Southeast Data, Assessment, and Review

SEDAR 55

Stock Assessment Report

South Atlantic Vermilion Snapper

April 2018

SEDAR
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North Charleston, SC 29405

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South Atlantic Vermilion Snapper

SECTION I: Introduction

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I. Introduction

1. SEDAR Process Description

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

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

SEDAR is typically organized around three stages. First is the Data Stage, where a workshop is held during which fisheries, monitoring, and life history data are reviewed and compiled. Second is the Assessment Stage, which is conducted via a workshop and/or series of webinars, during which assessment models are developed and population parameters are estimated using the information provided from the Data Workshop. The final stage is the Review Workshop, during which independent experts review the input data, assessment methods, and assessment products. The completed assessment, including the reports of all 3 workshops and all supporting documentation, is then forwarded to the Council SSC for certification as 'appropriate for management' and development of specific management recommendations.

SEDAR workshops and webinars are public meetings organized by SEDAR staff and the lead Council. Workshop participants are drawn from state and federal agencies, non-government organizations, Council members, Council advisors, and the fishing industry with a goal of including a broad range of disciplines and perspectives. All participants are expected to contribute to the process by preparing working papers, contributing, providing assessment analyses, and completing the workshop report.

SEDAR Review Workshop Panels consist of a chair, three reviewers appointed by the Center for Independent Experts (CIE), and one or more SSC representatives appointed by each council having jurisdiction over the stocks assessed. The Review Workshop Chair is appointed by the council having jurisdiction over the stocks assessed and is a member of that council's SSC. Participating councils may appoint representatives of their SSC, Advisory, and other panels as observers.

2. Management Overview

2.1 Fishery Management Plan and Amendments

The following summary describes only those management actions that likely affect Vermilion Snapper fisheries and harvest.

Original SAMFC FMP

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

****Measures in the original FMP that would have affected vermilion snapper included the 4" trawl mesh size regulation to achieve a 12 in TL size limit.****

SAFMC FMP Amendments affecting vermilion snapper

Description of Action	FMP/Amendment	Effective Date
-Prohibit trawl nets between Cape Hatteras, North Carolina, and Cape Canaveral, Florida	Amendment 1	1/12/89
-Prohibit fish traps, entanglement nets & longlines within 50 fathoms -Recreational Bag limit of 10 vermilion per person per day -10" TL recreational minimum size limit -12" TL commercial minimum size limit	Amendment 4	1/1/92
Oculina Experimental Closed Area	Amendment 6	6/27/94
-Require charter vessels and headboats to obtain federal permit -Longlines prohibited south of St. Lucie Inlet and north of this latitude inside 50 fathoms	Amendment 7	Permitting requirement: 12/23/94 Other regs pertinent to Vermilion Snapper: 1/23/95

-Limited entry program for commercial fishery: unlimited transferable permits and 225-lb non-transferable permits	Amendment 8	8/17/98
-Recreational size limit increased to 11" TL -Vessels with longlines may only possess deepwater species -Limits possession to the bag limit and prohibits sale & purchase of red porgy, black grouper, and gag grouper during March and April	Amendment 9	2/24/99
-Modified framework procedures in SA FMPs to allow the addition of biomass levels and age-structured analyses to FMPs -Maximum sustainable yield (MSY) proxy = 30% static SPR -OY = 40% static SPR - Vermilion snapper: overfished (static SPR = 21-27%) -Approved definitions for overfished and overfishing. -MSST = [(1-M) or 0.5 whichever is greater]*BMSY. -MFMT = F_{MSY}	Amendment 11 (included in Comprehensive SFA Amendment)	12/2/99
-Defined EFH and EFH-HAPCs for managed species	Amendment 10 (included in Comprehensive EFH Amendment)	07/14/00
-Limit possession (commercial and recreational) of red porgy to 1 per person per day or 1 per person per trip, whichever is more restrictive, during January-April each year -Red porgy commercial trip limit of 50 lbs from May 1 – Dec 31	Amendment 12	8/29/00
-Commercial quota set at 1.1 million lbs gutted weight -Recreational size limit increased to 12" TL. -After the commercial quota is met, all purchase and sale is prohibited and harvest and/or possession is limited to the bag limit.	Amendment 13 C	10/23/06
-Establish seasonal closure of recreational fishery November 1 through March 31 -Reduce bag limit to 5 per person per day but no vermilion snapper can be retained by captain or crew of charter vessel or headboat -Establish commercial split season and semi-annual commercial quotas -Revised MSY, OY (75%Fmsy), defined MSST; established TAC for 2009 onwards based on the yield at F_{OY}; and established interim allocations (68% C/32% R) -Establish a directed commercial quota (after Post Quota Bycatch Mortality has been subtracted) based on interim allocations -Allow the NMFS RA to make adjustments to	Amendment 16	7/29/09

management measures based on the SEDAR 17 (2008) benchmark assessment *after* submission of Amendment 16*		
-Establish accountability measures for vermilion snapper (commercial in-season closure, recreational in-season closure if overfished and payback of overage for rec sector regardless of species status.	Amendment 17B	1/31/11
-Require use of non-stainless steel circle hooks when fishing for snapper grouper species with hook-and-line gear north of 28 degrees North Latitude	Amendment 17A	3/3/11
-Limit harvest and possession of snapper grouper species (with non-prohibited fishing gear) in SMZs off SC to the recreational bag limit. -Designate new EFH-HAPCs for snapper grouper species	Comprehensive Ecosystem-Based Amendment 2 (Amendment 23)	1/30/12
-Remove some species from the snapper grouper FMU and designate Ecosystem Component species	Comprehensive ACL Amendment (Amendment 25)	4/16/12
-Increase number of allowable crew to 4 on dual-permitted vessels fishing commercially -Remove prohibition on retaining the vermilion bag limit by captain and crew on federally permitted for-hire vessels.	Amendment 27	1/27/14
-Require weekly electronic reporting for headboats in the South Atlantic	Generic Headboat Reporting Amendment (Amendment 31)	1/27/14
-Require weekly electronic reporting for SA and Gulf of Mexico dealers -Create a single dealer permit	Dealer Reporting Generic Amendment	8/7/14
-Establish a split commercial season, a commercial trip limit for gray triggerfish, and minimum size limit for gray triggerfish	Amendment 29	7/1/15
-Establish Spawning SMZs in SA region	Amendment 36	TBD (2017)

*Hence, values in the Final Rule for Amendment 16 do not match the Council's preferred alternatives in the amendment.

SAFMC FMP Regulatory Amendments affecting vermilion snapper

Description of Action	Amendment	Effective Date
-Establish a 1,500 lbs gw commercial trip limit	Regulatory Amendment 9	7/15/11
-Revise recreational AM	Regulatory Amendment 14	12/8/14
-Revise commercial and recreational ACLs -Modify commercial trip limit: 1,000 lbs gw with step-down to 500 lbs gw when 75% of commercial ACL is met -Remove restriction on 5-month (Nov 1-March 31) seasonal restriction on recreational harvest	Regulatory Amendment 18	9/5/13
-Re-define MSST for vermilion and others snapper grouper species with low natural mortality	Regulatory Amendment 21	11/6/14

2.2 Emergency and Interim Rules (if any)

None

2.3 Secretarial Amendments (if any)

None

2.4 Control Date Notices (if any)

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 (04/23/97 62 FR 22995) - Anyone entering federal black sea bass pot fishery off S. Atlantic states after 04/23/97 was not assured of future access if limited entry program developed.

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 (02/20/09 74 FR 7849) - Anyone entering federal black sea bass pot fishery off S. Atlantic states after 12/04/08 was not assured of future access if limited entry program developed.

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.

2.5 Management Program Specifications

Table 2.5.1. General Management Information
South Atlantic

Species	Vermilion Snapper (*Rhomboplites aurorubens*)
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 SERO / Council	SAFMC: Myra Brouwer SERO: Rick DeVictor
Current stock exploitation status	Not undergoing overfishing
Current stock biomass status	Not overfished

Table 2.5.2 Specific Management Criteria

Criteria		South Atlantic – Current (2012 SEDAR 17 Update)		
	Definition	Base Run Values	Units	Median of Base Run MCBs
MSST	$(1-M)*SSB_{MSY}$	4.66	1E12 eggs	
MFMT	F_{MSY}, if available; F_{MSY} proxy if not[2]	0.75	Per year	
F_{MSY}	F_{MSY}	0.75	Per year	
MSY	Yield at F_{MSY}, landings and discards, pounds and numbers	1,563	1000 lb	
B_{MSY}[1]	Total or spawning stock, to be defined	2,252	Metric tons	
R_{MSY}	Recruits at MSY	3,718	1000 age-1 fish	
F Target	75% F_{MSY}	0.563	Per year	
Yield at F_{TARGET} (equilibrium)	Landings and discards, pounds and numbers	1,551	1000 lb	
M	Natural mortality, average across ages	0.22		
Terminal F (2011)	Exploitation	0.58		

Terminal Biomass (2011)[1]	Biomass	2,190	Metric tons	
Exploitation Status	$F_{2009\text{-}2011}/F_{MSY}$	0.67	--	
Biomass Status[1]	SSB_{2011}/MSST SSB_{2011}/SSB_{MSY}	1.26 098	-- ---	
Generation Time			years	
$T_{REBUILD}$ (if appropriate)				

Criteria	South Atlantic – Proposed (values from SEDAR 55)		
	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, average across ages		
Terminal F	Exploitation		
Terminal Biomass[1]	Biomass		
Exploitation Status	F/MFMT		
Biomass Status[1]	B/MSST		
	B/B_{MSY}		
Generation Time			
$T_{REBUILD}$ (if appropriate)			

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

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

Table 2.5.3. Stock Rebuilding Information
Stock not overfished, so no rebuilding plan in place.

Table 2.5.4. Stock Projection Information
South Atlantic

First Year of Management	Assume management begins in 2019. 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 2018 fishing year.
Interim basis	SEDAR 55 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 2.5.5. Base Run Projections Specifications. Long Term and Equilibrium conditions.

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

	$F_{REBUILD}$	X		
	F=0	X		

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

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

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

Table 2.5.7. 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 Vermilion Snapper	1,269,000 lbs ww
Commercial ACL for Vermilion Snapper	862,920 lbs ww
Recreational ACL for Vermilion Snapper	406,080 lbs ww
Next Scheduled Quota Change	n/a
Annual or averaged quota?	annual
If averaged, number of years to average	
Does the quota include bycatch/discard ?	No, landings only

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

Total ACL set equal to ABC. ABC based on projections at P*=0.275 for 2013 through 2016 from SEDAR 17 Update assessment (2012). The ABC/ACL for 2016 remains until modified.

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

No. Discards are accounted for in specifying the ABC in terms of landed catch and not total kill.

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

2.6 Management and Regulatory Timeline

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

Table 2.6.1 South Atlantic Vermilion Snapper Federal Commercial Regulatory History

prepared by: Myra Brouwer

Year	Quota (lbs)	ACL (lbs)	Days Open	fishing season	reason for closure	season start date (first day implemented)	season end date (last day effective)	Size limit (in TL)	size limit start date	size limit end date	Retention Limit (lbs gw)	Retention Limit Start Date	Retention Limit End Date
1983[A]	NA	NA	365	open	NA	1-Jan	31-Dec	NA	31-Aug	31-Dec	none	NA	NA
1984	NA	NA	365	open	NA	1-Jan	31-Dec	NA	1-Jan	31-Dec	none	NA	NA
1985	NA	NA	365	open	NA	1-Jan	31-Dec	NA	1-Jan	31-Dec	none	NA	NA
1986	NA	NA	365	open	NA	1-Jan	31-Dec	NA	1-Jan	31-Dec	none	NA	NA
1987	NA	NA	365	open	NA	1-Jan	31-Dec	NA	1-Jan	31-Dec	none	NA	NA
1988	NA	NA	365	open	NA	1-Jan	31-Dec	NA	1-Jan	31-Dec	none	NA	NA
1989	NA	NA	365	open	NA	1-Jan	31-Dec	NA	1-Jan	31-Dec	none	NA	NA
1990	NA	NA	365	open	NA	1-Jan	31-Dec	NA	1-Jan	31-Dec	none	NA	NA
1991	NA	NA	365	open	NA	1-Jan	31-Dec	NA	1-Jan	31-Dec	none	NA	NA
1992[B]	NA	NA	365	open	NA	1-Jan	31-Dec	12[B]	1-Jan	31-Dec	none	NA	NA
1993	NA	NA	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	none	NA	NA
1994	NA	NA	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	none	NA	NA
1995	NA	NA	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	none	NA	NA
1996	NA	NA	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	none	NA	NA
1997	NA	NA	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	none	NA	NA
1998	NA	NA	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	none	NA	NA
1999	NA	NA	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	none	NA	NA
2000	NA	NA	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	none	NA	NA
2001	NA	NA	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	none	NA	NA
2002	NA	NA	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	none	NA	NA
2003	NA	NA	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	none	NA	NA
2004	NA	NA	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	none	NA	NA
2005	NA	NA	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	none	NA	NA
2006[C]	NA	NA	365	open	NA	1-Jan	22-Oct	12	1-Jan	22-Oct	none	NA	NA
	1,100,000 gw			open	NA	23-Oct	31-Dec	12	23-Oct	31-Dec	none	NA	NA
2007	1,100,000 gw		365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	none	NA	NA
2008	1,100,000 gw		365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	none	NA	NA
2009[D]	1,100,000 gw		181	open	NA	1-Jan	28-Jul	12	1-Jan	30-Jun	none	NA	NA
	302,523 gw		80	open	NA	29-Jul	18-Sep	12	29-Jul	18-Sep	none	NA	NA
			104	closed	quota met	19-Sep	31-Dec						
2010[E]	315,523 gw		69	open	NA	1-Jan	9-Mar	12	1-Jan	9-Mar	none	NA	NA
			112	closed	quota met	10-Mar	30-Jun						
	302,523 gw		98	open	NA	1-Jul	6-Oct	12	1-Jul	6-Oct	none	NA	NA
			86	closed	quota met	7-Oct	31-Dec						
2011[E,F,G]	315,523 gw		69	open	NA	1-Jan	10-Mar	12	1-Jan	10-Mar	none	NA	NA
			51	closed	quota projected to be met	11-Mar	30-Apr						
			8	re-open	to meet quota	1-May	8-May	12	1-May	8-May	none	NA	NA
			53	closed	quota met	9-May	30-Jun						
	302,523 gw		14	open	NA	1-Jul	14-Jul	12	1-Jul	14-Jul	none	NA	NA
			78	open	NA	15-Jul	30-Sep	12	15-Jul	30-Sep	1500[G]	15-Jul	30-Sep
			92	closed	quota met	1-Oct	31-Dec						
2012[E,F,G]	315,523 gw		60	open	NA	1-Jan	29-Feb	12	1-Jan	29-Feb	1,500	1-Jan	29-Feb
			122	closed	quota met	1-Mar	30-Jun						
	302,523 gw		90	open	NA	1-Jul	28-Sep	12	1-Jul	28-Sep	1,500	1-Jul	28-Sep
			94	closed	quota met	29-Sep	31-Dec						
2013[E,F,G,H]	315,523 gw[I]		43	open	NA	1-Jan	12-Feb	12	1-Jan	31-Dec	1,500	1-Jan	13-Feb
			138	closed	quota met	13-Feb	30-Jun						
	613,278 ww[I]		66	open	NA	1-Jul	4-Sep	12	1-Jul	4-Sep	1,500	1-Jul	4-Sep
			89	open	NA	5-Sep	2-Dec	12	5-Sep	2-Dec	1000[H]	5-Sep	2-Dec
			29	closed	quota met	3-Dec	31-Dec						
2014[E,F,H]	446,080 ww		69	open	NA	1-Jan	10-Mar	12	1-Jan	10-Mar	1000[H]	1-Jan	10-Mar
			40	open	NA	11-Mar	19-Apr	12	11-Mar	19-Apr	500[H]	11-Mar	19-Apr
			72	closed	quota met	20-Apr	30-Jun						
	446,080 ww		53	open	NA	1-Jul	22-Aug	12	1-Jul	22-Aug	1000[H]	1-Jul	22-Aug
			21	open	NA	23-Aug	12-Sep	12	23-Aug	12-Sep	500[H]	23-Aug	12-Sep
			110	closed	quota met	13-Sep	31-Dec						
2015[E,F,H]	438,260 ww		60	open	NA	1-Jan	1-Mar	12	1-Jan	1-Mar	1000[H]	1-Jan	1-Mar
			45	open	NA	2-Mar	15-Apr	12	2-Mar	15-Apr	500[H]	2-Mar	15-Apr
			76	closed	quota met	16-Apr	30-Jun						
	438,260 ww		71	open	NA	1-Jul	9-Sep	12	1-Jul	9-Sep	1000[H]	1-Jul	9-Sep
			13	open	NA	10-Sep	22-Sep	12	10-Sep	22-Sep	500[H]	10-Sep	22-Sep
			100	closed	quota met	23-Sep	31-Dec						
2016[E,F,H]	431,460 ww		61	open	N/A	1-Jan	1-Mar	12	1-Jan	1-Mar	1000[H]	1-Jan	1-Mar
			27	open	N/A	2-Mar	28-Mar	12	2-Mar	28-Mar	500[H]	2-Mar	28-Mar
			94	closed	quota met	29-Mar	30-Jun						
	432,305 ww[J]		58	open	NA	1-Jul	27-Aug	12	1-Jul	27-Aug	1000[H]	1-Jul	27-Aug
			44	open	NA	28-Aug	10-Oct	12	28-Aug	10-Oct	500[H]	28-Aug	10-Oct
			64	closed	quota projected to be met	11-Oct	13-Dec						
			2	reopened	to meet quota	14-Dec	15-Dec	12	14-Dec	15-Dec	500[H]	14-Dec	15-Dec
			16	closed	quota met	16-Dec	31-Dec						

A: Original SAFMC FMP effective 8/31/1983 included the 4" trawl mesh size regulation to achieve a 12 in TL size limit.

B: Amendment 4 (effective date 1/1/92) included establishment of commercial 12 in TL size limit

C: Amendment 13C (effective 10/23/2017) included establishment of commercial quota; after commercial quota met - all purchase and sale prohibited and harvest and/or possession limited to recreational bag limit

D: Amendment 16 (effective 7/29/2009) included establishment of commercial split season and semi-annual quotas

E: Annual ACL is equal to combined quotas from the two split seasons each calendar year. From 2009-2012 PBQM was subtracted to get directed commercial quotas.

F:Amendment 17A (effective 3/3/2011) require use of non-stainless steel circle hooks when fishing for snapper grouper species with hook and line gear N of 28 degrees N latitude

G: Regulatory Amendment 9 (effective 7/15/2011) included establishment of 1,500 lbs gw commercial trip limit

H: Regulatory Amendment 18 (effective 9/5/13) included revisions to ACLs; modification of commercial trip limit to 1000 lb gw with step-down to 500 lbs gw when 75% commercial ACL met

I: First split season quota was 315,532 lbs gw, and the season was closed on 2/13/13 due to meeting the ACL. When Reg Amendment 18 went into effect (9/5/13), the first season and second season quota were both changed to 466,480 lbs ww. The total rollover from the first season was calculated (to be 146,798 lbs ww) and the new second season quota was calculated to be 613,278 lbs ww (466,480 lbs quota + 146,798 lbs rollover).

J: Implemented quota was 431,460 lbs ww - but second split season quota for 2016 increased to include rollover from first split season in 2016

lbs = pounds

gw = gutted weight

ww = whole weight

2.6.2 South Atlantic Vermilion Snapper Federal Recreational Regulatory History
prepared by: Myra Brouwer

Year	Quota (lbs)	ACL (lbs)	Days Open	fishing season	reason for closure	season start date (first day implemented)	season end date (last day effective)	Size limit (in TL)	size limit start date	size limit end date	Retention Limit (# fish)	Retention Limit Start Date	Retention Limit End Date
1983[A]	NA	NA	365	open	NA	1-Jan	31-Dec	NA	31-Aug	31-Dec	NA	NA	NA
1984	NA	NA	365	open	NA	1-Jan	31-Dec	NA	1-Jan	31-Dec	NA	NA	NA
1985	NA	NA	365	open	NA	1-Jan	31-Dec	NA	1-Jan	31-Dec	NA	NA	NA
1986	NA	NA	365	open	NA	1-Jan	31-Dec	NA	1-Jan	31-Dec	NA	NA	NA
1987	NA	NA	365	open	NA	1-Jan	31-Dec	NA	1-Jan	31-Dec	NA	NA	NA
1988	NA	NA	365	open	NA	1-Jan	31-Dec	NA	1-Jan	31-Dec	NA	NA	NA
1989	NA	NA	365	open	NA	1-Jan	31-Dec	NA	1-Jan	31-Dec	NA	NA	NA
1990	NA	NA	365	open	NA	1-Jan	31-Dec	NA	1-Jan	31-Dec	NA	NA	NA
1991	NA	NA	365	open	NA	1-Jan	31-Dec	NA	1-Jan	31-Dec	NA	NA	NA
1992 [B]	NA	NA	365	open	NA	1-Jan	31-Dec	10 [B]	1-Jan	31-Dec	10 [B]	1-Jan	31-Dec
1993	NA	NA	365	open	NA	1-Jan	31-Dec	10	1-Jan	31-Dec	10	1-Jan	31-Dec
1994	NA	NA	365	open	NA	1-Jan	31-Dec	10	1-Jan	31-Dec	10	1-Jan	31-Dec
1995	NA	NA	365	open	NA	1-Jan	31-Dec	10	1-Jan	31-Dec	10	1-Jan	31-Dec
1996	NA	NA	365	open	NA	1-Jan	31-Dec	10	1-Jan	31-Dec	10	1-Jan	31-Dec
1997	NA	NA	365	open	NA	1-Jan	31-Dec	10	1-Jan	31-Dec	10	1-Jan	31-Dec
1998	NA	NA	365	open	NA	1-Jan	31-Dec	10	1-Jan	31-Dec	10	1-Jan	31-Dec
1999 [C]	NA	NA	54	open	NA	1-Jan	23-Feb	10	1-Jan	31-Dec	10	1-Jan	31-Dec
			311	open	NA	24-Feb	31-Dec	11 [C]	24-Feb	31-Dec	10	24-Feb	31-Dec
2000	NA	NA	365	open	NA	1-Jan	31-Dec	11	1-Jan	31-Dec	10	1-Jan	31-Dec
2001	NA	NA	365	open	NA	1-Jan	31-Dec	11	1-Jan	31-Dec	10	1-Jan	31-Dec
2002	NA	NA	365	open	NA	1-Jan	31-Dec	11	1-Jan	31-Dec	10	1-Jan	31-Dec
2003	NA	NA	365	open	NA	1-Jan	31-Dec	11	1-Jan	31-Dec	10	1-Jan	31-Dec
2004	NA	NA	365	open	NA	1-Jan	31-Dec	11	1-Jan	31-Dec	10	1-Jan	31-Dec
2005	NA	NA	365	open	NA	1-Jan	31-Dec	11	1-Jan	31-Dec	10	1-Jan	31-Dec
2006 [D]	NA	NA	295	open	NA	1-Jan	22-Oct	11	1-Jan	22-Oct	10	1-Jan	22-Oct
			70	open	NA	23-Oct	31-Dec	12 [D]	23-Oct	31-Dec	10	23-Oct	31-Dec
2007	NA	NA	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	10	1-Jan	31-Dec
2008	NA	NA	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	10	1-Jan	31-Dec
2009 [E]			209	open	NA	1-Jan	28-Jul	12	1-Jan	28-Jul	10	1-Jan	28-Jul
	see ACL	307,315 gw	95	open	NA	29-Jul	31-Oct	12	29-Jul	31-Oct	5 [E]	29-Jul	31-Oct
			61	closed	seasonal [E]	1-Nov	31-Dec						
2010			90	closed	seasonal [E]	1-Jan	31-Mar						
	see ACL	307,315 gw	214	open	NA	1-Apr	31-Oct	12	1-Apr	31-Oct	5	1-Apr	31-Oct
			61	closed	seasonal [E]	1-Nov	31-Dec						
2011 [F]			90	closed	seasonal [E]	1-Jan	31-Mar						
	see ACL	307,315 gw	214	open	NA	1-Apr	31-Oct	12	1-Apr	31-Oct	5	1-Apr	31-Oct
			61	closed	seasonal [E]	1-Nov	31-Dec						
2012 [F]			90	closed	seasonal [E]	1-Jan	31-Mar						
	see ACL	307,315 gw	214	open	NA	1-Apr	31-Oct	12	1-Apr	31-Oct	5	1-Apr	31-Oct
			61	closed	seasonal [E]	1-Nov	31-Dec						
2013 [F,G]			90	closed	seasonal [E]	1-Jan	31-Mar						
	see ACL	307,315 gw	157	open	NA	1-Apr	4-Sep	12	1-Apr	31-Dec	5	1-Apr	4-Sep
	see ACL	439,040 ww / 395,532 gw	118	open	NA	5-Sep	31-Dec	12	5-Sep	31-Dec	5	5-Sep	31-Dec
2014 [F, G, H]		419,840 ww / 378,234 gw	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	5	1-Jan	31-Dec
2015 [F,G,H]		412,480 ww / 371,604 gw	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	5	1-Jan	31-Dec
2016 [F,G,H]		406,080 ww / 365,838 gw	365	open	NA	1-Jan	31-Dec	12	1-Jan	31-Dec	5	1-Jan	31-Dec

A: Original SAFMC FMP effective 8/31/1983 -included the 4" trawl mesh size regulation to achieve a 12 in TL size limit.
B: Amendment 4 (effective date 1/1/92) included establishment of recreational 10 in TL size limit and 10 fish/person/day bag limit
C: Amendment 9 (effective 2/24/99) included establishment of recreational 11in TL size limit
D: Amendment 13C (effective 10/23/06) included establishment of recreational 12in TL size limit
E: Amendment 16 (effective 7/29/09) included establishment of recreational seasonal closure (Nov 1-Mar 31), 5 fish/person/day bag limit, no capt or crew on for-hire vessels can retain bag limit
F: Amendment 17A (effective 3/3/2011) require use of non-stainless steel circle hooks when fishing for snapper grouper species with hook and line gear N of 28 degrees N latitude
G: Regulatory Amendment 18 (effective 9/5/13) included removal of recreational seasonal closure and implemented new ACLs; new ACLs listed in both gutted and whole weight in each cell
H: Amendment 27 (effective 1/27/14) included removal of prohibition on on for-hire captain and crew retaining bag limit

gw = gutted weight
ww = whole weight

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

Recreational: There has not been a recreational closure due to the ACL being met. However, a seasonal closure from Nov 1 – March 31 was established through Amendment 16 (effective 7/29/09). Recreational seasonal closure was removed through Regulatory Amendment 18 (effective 9/5/13).

Commercial:

- 2009: closed Sept 19 – Dec 31 due to quota being met
- 2010: closed March 10 – June 30 due to first split season quota being met
  closed Oct 7 – Dec 31 due to second split season quota being met
- 2011: closed March 11 – April 30 due to first split season quota projected to be met;
  re-opened May 1-8 and then closed again May 9 – June 30 due to first split season quota being met
  closed Oct 1 – Dec 31 due to second split season quota being met
- 2012: closed March 1 – June 30 due to first split season quota being met
  closed Sept 29 – Dec 31 due to second split season quota being met
- 2013: closed Feb 14 – June 30 due to first split season quota being met
  closed Dec 3 – Dec 31 due to second split season quota being met
- 2014: closed Apr 20 – June 30 due to first split season quota being met
  closed Sept 13 – Dec 31 due to second split season quota being met
- 2015: closed Apr 16 – June 30 due to first split season quota being met
  closed Sept 23 – Dec 31 due to second split season quota being met
- 2016: closed March 30 – June 30 due to first split season quota being met
  closed Oct 11 – Dec 13 due to second split season quota projected to be met;
  re-opened Dec 14-15 and then closed Dec 16-31 due to second split season quota being met

Table 7. State Regulatory History

North Carolina:

There are currently no North Carolina state-specific regulations for vermilion snapper. North Carolina has complemented federal regulations for all snapper grouper species via proclamation authority since 1991. Between 1996 and 2005, species-specific regulations were added to the proclamation authority contained in rule 15A NCAC 03M .0506. Specific to vermilion snapper, this rule was amended effective March 1, 1996 to include the following Sub-items:

(k) Vermilion Snapper:

(1) It is unlawful to possess vermilion snapper (beeliner) less than 12 inches total length except that persons fishing under the bag limit established in Subparagraph (2) of this paragraph may possess 10 inch vermilion snapper.

(2) It is unlawful to possess more than 10 vermilion snapper per person per day taken for non-commercial purposes.

….

(p) Combined Bag Limit for Snapper. It is unlawful to possess more than 10 vermilion snappers and 10 other species of snappers, of which no more than two may be red snapper, taken in any one day unless fishing aboard a vessel holding a federal vessel permit for snapper-grouper authorizing the bag limit to be exceeded.

In 1999, the above sub-items in rule 15A NCAC 03M .0506 were restructured as follows (effective May 24, 1999):

(l) Vermilion Snapper:

(1) For recreational purposes:

(A) It is unlawful to possess vermilion snapper (beeliner) less than 11 inches total length.

(B) It is unlawful to possess more than 10 vermilion snapper per person per day.

(2) It is unlawful to possess or sell vermilion snapper (beeliner) less than 12 inches total length with a valid Federal Commercial Snapper Grouper permit.

….

(p) Combined Bag Limits:

(1) It is unlawful to possess more than 10 vermilion snapper and 10 other snappers per person per day of which no more than two may be red snapper without a valid Federal Commercial Snapper Grouper permit.

….

Effective January 1, 2002 rule 15A 03M .0506 sub-item (p) referencing vermilion snapper possession limits in conjunction with the snapper aggregate bag limit was removed.

In August 2002, North Carolina adopted its Inter-Jurisdictional Fishery Management Plan (IJ FMP), which incorporates all ASMFC and council-managed species by reference, and adopts all federal regulations as minimum standards for management. In completing the 2008 update to the IJ FMP, all species-specific regulations were removed from rule 15A NCAC 03M .0506, and proclamation authority to implement changes in management was moved to rule 15A NCAC 03M .0512. 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, size limits, trip limits, 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.

South Carolina:

Prior to 1992, South Carolina did not have regulations for Vermilion Snapper. Starting in 1992, South Carolina state regulations mirrored federal regulations per SC code of law (see below).

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

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

- SC Code of Laws Section 50-5-2730
  ‘Unless otherwise provided by law, any regulations promulgated by the federal government under the Fishery Conservation and Management Act (PL94-265) or the Atlantic Tuna Conservation Act (PL 94-70) which establishes seasons, fishing periods, gear restrictions, sales restrictions, or bag, catch, size, or possession limits on fish are declared to be the law of this State and apply statewide including in state waters.”

2013: SC Code of Laws Section 50-5-2730 amended as follows:

SECTION 50-5-2730. Federal fishing regulations declared to be law of State; exception for black sea bass.

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

(B) This provision does not apply to black sea bass (*Centropristis striata*) whose lawful catch limit is five fish per person per day or the same as the federal limit for black sea bass, whichever is higher. The lawful minimum size is thirteen inches total length. Additionally, there is no closed season on the catching of black sea bass (Centropristis striata).

Georgia:

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

Florida:

Vermilion Snapper Regulation History (Atlantic only)

Year	Minimum Size Limit (TL)	Recreational Possession Limit	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	Prohibited use of longline gear to harvest snapper or grouper commercially. Created a bycatch allowance of 5% for harvesters using this gear. Prohibited use of stab nets (or sink nets) to take snapper or grouper in Atlantic state waters of Monroe County. Required snapper and grouper to be landed in whole condition (head and tail intact).	Dec. 11, 1986
1987	None	2 fish or 250 pounds, whichever is greater		n.d.
1988	None	2 fish or 250 pounds, whichever is greater		
1989	None	2 fish or 100 pounds, whichever is greater		n.d.
1990	Recreational: 8” Commercial: 8”	2 fish or 100 pounds, whichever is greater	Designated all snapper and grouper as "restricted species." Established a minimum size limit of 8 inches.	Feb. 1, 1990

			Restricted allowable gear for harvest of snapper and grouper to be: hook and line, black sea bass trap, spear, gig, or lance (except powerheads, bangsticks, or explosive devices). Prohibited all commercial harvest of snapper, grouper, and sea bass in state waters whenever harvest of that species is prohibited in adjacent federal waters.	
1991	Recreational: 8” Commercial: 8”	2 fish or 100 pounds, whichever is greater		
1992	Recreational: 10” Commercial: 12”	2 fish or 100 pounds, whichever is greater	Increased the minimum size limit to 10 inches for recreational harvest and 12 inches for commercial harvest.	Dec. 31, 1992
1993	Recreational: 10” Commercial: 12”	2 fish or 100 pounds, whichever is greater		
1994	Recreational: 10” Commercial: 12”	10 fish/person	Allowed a two-day possession limit for reef fish for persons aboard charter and headboats on trips exceeding 24 hours provided the vessel is equipped with a permanent berth for each passenger aboard, and each passenger has a receipt verifying the trip length. Modified rule language to set the same state and federal definitions of Gulf of Mexico and Atlantic Ocean regions.	March 1, 1994
1995	Recreational: 10” Commercial: 12”	10 fish/person		
1996	Recreational: 10”	10 fish/person		

	Commercial: 12”			
1997	Recreational: 10” Commercial: 12”	10 fish/person		
1998	Recreational: 10” Commercial: 12”	10 fish/person		
1999	Recreational: 10” Commercial: 12”	10 fish/person		
2000	Recreational: 10” Commercial: 12”	10 fish/person		
2001	Recreational: 10” Commercial: 12”	10 fish/person		
2002	Recreational: 10” Commercial: 12”	10 fish/person		
2003	Recreational: 10” Commercial: 12”	10 fish/person		
2004	Recreational: 10” Commercial: 12”	10 fish/person		
2005	Recreational: 11” Commercial: 12”	10 fish/person	Increased the recreational minimum size limit to 11 inches.	Sept. 16, 2005
2006	Recreational: 11” Commercial: 12”	10 fish/person		
2007	Recreational: 12” Commercial: 12”	10 fish/person	Increased the recreational minimum size limit to 12 inches. Set commercial trip limits in the Atlantic that were the same as trip limits in federal waters. Prohibited commercial fishermen from harvesting or possessing the recreational bag limit of reef fish species on commercial trips.	July 1, 2007
2008	Recreational: 12” Commercial: 12”	10 fish/person		
2009	Recreational: 12” Commercial: 12”	5 fish/person	Prohibited the captain and crew on for-hire vessels in the Atlantic from keeping vermilion snapper.	Oct. 16, 2009

			Established a Nov. 1 - March 31 closed season for vermilion snapper in Atlantic state waters.	
2010	Recreational: 12” Commercial: 12”	5 fish/person	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: 12” Commercial: 12”	5 fish/person		
2012	Recreational: 12” Commercial: 12”	5 fish/person		
2013	Recreational: 12” Commercial: 12”	5 fish/person	Eliminated the Nov.1 - March 31 recreational closure in Atlantic state waters.	Oct. 31, 2013
2014	Recreational: 12” Commercial: 12”	5 fish/person	Eliminated language prohibiting captain and crew or for-hire vessels from retaining recreational bag limits of vermilion snapper on for-hire trips in Atlantic state waters.	March 13, 2014
2015	Recreational: 12” Commercial: 12”	5 fish/person		
2016	Recreational: 12” Commercial: 12”	5 fish/person		
2017	Recreational: 12” Commercial: 12”	5 fish/person		

References

None provided.

3. Assessment History

The first benchmark assessment of South Atlantic Vermilion Snapper was completed in 2002 under SEDAR 2. The 2002 assessment applied a catch-at-length model formulation to data extending through 2001. A catch-at-age model and an age-aggregated surplus production model were developed but did not result in reliable estimates of stock status or trends in biomass and fishing mortality. The base run of the assessment model indicated spawning stock biomass had increased over the assessment period and that the stock was not overfished, but that overfishing

was occurring. An update of the SEDAR 2 benchmark assessment was conducted in 2007 using the same catch-at-length model and data inputs, but applied MSY proxies to determine stock status. Results of this update assessment also indicated overfishing was occurring.
A benchmark assessment of Vermilion Snapper was conducted under SEDAR 17. The major change in the assessment methodology was the development of a catch-at-age model rather than a catch-at-length model. The catch-at-age model was applied to data extending through 2007. Stock reduction analysis (SRA) and an age-aggregated surplus production model were developed as supplementary models. The assessment indicated a declining trend in spawning stock biomass since the 1980s, but the stock was not considered overfished at the end of the assessment period (2007). Fishing mortality gradually increased from the 1990s to the 2000s, and the assessment indicated that the stock was experiencing overfishing. An update to the SEDAR 17 benchmark assessment applied the same catch-at-age model to data extending through 2011. The terminal estimate of spawning stock biomass was the lowest of the time series, but similar to the benchmark, the stock was not considered overfished. Total landings declined since the benchmark assessment so that by the end of the assessment (2011) overfishing was no longer occurring.

References (available from SEDAR website):

Anonymous. 2003. Complete Assessment and Review Report of South Atlantic Vermilion Snapper. Results of a series of workshops convened between October 2002 and February 2003. SEDAR2-SAR2. South Atlantic Fishery Management Council, Charleston, SC.

Anonymous. 2007. Report of Stock Assessment: Vermilion Snapper. SEDAR Update Process #3. Assessment Workshop of April 2-4, 2007. NOAA Fisheries, Sustainable Fisheries Branch, Beaufort, North Carolina, 43 pp.

SEDAR 17. 2008. SEDAR 17: South Atlantic Vermilion Snapper. SEDAR, North Charleston, SC.

SEDAR17-update, 2012. Stock Assessment of Vermilion Snapper off the Southeastern United States: SEDAR Update Assessment, SEDAR, North Charleston, SC.

4. Regional Maps

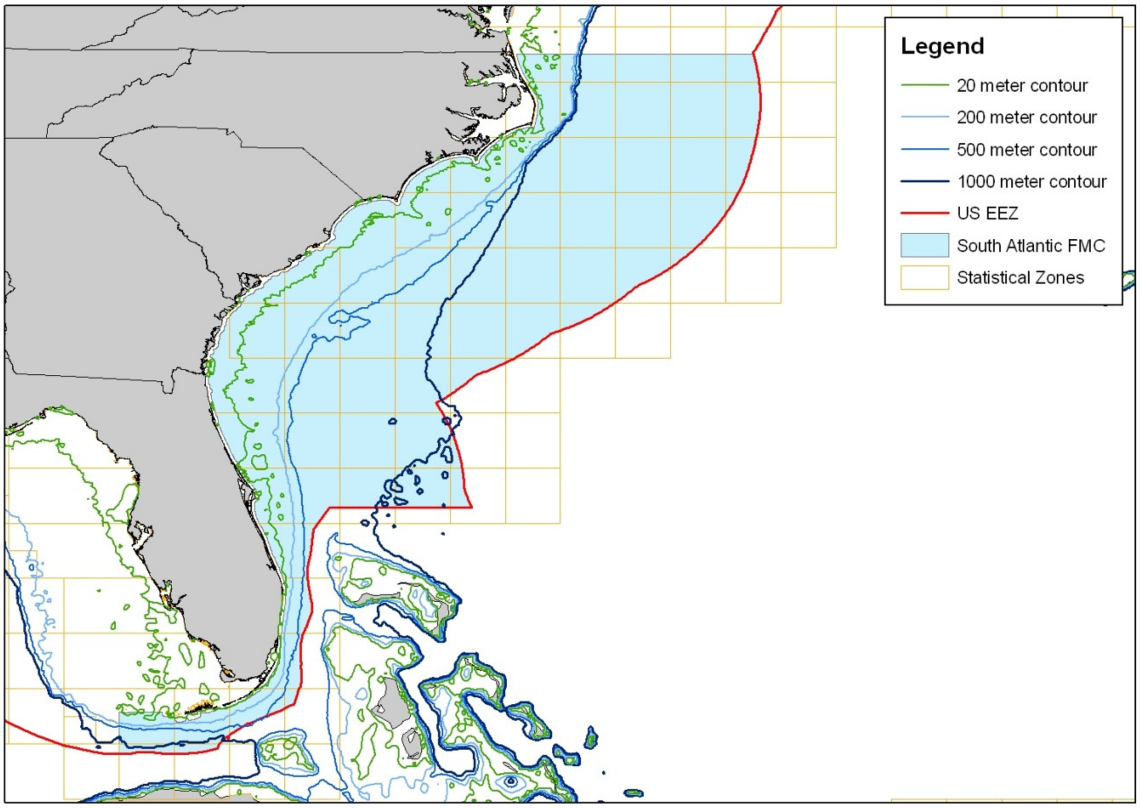

Figure 4.1: South Atlantic Fishery Management Council and EEZ boundaries.

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
AP	Advisory Panel
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
SG	Snapper Grouper
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 55

South Atlantic Vermilion Snapper

SECTION II: Assessment Report

April 2018

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

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Executive Summary

This standard assessment evaluated the stock of vermilion snapper (*Rhomboplites aurorubens*) off the southeastern United States[1]. The primary objectives were to improve and update the SEDAR17 benchmark assessment and the 2012 update of vermilion snapper, and to conduct new stock projections. For this assessment, data compilation and assessment methods were guided by methodology of SEDAR17, as well as by current SEDAR practices. The assessment period was 1946-2016.

Available data on this stock included indices of abundance, landings, discards, and samples of annual length and age compositions from fishery dependent and fishery independent sources. Five indices of abundance were fitted by the model: one from the recreational headboat fleet, one from the general recreational fleet, one from the commercial handline fleet, one from the SERFS that combined chevron trap and video sampling, and one from the MARMAP Florida snapper trap survey. Age compositions were available from both fishery dependent and fishery independent sources, and data on landings and discards were available from recreational and commercial fleets.

The primary model used in the SEDAR17 benchmark assessment and the 2012 update was the Beaufort Assessment Model (BAM), a statistical catch-age formulation. A base run of BAM was configured to provide point estimates of key management quantities, such as stock and fishery status. Uncertainty in estimates from the base run was evaluated through a mixed Monte Carlo/Bootstrap (MCB) procedure. Median values from the uncertainty analysis are also provided.

Results suggest that spawning stock declined until the 1990s, and has fluctuated with little trend since then. The terminal (2016) base-run estimate of spawning stock was above MSST ($SSB_{2016}/MSST = 1.51$), as was the median estimate ($SSB_{2016}/MSST = 1.54$), indicating that the stock is not currently overfished. The terminal estimate of the fishing rate, which is based on a three-year geometric mean, is below F_{MSY} for both the base run ($F_{2014\text{-}2016}/F_{MSY} = 0.609$) as well as the median estimate of the MCBs ($F_{2014\text{-}2016}/F_{MSY} = 0.564$). Thus, this assessment indicates that the stock is not overfished and is not experiencing overfishing.

The MCB analysis indicates that these estimates of stock and fishery status are robust. Of all MCB runs, 92.3% were in qualitative agreement that the stock is not overfished ($SSB_{2016}/MSST > 1.0$), and 83.2% that the stock is not experiencing overfishing ($F_{2014\text{-}2016}/F_{MSY} < 1.0$).

The estimated population trends of this standard assessment are quite similar to those from the SEDAR17 benchmark and the 2012 update assessment. However, the three assessments did show some differences in results, which was not surprising given several modifications made to both the data and model (described throughout the report). Compared to the 2012 update, this assessment suggests slightly lower 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. Introduction

1.1 Workshop Time and Place

SEDAR 55 was conducted as a Standard Assessment through a series of webinars. The assessment was originally scheduled to occur over a series of webinars between August 2017 and February 2018. The Data Scoping webinar was held on August 8, 2017 and the first Assessment Scoping webinar was held on October 20, 2017. Due to delays in data submission driven by Hurricane Irma, the schedule was extended approximately one month. A second Assessment Scoping webinar was held November 28, 2017 and a series of four Assessment webinars were held on January 11, 2018; February 9, 2018; March 5, 2018; and March 13, 2018.

1.2 Terms of Reference

1. Prepare a standard assessment, based on the approved 2012 SEDAR 17 South Atlantic Vermilion Snapper Update assessment with data through 2016. Provide commercial and recreational landings and discards in pounds and numbers. Provide a model consistent with the 2012 SEDAR 17 Update assessment configuration and revise configurations as necessary to incorporate and evaluate any changes in model inputs or parameterization approved during this assessment.

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 the inclusion of the SERFS video index
    - Incorporate the latest BAM model configurations, and detail the changes made, and impacts of those changes, between the 2012 SEDAR 17 update model and the proposed SEDAR 55 model.
    - Re-consider error distributions for fitting 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 2012 SEDAR 17 Update assessment.

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

5. Provide stock projections, including a 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 2019. However, it is possible the SAFMC could take action as early as mid-2018 and the panel is asked how this should be addressed in the projections. 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

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.

1.3 List of Participants

ASSESSMENT PANELISTS
ANALYTICAL TEAM

Kevin Craig	Lead analyst	SEFSC Beaufort
Eric Fitzpatrick	Data compiler	SEFSC Beaufort
Nate Bacheler	Data provider	SEFSC Beaufort
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Wally Bubley	Data provider	SC DNR
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Anne Lange	SSC	SAFMC SSC
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Kyle Shertzer	Assessment Team	SEFSC Beaufort
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STAFF

Julia Byrd	Coordinator	SEDAR
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Alan Bianchi, NCDMF
John Carmichael, SAFMC / SEDAR
Jack Cox, Snapper Grouper AP
Michelle Duval, NCDMF / SAFMC
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Refik Ohrun, SEFSC Miami
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Amanda Tong, NCDMF
Chris Wilson, NCDMF
David Wyanski, SCDNR

1.4 Document List

SEDAR 55 Document List

Document #	Title	Authors
Documents Prepared for SEDAR 56		
SEDAR55-WP01	Standardized video counts of Southeast U.S. Atlantic vermilion snapper (*Rhomboplites aurobens*) from the Southeast Reef Fish Survey	Cheshire et al. 2017
SEDAR55-WP02	Vemilion Snapper Fishery-Independent Index of Abundance in US South Atlantic Waters Based on a Chevron Trap Survey (1990-2016)	Bubley and Smart 2017
SEDAR55-WP03	Update of Vermilion Snapper, *Rhomboplites aurobens*, Reproductive Life History from the MARMAP/SERFS program	Bubley & Wyanski 2017
SEDAR55-WP04	Estimates of Historic Recreational Landings of Vermilion Snapper in the South Atlantic Using the FHWAR Census Method	Brennan 2017
SEDAR55-WP05	Vermilion Snapper Length Frequencies from At-Sea Headboat and Charter Observer Surveys in the South Atlantic, 2005 to 2016	Lazarre et al. 2017
SEDAR55-WP06	Commercial age and length compositions for U.S. vermilion snapper (*Rhomboplites aurorubens*)	NMFS-SFB 2017
SEDAR55-WP07	Integrated data from chevron traps and video cameras into a standardized index of abundance for vermilion snapper (*Rhomboplites aurorubens*)	Gwinn et al. 2017
SEDAR55-WP08	Discards of vermilion snapper (*Rhomboplites aurorubens*) for the headboat fishery in the US South Atlantic	FEB-NMFS 2017
SEDAR55-WP09	South Atlantic U.S. vermilion snapper (*Rhomboplites aurorubens*) age and length composition from the recreational fisheries	FEB-NMFS 2017
Final Assessment Report		
SEDAR55-SAR1	Assessment of South Atlantic Vermilion Snapper	To be prepared by SEDAR 55
Reference Documents		

SEDAR55-RD01	2012 SEDAR 25 South Atlantic Vermilion Snapper Update Assessment Report	2012 SEDAR 17 Update
SEDAR55-RD02	SEDAR 17 Stock Assessment Report: South Atlantic Vermilion Snapper	SEDAR 17
SEDAR55-RD03	List of documents and working papers for SEDAR 17 (South Atlantic Vermilion Snapper) – most documents available on the SEDAR website.	
SEDAR55-RD04	Southeast Reef Fish Survey Video Index Development Workshop	Bacheler and Carmichael 2014
SEDAR55-RD05	Overview of sampling gears and standard protocols used by the Southeast Reef Fish Survey and its partners	Smart et al. 2014
SEDAR55-RD06	Technical documentation of the Beaufort Assessment Model (BAM)	Williams and Shertzer 2015
SEDAR55-RD07	Hierarchical analysis of multiple noisy abundance indices	Conn 2010
SEDAR55-RD08	Reproductive seasonality, maturation, fecundity, and spawning frequency of the Vermilion Snapper, *Rhomboplites aurorubens*, off the Southeastern United States	Cueller et al. 1996
SEDAR55-RD09	SAFMC Snapper Grouper Advisory Panel Vermilion Snapper Fishery Performance Report November 2017	SAFMC Snapper Grouper AP
SEDAR55-RD10	Revisiting data weighting in fisheries stock assessment models	Francis 2017
SEDAR55-RD11	Model-based estimates of effective sample size in stock assessment models using the Dirichlet-multinomial distribution	Thorson et al. 2017

1.5 Statements Addressing Each Term of Reference

The following are the terms of reference with a statement explaining how each was addressed in the assessment report.

1. Prepare a standard assessment, based on the approved 2012 SEDAR 17 South Atlantic Vermilion Snapper Update assessment with data through 2016. Provide commercial and recreational landings and discards in pounds and numbers. Provide a model consistent with the 2012 SEDAR 17 Update assessment configuration and revise configurations as necessary to incorporate and evaluate any changes in model inputs or parameterization approved during this assessment.

   The updated assessment model includes data through 2016. A sensitivity run (labeled S26) mimics the 2012 SEDAR17 update assessment configuration as closely as possible (Section 4.10).

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 the inclusion of the SERFS video index
   - Incorporate the latest BAM model configurations, and detail the changes made, and impacts of those changes, between the 2012 SEDAR 17 update model and the proposed SEDAR 55 model.
   - Re-consider error distributions for fitting age and length composition data

   The SERFS video index was constructed (SEDAR55-WP01), considered by the Assessment Panel, and ultimately included in the assessment. The assessment model is the current version of BAM. The Dirichlet-multinomial likelihood was used to model length and age compositions, which provided an improved fit when compared to the SEDAR 17 benchmark and update. The use of length compositions when age compositions were available was considered by the Panel, and a change was made to only use length compositions when sufficient age compositions were not available.

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 2012 SEDAR 17 Update assessment.

Input data, including any deviations from the 2012 SEDAR17 update assessment, are described and tabulated in Section 2. The assessment model, including any deviations from SEDAR17, is documented in Section 3.

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.

   Parameter estimates are provided in Appendix B. Status indicators and benchmarks, along with standard errors, are in Table 18. Comparisons between the 2012 SEDAR17 update and the SEDAR55 assessment are 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 2019. However, it is possible the SAFMC could take action as early as mid-2018 and the panel is asked how this should be addressed in the projections. 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

   The projections are described in Sections 3.8.2 and 4.10, and illustrated in tables 20-22 and figures 57-59.

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.

   See this report.

2 Data Review and Update

In the SEDAR17 benchmark assessment (SEDAR17 2008), the assessment period was 1946–2007. An update to that assessment included data through 2011 (SEDAR17-update 2012). The assessment period of the current assessment was 1946–2016. Most data sources from the SEDAR17 benchmark and the 2012 update assessment were updated using current methodologies. The input data for this assessment are described below, with focus on modifications since the SEDAR17 update.

2.1 Data Review

In this standard assessment, the Beaufort assessment model (BAM) was fitted to similar data sources as in the SEDAR17 update with some modifications and additions:

- Life history: Natural mortality, growth, maturity, batch fecundity, and spawning frequency
- Landings: Commercial handlines, commercial historic trawl, commercial other, headboat (sampled by SRHS), and general recreational (sampled by MRIP)
- Discards: Commercial handlines, headboat, and general recreational
- Indices of abundance: SERFS chevron trap/video, commercial handline, headboat, general recreational, Florida snapper trap
- Length compositions of surveys, landings, and discards: Commercial handlines, headboat discards, commercial handline discards
- Age compositions of surveys and landings: Commercial handlines, headboat, general recreational, SERFS chevron trap

2.2 Data Update

2.2.1 Life History

Life history information that was unchanged from the 2012 update assessment (which was also the same as the SEDAR17 benchmark) included age-dependent natural mortality rate, somatic growth rate, and the length-weight relationship. The von Bertalanffy growth parameters were $L_\infty = 506.0$ mm, $K = 0.12$ yr^{-1}, and $t_0 = -3.5$ yr. Age-specific natural mortality followed the Lorenzen estimator (Lorenzen 1996), scaled to the Hoenig (age-independent) point estimate of $M = 0.22$. This point estimate was derived using a maximum observed age of 19 yr. The age-specific Charnov estimator (Charnov et al. 2015) was used in a sensitivity run. As noted in other SEDAR reports, the Charnov et al. (2015) equation is an improvement over the empirical relationship of Gislason et al. (2010), which itself was a more comprehensive meta-analysis than that of Lorenzen (1996). However, like the Lorenzen estimator, the Charnov estimator may require rescaling, which was not attempted here. Maturity, length-dependent batch fecundity, and age-dependent spawning frequency were updated for the current assessment with more recent data (SEDAR55-WP03 2017). For female maturity, 91% of age 1 fish were mature and 99-100% were mature at age 2 to 12+. This was a slight change from the SEDAR17 benchmark and 2012 update assessments which assumed 80% mature at age 1 and 100% mature thereafter. Life-history information is summarized in Table 1.

2.2.2 Commercial Landings and Discards

Estimates of commercial landings were updated for 1947-2016 using current methods. As in SEDAR17, three commercial fleets for vermilion snapper were modeled: handlines, historic trawl, and other (pots, traps, diving, trawl, miscellaneous). Landings from historic trawl (1961-62) were unchanged from SEDAR17. Estimates of commercial handline discards were developed from logbook data by the SEFSC for 1992–2016 and were assumed negligible prior to this time, as in SEDAR17. The commercial discard mortality rate was assumed to be 0.41. Commercial landings and discards, as provided and fitted by the assessment model, are shown in Table 2.

2.2.3 Recreational Landings and Discards

The headboat and general recreational landings and discards were updated for 1947–2016 based on data from the SRHS and from MRIP (SEDAR55-WP04 2017; SEDAR55-WP08 2017). The discard mortality rate was assumed to be 0.38 for both the headboat and general recreational fleets. Historical recreational landings (1947–1980) were estimated using the FHWAR (Fishing, Hunting, and Wildlife-Associated Recreational Survey) census method, which has been used in recent SEDAR assessments, rather than an older method based on Saltwater Angler Surveys (SWAS) (SEDAR55-WP04 2017). Recreational landings and discards, as provided and fitted by the assessment model, are shown in Table 2.

2.2.4 Indices of Abundance

In the 2012 update assessment for vermilion snapper, an evaluation of each of the fishery dependent indices (commercial handline, headboat, and MRFSS) used in the SEDAR17 benchmark assessment indicated they were not reliable estimators of relative abundance after 2008 due to regulatory effects on catch per effort (change in recreational bag limits, commercial trip limits, and split-season ACLs). Because the regulatory effects leading to this decision persist through the terminal year of the current assessment (2016), these three indices were retained without modification (2008 terminal year) from SEDAR17 (Table 3, Figure 1). Two fishery independent indices were included in SEDAR17: MARMAP Florida snapper trap (1983–1987) and MARMAP chevron trap (1990–2011). The Florida snapper trap index was retained unmodified from the 2012 update. Following the SEDAR55 Terms of Reference, the SERFS video data were considered as a new source of information for this assessment. A standardized index was developed separately from video data (SEDAR55-WP01 2017) and from SERFS chevron trap data (SEDAR55-WP02 2017) and, similar to previous assessments (e.g., SEDAR41 and SEDAR53), the two indices were combined using the Conn method (Conn 2010). Indices fitted by the assessment model are shown in Table 3 and Figure 1. Sensitivity runs of the assessment model used only the standardized index from SERFS chevron trap data (1990–2016), only the video data (2011–2016), or used an alternative method of combining trap and video data (SEDAR55-WP07 2017).

2.2.5 Length Compositions

Length compositions (TL) for all data sources were developed in 1-cm bins over the range 15–60 cm (labeled at bin center). All lengths below and above the minimum and maximum bins were pooled. The commercial handline, commercial other, and headboat lengths were weighted by the landings (SEDAR55-WP06 2017; SEDAR55-WP09 2017). General recreational length compositions were not weighted due to limited sample sizes and disparities in sampling among modes of the general recreational fleet (i.e., most landings from private mode but most length samples from charterboat mode). As in the SEDAR17 benchmark and 2012 update assessments, length compositions from chevron traps were not included in the current assessment. Nominal length compositions were updated for headboat discards from observer data and for commercial handline discards from logbook data. All years of length compositions were included in the 2012 update assessment. However, including both length and age compositions from the same fleet can result in overweighting of composition data, and recent SEDAR assessments have removed length composition data when sufficient age composition data are available (e.g., SEDAR 41, SEDAR 56). In the current assessment for vermilion snapper, age compositions were not fit well when length compositions were included, particularly for the commercial handline and headboat fleets. The fit to the general recreational age compositions was also improved when length compositions were excluded. Given these considerations and the high variation in length-at-age of vermilion snapper (Figure 2), the SEDAR55 assessment panel recommended excluding length composition data except when no age composition data were available. As a result, only length composition data from commercial handlines from the period 1984–1991 (the first selectivity period) and from headboat and commercial handline discards were included in the assessment model. A sensitivity run included all length composition data in the the model. Sample sizes of length composition data are shown in Tables 4 and 5.

2.2.6 Age Compositions

Age compositions were developed based on calendar ages for ages 1–12, with the maximum age an accumulator group for ages 12 and older. For the commercial and recreational fleets, the age compositions were weighted by the length compositions to address any bias in selection of fish to be aged (SEDAR55-WP06 2017; SEDAR55-WP09 2017). The assessment excluded years with small sample sizes ($<$ 10 trips), generally keeping years used in the 2012 update and then adding years 2012–2016. The 2012 update only included age compositions from the fishery independent MARMAP trap survey from years 2002–2011. The current assessment included additional years of SERFS trap age compositions (1990–2016). Sample sizes of age composition data are shown in Tables 4 and 5.

3 Stock Assessment Methods

This assessment updates the primary model applied during the 2012 update of the SEDAR17 benchmark assessment of South Atlantic vermilion snapper. The methods are reviewed below, and modifications since the 2012 update assessment are highlighted.

