Pre-review draft of the Assessment Report

8-26-10

SEDAR24-AW13

This draft report was released for a public comment period that occurred during August 26-Sept 6, 2010. Following the public comment period the draft was made into a working document for the Assessment Process. This is working document SEDAR24-AW13. The final assessment report will be available on Sept 29, 2010.

SEDAR

SouthEast Data, Assessment, and Review

South Atlantic Red Snapper

SECTION III: Assessment Report

August 2010

.

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

Table of Contents (to be completed)

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 will continue September 7-29, 2010, to address comments regarding the Assessment report. Specific assessment webinar dates will be 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:

10. F=0, F=current, F=Fmsy, Ftarget (OY),
11. F=Frebuild (max that rebuild in allowed time)

    a. If stock is overfishing

12. F=Fcurrent, F=Fmsy, F= Ftarget (OY)

    a. If stock is neither overfished nor overfishing

13. F=Fcurrent, F=Fmsy, F=Ftarget (OY)
14. 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.
15. 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.
16. No later than September 27, 2010, complete the Assessment Workshop Report (Section III of the SEDAR Stock Assessment Report). March 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.
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
First	Last	Web1	Web2	Web 2b	Web 2c	Web 2d	Web 3	Web 3b	Web 3c
PANELISTS									
Steve	Amick								
Luiz	Barbieri	x	x	x	x			x	x
Zach	Bowen								
Bobby	Cardin				x	x	x	x	
Rob	Cheshire	x	x	x	x	x	x	x	x
Chip	Collier	x	x	x				x	x
Andy	Cooper	x		x	x			x	x
Kenny	Fex	x		x					x
Frank	Hester		x	x	x	x	x	x	x
Jim	Ianelli	x	x	x	x	x		x	
Paul	Spencer		x			x		x	x
Robert	Johnson							x	x
Brian	Linton	x	x		x			x	x
Mike	Murphy	x	x		x	x			
Behzad	Mahmoudi		x				x	x	
Jennifer	Potts		x						
Amy	Schueller	x	x	x	x	x	x	x	x
Kyle	Shertzer	x	x	x	x	x	x	x	x
Rodney	Smith								
Doug	Vaughan	x	x	x	x	x	x	x	x
Erik	Williams	x	x	x	x	x	x	x	x
John	Quinlan	x	x	x	x	x		x	x

COUNCIL									
George	Geiger	x	x	x	x	x	x	x	x
Charlie	Phillips	x	n	x	x	x	x	x	x
STAFF									
John	Carmichael	x	x		x	x		x	
Rick	DeVictor		x			x			
Kari	Fenske	x	x	x	x	x	x	x	x
Rachael	Lindsay								x
Bob	Mahood					x			
Julie	Neer	x	x	x	x	x		x	x
Dale	Theiling	x	x						
Gregg	Waugh							x	x
OBSERVERS									
Joey	Ballenger	x	x	x				x	
Dick	Brame		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
Sera	Drevenak	x	x	x	x	x	x	x	x
Nick	Farmer							x	
Ted	Forsgren	x	x	x		x	x		
Bob	Gill			x	x				
Rebekah	Hamed				x	x			

Mathew	Hardy		x						
Ben	Hartig			x					
Rusty	Hudson	x	x	x	x	x	x	x	x
Jimmy	Hull		x		x	x		x	x
John	Iarson		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
Jack	Mountford		x						
David	Nelson		x		x	x	x	x	x
Don	Newhauser		x	x			x		
Bonnie	Ponwith			x					
Marcel	Reichert		x	x					
Jessica	Stephen		x	x					
Andy	Strelcheck		x			x			
Ken	Stump				x				
Jon	Turner		x						
Jim	Waters		x	x			x	x	
Karl	Wickstrom		x	x	x	x	x		

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

Document #	Title	Authors
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
	Reference Documents Added During Assessment Process	
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

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. The length and age composition data, ageing error matrix, and generation time tables are large and not easily tabulated for reports. The Microsoft Excel workbook, RS_AW_InputFINAL.xlsx, contains these data and other information used in sensitivity runs and bootstrap procedures (e.g. upper and lower bounds on the point estimate of discard mortality). Data considerations for surplus-production and SRA models are covered in those sections.

A summary of the base run model input is given in tables 1-4. 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 complete by the deadline for the final data workbook for the DW. 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 handline gears were provided and approved for use in sensitivity runs and bootstrap procedures. The sample sizes for 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 and the SEDAR 24 AW spreadsheet for age compositions.

2.2 Data Updates and Revisions

2.2.1 Landings An error 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 24 and indicated any method to separate the landings would give poor estimates. 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).

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 steepness of the increase. Examination of age and length compositions showed evidence of a strong year class recruiting to the fishery but the panel generally felt 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.

The SEDAR 24 AW panel felt the commercial ratio method used to estimate historical landings was inadequate to capture the inter-annual variability displayed in the predicted estimates. The scale of the historical landings is important to the model but not the annual variability. 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 was unlikely to have no discards 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 diving length composition was reduced to just 2007 instead of pooling across years since almost all the samples in the pooled composition came from 2007.

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).
$G = \mathrm{P}lxbxx/\mathrm{P}lxbx$
where summation was over ages x=1 through 100 (by which age cumulative survival is essentially zero), *lx* is the number of fish at age starting with 1 fish at age 1 and decrementing based on natural mortality only, and *bx* is per capita birth rate at age. Because biomass is used as a proxy for reproduction in our model, we substitute the product of *PfxMfxWx* for *bx* in this equation, where *Pfx* is the proportion female at age, *Mmx* is the proportion of mature females at age, and *Wx* 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	Handline	CV Handline
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 (handline). 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	Handline	Diving	Handline discard	ForHire	Private	Handline	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	
2001	151			168	6		27		28	124
2002	200			167			105		10	30
2003	191			223	12		108		10	
2004	154			174			98		30	
2005	118		44				130			
2006	125		30				123			
2007	86		65	142			51		138	
2008	117		63				52			
2009	210		56	135	10	6	359	11	294	17

Table 2. Red Snapper length and age composition sample sizes (number of trips sampled).

	Recreational				Commercial		
	Landings		Discards		Landings		Discards
	Numbers (1000's)				Whole Pounds (1000's)		
Year	ForHire	Private	ForHire	Private	Handline	diving	Handline
1955	150.885	29.714			497.800		
1956	165.256	39.009			484.300		
1957	179.645	48.918			868.900		
1958	186.606	57.392			617.300		
1959	189.092	65.019			662.700		
1960	188.831	71.844			677.100		
1961	184.514	77.015			799.800		
1962	175.490	80.303			662.577		
1963	169.065	85.378			504.840		
1964	174.034	96.962			559.491		
1965	191.198	115.819			656.795		
1966	214.089	138.365			740.057		
1967	231.702	157.512			963.706		
1968	231.522	164.458			1069.332		
1969	211.261	157.125			700.493		
1970	183.356	144.275			640.918		
1971	158.780	134.286			543.433		
1972	144.995	133.576			468.602		
1973	145.838	146.128			387.344		
1974	158.545	169.804			632.507		
1975	171.132	192.748			745.363		
1976	174.612	205.356			619.011		
1977	168.119	206.069			649.273		
1978	152.125	194.560			589.918		
1979	129.685	174.180			409.939		
1980	105.730	151.399			380.596		
1981	69.519	121.730			371.379		
1982	37.726	52.932			306.128		
1983	59.229	43.885	42.281	8.679	310.268		
1984	60.094	161.385	121.668	22.845	248.195	1.317	
1985	97.119	178.659	27.775	63.501	240.971	2.547	
1986	98.995	78.195	0.158	8.679	215.743	0.508	
1987	40.286	51.281	0.158	106.560	187.211	0.030	
1988	62.664	98.608	0.158	48.373	164.123	0.013	
1989	44.461	107.354	0.158	20.038	258.478	0.006	
1990	26.656	11.091	0.158	8.679	215.047	1.859	
1991	30.623	31.351	0.697	35.853	134.032	5.898	
1992	45.611	38.345	17.936	19.492	89.062	9.614	14.233
1993	14.948	10.864	33.397	48.989	189.994	5.611	14.926
1994	22.589	13.567	7.359	62.577	179.615	13.116	20.638
1995	22.423	2.386	24.366	37.932	166.772	10.037	19.437
1996	8.681	11.419	5.053	17.628	130.650	6.153	24.867
1997	62.935	3.545	19.038	8.679	101.232	7.531	27.458
1998	18.112	7.585	8.856	22.970	80.009	8.063	21.106
1999	49.363	22.660	47.594	132.663	80.506	9.974	19.387
2000	19.508	57.664	32.530	223.334	92.109	10.376	18.975
2001	21.879	40.185	32.845	179.264	175.233	18.238	19.014
2002	30.115	33.865	25.886	105.891	163.092	22.097	42.356
2003	23.899	16.111	21.700	139.401	118.803	17.454	13.973
2004	24.796	25.390	37.465	163.953	149.791	19.647	5.170
2005	23.113	21.172	49.435	79.725	118.015	9.344	4.999
2006	17.293	14.541	23.194	115.593	80.291	4.163	7.425
2007	17.326	31.324	118.249	339.128	104.737	7.514	14.759
2008	41.780	84.502	59.846	352.213	240.735	6.304	15.512
2009	50.210	92.814	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

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.

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. 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 and is described in a supporting document (SEDAR-24-RW02). Abbreviations used in this report 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.

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. 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 (commercial, 0.48; for-hire, 0.41; and private, 0.39). 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 1955–2009. 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). Initial (1955) numbers at age assumed the stable age structure that corresponded to the initial, estimated total mortality rate and catch-weighted average selectivity.

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. 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.

Recruitment Estimated 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; because h is often difficult to estimate reliably (Conn et al. 2010), a normal prior distribution was used to inform estimation (SEDAR-24-AW06). In years when composition data could provide information on year-class strength (1973–2009), estimated recruitment varied with lognormal residuals. In years prior, recruitment followed the Beverton–Holt model precisely (similar to an age-structured production model).

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 for-hire/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, historical landings of for-hire and private fleets were estimated indirectly by the DW using a ratio method, and they are treated in this assessment as a 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). 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. 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.

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.

Diffuse priors were used for estimating parameters of selectivity functions. These priors assumed normal distributions with $CV = 1.0$, and were intended to provide only weak information to help the optimization routine during model execution. Priors help by steering estimation away from parameter space with no response in the likelihood surface. Without these diffuse priors, it is possible during the optimization search that a selectivity parameter could become unimportant, for example if its bounds were set too wide and depending on values of other parameters. When this happens, the likelihood gradient with respect to the aimless parameter approaches zero even if the parameter is not at its globally best value. Diffuse priors help avoid that situation.

Indices of abundance The model was fit to three fishery dependent indices of 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 abundance to estimated 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 [0.0,0.04] 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).

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 ($\mathrm{SSB}_{\mathrm{MSY}}$). In this assessment, spawning biomass measures total gonad weight of mature females. These benchmarks are conditional on the estimated selectivity functions. 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 CVs of landings and discards (in arithmetic space) were assumed equal to 0.05, to achieve a close fit to these time series while allowing some imprecision. The CVs of indices varied annually and 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. This approach reflects the belief that individual fish caught per trip do not represent independent samples, but rather the basic sampling unit occurs at the level of trip.

In addition to likelihoods, several penalties and prior distributions were included in the compound objective function. In some cases, as with spawner-recruit steepness and selectivity slope parameters, priors were applied. Variability around the spawner-recruit curve was assumed lognormal. Priors and penalties 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.

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). However, in the base-run application to red snapper, all weights to data sources were set to 1.0.

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) linearly increasing catchability with slope of 0.02 until 2003 and constant after then; and 4) descending limb of selectivity for-hire and private recreational fleets saturates at the value 0.3. 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 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 to constant $M = 0.05$ so as to provide the same cumulative survival through the oldest observed age)
- S2: High M at age (Lorenzen estimates rescaled to constant $M = 0.12$ so as to provide the same cumulative survival through the oldest observed age)
- S3: Low discard mortality probabilities (commercial lines $\delta = 0.34$, for-hire $\delta = 0.29$, private $\delta = 0.27$)
- S4: High discard mortality probabilities (commercial lines $\delta = 0.62$, for-hire $\delta = 0.54$, private $\delta = 0.52$)
- S5: Constant catchability
- S6: Linearly increasing catchability with slope of 0.04 until 2003 and constant after then
- S7: Random walk catchability for each fleet (standard deviation of 0.1)
- S8: Ageing error matrix included
- S9: Continuity run (features include linearly increasing catchability with slope of 0.02 throughout the entire assessment period, flat-topped selectivities for for-hire and recreational fleets, and spawning biomass based on body weight rather than gonad weight.)

- 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.
- S11: Low landings and discards for for-hire and private recreational fleets (historic values based on the 20^{th} percentile of ratio to commercial landings, 1981–2009 values based on point estimates minus 1 standard error)
- S12: High landings and discards for for-hire and private recreational fleets (historic values based on the 80^{th} percentile of ratio to commercial landings, 1981–2009 values based on point estimates plus 1 standard error)
- S13: Low landings and discards for commercial lines and dive fleets (values based on point estimates minus 1 standard error)
- S14: High landings and discards for commercial lines and dive fleets (values based on point estimates plus 1 standard error)
- S15: Headboat index de-emphasized through external weighting ($\omega_5^2 = 0.5$)
- S16: Headboat index emphasized through external weighting ($\omega_5^2 = 2.0$)
- S17: Commercial lines index de-emphasized through external weighting ($\omega_5^1 = 0.5$)
- S18: Commercial lines index emphasized through external weighting ($\omega_5^1 = 2.0$)
- S19: Age composition data de-emphasized through external weighting ($\omega_2 = 0.5$)
- S20: Age composition data emphasized through external weighting ($\omega_2 = 2.0$)
- S21: Length composition data de-emphasized through external weighting ($\omega_1 = 0.5$)
- S22: Length composition data emphasized through external weighting ($\omega_1 = 2.0$)
- S23: Flat-topped commercial lines selectivity; descending limb of recreational selectivities saturates at 0.1
- S24: Flat-topped commercial lines selectivity; descending limb of recreational selectivities saturates at 0.5
- S25: Dome-shaped commercial lines selectivity, descending limb saturates at 0.75; descending limb of recreational selectivities saturates at 0.1
- S26: Dome-shaped commercial lines selectivity, descending limb saturates at 0.75; descending limb of recreational selectivities saturates at 0.3
- S27: Dome-shaped commercial lines selectivity, descending limb saturates at 0.75; descending limb of recreational selectivities saturates at 0.5
- S28: Dome-shaped commercial lines selectivity, descending limb saturates at 0.5; descending limb of recreational selectivities saturates at 0.1
- S29: Dome-shaped commercial lines selectivity, descending limb saturates at 0.5; descending limb of recreational selectivities saturates at 0.3
- S30: Dome-shaped commercial lines selectivity, descending limb saturates at 0.5; descending limb of recreational selectivities saturates at 0.5
- S31: Compound extreme 1: high bound on natural mortality (S2), low bounds on discard mortalities (S3), constant catchability (S5), lowest dome-shaped selectivities (S28)
- S32: Compound extreme 2: low bound on natural mortality (S1), high bounds on discard mortalities (S4), increasing catchability of 0.04 (S6), highest selectivities (S24)

- S33: Retrospective run with data through 2008
- S34: Retrospective run with data through 2007
- S35: Retrospective run with data through 2006
- S36: Retrospective run with data through 2005

3.1.1.4 **Parameters Estimated** The model estimated annual fishing mortality rates of each fishery, selectivity parameters, catchability coefficients associated with indices, Beverton–Holt spawner-recruit parameters, 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 Fs 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 estimated variance (σ^2) of recruitment deviation: $\varsigma = \exp(\sigma^2/2)$. Then, equilibrium recruitment (R_{eq}) associated with any F is,

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

where R_0 is virgin recruitment, h is steepness, and 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).

