Southeast Data, Assessment, and Review

SEDAR 36
Stock Assessment Report

South Atlantic Snowy Grouper

September 2013*

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SEDAR
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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; and Interstate Commission representatives: Executive Directors of the Atlantic States and Gulf States Marine Fisheries Commissions.

SEDAR is organized around three workshops. First is the Data Workshop, during which fisheries, monitoring, and life history data are reviewed and compiled. Second is the Assessment process, which is conducted via a workshop and several webinars, during which assessment models are developed and population parameters are estimated using the information provided from the Data Workshop. Third and final 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 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 the snowy grouper fishery and harvest.

Original SAMFC FMP

The Fishery Management Plan (FMP), Regulatory Impact Review, and Final Environmental Impact Statement for the Snapper Grouper Fishery of the South Atlantic Region, approved in 1983 and implemented in August of 1983, established a management regime for the fishery for snappers, groupers, and related demersal species of the continental shelf of the southeastern United States in the exclusive economic zone (EEZ) under the area of authority of the South Atlantic Fishery Management Council and the territorial seas of the states, extending from the North Carolina/Virginia border through the Atlantic side of the Florida Keys to 83° W longitude. In the case of the sea basses (black sea bass, bank sea bass, and rock sea bass), the fishery management unit/management regime applies only from Cape Hatteras, North Carolina south. Regulations apply only to federal waters.

SAFMC FMP Amendments affecting snowy grouper

Description of Action	FMP/Amendment	Effective Date
Prohibit trawls (roller rig trawls) from Cape Hatteras, NC to Cape Canaveral, FL.	Amendment 1	1/12/89
Prohibited fish traps, entanglement nets and longlines within 50 fathoms; established a 5 grouper bag limit, defined overfishing/overfished and established rebuilding timeframe: red snapper and groupers ≤ 15 years (year 1 = 1991).	Amendment 4	1/1/92
Snowy grouper commercial quota phased in: 1994: 540,314 pounds gutted weight (gw) 1995: 442,448 pounds gw 1996 onwards: 344,508 pounds gw Commercial trip limit = 2,500 pounds gw; Commercial bycatch limit = 300 pounds gw; Snowy grouper added to the grouper aggregate bag limit; Established Oculina Experimental Closed Area.	Amendment 6	6/27/94
Established a limited entry program for the snapper grouper fishery: unlimited transferable permits and 225-lb non-transferable permits.	Amendment 8	12/14/98
Vessels with longlines may only possess deepwater species	Amendment 9	2/24/99
Established MSY proxy = 30% static SPR except for goliath and Nassau grouper OY: hermaphroditic groupers = 45% static SPR;	Amendment 11	12/02/99

all other species = 40% static SPR Specified overfished/overfishing evaluations - Snowy grouper: overfished (static SPR = 5=15%) Specified overfishing level: goliath and Nassau grouper = F>F40% static SPR; all other species: = F>F30% static SPR Approved definitions for overfished and overfishing. MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}. MFMT = F_{MSY}		
Extended for an indefinite period the regulation prohibiting fishing for and possessing snapper grouper species within the Oculina Experimental Closed Area.	Amendment 13A	04/26/04
Reduced the annual commercial quota from 344,508 pounds gw to 151,000 pounds gw in Year 1; to 118,000 pounds gw in Year 2; and to 84,000 pounds gw in Year 3 onwards until modified. Specified a commercial trip limit of 275 pounds gw in Year 1; 175 pounds gw in Year 2; and 100 pounds gw in Year 3 onwards until modified. After the commercial quota is met, all purchase and sale is prohibited and harvest and/or possession is limited to the bag limit. Limited possession of snowy grouper to one per person per day within the 5-grouper per person per day aggregate recreational bag limit.	Amendment 13C	10/23/06
Established eight deepwater Type II marine protected areas (MPAs) to protect a portion of the population and habitat of long-lived deepwater snapper grouper species.	Amendment 14	2/12/09
Updated management reference points for snowy grouper: MSY equals the yield produced by F_{MSY}. MSY and F_{MSY} are defined by the most recent SEDAR. For snowy grouper: F_{MSY} = 0.05 and MSY = 313,056 pounds ww. OY = 75%F_{MSY} = 303,871 pounds ww. MSST equals SSB_{MSY}(0.75) = 3,498,735 lbs ww. Define a rebuilding schedule as the maximum recommended period to rebuild if T_{MIN} > 10 years. The maximum recommended period equals T_{MIN} + one generation time = 34 years for snowy grouper. 2006 was Year 1. Defined a rebuilding strategy for snowy grouper that maintains a modified/constant fishing mortality rate throughout the rebuilding timeframe. The TAC specified for 2009 would remain in effect beyond 2009 until modified = 102,960 pounds ww.	Amendment 15A	3/20/08

Prohibited the sale of bag-limit caught snapper grouper species. Changed the commercial permit renewal period and transferability requirements. Implemented a plan to monitor and address bycatch. Established allocations for snowy grouper (95% commercial & 5% recreational)	Amendment 15B	12/16/09
Reduced 5-fish aggregate grouper bag limit, including snowy grouper, to a 3-fish aggregate. Captain and crew on for-hire trips cannot retain the bag limit of species within the 3-fish grouper aggregate.	Amendment 16	7/29/09
Specified annual catch limits (ACLs), annual catch targets, and accountability measures (AMs), where necessary, for 9 species undergoing overfishing, including snowy grouper: Establish a recreational daily bag limit of 1 snowy grouper per *vessel*. Implemented AMs for the recreational sector: If the recreational ACL is exceeded, the length of the following fishing season would be reduced by the amount necessary to ensure landings do not exceed the recreational ACL for the following fishing season. Compare the recreational ACL with projected recreational landings over a range of years. For 2010, use only 2010 landings. For 2011, use the average landings of 2010 and 2011. For 2012 and beyond, use the most recent three-year running average. Updated the framework procedure for specification of total allowable catch. Prohibited harvest of 6 deepwater species, including snowy grouper, seaward of 240 feet to curb bycatch of speckled hind and warsaw grouper. Specified ACL=0 (landings only) for speckled hind and warsaw grouper.	Amendment 17B	1/31/11
Eliminated the 240' harvest prohibition for 6 deepwater species, including snowy grouper, that was established in Amendment 17B.	Regulatory Amendment 11	5/10/12

2.2. Emergency and Interim Rules

SAFMC None for snowy grouper.

2.3. Secretarial Amendments

SAFMC None for snowy grouper.

2.4. Control Date Notices

SAFMC:

1. Notice of Control Date (07/30/91 56 FR 36052) - Anyone entering **federal snapper grouper fishery (other than for wreckfish)** in the EEZ off S. Atlantic states after 07/30/91 was not assured of future access if limited entry program developed.
2. Notice of Control Date (10/14/05 70 FR 60058) - Anyone entering **federal snapper grouper fishery** off S. Atlantic states after 10/14/05 was not assured of future access if limited entry program developed.
3. Notice of Control Date (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.

2.5. Management Program Specifications

Table 2.5.1. General Management Information
South Atlantic

Species	Snowy Grouper
Management Unit	Southeastern US
Management Unit Definition	NC/VA boundary southward to the SAFMC/GMFMC boundary
Management Entity	South Atlantic Fishery Management Council
Management Contacts	SAFMC: Myra Brouwer/Gregg Waugh SERO: Jack McGovern/Rick DeVictor
Current stock exploitation status*	Overfishing
Current stock biomass status*	Overfished

*As listed in the most recent Annual Report to Congress on the Status of the Nation's Fisheries.

NOTE: The snowy grouper stock in the South Atlantic is listed as undergoing overfishing and being overfished in the most recent Annual Report to Congress on the Status of the Nation's Fisheries. The stock status was determined through the most recent stock assessment completed in 2004. The Council and NMFS implemented regulations in 2006 that they have determined are sufficient to end overfishing and rebuild the stock in the specified time frame. The rebuilding plan was implemented in 2008. Any change in stock status determination, as determined through a stock assessment, will be reflected in the Annual Report to Congress.

Table 2.5.2. Management Parameters

Criteria	South Atlantic - Current		South Atlantic - Proposed (values from SEDAR 36)		
	Definition	Values	Definition	Base Run Values	Median of Base Run MCBs
MSST[1]	0.75 * SSB_{MSY}	3,498,735 lbs ww	0.75 * SSB_{MSY}		
MFMT	F_{MSY}	0.050	F_{MSY}		
F_{MSY}	F_{MSY}	0.050	F_{MSY}		
MSY	Yield at F_{MSY}	313,056 lbs ww	Yield at F_{MSY}, landings and discards, pounds and numbers		
B_{MSY}	SSB_{MSY}	4,664,981 lbs ww	based on SSB		
R_{MSY}			Recruits at MSY		
F Target			75% F_{MSY}		
Yield at F_{TARGET} (equilibrium)			Landings and discards, pounds and numbers		
M	M	0.10 - 0.25 (0.15) (Potts et al. 1998)	Natural mortality, average across ages		
Terminal F		0.154	Exploitation		
Terminal Biomass[1]	SSB in 2002	869,503 lbs ww	SSB		
Exploitation Status	F/MFMT	3.04	F/MFMT		
Biomass Status[1]	B/MSST	0.21	B/MSST		
	B/B_{MSY}	0.18	B/B_{MSY}		
Generation Time		20.8 years			
$T_{REBUILD}$ (if appropriate)			34Y; start 2003, end 2039		

1. Biomass values reported for management parameters and status determinations should be based on 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.

The snowy grouper stock has been assessed for the 1988, 1990, 1996, and 1999 fishing years (Staff 1991; Huntsman et al. 1992; Potts et al. 1998; Potts and Brennan 2001). The 1988 and 1990 assessments used limited age and growth data and 1/2 L∞ as the age of maturity to estimate static spawning potential ratio (SPR). The 1996 and 1999 assessments used up-to-date age data and reproductive biology data. The resulting static SPRs were 15%, 15%, 5%, and 10% for the 1988, 1990, 1996, and 1999 fishing years, respectively.

Snowy grouper was assessed through SEDAR 4 using a statistical catch-at-age model.

The snowy grouper assessment suggested that fishing mortality first exceeded F_{MSY} in the mid 1970s and continued through the end of the assessment period (2002). The response to fishing pressure was a steady population decline to levels below SSB_{MSY} starting in the early 1980s. SEDAR 4 concluded that snowy grouper was overfished and undergoing overfishing in 2002.

References Cited:

Staff of Beaufort Laboratory, Southeast Fisheries Science Center. 1991. South Atlantic snapper grouper assessment 1991. Report to the South Atlantic Fishery Management Council, One Southpark Circle, Suite 306, Charleston, SC 29407. 21 p.

Huntsman, G. R., J. C. Potts, R. Mays, R. L. Dixon, P. W. Willis, M. Burton, and B. W. Harvey. 1992. A stock assessment of the Snapper-Grouper Complex in the U.S. South Atlantic based on the fish caught in 1990. Report to the South Atlantic Fishery Management Council, One Southpark Circle, Suite 306, Charleston, SC 29407, 104p.

Potts, J. C., M. L. Burton, and C. S. Manooch III. 1998. Trends in catch data and estimated static SPR values for fifteen species of reef fish landed along the southeastern United States. Report to the South Atlantic Fishery Management Council, One Southpark Circle, Suite 306, Charleston, SC 29407. 45p.

Potts, J. C., and K. Brennan. 2001. Trends in catch data and estimated static SPR values for fifteen species of reef fish landed along the southeastern United States. Report to the South Atlantic Fishery Management Council, One Southpark Circle, Suite 306, Charleston, SC 29407. 41 p.

Stock Rebuilding Information

Snowy grouper is in a 34-year rebuilding schedule

Table 2.5.3. General Projection Specifications

South Atlantic

First Year of Management	2015
Interim basis	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 2.5.4. Base Run Projections Specifications. Long Term and Equilibrium conditions.

Criteria	Definition	If overfished	If overfishing	Neither overfished nor overfishing
Projection Span	Years	to 2039	10	10
Projection Values	$F_{CURRENT}$	X	X	X
	F_{MSY}		X	X
	75% F_{MSY}	X	X	X
	$F_{REBUILD} = F_{MSY}$[1]	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.

[1] Snapper Grouper Amendment 15A specified the rebuilding strategy for snowy grouper, based on a modified constant F strategy with F-rebuild = F_{MSY}.

Table 2.5.5. P-star projections. Short term specifications for OFL and ABC recommendations. NOTE: The SSC recommended a P* of 30% during initial ABC control rule consideration.

Criteria		Overfished	Not overfished
Projection Span	Years	to 2039	5
Probability Values	50%	Probability of stock rebuild	Probability of overfishing
	30%		

Table 2.5.6. Quota Calculation Details

	Commercial	Recreational	Total Allowable Catch
Current Quota Value	82,900 pounds gw (97,812 pounds ww)	523 fish (4,400 pounds gw)	102,960 pounds ww
Next Scheduled Quota Change	NA	NA	NA
Annual or averaged quota?	NA	NA	NA
If averaged, number of years to average	NA	NA	NA
Does the quota account for bycatch/discard?	Yes	Yes	Yes

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

Allowable catch was allocated based on average landings from the years 1986-2005.

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

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

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

No.

2.6. Management and Regulatory Timeline

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

Table 2.6.1. Annual Commercial Snowy Grouper Regulatory Summary.

	Fishing Year	Size Limit	Possession Limit	Other Regulations
8/31/83	Calendar Year	None	None	4 in. trawl mesh size
1983	Calendar Year	None	None	4 in. trawl mesh size
1984	Calendar Year	None	None	4 in. trawl mesh size
1985	Calendar Year	None	None	4 in. trawl mesh size
1986	Calendar Year	None	None	4 in. trawl mesh size
1987	Calendar Year	None	None	4 in. trawl mesh size
1988	Calendar Year	None	None	4 in. trawl mesh size
1989	Calendar Year	None	None	Trawls prohibited Cape Hatteras to Cape Canaveral
1990	Calendar Year	None	None	Trawls prohibited Cape Hatteras to Cape Canaveral
1991	Calendar Year	None	None	Trawls prohibited Cape Hatteras to Cape Canaveral
1992	Calendar Year	None	None	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited
1993	Calendar Year	None	None	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited
1994	Calendar Year	None	Effective 6/27/94: Quota = 540,314 pounds gw Trip limit = 2,500 pounds gw Bycatch = 300 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited. Effective 6/27/94: Oculina Experimental Closed Area established with prohibition of all

				bottom fishing.
1995	Calendar Year	None	Quota = 442,448 pounds gw Trip limit = 2,500 pounds gw Bycatch = 300 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited. All bottom fishing prohibited in OECA.
1996	Calendar Year	None	Quota = 344,508 pounds gw Trip limit = 2,500 pounds gw Bycatch = 300 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited. All bottom fishing prohibited in OECA.
1997	Calendar Year	None	Quota = 344,508 pounds gw Trip limit = 2,500 pounds gw Bycatch = 300 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited
1998	Calendar Year	None	Quota = 344,508 pounds gw Trip limit = 2,500 pounds gw Bycatch = 300 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited. All bottom fishing prohibited in OECA.
1999	Calendar Year	None	Quota = 344,508 pounds gw Trip limit = 2,500 pounds gw Bycatch = 300 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited. All bottom fishing prohibited in OECA. Vessels with longlines may only possess deepwater species.
2000	Calendar Year	None	Quota = 344,508 pounds gw Trip limit = 2,500 pounds gw Bycatch = 300 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50

				fathoms prohibited; vessels with longlines may only possess deepwater species.
2001	Calendar Year	None	Quota = 344,508 pounds gw Trip limit = 2,500 pounds gw Bycatch = 300 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited. All bottom fishing prohibited in OECA. Vessels with longlines may only possess deepwater species.
2002	Calendar Year	None	Quota = 344,508 pounds gw Trip limit = 2,500 pounds gw Bycatch = 300 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited. All bottom fishing prohibited in OECA. Vessels with longlines may only possess deepwater species.
2003	Calendar Year	None	Quota = 344,508 pounds gw Trip limit = 2,500 pounds gw Bycatch = 300 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited. All bottom fishing prohibited in OECA. Vessels with longlines may only possess deepwater species.
2004	Calendar Year	None	Quota = 344,508 pounds gw Trip limit = 2,500 pounds gw Bycatch = 300 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited. All bottom fishing prohibited in OECA. Vessels with longlines may only possess deepwater species.
2005	Calendar Year	None	Quota = 344,508 pounds gw Trip limit = 2,500 pounds gw	Trawls prohibited Cape Hatteras to Cape

			Bycatch = 300 pounds gw	Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited. All bottom fishing prohibited in OECA. Vessels with longlines may only possess deepwater species.
2006	Calendar Year	None	Effective 10/23/06: Quota = 151,000 pounds gw Trip limit = 275 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited. All bottom fishing prohibited in OECA. Vessels with longlines may only possess deepwater species.
2007	Calendar Year	None	Quota = 118,000 pounds gw Trip limit = 175 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited. All bottom fishing prohibited in OECA. Vessels with longlines may only possess deepwater species.
2008	Calendar Year	None	Quota = 84,000 pounds gw Trip limit = 100 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited. All bottom fishing prohibited in OECA. Vessels with longlines may only possess deepwater species.
2009	Calendar Year	None	TAC = 102,960 ww Commercial Quota = 89,200 pounds gw Trip limit = 100 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited. All bottom fishing prohibited in OECA. Vessels with

				longlines may only possess deepwater species. Effective 2/12/09: Eight deepwater MPAs established where all bottom fishing is prohibited. Effective 12/16/09: Commercial allocation = 95% of ACL.
2010	Calendar Year	None	Quota = 82,900 pounds gw Trip limit = 100 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited. All bottom fishing prohibited in OECA. Vessels with longlines may only possess deepwater species. All bottom fishing prohibited in deepwater MPAs. 95% commercial allocation.
2011	Calendar Year	None	Quota = 82,900 pounds gw Trip limit = 100 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and longlines within 50 fathoms prohibited. All bottom fishing prohibited in OECA. Vessels with longlines may only possess deepwater species. All bottom fishing prohibited in deepwater MPAs. 95% commercial allocation. Effective 1/31/11: prohibition on harvest of 6 deepwater species seaward of 240 feet.
2012	Calendar Year	None	Quota = 82,900 pounds gw Trip limit = 100 pounds gw	Trawls prohibited Cape Hatteras to Cape Canaveral; fish traps, entanglement nets and

				longlines within 50 fathoms prohibited. All bottom fishing prohibited in OECA. Vessels with longlines may only possess deepwater species. All bottom fishing prohibited in deepwater MPAs. 95% commercial allocation. Effective 5/10/12: prohibition of 6 deepwater species seaward of 240-foot closure removed.

Table 2.6.2. Annual Recreational Snowy Grouper Regulatory Summary

Year	Fishing Year	Size Limit	Bag Limit
8/31/82	Calendar Year	None	None
1983	Calendar Year	None	None
1984	Calendar Year	None	None
1985	Calendar Year	None	None
1986	Calendar Year	None	None
1987	Calendar Year	None	None
1988	Calendar Year	None	None
1989	Calendar Year	None	None
1990	Calendar Year	None	None
1991	Calendar Year	None	None
1992	Calendar Year	None	None
1993	Calendar Year	None	None
1994	Calendar Year	None	Effective 6/27/94: Snowy grouper added to 5-grouper aggregate bag limit. All bottom fishing prohibited in Oculina Experimental Closed Area.
1995	Calendar Year	None	5-grouper aggregate bag limit, including snowy grouper. All bottom fishing prohibited in Oculina Experimental Closed Area.
1996	Calendar Year	None	5-grouper aggregate bag limit, including snowy grouper. All bottom fishing prohibited in Oculina Experimental Closed Area.
1997	Calendar Year	None	5-grouper aggregate bag limit, including snowy grouper. All bottom fishing prohibited in Oculina Experimental Closed Area.
1998	Calendar Year	None	5-grouper aggregate bag limit, including snowy grouper. All bottom fishing prohibited in Oculina Experimental Closed Area.
1999	Calendar Year	None	5-grouper aggregate bag limit, including snowy grouper. All bottom fishing prohibited in Oculina Experimental Closed Area.
2000	Calendar Year	None	5-grouper aggregate bag limit, including snowy grouper. All bottom fishing prohibited in Oculina Experimental Closed Area.
2001	Calendar Year	None	5-grouper aggregate bag limit, including snowy grouper. All bottom fishing prohibited in Oculina Experimental Closed Area.
2002	Calendar Year	None	5-grouper aggregate bag limit, including snowy grouper. All bottom fishing prohibited in Oculina Experimental Closed Area.

2003	Calendar Year	None	5-grouper aggregate bag limit, including snowy grouper. All bottom fishing prohibited in Oculina Experimental Closed Area.
2004	Calendar Year	None	5-grouper aggregate bag limit, including snowy grouper. All bottom fishing prohibited in Oculina Experimental Closed Area.
2005	Calendar Year	None	5-grouper aggregate bag limit, including snowy grouper. All bottom fishing prohibited in Oculina Experimental Closed Area.
2006	Calendar Year	None	5-grouper aggregate bag limit, including snowy grouper. All bottom fishing prohibited in Oculina Experimental Closed Area. Effective 10/26/06: recreational limit of 1 snowy grouper per person per day within the 5-grouper aggregate.
2007	Calendar Year	None	1 per person per day within the 5-grouper aggregate. All bottom fishing prohibited in Oculina Experimental Closed Area.
2008	Calendar Year	None	1 per person per day within the 5-grouper aggregate. All bottom fishing prohibited in Oculina Experimental Closed Area.
2009	Calendar Year	None	1 per person per day within the 3-grouper aggregate. All bottom fishing prohibited in Oculina Experimental Closed Area. Effective 7/29/09: Grouper aggregate reduced to 3 fish; zero retention by captain and crew on for-hire vessels. Effective 12/16/09: Sale of bag limit caught snapper grouper species prohibited. Recreational allocation = 5% of ACL
2010	Calendar Year	None	1 per person per day within the 3-grouper aggregate. All bottom fishing prohibited in Oculina Experimental Closed Area. Grouper aggregate = 3 with zero retention by captain and crew on for-hire vessels. Sale of bag limit caught snapper grouper species prohibited. Recreational allocation = 5% of ACL = 523 fish.
2011	Calendar Year	None	Effective 1/31/11: Limit 1 per vessel per day within the 3-grouper aggregate. All bottom fishing prohibited in Oculina Experimental Closed Area. Grouper aggregate = 3 with zero retention by captain and crew on

			for-hire vessels. Sale of bag limit caught snapper grouper species prohibited. Recreational allocation = 5% of ACL = 523 fish
2012	Calendar Year	None	1 per vessel per day within the 3-grouper aggregate. All bottom fishing prohibited in Oculina Experimental Closed Area. Grouper aggregate = 3 with zero retention by captain and crew on for-hire vessels. Sale of bag limit caught snapper grouper species prohibited. Recreational allocation = 5% of ACL = 523 fish

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

Commercial: October 23, 2006; December 19, 2012.

Recreational: none

Table 7. State Regulatory History

North Carolina

There are no NC state regulations for snowy grouper. NC complements the federal regulations via proclamation authority based on NC code sections: 15A NCAC 03M .0506 and 15A NCAC 03M .0512 (see below). All current snapper grouper regulations are contained in a single proclamation, which gets updated anytime there is an opening/closing of a particular species in the complex, as well as any changes in allowable gear, etc. The most current Snapper Grouper proclamation (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:
Sec. 50-5-2730 of the SC Code states:
"Unless otherwise provided by law, any regulations promulgated by the federal government under the Fishery Conservation and Management Act (PL94-265) or the Atlantic Tuna Conservation Act (PL 94-70) which establishes seasons, fishing periods, gear restrictions, sales restrictions, or bag, catch, size, or possession limits on fish are declared to be the law of this State and apply statewide including in state waters."

As such, SC snowy grouper regulations are (and have been) pulled directly from the federal regulations as promulgated under Magnuson. I am not aware of any separate snowy grouper regulations that have been codified in the SC Code.

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

Florida:
Snowy Grouper Regulation History

Year	Size Limit	Possession Limit	Other Regulation Changes
1986	None	5 per recreational fisherman daily	

1987	None	5 per recreational fisherman daily	
1988	None	5 per recreational fisherman daily	
1989	None	5 per recreational fisherman daily	
1990	None	5 per recreational fisherman daily	Designates all snapper and grouper species as ”restricted species”
			Must be landed in whole condition
1991	None	5 per recreational fisherman daily	
1992	None	5 per recreational fisherman daily	
1993	None	5 per recreational fisherman daily	
1994	None	5 per recreational fisherman daily	
1995	None	5 per recreational fisherman daily	
1996	None	5 per recreational fisherman daily	
1997	None	5 per recreational fisherman daily	
1998	None	5 per recreational fisherman daily	
1999	None	5 per recreational fisherman daily	
2000	None	5 per recreational fisherman daily	
2001	None	5 per recreational fisherman daily	
2002	None	5 per recreational fisherman daily	
2003	None	5 per recreational fisherman daily	
2004	None	5 per recreational fisherman daily	

2005	None	5 per recreational fisherman daily	
2006	None	5 per recreational fisherman daily	
2007	None	1 within the 5 fish daily aggregate	
2008	None	1 within the 5 fish daily aggregate	
2009	None	1 within the 5 fish daily aggregate	
2010	None	1 within the 3 fish daily aggregate	Establishes a 3 fish per person daily aggregate for all grouper in Atlantic and Monroe County state waters
2011	None	1 within the 3 fish daily aggregate	
2012	None	1 within the 3 fish daily aggregate	

REEF FISH, CH 46-14, F.A.C. (Effective December 11, 1986)

- Grouper Bag limit: 5 per recreational fisherman daily, with off-the-water possession limit of 10 per recreational fisherman, for any combination of groupers, excluding rock hind and red hind
- Use of longline gear by commercial fishermen prohibited; bycatch allowance of 5% is permitted harvesters of other species using this gear
- Use of stab nets (or sink nets) to take snapper or grouper is prohibited in Atlantic waters of Monroe County
- 5% of snapper and grouper in possession of harvester may be smaller than the minimum size limit
- Must be landed in whole condition (head and tail intact)

REEF FISH, CH 46-14, F.A.C. (Effective February 1, 1990)

- Designates all snapper and grouper as ”restricted species”
- Snapper and grouper must be landed in whole condition

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

- Allows the Atlantic recreational harvest of one golden tilefish and one snowy grouper within the five-fish daily aggregate grouper bag limit

REEF FISH, CH 68B-14, F.A.C. (Effective January 19, 2010)

- Establishes a 3 fish per person aggregate daily recreational bag limit for all grouper in Atlantic and Monroe County state waters

3. Assessement History

Prior to SEDAR, the South Atlantic snowy grouper stock was examined for trends in CPUE and landings, and was analyzed using catch curves and static spawning potential ratio (SPR) for the years 1988 (Staff 1991), 1990 (Huntsman et al. 1992), 1996 (Potts et al. 1998), and 1999 (Potts and Brennan 2001). Age and life-history information were quite limited for the earlier two analyses, but were updated for the latter two. Given the fishing mortality rates implied by catch curves, the resulting static SPRs were 15%, 15%, 5%, and 10% for 1988, 1990, 1996, and 1999, respectively.

In 2004, the snowy grouper stock was first assessed through SEDAR as a benchmark assessment (SEDAR 2004). That assessment (SEDAR-4) applied a statistical catch-age model to data through 2002. The results indicated that fishing mortality first exceeded F_{MSY} in the mid-1970s, and overfishing continued through the end of the assessment period. During that time, the population declined to levels below SSB_{MSY} starting in the early 1980s. SEDAR-4 concluded that the stock was overfished and experiencing overfishing in 2002.

References Cited:

Staff of Beaufort Laboratory, Southeast Fisheries Science Center. 1991. South Atlantic snapper grouper assessment 1991. Report to the South Atlantic Fishery Management Council, One Southpark Circle, Suite 306, Charleston, SC 29407. 21 p.

Huntsman, G. R., J. C. Potts, R. Mays, R. L. Dixon, P. W. Willis, M. Burton, and B. W. Harvey. 1992. A stock assessment of the Snapper-Grouper Complex in the U.S. South Atlantic based on the fish caught in 1990. Report to the South Atlantic Fishery Management Council, One Southpark Circle, Suite 306, Charleston, SC 29407, 104p.

Potts, J. C., M. L. Burton, and C. S. Manooch III. 1998. Trends in catch data and estimated static SPR values for fifteen species of reef fish landed along the southeastern United States. Report to the South Atlantic Fishery Management Council, One Southpark Circle, Suite 306, Charleston, SC 29407. 45p.

Potts, J. C., and K. Brennan. 2001. Trends in catch data and estimated static SPR values for fifteen species of reef fish landed along the southeastern United States. Report to the South Atlantic Fishery Management Council, One Southpark Circle, Suite 306, Charleston, SC 29407. 41 p.

SEDAR. 2004. Stock Assessment of the Deepwater Snapper-Grouper Complex in the South Atlantic. SEDAR 4 Stock Assessment Report 1. Available: http://www.sefsc.noaa.gov/sedar/download/SEDAR4-FinalSAR%20200606.pdf?id=DOCUMENT

4. Regional Maps

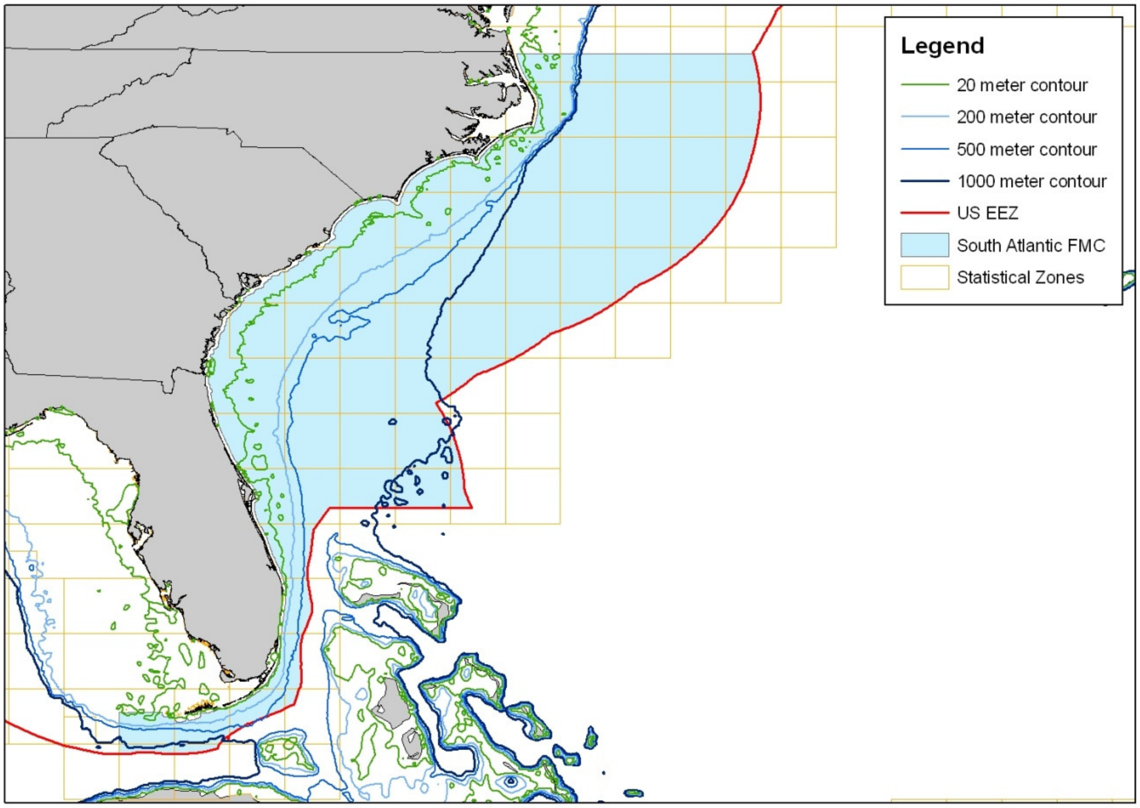

Figure 4.1. South Atlantic Fishery Management Council and EEZ boundaries.

5. SEDAR Abbreviations

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
ASMFC	Atlantic States Marine Fisheries Commission
B	stock biomass level
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 Fisheries 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
M	natural mortality (instantaneous)

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

SEDAR

Southeast Data, Assessment, and Review

SEDAR 36

South Atlantic Snowy Grouper

Stock Assessment Report

September 2013*

***Revised January 13, 2014**

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

Document History

September, 2013 Original release.

January, 2014 This release corrects a mistake in the original release relating to projections and their documentation. The earlier document assumed in projections that 97.3% of removals were landings (the remainder, discards); the intended value, and that used in this revision, is 97.7%. This revision affects text in section 3.8.1, text in captions for all projection tables, and the projected level of removals in 2013–2014.

Contents

List of Tables

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Executive Summary

This standard assessment evaluated the stock of snowy grouper (*Epinephelus niveatus* or *Hyporthodus niveatus*) off the southeastern United States[1]. The primary objectives were to update and improve the 2004 SEDAR4 benchmark assessment of snowy grouper and to conduct new stock projections. Using data through 2002, SEDAR4 had indicated that the stock was overfished and undergoing overfishing, and in response, a rebuilding plan was implemented to achieve stock recovery in the year 2039. For this assessment, data compilation and assessment methods were guided by methodology of SEDAR4, as well as of the concurrent SEDAR32. The assessment period is 1974–2012.

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. Three indices of abundance were fitted by the model: one from the recreational headboat fleet and two fishery independent MARMAP surveys using chevron traps and vertical longlines. One sensitivity run included an index developed from commercial handline data (logbooks). Data on landings and discards were available from recreational and commercial fleets.

The primary model used in SEDAR4—and updated here—was the Beaufort Assessment Model (BAM), a statistical catch-age formulation. A base run of BAM was configured to provide estimates of key management quantities, such as stock and fishery status. Uncertainty in estimates from the base run was evaluated through a mixed Monte Carlo/Bootstrap (MCB) procedure. Median values from the uncertainty analysis are also provided.

Results suggest that spawning stock declined until the mid-1990s and then increased gradually over the last decade. The terminal (2012) base-run estimate of spawning stock was below SSB_{MSY} ($SSB_{2012}/SSB_{MSY} = 0.49$), as was the median estimate ($SSB_{2012}/SSB_{MSY} = 0.38$), indicating that the stock remains overfished. The estimated fishing rate has exceeded the MFMT (represented by F_{MSY}) for most of the assessment period, but only once in the last six years. This one overage occurred in 2012, when the recreational fleet exceeded its quota. Still, the terminal estimate, which is based on a three-year geometric mean, is below F_{MSY} in the case of the base run ($F_{2010-2012}/F_{MSY} = 0.59$) and the median ($F_{2010-2012}/F_{MSY} = 0.70$). Thus, this assessment indicates that the stock has not yet recovered to its biomass target, but is no longer experiencing overfishing.

The MCB analysis indicates that these estimates of stock and fishery status are robust, but also reveals some uncertainty in the conclusions. Of all MCB runs, 89% were in qualitative agreement that the stock has not yet recovered (SSB_{2012}/SSB_{MSY} <1.0), and 76% that the stock is not experiencing overfishing ($F_{2010-2012}/F_{MSY}$ <1.0).

The estimated trends of this standard assessment are quite similar to those from the SEDAR4 benchmark. However, the two assessments did show some differences in results, which was not surprising given several modifications made to both the data and model (described throughout the report). Of those modifications, an increased value of steepness and higher natural mortality at age were likely the primary drivers of any differences in results. Compared to SEDAR4, this assessment suggests lower values of SSB_{MSY} and higher values of F_{MSY} and MSY.

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

1. Introduction

1.1 Assessment Time and Place

The SEDAR 36 Standard Assessment was held via a series of webinars from June through September 2013. The pre-data deadline webinar was held June 3, 2013. Specific assessment webinar dates were July 12, July 26, August 23, and September 4, 2013.

1.2 Terms of Reference

Panel responses are italicized.

1. Update the approved SEDAR 4 Snowy Grouper model with data through 2012. Provide a model consistent with the SEDAR 4 base assessment configuration and revised configurations as necessary to incorporate and evaluate any changes allowed for this update.

   This assessment applied the modern BAM to snowy grouper data updated since SEDAR4. The terminal year of this assessment is 2012. A sensitivity run was developed to mimic the SEDAR4 configuration as closely as possible (Sections 3.3 and 4.11).

2. Evaluate and document the following specific changes in input data or deviations from the benchmark model. (List below each topic or new dataset that will be considered in this assessment.)
   - Incorporate the latest BAM model configuration.
   - Consider any new survey indices now available.
   - Consider updated life history information if available.
   - Provide a probability analysis of future yields and stock status.

   Input data, including deviations from SEDAR4, are described in Section 2. The latest BAM configuration, as applied to snowy grouper, is described in Section 3. Projections of future yields and stock status are provided in Section 4.11.

3. Document any changes or corrections made to model and input datasets and provide updated input data tables. Provide commercial and recreational discards in pounds and numbers.

   See Section 2. Commercial landings data were available in weight only (not numbers), but model predictions of total removals are available in weight and numbers (Tables 16, 17).

4. Update model parameter estimates and their variances, model uncertainties, estimates of stock status and management benchmarks, and provide the probability of overfishing occurring at specified future harvest and exploitation levels.
   - Provide fixed-F yield and status projections based on P-rebuild = 50% and 70% in 2039. (50% is the status quo and 70% is the preliminary SSC recommendation provided 'for example' in the ABC control rule.)
   - Provide a projection of yield and status at Fmsy through 2039.

Estimates of parameters, uncertainties, stock status, and benchmarks, as well as the requested projection scenarios, are described throughout Section 4.

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

   See this report.

1.3 List of Participants

Assessment Panelists

Kyle Shertzer	Lead Analyst	NMFS Beaufort
Rob Cheshire	Data Compiler	NMFS Beaufort
Joey Ballenger	Data provider	SCDNR
Ken Brennan	Data provider	NMFS Beaufort
Chip Collier	SSC	SAFMC
Eric Johnson	SSC	SAFMC
Jennifer Potts	Data provider	NMFS Beaufort
Marcel Reichert	SSC	SAFMC
Tracey Smart	Data provider	SCDNR
Doug Vaughan	SSC	SAFMC
Erik Williams	Assessment team	NMFS Beaufort
David Wyanski	Data provider	SCDNR

Appointed Observers

Rob Harris	Fishing Industry	Recreational, FL
Jack Perrett	Fishing Industry	Recreational, GA
Jeff Oden	Fishing Industry	Commercial, NC

Council Representatives

Michelle Duval	Council Member	SAFMC
Ben Hartig	Council Member	SAFMC

Council and Agency Staff

Julia Byrd	Coordinator	SEDAR
Andrea Grabman	Admin.	SEDAR
Mike Errigo	Council Staff	SAFMC
Myra Brouwer	Council Staff	SAFMC
Mike Larkin	SERO	SERO
John Carmichael	SEDAR/Council Staff	SEDAR/SAFMC
Brian Langseth	Observer	NMFS Beaufort

Non-panelist Data Providers

Neil Baertlein, NMFS Miami
Alan Bianchi, NCDMF
Steve Brown, FL FWC
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Julie Defilippi, ACCSP
Amy Dukes, SCDNR
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Eric Hiltz, SCDNR
Kathy Knowlton, GADNR
Ed Martino, ACCSP
Vivian Matter, NMFS Miami
Kevin McCarthy, NMFS Miami
Beverly Sauls, FL FWC
Chris Wilson, FLFWC

Webinar Attendees

Peter Barile
Patrick Caton
Joe Cimino
Willie Closs
Barrett Colby
Lew Coggins
Rusty Hudson
Joshua McCoy
Sherri McCoy
Jeanna Merrifield
Mike Merrifield

1.4 List of Assessment Working Papers

South Atlantic snowy grouper standard assessment document list.

Document #	Title	Authors
Documents Prepared for the Assessment Process		
SEDAR36-WP01	MRIP Recreational Survey Data for Snowy Grouper in the Atlantic	Matter 2013
SEDAR36-WP02	Snowy Grouper Fishery-Independent Indices of Abundance in US South Atlantic Waters Based on Chevron Trap and Short-bottom Longline Surveys	Ballenger and Smart 2013
SEDAR36-WP03	Standardized catch rates of U.S. snowy grouper (*Epinephelus niveatus*) from commercial logbook handline data	Sustainable Fisheries Branch, NMFS 2013
SEDAR36-WP04	Standardized catch rates of U.S. snowy grouper (*Epinephelus niveatus*) from commercial logbook longline data	Sustainable Fisheries Branch, NMFS 2013
SEDAR36-WP05	Standardized catch rates of Southeast US Atlantic snowy grouper (*Epinephelus niveatus*) from headboat logbook data	Sustainable Fisheries Branch, NMFS 2013
SEDAR36-WP06	Age and length composition weighting for U.S. snowy grouper (*Epinephelus niveatus*)	Sustainable Fisheries Branch, NMFS 2013
SEDAR36-WP07	Calculated discards of snowy grouper from US South Atlantic commercial fishing vessels	McCarthy 2013
SEDAR36-WP08	Marine Resources Monitoring, Assessment and Prediction Program: Report on the Status of the Life History of Snowy Grouper, *Hyporthodus niveatus*, for the SEDAR36 Standard Stock Assessment	Wyanski et al. 2013
SEDAR36-WP09	Report on Age Determination Workshops for Snowy Grouper, *Hyporthodus niveatus*, March 2009 and October 2012	Wyanski et al. 2013
SEDAR36-WP10	Marine Resources Monitoring, Assessment and Prediction Program: Snowy Grouper Length and Age Compositions for the SEDAR36 Standard	Smart 2013

	Stock Assessment	
SEDAR36-WP11	Commercial Landings of Snowy Grouper in the U.S. Atlantic, 1950-2012	N. Baertlein et al. 2013
SEDAR36-WP12	Southeast Region Headboat Survey Data for Snowy Grouper (*Epinephelus niveatus*) in the Atlantic.	Sustainable Fisheries Branch, NMFS 2013
SEDAR36-WP13	South Atlantic Snowy Grouper: Public Comments	Various authors
SEDAR36-WP14	Catch curves for snowy grouper from the commercial handline and longline fleets	Sustainable Fisheries Branch, NMFS 2013
SEDAR36-WP15	Beaufort Assessment Model of Southeast US Atlantic snowy grouper (*Epinephelus niveatus* or *Hyporthodus niveatus*): AD Model Builder code and data input file	Sustainable Fisheries Branch, NMFS 2013
	Final Assessment Reports	
SEDAR36-SAR1	Standard Assessment of Snowy Grouper in the US South Atlantic	To be prepared by SEDAR 36
	Reference Documents	
SEDAR36-RD01	List of documents and working papers for SEDAR 4 (Caribbean – Atlantic Deepwater Snapper Grouper) – all documents available on the SEDAR website.	SEDAR 4
SEDAR36-RD02	Developing a two-step fishery-independent design to estimate the relative abundance of deepwater reef fish: Application to a marine protected area off the southeastern United States coast	Rudershausen et al. 2010
SEDAR36-RD03	Comparison of Reef Fish Catch per Unit Effort and Total Mortality between the 1970s and 2005–2006 in Onslow Bay, North Carolina	Rudershausen et al. 2008
SEDAR36-RD04	Source document for the snapper-grouper fishery of the South Atlantic region.	SAFMC 1983
SEDAR36-RD05	FMP, regulatory impact review, and final environmental impact statement for the SG fishery of the South Atlantic region	SAFMC 1983
SEDAR36-RD06	MRFSS to MRIP Adjustment Ratios and Weight Estimation Procedures for South Atlantic and Gulf of Mexico Managed Species	Matter and Rios 2013
SEDAR36-RD07	Validation of ages for species of the deepwater snapper/grouper complex off the southeastern coast of the United States	Harris 2005
SEDAR36-RD08	Spawner-recruit relationships of demersal marine	Shertzer and Conn

	fishes: prior distribution of steepness	2012
SEDAR36-RD09	Data weighting in statistical fisheries stock assessment models	Francis 2011
SEDAR36-RD10	Corrigendum to Francis 2011 paper	Francis

2 Data Review and Update

In the SEDAR4 benchmark assessment (SEDAR4 2004), the assessment period was 1962–2002. In this assessment, the period was modified to 1974–2012. Data sources from SEDAR4 were also considered here; however, all data were updated, including data prior to 2003, using current methodologies. The input data for this assessment are described below, with focus on modifications from SEDAR4.

2.1 Data Review

In this standard assessment, the Beaufort assessment model (BAM) was fitted to the similar data sources as in SEDAR4 with some modifications and additions.

- Life history: Natural mortality, Growth, Maturity, Proportion female
- Removals (landings and dead discards combined): Commercial handline, Commercial longline, Recreational (as sampled by MRIP and SRHS)
- Indices of abundance: MARMAP chevron trap, MARMAP vertical longline, Recreational (SRHS), Commercial handline as a sensitivity run
- Length compositions of surveys or landings: Commercial handline, Commercial longline, Recreational
- Age compositions of surveys or landings: MARMAP chevron trap, MARMAP vertical longline, Commercial handline, Commercial longline, Recreational

2.2 Data Update

2.2.1 Life History

The length-weight relationship from SEDAR4 was used in this assessment, and a new gutted weight to whole weight conversion was computed (WW=1.082GW). Life history information was revised for SEDAR36 to include additional samples. Female maturity and proportion female at age were updated (SEDAR36-WP08 2013), as were estimates of the von Bertalanffy growth parameters ($\widehat{L_\infty} = 1065$ mm, $\widehat{K} = 0.094$ yr^{-1}, and $\widehat{t_0} = -2.88$ yr). Age-specific mortality was estimated using the Charnov et al. (2012) equation, a departure from the Lorenzen equation (Lorenzen 1996) of SEDAR4 but following recommendations in the concurrent SEDAR32. As noted in the SEDAR32 blueline tilefish DW report, the Charnov et al. (2012) 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). The Charnov mortality curve was scaled to the Hewitt and Hoenig (2005) point estimate, M = 0.12. This point estimate was derived using a maximum observed age of 35. Life-history information is summarized in Table 1.

2.2.2 Commercial Landings and Discards

Estimates of commercial landings were developed for 1950-2012 using current methods and SEDAR36 guidelines (SEDAR36-WP11 2013). The two dominant fleets for snowy grouper were modeled in the assessment: handline and longline. The small amount of landings from the commercial "other gear" category was grouped with those of the handline fleet; SEDAR4 had apportioned landings from this category into handline and longline fleets in proportion to their annual landings. The commercial longline time series was started in 1978, as estimates before then are either zero or trivial (1963, 1964, 1969). Estimates of commercial discards were not available for SEDAR4, but were developed for this assessment based on (non-filtered) estimates of SEDAR36-WP07 (2013). Because discard estimates were very small relative to landings, and because no discard composition data were available to estimate discard selectivity, the commercial discards were combined with landings to form a single time series of total removals (landings plus dead discards) for each commercial fleet. This required converting commercial discards in numbers to weight, which was done by assuming the mean weight at age 2.5. The commercial discard mortality rate of this deepwater species was assumed to be 100%. Commercial landings and discards, as supplied by data providers, are shown in Tables 2 and 3, and total removals as used in the assessment in Table 4.

2.2.3 Recreational Landings and Discards

The headboat landings and discards were estimated from the SRHS for 1972–2012 (SEDAR36-WP12 2013). The landings and discards from the general recreational fleet were estimated from the MRIP (SEDAR4 used MRFSS). Direct estimates from MRIP were available for 2004–2011, and MRFSS estimates for 1981–2003 were converted for consistency with MRIP (SEDAR36-WP01 2013). Several years of MRIP estimates were deemed by the assessment panel as unrealistic: a large spike in 1981 was traced to inflation of a single intercept from the Florida Keys, and several years (1985, 1986, and 1989) had estimates of zero landings during a time when positive recreational catches were documented (Epperly and Dodrill 1995). For these years, MRIP estimates were replaced using the ratio of MRIP to headboat landings (1.95), based on the geometric mean landings from the nearby years, 1982–1984, 1986, and 1987. The headboat and MRIP estimates were combined into one recreational fleet. This was done in the interest of parsimony, and seemed justified because headboat landings are a relatively small proportion (<10%) of total recreational landings, and because composition data are not sufficient to estimate separate selectivities (SEDAR4 assumed that the general recreational selectivity mirrored that of the headboat fleet).

