per recruit relative to that at the unfished level) over a range of F. Both curves are based on average selectivity from the end of the assessment period.

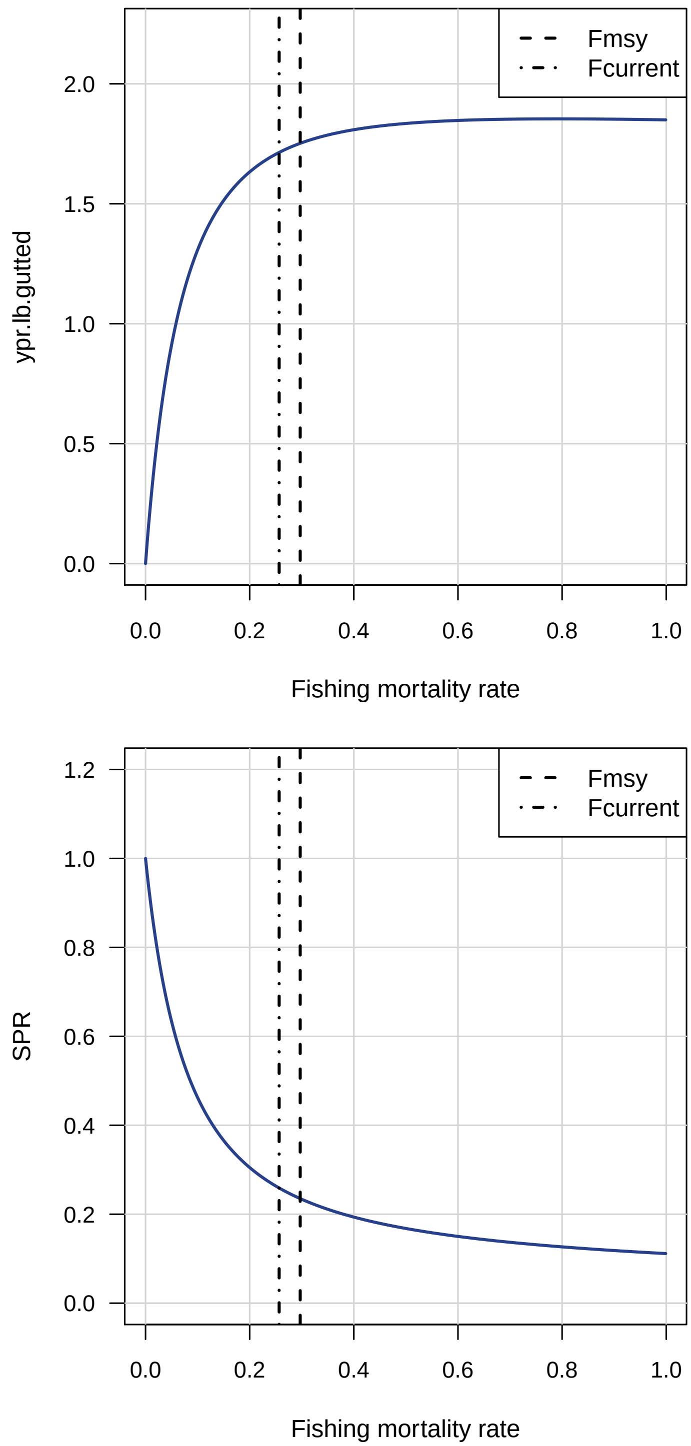


Figure 23. The top panels shows equilibrium landings at F. The peak occurs where fishing rate is $F_{\text{MSY}} = 0.3$ and equilibrium landings are MSY = 518 (1000 lb GW). The bottom panel shows equilibrium spawning biomass at F. Both curves are based on average selectivity from the end of the assessment period.

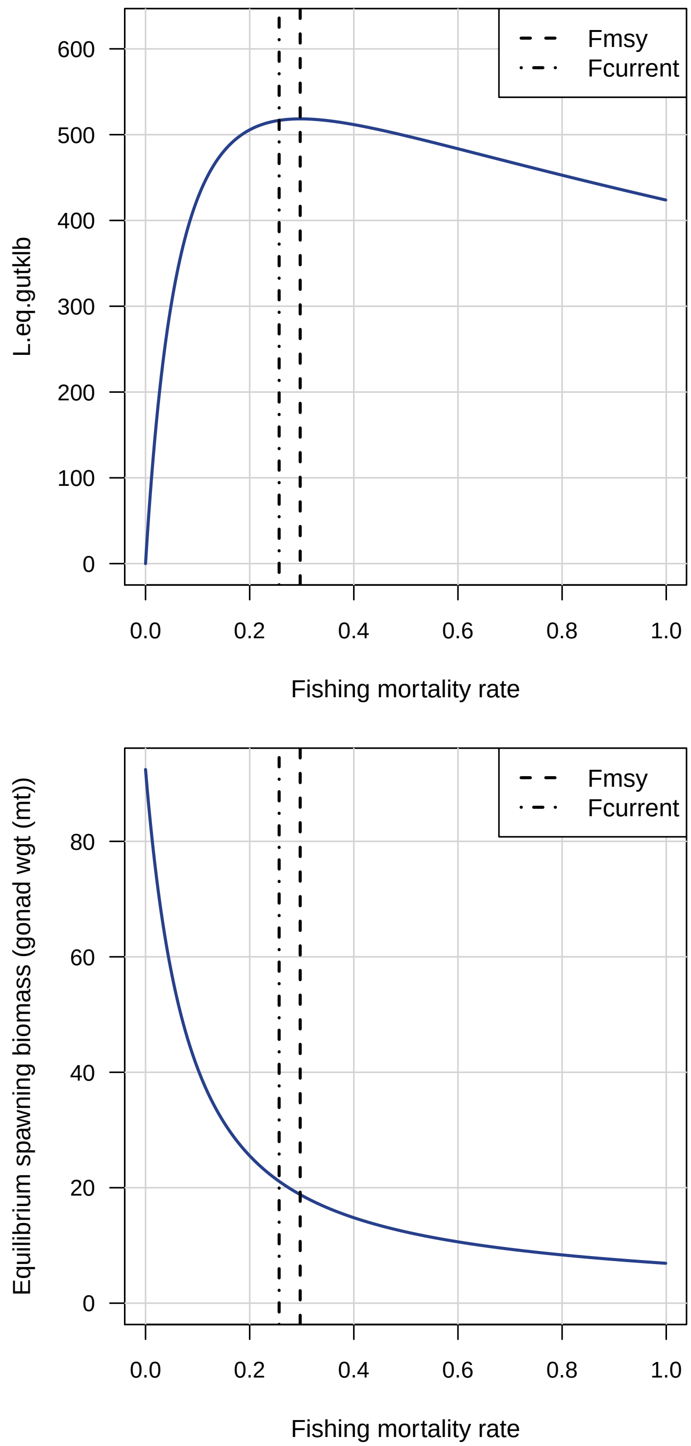


Figure 24. Probability densities of MSY*-related benchmarks from MCBE analysis (n = 4050). Vertical lines represent point estimates from the BAM base run; dashed vertical lines represent medians from the MCBE runs.*

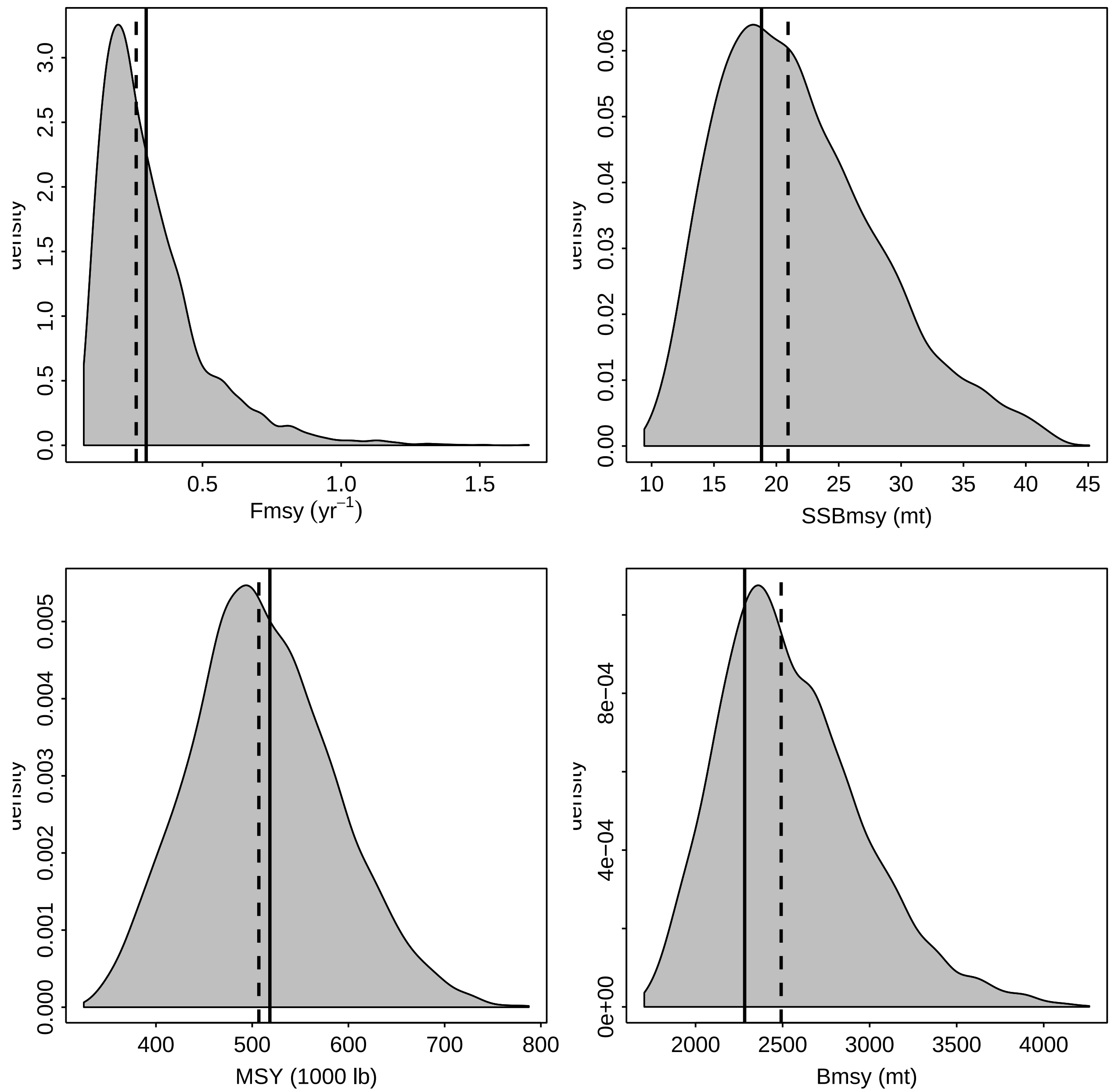


Figure 25. Estimated time series of SSB *and F relative to benchmarks: (top) spawning biomass relative to the minimum stock size threshold (*MSST*), (bottom) F relative to F_{MSY}. Shaded region represents 95% confidence bands from the MCBE runs ($n = 4050$).*