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).

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 Fs corresponding to X% spawning potential ratio (i.e., spawners per recruit relative to that at the unfished level). These quantities may serve as proxies for F_{MSY}, if 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, catchability increase, 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). Of the 3000 trials, approximately 1.2% were discarded, because the model didn't properly converge (in all of these cases the spawner-recruit parameter steepness hit its prescribed upper bound of 0.99). This left n=2963 trials used to characterize uncertainty.

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 ($\hat{O}_{s,y}$),

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

The term $\sigma^2_{s,y}/2$ is a bias correction that centers the multiplicative error on the value of 1.0. Standard deviations in logspace 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. 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]).

Increase in catchability The slope of linear increase in catchability was drawn from a uniform distribution over the range [0.0, 0.04]. In all cases, catchability was assumed constant after 2003.

For-hire and private recreational selectivity In each MCB trial, the descending limb of the for-hire and private recreational selectivity saturated at a value 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 20^{th} and 80^{th} percentiles of observed ratios from which the point estimates were generated. Those bounds were then standardized around the value of one, and a uniform random number was drawn and applied as a multiplier to the historical time series (this approach conveniently preserves the smoothed structure). For for-hire historical landings, the multiplier was drawn from the range [0.68, 1.38], and for private historical landings, the multiplier was drawn from the range [0.44, 1.53].

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, 2010–2045. 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 (without bias correction) of each MCB fit was used to compute expected annual recruitment values ($\bar{R}_y$). Variability was added to the expected 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 $\hat{\sigma}$, where $\hat{\sigma}$ is the estimated 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). Thus, most projections were run to 2045, with 2044 being the critical year for rebuilding. Rebuilding is defined by the criterion that X% of projection replicates achieve stock recovery (i.e., $\text{SSB} \geq \text{SSB}_{\text{MSY}}$).

In addition, the rebuilding time frame was re-examined based on results of this assessment. Under U.S. regulations, the maximum allowable rebuilding time frame is 10 years, if a stock can rebuild within 10 years with $F = 0$. If not, the maximum allowable rebuilding time frame is one generation time (22 years for red snapper) plus the time required to achieve rebuilding with $F = 0$.

Projection scenarios Eleven constant-F projection scenarios were considered. Unless otherwise stated, the fishing rate in 2010 was F_{current}. 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 2044
- Scenario 9: $F = F_{\text{rebuild}}$, with probability 0.7 in the year 2044
- Scenario 10: $F = F_{\text{rebuild}}$, with probability 0.9 in the year 2044
- Scenario 11: $F = F_{\text{rebuild}}$, with probability 0.5 in the year 2019

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. Annual fits to length compositions from each fishery were reasonable in most years, as were fits to 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 is defined as the arc cosine of the dot product of two vectors.

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 were reasonable (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 0.44 (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 (as assumed), with an estimated quick descent from the age at full selection (age 3).

Estimated 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). Estimated 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.

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: steepness $\hat{h} = 0.97$, unfished age-1 recruitment $\widehat{R_0} = 498,328$, unfished spawning biomass per recruit $\phi_0 = 9.322e{-}4$, and empirical standard deviation of recruitment residuals in log space $\hat{\sigma} = 0.58$ (which resulted in bias correction $\hat{\varsigma} = 1.18$). Uncertainty in these quantities was estimated through the Monte Carlo/bootstrap (MCB) analysis (Figure 3.38). Although the estimate of steepness is high, it generally did not hit its upper bound and appears to be robust across MCB trials.

3.1.2.9 **Per Recruit and Equilibrium Analyses** Static spawning potential ratio (static SPR) shows a general trend of decline until the mid-1970s, and since then a stable trend at low values (Figure 3.39, Table 3.4).

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 0.18, 0.13, and 0.09, respectively. For comparison, F_{MSY} corresponds to about 21% SPR. Although this rate of fishing appears high relative to $F_{X\%}$ proxies, it occurs because the size limit offers some protection for spawners and because of the high estimate of steepness.

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 spawner-recruit curve with bias correction (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 $F_{\text{MSY}} = 0.24\ \text{y}^{-1}$, MSY = 2192 klb, $B_{\text{MSY}} = 10750$ mt, and $\text{SSB}_{\text{MSY}} = 112$ 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 mid-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 $\text{SSB}_{2009}/\text{MSST} = 0.07$ (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 2, 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). 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 $F_{2007-2009}/F_{\text{MSY}} = 3.64$ (Table 3.14). This estimate indicates current overfishing and appears robust across MCB trials (Figures 3.45, 3.46).

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), catchability (Figure 3.50), ageing error (Figure 3.51), continuity assumptions (Figure 3.52), starting year of the assessment model (Figure 3.53), landings streams (Figure 3.54), component weights of data sources (Figure 3.55), selectivity patterns (Figure 3.56), and compound extremes (Figure 3.57). In concert, sensitivity analyses suggested that qualitative results of the base run and MCB analysis were robust: the tendency was toward the status estimate of overfished, and toward the estimate of overfishing (Figure 3.59, Table 3.15). Retrospective analyses did not reveal strong patterns of overestimation or underestimation (Figure 3.58).

3.1.2.13 **Projections** Projection scenario 1, in which $F = 0$, predicted the stock could rebuild within 10 years with greater than 50% chance of recovery (Figure 3.60). If used to define the rebuilding time frame, this result would suggest that rebuilding should occur in 2019 (or by the start of 2020).

The projection with F at F_{current} predicted the stock to remain at low levels (Figure 3.61, Table 3.16). Projections with F at 65%, 75%, 85%, or 100% of F_{MSY} predicted increased biomass and landings (Figures 3.62–3.65, 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 3.66, Table 3.21). The F_{rebuild} projections did allow stock recovery, by design (Figures 3.67, 3.68, Tables 3.22, 3.23). Two F_{rebuild} projections (S8 and S10) were not completed in time for this draft report.

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, decomposing population dynamics into multiple processes including growth, mortality, and recruitment. A simplified approach, which may sacrifice some bias in favor of precision, is to aggregate data across age or length classes, and to summarize the relationship between 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 handline landings (see SEDAR-24 DW report). The charter boat portion of the for hire fleet and private 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 landings were combined with discards in weight for total removals (Table 3.24).

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 handline 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 3.24).

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 to the series to the mean. The commercial lines index was developed in pounds per hook hour. (Table 3.24).

An additional index was generated that incorporates a 2% catchability increase per year from the beginning of the earliest index (1976) until 2003 to match the AW recommendations on catchability. Many surplus–production model runs were completed prior to this decision and are presented here as there is considerable uncertainty in the degree and functional form of the catchability changes.

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:

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

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. These combinations are defined in Table 3.25. Initial runs indicated the model had difficulty estimating the ratio of initial biomass to carrying capacity ($B1/k$) and either did not converge or gave unrealistic results. Runs with $B1/k$ fixed at 0.2, 0.4, 0.6, and 0.8 were suggested to test the sensitivity of the model fit. This was implemented fully for the runs without catchability increase. Runs with catchability increasing were suggested later in the assessment process and due to time constraints a limited number of runs were completed to complement the estimated value of $B1/k$ from 0.4 to 0.8.

3.2.2 Model 2 Results

3.2.2.1 Model Fit The fit to the indices were similar across runs. Runs with higher $B1/k$ values (estimated or fixed) had higher CPUE values during the earliest part of the landings series where there were no observed indices. The runs with no catchability increase fit the early headboat index slightly better than the runs with catchability increase (Figure 3.69). All runs missed the reduction in CPUE in 2006 and subsequent increase until 2009 for both the headboat and commercial lines indices (Figures 3.69 and 3.70). 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 the run that best matched the base BAM run. Of the 1000 runs 40 were excluded because they were near the lower bound set for carry capacity and gave spurious estimates. Uncertainty can also be examined across the different configurations of model runs with the caveat that not all runs are equally likely. For example a $B1/k$ value of 0.8 in 1976 seems unlikely, as does a $B1/k$ estimate of 0.2 in 1950.

Estimated values of $B1/k$ varied from 0.33 to 0.41 across all runs except those that started in the highest year of the landings (1968) which estimated $B1/k$ at 0.56 and 0.88 (Table 3.25). The bootstrap estimated the 80% confidence interval of $B1/k$ between 0.19 and 0.53 with a point estimate of 0.32. MSY estimates ranged from 0.97 to 2.2 million pounds for all runs except for the run with high recreational landings which was around 3 million pounds for different levels of $B1/k$ (Table 3.26). Bootstrap runs estimated MSY between 1.7 and 3.1 million pounds with 80% confidence and a point estimate of 2.0 million pounds. F_{MSY} estimates from the different runs ranged from 0.16 to .31 (Table 3.27). The 80% confidence interval from the bootstrap estimated F_{MSY} between 0.17 and 2.0. B_{MSY} estimates varied from 3.2 to 22.1 million pounds. The low value comes from the run starting in 1976 with high $B1/k$ and the high value is from the high recreational landings run with a low $B1/k$, both of which are unlikely (Table 3.28). The bootstrap run estimated an 80% confidence that B_{MSY} is between 5.0 and 12.2 million pounds with a point estimate at 9.5 million pounds.

Output from the ASPIC run 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 wide 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 (Tables 3.29 and 3.29). Estimates of F/F_{MSY} for all runs range from 2.21 to 3.67 and B_{2010}/MSST ranges from 0.15 to 0.58. The bootstrap run estimates the 80% confidence interval of F/F_{MSY} between 2.2 and 8.0 and B_{2010}/MSST between 0.06 and 0.34. Uncertainty in results was evaluated by comparing model configurations (Figures 3.71 and 3.72). The historical values differ as expected due to uncertainty in landings. However, the recent trends and final estimates are very similar across runs. Confidence intervals (80%) for B/MSST and F/F_{MSY} from the 960 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 3.74). Kernel density plots were generated to evaluate the shape of the distribution of the current relative fishing mortality rate F/F_{MSY} and biomass relative to the minimum spawning stock threshold B/MSST (Figure 3.73).

3.2.2.4 **Discussion — Surplus Production Model** The production model estimates that current stock size is below MSST and that the current level of fishing is above the limit reference point F_{MSY} across all runs. 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/MSST. 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 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 ($\text{SSB}_{2009}/\text{MSST} = 0.07$), and that overfishing is occurring ($F_{2007-2009}/F_{\text{MSY}} = 3.64$). These results did not appear subject to retrospective error and were consistent across all configurations used in sensitivity runs. In addition, the same qualitative findings resulted from production model applications and stochastic stock reduction analysis (SEDAR24-RW-02). 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. Compared to other species, this stock of red snapper matures young relative to its maximum observed age. 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).

One 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. 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 age or length composition data, and thus it was not possible to estimate variability of year-class strength in the 1950s and 1960s. If potential stock productivity was higher in the 1950s and 1960s than in more recent time, this assessment could be overestimating steepness and underestimating the long-term potential MSY. Alternatively, the stock dynamics and productivity in the recent years might have resulted from environmental or ecological changes, and therefore the results from this assessment would represent our best estimate for the near future.

