SEDAR

SouthEast Data, Assessment, and Review

South Atlantic Red Snapper

SECTION III: Assessment Report

September 2010

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

Table of Contents

1 Workshop Proceedings

1.1 Introduction

1.1.1 Assessment times and places

The SEDAR 24 Assessement Stage I was conducted through a series of webinars between June 18 and August 24, 2010. Specific assessment webinar dates were June 18, July 14, August 6, August 9, August 11, August 13, August 18, August 20, and August 24, 2010.

The SEDAR 24 Assessment Stage II occurred during September 7-29, 2010, and addressed comments on the Assessment report. Specific assessment webinar dates were September 9 and September 21, 2010.

1.1.2 Terms of Reference

Assessment Process I

1. Review any changes in data following the data workshop and any analyses suggested by the data workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.
2. Develop population assessment models that are compatible with available data and recommend which model and configuration is deemed most reliable or useful for providing advice. Document all input data, assumptions, and equations. Include a model configuration consistent with the SEDAR 15 base run and additional recent data observations.
3. Provide estimates of stock population parameters (fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, etc); include appropriate and representative measures of precision for parameter estimates.
4. Characterize uncertainty in the assessment and estimated values, considering components such as input data, modeling approach, and model configuration. Provide appropriate measures of model performance, reliability, and 'goodness of fit'.
5. Provide yield-per-recruit, spawner-per-recruit, and stock-recruitment evaluations including figures and tables of complete parameters.
6. Provide estimates for SFA criteria consistent with applicable FMPs, proposed FMPs and Amendments, other ongoing or proposed management programs, and National Standards. This may include evaluating existing SFA benchmarks, estimating alternative SFA benchmarks, and recommending proxy values; specific criteria for evaluation will be specified in the management summary.
7. Provide declarations of stock status relative to SFA benchmarks, considering both existing and proposed management parameters.
8. Perform a probabilistic analysis of proposed reference points and provide the probability of overfishing at various harvest or exploitation levels and, if the stock is determined to be overfished, the probability of rebuilding within mandated time periods as described in the management summary.
9. Project future stock conditions (biomass, abundance, and exploitation) and develop rebuilding schedules if warranted; include estimated generation time. Stock projections shall be developed in accordance with the following:

a. If stock is overfished:
   F=0, F=current, F=F_{msy}, F_{target} (OY),
   F=$F_{rebuild}$ (max that rebuild in allowed time)
b. If stock is overfishing
   F=$F_{current}$, F=F_{msy}, F= F_{target} (OY)
c. If stock is neither overfished nor overfishing
   F=$F_{current}$, F=F_{msy}, F=F_{target} (OY)

10. Provide recommendations for future research and data collection (field and assessment); be as specific as practicable in describing sampling design and sampling intensity and emphasize items which will improve future assessment capabilities and reliability.
11. Prepare an accessible, documented, labeled, and formatted spreadsheet containing all model parameter estimates and all relevant population information resulting from model estimates and any projection and simulation exercises. Include all data included in assessment report tables and all data that support assessment workshop figures.
12. No later than September 27, 2010, complete the Assessment Workshop Report (Section III of the SEDAR Stock Assessment Report).

Assessment Process II

1. Review comments submitted during the open pre-review period and review prior recommendations and assessment results in light of submitted comments.
2. Consider whether corrections, revisions, or additional analyses are justified.
3. Address submitted comments as appropriate and document results through working papers, addenda to the assessment report, or corrections to the assessment report.

1.1.3 List of Participants

x = present

	Date:	18-Jun	14-Jul	6-Aug	9-Aug	11-Aug	13-Aug	18-Aug	20-Aug	9-Sep	21-Sep
First	Last	Web1	Web2	Web 2b	Web 2c	Web 2d	Web 3	Web 3b	Web 3c	Web	Web
PANELISTS											
Steve	Amick										
Luiz	Barbieri	x	x	x	x			x	x	x	x
Zach	Bowen										
Bobby	Cardin				x	x	x	x			x
Rob	Cheshire	x	x	x	x	x	x	x	x	x	x
Chip	Collier	x	x	x				x	x	x	x
Andy	Cooper	x		x	x			x	x	x	x
Kenny	Fex	x		x					x		
Frank	Hester		x	x	x	x	x	x	x	x	x
Jim	Ianelli	x	x	x	x	x		x		x	x
Paul	Spencer		x			x		x	x	x	
Robert	Johnson							x	x		
Brian	Linton	x	x		x			x	x		x
Mike	Murphy	x	x		x	x				x	x
Behzad	Mahmoudi		x				x	x		x	x
Jennifer	Potts		x								x
Amy	Schueller	x	x	x	x	x	x	x	x	x	x
Kyle	Shertzer	x	x	x	x	x	x	x	x	x	x
Rodney	Smith										
Doug	Vaughan	x	x	x	x	x	x	x	x		x
Erik	Williams	x	x	x	x	x	x	x	x	x	x
John	Quinlan	x	x	x	x	x		x	x	x	x

COUNCIL											
George	Geiger	x	x	x	x	x	x	x	x	x	x
Charlie	Phillips	x		x	x	x	x	x	x	x	x
STAFF											
John	Carmichael	x	x		x	x		x		x	x
Rick	DeVictor		x			x				x	
Kari	Fenske	x	x	x	x	x	x	x	x	x	x
Rachael	Lindsay								x		
Bob	Mahood					x				x	
Julie	Neer	x	x	x	x	x		x	x	x	x
Dale	Theiling	x	x								
Gregg	Waugh							x	x		
Myra	Brouwer									x	
OBSERVERS											
Joey	Ballenger	x	x	x				x			
Dick	Brame		x	x	x	x		x	x	x	x
Chester	Brewer			x							
Richard	Cody	x									
Roy	Crabtree		x								
Scott	Crosson			x	x						
David	Cupka				x						
Mac	Currin							x	x	x	x
Sera	Drevenak	x	x	x	x	x	x	x	x		x
Nick	Farmer							x			x
Ted	Forsgren	x	x	x		x	x			x	x
Bob	Gill			x	x					x	
Rebekah	Hamed				x	x					
Mathew	Hardy		x								

Ben	Hartig			x							
Rusty	Hudson	x	x	x	x	x	x	x	x	x	x
Jimmy	Hull		x		x	x		x	x	x	x
John	Larson		x	x		x	x		x	x	x
Michael	Kennedy	x	x	x	x	x	x				
Anne	Lange	x									
Patrick	Magrady		x								
Jack	McGovern		x			x		x	x	x	x
Jack	Mountford		x								
David	Nelson		x		x	x	x	x	x	x	x
Don	Newhauser		x	x			x				
Bonnie	Ponwith			x							
Marcel	Reichert		x	x						x	x
Jessica	Stephen		x	x							
Andy	Strelcheck		x			x					
Ken	Stump				x						
Jon	Turner		x								
Jim	Waters		x	x			x	x		x	
Karl	Wickstrom		x	x	x	x	x			x	x

1.1.4 List of assessment working papers and reference documents added since the data workshop report

Documents Prepared for the Assessment Workshop		
SEDAR24-AW01	Assessment History of Red Snapper (*Lutjanus campechanus*) in the U.S. Atlantic	Sustainable Fisheries Branch, NMFS 2010
SEDAR24-AW02	The Beaufort Assessment Model (BAM) with application to red grouper1: mathematical description, implementation details, and computer code	Sustainable Fisheries Branch, NMFS 2010
SEDAR24-AW03	Standardized discard rates of U.S. Atlantic red snapper (*Lutjanus campechanus*) from headboat at sea observer data.	Sustainable Fisheries Branch, NMFS 2010
SEDAR24-AW04	Additional age data of south Atlantic red snapper (*Lutjanus campechanus*) from Florida Fish and Wildlife's dependent monitoring program	J. Tunnell, 2010
SEDAR24-AW05	Selectivity of red snapper in the southeast U.S. Atlantic: dome-shaped or flat-topped?	Sustainable Fisheries Branch, NMFS 2010
SEDAR24-AW06	Spawner-recruit relationships of demersal marine fishes: Prior distribution of steepness for possible use in SEDAR stock assessments	Sustainable Fisheries Branch, NMFS 2010
SEDAR24-AW07	Red snapper: Regression and Chapman-Robson estimators of total mortality from catch curve data	Sustainable Fisheries Branch, NMFS 2010
SEDAR24-AW08	Overviews of NMFS fishery-dependent data source surveys referenced in the SEDAR 24 data workshop report	SEDAR 2010, Compiled by J. Carmichael
SEDAR24-AW09	Vulnerability to Capture of Red Snapper (*Lutjanus campechanus*) in the Fisheries of the Southeast United States - a Preliminary look	F. Hester and D. Nelson, 2010
SEDAR24-AW10	South Atlantic Red Snapper Fishery – A Fisherman's Perspective	D. Nelson, 2009
SEDAR24-AW11	Additional information for red snapper selectivity	F. Hester, 2010
SEDAR24-AW12	Selectivity of red snapper in the South Atlantic More than Just Depth	D. Nelson, 2010
SEDAR24-AW13	Pre-review draft of the Assessment Report, public comment version 8-26-10	SEDAR 2010
Reference Documents		
SEDAR24-RD64	Shelf -edge and upper slope reef fish assemblages in the South Atlantic Bight: habitat characteristics, spatial variation, and reproductive behavior	C. M. Schobernd, G. R. Sedberry 2009

SEDAR24-RD65	A survey of the number of anglers and of their fishing effort and expenditures in the coastal recreational fishery of Florida	Ellis et al., 1958

1.2 Terms of Reference Roadmap

Assessment Process I

1. Review any changes in data following the data workshop and any analyses suggested by the data workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.

Data are summarized in the DW report, and updates to data are described in section 2 of the AW report.

2. Develop population assessment models that are compatible with available data and recommend which model and configuration is deemed most reliable or useful for providing advice. Document all input data, assumptions, and equations. Include a model configuration consistent with the SEDAR 15 base run and additional recent data observations.

The assessment models are described in section 3 of the AW report. A continuity run was configured as a sensitivity run of the SEDAR 24 implementation.

3. Provide estimates of stock population parameters (fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, etc); include appropriate and representative measures of precision for parameter estimates.

These estimates are described in section 3 of the AW report.

4. Characterize uncertainty in the assessment and estimated values, considering components such as input data, modeling approach, and model configuration. Provide appropriate measures of model performance, reliability, and 'goodness of fit'.

Uncertainty and performance metrics are described in section 3 of the AW report.

5. Provide yield-per-recruit, spawner-per-recruit, and stock-recruitment evaluations including figures and tables of complete parameters.

These estimates are provided in section 3 of the AW report.

6. Provide estimates for SFA criteria consistent with applicable FMPs, proposed FMPs and Amendments, other ongoing or proposed management programs, and National Standards. This may include evaluating existing SFA benchmarks, estimating alternative SFA benchmarks, and recommending proxy values; specific criteria for evaluation will be specified in the management summary.

Estimated management benchmarks and alternatives are provided in section 3 of the AW report.

7. Provide declarations of stock status relative to SFA benchmarks, considering both existing and proposed management parameters.

Estimates of stock status are provided in section 3 of the AW report.

8. Perform a probabilistic analysis of proposed reference points and provide the probability of overfishing at various harvest or exploitation levels and, if the stock is determined to be overfished, the probability of rebuilding within mandated time periods as described in the management summary.

Probabilistic analyses were performed as part of the rebuilding projections, described in section 3 of the AW report.

9. Project future stock conditions (biomass, abundance, and exploitation) and develop rebuilding schedules if warranted; include estimated generation time. Stock projections shall be developed in accordance with the following:
A) If stock is overfished:
F=0, F=current, F=Fmsy, Ftarget (OY),
F=Frebuild (max that rebuild in allowed time)
B) If stock is overfishing
F=Fcurrent, F=Fmsy, F= Ftarget (OY)
C) If stock is neither overfished nor overfishing
F=Fcurrent, F=Fmsy, F=Ftarget (OY)

Projections are described in section 3 of the AW report. The scenarios examined fall into category A (overfished) and additionally include a scenario that simulates the current moratorium.

10. Provide recommendations for future research and data collection (field and assessment); be as specific as practicable in describing sampling design and sampling intensity and emphasize items which will improve future assessment capabilities and reliability.

Research recommendations are listed in Section IV.

11. Prepare an accessible, documented, labeled, and formatted spreadsheet containing all model parameter estimates and all relevant population information resulting from model estimates and any projection and simulation exercises. Include all data included in assessment report tables and all data that support assessment workshop figures.

An ASCII file of model output was supplied. This file could be read into spreadsheet software such as Excel.

12. No later than September 27, 2010, complete the Assessment Workshop Report (Section III of the SEDAR Stock Assessment Report).

The report will be available on September 29, 2010.

Assessment Process II

1. Review comments submitted during the open pre-review period and review prior recommendations and assessment results in light of submitted comments.

Submitted comments were reviewed and discussed during a webinar on September 9, 2010. A summary of comments is included in section 4.2 of the assessment report.

2. Consider whether corrections, revisions, or additional analyses are justified.

During the September 9, 2010 webinar the assessment panelists discussed whether changes to the model were necessary. Specific changes to the model that were made as a result of comments are detailed in section 4.3 of the assessment report.

3. Address submitted comments as appropriate and document results through working papers, addenda to the assessment report, or corrections to the assessment report.

Section 4.3 of the assessment report contains responses to public comments.

2 Data Review and Update

Processing of data for the assessment is described in the SEDAR 24 Red Snapper Data Workshop Report. This section summarizes the data input for the Beaufort Assessment Model (BAM) base run and describes additional processing prior to and during the AW. A summary of the base run model input is given in Tables 1-5. The units and significant digits are consistent with the input values.

2.1 Additional Data Several data elements were discussed and recommended at the SEDAR 24 DW but were not completed by the DW panel. The headboat discard index was completed and approved for use by the SEDAR 24 AW panel. (Table 1). The upper and lower bounds of the point estimates of discard mortality for the for-hire, private, and commercial line gears were provided and approved for use in sensitivity runs and bootstrap procedures. The sample sizes of annual headboat discard length compositions were provided and approved by the AW panel (Table 2). Additional recreational age samples from Florida were discovered after the SEDAR 24 DW. The AW panel recommended including these additional samples. The age compositions and sample size were updated accordingly (see Table 2 for sample sizes).

2.2 Data Updates and Revisions

2.2.1 Landings An inconsistency in the 1981-85 MRFSS charter landings estimates was discovered during the AW. For these years headboat landings were included with charter landings and represented the primary source for dockside sampling for those years. MRFSS personnel were contacted but were unable to separate the headboat and charter landings for SEDAR. The AW panel recommended applying the geometric mean of the ratio of charter landings to headboat landings from 1986-1991 to the headboat landings for 1981-85 to generate the charter boat landings. These values were combined with the headboat landings to give the for-hire landings estimates (Table 3).

For estimating historical recreational landings, the SEDAR 24 DW applied a ratio method (described later). This method was applied in numbers of fish, which required converting commercial landings from weight to numbers. The SEDAR 24 DW converted commercial line landings from pounds to numbers using an average weight. For early years with poor or no sampling the average weight was borrowed from later years. The SEDAR 24 AW panel agreed with this approach but disagreed with the value used for average red snapper weight because the average size of landed fish has decreased due to the limited number of older fish. Comments from experienced fishermen indicated that the historical recreational landings provided by the DW were too high. The average weight was changed from 4.2 pounds to 9 pounds for 1955-1980, as suggested by fishermen on the panel. The net effect of this change was a reduction in estimated for-hire and private recreational landings from the commercial ratio method. The commercial landings were input the BAM in the units in which they were reported (pounds) and remained unchanged.

The SEDAR 24 AW panelists were concerned about the spike in MRFSS charter and private landings in 1984-85 which were not reflected to the same degree in the other sectors. The panel wanted to preserve the increase in landings but deflate the magnitude of the increase.

Examination of age and length compositions showed evidence of a strong year class recruiting to the fishery but the panel generally thought the MRFSS estimates exaggerated the increase. Several methods were examined for removing the spikes including smoothing options and averaging adjacent years landings. The panel recommended smoothing the MRFSS private landings (1981-2009) using a cubic spline procedure weighted by the inverse of the annual CVs. This was implemented in R programming software with the smoothing parameter (spar) set to 0. The correction of the 1981-85 landings scaled the 1984-85 spike in MRFSS charter landings to the headboat and no smoothing was required. These changes were incorporated in the for-hire and private recreational landings for input into the model (Table 3).

The commercial ratio method estimates of historical recreational landings were recalculated with the adjusted recreational data from 1981-2009 and the adjusted commercial landings in number. The SEDAR 24 AW panel chose to use the median instead of the mean ratio of commercial line to recreational fleets in estimating recreational.

The SEDAR 24 AW panel agreed with the DW CIE reviewer that the commercial ratio method used to estimate historical landings was inadequate to capture the inter-annual variability displayed in the predicted estimates, but it might well approximate the scale of the historical landings. The panel recommended smoothing the historical recreational landings with a cubic spline procedure to be consistent with the smoothing of later data. The smoothing parameter was set slightly higher (0.5) than the smoothing parameter used for the 1981-2009 private landings to reflect the inability of the commercial ratio method to predict the inter-annual variability in landings.

2.2.2 Discards MRFSS charter and private estimates of discards had missing values for several years in the early MRFSS estimates (early 1980s). Analysts felt this would cause problems within the model and that it zero discards was unlikely, particularly following a year with discards and no regulation change. The AW panel considered options for filling in the missing values and recommended the minimum discard estimate from the entire series for each sector be substituted for missing values.

2.2.3 Length and Age Compositions Age compositions were pooled at 20 years. The ageing error matrix was adjusted to a maximum age of 20 years to match the age compositions. Length composition bins were pooled into 3 cm bins from 18cm to 101cm labeled at the midpoint. Lengths less than 18cm were dropped from composition and lengths greater than 101 cm were pooled into the 100 cm bin. The private recreational length composition sample sizes were low and therefore pooled across years to match regulation periods (1983-1991 and 1992-2009). The commercial lines length composition was reduced to just 2007 instead of pooling across years since almost all the samples in the pooled composition came from 2007.

Following advice of the CIE reviews of the draft assessment report, length composition data were removed if corresponding (same fleet, year) age composition data were available. Exceptions were made in favor of length composition data if the sample size of age composition data was small (N<30). However, for commercial diving in 2009m age compositions were retained despite N<30, because age composition N exceeded length composition N.

2.2.4 Life History Generation time is not typically computed at the data workshop but may be required for stock projection.

Generation time (G) was estimated from Eq. 3.4 in Gotelli (1998, p. 57).

$G = \sum l_x b_x x / \sum l_x b_x$

where summation was over ages x=1 through 100 (by which age cumulative survival is essentially zero), l_x is the number of fish at age starting with 1 fish at age 1 and decrementing based on natural mortality only, and b_x is per capita birth rate at age. Because biomass is used as a proxy for reproduction in our model, we substitute the product of $P_{fx}M_{fx}W_x$ for b_x in this equation, where P_{fx} is the proportion female at age, M_{fx} is the proportion of mature females at age, and W_x is expected gonad weight at age. This weighted average of age for mature biomass yields an estimate of 22 years (rounded up from 21.7 yrs.).

References

Gotelli, N. J. 1998. A Primer of Ecology 2nd Edition. Sinauer Associates, Inc., Sunderland, MA, 236p.

	Recreational				Commercial	
	Indices					
Year	Headboat	CV Headboat	Headboat discard	CV-Headboat discard	Lines	CV Lines
1976	2.30	0.07				
1977	2.24	0.07				
1978	2.11	0.05				
1979	2.12	0.06				
1980	1.42	0.05				
1981	2.88	0.05				
1982	1.14	0.05				
1983	1.53	0.05				
1984	1.31	0.05				
1985	1.99	0.05				
1986	0.47	0.05				
1987	0.56	0.05				
1988	0.54	0.06				
1989	0.91	0.05				
1990	0.84	0.05				
1991	0.65	0.06				
1992	0.08	0.07				
1993	0.15	0.07			1.14	0.06
1994	0.26	0.07			0.91	0.05
1995	0.28	0.06			0.92	0.05
1996	0.25	0.07			0.57	0.06
1997	0.27	0.08			0.57	0.06
1998	0.24	0.06			0.63	0.06
1999	0.30	0.06			0.76	0.06
2000	0.42	0.06			0.75	0.06
2001	0.80	0.06			1.22	0.05
2002	0.96	0.06			1.37	0.05
2003	0.53	0.07			1.11	0.05
2004	0.83	0.05			1.44	0.05
2005	0.80	0.06	0.56	0.30	1.23	0.06
2006	0.45	0.06	0.41	0.37	0.61	0.07
2007	0.46	0.06	2.02	0.17	0.66	0.07
2008	1.86	0.05	1.39	0.21	1.20	0.07
2009	2.04	0.05	0.63	0.27	1.92	0.07

Table 1. Red snapper indices of abundance in fish/angler (headboat and headboat discard) and pounds/hook hour (lines). Headboat indices were applied to the for-hire sector.

	Recreational			Commercial			Recreational		Commercial	
	Length Comp. Sample Size (trips)						Age Comp. Sample Size (trips)			
Year	ForHire	Private	Headboat discard	Lines	Diving	Lines discard	ForHire	Private	Lines	Diving
1976	115									
1977	195						~~22~~			
1978	~~208~~						83			
1979	~~91~~						32			
1980	~~93~~						36			
1981	~~208~~						145			
1982	~~155~~						56			
1983	~~308~~	79 pooled					173			
1984	~~406~~						178			
1985	~~364~~			153			161			
1986	~~264~~			90			100			
1987	~~164~~						64			
1988	128			105			~~20~~			
1989	~~172~~						32			
1990	140			98			23			
1991	71			149			~~20~~			
1992	55	165 pooled		89			~~10~~		~~18~~	
1993	107			128			~~14~~			
1994	83			132			~~11~~			
1995	84			145			~~11~~		~~13~~	
1996	~~79~~			~~115~~			58		58	
1997	54			84			~~12~~		144	
1998	92			~~106~~					37	
1999	113			~~153~~	13				156	
2000	94			~~133~~	9				257	124
2001	151			168	~~6~~		~~27~~		~~28~~	30
2002	~~200~~			167			105		~~10~~	
2003	~~191~~			223	12		108		~~10~~	
2004	~~154~~			~~174~~			98		30	
2005	~~118~~		44				130			
2006	~~125~~		30				123			
2007	~~86~~		65	~~142~~		6	51		138	
2008	~~117~~		63				52			
2009	~~210~~		56	~~135~~	~~10~~		359	11	294	17

Table 2. Red Snapper length and age composition sample sizes (number of trips sampled). A strikethrough indicates data that were excluded from the BAM (see text).

	Recreational				Commercial		
	Landings		Discards		Landings		Discards
	Numbers (1000's)				Whole Pounds (1000's)		
Year	ForHire	Private	ForHire	Private	Lines	diving	Lines
1955	48.540	0.000			497.800		
1956	51.832	1.899			484.300		
1957	54.379	4.206			868.900		
1958	57.889	6.894			617.300		
1959	62.884	10.093			662.700		
1960	68.301	13.763			677.100		
1961	74.807	18.067			799.800		
1962	81.321	22.657			662.577		
1963	84.472	26.582			504.840		
1964	85.598	30.115			559.491		
1965	85.480	33.277			656.795		
1966	83.527	35.672			740.057		
1967	79.441	37.195			963.706		
1968	76.530	39.544			1069.332		
1969	78.771	44.904			700.493		
1970	86.525	53.626			640.918		
1971	96.861	64.051			543.433		
1972	104.809	72.901			468.602		
1973	104.716	76.108			387.344		
1974	95.537	72.701			632.507		
1975	82.889	66.731			745.363		
1976	71.743	62.080			619.011		
1977	65.493	61.735			649.273		
1978	65.872	67.536			589.918		
1979	71.612	78.477			409.939		
1980	77.286	89.063			380.596		
1981	78.829	94.852			371.379		
1982	75.868	95.145			306.128		
1983	68.640	89.822	42.281	8.679	310.268		
1984	58.535	80.445	121.668	22.845	248.195	1.317	
1985	47.760	69.978	27.775	63.501	240.971	2.547	
1986	69.519	121.730	0.158	8.679	215.743	0.508	
1987	37.726	52.932	0.158	106.560	187.211	0.030	
1988	59.229	43.885	0.158	48.373	164.123	0.013	
1989	60.094	161.385	0.158	20.038	258.478	0.006	
1990	97.119	178.659	0.158	8.679	215.047	1.859	
1991	98.995	78.195	0.697	35.853	134.032	5.898	
1992	40.286	51.281	17.936	19.492	89.062	9.614	14.233
1993	62.664	98.608	33.397	48.989	189.994	5.611	14.926
1994	44.461	107.354	7.359	62.577	179.615	13.116	20.638
1995	26.656	11.091	24.366	37.932	166.772	10.037	19.437
1996	30.623	31.351	5.053	17.628	130.650	6.153	24.867
1997	45.611	38.345	19.038	8.679	101.232	7.531	27.458
1998	14.948	10.864	8.856	22.970	80.009	8.063	21.106
1999	22.589	13.567	47.594	132.663	80.506	9.974	19.387
2000	22.423	2.386	32.530	223.334	92.109	10.376	18.975
2001	8.681	11.419	32.845	179.264	175.233	18.238	19.014
2002	62.935	3.545	25.886	105.891	163.092	22.097	42.356
2003	18.112	7.585	21.700	139.401	118.803	17.454	13.973
2004	49.363	22.660	37.465	163.953	149.791	19.647	5.170
2005	19.508	57.664	49.435	79.725	118.015	9.344	4.999
2006	21.879	40.185	23.194	115.593	80.291	4.163	7.425
2007	30.115	33.865	118.249	339.128	104.737	7.514	14.759
2008	23.899	16.111	59.846	352.213	240.735	6.304	15.512
2009	24.796	25.390	35.131	183.886	341.241	8.011	20.402

Table 3. Red snapper landings as input into the BAM base model.

Equation/Conversion	units	Linf	k	t0	a	b
von Bertalanffy growth	mm	902.00(4.29)	0.24(0.004)	-0.03(0.03)		
WW-FL Conversion	mm,grams				7.150E-06	3.12
WW-GW conversion	grams				3.142E-05	1.743
Equation/Conversion	model					
von Bertalanffy growth	$L(t)=L_\infty*[1-\exp(-K*(age-t_0))]$					
WW-FL Conversion	W=aFL^b					
WW-GW conversion	Gt=aWt^b					

Table 4. Red snapper input parameters for the von Bertalanffy growth equation, whole weight-fork length conversion, and whole weight-gonad weight conversion. The standard error of the growth parameters are in parentheses.

Age	Percent Females Mature	Natural Mortality
1	22.1%	0.3
2	54.9%	0.17
3	83.9%	0.13
4	95.7%	0.11
5	99.0%	0.1
6	99.8%	0.09
7	99.9%	0.09
8	100.0%	0.08
9	100.0%	0.08
10	100.0%	0.08
11	100.0%	0.08
12	100.0%	0.07
13	100.0%	0.07
14	100.0%	0.07
15	100.0%	0.07
16	100.0%	0.07
17	100.0%	0.07
18	100.0%	0.07
19	100.0%	0.07
20+	100.0%	0.07

Table 5. Red snapper female maturity and age-dependent natural mortality as input to the BAM base run.

3 Stock Assessment Models and Results

Four different models were discussed for red snapper during the Assessment Workshop (AW): the Beaufort statistical catch-age model (BAM), virtual population analysis (VPA), stochastic stock reduction analysis (SSRA), and surplus-production models (ASPIC). The BAM was selected at the AW to be the primary assessment model. This report focuses on the BAM, as well as surplus-production models. In addition, catch curve analysis was used to examine mortality (SEDAR-24-AW07). An SSRA application received preliminary examination by the AW panel, but was not completed in time for this report. Abbreviations used herein are defined in Appendix A.

A VPA was not pursued, for several reasons. A major assumption of VPAs is that catch at age of each fleet in each year is known precisely, which is not a valid assumption for U.S. Atlantic snapper-grouper stocks in general, and the red snapper stock in particular. For example, only seven private recreational (a dominant fleet for red snapper) fishing trips were sampled for red snapper ages prior to 2009. Thus, developing catch-age matrices would require strong assumptions to fill in the data gaps; this obstacle is not insurmountable in principle, but if pursued, should likely be done at a Data Workshop by data providers who are most familiar with the strengths and weaknesses of each data set. Relaxing the assumption of known catch at age was one reason for the advent of statistical catch-age models (e.g., BAM). The AW panel thought that committing its limited resources to the BAM, SSRA, and surplus-production models would be more productive.

A draft assessment report was issued on August 26, 2010. This revised report includes changes that were made in response to comments from the public, AW panelists, and an independent (CIE) reviewer. Although a second draft was not issued for additional comment, all changes in methods and base-run results were reviewed and accepted by the AW panel during its final webinar on September 21, 2010.

3.1 Model 1: Beaufort Assessment Model

3.1.1 Model 1 Methods

3.1.1.1 **Overview** The primary model in this assessment was the Beaufort statistical catch-age model (BAM). The model was implemented with the AD Model Builder software (ADMB Foundation 2009), and its structure and equations are detailed in SEDAR-24-RW-01. In essence, a statistical catch-age model simulates a population forward in time while including fishing processes (Quinn and Deriso 1999; Shertzer et al. 2008*a*). Quantities to be estimated are systematically varied until characteristics of the simulated populations match available data on the real population. Statistical catch-age models share many attributes with ADAPT-style tuned and untuned VPAs.

The method of forward projection has a long history in fishery models. It was introduced by Pella and Tomlinson (1969) for fitting production models and then used by Fournier and Archibald (1982), Deriso et al. (1985) in their CAGEAN model, and Methot (1989; 2009) in his stock-synthesis model. The catch-age model of this assessment is similar in structure to the CAGEAN and stock-synthesis models. Versions of this assessment model have been used in previous SEDAR assessments of reef fishes in the U.S. South Atlantic, such as red porgy, black sea bass, tilefish, snowy grouper, gag grouper, greater amberjack, vermilion snapper, Spanish mackerel, and red grouper, as well as in the previous (SEDAR-15) benchmark assessment of red snapper.

3.1.1.2 **Data Sources** The catch-age model included data from four fleets that caught southeastern U.S. red snapper: commercial lines (primarily handlines), commercial dive, recreational for-hire (headboats and charterboats), and recreational private boats. The model was fit to data on annual landings (in units of 1000 lb whole weight for commercial fleets, 1000 fish for recreational fleets), annual discard mortalities (in units of 1000 fish for commercial lines and recreational fleets), annual length compositions of landings, annual age compositions of landings, annual length compositions of discards, three fishery dependent indices of abundance (commercial lines, headboat, and headboat discards). Not all of the above data sources were available for all fleets in all years. Data used in the model are tabulated in the DW report and in §III(2) of this report.

3.1.1.3 **Model Configuration and Equations** Model structure and equations of the BAM are detailed in SEDAR-24-RW01, along with AD Model Builder code for implementation. The assessment time period was 1976–2009, with an initialization period of 1955–1975. A general description of the assessment model follows:

Natural mortality rate The natural mortality rate (M) was assumed constant over time, but decreasing with age. The form of M as a function of age was based on Lorenzen (1996). The Lorenzen (1996) approach inversely relates the natural mortality at age to mean weight at age W_a by the power function $M_a = \alpha W_a^{\beta}$, where α is a scale parameter and β is a shape parameter. Lorenzen (1996) provided point estimates of α and β for oceanic fishes, which were used for this assessment. As in previous SEDAR assessments, the Lorenzen estimates of M_a were rescaled to provide the same fraction of fish surviving through the oldest observed age (54 years) as would occur with constant $M = 0.08$ from the DW. This approach using cumulative mortality is consistent with the findings of Hoenig (1983) and Hewitt and Hoenig (2005).

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 $1 - 20^+$, where the oldest age class 20^+ allowed for the accumulation of fish (i.e., plus group).

Initialization period Initial (1955) numbers at age assumed the stable age structure computed from expected recruitment and the initial, age-specific total mortality rate. That initial mortality was the sum of natural mortality and fishing mortality, where fishing mortality was the product of an initial fishing rate (F_{init}) and catch-weighted average selectivity. The initial fishing rate was chosen using an iterative approach. First, the assessment model was run using the nearly complete catch history (starting from the year 1901) provided by the DW, to indicate a plausible level of biomass depletion in 1955 ($B_{1955}/B_0 \approx 0.8$). Then, F_{init} was adjusted to approximate that level; the value used in the base model run was $F_{init} = 0.02$.

The initial recruitment in 1955 was assumed to be the expected value from the spawner-recruit curve. For the remainder of the initialization period (1955–1975), recruitment was permitted to deviate from the spawner-recruit curve. However, without CPUE or age/length composition data prior to 1976, there is little information to estimate those historic recruitment deviations with accuracy. Thus, the estimates of historic recruitment should not be considered reliable. Instead, the deviations were permitted to allow the model maximum flexibility to match CPUE and age/length composition data near the onset of the assessment period (1976–2009), as well as to minimize influence of the historic (initialization) period on the estimated spawner-recruit curve and thus management benchmarks. For this latter reason, recruitment deviations were estimated in two stanzas, 1956–1974 and 1975–2009. The log recruitment deviations in the early stanza were not constrained to sum to zero (although values were penalized for deviating from zero to provide some response in the likelihood surface). The likelihood component used to estimate the spawner-recruit curve included recruitment deviations only from the second stanza.

Growth Mean size at age of the population (total length, TL) was modeled with the von Bertalanffy equation, and weight at age (whole weight, WW) was modeled as a function of total length (Figure 3.1, Table 3.1). Parameters of growth and conversions (TL-WW) were estimated by the DW and were treated as input to the assessment model. For fitting length composition data, the distribution of size at age was assumed normal with standard deviation estimated by the assessment model. Assuming a constant standard deviation provided age-specific coefficients of variation that decreased until reaching an asymptote (where growth saturated), as was observed in size at age data. For fishery length composition data collected under a size limit regulation, the normal distribution of size at age was truncated at the size limit, such that length compositions of landings would include only fish of legal size. Similarly, length compositions of discards would include only fish below the size limit. Mean length at age of landings and discards were computed from these truncated distributions, and thus average weight at age of landings and discards would differ from those in the population at large.

Sex ratio The sex ratio was assumed to be 50:50, as suggested by the DW.

Female maturity Female maturity was modeled with a logistic function; parameters for this model were provided by the DW and treated as input to the assessment model (Table 3.1).

Spawning biomass Spawning biomass was modeled as total gonad biomass of mature females measured at the time of peak spawning. For red snapper, peak spawning was considered to occur at the end of July.

Ideally, recruitment would be predicted from population fecundity, but the DW believed that fecundity data were too sparse for use in the assessment. Without data on fecundity, many assessments apply the proxy of spawning biomass. Often, spawning biomass is defined as total body weight of mature females, as was done in SEDAR-15. However, in this assessment, the DW recommended total gonad biomass of mature females as a more direct measure of egg production.

Recruitment Expected recruitment of age-1 fish was predicted from spawning biomass using the Beverton–Holt spawner-recruit model. Steepness, h, is a key parameter of this model, and unfortunately it is often difficult to estimate reliably (Conn et al. 2010). In this assessment, many initial attempts to estimate steepness resulted in a value near its upper bound of 1.0, indicating that the data were insufficient for estimation. Thus, steepness was fixed at $h = 0.85$, the mode of a beta distribution estimated through meta-analysis (SEDAR-24-AW06).

Annual variation in recruitment was assumed to occur with lognormal deviations. The spawner-recruit curve was estimated using the lognormal residuals only from years when composition data could provide information on year-class strength (1975–2009) (as described above in the *Initialization period* section).

Landings Time series of landings from four fleets were modeled: commercial lines, commercial dive, for-hire, and private 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 DW provided observed landings back to the first assessment year (1955) for each fleet. However, sampling of headboats began in 1972 and other recreational sectors in 1981. Thus, historic landings of for-hire and private fleets were estimated indirectly by the DW using a ratio method, subsequently refined by the AW. Historic landings were considered (and treated) in this assessment as a primary source of uncertainty.

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 probabilities. Discards were assumed to have fleet-specific mortality probabilities, as suggested by the DW (commercial lines, 0.48; for-hire, 0.41; private, 0.39). Annual discard mortalities, as fit by the model, were computed by multiplying total discards (tabulated in the DW report) by the fleet-specific release mortality probability. For for-hire and private fleets, discard time series were assumed to begin in 1983, with the start of the 12-inch size limit; for the commercial lines fleet, discards were modeled starting in 1992 with the 20-inch size limit. Discards from the commercial dive fleet were assumed negligible and not modeled.

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 Selectivity curves applied to landings were estimated using a parametric approach. This approach applies plausible structure on the shape of the curves, and achieves greater parsimony than occurs with unique parameters for each age. Flat-topped selectivities were modeled as a two-parameter logistic function. Dome-shaped selectivities were modeled by combining two logistic functions: a two-parameter logistic function to describe the ascending limb of the curve, and a three-parameter logistic function to describe the descending limb. The two functions were joined at the age of full selection, which was fixed for each model run. Choice of this age was made iteratively, first by fitting all fleets with flat-topped selectivities to indicate the onset age of full selection, and then by comparing fits (likelihood values from age compositions) of dome-shaped selectivities with the peak near that onset. To model landings, the AW Panel recommended flat-topped selectivity for commercial lines and dome-shaped selectivity for commercial dive, for-hire, and private recreational fleets.

The assessment panel devoted substantial discussion and exploration to the pattern (flat-topped or dome-shaped) of selectivity at age. Several working papers (SEDAR24-AW05, SEDAR24-AW09, SEDAR24-AW12) helped guide the panel's decisions by providing insight into selectivity based on length and age compositions, depth distributions of fishing effort, skill levels of fishermen, and how circumstances contrasted between the Atlantic and Gulf of Mexico. The choice of flat-topped selectivity for commercial lines landings and dome-shaped for all others was based on several criteria. Two related considerations were the fleet-specific depths of fishing effort and the distribution of age at depth. In general, the commercial lines fleet fish in deeper water than other fleets, and although there was only weak correlation between depth and age of older fish (5^{+}), younger fish (1–5) were more readily caught in shallower depths (SEDAR24-AW05). It was also suggested that commercial gear and fishermen can better handle larger fish (SEDAR24-AW12). Catch curve data were consistent with the hypothesis that older fish are more vulnerable to the commercial lines fleet than to recreational fleets (SEDAR24-AW05, SEDAR24-AW07).

Selectivity of each fleet was fixed within each block of size-limit regulations, but was permitted to vary among blocks where possible or reasonable. Fisheries experienced three blocks of size-limit regulations (no limit prior to 1983, 12-inch limit during 1983–1991, and 20-inch limit during 1992–2009). 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 private recreational fleet had little age or length composition data, this fleet assumed no change in selectivity with implementation of the 12-inch size limit, but did allow a change with the 20-inch limit. Furthermore, the descending limb of this selectivity mirrored that of the for-hire fleet. With no composition data for commercial dive prior to the last regulatory block, commercial dive selectivity was assumed constant over time. Commercial lines selectivities in the first and second regulatory blocks were set equal, consistent with the DW recommendation that the 12-inch size limit had little effect on commercial line fishing. Selectivities of fishery dependent indices were the same as those of the relevant fleet.

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 for-hire discard selectivity was that the value for age 1 was estimated, age 2 was assumed to have full selection, and selectivity for each age 3^+ was set equal to the age-specific probability of being below the size limit, given the estimated normal distribution of size at age. In this way, selectivity would change with modification in the size limit. A similar approach was taken for commercial line discard selectivity, but distinct values for age 1 and age 2 were estimated, age 3 was assumed to have full selection, and ages 4^+ were set to probabilities of being below the size limit. For private recreational discards, no age or length composition data were available, and thus selectivity of those discards mirrored that of the for-hire fleet.

Indices of abundance The model was fit to three fishery dependent indices of relative abundance (headboat 1976–2009; headboat discards 2005–2009; and commercial lines 1993–2009). Predicted indices were conditional on selectivity of the corresponding fleet (for-hire, for-hire discards, or commercial lines) and were computed from abundance at the midpoint of the year or, in the case of commercial lines, biomass. The for-hire discard index, although short in duration, tracks young fish and was included as a measure of recruitment strength at the end of the assessment period.

Catchability In the BAM, catchability scales indices of relative abundance to estimated population abundance at large. Several options for time-varying catchability were implemented in the BAM following recommendations of the 2009 SEDAR procedural workshop on catchability (SEDAR Procedural Guidance 2009). In particular, the BAM allows for density dependence, linear trends, and random walk, as well as time-invariant catchability. Parameters for these models could be estimated or fixed based on *a priori* considerations. The AW considered time-varying catchability, but did not believe that the data were sufficient for estimating annual variation, particularly without reliable fishery independent indices of abundance. However, the AW did believe that catchability has generally increased over time as a result of improved technology (SEDAR Procedural Guidance 2009) and as estimated for reef fishes (including red snapper) in the Gulf of Mexico (Thorson and Berkson 2010). Thus, the AW recommended linearly increasing catchability with a slope in the range of [0%, 4%]. The increase was assumed to begin with the first year of the index (1976 for headboat; 1993 for commercial lines) and continue until 2003, after which catchability was assumed constant. Choice of the year 2003 was based on recommendations from fishermen regarding when the effects of Global Positioning Systems likely saturated in the southeast U.S. Atlantic (SEDAR 2009). Catchability of the headboat discard index, which started in 2005, was assumed constant.

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. Computed benchmarks included MSY, fishing mortality rate at MSY (F_{MSY}), and spawning biomass at MSY (SSB_{MSY}). In this assessment, spawning biomass measures total gonad weight of mature females. These benchmarks are conditional on the estimated selectivity functions and the relative contributions of each fleet's fishing mortality. The selectivity pattern used here was the effort-weighted selectivities at age, with effort from each fishery (including discard mortalities) estimated as the full F averaged over the last three years of the assessment.

Fitting criterion The fitting criterion was a penalized likelihood approach in which observed landings and 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. Length and age composition data were fit using multinomial likelihoods.

The model includes the capability for each component of the likelihood to be weighted by user-supplied values (for instance, to give more influence to desired data sources). For data components, these weights were applied by either adjusting CVs (lognormal components) or adjusting effective sample sizes (multinomial components). In this application to red snapper, CVs of landings and discards (in arithmetic space) were assumed equal to 0.05, to achieve a close fit to these time series yet allowing some imprecision. In practice, the small CVs are a matter of computational convenience, as they help achieve the desired result of close fits to the landings, while avoiding having to solve the Baranov equation iteratively (which is complex when there are multiple fisheries). Weights on other data components (indices, age/length compositions) were adjusted iteratively, starting from initial weights as follows. The CVs of indices were set equal to the values estimated by the DW. Effective sample sizes of the multinomial components were assumed equal to the number of trips sampled annually, rather than the number of fish measured, reflecting the belief that the basic sampling unit occurs at the level of trip. These initial weights were then adjusted until standard deviations of normalized residuals were near 1.0 (SEDAR24-RW03).

In addition, a lognormal likelihood was applied to the spawner-recruit relationship. The compound objective function also included several penalties or prior distributions (e.g., on estimated parameters selectivity functions). Penalties or 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.

Configuration of base run The base run was configured as described above with data provided by the DW. Some key features include 1) discard mortalities of 0.48 for commercial lines fleet, 0.41 for the for-hire fleet, and 0.39 for the private recreational fleet; 2) age-dependent natural mortality scaled to M=0.08; 3) steepness fixed at $h = 0.85$; 4) linearly increasing catchability with slope of 2% until 2003 and constant after then; and 5) dome-shaped selectivities of commercial dive, for-hire, and private recreational landings (for-hire and private selectivities assumed to saturate at 0.3), and flat-topped selectivity of commercial lines. The AW did not consider this configuration to represent reality better than all other possible configurations, and attempted to portray uncertainty in point estimates through sensitivity analyses and through a Monte-Carlo/bootstrap approach (described below).

Sensitivity and retrospective analyses Sensitivity of results to some key model inputs and assumptions was examined through sensitivity analyses. These model runs, as well as retrospective analyses, vary from the base run as follows.

- S1: Low M at age (Lorenzen estimates rescaled so as to provide the same cumulative survival through the oldest observed age as would constant $M = 0.05$)
- S2: High M at age (Lorenzen estimates rescaled so as to provide the same cumulative survival through the oldest observed age as would constant $M = 0.12$)
- S3: High age-1 M ($M_1 = 0.6$, and M_{2+} scaled from the base run such that M_{1+} provides the same cumulative survival through the oldest observed age as would constant $M = 0.08$)
- S4: Low discard mortality probabilities (commercial lines $\delta = 0.34$, for-hire $\delta = 0.29$, private $\delta = 0.27$)
- S5: High discard mortality probabilities (commercial lines $\delta = 0.62$, for-hire $\delta = 0.54$, private $\delta = 0.52$)
- S6: Steepness $h = 0.75$
- S7: Steepness $h = 0.95$
- S8: Steepness h estimated
- S9: Standard deviation of recruitment residuals in log space $\sigma = 0.4$
- S10: Standard deviation of recruitment residuals in log space $\sigma = 0.8$
- S11: Constant catchability
- S12: Linearly increasing catchability with slope of 4% until 2003 and constant after then
- S13: Random walk catchability for each index of abundance (standard deviation of 0.1)

- S14: Ageing error matrix included
- S15: Continuity run 1. Features include linearly increasing catchability with slope of 2% throughout the entire assessment period, and flat-topped selectivities for for-hire and recreational fleets. In this run, spawning biomass is based on gonad weight.
- S16: Continuity run 2. Features include linearly increasing catchability with slope of 2% throughout the entire assessment period, flat-topped selectivities for for-hire and recreational fleets, and spawning biomass based on mature female body weight rather than gonad weight.
- S17: Starting year of the model was 1976. Initial (1976) numbers at age were estimated in this sensitivity run, with penalized deviation from the stable age structure that corresponded to the initialization fishing mortality rate ($F_{init} = 0.12$, the geometric mean of base-run full F in years prior to 1976).
- S18: Starting year of the model was 1986. Initial (1986) numbers at age were estimated in this sensitivity run, with penalized deviation from the stable age structure that corresponded to the initialization fishing mortality rate ($F_{init} = 0.19$, the geometric mean of base-run full F in years prior to 1986).
- S19: Initialization (1955) fishing mortality rate $F_{init} = 0.01$, which provides an approximate initial depletion level of $B_{1955}/B_0 \approx 0.9$.
- S20: Initialization (1955) fishing mortality rate $F_{init} = 0.04$, which provides an approximate initial depletion level of $B_{1955}/B_0 \approx 0.6$.
- S21: Low landings and discards for for-hire and private recreational fleets (historic values equal to 0.3 (for-hire) or 0.2 (private) times the base levels, 1981–2009 values equal to point estimates minus 1 standard error)
- S22: High landings and discards for for-hire and private recreational fleets (historic values equal to 1.7 (for-hire) or 1.8 (private) times the base levels, 1981–2009 values equal to point estimates plus 1 standard error)
- S23: Low landings and discards for commercial lines and dive fleets (values based on point estimates minus 1 standard error)
- S24: High landings and discards for commercial lines and dive fleets (values based on point estimates plus 1 standard error)
- S25: Headboat index de-emphasized by halving its likelihood weight
- S26: Headboat index emphasized by doubling its likelihood weight
- S27: Commercial lines index de-emphasized by halving its likelihood weight
- S28: Commercial lines index emphasized by doubling its likelihood weight
- S29: Age composition data de-emphasized by halving their likelihood weights
- S30: Age composition data emphasized by doubling their likelihood weights
- S31: Length composition data de-emphasized by halving their likelihood weights
- S32: Length composition data emphasized by doubling their likelihood weights
- S33: Flat-topped commercial lines selectivity; descending limb of recreational selectivities saturates at 0.1
- S34: Flat-topped commercial lines selectivity; descending limb of recreational selectivities saturates at 0.5
- S35: Dome-shaped commercial lines selectivity, descending limb saturates at 0.75; descending limb of recreational selectivities saturates at 0.1

- S36: Dome-shaped commercial lines selectivity, descending limb saturates at 0.75; descending limb of recreational selectivities saturates at 0.3
- S37: Dome-shaped commercial lines selectivity, descending limb saturates at 0.75; descending limb of recreational selectivities saturates at 0.5
- S38: Dome-shaped commercial lines selectivity, descending limb saturates at 0.5; descending limb of recreational selectivities saturates at 0.1
- S39: Dome-shaped commercial lines selectivity, descending limb saturates at 0.5; descending limb of recreational selectivities saturates at 0.3
- S40: Dome-shaped commercial lines selectivity, descending limb saturates at 0.5; descending limb of recreational selectivities saturates at 0.5
- S41: Compound extreme 1: high bound on natural mortality (S2), low bounds on discard mortalities (S4), constant catchability (S11), lowest dome-shaped selectivities (S238)
- S42: Compound extreme 2: low bound on natural mortality (S1), high bounds on discard mortalities (S5), increasing catchability of 4% (S12), highest selectivities (S34)
- S43: Retrospective run with data through 2008
- S44: Retrospective run with data through 2007
- S45: Retrospective run with data through 2006
- S46: Retrospective run with data through 2005

Retrospective analyses should be interpreted with caution, because several data sources were removed by the successive truncations. Age composition data from the private fleet were available only in 2009, and were therefore removed from all retrospective runs. Length composition data from commercial lines discards were available only in 2007, and were therefore removed from runs S45 and S46. Consequently, in those two runs, the discard selectivity of commercial lines was fixed at the ogive of the base run. The headboat discard index began in 2005 and thus, as a single-year index in run S46, provided no information on relative abundance.

3.1.1.4 **Parameters Estimated** The model estimated annual fishing mortality rates of each fishery, selectivity parameters, catchability coefficients associated with indices, asymptotic recruitment of the spawner-recruit model, annual recruitment deviations, and standard deviation of size at age. Estimated parameters are described mathematically in the document, SEDAR-24-RW01.

3.1.1.5 **Catch Curve Analysis** Catch curve analysis was conducted to provide estimates of total mortality ($Z = F + M$) from age composition data. These analyses are detailed in SEDAR-24-AW07. In short, catch curves were represented by synthetic cohorts (i.e., proportions at age within years) and limited true cohorts, and were analyzed using the Chapman–Robson estimator and using linear regression of the log-transformed proportions at age. Catch curve analysis requires the assumptions that mortality and catchability remain constant with age, and when using synthetic cohorts, that recruitment is constant. These assumptions are rarely met, if ever, by fish populations. Thus, the application of catch curve analysis here is for diagnostic purposes, primarily for comparing the general range of estimated mortality rates of catch curves with those of other models.

3.1.1.6 **Per Recruit and Equilibrium Analyses** Static spawning potential ratio (static SPR) of each year was computed as the asymptotic spawners per recruit given that year's fishery-specific *F*s and selectivities, divided by spawners per recruit that would be obtained in an unexploited stock. In this form, static SPR ranges between zero and one, and it represents SPR that would be achieved under an equilibrium age structure given the year-specific F (hence the word *static*).

Yield per recruit and spawning potential ratio were computed as functions of F, as were equilibrium landings and spawning biomass. Equilibrium landings and discards were also computed as functions of biomass B, which itself is a function of F. As in computation of MSY-related benchmarks (described in §3.1.1.7), per recruit and equilibrium analyses applied the most recent selectivity patterns averaged across fisheries, weighted by each fleet's F from the last three years (2007–2009).

3.1.1.7 **Benchmark/Reference Point Methods** In this assessment of red snapper, the quantities F_{MSY}, SSB_{MSY}, B_{MSY}, and MSY were estimated by the method of Shepherd (1982). In that method, the point of maximum yield is identified from the spawner-recruit curve and parameters describing growth, natural mortality, maturity, and selectivity. The value of F_{MSY} is the F that maximizes equilibrium landings.

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

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

where R_0 is virgin recruitment, h is steepness, and Φ_F is spawning potential ratio given growth, maturity, and total mortality at age (including natural, fishing, and discard 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 (excluding discards), and the estimate of MSY is that ASY. The estimate of SSB_{MSY} follows from the corresponding equilibrium age structure, as does the 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 fishery, where each fishery-specific selectivity was weighted in proportion to its corresponding estimate of F averaged over the last three years (2007–2009). If the selectivities or relative fishing mortalities among fleets were to change, so would the estimates of MSY and related benchmarks.

The maximum fishing mortality threshold (MFMT) is defined by the SAFMC as F_{MSY}, and the minimum stock size threshold (MSST) as $\text{MSST} = (1-M)\text{SSB}_{\text{MSY}}$ (Restrepo et al. 1998), with constant M here equated to 0.08. Overfishing is defined as $F >$ MFMT and overfished as SSB $<$ MSST. Current status of the stock is represented by SSB in the latest assessment year (2009), and current status of the fishery is represented by the geometric mean of F from the latest three years (2007–2009). The geometric mean, rather than arithmetic, was chosen because it tends to be more robust to outliers.

In addition to the MSY-related benchmarks, proxies were computed based on per recruit analyses. These proxies include $F_{30\%}$, $F_{40\%}$, and $F_{50\%}$ along with their associated yields. The values of $F_{X\%}$ are defined as those *F*s 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 the spawner-recruit relationship cannot be estimated reliably. Mace (1994) recommended $F_{40\%}$ as a proxy; however, later studies have found that $F_{40\%}$ is too high of a fishing rate across many life-history strategies (Williams and Shertzer 2003; Brooks et al. 2009) and can lead to undesirably low levels of biomass and recruitment (Clark 2002).

3.1.1.8 **Uncertainty and Measures of Precision** Uncertainty was in part examined through use of multiple models and sensitivity runs. For the base run of the catch-age model (BAM), uncertainty in results and precision of estimates was computed more thoroughly through a mixed Monte Carlo and bootstrap (MCB) approach. 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 (Restrepo et al. 1992; Legault et al. 2001; SEDAR 2004; 2009). The approach translates uncertainty in model input into uncertainty in model output, by fitting the model many times with different values of "observed" data and key input parameters. A chief advantage of the approach is that the results describe a range of possible outcomes, so that uncertainty is characterized more thoroughly than it could be by any single fit or handful of sensitivity runs. A minor disadvantage of the approach is that computational demands are relatively high.

In this assessment, the BAM was successively re-fit n=3000 trials that differed from the original inputs by bootstrapping on data sources, and by Monte Carlo sampling of natural mortality, discard mortality, spawner-recruit parameters (h and σ), catchability increase, initialization fishing rate, recreational selectivity, and historical recreational landings (implementations described below). This number of trials was sufficient for convergence of standard errors in management quantities (Figure 3.2).

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.

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

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

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

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

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

Natural mortality Point estimates of natural mortality ($M = 0.08$) were provided by the DW, but with some uncertainty. To carry forward this source of uncertainty, Monte Carlo sampling was used to generate deviations from the point estimate. A new M value was drawn for each MCB trial from a truncated normal distribution (range [0.05, 0.12]) with mean equal to the point estimate ($M = 0.08$) and standard deviation set to provide a lower 95% confidence limit at 0.05 (the low end of the DW range). Each realized value of M was used to scale the age-specific Lorenzen M, as in the base run.

Discard mortalities Similarly, for discard mortalities, new δ values were drawn from normal distributions for each fleet, for each MCB trial. Each distribution was centered on the point estimates provided by the DW (commercial lines, 0.48; for-hire, 0.41; private, 0.39) and had standard deviations computed by the AW (~ 0.05 for each fleet). The distributions were truncated at their 95% confidence limits (commercial lines, [0.34, 0.62]; for-hire, [0.29, 0.54]; private, [0.27, 0.52]).

Spawner-recruit model Steepness was drawn from the beta distribution $\beta(5.50, 1.81)$, as estimated through meta-analysis (SEDAR24-AW06). That distribution was truncated to the range [0.6, 0.999], in part because the model performed better at the higher values, but also because that range was believed to capture the bulk of uncertainty in steepness for this stock. Standard deviation (σ) of recruitment residuals in log space, as used in the lognormal likelihood to estimate the spawner-recruit model, was drawn from a uniform distribution in the range [0.4, 0.8].

Increase in catchability The slope of linear increase in catchability was drawn from a uniform distribution in the range [0%, 4%]. In all cases, catchability was assumed constant after 2003.

Initial fishing mortality rate The initial fishing mortality rate (F_{init}) was drawn from a uniform distribution in the range [0.01, 0.04], which provided an initial biomass depletion level (B_{1955}/B_0) on the approximate range of [0.6, 0.9].

For-hire and private recreational selectivity The asymptote of the descending limb of the for-hire and private recreational selectivity was drawn at random from a uniform distribution spanning the range [0.1, 0.5].

Historical recreational landings The DW provided historical recreational (for-hire and private) landings estimates using ratios to commercial landings (in addition, the private fleet landings were interpolated linearly to zero in 1950). Uncertainty in these ratios was based on the percentiles of observed ratios from which the point estimates (medians) were generated. With each MCB run, a uniform random number, centered on one, was drawn and applied as a multiplier to the historical time series (this approach conveniently preserves the smoothed structure). The bounds of the uniform distributions were computed using the distance from the median of either the 20^{th} or 80^{th} percentile, whichever was greater, and were then standardized around the value of one (from the median). For for-hire historical landings, the multiplier was drawn from the range [0.3, 1.7], and for private historical landings, the multiplier was drawn from the range [0.2, 1.8].

3.1.1.9 **Acceptable Biological Catch** When a stock is not overfished, acceptable biological catch (ABC) could be computed through probability-based approaches, such as that of Shertzer et al. (2008*b*), designed to avoid overfishing. However, for overfished stocks, rebuilding projections would likely supersede other approaches for computing ABCs.

3.1.1.10 **Projection Methods** Projections were run to predict stock status in years after the assessment, 2010–2050. In most projections, this time frame included one year (2010) with fishing at the current fishing rate, but with landings converted to discards (to reflect the 2010 moratorium on red snapper), and the remaining years at the projection rate.

The structure of the projection model was the same as that of the assessment model, and parameter estimates were those from the assessment results. Time-varying quantities, such as fishery selectivity curves, were fixed to the most recent values of the assessment period. Fully selected F was apportioned between landings and discard mortalities according to the selectivity curves averaged across fisheries, using geometric mean F from the last three years of the assessment period.

Central tendencies of SSB (mid-year), 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 SSB_{MSY}. Uncertainty in future time series was quantified through projections that extended the Monte Carlo/Bootstrap (MCB) fits of the stock assessment model.

Initialization of projections Fishing rates that define the projections were assumed to start in 2011, which is the earliest year management could react to this assessment. Because the assessment period ended in 2009, the projections required an initialization period (2010). Point estimates of initial abundance at age in the projection (start of 2010), other than at age 1, were taken to be the 2009 estimates from the assessment, discounted by 2009 natural and fishing mortalities. The initial abundance at age 1 was computed using the estimated spawner-recruit model and the 2009 estimate of SSB. The fully selected fishing mortality rate applied in the initialization period was $F = F_{\text{current}}$ (geometric mean of fully selected F during 2007–2009), but without mortality from the commercial dive fleet.

Moratorium In 2010, a moratorium on red snapper was implemented. This was modeled in a three-step process. First, the current fishing rates by fleet, discounted by expected reduction in fishing effort, were applied to estimate landings by fleet. Second, all caught fish were assumed released, and fleet-specific discard mortality probabilities were applied to convert the potential landings to dead discards. Third, an optimization procedure was used to estimate the fishing mortality rates that produce those dead discards, as well as the mortality rates associated with undersized fish. That is, six mortality rates were estimated: the Fs of legal-sized discards and undersized discards from commercial lines, for-hire, and private recreational fleets. These rates were then applied to compute the total dead discards and total mortality rates used to project the population forward in time. For most projection scenarios (described below), these mortality rates applied only in 2010, but one projection scenario (Scenario 7) applied the moratorium mortality rates throughout.

Because red snapper are but one species of a multispecies fishery, the AW believed that the moratorium on red snapper would not have a large effect on fishing effort. Thus fishing effort during the moratorium was assumed to be 80%–100% of current fishing effort. The central-tendency projections used the midpoint (90%) of that range.

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 natural mortality and in discard mortality, as well as in estimated quantities such as spawner-recruit parameters, selectivity curves, and in initial (start of 2010) abundance of ages 2^+. Initial and subsequent recruitment values were generated with stochasticity using a Monte Carlo procedure, in which the estimated Beverton–Holt model of each MCB fit was used to compute mean annual recruitment values ($\bar{R}_y$).

Variability was added to the mean values by choosing multiplicative deviations at random from a lognormal distribution,

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

Here ϵ_y was drawn from a normal distribution with mean 0 and standard deviation σ, where σ is the standard deviation from the base assessment model. In addition, moratorium fishing effort relative to the current level was drawn for each replicate projection from a uniform distribution spanning the range [0.8, 1.0].

The procedure generated 30,000 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 stochastic recruitment streams and stochastic effort reduction during the moratorium. Precision of projections was represented graphically by the 5^{th} and 95^{th} percentiles of the replicate projections.

Rebuilding time frame Based on the 2008 (SEDAR-15) benchmark assessment of red snapper, a rebuilding plan is now under consideration by the SAFMC. Under this rebuilding plan, year one is 2010 and the target time frame for rebuilding is by the start of 2045 (i.e., during the year 2044). Rebuilding is defined by the criterion that X% of projection replicates achieve stock recovery (i.e., SSB ≥ SSB_{MSY}).

The rebuilding time frame was re-examined based on results of this assessment. Under U.S. regulations, if a stock can rebuild within 10 years under $F = 0$, the maximum allowable rebuilding time frame is 10 years. If not, the maximum allowable rebuilding time frame is one generation time (estimated to be 22 years; see §III(2)) plus the time required to achieve rebuilding under $F = 0$. This time was based on the proportion $X = 50\%$ of successfully rebuilt replicates.

Projection scenarios Ten constant-F projection scenarios were considered. In each, the fishing rate in 2010 applied the moratorium based on F_{current}(as described above). The F_{rebuild} is defined as the maximum F that achieves rebuilding (0.5, 0.7, or 0.9 probability) in the allowable time frame.

- Scenario 1: $F = 0$
- Scenario 2: $F = F_{\text{current}}$
- Scenario 3: $F = 65\% F_{\text{MSY}}$
- Scenario 4: $F = 75\% F_{\text{MSY}}$
- Scenario 5: $F = 85\% F_{\text{MSY}}$
- Scenario 6: $F = F_{\text{MSY}}$
- Scenario 7: $F = F_{\text{current}}$, but reduced to account for continued moratorium throughout the projection
- Scenario 8: $F = F_{\text{rebuild}}$, with probability 0.5 in the year 2047
- Scenario 9: $F = F_{\text{rebuild}}$, with probability 0.7 in the year 2047
- Scenario 10: $F = F_{\text{rebuild}}$, with probability 0.9 in the year 2047

3.1.2 **Model 1 Results**

3.1.2.1 **Measures of Overall Model Fit** Generally, the Beaufort Assessment Model (BAM) fit well to the available data. Predicted length compositions from each fishery were reasonably close to observed data in most years, as were predicted age compositions (Figure 3.3). Residuals of fits to age and length compositions, by year and fishery, are summarized with bubble plots; differences between annual observed and predicted vectors are summarized with angular deviation (Figure 3.4–3.13). Angular deviation (measured in degrees) is defined as the arc cosine of the dot product of two vectors. A value of 0° indicates perfect agreement between the two vectors, and a value of 90° indicates perfect disagreement (i.e., the vectors are perpendicular).

The residuals from fits to length compositions show some consistent patterns of positive and negative values across years for the same length bins. These patterns might in part be a reflection of simplifying assumptions for modeling growth. For instance, the transition from age to length applied an age-length transition matrix, constructed with fixed growth parameters and one estimated parameter for standard deviation of length at age. More complex growth models are possible but would likely require additional data to support estimation of additional parameters. Furthermore, this model assumes that only legal-sized fish were retained, which would result in negative residuals for any observed fish below the minimum size limit.

The model was configured to fit observed commercial and recreational landings closely (Figures 3.14–3.17), as well as observed discards (Figures 3.18–3.20).

Fits to indices of abundance captured the general trends but not all annual fluctuations (Figures 3.21–3.23). Since the early 1990s, the general trend in the commercial and for-hire indices is one of increase.

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

3.1.2.3 **Stock Abundance and Recruitment** In general, estimated abundance at age shows a truncation of the older ages (Figure 3.24; Table 3.2). Total estimated abundance at the end of the assessment period shows sharp increase, reaching levels not seen since the late 1970s, albeit with a quite different age structure. This increase appears to be driven by recent recruitment. Annual number of recruits is shown in Table 3.2 (age-1 column) and in Figure 3.25. Notably strong year classes (age-1 fish) were predicted to have occurred in 2006 and 2007.

3.1.2.4 **Total and Spawning Biomass** Estimated biomass at age follows a similar pattern as abundance at age (Figure 3.26; Table 3.3). Total biomass and spawning biomass show similar trends—general decline until the mid-1990s, and general increase since then but with a downturn at the end of the time series (Figure 3.27; Table 3.4).

3.1.2.5 **Selectivity** Selectivity of landings from commercial lines shifted to older ages with implementation of the 20-inch size limit in 1992 (shown in Figure 3.28). In the most recent period, fish were estimated to be near fully selected by age 4. Selectivity of landings from commercial dive was dome-shaped, saturating by age 10 at a value near 0.2 (Figure 3.28). Selectivities of landings from the for-hire fleet are shown in Figure 3.29, and those of the private recreational fleet in Figure 3.30. For both of these fleets, the descending limb saturates at 0.3 (assumed), with an estimated descent from the age at full selection (age 3).

Selectivity of discard mortalities from the commercial line was mostly on age-2 and age-3 fish, with relatively small (but positive) selection of age-1 and age-4 fish (Figure 3.31). Selectivity of discard mortalities from the recreational (for-hire and private) fleets was mostly of age 2-fish but included age-1 fish; since 1992, it included age-3 and some age-4 fish. For the 20-inch size limit in place at the end of the assessment period, few age-5^+ fish were undersized.

Average selectivities of landings and of discard mortalities were computed from F-weighted selectivities in the most recent period of regulations (Figure 3.32). These average selectivities were used to compute benchmarks and central-tendency projections. All selectivities from the most recent period, including average selectivities, are tabulated in Table 3.5.

3.1.2.6 **Fishing Mortality** The estimated fishing mortality rates (F) increased through the 1970s, and since then have been quite variable (Figure 3.33). Recreational fleets dominate the total F (Table 3.6).

Estimates of total F at age are shown in Table 3.7. In any given year, the maximum F at age (i.e., apical F) may be less than that year's sum of fully selected Fs across fleets. This inequality is due to the combination of two features of estimated selectivities: full selection occurs at different ages among gears and several sources of mortality have dome-shaped selectivity.

Table 3.8 shows total landings at age in numbers, and Table 3.9 in 1000 lb. In general, the majority of estimated landings are from for-hire and private recreational fleets (Figures 3.34, 3.35; Tables 3.10, 3.11). Estimated discard mortalities occur on a smaller scale than landings (Figure 3.36; Tables 3.12, 3.13)

3.1.2.7 **Catch Curve Analysis** Catch curve analysis suggested total mortality rate ($Z = F + M$) ranged from near 0.0 to greater than 1.0, but the bulk of the point estimates were between 0.4 and 1.0 (SEDAR-24-AW07). Based on the constant estimate of natural mortality, $M = 0.08$, these values of Z suggest that fully selected fishing mortality rate is on the scale of $F = 0.32$ to $F = 0.92$, generally consistent with estimates from the catch-age model (Figure 3.33, Table 3.4). Nonetheless, estimates of mortality from catch curve analysis are not readily comparable to those from the BAM because of dome-shaped selectivity.

3.1.2.8 **Spawner-Recruitment Parameters** The estimated Beverton–Holt spawner-recruit curve is shown in Figure 3.37, along with the effect of density dependence on recruitment, depicted graphically by recruits per spawner as a function of spawners. Values of recruitment-related parameters were as follows: assumed steepness $h = 0.85$, unfished age-1 recruitment $\widehat{R_0} = 534,756$, unfished spawning biomass per recruit $\phi_0 = 9.322e{-}4$, and assumed standard deviation of recruitment residuals in log space $\sigma = 0.6$ (which resulted in bias correction $\varsigma = 1.20$). The empirical standard deviation of recruitment residuals in log space was $\hat{\sigma} = 0.83$. Uncertainty in these quantities was estimated through the Monte Carlo/bootstrap (MCB) analysis (Figure 3.38).

3.1.2.9 **Per Recruit and Equilibrium Analyses** Static spawning potential ratio (static SPR) shows a general trend of decline until the early 1980s, and since then a stable trend at low values, perhaps some small increase (Figure 3.39, Table 3.4). Values lower than the MSY level imply that, given estimated fishing rates, population equilibria would be lower than desirable (as defined by MSY).

Yield per recruit and spawning potential ratio were computed as functions of F (Figure 3.40). As in computation of MSY-related benchmarks, per recruit analyses applied the most recent selectivity patterns averaged across fisheries, weighted by F from the last three years (2007–2009). The Fs that provide 30%, 40%, and 50% SPR are 0.17, 0.13, and 0.09, respectively. For comparison, F_{MSY} corresponds to about 29% SPR. Although this rate of fishing appears high relative to $F_{X\%}$ proxies, it occurs here because red snapper mature relatively quickly, the size limit offers some protection for spawners, and because the assumed steepness of $h = 0.85$ relates to a relatively productive stock.

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of F (Figures 3.41). By definition, the F that maximizes equilibrium landings is F_{MSY}, and the corresponding landings and spawning biomass are MSY and SSB_{MSY}. Equilibrium landings and discards could also be viewed as functions of biomass B, which itself is a function of F (Figure 3.42).

3.1.2.10 **Benchmarks / Reference Points** As described in §3.1.1.7, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the expected spawner-recruit curve (Figure 3.37). This approach is consistent with methods used in rebuilding projections (i.e., fishing at F_{MSY} yields MSY from a stock size of SSB_{MSY}). Reference points estimated were F_{MSY}, MSY, B_{MSY} and SSB_{MSY}. Based on F_{MSY}, three possible values of F at optimum yield (OY) were considered—$F_{\text{OY}} = 65\%F_{\text{MSY}}$, $F_{\text{OY}} = 75\%F_{\text{MSY}}$, and $F_{\text{OY}} = 85\%F_{\text{MSY}}$—and for each, the corresponding yield was computed. Standard errors of benchmarks were approximated as those from Monte Carlo/bootstrap analysis (§3.1.1.8).