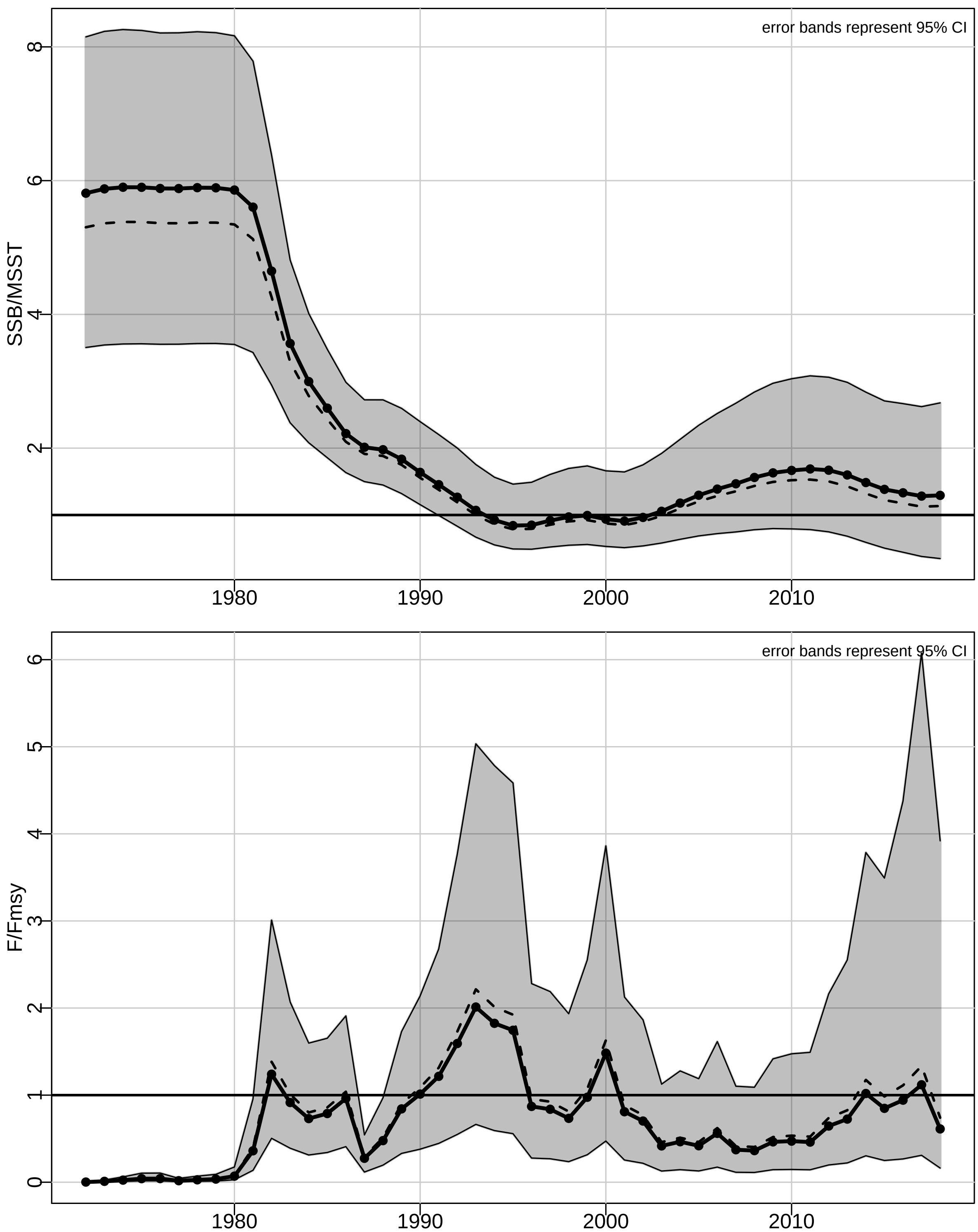
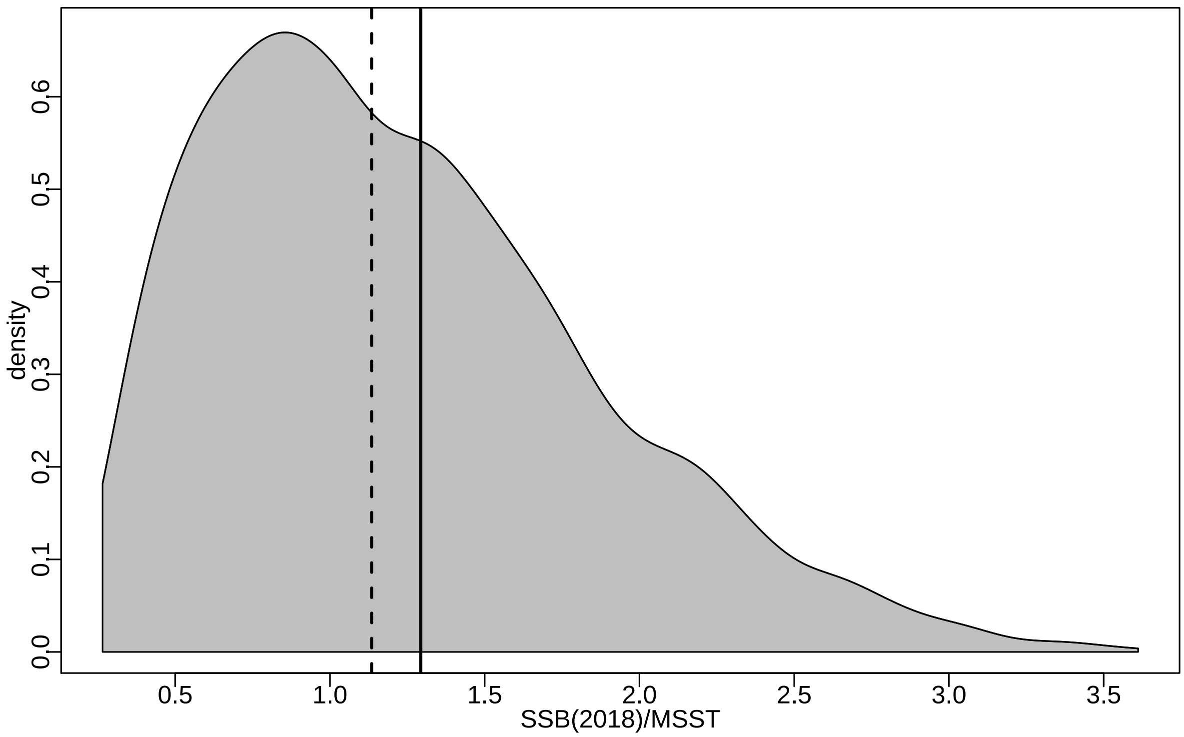


Figure 26. Probability densities of terminal status estimates from MCBE analysis of the Beaufort Assessment Model ($n = 4050$). Vertical lines represent point estimates from the BAM base run; dashed vertical lines represent medians from the MCBE runs.



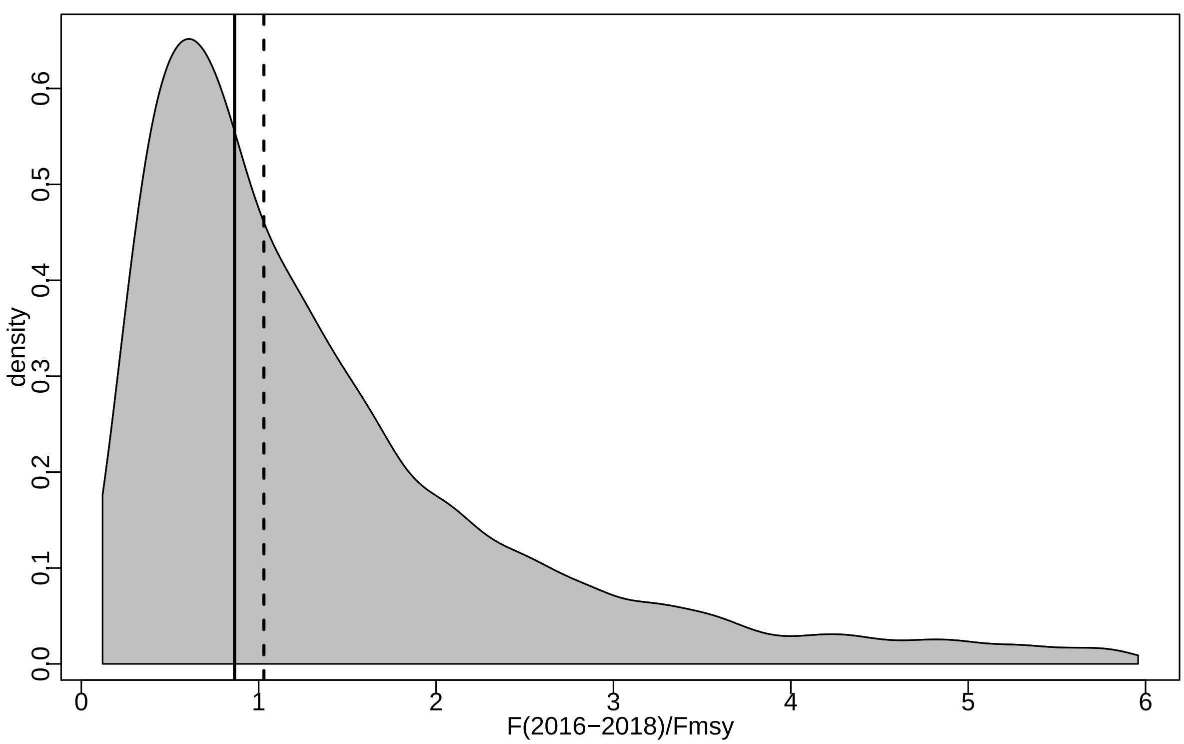


Figure 27. Phase plot of terminal status estimates from MCBE analysis of the Beaufort Assessment Model ($n = 4050$). Stock status is plotted along the vertical axis relative to MSST. *The intersection of crosshairs indicates estimates from the BAM base run; lengths of crosshairs defined by* 5^{th} *and* 95^{th} *percentiles of MCBE runs.*

