SEDAR

Southeast Data, Assessment, and Review

SEDAR 59

South Atlantic Greater Amberjack

Stock Assessment Report

March 2020

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

Please cite this document as:

SEDAR. 2020. SEDAR – South Atlantic Greater Amberjack Stock Assessment Report. SEDAR, North Charleston SC. 142 pp. available online at: http://sedarweb.org/sedar-59

Table of Contents

Each Section is numbered Separately

SEDAR

Southeast Data, Assessment, and Review

SEDAR 59

South Atlantic Greater Amberjack

Section I: Introduction

March 2020

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

Table of Contents

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 59 addressed the stock assessment for South Atlantic Greater Amberjack. The assessment process consisted of a series of webinars. Assessment webinars were held between March 2018 – January 2020.The Stock Assessment Report is organized into 2 sections. Section I –Introduction contains a brief description of the SEDAR Process, Assessment and Management Histories for the species of interest, and the management specifications requested by the Cooperator. Section II is the Assessment Process report. This section details the assessment model, as well as documents any data recommendations that arise for new data sets presented during this assessment process, or changes to data sets used previously.

The final Stock Assessment Reports (SAR) for South Atlantic Greater Amberjack was disseminated to the public in March 2020. 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 2020 meeting, followed by the Council receiving that information at its June 2020 meeting. Documentation on SSC recommendations is not part of the SEDAR process and is handled through each Council.

2. Management Overview

2.1 SAFMC Fishery Management Plan and Amendments

The following summary describes only those management actions that likely affect Greater Amberjack fisheries and harvest.

Original SAFMC FMP

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

SAFMC FMP Amendments affecting Greater Amberjack

Description of Action	FMP/Amendment	Effective Date
-4” Trawl mesh size (to achieve 12” TL minimum size limit for vermilion snapper)	Snapper Grouper FMP	8/31/1983
-Prohibit trawls south of Cape Hatteras and north of Cape Canaveral	Amendment 1	1/12/1989
-Prohibited gear: fish traps except black sea bass traps north of Cape Canaveral, FL; entanglement nets; longline gear inside 50 fathoms; bottom longlines to harvest wreckfish; powerheads and bangsticks in designated SMZs off S. Carolina. Defined overfishing/overfished and established rebuilding timeframe: other snappers, greater amberjack, black sea bass, red porgy ≤ 10 years (year 1 = 1991). Established 28” FL limit for greater amberjack (recreational only); 36” FL or 28” core length for greater amberjack (commercial only); bag limit 3 greater amberjack; spawning season closure – commercial harvest greater amberjack > 3 fish bag prohibited in April south of Cape Canaveral. -Added spadefish, lesser amberjack, and banded rudderfish to the management unit -Required report of catch/effort from fishermen and dealers -Required offloading with head and fins intact with limited exception for greater amberjack (see above)	Amendment 4	1/1/1992
-*Oculina* Experimental Closed Area. -100% logbook coverage upon permit renewal	Amendment 6	6/27/1994

-Require dealer, charter, and headboat federal permits -Restrict sale/purchase of snapper grouper species -Adjusted bag limit and crew specs for charter and headboat	Amendment 7	1/23/1995
-Limited entry program; transferable permits and 225 lb non-transferable permits.	Amendment 8	12/14/1998
- One fish greater amberjack bag limit (recreational); -During April, limit to 1/person/day or 1/trip, whichever is more restrictive (commercial, charter vessel/headboat) regardless of where harvested -No purchase or sale in April; -Quota (commercial) = 1,169,931 lbs gutted weight, harvest prohibited after quota is met; -Fishing year begins May 1 -Prohibited coring (28" FL recreational; 36" FL commercial) - Prohibit bag limit sales of greater amberjack when the commercial fishery is closed -	Amendment 9	2/24/1999
Approved definitions for overfished and overfishing. MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}. MFMT = F_{MSY}	Amendment 11	12/2/1999
-1,000 lb commercial trip limit for greater amberjack	Amendment 9 (resubmitted)	10/13/2000
-Extended for an indefinite period the regulation prohibiting fishing for and possessing snapper grouper species within the *Oculina* Experimental Closed Area.	Amendment 13A	4/26/2004
-Established eight deepwater Type II marine protected areas (MPAs)	Amendment 14	2/12/2009
-Prohibited the sale of snapper grouper species harvested or possessed in the EEZ under the bag limits and prohibited the sale of snapper grouper harvested or possessed under the bag limits by vessels with a Federal charter vessel/headboat permit regardless of where harvested	Amendment 15B	2/15/2010
-Required dehooking tools when catching snapper grouper species to reduce recreational and commercial bycatch mortality.	Amendment 16	7/29/2009
- Required use of non-stainless-steel circle hooks when fishing for snapper grouper species with hook-and-line gear north of 28 deg. N latitude in the South Atlantic EEZ	Amendment 17A	3/3/2011

-Limited harvest of snapper grouper species in SC SMZs to the bag limit;	Comprehensive Ecosystem-based Amendment 2 (Amendment 23)	1/30/2012
-Reorganized FMU into 6 complexes (deepwater, jacks, snappers, grunts, shallow-water groupers, porgies); -Established acceptable biological catch (ABC) control rule and established ABCs, ACLs, and AMs for species not undergoing overfishing; removed species from FMU and designated others as Ecosystem Component species; established sector allocations for unassessed species. Commercial ACL =800,163 lbs ww Recreational ACL = 1,167,837 lbs ww	Comprehensive Annual Catch Limit Amendment (Amendment 25)	4/16/2012
-Included under the Generic charter/headboat reporting amendment, that modified required logbook reporting for headboat vessels to require electronic reporting, regarding snapper grouper landings	Joint SA and GM Generic Headboat Reporting (Amendment 31)	1/27/2014
-Modified AMs for greater amberjack and other snapper grouper species.	Amendment 34	2/22/2016
-Established SMZs to enhance protection for snapper grouper species in spawning condition	Amendment 36	7/31/2017

SAFMC Regulatory Amendments affecting Greater Amberjack

Description of Action	Amendment	Effective Date
Established 8 SMZs off SC where only hand-held, hook-and-line gear, and spearfishing (excluding powerheads) was allowed.	Regulatory Amendment 5	7/31/1993
Established 10 SMZs at artificial reefs off South Carolina	Regulatory Amendment 7	1/29/1999
-Established 12 SMZs at artificial reefs off Georgia, revised boundaries of 7 existing SMZs, restricted fishing in new and revised SMZs	Regulatory Amendment 8	11/15/2000
-Increased trip limit for greater amberjack to 1,200 lbs gw	Regulatory Amendment 9	7/15/2011
-Modified the commercial and recreational fishing year for greater amberjack: March 1 to end of February	Regulatory Amendment 14	12/8/2014
-Modified the definition of the overfished threshold (MSST) for greater amberjack and seven other snapper grouper species.	Regulatory Amendment 21	11/6/2014

2.2 Emergency and Interim Rules
None

2.3 Secretarial Amendments
None

2.4 Control Date Notices

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.

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.

Notice of Control Date (10/26/2007 72 FR 60794) - Considered measures to limit participation in the snapper grouper for-hire sector effective 3/8/07.

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.

Notice of Control Date (06/15/2016 81 FR 66244) - fishermen who enter the federal for-hire recreational sector for the Snapper Grouper fishery after June 15, 2016, will not be assured of future access should a management regime that limits participation in the sector be prepared and implemented.

Table 2.4.1. General Management Information South Atlantic

Management Program Specifications	SERO: Rick DeVictor
Current stock exploitation status	Not undergoing overfishing
Current stock biomass status	Not overfished
Species	Greater Amberjack (*Seriola dumerili*)
Management Unit	Southeastern US
Management Unit Definition	All waters within South Atlantic Fishery Management Council Boundaries
Management Entity	South Atlantic Fishery Management Council
Management Contacts	SAFMC: Myra Brouwer

Table 2.4.2. Management Parameters

Criteria		South Atlantic – Current (SEDAR 15)		
	Definition	Base Run Values	Units	Median of Base Run MCBs
MSST	$(1-M)*SSB_{MSY}$	1455	Metric tons	
MFMT	F_{MSY}, if available; F_{MSY} proxy if not[2]	0.424	per year	
F_{MSY}	F_{MSY}	0.424	per year	
MSY	Yield at F_{MSY}, landings and discards, pounds and numbers	2005	1000 lbs	
B_{MSY}[1]	Total Biomass	5491	metric tons	
	SSB	1940		
R_{MSY}	Recruits at MSY	435	1000s	
F Target	75% F_{MSY}	0.318	per year	
Yield at F_{TARGET} (equilibrium)	Landings and discards, pounds and numbers	1968	1000 lbs	
M	Natural mortality, Lorenzen scalar	0.25		
Terminal F (2006)	Exploitation	0.225	per year	
Terminal Biomass (2006)[1]	Biomass (SSB)	5617	Metric tons	
Exploitation Status	F_{2006}/F_{MSY}	0.531		
Biomass Status[1]	$SSB_{2006}/MSST$	1.461		
	SSB_{2006}/SSB_{MSY}	1.096		
Generation Time				
$T_{REBUILD}$ (if appropriate)				

Table 2.4.2. Continued Management Parameters

Criteria	South Atlantic – Proposed (values from SEDAR 59)		
	Definition	Base Run Values	Median of Base Run MCBs
MSST[1]	75%SSB_{MSY}		
MFMT	F_{MSY}, if available; $F_{30\%\ SPR}$ proxy [2]		
F_{MSY}	F_{MSY}		
MSY	Yield at F_{MSY}, landings and discards, pounds and numbers		
B_{MSY}[1]	Total or spawning stock, to be defined		
R_{MSY}	Recruits at MSY		
F Target	75% F_{MSY}		
Yield at F_{TARGET} (equilibrium)	Landings and discards, pounds and numbers		
M	Natural mortality, point estimate scalar		
$F_{CURRENT}$	Exploitation		
Terminal Biomass[1]	Biomass		
Exploitation Status	$F_{CURRENT}$ /MFMT		
Biomass Status[1]	B/MSST		
	B/B_{MSY}		
Generation Time			
$T_{REBUILD}$ (if appropriate)			

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

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 2.4.3. Stock Rebuilding Information

Stock not overfished, so no rebuilding plan in place.

Table 2.4.4. General Projection Specifications

South Atlantic

First Year of Management	Assume management begins in 2020. However if there are no changes to the reference points, a projection with the revised ABC and OFL should be provided assuming that landings limits are changed in the 2019 fishing year.
Interim basis	SEDAR 59 ToR ask the Panel to provide guidance on appropriate assumptions to address harvest and mortality levels in interim years; recent SEDAR assessments have asked for ACL, if ACL is met Average exploitation, if ACL is not met
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 2.4.5. 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 2.4.6. P-star projections. Short term specifications for OFL and ABC recommendations. Additional P-star projections may be requested by the SSC once the ABC control rule is applied.

Basis	Value	Years to Project	P* applies to
P*	50%	Interim + 5	Probability of overfishing
P*	40%	Interim + 5	Probability of overfishing
Exploitation	F_{MSY}	Interim + 5	NA
Exploitation	75% of F_{MSY}	Interim + 5	NA

Table 2.4.7. Quota Calculation Details

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

Current Acceptable Biological Catch (ABC) and Total Annual Catch Level (ACL) Value for Greater Amberjack	
Commercial ACL for Greater Amberjack	
Recreational ACL for Greater Amberjack	
Next Scheduled Quota Change	
Annual or averaged quota?	annual
If averaged, number of years to average	
Does the quota include bycatch/discard ?	Yes, see below

How is the quota calculated - conditioned upon exploitation or average landings?
The current ABC is derived from the SEDAR 15 assessment and is the yield at 75% F_{MSY} when the stock is at equilibrium. Therefore, the current quota is conditioned on exploitation.

Does the quota include bycatch/discard estimates? If so, what is the source of the bycatch/discard values? What are the bycatch/discard allowances?
When the model estimates the potential landings at 75% F_{MSY}, which becomes the quota, it also estimates the number of discards associated with harvesting that amount of Greater Amberjack using a discard exploitation rate associated with that level of harvest. These discards are taken into account by the model when calculating total removals from the population due to fishing when giving an estimate of sustainable harvest at MSY levels. Therefore, discards are accounted for in the quota calculations.

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

2.5 Management and Regulatory Timeline

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

South Atlantic Greater Amberjack Commercial Regulatory History **prepared by: Myra Brouwer**

$	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
1992 [A]		NA	90	open		1-Jan	31-Mar	36 inches FL or 28 inches core length [A]	1-Jan	31-Mar						
			29	open with seasonal limitation A	seasonal	1-Apr	30-Apr	36 inches FL or 28 inches core length [A]	1-Apr	30-Apr	3 fish [A]	1-Apr	30-Apr			
			244	open		1-May	31-Dec	36 inches FL or 28 inches core length [A]	1-May	31-Dec						
1993 [A]		NA	89	open		1-Jan	31-Mar	36 inches FL or 28 inches core length [A]	1-Jan	31-Mar						
			29	open with seasonal limitation A	seasonal	1-Apr	30-Apr	36 inches FL or 28 inches core length [A]	1-Apr	30-Apr	3 fish [A]	1-Apr	30-Apr			
			244	open		1-May	31-Dec	36 inches FL or 28 inches core length [A]	1-May	31-Dec						
1994 [A]		NA	89	open		1-Jan	31-Mar	36 inches FL or 28 inches core length [A]	1-Jan	31-Mar						
			29	open with seasonal limitation A	seasonal	1-Apr	30-Apr	36 inches FL or 28 inches core length [A]	1-Apr	30-Apr	3 fish [A]	1-Apr	30-Apr			
			244	open		1-May	31-Dec	36 inches FL or 28 inches core length [A]	1-May	31-Dec						
1995 [A]		NA	89	open		1-Jan	31-Mar	36 inches FL or 28 inches core length [A]	1-Jan	31-Mar						
			29	open with seasonal limitation A	seasonal	1-Apr	30-Apr	36 inches FL or 28 inches core length [A]	1-Apr	30-Apr	3 fish [A]	1-Apr	30-Apr			
			244	open		1-May	31-Dec	36 inches FL or 28 inches core length [A]	1-May	31-Dec						
1996		NA	90	open		1-Jan	31-Mar	36 inches FL or 28 inches core length [A]	1-Jan	31-Mar						
			29	open with seasonal limitation A	seasonal	1-Apr	30-Apr	36 inches FL or 28 inches core length [A]	1-Apr	30-Apr	3 fish [A]	1-Apr	30-Apr			
			244	open		1-May	31-Dec	36 inches FL or 28 inches core length [A]	1-May	31-Dec						
1997		NA	89	open		1-Jan	31-Mar	36 inches FL or 28 inches core length [A]	1-Jan	31-Mar						
			29	open with seasonal limitation A	seasonal	1-Apr	30-Apr	36 inches FL or 28 inches core length [A]	1-Apr	30-Apr	3 fish [A]	1-Apr	30-Apr			
			244	open		1-May	31-Dec	36 inches FL or 28 inches core length [A]	1-May	31-Dec						
1998		NA	89	open		1-Jan	31-Mar	36 inches FL or 28 inches core length [A]	1-Jan	31-Mar						
			29	open with seasonal limitation A	seasonal	1-Apr	30-Apr	36 inches FL or 28 inches core length [A]	1-Apr	30-Apr	3 fish [A]	1-Apr	30-Apr			
			244	open		1-May	31-Dec	36 inches FL or 28 inches core length [A]	1-May	31-Dec						
1999		NA	53	open		1-Jan	23-Feb	36 inches FL or 28 inches core length [A]	1-Jan	23-Feb						
1999 [B]	1,169,931 (lbs gw) [B]		35	open		24-Feb	31-Mar	36 inches FL [B]	24-Feb	31-Mar						
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
1999/2000 [B]	1,169,931 (lbs gw) [B]	NA	335	open		1-May	31-Mar	36 inches FL [B]	1-May	31-Mar		1-May	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]			1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
2000/2001 [B]	1,169,931 (lbs gw) [B]	NA	164	open		1-May	12-Oct	36 inches FL [B]	1-May	12-Oct		1-May	12-Oct			
			169	open		13-Oct	31-Mar	36 inches FL [B]	13-Oct	31-Mar	1,000 lbs gw [C]	13-Oct	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
2001/2002 [B]	1,169,931 (lbs gw) [B]	NA	334	open		1-May	31-Mar	36 inches FL [B]	1-May	31-Mar	1,000 lbs gw [C]	1-May	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
2002/2003 [B]	1,169,931 (lbs gw) [B]	NA	334	open		1-May	31-Mar	36 inches FL [B]	1-May	31-Mar	1,000 lbs gw [C]	1-May	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	31-Mar			
2003/2004 [B]	1,169,931 (lbs gw) [B]	NA	335	open		1-May	31-Mar	36 inches FL [B]	1-May	31-Mar	1,000 lbs gw [C]	1-May	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
2004/2005 [B]	1,169,931 (lbs gw) [B]	NA	334	open		1-May	31-Mar	36 inches FL [B]	1-May	31-Mar	1,000 lbs gw [C]	1-May	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
2005/2006 [B]	1,169,931 (lbs gw) [B]	NA	334	open		1-May	31-Mar	36 inches FL [B]	1-May	31-Mar	1,000 lbs gw [C]	1-May	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
2006/2007 [B]	1,169,931 (lbs gw) [B]	NA	334	open		1-May	31-Mar	36 inches FL [B]	1-May	31-Mar	1,000 lbs gw [C]	1-May	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
2007/2008 [B]	1,169,931 (lbs gw) [B]	NA	335	open		1-May	31-Mar	36 inches FL [B]	1-May	31-Mar	1,000 lbs gw [C]	1-May	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
2008/2009 [B]	1,169,931 (lbs gw) [B]	NA	334	open		1-May	31-Mar	36 inches FL [B]	1-May	31-Mar	1,000 lbs gw [C]	1-May	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
2009/2010 [B]	1,169,931 (lbs gw) [B]	NA	334	open		1-May	31-Mar	36 inches FL [B]	1-May	31-Mar	1,000 lbs gw [C]	1-May	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
2010/2011 [B]	1,169,931 (lbs gw) [B]	NA	334	open		1-May	31-Mar	36 inches FL [B]	1-May	31-Mar	1,000 lbs gw [C]	1-May	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
2011/2012 [B]	1,169,931 (lbs gw) [B]	NA	74	open		1-May	14-Jul	36 inches FL [B]	1-May	14-Jul	1,000 lbs gw [C]	1-May	14-Jul			
			260	open		15-Jul	31-Mar	36 inches FL [B]	15-Jul	31-Mar	1,200 lbs gw [D]	15-Jul	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
2012/2013 [B]		800,163 (lbs ww) [E]	334	open		1-May	31-Mar	36 inches FL [B]	1-May	31-Mar	1,200 lbs gw [D]	1-May	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
2013/2014 [B]		800,163 (lbs ww) [E]	334	open		1-May	31-Mar	36 inches FL [B]	1-May	31-Mar	1,200 lbs gw [D]	1-May	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
2014/2015 [B,F]		769,388 (lbs gw) [G]	220	open		1-May	7-Dec	36 inches FL [B]	1-May	7-Dec	1,200 lbs gw [D]	1-May	7-Dec			
			82	open [F]		8-Dec	28-Feb	36 inches FL [B]	8-Dec	28-Feb		8-Dec	28-Feb			
2015/2016 [F]		769,388 (lbs gw) [G]	30	open		1-Mar	31-Mar	36 inches FL [B]	1-Mar	31-Mar	1,200 lbs gw [D]	1-Mar	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
			264	open		1-May	20-Jan	36 inches FL [B]	1-May	20-Jan	1,200 lbs gw [D]	1-May	20-Jan			
			38	closed	ACL met	21-Jan	28-Feb									
2016/2017 [F]		769,388 (lbs gw) [G]	30	open		1-Mar	31-Mar	36 inches FL [B]	1-Mar	31-Mar	1,200 lbs gw [D]	1-Mar	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
			155	open		1-May	3-Oct	36 inches FL [B]	1-May	3-Oct	1,200 lbs gw [D]	1-May	3-Oct			
			147	closed	ACL met	4-Oct	28-Feb									
2017/2018 [F]		769,388 (lbs gw) [G]	30	open		1-Mar	31-Mar	36 inches FL [B]	1-Mar	31-Mar	1,200 lbs gw [D]	1-Mar	31-Mar			
			29	restriction on commercial sale and purchase [B]	seasonal	1-Apr	30-Apr	36 inches FL [B]	1-Apr	30-Apr	1 fish per person per day or 1 fish per trip whichever more restrictive [B]	1-Apr	30-Apr			
			169	open		1-May	17-Oct	36 inches FL [B]	1-May	28-Feb	1,200 lbs gw [D]	1-May	28-Feb			
			133	closed	ACL met	18-Oct	28-Feb									

A = Amendment 4 (effective 1/1/1992) included implementation of commercial size limit (36 in FL or 28 in core length); restricted retention limit in April to 3 fish/person/day south of Cape Canaveral (FR states "During April each year, south of Cape Canaveral, Florida, the possession of greater amberjack in or from the EEZ is limited to the bag limit, regardless of whether or not the vessel from where such amberjack were taken has a vessel permit.")

B = Amendment 9 (effective 2/24/1999) included implementation of commercial quota; set fishing year May 1 - April 31; prohibited coring; during April set the retention limit of commercial and for-hire permitted vessels at 1/person/day or 1/trip whichever is more restrictive; prohibited bag limit sales when commercial fishery closed - (FR states, "During April, each year, the possession of greater amberjack in or from the South Atlantic EEZ and in the South Atlantic on board a vessel for which a valid Federal commercial or charter vessel/headboat permit for South Atlantic snapper-grouper has been issued, without regard to where such greater amberjack were harvested, is limited to one per person per day or one per person per trip, whichever is more restrictive. Such greater amberjack are subject to the prohibition on sale or purchase, as specified in §622.92(g).)

C = Amendment 9 was resubmitted and implemented commerical trip limit of 1000 lb gw (effective 10/13/2000)

D = Regulatory Amendment 9 (effective 7/15/2011) increased commercial trip limit to 1200 lb gw

E = Comprehensive ACL Amendment (Amendment 25; effective 4/16/2012) implemented commercial and recreational ACLs

F = Regulatory Amendment 14 (effective 12/8/2014) changed fishing from March 1 through the end of February

G = Per SERO, change in ACL likely due to conversion from ww to gw; not due to regulatory action

South Atlantic Greater Amberjack Recreational Regulatory History

prepared by: Myra Brouwer

Year	Quota (# fish)	ACL (lbs ww)	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
1992	NA	NA	365	open		1-Jan	31-Dec	28 inches FL A	1-Jan	31-Dec	3 per person per day A	1-Jan	31-Dec			
1993	NA	NA	365	open		1-Jan	31-Dec	28 inches FL A	1-Jan	31-Dec	3 per person per day A	1-Jan	31-Dec			
1994	NA	NA	365	open		1-Jan	31-Dec	28 inches FL A	1-Jan	31-Dec	3 per person per day A	1-Jan	31-Dec			
1995	NA	NA	365	open		1-Jan	31-Dec	28 inches FL A	1-Jan	31-Dec	3 per person per day A	1-Jan	31-Dec			
1996	NA	NA	365	open		1-Jan	31-Dec	28 inches FL A	1-Jan	31-Dec	3 per person per day A	1-Jan	31-Dec			
1997	NA	NA	365	open		1-Jan	31-Dec	28 inches FL A	1-Jan	31-Dec	3 per person per day A	1-Jan	31-Dec			
1998	NA	NA	365	open		1-Jan	31-Dec	28 inches FL A	1-Jan	31-Dec	3 per person per day A	1-Jan	31-Dec			
1999	NA	NA	53	open		1-Jan	23-Feb	28 inches FL A	1-Jan	23-Feb	3 per person per day A	1-Jan	23-Feb			
1998/1999 B	NA	NA	65	open		24-Feb	30-Apr	28 inches FL A	24-Feb	30-Apr	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	24-Feb	30-Apr			
1999/2000 B	NA	NA	365	open		1-May	30-Apr	28 inches FL A	1-May	30-Apr	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-May	30-Apr			
2000/2001 B	NA	NA	365	open		1-May	30-Apr	28 inches FL A	1-May	30-Apr	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-May	30-Apr			
2001/2002 B	NA	NA	365	open		1-May	30-Apr	28 inches FL A	1-May	30-Apr	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-May	30-Apr			
2002/2003 B	NA	NA	365	open		1-May	30-Apr	28 inches FL A	1-May	30-Apr	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-May	30-Apr			
2003/2004 B	NA	NA	365	open		1-May	30-Apr	28 inches FL A	1-May	30-Apr	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-May	30-Apr			
2004/2005 B	NA	NA	365	open		1-May	30-Apr	28 inches FL A	1-May	30-Apr	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-May	30-Apr			
2005/2006 B	NA	NA	365	open		1-May	30-Apr	28 inches FL A	1-May	30-Apr	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-May	30-Apr			
2006/2007 B	NA	NA	365	open		1-May	30-Apr	28 inches FL A	1-May	30-Apr	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-May	30-Apr			
2007/2008 B	NA	NA	365	open		1-May	30-Apr	28 inches FL A	1-May	30-Apr	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-May	30-Apr			
2008/2009 B	NA	NA	365	open		1-May	30-Apr	28 inches FL A	1-May	30-Apr	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-May	30-Apr			
2009/2010 B	NA	NA	365	open		1-May	30-Apr	28 inches FL A	1-May	30-Apr	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-May	30-Apr			
2010/2011 B	NA	NA	365	open		1-May	30-Apr	28 inches FL A	1-May	30-Apr	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-May	30-Apr			
2011/2012 B	NA	NA	350	open		1-May	15-Apr	28 inches FL A	1-May	15-Apr	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-May	15-Apr			
	NA	1167837 C	14	open		16-Apr	30-Apr	28 inches FL A	16-Apr	30-Apr	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	16-Apr	30-Apr			
2012/2013 B	NA	1167837 C	365	open		1-May	30-Apr	28 inches FL A	1-May	30-Apr	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-May	30-Apr			
2013/2014 B	NA	1167837 C	365	open		1-May	30-Apr	28 inches FL A	1-May	30-Apr	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-May	20-Apr			
2014/2015 B	NA	1167837 C	220	open		1-May	7-Dec	28 inches FL A	1-May	7-Dec	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-May	7-Dec			
2014/2015 D			82	open D		8-Dec	28-Feb	28 inches FL A	8-Dec	28-Feb	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	8-Dec	28-Feb			
2015/2016 D	NA	1167837 C	365	open		1-Mar	28-Feb	28 inches FL A	1-Mar	28-Feb	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-Mar	28-Feb			
2016/2017 D	NA	1167837 C	273	open		1-Mar	29-Nov	28 inches FL A	1-Mar	29-Nov	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-Mar	29-Nov			
			90	closed	ACL met	30-Nov	28-Feb									
2017/2018 D	NA	1167837 C	243	open		1-Mar	30-Oct	28 inches FL A	1-Mar	30-Oct	1 per person per day; in April for hire vessels have retention limit of 1 per person per day or 1 per trip whichever is most restrictive B	1-Mar	30-Oct			
	NA		120	closed	ACL met	31-Oct	28-Feb									

A = Amendment 4 implemented 28 in FL size limit and 3/person/day bag limit (effective date 1/1/1992); also stated "During April each year, south of Cape Canaveral, Florida, the possession of greater amberjack in or from the EEZ is limited to the bag limit, regardless of whether or not the vessel from where such amberjack were taken has a vessel permit."

B = Amendment 9 (effective 2/24/1999) included fishing year change to May 1-Apr 30; change in recreational bag limit to 1/person/day; in April Charter and Headboat bag limit 1/person/day or 1/trip whichever more restrictive; (FR states, "During April, each year, the possession of greater amberjack in or from the South Atlantic EEZ and in the South Atlantic on board a vessel for which a valid Federal commercial or charter vessel/headboat permit for South Atlantic snapper-grouper has been issued, without regard to where such greater amberjack were harvested, is limited to one per person per day or one per person per trip, whichever is more restrictive. Such greater amberjack are subject to the prohibition on sale or purchase, as specified in §622.92(g).)

C = Comprehensive ACL Amendment (Amendment 25; effective 4/16/2012) implemented recreational and commercial ACLs D = Regulatory Amendment 14 (effective 12/8/2014) changed fishing year from March 1 - end of Feb

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

Commercial:

Season		Date
2015/2016	Closed	01/21/2016
2016/2017	Closed	10/4/2016
2017/2018	Closed	10/18/2017

Recreational:

Season		Date
2016/2017	Closed	11/30/2016
2017/2018	Closed	10/31/2017

2.6 State Regulatory History

2.6.1 North Carolina:

There are currently no North Carolina state-specific regulations for greater amberjack. 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 greater amberjack, this rule was amended effective March 1, 1996 to include the following Sub-item:

15A NCAC 03M .0506 SNAPPER-GROUPER

….

(j) Greater amberjack:

(1) It is unlawful to possess greater amberjack less than 36 inches fork length, except that persons fishing under the bag limit established under Sub-paragraph (2) of this Paragraph may possess a minimum 28 inch amberjack

(2) It is unlawful to possess more than three greater amberjack per person per day.

This sub-item of rule 15A NCAC 03M .0506 was amended to reflect a number of management changes effective May 1, 1999:

(j) Greater amberjack:

(1) For recreational purposes:

(A) It is unlawful to possess greater amberjack less than 28 inches fork length.

(B) It is unlawful to possess more than one greater amberjack per person per day.

(2) It is unlawful to sell or purchase greater amberjack less than 36 inches fork length.

(3) It is unlawful to possess more than one greater amberjack per person per day without a valid Federal Commercial Snapper-Grouper Permit.

(4) It is unlawful to possess more than one greater amberjack per person per day during the month of April.

(5) It is unlawful to sell or purchase greater amberjack during any closed season.

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 effective October 1, 2008 and proclamation authority to implement changes in management was moved to rule 15A NCAC 03M .0512. An information update to the IJ FMP was completed and approved in November 2015 and contained no additional regulatory changes. Since the 2008 IJ FMP update, all snapper grouper regulations were contained in a single proclamation, which was updated anytime an opening/closing of a particular species in the complex occurred, as well as any changes in allowable gear, required permits, etc. Beginning in 2015, commercial and recreational regulations have been 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.

2.6.2 South Carolina:

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

2000: SC Marine-related Laws reorganized under SC Code of Laws Title 50 Chapter 5. SC Code of Laws Section 50-5-2730 reads – "Unless otherwise provided by law, any regulations promulgated by the federal government under the Fishery Conservation and Management Act (PL94-265) or the Atlantic Tuna Conservation Act (PL 94-70) which establishes seasons, fishing periods, gear restrictions, sales restrictions, or bag, catch, size, or possession limits on fish are declared to be the law of this State and apply statewide including in state waters." As such, SC amberjack –related regulation is pulled directly from the federal regulations as promulgated under Magnuson. No changes have been made to this approach in covering amberjack since the Chapter 5 rewrite.

2.6.3 Georgia:

Please note that GA regulations are for Amberjack generally, not just Greater Amberjack.

The Georgia Legislature, the Board of Natural Resources and the Department of Natural Resources, an executive agency, share regulatory responsibilities for wildlife in the state of Georgia with the Board and Department as subordinates. Title 27 (Game and Fish Code) Chapter 4 of the Georgia Statutes contain the laws directly related to the management of wildlife including marine fishes (O.C.G.A. 27-4-10). In 2012, the legislature amended the Game and Fish Code extensively and in doing so granted the Board and Department additional powers to promulgate regulations affecting marine fisheries. Previously the legislature maintained management authority over a select group of marine fishes while allowing the Board and Department authority over others. With the 2012 amendment, the legislature set parameters within which the Board and Department regulate marine fishes. Board of Natural Resources Rule 391-2-4-.04, Saltwater Finfishing, contains regulations for these fishes, including amberjacks.

Current Amberjack Regulations in Georgia (April 2018)
Open year round, one fish per person per day, 28-inch fork length minimum size. (Board Rule 391-2-4-.04 (3)(a))

License Requirements
In Georgia, a license is required to fish recreationally (O.C.G.A. 27-2-1) or commercially (O.C.G.A. 27-4-110). Recreational fishing licenses are required of residents and non-residents fishing in state territorial waters as well as the EEZ. All persons under the age of 16, regardless of residency, and residents born before July 1, 1952 are not required to purchase recreational licenses. Other exemptions exist for active military and individuals with disabilities, check with the GADNR for details. Commercial fishing licenses are required to sell seafood landed in Georgia from Georgia waters or from the EEZ.

Penalties for Violations
Penalties for violations of Georgia laws and regulations are established in Georgia Statutes. Most violations of game and fish laws are misdemeanors though some may be elevated to misdemeanors of high and aggravated nature, Title 27, Chapter 4.

Gear Restrictions
There are few restrictions on recreational gear for the harvest of amberjacks; only gig and gillnet are prohibited. Commercially, amberjacks may be harvested using trawl nets, cast nets, seines, and pole-and line, though only pole-and-line are practical. (Board Rule 391-2-4-.12)Commercial Landings and Data Reporting Requirements
Georgia requires commercial harvesters (O.C.G.A. 27-4-118) and seafood dealers (O.C.G.A. 27- 4-136) to submit landings data. Information to be supplied for each trip includes trip date; vessel identification; trip number; species; quantity; units of measure; disposition; value; county or port landed; state landed; dealer identification; unloading date; market; grade; gear; quantity of gear; days at sea; number of crew; fishing time; and number of sets.

Commercial finfish harvest limits are equivalent to recreational limits unless otherwise noted. This means that commercial harvesters may land and sell no more than one amberjack per person per day and minimum size and landing restrictions are the same as recreational. (Board Rule
391-2-4-.04)

Other Restrictions
Amberjacks, as with all marine species except sharks, must be landed with head and fins intact. Transfer between vessels at sea is prohibited. (Board Rule 391-2-4-.04 (5)(a) and (b)).

Management Chronology

1957: Gill nets prohibited in state waters.

1989: The Georgia Legislature established O.C.G.A. 27-4-130.1, Open seasons, creel limits, and minimum size limits for certain finfish species. For amberjacks, a closed season of January 1 through March 15 was established ((a)(6)). Furthermore, the legislature authorized the Board to manage amberjack seasons beyond this closed season as well as to set size limits between 20 and 50 inches and to establish a maximum daily creel not to exceed 10 fish ((b)(6)).

1989: The Board of Natural Resources adopted Rule 391-2-4-.04, Saltwater Finfishing. Specifically for amberjacks, it established a March 16th to December 31st open season ((3)(f)), a three amberjack per person daily creel and possession limit ((4)(f)), and a 28-inch fork length minimum size ((5)(f)).

2000: The Board of Natural Resources amended Rule 391-2-4-.04, Saltwater Finfishing. A one amberjack per person daily creel and possession limit ((4)(f)) was established. A no commercial sale period was also created for April 1-April 30.

2012: The Georgia Legislature repealed O.C.G.A. 27-4-130.1 and moved those species therein to
O.C.G.A. 27-4-10. Amberjack ((a)(21)) parameters were set at 0 to 50 inches and five fish. Further, the board was authorized to set size limits, open seasons, creel and possession limits and possession and landing specifications on a state-wide, regional and local basis. Finally, the Commissioner of the Department was empowered to close waters to recreational and commercial fishing by species for a period of up to six months within a calendar year.

2012: The Board of Natural Resources implemented the necessary requirements of the Legislative repeal while keeping amberjack management intact, with the exception of resorting species; amberjacks became letter (a).

2014: The Board of Natural Resources amended 391-2-4-.04, Saltwater Finfishing, for Amberjack ((3)(a)) to allow fishing all year, but kept the one amberjack per person creel and possession limit and the 28-inch fork length minimum size limit as well as the landing restrictions of head and fins intact and prohibition on transfer at sea.

2.6.4 Florida:

Greater Amberjack Regulation History (Atlantic only)

Year	Minimum Size Limit (FL)	Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
1980	None	None		
1981	None	None		
1982	None	None		
1983	None	None		
1984	None	None		
1985	None	None		
1986	None	None		
1987	None	Recreational: 2 fish or 250 pounds per person, whichever is greater Commercial: No limit		
1988	None	Recreational: 2 fish or 250 pounds per person, whichever is greater Commercial: No limit		
1989	None	Recreational: 2 fish or 100 pounds per person, whichever is greater Commercial: No limit		

1990	Recreational: 28” Commercial: 36”	Recreational; 3 fish per person Commercial: No limit	Designated amberjack as a "restricted species." Established a minimum size limit of 28 inches. Prohibited the sale of amberjack less than 36 inches or 28 inches with head-only removed. Set a recreational daily bag limit of 3 fish per person. Required amberjack to be landed in whole condition (may be landed with head-only removed for commercial harvest). Prohibited all commercial harvest of amberjack in state waters whenever harvest is prohibited in adjacent federal waters. Required a federal reef fish permit to harvest amberjack if the permit is required in adjacent federal waters.	Feb. 1, 1990
1991	Recreational: 28” Commercial: 36”	Recreational; 3 fish per person Commercial: No limit		
1992	Recreational: 28” Commercial: 36”	Recreational; 3 fish per person Commercial: No limit	Restricted all harvest of amberjack in April and May to the bag limit. Required all amberjack to be landed with heads and tails intact (the coring provision for greater amberjack still applies). Prohibited persons from harvesting greater amberjack under both recreational and commercial rules on the same trip.	Dec. 31, 1992
1993	Recreational: 28” Commercial: 36”	Recreational; 3 fish per person Commercial: No limit		

1994	Recreational: 28” Commercial: 36”	Recreational; 3 fish per person Commercial: No limit		
1995	Recreational: 28” Commercial: 36”	Recreational; 3 fish per person Commercial: No limit		
1996	Recreational: 28” Commercial: 36”	Recreational; 3 fish per person (1 fish person in Monroe County) Commercial: No limit	(1) Prohibited the sale of all amberjack species (including greater amberjack, lesser amberjack, banded rudderfish, and Almaco jack) during the April/May closed commercial season. (2) In Monroe County waters only, reduced the daily recreational bag limit for amberjack of any species (including greater amberjack, lesser amberjack, banded rudderfish, and Almaco jack) to 1 fish per person.	(1) April 1, 1996 (2) July 1, 1996
1997	Recreational: 28” Commercial: 36”	Recreational; 3 fish per person (1 fish person in Monroe County) Commercial: No limit		

1998	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: No limit	(1) Reduced the recreational daily bag limit for greater amberjack to 1 fish per person statewide. Prohibited the sale of any amberjack species (greater and lesser amberjack, banded rudderfish, and Almaco jack) during March, April, and May. Prohibited the sale of any amberjack species less than 36 inches at any time. Required all amberjack to be landed in	(1) Jan. 1, 1998 (2) Dec. 31, 1998
			whole condition (including such fish harvested commercially). (2) Revised the name of the federal licenses required to harvest amberjack in the South Atlantic to conform with federal changes.	
1999	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: No limit		
2000	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: No limit	Merged the amberjack rules into the reef fish chapter. Conformed the amberjack commercial licensing requirements to those of reef fish (with a clarification that the appropriate federal commercial permit is a condition of sale for all species in the rule).	Jan. 1, 2000
2001	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: 1,000 lbs. per vessel	Established a commercial vessel limit of 1,000 lbs. per day	March 1, 2001

2002	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: 1,000 lbs. per vessel		
2003	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: Same as federal waters	Changed rule language regarding possession of amberjack during commercial trips to correspond with federal regulations.	Jan. 1, 2003
2004	Recreational: 28” Commercial:	Recreational: 1 fish per person		
	36”	Commercial: Same as federal waters		
2005	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: Same as federal waters		
2006	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: Same as federal waters		
2007	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: Same as federal waters		

2008	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: Same as federal waters		
2009	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: Same as federal waters		
2010	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: Same as federal waters	Required dehooking tools aboard commercial and recreational vessels for anglers to use as needed to remove hooks from Atlantic reef fish.	Jan. 19, 2010
2011	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: Same as federal waters		
2012	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: Same as federal waters		
2013	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: Same as federal waters		

2014	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: Same as federal waters		
2015	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: Same as federal waters		
2016	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: Same as federal waters		
2017	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: Same as federal waters		
2018	Recreational: 28” Commercial: 36”	Recreational: 1 fish per person Commercial: Same as federal waters		

References
None provided.

3. Assessment History & Review

In the early 1990s, a series of unnumbered reports were prepared by the SAFMC Plan Development Team (1990) and later by the Beaufort Reef fish Team (1991, 1992, 1993), in which snapshot analyses were conducted for a list of snapper-grouper species, including Greater Amberjack. These analyses included the estimation of SPR (spawning potential ratio) based on a single year of data, and were intended to highlight species for future assessments. SPR was also estimated in this manner in the report by Potts and Brennan (1998). However, the only assessment conducted on this stock of Greater Amberjack was by Legault and Turner (Evaluations of the Atlantic Greater Amberjack, *Seriola dumerili*, Stock Status, July 1999, *Sustainable Fisheries Division Contribution* SFD-98/99-63). In 1999, alternative stock assessment methods (Delury depletion and ASPIC models) were applied to Greater Amberjack data from the Florida Atlantic coast (Nassau County to Miami) by the FL FWCC. In 2008, the SEFSC conducted an assessment using a statistical catch-age model, BAM. The data sources available for greater amberjack in the US South Atlantic have not changed substantially since the last assessment effort.

