Southeast Data, Assessment, and Review

SEDAR 53

Stock Assessment Report

South Atlantic Red Grouper

February 2017

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

Please cite this document as:

SEDAR. 2017. SEDAR 53 – South Atlantic Red Grouper Assessment Report. SEDAR, North Charleston SC. 159 pp. available online at: http://sedarweb.org/sedar-53 .

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SECTION I: Introduction

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I. Introduction

1. SEDAR Process Description

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

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

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

SEDAR workshops 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 red grouper fisheries and harvest.

Original SAFMC Fishery Management Plan

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

SAFMC FMP Amendments affecting red grouper

Description of Action	FMP/Amendment	Effective Date
Establish a 12" total length minimum size limit for red grouper. Established a 4" trawl mesh size.	Original FMP	8/31/83
Prohibit trawls to harvest fish south of Cape Hatteras, NC and north of Cape Canaveral, FL; directed fishery as vessel with trawl gear and ≥200 lb snapper grouper species on board	Amendment 1 (SAFMC 1988)	1/12/89
Prohibit fish traps, entanglement nets & longlines within 50 fathoms; defined overfishing/overfished and established rebuilding timeframe: groupers ≤ 15 years (year 1 = 1991); aggregate bag limit of 5 groupers per person per day excluding Nassau and goliath grouper[1];	Amendment 4 (SAFMC 1991)	1/1/92

Red grouper 20" TL commercial and recreational minimum size limit		
Included golden tilefish in grouper recreational aggregate bag limit; created *Oculina* Experimental Closed Area	Amendment 6 (SAFMC 1993)	7/27/94
Required dealer, charter and headboat federal permits; allowed sale under specified conditions; specified allowable gear and made allowance for experimental gear; allowed multi-gear trips in NC; added localized overfishing to list of problems and objectives; adjusted bag limit and crew specs. for charter and head boats	Amendment 7 (1994)	1/23/95
Limited entry program: transferable permits and 225-lb non-transferable permits	Amendment 8 (SAFMC 1997)	12/14/98
Within the 5 fish aggregate grouper bag limit, no more than 2 fish may be gag or black grouper (individually or in combination); black grouper (recreational and commercial): no harvest or possession > bag limit, and no purchase or sale during March and April; vessels with longlines may only possess deepwater species, Specified 20 " minimum size limit for red grouper.	Amendment 9 (SAFMC 1998a)	2/24/99
Identified essential fish habitat (EFH) and established habitat areas of particular concern (HAPC) for species in the snapper grouper FMU	Amendment 10 (SAFMC 1998b)	7/14/00
MSY proxy for red grouper is 30% static SPR; OY proxy is 45% static SPR; Overfishing level = F>F30% static SPR. Approved definitions for overfished and overfishing. MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}. MFMT = F_{MSY}.	Amendment 11 (SAFMC 1998c)	12/2/99

Extended for an indefinite period the regulation prohibiting fishing for and possessing snapper grouper species within the *Oculina* Experimental Closed Area.	Amendment 13A (SAFMC 2003)	4/26/04
Established eight deepwater Type II marine protected areas to protect a portion of the population and habitat of long-lived deepwater snapper grouper species	Amendment 14 (SAFMC 2007)	2/12/09
Prohibited the sale of bag-limit caught snapper grouper species	Amendment 15B (SAFMC 2008)	2/15/10
Reduced the 5 aggregate grouper bag limit to 3; recreational and commercial shallow water grouper spawning closure January through April; captain and crew on for-hire trips cannot retain the bag limit of vermilion snapper and species within the 3-fish grouper aggregate; Reduce the 2 gag/black bag (individually or in combination) bag limit from 2 to 1; when gag quota met, prohibit harvest of, possession, and retention of shallow water groupers (which includes red grouper)	Amendment 16 (SAFMC 2009)	7/29/09
Required use of non-stainless steel circle hooks when fishing for snapper grouper species with hook-and-line gear north of 28 deg. N latitude in the South Atlantic EEZ	Amendment 17A (SAFMC 2010a)	3/3/11
Specified AMs for red grouper: of overfished and sector ACL is met or projected to be met, prohibit harvest and retention. If ACL exceeded, independent of stock status, reduce sector ACL in the following fishing season by amount of overage. Rec ACL compared to rec landings using only 2010 landings for	Amendment 17B (SAFMC 2010b)	1/30/11

2010, an average of 2010 and 2011 for 2011, and a 3-year running average for 2012 and beyond; established aggregate ACLs (commercial and recreational) for gag, black grouper and red grouper; prohibited commercial possession of shallow water groupers (incl. red grouper) when gag ACL or aggregate (gag, black and red) is met or projected to be met.		
Established ABC control rules, establish ABCs, ACLs, and AMs for species not undergoing overfishing; removed some species from South Atlantic FMU and designate others as ecosystem component species; specified allocations between the commercial and, recreational sectors for species not undergoing overfishing; limited the total mortality for federally managed species in the South Atlantic to the ACLs.	Amendment 25 (Comprehensive ACL Amendment) (SAFMC 2011a)	4/16/12
Implemented benchmarks from SEDAR 19, established rebuilding plan (including ACLs, rec ACT, OY, and allocations – 44% comm and 56% rec) for red grouper; modified AMs; eliminated commercial and recreational aggregate ACLs (gag, black and red) and corresponding AMs. Changed MSST to equal 75% of SSB_{MSY}.	Amendment 24 (SAFMC 2011b)	7/11/12
Modified the crew member limit on dual-permitted snapper grouper vessels; modified the restriction on retention of bag limit quantities of some snapper grouper species by captain and crew of for-hire vessels; minimized regulatory delay when adjustments to snapper grouper species' ABC, ACLs, and ACTs are needed as a result of new stock assessments.	Amendment 27 SAFMC 2014)	1/27/14
Modified AMs for snapper grouper species, incl. red grouper	Amendment 34 (SAFMC 2015)	2/22/16

SAFMC Regulatory Amendments affecting red grouper

Description of Action	Amendment	Effective Date
Modified the existing gag commercial ACL and AM for gag that requires a closure of all other shallow water groupers (incl. red grouper) in the South Atlantic when the gag commercial ACL is met or projected to be met.	Regulatory Amendment 15 (SAFMC 2013)	9/12/13

2.2 Emergency and Interim Rules (if any)

None

2.3 Secretarial Amendments (if any)

None

2.4 Control Date Notices (if any)

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

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

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

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

2.5 Management Program Specifications

Table 2.5.1. General Management Information

South Atlantic

Species	Red Grouper (*Epinephelus morio*)
Management Unit	Southeastern US
Management Unit Definition	All waters within South Atlantic Fishery Management Council Boundaries
Management Entity	South Atlantic Fishery Management Council
Management Contacts SERO / Council	SAFMC: Myra Brouwer SERO: Rick DeVictor
Current stock exploitation status	Not undergoing overfishing[1]
Current stock biomass status	Not overfished[2]

[1] In Amendment 24, the overfishing criteria for red grouper was modified so that a stock is subject to overfishing if (a) the fishing mortality rate equals or exceeds the MFMT during an assessment year; or (b) total landings exceed the overfishing level (OFL) during a non-assessment year. After comparing the OFL to landings, it has been determined to not be undergoing overfishing.

[2] In Amendment 24 (approved May 25, 2012), MSST was revised from MSST=(1-M)SSBMSY to MSST=75%SSBMSY. The MSST value changed from the change to the MSST equation. The ratio of the most recent estimate of spawning stock biomass from the most recent assessment (SEDAR 19) and the newly calculated MSST supports a determination that the stock is no longer overfished, but is still being managed under a rebuilding plan.

Table 2.5.2 Management Parameters

All values in this table, unless otherwise noted, are from SEDAR 19

Criteria	South Atlantic – Current (SEDAR 19)	
	Definition	Base Run Values
MSST[1] (pounds whole weight)	MSST equals 75% of SSB_{MSY}[2]	4,285,742
MFMT (per year)	F_{MSY}	0.221
F_{MSY}	F_{MSY}	0.221
MSY (1000 pounds whole weight)	Yield at F_{MSY}, landings and discards, pounds and numbers	1,110
B_{MSY}[1] (metric tons)	Biomass at MSY	3,680
R_{MSY}	Recruits at MSY	
SSB_{MSY} (metric tons)	SSB at MSY	2,592
F Target	75% F_{MSY}	0.166
Yield at F_{TARGET} (equilibrium)	Landings and discards, pounds and numbers	1,089
OY (1000 pounds whole	Yield at F_{OY}	OY (65% F_{MSY})= 1,064

weight)		OY (75% F_{MSY})= 1,089 OY (85% F_{MSY}= 1,103
M	Natural mortality, average across ages	0.14
Terminal F	Exploitation	0.340
Terminal Biomass[1] (metric tons)	SSB in 2008	2,051
Exploitation Status	$F_{current}/F_{MSY}$	1.35
Biomass Status[1]	SSB_{2008}/MSST	0.92
Generation Time		
$T_{REBUILD}$ (if appropriate)		

Criteria	South Atlantic – Proposed (values from SEDAR 53)		
	Definition	Base Run Values	Median of Base Run MCBs
MSST[1]	75% of SSB_{MSY}		
MFMT	F_{MSY}, if available; or F_{MSY} proxy [3]		
F_{MSY}	F_{MSY}		
MSY	Yield at F_{MSY}, landings and discards, pounds and numbers		
B_{MSY}[1]	Total or spawning stock, to be defined		
R_{MSY}	Recruits at MSY		
F Target	75% F_{MSY}		
Yield at F_{TARGET} (equilibrium)	Landings and discards, pounds and numbers		
M	Natural mortality, average across ages		
Terminal F	Exploitation		
Terminal Biomass[1]	Biomass		
Exploitation Status	F/MFMT		
Biomass Status[1]	B/MSST		
	B/B_{MSY}		
Generation Time			
$T_{REBUILD}$ (if appropriate)			

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

2. MSST definition was changed after the completion of SEDAR 19 through Snapper Grouper Amendment 24 from MSST=(1-M)SSBMSY to MSST=75%SSBMSY.

3. If an acceptable estimate of F_{MSY} is not provided by the assessment a proxy value may be considered. $F_{30\%SPR}$ was used before Amendment 24, but Amendment 24 changed the definition to use the latest information recommended by SEDAR/SSC. SEDAR 19 determined the F_{MSY} value so there is not currently a F_{MSY} proxy.

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

Table 2.5.3. Stock Rebuilding Information

From Amendment 24:

Define a **rebuilding schedule** as the maximum period allowed to rebuild (T_{MAX}). This would equal 10 years with the rebuilding time period ending in 2020. 2011 is Year 1.

Define a **rebuilding strategy** for red grouper that sets ABC equal to the yield at 75%F_{MSY}. Under this strategy, the fishery would have at least a 50% chance of rebuilding to SSB_{MSY} by 2016 and 81% chance of rebuilding to SSB_{MSY} by 2020.

- The Overfishing Limit is the yield at F_{MSY}.
- The Acceptable Biological Catch recommendation from the Scientific and Statistical Committee is the projected yield stream with a 70% probability of rebuilding success.
- The Acceptable Biological Catch values without dead discards would be 573,000 lbs whole weight (2011), 647,000 lbs whole weight (2012), 718,000 lbs whole weight (2013), and 780,000 lbs whole weight (2014).

Year	F (per year)	Probability of Rebuilt Stock	Projections		
			Landings	Discards	Total
2009	0.298	0	1,098,000	61,000	1,159,000
2010	0.298	0	985,000	70,000	1,055,000
2011 (Year 1)	0.166	0.01	573,000	40,000	613,000
2012	0.166	0.07	647,000	40,000	687,000
2013	0.166	0.18	718,000	41,000	759,000
2014	0.166	0.31	780,000	41,000	821,000
2015	0.166	0.44	834,000	41,000	875,000
2016	0.166	0.55	880,000	42,000	922,000
2017	0.166	0.64	919,000	42,000	961,000

2018	0.166	0.72	951,000	42,000	993,000
2019	0.166	0.77	977,000	42,000	1,019,000
2020	0.166	0.81	999,000	42,000	1,041,000

Table 2.5.4. General Projection Specifications
South Atlantic

First Year of Management	2018
Interim basis	ACL, if landings are within 10% of the ACL; average landings otherwise
Projection Outputs	
Landings	Pounds and numbers
Discards	Pounds and numbers
Exploitation	F & Probability F>MFMT
Biomass (total or SSB, as appropriate)	B & Probability B>MSST (and Prob. B>B_{MSY} if under rebuilding plan)
Recruits	Number

Table 2.5.5. Base Run Projections Specifications. Long Term and Equilibrium conditions. Red Grouper is currently in a rebuilding plan, implemented in Snapper Grouper Amendment 24. The rebuilding plan is 10 years, ending in 2020. Rebuilding is based on fixed exploitation at 75%F_{MSY}

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

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

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

Basis	Value	Years to Project	P* applies to

P*	50%	Interim + 5	Probability of overfishing
Exploitation	75% of F_{MSY}	Interim + 5	NA

Table 2.5.7. Quota Calculation Details
If the stock is managed by quota, please provide the following information (pounds whole weight)

Current Acceptable Biological Catch (ABC) and Total Annual Catch Level (ACL) Value for Red Grouper	780,000
Commercial ACL for Red Grouper	343,200
Recreational ACL for Red Grouper	436,800
Next Scheduled Quota Change	N/A
Annual or averaged quota?	Annual
If averaged, number of years to average	
Does the quota include bycatch/discard?	No

How is the quota calculated - conditioned upon exploitation or average landings?
ACL = OY = ABC. ABC equal to the yield at 75%F_{MSY}. Specify commercial and recreational ACLs for red grouper for 2012, 2013, and 2014 and beyond. The ACL for 2014 would remain in effect until modified. ACLs in 2013 and 2014 will not increase automatically in a subsequent year if present year projected catch has exceeded the total ACL.

Does the quota include bycatch/discard estimates? I f so, what is the source of the bycatch/discard values? What are the bycatch/discard allowances?
ACL does not include bycatch/discards

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

2.6 Management and Regulatory Timeline
The following tables provide a timeline of federal management actions by fishery.

Table 2.6.1 South Atlantic Red Grouper Federal Commercial Regulatory History
prepared by: Myra Brouwer

Year	Quota (lbs)	ACL (units)	Days Open	fishing season	reason for closure	season start date (first day implemented	season end date (last day effective)	Size limit (inche	size limit start dat	size limit end date	Retention Limit (units	Retention Limit Start Date	Retention Limit End Date	Aggregate Retention Limit (units)	ggregate Retention Limit Start Da	Aggregate Retention Limit End Date
1983	None	NA	365	open		1-Jan	31-Dec	12	31-Aug	31-Dec	NA	NA	NA	None	NA	NA
1984	None	NA	365	open		1-Jan	31-Dec	12	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
1985	None	NA	365	open		1-Jan	31-Dec	12	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
1986	None	NA	365	open		1-Jan	31-Dec	12	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
1987	None	NA	365	open		1-Jan	31-Dec	12	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
1988	None	NA	365	open		1-Jan	31-Dec	12	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
1989	None	NA	365	open		1-Jan	31-Dec	12	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
1990	None	NA	365	open		1-Jan	31-Dec	12	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
1991	None	NA	365	open		1-Jan	31-Dec	12	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
1992	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
1993	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
1994	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
1995	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
1996	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
1997	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
1998	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
1999	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
2000	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
2001	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
2002	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
2003	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
2004	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
2005	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
2006	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
2007	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
2008	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
2009[A]	None	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	NA	NA	NA	None	NA	NA
2010[A]	None	NA	245	open		1-May	31-Dec	20	1-May	31-Dec	NA	NA	NA	None	NA	NA
2011[A]	662,403[B]	see quota	245	open		1-May	31-Dec	20	1-May	31-Dec	NA	NA	NA	None	NA	NA
2012[A]	662,403[B]	see quota	72	open		1-May	10-Jul	20	1-May	10-Jul	NA	NA	NA	None	NA	NA
	284680[C]	see quota	101	open		11-Jul	20-Oct	20	11-Jul	20-Oct	NA	NA	NA	None	NA	NA
			23	closed	shallow water groupers closed because gag commercial ACL estimated to be reached	21-Oct	12-Nov	20	21-Oct	12-Nov	NA	NA	NA	None	NA	NA
			9	open	shallow water groupers reopened because gag commercial ACL not met	13-Nov	21-Nov	20	13-Nov	21-Nov	NA	NA	NA	None	NA	NA
			40	closed	shallow water groupers closed because gag commercial ACL estimated to be reached	22-Nov	31-Dec	20	22-Nov	31-Dec	NA	NA	NA	None	NA	NA
2013[A]	315920[C]	see quota	245	open		1-May	31-Dec	20	1-May	31-Dec	NA	NA	NA	None	NA	NA
2014[A]	343200[C]	see quota	245	open		1-May	31-Dec	20	1-May	31-Dec	NA	NA	NA	None	NA	NA
2015[A]	343200[C]	see quota	245	open		1-May	31-Dec	20	1-May	31-Dec		NA	NA	None	NA	NA

Fishing year = Calendar Year

A = Annual shallow water grouper closure effective 7/29/09; shallow water grouper closure includes: gag, black grouper, red grouper, scamp, red hind, rock hind, yellowmouth grouper, yellowfin grouper, graysby, and coney

B = Commercial aggregate quota for gag, black grouper, and red grouper (Am 17B effective 1/30/11); units = lbs gw

C= aggregate commercial quota for gag, black grouper, and red grouper was eliminated through Amendment 24 (effective 7/11/12); units = lbs ww

Note: lbs = pounds; gw = gutted weight

Table 2.6.2 South Atlantic Red Grouper Federal Recreational Regulatory History

prepared by: Myra Brouwer

Year	Quota (lbs)	ACL (lbs)	Days Open	fishing season	reason for closure	season start date (first day implemented)	season end date (last day effective)	Size limit (inches, total length)	size limit start date	size limit end date	Retention Limit (# fish)	Retention Limit Start Date	Retention Limit End Date	Aggregate Retention Limit[1] (# fish)	Aggregate Retention Limit Start Date	Aggregate Retention Limit End Date
1983	NA	NA	365	open		1-Jan	31-Dec	12	31-Aug	31-Dec	NA	NA	NA	NA	NA	NA
1984	NA	NA	365	open		1-Jan	31-Dec	12	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA
1985	NA	NA	365	open		1-Jan	31-Dec	12	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA
1986	NA	NA	365	open		1-Jan	31-Dec	12	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA
1987	NA	NA	365	open		1-Jan	31-Dec	12	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA
1988	NA	NA	365	open		1-Jan	31-Dec	12	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA
1989	NA	NA	365	open		1-Jan	31-Dec	12	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA
1990	NA	NA	365	open		1-Jan	31-Dec	12	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA
1991	NA	NA	365	open		1-Jan	31-Dec	12	1-Jan	31-Dec	NA	NA	NA	NA	NA	NA
1992	NA	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	5/person/day [A]	1-Jan	31-Dec	5/person/day [A]	1-Jan	31-Dec
1993	NA	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	5/person/day [A]	1-Jan	31-Dec	5/person/day [A]	1-Jan	31-Dec
1994	NA	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	5/person/day [A,B]	1-Jan	31-Dec	5/person/day [A,B]	1-Jan	31-Dec
1995	NA	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	5/person/day [A,B]	1-Jan	31-Dec	5/person/day [A,B]	1-Jan	31-Dec
1996	NA	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	5/person/day [A,B]	1-Jan	31-Dec	5/person/day [A,B]	1-Jan	31-Dec
1997	NA	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	5/person/day [A,B]	1-Jan	31-Dec	5/person/day [A,B]	1-Jan	31-Dec
1998	NA	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	5/person/day [A,B]	1-Jan	31-Dec	5/person/day [A,B]	1-Jan	31-Dec
1999	NA	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec
2000	NA	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec
2001	NA	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec
2002	NA	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec
2003	NA	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec
2004	NA	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec
2005	NA	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec
2006	NA	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec
2007	NA	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec
2008	NA	NA	365	open		1-Jan	31-Dec	20	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec	5/person/day [A,B,C]	1-Jan	31-Dec
2009 [D,E]	NA	NA	365	open		1-Jan	28-Jul	20	1-Jan	28-Jul	5/person/day [A,B,C]	1-Jan	28-Jul	5/person/day [A,B,C]	1-Jan	28-Jul
				open		29-Jul	31-Dec	20	29-Jul	31-Dec	3/person/day [D]	29-Jul	31-Dec	3/person/day [D,E]	29-Jul	31-Dec
2010 [D,E]	NA	NA	245	open		1-May	31-Dec	20	1-May	31-Dec	3/person/day [D]	1-May	31-Dec	3/person/day [D,E]	1-May	31-Dec
2011 [D,E]	See ACL	648,663[J]	245	open		1-May	31-Dec	20	1-May	31-Dec	3/person/day [D]	1-May	31-Dec	3/person/day [D,E,G]	1-May	31-Dec
2012 [D,E,F]	See ACL	648,663[J]	72	open		1-May	10-Jul	20	1-May	10-Jul	3/person/day [D]	1-May	10-Jul	3/person/day [D,E,G,H]	1-May	10-Jul
	See ACL	362,320[K]	173	open		11-Jul	31-Dec	20	11-Jul	31-Dec	3/person/day [D]	11-Jul	31-Dec	3/person/day [D,E,G,H]	11-Jul	31-Dec
2013 [D,E,F]	See ACL	402,080 [K]	245	open		1-May	31-Dec	20	1-May	31-Dec	3/person/day [D]	1-May	31-Dec	3/person/day [D,E,G,H]	1-May	31-Dec
2014 [D,E,F,I]	See ACL	436,800 [K]	245	open		1-May	31-Dec	20	1-May	31-Dec	3/person/day [D]	1-May	31-Dec	3/person/day [D,E,G,H]	1-May	31-Dec
2015 [D,E,F,I]	See ACL	436,800 [K]	245	open		1-May	31-Dec	20	1-May	31-Dec	3/person/day [D]	1-May	31-Dec	3/person/day [D,E,G,H]	1-May	31-Dec

Fishing year = Calendar Year

Note: Starting in 1992, the aggregate grouper bag limit included gag, scamp, red grouper, black grouper, speckled hind, snowy grouper, warsaw grouper, rock hind, red hind, coney, graysby, misty grouper, yellowedge grouper, yellowmouth grouper, yellowfin grouper, and tiger grouper. Golden tilefish, blueline tilefish, and sand tilefish were added to the aggregate in 1994 (SG Amendment 6). Unless otherwise noted below these species remain in the aggregate bag limit throughout the time series.

A = Aggregate grouper bag limit (includes gag, scamp, red grouper, black grouper, speckled hind, snowy grouper, warsaw grouper, rock hind, red hind, coney, graysby, misty grouper, yellowedge grouper, yellowmouth grouper, yellowfin grouper, tiger grouper) of 5/person/day; specifies 1 speckled hind and 1 warsaw grouper in 5 grouper aggregate (Amendment 4; effective date 1/1/1992)

B = Golden tilefish, blueline tilefish, and sand tilefish added to the aggregate grouper bag limit of 5/person/day; (Amendment 6; effective date 7/27/1994).

C = Aggregate grouper bag limit specifies no more than 2 can be gag or black grouper (Amendment 9; effective date 2/24/1999)

D = Shallow water grouper spawning closure implemented and grouper aggregate reduced to 3 (Amendment 16 effective 7/29/09); shallow water grouper closure includes: gag, black grouper, red grouper, scamp, red hind, rock hind, yellowmouth grouper, yellowfin grouper, graysby, and coney

E = Prohibited sale of bag-limit caught snapper grouper species, including red grouper (Amendment 15B; effective date:12/16/2009).

F = Amendment 24 implements red grouper rebuilding plan (effective 7/11/12)

G = Harvest of speckled hind and warsaw grouper prohibited (e.g. removed from grouper aggregate bag limit; Amendment 17B; effective date: 1/31/11)

H = Tiger grouper removed from FMU (and therefore removed from aggregate bag limit; effective April 16, 2012)

I = Captain and crew on for-hire trips can retain bag limit of snapper grouper species (Amendment 27; effective date 1/27/2014)

J = Recreational aggregate quota for gag, black grouper, and red grouper (Am 17B effective 1/30/11); unit for aggregate quota = lbs gw

K = aggregate recreational quota for gag, black grouper, and red grouper was eliminated through Amendment 24 (effective 7/11/12); unit for quota is lbs ww

Note

Table 7. State Regulatory History

North Carolina:

There are currently no North Carolina state-specific regulations for red grouper. North Carolina has complemented federal regulations for all snapper grouper species via proclamation authority since 1991. Between 1992 and 2005, species-specific regulations were added to the proclamation authority contained in rule 15A NCAC 03M .0506. Specific to red grouper, this rule was amended effective March 1, 1996 to include the following Sub-item: (f) It is unlawful to possess red grouper less than 20 inches total length.

In 2002, North Carolina adopted its Inter-Jurisdictional Fishery Management Plan (IJ FMP), which incorporates all ASMFC and council-managed species by reference, and adopts all federal regulations as minimum standards for management. In completing the 2008 update to the IJ FMP, all species-specific regulations were removed from rule 15A NCAC 03M .0506, and proclamation authority to implement changes in management was moved to rule 15A NCAC 03M .0512. An information update to the IJ FMP was completed and approved in November 2015 and contained no additional regulatory changes. Since the 2008 IJ FMP update, all snapper grouper regulations were contained in a single proclamation, which was updated anytime an opening/closing of a particular species in the complex occurred, as well as any changes in allowable gear, required permits, etc. Beginning in 2015, commercial and recreational regulations have been contained in separate proclamations. The most current Snapper Grouper proclamations (and all previous versions) can be found using this link: http://portal.ncdenr.org/web/mf/proclamations.

15A NCAC 03M .0506 SNAPPER-GROUPER COMPLEX

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

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

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

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

(a) In order to comply with management requirements incorporated in Federal Fishery Management Council Management Plans or Atlantic States Marine Fisheries Commission Management Plans or to implement state management measures, the Fisheries Director may, by proclamation, take any or all of the following actions for species listed in the Interjurisdictional Fisheries Management Plan:

(1) Specify size;
(2) Specify seasons;
(3) Specify areas;
(4) Specify quantity;
(5) Specify means and methods; and
(6) Require submission of statistical and biological data.

(b) Proclamations issued under this Rule shall be subject to approval, cancellation, or modification by the Marine Fisheries Commission at its next regularly scheduled meeting or an emergency meeting held pursuant to G.S. 113-221.1.

History Note: Authority G.S. 113-134; 113-182; 113-221; 113-221.1; 143B-289.4;
Eff. March 1, 1996;
Amended Eff. October 1, 2008.

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

Georgia:

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

Florida:

Annual Commercial Red Grouper Regulatory Summary – Atlantic Florida

Year	Minimum Size Limit	Trip Limit	Regulation Changes and Effective Date
1983	12 inches FL[1]		No more than 10% of individuals may be undersize (FL Statutes Chapter 370.11, effective ~7/1/1977)
1984			
1985	18 inches FL (effective 7/29/1985)		No more than 10% of individuals may be undersize (effective 7/29/185)
1986			Use of longline gear for reef fish in state waters by commercial fishermen prohibited; bycatch allowance of 5% is permitted for 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 a commercial harvester may be smaller than the minimum size limit. Reef fish must be landed in whole condition (head and tail intact). (effective 12/11/1986)
1987			
1988			
1989			
1990	20 inches TL (effective 2/1/1990)		All snapper and grouper designated as "restricted species;" allowable gear for snappers and groupers are hook and line, black sea bass traps, spears, gigs, or lance (except powerheads, bangsticks, or explosive devices); all commercial harvest of any species of snapper, grouper, and sea bass is prohibited in state waters whenever harvest of that species is prohibited in adjacent federal waters; snapper and grouper must be landed in whole condition (effective 2/1/1990)
1991			
1992			

1993			Use of longline gear in state waters prohibited (effective 1/1/1993). Persons who possess either a Gulf of Mexico or a South Atlantic federal reef fish permit may commercially harvest snappers and grouper (except red snapper) in all state waters until July 1, 1995 (effective 10/18/1993).
1994			Modifies rule language to provide the same definitions of Gulf of Mexico and Atlantic Ocean regions (effective 3/1/1994)
1995			Continues allowance from 1993—persons who possess either a Gulf of Mexico or a South Atlantic federal reef fish permit may commercially harvest snappers and grouper in all state waters —through December 31, 1995 (effective 7/1/1995).
1996			Continues allowance from 1993—persons who possess either a Gulf of Mexico or a South Atlantic federal reef fish permit may commercially harvest snappers and grouper in all state waters —through December 31, 1996 (effective 1/1/1996). Continues allowance from 1993—persons who possess either a Gulf of Mexico or a South Atlantic federal reef fish permit may commercially harvest snappers and grouper in all state waters —through December 31, 1997 (effective 11/27/1996).
1997			
1998			Commercial closure language standardized (effective 12/31/1998)
1999			
2000			Eliminated the 5-day commercial season closure extension in the reef fish rule. Restored the documentation requirement for reef fish species possessed during a closure period. (effective 1/1/2000)

2001			
2002			
2003			
2004			
2005			
2006			For the purposes of determining the legal size of reef fish species, "total length" means the straight line distance from the most forward point of the head with the mouth closed, to the farthest tip of the tail with the tail compressed or squeezed, while the fish is lying on its side. (effective 7/1/2006)
2007		Sets commercial trip limits in the Atlantic that are the same as trip limits in federal waters (effective 7/1/2007)	Commercial fishermen are prohibited from harvesting or possessing the recreational bag limit of reef fish species on commercial trips (effective 7/1/2007)
2008			
2009			
2010			Harvest of shallow-water groupers[2] is prohibited from Jan. 1 – April 30 in Atlantic and Monroe County state waters. Dehooking tools must be aboard commercial and recreational vessels for use as needed to remove hooks from Atlantic reef fish. (effective 1/19/2010).
2011			
2012			
2013			
2014			
2015			

[1] Measurement specified as "from the tip of the nose to the rear center edge of the tail (i.e., a fork length)."

[2] Shallow-water grouper includes gag, black grouper, red grouper, scamp, red hind, rock hind, coney, graysby, yellowfin grouper, yellowmouth grouper, and tiger grouper.

Annual Recreational Red Grouper Regulatory Summary – Atlantic Florida

Year	Minimum Size Limit	Bag and Possession Limit	Regulation Changes and Effective Date
1983	12 inches FL[1]		No more than 10% of individuals may be undersized (FL Statutes Chapter 370.11, effective ~7/1/1977)
1984			
1985	18 inches FL (effective 7/29/1985)		No more than 10% of individuals may be undersized (effective 7/29/1985)
1986		5 grouper per recreational angler daily, with off-the-water possession limit of 20 grouper per recreational angler, for any combination of groupers, excluding rock hind and red hind (effective 12/11/1986)	5% of snapper and grouper in possession of harvester may be smaller than the minimum size limit. Reef fish must be landed in whole condition. (effective 12/1//1986)
1987			
1988			
1989			
1990	20 inches TL (effective 2/1/1990)	5 grouper daily per person for any combination of grouper, with off-the-water possession limit of 10 grouper per person for any combination of grouper (effective 2/1/1990)	All snapper and grouper designated as "restricted species;" allowable gear for snappers and groupers are hook and line, black sea bass traps, spears, gigs, or lance (except powerheads, bangsticks, or explosive devices); snapper and grouper must be landed in whole condition (effective 2/1/1990)
1991			
1992			
1993			
1994			Persons aboard charter and headboats on trips exceeding 24 hours are allowed a 2-day possession limit for reef fish statewide provided the vessel is equipped with a permanent berth for each passenger aboard and each passenger has a receipt

			verifying the trip length. Modifies rule language to provide the same definitions of Gulf of Mexico and Atlantic Ocean regions. (effective 3/1/1994)
1995			
1996			
1997			
1998			
1999			
2000			
2001			
2002			
2003			
2004			
2005			
2006			Specifies total length (TL) measurement means the straight line distance from the most forward point of the head with the mouth closed, to the farthest tip of the tail with the tail compressed or squeezed, while the fish is lying on its side (effective 7/1/2006)
2007			Commercial fishermen are prohibited from harvesting or possessing the recreational bag limit of reef fish species on commercial trips (effective 7/1/2007)
2008			
2009			
2010		3 fish per person aggregate daily bag limit for all grouper in Atlantic and Monroe County state waters (effective 1/19/2010)	Prohibited captain and crew of for-hire vessels from retaining any species in the aggregate grouper bag limit. Harvest of shallow-water groupers[2] is prohibited from Jan. 1 – April 30 in Atlantic and Monroe County state waters. Dehooking tools must be aboard commercial and recreational vessels for use as needed to remove hooks from Atlantic reef fish. (effective 1/19/2010)
2011			
2012			

2013			
2014			Eliminated language that prohibited captain and crew of for-hire vessels from retaining recreational bag limits of vermilion snappers, groupers, and golden tilefish on for-hire trips in state waters of the Atlantic (including Monroe County for groupers and golden tilefish) (effective 3/13/2014).
2015			

[1] Measurement specified as "from the tip of the nose to the rear center edge of the tail (i.e., a fork length)."
[2] Shallow-water grouper includes gag, black grouper, red grouper, scamp, red hind, rock hind, coney, graysby, yellowfin grouper, yellowmouth grouper, and tiger grouper.

References
None provided.

3. Assessment History

Prior to SEDAR-19, South Atlantic red grouper had been examined in a trends report using catch curve analysis and catch-per-unit-effort, with data through 1999 (Potts and Brennan, 2001). That report examined several constant, natural mortality rates (M=0.15, 0.20, 0.25, and 0.30), but considered M=0.20 to be the base level. For M=0.20, terminal static SPR was estimated at 16%, and full F relative to FMSY proxies indicated that overfishing was occurring.

SEDAR-19 was the first formal stock assessment of South Atlantic red grouper, with data through 2008. That assessment applied Lorenzen's age-based natural mortality, which was scaled to a constant value of M=0.14. SEDAR-19 estimated that overfishing was occurring (F_{2008}/FMSY=1.35) and that the stock was overfished (SSB_{2008}/MSST=0.92). The overfished designation was based on the definition of MSST=(1-M)SSB_{MSY}. In 2012, Amendment 24 changed the definition to MSST=75%SSB_{MSY}, and subsequently the stock was no longer considered to be overfished.

References
Potts, JC 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 prepared for the SAFMC.

4. Regional Maps

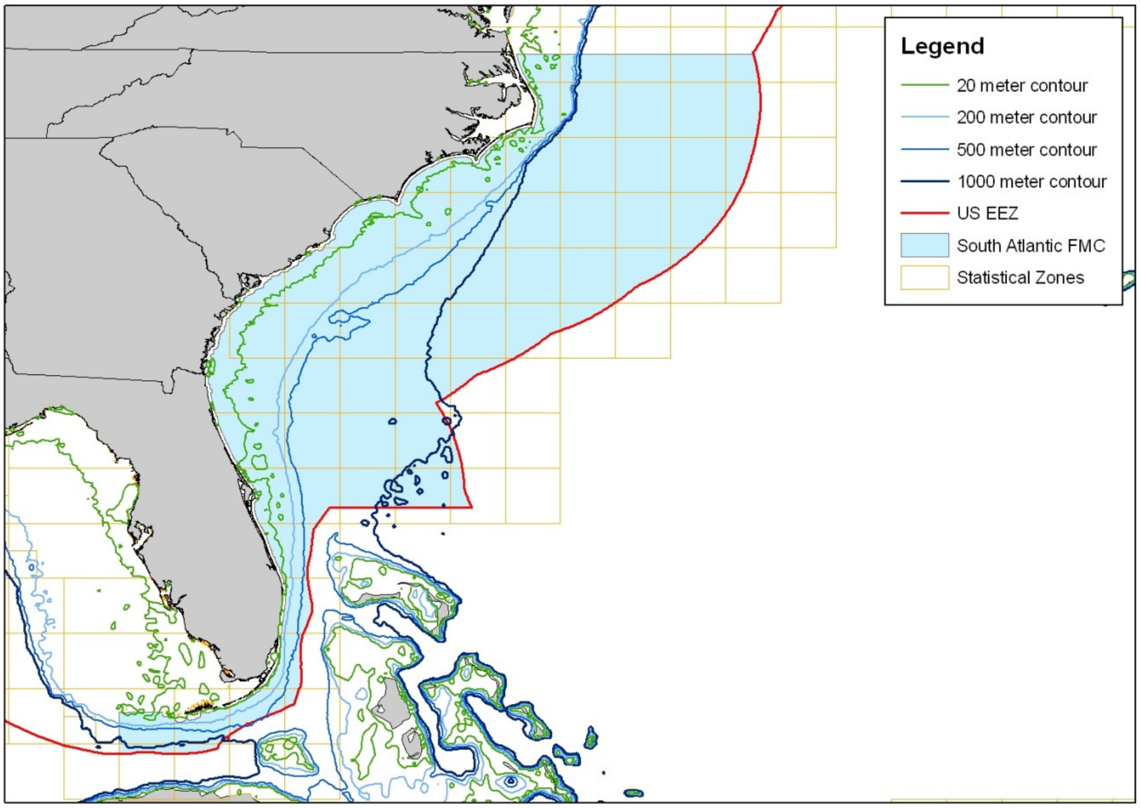

Figure 4.1: South Atlantic Fishery Management Council and EEZ boundaries.

5. SEDAR Abbreviations

APAIS	Access Point Angler Intercept Survey
ABC	Allowable Biological Catch
ACCSP	Atlantic Coastal Cooperative Statistics Program
ADMB	AD Model Builder software program
ALS	Accumulated Landings System; SEFSC fisheries data collection program
AMRD	Alabama Marine Resources Division
ASMFC	Atlantic States Marine Fisheries Commission
B	stock biomass level
BAM	Beaufort Assessment Model
BMSY	value of B capable of producing MSY on a continuing basis

CFMC	Caribbean Fishery Management Council
CIE	Center for Independent Experts
CPUE	catch per unit of effort
EEZ	exclusive economic zone
F	fishing mortality (instantaneous)
FMSY	fishing mortality to produce MSY under equilibrium conditions
FOY	fishing mortality rate to produce Optimum Yield under equilibrium
FXX% SPR	fishing mortality rate that will result in retaining XX% of the maximum spawning production under equilibrium conditions
FMAX	fishing mortality that maximizes the average weight yield per fish recruited to the fishery
F0	a fishing mortality close to, but slightly less than, Fmax
FL FWCC	Florida Fish and Wildlife Conservation Commission
FWRI	(State of) Florida Fish and Wildlife Research Institute
GA DNR	Georgia Department of Natural Resources
GLM	general linear model
GMFMC	Gulf of Mexico Fishery Management Council
GSMFC	Gulf States Marine Fisheries Commission
GULF FIN	GSMFC Fisheries Information Network
HMS	Highly Migratory Species
LDWF	Louisiana Department of Wildlife and Fisheries
M	natural mortality (instantaneous)
MARMAP	Marine Resources Monitoring, Assessment, and Prediction
MDMR	Mississippi Department of Marine Resources
MFMT	maximum fishing mortality threshold, a value of F above which overfishing is deemed to be occurring
MRFSS	Marine Recreational Fisheries Statistics Survey; combines a telephone survey of households to estimate number of trips with creel surveys to estimate catch and effort per trip
MRIP	Marine Recreational Information Program
MSST	minimum stock size threshold, a value of B below which the stock is deemed to be overfished
MSY	maximum sustainable yield

NC DMF	North Carolina Division of Marine Fisheries
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
OY	optimum yield
SAFMC	South Atlantic Fishery Management Council
SAS	Statistical Analysis Software, SAS Corporation
SC DNR	South Carolina Department of Natural Resources
SEAMAP	Southeast Area Monitoring and Assessment Program
SEDAR	Southeast Data, Assessment and Review
SEFIS	Southeast Fishery-Independent Survey
SEFSC	Fisheries Southeast Fisheries Science Center, National Marine Fisheries Service
SERO	Fisheries Southeast Regional Office, National Marine Fisheries Service
SPR	spawning potential ratio, stock biomass relative to an unfished state of the stock
SSB	Spawning Stock Biomass
SSC	Science and Statistics Committee
TIP	Trip Incident Program; biological data collection program of the SEFSC and Southeast States.
TPWD	Texas Parks and Wildlife Department
Z	total mortality, the sum of M and F

SEDAR

Southeast Data, Assessment, and Review

SEDAR 53

South Atlantic Red Grouper

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SECTION II: Assessment Report

February 2017

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

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Executive Summary

This standard assessment evaluated the stock of red grouper (*Epinephelus morio*) off the southeastern United States[1]. The primary objectives were to update and improve the 2010 SEDAR19 benchmark assessment of red grouper and to conduct new stock projections. Using data through 2008, SEDAR19 had indicated that the stock was overfished and undergoing overfishing. However in 2012, Amendment 24 changed the definition to MSST=75%SSB_{MSY}, and subsequently the stock was no longer considered to be overfished. For this assessment, data compilation and assessment methods were guided by methodology of SEDAR19, as well as by current SEDAR practices. The assessment period is 1976-2015.

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, one from the commercial handline fleet, and one from the SERFS that combined chevron trap and video sampling. One sensitivity run included an index developed during SEDAR19 from MRFSS data. Data on landings and discards were available from recreational and commercial fleets.

The primary model used in SEDAR19 – and updated here – was the Beaufort Assessment Model (BAM), a statistical catch-age formulation. A base run of BAM was configured to provide point estimates of key management quantities, such as stock and fishery status. Uncertainty in estimates from the base run was evaluated through a mixed Monte Carlo Bootstrap (MCB) procedure. Median values from the uncertainty analysis are also provided.

Results suggest that spawning stock declined until the late 1980s, then increased until the mid-2000s, and has decreased since. The terminal (2015) base-run estimate of spawning stock was below the MSST (SSB_{2015}/MSST = 0.38), as was the median estimate ((SSB_{2015}/MSST = 0.37), indicating that the stock is currently overfished. The estimated fishing rate has exceeded MFMT (represented by F_{MSY}) for the entire assessment period. The terminal estimate, which is based on a three-year geometric mean, is above F_{MSY} in the case of the base run ($F_{2013\text{-}2015}/F_{MSY}$ = 1.54) and the median ($F_{2013\text{-}2015}/F_{MSY}$ = 1.58). Thus, this assessment indicates that the stock is overfished and is experiencing overfishing.

The MCB analysis indicates that these estimates of stock and fishery status are robust, but with some uncertainty in the conclusions. Of all MCB runs, 99.7% were in qualitative agreement that the stock is overfished (SSB_{2015}/MSST < 1.0), and 89.1% that the stock is experiencing overfishing ($F_{2013\text{-}2015}/F_{MSY}$ > 1.0).

The estimated trends of this standard assessment are quite similar to those from the SEDAR19 benchmark. However, the two assessments did show some differences in results, which was not surprising given several modifications made to both the data and model (described throughout the report). Compared to SEDAR19, this assessment suggests lower values of F_{MSY} and MSY, and a higher value of SSB_{MSY}.

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

1. Introduction

1.1 Workshop Time and Place

The SEDAR 53 Standard Assessment Process was conducted through a series of webinars held from August 2016 to January 2017. Four webinars were held in total: a Data Scoping webinar on August 17, 2016; an Assessment Scoping webinar on October 12, 2016; and two Assessment webinars on November 30, 2016 and January 11, 2017.

1.2 Terms of Reference

1. Update the approved SEDAR 19 South Atlantic red grouper base model with data through 2015. Provide a model consistent with the SEDAR 19 base assessment configuration and revised configurations as necessary to incorporate and evaluate any changes in model inputs or parameterization approved during this assessment.

2. Evaluate and document the following specific changes in input data or deviations from the benchmark model. (List below each topic or new dataset that will be considered in this assessment.)
    - Consider the inclusion of the SERFS video index
    - Incorporate the latest BAM model configuration

3. Document any changes or corrections made to the model and input datasets and provide updated input data tables. Fully document and describe the impacts (on population parameters and management benchmarks) of any changes to the model structure, methods, application or fitting procedures made between this assessment and the SEDAR 19 assessment. Provide commercial and recreational landings and discards in pounds and numbers.

4. Update model parameter estimates and their variances, model uncertainties, and estimates of stock status and management benchmarks. Compare population parameter trends and management benchmarks estimated in this assessment with values from the previous assessment (SEDAR 19), and comment on the impacts of changes in data, assumptions or assessment methods on estimated population conditions and benchmarks.

5. Provide stock projections, including a pdf for biological reference point estimates and yield separated for landings and discards reported in pounds and numbers. Projection results are required through 2020. Projection criteria:
    - To determine OFL: apply an annual probability of overfishing = 50%.
    - To evaluate the existing rebuilding plan: base on fixed exploitation at 75% Fmsy. In addition to reporting yield and stock status as described above, for this projection also report the probability that SSB>SSBmsy.

- Potential Alternative Rebuilding: If results of this projection indicate that the stock is not rebuilt by 2020 (as evidenced by SSB>SSBmsy at 50% probability), provide an additional projection based on a fixed exploitation rate (Frebuild) where Frebuild is defined as the maximum exploitation rate that provides 0.70 probability of rebuilding (SSB>SSBmsy) by 2020.

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

1.3 List of Participants

ASSESSMENT PANELISTS		
Kyle Shertzer	Lead analyst	SEFSC Beaufort
Rob Cheshire	Data compiler	SEFSC Beaufort
Nate Bacheler	Data provider	SEFSC Beaufort
Joey Ballenger	Data provider	SC DNR
John Boreman	SSC	SAFMC SSC
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Kevin Craig	Assessment Team	SEFSC Beaufort
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APPOINTED COUNCIL REPRESENTATIVES		
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COUNCIL AND AGENCY STAFF		
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1.4 Document List

SEDAR 53 Document List

Document #	Title	Authors
Documents Prepared for SEDAR 53		
SEDAR53-WP01	Standardized video counts of Southeast U.S. Atlantic red grouper (*Epinephelus morio*) from the Southeast Reef Fish Survey	Shertzer & Bacheler 2016
SEDAR53-WP02	Standardized catch rates of Red Grouper (*Epinephelus morio*) in the southeast U.S. from headboat logbook data	SFB-NMFS 2016
SEDAR53-WP03	Standardized catch rates of Red Grouper (*Epinephelus morio*) in the southeast U.S. from commercial logbook data	SFB-NMFS 2016
SEDAR53-WP04	Fishery Independent Chevron Trap Index Information for the SEDAR 53 Red Grouper Standard Assessment	Reichert & Bubley 2017
SEDAR53-WP05	Commercial age and length composition weighting for U.S. red grouper (*Epinephelus morio*)	SFB-NMFS 2016
SEDAR53-WP06	Recreational Survey Data for Red Grouper in the	Matter & Fitzpatrick

	South Atlantic	2016
SEDAR53-WP07	Discards of Red Grouper (*Epinephelus morio*) for the headboat fishery in the US South Atlantic	FEB-NMFS 2016
SEDAR53-WP08	South Atlantic U.S. Red Grouper (*Epinephelus morio*) age and length composition from the recreational fisheries	FEB-NMFS 2016
Final Assessment Report		
SEDAR53-SAR1	Assessment of South Atlantic Red Grouper	To be prepared by SEDAR 53
Reference Documents		
SEDAR53-RD01	SEDAR 19 South Atlantic Red Grouper Stock Assessment Report	SEDAR 19
SEDAR53-RD02	List of documents and working papers for SEDAR 19 (South Atlantic Red Grouper) – all documents available on the SEDAR website.	SEDAR 19
SEDAR53-RD03	Southeast Reef Fish Survey Video Index Development Workshop	Bacheler and Carmichael 2014
SEDAR53-RD04	Overview of sampling gears and standard protocols used by the Southeast Reef Fish Survey and its partners	Smart et al. 2014
SEDAR53-RD05	Technical documentation of the Beaufort Assessment Model (BAM)	Williams and Shertzer 2015
SEDAR53-RD06	Survival of Red Grouper (*Epinephalus morio*) and Red Snapper (*Lutjanus campechanus*) caught on j-hooks and circle hooks in the Florida recreational and recreational for-hire fisheries	Burns and Froeschke 2012
SEDAR53-RD07	Estimating natural mortality rates and simulating fishing scenarios for Gulf of Mexico red grouper (*Epinephelus morio*) using the ecosystem model OSMOSE-WFS	Gruss et al. 2016
SEDAR53-RD08	Data weighting in statistical fisheries stock assessment models	Francis 2011
SEDAR53-RD09	Corrigendum to Francis 2011 paper	Francis
SEDAR53-RD10	Replacing the multinomial in stock assessment models: A first step	Francis 2014
SEDAR53-RD11	Revisiting data weighting in fisheries stock assessment models	Francis 2016
SEDAR53-RD12	Model-based estimates of effective sample size in stock assessment models using the Dirichlet-	Thorson et al. 2016

	multinomial distribution	

1.5 Statements Addressing Each Term of Reference

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

1. Update the approved SEDAR 19 South Atlantic red grouper base model with data through 2015. Provide a model consistent with the SEDAR 19 base assessment configuration and revised configurations as necessary to incorporate and evaluate any changes in model inputs or parameterization approved during this assessment.

The updated assessment model includes data through 2015. A sensitivity run (labeled S8) mimics the SEDAR19 configuration (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.)
   - Consider the inclusion of the SERFS video index
   - Incorporate the latest BAM model configuration

The SERFS video index was constructed (SEDAR53-WP01), considered by the Assessment Panel, and ultimately included in the assessment. The assessment model is the current version of BAM.

3. Document any changes or corrections made to the model and input datasets and provide updated input data tables. Fully document and describe the impacts (on population parameters and management benchmarks) of any changes to the model structure, methods, application or fitting procedures made between this assessment and the SEDAR 19 assessment. Provide commercial and recreational landings and discards in pounds and numbers.

Input data, including any deviations from SEDAR19, are described and tabulated in Section 2. The assessment model, including any deviations from SEDAR19, is documented in Section 3. A summary list of data and model changes from SEDAR19 is provided in Section 5.1. Commercial and recreational landings and discards in pounds and numbers are tabulated in the report.

4. Update model parameter estimates and their variances, model uncertainties, and estimates of stock status and management benchmarks. Compare population parameter trends and management benchmarks estimated in this assessment with values from the previous assessment (SEDAR 19), and comment on the impacts of changes in data, assumptions or assessment methods on estimated population conditions and benchmarks.

Parameter estimates are provided in Appendix B. Status indicators and benchmarks, along with standard errors, are in Table 18. Comparisons between SEDAR19 and SEDAR53 assessments are in Section 4.10.1, in Figures 3, 38, and 42, and in associated text.

5. Provide stock projections, including a pdf for biological reference point estimates and yield separated for landings and discards reported in pounds and numbers. Projection results are required through 2020. Projection criteria:
    - To determine OFL: apply an annual probability of overfishing = 50%.
    - To evaluate the existing rebuilding plan: base on fixed exploitation at 75% Fmsy. In addition to reporting yield and stock status as described above, for this projection also report the probability that SSB>SSBmsy.
        - Potential Alternative Rebuilding: If results of this projection indicate that the stock is not rebuilt by 2020 (as evidenced by SSB>SSBmsy at 50% probability), provide an additional projection based on a fixed exploitation rate (Frebuild) where Frebuild is defined as the maximum exploitation rate that provides 0.70 probability of rebuilding (SSB>SSBmsy) by 2020.

Projections were extended to 2030 or 2040, depending on the scenario. Projections specified by the TOR, as well as several additional scenarios identified by the Assessment Panel, are described in Sections 3.8 and 4.12.

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

See this report.

2 Data Review and Update

In the SEDAR19 benchmark assessment (SEDAR19 2009), the assessment period was 1976–2008. In this assessment, the period was modified to 1976–2015. Data sources from SEDAR19 were also considered here; however, all data were updated, including data prior to 2008, using current methodologies. The input data for this assessment are described below, with focus on modifications from SEDAR19.

2.1 Data Review

In this standard assessment, the Beaufort assessment model (BAM) was fitted to the similar data sources as in SEDAR19 with some modifications and additions.

- Life history: Natural mortality, Growth, Maturity, Proportion female
- Landings: Commercial lines (handline and longline), Commercial other, Headboat (sampled by SRHS), and General recreational (sampled by MRIP)
- Discards: Commercial lines (handline only), Headboat, and General recreational
- Indices of abundance: SERFS chevron trap/video, Commercial handline, Headboat
- Length compositions of surveys, landings, and discards: Commercial lines, Commercial other, Headboat, General recreational, Headboat discards, SERFS chevron trap/video
- Age compositions of surveys and landings: Commercial lines, Headboat, General recreational, SERFS chevron trap/video

2.2 Data Update

2.2.1 Life History

Life history information from SEDAR19 was used in this assessment. This included the age-dependent natural mortality rate, somatic growth, maturity, and proportion female at age. The von Bertalanffy growth parameters of SEDAR19 were $L_\infty = 848.2$ mm, $K = 0.213$ yr^{-1}, and $t_0 = -0.67$ yr. Age-specific natural mortality followed the Lorenzen estimator Lorenzen (1996), scaled to the Hoenig (age-independent) point estimate of $M = 0.14$. This point estimate was derived using a maximum observed age of 26. The age-specific Charnov estimator (Charnov et al. 2015) was used in a sensitivity run. As noted in other SEDAR reports, the Charnov et al. (2015) equation is an improvement over the empirical relationship of Gislason et al. (2010), which itself was a more comprehensive meta-analysis than that of Lorenzen (1996). However, like the Lorenzen estimator, the Charnov estimator may require rescaling, which was not attempted here. Life-history information is summarized in Table 1.

2.2.2 Commercial Landings and Discards

Estimates of commercial landings were developed for 1976-2015 using current methods. Two commercial fleets for red grouper were modeled in the assessment: lines (handline and longline) and other (pots, traps, diving, trawl, miscellaneous). Estimates of commercial discards (handline only) were developed from logbook data by the SEFSC for 1993–2015. The commercial discard mortality rate was assumed to be 0.2. Commercial landings and discards, as provided and fitted by the assessment model, are shown in Table 2.

2.2.3 Recreational Landings and Discards

The recreational headboat landings were estimated for 1976–2015 (SEDAR53-WP06 2016), and discards for 2004–2015 (SEDAR53-WP07 2016), with both time series based on data from the SRHS. However, as in SEDAR19, the discard estimate for 2004 was not used in the assessment model, because that was the first year of collecting discard data in the SRHS logbooks and there was lack of clarity in reporting this newly introduced field. The general recreational landings and discards for 1981–2015 were estimated with data from the MRIP (SEDAR53-WP06 2016), and those estimates were smoothed using a cubic spline with smoothing parameter set to 0 and weighted by the inverse of the annual CVs, as in SEDAR19. The recreational discard mortality rate was assumed to be 0.2. Recreational landings and discards, as provided and fitted by the assessment model, are shown in Table 2.