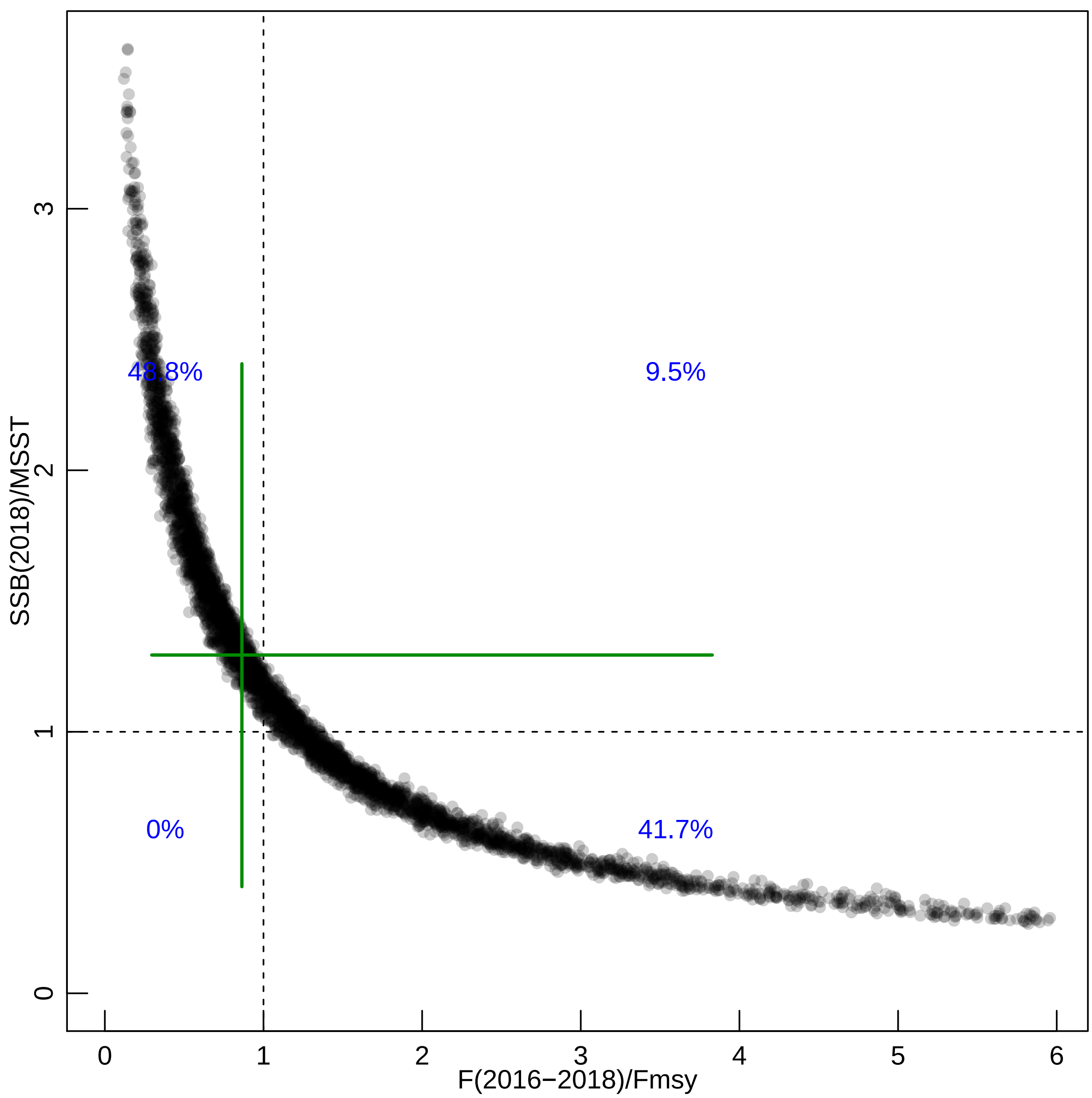


Figure 28. Estimated age structure from a series of individual years during the assessment, relative to the equilibrium expected at F_{MSY}.

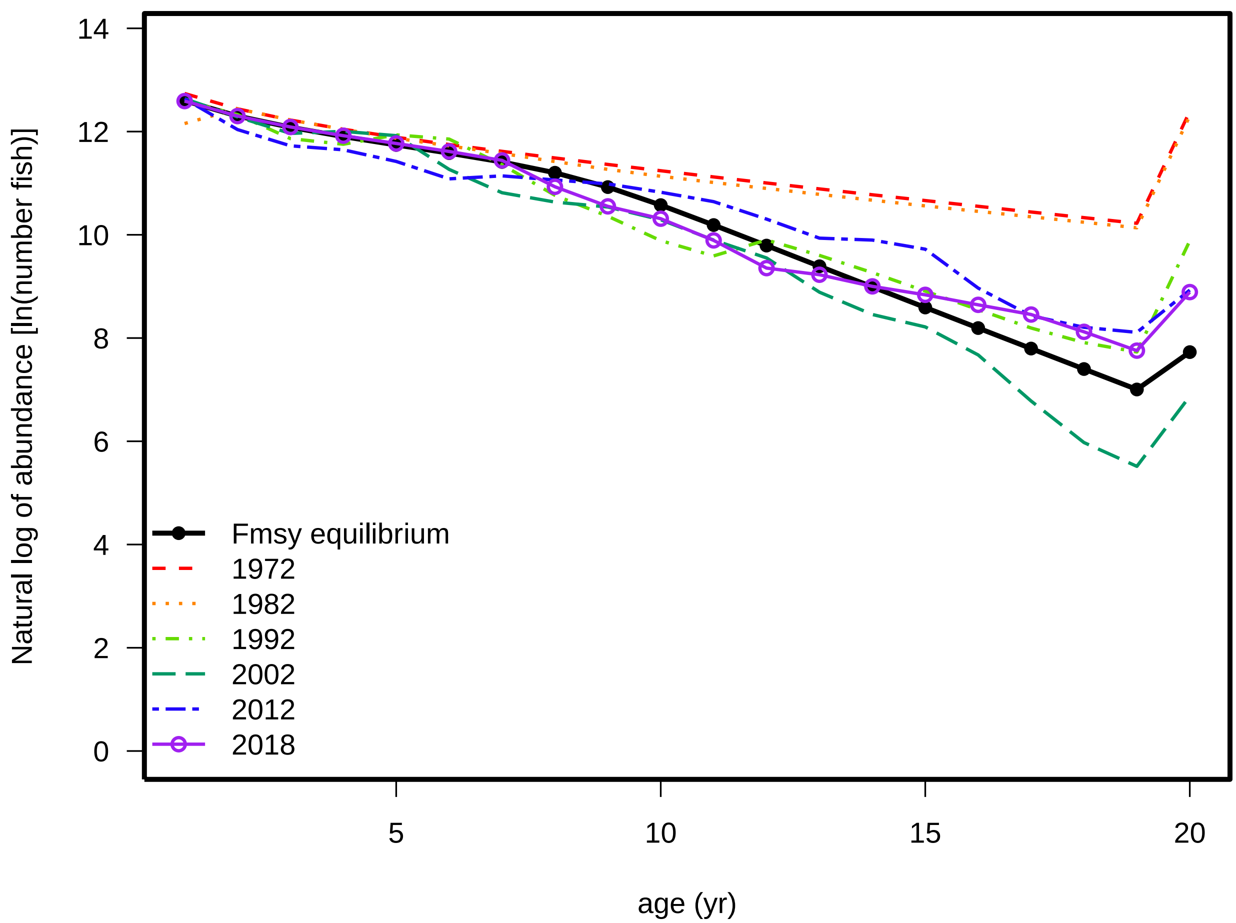


Figure 29. Sensitivity to low and high fixed values of natural mortality: (S1-S2). Estimated time series of F and SSB relative to benchmarks, as well as biomass (B) and number of recruits. Solid line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored broken lines, represented in the legend. (top left) F relative to F_{MSY}. (top right) spawning stock biomass (SSB) relative to MSST. (bottom left) biomass (B). (bottom right) number of recruits.

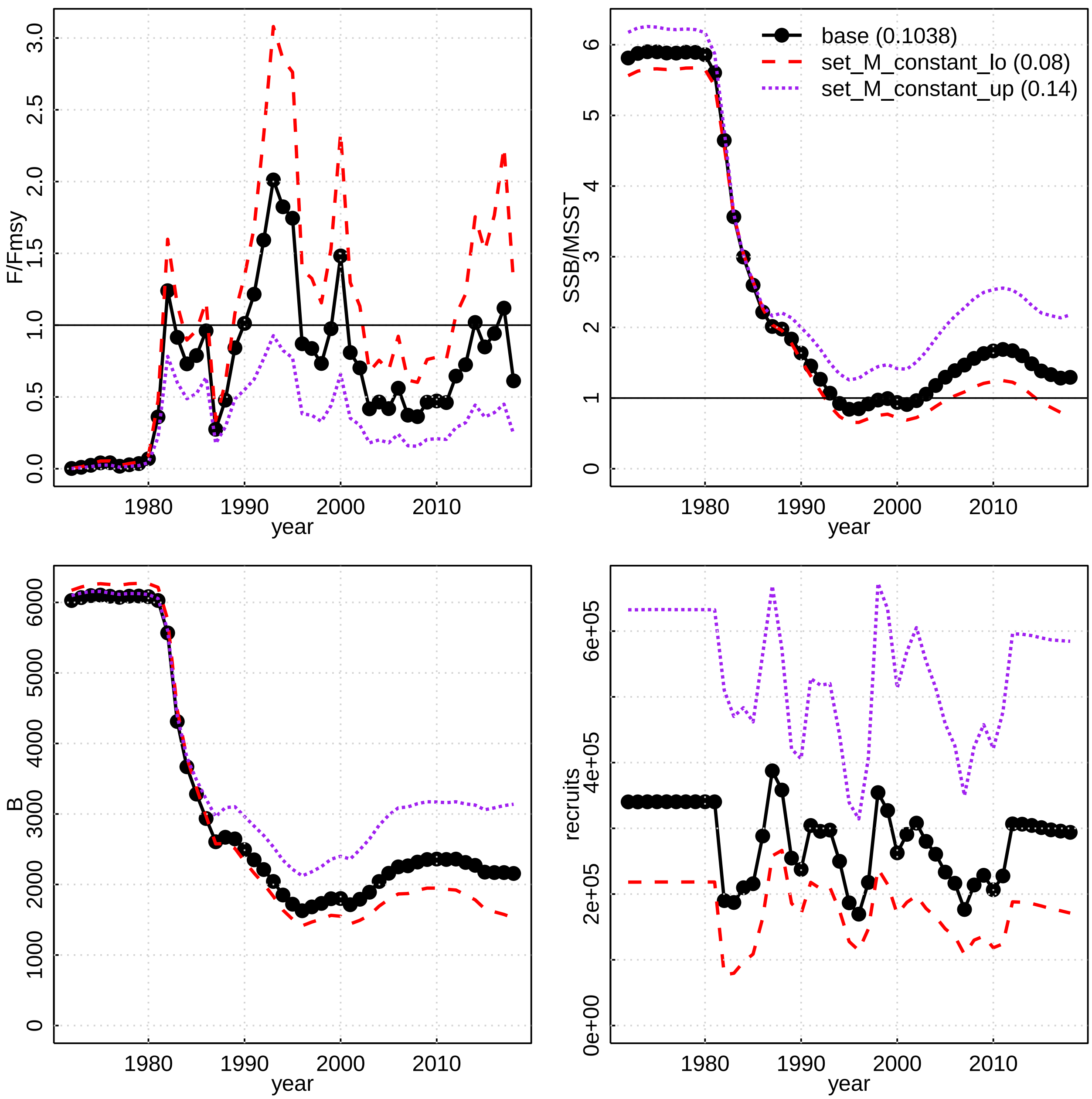


Figure 30. Sensitivity to low and high fixed values of steepness: (S3-S4). Estimated time series of F and SSB relative to benchmarks, as well as biomass (B) and number of recruits. Solid line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored broken lines, represented in the legend. (top left) F relative to F_{MSY}. (top right) spawning stock biomass (SSB) relative to MSST. (bottom left) biomass (B). (bottom right) number of recruits.