All recreational landings and discards were combined into a single time series of total removals (landings plus dead discards). The recreational discard mortality rate of this deepwater species was assumed to be 100%. Recreational landings and discards, as supplied by data providers, are shown in Tables 2 and 3, and total removals as used in the assessment in Table 4.

2.2.4 Indices of Abundance

Each of the indices of abundance used in SEDAR4 were re-evaluated (Table 5, Figure 1). The headboat logbook index (positive trips only) was used in the SEDAR4 assessment. For SEDAR36, alternative methods were evaluated to identify trips with effort directed at snowy grouper. However, the chosen model was consistent with the SEDAR4 decision to use a GLM on all positive snowy grouper trips. SEDAR4 started the headboat index in 1973, but for this assessment, the index was started in 1978 because that year begins complete spatial coverage of headboat sampling throughout the South Atlantic. The index was ended in 2010, because new recreational regulations in 2011 (1 fish/vessel/day) were believed to affect the ability of this index to track abundance (SEDAR36-WP05 2013). Area north of Cape Hatteras (SRHS area one) was excluded from the data set, because that area was not sampled consistently over time (not at all in many years). The MARMAP chevron trap index (1996–2012) and vertical longline (short-bottom longline) index (1996–2011) were standardized using a zero-inflated model (SEDAR36-WP02 2013). This method differed from SEDAR4, which used nominal MARMAP indices. In addition, the chevron trap index was started in a later year for this assessment (1990 for SEDAR4), because of very low sample sizes prior to 1996, and the vertical longline index ended in 2011, because 2012 sampling was severely limited due to budget cuts.

A commercial handline index, developed from logbook data, was considered but rejected in SEDAR4. That index was reconstructed for SEDAR36 for 1993–2005; trip limits imposed in 2006 prevented consideration of the most recent years of these data (SEDAR36-WP03 2013). This index was not recommended for use in the base assessment model, for reasons similar to those given in SEDAR4, among them: 1) effective effort is especially difficult to define for deepwater species, and 2) the species' aggregative nature and confined habitat locations makes them particularly susceptible to rapid depletion at local levels. Either of those reasons could result in an index that does not track abundance. However, the commercial handline index was considered here in a sensitivity run. A commercial logbook longline index was also constructed, but rejected primarily because of small sample sizes (SEDAR36-WP04 2013). Data from both MRIP and the SCDNR charterboat survey were investigated for the possibility of supporting index development, but in both cases, data webinar panelists found the sample sizes to be insufficient.

2.2.5 Length Compositions

Length compositions for all data sources were developed in 1-cm bins and later pooled into 3-cm bins over the range 22–109 cm (labeled at bin center). All lengths below and above the minimum and maximum bins were pooled. The commercial handline, commercial longline, and recreational lengths were weighted by the landings (SEDAR36-WP06 2013). Length compositions were also developed for the MARMAP chevron trap and vertical longline gears (SEDAR36-WP10 2013), however these lengths were not used in the assessment in favor of corresponding age compositions. For inclusion, length compositions in any given year had to meet the sample size criteria of $nfish > 25$ and $ntrips \geq 5$ (Tables 6 and 7).

2.2.6 Age Compositions

Age compositions were developed using increment counts directly. Approximately 7700 fish have been aged since SEDAR4. In composition data, the upper range was pooled at 14 years old (SEDAR4 used 35 years). For the commercial gears, the age compositions were weighted by the length compositions in attempt to address bias in selection of fish to be aged. In several cases (commercial handline age compositions 1992, 1999–2001), the sampling bias appeared extreme and these compositions were excluded. The recreational age compositions were not weighted, because sample sizes were insufficient to do so (SEDAR36-WP06 2013). Age compositions for MARMAP chevron trap and vertical longline were developed for SEDAR36; these were not available for SEDAR4 (SEDAR36-WP10 2013). For inclusion, age compositions in any given year had to meet the sample size criteria of $nfish > 25$ and $ntrips \geq 5$ (Tables 6 and 7). Age composition was preferred over length composition when both were available from a given fleet in a given year.

2.2.7 Additional Data Considerations

Age data from SCDNR were not included in the SEDAR4 benchmark assessment because of potential differences between NMFS and SCDNR protocols for determining the age of snowy grouper, and because of preliminary evidence from a bomb-radiocarbon validation study suggesting that the SCDNR age assignments may have been too low (SEDAR4 2004). Complete results from that age validation study (SEDAR36-RD07 2013) and an inter-laboratory ageing calibration study (SEDAR36-WP09 2013) have resolved the issues identified in SEDAR4 (2004). These validation and calibration studies supported combining snowy grouper age readings from the two laboratories (NMFS and SCDNR), and therefore all available age data were used in this assessment.

Although the assessment modeled landings and dead discards as total removals, future management (e.g., quotas) may be based on landings only, and thus for application to projections, the ratio of total landings to total removals was estimated post-hoc. This ratio was calculated in weight and was based on observed data during 2007–2012, when regulations have been relatively consistent. The average weight of fish at age 2.5 was used to convert discards in number to weight. Based on these methods, total removals comprised on average 97.7% landings and 2.3% dead discards.

To make this assessment a clean depiction of the stock in the U.S. South Atlantic, the limited data from north of the NC–VA border were excluded from the model input. A commercial fishery has developed off Virginia in recent years, but landings north of NC still only accounts for 0.6% of the total commercial landings. Recreational landings north of NC have likely increased as well, but the SRHS does not sample in those locations and MRIP has observed few removals (30 fish and only in 2012). No age or length data were available from the commercial fleet, and from the recreational fleet, only 7 fish were aged (but not measured). The assessment panel noted that although a fishery for snowy grouper has developed off VA over the past decade, the proportion of the total stock north of NC is likely to be small relative to that in the South Atlantic. Furthermore, because of oceanographic conditions, spawners from the northern part of the range likely contribute little or nothing to stock productivity in the South Atlantic.

Data available for this update assessment are summarized in Tables 1–7.

3 Stock Assessment Methods

This assessment updates the primary model applied during SEDAR4 to South Atlantic snowy grouper. The methods are reviewed below, and modifications since SEDAR4 are flagged.

3.1 Overview

The primary model in this assessment was the Beaufort assessment model (BAM), which applies a statistical catch-age formulation. The model was implemented with the AD Model Builder software (Fournier et al. 2012). In essence, the model simulates a population forward in time while including fishing processes (Quinn and Deriso 1999; Shertzer et al. 2008). Quantities to be estimated are systematically varied until characteristics of the simulated population matches available data on the real population. The model is similar in structure to Stock Synthesis (Methot 1989; 2009). Versions of BAM have been used in previous SEDAR assessments of reef fishes in the U.S. South Atlantic, such as red porgy, black sea bass, tilefish, blueline tilefish, gag, greater amberjack, red grouper, vermilion snapper, and red snapper, as well as in the previous SEDAR assessment of snowy grouper (SEDAR4 2004).

3.2 Data Sources

The catch-age model included data from three fleets that caught snowy grouper in southeastern U.S. waters: recreational (headboat + general recreational), commercial handlines (hook-and-line), and commercial longlines. The model was fitted to data on annual removals (in numbers for the recreational fleet, in whole weight for commercial fleets); annual length compositions of removals; annual age compositions of removals and surveys; one fishery dependent index of abundance (headboat); and two fishery independent indices of abundance (MARMAP chevron traps and vertical longlines). Removals included landings and dead discards, assuming 100% mortality rate of discards. Data used in the model are tabulated in §2 of this report.

3.3 Model Configuration and Equations

The assessment time period was 1974–2012. A general description of the assessment model follows.

Stock dynamics In the assessment model, new biomass was acquired through growth and recruitment, while abundance of existing cohorts experienced exponential decay from fishing and natural mortality. The population was assumed closed to immigration and emigration. The model included age classes $1 - 25^{+}$, where the oldest age class 25^{+} allowed for the accumulation of fish (i.e., plus group).

Initialization Initial (1974) abundance at age was estimated in the model as follows. First, the equilibrium age structure was computed for ages 1–25 based on natural and fishing mortality (F_{init}), where F_{init} was assumed $F_{\text{init}} = 0.03$ to be small given the relatively low volume of landings prior to the assessment period. Second, lognormal deviations around that equilibrium age structure were estimated. The deviations were lightly penalized, such that the initial abundance of each age could vary from equilibrium if suggested by early composition data, but remain estimable if data were uninformative. Given the initial abundance of ages 2–25, initial (1974) abundance of age-1 fish was computed using the same methods as for recruits in other years (described below).

Natural mortality rate The natural mortality rate (M) was assumed constant over time, but decreasing with age. The form of M as a function of age was based on Charnov et al. (2012), a change from SEDAR4 which based natural mortality on the findings of Lorenzen (1996). The Charnov et al. (2012) approach inversely relates the natural mortality at age to somatic growth. As in previous SEDAR assessments, the age-dependent estimates of M_a were rescaled to provide the same fraction of fish surviving from age 4 through the oldest observed age (35 yr) as would occur with constant $M = 0.12$. This approach using cumulative mortality allows that fraction at the oldest age to be consistent with the findings of Hoenig (1983) and Hewitt and Hoenig (2005).

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) was modeled as a function of total length (Table 1, Figure 2). Parameters of growth and conversion (TL-WW) were estimated external to the assessment model and were treated as input. The von Bertalanffy parameter estimates were $L_{\infty} = 1065$, $K = 0.094$, and $t_0 = -2.88$. For fitting length composition data, the distribution of size at age was assumed normal with CV estimated by the assessment model ($\widehat{\text{CV}} = 13.4\%$).

Maturity and sex ratio Maturity at age of females was modeled as 0% for ages 1 and 2, and as an increasing logistic function for ages 3^{+}. The age at 50% female maturity was estimated to be 5.6 years. All males were considered mature.

Snowy grouper is a protogynous hermaphrodite. The proportion male at age was modeled as 0% for ages 1–4, and as an increasing cumulative normal function for ages 5^{+}. The age at 50% transition was estimated to be 17 years.

Ogives describing maturity and sex ratio were provided by MARMAP scientists, and were treated as input to the assessment model.

Spawning stock Spawning biomass was modeled as total mature biomass (males and females). Spawning biomass was computed each year from number at age when spawning peaks. For snowy grouper, peak spawning was considered to occur at the midpoint of the year. This marks a modification from SEDAR4, which computed spawning biomass at the start of each year.

Recruitment Expected recruitment of age-1 fish was predicted from spawning stock using the Beverton–Holt spawner-recruit model. Annual variation in recruitment was assumed to occur with lognormal deviations starting in 1974, when composition data could provide information on year-class strength.

For modeling recruitment, this standard assessment implemented one notable change to the SEDAR4 model. The previous assessment was unable to estimate the steepness parameter of the spawner-recruit model, but instead fixed steepness at $h = 0.7$. In this assessment, steepness remained non-estimable, but was fixed at $h = 0.84$, consistent with meta-analysis conducted since SEDAR4 (Shertzer and Conn 2012). Sensitivity runs and uncertainty analyses considered other values of steepness.

Removals (landings and dead discards) Time series of removals from three fleets were modeled: commercial handline (1974–2012), commercial longline (1978–2012), and recreational (1974–2012). Removals were modeled with the Baranov catch equation (Baranov 1918) and were fitted in either weight or numbers, depending on how the data were collected (1000 lb whole weight for commercial fleets, and 1000 fish for recreational). For each fleet, the relatively small amount of discards were combined with landings to form a single time series of removals, assuming release mortality rate of 100%.

Fishing For each time series of removals, the assessment model estimated a separate full fishing mortality rate (F). Age-specific rates were then computed as the product of full F and selectivity at age. In SEDAR4, the across-fleet annual F was represented by the sum of fleet-specific full Fs. In this assessment, the across-fleet annual F was represented by apical F, computed as the maximum of F at age summed across fleets. The two approaches may differ under the presence of dome-shaped selectivities that peak at different ages. The change in approach here was adopted in response to comments made by the SEDAR17 review panel, and has been used in the BAM since.

Selectivities Selectivities were estimated using either a two-parameter logistic model (flat-topped) or a four-parameter logistic-exponential model (dome-shaped, described below). This parametric approach reduces the number of estimated parameters and imposes theoretical structure on the estimates. Critical to estimating selectivity parameters are age and size composition data.

In SEDAR4, dome-shaped selectivities were estimated using a double logistic model. More recent assessments have found parameters of that model to lack identifiability, likely because it typically requires re-scaling to peak at one. Thus in this assessment, dome-shaped selectivity was modeled by 1) estimating logistic selectivity for ages prior to full selection (two estimated parameters, $\widehat{\eta}$ and $\widehat{\alpha}_{50}$), 2) assuming the age at full selection (fixed parameter, a_f), and 3) estimating the descending limb using a negative exponential model (one estimated parameter, $\widehat{\sigma}$):

$$\text{selex}_a = \begin{cases} \frac{1}{1+\exp[-\widehat{\eta}(a-\widehat{\alpha}_{50})]} & : \; a < a_f \\ 1.0 & : \; a = a_f \\ \exp\left(-\left(\frac{(a-a_f)}{\widehat{\sigma}}\right)^2\right) & : \; a > a_f \end{cases} \tag{1}$$

As in SEDAR4, dome-shaped selectivity was applied to the MARMAP chevron trap survey and to the recreational fleet. Following SEDAR4, the recreational selectivity was blocked into three time periods. Here those periods are 1974–1977, 1978–1991, and 1992–2012. However, in SEDAR4, the middle time block was modeled using linear interpolation of parameters between the first and third blocks, such that selectivity changed annually during the middle block. In SEDAR36, parameters of each time block were estimated distinctly, and selectivity was held constant within each block. For each dome-shaped selectivity, the age at full selection was fixed at values most consistent with age and length composition data (as indicated by likelihood values of model runs using various values of a_f). For the chevron trap gear, this value was $a_f = 6$, and for the recreational fleet, $a_f = 11, 6,$ and 8 for the three blocks, respectively. For consistency with age composition data, which used age 14 as the plus group, selectivity of ages 15^+ was assumed equal to that of age 14.

Flat-topped selectivity was applied to the MARMAP vertical longline survey and to both commercial fleets. In SEDAR4, the commercial handline fleet assumed dome-shaped selectivity, but that decision was revisited by the

SEDAR36 assessment panel, and flat-topped selectivity was recommended based on similarity in age compositions between commercial handline and commercial longline gears. As in SEDAR4, selectivities of commercial gears were assumed constant through time, however time blocks were considered in sensitivity analyses.

The current configuration of BAM allows for priors to be placed on selectivity parameters. In this assessment, normal prior distributions were applied during estimation. These priors were loose ($CV = 0.5$), used primarily to avoid search space in the optimization with potentially no curvature in the likelihood surface.

Indices of abundance The model was fitted to two fishery independent indices of abundance (MARMAP chevron trap 1996-2012; vertical longlines 1996–2011) and to one fishery dependent index of abundance (headboat 1978–2010). A sensitivity run included a commercial handline index developed from logbook data. Predicted indices 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 each index was assumed constant through time.

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 (SSB_{MSY}). In this assessment, spawning stock measures total biomass of mature males and 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.

Fitting criterion The fitting criterion was a likelihood approach in which observed removals (landings and discards) were fit closely, and observed composition data and abundance indices were fit to the degree that they were compatible. Removals and index data were fit using lognormal likelihoods. Length and age composition data were fit using robust multinomial likelihoods (Francis 2011), and only from years that met minimum sample size criteria ($nfish > 25$ and $ntrips \geq 5$).

SEDAR4 also included a least-squares penalty term for log deviations of annual recruitment, permitting estimation of the Beverton–Holt spawner-recruit parameters internal to the assessment model. Instead, this current assessment applied the lognormal likelihood:

$$\Lambda_{\text{SR}} = n \log(\widehat{\sigma}_R) + \sum_{y \geq 1974}^{2011} \frac{[(R_y + (\widehat{\sigma}_R^2/2)]^2}{2\widehat{\sigma}_R^2} \tag{2}$$

where Λ_{SR} is the spawner-recruit likelihood component, R_y are annual recruitment deviations in log space, n is the number of years of recruitment deviations (here starting in 1974), and $\widehat{\sigma}_R$ is the estimated standard deviation. Recruitment deviations are not estimated after 2011, because the data cannot inform such estimates. Instead, predicted recruitment after 2011 (2012 and a projection to 2013) is taken as the expected value from the estimated spawner-recruit curve (mean unbiased in arithmetic space). The total likelihood also included a least-squares penalty term (as in SEDAR4) on residuals prior to 1992, to discourage large deviation from zero in years less informed by data that become available in the mid-1990s, particularly MARMAP indices and age composition data.

The influence of each dataset on the overall model fit was determined by the specification of the error terms in each likelihood component. In the case of lognormal likelihoods, error was quantified by the inverse of the annual coefficient of variation, and for the multinomial components, by the annual sample sizes. These terms determine the influence of each year of data relative to other years of the same data source. In SEDAR4, the relative influence of different datasets and penalty terms was also influenced by external weights (ω_i) chosen by the AW. In this assessment, these weights were applied by either adjusting CVs (lognormal components) or adjusting effective sample sizes (multinomial components). The CVs of removals (in arithmetic space) were assumed equal to 0.05 to achieve a close fit to these data while allowing some imprecision. In practice, the small CVs are a matter of computational convenience, as they help achieve the desired result of close fits to the removals, while avoiding having to solve the Baranov equation iteratively (which is complex when there are multiple fisheries). Weights on other data components (indices, age/length compositions) were adjusted iteratively, starting from initial weights as follows. The CVs of indices were set equal to the values estimated by the data providers. Effective sample sizes of the multinomial components were assumed equal to the number of trips sampled annually (Table 7), rather than the number of fish measured, reflecting the belief that the basic sampling unit occurs at the level of trip. These initial weights were then adjusted until standard deviations of normalized residuals (SDNRs) were near 1.0, following the method of Francis (2011). In sensitivity runs, weights on the three indices were adjusted upward to explore their effects (not because up-weighted runs were considered equally plausible).

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).

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

Sensitivity analyses Sensitivity runs were chosen to investigate issues that arose specifically with this standard assessment. They were intended to demonstrate directionality of results with changes in inputs or simply to explore model behavior, and not all were considered equally plausible (e.g., the assessment panel flagged S11 as being less plausible because it displayed hyper-variable recruitment). These model runs vary from the base run as follows.

- S1: Low natural mortality $M = 0.08$ used to scale the age-dependent vector of Charnov et al. (2012)
- S2: High natural mortality $M = 0.16$ used to scale the age-dependent vector of Charnov et al. (2012)
- S3: Steepness $h = 0.74$, lower than in the base run
- S4: Steepness $h = 0.94$, higher than in the base run
- S5: $F_{\text{init}} = 0.015$, 50% lower than in the base run
- S6: $F_{\text{init}} = 0.045$, 50% higher than in the base run
- S7: Population initialized (1974) with equilibrium age structure, given natural mortality and $F_{\text{init}} = 0.03$
- S8: Commercial handline index included; applies same index weight as for the recreational index
- S9: Up-weight indices two-fold the weights applied in the base run
- S10: Up-weight indices four-fold the weights applied in the base run
- S11: Up-weight indices eight-fold the weights applied in the base run
- S12: Recreational selectivity assumed constant through time (no time blocks)
- S13: Two commercial selectivity blocks for handline and longline; 1974–2006, 2007–2012
- S14: Drop commercial age composition data (both fleets) prior to 2007
- S15: SEDAR4 configuration, including dome-shaped selectivity for commercial handlines, steepness fixed at 0.7, and SEDAR4 life-history characteristics (growth, maturity, sex ratio, natural mortality)

- S16: SSB based only on mature female biomass
- S17: SSB based only on mature male biomass

Retrospective analyses were also conducted, incrementally dropping one year at a time for five iterations. Thus, in these runs, the terminal years were 2011, 2010, 2009, 2008, or 2007.

3.4 Parameters Estimated

The model estimated annual fishing mortality rates of each fleet, selectivity parameters, catchability coefficients associated with 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 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 (2010–2012).

3.6 Benchmark/Reference Point Methods

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

$$R_{eq} = \frac{R_0\left[\varsigma 0.8h\Phi_F - 0.2(1-h)\right]}{(h-0.2)\Phi_F} \tag{3}$$

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 $\mathrm{SSB}_{\mathrm{MSY}}$ follows from the corresponding equilibrium age structure.

Estimates of MSY and related benchmarks are conditional on selectivity pattern. The selectivity pattern used here was an average of terminal-year selectivities from each fleet, where each fleet-specific selectivity was weighted in proportion to its corresponding estimate of F averaged over the last three years (2010–2012). If the selectivities or relative fishing mortalities among fleets were to change, so would the estimates of MSY and related benchmarks.

The maximum fishing mortality threshold (MFMT) is defined by the SAFMC as F_{MSY}, and the minimum stock size threshold (MSST) as 75%SSB_{MSY}. Overfishing is defined as $F >$ MFMT and overfished as SSB $<$ MSST. However, because this stock is currently under a rebuilding plan, increased emphasis is given to SSB relative to SSB_{MSY} (rather than MSST), as SSB_{MSY} is the rebuilding target. Current status of the stock is represented by SSB in the latest assessment year (2012), and current status of the fishery is represented by the geometric mean of F from the latest three years (2010–2012). Although SEDAR4 used only the terminal-year F to gauge the fishing status, more recent SEDAR assessments have considered the mean over the terminal three years to be a more robust metric.

In addition to the MSY-related benchmarks, the assessment considered proxies based on per recruit analyses (e.g., $F_{40\%}$). The values of $F_{X\%}$ are defined as those Fs corresponding to X% spawning potential ratio, i.e., spawners (population fecundity) per recruit relative to that at the unfished level. These quantities may serve as proxies for F_{MSY}, if the spawner-recruit relationship cannot be estimated reliably. Mace (1994) recommended $F_{40\%}$ as a proxy, as did Legault and Brooks (2013). Other studies have found that $F_{40\%}$ is too high of a fishing rate across many life-history strategies (Williams and Shertzer 2003; Brooks et al. 2009) and can lead to undesirably low levels of biomass and recruitment (Clark 2002).

3.7 Uncertainty and Measures of Precision

As in SEDAR4, 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), SEDAR4 (2004), and many South Atlantic SEDAR assessments since SEDAR19 (2009). The approach is among those recommended for use in SEDAR assessments (SEDAR Procedural Guidance 2010).

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

In this assessment, the BAM was successively re-fit in $n = 4000$ trials that differed from the original inputs by bootstrapping on data sources, and by Monte Carlo sampling of several key input parameters. The value of $n = 4000$ was chosen because a minimum of 3000 runs were desired, and it was anticipated that not all runs would converge or otherwise be valid. Of the 4000 trials, approximately 1.25% were discarded, because the model did not properly converge (in most cases, an estimated quantity was at or exceeded its upper bound). This left $n = 3950$ 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 ($\hat{O}_{s,y}$),

$$O_{s,y} = \hat{O}_{s,y}[\exp(x_{s,y} - \sigma^2_{s,y}/2)] \tag{4}$$

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 5 of this assessment report).

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

3.7.2 Monte Carlo sampling

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

Natural mortality Point estimates of natural mortality ($M = 0.12$) were given by the life-history data providers, but with some uncertainty. To carry forward this source of uncertainty, Monte Carlo sampling was used to generate deviations from the point estimate. A new M value was drawn for each MCB trial from a uniform distribution [0.08, 0.16]. The assessment panel agreed to these bounds after initially considering the range [0.1, 0.14], which was ultimately considered to be too narrow. Each realized value of M was used to scale the age-specific Charnov ogive, as in the base run.

Spawner-recruit parameters In initial trials of the assessment model, steepness approached its upper bound if freely estimated. This was more likely a result of poor estimation than an indication that steepness is near 1.0 (Conn et al. 2010). Consequently, steepness was fixed in the MCB analysis, drawn from a truncated beta distribution [0.32, 0.99], with parameters estimated by (Shertzer and Conn 2012). The lower bound (0.32) was the smallest observed value of steepness in the data analyzed by Shertzer and Conn (2012).

Initialization The initial abundance at age (in 1974) was estimated with a light penalty for deviating from the equilibrium abundance at age. That equilibrium was computed given the natural mortality rate and an initial fishing mortality rate, F_{init}. In the base run, $F_{\text{init}} = 0.03$. In MCB runs, F_{init} was drawn from a uniform distribution with bounds at ±50% of 0.03, [0.015, 0.045].

3.8 Projections

Projections were run to predict stock status in years after the assessment, 2013–2039. The year 2039 is the last year of the current rebuilding plan.

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 recreational selectivity, were fixed to the most recent values of the assessment period. A single selectivity curve was applied to calculate removals, averaged across fleets using geometric mean Fs from the last three years of the assessment period, similar to computation of MSY benchmarks (§3.6).

Expected values of SSB (time of peak spawning), F, recruits, and removals 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 SSB_{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

In the assessment, the terminal years of recruitment (2012 and start of year 2013) were computed without deviation from the spawner-recruit curve, but corrected to be unbiased in arithmetic space. This influenced the estimated abundances of ages 1 and 2 ($N_{1,2}$) in 2013 when projections begin. 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 (2013) of projections included this variability in $N_{1,2}$. 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 2012 and 2013 predictions.

Fishing rates that define the projections were assumed to start in 2015, which is the earliest year management could react to this assessment. Because the assessment period ended in 2012, the projections required an initialization period (2013–2014). The level of landings in this period was assumed equal to the current quota of 102,960 lb whole weight, scaled up to represent total removals (i.e., account for dead discards), by assuming that 97.7% of removals are landings (§2.2.7). Thus, the level of removals in this period was assumed equal to $102960/0.977 = 105,384$ lb whole weight.

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, and F_{init}, as well as in estimated quantities such as remaining spawner-recruit parameters, selectivity curves, and in initial (start of 2013) abundance at age.

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 ($\bar{R}_y$). Variability was added to the mean values by choosing multiplicative deviations at random from a lognormal distribution,

$$R_y = \bar{R}_y \exp(\epsilon_y). \tag{5}$$

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 10^{th} and 90^{th} percentiles of the replicate projections.

Rebuilding time frame Based on results from the previous SEDAR4 benchmark assessment, snowy grouper is currently under a rebuilding plan. In this plan, the terminal year is 2039, and rebuilding is defined by the criterion that projection replicates achieve stock recovery (i.e., $\text{SSB}_{2039} \geq \text{SSB}_{\text{MSY}}$) with probability of at least 50%. Here, the probability of stock recovery in each year of the rebuilding plan was computed as the proportion of stochastic projections where $\text{SSB} \geq \text{SSB}_{\text{MSY}}$, with SSB_{MSY} taken to be iteration-specific (i.e., from that particular MCB run).

Projection scenarios Five projection scenarios were considered.

- Scenario 1: $F = F_{\text{current}}$
- Scenario 2: $F = F_{\text{MSY}}$
- Scenario 3: $F = 75\% F_{\text{MSY}}$
- Scenario 4: $F = F_{\text{rebuild}}$, with rebuilding probability of 0.5 in 2039
- Scenario 4: $F = F_{\text{rebuild}}$, with rebuilding probability of 0.7 in 2039

The F_{rebuild} is defined as the maximum F that achieves rebuilding in the allowable time frame.

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 from each fishery 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 4–6). Fits to indices of abundance generally captured the observed trends but not all annual fluctuations (Figures 7–9).

4.2 Parameter Estimates

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

4.3 Stock Abundance and Recruitment

In general, estimated abundance at age showed truncation of the older ages through most of the assessment period, but with some signs of increase during the last decade (Figure 10; Table 8). Total estimated abundance was at its lowest value in the mid-2000s, but more recently was estimated to be near levels comparable to those in the 1980s and 1990s . Annual number of recruits is shown in Table 8 (age-1 column) and in Figure 11. The highest recruitment values were predicted to have occurred in the mid-1970s. The most recent strong recruitment events (age-1 fish) were predicted to have occurred in 2000–2003.

4.4 Total and Spawning Biomass

Estimated biomass at age followed a similar pattern as abundance at age (Figure 12; Table 9). Total biomass and spawning biomass showed similar trends—general decline through the mid-1980s, and relatively stable or slowly increasing patterns since the mid-1990s (Figure 13; Table 10).

4.5 Selectivity

Selectivities of the two MARMAP gears are shown in Figure 14, and selectivities of removals from commercial and recreational fleets are shown in Figures 15–16. In the most recent years, full selection occurred near ages 5–7, depending on the fleet.

Average selectivity of removals (landings and dead discards) was computed from F-weighted selectivities in the most recent three assessment years (Figure 17). 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 11.

4.6 Fishing Mortality and Removals

The estimated fishing mortality rates (F) have shown a general pattern of initial increase and then decrease since the mid-1990s, with much variability across years (Figure 18; Table 12). Since 2000, the commercial handline fleet has been the largest contributor to total F, but was exceeded in 2012 by the recreational fleet.

Estimates of total F at age are shown in Table 13. In any given year, the maximum F at age (i.e., apical F) may be less than that year's sum of fully selected Fs across fleets. This inequality is due to the combination of two features of estimated selectivities: full selection occurs at different ages among gears and several sources of mortality have dome-shaped selectivity.

Table 14 shows total landings at age in numbers, and Table 15 in weight. Similar to fishing rates, since 2000 the majority of estimated removals were from the commercial sector, but in 2012 from the recreational sector (Figures 19, 20; Tables 16, 17). Also since 2000, total removals remained below the level at MSY (Figure 20).

4.7 Spawner-Recruitment Parameters

The estimated Beverton–Holt spawner-recruit curve is shown in Figure 21, along with the effect of density dependence on recruitment, depicted graphically by recruits per spawner as a function of spawning stock (mt). Values of recruitment-related parameters were as follows: steepness $h = 0.84$ (fixed), unfished age-1 recruitment $\widehat{R_0} = 306450$, unfished spawners (mt) per recruit $\phi_0 = 0.0124$, and standard deviation of recruitment residuals in log space $\widehat{\sigma}_R = 0.55$ (which resulted in bias correction of $\varsigma = 1.17$). Uncertainty in these quantities was estimated through the MCB analysis (Figure 22).

4.8 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F (Figure 23). 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 (2010–2012). The yield per recruit curve was strictly increasing, but was not well defined in the sense that a wide range of F provided nearly identical yield per recruit. The F that provides 50% SPR is $F_{50\%} = 0.06$, $F_{40\%} = 0.08$, and $F_{30\%} = 0.11$. For comparison, F_{MSY} from the base run corresponds to about 23% SPR.

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of F (Figure 24). By definition, the F that maximizes equilibrium landings is F_{MSY}, and the corresponding landings and spawning biomass are MSY and $\mathrm{SSB}_{\mathrm{MSY}}$. Equilibrium landings and discards could also be viewed as functions of biomass B, which itself is a function of F (Figure 25).

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 21). Reference points estimated were F_{MSY}, MSY, B_{MSY} and SSB_{MSY}. Based on F_{MSY}, three possible values of F at optimum yield (OY) were considered—$F_{\text{OY}} = 65\% F_{\text{MSY}}$, $F_{\text{OY}} = 75\% F_{\text{MSY}}$, and $F_{\text{OY}} = 85\% F_{\text{MSY}}$—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 $F_{\text{MSY}} = 0.14$ (y^{-1}), MSY = 418.6 (1000 lb), $B_{\text{MSY}} = 2091.7$ (mt), and $\text{SSB}_{\text{MSY}} = 872.3$ (mt). Median estimates were $F_{\text{MSY}} = 0.12$ (y^{-1}), MSY = 441.4 (1000 lb), $B_{\text{MSY}} = 2590.2$ (mt), and $\text{SSB}_{\text{MSY}} = 1177.0$ (mt). Distributions of these benchmarks from the MCB analysis are shown in Figure 26.

4.10 Status of the Stock and Fishery

Estimated time series of stock status (SSB/MSST and $\text{SSB}/\text{SSB}_{\text{MSY}}$) showed general decline throughout the beginning of the assessment period, and modest increase since the mid-1990s (Figure 27, Table 10). Base-run estimates of spawning biomass have remained below the threshold (MSST) since the mid-1980s. Current stock status was estimated in the base run to be $\text{SSB}_{2012}/\text{MSST} = 0.65$ and $\text{SSB}_{2012}/\text{SSB}_{\text{MSY}} = 0.49$ (Table 18), indicating that the stock has not yet recovered to SSB_{MSY}. Median values from the MCB analysis indicated similar results ($\text{SSB}_{2012}/\text{MSST} = 0.50$ and $\text{SSB}_{2012}/\text{SSB}_{\text{MSY}} = 0.38$). The uncertainty analysis suggested that the terminal estimate of stock status is robust (Figures 28, 29). Of the MCB runs, approximately 89% indicated that the stock was below SSB_{MSY} in 2012. Age structure estimated by the base run generally showed fewer older fish than the (equilibrium) age structure expected at MSY, but it also showed increases since 2000 (Figure 30).

The estimated time series of F/F_{MSY} suggests that overfishing has occurred throughout most of the assessment period (Table 10), but with some uncertainty demonstrated by the MCB analysis (Figure 27). Current fishery status in the terminal year, with current F represented by the geometric mean from 2010–2012, was estimated by the base run to be $F_{2010-2012}/F_{\text{MSY}} = 0.59$, and the median value was $F_{2010-2012}/F_{\text{MSY}} = 0.59$ (Table 18). The fishery status was less robust than the stock status (Figures 28, 29). Of the MCB runs, approximately 76% agreed with the base run that the stock is not currently experiencing overfishing.

4.10.1 Comparison to Previous Assessment

Time series of stock and fishery status estimated by this assessment are similar to those from the previous, SEDAR4 assessment (Figure 31). Trends in F/F_{MSY} from the two assessments generally track each other, but SEDAR36 estimated that overfishing has been less severe. Trends in $\text{SSB}/\text{SSB}_{\text{MSY}}$ track quite closely. On the absolute scale (plots not shown), the values of F are very close, suggesting that differences in F/F_{MSY} are driven primarily by the denominator, F_{MSY}. The values of SSB were somewhat higher in SEDAR4, suggesting that estimates of SSB_{MSY} scale with those of SSB. Most of the differences in results are due to SEDAR36 using a higher value of steepness and lower values of age-dependent natural mortality, and the consequent effects on other parameter (e.g., R_0).

4.11 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. In some cases, sensitivity runs are simply a tool for better understanding model behavior, and therefore all runs are not considered equally plausible in the sense of alternative states of nature. Time series of F/F_{MSY} and $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$ are plotted to demonstrate sensitivity to natural mortality (Figure 32), steepness (Figure 33), initial conditions (Figure 34), commercial handline index (Figure 35), index weights (Figure 36), selectivity blocks and commercial age compositions (Figure 37), SEDAR4 configuration (Figure 38), and the measure of SSB (Figure 39). Two of these runs suggested the stock to be overfished and undergoing overfishing, one suggested the stock to be recovered, and the majority agreed with the status indicated by the base run (Figure 40, Table 19). Results appeared to be most sensitive to natural mortality and steepness.

Retrospective analyses did not suggest any patterns of substantial over- or underestimation in terminal-year estimates of fishing mortality rate or of SSB (Figure 41). However, the analysis did reveal a pattern of overestimating recruitment in the terminal year. This occurred because, without information to estimate terminal-year recruitment, the prediction was constrained to fall on the bias-corrected (mean unbiased in arithmetic space) spawner-recruit curve. A potential consequence is that deterministic projections of the base run may be overly optimistic. The stochastic projections, however, adjusted the terminal-year recruitment values (median unbiased) before including lognormal deviations, and would therefore not be influenced by the this retrospective pattern.

4.12 Projections

Projections based on $F = F_{\mathrm{current}}$ allowed the spawning stock to grow such that the majority of replicate projections recovered to $\mathrm{SSB}_{\mathrm{MSY}}$ by 2039 (Figure 42, Table 20). This was not the case for projections based on $F = F_{\mathrm{MSY}}$ (Figure 43, Table 21), but remained so if fishing rate were reduced to $F = 75\%F_{\mathrm{MSY}}$ (Figure 44, Table 22). Interestingly, projections with $F = F_{\mathrm{current}}$ showed a lower probability of stock recovery than did projections with $F = 75\%F_{\mathrm{MSY}}$, despite having a lower median fishing rate. This occurred because the distribution of F_{MSY} is wider and more skewed than that of F_{current}. By design, projections based on $F = F_{\mathrm{rebuild}}$ showed recovery with the desired probability in 2039 (Figures 45–46, Tables 23–24).

5 Discussion

5.1 Comments on the Assessment

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

The base run of the BAM indicated that the stock remains overfished ($\mathrm{SSB}_{2012}/\mathrm{SSB}_{\mathrm{MSY}} = 0.49$), but that overfishing is not occurring ($F_{2010-2012}/F_{\mathrm{MSY}} = 0.59$). Median values from the MCB analyses were in qualitative agreement with those results ($\mathrm{SSB}_{2012}/\mathrm{SSB}_{\mathrm{MSY}} = 0.38$ and $F_{2010-2012}/F_{\mathrm{MSY}} = 0.70$). This assessment estimates that, since the mid-1990s, the stock has been increasing at a modest rate. At current fishing mortality, the stock is projected to recover within the rebuilding time frame with probability greater than 0.5.

In addition to including the more recent years of data, this standard assessment contained several modifications to the previous data of SEDAR4, such as the use of MRIP estimates instead of MRFSS, the re-evaluation (delta-GLM modeling) of indices of abundance, inclusion of discard estimates for all fleets, and $\sim$ 7700 additional ages. Furthermore, life-history information was updated, including female maturity, sex ratio, growth, natural mortality, and steepness. The assessment model itself was also modernized to the current version of BAM. The sum of these improvements should result in a more robust assessment.

In general, fishery dependent indices of abundance may not track actual abundance well, because of factors such as hyperdepletion or hyperstability. Furthermore, this issue can be exacerbated by management measures. In this assessment, the fishery dependent index was not extended beyond 2010, because of the implementation of restrictive trip limits. As such management measures become more common in the southeast U.S., the continued utility of fishery dependent indices in SEDAR stock assessments will be questionable. This situation amplifies the importance of fishery independent sampling.

Most assessed stocks in the southeast U.S. have shown histories of heavy exploitation. High rates of fishing mortality can lead to adaptive responses in life-history characteristics, such as growth and maturity schedules. Such adaptations can affect expected yield and stock recovery, and thus resource managers might wish to consider possible evolutionary effects of fishing in their management plans (Dunlop et al. 2009; Enberg et al. 2009).

The assessment accounted for the protogyny of snowy grouper implicitly by measuring spawning stock as the sum of male and female mature biomass, as recommended by Brooks et al. (2008). Accounting for protogynous sex change is important for stock assessments (Alonzo et al. 2008), and the approach taken here has the advantage of being tractable. However, it ignores possible dynamics of sexual transition, which may be quite complex (e.g., density dependent, mating-system dependent, occurring at local spatial scales). In addition, a protogynous life history accompanied by size- or age-selective harvest places disproportionate fishing pressure on males. This situation creates the possibility for population growth to become limited by the proportion of males. When this occurs, accounting for male (sperm) limitation may be important to the stock assessment (Alonzo and Mangel 2004; Brooks et al. 2008); however, in practice there is typically little or no information available to quantify sperm limitation. In this assessment, the proportion of adult fish that are male drops below 5% in some years, and is below 10% in recent years (Table 10). The equilibrium proportion of adult fish that are male at MSY is near 12% (in numbers), but again, this estimate does not explicitly account for the dynamics of sperm limitation.

Because steepness could not be estimated reliably in this assessment, its value in the base run was fixed at the mode of its prior distribution (Shertzer and Conn 2012). 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, further 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, coming from a prior distribution estimated through meta-analysis.

5.2 Comments on the Projections

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

- In general, projections of fish stocks are highly uncertain, particularly in the long term (e.g., beyond 5–10 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.
- 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.
- 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 retrospective analysis showed a pattern of overestimating recruitment in the terminal year (2012), and this pattern was likely also true for the assessment's projection year (to the start of 2013). As a consequence, deterministic projections of the base run may be overly optimistic, if initial (2013) abundance of ages one and two are biased high. The stochastic projections, however, adjusted the terminal-year recruitment values (median unbiased) before including lognormal deviations, and would therefore not be influenced by the this retrospective pattern.

5.3 Research Recommendations

- Increased fishery independent information, particularly for developing reliable indices of abundance, would greatly improve the assessments of deepwater species.
- More age samples should be collected from the general recreational sector and with more complete spatial coverage.
- Snowy grouper 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 snowy grouper 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 snowy grouper? Are there well defined zoogeographic breaks (e.g., Cape Hatteras) that should define stock structure? Research into these questions could help inform future stock assessments.
- Protogynous life history: 1) Investigate possible effects of hermaphroditism on the steepness parameter; 2) Investigate the sexual transition for temporal patterns, considering possible mechanistic explanations if any patterns are identified; 3) Investigate methods for incorporating the dynamics of sexual transition in assessment models.
- In this assessment, the number of spawning events per mature female per year was implicitly assumed to be constant. The underlying assumptions are that spawning frequency and spawning season duration do not change with age or size. Research is needed to address whether these assumptions for snowy grouper are valid.

Age or size dependence in spawning frequency and/or spawning season duration would have implications for estimating spawning potential as it relates to age structure in the stock assessment (Fitzhugh et al. 2012).

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7 Tables

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

Age	Avg. TL (mm)	Avg. TL (in)	CV length	Avg. Whole weight (kg)	Avg. Whole weight (lb)	Fem. maturity	Proportion Female	Nat. mortality
1	359.3	14.1	0.13	0.76	1.68	0.00	1.00	0.439
2	422.6	16.6	0.13	1.21	2.66	0.00	1.00	0.344
3	480.2	18.9	0.13	1.73	3.81	0.13	1.00	0.284
4	532.6	21.0	0.13	2.32	5.11	0.24	1.00	0.243
5	580.3	22.8	0.13	2.95	6.51	0.39	0.98	0.214
6	623.8	24.6	0.13	3.62	7.98	0.57	0.97	0.192
7	663.3	26.1	0.13	4.31	9.49	0.73	0.95	0.175
8	699.3	27.5	0.13	5.00	11.02	0.85	0.93	0.161
9	732.1	28.8	0.13	5.69	12.54	0.92	0.91	0.151
10	761.9	30.0	0.13	6.37	14.04	0.96	0.88	0.142
11	789.1	31.1	0.13	7.03	15.50	0.98	0.84	0.135
12	813.8	32.0	0.13	7.67	16.91	0.99	0.80	0.129
13	836.3	32.9	0.13	8.29	18.27	1.00	0.75	0.123
14	856.8	33.7	0.13	8.87	19.56	1.00	0.69	0.119
15	875.4	34.5	0.13	9.43	20.79	1.00	0.63	0.115
16	892.4	35.1	0.13	9.95	21.94	1.00	0.57	0.112
17	907.9	35.7	0.13	10.45	23.03	1.00	0.50	0.109
18	921.9	36.3	0.13	10.91	24.05	1.00	0.43	0.107
19	934.7	36.8	0.13	11.34	25.01	1.00	0.37	0.104
20	946.4	37.3	0.13	11.75	25.90	1.00	0.31	0.102
21	957.0	37.7	0.13	12.12	26.73	1.00	0.25	0.101
22	966.6	38.1	0.13	12.47	27.50	1.00	0.20	0.099
23	975.4	38.4	0.13	12.80	28.21	1.00	0.16	0.098
24	983.4	38.7	0.13	13.09	28.87	1.00	0.12	0.097
25	990.7	39.0	0.13	13.37	29.48	1.00	0.03	0.096

Table 2. Observed time series of landings and discards in numbers (fish kept for bait reported separately) as provided for commercial lines (cH), commercial longline (cL), and headboat (hb), and recreational (mrip) fleets.

	Landings (1000s)				Discards (1000s)				Bait (1000s)
Year	cH	cL	hb	mrip	cH	cL	hb	mrip	cH
1972	NA	NA	1.035	NA	NA	NA	NA	NA	NA
1973	NA	NA	0.636	NA	NA	NA	NA	NA	NA
1974	NA	NA	1.793	NA	NA	NA	NA	NA	NA
1975	NA	NA	1.039	NA	NA	NA	NA	NA	NA
1976	NA	NA	2.486	NA	NA	NA	NA	NA	NA
1977	NA	NA	1.157	NA	NA	NA	NA	NA	NA
1978	NA	NA	0.797	NA	NA	NA	NA	NA	NA
1979	NA	NA	1.142	NA	NA	NA	NA	NA	NA
1980	NA	NA	2.264	NA	NA	NA	NA	NA	NA
1981	NA	NA	3.046	82.200	NA	NA	NA	0.000	NA
1982	NA	NA	2.243	3.084	NA	NA	NA	0.220	NA
1983	NA	NA	3.895	6.132	NA	NA	NA	0.000	NA
1984	NA	NA	0.570	1.796	NA	NA	NA	0.000	NA
1985	NA	NA	1.108	0.000	NA	NA	NA	0.000	NA
1986	NA	NA	2.676	0.000	NA	NA	NA	0.000	NA
1987	NA	NA	1.134	1.626	NA	NA	NA	2.546	NA
1988	NA	NA	0.953	2.775	NA	NA	NA	0.000	NA
1989	NA	NA	1.118	0.000	NA	NA	NA	0.000	NA
1990	NA	NA	0.677	0.282	NA	NA	NA	0.808	NA
1991	NA	NA	0.529	0.251	NA	NA	NA	0.000	NA
1992	NA	NA	0.238	2.600	NA	NA	NA	0.518	NA
1993	NA	NA	0.325	9.338	0.211	0.078	NA	0.000	0.046
1994	NA	NA	0.438	0.470	0.264	0.093	NA	0.054	0.058
1995	NA	NA	0.395	9.745	0.262	0.072	NA	0.588	0.057
1996	NA	NA	0.722	0.764	0.259	0.061	NA	0.521	0.057
1997	NA	NA	0.411	19.907	0.280	0.059	NA	0.000	0.062
1998	NA	NA	0.172	0.370	0.209	0.054	NA	0.000	0.046
1999	NA	NA	0.142	8.362	0.175	0.049	NA	0.212	0.038
2000	NA	NA	0.178	2.559	0.182	0.065	NA	0.702	0.040
2001	NA	NA	0.411	15.836	0.191	0.055	NA	0.404	0.042
2002	NA	NA	0.200	4.397	0.180	0.052	NA	1.211	0.040
2003	NA	NA	0.066	5.145	0.157	0.050	NA	0.638	0.035
2004	NA	NA	0.180	12.972	0.140	0.038	0.020	0.542	0.031
2005	NA	NA	0.347	20.442	0.130	0.023	0.070	1.651	0.028
2006	NA	NA	0.097	18.675	0.140	0.036	0.020	0.067	0.031
2007	NA	NA	0.173	4.450	0.148	0.013	0.024	1.149	0.032
2008	NA	NA	0.053	2.504	0.148	0.014	0.021	0.648	0.032
2009	NA	NA	0.108	5.476	0.160	0.022	0.096	1.583	0.035
2010	NA	NA	0.077	5.815	0.132	0.024	0.048	0.115	0.029
2011	NA	NA	0.063	0.084	0.122	0.015	0.041	0.059	0.027
2012	NA	NA	0.060	16.628	0.102	0.023	0.051	2.655	0.022

Table 3. Observed time series of landings and discards (fish kept for bait reported separately) in whole weight (1000 lb) as provided for commercial lines (cH), commercial longline (cL), and headboat (hb), and recreational (mrip) fleets. Commercial discards in number were converted to pounds using the estimate of weight at age 2.5 (2.64 lb).