4. Regional Maps

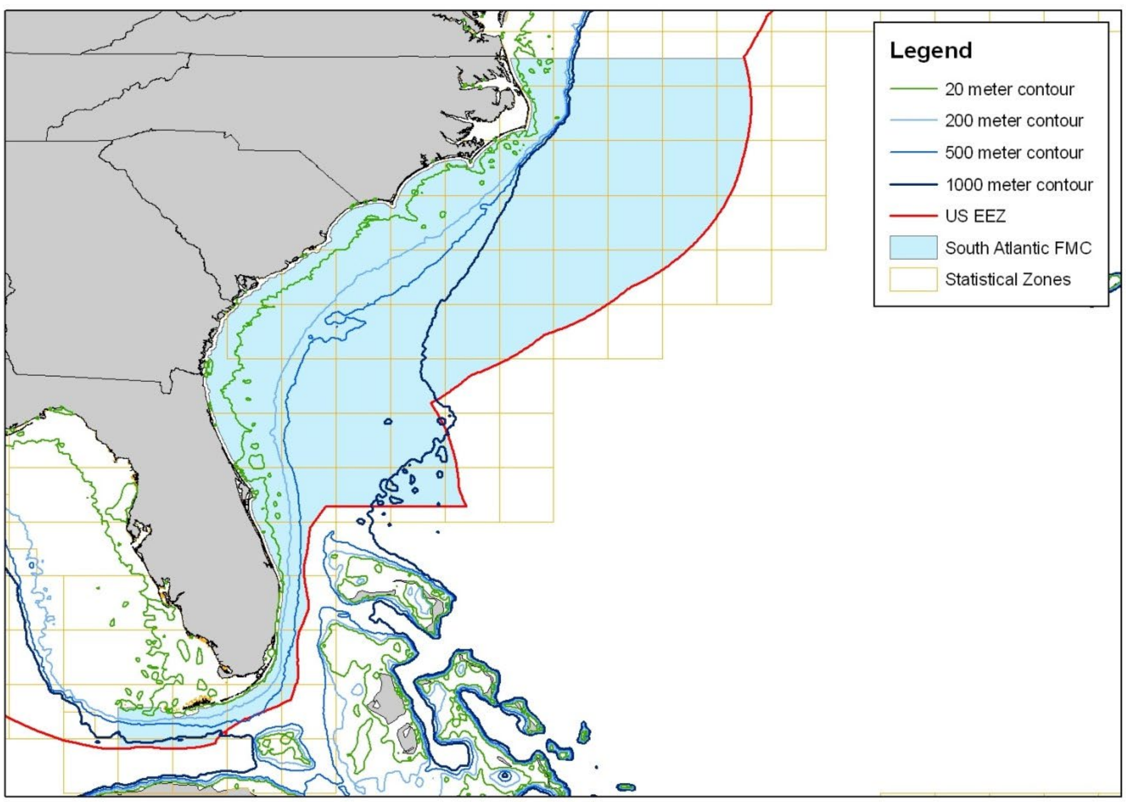


Figure 4.1: South Atlantic Fishery Management Council and EEZ boundaries.

5. SEDAR Abbreviations

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

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

SEDAR

Southeast Data, Assessment, and Review

SEDAR 59

South Atlantic Greater Amberjack

Section II: Assessment Report

March 2020

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

List of Tables

List of Figures

1. Introduction

This standard assessment evaluated the stock of Greater Amberjack, *Seriola dumerili* , off the southeastern United States within the South Atlantic Fishery Management Council's (SAFMC) jurisdiction[1]. The primary objectives of this assessment were to consider new and existing data sources, provide stock status, and conduct new stock projections. Data compilation and assessment methods were guided by the methodology of SEDAR15, as well as by current best SEDAR practices. The assessment period is 1980–2017.

Available data on this stock included one fishery-independent and two fishery-dependent indices of abundance, landings, discards, and samples of annual length and age compositions from fishery-dependent sources. Data on landings and discards were available from the recreational and commercial fleets.

The primary model used is the Beaufort Assessment Model (BAM), an integrated catch-age formulation. A base run of BAM was configured to provide point estimates of key management quantities, such as stock and fishery status. Uncertainty in estimates from the base run was evaluated through an ensemble modeling approach as well as sensitivities and retrospective analyses.

The terminal (2017) base run estimate of spawning stock biomass was above the MSST (SSB_{2017}/MSST =2.80) indicating that the stock is not overfished. The estimated fishing rate in each year is below F_{MSY}, and the terminal estimate, which is based on a three-year geometric mean, is below F_{MSY} in the base run ($F_{2015–2017}/F_{MSY}$ = 0.69). Thus, this assessment indicates that the stock is not overfished and not undergoing overfishing.

The ensemble modeling indicates that these estimates of stock and fishery status are robust, with minimal uncertainty in the status conclusions. Of all models within the ensemble, about 99.9% were in qualitative agreement that the stock is not overfished (SSB_{2017}/MSST > 1.0), and about 98% that the stock is not undergoing overfishing ($F_{2015–2017}/F_{MSY}$ < 1.0). The status estimates are most sensitive to the values used for natural mortality.

The estimated population trends of this benchmark assessment are quite similar to those from the SEDAR15 benchmark. However, the two assessments did show some differences in results, which was not surprising given several modifications made to both the data and model (described throughout the report). Compared to the SEDAR15 benchmark, this assessment suggests higher values of F_{MSY} and MSY, and a higher value of SSB_{MSY}.

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

1.1 Workshop Time and Place

The SEDAR 59 Assessment of South Atlantic Greater Amberjack occurred over a series of webinars held on the following dates: March 30, 2018; December 14, 2018; November 1, 2019; December 16, 2019; and January 22, 2020.

1.2 Terms of Reference

Prepare a standard assessment, based on the approved SEDAR 15 South Atlantic Greater Amberjack assessment with data through 2017. 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.)
    - Consider including the SERFS video and HB at sea indices of abundance.
    - Incorporate the latest BAM model configurations and updates to data calculation methodologies, detailing the changes made and the impacts of those changes between the SEDAR 15 model and the proposed SEDAR 59 model.
    - Re-consider use of age and length composition data.
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 SEDAR 15 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 pdf for biological reference point estimates and yield separated for landings and discards reported in pounds and numbers. Projection results are required through 2023, with projected fishing level changes beginning in late 2019. The panel shall provide guidance on appropriate assumptions to address harvest and mortality levels in the interim years between the assessment terminal year (2016) and the first year of management (2019). Projection criteria:
    - To determine OFL: (1) P*=50%; (2) Fmsy
    - To determine ABC: (1)P*=40%; (2) 75%Fmsy

1.3 List of Participants

Appointee	Function	Affiliation
ANALYTICAL TEAM		
Kevin Craig	Lead analyst	SEFSC Beaufort
Eric Fitzpatrick	Data compiler	SEFSC Beaufort
PANELISTS		
Nate Bacheler	Data provider	SEFSC Beaufort
Alan Bianchi	Data provider	NC DMF
Rob Cheshire	Data provider	SEFSC Beaufort
Julie DeFilippi-Simpson	Data Provider	ACCSP
Kevin Kolmos	Data provider	SC DNR
Anne Lange	SSC	SAFMC SSC
Vivian Matter	Data provider	SEFSC Miami
Andy Ostrowski	Data provider	SEFSC Beaufort
Jennifer Potts	Data provider	SEFSC Beaufort
Fred Serchuk	SSC	SAFMC SSC
Kyle Shertzer	Assessment Team	SEFSC Beaufort
Tracey Smart	Data provider	SC DNR
Erik Williams	Assessment Team	SEFSC Beaufort
Beth Wrege	Data provider	SEFSC Miami
APPOINTED OBSERVERS		
Andy Piland	Fisherman	NC / SG AP
Paul Nelson	Fisherman	FL
APPOINTED COUNCIL MEMBERS		
Chris Conklin	Council member	SAFMC
STAFF		
Kathleen Howington	Coordinator	SEDAR
Myra Brouwer	Council lead	SAFMC
Mike Errigo	Fishery Biologist	SAFMC
Mike Larkin	Fishery Biologist	SERO
Julia Byrd	Observer	SAFMC

1.3 List Of Participants Continued

NON-PANEL DATA PROVIDERS

Larry Beerkircher	Data Provider	SEFSC Miami
Ken Brennan	Data Provider	SEFSC Beaufort
Steve Brown	Data Provider	FL FWCC
Julie Califf	Data Provider	GA DNR
Amy Dukes/Eric Hiltz	Data Provider	SC DNR
Kelly Fitzpatrick	Data Provider	SEFSC Beaufort
Kevin McCarthy	Data Provider	SEFSC Miami
Amanda Tong	Data Provider	NC DMF
Beverly Sauls/Dominique Lazarre	Data Provider	FL FWCC
Chris Wilson	Data Provider	NC DMF

Other Webinar Attendees

Andrew Cathey	Observer	NCDMF
Marcel Reichert	Observer	SCDNR
Katie Siegfried	Observer	SEFSC Beaufort
McLean Seward	Observer	NCDMF
Peter Barile	Observer	
Ben Duffin	Observer	

1.4 List of Assessment Workshop Working Papers

Document #	Title	Authors
Documents Prepared for SEDAR 59		
SEDAR59-WP01	Standardized video counts of Southeast U.S. Atlantic Greater Amberjack (*Seriola dumerili*) from the Southeast Reef Fish Survey	Cheshire and Bacheler 2018
SEDAR59-WP02	Life History Contributions in Support of the SEDAR 59 Assessment of South Atlantic Greater Amberjack by MARMAP, SERFS, and the SEFSC	Smart and Kolmos 2018
SEDAR59-WP03	Standardized catch rates of greater amberjack (*Seriola dumerili*) in the southeast U.S. from headboat logbook data	SFB-NMFS 2018
SEDAR59-WP04	Standardized catch rates of greater amberjack (*Seriola dumerili*) in the southeast U.S. from commercial logbook data	SFB-NMFS 2018
SEDAR59-WP05	Commercial age and length composition weighting for U.S. greater amberjack (*Seriola dumerili*)	SFB-NMFS 2018
SEDAR59-WP06	Standardized catch rates of greater amberjack (*Seriola dumerili*) in the southeast U.S. from headboat at-sea observer data	SFB-NMFS 2018
SEDAR59-WP07	Commercial landings - Not Received	Wrege & Simpson
SEDAR59-WP08	A Summary of Greater Amberjack Discard Data from Recreational Fishery Surveys on the East Coast of Florida	Duffin 2018
SEDAR59-WP09	MRIP - Not Received	Matter
SEDAR59 – WP10	Discards of Greater Amberjack Calculated for Vessels with Federal Fishing Permits in the US South Atlantic	Diaz and McCarthy, 2019
SEDAR59-WP11	South Atlantic U.S. greater amberjack (Seriola dummerili) age and length composition from the recreational fisheries	SEFSC, 2019

1.4 List of Assessment Workshop Working Papers Cont.

Document #	Title	Authors
Reference Documents for SEDAR 59		
SEDAR59-RD01	SEDAR 15 Stock Assessment Report: South Atlantic Greater Amberjack	SEDAR 15
SEDAR59-RD02	List of documents and working papers for SEDAR 15 (South Atlantic Greater Amberjack) – most documents available on the SEDAR website.	SEDAR 15
SEDAR59-RD03	Southeast Reef Fish Survey Video Index Development Workshop	Bacheler and Carmichael 2014
SEDAR59-RD04	Overview of sampling gears and standard protocols used by the Southeast Reef Fish Survey and its partners	Smart et al. 2014
SEDAR59-RD05	Technical documentation of the Beaufort Assessment Model (BAM)	Williams and Shertzer 2015
SEDAR59-RD06	Snapper Grouper Advisory Panel Greater Amberjack Fishery Performance Report: April 2018	SAFMC Snapper Grouper AP
SEDAR59-RD07	Biotelemetry based estimates of greater amberjack (*Seriola dumerili*) post-release mortality in the northern Gulf of Mexico	Jackson et al. 2018
SEDAR59-RD08	Release mortality of Gulf of Mexico greater amberjack from commercial and recreational hook-and-line fisheries: Integration of fishing practices, environmental parameters, and fish physiological attributes	Murie and Parkyn 2013
SEDAR59-RD09	SEDAR61-WP19: Model-estimated conversion factors for calibrating Coastal Household Telephone Survey (CHTS) charterboat catch and effort estimates with For-Hire Survey (FHS) estimates in the Atlantic and Gulf of Mexico with application to red grouper and greater amberjack	Dettloff and Matter 2019

1.5 Statements Addressing each Term of Reference

Responses are in italics below each TOR

1. Prepare a standard assessment, based on the approved SEDAR 15 South Atlantic Greater Amberjack assessment with data through 2017. Provide commercial and recreational landings and discards in pounds and numbers.
   Section 2.2.1 provides the input landings and discards.

2. Evaluate and document the following specific changes in input data or deviations from the update model.
   - Consider including the SERFS video and HB at sea indices of abundance.
   - Incorporate the latest BAM model configurations and updates to data calculation methodologies, detailing the changes made and the impacts of those changes between the SEDAR 15 model and the proposed SEDAR 59 model.
   - Re-consider use of age and length composition data.

   Section 2.2 reviews the data and explains the deviations from the previous assessment. The impacts of changing model structure or input data are shown through sensitivity analysis. In particular, sensitivities S1, S4, and S11:15 incorporate the previous assessment's data and/or assumptions. The SERFS index was included, but the Panel did not recommend the HB at sea index for use.

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 SEDAR 15 assessment.

   Section 3.2 contains the data sources used in the model, and section 3.3 describes the model configuration.

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.
   Section 3.6 describes how the benchmarks are derived, and requested values are in Tables 6-18 and measures of precision are shown in Figures 26, and 29-32. Comparison plots are provided in Figures 47 and 48 and a discussion is in section 4.9.2.

5. Provide stock projections, including a pdf for biological reference point estimates and yield separated for landings and discards reported in pounds and numbers. Projection results are required through 2023, with projected fishing level changes beginning in late 2019. The panel shall provide guidance on appropriate assumptions to address harvest and mortality levels in the interim years between the assessment terminal year (2016) and the first year of management (2019). Projection criteria:
   - To determine OFL: (1) P*=50%; (2) Fmsy
   - To determine ABC: (1)P*=40%; (2) 75%Fmsy

   Section 3.8.3 describes the projection scenarios. An $F_{current}$ *scenario was also done. Results are described in section 4.11 and shown in Tables 20-22 and Figures 44-46.*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.

   The research recommendations were compiled from members of the Panel and reported in section 5.3 of the report.

6. Develop a stock assessment update report to address these TORS and fully document the input data, methods, and results of the stock assessment update.
   Complete, and the report was submitted in a timely manner.

2 Data Review and Update

In this standard assessment, the start year is 1980 and the terminal year is 2017. The start year of 1980 was chosen because it is the first year of the headboat index, one of the earliest datasets used in the model. The Assessment Panel discussed using the SEDAR15 start year of 1946, and there was concern that much of the data prior to 1980 was highly uncertain. The Panel discussed the perceived year of virgin conditions and whether the onset of the fishery was properly reflected in the data. After investigatory runs, the Panel decided to start the model when the best data became available. There were minimal commercial landings reported prior to 1980 and non-hindcasted recreational landings, recreational discards, and commercial discards were not available. The SEDAR15 start year was run as a sensitivity using hindcasted recreational removals based on the FWHAR method. The start year did not affect model results, therefore for parsimony in the model we went forward with 1980 as the start year. The input data for this assessment are described below, with focus on modifications from SEDAR15 recommended by the Panel:

2.1 Data Review

In this standard assessment, the Beaufort Assessment Model (BAM) was fitted to data sources similar to those used in the SEDAR15 benchmark with some modifications and additions.

- Landings: Commercial (all gears), General recreational (headboat, charterboat, and private boat modes)
- Discards: Commercial (all gears), General recreational (all modes)
- Indices of abundance: Commercial handline, Headboat, Video
- Length compositions: Headboat-at-sea discards
- Age compositions of landings: Commercial handline, General recreational

In addition to data fitted by the model, this assessment utilized life-history information that was treated as input. Natural mortality, female maturity at age, and the population growth curve were updated from the last assessment while sex ratio, time of peaking spawning, and discard mortality were the same as in SEDAR15.

2.2 Data Update

The following is a summary of the data differences between this standard assessment and the SEDAR15 benchmark assessment. Data available for this assessment are summarized in Tables 1–5.

- Fleet Structure: All commercial landings were combined as a single pooled fleet compared to a smaller commercial pooled fleet (handline, longline, other) and a commercial dive fleet in SEDAR15. Similarly, general recreational and headboat landings were pooled as a single recreational fleet compared to separate general recreational and headboat fleets in SEDAR15. Commercial and recreational discards were updated through 2017 and modeled as separate removal streams as in SEDAR15. The estimates for commercial and recreational discards are either model- or ratio-based, therefore the entire time series of estimates was updated.
- Indices of abundance: Two fishery-dependent indices of abundance, the commercial handline index and the headboat index, were used in this assessment, similar to SEDAR15. A MRFSS index was considered in SEDAR15 but was removed during the assessment phase and so was not re-considered here. A fishery-dependent headboat-at-sea discard index was also considered in the current assessment but was not included due to very low sample sizes. A fishery-independent video index was included in the current assessment.

- Size/age compositions of landings: Commercial and general recreational composition data were updated through 2017, the terminal year of the assessment. General recreational and commercial length compositions were not used in the current assessment due to conflicts with the age data, but were included in SEDAR15.
- Life History: The von Bertalannfy growth curve and the female maturity schedule were updated with additional samples collected since SEDAR15. Discard mortality was set to 0.2 for both the commercial and recreational fleets, the same as in SEDAR15. Other life history inputs were the same as SEDAR15.
- The data weighting method used in SEDAR15 was not used in the current assessment. Rather, the indices were weighted using the iterative reweighting procedure recommended by Francis (2011). The Dirichlet multinomial distribution was used for composition data. The Dirichlet multinomial is a self-weighting distribution, thus removing the need for external weights on the composition data.
- Natural mortality was also updated from the Lorenzen curve used in SEDAR15 to the Charnov curve (Charnov et al. 2013) used in more recent SEDAR assessments. The Charnov et al. method is a meta–analysis that includes data from multiple studies that estimate natural mortality. The Lorenzen method (Lorenzen 1996) used in SEDAR15 is one method used in the Charnov et al. meta–analysis.

2.2.1 Fleet Structure

Commmercial dive landings accounted for less than 2% of all commercial landings. Age and length composition data needed to estimate selectivity of the commercial dive fleet were also limited, with only one year meeting a minimum sample size cutoff of 10 trips (most were 1–3 trips). Review of the limited composition data for the dive fleet indicated it did not differ substantially from that of other commercial gears; therefore, the Panel recommended pooling dive landings with those from the other commercial gears.

Similarly, headboat landings accounted for less than 9% on average of annual recreational landings and less than 4% over the last 10 years. Length and age composition data needed to estimate separate selectivities for general recreational and headboat fleets were also limited. Review of available composition data indicated that headboat landings were comprised of slightly smaller fish but overlap of lengths was high, and age compositions did not indicate substantial differences. Discussions with the Panel indicated that fishing and discarding practices between headboat and general recreational anglers were generally similar with respect to greater amberjack. Given the limited composition data and that headboat comprised a small proportion of the recreational landings, the Panel recommended pooling the two fleets.

Commercial discards were available from 1993–2017 and were assumed negligible before 1993. Recreational discards were available from 1980–2017. Both were modeled as separate removal streams as in SEDAR15.

2.2.2 Recreational Landings and Discards

Recalibrated MRIP data were used as input for the landings and discards for all recreational modes except headboat from 1981 through 2017. For 1980, the FHWAR method was used to generate an estimate of recreational landings and discards (see SEDAR 58 (SEDAR 2019)). Headboat landings were provided through 2017, and headboat discards were calculated using a model-based approach. Headboat and general recreational landings were combined into one general recreational fleet, and headboat and general recreational discards were combined into a separate time series of recreational discards, consistent with SEDAR15.

2.2.3 Commercial Landings and Discards

Commercial landings were updated through 2017. The commercial discards were revised for the entire time series, as it is a model-based approach, and provided through 2017. Commercial landings and discards were modeled as separate time series, consistent with SEDAR15.

2.2.4 Indices of Abundance

The commercial handline index was standardized and updated from 1993–2017 using a delta-GLM approach, similar to SEDAR15. The headboat index was also updated with two modifications since SEDAR15. Due to recent closures that affect catch per effort in the fishery, November to April samples were filtered in order to extend the terminal year of the index to 2017. Second, the start year of the index was changed from 1978 in SEDAR15 to 1980 in the current assessment due to reporting issues primarily in South Florida in 1978–1979. A headboat-at-sea index was also explored for possible inclusion, but there were insufficient data to develop a discard-only index. A combined landings and discards index was developed, but was strongly correlated with the headboat logbook index, and so was excluded from the assessment. A new fishery-independent video index (2011–2017) was developed for this assessment from the SERFS program using a zero-inflated negative binomial model. The year 2010 was excluded due to limited spatial coverage. Trap samples from SERFS and from earlier MARMAP trap sampling were also investigated to determine if a trap index could be developed as well. Trap sample sizes were very limited (50 fish captured at 47 stations in 11 years) and so only a video index was developed. As in past SEDAR assessments, CVs on fishery-dependent indices were set to 0.2 given the large sample sizes for fishery-dependent data. This avoided the situation where fishery-dependent indices were considered more certain than fishery-independent indices.

2.2.5 Length Compositions

Commercial and recreational length compositions were updated through 2017. The Panel considered several possible applications of length composition data, such as including length compositions in years with no or limited age composition data, as well as pooling length compositions over years to generate a single combined length composition. However, no growth curve is estimated internally in the model, and length-at-age is highly variable for greater amberjack. Length composition data were also in conflict with age composition data. Including length compositions resulted in a poorer fit to commercial handline and general recreational age compositions as well to all three abundance indices (headboat, commercial handline, and video). In particular, inclusion of length compositions appeared to dampen signals of year class strength evident in the age compositions and also reflected in patterns of annual variability in the indices. Therefore, the Panel recommended removing length compositions. The one exception was headboat-at-sea discard length compositions, which had no corresponding age compositions. Annual sample sizes were small (10–34 trips and 11–57 fish) and so data were pooled over years and weighted by sample size (number of trips) in order to estimate selectivity of recreational discards.

2.2.6 Age Compositions

The commercial and recreational age compositions were updated through 2017. The last two years of the assessment (2016 and 2017) did not meet minimum sample size requirements (10 trips, 30 fish) for annual age compositions from the commercial fleet (8 trips in 2016 and 29 fish in 2017). After reviewing the commercial age compositions relative to other years and given these were the two terminal years of the assessment, the Panel decided to retain these additional years of commercial age compositions.

2.2.7 Life History Data

The von Bertalannfy growth curve was updated with additional samples collected since SEDAR15. The curve was fit using a truncated (at the size limit) normal distribution and inverse-weighted by sample size as in SEDAR15. The updated growth curve did not differ substantially from that used in SEDAR15. The female maturity schedule was updated with ~ 300 additional samples since SEDAR15. Data on female maturity were fit with several alternative models and compared using AIC. A probit model provided the best fit and yielded an age at 50% female maturity of ~ 1. The updated maturity schedule differed from that used in SEDAR15 in that a higher proportion of younger fish (primarily age-1 and age-2) were considered mature. The natural mortality schedule was updated from the Lorenzen age-based curve to the Charnov age-based curve, which is based on a more recent meta-analysis and has been used in most recent SEDAR assessments. The Lorenzen cumulative survival to maximum age (tmax = 17) was high in SEDAR15 (4.2%), while the Charnov curve gave a more reasonable cumulative survival to maximum age (1.2%). The Charnov curve indicated higher natural mortality at age compared to the Lorenzen curve used in SEDAR15. The Panel recommended using the Charnov curve but scaling to give a cumulative survival to maximum age of 1.5% to be consistent with other SEDAR assessments. Given these changes in life history inputs to the model, the Panel also recommended sensitivity analyses using the SEDAR15 life history inputs.

3 Stock Assessment Methods

This assessment updates the primary model applied during the SEDAR15 benchmark for greater amberjack. The methods are reviewed below, and any changes since the SEDAR15 benchmark are noted.

3.1 Overview

This assessment used the Beaufort Assessment Model (BAM, Williams and Shertzer 2015), which applies an integrated catch-age formulation, implemented with the AD Model Builder software (Fournier et al. 2012). In essence, the model simulates a population forward in time while including fishing processes (Quinn and Deriso 1999; Shertzer et al. 2014). Quantities to be estimated are systematically varied until characteristics of the simulated population match available data on the real population. The model is similar in structure to Stock Synthesis (Methot and Wetzel 2013). Versions of BAM have been used in previous SEDAR assessments of reef fishes in the U.S. South Atlantic and is now the primary model used in stock assessments in the region.

3.2 Data Sources

The catch-age model included data from two fleets that caught greater amberjack in southeastern U.S. waters from the Florida Keys to the North Carolina-Virginia border: a commercial fleet and a general recreational fleet. The model was fitted to data on annual landing and annual discards (in units of 1000 lb whole weight for commercial and 1000 fish for general recreational). The discard mortaity rate was set to 0.2, the same as for SEDAR15. The model was also fitted to annual age compositions of general recreational landings, annual age compositions of commercial landings, a pooled length composition of headboat discards, two fishery-dependent indices (headboat and commercial handline), and one fishery-independent index (video). Data used in the model are tabulated in §2 of this report.

3.3 Model Configuration

Model structure and equations of the BAM are detailed in Williams and Shertzer (2015). The assessment time period was 1980–2017. A general description of the assessment model follows.

3.3.1 Stock dynamics

In the assessment model, new biomass was acquired through growth and recruitment, while abundance of existing cohorts experienced exponential decay from fishing and natural mortality. The population was assumed closed to immigration and emigration. The model included age classes $1 - 10^{+}$, where the oldest age class 10^{+} allowed for the accumulation of fish (i.e., plus group).

3.3.2 Initialization

Initial (1980) abundance at age was estimated in the model as follows. First, the equilibrium age structure was computed for ages 2–10 based on natural and initial fishing mortality (F_{init}), where F_{init} was assumed equal to the geometric mean of estimated F for the period 1980–1982. Second, lognormal deviations around that equilibrium age structure were estimated. The deviations were lightly penalized, such that the initial abundance of each age could vary from equilibrium if suggested by early composition data, but remain estimable if data were uninformative. Early runs indicated that initial age structure did not vary much from that at equilibrium age. Given that the Panel recommended removal of all landings length compositions, which would have informed the intialization, an equilibrium age structure was assumed for the initial year of the model. Given the initial abundance of ages 2–10, initial (1980) abundance of age-1 fish was computed using the same methods as for recruits in other years (described below).

3.3.3 Growth

Mean size at age of the population (total length, TL) was modeled with the von Bertalanffy equation (Figure 1), and weight at age (whole weight, WW) was modeled as a function of total length. Growth parameters were updated from those in SEDAR15 while conversion equations (TL-WW) were unchanged; both were treated as input to the assessment model. The von Bertalanffy parameter estimates for the population were $L_\infty = 1204$, $K = 0.284$, and $t_0 = -0.786$. For fitting the discard length composition data, the distribution of size at age was assumed normal with coefficient of variation (CV) estimated by the assessment model.

3.3.4 Natural mortality rate

The natural mortality rate (M) was assumed constant over time, but decreasing with age. The form of M as a function of age was based on Charnov et al. (2013). The Charnov et al. (2013) approach relates the natural mortality at age to the von Bertalanffy growth equation parameters (of the whole population) and length at age: $\mathrm{M}_a = K \times [L_a/L_\infty]^{-1.5}$, where L_∞ and K are von Bertalanffy parameters and L_a is length at age.

3.3.5 Female maturity and spawning stock

The maturity schedule was updated with new data since SEDAR15. The age at 50% female maturity was estimated to be ~ 1 year and nearly all fish were mature by age-3. Spawning stock was modeled as biomass of mature females measured at the time of peak spawning. For greater amberjack, peak spawning was considered to occur mid–April, the same as in SEDAR15.

3.3.6 Recruitment

In this assessment, steepness was not estimable, even when applying a prior distribution to inform the estimation (Shertzer and Conn 2012). Likelihood profiles showed no minimum in the likelihood surface indicating the stock–recruit relationship is not well–defined. The Panel considered fixing steepness based on the profile or assuming an average recruitment and choosing a proxy to compute the relevant benchmarks. To maintain consistency with SEDAR15 the Panel recommending fixing steepness at the midpoint of the flat portion of the likelihood profile (0.87). The effect of different values of steepness were assessed via sensitivity analysis and ensemble modeling. Expected recruitment of age-1 fish was predicted from the stock-recruitment with annual variation in recruitment assumed to occur with lognormal deviations beginning in 1980.

3.3.7 Landings

The model included time series of landings from two fleets: commercial (all gear) and general recreational (headboat, charterboat, and private boats combined). Landings were modeled with the Baranov catch equation (Baranov 1918) and were fitted in units of weight (1000 lb whole weight for commercial and 1000 fish for recreational). Observed landings were provided back to the first assessment year (1980) for each fleet.

3.3.8 Discards

Commercial discards were provided from 1992 to 2017 and were assumed zero prior to this time period. Discards from the general recreational fleet were available from 1980-2017. Commercial and recreational discards were modeled separately from their respective landings assuming a discard mortality rate of 0.2 for both fleets, as in SEDAR15.

3.3.9 Fishing

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.

3.3.10 Selectivities

Selectivity curves were estimated using a parametric approach. This approach applies plausible structure on the shape of the selectivity curves, and achieves greater parsimony than occurs with unique parameters for each age. Age and length composition data are critical for estimating selectivity parameters, and ideally, a model would have sufficient composition data from each fleet over time to estimate distinct selectivities. Given the limited data available for greater amberjack, this was not the case and several assumptions were made regarding the shape of the selectivity curve for different components of the removals and for the indices. Selectivities of landings from all fleets were modeled as flat-topped, using a two-parameter logistic function. The selectivity of the fishery-dependent indices (headboat and commercial handline) were assumed the same as the general recreational and commercial fleets. These were the same assumptions made in SEDAR15.

In past SEDAR assessments for other species, selectivity of the fishery–independent video index has been informed by the age and length compositions of fish caught in the associated Chevron traps from the SERFS survey. Sample sizes of greater amberjack in Chevron traps were limited, however, with only 4 to 5 fish caught per year (50 fish total). Even so, the lengths of greater amberjack caught in Chevron traps ranged from 230 to 1490 mm, indicating nearly the full size range of greater amberjack modeled were available to the Chevron trap. A broad range of ages (Ages 1–5) were also represented in the Chevron traps. However, the Panel was concerned the Chevron traps were not a good indicator of the age composition of greater amberjack from the video due to the low sample size and the likelihood of size selectivity for smaller greater amberjack in the Chevron trap compared to the video. Inspection of the pooled age composition of greater amberjack from Chevron traps indicated an age composition that was similar in shape to the natural mortality vector, which would be expected if selectivity was the same across ages. Given these considerations, the Panel recommended that selectivity of the video index be set to 1.0 for all modeled ages.

Two selectivity time blocks around the recreational and commercial size limits implemented in 1992 were modeled in SEDAR15. For the current assessment the Panel recommended removing the two selectivity blocks around the 1992 size limit and assuming time–invariant selectivity for both the general recreational and commercial fleets. There were two reasons for this change. First, evaluation of the available length data indicated no shift in landed lengths after the implementation of the size limit. For the commercial fleet, only three years of limited length compositions (13–37 trips) were available prior to the 1992 36–inch minimum size limit, and investigation of these three years indicated the length compositions differed considerably in regional sampling between Florida and the Carolinas, suggesting they were not representative of the modeled stock. For the recreational fleet, nine years of length data were available prior to the 1992 28–inch minimum size limit, and there was little change in the proportion of fish below the size limit after 1992. This suggests the size limit had little effect on the lengths of fish retained in the landings. Second, information to estimate selectivity prior to 1992 was limited for both fleets. There were no age composition data available prior to the size limit and estimates of selectivity based on length compositions indicated a shift to younger rather than older fish for both fleets after the size limits were implemented. This created a mismatch whereby age compositions provide the primary source of information on selectivity after the size limit regulation, while length compositions are the only source of information on selectivity prior to the size limit. This mismatch leads to shifts in selectivity that are inconsistent with size-limit regulations due to the conflict between lengths and ages identified above. Given these considerations, the Panel recommended assuming time–invariant selectivity for both fleets.

For recreational discards, the Panel recommended using the pooled headboat-at-sea discard length composition (2013–2017) to inform selectivity of recreational discards for the duration of the assessment period (1980–2017). These data were pooled and weighted by annual sample sizes (number of trips), and fit assuming a negative exponential function. For commercial discards the Panel considered the approach used in SEDAR15 where selectivity of age-1 discards was estimated assuming a logit function, age-2 was fixed at 1.0 and the probability that fish were below the size limit for age 3–10. However, discussion with members of the Panel suggested processes leading to commercial discarding did not differ substantially from those leading to recreational discarding and so a similar selectivity function was assumed for commercial discards whereby the selectivity of age 1–10 was fixed at the probability that fish of a given age were below the 36–inch minimum size limit. Commercial discards comprise a small proportion of total removals and were assumed neglible prior to 1992; therefore, assumptions regarding selectivity of commercial discards were only relevant during the time frame that size limit regulations were in place (after 1992). One panel member suggested commercial fishermen retained smaller fish prior to the 1992 size limit due to the perception that they harbored a lower parasite load, while the limited length composition data available indicated larger fish were retained prior to the 1992 size limit. Given this discrepancy, the Panel recommended sensitivities that shifted the $A50$ of commercial landings to both younger and older ages.

3.3.11 Indices of abundance

The model was fit to a fishery–dependent index standardized from commercial logbooks (1993–2017), a fishery–dependent index standardized from headboat logbooks (1980–2017), and a fishery-independent video index (2011–2017). The predicted indices are conditional on selectivities and were computed from abundance at the midpoint of the year.

3.3.12 Catchability

In the BAM, catchability scales indices of relative abundance to estimated population abundance at large. Several options for time-varying catchability were implemented in the BAM following recommendations of the 2009 SEDAR procedural workshop on catchability (SEDAR Procedural Guidance 2009). In particular, the BAM allows for density dependence, linear trends, and random walk, as well as time-invariant catchability. For greater amberjack, catchability of the index was assumed to be constant, as the Panel decided there was little reason to think that catchability for greater amberjack has changed since 1980.

3.3.13 Biological reference points

Biological reference points (benchmarks) included MSY, fishing mortality rate at MSY (F_{MSY}), and spawning stock at MSY ($\mathrm{SSB}_{\mathrm{MSY}}$)(Gabriel and Mace 1999). In this assessment, spawning stock measures biomass 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.

3.3.14 Fitting criterion

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

The SEDAR15 benchmark fit the composition data using the multinomial distribution, and many SEDAR assessments since then have applied a robust version of the multinomial likelihood, as recommended by Francis (2011). More recent work has questioned the use of the multinomial distribution in stock assessment models (Francis 2014), and of the alternative distributions, two appear most promising, the Dirichlet-multinomial and logistic-normal (Francis 2017; Thorson et al. 2017). Both are self-weighting and therefore iterative re-weighting (e.g., Francis (2011)) is unnecessary, and both better account for intra-haul correlations (i.e., fish caught in the same set are more alike in length or age than fish caught in a different set). The Dirichlet-multinomial allows for observed zeros (the logistic-normal does not), and has recently been implemented in Stock Synthesis (Methot and Wetzel 2013). This assessment used the Dirichlet-multinomial distribution in the base run.

The model includes the capability for each component of the likelihood to be weighted by user-supplied values. When applied to indices, these weights modified the effect of the input CVs. Weights on the index were adjusted iteratively, starting from initial weights in an attempt to achieve standard deviations of normalized residuals (SDNRs) near 1.0. Landings are technically fit in the model, but set up in such a way that they are matched very closely and essentially assumed to be known without error. This is a computational convenience. Uncertainty in landings estimates are addressed through an ensemble approach described below.

The compound objective function also included a prior distribution for the commercial age composition Dirchlet parameter. Additional penalties or priors were applied to all parameters in the ensemble model to maintain parameter estimates near reasonable values, and to prevent the optimization routine from drifting into parameter space with negligible gradient in the likelihood.

3.3.15 Configuration of base run

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

3.3.16 Sensitivity analyses

Sensitivity runs were chosen to investigate issues that arose specifically with this benchmark assessment. They were intended to demonstrate directionality of results with changes in inputs or simply to explore model behavior, and not all were considered equally plausible. Sensitivity runs vary from the base run as follows.

- S1: Start model in 1947.
- S2: Low M, a lower bound of 0.14 for age 10.
- S3: High M, an upper bound of 0.58 for age 10.
- S4: SEDAR15 maturity, growth, natural mortality, and steepness.
- S5: Low discard mortality (0.1).
- S6: High discard mortality (0.3).
- S7: Low steepness (0.74).
- S8: High steepness (0.99).
- S9: Shift commercial selectivity A50 to 2.0.
- S10: Shift commercial selectivity A50 to 4.0.
- S11: SEDAR15 growth curve.
- S12: SEDAR15 female maturity schedule.
- S13: SEDAR15 growth curve, female maturity, and steepness.
- S14: SEDAR15 growth curve, female maturity, and natural mortality.
- S15: SEDAR15 natural mortality.
- S16: Runs a–d are the 4 retrospective peels. Retrospective analyses, or peels, were run by incrementally dropping one year at a time for four iterations making the terminal years 2016, 2015, 2014, and 2013.

3.4 Parameters Estimated

The model estimated 186 parameters. This included recruitment parameters (2), annual recruitment deviations (28), Dirichlet-multinomial variance inflation factors for each composition (3), parameters characterizing selectivity (5) and catchability (3), average F for each fleet (4) and annual F deviations (140), and CV of size at age (1). Not all of these parameters equate to statistical degrees of freedom, particularly the F parameters are constrained to match the landings and thus represent a computational convenience rather than freely estimated parameters.

3.5 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F, as were equilibrium landings and spawning biomass. Equilibrium landings were also computed as functions of biomass B, which itself is a function of F. As in computation of MSY proxy-related benchmarks (described in §3.6), per recruit and equilibrium analyses applied the most recent selectivity patterns averaged across fleets, weighted by each fleet's F from the last three years of the assessment (2015–2017).

3.6 Benchmark/Reference Point Methods

In this assessment of greater amberjack, 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 removals.

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

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

where R_0 is virgin recruitment, h is steepness, and $\Phi_F = \phi_F/\phi_0$ is spawning potential ratio given growth, maturity, and total mortality at age (including natural and fishing mortality rates). 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, as does the benchmark estimate of discard mortalities (D_{MSY}), here separated from ASY (and consequently, MSY).

Estimates of MSY and related benchmarks are conditional on selectivity pattern. The selectivity pattern used here was an average of terminal-year selectivities from each fleet, where each fleet-specific selectivity was weighted in proportion to its corresponding estimate of F averaged over the last three years (2015–2017). 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 proposed to be set to F_{MSY}, and the minimum stock size threshold (MSST) as $\text{MSST} = 75\%\text{SSB}_{\text{MSY}}$. Overfishing is defined as $F >$ MFMT and overfished as SSB $<$ MSST. Current status of the stock is represented by SSB in the latest assessment year (2017), and current status of the fishery is represented by the geometric mean of F from the latest three years (2015–2017).

3.7 Uncertainty and Measures of Precision

For the base run of the catch-age model (BAM), uncertainty in results and precision of estimates was computed through an ensemble modeling approach (Scott et al. 2016) 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; SEDAR 2004; 2009; 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 assessment model many times with different values of "observed" data and key input parameters. A chief advantage of the ensemble modeling approach is that the resulting ensemble model describes a range of possible outcomes, so that uncertainty is characterized more thoroughly than it could be by any single fit or handful of sensitivity runs. A minor disadvantage of the approach is that computational demands are relatively high, though parallel computing can somewhat mitigate those demands.

In this assessment, the BAM was successively re-fit in $n = 3499$ trials that differed from the original inputs by bootstrapping on data sources, and by Monte Carlo sampling of several key input parameters. The 3499 trials were based on a trim of the 6000 initial runs where only runs where $F_{\text{MSY}} < 2.0$, $R_0 < 8,000,000$, and $\sigma_R^2 < 1.0$ were retained. The $n = 3499$ trials used to characterize uncertainty were sufficient for convergence of standard errors in management quantities.

The ensemble model should be interpreted as providing an approximation to the uncertainty associated with each output. The results are approximate as all runs are given equal weight in the results, yet some might provide better fits to data than others.