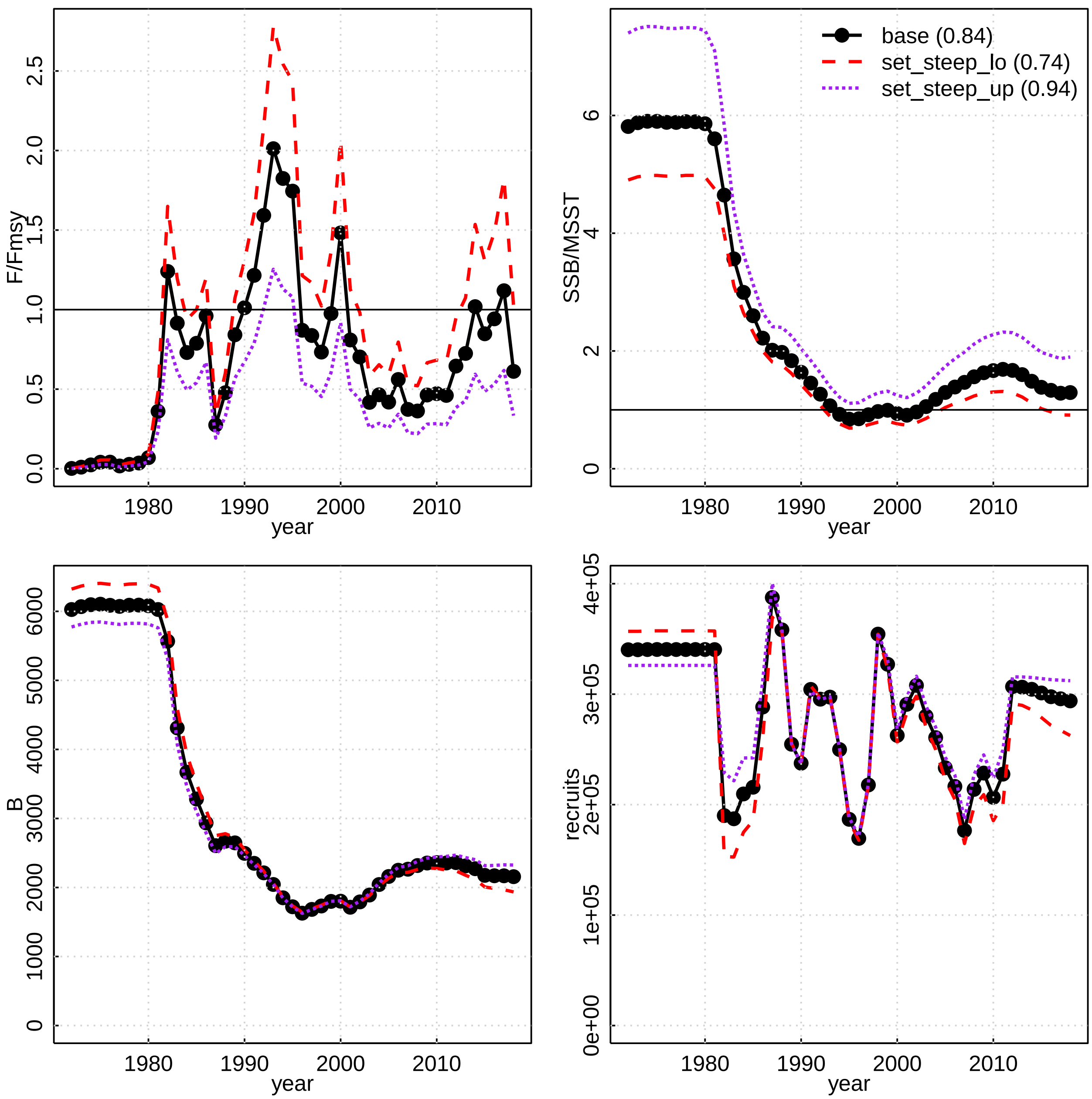


Figure 31. Sensitivity to higher values of F_{init} based on likelihood profiling: (S5-S6). Estimated time series of F and SSB relative to benchmarks, as well as biomass (B) and number of recruits. Solid line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored broken lines, represented in the legend. (top left) F relative to F_{MSY}. (top right) spawning stock biomass (SSB) relative to MSST. (bottom left) biomass (B). (bottom right) number of recruits.

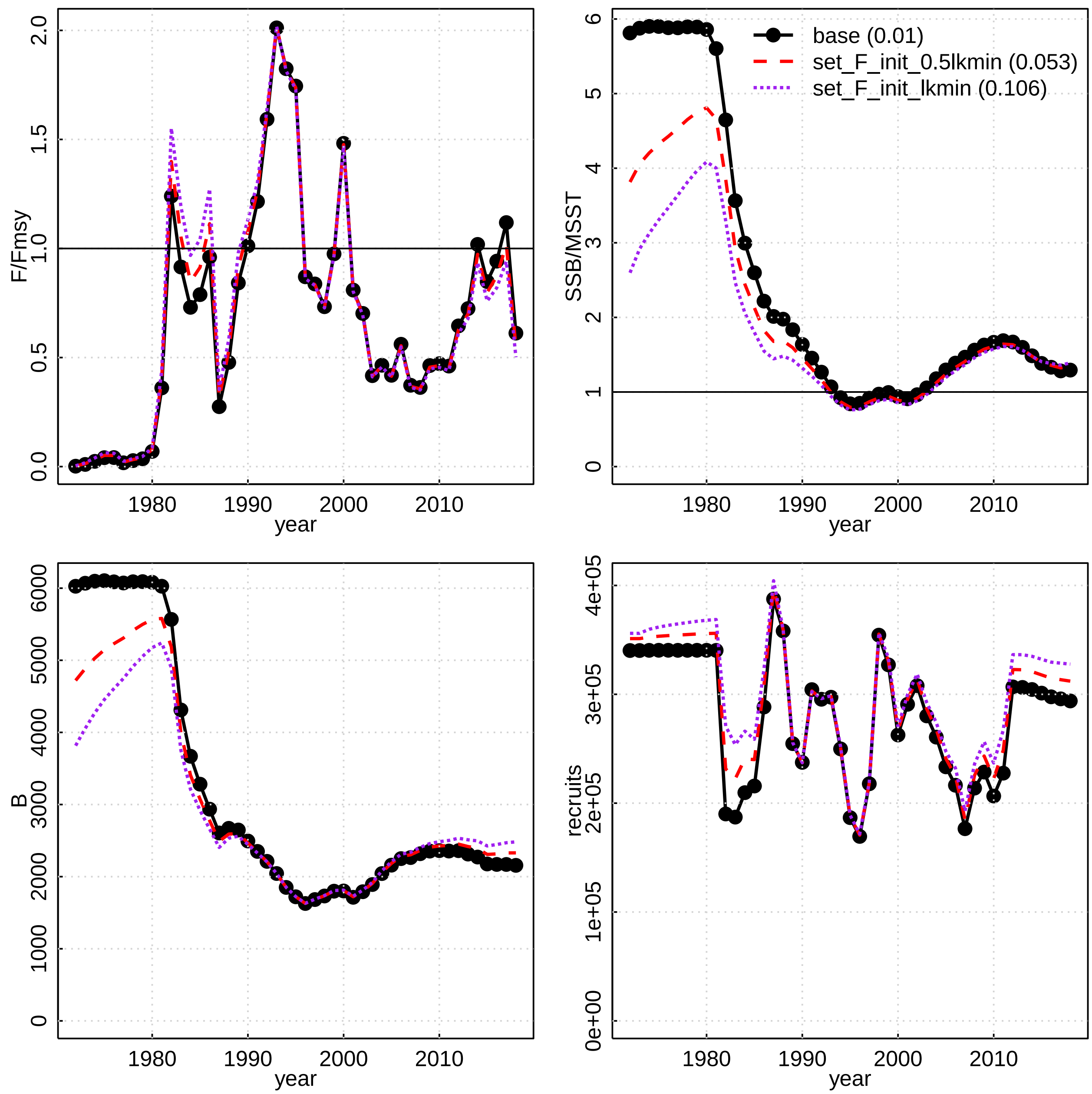


Figure 32. Sensitivity to downweighting (1/10×) or upweghting (10×) the MARMAP longline index: (S7-S8). Estimated time series of F and SSB relative to benchmarks, as well as biomass (B) and number of recruits. Solid line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored broken lines, represented in the legend. (top left) F relative to F_{MSY}. *(top right) spawning stock biomass (*SSB*) relative to* MSST. *(bottom left) biomass (B). (bottom right) number of recruits.*