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.
- 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	0.22	0.30	0.66	0.00	0.22
2	410.5	16.2	0.15	1.02	2.25	0.01	0.55
3	515.4	20.3	0.12	2.07	4.57	0.02	0.84
4	597.9	23.5	0.10	3.29	7.26	0.04	0.96
5	662.8	26.1	0.09	4.54	10.01	0.07	0.99
6	713.8	28.1	0.09	5.72	12.61	0.11	1.00
7	754.0	29.7	0.08	6.79	14.96	0.15	1.00
8	785.6	30.9	0.08	7.71	17.01	0.19	1.00
9	810.4	31.9	0.08	8.50	18.74	0.22	1.00
10	829.9	32.7	0.07	9.16	20.19	0.25	1.00
11	845.3	33.3	0.07	9.70	21.38	0.28	1.00
12	857.4	33.8	0.07	10.14	22.35	0.30	1.00
13	866.9	34.1	0.07	10.49	23.13	0.32	1.00
14	874.4	34.4	0.07	10.78	23.76	0.34	1.00
15	880.3	34.7	0.07	11.00	24.26	0.35	1.00
16	884.9	34.8	0.07	11.19	24.66	0.36	1.00
17	888.6	35.0	0.07	11.33	24.98	0.37	1.00
18	891.4	35.1	0.07	11.44	25.23	0.37	1.00
19	893.7	35.2	0.07	11.53	25.43	0.38	1.00
20	895.5	35.3	0.07	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	576.80	418.72	303.63	227.72	181.99	150.19	125.46	104.81	88.44	74.63	62.98	53.14	45.30	38.61	32.91	28.05	23.90	20.37	17.37	100.23	2675.24
1956	576.80	414.83	295.83	222.44	182.80	153.00	127.98	106.93	90.23	76.14	64.25	54.22	46.21	39.39	33.57	28.61	24.39	20.79	17.72	102.25	2678.39
1957	577.18	413.20	286.64	211.87	176.40	152.64	129.56	108.40	91.48	77.20	65.14	54.97	46.85	39.93	34.04	29.01	24.73	21.07	17.96	103.67	2661.94
1958	577.06	411.22	273.52	196.24	162.63	143.48	125.98	106.96	90.39	76.29	64.37	54.32	46.30	39.46	33.63	28.67	24.43	20.83	17.75	102.45	2595.97
1959	576.74	409.88	269.16	185.24	150.44	132.74	118.89	104.42	89.56	75.68	63.87	53.90	45.94	39.15	33.37	28.44	24.24	20.66	17.61	101.65	2541.61
1960	576.32	408.55	263.39	178.82	140.31	121.79	109.14	97.78	86.75	74.40	62.87	53.06	45.22	38.55	32.85	28.00	23.87	20.34	17.34	100.07	2479.42
1961	575.73	407.36	258.65	172.29	134.18	112.88	99.53	89.22	80.74	71.63	61.43	51.92	44.25	37.72	32.15	27.40	23.36	19.91	16.97	97.92	2415.24
1962	574.92	406.31	253.96	166.42	127.66	106.80	91.28	80.52	72.91	65.98	58.54	50.20	42.85	36.53	31.13	26.54	22.62	19.28	16.43	94.83	2345.69
1963	574.04	405.94	254.56	164.25	123.96	102.15	86.83	74.24	66.15	59.89	54.20	48.09	41.65	35.56	30.31	25.83	22.02	18.77	15.99	92.32	2296.73
1964	573.24	405.43	255.59	165.50	123.10	99.85	83.61	71.10	61.40	54.71	49.54	44.83	40.17	34.80	29.70	25.32	21.58	18.39	15.68	90.48	2264.00
1965	572.35	403.32	248.59	161.63	121.93	97.99	80.80	67.68	58.14	50.21	44.73	40.51	37.03	33.18	28.74	24.53	20.91	17.82	15.19	87.68	2212.95
1966	571.03	399.02	232.94	147.76	114.67	94.62	77.40	63.86	54.03	46.41	40.08	35.71	32.66	29.85	26.75	23.17	19.78	16.86	14.37	82.94	2123.90
1967	568.94	392.60	210.87	126.31	99.23	85.84	72.22	59.12	49.26	41.68	35.80	30.92	27.82	25.45	23.26	20.84	18.06	15.41	13.14	75.83	1992.61
1968	565.42	384.42	184.17	101.02	78.36	70.19	62.05	52.25	43.20	36.00	30.46	26.16	22.82	20.54	18.78	17.17	15.38	13.33	11.38	65.66	1818.74
1969	559.73	376.48	162.49	79.13	58.36	52.61	48.25	42.69	36.31	30.02	25.01	21.16	18.36	16.02	14.41	13.18	12.05	10.80	9.35	54.07	1640.49
1970	552.48	372.22	159.66	70.12	46.23	39.76	36.71	33.70	30.11	25.61	21.17	17.65	15.08	13.08	11.41	10.27	9.39	8.59	7.69	45.19	1526.13
1971	544.36	370.04	163.51	71.36	41.63	31.70	27.90	25.78	23.90	21.36	18.16	15.02	12.64	10.80	9.37	8.18	7.36	6.73	6.15	37.88	1453.82
1972	535.93	368.19	172.00	77.41	43.77	29.12	22.66	19.95	18.62	17.27	15.43	13.12	10.96	9.23	7.88	6.84	5.97	5.37	4.91	32.14	1416.75
1973	597.03	364.38	176.40	83.98	48.37	30.99	21.06	16.40	14.59	13.61	12.62	11.28	9.69	8.09	6.81	5.82	5.05	4.41	3.96	27.35	1461.89
1974	591.64	404.91	172.41	85.03	52.30	34.31	22.46	15.27	12.01	10.69	9.97	9.25	8.35	7.17	5.99	5.04	4.31	3.74	3.26	23.17	1481.28
1975	685.84	395.95	169.82	73.10	48.06	34.21	22.96	15.05	10.33	8.13	7.23	6.75	6.32	5.71	4.90	4.09	3.45	2.94	2.55	18.07	1525.47
1976	858.05	450.19	142.47	61.26	36.93	28.81	21.04	14.14	9.36	6.43	5.05	4.50	4.24	3.97	3.58	3.08	2.57	2.16	1.85	12.95	1672.61
1977	649.08	563.08	161.52	51.22	30.93	22.15	17.73	12.96	8.80	5.82	4.00	3.15	2.83	2.66	2.49	2.25	1.93	1.62	1.36	9.30	1554.87
1978	547.99	430.03	210.31	60.42	26.13	18.46	13.55	10.85	8.01	5.44	3.60	2.47	1.96	1.76	1.66	1.56	1.41	1.21	1.01	6.66	1354.49
1979	373.53	360.71	153.63	75.10	29.97	15.31	11.10	8.15	6.60	4.87	3.30	2.19	1.52	1.21	1.08	1.02	0.96	0.86	0.74	4.71	1056.55
1980	663.75	243.15	123.11	52.42	36.97	17.77	9.33	6.77	5.02	4.06	3.00	2.04	1.36	0.94	0.75	0.67	0.64	0.59	0.54	3.39	1176.27
1981	123.46	431.74	80.84	40.79	25.11	21.35	10.54	5.54	4.06	3.01	2.44	1.80	1.23	0.82	0.57	0.45	0.41	0.39	0.36	2.38	757.30
1982	235.04	83.60	183.38	34.48	22.48	15.76	13.70	6.77	3.59	2.63	1.95	1.58	1.18	0.81	0.54	0.37	0.30	0.27	0.25	1.79	610.49
1983	507.49	162.61	41.15	91.27	20.81	14.96	10.68	9.29	4.64	2.46	1.80	1.34	1.09	0.82	0.56	0.37	0.26	0.21	0.19	1.42	873.39
1984	628.42	338.89	70.41	20.15	54.49	13.73	10.06	7.19	6.31	3.15	1.67	1.23	0.92	0.75	0.56	0.38	0.26	0.18	0.14	1.10	1159.99
1985	210.92	399.29	105.50	26.82	10.69	34.20	8.84	6.48	4.68	4.11	2.05	1.09	0.81	0.60	0.49	0.37	0.25	0.17	0.12	0.82	818.30
1986	165.66	131.20	114.56	34.59	13.10	6.40	21.09	5.46	4.05	2.92	2.57	1.28	0.69	0.51	0.38	0.31	0.23	0.16	0.11	0.59	505.85
1987	292.01	100.94	36.50	32.86	15.55	7.40	3.73	12.31	3.22	2.39	1.72	1.51	0.76	0.41	0.30	0.23	0.19	0.14	0.09	0.41	512.68
1988	342.56	178.94	26.78	14.75	17.76	9.74	4.74	2.39	7.97	2.09	1.55	1.12	0.99	0.50	0.27	0.20	0.15	0.12	0.09	0.33	613.03
1989	208.38	213.84	52.06	8.76	7.12	10.45	5.90	2.88	1.46	4.88	1.28	0.95	0.69	0.61	0.31	0.17	0.12	0.09	0.08	0.26	520.28
1990	144.43	134.22	67.32	17.00	4.04	3.92	5.90	3.33	1.64	0.84	2.79	0.73	0.55	0.40	0.35	0.18	0.10	0.07	0.05	0.19	388.05
1991	174.28	101.20	73.66	38.48	10.81	2.72	2.67	4.03	2.30	1.13	0.58	1.92	0.51	0.38	0.28	0.25	0.12	0.07	0.05	0.17	415.60
1992	190.50	117.19	46.54	39.74	24.66	7.59	1.94	1.92	2.92	1.67	0.82	0.42	1.41	0.37	0.28	0.20	0.18	0.09	0.05	0.16	438.65
1993	130.67	137.83	79.34	7.10	13.02	11.74	3.79	0.98	0.97	1.49	0.85	0.42	0.22	0.72	0.19	0.14	0.10	0.09	0.05	0.11	389.81
1994	108.51	92.93	88.97	36.00	3.89	7.91	7.28	2.35	0.61	0.61	0.93	0.53	0.27	0.14	0.46	0.12	0.09	0.07	0.06	0.10	351.85
1995	101.40	76.71	57.01	36.58	19.43	2.38	4.95	4.58	1.50	0.39	0.39	0.60	0.34	0.17	0.09	0.30	0.08	0.06	0.04	0.10	307.10
1996	118.24	71.16	44.53	24.04	20.63	12.29	1.54	3.21	3.01	0.99	0.26	0.26	0.40	0.23	0.11	0.06	0.20	0.05	0.04	0.10	301.33
1997	204.74	85.40	48.22	19.97	14.38	13.73	8.35	1.05	2.21	2.07	0.68	0.18	0.18	0.28	0.16	0.08	0.04	0.14	0.04	0.09	401.99
1998	246.79	147.55	52.25	7.65	6.83	6.93	6.91	4.23	0.54	1.13	1.06	0.35	0.09	0.09	0.14	0.08	0.04	0.02	0.07	0.07	482.82
1999	397.69	179.80	107.00	22.98	4.38	4.45	4.63	4.64	2.87	0.36	0.77	0.72	0.24	0.06	0.06	0.10	0.06	0.03	0.01	0.09	730.96
2000	346.53	277.50	102.13	30.89	10.97	2.62	2.75	2.87	2.91	1.80	0.23	0.48	0.46	0.15	0.04	0.04	0.06	0.04	0.02	0.07	782.56
2001	189.61	240.73	158.25	26.20	13.71	6.25	1.54	1.63	1.72	1.75	1.08	0.14	0.29	0.28	0.09	0.02	0.02	0.04	0.02	0.05	643.42
2002	263.26	132.25	140.78	61.35	13.75	8.32	3.89	0.97	1.03	1.09	1.11	0.69	0.09	0.19	0.18	0.06	0.02	0.02	0.02	0.05	629.11
2003	257.77	183.97	75.20	50.57	32.81	8.60	5.35	2.51	0.63	0.68	0.72	0.73	0.46	0.06	0.12	0.12	0.04	0.01	0.01	0.05	620.40
2004	118.09	180.25	108.55	32.84	30.20	22.36	6.00	3.75	1.78	0.45	0.48	0.51	0.52	0.33	0.04	0.09	0.08	0.03	0.01	0.04	506.42
2005	59.21	80.77	95.35	43.67	18.70	19.93	15.14	4.08	2.58	1.23	0.31	0.33	0.35	0.36	0.23	0.03	0.06	0.06	0.02	0.03	342.46
2006	901.01	39.68	38.08	38.09	26.13	12.99	14.19	10.80	2.95	1.86	0.89	0.22	0.24	0.26	0.27	0.17	0.02	0.05	0.04	0.04	1087.97
2007	636.76	630.42	23.48	15.80	23.07	18.41	9.37	10.25	7.89	2.15	1.36	0.65	0.17	0.18	0.19	0.20	0.12	0.02	0.03	0.06	1380.59
2008	455.35	445.90	379.02	5.41	6.67	12.94	10.72	5.48	6.06	4.67	1.27	0.80	0.39	0.10	0.11	0.11	0.12	0.07	0.01	0.06	1335.26
2009	212.57	318.91	270.58	168.36	3.20	4.49	8.90	7.39	3.82	4.22	3.25	0.89	0.57	0.27	0.07	0.08	0.08	0.08	0.05	0.05	1007.82
2010	334.79	150.87	206.56	111.83	94.25	2.07	2.98	5.91	4.96	2.56	2.83	2.18	0.60	0.38	0.18	0.05	0.05	0.05	0.06	0.07	923.24