Estimates of benchmarks are summarized in Table 3.14. Point estimates of MSY-related quantities were $F_{\text{MSY}} = 0.178\ \text{y}^{-1}$, MSY = 1842 klb, $B_{\text{MSY}} = 13632$ mt, and $\text{SSB}_{\text{MSY}} = 156$ mt. Distributions of these benchmarks are shown in Figure 3.43.

3.1.2.11 **Status of the Stock and Fishery** Estimated time series of stock status (SSB/MSST) shows decline until the late 1980s, and then some increase since the mid-1990s, (Figure 3.44, Table 3.4). The increase in stock status appears to have been initiated by the 1992 management regulations, and then perhaps reinforced by strong recruitment events. Base-run estimates of spawning biomass have remained below MSST throughout most of the time series. Current stock status was estimated in the base run to be $\text{SSB}_{2009}/\text{MSST} = 0.09$ (Table 3.14). Uncertainty from the MCB analysis suggests that the estimate of overfished status (i.e., SSB < MSST) is robust (Figures 3.45, 3.46). Age structure estimated by the base run shows fewer older fish than the (equilibrium) age structure expected at MSY (Figure 3.47). However, in the terminal year (2009), ages 3 and 4 approach the MSY age structure as a result of recent strong year classes.

The estimated time series of F/F_{MSY} suggests that overfishing has been occurring throughout most of the assessment period (Figure 3.44, Table 3.4). Spikes in 1992 and 1997 are due primarily to recreational fleets (Figure 3.33), occurring because increased landings (both years for for-hire; 1992 for private) coincided with relatively low abundances of the ages most exploited by these fleets. Current fishery status in the terminal year, with current F represented by the geometric mean from 2007–2009, is estimated by the base run to be $F_{2007-2009}/F_{\text{MSY}} = 4.12$ (Table 3.14). This estimate indicates current overfishing and appears robust across MCB trials (Figures 3.45, 3.46). It might, however, be subject to some retrospective error, as described below.

3.1.2.12 **Sensitivity and Retrospective Analyses** Sensitivity runs, described in §3.1.1.3, may be useful for evaluating implications of assumptions in the base assessment model, and for interpreting MCB results in terms of expected effects from input parameters. Plotted are time series of F/F_{MSY} and SSB/MSST for sensitivity to natural mortality (Figure 3.48), discard mortality (Figure 3.49), spawner-recruit parameters (Figure 3.50), catchability (Figure 3.51), ageing error (Figure 3.52), continuity assumptions (Figure 3.53), starting year of the assessment model (Figure 3.54), initialization fishing mortality rate (Figure 3.55), landings streams (Figure 3.56), component weights of data sources (Figure 3.57), selectivity patterns (Figure 3.58), and compound extremes (Figure 3.59). The quantitative results appeared most sensitive to the scale of natural mortality, steepness, recreational landings and discards, and compound extremes. (Note that the sensitivity runs with alternative recreational landings and discards considered the full time series, not just the historic portion as applied in the MCB analysis.) The qualitative results, however, were the same across all sensitivity runs; the tendency was toward the status estimates of overfished and overfishing (Figure 3.60, Table 3.15). In concert, sensitivity analyses suggested that qualitative results of the base run and MCB analysis were robust.

Retrospective analyses suggested a pattern of overestimating terminal fishing rate, and a small degree of underestimating terminal spawning biomass (Figure 3.61). The high estimated fishing rates in the terminal year were due primarily to F's associated with recreational discard mortality. These terminal F's were high because discards comprised young fish (almost entirely), yet predicted terminal recruitments were typically underestimated. Although this pattern is indicative of retrospective error, the concern may be minimized here for two reasons. First, the headboat discard index suggests that recruitment actually did decrease in the terminal year, and thus the low 2009 recruitment estimate may be realistic. Second, the overfishing status is gauged by the geometric mean of the terminal three years, which would dampen any overestimation in the terminal year F. If 2009 were excluded from the estimate of F_{current}, the base-run estimate of terminal fishery status would change from $F_{2007-2009}/F_{\text{MSY}} = 4.1$ to $F_{2007-2008}/F_{\text{MSY}} = 3.7$. Also, as mentioned previously, retrospective results should be interpreted with caution as not all data sources survived the truncation of terminal years.

3.1.2.13 **Projections** Projection scenario 1, in which $F = 0$, predicted the chance of rebuilding to reach at least 50% in the year 2025 (Figure 3.62). If used to define the rebuilding time frame, this result plus one generation time (22 years) would suggest that rebuilding should occur in 2047 (or by the start of 2048).

The projection with F at F_{current} predicted the stock to remain at low levels (Figure 3.63, Table 3.16). It suggests further that the F_{current} is not sustainable without consistently higher than expected recruitment, as has occurred near the end of the assessment period. Projections with F at 65%, 75%, 85%, or 100% of F_{MSY} predicted increased biomass and landings (Figures 3.64–3.67, Tables 3.17–3.20). The continued moratorium projection also predicted increased biomass, but suggested that the moratorium alone is insufficient for stock recovery (Figure 3.68, Table 3.21). The F_{rebuild} projections did allow stock recovery (by design) in the year 2047 (Figures 3.69–3.71, Tables 3.22–3.24).

3.2 Model 2: Surplus Production Model

3.2.1 Model 2 Methods

3.2.1.1 **Overview** Assessments based on age or length structure are often favored because they incorporate more data on the structure of the population. However, these approaches typically involve fitting a large number of parameters and decomposing population dynamics into multiple processes including growth, mortality, and recruitment. A simplified approach is to aggregate data across age or length classes, and to summarize the relationship among complex population processes by using a simple mathematical model such as a logistic population model.

A logistic surplus production model, implemented in ASPIC (Prager 2005), was used to estimate stock status of red snapper off the southeastern U.S. While primary assessment of the stock was performed via the age-structured BAM, the surplus production approach was intended as a complement, and for additional verification that the age-structured approach was providing reasonable results.

3.2.1.2 **Data Sources** For use in the production model, data developed at the DW required some additional formatting, described below.

Landings The landings input to ASPIC must be in units of biomass. Headboat (1976–present) and MRFSS Private and Charter mode (1981–present) recreational landings in numbers and whole pounds were developed at the SEDAR-24 DW and adjusted during the development of data for input into the age–structured model. Historical landings (1950–1980) in numbers were developed during the SEDAR-24 DW using ratios to commercial lines landings (see SEDAR-24 DW report). These ratios and resulting estimates were adjusted by the SEDAR-24 AW panel. The for–hire fleet and private fleet landings in number were converted to pounds using the annual average weight of red snapper from the headboat survey during 1972–1980. The 1950–1971 estimated recreational for-hire and private landings in number were converted to weight using the average of the 1972–1974 annual headboat mean weights (4.2 lb). Commercial landings were developed in pounds and required no conversions. The recommended removals and three alternate series of landings were developed at the SEDAR-24 DW and adjusted by the SEDAR-24 AW panel for input to the age–structured model. These include lower and upper bounds for the commercial ratio method and the adjusted saltwater angling survey (SWAS) estimates of historical landings. The upper and lower bounds were converted to pounds as described above. The SWAS estimates were converted using the headboat average weights for the entire series. The commercial and recreational landings were combined with discards in weight for total removals (Table 3.25).

Dead Discards Discard estimates were generated in numbers at the SEDAR-24 DW and adjusted during the development of data for input into the age–structured model. The for–hire and private discard estimates began in 1981. The commercial lines discard estimates (in numbers) started in 1992 when the 20-inch size limit was enacted. The weight of recreationally discarded fish was determined for each regulation period (1983-1991,1992-present) by calculating the sum of the products of the mean weight at each length bin (using the weight–length relationship) by the proportion of fish in that bin up to the size limit. Discards prior to the 1983 regulation were given the same average weight as the 1983-1991 period since there was little change in the length compositions from 1982–1983. The average weight of commercially discarded fish from 1992-present was determined from observed fish (2.9 lbs). For ASPIC, the dead discards were combined with landings in weight to represent total removals (Table 3.25).

Indices of Abundance The headboat index for red snapper was developed in numbers of landed fish per angler hour. The surplus–production model requires input in pounds and therefore the headboat index was converted by multiplying the annual index by the annual mean weight from the headboat survey and scaling the series to the mean. The commercial lines index was developed in pounds per hook hour. (Table 3.25).

The headboat and commercial line indices were adjusted during the SEDAR 24 AW to reflect an assumption of 2% catchability increase per year from the beginning of the earliest index (1976) until 2003 and then saturating until present.

3.2.1.3 **Model Configuration and Equations** Production modeling used the model formulation and ASPIC software of Prager (1994; 2005). This is an observation-error estimator of the continuous-time form of the Schaefer (logistic) production model (Schaefer 1954; 1957). Estimation was conditioned on catch.

The logistic model for population growth is the simplest form of a differential equation which satisfies a number of ecologically realistic constraints, such as a carrying capacity (a consequence of limited resources). When written in terms of stock biomass, this model specifies that

$$\frac{dB_t}{dt} = rB_t - \frac{r}{K}B_t^2, \tag{4}$$

where B_t is biomass in year t, r is the intrinsic rate of increase in absence of density dependence, and K is carrying capacity (Schaefer 1954; 1957). This equation may be rewritten to account for the effects of fishing by introducing an instantaneous fishing mortality term, F_t:

$$\frac{dB_t}{dt} = (r - F_t)B_t - \frac{r}{K}B_t^2. \tag{5}$$

By writing the term F_t as a function of catchability coefficients and effort expended by fishermen in different fisheries, Prager (1994) showed how to estimate model parameters from time series of yield and effort. Nonparametric confidence intervals on parameters were estimated through bootstrap.

For red snapper, the model was configured using various combinations of removals, starting dates, and assumptions about changes in catchability resulting in 75 configurations. Three of these runs are presented here as many of the early runs became obsolete with changes to the historical recreational landings during the SEDAR-24 AW. The model was configured to use the total removals as recommended by the SEDAR-24 AW panel and the adjusted SWAS landings. Another run using the recommended removals without increasing catchability was completed to evaluate the effect of catchability assumptions. A run starting in 1976 was completed to determine the influence of the highly uncertain historical recreational landings. With the exception of the run incorporating the SWAS removal estimates, 1000 bootstrap runs were conducted to evaluate the confidence in the model fit and parameter estimates. The bias-corrected bootstrap confidence intervals were wide and irregular for some runs. For this reason, simple percentile confidence intervals were calculated. Subsets of the bootstrap runs were examined to determine the influence of estimated $B1/k$ values on the parameter estimates and stock status.

3.2.2 Model 2 Results

3.2.2.1 **Model Fit** The fit to the indices were similar across runs. Truncating the model to start in 1976 had almost no effect on the fit to the indices (Figure 3.72). The runs with no catchability increase fit the early headboat index slightly better than the runs with catchability increase (Figure 3.72). All runs missed the reduction in CPUE in 2006 and subsequent increase until 2009 for both indices (Figure 3.72). CPUE was estimated to increase linearly from about 2004 until 2007 and then decrease slightly in 2008 and 2009 for all runs. Because all runs were conditioned on catch, landings were fit exactly.

3.2.2.2 **Parameter Estimates and Uncertainty** Confidence intervals on the parameters and stock status were evaluated by bootstrapping 1000 runs for each model configuration. No bootstrap runs were completed for configuration using the SWAS landings estimates. It is presented here primarily because it was suggested by the DW as an alternative time series of historical landings.

Estimated values of $B1/K$ varied widely across bootstrap runs of a single model configuration and across runs (Table 3.26 and Figures 3.73 – 3.75). However, the value of $B1/K$ had little influence on the status of the stock and fishery with a few extreme cases. Of the bootstrap runs matched to the BAM base run, only the 69 with $B1/K$ estimated above 0.5 had a slightly different relative biomass distribution and higher average B/B_{MSY}. The estimated F/F_{MSY} was similar across all values of $B1/K$ (Figure 3.73). In the model configuration with no catchability increase there were 194 runs with $B1/K$ estimated below 0.25 which showed slightly different distribution of B/B_{MSY} but no difference in F/F_{MSY} (Figure 3.74). No estimates of $B1/K$ were below 0.25 for the configuration starting in 1976. The distribution of status values from the different levels of $B1/K$ were very similar (Figure 3.75).

Output from the ASPIC bootstrap runs configured as closely as possible to the base run of the BAM is in Appendix C.

3.2.2.3 **Status of the Stock and Fishery** Across a range of historical landings and assumptions of catchability and initial biomass, the models estimated red snapper are overfished and current fishing mortality (2009) is above levels that optimize sustained yield (Table 3.26 and Figure 3.76). Estimates of F/F_{MSY} for all runs range from 3.47 to 4.78 and B_{2010}/B_{MSY} ranges from 0.16 to 0.29. The bootstrap run matched to the BAM base run estimated the 80% bias-corrected confidence interval of F/F_{MSY} between 2.28 and 8.05 and B_{2010}/B_{MSY} between 0.08 and 0.53. The recent trends in B/B_{MSY} and F/F_{MSY} are very similar across runs. Confidence intervals (80%) for B/B_{MSY} and F/F_{MSY} from the 1000 bootstrap runs show increased uncertainty in the biomass estimate at the beginning and end of the series and little uncertainty in the F/F_{MSY} estimate (Figure 3.76).

3.2.2.4 **Discussion — Surplus Production Model** The production model estimates that current stock size is below MSY and that the current level of fishing is above the limit reference point F_{MSY} across all runs, similar to results from the BAM (Figure 3.77). The general effect of including an increase in catchability increased the estimate of current F/F_{MSY} and decreased the estimate of current stock status B/B_{MSY}. The surplus production model, because it omits population age and size structure, does not make use of data on those characteristics. Because such data are available for red snapper, a model that uses them would normally be preferred for a detailed assessment on which to base management.

3.3 Discussion

3.3.1 Comments on Assessment Results

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

The base run of the Beaufort catch-age assessment model indicated that the stock is overfished ($SSB_{2009}/MSST$ = 0.09), and that overfishing is occurring ($F_{2007-2009}/F_{MSY} = 4.12$). These results were consistent across all configurations used in sensitivity runs. In addition, the same qualitative findings resulted from the production model applications. It should be noted that overfishing can be sustainable, but in the long-term, it tends to result in lower than desirable levels of stock size. The increase in biomass since the mid-1990s could indicate that the federal regulations implemented in 1992 have been effective, however those regulations do not appear adequate for rebuilding the stock.

Although qualitative results were robust, uncertainties remain, as in all assessments. Several sources of uncertainty are discussed below.

This assessment lacked a reliable fishery independent index of abundance. Thus, the fishery dependent indices were the primary source of information on relative abundance. In general, fishery independent indices are preferable. Nonetheless, steps were taken to make the available fishery dependent indices as reliable as possible (using trip selection and standardization methods to develop the indices, and using time-varying catchability to fit them). In addition, the headboat index was developed from a multispecies fishery, which would tend to minimize effects of targeting that could otherwise occur with fleets focused primarily on the species of interest. A new fishery independent sampling program was initiated in the summer of 2010, and this new data source is expected to be available for the next benchmark assessment.

Compared to other fishes, the South Atlantic and Gulf of Mexico stocks of red snapper demonstrate rapid body growth and early maturity relative to their potential longevity (Charnov 1993; Beverton 1992). This could indicate that life-history characteristics, such as growth and maturity schedules, have adapted over time in response to exploitation. Resource managers might wish to consider possible evolutionary effects of fishing (Dunlop et al. 2009).

A source of uncertainty not modeled here is the aggregation of headboats and charterboats into the for-hire fleet, which was recommended by the DW. It was recognized by the AW that charterboats generally fish in deeper water than headboats. Depth of the entire for-hire fleet was accounted for when estimating discard mortality rates, by aggregating the depth distributions of the two components (headboats and charterboats) weighted by their respective landings. However, if selectivities differ between headboats and charterboats, the estimated selectivity of the for-hire fleet should be considered to represent the "average." Charterboat landings were generally higher than those of headboats, so if depths fished by charterboats resulted in selectivity that is less dome-shaped than the pattern used here, results of this assessment would likely be overly optimistic.

Among the many decisions deliberated over by the AW panel was choice of the starting year of the model. The panel thought that it was important to include the 1960s, when landings appeared to have peaked, and to examine sensitivity to those landings through sensitivity and uncertainty analyses. Ignoring this early time frame could have ignored potential stock productivity (Rosenberg et al. 2005). However, the historical period (pre-1976) did not include CPUE or composition data, and thus the model had little or no information to estimate variability of year-class strength in the 1950s and 1960s. Thus, the estimates of historic recruitment should not be considered reliable. Instead, the historic period was viewed by the AW panel as an initialization era leading up to the assessment period of 1976–2009, used to estimate age structure at the onset of CPUE and composition data. Those early recruitment deviations were excluded from the likelihood component of the spawner-recruit curve. Sensitivity runs starting in 1976 or 1986 provided results similar to those of the base run starting in 1955.

Perhaps the greatest uncertainty in this assessment was the spawner-recruit relationship. Steepness could not be estimated reliably (tended toward its upper bound), and R_0, although estimated, relied on predicted recruitment events that occurred at low stock sizes. Potential stock productivity at high stock sizes remains to be observed. It is possible that this assessment under-predicted potential productivity by underestimating R_0, or perhaps over-predicted productivity at high stock sizes, if increased spawners were to have an increasing deleterious effect on recruitment (although mechanisms underlying Ricker dynamics are not known to occur for this stock). Either way, the long-term potential for MSY is, for now, uncertain. Still, the stock dynamics and productivity in recent years might be more relevant to current environmental or ecological conditions, and therefore the results from this assessment would represent our best estimate for the near future.

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

The assessment predicted relatively high abundance in recent years. This prediction is consistent with reports from fishermen of increased abundance. However, this increase appears to be the result of unusually strong year classes (age-1) in 2006 and 2007. The observed age structure of landings remains more truncated than would be expected from a healthy population of a fish with maximum age that exceeds 50 years.

3.3.2 **Comments on Projections**

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

- In general, projections of fish stocks are highly uncertain, particularly in the long term (e.g., beyond 5–10 years).
- Although projections included many major sources of uncertainty, they did not include structural (model) uncertainty. That is, projection results are conditional on one set of functional forms used to describe population dynamics, selectivity, recruitment, etc.
- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect projection results.
- During the moratorium, fishing effort was assumed to range between 80% and 100% of the current level. This range should be examined when data become available to do so.
- Discard mortality rates during the moratorium were assumed to be those estimated from the DW. However, the depth distributions used to estimate those discard mortality rates were based on fish released because of the size-limit regulation. If fish of all sizes are released, as in a moratorium, those depth distributions would likely shift toward deeper waters, resulting in higher discard mortality rates. Thus, the moratorium projection values likely underestimate the effects of release mortality.
- The projections assumed that the estimated spawner-recruit relationship applies in the future and that past residuals represent future uncertainty in recruitment. If future recruitment is characterized by runs of large or small year classes, possibly due to environmental or ecological conditions, stock trajectories may be affected.

3.4 References

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3.5 Tables

Table 3.1. Life-history characteristics at age of the population, including average body size and weight (mid-year), gonad weight, and proportion females mature.

Age	Total length (mm)	Total length (in)	CV length	Whole weight (kg)	Whole weight (lb)	Gonad weight (kg)	Female maturity
1	277.2	10.9	0.18	0.30	0.66	0.00	0.22
2	410.5	16.2	0.12	1.02	2.25	0.01	0.55
3	515.4	20.3	0.10	2.07	4.57	0.02	0.84
4	597.9	23.5	0.08	3.29	7.26	0.04	0.96
5	662.8	26.1	0.08	4.54	10.01	0.07	0.99
6	713.8	28.1	0.07	5.72	12.61	0.11	1.00
7	754.0	29.7	0.07	6.79	14.96	0.15	1.00
8	785.6	30.9	0.06	7.71	17.01	0.19	1.00
9	810.4	31.9	0.06	8.50	18.74	0.22	1.00
10	829.9	32.7	0.06	9.16	20.19	0.25	1.00
11	845.3	33.3	0.06	9.70	21.38	0.28	1.00
12	857.4	33.8	0.06	10.14	22.35	0.30	1.00
13	866.9	34.1	0.06	10.49	23.13	0.32	1.00
14	874.4	34.4	0.06	10.78	23.76	0.34	1.00
15	880.3	34.7	0.06	11.00	24.26	0.35	1.00
16	884.9	34.8	0.06	11.19	24.66	0.36	1.00
17	888.6	35.0	0.06	11.33	24.98	0.37	1.00
18	891.4	35.1	0.06	11.44	25.23	0.37	1.00
19	893.7	35.2	0.06	11.53	25.43	0.38	1.00
20	895.5	35.3	0.06	11.61	25.59	0.38	1.00

Table 3.2. Estimated total abundance at age (1000 fish) at start of year.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1955	637.38	468.18	388.12	334.06	293.53	260.85	234.66	211.56	192.85	175.86	160.39	146.28	134.76	124.14	114.37	105.36	97.06	89.41	82.37	963.36	5214.55
1956	367.65	462.59	382.49	327.84	288.42	256.90	232.05	210.00	191.80	175.02	159.66	145.63	134.16	123.59	113.86	104.89	96.63	89.02	82.00	959.07	4903.26
1957	360.67	265.82	376.04	320.87	281.23	250.99	227.56	207.05	189.95	173.71	158.58	144.68	133.29	122.80	113.13	104.21	96.01	88.44	81.48	952.92	4649.42
1958	353.87	259.46	213.70	311.03	271.52	241.65	219.90	201.14	185.67	170.61	156.10	142.53	131.34	121.01	111.48	102.70	94.61	87.16	80.29	939.07	4394.87
1959	347.09	253.64	208.06	175.86	261.99	232.46	211.30	194.30	180.45	166.89	153.44	140.41	129.50	119.34	109.95	101.29	93.31	85.96	79.19	926.18	4170.62
1960	340.27	247.94	202.26	169.69	146.89	222.61	202.05	185.86	173.66	161.63	149.58	137.55	127.14	117.26	108.06	99.56	91.72	84.50	77.84	910.39	3956.44
1961	333.23	242.39	196.80	163.64	140.67	123.97	192.48	177.03	165.58	155.08	144.44	133.70	124.19	114.80	105.88	97.57	89.90	82.82	76.29	892.30	3752.75
1962	326.21	236.94	191.46	157.94	134.60	117.87	106.54	167.79	157.00	147.23	138.00	128.56	120.21	111.66	103.22	95.20	87.73	80.82	74.46	870.86	3554.29
1963	319.21	231.94	187.31	153.45	129.76	112.70	101.28	92.91	148.91	139.71	131.12	122.93	115.68	108.16	100.47	92.88	85.66	78.94	72.73	850.63	3376.37
1964	311.96	226.92	183.54	149.89	125.90	108.54	96.82	88.37	82.53	132.65	124.56	116.93	110.73	104.21	97.44	90.51	83.67	77.17	71.11	831.80	3215.24
1965	304.46	221.04	178.43	145.14	121.60	104.26	92.50	83.96	78.10	73.16	117.71	110.56	104.84	99.29	93.44	87.37	81.16	75.02	69.19	809.58	3050.78
1966	296.76	214.19	171.62	138.07	115.36	98.86	87.56	79.33	73.51	68.63	64.37	103.60	98.30	93.21	88.28	83.08	77.68	72.16	66.70	781.34	2872.63
1967	288.81	206.71	163.53	129.04	106.80	91.53	81.45	74.02	68.64	63.90	59.74	56.06	91.13	86.47	82.00	77.66	73.08	68.34	63.48	746.02	2678.40
1968	280.56	199.06	154.56	118.80	96.59	82.26	73.61	67.56	62.99	58.73	54.77	51.23	48.57	78.96	74.92	71.05	67.29	63.32	59.21	701.37	2465.43
1969	272.52	192.15	146.79	109.59	86.89	72.85	65.02	60.22	56.81	53.30	49.79	46.46	43.90	41.61	67.66	64.20	60.88	57.66	54.26	651.73	2254.27
1970	263.45	186.99	142.79	104.63	80.60	65.92	57.95	53.56	50.99	48.41	45.50	42.53	40.09	37.89	35.91	58.39	55.41	52.54	49.76	609.30	2082.60
1971	252.87	181.78	139.94	102.59	77.52	61.54	52.69	47.89	45.47	43.56	41.42	38.96	36.79	34.68	32.77	31.07	50.51	47.93	45.45	570.07	1935.47
1972	240.23	175.52	137.23	101.52	76.71	59.69	49.52	43.77	40.84	39.00	37.42	35.61	33.83	31.95	30.11	28.46	26.98	43.86	41.62	534.53	1808.39
1973	228.93	167.12	132.90	99.49	75.87	59.04	48.03	41.15	37.34	35.05	33.52	32.19	30.94	29.40	27.76	26.17	24.73	23.44	38.11	500.65	1691.82
1974	261.71	158.59	125.75	94.51	73.03	57.49	46.97	39.61	34.92	31.89	29.99	28.70	27.84	26.76	25.43	24.01	22.64	21.39	20.28	466.05	1617.58
1975	281.23	179.44	116.04	84.69	65.86	52.77	43.97	37.53	32.69	29.04	26.59	25.02	24.20	23.47	22.56	21.44	20.24	19.08	18.03	409.98	1533.90
1976	479.75	190.79	127.81	73.63	55.77	45.22	38.73	34.03	30.14	26.50	23.61	21.64	20.57	19.89	19.30	18.55	17.63	16.64	15.69	351.91	1627.79
1977	195.67	327.75	136.77	79.95	47.85	37.86	32.92	29.82	27.23	24.35	21.48	19.16	17.74	16.86	16.31	15.82	15.21	14.45	13.64	301.36	1392.19
1978	155.53	132.78	231.52	83.83	50.94	31.90	27.13	25.02	23.58	21.75	19.52	17.24	15.53	14.38	13.67	13.22	12.83	12.33	11.72	255.40	1169.82
1979	159.85	104.85	93.22	143.53	53.98	34.27	23.01	20.71	19.84	18.89	17.48	15.70	14.01	12.62	11.69	11.11	10.75	10.42	10.02	217.07	1003.02
1980	187.97	107.66	73.84	57.11	91.47	36.02	24.63	17.57	16.46	15.94	15.22	14.10	12.80	11.42	10.29	9.53	9.06	8.76	8.50	185.13	913.47
1981	150.71	127.65	76.30	45.02	36.23	60.77	25.79	18.73	13.91	13.18	12.81	12.24	11.46	10.40	9.28	8.36	7.74	7.36	7.12	157.34	812.39
1982	160.20	95.63	79.15	32.35	20.29	17.79	34.52	16.63	13.01	9.88	9.43	9.18	8.87	8.30	7.54	6.72	6.06	5.61	5.33	119.16	665.64
1983	637.20	107.99	66.34	45.90	19.56	12.91	12.30	25.55	12.86	10.19	7.77	7.42	7.30	7.05	6.60	5.99	5.35	4.82	4.46	99.01	1106.57
1984	647.89	436.89	66.47	37.49	27.07	12.17	8.75	8.96	19.48	9.94	7.90	6.03	5.82	5.73	5.53	5.18	4.70	4.19	3.78	81.17	1405.13
1985	126.93	435.52	246.68	23.10	14.00	11.27	6.09	5.15	5.79	12.96	6.67	5.32	4.10	3.96	3.90	3.77	3.53	3.20	2.85	57.82	982.61
1986	82.45	84.57	236.84	90.48	9.07	6.09	5.82	3.66	3.38	3.90	8.80	4.54	3.66	2.83	2.73	2.68	2.59	2.43	2.20	41.77	600.49
1987	509.49	55.31	46.40	108.47	43.78	4.73	3.60	3.84	2.58	2.43	2.82	6.38	3.33	2.68	2.07	2.00	1.97	1.90	1.78	32.21	837.77
1988	76.67	332.58	29.87	25.12	61.42	26.23	3.11	2.56	2.87	1.95	1.84	2.14	4.90	2.56	2.06	1.59	1.53	1.51	1.46	26.11	608.08
1989	176.82	51.50	182.28	10.28	9.29	25.29	12.97	1.81	1.63	1.88	1.29	1.22	1.44	3.29	1.72	1.38	1.07	1.03	1.01	18.51	505.74
1990	178.60	116.37	25.11	55.29	3.36	3.40	11.21	6.82	1.05	0.97	1.13	0.78	0.75	0.88	2.01	1.05	0.84	0.65	0.63	11.93	422.84
1991	261.90	124.99	72.29	14.72	33.53	2.12	2.27	7.86	4.94	0.77	0.71	0.83	0.58	0.55	0.65	1.49	0.78	0.63	0.48	9.30	541.38
1992	225.84	179.69	75.77	39.04	8.28	19.90	1.37	1.59	5.75	3.67	0.57	0.53	0.63	0.44	0.42	0.49	1.12	0.59	0.47	7.38	573.54
1993	161.26	162.73	135.37	22.08	13.04	3.12	9.17	0.76	0.97	3.63	2.34	0.36	0.34	0.40	0.28	0.27	0.32	0.73	0.38	5.07	522.62
1994	153.34	112.85	115.14	78.47	14.19	8.69	2.18	6.64	0.56	0.73	2.73	1.76	0.28	0.26	0.31	0.21	0.21	0.24	0.55	4.14	503.48
1995	36.10	106.73	77.96	63.92	50.15	9.45	6.12	1.60	5.04	0.43	0.56	2.09	1.36	0.21	0.20	0.24	0.17	0.16	0.19	3.63	366.32
1996	153.35	24.64	69.77	44.97	43.98	35.78	7.04	4.70	1.26	3.99	0.34	0.44	1.68	1.09	0.17	0.16	0.19	0.13	0.13	3.07	396.90
1997	256.49	108.63	17.26	40.71	32.57	32.92	27.82	5.62	3.84	1.04	3.28	0.28	0.37	1.39	0.91	0.14	0.13	0.16	0.11	2.65	536.33
1998	236.47	183.33	75.60	5.33	16.49	14.62	17.38	16.94	3.72	2.61	0.71	2.25	0.20	0.25	0.97	0.63	0.10	0.09	0.11	1.92	579.72
1999	511.16	171.30	140.91	44.77	3.52	11.36	10.72	13.39	13.52	2.99	2.10	0.57	1.84	0.16	0.21	0.79	0.51	0.08	0.08	1.65	931.65
2000	450.85	348.44	113.10	65.26	24.47	2.06	7.38	7.60	10.03	10.29	2.29	1.61	0.44	1.42	0.12	0.16	0.61	0.40	0.06	1.34	1047.94
2001	199.79	306.34	230.05	50.72	34.37	13.87	1.31	5.13	5.60	7.51	7.75	1.73	1.23	0.34	1.08	0.09	0.12	0.47	0.30	1.07	868.87
2002	164.90	135.98	203.78	131.17	33.02	23.40	10.03	0.99	4.03	4.43	5.97	6.16	1.39	0.99	0.27	0.87	0.08	0.10	0.37	1.10	729.01
2003	248.12	111.36	86.64	113.62	89.28	23.48	17.56	7.84	0.80	3.28	3.62	4.87	5.07	1.14	0.81	0.22	0.72	0.06	0.08	1.22	719.78
2004	120.23	161.70	65.85	51.71	82.75	67.62	18.56	14.33	6.57	0.67	2.77	3.05	4.15	4.33	0.97	0.69	0.19	0.61	0.05	1.11	607.91
2005	66.28	74.84	85.91	34.98	34.15	57.57	50.02	14.41	11.52	5.33	0.55	2.25	2.51	3.41	3.56	0.80	0.57	0.16	0.50	0.95	450.26
2006	793.57	40.23	37.25	44.79	23.39	24.10	43.15	39.31	11.72	9.45	4.38	0.45	1.87	2.09	2.84	2.96	0.67	0.47	0.13	1.21	1084.01
2007	582.30	546.85	27.53	22.36	31.03	16.92	18.45	34.54	32.50	9.77	7.89	3.66	0.38	1.58	1.76	2.40	2.50	0.56	0.40	1.13	1344.52
2008	162.97	385.01	338.24	12.70	12.33	18.36	11.10	13.21	26.10	24.95	7.54	6.10	2.86	0.30	1.23	1.38	1.87	1.95	0.44	1.20	1029.83
2009	78.20	104.63	221.04	152.33	6.95	7.23	11.87	7.78	9.75	19.55	18.77	5.68	4.64	2.18	0.23	0.94	1.05	1.42	1.49	1.25	656.97
2010	196.24	46.66	48.91	78.31	72.92	3.63	4.24	7.68	5.35	6.82	13.75	13.23	4.04	3.31	1.55	0.16	0.67	0.75	1.01	1.94	511.19

Table 3.3. Estimated biomass at age (1000 lb) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1955	420.4	1051.2	1772.1	2423.8	2937.4	3290.2	3511.1	3597.7	3614.0	3550.1	3428.6	3268.8	3116.7	2949.3	2774.5	2598.1	2424.4	2256.0	2094.6	24650.1	75729.0
1956	242.5	1038.6	1746.3	2378.8	2886.3	3240.4	3471.8	3571.3	3594.4	3533.3	3413.0	3254.2	3102.8	2936.1	2762.2	2586.5	2413.6	2245.8	2085.4	24540.3	75043.4
1957	237.9	596.8	1717.0	2328.1	2814.2	3165.8	3404.8	3521.0	3559.8	3506.7	3390.0	3232.9	3082.9	2917.4	2744.3	2569.9	2398.0	2231.5	2071.9	24382.9	73873.8
1958	233.5	582.5	975.8	2256.9	2717.2	3048.1	3290.2	3420.5	3479.6	3444.3	3337.1	3184.8	3037.8	2874.8	2704.4	2532.7	2363.1	2199.1	2041.9	24028.6	71752.3
1959	228.8	569.5	950.0	1276.0	2621.7	2932.1	3161.4	3304.1	3381.7	3369.1	3280.0	3137.6	2995.0	2835.1	2667.4	2497.8	2330.7	2168.9	2013.9	23698.8	69419.8
1960	224.4	556.7	923.5	1231.3	1469.8	2807.8	3023.2	3160.5	3254.5	3262.8	3197.6	3073.7	2940.7	2785.8	2621.5	2455.1	2291.0	2131.9	1979.5	23294.7	66685.7
1961	219.8	544.1	898.6	1187.4	1407.7	1563.7	2879.9	3010.4	3103.0	3130.6	3087.8	2987.7	2872.4	2727.3	2568.6	2406.1	2245.4	2089.5	1940.1	22831.7	63701.7
1962	215.2	532.0	874.1	1146.0	1347.0	1486.8	1593.9	2853.4	2942.3	2972.1	2950.0	2872.8	2780.3	2652.8	2504.0	2347.5	2191.2	2039.3	1893.6	22283.2	60477.2
1963	210.5	520.7	855.2	1113.3	1298.5	1421.5	1515.2	1580.1	2790.6	2820.4	2803.0	2747.0	2675.5	2569.7	2437.4	2290.4	2139.6	1991.7	1849.5	21765.6	57395.2
1964	205.7	509.5	838.0	1087.5	1259.9	1369.1	1448.7	1502.9	1546.8	2677.7	2662.7	2612.9	2561.1	2475.8	2363.8	2232.0	2089.8	1946.9	1808.5	21283.7	54482.4
1965	200.8	496.3	814.6	1053.1	1216.7	1315.1	1384.1	1427.9	1463.6	1476.9	2516.1	2470.5	2424.6	2358.7	2266.8	2154.6	2027.2	1892.7	1759.5	20715.3	51435.0
1966	195.8	480.8	783.5	1001.8	1154.3	1246.9	1310.0	1349.0	1377.7	1385.6	1376.1	2315.1	2273.4	2214.5	2141.6	2048.8	1940.3	1820.6	1696.2	19992.6	48104.9
1967	190.5	464.1	746.7	936.3	1068.6	1154.6	1218.7	1258.8	1286.4	1289.9	1277.1	1252.7	2107.8	2054.3	1989.2	1915.2	1825.4	1724.0	1614.2	19088.9	44463.1
1968	185.0	446.9	705.7	862.0	966.5	1037.5	1101.2	1148.8	1180.6	1185.6	1170.9	1144.9	1123.3	1875.7	1817.5	1752.0	1680.6	1597.7	1505.5	17946.3	40434.8
1969	179.7	431.4	670.2	795.2	869.5	918.9	972.9	1024.0	1064.6	1075.9	1064.4	1038.2	1015.2	988.6	1641.3	1583.1	1520.5	1454.6	1379.9	16676.2	36364.4
1970	173.7	419.8	651.9	759.3	806.5	831.4	867.1	910.7	955.7	977.1	972.7	950.4	927.3	900.1	871.3	1439.8	1383.8	1325.6	1265.5	15590.4	32980.3
1971	166.7	408.1	638.9	744.3	775.8	776.2	788.4	814.4	852.1	879.2	885.4	870.6	850.8	823.9	795.0	766.1	1261.5	1209.2	1155.7	14586.7	30049.2
1972	158.5	394.0	626.6	736.6	767.6	752.9	741.0	744.3	765.4	787.3	800.1	795.6	782.4	759.1	730.6	701.7	674.0	1106.7	1058.4	13677.5	27559.6
1973	151.0	375.2	606.7	721.8	759.3	744.7	718.5	699.7	699.7	707.5	716.7	719.1	715.6	698.4	673.5	645.3	617.7	591.5	969.2	12810.4	25341.7
1974	172.6	356.0	574.1	685.9	730.8	725.1	702.8	673.7	654.3	643.7	641.1	641.3	644.0	635.8	616.9	592.2	565.5	539.7	515.7	11925.2	23236.3
1975	185.4	402.8	529.8	614.4	659.2	665.6	657.9	638.2	612.7	586.2	568.4	559.1	559.5	557.5	547.4	528.7	505.7	481.5	458.6	10490.5	20809.4
1976	316.4	428.4	583.6	534.2	558.0	570.3	579.6	578.7	564.8	535.1	504.6	483.5	475.8	472.7	468.0	457.5	440.3	420.0	399.0	9004.6	18374.9
1977	129.0	735.9	624.3	580.0	478.8	477.5	492.5	507.1	510.1	491.6	459.2	428.1	410.3	400.6	395.7	390.0	379.9	364.6	347.0	7711.1	16313.5
1978	102.5	298.1	1057.1	608.3	509.7	402.3	406.1	425.5	441.8	439.2	417.3	385.1	359.1	341.7	331.8	326.1	320.3	311.1	297.8	6534.9	14315.9
1979	105.4	235.5	425.7	1041.5	540.1	432.3	344.4	352.1	371.9	381.4	373.7	351.0	323.9	299.8	283.5	274.0	268.3	263.0	254.9	5554.3	12476.4
1980	123.9	241.6	337.1	414.5	915.4	454.4	368.6	298.7	308.4	321.9	325.4	315.3	296.1	271.2	249.6	235.0	226.2	221.1	216.1	4737.1	10877.2
1981	99.4	286.6	348.3	326.7	362.4	766.5	385.8	318.6	260.8	266.1	273.8	273.6	265.0	247.1	225.1	206.1	193.3	185.6	181.0	4025.9	9498.0
1982	105.6	214.7	361.3	234.8	203.0	224.4	516.5	282.9	243.8	199.5	201.5	205.0	205.0	197.3	182.8	165.8	151.2	141.5	135.6	3049.2	7221.5
1983	420.2	242.5	302.9	333.1	195.8	162.9	184.1	434.3	241.2	205.7	166.0	165.8	168.9	167.6	160.3	147.7	133.6	121.5	113.5	2533.6	6600.6
1984	427.3	980.8	303.6	272.1	270.9	153.4	131.0	152.3	365.1	200.6	168.9	134.7	134.5	136.0	134.3	127.6	117.5	105.8	96.1	2077.0	6489.5
1985	83.8	977.8	1126.3	167.6	140.2	142.2	91.1	87.7	108.5	261.7	142.6	118.8	94.8	94.1	94.6	92.8	88.0	80.7	72.5	1479.3	5545.1
1986	54.5	189.8	1081.4	656.5	90.8	76.7	87.1	62.2	63.3	78.7	188.3	101.4	84.7	67.0	66.1	66.1	64.8	61.3	56.0	1069.0	4265.7
1987	336.0	124.1	211.9	787.1	438.1	59.7	54.0	65.3	48.3	48.9	60.2	142.6	76.9	63.7	50.3	49.2	49.2	47.8	45.2	824.3	3583.0
1988	50.5	746.7	136.5	182.3	614.6	330.9	46.5	43.4	53.8	39.5	39.5	47.8	113.3	60.6	50.0	39.2	38.4	38.1	37.0	668.2	3376.8
1989	116.6	115.5	832.2	74.5	93.0	319.0	194.2	30.9	30.6	37.9	27.6	27.3	33.3	78.0	41.7	34.2	26.7	26.0	25.8	473.8	2638.7
1990	117.7	261.2	114.6	401.2	33.7	42.8	167.8	116.0	19.6	19.6	24.3	17.4	17.2	20.9	48.7	25.8	21.2	16.5	16.1	305.1	1807.6
1991	172.6	280.6	330.0	106.9	335.5	26.7	34.0	133.6	92.6	15.4	15.2	18.5	13.4	13.2	15.9	36.6	19.4	15.9	12.3	237.9	1926.4
1992	149.0	403.4	345.9	283.3	82.9	251.1	20.5	26.9	107.8	74.1	12.1	11.9	14.6	10.4	10.1	12.1	28.0	14.8	11.9	188.7	2059.6
1993	106.3	365.3	618.0	160.3	130.5	39.2	137.1	12.8	18.1	73.2	50.0	8.2	7.9	9.7	6.8	6.6	7.9	18.3	9.7	129.9	1916.0
1994	101.2	253.3	525.6	569.2	142.0	109.6	32.6	112.9	10.6	14.8	58.2	39.2	6.4	6.2	7.5	5.3	5.1	6.2	14.1	105.8	2126.1
1995	23.8	239.6	355.8	463.9	501.8	119.3	91.5	27.3	94.4	8.8	11.9	46.7	31.5	5.1	4.9	6.0	4.2	4.0	4.9	93.0	2138.0
1996	101.2	55.3	318.6	326.3	440.0	451.3	105.4	79.8	23.6	80.7	7.3	9.9	38.8	26.0	4.2	4.0	4.9	3.3	3.3	78.5	2162.3
1997	169.1	243.8	78.7	295.4	326.1	415.4	416.2	95.5	71.9	20.9	70.1	6.4	8.6	33.1	22.0	3.5	3.3	4.0	2.9	67.9	2354.8
1998	155.9	411.6	345.2	38.8	164.9	184.3	260.1	288.1	69.7	52.7	15.2	50.3	4.4	6.0	23.4	15.4	2.4	2.4	2.9	48.9	2142.9
1999	337.1	384.7	643.3	324.7	35.3	143.3	160.5	227.7	253.3	60.4	45.0	12.8	42.5	3.7	5.1	19.4	12.8	2.0	2.0	42.3	2758.2
2000	297.4	782.4	516.3	473.6	244.9	26.0	110.5	129.2	188.1	207.7	48.9	35.9	10.4	33.7	3.1	4.0	15.2	9.9	1.5	34.2	3172.9
2001	131.8	687.8	1050.3	368.0	343.9	174.8	19.6	87.3	104.9	151.7	165.6	38.6	28.4	7.9	26.2	2.4	3.1	11.7	7.7	27.3	3439.2
2002	108.7	305.3	930.4	951.7	330.5	295.2	149.9	16.8	75.4	89.5	127.4	137.6	32.0	23.4	6.6	21.4	2.0	2.4	9.5	28.2	3644.2
2003	163.6	250.0	395.5	824.3	893.3	296.1	262.8	133.4	15.0	66.1	77.4	108.7	117.3	27.1	19.6	5.5	17.9	1.5	2.0	31.1	3708.8
2004	79.4	363.1	300.7	375.2	828.1	853.0	277.8	243.6	123.2	13.7	59.1	68.1	95.9	102.7	23.6	17.0	4.9	15.4	1.3	28.2	3874.0
2005	43.7	168.0	392.2	253.8	341.7	726.2	748.2	245.2	215.8	107.6	11.7	50.3	58.0	81.1	86.4	19.8	14.3	4.0	12.8	24.5	3605.0
2006	523.4	90.4	170.0	325.0	234.1	304.0	645.5	668.4	219.6	190.7	93.7	10.1	43.2	49.6	68.8	73.0	16.5	11.9	3.3	31.1	3772.3
2007	384.0	1227.8	125.7	162.3	310.4	213.4	276.0	587.3	609.1	197.1	168.7	81.8	8.8	37.5	42.8	59.1	62.4	14.1	10.1	28.9	4607.9
2008	107.6	864.4	1544.3	92.2	123.2	231.7	166.0	224.7	489.2	503.8	161.2	136.2	66.1	7.1	30.0	34.0	46.7	49.2	11.2	30.6	4919.0
2009	51.6	235.0	1009.3	1105.4	69.7	91.3	177.7	132.3	182.8	394.6	401.2	126.8	107.4	51.8	5.5	23.1	26.2	35.9	37.7	32.0	4296.8
2010	129.4	104.7	223.3	568.1	729.7	45.9	63.5	130.7	100.3	137.8	294.1	295.6	93.5	78.5	37.7	4.0	16.8	18.7	25.8	49.8	3147.8

Table 3.4. Estimated time series and status indicators. Fishing mortality rate is apical F, which includes discard mortalities. Total biomass (B, mt) is at the start of the year, and spawning biomass (SSB, female gonad weight, mt) at the end of July (time of peak spawning). The MSST *is defined by* $\text{MSST} = (1 - M)\text{SSB}_{\text{MSY}}$, *with constant* $M = 0.08$. *SPR is static spawning potential ratio.*

Year	F	F/F_{MSY}	B	B/B_{unfished}	SSB	$\text{SSB}/\text{SSB}_{\text{MSY}}$	SSB/MSST	SPR
1955	0.0388	0.219	34350	0.7791	452.75	2.9021	3.1544	0.65635
1956	0.0457	0.257	34039	0.7721	448.13	2.8724	3.1222	0.61984
1957	0.0598	0.337	33509	0.7600	441.81	2.8320	3.0782	0.52642
1958	0.0649	0.366	32546	0.7382	433.00	2.7755	3.0168	0.51935
1959	0.0738	0.416	31488	0.7142	421.94	2.7046	2.9398	0.48047
1960	0.0818	0.461	30248	0.6861	408.15	2.6162	2.8437	0.44972
1961	0.0900	0.507	28895	0.6554	391.82	2.5115	2.7299	0.41530
1962	0.0913	0.514	27432	0.6222	374.36	2.3996	2.6083	0.41744
1963	0.0929	0.523	26034	0.5905	357.01	2.2884	2.4874	0.42062
1964	0.1048	0.590	24713	0.5605	338.88	2.1722	2.3610	0.38126
1965	0.1264	0.712	23331	0.5292	318.82	2.0436	2.2213	0.32023
1966	0.1552	0.874	21820	0.4949	296.53	1.9007	2.0660	0.25749
1967	0.1895	1.068	20168	0.4575	271.67	1.7414	1.8928	0.19712
1968	0.2139	1.205	18341	0.4160	245.38	1.5729	1.7096	0.16464
1969	0.2085	1.175	16495	0.3741	221.35	1.4188	1.5422	0.17815
1970	0.2007	1.130	14960	0.3393	200.54	1.2855	1.3972	0.18817
1971	0.1909	1.076	13630	0.3092	182.43	1.1693	1.2710	0.20315
1972	0.1916	1.080	12501	0.2835	166.49	1.0672	1.1600	0.20473
1973	0.2109	1.188	11495	0.2607	151.76	0.9727	1.0573	0.18398
1974	0.2653	1.494	10540	0.2391	136.08	0.8723	0.9481	0.12473
1975	0.3249	1.830	9439	0.2141	118.98	0.7627	0.8290	0.08656
1976	0.3391	1.911	8335	0.1890	102.92	0.6597	0.7171	0.08276
1977	0.3595	2.026	7400	0.1678	88.76	0.5690	0.6184	0.07211
1978	0.3481	1.961	6494	0.1473	76.87	0.4927	0.5356	0.07450
1979	0.3599	2.027	5659	0.1284	66.92	0.4290	0.4663	0.07320
1980	0.3647	2.055	4934	0.1119	58.18	0.3729	0.4053	0.07206
1981	0.7281	4.102	4308	0.0977	46.82	0.3001	0.3262	0.01518
1982	0.4148	2.337	3276	0.0743	37.98	0.2435	0.2646	0.05481
1983	0.4408	2.484	2994	0.0679	32.13	0.2060	0.2239	0.04348
1984	0.9267	5.221	2944	0.0668	24.99	0.1602	0.1741	0.00864
1985	0.8729	4.918	2515	0.0570	18.96	0.1215	0.1321	0.00934
1986	0.6509	3.667	1935	0.0439	15.35	0.0984	0.1069	0.01759
1987	0.4836	2.724	1625	0.0369	13.15	0.0843	0.0916	0.02992
1988	0.9366	5.276	1532	0.0347	10.43	0.0668	0.0727	0.00810
1989	1.0629	5.988	1197	0.0271	7.41	0.0475	0.0517	0.00525
1990	0.4038	2.275	820	0.0186	5.93	0.0380	0.0413	0.04084
1991	0.4860	2.738	874	0.0198	5.54	0.0355	0.0386	0.03275
1992	1.1032	6.215	934	0.0212	4.65	0.0298	0.0324	0.00889
1993	0.4153	2.340	869	0.0197	4.53	0.0290	0.0315	0.05614
1994	0.4585	2.583	964	0.0219	5.18	0.0332	0.0361	0.05538
1995	0.4201	2.367	970	0.0220	5.97	0.0383	0.0416	0.07241
1996	0.4086	2.302	981	0.0222	6.87	0.0441	0.0479	0.10884
1997	1.0441	5.882	1068	0.0242	6.39	0.0410	0.0445	0.01162
1998	0.3940	2.220	972	0.0220	6.19	0.0397	0.0431	0.09093
1999	0.6398	3.604	1251	0.0284	6.62	0.0425	0.0462	0.03161
2000	0.6720	3.786	1439	0.0326	6.91	0.0443	0.0481	0.02719
2001	0.4318	2.433	1560	0.0354	7.92	0.0508	0.0552	0.06411
2002	0.4542	2.559	1653	0.0375	9.54	0.0612	0.0665	0.07510
2003	0.3862	2.175	1682	0.0382	11.34	0.0727	0.0790	0.10326
2004	0.5026	2.832	1757	0.0399	12.66	0.0812	0.0882	0.05114
2005	0.5278	2.974	1635	0.0371	13.33	0.0854	0.0928	0.05022
2006	0.3803	2.142	1711	0.0388	13.83	0.0887	0.0964	0.10552
2007	0.6439	3.627	2090	0.0474	13.81	0.0885	0.0962	0.03007
2008	0.6677	3.762	2231	0.0506	13.62	0.0873	0.0949	0.02422
2009	0.9076	5.113	1949	0.0442	12.43	0.0797	0.0866	0.01003
2010	.	.	1428	0.0324	.	.	.	.

Table 3.5. Selectivity at age (end-of-assessment time period) for commercial lines (cl), commercial dive (cd), for-hire (hb), private recreational (pvt), commercial lines discard mortalities (D.cl), for-hire discard mortalities (D.hb), private recreational discard mortalities (D.pvt), selectivity of landings averaged across fisheries (L.avg), and selectivity of discard mortalities averaged across fisheries (D.avg). TL is total length.

Age	TL(mm)	TL(in)	cl	co	hb	rec	D.cl	D.hb	D.rec	L.avg	D.avg	L.avg+D.avg
1	277.2	10.9	0.001	0.001	0.003	0.000	0.046	0.390	0.390	0.001	0.208	0.209
2	410.5	16.2	0.079	0.050	0.036	0.005	0.501	1.000	1.000	0.018	0.549	0.567
3	515.4	20.3	0.880	0.706	1.000	1.000	1.000	0.416	0.416	0.738	0.262	1.000
4	597.9	23.5	0.998	1.000	0.940	0.940	0.030	0.030	0.030	0.712	0.017	0.729
5	662.8	26.1	1.000	0.897	0.828	0.828	0.001	0.001	0.001	0.638	0.000	0.639
6	713.8	28.1	1.000	0.697	0.629	0.629	0.000	0.000	0.000	0.507	0.000	0.507
7	754.0	29.7	1.000	0.427	0.442	0.442	0.000	0.000	0.000	0.384	0.000	0.384
8	785.6	30.9	1.000	0.269	0.348	0.348	0.000	0.000	0.000	0.322	0.000	0.322
9	810.4	31.9	1.000	0.217	0.315	0.315	0.000	0.000	0.000	0.300	0.000	0.300
10	829.9	32.7	1.000	0.203	0.304	0.304	0.000	0.000	0.000	0.293	0.000	0.293
11	845.3	33.3	1.000	0.199	0.301	0.301	0.000	0.000	0.000	0.291	0.000	0.291
12	857.4	33.8	1.000	0.198	0.300	0.300	0.000	0.000	0.000	0.291	0.000	0.291
13	866.9	34.1	1.000	0.198	0.300	0.300	0.000	0.000	0.000	0.290	0.000	0.290
14	874.4	34.4	1.000	0.198	0.300	0.300	0.000	0.000	0.000	0.290	0.000	0.290
15	880.3	34.7	1.000	0.198	0.300	0.300	0.000	0.000	0.000	0.290	0.000	0.290
16	884.9	34.8	1.000	0.198	0.300	0.300	0.000	0.000	0.000	0.290	0.000	0.290
17	888.6	35.0	1.000	0.198	0.300	0.300	0.000	0.000	0.000	0.290	0.000	0.290
18	891.4	35.1	1.000	0.198	0.300	0.300	0.000	0.000	0.000	0.290	0.000	0.290
19	893.7	35.2	1.000	0.198	0.300	0.300	0.000	0.000	0.000	0.290	0.000	0.290
20	895.5	35.3	1.000	0.198	0.300	0.300	0.000	0.000	0.000	0.290	0.000	0.290

Table 3.6. Estimated time series of fully selected fishing mortality rates for commercial lines (F.cl), commercial dive (F.cd), for-hire (F.hb), private recreational (F.pvt), commercial lines discard mortalities (F.cl.D), for-hire discard mortalities (F.hb.D), private recreational discard mortalities (F.pvt.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.cl	F.cd	F.hb	F.pvt	F.cl.D	F.hb.D	F.pvt.D	Apical F
1955	0.007	0.000	0.025	0.007	0.000	0.000	0.000	0.039
1956	0.007	0.000	0.030	0.009	0.000	0.000	0.000	0.046
1957	0.012	0.000	0.035	0.012	0.000	0.000	0.000	0.060
1958	0.009	0.000	0.040	0.016	0.000	0.000	0.000	0.065
1959	0.010	0.000	0.044	0.020	0.000	0.000	0.000	0.074
1960	0.011	0.000	0.047	0.024	0.000	0.000	0.000	0.082
1961	0.013	0.000	0.049	0.027	0.000	0.000	0.000	0.090
1962	0.012	0.000	0.049	0.030	0.000	0.000	0.000	0.091
1963	0.009	0.000	0.050	0.034	0.000	0.000	0.000	0.093
1964	0.011	0.000	0.053	0.040	0.000	0.000	0.000	0.105
1965	0.014	0.000	0.062	0.051	0.000	0.000	0.000	0.126
1966	0.017	0.000	0.073	0.065	0.000	0.000	0.000	0.155
1967	0.024	0.000	0.085	0.081	0.000	0.000	0.000	0.190
1968	0.029	0.000	0.092	0.093	0.000	0.000	0.000	0.214
1969	0.021	0.000	0.091	0.097	0.000	0.000	0.000	0.209
1970	0.021	0.000	0.084	0.096	0.000	0.000	0.000	0.201
1971	0.020	0.000	0.076	0.095	0.000	0.000	0.000	0.191
1972	0.019	0.000	0.073	0.100	0.000	0.000	0.000	0.192
1973	0.017	0.000	0.078	0.116	0.000	0.000	0.000	0.211
1974	0.030	0.000	0.088	0.147	0.000	0.000	0.000	0.265
1975	0.040	0.000	0.099	0.185	0.000	0.000	0.000	0.325
1976	0.038	0.000	0.089	0.211	0.000	0.000	0.000	0.339
1977	0.046	0.000	0.097	0.217	0.000	0.000	0.000	0.360
1978	0.047	0.000	0.106	0.195	0.000	0.000	0.000	0.348
1979	0.038	0.000	0.107	0.215	0.000	0.000	0.000	0.360
1980	0.040	0.000	0.096	0.229	0.000	0.000	0.000	0.365
1981	0.048	0.000	0.169	0.511	0.000	0.000	0.000	0.728
1982	0.049	0.000	0.103	0.263	0.000	0.000	0.000	0.415
1983	0.058	0.000	0.161	0.222	0.000	0.059	0.012	0.441
1984	0.053	0.001	0.106	0.768	0.000	0.092	0.016	0.927
1985	0.059	0.002	0.178	0.635	0.000	0.031	0.067	0.873
1986	0.066	0.000	0.297	0.288	0.000	0.001	0.038	0.651
1987	0.069	0.000	0.135	0.279	0.000	0.000	0.204	0.484
1988	0.068	0.000	0.182	0.687	0.000	0.000	0.069	0.937
1989	0.148	0.000	0.212	0.702	0.000	0.001	0.084	1.063
1990	0.156	0.003	0.134	0.112	0.000	0.000	0.022	0.404
1991	0.095	0.009	0.128	0.257	0.000	0.002	0.076	0.486
1992	0.080	0.015	0.500	0.446	0.052	0.029	0.030	1.103
1993	0.150	0.007	0.103	0.078	0.040	0.058	0.081	0.415
1994	0.119	0.012	0.132	0.081	0.070	0.017	0.133	0.458
1995	0.102	0.008	0.140	0.015	0.088	0.080	0.118	0.420
1996	0.074	0.005	0.058	0.076	0.167	0.022	0.072	0.409
1997	0.068	0.008	0.713	0.042	0.197	0.043	0.019	1.044
1998	0.056	0.011	0.173	0.077	0.068	0.014	0.034	0.394
1999	0.047	0.010	0.309	0.147	0.049	0.056	0.148	0.640
2000	0.052	0.009	0.119	0.373	0.038	0.029	0.187	0.672
2001	0.076	0.012	0.083	0.156	0.029	0.034	0.178	0.432
2002	0.058	0.011	0.098	0.111	0.093	0.046	0.179	0.454
2003	0.040	0.008	0.093	0.064	0.054	0.045	0.276	0.386
2004	0.050	0.010	0.120	0.126	0.022	0.086	0.356	0.503
2005	0.040	0.006	0.128	0.118	0.026	0.200	0.306	0.528
2006	0.028	0.003	0.125	0.108	0.046	0.031	0.148	0.380
2007	0.039	0.007	0.149	0.309	0.027	0.077	0.209	0.644
2008	0.073	0.004	0.140	0.291	0.019	0.055	0.308	0.668
2009	0.111	0.004	0.184	0.342	0.054	0.091	0.454	0.908

Table 3.7. Estimated instantaneous fishing mortality rate (per yr) at age, including discard mortality

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1955	0.021	0.032	0.039	0.037	0.033	0.027	0.021	0.018	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
1956	0.024	0.037	0.046	0.043	0.039	0.031	0.024	0.020	0.019	0.019	0.019	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018
1957	0.029	0.048	0.060	0.057	0.052	0.042	0.033	0.029	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027
1958	0.033	0.051	0.065	0.062	0.055	0.044	0.034	0.029	0.027	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026
1959	0.036	0.056	0.074	0.070	0.063	0.050	0.038	0.032	0.030	0.030	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
1960	0.039	0.061	0.082	0.078	0.070	0.055	0.042	0.036	0.033	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
1961	0.041	0.066	0.090	0.085	0.077	0.062	0.047	0.040	0.037	0.037	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
1962	0.041	0.065	0.091	0.087	0.078	0.062	0.047	0.039	0.037	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
1963	0.041	0.064	0.093	0.088	0.079	0.062	0.046	0.038	0.036	0.035	0.035	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
1964	0.045	0.070	0.105	0.099	0.089	0.070	0.052	0.044	0.040	0.040	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
1965	0.052	0.083	0.126	0.120	0.107	0.085	0.064	0.053	0.049	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048
1966	0.062	0.100	0.155	0.147	0.131	0.104	0.078	0.065	0.060	0.059	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058
1967	0.072	0.121	0.190	0.180	0.161	0.128	0.097	0.081	0.076	0.074	0.074	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073
1968	0.079	0.135	0.214	0.203	0.182	0.145	0.111	0.093	0.087	0.085	0.085	0.085	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084
1969	0.077	0.127	0.209	0.197	0.176	0.139	0.104	0.086	0.080	0.078	0.078	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077
1970	0.071	0.120	0.201	0.190	0.170	0.134	0.101	0.084	0.078	0.076	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
1971	0.065	0.111	0.191	0.181	0.161	0.127	0.095	0.079	0.074	0.072	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071
1972	0.063	0.108	0.192	0.181	0.162	0.127	0.095	0.079	0.073	0.071	0.071	0.071	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
1973	0.067	0.114	0.211	0.199	0.177	0.139	0.103	0.084	0.078	0.076	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
1974	0.077	0.142	0.265	0.251	0.225	0.178	0.134	0.112	0.104	0.102	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101
1975	0.088	0.169	0.325	0.308	0.276	0.219	0.166	0.139	0.130	0.127	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126
1976	0.081	0.163	0.339	0.321	0.287	0.227	0.171	0.143	0.133	0.130	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129
1977	0.088	0.178	0.360	0.341	0.306	0.243	0.184	0.155	0.144	0.141	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
1978	0.094	0.184	0.348	0.330	0.296	0.236	0.180	0.152	0.142	0.139	0.138	0.138	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137
1979	0.095	0.181	0.360	0.341	0.304	0.240	0.180	0.150	0.139	0.136	0.135	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134
1980	0.087	0.174	0.365	0.345	0.309	0.244	0.184	0.153	0.142	0.139	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
1981	0.155	0.308	0.728	0.687	0.611	0.476	0.349	0.285	0.262	0.255	0.253	0.252	0.252	0.252	0.252	0.252	0.252	0.252	0.252	0.252
1982	0.094	0.196	0.415	0.393	0.352	0.279	0.211	0.177	0.164	0.161	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159
1983	0.077	0.315	0.441	0.418	0.375	0.299	0.227	0.191	0.178	0.174	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173
1984	0.097	0.402	0.927	0.875	0.777	0.602	0.439	0.357	0.328	0.319	0.316	0.315	0.315	0.315	0.315	0.315	0.315	0.315	0.315	0.315
1985	0.106	0.439	0.873	0.825	0.734	0.571	0.419	0.342	0.315	0.307	0.304	0.303	0.303	0.303	0.303	0.303	0.303	0.303	0.303	0.303
1986	0.099	0.430	0.651	0.616	0.550	0.434	0.325	0.269	0.250	0.244	0.242	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241
1987	0.127	0.446	0.484	0.459	0.412	0.330	0.253	0.214	0.200	0.195	0.194	0.194	0.194	0.194	0.194	0.194	0.194	0.194	0.194	0.194
1988	0.098	0.431	0.937	0.884	0.787	0.614	0.452	0.370	0.341	0.332	0.329	0.329	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328
1989	0.118	0.548	1.063	1.008	0.906	0.723	0.553	0.467	0.436	0.427	0.424	0.423	0.423	0.423	0.423	0.423	0.423	0.423	0.423	0.423
1990	0.057	0.306	0.404	0.390	0.362	0.313	0.266	0.242	0.234	0.231	0.231	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
1991	0.077	0.331	0.486	0.466	0.422	0.343	0.269	0.231	0.218	0.214	0.213	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212
1992	0.028	0.113	1.103	0.987	0.876	0.685	0.504	0.413	0.381	0.371	0.368	0.367	0.367	0.367	0.367	0.366	0.366	0.366	0.366	0.366
1993	0.057	0.176	0.415	0.332	0.306	0.268	0.233	0.214	0.208	0.206	0.206	0.205	0.205	0.205	0.205	0.205	0.205	0.205	0.205	0.205
1994	0.062	0.200	0.458	0.338	0.306	0.261	0.218	0.196	0.188	0.186	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185
1995	0.082	0.255	0.420	0.264	0.238	0.205	0.174	0.158	0.152	0.151	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
1996	0.045	0.186	0.409	0.213	0.190	0.162	0.135	0.122	0.117	0.116	0.115	0.115	0.115	0.115	0.115	0.115	0.115	0.115	0.115	0.115
1997	0.036	0.192	1.044	0.794	0.701	0.549	0.406	0.333	0.308	0.300	0.297	0.297	0.297	0.296	0.296	0.296	0.296	0.296	0.296	0.296
1998	0.022	0.093	0.394	0.304	0.272	0.220	0.171	0.146	0.137	0.134	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133
1999	0.083	0.245	0.640	0.494	0.435	0.341	0.254	0.209	0.193	0.188	0.187	0.187	0.186	0.186	0.186	0.186	0.186	0.186	0.186	0.186
2000	0.086	0.245	0.672	0.531	0.468	0.368	0.274	0.226	0.209	0.203	0.202	0.202	0.201	0.201	0.201	0.201	0.201	0.201	0.201	0.201
2001	0.085	0.238	0.432	0.319	0.284	0.234	0.187	0.162	0.154	0.151	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
2002	0.093	0.281	0.454	0.275	0.241	0.197	0.155	0.134	0.126	0.124	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123
2003	0.128	0.355	0.386	0.207	0.178	0.145	0.113	0.097	0.092	0.090	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089
2004	0.174	0.462	0.503	0.305	0.263	0.212	0.163	0.138	0.129	0.127	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126
2005	0.199	0.528	0.521	0.292	0.249	0.198	0.151	0.127	0.118	0.116	0.115	0.115	0.115	0.115	0.115	0.115	0.115	0.115	0.115	0.115
2006	0.072	0.209	0.380	0.257	0.224	0.177	0.133	0.110	0.102	0.100	0.099	0.099	0.099	0.099	0.099	0.099	0.099	0.099	0.099	0.099
2007	0.114	0.310	0.644	0.486	0.425	0.332	0.244	0.200	0.184	0.179	0.178	0.178	0.178	0.178	0.178	0.178	0.178	0.178	0.178	0.178
2008	0.143	0.385	0.668	0.493	0.433	0.346	0.265	0.224	0.209	0.205	0.203	0.203	0.203	0.203	0.203	0.203	0.203	0.203	0.203	0.203
2009	0.216	0.590	0.908	0.627	0.550	0.444	0.345	0.295	0.277	0.272	0.270	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269