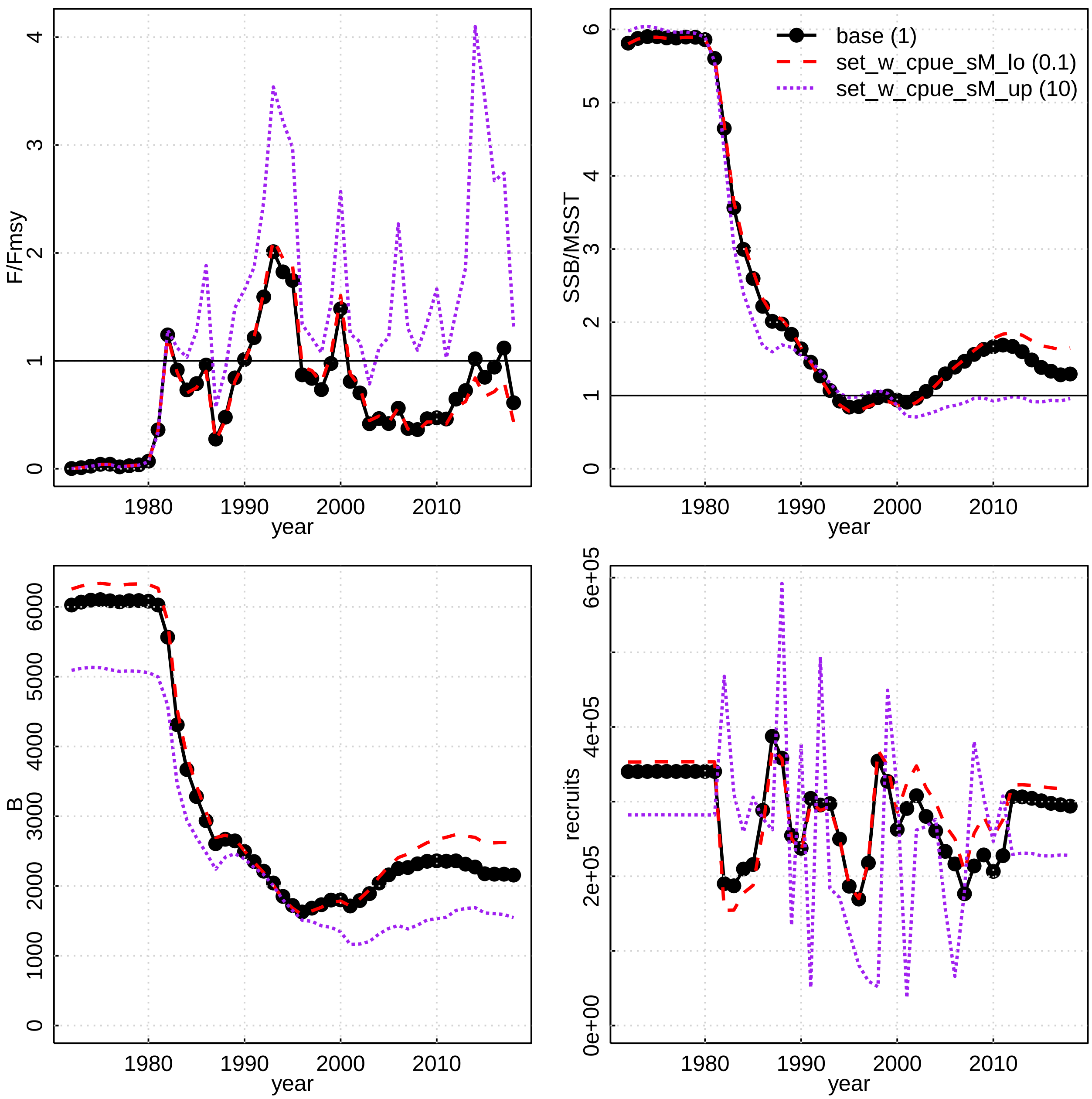


Figure 33. Sensitivity to using alternate recruitment estimates for years at the end of the assessment (2012-2018) where recruitment deviations were not estimated, based on geometric mean recruitment deviation from the last six years where recruitment deviations were estimated (2006-2011): (S9). Estimated time series of F and SSB relative to benchmarks, as well as biomass (B) and number of recruits. Solid line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored broken lines, represented in the legend. (top left) F relative to F_{MSY}*. (top right) spawning stock biomass (*SSB*) relative to* MSST*. (bottom left) biomass (B). (bottom right) number of recruits.*

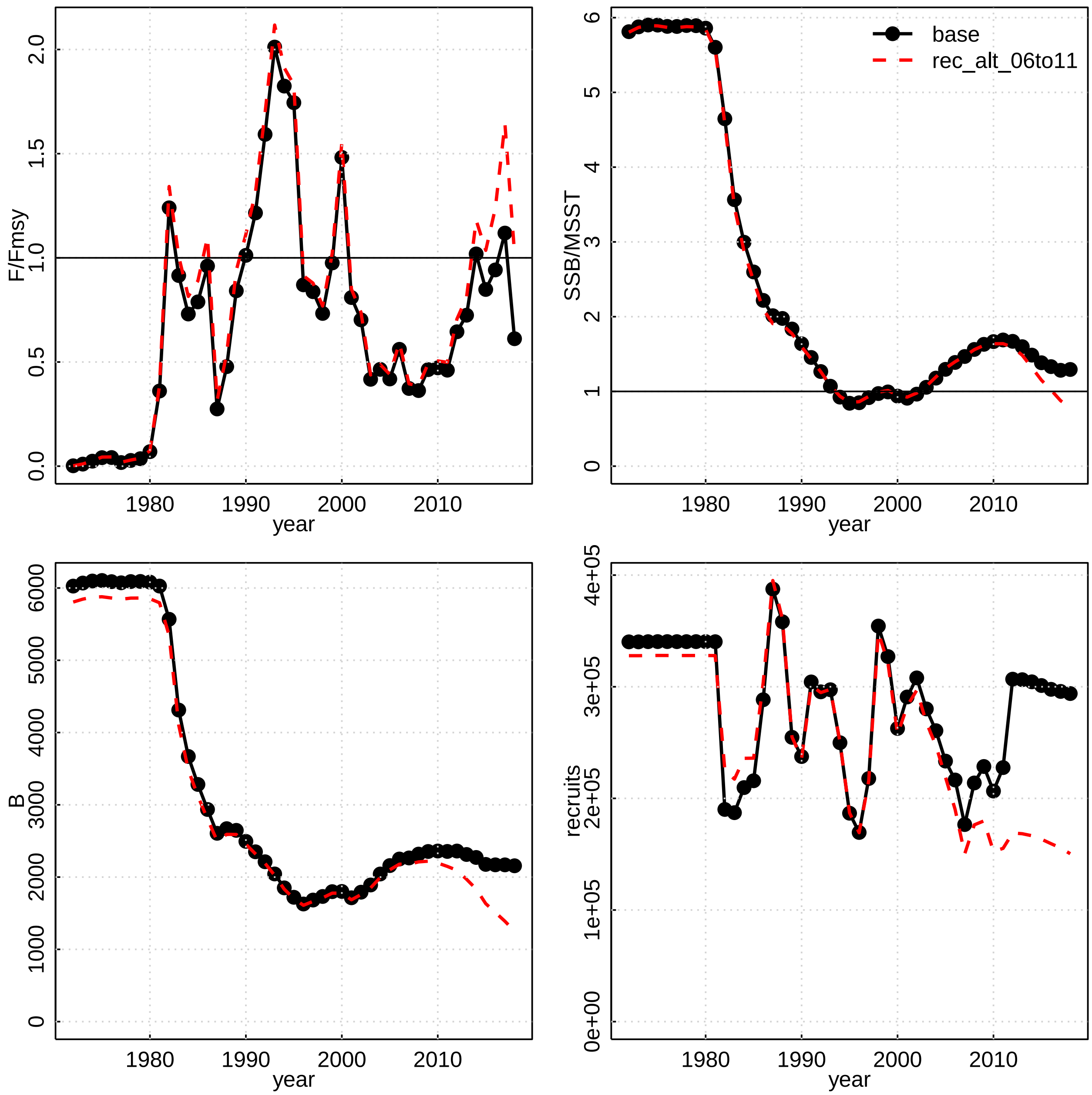


Figure 34. Phase plots of terminal status estimates from BAM sensitivity runs. Point colors and shapes are indicated in the legend. The number of each sensitivity run is also plotted in black text over each point. The base run is represented by a black point labeled "base".

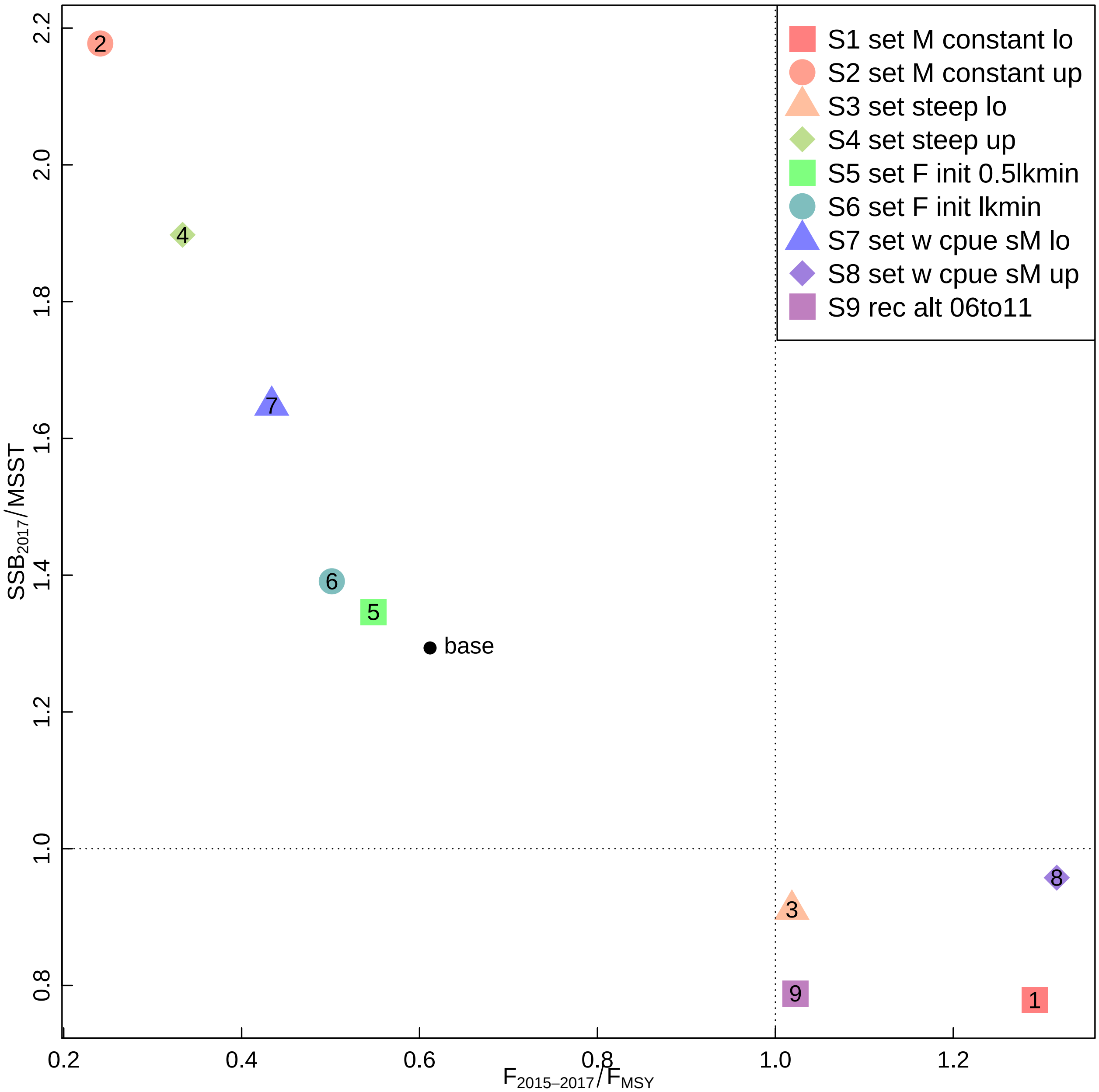


*Figure 35. Retrospective analysis reducing the terminal year of the assessment from 2018 to values over a range from 2010 to 2017 . Estimated time series of F and SSB relative to benchmarks, as well as biomass (B) and number of recruits. Solid line and solid circles indicate estimates from the BAM base run. Solid colored points in the top and bottom left panels emphasize values in the terminal year of the assessment. Solid colored points in the bottom right panel emphasize values in the last year for which recruiment deviations were estimated. Retrospective runs are indicated by colored broken lines, represented in the legend. (top left) F relative to F_{MSY}. (top right) spawning stock biomass (*SSB*) relative to* MSST*. (bottom left) biomass (B). (bottom right) number of recruits.*