3.1 Overview

This assessment used the Beaufort Assessment Model (BAM, Williams and Shertzer 2015), which applies a statistical catch-age formulation, implemented with the AD Model Builder software (Fournier et al. 2012). In essence, the model simulates a population forward in time while including fishing processes (Quinn and Deriso 1999; Shertzer et al. 2008). Quantities to be estimated are systematically varied until characteristics of the simulated population match available data on the real population. The model is similar in structure to Stock Synthesis (Methot and Wetzel 2013). Versions of BAM have been used in previous SEDAR assessments of reef fishes and other species in the U.S. South Atlantic, such as red porgy, black sea bass, tilefish, blueline tilefish, gag, greater amberjack, snowy grouper, red grouper, and red snapper, as well as in the previous SEDAR assessments of vermilion snapper (SEDAR17 2008).

3.2 Data Sources

The catch-age model included data from five fleets that caught vermilion snapper in southeastern U.S. waters: commercial handlines, commercial historic trawl, commercial other (pots, traps, diving, trawl, miscellaneous), recreational headboat, and general recreational. The model was fitted to data on annual landings (in numbers for the recreational fleets, in whole weight for commercial fleets); annual discards (in numbers, with a 0.41 release mortality rate applied for commercial lines and a rate of 0.38 applied for recreational discards); annual length compositions of landings and discards; annual age compositions of landings and the SERFS; three fishery dependent indices of abundance (commercial handline, headboat, MRFSS); and two fishery-independent indices of abundance (SERFS combined chevron trap and video gears, MARMAP Florida snapper trap). Data used in the model are tabulated in §2 of this report.

Several changes to the 2012 update assessment data sources were made for SEDAR55. Reproductive inputs to the assessment model (age at maturity, batch fecundity, spawning frequency) were updated based on new data (SEDAR55-WP07 2017). Age compositions from the SERFS trap data were extended back to 1990 whereas age compositions in the 2012 update began in 2002. The SEDAR55 assessment panel recommended using the FHWAR method rather than the SWAS method to develop historical recreational removals (SEDAR55-WP04 2017). The headboat and general recreational length compositions and the commercial length compositions (after 1992 when ages became available) were excluded by the SEDAR55 assessment panel due to conflicts with the available age data. Finally, the SERFS video data were included along with the chevron trap data for creating the fishery independent index. The video survey was initiated after the 2012 update assessment, and it was considered here as part of the TOR.

3.3 Model Configuration

Model structure and equations of the BAM are detailed in Williams and Shertzer (2015). The assessment time period was 1946–2016. A description of the application to vermilion snapper 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 $1 - 12^{+}$, where the oldest age class 12^{+} allowed for the accumulation of fish (i.e., plus group).

3.3.2 Initialization

The initial stock (1946) was assumed to be at the unfished (virgin) biomass and age structure.

3.3.3 Somatic growth

Mean total length (TL, in units of mm) at age of the population was modeled with the von Bertalanffy equation, and weight at age (whole weight, WW, in units of kg) was modeled as a function of total length (Table 1, Figure 2). Parameters of growth were estimated external to the assessment model and were treated as input. The von Bertalanffy parameter estimates were $L_\infty = 506.0$, $K = 0.12$, and $t_0 = -3.5$. Length was converted to weight as $WW = (2.1\text{E}{-}05)TL^{2.91}$. For fitting length composition data, the distribution of size at age was assumed normal with CV estimated by the assessment model ($\widehat{\text{CV}} = 16.07\%$).

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 Lorenzen (1996). The Lorenzen (1996) approach inversely relates the natural mortality at age to mean weight at age W_a by the power function $M_a = \alpha W_a^{\beta}$, where α is a scale parameter and β is a shape parameter. Lorenzen (1996) provided point estimates of α and β for oceanic fishes, which were used for this assessment. As in the SEDAR17 benchmark and the 2012 update, the Lorenzen estimates of M_a were rescaled to provide the same fraction of fish surviving from age 1 through the oldest observed age (19 years) as would occur with constant $M = 0.22$. This approach using cumulative mortality is consistent with the findings of Hoenig (1983) and Hewitt and Hoenig (2005).

In addition to the Lorenzen estimator, this assessment also considered the Charnov estimator (Charnov et al. 2015) in a sensitivity run. The Charnov et al. (2015) approach inversely relates the natural mortality at age to somatic growth, $M_a = K \times [L_a/L_\infty]^{-1.5}$. This estimator was not rescaled and results in cumulative survival to the maximum observed age of 2.6%, which is higher than the 1.5% cumulative survival to maximum age at $M = 0.22$.

3.3.5 Maturity and fecundity

Female maturity was modeled as 91% mature at age 1 and 99-100% mature at age 2 to 12+. For spawning females, annual egg production was computed as number of eggs spawned per batch (a function of length) multiplied by the number of batches per year (a function of age). Annual number of batches was 34 for age 1 fish and 44.5 for fish ages 2 to 12+. Ogives describing maturity, fecundity, and spawning frequency (Table 1) were treated as input to the assessment model.

3.3.6 Spawning stock

Spawning biomass was modeled as population egg production, assuming a sex ratio of 68% female. Spawning biomass was computed each year from numbers at age when spawning peaks, assumed to occur at the midpoint of the year for vermilion snapper.

3.3.7 Recruitment

Expected recruitment of age-1 fish was predicted from spawning stock (population egg production) using the Beverton–Holt spawner-recruit model. Annual variation in recruitment was assumed to occur with lognormal deviations starting in 1976.

The 2012 update assessment estimated steepness at $\hat{h} = 0.71$. In the current assessment, steepness was estimated at $\hat{h} = 0.69$, but the estimate was highly unstable. The SEDAR55 assessment panel examined likelihood profiles for steepness and found that the profile was relatively flat between 0.43 and 0.99, within two negative log-likelihood units of the minimum at $h = 0.69$. When steepness is not estimable or poorly estimated, prior SEDAR assessments have used a fixed value at the midpoint of the flat portion of the profile. For this assessment the midpoint of the flat portion of the profile was $h = 0.71$. Given the similarity of the current estimate of steepness to the profile midpoint and to that from the 2012 update, the panel recommended fixing steepness at $h = 0.69$. Sensitivity runs examined values at the boundaries of the profile range, and uncertainty analyses included the full range from $h = 0.43$ to $h = 0.99$.

3.3.8 Landings

Time series of landing from five fleets were modeled: commercial handlines (1958–2016), commercial historic trawl (1961–1962), commercial other (1971–2016), recreational headboat (1947–2016), and general recreational (1947-2016). Landings were modeled with the Baranov catch equation (Baranov 1918) and were fitted in either weight or numbers, depending on how the data were collected (1000 lb whole weight for commercial fleets and 1000 fish for recreational fleets). Landings for the general recreational fleet started in 1981 with the initiation of the MRFSS program. For the current assessment, general recreational landings were updated using MRIP methodology rather than MRFSS methodology. In SEDAR17 and the 2012 update, recreational removals for the years 1947–1980 were reconstructed using Saltwater Angler Surveys (SWAS). The SEDAR55 assessment panel recommended using the more recent FHWAR census method (SEDAR55-WP04 2017), which has been used in most recent SEDAR assessments, for reconstructing historical recreational removals. The effect of this change in methodology was evaluated via sensitivity analysis.

3.3.9 Discards

Commercial handline discard mortalities were modeled starting in 1992 with the implementation of the 12-inch minimum size limit regulation. As in SEDAR17, headboat and general recreational discard mortalities were modeled for the entire time series (1947–2016), because MRFSS data indicated that recreational discards occurred prior to when size limits were implemented (1992). As with landings, discard mortalities (in units of 1000 fish) were modeled with the Baranov catch equation (Baranov 1918), which required estimates of discard selectivities (described below) and discard mortality rates. Headboat and recreational discard mortality rate was 0.38 and the commercial discard mortality rate was 0.41.

3.3.10 Fishing

For each time series of landings and discard mortalities, a separate full fishing mortality rate (F) was estimated. 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.

3.3.11 Selectivities

Selectivities were modeled in a similar manner to the 2012 update assessment. Selectivity of each fleet was fixed within each period of size-limit regulations, but was permitted to vary among periods. Commercial fisheries experienced two periods of size-limit regulations (no limit prior to 1992; 12-inch limit during 1992–2016), and recreational fisheries experienced four periods (no limit prior to 1992; 10-inch limit during 1992-1998; 11-inch limit during 1999-2006; and 12-inch limit during 2007-2016). In most cases, selectivities were estimated using a two-parametric logistic model (flat-topped). This approach restricts the number of estimated parameters and imposes theoretical structure on the shape of the curve. Age and length composition data are critical for estimating selectivity parameters, and ideally a model would have sufficient composition data from each fleet over time to estimate distinct selectivities in each period of regulations. That was not the case here, and thus additional assumptions were applied to define selectivities, as follows.

Selectivity of commercial fleets was modeled in the same manner as in the 2012 update assessment. Commercial handline selectivity was modeled using two separate logistic functions corresponding to the change in size limit in 1992. Commercial combined gears had limited length composition data and no age compositions; because of the small size of these fish, it was assumed that this gear had full selectivity for age-1 fish, 0.5 for age-2 fish, and 0 for age-3+ fish. The commercial combined length composition data came primarily from trawls, which were banned from South Atlantic federal waters in January of 1989. Starting in 1989 when the commercial combined gear was comprised mostly of gears other than trawls (traps, pots, miscellaneous lines), selectivity was assumed to be the same as that of commercial handlines.

As in the 2012 update assessment, headboat and general recreational selectivities were modeled using logistic functions corresponding to the change in size limit in 1992, 1999, and 2007. In the update, general recreational selectivity mirrored that of the headboat fleet in the first two regulatory periods but was estimated separately for the second two regulatory periods. Inspection of separately estimated selectivities for the two recent regulatory periods from the 2012 update assessment indicated little difference between the headboat and recreational fleets (SEDAR17-update 2012). The SEDAR55 assessment panel felt there was little difference in selectivity of vermilion snapper between the general recreational and headboat fleets, and recommended estimating a single selectivity to be applied to both fleets.

As in the 2012 update assessment, MARMAP Florida snapper traps were assumed to catch only age-1 fish, because length compositions contained relatively small fish and no age compositions were available. SERFS chevron traps had age composition data and was estimated to be dome-shaped. In the SEDAR17 benchmark and 2012 update assessments, age data were only available from 2002–2011 for chevron traps and dome-shaped selectivity for this fleet was only partially estimable. In the current assessment, age data for chevron traps were available from 1990–2016 and dome-shaped selectivity was estimated using a three-parameter logistic exponential model, assuming full selectivity at age-3. Full selection at age 3 was most consistent with SERFS age composition data and was the recommendation from the SEDAR17 benchmark and 2012 update assessments. Selectivity of the SERFS video was assumed to be the same as that of the chevron trap gear.

As in the 2012 update, selectivity of discards was partially estimated, assuming that discards consisted primarily of undersized fish, as implied by observed length compositions of discards. The general approach taken for discard selectivity was to fix the value for age-1 fish at zero, estimate the value for age-2 fish, assume full selection for age-3 fish, and fix the selectivity at the age-specific probability of being below the size limit given a normal distribution of size at age for fish age 4 and older. Given available data on discards, some additional assumptions were necessary: Headboat and general recreational fleets were assumed to have the same discard selectivities; Recreational discard selectivity in period 1 was assumed to be the same as that during period 2; selectivity of age-2 fish in recreational period 2 was assumed to be the same as the estimate from period 3; selectivity of age-2 fish in commercial period 2 was assumed to be the same as the estimate from commercial period 3; and starting in 2009, the descending limb of commercial discards selectivity (ages-4+) was estimated using a negative exponential function in order to account for a shift toward legal-sized fish in the length compositions of commercial discards, presumably resulting from closed periods when split-season quotas were met. Such a shift was not apparent in length compositions of recreational discards, and was therefore not adopted for the recreational discard selectivities.

Selectivities of fishery dependent indices were assumed the same as those of landings from the relevant fleet.

3.3.12 Indices of abundance

The model was fit to two fishery independent indices of abundance (SERFS 1990–2016; MARMAP Florida snapper trap 1983–1987) and to three fishery dependent indices of abundance (headboat 1976–2008; MRIP general recreational 1987–2008; and commercial handline 1993–2008) (Table 3 and Figure 1). Predicted indices were conditional on selectivity of the fleet or survey and were computed from numbers at age at the midpoint of the year or, in the case of commercial handline, weight at age. Catchability associated with the SERFS index was assumed constant through time. Catchability of the three fishery dependent indices varied over time, and was modeled with a random walk

(Wilberg and Bence 2006; SEDAR Procedural Guidance 2009; Wilberg et al. 2010). This was a modification from SEDAR17 and the 2012 update assessment, which assumed a linear increasing trend in catchability for all fishery dependent indices through 2008. The effect of this change was evaluated via sensitivity analysis.

3.3.13 Biological reference points

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

3.3.14 Fitting criterion

The fitting criterion was a likelihood approach in which observed landings and dead discards were fit closely, and observed composition data and abundance indices were fit to the degree that they were compatible. Landings, discards, and index data were fit using lognormal likelihoods, with annual CV=0.05 (landings and discards) or estimated CVs from a standardization procedure (indices). Length and age composition data were fit using the Dirichlet-multinomial distribution with sample size represented by the annual number of trips adjusted by an estimated variance inflation factor. This was a change from the SEDAR17 and the 2012 update, which assumed a multinomial distribution for composition data. The use of the multinomial distribution in stock assessment models has been questioned (Francis 2014), and recent SEDAR assessments (e.g., SEDAR 53 red grouper) have used the Dirichlet-multinomial (Francis 2017; Thorson et al. 2017). The Dirichlet-multinomial is self-weighting and therefore iterative re-weighting (e.g., Francis 2011) is unnecessary, and better accounts for intra-haul correlations (i.e., fish caught in the same set are more alike in length or age than fish caught in different sets). The Dirichlet-multinomial also allows for observed zeros and has recently been implemented in Stock Synthesis (Methot and Wetzel 2013; Thorson et al. 2017). The current assessment used the Dirichlet-multinomial distribution in the base run but considered the multinomial distribution in a sensitivity run.

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

3.3.15 Configuration of base run

The base run was configured as described above. Some key features include 1) discard mortality of 0.41 for commercial fleets and 0.38 for recreational fleets, 2) Lorenzen age-based natural mortality scaled to $M = 0.22$, 3) a Beverton-Holt spawner-recruit model with spawning stock computed from population egg production, and 4) steepness fixed at $h = 0.69$. The base run does not necessarily represent reality better than all other possible configurations, and thus this assessment attempted to portray uncertainty in point estimates through sensitivity and retrospective analyses, and through a Monte-Carlo/bootstrap approach (described below).

3.3.16 Sensitivity analyses

Sensitivity runs were chosen 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: Low natural mortality ($M = 0.16$) used to scale the Lorenzen (1996) age-based estimator.
- S2: High natural mortality ($M = 0.28$) used to scale the Lorenzen (1996) age-based estimator.
- S3: Constant natural mortality ($M = 0.22$) based on Hoenig point estimate.
- S4: Natural mortality follows the Charnov et al. (2015) age-based estimator with no rescaling.
- S5: Steepness ($h = 0.84$) at the mode of Shertzer and Conn (2012).
- S6: Steepness ($h = 0.43$) at the lower bound of the range identified by likelihood profiling.
- S7: Steepness ($h = 0.99$) at the upper bound of the range identified by likelihood profiling.
- S8: Maturity, size dependent batch fecundity, and constant spawning frequency with age from SEDAR17.
- S9: Saltwater Angler Survey (SWAS) method for estimating historical recreational removals.
- S10: 1.25 X FHWAR historical recreational removals.
- S11: 0.75 X FHWAR historical recreational removals.
- S12: Include length composition data.
- S13: SERFS chevron trap index only (no video).
- S14: SERFS video index only (no trap).
- S15: SERFS trap and video index combined based on Gwinn method (SEDAR55-WP07 2017).
- S16: Upweight combined SERFS trap/video index 2X.
- S17: Upweight combined SERFS trap/video index 4X.
- S18: Upweight combined SERFS trap/video index 8X.
- S19: Remove 1990 (low) value from combined SERFS trap/video index.
- S20: Remove 1990 (low) and 1991 (high) values from combined SERFS trap/video index.
- S21: Block SERFS trap/video index catchability around expansion of the survey (1990-2010, 2011-2016).
- S22: Constant catchability on fishery dependent indices.
- S23: Linearly increasing catchability (2% per year) on fishery dependent indices.
- S24: Multinomial likelihood for composition data.
- S25: No ageing error matrix.
- S26: Continuity configuration, including the multinomial likelihood for composition data, inclusion of length compositions, linear increasing catchability on fishery dependent indices, only SERFS trap index (no video), limited SERFS age compositions (2002-2016), steepness fixed at $h = 0.71$, and reproductive inputs (maturity, batch fecundity, spawning frequency) from SEDAR17.

Retrospective analyses were also conducted, incrementally dropping one year at a time for five iterations, thus reaching back to the terminal year of the last assessment. In these runs, the terminal years were 2015, 2014, 2013, 2012, 2011.

3.4 Parameters Estimated

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

3.5 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F, as were equilibrium landings, discards, and spawning biomass. Equilibrium landings and discards were also computed as functions of biomass B, which itself is a function of F. As in computation of MSY-related benchmarks (described in §3.6), 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 (2014–2016).

3.6 Benchmark/Reference Point Methods

In this assessment of vermilion snapper, 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 (2014–2016). If the selectivities or relative fishing mortalities among fleets were to change, so would the estimates of MSY and related benchmarks.

For this stock, the maximum fishing mortality threshold (MFMT) is defined by the SAFMC as F_{MSY}, and the minimum stock size threshold (MSST) as $75\%\text{SSB}_{\text{MSY}}$. 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 (2016), and current status of the fishery is represented by the geometric mean of F from the latest three years (2014–2016).

3.7 Uncertainty and Measures of Precision

As in SEDAR17, this assessment used a mixed Monte Carlo and bootstrap (MCB) approach to characterize uncertainty in results of the base run. Monte Carlo and bootstrap methods (Efron and Tibshirani 1993; Manly 1997) are often used to characterize uncertainty in ecological studies, and the mixed approach has been applied successfully in stock assessment, including Restrepo et al. (1992), Legault et al. (2001), SEDAR17 (2008), and many South Atlantic SEDAR assessments since SEDAR17 (2008). The approach is among those recommended for use in SEDAR assessments (SEDAR Procedural Guidance 2010).

The MCB approach translates uncertainty in model input into uncertainty in model output by fitting the model many times with different values of "observed" data and key input parameters. A chief advantage of the approach is that the results describe a range of possible outcomes, so that uncertainty is characterized more thoroughly than it could be by any single fit or handful of sensitivity runs. A minor disadvantage of the approach is that computational demands are relatively high.

In this assessment, the BAM was successively re-fit in $n = 3800$ trials that differed from the original inputs by bootstrapping on data sources, and by Monte Carlo sampling of several key input parameters. Of the 3800 trials, approximately 8.9% were discarded, based on a 0.5% trim on $R0$ or because the model did not properly converge. This left $n = 3462$ MCB trials used to characterize uncertainty, which was sufficient for convergence of standard errors in management quantities.

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

3.7.1 Bootstrap of observed data

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

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

The term $\sigma^2_{s,y}/2$ is a bias correction that centers the multiplicative error on the value of 1.0. Standard deviations in log space were computed from CVs in arithmetic space, $\sigma_{s,y} = \sqrt{\log(1.0 + CV^2_{s,y})}$. As used for fitting the base run, CVs of removals were assumed to be 0.05, and CVs of indices of abundance were those provided by, or modified from, the data providers (tabulated in Table 3 of this assessment report).

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

3.7.2 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.

3.7.2.1 Natural and discard mortalities

Point estimates of natural mortality ($M = 0.22$) and discard mortality ($\delta = 0.38$ for recreational fleets and $\delta = 0.41$ for commercial fleets) were those provided by the DW from SEDAR17, but with some uncertainty. To carry forward these sources of uncertainty, Monte Carlo sampling was used to generate deviations from the point estimates. For discard mortality, a new δ value was drawn for each MCB trial from a truncated normal distribution [0.24 to 0.53 for commercial handlines and 0.2 to 0.5 for headboat and general recreational fleets] with mean equal to the point estimate and standard deviation set to provide an upper 95% confidence limit at the upper boundary. For natural mortality, a new M value was drawn for each MCB trial from a truncated normal distribution (range [0.16, 0.28]) with mean equal to the point estimate ($M = 0.22$) and standard deviation set to provide upper and lower confidence limits at the boundaries. Each realized value of M was used to scale the age-specific Lorenzen M, as in the base run.

3.7.2.2 Steepness

In initial trials of the assessment model, steepness was estimable but highly unstable. Consequently, steepness was included in the MCB analysis, drawn from a truncated normal distribution [0.43, 0.99] with mean at the point estimate ($h = 0.69$) and standard deviation set to provide the 95% confidence interval at the upper bound. The bounds were chosen as the range of values consistent with the vermilion snapper data, as indicated by likelihood profiling on steepness.

3.7.2.3 Historical recreational removals

In the current assessment, historical recreational removals (1946–1980) prior to the introduction of MRFSS in 1981 were estimated using the FHWAR method (SEDAR55-WP07 2017), an improvement over the method based on Saltwater Angler Surveys (SWAS) that was used in the SEDAR17 benchmark and the 2012 update assessment. In MCB runs, a scalar applied to new historical (1947-1980) recreational time series was drawn from a uniform distribution spanning 75% to 125% of that used in the base run.

3.8 Projections

Projections were run to predict stock status in years after the assessment, 2017–2023.

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 at the most recent values of the assessment period. A single selectivity curve was applied to calculate landings, and one applied to calculate dead discards, each computed by averaging selectivities across fleets using geometric mean Fs from the last three years of the assessment period, similar to computation of MSY benchmarks (§3.6).

Expected values of SSB (time of peak spawning), F, recruits, landings, and discards were represented by deterministic projections using parameter estimates from the base run. These projections 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 Monte Carlo/Bootstrap (MCB) fits of the stock assessment model.

3.8.1 Initialization of projections

Although the terminal year of the assessment is 2016, the assessment model computes abundance at age (N_a) at the start of 2017. For projections, those estimates were used to initialize N_a. However, the assessment has no information to inform the strength of 2017 recruitment, and thus it computes 2017 recruits (N_1) as the expected value, that is, without deviation from the spawner-recruit curve, and corrected to be unbiased in arithmetic space. In the stochastic projections, lognormal stochasticity was applied to these abundances after adjusting them to be unbiased in log space, with variability based on the estimate of σ_R. Thus, the initial abundance in year one (2017) of projections included this variability in N_1. The deterministic projections were not adjusted in this manner, because deterministic recruitment follows the bias-corrected (arithmetic space) spawner-recruit curve precisely, consistent with the assessment's 2017 predictions.

Fishing rates that define the projections were assumed to start in 2019. Because the assessment period ended in 2016, the projections required an initialization period (2017–2018). F_{current} 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 MCB assessment model fit. Thus, projections carried forward uncertainties in steepness, natural mortality, discard mortality, and historical recreational removals as well as in estimated quantities such as the remaining spawner-recruit parameters and selectivity curves.

Initial and subsequent recruitment values were generated with stochasticity using a Monte Carlo procedure, in which the estimated Beverton–Holt model of each MCB fit was used to compute mean annual recruitment values ($\bar{R}_y$). Annual variability was added to the mean values by choosing multiplicative deviations at random from a lognormal distribution,

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

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

The procedure generated 20,000 replicate projections of MCB model fits drawn at random (with replacement) from the MCB runs. In cases where the same MCB 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.

Projection scenarios The SEDAR55 TOR described four projections scenarios: $F = F_{\text{MSY}}$ to define OFL with a 50% probability of overfishing, $P^\star = 0.5$, $P^\star = 0.4$, and $F = 75\% F_{\text{MSY}}$. $F = F_{\text{MSY}}$ is identical to the $P^\star = 0.5$ projection, so three projection scenarios were considered. In each, the landings in the interim period were calculated based on F_{current}.

- Scenario 1: $F = F_{\text{MSY}}$, with F_{current} assumed for the interim period (Identical to $P^\star = 0.5$).
- Scenario 2: $P^\star = 0.4$, with F_{current} assumed for the interim period.
- Scenario 3: $F = 75\% F_{\text{MSY}}$, with F_{current} assumed for the interim period.

4 Stock Assessment Results

4.1 Measures of Overall Model Fit

In general, the Beaufort Assessment Model (BAM) fit well to the available data. Predicted length compositions were reasonably close to observed data in most years, as were predicted age compositions (Figure 3). The model was configured to fit observed commercial and recreational removals closely (Figures 4–11). Fits to indices of abundance generally captured the observed trends but not all annual fluctuations (Figures 12–15). The model fit to the fishery independent SERFS index was within the error bars of the standardization for most years prior to 2010. The model did not capture the general downward trend in the index since the 1990s, nor the decline and subsequent increase in the index at the end of the time series (2010–2016). This lack of fit to the index was due primarily to a conflict with the age composition data (Figure 3), which suggested multiple strong year classes in the 2000s from independently sampled fleets, as well as some conflict with the landings, which have declined nearly two-fold since the early 2000s, a period during which the index also declined. The SEDAR55 assessment panel discussed this issue at length and decided to retain the SERFS index in the model but not to increase the weight on the index in order to improve the fit. The effect of increasing the weight on the SERFS index was investigated via sensitivity analysis.

4.2 Parameter Estimates

Estimates of all parameters from the BAM 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

In general, estimated abundance at age shows a structure that has been relatively consistent through time, reflecting effects of year-class strength and annual fishing mortality, but without severe age truncation (Figure 17; Table 6). Total estimated abundance decreased until the 1990s, then fluctuated with little trend through the 2000s. Estimated abundance has increased slightly over the last five years. Annual number of recruits is shown in Table 6 (age-1 column) and in Figure 18. The highest recruitment values were predicted to have occurred in 2002, 2006, and 2008. Since then, recruitment has been mostly average or below expectation with the exception of slightly above average recruitment in 2011.

4.4 Total and Spawning Biomass

Estimated biomass at age followed a similar pattern as abundance at age (Figure 19; Table 7). Total biomass and spawning biomass showed similar trends—general decline until the 1990s, with little trend thereafter (Figure 20; Table 8).

4.5 Selectivity

Selectivity of the fishery independent surveys (SERFS chevron trap/video gear and MARMAP Florida snapper trap) is shown in Figure 21. Selectivities of landings from commercial and recreational fleets are shown in Figures 22–23, and selectivities of discard mortalities are in Figures 24–25. In the most recent years, full selection of landings occurred near age 3–4.

Average selectivities of landings and of dead discards were computed from F-weighted selectivities in the most recent three assessment years (Figure 26). This average selectivity was used in computation of point estimates of benchmarks, as well as in projections. All selectivities from the most recent period, including average selectivities, are tabulated in Table 9.

4.6 Fishing Mortality, Landings, and Discards

The estimated fishing mortality rates (F) increased through the 1980s and 1990s and have shown much variability across years since then, with some of the lowest values in early 2010s but increasing fishing mortality over the last 3 years (Figure 27; Table 10). The commercial handline fleet has been the largest contributor to total F followed by the headboat and general recreational fleets. Commercial gear other than handlines, consisting mostly of trawls, were a substantial source of landings in the 1980s prior to the implementation of a trawl ban in 1989, but have been small since then.

Estimates of total F at age are shown in Table 11. In any given year, the maximum F at age (i.e., apical F) may be less than that year's sum of fully selected Fs across fleets. This inequality is due to the combination of two features of estimated selectivities: full selection occurs at different ages among gears and at least one source of fishing mortality has dome-shaped selectivity.

Table 12 shows total landings at age in numbers, and Table 13 in weight. The commercial handline fleet takes the most landings, in both numbers and weight (Figures 28, 29; Tables 14, 15). In recent years, total landings have been near but slightly below MSY (Figure 29). Estimated discard mortalities occurred on a smaller scale than landings and have varied with little trend since the 1990s (Figures 30, 31; Tables 16, 17).

4.7 Spawner-Recruitment Parameters

The estimated Beverton–Holt spawner-recruit curve is shown in Figure 32, along with the effect of density dependence on recruitment, depicted graphically by recruits per spawner as a function of spawning stock (population egg production). Values of recruitment-related parameters were as follows: steepness $h = 0.69$, unfished age-1 recruitment $\widehat{R_0} = 6,298,896$, unfished spawners (mt) per recruit $\phi_0 = 7.44e - 6$, and standard deviation of recruitment residuals in log space $\widehat{\sigma}_R = 0.29$ (which resulted in bias correction of $\varsigma = 1.04$). Uncertainty in these quantities was estimated through the MCB analysis (Figure 33).

4.8 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F (Figure 34). As in computation of MSY-related benchmarks, per recruit analyses applied the most recent selectivity patterns averaged across fleets, weighted by F from the last three years (2014–2016).

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of F (Figure 35). By definition, the F that maximizes equilibrium landings is F_{MSY}, and the corresponding landings and spawning biomass are MSY and $\mathrm{SSB}_{\mathrm{MSY}}$.

4.9 Benchmarks / Reference Points

As described in §3.6, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the expected spawner-recruit curve (Figure 32). Reference points estimated were F_{MSY}, MSY, B_{MSY} and $\mathrm{SSB}_{\mathrm{MSY}}$. Based on F_{MSY}, three possible values of F at optimum yield (OY) were considered—$F_{\mathrm{OY}} = 65\% F_{\mathrm{MSY}}$, $F_{\mathrm{OY}} = 75\% F_{\mathrm{MSY}}$, and $F_{\mathrm{OY}} = 85\% F_{\mathrm{MSY}}$—and for each, the corresponding yield was computed. Standard errors of benchmarks were approximated as those from MCB analysis (§3.7).

Maximum likelihood estimates (base run) of benchmarks, as well as median values from MCB analysis, are summarized in Table 18. Point estimates of MSY-related quantities were $F_{\mathrm{MSY}} = 0.41$ (y^{-1}), MSY = 1305.8 (1000 lb), $B_{\mathrm{MSY}} = 4249.2$ (mt), and $\mathrm{SSB}_{\mathrm{MSY}} = 18.3$ (1E12 eggs). Median estimates were $F_{\mathrm{MSY}} = 0.44$ (y^{-1}), MSY = 1339.6 (1000 lb), $B_{\mathrm{MSY}} = 4030.8$ (mt), and $\mathrm{SSB}_{\mathrm{MSY}} = 17.2$ (1E12 eggs). Distributions of these benchmarks from the MCB analysis are shown in Figure 37.

4.9.1 Status of the Stock and Fishery

Estimated time series of stock status (SSB/MSST and $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$), conditioned on recent selectivity patterns, showed general decline throughout the beginning of the assessment period until the early 1990s, and fluctuated without trend since then (Figure 38, Table 8). Base-run estimates of spawning biomass have remained above the threshold (MSST) throughout the assessment period. Current stock status was estimated in the base run to be $\mathrm{SSB}_{2016}/\mathrm{MSST} = 1.51$ and $\mathrm{SSB}_{2016}/\mathrm{SSB}_{\mathrm{MSY}} = 1.13$ (Table 18), indicating that the stock is not overfished and is quite close to $\mathrm{SSB}_{\mathrm{MSY}}$. Median values from the MCB analysis indicated similar results ($\mathrm{SSB}_{2016}/\mathrm{MSST} = 1.54$ and $\mathrm{SSB}_{2016}/\mathrm{SSB}_{\mathrm{MSY}} = 1.16$). The uncertainty analysis suggested that the terminal estimate of stock status is robust (Figures 39, 40). Of the MCB runs, 71.8% indicated that the stock in 2016 was above $\mathrm{SSB}_{\mathrm{MSY}}$, and 92.3% that the stock was above MSST. Age structure estimated by the base run generally showed more fish of all ages than the (equilibrium) age structure expected at MSY (Figure 41). The 2016 age structure showed more old fish than in previous years, reflecting strong recruitment in the 2000s, and it showed slightly fewer young fish, reflecting the average to below average recruitment in recent years.

The estimated time series of F/F_{MSY} suggests that overfishing has occurred periodically over the assessment period (Table 8), but with much uncertainty in the terminal years as demonstrated by the MCB analysis (Figure 38). Current fishery status in the terminal year, with current F represented by the geometric mean from the period 2014–2016, was estimated by the base run to be $F_{2014-2016}/F_{\mathrm{MSY}} = 0.609$, and the median value was $F_{2014-2016}/F_{\mathrm{MSY}} = 0.564$ (Table 18). The fishery status was less robust than the stock status (Figures 39, 40). Of the MCB runs, approximately 83.2% agreed with the base run that the stock is currently not experiencing overfishing.

4.9.2 Comparison to Previous Assessment

Time series of stock and fishery status estimated by this assessment were similar in pattern to those from the previous SEDAR17 benchmark assessment and the 2012 update (Figure 42). Trends in $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$ from the two assessments tracked each other closely, particularly since the 1990s. Trends in F/F_{MSY} generally tracked each other as well, with neither assessment indicated much overfishing. The 2012 update assessment estimated $F_{\mathrm{MSY}} = 0.75$ and MSY = 1563 (1000 lb). SEDAR55 estimated $F_{\mathrm{MSY}} = 0.41$ and MSY = 1305.8 (1000 lb).

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 MCB results in terms of expected effects of input parameters. Sensitivity runs are a tool for better understanding model behavior, and therefore should not be used as the basis for management. All runs are not considered equally plausible in the sense of alternative states of nature. Time series of F/F_{MSY} and $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$ demonstrate the sensitivity of the assessment model to natural mortality (Figure 43), steepness (Figure 44), reproductive parameters (Figure 45), historical recreational removals (Figure 46), inclusion of length compositions (Figure 47), the SERFS index (Figure 48, 49, 50), catchability (Figure 51), use of the multinomial distribution (Figure 52), ageing error (Figure 53), and the

SEDAR17 configuration (Figure 54). Results appeared to be most sensitive to natural mortality, steepness, inclusion of length compositions, and the degree of upweighting of the SERFS index. The majority of the runs agreed with the status indicated by the base run (Figure 55, Table 19), though runs with low steepness, low natural mortality, or upweighting of the CVID index suggested a different exploitation or biomass status.

Retrospective analyses suggested some overestimation of terminal-year fishing mortality starting in 2011 (Figure 56). This pattern appeared mostly due to underestimation of the 2006–2008 year classes, which resulted in several years with underestimated SSB.

4.11 Projections

Projections based on $F = F_{\mathrm{MSY}}$, which is higher than F_{current} drove the stock down toward MSY by the terminal year of the projections (2023) (Figures 57, Table 20). The $F = 75\% F_{\mathrm{MSY}}$ projection scenario resulted in slight increases in spawning biomass over the projection period (Figure 59, Table 21). The $P^{\star} = 0.40$ projection was similar to the $F = F_{\mathrm{MSY}}$ scenario (Figure 58, Table 22).

5 Discussion

5.1 Comments on the Assessment

The base run of the BAM indicated that the stock is not overfished ($\mathrm{SSB}_{2016}/\mathrm{MSST} = 1.51$), and that overfishing is not occurring ($F_{2014-2016}/F_{\mathrm{MSY}} = 0.609$). Median values from the MCB analyses were in qualitative agreement with those results ($\mathrm{SSB}_{2016}/\mathrm{MSST} = 1.54$ and $F_{2014-2016}/F_{\mathrm{MSY}} = 0.564$).

As in the 2012 update, this assessment estimated that spawning biomass declined until the 1990s and has fluctuated with little trend since then. The stock is currently estimated to be near a biomass that produces MSY, a similar result to the 2012 update assessment. Age compositions played a prominent role in this assessment, and strong year classes in the 2000s evident in multiple, independently sampled fleets contributed to relatively high spawning biomass in recent years. However, recent recruitment has been about average or below average, suggesting this pattern may not persist into the future.

In this assessment, the SERFS index was not fit particularly closely, most notably with a run of negative residuals at the end of the time series. A similar pattern was noted in a recent assessment of red grouper (SEDAR53 2017). The lack of fit of the SERFS index was primarily due to a conflict with the age compositions from the SERFS trap sampling as well as from other fishery dependent sources. The SERFS index was also poorly correlated with commercial handline, general recreational, and headboat indices for the years they overlapped (Pearson r=-0.19 to 0.075), though fishery dependent indices of abundance may not track actual abundance either due to factor such as hyperdepletion or hyperstability. Because vermilion snapper are a schooling species that utilize the upper water column and show diel patterns in vertical migration, the SERFS trap and video gear may not reflect patterns in local abundance among sampling site, but may adequately capture the available age composition of fish. Alternatively, the development and standardization of the index may need to be revisited, possibly using presence/absence rather than CPUE as a response variable. The SEDAR55 assessment panel discussed these issues at length and ultimately decided that the age compositions were more reliable given that patterns were similar across independently sampled fleets and surveys. As noted previously, improved fits to the recent fishery independent index values, as in sensitivity runs 16-18, resulted in a more depleted stock status than in the base run. Thus, if those lower values in the SERFS index reflect stock size rather than observation error, the base run could be overly optimistic.

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. If selectivity patterns change in the future, for example as a result of new size limits or different relative catch allocations among sectors, estimates of benchmarks would likely change as well.

In addition to including the more recent years of data, this standard assessment contained several modifications to the data of SEDAR17, as well as to the BAM implementation. The main modifications, as described throughout this report, were the following:

- The recreational landings and discards were estimated using MRIP methodology and the FHWAR method for historical removals, rather than MRFSS and SWAS methodologies.
- Length compositions were excluded except when age compositions were not available.
- Additional years of MARMAP age compositions (1990-2001) were included.
- SERFS video data were included in combination with the SERFS trap data.
- Steepness was fixed at $h = 0.69$.
- Selectivities of the general recreational and headboat fleets mirrored each other throughout the assessment period rather than only during recreational periods 1 and 2.
- Catchability of fishery dependent indices was modeled with annual variation (random walk).
- Age and length compositions were fitted using the Dirichlet-multinomial distribution.
- Reproductive parameters (age at maturity, batch fecundity) were updated with more recent data and spawning frequency was a function of age rather than constant.

Because steepness could not be estimated reliably in this assessment, its value in the base run was fixed at the estimated value (0.69) which is near the midpoint of the range implied by likelihood profiling. 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 both the SEDAR17 benchmark and the 2012 update assessments of vermilion snapper 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 5–10 years).
- Although projections included many major sources of uncertainty, they did not include structural (model) uncertainty. That is, projection results are conditional on one set of functional forms used to describe population dynamics, selectivity, recruitment, etc.

- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect projection results.
- 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.
- The projections assumed that the estimated spawner-recruit relationship applies in the future and that past residuals represent future uncertainty in recruitment. If future recruitment is characterized by runs of large or small year classes, possibly due to environmental or ecological conditions, stock projections may be affected. For example, the large 2008 year was not well estimated at the time of the SEDAR17 update assessment, and resulted in those projections being overly pessimistic.
- It remains to be seen whether the average to below average recruitment in recent years will continue into the future. That possibility exists and could influence considerations of risk tolerance.

5.3 Research Recommendations

- Further investigate discrepancies between age composition data and indices of abundance
- Further develop methods to standardize and combine SERFS chevron trap and video gears for creating indices of abundance
- Evaluate sample size cutoffs and weighting procedures for age and length compositions. What should be the minimum standards, and how does this interplay with the number of age and length classes modeled in the assessment?
- In stock assessment, various likelihood formulations have been used for fitting age and length composition data. The multinomial distribution and its robust versions have been the most widely applied. However, more recently the Dirichlet-multinomial and logistic-normal have attracted attention. A simulation study could shed light on the performance of these various likelihood formulations under sampling conditions realistic in the southeast U.S.
- Vermilion snapper were modeled in this assessment as a unit stock off the southeastern U.S. For any stock, variation in exploitation and life-history characteristics might be expected at finer geographic scales. Modeling such sub-stock structure would require more data, such as information on the movements and migrations of adults and juveniles, as well as spatial patterns of larval dispersal and recruitment. Even when fine-scale spatial structure exists, incorporating it into a model may or may not lead to better assessment results (e.g., greater precision, less bias). Spatial structure in a vermilion snapper assessment model might range from the very broad (e.g., a single Atlantic stock) to the very narrow (e.g., a connected network of meta-populations living on individual reefs). What is the optimal level of spatial structure to model in an assessment of snapper-grouper species such as vermilion snapper? Are there well defined zoogeographic breaks (e.g., Florida keys, Cape Hatteras) that should define stock structure? How much connectivity exists between the Gulf of Mexico and Atlantic stocks?

6 References

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

Beddington, J. R., and J. G. Cooke, 1983. The potential yield of fish stocks. FAO Fish. Tech. Pap. 242, 47 p.

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. 2015. Evolutionary assembly rules for fish life histories. Fish and Fisheries **14**:213–224.

Conn, P. B. 2010. Hierarchical analysis of multiple noisy abundance indices. Canadian Journal of Fisheries and Aquatic Sciences .

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. 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.

Gislason, H., N. Daan, J. Rice, and J. Pope. 2010. Size, growth, temperature and the natural mortality of marine fish. Fish and Fisheries **11**:149–158.

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

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

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.

Mertz, G., and R. Myers. 1996. Influence of fecundity on recruitment variability of marine fish. Canadian Journal of Fisheries and Aquatic Sciences **53**:1618–1625.

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

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.

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.

SEDAR17, 2008. SEDAR 17: South Atlantic Vermilion Snapper. SEDAR, North Charleston, SC.

SEDAR17-update, 2012. Stock Assessment of Vermilion Snapper off the Southeastern United States: SEDAR Update Assessment. SEDAR, North Charleston, SC.

SEDAR53, 2017. Stock Assessment of Red Grouper off the Southeastern United States: SEDAR Standard Assessment. SEDAR, North Charleston, SC.

SEDAR55-WP01, 2017. Standardized video counts of Southeast U.S. Atlantic vermilion snapper (*Rhomboplites aurorubens*) from the Southeast Reef Fish Survey. SEDAR55-WP01. SEDAR, North Charleston, SC.

SEDAR55-WP02, 2017. Vermilion Snapper Fishery-Independent Index of Abundance in US South Atlantic waters based on a chevron trap survey (1990-2016). SEDAR55-WP02. SEDAR, North Charleston, SC.

SEDAR55-WP03, 2017. Update of Vermilion Snapper, *Rhomboplites aurorubens*, Reproductive Life History from the MARMAP/SERFS Program. SEDAR55-WP03. SEDAR, North Charleston, SC.

SEDAR55-WP04, 2017. Estimates of Historic Recreational Landings of Vermilion Snapper in the South Atlantic Using the FHWAR Census Method. SEDAR55-WP04. SEDAR, North Charleston, SC.

SEDAR55-WP06, 2017. Commercial age and length compositions for U.S. vermilion snapper, *Rhomboplites aurorubens*. SEDAR55-WP06. SEDAR, North Charleston, SC.

SEDAR55-WP07, 2017. Integrating data from chevron traps and video cameras into a standardized index of abundance for vermilion snapper, *Rhomboplites aurorubens*. SEDAR55-WP07. SEDAR, North Charleston, SC.

SEDAR55-WP08, 2017. Discards of vermilion snapper (*Rhomboplites aurorubens*) for the headboat fishery in the US South Atlantic. SEDAR55-WP08. SEDAR, North Charleston, SC.

SEDAR55-WP09, 2017. South Atlantic U.S. vermilion snapper (*Rhomboplites aurorubens*) age and length composition from the recreational fisheries. SEDAR55-WP09. SEDAR, North Charleston, SC.

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

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

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

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.

Wilberg, M. J., and J. R. Bence. 2006. Performance of time-varying catchability estimators in statistical catch-at-age analysis. Canadian Journal of Fisheries and Aquatic Science **63**:22752285.

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

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

7 Tables

Table 1. Life-history characteristics at age, including average mid-year total length (TL) and whole weight (WW), batch fecundity (eggs), annual proportion females mature (Fem. mat.), annual number of batches (N), and natural mortality at age (M). The CV of length was estimated by the assessment model; other values were treated as input.

Age	Avg. TL (mm)	Avg. TL (in)	CV length	Avg. WW (kg)	Avg. WW (lb)	fecundity (eggs E12)	Fem. mat.	Batches	M
1	228.3	9.0	0.16	0.15	0.33	0.03	0.911	34.0	0.341
2	259.7	10.2	0.16	0.22	0.48	0.05	0.988	44.5	0.304
3	287.6	11.3	0.16	0.29	0.65	0.06	0.994	44.5	0.278
4	312.3	12.3	0.16	0.37	0.83	0.07	0.996	44.5	0.258
5	334.2	13.2	0.16	0.46	1.01	0.08	0.997	44.5	0.243
6	353.6	13.9	0.16	0.54	1.19	0.09	0.997	44.5	0.231
7	370.8	14.6	0.16	0.62	1.36	0.10	0.998	44.5	0.222
8	386.1	15.2	0.16	0.69	1.53	0.10	0.998	44.5	0.214
9	399.7	15.7	0.16	0.77	1.69	0.11	0.998	44.5	0.208
10	411.7	16.2	0.16	0.84	1.85	0.12	0.998	44.5	0.202
11	422.4	16.6	0.16	0.90	1.99	0.12	0.999	44.5	0.198
12	431.8	17.0	0.16	0.96	2.12	0.13	1.000	44.5	0.194

Table 2. Observed time series of landings (L) and discards (D) for commercial handlines (cH), commercial historic trawl (cHTR), commercial other (cO), recreational headboat (HB), and general recreational (GR). Commercial landings are in units of 1000 lb whole weight. Recreational landings and all discards are in units of 1000 fish. Discards include all released fish, live or dead.

Year	L.cH	L.cHTR	L.cO	L.HB	L.GR	D.cH	D.HB	D.GR
1947	.	.	.	12.527	4.966	.	0.218	0.814
1948	.	.	.	25.057	9.933	.	0.436	1.629
1949	.	.	.	37.587	14.900	.	0.654	2.443
1950	.	.	.	50.117	19.867	.	0.872	3.257
1951	.	.	.	62.647	24.834	.	1.090	4.072
1952	.	.	.	75.177	29.801	.	1.308	4.886
1953	.	.	.	87.707	34.768	.	1.526	5.700
1954	.	.	.	100.237	39.735	.	1.743	6.515
1955	.	.	.	112.767	44.702	.	1.962	7.329
1956	.	.	.	123.788	49.071	.	2.153	8.045
1957	.	.	.	134.809	53.440	.	2.345	8.762
1958	0.192	.	.	145.830	57.809	.	2.537	9.478
1959	1.248	.	.	156.851	62.178	.	2.728	10.194
1960	1.728	.	.	167.871	66.546	.	2.920	10.910
1961	19.099	24.030	.	183.073	72.573	.	3.184	11.898
1962	11.785	41.524	.	198.275	78.599	.	3.449	12.886
1963	19.251	.	.	213.477	84.625	.	3.713	13.874
1964	6.460	.	.	228.679	90.651	.	3.977	14.862
1965	19.052	.	.	243.881	96.678	.	4.242	15.850
1966	2.703	.	.	245.309	97.244	.	4.267	15.943
1967	14.012	.	.	246.738	97.810	.	4.292	16.036
1968	31.857	.	.	248.166	98.376	.	4.316	16.129
1969	31.090	.	.	249.595	98.943	.	4.341	16.222
1970	19.502	.	.	251.023	99.509	.	4.366	16.315
1971	66.083	.	0.520	275.832	109.344	.	4.798	17.927
1972	68.050	.	12.009	300.642	119.178	.	5.229	19.539
1973	56.683	.	6.337	325.451	129.013	.	5.661	21.152
1974	115.844	.	2.904	350.261	138.848	.	6.093	22.764
1975	191.279	.	3.267	375.070	148.683	.	6.524	24.377
1976	157.933	.	7.812	379.302	150.360	.	6.598	24.652
1977	263.456	.	11.592	383.534	152.038	.	6.671	24.926
1978	344.209	.	1.325	387.767	153.716	.	6.745	25.202
1979	430.151	.	54.530	391.999	155.393	.	6.818	25.477
1980	489.648	.	261.272	396.231	157.071	.	6.892	25.752
1981	508.210	.	239.680	270.987	13.531	.	4.714	17.341
1982	681.378	.	209.285	362.321	134.141	.	6.302	8.931
1983	637.587	.	151.942	399.040	338.756	.	6.941	0.154
1984	753.487	.	100.104	324.429	91.692	.	5.643	2.510
1985	933.360	.	10.953	529.803	345.012	.	9.215	3.543
1986	906.542	.	12.952	533.101	47.062	.	9.273	8.719

Table 2. (continued)

Year	L.cH	L.cHTR	L.cO	L.HB	L.GR	D.cH	D.HB	D.GR
1987	719.357	.	29.039	731.007	128.160	.	12.715	0.974
1988	894.212	.	90.390	740.891	115.303	.	12.887	26.302
1989	1118.347	.	12.239	661.251	228.391	.	11.502	61.120
1990	1206.455	.	80.901	655.859	133.755	.	11.408	76.684
1991	1351.568	.	39.643	600.501	161.196	.	10.445	43.992
1992	744.796	.	0.206	345.266	82.532	26.572	27.400	46.925
1993	866.172	.	6.175	327.027	98.732	62.642	25.952	43.353
1994	948.450	.	6.636	369.720	53.693	74.121	29.340	55.261
1995	926.075	.	1.439	354.766	60.380	80.544	28.153	104.743
1996	720.280	.	22.496	340.340	66.743	78.867	27.009	24.159
1997	759.697	.	0.815	364.742	80.685	73.417	28.945	23.339
1998	708.816	.	0.390	341.563	63.178	54.564	27.106	51.378
1999	878.397	.	1.266	381.936	122.371	45.407	32.867	202.429
2000	1342.816	.	4.349	428.235	191.625	45.366	36.851	203.888
2001	1627.673	.	2.124	418.876	167.203	55.847	36.046	98.833
2002	1325.245	.	3.415	335.543	133.113	113.361	28.875	99.155
2003	728.651	.	0.341	251.796	160.568	43.385	21.668	158.263
2004	1085.962	.	0.200	329.081	189.290	29.329	33.428	96.826
2005	1098.115	.	0.830	275.450	103.565	27.942	19.951	61.210
2006	826.287	.	1.161	344.724	197.160	20.611	29.009	68.337
2007	1061.664	.	3.070	507.970	107.089	19.972	48.554	128.183
2008	1187.954	.	3.242	262.851	225.754	39.602	50.385	412.838
2009	892.184	.	1.844	225.311	178.308	30.741	53.094	144.996
2010	927.915	.	16.537	138.405	71.786	40.574	35.992	71.974
2011	968.581	.	20.171	133.402	72.510	29.922	34.543	25.202
2012	956.978	.	8.916	124.043	54.663	17.314	29.999	40.264
2013	957.748	.	5.417	107.125	80.599	23.396	17.835	6.542
2014	920.263	.	1.085	135.572	199.208	21.632	25.978	66.513
2015	881.323	.	2.160	119.031	143.341	19.926	37.329	92.660
2016	817.474	.	1.447	250.434	195.465	13.411	37.695	101.791

Table 3. Observed indices of abundance and CVs (CV) from commercial handlines (U.cH), headboat (U.HB), general rec (U.GR), SERFS chevron trap/video (U.CVID), MARMAP Florida snapper trap (U.FST).

Year	U.cH	U.cH CV	U.HB	U.HB CV	U.GR	U.GR CV	U.CVID	U.CVID CV	U.FST	U.FST CV
1976	.	.	1.25	0.21	.	.	.	.	.	.
1977	.	.	1.06	0.23	.	.	.	.	.	.
1978	.	.	1.65	0.18	.	.	.	.	.	.
1979	.	.	1.59	0.20	.	.	.	.	.	.
1980	.	.	0.92	0.24	.	.	.	.	.	.
1981	.	.	1.05	0.24	.	.	.	.	.	.
1982	.	.	0.88	0.23	.	.	.	.	.	.
1983	.	.	1.32	0.17	.	.	.	.	1.43	0.30
1984	.	.	1.10	0.20	.	.	.	.	0.72	0.28
1985	.	.	1.34	0.18	.	.	.	.	1.18	0.27
1986	.	.	1.10	0.16	.	.	.	.	1.18	0.24
1987	.	.	1.36	0.16	1.21	0.30	.	.	0.50	0.25
1988	.	.	1.45	0.16	0.83	0.19	.	.	.	.
1989	.	.	1.15	0.21	0.98	0.16	.	.	.	.
1990	.	.	1.16	0.20	1.86	0.25	0.59	0.37	.	.
1991	.	.	1.06	0.21	1.50	0.20	3.04	0.29	.	.
1992	.	.	0.50	0.25	0.95	0.16	1.12	0.34	.	.
1993	0.65	0.28	0.49	0.26	0.93	0.14	1.27	0.32	.	.
1994	0.73	0.25	0.49	0.28	0.65	0.11	2.23	0.30	.	.
1995	0.85	0.22	0.53	0.28	0.83	0.20	1.63	0.31	.	.
1996	0.74	0.25	0.57	0.27	1.20	0.20	1.12	0.34	.	.
1997	0.85	0.25	0.82	0.29	0.68	0.15	0.76	0.36	.	.
1998	0.83	0.26	0.68	0.25	0.90	0.12	0.74	0.35	.	.
1999	1.02	0.26	0.81	0.25	1.14	0.09	1.10	0.35	.	.
2000	1.22	0.26	1.02	0.25	1.14	0.10	1.39	0.33	.	.
2001	1.25	0.24	1.06	0.24	1.07	0.09	1.31	0.33	.	.
2002	1.18	0.24	1.19	0.23	0.91	0.10	1.82	0.31	.	.
2003	0.95	0.30	0.74	0.30	1.09	0.10	0.51	0.41	.	.
2004	1.09	0.30	1.04	0.21	1.16	0.13	0.68	0.37	.	.
2005	1.29	0.28	0.94	0.27	0.68	0.21	0.71	0.36	.	.
2006	1.07	0.30	1.00	0.24	0.97	0.17	0.45	0.40	.	.
2007	1.08	0.27	0.89	0.25	0.56	0.12	1.01	0.35	.	.
2008	1.18	0.27	0.80	0.26	0.74	0.15	0.97	0.35	.	.
2009	.	.	.	.	.	.	1.02	0.34	.	.
2010	.	.	.	.	.	.	0.62	0.35	.	.
2011	.	.	.	.	.	.	0.55	0.28	.	.
2012	.	.	.	.	.	.	0.40	0.30	.	.
2013	.	.	.	.	.	.	0.26	0.31	.	.
2014	.	.	.	.	.	.	0.40	0.38	.	.
2015	.	.	.	.	.	.	0.54	0.27	.	.
2016	.	.	.	.	.	.	0.77	0.28	.	.

Table 4. Sample sizes (number fish, nf) of length compositions (lc) or age compositions (ac) by fleet or survey. Data sources are commercial handlines (cH), commercial other (cO), headboat (HB), general recreational (GR), headboat discards (HB.D), and SERFS chevron trap (CVT). Years shown are those used in the assessment model.

Year	lc.cH.nf	lc.HB.D.nf	ac.cH.nf	ac.HB.nf	ac.GR.nf	ac.CVT.nf
1976	.	.	.	.	.	.
1977	.	.	.	.	.	.
1978	.	.	.	.	.	.
1979	.	.	.	.	.	.
1980	.	.	.	.	.	.
1981	.	.	.	107	.	.
1982	.	.	.	.	.	.
1983	.	.	.	.	.	.
1984	8353	.	.	.	.	.
1985	9818	.	.	.	.	.
1986	7880	.	.	88	.	.
1987	7112	.	.	.	.	.
1988	5554	.	.	.	.	.
1989	5620	.	.	.	.	.
1990	5845	.	.	.	.	843
1991	9384	.	.	157	.	3079
1992	.	.	82	40	.	1345
1993	.	.	.	39	.	1339
1994	.	.	135	250	.	3604
1995	.	.	313	174	.	1795
1996	.	.	.	62	.	3191
1997	.	.	43	.	.	1898
1998	.	.	100	.	.	1381
1999	.	.	122	.	.	781
2000	.	.	179	.	.	1772
2001	.	.	222	.	.	1404
2002	.	.	.	.	188	1833
2003	.	.	133	102	369	276
2004	.	176	313	308	268	411
2005	.	652	764	487	299	791
2006	.	514	2765	702	220	416
2007	.	1013	4930	806	.	1274
2008	.	1091	3649	372	.	676
2009	.	1486	2315	678	.	973
2010	.	755	3769	791	.	611
2011	.	730	4739	275	.	967
2012	.	626	3985	613	.	511
2013	.	405	3159	948	41	472
2014	.	325	2929	895	.	1103
2015	.	601	2907	770	106	2072
2016	.	1002	3083	1789	.	2174

Table 5. Sample sizes (number trips, n) of length compositions (lc) or age compositions (ac) by fleet or survey. Data sources are commercial handlines (cH), commercial other (cO), headboat (HB), general recreational (GR), headboat discards (HB.D), and SERFS chevron trap (CVT). Years shown are those used in the assessment model.