Table 3.8. Estimated total landings at age in numbers (1000 fish)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1955	11.19	13.62	13.86	11.46	9.16	6.64	4.67	3.63	3.12	2.79	2.53	2.31	2.13	1.96	1.81	1.67	1.53	1.41	1.30	15.24
1956	7.63	15.51	16.03	13.18	10.50	7.56	5.27	4.07	3.48	3.11	2.82	2.58	2.37	2.19	2.01	1.86	1.71	1.57	1.45	16.96
1957	9.02	11.51	20.48	16.84	13.48	9.93	7.15	5.68	4.93	4.43	4.02	3.68	3.39	3.12	2.88	2.65	2.44	2.25	2.07	24.23
1958	9.93	11.82	12.61	17.60	13.91	10.00	6.99	5.44	4.70	4.22	3.84	3.52	3.24	2.98	2.75	2.53	2.33	2.15	1.98	23.16
1959	10.73	12.80	13.90	11.27	15.20	10.89	7.60	5.94	5.16	4.67	4.26	3.91	3.61	3.32	3.06	2.82	2.60	2.39	2.20	25.79
1960	11.31	13.51	14.92	12.00	9.41	11.49	7.99	6.24	5.44	4.96	4.56	4.20	3.88	3.58	3.30	3.04	2.80	2.58	2.38	27.79
1961	11.59	14.22	15.89	12.69	9.90	7.08	8.50	6.68	5.85	5.37	4.97	4.61	4.28	3.96	3.65	3.37	3.10	2.86	2.63	30.78
1962	11.35	13.73	15.68	12.40	9.57	6.75	4.67	6.23	5.44	4.99	4.65	4.34	4.06	3.77	3.48	3.21	2.96	2.73	2.51	29.38
1963	11.15	13.24	15.60	12.24	9.33	6.47	4.39	3.37	5.01	4.59	4.28	4.02	3.78	3.54	3.28	3.04	2.80	2.58	2.38	27.81
1964	11.76	14.20	17.14	13.41	10.17	7.01	4.73	3.63	3.15	4.94	4.61	4.34	4.10	3.86	3.61	3.35	3.10	2.86	2.63	30.82
1965	13.26	16.21	19.90	15.52	11.76	8.09	5.45	4.16	3.60	3.30	5.27	4.96	4.70	4.45	4.19	3.92	3.64	3.36	3.10	36.29
1966	15.34	18.75	23.17	17.88	13.53	9.32	6.28	4.79	4.13	3.77	3.51	5.66	5.37	5.09	4.82	4.54	4.24	3.94	3.64	42.66
1967	17.39	21.66	26.53	20.12	15.13	10.52	7.21	5.56	4.82	4.39	4.08	3.84	6.23	5.91	5.61	5.31	5.00	4.67	4.34	51.00
1968	18.34	23.11	27.97	20.69	15.33	10.65	7.39	5.79	5.06	4.61	4.28	4.01	3.80	6.18	5.86	5.56	5.27	4.95	4.63	54.88
1969	17.41	21.10	25.97	18.61	13.38	9.05	6.15	4.79	4.20	3.85	3.57	3.34	3.16	2.99	4.86	4.61	4.38	4.14	3.90	46.84
1970	15.64	19.46	24.40	17.17	11.99	7.91	5.31	4.13	3.66	3.40	3.17	2.97	2.80	2.65	2.51	4.08	3.87	3.67	3.48	42.56
1971	13.80	17.61	22.85	16.08	11.01	7.04	4.59	3.51	3.10	2.90	2.74	2.58	2.44	2.30	2.17	2.06	3.35	3.18	3.01	37.79
1972	12.67	16.57	22.49	15.96	10.92	6.83	4.30	3.19	2.76	2.58	2.46	2.34	2.22	2.10	1.98	1.87	1.77	2.88	2.74	35.14
1973	12.85	16.65	23.75	17.05	11.76	7.32	4.48	3.20	2.69	2.46	2.34	2.25	2.16	2.05	1.94	1.83	1.73	1.64	2.66	34.94
1974	16.88	19.39	27.55	19.93	14.02	8.98	5.65	4.04	3.32	2.97	2.77	2.66	2.58	2.48	2.36	2.22	2.10	1.98	1.88	43.17
1975	20.52	25.76	30.29	21.31	15.15	9.95	6.45	4.70	3.83	3.33	3.03	2.86	2.77	2.68	2.58	2.45	2.31	2.18	2.06	46.84
1976	32.32	26.43	34.60	19.21	13.29	8.81	5.84	4.37	3.61	3.11	2.75	2.53	2.40	2.32	2.25	2.16	2.06	1.94	1.83	41.07
1977	14.23	49.17	38.88	21.93	12.02	7.82	5.31	4.12	3.52	3.08	2.70	2.42	2.24	2.13	2.06	1.99	1.92	1.82	1.72	37.99
1978	12.12	20.55	64.07	22.39	12.47	6.43	4.29	3.39	3.00	2.71	2.42	2.14	1.93	1.78	1.70	1.64	1.59	1.53	1.45	31.70
1979	12.58	15.98	26.52	39.35	13.52	7.01	3.63	2.77	2.48	2.31	2.12	1.91	1.70	1.53	1.42	1.35	1.31	1.27	1.22	26.37
1980	13.55	15.87	21.24	15.84	23.19	7.48	3.96	2.40	2.10	1.99	1.89	1.75	1.59	1.42	1.28	1.18	1.13	1.09	1.06	23.00
1981	18.74	31.25	37.29	21.32	15.84	22.07	7.28	4.47	3.09	2.86	2.76	2.64	2.47	2.24	2.00	1.80	1.67	1.59	1.53	33.92
1982	12.50	15.68	25.31	9.99	5.74	4.15	6.29	2.59	1.90	1.41	1.34	1.31	1.26	1.18	1.07	0.96	0.86	0.80	0.76	16.94
1983	26.43	20.92	22.28	14.90	5.84	3.19	2.40	4.28	2.02	1.57	1.19	1.14	1.12	1.08	1.01	0.92	0.82	0.74	0.68	15.19
1984	29.32	97.54	38.03	20.86	14.00	5.29	2.99	2.59	5.24	2.61	2.06	1.58	1.52	1.50	1.45	1.35	1.23	1.10	0.99	21.21
1985	7.05	111.11	135.95	12.38	6.97	4.71	2.00	1.44	1.51	3.30	1.68	1.35	1.04	1.00	0.99	0.95	0.89	0.81	0.72	14.63
1986	5.73	24.93	107.00	39.62	3.67	2.05	1.55	0.83	0.72	0.81	1.82	0.94	0.76	0.59	0.57	0.56	0.54	0.50	0.46	8.66
1987	19.36	9.96	16.77	37.95	14.13	1.28	0.77	0.71	0.45	0.42	0.48	1.09	0.57	0.46	0.35	0.34	0.33	0.32	0.30	5.49
1988	4.50	90.59	17.20	14.08	32.05	11.56	1.09	0.76	0.80	0.53	0.50	0.58	1.33	0.69	0.56	0.43	0.42	0.41	0.40	7.07
1989	12.34	17.04	113.15	6.24	5.31	12.52	5.29	0.65	0.56	0.63	0.43	0.41	0.48	1.10	0.57	0.46	0.36	0.34	0.34	6.18
1990	7.22	26.23	7.86	16.97	0.97	0.87	2.51	1.41	0.21	0.19	0.22	0.16	0.15	0.17	0.40	0.21	0.17	0.13	0.13	2.37
1991	10.12	24.86	26.23	5.21	11.02	0.59	0.51	1.56	0.93	0.14	0.13	0.15	0.11	0.10	0.12	0.28	0.14	0.12	0.09	1.72
1992	0.39	4.31	44.69	23.32	4.63	9.48	0.52	0.52	1.75	1.09	0.17	0.16	0.19	0.13	0.12	0.15	0.33	0.17	0.14	2.19
1993	0.07	2.24	33.12	5.82	3.28	0.70	1.82	0.14	0.18	0.65	0.42	0.07	0.06	0.07	0.05	0.05	0.06	0.13	0.07	0.91
1994	0.08	1.43	28.41	20.95	3.57	1.92	0.41	1.14	0.09	0.12	0.44	0.29	0.05	0.04	0.05	0.03	0.03	0.04	0.09	0.68
1995	0.02	1.18	15.01	13.62	10.10	1.68	0.93	0.23	0.68	0.06	0.07	0.28	0.18	0.03	0.03	0.03	0.02	0.02	0.03	0.49
1996	0.04	0.18	10.93	7.87	7.23	5.12	0.85	0.52	0.13	0.42	0.04	0.05	0.18	0.11	0.02	0.02	0.02	0.01	0.01	0.32
1997	0.56	2.90	8.34	21.07	15.71	13.35	8.90	1.53	0.98	0.26	0.81	0.07	0.09	0.35	0.23	0.04	0.03	0.04	0.03	0.66
1998	0.14	1.87	18.03	1.31	3.75	2.77	2.61	2.21	0.46	0.31	0.09	0.27	0.02	0.03	0.12	0.08	0.01	0.01	0.01	0.23
1999	0.51	2.28	49.69	16.35	1.19	3.15	2.30	2.43	2.29	0.49	0.35	0.09	0.30	0.03	0.03	0.13	0.08	0.01	0.01	0.27
2000	0.25	3.11	42.35	25.23	8.73	0.61	1.69	1.48	1.82	1.82	0.40	0.28	0.08	0.25	0.02	0.03	0.11	0.07	0.01	0.24
2001	0.07	2.62	55.26	12.87	8.11	2.77	0.21	0.74	0.77	1.01	1.04	0.23	0.17	0.05	0.15	0.01	0.02	0.06	0.04	0.14
2002	0.06	1.02	41.33	28.89	6.74	4.01	1.38	0.12	0.46	0.50	0.67	0.69	0.16	0.11	0.03	0.10	0.01	0.01	0.04	0.12
2003	0.08	0.63	13.41	19.08	13.85	3.03	1.80	0.70	0.07	0.27	0.30	0.40	0.42	0.09	0.07	0.02	0.06	0.01	0.01	0.10
2004	0.05	1.14	14.49	12.32	18.22	12.35	2.67	1.78	0.77	0.08	0.31	0.35	0.47	0.49	0.11	0.08	0.02	0.07	0.01	0.13
2005	0.03	0.47	17.99	7.96	7.16	9.91	6.71	1.65	1.24	0.56	0.06	0.24	0.26	0.36	0.37	0.08	0.06	0.02	0.05	0.10
2006	0.34	0.25	7.59	9.38	4.48	3.74	5.13	3.95	1.10	0.86	0.40	0.04	0.17	0.19	0.26	0.27	0.06	0.04	0.01	0.11
2007	0.34	4.54	9.53	8.02	10.24	4.58	3.83	6.02	5.26	1.54	1.24	0.58	0.06	0.25	0.28	0.38	0.39	0.09	0.06	0.18
2008	0.09	3.71	115.93	4.59	4.13	5.15	2.47	2.55	4.74	4.44	1.33	1.08	0.51	0.05	0.22	0.24	0.33	0.35	0.08	0.21
2009	0.06	1.28	86.12	65.64	2.81	2.49	3.32	1.91	2.27	4.48	4.28	1.30	1.06	0.50	0.05	0.21	0.24	0.33	0.34	0.28

Table 3.9. Estimated total 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	17	18	19	20
1955	7.38	30.58	63.26	83.16	91.64	83.76	69.92	61.81	58.46	56.32	54.08	51.73	49.30	46.64	43.88	41.09	38.34	35.68	33.13	389.83
1956	5.03	34.83	73.17	95.62	105.10	95.38	78.80	69.14	65.19	62.74	60.23	57.60	54.90	51.94	48.86	45.75	42.69	39.73	36.89	434.08
1957	5.95	25.85	93.52	122.17	134.94	125.26	107.04	96.58	92.37	89.40	85.97	82.26	78.41	74.19	69.79	65.35	60.98	56.74	52.69	620.03
1958	6.55	26.54	57.55	127.70	139.23	126.08	104.61	92.51	88.04	85.29	82.11	78.60	74.93	70.90	66.70	62.46	58.28	54.23	50.35	592.57
1959	7.07	28.74	63.45	81.76	152.14	137.30	113.69	100.97	96.63	94.20	91.12	87.43	83.41	78.94	74.27	69.55	64.90	60.39	56.07	659.85
1960	7.46	30.34	68.11	87.10	94.14	144.94	119.57	106.03	101.99	100.03	97.39	93.90	89.79	85.05	80.03	74.95	69.94	65.08	60.43	711.11
1961	7.64	31.93	72.57	92.10	99.10	89.29	127.18	113.58	109.71	108.40	106.25	103.13	99.09	94.08	88.60	82.99	77.45	72.07	66.92	787.51
1962	7.48	30.83	71.58	90.01	95.76	85.14	69.85	105.91	101.96	100.73	99.32	97.01	93.83	89.51	84.49	79.21	73.94	68.81	63.89	751.87
1963	7.36	29.73	71.22	88.79	93.39	81.61	65.61	57.27	93.93	92.68	91.45	89.87	87.48	84.01	79.68	74.87	69.94	65.11	60.46	711.52
1964	7.75	31.88	78.25	97.29	101.77	88.48	70.82	61.65	58.97	99.71	98.45	96.88	94.91	91.72	87.57	82.69	77.42	72.13	66.99	788.50
1965	8.75	36.41	90.84	112.58	117.63	102.03	81.54	70.76	67.49	66.53	112.56	110.84	108.72	105.74	101.61	96.58	90.87	84.85	78.87	928.59
1966	10.12	42.09	105.79	129.76	135.36	117.58	93.95	81.42	77.38	76.03	74.99	126.51	124.17	120.93	116.94	111.87	105.95	99.41	92.62	1091.67
1967	11.47	48.62	121.13	145.99	151.44	132.70	107.82	94.57	90.28	88.57	87.11	85.70	144.12	140.45	136.00	130.92	124.80	117.87	110.35	1304.97
1968	12.09	51.88	127.71	150.11	153.36	134.27	110.53	98.44	94.74	93.16	91.41	89.66	87.91	146.79	142.23	137.10	131.51	125.01	117.82	1404.31
1969	11.48	47.38	118.56	135.06	133.93	114.09	91.95	81.41	78.72	77.72	76.34	74.67	72.99	71.06	117.96	113.78	109.29	104.55	99.16	1198.49
1970	10.32	43.69	111.38	124.55	120.02	99.83	79.40	70.28	68.66	68.60	67.82	66.45	64.79	62.88	60.87	100.59	96.68	92.60	88.40	1089.11
1971	9.10	39.55	104.34	116.68	110.22	88.83	68.67	59.70	58.11	58.58	58.58	57.76	56.41	54.61	52.70	50.78	83.63	80.15	76.61	966.92
1972	8.35	37.20	102.67	115.83	109.32	86.17	64.33	54.22	51.80	52.03	52.49	52.36	51.46	49.90	48.03	46.14	44.30	72.76	69.58	899.24
1973	8.47	37.38	108.42	123.68	117.65	92.36	67.06	54.39	50.36	49.65	49.92	50.24	49.95	48.74	47.00	45.03	43.11	41.28	67.64	893.97
1974	11.13	43.54	125.80	144.58	140.30	113.23	84.50	68.68	62.27	59.91	59.26	59.47	59.67	58.90	57.15	54.86	52.38	50.00	47.77	1104.74
1975	13.53	57.84	138.29	154.60	151.60	125.53	96.50	79.92	71.81	67.26	64.80	63.93	63.95	63.71	62.53	60.40	57.77	55.01	52.40	1198.55
1976	21.31	59.35	157.95	139.36	132.98	111.18	87.44	74.24	67.69	62.71	58.78	56.47	55.54	55.16	54.63	53.38	51.38	49.01	46.56	1050.87
1977	9.38	110.39	177.52	159.11	120.27	98.67	79.46	69.98	65.97	62.24	57.77	54.01	51.73	50.51	49.88	49.18	47.89	45.96	43.75	972.19
1978	7.99	46.14	292.51	162.42	124.74	81.14	64.14	57.68	56.20	54.72	51.68	47.84	44.59	42.40	41.17	40.47	39.76	38.61	36.98	811.09
1979	8.30	35.87	121.09	285.51	135.27	88.43	54.36	47.12	46.41	46.53	45.30	42.65	39.35	36.42	34.43	33.28	32.60	31.94	30.95	674.64
1980	8.94	35.64	96.99	114.93	232.05	94.32	59.24	40.80	39.35	40.15	40.34	39.18	36.78	33.70	31.00	29.18	28.11	27.45	26.84	588.43
1981	12.36	70.17	170.27	154.73	158.55	278.42	108.98	76.02	57.86	57.65	58.90	59.02	57.14	53.26	48.52	44.44	41.68	40.03	39.02	867.81
1982	8.24	35.20	115.57	72.48	57.48	52.38	94.12	44.04	35.55	28.48	28.58	29.18	29.16	28.04	25.99	23.56	21.51	20.12	19.28	433.40
1983	30.04	47.43	101.74	108.13	58.43	40.29	35.84	72.73	37.89	31.67	25.42	25.45	25.90	25.70	24.57	22.67	20.48	18.64	17.40	388.60
1984	33.33	221.18	173.64	151.34	140.13	66.70	44.67	44.03	98.20	52.69	44.05	35.25	35.17	35.55	35.08	33.38	30.69	27.65	25.11	542.74
1985	8.02	251.93	620.71	89.82	69.74	59.39	29.93	24.48	28.22	66.53	36.01	30.09	24.02	23.81	23.92	23.50	22.28	20.43	18.37	374.33
1986	6.52	56.52	488.51	287.49	36.74	25.91	23.13	14.14	13.47	16.39	38.94	21.06	17.55	13.92	13.71	13.72	13.43	12.70	11.62	221.62
1987	22.00	22.59	76.57	275.38	141.38	16.09	11.54	12.10	8.42	8.38	10.24	24.29	13.10	10.85	8.55	8.39	8.36	8.16	7.70	140.35
1988	5.12	205.40	78.54	102.14	320.73	145.81	16.25	12.97	14.95	10.72	10.66	12.98	30.70	16.44	13.53	10.62	10.38	10.32	10.05	180.98
1989	14.03	38.63	516.62	45.28	53.12	157.95	79.18	11.06	10.42	12.71	9.20	9.14	11.11	26.09	13.90	11.38	8.90	8.68	8.61	158.14
1990	8.20	59.47	35.86	123.17	9.76	11.03	37.54	24.02	3.94	3.91	4.80	3.47	3.44	4.15	9.69	5.14	4.20	3.27	3.18	60.69
1991	11.50	56.37	119.75	37.82	110.24	7.44	7.69	26.57	17.46	2.86	2.81	3.44	2.47	2.43	2.92	6.79	3.59	2.92	2.27	44.02
1992	1.86	21.14	248.93	172.30	46.36	119.60	7.81	8.80	32.88	22.09	3.61	3.53	4.30	3.07	3.01	3.59	8.33	4.39	3.56	56.06
1993	0.35	11.00	184.47	43.03	32.80	8.87	27.29	2.39	3.28	13.14	8.93	1.46	1.43	1.73	1.23	1.19	1.42	3.28	1.73	23.30
1994	0.38	7.03	158.26	154.81	35.77	24.16	6.13	19.37	1.75	2.40	9.49	6.42	1.05	1.01	1.22	0.86	0.84	0.99	2.29	17.31
1995	0.09	5.79	83.59	100.68	101.17	21.16	13.98	3.83	12.84	1.17	1.60	6.29	4.24	0.69	0.66	0.79	0.56	0.54	0.64	12.51
1996	0.19	0.87	60.90	58.19	72.43	64.53	12.77	8.83	2.52	8.48	0.77	1.04	4.08	2.73	0.44	0.42	0.50	0.35	0.34	8.25
1997	2.64	14.23	46.45	155.72	157.28	168.41	133.17	26.09	18.35	5.22	17.39	1.56	2.11	8.22	5.46	0.88	0.84	0.99	0.70	16.85
1998	0.67	9.18	100.42	9.72	37.51	34.92	39.11	37.56	8.56	6.34	1.82	6.06	0.54	0.73	2.82	1.87	0.30	0.28	0.34	5.90
1999	2.41	11.16	276.77	120.84	11.88	39.76	34.43	41.33	42.83	9.98	7.38	2.11	6.99	0.62	0.83	3.20	2.11	0.34	0.32	6.96
2000	1.16	15.24	235.87	186.43	87.41	7.68	25.33	25.14	34.07	36.80	8.61	6.35	1.81	5.96	0.53	0.70	2.69	1.77	0.28	6.04
2001	0.35	12.84	307.83	95.09	81.20	34.99	3.19	12.57	14.38	20.45	22.23	5.19	3.82	1.08	3.54	0.31	0.41	1.58	1.04	3.68
2002	0.30	4.99	230.19	213.48	67.49	50.59	20.67	2.03	8.62	10.05	14.24	15.42	3.59	2.62	0.74	2.40	0.21	0.28	1.06	3.16
2003	0.38	3.11	74.72	141.00	138.62	38.19	26.93	11.88	1.26	5.46	6.35	8.96	9.67	2.23	1.62	0.45	1.48	0.13	0.17	2.56
2004	0.24	5.57	80.70	91.02	182.41	155.75	40.00	30.26	14.39	1.56	6.73	7.79	10.96	11.74	2.70	1.95	0.54	1.76	0.15	3.23
2005	0.13	2.29	100.19	58.84	71.72	125.06	100.36	28.08	23.16	11.30	1.22	5.27	6.07	8.49	9.03	2.07	1.49	0.41	1.34	2.55
2006	1.62	1.23	42.26	69.35	44.81	47.20	76.80	67.11	20.54	17.43	8.50	0.92	3.94	4.51	6.26	6.63	1.51	1.09	0.30	2.82
2007	1.61	22.28	53.11	59.30	102.57	57.73	57.33	102.45	98.65	31.17	26.48	12.88	1.39	5.90	6.72	9.29	9.81	2.23	1.60	4.56
2008	0.44	18.19	645.75	33.92	41.39	64.97	37.02	43.32	88.80	89.66	28.51	24.19	11.73	1.25	5.31	6.02	8.29	8.73	1.98	5.43
2009	0.27	6.27	479.73	485.06	28.14	31.40	49.71	32.54	42.57	90.36	91.40	28.99	24.52	11.81	1.25	5.29	5.97	8.21	8.63	7.28

Table 3.10. Estimated time series of landings in numbers (1000 fish) for commercial lines (L.cl), commercial combined (L.cd), for-hire (L.hb), and private recreational (L.pvt)

Year	L.cl	L.cd	L.hb	L.pvt	Total
1955	29.95	0.00	68.34	13.76	112.05
1956	28.94	0.00	74.85	18.07	121.86
1957	50.16	0.00	81.38	22.66	154.20
1958	34.58	0.00	84.54	26.59	145.71
1959	36.31	0.00	85.67	30.12	152.11
1960	36.53	0.00	85.56	33.29	155.37
1961	42.71	0.00	83.61	35.69	162.00
1962	35.17	0.00	79.52	37.21	151.90
1963	26.73	0.00	76.60	39.57	142.90
1964	29.62	0.00	78.85	44.93	153.41
1965	34.82	0.00	86.63	53.67	175.12
1966	39.30	0.00	97.00	64.12	200.42
1967	51.33	0.00	104.99	72.99	229.31
1968	57.23	0.00	104.90	76.22	238.35
1969	37.79	0.00	95.70	72.80	206.30
1970	34.99	0.00	83.02	66.82	184.84
1971	30.12	0.00	71.85	62.16	164.13
1972	26.37	0.00	65.59	61.82	153.78
1973	22.09	0.00	65.97	67.65	155.71
1974	36.55	0.00	71.73	78.64	186.93
1975	44.37	0.00	77.39	89.30	211.05
1976	38.95	0.00	78.86	95.09	212.90
1977	45.85	0.00	75.90	95.31	217.06
1978	40.67	0.00	68.69	89.94	199.30
1979	27.17	0.00	58.58	80.57	166.33
1980	25.12	0.00	47.79	70.10	143.00
1981	25.05	0.00	69.61	122.19	216.85
1982	21.19	0.00	37.77	53.07	112.03
1983	24.42	0.00	59.31	43.99	127.72
1984	30.00	0.13	60.08	162.25	252.45
1985	34.43	0.35	97.04	178.65	310.48
1986	24.85	0.07	99.10	78.28	202.30
1987	19.91	0.00	40.29	51.32	111.52
1988	24.51	0.00	62.54	98.49	185.54
1989	32.42	0.00	44.46	107.51	184.40
1990	30.55	0.23	26.68	11.10	68.55
1991	21.31	0.78	30.64	31.40	84.13
1992	9.08	1.21	45.73	38.44	94.46
1993	23.30	0.81	14.94	10.86	49.91
1994	21.91	1.80	22.59	13.57	59.87
1995	18.65	1.24	22.42	2.39	44.70
1996	13.29	0.70	8.68	11.41	34.08
1997	8.75	0.75	62.89	3.54	75.94
1998	7.71	0.94	18.10	7.58	34.34
1999	8.78	1.33	49.25	22.64	81.99
2000	10.24	1.38	19.49	57.46	88.57
2001	21.75	2.57	21.87	40.16	86.35
2002	19.56	2.95	30.09	33.84	86.44
2003	12.36	2.04	23.89	16.11	54.39
2004	13.73	2.04	24.77	25.37	65.90
2005	10.08	0.94	23.09	21.16	55.27
2006	6.15	0.40	17.29	14.54	38.37
2007	8.06	0.74	17.32	31.31	57.43
2008	25.40	0.86	41.72	84.24	152.22
2009	35.20	1.05	50.14	92.57	178.97

Table 3.11. Estimated time series of landings in whole weight (1000 lb) for commercial lines (L.cl), commercial other (L.cd), for-hire (L.hb), and private recreational (L.pvt)

Year	L.cl	L.cd	L.hb	L.pvt	Total
1955	497.92	0.00	703.84	188.24	1390.00
1956	484.42	0.00	824.35	248.89	1557.66
1957	869.31	0.00	952.27	317.92	2139.50
1958	617.52	0.00	1032.46	395.25	2045.22
1959	662.96	0.00	1073.06	465.85	2201.87
1960	677.39	0.00	1082.99	526.99	2287.38
1961	800.22	0.00	1058.43	570.93	2429.59
1962	662.89	0.00	1001.28	596.96	2261.12
1963	505.03	0.00	957.22	633.77	2096.01
1964	559.74	0.00	976.81	717.28	2253.84
1965	657.16	0.00	1063.03	853.59	2573.78
1966	740.55	0.00	1177.49	1016.48	2934.52
1967	964.60	0.00	1256.95	1153.34	3374.89
1968	1070.51	0.00	1231.92	1197.62	3500.05
1969	701.03	0.00	1095.58	1131.97	2928.58
1970	641.40	0.00	923.86	1021.66	2586.93
1971	543.81	0.00	777.41	930.71	2251.93
1972	468.90	0.00	693.13	906.15	2068.18
1973	387.56	0.00	684.07	974.66	2046.29
1974	633.14	0.00	706.54	1118.46	2458.14
1975	746.32	0.00	706.34	1247.28	2699.93
1976	619.61	0.00	573.93	1252.47	2446.00
1977	649.73	0.00	571.33	1154.81	2375.86
1978	590.31	0.00	564.67	987.29	2142.26
1979	410.17	0.00	502.53	957.76	1870.46
1980	380.83	0.00	389.89	872.70	1643.42
1981	371.67	0.00	548.41	1534.75	2454.84
1982	306.45	0.00	268.07	627.82	1202.34
1983	310.67	0.00	381.76	466.58	1159.02
1984	248.37	1.32	260.55	1360.31	1870.56
1985	241.02	2.55	430.42	1171.53	1845.52
1986	215.76	0.51	592.84	537.97	1347.08
1987	187.17	0.03	226.51	420.71	834.43
1988	163.97	0.01	284.61	770.69	1219.28
1989	258.29	0.01	235.14	710.72	1204.15
1990	214.96	1.86	122.02	80.10	418.93
1991	133.98	5.90	128.81	202.68	471.37
1992	89.03	9.61	363.59	313.00	775.24
1993	189.81	5.61	102.03	74.86	372.31
1994	179.57	13.12	161.33	97.50	451.52
1995	166.70	10.04	177.09	18.98	372.80
1996	130.61	6.15	74.12	97.78	308.66
1997	101.24	7.53	637.11	36.67	782.55
1998	80.02	8.06	151.57	64.99	304.64
1999	80.52	9.97	362.88	168.86	622.24
2000	92.13	10.38	146.29	441.08	689.87
2001	175.32	18.24	151.48	280.75	625.78
2002	163.11	22.10	219.31	247.60	652.12
2003	118.79	17.45	202.00	136.94	475.19
2004	149.73	19.65	236.07	244.04	649.48
2005	117.99	9.34	224.78	206.96	559.07
2006	80.29	4.16	183.87	156.50	424.82
2007	104.72	7.51	187.91	366.92	667.06
2008	240.48	6.30	301.94	616.19	1164.92
2009	340.89	8.01	382.32	708.17	1439.40

Table 3.12. Estimated time series of dead discards in numbers (1000 fish) for commercial lines (D.cl), for-hire (D.hb), and private recreational (D.pvt)

Year	D.cl	D.hb	D.pvt	Total
1983	0.00	17.33	3.38	20.72
1984	0.00	49.82	8.91	58.72
1985	0.00	11.39	24.75	36.14
1986	0.00	0.06	3.38	3.45
1987	0.00	0.06	41.51	41.58
1988	0.00	0.06	18.85	18.91
1989	0.00	0.06	7.81	7.88
1990	0.00	0.06	3.38	3.45
1991	0.00	0.29	13.98	14.27
1992	6.83	7.35	7.60	21.78
1993	7.16	13.68	19.08	39.92
1994	9.90	3.02	24.35	37.27
1995	9.32	9.98	14.78	34.08
1996	11.92	2.07	6.87	20.86
1997	13.16	7.80	3.38	24.35
1998	10.12	3.63	8.95	22.70
1999	9.30	19.49	51.56	80.35
2000	9.10	13.33	86.74	109.17
2001	9.12	13.46	69.61	92.19
2002	20.30	10.61	41.18	72.08
2003	6.70	8.89	54.17	69.77
2004	2.48	15.35	63.71	81.54
2005	2.40	20.26	31.07	53.73
2006	3.56	9.51	45.04	58.11
2007	7.08	48.40	131.63	187.11
2008	7.44	24.51	136.62	168.58
2009	9.79	14.40	71.59	95.77

Table 3.13. Estimated time series of dead discards in whole weight (1000 lb) for commercial lines (D.cl), for-hire (D.hb), and private recreational (D.pvt)

Year	D.cl	D.hb	D.pvt	Total
1983	0.00	9.13	1.78	10.92
1984	0.00	28.80	5.15	33.95
1985	0.00	7.08	15.39	22.46
1986	0.00	0.04	2.01	2.04
1987	0.00	0.03	21.29	21.33
1988	0.00	0.04	11.78	11.82
1989	0.00	0.04	4.24	4.28
1990	0.00	0.04	1.96	1.99
1991	0.00	0.16	7.91	8.07
1992	16.99	13.42	13.88	44.29
1993	20.26	28.34	39.53	88.12
1994	28.43	6.11	49.31	83.85
1995	26.67	23.00	34.05	83.72
1996	35.55	3.49	11.56	50.60
1997	28.43	11.81	5.12	45.37
1998	25.95	6.71	16.56	49.22
1999	24.69	31.43	83.17	139.30
2000	22.52	24.02	156.32	202.87
2001	25.81	29.15	150.80	205.76
2002	61.00	23.25	90.28	174.53
2003	18.51	15.79	96.22	130.53
2004	6.58	30.99	128.66	166.23
2005	7.12	44.70	68.56	120.38
2006	7.34	9.14	43.31	59.80
2007	15.24	85.09	231.43	331.76
2008	21.44	55.76	310.78	387.97
2009	30.33	34.88	173.44	238.65

Table 3.14. Estimated status indicators, benchmarks, and related quantities from the Beaufort catch-age model, conditional on estimated current selectivities averaged across fisheries. Precision is represented by standard errors (SE) approximated from Monte Carlo/Bootstrap analysis. Estimates of yield do not include discards; D_{MSY} represents discard mortalities expected when fishing at F_{MSY}. Rate estimates (F) are in units of y^{-1}; status indicators are dimensionless; and biomass estimates are in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) is measured by total gonad weight of mature females. Symbols, abbreviations, and acronyms are listed in Appendix A.

Quantity	Units	Estimate	SE
F_{MSY}	y^{-1}	0.178	0.029
$85\%F_{MSY}$	y^{-1}	0.151	0.025
$75\%F_{MSY}$	y^{-1}	0.133	0.022
$65\%F_{MSY}$	y^{-1}	0.115	0.019
$F_{30\%}$	y^{-1}	0.170	0.024
$F_{40\%}$	y^{-1}	0.125	0.019
$F_{50\%}$	y^{-1}	0.092	0.014
B_{MSY}	mt	13632	4768
SSB_{MSY}	mt	156	65
MSST	mt	144	61
MSY	1000 lb	1842	311
D_{MSY}	1000 fish	67	17
R_{MSY}	1000 age-1 fish	584	157
Y at $85\%F_{MSY}$	1000 lb	1821	301
Y at $75\%F_{MSY}$	1000 lb	1780	299
Y at $65\%F_{MSY}$	1000 lb	1712	287
$F_{2007-2009}/F_{MSY}$	—	4.12	0.54
SSB_{2009}/MSST	—	0.09	0.03

Table 3.15. Results from sensitivity runs of the Beaufort catch-age model. Current F represented by geometric mean of last three assessment years. Spawning biomass was based on total gonad weight of mature females, with the exception of S16 (*) which used body weight of mature females. See text for full description of sensitivity runs.

Run	Description	F_{MSY}	SSB_{MSY} (mt)	B_{MSY} (mt)	MSY(1000 lb)	$F_{2007-2009}/F_{MSY}$	SSB_{2009}/MSST	steep	R0(1000)
Base	—	0.178	156	13632	1842	4.12	0.09	0.85	535
S1	low M	0.154	239	18242	1726	5.05	0.08	0.85	330
S2	high M	0.209	81	8620	1620	3.33	0.12	0.85	734
S3	M1=0.6	0.175	164	14142	1865	4.18	0.09	0.85	690
S4	low disc M	0.176	145	12808	1888	4.06	0.08	0.85	514
S5	high disc M	0.18	167	14440	1798	4.16	0.09	0.85	555
S6	h=0.75	0.163	203	17104	1838	4.23	0.1	0.75	609
S7	h=0.95	0.197	96	8894	1598	4.17	0.07	0.95	395
S8	h est	0.207	66	6298	1274	4.14	0.09	0.98	296
S9	Rsigma=0.4	0.171	153	13273	1720	3.97	0.1	0.85	571
S10	Rsigma=0.8	0.184	162	14255	2016	4.19	0.07	0.85	491
S11	q const	0.176	157	13662	1814	3.64	0.11	0.85	535
S12	q 0.04	0.179	156	13628	1863	4.45	0.08	0.85	535
S13	rand walk q	0.178	157	13636	1792	3.68	0.11	0.85	532
S14	age error	0.181	155	13564	1822	4.14	0.09	0.85	530
S15	continuity 1	0.083	160	14599	2331	5.71	0.07	0.85	557
S16	continuity 2	0.092	5415*	12460	2163	5.58	0.1	0.85	497
S17	styr 1976	0.168	189	16596	2297	4.06	0.07	0.85	659
S18	styr 1986	0.14	190	16844	2416	3.72	0.08	0.85	671
S19	Finit 0.01	0.179	151	13235	1785	4.13	0.09	0.85	518
S20	Finit 0.04	0.176	164	14374	1948	4.09	0.08	0.85	565
S21	low recr LD	0.183	86	7555	1023	4.67	0.11	0.85	293
S22	high recr LD	0.177	223	19477	2630	3.81	0.08	0.85	768
S23	low comm LD	0.178	145	12659	1711	4.2	0.09	0.85	497
S24	high comm LD	0.177	168	14661	1980	4.04	0.09	0.85	574
S25	U.hb 0.5	0.175	152	13338	1821	4.82	0.07	0.85	527
S26	U.hb 2	0.191	164	14285	1899	3.14	0.12	0.85	549
S27	U.cl 0.5	0.182	158	13783	1807	3.7	0.11	0.85	535
S28	U.cl 2	0.168	153	13471	1920	4.56	0.07	0.85	538
S29	age 0.5	0.178	154	13460	1816	4.01	0.09	0.85	528
S30	age 2	0.178	159	13914	1881	4.26	0.08	0.85	545
S31	len 0.5	0.177	150	13099	1758	3.84	0.1	0.85	512
S32	len 2	0.18	162	14132	1924	4.44	0.08	0.85	555
S33	comm 1.0 recr 0.1	0.191	148	13020	1791	4	0.08	0.85	521
S34	comm 1.0 recr 0.5	0.15	160	14198	2015	4.4	0.08	0.85	548
S35	comm 0.75 recr 0.1	0.206	144	12539	1681	3.73	0.1	0.85	502
S36	comm 0.75 recr 0.3	0.19	152	13272	1754	3.89	0.1	0.85	516
S37	comm 0.75 recr 0.5	0.156	156	13815	1932	4.18	0.09	0.85	530
S38	comm 0.5 recr 0.1	0.234	137	11792	1513	3.37	0.12	0.85	475
S39	comm 0.5 recr 0.3	0.201	147	12758	1655	3.63	0.12	0.85	494
S40	comm 0.5 recr 0.5	0.162	151	13276	1830	3.92	0.11	0.85	508
S41	extreme 1	0.305	63	6573	1246	2.23	0.23	0.85	603
S42	extreme 2	0.129	254	19515	1854	5.92	0.08	0.85	345

Table 3.16. Projection results under scenario 2—fishing mortality rate fixed at $F = F_{current}$. F = fishing mortality rate (per year), Pr(SSB > SSB_{MSY}) = proportion of stochastic projection replicates exceeding SSB_{MSY}, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are F_{MSY} = 0.178 (per yr), SSB_{MSY} = 156 (mt), and MSY = 1842 (1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(mt)	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2010	0.416	0	11.49	235	62	306	0	0	0
2011	0.727	0	13.76	223	79	137	75	837	837
2012	0.727	0	10.72	251	85	153	71	726	1563
2013	0.727	0	9.6	213	85	159	66	641	2204
2014	0.727	0	8.65	197	77	146	67	615	2820
2015	0.727	0	7.79	183	70	132	62	569	3389
2016	0.727	0	7.01	169	65	122	57	524	3913
2017	0.727	0	6.31	156	60	113	53	481	4393
2018	0.727	0	5.7	144	56	105	49	440	4834
2019	0.727	0	5.16	133	51	97	45	404	5238
2020	0.727	0	4.69	123	47	89	42	371	5608
2021	0.727	0	4.27	113	44	82	38	340	5949
2022	0.727	0	3.89	105	40	76	35	313	6261
2023	0.727	0	3.56	97	37	70	32	288	6549
2024	0.727	0	3.26	90	34	65	30	265	6814
2025	0.727	0	2.99	83	32	60	28	244	7059
2026	0.727	0	2.75	77	30	56	26	226	7284
2027	0.727	0	2.53	71	27	52	24	208	7492
2028	0.727	0	2.33	66	25	48	22	193	7685
2029	0.727	0	2.15	62	24	44	20	178	7863
2030	0.727	0	1.98	57	22	41	19	165	8028
2031	0.727	0	1.83	53	20	38	17	153	8181
2032	0.727	0	1.69	49	19	36	16	142	8322
2033	0.727	0	1.56	46	18	33	15	131	8454
2034	0.727	0	1.45	43	16	31	14	122	8575
2035	0.727	0	1.34	40	15	29	13	113	8688
2036	0.727	0	1.24	37	14	27	12	105	8793
2037	0.727	0	1.15	34	13	25	11	97	8891
2038	0.727	0	1.07	32	12	23	10	90	8981
2039	0.727	0	0.99	30	11	21	10	84	9065
2040	0.727	0	0.92	28	11	20	9	78	9143
2041	0.727	0	0.85	26	10	19	8	73	9216
2042	0.727	0	0.79	24	9	17	8	68	9284
2043	0.727	0	0.74	22	9	16	7	63	9347
2044	0.727	0	0.69	21	8	15	7	59	9405
2045	0.727	0	0.64	19	7	14	6	54	9460
2046	0.727	0	0.59	18	7	13	6	51	9510
2047	0.727	0	0.55	17	6	12	5	47	9558
2048	0.727	0	0.51	16	6	11	5	44	9601
2049	0.727	0	0.48	15	6	10	5	41	9642
2050	0.727	0	0.44	14	5	10	4	38	9681

Table 3.17. Projection results under scenario 3—fishing mortality rate fixed at $F = 65\%F_{MSY}$. F = fishing mortality rate (per year), Pr(SSB > SSB_{MSY}) = proportion of stochastic projection replicates exceeding SSB_{MSY}, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are F_{MSY} = 0.178 (per yr), SSB_{MSY} = 156 (mt), and MSY = 1842 (1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(mt)	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2010	0.416	0	11.49	235	62	306	0	0	0
2011	0.115	0	13.76	223	14	25	14	156	156
2012	0.115	0	16.21	251	18	35	20	190	346
2013	0.115	0	18.93	277	19	38	25	227	573
2014	0.115	0	22.25	302	22	43	30	275	847
2015	0.115	0	26.17	329	24	47	35	325	1172
2016	0.115	0	30.66	356	26	51	39	374	1547
2017	0.115	0	35.73	383	28	55	44	425	1972
2018	0.115	0	41.38	407	30	59	48	477	2449
2019	0.115	0	47.52	430	32	63	53	532	2981
2020	0.115	0	54.08	451	33	67	58	588	3569
2021	0.115	0	61.04	470	35	70	62	645	4213
2022	0.115	0	68.32	486	36	73	67	702	4915
2023	0.115	0	75.86	501	38	76	71	759	5674
2024	0.115	0	83.59	514	39	78	75	815	6489
2025	0.115	0.01	91.43	525	40	81	79	869	7358
2026	0.115	0.02	99.3	535	41	82	83	922	8279
2027	0.115	0.04	107.13	544	41	84	86	972	9252
2028	0.115	0.07	114.88	551	42	85	89	1021	10,273
2029	0.115	0.11	122.5	558	43	87	92	1068	11,341
2030	0.115	0.17	129.92	564	43	88	94	1112	12,453
2031	0.115	0.25	137.11	569	44	89	97	1154	13,607
2032	0.115	0.34	144.04	574	44	90	99	1194	14,801
2033	0.115	0.43	150.69	578	44	90	101	1231	16,032
2034	0.115	0.52	157.03	581	45	91	103	1266	17,298
2035	0.115	0.61	163.06	584	45	92	105	1299	18,597
2036	0.115	0.69	168.78	587	45	92	107	1330	19,928
2037	0.115	0.75	174.17	589	45	93	108	1359	21,287
2038	0.115	0.8	179.25	592	46	93	110	1386	22,673
2039	0.115	0.85	184.02	594	46	93	111	1411	24,083
2040	0.115	0.89	188.48	595	46	94	112	1434	25,518
2041	0.115	0.92	192.66	597	46	94	113	1456	26,973
2042	0.115	0.94	196.55	598	46	94	114	1476	28,449
2043	0.115	0.95	200.18	600	46	94	115	1494	29,944
2044	0.115	0.96	203.55	601	46	95	116	1512	31,455
2045	0.115	0.97	206.68	602	47	95	117	1527	32,983
2046	0.115	0.98	209.58	603	47	95	117	1542	34,525
2047	0.115	0.98	212.28	604	47	95	118	1556	36,080
2048	0.115	0.99	214.77	604	47	95	119	1568	37,649
2049	0.115	0.99	217.07	605	47	95	119	1580	39,228
2050	0.115	0.99	219.2	606	47	96	120	1590	40,819

Table 3.18. Projection results under scenario 4—fishing mortality rate fixed at $F = 75\%F_{MSY}$. F = fishing mortality rate (per year), Pr(SSB > SSB_{MSY}) = proportion of stochastic projection replicates exceeding SSB_{MSY}, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are F_{MSY} = 0.178 (per yr), SSB_{MSY} = 156 (mt), and MSY = 1842 (1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(mt)	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2010	0.416	0	11.49	235	62	306	0	0	0
2011	0.133	0	13.76	223	16	29	16	179	179
2012	0.133	0	16.02	251	20	40	23	216	395
2013	0.133	0	18.54	275	22	44	28	256	650
2014	0.133	0	21.61	299	24	48	33	307	957
2015	0.133	0	25.21	324	27	53	38	361	1318
2016	0.133	0	29.3	350	29	57	43	413	1731
2017	0.133	0	33.89	375	31	62	48	465	2196
2018	0.133	0	38.97	399	33	66	53	520	2717
2019	0.133	0	44.46	421	35	71	58	577	3294
2020	0.133	0	50.31	441	37	75	63	635	3929
2021	0.133	0	56.48	460	39	78	68	694	4623
2022	0.133	0	62.92	476	41	82	72	753	5376
2023	0.133	0	69.56	490	42	85	77	812	6188
2024	0.133	0	76.34	503	43	87	81	869	7057
2025	0.133	0	83.21	515	45	90	85	925	7983
2026	0.133	0.01	90.09	525	46	92	89	980	8962
2027	0.133	0.01	96.93	534	46	94	92	1032	9995
2028	0.133	0.02	103.68	541	47	96	96	1082	11,077
2029	0.133	0.04	110.31	548	48	97	99	1130	12,207
2030	0.133	0.07	116.77	554	49	98	101	1175	13,382
2031	0.133	0.1	123.01	560	49	99	104	1219	14,601
2032	0.133	0.15	129.02	564	50	100	106	1259	15,860
2033	0.133	0.21	134.78	568	50	101	109	1297	17,157
2034	0.133	0.27	140.28	572	50	102	111	1333	18,491
2035	0.133	0.34	145.5	575	51	103	113	1367	19,858
2036	0.133	0.41	150.44	578	51	103	114	1398	21,256
2037	0.133	0.48	155.1	581	51	104	116	1428	22,684
2038	0.133	0.55	159.48	583	51	104	117	1455	24,139
2039	0.133	0.6	163.59	585	52	105	119	1481	25,620
2040	0.133	0.66	167.44	587	52	105	120	1504	27,124
2041	0.133	0.71	171.03	589	52	106	121	1526	28,650
2042	0.133	0.76	174.38	590	52	106	122	1546	30,196
2043	0.133	0.79	177.49	592	52	106	123	1565	31,761
2044	0.133	0.82	180.38	593	52	106	124	1582	33,344
2045	0.133	0.85	183.07	594	52	107	125	1598	34,942
2046	0.133	0.87	185.55	595	53	107	125	1613	36,555
2047	0.133	0.89	187.85	596	53	107	126	1627	38,182
2048	0.133	0.91	189.98	597	53	107	127	1639	39,821
2049	0.133	0.92	191.94	597	53	107	127	1651	41,472
2050	0.133	0.93	193.75	598	53	107	128	1661	43,133

Table 3.19. Projection results under scenario 5—fishing mortality rate fixed at $F = 85\%F_{MSY}$. *F = fishing mortality rate (per year), Pr(*$SSB > SSB_{MSY}$*) = proportion of stochastic projection replicates exceeding* SSB_{MSY}*, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000* lb *whole weight), L = landings (1000 fish or 1000* lb *whole weight), and Sum L = cumulative landings (1000* lb*). For reference, estimated benchmarks are* F_{MSY} = 0.178 *(per yr),* SSB_{MSY} = 156 *(mt), and* MSY = 1842 *(1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(mt)	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2010	0.416	0	11.49	235	62	306	0	0	0
2011	0.151	0	13.76	223	19	33	19	201	201
2012	0.151	0	15.82	251	23	45	25	241	443
2013	0.151	0	18.17	273	25	49	31	283	726
2014	0.151	0	21	295	27	54	37	337	1063
2015	0.151	0	24.29	320	30	58	42	393	1456
2016	0.151	0	28	344	32	63	47	447	1903
2017	0.151	0	32.15	368	34	68	52	501	2404
2018	0.151	0	36.7	390	37	73	57	557	2961
2019	0.151	0	41.61	412	39	77	62	615	3576
2020	0.151	0	46.81	431	41	82	67	674	4250
2021	0.151	0	52.26	449	43	86	72	734	4984
2022	0.151	0	57.94	465	45	89	77	794	5777
2023	0.151	0	63.77	479	46	93	81	853	6630
2024	0.151	0	69.72	492	48	96	86	911	7541
2025	0.151	0	75.72	504	49	98	90	968	8509
2026	0.151	0	81.72	514	50	101	94	1023	9532
2027	0.151	0	87.67	523	51	103	97	1075	10,607
2028	0.151	0.01	93.55	531	52	105	101	1126	11,734
2029	0.151	0.01	99.31	538	53	106	104	1174	12,908
2030	0.151	0.02	104.9	544	53	108	107	1220	14,128
2031	0.151	0.03	110.32	549	54	109	110	1263	15,391
2032	0.151	0.05	115.52	554	55	110	112	1304	16,695
2033	0.151	0.08	120.51	559	55	111	114	1343	18,038
2034	0.151	0.11	125.26	562	55	112	116	1379	19,417
2035	0.151	0.14	129.77	566	56	113	118	1412	20,829
2036	0.151	0.18	134.04	569	56	114	120	1444	22,273
2037	0.151	0.22	138.07	572	56	114	122	1473	23,747
2038	0.151	0.27	141.85	574	57	115	123	1501	25,247
2039	0.151	0.32	145.4	576	57	115	125	1526	26,773
2040	0.151	0.36	148.71	578	57	116	126	1550	28,323
2041	0.151	0.41	151.81	580	57	116	127	1572	29,895
2042	0.151	0.46	154.69	582	58	117	128	1592	31,486
2043	0.151	0.5	157.37	583	58	117	129	1610	33,097
2044	0.151	0.54	159.86	584	58	117	130	1628	34,725
2045	0.151	0.58	162.16	585	58	118	131	1644	36,368
2046	0.151	0.61	164.29	587	58	118	132	1658	38,026
2047	0.151	0.64	166.26	587	58	118	132	1672	39,698
2048	0.151	0.67	168.08	588	58	118	133	1684	41,382
2049	0.151	0.69	169.76	589	58	118	134	1695	43,077
2050	0.151	0.71	171.31	590	58	119	134	1706	44,783

*Table 3.20. Projection results under scenario 6—fishing mortality rate fixed at $F = F_{MSY}$. F = fishing mortality rate (per year), Pr(*SSB > SSB_{MSY}*) = proportion of stochastic projection replicates exceeding* SSB_{MSY}*, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000* lb *whole weight), L = landings (1000 fish or 1000* lb *whole weight), and Sum L = cumulative landings (1000* lb*). For reference, estimated benchmarks are* F_{MSY} = 0.178 *(per yr),* SSB_{MSY} = 156 *(mt), and* MSY = 1842 *(1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(mt)	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2010	0.416	0	11.49	235	62	306	0	0	0
2011	0.178	0	13.76	223	22	39	22	235	235
2012	0.178	0	15.53	251	26	52	29	278	513
2013	0.178	0	17.62	270	29	56	35	321	834
2014	0.178	0	20.11	290	31	62	41	378	1212
2015	0.178	0	22.98	312	34	66	47	436	1648
2016	0.178	0	26.17	335	36	71	52	491	2139
2017	0.178	0	29.71	356	39	76	57	546	2685
2018	0.178	0	33.56	377	41	81	62	602	3287
2019	0.178	0	37.68	397	44	86	67	660	3947
2020	0.178	0	42.01	416	46	91	72	718	4665
2021	0.178	0	46.52	433	48	95	77	778	5443
2022	0.178	0	51.19	448	50	99	82	837	6280
2023	0.178	0	55.97	462	52	103	86	895	7175
2024	0.178	0	60.82	475	53	106	91	953	8128
2025	0.178	0	65.7	486	55	109	95	1009	9137
2026	0.178	0	70.56	496	56	112	99	1063	10,199
2027	0.178	0	75.37	505	57	115	103	1115	11,314
2028	0.178	0	80.11	513	58	117	106	1164	12,478
2029	0.178	0	84.75	520	59	119	110	1212	13,690
2030	0.178	0	89.26	527	60	120	113	1257	14,947
2031	0.178	0	93.61	533	61	122	115	1299	16,247
2032	0.178	0.01	97.79	538	61	123	118	1340	17,586
2033	0.178	0.01	101.79	542	62	125	120	1377	18,963
2034	0.178	0.02	105.61	546	62	126	122	1413	20,376
2035	0.178	0.02	109.23	550	63	127	124	1446	21,822
2036	0.178	0.03	112.65	553	63	128	126	1477	23,299
2037	0.178	0.04	115.87	556	64	128	128	1505	24,804
2038	0.178	0.05	118.9	559	64	129	129	1532	26,336
2039	0.178	0.06	121.74	561	64	130	131	1557	27,893
2040	0.178	0.08	124.4	563	65	130	132	1580	29,473
2041	0.178	0.09	126.88	565	65	131	133	1601	31,075
2042	0.178	0.11	129.18	567	65	131	134	1621	32,696
2043	0.178	0.13	131.32	569	65	132	135	1639	34,335
2044	0.178	0.14	133.31	570	65	132	136	1656	35,991
2045	0.178	0.16	135.15	571	66	132	137	1672	37,663
2046	0.178	0.18	136.85	572	66	133	138	1686	39,349
2047	0.178	0.2	138.43	573	66	133	139	1699	41,048
2048	0.178	0.21	139.88	574	66	133	139	1711	42,759
2049	0.178	0.23	141.22	575	66	133	140	1722	44,481
2050	0.178	0.25	142.45	576	66	134	141	1732	46,213

Table 3.21. Projection results under scenario 7—fishing mortality rate fixed at $F = F_{current}$, but all potential landings converted to discards (continued moratorium). F = fishing mortality rate (per year), Pr(SSB > SSB_{MSY}) = proportion of stochastic projection replicates exceeding SSB_{MSY}, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are F_{MSY} = 0.178 (per yr), SSB_{MSY} = 156 (mt), and MSY = 1842 (1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(mt)	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2010	0.416	0	11.49	235	62	306	0	0	0
2011	0.416	0	13.76	223	78	344	0	0	0
2012	0.416	0	15.21	251	91	395	0	0	0
2013	0.416	0	16.81	267	99	427	0	0	0
2014	0.416	0	18.59	283	108	473	0	0	0
2015	0.416	0	20.52	299	116	519	0	0	0
2016	0.416	0	22.57	316	124	563	0	0	0
2017	0.416	0	24.77	332	131	606	0	0	0
2018	0.416	0	27.12	347	139	650	0	0	0
2019	0.416	0	29.57	362	146	693	0	0	0
2020	0.416	0	32.1	377	153	736	0	0	0
2021	0.416	0	34.7	390	160	779	0	0	0
2022	0.416	0	37.35	403	167	821	0	0	0
2023	0.416	0	40.04	414	173	863	0	0	0
2024	0.416	0	42.75	425	179	904	0	0	0
2025	0.416	0	45.47	435	184	943	0	0	0
2026	0.416	0	48.16	445	189	981	0	0	0
2027	0.416	0	50.82	453	194	1018	0	0	0
2028	0.416	0	53.44	461	199	1053	0	0	0
2029	0.416	0	56.01	468	203	1086	0	0	0
2030	0.416	0	58.52	475	207	1118	0	0	0
2031	0.416	0	60.96	481	211	1149	0	0	0
2032	0.416	0	63.31	486	214	1177	0	0	0
2033	0.416	0	65.58	491	217	1205	0	0	0
2034	0.416	0	67.75	496	220	1230	0	0	0
2035	0.416	0	69.84	500	223	1255	0	0	0
2036	0.416	0	71.82	504	225	1277	0	0	0
2037	0.416	0	73.71	507	227	1299	0	0	0
2038	0.416	0	75.5	510	229	1319	0	0	0
2039	0.416	0	77.2	513	231	1337	0	0	0
2040	0.416	0	78.8	516	233	1355	0	0	0
2041	0.416	0	80.31	518	235	1371	0	0	0
2042	0.416	0	81.73	521	236	1386	0	0	0
2043	0.416	0	83.07	523	238	1401	0	0	0
2044	0.416	0	84.32	524	239	1414	0	0	0
2045	0.416	0	85.48	526	240	1426	0	0	0
2046	0.416	0	86.58	528	241	1438	0	0	0
2047	0.416	0	87.6	529	242	1448	0	0	0
2048	0.416	0	88.55	530	243	1458	0	0	0
2049	0.416	0	89.44	532	244	1467	0	0	0
2050	0.416	0	90.26	533	245	1475	0	0	0

Table 3.22. Projection results under scenario 8—fishing mortality rate fixed at $F = F_{rebuild}$, with rebuilding probability of 0.5 in 2047. F = fishing mortality rate (per year), Pr($SSB > SSB_{MSY}$) = proportion of stochastic projection replicates exceeding SSB_{MSY}, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb *whole weight), L = landings (1000 fish or 1000* lb *whole weight), and Sum L = cumulative landings (1000* lb*). For reference, estimated benchmarks are F_{MSY} = 0.178 (per yr), SSB_{MSY} = 156 (mt), and* MSY = 1842 *(1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(mt)	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2010	0.416	0	11.49	235	62	306	0	0	0
2011	0.158	0	13.76	223	19	34	19	211	211
2012	0.158	0	15.74	251	24	46	26	251	462
2013	0.158	0	18.02	272	26	51	32	293	755
2014	0.158	0	20.76	294	28	56	38	348	1103
2015	0.158	0	23.93	318	31	60	43	405	1509
2016	0.158	0	27.5	341	33	65	48	460	1968
2017	0.158	0	31.47	365	35	70	53	514	2482
2018	0.158	0	35.83	387	38	75	58	570	3053
2019	0.158	0	40.52	408	40	80	63	628	3681
2020	0.158	0	45.47	427	42	84	68	687	4368
2021	0.158	0	50.66	445	44	88	73	747	5116
2022	0.158	0	56.05	461	46	92	78	807	5923
2023	0.158	0	61.58	475	48	96	83	866	6789
2024	0.158	0	67.22	488	49	99	87	925	7714
2025	0.158	0	72.9	499	51	101	91	981	8695
2026	0.158	0	78.58	509	52	104	95	1036	9731
2027	0.158	0	84.2	518	53	106	99	1089	10,820
2028	0.158	0	89.75	526	54	108	103	1139	11,960
2029	0.158	0.01	95.19	533	55	110	106	1187	13,147
2030	0.158	0.01	100.48	539	55	111	109	1233	14,380
2031	0.158	0.02	105.58	545	56	113	111	1276	15,657
2032	0.158	0.03	110.5	550	56	114	114	1317	16,974
2033	0.158	0.05	115.2	554	57	115	116	1356	18,329
2034	0.158	0.07	119.68	558	57	116	118	1392	19,721
2035	0.158	0.09	123.94	562	58	117	120	1425	21,146
2036	0.158	0.12	127.96	565	58	118	122	1457	22,603
2037	0.158	0.15	131.76	568	59	118	124	1486	24,089
2038	0.158	0.19	135.32	570	59	119	125	1513	25,602
2039	0.158	0.22	138.66	572	59	119	127	1539	27,140
2040	0.158	0.26	141.79	574	59	120	128	1562	28,702
2041	0.158	0.3	144.7	576	60	120	129	1584	30,286
2042	0.158	0.34	147.42	578	60	121	130	1604	31,890
2043	0.158	0.38	149.94	579	60	121	131	1622	33,512
2044	0.158	0.41	152.28	581	60	121	132	1640	35,152
2045	0.158	0.45	154.45	582	60	122	133	1655	36,807
2046	0.158	0.48	156.46	583	60	122	134	1670	38,477
2047	0.158	0.51	158.31	584	60	122	134	1683	40,160
2048	0.158	0.54	160.02	585	60	122	135	1696	41,856
2049	0.158	0.56	161.6	586	61	123	136	1707	43,563
2050	0.158	0.59	163.06	586	61	123	136	1717	45,280

Table 3.23. Projection results under scenario 9—fishing mortality rate fixed at $F = F_{rebuild}$, with rebuilding probability of 0.7 in 2047. F = fishing mortality rate (per year), Pr(SSB > SSB_{MSY}) = proportion of stochastic projection replicates exceeding SSB_{MSY}, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb *whole weight), L = landings (1000 fish or 1000* lb *whole weight), and Sum L = cumulative landings (1000* lb*). For reference, estimated benchmarks are F_{MSY} = 0.178 (per yr), SSB_{MSY} = 156 (mt), and* MSY = 1842 *(1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(mt)	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2010	0.416	0	11.49	235	62	306	0	0	0
2011	0.147	0	13.76	223	18	32	18	197	197
2012	0.147	0	15.86	251	22	43	25	236	432
2013	0.147	0	18.25	273	24	48	30	277	709
2014	0.147	0	21.13	296	27	53	36	331	1040
2015	0.147	0	24.48	321	29	57	41	386	1426
2016	0.147	0	28.28	345	31	62	46	440	1866
2017	0.147	0	32.52	369	34	67	51	494	2360
2018	0.147	0	37.19	392	36	71	56	550	2909
2019	0.147	0	42.22	414	38	76	61	607	3517
2020	0.147	0	47.55	434	40	80	66	666	4183
2021	0.147	0	53.16	451	42	84	71	726	4909
2022	0.147	0	58.99	467	44	88	76	786	5694
2023	0.147	0	64.99	482	45	91	80	845	6539
2024	0.147	0	71.11	495	47	94	85	903	7442
2025	0.147	0	77.3	506	48	97	89	960	8402
2026	0.147	0	83.48	516	49	99	93	1015	9417
2027	0.147	0	89.62	525	50	101	96	1067	10,484
2028	0.147	0.01	95.67	533	51	103	100	1118	11,602
2029	0.147	0.02	101.61	540	52	104	103	1166	12,768
2030	0.147	0.03	107.39	546	52	106	106	1212	13,980
2031	0.147	0.04	112.98	552	53	107	108	1255	15,235
2032	0.147	0.07	118.35	556	53	108	111	1296	16,531
2033	0.147	0.1	123.5	561	54	109	113	1334	17,865
2034	0.147	0.13	128.4	565	54	110	115	1370	19,236
2035	0.147	0.17	133.06	568	55	111	117	1404	20,640
2036	0.147	0.22	137.47	571	55	111	119	1436	22,076
2037	0.147	0.27	141.62	574	55	112	121	1465	23,541
2038	0.147	0.32	145.53	576	56	113	122	1493	25,034
2039	0.147	0.38	149.19	578	56	113	123	1518	26,552
2040	0.147	0.43	152.62	580	56	114	125	1542	28,093
2041	0.147	0.48	155.81	582	56	114	126	1564	29,657
2042	0.147	0.52	158.79	584	56	114	127	1584	31,241
2043	0.147	0.57	161.56	585	57	115	128	1602	32,843
2044	0.147	0.61	164.13	586	57	115	129	1620	34,463
2045	0.147	0.64	166.51	587	57	115	130	1636	36,098
2046	0.147	0.68	168.71	588	57	115	130	1650	37,749
2047	0.147	0.71	170.75	589	57	116	131	1664	39,413
2048	0.147	0.73	172.64	590	57	116	132	1676	41,089
2049	0.147	0.76	174.37	591	57	116	132	1688	42,777
2050	0.147	0.78	175.97	592	57	116	133	1698	44,475

*Table 3.24. Projection results under scenario 10—fishing mortality rate fixed at F = $F_{rebuild}$, with rebuilding probability of 0.9 in 2047. F = fishing mortality rate (per year), Pr(*SSB > SSB_{MSY}*) = proportion of stochastic projection replicates exceeding* SSB_{MSY}*, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000* lb *whole weight), L = landings (1000 fish or 1000* lb *whole weight), and Sum L = cumulative landings (1000* lb*). For reference, estimated benchmarks are* F_{MSY} = 0.178 *(per yr),* SSB_{MSY} = 156 *(mt), and* MSY = 1842 *(1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(mt)	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2010	0.416	0	11.49	235	62	306	0	0	0
2011	0.132	0	13.76	223	16	29	16	177	177
2012	0.132	0	16.03	251	20	39	22	215	392
2013	0.132	0	18.57	275	22	43	28	254	646
2014	0.132	0	21.65	299	24	48	33	305	951
2015	0.132	0	25.27	325	26	52	38	358	1309
2016	0.132	0	29.38	351	29	57	43	410	1719
2017	0.132	0	34	376	31	61	48	463	2183
2018	0.132	0	39.12	399	33	66	53	518	2700
2019	0.132	0	44.65	422	35	70	58	574	3275
2020	0.132	0	50.54	442	37	74	62	632	3907
2021	0.132	0	56.76	460	39	78	67	691	4598
2022	0.132	0	63.24	477	40	81	72	750	5349
2023	0.132	0	69.94	491	42	84	76	809	6157
2024	0.132	0	76.78	504	43	87	81	866	7024
2025	0.132	0	83.71	515	44	89	85	922	7946
2026	0.132	0.01	90.65	525	45	91	88	977	8923
2027	0.132	0.01	97.54	534	46	93	92	1029	9951
2028	0.132	0.03	104.36	542	47	95	95	1079	11,030
2029	0.132	0.04	111.05	549	48	96	98	1127	12,157
2030	0.132	0.07	117.56	555	48	98	101	1172	13,329
2031	0.132	0.11	123.86	560	49	99	104	1215	14,544
2032	0.132	0.16	129.93	565	49	100	106	1256	15,800
2033	0.132	0.22	135.74	569	50	101	108	1294	17,094
2034	0.132	0.28	141.28	573	50	101	110	1330	18,423
2035	0.132	0.35	146.55	576	50	102	112	1363	19,787
2036	0.132	0.43	151.54	579	51	103	114	1395	21,182
2037	0.132	0.5	156.24	581	51	103	115	1424	22,606
2038	0.132	0.56	160.67	584	51	104	117	1451	24,057
2039	0.132	0.62	164.82	586	51	104	118	1477	25,534
2040	0.132	0.68	168.7	588	51	104	119	1500	27,035
2041	0.132	0.73	172.33	589	52	105	121	1522	28,557
2042	0.132	0.77	175.71	591	52	105	122	1543	30,100
2043	0.132	0.81	178.85	592	52	105	123	1561	31,661
2044	0.132	0.84	181.77	593	52	106	123	1579	33,240
2045	0.132	0.86	184.48	595	52	106	124	1595	34,834
2046	0.132	0.88	186.99	595	52	106	125	1609	36,444
2047	0.132	0.9	189.31	596	52	106	126	1623	38,067
2048	0.132	0.92	191.46	597	52	106	126	1636	39,702
2049	0.132	0.93	193.44	598	52	107	127	1647	41,350
2050	0.132	0.94	195.27	599	52	107	127	1658	43,007

Table 3.25. Input for Surplus-production model runs. Total removals in million pounds from the historical time period (1950–1980) and adjusted Saltwater Angling Survey (SWAS) recreational estimates. The removals from 1981–2009 are identical for all runs. The indices for headboat and commercial logbook are in units of pounds per angler hour and pounds per hook hour. An alternate series with a 2% increase in catchability starting in 1976 and saturating in 2003 after which there is no increase was developed by the SEDAR-24 AW panel.

	Historic Removals (million pounds)		Indices			Removals (million pounds)	Indices			
Year	Proposed	SWAS	Headboat	Headboat 2%catch inc.	Year	Proposed	Headboat	Headboat 2% catch. Inc.	Com. Logbook	Com. Logbook 2% catch. Inc.
1950	0.807	0.697			1981	1.011	2.07	1.87		
1951	1.014	0.941			1982	0.798	1.26	1.11		
1952	0.930	0.897			1983	0.566	0.81	0.70		
1953	1.000	0.995			1984	0.827	0.75	0.63		
1954	1.271	1.276			1985	0.965	1.15	0.94		
1955	1.254	1.260			1986	0.376	0.34	0.27		
1956	1.340	1.331			1987	0.438	0.40	0.31		
1957	1.826	1.800			1988	0.451	0.42	0.32		
1958	1.639	1.633			1989	0.585	0.61	0.45		
1959	1.727	1.763			1990	0.462	0.58	0.42		
1960	1.769	1.862			1991	0.385	0.75	0.52		
1961	1.895	1.900			1992	0.761	0.09	0.06		
1962	1.734	1.678			1993	0.466	0.19	0.13	1.14	0.75
1963	1.570	1.435			1994	0.497	0.30	0.19	0.91	0.58
1964	1.694	1.404			1995	0.358	0.40	0.25	0.92	0.57
1965	1.942	1.417			1996	0.310	0.46	0.28	0.57	0.34
1966	2.216	1.914			1997	0.330	0.52	0.30	0.57	0.33
1967	2.593	2.553			1998	0.282	0.29	0.16	0.63	0.35
1968	2.727	3.073			1999	0.459	0.42	0.23	0.76	0.41
1969	2.243	3.118			2000	0.835	0.54	0.28	0.75	0.39
1970	2.013	3.473			2001	0.758	1.01	0.50	1.22	0.61
1971	1.770	3.203			2002	0.738	1.16	0.56	1.37	0.66
1972	1.625	3.088			2003	0.568	0.85	0.39	1.11	0.51
1973	1.447	2.709			2004	0.696	1.35	0.62	1.44	0.66
1974	1.988	2.652			2005	0.542	1.17	0.54	1.23	0.56
1975	2.238	2.514			2006	0.473	0.70	0.32	0.61	0.28
1976	1.952	2.143	1.80	1.80	2007	0.813	0.55	0.25	0.66	0.31
1977	2.313	2.327	2.14	2.10	2008	1.362	2.49	1.15	1.20	0.55
1978	1.924	1.884	1.74	1.67	2009	1.525	2.95	1.36	1.92	0.88
1979	2.034	2.138	2.64	2.49						
1980	1.262	1.290	1.08	0.99						

Table 3.26. Red snapper–Parameter estimates and status values from the surplus-production model runs with the 10th and 90th bias-corrected confidence limits where bootstrap runs were completed.

Run	Value	B1/K	MSY	K	q(headboat)	q(Comm.Line)	B(2010)/Bmsy	F(2009)/Fmsy
Match to BAM base run	Estimate	0.36	1.251E+06	1.248E+07	2.65E-07	2.46E-07	0.25	3.85
	10% CL	0.35	9.974E+05	1.096E+07	1.67E-07	1.31E-07	0.08	2.25
	90% CL	1.02	1.266E+06	2.041E+07	3.44E-07	3.42E-07	0.53	8.05
Match to BAM base run no catchability increase	Estimate	0.61	9.288E+05	7.747E+06	2.95E-07	2.73E-07	0.23	4.78
	10% CL	0.57	8.293E+05	6.602E+06	1.94E-07	1.72E-07	0.06	2.31
	90% CL	0.97	9.525E+05	1.152E+07	3.82E-07	3.90E-07	0.67	9.13
Match to BAM base run Start in 1976	Estimate	0.43	1.054E+06	7.152E+06	3.67E-07	3.59E-07	0.29	3.62
	10% CL	0.29	1.037E+06	6.613E+06	3.05E-07	3.00E-07	0.06	2.36
	90% CL	0.45	1.513E+06	9.752E+06	4.94E-07	5.41E-07	0.52	7.51
SWAS removals	Estimate	0.38	2.216E+06	1.840E+07	3.21E-07	5.21E-07	0.16	3.47

3.6 Figures

Figure 3.1. Mean length at age (mm) and estimated 95% confidence interval of the population.

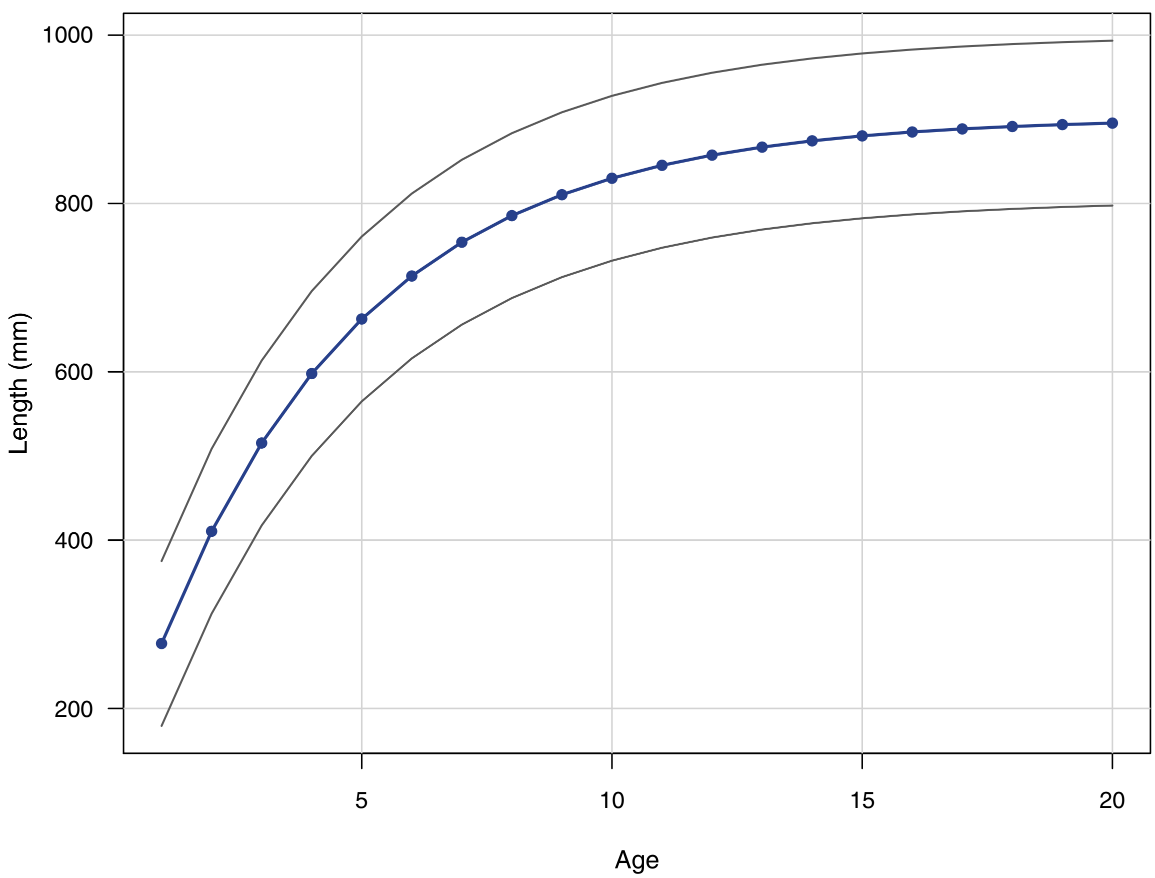


Figure 3.2. Standard errors of management quantities with increased number of Monte Carlo/bootstrap trials.