	Landings (1000 lb)				Discards (1000 lb)				Bait (1000 lb)
Year	cH	cL	hb	mrip	cH	cL	hb	mrip	cH
1950	130.210	0.000	NA	NA	NA	NA	NA	NA	NA
1951	186.593	0.000	NA	NA	NA	NA	NA	NA	NA
1952	128.693	0.000	NA	NA	NA	NA	NA	NA	NA
1953	106.578	0.000	NA	NA	NA	NA	NA	NA	NA
1954	106.671	0.000	NA	NA	NA	NA	NA	NA	NA
1955	54.037	0.000	NA	NA	NA	NA	NA	NA	NA
1956	61.009	0.000	NA	NA	NA	NA	NA	NA	NA
1957	108.342	0.000	NA	NA	NA	NA	NA	NA	NA
1958	36.197	0.000	NA	NA	NA	NA	NA	NA	NA
1959	29.476	0.000	NA	NA	NA	NA	NA	NA	NA
1960	37.844	0.000	NA	NA	NA	NA	NA	NA	NA
1961	38.003	0.000	NA	NA	NA	NA	NA	NA	NA
1962	80.274	0.000	NA	NA	NA	NA	NA	NA	NA
1963	76.466	1.686	NA	NA	NA	NA	NA	NA	NA
1964	80.029	1.541	NA	NA	NA	NA	NA	NA	NA
1965	74.892	0.000	NA	NA	NA	NA	NA	NA	NA
1966	56.792	0.000	NA	NA	NA	NA	NA	NA	NA
1967	116.464	0.000	NA	NA	NA	NA	NA	NA	NA
1968	145.338	0.000	NA	NA	NA	NA	NA	NA	NA
1969	111.419	0.118	NA	NA	NA	NA	NA	NA	NA
1970	157.429	0.000	NA	NA	NA	NA	NA	NA	NA
1971	159.123	0.000	NA	NA	NA	NA	NA	NA	NA
1972	144.897	0.000	11.288	NA	NA	NA	NA	NA	NA
1973	140.448	0.000	10.979	NA	NA	NA	NA	NA	NA
1974	187.166	0.000	21.120	NA	NA	NA	NA	NA	NA
1975	216.420	0.000	13.580	NA	NA	NA	NA	NA	NA
1976	278.825	0.000	24.603	NA	NA	NA	NA	NA	NA
1977	258.187	0.000	7.650	NA	NA	NA	NA	NA	NA
1978	422.466	45.868	10.097	NA	NA	NA	NA	NA	NA
1979	383.351	41.965	9.877	NA	NA	NA	NA	NA	NA
1980	313.306	42.735	19.841	NA	NA	NA	NA	NA	NA
1981	575.649	47.161	16.860	574.305	NA	NA	NA	NA	NA
1982	425.884	103.695	16.579	41.056	NA	NA	NA	NA	NA
1983	511.620	323.408	23.489	81.631	NA	NA	NA	NA	NA
1984	359.687	225.399	2.426	23.902	NA	NA	NA	NA	NA
1985	305.280	149.225	4.328	0.000	NA	NA	NA	NA	NA
1986	316.436	171.107	8.461	0.000	NA	NA	NA	NA	NA
1987	240.634	183.702	4.415	21.646	NA	NA	NA	NA	NA
1988	180.224	153.103	3.279	36.940	NA	NA	NA	NA	NA
1989	334.531	191.677	4.028	0.000	NA	NA	NA	NA	NA
1990	384.722	227.529	2.847	3.758	NA	NA	NA	NA	NA
1991	336.503	154.204	2.186	3.346	NA	NA	NA	NA	NA
1992	355.705	226.727	0.877	34.614	NA	NA	NA	NA	NA
1993	252.960	196.670	1.088	124.310	0.556	0.207	NA	NA	0.122
1994	178.368	109.419	0.730	6.257	0.697	0.246	NA	NA	0.153
1995	259.881	97.469	0.728	129.718	0.691	0.190	NA	NA	0.152
1996	234.680	64.304	3.422	10.173	0.685	0.160	NA	NA	0.151
1997	339.620	174.130	2.209	265.003	0.740	0.155	NA	NA	0.163
1998	225.589	84.563	1.299	4.932	0.551	0.144	NA	NA	0.121
1999	335.745	92.135	0.515	107.088	0.462	0.128	NA	NA	0.102
2000	262.446	100.481	0.513	31.953	0.482	0.173	NA	NA	0.106
2001	246.475	42.862	0.953	209.228	0.503	0.146	NA	NA	0.111
2002	223.289	26.952	0.578	57.868	0.476	0.137	NA	NA	0.105
2003	183.983	22.564	0.467	67.010	0.415	0.132	NA	NA	0.091
2004	177.472	53.759	0.382	156.380	0.369	0.100	NA	NA	0.081
2005	187.454	36.256	1.617	266.869	0.342	0.061	NA	NA	0.075
2006	185.890	42.481	0.669	244.510	0.369	0.095	NA	NA	0.081
2007	111.384	3.701	0.283	73.848	0.390	0.033	NA	NA	0.086
2008	66.913	10.815	0.091	31.057	0.390	0.036	NA	NA	0.086
2009	71.527	8.296	0.204	68.497	0.422	0.057	NA	NA	0.093
2010	87.825	3.074	0.139	94.576	0.349	0.063	NA	NA	0.077
2011	39.447	1.450	0.067	0.793	0.322	0.039	NA	NA	0.071
2012	93.060	2.750	0.085	95.224	0.269	0.060	NA	NA	0.059

Table 4. Observed time series of removals (landings and discards combined) as used in the assessment for commercial lines (cH), commercial longline (cL), and general recreational (rec). Commercial values are in units of 1000 lb whole weight. Recreational values are in units of 1000 fish.

Year	cH	cL	rec
1974	187.17	.	5.30
1975	216.42	.	3.07
1976	278.83	.	7.34
1977	258.19	.	3.42
1978	422.47	45.87	2.35
1979	383.35	41.96	3.37
1980	313.31	42.74	6.69
1981	575.65	47.16	9.00
1982	425.88	103.69	5.55
1983	511.62	323.41	10.03
1984	359.69	225.40	2.37
1985	305.28	149.22	3.27
1986	316.44	171.11	7.90
1987	240.63	183.70	5.31
1988	180.22	153.10	3.73
1989	334.53	191.68	3.30
1990	384.72	227.53	1.77
1991	336.50	154.20	0.78
1992	355.71	226.73	3.36
1993	253.02	196.88	9.66
1994	179.22	109.67	0.96
1995	260.72	97.66	10.73
1996	235.52	64.46	2.01
1997	340.52	174.29	20.32
1998	226.25	84.71	0.54
1999	335.82	91.30	8.72
2000	263.02	100.10	3.44
2001	247.09	43.01	16.65
2002	223.83	27.09	5.81
2003	184.44	22.70	5.85
2004	177.86	53.86	13.71
2005	187.87	36.32	22.51
2006	186.31	42.58	18.86
2007	111.79	3.70	5.80
2008	66.99	10.85	3.23
2009	71.95	7.93	7.26
2010	88.20	3.08	6.06
2011	39.84	1.26	0.25
2012	93.39	2.70	19.39

Table 5. Observed indices of abundance and CVs from MARMAP chevron trap (cvt), MARMAP vertical longline (vll), and headboats (hb). The commercial line (cH) index was included in a sensitivity run.

Year	cvt	cvt CV	vll	vll CV	hb	hb CV	cH	cH CV
1978	.	.	.	.	1.58	0.14	.	.
1979	.	.	.	.	1.22	0.15	.	.
1980	.	.	.	.	2.38	0.13	.	.
1981	.	.	.	.	2.18	0.15	.	.
1982	.	.	.	.	0.97	0.11	.	.
1983	.	.	.	.	1.26	0.09	.	.
1984	.	.	.	.	0.85	0.12	.	.
1985	.	.	.	.	0.84	0.10	.	.
1986	.	.	.	.	0.87	0.10	.	.
1987	.	.	.	.	1.17	0.11	.	.
1988	.	.	.	.	1.11	0.12	.	.
1989	.	.	.	.	1.39	0.10	.	.
1990	.	.	.	.	0.93	0.15	.	.
1991	.	.	.	.	1.02	0.14	.	.
1992	.	.	.	.	0.68	0.14	.	.
1993	.	.	.	.	0.49	0.12	0.77	0.07
1994	.	.	.	.	0.57	0.11	0.66	0.06
1995	.	.	.	.	0.77	0.16	0.70	0.05
1996	0.70	0.42	0.47	0.42	0.96	0.14	0.82	0.05
1997	1.04	0.33	0.70	0.28	0.75	0.23	0.96	0.05
1998	0.59	0.39	0.68	0.38	0.72	0.17	1.04	0.05
1999	1.36	0.50	0.93	0.27	0.80	0.21	1.40	0.06
2000	0.14	0.81	0.70	0.26	0.75	0.17	1.05	0.06
2001	2.04	0.21	1.00	0.25	0.92	0.17	0.94	0.05
2002	3.50	0.29	1.38	0.29	1.08	0.34	0.93	0.05
2003	1.10	0.27	0.97	0.20	1.36	0.35	1.16	0.05
2004	0.69	0.52	0.42	0.70	0.54	0.13	1.34	0.06
2005	1.36	0.65	1.01	0.23	0.64	0.17	1.24	0.07
2006	0.77	0.29	0.67	0.26	0.96	0.31	.	.
2007	0.89	0.55	1.35	0.28	0.91	0.22	.	.
2008	0.15	0.92	1.78	0.18	0.54	0.18	.	.
2009	0.43	0.54	2.24	0.26	0.94	0.16	.	.
2010	0.75	0.35	0.93	0.19	0.85	0.25	.	.
2011	0.46	0.38	0.78	0.33	.	.	.	.
2012	1.03	0.28	.	.	.	.	.	.

Table 6. Sample sizes (number of fish) of length compositions (len) or age compositions (age) by survey or fleet. Data sources are MARMAP chevron trap (cvt), MARMAP vertical longline (vll), commercial lines (cH), commercial longline (cL), and general recreational (rec). Bold font indicates years that were used in the model.

Year	len.cH	len.cL	len.rec	age.cvt	age.vll	age.cH	age.cL	age.rec
1974	NA	NA	**242**	NA	NA	NA	NA	NA
1975	NA	NA	**196**	NA	NA	NA	NA	NA
1976	NA	NA	**233**	NA	NA	NA	NA	NA
1977	NA	NA	**122**	NA	NA	NA	NA	NA
1978	NA	NA	**51**	NA	NA	NA	NA	NA
1979	NA	NA	**48**	NA	NA	NA	NA	NA
1980	NA	NA	**54**	NA	NA	NA	NA	21
1981	NA	NA	85	NA	NA	NA	NA	**45**
1982	NA	NA	24	NA	NA	NA	NA	1
1983	**95**	NA	**75**	NA	NA	NA	NA	17
1984	**2098**	**1139**	**43**	NA	NA	NA	NA	11
1985	**3645**	**1065**	**72**	NA	NA	NA	NA	6
1986	**1625**	**1286**	**77**	NA	NA	NA	NA	18
1987	**1395**	**565**	**36**	NA	NA	NA	NA	1
1988	**795**	**461**	**47**	NA	NA	NA	NA	0
1989	**1279**	**341**	**51**	NA	NA	NA	NA	15
1990	**1677**	**714**	7	NA	NA	NA	NA	4
1991	**1659**	**917**	6	NA	NA	NA	NA	2
1992	**2997**	**1700**	2	NA	NA	NA	NA	1
1993	**2339**	**4668**	10	4	NA	38	NA	4
1994	**1922**	**807**	17	19	NA	3	NA	3
1995	**4544**	**1755**	21	59	NA	1	NA	1
1996	**2143**	**757**	**108**	**56**	13	5	NA	7
1997	1091	**1355**	**144**	**61**	**38**	**105**	NA	2
1998	1722	472	**69**	20	25	**72**	**62**	0
1999	**2401**	1277	34	7	**33**	64	**64**	0
2000	**2261**	862	15	5	**36**	87	**109**	0
2001	**1785**	904	**49**	**38**	**42**	70	**104**	0
2002	1280	957	24	**28**	**27**	**60**	**117**	4
2003	1521	372	30	19	**52**	**83**	**69**	**185**
2004	2131	450	53	22	10	**215**	**86**	**62**
2005	1359	106	30	4	**36**	**381**	**41**	5
2006	1726	234	43	10	**30**	**189**	**161**	19
2007	1182	40	56	11	15	**963**	**33**	7
2008	641	61	35	2	**61**	**538**	**53**	13
2009	600	105	53	6	21	**455**	**51**	8
2010	865	63	86	13	**98**	**735**	**35**	8
2011	658	9	3	18	**127**	**599**	1	2
2012	926	52	20	**44**	NA	**834**	**44**	2

Table 7. Sample sizes (number of trips) of length compositions (len) or age compositions (age) by survey or fleet. Data sources are MARMAP chevron trap (cvt), MARMAP vertical longline (vll), commercial lines (cH), commercial longline (cL), and general recreational (rec). Bold font indicates years that were used in the model.

Year	len.cH	len.cL	len.rec	age.cvt	age.vll	age.cH	age.cL	age.rec
1974	NA	NA	**45**	NA	NA	NA	NA	NA
1975	NA	NA	**37**	NA	NA	NA	NA	NA
1976	NA	NA	**49**	NA	NA	NA	NA	NA
1977	NA	NA	**16**	NA	NA	NA	NA	NA
1978	NA	NA	**18**	NA	NA	NA	NA	NA
1979	NA	NA	**13**	NA	NA	NA	NA	NA
1980	NA	NA	**16**	NA	NA	NA	NA	7
1981	NA	NA	16	NA	NA	NA	NA	**9**
1982	NA	NA	12	NA	NA	NA	NA	1
1983	**8**	NA	**27**	NA	NA	NA	NA	9
1984	**84**	**24**	**16**	NA	NA	NA	NA	4
1985	**136**	**28**	**36**	NA	NA	NA	NA	6
1986	**110**	**19**	**29**	NA	NA	NA	NA	9
1987	**90**	**14**	**19**	NA	NA	NA	NA	1
1988	**82**	**14**	**19**	NA	NA	NA	NA	0
1989	**91**	**7**	**17**	NA	NA	NA	NA	6
1990	**83**	**15**	5	NA	NA	NA	NA	4
1991	**102**	**22**	3	NA	NA	NA	NA	2
1992	**111**	**63**	2	NA	NA	NA	NA	1
1993	**108**	**100**	7	1	NA	6	NA	4
1994	**92**	**41**	12	3	NA	2	NA	2
1995	**137**	**48**	6	9	NA	1	NA	1
1996	**105**	**18**	**21**	**20**	9	1	NA	5
1997	85	**33**	**26**	**18**	**14**	**11**	NA	2
1998	81	21	**17**	8	12	**12**	**7**	0
1999	**115**	29	1	4	**14**	7	**6**	0
2000	**132**	32	4	3	**19**	15	**11**	0
2001	**124**	28	**8**	**13**	**18**	10	**10**	0
2002	72	37	3	**10**	**10**	**9**	**9**	2
2003	91	29	5	8	**25**	**7**	**6**	**13**
2004	89	19	7	13	6	**18**	**5**	**16**
2005	80	8	4	3	**19**	**49**	**6**	5
2006	76	23	1	8	**15**	**36**	**19**	5
2007	133	11	4	6	6	**110**	**9**	5
2008	111	10	1	2	**20**	**101**	**12**	7
2009	111	33	1	5	5	**115**	**21**	1
2010	133	19	4	9	**43**	**111**	**13**	2
2011	94	4	1	11	**57**	**89**	1	1
2012	132	11	5	**23**	NA	**113**	**10**	2

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
1974	246.96	118.89	68.78	45.61	33.45	28.01	25.75	24.54	24.17	24.24	20.33	14.66	11.47	9.90	8.78	7.83	7.01	6.28	5.64	5.07	4.56	4.11	3.70	3.34	15.19	768.26
1975	584.47	158.78	82.99	49.68	33.80	25.38	21.70	20.29	19.61	19.51	19.74	16.67	12.16	9.65	8.41	7.49	6.70	6.01	5.40	4.86	4.38	3.95	3.56	3.21	16.10	1144.53
1976	470.87	375.72	110.68	59.79	36.79	25.68	19.70	17.12	16.23	15.85	15.91	16.21	13.81	10.19	8.15	7.13	6.36	5.71	5.14	4.63	4.18	3.77	3.40	3.07	16.68	1272.74
1977	267.75	302.37	260.34	78.42	43.20	27.18	19.36	15.10	13.31	12.74	12.56	12.69	13.09	11.36	8.47	6.80	5.97	5.34	4.81	4.33	3.91	3.53	3.19	2.89	16.80	1155.50
1978	236.89	172.08	210.41	186.75	57.80	32.66	20.99	15.20	12.02	10.71	10.35	10.26	10.46	10.91	9.53	7.13	5.74	5.06	4.54	4.09	3.70	3.34	3.02	2.74	16.89	1063.28
1979	105.20	151.70	118.30	146.90	133.11	42.11	24.23	15.88	11.69	9.35	8.40	8.17	8.16	8.37	8.76	7.68	5.77	4.66	4.11	3.70	3.34	3.02	2.74	2.48	16.12	853.92
1980	101.62	67.30	104.31	82.82	105.12	97.40	31.35	18.42	12.29	9.15	7.38	6.68	6.54	6.57	6.76	7.11	6.25	4.71	3.81	3.37	3.04	2.75	2.49	2.26	15.38	714.88
1981	101.92	64.77	46.20	73.24	59.49	77.15	72.47	23.94	14.41	9.73	7.31	5.94	5.41	5.33	5.37	5.55	5.85	5.16	3.90	3.16	2.80	2.53	2.29	2.08	14.76	620.76
1982	215.24	64.37	43.14	30.30	48.38	40.00	52.31	50.75	17.29	10.55	7.19	5.44	4.45	4.07	4.03	4.08	4.23	4.47	3.95	2.99	2.43	2.16	1.95	1.77	13.03	638.58
1983	155.92	136.55	43.30	28.81	20.34	32.86	27.42	36.85	36.70	12.66	7.80	5.35	4.08	3.35	3.08	3.06	3.10	3.23	3.42	3.03	2.30	1.87	1.67	1.51	11.45	589.72
1984	169.04	97.49	88.64	26.71	17.06	11.73	18.71	16.20	22.66	22.92	7.98	4.95	3.42	2.62	2.16	2.00	1.99	2.02	2.11	2.24	1.99	1.51	1.23	1.10	8.56	537.04
1985	337.38	107.42	64.95	57.01	16.68	10.45	7.20	11.70	10.34	14.63	14.93	5.24	3.27	2.27	1.75	1.45	1.34	1.34	1.36	1.43	1.52	1.35	1.03	0.84	6.58	683.45
1986	282.98	214.37	71.61	41.92	35.98	10.41	6.55	4.60	7.64	6.83	9.75	10.02	3.54	2.22	1.55	1.20	0.99	0.92	0.92	0.94	0.99	1.06	0.94	0.72	5.18	723.83
1987	302.90	178.39	140.43	44.57	25.04	20.94	6.02	3.89	2.81	4.73	4.27	6.14	6.35	2.25	1.42	0.99	0.77	0.64	0.60	0.60	0.61	0.64	0.69	0.61	3.86	760.18
1988	368.96	192.18	118.87	90.35	27.42	14.86	12.33	3.62	2.39	1.75	2.97	2.70	3.90	4.06	1.45	0.92	0.64	0.50	0.42	0.39	0.39	0.40	0.42	0.45	2.94	855.28
1989	242.63	235.27	130.26	79.61	58.78	17.37	9.40	7.94	2.37	1.59	1.17	2.00	1.83	2.66	2.78	0.99	0.63	0.44	0.35	0.29	0.27	0.27	0.28	0.30	2.37	801.86
1990	203.20	154.01	154.84	80.72	46.59	32.99	9.69	5.32	4.58	1.38	0.93	0.69	1.19	1.10	1.60	1.68	0.60	0.38	0.27	0.21	0.18	0.17	0.17	0.17	1.65	704.33
1991	235.86	128.84	99.95	92.01	44.15	23.97	16.76	4.98	2.78	2.42	0.74	0.50	0.37	0.65	0.60	0.88	0.92	0.33	0.21	0.15	0.12	0.10	0.09	0.09	1.01	658.50
1992	213.99	149.83	84.04	60.31	52.26	24.13	13.06	9.25	2.79	1.57	1.38	0.42	0.29	0.22	0.38	0.35	0.52	0.54	0.20	0.13	0.09	0.07	0.06	0.06	0.66	616.59
1993	224.46	135.47	95.38	47.09	29.97	23.80	10.77	5.87	4.21	1.28	0.73	0.65	0.20	0.14	0.10	0.18	0.17	0.25	0.26	0.10	0.06	0.04	0.03	0.03	0.35	581.62
1994	410.06	142.15	86.65	53.67	22.89	13.05	10.08	4.59	2.53	1.84	0.57	0.33	0.29	0.09	0.06	0.05	0.08	0.08	0.12	0.12	0.04	0.03	0.02	0.02	0.18	749.59
1995	405.62	261.31	94.05	53.93	31.23	12.64	7.16	5.59	2.58	1.44	1.05	0.33	0.19	0.17	0.05	0.04	0.03	0.05	0.05	0.07	0.07	0.03	0.02	0.01	0.12	877.81
1996	285.68	257.15	168.10	54.25	28.26	15.45	6.21	3.55	2.81	1.31	0.74	0.55	0.17	0.10	0.09	0.03	0.02	0.02	0.03	0.03	0.04	0.04	0.01	0.01	0.07	824.70
1997	219.02	182.14	170.60	106.00	33.00	16.89	9.29	3.78	2.19	1.75	0.82	0.47	0.35	0.11	0.07	0.06	0.02	0.01	0.01	0.02	0.02	0.03	0.03	0.01	0.05	746.72
1998	179.37	138.62	116.24	95.58	51.77	14.69	7.37	4.08	1.68	0.99	0.80	0.38	0.22	0.17	0.05	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	612.16
1999	237.71	114.49	92.57	74.57	59.43	31.63	9.02	4.58	2.57	1.07	0.63	0.52	0.25	0.14	0.11	0.04	0.02	0.02	0.01	0.00	0.00	0.01	0.01	0.01	0.03	629.44
2000	286.26	150.77	73.75	53.95	40.70	31.52	16.82	4.86	2.50	1.42	0.60	0.36	0.29	0.14	0.08	0.06	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.02	664.17
2001	265.24	182.06	98.61	44.74	30.99	22.70	17.62	9.52	2.79	1.45	0.83	0.35	0.21	0.18	0.09	0.05	0.04	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.02	677.51
2002	346.05	168.43	118.43	58.81	25.10	17.06	12.59	9.90	5.42	1.61	0.85	0.49	0.21	0.13	0.11	0.05	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.01	765.33
2003	250.89	220.65	111.88	75.14	36.61	15.68	10.81	8.10	6.46	3.58	1.07	0.57	0.33	0.15	0.09	0.08	0.04	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.01	742.19
2004	134.22	160.44	149.16	74.29	49.67	24.44	10.64	7.45	5.66	4.56	2.55	0.77	0.41	0.24	0.11	0.07	0.06	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.01	624.82
2005	106.21	85.81	108.54	98.69	47.99	31.87	15.85	7.00	4.97	3.82	3.11	1.76	0.54	0.29	0.17	0.08	0.05	0.04	0.02	0.01	0.01	0.00	0.00	0.00	0.01	516.85
2006	65.11	67.81	57.68	70.49	61.98	29.94	20.12	10.15	4.55	3.26	2.54	2.10	1.21	0.38	0.21	0.12	0.05	0.03	0.03	0.01	0.01	0.01	0.00	0.00	0.01	397.82
2007	78.23	41.55	45.46	37.21	43.92	38.34	18.73	12.77	6.53	2.96	2.15	1.70	1.43	0.83	0.26	0.15	0.09	0.04	0.02	0.02	0.01	0.01	0.00	0.00	0.00	332.42
2008	119.76	50.15	28.54	31.46	26.04	31.32	27.87	13.84	9.57	4.95	2.26	1.66	1.32	1.12	0.66	0.21	0.12	0.07	0.03	0.02	0.02	0.01	0.00	0.00	0.01	351.02
2009	198.41	76.95	34.87	20.39	22.93	19.36	23.74	21.48	10.82	7.56	3.94	1.82	1.35	1.08	0.92	0.55	0.17	0.10	0.06	0.03	0.02	0.01	0.01	0.00	0.01	446.56
2010	171.27	127.34	53.23	24.53	14.47	16.53	14.22	17.72	16.25	8.27	5.84	3.08	1.44	1.08	0.87	0.75	0.44	0.14	0.08	0.05	0.02	0.01	0.01	0.01	0.01	477.66
2011	145.65	109.89	87.91	37.30	17.40	10.45	12.17	10.64	13.45	12.47	6.41	4.58	2.44	1.15	0.87	0.71	0.61	0.36	0.11	0.06	0.04	0.02	0.01	0.01	0.01	474.72
2012	256.64	93.76	77.23	64.71	28.44	13.63	8.37	9.92	8.79	11.22	10.50	5.44	3.90	2.09	0.99	0.75	0.61	0.53	0.31	0.10	0.06	0.03	0.02	0.01	0.02	598.08
2013	259.29	164.39	64.30	52.86	43.73	19.33	9.42	5.88	7.05	6.33	8.19	7.77	4.09	2.99	1.63	0.77	0.59	0.48	0.41	0.25	0.08	0.04	0.03	0.01	0.02	659.92

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
1974	415.1	315.9	262.1	233.0	217.8	223.5	244.5	270.5	303.4	340.4	315.0	248.0	209.4	193.6	182.3	171.7	161.4	151.0	141.1	131.4	121.9	112.9	104.5	96.3	447.8	5614.7
1975	982.4	422.0	316.4	253.8	220.0	202.6	206.1	223.5	246.0	274.0	306.0	282.0	222.0	188.7	174.8	164.2	154.3	144.6	135.1	125.9	117.1	108.7	100.5	92.8	474.7	6138.3
1976	791.5	998.5	422.0	305.3	239.4	205.0	187.0	188.7	203.7	222.4	246.7	274.0	252.2	199.3	169.3	156.3	146.6	137.3	128.5	119.9	111.6	103.6	95.9	88.6	491.6	6485.1
1977	450.0	803.6	992.5	400.6	281.1	216.9	183.9	166.4	166.9	179.0	194.7	214.7	239.2	222.0	175.9	149.3	137.3	128.5	120.2	112.2	104.5	97.2	90.2	83.3	495.2	6405.3
1978	398.2	457.2	802.0	953.9	376.3	260.6	199.3	167.6	150.8	150.4	160.3	173.5	191.1	213.4	198.0	156.5	132.3	121.7	113.5	106.0	98.8	91.9	85.3	78.9	498.0	6336.1
1979	176.8	403.2	451.1	750.5	866.4	336.2	230.2	175.0	146.6	131.2	130.3	138.2	149.0	163.6	182.1	168.4	132.7	112.0	102.7	95.7	89.3	83.1	77.2	71.7	475.1	5838.1
1980	170.9	178.8	397.7	423.1	684.3	777.4	297.6	203.0	154.1	128.5	114.4	113.1	119.5	128.5	140.7	155.9	144.0	113.3	95.2	87.3	81.1	75.6	70.3	65.3	453.5	5372.9
1981	171.3	172.2	176.1	374.1	387.4	615.8	688.1	263.9	180.8	136.7	113.3	100.5	98.8	104.1	111.6	121.9	134.7	124.1	97.4	81.8	75.0	69.7	64.8	60.0	435.0	4958.6
1982	361.8	171.1	164.5	154.8	315.0	319.2	496.7	559.3	216.9	148.2	111.6	92.2	81.4	79.6	83.8	89.5	97.4	107.6	98.8	77.4	65.0	59.3	55.1	51.1	384.0	4441.2
1983	262.1	362.9	165.1	147.3	132.3	262.4	260.4	406.1	460.3	177.9	120.8	90.6	74.5	65.5	63.9	67.0	71.4	77.6	85.5	78.5	61.5	51.6	47.0	43.4	337.5	3973.6
1984	284.2	259.0	338.0	136.5	111.1	93.7	177.7	178.6	284.2	321.9	123.7	83.8	62.4	51.1	45.0	43.9	45.9	48.7	52.7	58.0	53.1	41.4	34.8	31.7	252.2	3213.0
1985	567.0	285.5	247.6	291.2	108.5	83.3	68.3	129.0	129.6	205.5	231.5	88.6	59.7	44.3	36.4	31.7	30.9	32.2	34.2	37.0	40.6	37.0	29.1	24.3	194.0	3067.1
1986	475.5	569.7	272.9	214.1	234.1	83.1	62.2	50.7	95.9	95.9	151.2	169.5	64.6	43.4	32.2	26.2	22.9	22.3	23.1	24.5	26.5	29.1	26.5	20.7	152.8	2989.5
1987	509.0	474.0	535.3	227.7	162.9	167.1	57.1	43.0	35.3	66.4	66.1	103.8	116.0	44.1	29.5	21.8	17.6	15.4	15.0	15.4	16.5	17.6	19.4	17.6	113.8	2908.1
1988	620.2	510.8	453.3	461.6	178.6	118.6	117.1	39.9	30.0	24.5	46.1	45.6	71.2	79.4	30.0	20.1	14.8	11.9	10.4	10.1	10.4	11.0	11.9	13.0	86.6	3026.9
1989	407.9	625.2	496.5	406.8	382.7	138.7	89.3	87.5	29.8	22.3	18.1	34.0	33.5	52.0	57.8	21.8	14.6	10.8	8.6	7.5	7.3	7.5	7.9	8.6	70.1	3045.9
1990	341.5	409.2	590.4	412.3	303.4	263.2	91.9	58.6	57.5	19.4	14.6	11.7	21.8	21.4	33.3	36.8	13.9	9.3	6.8	5.5	4.9	4.6	4.6	5.1	48.5	2790.2
1991	396.4	342.4	381.0	470.0	287.5	191.4	159.2	54.9	34.8	34.0	11.5	8.4	6.8	12.8	12.3	19.2	21.2	7.9	5.3	4.0	3.1	2.6	2.6	2.6	30.0	2502.0
1992	359.6	398.2	320.3	308.0	340.2	192.5	123.9	102.1	35.1	22.0	21.4	7.3	5.3	4.2	7.9	7.7	11.9	13.0	4.9	3.3	2.4	2.0	1.8	1.5	19.4	2316.0
1993	377.2	360.0	363.5	240.5	195.1	190.0	102.3	64.8	52.9	18.1	11.2	11.0	3.7	2.6	2.2	4.0	4.0	6.0	6.6	2.4	1.5	1.1	0.9	0.9	10.4	2033.1
1994	689.2	377.7	330.3	274.3	149.0	104.1	95.7	50.7	31.7	25.8	8.8	5.5	5.3	1.8	1.3	1.1	2.0	2.0	2.9	3.3	1.1	0.9	0.7	0.4	5.3	2170.7
1995	681.7	694.5	358.5	275.6	203.3	101.0	67.9	61.5	32.4	20.1	16.3	5.5	3.5	3.3	1.1	0.9	0.7	1.1	1.1	1.8	2.0	0.7	0.4	0.4	3.5	2538.8
1996	480.2	683.4	640.9	277.1	183.9	123.2	58.9	39.2	35.3	18.3	11.5	9.3	3.1	2.0	2.0	0.7	0.4	0.4	0.7	0.7	1.1	1.1	0.4	0.2	2.2	2575.9
1997	368.2	483.9	650.4	541.5	214.7	134.7	88.2	41.7	27.6	24.5	12.8	7.9	6.4	2.2	1.3	1.3	0.4	0.2	0.2	0.4	0.4	0.7	0.7	0.2	1.5	2612.7
1998	301.4	368.4	443.1	488.3	337.1	117.3	69.9	45.0	21.2	13.9	12.3	6.4	4.0	3.3	1.1	0.7	0.7	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.9	2236.6
1999	399.5	304.2	353.0	381.0	386.9	252.4	85.8	50.5	32.2	15.0	9.9	8.8	4.6	2.9	2.2	0.9	0.4	0.4	0.2	0.2	0.0	0.2	0.2	0.2	0.9	2292.1
2000	481.0	400.6	281.1	275.6	265.0	251.5	159.8	53.6	31.3	19.8	9.3	6.0	5.3	2.9	1.8	1.3	0.4	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.7	2248.5
2001	445.8	483.9	375.9	228.6	201.7	181.2	167.3	104.9	35.1	20.3	12.8	6.0	4.0	3.5	1.8	1.1	0.9	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.4	2275.8
2002	581.6	447.5	451.5	300.5	163.4	136.0	119.5	109.1	68.1	22.5	13.2	8.4	4.0	2.6	2.2	1.1	0.7	0.7	0.2	0.2	0.2	0.0	0.0	0.0	0.4	2433.5
2003	421.7	586.4	426.6	383.8	238.3	125.2	102.7	89.3	81.1	50.3	16.5	9.7	6.2	2.9	1.8	1.8	0.9	0.4	0.4	0.2	0.0	0.0	0.0	0.0	0.2	2546.3
2004	225.5	426.4	568.6	379.4	323.4	195.1	101.0	82.2	71.0	64.2	39.5	13.0	7.5	4.9	2.2	1.5	1.3	0.7	0.4	0.4	0.2	0.0	0.0	0.0	0.2	2508.4
2005	178.6	228.0	413.8	504.2	312.4	254.4	150.6	77.2	62.4	53.6	48.3	29.8	9.9	5.7	3.5	1.8	1.1	0.9	0.4	0.2	0.2	0.0	0.0	0.0	0.2	2337.3
2006	109.3	180.1	219.8	360.0	403.4	239.0	191.1	112.0	57.1	45.9	39.5	35.5	22.0	7.3	4.4	2.6	1.3	0.9	0.7	0.4	0.2	0.2	0.0	0.0	0.2	2033.1
2007	131.4	110.5	173.3	190.0	285.9	306.0	177.9	140.7	82.0	41.4	33.3	28.7	26.0	16.3	5.5	3.1	2.0	0.9	0.7	0.4	0.2	0.2	0.2	0.0	0.2	1757.1
2008	201.3	133.4	108.9	160.7	169.5	250.0	264.6	152.6	119.9	69.4	35.1	28.2	24.3	22.0	13.7	4.6	2.6	1.8	0.9	0.4	0.4	0.2	0.2	0.2	0.2	1764.6
2009	333.6	204.4	132.9	104.1	149.3	154.5	225.5	236.8	135.6	106.0	61.1	30.9	24.7	21.2	19.2	11.9	4.0	2.4	1.5	0.7	0.4	0.4	0.2	0.2	0.2	1961.5
2010	287.9	338.4	202.8	125.2	94.1	132.1	134.9	195.3	203.9	116.2	90.6	52.0	26.2	20.9	18.1	16.3	10.1	3.3	2.0	1.3	0.7	0.4	0.2	0.2	0.2	2074.1
2011	244.7	292.1	335.1	190.5	113.3	83.3	115.5	117.3	168.7	175.0	99.4	77.4	44.5	22.5	18.1	15.4	13.9	8.6	2.9	1.8	1.1	0.4	0.2	0.2	0.4	2142.9
2012	431.4	249.1	294.3	330.5	185.2	108.9	79.6	109.3	110.2	157.6	162.7	91.9	71.4	41.0	20.5	16.5	14.1	12.8	7.9	2.6	1.5	0.9	0.4	0.2	0.7	2501.1
2013	435.9	437.0	245.2	270.1	284.6	154.3	89.5	64.8	88.4	88.8	127.0	131.4	74.7	58.4	33.7	17.0	13.4	11.5	10.4	6.4	2.2	1.3	0.7	0.4	0.7	2647.5

Table 10. Estimated time series of status indicators, fishing mortality, and biomass. Fishing mortality rate is apical F. Total biomass (B, mt) is at the start of the year, and spawning biomass (SSB, mt) at the time of peak spawning (mid-year). The MSST *is defined by* $\text{MSST} = (1 - M)\text{SSB}_{\text{MSY}}$, *with constant* $M = 0.12$. *Prop.fem is the estimated proportion of mature fish that are female.*

Year	F	F/F_{MSY}	B	B/B_{unfished}	SSB	SSB/SSB$_{\text{MSY}}$	SSB/MSST	Prop.fem
1974	0.0634	0.442	2547	0.410	1725	1.977	2.636	0.789
1975	0.0620	0.432	2784	0.448	1625	1.863	2.484	0.784
1976	0.0909	0.634	2942	0.474	1540	1.766	2.354	0.784
1977	0.0666	0.464	2905	0.468	1495	1.714	2.286	0.799
1978	0.1064	0.741	2874	0.463	1461	1.675	2.233	0.815
1979	0.1031	0.718	2648	0.426	1425	1.633	2.178	0.823
1980	0.1036	0.722	2437	0.392	1414	1.621	2.162	0.829
1981	0.1965	1.369	2249	0.362	1341	1.537	2.049	0.830
1982	0.1856	1.294	2014	0.324	1205	1.381	1.842	0.827
1983	0.3714	2.588	1802	0.290	985	1.129	1.505	0.823
1984	0.2966	2.067	1457	0.235	757	0.868	1.157	0.825
1985	0.2754	1.919	1391	0.224	602	0.690	0.920	0.830
1986	0.3561	2.481	1356	0.218	479	0.549	0.732	0.838
1987	0.3376	2.353	1319	0.212	393	0.451	0.601	0.864
1988	0.2661	1.854	1373	0.221	354	0.406	0.541	0.889
1989	0.3932	2.740	1382	0.222	329	0.378	0.503	0.905
1990	0.4895	3.411	1266	0.204	294	0.337	0.449	0.923
1991	0.4194	2.923	1135	0.183	263	0.301	0.402	0.933
1992	0.6256	4.360	1051	0.169	221	0.253	0.338	0.935
1993	0.6804	4.741	922	0.148	171	0.196	0.261	0.943
1994	0.4170	2.906	985	0.159	151	0.173	0.231	0.951
1995	0.5272	3.674	1152	0.185	146	0.167	0.223	0.954
1996	0.3216	2.241	1168	0.188	164	0.188	0.250	0.963
1997	0.6493	4.525	1185	0.191	177	0.203	0.271	0.967
1998	0.2999	2.090	1014	0.163	191	0.219	0.293	0.964
1999	0.4443	3.096	1040	0.167	209	0.239	0.319	0.957
2000	0.3952	2.754	1020	0.164	205	0.235	0.313	0.953
2001	0.4016	2.798	1032	0.166	201	0.230	0.307	0.953
2002	0.2659	1.853	1104	0.178	210	0.241	0.321	0.956
2003	0.1975	1.376	1155	0.186	238	0.273	0.364	0.955
2004	0.2440	1.701	1138	0.183	278	0.319	0.425	0.953
2005	0.2709	1.888	1060	0.171	305	0.350	0.466	0.951
2006	0.2803	1.953	922	0.148	314	0.360	0.480	0.943
2007	0.1275	0.888	797	0.128	331	0.379	0.505	0.935
2008	0.0855	0.596	800	0.129	362	0.415	0.553	0.928
2009	0.1179	0.822	890	0.143	382	0.438	0.584	0.920
2010	0.1147	0.800	941	0.151	389	0.446	0.594	0.914
2011	0.0300	0.209	972	0.156	413	0.473	0.631	0.912
2012	0.1796	1.251	1134	0.183	427	0.489	0.652	0.909
2013	.	.	1201	0.193	.	.	.	0.904

Table 11. Selectivity at age for MARMAP chevron traps (cvt), MARMAP vertical longlines (vll), commercial handlines (cH), commercial longlines (cL), and selectivity of removals averaged across fleets (avg). TL is total length. For time-varying selectivities, values shown are from the terminal assessment year.

Age	TL(mm)	TL(in)	cvt	vll	cH	cL	rec	avg
1	359.3	14.1	0.005	0.000	0.051	0.006	0.028	0.043
2	422.6	16.6	0.050	0.004	0.313	0.033	0.123	0.249
3	480.2	18.9	0.342	0.037	0.793	0.151	0.403	0.661
4	532.6	21.0	0.836	0.254	0.970	0.482	0.765	0.896
5	580.3	22.8	0.980	0.753	0.996	0.830	0.940	0.975
6	623.8	24.6	1.000	0.965	1.000	0.962	0.987	0.995
7	663.3	26.1	0.091	0.996	1.000	0.993	0.997	0.999
8	699.3	27.5	0.000	1.000	1.000	0.999	1.000	1.000
9	732.1	28.8	0.000	1.000	1.000	1.000	0.986	0.996
10	761.9	30.0	0.000	1.000	1.000	1.000	0.946	0.984
11	789.1	31.1	0.000	1.000	1.000	1.000	0.883	0.966
12	813.8	32.0	0.000	1.000	1.000	1.000	0.801	0.942
13	836.3	32.9	0.000	1.000	1.000	1.000	0.707	0.914
14	856.8	33.7	0.000	1.000	1.000	1.000	0.607	0.885
15	875.4	34.5	0.000	1.000	1.000	1.000	0.607	0.885
16	892.4	35.1	0.000	1.000	1.000	1.000	0.607	0.885
17	907.9	35.7	0.000	1.000	1.000	1.000	0.607	0.885
18	921.9	36.3	0.000	1.000	1.000	1.000	0.607	0.885
19	934.7	36.8	0.000	1.000	1.000	1.000	0.607	0.885
20	946.4	37.3	0.000	1.000	1.000	1.000	0.607	0.885
21	957.0	37.7	0.000	1.000	1.000	1.000	0.607	0.885
22	966.6	38.1	0.000	1.000	1.000	1.000	0.607	0.885
23	975.4	38.4	0.000	1.000	1.000	1.000	0.607	0.885
24	983.4	38.7	0.000	1.000	1.000	1.000	0.607	0.885
25	990.7	39.0	0.000	1.000	1.000	1.000	0.607	0.885

Table 12. Estimated time series of fully selected fishing mortality rates for commercial handlines (F.cH), commercial longlines (F.cL), recreational (F.rec). 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.cL	F.rec	Apical F
1974	0.042	0.000	0.021	0.063
1975	0.050	0.000	0.012	0.062
1976	0.063	0.000	0.028	0.091
1977	0.056	0.000	0.011	0.067
1978	0.089	0.012	0.006	0.106
1979	0.083	0.011	0.010	0.103
1980	0.071	0.011	0.022	0.104
1981	0.147	0.013	0.037	0.196
1982	0.127	0.033	0.027	0.186
1983	0.188	0.131	0.057	0.371
1984	0.166	0.121	0.015	0.297
1985	0.165	0.099	0.015	0.275
1986	0.192	0.136	0.033	0.356
1987	0.152	0.172	0.020	0.338
1988	0.111	0.148	0.012	0.266
1989	0.203	0.186	0.011	0.393
1990	0.248	0.239	0.007	0.490
1991	0.243	0.176	0.003	0.419
1992	0.304	0.300	0.022	0.626
1993	0.263	0.341	0.077	0.680
1994	0.195	0.214	0.008	0.417
1995	0.260	0.190	0.078	0.527
1996	0.195	0.114	0.012	0.322
1997	0.263	0.273	0.114	0.649
1998	0.177	0.119	0.003	0.300
1999	0.274	0.119	0.052	0.444
2000	0.234	0.138	0.023	0.395
2001	0.223	0.064	0.115	0.402
2002	0.189	0.040	0.037	0.266
2003	0.136	0.029	0.033	0.198
2004	0.116	0.058	0.069	0.244
2005	0.122	0.036	0.114	0.271
2006	0.132	0.041	0.107	0.280
2007	0.086	0.004	0.038	0.127
2008	0.053	0.010	0.023	0.086
2009	0.056	0.007	0.054	0.118
2010	0.067	0.003	0.045	0.115
2011	0.027	0.001	0.002	0.030
2012	0.060	0.002	0.118	0.180

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1974	0.003	0.015	0.041	0.057	0.062	0.063	0.063	0.063	0.063	0.063	0.063	0.058	0.049	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044
1975	0.003	0.017	0.044	0.057	0.061	0.062	0.062	0.062	0.062	0.062	0.062	0.059	0.054	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051
1976	0.004	0.023	0.061	0.082	0.089	0.090	0.091	0.091	0.091	0.091	0.091	0.084	0.073	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066
1977	0.003	0.019	0.048	0.062	0.066	0.066	0.067	0.067	0.067	0.067	0.067	0.064	0.059	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
1978	0.007	0.031	0.075	0.096	0.103	0.106	0.104	0.102	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101
1979	0.008	0.031	0.072	0.092	0.098	0.103	0.099	0.095	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094
1980	0.011	0.032	0.070	0.088	0.095	0.104	0.095	0.085	0.083	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082
1981	0.021	0.062	0.138	0.172	0.183	0.196	0.181	0.164	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160
1982	0.016	0.052	0.120	0.156	0.173	0.186	0.175	0.163	0.161	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160
1983	0.031	0.088	0.199	0.281	0.336	0.371	0.351	0.325	0.320	0.319	0.319	0.319	0.319	0.319	0.319	0.319	0.319	0.319	0.319	0.319	0.319	0.319	0.319	0.319	0.319
1984	0.014	0.062	0.157	0.228	0.276	0.297	0.294	0.288	0.287	0.287	0.287	0.287	0.287	0.287	0.287	0.287	0.287	0.287	0.287	0.287	0.287	0.287	0.287	0.287	0.287
1985	0.015	0.062	0.154	0.217	0.257	0.275	0.272	0.265	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264
1986	0.022	0.079	0.190	0.272	0.327	0.356	0.346	0.331	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328
1987	0.016	0.062	0.157	0.243	0.308	0.338	0.334	0.326	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324
1988	0.011	0.045	0.117	0.187	0.242	0.266	0.265	0.261	0.260	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259
1989	0.016	0.074	0.195	0.293	0.364	0.392	0.393	0.389	0.388	0.388	0.388	0.388	0.388	0.388	0.388	0.388	0.388	0.388	0.388	0.388	0.388	0.388	0.388	0.388	0.388
1990	0.017	0.088	0.237	0.360	0.451	0.485	0.490	0.488	0.487	0.487	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488
1991	0.015	0.083	0.221	0.323	0.390	0.415	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419
1992	0.018	0.108	0.295	0.456	0.573	0.614	0.624	0.626	0.626	0.625	0.623	0.622	0.619	0.617	0.617	0.617	0.617	0.617	0.617	0.617	0.617	0.617	0.617	0.617	0.617
1993	0.018	0.103	0.291	0.478	0.617	0.667	0.678	0.680	0.680	0.677	0.672	0.665	0.658	0.650	0.650	0.650	0.650	0.650	0.650	0.650	0.650	0.650	0.650	0.650	0.650
1994	0.012	0.069	0.190	0.298	0.380	0.409	0.416	0.417	0.417	0.417	0.416	0.416	0.415	0.414	0.414	0.414	0.414	0.414	0.414	0.414	0.414	0.414	0.414	0.414	0.414
1995	0.017	0.097	0.266	0.403	0.490	0.519	0.526	0.527	0.526	0.523	0.518	0.512	0.505	0.497	0.497	0.497	0.497	0.497	0.497	0.497	0.497	0.497	0.497	0.497	0.497
1996	0.011	0.066	0.177	0.254	0.301	0.317	0.321	0.322	0.322	0.321	0.320	0.319	0.318	0.317	0.317	0.317	0.317	0.317	0.317	0.317	0.317	0.317	0.317	0.317	0.317
1997	0.018	0.105	0.295	0.473	0.595	0.638	0.647	0.649	0.648	0.644	0.636	0.627	0.616	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605
1998	0.010	0.060	0.160	0.232	0.279	0.295	0.299	0.300	0.300	0.300	0.300	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299
1999	0.016	0.096	0.256	0.363	0.420	0.439	0.443	0.444	0.444	0.442	0.438	0.434	0.429	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424
2000	0.014	0.081	0.216	0.311	0.370	0.390	0.394	0.395	0.395	0.394	0.393	0.391	0.389	0.386	0.386	0.386	0.386	0.386	0.386	0.386	0.386	0.386	0.386	0.386	0.386
2001	0.015	0.086	0.233	0.335	0.383	0.398	0.401	0.402	0.400	0.395	0.388	0.379	0.368	0.357	0.357	0.357	0.357	0.357	0.357	0.357	0.357	0.357	0.357	0.357	0.357
2002	0.011	0.065	0.171	0.231	0.256	0.264	0.266	0.266	0.265	0.264	0.262	0.259	0.255	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251
2003	0.008	0.048	0.125	0.171	0.190	0.196	0.197	0.198	0.197	0.196	0.194	0.191	0.188	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185
2004	0.008	0.047	0.129	0.194	0.230	0.241	0.244	0.244	0.243	0.240	0.236	0.230	0.224	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217
2005	0.010	0.053	0.148	0.222	0.258	0.268	0.270	0.271	0.269	0.265	0.258	0.248	0.238	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226
2006	0.010	0.056	0.154	0.230	0.266	0.277	0.280	0.280	0.279	0.275	0.268	0.259	0.249	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.238
2007	0.006	0.032	0.084	0.114	0.124	0.127	0.127	0.127	0.127	0.125	0.123	0.120	0.116	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113
2008	0.003	0.020	0.052	0.073	0.082	0.085	0.085	0.086	0.085	0.084	0.083	0.081	0.079	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077
2009	0.004	0.025	0.068	0.100	0.113	0.117	0.118	0.118	0.117	0.115	0.112	0.107	0.102	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097
2010	0.005	0.027	0.072	0.101	0.111	0.114	0.115	0.115	0.114	0.112	0.109	0.106	0.102	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097
2011	0.001	0.009	0.022	0.028	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
2012	0.006	0.033	0.095	0.149	0.172	0.178	0.179	0.180	0.178	0.173	0.166	0.156	0.145	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133