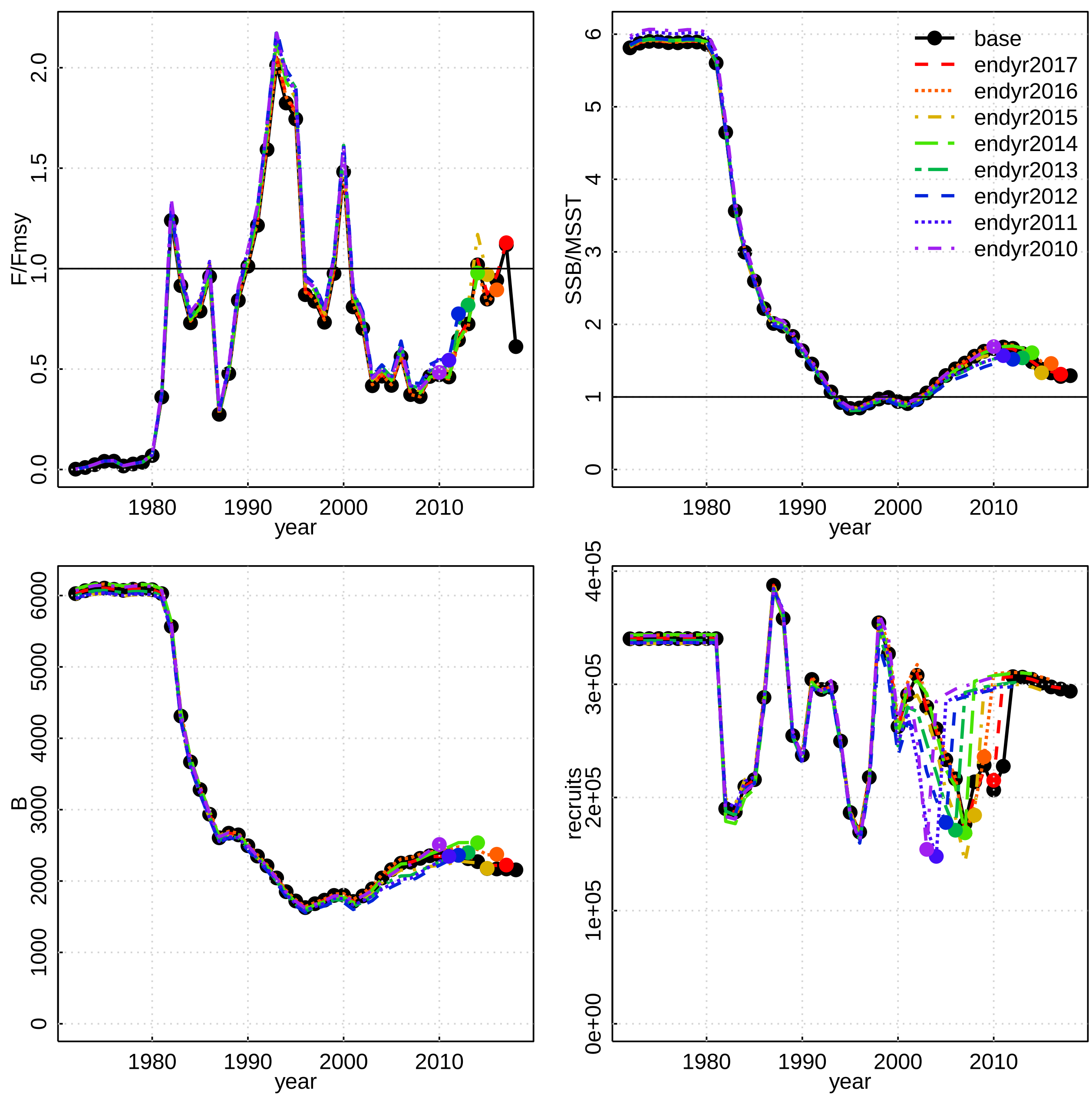


Figure 36. Plots of SSB*, landings, recruits, F, and the probability that* SSB > MSST *for projections with fishing mortality rate at fixed F that provides $P^* = 0.50$. In all panels except the bottom right, expected values (base run) represented by solid lines with solid circles, medians represented 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 blue lines mark* MSY*-related quantities; dashed horizontal green lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In the bottom right panel, the curve represents the proportion of projection replicates for which SSB exceeds the replicate-specific* MSST*.*

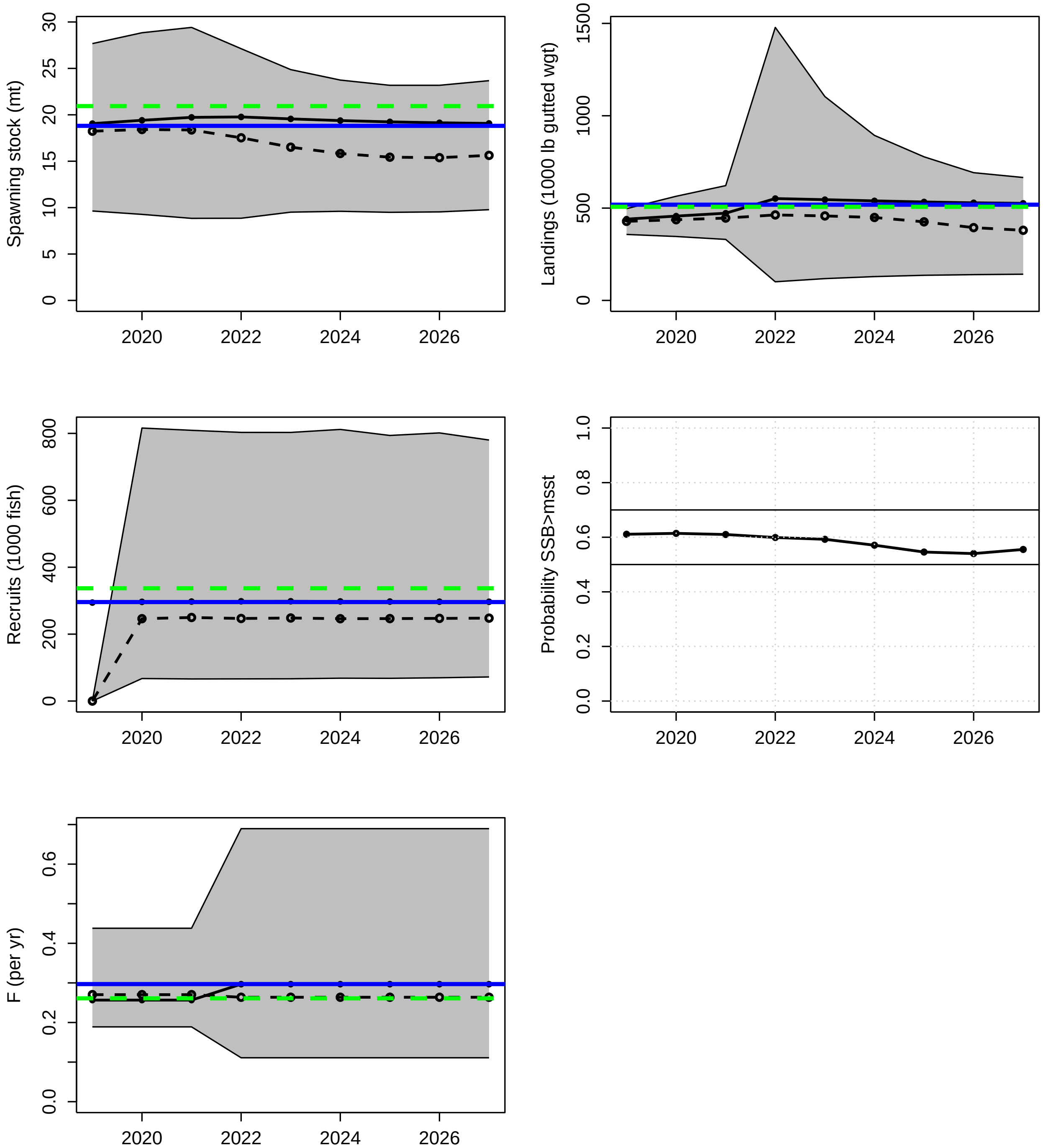


Figure 37. Plots of SSB*, landings, recruits,* F*, and the probability that* SSB > MSST *for projections with fishing mortality rate fixed at* $F = F_{\mathrm{MSY}}$*. In all panels except the bottom right, expected values (base run) represented by solid lines with solid circles, medians represented 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 blue lines mark* MSY*-related quantities; dashed horizontal green lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In the bottom right panel, the curve represents the proportion of projection replicates for which SSB exceeds the replicate-specific* MSST*.*