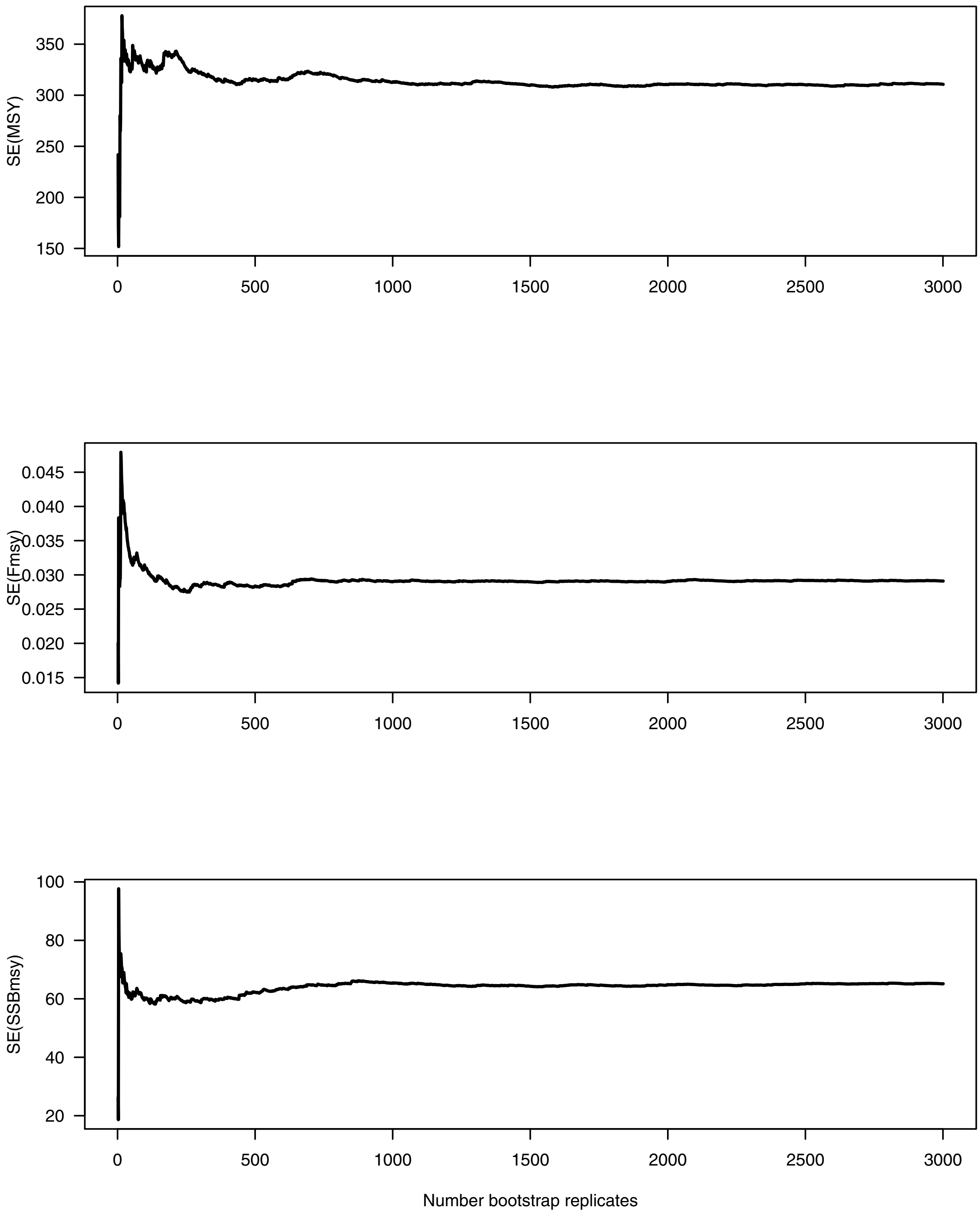


Figure 3.3. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, cl to commercial lines, cd to commercial dive, hb to for-hire, pvt to private recreational, cl.D to commercial discards, and hb.D to for-hire discards. The two years of pvt length compositions represent compositions pooled across years within the relevant time block of size-limit regulations. N indicates the number of trips from which individual fish samples were taken.

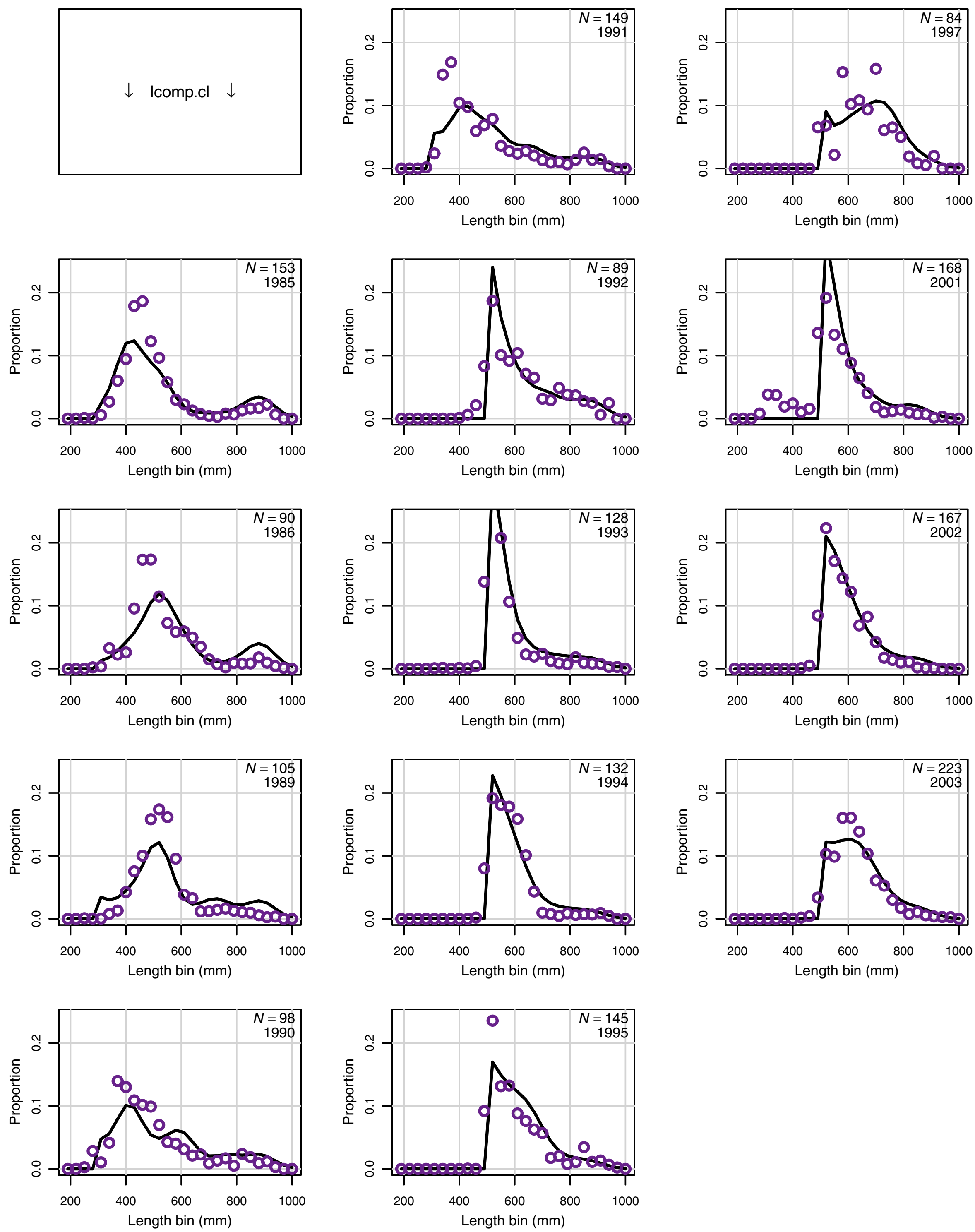


Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

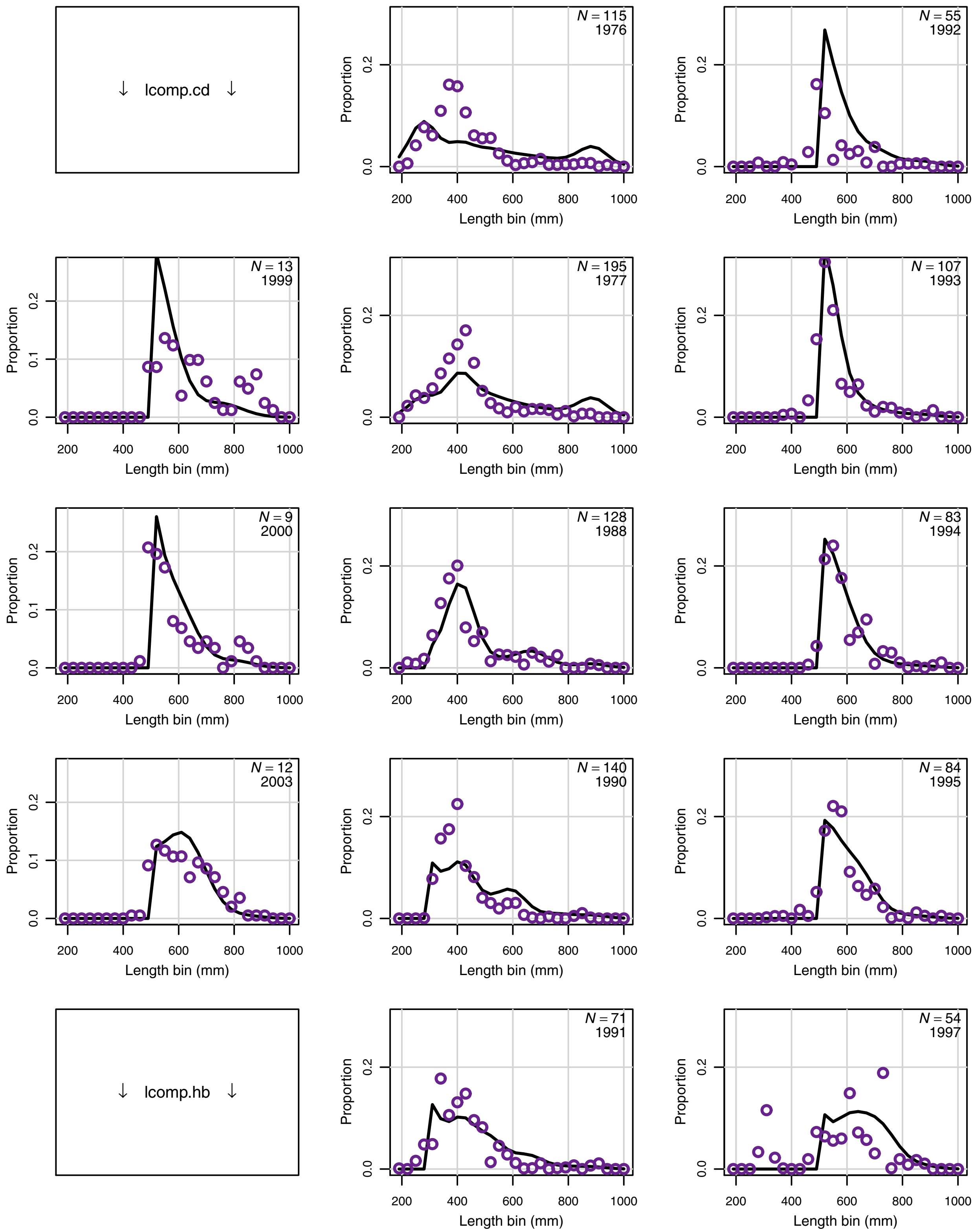


Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

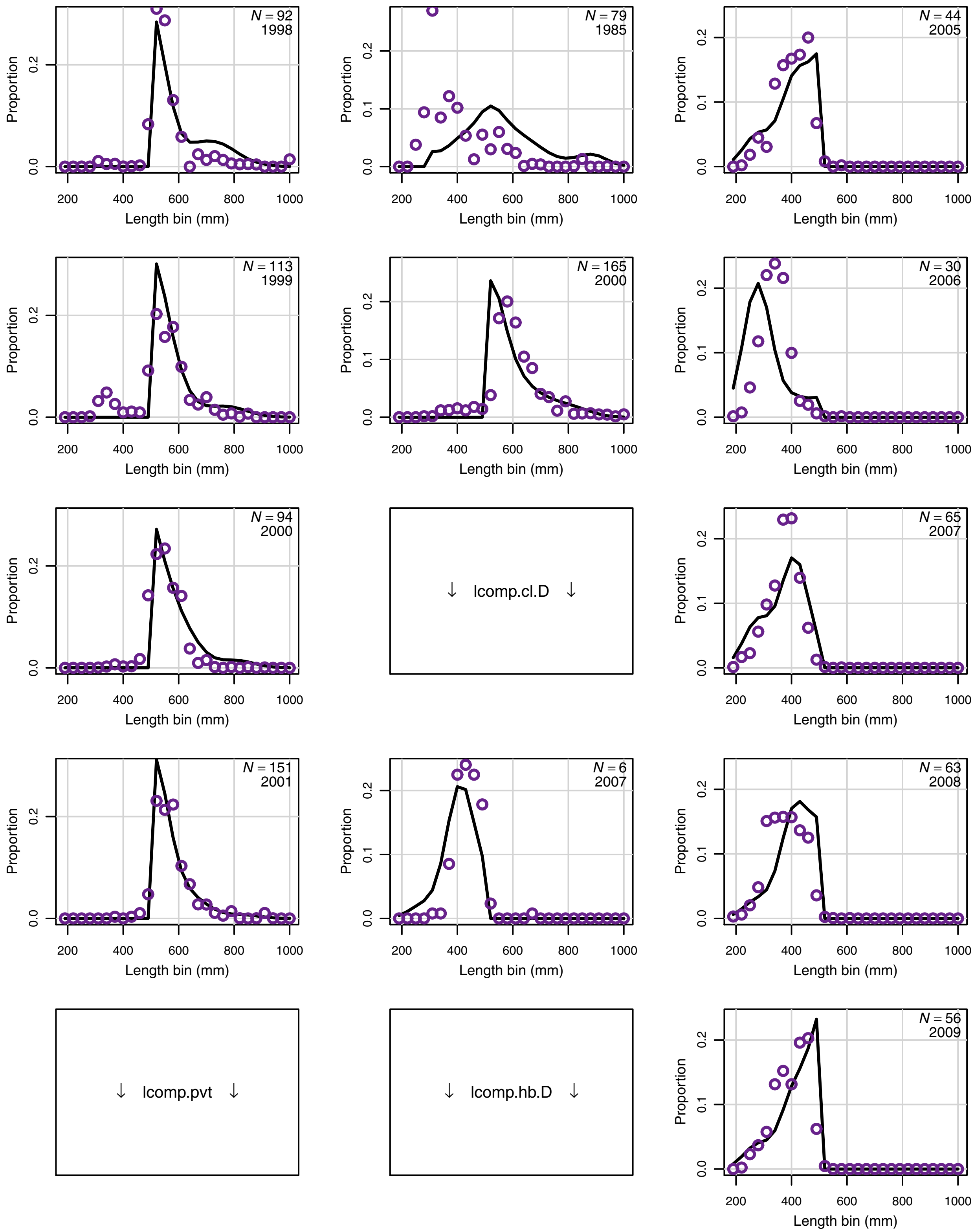


Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

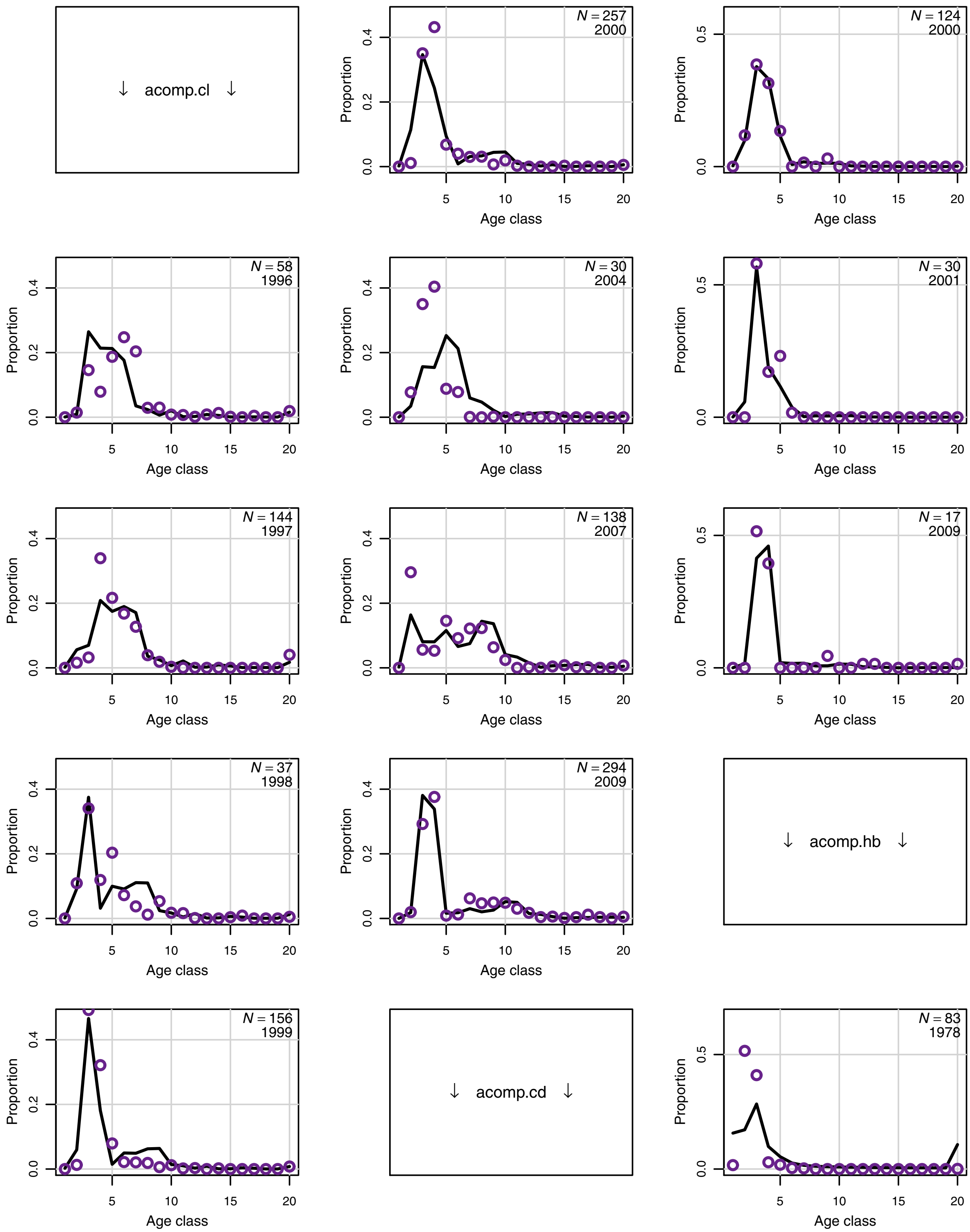


Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

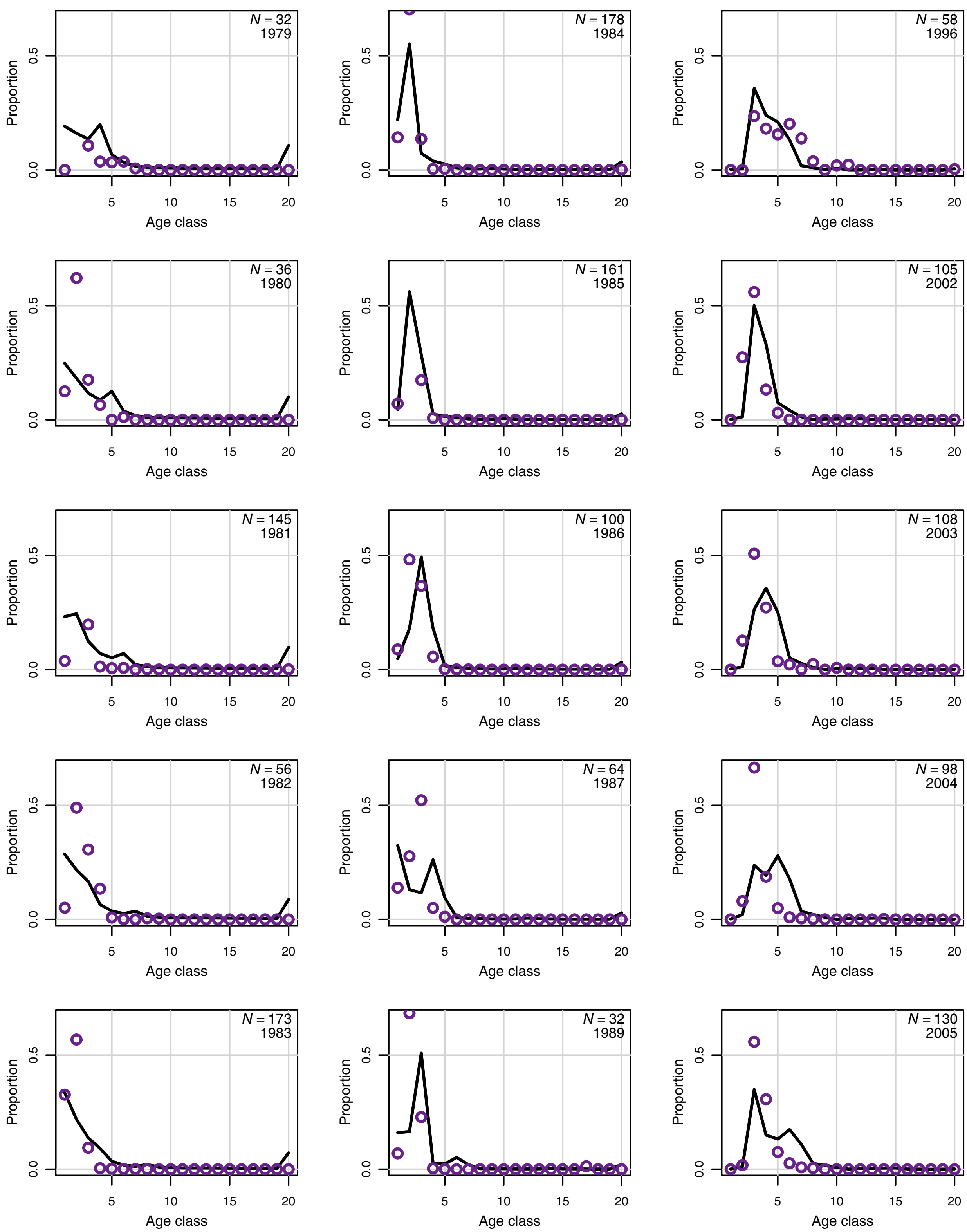


Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

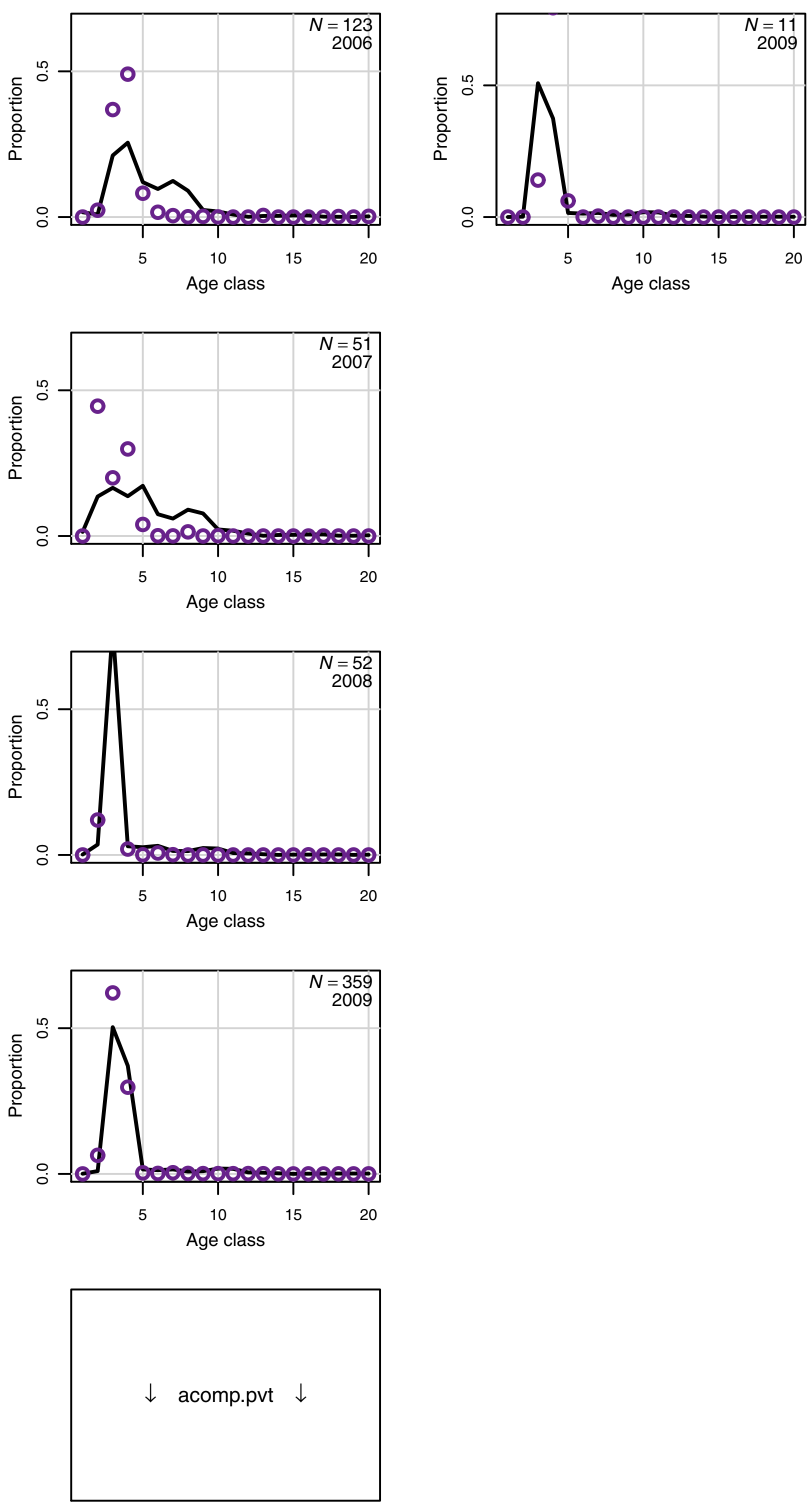


Figure 3.4. Top panel is a bubble plot of length composition residuals from commercial lines landings; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

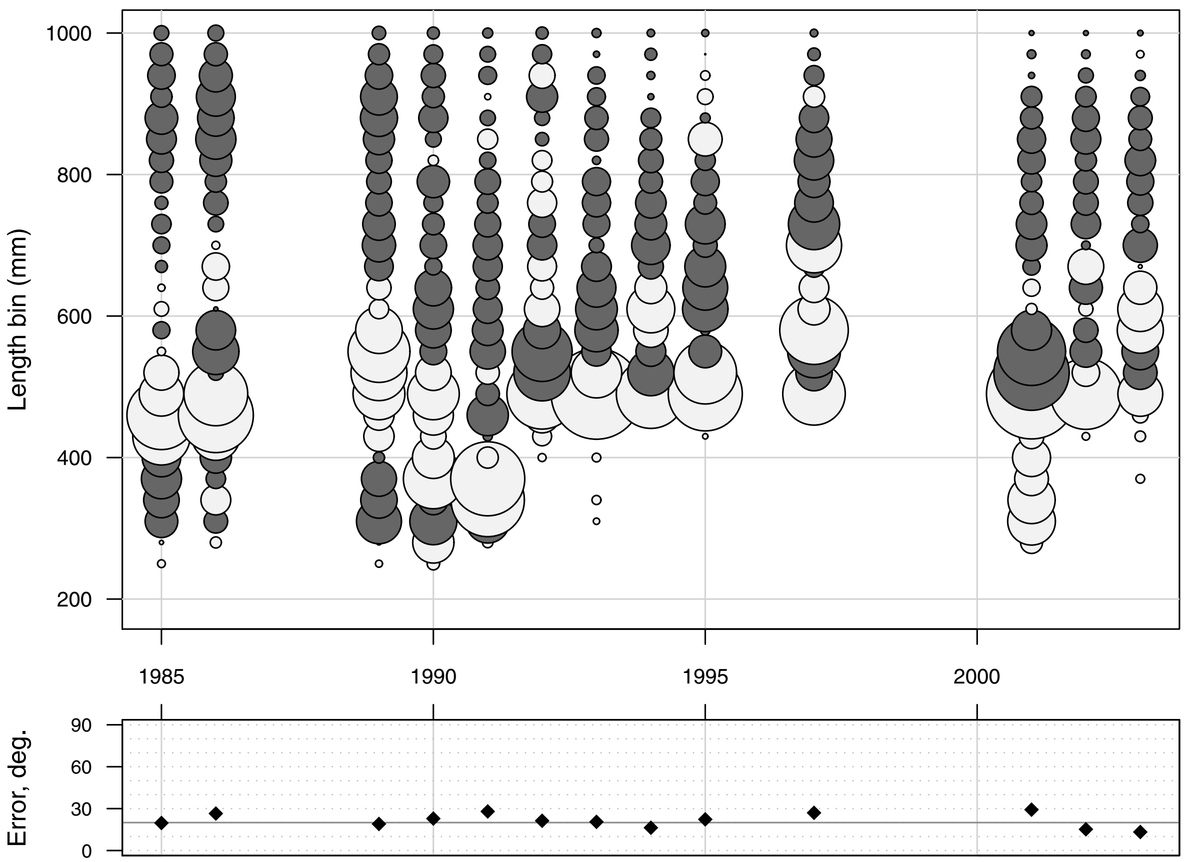


Figure 3.5. Top panel is a bubble plot of length composition residuals from commercial dive landings; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

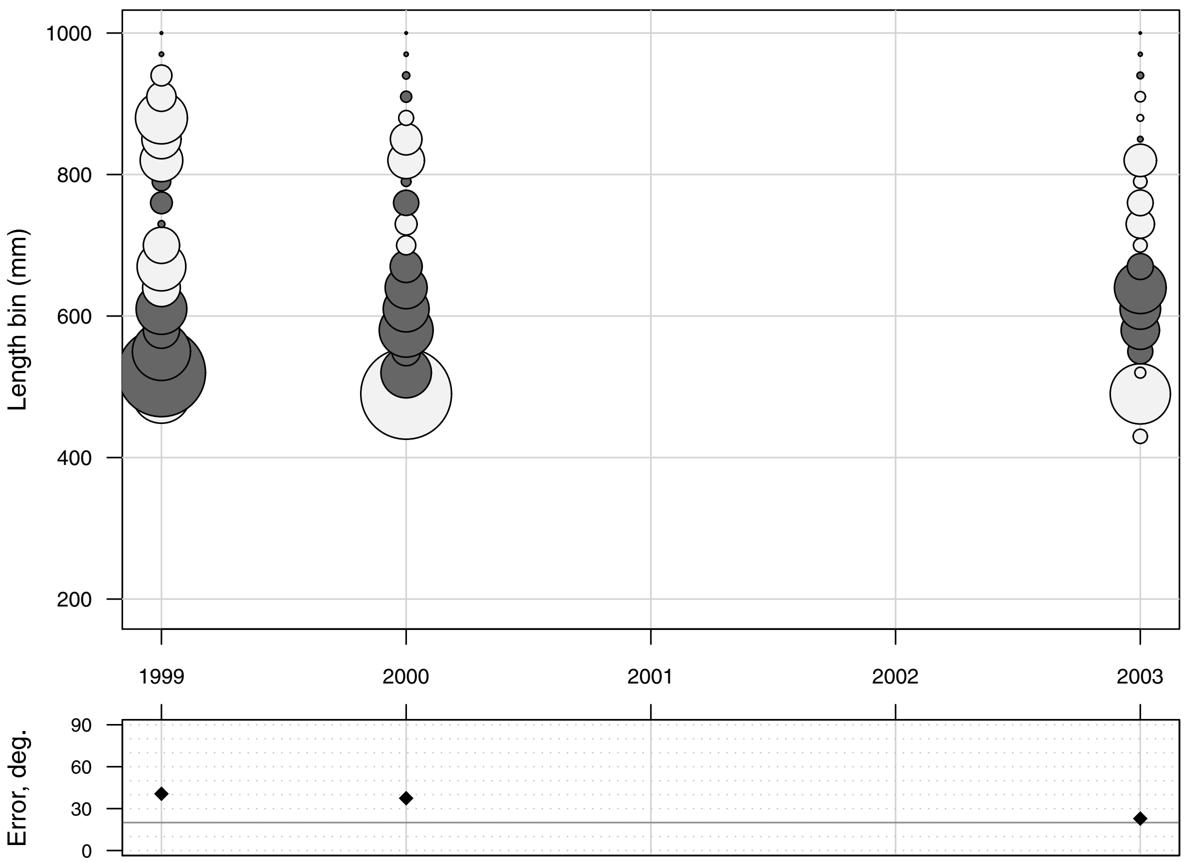


Figure 3.6. Top panel is a bubble plot of length composition residuals from for-hire landings; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

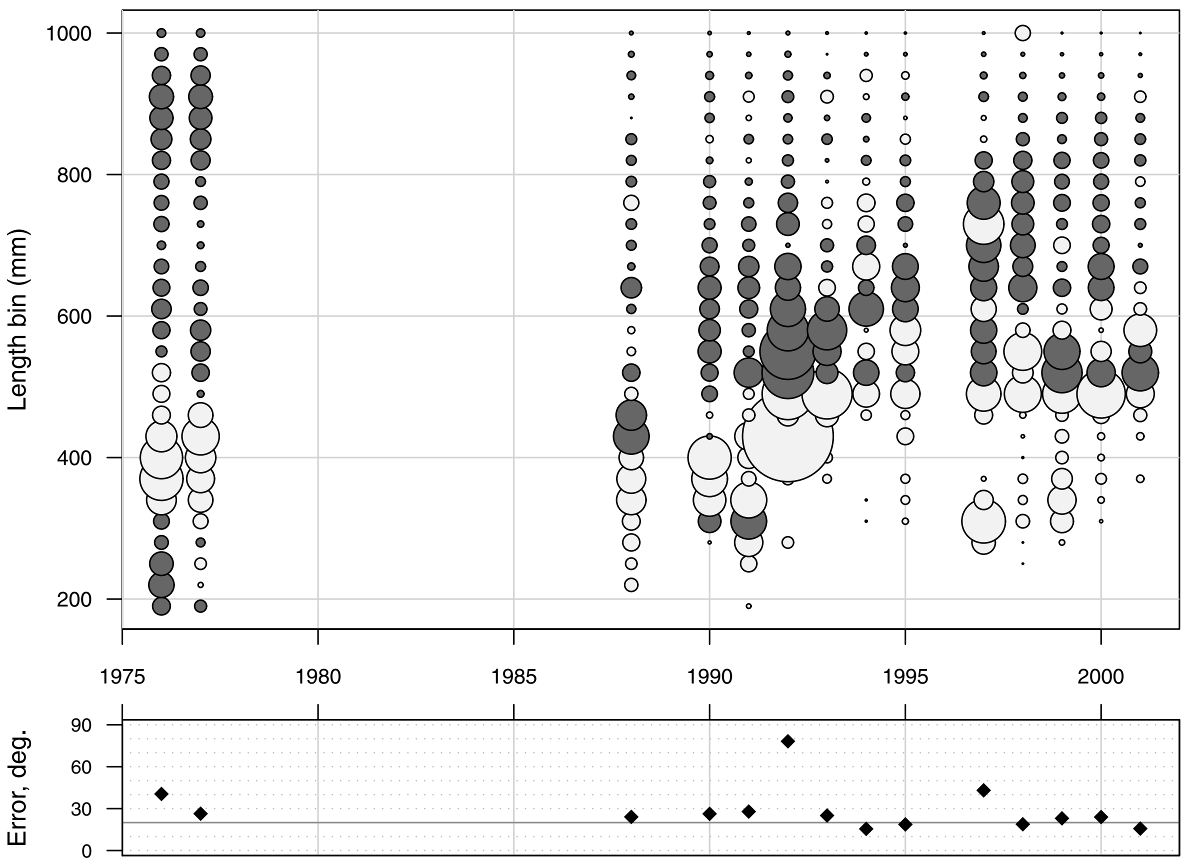


Figure 3.7. Top panel is a bubble plot of length composition residuals from private recreational landings; Dark represents overestimates and light underestimates. The two years shown represent length compositions pooled across years within the relevant time block of size-limit regulations. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

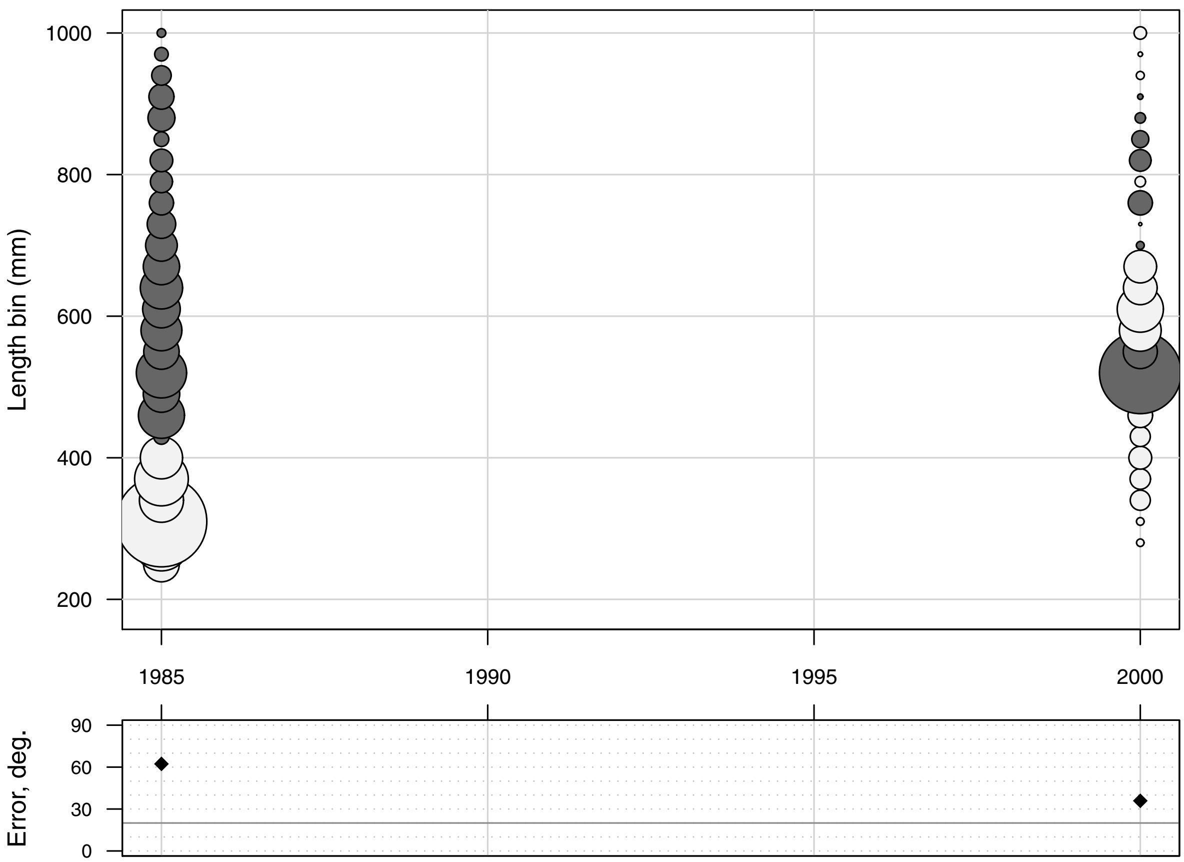


Figure 3.8. Top panel is a bubble plot of length composition residuals from commercial lines discards; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

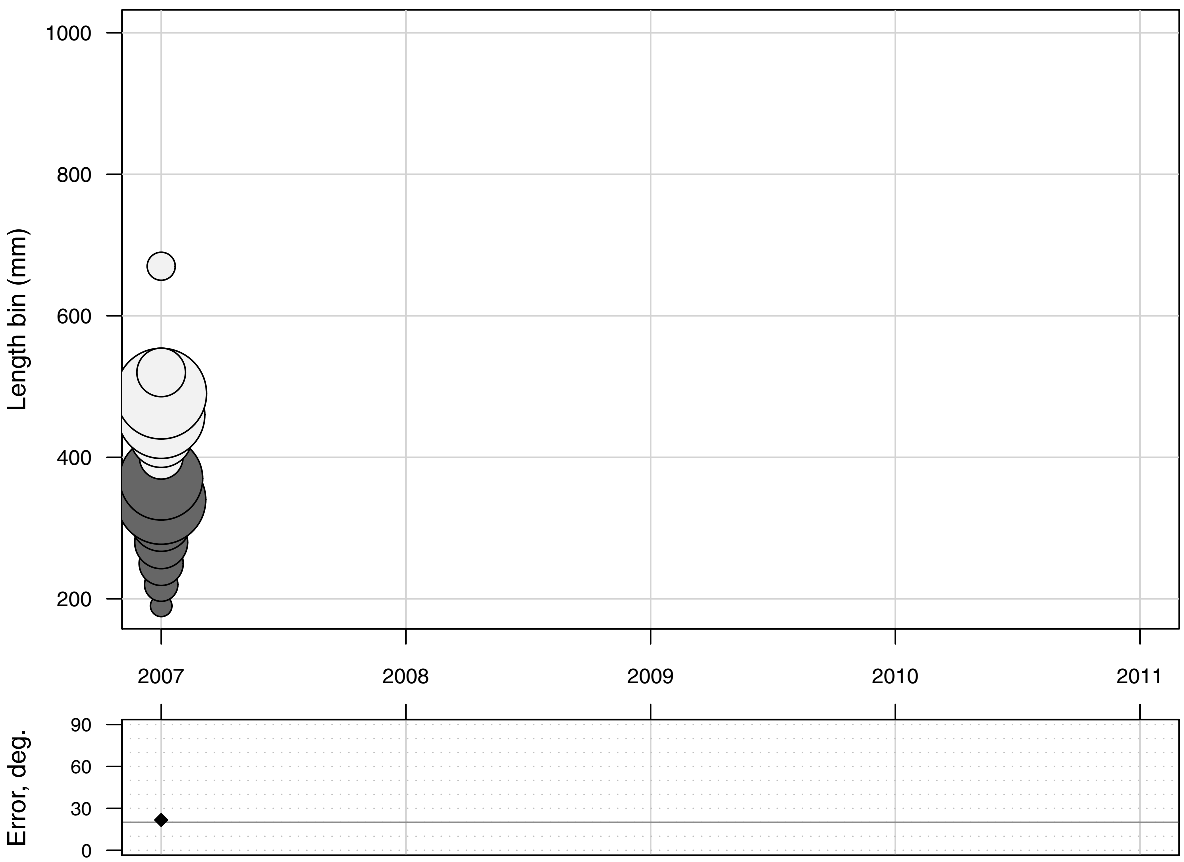


Figure 3.9. Top panel is a bubble plot of length composition residuals from for-hire discards; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

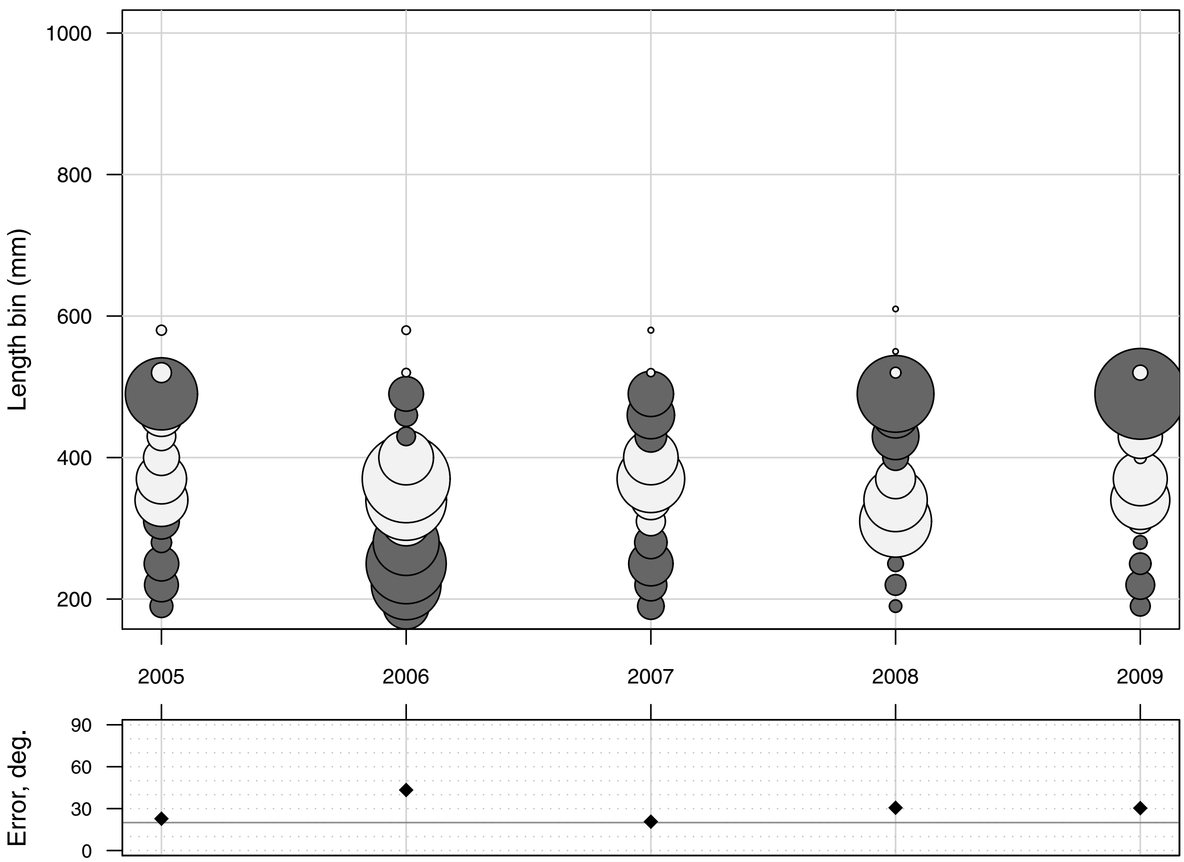


Figure 3.10. Top panel is a bubble plot of age composition residuals from commercial lines landings; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

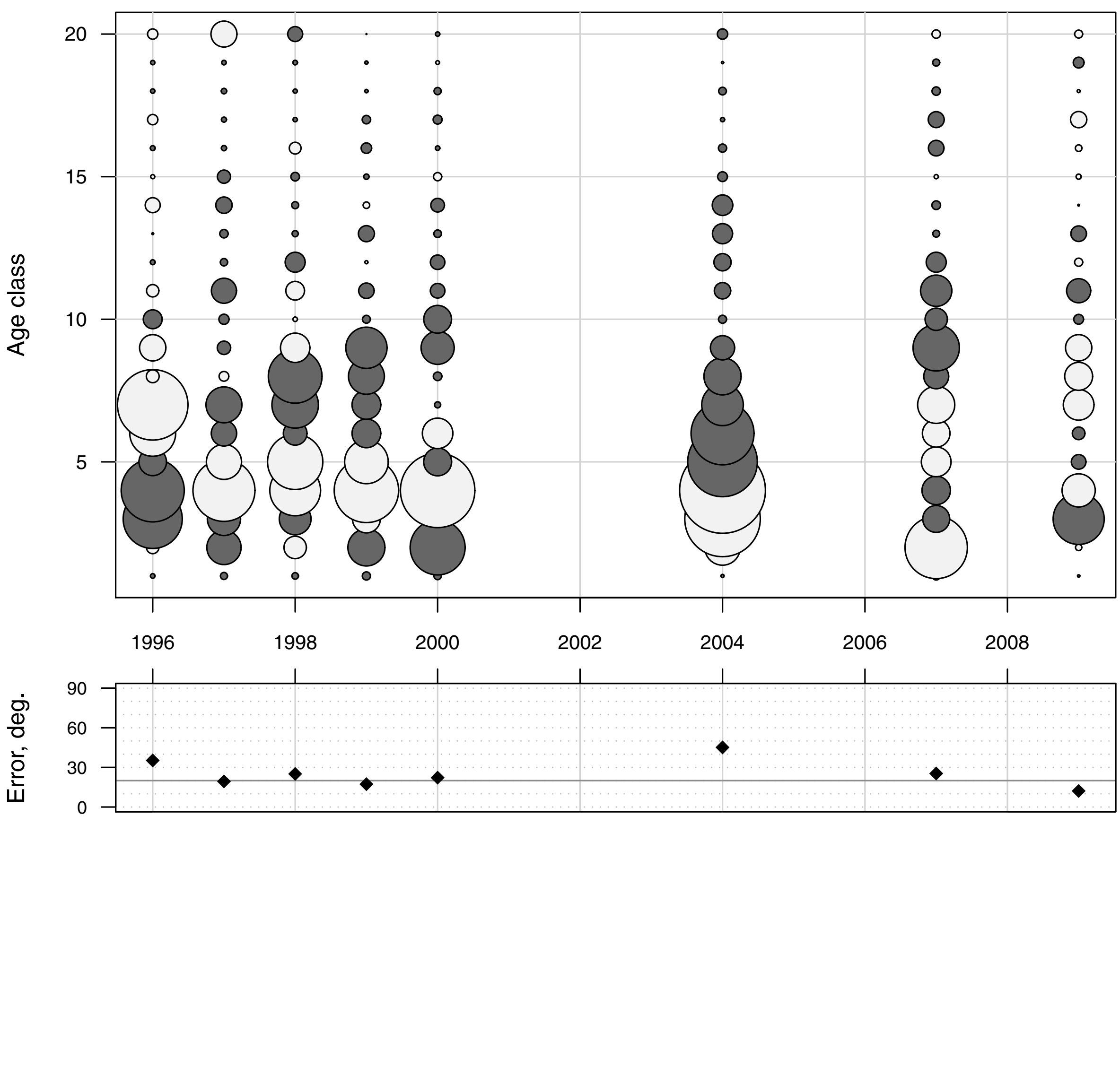


Figure 3.11. Top panel is a bubble plot of age composition residuals from commercial dive landings; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

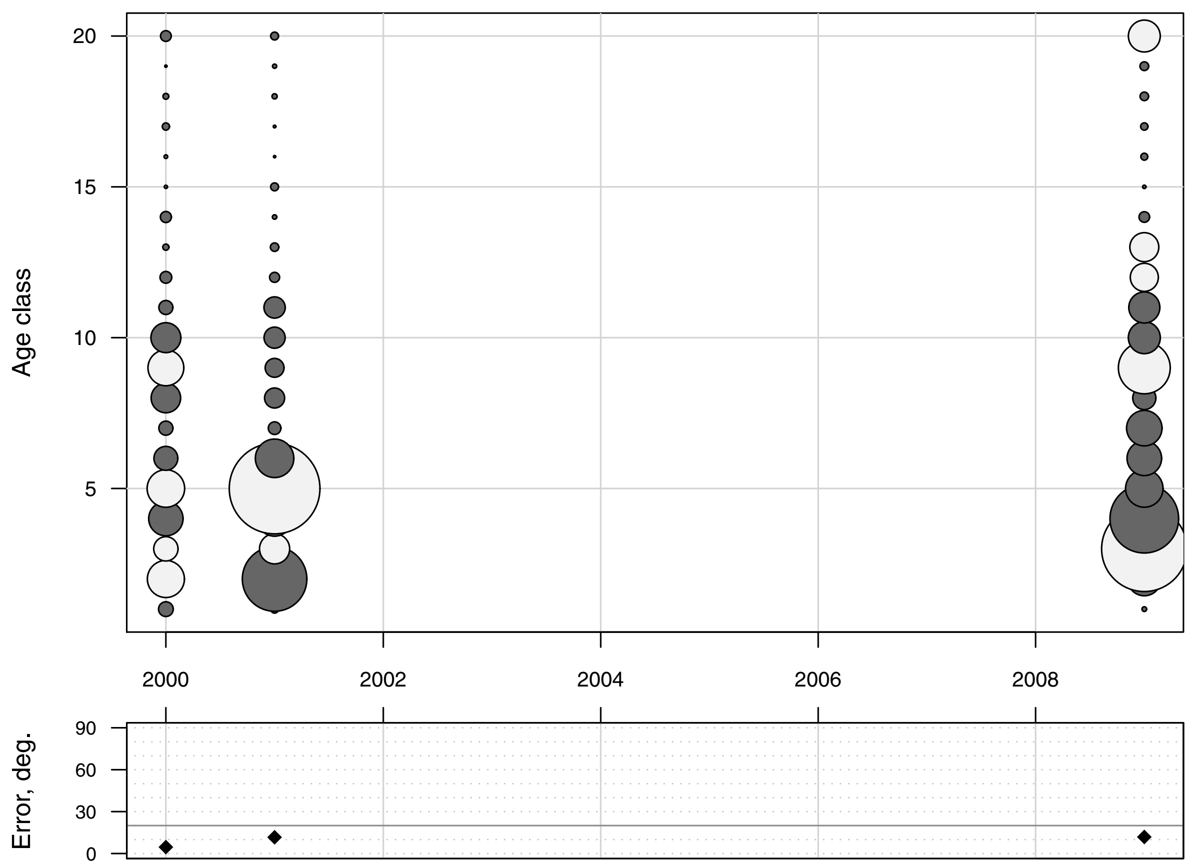


Figure 3.12. Top panel is a bubble plot of age composition residuals from for-hire landings; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

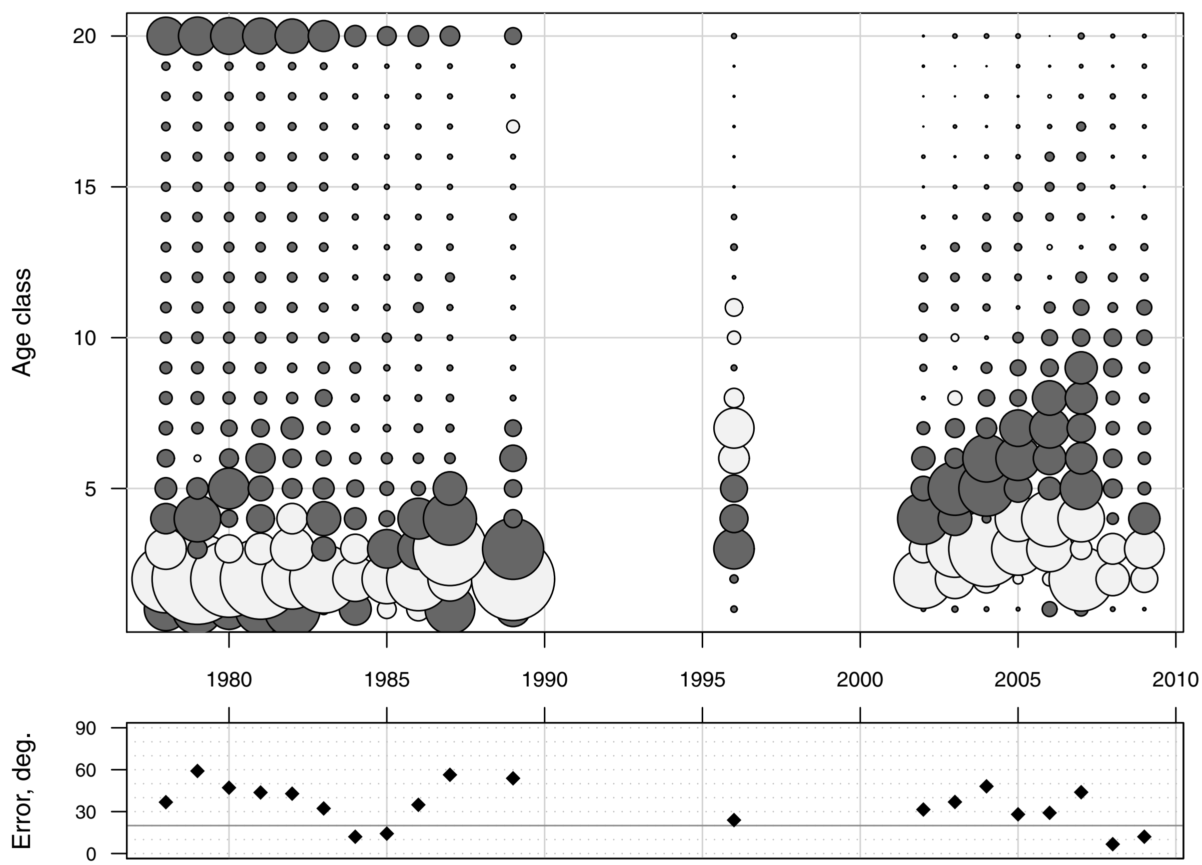


Figure 3.13. Top panel is a bubble plot of age composition residuals from private recreational landings; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

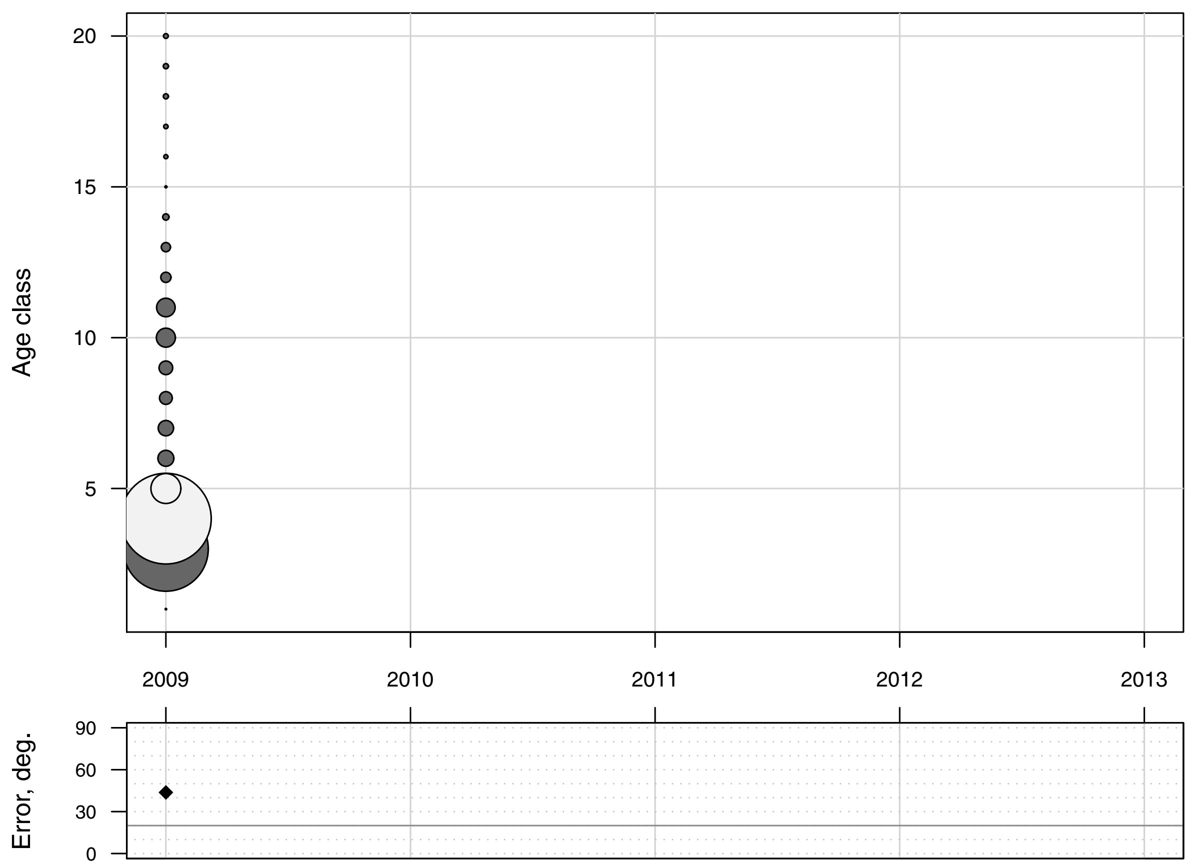


Figure 3.14. Observed (open circles) and estimated (line, solid circles) commercial lines landings (1000 lb whole weight).

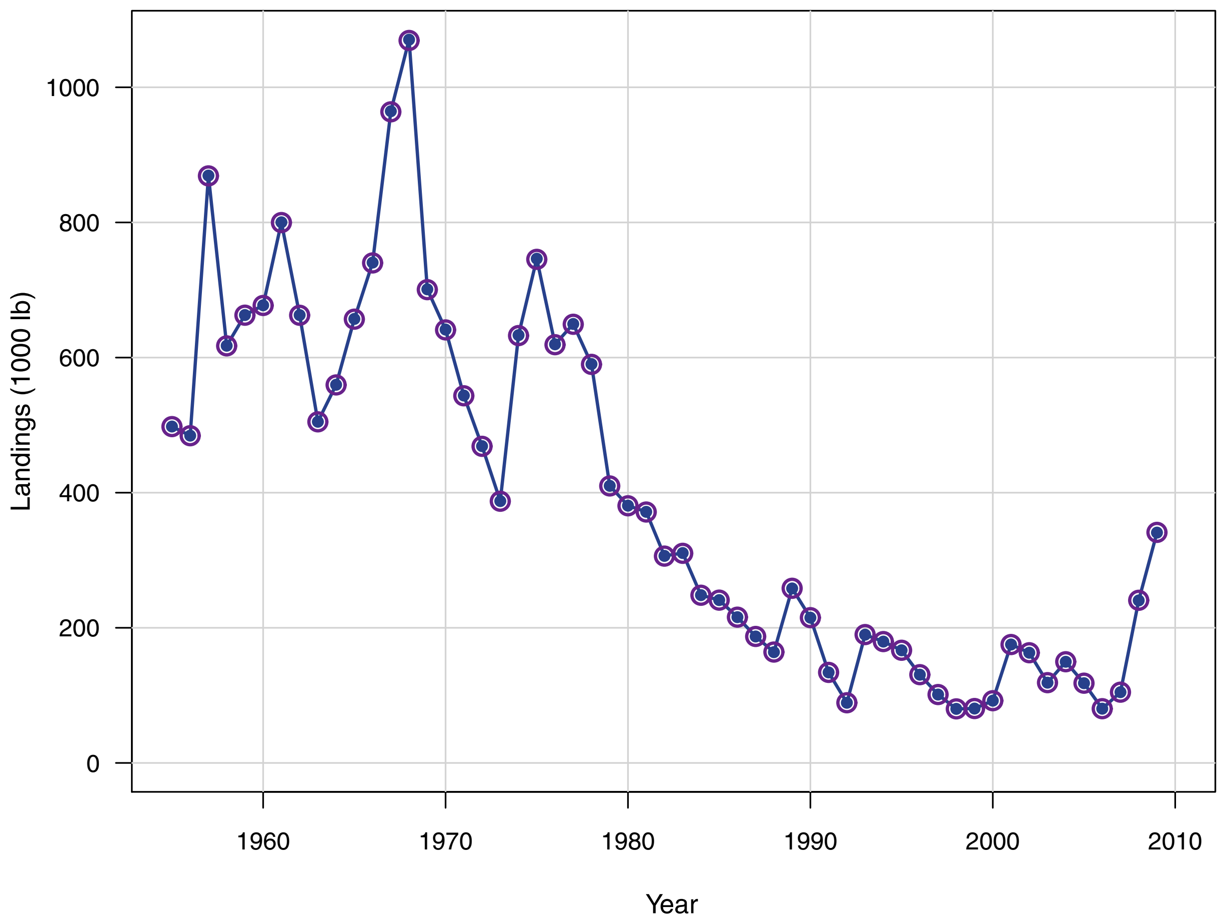


Figure 3.15. Observed (open circles) and estimated (line, solid circles) commercial dive (1000 lb whole weight).

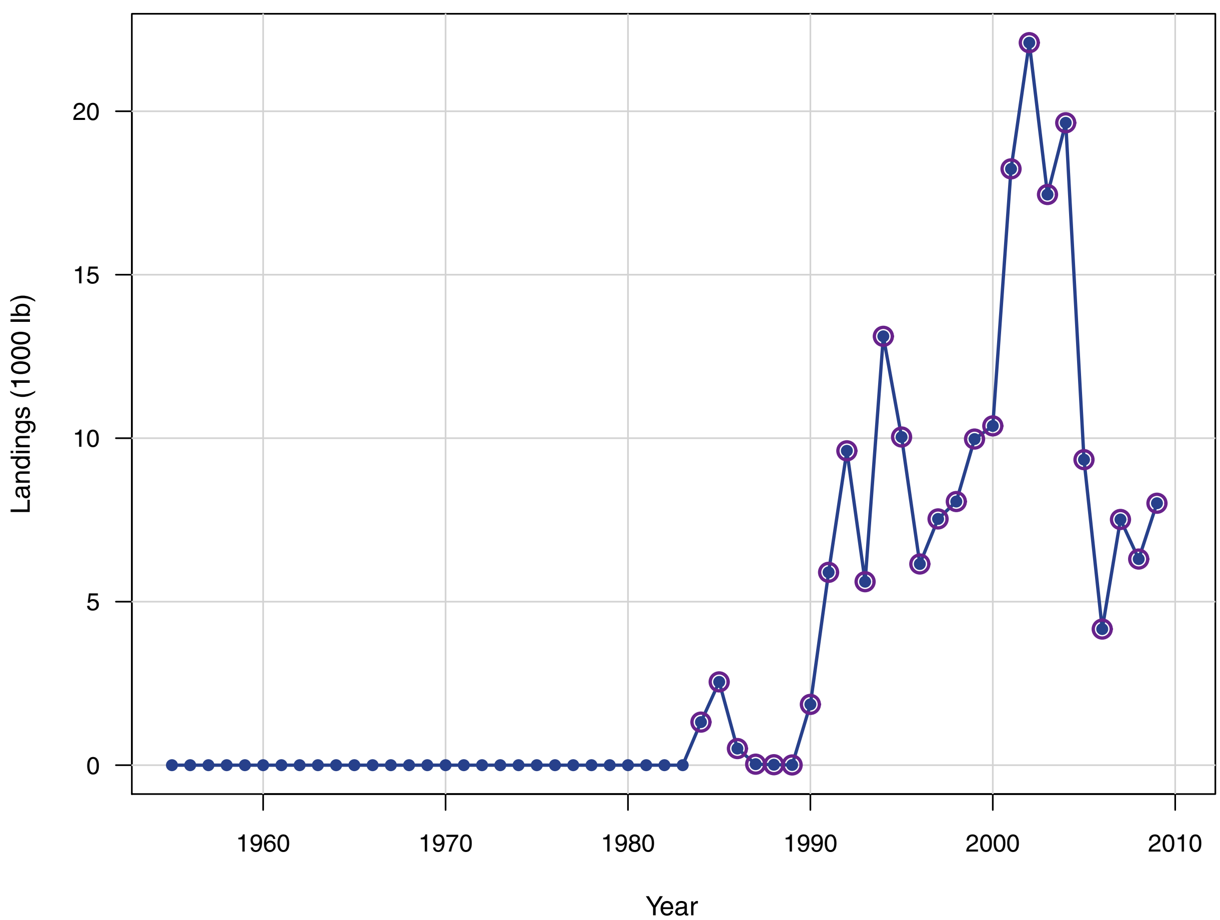


Figure 3.16. Observed (open circles) and estimated (line, solid circles) for-hire landings (1000 fish).

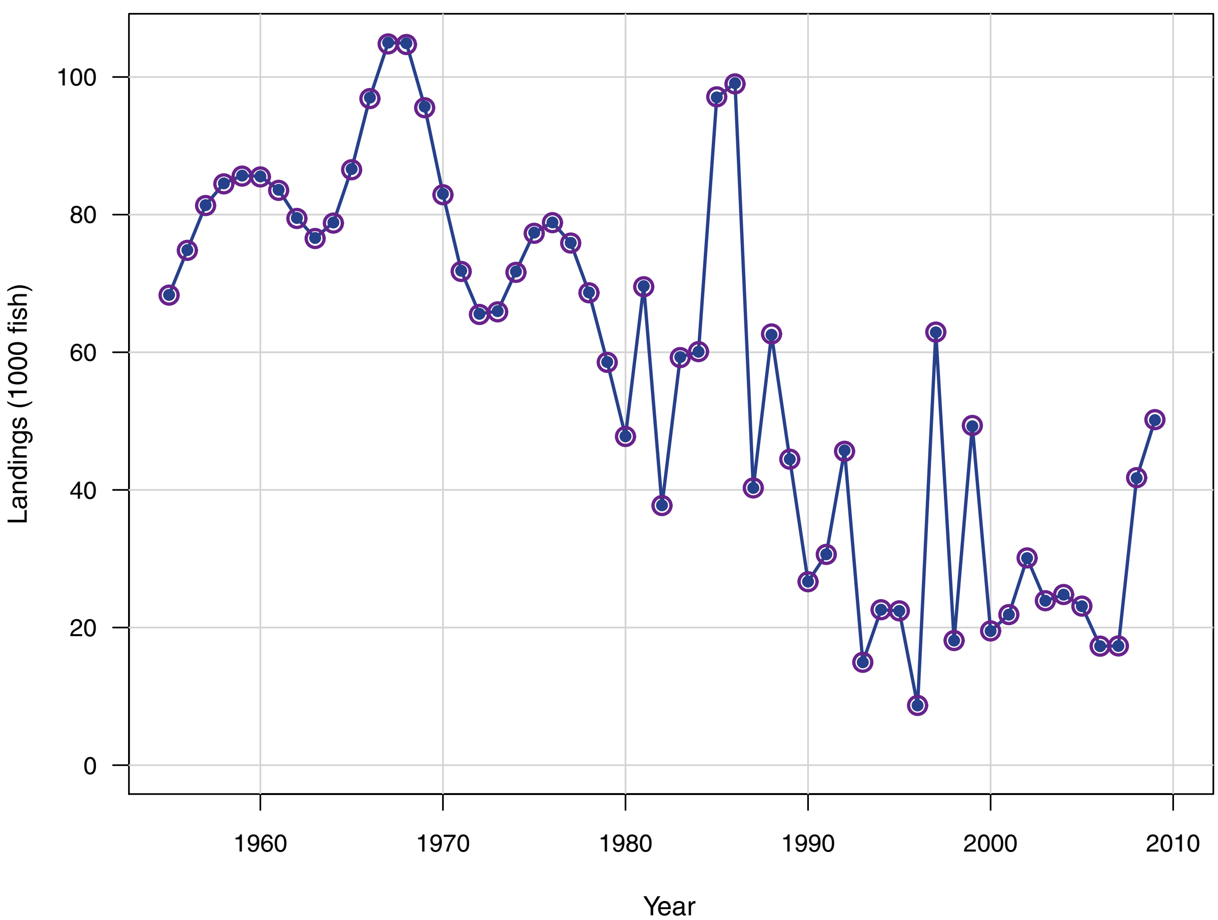


Figure 3.17. Observed (open circles) and estimated (line, solid circles) private recreational landings (1000 fish). In years without observations, values were predicted using average F (see §3.1.1.3 for details).