3.7.1 Bootstrap of observed data

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

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

The term $\sigma^2_{s,y}/2$ is a bias correction that centers the multiplicative error on the value of 1.0. Standard deviations in log space were computed from CVs in arithmetic space, $\sigma_{s,y} = \sqrt{\log(1.0 + CV^2_{s,y})}$. As used for fitting the base run, CVs of commercial landings in all years were assumed to be 0.05. The CVs for recreational landings and both commercial and recreational discards were those provided by the data providers (see Table 3) as were the CVs of indices of abundance (see Table 4).

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

3.7.2 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 Because natural mortality is highly uncertain, the Panel recommended that M be varied in the ensemble modeling approach in a way consistent with Charnov et al. (2013). The model in Charnov et al. (2013)

is based on a linear regression in log space of the relationship between M and von Bertalanffy growth parameters. Charnov et al. (2013) provides estimates of the standard error of the slope and intercept of that regression. In this step of the ensemble modeling, those estimates of uncertainty were used to generate a new slope and intercept, assuming normal distributions, from which a new natural mortality vector at age was computed for each of the ensemble model runs. The variance of the estimate of natural mortality was increased by a factor of 2.9 in order to match the spread of estimates reported in the meta-analysis of Charnov et al. (2013).

Discard mortalities Uncertainty in discard mortality rates (δ) were included in the ensemble modeling based on the estimates and range of discard mortality reported in SEDAR15. A new value for commercial and recreational discard mortality was drawn for each model run from a uniform distribution (range [0.1, 0.3]) with center equal to the point estimate ($\delta = 0.2$).

Steepness Because steepness was fixed in the base run of the model, the Panel recommended including uncertainty in steepness in the ensemble modeling. The point estimate of steepness was based on the mid-point of the flat portion of the likelihood profile defined as + or − two log-likelihood units. A new value of steepness was drawn for each model run from a truncated normal distribution (range [0.74, 0.99]) with center equal to the point estimate ($\delta = 0.87$).

3.8 Projections—Probabilistic Analysis

Projections were run to predict stock status in years after the assessment, 2018–2024, as described 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 (§3.6).

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.

3.8.1 Initialization of projections

Although the terminal year of the assessment is 2017, the assessment model computes abundance at age (N_a) at the start of 2018. For projections, those estimates were used to initialize N_a. However, the assessment has no information to inform the strength of 2018 recruitment, and thus it computes 2018 recruits (N_1) as the expected value, that is, without deviation from the estimate of mean recruitment, 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 (2018) of the projection period included this variability in N_1. The deterministic projections were not adjusted in this manner, because deterministic recruitment follows mean recruitment.

Fishing rates that define the projections were assumed to start in 2020. Because the assessment period ended in 2017, the projections required an initialization period (2018 and 2019). L_{current} (an average of the last three years of the assessment, 2015-2017) was assumed during the interim period.

3.8.2 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 modeling. Thus, projections carried forward uncertainties in natural mortality, discard mortality, and steepness as well as in estimated quantities such as spawner-recruit parameters (R_0 and σ_R), selectivity curves, and in initial (start of 2018) 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 mean annual recruitment values ($\bar{R}_y$). Variability is added to the mean values by choosing multiplicative deviations at random from a lognormal distribution,

$$R_y = \bar{R}_y \exp(\epsilon_y). \tag{3}$$

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 component.

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.

3.8.3 Projection scenarios

The TORs for this assessment described three projections scenarios: $F = F_{\mathrm{MSY}}$, $F = 75\%F_{\mathrm{MSY}}$, and $F = F_{\mathrm{current}}$. In each, the landings in the interim period (2018–2019) were assumed to be L_{current}.

- Scenario 1: $F = F_{\mathrm{current}}$, with L_{current} assumed for the interim period.
- Scenario 2: $F = F_{\mathrm{MSY}}$, with L_{current} assumed for the interim period.
- Scenario 3: $F = 75\%F_{\mathrm{MSY}}$, with L_{current} assumed for the interim period.

4 Stock Assessment Results

4.1 Measures of Overall Model Fit

The Beaufort Assessment Model (BAM) fit well to the available data. Predicted age compositions from the general recreational and commercial fisheries were reasonably close to observed data, as were predicted pooled discard length compositions (Figure 3). The model was configured to fit observed commercial and recreational landings closely (Figures 4–5). The fit to the three indices of abundance generally captured the observed trend but not all annual fluctuations (Figure 8).

4.2 Parameter Estimates

Estimates of all parameters from the catch-age model are shown in Appendix B. Estimates of management quantities and some key parameters, such as those of the spawner-recruit model, are reported in sections below.

4.3 Stock Abundance and Recruitment

Estimated abundance at age shows little trend, with several low abundance years in the mid-1990s and early-2000s and the highest abundance years generally occurring since the mid 2000s (Figure 11; Table 6). Total estimated abundance at the end of the assessment period showed a slight decline from the highest point in the time series (2013). Annual number of recruits is shown in Table 6 (age-1 column) and in Figure 12. Strong recruitment was predicted for the most recent decade, following a period of generally below average recruitment in the mid-1990s and early 2000s. Recruitment over the most recent three years has been similar to the average recruitment over the assessment period (1980–2017).

4.4 Total and Spawning Biomass

Estimated biomass at age, as well as total biomass and spawning biomass followed a similar pattern as abundance at age (Figures 13 and 14 ; Tables 7 and 8).

4.5 Selectivity

Selectivities of landings from commercial and recreational fleets are shown in Figures 15–17. Full selection occurred near age-4 for the general recreational fleet and age-5 for the commercial fleet. Recreational discards were comprised primarily of age-1 and some age-2 fish. Age-1 and age-2 were the most prominent in the commercial discards as well, though all age classes were represented as discards were assumed proportional to the probability that fish were below the commercial size limit for a given age.

Average selectivities of landings were computed from F-weighted selectivities in the most recent period of regulations (Figure 21). These average selectivities were used to compute benchmarks. All selectivities from the most recent period, including average selectivities, are tabulated in Table 9.

4.6 Fishing Mortality and Landings

The estimated fishing mortality rates (F) has shown a declining trend since its peak in the early 1990s (Figure 22). The general recreational fleet has been the largest contributor to total F (Table 10). Estimates of total F at age are shown in Table 11. Table 12 shows total landings at age in numbers, and Table 13 in weight. In general, the majority of estimated landings were from the general recreational fleet (Figures 23, 24; Tables 14, 15).

4.7 Spawner-Recruitment Parameters

The spawner-recruit relationship with fixed steepness is shown in Figure 25 depicted graphically by recruits per spawner as a function of spawners. Values of recruitment-related parameters were as follows: unfished age-1 recruitment $\widehat{R_0} = 1,229,306$, and standard deviation of recruitment residuals in log space $\widehat{\sigma_R} = 0.312$. Uncertainty in these quantities was estimated through the ensemble modeling (Figure 26).

4.8 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F (Figure 27). Per recruit analyses applied the most recent selectivity patterns averaged across fleets, weighted by F from the last three years (2015–2017).

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of F (Figure 28).

4.9 Benchmarks / Reference Points

As described in §3.6, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the expected recruitment (Figure25). Reference points estimated were F_{MSY}, MSY, B_{MSY} and $\mathrm{SSB}_{\mathrm{MSY}}$. Standard deviations of benchmarks were approximated as those from ensemble model (§3.7).

Estimates of benchmarks are summarized in Table 18. Point estimates of MSY-related quantities were $F_{\mathrm{MSY}} = 0.69$ (y^{-1}), MSY $= 2342$ (klb), $B_{\mathrm{MSY}} = 6201$ (mt), and $\mathrm{SSB}_{\mathrm{MSY}} = 3291$ (mt). Distributions of these benchmarks from the ensemble model are shown in Figure 29.

4.9.1 Status of the Stock and Fishery

The estimated time series of spawning stock biomass showed a decline from the 1980s through the 1990s and then a consistent increase since then (Figure 14). Current stock status was estimated in the base run to be $\mathrm{SSB}_{2017}/\mathrm{MSST} = 2.80$ and $\mathrm{SSB}_{2017}/\mathrm{SSB}_{\mathrm{MSY}} = 2.10$ (Table 18 and Figure 30), indicating that the stock is not overfished. Uncertainty from the ensemble modeling suggested that the estimate of SSB relative to both $\mathrm{SSB}_{\mathrm{MSY}}$ and SSB/MSST is robust (Figures 31, 32), with about 99.9% of ensemble modeling runs indicate the stock is above MSST, while only 0.1% of the models in the ensemble indicated an overfished status. Age structure estimated by the base run was very similar to the equilibrium age structure expected at MSY and has not varied substantially over time (Figure 33).

The estimated time series of fishing mortality rate increased from the 1980s through the early 1990s, declined through the early 2000s, and has been relatively stable since then (Figure 22). Current fishery status in the terminal year, with current F represented by the geometric mean from 2015–2017, was estimated by the base run to be $F_{2015-2017}/F_{\mathrm{MSY}} = 0.40$ (Table 18 and Figures 31 and 32). The results of the ensemble model are consistent with those results, as only 3.0% of models within the ensemble estimate the stock is undergoing overfishing.

4.9.2 Comparison to previous assessment

When estimates from this assessment are compared to estimates from the SEDAR15 assessment for greater amberjack, a notable difference is the magnitude of the recruits and spawning stock biomass estimates (Figure 35). In this assessment, updated and recalibrated MRIP estimates of general recreational landings and discards were used. Those estimates are several times higher per year than the estimates used in SEDAR15, and are the result of an improvement in the estimation of recreational effort (for details of how the MRIP is an improvement of MRFSS, see https://www.fisheries.noaa.gov/recreational-fishing-data/how-marine-recreational-information-program-has-improved). Regardless of the magnitude of recruits and SSB, the status benchmarks remain on similar scales (Figure 34). The time trends in abundance, recruitment, and relative status are very similar between this assessment and the last as well (e.g. Figures 34 and 35). Natural mortality estimates and the maturity ogive also differ between SEDAR15 and this assessment, and likely contribute to the model estimating a more productive stock. Length and age composition data are fit better using the Dirichlet-multinomial distribution in this assessment (Figures 3 in both reports), as are the indices of abundance using the iterative reweighting process.

4.10 Sensitivity and Retrospective Analyses

Sensitivity runs, described in §3.3, were used for exploring data or model issues that arose during the assessment process, for evaluating implications of assumptions in the base assessment model, and for interpreting ensemble model results in terms of expected effects of input parameters (Figures 36–43). Sensitivity runs are a tool for better understanding model behavior, and therefore should not be used as the basis for management. All runs are not considered equally plausible or representative of alternative states of nature.

Time series of F/F_{MSY} and $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$ demonstrate the model was not sensitive to the start year, moderately sensitive to discard mortality and steepness, and most sensitive to natural mortality (Figure 37) and the life history inputs (Figure 42). Of the life history inputs, the growth curve and the female maturity schedule had little effect, while natural mortality and steepness had larger effects. The shift in selectivity of the commercial handline fishery to younger ages had a moderately large effect on F/F_{MSY} and $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$, while the shift to older ages had a smaller effect. The majority of the runs agreed with the status indicated by the base run (Figure 43, Table 19). The only sensitivities for which status varied from that in the base run were very low natural mortality, or the combination of late maturity, low steepness, and moderately low natural mortality.

Retrospective analyses did not suggest any patterns of substantial over- or underestimation in terminal-year estimates starting in 2017 (Figures 44 and 45).

4.11 Projections

Projections based on $F = F_{\mathrm{MSY}}$, which is higher than F_{current} drove the stock towards MSY values (Figures 46 and 47, Tables 20 and 21). The $75\%F_{\mathrm{MSY}}$ projection was similar to the $F = F_{\mathrm{MSY}}$ scenario (Figure 48, Table 22).

5 Discussion

5.1 Comments on the Assessment

Estimated benchmarks played a central role in this assessment; Values of $\mathrm{SSB}_{\mathrm{MSY}}$ and F_{MSY} were used to gauge the status of the stock and fishery. Computation of benchmarks was conditional on selectivity, and if selectivity patterns change again 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 ($\mathrm{SSB}_{2017}/\mathrm{MSST} = 2.80$), and that overfishing is not occurring ($F_{2015-2017}/F_{\mathrm{MSY}} = 0.40$). The ensemble model indicated that the stock status is most likely above MSST with 99.7% of the runs indicating the stock is not overfished. Only about 0.3% of the ensemble model runs indicate that the stock is experiencing overfishing. The population abundance has been at its highest level over the last decade, a period when recruitment has been relatively high. Similarly, the low period of abundance in the mid 1990s and early 2000s coincides with a period of below average recruitment. The relatively high recruitment over the last decade combined with relatively stable landings accounts for the current status of the stock. Landings have increased in the last 4–5 years, however, while biomass has declined and recruitment has been closer to the long-term average. Continued increases in landings under average or declining recruitment could lead to further declines in the stock.

In addition to including the more recent years of data, this standard assessment contained several modifications to the data of SEDAR15, as well as to the BAM implementation. The main modifications, as described throughout this report, were the following:

- The recreational landings and discards were based on the MRIP re-calibrated data which increased the recreational removals relative to SEDAR15.
- Length compositions were excluded except for those from headboat-at-sea discards.
- Headboat and general recreational landings were combined as a single fleet. Commercial lines and dive landings were also combined as a single fleet.
- A SERFS video index was included.
- Steepness was fixed at $h = 0.87$.
- Selectivity blocks around size-limit regulations were removed.
- Catchability of fishery dependent indices was assumed constant rather than linearly increasing.
- Age and length compositions were fitted using the Dirichlet-multinomial distribution.
- Reproductive parameters (growth, age at maturity, natural mortality) were updated with more recent data.

The fishery–independent video index is a promising approach to track the abundance of greater amberjack. In general, fishery–dependent indices may not track actual abundance well because of factors such as hyperstability and regulatory changes such as fishery closures. As such management measures become more common in the southeast U.S., the utility of fishery–dependent indices for tracking population abundance may decline, highlighting the importance of fishery–independent sampling.

This assessment highlighted the need for continued and increased age sampling. Sufficient age composition data is critical for characterizing year class strength and for informing selectivity patterns of various fishing fleets. Length composition data have less utility in this regard due to the typically large variation in length-at-age for many southeast U.S. species; this was particularly true for greater amberjack. The lack of long-term age composition data made estimating changes in selectivity due to size limit regulations difficult. The size limits for greater amberjack implemented in 1992 appeared to have little influence on the length distributions of fish in the landings. However, sufficient data to estimate selectivity during this early period was not available, and so the composition of early removals and discards is uncertain.

Because steepness could not be estimated reliably in this assessment, its value in the base run was fixed at the midpoint of the likelihood profile (0.87). Thus, MSY-based management quantities from the base run are conditional on that value of steepness (Mangel et al. 2013). An alternative approach would be to choose a proxy for F_{MSY}, most likely $F_{X\%}$ (such as $F_{30\%}$ or $F_{40\%}$). However, such proxies do not provide biomass-based benchmarks. If managers wish to gauge stock status, assumptions about equilibrium recruitment levels would be necessary. Furthermore, choice of X% implies an underlying steepness, as described by Brooks et al. (2009). Thus, choosing a proxy equates to choosing steepness. Given the two alternative approaches, it seems preferable to focus on steepness, as its value is less arbitrary, and the SEDAR15 benchmark of greater amberjack reported steepness.

5.2 Comments on the Projections

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

- In general, projections of fish stocks are highly uncertain, particularly in the long term (e.g., beyond 5 years).
- Although projections included many major sources of uncertainty, they did not include structural (model) uncertainty. That is, projection results are conditional on one set of functional forms used to describe population dynamics, selectivity, recruitment, etc.

- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect projection results.
- The projections assumed that the estimated level of recruitment 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. In this assessment, recruitment was above average for most years since the mid–2000s but has declined to near average recruitment in the last three years. If this decline continues to recruitment levels characteristic of the 1990s and early 2000s, then stock projections may be overly optimistic.
- Projections apply the Baranov catch equation to relate F and landings using a one-year time step, as in the assessment. The catch equation implicitly assumes that mortality occurs throughout the year. This assumption is violated when seasonal closures are in effect, introducing additional and unquantified uncertainty into the projection results.

5.3 Research Recommendations

- Develop methods to characterize length and age composition of greater amberjack observed on videos from the SERFS fishery–independent survey. Trap sampling of greater amberjack was limited and potentially biased due to size selectivity of the gear.
- Implement a systematic age sampling program for both the general recreational and commercial sectors. Age samples were important in this assessment for identifying strong year classes but sample sizes were relatively small and disparate in time and space.
- Better characterize reproductive parameters including age at maturity, batch fecundity, spawning seasonality, and spawning frequency. Mature female biomass was the measure of reproductive potential for greater amberjack in the assessment, but may be biased if reproductive parameters vary significantly with size or age.
- Age-dependent natural mortality was estimated by indirect methods for this assessment of greater amberjack. Telemetry- and conventional-tag programs may be possible for greater amberjack to improve estimates of estimating mortality.
- Better characterize the migratory dynamics of the stock and the potential for distribution shifts.

6 References

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

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

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

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

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.

Gabriel, W. L., and P. M. Mace, 1999. A review of biological reference points in the context of the precautionary approach. NOAA Technical Memorandum-F/SPO-40.

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

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

Mangel, M., A. D. MacCall, J. Brodziak, E. J. Dick, R. E. Forrest, R. Pourzand, and S. Ralston. 2013. A perspective on steepness, reference points, and stock assessment. Canadian Journal of Fisheries and Aquatic Sciences **70**:930–940.

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

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

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

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

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

SEDAR, 2009. SEDAR 19: South Atlantic Red Grouper.

SEDAR, 2010. SEDAR 24: South Atlantic Red Snapper.

SEDAR, 2019. SEDAR 58: South Atlantic Cobia.

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

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

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., E. H. Williams, M. H. Prager, and D. S. Vaughan, 2014. 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.

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

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

7 Tables

Table 1. Life-history characteristics at age, including average body length and weight (mid-year), proportion females mature, and natural mortality at age. The CV of length was estimated by the assessment model; other values were treated as input.

Age	Total length (mm)	Total length (in)	CV length	Whole wgt (kg)	Whole wgt (lb)	Fem. mat.	prop. fem.	M
1	575.0	22.6	0.24	1.76	3.88	0.53	0.5	0.82
2	730.5	28.8	0.24	3.45	7.61	0.89	0.5	0.57
3	847.6	33.4	0.24	5.25	11.57	0.99	0.5	0.46
4	935.7	36.8	0.24	6.93	15.28	1.00	0.5	0.39
5	1002.0	39.4	0.24	8.41	18.53	1.00	0.5	0.35
6	1052.0	41.4	0.24	9.64	21.25	1.00	0.5	0.33
7	1089.5	42.9	0.24	10.64	23.46	1.00	0.5	0.31
8	1117.8	44.0	0.24	11.44	25.21	1.00	0.5	0.30
9	1139.1	44.8	0.24	12.06	26.59	1.00	0.5	0.29
10	1155.2	45.5	0.24	12.55	27.66	1.00	0.5	0.29

Table 2. Observed time series of landings (L) and discards (D) for the commercial (comm) and general recreational (GR) fleets. Landings are in units of 1000 lb whole weight for commercial landings, and in units of 1000 fish for general recreational landings and all discards.

Year	L.comm	L.GR	D.comm	D.GR
1980	62.922	98.653	.	23.232
1981	85.751	187.498	.	12.060
1982	155.033	82.041	.	11.752
1983	108.971	56.998	.	2.063
1984	175.074	75.899	.	17.758
1985	148.872	97.440	.	15.806
1986	386.780	182.346	.	100.956
1987	1036.474	95.383	.	41.291
1988	1011.197	146.579	.	9.728
1989	1174.861	134.465	.	7.316
1990	1500.683	307.945	.	13.045
1991	1853.451	85.747	.	52.188
1992	1926.846	107.937	1.754	39.228
1993	1423.071	67.586	2.834	26.240
1994	1499.799	82.161	3.486	7.518
1995	1353.057	42.561	3.390	14.704
1996	1146.815	95.998	3.434	25.392
1997	1123.720	22.723	3.424	5.588
1998	961.728	28.681	2.808	12.200
1999	774.179	92.143	2.330	28.344
2000	740.868	57.334	2.336	19.109
2001	795.218	110.835	2.626	9.058
2002	815.128	104.510	1.418	18.060
2003	707.904	92.607	0.324	23.491
2004	911.912	42.301	0.038	17.731
2005	895.003	31.725	0.284	16.914
2006	561.840	126.732	0.136	16.194
2007	605.047	98.813	1.928	16.155
2008	757.271	114.686	1.256	61.204
2009	886.670	96.814	0.114	39.110
2010	1067.656	136.560	0.352	20.510
2011	1019.781	35.927	0.136	12.965
2012	974.630	83.814	0.410	19.636
2013	897.749	76.223	0.078	23.902
2014	1015.686	106.278	0.122	50.596
2015	853.874	162.841	0.418	68.415
2016	827.034	173.494	0.650	62.550
2017	852.265	124.519	0.466	54.167

Table 3. Landings (L) and Discards (D) CVs used in the ensemble model for the commercial (Comm) and general recreational (GR) fleets.

Year	GR L	Comm HL D	GR D
1980	0.43	0.00	0.73
1981	0.43	0.00	0.73
1982	0.45	0.00	0.49
1983	0.40	0.00	0.65
1984	0.16	0.00	0.51
1985	0.43	0.00	0.41
1986	0.34	0.00	0.70
1987	0.26	0.00	0.64
1988	0.53	0.00	0.46
1989	0.51	0.00	0.31
1990	0.50	0.00	0.39
1991	0.34	0.00	0.52
1992	0.29	0.50	0.45
1993	0.37	0.50	0.35
1994	0.44	0.50	0.32
1995	0.31	0.50	0.84
1996	0.51	0.50	0.47
1997	0.31	0.50	0.39
1998	0.31	0.50	0.37
1999	0.18	0.50	0.30
2000	0.22	0.50	0.24
2001	0.51	0.50	0.26
2002	0.24	0.50	0.32
2003	0.24	0.50	0.21
2004	0.19	0.50	0.43
2005	0.20	0.50	0.31
2006	0.39	0.50	0.35
2007	0.25	0.50	0.26
2008	0.19	0.50	0.33
2009	0.18	0.50	0.32
2010	0.30	0.50	0.55
2011	0.24	0.50	0.41
2012	0.27	0.50	0.46
2013	0.28	0.50	0.31
2014	0.30	0.50	0.32
2015	0.21	0.50	0.23
2016	0.19	0.50	0.26
2017	0.30	0.50	0.29

Table 4. Observed indices of abundance and their corresponding CVs (headboats, HB, commercial handlines, cH, and the SERFS video survey, VID).

Year	HB	HB CV	cH	cH CV	VID	VID.CV
1980	0.86	0.2	.	.	.	.
1981	0.55	0.2	.	.	.	.
1982	0.75	0.2	.	.	.	.
1983	0.82	0.2	.	.	.	.
1984	0.62	0.2	.	.	.	.
1985	0.90	0.2	.	.	.	.
1986	1.01	0.2	.	.	.	.
1987	1.35	0.2	.	.	.	.
1988	0.79	0.2	.	.	.	.
1989	0.50	0.2	.	.	.	.
1990	0.82	0.2	.	.	.	.
1991	0.81	0.2	.	.	.	.
1992	0.77	0.2	.	.	.	.
1993	0.82	0.2	0.66	0.2	.	.
1994	0.61	0.2	0.80	0.2	.	.
1995	0.68	0.2	0.85	0.2	.	.
1996	0.87	0.2	0.85	0.2	.	.
1997	0.48	0.2	0.82	0.2	.	.
1998	0.55	0.2	0.79	0.2	.	.
1999	0.97	0.2	0.47	0.2	.	.
2000	1.29	0.2	0.61	0.2	.	.
2001	1.03	0.2	0.75	0.2	.	.
2002	1.26	0.2	0.79	0.2	.	.
2003	1.38	0.2	0.84	0.2	.	.
2004	1.07	0.2	1.12	0.2	.	.
2005	0.64	0.2	1.09	0.2	.	.
2006	0.58	0.2	1.08	0.2	.	.
2007	1.57	0.2	0.72	0.2	.	.
2008	1.30	0.2	0.82	0.2	.	.
2009	1.80	0.2	0.94	0.2	.	.
2010	1.03	0.2	1.41	0.2	.	.
2011	0.71	0.2	1.38	0.2	0.56	0.21
2012	0.66	0.2	1.23	0.2	1.66	0.17
2013	1.56	0.2	1.28	0.2	0.70	0.15
2014	1.44	0.2	1.22	0.2	1.20	0.12
2015	1.82	0.2	1.24	0.2	1.15	0.12
2016	2.13	0.2	1.52	0.2	0.95	0.13
2017	1.21	0.2	1.73	0.2	0.78	0.15

Table 5. Sample sizes (number of fish) of length compositions (len) or age compositions (age) by fleet. Data sources are commercial lines (cH) and general recreational modes (GR). The general recreational discards are a pooled composition from 2013-2017.

Year	len.GR.D	age.GR	age.cH
1999	.	.	.
2000	.	.	15
2001	.	.	26
2002	.	71	36
2003	.	117	30
2004	.	108	15
2005	.	87	.
2006	.	22	.
2007	.	.	.
2008	.	.	.
2009	.	10	23
2010	.	11	22
2011	.	.	18
2012	.	13	21
2013	129	.	23
2014	.	.	39
2015	.	12	18
2016	.	.	8
2017	.	20	12

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

Year	1	2	3	4	5	6	7	8	9	10	Total
1980	1401.81	613.63	324.18	178.68	104.28	63.26	39.15	24.72	15.76	28.53	2793.99
1981	1401.81	599.32	327.86	182.87	107.09	64.99	40.22	25.39	16.19	29.31	2795.06
1982	1400.84	603.48	303.09	166.10	97.77	59.50	36.84	23.26	14.83	26.84	2732.54
1983	1398.66	606.65	324.67	172.59	99.86	61.06	37.91	23.94	15.27	27.63	2768.23
1984	1401.64	612.87	331.95	191.46	108.02	64.97	40.52	25.67	16.37	29.63	2823.10
1985	1404.59	603.55	332.18	191.75	116.83	68.48	42.01	26.73	17.10	30.97	2834.19
1986	1405.38	605.47	323.39	187.86	114.66	72.59	43.40	27.16	17.46	31.71	2829.07
1987	1402.81	548.74	307.68	163.51	98.32	62.19	40.16	24.49	15.48	28.31	2691.68
1988	1395.90	587.86	290.93	163.96	85.98	53.18	34.29	22.59	13.92	25.13	2673.73
1989	1391.06	602.97	299.95	143.25	78.73	42.41	26.73	17.58	11.70	20.43	2634.81
1990	1609.75	602.54	308.20	145.65	65.84	37.00	20.31	13.06	8.68	16.01	2827.04
1991	1712.31	684.49	262.76	105.07	42.75	19.51	11.16	6.25	4.06	7.75	2856.11
1992	1530.62	715.00	353.15	114.50	34.80	14.00	6.50	3.79	2.15	4.09	2778.61
1993	1297.42	642.42	363.69	148.01	35.65	10.68	4.37	2.07	1.22	2.03	2507.55
1994	1080.29	550.47	340.22	177.83	61.52	14.90	4.55	1.90	0.91	1.44	2234.02
1995	985.41	466.67	288.06	164.73	74.75	26.09	6.44	2.00	0.84	1.05	2016.05
1996	690.46	421.69	251.56	150.34	77.12	35.48	12.62	3.18	1.00	0.96	1644.39
1997	674.93	284.15	215.57	120.12	65.57	34.21	16.04	5.82	1.48	0.92	1418.82
1998	1315.89	291.59	154.72	115.77	58.73	32.58	17.32	8.28	3.04	1.26	1999.19
1999	1305.32	568.36	157.82	82.59	56.96	29.41	16.62	9.02	4.36	2.28	2232.75
2000	1184.76	550.68	289.99	75.64	36.74	25.83	13.59	7.84	4.29	3.19	2192.56
2001	2116.92	506.04	293.55	152.27	37.43	18.57	13.30	7.14	4.16	4.01	3153.41
2002	1035.96	917.48	259.74	144.08	70.94	17.83	9.02	6.59	3.57	4.13	2469.36
2003	807.16	441.18	480.01	132.67	70.37	35.47	9.09	4.69	3.46	4.09	1988.19
2004	887.85	338.20	233.03	253.99	69.25	37.77	19.41	5.07	2.64	4.30	1851.52
2005	782.42	378.32	183.96	129.82	138.70	38.85	21.60	11.32	2.99	4.13	1692.12
2006	1897.35	332.65	206.92	103.43	71.37	78.29	22.35	12.68	6.71	4.27	2736.02
2007	1740.63	816.14	166.47	99.31	49.35	35.08	39.24	11.43	6.55	5.73	2969.92
2008	1768.64	750.03	425.51	85.80	50.28	25.69	18.61	21.24	6.25	6.78	3158.84
2009	1253.02	733.95	392.11	218.87	42.84	25.76	13.41	9.92	11.43	7.08	2708.39
2010	1444.55	523.73	389.81	208.42	113.64	22.84	14.00	7.44	5.55	10.47	2740.45
2011	1157.35	617.77	270.01	194.63	100.47	56.17	11.51	7.20	3.86	8.40	2427.36
2012	2091.73	500.10	339.34	152.85	107.51	56.96	32.46	6.78	4.28	7.38	3299.41
2013	1601.74	903.67	266.45	181.64	80.04	57.82	31.23	18.16	3.83	6.65	3151.24
2014	2395.87	687.09	486.85	146.31	98.40	44.59	32.84	18.09	10.62	6.20	3926.85
2015	1815.80	1017.07	365.55	260.23	76.70	53.00	24.48	18.39	10.24	9.61	3651.06
2016	1383.63	749.95	529.40	189.36	134.47	40.84	28.77	13.56	10.29	11.21	3091.48
2017	1138.59	564.39	387.99	271.84	97.43	71.34	22.09	15.88	7.56	12.11	2589.21
2018	1401.47	463.43	296.75	205.67	144.73	53.50	39.94	12.62	9.16	11.46	2638.74

Table 7. Estimated biomass at age (1000 lb) at start of year

Year	1	2	3	4	5	6	7	8	9	10	Total
1980	5439.2	4671.2	3750.1	2730.6	1932.6	1344.4	918.4	623.2	419.1	789.0	22617.7
1981	5439.2	4562.2	3792.6	2794.6	1984.6	1381.0	943.6	640.2	430.6	810.6	22779.5
1982	5435.5	4594.0	3506.0	2538.2	1811.8	1264.6	864.2	586.4	394.4	742.3	21737.4
1983	5427.1	4618.0	3755.6	2637.4	1850.6	1297.6	889.3	603.6	406.1	764.3	22249.5
1984	5438.6	4665.4	3840.0	2925.8	2001.8	1380.5	950.6	647.1	435.4	819.7	23104.9
1985	5450.0	4594.4	3842.4	2930.4	2165.2	1455.3	985.5	674.2	454.8	856.5	23408.7
1986	5453.1	4609.0	3740.8	2870.9	2124.8	1542.6	1018.1	685.0	464.3	877.0	23385.8
1987	5443.2	4177.3	3559.1	2498.7	1822.1	1321.5	942.0	617.5	411.8	783.1	21576.2
1988	5416.3	4474.9	3365.4	2505.6	1593.5	1130.1	804.2	569.5	369.9	695.1	20925.0
1989	5397.6	4590.0	3469.6	2189.2	1459.0	901.2	627.2	443.3	311.1	565.0	19953.4
1990	6246.1	4586.7	3565.1	2225.8	1220.3	786.4	476.4	329.4	230.8	442.9	20109.7
1991	6644.1	5210.6	3039.5	1605.6	792.3	414.5	261.9	157.6	108.0	214.5	18448.5
1992	5939.0	5442.8	4085.2	1749.8	644.9	297.6	152.6	95.7	57.1	113.3	18577.9
1993	5034.3	4890.3	4207.1	2261.9	660.5	226.9	102.5	52.2	32.4	56.0	17524.3
1994	4191.6	4190.5	3935.5	2717.6	1140.0	316.6	106.7	47.8	24.0	39.7	16710.4
1995	3823.7	3552.5	3332.3	2517.5	1385.2	554.5	151.0	50.5	22.5	29.1	15418.5
1996	2679.1	3210.2	2910.1	2297.4	1429.0	754.0	296.1	80.0	26.5	26.5	13708.8
1997	2618.9	2163.2	2493.6	1835.8	1215.2	727.1	376.3	146.8	39.2	25.4	11641.3
1998	5105.9	2219.8	1789.7	1769.2	1088.4	692.3	406.3	208.8	80.7	35.1	13396.2
1999	5064.9	4326.6	1825.6	1262.1	1055.6	625.0	390.0	227.3	115.7	63.3	14956.2
2000	4597.1	4192.1	3354.6	1155.9	680.8	549.0	318.8	197.5	114.2	88.4	15248.5
2001	8214.2	3852.1	3395.8	2327.0	693.6	394.6	312.2	180.1	110.7	111.1	19591.2
2002	4019.7	6984.2	3004.7	2202.0	1314.6	379.0	211.6	166.2	95.0	114.2	18491.3
2003	3131.9	3358.5	5552.6	2027.6	1304.0	753.8	213.2	118.2	92.2	113.1	16665.0
2004	3444.9	2574.6	2695.6	3881.5	1283.3	802.7	455.5	127.9	70.3	118.8	15455.3
2005	3036.0	2879.9	2127.9	1983.9	2570.4	825.4	506.6	285.5	79.6	114.2	14409.9
2006	7362.1	2532.2	2393.6	1580.7	1322.6	1663.6	524.3	319.7	178.6	117.9	17995.5
2007	6754.1	6212.8	1925.5	1517.7	914.7	745.4	920.4	288.1	174.2	158.3	19611.2
2008	6862.8	5709.5	4922.3	1311.3	931.9	545.9	436.7	535.5	166.2	187.4	21609.3
2009	4862.1	5587.2	4535.8	3344.6	793.9	547.4	314.6	250.0	304.0	195.8	20735.6
2010	5605.3	3986.8	4509.1	3185.0	2105.9	485.5	328.5	187.6	147.7	289.7	20830.8
2011	4490.8	4702.7	3123.5	2974.3	1861.8	1193.6	269.8	181.4	102.7	232.4	19133.0
2012	8116.3	3806.9	3925.3	2335.8	1992.3	1210.6	761.5	171.1	114.0	203.9	22638.2
2013	6215.1	6879.1	3082.1	2775.8	1483.3	1228.9	732.6	457.9	101.9	184.1	23140.8
2014	9296.5	5230.5	5631.7	2235.9	1823.4	947.5	770.3	456.1	282.4	171.5	26845.9
2015	7045.8	7742.4	4228.7	3976.7	1421.3	1126.1	574.3	463.9	272.3	265.9	27117.1
2016	5368.7	5708.9	6124.0	2893.8	2492.1	867.7	674.8	341.9	273.6	310.2	25055.8
2017	4418.1	4296.4	4488.2	4154.2	1805.6	1516.1	518.3	400.4	200.8	334.9	22132.7
2018	5437.9	3527.8	3432.8	3143.1	2682.1	1136.9	937.0	318.1	243.6	316.8	21176.5

Table 8. Estimated time series and status indicators. Fishing mortality rate is apical F. Total biomass (B, mt) is at the start of the year, and spawning biomass (SSB mature female biomass) at the time of peak spawning (mid-April). The $MSST$ is defined by $\mathrm{MSST} = 0.75\% SSBmsy$*. Prop.fem is proportion of age-*2^{+} *population that is female.*

Year	F	$F/Fmsy$	B	B/B_{unfished}	SSB	$SSB/SSBmsy$	$SSB/MSST$	Prop.fem
1980	0.123	0.179	10259	0.736	6944	2.11	2.81	0.5
1981	0.238	0.346	10333	0.741	6854	2.08	2.78	0.5
1982	0.121	0.176	9860	0.707	6661	2.02	2.70	0.5
1983	0.080	0.116	10092	0.724	6929	2.11	2.81	0.5
1984	0.106	0.154	10480	0.752	7214	2.19	2.92	0.5
1985	0.126	0.183	10618	0.762	7295	2.22	2.96	0.5
1986	0.262	0.382	10608	0.761	7039	2.14	2.85	0.5
1987	0.265	0.386	9787	0.702	6429	1.95	2.60	0.5
1988	0.358	0.521	9491	0.681	6058	1.84	2.45	0.5
1989	0.406	0.592	9051	0.649	5667	1.72	2.30	0.5
1990	0.868	1.265	9122	0.654	5004	1.52	2.03	0.5
1991	0.769	1.120	8368	0.600	4614	1.40	1.87	0.5
1992	0.835	1.215	8427	0.604	4806	1.46	1.95	0.5
1993	0.524	0.763	7949	0.570	4862	1.48	1.97	0.5
1994	0.509	0.742	7580	0.544	4784	1.45	1.94	0.5
1995	0.397	0.578	6994	0.502	4518	1.37	1.83	0.5
1996	0.464	0.675	6218	0.446	4121	1.25	1.67	0.5
1997	0.351	0.511	5280	0.379	3522	1.07	1.43	0.5
1998	0.343	0.499	6076	0.436	3480	1.06	1.41	0.5
1999	0.442	0.643	6784	0.487	3941	1.20	1.60	0.5
2000	0.334	0.486	6917	0.496	4270	1.30	1.73	0.5
2001	0.392	0.571	8886	0.637	4801	1.46	1.94	0.5
2002	0.344	0.501	8388	0.602	5540	1.68	2.24	0.5
2003	0.273	0.397	7559	0.542	5236	1.59	2.12	0.5
2004	0.229	0.333	7010	0.503	4781	1.45	1.94	0.5
2005	0.223	0.324	6536	0.469	4512	1.37	1.83	0.5
2006	0.361	0.525	8163	0.585	4480	1.36	1.81	0.5
2007	0.304	0.442	8895	0.638	5242	1.59	2.12	0.5
2008	0.320	0.465	9802	0.703	5937	1.80	2.41	0.5
2009	0.280	0.407	9405	0.675	6220	1.89	2.52	0.5
2010	0.356	0.518	9449	0.678	5979	1.82	2.42	0.5
2011	0.218	0.318	8679	0.622	5845	1.78	2.37	0.5
2012	0.271	0.395	10268	0.736	6075	1.85	2.46	0.5
2013	0.236	0.344	10496	0.753	6778	2.06	2.75	0.5
2014	0.270	0.393	12177	0.873	7275	2.21	2.95	0.5
2015	0.281	0.409	12300	0.882	7903	2.40	3.20	0.5
2016	0.284	0.414	11365	0.815	7633	2.32	3.09	0.5
2017	0.250	0.364	10039	0.720	6913	2.10	2.80	0.5
2018	.	.	9605	0.689	.	.	.	0.5

Table 9. Selectivity at age for the commercial fleet (comm), general recreational fleet (GR), SERFS, landings averaged across fisheries (L.avg), discards averaged across fisheries (D.avg), and weighted sum of landings and discards (LandD.avg). TL is total length.

Age	TL(mm)	TL(in)	comm	comm.D	GR	GR.D	SERFS	L.avg	D.avg	LandD.avg
1	575.0	22.6	0.002	1.000	0.044	1	1	0.027	0.242	0.269
2	730.5	28.8	0.032	0.854	0.491	0	1	0.299	0.001	0.300
3	847.6	33.4	0.371	0.629	0.953	0	1	0.709	0.001	0.710
4	935.7	36.8	0.913	0.462	0.998	0	1	0.962	0.000	0.963
5	1002.0	39.4	0.995	0.357	1.000	0	1	0.997	0.000	0.998
6	1052.0	41.4	1.000	0.292	1.000	0	1	1.000	0.000	1.000
7	1089.5	42.9	1.000	0.251	1.000	0	1	1.000	0.000	1.000
8	1117.8	44.0	1.000	0.223	1.000	0	1	1.000	0.000	1.000
9	1139.1	44.8	1.000	0.205	1.000	0	1	1.000	0.000	1.000
10	1155.2	45.5	1.000	0.192	1.000	0	1	1.000	0.000	1.000

Table 10. Estimated time series of fully selected fishing mortality rates for the commercial fleet landings and discards (F.comm and F.comm.D) and the general recreational fleet landings and discards (F.GR and F.GR.D). Also shown is apical F, the maximum F at age summed across fleets.