Table 14. Estimated total removals (landings and dead discards) at age in numbers (1000 fish)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1974	0.54	1.55	2.42	2.23	1.81	1.56	1.45	1.39	1.38	1.39	1.17	0.78	0.52	0.40	0.36	0.32	0.28	0.26	0.23	0.21	0.19	0.17	0.15	0.14	0.62
1975	1.35	2.25	3.11	2.46	1.80	1.39	1.20	1.13	1.09	1.09	1.11	0.90	0.60	0.45	0.39	0.35	0.31	0.28	0.25	0.23	0.21	0.19	0.17	0.15	0.76
1976	1.50	7.19	5.67	4.18	2.82	2.02	1.57	1.38	1.31	1.29	1.29	1.23	0.91	0.61	0.49	0.43	0.38	0.35	0.31	0.28	0.25	0.23	0.21	0.19	1.01
1977	0.68	4.72	10.68	4.20	2.47	1.59	1.14	0.90	0.80	0.77	0.76	0.74	0.71	0.59	0.44	0.35	0.31	0.28	0.25	0.23	0.20	0.19	0.17	0.15	0.88
1978	1.28	4.41	13.31	15.14	5.09	3.00	1.91	1.36	1.07	0.96	0.93	0.93	0.95	0.99	0.86	0.65	0.52	0.46	0.41	0.37	0.34	0.31	0.28	0.25	1.55
1979	0.66	3.86	7.21	11.44	11.25	3.76	2.10	1.33	0.97	0.78	0.70	0.69	0.69	0.71	0.74	0.65	0.49	0.40	0.35	0.31	0.28	0.26	0.23	0.21	1.38
1980	0.93	1.80	6.12	6.19	8.62	8.74	2.60	1.38	0.90	0.68	0.55	0.50	0.49	0.49	0.51	0.53	0.47	0.35	0.29	0.25	0.23	0.21	0.19	0.17	1.16
1981	1.68	3.33	5.20	10.29	8.99	12.56	11.05	3.35	1.99	1.35	1.01	0.83	0.75	0.74	0.75	0.78	0.82	0.73	0.55	0.45	0.40	0.36	0.32	0.29	2.09
1982	2.77	2.78	4.25	3.89	6.93	6.18	7.74	7.08	2.39	1.46	1.00	0.76	0.62	0.57	0.56	0.57	0.59	0.63	0.56	0.42	0.34	0.31	0.28	0.25	1.84
1983	3.80	9.77	6.84	6.30	5.26	9.33	7.48	9.49	9.36	3.24	2.00	1.38	1.05	0.87	0.80	0.79	0.81	0.84	0.89	0.79	0.60	0.49	0.43	0.39	2.99
1984	1.96	4.98	11.28	4.86	3.72	2.75	4.39	3.76	5.26	5.34	1.87	1.16	0.80	0.62	0.51	0.47	0.47	0.48	0.50	0.53	0.47	0.36	0.29	0.26	2.04
1985	3.94	5.44	8.10	9.92	3.42	2.30	1.58	2.53	2.23	3.17	3.25	1.14	0.71	0.50	0.38	0.32	0.29	0.29	0.30	0.32	0.34	0.30	0.23	0.19	1.46
1986	5.08	13.80	10.84	8.92	9.09	2.85	1.77	1.20	1.99	1.79	2.56	2.64	0.93	0.59	0.41	0.32	0.26	0.25	0.25	0.25	0.26	0.28	0.25	0.19	1.38
1987	3.88	9.08	17.83	8.57	6.01	5.49	1.58	1.00	0.73	1.23	1.11	1.60	1.66	0.59	0.37	0.26	0.20	0.17	0.16	0.16	0.16	0.17	0.18	0.16	1.02
1988	3.25	7.16	11.45	13.72	5.34	3.17	2.65	0.77	0.51	0.37	0.64	0.58	0.84	0.88	0.31	0.20	0.14	0.11	0.09	0.08	0.09	0.09	0.09	0.10	0.64
1989	3.02	14.29	20.14	18.05	16.24	5.16	2.82	2.38	0.71	0.48	0.35	0.61	0.56	0.81	0.85	0.30	0.19	0.14	0.11	0.09	0.08	0.08	0.09	0.09	0.73
1990	2.71	11.05	28.55	21.84	15.33	11.63	3.46	1.91	1.65	0.50	0.34	0.25	0.44	0.40	0.59	0.62	0.22	0.14	0.10	0.08	0.07	0.06	0.06	0.06	0.61
1991	2.79	8.73	17.35	22.67	12.94	7.46	5.30	1.58	0.89	0.78	0.24	0.16	0.12	0.21	0.19	0.29	0.30	0.11	0.07	0.05	0.04	0.03	0.03	0.03	0.33
1992	3.12	12.97	18.84	19.80	20.72	10.17	5.61	4.01	1.21	0.69	0.60	0.19	0.13	0.10	0.17	0.15	0.23	0.24	0.09	0.06	0.04	0.03	0.03	0.02	0.29
1993	3.22	11.24	21.11	16.05	12.56	10.65	4.91	2.70	1.95	0.59	0.34	0.30	0.09	0.06	0.05	0.08	0.08	0.11	0.12	0.04	0.03	0.02	0.02	0.01	0.16
1994	3.83	8.03	13.12	12.37	6.55	4.01	3.16	1.45	0.81	0.59	0.18	0.10	0.09	0.03	0.02	0.02	0.03	0.03	0.04	0.04	0.01	0.01	0.01	0.01	0.06
1995	5.46	20.53	19.26	16.02	10.98	4.70	2.70	2.13	0.98	0.55	0.40	0.12	0.07	0.06	0.02	0.01	0.01	0.02	0.02	0.03	0.03	0.01	0.01	0.00	0.04
1996	2.55	14.00	23.86	10.86	6.65	3.84	1.57	0.91	0.72	0.34	0.19	0.14	0.04	0.03	0.02	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.02
1997	3.24	15.42	38.25	35.83	13.47	7.32	4.10	1.68	0.98	0.78	0.37	0.21	0.15	0.05	0.03	0.03	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.02
1998	1.44	6.82	15.02	17.66	11.40	3.43	1.75	0.98	0.41	0.24	0.19	0.09	0.05	0.04	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
1999	3.11	8.88	18.31	20.28	18.49	10.30	2.98	1.53	0.86	0.36	0.21	0.17	0.08	0.05	0.04	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2000	3.12	9.90	12.53	12.89	11.40	9.32	5.06	1.47	0.76	0.43	0.18	0.11	0.09	0.04	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2001	3.22	12.73	17.93	11.38	8.94	6.82	5.37	2.92	0.86	0.44	0.25	0.10	0.06	0.05	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	3.07	8.99	16.27	10.82	5.13	3.61	2.70	2.14	1.18	0.35	0.18	0.11	0.05	0.03	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	1.64	8.68	11.52	10.52	5.73	2.55	1.78	1.35	1.08	0.59	0.18	0.09	0.05	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	0.90	6.22	15.77	11.68	9.21	4.78	2.12	1.50	1.14	0.91	0.50	0.15	0.08	0.05	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.83	3.77	13.02	17.53	9.86	6.85	3.46	1.54	1.09	0.83	0.66	0.36	0.11	0.06	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2006	0.53	3.12	7.20	12.92	13.12	6.63	4.52	2.30	1.03	0.73	0.56	0.45	0.25	0.08	0.04	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
2007	0.35	1.10	3.20	3.57	4.63	4.16	2.06	1.41	0.72	0.33	0.23	0.18	0.15	0.08	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2008	0.33	0.82	1.27	1.98	1.85	2.32	2.10	1.05	0.73	0.37	0.17	0.12	0.09	0.08	0.05	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2009	0.72	1.58	1.99	1.72	2.21	1.95	2.42	2.21	1.11	0.77	0.39	0.17	0.12	0.09	0.08	0.05	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.65	2.83	3.21	2.09	1.38	1.62	1.41	1.78	1.63	0.82	0.57	0.29	0.13	0.09	0.08	0.07	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
2011	0.17	0.81	1.70	0.92	0.46	0.28	0.33	0.29	0.37	0.34	0.18	0.13	0.07	0.03	0.02	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2012	1.33	2.60	6.11	7.97	4.06	2.03	1.26	1.51	1.33	1.67	1.50	0.74	0.50	0.25	0.12	0.09	0.07	0.06	0.04	0.01	0.01	0.00	0.00	0.00	0.00

Table 15. Estimated total removals (landings and dead discards) at age in whole weight (1000 lb)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1974	1.62	7.58	16.68	19.58	19.70	20.70	22.88	25.50	28.73	32.39	30.08	22.66	17.53	15.31	14.45	13.64	12.82	12.02	11.23	10.47	9.73	9.02	8.34	7.70	35.80
1975	4.28	11.47	22.47	23.11	21.24	19.92	20.46	22.36	24.72	27.65	30.99	27.92	21.05	17.41	16.16	15.21	14.31	13.42	12.55	11.71	10.90	10.11	9.36	8.64	44.27
1976	4.60	35.66	39.56	37.40	31.41	27.46	25.32	25.74	27.90	30.63	34.06	36.48	31.19	23.50	20.01	18.51	17.37	16.30	15.26	14.25	13.28	12.33	11.43	10.56	58.63
1977	2.17	24.24	77.92	40.05	29.69	23.31	19.94	18.18	18.33	19.73	21.53	23.34	25.13	22.84	18.14	15.39	14.20	13.30	12.45	11.64	10.85	10.09	9.36	8.66	51.49
1978	3.59	22.14	96.89	142.20	58.33	41.30	31.44	26.24	23.66	23.68	25.34	27.51	30.38	33.98	31.59	25.01	21.17	19.48	18.20	17.02	15.88	14.78	13.72	12.71	80.18
1979	1.70	18.85	51.79	106.32	127.92	51.05	34.47	25.74	21.56	19.37	19.28	20.52	22.19	24.42	27.22	25.22	19.91	16.81	15.44	14.40	13.44	12.52	11.64	10.79	71.70
1980	2.05	8.05	41.67	54.60	92.46	110.46	40.42	26.07	19.61	16.41	14.66	14.51	15.39	16.57	18.17	20.19	18.66	14.70	12.38	11.36	10.57	9.85	9.17	8.51	59.16
1981	3.84	15.27	36.28	94.27	101.82	168.73	182.38	67.11	45.69	34.67	28.86	25.65	25.29	26.71	28.67	31.34	34.73	32.02	25.17	21.17	19.38	18.01	16.76	15.57	112.79
1982	6.49	12.86	29.16	33.55	70.96	74.59	112.86	122.80	47.41	32.50	24.54	20.32	17.99	17.67	18.60	19.90	21.70	23.98	22.07	17.32	14.54	13.29	12.33	11.46	86.11
1983	8.23	42.06	43.04	45.88	42.27	86.97	82.88	123.16	138.45	53.66	36.60	27.49	22.67	19.99	19.57	20.53	21.91	23.83	26.28	24.15	18.91	15.85	14.47	13.41	104.07
1984	5.05	23.42	73.89	35.95	29.88	25.62	48.17	47.90	76.32	86.75	33.47	22.71	16.99	13.96	12.26	11.97	12.53	13.33	14.47	15.94	14.61	11.43	9.57	8.72	69.44
1985	10.18	25.80	54.12	76.97	29.41	23.03	18.68	34.85	35.07	55.75	63.02	24.19	16.34	12.18	9.97	8.74	8.50	8.88	9.43	10.22	11.23	10.28	8.03	6.71	53.81
1986	11.94	62.43	69.89	65.65	73.28	26.64	19.51	15.50	29.21	29.33	46.37	52.15	19.93	13.42	9.97	8.14	7.11	6.90	7.19	7.62	8.25	9.05	8.27	6.45	47.69
1987	9.25	40.41	108.82	55.35	40.20	42.00	14.11	10.38	8.53	16.13	16.11	25.34	28.38	10.81	7.25	5.37	4.37	3.81	3.69	3.84	4.06	4.39	4.81	4.39	28.19
1988	7.83	31.64	68.16	83.65	32.94	22.28	21.70	7.27	5.47	4.49	8.45	8.40	13.15	14.68	5.57	3.73	2.75	2.23	1.94	1.88	1.95	2.06	2.22	2.43	16.18
1989	8.09	67.19	129.07	125.85	119.57	43.70	28.00	27.34	9.32	7.00	5.73	10.71	10.60	16.54	18.39	6.96	4.64	3.42	2.77	2.41	2.32	2.41	2.54	2.74	22.47
1990	7.62	52.55	182.83	150.41	110.65	96.24	33.62	21.47	21.09	7.16	5.35	4.35	8.10	7.99	12.43	13.78	5.20	3.46	2.54	2.06	1.78	1.72	1.78	1.87	18.25
1991	8.30	42.78	115.95	170.18	105.09	70.22	58.62	20.30	12.95	12.65	4.27	3.17	2.57	4.77	4.69	7.27	8.04	3.03	2.01	1.47	1.19	1.03	0.99	1.03	11.37
1992	9.18	61.76	119.41	134.45	147.60	83.24	53.81	44.50	15.33	9.71	9.41	3.15	2.33	1.87	3.47	3.40	5.25	5.79	2.17	1.44	1.06	0.85	0.74	0.71	8.67
1993	8.83	50.49	123.91	97.53	79.02	76.72	41.48	26.41	21.61	7.37	4.62	4.43	1.47	1.08	0.87	1.60	1.56	2.41	2.65	1.00	0.66	0.48	0.39	0.33	4.18
1994	11.22	38.04	82.20	81.37	44.50	31.13	28.76	15.29	9.64	7.85	2.68	1.69	1.63	0.55	0.41	0.33	0.60	0.59	0.90	0.99	0.37	0.25	0.18	0.14	1.64
1995	15.81	96.73	122.44	114.49	86.34	43.11	29.20	26.63	14.01	8.74	7.04	2.37	1.48	1.41	0.47	0.35	0.28	0.52	0.50	0.77	0.85	0.32	0.21	0.15	1.49
1996	7.88	69.34	161.67	84.85	57.66	38.93	18.74	12.52	11.31	5.92	3.69	2.98	1.01	0.64	0.62	0.21	0.15	0.12	0.22	0.22	0.33	0.36	0.14	0.09	0.69
1997	8.91	69.48	228.20	230.54	92.81	58.36	38.38	18.25	12.06	10.77	5.57	3.42	2.73	0.91	0.58	0.56	0.19	0.14	0.11	0.20	0.19	0.30	0.32	0.12	0.68
1998	4.44	33.74	101.15	134.70	94.86	33.21	19.94	12.90	6.08	4.00	3.59	1.87	1.17	0.95	0.33	0.20	0.20	0.07	0.05	0.04	0.07	0.07	0.10	0.11	0.27
1999	9.48	43.70	124.07	163.07	170.27	112.05	38.29	22.73	14.57	6.80	4.44	3.93	2.03	1.26	1.02	0.35	0.22	0.21	0.07	0.05	0.04	0.07	0.07	0.11	0.40
2000	9.54	48.73	84.23	99.83	97.99	93.64	59.84	20.20	11.88	7.56	3.52	2.29	2.04	1.06	0.66	0.53	0.18	0.11	0.11	0.04	0.03	0.02	0.04	0.04	0.26
2001	9.37	60.44	117.50	90.39	83.94	76.59	71.32	45.04	15.04	8.74	5.49	2.52	1.62	1.42	0.74	0.46	0.37	0.13	0.08	0.07	0.02	0.02	0.01	0.03	0.20
2002	9.58	45.15	114.30	94.63	53.70	45.37	40.17	36.94	23.11	7.67	4.46	2.82	1.31	0.85	0.76	0.40	0.25	0.20	0.07	0.04	0.04	0.01	0.01	0.01	0.12
2003	5.06	43.27	80.20	90.89	59.21	31.59	26.14	22.90	20.86	12.93	4.26	2.46	1.55	0.72	0.47	0.42	0.22	0.13	0.11	0.04	0.02	0.02	0.01	0.01	0.07
2004	2.53	28.69	98.99	85.69	77.56	47.65	24.91	20.40	17.67	15.89	9.71	3.16	1.80	1.12	0.52	0.34	0.30	0.16	0.10	0.08	0.03	0.02	0.02	0.01	0.05
2005	2.26	16.95	80.22	130.16	86.96	72.46	43.30	22.37	18.09	15.45	13.71	8.29	2.67	1.51	0.96	0.45	0.29	0.26	0.13	0.08	0.07	0.02	0.01	0.01	0.05
2006	1.46	14.23	45.01	97.08	116.68	70.59	57.00	33.62	17.16	13.71	11.64	10.32	6.26	2.03	1.19	0.76	0.35	0.23	0.20	0.10	0.06	0.05	0.02	0.01	0.04
2007	1.05	5.38	21.99	31.30	50.21	54.85	32.19	25.66	14.97	7.57	6.04	5.15	4.61	2.83	0.95	0.56	0.35	0.16	0.11	0.09	0.05	0.03	0.02	0.01	0.03
2008	0.98	3.99	8.55	16.46	18.52	27.87	29.81	17.31	13.65	7.88	3.95	3.13	2.66	2.37	1.49	0.50	0.29	0.18	0.08	0.06	0.05	0.02	0.02	0.01	0.02
2009	1.97	7.17	12.47	13.30	20.78	22.09	32.59	34.49	19.78	15.34	8.70	4.28	3.33	2.77	2.52	1.57	0.52	0.31	0.19	0.09	0.06	0.05	0.03	0.02	0.03
2010	1.89	13.40	21.21	17.41	14.12	20.24	20.93	30.51	31.90	18.08	13.94	7.89	3.89	3.05	2.63	2.38	1.48	0.49	0.29	0.18	0.08	0.05	0.05	0.02	0.04
2011	0.56	4.24	12.65	9.03	5.61	4.19	5.86	5.99	8.66	9.01	5.13	3.99	2.30	1.16	0.93	0.80	0.72	0.45	0.15	0.09	0.05	0.03	0.02	0.01	0.02
2012	3.29	10.76	34.83	56.26	35.24	21.41	15.84	21.96	22.12	31.17	31.37	17.10	12.67	6.90	3.48	2.79	2.39	2.15	1.33	0.44	0.26	0.16	0.07	0.05	0.10

Table 16. Estimated time series of removals (landings and dead discards) in numbers (1000 fish) for commercial handlines (L.cH), commercial longlines (L.cL), and recreational (L.rec).

Year	L.cH	L.cL	L.rec	Total
1974	16.19	0.00	5.30	21.49
1975	20.15	0.00	3.07	23.22
1976	29.78	0.00	7.34	37.12
1977	30.76	0.00	3.42	34.18
1978	50.99	3.98	2.35	57.32
1979	44.27	3.82	3.37	51.46
1980	33.80	3.85	6.69	44.34
1981	57.57	4.07	9.00	70.64
1982	40.74	8.49	5.55	54.78
1983	50.47	25.49	10.04	86.00
1984	38.94	17.82	2.37	59.13
1985	36.80	12.57	3.27	52.64
1986	44.50	15.76	7.91	68.16
1987	38.97	19.08	5.31	63.37
1988	31.41	18.13	3.73	53.27
1989	60.55	24.50	3.30	88.35
1990	70.39	30.51	1.77	102.67
1991	60.72	21.19	0.78	82.69
1992	65.04	31.09	3.36	99.48
1993	49.14	27.70	9.65	86.50
1994	37.32	16.32	0.96	54.60
1995	58.24	15.20	10.73	84.17
1996	53.29	10.48	2.01	65.79
1997	73.01	28.67	20.30	121.98
1998	45.49	13.54	0.54	59.57
1999	63.29	13.69	8.71	85.69
2000	49.62	14.32	3.44	67.37
2001	48.43	6.08	16.64	71.15
2002	44.97	3.90	5.81	54.69
2003	36.67	3.29	5.85	45.82
2004	33.63	7.70	13.72	55.05
2005	32.52	5.04	22.48	60.03
2006	29.17	5.56	18.80	53.54
2007	15.99	0.45	5.79	22.23
2008	8.92	1.21	3.23	13.37
2009	9.53	0.83	7.26	17.62
2010	12.33	0.31	6.06	18.71
2011	5.77	0.13	0.25	6.15
2012	13.59	0.29	19.39	33.26

Table 17. Estimated time series of removals (landings and dead discards) in whole weight (1000 lb) for commercial handlines (L.cH), commercial longlines (L.cL), and recreational (L.rec).

Year	L.cH	L.cL	L.rec	Total
1974	187.58	0.00	51.04	238.61
1975	216.96	0.00	27.77	244.73
1976	279.61	0.00	59.61	339.23
1977	258.58	0.00	24.84	283.42
1978	423.17	45.89	10.11	479.16
1979	383.66	41.97	16.96	442.59
1980	313.66	42.75	38.35	394.76
1981	579.10	47.18	54.02	680.30
1982	428.51	103.84	27.98	560.32
1983	516.25	325.06	43.84	885.15
1984	362.65	226.29	9.03	597.96
1985	307.44	149.54	10.55	467.53
1986	317.98	171.47	25.94	515.39
1987	240.95	183.87	18.13	442.94
1988	180.15	152.99	12.78	345.92
1989	333.74	191.27	12.28	537.30
1990	383.59	226.90	7.11	617.60
1991	335.42	153.90	3.11	492.43
1992	354.39	226.09	20.52	600.99
1993	252.34	196.41	56.41	505.17
1994	178.85	109.53	5.24	293.63
1995	260.17	97.57	55.38	413.12
1996	235.11	64.43	10.09	309.63
1997	339.39	173.95	105.01	618.34
1998	225.57	84.58	2.96	313.10
1999	334.15	91.16	51.00	476.32
2000	261.88	99.91	20.60	382.39
2001	246.74	43.00	98.06	387.80
2002	224.32	27.11	33.32	284.75
2003	184.89	22.71	33.77	241.37
2004	177.82	53.91	81.76	313.48
2005	187.31	36.32	142.12	365.75
2006	185.38	42.55	129.07	357.00
2007	111.43	3.70	43.31	158.44
2008	66.91	10.85	26.02	103.78
2009	71.95	7.93	60.56	140.44
2010	88.26	3.08	49.65	140.99
2011	39.84	1.26	1.96	43.07
2012	93.38	2.70	147.40	243.48

Table 18. Estimated status indicators, benchmarks, and related quantities from the base run of the Beaufort catch-age model, conditional on estimated current selectivities averaged across fleets. Also presented are median values and measures of precision (standard errors, SE) from the Monte Carlo/Bootstrap analysis. Measures of yield describe total removals, of which $\sim 97.3\%$ *were estimated to be landings, and the remainder, dead discards. Rate estimates (F) are in units of* y^{-1}*; status indicators are dimensionless; and biomass estimates are in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) is measured as total (males and females) mature biomass.*

Quantity	Units	Estimate	Median	SE
F_{MSY}	y^{-1}	0.14	0.12	0.07
$85\%F_{\mathrm{MSY}}$	y^{-1}	0.12	0.10	0.06
$75\%F_{\mathrm{MSY}}$	y^{-1}	0.11	0.09	0.05
$65\%F_{\mathrm{MSY}}$	y^{-1}	0.09	0.08	0.04
$F_{30\%}$	y^{-1}	0.11	0.11	0.02
$F_{40\%}$	y^{-1}	0.08	0.08	0.01
$F_{50\%}$	y^{-1}	0.06	0.05	0.01
B_{MSY}	mt	2091.7	2590.2	1937
$\mathrm{SSB}_{\mathrm{MSY}}$	mt	872.3	1177.0	1384
MSST	mt	654.2	882.7	1038
MSY	1000 lb	418.6	441.4	134
R_{MSY}	1000 age-1 fish	308	361	149
Y at $85\%F_{\mathrm{MSY}}$	1000 lb	414.8	436.6	131
Y at $75\%F_{\mathrm{MSY}}$	1000 lb	407.3	427.6	127
Y at $65\%F_{\mathrm{MSY}}$	1000 lb	394.8	412.5	120
$F_{2010-2012}/F_{\mathrm{MSY}}$	—	0.59	0.70	0.35
$\mathrm{SSB}_{2012}/\mathrm{MSST}$	—	0.65	0.50	0.60
$\mathrm{SSB}_{2012}/\mathrm{SSB}_{\mathrm{MSY}}$	—	0.49	0.38	0.45

Table 19. Results from sensitivity runs of the Beaufort catch-age 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)
Base	—	0.144	872	419	0.59	0.49	0.84	306
S1	M=0.08	0.093	2298	564	1.24	0.15	0.84	204
S2	M=0.16	0.22	423	387	0.35	1.05	0.84	468
S3	h=0.74	0.11	1329	461	0.79	0.32	0.74	369
S4	h=0.94	0.216	473	383	0.4	0.88	0.94	249
S5	Finit=0.015	0.144	849	408	0.61	0.49	0.84	298
S6	Finit=0.045	0.144	896	430	0.58	0.48	0.84	315
S7	Ninit	0.144	730	354	0.69	0.51	0.84	252
S8	comm index	0.147	875	425	0.61	0.47	0.84	302
S9	Indices 2X	0.147	871	422	0.6	0.48	0.84	302
S10	Indices 4X	0.146	843	420	0.6	0.48	0.84	282
S11	Indices 8X	0.139	826	428	0.35	0.83	0.84	256
S12	Rec selex const	0.142	881	421	0.55	0.46	0.84	311
S13	Comm selex blocks	0.149	867	412	0.57	0.48	0.84	311
S14	Drop pre-2007 comm agec	0.139	854	407	0.58	0.52	0.84	302
S15	continuity	0.104	3434	597	1.03	0.15	0.7	303
S16	Female SSB	0.183	511	397	0.48	0.7	0.84	267
S17	Male SSB	0.091	451	473	0.71	0.26	0.84	397

Table 20. Projection results with fishing mortality rate fixed at $F = F_{\text{current}}$ starting in 2015. F = fishing mortality rate (per year), pr.rebuild = proportion of stochastic projection replicates with SSB $\geq$ SSB$_{\text{MSY}}$*, S = spawning stock (mt) at peak spawning time, Rm = total removals (landings and dead discards) expressed in numbers (1000s) or whole weight (*lb*). Total removals presented here would need reduction if values are used to develop quotas based only on landings; recent data suggest that $\sim$ 97.7% of total removals are landings (the remainder being dead discards). The extension* base *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	pr.rebuild	F.base	F.med	S.base(mt)	S.med(mt)	Rm.base(1000)	Rm.med(1000)	Rm.base(1000 lb)	Rm.med(1000 lb)
2013	0.120	0.07	0.07	437	450	15	15	105	105
2014	0.148	0.06	0.06	483	487	16	15	105	105
2015	0.182	0.09	0.08	534	527	25	22	167	151
2016	0.208	0.09	0.08	587	568	27	24	184	164
2017	0.244	0.09	0.08	646	614	29	25	200	176
2018	0.280	0.09	0.08	707	664	31	27	215	188
2019	0.313	0.09	0.08	770	716	32	28	230	200
2020	0.342	0.09	0.08	830	768	33	29	243	212
2021	0.369	0.09	0.08	889	816	35	30	256	222
2022	0.394	0.09	0.08	944	864	36	31	268	233
2023	0.418	0.09	0.08	996	910	37	32	279	243
2024	0.439	0.09	0.08	1045	954	38	33	289	252
2025	0.460	0.09	0.08	1091	996	38	34	298	262
2026	0.479	0.09	0.08	1133	1038	39	35	307	270
2027	0.496	0.09	0.08	1173	1076	40	35	315	278
2028	0.512	0.09	0.08	1209	1112	40	36	322	285
2029	0.527	0.09	0.08	1242	1144	41	37	328	292
2030	0.540	0.09	0.08	1273	1173	41	37	334	298
2031	0.553	0.09	0.08	1300	1202	42	38	340	304
2032	0.565	0.09	0.08	1326	1230	42	38	345	309
2033	0.576	0.09	0.08	1349	1257	42	39	349	315
2034	0.586	0.09	0.08	1369	1281	42	39	353	320
2035	0.595	0.09	0.08	1388	1304	43	40	356	326
2036	0.604	0.09	0.08	1405	1326	43	40	360	331
2037	0.614	0.09	0.08	1420	1347	43	40	362	334
2038	0.623	0.09	0.08	1433	1368	43	41	365	338
2039	0.631	0.09	0.08	1445	1386	43	41	367	342

Table 21. Projection results with fishing mortality rate fixed at $F = F_{\mathrm{MSY}}$ starting in 2015. F = fishing mortality rate (per year), pr.rebuild = proportion of stochastic projection replicates with $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$, *S = spawning stock (mt) at peak spawning time, Rm = total removals (landings and dead discards) expressed in numbers (1000s) or whole weight (*lb*). Total removals presented here would need reduction if values are used to develop quotas based only on landings; recent data suggest that* $\sim 97.7\%$ *of total removals are landings (the remainder being dead discards). The extension* base *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	pr.rebuild	F.base	F.med	S.base(mt)	S.med(mt)	Rm.base(1000)	Rm.med(1000)	Rm.base(1000 lb)	Rm.med(1000 lb)
2013	0.120	0.07	0.07	437	450	15	15	105	105
2014	0.148	0.06	0.06	483	487	16	15	105	105
2015	0.167	0.14	0.12	520	514	41	33	274	222
2016	0.163	0.14	0.12	542	529	43	35	288	235
2017	0.162	0.14	0.12	567	550	45	36	302	248
2018	0.161	0.14	0.12	594	573	46	38	314	259
2019	0.161	0.14	0.12	620	598	47	39	325	272
2020	0.160	0.14	0.12	644	623	49	41	335	282
2021	0.159	0.14	0.12	667	649	49	42	343	292
2022	0.159	0.14	0.12	688	676	50	43	351	301
2023	0.159	0.14	0.12	707	700	51	44	359	308
2024	0.164	0.14	0.12	724	726	52	45	365	316
2025	0.170	0.14	0.12	740	751	52	45	371	322
2026	0.176	0.14	0.12	754	774	53	46	376	329
2027	0.182	0.14	0.12	767	798	53	47	381	335
2028	0.186	0.14	0.12	779	819	54	47	385	341
2029	0.192	0.14	0.12	789	840	54	48	389	346
2030	0.199	0.14	0.12	798	861	54	48	392	350
2031	0.207	0.14	0.12	807	879	54	49	395	354
2032	0.214	0.14	0.12	814	897	55	49	398	359
2033	0.221	0.14	0.12	821	916	55	50	400	364
2034	0.228	0.14	0.12	827	933	55	50	403	368
2035	0.234	0.14	0.12	832	947	55	51	404	372
2036	0.244	0.14	0.12	837	963	55	51	406	376
2037	0.252	0.14	0.12	841	978	56	52	408	380
2038	0.258	0.14	0.12	845	992	56	52	409	384
2039	0.264	0.14	0.12	848	1005	56	52	410	387

Table 22. Projection results with fishing mortality rate fixed at $F = 75\% F_{\mathrm{MSY}}$ starting in 2015. F = fishing mortality rate (per year), pr.rebuild = proportion of stochastic projection replicates with $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$, S = spawning stock (mt) at peak spawning time, Rm = total removals (landings and dead discards) expressed in numbers (1000s) or whole weight (lb). Total removals presented here would need reduction if values are used to develop quotas based only on landings; recent data suggest that ∼ 97.7% of total removals are landings (the remainder being dead discards). The extension base *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	pr.rebuild	F.base	F.med	S.base(mt)	S.med(mt)	Rm.base(1000)	Rm.med(1000)	Rm.base(1000 lb)	Rm.med(1000 lb)
2013	0.120	0.07	0.07	437	450	15	15	105	105
2014	0.148	0.06	0.06	483	487	16	15	105	105
2015	0.173	0.11	0.09	528	522	31	25	209	168
2016	0.185	0.11	0.09	569	553	34	27	226	183
2017	0.203	0.11	0.09	614	590	35	29	242	197
2018	0.224	0.11	0.09	661	629	37	30	257	210
2019	0.247	0.11	0.09	708	671	39	32	271	224
2020	0.272	0.11	0.09	753	712	40	33	284	237
2021	0.297	0.11	0.09	795	754	41	34	296	249
2022	0.323	0.11	0.09	835	794	42	36	307	261
2023	0.349	0.11	0.09	872	836	43	37	317	271
2024	0.374	0.11	0.09	906	878	44	38	326	281
2025	0.398	0.11	0.09	938	917	45	39	334	290
2026	0.424	0.11	0.09	967	956	45	39	342	298
2027	0.448	0.11	0.09	993	994	46	40	349	307
2028	0.472	0.11	0.09	1017	1032	46	41	355	314
2029	0.495	0.11	0.09	1040	1070	47	42	361	320
2030	0.518	0.11	0.09	1060	1104	47	42	366	326
2031	0.541	0.11	0.09	1078	1137	48	43	371	332
2032	0.563	0.11	0.09	1094	1169	48	43	375	338
2033	0.584	0.11	0.09	1109	1199	48	44	378	344
2034	0.602	0.11	0.09	1122	1229	48	44	382	349
2035	0.620	0.11	0.09	1134	1257	49	45	385	354
2036	0.636	0.11	0.09	1145	1282	49	45	387	359
2037	0.655	0.11	0.09	1154	1308	49	46	390	363
2038	0.672	0.11	0.09	1162	1332	49	46	392	367
2039	0.689	0.11	0.09	1170	1356	49	47	393	371

Table 23. Projection results with fishing mortality rate fixed at $F = F_{\text{rebuild}}$ starting in 2015 and providing a 50% probability of rebuilding. F = fishing mortality rate (per year), pr.rebuild = proportion of stochastic projection replicates with $\text{SSB} \geq \text{SSB}_{\text{MSY}}$, S = spawning stock (mt) at peak spawning time, Rm = total removals (landings and dead discards) expressed in numbers (1000s) or whole weight (lb). Total removals presented here would need reduction if values are used to develop quotas based only on landings; recent data suggest that $\sim$ 97.7% of total removals are landings (the remainder being dead discards). The extension base *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	pr.rebuild	F.base	F.med	S.base(mt)	S.med(mt)	Rm.base(1000)	Rm.med(1000)	Rm.base(1000 lb)	Rm.med(1000 lb)
2013	0.120	0.07	0.07	437	450	15	15	105	105
2014	0.148	0.06	0.06	483	487	16	15	105	105
2015	0.178	0.11	0.11	529	521	31	29	208	199
2016	0.197	0.11	0.11	570	547	33	31	225	213
2017	0.220	0.11	0.11	615	580	35	33	241	225
2018	0.246	0.11	0.11	662	615	37	34	256	237
2019	0.269	0.11	0.11	709	651	38	35	270	248
2020	0.291	0.11	0.11	755	685	40	36	283	259
2021	0.310	0.11	0.11	798	716	41	37	295	269
2022	0.328	0.11	0.11	838	747	42	38	306	278
2023	0.347	0.11	0.11	875	778	43	39	316	287
2024	0.362	0.11	0.11	909	805	44	40	325	295
2025	0.378	0.11	0.11	941	831	44	41	334	302
2026	0.391	0.11	0.11	971	857	45	41	341	309
2027	0.403	0.11	0.11	998	880	46	42	348	316
2028	0.415	0.11	0.11	1022	900	46	42	355	322
2029	0.425	0.11	0.11	1045	921	47	43	360	327
2030	0.437	0.11	0.11	1065	938	47	43	365	331
2031	0.446	0.11	0.11	1083	953	47	44	370	336
2032	0.454	0.11	0.11	1100	969	48	44	374	341
2033	0.462	0.11	0.11	1115	984	48	45	378	345
2034	0.470	0.11	0.11	1128	999	48	45	381	349
2035	0.477	0.11	0.11	1140	1012	48	46	384	353
2036	0.484	0.11	0.11	1151	1023	49	46	387	357
2037	0.491	0.11	0.11	1161	1036	49	46	389	360
2038	0.496	0.11	0.11	1169	1048	49	46	391	362
2039	0.502	0.11	0.11	1177	1057	49	47	393	366

Table 24. Projection results with fishing mortality rate fixed at $F = F_{\text{rebuild}}$ starting in 2015 and providing a 70% probability of rebuilding. F = fishing mortality rate (per year), pr.rebuild = proportion of stochastic projection replicates with $\text{SSB} \geq \text{SSB}_{\text{MSY}}$, S = spawning stock (mt) at peak spawning time, Rm = total removals (landings and dead discards) expressed in numbers (1000s) or whole weight (lb). Total removals presented here would need reduction if values are used to develop quotas based only on landings; recent data suggest that ∼ 97.7% of total removals are landings (the remainder being dead discards). The extension base *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	pr.rebuild	F.base	F.med	S.base(mt)	S.med(mt)	Rm.base(1000)	Rm.med(1000)	Rm.base(1000 lb)	Rm.med(1000 lb)
2013	0.120	0.07	0.07	437	450	15	15	105	105
2014	0.148	0.06	0.06	483	487	16	15	105	105
2015	0.183	0.07	0.07	538	530	21	20	140	134
2016	0.212	0.07	0.07	599	576	23	21	156	147
2017	0.252	0.07	0.07	666	629	25	23	171	160
2018	0.289	0.07	0.07	738	687	26	24	186	172
2019	0.324	0.07	0.07	812	746	28	26	200	184
2020	0.357	0.07	0.07	884	805	29	27	213	196
2021	0.388	0.07	0.07	954	861	30	28	226	207
2022	0.415	0.07	0.07	1021	917	31	29	238	218
2023	0.444	0.07	0.07	1085	971	32	30	249	228
2024	0.470	0.07	0.07	1145	1023	33	31	259	238
2025	0.494	0.07	0.07	1202	1073	34	31	269	247
2026	0.517	0.07	0.07	1256	1121	34	32	277	255
2027	0.539	0.07	0.07	1305	1168	35	33	285	264
2028	0.558	0.07	0.07	1351	1210	36	34	293	271
2029	0.577	0.07	0.07	1394	1251	36	34	300	278
2030	0.593	0.07	0.07	1433	1289	37	35	306	285
2031	0.609	0.07	0.07	1469	1326	37	35	312	291
2032	0.624	0.07	0.07	1502	1361	37	36	317	298
2033	0.636	0.07	0.07	1532	1392	38	36	322	303
2034	0.648	0.07	0.07	1560	1423	38	37	326	309
2035	0.660	0.07	0.07	1584	1452	38	37	330	315
2036	0.672	0.07	0.07	1607	1482	38	38	333	320
2037	0.683	0.07	0.07	1627	1510	38	38	336	324
2038	0.693	0.07	0.07	1645	1536	39	38	339	329
2039	0.702	0.07	0.07	1661	1560	39	39	341	333

8 Figures

Figure 1. Indices of abundance used in fitting the assessment model. CVT indicates the MARMAP chevron trap survey; HB the headboat data (recreational index); CommHL the commercial handline data; and VLL the MARMAP vertical longline survey (or, short-bottom longline). The commercial handline index was used only in a sensitivity run.

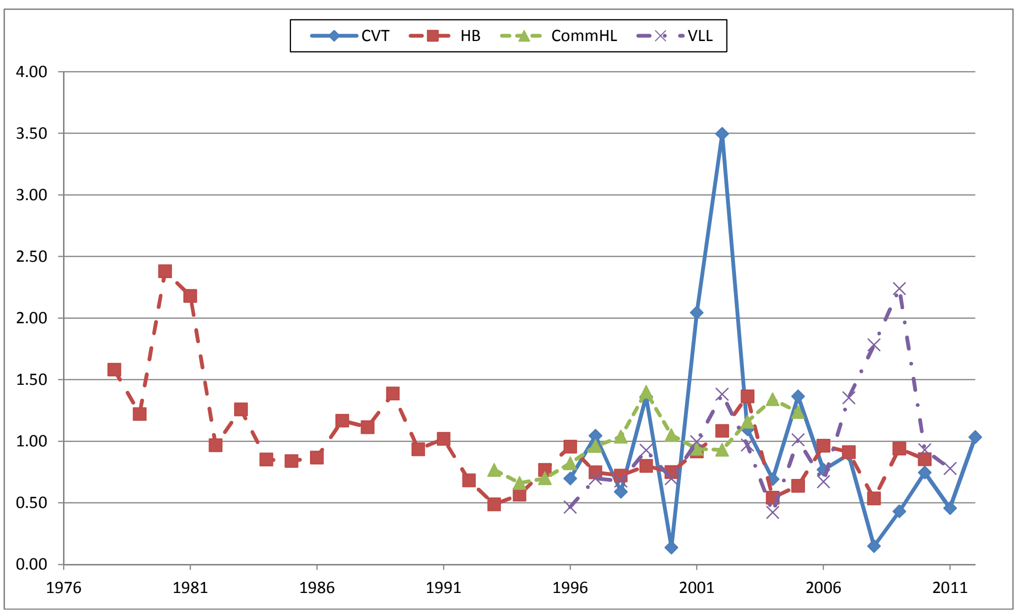


Figure 2. Mean total length at age (mm) and estimated upper and lower 95% confidence intervals of the population.