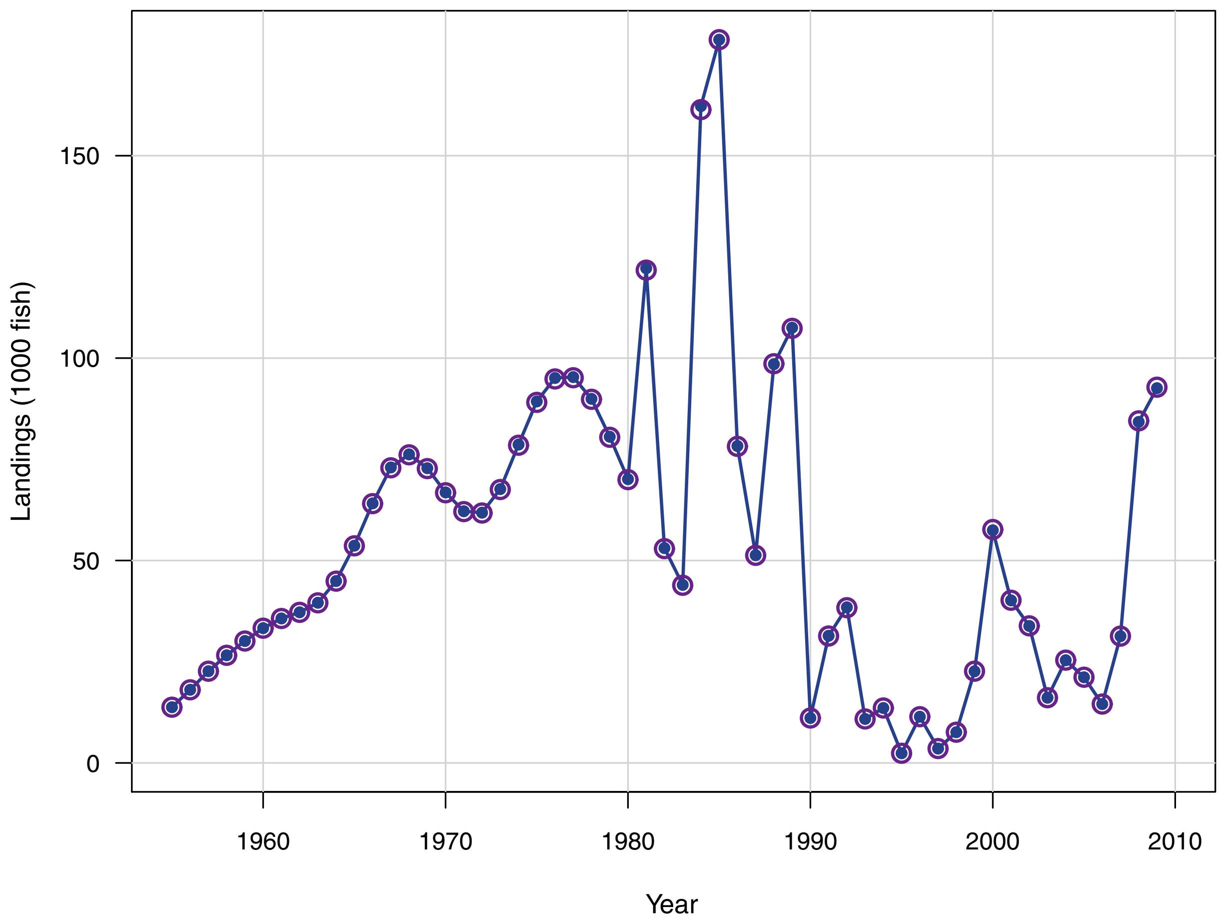


Figure 3.18. Observed (open circles) and estimated (line, solid circles) commercial lines discard mortalities (1000 dead fish).

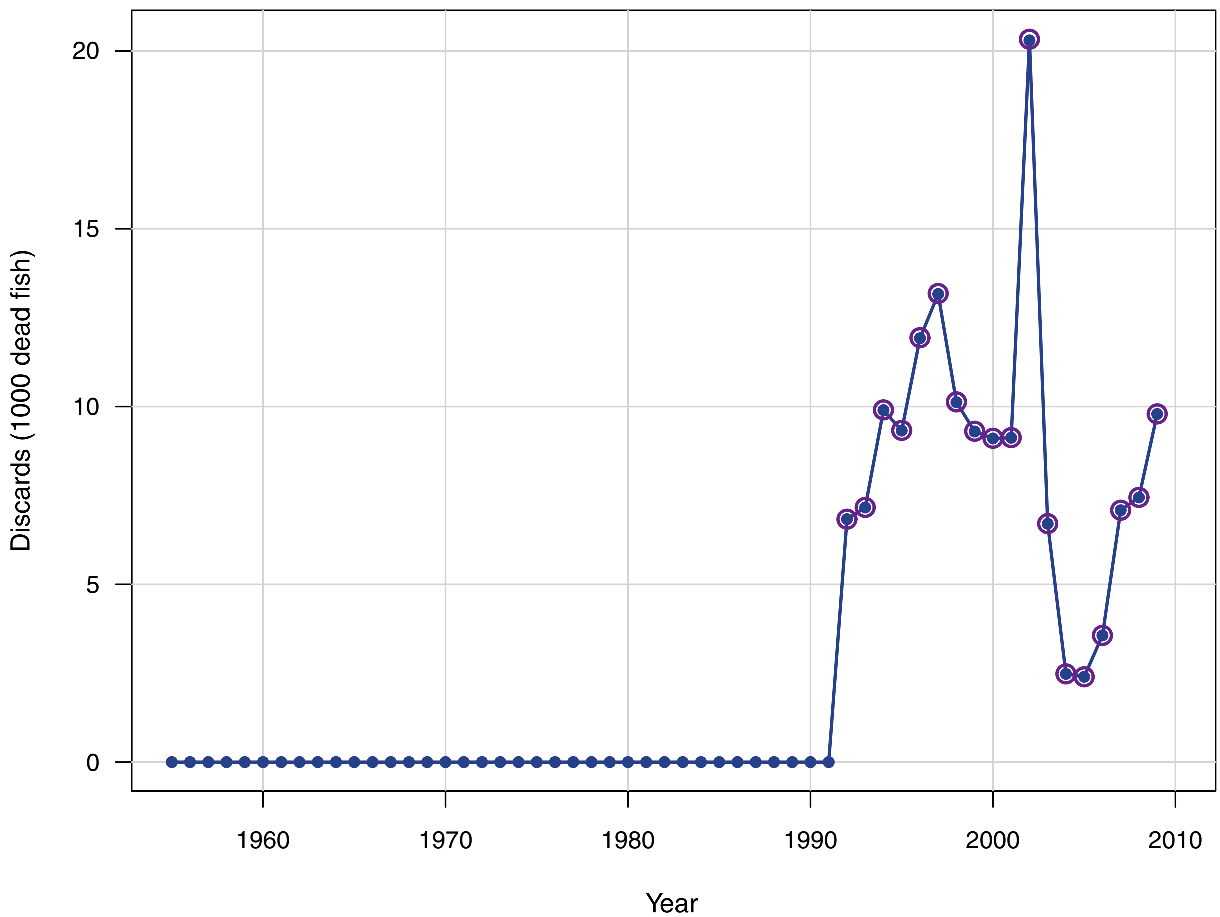


Figure 3.19. Observed (open circles) and estimated (line, solid circles) for-hire discard mortalities (1000 dead fish).

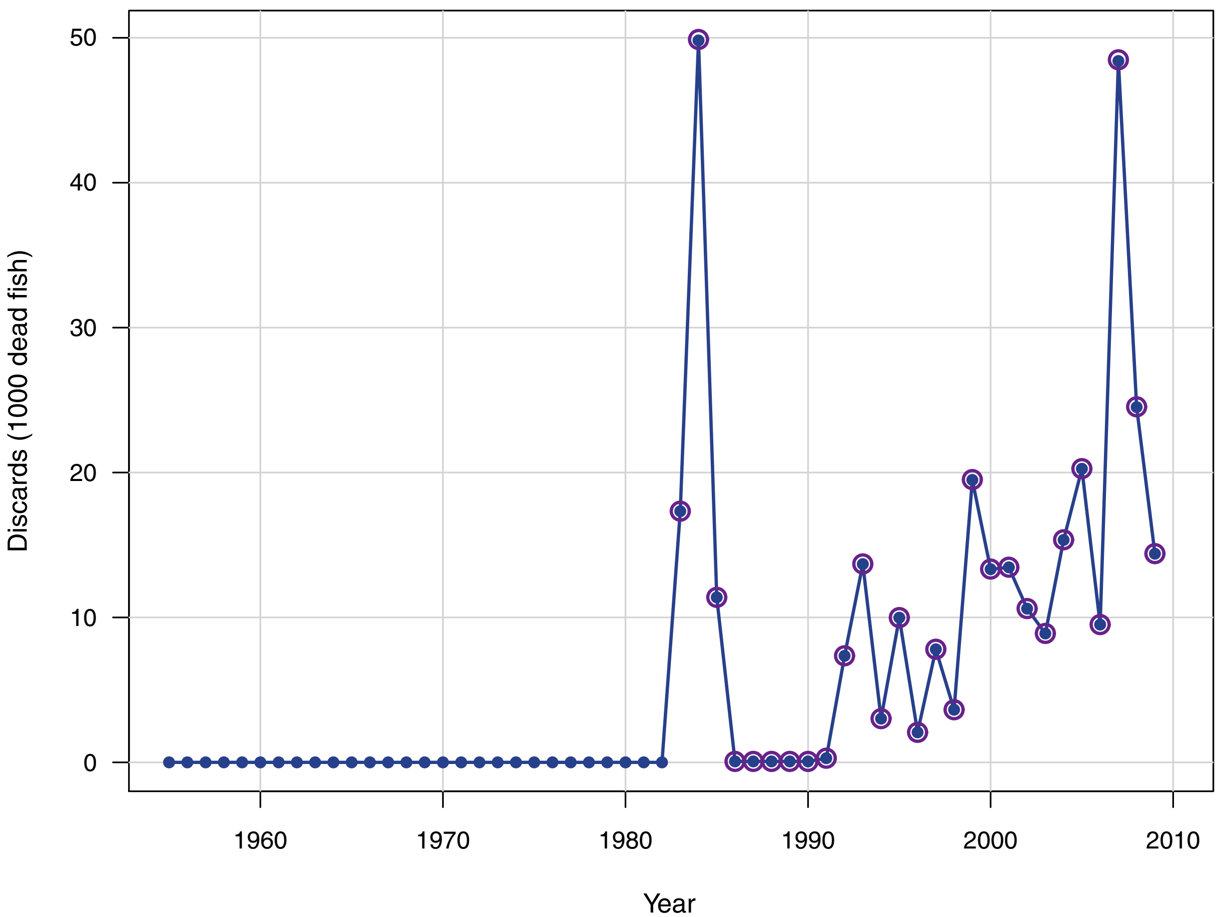


Figure 3.20. Observed (open circles) and estimated (line, solid circles) private recreational discard mortalities (1000 dead fish).

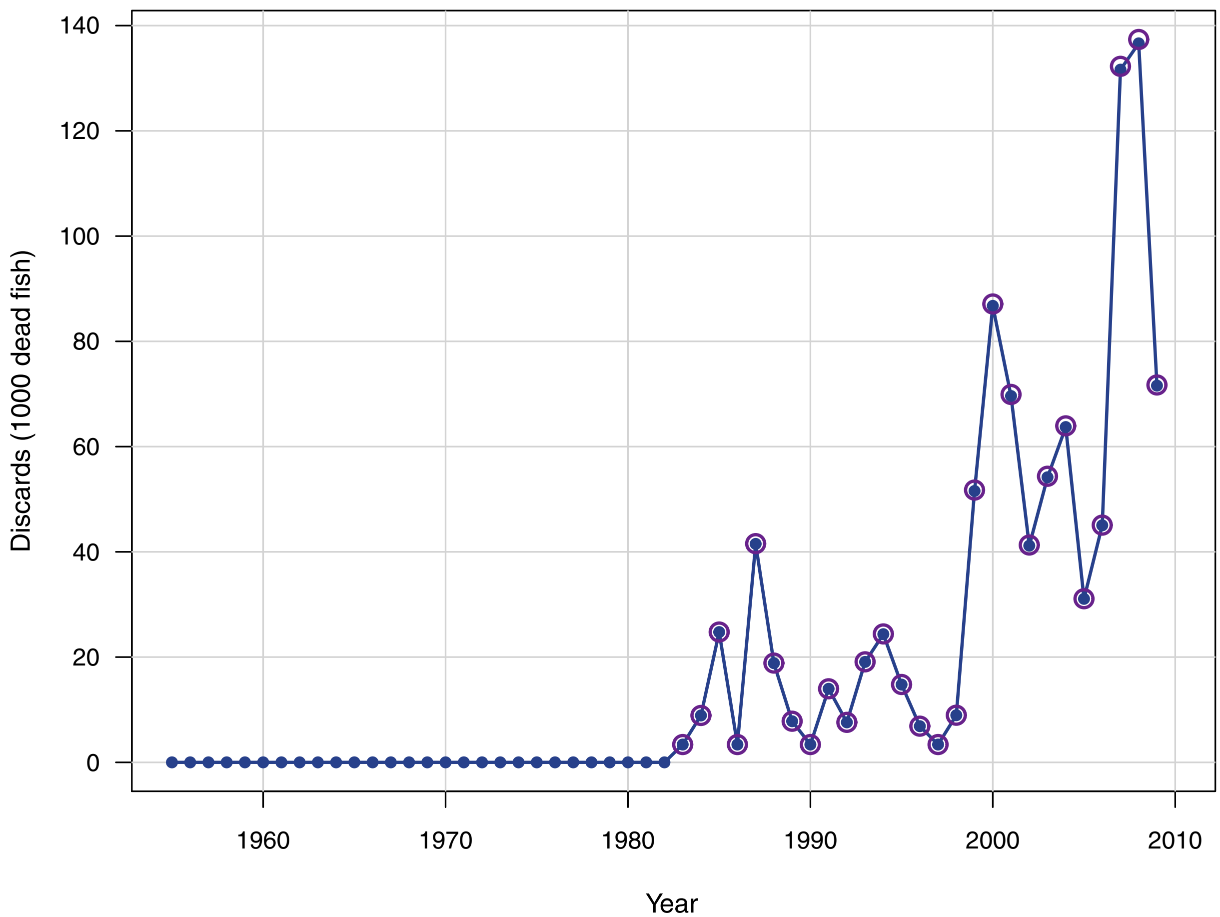


Figure 3.21. Observed (open circles) and estimated (line, solid circles) index of abundance from commercial lines.

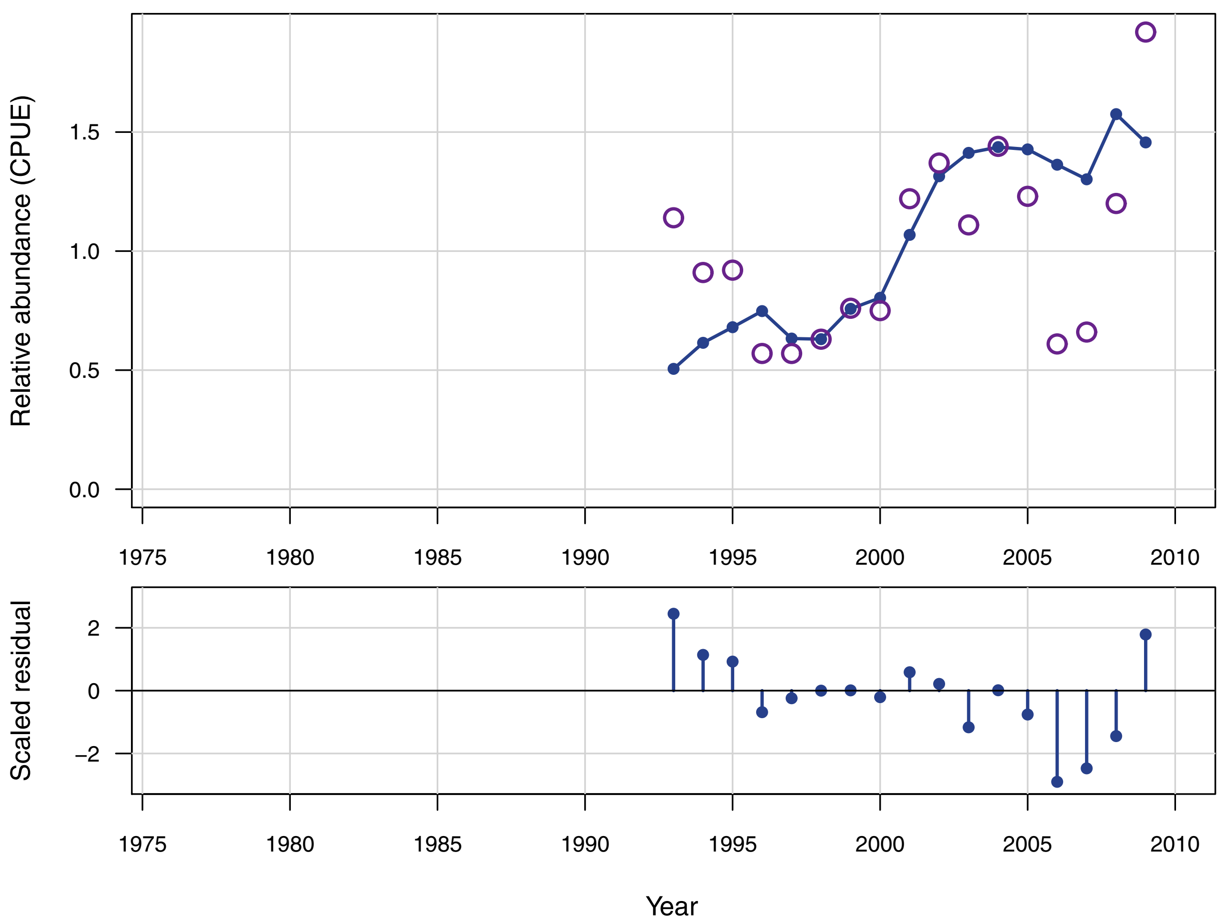


Figure 3.22. Observed (open circles) and estimated (line, solid circles) index of abundance from the for-hire (headboats) fleet.

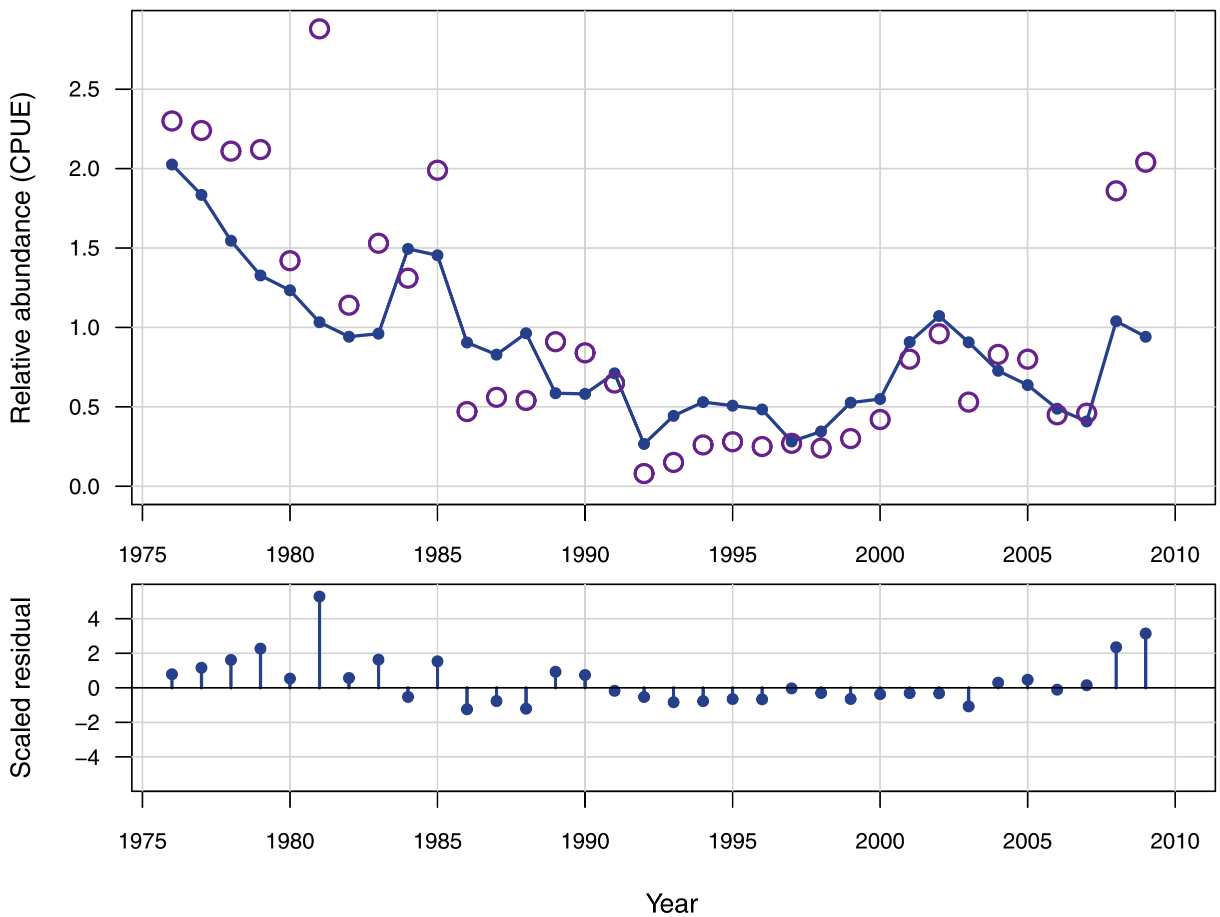


Figure 3.23. Observed (open circles) and estimated (line, solid circles) abundance from for-hire (headboat) discards.

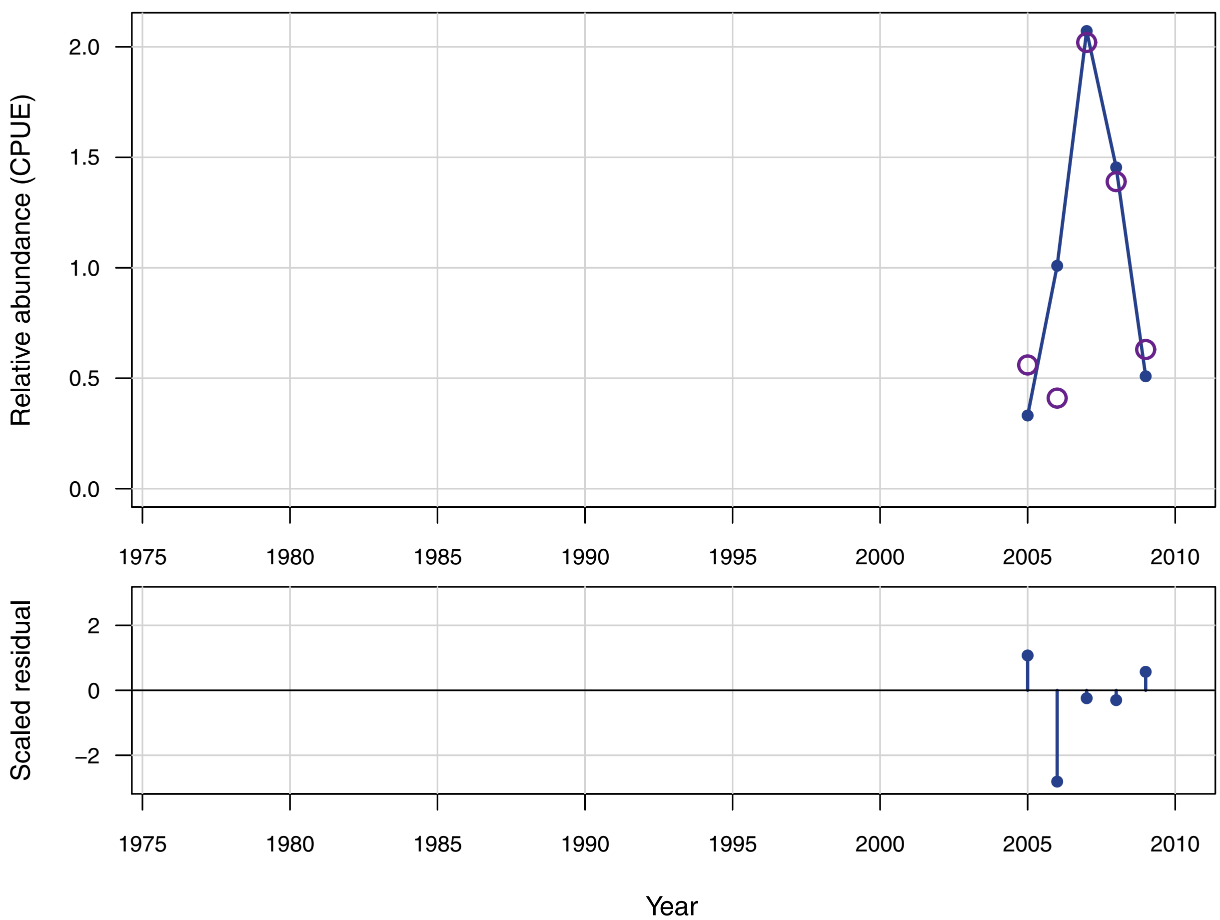


Figure 3.24. Estimated abundance at age at start of year.

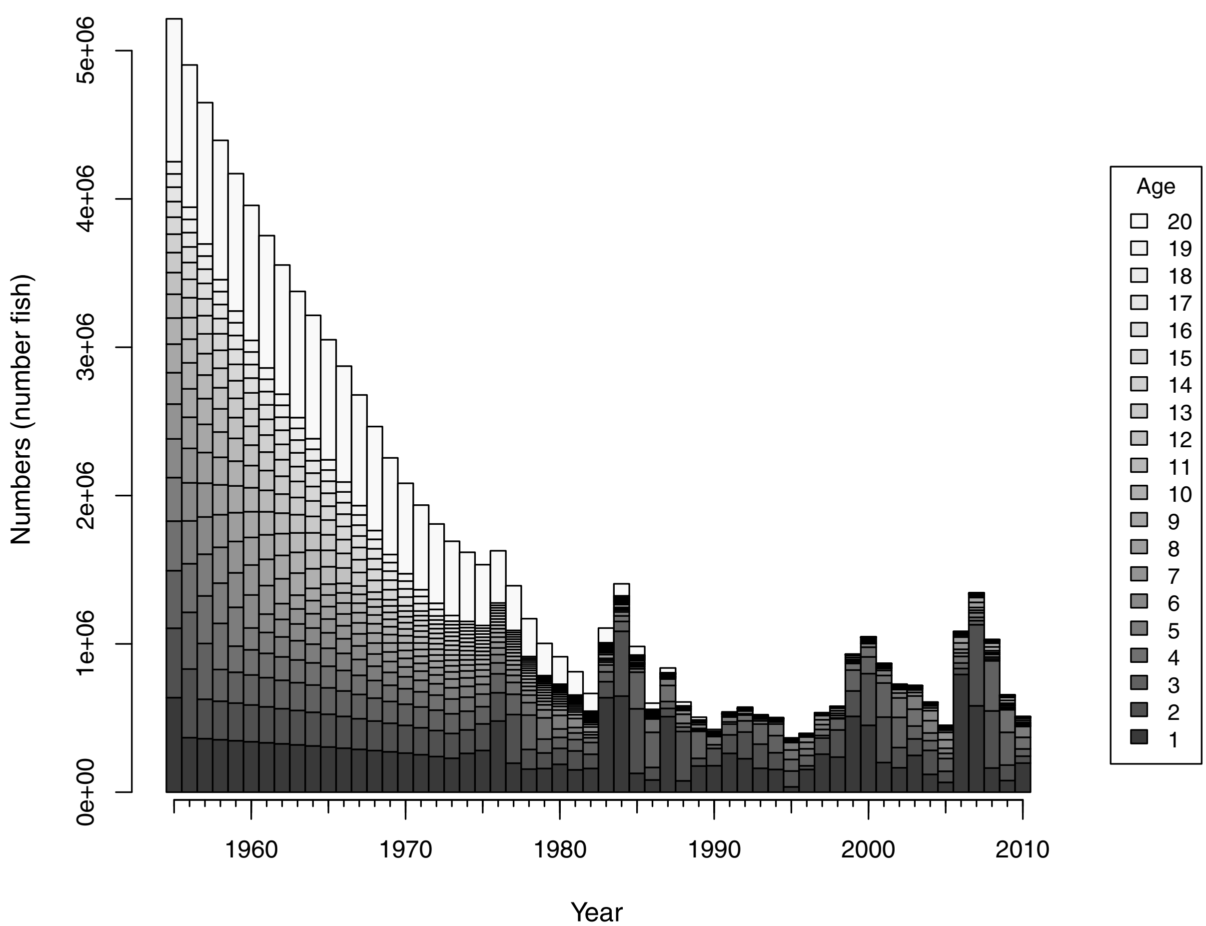


Figure 3.25. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates R_{MSY}. Bottom panel: log recruitment residuals.

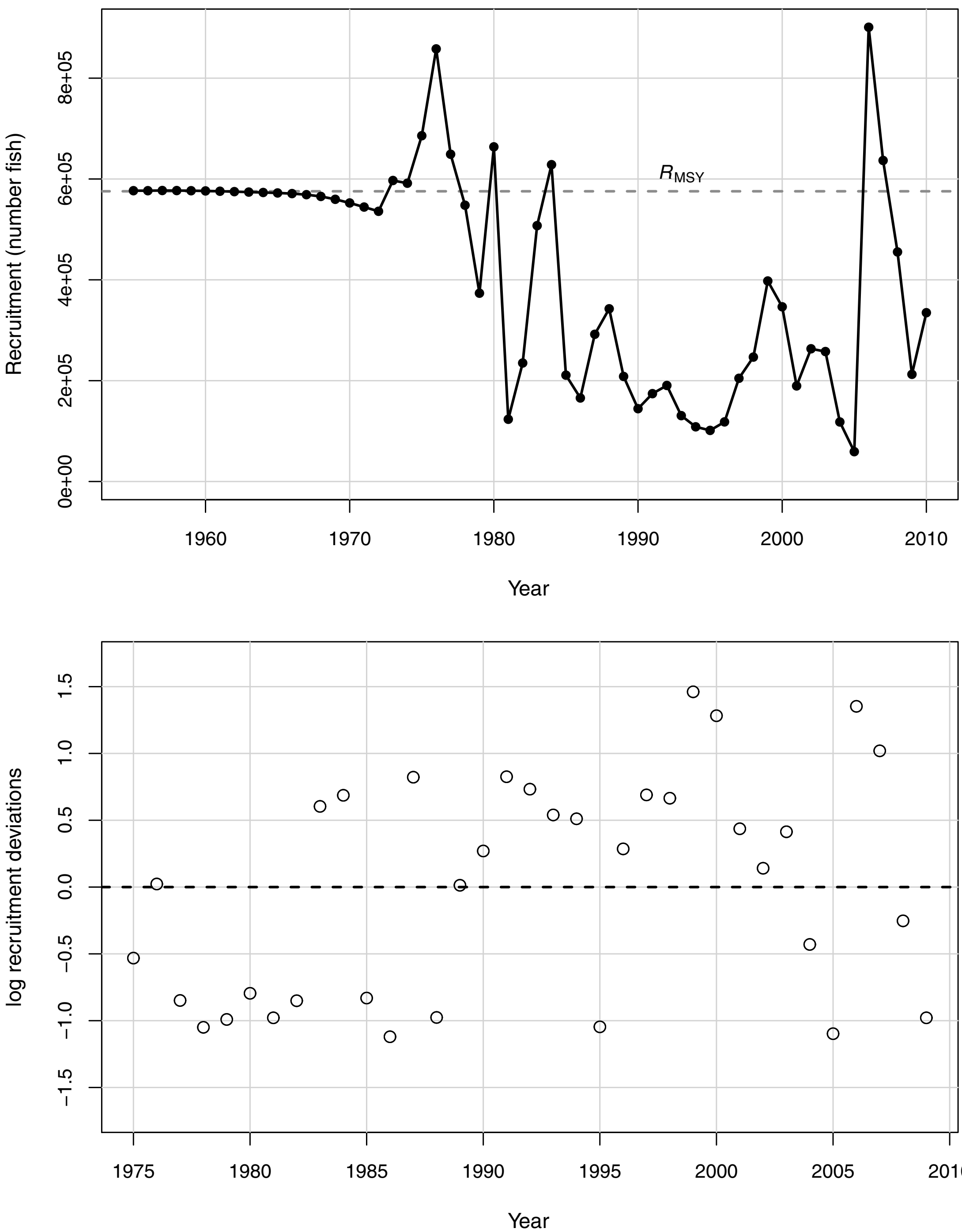


Figure 3.26. Estimated biomass at age at start of year.

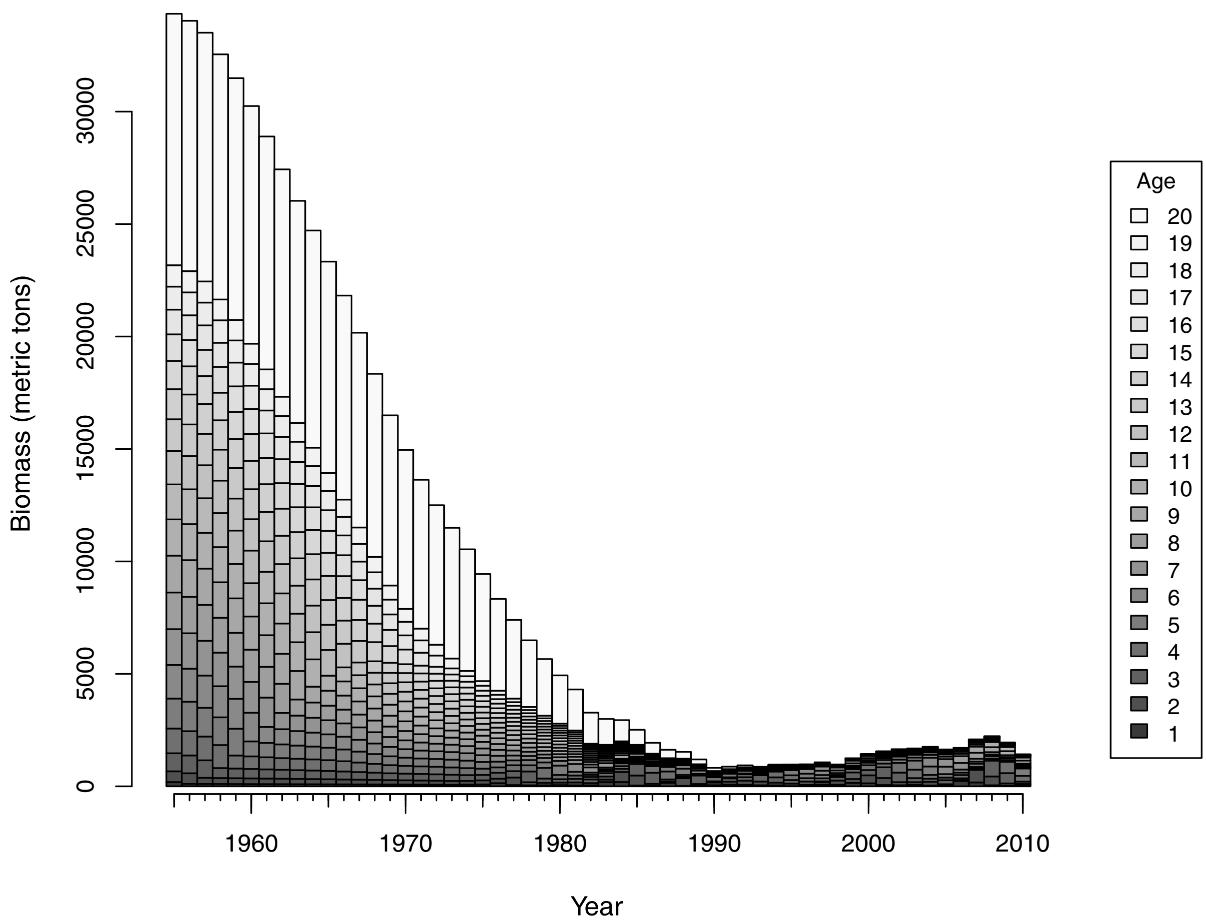


Figure 3.27. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates B_{MSY}. Bottom panel: Estimated spawning stock (gonad biomass of mature females) at time of peak spawning.

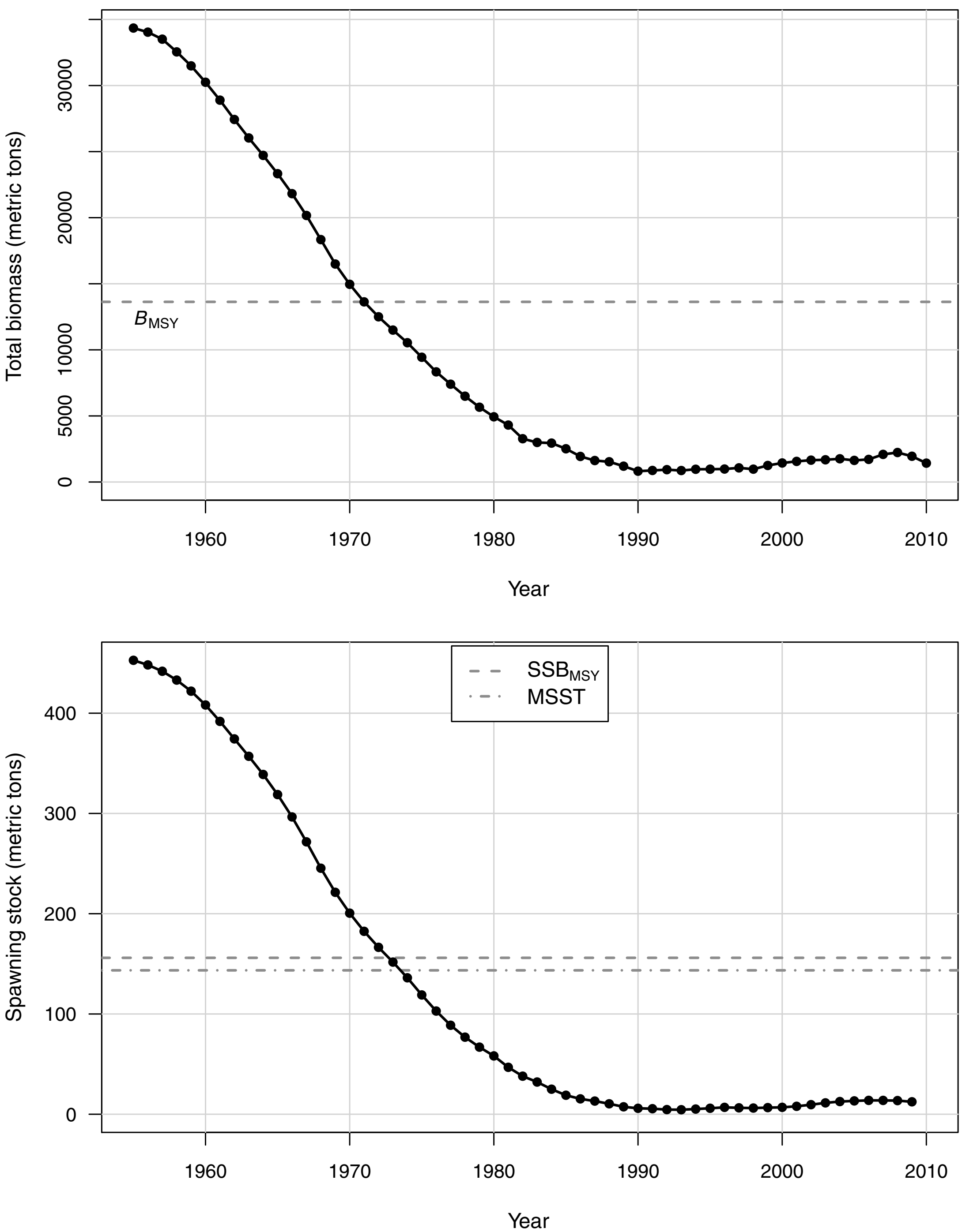


Figure 3.28. Selectivities of commercial fleets. Top panel: commercial lines, 1955–1991. Middle panel: commercial lines, 1992–2009. Bottom panel: commercial dive.

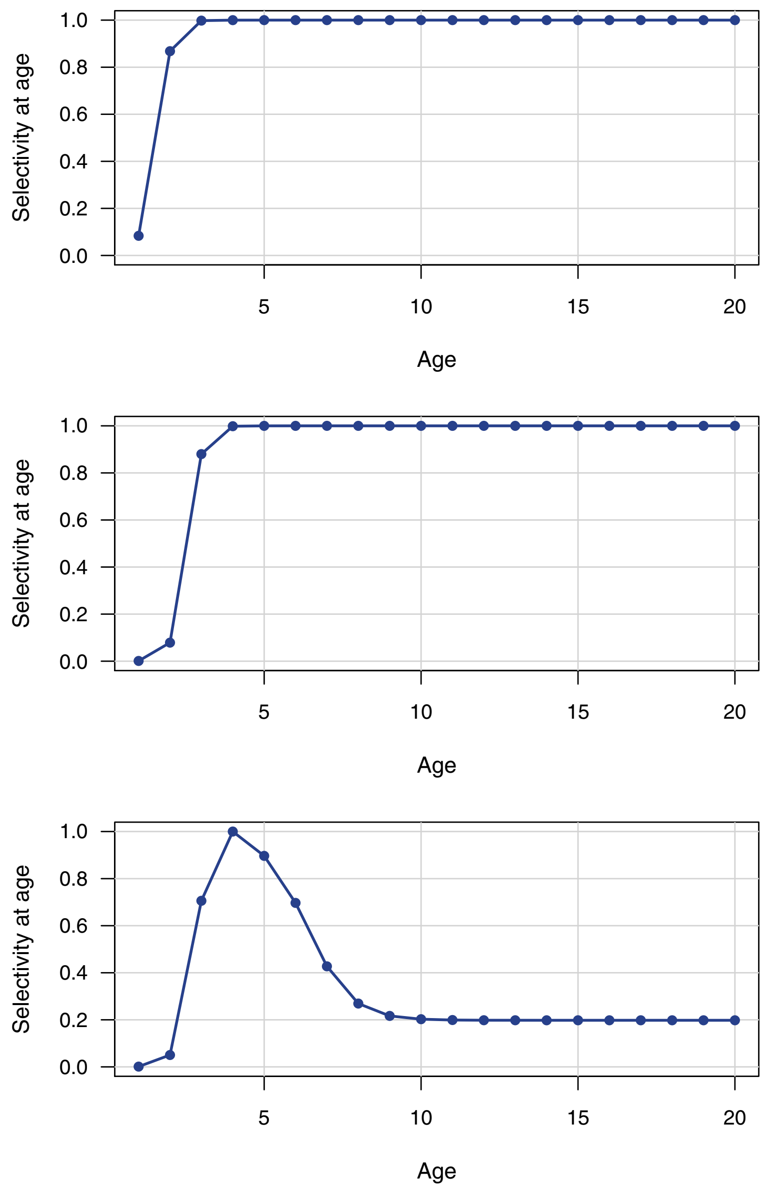


Figure 3.29. Selectivities of the for-hire fleet. Top panel: 1955–1983. Middle panel: 1983–1991. Bottom panel: 1992–2009.

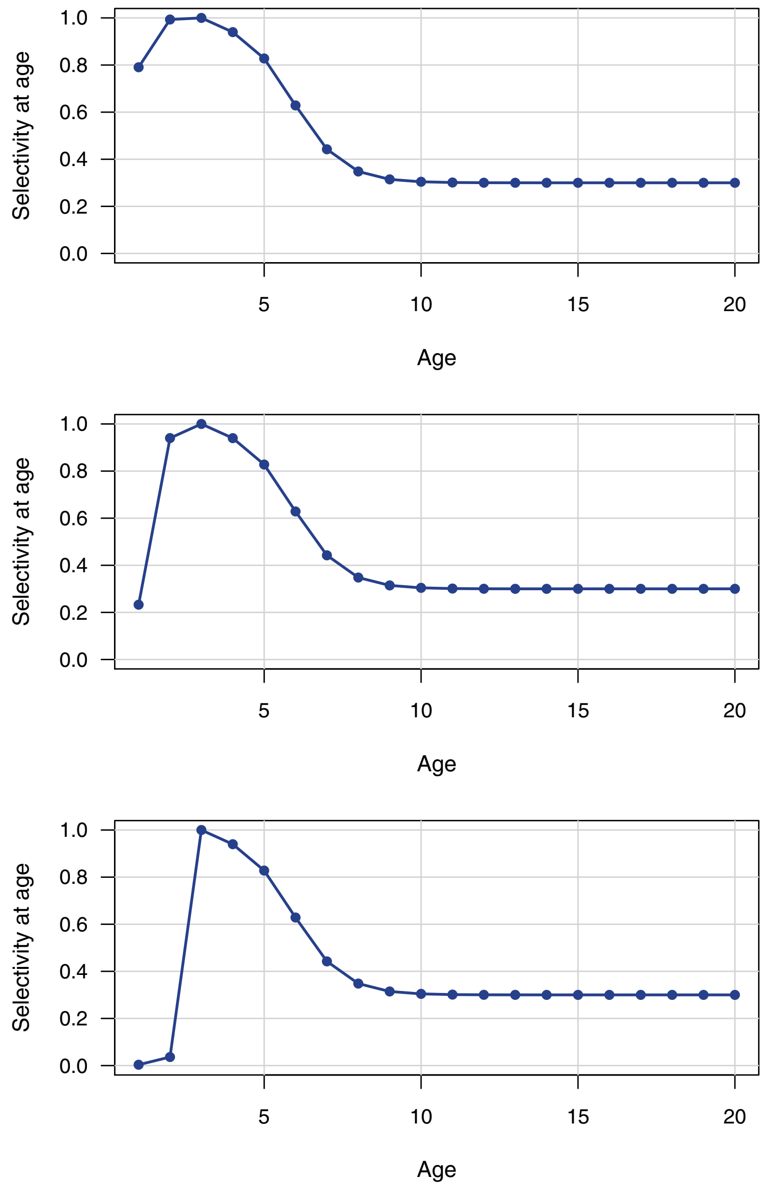


Figure 3.30. Selectivities of the private recreational fleet. Top panel: 1955–1983. Bottom panel: 1992–2009.

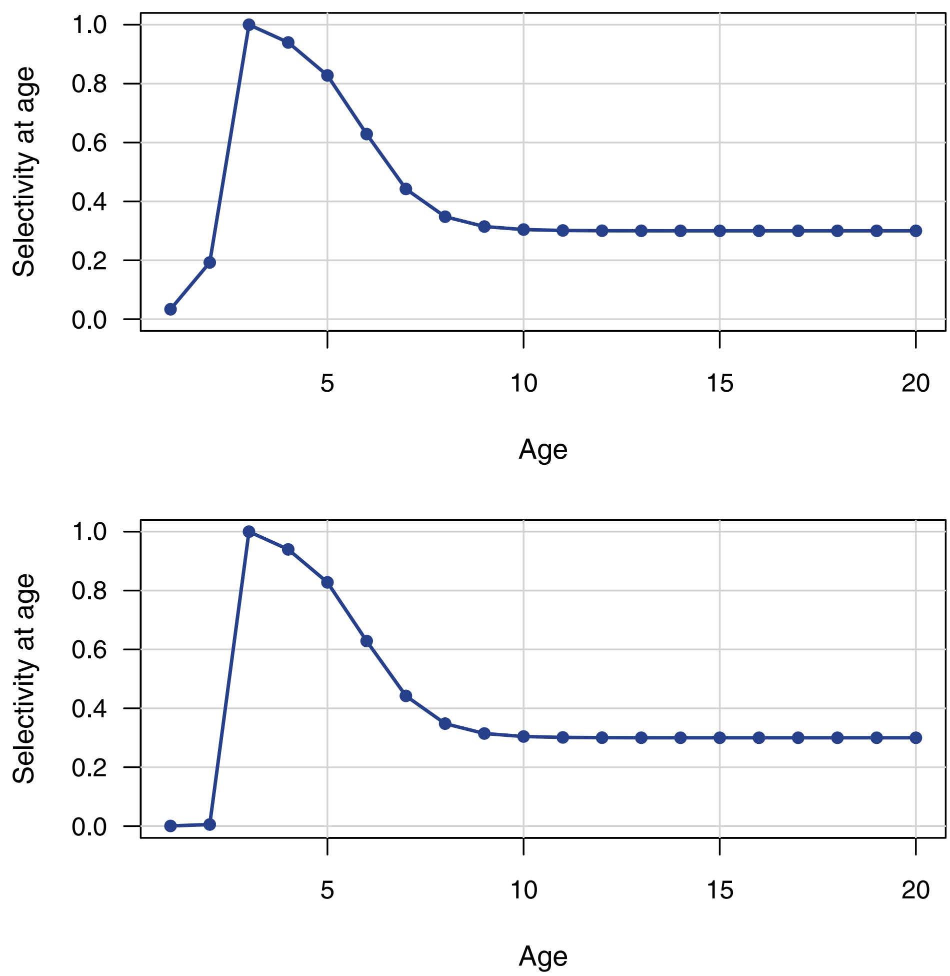


Figure 3.31. Selectivities of discard mortalities. Top panel: commercial lines, 1992–2009. Middle panel: recreational (for-hire and private), 1983–1991. Bottom panel: recreational (for-hire and private), 1992–2009.

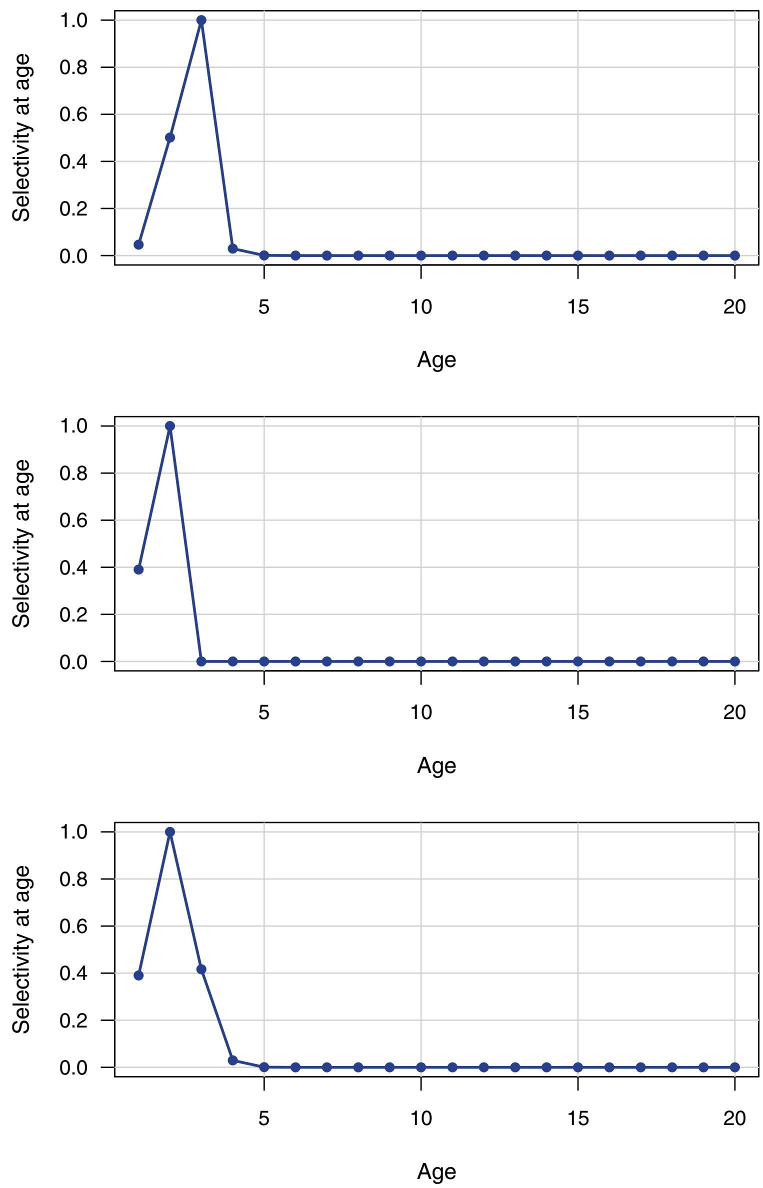


Figure 3.32. Average selectivities from the terminal assessment year (2009, 20-inch limit), weighted by geometric mean Fs from the last three assessment years, and used in computation of benchmarks and central-tendency projections. Top panel: average selectivity applied to landings. Middle panel: average selectivity applied to discard mortalities. Bottom panel: total average selectivity.

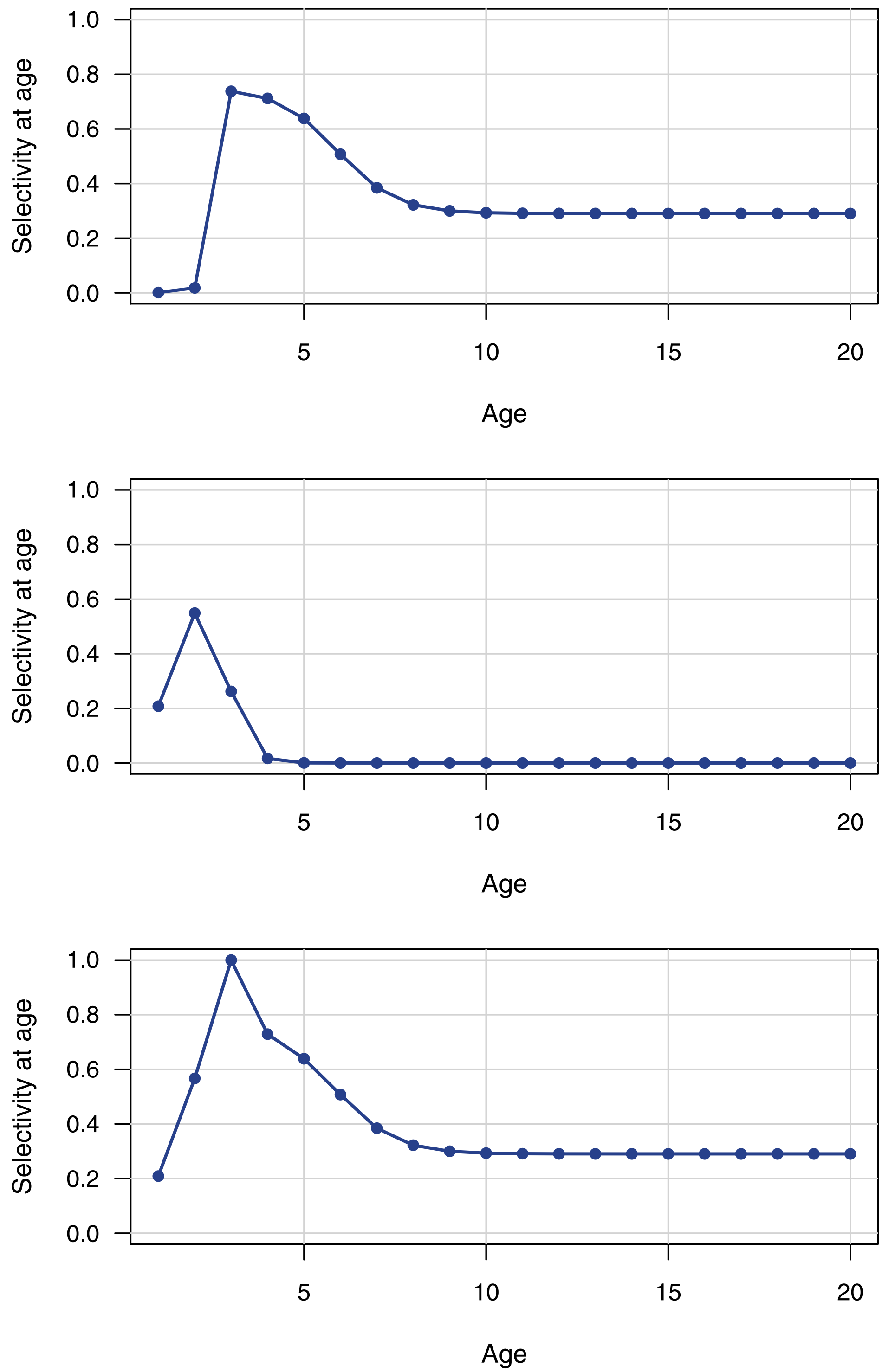


Figure 3.33. Estimated fully selected fishing mortality rate (per year) by fishery. cl refers to commercial lines, cd to commercial dive, hb to for-hire, pvt to private recreational, cl.D to commercial discard mortalities, hb.D to for-hire discard mortalities, and pvt.D to private recreational discard mortalities.

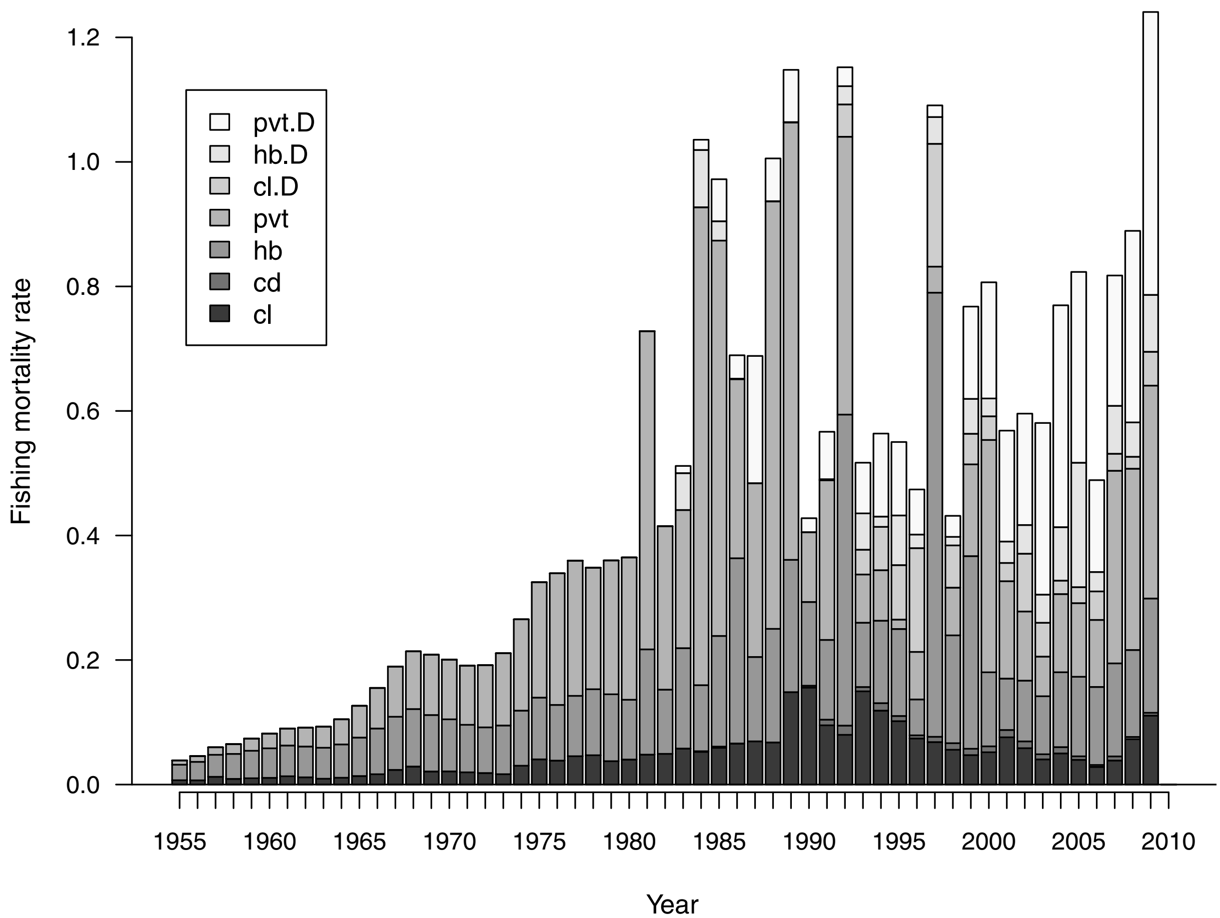


Figure 3.34. Estimated landings in numbers by fishery from the catch-age model. cl refers to commercial lines, cd to commercial dive, hb to for-hire, pvt to private recreational.

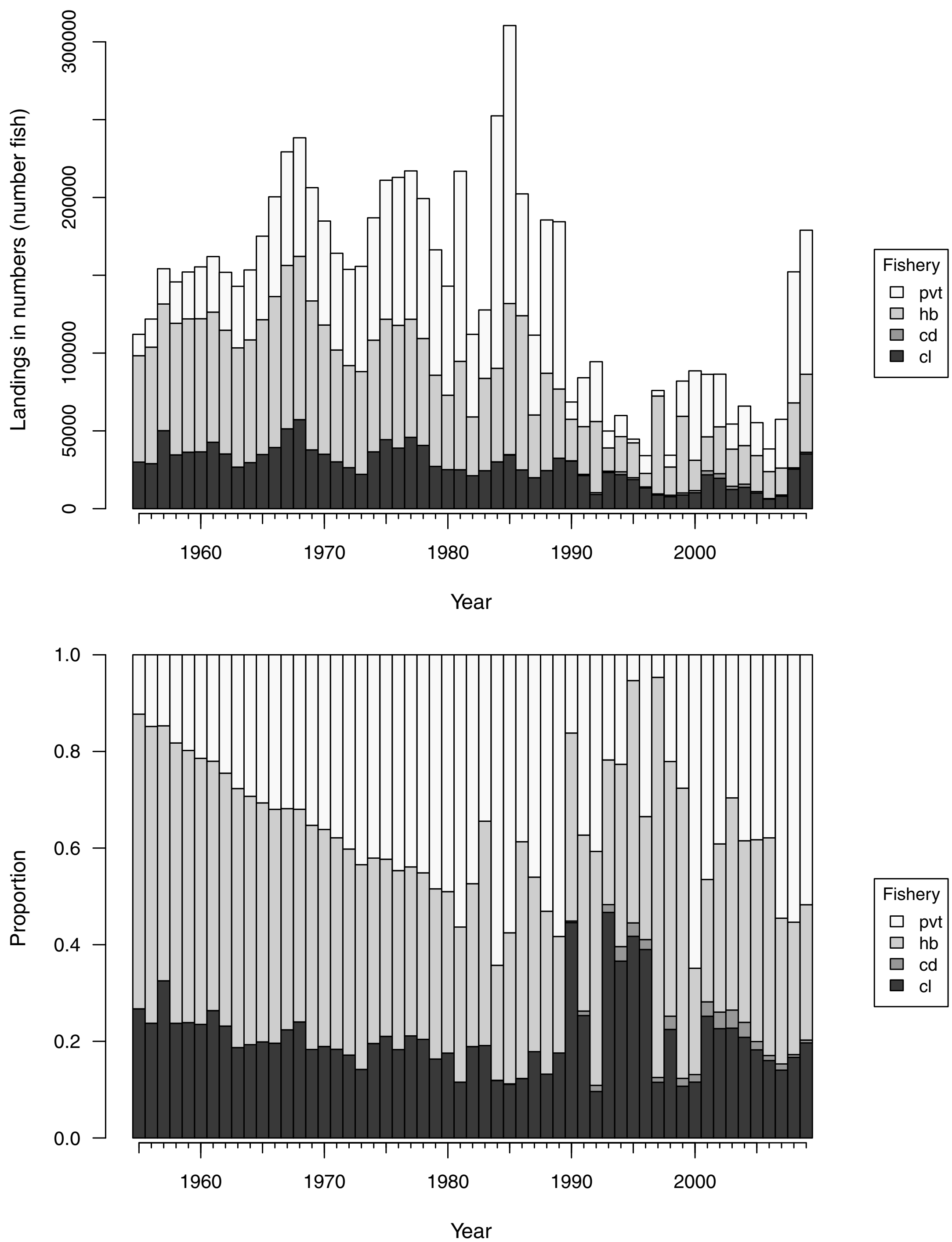


Figure 3.35. Estimated landings in whole weight by fishery from the catch-age model. cl refers to commercial lines, cd to commercial dive, hb to for-hire, pvt to private recreational. Horizontal dashed line in the top panel corresponds to the point estimate of MSY.

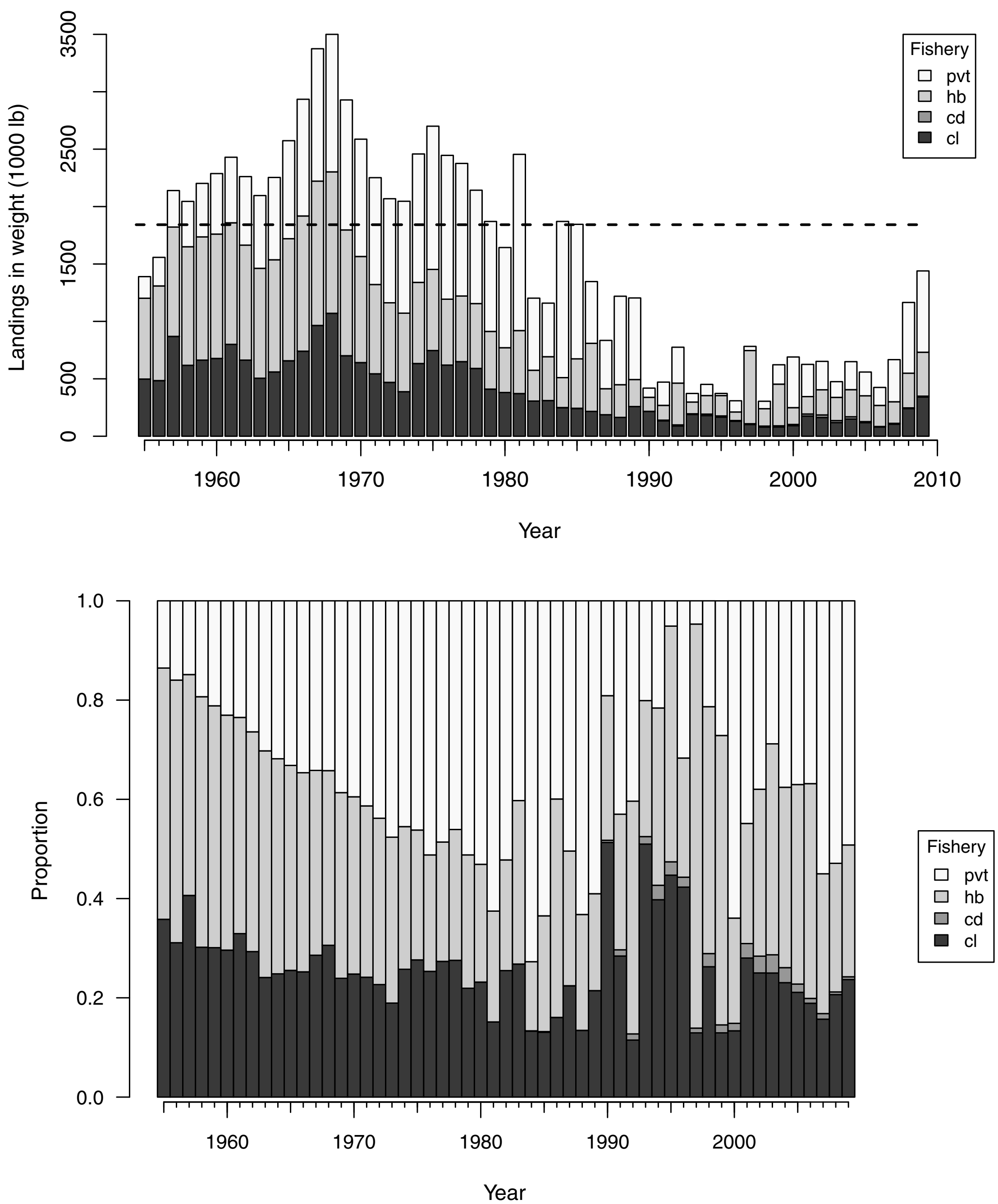


Figure 3.36. Estimated discard mortalities by fishery from the catch-age model. cl refers to commercial lines, hb to for-hire, pvt to private recreational.