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	380.3	940.1	1386.3	1652.4	1821.2	1894.4	1877.0	1782.4	1657.4	1506.6	1346.4	1187.6	1047.6	917.1	798.3	691.6	597.0	514.1	441.6	2564.6	25004.0
1956	380.3	931.5	1350.8	1614.0	1829.2	1929.9	1914.9	1818.4	1690.9	1537.1	1373.5	1211.7	1068.8	935.6	814.4	705.7	609.1	524.5	450.6	2616.4	25307.1
1957	380.7	927.7	1308.7	1537.3	1765.2	1925.3	1938.5	1843.5	1714.5	1558.4	1392.4	1228.4	1083.6	948.6	825.6	715.4	617.5	531.8	456.8	2652.6	25352.5
1958	380.5	923.3	1248.7	1424.0	1627.5	1809.8	1884.7	1819.0	1694.0	1539.9	1376.1	1213.9	1070.8	937.4	815.9	707.0	610.2	525.4	451.3	2621.3	24681.2
1959	380.3	920.2	1228.9	1343.9	1505.3	1674.4	1778.9	1775.8	1678.4	1527.8	1365.3	1204.4	1062.4	930.1	809.5	701.5	605.6	521.4	447.8	2601.0	24063.5
1960	380.1	917.3	1202.6	1297.4	1404.1	1536.2	1633.0	1662.9	1625.7	1501.8	1343.9	1185.6	1045.9	915.8	797.0	690.5	596.1	513.2	440.9	2560.4	23250.6
1961	379.6	914.7	1181.0	1250.0	1342.8	1423.7	1489.0	1517.2	1513.3	1446.0	1313.3	1160.1	1023.6	896.2	780.0	675.7	583.3	502.2	431.4	2505.6	22328.6
1962	379.2	912.3	1159.4	1207.5	1277.4	1347.0	1365.8	1369.3	1366.4	1332.0	1251.3	1121.7	991.0	867.7	755.3	654.3	564.8	486.3	417.8	2426.4	21253.4
1963	378.5	911.4	1162.3	1191.8	1240.5	1288.4	1299.2	1262.6	1239.7	1209.0	1158.7	1074.5	963.4	844.8	735.2	637.1	550.1	473.6	406.8	2362.3	20389.2
1964	378.1	910.3	1166.9	1200.9	1231.9	1259.5	1250.9	1209.0	1150.8	1104.3	1058.9	1001.8	929.0	826.7	720.5	624.3	539.0	464.1	398.6	2315.1	19740.6
1965	377.4	905.4	1134.9	1172.9	1220.0	1235.9	1209.0	1151.0	1089.5	1013.7	956.4	905.2	856.3	788.2	697.3	604.9	522.3	449.7	386.2	2243.4	18919.9
1966	376.5	896.0	1063.5	1072.1	1147.5	1193.6	1158.1	1086.0	1012.6	936.7	856.7	797.9	755.3	709.2	649.0	571.4	494.1	425.3	365.5	2122.2	17689.0
1967	375.2	881.4	962.8	916.5	993.0	1082.7	1080.7	1005.3	923.3	841.5	765.2	690.9	643.5	604.5	564.4	514.1	451.1	388.9	334.0	1940.3	15959.0
1968	372.8	863.1	840.8	733.0	784.2	885.4	928.4	888.5	809.5	726.6	651.0	584.7	527.8	487.9	455.7	423.3	384.3	336.2	289.2	1680.1	13652.8
1969	369.1	845.3	741.9	574.1	584.0	663.6	721.8	726.0	680.3	606.1	534.6	472.9	424.6	380.5	349.7	325.2	300.9	272.5	237.9	1383.4	11194.6
1970	364.4	835.8	729.1	508.8	462.5	501.6	549.2	573.0	564.4	517.0	452.6	394.4	348.8	310.9	276.9	253.3	234.6	216.7	195.6	1156.3	9445.5
1971	358.9	830.9	746.5	517.9	416.7	399.9	417.3	438.3	447.8	431.2	388.2	335.5	292.3	256.6	227.3	201.7	183.9	169.8	156.3	969.4	8186.4
1972	353.4	826.7	785.3	561.7	438.1	367.3	339.1	339.3	349.0	348.6	329.8	293.2	253.5	219.1	191.4	168.7	149.0	135.4	124.8	822.3	7395.4
1973	393.7	818.1	805.3	609.4	483.9	390.9	315.0	278.9	273.4	274.9	269.8	252.0	224.2	192.2	165.3	143.5	126.1	111.1	100.8	700.0	6928.7
1974	390.2	909.2	787.3	616.9	523.4	432.8	336.0	259.7	225.1	215.6	213.2	206.6	193.1	170.4	145.3	124.3	107.6	94.4	82.9	593.0	6626.7
1975	452.4	888.9	775.4	530.4	481.0	431.4	343.7	256.0	193.8	164.0	154.5	150.8	146.2	135.6	118.8	101.0	86.0	74.3	65.0	462.3	6011.3
1976	565.9	1010.8	650.4	444.5	369.5	363.3	314.8	240.3	175.3	129.6	108.0	100.5	98.1	94.4	86.9	75.8	64.2	54.7	47.0	331.4	5325.7
1977	428.1	1264.1	737.4	371.7	309.5	279.3	265.2	220.5	164.9	117.5	85.5	70.3	65.3	63.3	60.6	55.6	48.3	40.8	34.6	238.1	4920.3
1978	361.3	965.4	960.1	438.5	261.5	232.8	202.6	184.5	150.1	109.8	76.9	55.3	45.4	41.9	40.3	38.4	35.1	30.4	25.6	170.4	4427.1
1979	246.3	809.8	701.5	545.0	299.8	193.1	166.0	138.7	123.7	98.3	70.5	48.9	35.1	28.7	26.2	25.1	23.8	21.8	19.0	120.4	3741.9
1980	437.8	545.9	562.2	380.3	369.9	224.2	139.6	115.1	94.1	82.0	64.2	45.4	31.5	22.5	18.3	16.5	15.9	15.0	13.7	86.6	3280.5
1981	81.4	969.4	369.1	295.9	251.3	269.4	157.9	94.1	76.1	60.8	52.0	40.1	28.4	19.6	13.9	11.2	10.1	9.7	9.3	60.8	2880.8
1982	155.0	187.6	837.3	250.2	224.9	198.9	204.8	115.1	67.2	53.1	41.7	35.3	27.3	19.2	13.0	9.3	7.5	6.8	6.4	45.9	2506.9
1983	334.7	365.1	187.8	662.3	208.1	188.7	159.8	157.9	86.9	49.6	38.6	30.0	25.4	19.4	13.7	9.3	6.4	5.3	4.6	36.2	2589.6
1984	414.5	760.8	321.4	146.2	545.2	173.3	150.6	122.4	118.4	63.7	35.7	27.3	21.2	17.9	13.7	9.5	6.4	4.4	3.5	28.2	2984.0
1985	139.1	896.4	481.7	194.7	106.9	431.4	132.3	110.2	87.7	82.9	43.9	24.3	18.7	14.3	11.9	9.0	6.4	4.2	3.1	20.9	2820.2
1986	109.3	294.5	523.2	250.9	131.2	80.7	315.5	92.8	75.8	59.1	54.9	28.7	15.9	12.1	9.3	7.7	5.7	4.0	2.6	15.0	2088.9
1987	192.7	226.6	166.7	238.3	155.6	93.3	55.8	209.2	60.4	48.1	36.8	33.7	17.6	9.7	7.3	5.5	4.6	3.5	2.4	10.6	1579.0
1988	226.0	401.7	122.4	106.9	177.7	122.8	71.0	40.8	149.5	42.1	33.1	24.9	22.9	11.9	6.4	4.9	3.7	3.1	2.2	8.6	1582.5
1989	137.3	480.2	237.7	63.5	71.2	131.8	88.2	48.9	27.6	98.5	27.3	21.2	15.9	14.6	7.5	4.2	3.1	2.4	2.0	6.6	1489.4
1990	95.2	301.4	307.3	123.2	40.3	49.4	88.4	56.7	30.9	17.0	59.5	16.3	12.6	9.5	8.6	4.4	2.4	1.8	1.3	5.1	1231.3
1991	114.9	227.3	336.2	279.1	108.2	34.2	39.9	68.6	43.0	22.9	12.3	43.0	11.7	9.0	6.8	6.2	3.1	1.8	1.3	4.4	1373.9
1992	125.7	263.0	212.5	288.4	246.7	95.7	29.1	32.6	54.7	33.7	17.6	9.3	32.6	8.8	6.8	5.1	4.4	2.2	1.3	4.2	1474.5
1993	86.2	309.5	362.2	51.6	130.3	148.2	56.7	16.5	18.3	30.0	18.1	9.3	5.1	17.2	4.6	3.5	2.6	2.4	1.1	2.9	1276.0
1994	71.7	208.6	406.3	261.2	39.0	99.9	108.9	40.1	11.5	12.3	20.1	11.9	6.2	3.3	11.2	3.1	2.2	1.8	1.5	2.4	1322.6
1995	66.8	172.2	260.4	265.4	194.4	30.0	74.1	77.8	28.0	7.9	8.4	13.2	7.9	4.0	2.2	7.3	2.0	1.5	1.1	2.6	1227.3
1996	78.0	159.8	203.3	174.4	206.4	155.0	22.9	54.7	56.4	19.8	5.5	5.7	9.3	5.5	2.9	1.5	4.9	1.3	0.9	2.4	1170.7
1997	134.9	191.8	220.2	144.8	144.0	173.3	125.0	17.9	41.4	41.9	14.6	4.0	4.2	6.6	3.7	2.0	1.1	3.5	0.9	2.4	1277.8
1998	162.7	331.4	238.5	55.6	68.3	87.3	103.4	71.9	10.1	22.9	22.7	7.7	2.2	2.2	3.5	2.0	1.1	0.4	1.8	1.8	1197.3
1999	262.4	403.7	488.5	166.7	43.9	56.2	69.2	78.9	53.8	7.3	16.5	16.1	5.5	1.5	1.5	2.4	1.3	0.7	0.4	2.4	1679.0
2000	228.6	623.0	466.3	224.2	109.8	33.1	41.0	48.7	54.5	36.4	4.9	10.8	10.6	3.5	0.9	1.1	1.5	0.9	0.4	1.8	1902.1
2001	125.0	540.6	722.5	190.0	137.1	78.7	23.1	27.8	32.2	35.3	23.1	3.1	6.8	6.6	2.2	0.7	0.7	0.9	0.7	1.3	1958.4
2002	173.7	297.0	642.6	445.1	137.6	104.9	58.2	16.5	19.4	22.0	23.8	15.4	2.0	4.4	4.4	1.5	0.4	0.4	0.7	1.3	1971.2
2003	170.0	413.1	343.3	366.8	328.3	108.5	80.0	42.8	11.9	13.7	15.4	16.3	10.6	1.3	3.1	2.9	0.9	0.2	0.2	1.3	1930.6
2004	77.8	404.8	495.6	238.3	302.3	282.2	89.7	63.7	33.5	9.0	10.4	11.5	12.1	7.7	1.1	2.2	2.2	0.7	0.2	1.1	2045.7
2005	39.0	181.4	435.4	316.8	187.2	251.3	226.6	69.4	48.3	24.9	6.6	7.5	8.2	8.6	5.5	0.7	1.5	1.5	0.4	0.9	1821.9
2006	594.1	89.1	173.9	276.5	261.5	163.8	212.3	183.6	55.1	37.7	19.0	5.1	5.5	6.2	6.4	4.2	0.4	1.1	1.1	1.1	2097.7
2007	420.0	1415.4	107.1	114.6	230.8	232.1	140.2	174.4	147.9	43.4	29.1	14.6	3.7	4.2	4.6	4.9	3.1	0.4	0.9	1.5	3093.3
2008	300.3	1001.1	1730.4	39.2	66.8	163.1	160.3	93.0	113.5	94.1	27.1	18.1	9.0	2.4	2.6	2.9	2.9	1.8	0.2	1.5	3830.8
2009	140.2	716.1	1235.5	1221.6	32.0	56.7	133.2	125.7	71.4	85.3	69.4	19.8	13.0	6.4	1.8	1.8	2.0	2.0	1.3	1.1	3936.4
2010	220.7	338.9	943.1	811.3	943.1	26.2	44.5	100.5	92.8	51.6	60.6	48.7	13.9	9.0	4.4	1.1	1.3	1.3	1.3	1.8	3716.6

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* $\mathrm{MSST} = (1 - M)\mathrm{SSB}_{\mathrm{MSY}}$, *with constant* $M = 0.08$. *SPR is static spawning potential ratio.*

Year	F	F/F_{MSY}	B	B/B_{unfished}	SSB	$\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$	SSB/MSST	SPR
1955	0.181	0.747	11342	0.2815	120.36	1.0732	1.1666	0.25266
1956	0.204	0.840	11479	0.2849	123.24	1.0989	1.1945	0.22442
1957	0.249	1.026	11500	0.2854	122.29	1.0904	1.1853	0.15993
1958	0.260	1.071	11195	0.2778	119.91	1.0692	1.1622	0.16072
1959	0.279	1.150	10915	0.2709	116.84	1.0419	1.1324	0.14363
1960	0.294	1.214	10546	0.2617	112.75	1.0053	1.0928	0.13174
1961	0.311	1.282	10128	0.2514	107.64	0.9598	1.0432	0.11689
1962	0.306	1.261	9640	0.2393	102.52	0.9142	0.9937	0.12319
1963	0.301	1.239	9248	0.2295	98.28	0.8763	0.9525	0.13148
1964	0.328	1.354	8954	0.2222	93.94	0.8376	0.9104	0.11254
1965	0.390	1.609	8582	0.2130	88.17	0.7862	0.8546	0.08144
1966	0.482	1.988	8024	0.1991	80.27	0.7158	0.7780	0.05262
1967	0.606	2.499	7239	0.1797	69.68	0.6213	0.6753	0.02950
1968	0.715	2.947	6193	0.1537	57.27	0.5107	0.5551	0.01848
1969	0.710	2.930	5078	0.1260	46.47	0.4143	0.4504	0.01975
1970	0.675	2.785	4284	0.1063	38.17	0.3404	0.3700	0.02201
1971	0.618	2.547	3713	0.0922	32.05	0.2858	0.3107	0.02739
1972	0.587	2.420	3355	0.0833	27.71	0.2471	0.2686	0.03113
1973	0.600	2.473	3143	0.0780	24.54	0.2188	0.2378	0.03047
1974	0.728	3.002	3006	0.0746	21.13	0.1884	0.2048	0.01645
1975	0.890	3.669	2727	0.0677	17.01	0.1517	0.1649	0.00885
1976	0.893	3.682	2416	0.0600	13.48	0.1202	0.1307	0.00880
1977	0.853	3.519	2232	0.0554	11.06	0.0986	0.1072	0.00952
1978	0.900	3.710	2008	0.0498	9.28	0.0828	0.0900	0.00822
1979	0.945	3.898	1697	0.0421	7.90	0.0704	0.0765	0.00764
1980	0.975	4.019	1488	0.0369	6.67	0.0595	0.0647	0.00676
1981	0.722	2.978	1307	0.0324	6.06	0.0540	0.0587	0.01475
1982	0.568	2.341	1137	0.0282	6.05	0.0540	0.0587	0.02541
1983	0.667	2.751	1175	0.0292	6.08	0.0542	0.0589	0.02059
1984	0.997	4.111	1354	0.0336	5.89	0.0526	0.0571	0.00903
1985	1.079	4.448	1279	0.0317	5.40	0.0482	0.0524	0.00609
1986	1.119	4.614	947	0.0235	4.51	0.0402	0.0437	0.00439
1987	1.157	4.770	716	0.0178	3.81	0.0339	0.0369	0.00790
1988	1.065	4.390	718	0.0178	3.27	0.0292	0.0317	0.00590
1989	0.989	4.079	676	0.0168	2.70	0.0241	0.0262	0.00562
1990	0.430	1.773	558	0.0139	2.60	0.0232	0.0252	0.03507
1991	0.607	2.502	623	0.0155	2.95	0.0263	0.0286	0.03209
1992	1.750	7.215	669	0.0166	2.58	0.0230	0.0250	0.00511
1993	0.660	2.723	579	0.0144	2.38	0.0213	0.0231	0.02272
1994	0.759	3.129	600	0.0149	2.52	0.0225	0.0244	0.01987
1995	0.734	3.025	557	0.0138	2.61	0.0233	0.0253	0.02152
1996	0.672	2.770	531	0.0132	2.75	0.0245	0.0266	0.03316
1997	1.711	7.055	580	0.0144	2.34	0.0209	0.0227	0.00491
1998	0.692	2.852	543	0.0135	2.20	0.0196	0.0214	0.03220
1999	1.112	4.587	762	0.0189	2.36	0.0211	0.0229	0.01166
2000	1.231	5.075	863	0.0214	2.43	0.0216	0.0235	0.00915
2001	0.818	3.371	888	0.0220	2.77	0.0247	0.0268	0.01717
2002	0.894	3.686	894	0.0222	3.16	0.0282	0.0307	0.01711
2003	0.699	2.881	876	0.0217	3.64	0.0325	0.0353	0.03005
2004	0.781	3.219	928	0.0230	4.16	0.0371	0.0403	0.02115
2005	0.788	3.248	826	0.0205	4.50	0.0401	0.0436	0.02269
2006	0.750	3.091	951	0.0236	4.71	0.0420	0.0457	0.03269
2007	1.337	5.513	1403	0.0348	4.77	0.0425	0.0462	0.00839
2008	0.682	2.810	1738	0.0431	5.72	0.0510	0.0554	0.02943
2009	0.754	3.108	1786	0.0443	6.86	0.0612	0.0665	0.02516
2010	.	.	1686	0.0418	.	.	.	.

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	0.001	0.000	0.049	0.181	0.181	0.000	0.059	0.059
2	410.5	16.2	0.029	0.030	0.075	0.001	0.688	1.000	1.000	0.021	0.334	0.355
3	515.4	20.3	0.597	0.493	1.000	1.000	1.000	0.433	0.433	0.840	0.160	1.000
4	597.9	23.5	0.987	1.000	0.551	0.551	0.066	0.066	0.066	0.571	0.022	0.593
5	662.8	26.1	1.000	0.918	0.323	0.323	0.005	0.005	0.005	0.403	0.002	0.405
6	713.8	28.1	1.000	0.786	0.301	0.301	0.000	0.000	0.000	0.386	0.000	0.386
7	754.0	29.7	1.000	0.613	0.300	0.300	0.000	0.000	0.000	0.383	0.000	0.383
8	785.6	30.9	1.000	0.501	0.300	0.300	0.000	0.000	0.000	0.382	0.000	0.382
9	810.4	31.9	1.000	0.457	0.300	0.300	0.000	0.000	0.000	0.382	0.000	0.382
10	829.9	32.7	1.000	0.443	0.300	0.300	0.000	0.000	0.000	0.382	0.000	0.382
11	845.3	33.3	1.000	0.439	0.300	0.300	0.000	0.000	0.000	0.382	0.000	0.382
12	857.4	33.8	1.000	0.438	0.300	0.300	0.000	0.000	0.000	0.382	0.000	0.382
13	866.9	34.1	1.000	0.438	0.300	0.300	0.000	0.000	0.000	0.382	0.000	0.382
14	874.4	34.4	1.000	0.438	0.300	0.300	0.000	0.000	0.000	0.382	0.000	0.382
15	880.3	34.7	1.000	0.438	0.300	0.300	0.000	0.000	0.000	0.382	0.000	0.382
16	884.9	34.8	1.000	0.438	0.300	0.300	0.000	0.000	0.000	0.382	0.000	0.382
17	888.6	35.0	1.000	0.438	0.300	0.300	0.000	0.000	0.000	0.382	0.000	0.382
18	891.4	35.1	1.000	0.438	0.300	0.300	0.000	0.000	0.000	0.382	0.000	0.382
19	893.7	35.2	1.000	0.438	0.300	0.300	0.000	0.000	0.000	0.382	0.000	0.382
20	895.5	35.3	1.000	0.438	0.300	0.300	0.000	0.000	0.000	0.382	0.000	0.382