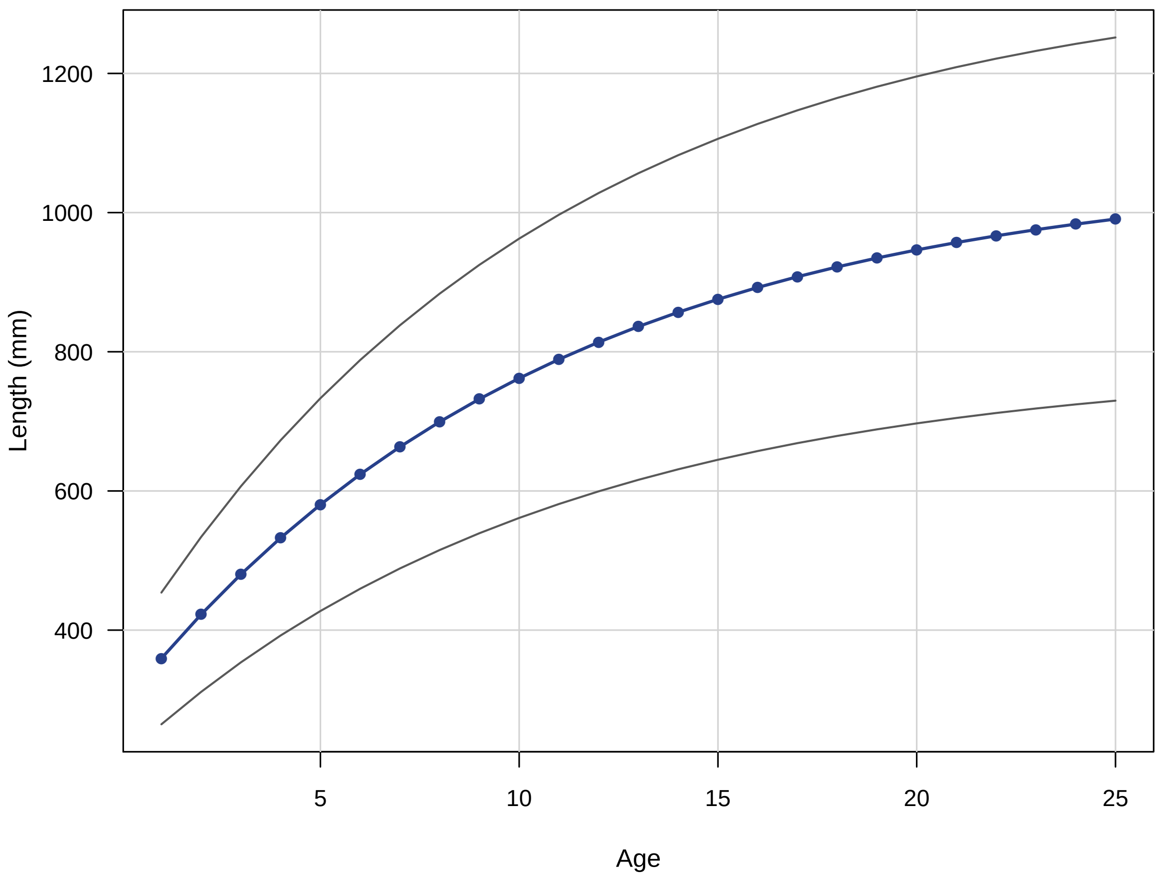


Figure 3. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, cvt to MARMAP chevron trap, vll to MARMAP vertical longline, cH to commercial handline, cL to commercial longline, and rec to recreational. $N = -99999$ *indicates that the composition was not used for fitting, in most cases because the sample size was below the cutoff.*

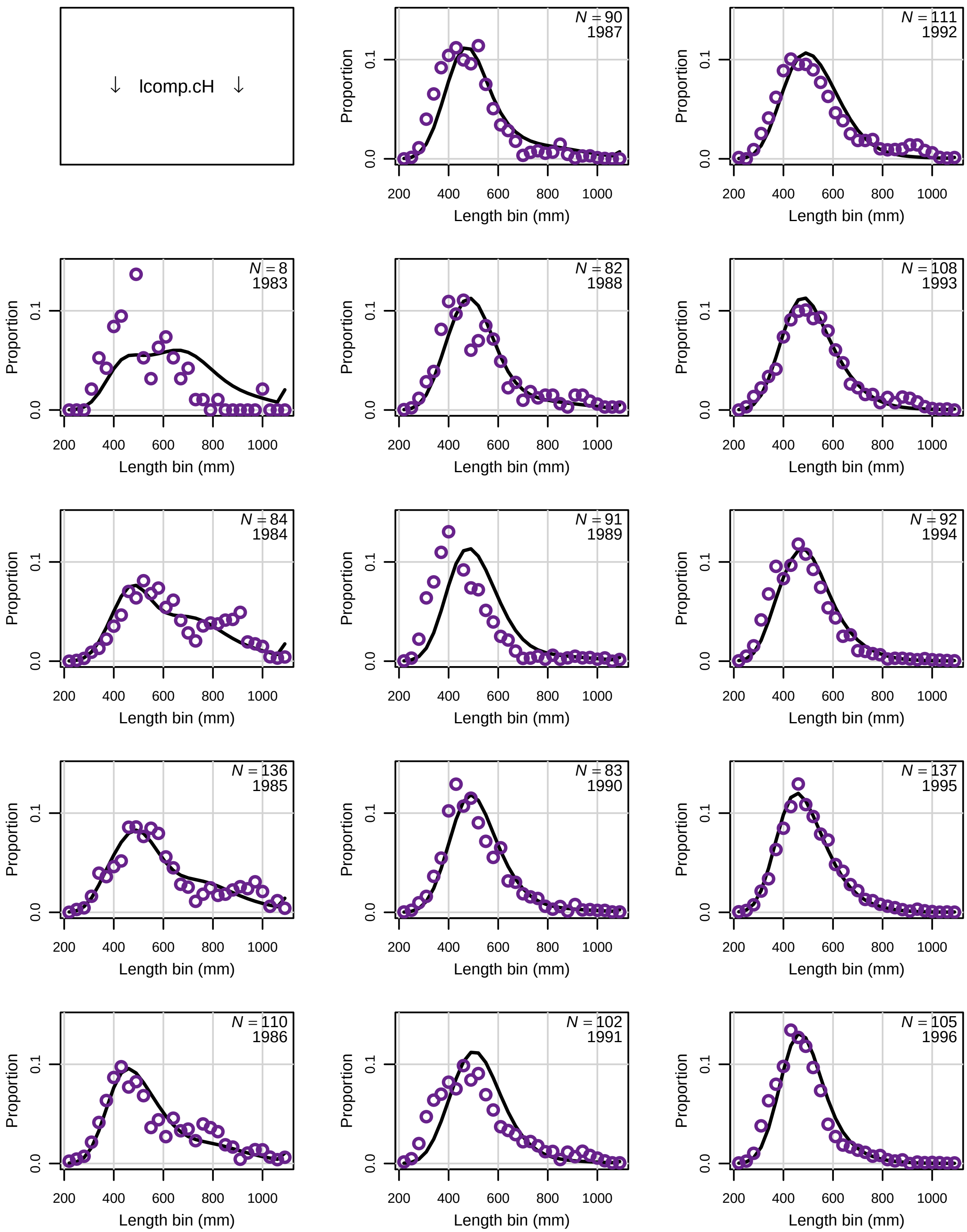


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

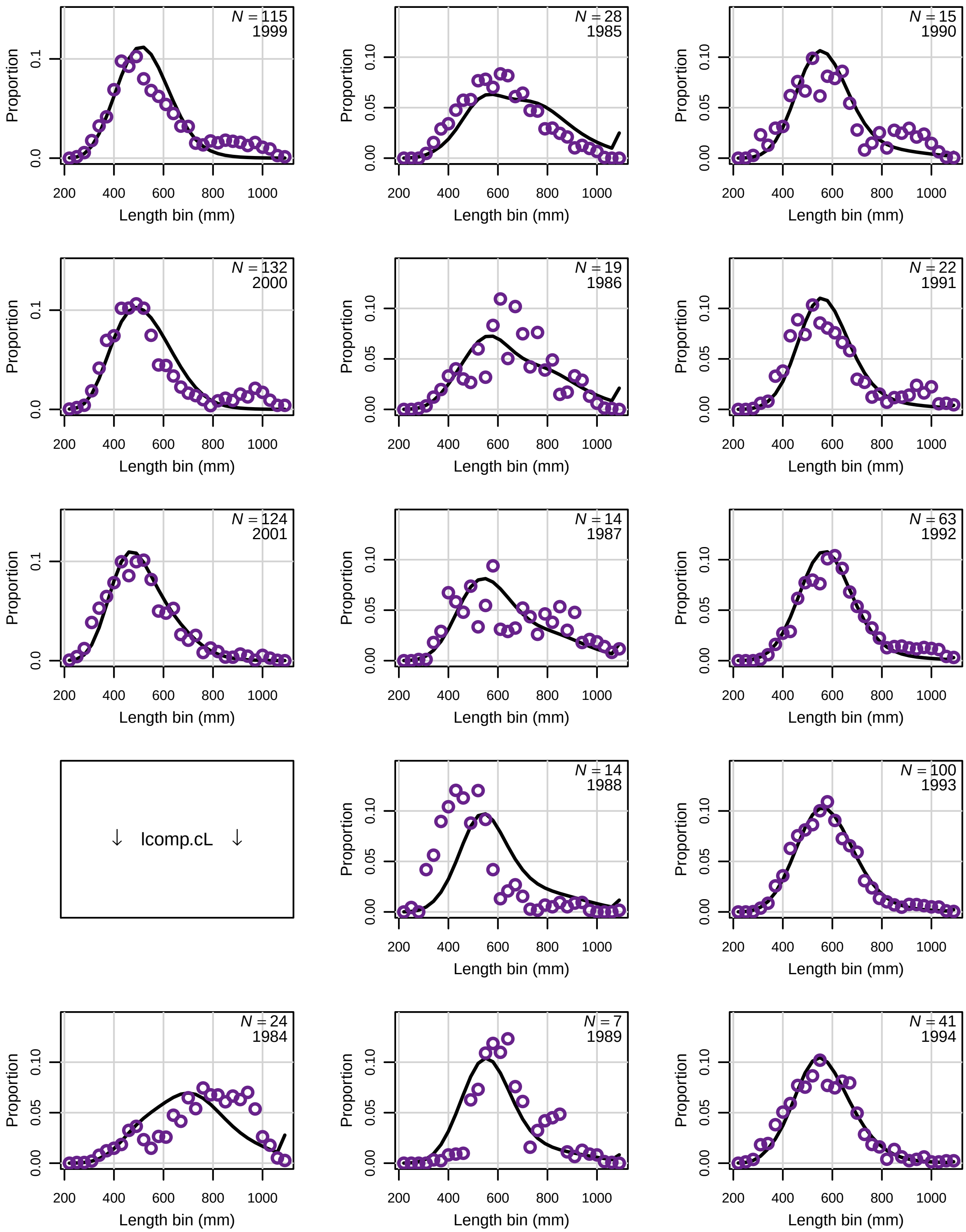


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

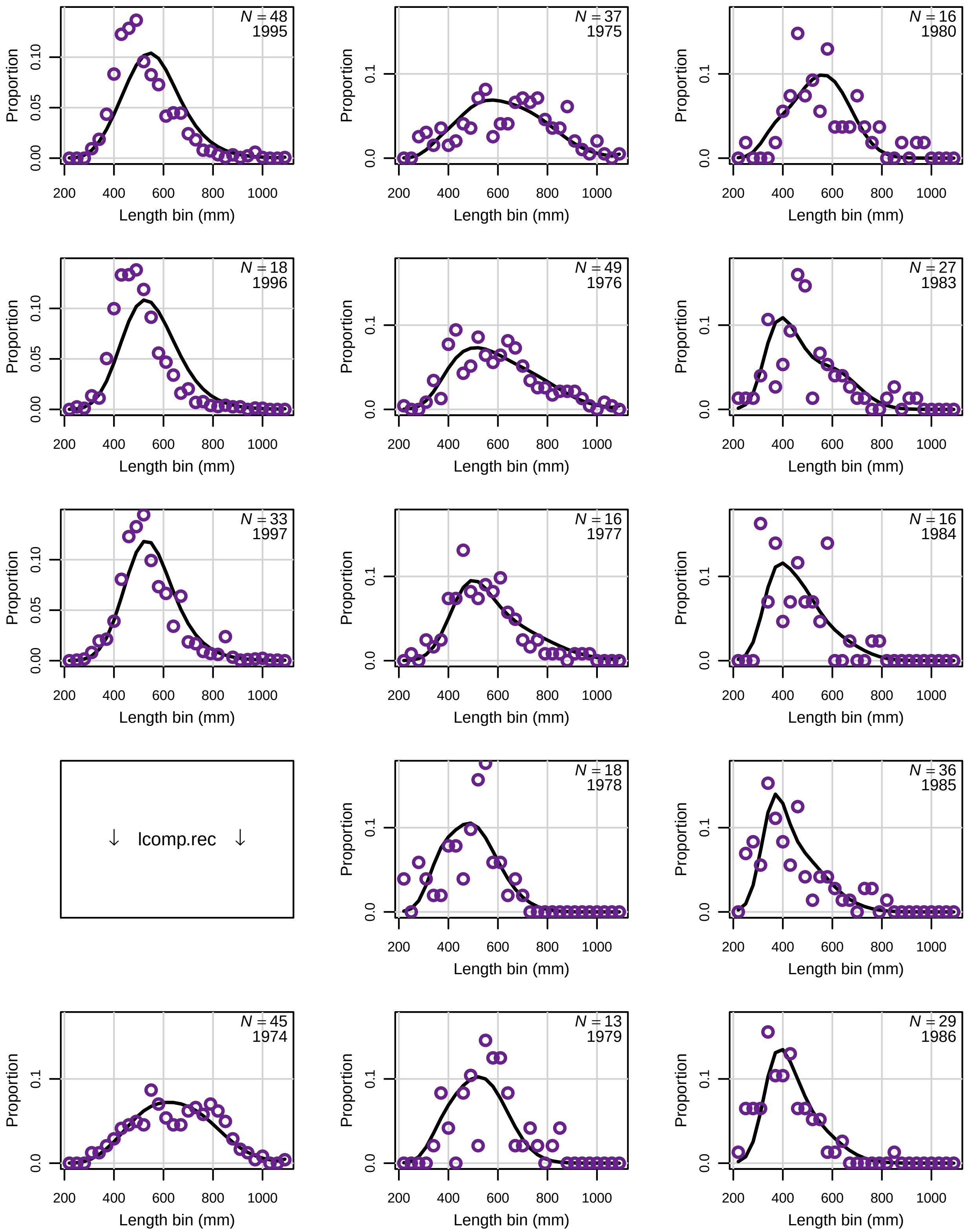


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

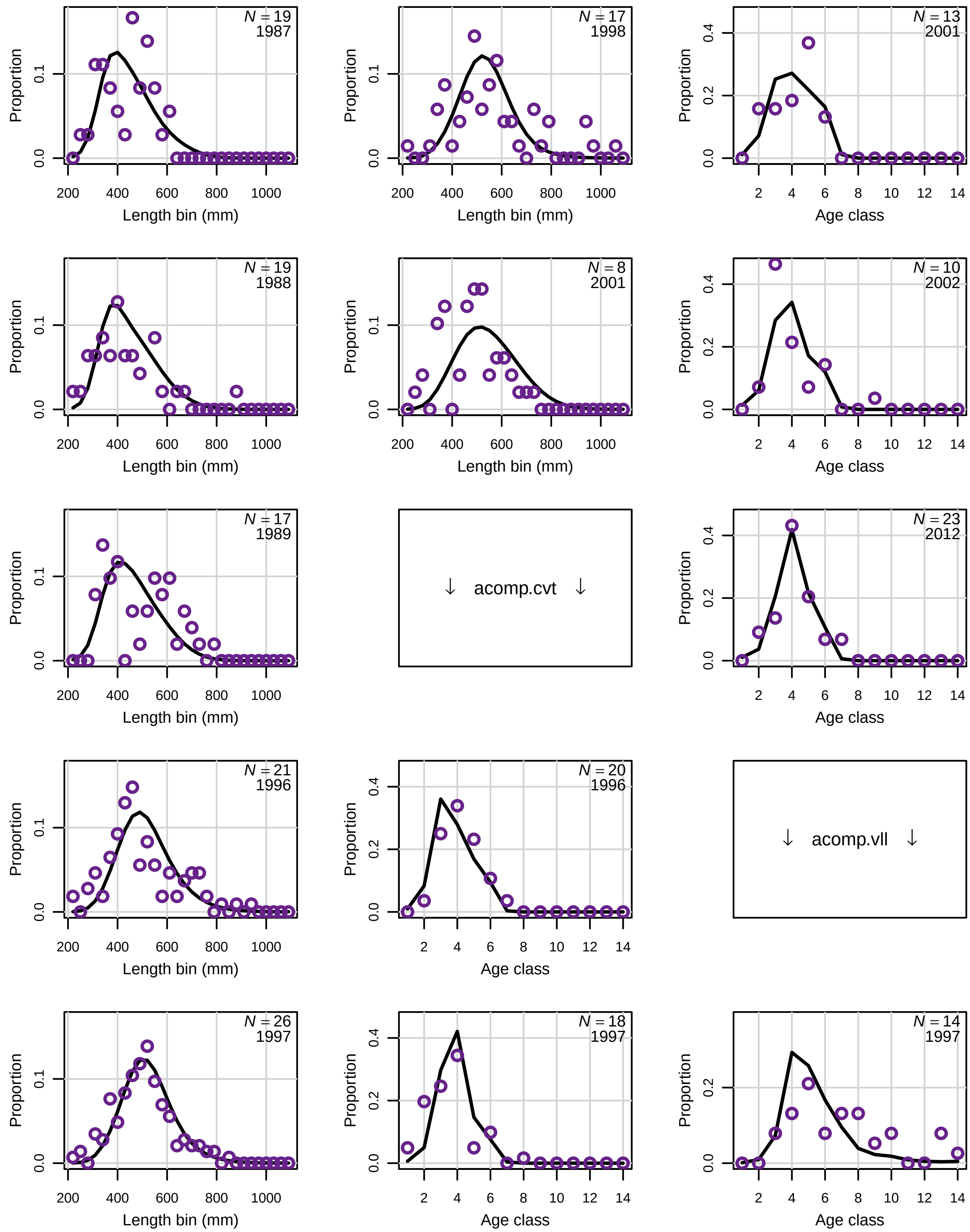


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

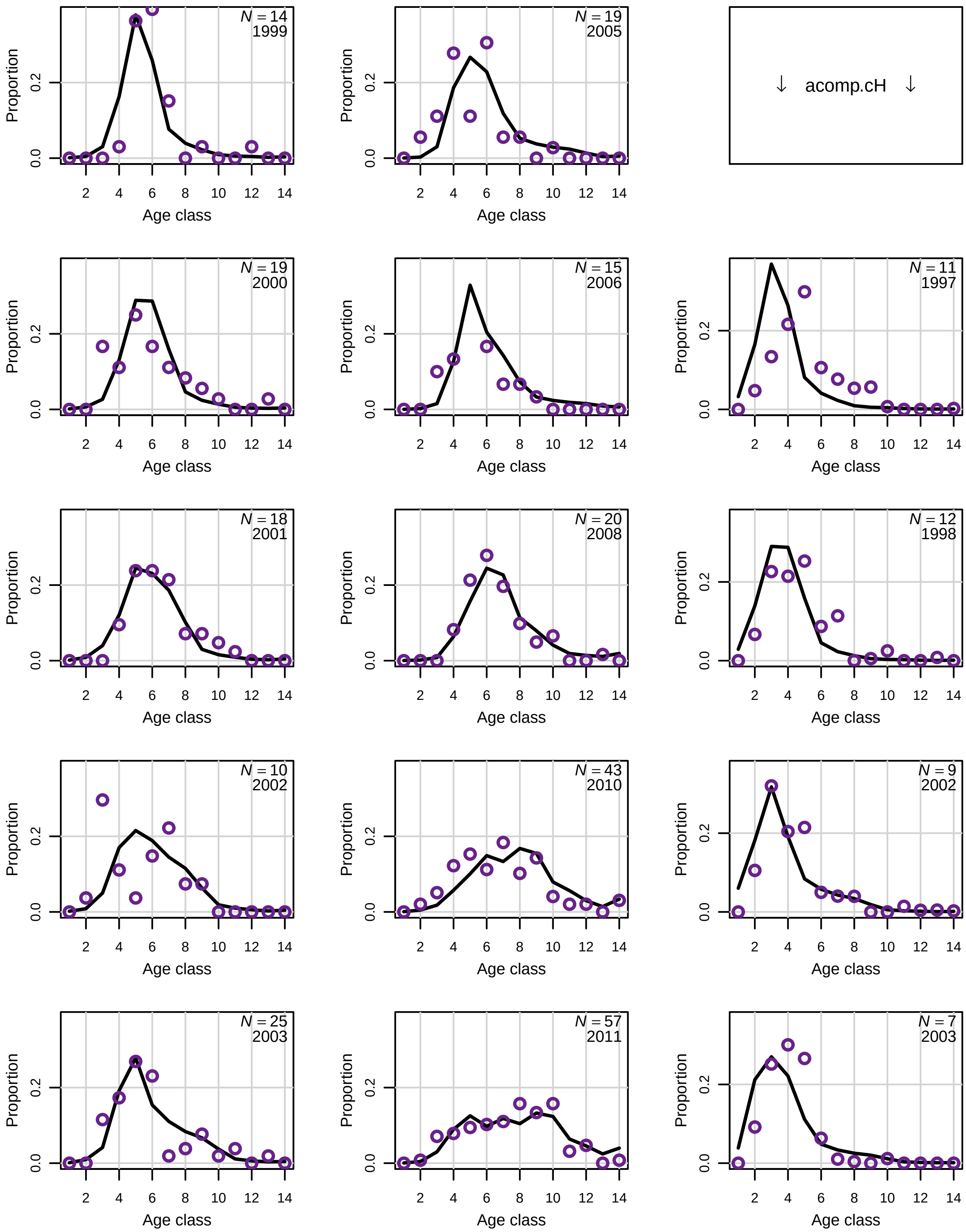


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

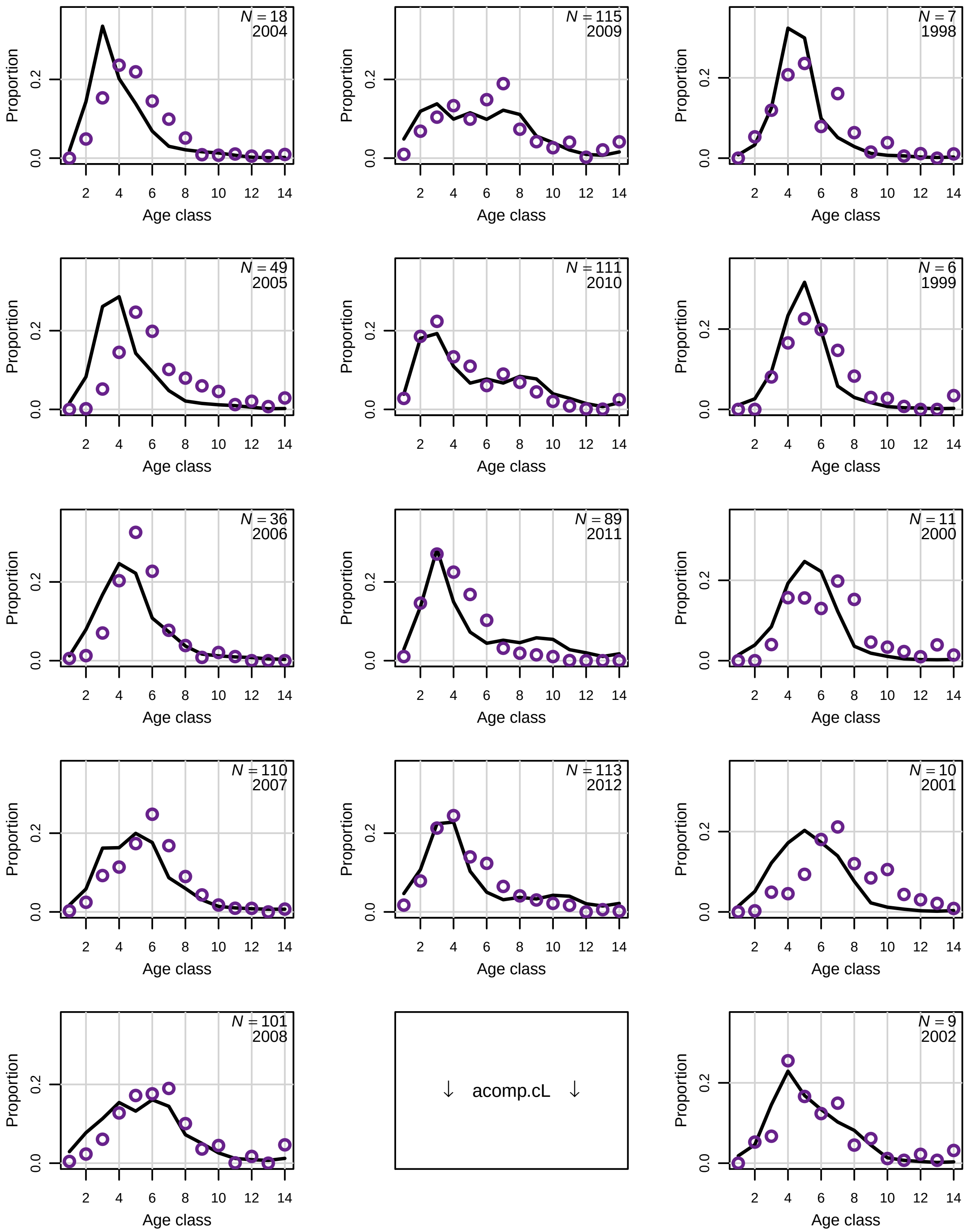


Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

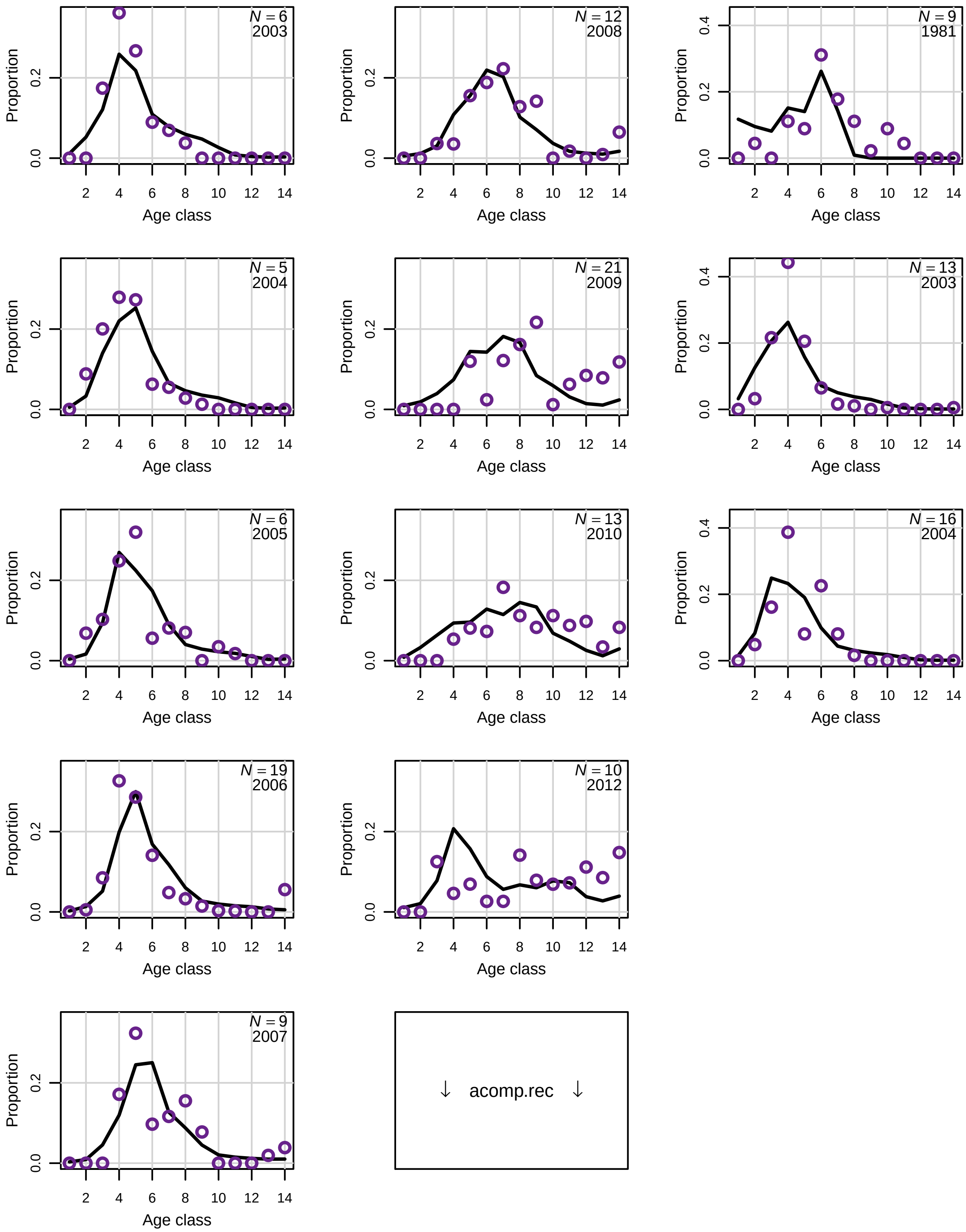


Figure 4. Observed (open circles) and estimated (solid line, circles) commercial handline removals (landings and dead discards, 1000 lb whole weight). Open and solid circles are indistinguishable.

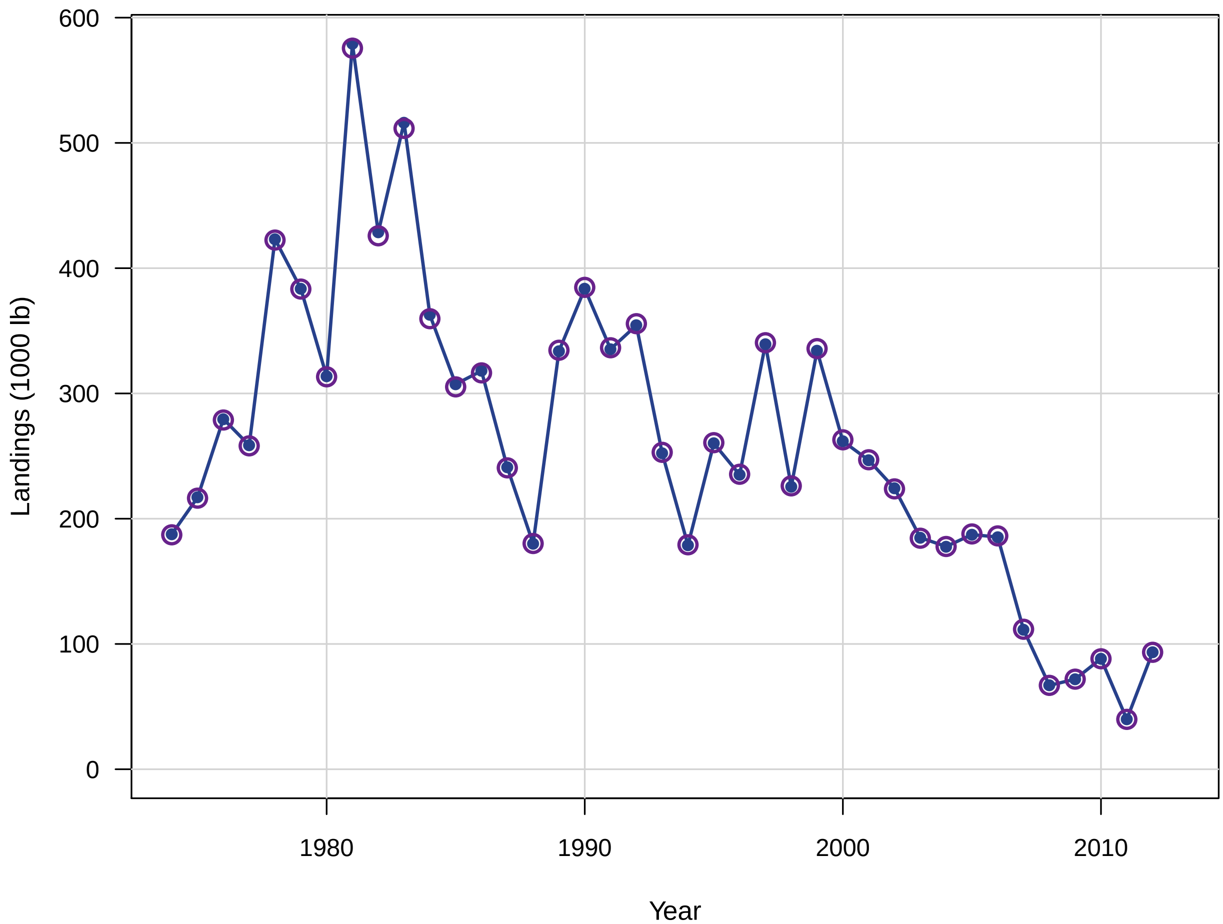


Figure 5. Observed (open circles) and estimated (solid line, circles) commercial longline removals (landings and dead discards, 1000 lb whole weight). Open and solid circles are indistinguishable.

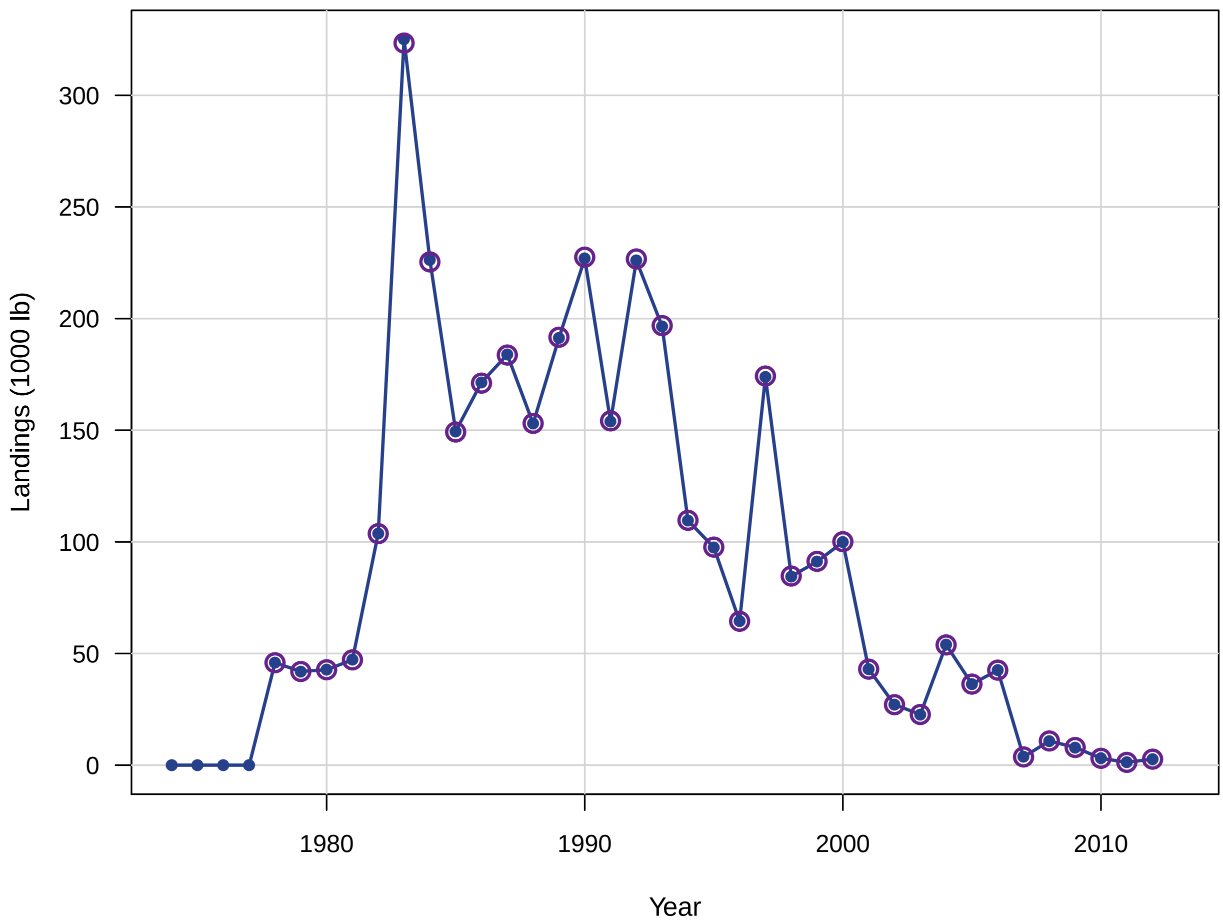


Figure 6. Observed (open circles) and estimated (solid line, circles) recreational removals (landings and dead discards, 1000 fish). Open and solid circles are indistinguishable.

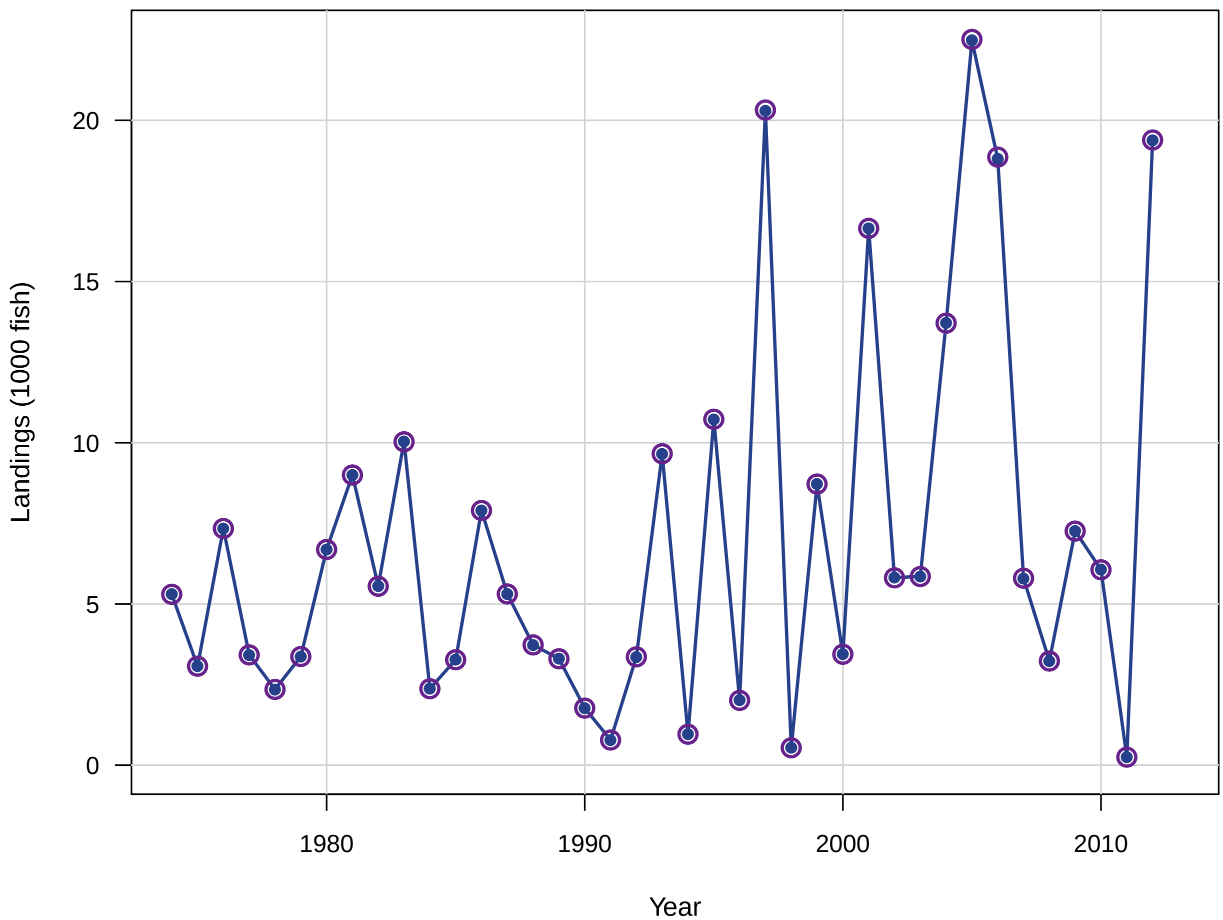


Figure 7. Observed (open circles) and estimated (solid line, circles) index of abundance from the MARMAP chevron trap survey.

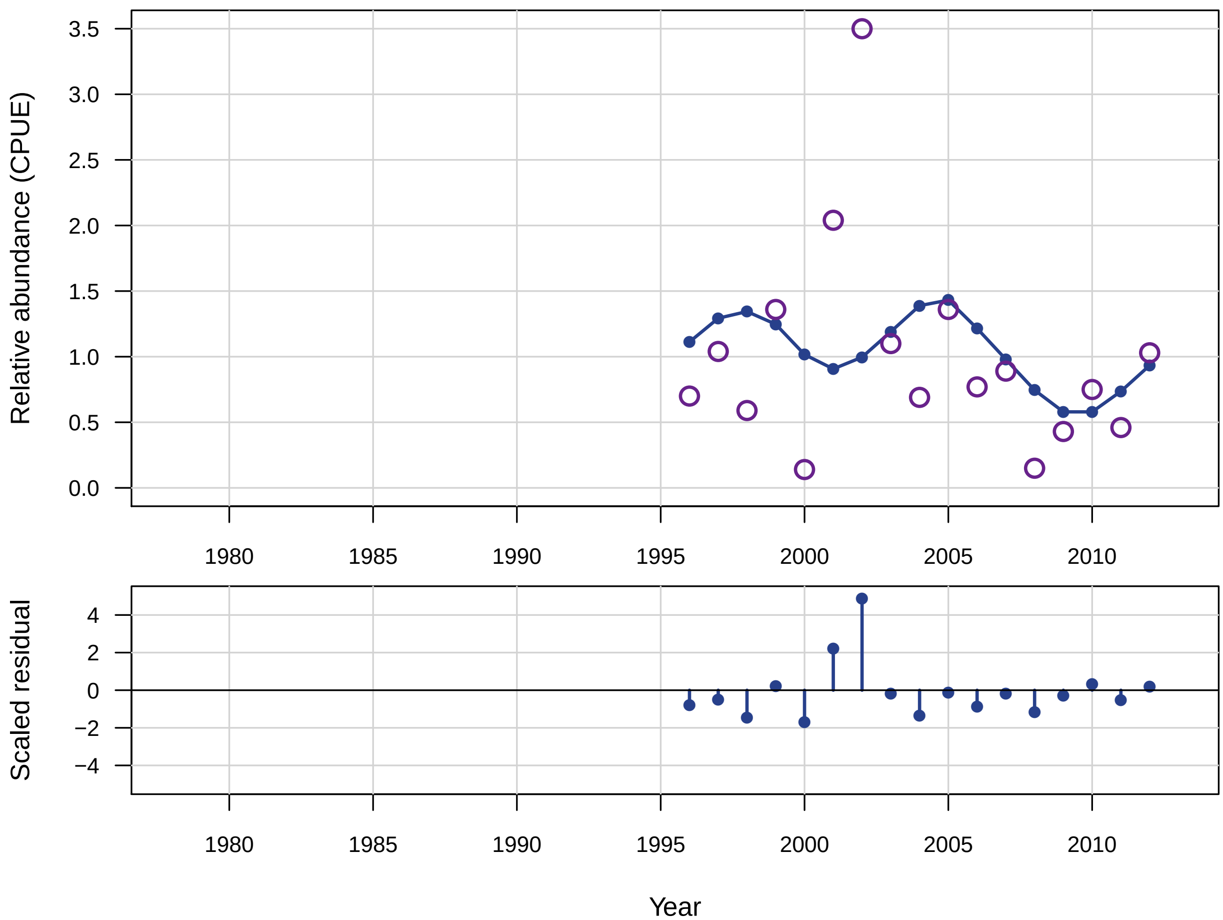


Figure 8. Observed (open circles) and estimated (solid line, circles) index of abundance from the MARMAP vertical longline survey.

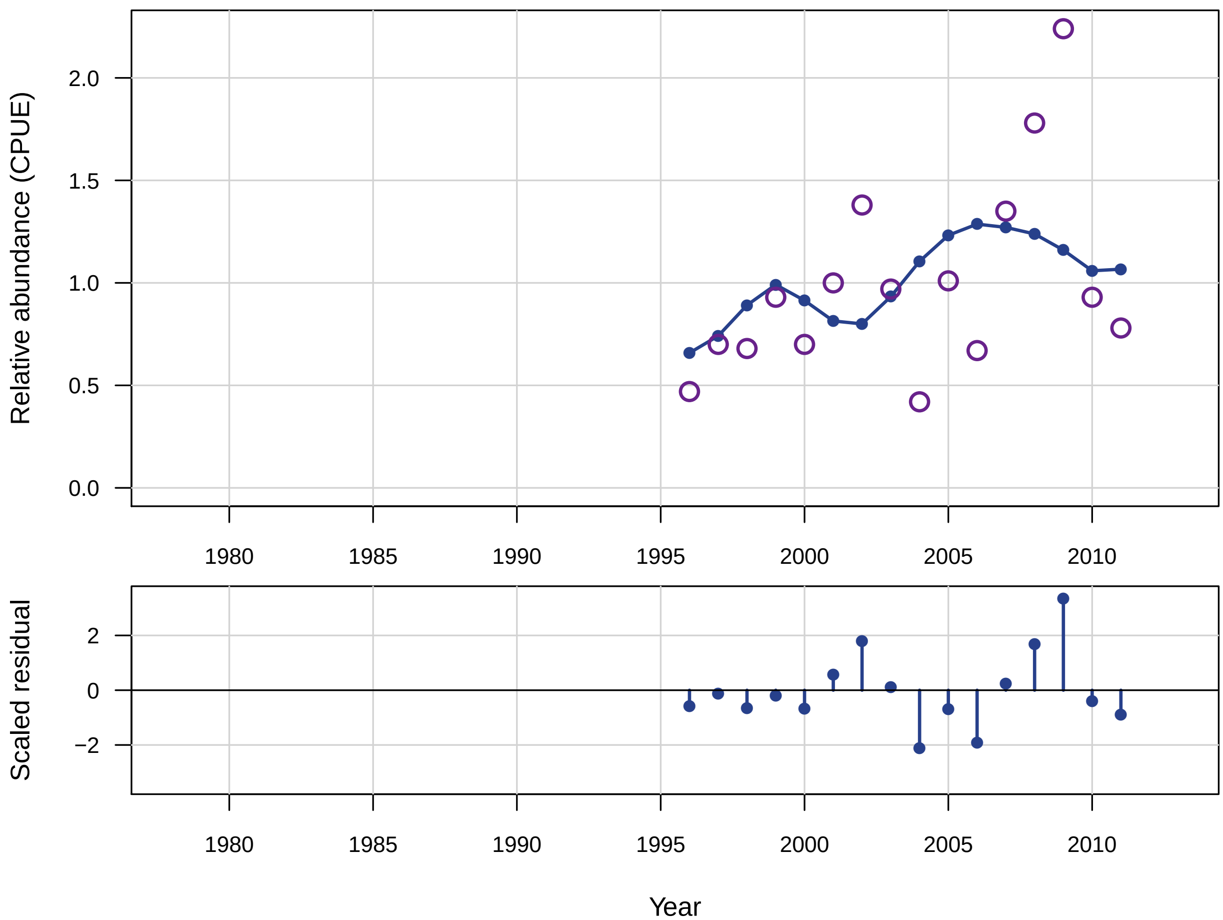


Figure 9. Observed (open circles) and estimated (solid line, circles) abundance from the recreational headboat fleet.

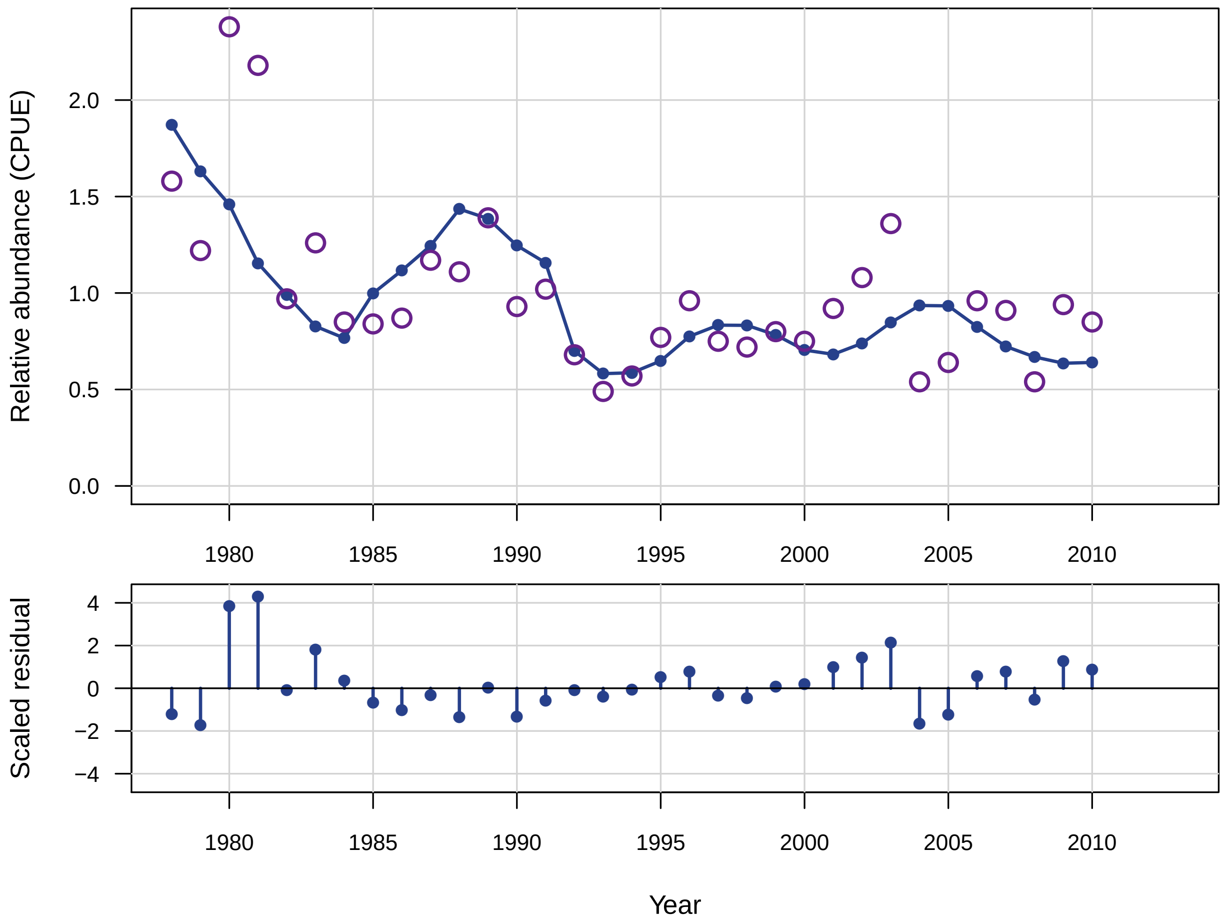


Figure 10. Estimated abundance at age at start of year.