Year	F.comm	F.GR	F.comm.D	F.GR.D	Apical F
1980	0.008	0.115	0.000	0.025	0.123
1981	0.011	0.227	0.000	0.013	0.238
1982	0.021	0.100	0.000	0.012	0.121
1983	0.014	0.066	0.000	0.002	0.080
1984	0.021	0.085	0.000	0.019	0.106
1985	0.017	0.109	0.000	0.017	0.126
1986	0.048	0.214	0.000	0.111	0.262
1987	0.143	0.122	0.000	0.044	0.265
1988	0.159	0.199	0.000	0.010	0.358
1989	0.215	0.192	0.000	0.008	0.406
1990	0.363	0.505	0.000	0.012	0.868
1991	0.623	0.146	0.000	0.046	0.769
1992	0.664	0.171	0.001	0.038	0.835
1993	0.421	0.103	0.002	0.030	0.524
1994	0.380	0.128	0.003	0.010	0.509
1995	0.325	0.071	0.003	0.022	0.397
1996	0.282	0.180	0.004	0.056	0.464
1997	0.299	0.050	0.004	0.012	0.351
1998	0.275	0.067	0.002	0.014	0.343
1999	0.251	0.190	0.002	0.032	0.442
2000	0.231	0.102	0.002	0.024	0.334
2001	0.211	0.181	0.001	0.006	0.392
2002	0.200	0.144	0.001	0.026	0.344
2003	0.144	0.129	0.000	0.044	0.273
2004	0.160	0.069	0.000	0.030	0.229
2005	0.166	0.057	0.000	0.032	0.223
2006	0.120	0.241	0.000	0.013	0.361
2007	0.150	0.154	0.001	0.014	0.304
2008	0.172	0.148	0.001	0.052	0.320
2009	0.163	0.117	0.000	0.047	0.280
2010	0.179	0.176	0.000	0.021	0.356
2011	0.170	0.048	0.000	0.017	0.218
2012	0.160	0.111	0.000	0.014	0.271
2013	0.147	0.089	0.000	0.022	0.236
2014	0.156	0.114	0.000	0.031	0.270
2015	0.120	0.161	0.000	0.057	0.281
2016	0.111	0.173	0.000	0.068	0.284
2017	0.109	0.140	0.000	0.072	0.250
2018	.	.	.	.	.

Table 11. Estimated instantaneous fishing mortality rate (per yr) at age

Year	1	2	3	4	5	6	7	8	9	10
1980	0.030	0.057	0.113	0.122	0.123	0.123	0.123	0.123	0.123	0.123
1981	0.023	0.112	0.220	0.236	0.238	0.238	0.238	0.238	0.238	0.238
1982	0.017	0.050	0.103	0.119	0.121	0.121	0.121	0.121	0.121	0.121
1983	0.005	0.033	0.068	0.079	0.080	0.080	0.080	0.080	0.080	0.080
1984	0.023	0.042	0.089	0.104	0.106	0.106	0.106	0.106	0.106	0.106
1985	0.022	0.054	0.110	0.124	0.126	0.126	0.126	0.126	0.126	0.126
1986	0.120	0.107	0.222	0.257	0.262	0.262	0.262	0.262	0.262	0.262
1987	0.050	0.065	0.169	0.253	0.265	0.265	0.265	0.265	0.265	0.265
1988	0.019	0.103	0.249	0.344	0.357	0.358	0.358	0.358	0.358	0.358
1989	0.017	0.101	0.262	0.387	0.405	0.406	0.406	0.406	0.406	0.406
1990	0.035	0.260	0.616	0.836	0.867	0.868	0.868	0.868	0.868	0.868
1991	0.053	0.092	0.371	0.715	0.766	0.769	0.769	0.769	0.769	0.769
1992	0.048	0.106	0.410	0.777	0.831	0.834	0.835	0.835	0.835	0.835
1993	0.037	0.066	0.255	0.488	0.522	0.524	0.524	0.524	0.524	0.524
1994	0.019	0.078	0.265	0.477	0.508	0.509	0.509	0.509	0.509	0.509
1995	0.029	0.048	0.190	0.369	0.395	0.397	0.397	0.397	0.397	0.396
1996	0.068	0.101	0.279	0.440	0.463	0.464	0.464	0.464	0.464	0.464
1997	0.019	0.038	0.162	0.326	0.350	0.351	0.351	0.351	0.350	0.350
1998	0.020	0.044	0.168	0.319	0.342	0.343	0.343	0.343	0.343	0.343
1999	0.043	0.103	0.275	0.420	0.441	0.442	0.442	0.442	0.442	0.442
2000	0.031	0.059	0.184	0.314	0.332	0.334	0.334	0.333	0.333	0.333
2001	0.016	0.097	0.252	0.374	0.391	0.392	0.392	0.392	0.392	0.392
2002	0.034	0.078	0.212	0.327	0.343	0.344	0.344	0.344	0.344	0.344
2003	0.050	0.068	0.177	0.260	0.272	0.273	0.273	0.273	0.273	0.273
2004	0.033	0.039	0.125	0.215	0.228	0.229	0.229	0.229	0.229	0.229
2005	0.035	0.033	0.116	0.208	0.222	0.223	0.223	0.223	0.223	0.223
2006	0.024	0.122	0.274	0.350	0.360	0.361	0.361	0.361	0.361	0.361
2007	0.022	0.081	0.203	0.291	0.303	0.304	0.304	0.304	0.304	0.304
2008	0.060	0.079	0.205	0.305	0.319	0.320	0.320	0.320	0.320	0.320
2009	0.052	0.063	0.172	0.265	0.279	0.280	0.280	0.280	0.280	0.280
2010	0.029	0.092	0.235	0.340	0.355	0.356	0.356	0.356	0.356	0.356
2011	0.019	0.029	0.109	0.203	0.217	0.218	0.218	0.218	0.218	0.218
2012	0.019	0.060	0.165	0.257	0.270	0.271	0.271	0.271	0.271	0.271
2013	0.026	0.049	0.139	0.223	0.235	0.236	0.236	0.236	0.236	0.236
2014	0.037	0.061	0.166	0.256	0.269	0.270	0.270	0.270	0.270	0.270
2015	0.064	0.083	0.198	0.270	0.280	0.281	0.281	0.281	0.281	0.281
2016	0.077	0.089	0.207	0.274	0.284	0.284	0.284	0.284	0.284	0.284
2017	0.079	0.073	0.175	0.240	0.249	0.250	0.250	0.250	0.250	0.250

Table 12. Estimated total landings at age in numbers (1000 fish)

Year	1	2	3	4	5	6	7	8	9	10
1980	4.84	25.89	27.77	17.05	10.21	6.25	3.91	2.48	1.59	2.87
1981	9.55	48.56	52.34	32.10	19.24	11.79	7.36	4.67	2.99	5.41
1982	4.26	22.45	23.90	15.47	9.42	5.79	3.62	2.29	1.47	2.66
1983	2.82	15.02	17.19	10.83	6.48	4.00	2.51	1.59	1.02	1.85
1984	3.61	19.47	22.68	15.70	9.18	5.58	3.51	2.23	1.43	2.59
1985	4.61	24.24	27.85	18.63	11.71	6.93	4.29	2.74	1.76	3.19
1986	8.75	47.04	52.04	35.60	22.45	14.36	8.66	5.45	3.52	6.39
1987	5.32	26.22	38.69	30.48	19.44	12.44	8.10	4.97	3.15	5.77
1988	8.62	44.02	51.80	39.91	22.00	13.75	8.95	5.92	3.66	6.62
1989	8.40	44.42	56.04	38.57	22.39	12.19	7.76	5.12	3.42	5.98
1990	24.99	106.41	116.30	70.16	33.01	18.72	10.36	6.69	4.46	8.24
1991	8.72	45.96	66.15	45.47	19.73	9.10	5.25	2.95	1.93	3.68
1992	9.00	54.60	96.47	52.47	16.96	6.90	3.23	1.89	1.07	2.05
1993	4.66	30.45	66.06	47.98	12.40	3.76	1.55	0.74	0.44	0.73
1994	4.68	30.52	63.78	56.55	20.93	5.13	1.58	0.66	0.32	0.50
1995	2.50	15.82	39.92	42.44	20.77	7.34	1.83	0.57	0.24	0.30
1996	3.91	30.03	49.22	44.74	24.36	11.33	4.07	1.03	0.32	0.31
1997	1.27	7.29	25.53	27.76	16.42	8.67	4.10	1.50	0.38	0.24
1998	3.12	9.13	19.10	26.39	14.45	8.11	4.35	2.09	0.77	0.32
1999	7.78	41.96	30.66	23.73	17.32	9.05	5.16	2.81	1.36	0.72
2000	3.96	23.54	39.13	16.99	8.84	6.29	3.34	1.93	1.06	0.79
2001	12.10	35.37	52.68	39.74	10.33	5.18	3.75	2.02	1.18	1.14
2002	4.70	52.00	39.95	33.55	17.54	4.46	2.28	1.67	0.91	1.05
2003	3.23	22.19	62.61	25.37	14.25	7.27	1.88	0.97	0.72	0.85
2004	2.00	9.85	22.04	40.96	12.00	6.62	3.44	0.90	0.47	0.77
2005	1.48	9.42	16.17	20.34	23.43	6.64	3.73	1.96	0.52	0.72
2006	13.99	29.35	40.17	25.57	18.40	20.40	5.88	3.35	1.78	1.13
2007	8.36	48.22	24.60	20.90	10.97	7.88	8.90	2.60	1.50	1.31
2008	8.08	43.06	63.53	18.82	11.68	6.03	4.41	5.06	1.49	1.62
2009	4.59	34.11	49.97	42.61	8.87	5.40	2.84	2.11	2.44	1.51
2010	7.93	35.35	65.88	50.24	28.92	5.88	3.64	1.94	1.45	2.74
2011	1.91	13.48	22.43	29.86	16.67	9.44	1.95	1.23	0.66	1.44
2012	7.36	22.06	41.60	28.91	21.64	11.60	6.67	1.40	0.89	1.53
2013	4.57	32.67	27.93	30.28	14.25	10.42	5.68	3.32	0.70	1.22
2014	8.61	31.09	60.19	27.58	19.72	9.04	6.72	3.72	2.19	1.28
2015	8.86	61.81	52.94	51.45	15.95	11.14	5.19	3.92	2.19	2.06
2016	7.21	48.73	79.72	37.95	28.26	8.67	6.17	2.92	2.23	2.43
2017	4.84	30.21	50.12	48.43	18.28	13.53	4.23	3.05	1.46	2.34

Table 13. Estimated total landings at age in whole weight (1000 lb)

Year	1	2	3	4	5	6	7	8	9	10
1980	18.76	197.09	321.23	260.62	189.18	132.88	91.62	62.46	42.20	79.45
1981	37.06	369.65	605.46	490.60	356.59	250.49	172.69	117.72	79.53	149.71
1982	16.52	170.87	276.46	236.44	174.51	123.03	84.87	57.86	39.09	73.59
1983	10.95	114.30	198.83	165.51	120.13	85.10	58.87	40.15	27.13	51.07
1984	14.02	148.18	262.38	239.95	170.12	118.53	82.39	56.35	38.09	71.70
1985	17.90	184.50	322.13	284.68	216.92	147.25	100.66	69.17	46.88	88.29
1986	33.96	358.10	602.00	544.07	416.09	305.08	203.19	137.31	93.50	176.62
1987	20.64	199.56	447.52	465.81	360.22	264.26	190.10	125.20	83.85	159.45
1988	33.45	335.09	599.21	609.97	407.75	292.30	209.93	149.30	97.44	183.03
1989	32.58	338.13	648.25	589.39	414.96	259.11	181.93	129.20	91.06	165.38
1990	96.96	810.06	1345.35	1072.24	611.65	397.87	243.03	168.68	118.67	227.79
1991	33.85	349.84	765.23	694.85	365.67	193.44	123.22	74.46	51.22	101.73
1992	34.92	415.66	1115.95	801.85	314.38	146.66	75.75	47.72	28.57	56.74
1993	18.07	231.79	764.12	733.25	229.85	79.90	36.42	18.61	11.62	20.08
1994	18.17	232.34	737.78	864.26	387.88	109.00	37.03	16.69	8.45	13.94
1995	9.71	120.45	461.77	648.55	384.94	156.00	42.87	14.40	6.43	8.36
1996	15.15	228.57	569.35	683.79	451.36	240.80	95.38	25.92	8.63	8.60
1997	4.93	55.52	295.28	424.28	304.21	184.33	96.26	37.71	10.16	6.57
1998	12.09	69.54	220.97	403.24	267.70	172.38	102.10	52.72	20.47	8.87
1999	30.19	319.44	354.65	362.66	321.06	192.24	121.01	70.86	36.26	19.78
2000	15.36	179.20	452.70	259.64	163.76	133.61	78.32	48.76	28.30	21.90
2001	46.93	269.28	609.38	607.26	191.38	110.10	87.87	50.93	31.42	31.54
2002	18.24	395.85	462.08	512.78	325.11	94.80	53.40	42.14	24.21	29.11
2003	12.54	168.93	724.31	387.64	264.10	154.40	44.07	24.55	19.20	23.59
2004	7.75	75.00	255.01	625.92	222.32	140.77	80.60	22.75	12.56	21.25
2005	5.76	71.67	187.04	310.84	434.24	141.20	87.48	49.52	13.85	19.92
2006	54.28	223.39	464.68	390.78	341.03	433.43	137.82	84.41	47.35	31.29
2007	32.44	367.04	284.52	319.37	203.25	167.52	208.72	65.64	39.84	36.24
2008	31.35	327.77	734.95	287.60	216.46	128.24	103.52	127.54	39.75	44.85
2009	17.83	259.66	578.01	651.20	164.37	114.65	66.52	53.09	64.82	41.77
2010	30.78	269.11	762.03	767.84	535.96	124.90	85.28	48.91	38.69	75.87
2011	7.42	102.65	259.45	456.35	308.88	200.53	45.77	30.91	17.57	39.77
2012	28.58	167.96	481.23	441.74	401.06	246.52	156.50	35.32	23.63	42.31
2013	17.72	248.72	323.14	462.75	264.04	221.35	133.19	83.61	18.70	33.76
2014	33.39	236.63	696.26	421.43	365.42	192.08	157.60	93.76	58.32	35.39
2015	34.37	470.53	612.38	786.24	295.50	236.70	121.80	98.81	58.25	56.90
2016	28.00	370.95	922.20	579.93	523.67	184.33	144.66	73.60	59.17	67.08
2017	18.77	229.96	579.81	740.09	338.68	287.53	99.18	76.97	38.81	64.67

Table 14. Estimated time series of landings in numbers (1000 fish) for the commercial fleet (L.comm) and general recreational (L.GR))

Year	L.comm	L.GR	Total
1980	3.61	99.25	102.85
1981	4.91	189.11	194.02
1982	8.89	82.44	91.32
1983	6.26	57.05	63.31
1984	10.03	75.96	85.99
1985	8.48	97.47	105.95
1986	21.93	182.32	204.26
1987	59.17	95.39	154.56
1988	58.60	146.66	205.26
1989	69.91	134.38	204.29
1990	92.85	306.49	399.34
1991	123.32	85.63	208.95
1992	136.95	107.71	244.66
1993	101.29	67.47	168.76
1994	102.66	82.00	184.66
1995	89.21	42.53	131.74
1996	73.25	96.06	169.31
1997	70.41	22.75	93.16
1998	59.05	28.78	87.83
1999	47.89	92.66	140.55
2000	48.57	57.31	105.88
2001	52.64	110.84	163.48
2002	53.70	104.42	158.12
2003	47.04	92.31	139.35
2004	56.80	42.25	99.05
2005	52.69	31.72	84.42
2006	32.64	127.37	160.01
2007	36.14	99.09	135.23
2008	49.26	114.53	163.79
2009	57.98	96.45	154.44
2010	67.95	136.02	203.98
2011	63.12	35.95	99.07
2012	59.72	83.94	143.67
2013	54.73	76.31	131.04
2014	63.82	106.31	170.13
2015	53.37	162.13	215.50
2016	51.86	172.42	224.28
2017	52.21	124.27	176.48

Table 15. Estimated time series of landings in whole weight (1000 lb) for the commercial fleet (L.comm) and general recreational (L.GR).

Year	L.comm	L.GR	Total
1980	62.94	1332.55	1395.49
1981	85.78	2543.73	2629.51
1982	155.09	1098.14	1253.23
1983	108.98	763.07	872.05
1984	175.10	1026.60	1201.70
1985	148.88	1329.49	1478.37
1986	386.77	2483.16	2869.93
1987	1036.48	1280.13	2316.61
1988	1011.43	1906.02	2917.45
1989	1174.45	1675.54	2849.99
1990	1498.04	3594.26	5092.30
1991	1848.56	904.94	2753.49
1992	1920.33	1117.87	3038.20
1993	1417.97	725.74	2143.71
1994	1493.88	931.65	2425.53
1995	1349.57	503.91	1853.48
1996	1146.67	1180.85	2327.53
1997	1128.84	290.40	1419.24
1998	971.05	359.02	1330.07
1999	779.44	1048.72	1828.16
2000	740.31	641.22	1381.53
2001	794.66	1241.42	2036.08
2002	814.97	1142.74	1957.71
2003	705.54	1117.80	1823.34
2004	908.26	555.66	1463.93
2005	894.42	427.09	1321.51
2006	562.88	1645.59	2208.47
2007	607.10	1117.49	1724.59
2008	757.71	1284.33	2042.04
2009	884.29	1127.63	2011.92
2010	1063.56	1675.80	2739.35
2011	1021.82	447.47	1469.29
2012	977.72	1047.11	2024.83
2013	899.36	907.62	1806.98
2014	1017.44	1272.85	2290.29
2015	852.97	1918.52	2771.48
2016	824.76	2128.83	2953.59
2017	851.16	1623.31	2474.47

Table 16. Estimated time series of dead discards in numbers (1000 fish) for commercial (D.comm) and general recreational (D.rec).

Year	D.comm	D.rec
1980	0.00	23.24
1981	0.00	12.06
1982	0.00	11.75
1983	0.00	2.06
1984	0.00	17.76
1985	0.00	15.81
1986	0.00	100.96
1987	0.00	41.29
1988	0.00	9.73
1989	0.00	7.32
1990	0.00	13.04
1991	0.00	52.17
1992	1.75	39.22
1993	2.83	26.24
1994	3.49	7.52
1995	3.39	14.71
1996	3.43	25.41
1997	3.42	5.59
1998	2.81	12.20
1999	2.33	28.34
2000	2.34	19.11
2001	2.63	9.06
2002	1.42	18.06
2003	0.32	23.50
2004	0.04	17.73
2005	0.28	16.92
2006	0.14	16.19
2007	1.93	16.15
2008	1.26	61.17
2009	0.11	39.11
2010	0.35	20.51
2011	0.14	12.97
2012	0.41	19.63
2013	0.08	23.90
2014	0.12	50.57
2015	0.42	68.38
2016	0.65	62.54
2017	0.47	54.17
.	.	.

Table 17. Estimated time series of dead discards in whole weight (1000 lb) for commercial (D.comm) and general recreational (D.rec).

Year	D.comm	D.rec
1980	0.00	90.17
1981	0.00	46.80
1982	0.00	45.61
1983	0.00	8.00
1984	0.00	68.91
1985	0.00	61.33
1986	0.00	391.74
1987	0.00	160.23
1988	0.00	37.75
1989	0.00	28.39
1990	0.00	50.61
1991	0.00	202.41
1992	10.35	152.17
1993	17.58	101.81
1994	22.58	29.17
1995	22.24	57.06
1996	24.06	98.60
1997	23.32	21.69
1998	15.83	47.34
1999	13.49	109.97
2000	14.28	74.14
2001	14.31	35.14
2002	9.40	70.09
2003	2.35	91.20
2004	0.26	68.81
2005	1.98	65.64
2006	0.74	62.82
2007	11.09	62.67
2008	7.56	237.36
2009	0.76	151.75
2010	2.25	79.57
2011	0.91	50.31
2012	2.38	76.18
2013	0.49	92.72
2014	0.72	196.21
2015	2.68	265.31
2016	4.48	242.66
2017	3.32	210.19
.	.	.

Table 18. Estimated status indicators, benchmarks, and related quantities from the base run of the Beaufort Assessment Model, conditional on estimated current selectivities averaged across fleets. Median values and standard deviations (SD) approximated from the ensemble model are also provided. Rate estimates (F) are in units of y^{-1}*; status indicators are dimensionless; and biomass estimates are whole weight in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) is measured as mature female biomass.*

Quantity	Units	Estimate	Median	SD
F_{MSY}	y^{-1}	0.69	1.07	0.44
B_{MSY}	mt	6201	5080	776
SSB_{MSY}	mt	3291	2642	439
MSST	mt	2468	2066	595
MSY	1000 lb	2342	2474	393
R_{MSY}	1000 age-1 fish	1324	1056	343
$F_{2015-2017}/F_{\text{MSY}}$	—	0.40	0.28	0.23
$\text{SSB}_{2017}/\text{MSST}$	—	2.80	3.18	0.76
$\text{SSB}_{2017}/\text{SSB}_{\text{MSY}}$	—	2.10	2.39	0.57

Table 19. Results from sensitivity runs of the Beaufort catch-age model. Current F represented by geometric mean of last three assessment years.

Run	Description	F_{MSY}	SSB_{MSY} (mt)	msy(1000 lb)	msy(1000s)	$F_{current}/F_{MSY}$	SSB_{2017}/SSB_{MSY}	R0(1000)
Base	—	0.687	3291.18	2342	210	0.4	2.1	1357
S1	early start year	0.681	3301.48	2349	211	0.39	2.12	1363
S2	Low M	0.229	4847.22	1933	126	1.66	0.85	482
S3	High M	9.247	12101.94	14209	2042	0.01	2.95	24505
S4	S15 LH values all	0.26	5535.86	2542	116	1.31	1.11	594
S5	Low DiscM	0.937	2919.62	2559	246	0.29	2.37	1334
S6	High DiscM	0.566	3535.47	2196	189	0.48	1.96	1380
S7	Low steepness	0.538	3699.3	2230	190	0.5	1.89	1440
S8	High steepness	0.831	3026.8	2437	229	0.33	2.26	1308
S9	shift comm selex to younger ages	0.519	5114.98	3754	362	0.2	3.02	2261
S10	shift comm selex to older ages	0.828	3190.25	2246	201	0.43	1.99	1286
S11	S15 growth	0.688	3439.53	2489	201	0.4	2.11	1291
S12	S15 maturity	0.655	2830.73	2324	206	0.41	2.24	1365
S13	S15 growth, maturity, and steepness	0.505	3451.55	2345	177	0.54	1.97	1388
S14	S15 growth, maturity, and M	0.347	3509.14	2032	138	0.97	1.4	585
S15	S15 M	0.347	3651.38	1918	143	0.96	1.36	607

*Table 20. Projection results with fishing mortality rate fixed at $F = F_{\text{current}}$ starting in 2020. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000*lb*). 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(w)	L.med(w)
2018	1139	1078	0.28	0.34	6869	5396	196	185	2733	2683
2019	1425	1087	0.31	0.39	6125	5028	190	191	2733	2683
2020	1425	1081	0.25	0.30	5826	4887	142	142	1998	1922
2021	1425	1078	0.25	0.30	5820	4951	141	147	1950	1955
2022	1425	1086	0.25	0.30	5838	5025	143	150	1952	1998
2023	1425	1081	0.25	0.30	5854	5064	144	152	1959	2028
2024	1425	1084	0.25	0.30	5866	5090	145	153	1966	2041

*Table 21. Projection results with fishing mortality rate fixed at $F = F_{\text{MSY}}$ starting in 2020. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000*lb*). 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(w)	L.med(w)
2018	1139	1078	0.28	0.34	6869	5396	196	185	2733	2683
2019	1425	1087	0.31	0.39	6125	5028	190	191	2733	2683
2020	1425	1081	0.69	1.07	5299	4172	338	403	4681	5234
2021	1425	1078	0.69	1.07	4294	3263	272	300	3470	3439
2022	1425	1086	0.69	1.07	3851	2998	244	270	2924	2890
2023	1425	1081	0.69	1.07	3665	2927	233	263	2682	2744
2024	1425	1084	0.69	1.07	3590	2904	229	260	2584	2704

*Table 22. Projection results with fishing mortality rate fixed at $F = 75\% F_{\mathrm{MSY}}$ starting in 2020. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000*lb*). 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(w)	L.med(w)
2018	1139	1078	0.28	0.34	6869	5396	196	185	2733	2683
2019	1425	1087	0.31	0.39	6125	5028	190	191	2733	2683
2020	1425	1081	0.52	0.80	5499	4399	268	326	3731	4282
2021	1425	1078	0.52	0.80	4819	3724	234	267	3071	3219
2022	1425	1086	0.52	0.80	4481	3493	218	245	2746	2800
2023	1425	1081	0.52	0.80	4316	3421	211	239	2582	2659
2024	1425	1084	0.52	0.80	4238	3400	208	236	2503	2623

8 Figures

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

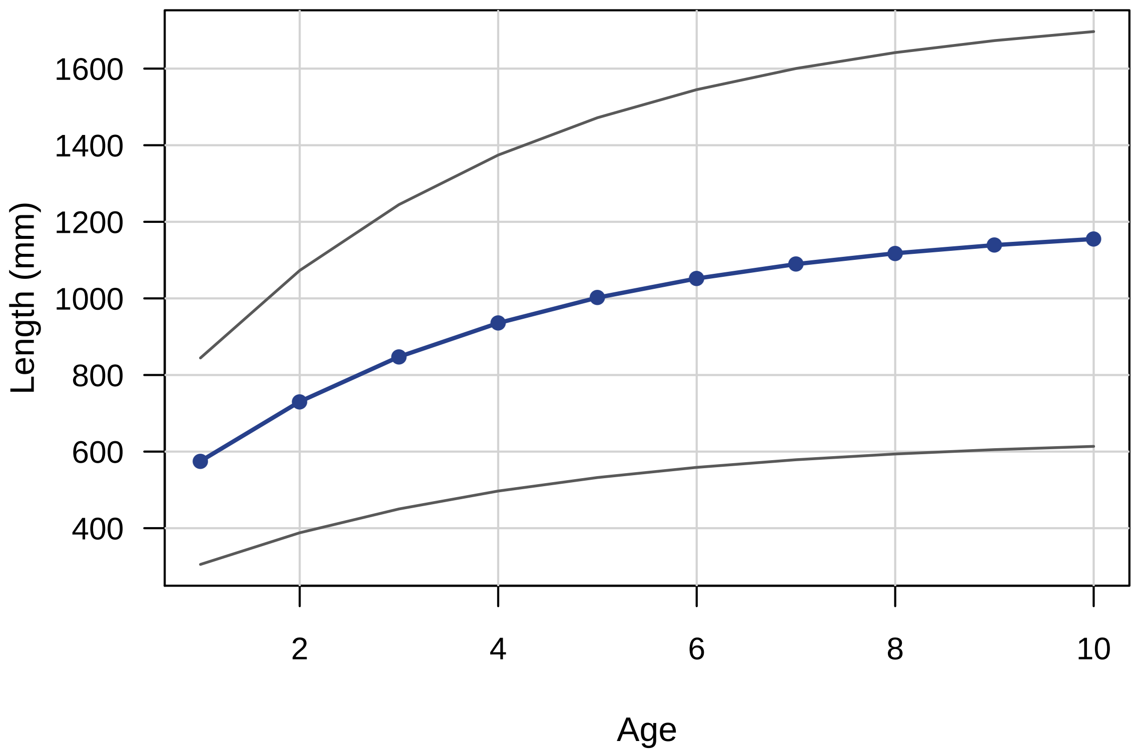


Figure 2. Indices of abundance used in fitting the assessment model. U.HB is the headboat logbook data, U.cH is the commercial handline logbook data, and U.VID is the SERFS video data.

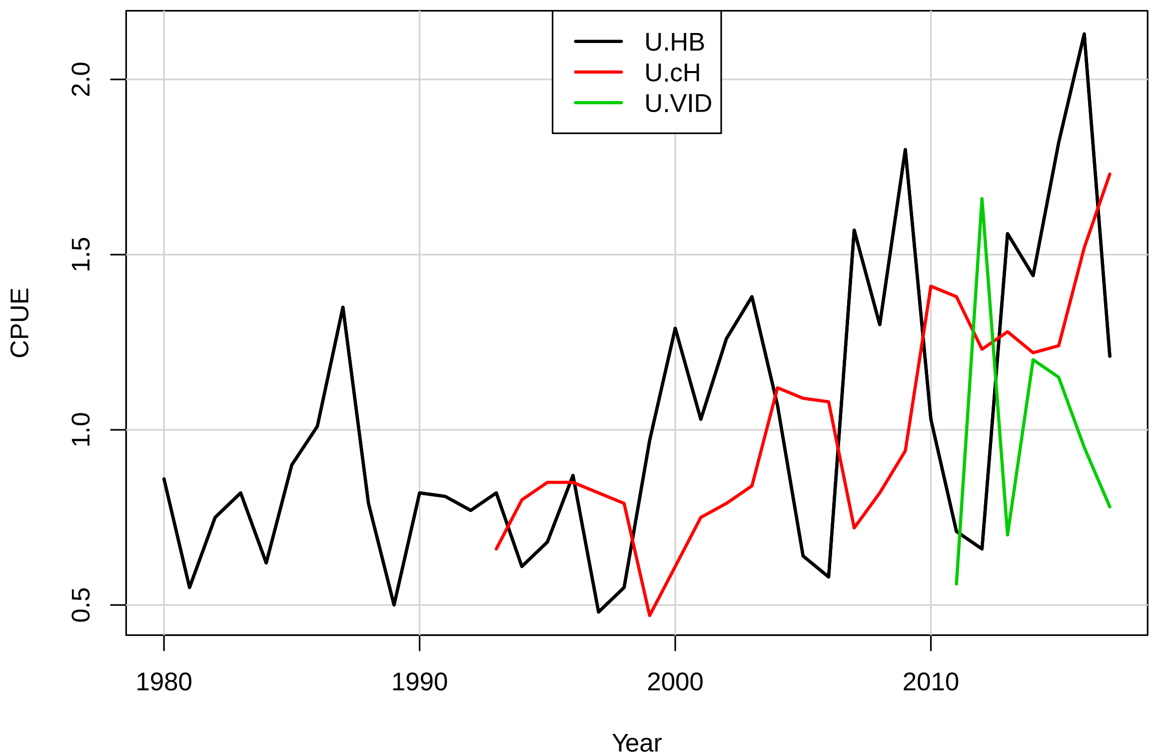


Figure 3. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet from the base run. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, comm to the commercial fleet, and GR to the general recreational fleet. N indicates the number of fish samples taken. For the commercial fleet, length compositions from 1986–2017 were pooled.

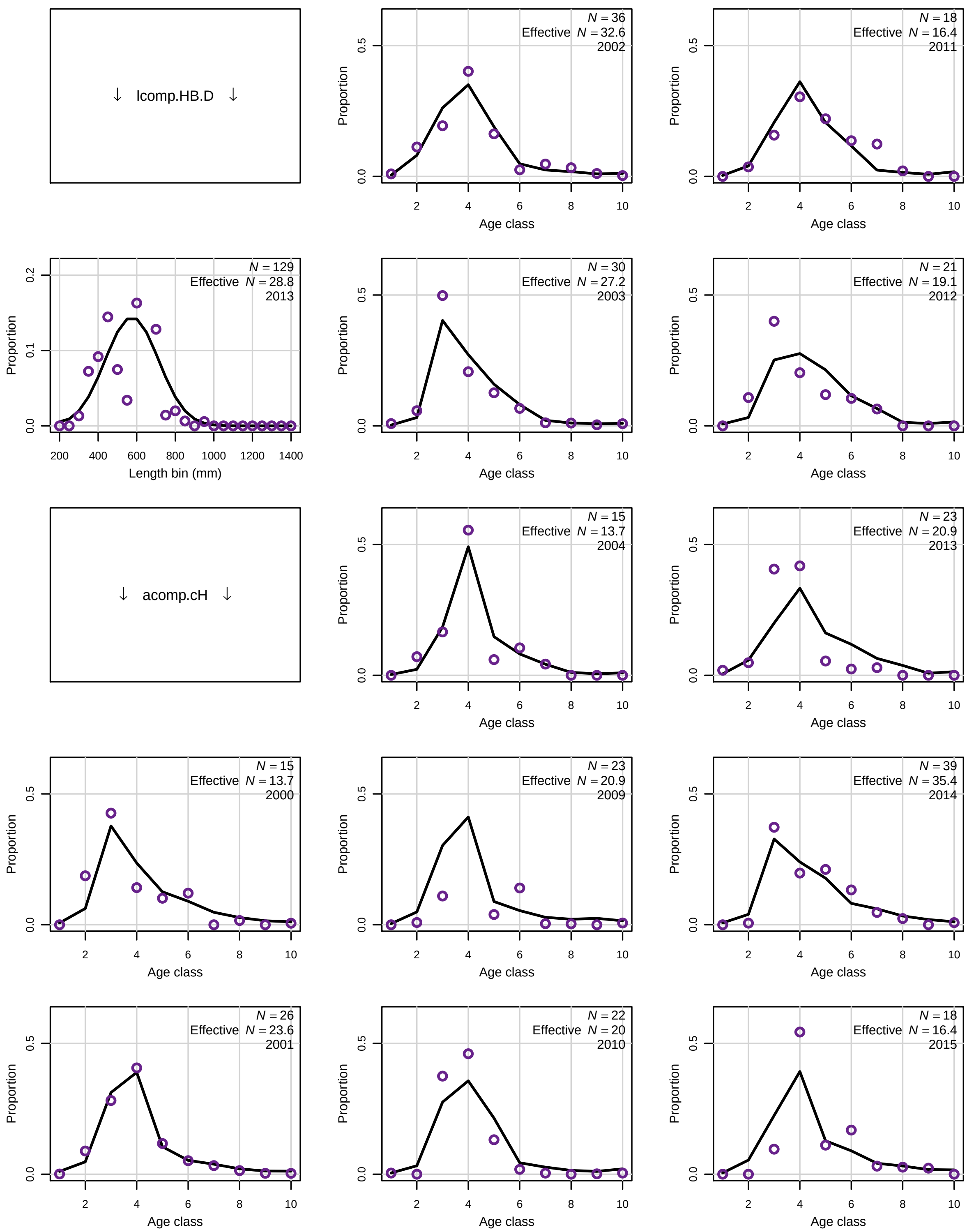


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey from the base run.

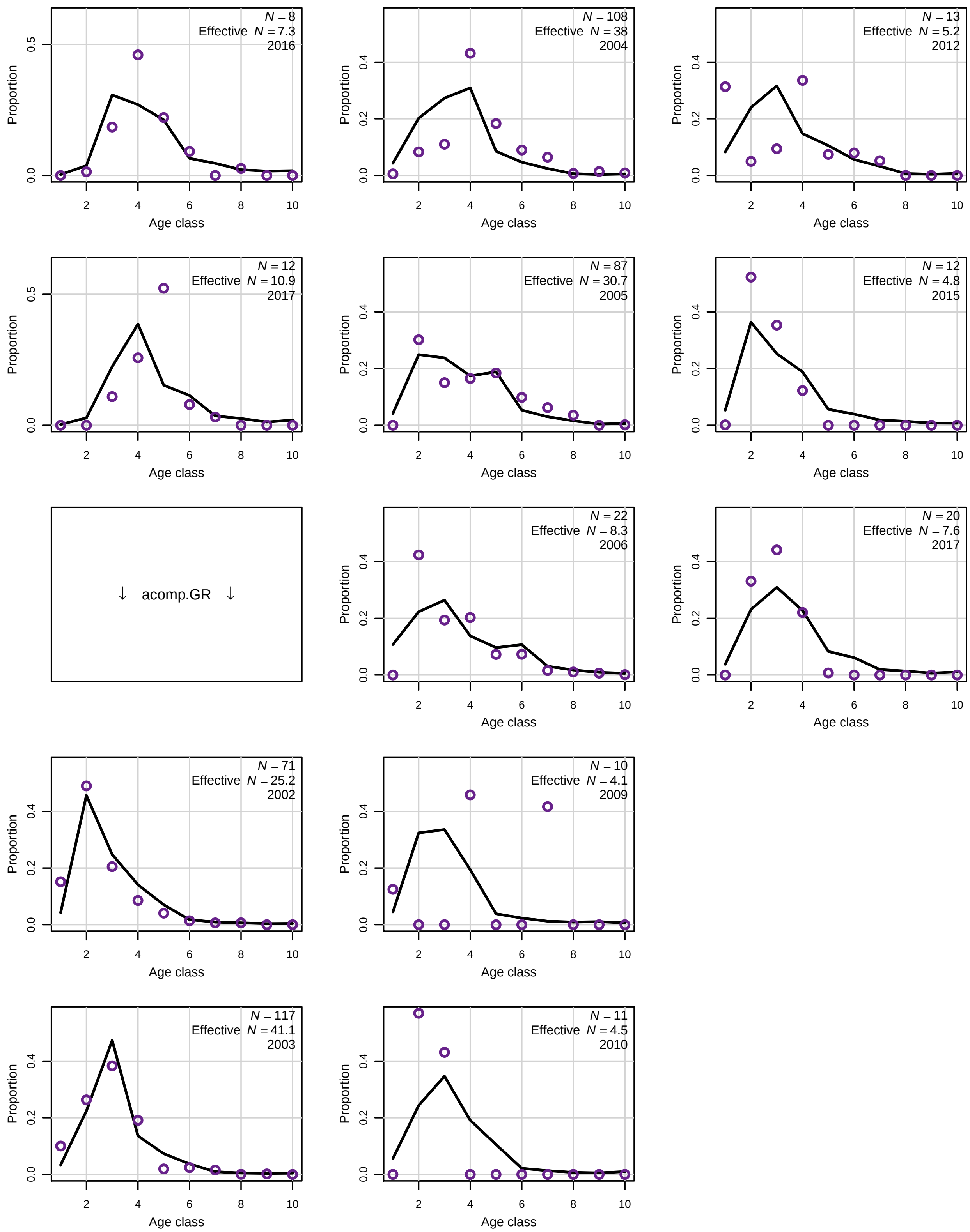


Figure 4. Observed (open circles) and estimated (line, solid circles) commercial landings (1000 lb whole weight).

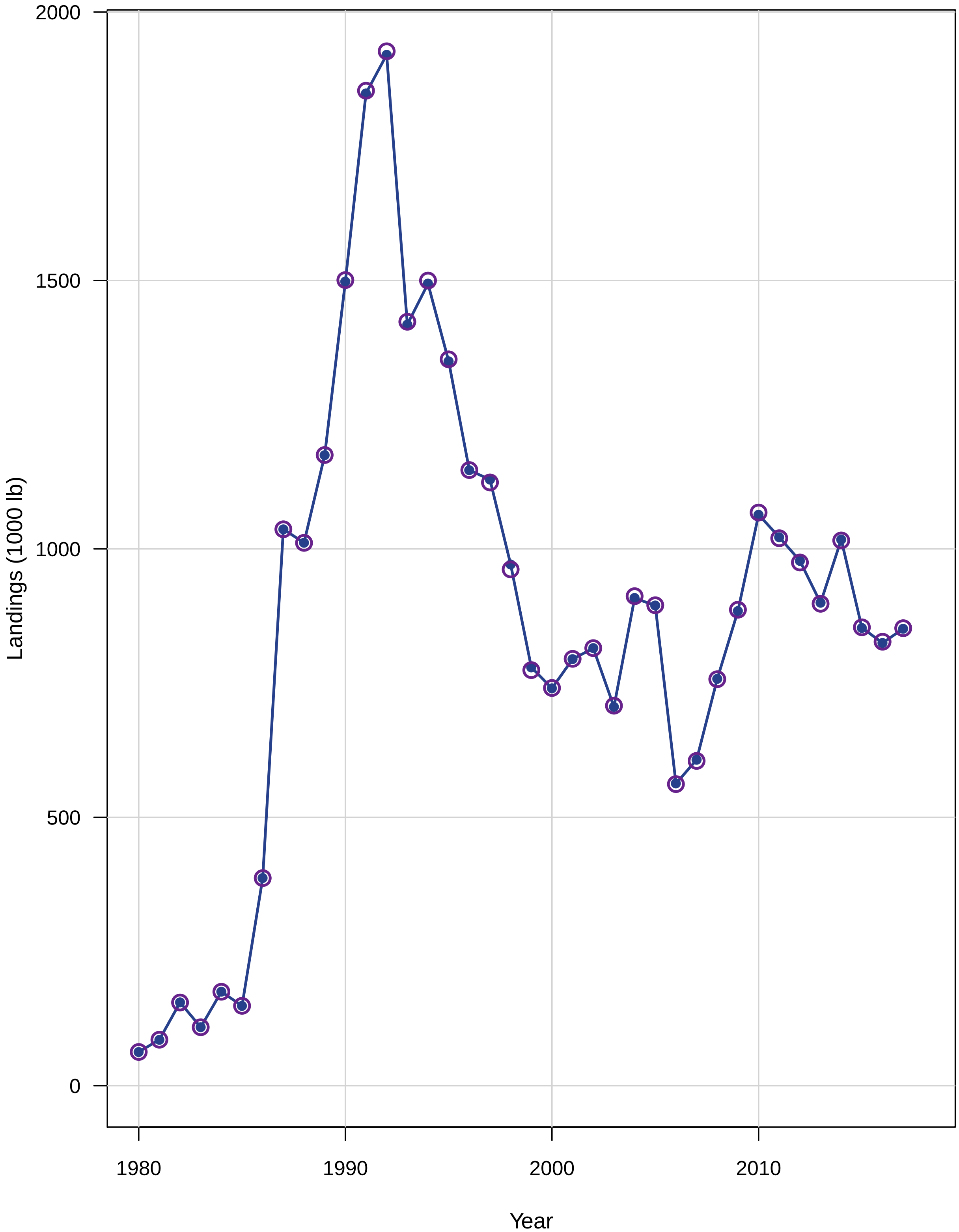


Figure 5. Observed (open circles) and estimated (line, solid circles) general recreational landings (1000 fish).