2.2.4 Indices of Abundance

Each of the indices of abundance used in SEDAR19 were re-evaluated, and three were retained for this assessment (Table 3, Figure 1): the SERFS chevron trap/video gear (SEDAR53-WP01 2016; SEDAR53-WP04 2017), commercial handline (SEDAR53-WP03 2016), and headboat (SEDAR53-WP02 2016). An index developed for SEDAR19 using MRFSS data was discarded by the SEDAR53 assessment panel, after evaluating its effect on the assessment and finding it to have almost no influence. However, a sensitivity run (the continuity run) of the assessment model did include the MRFSS index from SEDAR19. Following the SEDAR53 Terms of Reference, the SERFS video data were considered as a new source of information for this assessment. A standardized index was developed from those data (SEDAR53-WP01 2016), and as in SEDAR41, that index was combined with an index developed from the SERFS chevron trap gear using the Conn method (Conn 2010). A sensitivity run of the assessment model excluded video data, using only the standardized index from SERFS chevron trap data.

2.2.5 Length Compositions

Length compositions (TL) for all data sources were developed in 1-cm bins and later pooled into 3-cm bins over the range 16–118 cm (labeled at bin center). All lengths below and above the minimum and maximum bins were pooled. The commercial handline, commercial other, and recreational lengths were weighted by the landings (SEDAR53-WP05 2016; SEDAR53-WP08 2016). Length compositions were also developed for chevron traps from SERFS data, and for headboat discards from observer data. All years of recreational length compositions were included, with the exception of headboat discards in 2014 (small sample size). Following SEDAR19, all years after 1986 of commercial lines length compositions were included, and only three years (1986, 1987, 1989) of commercial other because of small sample sizes. All years of SERFS length compositions after 1997, except 2008, were included. Sample sizes of length composition data are shown in Tables 4 and 5.

2.2.6 Age Compositions

Age compositions were developed using increment counts, for ages 1–16, with the maximum age an accumulator group for ages 16 and older. For the commercial and recreational fleets, the age compositions were weighted by the length compositions in attempt to address any bias in selection of fish to be aged. The assessment excluded years with small sample sizes, generally keeping years used in SEDAR19 and the adding years 2009–2015. In some cases, years used in SEDAR19 were dropped here because of re-evaluation with current methods that resulted in smaller sample size, and in some cases years excluded from SEDAR19 were included here because of additional ageing of earlier samples (e.g., commercial ages in 1997–1999). Sample sizes of age composition data are shown in Tables 4 and 5.

3 Stock Assessment Methods

This assessment updates the primary model applied during SEDAR19 to South Atlantic red grouper. The methods are reviewed below, and modifications since SEDAR19 are highlighted.

3.1 Overview

This assessment used the Beaufort Assessment Model (BAM, Williams and Shertzer 2015), which applies a statistical catch-age formulation, implemented with the AD Model Builder software (Fournier et al. 2012). In essence, the model simulates a population forward in time while including fishing processes (Quinn and Deriso 1999; Shertzer et al. 2008). Quantities to be estimated are systematically varied until characteristics of the simulated population match available data on the real population. The model is similar in structure to Stock Synthesis (Methot and Wetzel 2013). Versions of BAM have been used in previous SEDAR assessments of reef fishes in the U.S. South Atlantic, such as red porgy, black sea bass, tilefish, blueline tilefish, gag, greater amberjack, snowy grouper, vermilion snapper, and red snapper, as well as in the previous SEDAR assessment of red grouper (SEDAR19 2009).

3.2 Data Sources

The catch-age model included data from four fleets that caught red grouper in southeastern U.S. waters: commercial lines (handline and longline), commercial other (pots, traps, diving, trawl, miscellaneous), recreational headboat, and general recreational. The model was fitted to data on annual landings (in numbers for the recreational fleet, in whole weight for commercial fleets); annual discards (in numbers, with a 0.2 release mortality rate applied); annual length compositions of landings, discards, and the SERFS; annual age compositions of landings and the SERFS; two fishery dependent indices of abundance (commercial handline, headboat); and one fishery independent index of abundance (SERFS combined chevron trap and video gears). Data used in the model are tabulated in §2 of this report.

Two changes to the SEDAR19 data sources were made for SEDAR53. First, an index developed for SEDAR19 using MRFSS data was discarded by the SEDAR53 assessment panel, after evaluating its effect on the assessment and finding it to have almost no influence. Second, the SERFS video data were included along with the chevron trap data for creating the fishery independent index. The video survey was initiated after SEDAR19, and it was considered here as part of the TOR. Sensitivity runs considered both the inclusion of the MRFSS index and the exclusion of SERFS video data.

3.3 Model Configuration

Model structure and equations of the BAM are detailed in Williams and Shertzer (2015). The assessment time period was 1976–2015. A description of the application to red grouper 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 $1 - 16^{+}$, where the oldest age class 16^{+} allowed for the accumulation of fish (i.e., plus group).

Initialization Initial (1976) abundance at age was estimated in the model as follows. First, the equilibrium age structure was computed for ages 1–16 based on natural and fishing mortality (F_{init}), where F_{init} was assumed equal to the geometric mean of estimated F for the period 1976–1978. 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 2–16, initial (1976) abundance of age-1 fish was computed using the same methods as for recruits in other years (described below).

Somatic growth Mean total length (TL, in units of mm) at age of the population was modeled with the von Bertalanffy equation, and weight at age (whole weight, WW, in units of kg) was modeled as a function of total length (Table 1, Figure 2). Parameters of growth were estimated external to the assessment model and were treated as input. The von Bertalanffy parameter estimates were $L_\infty = 848.2$, $K = 0.213$, and $t_0 = -0.67$. Length was converted to weight as $WW = (8.418\text{E}{-}09)TL^{3.1}$. For fitting length composition data, the distribution of size at age was assumed normal with CV estimated by the assessment model ($\widehat{\text{CV}} = 8.55\%$).

Natural mortality rate The natural mortality rate (M) was assumed constant over time, but decreasing with age. The form of M as a function of age was based on Lorenzen (1996). The Lorenzen (1996) approach inversely relates the natural mortality at age to mean weight at age W_a by the power function $\text{M}_a = \alpha W_a^\beta$, where α is a scale parameter and β is a shape parameter. Lorenzen (1996) provided point estimates of α and β for oceanic fishes, which were used for this assessment. As in SEDAR19 and other previous SEDAR assessments, the Lorenzen estimates of M_a were rescaled to provide the same fraction of fish (2.6% in this case) surviving through the oldest observed age (26 years) as would occur with constant $M = 0.14$. This approach using cumulative mortality is consistent with the findings of Hoenig (1983) and Hewitt and Hoenig (2005).

In addition to the Lorenzen estimator, this assessment also considered the Charnov estimator (Charnov et al. 2015) in a sensitivity run. The Charnov et al. (2015) approach inversely relates the natural mortality at age to somatic growth, $\text{M}_a = K \times [L_a/L_\infty]^{-1.5}$. This estimator was not rescaled and results in cumulative survival to the maximum observed age of 0.05%, which is much lower than that of $M = 0.14$.

Maturity and sex ratio Female maturity was modeled with a logistic function; parameters for this model were provided by the SEDAR19 DW. The age at 50% female maturity was estimated to be 2.8 years, and age-1 females were considered immature. All males were assumed mature.

Red grouper are a protogynous hermaphrodite. Transition from female to male was modeled with a logistic function, estimated by the SEDAR19 DW.

Ogives describing maturity and sex ratio (Table 1) were treated as input to the assessment model.

Spawning stock Spawning biomass was modeled as total (males+females) mature biomass at the time of peak spawning. For protogynous stocks, use of total mature biomass, rather than that of females or males only, has been found to provide more robust estimates of management quantities over a broad range of conditions (Brooks et al. 2008). For red grouper, peak spawning was considered to occur in mid-April.

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 1976, when composition data could provide information on year-class strength.

For modeling recruitment, this standard assessment implemented one notable change to the SEDAR19 model. The previous assessment was able to estimate the steepness parameter ($\hat{h} = 0.92$) of the spawner-recruit model. In this assessment, steepness was not estimable (hit the upper bound of 0.99), even when applying a prior distribution to inform the estimation (Shertzer and Conn 2012). The Assessment Panel examined likelihood profiles on steepness, and found evidence that steepness is likely greater than 0.75, but the profile was relatively flat between 0.75 and 0.99, within two negative-log-likelihood points of the minimum at $h = 0.99$. Thus, the panel concluded that steepness is likely in the range (0.75, 0.99) and, for the base run, fixed steepness at the midpoint $h = 0.87$ of that range. Sensitivity runs examined values at the boundaries of that range, and uncertainty analyses included the full range.

Landings Time series of landing from four fleets were modeled: commercial lines (handline, longline), commercial other (pots, traps, trawl, diving, miscellaneous), recreational headboat, and general recreational. Landings were modeled with the Baranov catch equation (Baranov 1918) and were fitted in either weight or numbers, depending on how the data were collected (1000 lb whole weight for commercial fleets, and 1000 fish for recreational fleets). The observed landings time series start in the first assessment year (1976) for each fleet except general recreational, because the MRFSS (MRIP) started in 1981. Thus for years 1976–1980, general recreational landings were predicted in the assessment model (but not fit to data), by applying the geometric mean recreational F from the years 1981–1983. A modification from SEDAR19 is that general recreational landings were estimated using MRIP methodology rather than MRFSS methodology.

Discards As with landings, discard mortalities (in units of 1000 fish) were modeled with the Baranov catch equation (Baranov 1918), which required estimates of discard selectivities and release mortality rates. Discards were assumed to have a mortality rate of 0.2 for all fleets, as suggested by the SEDAR19 DW. A more recent study found immediate release mortality of red grouper in the Gulf of Mexico to be 0.24 (Pulver 2017), and thus a sensitivity analysis used a release mortality of 0.4. This value is ad hoc, scaled up from 0.24 to account for delayed mortality, and is considered here not as necessarily a defensible estimate, but rather to examine model results if release mortality were something higher than 0.2.

For commercial lines and headboats, discard time series were assumed to begin in 1984, with the start of fishing regulations; for the general recreational fleet, data starting in 1981 were provided and used in the assessment. In years without observed discards (i.e., 1984–1991 for commercial lines, and 1984–2004 for headboat), predicted discards were generated in the assessment model, by applying the fleet-specific geometric mean discard F from years with data. Although average Fs were applied, the magnitude of modeled discards would change with fluctuations in abundance and with changes in regulations, because of corresponding modifications in discard selectivities (described below).

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

Selectivities

Generally, selectivity curves were estimated using a parametric approach. This approach restricts the number of estimated parameters and imposes theoretical structure on the shape of the curve. For most fleets and the survey, selectivities were estimated as a two-parameter logistic model (flat-topped). The exceptions were discards (described below) and the commercial other fleet, for which selectivity was modeled with the double logistic formulation (dome-shaped), a four-parameter model.

Selectivity of each fleet was fixed within each period of size-limit regulations, but was permitted to vary among periods. Fisheries experienced three periods of size-limit regulations (no limit prior to 1984, 12-inch limit during 1984–1991, and 20-inch limit during 1992–2015). Age and length composition data are critical for estimating selectivity parameters, and ideally, a model would have sufficient composition data from each fleet over time to estimate distinct selectivities in each period of regulations. That was not the case here, and thus additional assumptions were applied to define selectivities, as follows. Because the MRIP collected little age or length composition data on red grouper before 1992, general recreational selectivity mirrored that of the headboat fleet in the first two regulatory periods. Because composition data from the commercial fleets were lacking prior to 1984, commercial lines selectivities in the first and second regulatory periods were set equal, as were commercial other selectivities. In addition, the commercial other fleet lacked composition data after 1992; thus three of the four selectivity parameters in regulation period three were set equal to those of period two, and the fourth parameter, which controls the inflection of the ascending limb, was set equal to the age where mean size equals 20 inches (the size limit).

Selectivities of discards were partially estimated, assuming that discards consisted primarily of undersized fish, as implied by observed length compositions of discards. The general approach taken for discard selectivities was that the value for age-1 fish was estimated, age-2 fish were assumed to have full selection, and selectivity for age 2^+ fish was set equal to the age-specific probability of being below the size limit given the estimated normal distribution of size at age. Length compositions of discards were available only from the headboat fleet, and therefore some additional assumptions were necessary; in particular, selectivities of discards were assumed the same for all fleets.

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

Relative to SEDAR19, two changes were made regarding how selectivities were modeled. First, selectivity of the fishery independent survey was previously modeled as dome-shaped, but here modeled as flat-topped. This change was made for two reasons: 1) likelihood profiles indicated better fits to SERFS length and age composition data with flat-topped selectivity, and 2) catch-curve analysis revealed similar values of Z from SERFS, commercial lines, and headboat age compositions, which is consistent with the three having similar descending limbs in selectivity. The second change made for SEDAR53 was that the commercial other selectivity was modeled distinctly from that of the SERFS, whereas in SEDAR19, the two gears shared selectivity parameters. Although SERFS selectivity was changed to flat-topped, length compositions from commercial other still suggested dome-shaped selectivity for that fleet.

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 fit to one fishery independent index of abundance (SERFS 1990–2015) and to two fishery dependent indices of abundance (headboat 1980–2015 and commercial handline 1993–2015). As described previously, an index from MRFSS data (1991–2008) used in SEDAR19 was not used in the base model of this assessment, but was included in a sensitivity run. Predicted indices were conditional on selectivity of the fleet or survey and were computed from numbers at age at the midpoint of the year or, in the case of commercial handline, weight at age. Catchability associated with the SERFS index was assumed constant through time. Catchability of the two fishery dependent indices varied over time, and was modeled with a random walk (Wilberg and Bence 2006; SEDAR Procedural Guidance 2009; Wilberg et al. 2010). This was a modification from SEDAR19, which assumed constant catchability for all indices.

Biological reference points Biological reference points (benchmarks) were calculated based on maximum sustainable yield (MSY) estimates from the Beverton–Holt spawner-recruit model with bias correction (expected values in arithmetic space). Computed benchmarks included MSY, fishing mortality rate at MSY (F_{MSY}), and spawning stock at MSY ($\mathrm{SSB}_{\mathrm{MSY}}$). In this assessment, spawning stock measures 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 landings and dead discards were fit closely, and observed composition data and abundance indices were fit to the degree that they were compatible. Landings, discards, and index data were fit using lognormal likelihoods, with annual CV=0.05 (landings and discards) or estimated values from a standardization procedure (indices). Length and age composition data were fit using the Dirichlet-multinomial distribution, with sample size represented by the annual number of trips, adjusted by an estimated variance inflation factor.

SEDAR19 fit composition data using the multinomial distribution, and many SEDAR assessments since then have applied a robust version of the multinomial likelihood, as recommended by Francis (2011). More recent work has questioned use of the multinomial distribution in stock assessment models (Francis 2014), and of the alternative distributions, two appear most promising, the Dirichlet-multinomial and logistic-normal (Francis In Press; Thorson et al. In Press). Both are self-weighting and therefore iterative re-weighting (e.g., Francis 2011) is unnecessary, and both better account for intra-haul correlations (i.e., fish caught in the same set are more alike in length or age than fish caught in a different set). The Dirichlet-multinomial allows for observed zeros (the logistic-normal does not), and has recently been implemented in Stock Synthesis (Methot and Wetzel 2013; Thorson et al. In Press). Using the SEDAR19 data and assessment model, results with the Dirichlet-multinomial distribution were similar to those with the multinomial distribution (Figure 3). This SEDAR53 assessment used the Dirichlet-multinomial distribution in the base run, but considered the logistic-normal distribution in a sensitivity run.

For parameters defining selectivities, CV of size at age, σ_R, and Dirichlet-multinomial variance inflation factors, 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. Some key features include 1) discard mortality of 0.2 across fleets, 2) Lorenzen age-based natural mortality scaled to M=0.14, 3) a Beverton-Holt spawner-recruit model with spawning stock computed from the mature biomass of both sexes, and 4) steepness fixed at $h = 0.87$. The base run does not necessarily represent reality better than all other possible configurations, and thus this assessment attempted to portray uncertainty in point estimates through sensitivity and retrospective analyses, and through a Monte-Carlo/bootstrap approach (described below).

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. For example, S5 and S10 were highlighted by the Assessment Panel as runs that would require further vetting before any consideration in management. Sensitivity runs vary from the base run as follows.

- S1: Steepness $h = 0.99$, at the upper bound of the range identified by likelihood profiling.
- S2: Steepness $h = 0.75$, at the lower bound of the range identified by likelihood profiling.
- S3: High natural mortality $M = 0.2$ used to scale the Lorenzen (1996) age-based estimator.
- S4: Low natural mortality $M = 0.1$ used to scale the Lorenzen (1996) age-based estimator.
- S5: Natural mortality follows the Charnov et al. (2015) age-based estimator with no rescaling.
- S6: Up-weight the SERFS index by a factor of six.
- S7: No video data.
- S8: Continuity configuration, including the multinomial likelihood for composition data, commercial other selectivity mirrors that of SERFS, steepness $h = 0.92$, MRFSS index included, and constant catchability for all indices.
- S9: Logistic-normal likelihood applied to composition data.
- S10: Release mortality rate equals 0.4 for all discards.

Retrospective analyses were also conducted, incrementally dropping one year at a time for seven iterations, thus reaching back to the terminal year of the last assessment. In these runs, the terminal years were 2014, 2013, 2012, 2011, 2010, 2009, or 2008.

3.4 Parameters Estimated

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

3.5 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F, as were equilibrium landings, discards, and spawning biomass. Equilibrium landings and discards were also computed as functions of biomass B, which itself is a function of F. As in computation of MSY-related benchmarks (described in §3.6), per recruit and equilibrium analyses applied the most recent selectivity patterns averaged across fleets, weighted by each fleet's F from the last three years of the assessment (2013–2015).

3.6 Benchmark/Reference Point Methods

In this assessment of red 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 calculated from the spawner-recruit curve and parameters describing growth, natural mortality, maturity, and selectivity. The value of F_{MSY} is the F that maximizes equilibrium removals.

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

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

where R_0 is virgin recruitment, h is steepness, and $\Phi_F = \phi_F/\phi_0$ is spawning potential ratio given growth, maturity, and total mortality at age (including natural and fishing mortality rates). The R_{eq} and mortality schedule imply an equilibrium age structure and an average sustainable yield (ASY). The estimate of F_{MSY} is the F giving the highest ASY, and the estimate of MSY is that ASY. The estimate of $\mathrm{SSB}_{\mathrm{MSY}}$ follows from the corresponding equilibrium age structure, as does the benchmark estimate of discard mortalities (D_{MSY}), here separated from ASY (and consequently, MSY).

Estimates of MSY and related benchmarks are conditional on selectivity pattern. The selectivity pattern used here was an average of terminal-year selectivities from each fleet, where each fleet-specific selectivity was weighted in proportion to its corresponding estimate of F averaged over the last three years (2013–2015). If the selectivities or relative fishing mortalities among fleets were to change, so would the estimates of MSY and related benchmarks.

For this stock, the maximum fishing mortality threshold (MFMT) is defined by the SAFMC as F_{MSY}, and the minimum stock size threshold (MSST) as $75\%\mathrm{SSB}_{\mathrm{MSY}}$. Overfishing is defined as $F >$ MFMT and overfished as SSB $<$ MSST. However, for a stock under a rebuilding plan, increased emphasis is given to SSB relative to $\mathrm{SSB}_{\mathrm{MSY}}$ (rather than MSST), as $\mathrm{SSB}_{\mathrm{MSY}}$ is the rebuilding target. Current status of the stock is represented by SSB in the latest assessment year (2015), and current status of the fishery is represented by the geometric mean of F from the latest three years (2013–2015).

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 per recruit relative to that at the unfished level. These quantities may serve as proxies for F_{MSY} if necessary. 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 SEDAR19, 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), SEDAR19 (2009), 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 MCB approach translates uncertainty in model input into uncertainty in model output, by fitting the model many times with different values of "observed" data and key input parameters. A chief advantage of the approach is that the results describe a range of possible outcomes, so that uncertainty is characterized more thoroughly than it could be by any single fit or handful of sensitivity runs. A minor disadvantage of the approach is that computational demands are relatively high.

In this assessment, the BAM was successively re-fit in $n = 4000$ 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 1.4% were discarded, based on a 0.5% trim on $R0$ or because the model did not properly converge. This left $n = 3943$ 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 ($\hat{O}_{s,y}$),

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

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

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

3.7.2 Monte Carlo sampling

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

3.7.2.1 Natural and discard mortalities

Point estimates of natural mortality ($M = 0.14$) and discard mortality ($\delta = 0.2$) were provided by the DW, but with some uncertainty. To carry forward these sources of uncertainty, Monte Carlo sampling was used to generate deviations from the point estimates. For discard mortality, a new δ value was drawn for each MCB trial from a uniform distribution over the range suggested by the DW [0.1, 0.3]. For natural mortality, a new M value was drawn for each MCB trial from a truncated normal distribution (range [0.1, 0.2]) with mean equal to the point estimate ($M = 0.14$) and standard deviation set to provide a lower 95% confidence limit at 0.1 (the boundary nearest the mean). Each realized value of M was used to scale the age-specific Lorenzen M, as in the base run.

3.7.2.2 **Steepness** In initial trials of the assessment model, steepness 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 uniform distribution [0.75, 0.99]. The bounds were chosen as the range of values consistent with this red grouper data set, as indicated by likelihood profiling on steepness.

3.8 Projections

Projections were run to predict stock status in years after the assessment, 2016–2030. The year 2020 is the last year of the current rebuilding plan, however projections were run through 2030 because of possible revision to that 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 selectivity, were fixed to the most recent values of the assessment period. A single selectivity curve was applied to calculate landings, and one applied to calculate dead discards, each computed by averaging selectivities across fleets using geometric mean Fs from the last three years of the assessment period, similar to computation of MSY benchmarks (§3.6).

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

3.8.1 Initialization of projections

Although the terminal year of the assessment is 2015, the assessment model computes abundance at age (N_a) at the start of 2016. For projections, those estimates were used to initialize N_a. However, the assessment has no information to inform the strength of 2016 recruitment, and thus it computes 2016 recruits (N_1) as the expected value, that is, without deviation from the spawner-recruit curve, and corrected to be unbiased in arithmetic space. In the stochastic projections, lognormal stochasticity was applied to these abundances after adjusting them to be unbiased in log space, with variability based on the estimate of σ_R. Thus, the initial abundance in year one (2016) of projections included this variability in N_1. The deterministic projections were not adjusted in this manner, because deterministic recruitment follows the bias-corrected (arithmetic space) spawner-recruit curve precisely, consistent with the assessment's 2016 predictions.

Fishing rates that define the projections were assumed to start in 2017. Because the assessment period ended in 2015, the projections required an initialization period (2016). The level of total landings in this period was assumed equal to the current (2013–2015) average of 365,262 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 release mortality, as well as in estimated quantities such as the remaining spawner-recruit parameters, selectivity curves, and in initial (start of 2016) 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 ($\bar{R}_y$). Annual variability was added to the mean values by choosing multiplicative deviations at random from a lognormal distribution,

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

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

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

Rebuilding time frame Based on results from the previous SEDAR19 benchmark assessment, red grouper is currently under a rebuilding plan that extends through $T = 2020$. However, because it does not appear that the stock can rebuild by the end of 2020, the terminal year (T) of the rebuilding time frame may be revised, and thus SEDAR53 projections were extended through 2030 or 2040. Rebuilding is defined in the TOR by the criterion that projection replicates achieve stock recovery (i.e., $\text{SSB}_T \geq \text{SSB}_{\text{MSY}}$) with probability of at least 70%. 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).

The generation time (G) of red grouper was estimated to be 14 years, using the estimator described by Case (2000). This estimator follows a cohort of individuals from birth, sums all their reproductive output during their lifetimes at each age a, and averages to produce a mean age of reproduction,

$$G = \frac{\sum_{a=0}^{max} l_a b_a a}{\sum_{a=0}^{max} l_a b_a} \tag{4}$$

where l_a is survival rate to age a and b_a is the reproductive contribution at age a, here represented by total mature biomass. The maximum age (max) for this calculation is set sufficiently high to achieve an equilibrium value of generation time.

Projection scenarios The SEDAR53 TOR described three projections scenarios: $F = F_{\text{MSY}}$ to define OFL with a 50% probability of overfishing, $F = 75\% F_{\text{MSY}}$, and $F = F_{\text{rebuild}}$. The F_{rebuild} was defined as the maximum F that achieves rebuilding with 0.7 probability by 2020. However, because rebuilding could not be achieved by 2020 even with $F = 0$, the latter scenario was replaced with the $F = 0$ projection. These projections were extended through 2030.

The Assessment Panel (AP) noted that the assessment model estimated low recruitment values in the last decade of the assessment, and if that pattern were to continue into the future, the above projections may be overly optimistic. Thus, the AP examined recruitment scenarios with low recruitment. These scenarios were defined similarly to those described above, however rather than using the estimated spawner-recruit curve, mean projected recruitment was defined as follows. For the deterministic projection, recruitment equaled the geometric mean of the 2006–2015 values estimated by the base assessment model. For the stochastic projections, $\bar{R}_y$ was set equal to the MCB-specific geometric mean of the 2006–2015 estimates, divided by the MCB-specific bias correction. As in stochastic projections described above, annual variability was included as random lognormal deviations.

Because the current plan for rebuilding by 2020 does not appear to be achievable, two additional projection scenarios were considered in which the fishing rate is modified in 2019. The intent of starting in 2019 is to provide sufficient time for procedures that may be required to alter a rebuilding plan. One of these projections sets $F = 0$, which may be useful for redefining the rebuilding time frame, and the other sets $F = 75\% F_{\text{MSY}}$. In both, the level of landings in 2016–2018 was assumed equal to the current (2013–2015) average of 365,262 lb whole weight. These projections were extended through 2040.

Thus, this report contains a total of eight projections scenarios:

- Scenario 1: $F = F_{\text{MSY}}$ starting in 2017

- Scenario 2: $F = 75\%F_{\text{MSY}}$ starting in 2017
- Scenario 3: $F = 0$ starting in 2017
- Scenario 4: $F = F_{\text{MSY}}$ starting in 2017, with low recruitment
- Scenario 5: $F = 75\%F_{\text{MSY}}$ starting in 2017, with low recruitment
- Scenario 6: $F = 0$ starting in 2017, with low recruitment
- Scenario 7: $F = 0$ starting in 2019
- Scenario 8: $F = 75\%F_{\text{MSY}}$ starting in 2019

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 4). The model was configured to fit observed commercial and recreational removals closely (Figures 5–11). Fits to indices of abundance generally captured the observed trends but not all annual fluctuations (Figures 12–14).

4.2 Parameter Estimates

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

4.3 Stock Abundance and Recruitment

In general, estimated abundance at age shows a structure that has been relatively consistent through time, reflecting effects of year-class strength and annual fishing mortality, but without severe age truncation (Figure 15; Table 6). Total estimated abundance decreased until 1990, then increased to a peak in 2004, then decreased again until reaching its lowest values at the end of the assessment period 2013-2015. The uptick in 2016 should be interpreted with caution, as it is primarily based on the forecast of recruitment (age-1 fish), which is uniformed by data on year-class strength. Instead, the forecasted 2016 value is that expected from the spawner-recruit curve precisely, which is larger than any in the last decade. Annual number of recruits is shown in Table 6 (age-1 column) and in Figure 16. The highest recruitment values were predicted to have occurred in 2003–2004. Since then, recruitment has been below expectation.

4.4 Total and Spawning Biomass

Estimated biomass at age followed a similar pattern as abundance at age (Figure 17; Table 7). Total biomass and spawning biomass showed similar trends—general decline until 1990, increase until the mid-2000s, and decrease since (Figure 18; Table 8).

4.5 Selectivity

Selectivity of the SERFS chevron trap/video gear is shown in Figure 19. Selectivities of landings from commercial and recreational fleets are shown in Figures 20–21, and selectivities of discard mortalities (all fleets) are in Figure 22. In the most recent years, full selection of landings occurred near ages 4–7, depending on the fleet.

Average selectivities of landings and of dead discards were computed from F-weighted selectivities in the most recent three assessment years (Figure 23). This average selectivity was used in computation of point estimates of benchmarks, as well as in projections. All selectivities from the most recent period, including average selectivities, are tabulated in Table 9.

4.6 Fishing Mortality, Landings, and Discards

The estimated fishing mortality rates (F) have shown much variability across years, with some of the lowest values in the terminal three years (Figure 24; Table 10). The commercial lines and general recreational fleets have been the largest contributors to total F, with general recreational contributing most in recent years.

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

Table 12 shows total landings at age in numbers, and Table 13 in weight. The general recreational fleet takes the most landings, in both numbers and weight (Figures 25, 26; Tables 14, 15). In recent years, total landings remained below MSY (Figure 26). Estimated discard mortalities occurred on a smaller scale than landings (Figures 27, 28; Tables 16, 17).

4.7 Spawner-Recruitment Parameters

The estimated Beverton–Holt spawner-recruit curve is shown in Figure 29, 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 $h = 0.87$ (fixed), unfished age-1 recruitment $\widehat{R_0} = 359749$, unfished spawners (mt) per recruit $\phi_0 = 0.0241$, and standard deviation of recruitment residuals in log space $\widehat{\sigma}_R = 0.58$ (which resulted in bias correction of $\varsigma = 1.18$). Uncertainty in these quantities was estimated through the MCB analysis (Figure 30).

4.8 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F (Figure 31). 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 (2013–2015). The F that provides 40% SPR is $F_{40\%} = 0.10$, 30% is $F_{30\%} = 0.14$, and 20% is $F_{20\%} = 0.20$. For comparison, F_{MSY} from the base run corresponds to about 33% SPR.

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of F (Figure 32). By definition, the F that maximizes equilibrium landings is F_{MSY}, and the corresponding landings and spawning biomass are MSY and $\mathrm{SSB}_{\mathrm{MSY}}$.

4.9 Benchmarks / Reference Points

As described in §3.6, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the expected spawner-recruit curve (Figure 29). Reference points estimated were F_{MSY}, MSY, B_{MSY} and $\mathrm{SSB}_{\mathrm{MSY}}$. Based on F_{MSY}, three possible values of F at optimum yield (OY) were considered—$F_{\mathrm{OY}} = 65\% F_{\mathrm{MSY}}$, $F_{\mathrm{OY}} = 75\% F_{\mathrm{MSY}}$, and $F_{\mathrm{OY}} = 85\% F_{\mathrm{MSY}}$—and for each, the corresponding yield was computed. Standard errors of benchmarks were approximated as those from MCB analysis (§3.7).

Maximum likelihood estimates (base run) of benchmarks, as well as median values from MCB analysis, are summarized in Table 18. Point estimates of MSY-related quantities were $F_{\mathrm{MSY}} = 0.12$ (y^{-1}), MSY $= 794.3$ (1000 lb), $B_{\mathrm{MSY}} = 4188.3$ (mt), and $\mathrm{SSB}_{\mathrm{MSY}} = 3183.4$ (mt). The estimate of $\mathrm{SSB}_{\mathrm{MSY}}$ is about 37% of the unfished spawning biomass. Median estimates were $F_{\mathrm{MSY}} = 0.13$ (y^{-1}), MSY $= 806.7$ (1000 lb), $B_{\mathrm{MSY}} = 4149.6$ (mt), and $\mathrm{SSB}_{\mathrm{MSY}} = 3145.4$ (mt). Distributions of these benchmarks from the MCB analysis are shown in Figure 33.

4.10 Status of the Stock and Fishery

Estimated time series of stock status (SSB/MSST and $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$) showed general decline throughout the beginning of the assessment period, increase starting about 1990, and then decrease since 2007 (Figure 34, Table 8). Base-run estimates of spawning biomass have remained below the threshold (MSST) for most of the assessment period. Current stock status was estimated in the base run to be $\mathrm{SSB}_{2015}/\mathrm{MSST} = 0.38$ and $\mathrm{SSB}_{2015}/\mathrm{SSB}_{\mathrm{MSY}} = 0.29$ (Table 18), indicating that the stock has not yet recovered to $\mathrm{SSB}_{\mathrm{MSY}}$. Median values from the MCB analysis indicated similar results ($\mathrm{SSB}_{2015}/\mathrm{MSST} = 0.37$ and $\mathrm{SSB}_{2015}/\mathrm{SSB}_{\mathrm{MSY}} = 0.27$). The uncertainty analysis suggested that the terminal estimate of stock status is robust (Figures 35, 36). Of the MCB runs, 100% indicated that the stock in 2015 was below $\mathrm{SSB}_{\mathrm{MSY}}$, and 97.7% that the stock was below MSST. Age structure estimated by the base run generally showed fewer fish of all ages than the (equilibrium) age structure expected at MSY (Figure 37). The 2015 age structure showed more old fish than in previous years, reflecting the strong recruitment pulse in the early 2000's, and it showed fewer young fish, reflecting the poor recruitment in recent years.

The estimated time series of F/F_{MSY} suggests that overfishing has occurred throughout most of the assessment period (Table 8), but with some uncertainty in terminal years demonstrated by the MCB analysis (Figure 34). Current fishery status in the terminal year, with current F represented by the geometric mean from the period 2013–2015, was estimated by the base run to be $F_{2013-2015}/F_{\mathrm{MSY}} = 1.54$, and the median value was $F_{2013-2015}/F_{\mathrm{MSY}} = 1.54$ (Table 18). The fishery status was less robust than the stock status (Figures 35, 36). Of the MCB runs, approximately 89.1% agreed with the base run that the stock is currently experiencing overfishing.

4.10.1 Comparison to Previous Assessment

Time series of stock and fishery status estimated by this assessment were similar in pattern to those from the previous, SEDAR19 assessment (Figure 38). Trends in $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$ from the two assessments tracked each other closely. Trends in F/F_{MSY} generally tracked each other, but SEDAR53 estimated that overfishing has been more severe. On the absolute scale (plots not shown), the time series of SSB and F were similar, suggesting that differences in F/F_{MSY} were driven primarily by the denominator, F_{MSY}. Indeed, SEDAR19 estimated $F_{\mathrm{MSY}} = 0.22$ and SEDAR53 estimated $F_{\mathrm{MSY}} = 0.12$. This difference is likely due to estimated discard selectivities, with SEDAR53 showing increased prevalence of discard mortalities relative to landings.

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. Sensitivity runs are a tool for better understanding model behavior, and therefore should not be used as the basis for management. All runs are not considered equally plausible in the sense of alternative states of nature. Time series of F/F_{MSY} and $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$ demonstrate sensitivity to steepness (Figure 39), natural mortality (Figure 40), the SERFS index (Figure 41), SEDAR19 configuration (Figure 42), use of the logistic-normal distribution (Figure 43), and release mortality rate (Figure 44). The majority of these runs agreed with the status indicated by the base run (Figure 45, Table 19), although one suggested the stock is not overfished and two indicated that overfishing is not occurring. 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 starting in 2011 (Figure 46). However, prior to 2011, the analysis did reveal a pattern of overestimated recruitment in the terminal year. This resulted in several years with overestimated SSB.

4.12 Projections

Projections based on $F = F_{\mathrm{MSY}}$ allowed the spawning stock to increase with approximately 19% of replicate projections recovered to $\mathrm{SSB}_{\mathrm{MSY}}$ by 2030 (Figure 47, Table 20). Stock recovery was more rapid for projections based on $F = 75\%F_{\mathrm{MSY}}$ (Figure 48, Table 21). The $F = 0$ projections achieved recovery with about 0.08 probability in 2020, about 0.5 probability in 2023, and about 0.7 probability in 2025 (Figure 49, Table 22).

If recruitment were to remain low into the future, stock recovery is expected to be slower than in projection scenarios 1–3. With reductions in F from the current level to $F = F_{\mathrm{MSY}}$ or $F = 75\%F_{\mathrm{MSY}}$, the spawning biomass is projected to increase, but with 0.0 probability of recovery by 2030 (Figures 50–51, Tables 23–24). The $F = 0$ scenario with low recruitment achieved about 0.3 probability of recovery in 2030 (Figure 52, Table 25). These low-recruitment projections may be useful simply as exploratory "what if" scenarios for interpreting risk, or they may be useful for informing short-term catch levels.

If projected fishing rates were modified in 2019 (rather than 2017, as above), the $F = 0$ scenario achieved recovery with at least 0.5 probability in 2025 and at least 0.7 probability in 2027 (Figure 53, Table 26). With fishing rate of $F = 75\%F_{\mathrm{MSY}}$ starting in 2019, recovery was achieved with at least 0.5 probability in 2032 and at least 0.7 probability in 2036 (Figure 54, Table 27). The generation time of red grouper was estimated to be 14 years.

5 Discussion

5.1 Comments on the Assessment

The base run of the BAM indicated that the stock is overfished ($\mathrm{SSB}_{2015}/\mathrm{MSST} = 0.38$), and that overfishing is occurring ($F_{2013-2015}/F_{\mathrm{MSY}} = 1.54$). Median values from the MCB analyses were in qualitative agreement with those results ($\mathrm{SSB}_{2015}/\mathrm{MSST} = 0.37$ and $F_{2013-2015}/F_{\mathrm{MSY}} = 1.58$).

As in SEDAR19, this assessment estimated that spawning biomass increased from the 1990s until reaching a peak in 2006–2008. Those were the terminal years of SEDAR19, and subsequently this assessment estimated that spawning biomass and abundance have decreased, terminating in 2015 near the lowest values of the entire time series (1976–2015). This decrease appears to be due to a run of poor recruitment since 2005, combined with very high landings in 2007–2009, particularly from the general recreational fleet.

The recent poor recruitment may or may not continue into the future. The hypothesis of a productivity regime shift potentially merits consideration, but if so, should be evaluated systematically based on supporting evidence (e.g., Klaer et al. 2015). For now, it seems premature to conclude that a regime shift has occurred, because no mechanism for the recent poor recruitment has been identified, and because the duration (since 2005) has been less than the time of a single generation.

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

In addition to including the more recent years of data, this standard assessment contained several modifications to the data of SEDAR19, as well as to the BAM implementation. The main modifications, as described throughout this report, were the following:

- The recreational landings and discards were estimated through MRIP, rather than MRFSS, methodology.
- No MRFSS index.
- SERFS video data were included.
- Steepness was fixed at $h = 0.87$.
- Selectivities of the SERFS index and commercial other fleet were estimated as distinct curves. Selectivity of commercial other was dome-shaped, but unlike in SEDAR19, selectivity of SERFS was flat-topped.
- Catchability of fishery dependent indices was modeled with annual variation (random walk).
- Age and length compositions were fitted using the Dirichlet-multinomial distribution.

In general, fishery dependent indices of abundance may not track actual abundance well, because of factors such as hyperdepletion or hyperstability. This situation amplifies the importance of fishery independent sampling. In this assessment, the SERFS index was not fit particularly closely, most notably with a run of negative residuals at the end of the time series. Improved fits to those recent index values, as in sensitivity runs 6 and 7, resulted in a more depleted stock status than in the base run. Thus, if those lower values in the SERFS index reflect stock size rather than observation error, the base run could be overly optimistic.

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 red 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 is typically between 15% and 25% (Table 8). The equilibrium proportion of adult fish that are male at MSY is near 37% (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 midpoint (0.87) of the range implied by likelihood profiling. Thus MSY-based management quantities from the base run are conditional on that value of steepness (Mangel et al. 2013). An alternative approach would be to choose a proxy for F_{MSY}, most likely $F_{X\%}$ (such as $F_{30\%}$ or $F_{40\%}$). However, such proxies do not provide biomass-based benchmarks. If managers wish to gauge stock status, assumptions about equilibrium recruitment levels would be necessary. Furthermore, choice of X% implies an underlying steepness, as described by Brooks et al. (2009). Thus, choosing a proxy equates to choosing steepness. Given the two alternative approaches, it seems preferable to focus on steepness, as its value is less arbitrary, coming from a prior distribution estimated through meta-analysis (e.g., Shertzer and Conn 2012) or, in this assessment, through likelihood profiling with data on the stock being assessed.

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.
- Projections apply the Baranov catch equation to relate F and landings using a one-year time step, as in the assessment. The catch equation implicitly assumes that mortality occurs throughout the year. This assumption is violated when seasonal closures are in effect, introducing additional and unquantified uncertainty into the projection results.
- The projections assumed that the estimated spawner-recruit relationship applies in the future and that past residuals represent future uncertainty in recruitment. If future recruitment is characterized by runs of large or small year classes, possibly due to environmental or ecological conditions, stock projections may be affected. For example, the run of poor recruitment in recent years was unforeseeable at the time of SEDAR19, and resulted in those projections being overly optimistic.
- It remains to be seen whether the recent poor recruitment will continue into the future. That possibility exists and could play into considerations of risk tolerance. For example, a risk-averse strategy might use low-recruitment projections, such as those of scenarios 4–6, to set catch levels in the short term ($\leq$ 5 years) or until evidence supports that recruitment has rebounded. This short-term strategy could be adopted, even if long-term planning (management targets) relies on the expected levels of recruitment from the full time series. It seems premature to conclude that recent poor recruitment reflects a productivity regime shift.

5.3 Research Recommendations

- Further develop methods to combine SERFS chevron trap and video gears for creating indices of abundance.
- Evaluate sample size cutoffs for using age and length compositions. What should be the minimum standards, and how does this interplay with the number of age and length classes modeled in the assessment?
- It appears that the sampling intensity for fish comprising age and length compositions has diminished, particularly for the commercial sector in 2015. Why?

- In stock assessment, various likelihood formulations have been used for fitting age and length composition data. The multinomial distribution and its robust versions have been the most widely applied. However, more recently the Dirichlet-multinomial and logistic-normal have attracted attention. A simulation study could shed light on the performance of these various likelihood formulations under sampling conditions realistic in the southeast U.S.

- The assessment indicated that recruitment has been lower than expected since 2005. Why? Can environmental or ecological drivers of recruitment be identified? What are the mechanisms?

- Red 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 red 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 red grouper? Are there well defined zoogeographic breaks (e.g., Florida keys, Cape Hatteras) that should define stock structure? How much connectivity exists between the Gulf of Mexico and Atlantic stocks?

- 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 red 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 mid-year total length (TL) and whole weight (WW), annual proportion females mature (Fem. mat.), proportion female (Fem. prop.), and natural mortality at age (M). The CV of length was estimated by the assessment model; other values were treated as input.

Age	Avg. TL (mm)	Avg. TL (in)	CV length	Avg. WW (kg)	Avg. WW (lb)	Fem. mat.	Fem. prop.	M
1	313.9	12.4	0.09	0.46	1.02	0.00	1.00	0.299
2	416.4	16.4	0.09	1.11	2.45	0.35	0.96	0.229
3	499.3	19.7	0.09	1.95	4.30	0.54	0.93	0.193
4	566.2	22.3	0.09	2.88	6.35	0.71	0.88	0.171
5	620.3	24.4	0.09	3.82	8.43	0.84	0.80	0.157
6	664.0	26.1	0.09	4.72	10.41	0.92	0.70	0.147
7	699.4	27.5	0.09	5.54	12.22	0.96	0.59	0.140
8	727.9	28.7	0.09	6.28	13.84	0.98	0.47	0.135
9	751.0	29.6	0.09	6.91	15.24	0.99	0.35	0.131
10	769.6	30.3	0.09	7.46	16.45	1.00	0.24	0.128
11	784.7	30.9	0.09	7.92	17.46	1.00	0.15	0.126
12	796.9	31.4	0.09	8.31	18.32	1.00	0.09	0.124
13	806.7	31.8	0.09	8.63	19.03	1.00	0.05	0.122
14	814.7	32.1	0.09	8.90	19.62	1.00	0.02	0.121
15	821.1	32.3	0.09	9.12	20.10	1.00	0.00	0.120
16	826.3	32.5	0.09	9.30	20.50	1.00	0.00	0.120

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

Year	L.cH	L.cO	L.HB	L.GR	D.cH	D.HB	D.GR
1976	263.68	171.48	4.60	.	.	.	.
1977	209.25	135.15	5.61	.	.	.	.
1978	257.97	152.36	4.77	.	.	.	.
1979	234.45	135.08	9.38	.	.	.	.
1980	184.86	103.58	8.14	.	.	.	.
1981	210.66	125.99	7.96	116.12	.	.	3.358
1982	205.60	113.02	6.36	155.72	.	.	3.294
1983	203.61	118.82	9.89	275.93	.	.	30.144
1984	236.62	141.39	8.56	254.63	.	.	36.260
1985	201.47	100.64	8.78	95.48	.	.	1.004
1986	249.96	130.83	5.81	113.34	.	.	6.368
1987	189.76	118.24	7.04	93.40	.	.	21.180
1988	244.35	111.01	5.10	42.63	.	.	7.800
1989	230.24	113.74	3.62	88.34	.	.	1.150
1990	172.99	102.01	7.33	11.06	.	.	2.898
1991	139.21	74.86	2.73	7.50	.	.	29.712
1992	128.89	39.96	3.98	26.55	.	.	29.726
1993	168.20	16.48	4.79	55.67	3.074	.	12.648
1994	165.35	10.09	5.47	41.51	4.210	.	22.340
1995	230.11	9.41	5.25	42.58	3.560	.	20.536
1996	279.45	19.12	5.65	54.82	3.612	.	58.794
1997	311.00	18.84	8.06	47.43	4.352	.	62.120
1998	431.65	35.49	10.90	39.88	3.006	.	17.762
1999	404.75	17.03	7.26	23.55	2.482	.	17.576
2000	342.50	12.36	5.33	20.94	2.560	.	48.850
2001	327.78	43.89	4.94	21.49	2.360	.	28.046
2002	331.35	31.31	4.60	51.28	4.408	.	16.700
2003	307.36	22.16	4.02	54.36	2.190	.	23.620
2004	289.08	31.62	10.76	59.18	2.198	.	38.132
2005	202.09	13.27	11.47	39.46	2.054	1.948	35.920
2006	323.55	7.66	5.24	95.34	0.996	1.000	31.072
2007	569.33	15.03	5.16	150.14	1.724	0.828	20.194
2008	590.41	9.38	2.44	227.46	0.400	1.348	19.934
2009	366.03	7.66	1.43	159.70	0.298	2.454	24.176
2010	280.24	7.74	1.28	22.14	0.510	2.868	21.750
2011	199.63	9.52	1.56	36.75	0.356	1.322	15.384
2012	128.91	9.37	1.44	89.65	0.330	1.956	19.388
2013	93.31	8.21	1.16	29.70	3.582	1.948	24.984
2014	74.70	6.04	1.85	26.26	2.200	1.006	21.048
2015	51.92	6.52	1.74	25.79	3.750	1.284	18.628

Table 3. Observed indices of abundance and CVs (CV) from commercial handlines (U.cH), headboat (U.HB), and SERFS chevron traps/videos (U.CVT).