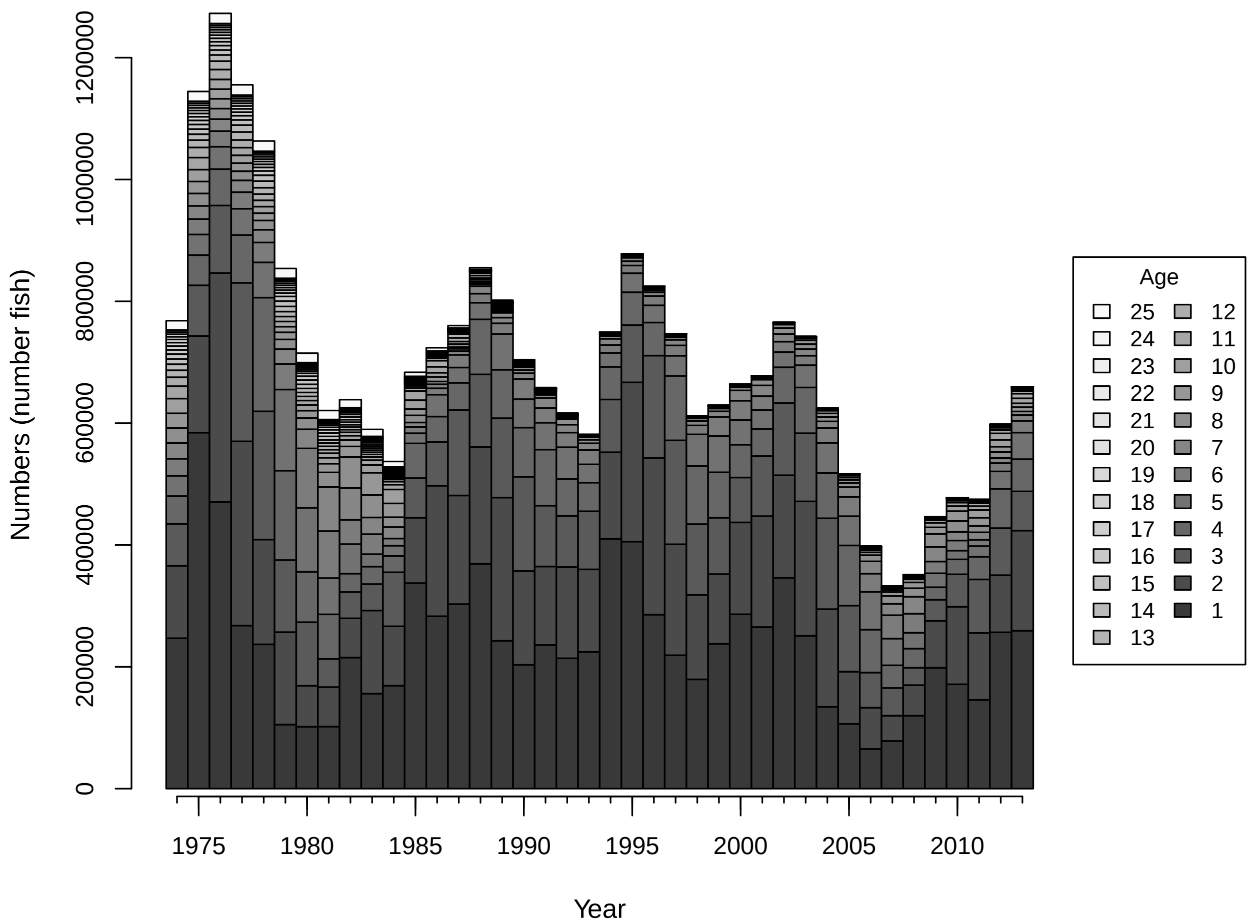
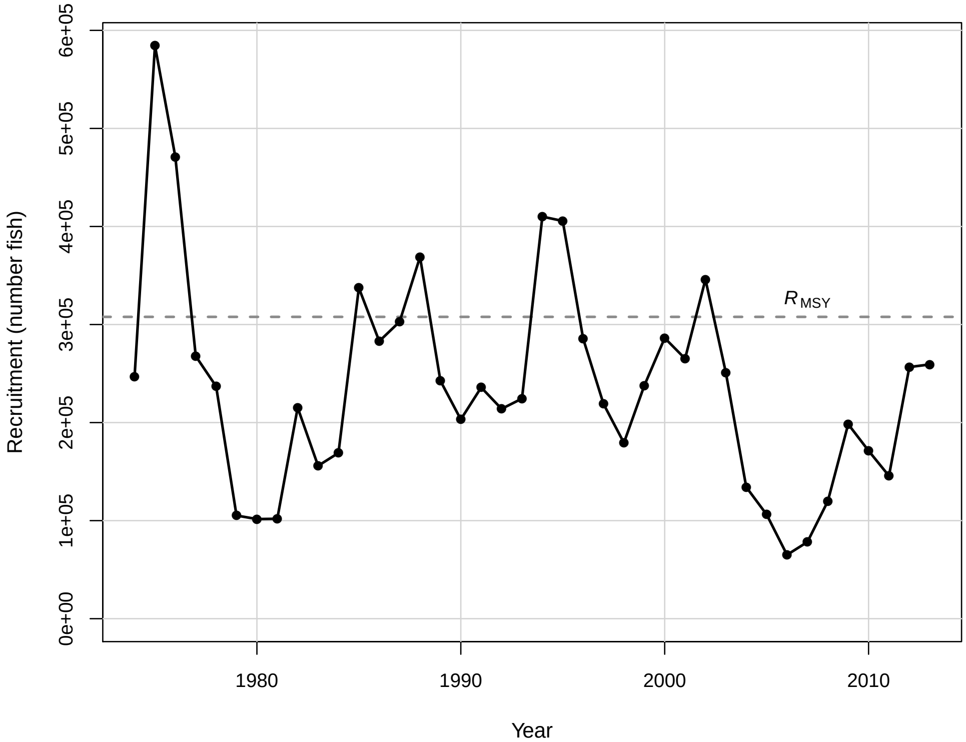


Figure 11. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates R_{MSY}. Bottom panel: log recruitment residuals.



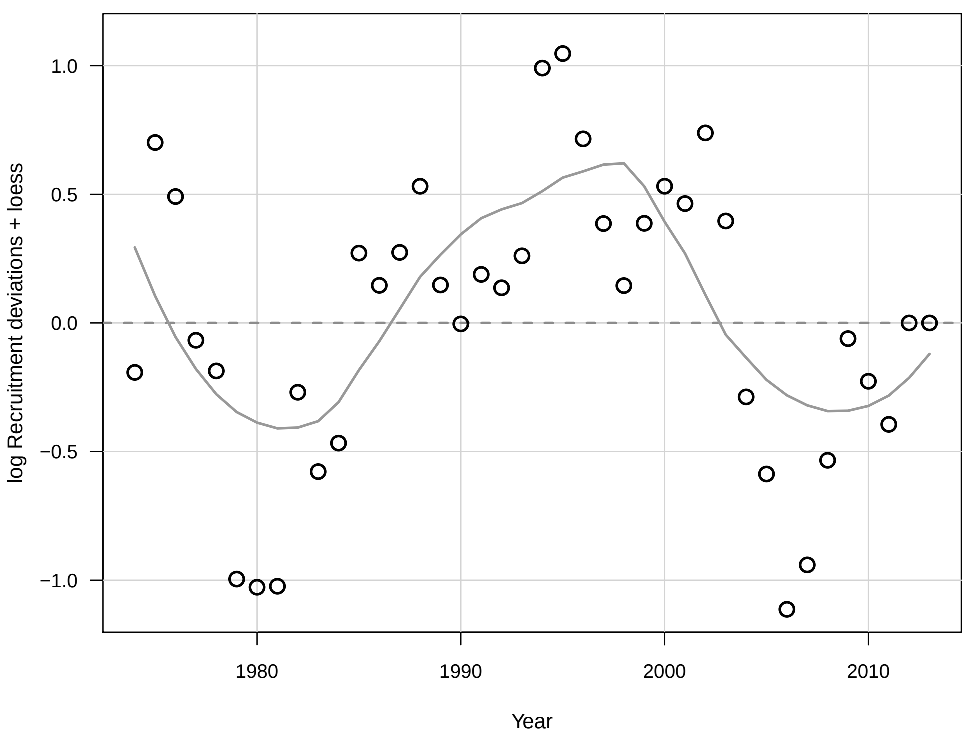


Figure 12. Estimated biomass at age at start of year.

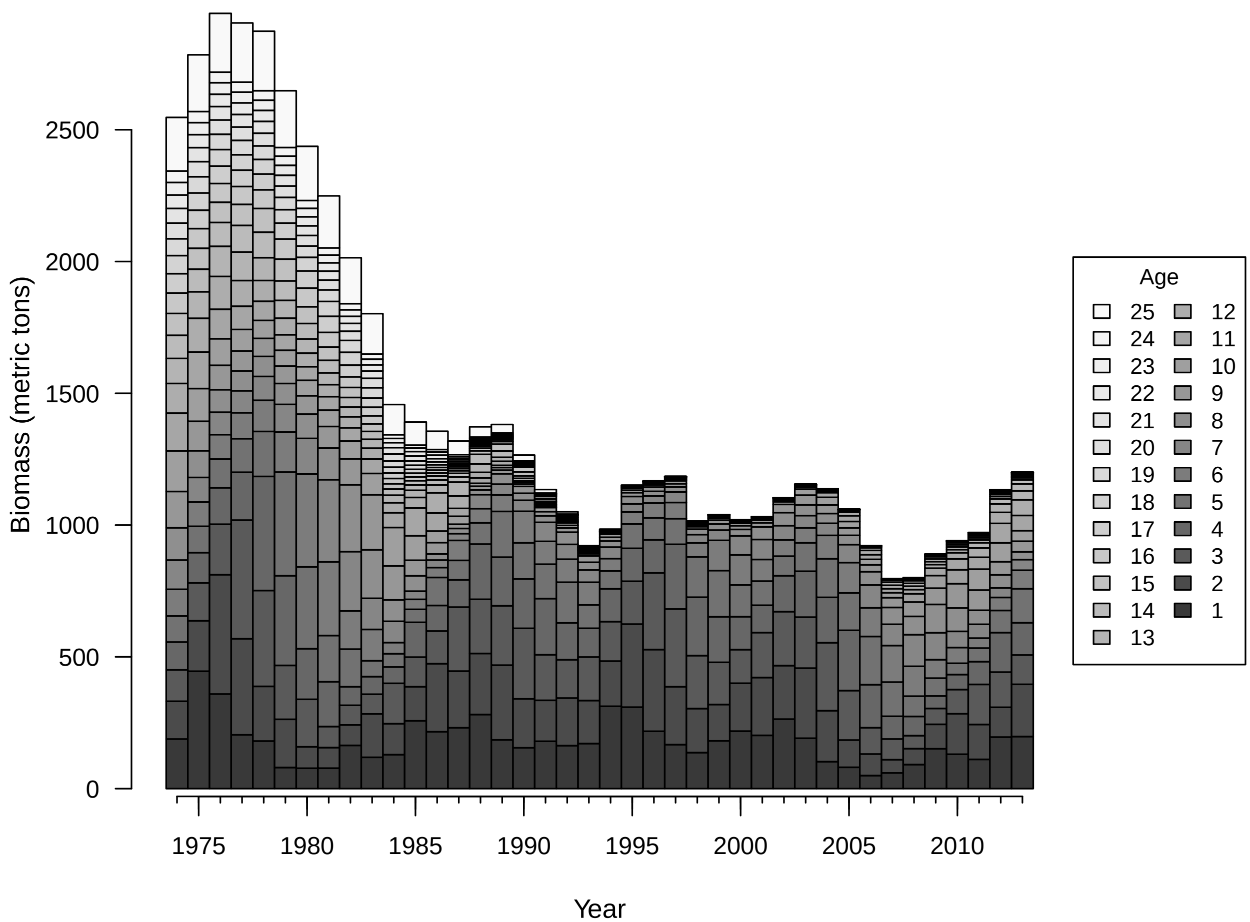
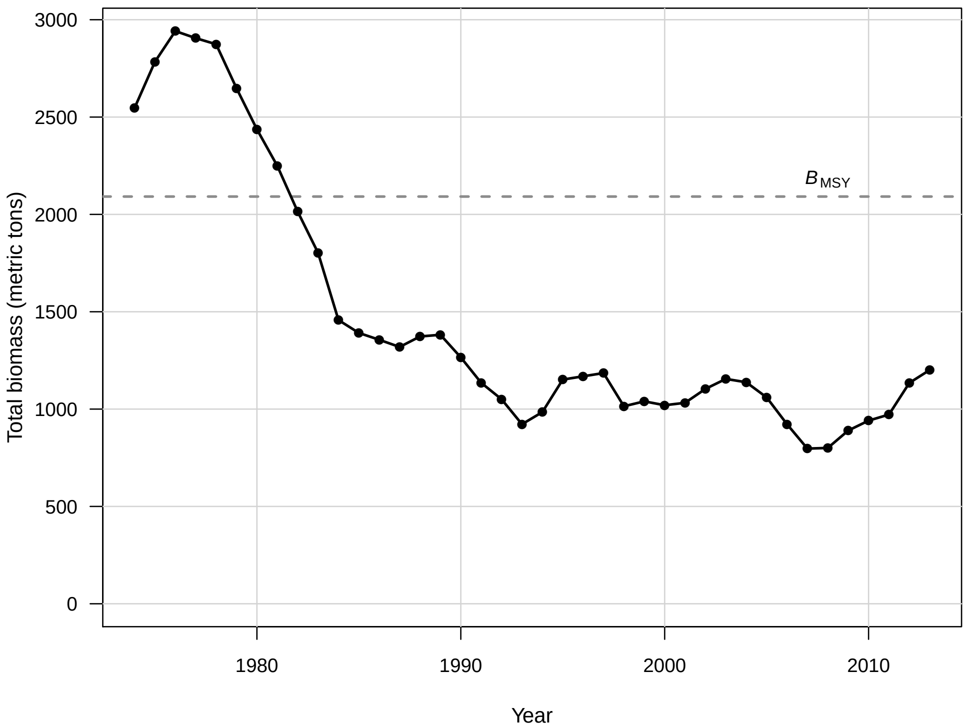


Figure 13. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates B_{MSY}. Bottom panel: Estimated spawning stock (population fecundity) at time of peak spawning.



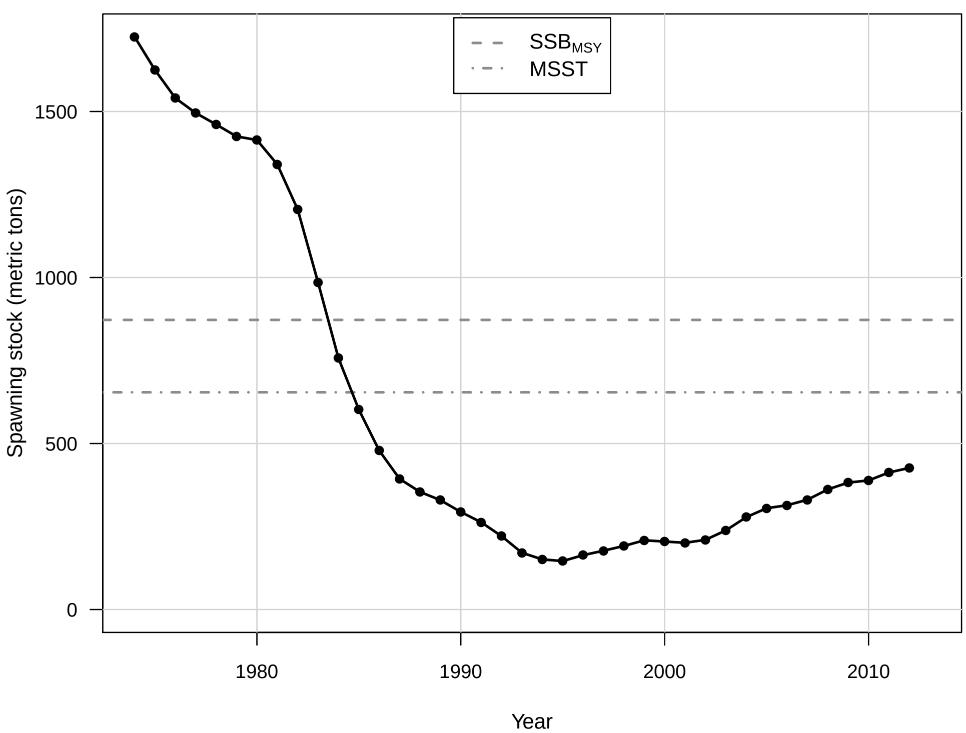


Figure 14. Selectivities of MARMAP gears. Top panel: chevron traps. Bottom panel: vertical longlines.

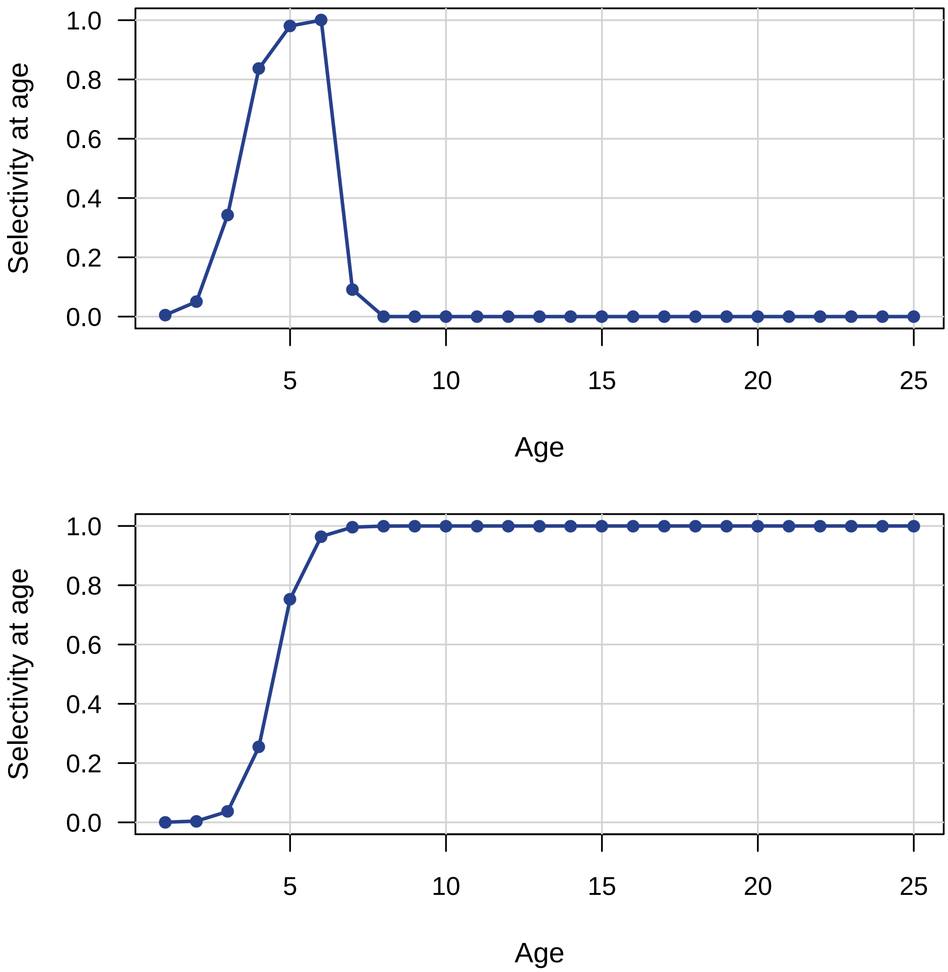


Figure 15. Estimated selectivities of commercial fleets. Top panel: commercial handline. Bottom panel: commercial longline.

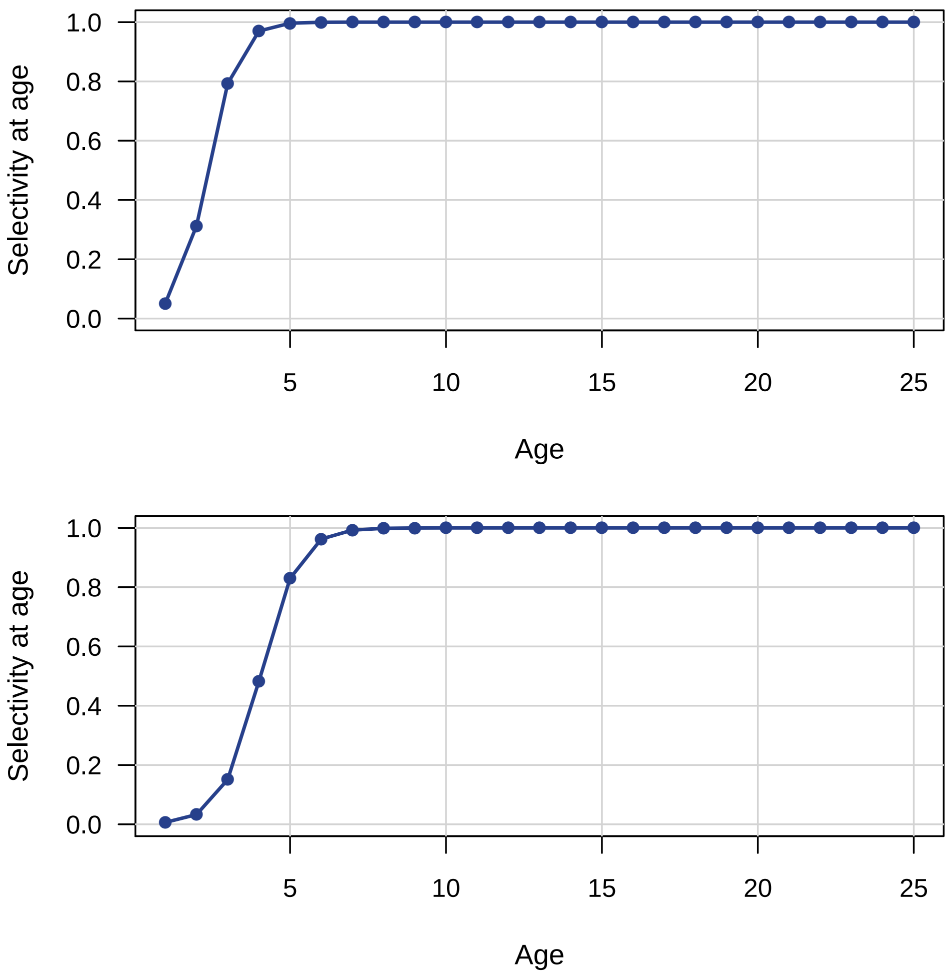


Figure 16. Estimated selectivities of the recreational fleet (headboat and general recreational). Top panel: block 1 (1974–1977). Middle panel: block 2 (1978–1991). Bottom panel: block 3 (1992-2012).

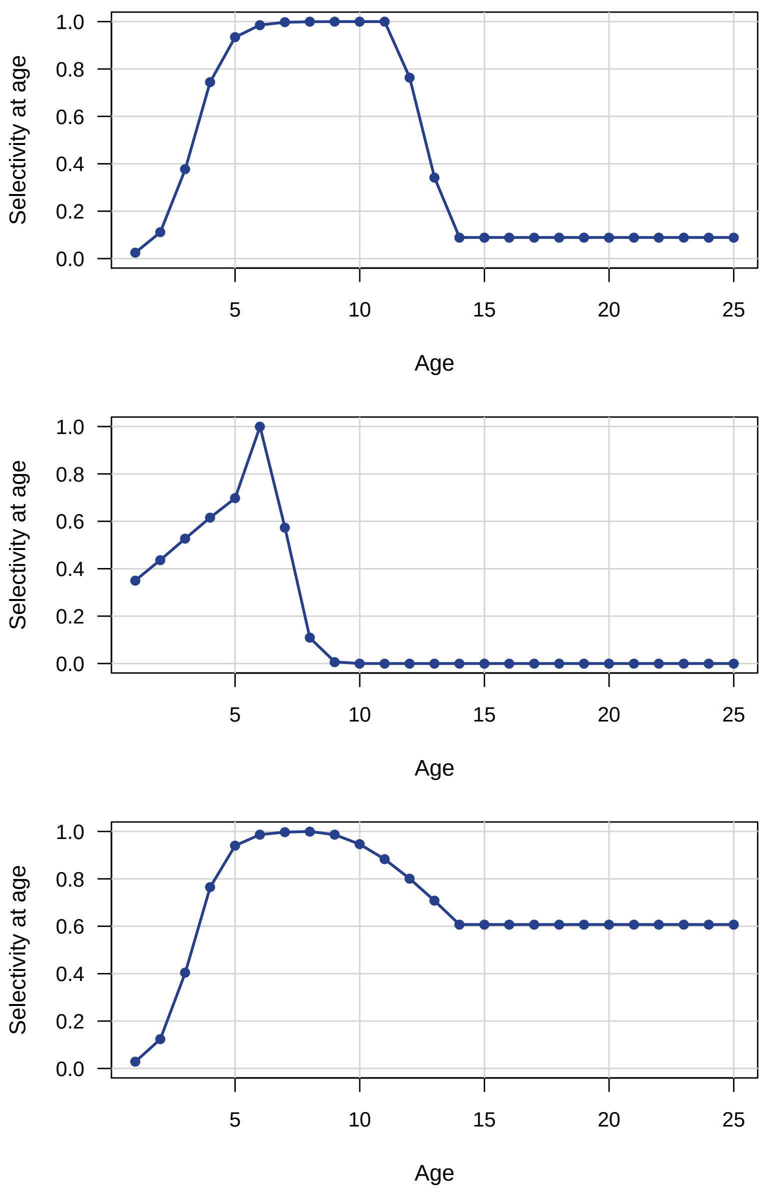


Figure 17. Average selectivity of removals (landings and dead discards) from the terminal assessment years, weighted by geometric mean Fs from the last three assessment years, and used in computation of benchmarks and projections.

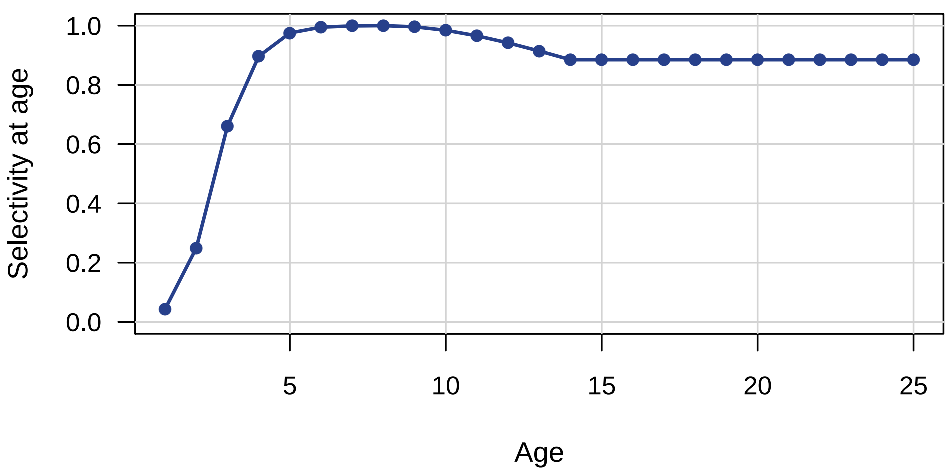


Figure 18. Estimated fully selected fishing mortality rate (per year) by fleet. cH refers to commercial handlines, cL to commercial longlines, and rec to recreational.

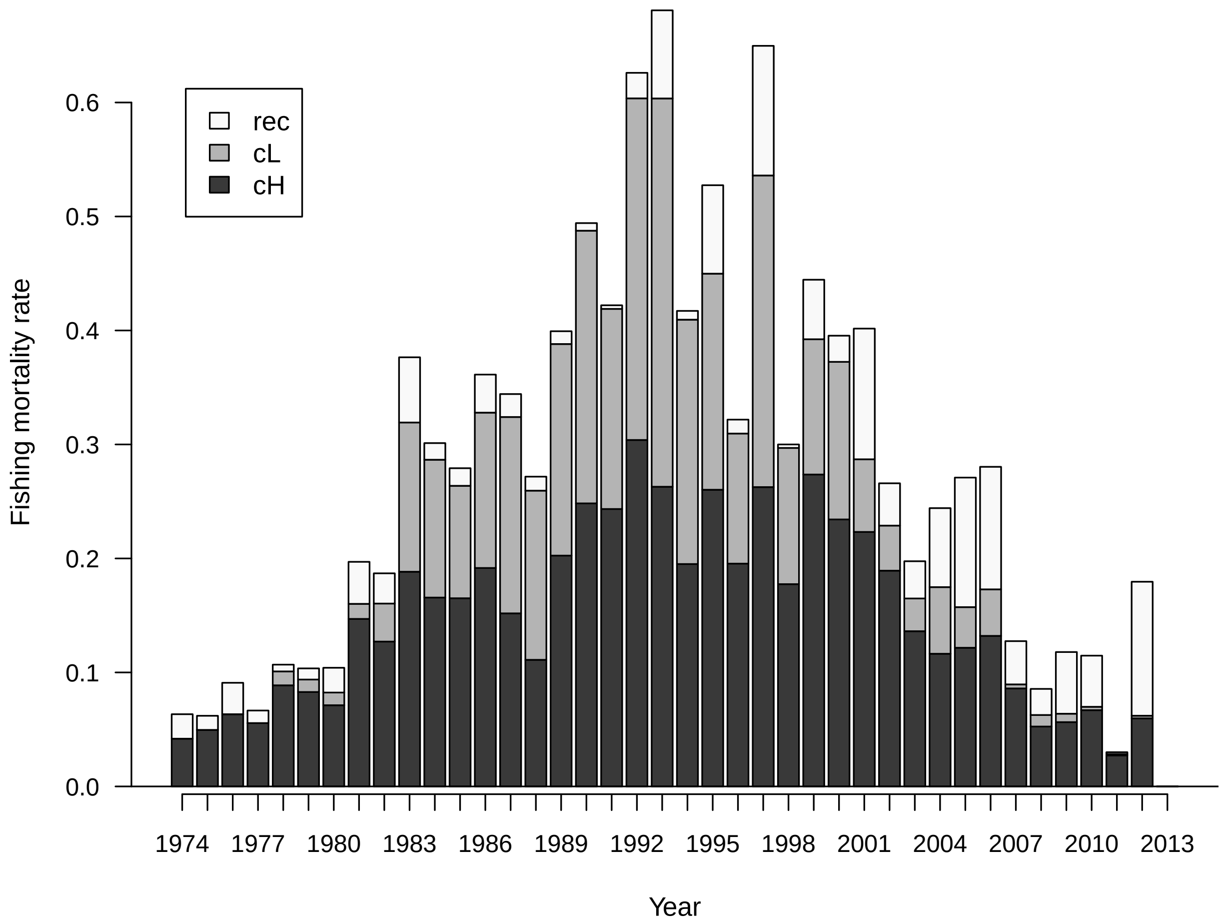


Figure 19. Estimated removals (landings and dead discards) in numbers by fleet from the catch-age model. cH refers to commercial handlines, cL to commercial longlines, and rec to recreational.

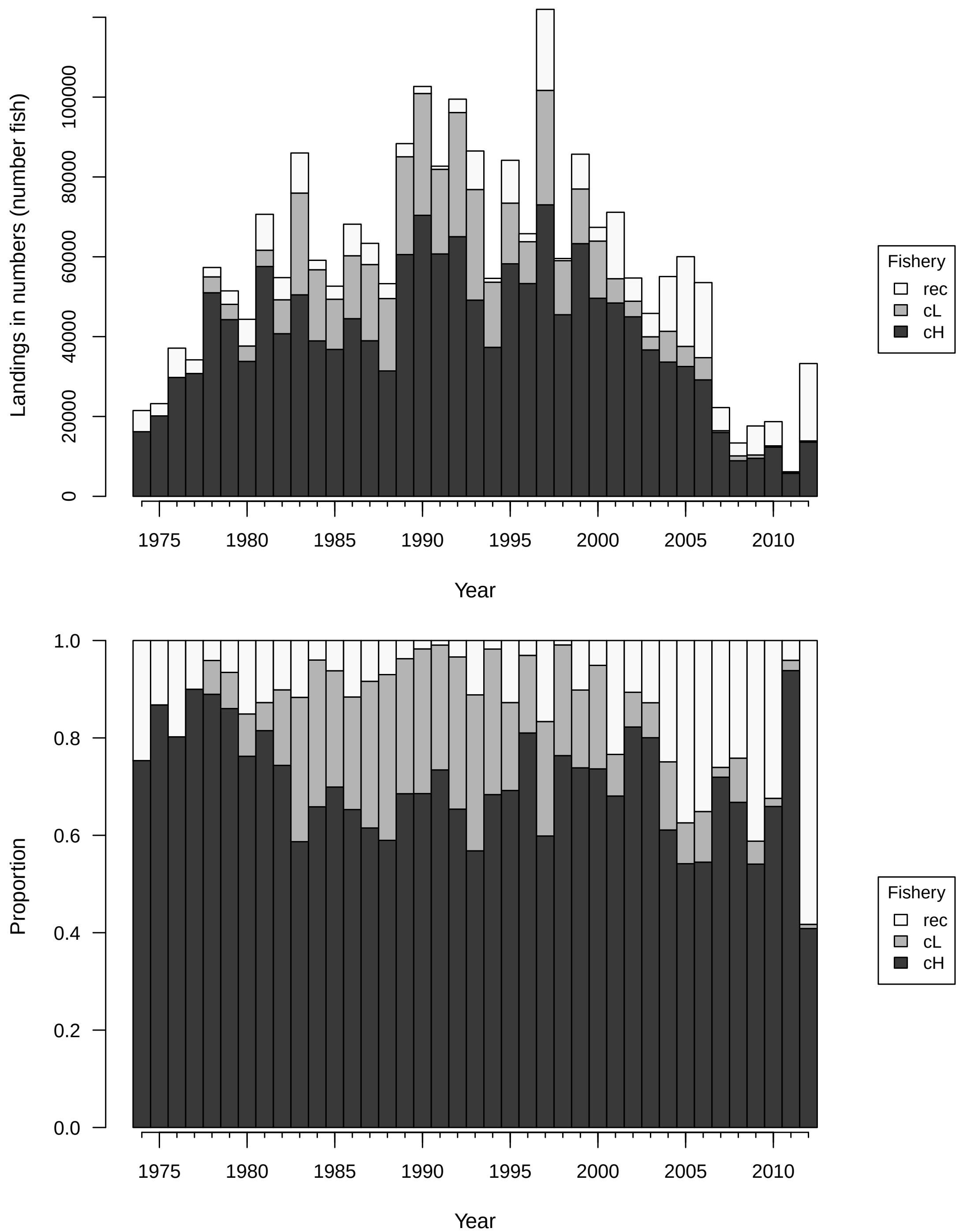


Figure 20. Estimated removals (landings and dead discards) in whole weight by fleet from the catch-age model. cH refers to commercial handlines, cL to commercial longlines, and rec to recreational. Horizontal dashed line in the top panel corresponds to the point estimate of MSY.

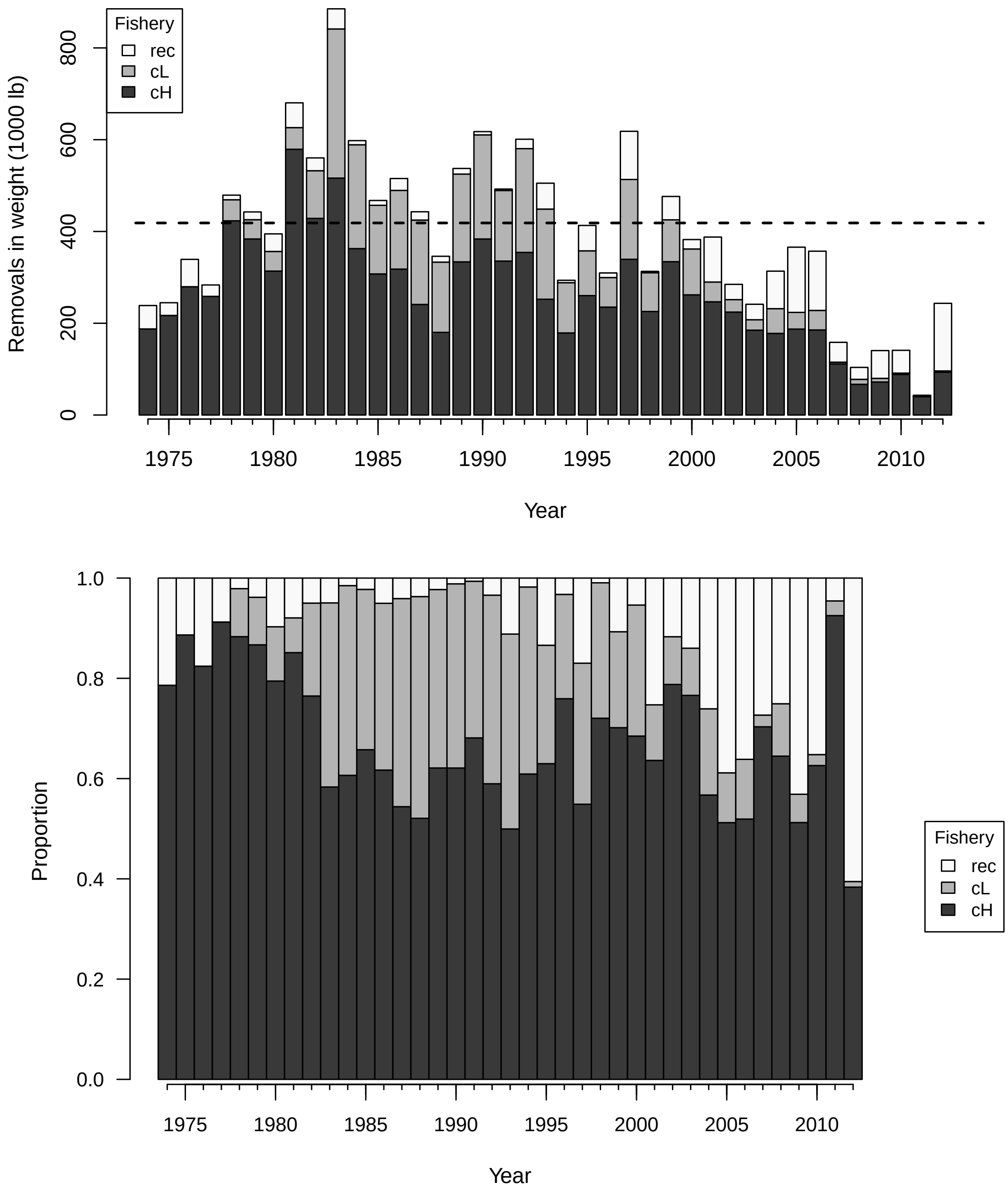


Figure 21. Top panel: Beverton–Holt spawner-recruit curves, with and without lognormal bias correction. The expected (upper) curve was used for computing management benchmarks. Bottom panel: log of recruits (number age-1 fish) per spawner as a function of spawners.

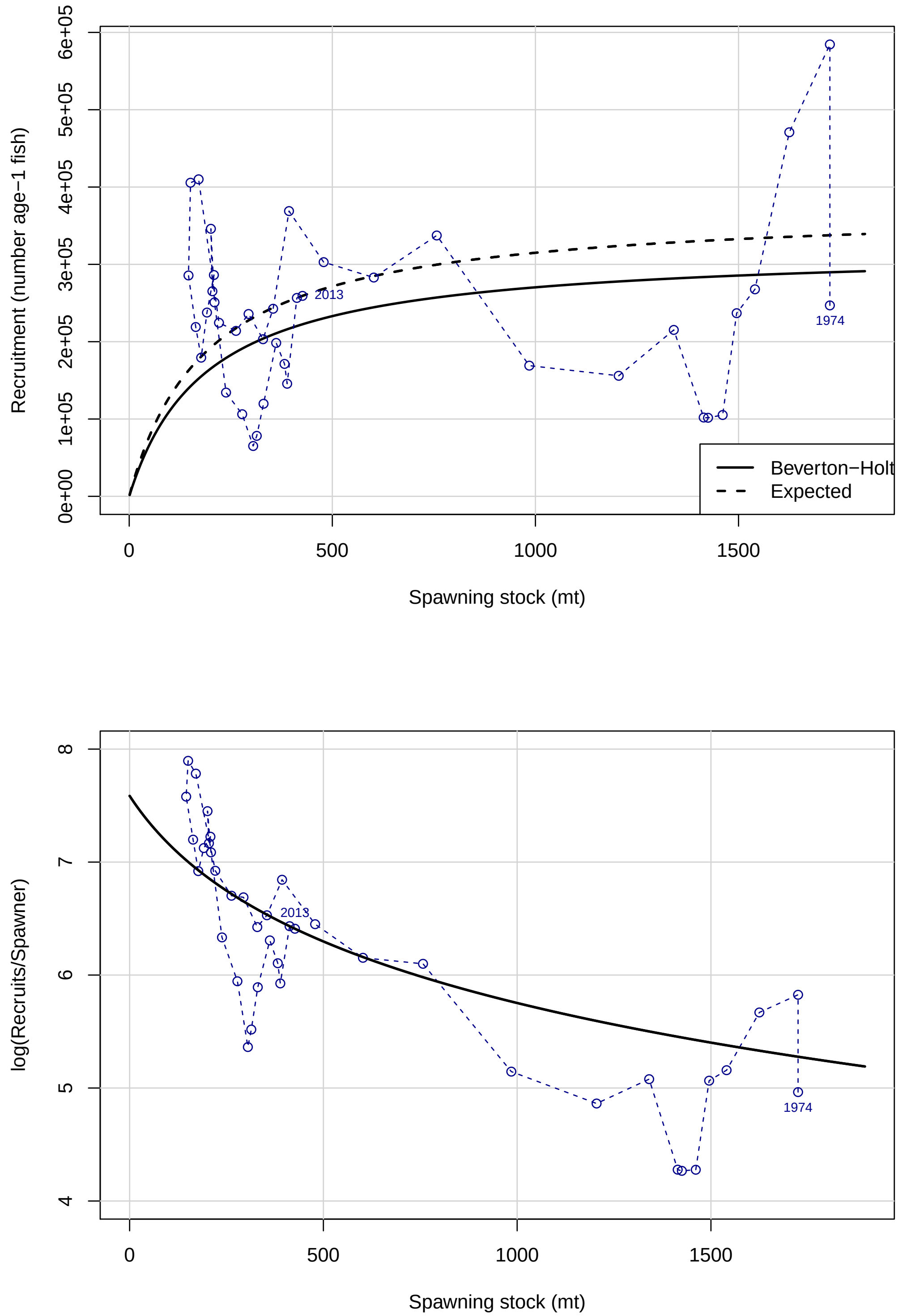


Figure 22. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-1 fish), steepness, unfished spawners per recruit, and standard deviation of recruitment residuals in log space. Solid vertical lines represent point estimates or values from the base run of the Beaufort Assessment Model; dashed vertical lines represent medians from the MCB runs.

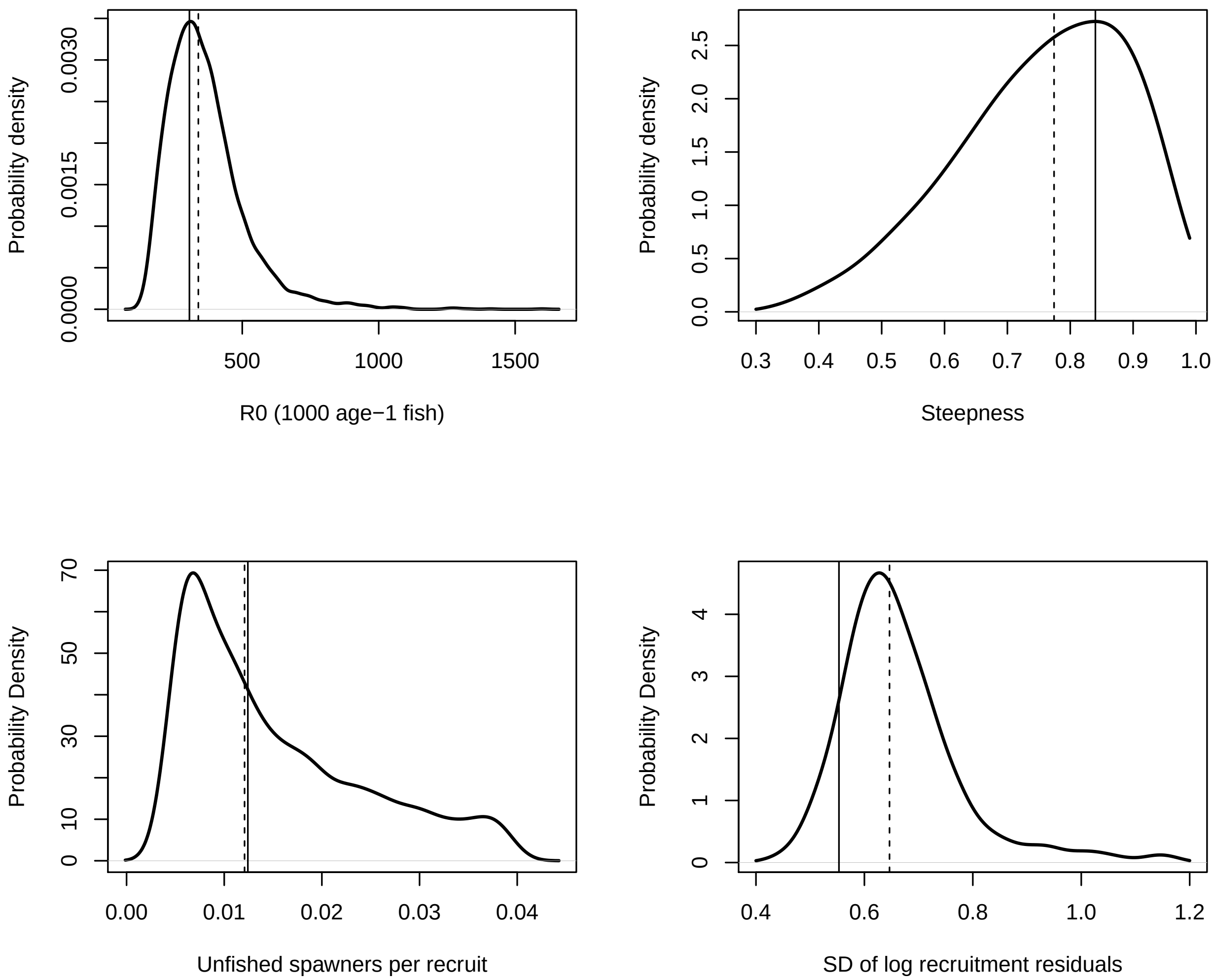


Figure 23. Top panel: yield per recruit. Bottom panel: spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the X% level of SPR provides $F_{X\%}$. Both curves are based on average selectivity from the end of the assessment period.