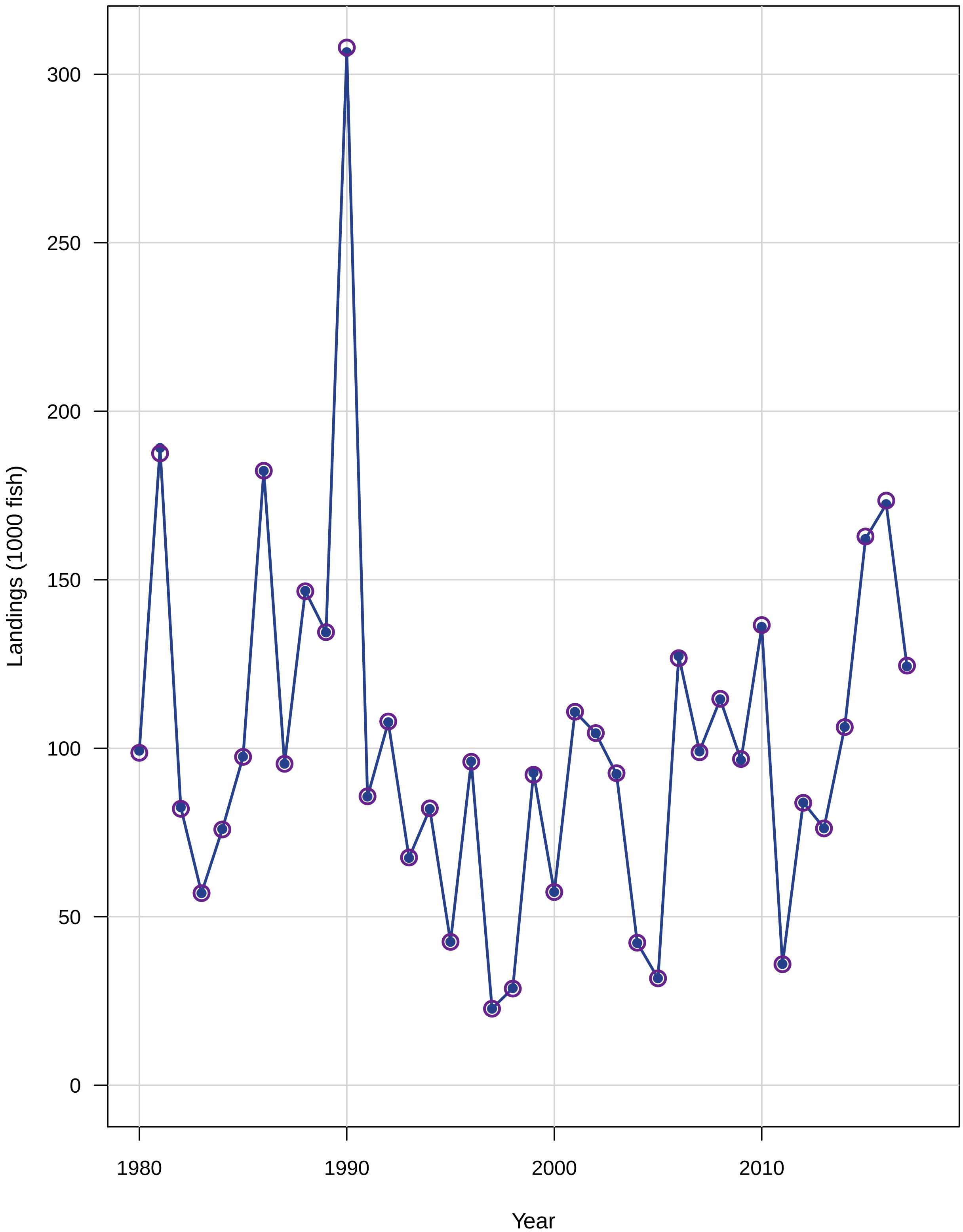


Figure 6. Observed (open circles) and estimated (line, solid circles) commercial discards (1000 fish).

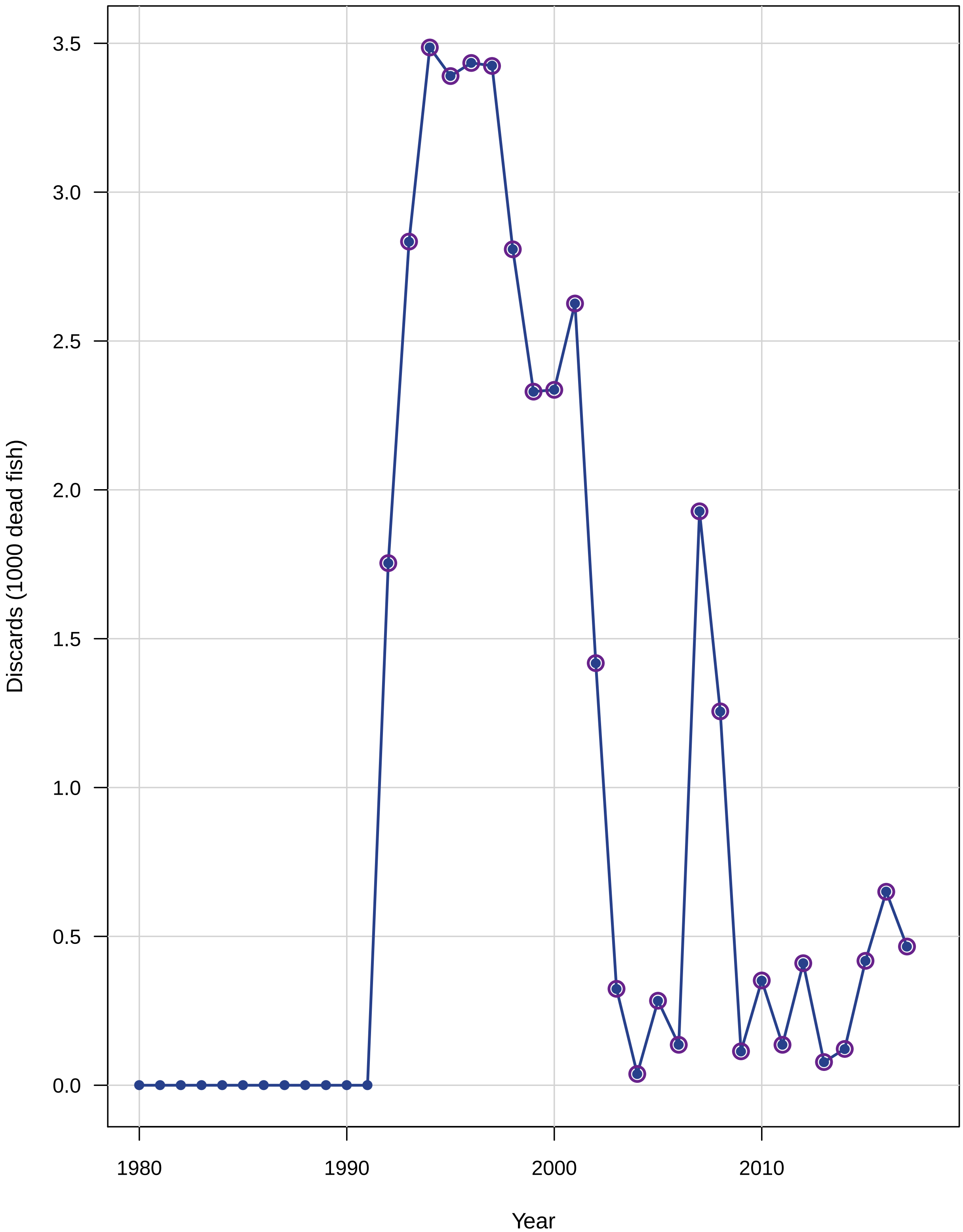


Figure 7. Observed (open circles) and estimated (line, solid circles) general recreational landings (1000 fish).

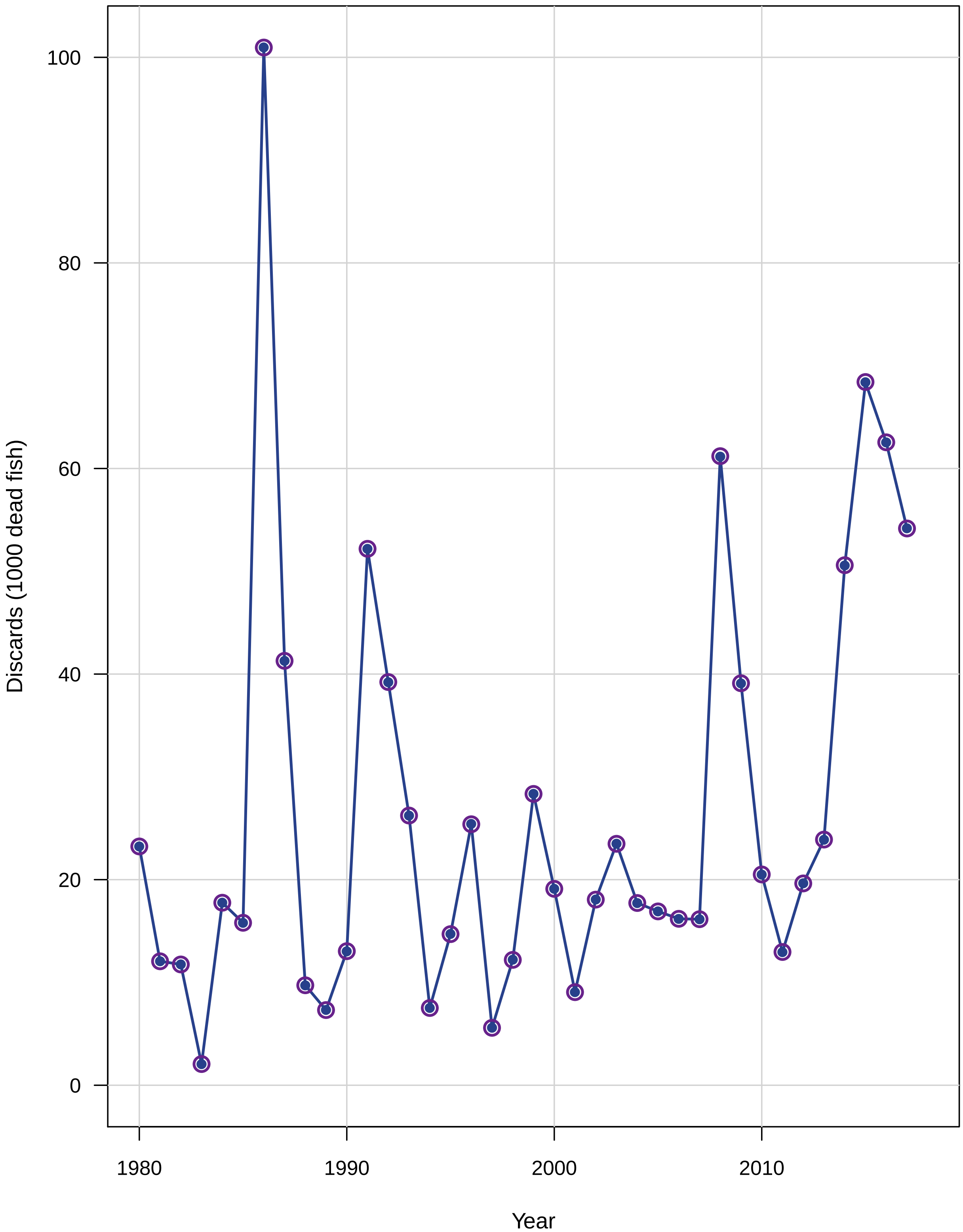


Figure 8. Observed (open circles) and estimated (line, solid circles) index of abundance from the headboat fleet.

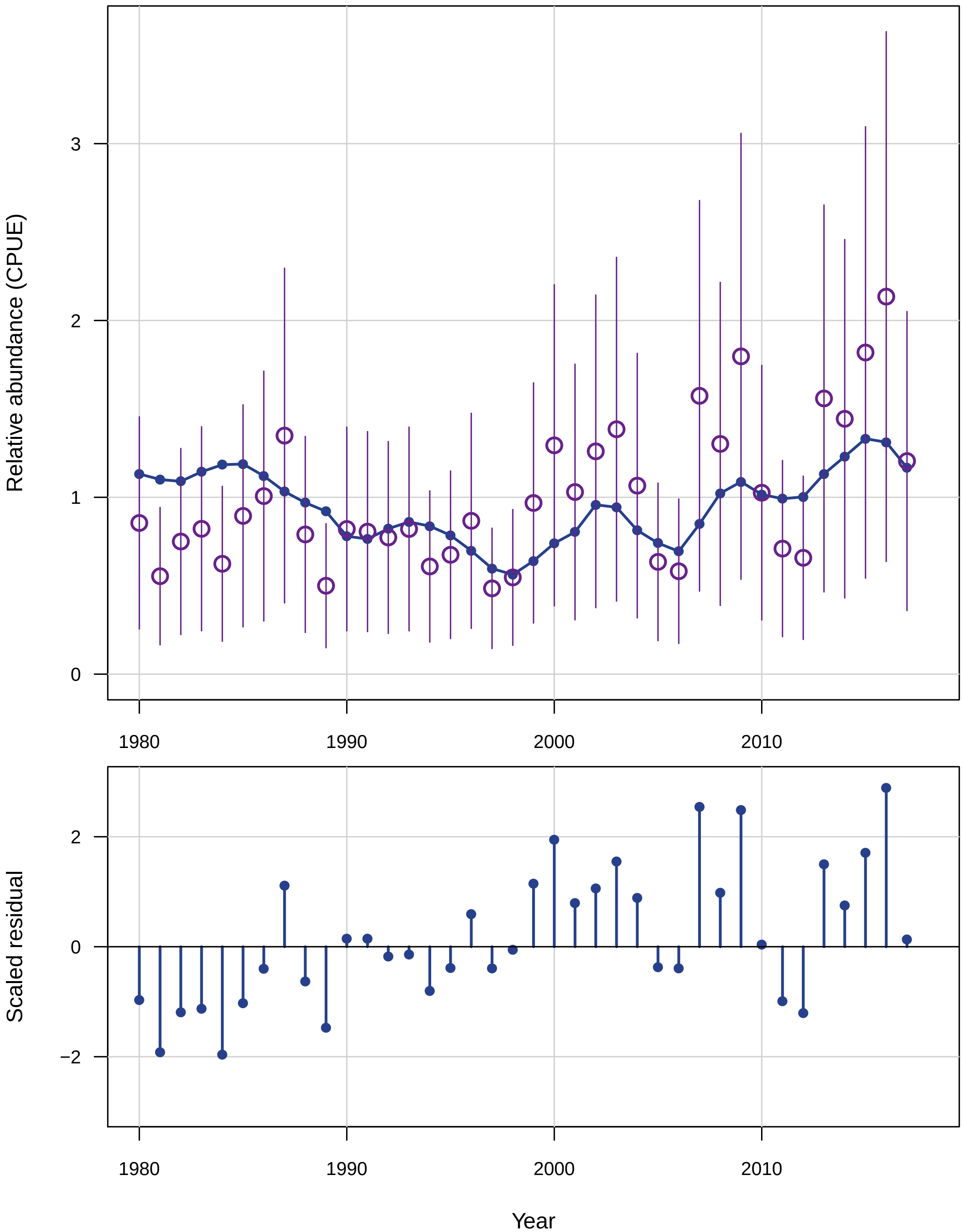


Figure 9. Observed (open circles) and estimated (line, solid circles) index of abundance from the commercial handline logbooks.

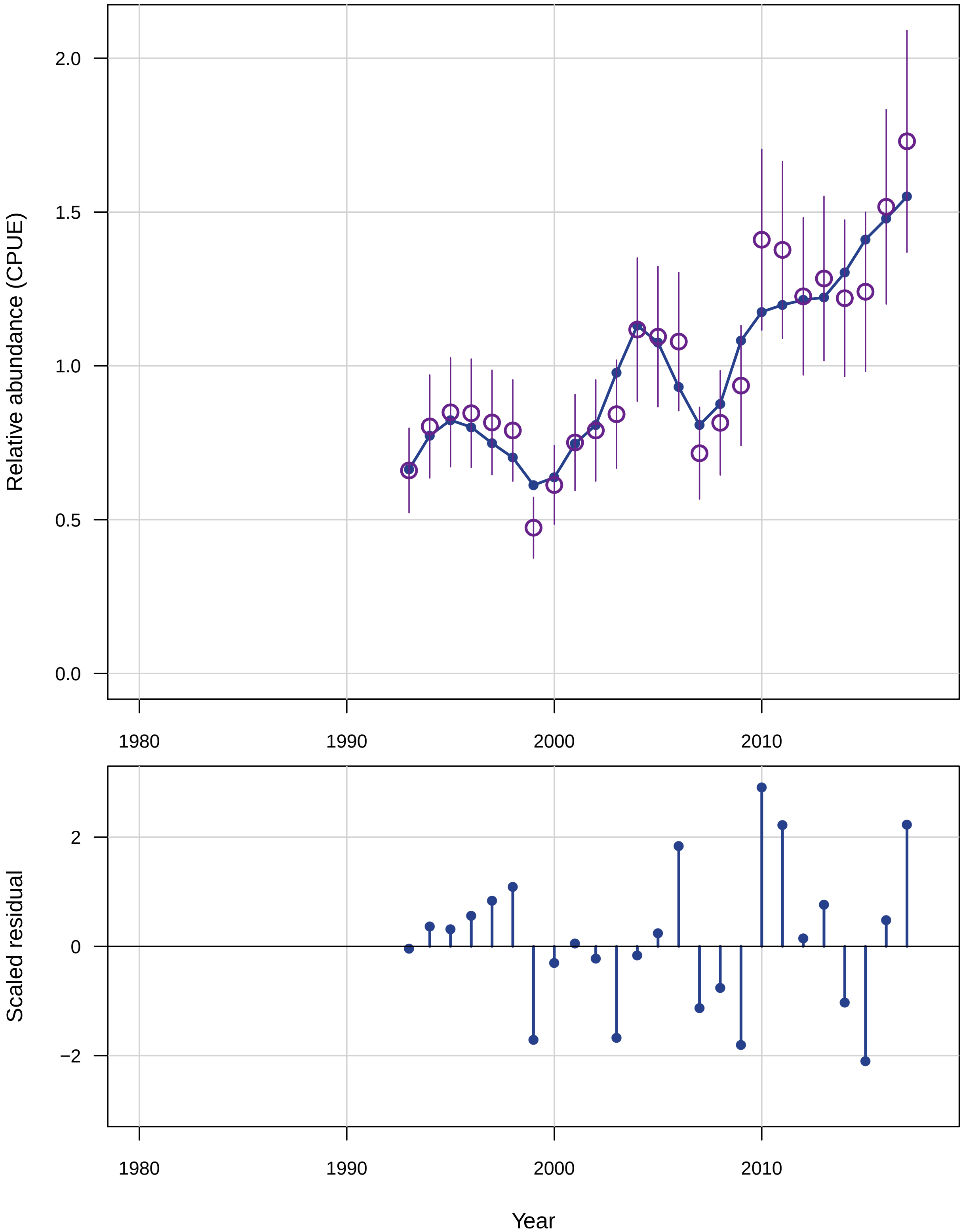


Figure 10. Observed (open circles) and estimated (line, solid circles) index of abundance from the SERFS video survey.

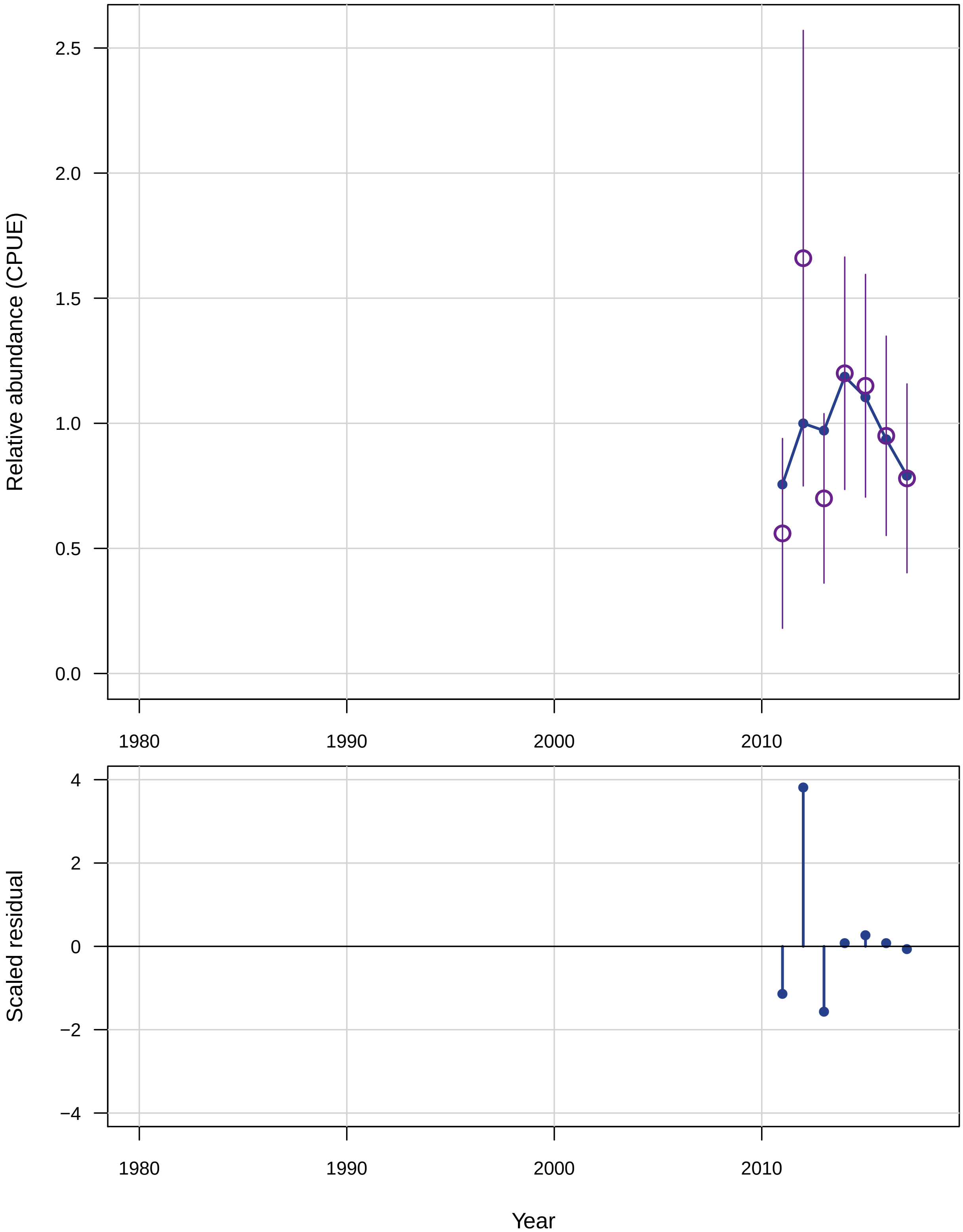


Figure 11. Estimated abundance at age at start of year.

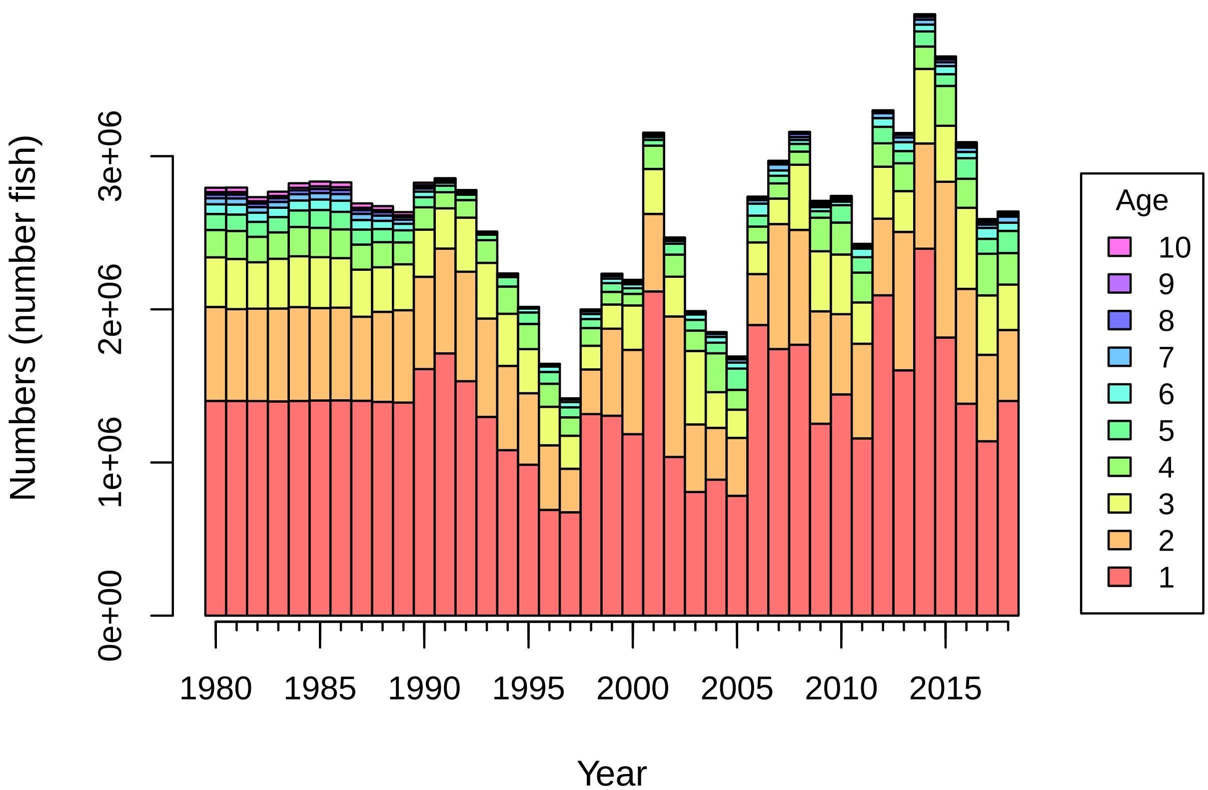


Figure 12. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates R_{MSY}. Bottom panel: log recruitment residuals.

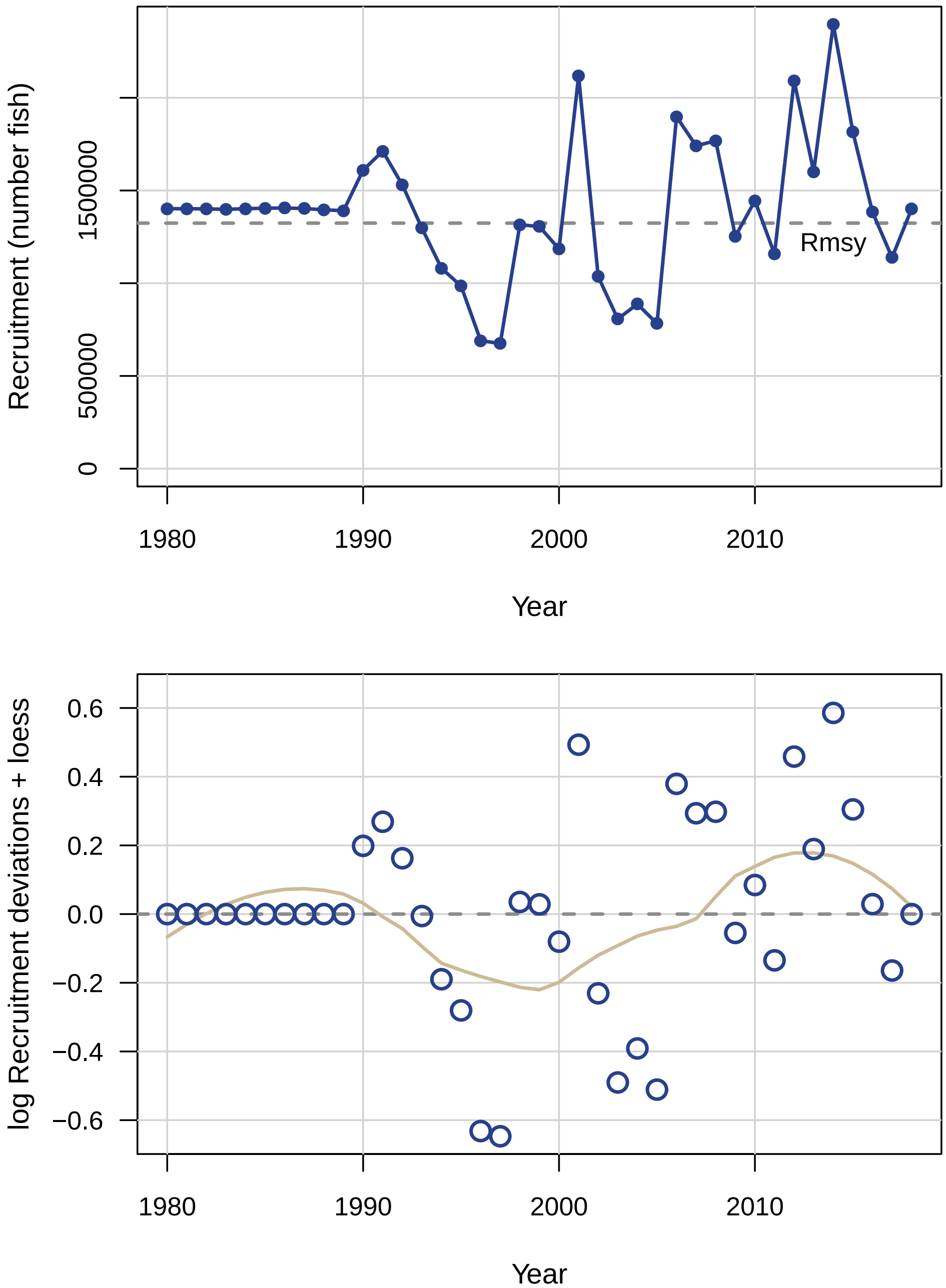


Figure 13. Estimated biomass at age at start of year.

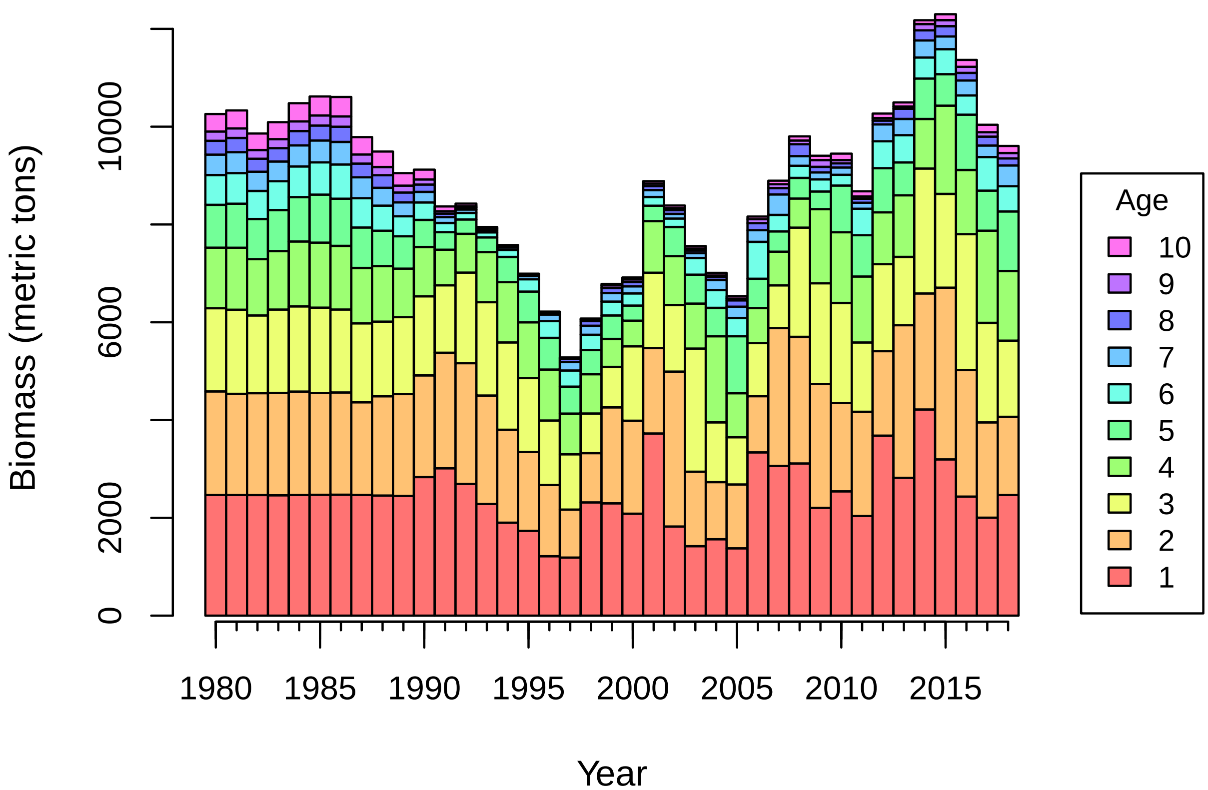


Figure 14. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates B_{MSY}. Bottom panel: Estimated spawning stock (mature female biomass) at time of peak spawning.

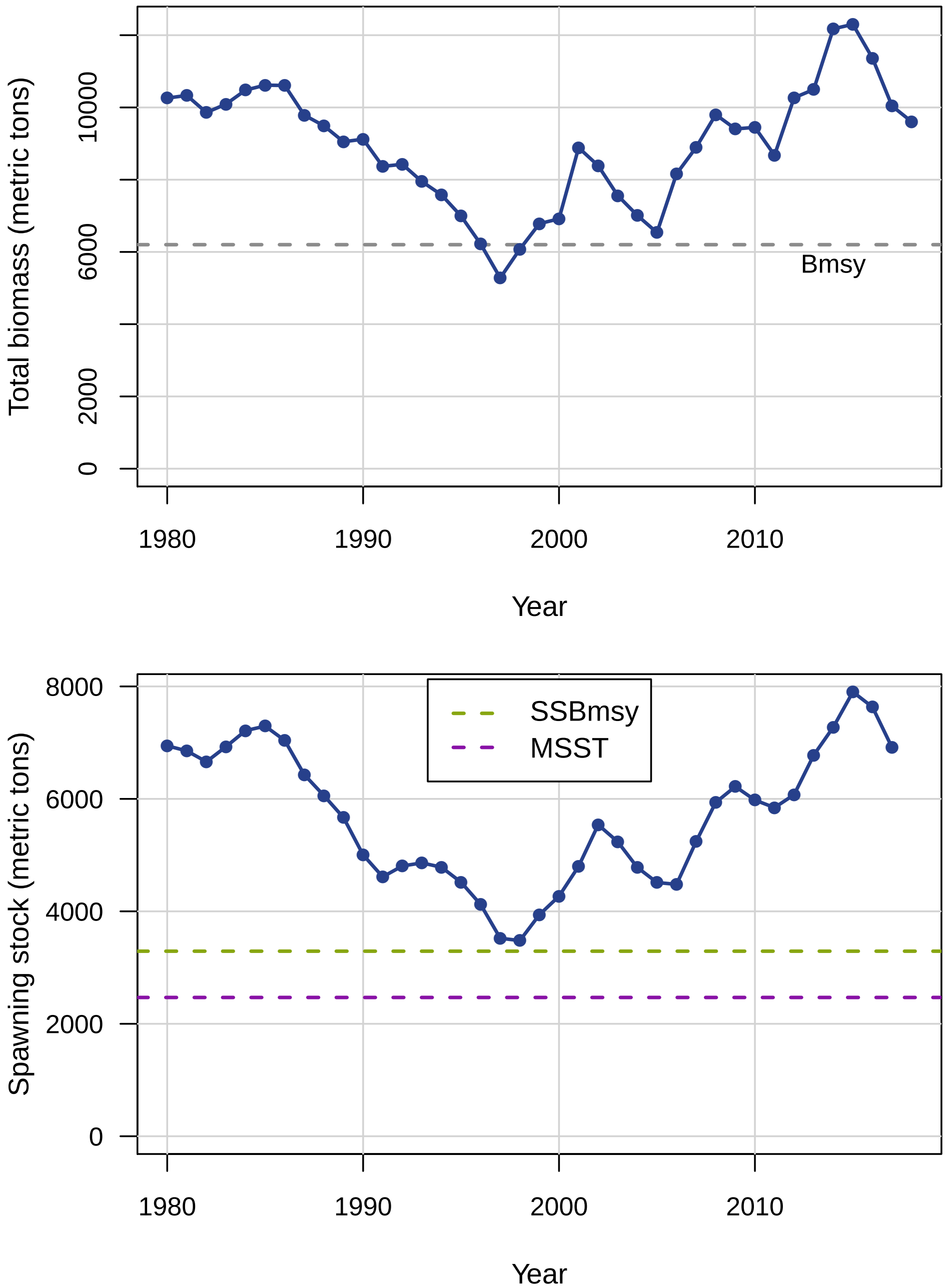


Figure 15. Estimated selectivity of the commercial fleet. Years indicated on plot signify the first year of a time block.

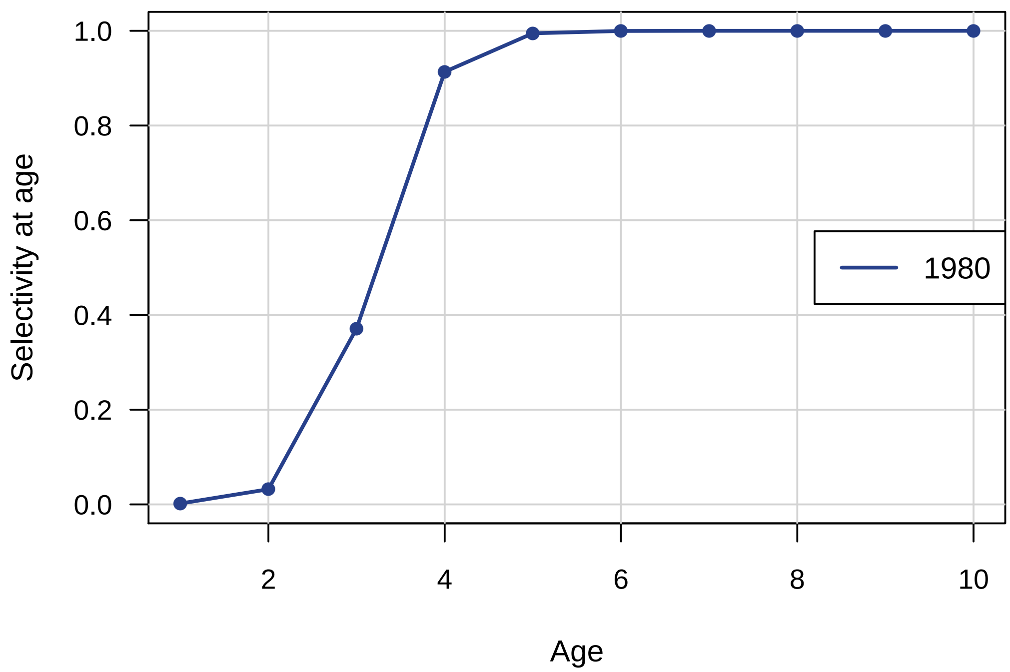


Figure 16. Estimated selectivity of the commercial fleet discards. Years indicated on plot signify the first year of a time block.