Year	lc.cH.n	lc.HB.D.n	ac.cH.n	ac.HB.n	ac.GR.n	ac.CVT.n
1976	.	.	.	.	.	.
1977	.	.	.	.	.	.
1978	.	.	.	.	.	.
1979	.	.	.	.	.	.
1980	.	.	.	.	.	.
1981	.	.	.	31	.	.
1982	.	.	.	.	.	.
1983	.	.	.	.	.	.
1984	162	.	.	.	.	.
1985	197	.	.	.	.	.
1986	142	.	.	17	.	.
1987	163	.	.	.	.	.
1988	133	.	.	.	.	.
1989	129	.	.	.	.	.
1990	126	.	.	.	.	108
1991	183	.	.	52	.	153
1992	.	.	10	21	.	111
1993	.	.	.	19	.	128
1994	.	.	18	68	.	177
1995	.	.	22	50	.	135
1996	.	.	.	19	.	170
1997	.	.	11	.	.	119
1998	.	.	15	.	.	113
1999	.	.	14	.	.	80
2000	.	.	16	.	.	114
2001	.	.	11	.	.	95
2002	.	.	.	.	47	121
2003	.	.	14	33	59	41
2004	.	16	53	86	58	70
2005	.	69	87	109	42	80
2006	.	65	265	171	28	57
2007	.	74	445	200	.	83
2008	.	90	382	123	.	70
2009	.	70	289	165	.	85
2010	.	53	251	140	.	114
2011	.	49	290	97	.	115
2012	.	64	266	102	.	140
2013	.	53	223	182	16	107
2014	.	50	197	158	.	165
2015	.	76	213	128	19	295
2016	.	82	211	296	.	394

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
1946	6601.77	4694.25	3463.70	2623.05	2026.56	1589.37	1261.55	1010.39	815.74	662.55	541.36	2518.51	27808.80
1947	6601.77	4694.04	3462.49	2621.76	2025.54	1588.57	1260.91	1009.88	815.33	662.21	541.09	2517.24	27800.83
1948	6601.17	4693.84	3460.84	2619.25	2023.53	1586.99	1259.66	1008.89	814.53	661.56	540.56	2514.78	27785.59
1949	6600.32	4693.00	3457.97	2615.11	2019.56	1583.84	1257.16	1006.89	812.92	660.26	539.50	2509.85	27756.39
1950	6598.95	4691.98	3454.63	2610.05	2014.33	1579.15	1253.42	1003.90	810.51	658.31	537.91	2502.46	27715.62
1951	6597.15	4690.60	3451.15	2604.63	2008.40	1573.48	1248.46	999.91	807.30	655.71	535.79	2492.62	27665.17
1952	6594.95	4688.90	3447.38	2599.08	2002.18	1567.25	1242.72	994.95	803.28	652.45	533.13	2480.33	27606.60
1953	6592.40	4686.91	3443.36	2593.31	1995.85	1560.80	1236.54	989.37	798.49	648.55	529.95	2465.61	27541.16
1954	6589.55	4684.68	3439.11	2587.34	1989.35	1554.27	1230.19	983.45	793.20	644.03	526.25	2448.47	27469.90
1955	6586.43	4682.23	3434.67	2581.18	1982.69	1547.59	1223.77	977.39	787.64	639.11	522.04	2428.95	27393.68
1956	6583.07	4679.57	3430.04	2574.85	1975.88	1540.79	1217.24	971.27	781.97	633.97	517.52	2407.07	27313.24
1957	6579.54	4676.80	3425.57	2568.72	1969.17	1534.05	1210.76	965.19	776.36	628.82	512.88	2383.33	27231.21
1958	6575.88	4673.90	3421.01	2562.71	1962.61	1527.40	1204.33	959.15	770.78	623.73	508.24	2358.00	27147.73
1959	6572.12	4670.91	3416.32	2556.59	1956.11	1520.83	1197.95	953.14	765.22	618.65	503.64	2331.38	27062.87
1960	6568.25	4667.85	3411.56	2550.37	1949.46	1514.23	1191.57	947.12	759.65	613.56	499.03	2303.61	26976.24
1961	6564.27	4664.70	3406.72	2544.08	1942.77	1507.56	1185.20	941.13	754.09	608.48	494.43	2275.03	26888.46
1962	6559.36	4621.56	3386.29	2536.53	1934.01	1498.62	1176.99	933.73	747.43	602.50	489.10	2242.42	26728.54
1963	6553.04	4588.40	3340.69	2517.47	1926.09	1490.48	1168.95	926.43	740.89	596.65	483.86	2209.73	26542.67
1964	6546.77	4652.18	3337.72	2479.55	1908.26	1481.47	1160.32	918.30	733.66	590.27	478.22	2174.80	26461.53
1965	6541.76	4647.16	3380.47	2473.71	1877.84	1466.98	1152.74	911.07	726.86	584.23	472.88	2140.99	26376.69
1966	6536.60	4643.02	3373.15	2501.45	1869.79	1440.30	1138.83	903.03	719.48	577.49	466.97	2104.56	26274.66
1967	6531.81	4639.27	3369.59	2495.59	1891.60	1435.43	1119.17	892.98	713.81	572.16	462.02	2072.42	26195.86
1968	6527.64	4635.78	3366.31	2492.27	1885.86	1450.70	1114.23	876.66	705.13	567.06	457.28	2040.40	26119.32
1969	6523.45	4632.73	3363.22	2489.09	1881.50	1444.12	1124.34	871.44	691.17	559.30	452.51	2007.70	26040.58
1970	6519.49	4629.67	3360.47	2486.25	1878.74	1440.53	1119.05	879.19	686.94	548.14	446.24	1977.23	25971.92
1971	6516.21	4626.78	3357.75	2483.80	1877.15	1439.32	1117.00	875.63	693.51	545.14	437.62	1948.98	25918.88
1972	6511.87	4622.66	3349.33	2475.09	1867.16	1429.89	1109.60	868.96	686.70	547.17	432.70	1908.24	25809.38
1973	6505.60	4599.58	3333.28	2462.45	1855.96	1418.64	1099.50	860.99	679.73	540.41	433.21	1866.97	25656.33
1974	6498.52	4603.52	3313.70	2444.21	1842.80	1407.79	1089.08	851.79	672.42	534.08	427.18	1831.51	25516.61
1975	6490.02	4603.17	3312.06	2422.53	1819.54	1387.91	1072.97	837.64	660.44	524.53	419.13	1785.54	25335.48
1976	6146.03	4595.46	3304.74	2413.51	1792.08	1358.45	1048.42	817.92	643.71	510.61	407.99	1727.38	24766.30
1977	6244.90	4343.96	3294.20	2406.27	1786.29	1339.88	1027.72	800.42	629.50	498.43	397.77	1675.61	24444.97
1978	5810.04	4406.95	3108.64	2394.20	1769.37	1322.10	1003.20	776.51	609.67	482.40	384.27	1610.16	23677.51
1979	5515.45	4115.45	3156.50	2255.12	1750.35	1298.11	981.00	751.17	586.14	463.00	368.57	1534.94	22775.79
1980	5795.62	3819.47	2910.60	2284.12	1637.09	1270.65	952.83	726.63	560.91	440.35	349.94	1449.20	22197.41
1981	5588.85	3666.47	2576.51	2098.90	1646.56	1176.70	923.29	698.67	537.14	417.16	329.48	1355.98	21015.69
1982	5524.19	3562.53	2516.29	1895.44	1539.00	1201.88	868.15	687.37	524.35	405.57	316.88	1289.64	20331.28
1983	7315.37	3558.51	2429.84	1817.06	1347.43	1079.94	851.88	620.88	495.56	380.33	295.95	1180.81	21373.54
1984	5289.18	4890.44	2438.21	1717.38	1260.94	922.20	746.49	594.14	436.52	350.51	270.63	1058.41	19975.07
1985	6353.41	3599.05	3443.78	1770.27	1210.87	869.30	641.69	524.08	420.48	310.79	251.06	958.84	20353.63

Table 6. (continued)

Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
1986	6278.57	4466.19	2503.64	2390.64	1170.79	771.93	558.77	416.15	342.62	276.55	205.64	806.33	20187.81
1987	4200.40	4421.62	3159.53	1779.88	1614.79	760.08	505.19	368.96	277.00	229.44	186.31	686.72	18189.91
1988	8635.74	2923.92	3058.49	2192.33	1184.94	1041.75	494.61	331.68	244.19	184.44	153.69	589.02	21034.81
1989	8709.66	5911.18	1989.76	2094.10	1416.73	730.73	647.39	310.14	209.68	155.31	118.02	478.71	22771.42
1990	4070.06	6146.26	4074.16	1353.00	1305.59	823.61	427.42	382.10	184.56	125.54	93.56	362.11	19347.97
1991	5703.00	2875.57	4277.09	2788.77	815.51	716.93	454.25	237.85	214.38	104.18	71.30	260.69	18519.52
1992	6972.43	4027.07	1995.92	2914.54	1628.20	423.73	373.47	238.72	126.02	114.28	55.87	179.34	19049.60
1993	6612.56	4955.93	2918.24	1367.36	1821.51	1029.99	271.49	241.62	155.76	82.75	75.51	156.56	19689.27
1994	4178.99	4700.07	3593.97	1970.01	821.44	1107.89	634.75	168.99	151.71	98.44	52.63	148.66	17627.56
1995	3887.06	2970.39	3403.95	2412.32	1167.63	493.08	673.92	390.03	104.75	94.66	61.81	127.34	15786.95
1996	5086.70	2762.93	2130.95	2263.18	1446.24	709.81	303.95	419.82	245.18	66.30	60.30	121.38	15616.74
1997	6201.22	3615.56	1998.59	1441.29	1400.09	906.83	451.23	195.25	272.12	159.99	43.54	120.20	16805.92
1998	8335.64	4407.39	2613.79	1335.14	863.92	849.75	557.94	280.53	122.48	171.85	101.70	104.87	19744.98
1999	6868.04	5924.56	3186.80	1758.72	806.72	528.40	526.66	349.30	177.17	77.86	109.94	133.01	20447.18
2000	6144.39	4882.59	4199.35	2034.10	1020.51	476.69	316.84	319.23	213.69	109.14	48.28	151.70	19916.51
2001	6004.21	4368.02	3454.94	2575.54	1052.49	537.46	254.74	171.15	174.04	117.30	60.31	111.37	18881.57
2002	10063.52	4268.35	3115.76	2087.65	1235.21	513.25	265.82	127.31	86.31	88.36	59.95	88.37	21999.86
2003	4066.19	7154.31	3039.13	1899.41	1047.66	631.35	266.35	139.51	67.46	46.06	47.48	80.27	18485.18
2004	3836.16	2890.82	5122.70	1993.31	1135.02	636.92	389.24	165.92	87.69	42.68	29.33	81.93	16411.73
2005	4974.93	2727.25	2076.10	3311.64	1121.27	648.95	369.11	227.84	97.97	52.11	25.53	67.04	15699.75
2006	10230.85	3536.92	1962.56	1361.07	1919.73	660.79	387.67	222.73	138.70	60.03	32.14	57.51	20570.70
2007	6911.28	7272.89	2524.25	1253.48	786.55	1128.09	393.64	233.29	135.22	84.76	36.92	55.52	20815.89
2008	11599.58	4914.22	5275.59	1517.37	634.48	405.49	590.44	208.36	124.67	72.78	45.93	50.47	25439.39
2009	4289.30	8247.88	3523.97	3147.44	764.94	327.18	212.95	314.29	112.15	67.66	39.81	53.14	21100.71
2010	3722.70	3049.92	6007.87	2309.13	1844.49	456.32	198.07	130.36	194.26	69.83	42.43	58.72	18084.08
2011	6059.12	2647.05	2234.99	4150.05	1444.48	1172.73	294.09	128.98	85.67	128.55	46.52	67.88	18460.11
2012	3639.99	4308.37	1941.46	1556.38	2657.56	939.95	773.37	195.92	86.70	57.98	87.59	78.51	16323.78
2013	3790.45	2588.23	3157.62	1346.57	989.65	1717.60	615.73	511.79	130.82	58.28	39.24	113.14	15059.12
2014	5019.52	2695.22	1902.88	2204.14	852.57	636.17	1118.28	404.80	339.39	87.33	39.16	103.16	15402.61
2015	5521.39	3569.14	1967.04	1273.35	1350.99	531.71	402.46	715.17	261.33	220.69	57.18	93.94	15964.38
2016	5501.27	3926.00	2596.77	1306.09	772.51	834.84	333.56	255.37	458.27	168.71	143.50	99.03	16395.93
2017	5752.11	3911.67	2855.52	1675.14	763.32	459.74	504.26	203.74	157.49	284.68	105.54	152.72	16825.93

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
1946	2194.9	2269.9	2252.0	2167.1	2039.3	1885.0	1718.1	1547.4	1381.2	1222.7	1076.3	5339.6	25093.7
1947	2194.9	2269.9	2251.4	2166.3	2038.2	1883.9	1717.2	1546.8	1380.5	1222.2	1075.6	5337.0	25083.5
1948	2194.7	2269.7	2250.3	2164.1	2036.2	1882.1	1715.6	1545.2	1379.2	1220.9	1074.5	5331.7	25064.1
1949	2194.3	2269.2	2248.5	2160.8	2032.2	1878.3	1712.1	1542.1	1376.3	1218.5	1072.5	5321.3	25026.2
1950	2193.8	2268.8	2246.3	2156.6	2026.9	1872.8	1707.0	1537.5	1372.4	1215.0	1069.2	5305.6	24972.0
1951	2193.4	2268.1	2243.9	2151.9	2021.0	1866.0	1700.2	1531.3	1366.9	1210.1	1065.1	5284.7	24903.0
1952	2192.5	2267.2	2241.4	2147.5	2014.6	1858.7	1692.5	1523.8	1360.0	1204.2	1059.8	5258.7	24821.2
1953	2191.6	2266.4	2238.8	2142.7	2008.4	1851.0	1684.1	1515.2	1352.1	1196.9	1053.6	5227.6	24728.2
1954	2190.7	2265.3	2236.1	2137.8	2001.8	1843.3	1675.3	1506.2	1343.1	1188.5	1046.1	5191.2	24625.4
1955	2189.6	2264.1	2233.3	2132.5	1995.2	1835.3	1666.7	1496.9	1333.6	1179.5	1037.7	5149.8	24514.3
1956	2188.5	2262.8	2230.2	2127.5	1988.1	1827.2	1657.7	1487.7	1324.1	1170.0	1028.9	5103.5	24396.1
1957	2187.4	2261.5	2227.3	2122.4	1981.5	1819.3	1648.8	1478.2	1314.6	1160.5	1019.6	5053.0	24274.2
1958	2186.1	2260.0	2224.5	2117.3	1974.9	1811.3	1640.2	1468.9	1305.1	1151.0	1010.4	4999.4	24149.4
1959	2185.0	2258.6	2221.4	2112.2	1968.3	1803.6	1631.4	1459.9	1295.7	1141.8	1001.1	4943.0	24022.0
1960	2183.7	2257.1	2218.3	2107.2	1961.7	1795.9	1622.8	1450.6	1286.2	1132.3	992.1	4884.1	23891.7
1961	2182.4	2255.5	2215.0	2101.9	1954.8	1787.9	1614.2	1441.4	1276.9	1123.0	982.8	4823.5	23759.4
1962	2180.8	2234.8	2201.8	2095.7	1946.0	1777.4	1603.0	1430.1	1265.5	1112.0	972.2	4754.3	23573.4
1963	2178.6	2218.7	2172.2	2080.1	1938.1	1767.7	1592.0	1418.9	1254.4	1101.2	961.9	4685.0	23368.6
1964	2176.6	2249.6	2170.2	2048.8	1920.2	1756.9	1580.3	1406.5	1242.3	1089.3	950.6	4611.0	23201.9
1965	2174.9	2247.2	2198.0	2043.9	1889.6	1739.7	1569.9	1395.3	1230.6	1078.3	940.1	4539.3	23046.7
1966	2173.1	2245.2	2193.2	2066.8	1881.4	1708.1	1551.0	1383.0	1218.3	1065.7	928.4	4461.9	22876.3
1967	2171.6	2243.2	2191.0	2062.0	1903.5	1702.4	1524.3	1367.7	1208.6	1056.0	918.4	4393.8	22742.2
1968	2170.2	2241.7	2188.7	2059.1	1897.7	1720.5	1517.4	1342.6	1194.0	1046.5	909.0	4325.9	22613.5
1969	2168.7	2240.1	2186.8	2056.5	1893.3	1712.6	1531.3	1334.7	1170.2	1032.2	899.5	4256.7	22482.7
1970	2167.4	2238.6	2185.0	2054.3	1890.5	1708.4	1524.1	1346.6	1163.2	1011.7	887.1	4192.1	22368.5
1971	2166.3	2237.3	2183.2	2052.3	1888.9	1707.0	1521.2	1341.1	1174.2	1006.0	869.9	4132.1	22279.7
1972	2164.9	2235.3	2177.7	2045.0	1878.8	1695.8	1511.0	1330.9	1162.7	1009.7	860.2	4045.7	22118.1
1973	2162.7	2224.0	2167.4	2034.4	1867.5	1682.3	1497.4	1318.6	1150.8	997.4	861.1	3958.2	21922.6
1974	2160.5	2226.0	2154.6	2019.4	1854.3	1669.6	1483.3	1304.5	1138.5	985.7	849.2	3883.0	21728.8
1975	2157.7	2225.8	2153.5	2001.6	1830.9	1646.0	1461.2	1282.9	1118.2	968.0	833.1	3785.6	21464.9
1976	2043.2	2222.0	2148.8	1994.1	1803.4	1611.1	1427.9	1252.7	1090.0	942.3	811.1	3662.3	21008.7
1977	2076.1	2100.6	2142.0	1988.1	1797.4	1589.1	1399.7	1226.0	1065.9	919.8	790.8	3552.5	20647.8
1978	1931.7	2131.0	2021.2	1978.2	1780.5	1567.9	1366.2	1189.2	1032.2	890.2	763.9	3413.9	20066.3
1979	1833.6	1990.1	2052.3	1863.1	1761.3	1539.5	1336.0	1150.4	992.5	854.5	732.6	3254.2	19360.6
1980	1926.8	1846.8	1892.4	1887.2	1647.3	1506.9	1297.6	1112.9	949.8	812.6	695.8	3072.6	18648.9
1981	1858.1	1773.0	1675.3	1734.2	1656.8	1395.5	1257.5	1070.1	909.4	769.9	655.0	2874.8	17629.5
1982	1836.7	1722.7	1636.1	1566.2	1548.5	1425.3	1182.3	1052.7	887.8	748.5	629.9	2734.2	16971.0
1983	2432.1	1720.7	1579.8	1501.3	1355.8	1280.7	1160.1	950.9	839.1	702.0	588.4	2503.6	16614.5
1984	1758.4	2364.7	1585.3	1418.9	1268.8	1093.7	1016.6	910.1	739.2	646.8	537.9	2244.1	15584.7
1985	2112.2	1740.3	2239.2	1462.5	1218.5	1030.9	873.9	802.7	711.9	573.6	499.1	2032.9	15297.9

Table 7. (continued)

Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
1986	2087.3	2159.6	1627.9	1975.1	1178.2	915.4	761.0	637.4	580.0	510.4	408.7	1709.5	14550.7
1987	1396.4	2138.0	2054.3	1470.5	1624.8	901.5	688.1	565.0	468.9	423.5	370.4	1455.9	13557.5
1988	2871.1	1413.8	1988.6	1811.3	1192.3	1235.5	673.5	507.9	413.4	340.4	305.6	1248.9	14002.4
1989	2895.6	2858.3	1293.7	1730.2	1425.5	866.6	881.6	475.1	354.9	286.6	234.6	1015.0	14317.9
1990	1353.2	2972.1	2649.1	1118.0	1313.7	976.9	582.0	585.1	312.4	231.7	186.1	767.6	13047.8
1991	1896.0	1390.5	2780.9	2304.1	820.6	850.3	618.6	364.2	362.9	192.2	141.8	552.7	12275.1
1992	2317.9	1947.3	1297.9	2408.1	1638.5	502.4	508.6	365.5	213.4	211.0	111.1	380.3	11901.9
1993	2198.5	2396.4	1897.5	1129.6	1832.9	1221.6	369.7	370.2	263.7	152.8	150.1	332.0	12314.8
1994	1389.4	2272.7	2336.9	1627.7	826.5	1314.0	864.4	258.8	256.8	181.7	104.7	315.3	11748.7
1995	1292.4	1436.3	2213.2	1993.2	1174.8	584.7	917.8	597.5	177.5	174.6	122.8	270.1	10954.8
1996	1691.2	1336.0	1385.6	1870.0	1455.3	841.7	414.0	643.1	415.1	122.4	119.9	257.3	10551.3
1997	2061.5	1748.3	1299.4	1190.9	1408.8	1075.4	614.4	298.9	460.8	295.2	86.6	254.9	10795.6
1998	2771.2	2131.2	1699.5	1103.2	869.3	1007.7	759.9	429.7	207.5	317.2	202.2	222.4	11720.7
1999	2283.3	2864.9	2072.1	1453.1	811.7	626.6	717.2	535.1	300.0	143.7	218.5	282.0	12308.2
2000	2042.8	2360.9	2730.4	1680.6	1026.9	565.3	431.4	489.0	361.8	201.5	95.9	321.7	12308.2
2001	1996.1	2112.2	2246.5	2127.9	1059.1	637.4	347.0	262.1	294.8	216.5	119.9	236.1	11655.4
2002	3345.7	2064.0	2025.8	1724.9	1243.0	608.7	362.0	194.9	146.2	163.1	119.3	187.4	12184.7
2003	1351.9	3459.5	1976.0	1569.3	1054.3	748.7	362.7	213.6	114.2	85.1	94.4	170.2	11199.9
2004	1275.4	1398.0	3330.7	1646.9	1142.2	755.3	530.0	254.2	148.4	78.7	58.4	173.7	10791.9
2005	1653.9	1318.8	1349.9	2736.2	1128.3	769.6	502.7	349.0	165.8	96.1	50.7	142.2	10263.2
2006	3401.3	1710.3	1276.0	1124.6	1931.7	783.7	528.0	341.1	234.8	110.9	63.9	121.9	11628.1
2007	2297.7	3516.8	1641.3	1035.7	791.5	1337.8	536.2	357.4	229.1	156.5	73.4	117.7	12090.6
2008	3856.3	2376.4	3430.2	1253.8	638.5	480.8	804.0	319.2	211.2	134.3	91.3	106.9	13702.8
2009	1426.0	3988.2	2291.3	2600.6	769.6	388.0	289.9	481.3	189.8	124.8	79.1	112.7	12741.6
2010	1237.7	1474.7	3906.4	1907.9	1856.1	541.2	269.8	199.7	328.9	129.0	84.4	124.6	12059.9
2011	2014.4	1280.0	1453.3	3428.9	1453.5	1390.9	400.6	197.5	145.1	237.2	92.6	144.0	12237.6
2012	1210.1	2083.4	1262.4	1286.0	2674.2	1114.7	1053.1	300.0	146.8	106.9	174.2	166.4	11578.2
2013	1260.2	1251.6	2053.2	1112.7	995.8	2037.1	838.6	783.7	221.6	107.6	78.0	239.9	10979.5
2014	1668.7	1303.4	1237.2	1821.0	857.8	754.4	1523.0	619.9	574.7	161.2	77.8	218.7	10818.1
2015	1835.6	1725.8	1278.9	1052.0	1359.4	630.5	548.1	1095.3	442.5	407.2	113.8	199.1	10688.7
2016	1829.0	1898.4	1688.5	1079.2	777.4	990.1	454.4	391.1	776.0	311.3	285.3	209.9	10690.2

Table 8. Estimated time series of status indicators, fishing mortality, and biomass. Fishing mortality rate is apical F. Total biomass (B, mt) is at the start of the year, and spawning biomass (SSB, mt) is at the time of peak spawning. The MSST *is defined as 75%*$\mathrm{SSB_{MSY}}$.

Year	F	F/F_{MSY}	B	B/B_{unfished}	SSB	$\mathrm{SSB/SSB_{MSY}}$	SSB/MSST
1946	0.000504	0.00123	11382	1.000	49.1	2.68	3.58
1947	0.001101	0.00268	11378	1.000	49.1	2.68	3.58
1948	0.002204	0.00537	11369	0.999	49.0	2.68	3.57
1949	0.003312	0.00807	11352	0.997	48.9	2.67	3.56
1950	0.004427	0.01079	11327	0.995	48.8	2.67	3.56
1951	0.005548	0.01352	11296	0.992	48.7	2.66	3.54
1952	0.006679	0.01627	11259	0.989	48.5	2.65	3.53
1953	0.007818	0.01905	11217	0.985	48.3	2.64	3.52
1954	0.008967	0.02185	11170	0.981	48.1	2.63	3.50
1955	0.010128	0.02468	11120	0.977	47.9	2.61	3.49
1956	0.011162	0.02720	11066	0.972	47.6	2.60	3.47
1957	0.012206	0.02974	11011	0.967	47.4	2.59	3.45
1958	0.013259	0.03231	10954	0.962	47.2	2.58	3.43
1959	0.014326	0.03491	10896	0.957	46.9	2.56	3.42
1960	0.015401	0.03753	10837	0.952	46.7	2.55	3.40
1961	0.016952	0.04131	10777	0.947	46.3	2.53	3.38
1962	0.020557	0.05009	10693	0.939	45.9	2.51	3.35
1963	0.020097	0.04897	10600	0.931	45.6	2.49	3.32
1964	0.021568	0.05255	10524	0.925	45.3	2.47	3.30
1965	0.023146	0.05640	10454	0.918	45.0	2.46	3.27
1966	0.023322	0.05683	10376	0.912	44.7	2.44	3.25
1967	0.023596	0.05749	10316	0.906	44.4	2.43	3.24
1968	0.023899	0.05823	10257	0.901	44.2	2.41	3.22
1969	0.024124	0.05878	10198	0.896	44.0	2.40	3.20
1970	0.024289	0.05918	10146	0.891	43.8	2.39	3.19
1971	0.029176	0.07109	10106	0.888	43.5	2.38	3.17
1972	0.031743	0.07735	10033	0.881	43.2	2.36	3.15
1973	0.033378	0.08133	9944	0.874	42.8	2.34	3.12
1974	0.040595	0.09892	9856	0.866	42.3	2.31	3.08
1975	0.049513	0.12065	9736	0.855	41.7	2.28	3.04
1976	0.048001	0.11696	9529	0.837	40.9	2.24	2.98
1977	0.058387	0.14227	9366	0.823	40.1	2.19	2.92
1978	0.067405	0.16424	9102	0.800	38.9	2.13	2.84
1979	0.078225	0.19061	8782	0.772	37.4	2.04	2.72
1980	0.116875	0.28478	8459	0.743	35.6	1.94	2.59
1981	0.109303	0.26633	7997	0.703	33.9	1.85	2.47
1982	0.113216	0.27587	7698	0.676	32.1	1.76	2.34
1983	0.138334	0.33707	7536	0.662	31.2	1.70	2.27
1984	0.131738	0.32100	7069	0.621	30.1	1.64	2.19
1985	0.211069	0.51430	6939	0.610	28.9	1.58	2.10

Table 8. (continued)

Year	F	F/F_{MSY}	B	B/B_{unfished}	SSB	$\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$	SSB/MSST
1986	0.193056	0.47041	6600	0.580	28.1	1.53	2.04
1987	0.198755	0.48429	6150	0.540	26.4	1.44	1.92
1988	0.244725	0.59631	6351	0.558	26.4	1.44	1.92
1989	0.305283	0.74387	6495	0.571	27.4	1.49	1.99
1990	0.364127	0.88725	5918	0.520	25.7	1.40	1.87
1991	0.421344	1.02667	5568	0.489	23.5	1.28	1.71
1992	0.214929	0.52371	5399	0.474	23.6	1.29	1.72
1993	0.254201	0.61940	5586	0.491	24.4	1.34	1.78
1994	0.267383	0.65152	5329	0.468	23.5	1.28	1.71
1995	0.254737	0.62070	4969	0.437	21.6	1.18	1.57
1996	0.223769	0.54525	4786	0.420	20.6	1.13	1.50
1997	0.256347	0.62463	4897	0.430	20.9	1.14	1.52
1998	0.248620	0.60580	5316	0.467	22.9	1.25	1.67
1999	0.286281	0.69757	5583	0.490	24.4	1.33	1.78
2000	0.400893	0.97683	5583	0.490	23.8	1.30	1.73
2001	0.476821	1.16184	5287	0.464	22.1	1.21	1.61
2002	0.431481	1.05137	5527	0.486	23.1	1.26	1.69
2003	0.256890	0.62595	5080	0.446	23.3	1.27	1.70
2004	0.317333	0.77323	4895	0.430	21.5	1.18	1.57
2005	0.287258	0.69995	4655	0.409	20.0	1.09	1.46
2006	0.290376	0.70754	5274	0.463	22.2	1.21	1.62
2007	0.422870	1.03039	5484	0.482	23.8	1.30	1.73
2008	0.426932	1.04028	6216	0.546	26.5	1.44	1.93
2009	0.276385	0.67345	5780	0.508	26.7	1.46	1.94
2010	0.211122	0.51443	5470	0.481	25.0	1.37	1.82
2011	0.187713	0.45739	5551	0.488	24.5	1.34	1.78
2012	0.194768	0.47458	5252	0.461	23.3	1.27	1.70
2013	0.199064	0.48505	4980	0.438	21.7	1.19	1.58
2014	0.231497	0.56408	4907	0.431	20.8	1.14	1.52
2015	0.241758	0.58908	4848	0.426	20.7	1.13	1.50
2016	0.279118	0.68011	4849	0.426	20.7	1.13	1.51
2017	.	.	4845	0.426	.	.	.

Table 9. Selectivity at age for MARMAP Florida snapper traps (FST), SERFS chevron trap/video index (CVID), historic commercial trawl (cHTR), commercial handlines (cH), headboat (HB), recreational (GR), commercial discard mortalities (D.cH), headboat discard mortalities (D.HB), selectivity of landings averaged across fisheries (L.avg), and selectivity of discard mortalities averaged across fisheries (D.avg). Selectivity of landings from the commercial combined was assumed equal to that from commercial handlines. The selectivity of discards from the general recreational fleet was assumed equal to that from the headboat fleet, and the selectivity for the commercial other fleet was assumed equal to that from commercial handlines. TL is total length. For time-varying selectivities, values shown are from the terminal assessment year.

Age	TL(mm)	TL(in)	FST	CVID	cHTR	cH	HB	GR	D.cH	D.HB	L.avg	D.avg	L.avg+D.avg
1	228.3	8.988	1	0.004	0.000	1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	259.7	10.225	0	0.373	0.001	0.5	0.031	0.031	0.269	0.334	0.008	0.044	0.052
3	287.6	11.321	0	1.000	0.295	0.0	0.867	0.867	1.000	1.000	0.414	0.134	0.549
4	312.3	12.294	0	0.997	0.996	0.0	0.999	0.999	0.977	0.455	0.932	0.068	1.000
5	334.2	13.156	0	0.989	1.000	0.0	1.000	1.000	0.910	0.343	0.935	0.053	0.988
6	353.6	13.921	0	0.975	1.000	0.0	1.000	1.000	0.808	0.264	0.935	0.042	0.977
7	370.8	14.600	0	0.955	1.000	0.0	1.000	1.000	0.684	0.207	0.935	0.034	0.969
8	386.1	15.201	0	0.931	1.000	0.0	1.000	1.000	0.553	0.168	0.935	0.028	0.962
9	399.7	15.735	0	0.902	1.000	0.0	1.000	1.000	0.426	0.139	0.935	0.022	0.957
10	411.7	16.208	0	0.869	1.000	0.0	1.000	1.000	0.313	0.117	0.935	0.018	0.953
11	422.4	16.628	0	0.833	1.000	0.0	1.000	1.000	0.219	0.101	0.935	0.015	0.950
12	431.8	17.001	0	0.794	1.000	0.0	1.000	1.000	0.147	0.089	0.935	0.013	0.948

Table 10. Estimated time series of fully selected fishing mortality rates for commercial handlines (F.cH), historic commercial trawl (F.cHTR), commercial other (F.cO), headboat (F.HB), general recreational (F.GR), commercial discard mortalities (F.cH.D), headboat discard mortalities (F.HB.D), and general recreational discard mortalities (F.GR.D). Also shown is apical F, the maximum F at age summed across fleets, which may not equal the sum of fully selected F's because of dome-shaped selectivities.

Year	F.cH	F.cHTR	F.cO	F.HB	F.GR	F.cH.D	F.HB.D	F.GR.D	Apical F
1946	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001
1947	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.001
1948	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.002
1949	0.000	0.000	0.000	0.002	0.001	0.000	0.000	0.000	0.003
1950	0.000	0.000	0.000	0.003	0.001	0.000	0.000	0.000	0.004
1951	0.000	0.000	0.000	0.004	0.001	0.000	0.000	0.001	0.006
1952	0.000	0.000	0.000	0.004	0.002	0.000	0.000	0.001	0.007
1953	0.000	0.000	0.000	0.005	0.002	0.000	0.000	0.001	0.008
1954	0.000	0.000	0.000	0.006	0.002	0.000	0.000	0.001	0.009
1955	0.000	0.000	0.000	0.006	0.003	0.000	0.000	0.001	0.010
1956	0.000	0.000	0.000	0.007	0.003	0.000	0.000	0.001	0.011
1957	0.000	0.000	0.000	0.008	0.003	0.000	0.000	0.001	0.012
1958	0.000	0.000	0.000	0.008	0.003	0.000	0.000	0.001	0.013
1959	0.000	0.000	0.000	0.009	0.004	0.000	0.000	0.001	0.014
1960	0.000	0.000	0.000	0.010	0.004	0.000	0.000	0.002	0.015
1961	0.001	0.009	0.000	0.011	0.004	0.000	0.000	0.002	0.017
1962	0.001	0.015	0.000	0.012	0.005	0.000	0.000	0.002	0.021
1963	0.001	0.000	0.000	0.013	0.005	0.000	0.001	0.002	0.020
1964	0.000	0.000	0.000	0.014	0.005	0.000	0.001	0.002	0.022
1965	0.001	0.000	0.000	0.015	0.006	0.000	0.001	0.002	0.023
1966	0.000	0.000	0.000	0.015	0.006	0.000	0.001	0.002	0.023
1967	0.001	0.000	0.000	0.015	0.006	0.000	0.001	0.002	0.024
1968	0.002	0.000	0.000	0.015	0.006	0.000	0.001	0.002	0.024
1969	0.002	0.000	0.000	0.015	0.006	0.000	0.001	0.002	0.024
1970	0.001	0.000	0.000	0.015	0.006	0.000	0.001	0.002	0.024
1971	0.005	0.000	0.000	0.017	0.007	0.000	0.001	0.003	0.029
1972	0.005	0.000	0.004	0.019	0.007	0.000	0.001	0.003	0.032
1973	0.004	0.000	0.002	0.020	0.008	0.000	0.001	0.003	0.033
1974	0.009	0.000	0.001	0.022	0.009	0.000	0.001	0.003	0.041
1975	0.015	0.000	0.001	0.024	0.010	0.000	0.001	0.004	0.050
1976	0.013	0.000	0.003	0.025	0.010	0.000	0.001	0.004	0.048
1977	0.022	0.000	0.004	0.026	0.010	0.000	0.001	0.004	0.058
1978	0.030	0.000	0.001	0.027	0.011	0.000	0.001	0.004	0.067
1979	0.039	0.000	0.023	0.028	0.011	0.000	0.001	0.004	0.078
1980	0.046	0.000	0.113	0.030	0.012	0.000	0.001	0.005	0.117
1981	0.050	0.000	0.107	0.021	0.001	0.000	0.001	0.003	0.109
1982	0.072	0.000	0.095	0.030	0.011	0.000	0.001	0.002	0.113
1983	0.073	0.000	0.056	0.035	0.030	0.000	0.001	0.000	0.138
1984	0.095	0.000	0.041	0.028	0.008	0.000	0.001	0.000	0.132
1985	0.132	0.000	0.004	0.048	0.031	0.000	0.002	0.001	0.211

Table 10. (continued)

Year	F.cH	F.cHTR	F.cO	F.HB	F.GR	F.cH.D	F.HB.D	F.GR.D	Apical F
1986	0.139	0.000	0.005	0.049	0.004	0.000	0.002	0.002	0.193
1987	0.118	0.000	0.014	0.068	0.012	0.000	0.002	0.000	0.199
1988	0.158	0.000	0.030	0.074	0.012	0.000	0.003	0.005	0.245
1989	0.218	0.000	0.002	0.063	0.022	0.000	0.002	0.010	0.305
1990	0.277	0.000	0.015	0.059	0.012	0.000	0.001	0.010	0.364
1991	0.336	0.000	0.007	0.061	0.016	0.000	0.002	0.007	0.421
1992	0.138	0.000	0.000	0.059	0.014	0.006	0.006	0.009	0.215
1993	0.172	0.000	0.001	0.058	0.018	0.013	0.004	0.007	0.254
1994	0.187	0.000	0.001	0.064	0.009	0.014	0.005	0.009	0.267
1995	0.175	0.000	0.000	0.060	0.010	0.016	0.005	0.020	0.255
1996	0.137	0.000	0.004	0.062	0.012	0.020	0.007	0.006	0.224
1997	0.158	0.000	0.000	0.073	0.016	0.020	0.007	0.005	0.256
1998	0.159	0.000	0.000	0.071	0.013	0.013	0.005	0.010	0.249
1999	0.198	0.000	0.000	0.056	0.018	0.009	0.005	0.029	0.286
2000	0.302	0.000	0.001	0.059	0.026	0.008	0.005	0.028	0.401
2001	0.380	0.000	0.000	0.062	0.025	0.011	0.006	0.016	0.477
2002	0.339	0.000	0.001	0.054	0.021	0.025	0.005	0.017	0.431
2003	0.185	0.000	0.000	0.038	0.024	0.008	0.003	0.020	0.257
2004	0.244	0.000	0.000	0.042	0.024	0.005	0.005	0.014	0.317
2005	0.222	0.000	0.000	0.042	0.016	0.007	0.004	0.013	0.287
2006	0.188	0.000	0.000	0.060	0.034	0.006	0.006	0.015	0.290
2007	0.280	0.000	0.001	0.103	0.022	0.004	0.010	0.026	0.423
2008	0.315	0.000	0.001	0.041	0.035	0.006	0.008	0.065	0.427
2009	0.199	0.000	0.000	0.034	0.027	0.004	0.008	0.022	0.276
2010	0.174	0.000	0.003	0.016	0.008	0.004	0.005	0.010	0.211
2011	0.150	0.000	0.003	0.017	0.009	0.004	0.007	0.005	0.188
2012	0.158	0.000	0.001	0.018	0.008	0.002	0.007	0.009	0.195
2013	0.166	0.000	0.001	0.016	0.012	0.003	0.004	0.001	0.199
2014	0.162	0.000	0.000	0.022	0.033	0.004	0.007	0.018	0.231
2015	0.174	0.000	0.000	0.022	0.026	0.004	0.010	0.024	0.242
2016	0.179	0.000	0.000	0.047	0.036	0.002	0.009	0.024	0.279

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

Year	1	2	3	4	5	6	7	8	9	10	11	12
1946	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1947	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1948	0.000	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
1949	0.000	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
1950	0.000	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
1951	0.000	0.004	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
1952	0.001	0.005	0.007	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
1953	0.001	0.006	0.008	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
1954	0.001	0.006	0.009	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
1955	0.001	0.007	0.010	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
1956	0.001	0.008	0.011	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
1957	0.001	0.009	0.012	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
1958	0.001	0.009	0.013	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
1959	0.001	0.010	0.014	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
1960	0.001	0.011	0.015	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
1961	0.010	0.016	0.017	0.016	0.017	0.017	0.016	0.016	0.016	0.016	0.016	0.016
1962	0.016	0.021	0.018	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
1963	0.002	0.014	0.020	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
1964	0.002	0.015	0.022	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
1965	0.002	0.016	0.023	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022
1966	0.002	0.017	0.023	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021
1967	0.002	0.017	0.024	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022
1968	0.002	0.017	0.024	0.023	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
1969	0.002	0.017	0.024	0.023	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
1970	0.002	0.017	0.024	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023
1971	0.002	0.019	0.027	0.027	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
1972	0.007	0.023	0.030	0.030	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.031
1973	0.005	0.024	0.032	0.032	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
1974	0.004	0.025	0.035	0.037	0.040	0.041	0.041	0.040	0.040	0.040	0.040	0.040
1975	0.004	0.027	0.038	0.043	0.049	0.050	0.049	0.049	0.049	0.049	0.049	0.049
1976	0.006	0.029	0.039	0.043	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048
1977	0.008	0.031	0.041	0.049	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058
1978	0.004	0.030	0.043	0.055	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067
1979	0.026	0.042	0.045	0.062	0.077	0.078	0.078	0.078	0.078	0.078	0.078	0.078
1980	0.117	0.090	0.049	0.069	0.087	0.088	0.088	0.088	0.088	0.088	0.088	0.088
1981	0.109	0.072	0.029	0.052	0.072	0.073	0.073	0.073	0.073	0.073	0.073	0.073
1982	0.099	0.079	0.048	0.083	0.111	0.113	0.113	0.113	0.113	0.113	0.113	0.113
1983	0.062	0.074	0.069	0.107	0.136	0.138	0.138	0.138	0.138	0.138	0.138	0.138
1984	0.044	0.047	0.042	0.091	0.129	0.132	0.132	0.132	0.132	0.132	0.132	0.132
1985	0.011	0.059	0.087	0.155	0.207	0.211	0.211	0.211	0.211	0.211	0.211	0.211

Table 11. (continued)

Year	1	2	3	4	5	6	7	8	9	10	11	12
1986	0.010	0.042	0.063	0.134	0.189	0.193	0.193	0.193	0.193	0.193	0.193	0.193
1987	0.021	0.065	0.087	0.149	0.195	0.199	0.199	0.199	0.199	0.199	0.199	0.199
1988	0.038	0.081	0.101	0.179	0.240	0.245	0.245	0.245	0.245	0.244	0.244	0.244
1989	0.008	0.068	0.108	0.214	0.299	0.305	0.305	0.305	0.305	0.305	0.305	0.305
1990	0.006	0.059	0.101	0.248	0.356	0.364	0.364	0.364	0.364	0.364	0.364	0.364
1991	0.007	0.061	0.106	0.280	0.412	0.421	0.421	0.421	0.421	0.421	0.421	0.421
1992	0.000	0.018	0.100	0.212	0.215	0.214	0.213	0.213	0.213	0.212	0.212	0.212
1993	0.000	0.017	0.115	0.252	0.254	0.253	0.252	0.251	0.251	0.251	0.250	0.250
1994	0.000	0.019	0.121	0.265	0.267	0.266	0.265	0.264	0.264	0.263	0.263	0.263
1995	0.000	0.028	0.130	0.254	0.255	0.253	0.251	0.250	0.249	0.249	0.249	0.248
1996	0.000	0.020	0.113	0.222	0.224	0.222	0.221	0.220	0.219	0.218	0.218	0.218
1997	0.000	0.020	0.125	0.254	0.256	0.255	0.253	0.252	0.252	0.251	0.251	0.250
1998	0.000	0.020	0.118	0.246	0.249	0.247	0.246	0.246	0.245	0.245	0.244	0.244
1999	0.000	0.040	0.171	0.286	0.283	0.280	0.279	0.277	0.276	0.276	0.275	0.275
2000	0.000	0.042	0.211	0.401	0.398	0.396	0.394	0.393	0.392	0.391	0.391	0.390
2001	0.000	0.034	0.226	0.477	0.475	0.473	0.472	0.471	0.470	0.469	0.469	0.469
2002	0.000	0.036	0.217	0.431	0.428	0.425	0.423	0.421	0.420	0.419	0.419	0.418
2003	0.000	0.030	0.144	0.257	0.255	0.253	0.251	0.250	0.250	0.249	0.249	0.249
2004	0.000	0.027	0.158	0.317	0.316	0.315	0.314	0.313	0.312	0.312	0.312	0.311
2005	0.000	0.025	0.144	0.287	0.286	0.284	0.283	0.282	0.282	0.281	0.281	0.281
2006	0.000	0.033	0.170	0.290	0.289	0.287	0.286	0.285	0.285	0.284	0.284	0.284
2007	0.000	0.017	0.231	0.423	0.420	0.416	0.414	0.413	0.411	0.411	0.410	0.409
2008	0.000	0.029	0.238	0.427	0.419	0.413	0.409	0.405	0.403	0.401	0.400	0.399
2009	0.000	0.013	0.145	0.276	0.274	0.271	0.269	0.267	0.266	0.265	0.264	0.263
2010	0.000	0.007	0.092	0.211	0.210	0.208	0.207	0.206	0.205	0.204	0.203	0.203
2011	0.000	0.006	0.084	0.188	0.187	0.185	0.184	0.183	0.182	0.182	0.181	0.181
2012	0.000	0.007	0.088	0.195	0.193	0.192	0.191	0.190	0.189	0.189	0.188	0.188
2013	0.000	0.004	0.081	0.199	0.199	0.198	0.197	0.197	0.196	0.196	0.195	0.195
2014	0.000	0.011	0.124	0.231	0.229	0.227	0.225	0.224	0.222	0.221	0.221	0.220
2015	0.000	0.014	0.131	0.242	0.238	0.235	0.233	0.231	0.230	0.228	0.228	0.227
2016	0.000	0.014	0.160	0.279	0.276	0.273	0.271	0.269	0.268	0.267	0.266	0.266

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

Year	1	2	3	4	5	6	7	8	9	10	11	12
1946	0.25	1.41	1.49	1.16	0.91	0.71	0.57	0.46	0.37	0.30	0.25	1.15
1947	0.49	2.73	2.89	2.25	1.75	1.38	1.10	0.89	0.72	0.58	0.48	2.23
1948	0.98	5.47	5.78	4.50	3.50	2.76	2.20	1.77	1.43	1.17	0.96	4.46
1949	1.47	8.22	8.68	6.75	5.25	4.14	3.30	2.66	2.15	1.75	1.43	6.68
1950	1.96	10.98	11.58	9.00	7.00	5.52	4.40	3.54	2.86	2.33	1.91	8.90
1951	2.46	13.75	14.49	11.25	8.74	6.89	5.49	4.41	3.57	2.91	2.38	11.11
1952	2.96	16.54	17.42	13.51	10.49	8.26	6.58	5.29	4.28	3.49	2.85	13.31
1953	3.47	19.36	20.36	15.77	12.24	9.63	7.66	6.15	4.98	4.06	3.32	15.48
1954	3.98	22.19	23.32	18.05	13.99	10.99	8.74	7.01	5.67	4.62	3.78	17.63
1955	4.49	25.04	26.30	20.33	15.74	12.36	9.82	7.87	6.36	5.18	4.24	19.75
1956	4.95	27.59	28.94	22.35	17.29	13.56	10.76	8.62	6.96	5.66	4.63	21.57
1957	5.41	30.15	31.60	24.38	18.84	14.76	11.70	9.36	7.55	6.14	5.01	23.35
1958	5.87	32.73	34.28	26.43	20.41	15.98	12.66	10.12	8.15	6.62	5.40	25.12
1959	6.34	35.33	36.98	28.57	22.09	17.28	13.67	10.92	8.79	7.13	5.81	26.97
1960	6.81	37.95	39.70	30.67	23.71	18.53	14.64	11.68	9.40	7.61	6.20	28.70
1961	54.86	58.60	43.64	35.04	27.85	21.79	17.21	13.72	11.02	8.92	7.26	33.48
1962	90.24	74.20	47.23	37.34	29.24	22.82	18.01	14.34	11.51	9.31	7.57	34.77
1963	8.84	48.47	50.65	40.81	32.37	25.24	19.89	15.82	12.69	10.25	8.33	38.10
1964	9.52	52.90	54.31	42.03	32.91	25.72	20.23	16.07	12.88	10.39	8.43	38.43
1965	10.19	56.63	59.06	46.00	36.08	28.40	22.42	17.79	14.23	11.47	9.30	42.21
1966	10.30	57.17	59.38	45.54	34.44	26.69	21.20	16.87	13.48	10.85	8.79	39.71
1967	10.39	57.71	60.04	46.92	36.51	27.91	21.86	17.51	14.03	11.28	9.13	41.02
1968	10.49	58.26	60.80	48.96	38.86	30.16	23.27	18.38	14.82	11.96	9.66	43.19
1969	10.59	58.80	61.33	49.31	39.06	30.24	23.65	18.40	14.64	11.88	9.63	42.80
1970	10.68	59.28	61.69	48.61	37.97	29.34	22.89	18.05	14.15	11.32	9.23	41.00
1971	12.81	65.75	68.51	57.73	47.17	36.56	28.50	22.43	17.82	14.04	11.30	50.41
1972	36.64	80.08	74.87	62.72	50.99	39.46	30.76	24.19	19.17	15.32	12.14	53.63
1973	26.63	82.17	81.04	66.46	53.25	41.10	32.00	25.15	19.92	15.88	12.75	55.07
1974	21.05	86.55	88.11	76.82	64.03	49.52	38.49	30.22	23.93	19.06	15.27	65.61
1975	23.03	93.90	96.22	88.96	76.69	59.37	46.12	36.14	28.58	22.76	18.22	77.79
1976	31.26	99.41	98.00	87.58	73.33	56.35	43.70	34.22	27.01	21.49	17.20	72.97
1977	39.98	99.64	102.25	100.46	88.33	67.37	51.92	40.60	32.02	25.43	20.33	85.81
1978	18.87	97.37	100.95	111.51	100.48	76.48	58.32	45.32	35.68	28.31	22.60	94.87
1979	122.04	133.89	108.55	118.20	114.69	86.77	65.90	50.65	39.64	31.40	25.05	104.50
1980	543.48	269.68	107.28	132.78	120.50	95.47	71.95	55.08	42.64	33.57	26.73	110.92
1981	491.85	211.90	55.10	92.87	100.63	73.76	58.18	44.20	34.08	26.54	21.00	86.60
1982	441.57	226.24	95.76	132.75	143.62	114.80	83.35	66.24	50.68	39.31	30.77	125.47
1983	371.51	216.34	138.76	162.99	152.51	124.73	98.87	72.34	57.90	44.56	34.74	138.88
1984	193.13	188.37	84.98	132.17	135.56	101.72	82.76	66.12	48.72	39.23	30.35	118.91
1985	61.34	172.86	244.62	224.76	201.72	148.07	109.84	90.05	72.45	53.70	43.46	166.29

Table 12. (continued)

Year	1	2	3	4	5	6	7	8	9	10	11	12
1986	51.04	149.98	127.27	264.43	179.28	121.20	88.18	65.92	54.43	44.05	32.82	128.93
1987	74.89	232.58	225.44	217.01	254.93	122.60	81.89	60.03	45.20	37.54	30.54	112.79
1988	273.59	182.19	236.63	314.54	224.88	202.22	96.49	64.95	47.95	36.32	30.32	116.43
1989	55.81	291.60	157.60	353.91	325.58	171.98	153.13	73.64	49.92	37.08	28.23	114.73
1990	22.04	258.04	303.88	261.18	348.49	225.27	117.49	105.43	51.06	34.83	26.01	100.84
1991	33.49	130.92	342.53	600.26	245.62	221.32	140.93	74.06	66.94	32.62	22.36	81.91
1992	2.23	18.00	131.32	479.68	275.34	72.18	63.91	41.01	21.71	19.75	9.67	31.11
1993	2.19	23.03	218.81	260.84	356.27	202.92	53.74	48.02	31.05	16.54	15.13	31.42
1994	1.34	21.10	277.95	393.00	167.82	227.99	131.24	35.08	31.59	20.56	11.01	31.17
1995	1.20	12.79	247.93	455.54	226.02	96.17	132.09	76.77	20.68	18.75	12.27	25.32
1996	1.65	12.48	142.00	378.54	248.66	122.99	52.93	73.41	43.00	11.66	10.63	21.44
1997	2.44	19.79	154.28	273.54	273.27	178.36	89.19	38.75	54.17	31.95	8.71	24.10
1998	3.06	22.52	195.80	248.64	165.30	163.81	108.06	54.55	23.89	33.62	19.94	20.60
1999	1.18	64.77	329.98	368.43	170.90	112.69	112.88	75.18	38.25	16.86	23.86	28.93
2000	1.20	60.89	562.02	576.00	292.16	137.36	91.74	92.82	62.32	31.93	14.15	44.55
2001	1.19	55.72	524.65	848.22	350.27	179.99	85.70	57.81	58.96	39.86	20.53	37.99
2002	1.73	47.28	419.58	623.67	373.20	156.12	81.27	39.09	26.58	27.30	18.56	27.41
2003	0.57	64.90	278.88	365.02	203.53	123.44	52.33	27.52	13.35	9.14	9.44	16.00
2004	0.58	28.35	557.29	468.49	269.57	152.20	93.44	39.99	21.20	10.35	7.13	19.94
2005	0.66	23.25	202.44	710.97	243.29	141.68	80.96	50.17	21.64	11.54	5.67	14.91
2006	2.20	48.62	227.24	294.59	419.82	145.41	85.71	49.44	30.88	13.40	7.19	12.89
2007	0.12	25.50	378.40	368.02	233.47	337.11	118.23	70.37	40.92	25.73	11.23	16.92
2008	0.12	10.88	657.36	429.54	181.99	117.26	171.77	60.92	36.59	21.43	13.56	14.93
2009	0.04	14.37	320.46	632.29	155.38	66.91	43.77	64.89	23.23	14.06	8.29	11.09
2010	0.01	2.28	367.24	369.21	298.13	74.22	32.37	21.40	31.99	11.53	7.02	9.74
2011	0.02	2.11	127.39	597.67	210.26	171.77	43.28	19.06	12.70	19.12	6.93	10.14
2012	0.01	3.45	113.83	232.00	400.45	142.52	117.82	29.97	13.31	8.93	13.51	12.14
2013	0.01	2.15	193.38	209.00	155.19	270.94	97.57	81.43	20.88	9.33	6.29	18.18
2014	0.04	4.24	149.98	377.92	147.78	111.00	196.10	71.30	59.98	15.48	6.96	18.37
2015	0.04	4.98	151.05	223.08	239.42	94.88	72.20	128.88	47.26	40.04	10.40	17.12
2016	0.06	9.16	262.91	264.56	158.21	172.14	69.13	53.16	95.72	35.35	30.13	20.84

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

Year	1	2	3	4	5	6	7	8	9	10	11	12
1946	0.08	0.68	0.97	0.96	0.91	0.85	0.78	0.70	0.63	0.56	0.49	2.44
1947	0.16	1.32	1.88	1.86	1.76	1.64	1.50	1.36	1.21	1.08	0.95	4.73
1948	0.33	2.65	3.76	3.72	3.53	3.28	3.00	2.71	2.43	2.16	1.90	9.45
1949	0.49	3.97	5.64	5.58	5.29	4.91	4.50	4.07	3.64	3.23	2.85	14.17
1950	0.65	5.31	7.53	7.43	7.04	6.55	5.99	5.42	4.85	4.31	3.80	18.88
1951	0.82	6.65	9.42	9.29	8.80	8.17	7.48	6.76	6.05	5.37	4.74	23.56
1952	0.98	8.00	11.33	11.16	10.56	9.79	8.96	8.10	7.25	6.44	5.67	28.21
1953	1.15	9.36	13.24	13.03	12.31	11.42	10.43	9.42	8.43	7.49	6.60	32.82
1954	1.32	10.73	15.16	14.91	14.08	13.04	11.90	10.74	9.60	8.53	7.52	37.38
1955	1.49	12.11	17.10	16.80	15.84	14.66	13.37	12.05	10.77	9.55	8.42	41.87
1956	1.64	13.34	18.82	18.47	17.40	16.08	14.65	13.20	11.78	10.44	9.20	45.72
1957	1.80	14.58	20.55	20.14	18.96	17.51	15.94	14.34	12.79	11.32	9.97	49.50
1958	1.95	15.83	22.29	21.84	20.54	18.95	17.24	15.50	13.81	12.21	10.74	53.25
1959	2.11	17.08	24.05	23.61	22.23	20.49	18.62	16.72	14.89	13.16	11.56	57.18
1960	2.27	18.35	25.81	25.34	23.86	21.97	19.94	17.90	15.91	14.05	12.33	60.84
1961	18.24	28.34	28.37	28.95	28.03	25.84	23.43	21.01	18.66	16.46	14.44	70.98
1962	30.00	35.88	30.71	30.85	29.43	27.07	24.52	21.96	19.49	17.18	15.05	73.72
1963	2.94	23.44	32.93	33.72	32.57	29.94	27.08	24.23	21.49	18.91	16.55	80.79
1964	3.16	25.58	35.31	34.73	33.11	30.50	27.55	24.61	21.80	19.18	16.77	81.48
1965	3.39	27.38	38.40	38.01	36.31	33.69	30.53	27.24	24.10	21.17	18.50	89.48
1966	3.42	27.65	38.61	37.63	34.66	31.66	28.87	25.84	22.83	20.03	17.48	84.18
1967	3.46	27.91	39.04	38.77	36.74	33.10	29.77	26.81	23.76	20.82	18.15	86.97
1968	3.49	28.17	39.53	40.46	39.11	35.76	31.69	28.15	25.10	22.07	19.20	91.56
1969	3.52	28.43	39.88	40.74	39.30	35.86	32.21	28.18	24.78	21.92	19.14	90.75
1970	3.55	28.66	40.11	40.16	38.21	34.79	31.17	27.65	23.95	20.89	18.36	86.92
1971	4.26	31.79	44.54	47.69	47.46	43.36	38.82	34.35	30.17	25.92	22.46	106.87
1972	12.18	38.72	48.68	51.82	51.31	46.80	41.90	37.04	32.46	28.27	24.13	113.70
1973	8.85	39.73	52.69	54.91	53.58	48.74	43.58	38.52	33.72	29.31	25.36	116.76
1974	7.00	41.85	57.29	63.47	64.43	58.73	52.42	46.28	40.51	35.17	30.36	139.10
1975	7.66	45.40	62.56	73.50	77.17	70.41	62.81	55.35	48.39	42.01	36.23	164.92
1976	10.39	48.07	63.72	72.36	73.79	66.83	59.51	52.41	45.73	39.66	34.20	154.72
1977	13.29	48.18	66.49	83.00	88.88	79.90	70.71	62.18	54.22	46.93	40.42	181.93
1978	6.27	47.08	65.64	92.13	101.11	90.70	79.42	69.40	60.42	52.26	44.92	201.15
1979	40.57	64.74	70.58	97.66	115.40	102.90	89.74	77.58	67.12	57.95	49.79	221.56
1980	180.68	130.40	69.76	109.70	121.25	113.23	97.99	84.36	72.20	61.96	53.14	235.16
1981	163.52	102.47	35.82	76.73	101.26	87.48	79.23	67.69	57.70	48.98	41.75	183.61
1982	146.80	109.40	62.26	109.68	144.51	136.15	113.51	101.46	85.81	72.55	61.17	266.03
1983	123.51	104.61	90.23	134.66	153.46	147.92	134.65	110.79	98.03	82.24	69.06	294.44
1984	64.21	91.09	55.25	109.20	136.41	120.64	112.71	101.27	82.49	72.40	60.33	252.12
1985	20.39	83.58	159.06	185.70	202.98	175.60	149.59	137.91	122.67	99.10	86.40	352.56

Table 13. (continued)

Year	1	2	3	4	5	6	7	8	9	10	11	12
1986	16.97	72.52	82.75	218.48	180.41	143.74	120.09	100.96	92.15	81.30	65.25	273.36
1987	24.90	112.47	146.59	179.29	256.52	145.40	111.53	91.94	76.53	69.29	60.72	239.13
1988	90.96	88.10	153.86	259.88	226.28	239.82	131.41	99.48	81.19	67.03	60.28	246.85
1989	18.56	141.00	102.47	292.41	327.61	203.96	208.55	112.78	84.53	68.44	56.13	243.24
1990	7.33	124.77	197.58	215.79	350.67	267.16	160.01	161.47	86.46	64.28	51.70	213.79
1991	11.13	63.31	222.71	495.95	247.15	262.47	191.93	113.43	113.33	60.20	44.46	173.67
1992	0.74	8.70	85.38	396.32	277.06	85.60	87.04	62.81	36.77	36.45	19.23	65.96
1993	0.73	11.14	142.27	215.51	358.50	240.66	73.19	73.54	52.57	30.53	30.07	66.62
1994	0.44	10.20	180.73	324.70	168.87	270.38	178.73	53.73	53.49	37.94	21.89	66.08
1995	0.40	6.18	161.20	376.38	227.43	114.05	179.89	117.57	35.02	34.60	24.38	53.68
1996	0.55	6.04	92.33	312.76	250.21	145.85	72.08	112.43	72.81	21.53	21.13	45.46
1997	0.81	9.57	100.31	226.00	274.97	211.53	121.46	59.35	91.73	58.96	17.32	51.10
1998	1.02	10.89	127.31	205.44	166.33	194.26	147.17	83.55	40.45	62.05	39.63	43.67
1999	0.39	31.32	214.56	304.41	171.96	133.64	153.72	115.15	64.77	31.12	47.43	61.33
2000	0.40	29.44	365.43	475.90	293.98	162.90	124.94	142.16	105.53	58.92	28.13	94.46
2001	0.40	26.95	341.13	700.82	352.46	213.45	116.72	88.54	99.84	73.56	40.82	80.54
2002	0.58	22.86	272.82	515.29	375.53	185.15	110.67	59.87	45.01	50.38	36.90	58.12
2003	0.19	31.38	181.33	301.59	204.80	146.40	71.26	42.15	22.60	16.87	18.77	33.91
2004	0.19	13.71	362.35	387.08	271.25	180.50	127.25	61.24	35.89	19.10	14.16	42.28
2005	0.22	11.24	131.63	587.42	244.81	168.03	110.26	76.85	36.64	21.31	11.27	31.61
2006	0.73	23.51	147.75	243.40	422.45	172.45	116.72	75.72	52.28	24.74	14.29	27.33
2007	0.04	12.33	246.04	304.07	234.93	399.80	161.01	107.77	69.28	47.48	22.32	35.88
2008	0.04	5.26	427.42	354.89	183.12	139.06	233.94	93.30	61.95	39.56	26.95	31.65
2009	0.01	6.95	208.36	522.41	156.36	79.35	59.61	99.38	39.34	25.95	16.48	23.52
2010	0.00	1.10	238.78	305.05	299.99	88.02	44.09	32.77	54.16	21.29	13.96	20.65
2011	0.01	1.02	82.83	493.81	211.57	203.70	58.94	29.19	21.50	35.28	13.78	21.49
2012	0.00	1.67	74.01	191.69	402.95	169.02	160.46	45.91	22.53	16.47	26.86	25.73
2013	0.00	1.04	125.74	172.68	156.16	321.32	132.88	124.71	35.35	17.22	12.51	38.55
2014	0.01	2.05	97.52	312.24	148.71	131.64	267.07	109.20	101.55	28.57	13.83	38.94
2015	0.01	2.41	98.21	184.31	240.92	112.53	98.33	197.39	80.02	73.90	20.67	36.30
2016	0.02	4.43	170.95	218.58	159.20	204.15	94.15	81.42	162.07	65.24	59.91	44.18

Table 14. Estimated time series of landings in numbers (1000 fish) for commercial handlines (L.cH), historic commercial trawl (L.cHTR), commercial other (L.cO), headboat (L.HB), and general recreational (L.GR).