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	0.022	0.000	0.132	0.027	0.000	0.000	0.000	0.181
1956	0.021	0.000	0.147	0.036	0.000	0.000	0.000	0.204
1957	0.039	0.000	0.164	0.046	0.000	0.000	0.000	0.249
1958	0.028	0.000	0.175	0.056	0.000	0.000	0.000	0.260
1959	0.031	0.000	0.182	0.065	0.000	0.000	0.000	0.279
1960	0.033	0.000	0.187	0.074	0.000	0.000	0.000	0.294
1961	0.041	0.000	0.188	0.082	0.000	0.000	0.000	0.311
1962	0.036	0.000	0.183	0.087	0.000	0.000	0.000	0.306
1963	0.028	0.000	0.178	0.094	0.000	0.000	0.000	0.301
1964	0.033	0.000	0.187	0.109	0.000	0.000	0.000	0.328
1965	0.040	0.000	0.214	0.136	0.000	0.000	0.000	0.390
1966	0.050	0.000	0.258	0.175	0.000	0.000	0.000	0.482
1967	0.074	0.000	0.310	0.222	0.000	0.000	0.000	0.606
1968	0.099	0.000	0.351	0.264	0.000	0.000	0.000	0.715
1969	0.080	0.000	0.352	0.279	0.000	0.000	0.000	0.710
1970	0.087	0.000	0.320	0.269	0.000	0.000	0.000	0.675
1971	0.085	0.000	0.280	0.253	0.000	0.000	0.000	0.618
1972	0.082	0.000	0.255	0.251	0.000	0.000	0.000	0.587
1973	0.073	0.000	0.254	0.273	0.000	0.000	0.000	0.600
1974	0.131	0.000	0.277	0.319	0.000	0.000	0.000	0.728
1975	0.183	0.000	0.318	0.389	0.000	0.000	0.000	0.890
1976	0.181	0.000	0.310	0.402	0.000	0.000	0.000	0.893
1977	0.207	0.000	0.277	0.369	0.000	0.000	0.000	0.853
1978	0.212	0.000	0.289	0.399	0.000	0.000	0.000	0.900
1979	0.173	0.000	0.315	0.458	0.000	0.000	0.000	0.945
1980	0.198	0.000	0.297	0.480	0.000	0.000	0.000	0.975
1981	0.195	0.000	0.181	0.346	0.000	0.000	0.000	0.722
1982	0.183	0.000	0.152	0.232	0.000	0.000	0.000	0.568
1983	0.187	0.000	0.212	0.185	0.000	0.094	0.018	0.667
1984	0.140	0.001	0.157	0.538	0.000	0.174	0.031	0.997
1985	0.135	0.003	0.280	0.569	0.000	0.044	0.096	1.079
1986	0.161	0.001	0.516	0.442	0.000	0.001	0.035	1.119
1987	0.173	0.000	0.243	0.361	0.000	0.001	0.418	1.157
1988	0.163	0.000	0.296	0.529	0.000	0.000	0.123	1.065
1989	0.262	0.000	0.205	0.522	0.000	0.000	0.050	0.989
1990	0.229	0.004	0.136	0.062	0.000	0.001	0.028	0.430
1991	0.131	0.010	0.165	0.186	0.000	0.003	0.145	0.607
1992	0.124	0.017	0.782	0.769	0.070	0.053	0.055	1.750
1993	0.273	0.012	0.191	0.158	0.052	0.087	0.122	0.660
1994	0.234	0.023	0.256	0.166	0.085	0.026	0.207	0.759
1995	0.221	0.017	0.330	0.038	0.110	0.107	0.159	0.734
1996	0.178	0.011	0.151	0.214	0.153	0.023	0.075	0.672
1997	0.164	0.016	1.301	0.091	0.169	0.071	0.031	1.711
1998	0.151	0.021	0.322	0.163	0.076	0.020	0.050	0.692
1999	0.124	0.020	0.548	0.292	0.053	0.086	0.227	1.112
2000	0.136	0.019	0.214	0.736	0.042	0.046	0.296	1.231
2001	0.211	0.027	0.164	0.338	0.038	0.052	0.269	0.818
2002	0.170	0.026	0.243	0.292	0.120	0.058	0.230	0.894
2003	0.120	0.020	0.253	0.190	0.041	0.043	0.263	0.699
2004	0.137	0.021	0.228	0.258	0.015	0.084	0.351	0.781
2005	0.103	0.010	0.237	0.226	0.023	0.215	0.330	0.788
2006	0.072	0.005	0.284	0.248	0.041	0.053	0.250	0.750
2007	0.105	0.010	0.238	0.881	0.019	0.081	0.223	1.337
2008	0.145	0.005	0.139	0.307	0.014	0.046	0.259	0.682
2009	0.157	0.004	0.179	0.354	0.026	0.038	0.190	0.754

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	0.030	0.177	0.181	0.110	0.073	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
1956	0.034	0.200	0.204	0.122	0.080	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076
1957	0.039	0.243	0.249	0.155	0.107	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
1958	0.042	0.254	0.260	0.156	0.103	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098
1959	0.045	0.272	0.279	0.168	0.111	0.106	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105
1960	0.047	0.287	0.294	0.177	0.118	0.112	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
1961	0.049	0.303	0.311	0.190	0.128	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122
1962	0.048	0.298	0.306	0.185	0.123	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117
1963	0.048	0.293	0.301	0.178	0.116	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110
1964	0.052	0.319	0.328	0.196	0.128	0.122	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121
1965	0.061	0.379	0.390	0.233	0.154	0.146	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145
1966	0.075	0.468	0.482	0.288	0.190	0.180	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179
1967	0.092	0.587	0.606	0.367	0.246	0.235	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234
1968	0.107	0.691	0.715	0.439	0.298	0.285	0.284	0.284	0.284	0.284	0.284	0.284	0.284	0.284	0.284	0.284	0.284	0.284	0.284	0.284
1969	0.108	0.688	0.710	0.427	0.284	0.270	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269
1970	0.101	0.653	0.675	0.411	0.277	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264
1971	0.091	0.596	0.618	0.379	0.258	0.246	0.245	0.245	0.245	0.245	0.245	0.245	0.245	0.245	0.245	0.245	0.245	0.245	0.245	0.245
1972	0.086	0.566	0.587	0.360	0.245	0.234	0.233	0.233	0.233	0.233	0.233	0.233	0.233	0.233	0.233	0.233	0.233	0.233	0.233	0.233
1973	0.088	0.578	0.600	0.364	0.244	0.232	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231
1974	0.102	0.699	0.728	0.460	0.324	0.311	0.311	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310
1975	0.121	0.852	0.890	0.573	0.412	0.396	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395
1976	0.121	0.855	0.893	0.573	0.411	0.396	0.395	0.394	0.394	0.394	0.394	0.394	0.394	0.394	0.394	0.394	0.394	0.394	0.394	0.394
1977	0.112	0.815	0.853	0.563	0.416	0.402	0.401	0.401	0.401	0.401	0.401	0.401	0.401	0.401	0.401	0.401	0.401	0.401	0.401	0.401
1978	0.118	0.859	0.900	0.591	0.434	0.419	0.418	0.418	0.418	0.418	0.418	0.418	0.418	0.418	0.418	0.418	0.418	0.418	0.418	0.418
1979	0.129	0.905	0.945	0.599	0.423	0.406	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405
1980	0.130	0.931	0.975	0.626	0.449	0.432	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431
1981	0.090	0.686	0.722	0.486	0.366	0.354	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353
1982	0.068	0.539	0.568	0.395	0.307	0.299	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298
1983	0.104	0.667	0.584	0.406	0.315	0.307	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306
1984	0.154	0.997	0.835	0.524	0.366	0.350	0.349	0.349	0.349	0.349	0.349	0.349	0.349	0.349	0.349	0.349	0.349	0.349	0.349	0.349
1985	0.175	1.079	0.985	0.606	0.413	0.394	0.392	0.391	0.391	0.391	0.391	0.391	0.391	0.391	0.391	0.391	0.391	0.391	0.391	0.391
1986	0.195	1.109	1.119	0.689	0.471	0.450	0.449	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448
1987	0.190	1.157	0.776	0.506	0.368	0.355	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354
1988	0.171	1.065	0.988	0.618	0.430	0.412	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411
1989	0.140	0.986	0.989	0.663	0.498	0.482	0.481	0.481	0.481	0.481	0.481	0.481	0.481	0.481	0.481	0.481	0.481	0.481	0.481	0.481
1990	0.056	0.430	0.429	0.343	0.297	0.292	0.291	0.291	0.291	0.290	0.290	0.290	0.290	0.290	0.290	0.290	0.290	0.290	0.290	0.290
1991	0.097	0.607	0.487	0.335	0.254	0.245	0.243	0.242	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241
1992	0.024	0.220	1.750	1.006	0.642	0.605	0.600	0.598	0.597	0.597	0.597	0.596	0.596	0.596	0.596	0.596	0.596	0.596	0.596	0.596
1993	0.041	0.268	0.660	0.491	0.398	0.388	0.385	0.384	0.383	0.383	0.383	0.383	0.383	0.383	0.383	0.383	0.383	0.383	0.383	0.383
1994	0.047	0.319	0.759	0.507	0.392	0.379	0.374	0.372	0.371	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370
1995	0.054	0.374	0.734	0.463	0.358	0.346	0.342	0.340	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339
1996	0.025	0.219	0.672	0.404	0.307	0.296	0.294	0.293	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292
1997	0.028	0.321	1.711	0.963	0.630	0.597	0.592	0.590	0.589	0.589	0.589	0.589	0.589	0.589	0.589	0.589	0.589	0.589	0.589	0.589
1998	0.017	0.151	0.692	0.447	0.327	0.313	0.309	0.307	0.306	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305
1999	0.060	0.396	1.112	0.629	0.416	0.393	0.388	0.386	0.385	0.385	0.385	0.385	0.385	0.385	0.385	0.385	0.385	0.385	0.385	0.385
2000	0.064	0.392	1.231	0.703	0.463	0.438	0.433	0.431	0.430	0.430	0.430	0.430	0.430	0.430	0.430	0.430	0.430	0.430	0.430	0.430
2001	0.060	0.366	0.818	0.535	0.399	0.383	0.378	0.375	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373
2002	0.058	0.394	0.894	0.516	0.369	0.352	0.347	0.344	0.343	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342
2003	0.058	0.358	0.699	0.405	0.283	0.269	0.265	0.263	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262
2004	0.080	0.467	0.781	0.453	0.315	0.300	0.295	0.293	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292
2005	0.100	0.582	0.788	0.404	0.264	0.250	0.248	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246
2006	0.057	0.355	0.750	0.392	0.250	0.236	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.234
2007	0.056	0.339	1.337	0.752	0.478	0.451	0.447	0.446	0.446	0.446	0.446	0.446	0.446	0.446	0.446	0.446	0.446	0.446	0.446	0.446
2008	0.056	0.330	0.682	0.415	0.296	0.284	0.282	0.281	0.281	0.281	0.281	0.281	0.281	0.281	0.281	0.281	0.281	0.281	0.281	0.281
2009	0.043	0.264	0.754	0.470	0.335	0.322	0.320	0.319	0.319	0.319	0.319	0.319	0.319	0.319	0.319	0.319	0.319	0.319	0.319	0.319