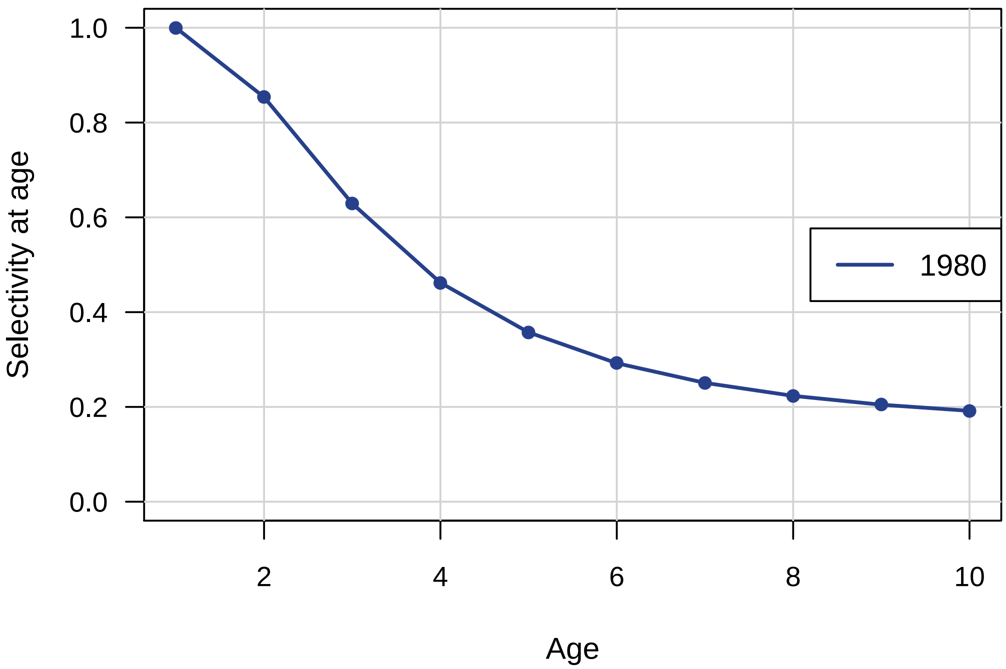


Figure 17. Estimated selectivities of the general recreational fleet. Years indicated on plot signify the first year of a time block.

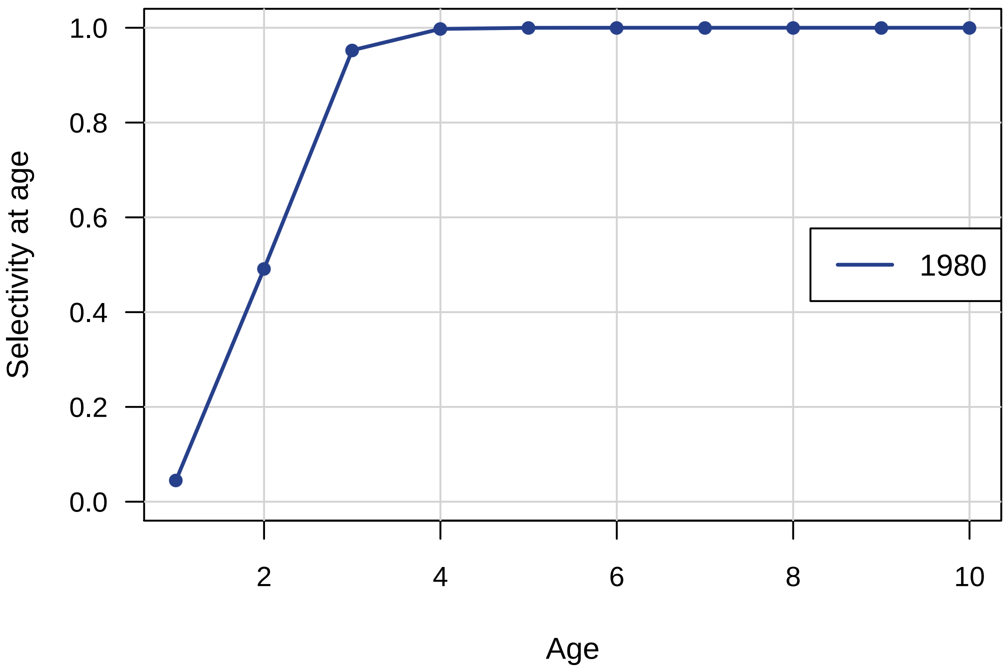


Figure 18. Estimated selectivities of the general recreational fleet discards. Years indicated on plot signify the first year of a time block.

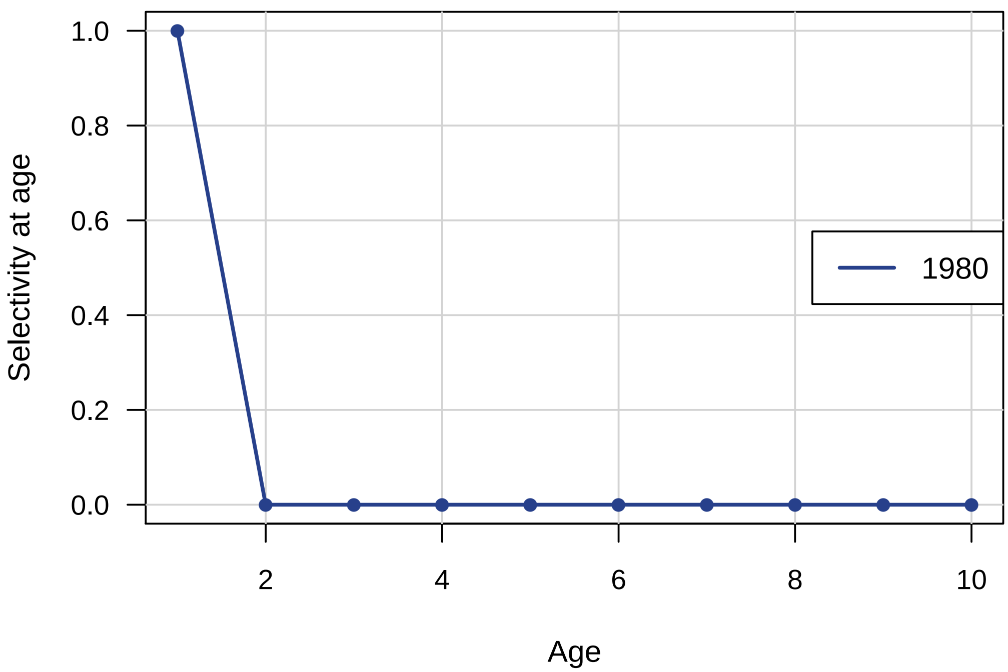


Figure 19. Average selectivity of landings from the terminal assessment years, weighted by geometric mean Fs from the last three assessment years, and used in computation of benchmarks and projections.

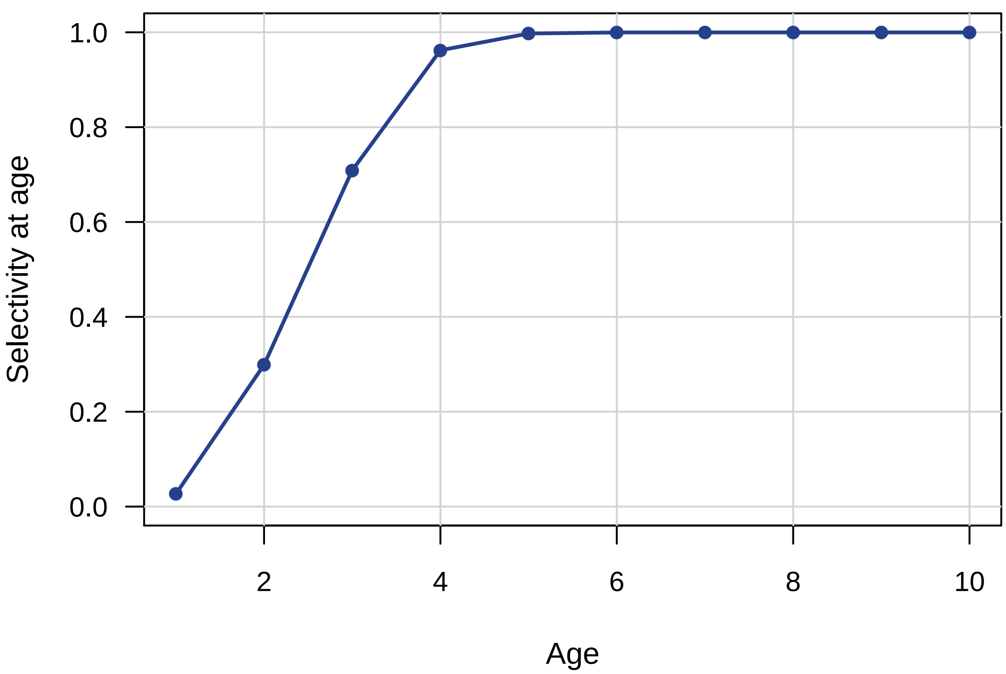


Figure 20. Average selectivity of discards from the terminal assessment years, weighted by geometric mean Fs from the last three assessment years, and used in computation of benchmarks and projections.

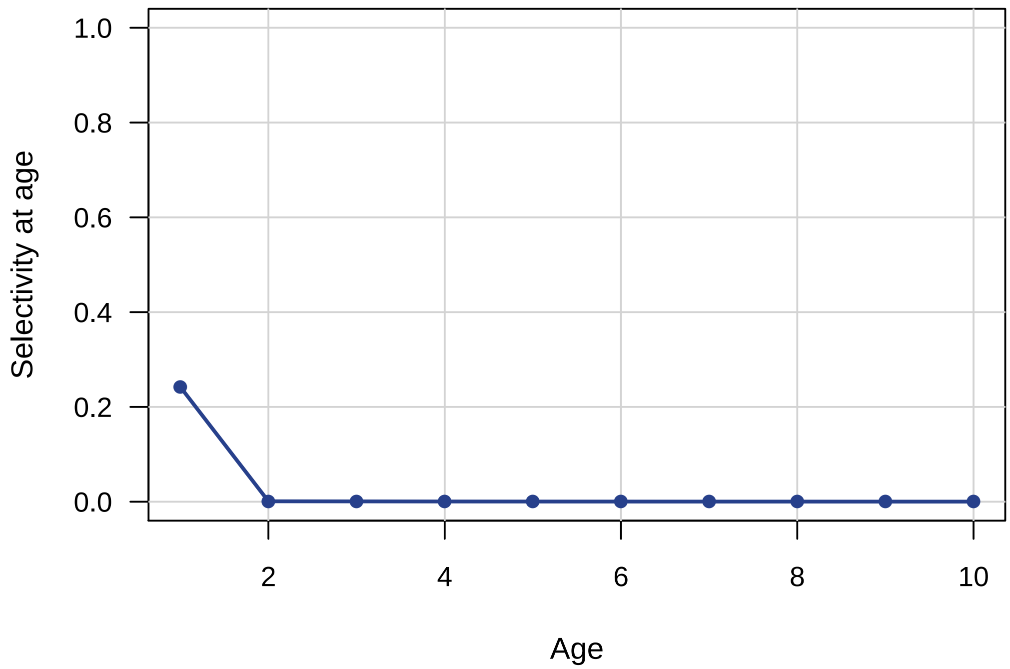


Figure 21. Average selectivity from the terminal assessment years, weighted by geometric mean Fs from the last three assessment years, and used in computation of benchmarks and projections.

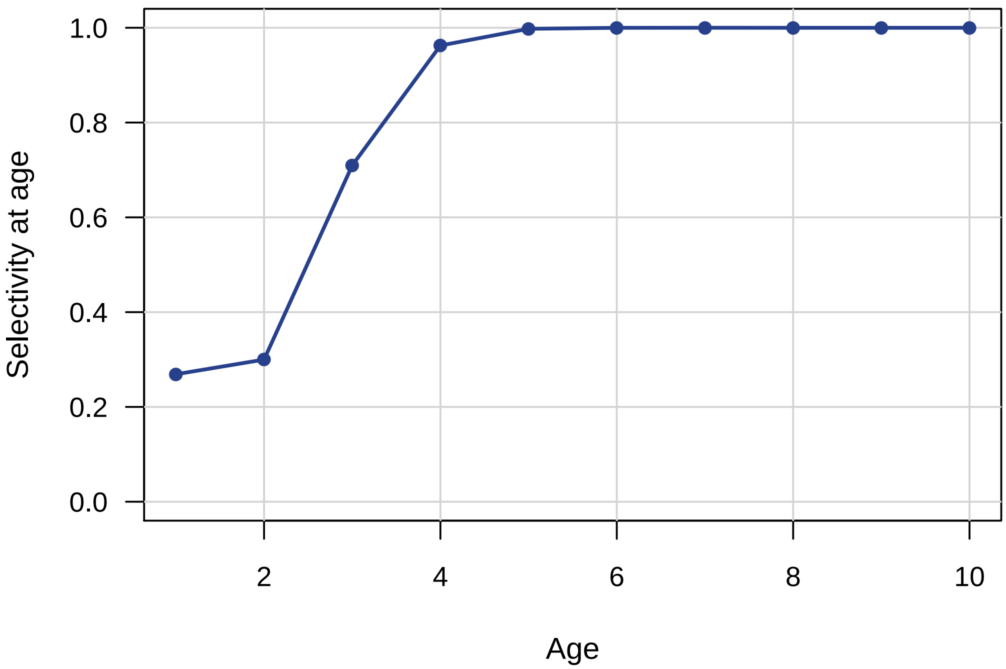


Figure 22. Estimated fully selected fishing mortality rate (per year) by fishery. comm refers to the commercial fleet, and GR to the general recreational fleet.

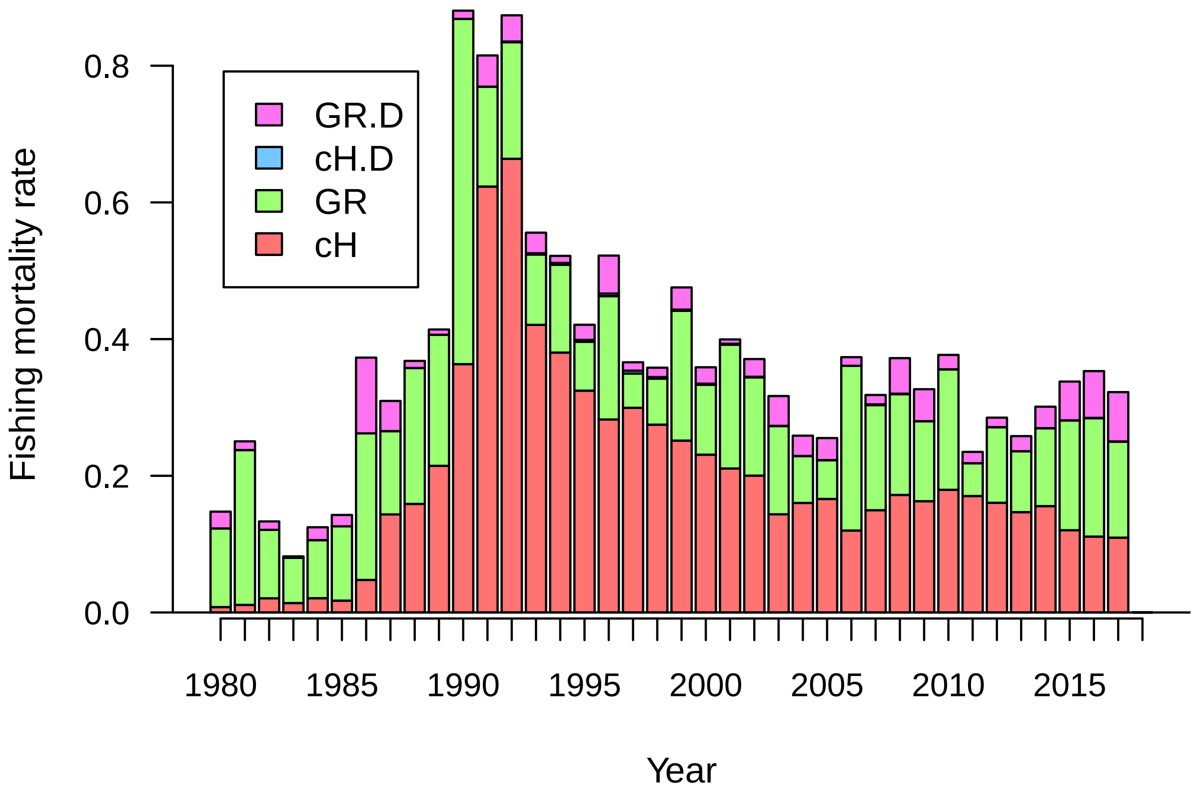


Figure 23. Estimated landings in numbers by fishery from the catch-age model. comm refers to the commercial fleet, and GR to the general recreational fleet.

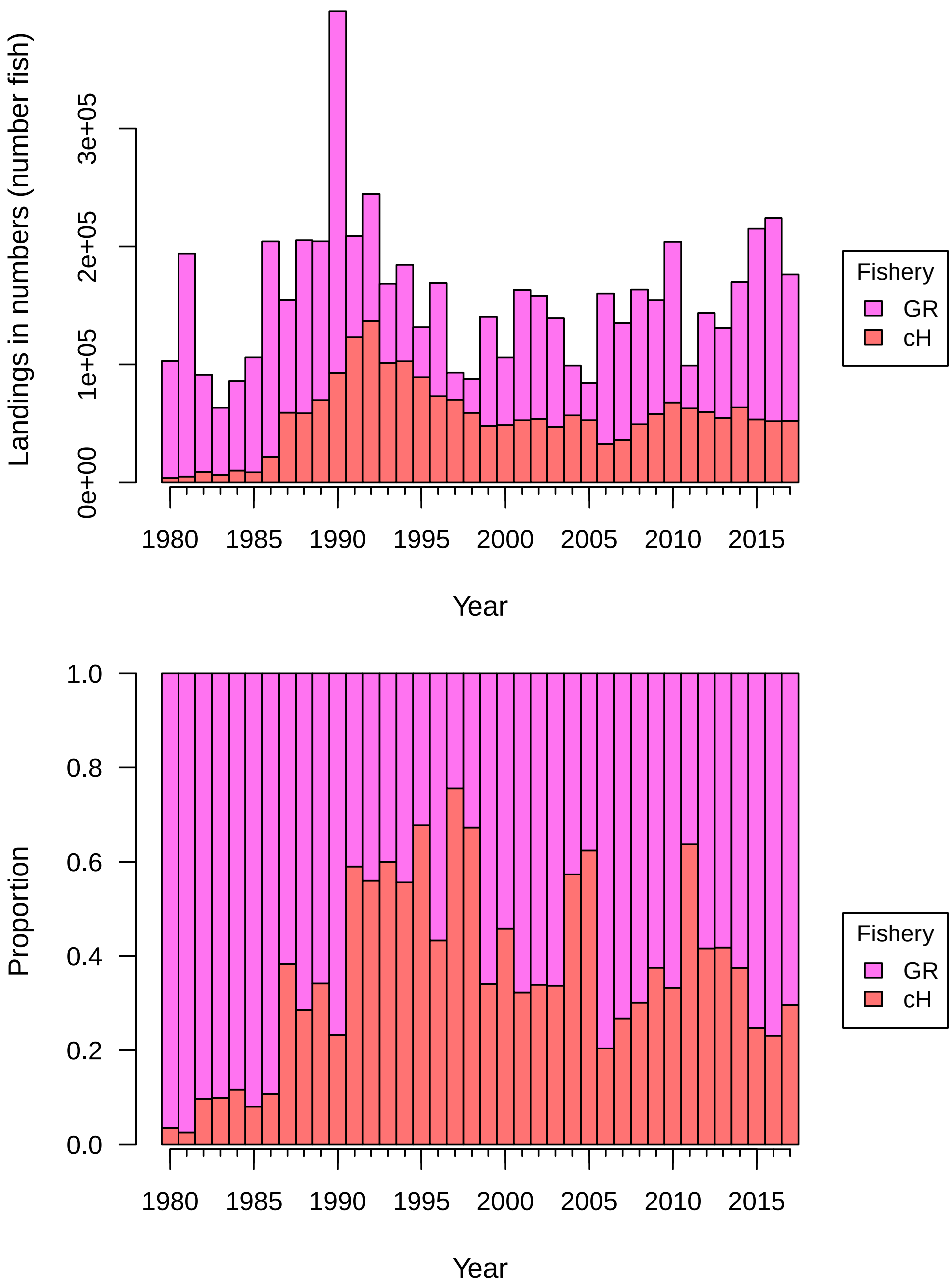


Figure 24. Estimated landings in whole weight by fishery from the catch-age model. comm refers to the commercial fleet, and GR to the general recreational fleet.

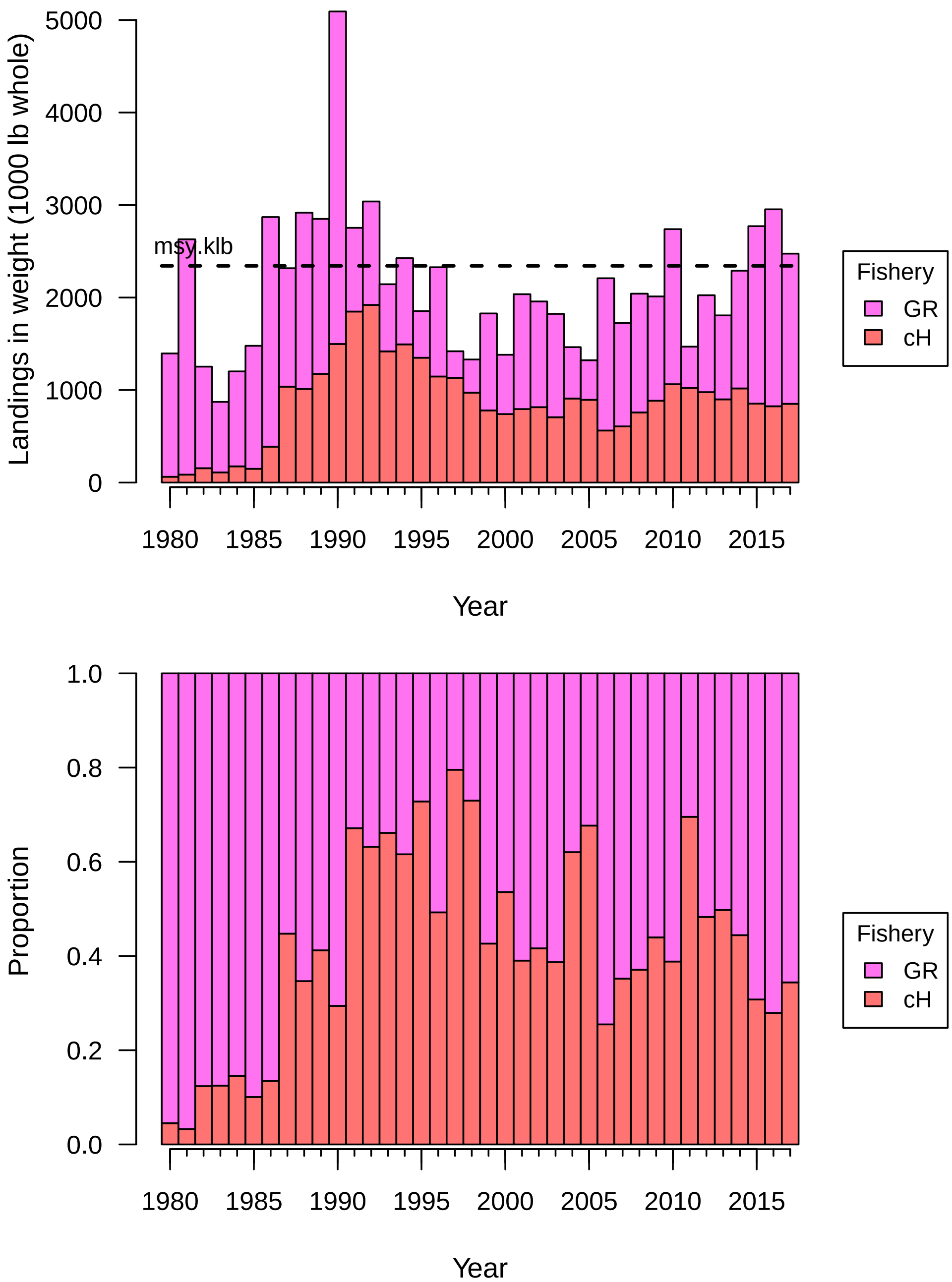


Figure 25. Top panel: Beverton–Holt spawner-recruit curves, with and without lognormal bias correction. The expected (upper) curve was used for computing management benchmarks. Years within panel indicate year of recruitment generated from spawning biomass. Bottom panel: log of recruits (number age-1 fish) per spawner as a function of spawners.

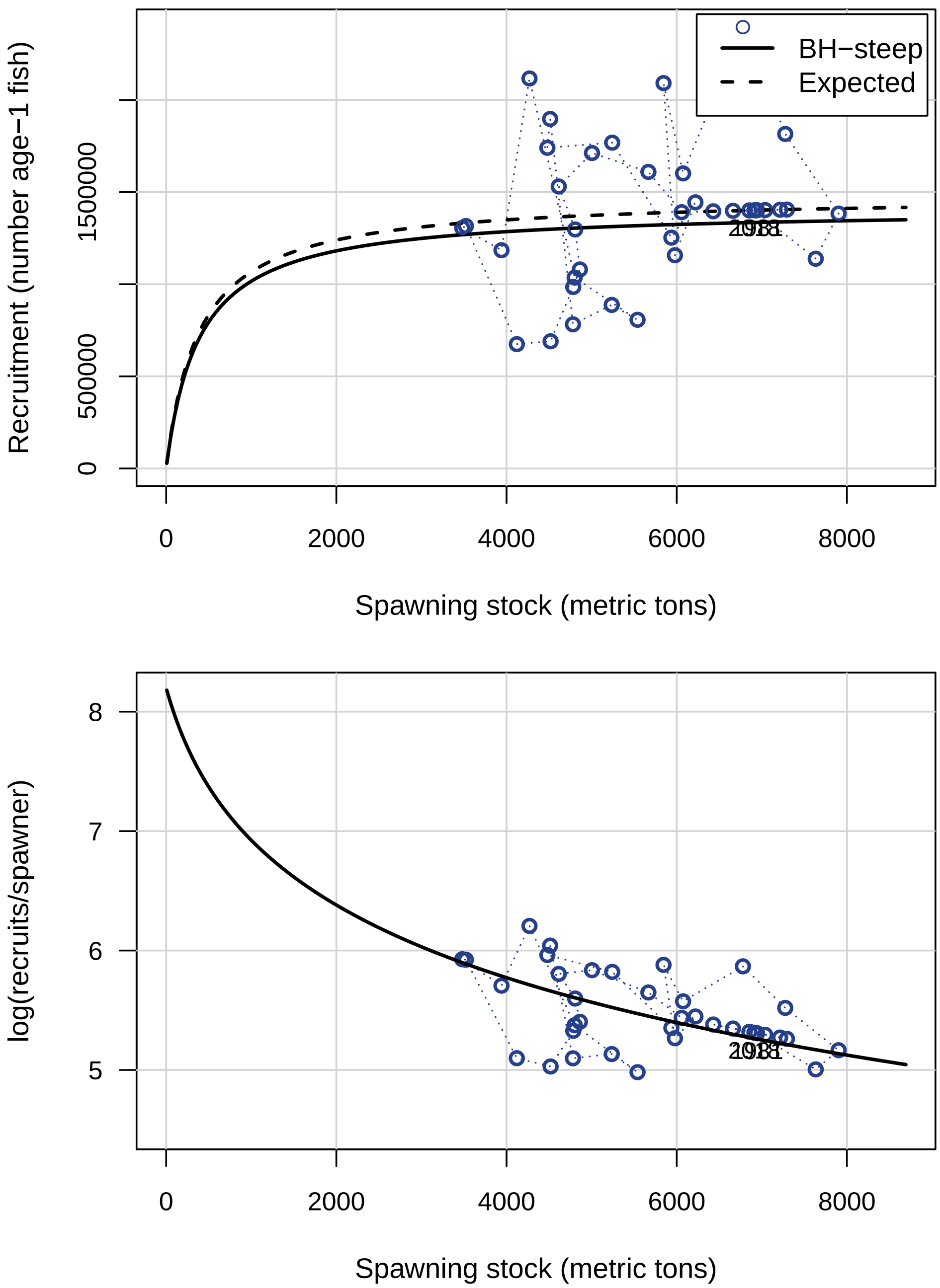


Figure 26. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-1 fish), the SD of recruitment residuals, steepness, and unfished spawners per recruit. Vertical lines represent point estimates or values from the base run of the Beaufort Assessment Model.

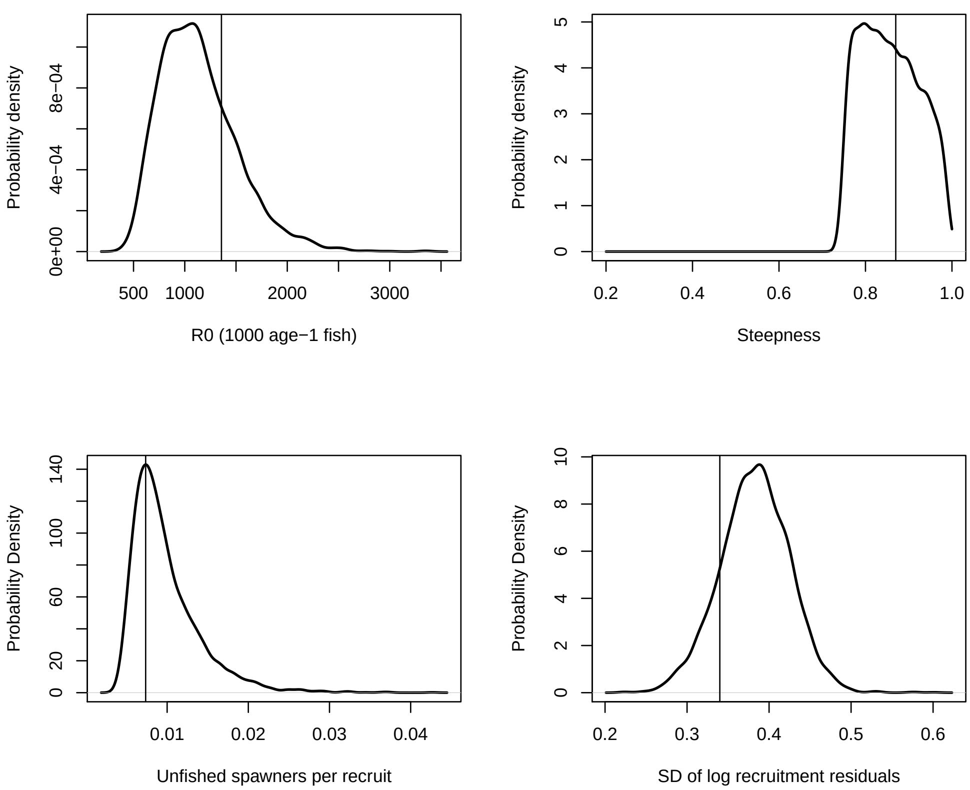
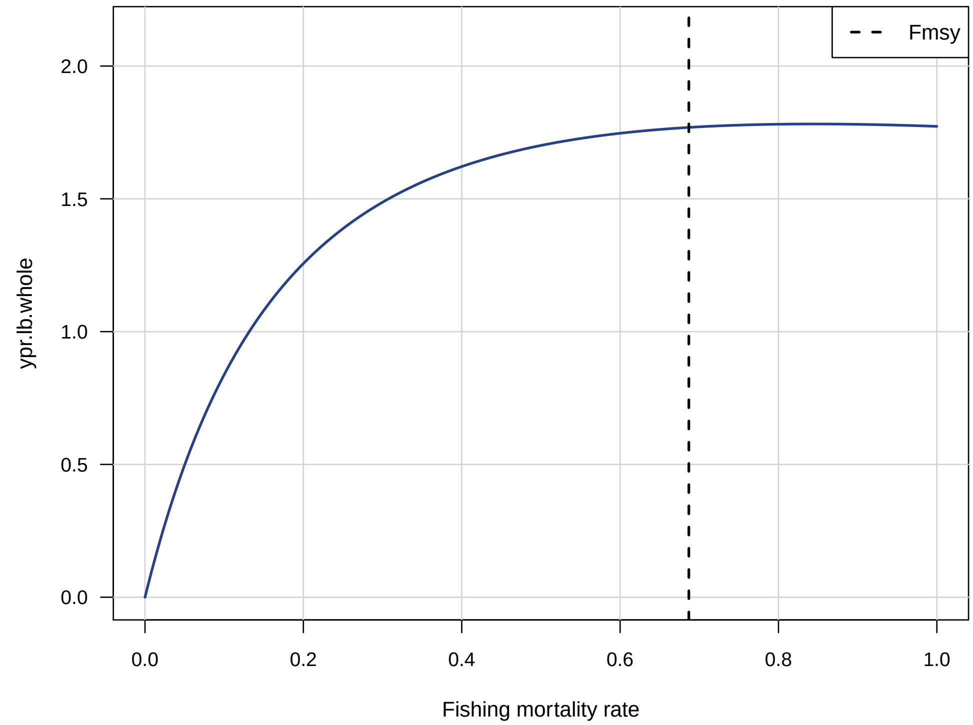


Figure 27. Top panel: yield per recruit (lb). Bottom panel: Spawning potential ratio (spawning biomass per recruit relative to that at the unfished level). Both curves are based on average selectivity from the end of the assessment period.



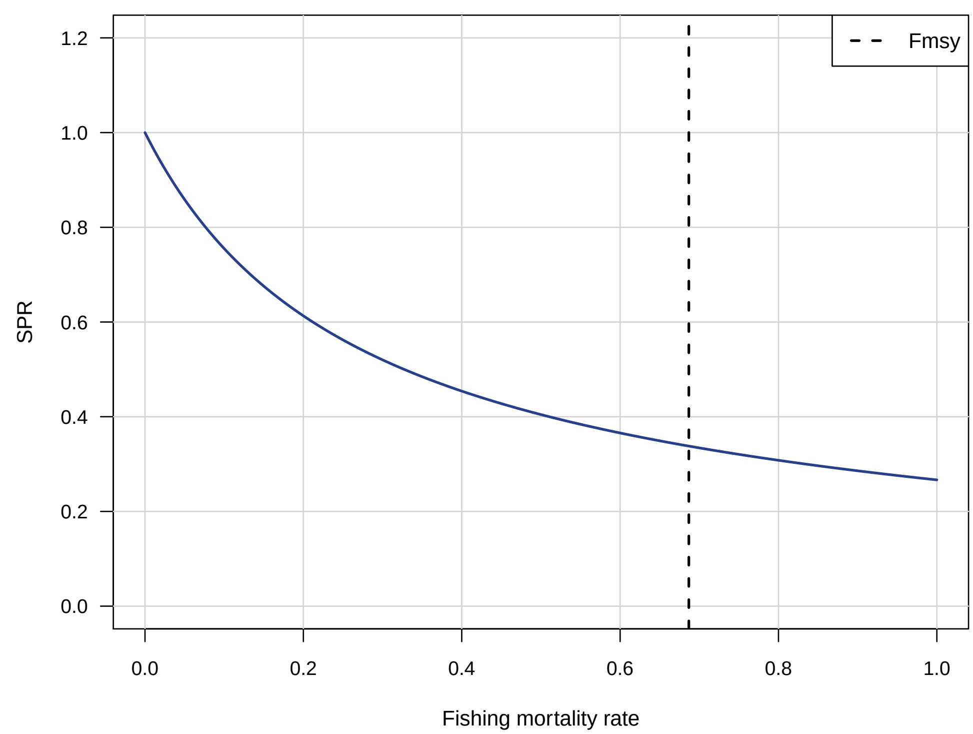


Figure 28. Top panel: equilibrium landings. The vertical line occurs where fishing rate is $F_{\mathrm{MSY}} = 0.69$ *and equilibrium landings are* MSY *(1000 lb). Bottom panel: equilibrium spawning biomass (mt). Both curves are based on average selectivity from the end of the assessment period.*

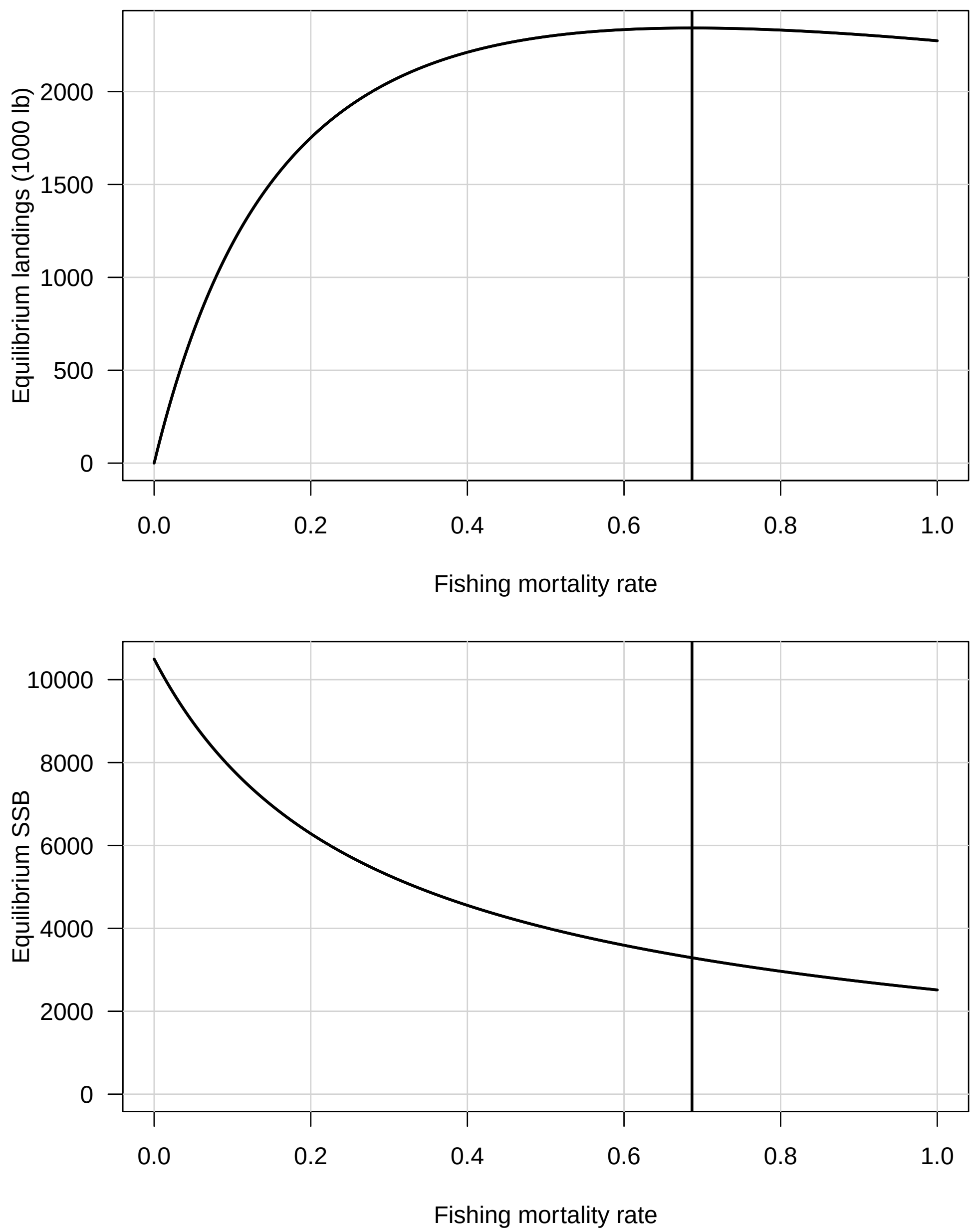


Figure 29. Probability densities of F_{MSY} benchmarks from the ensemble model of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.