Year	L.cH	L.cHTR	L.cO	L.HB	L.GR	Total
1946	0.00	0.00	0.00	0.00	9.04	9.04
1947	0.00	0.00	0.00	12.53	4.97	17.49
1948	0.00	0.00	0.00	25.06	9.93	34.99
1949	0.00	0.00	0.00	37.59	14.90	52.49
1950	0.00	0.00	0.00	50.12	19.87	69.98
1951	0.00	0.00	0.00	62.65	24.83	87.48
1952	0.00	0.00	0.00	75.18	29.80	104.98
1953	0.00	0.00	0.00	87.71	34.77	122.47
1954	0.00	0.00	0.00	100.24	39.73	139.97
1955	0.00	0.00	0.00	112.77	44.70	157.47
1956	0.00	0.00	0.00	123.79	49.07	172.86
1957	0.00	0.00	0.00	134.81	53.44	188.25
1958	0.13	0.00	0.00	145.83	57.81	203.77
1959	0.86	0.00	0.00	156.85	62.18	219.89
1960	1.20	0.00	0.00	167.87	66.55	235.61
1961	13.22	64.51	0.00	183.07	72.57	333.38
1962	8.17	111.54	0.00	198.27	78.60	396.58
1963	13.36	0.00	0.00	213.47	84.62	311.46
1964	4.49	0.00	0.00	228.68	90.65	323.81
1965	13.24	0.00	0.00	243.88	96.68	353.79
1966	1.88	0.00	0.00	245.30	97.24	344.43
1967	9.78	0.00	0.00	246.73	97.81	354.32
1968	22.28	0.00	0.00	248.16	98.37	368.81
1969	21.78	0.00	0.00	249.59	98.94	370.31
1970	13.69	0.00	0.00	251.01	99.51	364.21
1971	46.46	0.00	1.40	275.82	109.34	433.01
1972	47.91	0.00	32.25	300.62	119.17	499.96
1973	39.97	0.00	17.03	325.42	129.01	511.43
1974	81.80	0.00	7.80	350.22	138.84	578.67
1975	135.31	0.00	8.78	375.02	148.68	667.79
1976	112.04	0.00	20.90	379.25	150.35	662.53
1977	187.51	0.00	31.19	383.42	152.02	754.14
1978	245.89	0.00	3.54	387.65	153.70	790.78
1979	308.00	0.00	145.89	391.99	155.39	1001.27
1980	351.93	0.00	704.83	396.25	157.07	1610.09
1981	365.57	0.00	646.66	270.96	13.53	1296.72
1982	488.52	0.00	565.67	362.24	134.13	1550.56
1983	457.11	0.00	419.33	398.98	338.71	1614.12
1984	543.01	0.00	262.90	324.43	91.69	1222.03
1985	684.44	0.00	29.95	529.77	345.00	1589.16

Table 14. (continued)

Year	L.cH	L.cHTR	L.cO	L.HB	L.GR	Total
1986	692.61	0.00	34.80	533.06	47.06	1307.53
1987	560.69	0.00	75.54	731.06	128.16	1495.45
1988	714.99	0.00	255.03	741.18	115.31	1826.51
1989	913.14	0.00	10.83	660.89	228.35	1813.21
1990	991.52	0.00	74.50	654.82	133.71	1854.55
1991	1191.92	0.00	39.48	600.37	161.19	1992.96
1992	737.43	0.00	0.20	345.73	82.56	1165.92
1993	827.75	0.00	5.87	327.57	98.78	1259.97
1994	919.59	0.00	6.41	370.14	53.70	1349.84
1995	908.70	0.00	1.41	355.01	60.39	1325.51
1996	690.29	0.00	21.50	340.84	66.76	1119.39
1997	701.45	0.00	0.75	365.61	80.73	1148.54
1998	653.93	0.00	0.36	342.30	63.20	1059.79
1999	837.72	0.00	1.20	382.56	122.44	1343.91
2000	1342.51	0.00	4.32	428.60	191.70	1967.13
2001	1672.13	0.00	2.17	419.32	167.27	2260.90
2002	1369.01	0.00	3.50	336.09	133.20	1841.80
2003	751.01	0.00	0.35	252.08	160.68	1164.12
2004	1149.90	0.00	0.21	329.11	189.30	1668.51
2005	1127.44	0.00	0.86	275.34	103.55	1507.18
2006	794.32	0.00	1.12	344.78	197.18	1337.40
2007	1007.54	0.00	2.92	508.44	107.11	1626.01
2008	1224.43	0.00	3.35	262.83	225.74	1716.35
2009	949.25	0.00	1.96	225.29	178.29	1354.79
2010	997.26	0.00	17.77	138.35	71.77	1225.14
2011	993.84	0.00	20.81	133.32	72.49	1220.45
2012	900.91	0.00	8.44	123.95	54.65	1087.94
2013	871.83	0.00	4.98	107.01	80.53	1064.36
2014	824.16	0.00	0.99	135.32	198.67	1159.14
2015	765.47	0.00	1.90	118.87	143.11	1029.35
2016	724.28	0.00	1.29	250.38	195.43	1171.38

Table 15. Estimated time series of landings in whole weight (1000 lb) for commercial handlines (L.cH), historic commercial trawl (L.cHTR), commercial other (L.cO), headboat (L.HB), and general recreational (L.GR).

Year	L.cH	L.cHTR	L.cO	L.HB	L.GR	Total
1946	0.00	0.00	0.00	0.00	10.06	10.06
1947	0.00	0.00	0.00	13.93	5.52	19.45
1948	0.00	0.00	0.00	27.86	11.04	38.90
1949	0.00	0.00	0.00	41.78	16.56	58.34
1950	0.00	0.00	0.00	55.68	22.07	77.75
1951	0.00	0.00	0.00	69.55	27.57	97.12
1952	0.00	0.00	0.00	83.39	33.06	116.45
1953	0.00	0.00	0.00	97.19	38.53	135.71
1954	0.00	0.00	0.00	110.93	43.98	154.91
1955	0.00	0.00	0.00	124.63	49.40	174.03
1956	0.00	0.00	0.00	136.60	54.15	190.74
1957	0.00	0.00	0.00	148.51	58.87	207.39
1958	0.19	0.00	0.00	160.38	63.58	224.14
1959	1.25	0.00	0.00	172.18	68.26	241.69
1960	1.73	0.00	0.00	183.94	72.91	258.58
1961	19.10	24.03	0.00	200.24	79.38	322.74
1962	11.78	41.52	0.00	216.66	85.89	355.85
1963	19.25	0.00	0.00	232.98	92.36	344.59
1964	6.46	0.00	0.00	248.73	98.60	353.79
1965	19.05	0.00	0.00	264.35	104.79	388.20
1966	2.70	0.00	0.00	265.07	105.08	372.85
1967	14.01	0.00	0.00	265.88	105.40	385.29
1968	31.86	0.00	0.00	266.70	105.73	404.29
1969	31.09	0.00	0.00	267.55	106.06	404.71
1970	19.50	0.00	0.00	268.49	106.44	394.43
1971	66.08	0.00	0.52	294.38	116.70	477.69
1972	68.05	0.00	12.01	320.07	126.88	527.01
1973	56.68	0.00	6.34	345.70	137.05	545.77
1974	115.84	0.00	2.90	370.86	147.02	636.63
1975	191.27	0.00	3.27	395.21	156.68	746.42
1976	157.92	0.00	7.81	397.91	157.75	721.39
1977	263.41	0.00	11.59	401.81	159.31	836.12
1978	344.11	0.00	1.33	404.64	160.44	910.52
1979	430.09	0.00	54.53	408.89	162.09	1055.60
1980	489.59	0.00	261.32	414.58	164.34	1329.84
1981	507.97	0.00	239.75	284.33	14.20	1046.25
1982	680.78	0.00	209.32	378.92	140.30	1409.33
1983	637.20	0.00	151.92	408.07	346.43	1543.61
1984	753.22	0.00	100.10	315.60	89.20	1258.12
1985	933.27	0.00	10.95	503.46	327.86	1775.55

Table 15. (continued)

Year	L.cH	L.cHTR	L.cO	L.HB	L.GR	Total
1986	906.25	0.00	12.95	485.87	42.90	1447.97
1987	718.86	0.00	29.04	652.09	114.32	1514.30
1988	894.21	0.00	90.35	658.18	102.40	1745.13
1989	1119.46	0.00	12.24	541.03	186.94	1859.67
1990	1205.78	0.00	80.89	510.16	104.17	1901.01
1991	1351.50	0.00	39.64	479.79	128.81	1999.75
1992	747.10	0.00	0.21	334.82	79.95	1162.08
1993	870.72	0.00	6.18	321.49	96.95	1295.33
1994	951.81	0.00	6.64	356.95	51.79	1367.18
1995	927.91	0.00	1.44	343.08	58.36	1330.79
1996	722.35	0.00	22.50	341.44	66.88	1153.18
1997	763.35	0.00	0.82	375.94	83.01	1223.11
1998	712.18	0.00	0.39	345.42	63.78	1121.77
1999	883.36	0.00	1.27	337.25	107.93	1329.81
2000	1350.64	0.00	4.35	364.28	162.93	1882.20
2001	1636.47	0.00	2.12	355.01	141.62	2135.22
2002	1334.71	0.00	3.42	282.93	112.13	1733.18
2003	732.26	0.00	0.34	206.82	131.84	1071.26
2004	1089.64	0.00	0.20	269.91	155.25	1515.01
2005	1094.39	0.00	0.83	244.21	91.84	1431.27
2006	823.51	0.00	1.16	315.99	180.72	1321.38
2007	1060.57	0.00	3.07	476.85	100.46	1640.95
2008	1183.58	0.00	3.24	220.74	189.59	1597.16
2009	891.72	0.00	1.84	192.12	152.05	1237.73
2010	928.12	0.00	16.54	115.36	59.85	1119.87
2011	963.44	0.00	20.17	122.78	66.76	1173.15
2012	951.51	0.00	8.92	122.77	54.12	1137.31
2013	948.11	0.00	5.42	105.35	79.29	1138.16
2014	907.33	0.00	1.08	138.94	203.98	1251.34
2015	869.88	0.00	2.16	123.85	149.10	1144.99
2016	814.56	0.00	1.45	251.78	196.52	1264.30

Table 16. Estimated time series of discard mortalities in numbers (1000 fish) for commercial handlines (D.cH), headboat (D.HB), and general recreational (D.GR).

Year	D.cH	D.HB	D.GR	Total
1946	0.00	0.00	0.00	0.00
1947	0.00	0.22	0.81	0.81
1948	0.00	0.44	1.63	1.63
1949	0.00	0.65	2.44	2.44
1950	0.00	0.87	3.26	3.26
1951	0.00	1.09	4.07	4.07
1952	0.00	1.31	4.89	4.89
1953	0.00	1.53	5.70	5.70
1954	0.00	1.74	6.51	6.51
1955	0.00	1.96	7.33	7.33
1956	0.00	2.15	8.05	8.05
1957	0.00	2.34	8.76	8.76
1958	0.00	2.54	9.48	9.48
1959	0.00	2.73	10.19	10.19
1960	0.00	2.92	10.91	10.91
1961	0.00	3.18	11.90	11.90
1962	0.00	3.45	12.89	12.89
1963	0.00	3.71	13.87	13.87
1964	0.00	3.98	14.86	14.86
1965	0.00	4.24	15.85	15.85
1966	0.00	4.27	15.94	15.94
1967	0.00	4.29	16.04	16.04
1968	0.00	4.32	16.13	16.13
1969	0.00	4.34	16.22	16.22
1970	0.00	4.37	16.31	16.31
1971	0.00	4.80	17.93	17.93
1972	0.00	5.23	19.54	19.54
1973	0.00	5.66	21.15	21.15
1974	0.00	6.09	22.76	22.76
1975	0.00	6.52	24.38	24.38
1976	0.00	6.60	24.65	24.65
1977	0.00	6.67	24.93	24.93
1978	0.00	6.74	25.20	25.20
1979	0.00	6.82	25.48	25.48
1980	0.00	6.89	25.75	25.75
1981	0.00	4.71	17.34	17.34
1982	0.00	6.30	8.93	8.93
1983	0.00	6.94	0.15	0.15
1984	0.00	5.64	2.51	2.51
1985	0.00	9.22	3.54	3.54

Table 16. (continued)

Year	D.cH	D.HB	D.GR	Total
1986	0.00	9.27	8.72	8.72
1987	0.00	12.71	0.97	0.97
1988	0.00	12.89	26.30	26.30
1989	0.00	11.50	61.11	61.11
1990	0.00	11.41	76.66	76.66
1991	0.00	10.45	43.99	43.99
1992	26.57	27.40	46.93	100.90
1993	62.64	25.95	43.35	131.94
1994	74.12	29.34	55.26	158.72
1995	80.55	28.15	104.75	213.46
1996	78.90	27.01	24.16	130.07
1997	73.45	28.95	23.34	125.74
1998	54.57	27.11	51.38	133.06
1999	45.41	32.87	202.43	280.71
2000	45.36	36.85	203.86	286.07
2001	55.85	36.05	98.84	190.74
2002	113.41	28.88	99.18	241.47
2003	43.39	21.67	158.27	223.33
2004	29.33	33.43	96.81	159.57
2005	27.94	19.95	61.22	109.11
2006	20.61	29.01	68.37	118.00
2007	19.97	48.56	128.25	196.79
2008	39.61	50.39	413.34	503.34
2009	30.74	53.09	145.00	228.84
2010	40.57	35.99	71.95	148.50
2011	29.92	34.54	25.20	89.66
2012	17.31	29.99	40.25	87.56
2013	23.39	17.83	6.54	47.76
2014	21.63	25.98	66.50	114.10
2015	19.92	37.34	92.70	149.97
2016	13.41	37.70	101.85	152.96

Table 17. Estimated time series of discard mortalities in whole weight (1000 lb) for commercial handlines (D.cH), headboat (D.HB), and general recreational (D.GR).

Year	D.cH	D.HB	D.GR	Total
1946	0.00	0.00	0.00	0.00
1947	0.00	0.14	0.53	0.53
1948	0.00	0.29	1.07	1.07
1949	0.00	0.43	1.60	1.60
1950	0.00	0.57	2.13	2.13
1951	0.00	0.71	2.66	2.66
1952	0.00	0.85	3.19	3.19
1953	0.00	1.00	3.72	3.72
1954	0.00	1.14	4.25	4.25
1955	0.00	1.28	4.78	4.78
1956	0.00	1.40	5.25	5.25
1957	0.00	1.53	5.71	5.71
1958	0.00	1.65	6.17	6.17
1959	0.00	1.78	6.64	6.64
1960	0.00	1.90	7.10	7.10
1961	0.00	2.07	7.74	7.74
1962	0.00	2.24	8.38	8.38
1963	0.00	2.41	9.02	9.02
1964	0.00	2.58	9.64	9.64
1965	0.00	2.75	10.27	10.27
1966	0.00	2.76	10.32	10.32
1967	0.00	2.78	10.38	10.38
1968	0.00	2.79	10.43	10.43
1969	0.00	2.81	10.48	10.48
1970	0.00	2.82	10.54	10.54
1971	0.00	3.10	11.58	11.58
1972	0.00	3.37	12.61	12.61
1973	0.00	3.65	13.64	13.64
1974	0.00	3.92	14.66	14.66
1975	0.00	4.19	15.67	15.67
1976	0.00	4.23	15.82	15.82
1977	0.00	4.30	16.06	16.06
1978	0.00	4.33	16.16	16.16
1979	0.00	4.39	16.41	16.41
1980	0.00	4.46	16.68	16.68
1981	0.00	3.05	11.22	11.22
1982	0.00	4.06	5.76	5.76
1983	0.00	4.43	0.10	0.10
1984	0.00	3.45	1.53	1.53
1985	0.00	5.80	2.23	2.23

Table 17. (continued)

Year	D.cH	D.HB	D.GR	Total
1986	0.00	5.67	5.33	5.33
1987	0.00	7.80	0.60	0.60
1988	0.00	8.19	16.72	16.72
1989	0.00	6.71	35.64	35.64
1990	0.00	6.73	45.23	45.23
1991	0.00	6.58	27.73	27.73
1992	19.55	16.59	28.41	64.55
1993	44.61	15.44	25.79	85.85
1994	52.22	17.64	33.23	103.09
1995	58.48	17.65	65.66	141.79
1996	59.44	16.95	15.16	91.54
1997	54.35	17.50	14.11	85.96
1998	38.72	16.08	30.48	85.27
1999	31.14	19.68	121.22	172.04
2000	31.15	22.63	125.17	178.95
2001	38.78	22.27	61.05	122.10
2002	78.66	17.75	60.96	157.36
2003	28.99	12.66	92.47	134.13
2004	20.42	21.48	62.22	104.12
2005	20.78	13.10	40.19	74.07
2006	15.16	18.34	43.22	76.72
2007	13.36	31.73	83.78	128.87
2008	26.53	33.34	273.44	333.30
2009	22.56	34.55	94.35	151.46
2010	31.03	24.93	49.85	105.81
2011	25.26	26.04	19.00	70.29
2012	15.08	22.25	29.86	67.20
2013	20.33	13.22	4.85	38.41
2014	19.26	19.71	50.46	89.43
2015	17.34	27.29	67.75	112.38
2016	11.10	26.53	71.66	109.29

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. Also presented are median values and measures of precision (standard errors, SE) from the Monte Carlo/Bootstrap analysis. Rate estimates (F) are in units of y^{-1}*; status indicators are dimensionless; and biomass estimates (whole weight) are in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) is measured as population egg production. The definition of* MSST *considered in this assessment is* $\mathrm{MSST} = 75\%\mathrm{SSB}_{\mathrm{MSY}}$.

Quantity	Units	Estimate	Median	SE
F_{MSY}	y^{-1}	0.41	0.44	0.20
$85\%F_{\mathrm{MSY}}$	y^{-1}	0.35	0.37	0.17
$75\%F_{\mathrm{MSY}}$	y^{-1}	0.31	0.33	0.15
$65\%F_{\mathrm{MSY}}$	y^{-1}	0.27	0.29	0.13
B_{MSY}	mt	4249.2	4030.8	560.5
$\mathrm{SSB}_{\mathrm{MSY}}$	1E12 eggs	18.3	17.2	2.59
MSST	1E12 eggs	13.7	12.9	1.94
MSY	1000 lb	1305.8	1339.6	125.5
D_{MSY}	1000 fish	245.9	97.8	43.2
R_{MSY}	1000 age-1 fish	5591	5230	926
Y at $85\%F_{\mathrm{MSY}}$	1000 lb	1300.3	1334.9	127.2
Y at $75\%F_{\mathrm{MSY}}$	1000 lb	1288.2	1324.6	130.5
Y at $65\%F_{\mathrm{MSY}}$	1000 lb	1266.0	1305.2	136.0
$F_{2014-2016}/F_{\mathrm{MSY}}$	—	0.609	0.564	0.41
$\mathrm{SSB}_{2016}/\mathrm{MSST}$	—	1.51	1.54	0.34
$\mathrm{SSB}_{2016}/\mathrm{SSB}_{\mathrm{MSY}}$	—	1.13	1.16	0.25

Table 19. Results from sensitivity runs of the Beaufort Assessment Model. Current F represented by geometric mean of last three assessment years. Runs should not all be considered equally plausible.

Run	Description	F_{MSY}	$\mathrm{SSB}_{\mathrm{MSY}}$ (mt)	MSY(1000 lb)	$\mathrm{F}_{\mathrm{current}}/F_{\mathrm{MSY}}$	$\mathrm{SSB}_{2012}/\mathrm{SSB}_{\mathrm{MSY}}$	steep	R0(1000)	rec.sigma
Base	—	0.41	18.30	1306	0.61	1.13	0.69	6299	0.29
S1	M=0.16	0.222	20.49	1154	1.53	0.69	0.69	4450	0.34
S2	M=0.28	0.639	19.96	1575	0.31	1.38	0.69	9233	0.3
S3	Constant M=0.22	0.352	18.19	1290	0.72	1.06	0.69	4815	0.29
S4	Charnov M	0.31	19.31	1198	0.93	0.93	0.69	6334	0.31
S5	h=0.84	0.57	16.73	1392	0.42	1.29	0.84	6014	0.28
S6	h=0.43	0.179	25.59	1094	1.69	0.64	0.43	7644	0.33
S7	h=0.99	0.739	15.87	1462	0.32	1.4	0.99	5846	0.28
S8	Batch fec spawning freq	0.371	11.84	1275	0.68	1.1	0.69	6400	0.29
S9	SWAS rec removals	0.39	18.61	1292	0.65	1.1	0.69	6355	0.29
S10	1.25 x rec removals	0.39	18.73	1300	0.64	1.1	0.69	6396	0.29
S11	0.75 x rec removals	0.39	18.5	1285	0.65	1.1	0.69	6316	0.29
S12	include length comps	0.366	36.3	2336	0.25	1.41	0.69	11645	0.36
S13	trap index	0.39	18.52	1287	0.66	1.08	0.69	6319	0.29
S14	video index	0.381	20.08	1368	0.41	1.51	0.69	6878	0.26
S15	combined index (Gwinn)	0.395	18.14	1272	0.79	0.94	0.69	6154	0.32
S16	2X Upweight SERFS	0.404	18.02	1281	0.89	0.88	0.69	6119	0.33
S17	4X Upweight SERFS	0.446	17.78	1353	0.98	0.86	0.69	5757	0.48
S18	8X Upweight SERFS	0.5	18.26	1516	0.93	0.84	0.69	5105	0.75
S19	drop SERFS 1990	0.39	18.58	1291	0.65	1.09	0.69	6313	0.31
S20	drop SERFS 1990-91	0.388	18.81	1302	0.62	1.14	0.69	6435	0.28
S21	block SERFS q	0.383	19.5	1339	0.47	1.38	0.69	6669	0.28
S22	constant q on FD indices	0.39	18.37	1275	0.66	1.09	0.69	6272	0.29
S23	linear incr q on FD indices	0.392	18.46	1283	0.69	1.08	0.67	6307	0.29
S24	multinomial likelihood	0.392	18.58	1293	0.53	1.3	0.69	6346	0.29
S25	no ageing error matrix	0.366	19.12	1309	0.52	1.28	0.69	6615	0.26

Table 20. Projection results with fishing mortality rate fixed at $F = F_{\mathrm{MSY}}$ starting in 2019. 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*), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$*. The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2017	5752	5040	0.28	0.27	21	20	1167	1123	1220	1218	176	224	124	162	0.730
2018	5761	5067	0.28	0.28	21	20	1199	1168	1220	1218	182	238	128	169	0.727
2019	5774	5067	0.41	0.44	21	19	1673	1788	1669	1810	261	232	183	163	0.707
2020	5745	5038	0.41	0.44	20	18	1578	1643	1538	1614	257	227	178	157	0.633
2021	5698	4994	0.41	0.44	19	18	1526	1563	1459	1486	255	225	176	154	0.559
2022	5668	4972	0.41	0.44	19	17	1496	1525	1411	1412	253	223	174	153	0.515
2023	5646	4952	0.41	0.44	19	17	1476	1497	1380	1371	251	222	172	152	0.488

Table 21. Projection results with fishing mortality rate fixed at P=0.40 starting in 2019. 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*), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$*. The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2017	5752	5040	0.28	0.27	21	20	1167	1123	1220	1218	176	224	124	162	0.730
2018	5761	5067	0.28	0.28	21	20	1199	1168	1220	1218	182	238	128	169	0.727
2019	5774	5067	0.35	0.37	21	19	1457	1559	1454	1579	225	235	158	166	0.726
2020	5765	5057	0.35	0.37	21	19	1426	1492	1400	1478	225	233	157	163	0.707
2021	5746	5041	0.35	0.37	20	18	1409	1454	1366	1408	224	233	156	162	0.679
2022	5734	5035	0.35	0.37	20	18	1399	1433	1346	1362	224	232	156	161	0.663
2023	5725	5028	0.35	0.37	20	18	1391	1419	1333	1336	223	232	155	161	0.648

Table 22. Projection results with fishing mortality rate fixed at $F = 75\%F_{\mathrm{MSY}}$ starting in 2019. 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*), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$*. The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2017	5752	5040	0.28	0.27	21	20	1167	1123	1220	1218	176	224	124	162	0.730
2018	5761	5067	0.28	0.28	21	20	1199	1168	1220	1218	182	238	128	169	0.727
2019	5774	5067	0.31	0.33	21	20	1307	1400	1306	1420	201	238	141	168	0.738
2020	5779	5071	0.31	0.33	21	19	1313	1378	1294	1371	202	238	142	167	0.746
2021	5778	5071	0.31	0.33	21	19	1316	1365	1289	1338	203	238	143	167	0.751
2022	5778	5079	0.31	0.33	21	19	1319	1357	1287	1314	203	238	143	168	0.751
2023	5778	5082	0.31	0.33	21	19	1320	1352	1286	1299	203	240	143	168	0.757

8 Figures

Figure 1. Indices of abundance used in fitting the assessment model. U.HB indicates the headboat logbook data; U.cH the commercial handline logbook data; U.GR the MRIP recreational data; U.CVID the SERFS chevron trap/video survey; and U.FST the MARMAP Florida snapper trap survey.

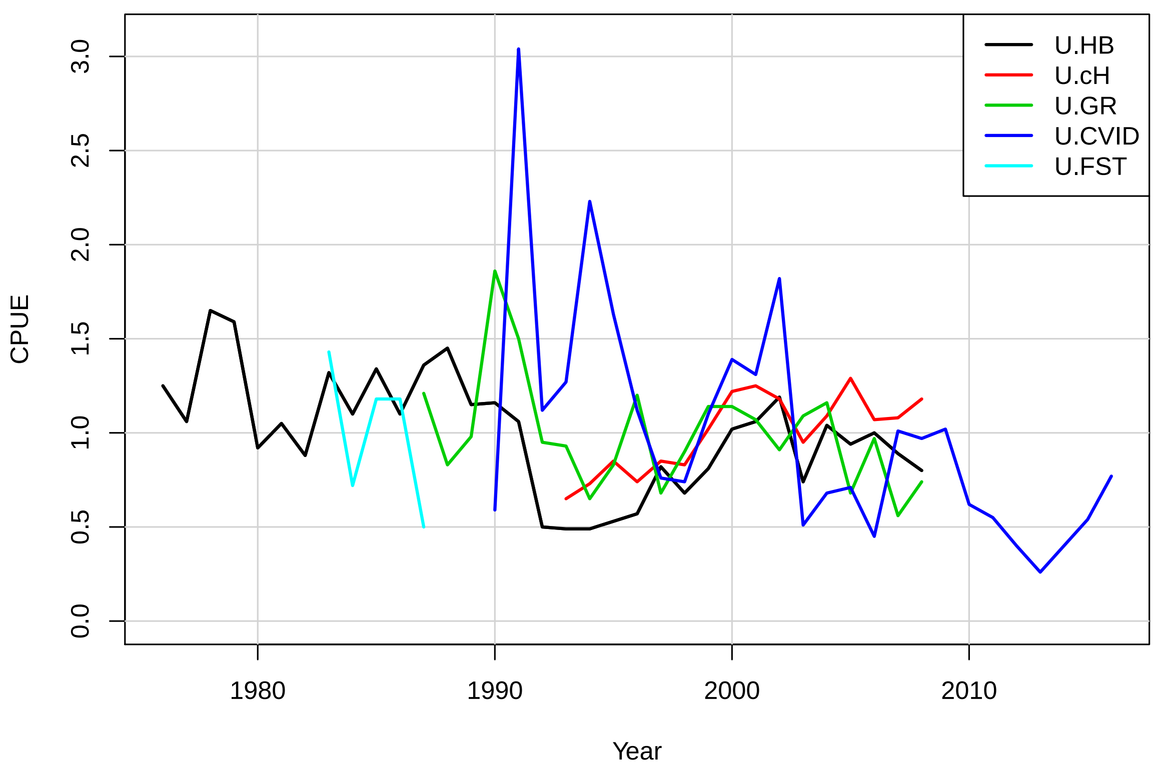


Figure 2. Mean total length at age (mm) and estimated upper and lower 95% confidence intervals of the population.

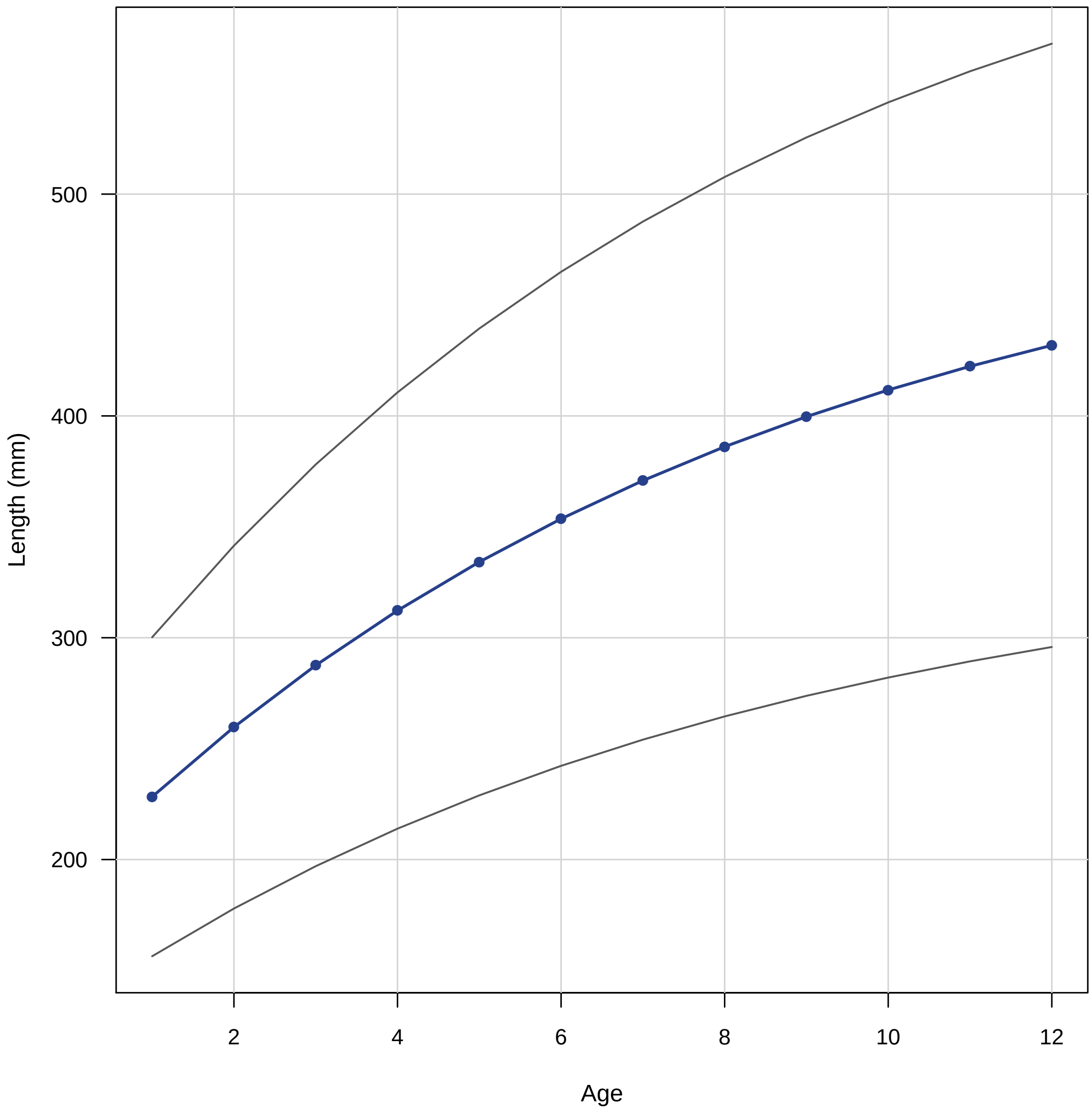


Figure 3. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, CVT to SERFS chevron trap gear, cH to commercial handlines, cO to commercial other, HB to headboat, HB.D to headboat discards, and GR to general recreational. $N = -99999$ *indicates that the composition was not used for fitting, in most cases because the sample size was below the cutoff.*

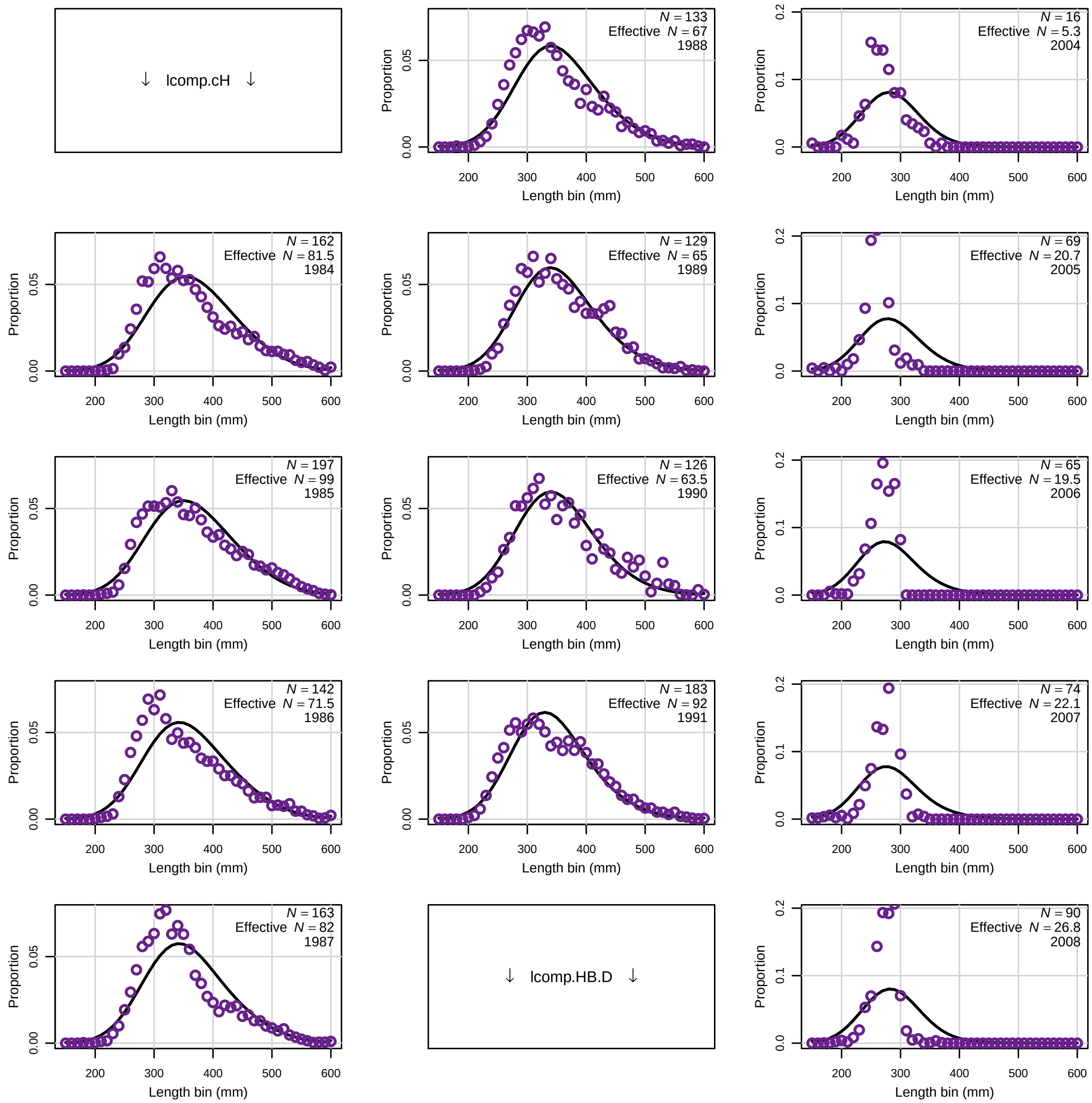


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

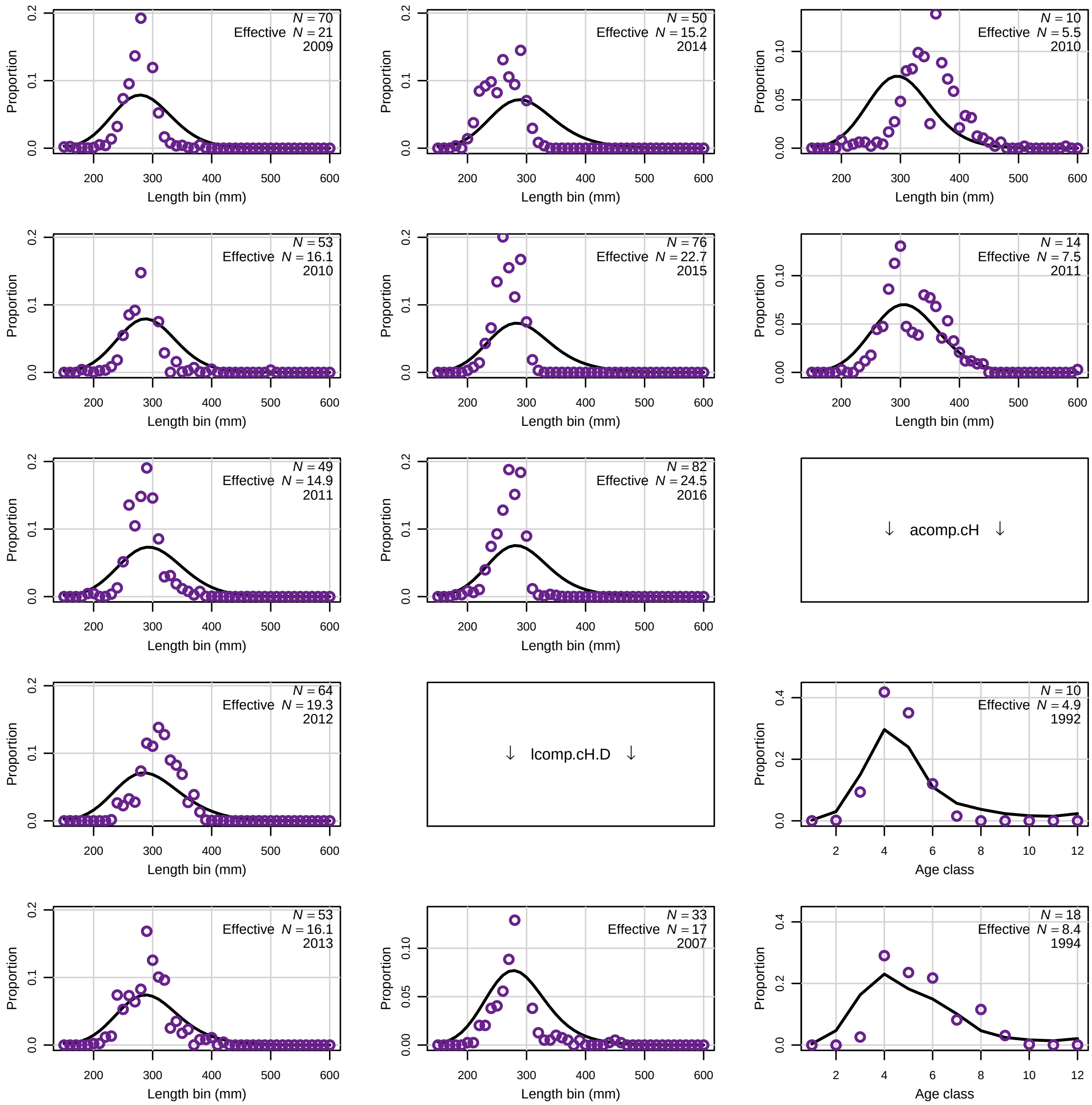


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

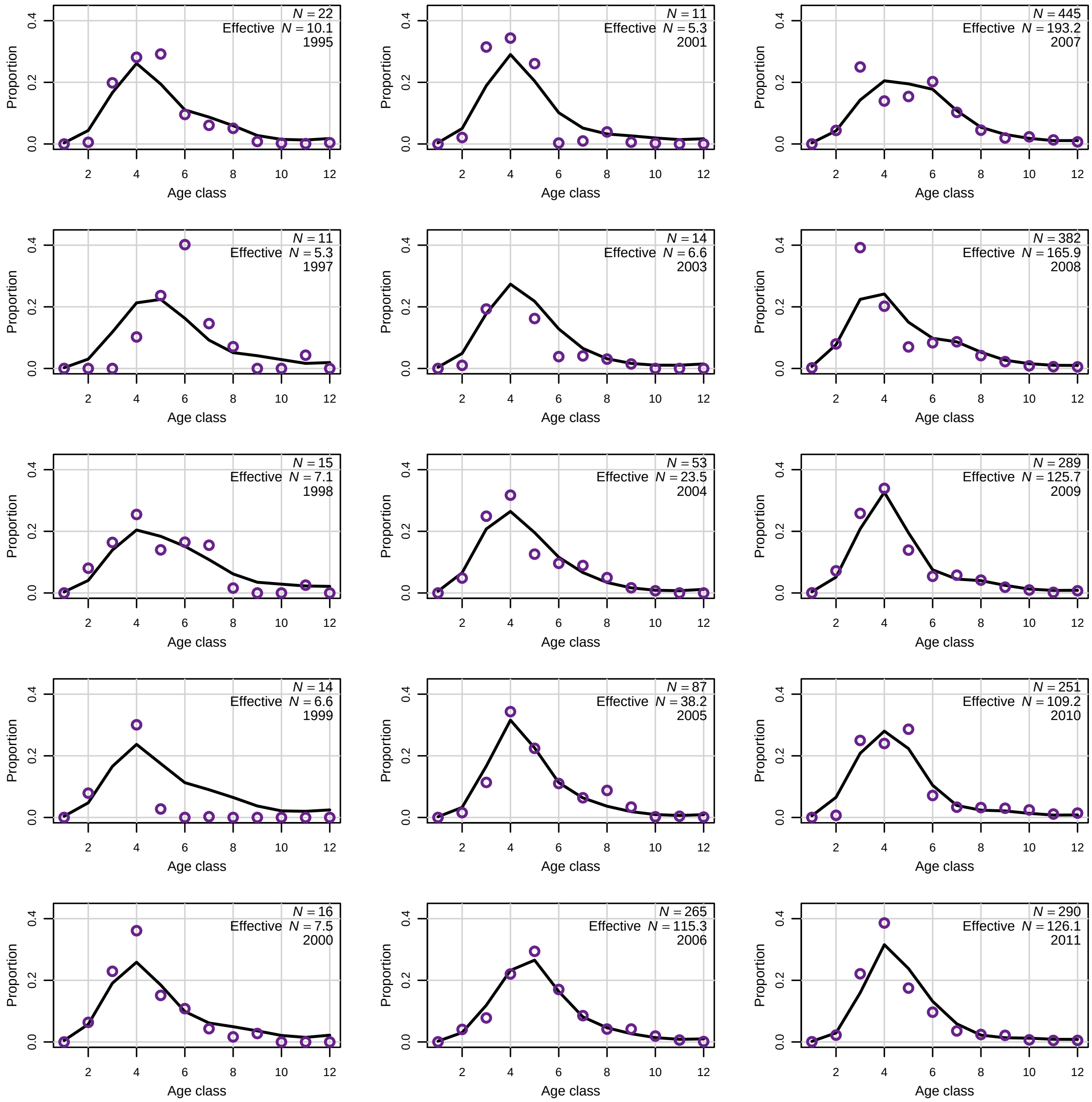


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

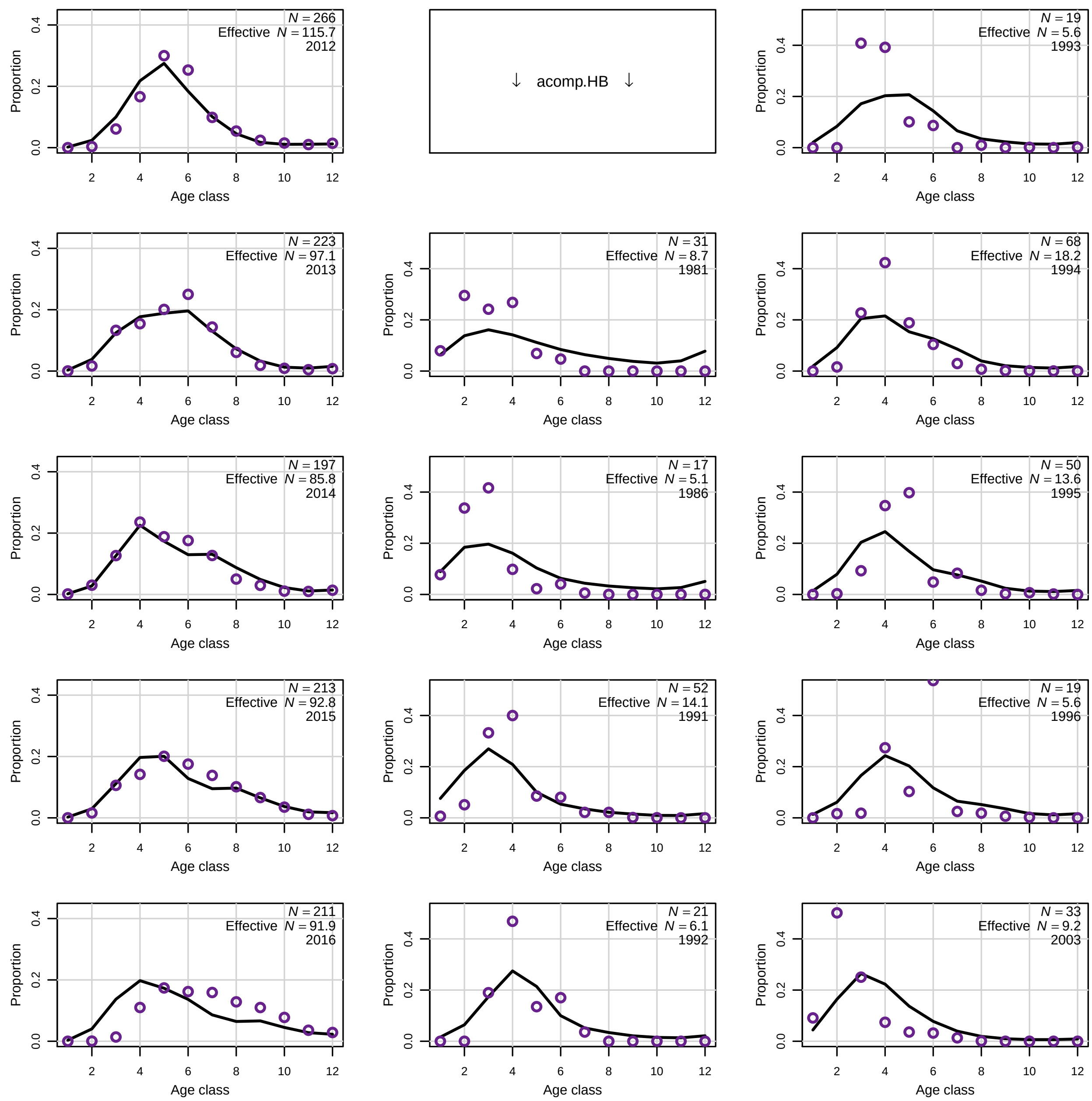


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

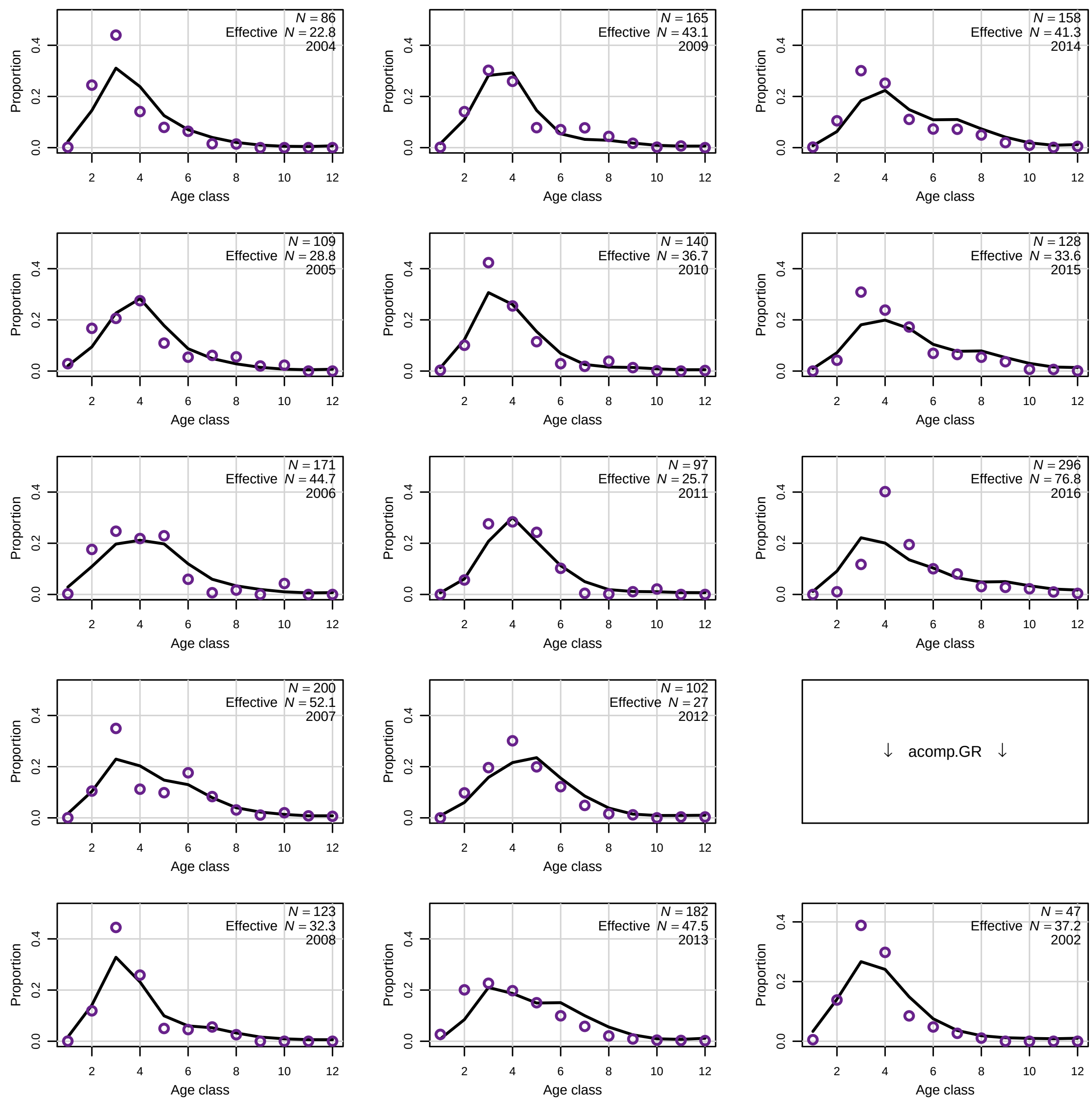


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

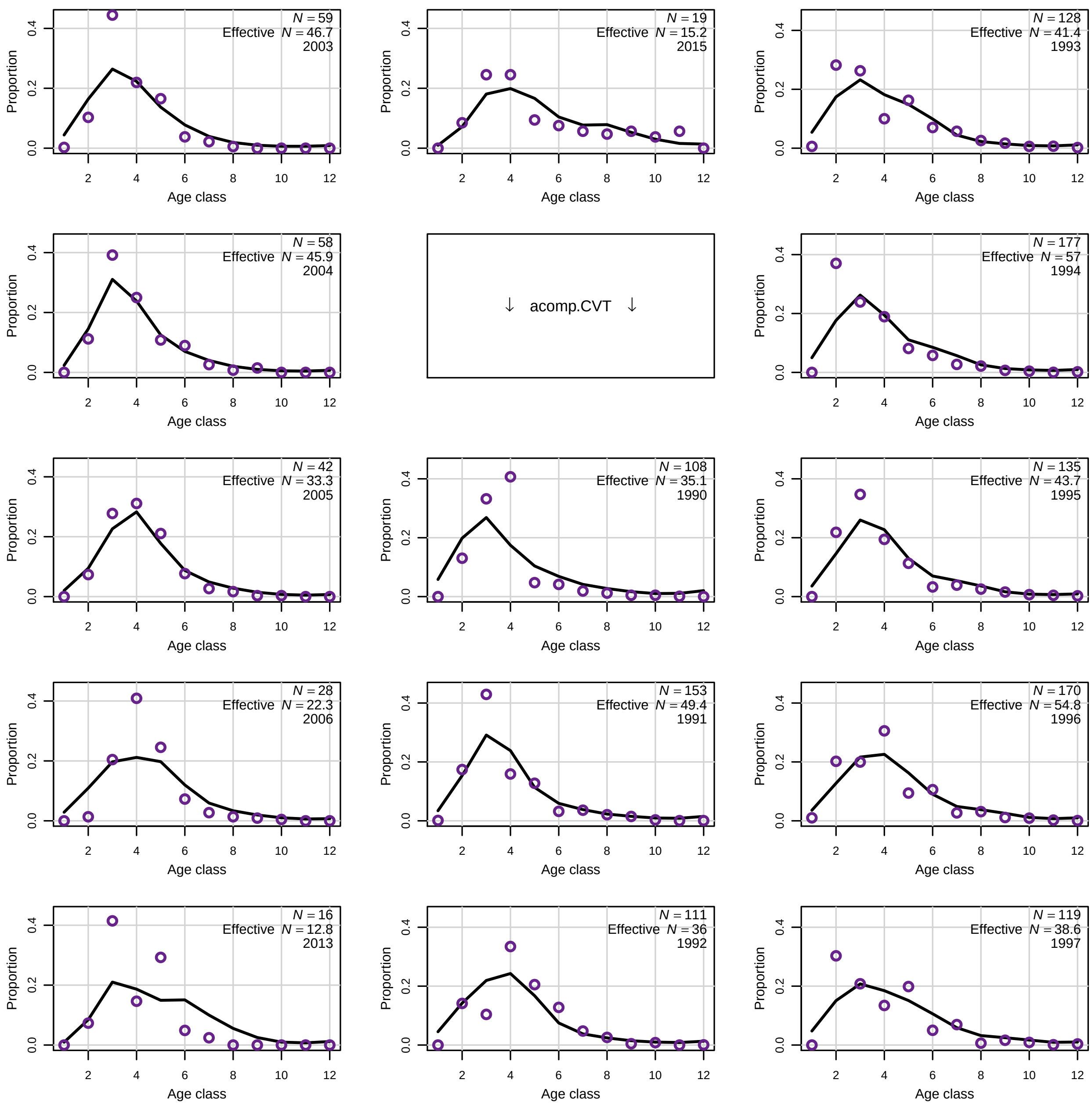


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

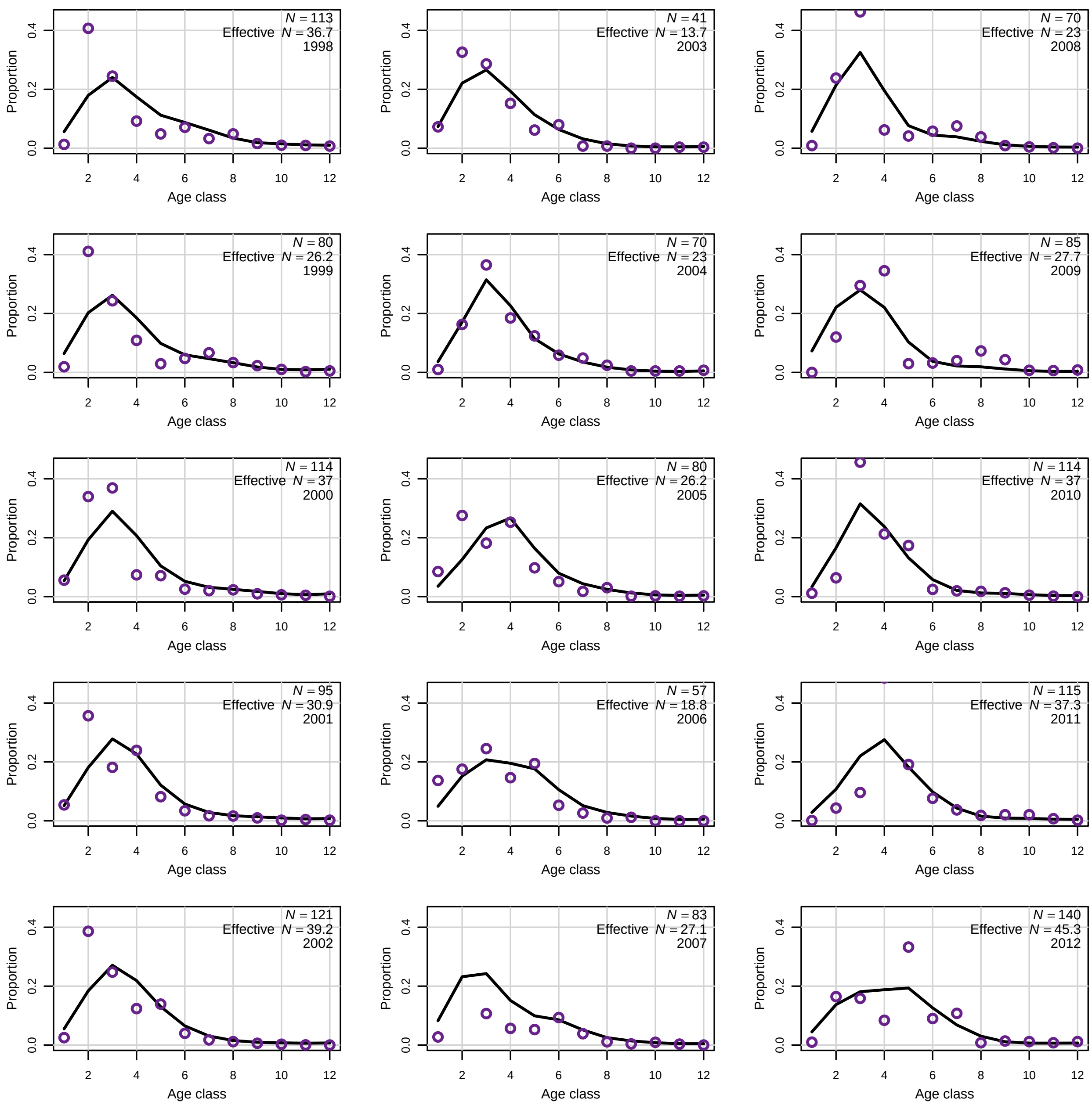


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

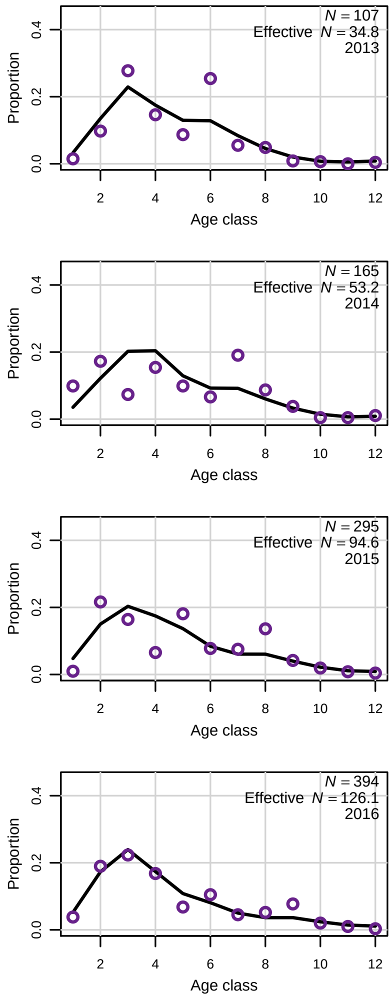


Figure 4. Observed (open circles) and estimated (solid line, circles) commercial handline landings (1000 lb whole weight). Open and solid circles may be indistinguishable in years with very close fits.