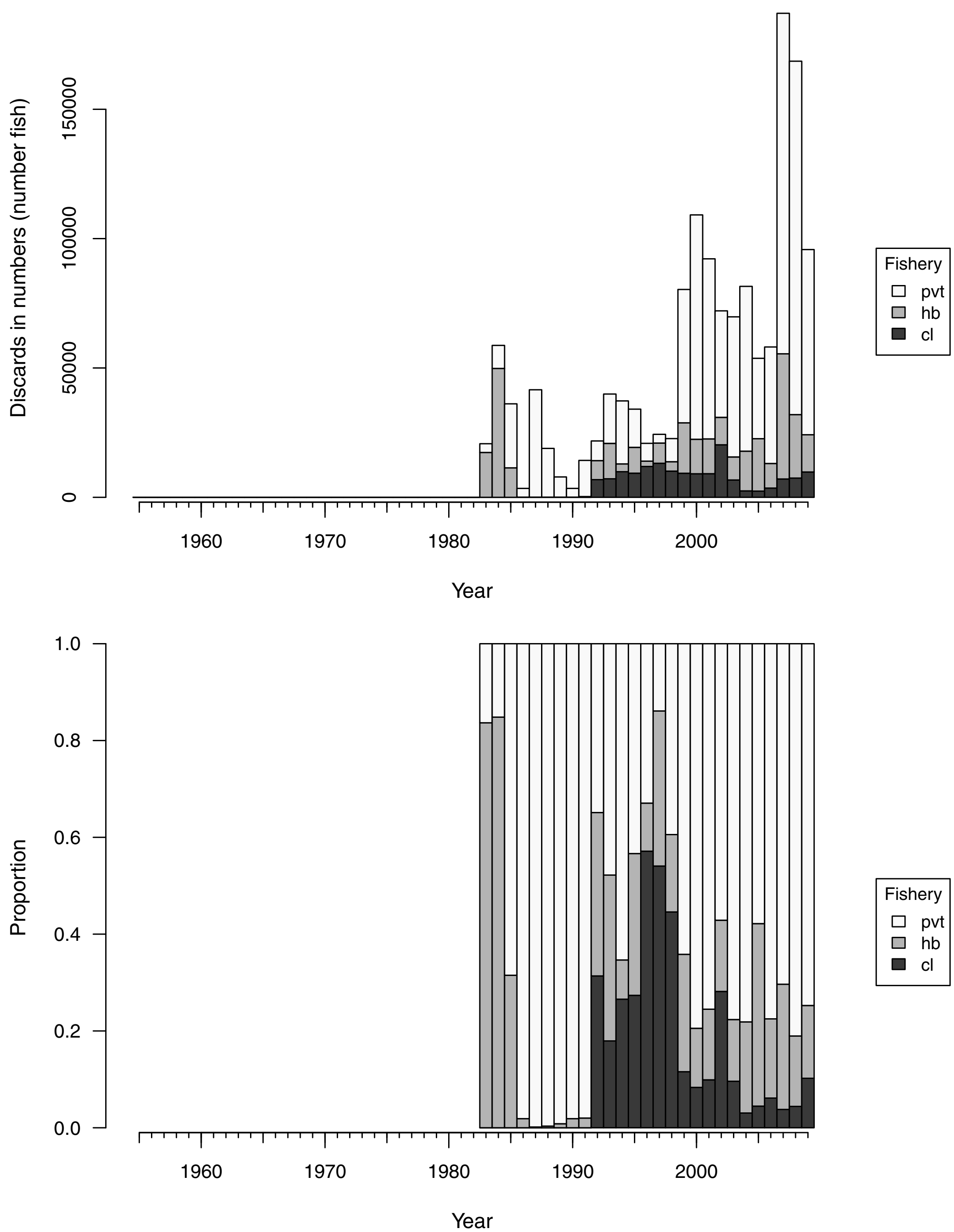
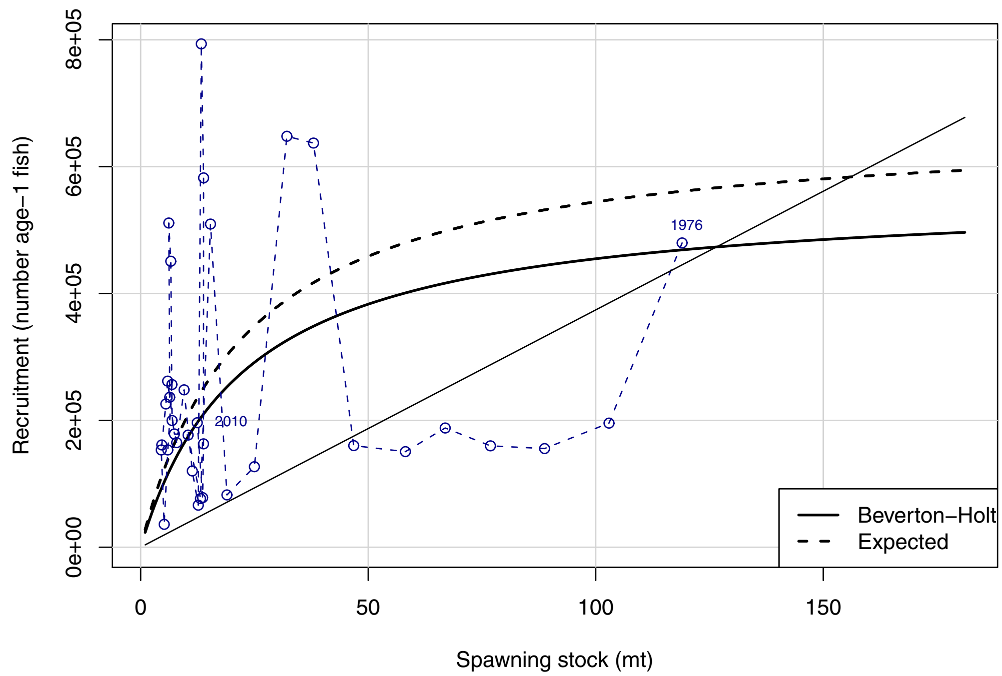


Figure 3.37. Top panel: Beverton–Holt spawner-recruit curves, with and without lognormal bias correction. The expected (upper) curve was used for computing management benchmarks. Years within panel indicate year of recruitment generated from spawning biomass one year prior. Diagonal line indicates MSY-level replacement. Bottom panel: log of recruits (number age-1 fish) per spawner (mature female gonad weight) as a function of spawners.



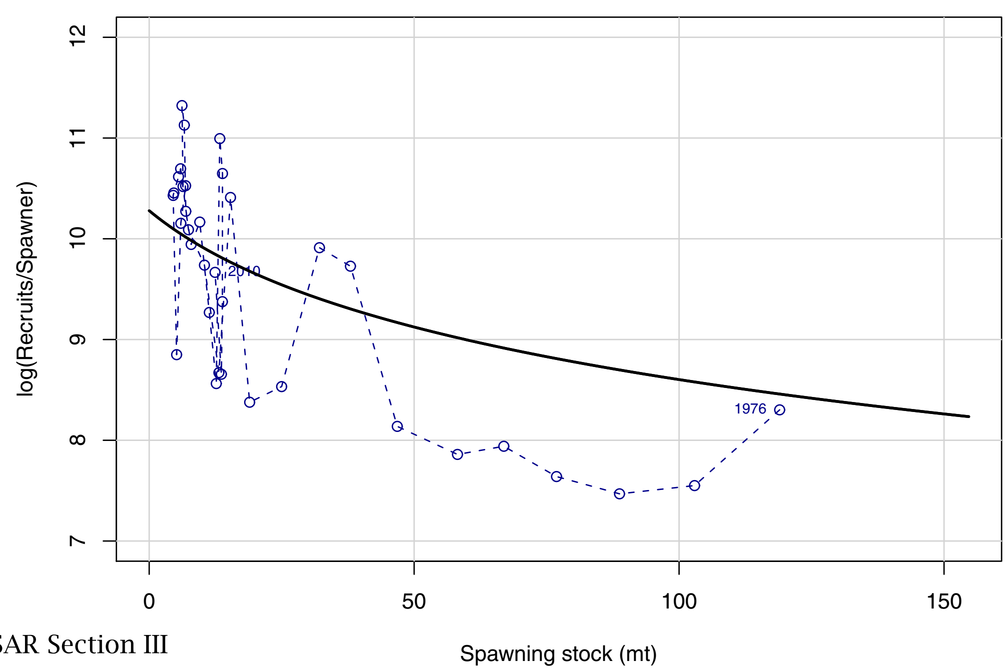


Figure 3.38. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-1 fish), steepness, unfished spawners per recruit, and standard deviation of recruitment residuals in log space. Vertical lines represent point estimates or values from the base run of the Beaufort Assessment Model.

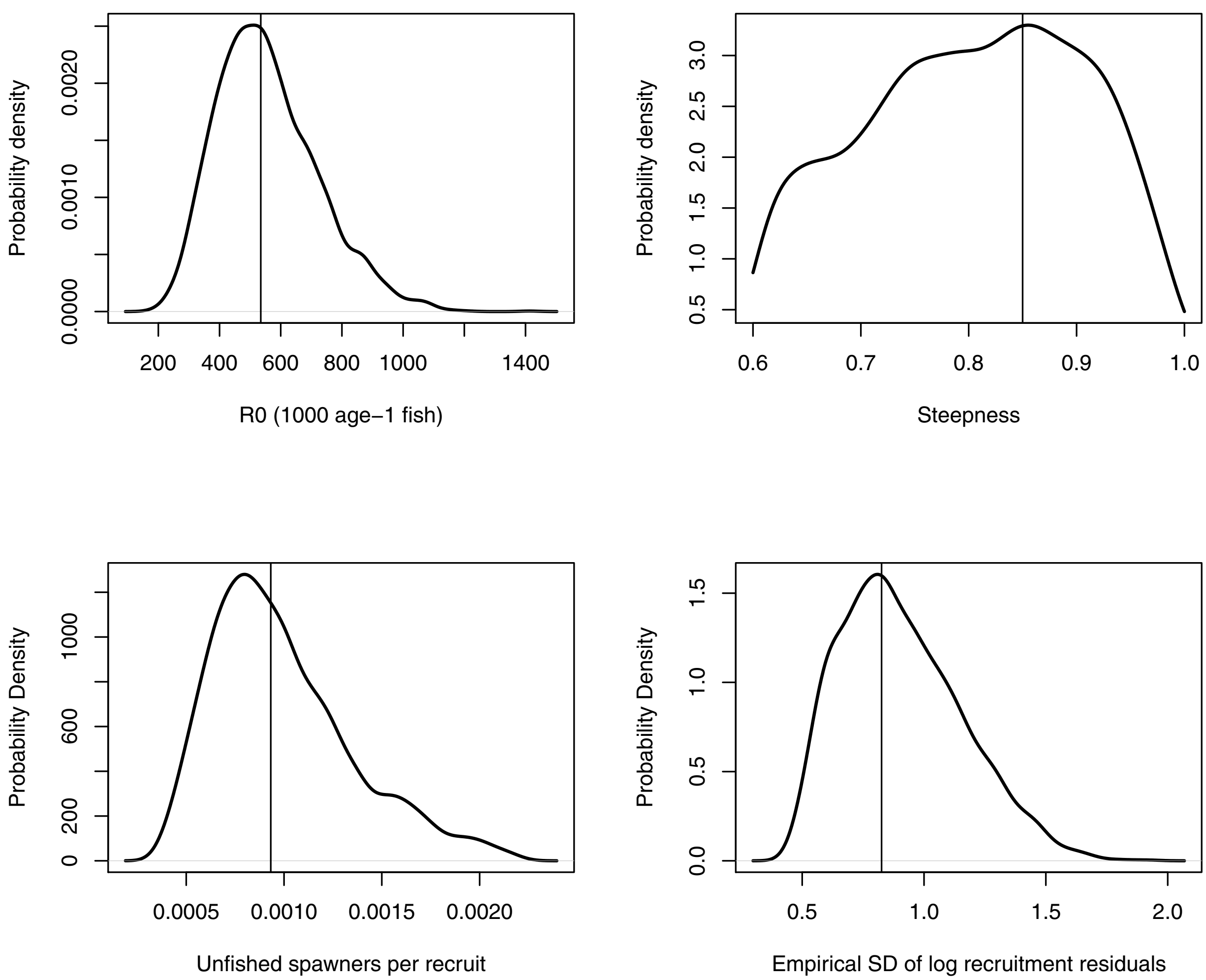


Figure 3.39. Estimated time series of static spawning potential ratio, the annual equilibrium spawners per recruit relative to that at the unfished level. Horizontal dashed line indicates the equilibrium MSY level.

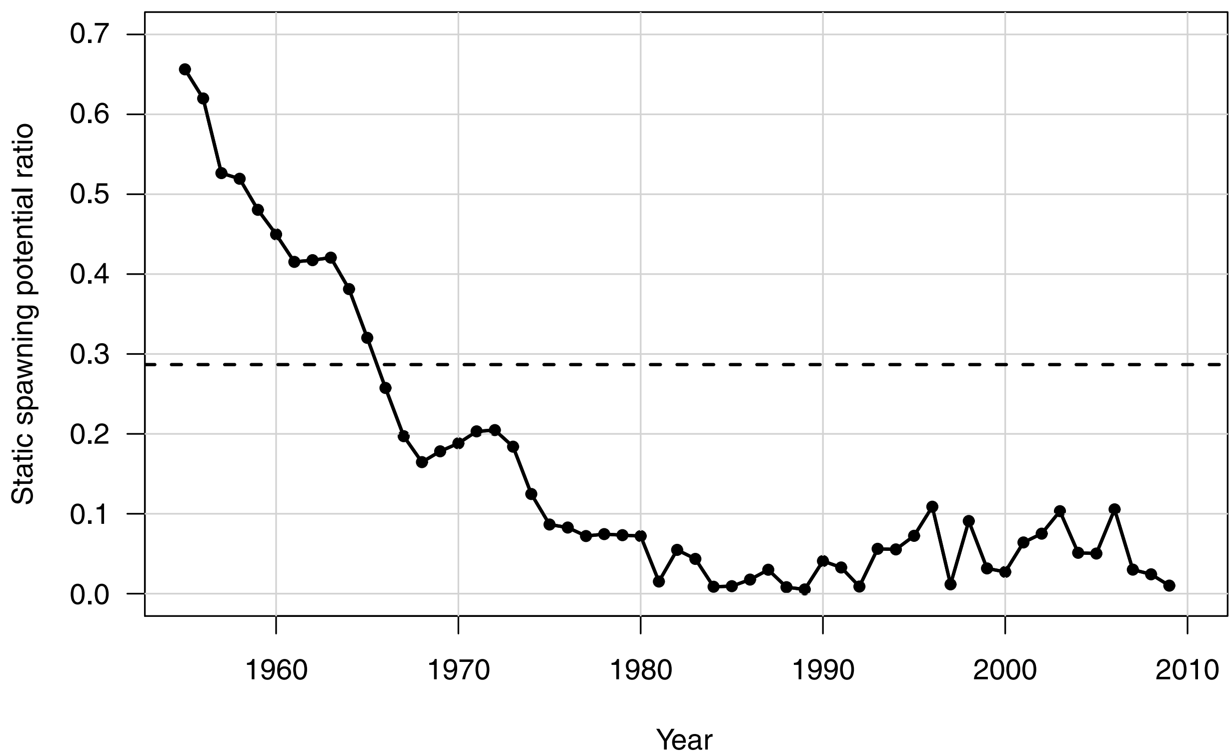


Figure 3.40. Top panel: yield per recruit. Bottom panel: spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the y% levels provide $F_{y\%}$. Both curves are based on average selectivity from the end of the assessment period.

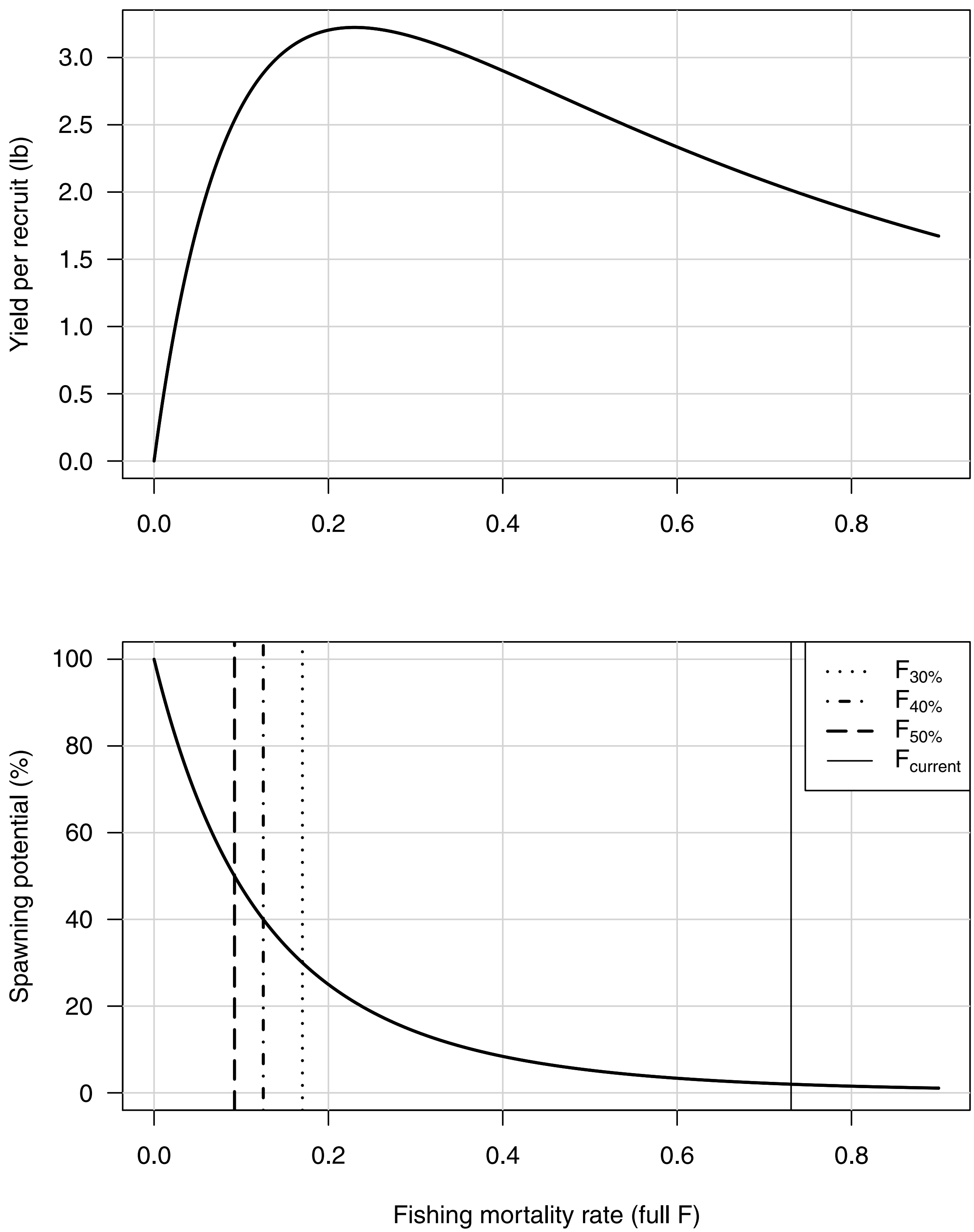


Figure 3.41. Top panel: equilibrium landings. The peak occurs where fishing rate is $F_{MSY} = 0.178$ *and equilibrium landings are* MSY = 1842 *(1000 lb). Bottom panel: equilibrium spawning biomass. Both curves are based on average selectivity from the end of the assessment period.*

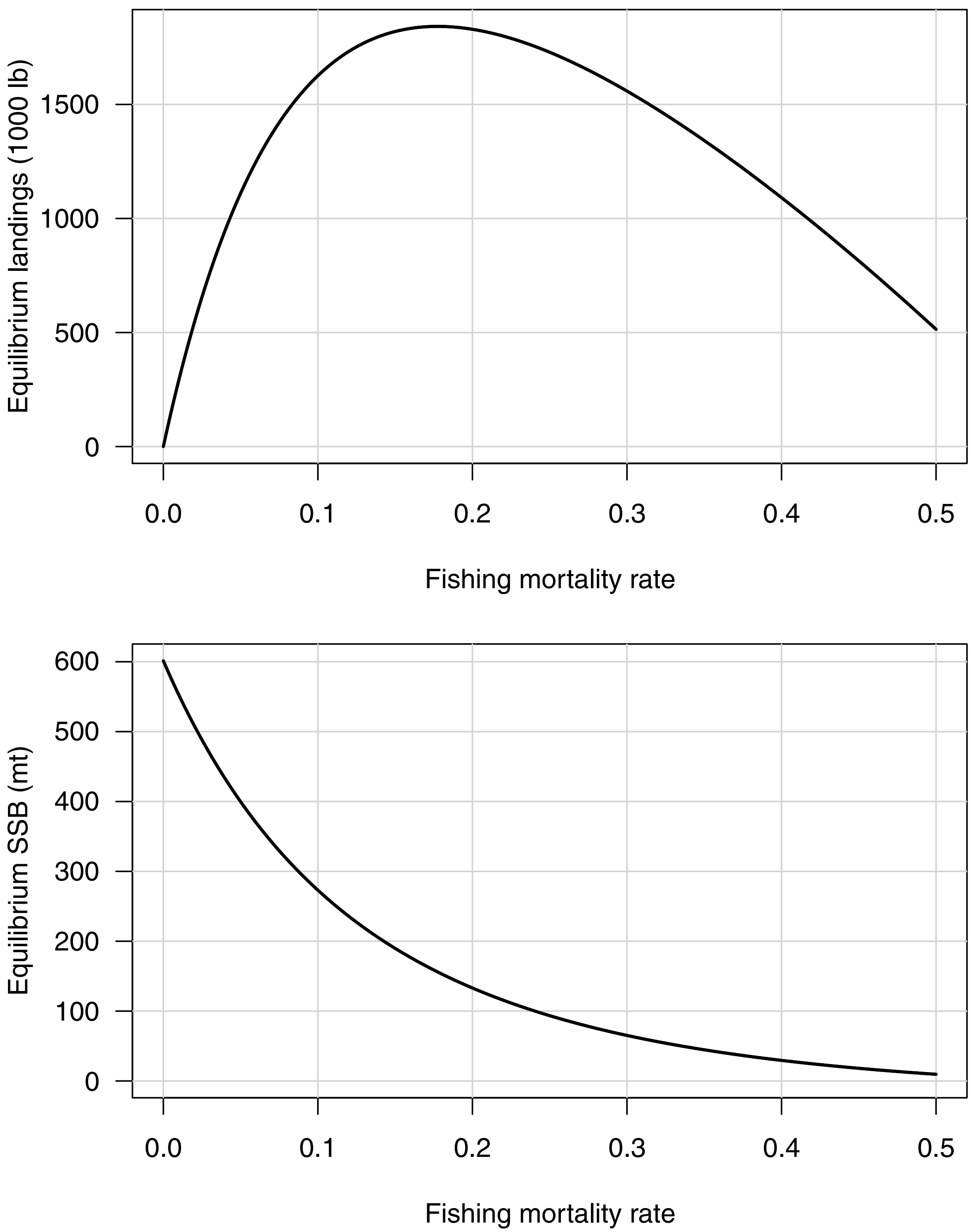


Figure 3.42. Top panel: equilibrium landings as a function of equilibrium biomass, which itself is a function of fishing mortality rate. The peak occurs where equilibrium biomass is B_{MSY} = 13632 *mt and equilibrium landings are* MSY = 1842 *(1000 lb). Bottom panel: equilibrium discard mortality as a function of equilibrium biomass.*

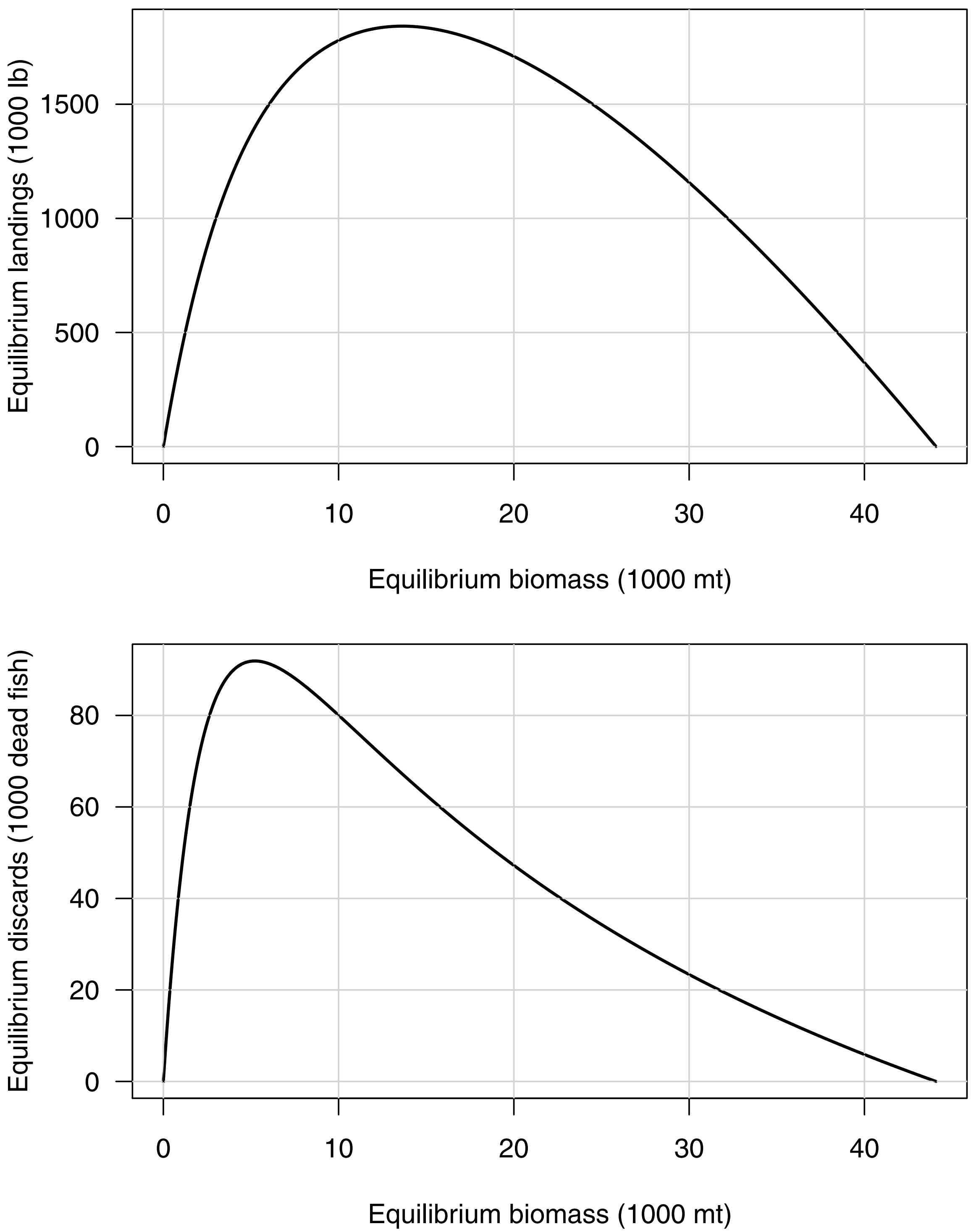


Figure 3.43. Probability densities of MSY*-related benchmarks from MCB analysis of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.*

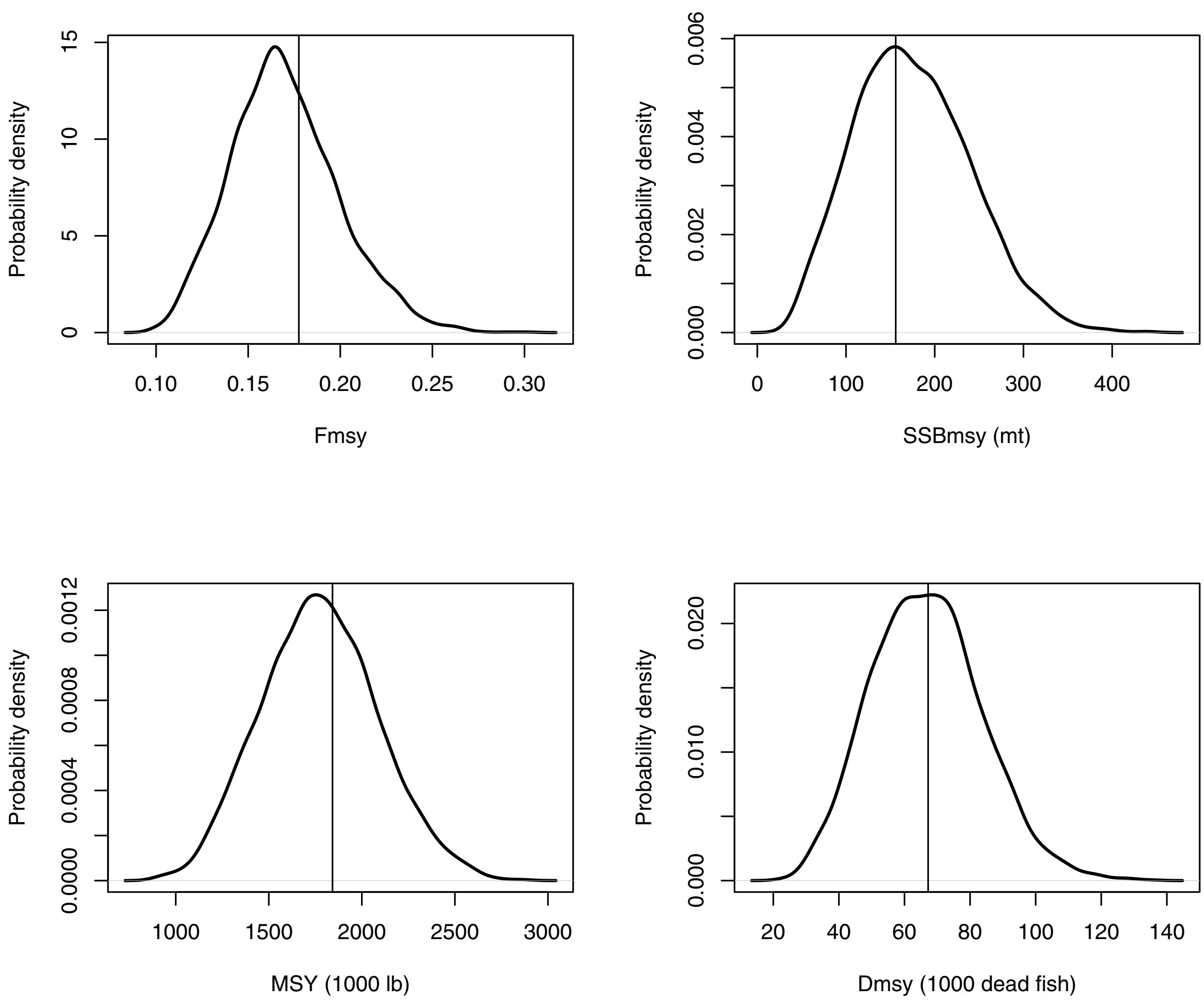


Figure 3.44. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; gray error bands indicate 5^{th} and 95^{th} percentiles of the MCB trials. Top panel: spawning biomass relative to the minimum stock size threshold (MSST). Bottom panel: F relative to F_{MSY}.

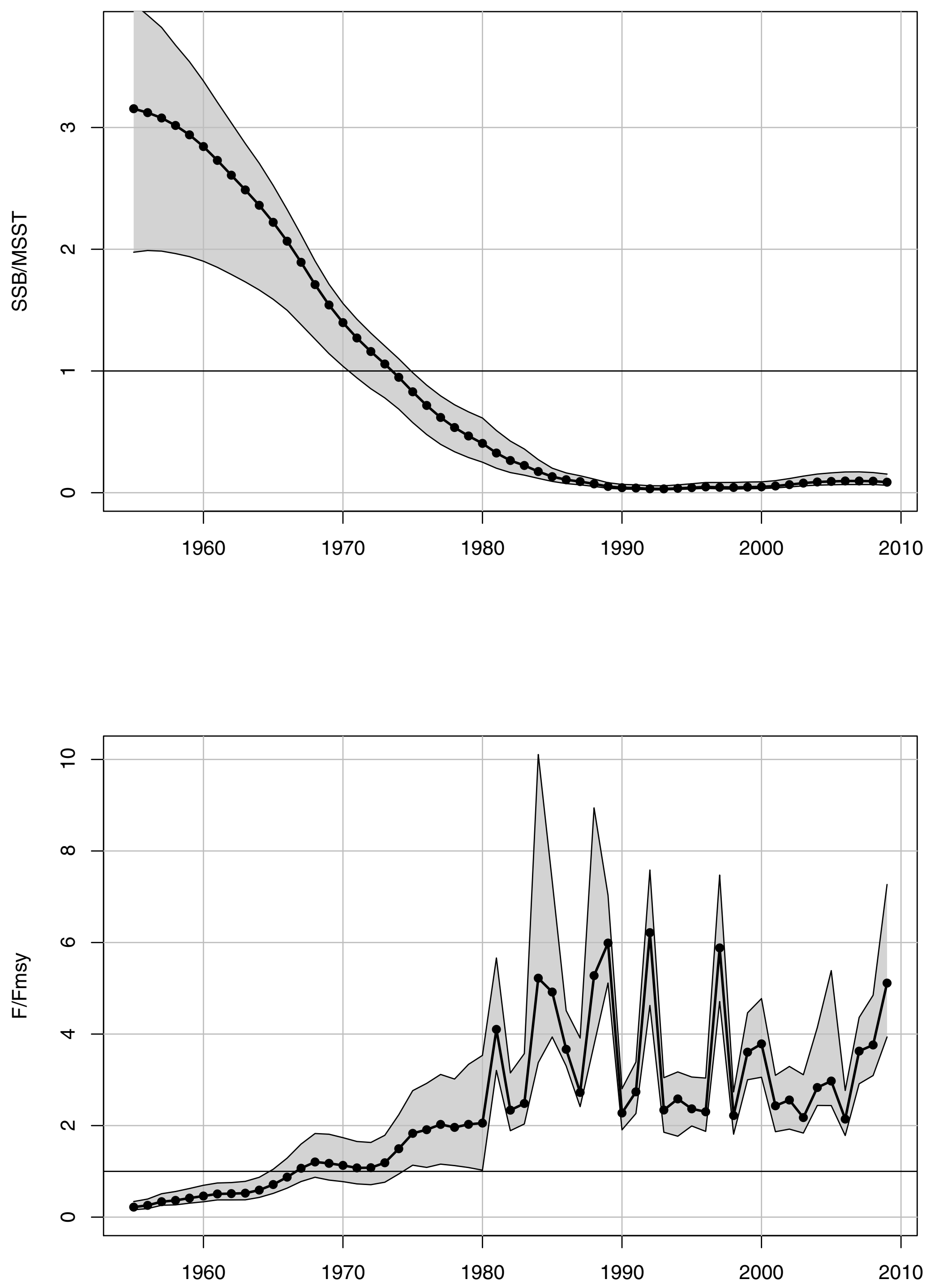
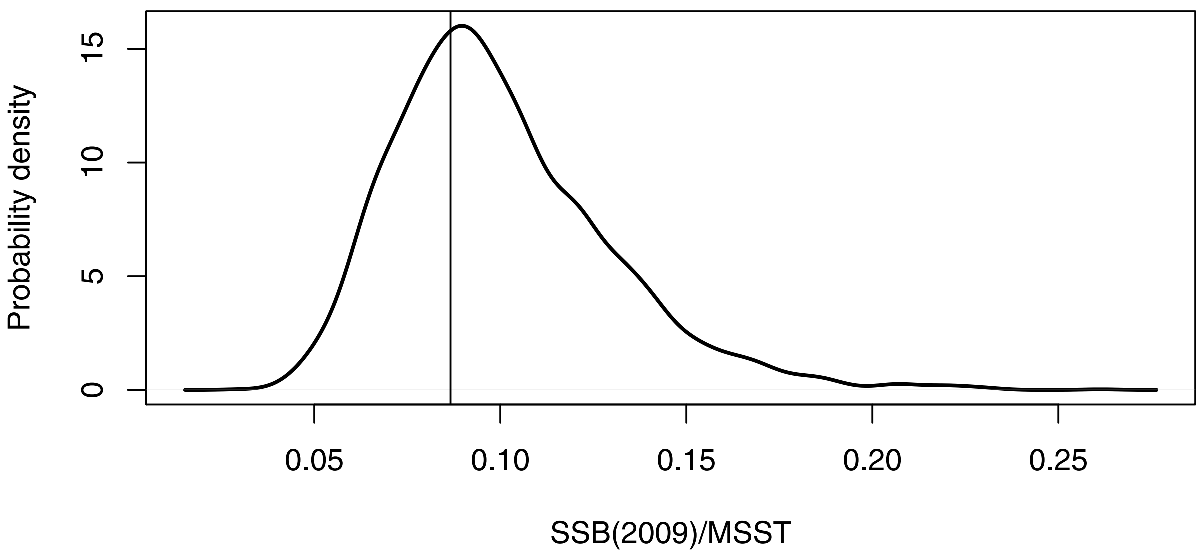


Figure 3.45. Probability densities of terminal status estimates from MCB analysis of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.



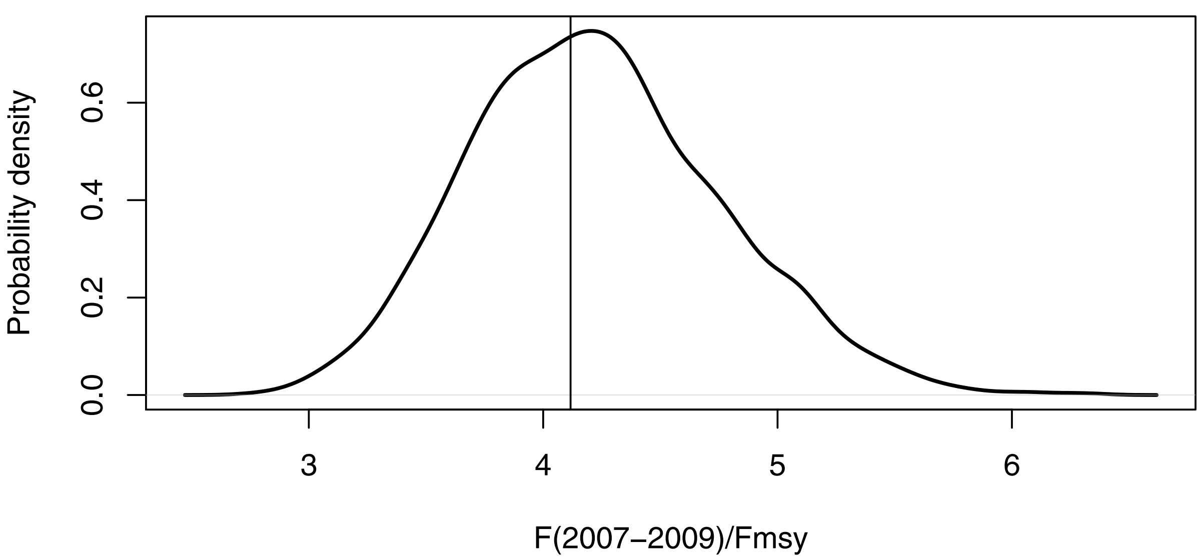


Figure 3.46. Phase plot of terminal status estimates from MCB analysis of the Beaufort Assessment Model. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by 5^{th} *and* 95^{th} *percentiles.*

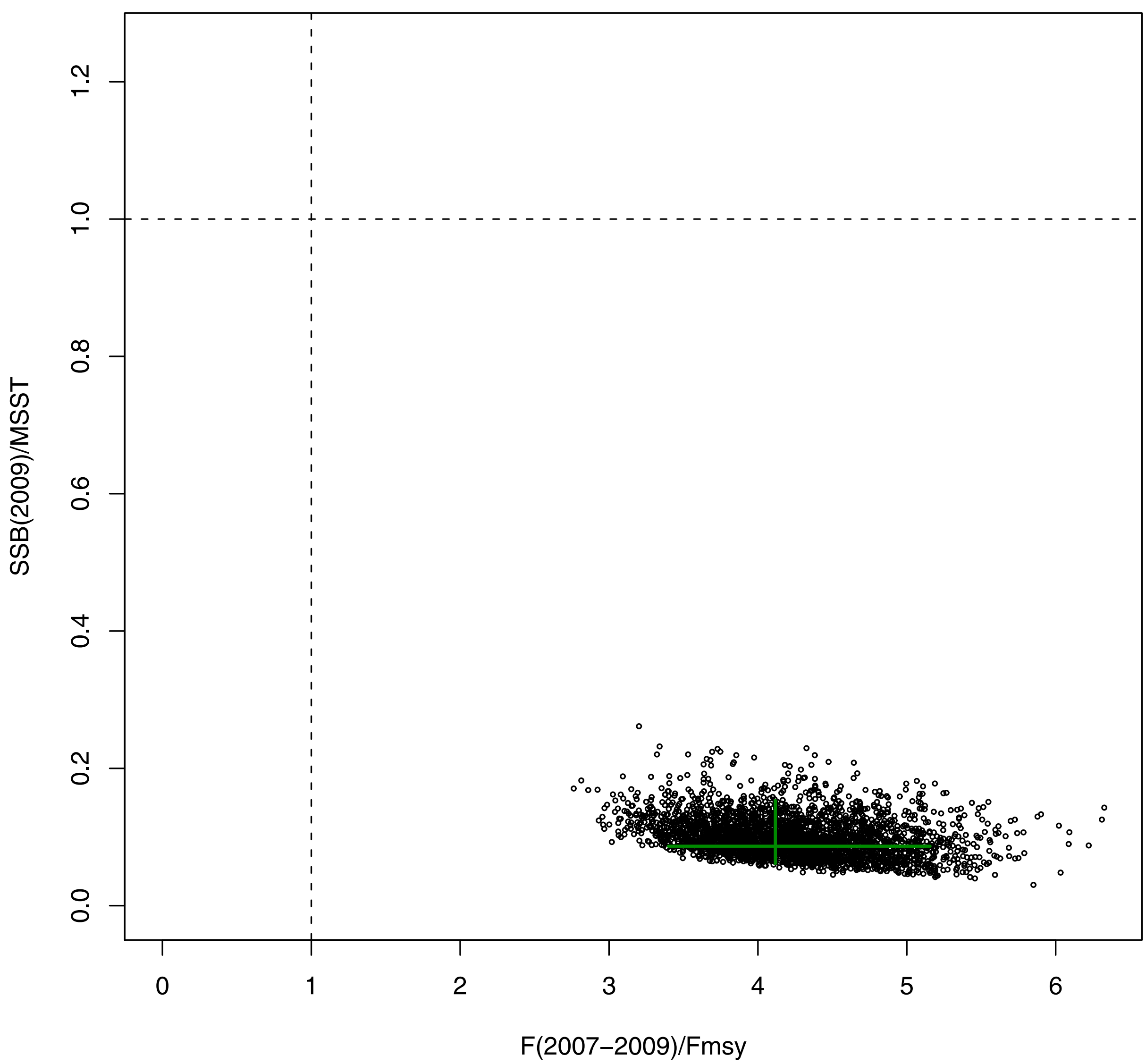


Figure 3.47. Age structure relative to the equilibrium expected at MSY.

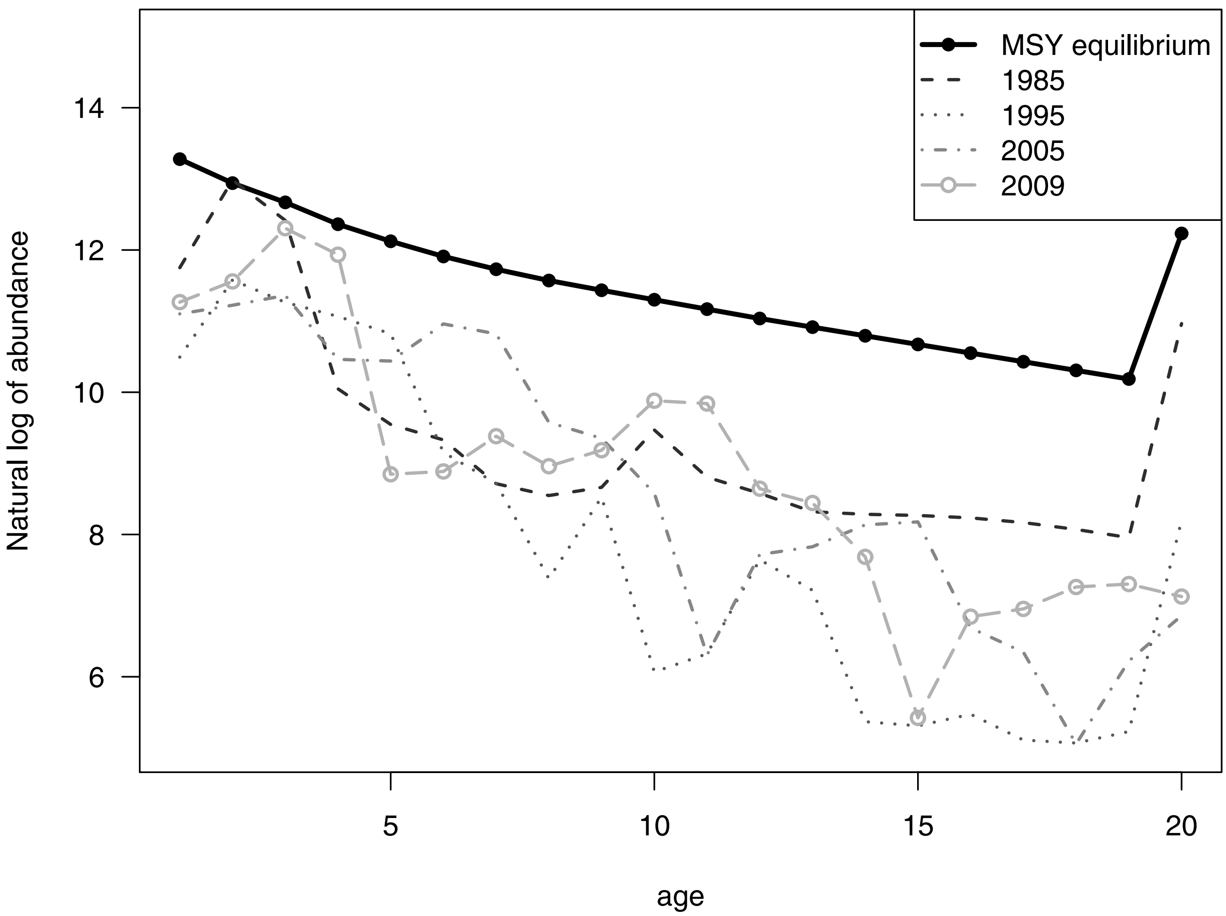


Figure 3.48. Sensitivity to changes in natural mortality (sensitivity runs S1–S3). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* MSST*. Imperceptible lines overlap results of the base run.*

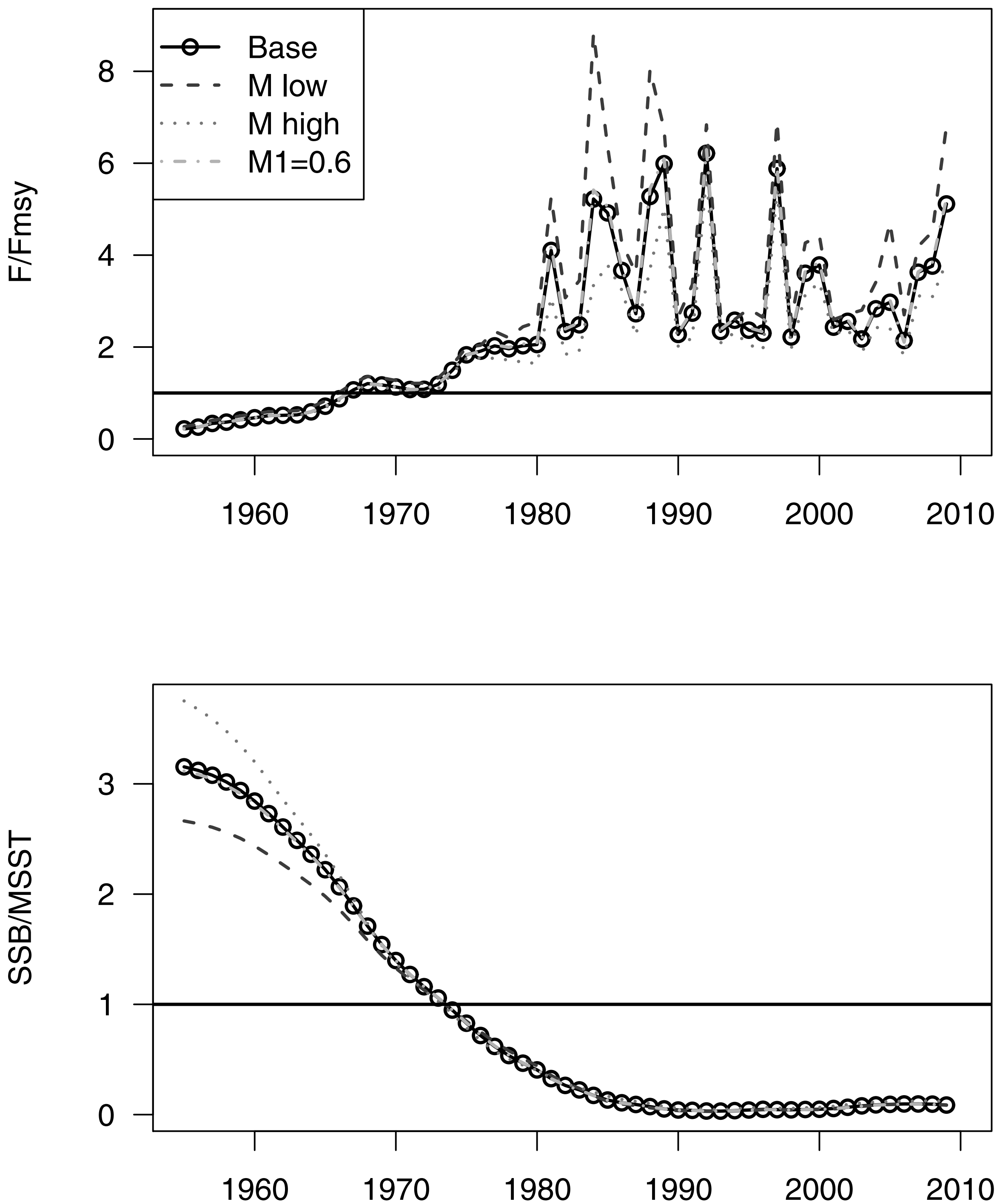
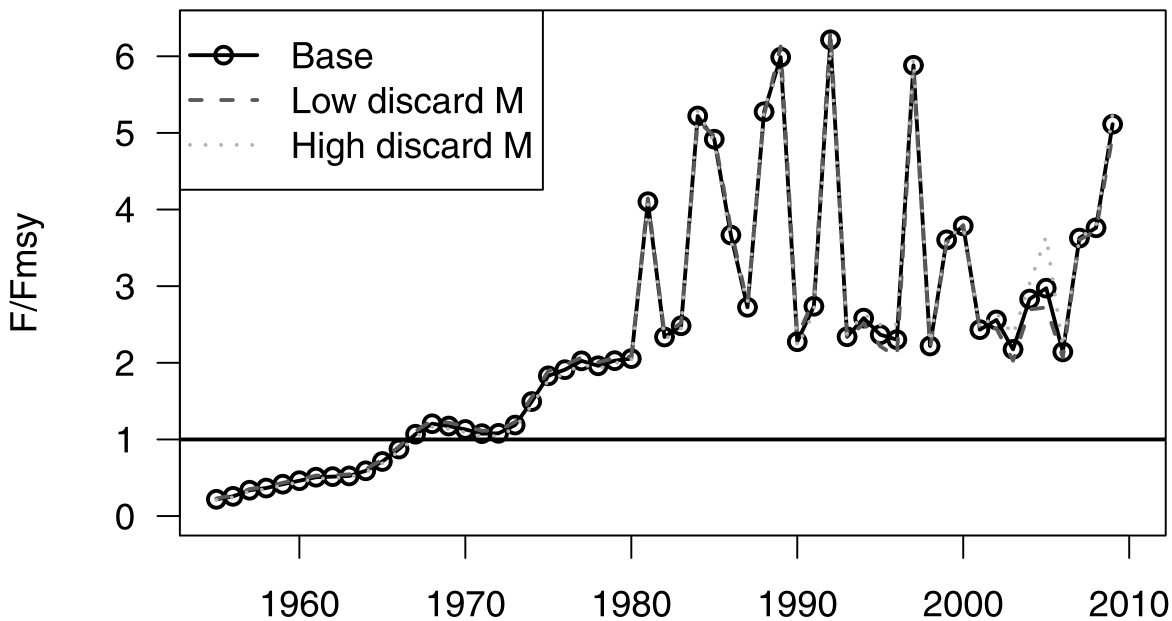


Figure 3.49. Sensitivity to discard mortality rates (sensitivity runs S4 and S5). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* MSST. *Imperceptible lines overlap results of the base run.*



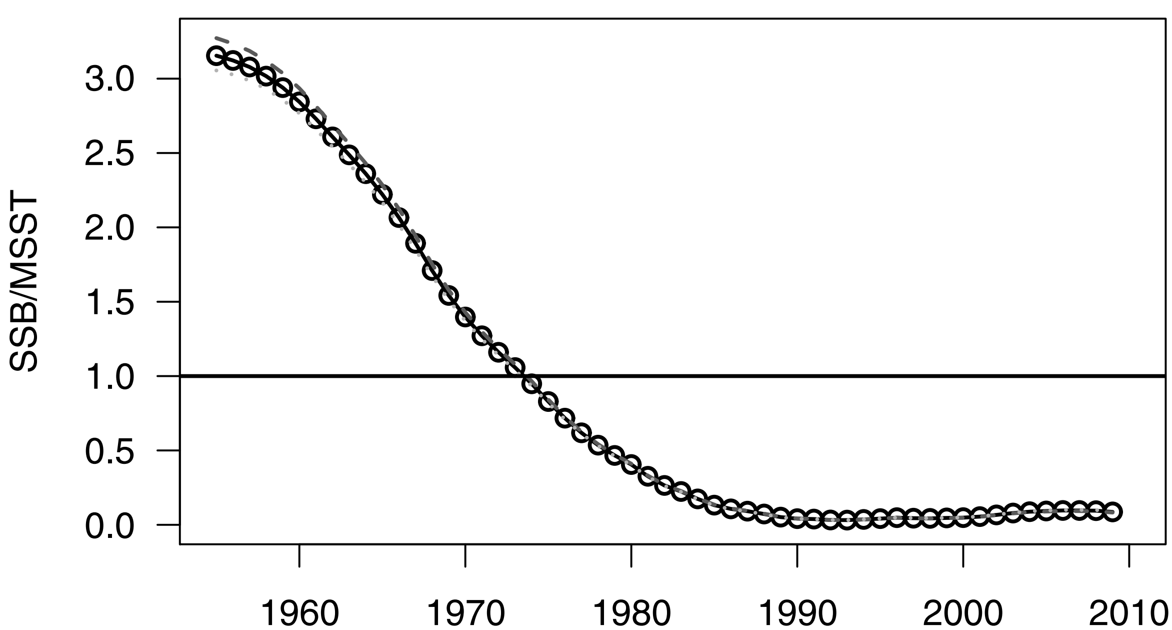


Figure 3.50. Sensitivity to spawner-recruit parameters (sensitivity runs S6–S10). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* MSST*. Imperceptible lines overlap results of the base run.*

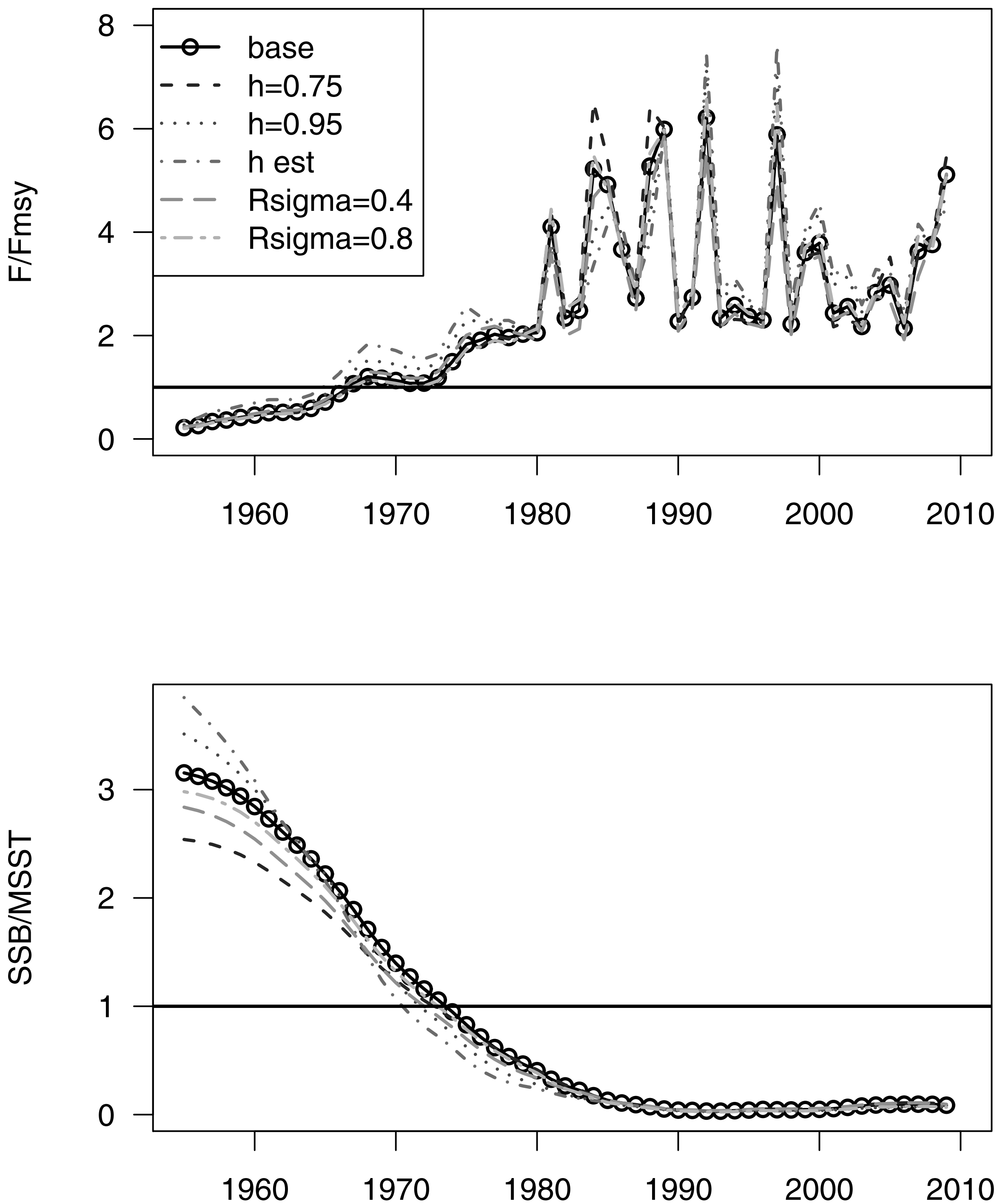


Figure 3.51. Sensitivity to catchability assumptions (sensitivity runs S11–S13). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB to MSST. Imperceptible lines overlap results of the base run.

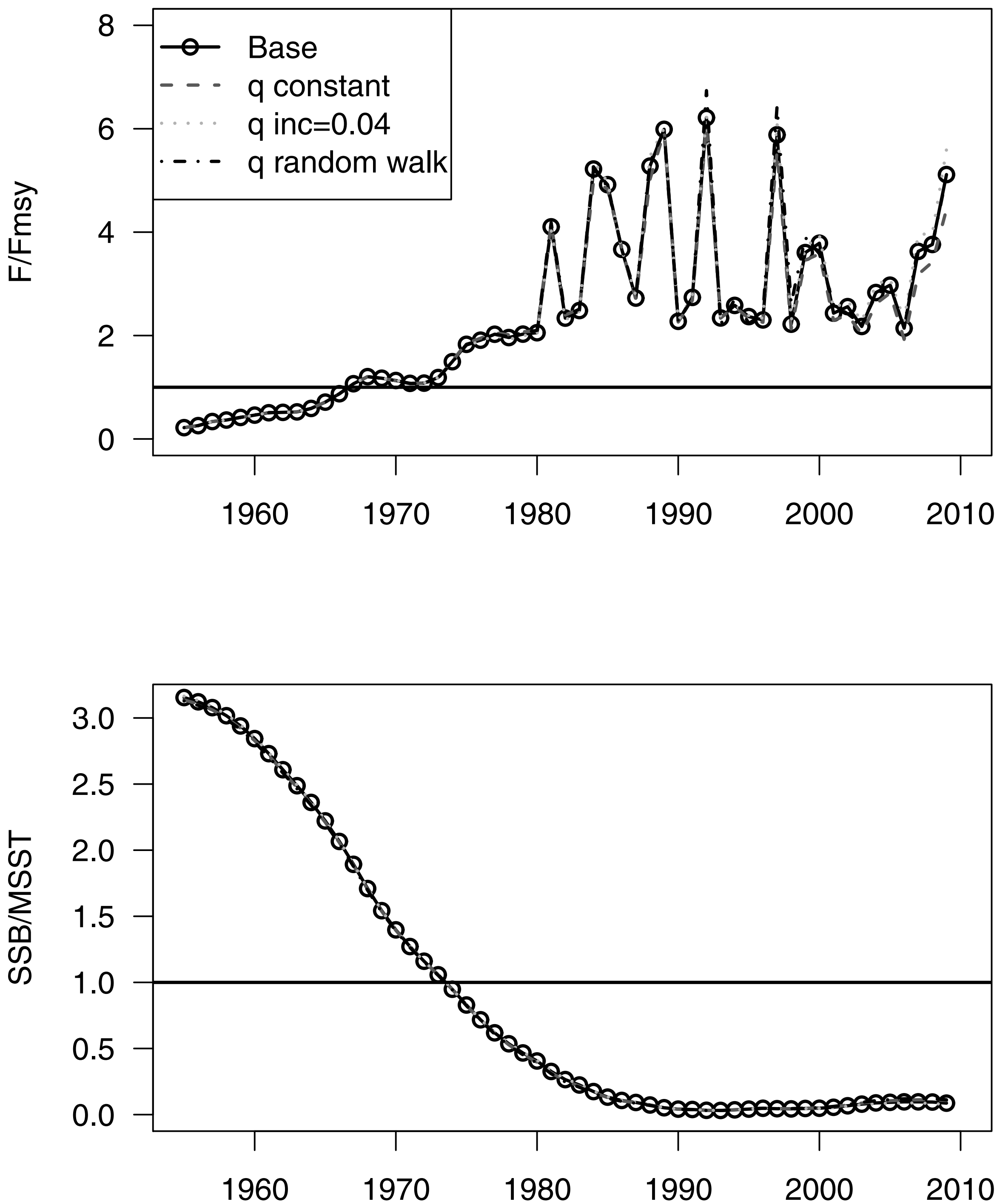
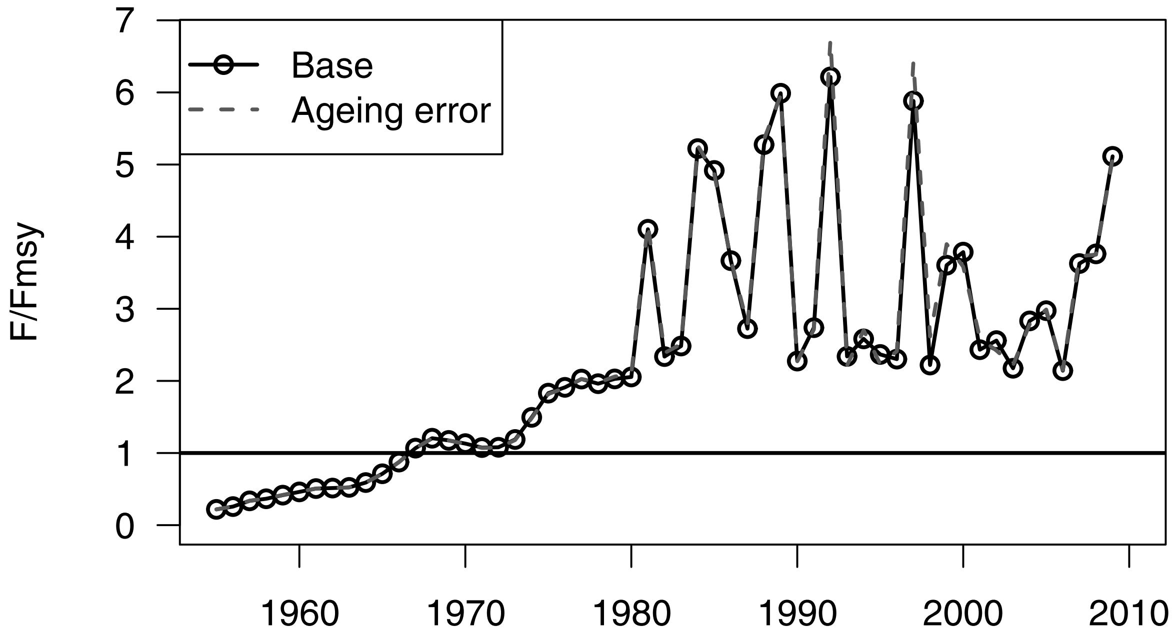


Figure 3.52. Sensitivity to ageing error (sensitivity run S14). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* MSST*. Imperceptible lines overlap results of the base run.*



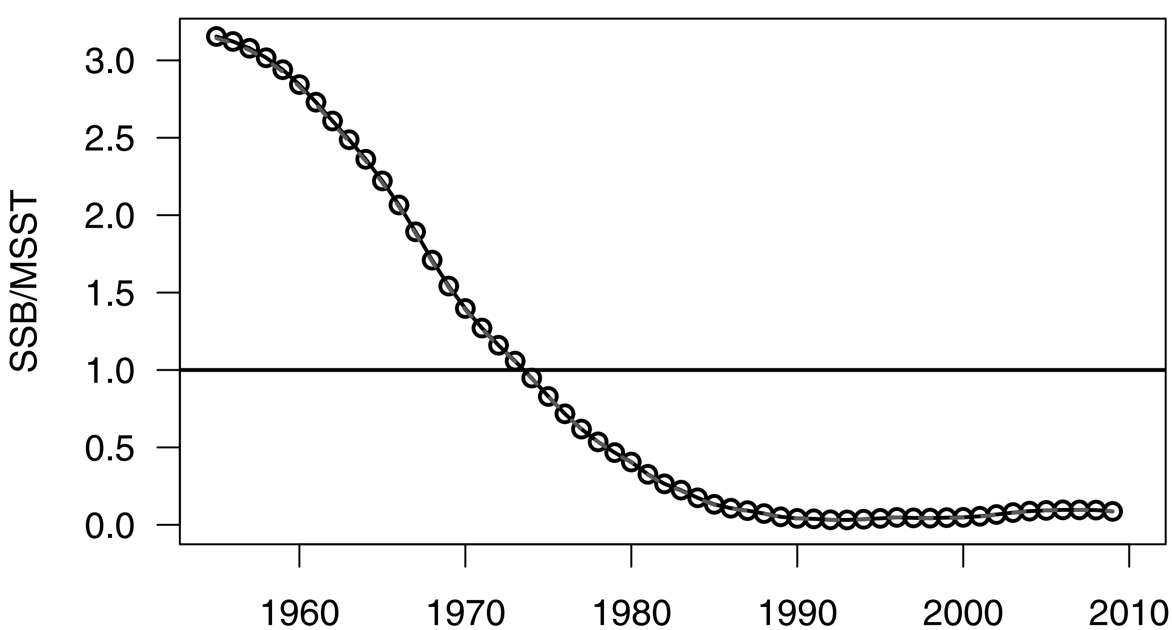


Figure 3.53. Comparison to continuity assumptions (sensitivity runs S15 and S16). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB to MSST. Imperceptible lines overlap results of the base run.

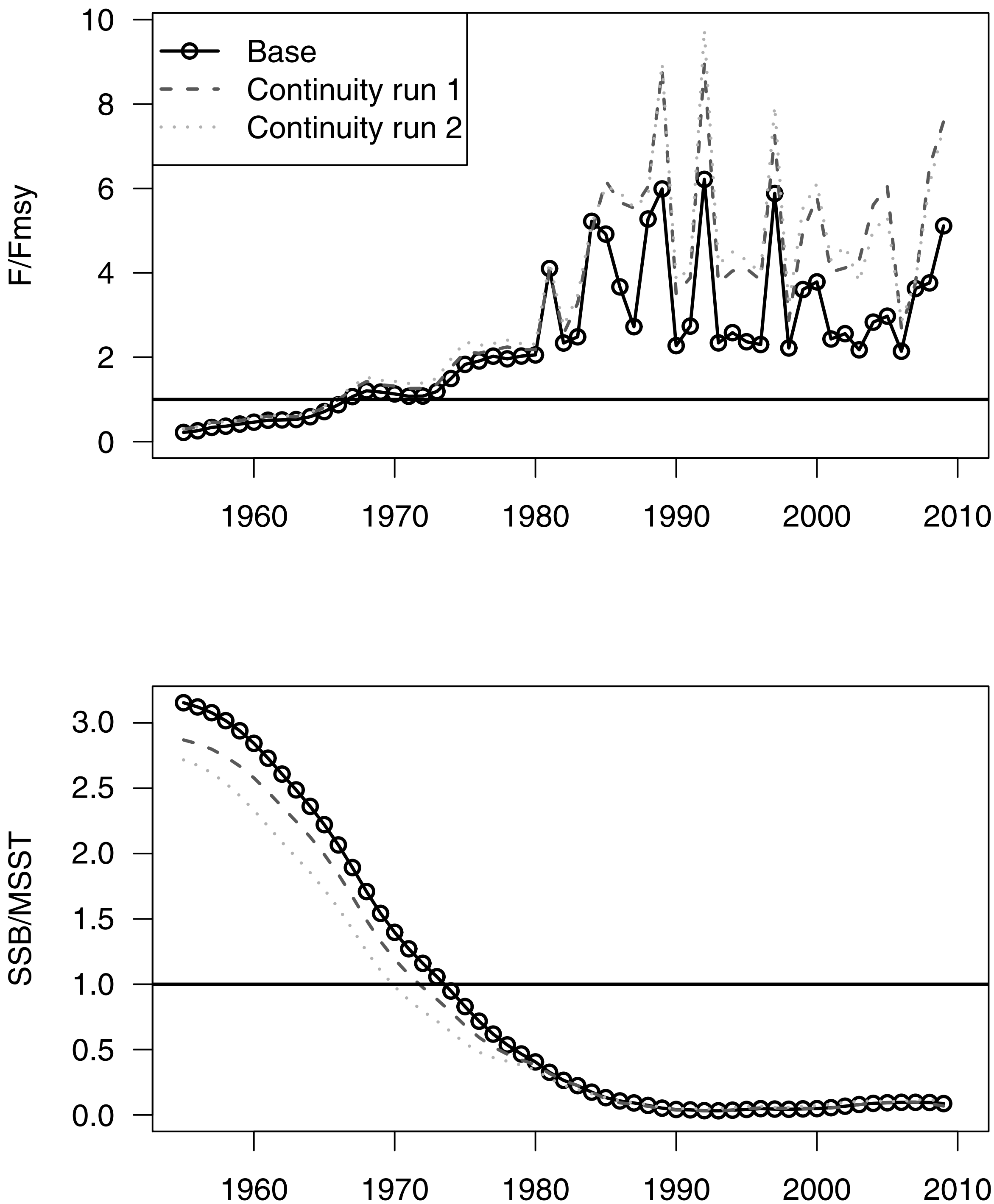


Figure 3.54. Sensitivity to starting year of the assessment model (sensitivity runs S17 and S18). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* MSST. *Imperceptible lines overlap results of the base run.*

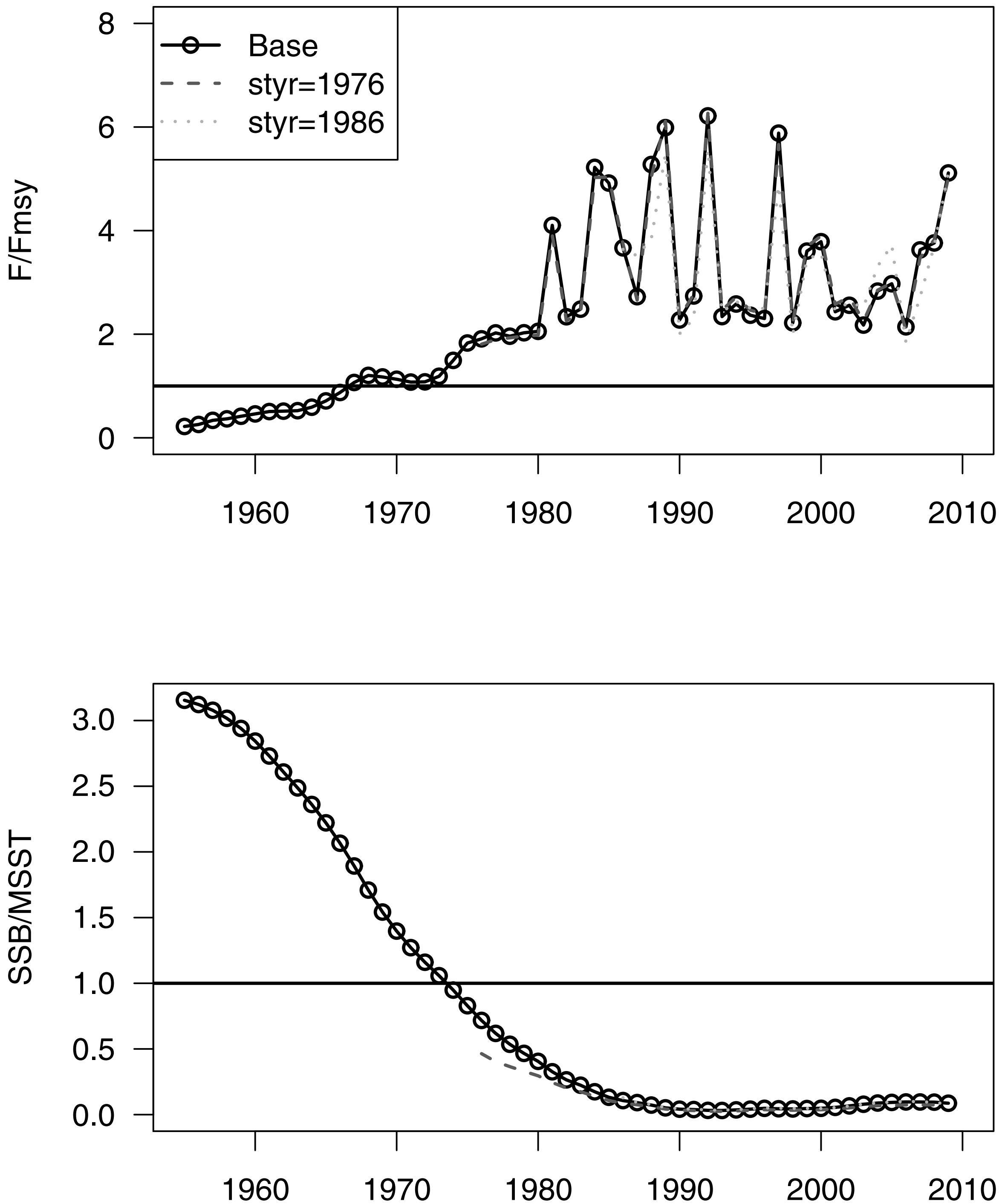


Figure 3.55. Sensitivity to the initialization fishing mortality rate (sensitivity runs S19 and S20). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB to MSST. Imperceptible lines overlap results of the base run.