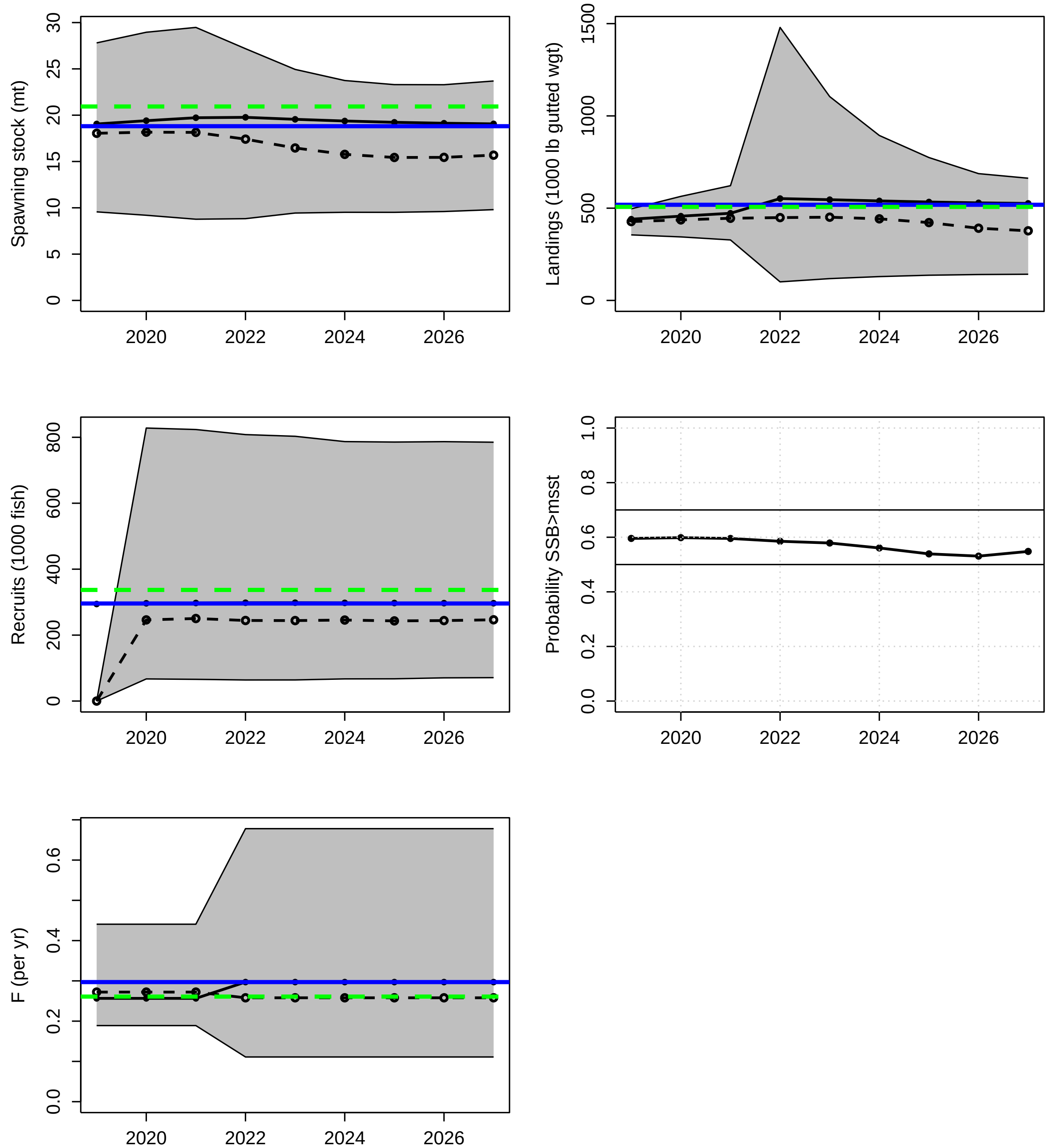


Figure 38. Plots of SSB*, landings, recruits,* F*, and the probability that* SSB > MSST *for projections with fishing mortality rate at fixed* F *that provides* $P^* = 0.30$*. In all panels except the bottom right, expected values (base run) represented by solid lines with solid circles, medians represented 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 blue lines mark* MSY*-related quantities; dashed horizontal green lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In the bottom right panel, the curve represents the proportion of projection replicates for which SSB exceeds the replicate-specific* MSST*.*

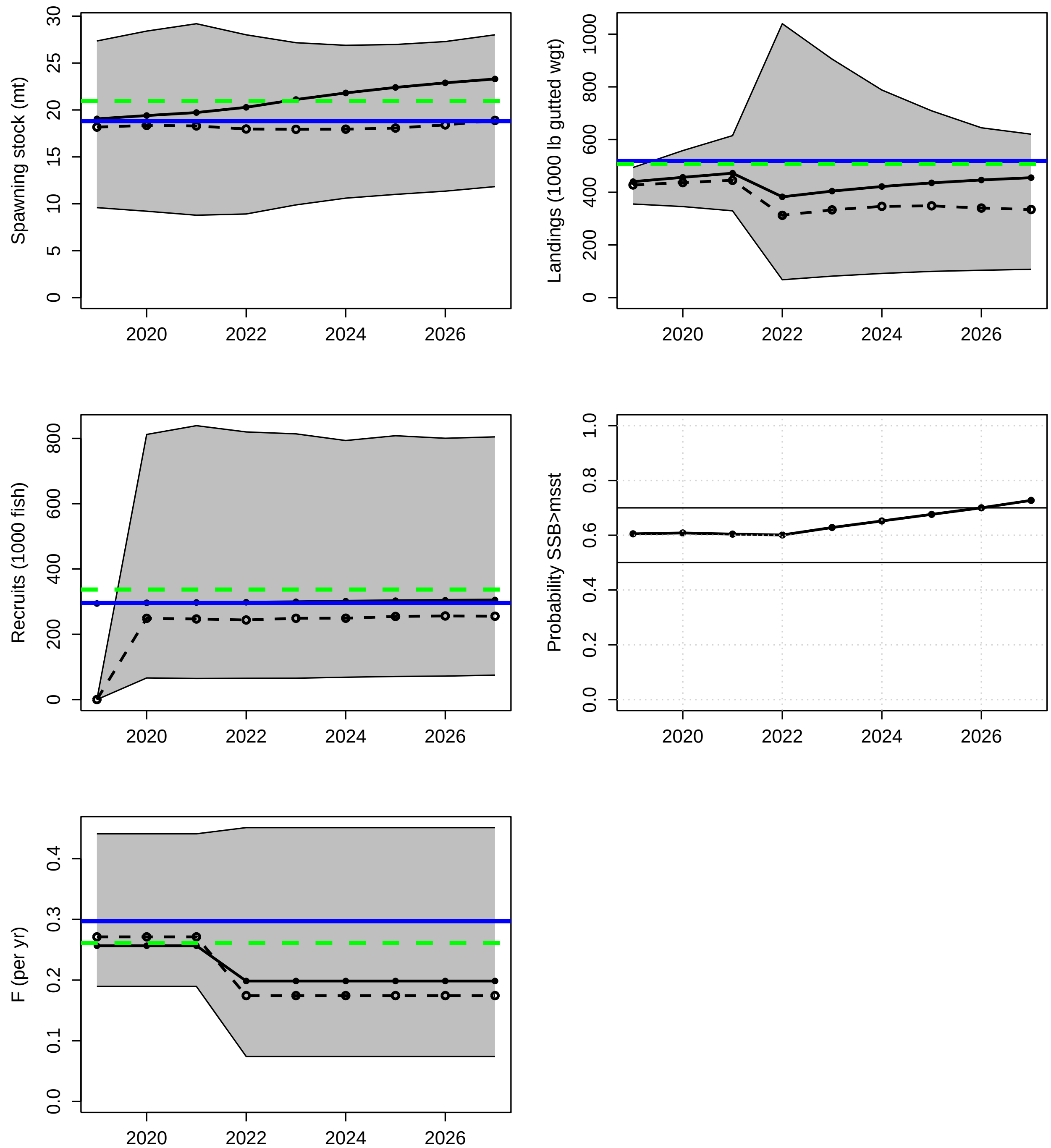
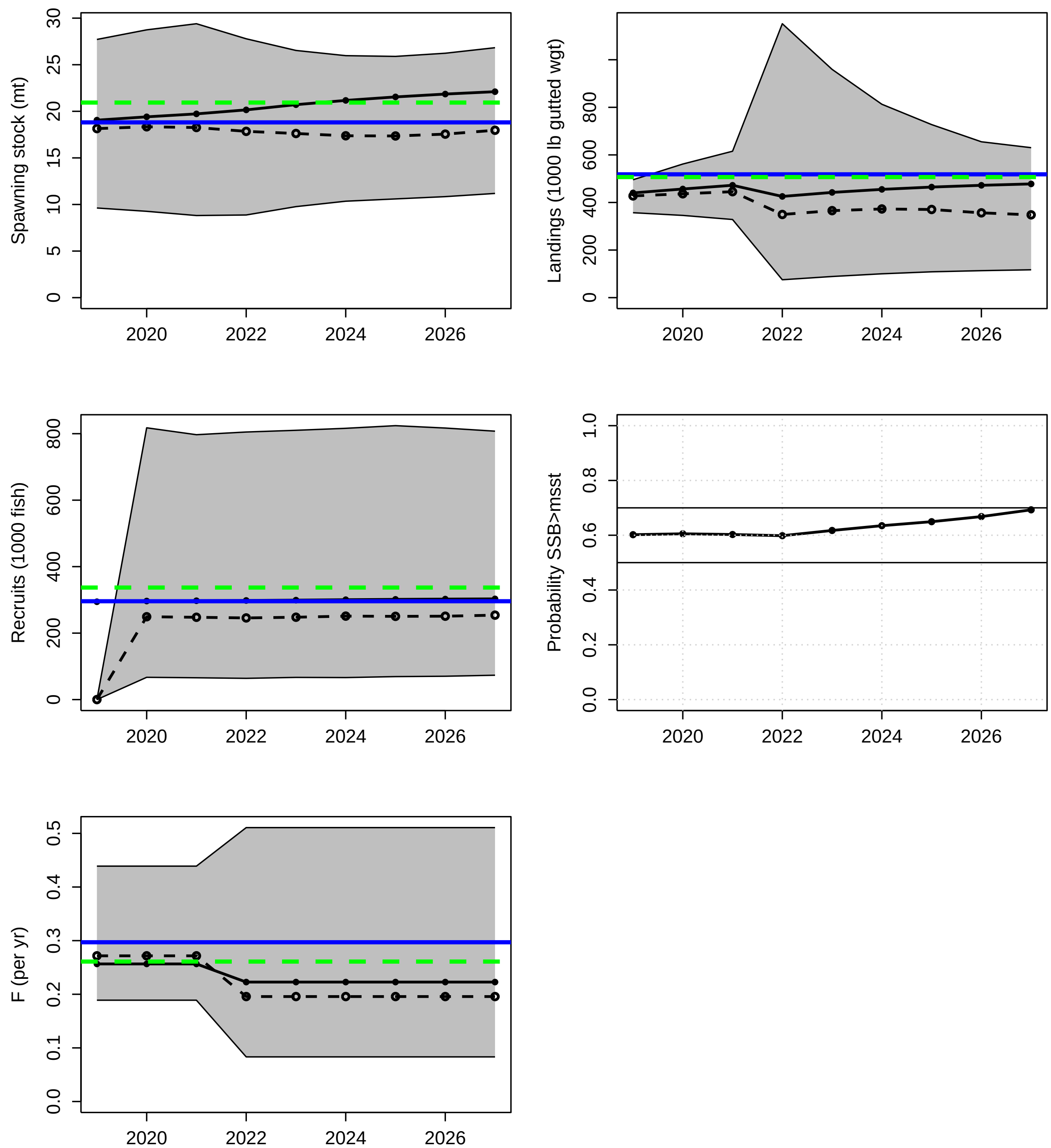


Figure 39. Plots of SSB*, landings, recruits,* F*, and the probability that* SSB $>$ MSST *for projections with fishing mortality rate fixed at* $F = 75\% F_{\mathrm{MSY}}$*. In all panels except the bottom right, expected values (base run) represented by solid lines with solid circles, medians represented 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 blue lines mark* MSY*-related quantities; dashed horizontal green lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In the bottom right panel, the curve represents the proportion of projection replicates for which SSB exceeds the replicate-specific* MSST*.*



Appendix A Parameter estimates from the Beaufort Assessment Model

Table 24. Names and estimated values of parameters estimated in the base run of the Beaufort Assessment Model.