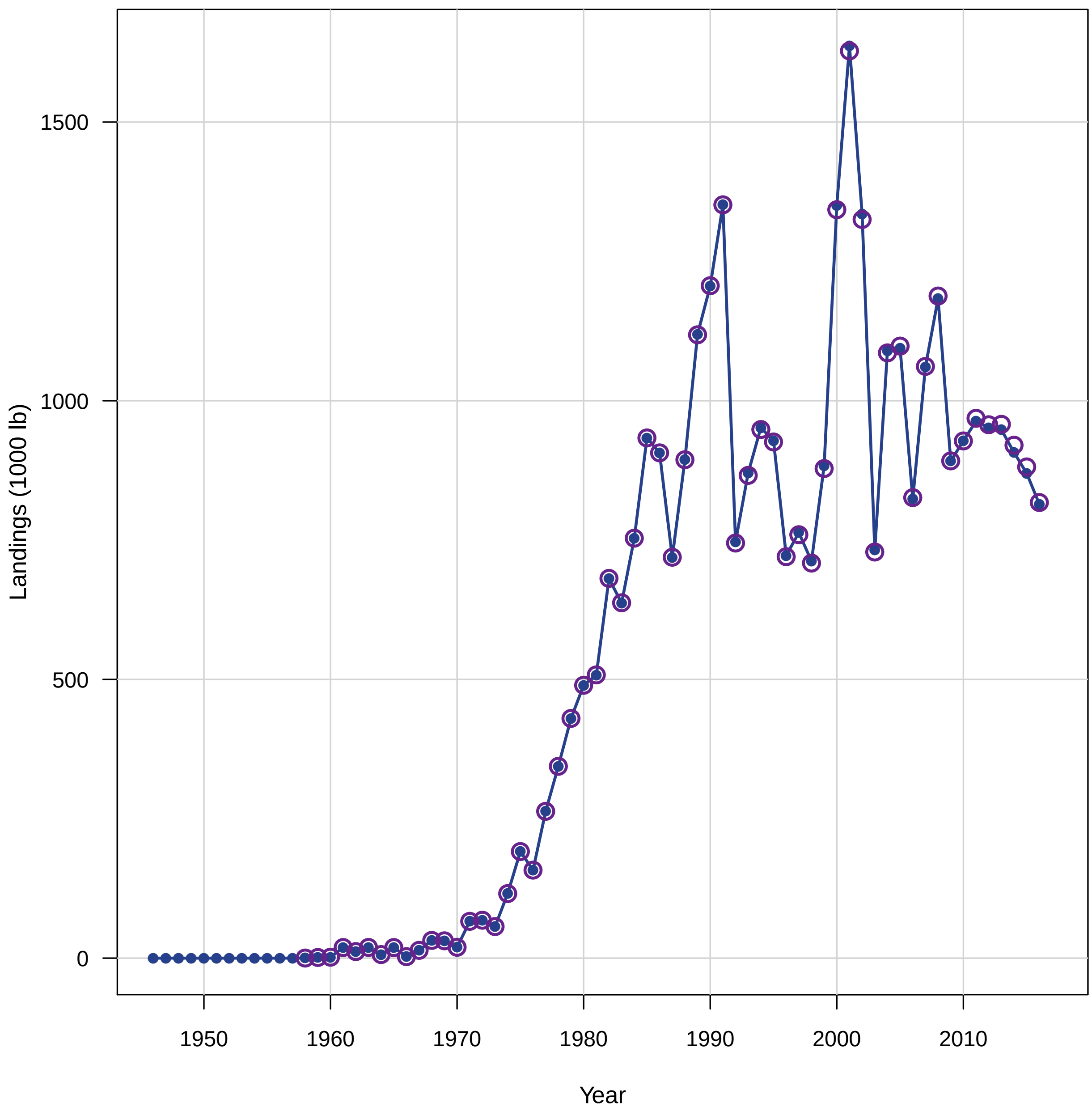


Figure 5. Observed (open circles) and estimated (solid line, circles) commercial other landings (1000 lb whole weight). Open and solid circles may be indistinguishable in years with very close fits.

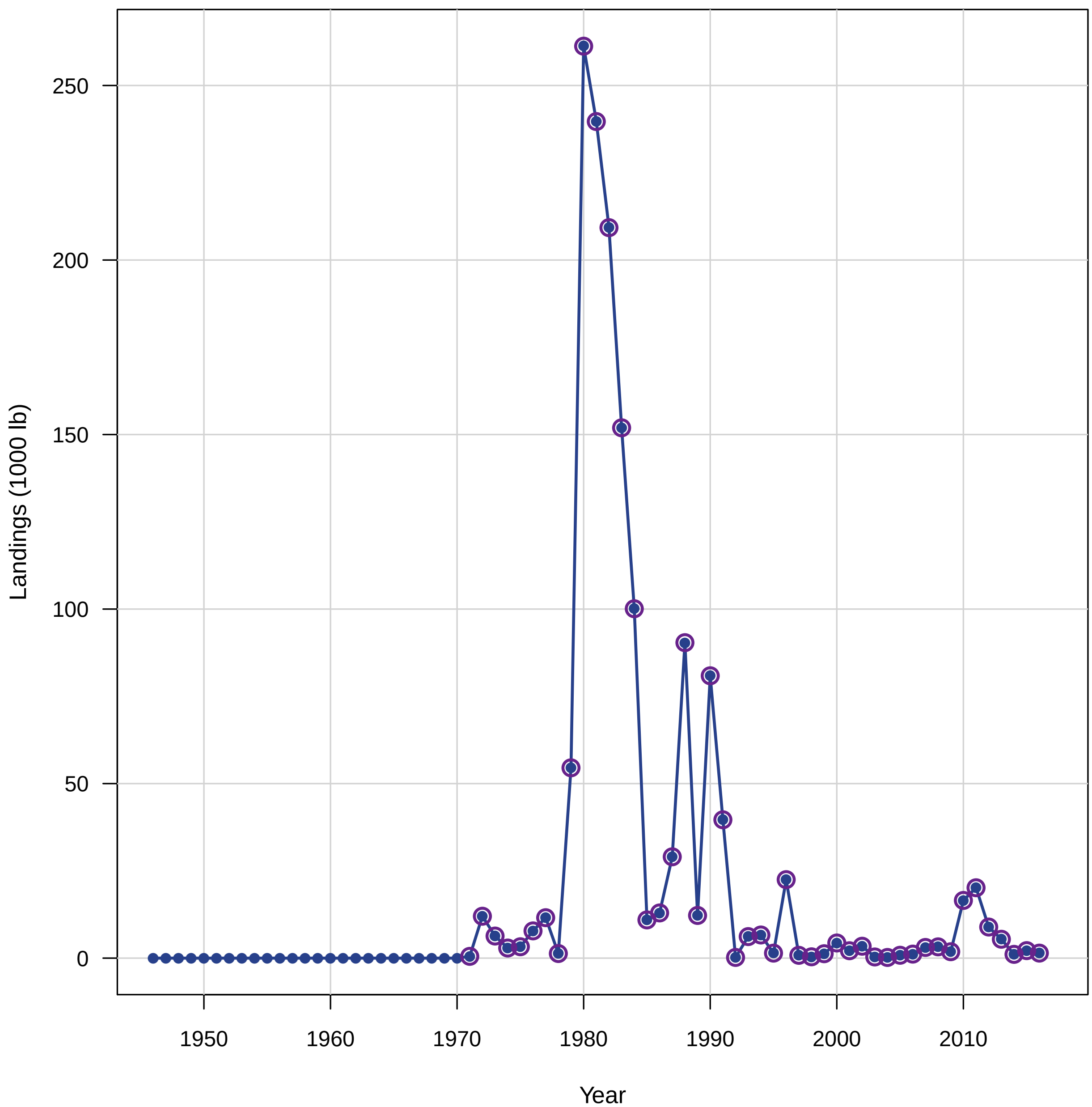


Figure 6. Observed (open circles) and estimated (solid line, circles) commercial historic trawl landings (1000 lb whole weight). Open and solid circles may be indistinguishable in years with very close fits.

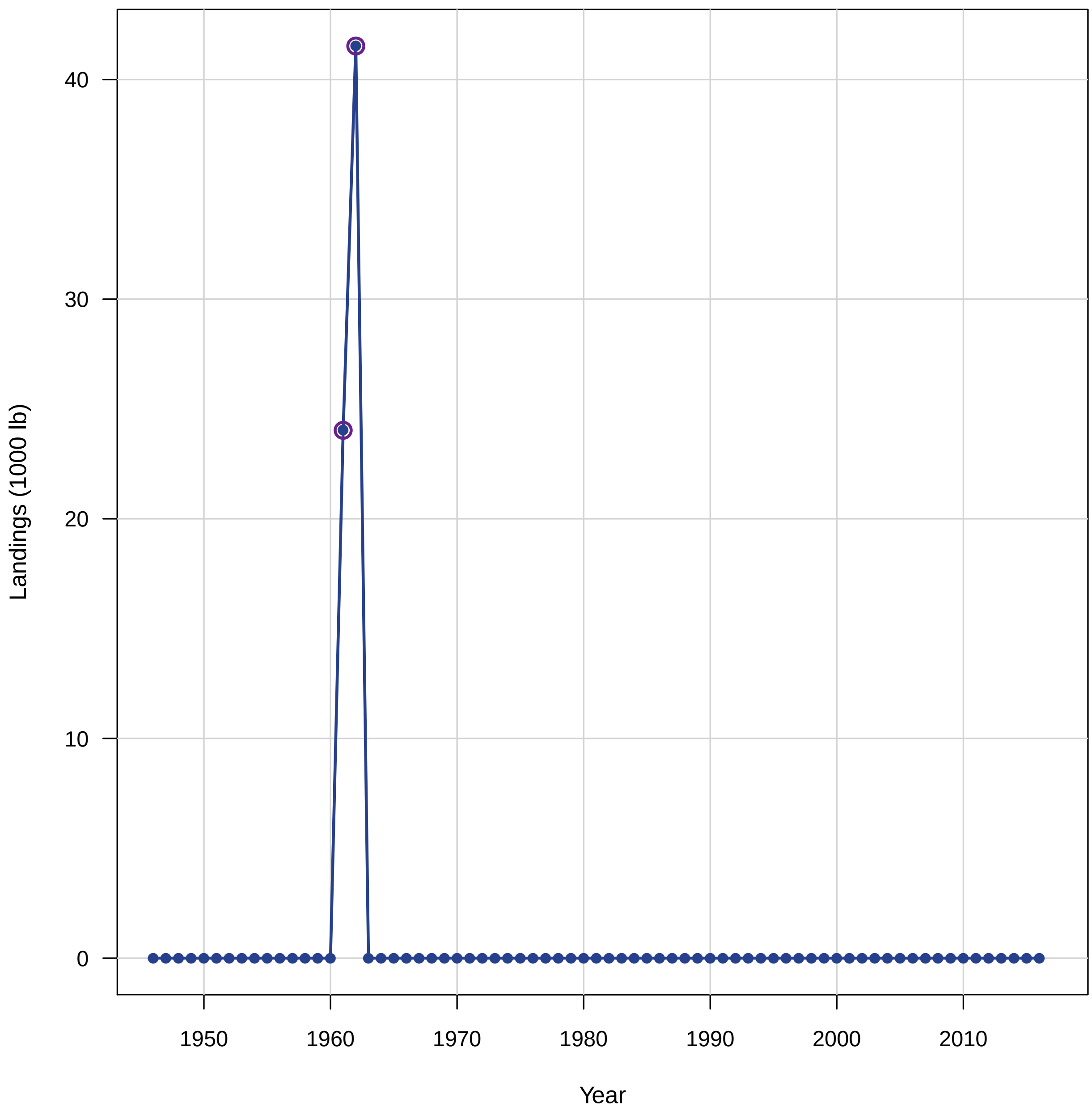


Figure 7. Observed (open circles) and estimated (solid line, circles) headboat landings (1000 fish). Open and solid circles may be indistinguishable in years with very close fits.

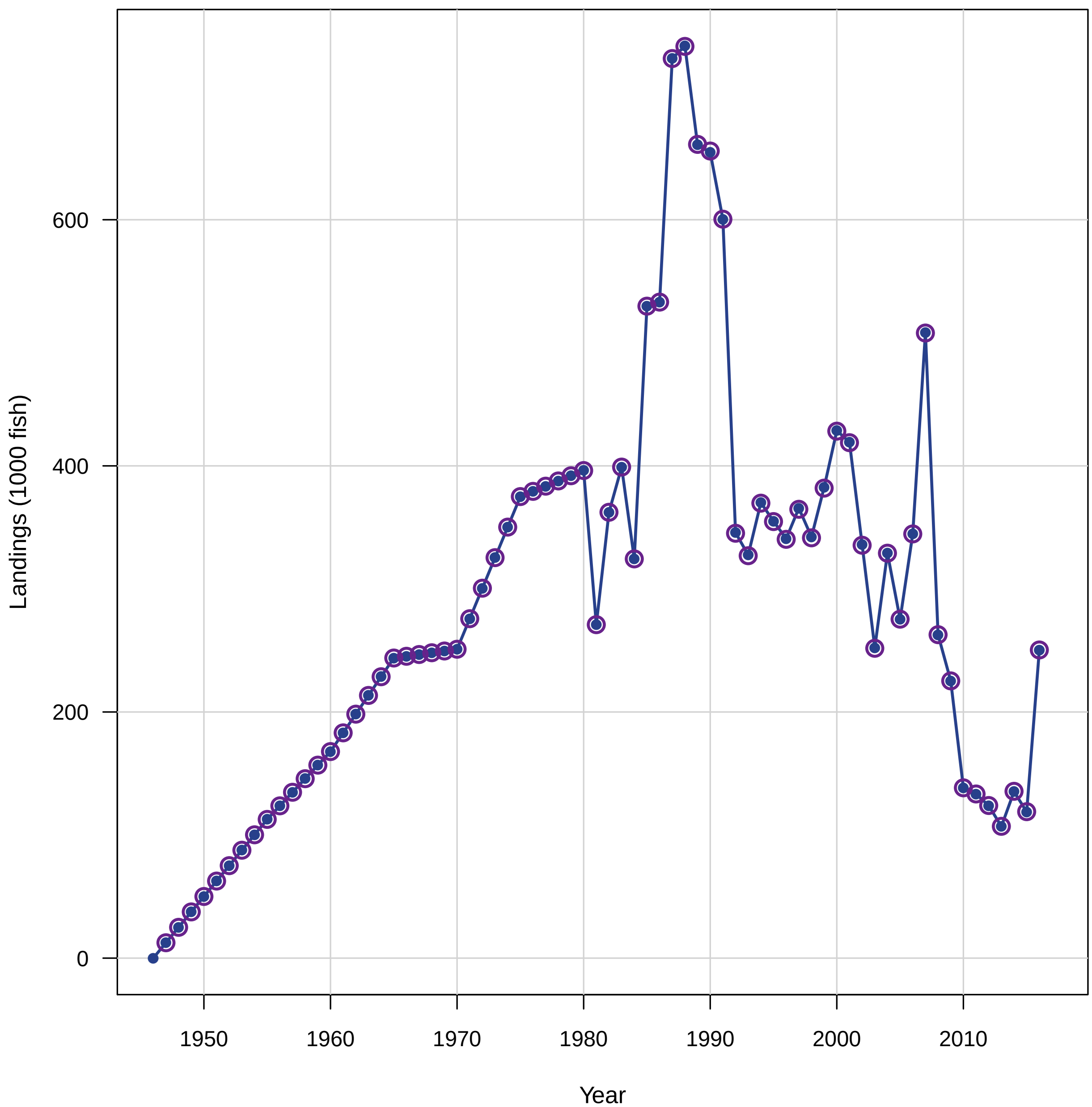


Figure 8. Observed (open circles) and estimated (solid line, circles) general recreational landings (1000 fish). Open and solid circles may be indistinguishable in years with very close fits.

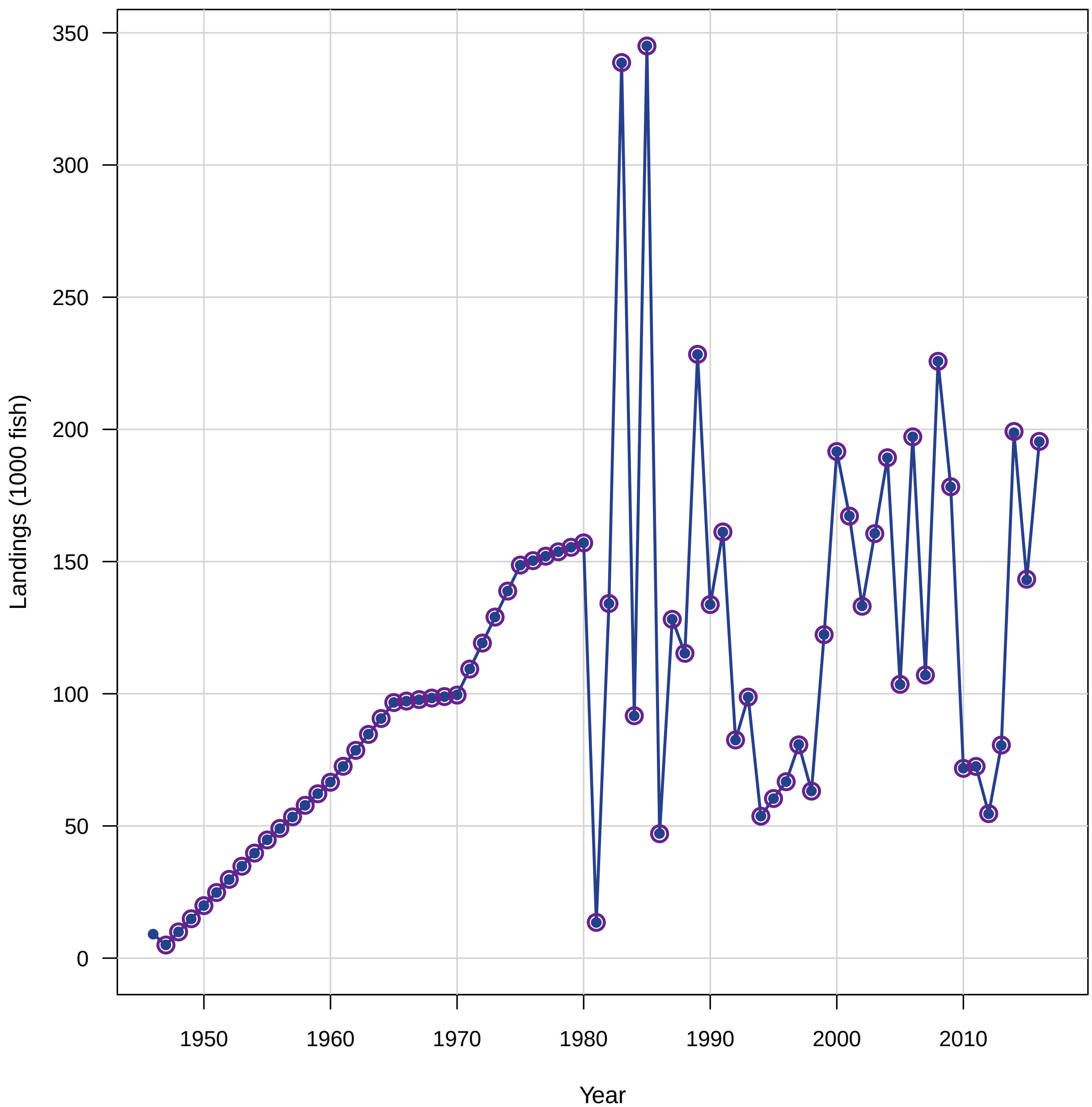


Figure 9. Observed (open circles) and estimated (solid line, circles) commercial handline discard mortalities (1000 dead fish). Open and solid circles may be indistinguishable in years with very close fits.

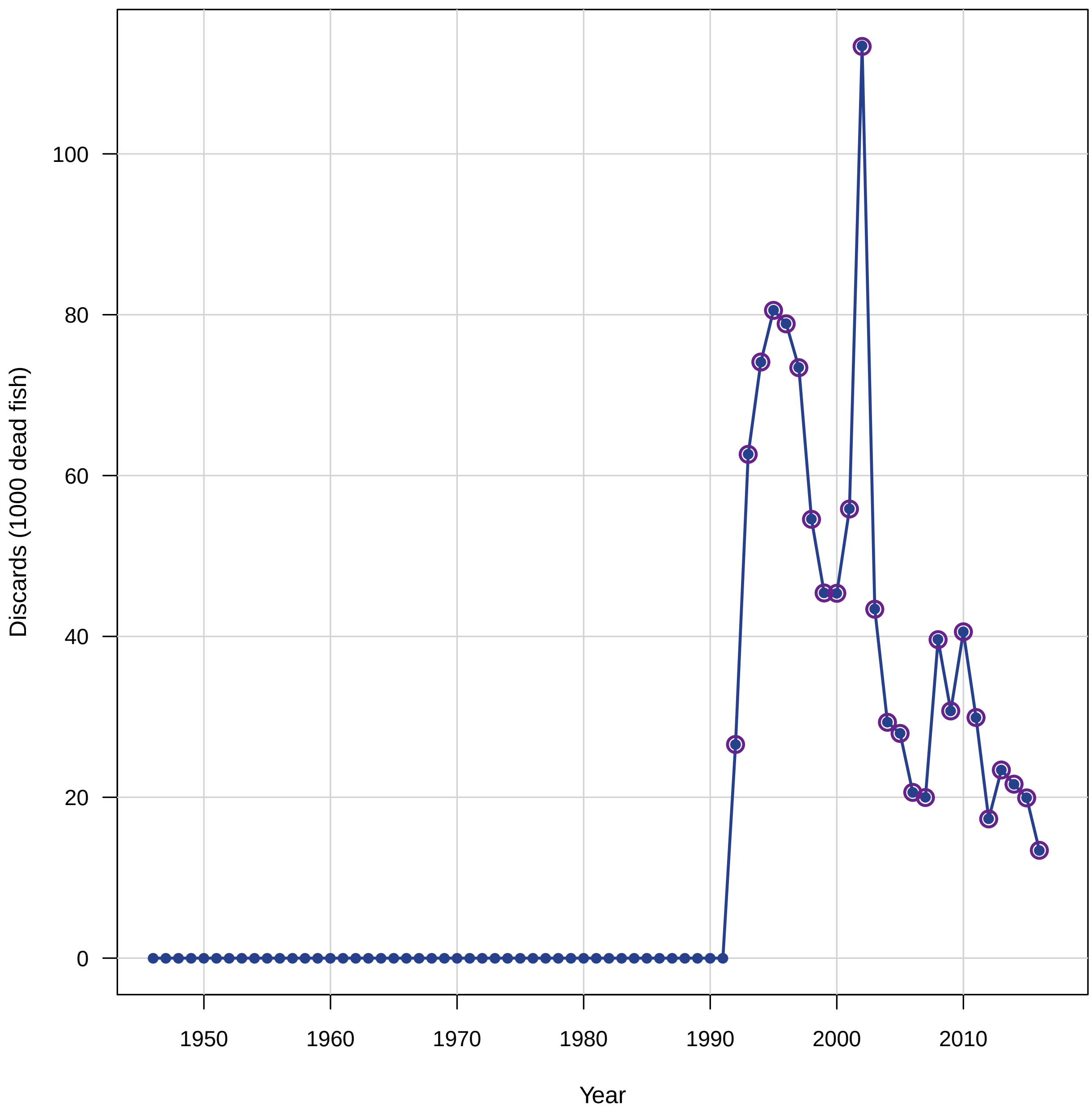


Figure 10. Observed (open circles) and estimated (solid line, circles) headboat discard mortalities (1000 dead fish). Open and solid circles may be indistinguishable in years with very close fits.

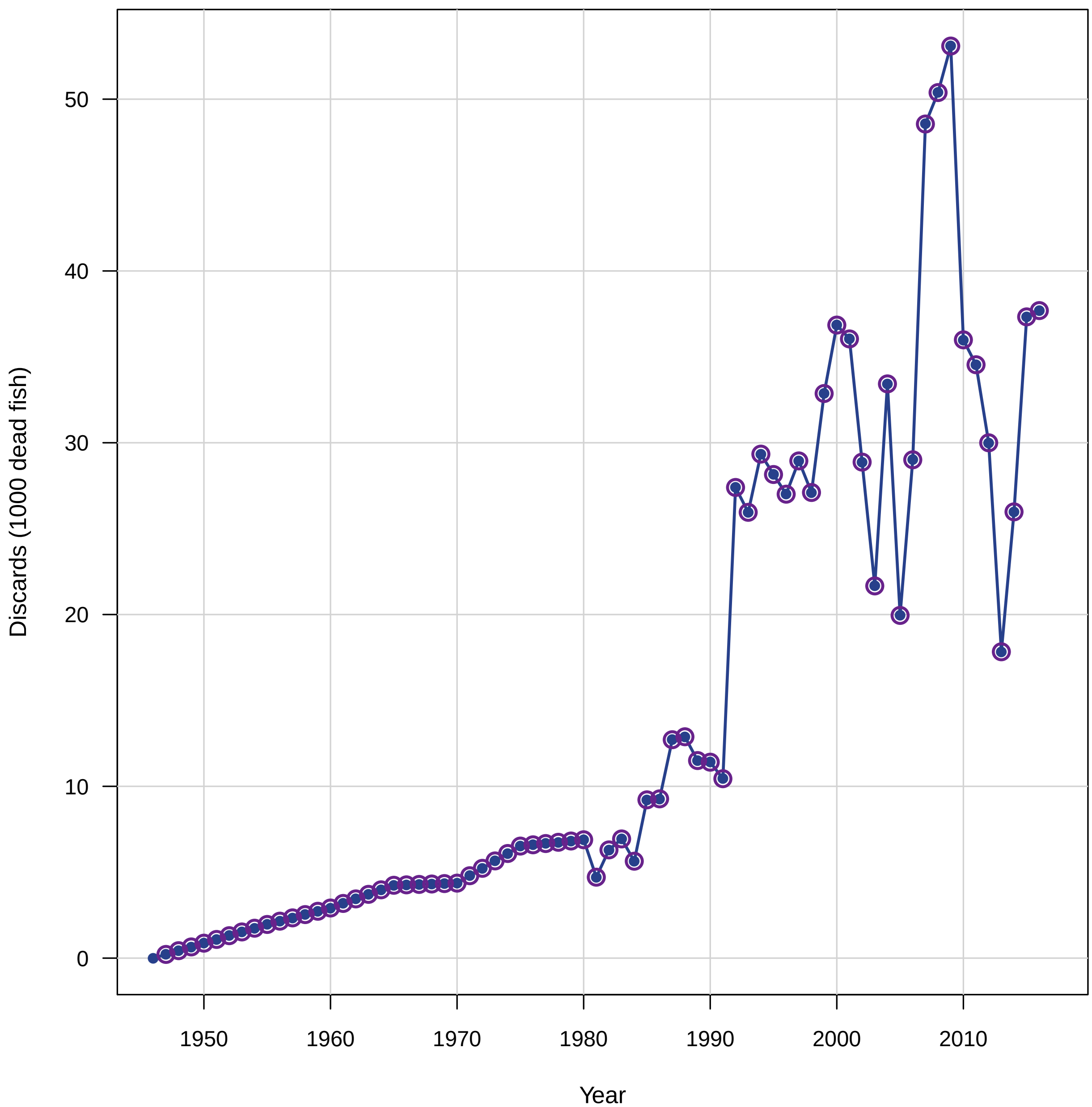


Figure 11. Observed (open circles) and estimated (solid line, circles) general recreational discard mortalities (1000 dead fish). Open and solid circles may be indistinguishable in years with very close fits.

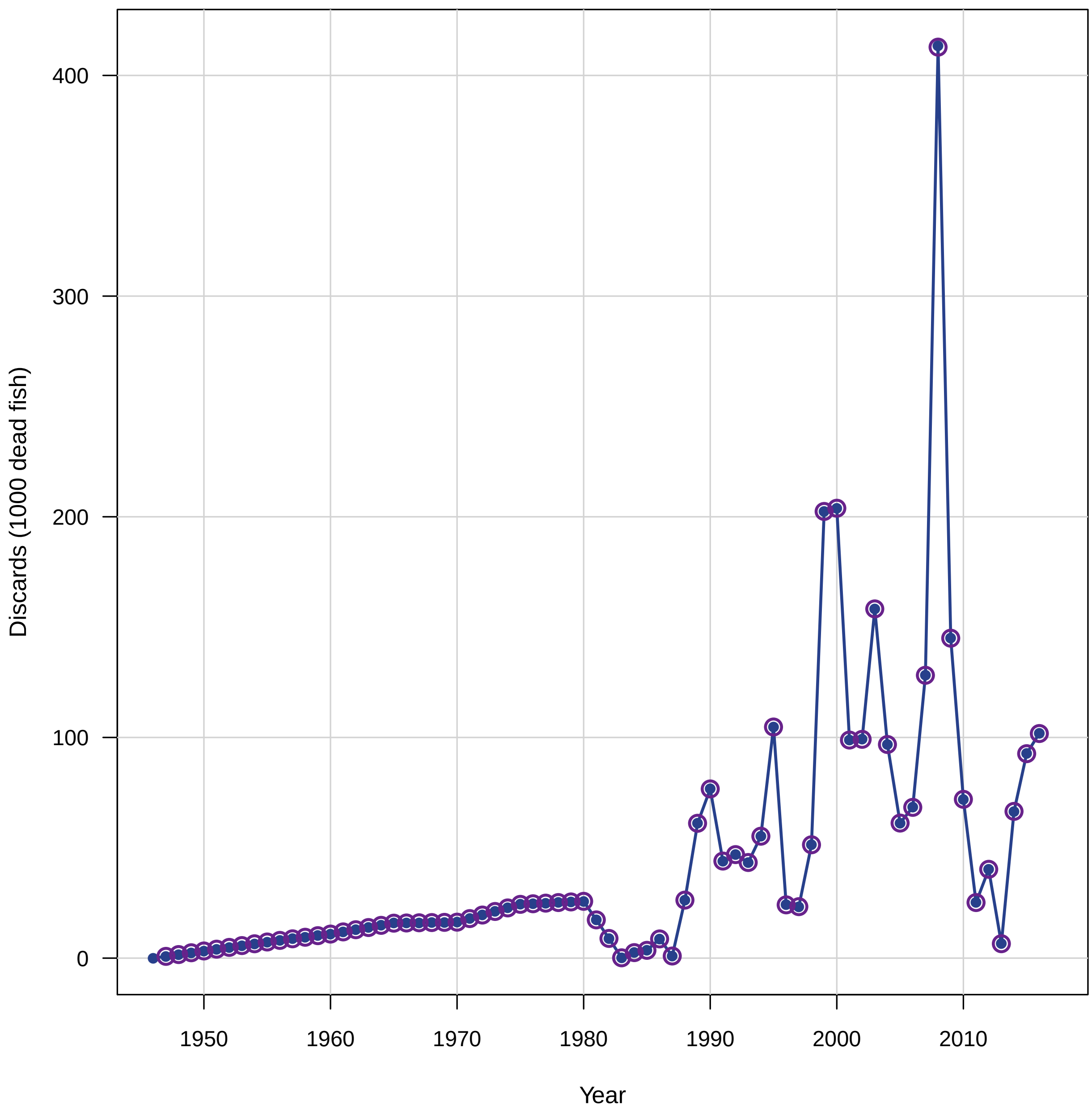


Figure 12. Observed (open circles) and estimated (solid line, circles) index of abundance from the SERFS chevron trap/video survey.

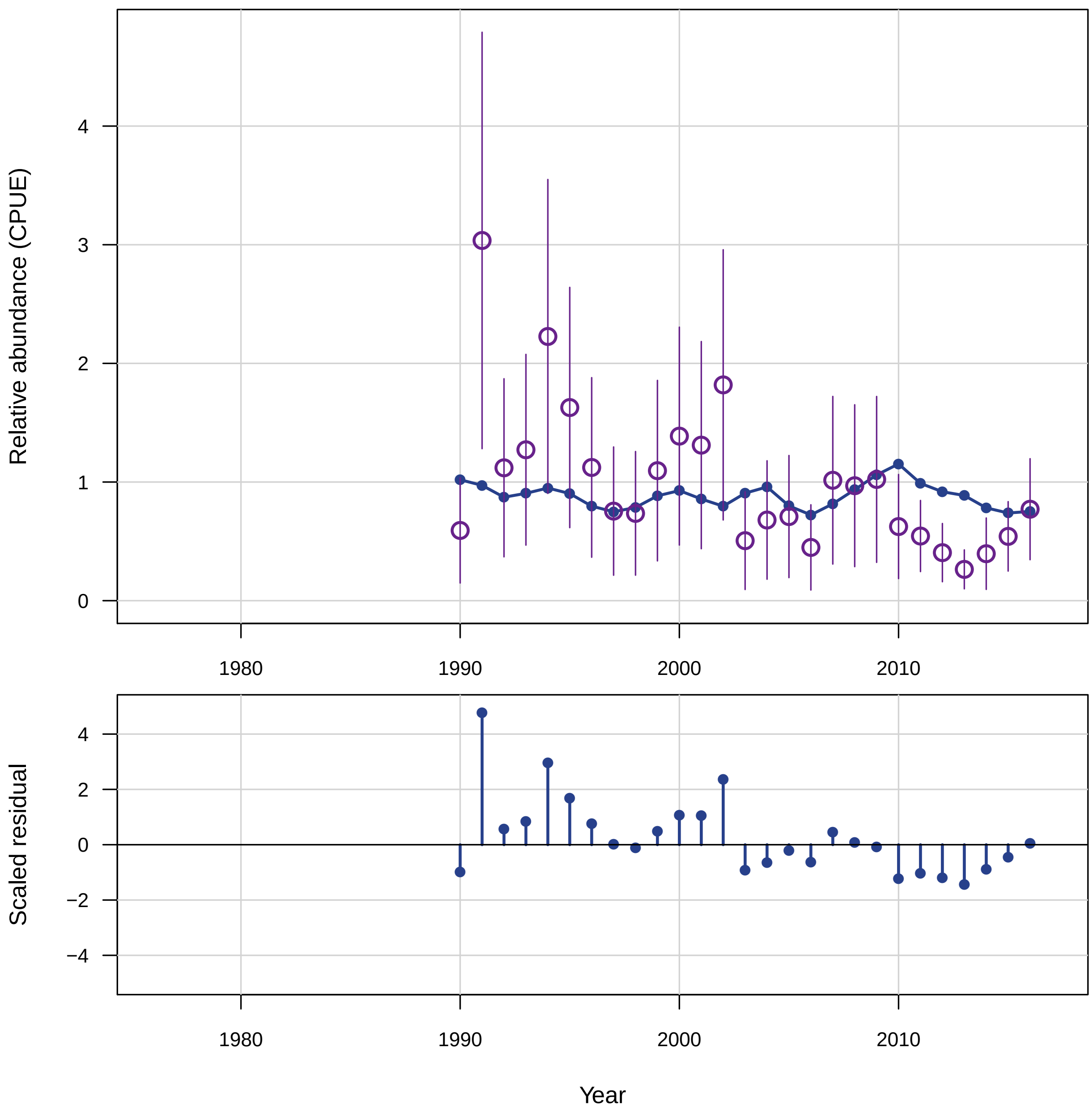


Figure 13. Observed (open circles) and estimated (solid line, circles) index of abundance from the MARMAP Florida snapper trap.

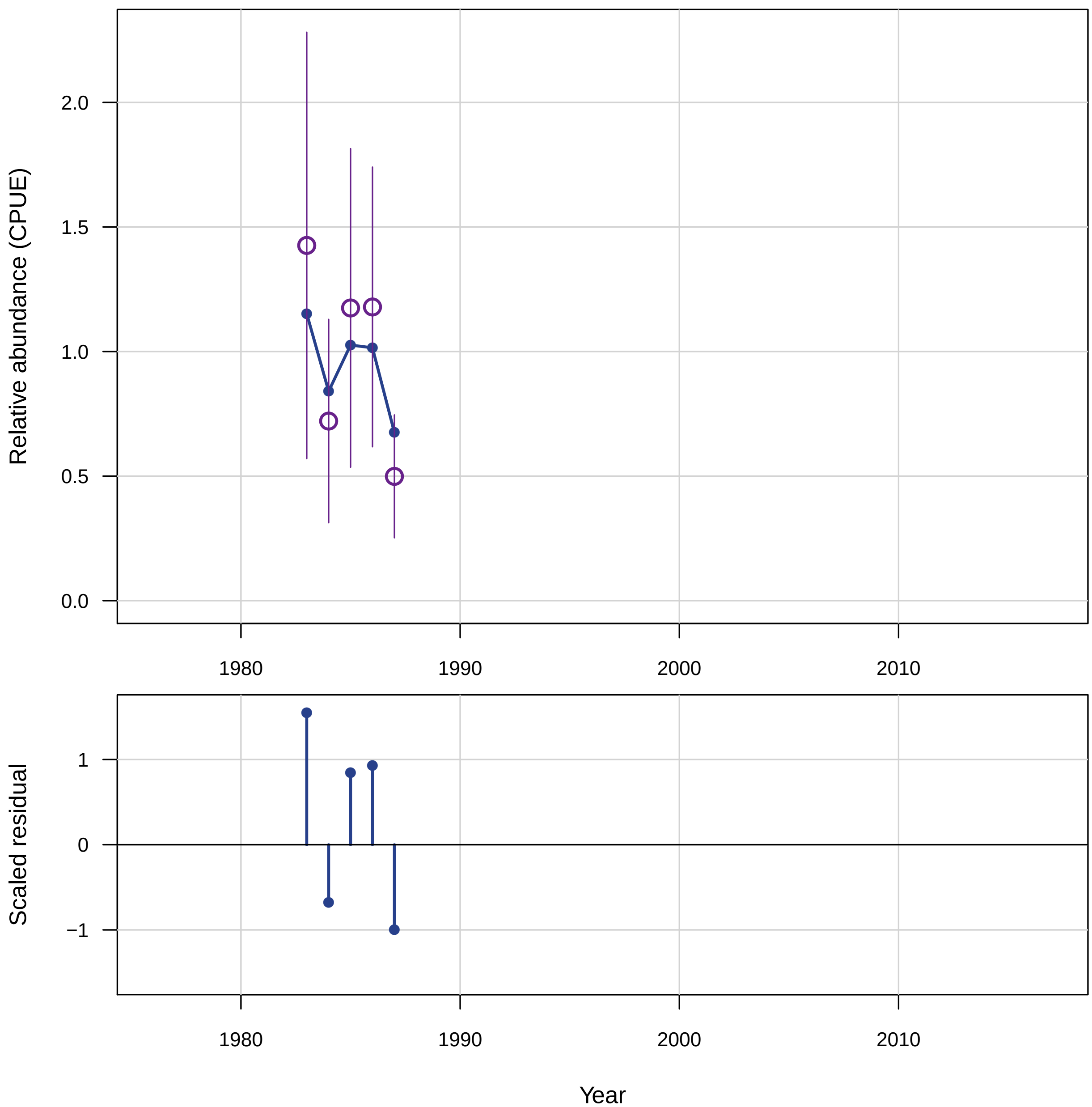


Figure 14. Observed (open circles) and estimated (solid line, circles) index of abundance from the commercial handline fleet.

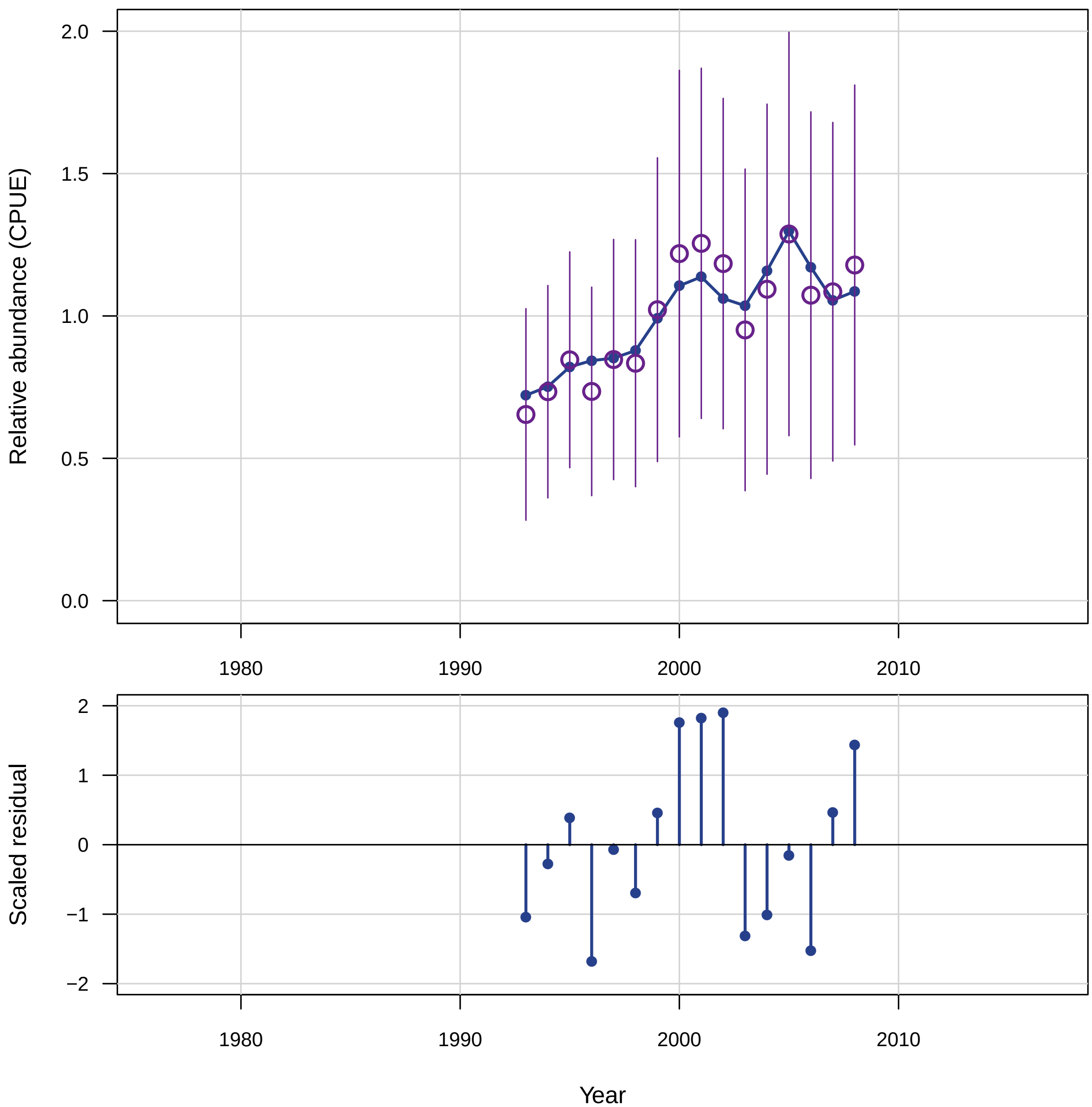


Figure 15. Observed (open circles) and estimated (solid line, circles) index of abundance from the recreational headboat fleet.

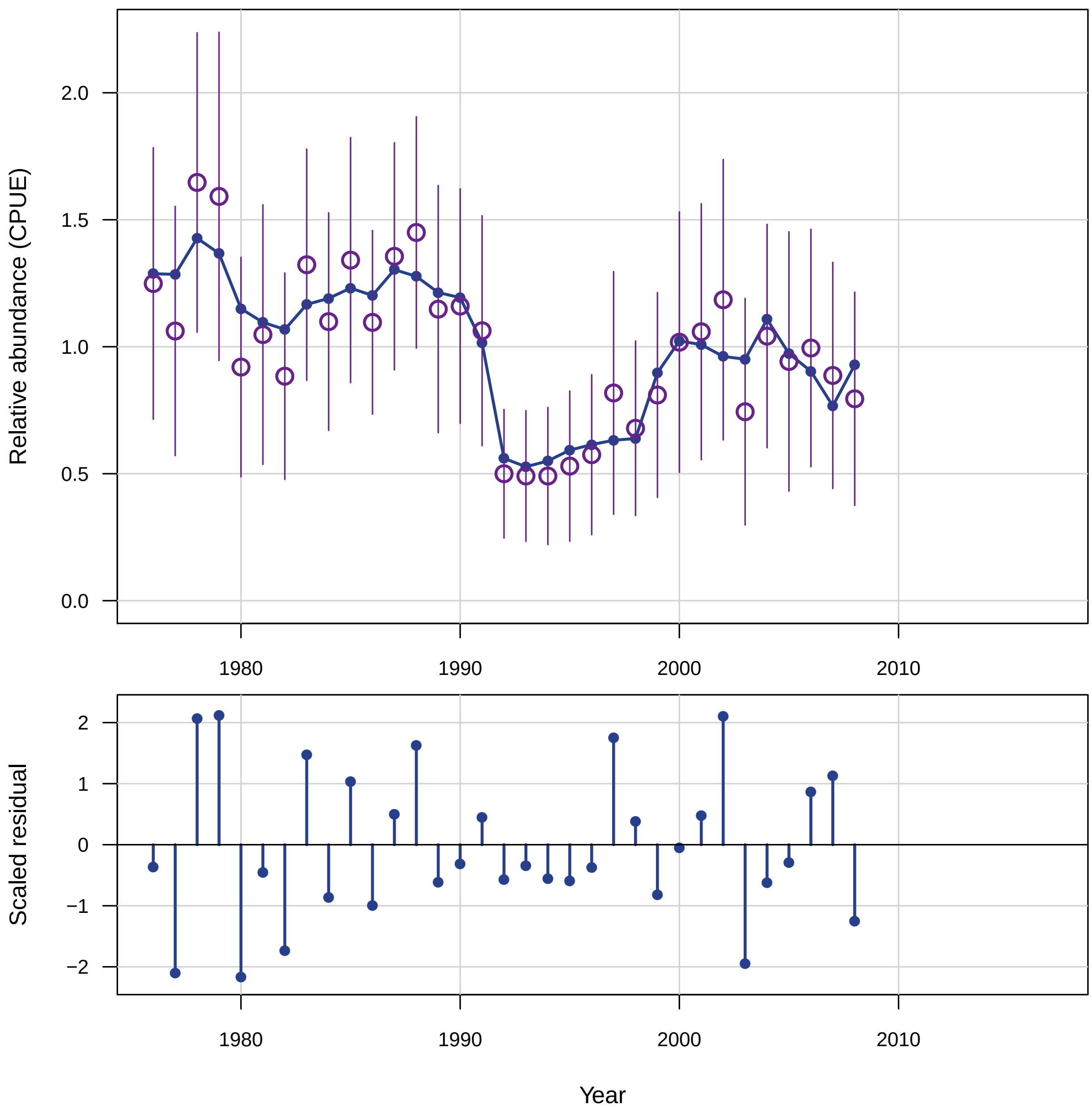


Figure 16. Observed (open circles) and estimated (solid line, circles) index abundance from the general recreational fleet.

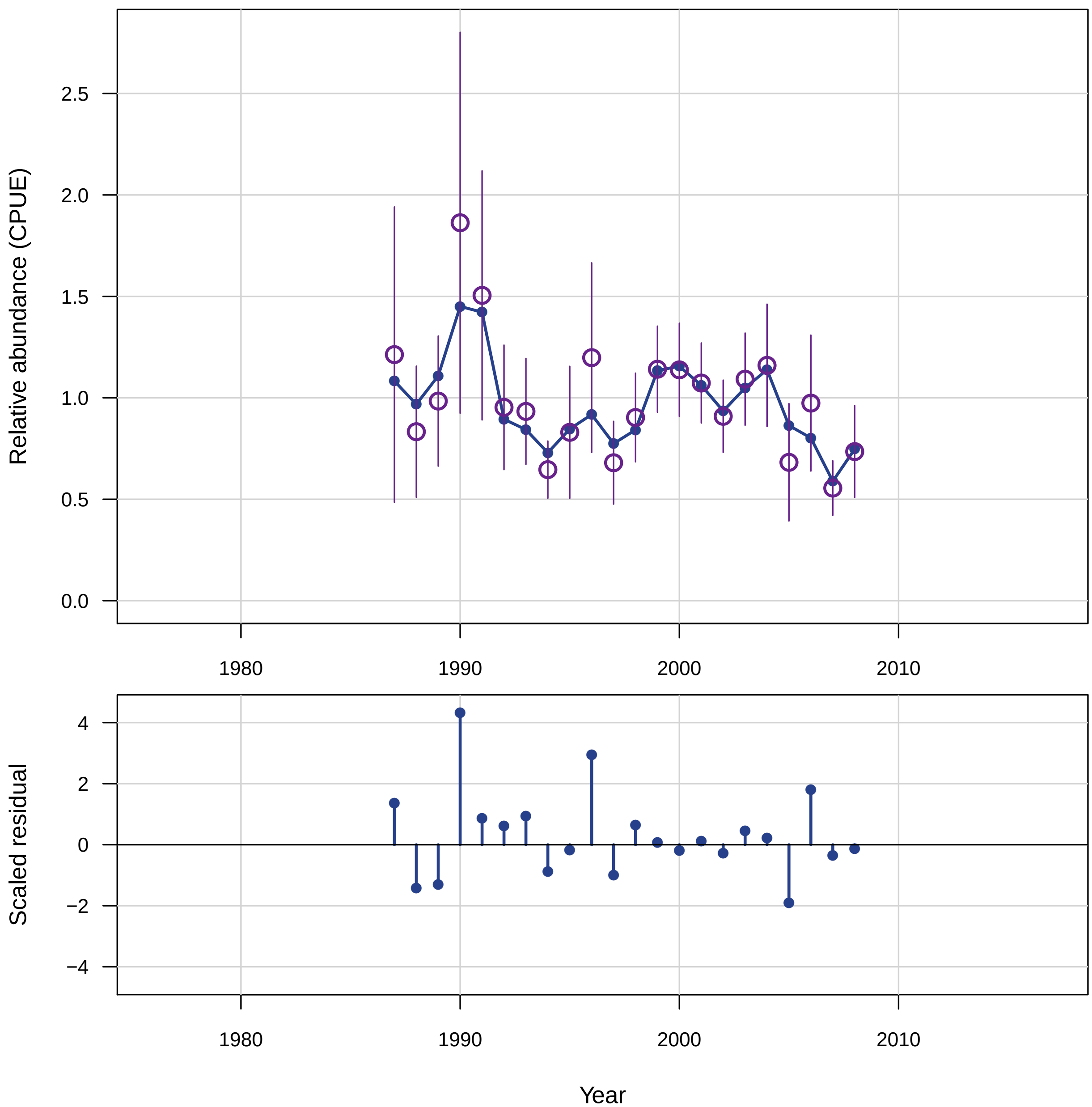


Figure 17. Estimated abundance at age at start of year.