Year	U.cH	U.cH CV	U.HB	U.HB CV	U.CVT	U.CVT CV
1980	.	.	0.98	0.13	.	.
1981	.	.	0.54	0.13	.	.
1982	.	.	0.66	0.18	.	.
1983	.	.	1.16	0.12	.	.
1984	.	.	0.78	0.14	.	.
1985	.	.	0.86	0.10	.	.
1986	.	.	0.90	0.08	.	.
1987	.	.	0.53	0.09	.	.
1988	.	.	0.80	0.10	.	.
1989	.	.	0.70	0.10	.	.
1990	.	.	0.42	0.11	0.46	0.67
1991	.	.	0.57	0.11	0.30	0.69
1992	.	.	0.73	0.09	0.57	0.62
1993	0.35	0.10	0.93	0.08	0.85	0.54
1994	0.26	0.09	0.97	0.09	1.10	0.49
1995	0.46	0.08	0.91	0.08	1.01	0.54
1996	0.57	0.07	1.35	0.07	0.83	0.54
1997	0.62	0.07	1.32	0.06	1.09	0.47
1998	1.13	0.06	1.81	0.06	1.18	0.44
1999	1.51	0.06	1.64	0.07	2.07	0.43
2000	1.01	0.07	1.15	0.07	1.10	0.46
2001	0.87	0.07	1.12	0.09	1.41	0.44
2002	0.74	0.07	0.68	0.12	1.68	0.42
2003	0.97	0.07	1.11	0.11	2.07	0.42
2004	0.79	0.07	1.73	0.07	1.86	0.41
2005	0.85	0.07	3.20	0.07	1.57	0.43
2006	1.31	0.07	2.11	0.08	1.46	0.45
2007	2.23	0.06	1.81	0.09	1.43	0.44
2008	2.64	0.06	0.51	0.12	1.14	0.48
2009	1.46	0.07	0.41	0.12	0.60	0.53
2010	1.71	0.07	0.64	0.09	0.68	0.50
2011	1.14	0.09	0.74	0.09	0.33	0.50
2012	0.88	0.10	0.51	0.10	0.34	0.48
2013	0.62	0.11	0.79	0.08	0.35	0.44
2014	0.57	0.11	0.59	0.09	0.31	0.67
2015	0.34	0.13	0.36	0.10	0.23	0.63

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

Year	lc.cH.nf	lc.cO.nf	lc.HB.nf	lc.GR.nf	lc.HB.D.nf	lc.CVT.nf	ac.cH.nf	ac.HB.nf	ac.GR.nf	ac.CVT.nf
1976	.	.	39	.	.	.	.	.	.	.
1977	.	.	96	.	.	.	.	.	.	.
1978	.	.	113	.	.	.	.	.	.	.
1979	.	.	142	.	.	.	.	36	.	.
1980	.	.	163	.	.	.	.	150	.	.
1981	.	.	218	.	.	.	.	161	.	.
1982	.	.	280	.	.	.	.	69	.	.
1983	.	.	368	.	.	.	.	35	.	.
1984	.	.	589	.	.	.	.	42	.	.
1985	.	.	574	.	.	.	.	.	.	.
1986	1017	1243	384	.	.	.	.	.	.	.
1987	1510	756	270	43	.	.	.	.	.	.
1988	1976	.	212	.	.	.	.	.	.	.
1989	770	357	242	.	.	.	.	.	.	.
1990	599	.	132	.	.	.	.	.	.	.
1991	624	.	64	.	.	.	.	.	.	.
1992	194	.	83	.	.	.	.	.	.	.
1993	428	.	91	.	.	.	.	.	.	.
1994	574	.	141	.	.	.	.	.	.	.
1995	1064	.	189	42	.	.	.	.	.	.
1996	363	.	207	35	.	.	.	.	.	.
1997	400	.	259	41	.	40	126	.	.	40
1998	688	.	456	55	.	78	1678	.	.	74
1999	1636	.	310	50	.	48	88	.	.	48
2000	1595	.	204	36	.	38	.	.	.	37
2001	850	.	160	60	.	38	.	.	.	37
2002	596	.	167	106	.	37	.	.	38	36
2003	805	.	121	88	.	37	.	.	27	36
2004	1238	.	80	82	.	40	231	33	18	39
2005	1299	.	148	.	264	29	490	79	.	29
2006	2042	.	137	54	154	44	828	59	.	44
2007	2737	.	127	134	125	43	1287	47	.	43
2008	2380	.	34	169	63	.	2107	.	.	.
2009	1389	.	.	42	213	19	998	.	.	19
2010	783	.	73	.	149	40	775	21	.	40
2011	685	.	93	.	52	18	702	54	.	18
2012	626	.	163	.	88	40	652	126	.	40
2013	402	.	129	30	107	43	335	99	.	43
2014	299	.	121	41	.	38	289	112	.	37
2015	95	.	93	36	47	30	84	40	.	30

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

Year	lc.cH.n	lc.cO.n	lc.HB.n	lc.GR.n	lc.HB.D.n	lc.CVT.n	ac.cH.n	ac.HB.n	ac.GR.n	ac.CVT.n
1976	.	.	18	.	.	.	.	.	.	.
1977	.	.	56	.	.	.	.	.	.	.
1978	.	.	53	.	.	.	.	.	.	.
1979	.	.	80	.	.	.	.	27	.	.
1980	.	.	94	.	.	.	.	73	.	.
1981	.	.	137	.	.	.	.	108	.	.
1982	.	.	162	.	.	.	.	48	.	.
1983	.	.	211	.	.	.	.	33	.	.
1984	.	.	277	.	.	.	.	40	.	.
1985	.	.	239	.	.	.	.	.	.	.
1986	33	13	197	.	.	.	.	.	.	.
1987	46	6	159	26	.	.	.	.	.	.
1988	67	.	140	.	.	.	.	.	.	.
1989	60	8	154	.	.	.	.	.	.	.
1990	73	.	87	.	.	.	.	.	.	.
1991	76	.	53	.	.	.	.	.	.	.
1992	42	.	59	.	.	.	.	.	.	.
1993	71	.	62	.	.	.	.	.	.	.
1994	76	.	102	.	.	.	.	.	.	.
1995	94	.	113	29	.	.	.	.	.	.
1996	79	.	138	29	.	.	.	.	.	.
1997	64	.	170	30	.	23	33	.	.	23
1998	105	.	267	42	.	28	85	.	.	26
1999	176	.	192	36	.	21	16	.	.	21
2000	214	.	132	25	.	25	.	.	.	24
2001	149	.	119	42	.	20	.	.	.	20
2002	116	.	132	64	.	21	.	.	26	21
2003	134	.	94	53	.	19	.	.	23	18
2004	181	.	65	36	.	21	55	29	16	21
2005	240	.	104	.	99	25	122	63	.	25
2006	282	.	93	14	68	18	206	52	.	18
2007	399	.	85	20	38	21	370	42	.	21
2008	369	.	28	48	25	.	362	.	.	.
2009	260	.	.	13	41	18	254	.	.	18
2010	176	.	60	.	50	27	194	19	.	27
2011	164	.	64	.	22	18	180	33	.	18
2012	134	.	75	.	30	36	162	53	.	36
2013	89	.	73	26	51	40	97	53	.	40
2014	74	.	58	31	.	37	98	52	.	36
2015	42	.	52	20	17	23	43	40	.	23

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
1976	508.18	303.92	212.60	454.40	297.59	44.03	40.69	12.19	13.69	4.51	2.76	1.72	1.09	0.69	0.44	0.84	1899.35
1977	448.75	350.30	188.50	128.21	276.57	183.16	27.42	25.61	7.74	8.74	2.89	1.78	1.11	0.70	0.45	0.83	1652.77
1978	494.06	309.72	217.70	114.12	78.49	171.42	114.92	17.38	16.37	4.98	5.65	1.88	1.16	0.72	0.46	0.84	1549.88
1979	547.36	338.58	189.94	129.47	68.46	47.65	105.41	71.49	10.92	10.36	3.17	3.61	1.20	0.74	0.47	0.83	1529.66
1980	323.71	374.50	206.47	112.15	77.08	41.23	29.06	65.05	44.54	6.85	6.54	2.01	2.29	0.77	0.47	0.83	1293.55
1981	352.30	222.47	230.36	123.26	67.57	46.97	25.43	18.13	40.92	28.21	4.36	4.18	1.29	1.47	0.49	0.84	1168.26
1982	485.77	243.20	144.21	148.02	79.92	44.32	31.22	17.11	12.32	28.02	19.43	3.02	2.90	0.89	1.03	0.93	1262.31
1983	508.95	331.98	150.30	87.13	90.09	49.18	27.62	19.69	10.89	7.90	18.07	12.58	1.96	1.89	0.58	1.28	1320.09
1984	350.56	318.53	163.44	72.27	41.98	43.85	24.25	13.79	9.93	5.54	4.04	9.29	6.49	1.01	0.98	0.97	1066.92
1985	328.59	215.01	138.23	63.31	27.54	16.09	17.05	9.57	5.52	4.01	2.26	1.65	3.82	2.68	0.42	0.80	836.56
1986	221.28	223.36	126.06	74.25	33.54	14.61	8.63	9.26	5.26	3.06	2.24	1.27	0.93	2.16	1.51	0.69	728.11
1987	426.85	144.09	117.69	59.42	34.03	15.31	6.74	4.04	4.40	2.53	1.48	1.09	0.62	0.46	1.06	1.09	820.90
1988	289.03	270.86	74.28	56.41	27.84	15.94	7.26	3.25	1.98	2.17	1.26	0.74	0.55	0.31	0.23	1.09	753.22
1989	129.61	192.31	164.81	42.86	31.44	15.33	8.83	4.07	1.84	1.13	1.26	0.73	0.43	0.32	0.18	0.78	595.93
1990	158.75	86.06	107.24	82.20	20.65	15.01	7.37	4.30	2.01	0.92	0.57	0.64	0.37	0.22	0.16	0.49	486.97
1991	291.48	107.46	56.42	69.47	52.55	13.21	9.72	4.85	2.87	1.35	0.62	0.39	0.44	0.26	0.15	0.45	611.68
1992	356.60	186.99	68.71	39.74	48.84	37.12	9.44	7.03	3.54	2.11	1.01	0.47	0.29	0.33	0.19	0.46	762.89
1993	220.95	247.46	137.14	47.61	25.60	29.59	21.99	5.63	4.24	2.16	1.30	0.62	0.29	0.18	0.20	0.41	745.38
1994	291.99	158.00	187.23	88.76	26.25	12.81	14.19	10.55	2.72	2.06	1.06	0.64	0.31	0.14	0.09	0.30	797.10
1995	517.28	204.48	117.23	129.91	56.18	15.03	7.00	7.75	5.79	1.50	1.14	0.59	0.35	0.17	0.08	0.22	1064.71
1996	518.56	369.10	154.93	82.94	82.95	31.77	8.03	3.73	4.14	3.11	0.81	0.62	0.32	0.19	0.09	0.16	1261.45
1997	230.12	356.22	267.79	103.91	49.98	44.10	15.93	4.01	1.87	2.09	1.58	0.41	0.32	0.16	0.10	0.13	1078.73
1998	140.08	153.90	251.30	183.54	66.44	28.04	23.23	8.35	2.12	0.99	1.12	0.84	0.22	0.17	0.09	0.12	860.57
1999	292.11	98.39	114.61	181.49	120.84	36.99	14.43	11.88	4.30	1.10	0.52	0.58	0.44	0.12	0.09	0.11	877.99
2000	370.61	205.67	73.64	86.04	130.17	77.35	22.43	8.72	7.22	2.62	0.67	0.32	0.36	0.27	0.07	0.12	986.31
2001	341.88	249.17	146.39	53.96	62.95	89.24	51.37	14.91	5.82	4.84	1.77	0.45	0.22	0.24	0.19	0.13	1023.53
2002	472.93	240.09	185.86	109.68	39.34	43.07	59.43	34.33	10.04	3.95	3.30	1.21	0.31	0.15	0.17	0.22	1204.08
2003	930.24	339.29	183.12	134.97	74.20	24.80	26.34	36.42	21.18	6.23	2.46	2.07	0.76	0.20	0.09	0.25	1782.62
2004	1164.39	672.42	261.07	134.15	92.27	47.46	15.41	16.40	22.81	13.33	3.94	1.56	1.31	0.48	0.13	0.22	2447.35
2005	269.79	840.33	516.34	190.67	91.45	59.29	29.76	9.69	10.38	14.52	8.53	2.53	1.01	0.85	0.31	0.22	2045.67
2006	109.93	194.23	645.33	397.37	144.34	67.39	43.24	21.79	7.13	7.67	10.78	6.35	1.89	0.75	0.63	0.40	1659.22
2007	112.29	77.65	146.01	482.44	291.32	102.48	47.18	30.37	15.38	5.06	5.46	7.68	4.53	1.35	0.54	0.74	1330.47
2008	206.89	77.18	56.55	103.04	327.25	188.94	65.09	30.03	19.42	9.88	3.26	3.52	4.97	2.94	0.88	0.83	1100.65
2009	308.02	142.26	55.98	35.25	56.55	171.37	96.90	33.45	15.50	10.07	5.14	1.70	1.84	2.60	1.54	0.90	939.06
2010	158.86	214.33	104.37	33.52	17.91	27.58	82.19	46.60	16.16	7.52	4.90	2.51	0.83	0.90	1.28	1.20	720.67
2011	151.83	110.59	158.55	78.02	24.83	12.75	19.28	57.60	32.83	11.44	5.34	3.49	1.79	0.59	0.65	1.77	671.36
2012	152.26	106.88	82.75	116.50	55.72	17.20	8.72	13.24	39.78	22.78	7.97	3.73	2.44	1.26	0.42	1.70	633.35
2013	81.56	104.54	77.46	52.82	67.32	31.63	9.71	4.94	7.55	22.80	13.11	4.60	2.16	1.42	0.73	1.23	483.56
2014	106.05	52.25	70.50	53.51	37.48	47.75	22.41	6.92	3.54	5.44	16.49	9.50	3.34	1.57	1.03	1.43	439.21
2015	151.48	68.60	35.63	49.22	38.37	26.99	34.44	16.26	5.05	2.60	4.00	12.16	7.03	2.47	1.17	1.83	457.30
2016	322.70	100.51	48.09	25.09	35.02	27.51	19.44	24.97	11.86	3.70	1.91	2.95	8.99	5.20	1.84	2.22	642.01

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
1976	518.5	744.5	914.0	2885.4	2507.5	458.1	497.4	168.7	208.6	74.1	48.3	31.5	20.7	13.7	8.8	17.2	9117.0
1977	457.9	858.0	810.4	814.2	2330.3	1906.1	335.1	354.3	117.9	143.7	50.5	32.6	21.2	13.9	9.0	17.0	8272.4
1978	504.2	758.8	935.9	724.7	661.4	1784.0	1404.6	240.5	249.6	81.8	98.8	34.4	22.0	14.3	9.3	17.2	7540.9
1979	558.4	829.4	816.6	822.1	576.9	495.8	1288.2	989.2	166.4	170.4	55.3	66.1	22.9	14.6	9.5	17.2	6898.7
1980	330.3	917.3	887.6	712.1	649.5	429.0	355.2	900.1	678.8	112.7	114.2	36.8	43.7	15.0	9.5	17.0	6208.9
1981	359.4	545.0	990.3	782.6	569.2	488.8	310.9	250.9	623.7	463.9	76.3	76.5	24.5	28.9	9.9	17.2	5618.3
1982	495.6	595.7	619.9	939.8	673.5	461.2	381.6	236.8	187.6	460.8	339.3	55.3	55.1	17.6	20.7	19.2	5559.8
1983	519.2	813.3	646.2	553.1	759.1	511.7	337.5	272.3	166.0	129.9	315.7	230.4	37.3	37.0	11.7	26.2	5366.9
1984	357.6	780.4	702.6	459.0	353.6	456.4	296.3	190.9	151.5	91.1	70.5	170.2	123.5	19.8	19.6	19.8	4262.6
1985	335.3	526.7	594.1	402.1	232.1	167.6	208.3	132.5	84.0	65.9	39.5	30.4	72.8	52.5	8.4	16.5	2968.5
1986	225.8	547.2	541.9	471.6	282.6	152.1	105.4	128.1	80.2	50.3	39.2	23.1	17.6	42.3	30.4	14.1	2752.0
1987	435.4	353.0	506.0	377.4	286.8	159.4	82.5	56.0	67.0	41.7	25.8	20.1	11.9	9.0	21.4	22.3	2475.1
1988	295.0	663.6	319.2	358.3	234.6	165.8	88.6	45.0	30.2	35.7	22.0	13.7	10.6	6.2	4.6	22.5	2315.3
1989	132.3	471.1	708.6	272.1	265.0	159.6	107.8	56.2	28.0	18.7	22.0	13.4	8.2	6.4	3.7	15.9	2289.1
1990	162.0	210.8	461.0	522.1	173.9	156.3	90.2	59.5	30.6	15.2	9.9	11.7	7.1	4.4	3.3	10.1	1927.9
1991	297.4	263.2	242.5	441.1	442.9	137.6	118.8	67.0	43.7	22.3	10.8	7.1	8.4	5.1	3.1	9.3	2120.2
1992	363.8	458.1	295.4	252.4	411.6	386.2	115.3	97.2	54.0	34.8	17.6	8.6	5.5	6.4	4.0	9.5	2520.3
1993	225.5	606.3	589.5	302.3	215.6	308.0	268.7	77.8	64.6	35.5	22.7	11.5	5.5	3.5	4.2	8.4	2749.6
1994	297.8	387.1	804.9	563.7	221.1	133.4	173.5	145.9	41.4	34.0	18.5	11.7	5.7	2.9	1.8	6.2	2849.5
1995	527.8	500.9	504.0	825.0	473.3	156.5	85.5	107.1	88.2	24.7	19.8	10.8	6.8	3.3	1.5	4.4	3340.0
1996	529.1	904.1	666.0	526.7	698.9	330.7	98.1	51.6	63.1	51.1	14.1	11.2	6.0	3.7	1.8	3.3	3959.9
1997	234.8	872.6	1151.3	659.8	421.1	459.0	194.7	55.6	28.4	34.4	27.6	7.5	6.0	3.1	2.0	2.6	4160.8
1998	142.9	377.0	1080.3	1165.6	559.8	291.9	284.0	115.5	32.2	16.3	19.4	15.4	4.2	3.3	1.8	2.6	4112.3
1999	298.1	241.0	492.7	1152.4	1018.1	384.9	176.4	164.5	65.5	18.1	9.0	10.6	8.4	2.2	1.8	2.2	4046.1
2000	378.1	503.8	316.6	546.3	1096.8	804.9	274.3	120.6	110.0	43.2	11.7	5.7	6.8	5.3	1.5	2.6	4228.5
2001	348.8	610.5	629.4	342.6	530.4	928.8	627.9	206.1	88.8	79.6	30.9	8.4	4.2	4.9	3.7	2.6	4447.4
2002	482.6	588.2	799.0	696.4	331.6	448.2	726.4	474.9	153.0	65.0	57.8	22.3	6.0	2.9	3.3	4.6	4861.6
2003	949.1	831.1	787.3	856.9	625.2	258.2	321.9	504.0	322.8	102.5	43.0	37.9	14.6	3.7	2.0	5.1	5665.0
2004	1188.1	1647.3	1122.4	851.9	777.4	493.8	188.3	226.9	347.7	219.4	68.8	28.7	24.9	9.5	2.4	4.4	7201.8
2005	275.4	2058.7	2219.8	1210.8	770.5	617.1	363.8	134.0	158.1	238.8	149.0	46.3	19.2	16.8	6.4	4.6	8288.7
2006	112.2	475.8	2774.3	2523.2	1216.3	701.3	528.4	301.6	108.7	126.1	188.3	116.2	35.9	14.8	12.8	8.2	9244.0
2007	114.6	190.3	627.7	3063.5	2454.6	1066.4	576.7	420.2	234.4	83.1	95.2	140.7	86.2	26.5	10.8	15.2	9206.1
2008	211.0	189.2	243.2	654.3	2757.5	1966.3	795.4	415.4	296.1	162.5	56.9	64.6	94.6	57.5	17.6	17.0	7998.8
2009	314.4	348.6	240.7	223.8	476.4	1783.3	1184.3	462.8	236.3	165.6	89.7	31.1	35.1	50.9	30.9	18.3	5692.1
2010	162.0	525.1	448.6	213.0	150.8	287.0	1004.4	644.9	246.3	123.7	85.5	45.9	15.9	17.6	25.6	24.5	4021.2
2011	155.0	270.9	681.7	495.4	209.2	132.7	235.7	797.0	500.4	188.1	93.3	63.9	34.0	11.7	13.0	36.4	3918.1
2012	155.4	261.9	355.8	739.9	469.6	179.0	106.5	183.2	606.3	374.6	139.1	68.3	46.5	24.7	8.4	34.8	3753.8
2013	83.1	256.2	332.9	335.3	567.2	329.2	118.6	68.3	115.1	375.0	228.8	84.2	41.0	27.8	14.6	25.1	3002.9
2014	108.2	128.1	303.1	339.7	315.7	496.9	273.8	95.7	54.0	89.5	287.9	173.9	63.5	30.9	20.7	29.3	2811.1
2015	154.5	168.0	153.2	312.6	323.2	280.9	420.9	225.1	76.9	42.8	69.9	222.7	133.6	48.5	23.4	37.5	2693.8
2016	329.2	246.3	206.8	159.4	295.2	286.4	237.7	345.5	180.8	60.8	33.3	54.0	171.1	102.1	36.8	45.6	2790.8

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

Year	F	F/F_{MSY}	B	B/B_{unfished}	SSB	$\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$	SSB/MSST	Prop.fem
1976	0.328	2.70	4135	0.3533	2592	0.814	1.086	0.824
1977	0.321	2.64	3752	0.3205	2468	0.775	1.034	0.804
1978	0.342	2.81	3420	0.2922	2241	0.704	0.939	0.787
1979	0.350	2.88	3129	0.2673	1992	0.626	0.834	0.780
1980	0.338	2.78	2816	0.2406	1803	0.566	0.755	0.782
1981	0.265	2.18	2548	0.2177	1671	0.525	0.700	0.778
1982	0.329	2.70	2522	0.2154	1591	0.500	0.667	0.776
1983	0.563	4.63	2434	0.2080	1378	0.433	0.577	0.784
1984	0.802	6.59	1934	0.1652	991	0.311	0.415	0.798
1985	0.477	3.92	1346	0.1150	714	0.224	0.299	0.812
1986	0.627	5.16	1248	0.1066	641	0.201	0.268	0.823
1987	0.601	4.95	1123	0.0959	526	0.165	0.220	0.825
1988	0.444	3.65	1050	0.0897	509	0.160	0.213	0.841
1989	0.585	4.81	1038	0.0887	526	0.165	0.220	0.843
1990	0.290	2.38	874	0.0747	504	0.158	0.211	0.834
1991	0.218	1.79	962	0.0822	560	0.176	0.234	0.822
1992	0.377	3.10	1143	0.0977	629	0.197	0.263	0.819
1993	0.594	4.89	1247	0.1065	665	0.209	0.279	0.830
1994	0.465	3.83	1293	0.1104	696	0.219	0.292	0.836
1995	0.491	4.04	1515	0.1294	781	0.245	0.327	0.836
1996	0.554	4.55	1796	0.1534	896	0.281	0.375	0.844
1997	0.505	4.15	1887	0.1612	1025	0.322	0.429	0.848
1998	0.531	4.36	1865	0.1593	1123	0.353	0.471	0.837
1999	0.363	2.99	1835	0.1568	1174	0.369	0.492	0.821
2000	0.269	2.21	1918	0.1639	1238	0.389	0.518	0.808
2001	0.263	2.16	2017	0.1723	1302	0.409	0.545	0.801
2002	0.350	2.88	2205	0.1884	1348	0.424	0.565	0.798
2003	0.334	2.75	2570	0.2195	1411	0.443	0.591	0.808
2004	0.324	2.66	3267	0.2791	1668	0.524	0.699	0.829
2005	0.172	1.41	3760	0.3212	2212	0.695	0.926	0.842
2006	0.214	1.76	4193	0.3582	2788	0.876	1.168	0.826
2007	0.312	2.57	4176	0.3567	2998	0.942	1.256	0.799
2008	0.526	4.33	3628	0.3099	2560	0.804	1.072	0.767
2009	0.592	4.87	2582	0.2206	1744	0.548	0.730	0.745
2010	0.215	1.77	1824	0.1558	1312	0.412	0.550	0.754
2011	0.236	1.94	1777	0.1518	1270	0.399	0.532	0.751
2012	0.427	3.51	1703	0.1455	1156	0.363	0.484	0.750
2013	0.199	1.63	1362	0.1164	994	0.312	0.416	0.754
2014	0.181	1.49	1275	0.1089	956	0.300	0.400	0.741
2015	0.181	1.49	1222	0.1044	911	0.286	0.381	0.731
2016	.	.	1266	0.1081	.	.	.	0.732

Table 9. Selectivity at age for commercial lines (cH), commercial other (cO), headboat (HB), general recreational (GR), discard mortalities (D), SERFS chevron trap/video (CVT), scaled selectivity of landings averaged across fleets (L.avg), and scaled selectivity of discard mortalities averaged across fleets (D.avg). TL is total length. For time-varying selectivities, values shown are from the terminal assessment year.

Age	TL(mm)	TL(in)	cH	cO	HB	GR	D	CVT	L.avg	D.avg	L.avg+D.avg
1	313.9	12.4	0.001	0.027	0.001	0.000	0.907	0.102	0.001	0.700	0.701
2	416.4	16.4	0.005	0.112	0.024	0.021	1.000	0.463	0.020	0.772	0.792
3	499.3	19.7	0.037	0.380	0.505	0.578	0.581	0.868	0.446	0.448	0.894
4	566.2	22.3	0.237	0.804	0.977	0.989	0.115	0.981	0.812	0.088	0.900
5	620.3	24.4	0.714	1.000	0.999	1.000	0.017	0.998	0.939	0.013	0.952
6	664.0	26.1	0.952	0.935	1.000	1.000	0.003	1.000	0.994	0.002	0.996
7	699.4	27.5	0.994	0.775	1.000	1.000	0.001	1.000	0.999	0.001	1.000
8	727.9	28.7	0.999	0.598	1.000	1.000	0.000	0.999	0.996	0.000	0.996
9	751.0	29.6	1.000	0.437	1.000	1.000	0.000	0.999	0.992	0.000	0.992
10	769.6	30.3	1.000	0.305	1.000	1.000	0.000	0.998	0.988	0.000	0.988
11	784.7	30.9	1.000	0.206	1.000	1.000	0.000	0.998	0.985	0.000	0.985
12	796.9	31.4	1.000	0.135	1.000	1.000	0.000	0.997	0.983	0.000	0.983
13	806.7	31.8	1.000	0.087	1.000	1.000	0.000	0.997	0.982	0.000	0.982
14	814.7	32.1	1.000	0.056	1.000	1.000	0.000	0.996	0.981	0.000	0.981
15	821.1	32.3	1.000	0.035	1.000	1.000	0.000	0.996	0.981	0.000	0.981
16	826.3	32.5	1.000	0.022	1.000	1.000	0.000	0.995	0.980	0.000	0.980

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

Year	F.cH	F.cO	F.HB	F.GR	F.cH.D	F.HB.D	F.GR.D	Apical F
1976	0.051	0.032	0.004	0.256	0.000	0.000	0.000	0.328
1977	0.042	0.031	0.006	0.256	0.000	0.000	0.000	0.321
1978	0.058	0.041	0.006	0.256	0.000	0.000	0.000	0.342
1979	0.059	0.042	0.012	0.256	0.000	0.000	0.000	0.350
1980	0.052	0.035	0.011	0.256	0.000	0.000	0.000	0.338
1981	0.063	0.045	0.012	0.165	0.000	0.000	0.008	0.265
1982	0.065	0.043	0.010	0.231	0.000	0.000	0.006	0.329
1983	0.077	0.051	0.016	0.443	0.000	0.000	0.050	0.563
1984	0.130	0.078	0.020	0.611	0.004	0.005	0.078	0.802
1985	0.148	0.066	0.025	0.274	0.004	0.005	0.002	0.477
1986	0.211	0.093	0.018	0.356	0.004	0.005	0.019	0.627
1987	0.190	0.094	0.026	0.342	0.004	0.005	0.051	0.601
1988	0.256	0.084	0.017	0.138	0.004	0.005	0.018	0.444
1989	0.241	0.087	0.012	0.296	0.004	0.005	0.005	0.585
1990	0.176	0.086	0.029	0.044	0.004	0.005	0.015	0.290
1991	0.123	0.060	0.011	0.029	0.004	0.005	0.099	0.218
1992	0.151	0.038	0.026	0.171	0.004	0.005	0.063	0.377
1993	0.225	0.016	0.030	0.328	0.007	0.005	0.028	0.594
1994	0.243	0.009	0.027	0.191	0.009	0.005	0.049	0.465
1995	0.285	0.007	0.023	0.179	0.006	0.005	0.032	0.491
1996	0.297	0.013	0.024	0.224	0.005	0.005	0.074	0.554
1997	0.317	0.011	0.028	0.154	0.007	0.005	0.101	0.505
1998	0.382	0.018	0.031	0.107	0.008	0.005	0.046	0.531
1999	0.274	0.007	0.020	0.065	0.006	0.005	0.046	0.363
2000	0.183	0.005	0.017	0.066	0.005	0.005	0.098	0.269
2001	0.164	0.020	0.016	0.068	0.004	0.005	0.050	0.263
2002	0.175	0.015	0.014	0.150	0.006	0.005	0.025	0.350
2003	0.167	0.010	0.011	0.149	0.002	0.005	0.021	0.334
2004	0.149	0.012	0.026	0.139	0.001	0.005	0.023	0.324
2005	0.088	0.004	0.019	0.062	0.002	0.002	0.029	0.172
2006	0.104	0.002	0.006	0.103	0.002	0.002	0.050	0.214
2007	0.135	0.003	0.006	0.170	0.006	0.003	0.074	0.312
2008	0.135	0.002	0.004	0.386	0.002	0.005	0.076	0.526
2009	0.117	0.003	0.004	0.470	0.001	0.006	0.063	0.592
2010	0.123	0.004	0.005	0.084	0.001	0.008	0.060	0.215
2011	0.100	0.006	0.006	0.127	0.001	0.004	0.051	0.236
2012	0.073	0.006	0.006	0.344	0.001	0.008	0.076	0.427
2013	0.057	0.006	0.005	0.132	0.019	0.010	0.132	0.199
2014	0.046	0.004	0.009	0.123	0.014	0.006	0.131	0.181
2015	0.032	0.005	0.009	0.136	0.019	0.007	0.096	0.181

Table 11. 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
1976	0.073	0.249	0.313	0.326	0.328	0.327	0.323	0.320	0.317	0.315	0.314	0.313	0.313	0.312	0.312	0.312
1977	0.072	0.247	0.309	0.320	0.321	0.319	0.316	0.312	0.310	0.308	0.307	0.306	0.305	0.305	0.305	0.305
1978	0.079	0.260	0.327	0.340	0.342	0.339	0.335	0.330	0.327	0.324	0.323	0.321	0.321	0.320	0.320	0.320
1979	0.081	0.266	0.334	0.348	0.350	0.347	0.343	0.338	0.335	0.332	0.330	0.329	0.329	0.328	0.328	0.328
1980	0.076	0.257	0.323	0.336	0.338	0.336	0.332	0.329	0.326	0.324	0.322	0.321	0.321	0.320	0.320	0.320
1981	0.072	0.205	0.249	0.262	0.265	0.261	0.256	0.251	0.248	0.245	0.243	0.242	0.241	0.241	0.240	0.240
1982	0.082	0.252	0.311	0.325	0.329	0.326	0.321	0.317	0.313	0.311	0.309	0.308	0.307	0.306	0.306	0.306
1983	0.170	0.480	0.539	0.559	0.563	0.560	0.554	0.549	0.545	0.542	0.540	0.538	0.538	0.537	0.537	0.536
1984	0.190	0.606	0.755	0.794	0.802	0.798	0.789	0.781	0.775	0.770	0.767	0.765	0.763	0.763	0.762	0.762
1985	0.087	0.305	0.428	0.464	0.477	0.476	0.471	0.464	0.459	0.455	0.452	0.450	0.449	0.448	0.448	0.448
1986	0.130	0.412	0.559	0.609	0.627	0.626	0.618	0.609	0.602	0.596	0.592	0.590	0.588	0.587	0.586	0.586
1987	0.156	0.434	0.542	0.587	0.601	0.599	0.590	0.581	0.573	0.568	0.564	0.561	0.560	0.559	0.558	0.558
1988	0.108	0.268	0.357	0.414	0.440	0.444	0.439	0.431	0.425	0.420	0.417	0.414	0.413	0.412	0.411	0.411
1989	0.110	0.355	0.503	0.559	0.582	0.585	0.579	0.571	0.564	0.559	0.555	0.553	0.551	0.550	0.550	0.549
1990	0.091	0.193	0.241	0.276	0.290	0.288	0.280	0.271	0.264	0.259	0.256	0.253	0.252	0.251	0.250	0.250
1991	0.145	0.218	0.157	0.181	0.191	0.189	0.184	0.178	0.173	0.169	0.167	0.165	0.164	0.163	0.163	0.163
1992	0.066	0.081	0.174	0.269	0.344	0.377	0.377	0.371	0.365	0.360	0.356	0.354	0.352	0.351	0.350	0.349
1993	0.036	0.050	0.242	0.424	0.535	0.588	0.594	0.593	0.590	0.588	0.586	0.585	0.584	0.584	0.583	0.583
1994	0.057	0.069	0.172	0.286	0.400	0.457	0.465	0.465	0.464	0.463	0.462	0.461	0.461	0.460	0.460	0.460
1995	0.039	0.049	0.153	0.278	0.413	0.480	0.491	0.491	0.490	0.489	0.488	0.488	0.488	0.487	0.487	0.487
1996	0.076	0.092	0.206	0.336	0.475	0.544	0.554	0.553	0.551	0.549	0.548	0.547	0.547	0.546	0.546	0.546
1997	0.103	0.120	0.185	0.276	0.421	0.494	0.505	0.505	0.503	0.502	0.501	0.500	0.499	0.499	0.499	0.499
1998	0.054	0.066	0.132	0.247	0.429	0.518	0.531	0.529	0.527	0.525	0.523	0.522	0.521	0.520	0.520	0.520
1999	0.052	0.061	0.094	0.161	0.289	0.353	0.363	0.363	0.362	0.361	0.361	0.360	0.360	0.359	0.359	0.359
2000	0.098	0.111	0.118	0.141	0.220	0.262	0.269	0.269	0.268	0.267	0.267	0.267	0.266	0.266	0.266	0.266
2001	0.054	0.064	0.096	0.145	0.223	0.260	0.263	0.260	0.257	0.255	0.253	0.251	0.250	0.250	0.249	0.249
2002	0.033	0.042	0.127	0.220	0.305	0.345	0.350	0.348	0.346	0.344	0.342	0.341	0.341	0.340	0.340	0.340
2003	0.026	0.033	0.118	0.209	0.290	0.329	0.334	0.333	0.332	0.330	0.329	0.329	0.328	0.328	0.328	0.327
2004	0.027	0.035	0.121	0.212	0.285	0.320	0.324	0.322	0.320	0.319	0.318	0.317	0.316	0.316	0.315	0.315
2005	0.030	0.035	0.069	0.107	0.148	0.169	0.172	0.171	0.171	0.170	0.170	0.170	0.169	0.169	0.169	0.169
2006	0.049	0.056	0.098	0.139	0.185	0.209	0.213	0.214	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213
2007	0.076	0.088	0.156	0.217	0.276	0.307	0.312	0.312	0.312	0.311	0.311	0.311	0.311	0.311	0.311	0.311
2008	0.075	0.092	0.280	0.429	0.490	0.521	0.526	0.526	0.526	0.526	0.525	0.525	0.525	0.525	0.525	0.525
2009	0.064	0.081	0.320	0.506	0.561	0.588	0.592	0.592	0.592	0.591	0.591	0.591	0.591	0.591	0.591	0.591
2010	0.063	0.072	0.098	0.129	0.183	0.211	0.215	0.215	0.215	0.214	0.214	0.213	0.213	0.213	0.213	0.213
2011	0.052	0.061	0.115	0.166	0.210	0.233	0.236	0.235	0.234	0.234	0.233	0.233	0.232	0.232	0.232	0.232
2012	0.077	0.093	0.256	0.377	0.409	0.425	0.427	0.427	0.426	0.425	0.424	0.424	0.423	0.423	0.423	0.423
2013	0.146	0.165	0.177	0.172	0.187	0.198	0.199	0.198	0.197	0.196	0.196	0.195	0.195	0.195	0.195	0.195
2014	0.137	0.154	0.166	0.162	0.171	0.180	0.181	0.180	0.179	0.179	0.178	0.178	0.178	0.178	0.177	0.177
2015	0.111	0.126	0.158	0.169	0.176	0.181	0.181	0.181	0.180	0.179	0.179	0.178	0.178	0.178	0.178	0.178

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1976	31.01	60.08	52.18	116.58	77.41	11.45	10.53	3.13	3.50	1.15	0.70	0.44	0.28	0.18	0.11	0.21
1977	26.93	68.76	45.78	32.39	70.64	46.72	6.95	6.45	1.94	2.18	0.72	0.44	0.28	0.17	0.11	0.21
1978	32.46	63.68	55.46	30.38	21.15	46.06	30.62	4.59	4.29	1.30	1.47	0.49	0.30	0.19	0.12	0.22
1979	36.67	70.94	49.30	35.12	18.80	13.06	28.65	19.26	2.92	2.76	0.84	0.96	0.32	0.20	0.12	0.22
1980	20.53	76.22	52.08	29.53	20.56	10.99	7.70	17.10	11.64	1.78	1.70	0.52	0.59	0.20	0.12	0.22
1981	19.08	35.57	46.41	26.23	14.59	10.08	5.38	3.78	8.44	5.77	0.89	0.85	0.26	0.30	0.10	0.17
1982	30.83	47.55	35.22	37.98	20.81	11.51	8.04	4.36	3.11	7.05	4.87	0.75	0.72	0.22	0.26	0.23
1983	50.59	102.24	57.46	34.57	36.16	19.74	11.04	7.83	4.31	3.12	7.12	4.95	0.77	0.74	0.23	0.50
1984	30.92	112.20	79.75	36.80	21.64	22.63	12.47	7.06	5.06	2.82	2.05	4.71	3.29	0.51	0.49	0.49
1985	20.97	48.95	44.11	21.76	9.73	5.71	6.00	3.34	1.91	1.38	0.77	0.57	1.31	0.91	0.14	0.27
1986	18.80	63.27	49.54	31.41	14.58	6.37	3.74	3.98	2.24	1.30	0.95	0.53	0.39	0.91	0.64	0.29
1987	34.92	39.41	45.19	24.46	14.34	6.46	2.82	1.68	1.81	1.03	0.60	0.44	0.25	0.19	0.43	0.44
1988	19.95	51.44	20.39	17.67	9.22	5.34	2.42	1.07	0.64	0.70	0.41	0.24	0.18	0.10	0.07	0.35
1989	10.45	49.76	59.68	17.00	12.94	6.36	3.64	1.67	0.75	0.46	0.51	0.29	0.17	0.13	0.07	0.31
1990	9.13	11.89	20.98	18.32	4.82	3.50	1.68	0.96	0.44	0.20	0.12	0.13	0.08	0.05	0.03	0.10
1991	11.16	9.59	7.49	10.62	8.46	2.12	1.52	0.74	0.43	0.20	0.09	0.06	0.06	0.04	0.02	0.06
1992	0.35	1.48	7.60	8.39	13.17	10.88	2.78	2.05	1.02	0.60	0.28	0.13	0.08	0.09	0.05	0.13
1993	0.13	2.29	24.38	15.06	9.88	12.31	9.26	2.37	1.78	0.91	0.54	0.26	0.12	0.08	0.09	0.17
1994	0.12	0.94	21.34	19.89	8.04	4.39	4.95	3.69	0.95	0.72	0.37	0.22	0.11	0.05	0.03	0.11
1995	0.19	1.16	12.74	28.56	17.66	5.36	2.55	2.83	2.11	0.55	0.42	0.21	0.13	0.06	0.03	0.08
1996	0.27	2.59	20.15	21.21	29.10	12.46	3.21	1.49	1.65	1.24	0.32	0.25	0.13	0.08	0.04	0.06
1997	0.11	2.02	26.53	22.06	15.90	16.08	5.93	1.50	0.70	0.78	0.59	0.15	0.12	0.06	0.04	0.05
1998	0.09	0.91	21.05	36.04	21.50	10.60	8.98	3.23	0.82	0.38	0.43	0.32	0.08	0.07	0.03	0.05
1999	0.10	0.34	6.05	23.91	28.08	10.27	4.12	3.40	1.23	0.31	0.15	0.17	0.13	0.03	0.03	0.03
2000	0.09	0.57	3.50	9.54	23.71	16.63	4.95	1.93	1.60	0.58	0.15	0.07	0.08	0.06	0.02	0.03
2001	0.19	1.04	7.79	6.39	11.60	19.02	11.12	3.21	1.24	1.03	0.37	0.10	0.04	0.05	0.04	0.03
2002	0.22	1.27	16.88	19.58	9.58	11.73	16.43	9.48	2.76	1.08	0.90	0.33	0.09	0.04	0.05	0.06
2003	0.34	1.60	16.06	23.15	17.32	6.49	7.00	9.69	5.62	1.65	0.65	0.55	0.20	0.05	0.02	0.06
2004	0.49	3.37	23.33	23.28	21.23	12.12	3.99	4.24	5.88	3.43	1.01	0.40	0.34	0.12	0.03	0.06
2005	0.04	1.94	22.75	17.26	11.64	8.57	4.39	1.43	1.53	2.14	1.25	0.37	0.15	0.12	0.05	0.03
2006	0.01	0.51	37.46	45.55	22.56	11.87	7.77	3.93	1.29	1.39	1.95	1.15	0.34	0.14	0.11	0.07
2007	0.02	0.31	13.20	83.00	64.92	25.26	11.84	7.64	3.87	1.27	1.38	1.94	1.14	0.34	0.14	0.19
2008	0.05	0.61	10.42	32.50	117.71	71.74	24.99	11.56	7.49	3.81	1.26	1.36	1.92	1.14	0.34	0.32
2009	0.08	1.34	12.23	12.76	22.59	71.31	40.67	14.07	6.53	4.25	2.17	0.72	0.78	1.10	0.65	0.38
2010	0.03	0.55	5.21	3.51	2.76	4.89	14.90	8.47	2.93	1.36	0.89	0.45	0.15	0.16	0.23	0.22
2011	0.03	0.38	11.19	10.54	4.35	2.47	3.79	11.33	6.45	2.24	1.05	0.68	0.35	0.12	0.13	0.35
2012	0.04	0.78	13.79	32.98	17.36	5.57	2.84	4.32	12.98	7.43	2.60	1.22	0.80	0.41	0.14	0.56
2013	0.02	0.33	5.39	6.87	10.47	5.27	1.63	0.83	1.27	3.82	2.19	0.77	0.36	0.24	0.12	0.21
2014	0.02	0.15	4.67	6.58	5.39	7.30	3.46	1.07	0.55	0.84	2.53	1.46	0.51	0.24	0.16	0.22
2015	0.03	0.22	2.60	6.48	5.66	4.16	5.34	2.52	0.78	0.40	0.62	1.87	1.08	0.38	0.18	0.28

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1976	31.63	147.19	224.34	740.28	652.30	119.20	128.64	43.35	53.34	18.88	12.26	8.00	5.24	3.44	2.26	4.35
1977	27.47	168.44	196.81	205.68	595.20	486.23	84.97	89.24	29.54	35.90	12.58	8.11	5.26	3.42	2.24	4.23
1978	33.12	155.99	238.42	192.89	178.18	479.33	374.22	63.52	65.42	21.36	25.67	8.92	5.71	3.68	2.39	4.44
1979	37.41	173.79	211.94	223.03	158.44	135.86	350.13	266.52	44.52	45.35	14.67	17.51	6.05	3.86	2.48	4.52
1980	20.94	186.72	223.88	187.54	173.23	114.33	94.05	236.62	177.44	29.34	29.63	9.52	11.31	3.89	2.47	4.41
1981	19.47	87.14	199.51	166.58	122.93	104.91	65.78	52.31	128.60	94.86	15.49	15.49	4.94	5.84	2.00	3.48
1982	31.46	116.49	151.40	241.14	175.30	119.80	98.22	60.35	47.47	115.88	84.99	13.81	13.76	4.37	5.14	4.75
1983	51.62	250.47	247.04	219.55	304.71	205.47	134.94	108.33	65.76	51.30	124.40	90.72	14.67	14.56	4.61	10.31
1984	31.55	274.85	342.86	233.68	182.38	235.50	152.36	97.63	77.15	46.31	35.81	86.20	62.51	10.06	9.94	10.02
1985	21.40	119.90	189.61	138.20	81.97	59.37	73.38	46.25	29.14	22.76	13.53	10.39	24.86	17.94	2.88	5.63
1986	19.19	155.00	212.96	199.44	122.82	66.33	45.71	55.04	34.18	21.34	16.54	9.78	7.47	17.80	12.80	5.97
1987	35.63	96.55	194.29	155.29	120.87	67.27	34.51	23.20	27.59	17.00	10.55	8.13	4.79	3.64	8.65	9.04
1988	20.35	126.01	87.67	112.19	77.71	55.62	29.56	14.80	9.81	11.57	7.08	4.36	3.35	1.96	1.49	7.14
1989	10.66	121.90	256.58	107.96	109.05	66.18	44.52	23.05	11.42	7.53	8.84	5.39	3.31	2.54	1.48	6.39
1990	9.31	29.12	90.21	116.30	40.65	36.45	20.59	13.27	6.69	3.25	2.12	2.46	1.49	0.91	0.69	2.11
1991	11.39	23.50	32.18	67.44	71.27	22.09	18.63	10.23	6.51	3.26	1.58	1.02	1.18	0.71	0.44	1.32
1992	0.36	3.63	32.66	53.25	110.96	113.22	33.94	28.32	15.54	9.91	4.96	2.40	1.55	1.80	1.08	2.61
1993	0.14	5.62	104.81	95.64	83.23	128.14	113.13	32.80	27.17	14.91	9.51	4.77	2.31	1.49	1.72	3.49
1994	0.12	2.30	91.75	126.27	67.73	45.69	60.55	51.06	14.49	11.84	6.43	4.07	2.03	0.98	0.63	2.16
1995	0.19	2.85	54.77	181.37	148.82	55.78	31.13	39.11	32.21	9.01	7.28	3.92	2.46	1.22	0.59	1.64
1996	0.27	6.35	86.65	134.71	245.22	129.71	39.18	20.61	25.22	20.42	5.64	4.51	2.41	1.51	0.74	1.33
1997	0.11	4.95	114.07	140.06	133.99	167.31	72.44	20.71	10.64	12.83	10.27	2.81	2.23	1.19	0.74	1.00
1998	0.09	2.23	90.50	228.86	181.20	110.33	109.73	44.71	12.45	6.29	7.50	5.95	1.62	1.28	0.68	0.98
1999	0.10	0.84	26.02	151.85	236.64	106.91	50.30	47.02	18.73	5.15	2.58	3.05	2.41	0.65	0.51	0.65
2000	0.09	1.40	15.05	60.58	199.74	173.08	60.48	26.69	24.32	9.53	2.59	1.29	1.51	1.18	0.32	0.56
2001	0.19	2.56	33.49	40.59	97.76	197.96	135.91	44.36	18.93	16.86	6.50	1.74	0.86	1.00	0.78	0.57
2002	0.23	3.10	72.56	124.30	80.71	122.06	200.80	131.09	42.07	17.81	15.77	6.05	1.62	0.79	0.92	1.23
2003	0.35	3.93	69.03	146.99	145.98	67.49	85.60	134.02	85.68	27.15	11.38	10.01	3.82	1.02	0.50	1.33
2004	0.50	8.26	100.30	147.80	178.88	126.10	48.78	58.68	89.63	56.38	17.65	7.33	6.40	2.43	0.64	1.14
2005	0.04	4.75	97.80	109.59	98.08	89.19	53.62	19.79	23.32	35.17	21.91	6.81	2.81	2.45	0.92	0.67
2006	0.01	1.24	161.03	289.22	190.08	123.49	95.00	54.39	19.64	22.81	34.02	21.02	6.49	2.67	2.31	1.49
2007	0.02	0.77	56.75	527.01	547.05	262.90	144.67	105.75	59.04	20.95	24.02	35.47	21.75	6.68	2.73	3.84
2008	0.05	1.49	44.81	206.40	991.84	746.64	305.36	159.93	114.11	62.67	21.97	24.94	36.56	22.29	6.81	6.60
2009	0.08	3.29	52.57	81.04	190.33	742.14	497.07	194.70	99.54	69.82	37.85	13.13	14.80	21.56	13.08	7.76
2010	0.03	1.35	22.42	22.27	23.26	50.90	182.10	117.13	44.73	22.45	15.52	8.32	2.86	3.21	4.65	4.44
2011	0.03	0.93	48.13	66.90	36.63	25.67	46.29	156.71	98.26	36.89	18.28	12.52	6.67	2.28	2.54	7.11
2012	0.04	1.90	59.26	209.39	146.23	57.95	34.74	59.77	197.86	122.25	45.40	22.31	15.18	8.04	2.74	11.38
2013	0.02	0.82	23.16	43.64	88.25	54.89	19.98	11.51	19.32	62.83	38.29	14.07	6.86	4.64	2.45	4.21
2014	0.02	0.38	20.09	41.76	45.41	76.01	42.29	14.77	8.33	13.76	44.25	26.73	9.76	4.73	3.19	4.50
2015	0.03	0.54	11.17	41.14	47.70	43.30	65.27	34.84	11.89	6.59	10.76	34.27	20.56	7.46	3.60	5.76

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

Year	L.cH	L.cO	L.HB	L.GR	Total
1976	38.07	36.11	4.60	290.16	368.94
1977	27.30	28.79	5.61	248.98	310.67
1978	32.33	34.96	4.77	220.71	292.76
1979	29.83	34.49	9.38	206.43	280.13
1980	23.63	25.87	8.14	193.84	251.48
1981	26.87	30.58	7.96	112.47	177.89
1982	26.63	29.42	6.36	151.09	213.51
1983	27.74	33.94	9.89	269.83	341.40
1984	34.57	41.68	8.56	258.06	342.88
1985	32.24	30.92	8.78	95.90	167.84
1986	40.93	37.90	5.81	114.30	198.94
1987	34.03	39.50	7.04	93.91	174.49
1988	45.88	36.62	5.10	42.60	130.19
1989	40.80	31.31	3.62	88.47	164.20
1990	28.32	25.72	7.33	11.06	72.44
1991	21.87	20.57	2.73	7.50	52.66
1992	12.88	5.65	3.98	26.57	49.08
1993	16.50	2.55	4.79	55.80	79.63
1994	17.27	1.64	5.47	41.52	65.91
1995	25.38	1.50	5.25	42.52	74.65
1996	30.63	3.06	5.65	54.92	94.26
1997	34.07	3.05	8.06	47.42	92.60
1998	48.44	5.43	10.90	39.82	104.59
1999	45.10	2.36	7.27	23.62	78.35
2000	35.54	1.58	5.34	21.03	63.49
2001	31.21	5.57	4.94	21.55	63.27
2002	30.29	4.23	4.60	51.35	90.47
2003	28.76	3.26	4.02	54.43	90.46
2004	28.14	5.07	10.77	59.34	103.31
2005	20.49	2.15	11.48	39.55	73.67
2006	34.26	1.14	5.24	95.45	136.09
2007	59.82	1.94	5.16	149.54	216.46
2008	57.42	1.05	2.44	226.31	287.22
2009	31.82	0.80	1.43	157.57	191.63
2010	22.48	0.87	1.28	22.10	46.73
2011	15.83	1.18	1.56	36.87	55.43
2012	10.68	1.19	1.44	90.48	103.80
2013	7.92	1.02	1.16	29.70	39.80
2014	6.23	0.72	1.85	26.35	35.15
2015	4.23	0.75	1.74	25.87	32.60

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

Year	L.cH	L.cO	L.HB	L.GR	Total
1976	262.59	170.93	27.47	1733.70	2194.69
1977	208.54	134.73	35.50	1576.56	1955.33
1978	257.17	151.82	30.54	1413.73	1853.26
1979	234.27	134.92	57.66	1269.24	1696.08
1980	184.75	103.52	49.04	1168.01	1505.32
1981	210.64	125.95	49.75	702.99	1089.33
1982	205.64	113.02	39.01	926.66	1284.33
1983	203.78	118.95	55.73	1519.98	1898.44
1984	236.89	141.73	48.51	1461.68	1888.80
1985	201.57	100.82	46.55	508.27	857.21
1986	250.52	131.23	30.03	590.58	1002.36
1987	190.02	118.47	35.48	473.05	817.02
1988	244.00	111.06	23.05	192.56	570.67
1989	230.09	113.93	17.41	425.39	786.81
1990	173.05	102.10	40.04	60.42	375.61
1991	139.23	74.76	15.68	43.08	272.75
1992	129.20	39.96	32.51	214.53	416.20
1993	168.91	16.48	35.67	407.81	628.87
1994	165.59	10.09	36.96	275.48	488.12
1995	229.58	9.41	36.99	296.38	572.36
1996	279.38	19.12	40.22	385.78	724.49
1997	311.80	18.84	53.78	310.92	695.34
1998	430.73	35.48	73.51	264.67	804.39
1999	406.96	17.04	54.34	175.10	653.43
2000	345.08	12.36	44.95	176.02	578.42
2001	329.34	43.94	42.80	184.00	600.08
2002	330.88	31.32	38.30	420.63	821.13
2003	306.18	22.17	32.46	433.45	794.26
2004	289.38	31.64	82.39	447.51	850.91
2005	202.34	13.27	80.17	271.16	566.93
2006	324.89	7.66	36.63	655.73	1024.91
2007	571.01	15.03	41.36	1191.99	1819.39
2008	590.21	9.38	23.04	2129.84	2752.47
2009	364.45	7.66	15.06	1651.60	2038.77
2010	279.14	7.74	13.24	225.52	525.64
2011	199.45	9.52	14.76	342.10	565.83
2012	128.91	9.37	13.56	842.61	994.45
2013	93.28	8.21	11.15	282.29	394.94
2014	74.71	6.04	18.26	256.95	355.96
2015	51.94	6.52	18.17	268.25	344.89

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

Year	D.cH	D.HB	D.GR	Total
1981	0.00	0.00	3.36	3.36
1982	0.00	0.00	3.29	3.29
1983	0.00	0.00	30.16	30.16
1984	1.83	2.23	36.32	40.38
1985	1.62	1.97	1.00	4.60
1986	1.29	1.56	6.37	9.22
1987	1.63	1.98	21.18	24.79
1988	1.68	2.04	7.80	11.52
1989	0.95	1.15	1.15	3.25
1990	0.74	0.90	2.90	4.54
1991	1.18	1.43	29.64	32.25
1992	1.84	2.24	29.67	33.74
1993	3.07	2.17	12.65	17.89
1994	4.21	2.19	22.35	28.75
1995	3.56	3.08	20.54	27.18
1996	3.61	3.77	58.76	66.14
1997	4.35	2.92	62.06	69.33
1998	3.01	1.82	17.78	22.61
1999	2.48	1.84	17.59	21.91
2000	2.56	2.38	48.84	53.78
2001	2.36	2.66	28.04	33.06
2002	4.41	3.23	16.70	24.34
2003	2.19	5.36	23.62	31.16
2004	2.20	7.79	38.12	48.12
2005	2.05	1.95	35.91	39.91
2006	1.00	1.00	31.08	33.08
2007	1.72	0.83	20.26	22.81
2008	0.40	1.35	19.99	21.74
2009	0.30	2.45	24.20	26.95
2010	0.51	2.87	21.78	25.16
2011	0.36	1.32	15.40	17.08
2012	0.33	1.96	19.39	21.67
2013	3.58	1.95	25.06	30.59
2014	2.20	1.01	21.11	24.32
2015	3.75	1.28	18.64	23.67

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

Year	D.cH	D.HB	D.GR	Total
1981	0.00	0.00	5.36	5.36
1982	0.00	0.00	4.99	4.99
1983	0.00	0.00	47.68	47.68
1984	3.08	3.74	61.04	67.86
1985	2.59	3.15	1.60	7.34
1986	2.24	2.72	11.07	16.03
1987	2.26	2.74	29.26	34.26
1988	2.91	3.54	13.51	19.96
1989	1.78	2.17	2.16	6.11
1990	1.15	1.40	4.49	7.04
1991	1.69	2.05	42.47	46.20
1992	3.31	4.02	53.31	60.64
1993	6.82	4.81	28.05	39.68
1994	9.25	4.80	49.11	63.17
1995	6.46	5.59	37.25	49.30
1996	7.08	7.38	115.15	129.61
1997	10.92	7.32	155.70	173.94
1998	8.54	5.18	50.51	64.24
1999	5.23	3.87	37.04	46.15
2000	4.82	4.48	91.97	101.26
2001	4.90	5.51	58.20	68.61
2002	8.81	6.46	33.39	48.66
2003	3.80	9.29	40.97	54.06
2004	4.06	14.38	70.35	88.79
2005	5.49	5.20	95.95	106.64
2006	3.48	3.49	108.63	115.61
2007	5.59	2.68	65.64	73.91
2008	0.81	2.72	40.39	43.93
2009	0.52	4.30	42.43	47.25
2010	1.17	6.55	49.76	57.48
2011	0.89	3.30	38.39	42.58
2012	0.75	4.42	43.85	49.03
2013	8.98	4.88	62.80	76.66
2014	5.08	2.32	48.70	56.09
2015	7.13	2.44	35.43	45.00

Table 18. Estimated status indicators, benchmarks, and related quantities from the base run of the Beaufort Assessment Model, conditional on estimated current selectivities averaged across fleets. Also presented are median values and measures of precision (standard errors, SE) from the Monte Carlo/Bootstrap analysis. Rate estimates (F) are in units of y^{-1}*; status indicators are dimensionless; and biomass estimates (whole weight) are in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) is measured as total (males and females) mature biomass. The definition of* MSST *considered in this assessment is* $\mathrm{MSST} = 75\%\mathrm{SSB}_{\mathrm{MSY}}$.