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	14.56	62.75	47.26	22.44	12.28	9.72	8.09	6.79	5.73	4.84	4.08	3.46	2.95	2.51	2.14	1.83	1.56	1.33	1.13	6.53
1956	16.46	69.24	51.26	24.20	13.43	10.75	8.97	7.53	6.35	5.36	4.52	3.84	3.27	2.79	2.37	2.02	1.73	1.47	1.25	7.23
1957	19.10	82.13	59.38	28.77	16.99	14.16	11.99	10.08	8.50	7.18	6.06	5.13	4.38	3.73	3.18	2.71	2.31	1.97	1.68	9.68
1958	20.56	85.08	58.83	26.85	15.16	12.81	11.21	9.57	8.08	6.82	5.76	4.88	4.16	3.55	3.02	2.58	2.20	1.87	1.60	9.21
1959	21.84	90.18	61.62	27.13	15.09	12.76	11.39	10.05	8.62	7.28	6.15	5.21	4.44	3.79	3.23	2.75	2.34	2.00	1.70	9.83
1960	22.87	94.16	63.20	27.54	14.83	12.34	11.02	9.92	8.80	7.55	6.38	5.41	4.61	3.93	3.35	2.85	2.43	2.07	1.77	10.20
1961	23.59	98.22	65.04	28.25	15.39	12.44	10.94	9.85	8.91	7.91	6.78	5.76	4.91	4.18	3.57	3.04	2.59	2.21	1.88	10.86
1962	23.32	96.58	62.95	26.60	14.07	11.29	9.62	8.53	7.72	6.99	6.20	5.34	4.56	3.89	3.31	2.82	2.41	2.05	1.75	10.09
1963	23.15	95.10	62.16	25.45	12.96	10.21	8.65	7.43	6.62	5.99	5.42	4.84	4.19	3.58	3.05	2.60	2.21	1.89	1.61	9.28
1964	24.93	102.33	67.30	27.89	14.11	10.95	9.14	7.81	6.74	6.01	5.44	4.95	4.43	3.84	3.28	2.79	2.38	2.03	1.73	9.98
1965	29.18	117.61	75.63	31.92	16.54	12.73	10.47	8.81	7.57	6.53	5.82	5.30	4.84	4.34	3.76	3.21	2.73	2.33	1.99	11.47
1966	35.56	138.00	83.98	35.12	18.87	14.93	12.18	10.09	8.54	7.33	6.33	5.67	5.19	4.74	4.25	3.68	3.14	2.68	2.28	13.17
1967	43.32	161.62	90.45	36.90	20.65	17.19	14.42	11.86	9.88	8.36	7.18	6.23	5.61	5.13	4.69	4.20	3.64	3.11	2.65	15.28
1968	49.57	178.12	88.87	34.11	19.29	16.68	14.71	12.44	10.28	8.57	7.25	6.26	5.46	4.91	4.49	4.11	3.68	3.19	2.72	15.71
1969	49.63	173.85	78.08	26.17	13.75	11.92	10.90	9.69	8.24	6.81	5.68	4.83	4.19	3.65	3.29	3.01	2.75	2.46	2.13	12.33
1970	45.88	165.58	74.05	22.48	10.68	8.85	8.15	7.52	6.72	5.71	4.72	3.95	3.38	2.93	2.56	2.30	2.11	1.92	1.72	10.13
1971	41.00	154.10	71.13	21.38	9.01	6.62	5.81	5.39	5.00	4.47	3.80	3.16	2.66	2.27	1.97	1.72	1.55	1.41	1.29	7.96
1972	38.16	147.49	72.06	22.25	9.07	5.82	4.52	4.00	3.73	3.46	3.09	2.64	2.21	1.86	1.59	1.38	1.20	1.08	0.99	6.47
1973	43.69	148.35	75.09	24.32	9.97	6.15	4.16	3.26	2.90	2.70	2.51	2.25	1.93	1.62	1.36	1.16	1.01	0.88	0.79	5.46
1974	49.52	189.10	84.27	29.83	13.83	8.80	5.75	3.93	3.09	2.75	2.56	2.39	2.16	1.85	1.55	1.30	1.11	0.96	0.84	5.98
1975	67.72	211.32	94.72	30.34	15.49	10.74	7.19	4.73	3.25	2.56	2.27	2.13	2.00	1.80	1.55	1.29	1.09	0.93	0.81	5.71
1976	84.90	240.80	79.65	25.45	11.89	9.03	6.58	4.44	2.94	2.02	1.59	1.42	1.34	1.25	1.13	0.97	0.81	0.68	0.58	4.09
1977	59.44	291.87	87.73	20.99	10.05	7.03	5.62	4.12	2.80	1.85	1.27	1.01	0.90	0.85	0.80	0.72	0.62	0.52	0.43	2.97
1978	52.93	230.75	118.14	25.67	8.79	6.06	4.44	3.57	2.64	1.79	1.19	0.82	0.65	0.58	0.55	0.52	0.47	0.40	0.33	2.20
1979	39.27	200.03	88.97	32.21	9.87	4.90	3.54	2.61	2.11	1.56	1.06	0.70	0.49	0.39	0.35	0.33	0.31	0.28	0.24	1.52
1980	70.17	137.25	72.63	23.23	12.77	5.98	3.13	2.28	1.69	1.37	1.01	0.69	0.46	0.32	0.25	0.23	0.22	0.20	0.18	1.15
1981	9.18	199.05	39.29	14.93	7.34	6.10	3.01	1.59	1.16	0.86	0.70	0.52	0.36	0.24	0.16	0.13	0.12	0.11	0.10	0.69
1982	13.45	32.27	74.95	10.70	5.68	3.90	3.39	1.68	0.89	0.65	0.49	0.39	0.29	0.20	0.13	0.09	0.07	0.07	0.06	0.45
1983	34.84	61.12	17.18	28.94	5.37	3.79	2.70	2.36	1.18	0.62	0.46	0.34	0.28	0.21	0.14	0.10	0.07	0.05	0.05	0.36
1984	58.77	158.37	37.72	7.82	15.93	3.89	2.84	2.04	1.79	0.89	0.47	0.35	0.26	0.21	0.16	0.11	0.07	0.05	0.04	0.31
1985	25.07	213.93	62.64	11.61	3.45	10.67	2.75	2.02	1.46	1.28	0.64	0.34	0.25	0.19	0.15	0.12	0.08	0.05	0.04	0.26
1986	24.68	79.49	73.20	16.42	4.70	2.23	7.31	1.90	1.41	1.02	0.89	0.45	0.24	0.18	0.13	0.11	0.08	0.06	0.04	0.21
1987	26.28	41.27	18.63	12.41	4.57	2.12	1.07	3.53	0.92	0.69	0.49	0.44	0.22	0.12	0.09	0.07	0.05	0.04	0.03	0.12
1988	40.67	96.76	15.93	6.47	5.93	3.15	1.53	0.78	2.59	0.68	0.50	0.36	0.32	0.16	0.09	0.06	0.05	0.04	0.03	0.11
1989	22.06	118.63	30.99	4.04	2.67	3.83	2.16	1.06	0.54	1.80	0.47	0.35	0.26	0.23	0.11	0.06	0.05	0.03	0.03	0.10
1990	6.15	40.57	22.14	4.69	0.99	0.95	1.43	0.81	0.40	0.20	0.68	0.18	0.13	0.10	0.09	0.04	0.02	0.02	0.01	0.05
1991	10.07	32.28	26.77	10.40	2.31	0.57	0.55	0.83	0.47	0.23	0.12	0.40	0.11	0.08	0.06	0.05	0.03	0.01	0.01	0.04
1992	0.09	6.16	34.26	23.80	11.16	3.31	0.84	0.83	1.27	0.72	0.36	0.18	0.61	0.16	0.12	0.09	0.08	0.04	0.02	0.07
1993	0.03	2.53	28.40	2.53	4.07	3.62	1.16	0.30	0.30	0.46	0.26	0.13	0.07	0.22	0.06	0.04	0.03	0.03	0.01	0.03
1994	0.03	1.97	33.75	13.05	1.20	2.39	2.18	0.70	0.18	0.18	0.28	0.16	0.08	0.04	0.14	0.04	0.03	0.02	0.02	0.03
1995	0.03	1.88	19.40	12.20	5.55	0.67	1.38	1.27	0.42	0.11	0.11	0.17	0.10	0.05	0.02	0.08	0.02	0.02	0.01	0.03
1996	0.02	1.00	14.61	7.29	5.18	3.02	0.38	0.79	0.73	0.24	0.06	0.06	0.10	0.06	0.03	0.01	0.05	0.01	0.01	0.02
1997	0.13	6.96	33.01	11.58	6.42	5.92	3.58	0.45	0.95	0.89	0.29	0.08	0.08	0.12	0.07	0.03	0.02	0.06	0.02	0.04
1998	0.06	3.70	20.86	2.56	1.82	1.79	1.76	1.07	0.14	0.29	0.27	0.09	0.02	0.02	0.04	0.02	0.01	0.01	0.02	0.02
1999	0.13	6.26	56.56	9.83	1.42	1.39	1.43	1.43	0.88	0.11	0.24	0.22	0.07	0.02	0.02	0.03	0.02	0.01	0.00	0.03
2000	0.07	4.49	58.09	14.33	3.87	0.89	0.93	0.97	0.98	0.61	0.08	0.16	0.16	0.05	0.01	0.01	0.02	0.01	0.01	0.02
2001	0.04	3.62	65.50	9.87	4.29	1.91	0.47	0.49	0.52	0.52	0.32	0.04	0.09	0.08	0.03	0.01	0.01	0.01	0.01	0.02
2002	0.06	2.44	57.23	22.30	4.03	2.37	1.09	0.27	0.29	0.31	0.31	0.19	0.02	0.05	0.05	0.02	0.00	0.00	0.01	0.01
2003	0.05	3.32	26.84	15.12	7.67	1.94	1.19	0.56	0.14	0.15	0.16	0.16	0.10	0.01	0.03	0.03	0.01	0.00	0.00	0.01
2004	0.02	2.92	41.17	10.64	7.74	5.55	1.47	0.92	0.44	0.11	0.12	0.12	0.13	0.08	0.01	0.02	0.02	0.01	0.00	0.01
2005	0.01	1.21	33.00	12.51	4.10	4.22	3.18	0.86	0.54	0.26	0.07	0.07	0.07	0.08	0.05	0.01	0.01	0.01	0.00	0.01
2006	0.15	0.73	14.62	11.05	5.47	2.62	2.84	2.17	0.59	0.37	0.18	0.05	0.05	0.05	0.05	0.03	0.00	0.01	0.01	0.01
2007	0.13	10.83	14.61	7.74	8.35	6.41	3.24	3.56	2.74	0.75	0.47	0.23	0.06	0.06	0.07	0.07	0.04	0.01	0.01	0.02
2008	0.07	5.26	138.95	1.66	1.62	3.06	2.52	1.29	1.43	1.10	0.30	0.19	0.09	0.02	0.03	0.03	0.03	0.02	0.00	0.01
2009	0.04	4.76	112.97	57.92	0.87	1.18	2.34	1.95	1.00	1.11	0.86	0.23	0.15	0.07	0.02	0.02	0.02	0.02	0.01	0.01

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	9.60	140.90	215.78	162.80	122.88	122.55	121.06	115.49	107.40	97.62	87.23	77.32	68.21	59.72	51.98	45.03	38.88	33.47	28.75	166.99
1956	10.86	155.46	234.05	175.61	134.41	135.66	134.16	128.00	119.03	108.20	96.68	85.70	75.60	66.19	57.61	49.91	43.09	37.10	31.87	185.07
1957	12.59	184.40	271.09	208.71	169.99	178.63	179.36	171.37	159.38	144.87	129.45	114.74	101.22	88.62	77.13	66.83	57.69	49.67	42.67	247.79
1958	13.56	191.03	268.62	194.83	151.75	161.60	167.78	162.67	151.50	137.72	123.06	109.08	96.23	84.25	73.33	63.53	54.85	47.22	40.56	235.57
1959	14.40	202.48	281.33	196.85	150.98	160.92	170.43	170.93	161.55	147.06	131.42	116.49	102.77	89.97	78.31	67.84	58.57	50.43	43.32	251.57
1960	15.08	211.41	288.54	199.82	148.38	155.59	164.88	168.69	164.92	152.35	136.34	120.86	106.62	93.35	81.24	70.39	60.77	52.32	44.94	261.01
1961	15.56	220.52	296.95	204.99	153.96	156.90	163.62	167.49	167.04	159.63	144.97	128.69	113.54	99.40	86.52	74.96	64.71	55.71	47.86	277.94
1962	15.38	216.84	287.41	193.03	140.80	142.40	143.94	144.97	144.66	141.02	132.48	119.35	105.44	92.32	80.35	69.62	60.10	51.74	44.45	258.14
1963	15.27	213.52	283.82	184.64	129.70	128.78	129.42	126.36	124.07	121.01	115.97	108.07	96.89	84.95	73.95	64.07	55.31	47.62	40.91	237.57
1964	16.44	229.76	307.28	202.35	141.16	138.11	136.73	132.77	126.36	121.27	116.28	110.53	102.52	91.22	79.51	68.89	59.48	51.21	43.99	255.46
1965	19.24	264.07	345.31	231.57	165.49	160.62	156.62	149.80	141.79	131.91	124.45	118.37	111.99	103.08	91.18	79.11	68.31	58.81	50.52	293.39
1966	23.45	309.84	383.43	254.79	188.87	188.35	182.20	171.64	160.03	148.07	135.42	126.72	119.96	112.63	103.06	90.75	78.46	67.56	58.04	337.04
1967	28.57	362.86	412.97	267.74	206.65	216.84	215.81	201.69	185.22	168.81	153.54	139.27	129.72	121.87	113.75	103.61	90.91	78.39	67.34	391.10
1968	32.69	399.90	405.76	247.46	193.02	210.38	220.01	211.52	192.72	173.00	155.00	139.82	126.24	116.69	108.98	101.27	91.91	80.42	69.19	401.85
1969	32.73	390.33	356.51	189.87	137.60	150.40	163.14	164.80	154.47	137.56	121.40	107.87	96.87	86.80	79.76	74.15	68.65	62.14	54.25	315.57
1970	30.26	371.77	338.07	163.10	106.88	111.67	121.96	127.81	125.87	115.32	100.97	88.37	78.16	69.66	62.05	56.76	52.58	48.55	43.85	259.14
1971	27.04	345.99	324.74	155.16	90.19	83.49	86.91	91.70	93.69	90.19	81.23	70.54	61.45	53.94	47.79	42.38	38.63	35.68	32.88	203.75
1972	25.16	331.14	329.00	161.44	90.80	73.42	67.59	67.96	69.90	69.81	66.07	59.02	51.01	44.10	38.49	33.94	29.99	27.26	25.13	165.48
1973	28.81	333.08	342.86	176.45	99.76	77.53	62.31	55.40	54.31	54.60	53.61	50.32	44.74	38.38	32.99	28.65	25.18	22.19	20.12	139.72
1974	32.66	424.57	384.74	216.47	138.37	110.98	85.99	66.75	57.86	55.44	54.80	53.36	49.85	43.99	37.51	32.10	27.78	24.35	21.41	153.13
1975	44.66	474.46	432.46	220.14	155.01	135.41	107.60	80.50	60.92	51.62	48.63	47.66	46.20	42.83	37.58	31.90	27.19	23.47	20.53	146.10
1976	55.99	540.63	363.66	184.66	118.97	113.87	98.42	75.51	55.08	40.74	33.94	31.70	30.93	29.76	27.43	23.95	20.26	17.23	14.84	104.57
1977	39.20	655.32	400.54	152.33	100.54	88.65	84.01	70.10	52.44	37.39	27.19	22.46	20.89	20.23	19.34	17.75	15.44	13.03	11.05	76.06
1978	34.90	518.07	539.39	186.27	87.95	76.49	66.46	60.78	49.45	36.16	25.34	18.28	15.03	13.87	13.35	12.71	11.62	10.08	8.49	56.37
1979	25.90	449.10	406.21	233.72	98.74	61.79	53.00	44.44	39.63	31.52	22.65	15.75	11.31	9.23	8.47	8.11	7.70	7.02	6.08	38.79
1980	46.28	308.16	331.62	168.57	127.83	75.44	46.87	38.82	31.74	27.66	21.63	15.42	10.67	7.60	6.17	5.63	5.38	5.09	4.63	29.39
1981	6.06	446.90	179.39	108.30	73.45	76.99	45.02	27.01	21.81	17.43	14.94	11.58	8.22	5.64	4.00	3.23	2.94	2.80	2.64	17.54
1982	8.87	72.46	342.19	77.61	56.80	49.25	50.68	28.60	16.73	13.20	10.37	8.82	6.80	4.79	3.27	2.31	1.86	1.68	1.60	11.46
1983	43.21	141.91	78.44	210.00	53.73	47.76	40.40	40.10	22.06	12.61	9.79	7.63	6.45	4.94	3.46	2.35	1.65	1.33	1.20	9.24
1984	72.88	367.72	172.27	56.75	159.40	49.08	42.52	34.68	33.55	18.04	10.14	7.80	6.05	5.08	3.87	2.70	1.83	1.28	1.02	8.01
1985	31.09	496.71	286.09	84.21	34.52	134.62	41.14	34.42	27.38	25.90	13.69	7.63	5.84	4.50	3.76	2.85	1.98	1.33	0.93	6.55
1986	30.61	184.58	334.29	119.13	47.06	28.07	109.43	32.35	26.42	20.55	19.11	10.02	5.56	4.23	3.23	2.69	2.03	1.41	0.95	5.27
1987	32.60	95.83	85.08	90.01	45.74	26.74	15.95	60.10	17.33	13.83	10.58	9.75	5.09	2.80	2.12	1.61	1.34	1.01	0.70	3.05
1988	50.44	224.66	72.75	46.98	59.29	39.76	22.93	13.20	48.49	13.67	10.72	8.13	7.47	3.87	2.12	1.59	1.21	1.00	0.75	2.78
1989	27.36	275.45	141.52	29.35	26.70	48.36	32.30	17.99	10.10	36.26	10.04	7.82	5.90	5.38	2.77	1.51	1.13	0.86	0.71	2.48
1990	7.63	94.20	101.12	34.00	9.92	12.01	21.38	13.76	7.47	4.10	14.46	3.97	3.08	2.31	2.09	1.07	0.58	0.43	0.33	1.21
1991	12.49	74.95	122.27	75.47	23.14	7.13	8.26	14.16	8.89	4.72	2.54	8.90	2.44	1.87	1.39	1.26	0.64	0.35	0.26	0.91
1992	0.41	31.44	201.47	180.58	112.18	41.73	12.60	14.15	23.75	14.60	7.62	4.08	14.20	3.85	2.95	2.18	1.96	1.00	0.54	1.81
1993	0.15	12.93	167.00	19.19	40.90	45.68	17.37	5.09	5.60	9.20	5.56	2.88	1.53	5.30	1.43	1.09	0.80	0.72	0.37	0.86
1994	0.13	10.04	198.45	99.00	12.08	30.16	32.60	11.97	3.43	3.69	5.95	3.57	1.84	0.97	3.34	0.90	0.68	0.50	0.45	0.76
1995	0.13	9.57	114.11	92.55	55.76	8.41	20.57	21.62	7.79	2.19	2.31	3.71	2.21	1.13	0.59	2.03	0.54	0.41	0.30	0.72
1996	0.10	5.10	85.90	55.27	52.08	38.13	5.62	13.35	13.75	4.85	1.34	1.41	2.24	1.33	0.68	0.35	1.21	0.32	0.24	0.60
1997	0.65	35.53	194.15	87.85	64.51	74.76	53.62	7.66	17.81	17.96	6.23	1.71	1.78	2.82	1.66	0.84	0.44	1.49	0.40	1.03
1998	0.28	18.86	122.67	19.45	18.25	22.53	26.35	18.27	2.55	5.80	5.75	1.98	0.54	0.56	0.88	0.52	0.26	0.14	0.46	0.44
1999	0.62	31.96	332.61	74.56	14.25	17.51	21.36	24.32	16.56	2.27	5.07	4.99	1.71	0.46	0.48	0.75	0.44	0.22	0.11	0.75
2000	0.34	22.89	341.59	108.69	38.88	11.24	13.86	16.46	18.37	12.25	1.65	3.66	3.59	1.22	0.33	0.34	0.53	0.31	0.15	0.60
2001	0.19	18.48	385.17	74.86	43.10	24.05	6.97	8.33	9.68	10.58	6.94	0.93	2.05	1.99	0.67	0.18	0.18	0.29	0.17	0.41
2002	0.28	12.46	336.55	169.20	40.50	29.88	16.37	4.61	5.41	6.17	6.63	4.32	0.57	1.26	1.22	0.41	0.11	0.11	0.17	0.34
2003	0.24	16.96	157.82	114.70	77.11	24.53	17.85	9.52	2.63	3.03	3.40	3.62	2.35	0.31	0.68	0.65	0.22	0.06	0.06	0.27
2004	0.11	14.92	242.08	80.72	77.79	70.05	22.02	15.59	8.16	2.21	2.51	2.79	2.96	1.90	0.25	0.54	0.52	0.17	0.05	0.26
2005	0.05	6.15	194.08	94.90	41.17	53.30	47.62	14.60	10.16	5.21	1.39	1.56	1.73	1.82	1.17	0.15	0.33	0.31	0.10	0.18
2006	0.74	3.74	85.96	83.83	55.01	33.00	42.49	36.87	11.07	7.54	3.81	1.01	1.13	1.24	1.30	0.83	0.11	0.23	0.22	0.20
2007	0.61	55.26	85.92	58.72	83.93	80.88	48.55	60.50	51.28	15.06	10.09	5.05	1.33	1.48	1.61	1.68	1.07	0.14	0.30	0.54
2008	0.32	26.84	817.14	12.59	16.28	38.61	37.76	21.99	26.79	22.22	6.42	4.26	2.12	0.56	0.61	0.67	0.69	0.44	0.06	0.34
2009	0.18	24.27	664.32	439.39	8.71	14.94	34.97	33.09	18.82	22.43	18.29	5.24	3.47	1.71	0.45	0.49	0.53	0.55	0.35	0.31