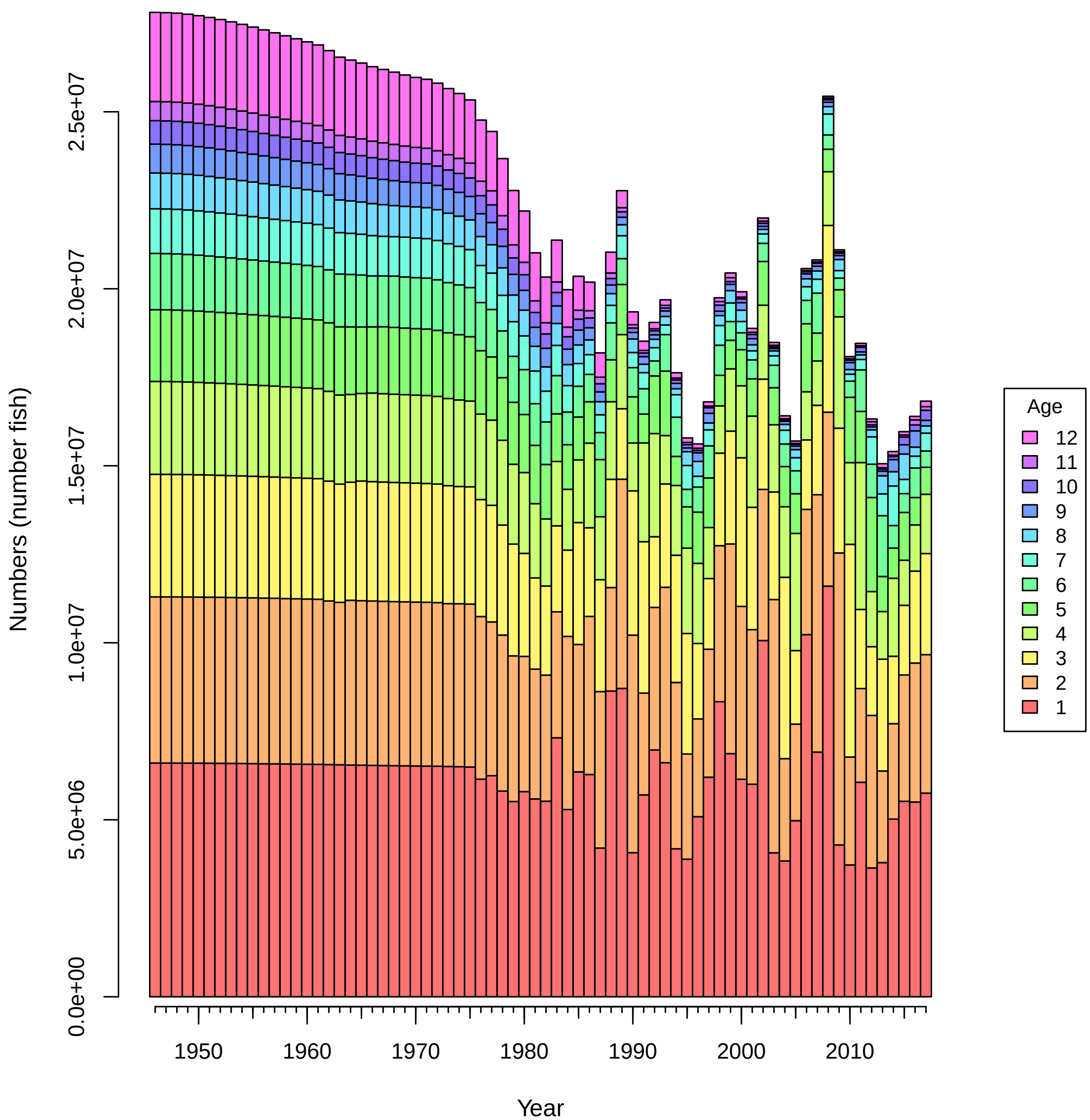
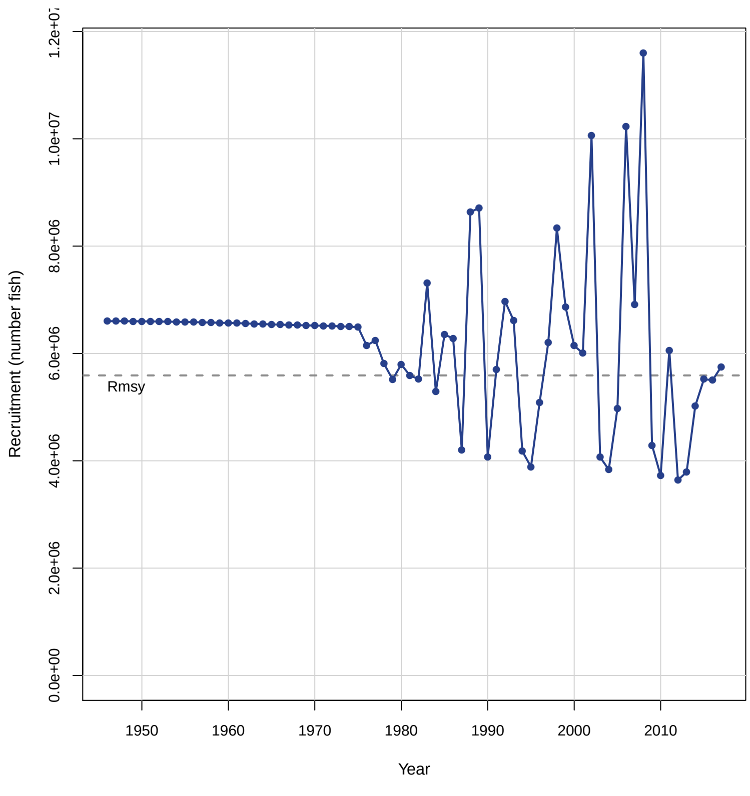


Figure 18. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates R_{MSY}. Bottom panel: log recruitment residuals. The residual in 2017 was not estimated, as recruitment in that year is uninformed by any data on year-class strength. Thus, the 2017 value shown in the top panel is that predicted from the spawner-recruit curve without deviation.



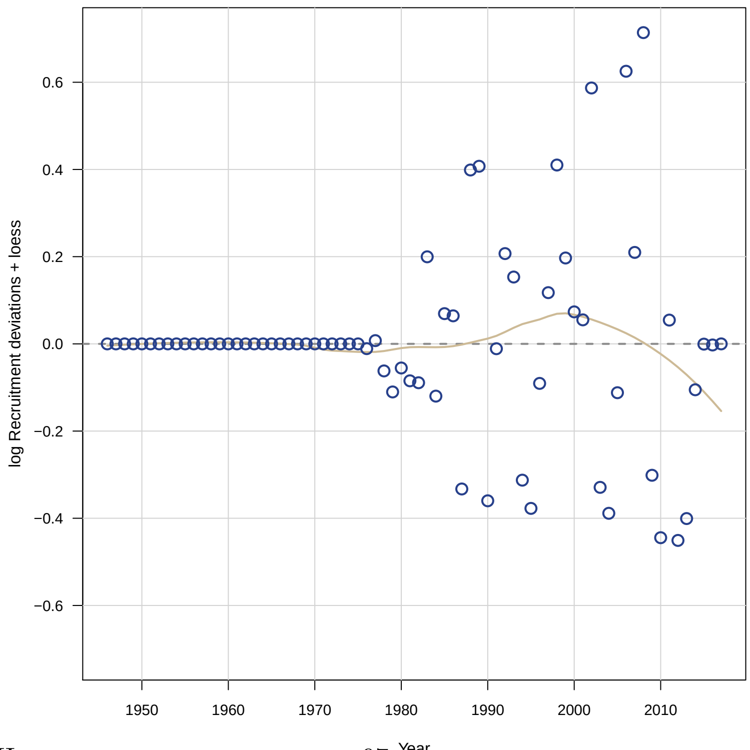


Figure 19. Estimated biomass at age at start of year.

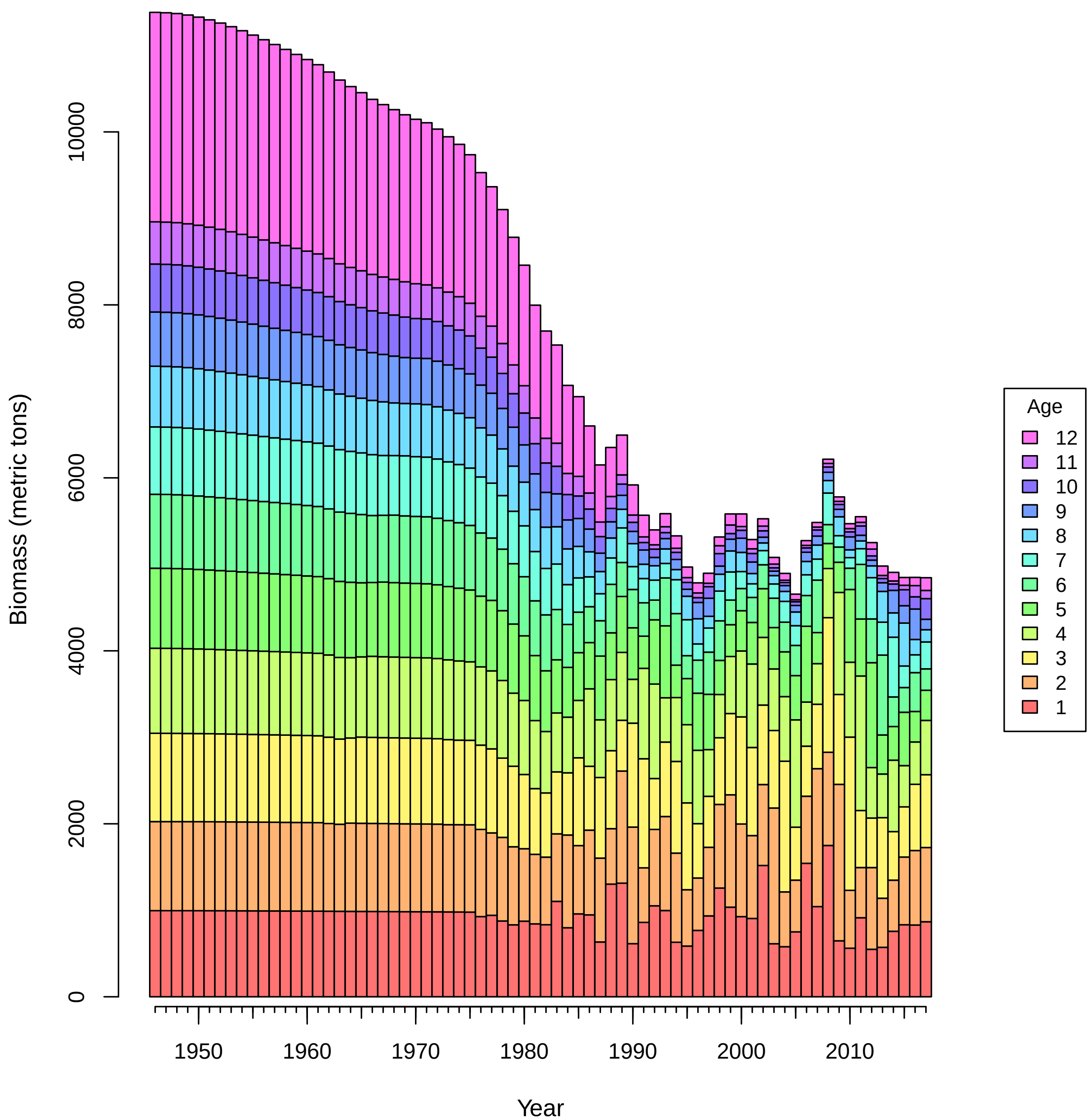


Figure 20. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates B_{MSY}. *Bottom panel: Estimated spawning stock (eggs) at time of peak spawning.*

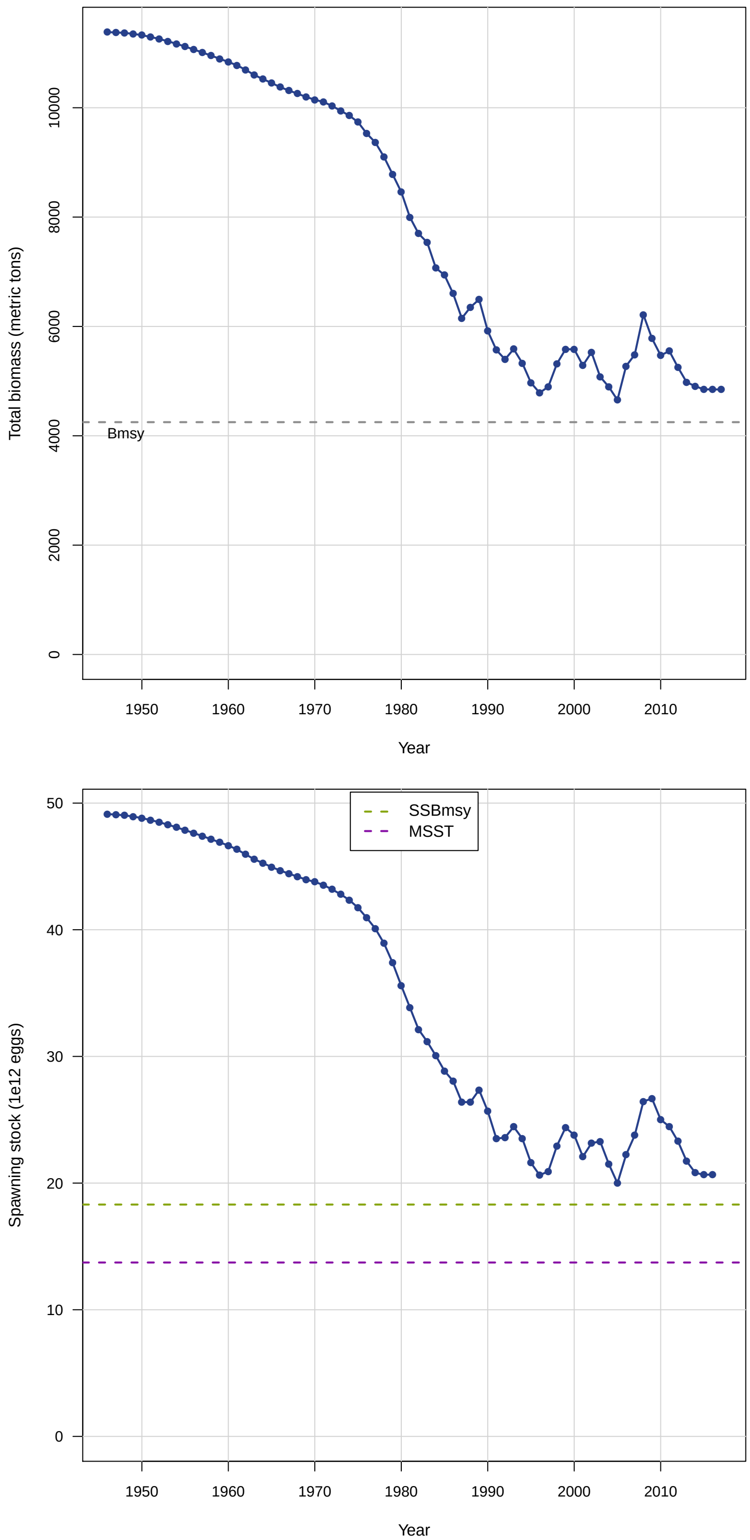


Figure 21. Estimated selectivities of fishery independent surveys. Top panel: SERFS trap/video gear. Bottom panel: MARMAP Florida snapper trap.

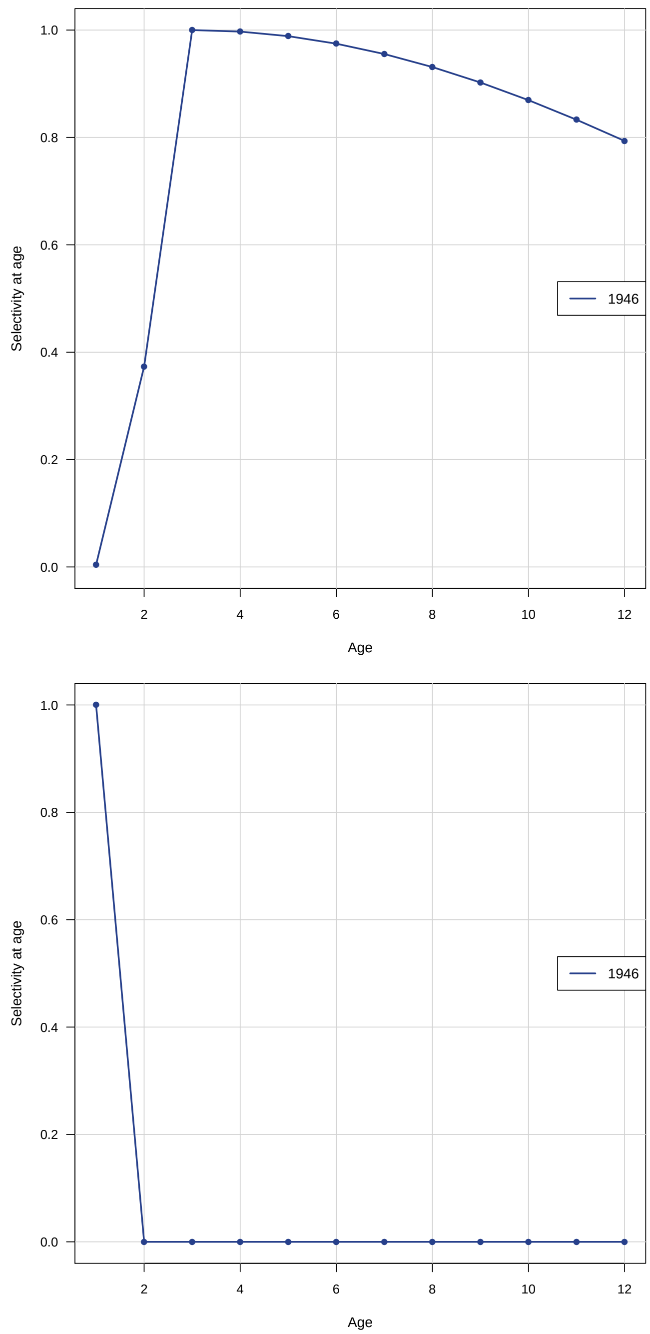


Figure 22. Estimated selectivities of commercial fleets. Years indicated on panels signify the first year of a time block. Top panel: commercial lines. Middle panel: commercial other. Bottom panel: commercial historic trawl.

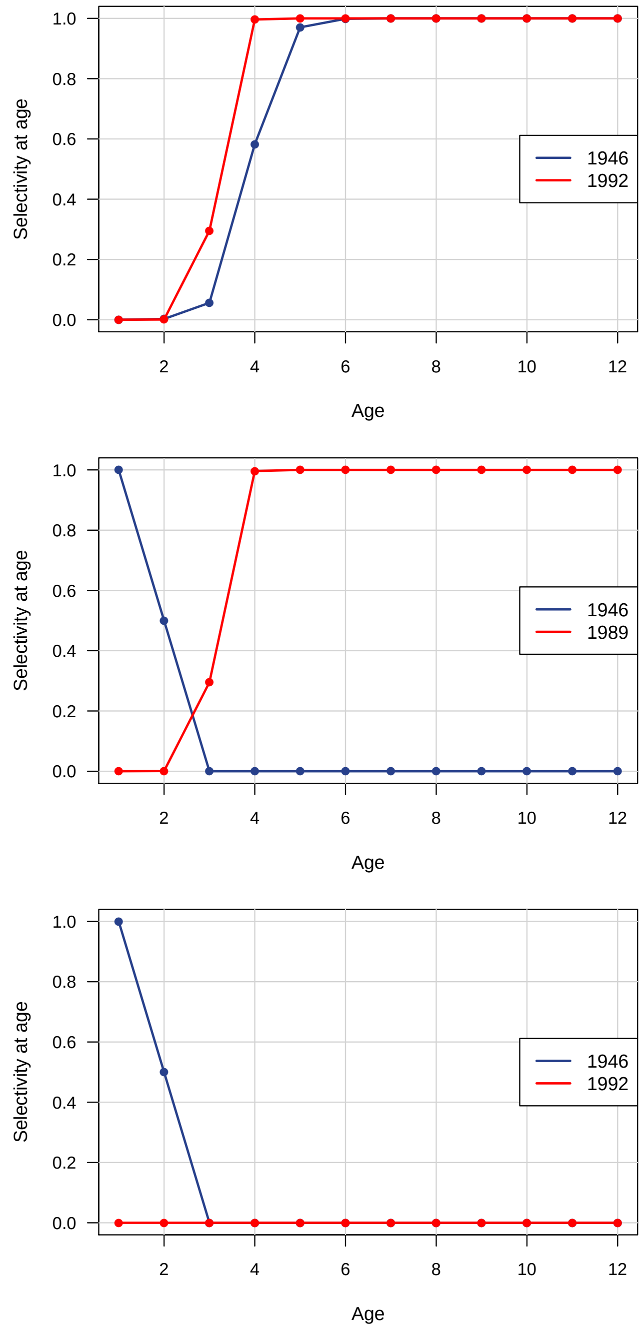


Figure 23. Estimated selectivities of recreational fleets (headboat and general recreational were assumed equal). Years indicated on panels signify the first year of a time block.

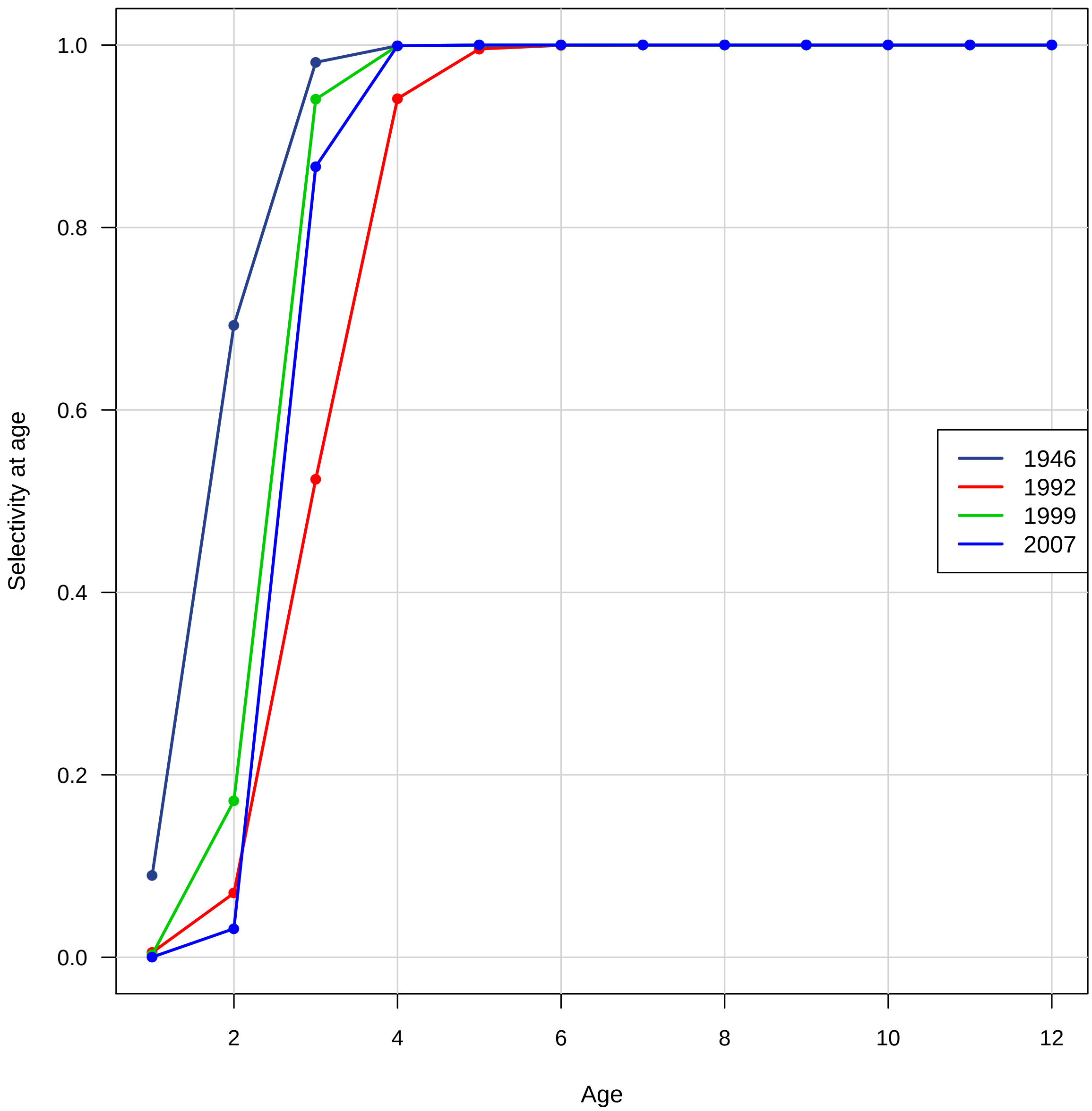


Figure 24. Estimated selectivity of discard mortalities from commercial handlines. Years indicated on panels signify the first year of a time block.

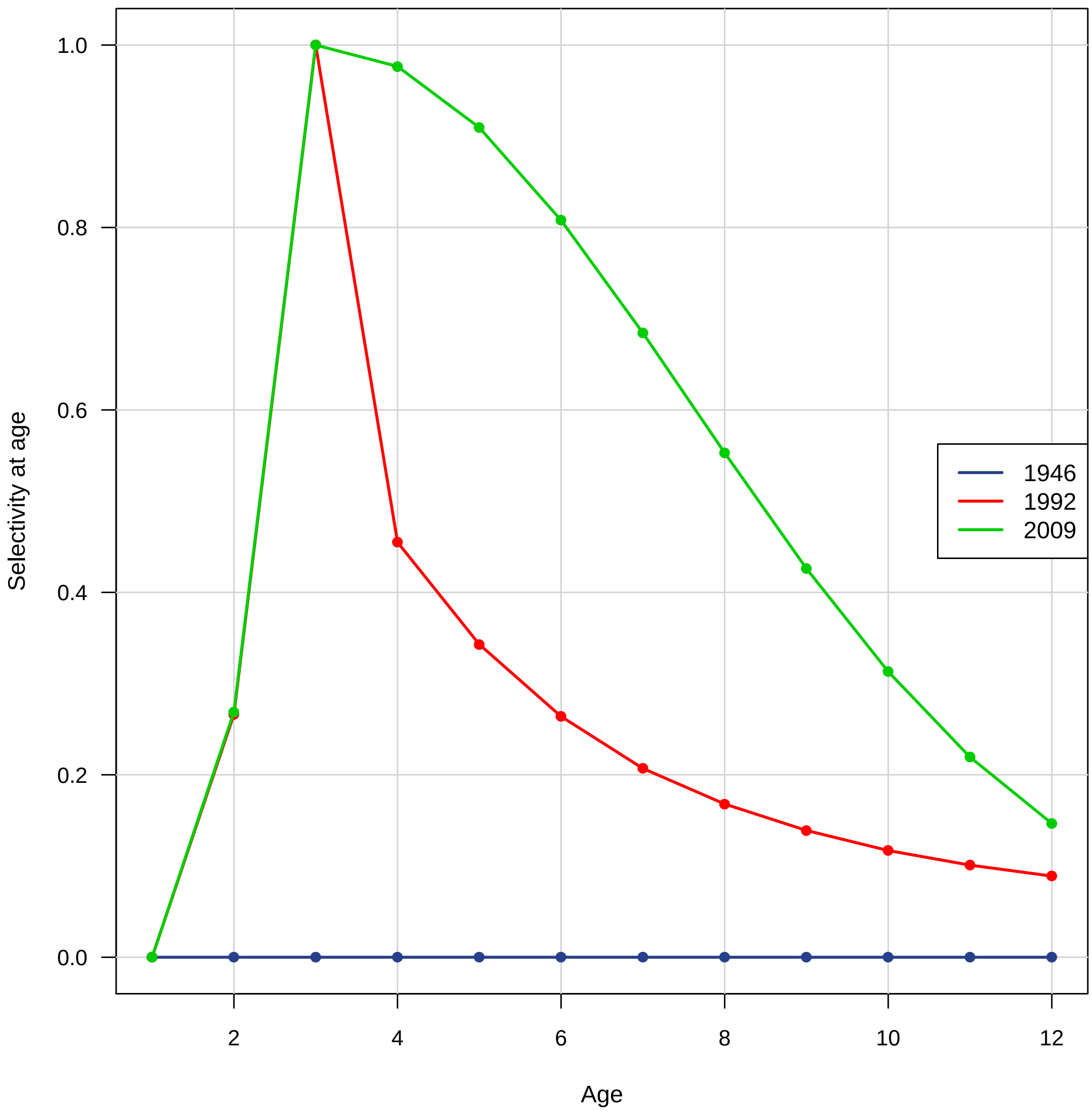


Figure 25. Estimated selectivity of discard mortalities from headboat and general recreational. Years indicated on panels signify the first year of a time block.

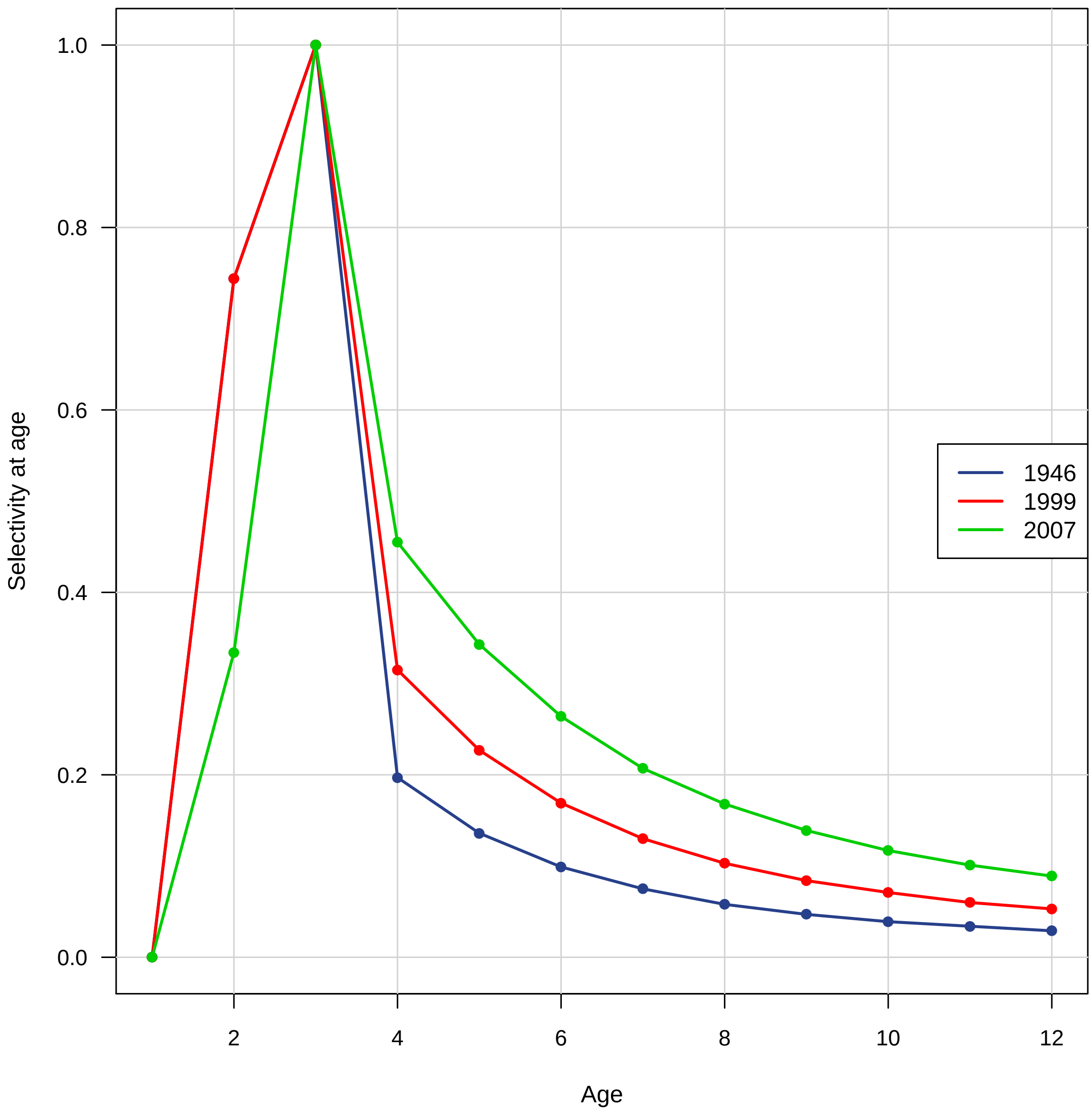


Figure 26. Average selectivities from the terminal assessment years, weighted by geometric mean Fs from the last three assessment years, and used in computation of benchmarks and projections. Top panel: average selectivity applied to landings. Middle panel: average selectivity applied to discard mortalities. Bottom panel: total average selectivity.

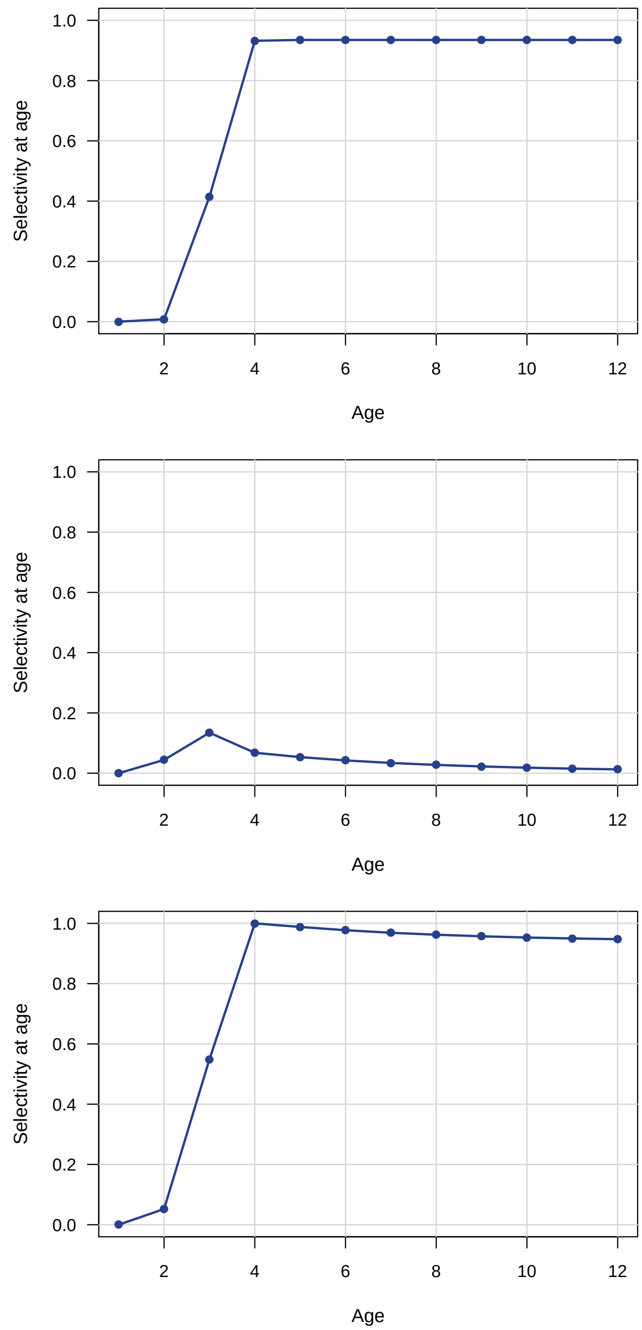


Figure 27. Estimated fully selected fishing mortality rate (per year) by fleet. cH refers to commercial handlines, cO to commercial other, cHTR to commercial historic trawl, HB to headboat, and GR to general recreational. D refers to discard mortalities.

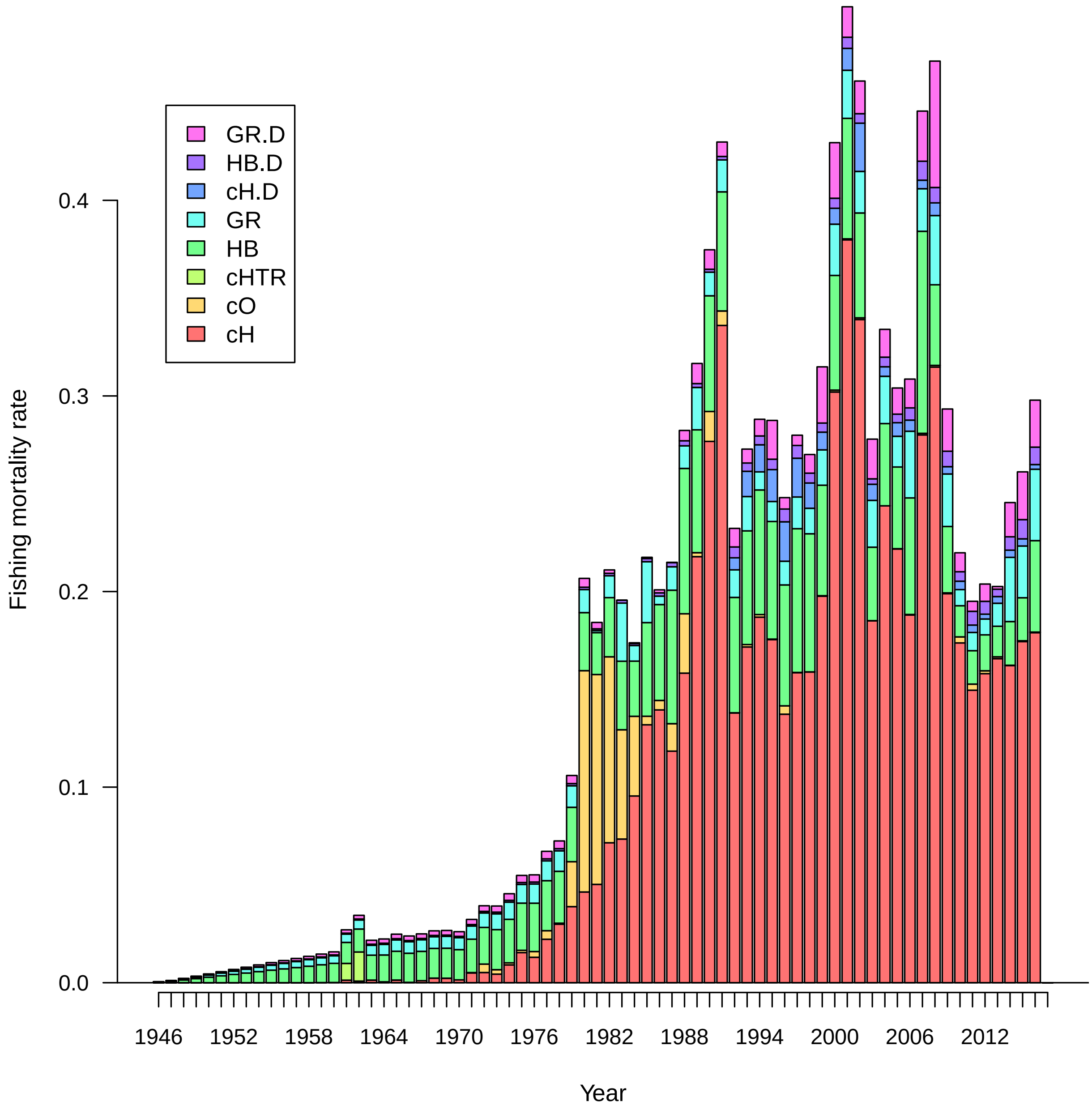


Figure 28. Estimated landings in numbers by fleet from the catch-age model. cH refers to commercial handlines, cO to commercial other, cHTR to commercial historic trawl, HB to headboat, and GR to general recreational.

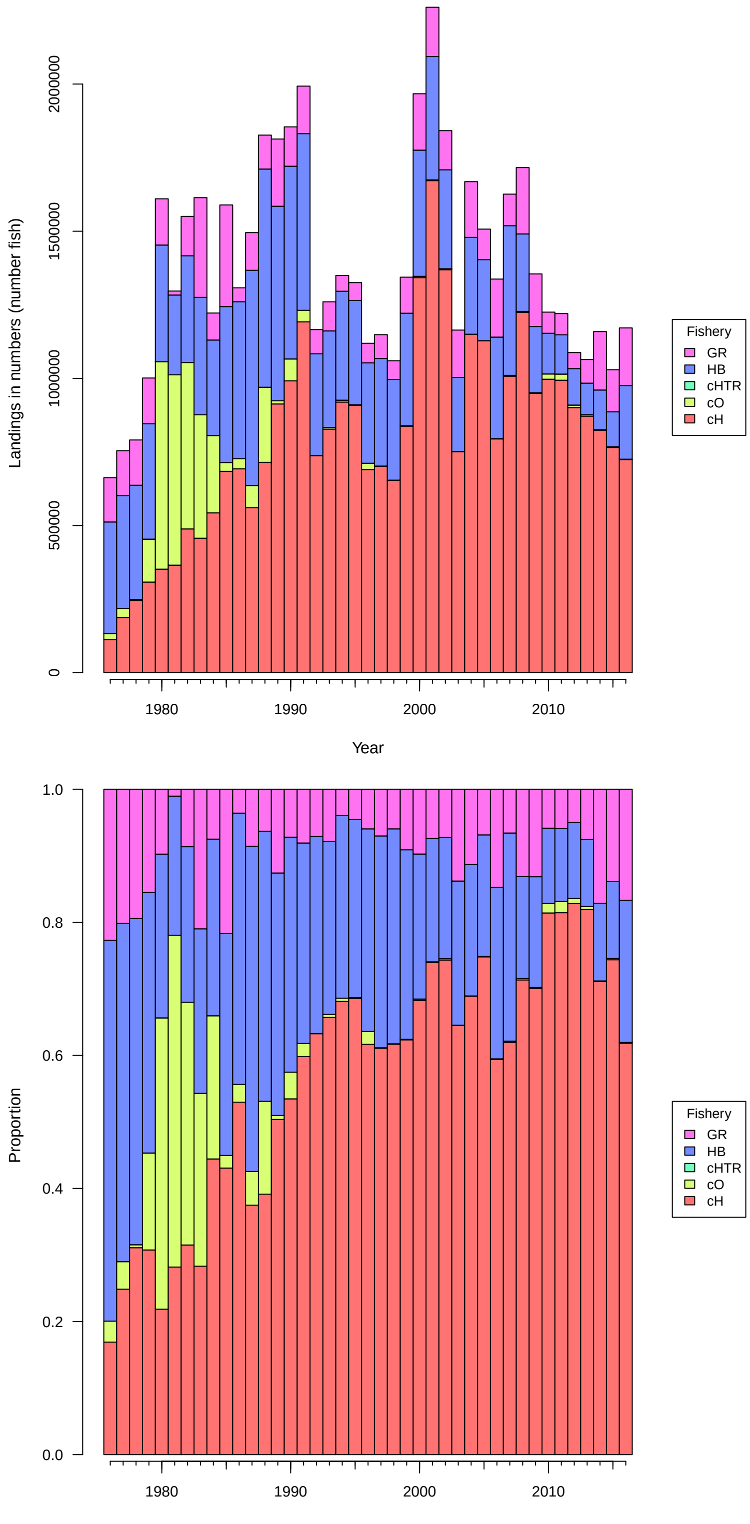


Figure 29. Estimated landings in whole weight by fleet from the catch-age model. cH refers to commercial handlines, cO to commercial other, cHTR to commercial historic trawl, HB to headboat, and GR to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of MSY.

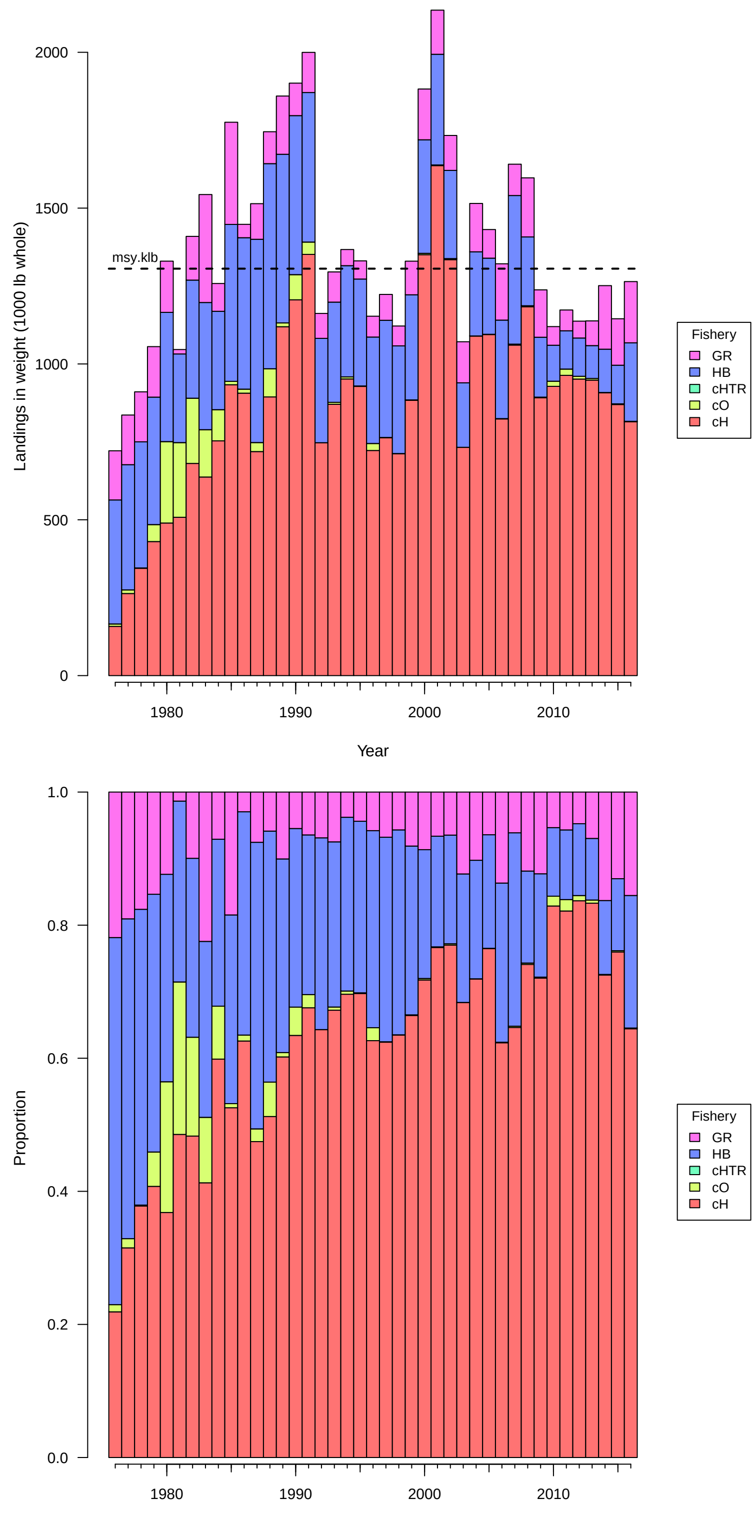


Figure 30. Estimated discard mortalities in numbers by fleet from the catch-age model. cH refers to commercial handlines, HB to headboat, and GR to general recreational.

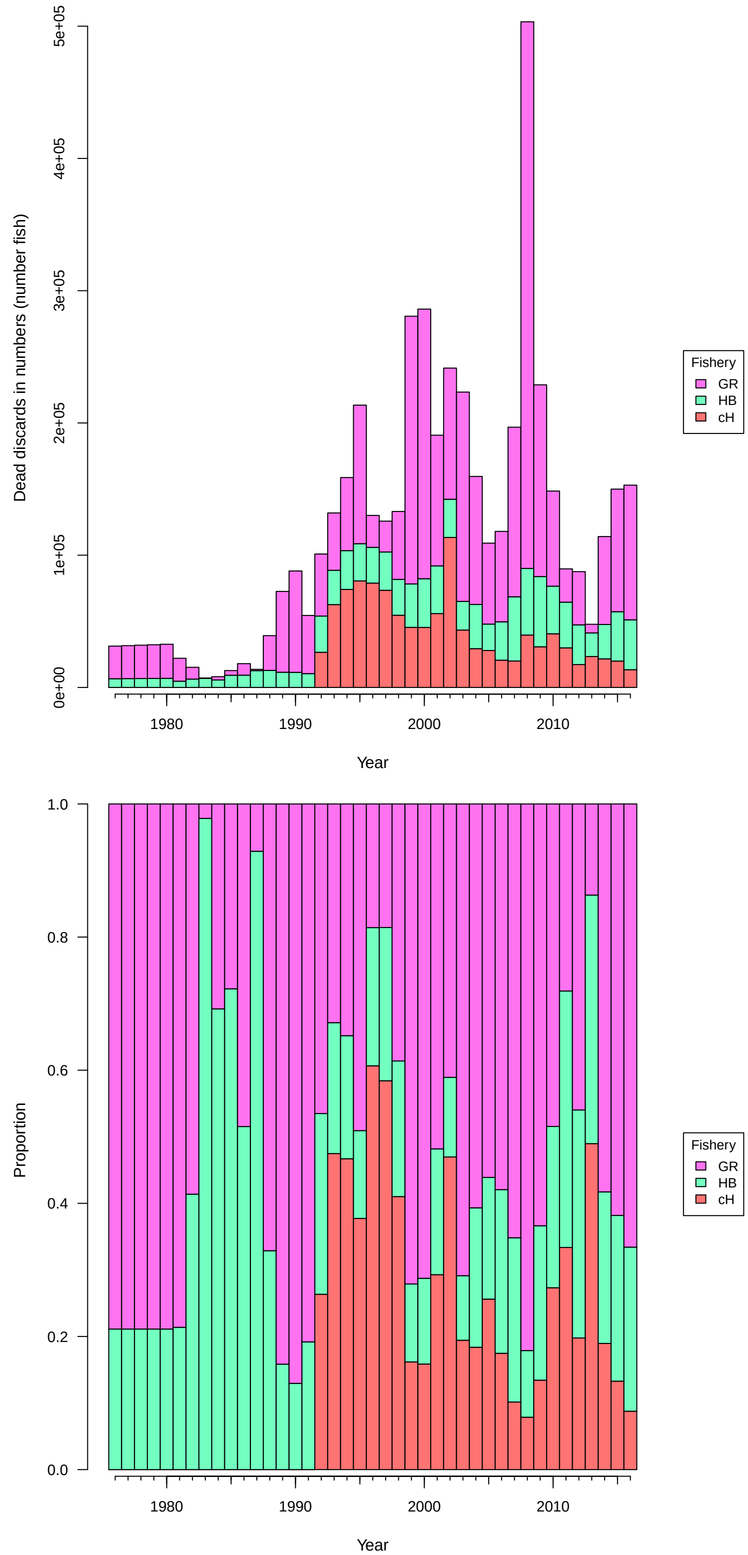


Figure 31. Estimated discard mortalities in weight by fleet from the catch-age model. cH refers to commercial handlines, HB to headboat, and GR to general recreational.

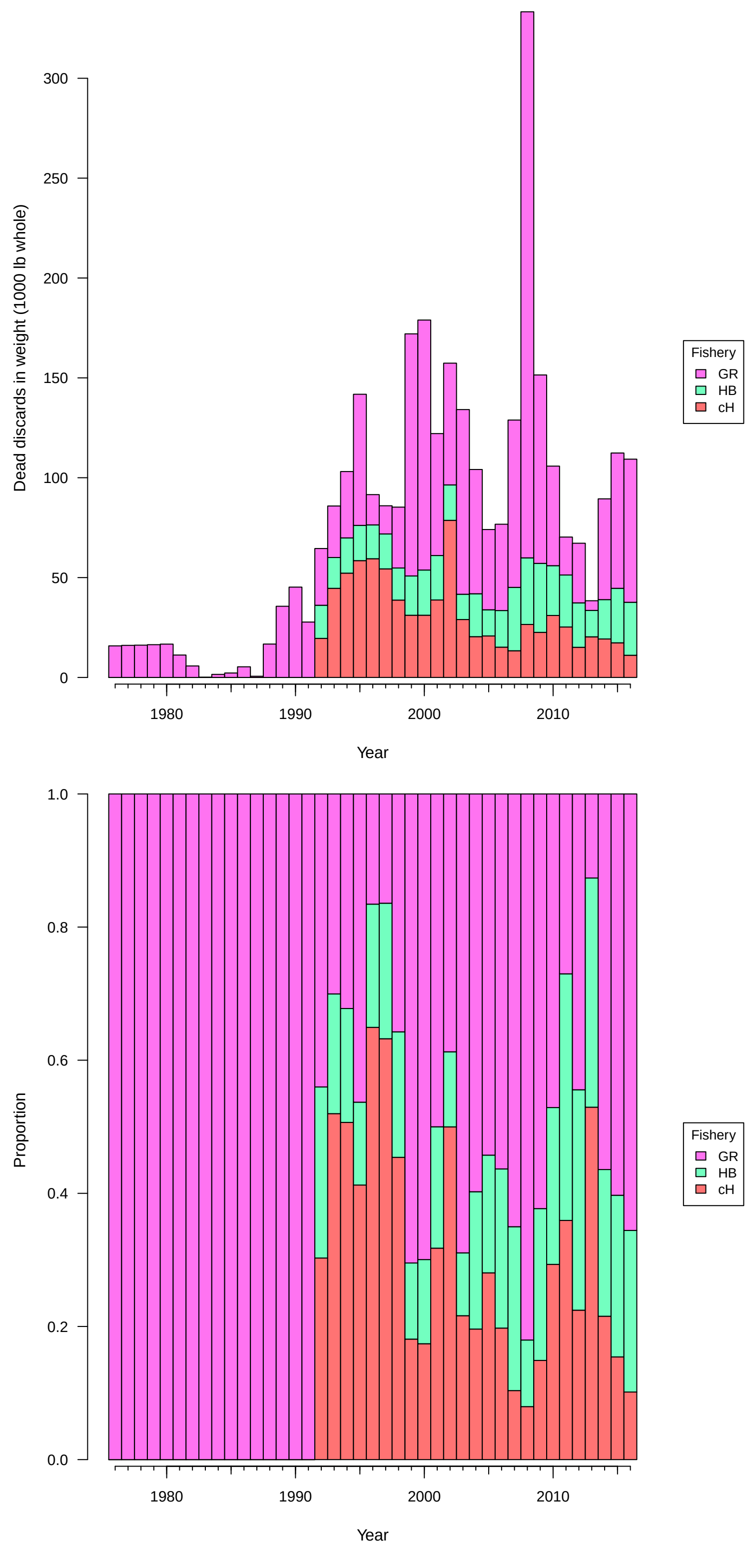


Figure 32. Top panel: Beverton–Holt spawner-recruit curves, with and without lognormal bias correction. The expected (upper) curve was used for computing management benchmarks. Bottom panel: log of recruits (number age-1 fish) per spawner as a function of spawners.

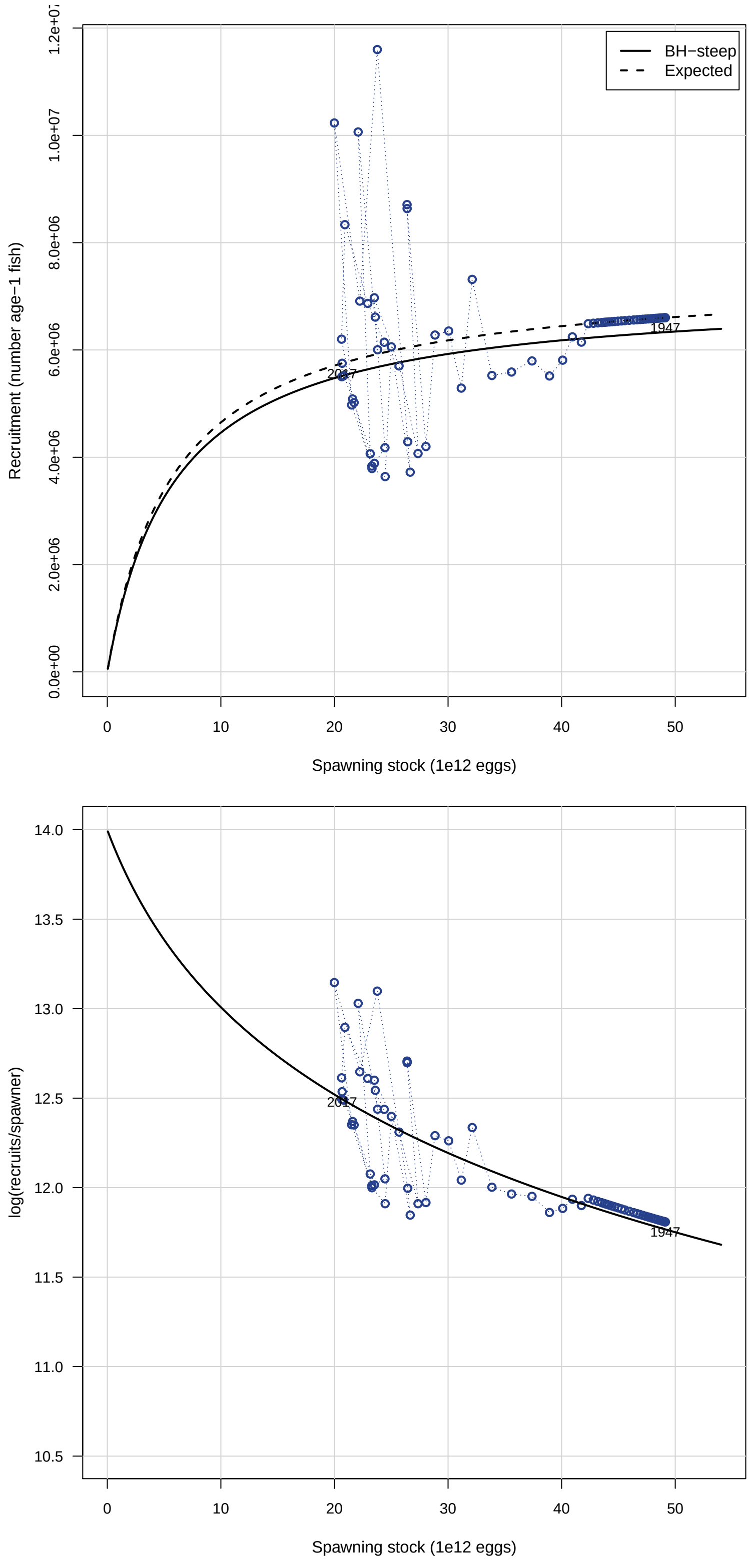


Figure 33. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-1 fish), steepness, unfished spawners per recruit, and standard deviation of recruitment residuals in log space. Solid vertical lines represent point estimates or values from the base run of the Beaufort Assessment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

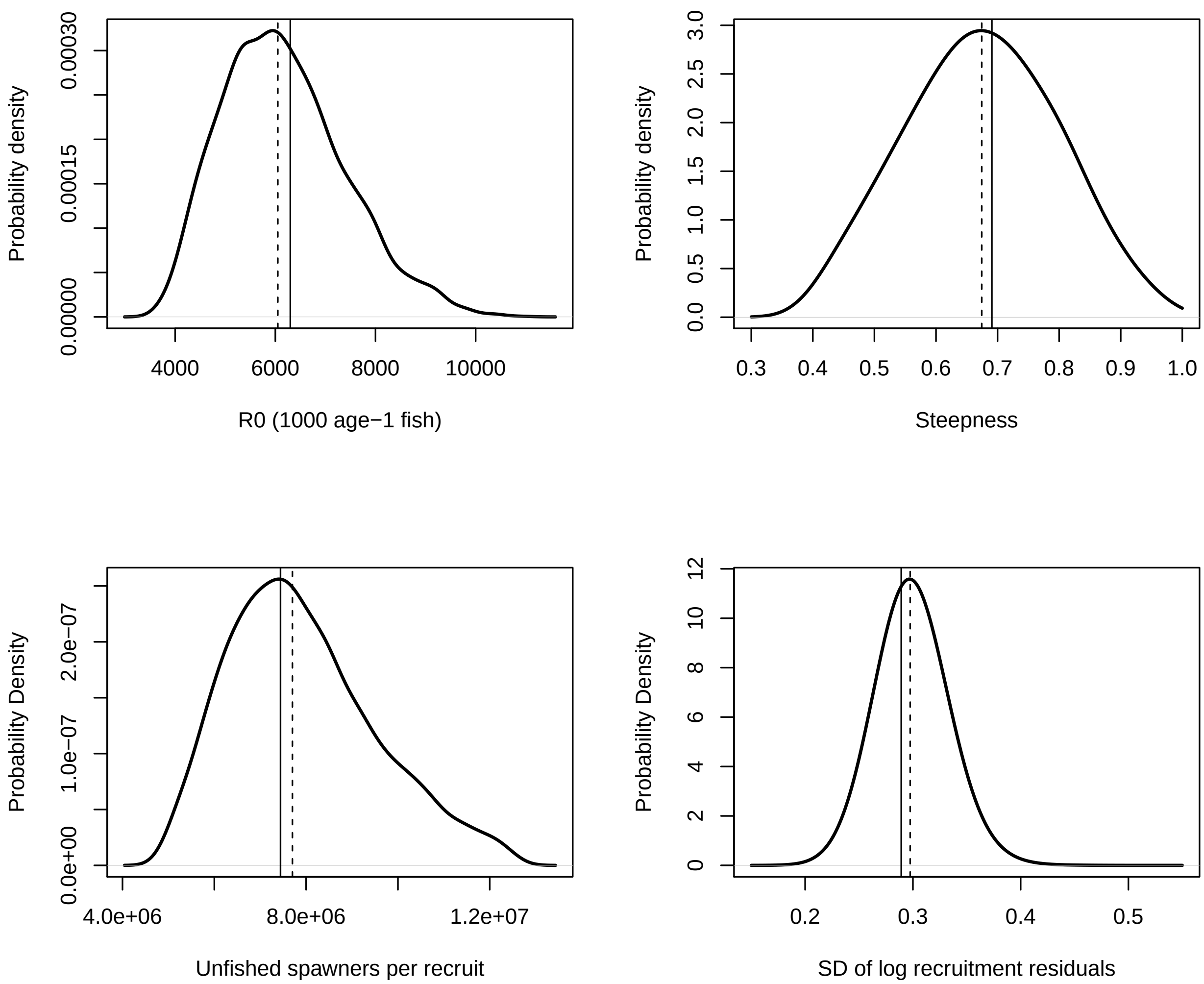


Figure 34. Top panel: yield per recruit (lb). Bottom panel: spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the X% level of SPR provides $F_{X\%}$. Both curves are based on average selectivity from the end of the assessment period.