Quantity	Units	Estimate	Median	SE
F_{MSY}	y^{-1}	0.12	0.13	0.02
$85\%F_{\mathrm{MSY}}$	y^{-1}	0.10	0.11	0.02
$75\%F_{\mathrm{MSY}}$	y^{-1}	0.09	0.09	0.02
$65\%F_{\mathrm{MSY}}$	y^{-1}	0.08	0.08	0.01
$F_{20\%}$	y^{-1}	0.20	0.21	0.03
$F_{30\%}$	y^{-1}	0.14	0.14	0.02
$F_{40\%}$	y^{-1}	0.10	0.10	0.01
B_{MSY}	mt	4188.3	4149.6	1333.
$\mathrm{SSB}_{\mathrm{MSY}}$	mt	3183.4	3145.4	1165.1
MSST	mt	2387.6	2359	873.8
MSY	1000 lb	794.3	806.7	180.0
D_{MSY}	1000 fish	60.9	61.2	13.5
R_{MSY}	1000 age-1 fish	399.8	414.8	69.2
Y at $85\%F_{\mathrm{MSY}}$	1000 lb	787.0	794.3	178.0
Y at $75\%F_{\mathrm{MSY}}$	1000 lb	772.0	779.7	174.1
Y at $65\%F_{\mathrm{MSY}}$	1000 lb	746.4	754.7	167.6
$F_{2013-2015}/F_{\mathrm{MSY}}$	—	1.54	1.58	0.57
$\mathrm{SSB}_{2015}/\mathrm{MSST}$	—	0.38	0.37	0.13
$\mathrm{SSB}_{2015}/\mathrm{SSB}_{\mathrm{MSY}}$	—	0.29	0.27	0.11

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

Run	Description	F_{MSY}	$\mathrm{SSB}_{\mathrm{MSY}}$ (mt)	MSY(1000 lb)	$\mathrm{F}_{\mathrm{current}}/F_{\mathrm{MSY}}$	$\mathrm{SSB}_{2015}/\mathrm{MSST}$	steep	R0(1000)
Base	—	0.122	3183	794	1.54	0.38	0.87	360
S1	h=0.99	0.139	2388	677	1.28	0.54	0.99	290
S2	h=0.75	0.105	5035	1089	2.01	0.21	0.75	520
S3	M=0.2	0.162	2018	637	0.85	0.82	0.87	490
S4	M=0.1	0.096	5641	1141	2.57	0.16	0.87	338
S5	M Charnov	0.264	1542	668	0.37	1.51	0.87	1614
S6	CVT wgt=6	0.13	2980	795	2.99	0.16	0.87	333
S7	No video	0.12	2997	740	3.74	0.13	0.87	316
S8	Continuity	0.122	2796	697	2.46	0.25	0.92	299
S9	LogisticNorm	0.144	3115	869	2.95	0.16	0.87	332
S10	Release M=0.4	0.137	3778	718	2.64	0.23	0.87	397

Table 20. Projection results with fishing mortality rate fixed at $F = F_{\mathrm{MSY}}$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2016	323	267	0.21	0.23	860	817	33	34	365	368	56	51	92	89	0.000
2017	318	259	0.12	0.13	867	823	19	19	203	198	42	36	79	69	0.000
2018	318	257	0.12	0.13	977	932	24	24	226	221	47	41	99	86	0.000
2019	329	267	0.12	0.13	1133	1076	31	30	268	263	49	42	105	91	0.001
2020	341	275	0.12	0.13	1318	1242	37	35	318	311	51	43	108	93	0.002
2021	352	286	0.12	0.13	1510	1412	42	40	369	359	52	45	112	97	0.006
2022	361	301	0.12	0.13	1699	1580	46	44	418	404	54	47	115	100	0.015
2023	369	306	0.12	0.13	1877	1739	50	48	463	446	55	48	119	104	0.028
2024	375	313	0.12	0.13	2042	1889	53	51	505	486	56	49	121	107	0.045
2025	380	317	0.12	0.13	2193	2028	56	54	543	523	57	50	123	110	0.066
2026	383	327	0.12	0.13	2328	2156	59	56	578	556	58	51	125	111	0.088
2027	386	329	0.12	0.13	2449	2275	61	59	608	586	58	52	126	113	0.112
2028	389	332	0.12	0.13	2556	2378	63	61	635	612	59	53	127	115	0.139
2029	391	333	0.12	0.13	2649	2476	64	62	659	637	59	53	128	116	0.165
2030	392	339	0.12	0.13	2730	2563	66	64	680	657	60	54	129	117	0.192

Table 21. Projection results with fishing mortality rate fixed at $F = 75\% F_{\mathrm{MSY}}$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$*. The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2016	323	267	0.21	0.23	860	817	33	34	365	368	56	51	92	89	0.000
2017	318	259	0.09	0.09	875	831	15	14	154	150	32	28	60	52	0.000
2018	319	258	0.09	0.09	1014	968	19	18	177	173	36	31	76	66	0.000
2019	332	269	0.09	0.09	1206	1148	25	24	216	212	38	33	82	71	0.001
2020	346	279	0.09	0.09	1434	1356	30	29	262	257	39	34	85	73	0.006
2021	358	291	0.09	0.09	1677	1572	35	33	310	303	41	35	88	76	0.022
2022	368	306	0.09	0.09	1920	1792	39	37	357	348	42	37	91	79	0.050
2023	376	313	0.09	0.09	2155	2006	43	41	403	390	43	38	94	83	0.091
2024	382	320	0.09	0.09	2377	2206	46	44	445	430	44	39	96	85	0.141
2025	387	325	0.09	0.09	2584	2398	49	47	485	469	45	40	98	87	0.201
2026	391	334	0.09	0.09	2773	2576	51	50	521	505	46	40	100	89	0.268
2027	394	337	0.09	0.09	2944	2742	54	52	554	536	46	41	101	91	0.337
2028	397	340	0.09	0.09	3098	2894	56	54	583	565	46	42	102	92	0.400
2029	399	341	0.09	0.09	3235	3031	57	56	609	592	47	42	102	93	0.464
2030	400	347	0.09	0.09	3355	3154	59	58	633	615	47	42	103	94	0.522

Table 22. Projection results with fishing mortality rate fixed at $F = 0$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\mathrm{SSB} \geq \mathrm{SSB_{MSY}}$. The extension b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2016	323	267	0.21	0.23	860	817	33	34	365	368	56	51	92	89	0.000
2017	318	259	0.00	0.00	900	856	0	0	0	0	0	0	0	0	0.000
2018	322	260	0.00	0.00	1133	1087	0	0	0	0	0	0	0	0	0.002
2019	341	277	0.00	0.00	1453	1393	0	0	0	0	0	0	0	0	0.018
2020	359	290	0.00	0.00	1850	1766	0	0	0	0	0	0	0	0	0.080
2021	374	305	0.00	0.00	2302	2190	0	0	0	0	0	0	0	0	0.200
2022	386	322	0.00	0.00	2788	2640	0	0	0	0	0	0	0	0	0.355
2023	394	330	0.00	0.00	3292	3105	0	0	0	0	0	0	0	0	0.510
2024	401	338	0.00	0.00	3801	3591	0	0	0	0	0	0	0	0	0.644
2025	406	343	0.00	0.00	4305	4068	0	0	0	0	0	0	0	0	0.746
2026	410	353	0.00	0.00	4796	4537	0	0	0	0	0	0	0	0	0.825
2027	413	355	0.00	0.00	5268	4992	0	0	0	0	0	0	0	0	0.883
2028	416	358	0.00	0.00	5718	5435	0	0	0	0	0	0	0	0	0.925
2029	418	359	0.00	0.00	6141	5853	0	0	0	0	0	0	0	0	0.953
2030	419	366	0.00	0.00	6537	6246	0	0	0	0	0	0	0	0	0.971

Table 23. Projection results with low recruitment and fishing mortality rate fixed at $F = F_{\mathrm{MSY}}$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2016	144	121	0.21	0.23	860	817	33	34	365	368	35	33	70	71	0
2017	144	120	0.12	0.13	824	780	19	19	202	197	21	18	44	40	0
2018	144	120	0.12	0.13	849	805	20	20	208	205	22	19	46	41	0
2019	144	120	0.12	0.13	881	835	21	21	217	213	22	19	47	42	0
2020	144	118	0.12	0.13	917	867	22	22	227	223	22	19	48	42	0
2021	144	119	0.12	0.13	952	897	23	23	237	231	22	19	48	42	0
2022	144	121	0.12	0.13	985	924	24	23	245	239	22	19	48	42	0
2023	144	120	0.12	0.13	1014	951	24	24	252	245	22	19	48	42	0
2024	144	120	0.12	0.13	1038	973	25	24	259	250	22	19	48	43	0
2025	144	119	0.12	0.13	1059	994	25	24	264	255	22	19	48	42	0
2026	144	121	0.12	0.13	1076	1011	25	25	268	259	22	19	48	42	0
2027	144	121	0.12	0.13	1089	1028	26	25	272	263	22	19	48	42	0
2028	144	121	0.12	0.13	1101	1040	26	25	275	266	22	19	48	42	0
2029	144	120	0.12	0.13	1110	1050	26	25	277	269	22	19	48	42	0
2030	144	121	0.12	0.13	1117	1060	26	25	279	271	22	19	48	42	0

Table 24. Projection results with low recruitment and fishing mortality rate fixed at $F = 75\% F_{\mathrm{MSY}}$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\mathrm{SSB} \geq \mathrm{SSB_{MSY}}$. The extension b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2016	144	121	0.21	0.23	860	817	33	34	365	368	35	33	70	71	0
2017	144	120	0.09	0.09	831	787	14	14	154	150	16	14	34	30	0
2018	144	120	0.09	0.09	881	837	16	15	163	161	17	15	36	32	0
2019	144	120	0.09	0.09	940	893	17	17	175	172	17	15	37	33	0
2020	144	118	0.09	0.09	1002	950	18	18	188	185	17	15	37	33	0
2021	144	119	0.09	0.09	1063	1005	19	19	200	196	17	15	37	33	0
2022	144	121	0.09	0.09	1120	1056	20	20	211	206	17	15	37	33	0
2023	144	120	0.09	0.09	1171	1103	21	20	221	215	17	15	37	33	0
2024	144	120	0.09	0.09	1216	1143	21	21	229	223	17	15	37	33	0
2025	144	119	0.09	0.09	1254	1179	22	21	237	230	17	15	37	33	0
2026	144	121	0.09	0.09	1286	1210	22	22	243	236	17	15	37	33	0
2027	144	121	0.09	0.09	1313	1239	22	22	248	241	17	15	37	33	0
2028	144	121	0.09	0.09	1336	1263	23	22	252	245	17	15	37	33	0
2029	144	120	0.09	0.09	1355	1283	23	22	256	249	17	15	37	33	0
2030	144	121	0.09	0.09	1371	1301	23	23	259	253	17	15	37	33	0

Table 25. Projection results with low recruitment and fishing mortality rate fixed at $F = 0$ starting in 2017. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$. The extension b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2016	144	121	0.21	0.23	860	817	33	34	365	368	35	33	70	71	0.000
2017	144	120	0.00	0.00	855	810	0	0	0	0	0	0	0	0	0.000
2018	144	120	0.00	0.00	987	942	0	0	0	0	0	0	0	0	0.000
2019	144	120	0.00	0.00	1141	1092	0	0	0	0	0	0	0	0	0.001
2020	144	118	0.00	0.00	1309	1255	0	0	0	0	0	0	0	0	0.006
2021	144	119	0.00	0.00	1485	1426	0	0	0	0	0	0	0	0	0.016
2022	144	121	0.00	0.00	1661	1592	0	0	0	0	0	0	0	0	0.032
2023	144	120	0.00	0.00	1831	1751	0	0	0	0	0	0	0	0	0.056
2024	144	120	0.00	0.00	1992	1899	0	0	0	0	0	0	0	0	0.086
2025	144	119	0.00	0.00	2142	2044	0	0	0	0	0	0	0	0	0.120
2026	144	121	0.00	0.00	2280	2175	0	0	0	0	0	0	0	0	0.156
2027	144	121	0.00	0.00	2407	2298	0	0	0	0	0	0	0	0	0.193
2028	144	121	0.00	0.00	2522	2411	0	0	0	0	0	0	0	0	0.231
2029	144	120	0.00	0.00	2627	2516	0	0	0	0	0	0	0	0	0.268
2030	144	121	0.00	0.00	2721	2606	0	0	0	0	0	0	0	0	0.302

Table 26. Projection results with fishing mortality rate fixed at $F = 0$ starting in 2019. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$. The extension b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2016	323	266	0.21	0.23	860	817	33	34	365	368	56	50	92	89	0.000
2017	318	261	0.23	0.25	839	794	35	35	365	367	77	70	144	133	0.000
2018	315	253	0.23	0.25	857	806	39	39	365	367	82	75	168	156	0.000
2019	317	249	0.00	0.00	974	914	0	0	0	0	0	0	0	0	0.002
2020	329	253	0.00	0.00	1290	1209	0	0	0	0	0	0	0	0	0.019
2021	351	273	0.00	0.00	1673	1566	0	0	0	0	0	0	0	0	0.070
2022	368	289	0.00	0.00	2111	1970	0	0	0	0	0	0	0	0	0.168
2023	381	304	0.00	0.00	2586	2408	0	0	0	0	0	0	0	0	0.297
2024	391	315	0.00	0.00	3084	2859	0	0	0	0	0	0	0	0	0.438
2025	399	321	0.00	0.00	3592	3336	0	0	0	0	0	0	0	0	0.566
2026	404	333	0.00	0.00	4099	3800	0	0	0	0	0	0	0	0	0.669
2027	409	338	0.00	0.00	4597	4261	0	0	0	0	0	0	0	0	0.751
2028	412	343	0.00	0.00	5078	4711	0	0	0	0	0	0	0	0	0.814
2029	415	343	0.00	0.00	5538	5157	0	0	0	0	0	0	0	0	0.862
2030	417	346	0.00	0.00	5973	5570	0	0	0	0	0	0	0	0	0.895
2031	419	350	0.00	0.00	6380	5943	0	0	0	0	0	0	0	0	0.919
2032	420	354	0.00	0.00	6758	6305	0	0	0	0	0	0	0	0	0.934
2033	421	356	0.00	0.00	7106	6654	0	0	0	0	0	0	0	0	0.946
2034	422	357	0.00	0.00	7425	6965	0	0	0	0	0	0	0	0	0.954
2035	423	357	0.00	0.00	7716	7248	0	0	0	0	0	0	0	0	0.960
2036	424	359	0.00	0.00	7981	7515	0	0	0	0	0	0	0	0	0.964
2037	424	359	0.00	0.00	8220	7774	0	0	0	0	0	0	0	0	0.967
2038	425	359	0.00	0.00	8437	8009	0	0	0	0	0	0	0	0	0.968
2039	425	360	0.00	0.00	8633	8207	0	0	0	0	0	0	0	0	0.969
2040	426	366	0.00	0.00	8809	8395	0	0	0	0	0	0	0	0	0.970

Table 27. Projection results with fishing mortality rate fixed at $F = 75\% F_{\mathrm{MSY}}$ starting in 2019. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$*. The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2016	323	266	0.21	0.23	860	817	33	34	365	368	56	50	92	89	0.000
2017	318	261	0.23	0.25	839	794	35	35	365	367	77	70	144	133	0.000
2018	315	253	0.23	0.25	857	806	39	39	365	367	82	75	168	156	0.000
2019	317	249	0.09	0.09	948	888	19	18	168	161	35	28	72	60	0.001
2020	326	252	0.09	0.09	1156	1079	24	23	208	200	37	30	79	65	0.005
2021	342	267	0.09	0.09	1389	1289	29	28	254	244	39	32	83	69	0.016
2022	356	278	0.09	0.09	1632	1507	34	32	302	289	41	33	87	73	0.035
2023	366	290	0.09	0.09	1876	1719	38	36	349	333	42	35	91	76	0.064
2024	375	299	0.09	0.09	2112	1925	42	40	394	375	43	36	94	80	0.103
2025	381	304	0.09	0.09	2337	2123	45	43	437	417	44	37	96	82	0.150
2026	386	315	0.09	0.09	2546	2306	48	46	478	455	45	38	98	84	0.203
2027	390	321	0.09	0.09	2739	2482	51	48	514	490	45	39	99	86	0.262
2028	394	325	0.09	0.09	2913	2642	53	51	548	522	46	40	100	88	0.323
2029	396	325	0.09	0.09	3071	2782	55	53	578	551	46	40	101	89	0.381
2030	398	327	0.09	0.09	3211	2912	57	55	605	578	47	40	102	89	0.438
2031	400	332	0.09	0.09	3334	3032	59	56	629	602	47	41	103	90	0.491
2032	402	335	0.09	0.09	3442	3141	60	58	649	621	47	41	103	91	0.539
2033	403	338	0.09	0.09	3536	3234	61	59	667	640	47	41	104	92	0.585
2034	404	339	0.09	0.09	3617	3324	62	60	682	658	47	42	104	93	0.628
2035	404	339	0.09	0.09	3687	3398	63	61	696	672	47	42	104	93	0.666
2036	405	342	0.09	0.09	3747	3471	63	62	707	685	47	42	104	93	0.702
2037	406	342	0.09	0.09	3798	3534	64	63	717	695	48	42	105	94	0.730
2038	406	342	0.09	0.09	3842	3585	65	63	725	705	48	42	105	94	0.755
2039	406	343	0.09	0.09	3879	3629	65	64	733	714	48	42	105	94	0.774
2040	407	349	0.09	0.09	3911	3668	65	64	739	721	48	43	105	95	0.793

8 Figures

Figure 1. Indices of abundance used in fitting the assessment model. U.CVT indicates the SERFS chevron trap/video survey; U.HB the headboat logbook data; and U.cH the commercial handline logbook data.

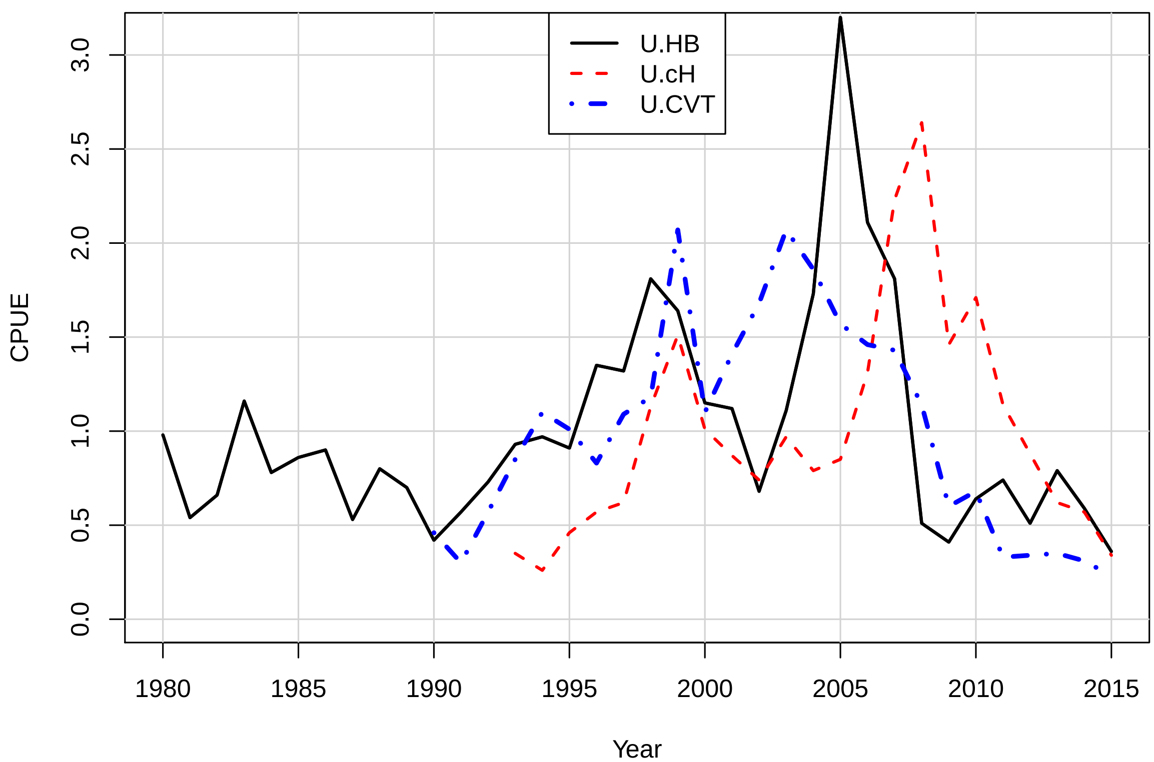


Figure 2. Mean total length at age (mm) and estimated upper and lower 95% confidence intervals of the population.

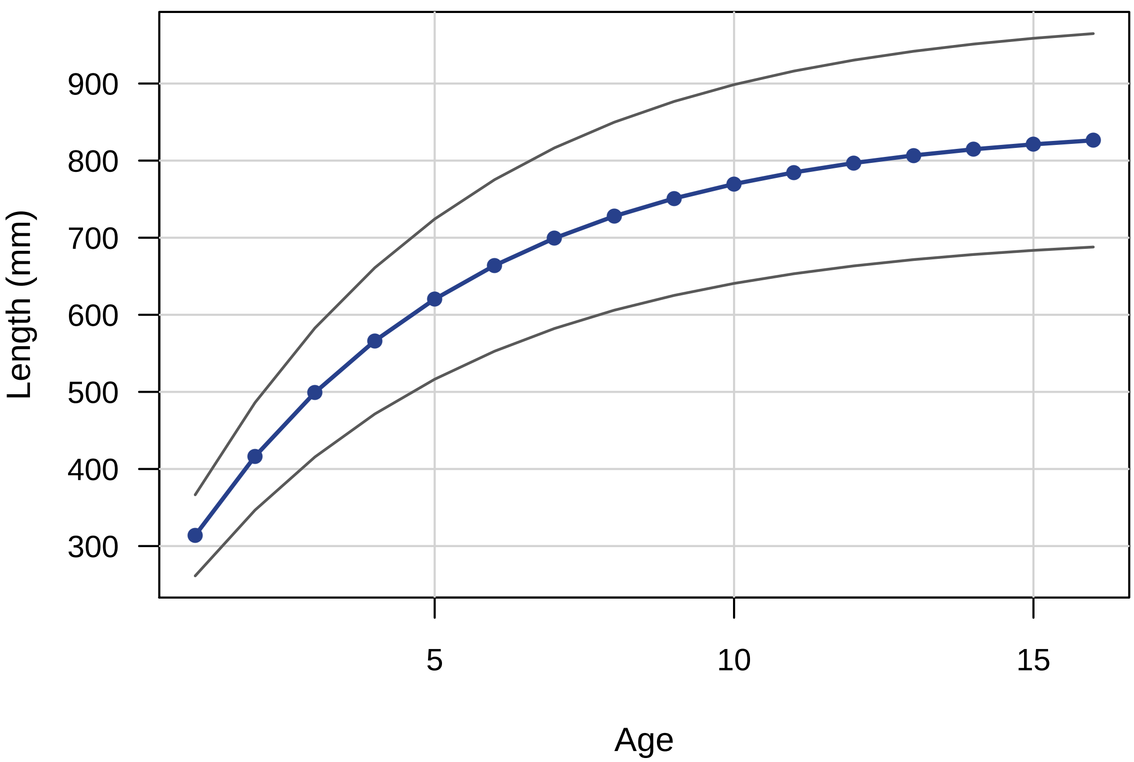


Figure 3. Comparison of results from assessments using the Dirichlet-multinomial and multinomial likelihoods to fit composition data. This comparison applies the SEDAR19 data and assessment model. Top left panel: Age-1 recruits. Bottom left panel: Abundance (1000 fish). Top right panel: F relative to F_{MSY}. *Bottom right panel: spawning biomass relative to* $\mathrm{SSB}_{\mathrm{MSY}}$.

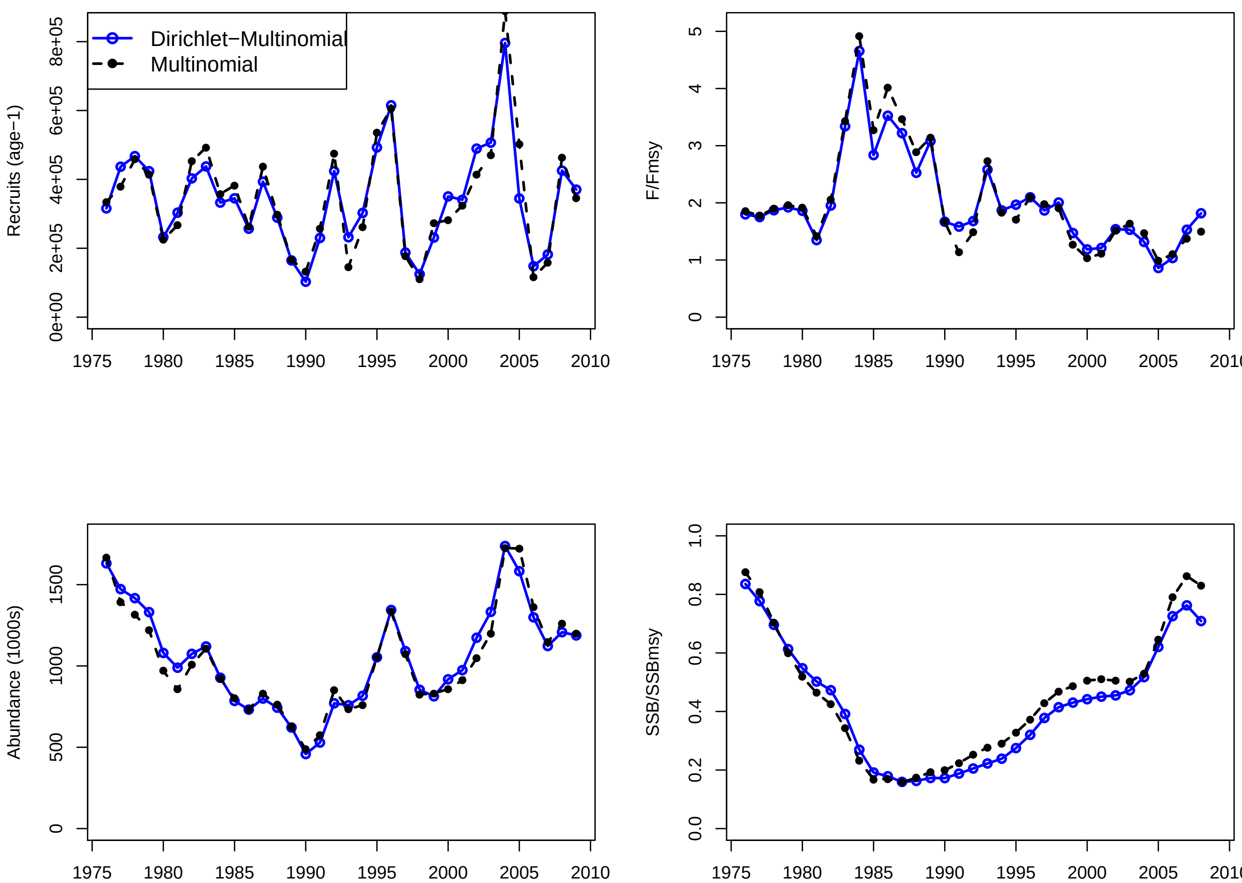


Figure 4. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, CVT to SERFS chevron trap/video gear, cH to commercial lines, cO to commercial other, HB to headboat, HB.D to headboat discards, and GR to general recreational. $N = -99999$ indicates that the composition was not used for fitting, in most cases because the sample size was below the cutoff.