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

Year	L.cl	L.cd	L.hb	L.pvt	Total
1955	41.30	0.00	150.95	29.72	221.97
1956	39.70	0.00	165.34	39.01	244.05
1957	70.41	0.00	179.75	48.93	299.09
1958	49.67	0.00	186.72	57.40	293.80
1959	53.16	0.00	189.22	65.03	307.42
1960	54.39	0.00	188.96	71.86	315.22
1961	64.63	0.00	184.65	77.04	326.31
1962	54.13	0.00	175.61	80.33	310.08
1963	41.81	0.00	169.18	85.41	296.40
1964	46.89	0.00	174.16	97.00	318.06
1965	55.52	0.00	191.37	115.88	362.77
1966	62.97	0.00	214.31	138.46	415.74
1967	82.78	0.00	231.97	157.64	472.38
1968	94.01	0.00	231.79	164.60	490.39
1969	64.67	0.00	211.46	157.24	433.37
1970	63.52	0.00	183.47	144.35	391.35
1971	58.55	0.00	158.83	134.33	351.70
1972	54.51	0.00	144.97	133.56	333.04
1973	47.82	0.00	145.73	146.02	339.56
1974	83.60	0.00	158.37	169.60	411.56
1975	104.26	0.00	170.91	192.47	467.65
1976	99.10	0.00	175.63	206.82	481.55
1977	122.45	0.00	170.01	209.13	501.59
1978	110.45	0.00	154.07	197.97	462.49
1979	75.43	0.00	133.59	181.71	390.73
1980	67.68	0.00	108.84	158.72	335.24
1981	81.71	0.00	72.49	131.44	285.64
1982	51.86	0.00	40.04	57.92	149.82
1983	51.92	0.00	62.40	45.83	160.15
1984	48.41	0.14	62.18	181.39	292.12
1985	48.50	0.29	99.88	188.33	337.00
1986	33.51	0.06	101.35	79.83	214.75
1987	25.98	0.00	38.73	48.44	113.16
1988	27.95	0.00	59.10	89.16	176.21
1989	49.51	0.00	42.75	97.19	189.46
1990	41.98	0.25	26.38	11.04	79.65
1991	23.62	0.79	30.16	30.82	85.39
1992	8.78	1.07	40.30	34.03	84.18
1993	18.85	0.66	14.30	10.47	44.29
1994	19.67	1.62	21.88	13.29	56.46
1995	17.85	1.18	22.08	2.38	43.49
1996	13.23	0.68	8.56	11.20	33.67
1997	9.62	0.79	56.78	3.52	70.71
1998	8.19	0.91	17.92	7.54	34.55
1999	9.34	1.27	47.33	22.17	80.10
2000	10.92	1.34	19.17	54.33	85.75
2001	22.82	2.47	21.98	40.57	87.83
2002	21.47	2.90	31.28	35.42	91.07
2003	14.12	2.09	24.75	16.54	57.50
2004	17.25	2.28	25.62	26.35	71.50
2005	12.97	1.04	24.16	22.09	60.27
2006	7.66	0.42	17.95	15.02	41.06
2007	9.41	0.75	17.41	31.81	59.39
2008	30.55	0.87	41.78	84.49	157.69
2009	42.76	1.07	49.93	91.79	185.55

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	497.87	0.00	1143.29	232.52	1873.68
1956	484.37	0.00	1270.18	309.72	2064.26
1957	869.12	0.00	1394.56	392.53	2656.21
1958	617.42	0.00	1449.94	461.36	2528.72
1959	662.84	0.00	1463.71	521.07	2647.62
1960	677.25	0.00	1449.03	571.21	2697.49
1961	800.03	0.00	1396.52	604.42	2800.97
1962	662.74	0.00	1303.02	618.69	2584.46
1963	504.94	0.00	1231.45	645.51	2381.90
1964	559.62	0.00	1249.09	722.60	2531.31
1965	656.99	0.00	1355.34	853.29	2865.62
1966	740.31	0.00	1494.31	1005.66	3240.28
1967	964.17	0.00	1574.47	1118.02	3656.66
1968	1069.93	0.00	1494.44	1113.47	3677.84
1969	700.76	0.00	1258.79	985.30	2944.86
1970	641.14	0.00	1001.45	830.19	2472.78
1971	543.59	0.00	800.76	713.02	2057.37
1972	468.69	0.00	689.86	668.17	1826.71
1973	387.35	0.00	658.28	695.36	1740.99
1974	632.47	0.00	676.45	763.17	2072.09
1975	745.31	0.00	678.60	810.96	2234.87
1976	621.00	0.00	602.86	758.29	1982.14
1977	654.51	0.00	553.99	715.44	1923.95
1978	595.48	0.00	530.69	714.89	1841.06
1979	417.96	0.00	479.88	681.31	1579.15
1980	391.70	0.00	359.04	563.84	1314.58
1981	392.00	0.00	239.42	444.46	1075.89
1982	333.00	0.00	174.07	262.28	769.35
1983	330.17	0.00	224.19	183.90	738.26
1984	257.98	1.32	189.68	605.72	1054.69
1985	244.01	2.55	337.12	661.44	1245.12
1986	215.28	0.51	420.66	350.51	986.96
1987	177.93	0.03	142.95	200.35	521.26
1988	155.28	0.01	179.01	297.49	631.79
1989	236.22	0.01	131.26	316.48	683.96
1990	204.10	1.86	89.72	39.44	335.12
1991	129.46	5.89	113.36	123.33	372.04
1992	85.12	9.57	305.97	272.42	673.08
1993	169.68	5.59	95.96	72.41	343.65
1994	168.08	13.05	147.98	91.40	420.51
1995	160.94	10.02	158.29	17.43	346.67
1996	127.56	6.15	64.08	86.08	283.87
1997	98.78	7.52	438.23	28.38	572.91
1998	79.22	8.05	124.16	55.12	266.55
1999	79.65	9.96	311.16	150.21	550.98
2000	90.72	10.36	124.97	370.90	596.95
2001	175.85	18.25	138.95	262.19	595.23
2002	170.39	22.23	206.61	237.35	636.58
2003	123.55	17.55	174.37	120.52	435.99
2004	156.40	19.75	179.72	189.71	545.58
2005	123.63	9.38	178.06	164.93	475.99
2006	82.15	4.17	153.39	130.61	370.33
2007	105.03	7.52	131.40	320.05	564.00
2008	236.29	6.30	259.75	534.38	1036.72
2009	336.66	8.01	330.28	617.57	1292.52

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

Year	D.cl	D.hb	D.pvt	Total
1983	0.00	17.46	3.39	20.85
1984	0.00	50.87	8.94	59.81
1985	0.00	11.42	24.90	36.32
1986	0.00	0.06	3.39	3.45
1987	0.00	0.06	40.84	40.91
1988	0.00	0.06	18.69	18.75
1989	0.00	0.06	7.80	7.86
1990	0.00	0.06	3.39	3.45
1991	0.00	0.29	14.00	14.28
1992	6.80	7.33	7.58	21.70
1993	7.12	13.63	18.99	39.75
1994	9.89	3.02	24.36	37.26
1995	9.34	10.00	14.82	34.17
1996	11.83	2.07	6.86	20.76
1997	13.13	7.80	3.38	24.32
1998	10.12	3.63	8.95	22.70
1999	9.27	19.44	51.20	79.91
2000	9.09	13.31	86.02	108.41
2001	9.14	13.48	70.18	92.80
2002	20.53	10.65	41.87	73.05
2003	6.71	8.90	54.47	70.09
2004	2.48	15.39	64.51	82.39
2005	2.40	20.39	31.39	54.18
2006	3.57	9.52	45.35	58.44
2007	7.09	48.59	133.03	188.71
2008	7.45	24.55	137.90	169.91
2009	9.79	14.40	71.65	95.85

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

Year	D.cl	D.hb	D.pvt	Total
1983	0.00	9.41	1.83	11.24
1984	0.00	28.11	4.94	33.05
1985	0.00	6.63	14.46	21.10
1986	0.00	0.04	1.91	1.94
1987	0.00	0.03	21.90	21.93
1988	0.00	0.04	10.30	10.33
1989	0.00	0.04	4.44	4.48
1990	0.00	0.04	1.94	1.98
1991	0.00	0.16	7.82	7.98
1992	15.27	13.89	14.36	43.51
1993	17.66	28.54	39.75	85.95
1994	25.86	6.52	52.66	85.04
1995	23.79	20.94	31.03	75.77
1996	29.11	4.15	13.74	47.00
1997	29.80	14.10	6.12	50.02
1998	23.13	6.91	17.05	47.10
1999	21.86	36.23	95.44	153.53
2000	20.87	25.95	167.71	214.54
2001	23.05	28.84	150.22	202.11
2002	53.14	21.79	85.67	160.60
2003	15.93	17.58	107.59	141.10
2004	6.28	33.32	139.63	179.22
2005	6.56	47.20	72.65	126.40
2006	6.59	10.75	51.21	68.56
2007	14.52	91.92	251.70	358.14
2008	19.27	52.79	296.47	368.52
2009	25.60	32.22	160.33	218.15

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}	0.243	0.040
85%F_{MSY}	y^{-1}	0.206	0.034
75%F_{MSY}	y^{-1}	0.182	0.030
65%F_{MSY}	y^{-1}	0.158	0.026
$F_{30\%}$	y^{-1}	0.175	0.033
$F_{40\%}$	y^{-1}	0.127	0.025
$F_{50\%}$	y^{-1}	0.092	0.019
B_{MSY}	mt	10750	2426
SSB_{MSY}	mt	112	32
MSST	mt	103	31
MSY	1000 lb	2192	381
D_{MSY}	1000 fish	49	9
R_{MSY}	1000 age-1 fish	576	108
Y at 85%F_{MSY}	1000 lb	2175	379
Y at 75%F_{MSY}	1000 lb	2141	374
Y at 65%F_{MSY}	1000 lb	2080	365
$F_{2007-2009}/F_{MSY}$	—	3.64	0.57
SSB_{2009}/MSST	—	0.07	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 S9 which used body weight of mature females. See text for full description of sensitivity runs.

Run	Description	F_{MSY}	SSB_{MSY} (mt)	MSY(1000 lb)	$F_{2007-2009}/F_{MSY}$	SSB_{2009}/MSST	steep	R0(1000)
Base	—	0.242	112	2192	3.64	0.07	0.972	498
S1	low M	0.189	200	2657	5.05	0.03	0.989	374
S2	high M	0.291	68	1875	2.7	0.13	0.93	737
S3	low disc M	0.246	109	2284	3.46	0.07	0.967	502
S4	high disc M	0.24	115	2111	3.81	0.07	0.976	494
S5	q const	0.248	114	2149	3.08	0.09	0.972	500
S6	q 0.04	0.239	111	2208	3.98	0.06	0.972	493
S7	rand walk q	0.239	117	2116	3.38	0.08	0.973	511
S8	age error	0.264	113	2123	3.58	0.07	0.973	490
S9	continuity	0.129	5061	2672	4.71	0.09	0.959	532
S10	styr 1976	0.237	148	2809	3.71	0.05	0.962	642
S11	low recr LD	0.236	73	1477	3.88	0.08	0.976	322
S12	high recr LD	0.248	153	2946	3.49	0.06	0.969	684
S13	low comm LD	0.245	102	2002	3.77	0.07	0.973	453
S14	high comm LD	0.24	123	2388	3.51	0.07	0.97	545
S15	U.hb 0.5	0.236	113	2206	4.05	0.05	0.971	510
S16	U.hb 2	0.251	111	2178	3.26	0.08	0.973	484
S17	U.cl 0.5	0.244	115	2167	3.18	0.08	0.972	504
S18	U.cl 2	0.239	109	2220	4.2	0.05	0.972	491
S19	age 0.5	0.257	110	2186	3.63	0.07	0.972	489
S20	age 2	0.233	113	2173	3.63	0.07	0.973	498
S21	len 0.5	0.236	109	2171	3.73	0.06	0.973	481
S22	len 2	0.25	114	2201	3.52	0.07	0.971	506
S23	comm 1.0 recr 0.1	0.308	106	1889	3.2	0.07	0.964	469
S24	comm 1.0 recr 0.5	0.196	113	2429	4	0.06	0.976	517
S25	comm 0.75 recr 0.1	0.322	106	1819	3.03	0.08	0.962	462
S26	comm 0.75 recr 0.3	0.247	113	2159	3.51	0.07	0.971	497
S27	comm 0.75 recr 0.5	0.197	115	2391	3.78	0.06	0.975	517
S28	comm 0.5 recr 0.1	0.343	106	1727	2.78	0.09	0.959	454
S29	comm 0.5 recr 0.3	0.254	114	2120	3.31	0.08	0.969	497
S30	comm 0.5 recr 0.5	0.2	114	2378	3.69	0.06	0.975	517
S31	extreme 1	0.386	72	1591	1.7	0.24	0.866	734
S32	extreme 2	0.144	226	3051	5.74	0.02	0.99	418