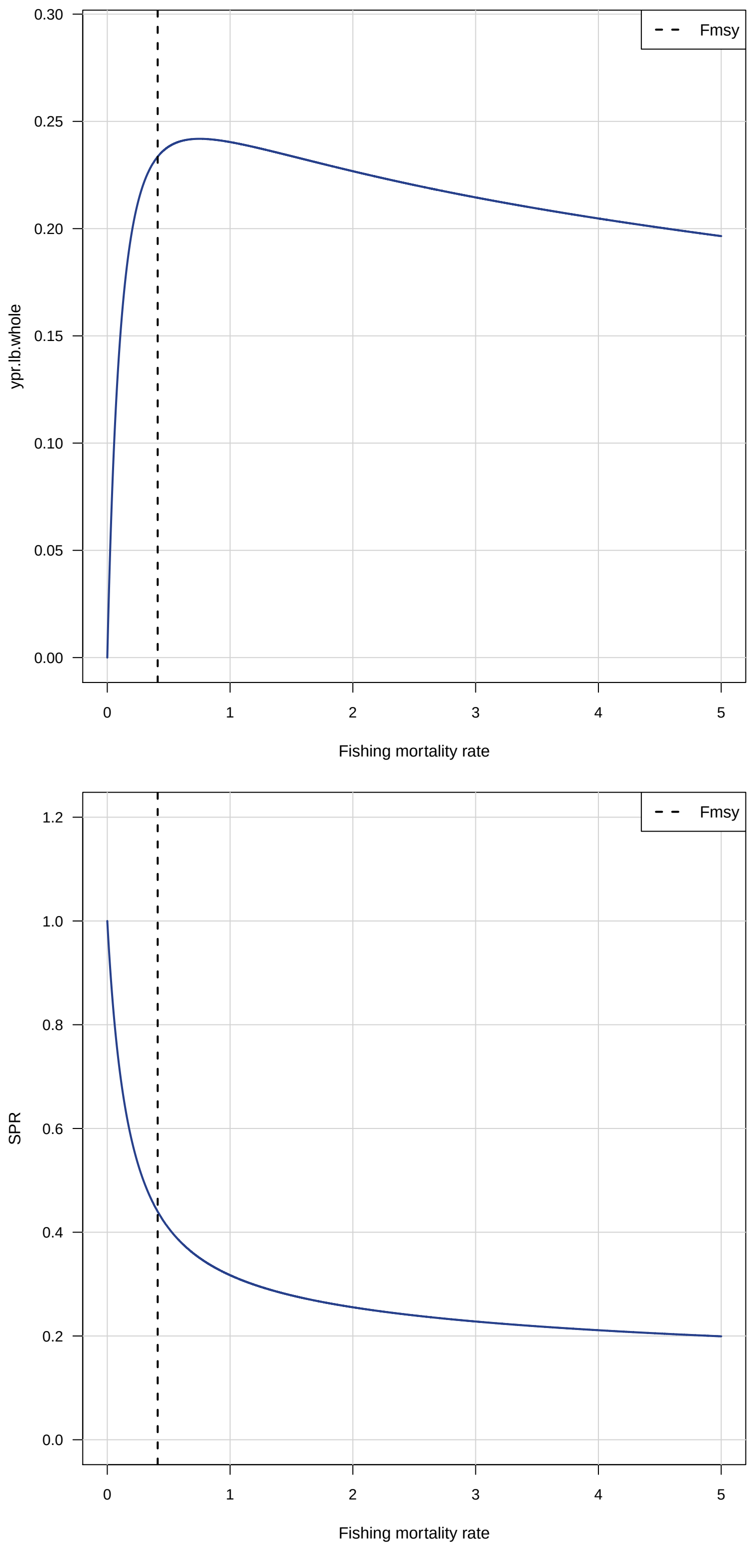


Figure 35. Top panel: equilibrium landings. The peak occurs where fishing rate is $F_{\mathrm{MSY}} = 0.41$ *and equilibrium landings (1000 lb) are* MSY = 1305.8 *(1000 lb). Bottom panel: equilibrium spawning biomass (eggs). Both curves are based on average selectivity from the end of the assessment period.*

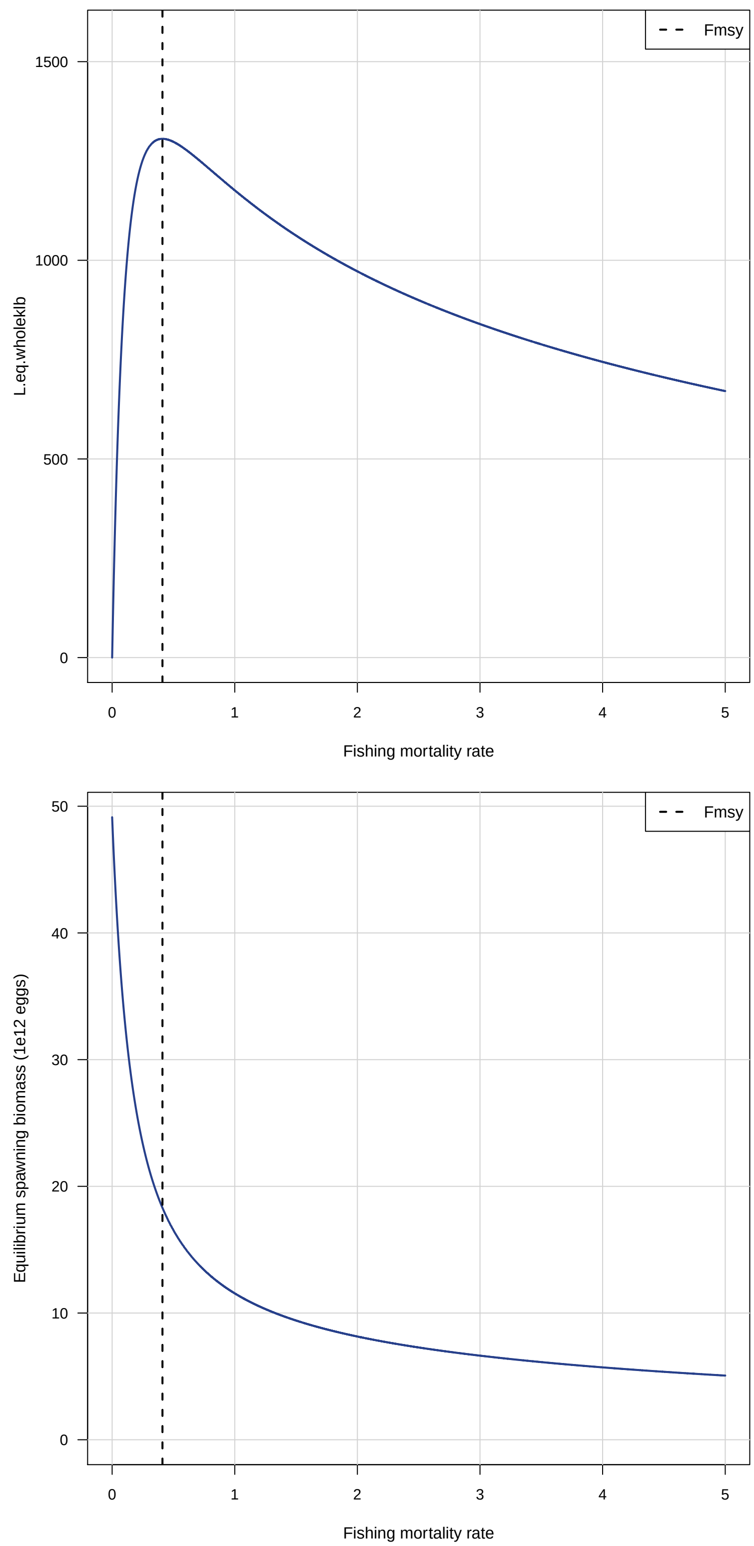


Figure 36. Equilibrium landings and discards as a function of equilibrium biomass, which itself is a function of fishing mortality rate. The peak occurs where equilibrium biomass is $B_{\mathrm{MSY}} = 4249.2$ *mt and equilibrium removals are* $\mathrm{MSY} = 1305.8$ *(1000 lb).*

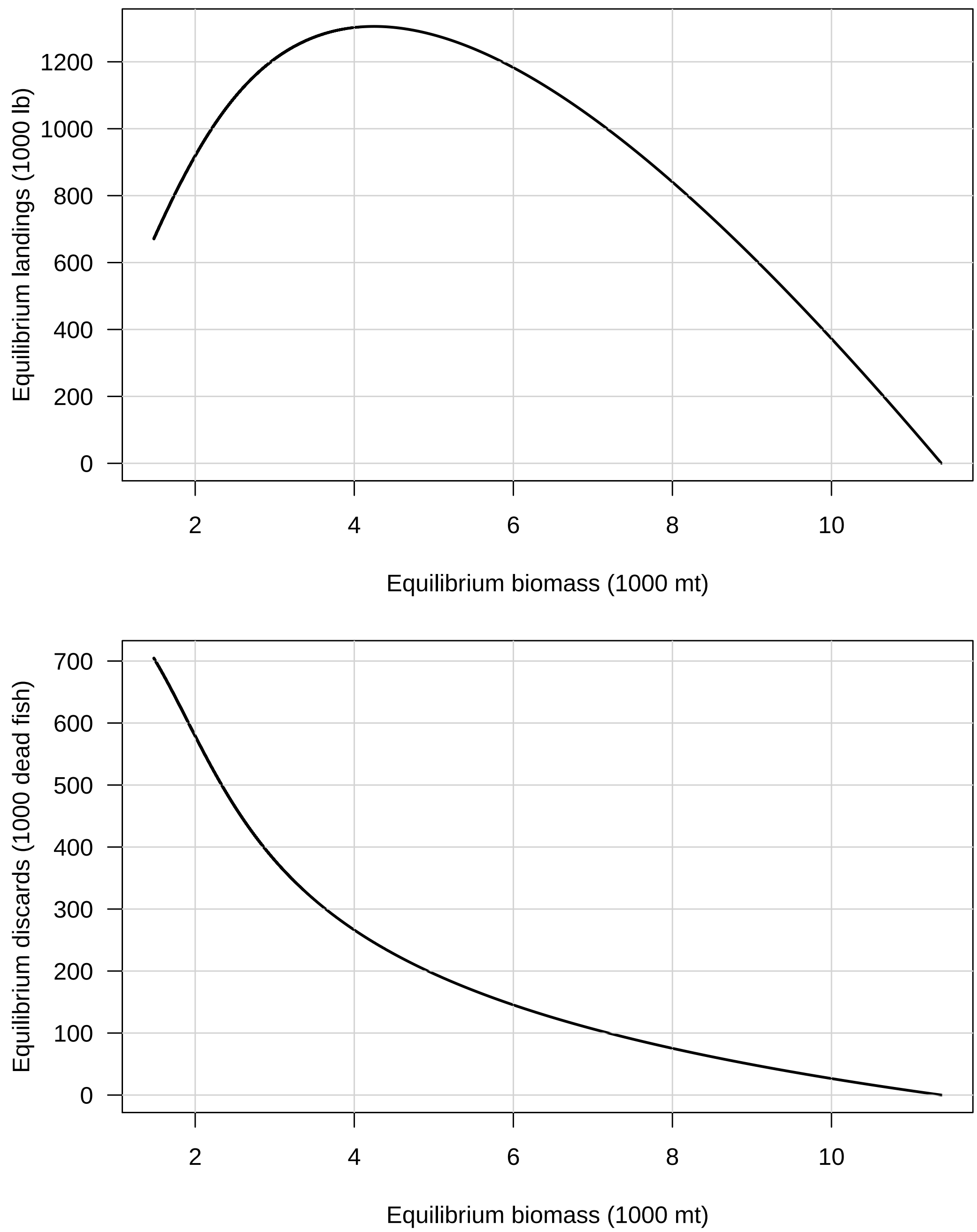


Figure 37. Probability densities of MSY*-related benchmarks from MCB analysis of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.*

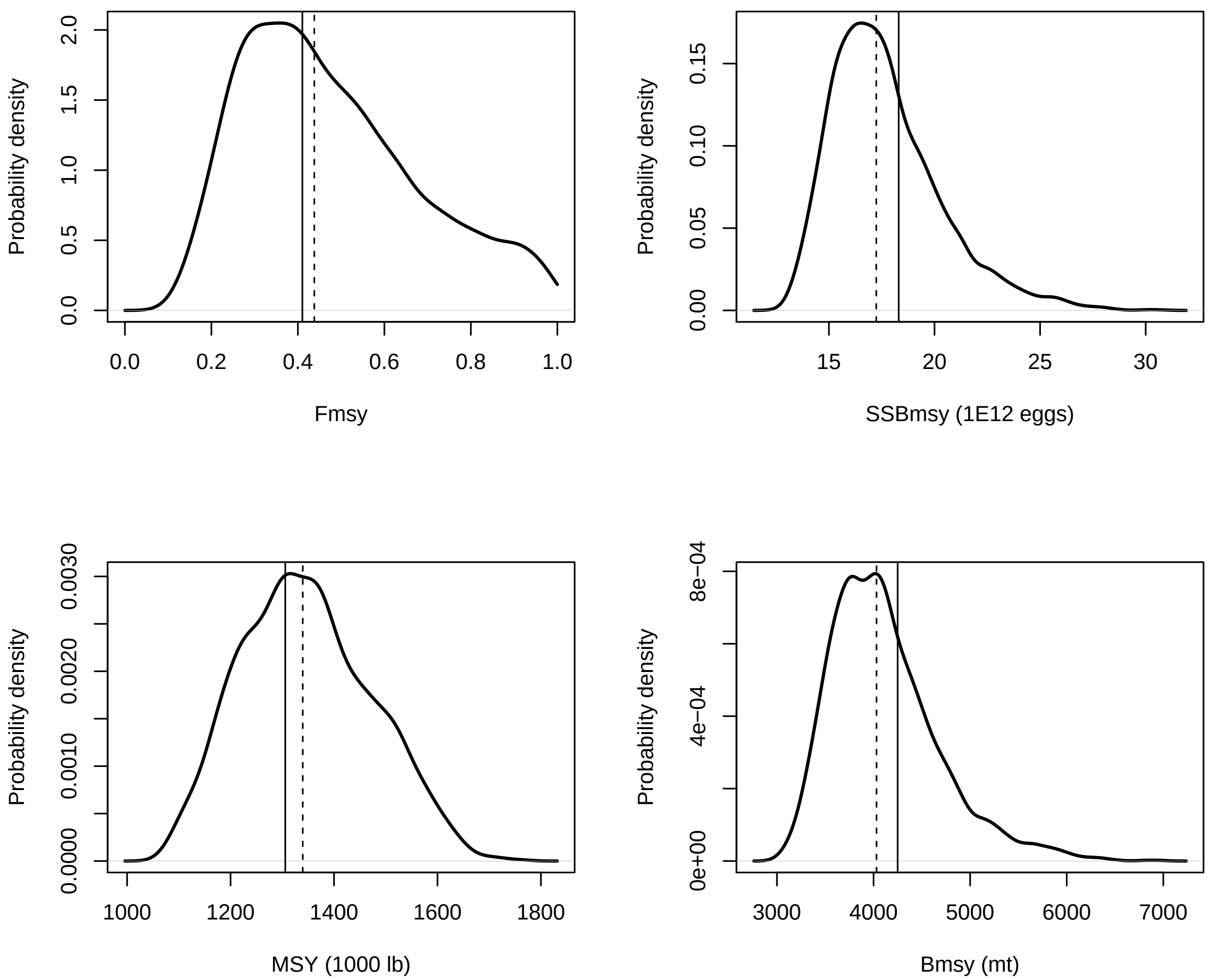


Figure 38. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; dashed lines represent median values; gray error bands indicate 5^{th} *and* 95^{th} *percentiles of the MCB trials. Top panel: spawning biomass relative to the minimum stock size threshold (*MSST*). Middle panel: spawning biomass relative to* $\mathrm{SSB}_{\mathrm{MSY}}$*. Bottom panel: F relative to* F_{MSY}*.*

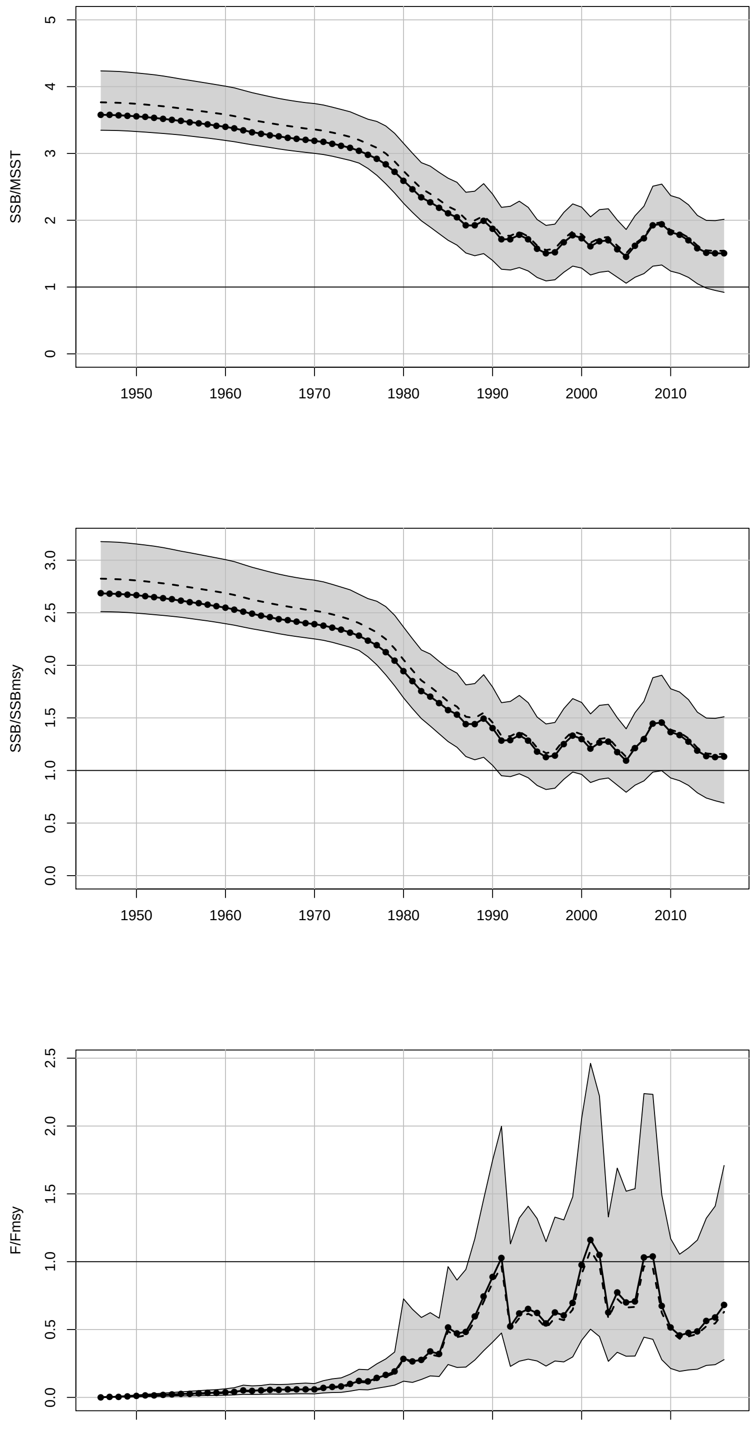


Figure 39. Probability densities of terminal status estimates from MCB analysis of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.

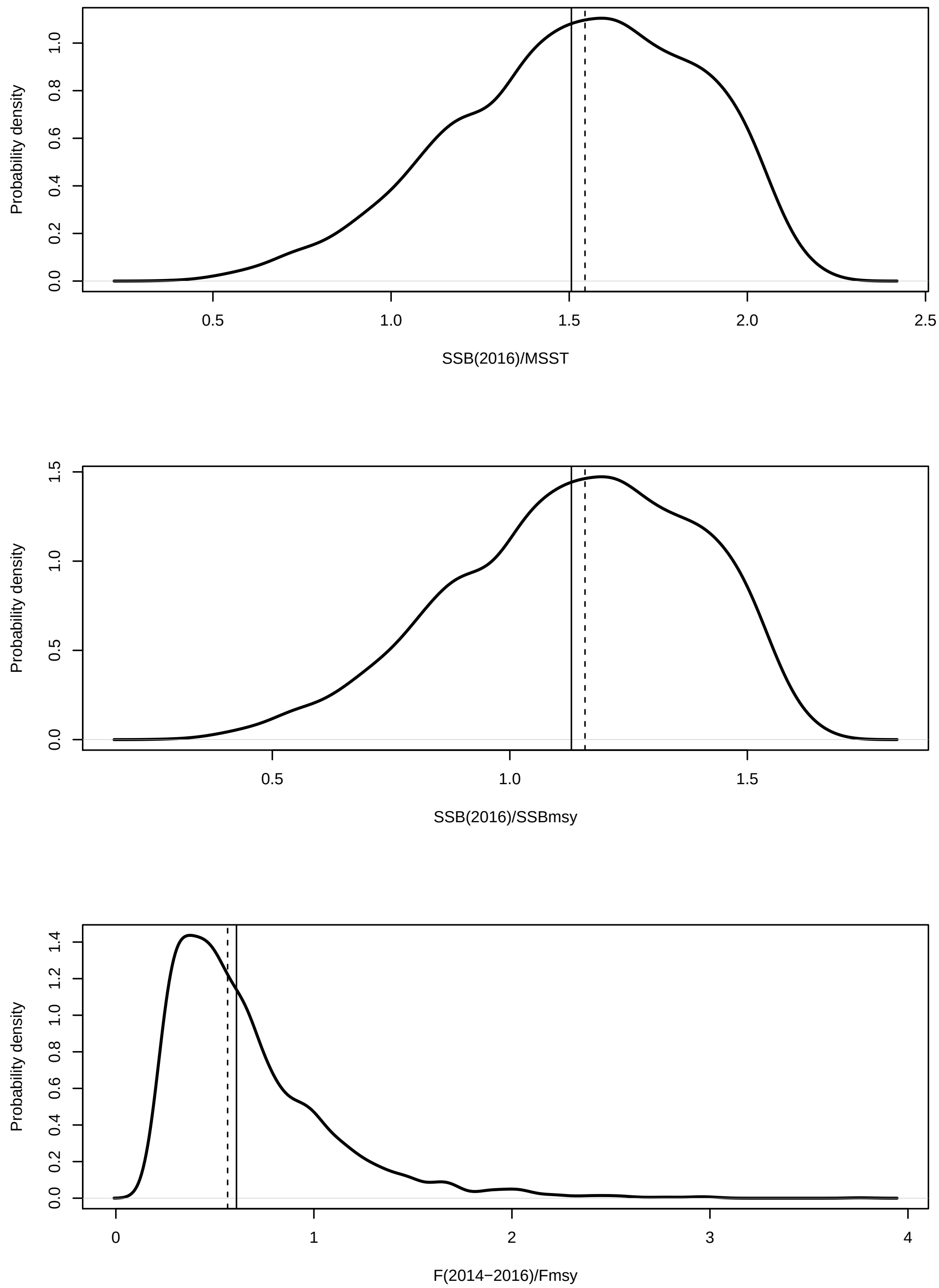


Figure 40. Phase plots of terminal status estimates from MCB analysis of the Beaufort Assessment Model. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by 5^{th} and 95^{th} percentiles. Proportion of runs falling in each quadrant indicated. Top panel shows stock status relative to MSST, bottom panel relative to $\mathrm{SSB}_{\mathrm{MSY}}$.

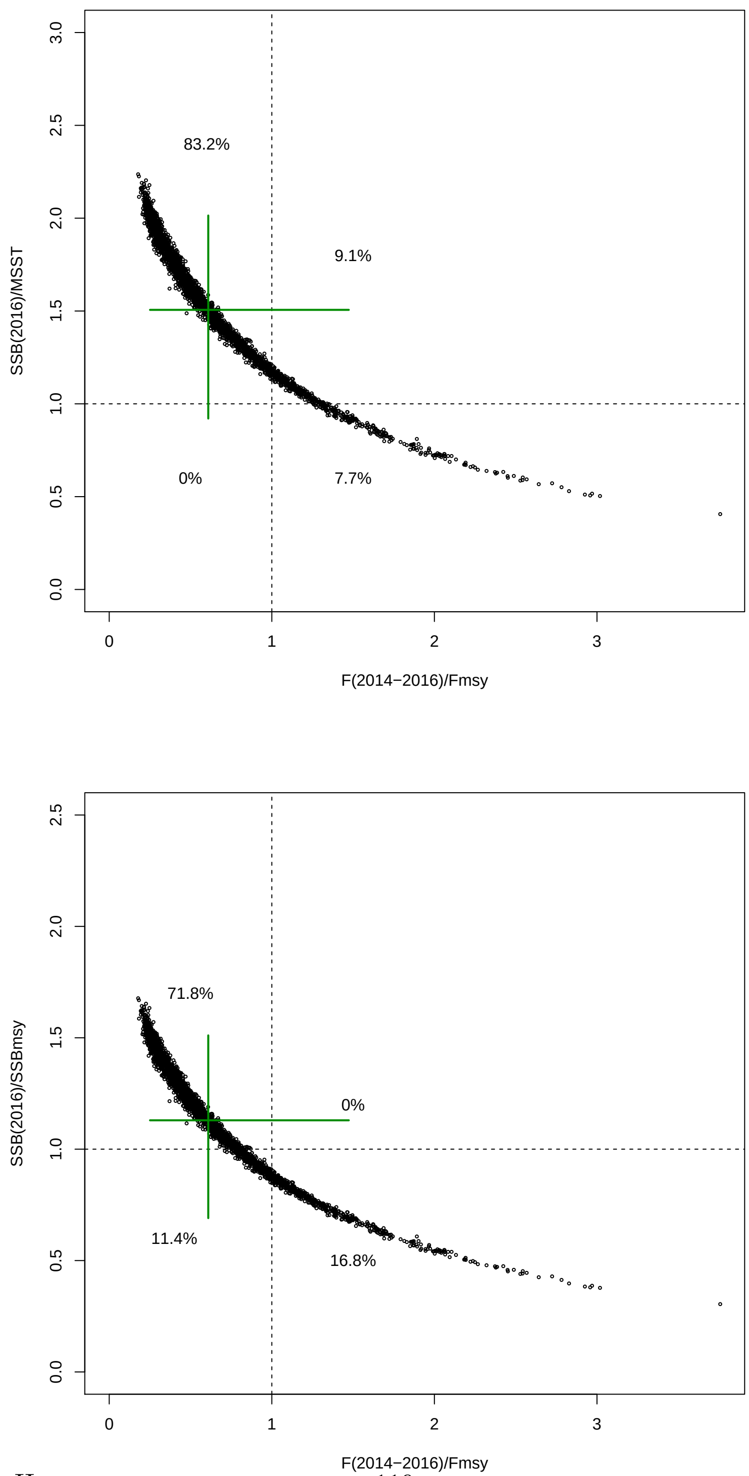


Figure 41. Age structure relative to the equilibrium expected at MSY.

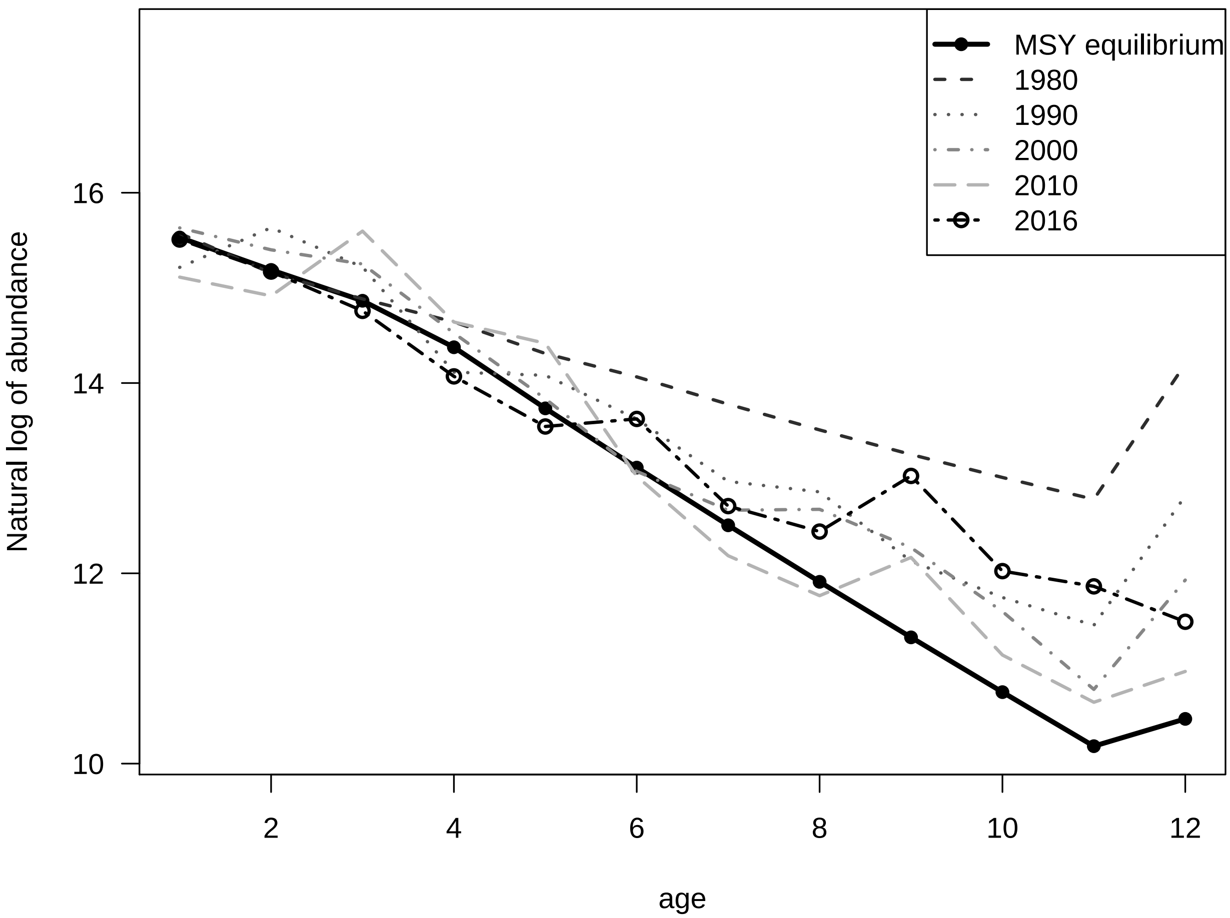


Figure 42. Comparison of results from this standard assessment with those from the SEDAR17 update assessment. Top panel: F relative to F_{MSY}. *Bottom panel: spawning biomass relative to* $\mathrm{SSB}_{\mathrm{MSY}}$.

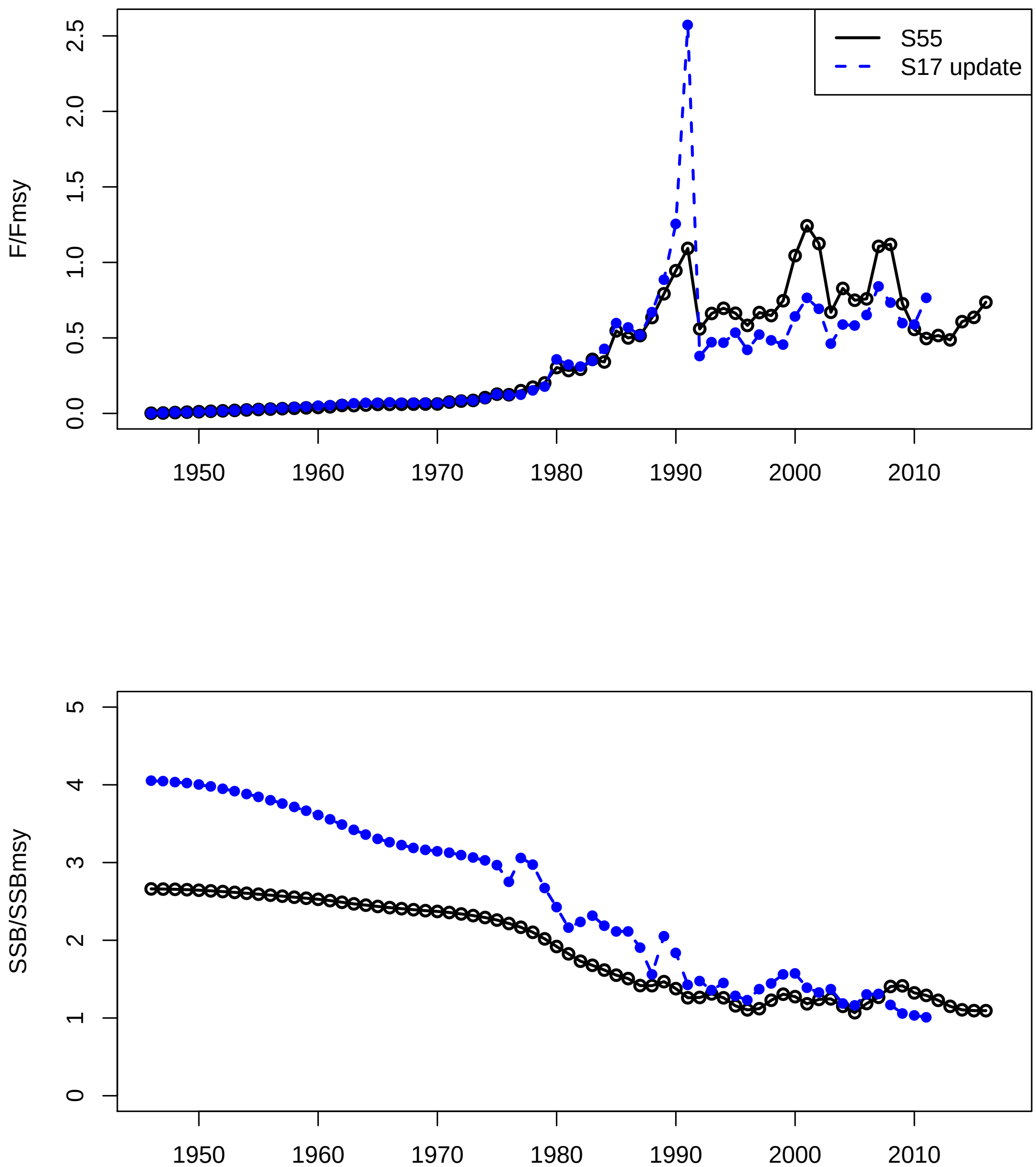


Figure 43. Sensitivity to natural mortality (sensitivity runs S1–S4). Top panel: Ratio of F to F_{MSY}. *Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

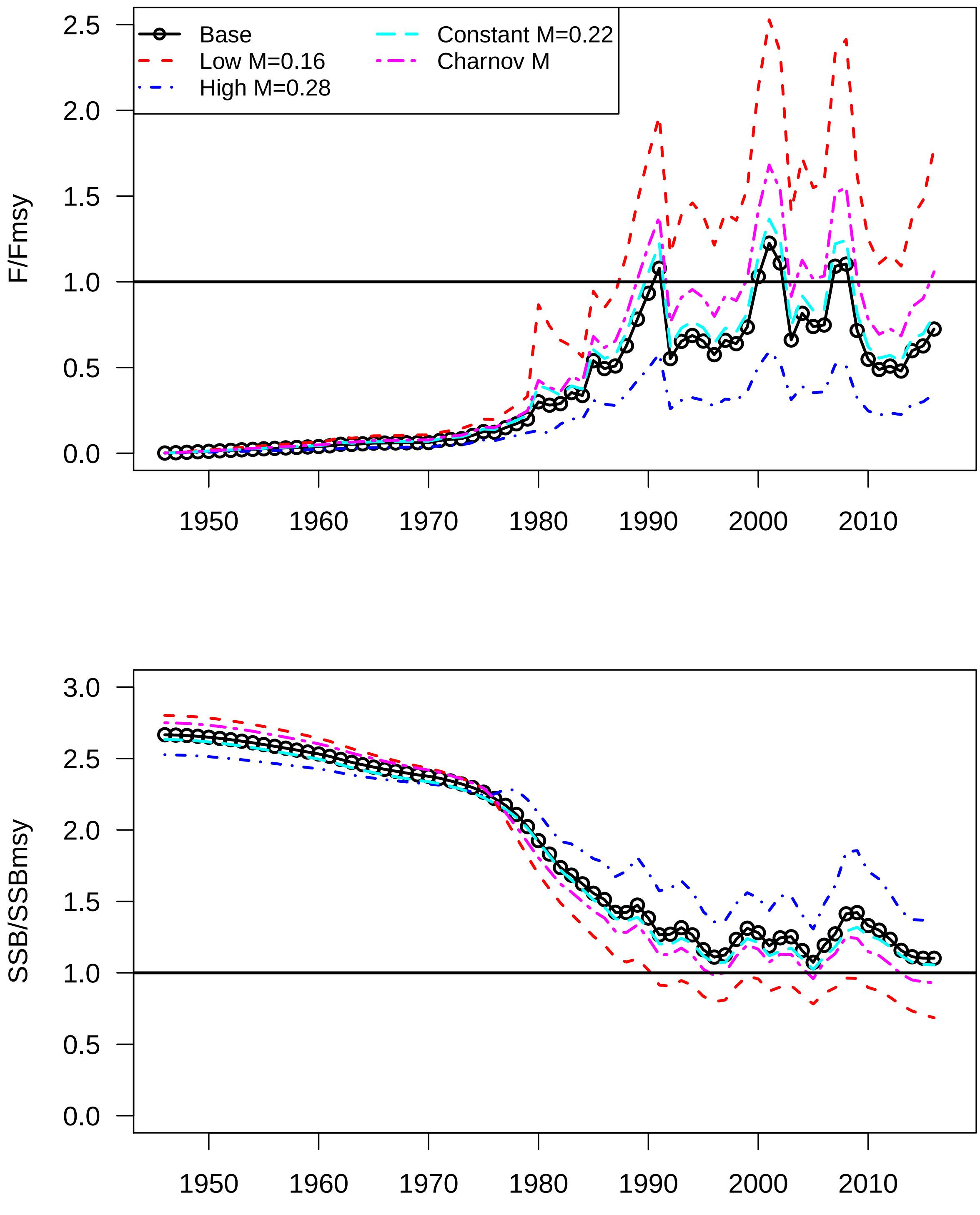


Figure 44. Sensitivity to changes in steepness (sensitivity runs S5–S7). Top panel: Ratio of F to F_{MSY}. *Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

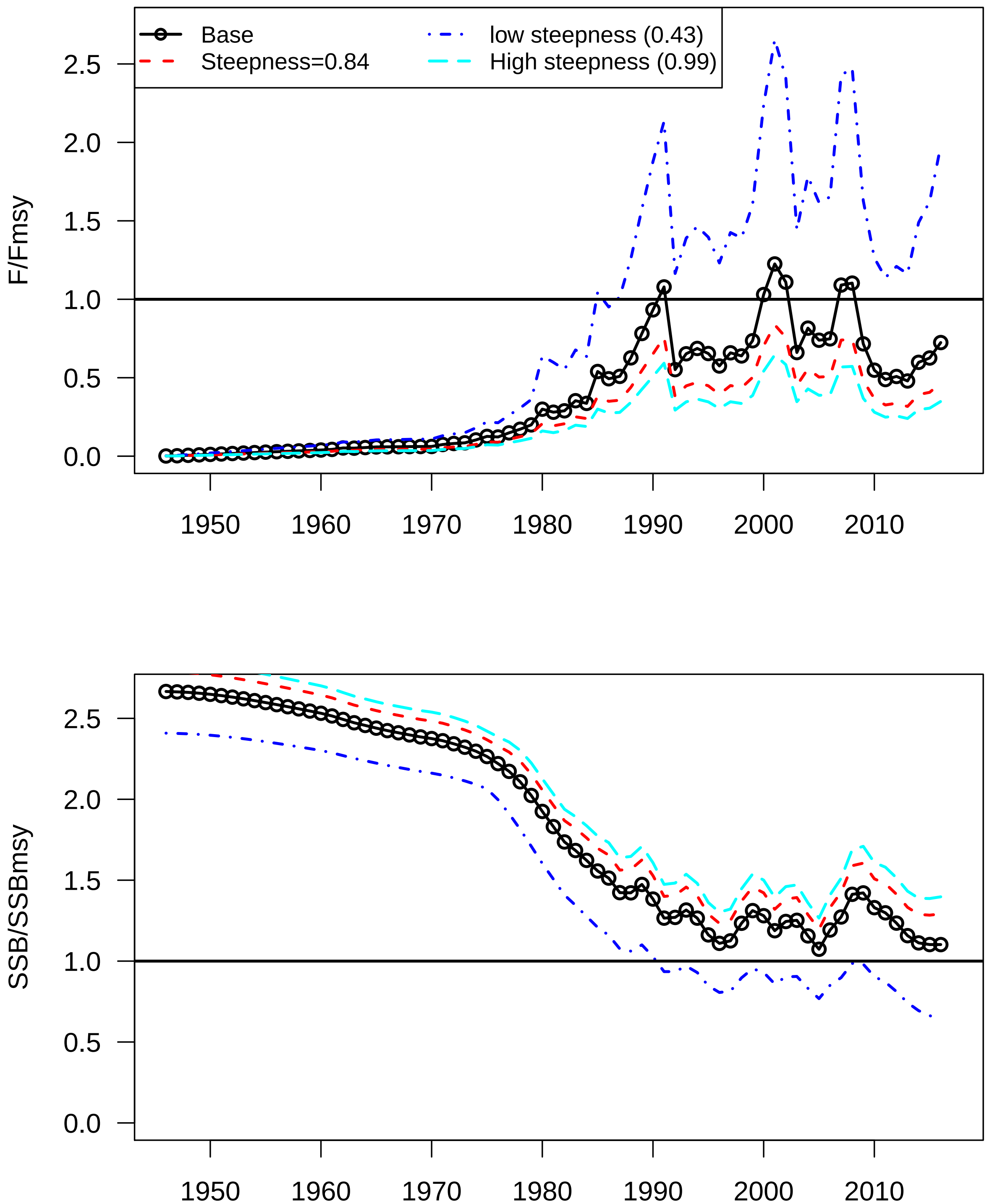


Figure 45. Sensitivity to reproduction (sensitivity runs S8). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

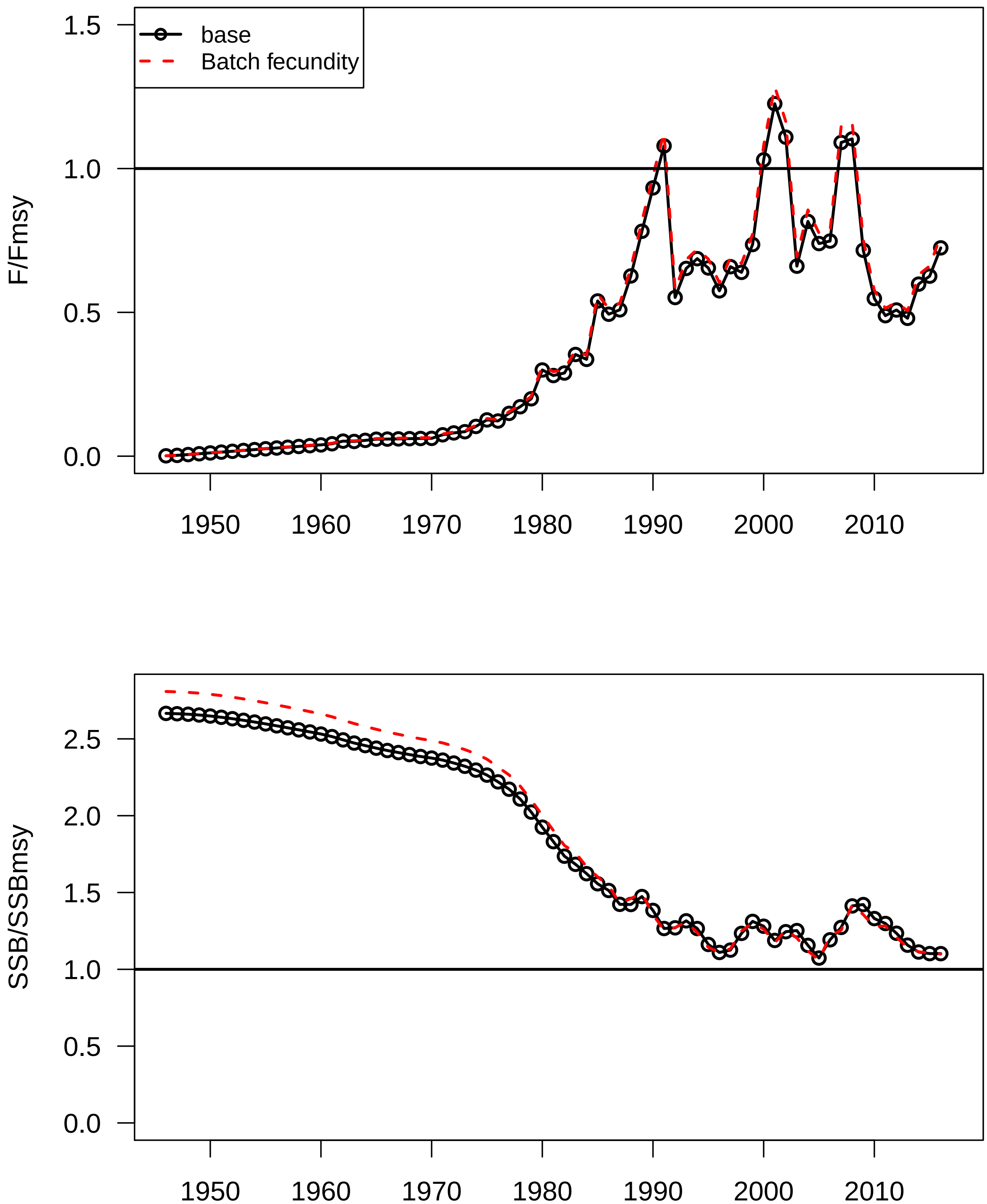


Figure 46. Sensitivity to historical recreational removals (sensitivity run S9–S11). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* SSB_{MSY}*.*

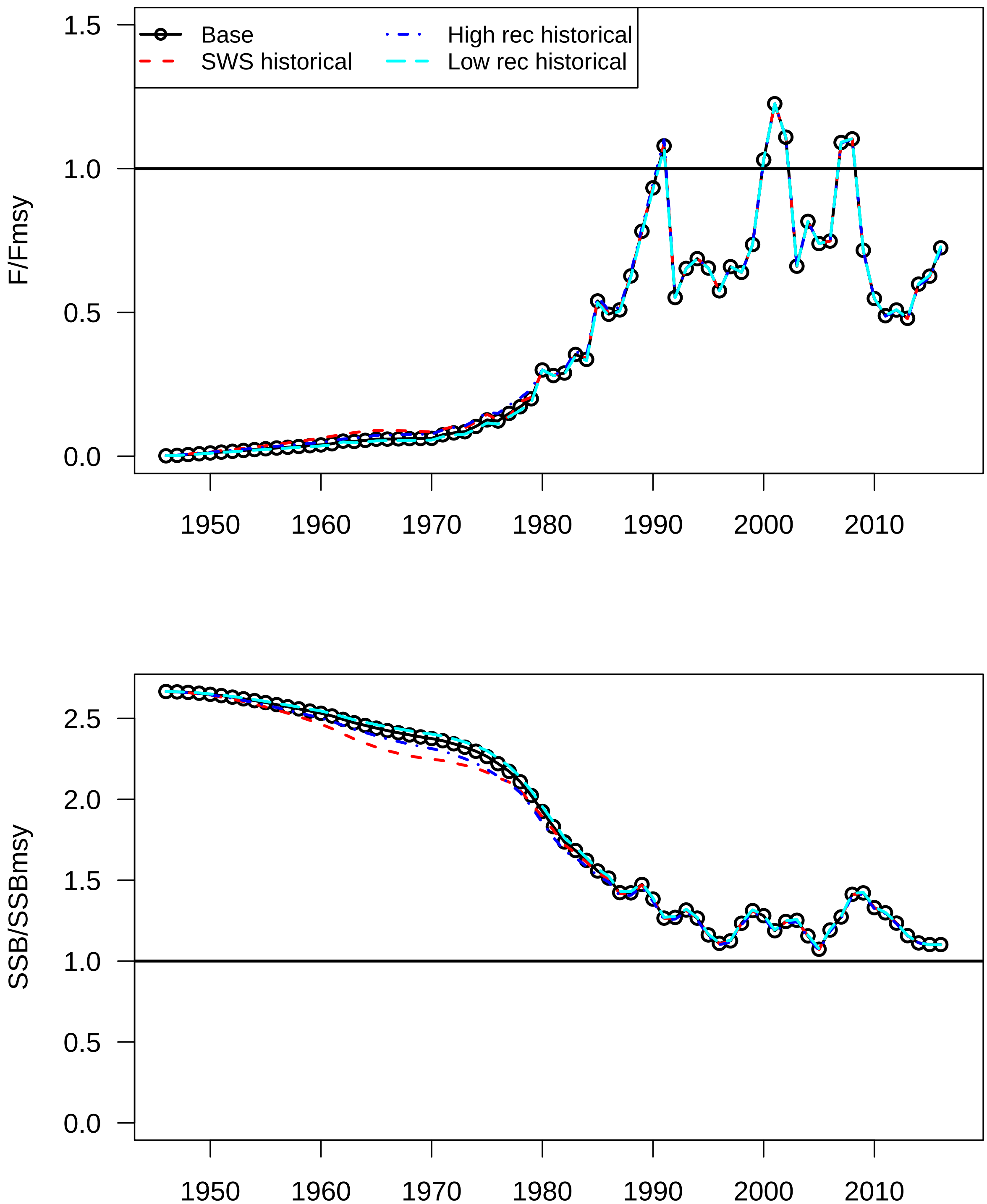


Figure 47. Sensitivity to inclusion of length compositions (sensitivity run S12). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

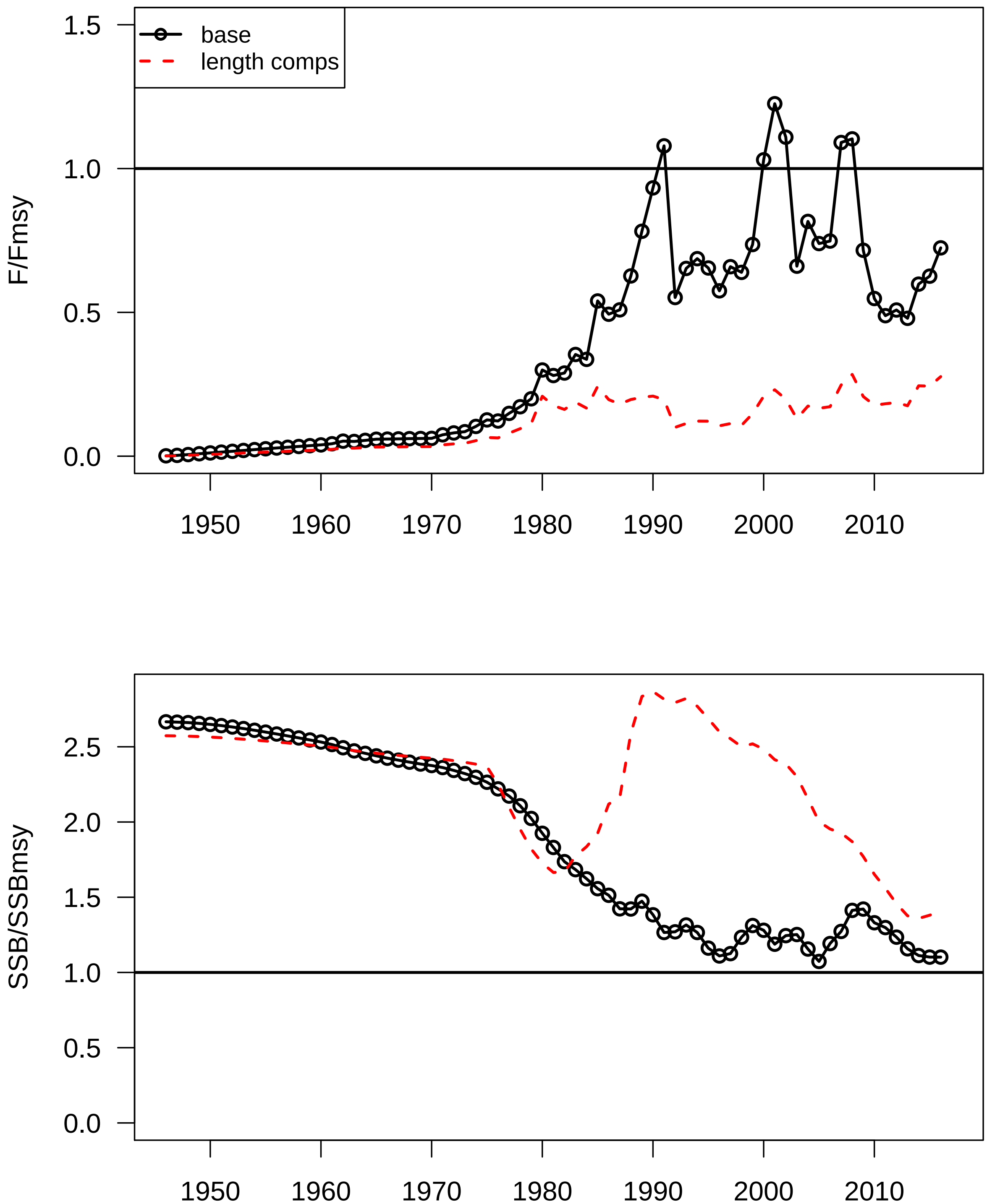


Figure 48. Sensitivity to SERFS trap/video index (sensitivity run S13–S15). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

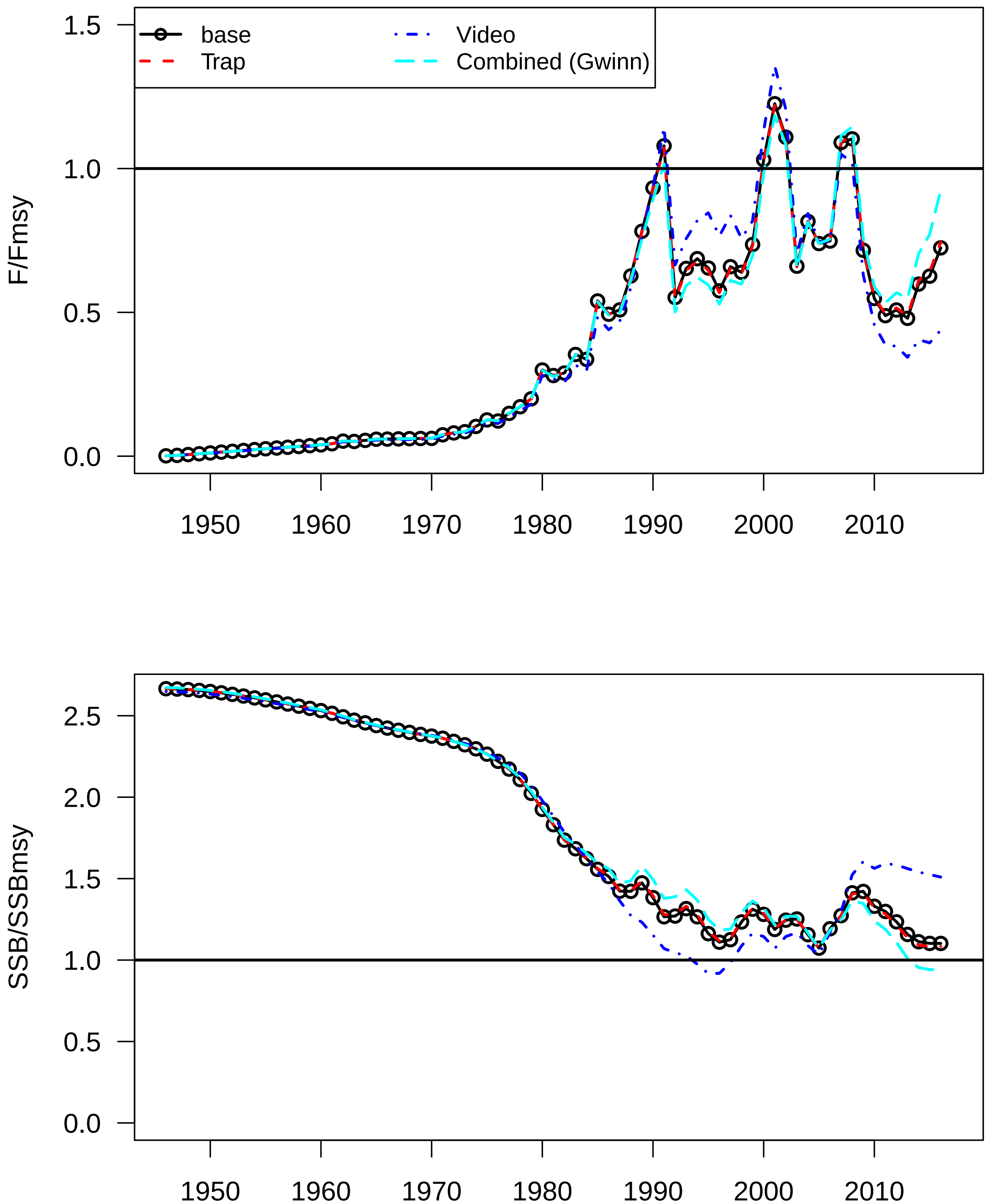


Figure 49. Sensitivity to upweighting SERFS trap/video index (sensitivity run S16–S18). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