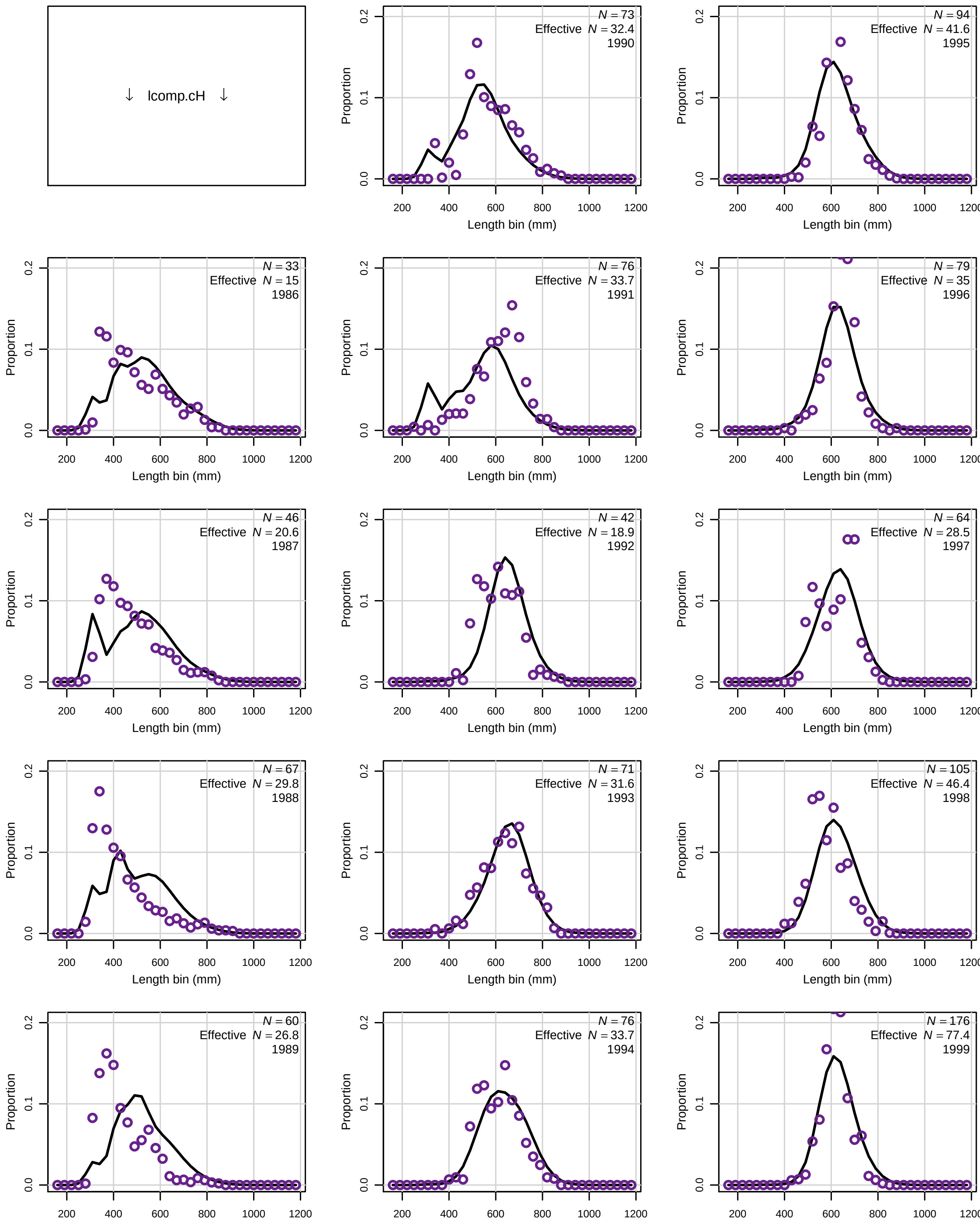


Figure 4. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

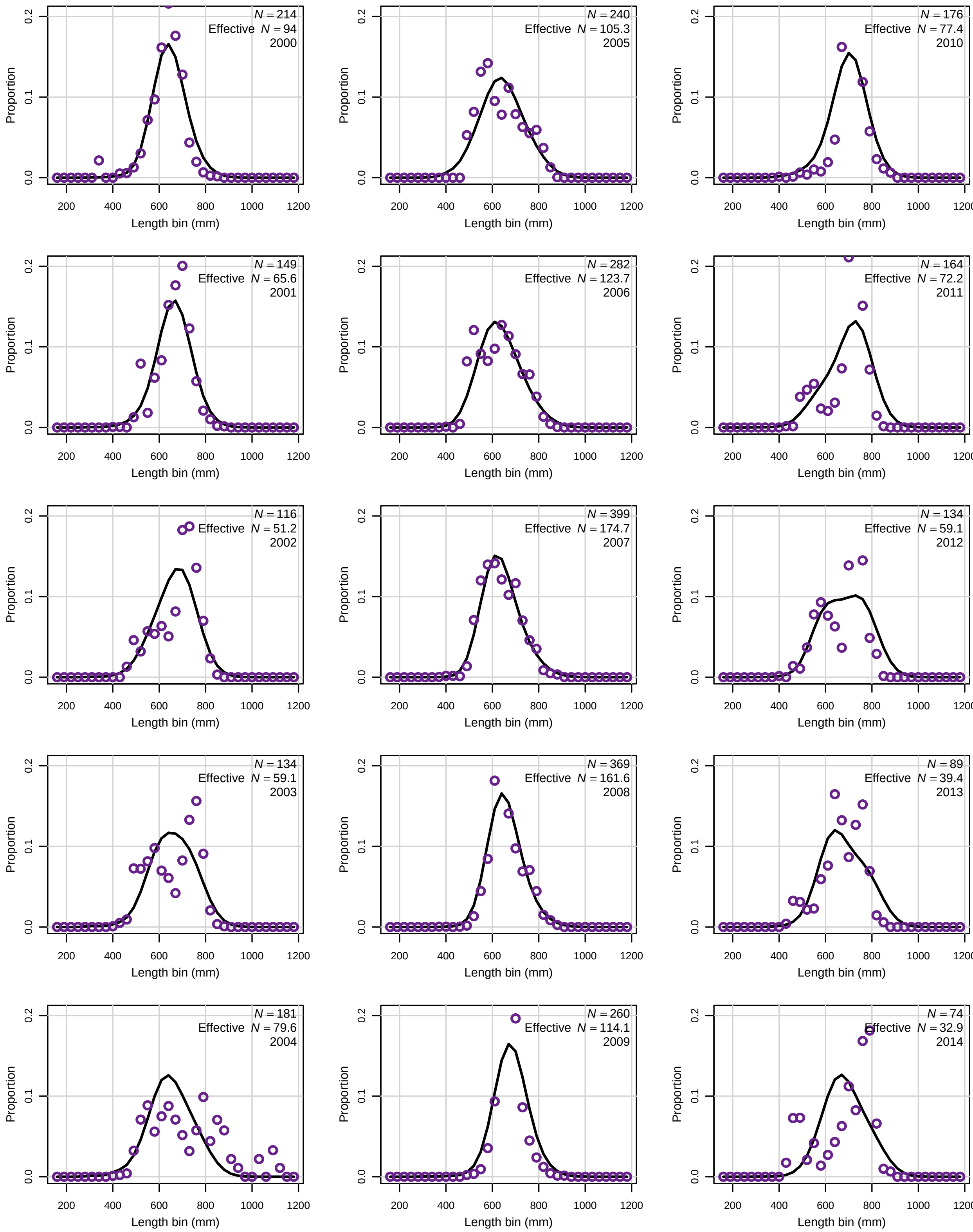


Figure 4. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

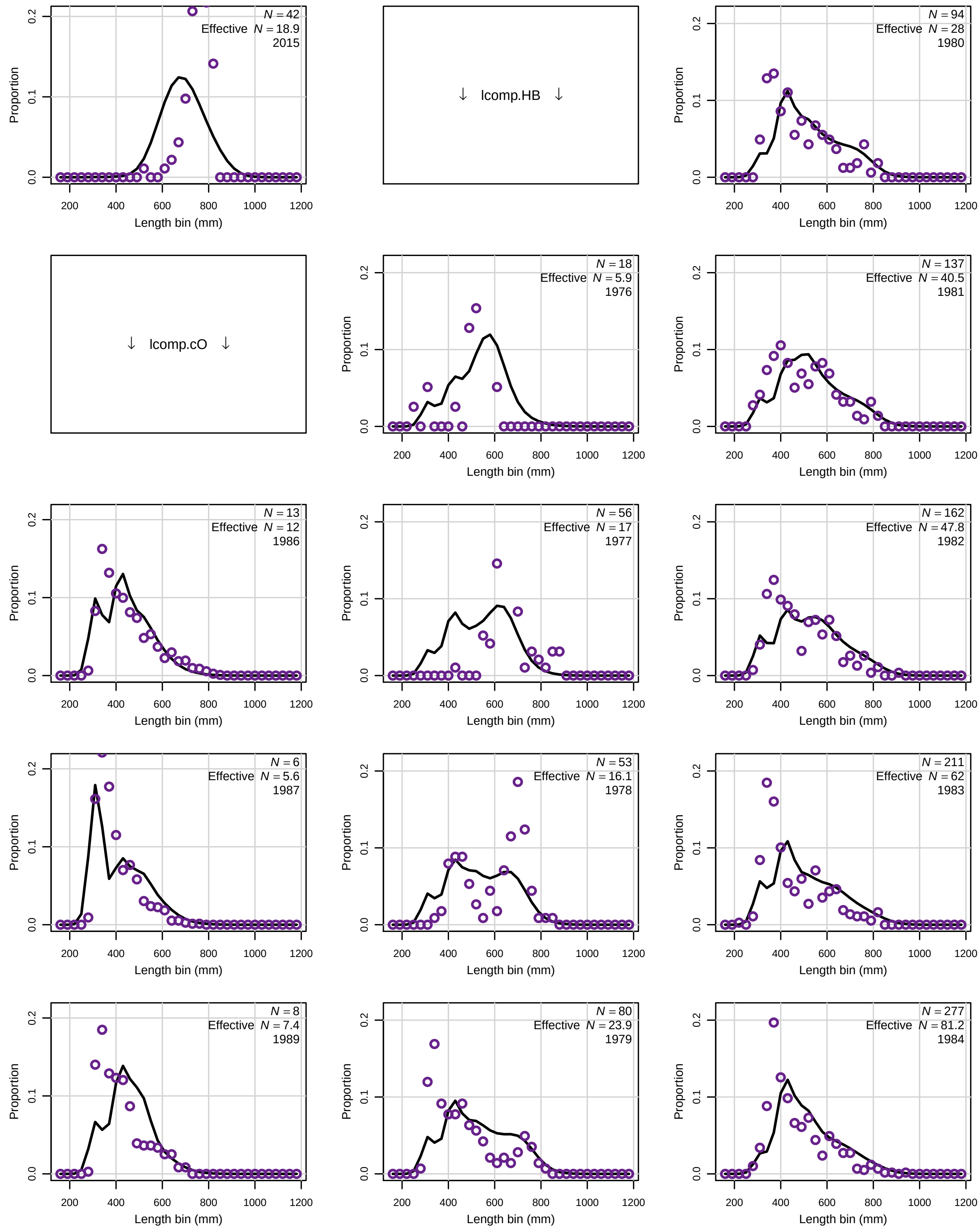


Figure 4. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

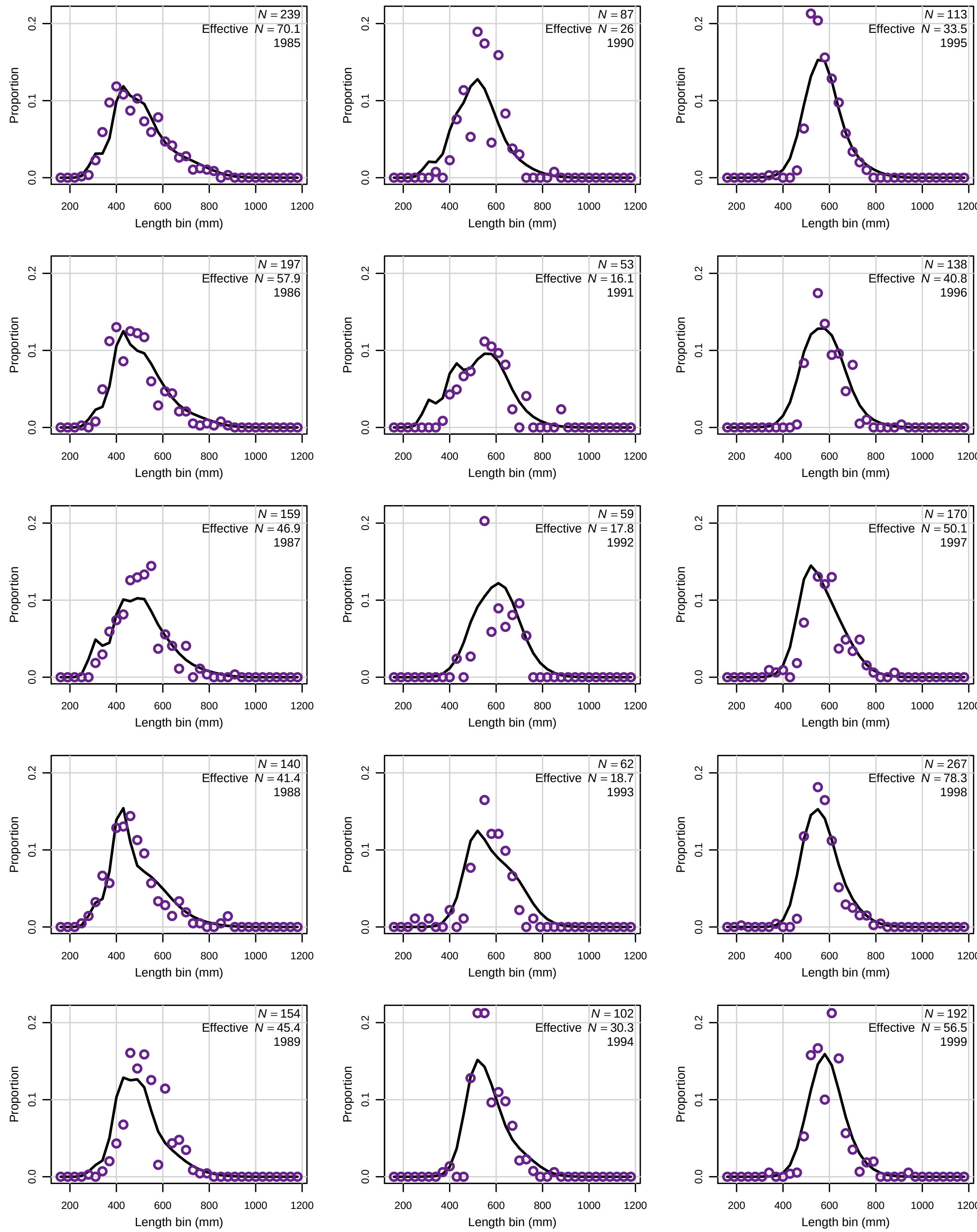


Figure 4. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

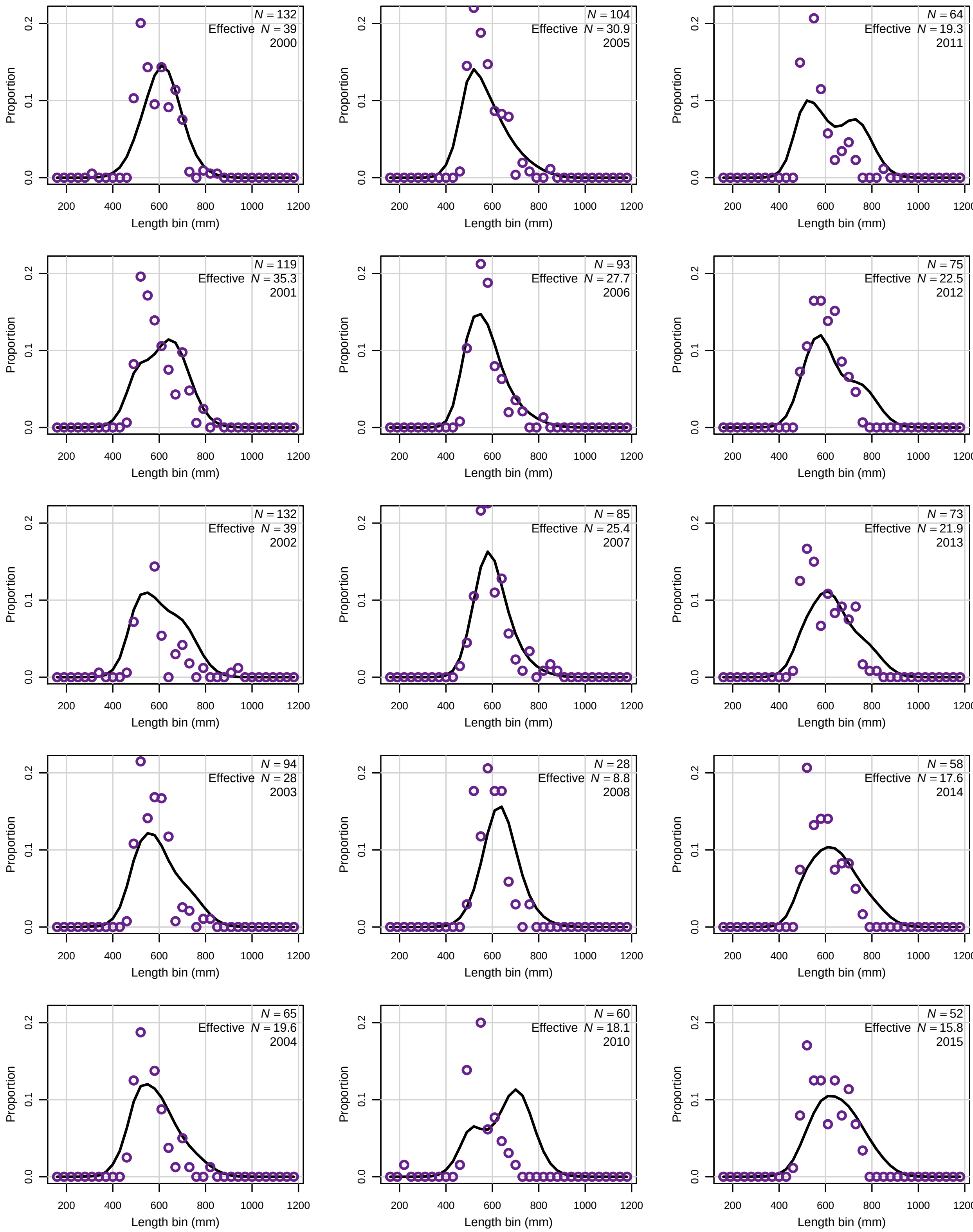


Figure 4. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

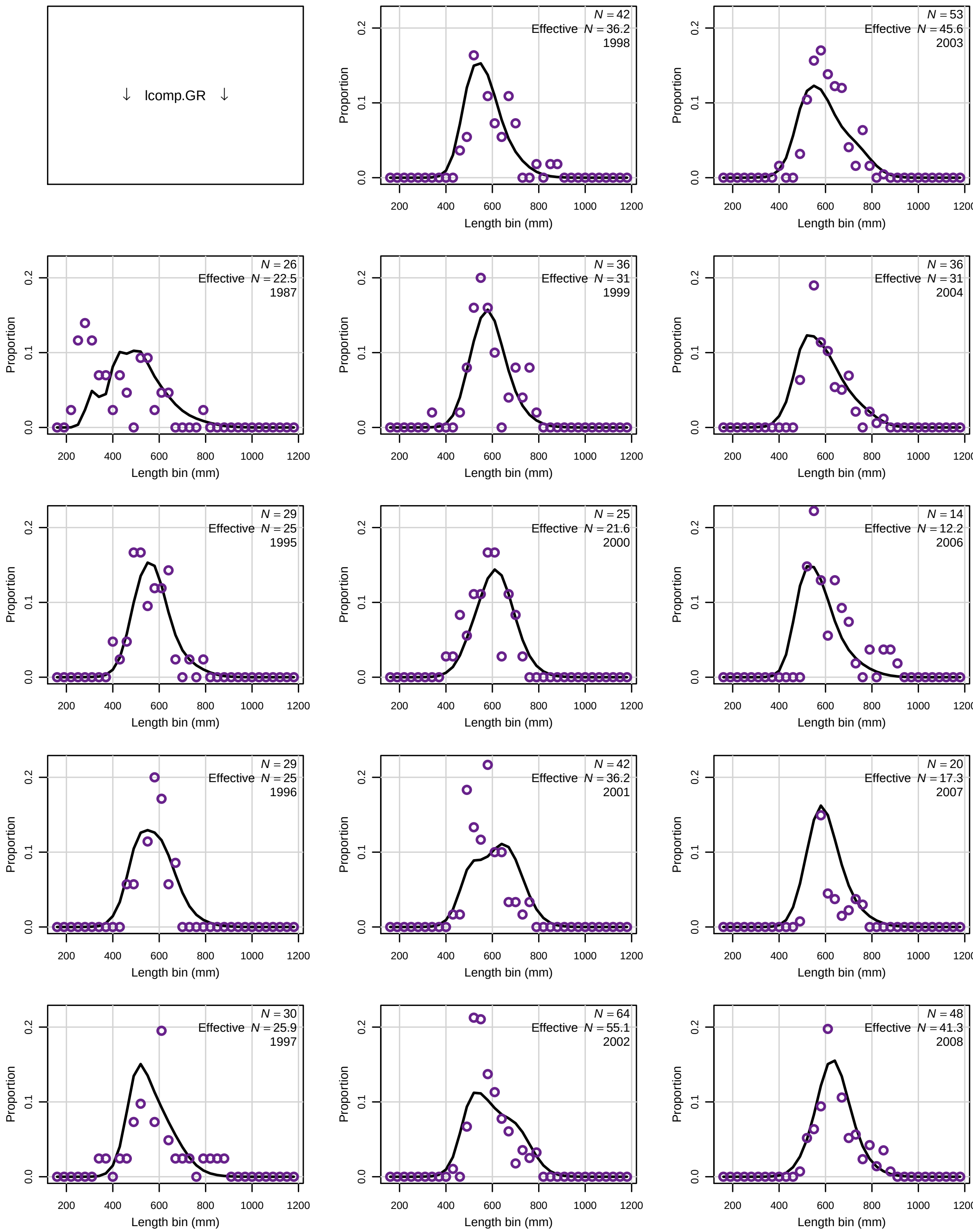


Figure 4. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

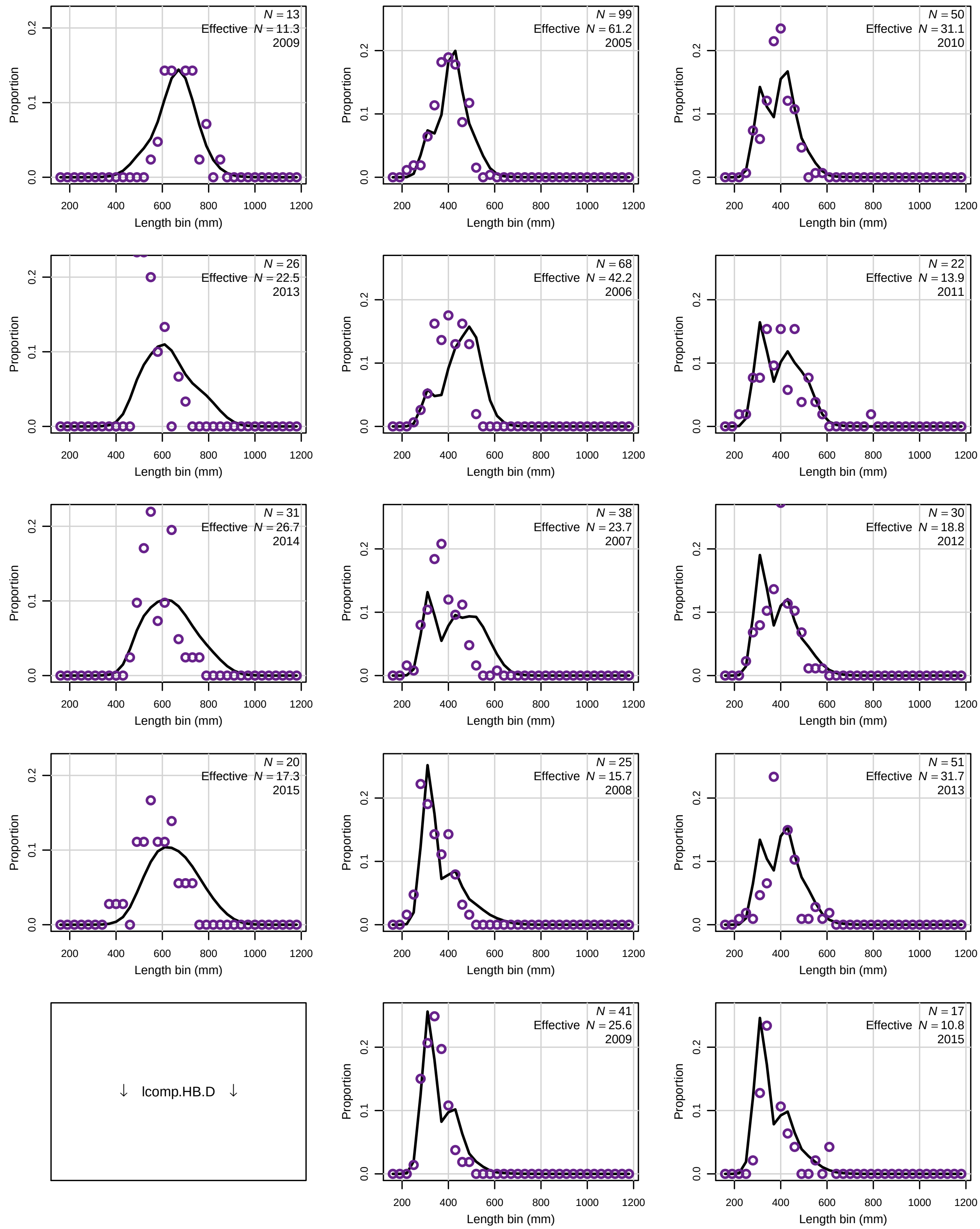


Figure 4. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

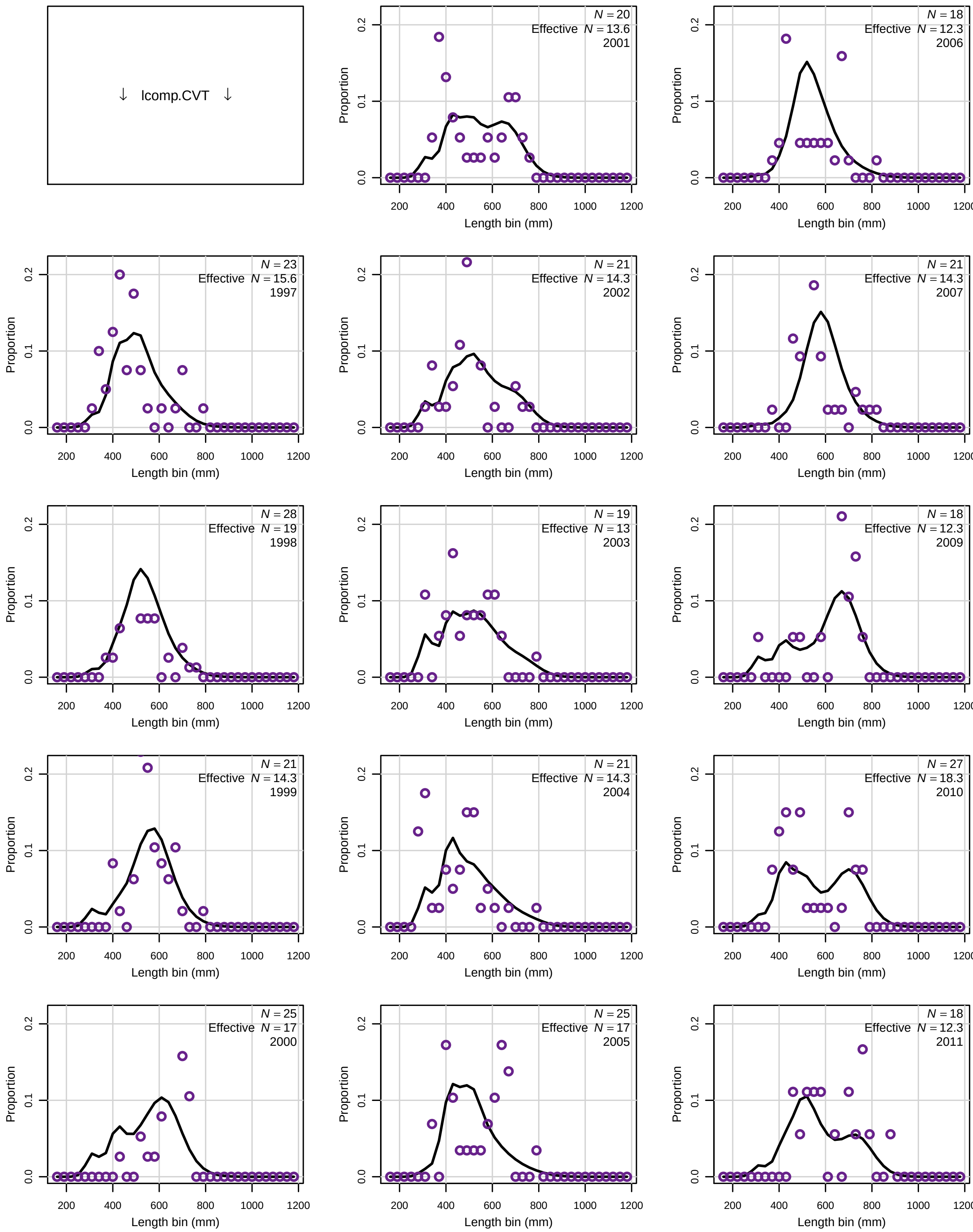


Figure 4. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

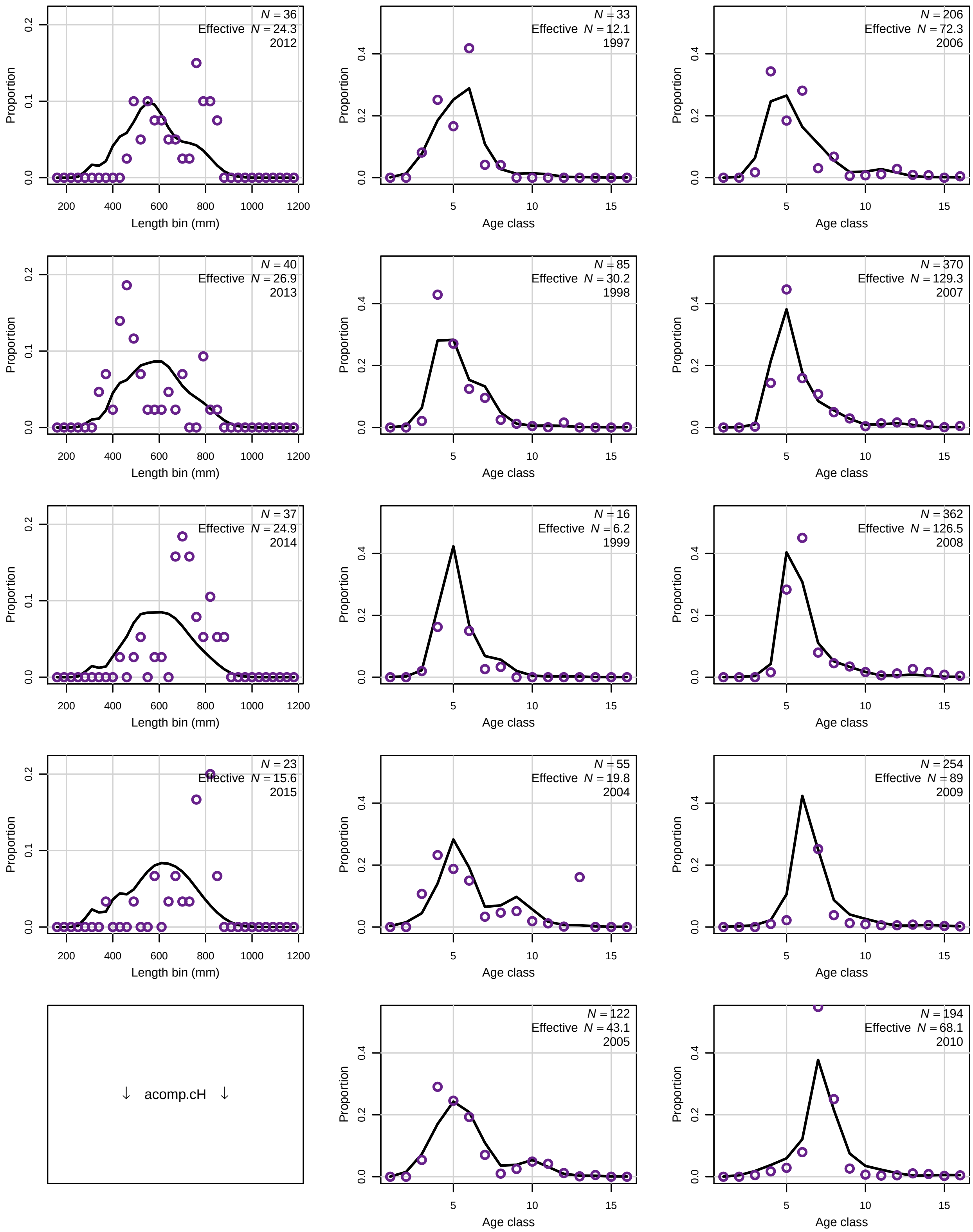


Figure 4. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

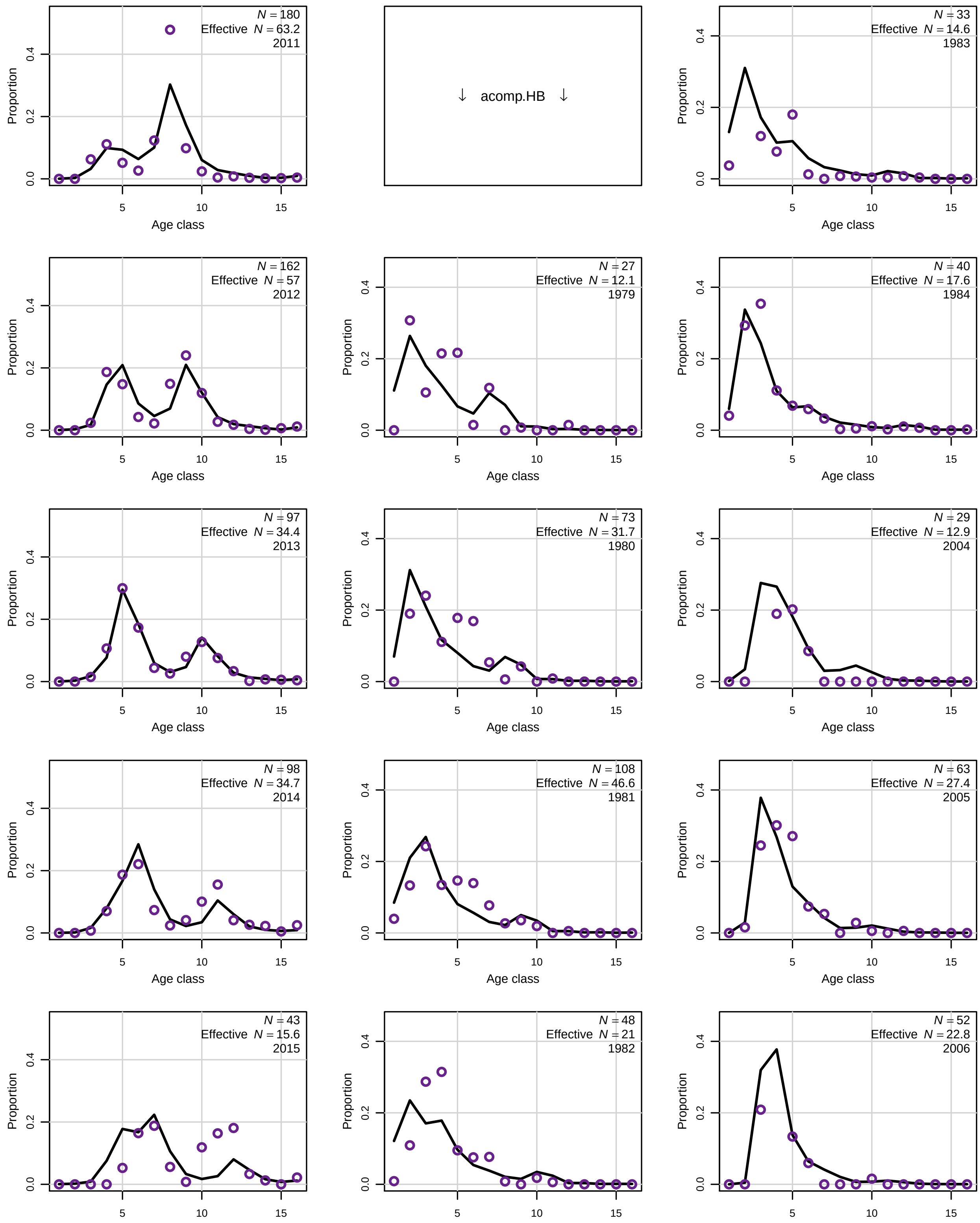


Figure 4. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

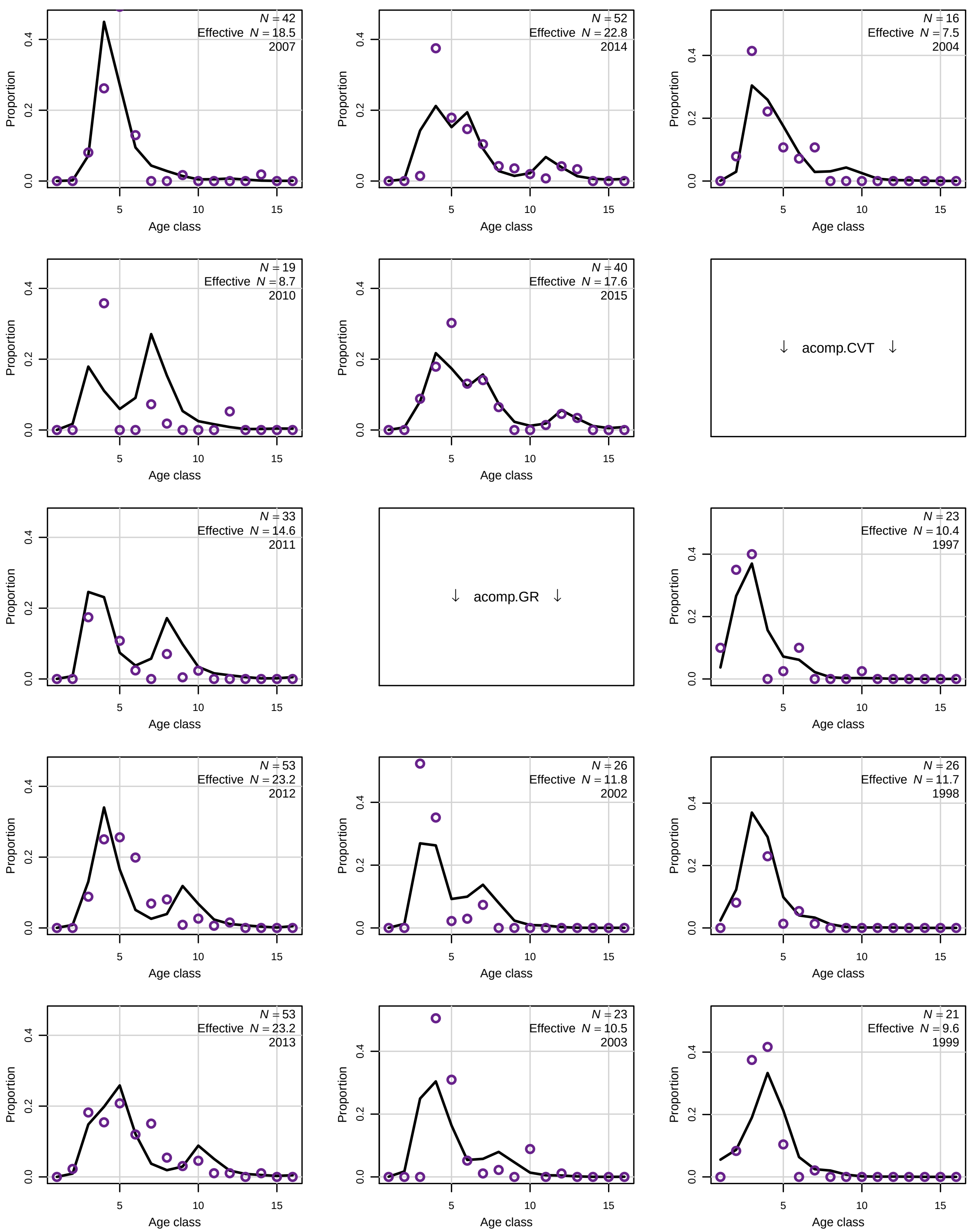


Figure 4. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

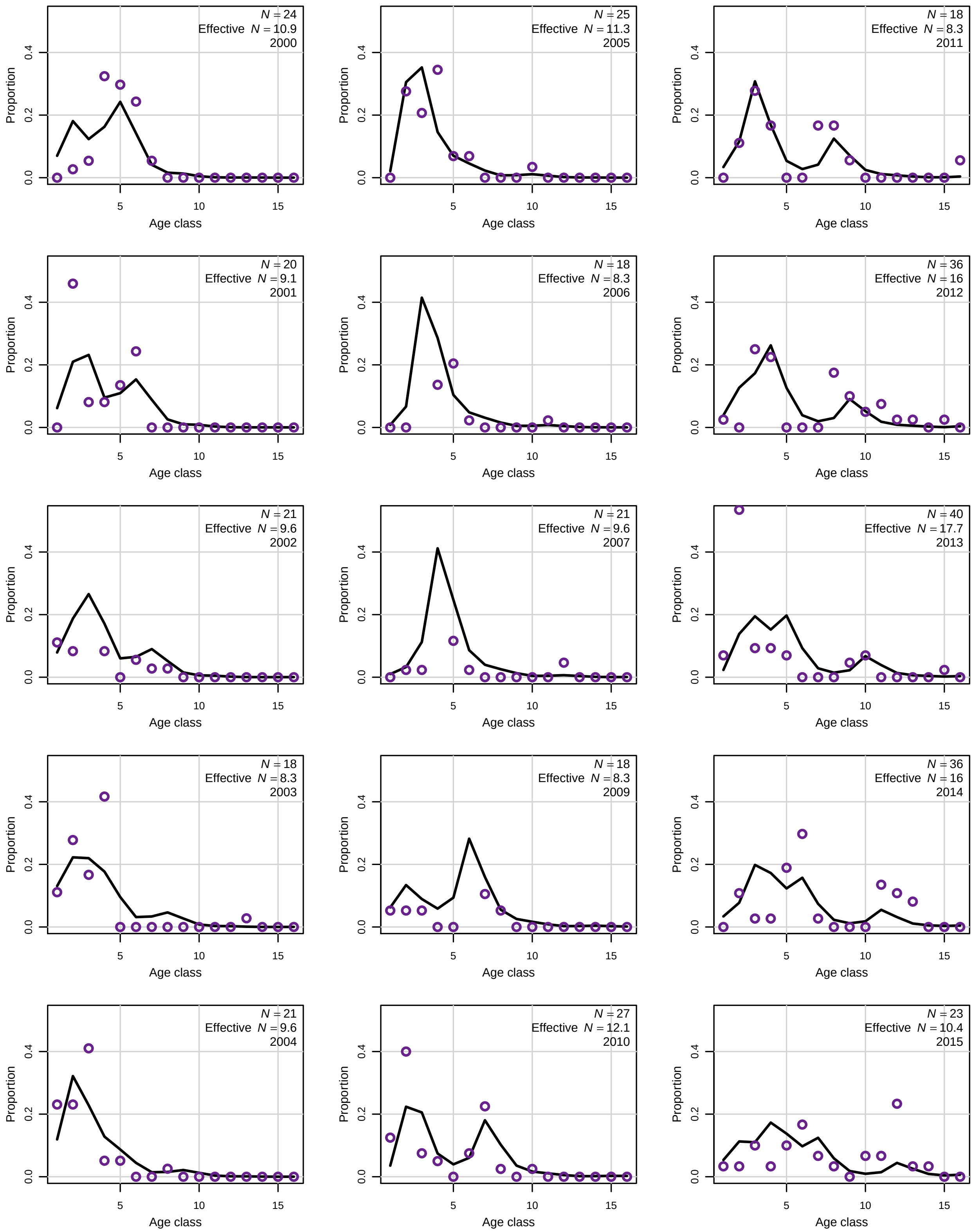


Figure 5. Observed (open circles) and estimated (solid line, circles) commercial lines (handline + longline) landings (1000 lb whole weight). Open and solid circles may be indistinguishable in years with very close fits.

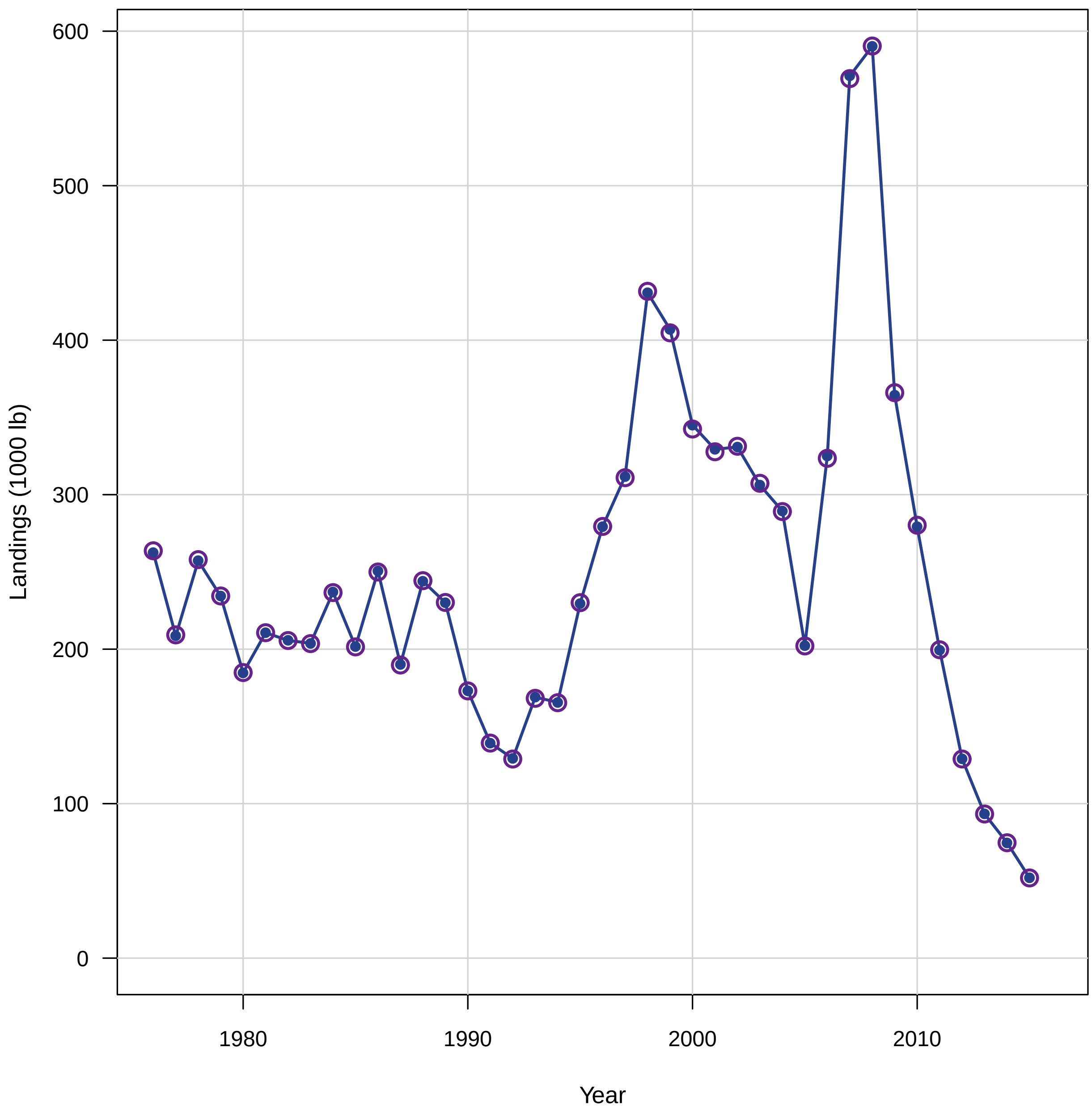


Figure 6. Observed (open circles) and estimated (solid line, circles) commercial other (1000 lb whole weight). Open and solid circles may be indistinguishable in years with very close fits.

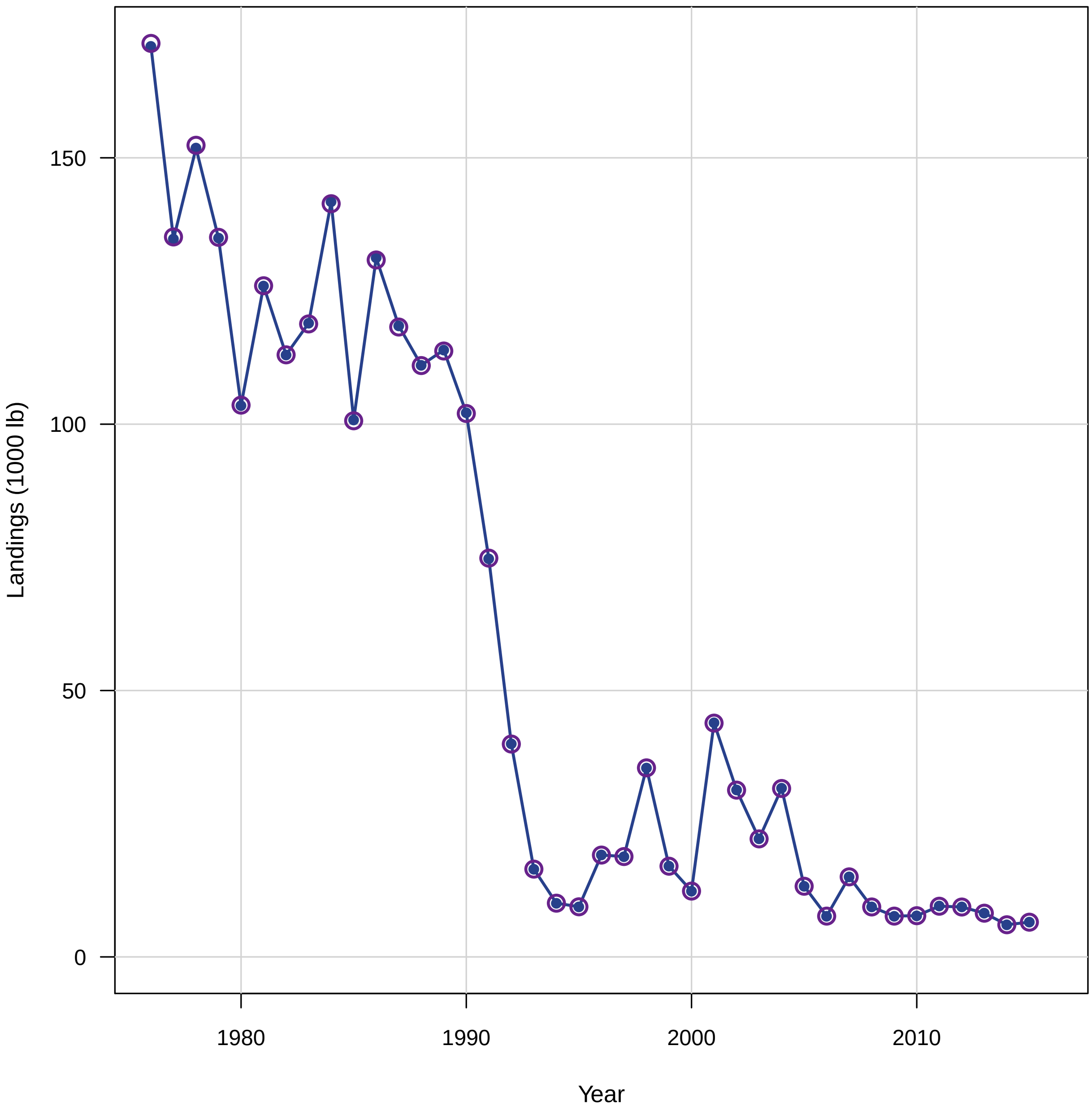


Figure 7. Observed (open circles) and estimated (solid line, circles) headboat landings (1000 fish). Open and solid circles may be indistinguishable in years with very close fits.

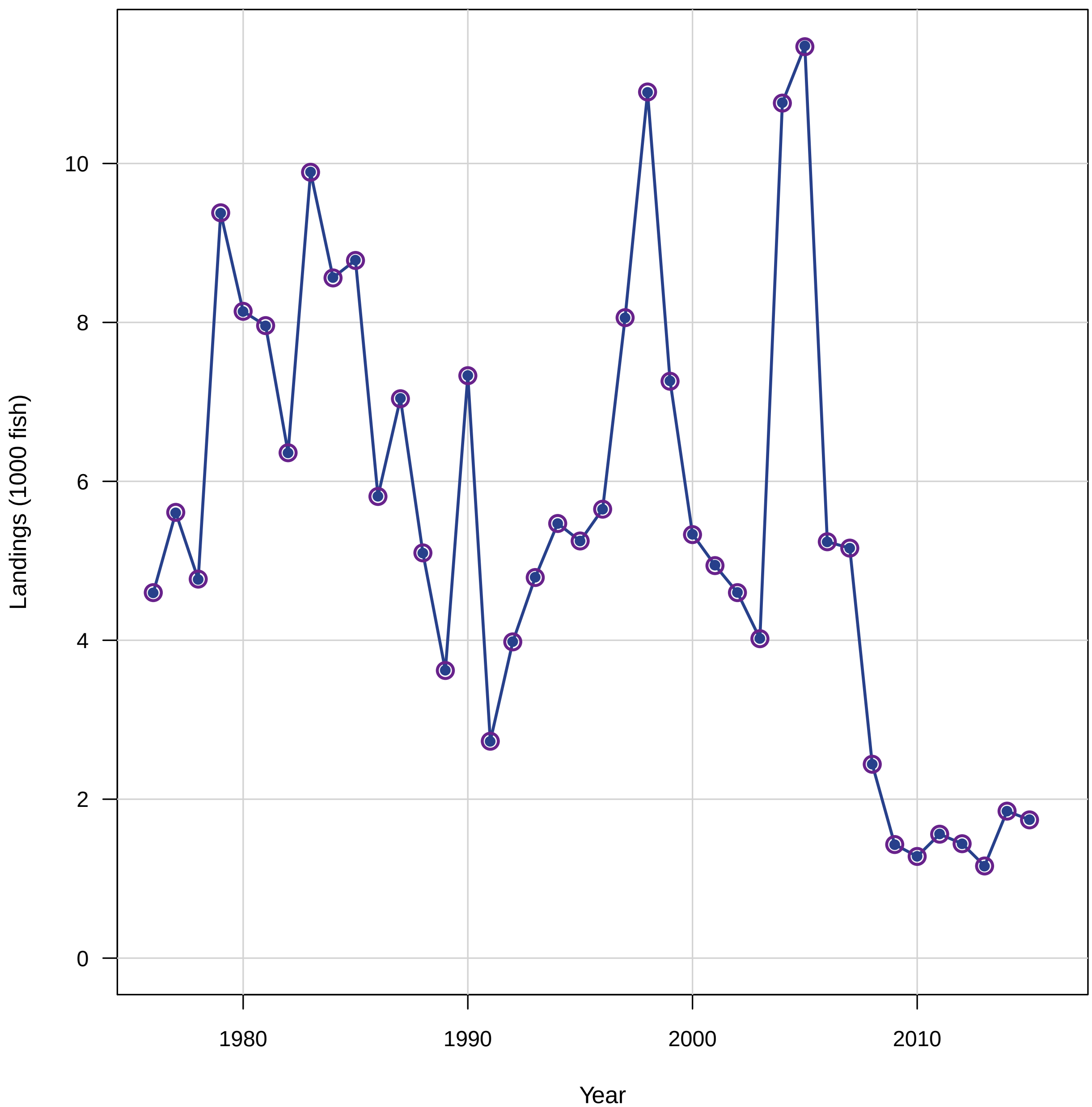


Figure 8. Observed (open circles) and estimated (solid line, circles) general recreational landings (1000 fish). Open and solid circles may be indistinguishable in years with very close fits.

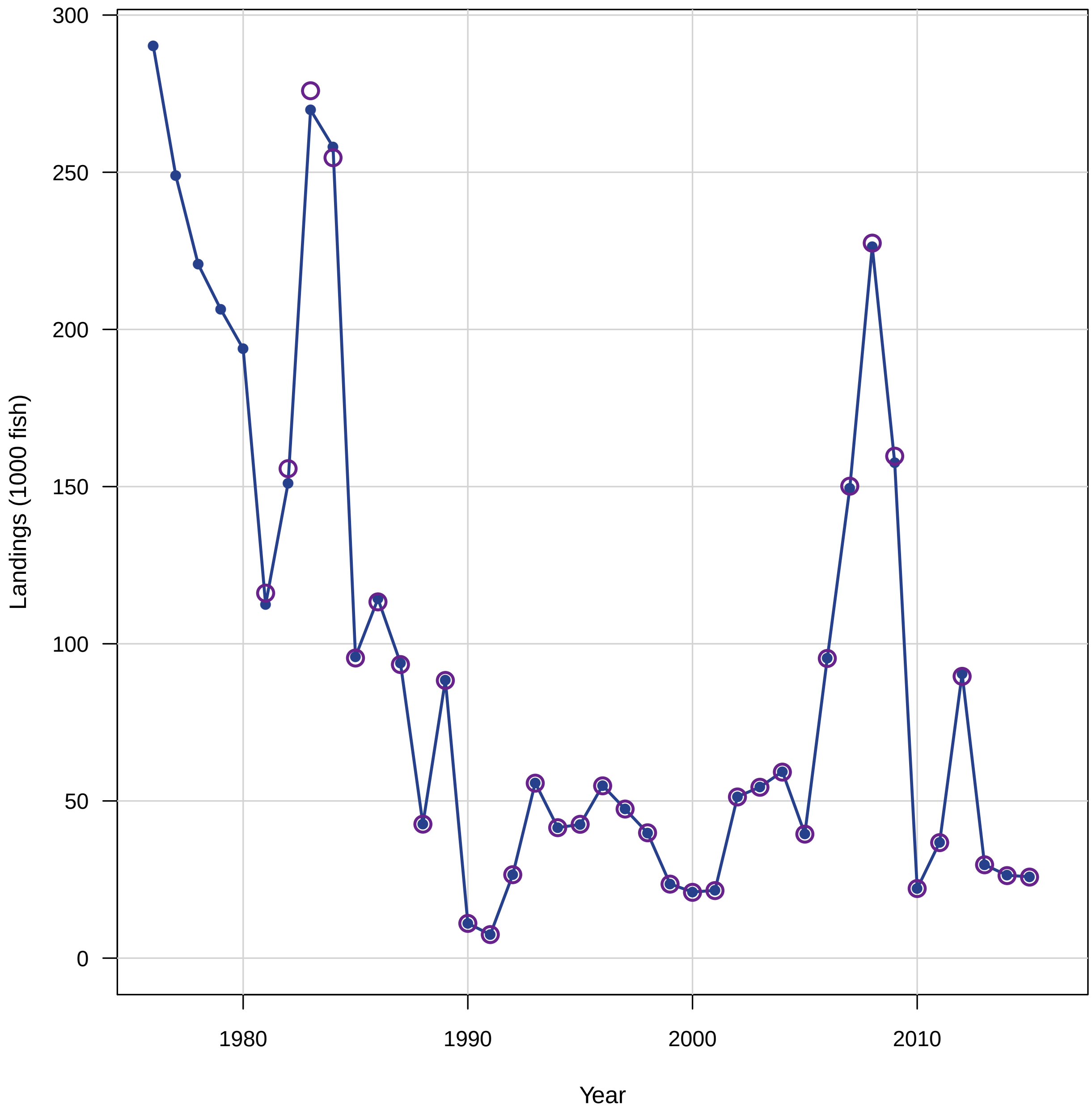


Figure 9. Observed (open circles) and estimated (solid line, circles) commercial lines discard mortalities (1000 dead fish). Open and solid circles may be indistinguishable in years with very close fits.

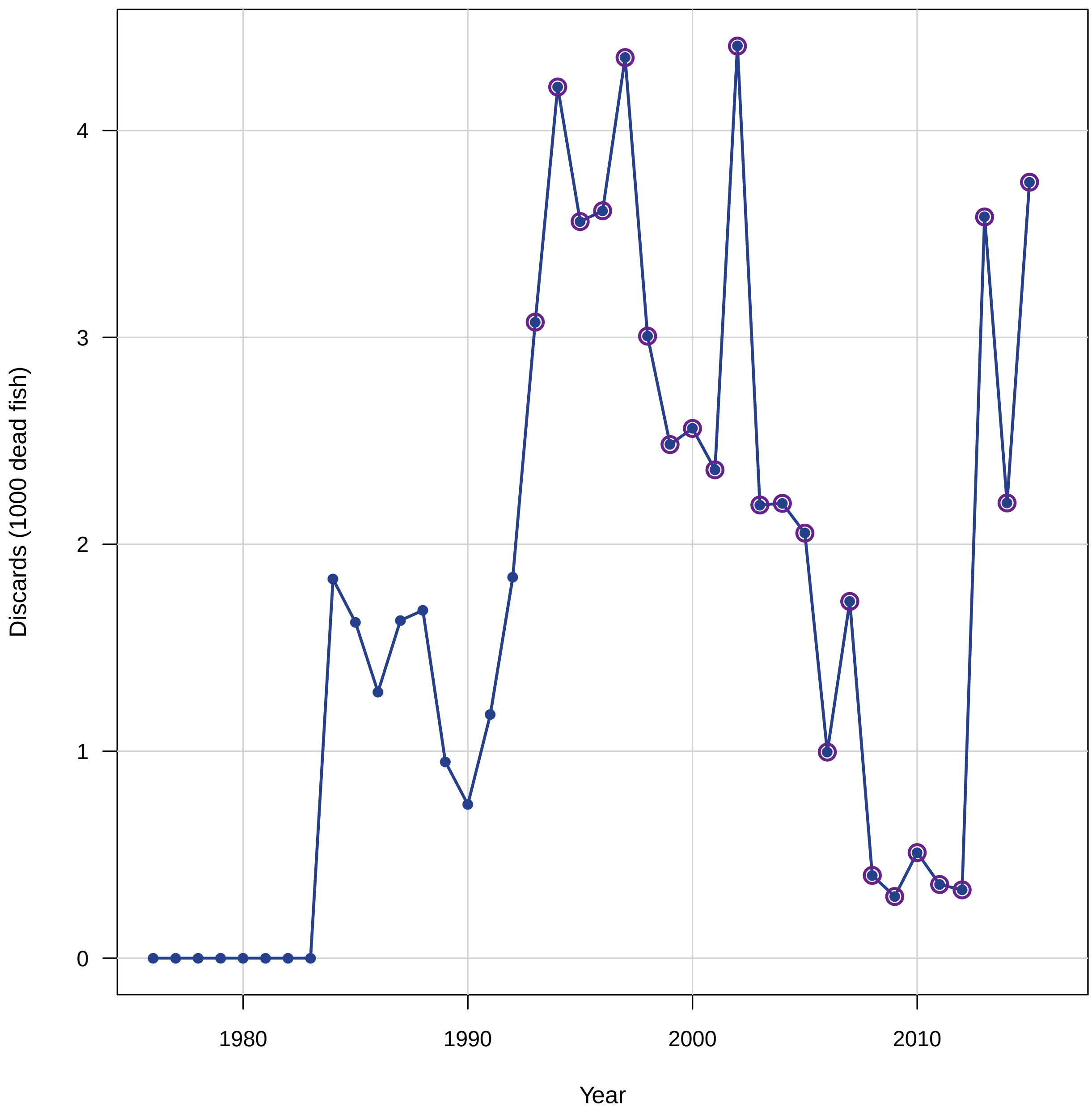


Figure 10. Observed (open circles) and estimated (solid line, circles) headboat discard mortalities (1000 dead fish). Open and solid circles may be indistinguishable in years with very close fits.

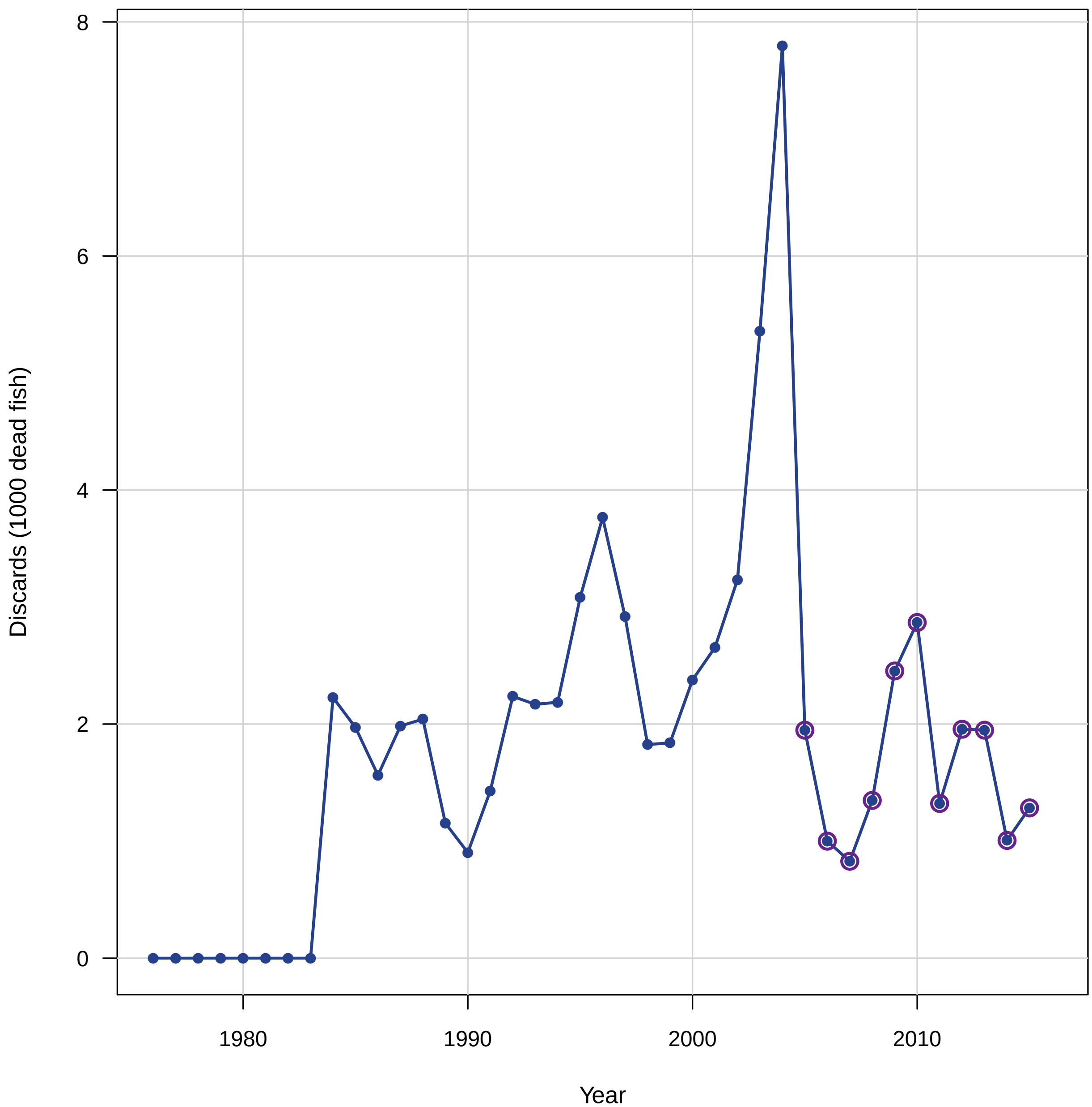


Figure 11. Observed (open circles) and estimated (solid line, circles) general recreational discard mortalities (1000 dead fish). Open and solid circles may be indistinguishable in years with very close fits.

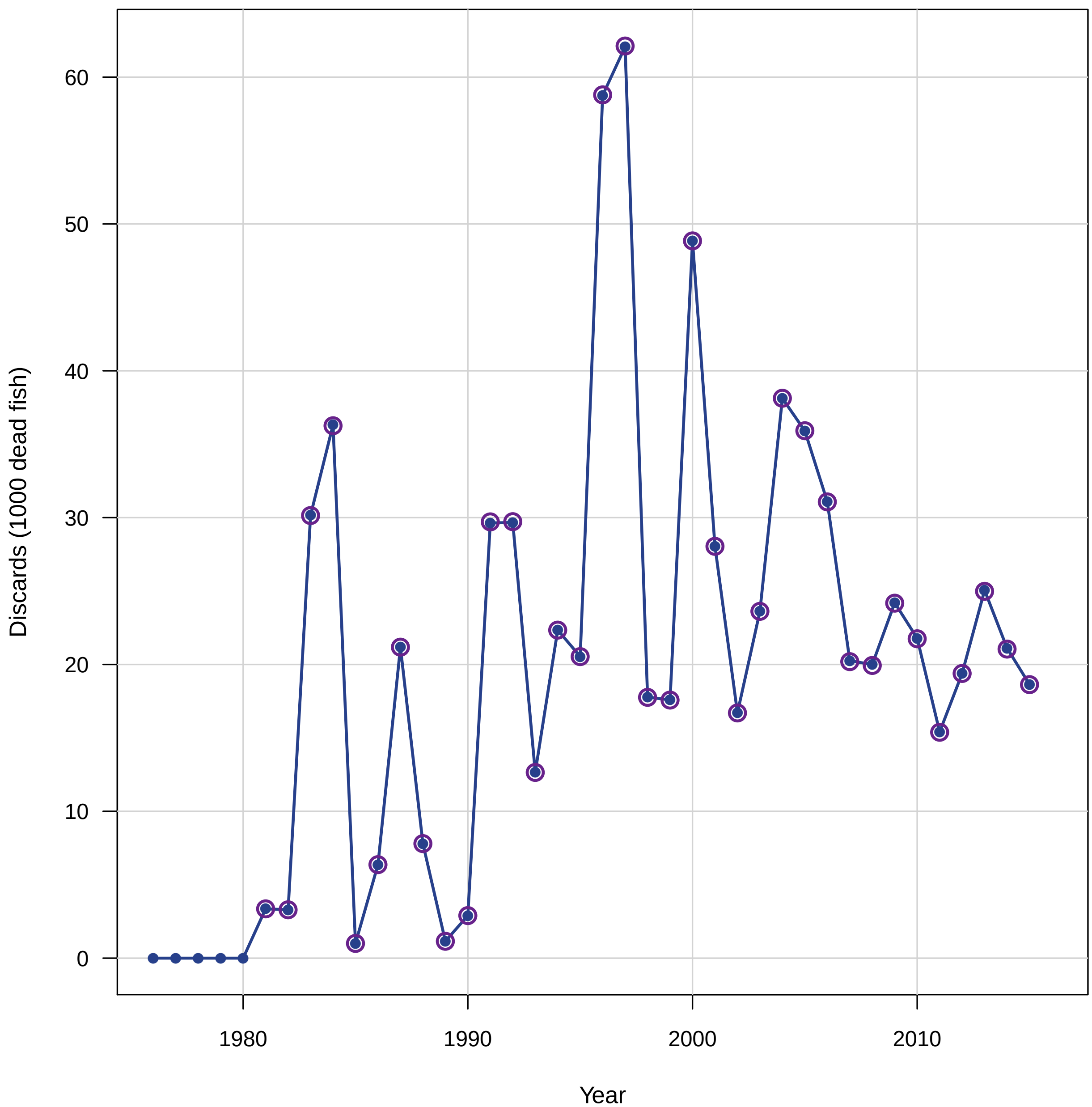


Figure 12. Observed (open circles) and estimated (solid line, circles) index of abundance from the SERFS chevron trap/video survey.

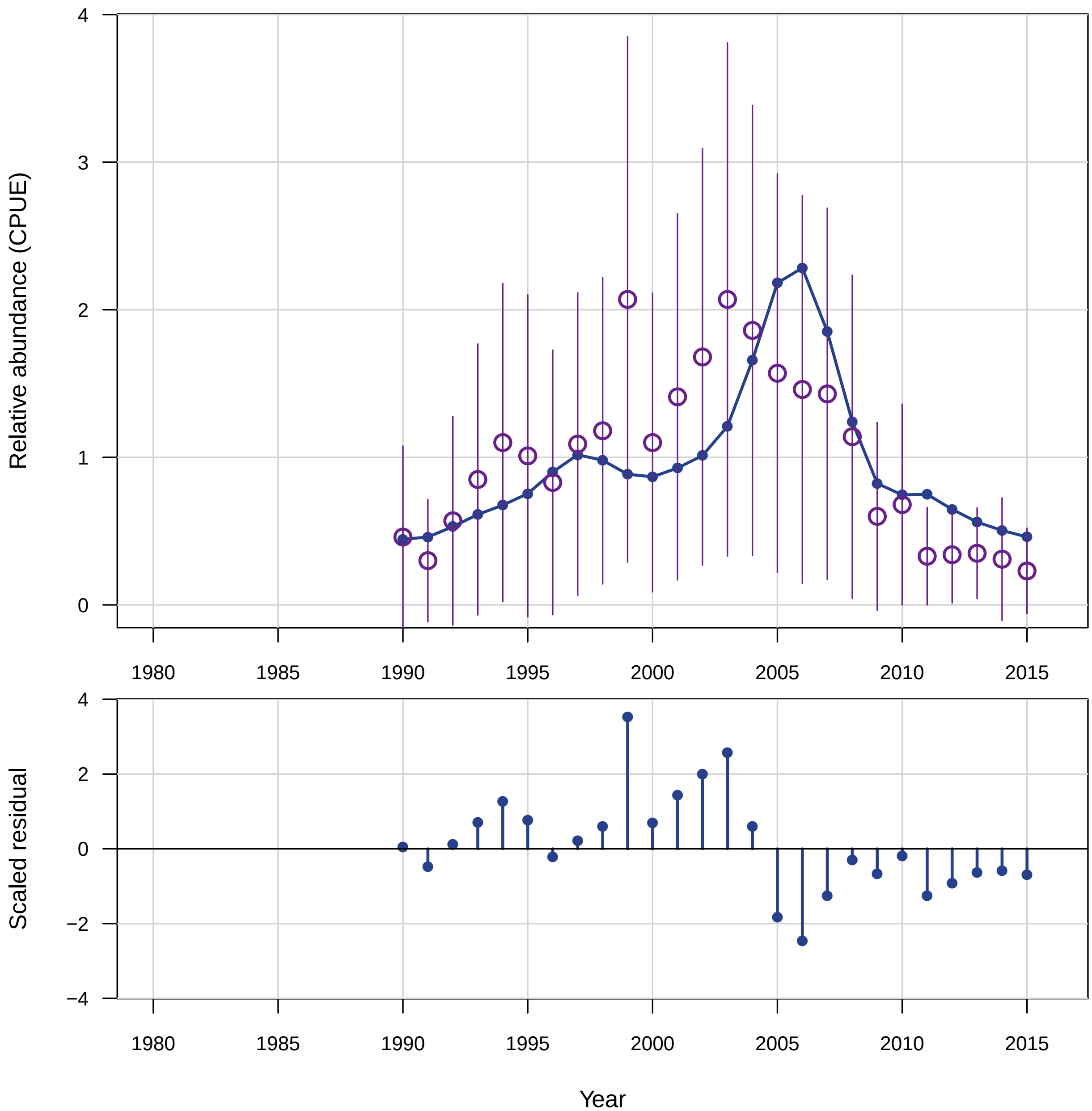


Figure 13. Observed (open circles) and estimated (solid line, circles) index of abundance from the commercial handline fleet.

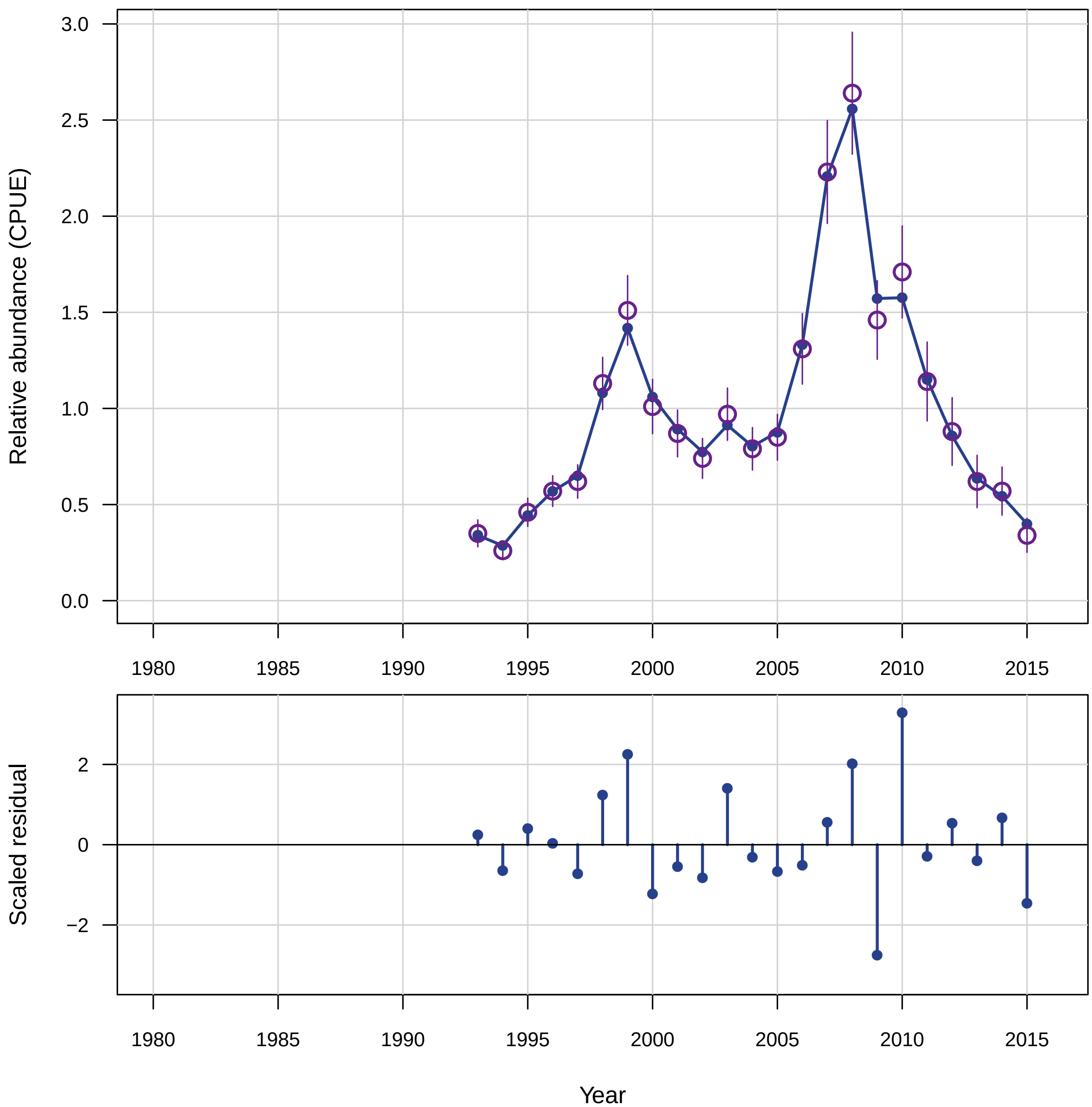


Figure 14. Observed (open circles) and estimated (solid line, circles) abundance from the recreational headboat fleet.

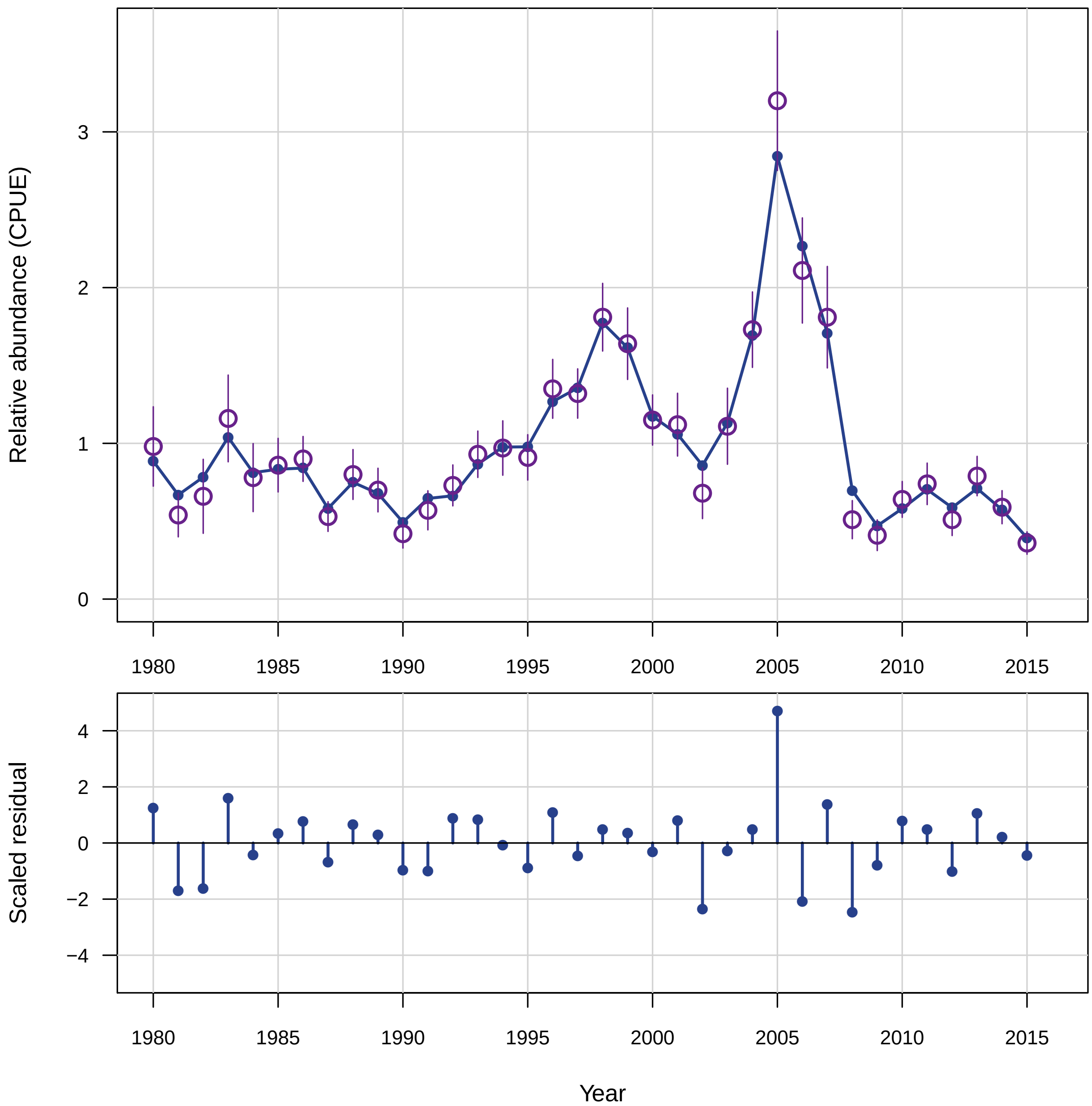


Figure 15. Estimated abundance at age at start of year.