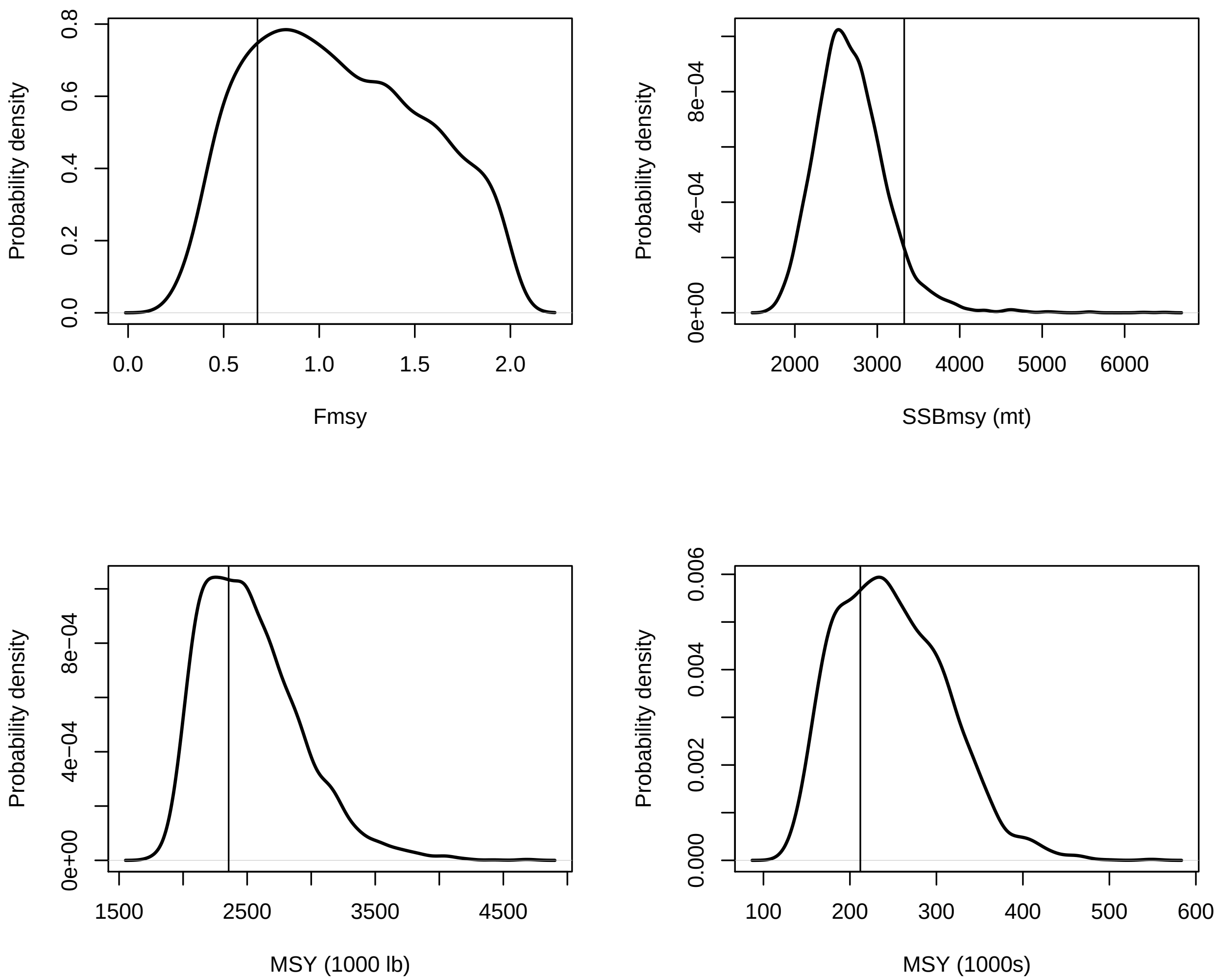


Figure 30. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; gray error bands indicate 5^{th} and 95^{th} percentiles of the ensemble modeling. Top panel: spawning biomass relative to the minimum stock size threshold (MSST). Middle panel: spawning biomass relative to $\mathrm{SSB}_{\mathrm{MSY}}$. Bottom panel: F relative to F_{MSY}.

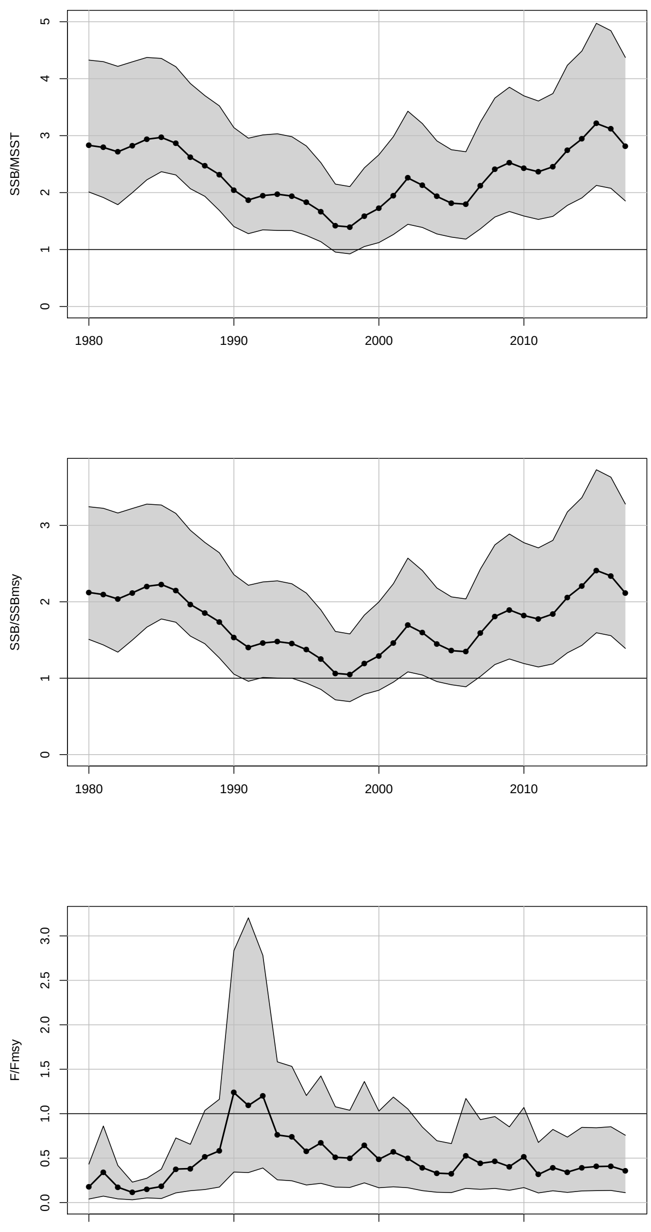


Figure 31. Probability densities of terminal status estimates from ensemble model of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.

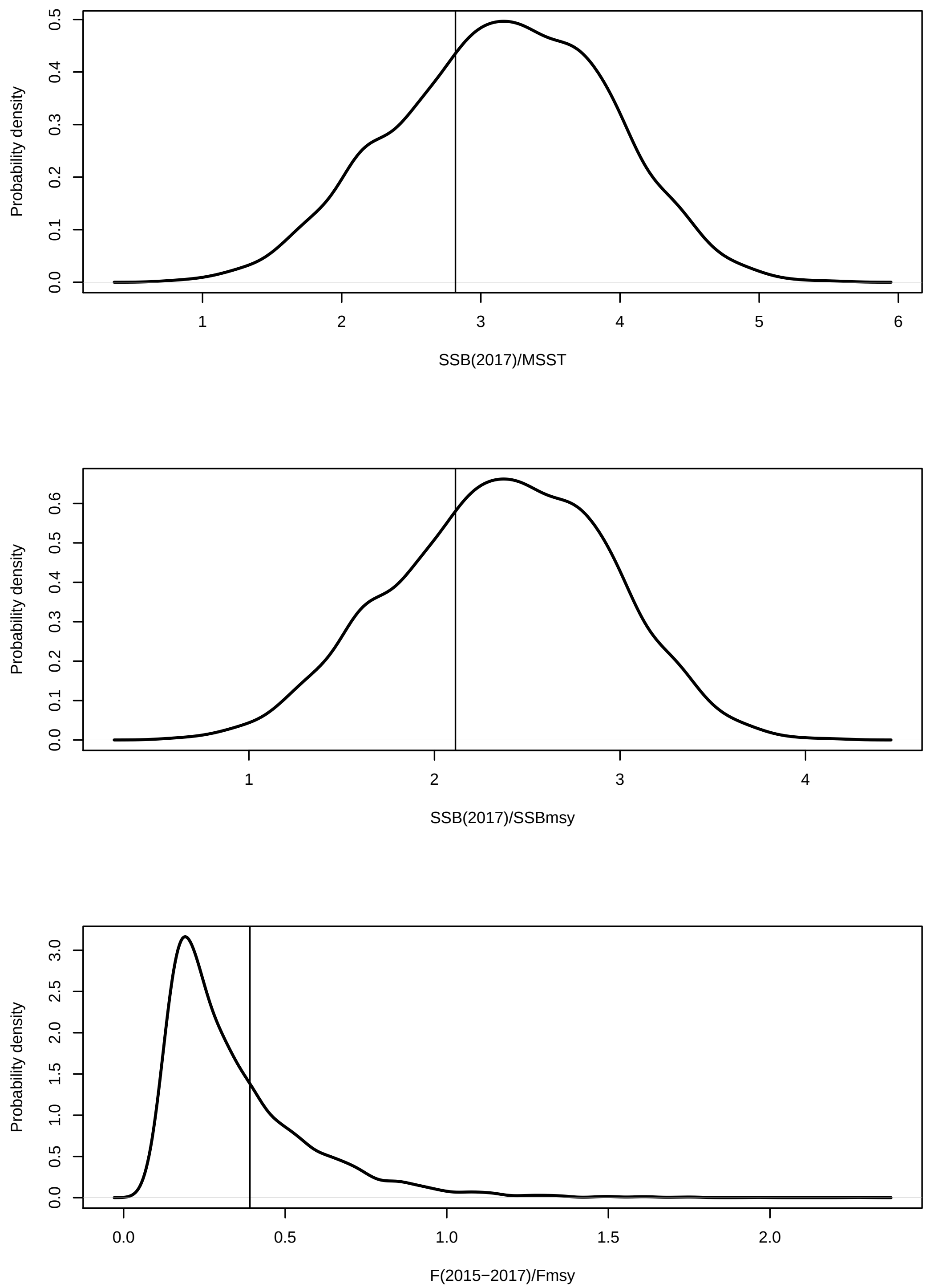
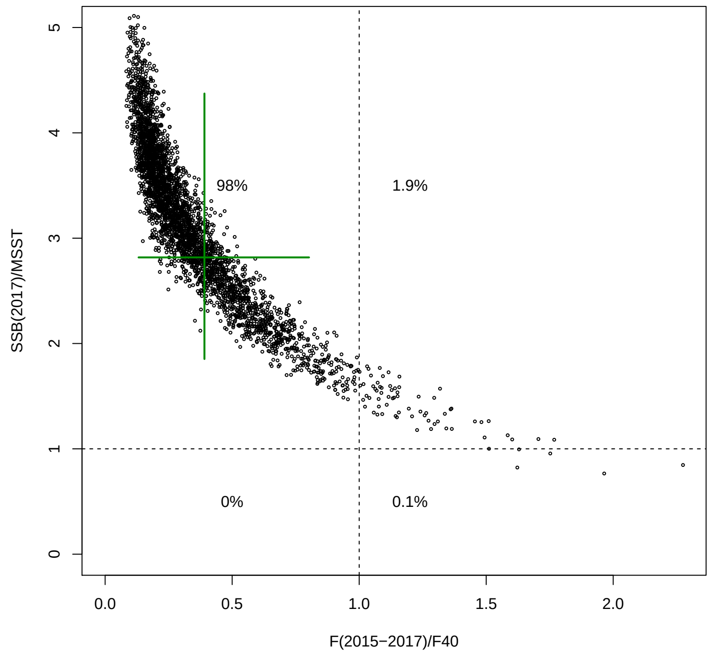


Figure 32. Phase plots of terminal status estimates from the ensemble model of the Beaufort Assessment Model. Top panel is status relative to MSST*, and the bottom panel is status relative to* $\mathrm{SSB}_{\mathrm{MSY}}$*. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by* 5^{th} *and* 95^{th} *percentiles.*



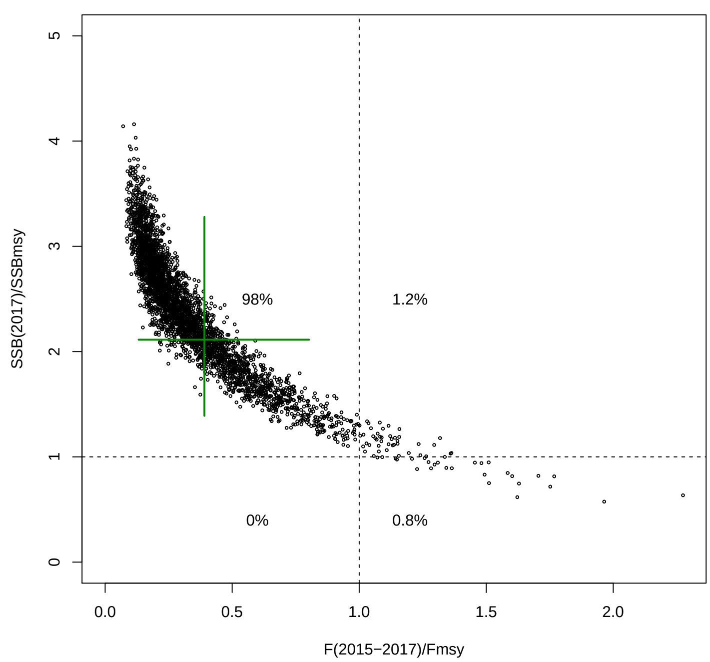


Figure 33. Age structure relative to the equilibrium expected at MSY.

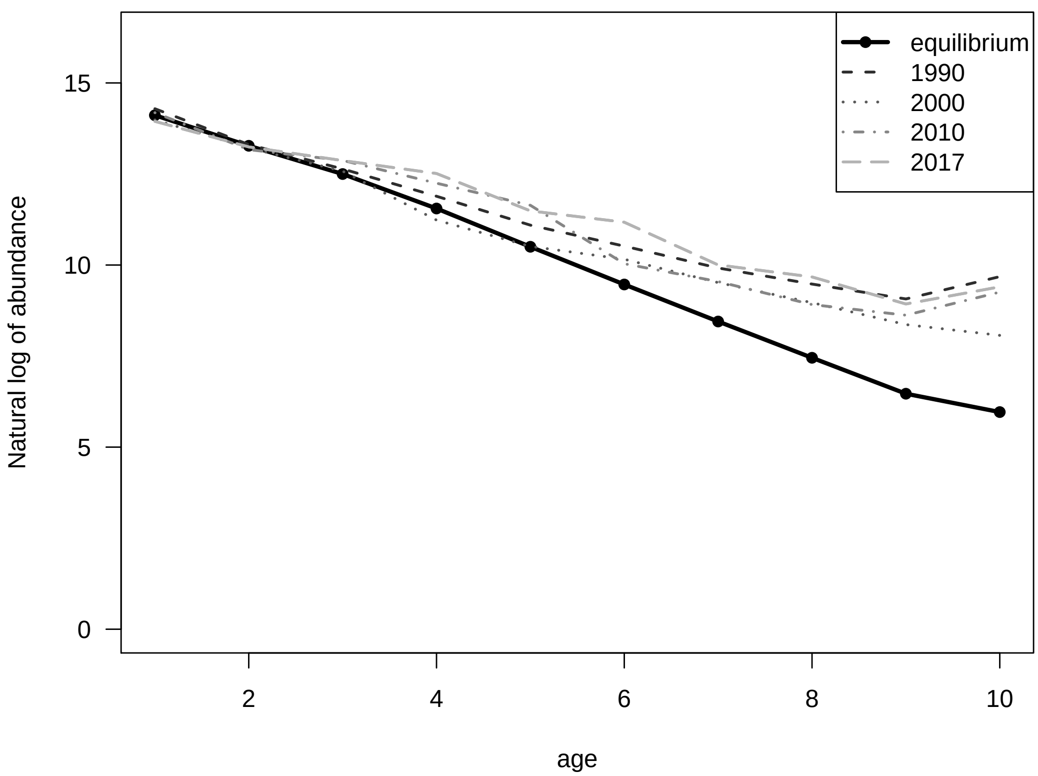
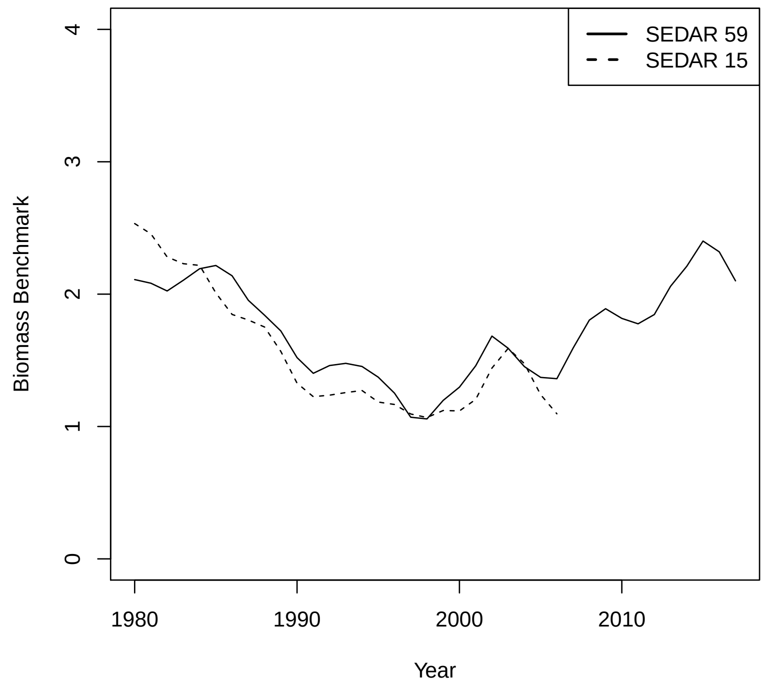


Figure 34. Comparing benchmark time series from current and last assessment. Solid line represents the base run of the current benchmark assessment and the dashed line represents the base run from the last assessment. Top panel: The biomass status time series. Bottom panel: The fishing status time series.



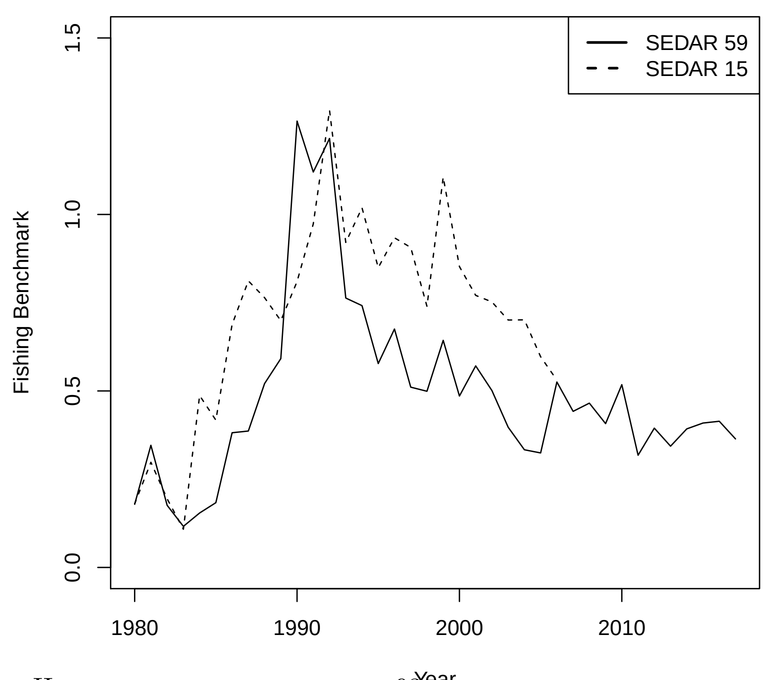
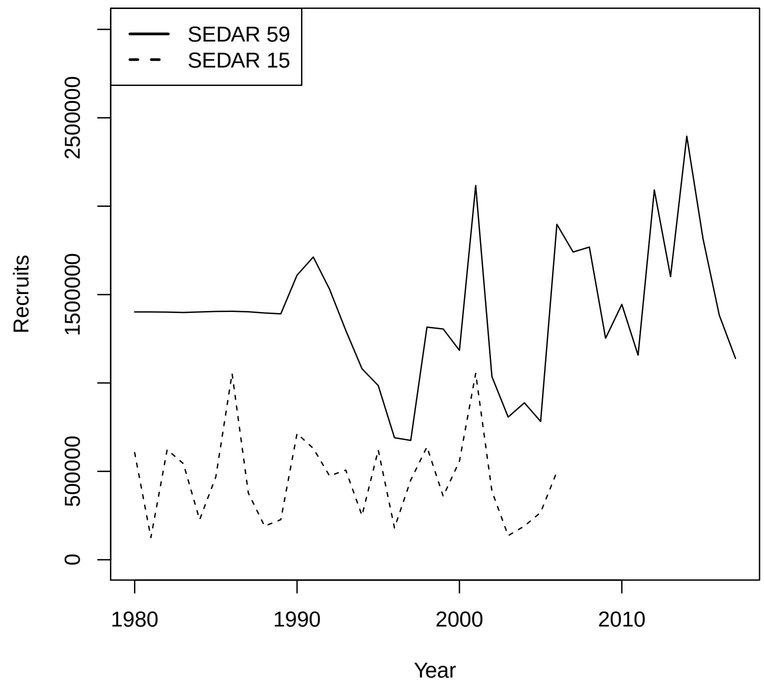


Figure 35. Comparing biological time series from current and last assessment. Solid line represents the base run of the current benchmark assessment and the dashed line represents the base run from the last assessment. Top panel: The recruits time series. Bottom panel: The spawning stock biomass time series.



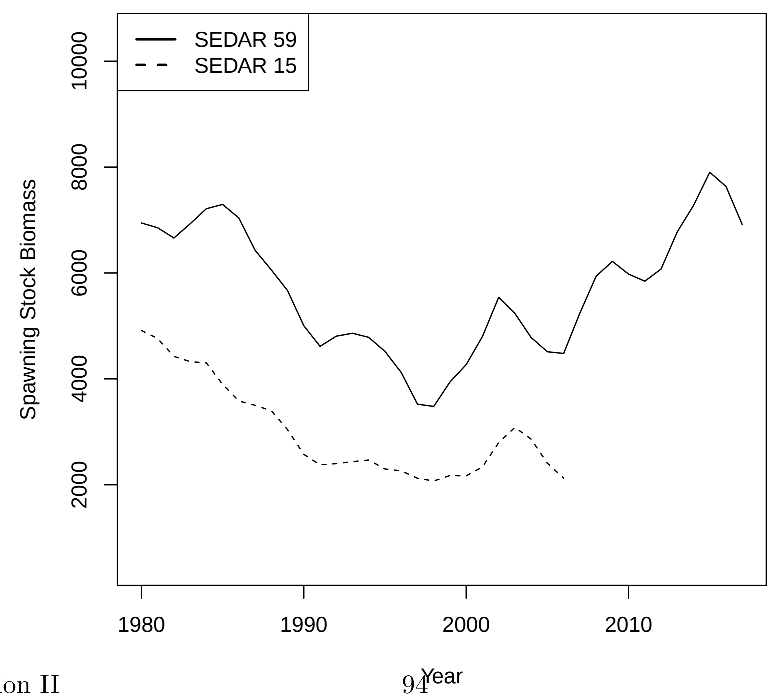
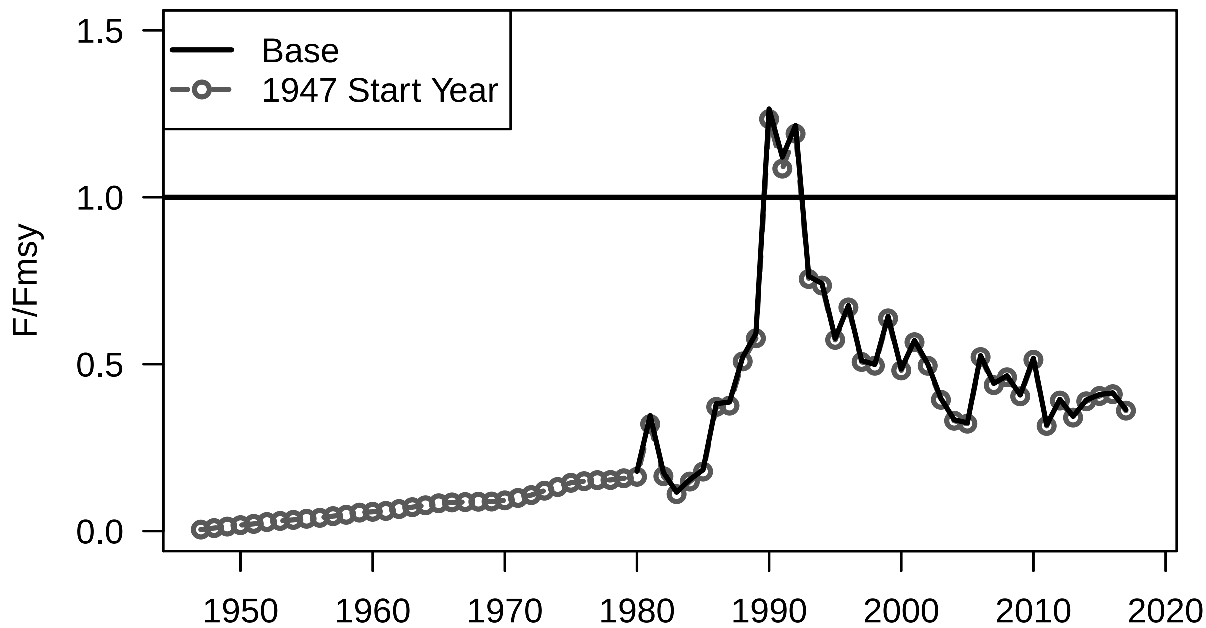


Figure 36. Sensitivity to an earlier start year (1947) (sensitivity run S1). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* SSB_{MSY}.



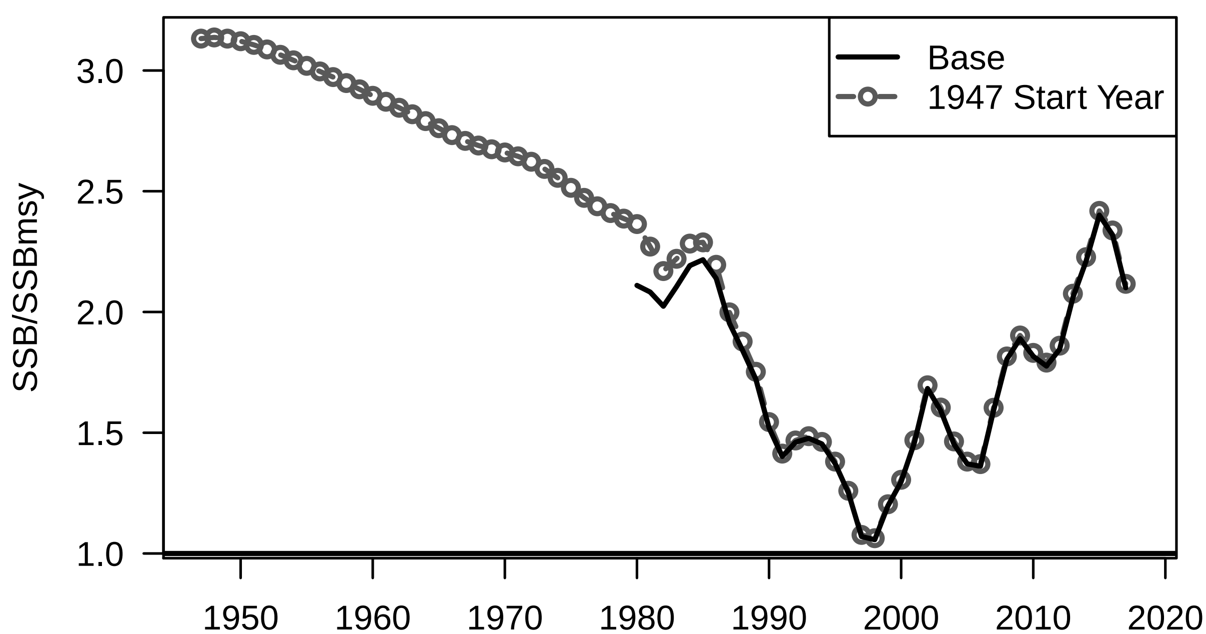
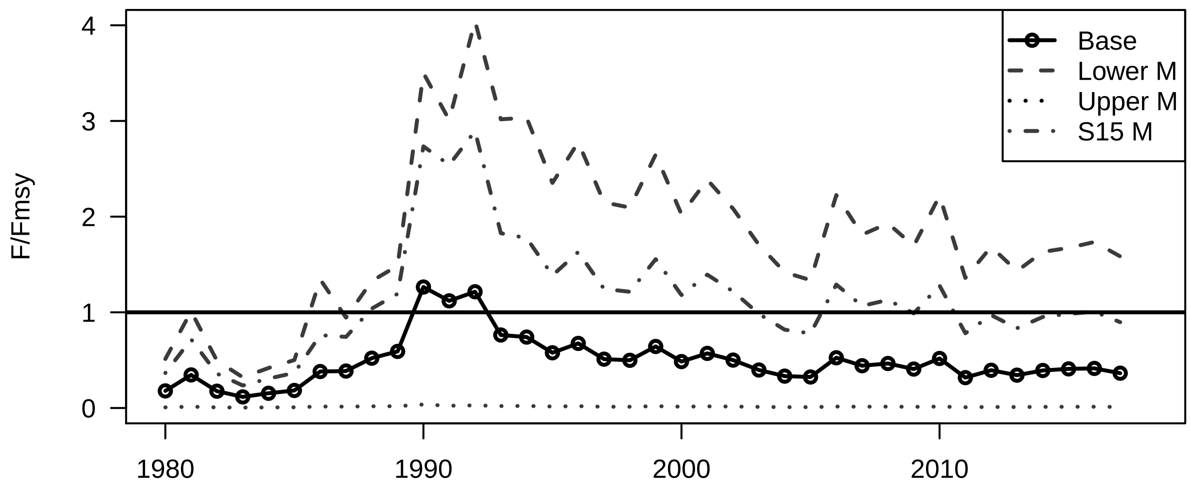


Figure 37. Sensitivity to a lower, upper, and SEDAR 15 value for natural mortality (sensitivity runs S2, S3, and S15). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* SSB_{MSY}.



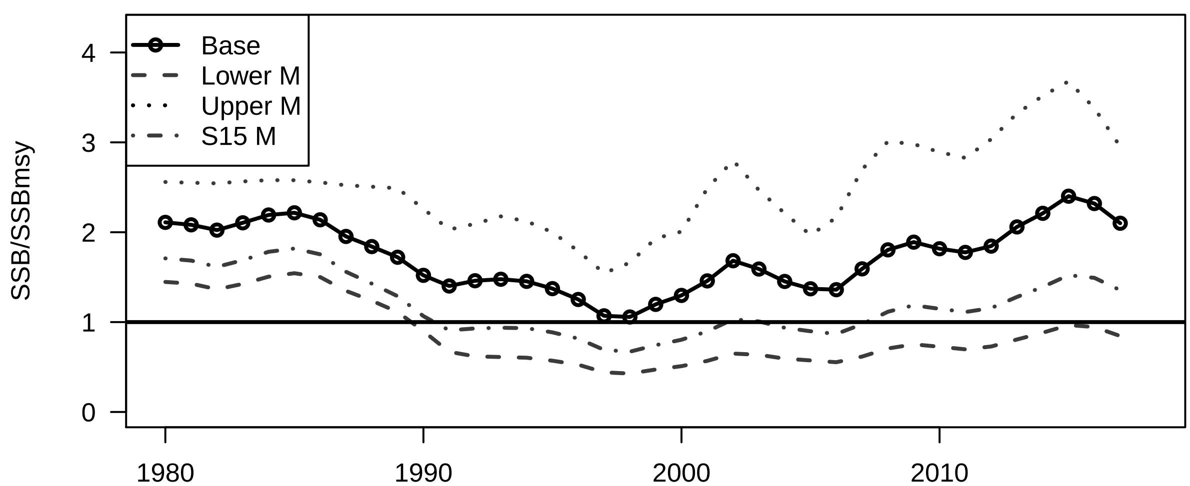
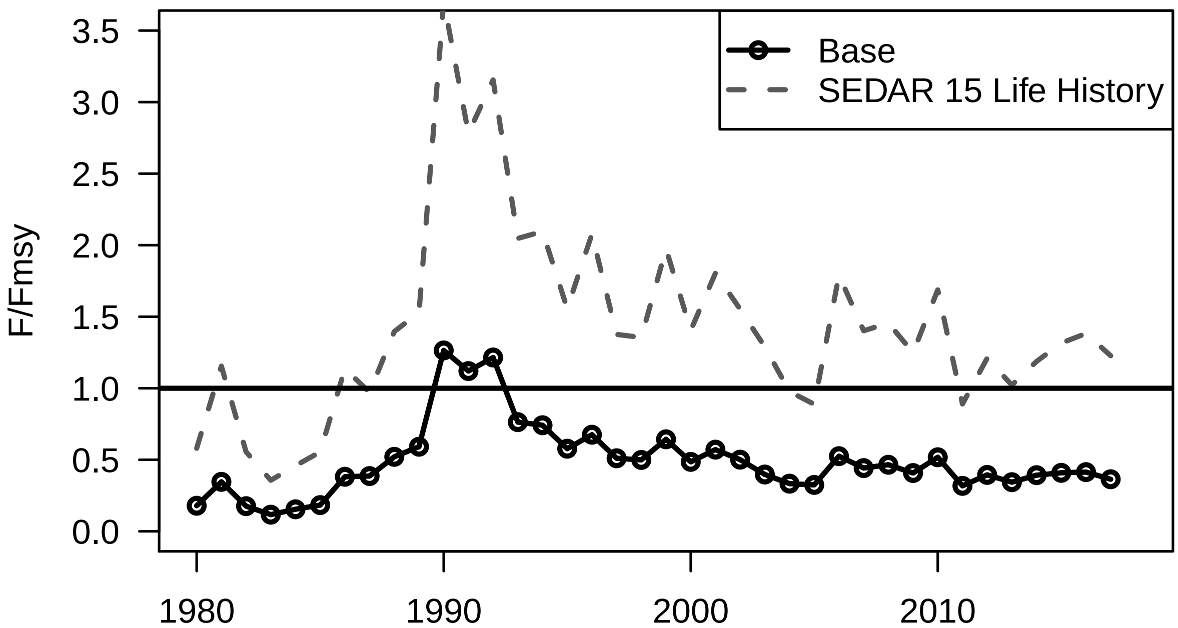


Figure 38. Sensitivity to SEDAR 15 life history values (sensitivity run S4). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.



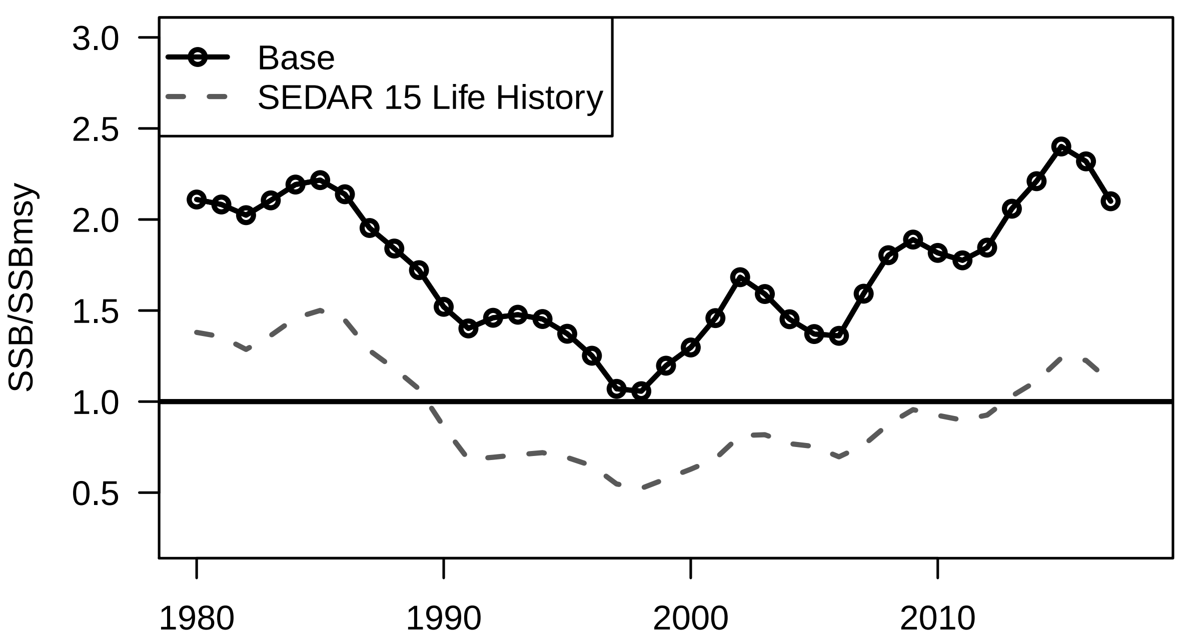


Figure 39. Sensitivity to a lower and upper discard mortality (sensitivity runs S5 and S6). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

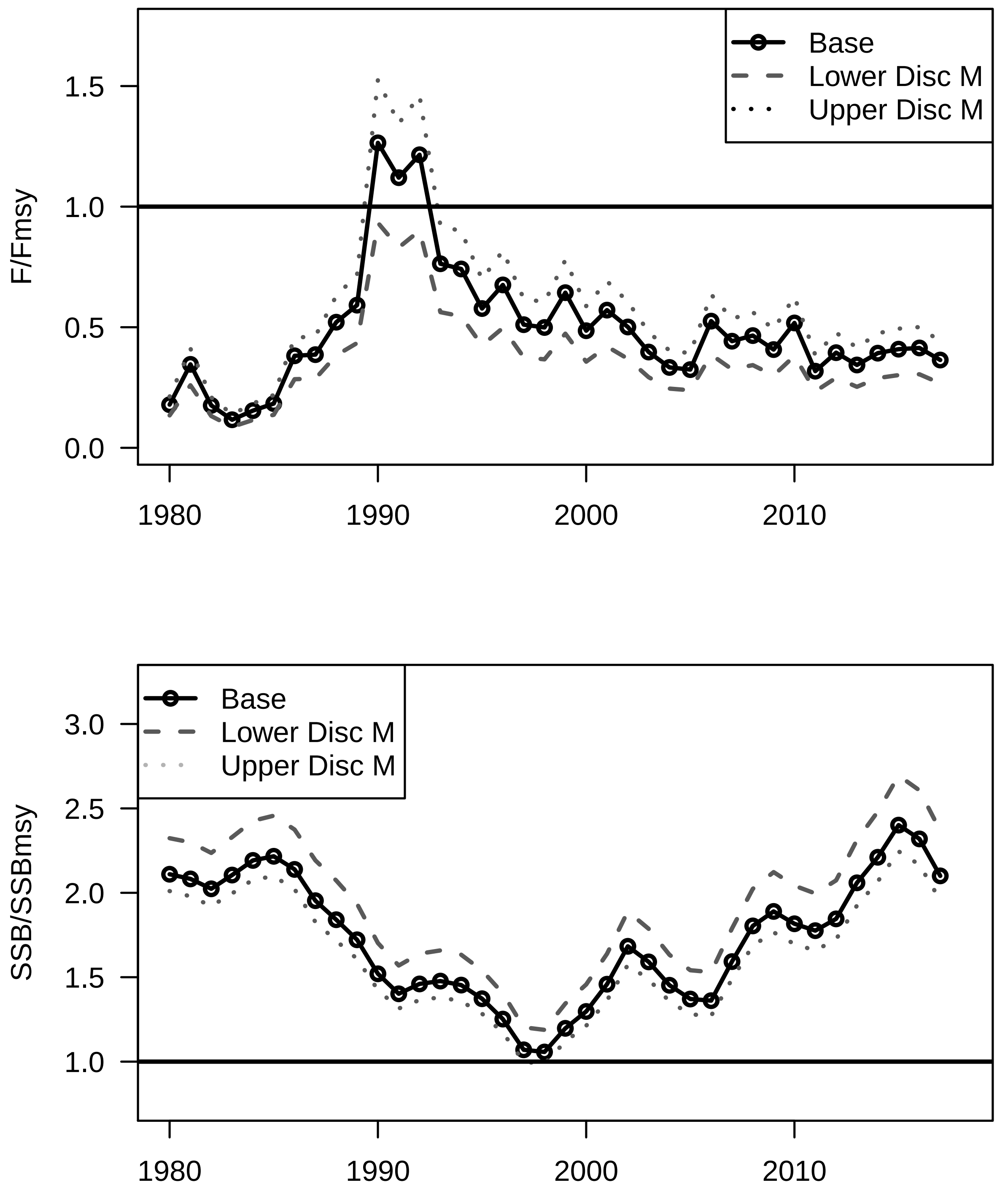


Figure 40. Sensitivity to a lower and upper steepness (sensitivity runs S7 and S8). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