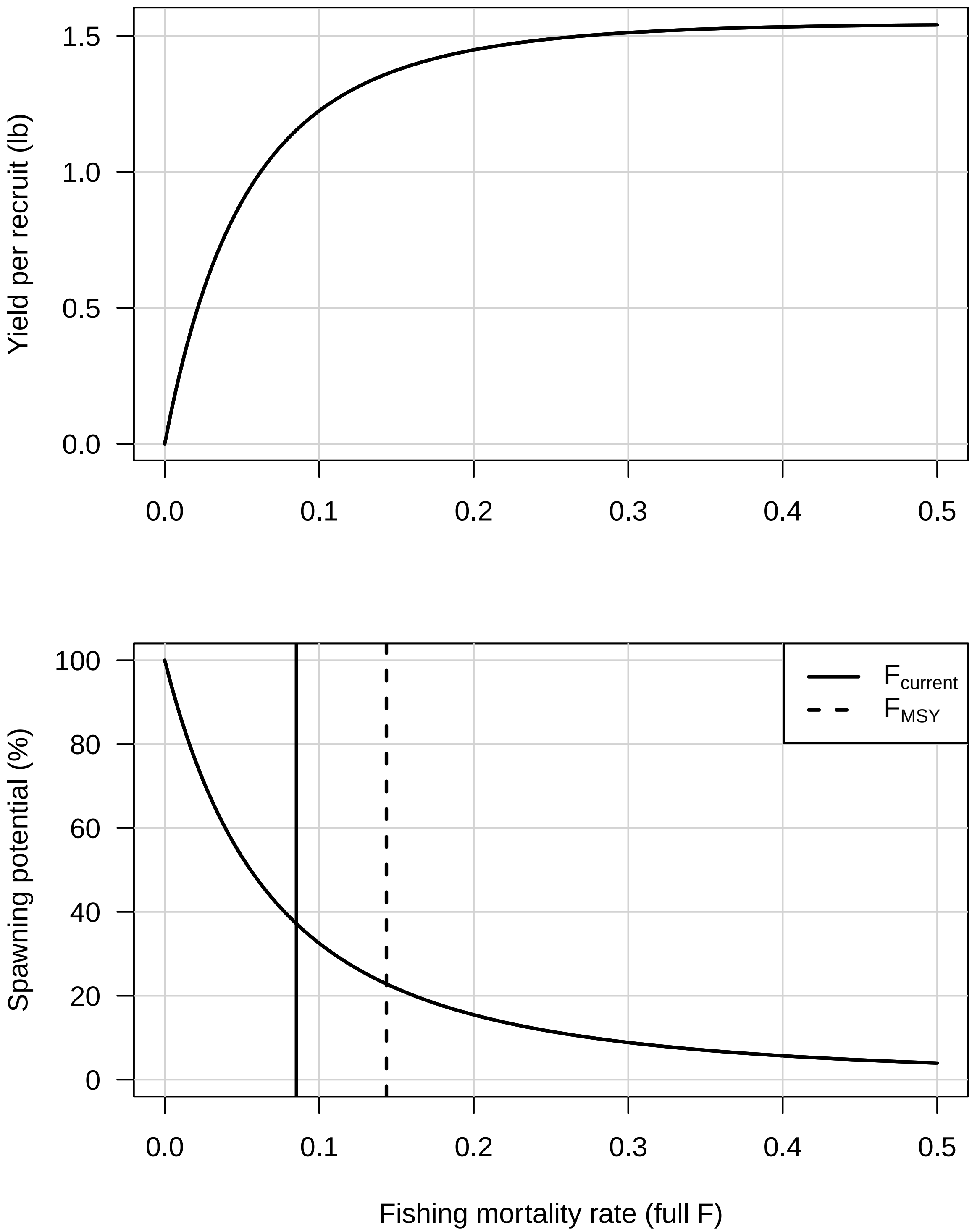


Figure 24. Top panel: equilibrium removals. The peak occurs where fishing rate is $F_{\mathrm{MSY}} = 0.14$ *and equilibrium landings are* $\mathrm{MSY} = 418.6$ *(1000 lb). Bottom panel: equilibrium spawning biomass. Both curves are based on average selectivity from the end of the assessment period.*

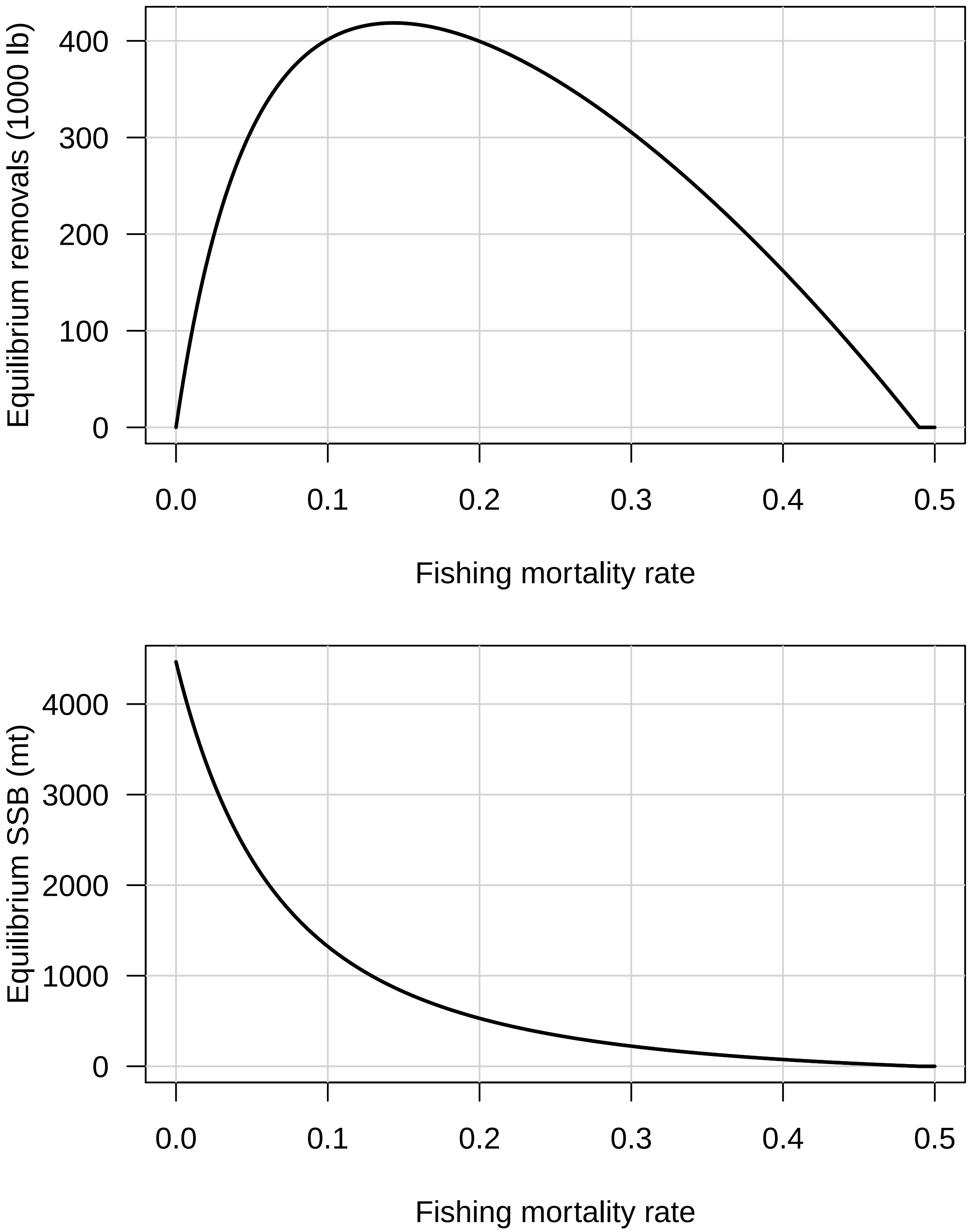


Figure 25. Equilibrium removals as a function of equilibrium biomass, which itself is a function of fishing mortality rate. The peak occurs where equilibrium biomass is $B_{\mathrm{MSY}} = 2091.7$ *mt and equilibrium removals are* $\mathrm{MSY} = 418.6$ *(1000 lb).*

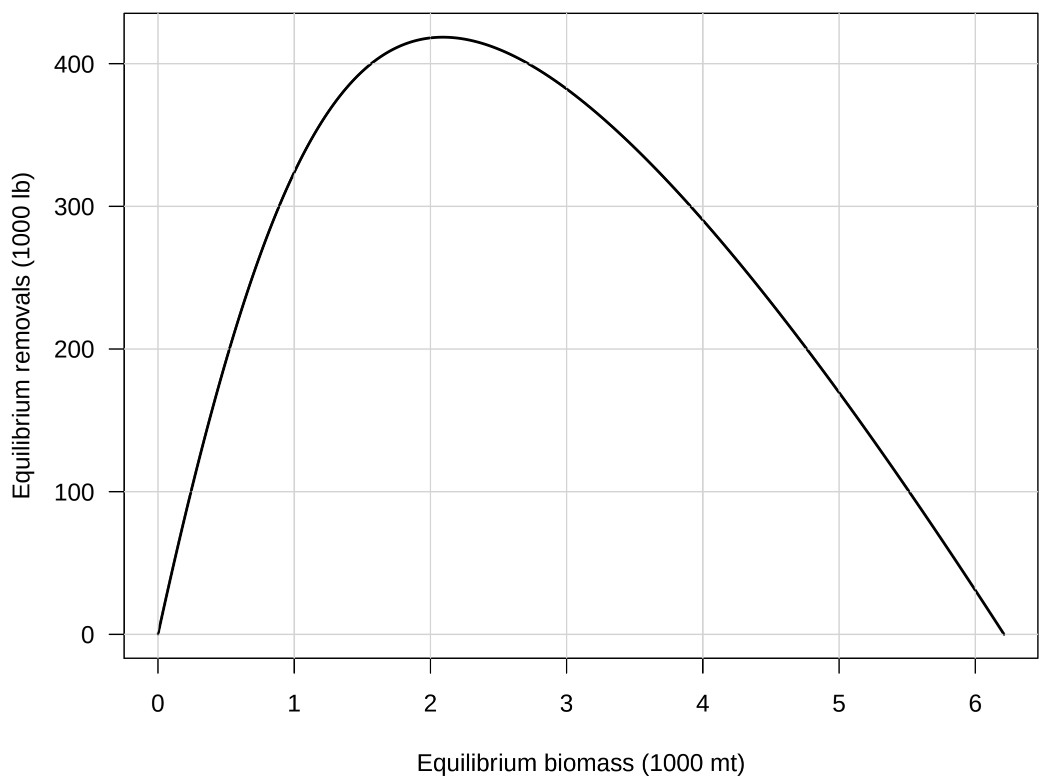


Figure 26. Probability densities of MSY*-related benchmarks from MCB analysis of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.*

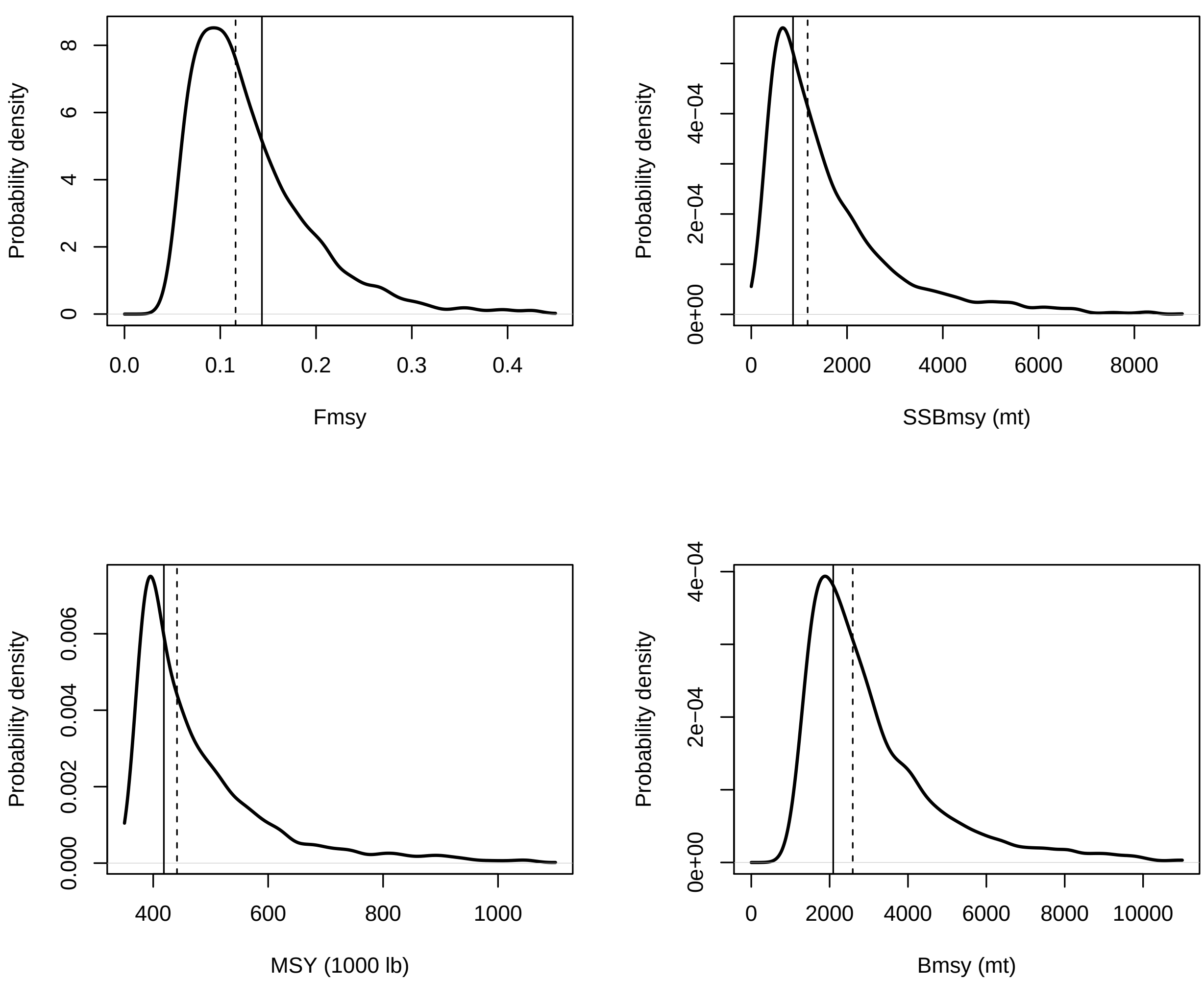


Figure 27. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; dashed lines represent median values; gray error bands indicate 5^{th} *and* 95^{th} *percentiles of the MCB trials. Top panel: spawning biomass relative to the minimum stock size threshold (*MSST*). Middle panel: spawning biomass relative to* $\mathrm{SSB}_{\mathrm{MSY}}$*. Bottom panel: F relative to* F_{MSY}*.*

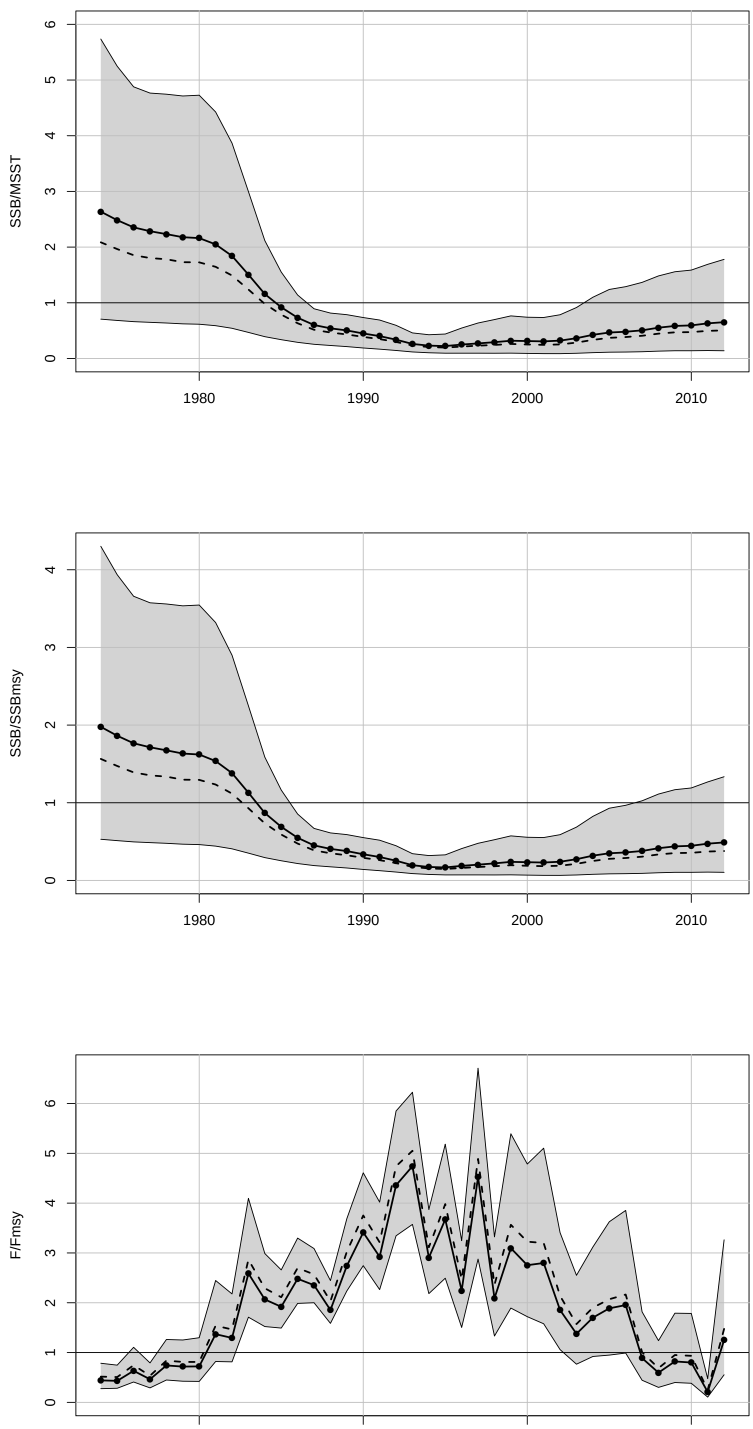


Figure 28. Probability densities of terminal status estimates from MCB analysis of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.

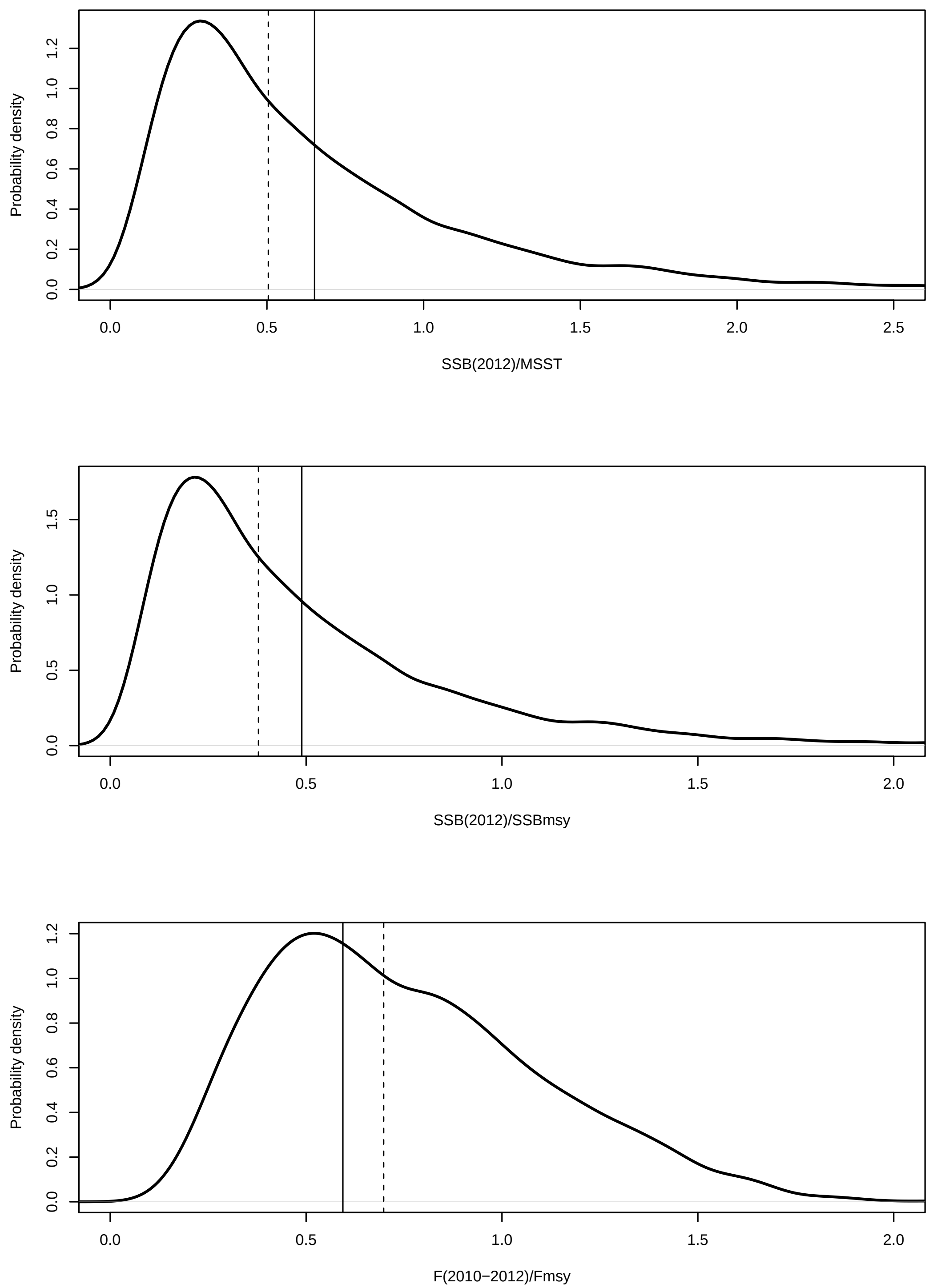
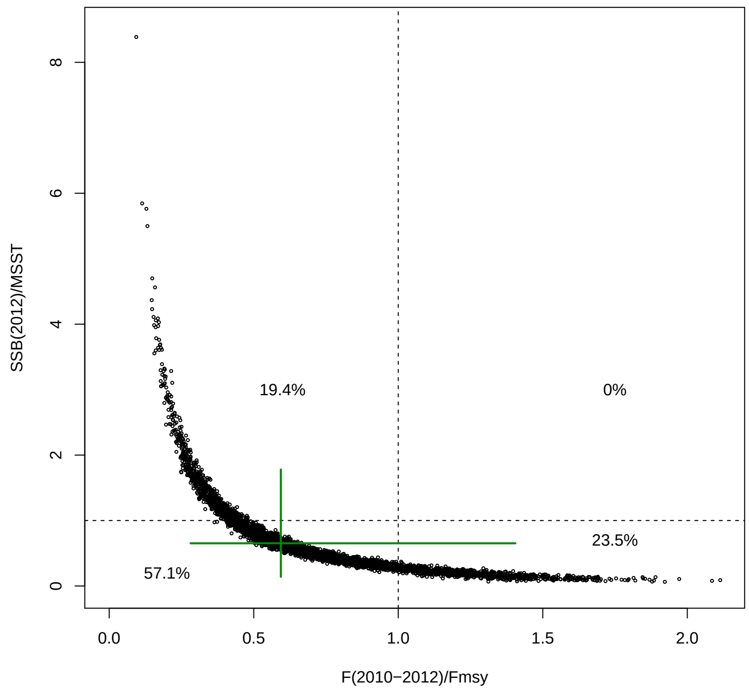


Figure 29. Phase plots of terminal status estimates from MCB analysis of the Beaufort Assessment Model. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by 5^{th} *and* 95^{th} *percentiles. Proportion of runs falling in each quadrant indicated.*



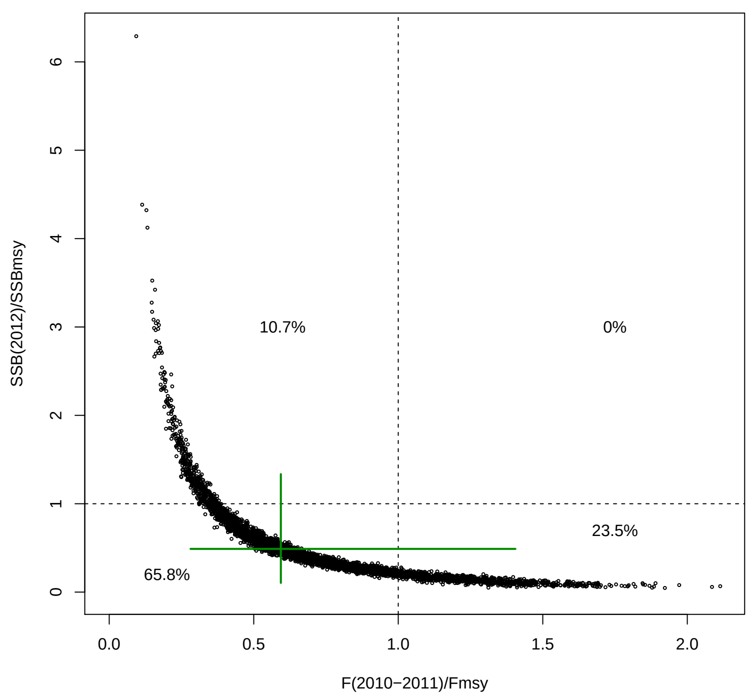


Figure 30. Age structure relative to the equilibrium expected at MSY*.*

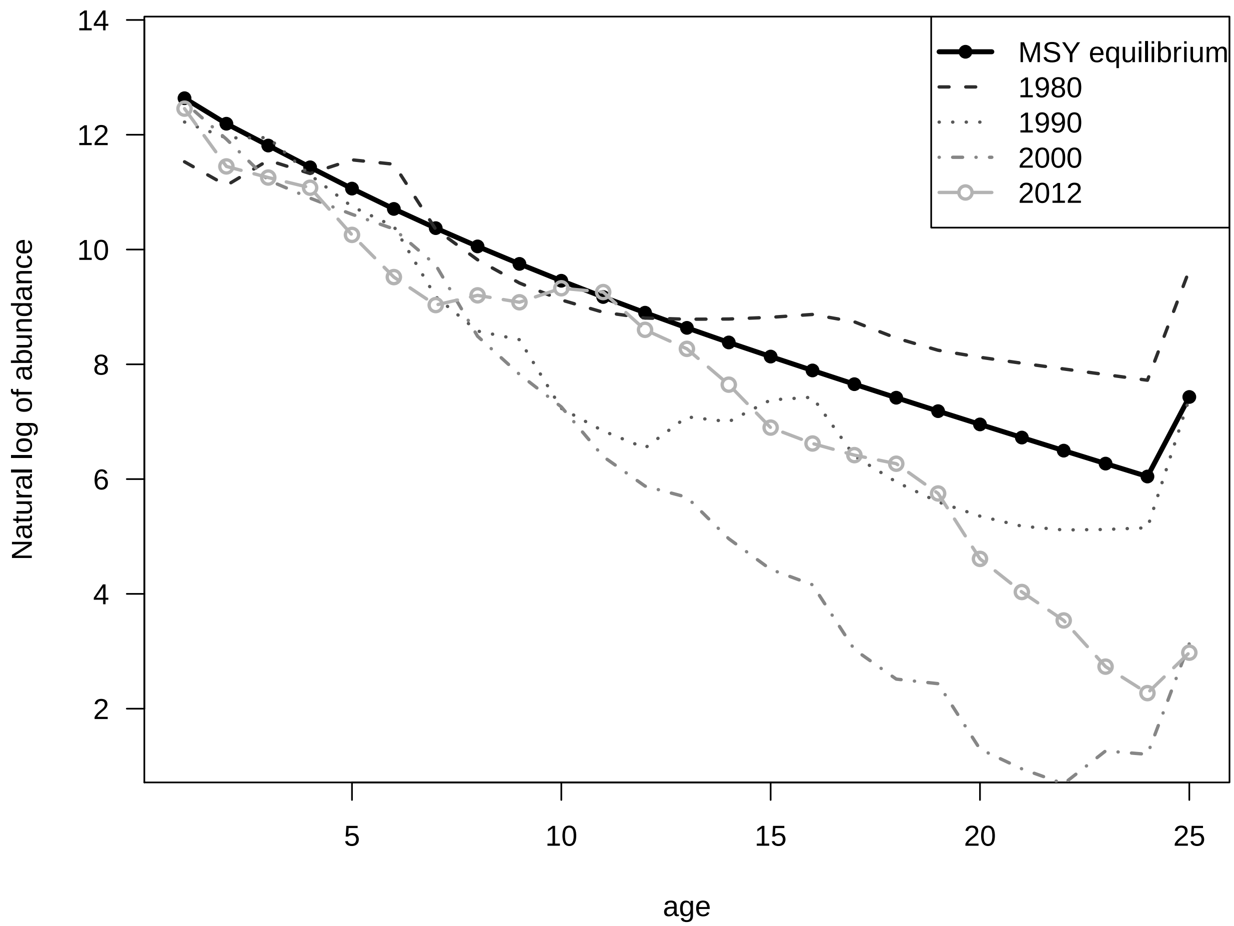
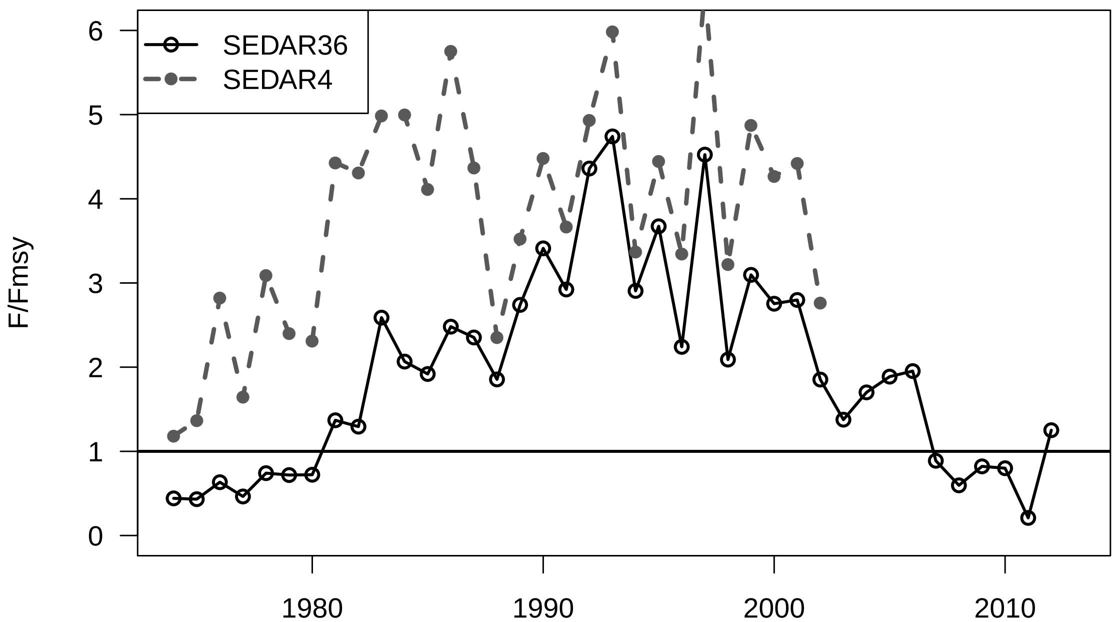


Figure 31. Comparison of results from this standard assessment and from the previous, SEDAR4 assessment. Top panel: F relative to F_{MSY}. Bottom panel: spawning biomass relative to the rebuilding target ($\mathrm{SSB}_{\mathrm{MSY}}$).



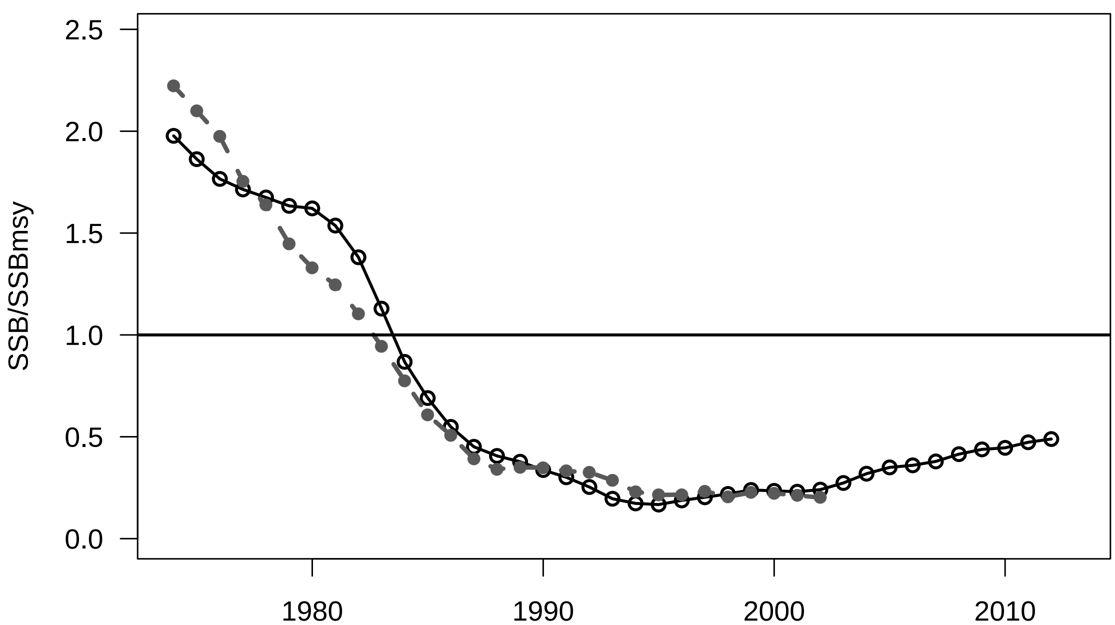


Figure 32. Sensitivity to changes in natural mortality (sensitivity runs S1–S2). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

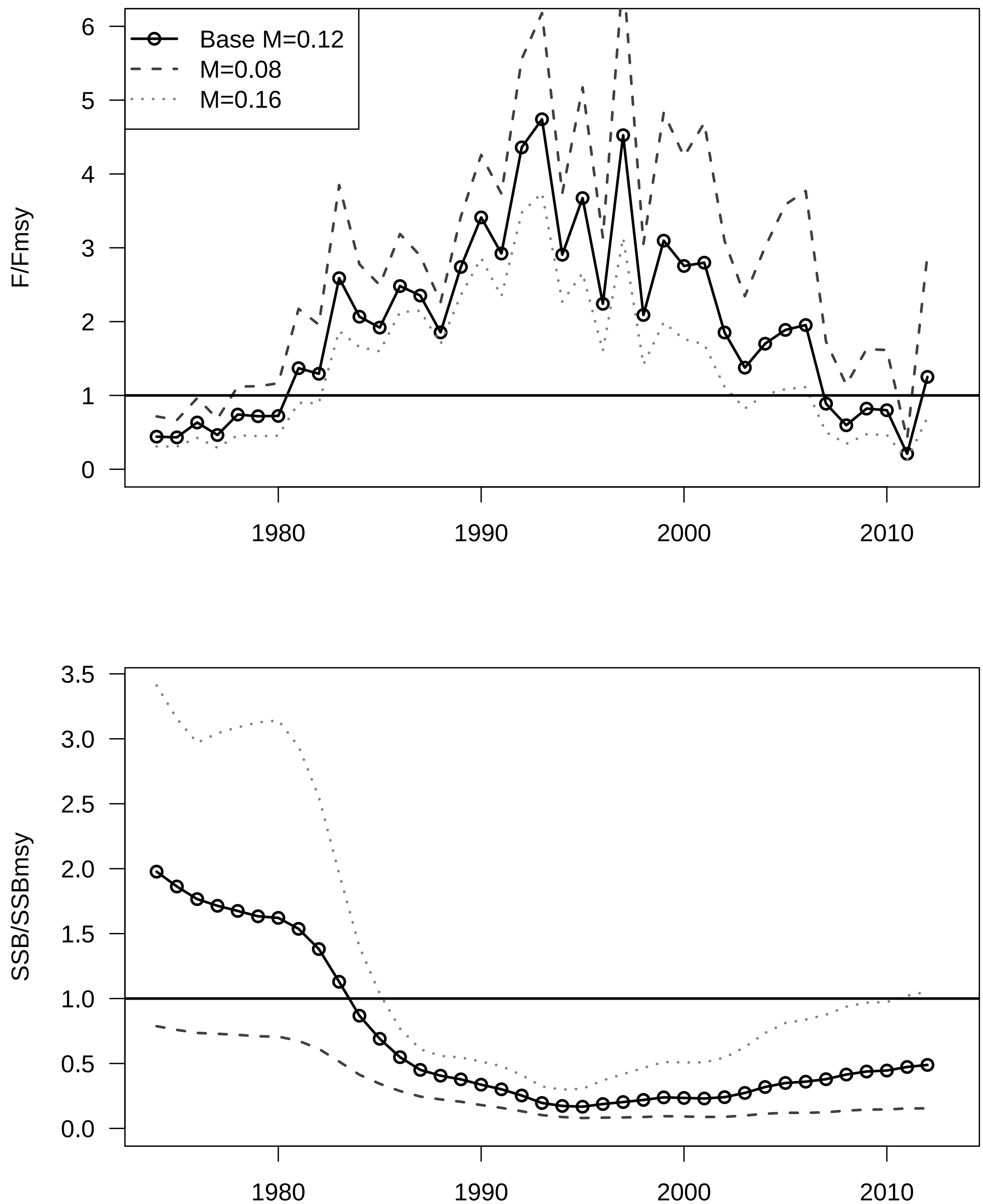


Figure 33. Sensitivity to steepness (sensitivity runs S3–S4). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

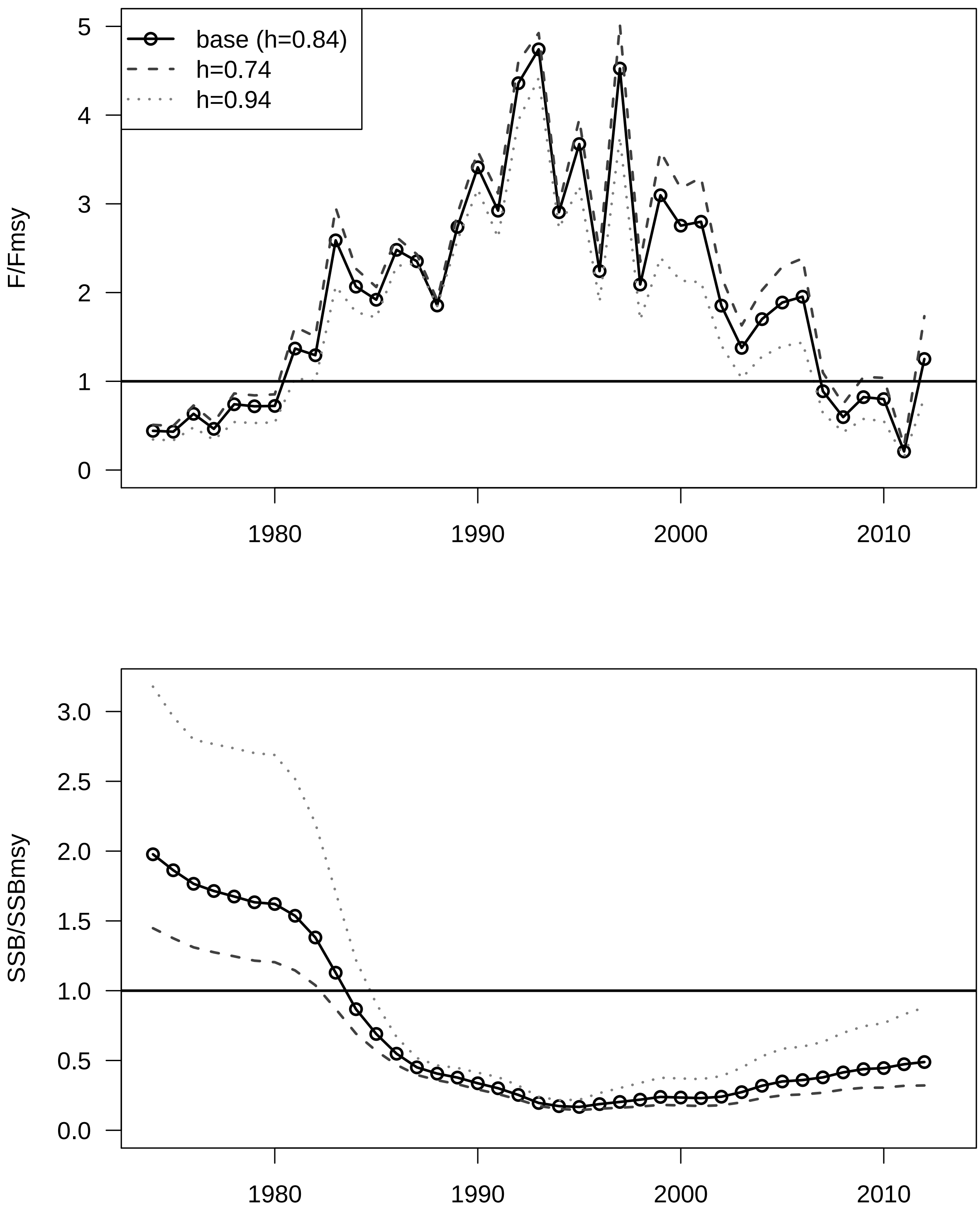


Figure 34. Sensitivity to initial (1974) conditions (sensitivity runs S5–S7). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

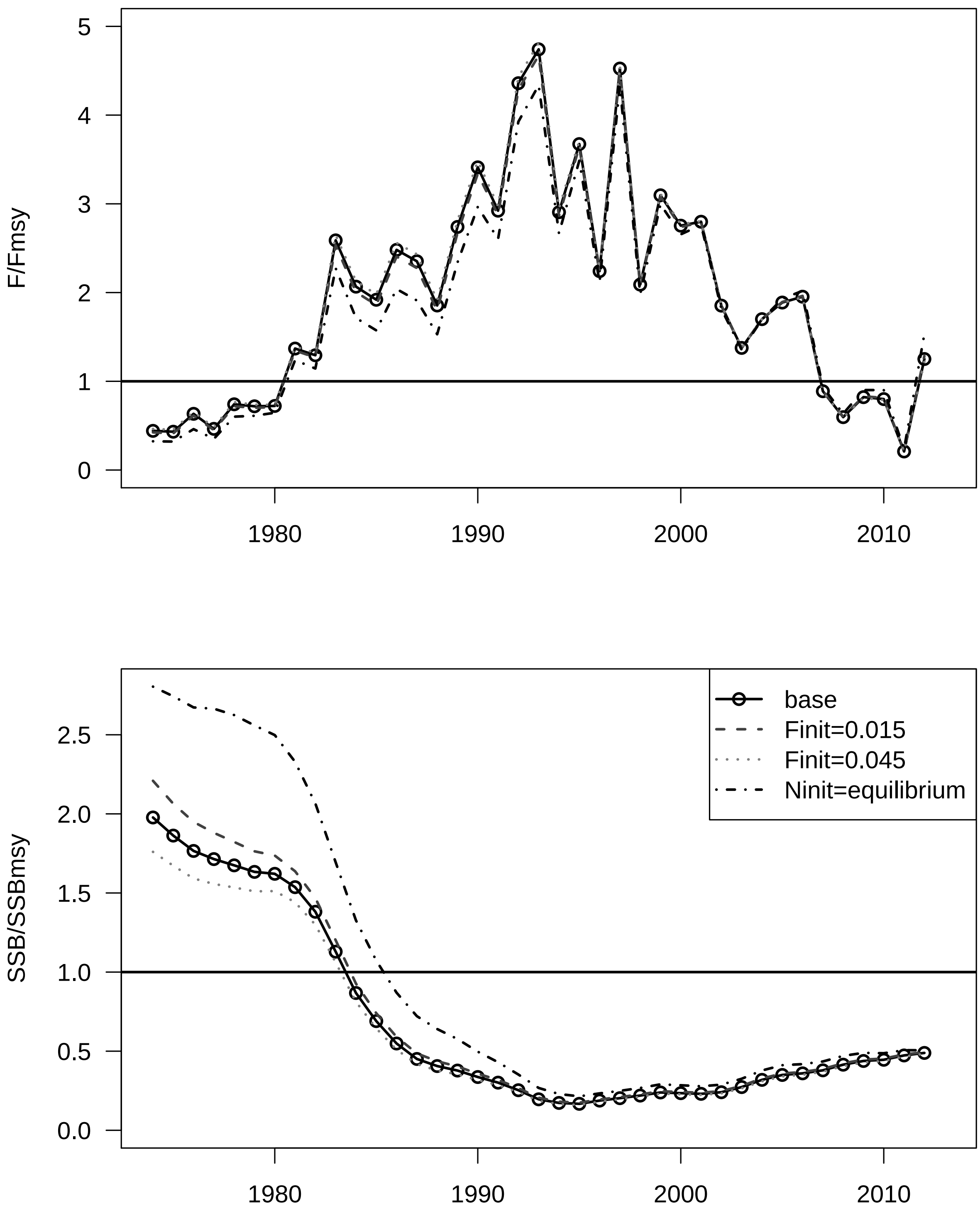


Figure 35. Sensitivity to the commercial handline index of abundance (sensitivity run S8). Top panel: Ratio of F to F_{MSY}. *Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

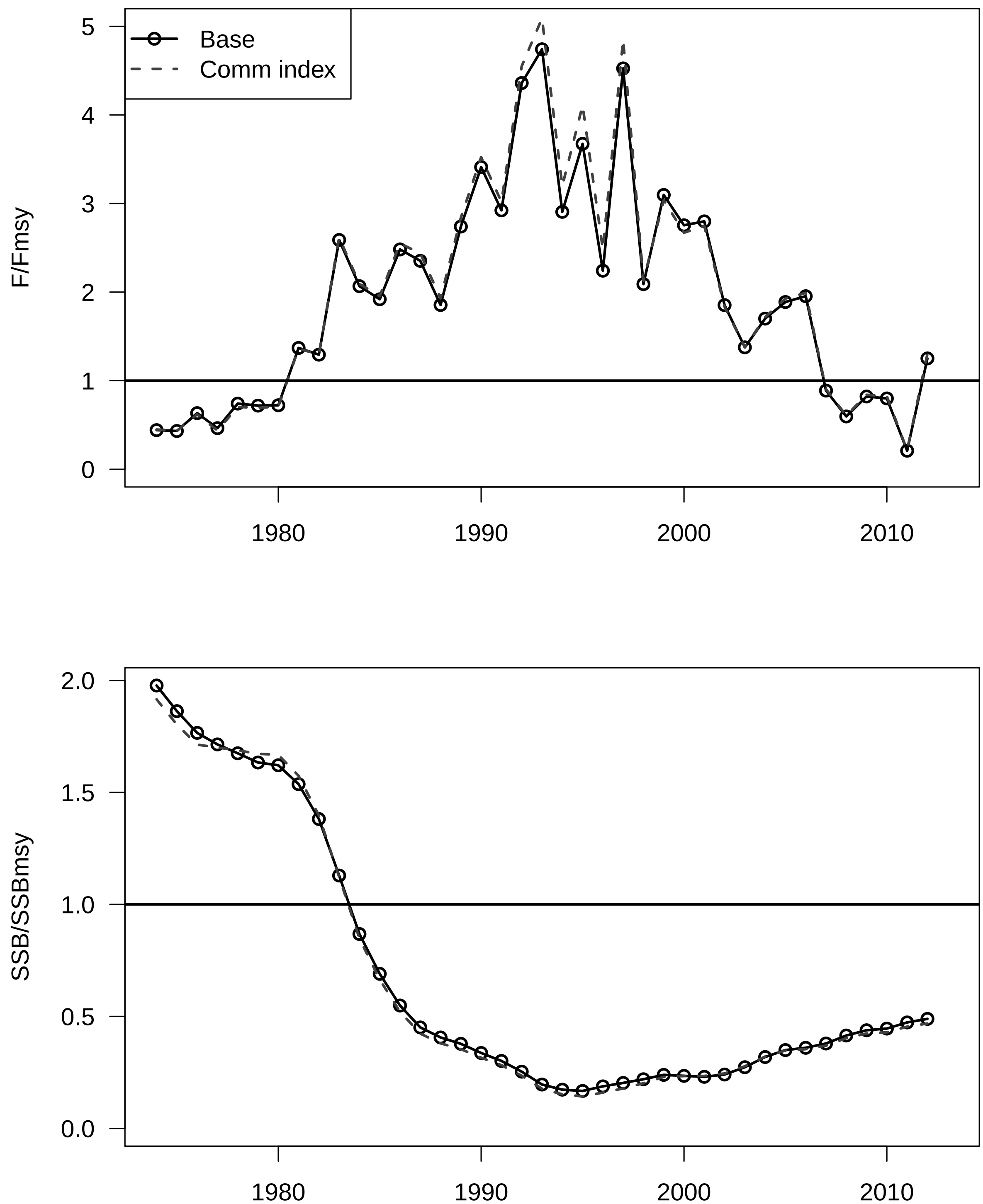


Figure 36. Sensitivity to weights applied to indices of abundance (sensitivity runs S9–S11). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$*.*