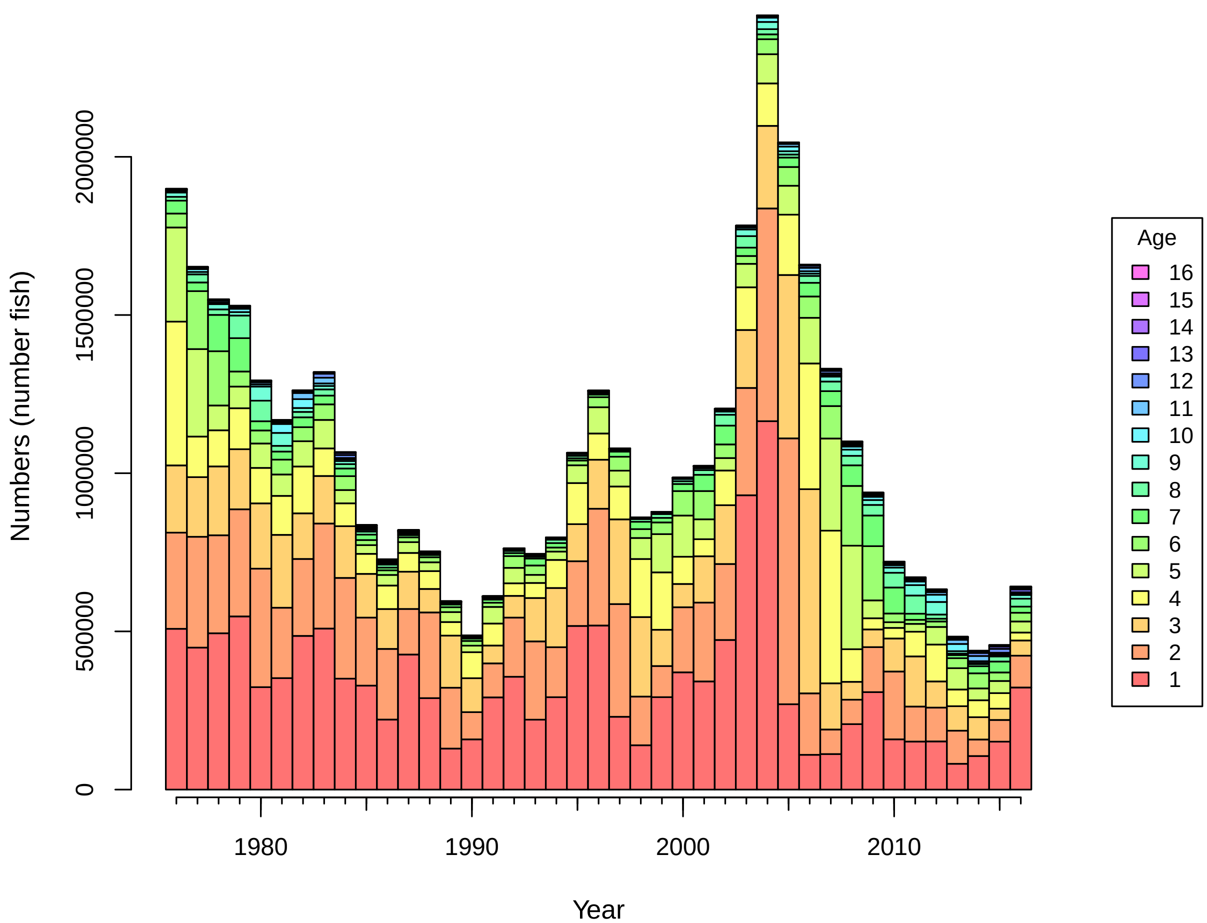


Figure 16. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates R_{MSY}. Bottom panel: log recruitment residuals. The residual in 2016 was not estimated, as recruitment in that year is uninformed by any data on year-class strength. Thus, the 2016 value shown in the top panel is that predicted from the spawner-recruit curve without deviation.

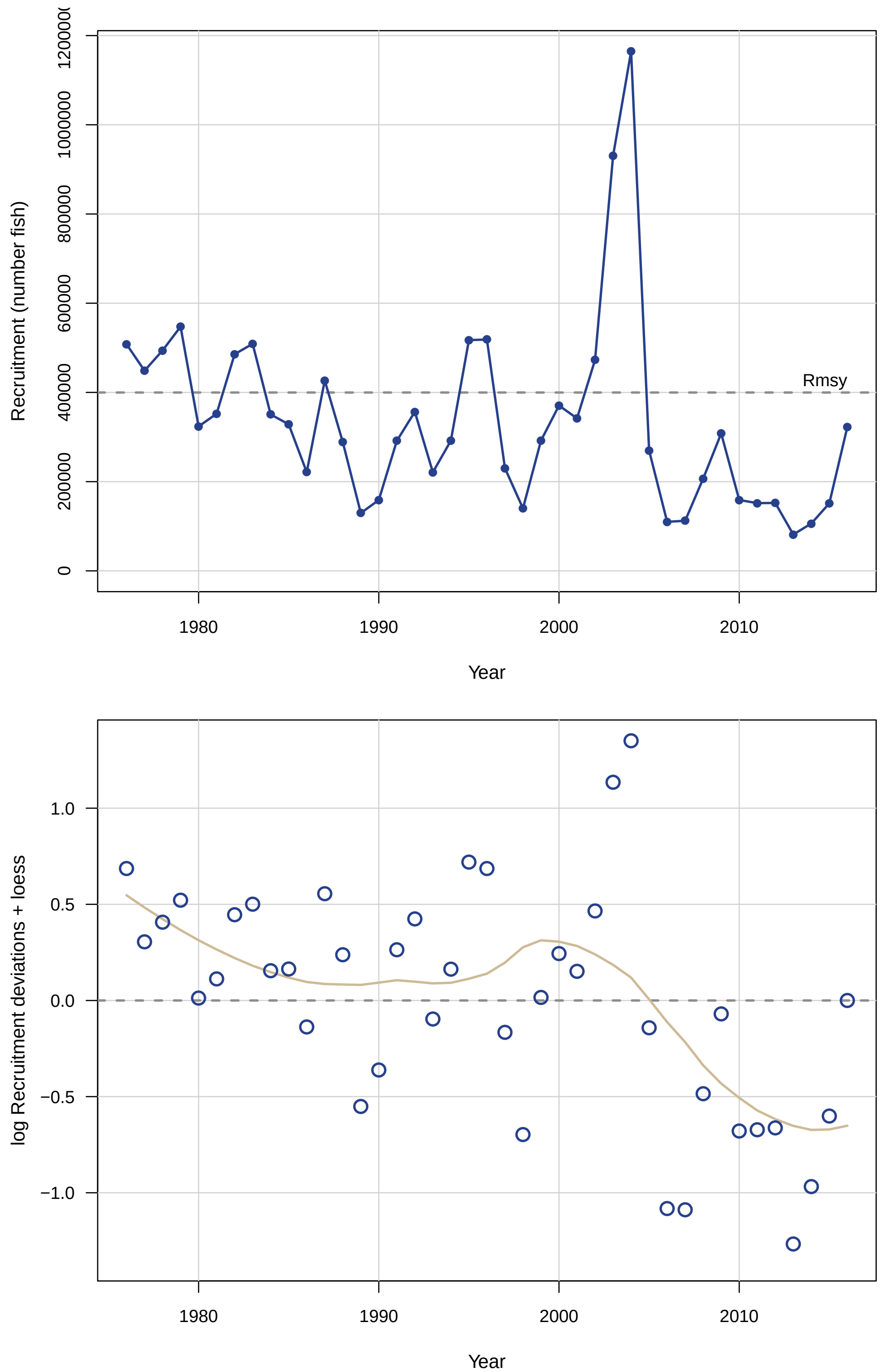


Figure 17. Estimated biomass at age at start of year.

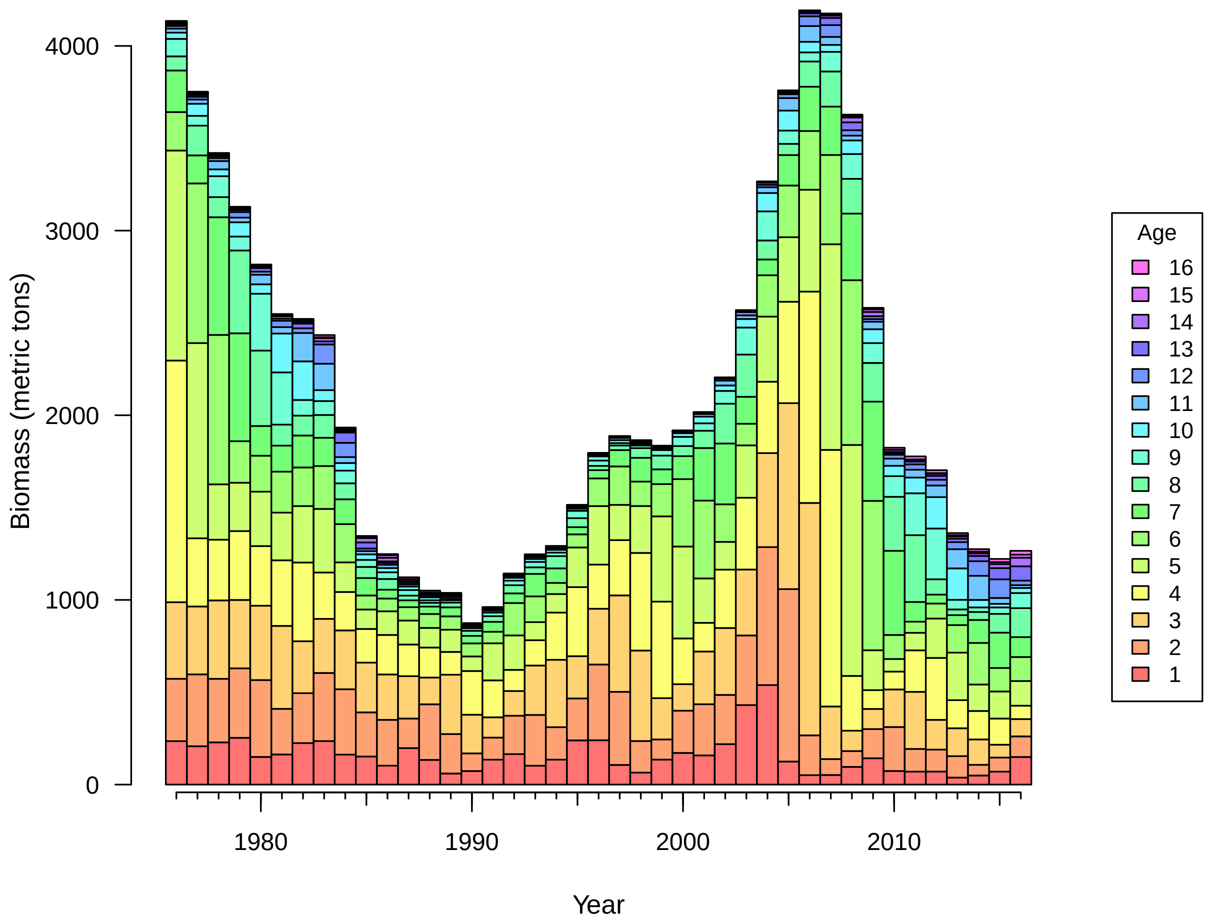


Figure 18. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates B_{MSY}. *Bottom panel: Estimated spawning stock (metric tons) at time of peak spawning.*

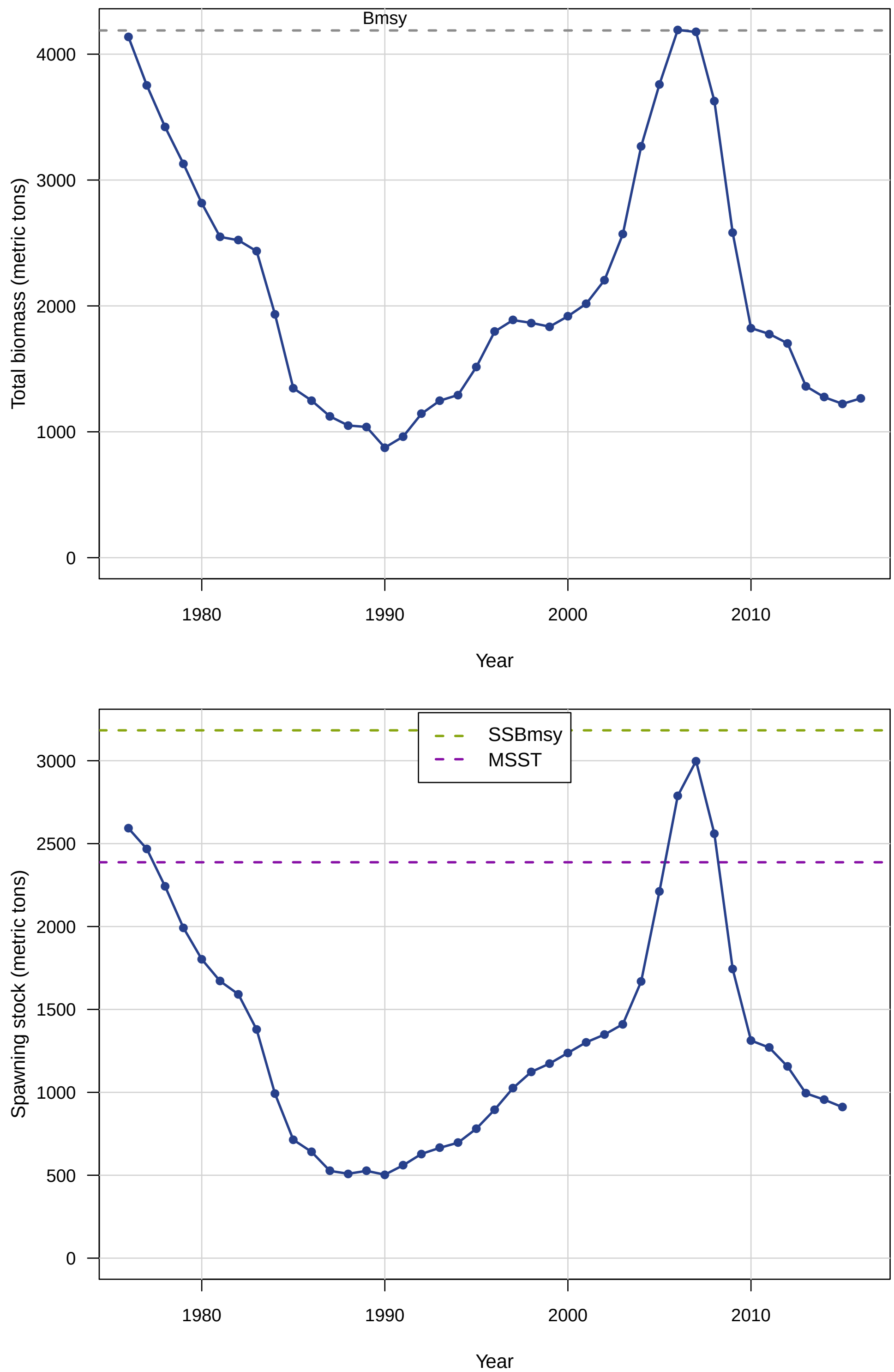


Figure 19. Selectivity (time-invariant) of SERFS chevron trap/video gear.

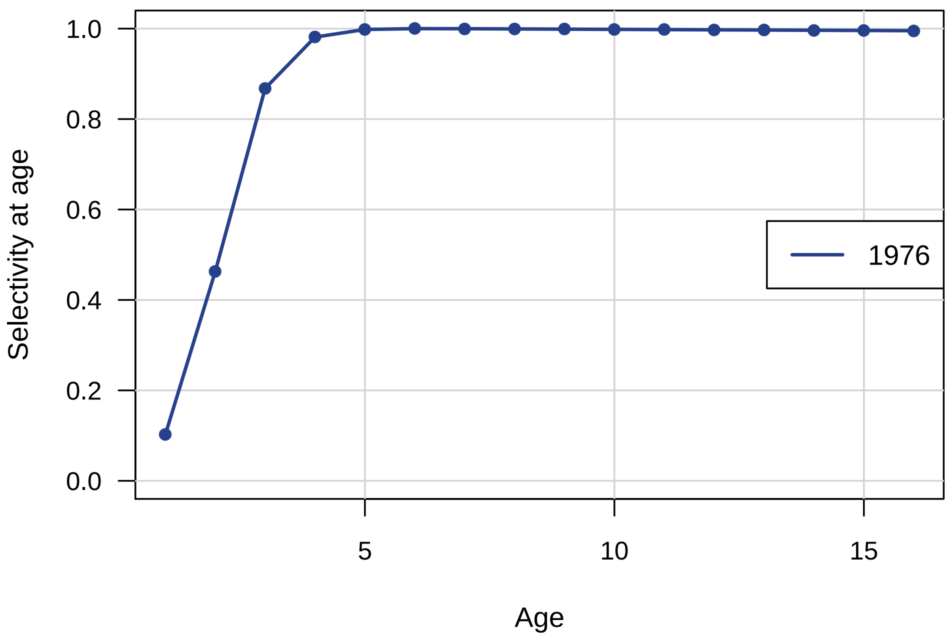


Figure 20. Estimated selectivities of commercial fleets. Years indicated on panels signify the first year of a time block. Top panel: commercial lines. Bottom panel: commercial other.

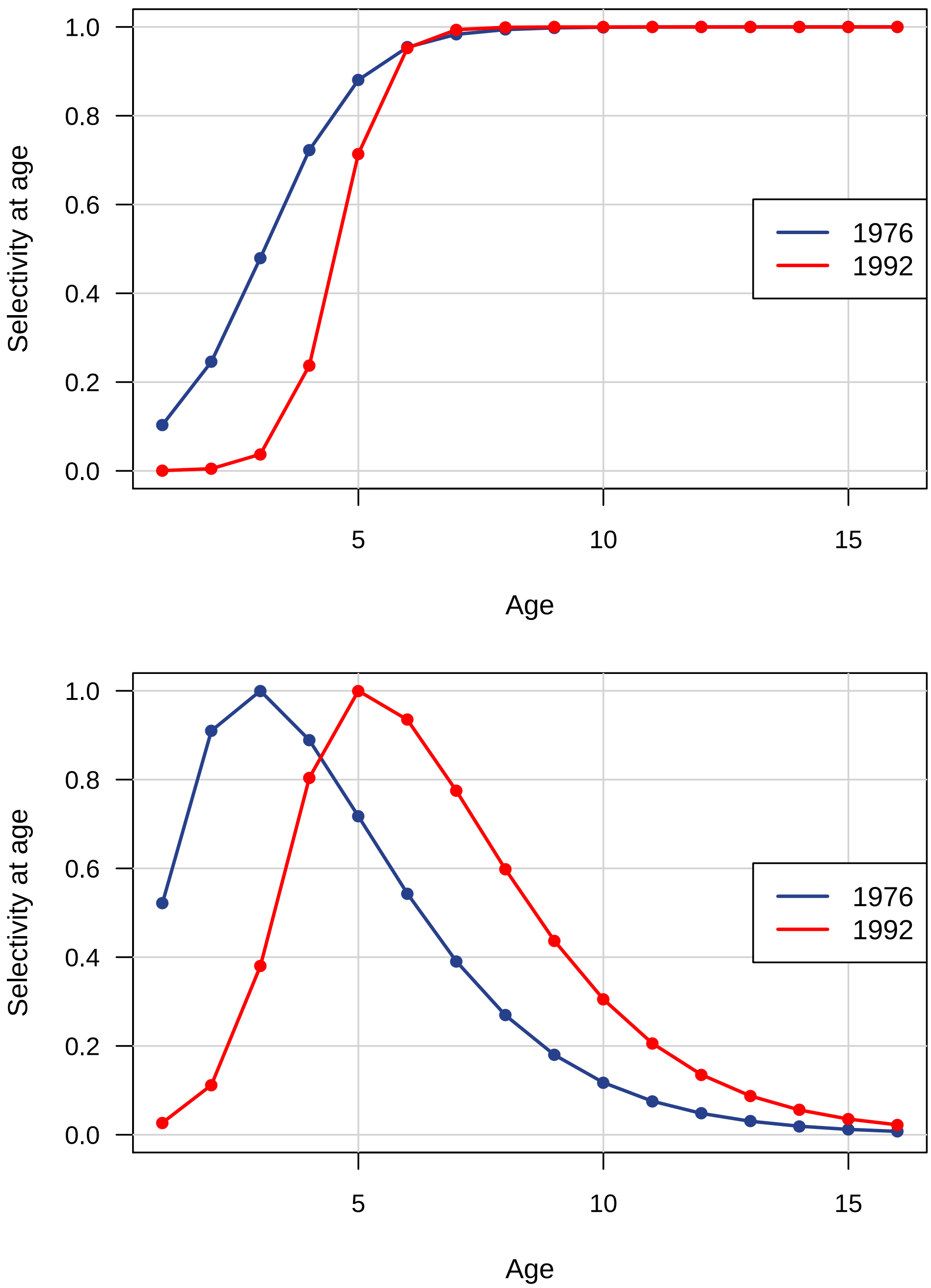
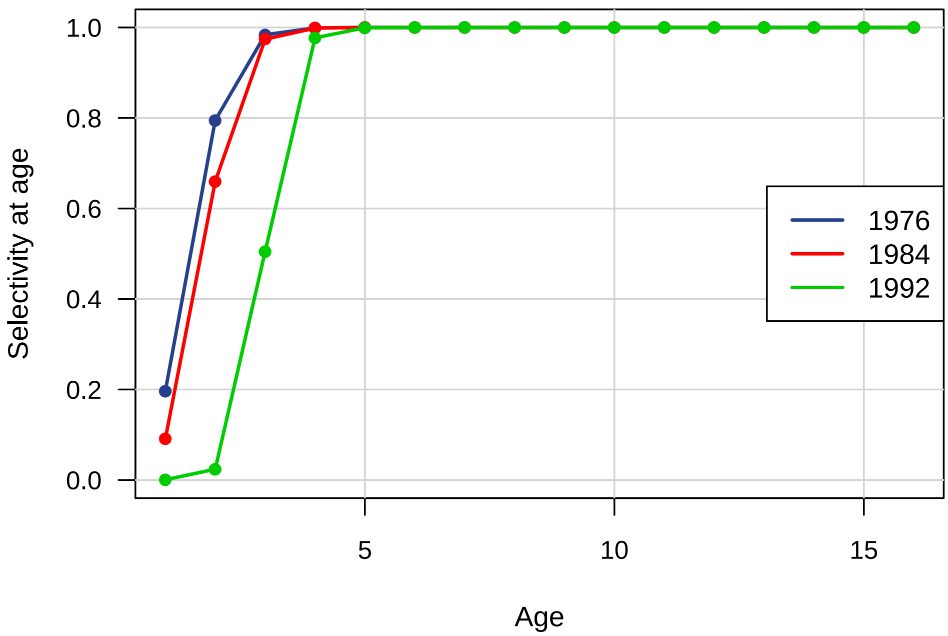


Figure 21. Estimated selectivities of headboat and general recreational fleets. Years indicated on panels signify the first year of a time block. Top panel: headboat. Bottom panel: general recreational.



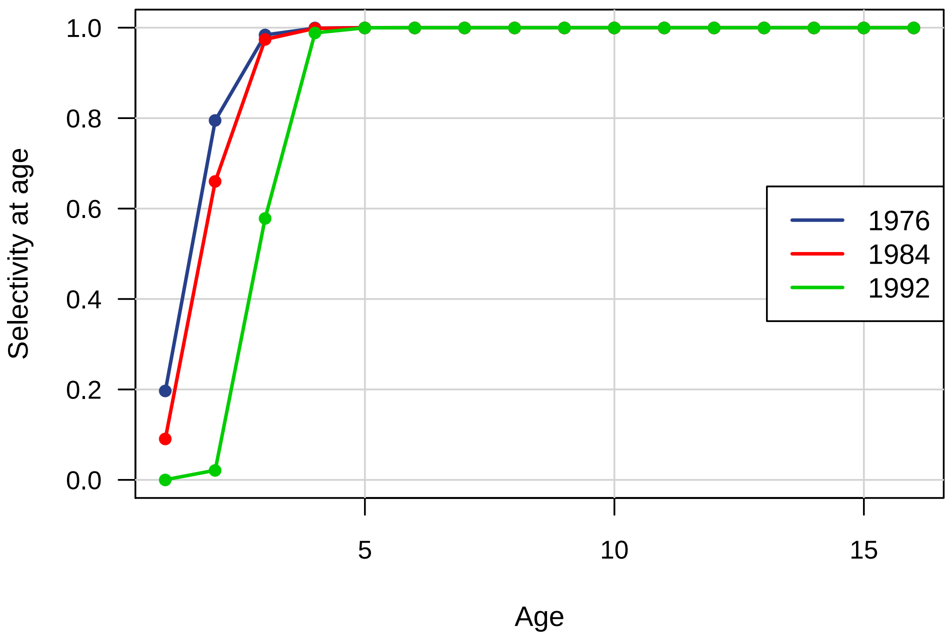


Figure 22. Estimated selectivity of discard mortalities from commercial lines, headboat, and general recreational. Years indicated on panels signify the first year of a time block.

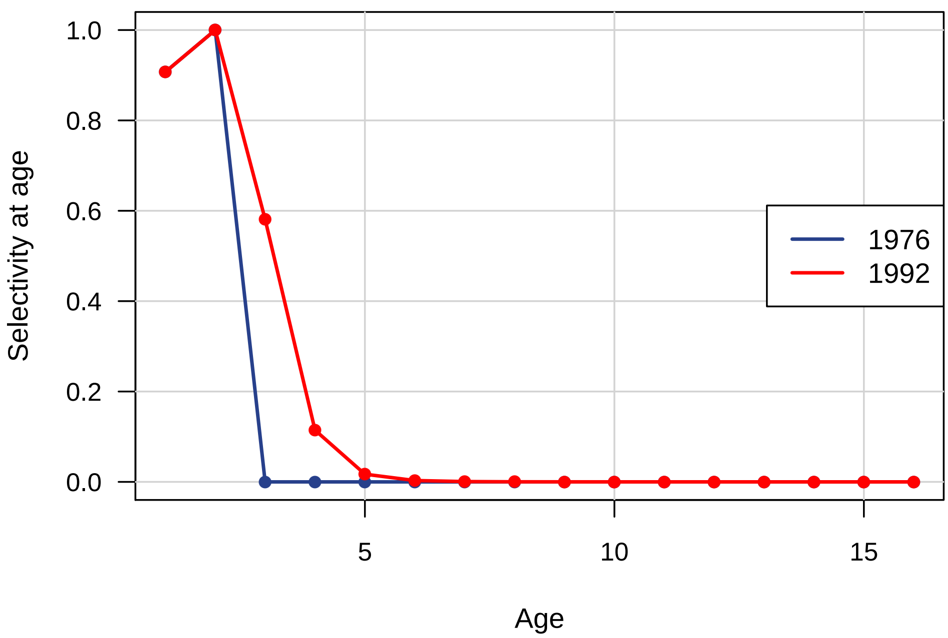


Figure 23. Average selectivities from the terminal assessment years, weighted by geometric mean Fs from the last three assessment years, and used in computation of benchmarks and projections. Top panel: average selectivity applied to landings. Middle panel: average selectivity applied to discard mortalities. Bottom panel: total average selectivity.

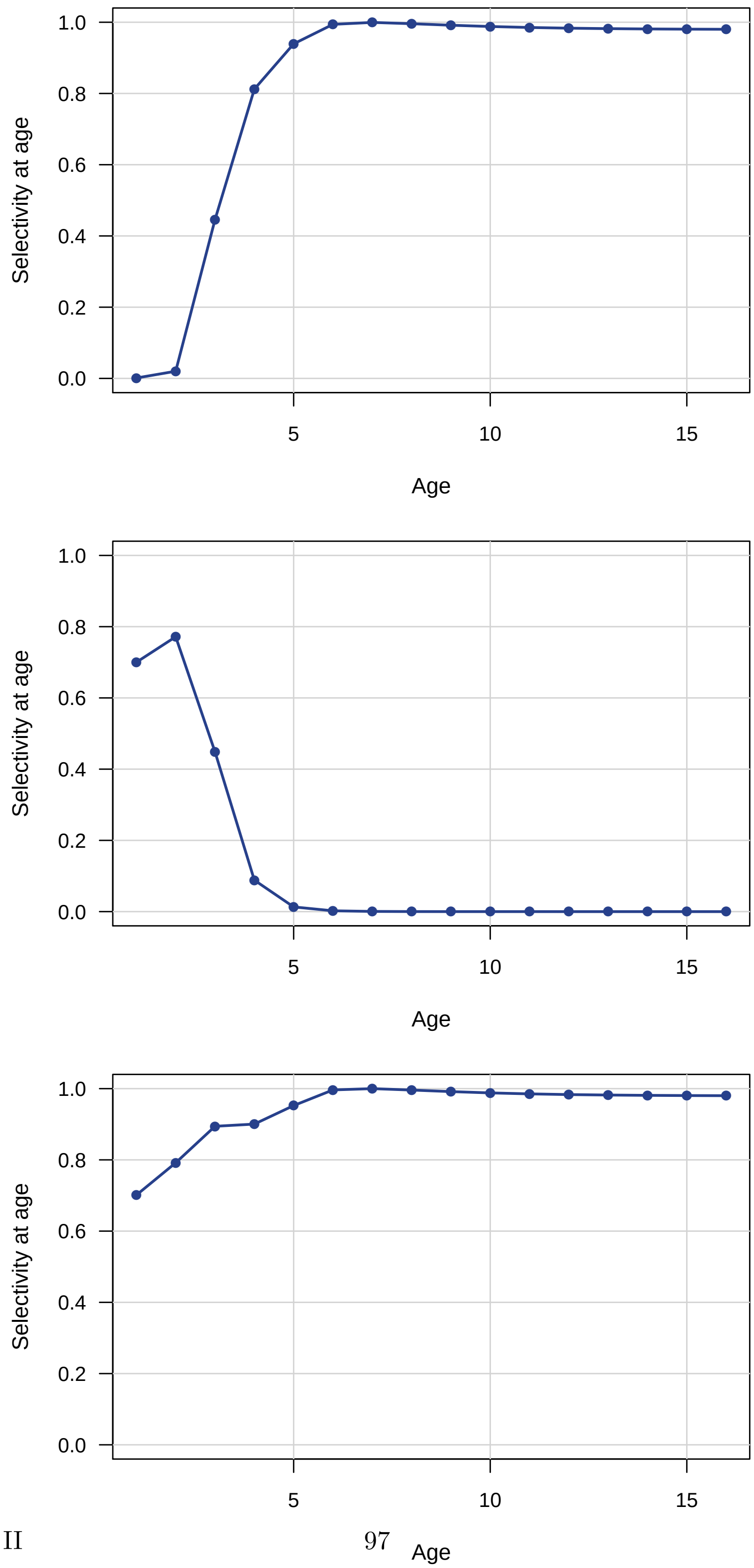


Figure 24. Estimated fully selected fishing mortality rate (per year) by fleet. cH refers to commercial lines, cO to commercial other, HB to headboat, and GR to general recreational. D refers to discard mortalities.

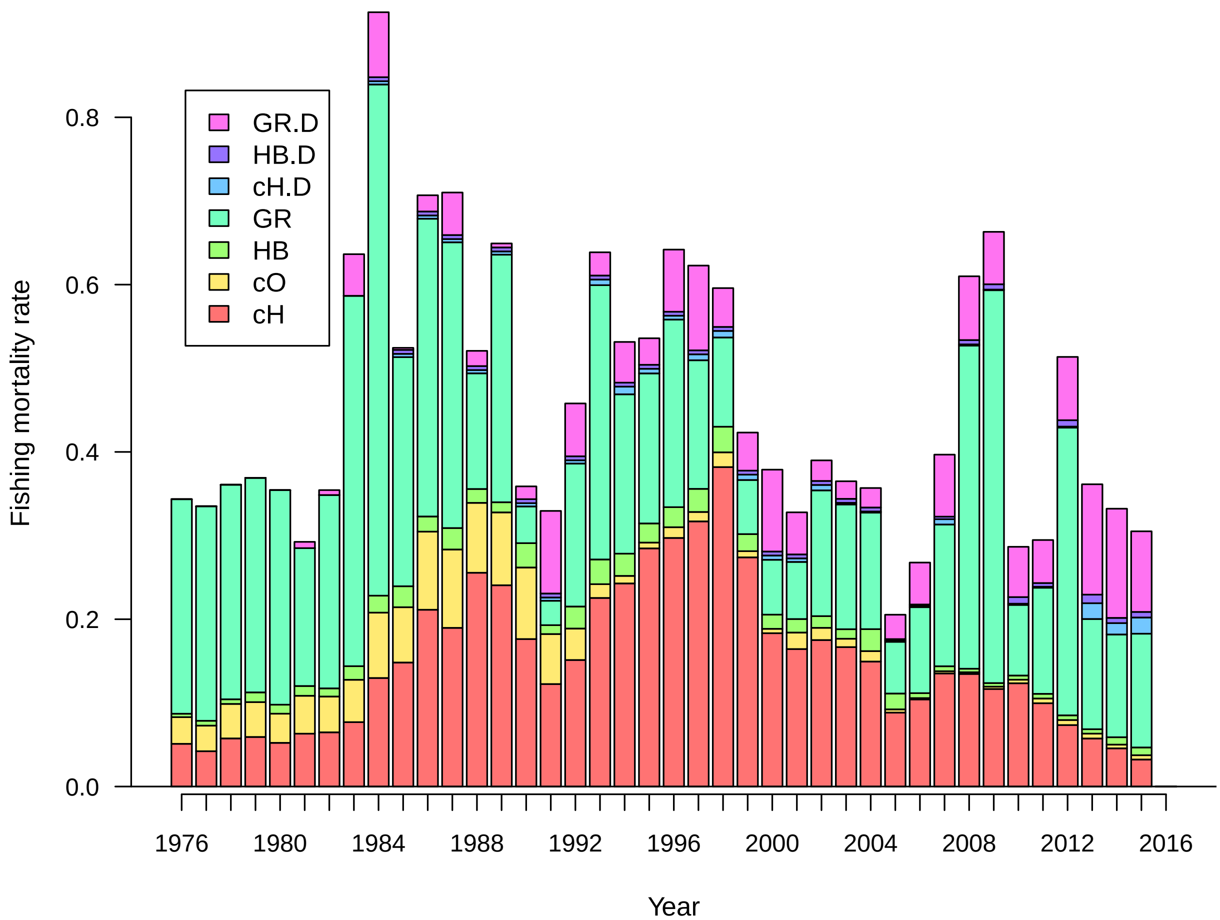


Figure 25. Estimated landings in numbers by fleet from the catch-age model. cH refers to commercial lines, cO to commercial other, HB to headboat, and GR to general recreational.

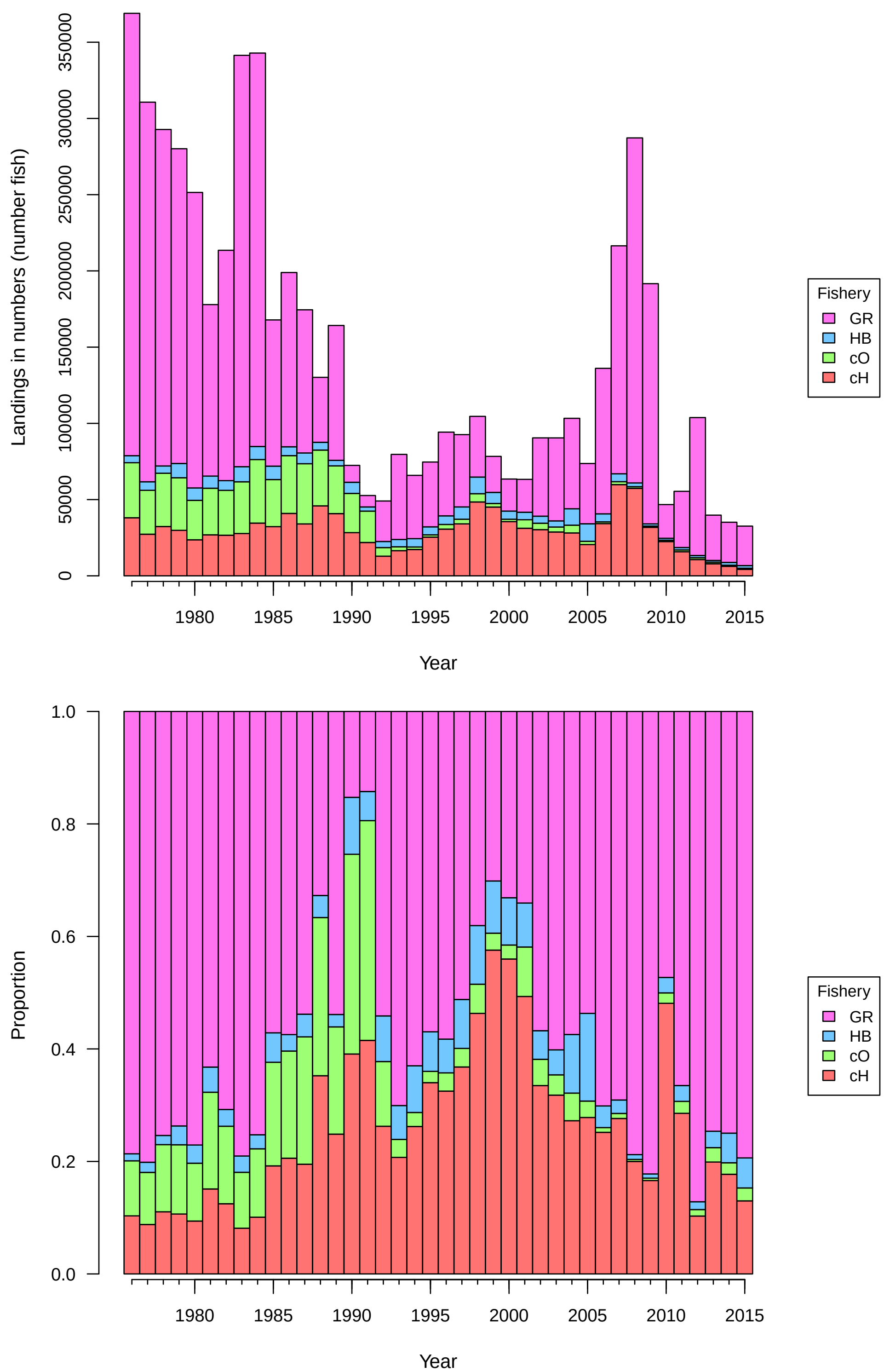


Figure 26. Estimated landings in whole weight by fleet from the catch-age model. cH refers to commercial lines, cO to commercial other, HB to headboat, and GR to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of MSY.

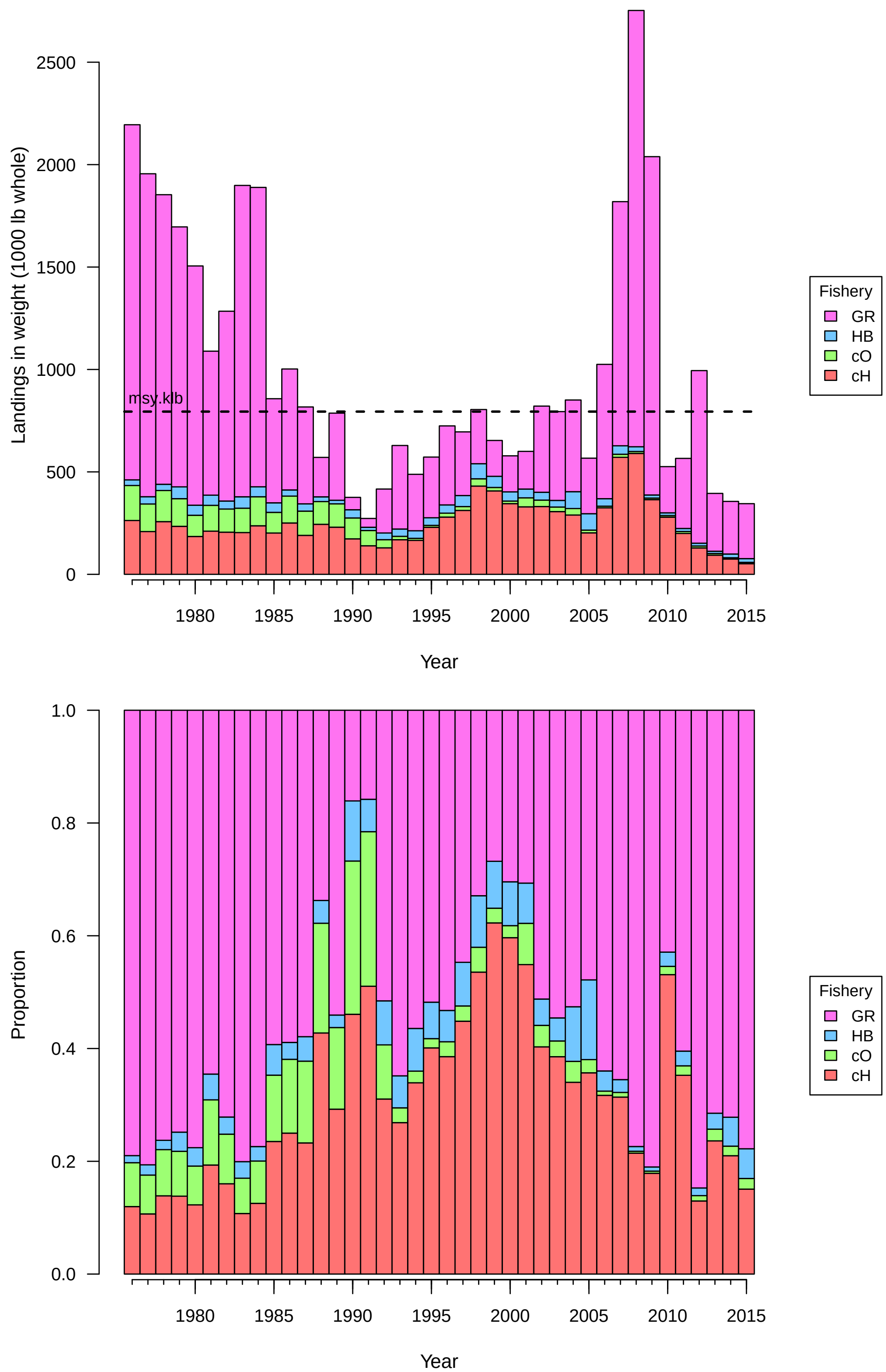


Figure 27. Estimated discard mortalities in numbers by fleet from the catch-age model. cH refers to commercial lines, HB to headboat, and GR to general recreational.

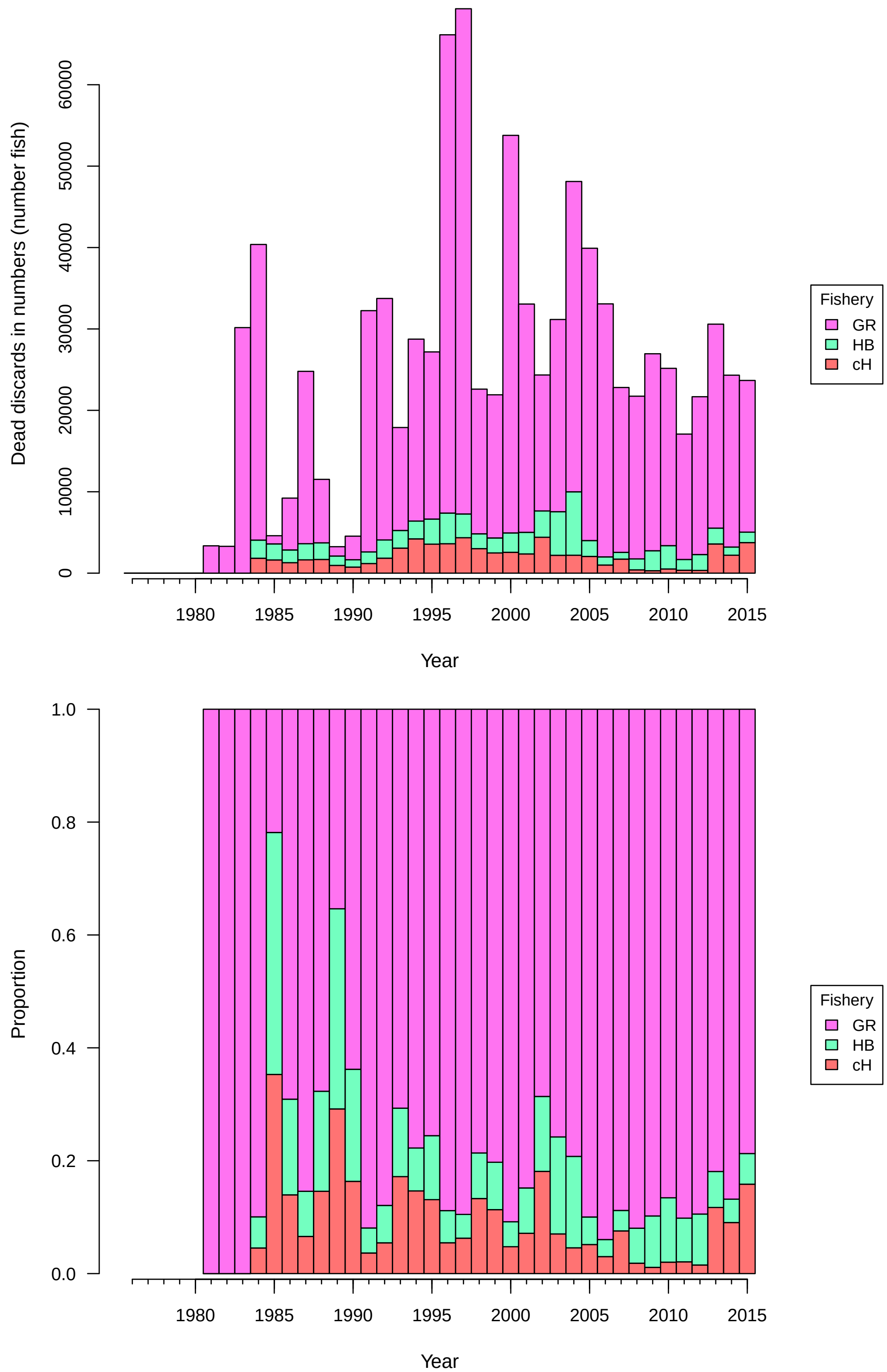


Figure 28. Estimated discard mortalities in weight by fleet from the catch-age model. cH refers to commercial lines, HB to headboat, and GR to general recreational.

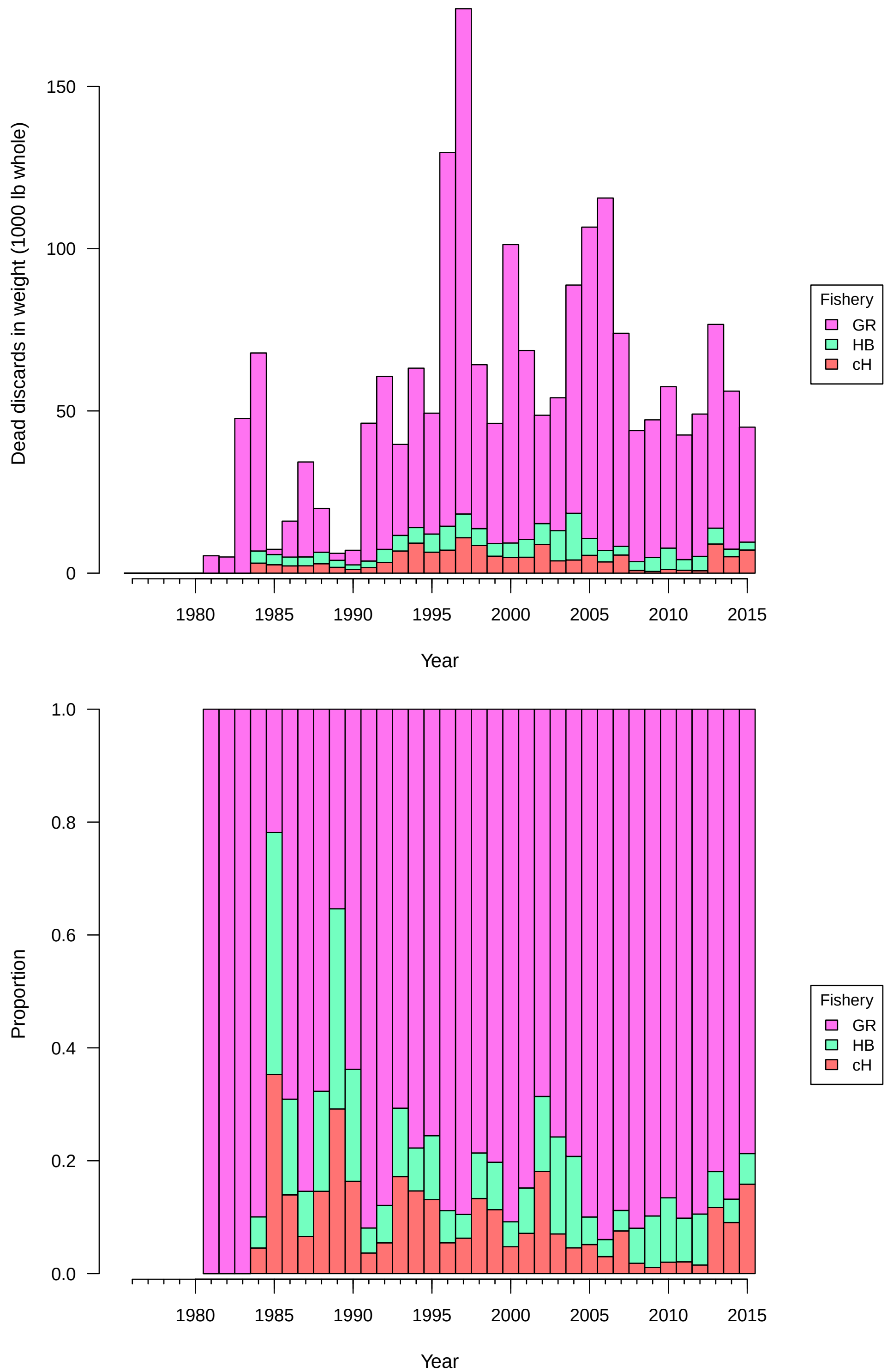


Figure 29. Top panel: Beverton–Holt spawner-recruit curves, with and without lognormal bias correction. The expected (upper) curve was used for computing management benchmarks. Bottom panel: log of recruits (number age-1 fish) per spawner as a function of spawners.

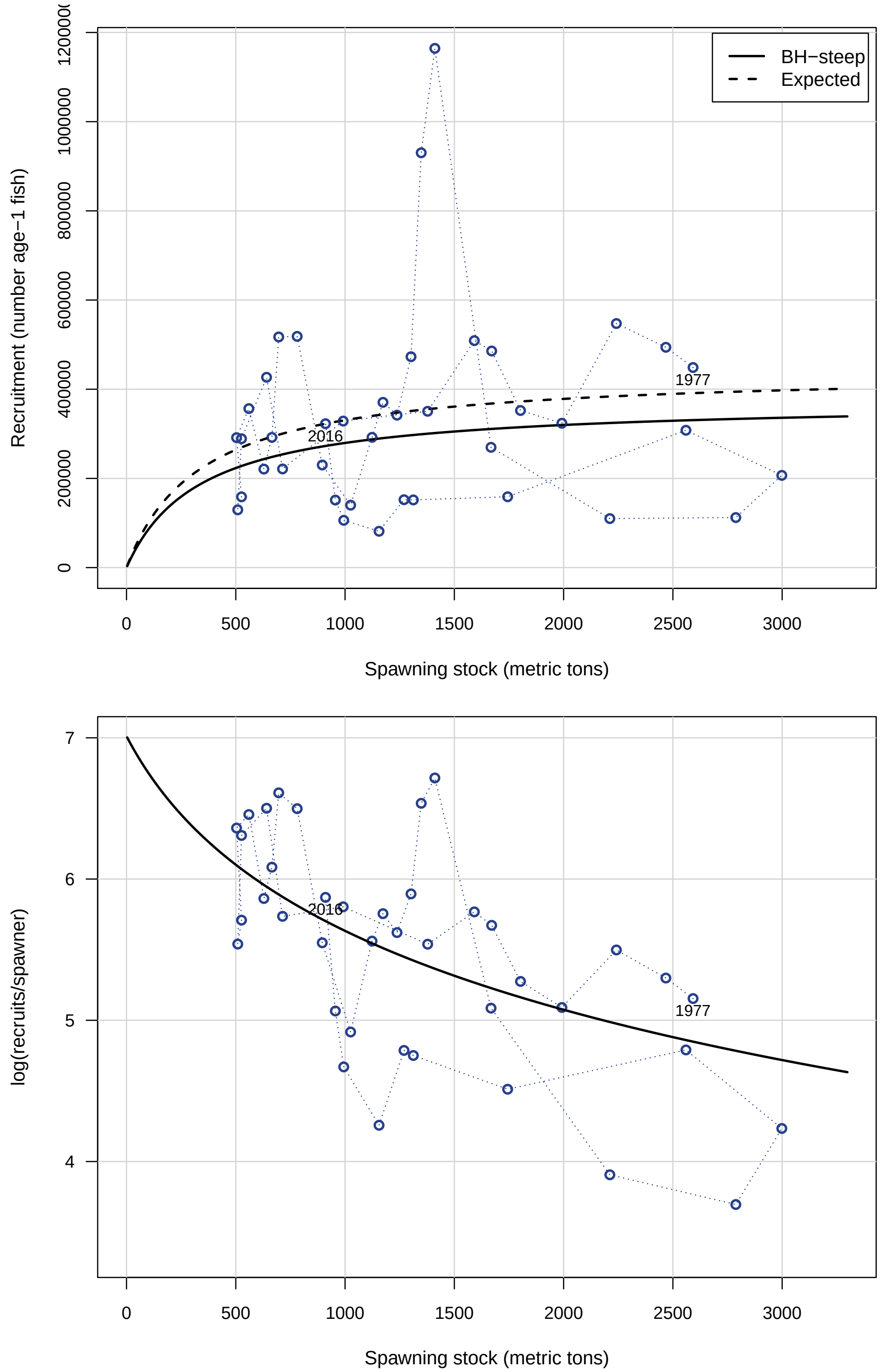


Figure 30. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-1 fish), steepness, unfished spawners per recruit, and standard deviation of recruitment residuals in log space. Solid vertical lines represent point estimates or values from the base run of the Beaufort Assessment Model; dashed vertical lines represent medians from the MCB runs.