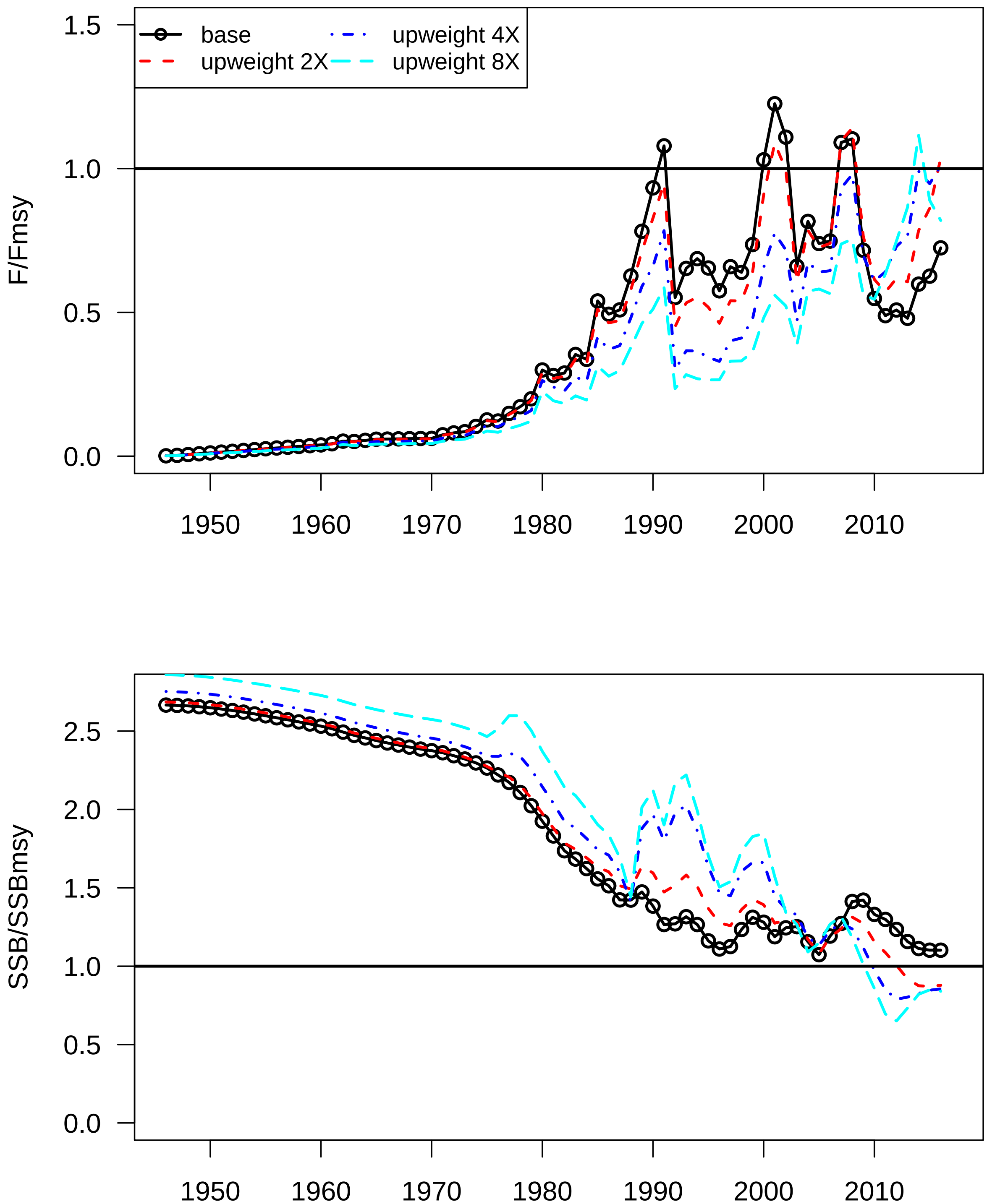


Figure 50. Sensitivity to removing early SERFS trap/video index values (sensitivity run S19–S20). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

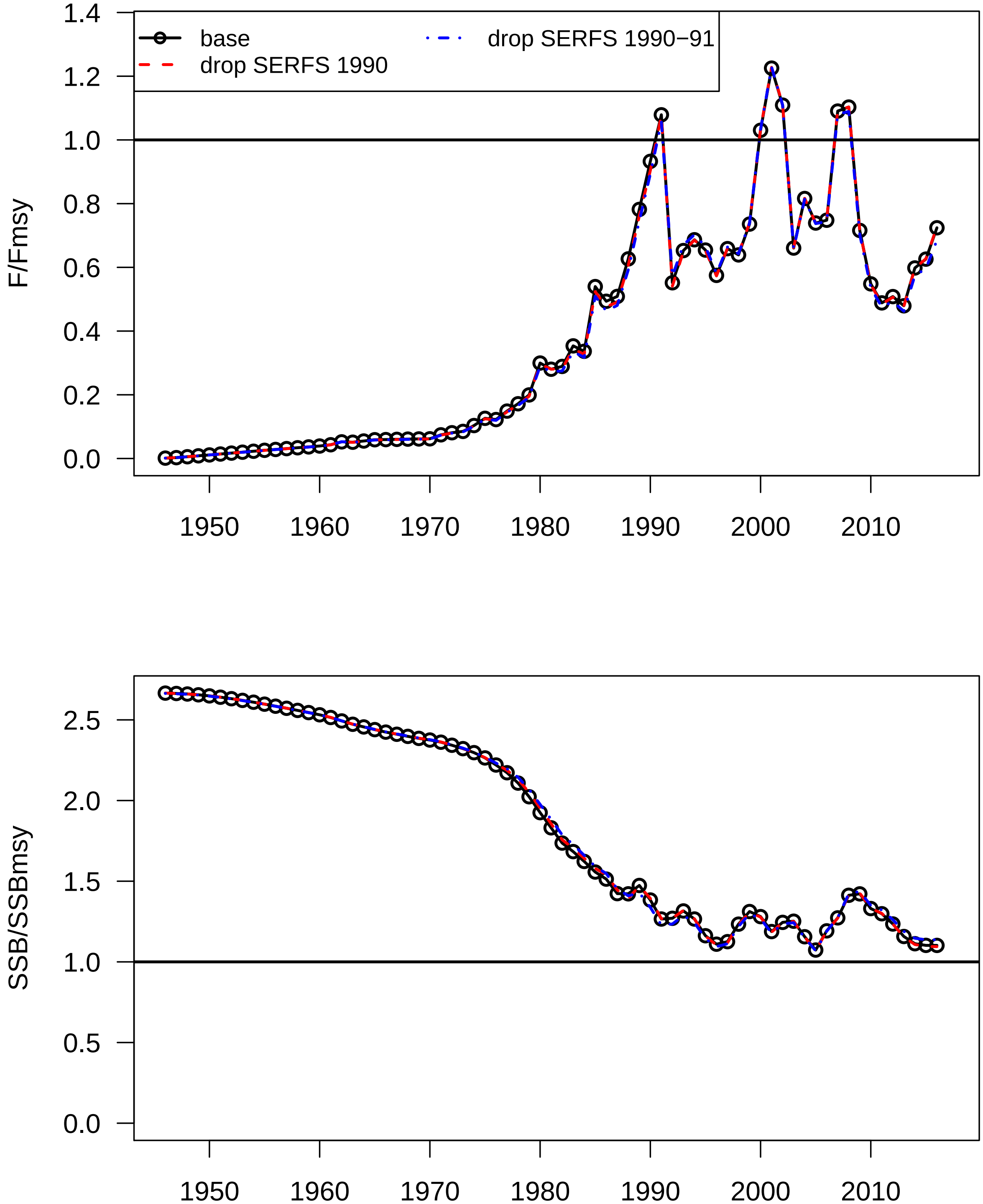


Figure 51. Sensitivity to catchability (sensitivity run S21–S23). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

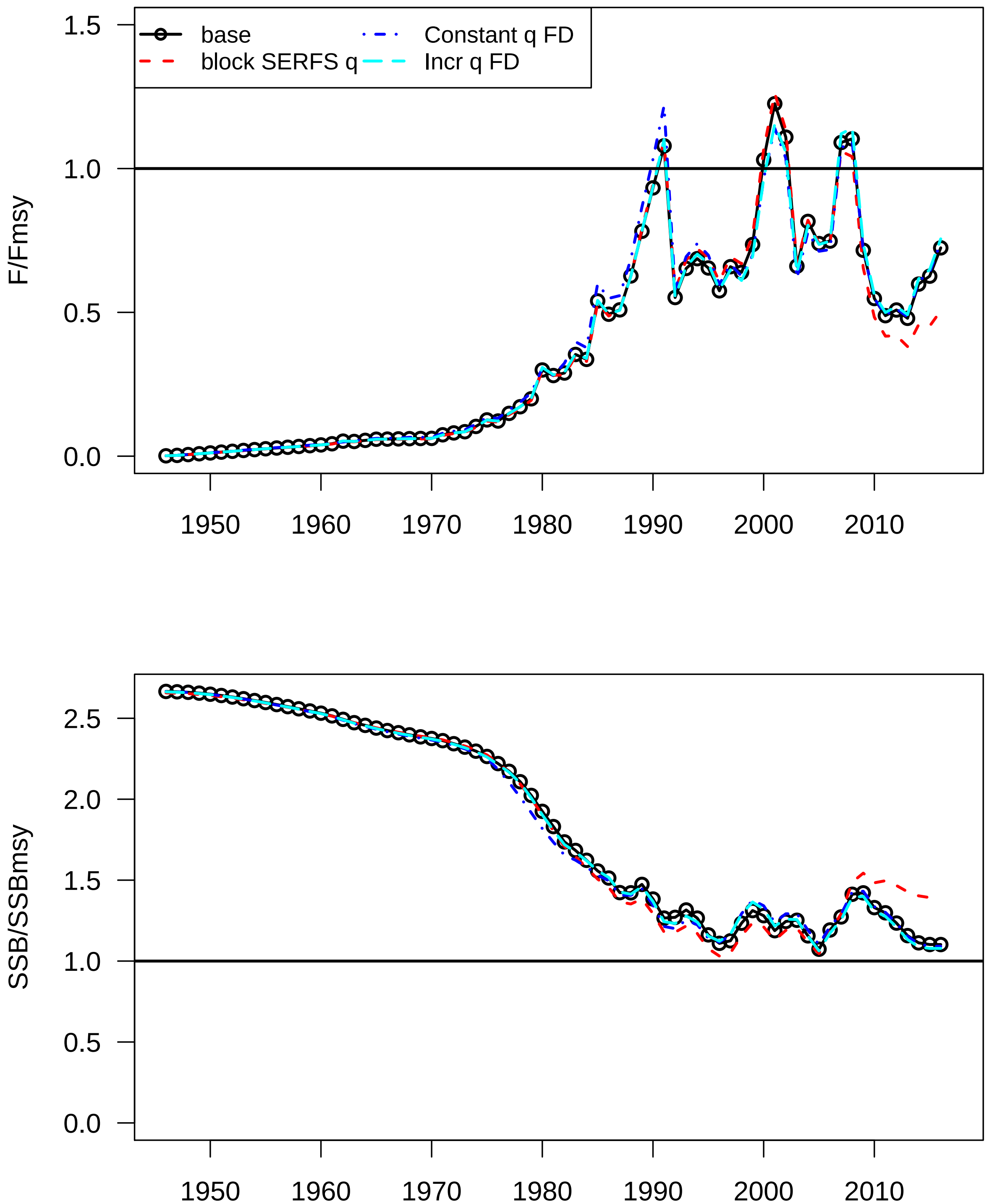
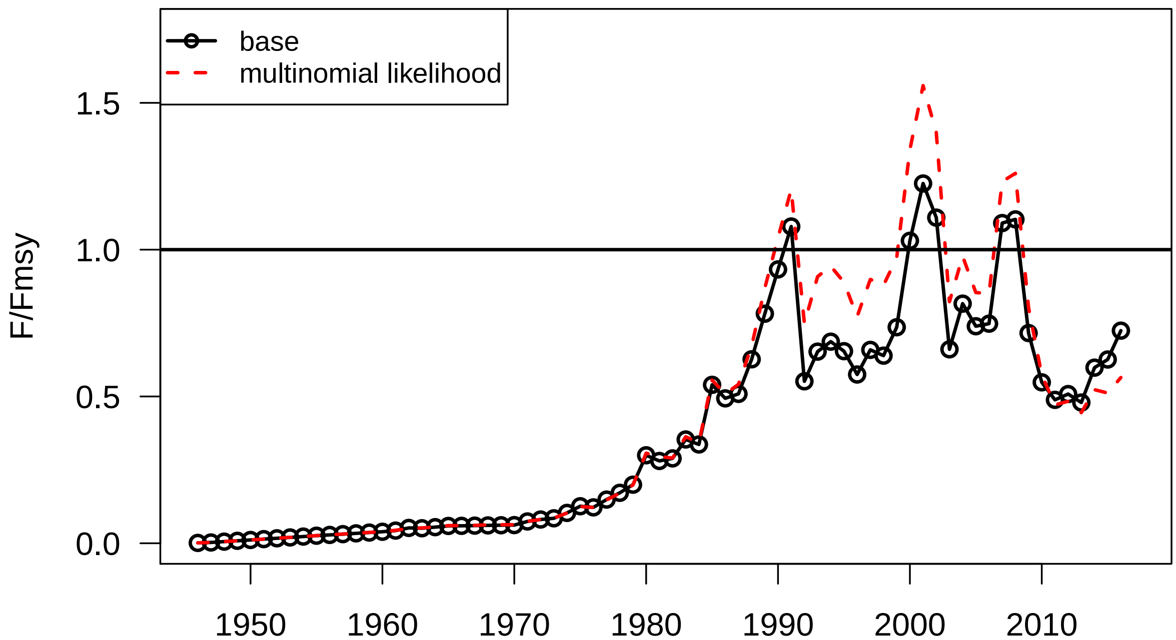


Figure 52. Sensitivity to the statistical distribution for composition data (sensitivity run S24). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.



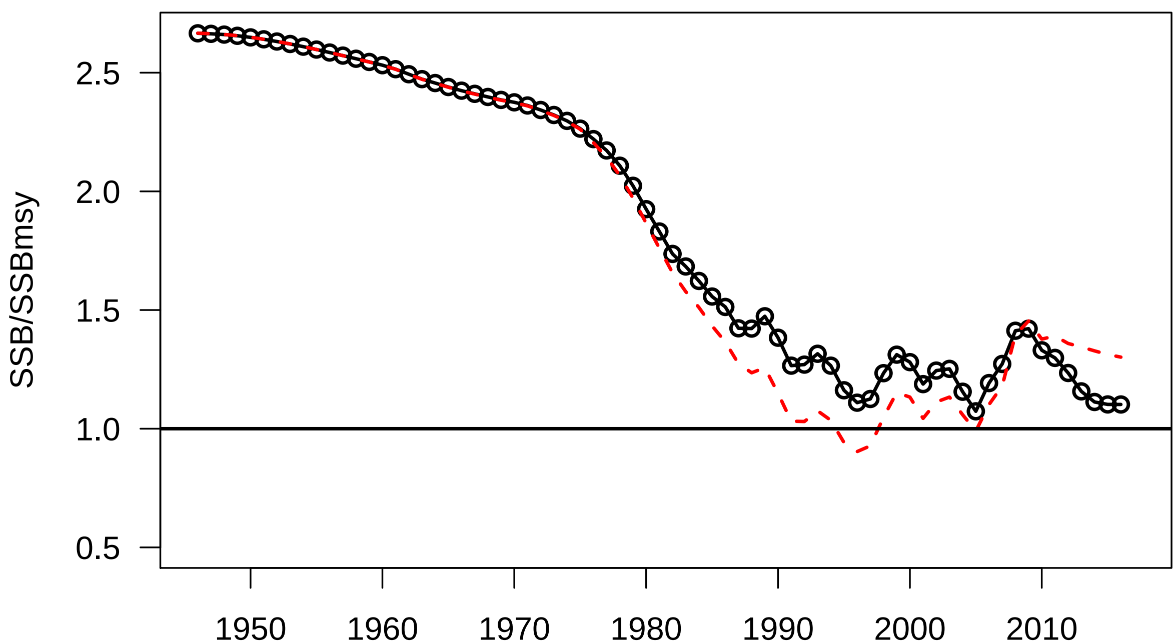


Figure 53. Sensitivity to the ageing error matrix (sensitivity run S25). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

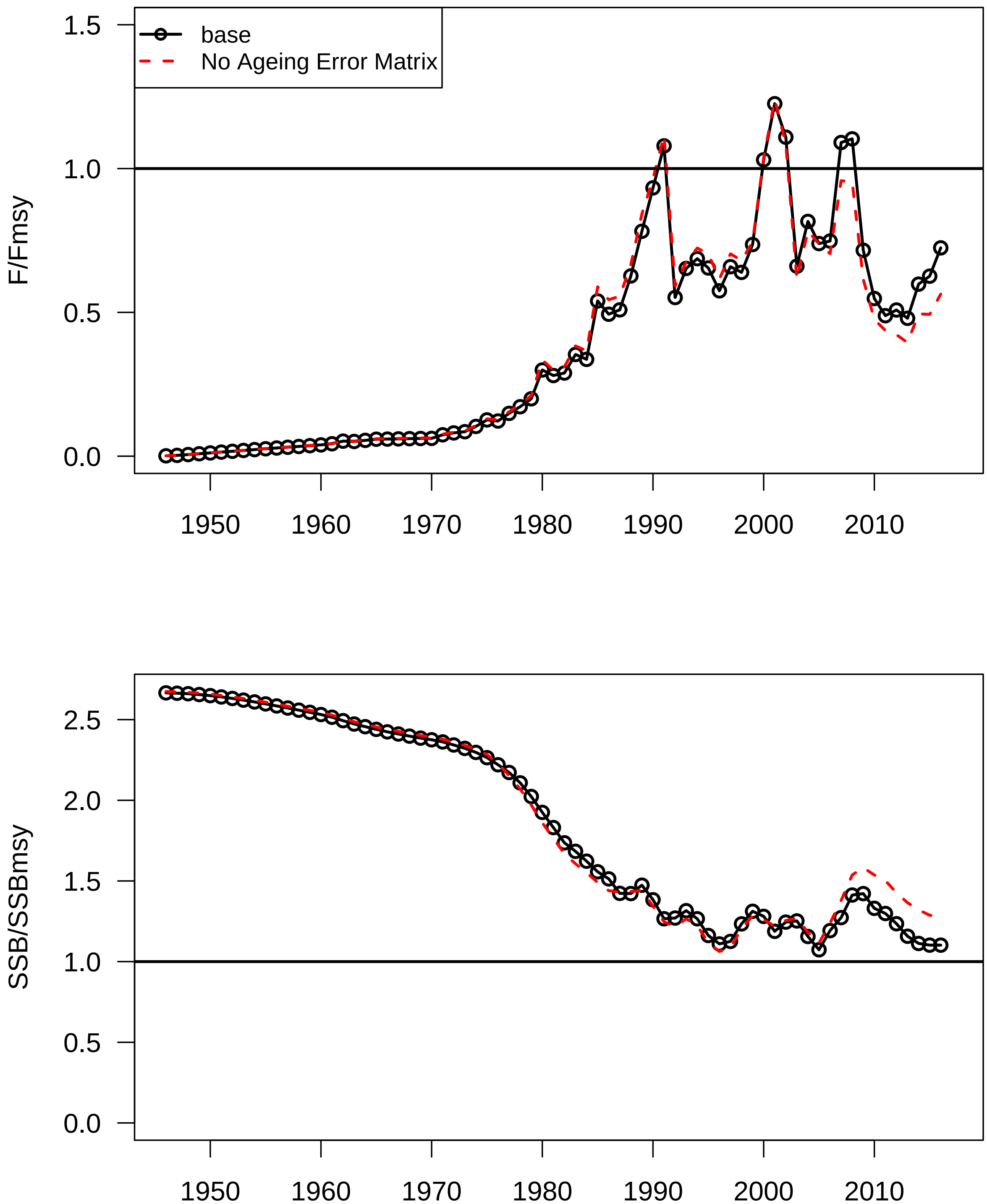


Figure 54. Sensitivity to the SEDAR17 continuity configuration (sensitivity run S26). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$*.*

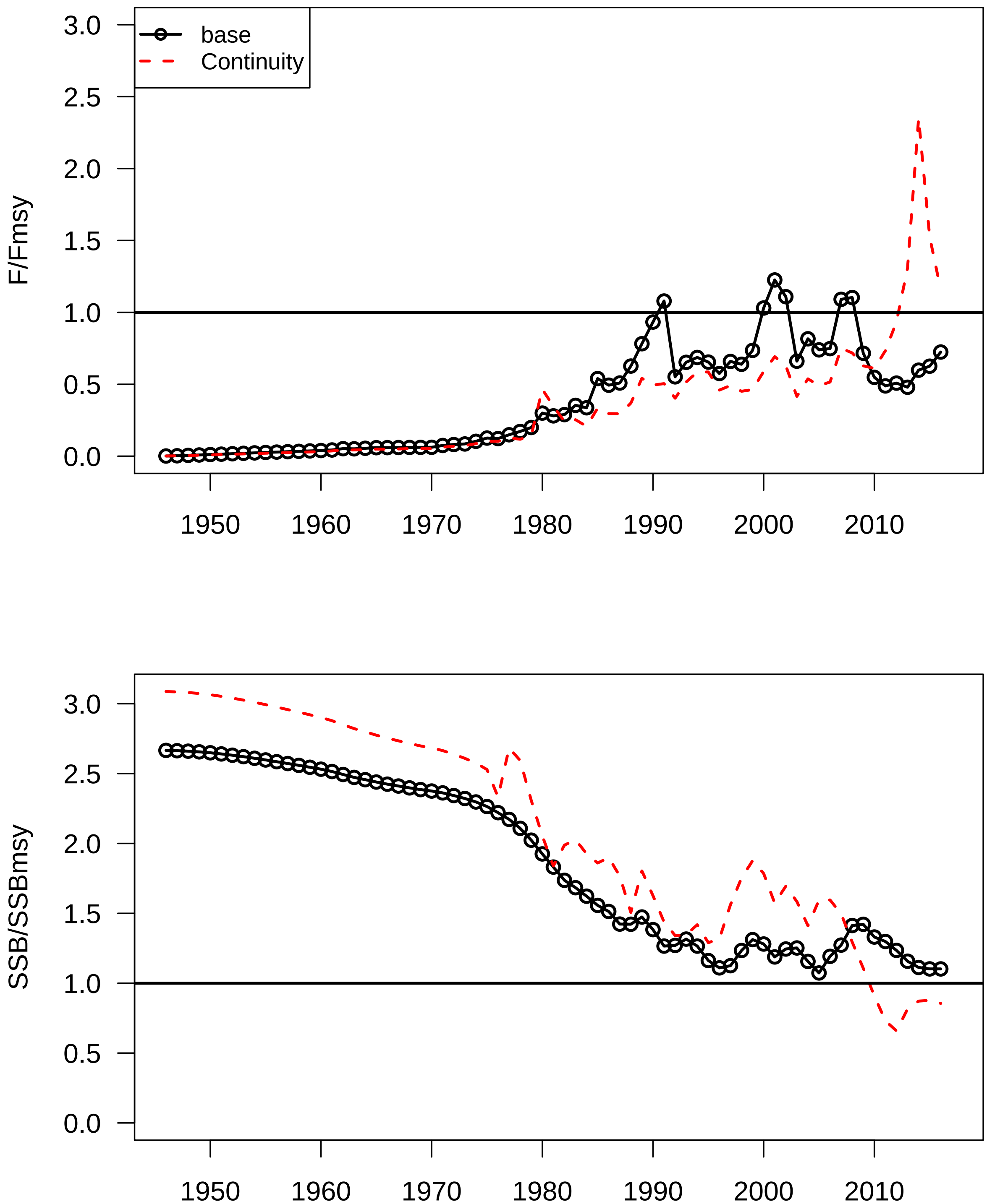


Figure 55. Phase plot of terminal status indicators from sensitivity runs of the Beaufort Assessment Model.

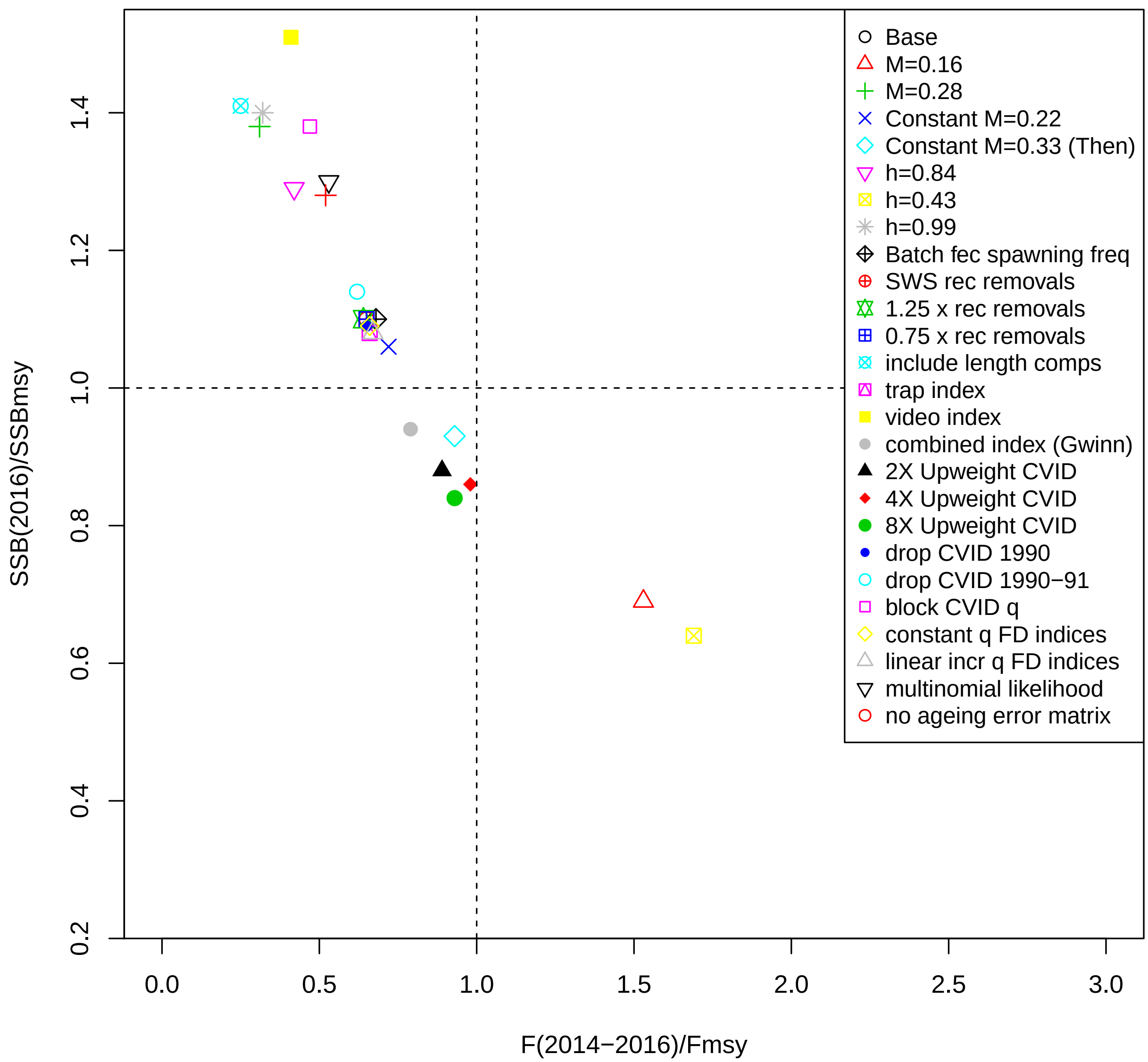


Figure 56. Retrospective analyses. Sensitivity to terminal year of data. Top panel: Fishing mortality rates. Middle panel: Recruits. Bottom panel: Spawning biomass. Closed circles show terminal-year estimates. Imperceptible lines overlap results of the base run.

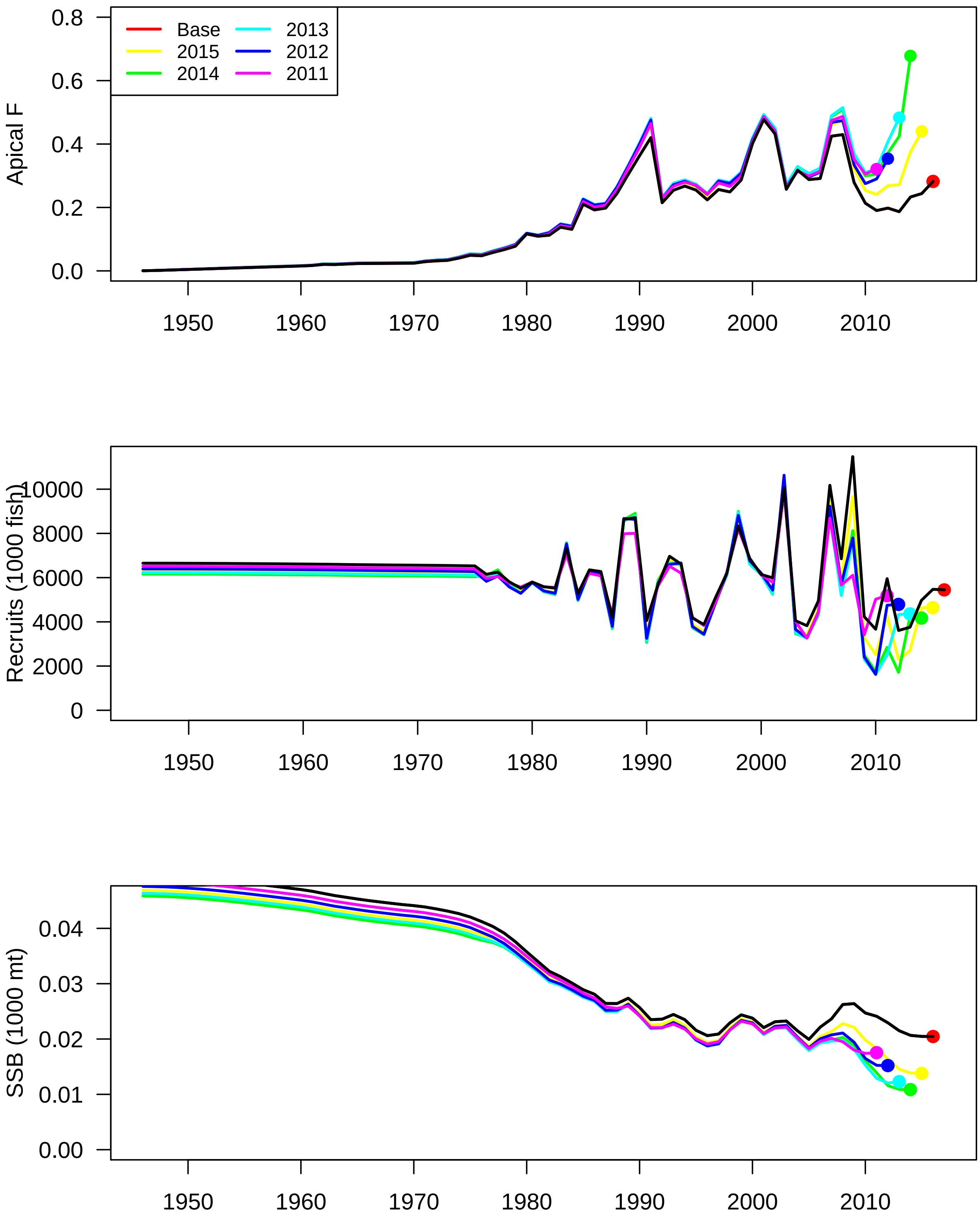


Figure 57. Projection results under scenario 1—fishing mortality rate at $F = F_{\mathrm{MSY}}$ with 2019 as the first year of new regulations. In all panels except the bottom right, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal 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. In the bottom right panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB_{MSY}}$.

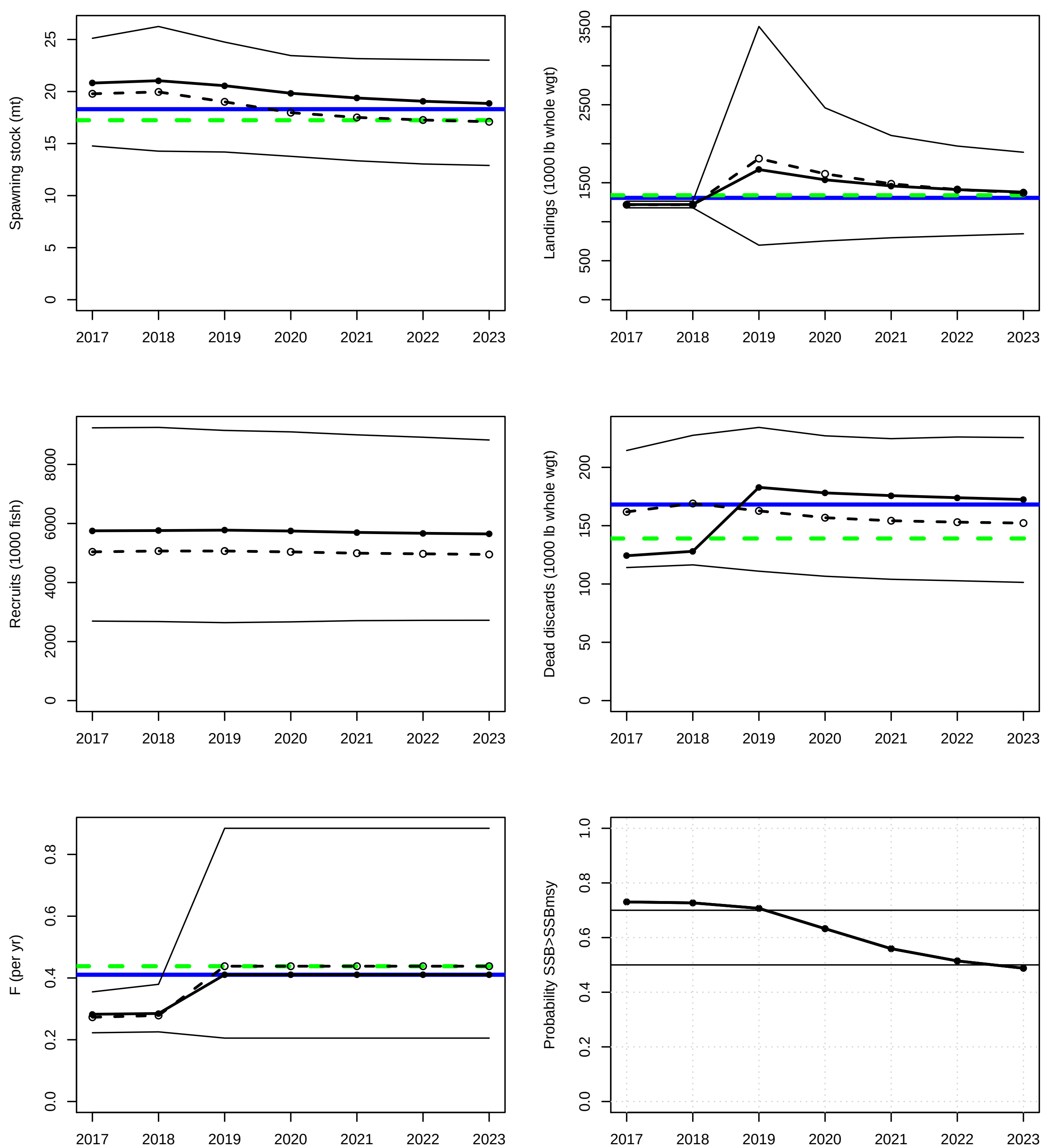


Figure 58. Projection results under scenario 2—fishing mortality rate fixed at $P^\star = 0.40$ *with 2019 as the first year of new regulations. In all panels except the bottom right, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to* 5^{th} *and* 95^{th} *percentiles of replicate projections. Solid horizontal 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. In the bottom right panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{MSY}}$.

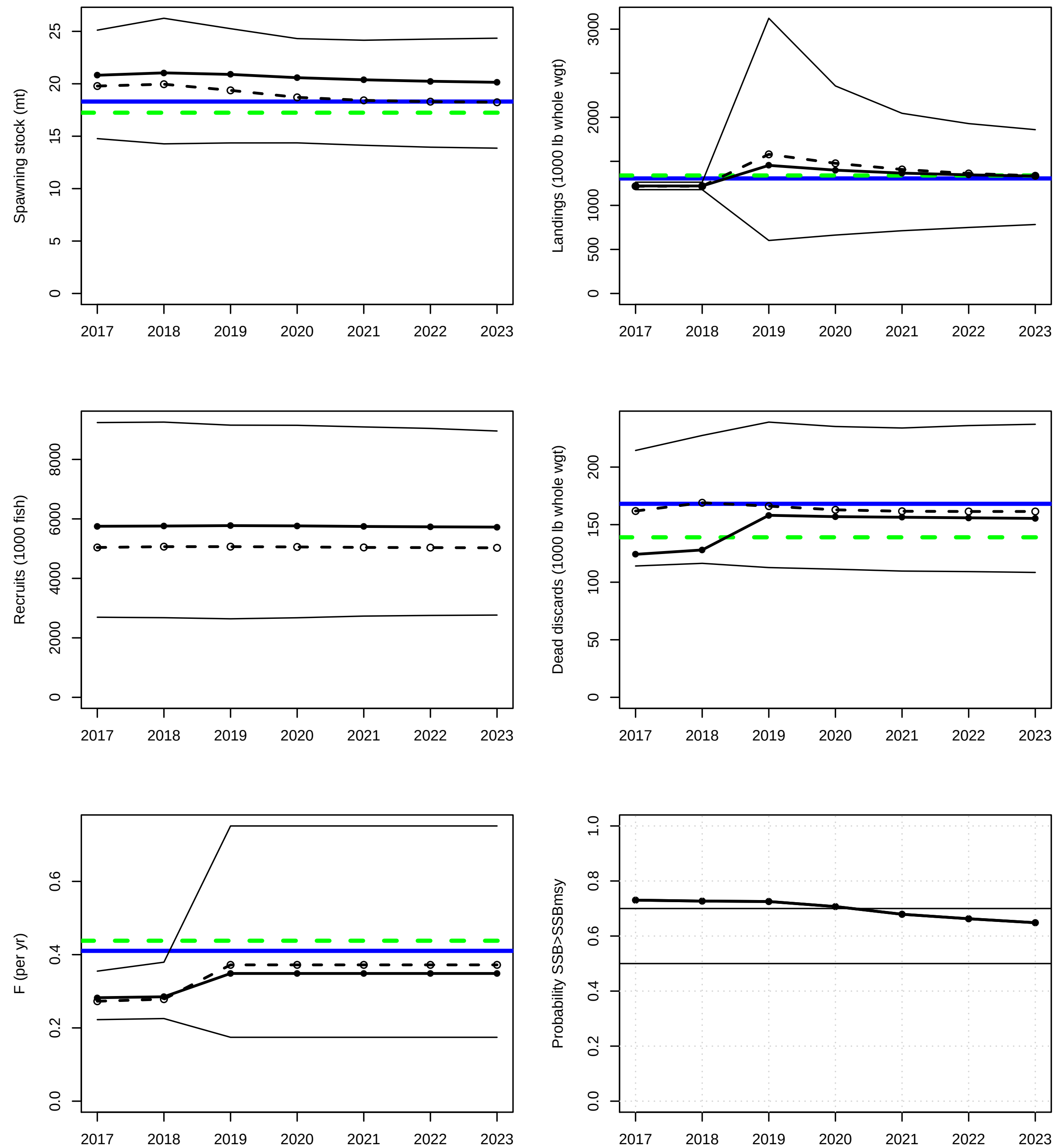
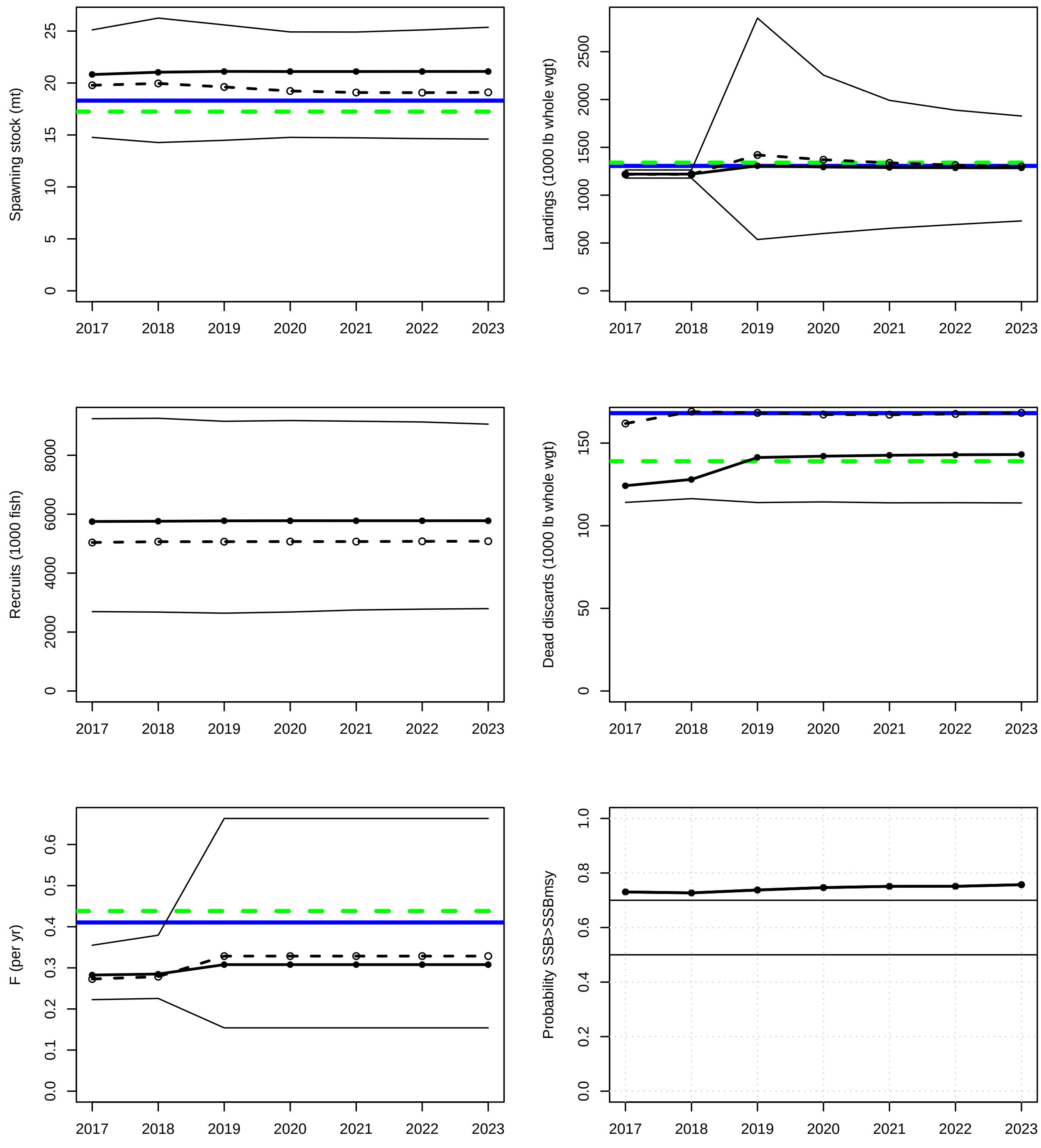


Figure 59. Projection results under scenario 3—fishing mortality rate at $F = 75\% F_{\text{MSY}}$ with 2019 as the first year of new regulations. In all panels except the bottom right, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal 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. In the bottom right panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* SSB_{MSY}.



Appendix A Abbreviations and symbols

Table 23. Acronyms and abbreviations used in this report

Symbol	Meaning
ABC	Acceptable Biological Catch
AW	Assessment Workshop
ASY	Average Sustainable Yield
B	Total biomass of stock, conventionally on January 1
BAM	Beaufort Assessment Model (a statistical catch-age formulation)
CPUE	Catch per unit effort; used after adjustment as an index of abundance
CV	Coefficient of variation
CVID	SERFS combined chevron trap and video survey
DW	Data Workshop
F	Instantaneous rate of fishing mortality
$F_{X\%}$	Fishing mortality rate at which SPR of X% can be attained
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 vermilion snapper as 75% $\mathrm{SSB}_{\mathrm{MSY}}$.
MSY	Maximum sustainable yield (per year)
mt	Metric ton(s). One mt is 1000 kg, or about 2205 lb.
N	Number of fish in a stock, conventionally on January 1
NC	State of North Carolina
NMFS	National Marine Fisheries Service, same as "NOAA Fisheries Service"
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
OY	Optimum yield; SFA specifies that OY $\leq$ MSY.
PSE	Proportional standard error
R	Recruitment
SAFMC	South Atlantic Fishery Management Council (also, Council)
SC	State of South Carolina
SCDNR	Department of Natural Resources of SC
SDNR	Standard deviation of normalized residuals
SEDAR	SouthEast Data Assessment and Review process
SERFS	Southeast Reef Fish Survey
SFA	Sustainable Fisheries Act; the Magnuson–Stevens Act, as amended
SL	Standard length (of a fish)
SRHS	Southeast Region Headboat Survey, conducted by NMFS-Beaufort laboratory
SPR	Spawning potential ratio
SSB	Spawning stock biomass; mature biomass of males and females
$\mathrm{SSB}_{\mathrm{MSY}}$	Level of SSB at which MSY can be attained
TIP	Trip Interview Program, a fishery-dependent biodata collection program of NMFS
TL	Total length (of a fish), as opposed to FL (fork length) or SL (standard length)
VPA	Virtual population analysis, an age-structured assessment
WW	Whole weight, as opposed to GW (gutted weight)
yr	Year(s)

Appendix B Parameter estimates from the Beaufort Assessment Model

```
# Number of parameters = 562  Objective function value = 24136.7  Maximum gradient component = 0.000893933
# Linf:
506.000000000
# K:
0.120000000000
# t0:
-3.50000000000
# len_cv_val:
0.160674777760
# log_Nage_dev:
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
# log_R0:
15.6558848967
# steep:
0.690761019712
# rec_sigma:
0.289191056632
# R_autocorr:
0.00000000000
# log_rec_dev:
 -0.0108766668048 0.00748147572304 -0.0620123754956 -0.110231638005 -0.0552636999531 -0.0847051508837 -0.0891104036576 0.199715101851 -0.119814275533
0.0693896418481 0.0643566807806 -0.332772325849 0.398810296863 0.407386330515 -0.359870579268 -0.0110649974694 0.207090594093 0.153350870961 -0.312529832407
-0.377297101926 -0.0906306582754 0.117523685520 0.410214658360 0.197017252063 0.0734314885665 0.0551390062287 0.586902410836 -0.329051151279 -0.388545028491
-0.111977850105 0.625277559343 0.209763499976 0.713873995902 -0.301345463417 -0.444512642112 0.0545844214588 -0.450767043490 -0.400608015994 -0.105233433395
-0.000593576266040 -0.00249506081394
# log_dm_cH_lc:
0.00000000000
# log_dm_HB_D_lc:
-0.896827693793
# log_dm_cH_D_lc:
0.00000000000
# log_dm_cH_ac:
-0.270166121439
# log_dm_HB_ac:
-1.06182677460
# log_dm_GR_ac:
1.30994361596
# log_dm_CVT_ac:
-0.761092990284
# selpar_A50_CVT:
2.10298475383
# selpar_slope_CVT:
5.02714971409
# selpar_A502_CVT:
18.7154145171
# selpar_slope2_CVT:
3.00000000000
# selpar_Age1_CVT_logit:
-5.70000000000
# selpar_Age2_CVT_logit:
-4.20000000000
# selpar_A50_cH1:
3.90202182257
# selpar_slope_cH1:
3.15365506152
# selpar_A50_cH2:
3.13442415735
# selpar_slope_cH2:
6.47577276481
# selpar_Age2_cH_D2_logit:
-1.01379039148
# selpar_A502_cH_D3:
6.49607990228
# selpar_A50_cO1:
1.42000000000
# selpar_slope_cO1:
3.62000000000
# selpar_A502_cO1:
1.50000000000
# selpar_slope2_cO1:
3.00000000000
# selpar_A50_HB1:
1.74028946924
# selpar_slope_HB1:
3.13256946253
# selpar_A502_HB1:
3.00000000000
# selpar_slope2_HB1:
0.0100000000000
# selpar_A50_HB2:
2.96425311799
# selpar_slope_HB2:
2.67752457966
# selpar_A502_HB2:
4.00000000000
# selpar_slope2_HB2:
0.0100000000000
# selpar_A50_HB3:
2.36319123087
# selpar_slope_HB3:
```

```
4.33475994203
# selpar_A502_HB3:
4.00000000000
# selpar_slope2_HB3:
1.00000000000
# selpar_A50_HB4:
2.64709610717
# selpar_slope_HB4:
5.30291428391
# selpar_A502_HB4:
4.00000000000
# selpar_slope2_HB4:
1.00000000000
# selpar_Age2_HB_D3_logit:
1.06686351429
# selpar_Age2_HB_D4_logit:
-0.689602191409
# selpar_A50_GR2:
2.10000000000
# selpar_slope_GR2:
3.60000000000
# selpar_A50_GR3:
2.10000000000
# selpar_slope_GR3:
3.60000000000
# selpar_A502_GR3:
4.00000000000
# selpar_slope2_GR3:
1.00000000000
# selpar_A50_GR4:
2.80000000000
# selpar_slope_GR4:
3.60000000000
# selpar_A502_GR4:
4.00000000000
# selpar_slope2_GR4:
1.00000000000
# log_q_cH:
-8.84865724085
# log_q_HB:
-16.2888831455
# log_q_GR:
-16.1010631338
# log_q_FST:
-15.4625000344
# log_q_CVT:
-15.9882321151
# q_RW_log_dev_cH:
 0.0379165503566 0.0494742334789 0.0310641863358 0.0995241653902 0.102290077333 0.126185312680 0.112832852079 0.0694855552162 0.0188371153667
-0.0374146162628 -0.00711635309620 0.0133785155602 0.0165161240715 0.0469709128856 0.0354079293328
# q_RW_log_dev_HB:
 0.0203456347365 0.130337224610 -0.00571232133142 -0.118690751004 0.00578679220481 0.0290550160027 0.139146165983 0.00955803035874 0.0737868699556
-0.00677908562476 0.0963577548414 0.0521394252880 -0.104337381085 -0.0666115938105 -0.0446627699268 -0.0756196360257 -0.0204255197780 0.0118247733638
0.0585653111243 0.103452834266 0.130998302958 0.0363325364275 0.00666918963931 0.0577267560034 0.0601150158521 0.0333437628011 -0.0851353254412
0.000291483545785 0.0424998847476 0.0562698205130 0.00239879773303 -0.0690194560549
# q_RW_log_dev_GR:
 -0.0395135060767 0.0824529028521 0.218813250471 0.0969376497672 0.0552245792691 -0.0188258531785 -0.175398349399 0.132571298999 0.148219402328
-0.0661778219633 0.109194075275 -0.0352481633356 -0.0550014758223 -0.00980098966690 -0.0468205955946 0.0412611272954 -0.0706351706059 -0.104227092183
0.0567754428736 -0.143030334510 -0.0213830991088
# M_constant:
0.220000000000
# log_avg_F_cH:
-3.46196217427
# log_F_dev_cH:
 -7.79688924844 -5.91735835981 -5.58399833117 -3.17251274488 -3.64570525254 -3.14455291578 -4.22490819735 -3.13115041298 -5.07328339402 -3.41893403694
-2.58880149967 -2.60479561031 -3.06417934883 -1.83540810092 -1.79470923220 -1.96520613045 -1.23499638268 -0.711724864725 -0.880325492208 -0.344640197688
-0.0470753918851 0.215436934280 0.391167202171 0.471628986266 0.824713564983 0.850810805099 1.11303546021 1.43605247725 1.49213981777 1.32820583230
1.61852062221 1.93796272915 2.17725420125 2.37139789154 1.48128390235 1.69968104791 1.78479614746 1.72131538226 1.47631004264 1.61987701351 1.62212162251
1.84040440230 2.26468046155 2.49390293950 2.38039755348 1.77470888509 2.05050124460 1.95571018002 1.79068787928 2.18926070415 2.30600265362 1.84702904379
1.71169577723 1.56179553288 1.61686236567 1.66426807595 1.64255099584 1.71561688886 1.74136787855
# log_avg_F_cO:
-6.42625346159
# log_F_dev_cO:
 -2.16130309233 0.980996102124 0.343672507563 -0.436313356920 -0.317183327121 0.591517919243 0.995927049250 -1.13212613170 2.65214012150 4.24728208403
4.19396720597 4.07318306514 3.54180899036 3.22582404675 0.991866727799 1.09638899965 2.16176887426 2.93150449423 0.230506188580 2.24744375362 1.52287387066
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# log_avg_F_cHTR:
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# log_F_dev_cHTR:
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# log_avg_F_HB:
-3.85447403708
# log_F_dev_HB:
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0.471090885752 -0.286435362313 -0.214395564375 -0.142717091783 -0.304604776062 0.0533764061688 0.0367195934188 0.791569087173
# log_avg_F_GR:
-4.83709606025
# log_F_dev_GR:
```

```
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0.245748991987 0.281805087371 0.329833453486 0.394605520008 -2.00296029066 0.345034057799 1.32197350956 0.00492201238990 1.36882050872 -0.605703273701 0.411111815041
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0.823966517451 1.19564789107 1.13107788688 0.985456309179 1.10481585659 1.11472556774 0.683325524342 1.45812847841 1.00940262528 1.49589656860 1.21976615924
0.0398958480642 0.158872456906 0.0208784456617 0.393775450503 1.41998901756 1.20490653372 1.52642613999
# log_avg_F_cH_D:
-4.96037386631
# log_F_dev_cH_D:
 -0.129158668970 0.609715195094 0.681180477311 0.843300021757 1.05647521796 1.03932445492 0.611011784950 0.254790284331 0.147212471301 0.468170214059
1.25784002461 0.160100743528 -0.365573645739 -0.00826075847581 -0.209082196589 -0.475083587218 -0.0790055887655 -0.629359793608 -0.489727157857 -0.616455095568
-1.04419266482 -0.715066347257 -0.644875998255 -0.649557516414 -1.07372187028
# log_avg_F_HB_D:
-6.64163971380
# log_F_dev_HB_D:
 -3.75766489611 -3.06281880385 -2.65648064403 -2.36716524387 -2.14237921557 -1.95864790991 -1.80268959105 -1.66751344217 -1.54778802112 -1.45277112388
-1.36554083909 -1.28514976646 -1.21030111154 -1.14051054082 -1.05071325685 -0.962395104191 -0.879459831356 -0.813981331935 -0.752600693743 -0.745165346198
-0.738147748636 -0.731108357754 -0.724102501053 -0.717386511875 -0.620932768234 -0.531066557075 -0.445675538333 -0.367500927574 -0.295428287205 -0.280199216132
-0.241030344500 -0.209068652957 -0.166203142705 -0.0753795885163 -0.386318077422 -0.0561600023139 0.0712324945473 -0.293563314076 0.207573256760 0.235949546510
0.482686100392 0.682769120347 0.395496702496 0.127900314122 0.295547250277 1.44679721169 1.18258008764 1.24285041820 1.40745416981 1.60907800562 1.60866667718
1.34974409496 1.27393384587 1.37004050010 1.47145026523 1.31445583807 0.756088846197 1.32547947113 1.20556513446 1.56599407501 2.00645271711 1.79773671688
1.80080164453 1.31140221817 1.68375387939 1.61738849465 1.05918010666 1.65615727251 2.01953980200 1.91926197159
# log_avg_F_GR_D:
-5.71742541983
# log_F_dev_GR_D:
 -3.36280292431 -2.66882904749 -2.26220023632 -1.97317549798 -1.74856382531 -1.56465816815 -1.40882440636 -1.27352373430 -1.15389519613 -1.05878935897
-0.971646734938 -0.891220371379 -0.816443409294 -0.746584987982 -0.656806297563 -0.568503909599 -0.485582181325 -0.420019936702 -0.358655615292 -0.351258817119
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0.152865522797 0.184871827086 0.227739697450 0.318554053305 -0.00786635177040 -0.631785257339 -4.66184190660 -2.02780092890 -1.67250628144 -0.749786293193
-3.01071424317 0.472003767284 1.14149629014 1.10883577563 0.809194171312 1.06063408216 0.771459075961 0.951729355147 1.79715869581 0.573366026487 0.469169247434
1.06503670742 2.16765146209 2.15638566196 1.55592266434 1.62416604009 1.82032197124 1.46468883448 1.40249673034 1.49886919442 2.05335294324 2.97793667638
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