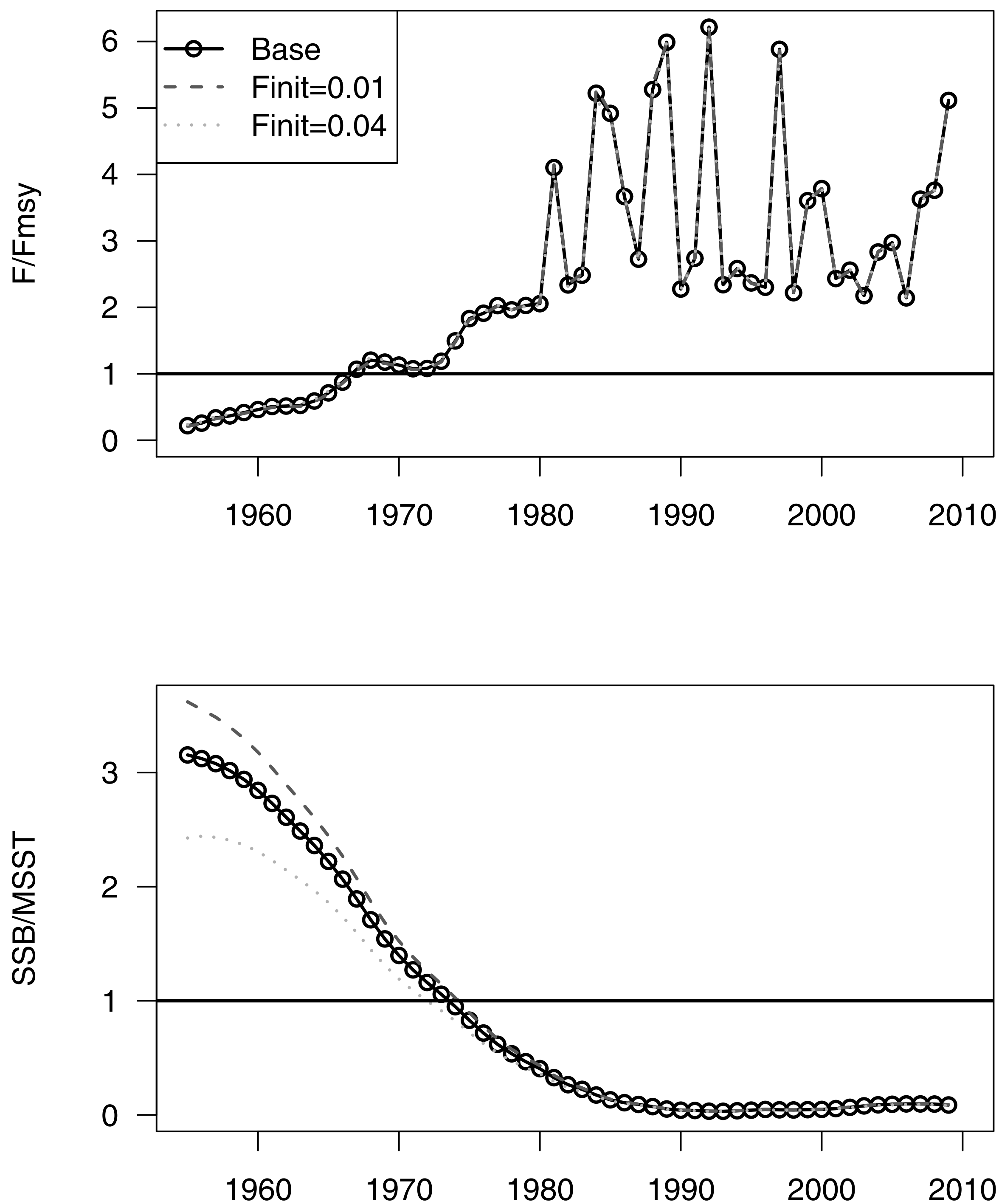


Figure 3.56. Sensitivity to landings streams (sensitivity runs S21–S24). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* MSST*. Imperceptible lines overlap results of the base run.*

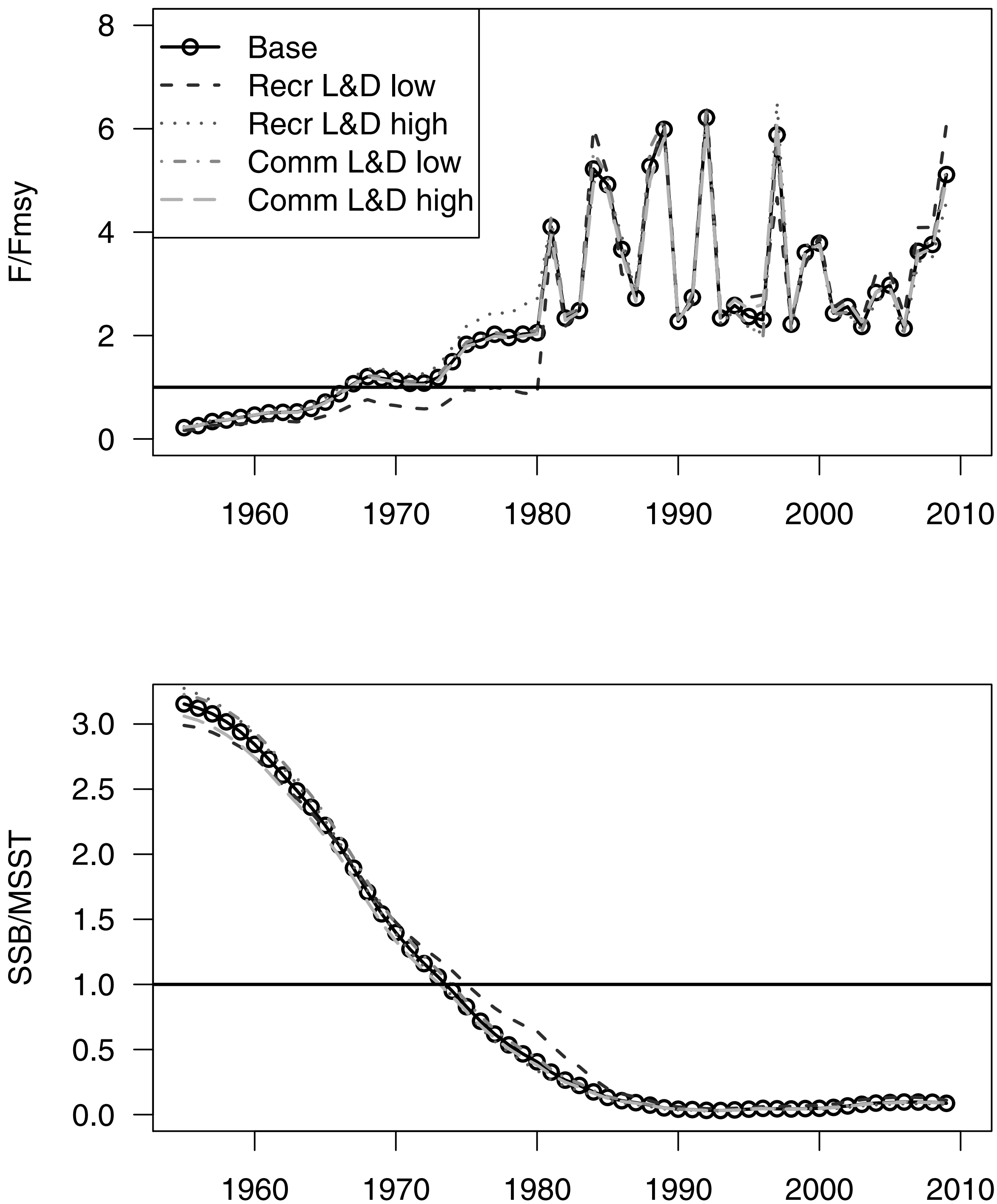


Figure 3.57. Sensitivity to component weights of data sources (sensitivity runs S25–S32). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* MSST. *Imperceptible lines overlap results of the base run.*

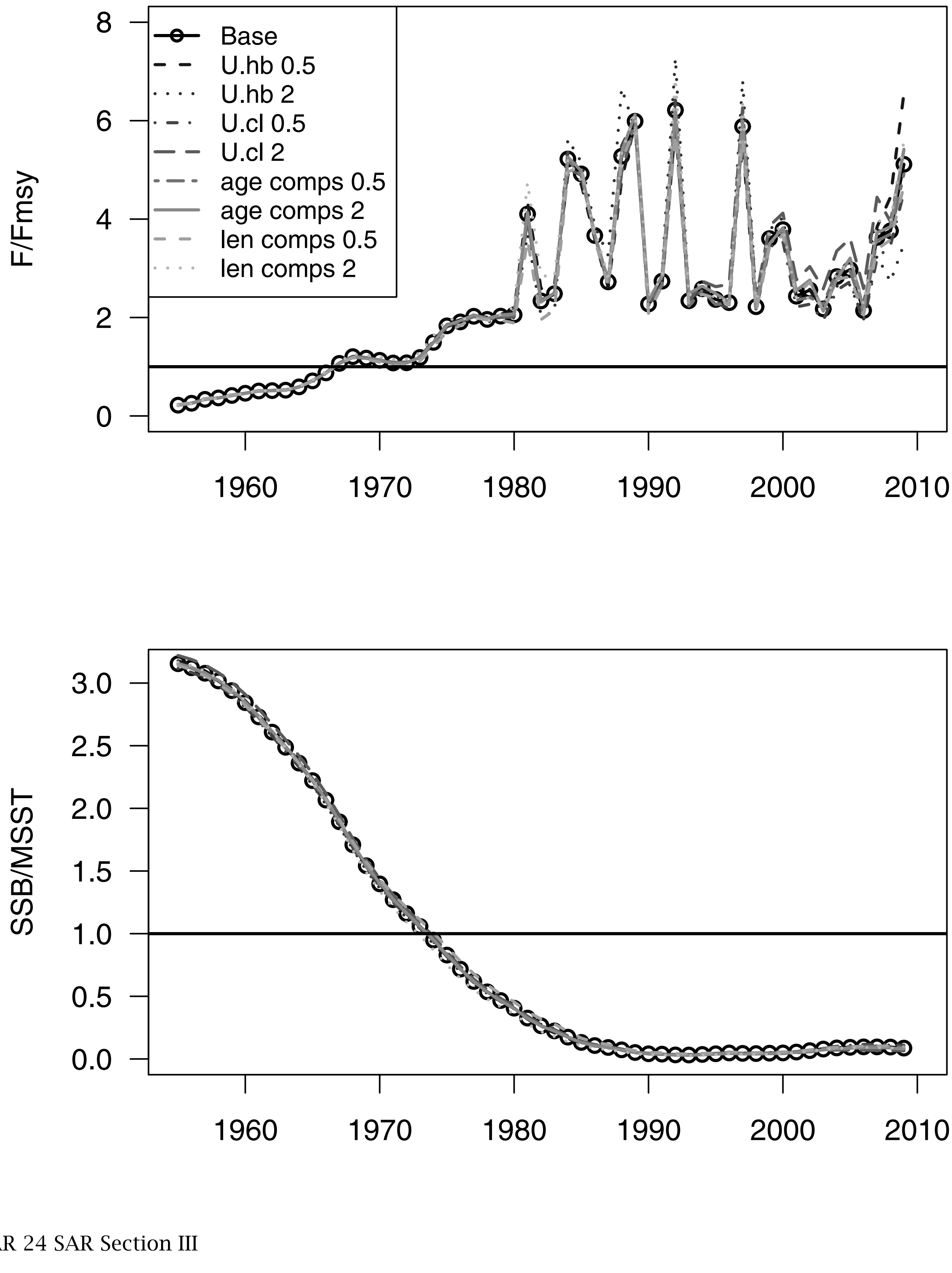
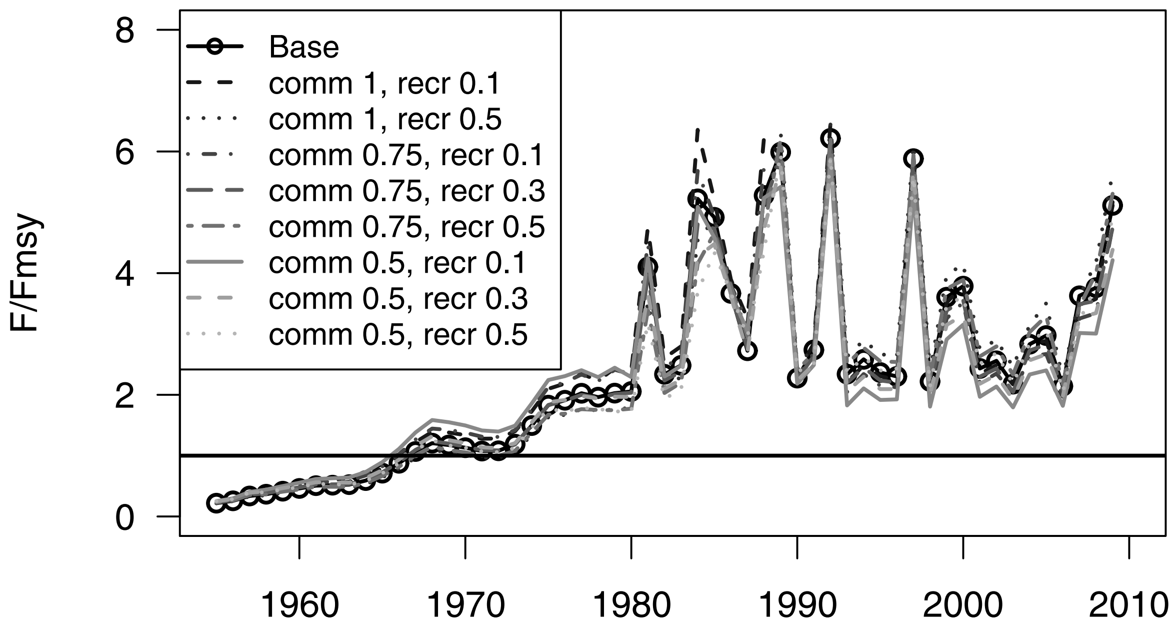


Figure 3.58. Sensitivity to selectivity patterns (sensitivity runs S33–S40). Top panel: Ratio of F *to* F_{MSY}*. Bottom panel: Ratio of* SSB *to* MSST*. Imperceptible lines overlap results of the base run.*



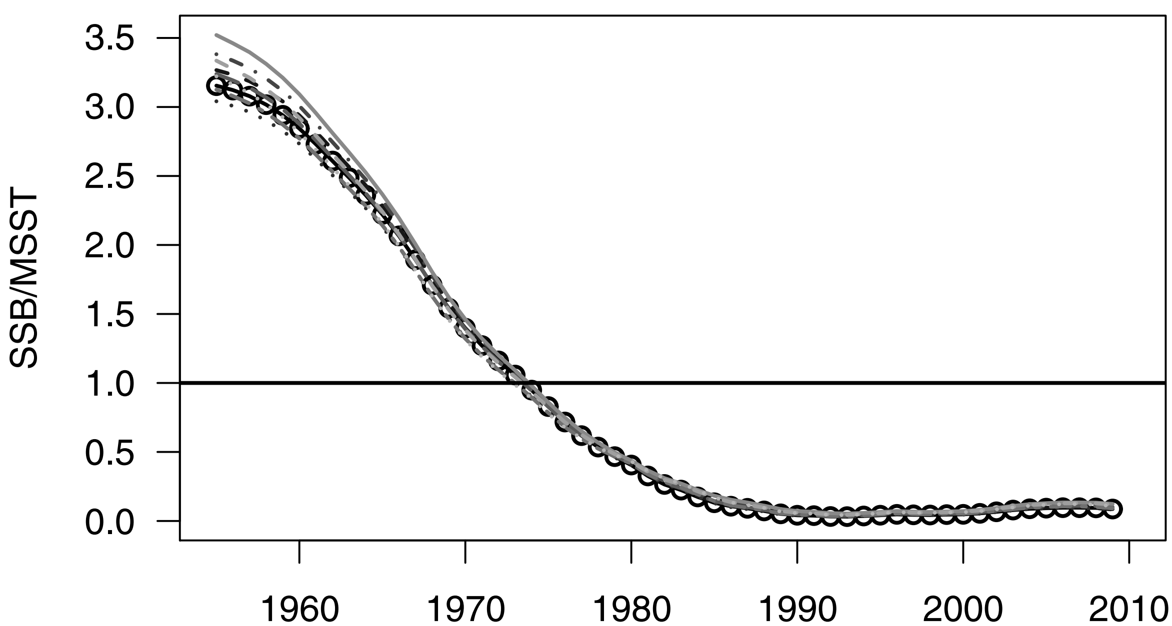


Figure 3.59. Sensitivity to compound extremes (sensitivity runs S41 and S42). Top panel: Ratio of F to F_{MSY}. *Bottom panel: Ratio of* SSB *to* MSST. *Imperceptible lines overlap results of the base run.*

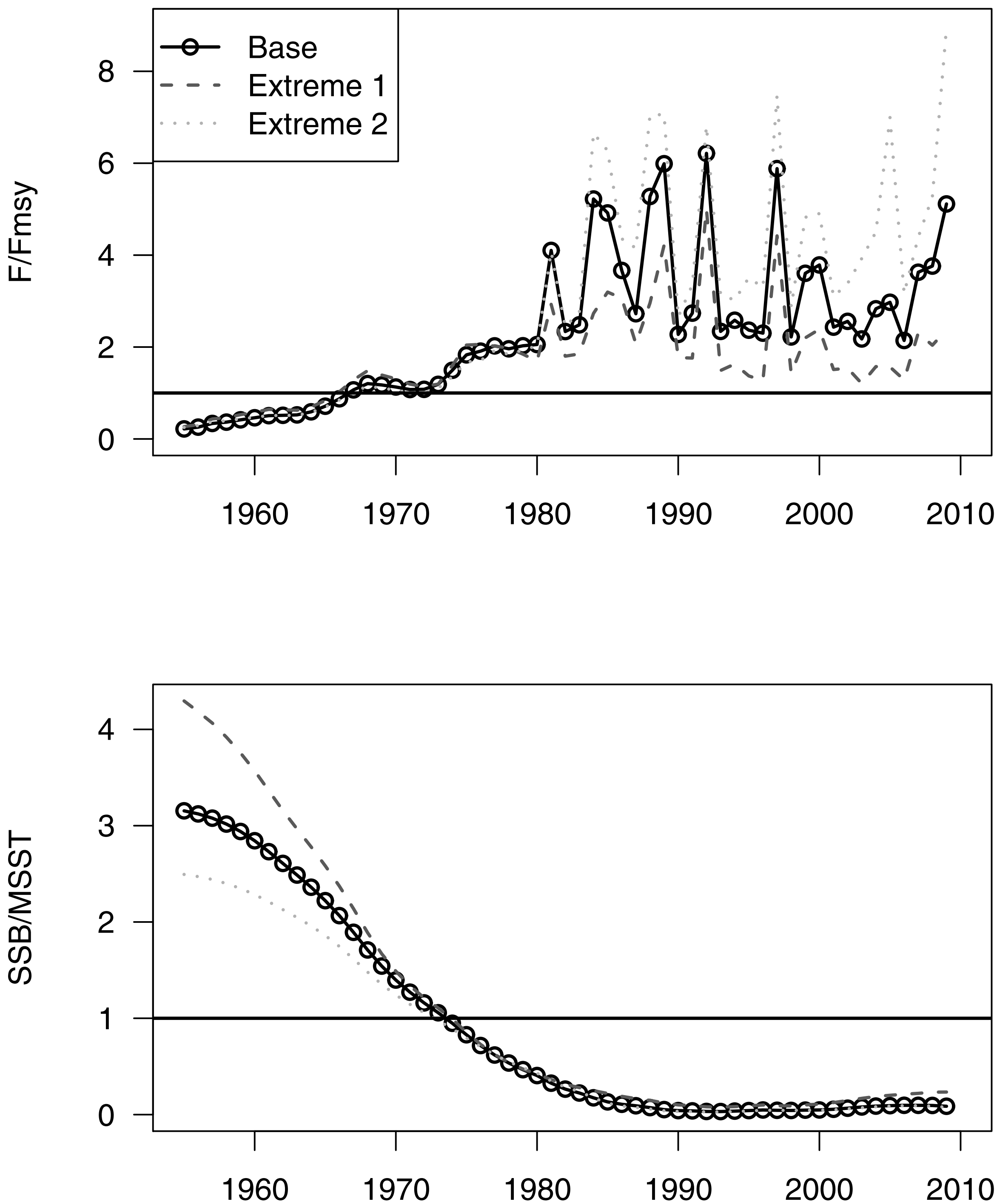


Figure 3.60. Phase plot of terminal status estimates from sensitivity runs of the Beaufort Assessment Model.

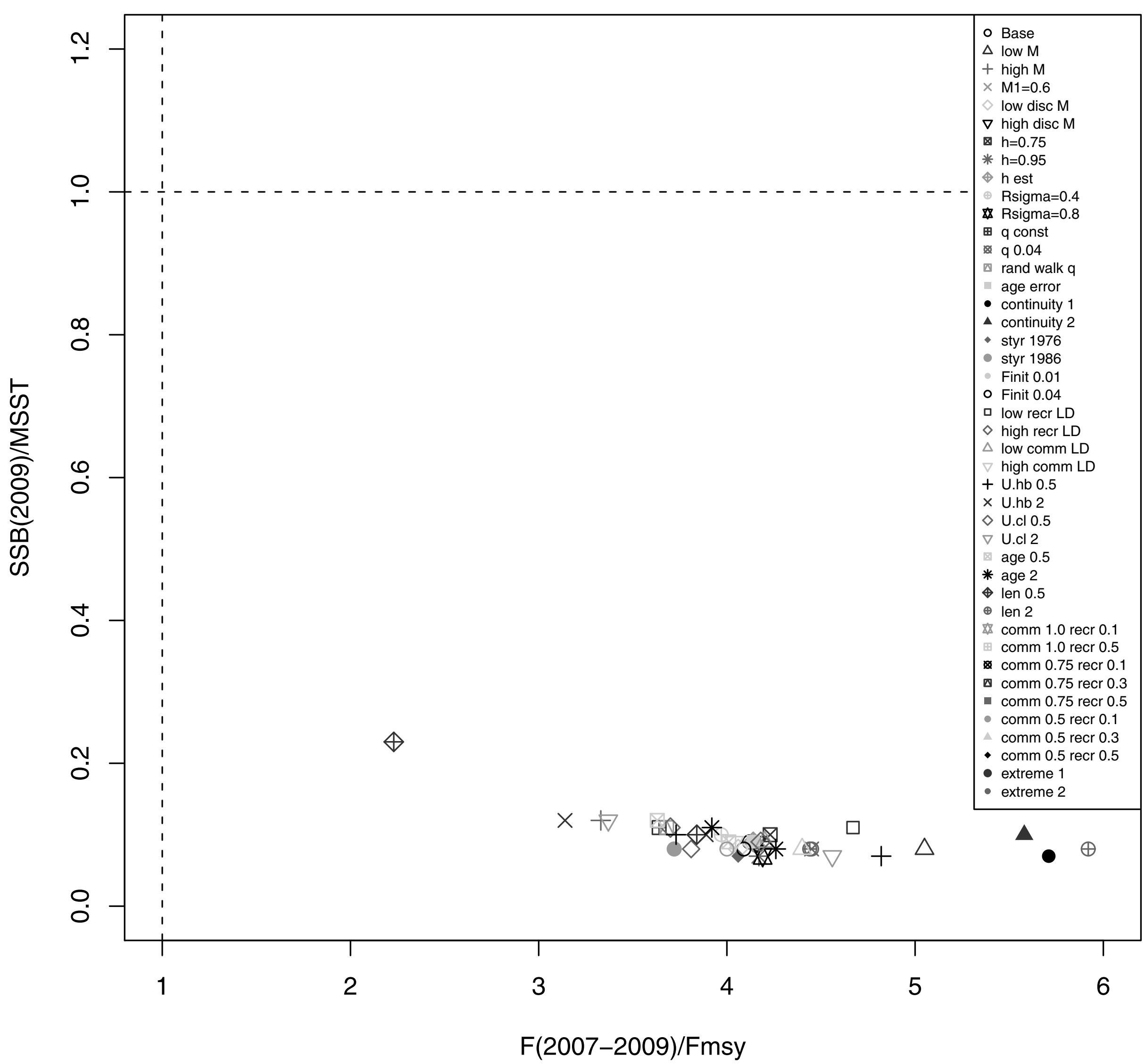


Figure 3.61. Retrospective analyses. Sensitivity to terminal year of data (sensitivity runs S43–S46). Top panel: Fishing mortality rate, where solid circles show geometric mean of terminal three years, as used to compute fishing status. Middle panel: Recruits. Bottom panel: Spawning biomass. Imperceptible lines overlap results of the base run.

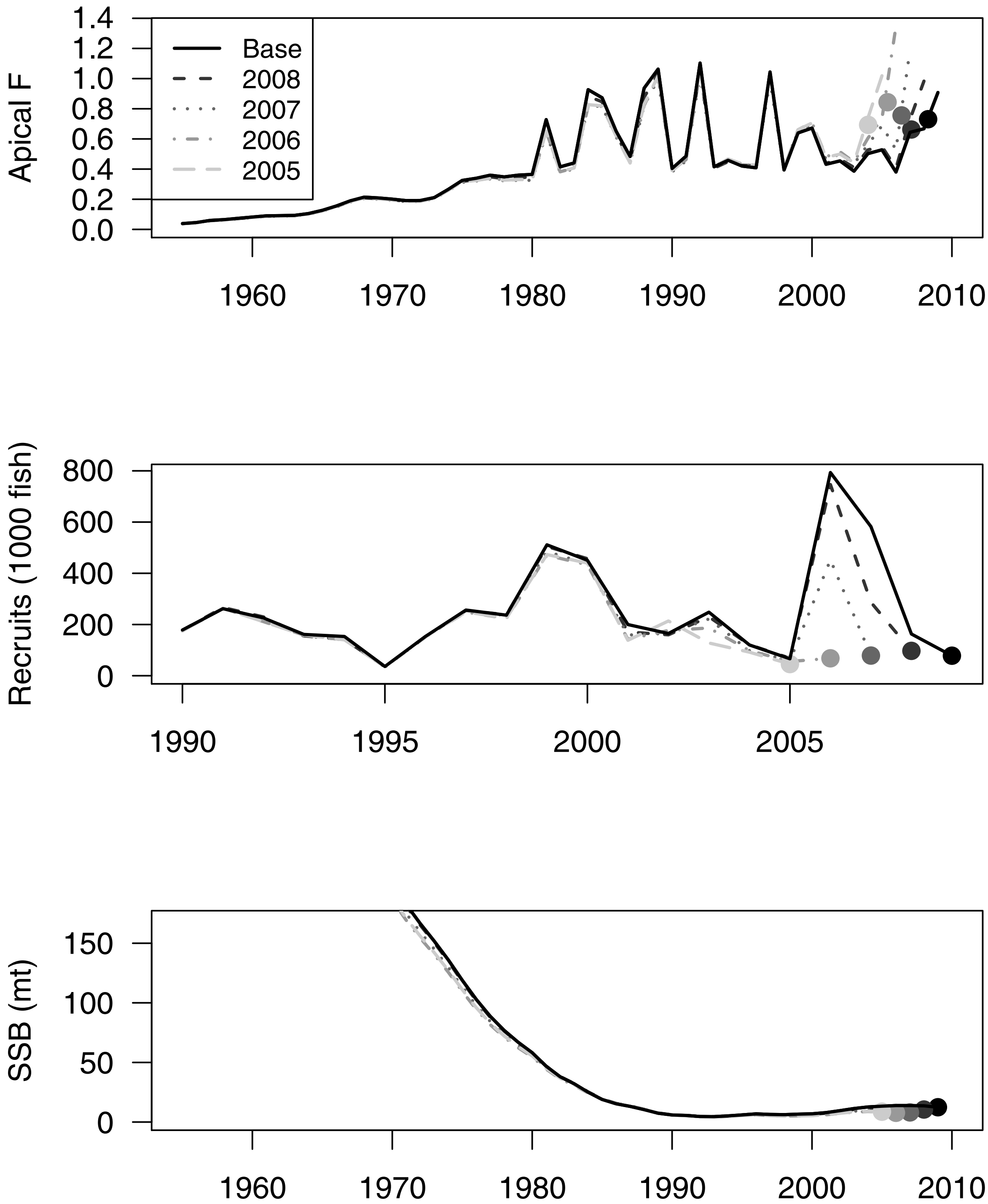


Figure 3.62. Projection results under scenario 1—fishing mortality rate fixed at F = 0. Curve represents the proportion of projection replicates for which SSB(mid-year) has reached at least $SSB_{MSY} = 156$.

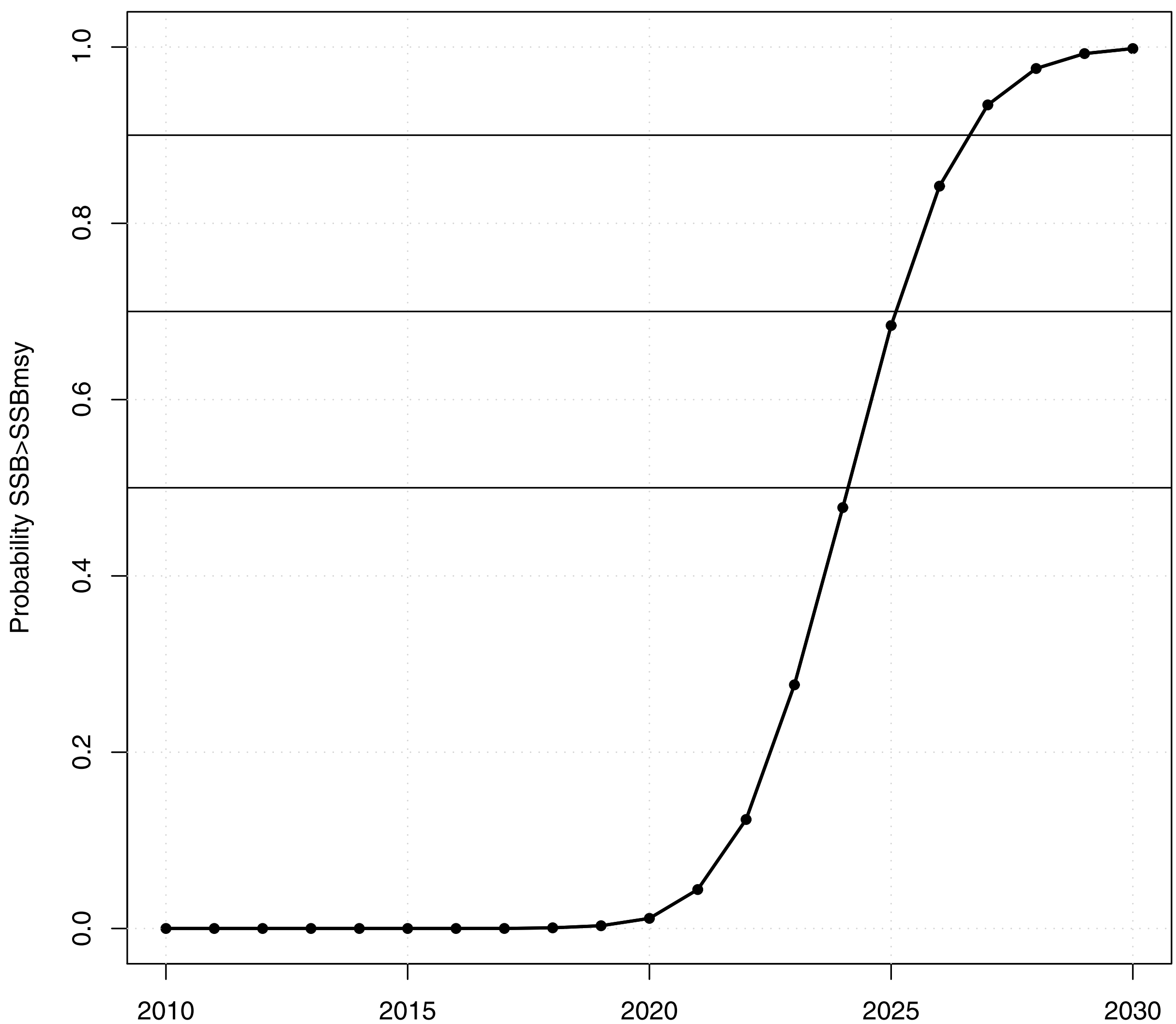


Figure 3.63. Projection results under scenario 2—fishing mortality rate fixed at $F = F_{\text{current}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

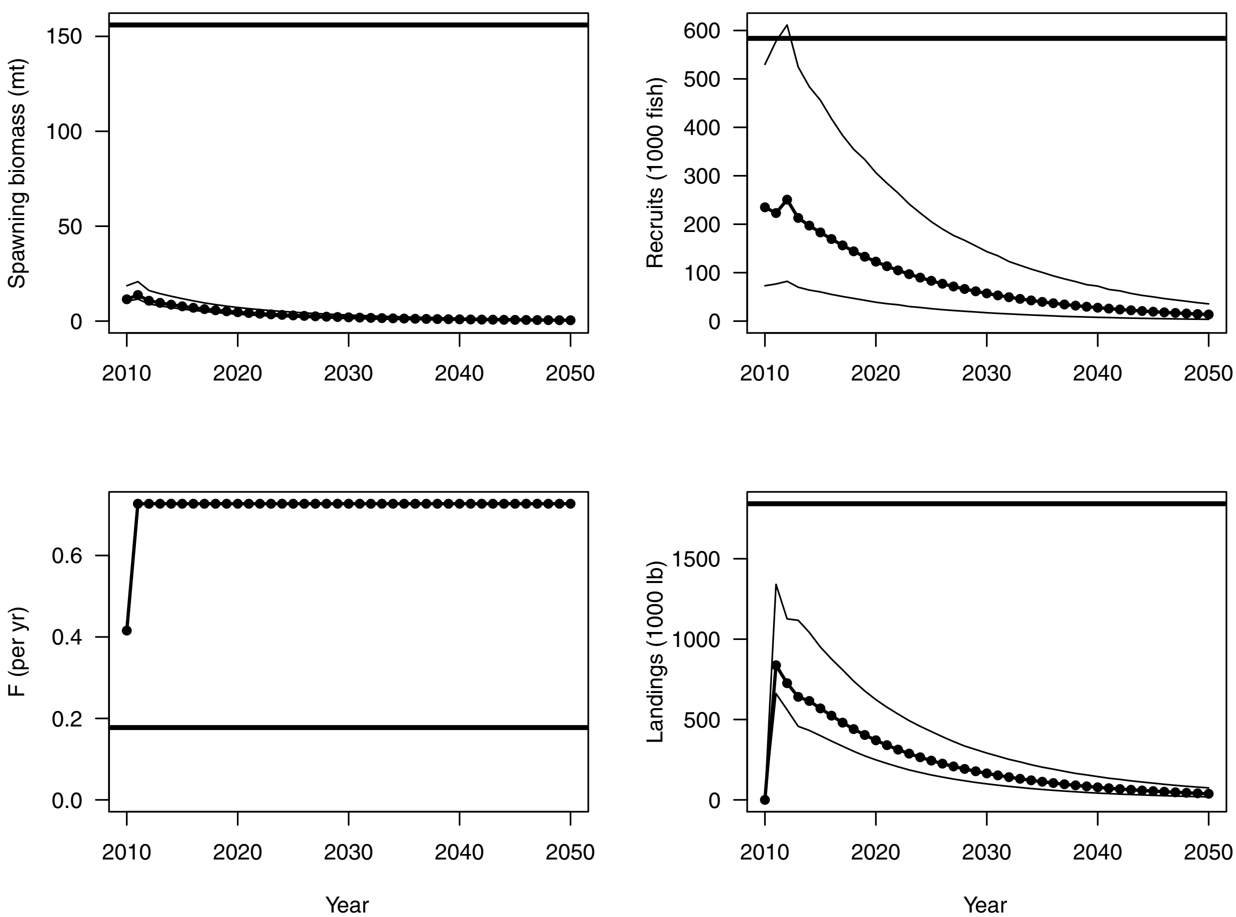


Figure 3.64. Projection results under scenario 3—fishing mortality rate fixed at $F = 65\%F_{\text{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

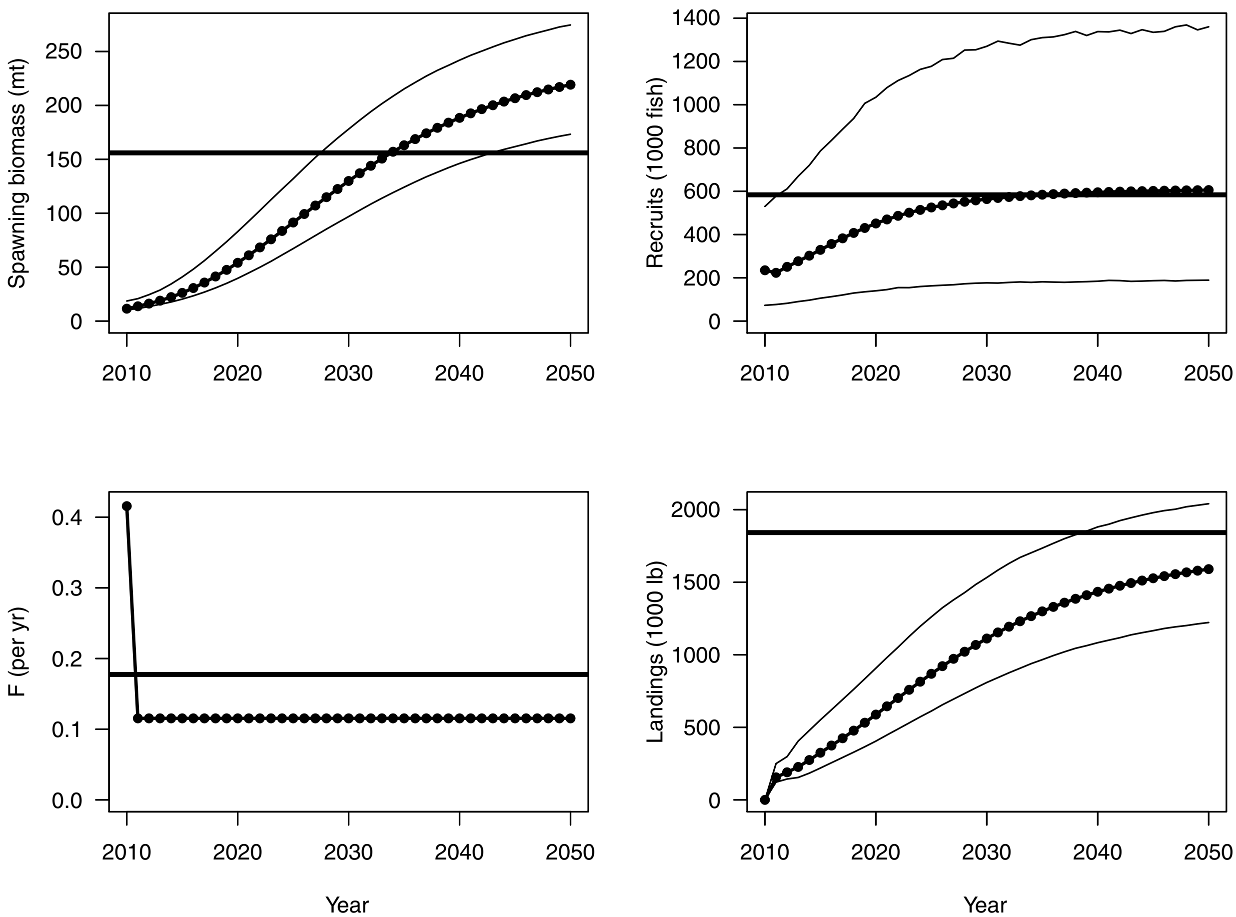


Figure 3.65. Projection results under scenario 4—fishing mortality rate fixed at $F = 75\%F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

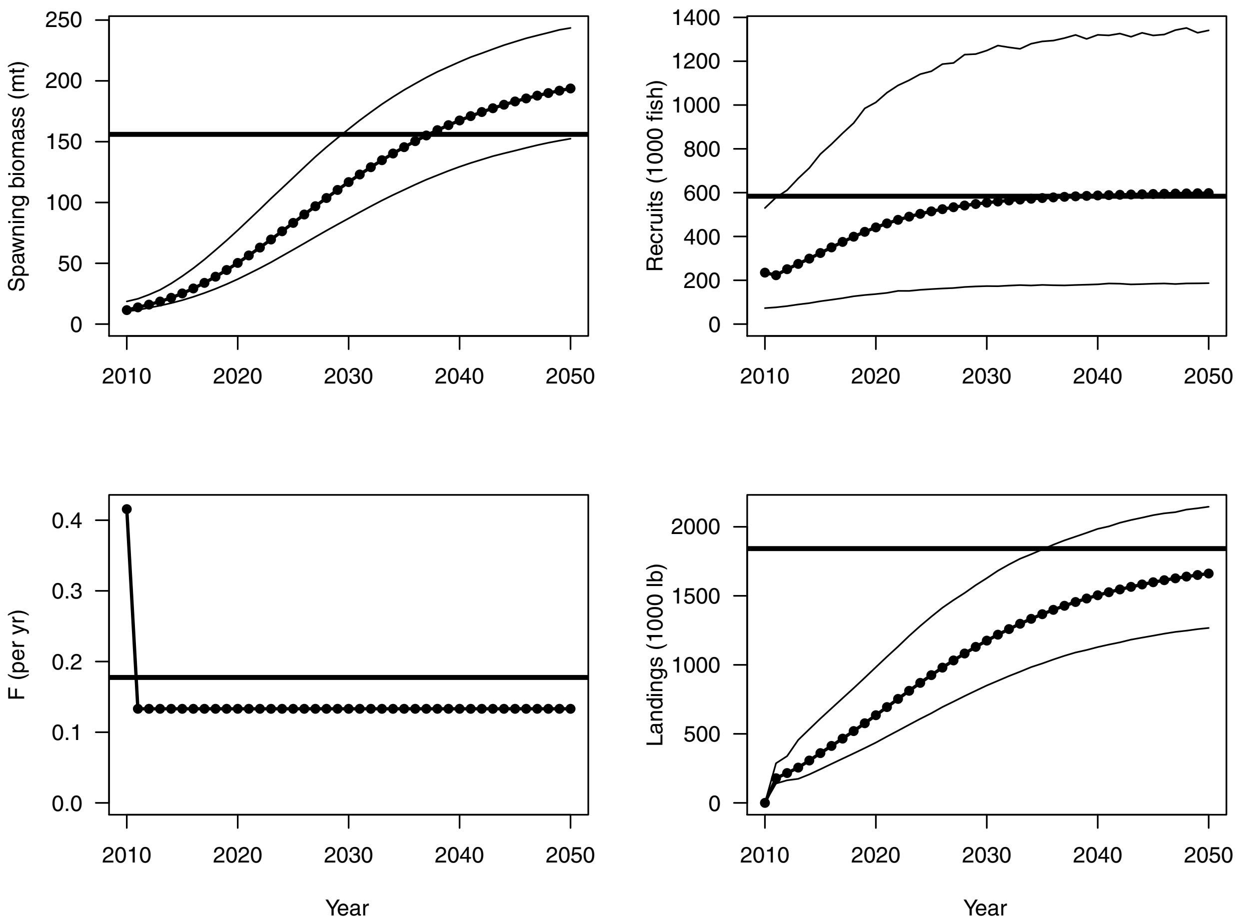


Figure 3.66. Projection results under scenario 5—fishing mortality rate fixed at $F = 85\% F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

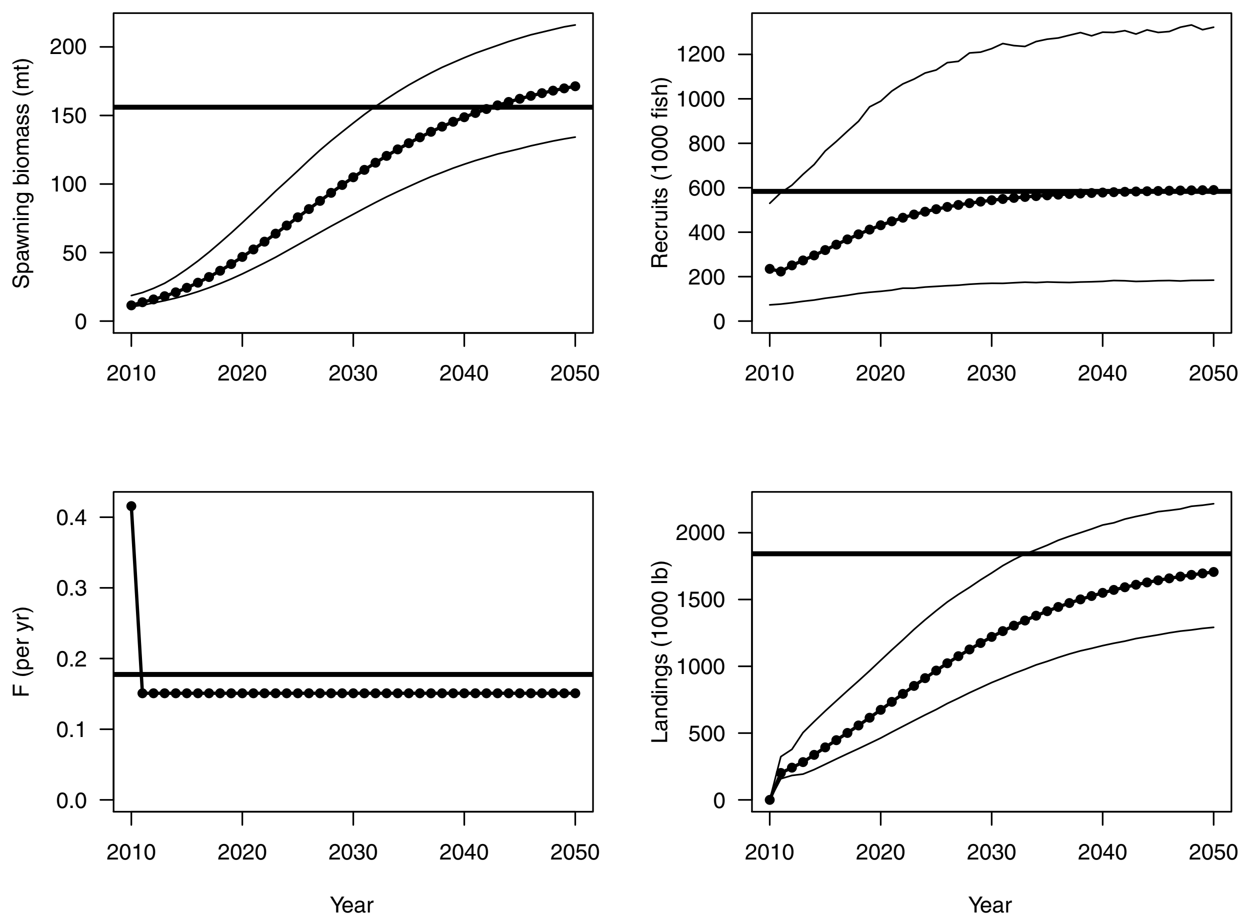


Figure 3.67. Projection results under scenario 6—fishing mortality rate fixed at $F = F_{\text{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

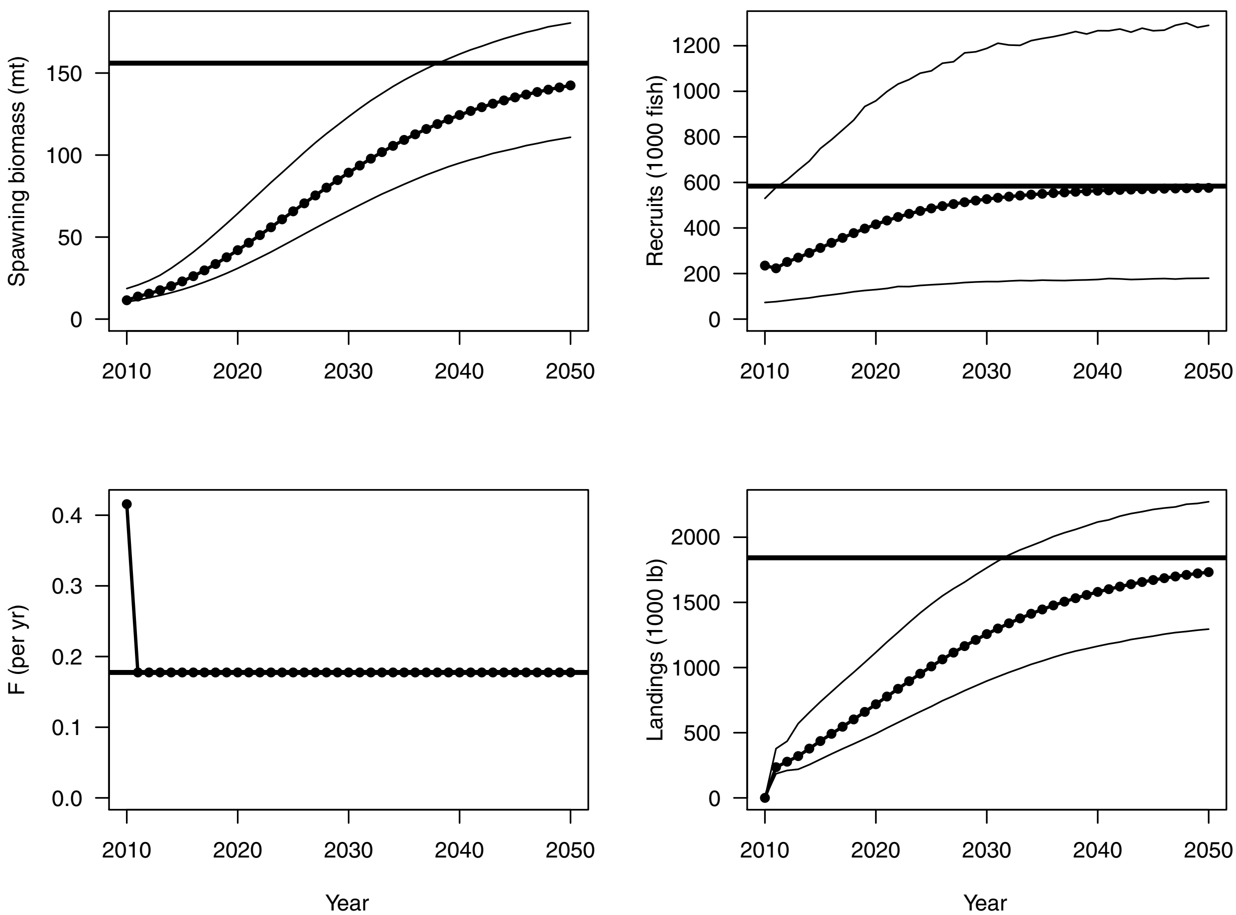


Figure 3.68. Projection results under scenario 7—moratorium projection (all potential landings converted to discards). Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} *and* 95^{th} *percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

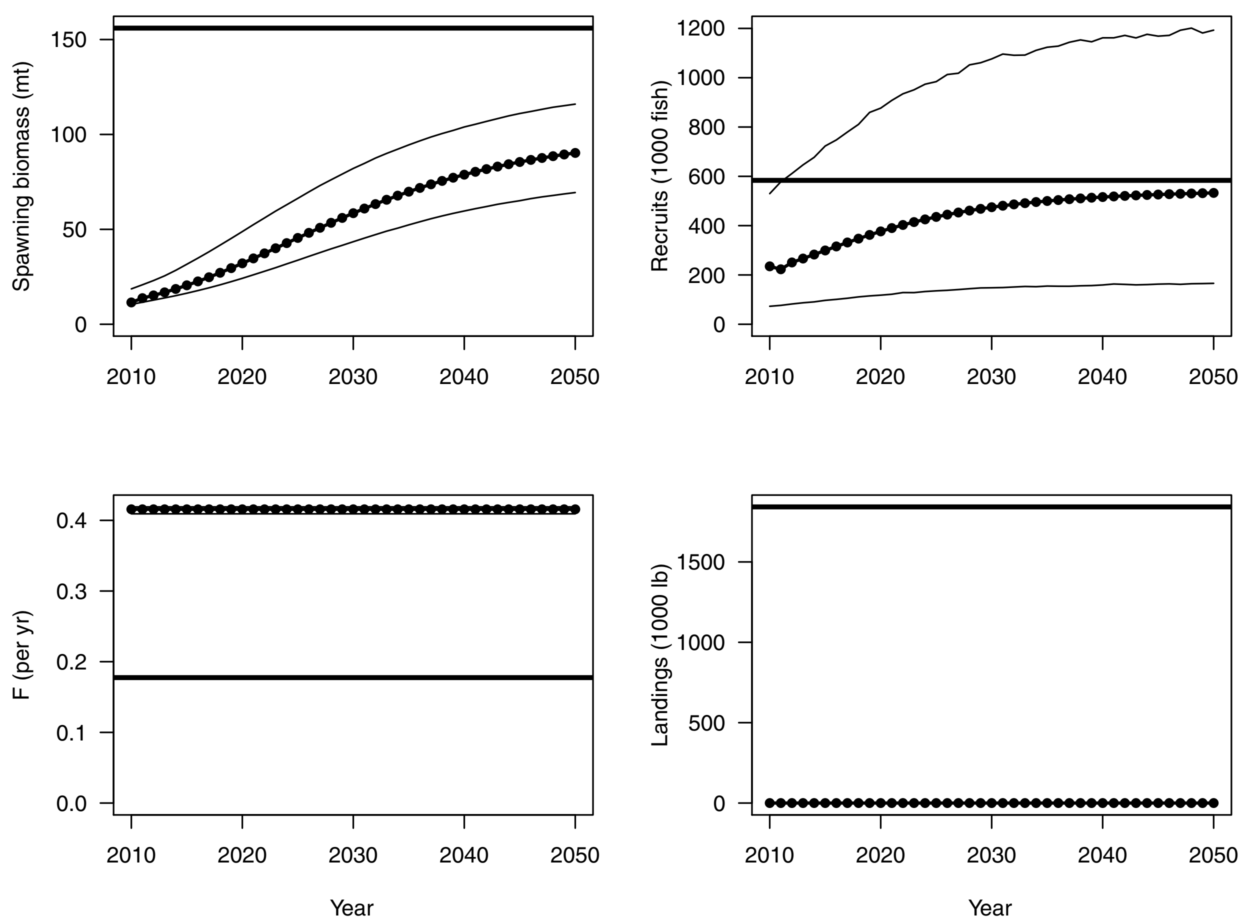


Figure 3.69. Projection results under scenario 8—fishing mortality rate fixed at $F = F_{\text{rebuild}}$, with rebuilding probability of 0.5 in 2047. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

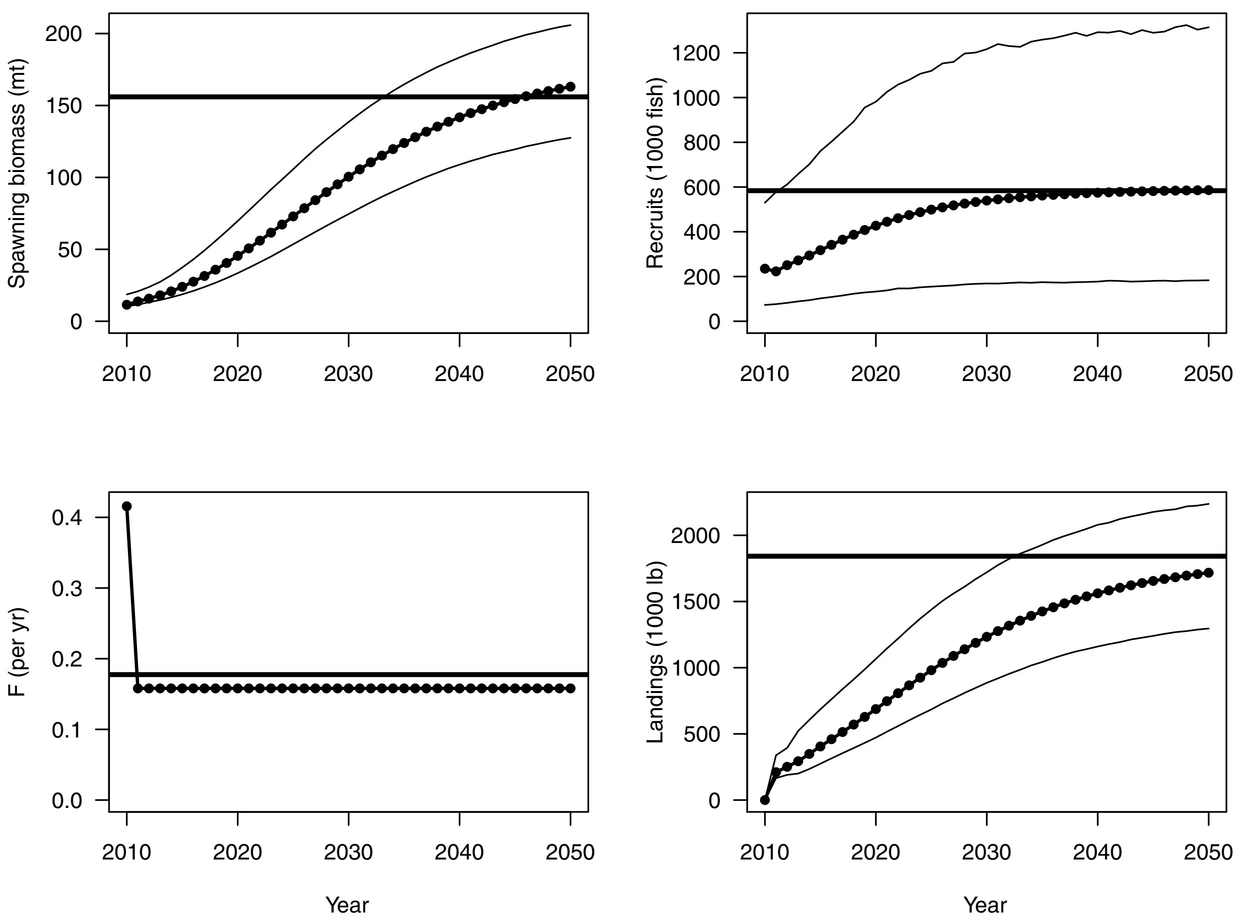


Figure 3.70. Projection results under scenario 9—fishing mortality rate fixed at $F = F_{\text{rebuild}}$*, with rebuilding probability of 0.70 in 2047. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to* 5^{th} *and* 95^{th} *percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

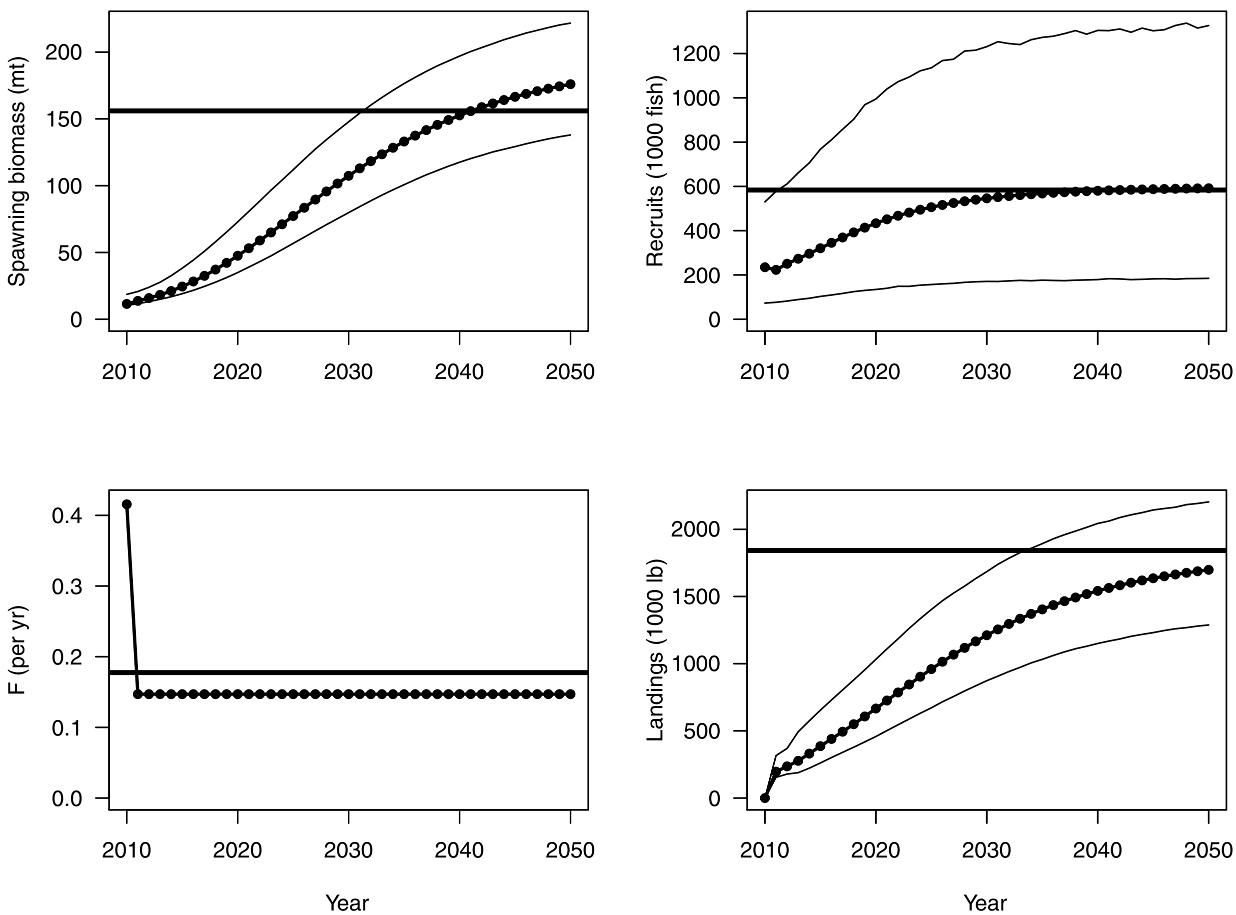


Figure 3.71. Projection results under scenario 10—fishing mortality rate fixed at $F = F_{\text{rebuild}}$, with rebuilding probability of 0.90 in 2047. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

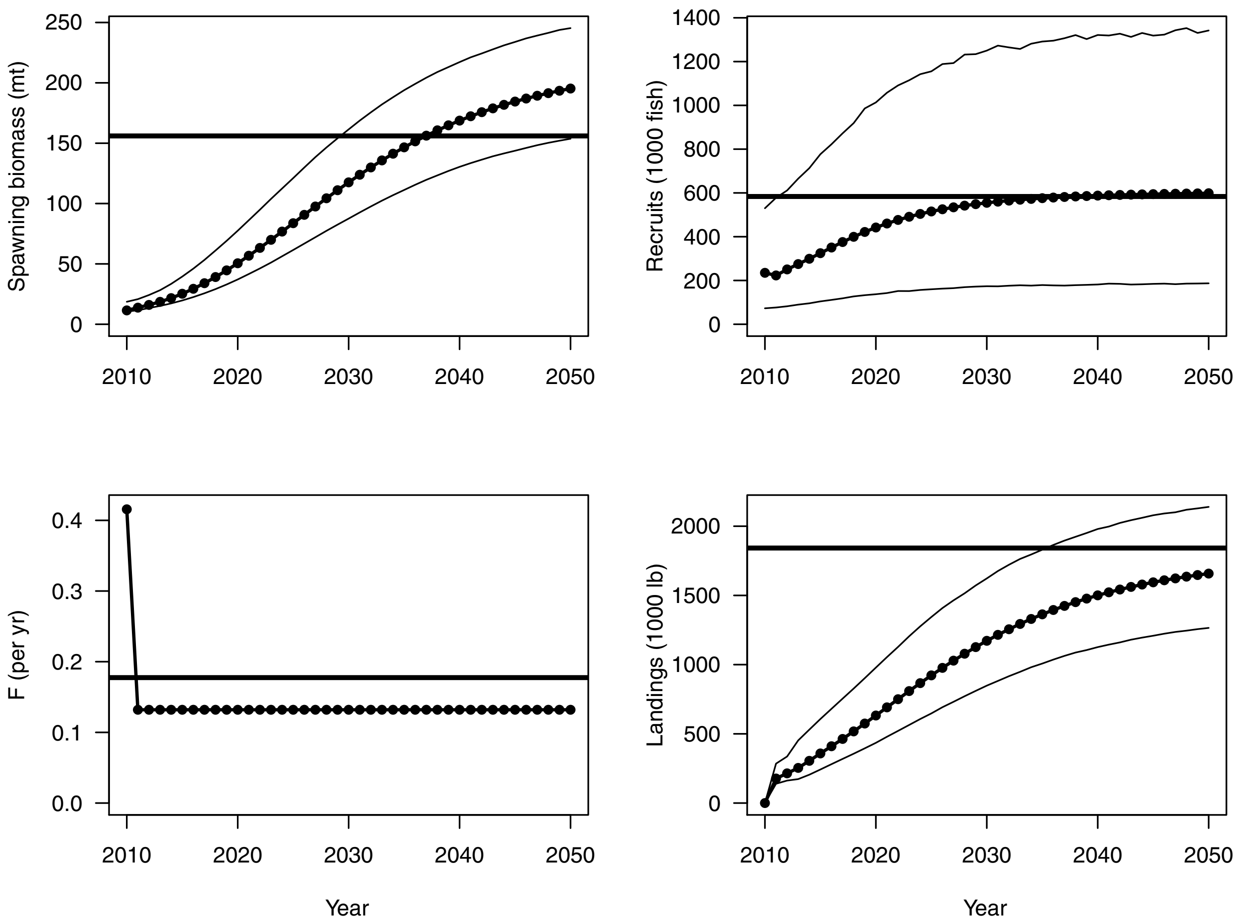


Figure 3.72. Red Snapper in Atlantic: Fit of production model to the headboat and commercial line indices with and without a 2% catchability increase since 1976 saturating in 2003.