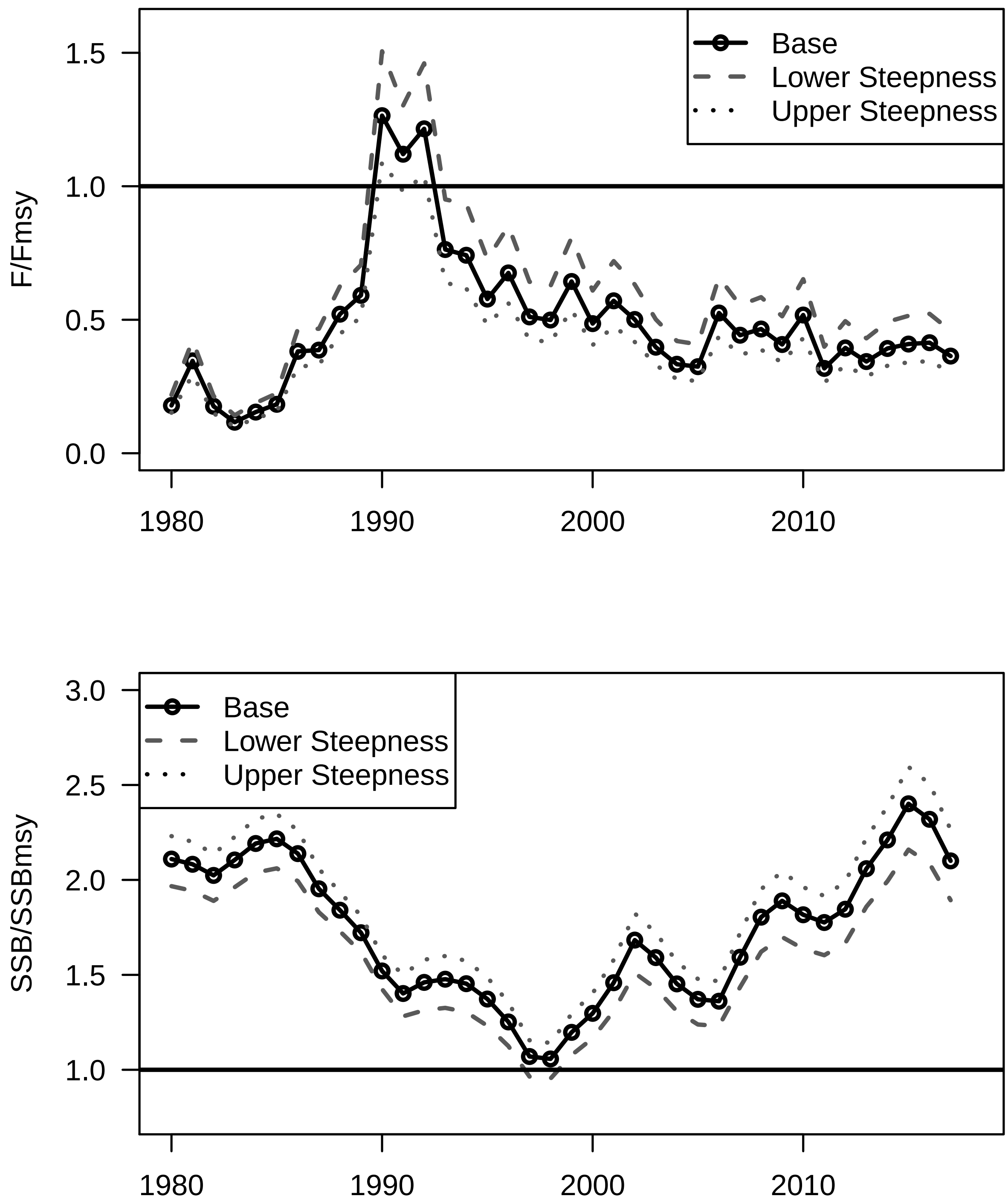


Figure 41. Sensitivity to a younger and older A50 parameter of the commercial selectivity function (sensitivity runs S9 and S10). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$*.*

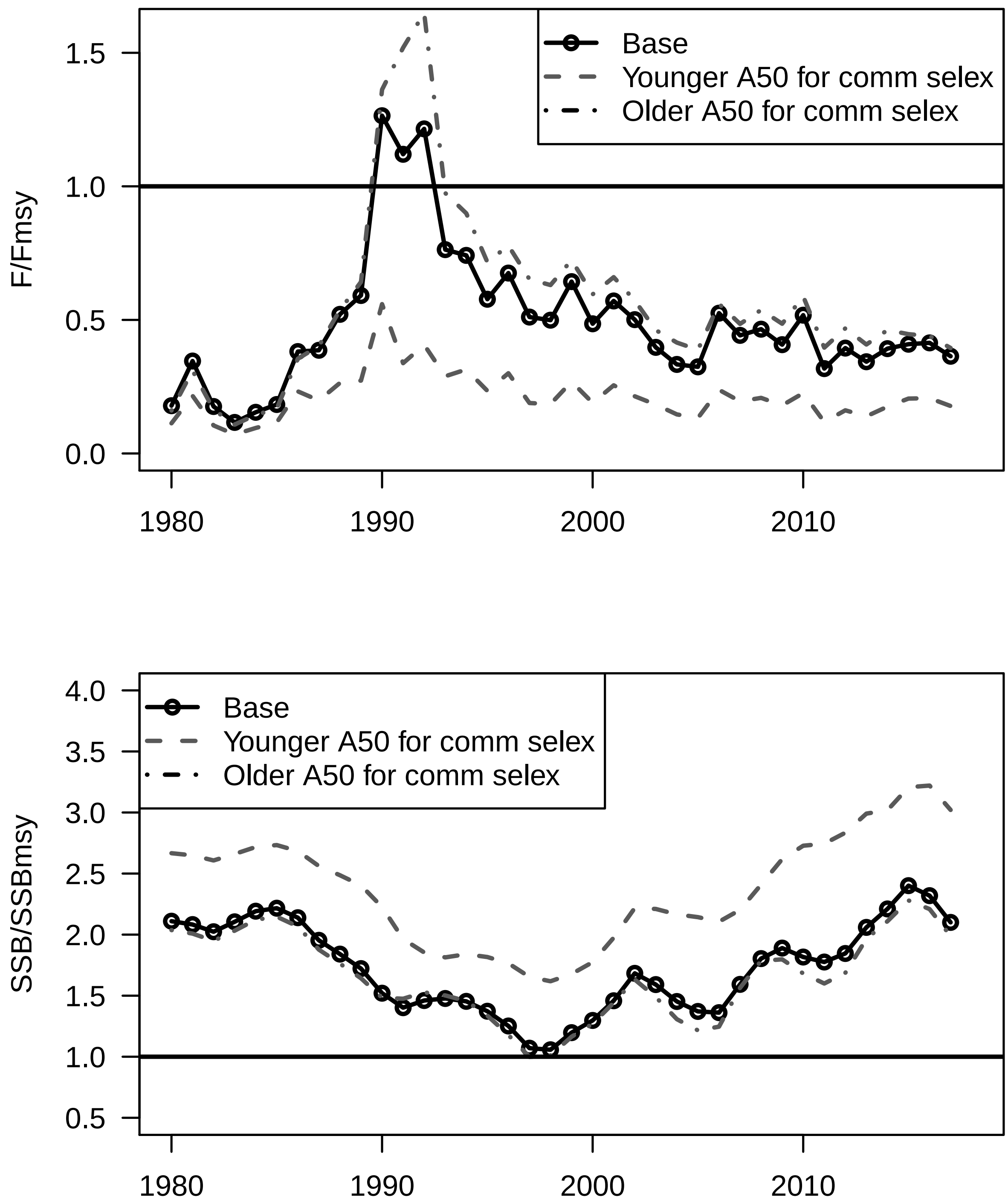
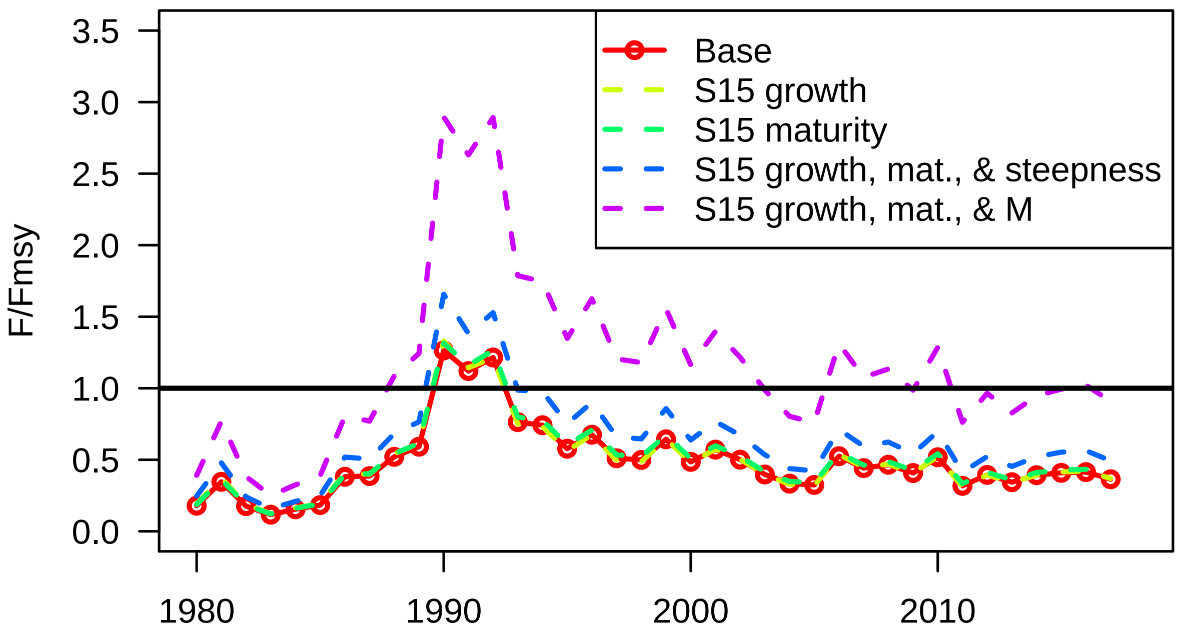


Figure 42. Sensitivity to SEDAR 15 growth curve, female maturity, steepness, and natural mortality individually and combined (sensitivity runs S11-S14). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* SSB_{MSY}.



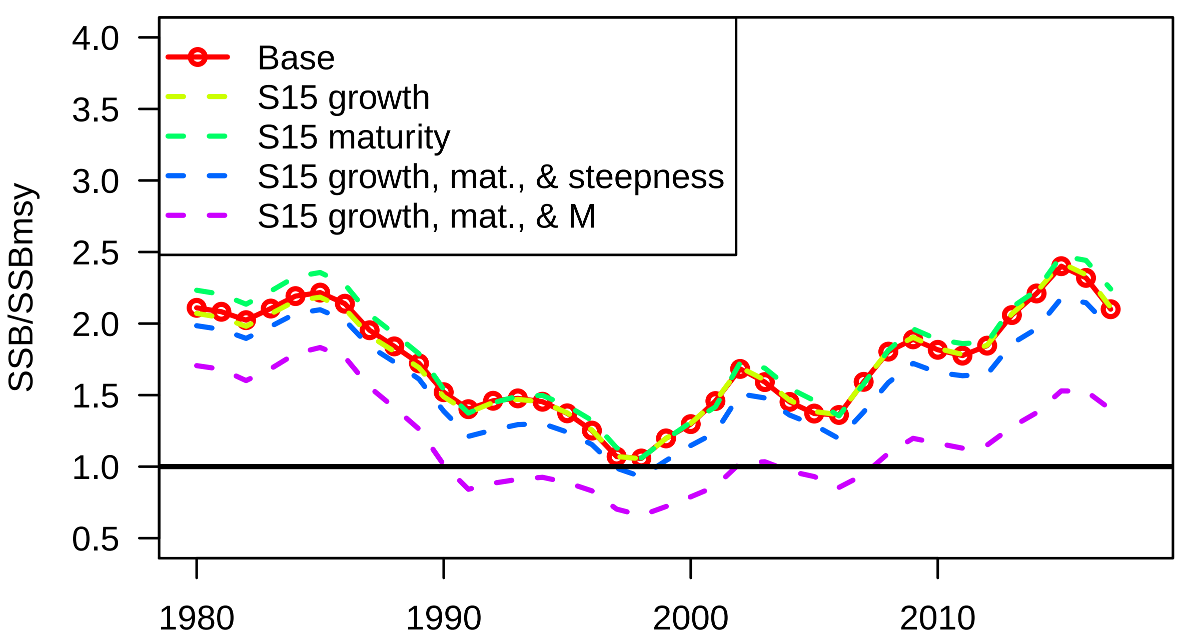


Figure 43. Phase plot of terminal status estimates from sensitivity runs of the Beaufort Assessment Model.

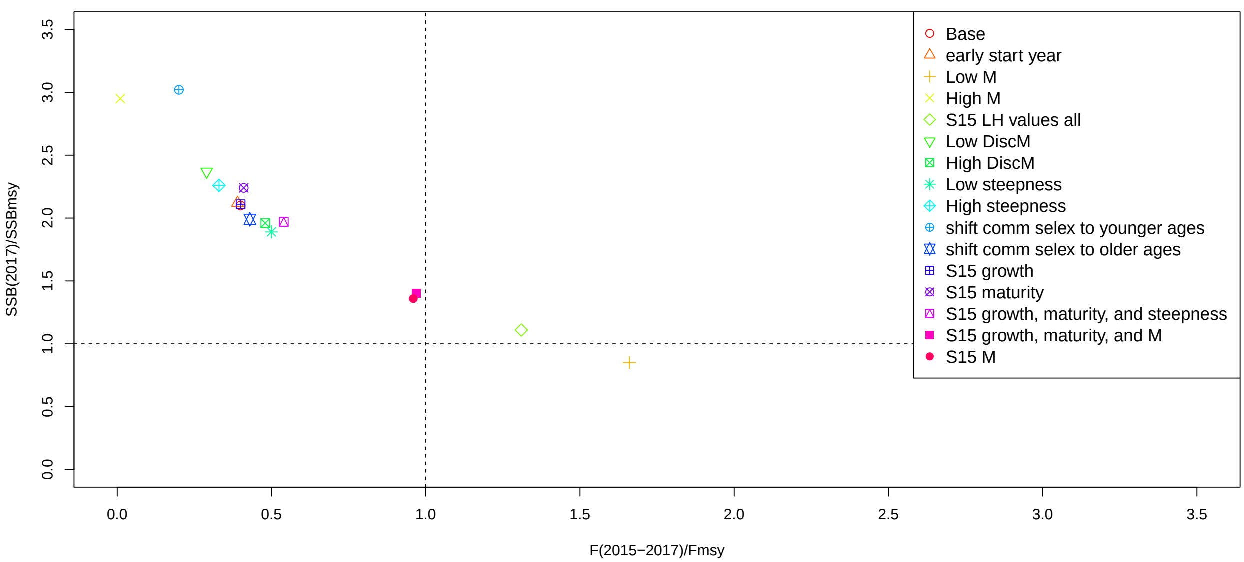


Figure 44. Retrospective analyses. Sensitivity to terminal year of data (sensitivity runs S16 a–d). Top panel: Recruits. Bottom panel: Spawning biomass. Closed circles show terminal-year estimates. Imperceptible lines overlap results of the base run.

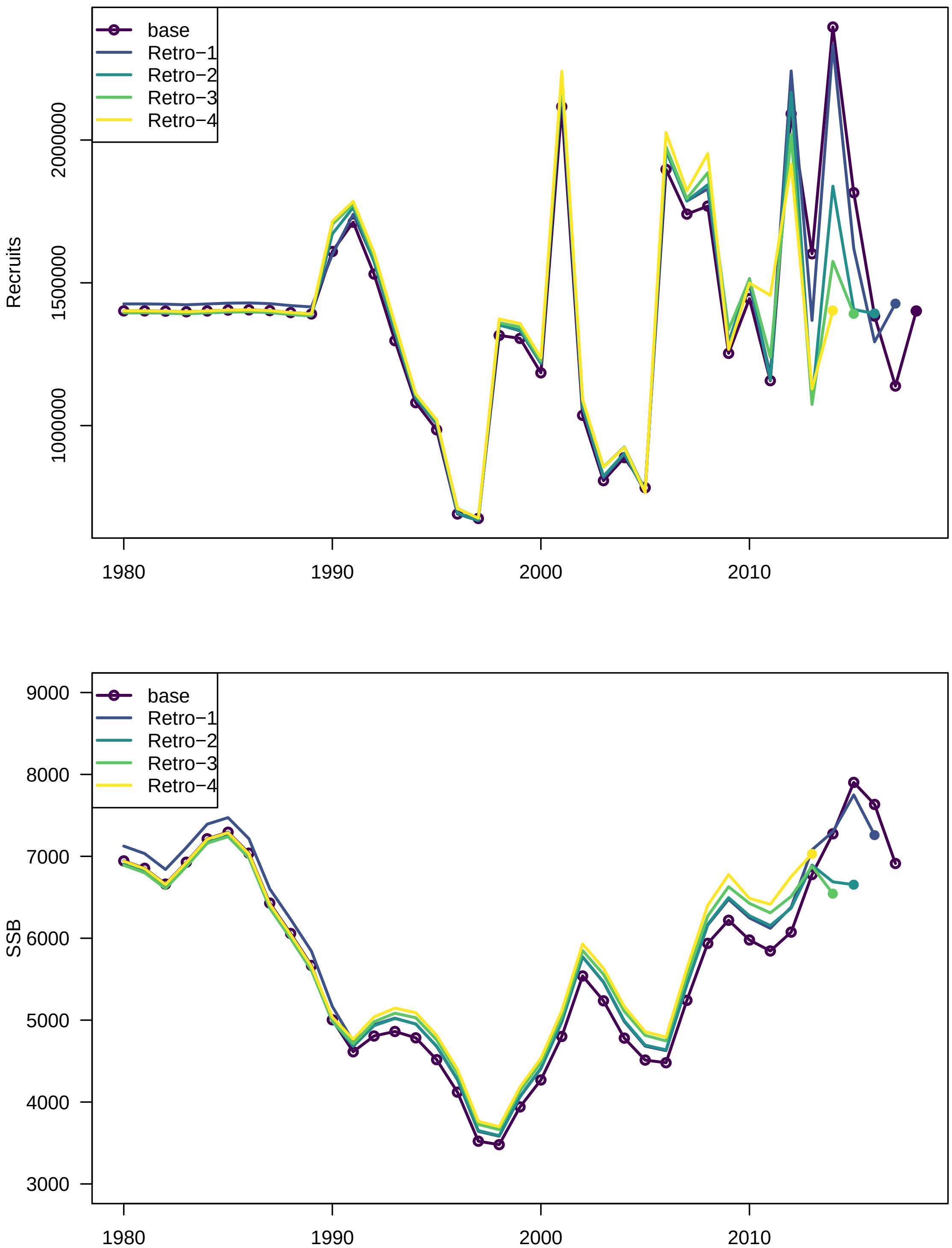


Figure 45. Retrospective status analyses. Sensitivity to terminal year of data (sensitivity runs S16a–d). Top panel: Fishing status. Bottom panel: Biomass status. Closed circles show terminal-year estimates. Imperceptible lines overlap results of the base run.

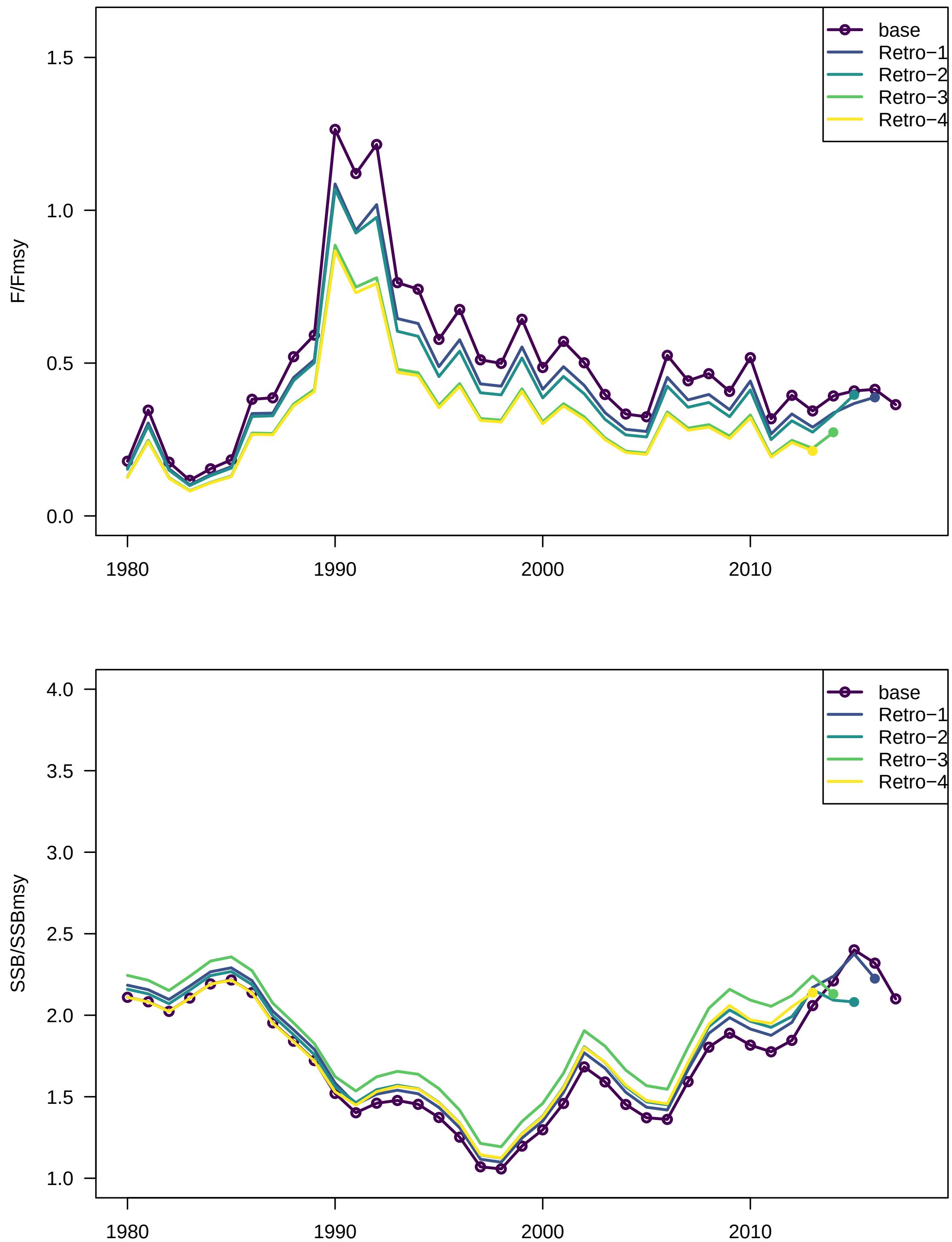


Figure 46. Projection results under scenario 1—fishing mortality rate fixed at F_{current}, with 2020 as the first year of new regulations. The interim years (2018–2019) use a mean of the 2014–2017 landings. In all panels, expected values represented by solid lines, median values represented by dashed lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities from the base run (solid blue lines) and medians from the MCB runs(dashed green lines). Spawning stock (SSB) is at time of peak spawning.*

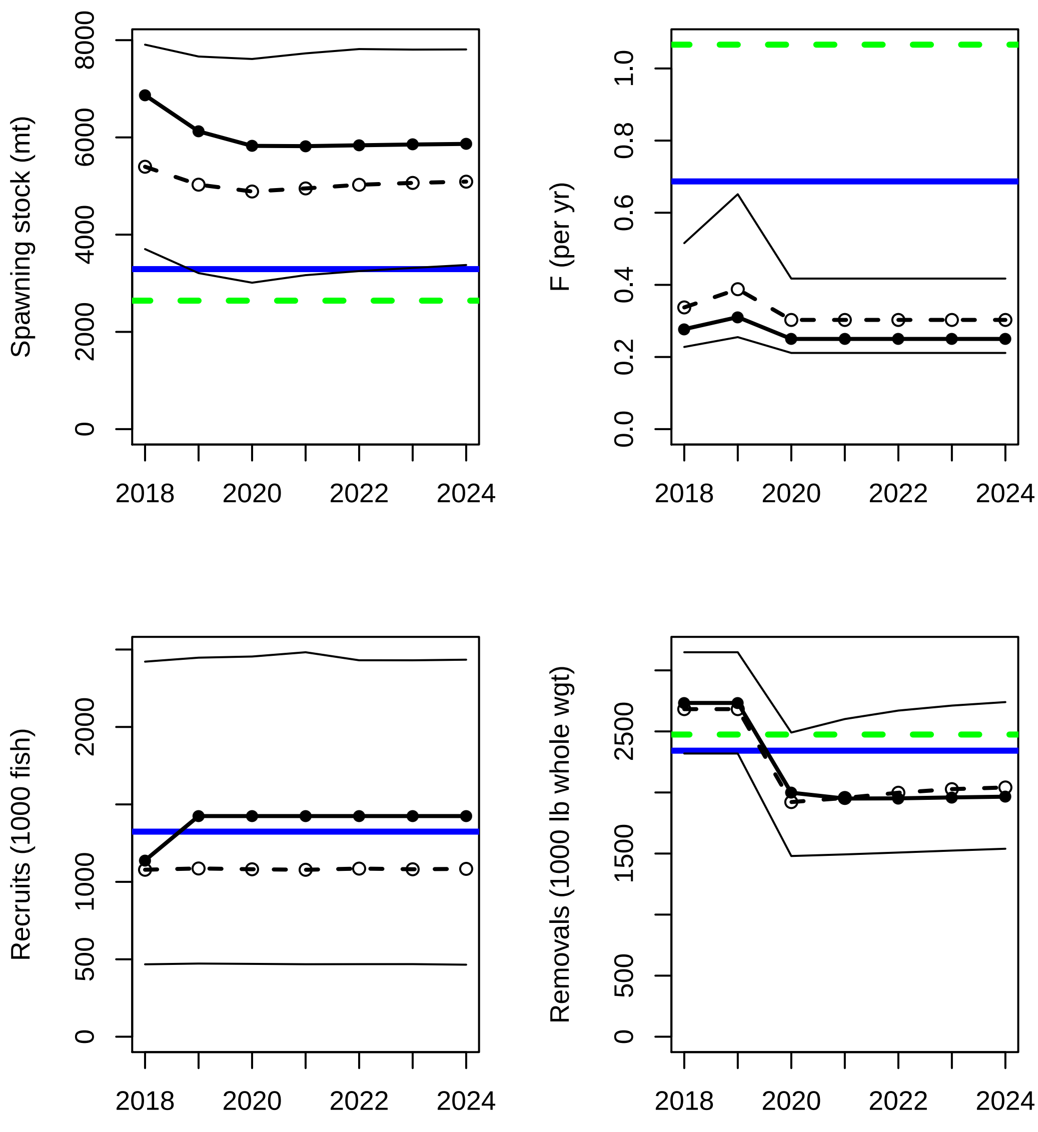


Figure 47. Projection results under scenario 2—fishing mortality rate fixed at $F = F_{\mathrm{MSY}}$, with 2020 as the first year of new regulations. The interim years (2018–2019) use a mean of the 2014–2017 landings. In all panels, expected values represented by solid lines, median values represented by dashed lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities from the base run (solid blue lines) and medians from the MCB runs(dashed green lines). Spawning stock (SSB) is at time of peak spawning.*

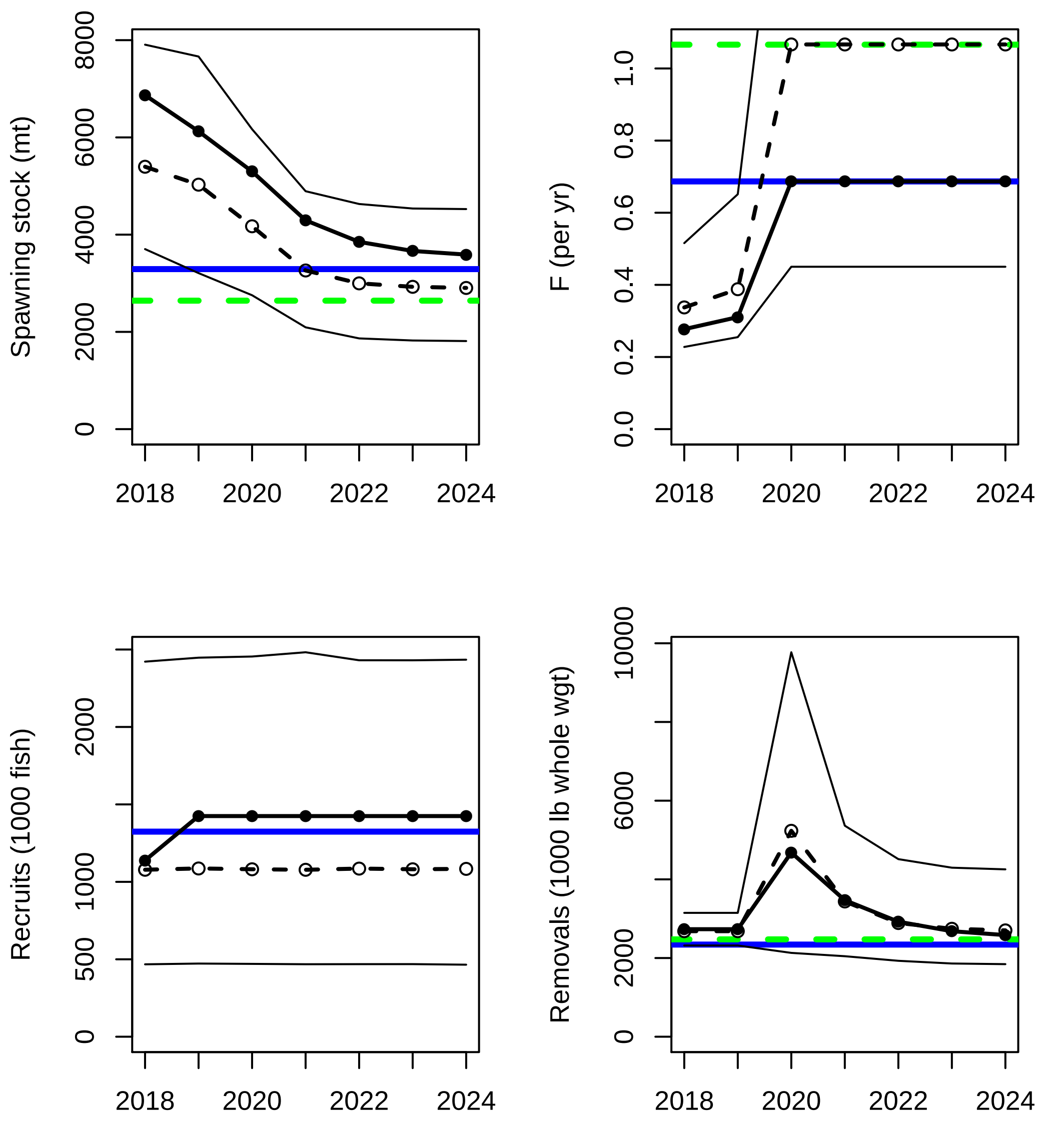
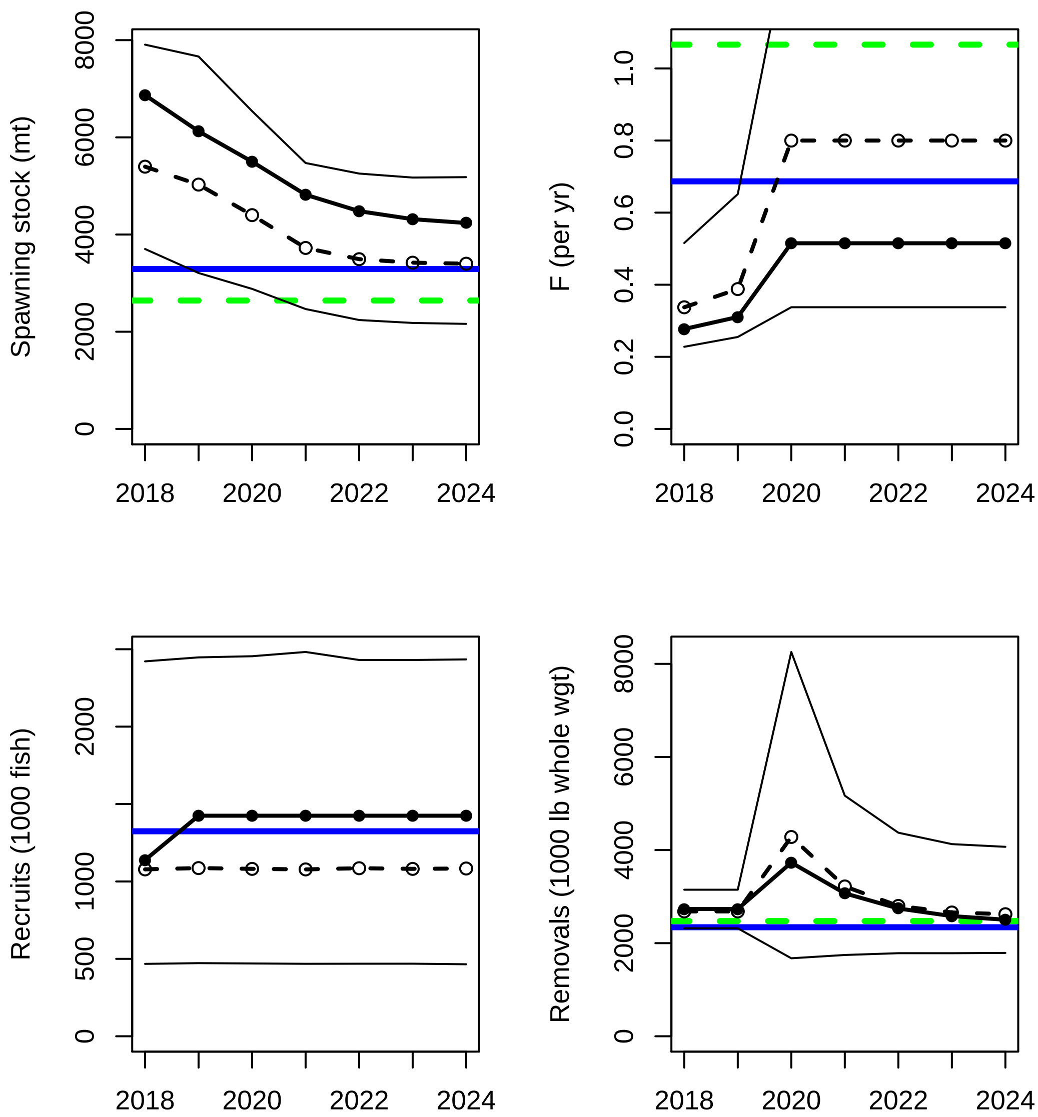


Figure 48. Projection results under scenario 3—fishing mortality rate fixed at $F = 75\%F_{\mathrm{MSY}}$, with 2020 as the first year of new regulations. The interim years (2018–2019) use a mean of the 2014–2017 landings. In all panels, expected values represented by solid lines, median values represented by dashed lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities from the base run (solid blue lines) and medians from the MCB runs(dashed green lines). Spawning stock (SSB) is at time of peak spawning.*



Appendix A Abbreviations and symbols

Table 23. Acronyms and abbreviations used in this report

Symbol	Meaning
ABC	Acceptable Biological Catch
AW	Assessment Workshop (here, for greater amberjack)
ASY	Average Sustainable Yield
B	Total biomass of stock, conventionally on January 1r
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 greater amberjack)
F	Instantaneous rate of fishing mortality
FHWAR	The survey for Fishing, Hunting, and Wildlife-Associated Recreation
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
MCB	Monte Carlo/Bootstrap, an approach to quantifying uncertainty in model results
MFMT	Maximum fishing-mortality threshold; a limit reference point used in U.S. fishery management; often based on F_{MSY}
mm	Millimeter(s); 1 inch = 25.4 mm
MRFSS	Marine Recreational Fisheries Statistics Survey, a data-collection program of NMFS, predecessor of MRIP
MRIP	Marine Recreational Information Program, a data-collection program of NMFS, descended from MRFSS
MSST	Minimum stock-size threshold; a limit reference point used in U.S. fishery management. The SAFMC has defined MSST for greater amberjack as $(1-M)\text{SSB}_{\text{MSY}} = 0.7\text{SSB}_{\text{MSY}}$.
MSY	Maximum sustainable yield (per year)
mt	Metric ton(s). One mt is 1000 kg, or about 2205 lb.
N	Number of fish in a stock, conventionally on January 1
NC	State of North Carolina
NMFS	National Marine Fisheries Service, same as "NOAA Fisheries Service"
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
OY	Optimum yield; SFA specifies that OY $\leq$ MSY.
PSE	Proportional standard error
R	Recruitment
SAFMC	South Atlantic Fishery Management Council (also, Council)
SC	State of South Carolina
SCDNR	Department of Natural Resources of SC
SDNR	Standard deviation of normalized residuals
SEDAR	SouthEast Data Assessment and Review process
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
SSB_{MSY}	Level of SSB at which MSY can be attained
TIP	Trip Interview Program, a fishery-dependent biodata collection program of NMFS
TL	Total length (of a fish), as opposed to FL (fork length) or SL (standard length)
VPA	Virtual population analysis, an age-structured assessment
WW	Whole weight, as opposed to GW (gutted weight)
yr	Year(s)

Appendix B Parameter estimates from the Beaufort Assessment Model

```
# Number of parameters = 186  Objective function value = 1600.47  Maximum gradient component = 8.71954e-005
# Linf:
1204.00000000
# K:
0.284000000000
# t0:
-0.786000000000
# len_cv_val:
0.239179163978
# log_Nage_dev:
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000
# log_R0:
14.1209594952
# steep:
0.870000000000
# rec_sigma:
0.311523140365
# R_autocorr:
0.00000000000
# log_rec_dev:
 0.198672576386 0.268875216247 0.162768451528 -0.00563806098503 -0.189635029857 -0.280359508378
 -0.631660735908 -0.646822332189 0.0353370957345 0.0284755383522 -0.0802245928170 0.493284154026
 -0.230593303200 -0.490162303653 -0.391104436055 -0.510970523537 0.379292149882 0.293655746424
 0.297980036055 -0.0547594554545 0.0846915191089 -0.134610419700 0.458640188542 0.189380621607
 0.585802820003 0.304877584428 0.0290399606782 -0.164232957269
# log_dm_GR_D_lc:
-1.27993198900
# log_dm_cH_ac:
2.24287810817
# log_dm_GR_ac:
-0.637260311507
# selpar_A50_cH1:
3.18266327429
# selpar_slope_cH1:
2.88276576107
# selpar_A50_GR1:
2.01121099754
# selpar_slope_GR1:
3.03530009923
# selpar_age1logit_D:
0.00000000000
# selpar_A50_GRD:
0.00000000000
# selpar_slope_GRD:
3.00000000000
# selpar_A502_GRD:
0.224345103575
# selpar_slope2_GRD:
1.00000000000
# log_q_cH:
-8.50497987958
# log_q_HB:
-13.5208697646
# log_q_VID:
-14.6302044458
# q_RW_log_dev_cH:
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000
# q_RW_log_dev_HB:

 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000
# M_constant:
0.140000000000
# log_avg_F_cH:
-2.03198384621
# log_F_dev_cH:
 -2.81127406642 -2.47348019613 -1.84624611527 -2.25165658226 -1.83729980942 -2.02425357078
 -1.01298141731 0.0903437726794 0.191831902062 0.492684257438 1.01950202888 1.55902110908
 1.62224391601 1.16639379351 1.06505376142 0.906743100544 0.767544864583 0.826100696927 0.740180956248
 0.651460439130 0.566291145916 0.474595636971 0.423828438929 0.0918498214026 0.201078661197
 0.236708850369 -0.0890475213557 0.132254280903 0.271425206678 0.216637345016 0.314174640810
 0.262138491309 0.202285624370 0.113573670362 0.171471077548 -0.0852644736188 -0.165810418413
 -0.180103319322
# log_avg_F_GR:
-2.06976478473
# log_F_dev_GR:
 -0.0928063590590 0.585464635412 -0.230899915128 -0.645938624536 -0.394606271388 -0.149383762589
 0.530205201819 -0.0344738752811 0.455173040539 0.418417968301 1.38690085615 0.146805822808
 0.300993001415 -0.204164987107 0.0178635097812 -0.570478073755 0.357615790520 -0.921957270760
 -0.627343291011 0.409089883800 -0.211585183258 0.361438129525 0.129282611780 0.0225849890504
 -0.608269426955 -0.801511473596 0.646470495440 0.197805827372 0.156168803661 -0.0757123808578
```

```
 0.333229088186 -0.968037317416 -0.132792658680 -0.348456946708 -0.101820059525 0.240573354482
 0.316942733793 0.107212133780
# log_avg_F_cH_D:
-7.63313155376
# log_F_dev_cH_D:
 0.781452303887 1.36279559487 1.70922670174 1.78584419575 2.05571102061 2.17006913758 1.56369223487
 1.27161007419 1.29137016999 1.02337177488 0.692238787936 -0.511546082840 -2.58935489719
 -0.487614068846 -1.77359158026 0.777415747950 0.311829102718 -1.90451026818 -0.779661013863
 -1.62239011569 -0.856054518953 -2.46234358882 -2.24106377644 -0.908745533802 -0.262185329230
 -0.397566072838
# log_avg_F_GR_D:
-3.78942861988
# log_F_dev_GR_D:
 0.0847184496987 -0.574058493289 -0.601820821974 -2.34541279617 -0.187209847710 -0.306261925846
 1.58972262299 0.667485801337 -0.786339322596 -1.06903612270 -0.628771590034 0.703327527810
 0.528020420012 0.286743791135 -0.787738268123 -0.0208497804953 0.898515417455 -0.613983404889
 -0.500914519311 0.360189236113 0.0576267651920 -1.27569883548 0.136821878565 0.656708660432
 0.272465957153 0.352741903823 -0.581989632927 -0.498924506950 0.832887945810 0.727148101226
 -0.0704871711344 -0.311819518241 -0.488620786331 -0.0221614699527 0.329247698512 0.919936307493
 1.10779798555 1.15999234386
```