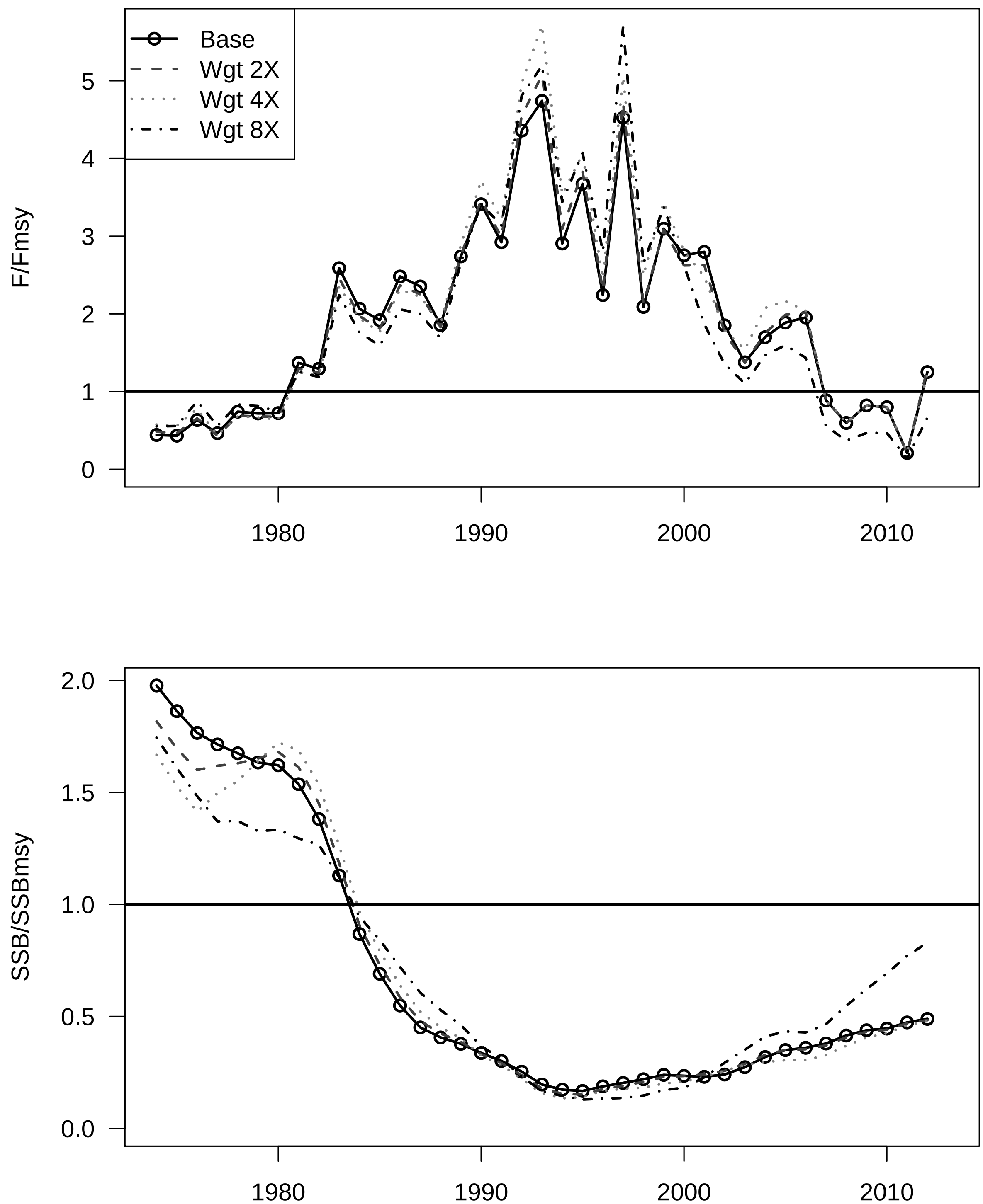


Figure 37. Sensitivity to selectivity blocks and commercial age compositions (sensitivity runs S12–S14). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

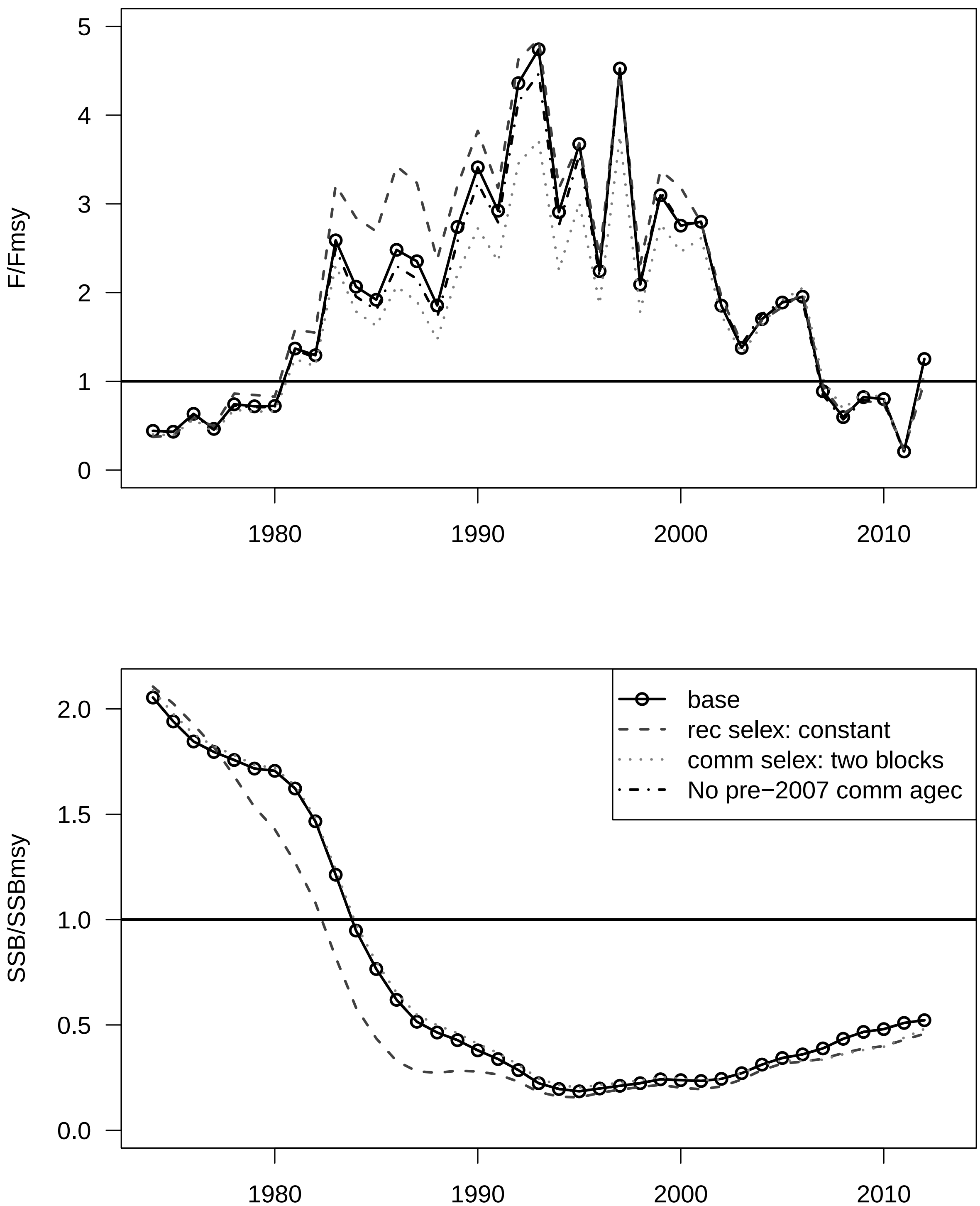


Figure 38. Sensitivity to the SEDAR4 configuration (sensitivity run S15). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

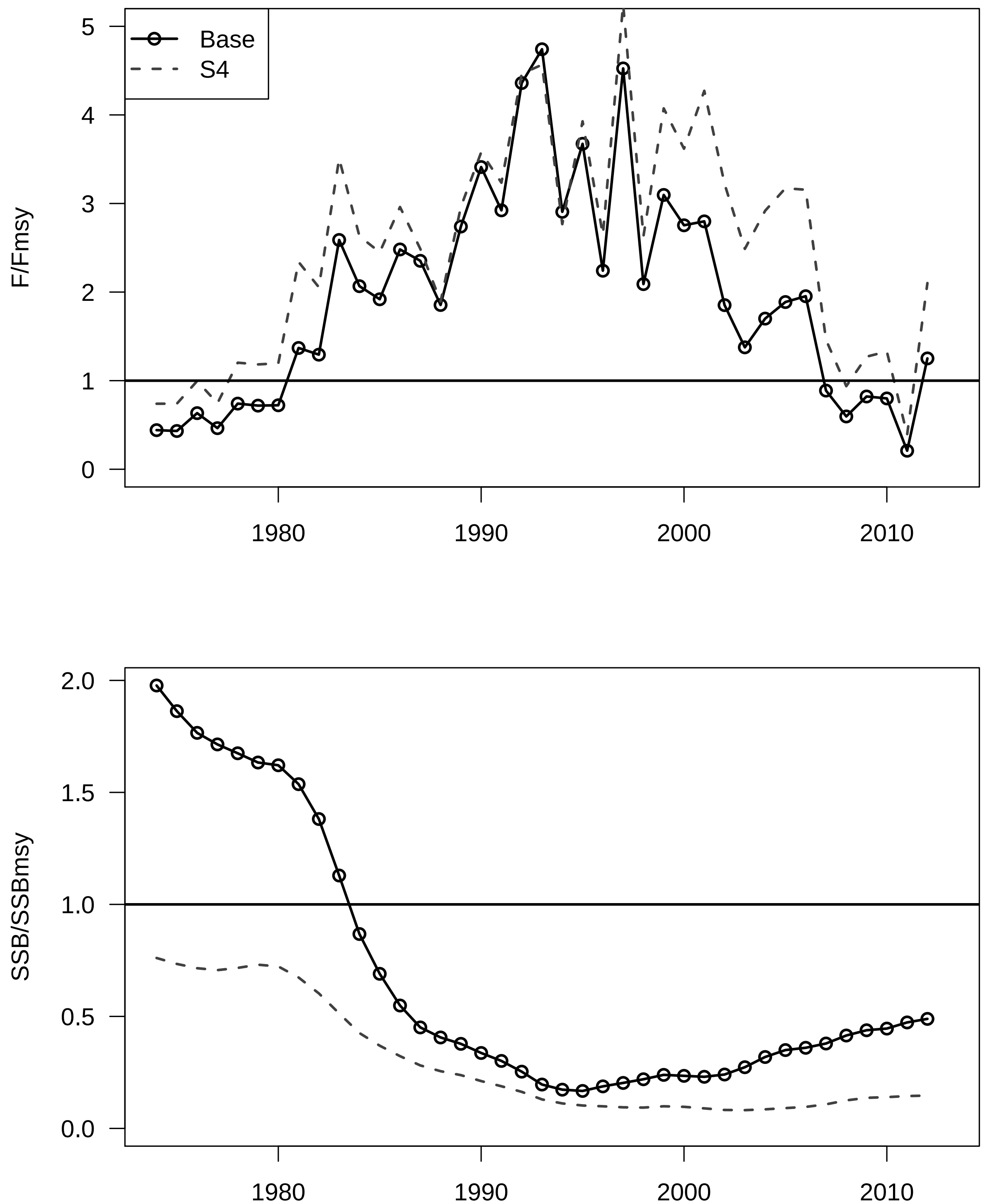


Figure 39. Sensitivity to measures of SSB *(sensitivity runs S16–S17). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

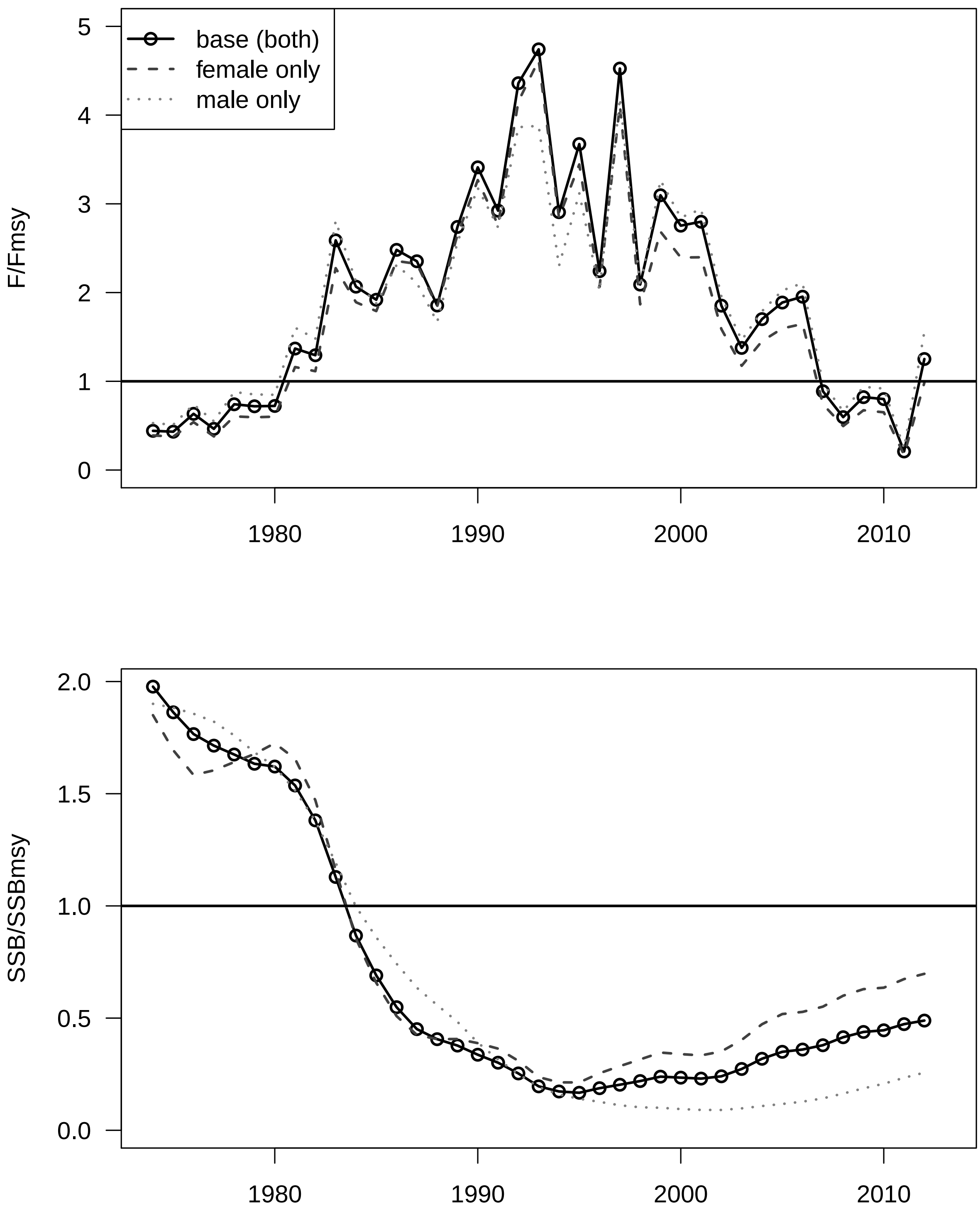


Figure 40. Phase plot of terminal status indicators from sensitivity runs of the Beaufort Assessment Model.

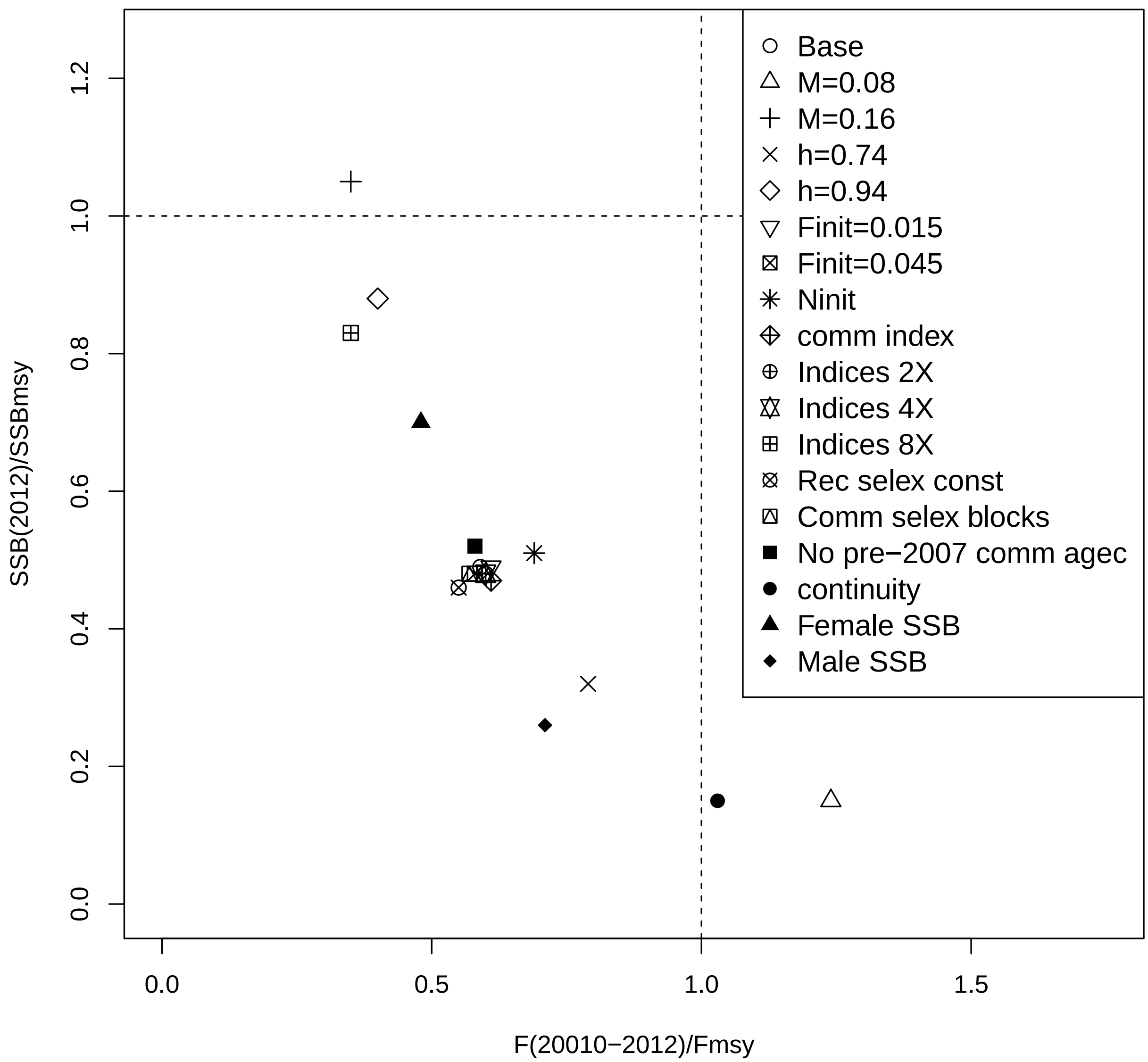


Figure 41. Retrospective analyses. Sensitivity to terminal year of data. Top panel: Fishing mortality rates. Middle panel: Recruits. Bottom panel: Spawning biomass. Closed circles show terminal-year estimates. Imperceptible lines overlap results of the base run.

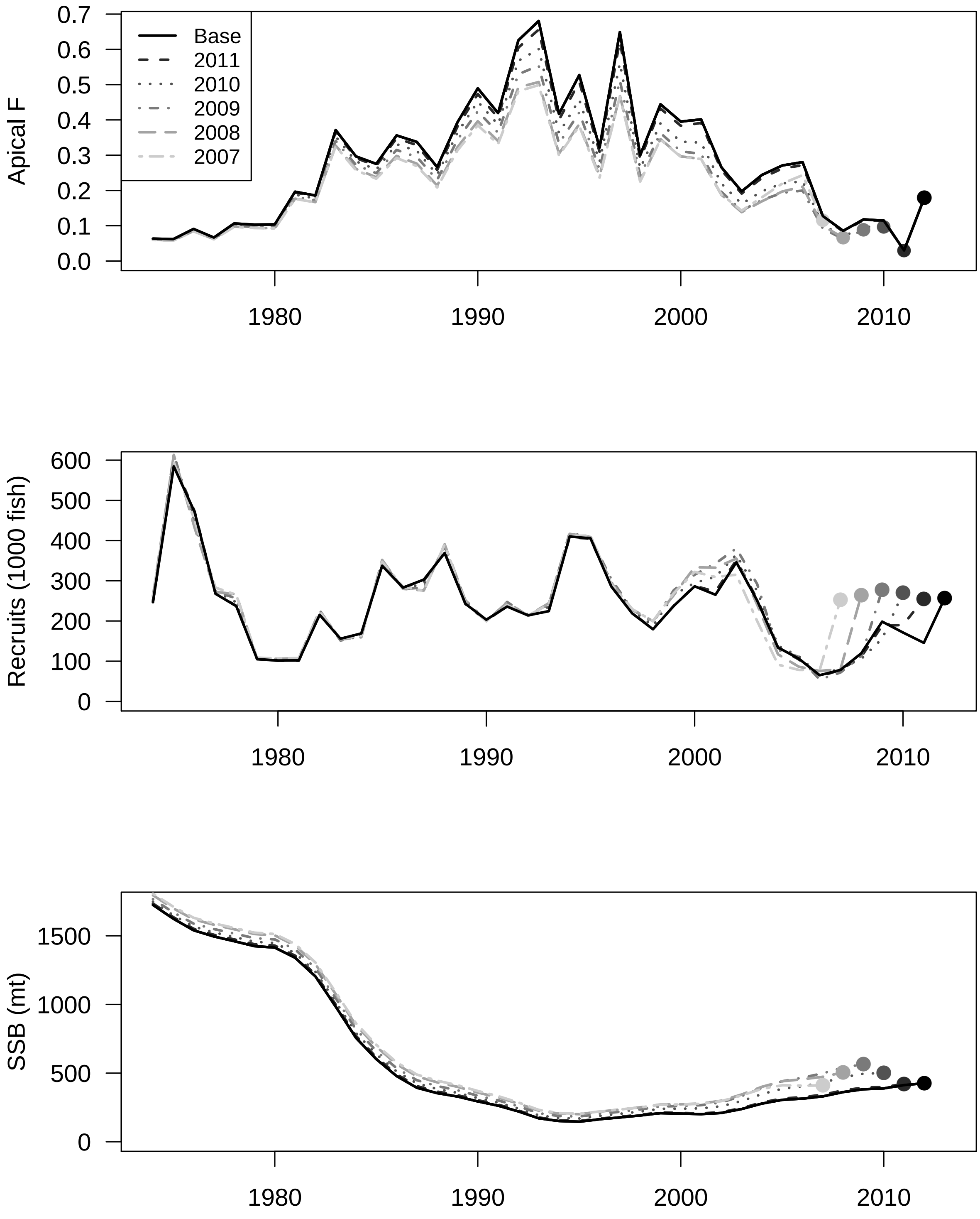
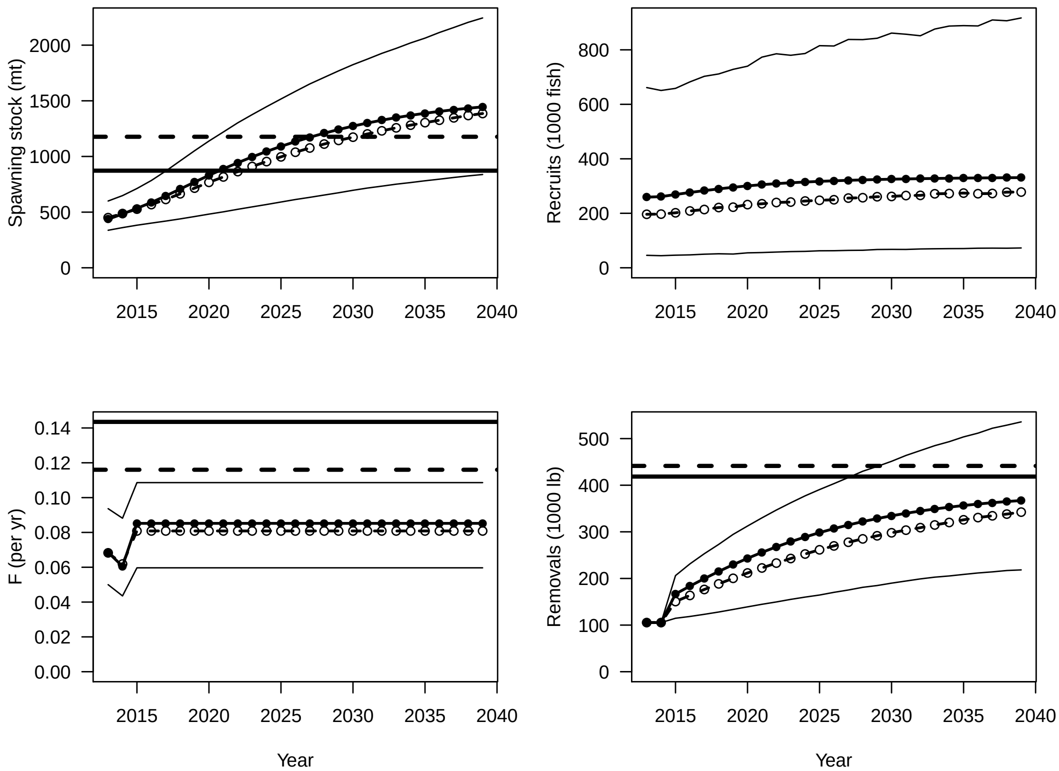


Figure 42. Projection results under scenario 1—fishing mortality rate at $F = F_{\mathrm{current}}$. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark MSY*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{MSY}}$.



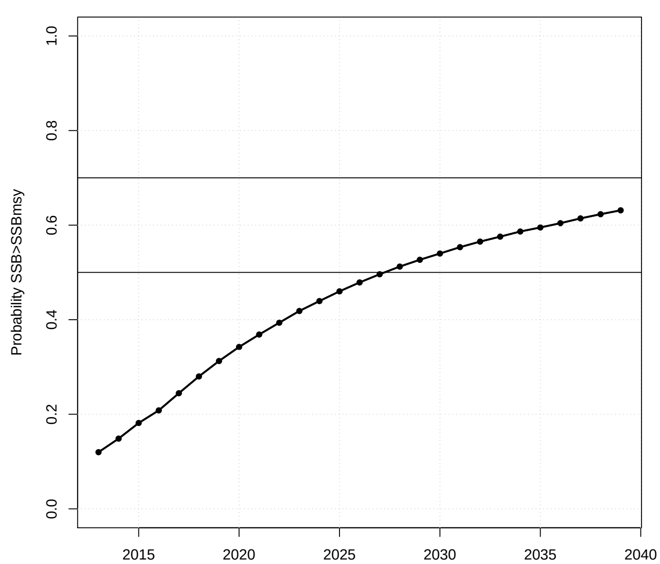


Figure 43. Projection results under scenario 2—fishing mortality rate at $F = F_{\mathrm{MSY}}$. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark MSY*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{MSY}}$.

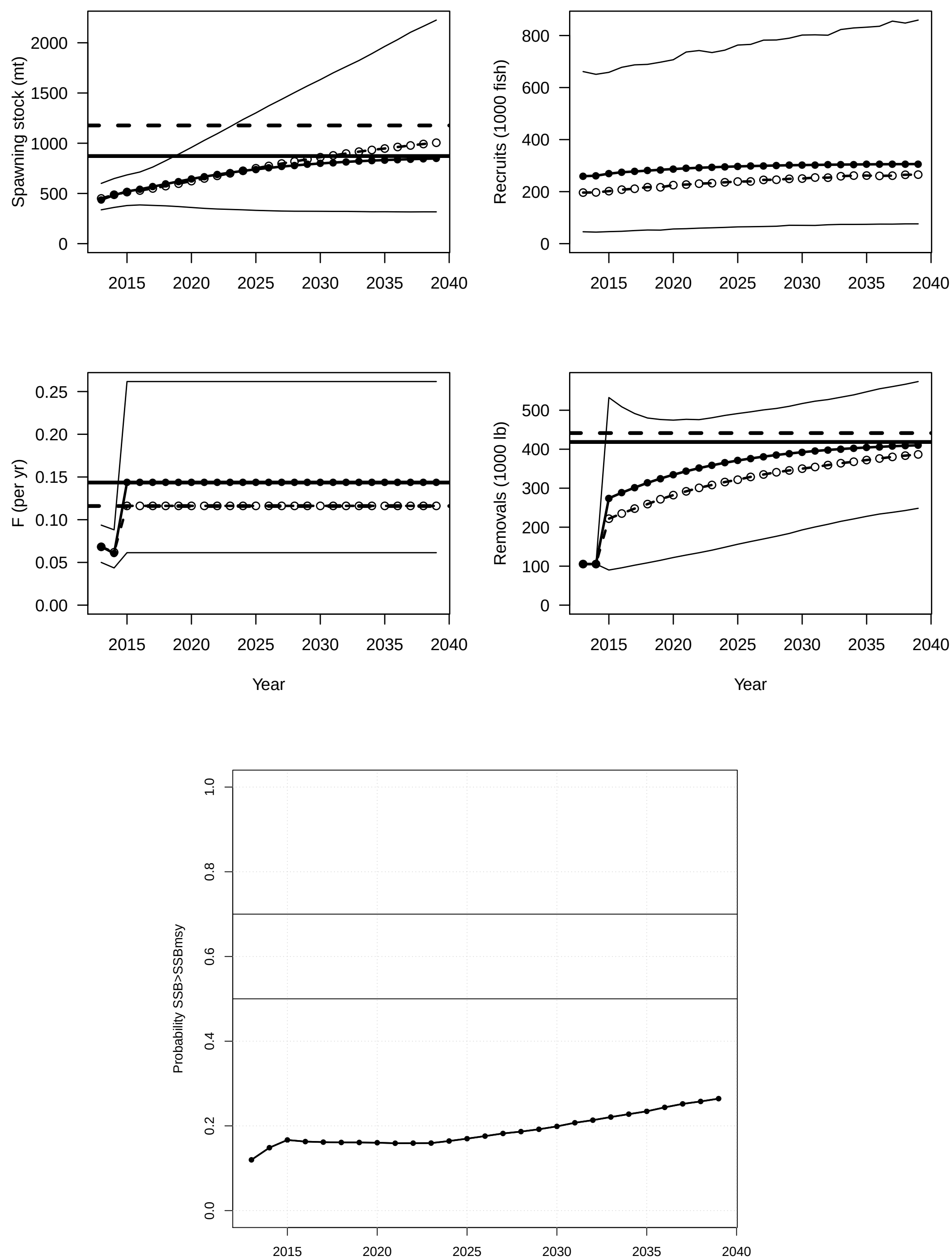


Figure 44. Projection results under scenario 3—fishing mortality rate at $F = 75\% F_{\mathrm{MSY}}$. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark MSY*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{MSY}}$.

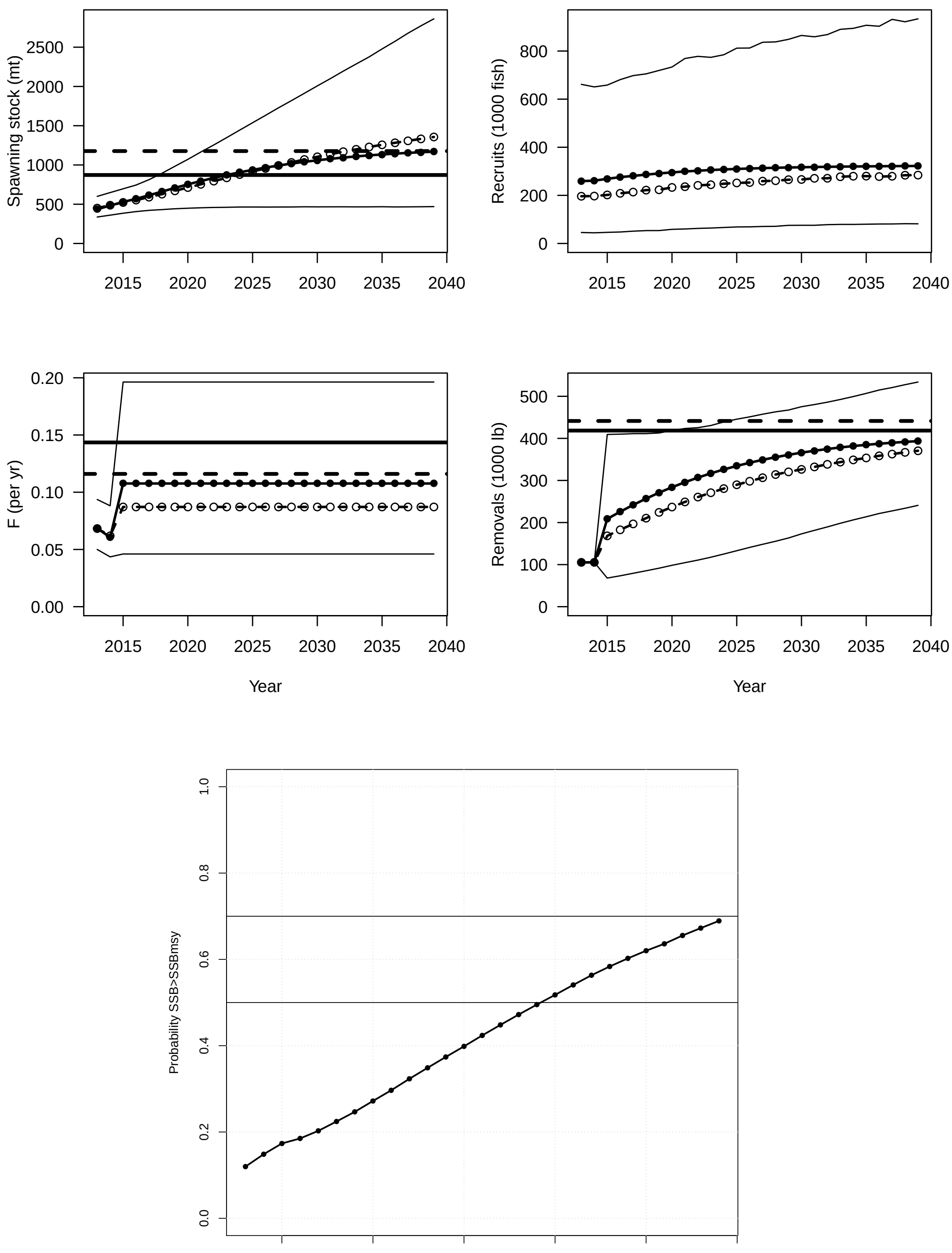


Figure 45. Projection results under scenario 4—fishing mortality rate at $F = F_{\mathrm{rebuild}}$, with rebuilding probability of 0.5 in 2039. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark MSY*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB_{MSY}}$.

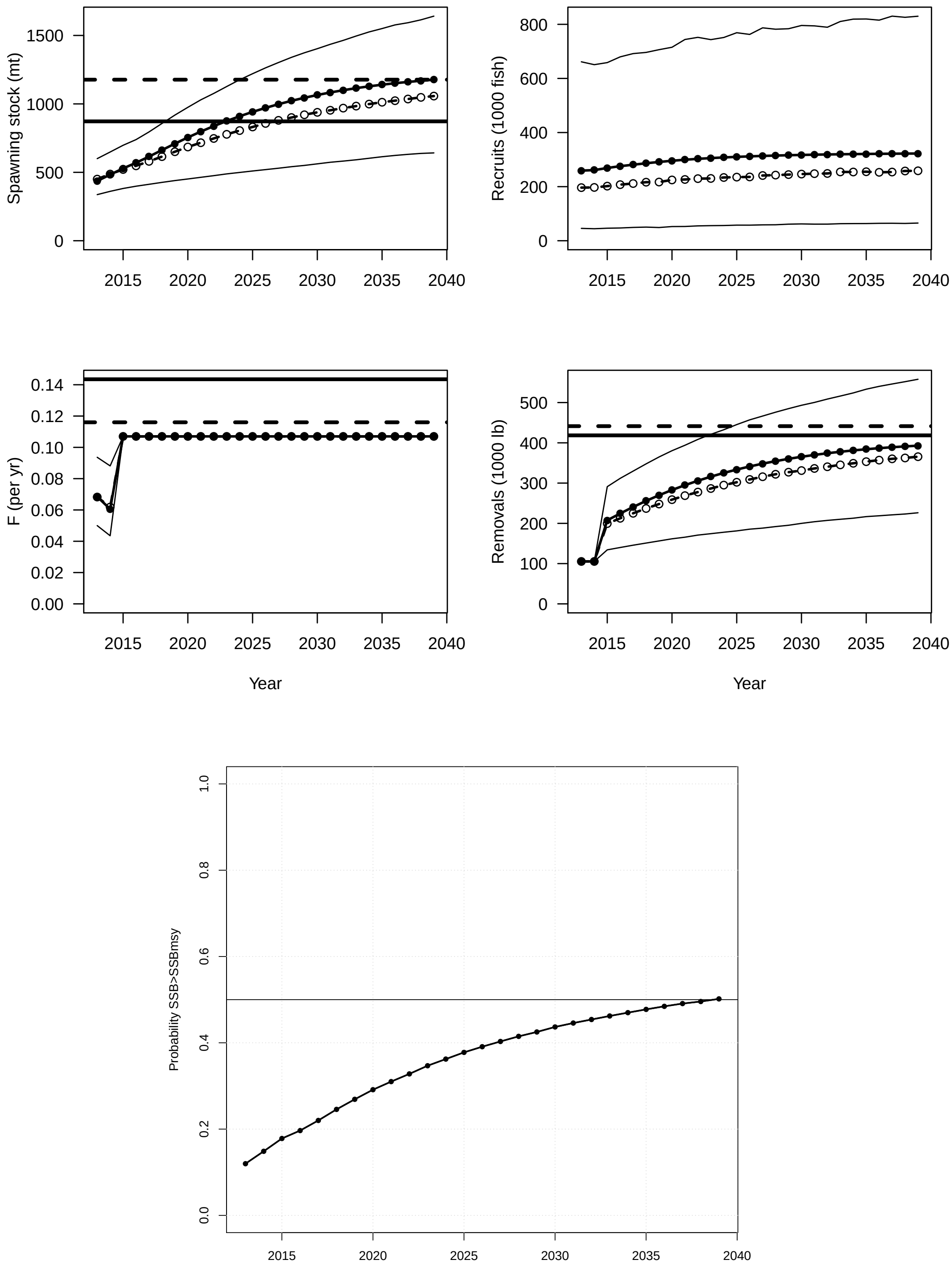
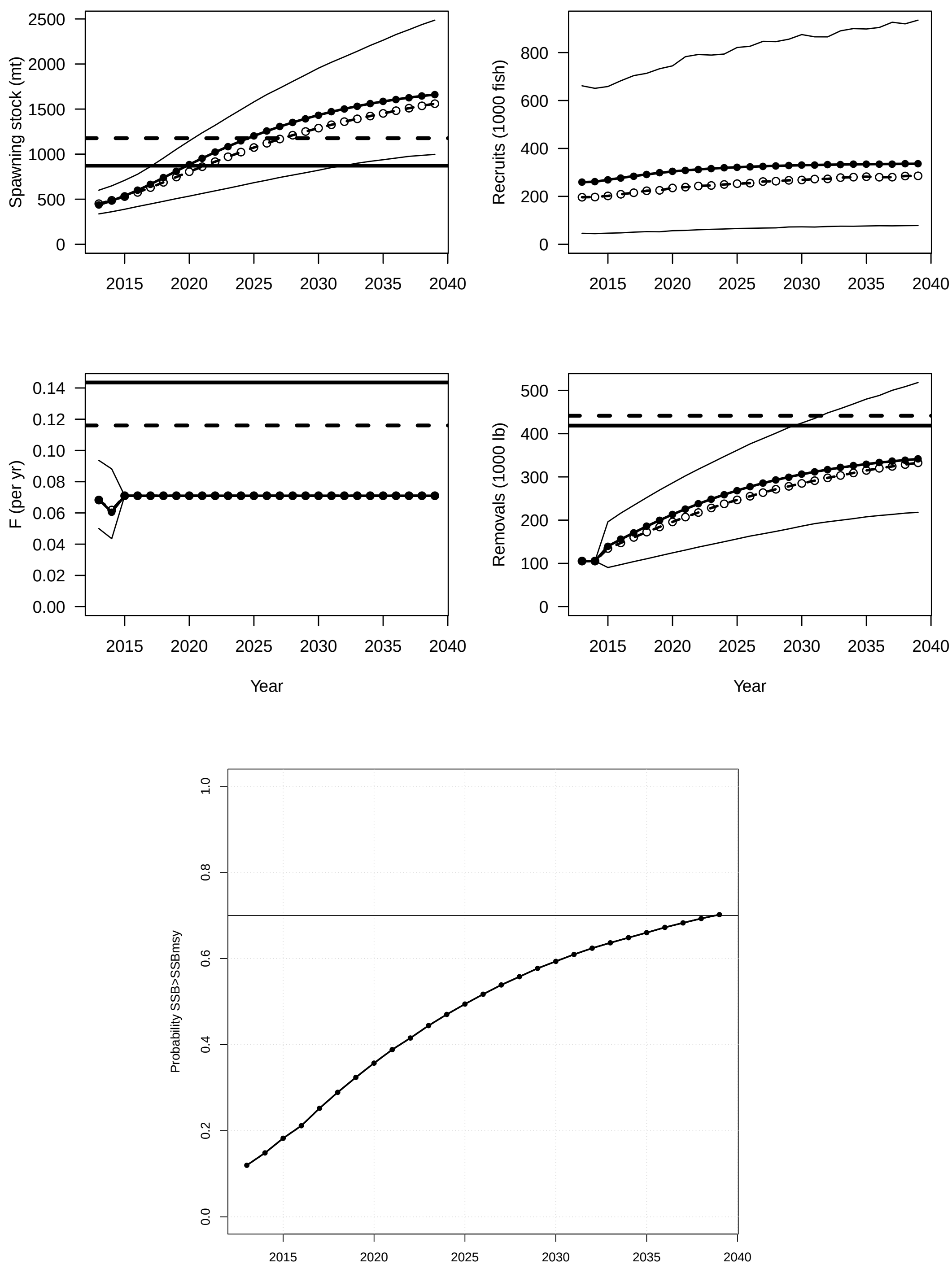


Figure 46. Projection results under scenario 5—fishing mortality rate at $F = F_{\text{rebuild}}$*, with rebuilding probability of 0.7 in 2039. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to* 5^{th} *and* 95^{th} *percentiles of replicate projections. Solid horizontal lines mark* MSY*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom 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 25. Acronyms and abbreviations used in this report

Symbol	Meaning
ABC	Acceptable Biological Catch
AW	Assessment Workshop (here, for snowy grouper)
ASY	Average Sustainable Yield
B	Total biomass of stock, conventionally on January 1
BAM	Beaufort Assessment Model (a statistical catch-age formulation)
CPUE	Catch per unit effort; used after adjustment as an index of abundance
CV	Coefficient of variation
DW	Data Workshop (here, for snowy grouper)
F	Instantaneous rate of fishing mortality
F_{MSY}	Fishing mortality rate at which MSY can be attained
FL	State of Florida
GA	State of Georgia
GLM	Generalized linear model
K	Average size of stock when not exploited by man; carrying capacity
kg	Kilogram(s); 1 kg is about 2.2 lb.
klb	Thousand pounds; thousands of pounds
lb	Pound(s); 1 lb is about 0.454 kg
m	Meter(s); 1 m is about 3.28 feet.
M	Instantaneous rate of natural (non-fishing) mortality
MARMAP	Marine Resources Monitoring, Assessment, and Prediction Program, a fishery-independent data collection program of SCDNR
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 snowy grouper as $(1 - M)\mathrm{SSB}_{\mathrm{MSY}} = 0.7\mathrm{SSB}_{\mathrm{MSY}}$.
MSY	Maximum sustainable yield (per year)
mt	Metric ton(s). One mt is 1000 kg, or about 2205 lb.
N	Number of fish in a stock, conventionally on January 1
NC	State of North Carolina
NMFS	National Marine Fisheries Service, same as "NOAA Fisheries Service"
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
OY	Optimum yield; SFA specifies that OY $\leq$ MSY.
PSE	Proportional standard error
R	Recruitment
SAFMC	South Atlantic Fishery Management Council (also, Council)
SC	State of South Carolina
SCDNR	Department of Natural Resources of SC
SDNR	Standard deviation of normalized residuals
SEDAR	SouthEast Data Assessment and Review process
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 = 202  Objective function value = -3693.52  Maximum gradient component = 1.85144e-005
# Linf:
1064.60000000
# K:
0.0940000000000
# t0:
-2.88000000000
# len_cv_val:
0.134394673313
# log_Nage_dev:
 -0.482835369238 -0.678418725968 -0.784836202679 -0.824842510713 -0.759028390995 -0.621244459294 -0.464202828672 -0.288307844878 -0.104691952253 -0.108718871821
 -0.270253337718 -0.359197476438 -0.358504579265 -0.337501034221 -0.313964473687 -0.290897371345 -0.268594136004 -0.247169400248 -0.226809723693 -0.207546386514
 -0.189350807335 -0.172340334628 -0.156044415811 -0.712460896236
# log_R0:
12.6328107703
# steep:
0.840000000000
# rec_sigma:
0.553100230928
# R_autocorr:
0.000000000000
# log_rec_dev:
 -0.192164341586 0.701504517094 0.491467677640 -0.0673037964825 -0.186473477560 -0.995505579348 -1.02726576831 -1.02346367750 -0.269374479279 -0.577876882425
 -0.467044194940 0.271591197418 0.146178678298 0.274279746461 0.531400207343 0.147641954033 -0.00370592987169 0.188753798386 0.136746829678 0.260906369883
 0.990842231805 1.04727653410 0.715626972888 0.386383367347 0.145184246252 0.387322653942 0.531514204796 0.464039119262 0.738806616799 0.396452043294
 -0.287506226794 -0.587095190618 -1.11311505979 -0.940456364792 -0.533780992901 -0.0609211902823 -0.226630480285 -0.394235333946
# selpar_L50_cvt:
3.28552405794
# selpar_slope_cvt:
2.28466470140
# selpar_afull_cvt:
6.00000000000
# selpar_sigma_cvt:
0.646184215715
# selpar_L50_vll:
4.49093797994
# selpar_slope_vll:
2.18975996682
# selpar_L50_cH:
2.36986344571
# selpar_slope_cH:
2.13042651219
# selpar_L50_cL:
4.04309020307
# selpar_slope_cL:
1.65546830401
# selpar_L50_rec:
3.32025110667
# selpar_slope_rec:
1.57673156250
# selpar_afull_rec:
11.0000000000
# selpar_sigma_rec:
1.92906620905
# selpar_L50_rec2:
2.70057628113
# selpar_slope_rec2:
0.362910065524
# selpar_afull_rec2:
6.00000000000
# selpar_sigma_rec2:
1.34118116536
# selpar_L50_rec3:
3.24912979679
# selpar_slope_rec3:
1.57026729521
# selpar_afull_rec3:
8.00000000000
# selpar_sigma_rec3:
8.49733882326
# log_q_cvt:
-11.6431172529
# log_q_vll:
-11.3707910157
# log_q_rec:
-12.2553744302
# log_q_cH:
-8.00000000000
# M_constant:
0.120000000000
# log_avg_F_rec:
-3.73052952587
# log_F_dev_rec:
 -0.109721228490 -0.659698645828 0.139029463259 -0.778917072959 -1.39449167569 -0.896073423304 -0.0987323333543 0.430491491251 0.100898816144
 0.869319269110 -0.495644336133 -0.438615592451 0.330963963263 -0.174997895406 -0.669520046413 -0.758827319073 -1.27812349291 -2.02172316328
 -0.0683279184026 1.17053756572 -1.13599806233 1.17455664801 -0.673648178778 1.55668932901 -2.05878550946 0.778075210309 -0.0435119205927
 1.56486419002 0.436908961918 0.309339087612 1.06101805945 1.55587061780 1.50020223700 0.459260295435 -0.0458566294996 0.813901529912 0.627130411796
 -2.66734722614 1.58950452350
# log_avg_F_cH:
```

```
-2.06569575289
# log_F_dev_cH:
 -1.10706280424 -0.938372391334 -0.693240279654 -0.824247560141 -0.356840602906 -0.425221644585 -0.576032358435 0.148146111314 0.00270322317635
 0.396187660940 0.268077270872 0.264348928491 0.413543238183 0.180662812164 -0.132069595321 0.468750286166 0.672607523194 0.652556878229 0.874708502269
 0.729703330967 0.431463845017 0.719603979184 0.433370256235 0.728549976737 0.336718877735 0.769757622707 0.614169583117 0.566218340246 0.401120955980
 0.0719866516722 -0.0852117925580 -0.0410214354791 0.0412170842172 -0.387995472116 -0.880320528975 -0.809564949963 -0.638640973734 -1.53800701326 -0.752323536105
# log_avg_F_cL:
-3.02954800395
# log_F_dev_cL:
 -1.37619729066 -1.48676865453 -1.46810244565 -1.29846587456 -0.371054236173 0.996378568523 0.916721325102 0.713132910156 1.03656701487 1.27072259799
 1.12193670184 1.34536768080 1.59909741034 1.28969502123 1.82454912017 1.95262934943 1.48948084311 1.36654761390 0.858936810009 1.73265764104
 0.904897846275 0.898057330351 1.05076264783 0.276607927202 -0.200456456916 -0.521237610665 0.190257882449 -0.304176310681 -0.168969693205 -2.61213201089
 -1.56542751113 -1.87787732861 -2.80139180687 -3.74115043605 -3.04159657600
# F_init:
0.0300000000000
```