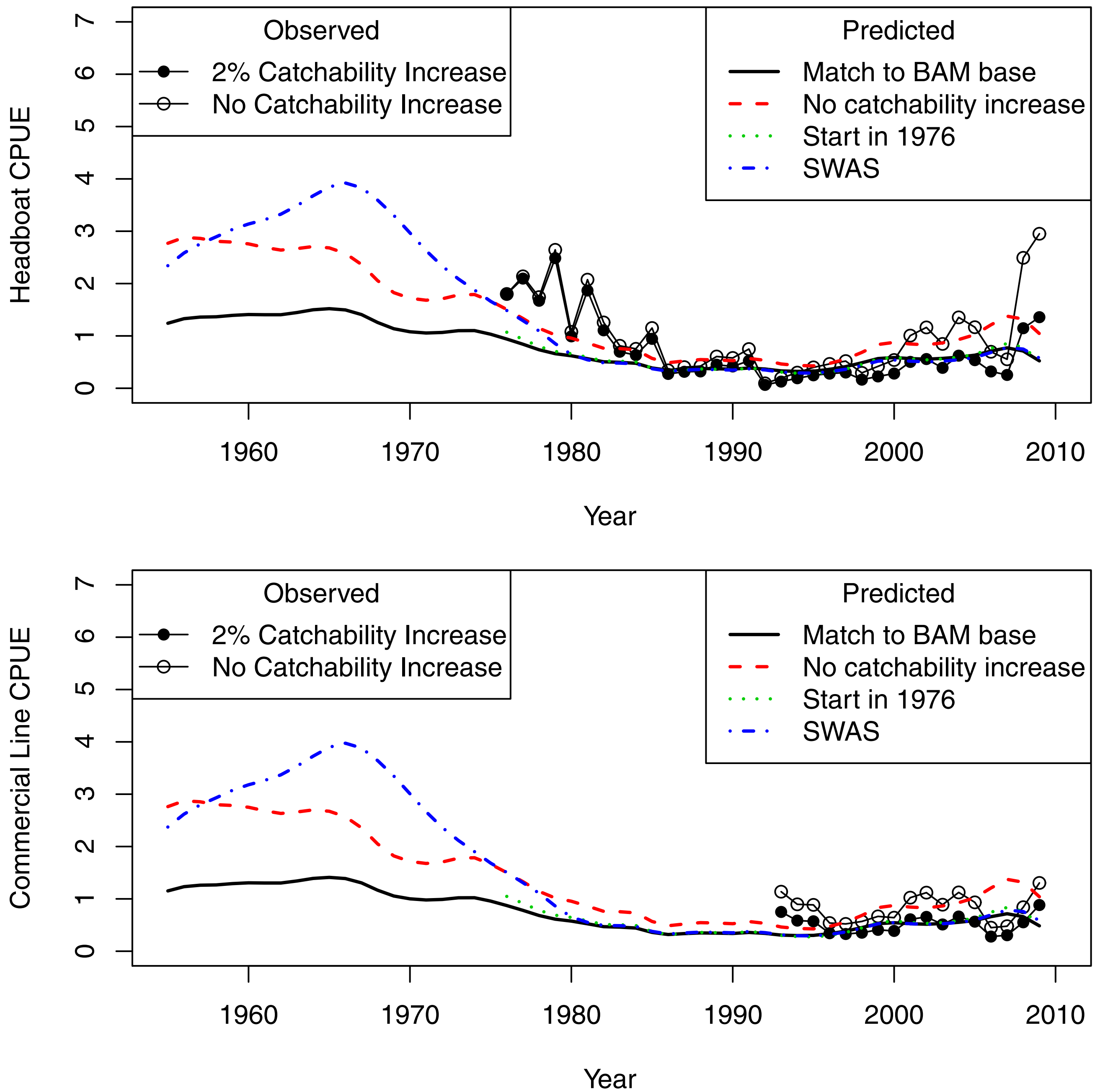


Figure 3.73. Red Snapper in Atlantic: Production model kernel density plots of parameters and status from 1000 bootstrap runs of the model configured to match the BAM data input as closely as possible. Subsets of the model runs are grouped together by estimates of $B1/K$ to evaluate its influence on parameter estimates and status.

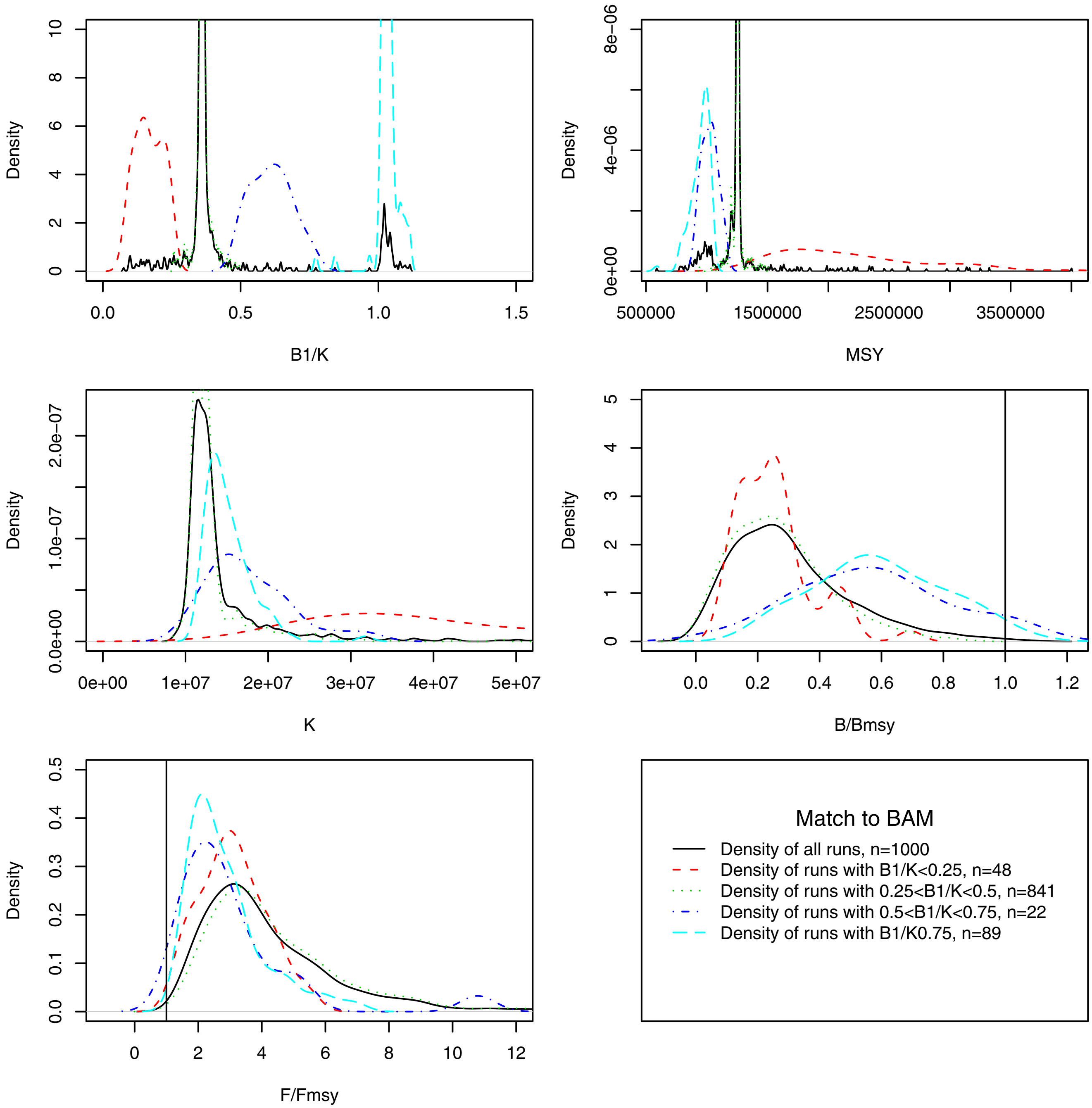


Figure 3.74. Red Snapper in Atlantic: Production model kernel density plots of parameters and status from 1000 bootstrap runs of the model configured to match the BAM data input as closely as possible without a 2 percent increase in catchability. Subsets of the model runs are grouped together by estimates of B1/K to evaluate its influence on parameter estimates and status.

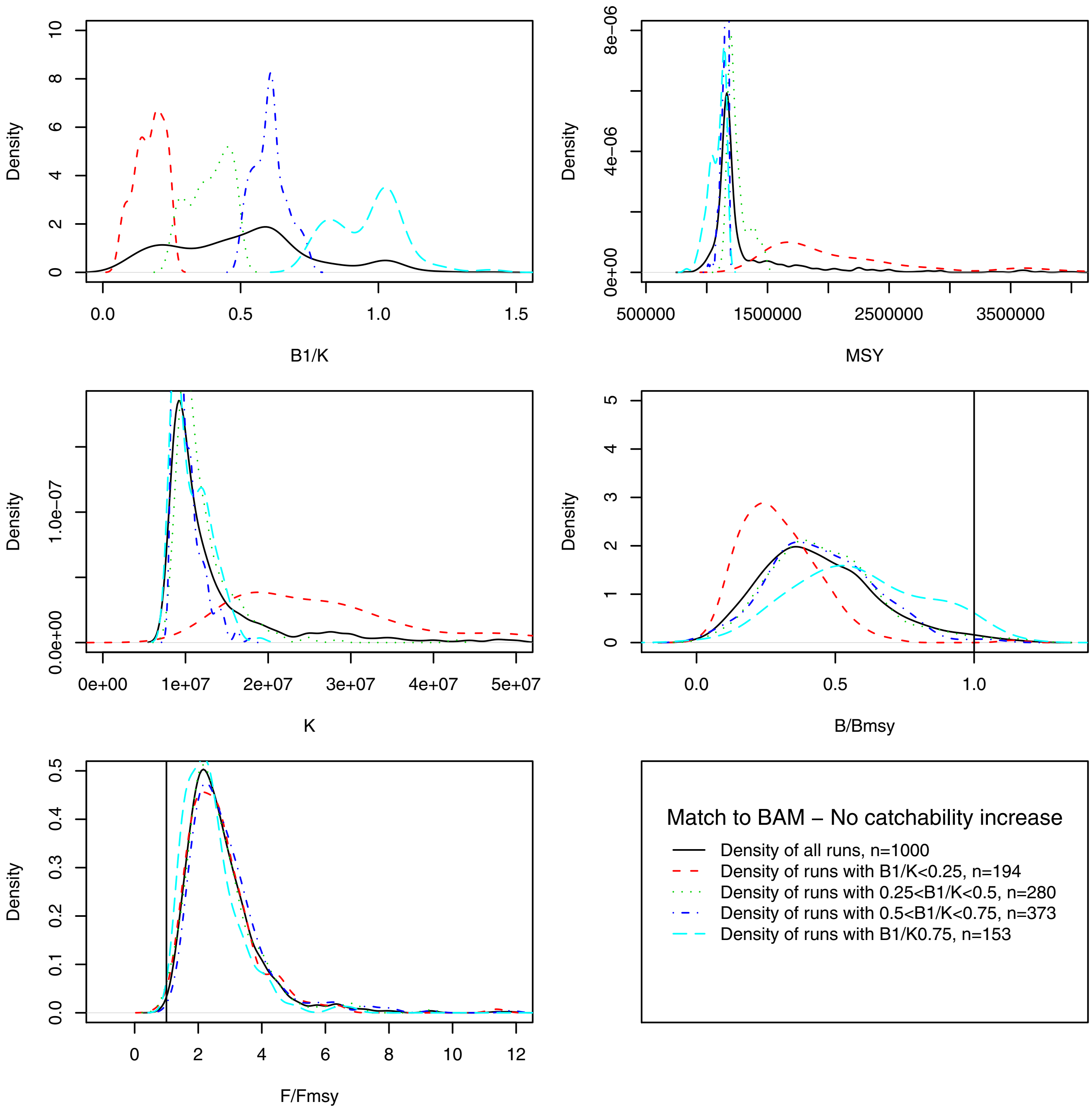


Figure 3.75. Red Snapper in Atlantic: Production model kernel density plots of parameters and status from 1000 bootstrap runs of the model configured to match the BAM data input as closely as possible and starting in 1976. Subsets of the model runs are grouped together by estimates of $B1/K$ to evaluate its influence on parameter estimates and status.

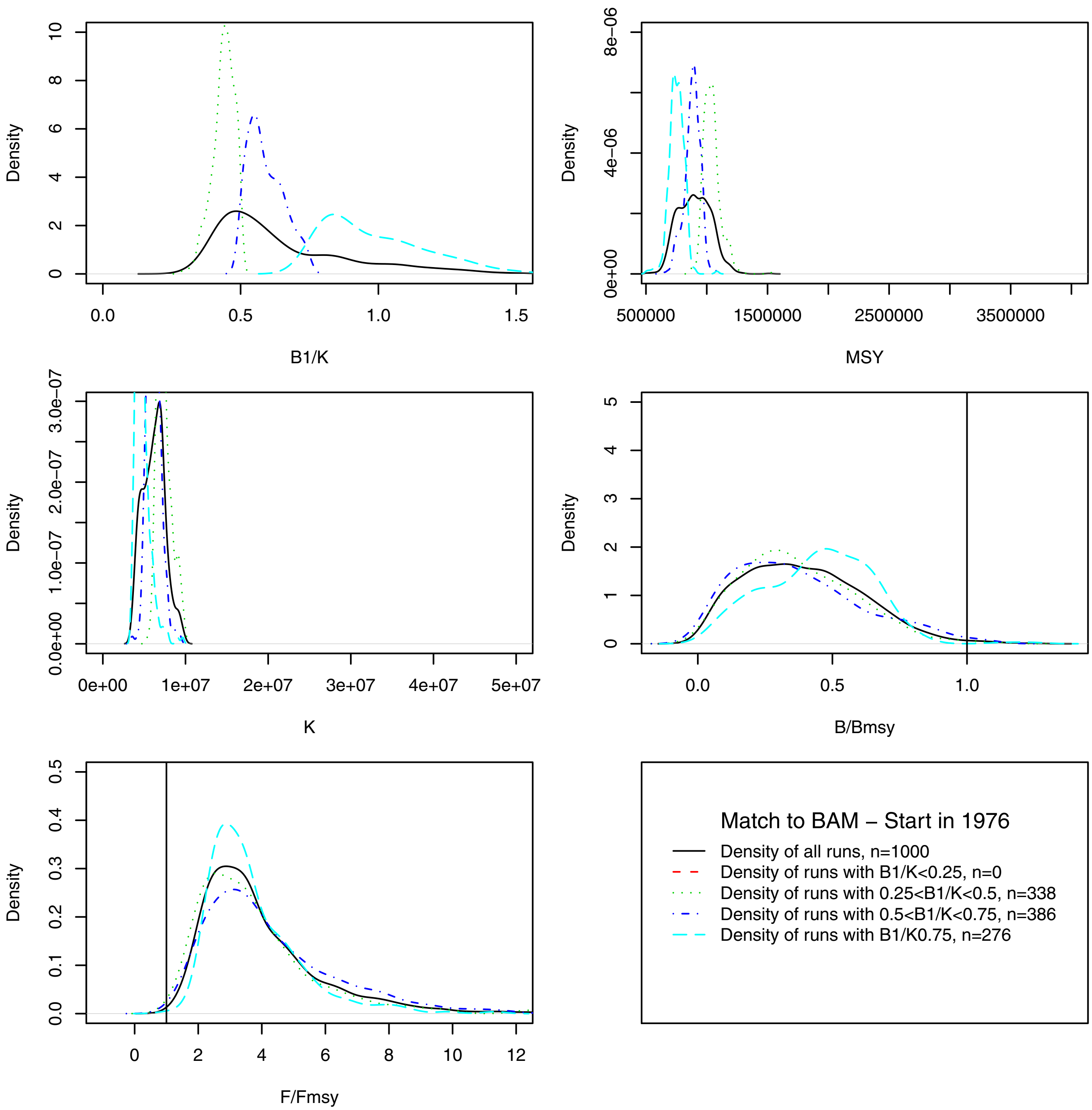


Figure 3.76. Red Snapper in Atlantic: Production model estimates of relative fishing rate F/F_{MSY} and biomass, B/B_{MSY}. Alternate runs were without the 2% catchability increase and with the model starting in 1976.

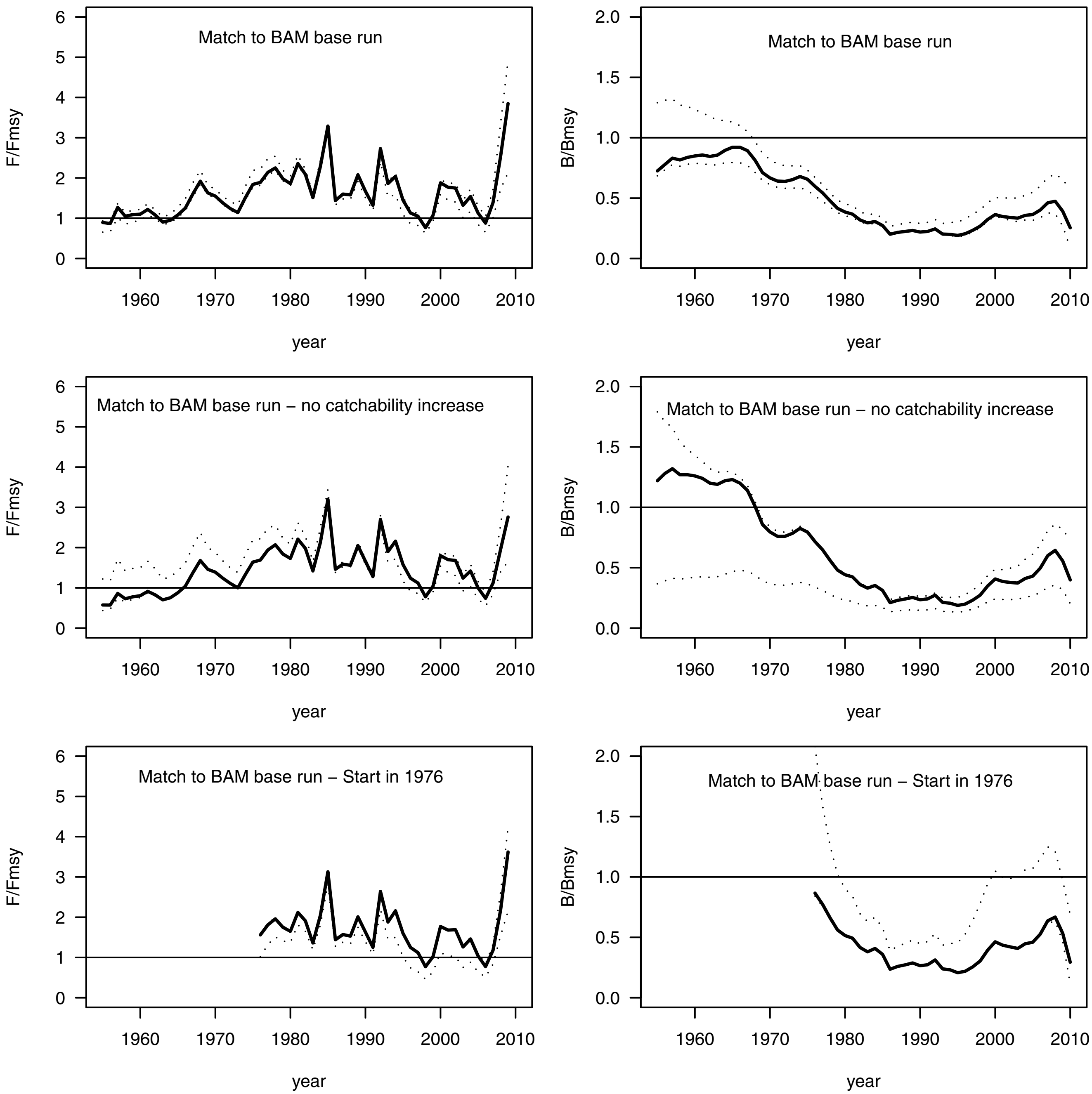
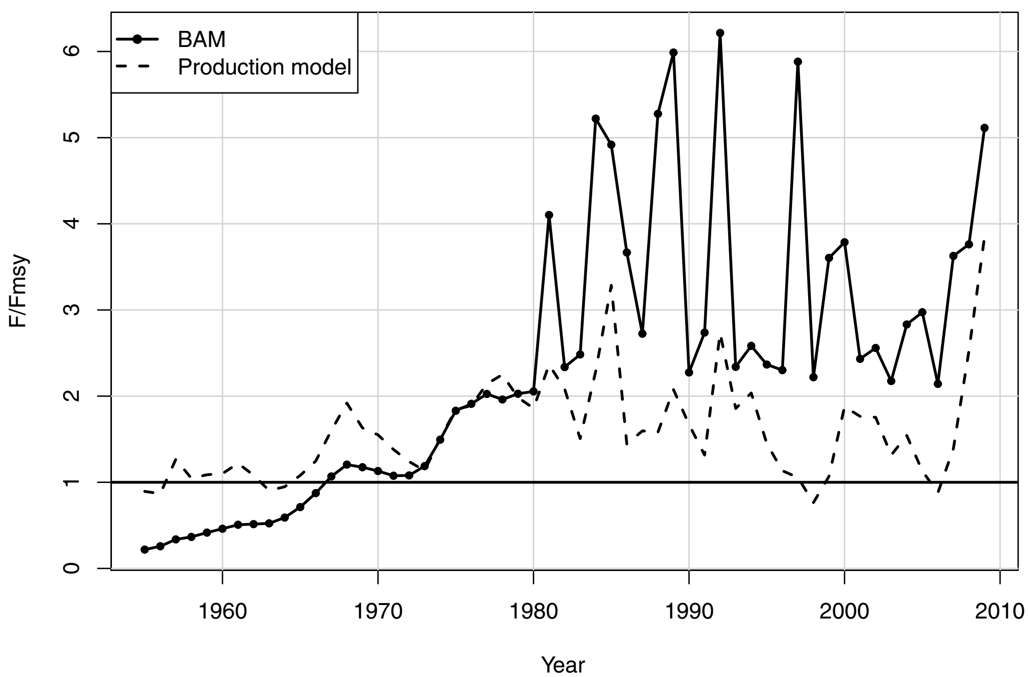


Figure 3.77. Red Snapper in Atlantic: Production model estimates of relative fishing rate F/F_{MSY} compared to the base-run estimates from the BAM. The production model run plotted is the one with inputs that resemble those of the BAM as closely as possible.



Appendix A Abbreviations and symbols

Table A.1. Acronyms and abbreviations used in this report

Symbol	Meaning
ABC	Acceptable Biological Catch
AW	Assessment Workshop (here, for red snapper)
ASY	Average Sustainable Yield
B	Total biomass of stock, conventionally on January 1r
BAM	Beaufort Assessment Model (a statistical catch-age formulation)
CPUE	Catch per unit effort; used after adjustment as an index of abundance
CV	Coefficient of variation
DW	Data Workshop (here, for red snapper)
F	Instantaneous rate of fishing mortality
F_{MSY}	Fishing mortality rate at which MSY can be attained
FL	State of Florida
GA	State of Georgia
GLM	Generalized linear model
K	Average size of stock when not exploited by man; carrying capacity
kg	Kilogram(s); 1 kg is about 2.2 lb.
klb	Thousand pounds; thousands of pounds
lb	Pound(s); 1 lb is about 0.454 kg
m	Meter(s); 1 m is about 3.28 feet.
M	Instantaneous rate of natural (non-fishing) mortality
MARMAP	Marine Resources Monitoring, Assessment, and Prediction Program, a fishery-independent data collection program of SCDNR
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
MSST	Minimum stock-size threshold; a limit reference point used in U.S. fishery management. The SAFMC has defined MSST for red snapper as $(1-M)\text{SSB}_{\text{MSY}} = 0.7\text{SSB}_{\text{MSY}}$.
MSY	Maximum sustainable yield (per year)
mt	Metric ton(s). One mt is 1000 kg, or about 2205 lb.
N	Number of fish in a stock, conventionally on January 1
NC	State of North Carolina
NMFS	National Marine Fisheries Service, same as "NOAA Fisheries Service"
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
OY	Optimum yield; SFA specifies that OY ≤ 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
SEDAR	SouthEast Data Assessment and Review process
SFA	Sustainable Fisheries Act; the Magnuson–Stevens Act, as amended
SL	Standard length (of a fish)
SPR	Spawning potential ratio
SRA	Stock reduction analysis
SS3	Stock Synthesis version 3, stock assessment software
SSB	Spawning stock biomass; mature biomass of males and females
SSB_{MSY}	Level of SSB at which MSY can be attained
SW	Scoping workshop; first of 3 workshops in SEDAR updates
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 = 355  Objective function value = 889.041  Maximum gradient component = 0.000735754
# len_sd_val:
49.9660752327
# log_R0:
13.1895667752
# log_rec_dev:
 -0.531531756462 0.0231140920057 -0.848755947452 -1.04958761708 -0.990878618859 -0.795173830122 -0.978367466829 -0.850790789831 0.603766943419
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 0.539725022112 0.511153451575 -1.04607646324 0.285682875805 0.689673676807 0.664971517814 1.46129063886 1.28232740809 0.436363858307 0.140753650931
 0.413902348920 -0.429485879495 -1.09743582951 1.35265415550 1.01957851121 -0.252843803092 -0.978437114409
# log_rec_historic_dev:
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 -0.542701008955 -0.564309783851 -0.586443983458 -0.608832640936 -0.629579427335 -0.654160866069 -0.685434813735 -0.726565394353 -0.764069771182 -0.618510945590
# selpar_L50_cL2:
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# selpar_slope_cL2:
4.28079637999
# selpar_L50_cL3:
2.55243464666
# selpar_slope_cL3:
4.45097975081
# selpar_Age1_cL_D3_logit:
-3.02328478552
# selpar_Age2_cL_D3_logit:
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# selpar_L50_cD3:
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# selpar_slope_cD3:
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# selpar_L502_cD:
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# selpar_slope2_cD:
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# selpar_min_cD:
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# selpar_L50_HB1:
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# selpar_slope_HB1:
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# selpar_L50_HB2:
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# selpar_slope_HB2:
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# selpar_L50_HB3:
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# selpar_slope_HB3:
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# selpar_L502_HB:
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# selpar_slope2_HB:
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# selpar_Age1_HB_D3_logit:
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# selpar_L50_PVT2:
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# selpar_slope_PVT2:
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# selpar_L50_PVT3:
4.15814039656
# selpar_slope_PVT3:
2.41379623809
# log_q_cL:
-7.81944142945
# log_q_HB:
-12.9786293855
# log_q_HBD:
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# log_avg_F_cL:
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# log_F_dev_cL:
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 0.110876671039 0.0602991464076 0.229194671692 0.262635900561 0.0369688603794 0.103831017677 0.283845388206 0.309945551412 0.467927076524 0.371729120102
 0.487819627665 0.595176163439 0.650753583828 0.625347289973 1.41060667491 1.45880118041 0.966014998913 0.790695509127 1.41940885414 1.18752147132 1.03374191660
 0.715519429837 0.633501133847 0.433556339819 0.266745125181 0.358985218810 0.740286215921 0.478588082759 0.109422638340 0.322483530392 0.0915373797718
 -0.245371298622 0.0631787541055 0.697084960956 1.11799285109
# log_avg_F_cD:
-5.88055575438
# log_F_dev_cD:
 -1.00613825935 -0.361475917939 -2.10042204269 -4.83876047226 -5.32919716615 -5.92007732126 0.0712452139240 1.18121570652 1.66841685151 0.908605469916
 1.46016834107 1.09344944302 0.578958420921 1.10693228556 1.33469989513 1.29281289762 1.22393166095 1.43626169630 1.35936350183 1.08260051879 1.28993572983
 0.710015224106 0.112275667933 0.869477094374 0.301704525608 0.474001034739
# log_avg_F_HB:
-2.28424810499
# log_F_dev_HB:
 -1.40721212681 -1.23462065136 -1.05927517553 -0.931690947746 -0.836497942983 -0.764118612051 -0.724641857316 -0.723229027898 -0.716606793805 -0.644232856909
 -0.500412630910 -0.327694983392 -0.177221739891 -0.0984624595713 -0.116824335991 -0.197667033478 -0.289021009476 -0.328648432517 -0.265191805961
 -0.140525385678 -0.0264943292569 -0.130100188688 -0.0497884507999 0.0402810841689 0.0529331493120 -0.0587648639297 0.506293196287 0.0116384120373 0.459343388774
```

```
 0.0402757245513 0.556879586833 1.07170132552 0.284960698259 0.582687814501 0.735195345275 0.277800885584 0.228810451214 1.59022544664 0.0135026538576
 0.262297629502 0.315761246119 -0.569103054179 1.94639515931 0.530510699004 1.11119135306 0.154807960871 -0.210462828217 -0.0428099891638 -0.0888717433254
 0.165888583802 0.226653562290 0.207005508351 0.382776340684 0.315353953913 0.589020097093
# log_avg_F_PVT:
-2.21953991460
# log_F_dev_PVT:
 -2.75339926218 -2.46373560948 -2.19919128293 -1.93423559964 -1.71253245837 -1.52509582414 -1.38164562548 -1.27924876808 -1.16697625583 -0.990332651023
 -0.756319172451 -0.510246206521 -0.297444075336 -0.159050663388 -0.114167794185 -0.124740607571 -0.134669795768 -0.0847810888897 0.0657745800244
 0.299411242981 0.533724504878 0.665134518109 0.692523659363 0.585372085951 0.682407343049 0.743607472211 1.54845832019 0.882111878663 0.713999028344
 1.95503034554 1.76533710073 0.973661167221 0.942500117702 1.84358889018 1.86627516523 0.0284084588703 0.859156544631 1.41248800895 -0.337696779046
 -0.292801200658 -1.97173987112 -0.352974953529 -0.954344160865 -0.349578614773 0.304834451129 1.23378622230 0.364069825123 0.0220689098347 -0.534907121998
 0.144301634861 0.0843713788973 -0.00906577884814 1.04636073674 0.985693458052 1.14646417236
# F_init:
0.0200000000000
# log_avg_F_cL_D:
-2.97433171792
# log_F_dev_cL_D:
 0.0159363505310 -0.250619810313 0.309702477446 0.538294086062 1.18275316082 1.35090096003 0.283838964884 -0.0390494673706 -0.295791881578 -0.554954500262
 0.596806786146 0.0615216561931 -0.858505997911 -0.687722938020 -0.109050372375 -0.626804249114 -0.978280749108 0.0610255239301
# log_avg_F_HB_D:
-4.05351591651
# log_F_dev_HB_D:
 1.22685582718 1.66762029730 0.580851765615 -3.18434898700 -3.99725282007 -4.29866568485 -3.21721005688 -3.70188478851 -2.41127080500 0.525028897532
 1.21212148248 -0.0500009161306 1.52420892327 0.228145030065 0.908229844808 -0.235919483127 1.17162805524 0.501560914842 0.684604042567 0.975966961208
 0.957976897370 1.59808936504 2.44314037504 0.584214900831 1.48907769796 1.15647379948 1.66075846375
# log_avg_F_PVT_D:
-2.36284823955
# log_F_dev_PVT_D:
 -2.09704289926 -1.74451756674 -0.333136131231 -0.918979473537 0.774825459068 -0.316094510407 -0.115407186389 -1.43656148675 -0.211750178904
 -1.13246689786 -0.145787368025 0.347895228993 0.225769841335 -0.263349128668 -1.61762578392 -1.02388593522 0.453935268783 0.683896874053 0.637514484215
 0.641820237125 1.07432830190 1.33084036551 1.18014886638 0.448991899948 0.798946438731 1.18383213114 1.57385914974
```

Appendix C ASPIC Output: Results of production model run matched to the base run of the BAM with a 2% increase in catchability and starting in 1955.

```
SAFMC Red Snapper (2010) Landings and Indices                                                        Page 1
                                                                           Tuesday, 28 Sep 2010 at 11:47:20
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 5.31)
                                                                                           BOT program mode
Author:    Michael H. Prager; NOAA Center for Coastal Fisheries and Habitat Research   LOGISTIC model mode
           101 Pivers Island Road; Beaufort, North Carolina  28516  USA                    YLD conditioning
           Mike.Prager@noaa.gov                                                            SSE optimization

Reference: Prager, M. H. 1994. A suite of extensions to a nonequilibrium           ASPIC User's Manual is available
           surplus-production model.  Fishery Bulletin 92: 374-389.                       gratis from the author.

CONTROL PARAMETERS (FROM INPUT FILE)                             Input file: e:\sedar 24\aspic\rs2010_301ic_boot.inp
-------------------------------------------------------------------------------------------------------------------
Operation of ASPIC:  Fit logistic (Schaefer) model by direct optimization with bootstrap.
Number of years analyzed:                       55          Number of bootstrap trials:                      1000
Number of data series:                           2          Bounds on MSY (min, max):       8.000E+03    7.000E+06
Objective function:                  Least squares          Bounds on K (min, max):         8.000E+06    9.000E+07
Relative conv. criterion (simplex):      1.000E-08          Monte Carlo search mode, trials:        0       100000
Relative conv. criterion (restart):      3.000E-08          Random number seed:                          82184571
Relative conv. criterion (effort):       1.000E-04          Identical convergences required in fitting:         6
Maximum F allowed in fitting:                8.000


PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS)                                             error code   0
-------------------------------------------------------------------------------------------------------------------
Normal convergence


CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
-------------------------------------------------------------------------------------------------------------------
                                       |
 1  Headboat Index (1976-2009), Tota...|   1.000
                                       |      34
                                       |
 2  Commercial                         |   0.563   1.000
                                       |      17      17
                                       --------------------------------------------------
                                               1       2


GOODNESS-OF-FIT AND WEIGHTING (NON-BOOTSTRAPPED ANALYSIS)
-------------------------------------------------------------------------------------------------------------------
                                                    Weighted           Weighted      Current    Inv. var.   R-squared
Loss component number and title                          SSE     N          MSE       weight       weight     in CPUE

Loss(-1)  SSE in yield                             0.000E+00
Loss(0)   Penalty for B1 > K                       0.000E+00     1          N/A    1.000E+00          N/A
Loss(1)   Headboat Index (1976-2009), Total Ldgs   1.744E+01    34    5.450E-01    1.000E+00    7.307E-01       0.155
Loss(2)   Commercial                               3.882E+00    17    2.588E-01    1.000E+00    1.539E+00      -0.967
.............................................................................................
TOTAL OBJECTIVE FUNCTION, MSE, RMSE:          2.13207919E+01          4.635E-01    6.808E-01
Estimated contrast index (ideal = 1.0):               0.3652          C* = (Bmax-Bmin)/K
Estimated nearness index (ideal = 1.0):               0.9605          N* = 1 - |min(B-Bmsy)|/K
SAFMC Red Snapper (2010) Landings and Indices                                                       Page 2


MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
-------------------------------------------------------------------------------------------------------------------
Parameter                                           Estimate     User/pgm guess    2nd guess    Estimated  User guess

B1/K      Starting relative biomass (in 1955)      3.625E-01          5.000E-01    7.071E-01            1           1
MSY       Maximum sustainable yield                1.251E+06          9.000E+05    7.731E+05            1           1
K         Maximum population size                  1.248E+07          1.000E+07    2.440E+07            1           1
phi       Shape of production curve (Bmsy/K)       0.5000             0.5000            ----            0           1
```

--------- Catchability Coefficients by Data Series ---------------

q(1)	Headboat Index (1976-2009), Total Ldgs	2.646E-07	5.000E-08	4.750E-06	1	1
q(2)	Commercial	2.455E-07	5.000E-08	4.750E-06	1	1

MANAGEMENT and DERIVED PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	Logistic formula	General formula
MSY	Maximum sustainable yield	1.251E+06	----	----
Bmsy	Stock biomass giving MSY	6.240E+06	K/2	K*n**(1/(1-n))
Fmsy	Fishing mortality rate at MSY	2.005E-01	MSY/Bmsy	MSY/Bmsy
n	Exponent in production function	2.0000	----	----
g	Fletcher's gamma	4.000E+00	----	[n**(n/(n-1))]/[n-1]
B./Bmsy	Ratio: B(2010)/Bmsy	2.535E-01	----	----
F./Fmsy	Ratio: F(2009)/Fmsy	3.849E+00	----	----
Fmsy/F.	Ratio: Fmsy/F(2009)	2.598E-01	----	----
Y.(Fmsy)	Approx. yield available at Fmsy in 2010	3.170E+05	MSY*B./Bmsy	MSY*B./Bmsy
	...as proportion of MSY	2.535E-01	----	----
Ye.	Equilibrium yield available in 2010	5.537E+05	4*MSY*(B/K-(B/K)**2)	g*MSY*(B/K-(B/K)**n)
	...as proportion of MSY	4.427E-01	----	----

--------- Fishing effort rate at MSY in units of each CE or CC series ---------

fmsy(1)	Headboat Index (1976-2009), Total Ldgs	7.576E+05	Fmsy/q(1)	Fmsy/q(1)

SAFMC Red Snapper (2010) Landings and Indices Page 3

ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

Obs	Year or ID	Estimated total F mort	Estimated starting biomass	Estimated average biomass	Observed total yield	Model total yield	Estimated surplus production	Ratio of F mort to Fmsy	Ratio of biomass to Bmsy
1	1955	0.179	4.524E+06	4.692E+06	8.414E+05	8.414E+05	1.174E+06	8.945E-01	7.250E-01
2	1956	0.174	4.856E+06	5.024E+06	8.731E+05	8.731E+05	1.203E+06	8.670E-01	7.783E-01
3	1957	0.254	5.186E+06	5.138E+06	1.304E+06	1.304E+06	1.212E+06	1.266E+00	8.311E-01
4	1958	0.210	5.093E+06	5.160E+06	1.082E+06	1.082E+06	1.213E+06	1.046E+00	8.163E-01
5	1959	0.218	5.225E+06	5.262E+06	1.147E+06	1.147E+06	1.220E+06	1.088E+00	8.373E-01
6	1960	0.221	5.297E+06	5.323E+06	1.174E+06	1.174E+06	1.224E+06	1.101E+00	8.490E-01
7	1961	0.245	5.347E+06	5.308E+06	1.299E+06	1.299E+06	1.223E+06	1.221E+00	8.569E-01
8	1962	0.217	5.271E+06	5.308E+06	1.151E+06	1.151E+06	1.223E+06	1.082E+00	8.448E-01
9	1963	0.181	5.343E+06	5.466E+06	9.908E+05	9.908E+05	1.231E+06	9.043E-01	8.563E-01
10	1964	0.190	5.584E+06	5.667E+06	1.077E+06	1.077E+06	1.240E+06	9.483E-01	8.949E-01
11	1965	0.216	5.747E+06	5.746E+06	1.244E+06	1.244E+06	1.243E+06	1.080E+00	9.210E-01
12	1966	0.250	5.746E+06	5.656E+06	1.414E+06	1.414E+06	1.240E+06	1.247E+00	9.209E-01
13	1967	0.321	5.572E+06	5.319E+06	1.708E+06	1.708E+06	1.223E+06	1.602E+00	8.930E-01
14	1968	0.385	5.087E+06	4.748E+06	1.826E+06	1.826E+06	1.178E+06	1.919E+00	8.153E-01
15	1969	0.327	4.439E+06	4.297E+06	1.405E+06	1.405E+06	1.129E+06	1.631E+00	7.114E-01
16	1970	0.311	4.163E+06	4.078E+06	1.267E+06	1.267E+06	1.101E+06	1.550E+00	6.673E-01
17	1971	0.277	3.997E+06	3.989E+06	1.104E+06	1.104E+06	1.088E+06	1.380E+00	6.405E-01
18	1972	0.249	3.981E+06	4.028E+06	1.001E+06	1.001E+06	1.094E+06	1.240E+00	6.380E-01
19	1973	0.228	4.073E+06	4.157E+06	9.459E+05	9.459E+05	1.111E+06	1.135E+00	6.528E-01
20	1974	0.303	4.239E+06	4.162E+06	1.261E+06	1.261E+06	1.112E+06	1.511E+00	6.794E-01
21	1975	0.370	4.090E+06	3.900E+06	1.442E+06	1.442E+06	1.075E+06	1.844E+00	6.555E-01
22	1976	0.379	3.723E+06	3.554E+06	1.346E+06	1.346E+06	1.019E+06	1.890E+00	5.967E-01
23	1977	0.429	3.396E+06	3.180E+06	1.365E+06	1.365E+06	9.495E+05	2.142E+00	5.442E-01
24	1978	0.451	2.980E+06	2.779E+06	1.253E+06	1.253E+06	8.656E+05	2.250E+00	4.776E-01
25	1979	0.398	2.592E+06	2.493E+06	9.918E+05	9.918E+05	7.999E+05	1.984E+00	4.154E-01
26	1980	0.373	2.400E+06	2.344E+06	8.735E+05	8.735E+05	7.632E+05	1.859E+00	3.846E-01
27	1981	0.474	2.290E+06	2.133E+06	1.011E+06	1.011E+06	7.088E+05	2.364E+00	3.670E-01
28	1982	0.418	1.987E+06	1.911E+06	7.985E+05	7.985E+05	6.487E+05	2.085E+00	3.185E-01
29	1983	0.302	1.838E+06	1.874E+06	5.661E+05	5.661E+05	6.385E+05	1.507E+00	2.945E-01
30	1984	0.459	1.910E+06	1.802E+06	8.272E+05	8.272E+05	6.182E+05	2.289E+00	3.061E-01
31	1985	0.659	1.701E+06	1.464E+06	9.647E+05	9.647E+05	5.177E+05	3.286E+00	2.726E-01
32	1986	0.290	1.254E+06	1.299E+06	3.761E+05	3.761E+05	4.666E+05	1.444E+00	2.010E-01
33	1987	0.320	1.344E+06	1.370E+06	4.383E+05	4.383E+05	4.889E+05	1.596E+00	2.155E-01

34	1988	0.317	1.395E+06	1.422E+06	4.506E+05	4.506E+05	5.052E+05	1.580E+00	2.236E-01
35	1989	0.416	1.450E+06	1.406E+06	5.852E+05	5.852E+05	5.003E+05	2.076E+00	2.323E-01
36	1990	0.335	1.365E+06	1.380E+06	4.620E+05	4.620E+05	4.920E+05	1.670E+00	2.187E-01
37	1991	0.264	1.395E+06	1.460E+06	3.851E+05	3.851E+05	5.169E+05	1.316E+00	2.235E-01
38	1992	0.548	1.526E+06	1.388E+06	7.607E+05	7.607E+05	4.944E+05	2.734E+00	2.446E-01
39	1993	0.372	1.260E+06	1.253E+06	4.663E+05	4.663E+05	4.519E+05	1.856E+00	2.020E-01
40	1994	0.408	1.246E+06	1.217E+06	4.969E+05	4.969E+05	4.404E+05	2.036E+00	1.997E-01
41	1995	0.290	1.189E+06	1.233E+06	3.580E+05	3.580E+05	4.455E+05	1.448E+00	1.906E-01
42	1996	0.227	1.277E+06	1.364E+06	3.102E+05	3.102E+05	4.870E+05	1.134E+00	2.046E-01
43	1997	0.211	1.454E+06	1.561E+06	3.298E+05	3.298E+05	5.474E+05	1.054E+00	2.330E-01
44	1998	0.153	1.671E+06	1.841E+06	2.822E+05	2.822E+05	6.289E+05	7.647E-01	2.679E-01
45	1999	0.214	2.018E+06	2.143E+06	4.593E+05	4.593E+05	7.115E+05	1.069E+00	3.234E-01
46	2000	0.377	2.270E+06	2.217E+06	8.350E+05	8.350E+05	7.310E+05	1.879E+00	3.638E-01
47	2001	0.354	2.166E+06	2.142E+06	7.581E+05	7.581E+05	7.115E+05	1.765E+00	3.472E-01
48	2002	0.352	2.120E+06	2.100E+06	7.384E+05	7.384E+05	7.004E+05	1.754E+00	3.397E-01
49	2003	0.264	2.082E+06	2.155E+06	5.682E+05	5.682E+05	7.147E+05	1.315E+00	3.336E-01
50	2004	0.309	2.228E+06	2.250E+06	6.959E+05	6.959E+05	7.394E+05	1.543E+00	3.571E-01
51	2005	0.227	2.272E+06	2.387E+06	5.418E+05	5.418E+05	7.739E+05	1.132E+00	3.641E-01
52	2006	0.176	2.504E+06	2.688E+06	4.731E+05	4.731E+05	8.452E+05	8.779E-01	4.013E-01
53	2007	0.279	2.876E+06	2.918E+06	8.135E+05	8.135E+05	8.963E+05	1.391E+00	4.609E-01
54	2008	0.507	2.959E+06	2.688E+06	1.362E+06	1.362E+06	8.449E+05	2.528E+00	4.742E-01
55	2009	0.772	2.441E+06	1.976E+06	1.525E+06	1.525E+06	6.648E+05	3.849E+00	3.913E-01
56	2010		1.581E+06						2.535E-01

SAFMC Red Snapper (2010) Landings and Indices Page 4

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED) Headboat Index (1976-2009), Total Ldgs w

Data type CC: CPUE-catch series Series weight: 1.000

Obs	Year	Observed CPUE	Estimated CPUE	Estim F	Observed yield	Model yield	Resid in log scale	Statist weight
1	1955	*	1.242E+00	0.1793	8.414E+05	8.414E+05	0.00000	1.000E+00
2	1956	*	1.329E+00	0.1738	8.731E+05	8.731E+05	0.00000	1.000E+00
3	1957	*	1.360E+00	0.2538	1.304E+06	1.304E+06	0.00000	1.000E+00
4	1958	*	1.366E+00	0.2097	1.082E+06	1.082E+06	0.00000	1.000E+00
5	1959	*	1.392E+00	0.2180	1.147E+06	1.147E+06	0.00000	1.000E+00
6	1960	*	1.409E+00	0.2206	1.174E+06	1.174E+06	0.00000	1.000E+00
7	1961	*	1.405E+00	0.2447	1.299E+06	1.299E+06	0.00000	1.000E+00
8	1962	*	1.405E+00	0.2168	1.151E+06	1.151E+06	0.00000	1.000E+00
9	1963	*	1.446E+00	0.1813	9.908E+05	9.908E+05	0.00000	1.000E+00
10	1964	*	1.500E+00	0.1901	1.077E+06	1.077E+06	0.00000	1.000E+00
11	1965	*	1.521E+00	0.2164	1.244E+06	1.244E+06	0.00000	1.000E+00
12	1966	*	1.497E+00	0.2500	1.414E+06	1.414E+06	0.00000	1.000E+00
13	1967	*	1.407E+00	0.3211	1.708E+06	1.708E+06	0.00000	1.000E+00
14	1968	*	1.256E+00	0.3847	1.826E+06	1.826E+06	0.00000	1.000E+00
15	1969	*	1.137E+00	0.3270	1.405E+06	1.405E+06	0.00000	1.000E+00
16	1970	*	1.079E+00	0.3108	1.267E+06	1.267E+06	0.00000	1.000E+00
17	1971	*	1.055E+00	0.2767	1.104E+06	1.104E+06	0.00000	1.000E+00
18	1972	*	1.066E+00	0.2486	1.001E+06	1.001E+06	0.00000	1.000E+00
19	1973	*	1.100E+00	0.2275	9.459E+05	9.459E+05	0.00000	1.000E+00
20	1974	*	1.101E+00	0.3029	1.261E+06	1.261E+06	0.00000	1.000E+00
21	1975	*	1.032E+00	0.3697	1.442E+06	1.442E+06	0.00000	1.000E+00
22	1976	1.801E+00	9.404E-01	0.3788	1.346E+06	1.346E+06	-0.64979	1.000E+00
23	1977	2.095E+00	8.414E-01	0.4294	1.365E+06	1.365E+06	-0.91240	1.000E+00
24	1978	1.671E+00	7.352E-01	0.4511	1.253E+06	1.253E+06	-0.82117	1.000E+00
25	1979	2.486E+00	6.598E-01	0.3978	9.918E+05	9.918E+05	-1.32642	1.000E+00
26	1980	9.914E-01	6.202E-01	0.3727	8.735E+05	8.735E+05	-0.46912	1.000E+00
27	1981	1.867E+00	5.645E-01	0.4740	1.011E+06	1.011E+06	-1.19627	1.000E+00
28	1982	1.107E+00	5.056E-01	0.4179	7.985E+05	7.985E+05	-0.78332	1.000E+00
29	1983	6.977E-01	4.959E-01	0.3021	5.661E+05	5.661E+05	-0.34148	1.000E+00
30	1984	6.327E-01	4.770E-01	0.4589	8.272E+05	8.272E+05	-0.28255	1.000E+00
31	1985	9.436E-01	3.875E-01	0.6587	9.647E+05	9.647E+05	-0.89000	1.000E+00
32	1986	2.734E-01	3.437E-01	0.2896	3.761E+05	3.761E+05	0.22874	1.000E+00
33	1987	3.145E-01	3.624E-01	0.3200	4.383E+05	4.383E+05	0.14181	1.000E+00
34	1988	3.214E-01	3.764E-01	0.3168	4.506E+05	4.506E+05	0.15790	1.000E+00
35	1989	4.488E-01	3.722E-01	0.4161	5.852E+05	5.852E+05	-0.18730	1.000E+00
36	1990	4.166E-01	3.651E-01	0.3348	4.620E+05	4.620E+05	-0.13185	1.000E+00
37	1991	5.245E-01	3.864E-01	0.2638	3.851E+05	3.851E+05	-0.30564	1.000E+00
38	1992	6.395E-02	3.673E-01	0.5480	7.607E+05	7.607E+05	1.74806	1.000E+00

39	1993	1.271E-01	3.316E-01	0.3722	4.663E+05	4.663E+05	0.95875	1.000E+00
40	1994	1.912E-01	3.221E-01	0.4082	4.969E+05	4.969E+05	0.52175	1.000E+00
41	1995	2.471E-01	3.262E-01	0.2903	3.580E+05	3.580E+05	0.27803	1.000E+00
42	1996	2.790E-01	3.609E-01	0.2274	3.102E+05	3.102E+05	0.25768	1.000E+00
43	1997	3.010E-01	4.130E-01	0.2113	3.298E+05	3.298E+05	0.31631	1.000E+00
44	1998	1.645E-01	4.871E-01	0.1533	2.822E+05	2.822E+05	1.08571	1.000E+00
45	1999	2.260E-01	5.671E-01	0.2143	4.593E+05	4.593E+05	0.92008	1.000E+00
46	2000	2.805E-01	5.867E-01	0.3766	8.350E+05	8.350E+05	0.73789	1.000E+00
47	2001	5.031E-01	5.669E-01	0.3539	7.581E+05	7.581E+05	0.11942	1.000E+00
48	2002	5.578E-01	5.558E-01	0.3516	7.384E+05	7.384E+05	-0.00373	1.000E+00
49	2003	3.895E-01	5.702E-01	0.2637	5.682E+05	5.682E+05	0.38103	1.000E+00
50	2004	6.227E-01	5.954E-01	0.3093	6.959E+05	6.959E+05	-0.04485	1.000E+00
51	2005	5.363E-01	6.317E-01	0.2270	5.418E+05	5.418E+05	0.16367	1.000E+00
52	2006	3.206E-01	7.113E-01	0.1760	4.731E+05	4.731E+05	0.79684	1.000E+00
53	2007	2.545E-01	7.720E-01	0.2788	8.135E+05	8.135E+05	1.10976	1.000E+00
54	2008	1.146E+00	7.113E-01	0.5067	1.362E+06	1.362E+06	-0.47719	1.000E+00
55	2009	1.358E+00	5.229E-01	0.7716	1.525E+06	1.525E+06	-0.95431	1.000E+00

* Asterisk indicates missing value(s).
SAFMC Red Snapper (2010) Landings and Indices Page 5

RESULTS FOR DATA SERIES # 2 (NON-BOOTSTRAPPED) Commercial

Data type I1: Abundance index (annual average) Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Statist weight
1	1955	0.000E+00	0.000E+00	--	*	1.152E+00	0.00000	1.000E+00
2	1956	0.000E+00	0.000E+00	--	*	1.233E+00	0.00000	1.000E+00
3	1957	0.000E+00	0.000E+00	--	*	1.261E+00	0.00000	1.000E+00
4	1958	0.000E+00	0.000E+00	--	*	1.267E+00	0.00000	1.000E+00
5	1959	0.000E+00	0.000E+00	--	*	1.292E+00	0.00000	1.000E+00
6	1960	0.000E+00	0.000E+00	--	*	1.307E+00	0.00000	1.000E+00
7	1961	0.000E+00	0.000E+00	--	*	1.303E+00	0.00000	1.000E+00
8	1962	0.000E+00	0.000E+00	--	*	1.303E+00	0.00000	1.000E+00
9	1963	0.000E+00	0.000E+00	--	*	1.342E+00	0.00000	1.000E+00
10	1964	0.000E+00	0.000E+00	--	*	1.391E+00	0.00000	1.000E+00
11	1965	0.000E+00	0.000E+00	--	*	1.411E+00	0.00000	1.000E+00
12	1966	0.000E+00	0.000E+00	--	*	1.388E+00	0.00000	1.000E+00
13	1967	0.000E+00	0.000E+00	--	*	1.306E+00	0.00000	1.000E+00
14	1968	0.000E+00	0.000E+00	--	*	1.165E+00	0.00000	1.000E+00
15	1969	0.000E+00	0.000E+00	--	*	1.055E+00	0.00000	1.000E+00
16	1970	0.000E+00	0.000E+00	--	*	1.001E+00	0.00000	1.000E+00
17	1971	0.000E+00	0.000E+00	--	*	9.791E-01	0.00000	1.000E+00
18	1972	0.000E+00	0.000E+00	--	*	9.888E-01	0.00000	1.000E+00
19	1973	0.000E+00	0.000E+00	--	*	1.021E+00	0.00000	1.000E+00
20	1974	0.000E+00	0.000E+00	--	*	1.022E+00	0.00000	1.000E+00
21	1975	0.000E+00	0.000E+00	--	*	9.573E-01	0.00000	1.000E+00
22	1976	0.000E+00	0.000E+00	--	*	8.724E-01	0.00000	1.000E+00
23	1977	0.000E+00	0.000E+00	--	*	7.805E-01	0.00000	1.000E+00
24	1978	0.000E+00	0.000E+00	--	*	6.821E-01	0.00000	1.000E+00
25	1979	0.000E+00	0.000E+00	--	*	6.121E-01	0.00000	1.000E+00
26	1980	0.000E+00	0.000E+00	--	*	5.753E-01	0.00000	1.000E+00
27	1981	0.000E+00	0.000E+00	--	*	5.237E-01	0.00000	1.000E+00
28	1982	0.000E+00	0.000E+00	--	*	4.691E-01	0.00000	1.000E+00
29	1983	0.000E+00	0.000E+00	--	*	4.600E-01	0.00000	1.000E+00
30	1984	0.000E+00	0.000E+00	--	*	4.425E-01	0.00000	1.000E+00
31	1985	0.000E+00	0.000E+00	--	*	3.595E-01	0.00000	1.000E+00
32	1986	0.000E+00	0.000E+00	--	*	3.189E-01	0.00000	1.000E+00
33	1987	0.000E+00	0.000E+00	--	*	3.362E-01	0.00000	1.000E+00
34	1988	0.000E+00	0.000E+00	--	*	3.491E-01	0.00000	1.000E+00
35	1989	0.000E+00	0.000E+00	--	*	3.452E-01	0.00000	1.000E+00
36	1990	0.000E+00	0.000E+00	--	*	3.387E-01	0.00000	1.000E+00
37	1991	0.000E+00	0.000E+00	--	*	3.584E-01	0.00000	1.000E+00
38	1992	0.000E+00	0.000E+00	--	*	3.408E-01	0.00000	1.000E+00
39	1993	1.000E+00	1.000E+00	--	7.504E-01	3.076E-01	0.89191	1.000E+00
40	1994	1.000E+00	1.000E+00	--	5.850E-01	2.988E-01	0.67176	1.000E+00
41	1995	1.000E+00	1.000E+00	--	5.716E-01	3.027E-01	0.63591	1.000E+00
42	1996	1.000E+00	1.000E+00	--	3.438E-01	3.348E-01	0.02638	1.000E+00

43	1997	1.000E+00	1.000E+00	--	3.289E-01	3.832E-01	-0.15285	1.000E+00
44	1998	1.000E+00	1.000E+00	--	3.539E-01	4.519E-01	-0.24441	1.000E+00
45	1999	1.000E+00	1.000E+00	--	4.082E-01	5.261E-01	-0.25360	1.000E+00
46	2000	1.000E+00	1.000E+00	--	3.874E-01	5.443E-01	-0.33999	1.000E+00
47	2001	1.000E+00	1.000E+00	--	6.090E-01	5.259E-01	0.14663	1.000E+00
48	2002	1.000E+00	1.000E+00	--	6.552E-01	5.156E-01	0.23964	1.000E+00
49	2003	1.000E+00	1.000E+00	--	5.111E-01	5.290E-01	-0.03443	1.000E+00
50	2004	1.000E+00	1.000E+00	--	6.624E-01	5.523E-01	0.18172	1.000E+00
51	2005	1.000E+00	1.000E+00	--	5.649E-01	5.860E-01	-0.03673	1.000E+00
52	2006	1.000E+00	1.000E+00	--	2.797E-01	6.599E-01	-0.85840	1.000E+00
53	2007	1.000E+00	1.000E+00	--	3.054E-01	7.162E-01	-0.85223	1.000E+00
54	2008	1.000E+00	1.000E+00	--	5.525E-01	6.598E-01	-0.17763	1.000E+00
55	2009	1.000E+00	1.000E+00	--	8.823E-01	4.850E-01	0.59827	1.000E+00

* Asterisk indicates missing value(s).
SAFMC Red Snapper (2010) Landings and Indices Page 6

ESTIMATES FROM BOOTSTRAPPED ANALYSIS

Param name	Point estimate	Estimated bias in pt estimate	Estimated relative bias	Bias-corrected approximate confidence limits 80% lower	80% upper	50% lower	50% upper	Inter-quartile range	Relative IQ range
B1/K	3.625E-01	5.486E-02	15.13%	3.491E-01	1.020E+00	3.574E-01	3.811E-01	2.372E-02	0.065
K	1.248E+07	2.563E+06	20.54%	1.096E+07	2.041E+07	1.137E+07	1.410E+07	2.726E+06	0.218
q(1)	2.646E-07	-2.457E-08	-9.28%	1.668E-07	3.442E-07	2.374E-07	3.084E-07	7.096E-08	0.268
q(2)	2.455E-07	-1.624E-08	-6.62%	1.306E-07	3.423E-07	1.927E-07	2.984E-07	1.057E-07	0.431
MSY	1.251E+06	1.281E+04	1.02%	9.973E+05	1.266E+06	1.227E+06	1.257E+06	2.942E+04	0.024
Ye(2010)	5.537E+05	4.346E+04	7.85%	1.731E+05	8.992E+05	3.261E+05	7.203E+05	3.942E+05	0.712
Y.@Fmsy	3.170E+05	5.981E+04	18.86%	8.833E+04	6.103E+05	1.732E+05	4.336E+05	2.604E+05	0.821
Bmsy	6.240E+06	1.282E+06	20.54%	5.480E+06	1.020E+07	5.687E+06	7.050E+06	1.363E+06	0.218
Fmsy	2.005E-01	-1.454E-02	-7.25%	1.192E-01	2.317E-01	1.695E-01	2.217E-01	5.217E-02	0.260
fmsy(1)	7.576E+05	3.822E+04	5.05%	6.395E+05	8.966E+05	6.830E+05	8.172E+05	1.342E+05	0.177
fmsy(2)	8.166E+05	4.608E+04	5.64%	6.242E+05	1.105E+06	7.101E+05	9.445E+05	2.344E+05	0.287
B./Bmsy	2.535E-01	5.465E-02	21.56%	7.884E-02	5.272E-01	1.402E-01	3.629E-01	2.227E-01	0.879
F./Fmsy	3.849E+00	5.564E-01	14.46%	2.251E+00	8.048E+00	2.966E+00	5.636E+00	2.669E+00	0.693
Ye./MSY	4.427E-01	4.086E-02	9.23%	1.515E-01	7.764E-01	2.608E-01	5.942E-01	3.334E-01	0.753
q2/q1	9.277E-01	3.104E-02	3.35%	7.019E-01	1.213E+00	7.888E-01	1.064E+00	2.753E-01	0.297

INFORMATION FOR REPAST (Prager, Porch, Shertzer, & Caddy. 2003. NAJFM 23: 349-361)

Unitless limit reference point in F (Fmsy/F.): 0.2598
CV of above (from bootstrap distribution): 0.5149

NOTES ON BOOTSTRAPPED ESTIMATES:

- Bootstrap results were computed from 1000 trials.
- Results are conditional on bounds set on MSY and K in the input file.
- All bootstrapped intervals are approximate. The statistical literature recommends using at least 1000 trials for accurate 95% intervals. The default 80% intervals used by ASPIC should require fewer trials for equivalent accuracy. Using at least 500 trials is recommended.
- Bias estimates are typically of high variance and therefore may be misleading.

Trials replaced for lack of convergence: 0
Trials replaced for q out-of-bounds: 0
Trials replaced for K out-of-bounds: 28
Trials replaced for MSY out of bounds: 2
Residual-adjustment factor: 1.0529

Elapsed time: 1 hours, 8 minutes, 43 seconds.

4 Comments and the Pre-Review Process

4.1 Comments from Panel Members

Submitted by Panelist Dr. Frank Hester on 9-28-10:
One panelist was concerned that the most recent changes made in the base case could not be reviewed by the AW before the document was released. The panelist has, where possible, joined in consensus building for SEDAR 24, but cannot accept unseen the new base case without an opportunity to review the changes and their results.

4.2 Pre-Review Process Introduction

A draft assessment report was made available for public comment from August 26 – September 6, 2010. The intent of public comment was to allow interested parties the opportunity to address the draft report of a SEDAR stock assessment before the report and assessment went to the Review Panel. The assessment panel made changes to the draft report in response to comments received.

Comments were made available to Assessment Process panelists as they were received. On September 9, 2010, the assessment panel met via webinar to review comments and recommend changes to the model and report. At the webinar panelists reviewed a summary of the comments and the recommended model and report changes are described in section 4.2.

During the September 9 webinar the panel also reviewed extensive comments provided by AW panelists. Changes resulting from this component of the pre-review are summarized in section 4.3.

4.3 Summary of Comments Received and Responses

A total of 43 comments (from 19 individuals) were received during the comment period. The comments were summarized and broken down into four general categories: 1) comments on data, 2) comments on model results, 3) comments on the SEDAR process, and 4) miscellaneous comments.

4.3.1 Comments on data

- Questioning the use and accuracy of historical data; suggest starting the model in later years (1986 was one suggestion)
- Questioning the use and accuracy of MRFSS data and MRFSS sample size adequacy
- Independent surveys are not very accurate for red snapper and fishery dependent monitored tagging and onboard observer programs would be better
- General comment that the assessment did not use real/relevant/sound science/data
- Concern that primarily fishery-dependent landings data are used for model inputs

- Dome shaped selectivity should be used
- Remove all effort data from south of X county (Martin County and Broward were suggested)
- Headboat and charter boat catch data should be separated
- Concern SEDAR did include recreational anecdotal information
- Discard mortality is too high and needs to be revisited
- Natural mortality is too low and needs to be revisited

Responses to comments on data

The data workshop panel and assessment panel acknowledge that there is uncertainty around early years of data. MRFSS data and associated uncertainty about the data are well documented. The data workshop panelists and the assessment panelists recommended the MRFSS data be used for the SEDAR 24 assessment.

The assessment panel recommended a sensitivity run that uses only data from 1976-2009. This is explained in the SEDAR 24 assessment report, section 3.1.1.3, Sensitivity #10: "S10: Starting year of the model was 1976. Initial (1976) numbers at age were estimated in this sensitivity run, with penalized deviation from the stable age structure that corresponded to the initial, estimated mortality rate." The results of the model beginning in 1976 were similar to the "base" model beginning in 1955 (Table 3.15 of the assessment report). In addition, based on public comment the panel recommended an additional sensitivity run that begins the model in 1986.

Existing independent surveys do not adequately capture red snapper, therefore no fishery independent surveys were included in the assessment model. New fishery independent sampling program efforts are underway that expand independent surveys and future programs will consider a variety of sampling gears. Many prior assessments have recommended an increase in observer coverage. The panel agreed that increased observer coverage would be useful.

In SEDAR 24 the assessment panel recommended that dome shaped selectivity be used for commercial dive, for-hire, and private recreational fleets. Only the commercial handline was not modeled with dome shaped selectivity. Separation of the headboat and chartboat data was discussed in the data workshop and again in the assessment webinars and was not recommended by either group.

The panel recommended contacting MRFSS to find out what level of post-stratification of MRFSS data was applied. The following is an excerpt of the response.

> "The catch rate sampling will appropriately include sample catches and sample effort (number of anglers interviewed) throughout the coast-wide unit based on the weighted representative sample design with respect to site selection. If the estimated activities at the sites and the resultant samples accurately represent that distribution of effort, then the state estimate will be unbiased even if regions within the state have variable catch rates."

> "… To conclude, our surveys were designed to sample and produce estimates at the state level. In Florida, the state-level has been set at East Florida, Nassau to Miami-Dade county. Although we are aware of potential biases in our design due to assumptions in sample distribution that may not be accurate, to divide our data via a stratification process will only produce less precise estimates of catch-rates that may or may not reflect true regional catch rates. We do not support any further post-stratification of EFL survey results. (post-stratification is generally only used for stock delineation, e.g., north and south of Hatteras, or to exclude Monroe county, FL from WFL 'state')."

Changes made to the model and report

- The panel recommended a sensitivity analysis starting the model in 1986.
- Add "improve fishery independent sampling" as research recommendation.

4.3.2 Comments on model results

- Questioning how estimated biomass could be below MSY in early years (1960) when there is a perception that few boats were operating over only the shallow part of habitat
- Questioning how abundance at age can be so low for old fish in recent years
- Questioning the difference in biomass/spawning stock/abundance-at-age estimated between SEDAR 15 and SEDAR 24 for given years
- Questioning how SA red snapper can have a small year class when at a healthy level of biomass

Responses to comments on model results

Several comments were received comparing the SEDAR 24 assessment to SEDAR 15 (South Atlantic red snapper 2008 assessment) and SEDAR 7 (Gulf of Mexico red snapper 2005 assessment). The data and decisions made about selectivity, catchability, landings, and discards in these models are very different and render comparison of results invalid.

Recruitment is driven by many factors, including environmental conditions and spawning stock biomass. A large spawning biomass does not guarantee high recruitment nor does a low SSB guarantee poor recruitment.

The Panel discussed perceived difficulties in estimating abundance of older fish in recent years, and the possibility that current values are underestimated. This is difficult to adequately evaluate due to the lack of independent abundance indices.

4.3.3 Comments on SEDAR process

- Questioning the degree of public input in the SEDAR process
- Suggestion that an independent review of red snapper should be done by a 3rd party.
- The assessment report if too long and too unreadable.
- Physical meetings are preferred for assessments, preference for a combination of webinars and physical meetings
- Not enough webinars were scheduled
- SEDAR is cutting corners because they are trying to reduce costs
- SEDAR 24 was rushed
- SEDAR 24 comment period was too short

Responses to comments on SEDAR process

SouthEast Data, Assessment and Review is a process that is continually evaluated and improved. The SEDAR steering committee will evaluate the webinar process and make suggestions on future directions. The SEDAR assessment process was moved to a webinar-only format to try to increase participation by fishermen and to reduce travel costs. The webinar format allows the analysts to get recommendations from the panel then go back to make changes to the model.

The SEDAR 24 red snapper assessment will be reviewed by an independent panel of experts from the Center for Independent Experts (CIE) in October, 2010. The assessment report released on August 26, 2010 was also reviewed by a CIE expert who is an experienced stock assessment scientist from outside the US.

The SEDAR process is intended to be open and transparent. Recreational and commercial fishermen were appointed as panelists to both the data workshop and the assessment process. All data workshop meetings and assessment webinars are open to the public and observers have been present at all red snapper assessment webinars.

The assessment report is necessarily long and detailed to cover all of the required detail that the reviewers will need to assess the validity of the work. We try to make the document as clear as possible, but acknowledge that the language and concepts of stock assessments are complex.

SEDAR 24 was rushed, intentionally, both in its initial planning and its completion date. Elevating the planned update to a benchmark in early 2010 significantly reduced the advance planning time that is devoted to most benchmarks. Furthermore, by requesting final results by December 2010, the Council knowingly imposed a strict and essentially rushed schedule to the entire process. Under normal circumstance the Council would have received results of SEDAR 24 in June 2011. The Council and all participants in the process were informed of the realities such a schedule imposed on the process and on their time to review various components of the assessment.

Changes made to the model and report

- Add "examine or develop ways to include anecdotal information in SEDAR assessments" as a research recommendation.

4.3.4 Miscellaneous comments

- The SEDAR 24 final report should specifically address the items in the Stokes CIE reviewer report
- Comment that additional models should be run (VPA and SVPA were suggested)
- Comment that constituents will not know whether a 10 year rebuilding time will be required before the end of the assessment process and comment period
- The panel should conduct a 16-inch minimum size analysis for red snapper

Responses to miscellaneous comments

Two models were prepared for SEDAR 24: the Beaufort Assessment Model, which is a forward-projecting statistical catch-at-age model, and a Surplus Production Model. The requests for a VPA have not been ignored and the reasons for not conducting a VPA model are discussed in Section 3 of the report, copied here.

> "A VPA was not pursued, for several reasons. A major assumption of VPAs is that catch at age of each fleet in each year is known precisely, which is not a valid assumption for U.S. Atlantic snapper-grouper stocks in general, and the red snapper stock in particular. For example, only seven private recreational (a dominant fleet for red snapper) fishing trips were sampled for red snapper ages prior to 2009. Thus, developing catch-age matrices would require strong assumptions to fill in the data gaps; this obstacle is not insurmountable in principle, but if pursued, should likely be done at a Data Workshop by data providers who are most familiar with the strengths and weaknesses of each data set. Relaxing the assumption of known catch at age was one reason for the advent of statistical catch-age models (e.g., BAM). The AW panel thought that committing its limited resources to the BAM, SSRA, and surplus-production models would be more productive."

The South Atlantic Council determines rebuilding probability, and a rebuilding plan must have at least a 50% chance of success. The management actions or analysis of alternatives that come from any SEDAR assessment are implemented outside the SEDAR process and cannot be done by SEDAR panels or through the SEDAR process.

The panel recommends that the SEDAR process develop a mechanism for dealing with CIE reviewer suggestions.

Changes made to the model and report

- Add elaboration in the data update section indicating the smoothing was done as a response to the data workshop CIE reviewer report.

4.4 Recommendations from the AW panel

4.4.1 Comments from panelists There was some overlap in public comment and panelist comments on the draft assessment report. For brevity, the duplicate issues are not reiterated here. After discussion, the following changes were made to the model:

- The panel recommended changing the commercial:recreational landings ratios back in time, using 9 lb for historical average commercial weight. This will reduce historical recreational (for-hire and private) landings
- Add more summary of the selectivity discussions by the panel to the AW report
- Add figure with total landings and MSY line superimposed on it to the AW report
- Explain the metric for SSB better in report
- Add explanation of the MC bootstraps and what they really mean (uncertainty estimates not probabilities)
- Give clearer explanation for initial F estimation
- Remove unused parameters in Appendix B