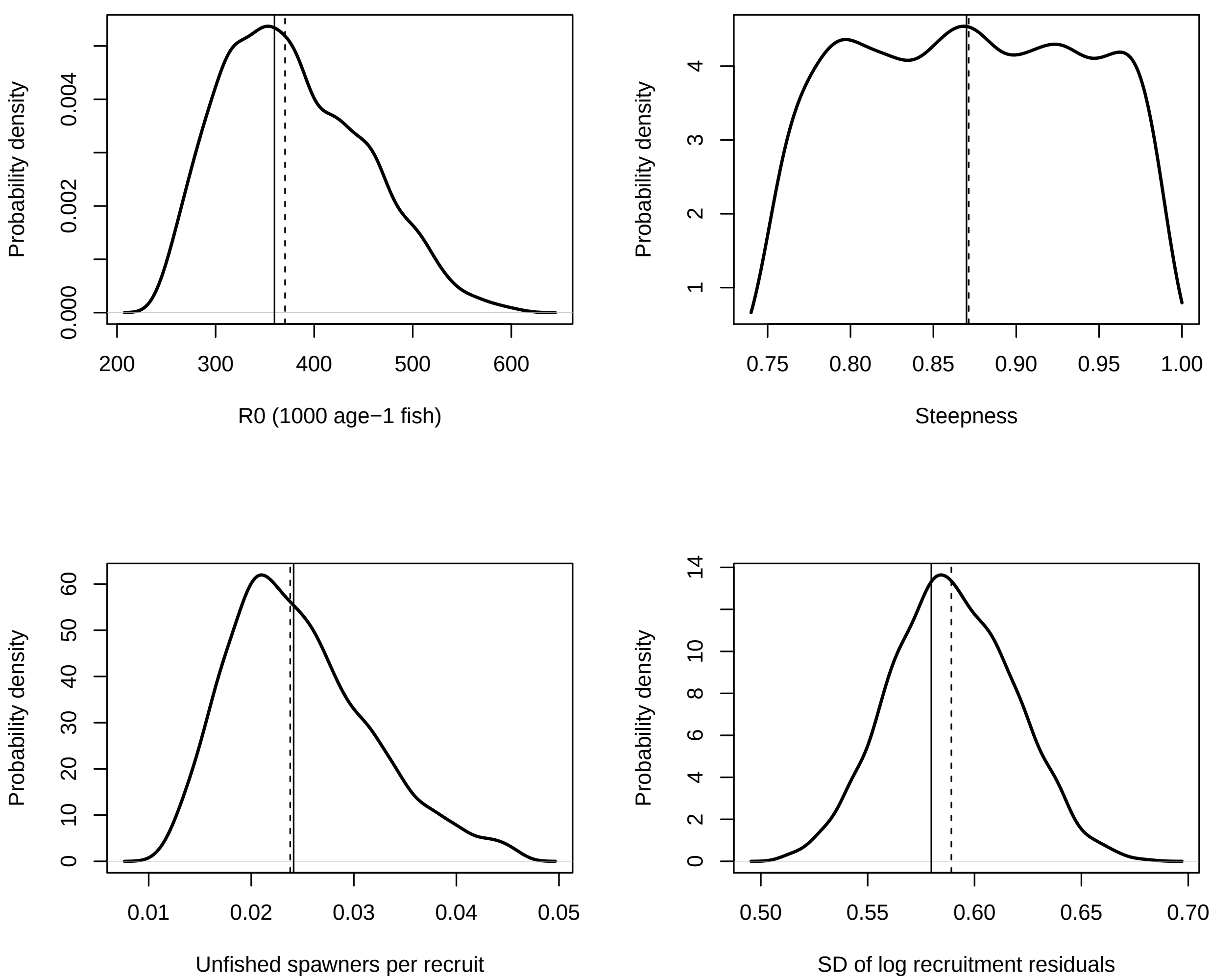


Figure 31. Top panel: yield per recruit (lb). Bottom panel: spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the X% level of SPR provides $F_{X\%}$. *Both curves are based on average selectivity from the end of the assessment period.*

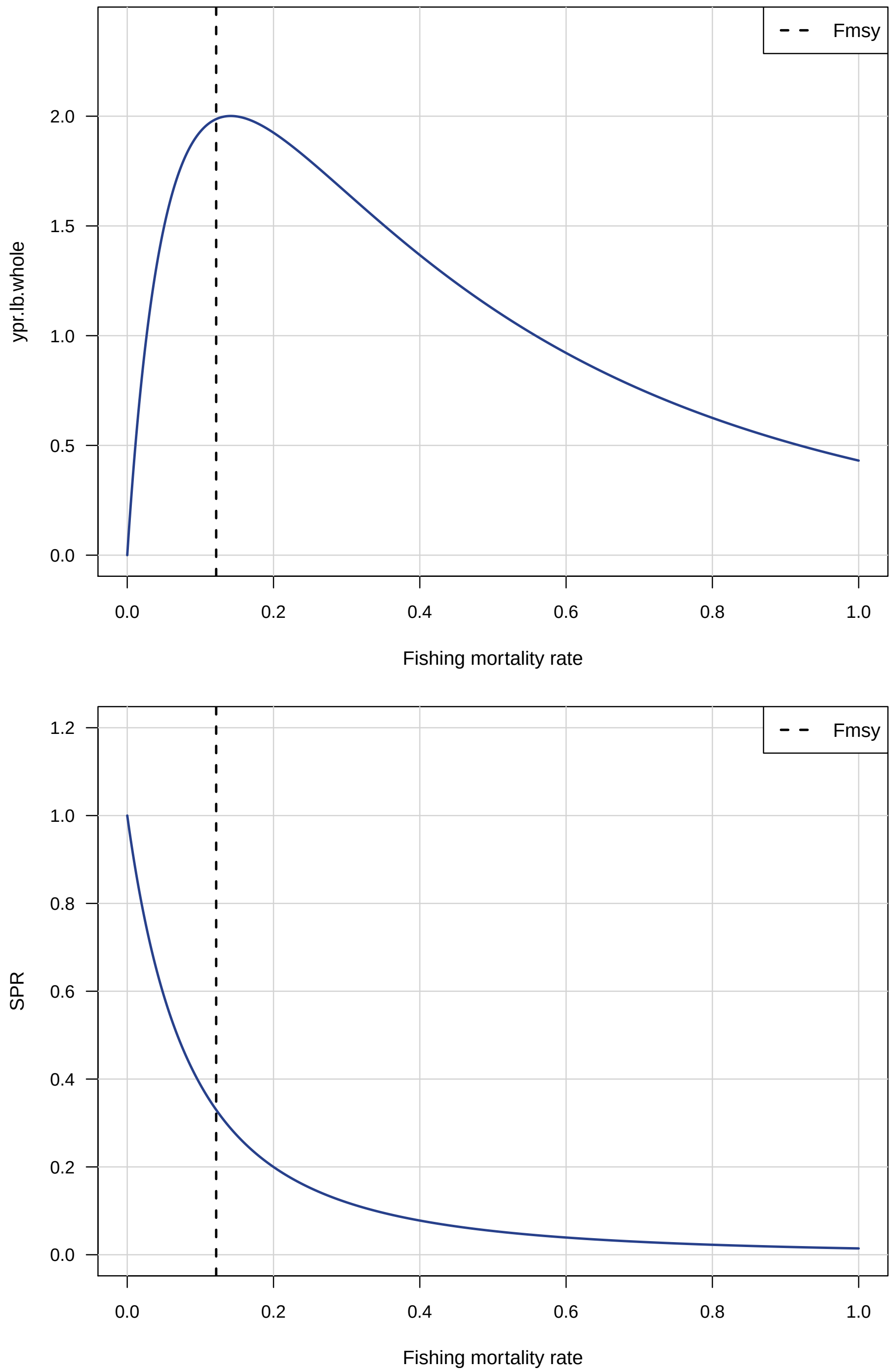
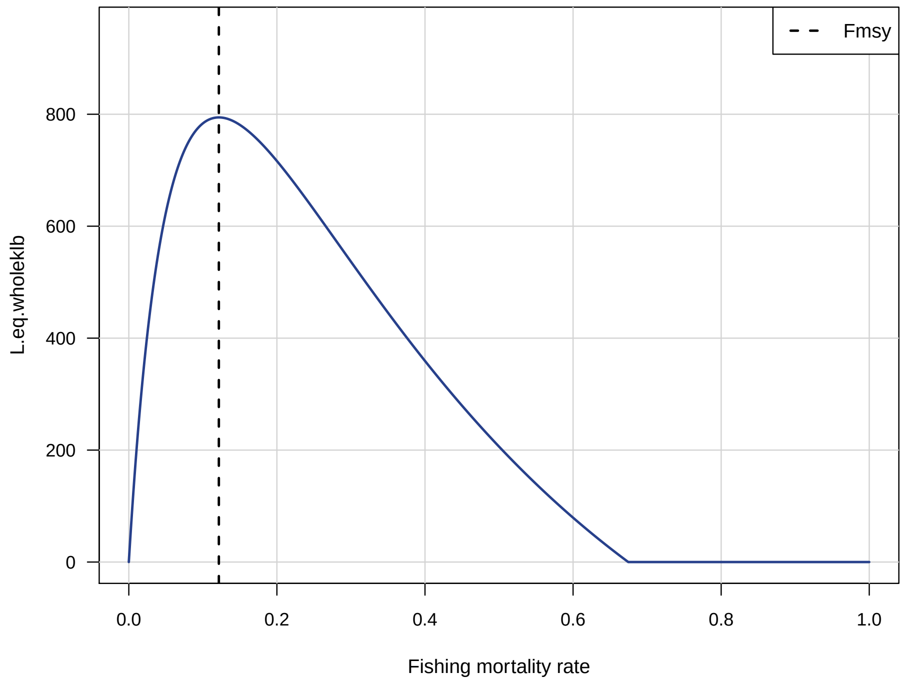


Figure 32. Top panel: equilibrium landings. The peak occurs where fishing rate is $F_{\mathrm{MSY}} = 0.12$ *and equilibrium landings (1000 lb) are* MSY = 794.3 *(1000 lb). Bottom panel: equilibrium spawning biomass (mt). Both curves are based on average selectivity from the end of the assessment period.*



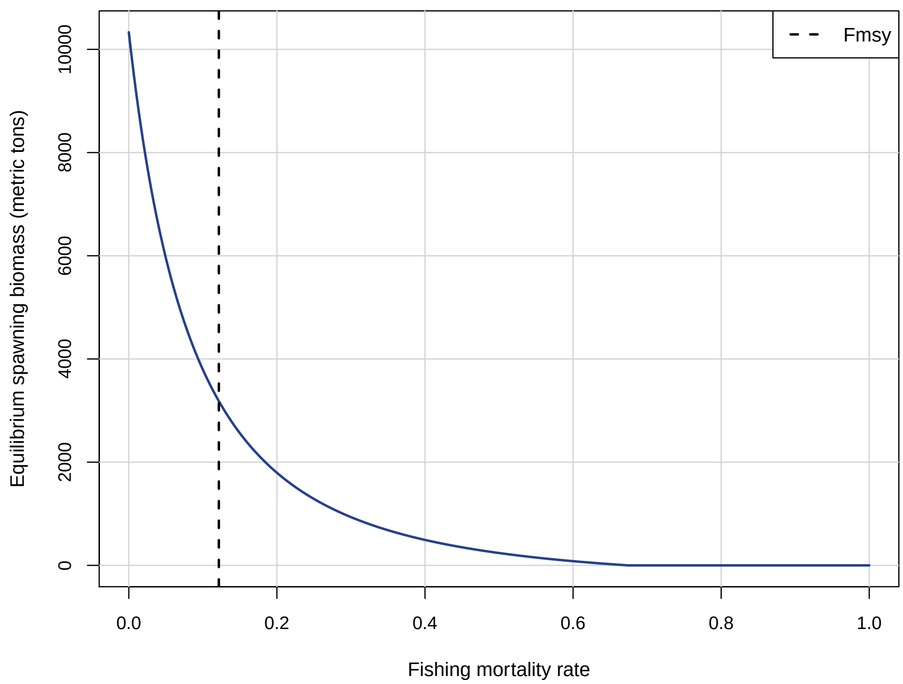


Figure 33. Probability densities of MSY*-related benchmarks from MCB analysis of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.*

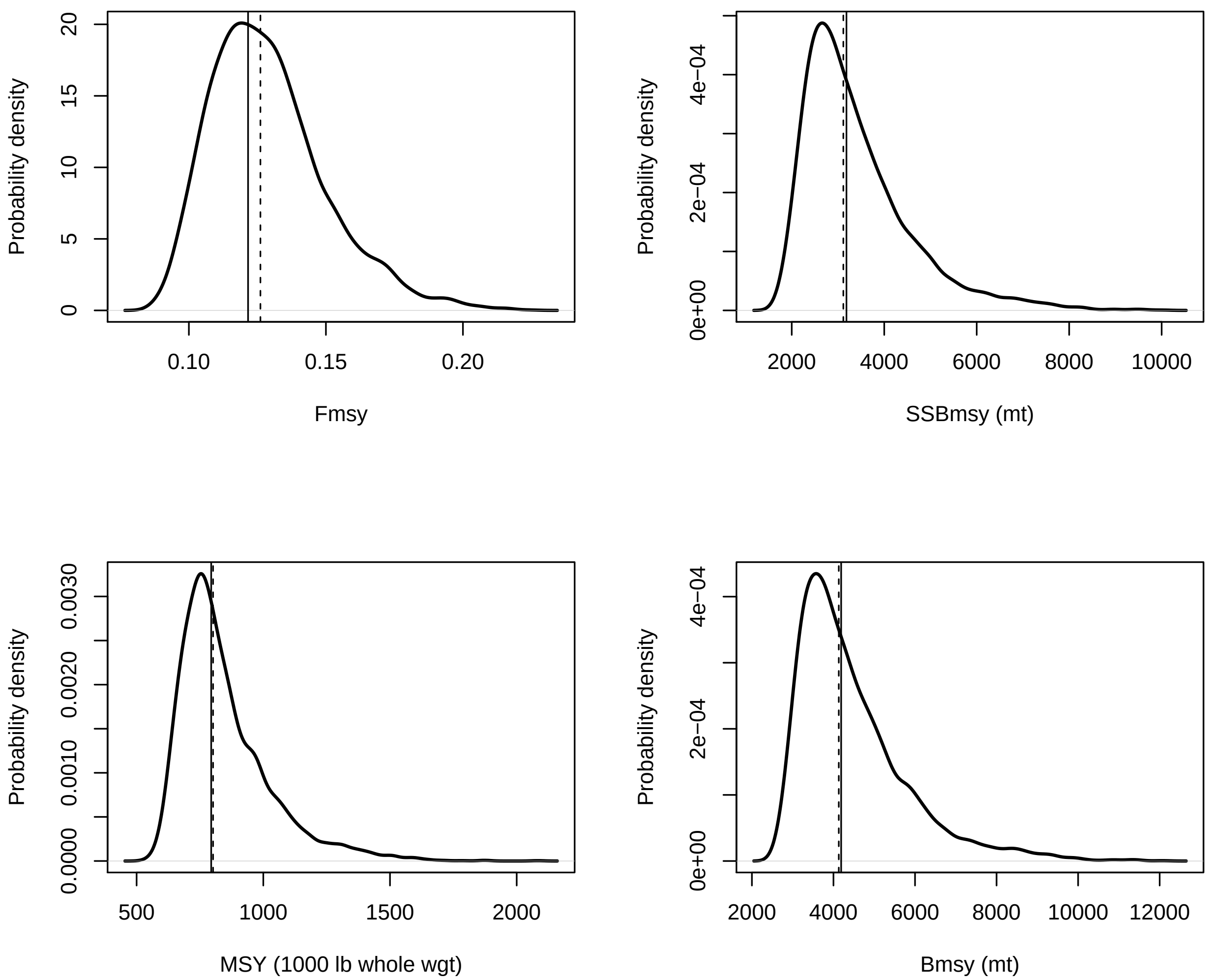


Figure 34. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; dashed lines represent median values; gray error bands indicate 5^{th} *and* 95^{th} *percentiles of the MCB trials. Top panel: spawning biomass relative to the minimum stock size threshold (*MSST*). Middle panel: spawning biomass relative to* $\mathrm{SSB}_{\mathrm{MSY}}$*. Bottom panel: F relative to* F_{MSY}*.*

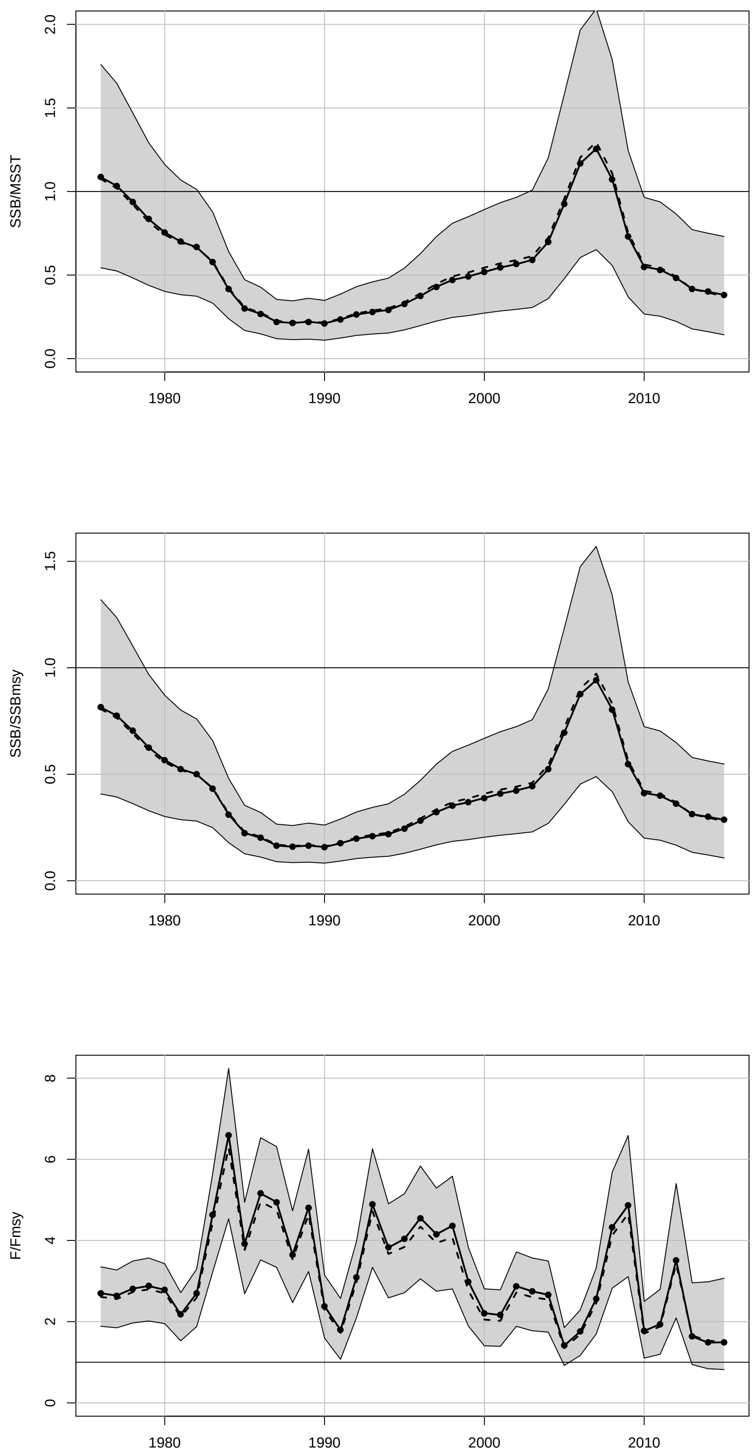


Figure 35. Probability densities of terminal status estimates from MCB analysis of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.

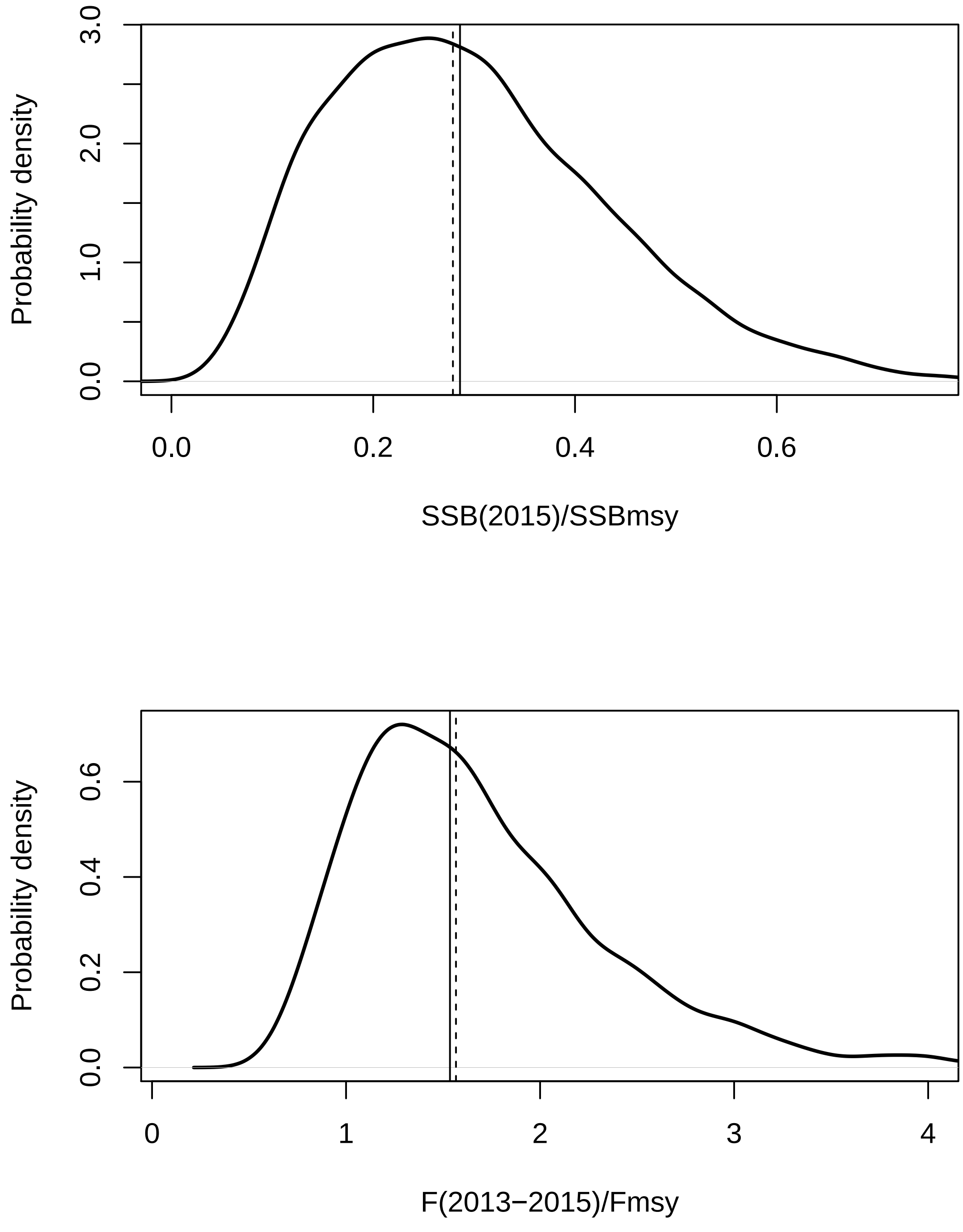
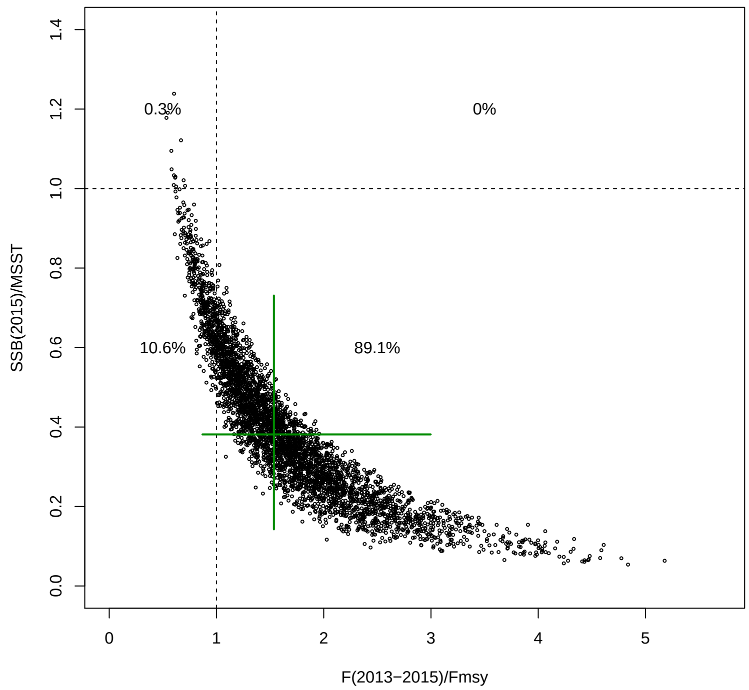


Figure 36. Phase plots of terminal status estimates from MCB analysis of the Beaufort Assessment Model. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by 5^{th} *and* 95^{th} *percentiles. Proportion of runs falling in each quadrant indicated.*



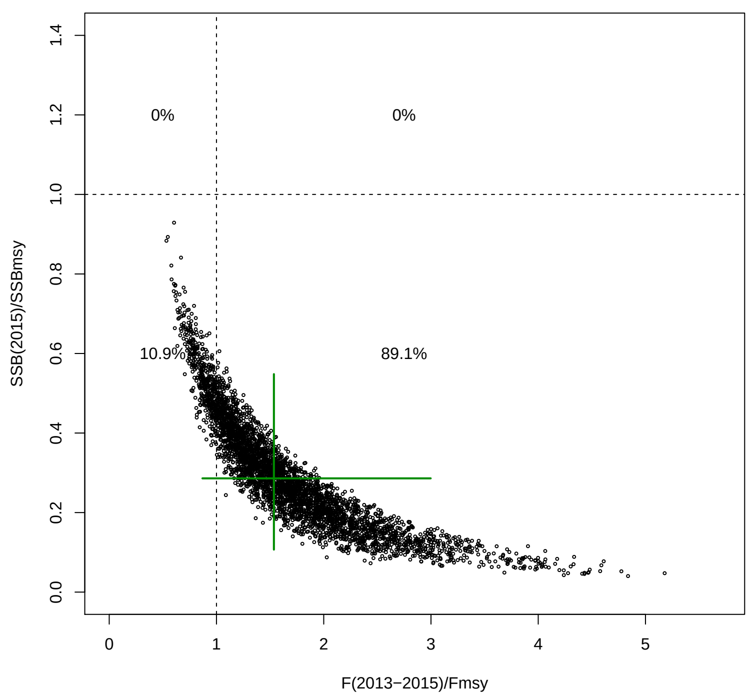


Figure 37. Age structure relative to the equilibrium expected at MSY*.*

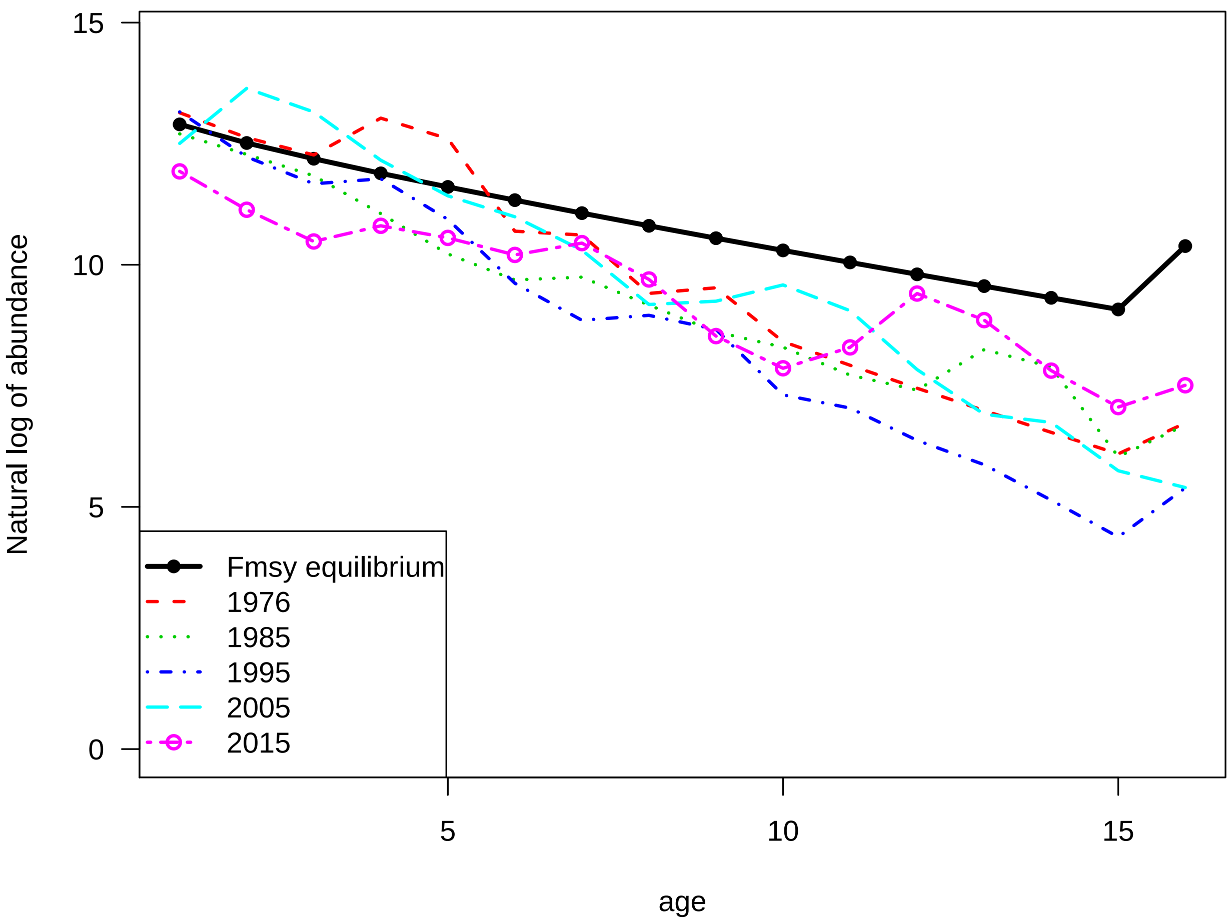


Figure 38. Comparison of results from this standard assessment with those from the previous, SEDAR19 assessment. Top panel: F relative to F_{MSY}*. Bottom panel: spawning biomass relative to* $\mathrm{SSB}_{\mathrm{MSY}}$*.*

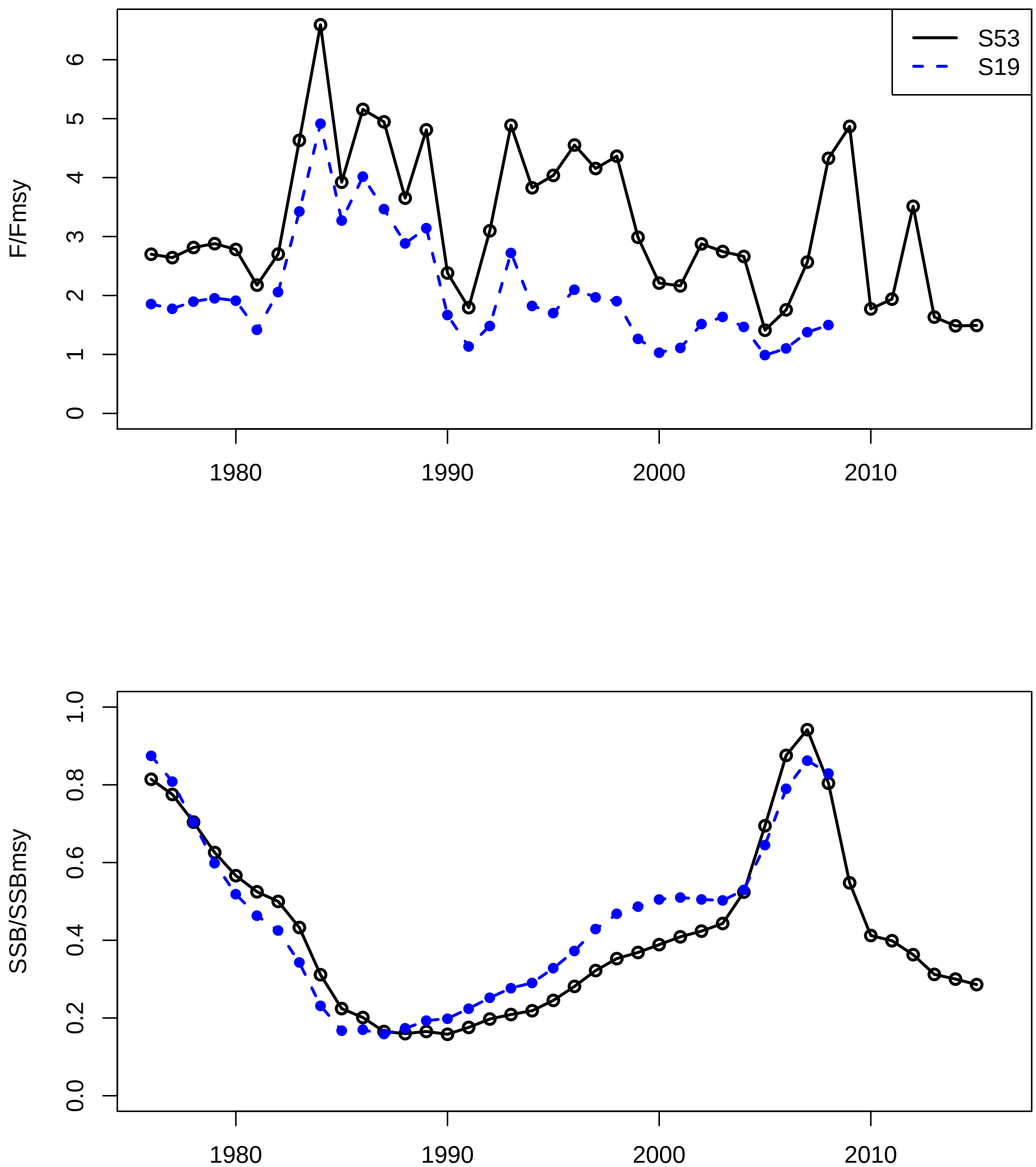


Figure 39. Sensitivity to changes in steepness (sensitivity runs S1–S2). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

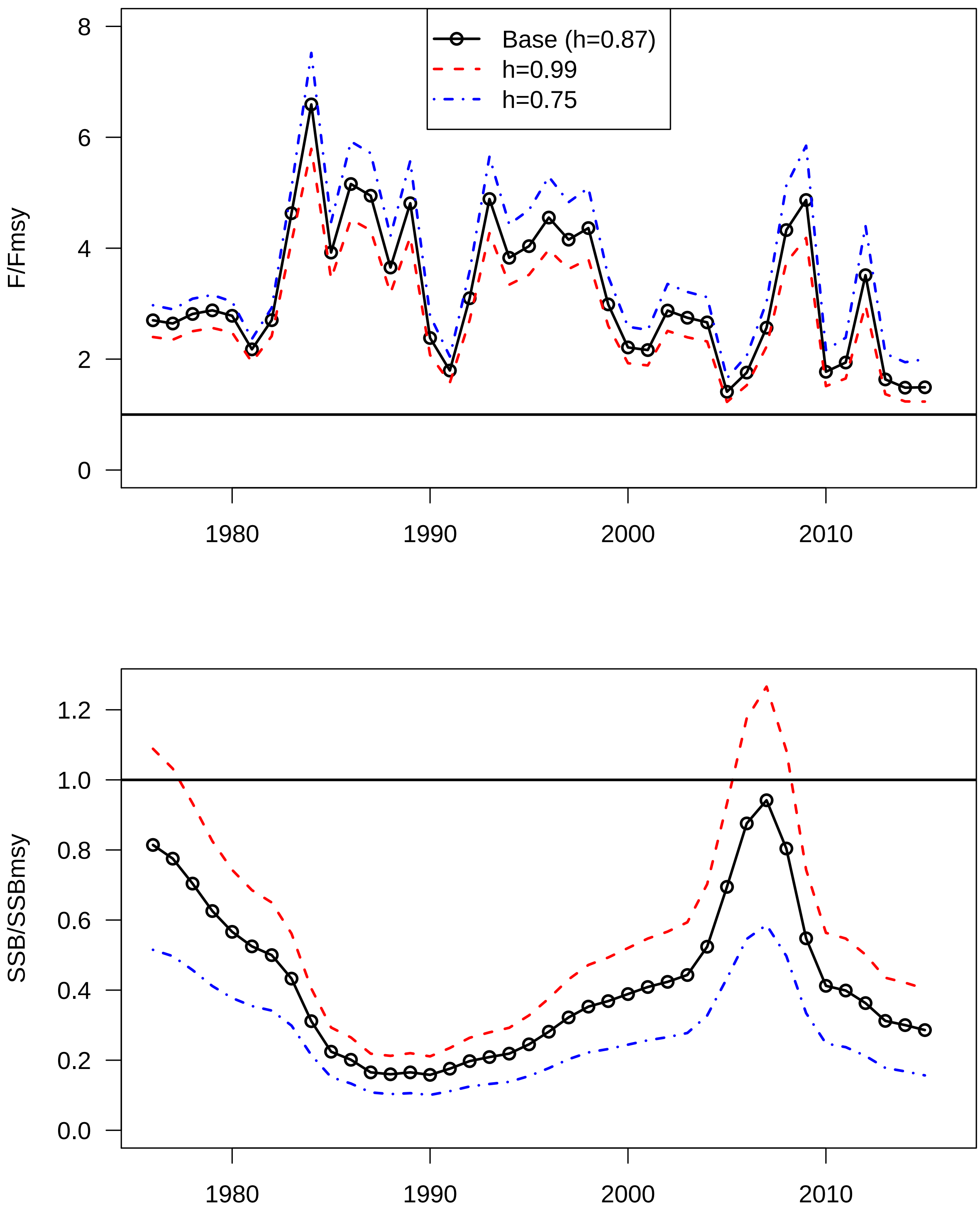


Figure 40. Sensitivity to natural mortality (sensitivity runs S3–S5). Top panel: Ratio of F to F_{MSY}. *Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

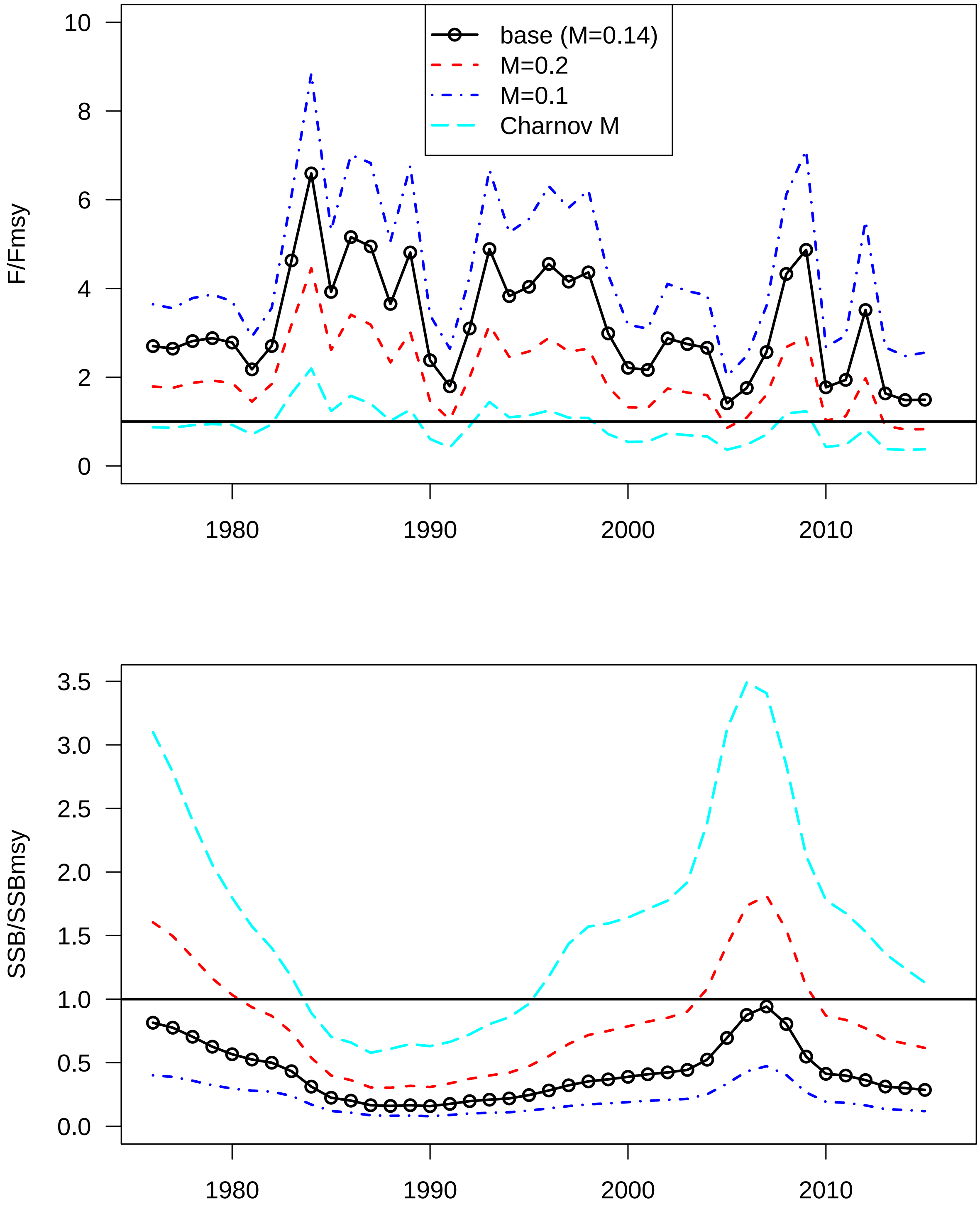


Figure 41. Sensitivity to SERFS index (sensitivity runs S6–S7). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* SSB_{MSY}.

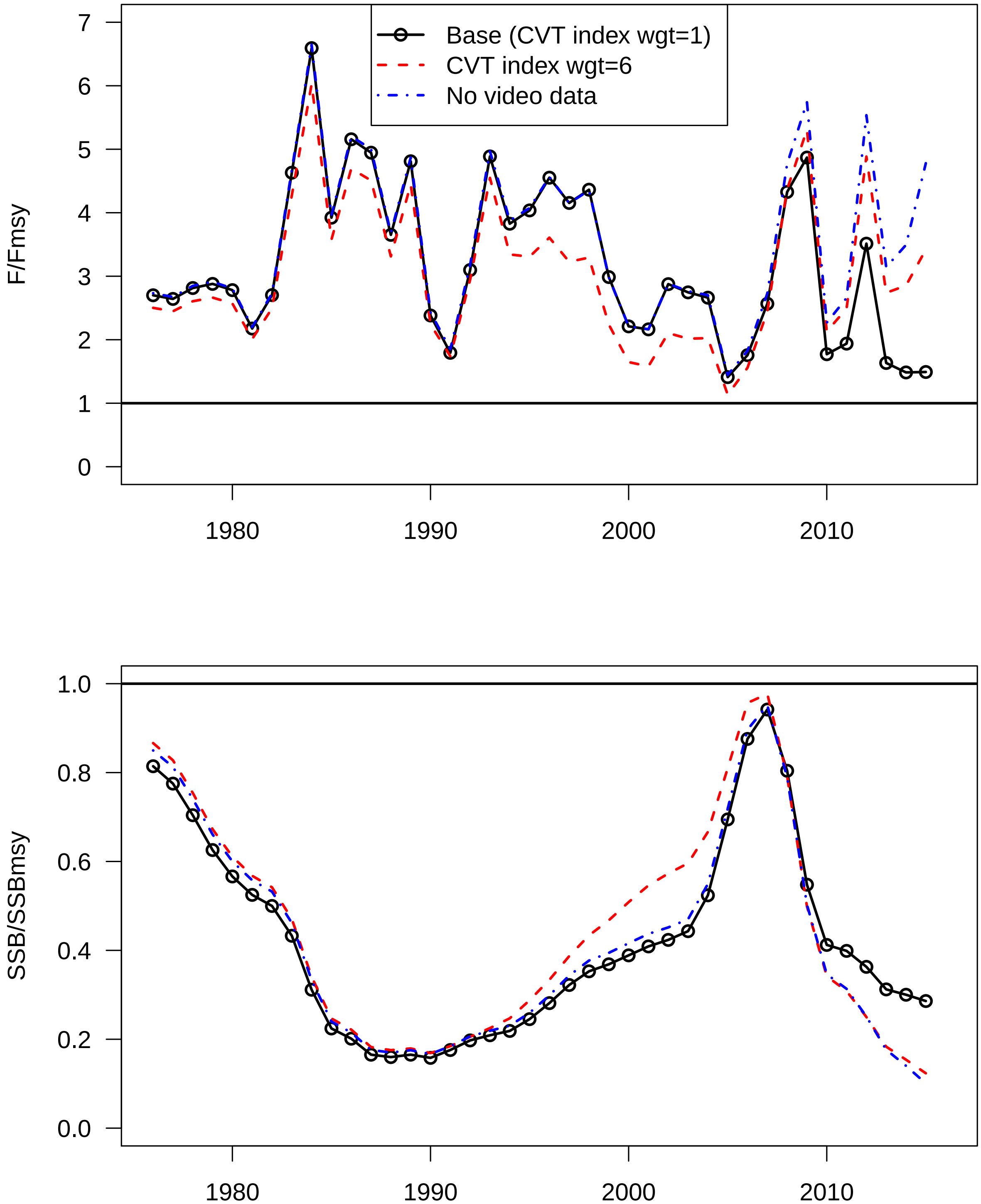
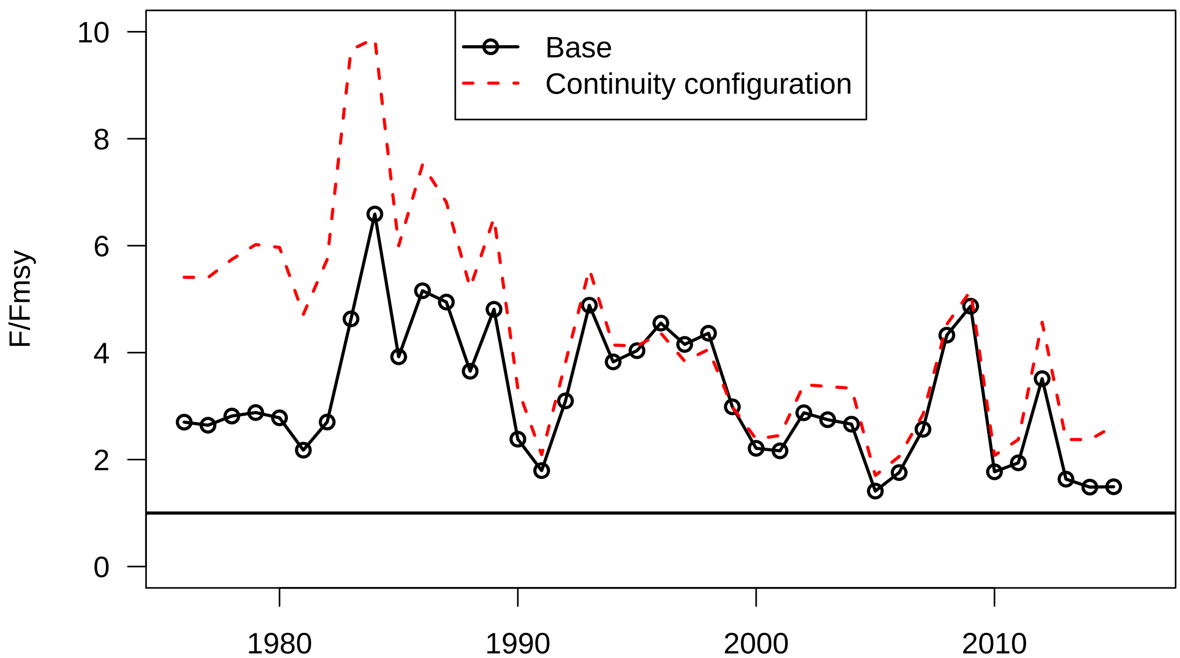


Figure 42. Sensitivity to the SEDAR19 continuity configuration (sensitivity run S8). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB to SSB_{MSY}.



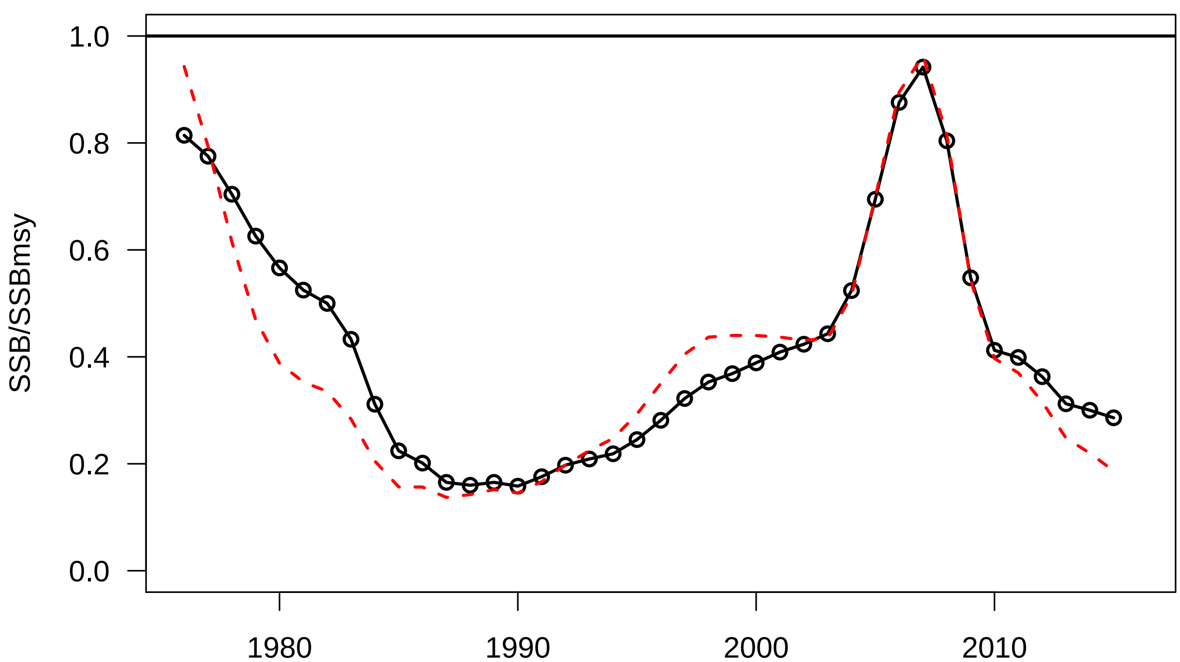


Figure 43. Sensitivity to the statistical distribution used for fitting composition data (sensitivity run S9). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

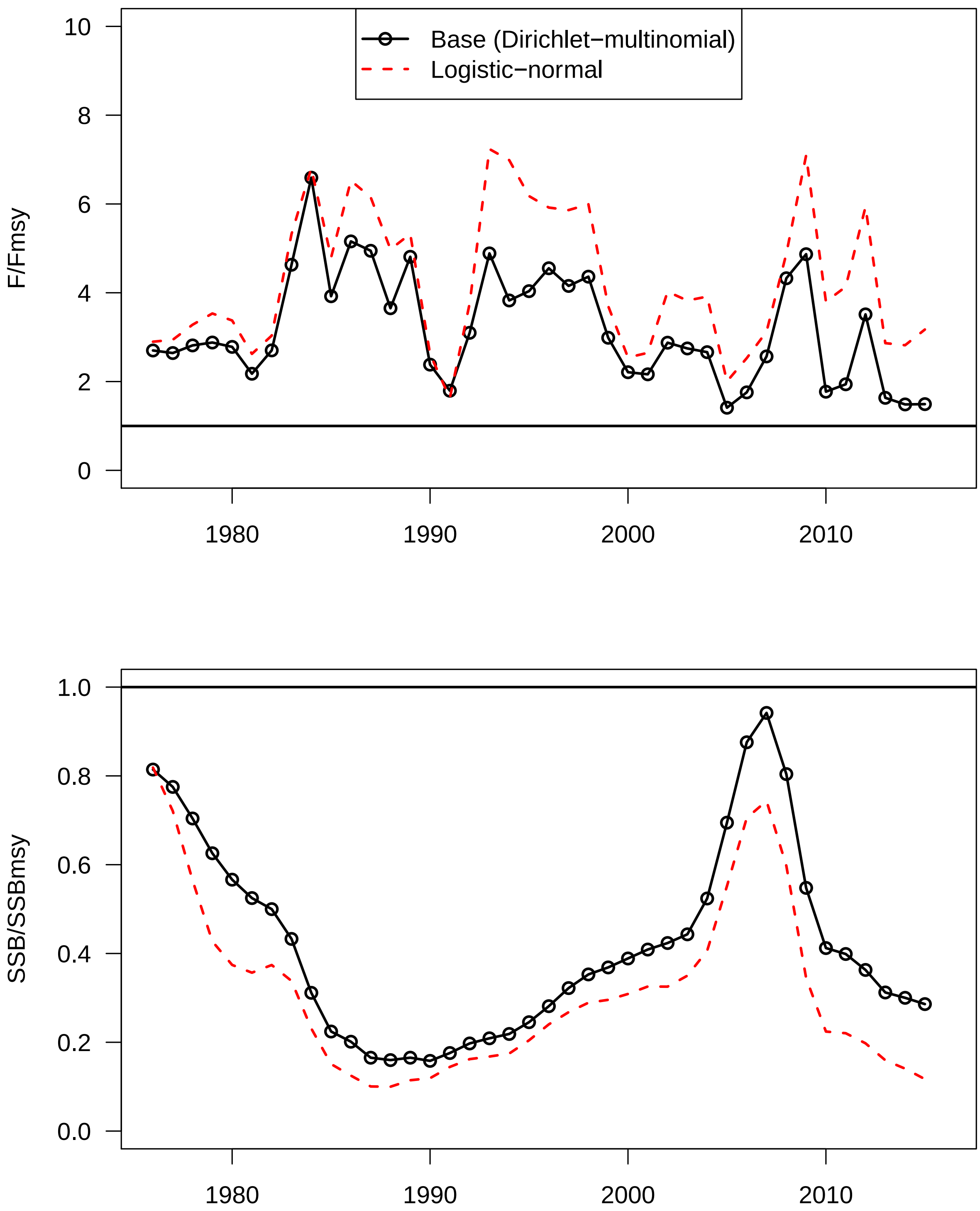
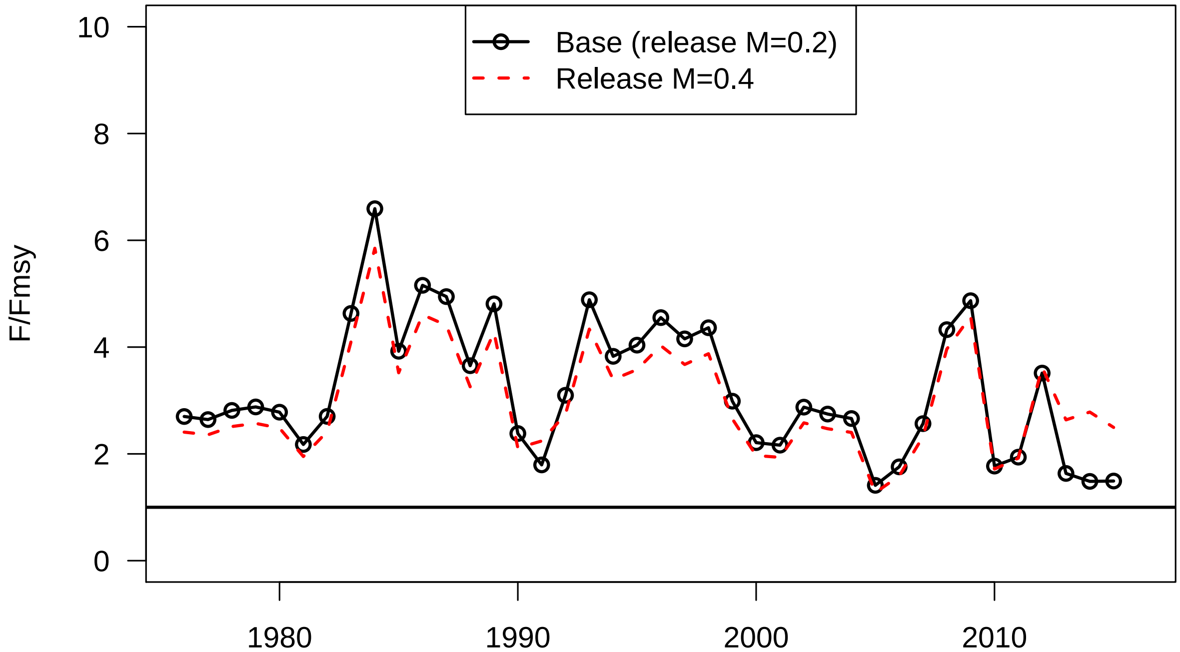


Figure 44. Sensitivity to the release mortality rate (sensitivity run S10). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.