ID	Parameter	Value
1	len.cv.val	0.144480
2	log.R0	12.555000
3	log.rec.dev.1982	−0.400070
4	log.rec.dev.1983	−0.406030
5	log.rec.dev.1984	−0.276290
6	log.rec.dev.1985	−0.234370
7	log.rec.dev.1986	0.068066
8	log.rec.dev.1987	0.379360
9	log.rec.dev.1988	0.311540
10	log.rec.dev.1989	−0.027184
11	log.rec.dev.1990	−0.087672
12	log.rec.dev.1991	0.175850
13	log.rec.dev.1992	0.164070
14	log.rec.dev.1993	0.193450
15	log.rec.dev.1994	0.051605
16	log.rec.dev.1995	−0.208290
17	log.rec.dev.1996	−0.283040
18	log.rec.dev.1997	−0.033862
19	log.rec.dev.1998	0.435030
20	log.rec.dev.1999	0.342070
21	log.rec.dev.2000	0.118020
22	log.rec.dev.2001	0.232520
23	log.rec.dev.2002	0.296440
24	log.rec.dev.2003	0.188370
25	log.rec.dev.2004	0.096883
26	log.rec.dev.2005	−0.035097
27	log.rec.dev.2006	−0.127450
28	log.rec.dev.2007	−0.342950
29	log.rec.dev.2008	−0.160360
30	log.rec.dev.2009	−0.103210
31	log.rec.dev.2010	−0.210680
32	log.rec.dev.2011	−0.116720
33	log.dm.lenc.rA	2.933500
34	log.dm.agec.cH	3.853600
35	log.dm.agec.cL	4.326300
36	log.dm.agec.sM	2.941300
37	selpar.L50.cH	5.493100
38	selpar.L50.cH2	5.799900
39	selpar.slope.cH	1.617100
40	selpar.slope.cH2	1.258200

Table 24. (continued)

ID	Parameter	Value
41	selpar.L50.cL	6.944600
42	selpar.L50.cL2	8.073900
43	selpar.slope.cL	1.619500
44	selpar.slope.cL2	1.274800
45	selpar.L50.rA	3.567600
46	selpar.slope.rA	5.129800
47	selpar.L50.sM	6.206700
48	selpar.slope.sM	1.309500
49	log.q.cpue.cL	−7.428600
50	log.q.cpue.sM	−7.893200
51	log.avg.F.L.cH	−4.677700
52	log.F.dev.L.cH.1972	−5.475600
53	log.F.dev.L.cH.1973	−3.786500
54	log.F.dev.L.cH.1974	−2.904700
55	log.F.dev.L.cH.1975	−2.367200
56	log.F.dev.L.cH.1976	−2.317300
57	log.F.dev.L.cH.1977	−2.383000
58	log.F.dev.L.cH.1978	−1.423200
59	log.F.dev.L.cH.1979	−1.750900
60	log.F.dev.L.cH.1980	−0.648550
61	log.F.dev.L.cH.1981	0.262100
62	log.F.dev.L.cH.1982	1.185700
63	log.F.dev.L.cH.1983	0.542130
64	log.F.dev.L.cH.1984	0.335850
65	log.F.dev.L.cH.1985	0.377700
66	log.F.dev.L.cH.1986	0.439680
67	log.F.dev.L.cH.1987	−0.559600
68	log.F.dev.L.cH.1988	−0.051351
69	log.F.dev.L.cH.1989	0.485830
70	log.F.dev.L.cH.1990	0.620050
71	log.F.dev.L.cH.1991	0.754710
72	log.F.dev.L.cH.1992	0.761050
73	log.F.dev.L.cH.1993	−0.461820
74	log.F.dev.L.cH.1994	1.730300
75	log.F.dev.L.cH.1995	1.609500
76	log.F.dev.L.cH.1996	0.855210
77	log.F.dev.L.cH.1997	0.848400
78	log.F.dev.L.cH.1998	0.581650
79	log.F.dev.L.cH.1999	0.345160
80	log.F.dev.L.cH.2000	0.793270

Table 24. (continued)

ID	Parameter	Value
81	log.F.dev.L.cH.2001	1.949800
82	log.F.dev.L.cH.2002	1.924800
83	log.F.dev.L.cH.2003	1.260800
84	log.F.dev.L.cH.2004	0.489400
85	log.F.dev.L.cH.2005	0.335990
86	log.F.dev.L.cH.2006	0.304690
87	log.F.dev.L.cH.2007	0.280790
88	log.F.dev.L.cH.2008	−0.434200
89	log.F.dev.L.cH.2009	−0.870290
90	log.F.dev.L.cH.2010	−0.278720
91	log.F.dev.L.cH.2011	−1.180800
92	log.F.dev.L.cH.2012	0.498350
93	log.F.dev.L.cH.2013	0.342780
94	log.F.dev.L.cH.2014	1.539700
95	log.F.dev.L.cH.2015	1.649500
96	log.F.dev.L.cH.2016	1.467400
97	log.F.dev.L.cH.2017	1.531900
98	log.F.dev.L.cH.2018	0.789490
99	log.avg.F.L.cL	−2.303100
100	log.F.dev.L.cL.1972	−5.285000
101	log.F.dev.L.cL.1973	−3.596400
102	log.F.dev.L.cL.1974	−2.715000
103	log.F.dev.L.cL.1975	−2.184600
104	log.F.dev.L.cL.1976	−2.172700
105	log.F.dev.L.cL.1977	−3.143200
106	log.F.dev.L.cL.1978	−2.826900
107	log.F.dev.L.cL.1979	−2.404500
108	log.F.dev.L.cL.1980	−1.844800
109	log.F.dev.L.cL.1981	−0.288100
110	log.F.dev.L.cL.1982	1.218000
111	log.F.dev.L.cL.1983	0.939640
112	log.F.dev.L.cL.1984	0.707430
113	log.F.dev.L.cL.1985	0.760660
114	log.F.dev.L.cL.1986	0.997260
115	log.F.dev.L.cL.1987	−0.275360
116	log.F.dev.L.cL.1988	0.285580
117	log.F.dev.L.cL.1989	0.854760
118	log.F.dev.L.cL.1990	1.041400
119	log.F.dev.L.cL.1991	1.227600
120	log.F.dev.L.cL.1992	1.509400

Table 24. (continued)

ID	Parameter	Value
121	log.F.dev.L.cL.1993	1.777600
122	log.F.dev.L.cL.1994	1.586400
123	log.F.dev.L.cL.1995	1.551000
124	log.F.dev.L.cL.1996	0.858960
125	log.F.dev.L.cL.1997	0.802540
126	log.F.dev.L.cL.1998	0.698080
127	log.F.dev.L.cL.1999	1.015800
128	log.F.dev.L.cL.2000	1.431100
129	log.F.dev.L.cL.2001	0.550910
130	log.F.dev.L.cL.2002	0.365260
131	log.F.dev.L.cL.2003	−0.122230
132	log.F.dev.L.cL.2004	0.172630
133	log.F.dev.L.cL.2005	0.017744
134	log.F.dev.L.cL.2006	0.418920
135	log.F.dev.L.cL.2007	−0.019883
136	log.F.dev.L.cL.2008	0.017014
137	log.F.dev.L.cL.2009	0.245160
138	log.F.dev.L.cL.2010	0.275210
139	log.F.dev.L.cL.2011	0.273930
140	log.F.dev.L.cL.2012	0.559320
141	log.F.dev.L.cL.2013	0.697690
142	log.F.dev.L.cL.2014	0.947990
143	log.F.dev.L.cL.2015	0.698980
144	log.F.dev.L.cL.2016	0.854950
145	log.F.dev.L.cL.2017	1.058500
146	log.F.dev.L.cL.2018	0.461440
147	log.avg.F.L.rA	−7.535800
148	log.F.dev.L.rA.1981	3.684100
149	log.F.dev.L.rA.1982	−4.805800
150	log.F.dev.L.rA.1983	−2.278600
151	log.F.dev.L.rA.1984	0.832650
152	log.F.dev.L.rA.1985	2.608200
153	log.F.dev.L.rA.1986	−3.754900
154	log.F.dev.L.rA.1987	−0.148420
155	log.F.dev.L.rA.1988	−1.569400
156	log.F.dev.L.rA.1989	−4.028300
157	log.F.dev.L.rA.1990	−1.555200
158	log.F.dev.L.rA.1991	−2.661600
159	log.F.dev.L.rA.1992	0.386710
160	log.F.dev.L.rA.1993	−3.691200

Table 24. (continued)

ID	Parameter	Value
161	log.F.dev.L.rA.1994	0.349720
162	log.F.dev.L.rA.1995	−3.531800
163	log.F.dev.L.rA.1996	−0.021641
164	log.F.dev.L.rA.1997	2.032300
165	log.F.dev.L.rA.1998	−1.443400
166	log.F.dev.L.rA.1999	−0.217880
167	log.F.dev.L.rA.2000	0.890550
168	log.F.dev.L.rA.2001	1.076800
169	log.F.dev.L.rA.2002	0.304610
170	log.F.dev.L.rA.2003	1.594900
171	log.F.dev.L.rA.2004	2.055400
172	log.F.dev.L.rA.2005	2.935600
173	log.F.dev.L.rA.2006	1.335900
174	log.F.dev.L.rA.2007	−0.212150
175	log.F.dev.L.rA.2008	−4.000300
176	log.F.dev.L.rA.2009	2.462400
177	log.F.dev.L.rA.2010	1.062700
178	log.F.dev.L.rA.2011	1.602400
179	log.F.dev.L.rA.2012	0.992940
180	log.F.dev.L.rA.2013	0.873600
181	log.F.dev.L.rA.2014	0.810340
182	log.F.dev.L.rA.2015	1.522900
183	log.F.dev.L.rA.2016	2.144200
184	log.F.dev.L.rA.2017	0.723900
185	log.F.dev.L.rA.2018	1.637800

Appendix B Abbreviations and Symbols

Table 25. Acronyms and abbreviations used in this report

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