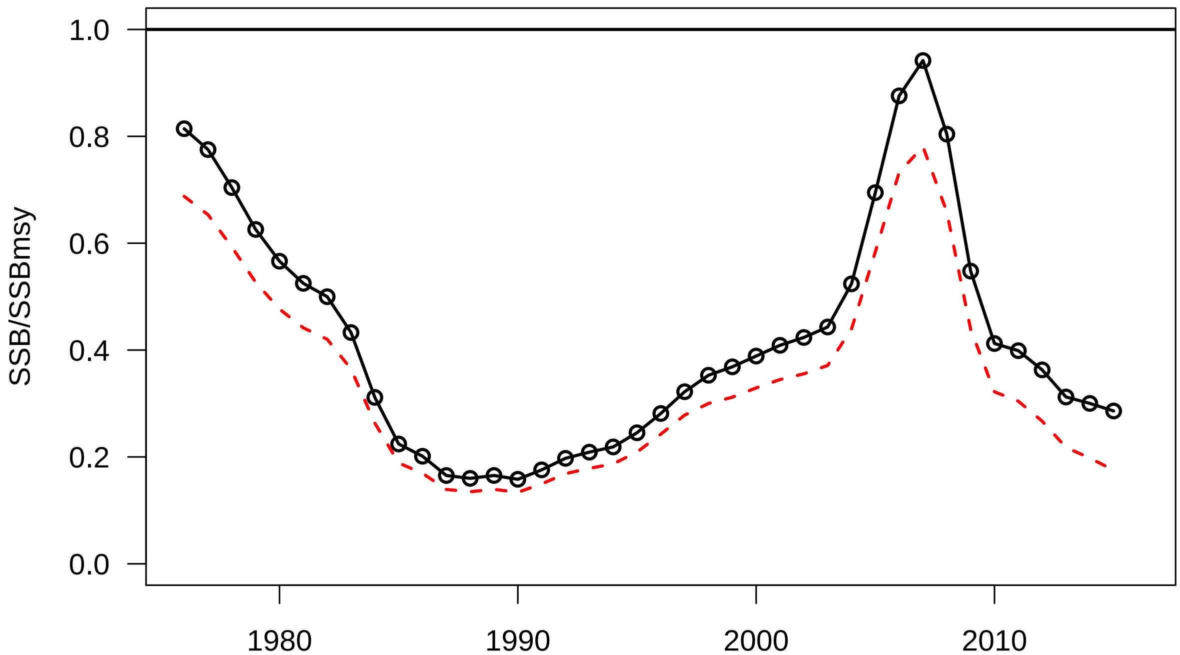


Figure 45. Phase plot of terminal status indicators from sensitivity runs of the Beaufort Assessment Model.

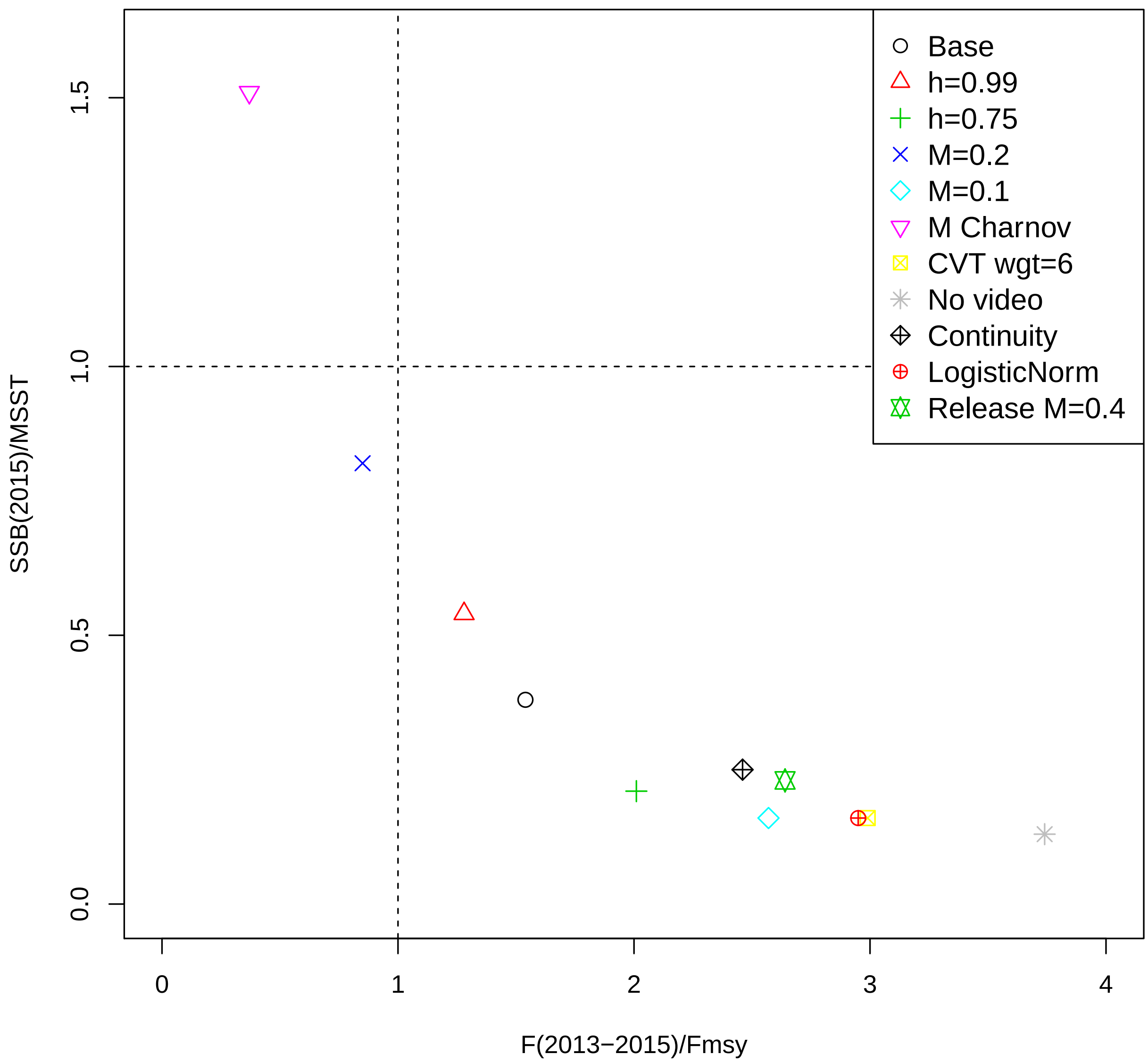


Figure 46. Retrospective analyses. Sensitivity to terminal year of data. Top panel: Fishing mortality rates. Middle panel: Recruits. Bottom panel: Spawning biomass. Closed circles show terminal-year estimates. Imperceptible lines overlap results of the base run.

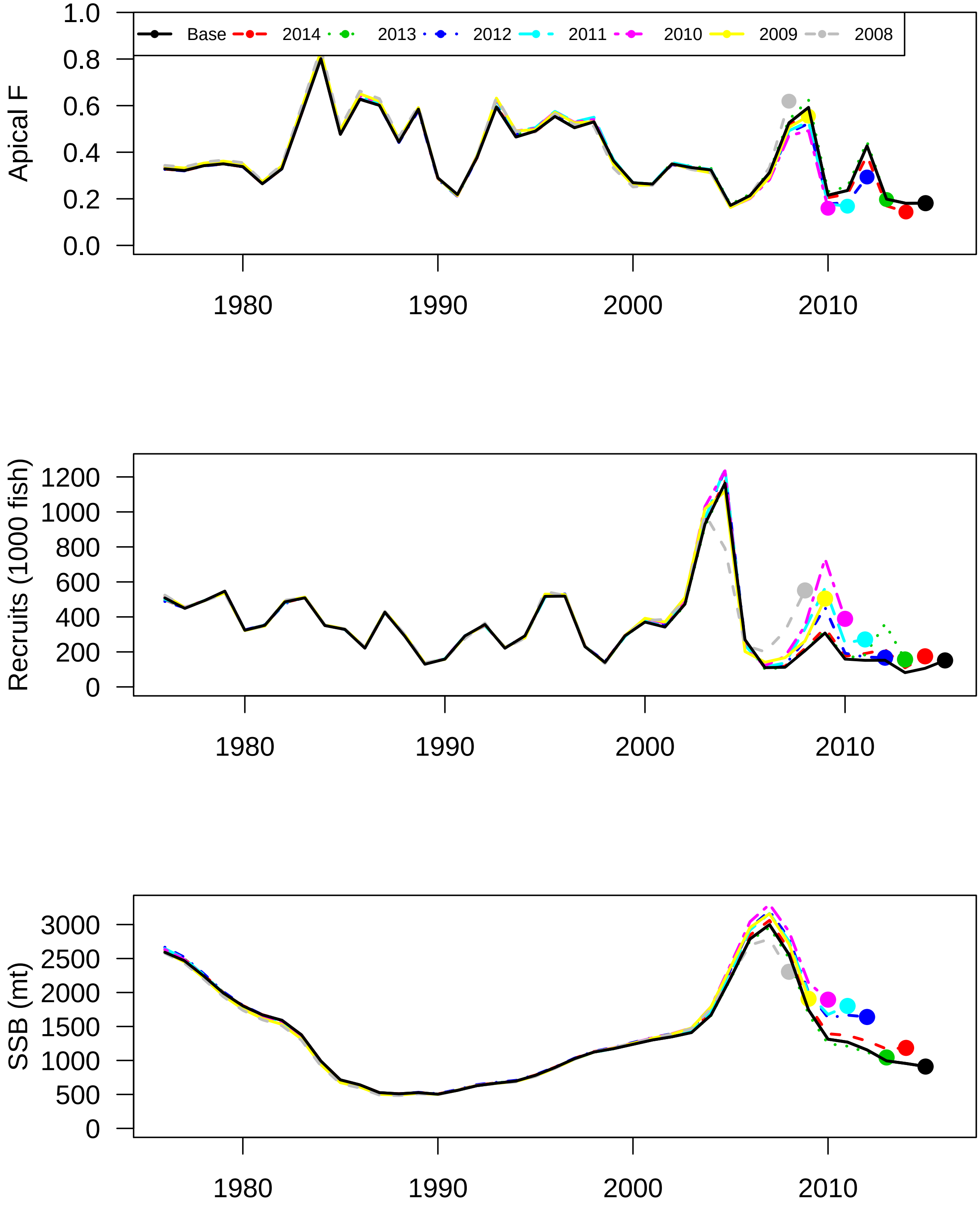


Figure 47. Projection results under scenario 1—fishing mortality rate at $F = F_{\mathrm{MSY}}$. In all panels except the bottom right, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark MSY-*related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In the bottom right panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{MSY}}$.

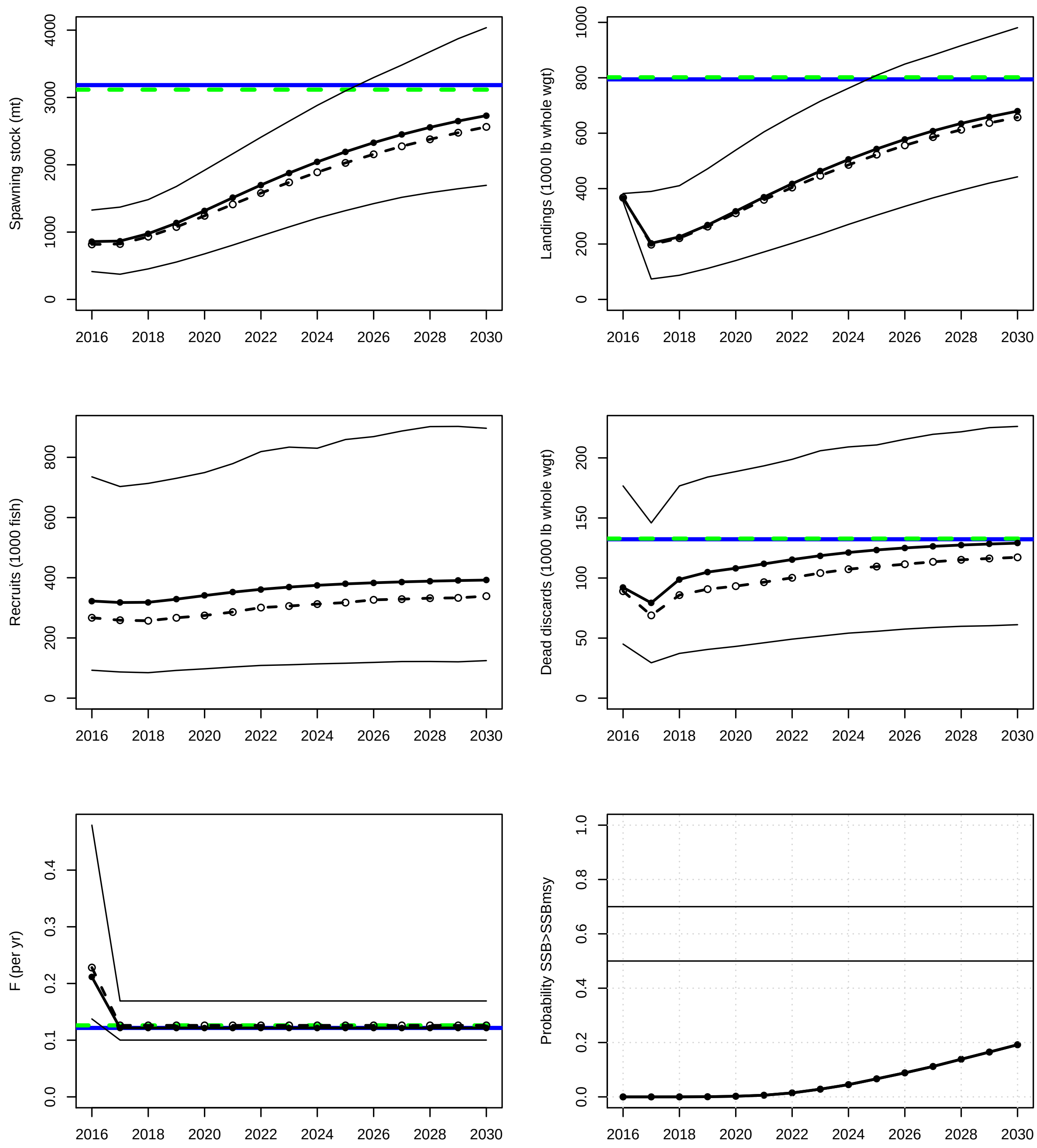


Figure 48. Projection results under scenario 2—fishing mortality rate at $F = 75\%F_{\mathrm{MSY}}$. In all panels except the bottom right, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark MSY*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In the bottom right panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{MSY}}$.

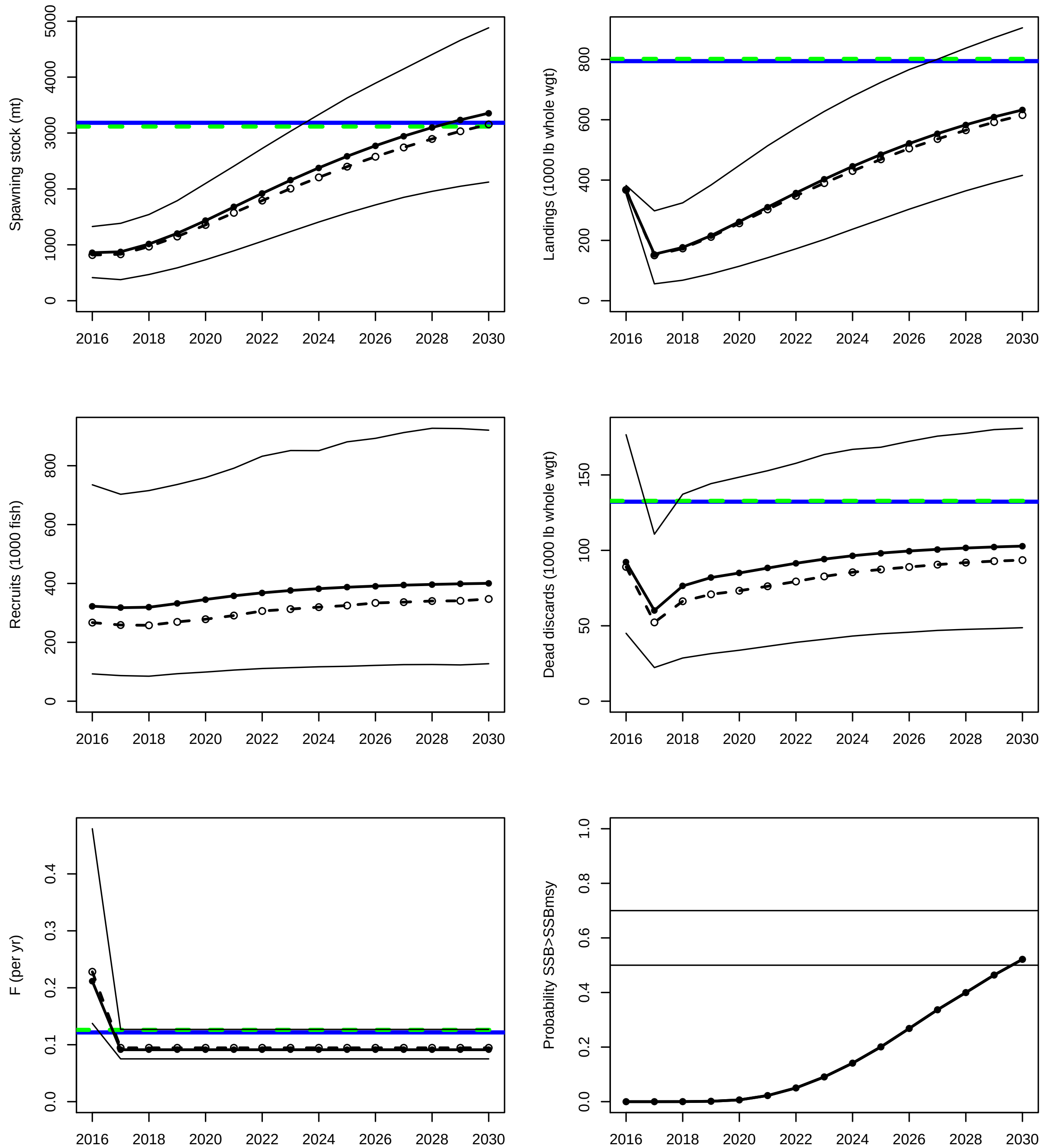


Figure 49. Projection results under scenario 3—fishing mortality rate at $F = 0$. In all panels except the bottom right, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark MSY*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In the bottom right panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* SSB_{MSY}.

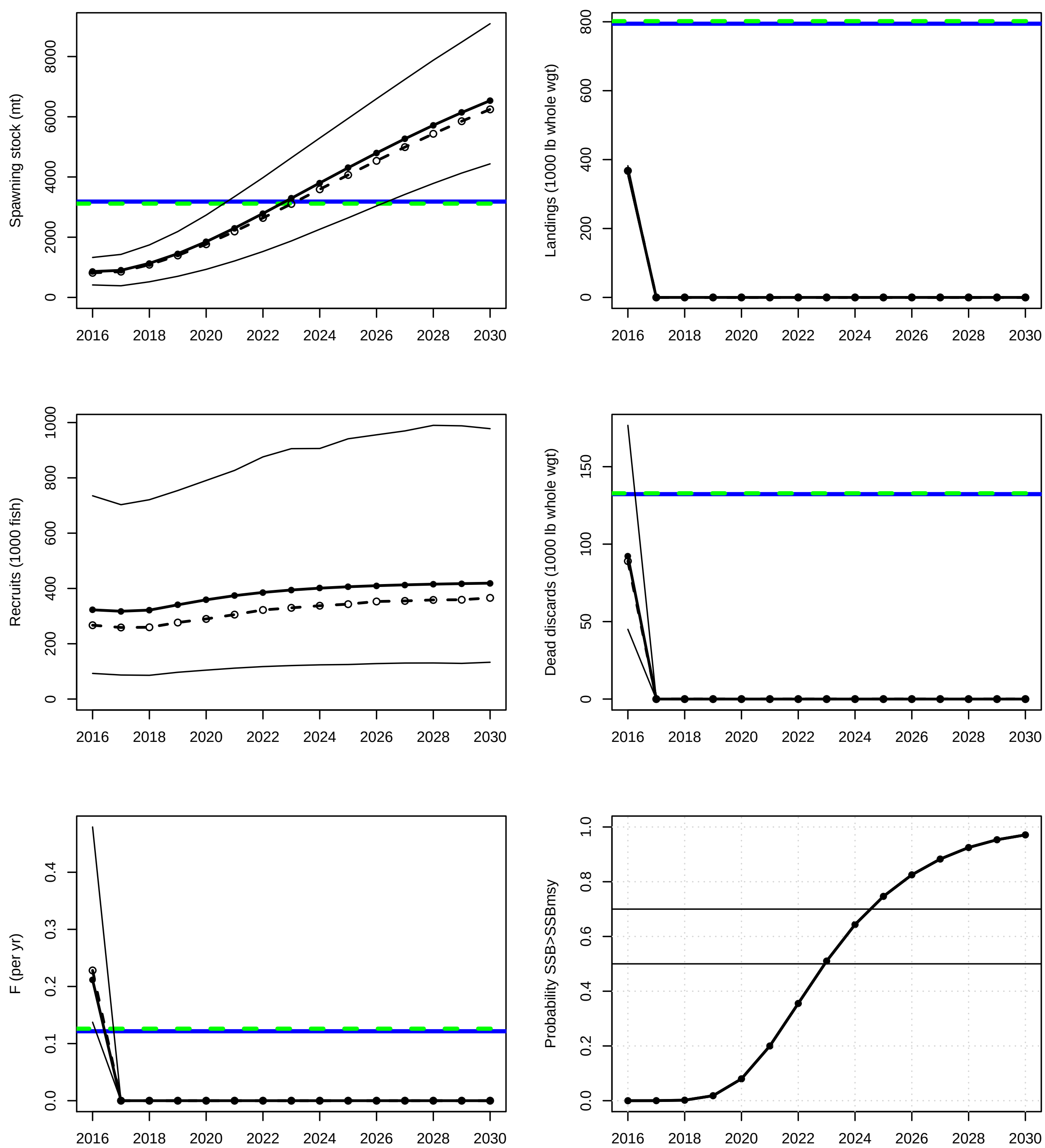


Figure 50. Projection results under scenario 4—fishing mortality rate at $F = F_{\mathrm{MSY}}$ and with low recruitment. In all panels except the bottom right, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark MSY*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In the bottom right panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{MSY}}$.

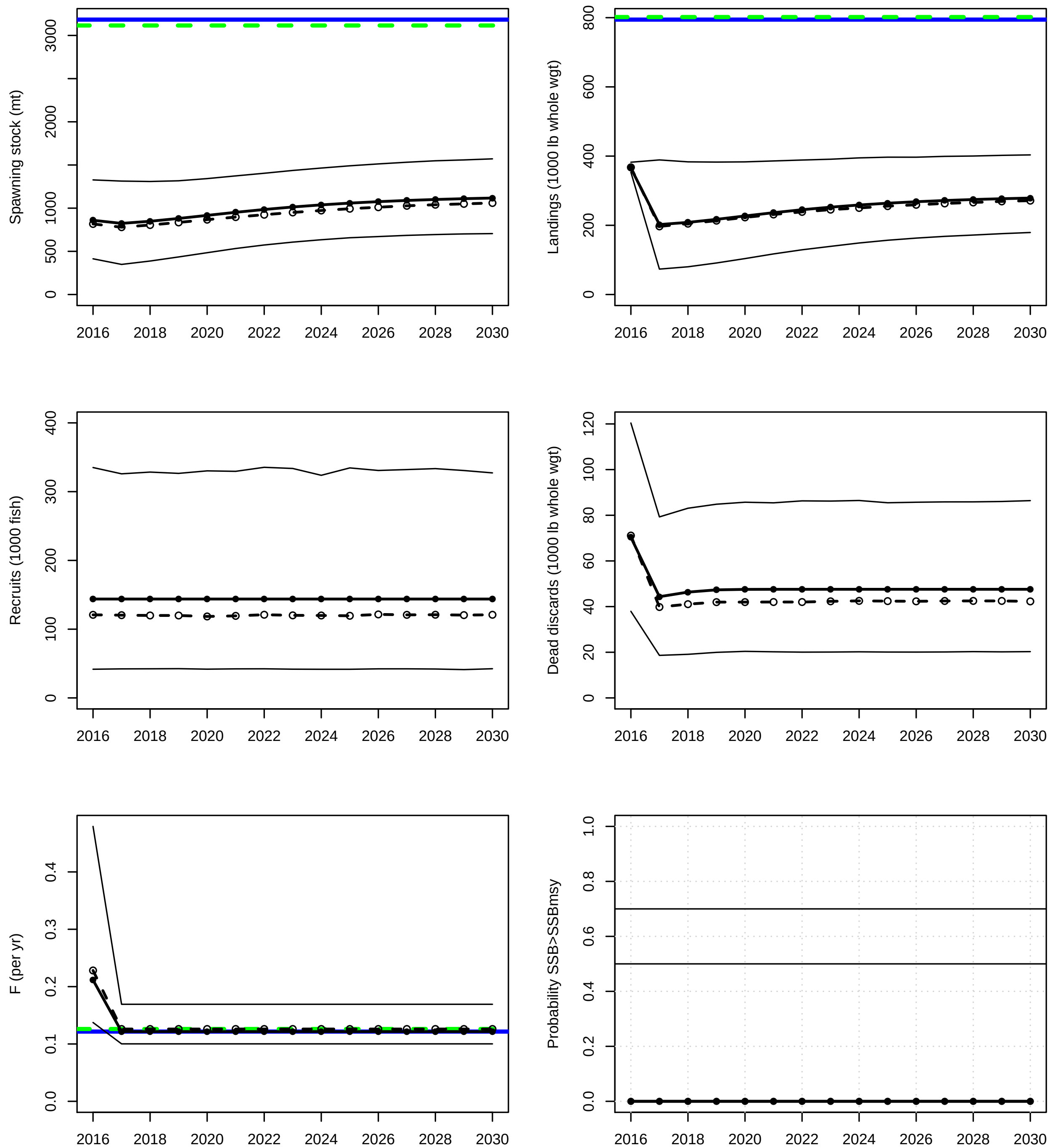


Figure 51. Projection results under scenario 5—fishing mortality rate at $F = 75\%F_{\mathrm{MSY}}$ and with low recruitment. In all panels except the bottom right, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark MSY*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In the bottom right panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB_{MSY}}$.

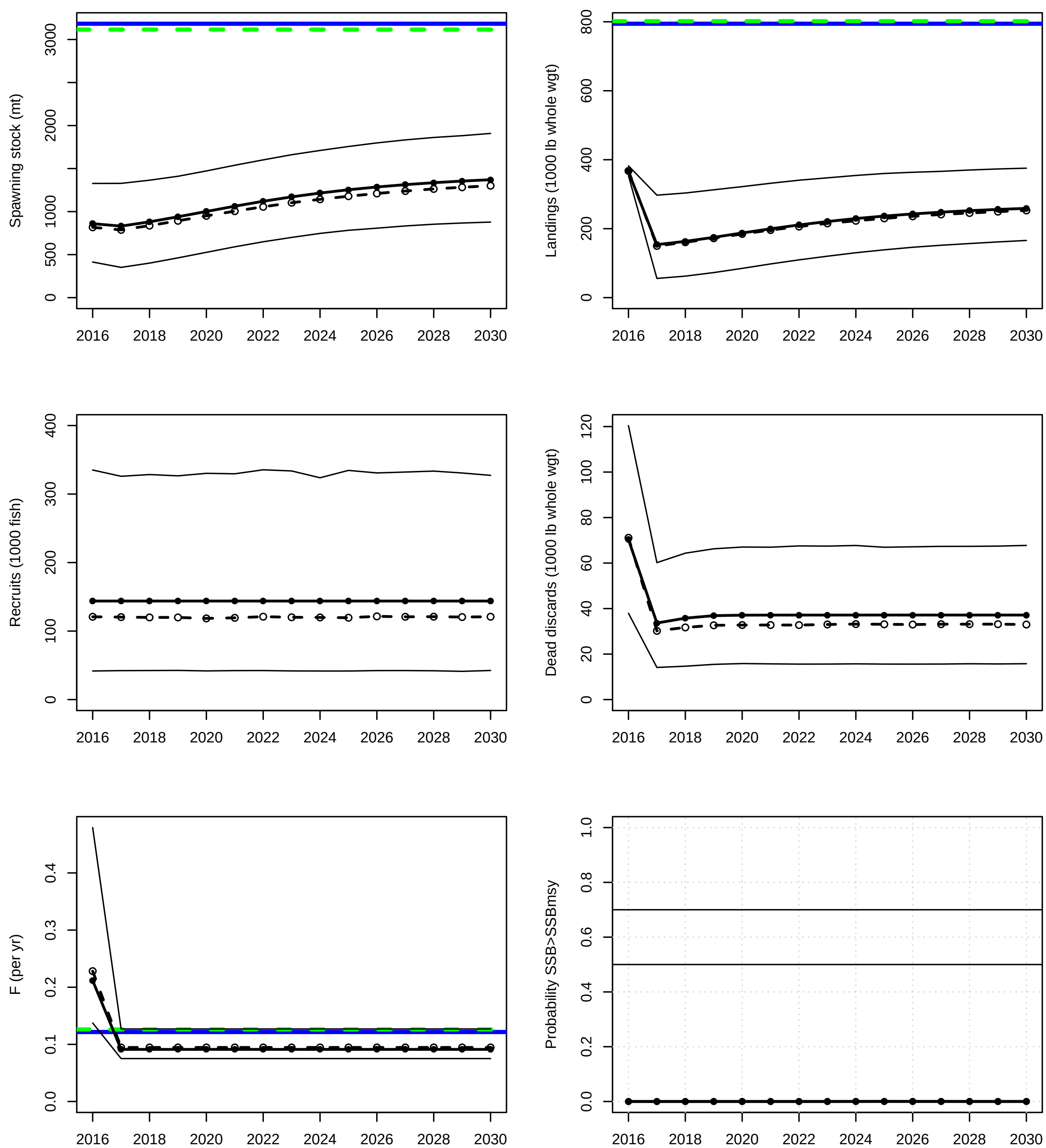


Figure 52. Projection results under scenario 6—fishing mortality rate at $F = 0$ and with low recruitment. In all panels except the bottom right, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark MSY*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In the bottom right panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{MSY}}$.

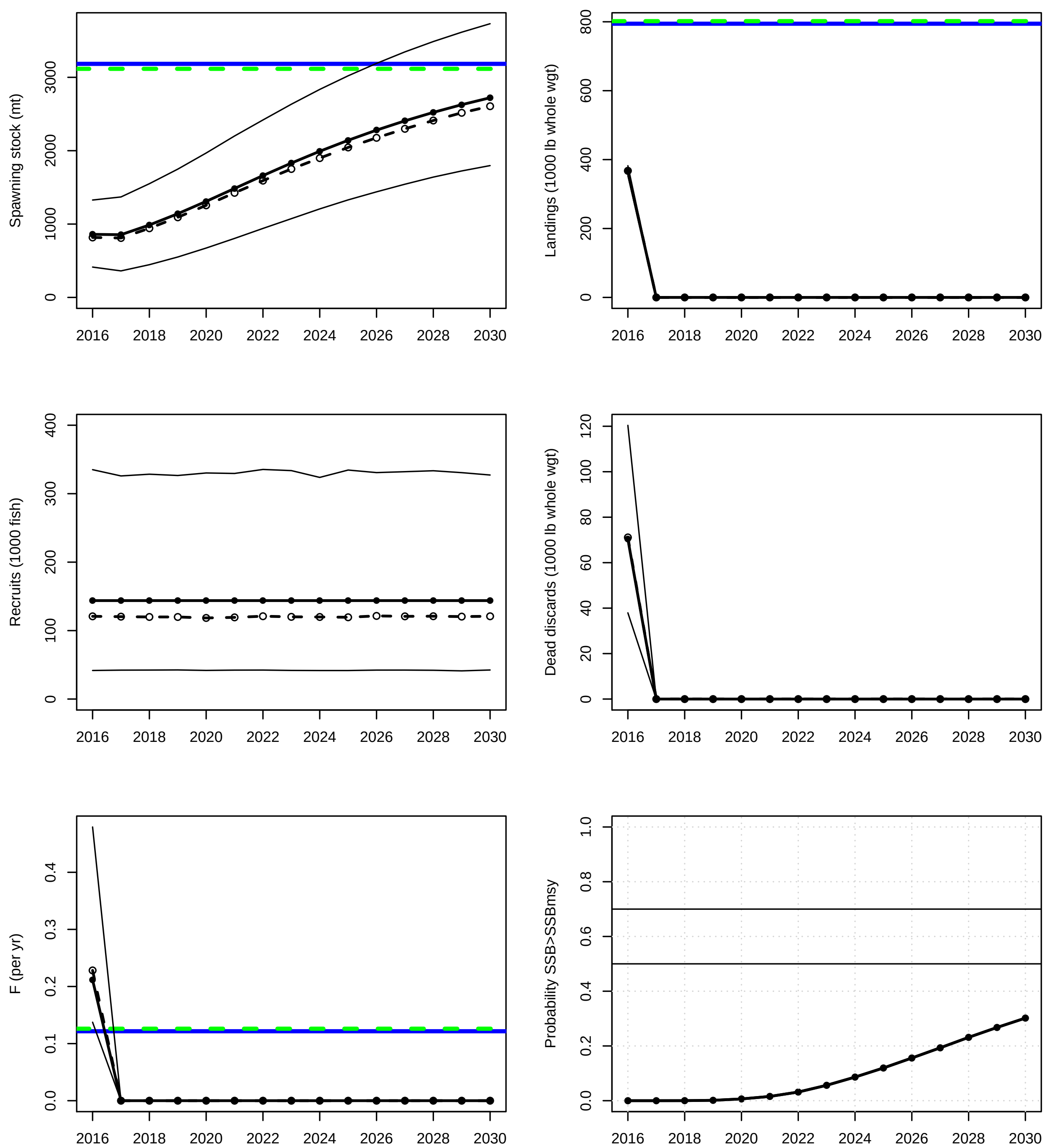


Figure 53. Projection results under scenario 7—fishing mortality rate at $F = 0$ starting in 2019. In all panels except the bottom right, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark MSY*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In the bottom right panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{MSY}}$.

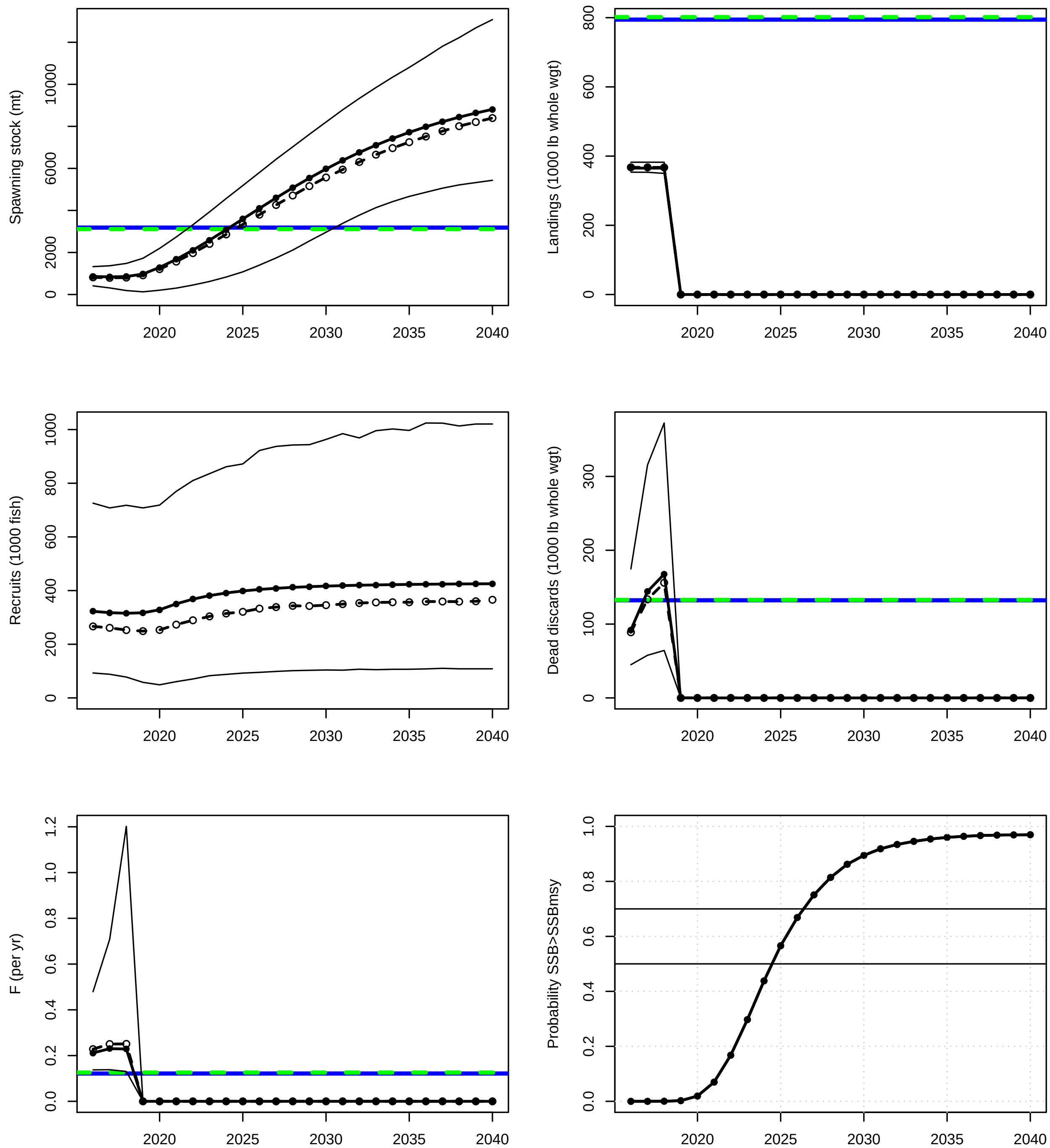
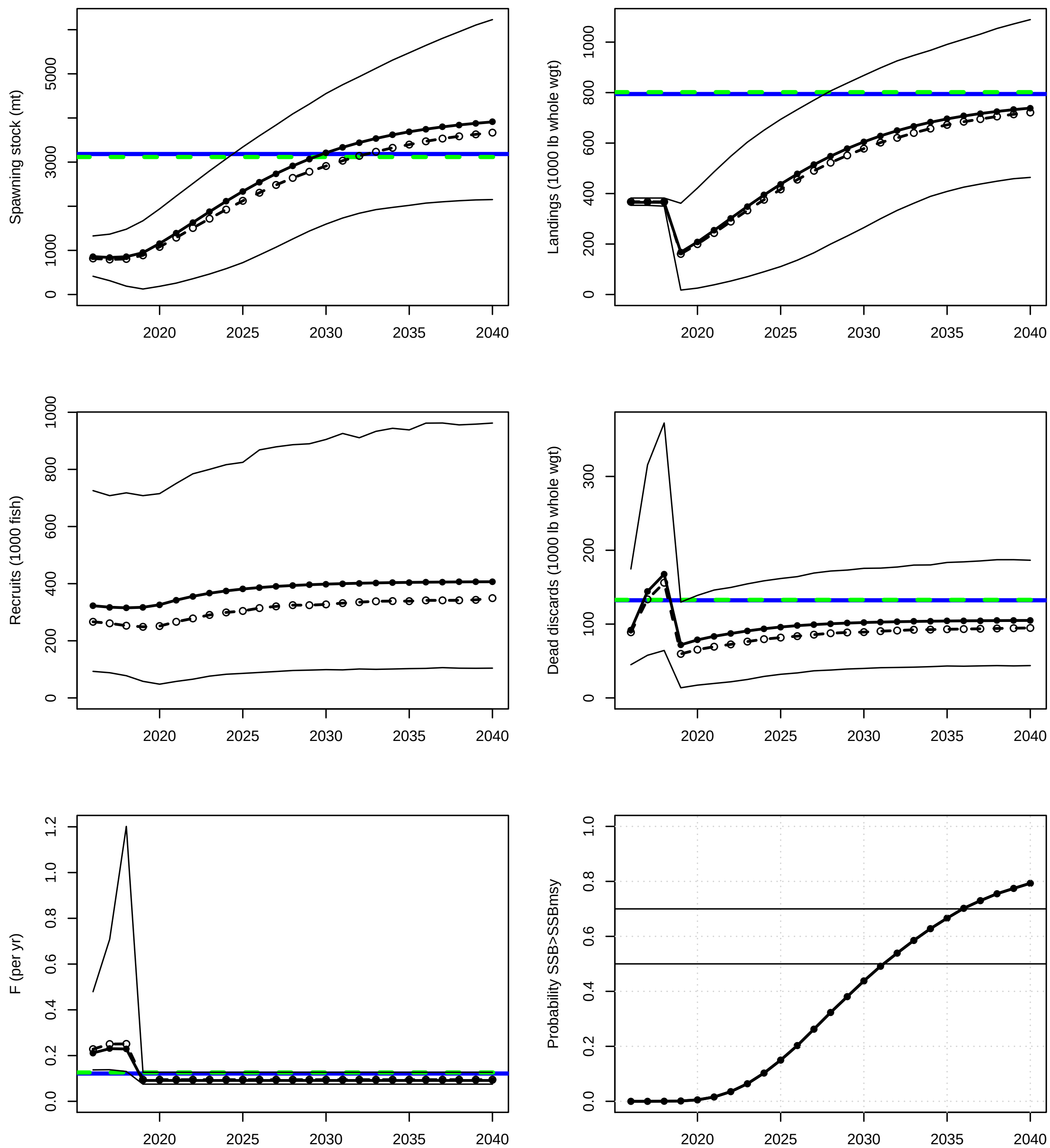


Figure 54. Projection results under scenario 8—fishing mortality rate at $F = 75\% F_{\mathrm{MSY}}$ starting in 2019. In all panels except the bottom right, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Solid horizontal lines mark MSY*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In the bottom right panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{MSY}}$.



Appendix A Abbreviations and symbols

Table 28. Acronyms and abbreviations used in this report

Symbol	Meaning
ABC	Acceptable Biological Catch
AW	Assessment Workshop
ASY	Average Sustainable Yield
B	Total biomass of stock, conventionally on January 1
BAM	Beaufort Assessment Model (a statistical catch-age formulation)
CPUE	Catch per unit effort; used after adjustment as an index of abundance
CV	Coefficient of variation
CVID	SERFS combined chevron trap and video survey
DW	Data Workshop
F	Instantaneous rate of fishing mortality
$F_{X\%}$	Fishing mortality rate at which SPR of X% can be attained
F_{MSY}	Fishing mortality rate at which MSY can be attained
FL	State of Florida
GA	State of Georgia
GLM	Generalized linear model
K	Average size of stock when not exploited by man; carrying capacity
kg	Kilogram(s); 1 kg is about 2.2 lb.
klb	Thousand pounds; thousands of pounds
lb	Pound(s); 1 lb is about 0.454 kg
m	Meter(s); 1 m is about 3.28 feet.
M	Instantaneous rate of natural (non-fishing) mortality
MARMAP	Marine Resources Monitoring, Assessment, and Prediction Program, a fishery-independent data collection program of SCDNR
MCB	Monte Carlo/Bootstrap, an approach to quantifying uncertainty in model results
MFMT	Maximum fishing-mortality threshold; a limit reference point used in U.S. fishery management; often based on F_{MSY}
mm	Millimeter(s); 1 inch = 25.4 mm
MRFSS	Marine Recreational Fisheries Statistics Survey, a data-collection program of NMFS, predecessor of MRIP
MRIP	Marine Recreational Information Program, a data-collection program of NMFS, descended from MRFSS
MSST	Minimum stock-size threshold; a limit reference point used in U.S. fishery management. The SAFMC has defined MSST for red grouper as 75% $\mathrm{SSB}_{\mathrm{MSY}}$.
MSY	Maximum sustainable yield (per year)
mt	Metric ton(s). One mt is 1000 kg, or about 2205 lb.
N	Number of fish in a stock, conventionally on January 1
NC	State of North Carolina
NMFS	National Marine Fisheries Service, same as “NOAA Fisheries Service”
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
OY	Optimum yield; SFA specifies that OY $\leq$ MSY.
PSE	Proportional standard error
R	Recruitment
SAFMC	South Atlantic Fishery Management Council (also, Council)
SC	State of South Carolina
SCDNR	Department of Natural Resources of SC
SDNR	Standard deviation of normalized residuals
SEDAR	SouthEast Data Assessment and Review process
SERFS	Southeast Reef Fish Survey
SFA	Sustainable Fisheries Act; the Magnuson–Stevens Act, as amended
SL	Standard length (of a fish)
SRHS	Southeast Region Headboat Survey, conducted by NMFS-Beaufort laboratory
SPR	Spawning potential ratio
SSB	Spawning stock biomass; mature biomass of males and females
$\mathrm{SSB}_{\mathrm{MSY}}$	Level of SSB at which MSY can be attained
TIP	Trip Interview Program, a fishery-dependent biodata collection program of NMFS
TL	Total length (of a fish), as opposed to FL (fork length) or SL (standard length)
VPA	Virtual population analysis, an age-structured assessment
WW	Whole weight, as opposed to GW (gutted weight)
yr	Year(s)

Appendix B Parameter estimates from the Beaufort Assessment Model

```
# Number of parameters = 378  Objective function value = 31247.9  Maximum gradient component = 9.34439e-005
# Linf:
848.210000000
# K:
0.213000000000
# t0:
-0.670000000000
# len_cv_val:
0.0854616550902
# log_Nage_dev:
 0.545691118755 0.668663623769 1.93673779765 2.01225419287 0.588402357074 0.984273314976 0.242863486989 0.814155061105 0.151527631205 0.106185946366 0.0722043660415
 0.0483002075790 0.0320545134296 0.0211738862574 0.0400073670329
# log_R0:
12.7931621942
# steep:
0.870000000000
# rec_sigma:
0.579787265547
# R_autocorr:
0.00000000000
# log_rec_dev:
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 0.555381427518 0.237910286004 -0.551048495948 -0.361403762505 0.263774203119 0.424314609223 -0.0963162805370 0.162972195569 0.719688997760 0.686264761225 -0.165604493355
 -0.697140068489 0.0159442035697 0.244058155280 0.151713340446 0.465635505872 1.13498525915 1.35061124441 -0.141860138750 -1.08186963489 -1.08832629968 -0.484815996996
 -0.0696770651918 -0.678806193441 -0.672226341675 -0.662543889968 -1.26622591629 -0.967680151202 -0.601006233383
# log_dm_cH_lc:
-0.255329644525
# log_dm_cO_lc:
2.36512249631
# log_dm_HB_lc:
-0.893205418784
# log_dm_GR_lc:
1.79915364088
# log_dm_HB_D_lc:
0.465725584414
# log_dm_CVT_lc:
0.685108339614
# log_dm_cH_ac:
-0.629286885969
# log_dm_HB_ac:
-0.296092016803
# log_dm_GR_ac:
-0.277327889588
# log_dm_CVT_ac:
-0.287559113602
# selpar_A50_cH2:
3.07838174036
# selpar_slope_cH2:
1.03995546921
# selpar_A50_cH3:
4.56029268813
# selpar_slope_cH3:
2.08242880039
# selpar_A50_cO2:
1.28778687654
# selpar_A50_cO3:
3.62000000000
# selpar_slope_cO2:
1.52168099893
# selpar_A502_cO2:
3.36354498321
# selpar_slope2_cO2:
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# selpar_A50_HB1:
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# selpar_slope_HB1:
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# selpar_A50_HB2:
1.77677672654
# selpar_slope_HB2:
2.96468043736
# selpar_A50_HB3:
2.99486383388
# selpar_slope_HB3:
3.72899575571
# selpar_A50_GR3:
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# selpar_slope_GR3:
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# selpar_age1logit_D:
2.28016046282
# selpar_A50_CVT:
2.07633634696
# selpar_slope_CVT:
2.02203214893
# selpar_A502_CVT:
30.0000000000
# selpar_slope2_CVT:
0.00100000000000
# log_q_cH:
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# log_q_HB:
-13.6470440492
# log_q_CVT:
-13.1449015895
# q_RW_log_dev_cH:
 -0.0862011444145 0.270665772582 0.0989062793809 0.0852182620020 0.371122970525 -0.00849815079292 -0.530524005605 -0.234657261720 -0.0808114785004
 0.192623325659 -0.181518578543 -0.0832313368091 0.108840319301 0.205936365148 0.119777575613 -0.144090410533 0.309331395787 -0.192014451058 -0.154333416477
```

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 -0.230591988997 -0.166659833886 -0.289132000395
# q_RW_log_dev_HB:
 -0.180880728771 0.202413500634 0.363426671830 0.133029895573 0.195293476251 0.102273476195 -0.214526376585 0.131571361641 -0.0632198811133 -0.157247972729
 0.246929923213 0.559615701303 0.203859396855 -0.126581457208 -0.103628501027 0.234555624893 -0.150340152156 0.0697683293799 -0.0980280920313 -0.197648861749
 -0.0731729106923 -0.281202220298 0.206671380009 0.253759986280 0.123271476528 -0.602622021992 -0.263882744543 -0.484341309784 0.170641240574 0.458859132367
 0.0988792286756 -0.0886517739547 0.337543777088 -0.163842489068 -0.266893763076
# M_constant:
0.140000000000
# log_avg_F_cH:
-2.08668481287
# log_F_dev_cH:
 -0.888138182512 -1.07839719653 -0.769154441736 -0.739594231342 -0.865827159158 -0.675181137621 -0.649840983512 -0.477708558821 0.0444670382649
 0.177756333381 0.532279576650 0.424231304796 0.722358010433 0.662048401194 0.351021954300 -0.0129589865841 0.197863662271 0.597035218894
 0.671196090718 0.830345231673 0.873234816635 0.937763133282 1.12396850311 0.791884416224 0.390005938290 0.280916305085 0.344220382997 0.294972038055
 0.185621473809 -0.339467737892 -0.175174239377 0.0858175720759 0.0811600506537 -0.0622822952527 -0.00518706531879 -0.220208472703 -0.524017623250
 -0.770539599143 -0.999923628348 -1.34656591370
# log_avg_F_cO:
-4.12430577372
# log_F_dev_cO:
 0.678687906712 0.637226183628 0.936199928868 0.946339440648 0.767727444325 1.03014679528 0.973476315105 1.14126447263 1.57493163545 1.40758835035
 1.75340313125 1.75663636060 1.64234788833 1.68403758501 1.66581851160 1.30710964613 0.843931218870 0.0165063125036 -0.585120331898 -0.851358583360
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 -1.14505413839
# log_avg_F_HB:
-4.38078622898
# log_F_dev_HB:
 -1.12489324965 -0.773367955126 -0.814983508708 -0.0716550899656 -0.150369570542 -0.0703860251903 -0.251837391725 0.260185690487 0.482639114258
 0.695323167770 0.368938905675 0.716272126660 0.279432575449 -0.0329653167033 0.843417096569 -0.164496539886 0.742950312916 0.858939862787
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 -0.0941771523518 0.741193141911 0.413748445891 -0.747638149490 -0.745321663385 -1.09345881126 -1.06795407967 -0.914679910656 -0.809648455080
 -0.805115010364 -0.866231632824 -0.349677430629 -0.300136282264
# log_avg_F_GR:
-1.82504507290
# log_F_dev_GR:
 0.0222227920514 0.360240275756 1.01040675974 1.33255351863 0.530043621006 0.792031685320 0.750882930499 -0.153577392707 0.607417020031
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 0.0501570417080 0.873761778908 1.06917201186 -0.646742233296 -0.239866608865 0.757594532980 -0.201880323134 -0.271738751078 -0.170165324425
# log_avg_F_cH_D:
-5.54200087100
# log_F_dev_cH_D:
 0.543846143396 0.850214496039 0.339111334368 0.153246789512 0.594943075222 0.694393708992 0.494613880437 0.269089507518 0.0770630658523
 0.504973956815 -0.699247871330 -1.07088858275 -0.854382601900 -0.891730762232 0.476587821452 -0.943299144418 -1.62501949241 -1.02371471458
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# log_avg_F_HB_D:
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# log_F_dev_HB_D:
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# log_avg_F_GR_D:
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# log_F_dev_GR_D:
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