*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} =* 0.24 *(per yr),* SSB_{MSY} = 112 *(mt), and* MSY = 2192 *(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	0.413	0	8.06	396	111	530	0	0	0
2011	0.877	0	12.47	416	95	188	154	1318	1318
2012	0.877	0	10.54	465	105	209	153	1290	2608
2013	0.877	0	10.25	448	113	229	152	1272	3880
2014	0.877	0	9.85	445	112	229	158	1285	5165
2015	0.877	0	9.43	440	110	226	155	1248	6413
2016	0.877	0	9.07	435	109	223	153	1220	7633
2017	0.877	0	8.78	431	108	221	151	1196	8829
2018	0.877	0	8.54	427	107	219	149	1176	10,006
2019	0.877	0	8.36	423	106	217	147	1159	11,165
2020	0.877	0	8.2	421	105	215	146	1145	12,310
2021	0.877	0	8.07	418	104	214	144	1132	13,442
2022	0.877	0	7.97	416	104	212	143	1122	14,563
2023	0.877	0	7.88	415	103	211	142	1113	15,676
2024	0.877	0	7.8	413	103	210	142	1105	16,781
2025	0.877	0	7.73	412	103	210	141	1099	17,879
2026	0.877	0	7.68	411	102	209	140	1093	18,972
2027	0.877	0	7.63	410	102	208	140	1088	20,060
2028	0.877	0	7.59	409	102	208	139	1084	21,144
2029	0.877	0	7.55	409	102	208	139	1080	22,225
2030	0.877	0	7.52	408	101	207	139	1077	23,302
2031	0.877	0	7.5	408	101	207	138	1075	24,377
2032	0.877	0	7.47	407	101	207	138	1073	25,450
2033	0.877	0	7.45	407	101	206	138	1071	26,520
2034	0.877	0	7.44	406	101	206	138	1069	27,589
2035	0.877	0	7.42	406	101	206	138	1067	28,657
2036	0.877	0	7.41	406	101	206	137	1066	29,723
2037	0.877	0	7.4	406	101	206	137	1065	30,788
2038	0.877	0	7.39	405	101	206	137	1064	31,852
2039	0.877	0	7.38	405	101	206	137	1063	32,915
2040	0.877	0	7.38	405	101	205	137	1063	33,978
2041	0.877	0	7.37	405	101	205	137	1062	35,040
2042	0.877	0	7.36	405	101	205	137	1062	36,102
2043	0.877	0	7.36	405	101	205	137	1061	37,163
2044	0.877	0	7.36	405	101	205	137	1061	38,224
2045	0.877	0	7.35	405	101	205	137	1060	39,284

Table 3.17. Projection results under scenario 3—fishing mortality rate fixed at $F = 65\%F_{\mathrm{MSY}}$. *F = fishing mortality rate (per year), Pr(*$\mathrm{SSB} > \mathrm{SSB}_{\mathrm{MSY}}$*) = proportion of stochastic projection replicates exceeding* $\mathrm{SSB}_{\mathrm{MSY}}$, *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* $F_{\mathrm{MSY}} = 0.24$ *(per yr),* $\mathrm{SSB}_{\mathrm{MSY}} = 112$ *(mt), and* MSY = 2192 *(1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

Year	F(per yr)	Pr(SSB > $\mathrm{SSB}_{\mathrm{MSY}}$)	SSB(mt)	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2010	0.413	0	8.06	396	111	530	0	0	0
2011	0.158	0	12.47	416	19	39	34	288	288
2012	0.158	0	17.69	465	23	50	49	401	689
2013	0.158	0	23.56	497	26	56	60	507	1195
2014	0.158	0	30.39	518	28	60	70	613	1808
2015	0.158	0	38.07	533	29	64	79	721	2529
2016	0.158	0	46.42	544	30	66	87	827	3356
2017	0.158	0	55.25	552	31	67	94	931	4286
2018	0.158	0.01	64.35	559	31	69	101	1032	5318
2019	0.158	0.03	73.5	563	32	69	106	1128	6446
2020	0.158	0.08	82.49	567	32	70	112	1218	7664
2021	0.158	0.16	91.18	570	32	71	116	1303	8967
2022	0.158	0.28	99.47	572	32	71	120	1382	10,349
2023	0.158	0.42	107.29	573	33	71	124	1454	11,802
2024	0.158	0.56	114.58	575	33	71	127	1520	13,322
2025	0.158	0.68	121.33	576	33	72	129	1580	14,902
2026	0.158	0.78	127.51	577	33	72	132	1634	16,536
2027	0.158	0.86	133.15	578	33	72	134	1683	18,220
2028	0.158	0.91	138.25	578	33	72	136	1727	19,947
2029	0.158	0.94	142.87	579	33	72	138	1767	21,714
2030	0.158	0.96	147.02	579	33	72	139	1802	23,516
2031	0.158	0.98	150.74	580	33	72	141	1834	25,349
2032	0.158	0.99	154.06	580	33	72	142	1862	27,211
2033	0.158	0.99	157.03	580	33	72	143	1887	29,098
2034	0.158	0.99	159.66	581	33	72	144	1909	31,006
2035	0.158	1	162.01	581	33	72	145	1928	32,935
2036	0.158	1	164.09	581	33	72	145	1946	34,881
2037	0.158	1	165.94	581	33	72	146	1961	36,842
2038	0.158	1	167.58	581	33	73	146	1975	38,817
2039	0.158	1	169.03	581	33	73	147	1987	40,804
2040	0.158	1	170.32	581	33	73	147	1998	42,802
2041	0.158	1	171.46	582	33	73	148	2007	44,809
2042	0.158	1	172.47	582	33	73	148	2016	46,825
2043	0.158	1	173.36	582	33	73	148	2023	48,848
2044	0.158	1	174.15	582	33	73	149	2030	50,877
2045	0.158	1	174.85	582	33	73	149	2035	52,913

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} = 0.24 (per yr), SSB_{MSY} = 112 (mt), and MSY = 2192 (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	0.413	0	8.06	396	111	530	0	0	0
2011	0.182	0	12.47	416	22	45	39	330	330
2012	0.182	0	17.38	465	27	57	55	453	783
2013	0.182	0	22.89	496	30	64	67	568	1352
2014	0.182	0	29.22	516	32	69	78	683	2034
2015	0.182	0	36.26	531	33	72	88	797	2832
2016	0.182	0	43.85	542	34	75	96	909	3741
2017	0.182	0	51.8	550	35	76	104	1018	4759
2018	0.182	0.01	59.93	556	36	78	111	1122	5882
2019	0.182	0.01	68.04	561	36	79	117	1222	7103
2020	0.182	0.04	75.95	565	37	80	122	1314	8418
2021	0.182	0.08	83.55	568	37	80	127	1400	9818
2022	0.182	0.14	90.74	570	37	81	131	1480	11,298
2023	0.182	0.23	97.47	572	37	81	134	1552	12,849
2024	0.182	0.34	103.7	573	37	81	137	1618	14,467
2025	0.182	0.45	109.43	574	37	81	140	1677	16,144
2026	0.182	0.55	114.64	575	37	82	143	1730	17,874
2027	0.182	0.64	119.36	576	37	82	145	1778	19,652
2028	0.182	0.72	123.61	577	38	82	147	1820	21,472
2029	0.182	0.78	127.42	577	38	82	148	1858	23,331
2030	0.182	0.83	130.82	578	38	82	150	1892	25,222
2031	0.182	0.87	133.85	578	38	82	151	1922	27,144
2032	0.182	0.9	136.54	578	38	82	152	1948	29,092
2033	0.182	0.92	138.92	579	38	82	153	1971	31,064
2034	0.182	0.94	141.02	579	38	82	154	1992	33,055
2035	0.182	0.95	142.88	579	38	82	155	2010	35,065
2036	0.182	0.96	144.51	579	38	82	155	2026	37,091
2037	0.182	0.97	145.95	579	38	82	156	2040	39,131
2038	0.182	0.97	147.22	580	38	82	157	2052	41,183
2039	0.182	0.98	148.34	580	38	82	157	2063	43,246
2040	0.182	0.98	149.32	580	38	82	157	2072	45,318
2041	0.182	0.98	150.19	580	38	82	158	2081	47,399
2042	0.182	0.98	150.95	580	38	82	158	2088	49,487
2043	0.182	0.99	151.61	580	38	83	158	2094	51,581
2044	0.182	0.99	152.2	580	38	83	159	2100	53,681
2045	0.182	0.99	152.71	580	38	83	159	2105	55,786

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} = 0.24 (per yr), SSB_{MSY} = 112 (mt), and MSY = 2192 (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	0.413	0	8.06	396	111	530	0	0	0
2011	0.206	0	12.47	416	25	51	44	371	371
2012	0.206	0	17.07	465	30	64	61	504	876
2013	0.206	0	22.24	494	33	71	74	626	1502
2014	0.206	0	28.09	514	36	77	85	747	2249
2015	0.206	0	34.55	529	37	81	96	867	3116
2016	0.206	0	41.43	540	38	83	105	982	4098
2017	0.206	0	48.57	548	39	85	113	1094	5192
2018	0.206	0	55.82	554	40	87	120	1200	6392
2019	0.206	0.01	63	559	40	88	126	1301	7693
2020	0.206	0.01	69.96	563	41	89	131	1394	9086
2021	0.206	0.03	76.58	566	41	89	136	1479	10,566
2022	0.206	0.06	82.81	568	41	90	140	1558	12,124
2023	0.206	0.1	88.6	570	42	90	143	1629	13,753
2024	0.206	0.16	93.93	571	42	91	147	1693	15,446
2025	0.206	0.23	98.79	572	42	91	149	1751	17,196
2026	0.206	0.31	103.18	573	42	91	152	1802	18,998
2027	0.206	0.38	107.13	574	42	91	154	1847	20,846
2028	0.206	0.45	110.66	575	42	91	156	1888	22,733
2029	0.206	0.52	113.81	575	42	92	157	1924	24,657
2030	0.206	0.58	116.61	576	42	92	159	1955	26,612
2031	0.206	0.64	119.07	576	42	92	160	1983	28,595
2032	0.206	0.68	121.25	577	42	92	161	2007	30,603
2033	0.206	0.72	123.16	577	42	92	162	2029	32,631
2034	0.206	0.75	124.84	577	42	92	163	2047	34,678
2035	0.206	0.78	126.31	577	42	92	163	2064	36,742
2036	0.206	0.8	127.6	578	42	92	164	2078	38,820
2037	0.206	0.82	128.73	578	42	92	164	2090	40,910
2038	0.206	0.83	129.72	578	42	92	165	2101	43,012
2039	0.206	0.84	130.58	578	42	92	165	2111	45,123
2040	0.206	0.86	131.33	578	42	92	166	2119	47,242
2041	0.206	0.87	131.99	578	42	92	166	2126	49,368
2042	0.206	0.87	132.56	578	42	92	166	2133	51,501
2043	0.206	0.88	133.06	578	42	92	166	2138	53,639
2044	0.206	0.88	133.5	578	42	92	167	2143	55,782
2045	0.206	0.89	133.88	578	42	92	167	2147	57,929

*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} =* 0.24 *(per yr),* SSB_{MSY} = 112 *(mt), and* MSY = 2192 *(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	0.413	0	8.06	396	111	530	0	0	0
2011	0.242	0	12.47	416	29	59	52	432	432
2012	0.242	0	16.62	465	35	74	70	576	1009
2013	0.242	0	21.3	492	39	82	83	707	1715
2014	0.242	0	26.49	511	41	89	96	834	2550
2015	0.242	0	32.13	525	43	93	106	958	3508
2016	0.242	0	38.05	536	44	96	116	1076	4584
2017	0.242	0	44.12	544	45	98	124	1189	5773
2018	0.242	0	50.21	550	46	100	131	1295	7068
2019	0.242	0	56.17	555	47	101	137	1394	8462
2020	0.242	0	61.88	559	47	102	143	1486	9948
2021	0.242	0.01	67.27	562	47	103	147	1569	11,516
2022	0.242	0.01	72.28	564	48	103	151	1644	13,160
2023	0.242	0.02	76.89	566	48	104	155	1711	14,872
2024	0.242	0.04	81.09	568	48	104	158	1772	16,644
2025	0.242	0.06	84.89	569	48	104	160	1825	18,469
2026	0.242	0.08	88.28	570	48	105	163	1873	20,341
2027	0.242	0.1	91.3	571	48	105	165	1914	22,256
2028	0.242	0.13	93.98	572	48	105	166	1951	24,207
2029	0.242	0.16	96.35	572	49	105	168	1983	26,190
2030	0.242	0.19	98.43	573	49	105	169	2011	28,201
2031	0.242	0.22	100.25	573	49	105	170	2035	30,236
2032	0.242	0.24	101.83	574	49	106	171	2056	32,292
2033	0.242	0.27	103.22	574	49	106	172	2075	34,367
2034	0.242	0.29	104.42	574	49	106	173	2091	36,458
2035	0.242	0.31	105.46	574	49	106	173	2105	38,562
2036	0.242	0.33	106.37	575	49	106	174	2117	40,679
2037	0.242	0.35	107.16	575	49	106	174	2127	42,806
2038	0.242	0.36	107.84	575	49	106	175	2136	44,942
2039	0.242	0.37	108.42	575	49	106	175	2144	47,086
2040	0.242	0.39	108.93	575	49	106	175	2150	49,236
2041	0.242	0.4	109.37	575	49	106	175	2156	51,392
2042	0.242	0.4	109.75	575	49	106	176	2161	53,553
2043	0.242	0.41	110.08	575	49	106	176	2165	55,718
2044	0.242	0.41	110.36	575	49	106	176	2169	57,888
2045	0.242	0.42	110.61	575	49	106	176	2172	60,060

Table 3.21. Projection results under scenario 7—fishing mortality rate fixed at $F = F_{\text{current}}$, 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} = 0.24 (per yr), SSB_{MSY} = 112 (mt), and MSY = 2192 (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	0.413	0	8.06	396	111	530	0	0	0
2011	0.413	0	12.47	416	119	556	0	0	0
2012	0.413	0	16.36	465	142	691	0	0	0
2013	0.413	0	20.58	490	159	809	0	0	0
2014	0.413	0	25.07	509	174	924	0	0	0
2015	0.413	0	29.79	522	186	1029	0	0	0
2016	0.413	0	34.62	532	196	1126	0	0	0
2017	0.413	0	39.49	540	204	1218	0	0	0
2018	0.413	0	44.32	546	211	1303	0	0	0
2019	0.413	0	49.02	551	217	1382	0	0	0
2020	0.413	0	53.5	554	222	1455	0	0	0
2021	0.413	0	57.71	558	226	1520	0	0	0
2022	0.413	0	61.63	560	230	1580	0	0	0
2023	0.413	0	65.22	562	233	1633	0	0	0
2024	0.413	0	68.5	564	236	1681	0	0	0
2025	0.413	0.01	71.47	565	238	1723	0	0	0
2026	0.413	0.01	74.12	566	240	1760	0	0	0
2027	0.413	0.01	76.49	567	242	1793	0	0	0
2028	0.413	0.01	78.59	568	244	1822	0	0	0
2029	0.413	0.02	80.45	568	245	1848	0	0	0
2030	0.413	0.02	82.09	569	246	1870	0	0	0
2031	0.413	0.03	83.53	569	247	1889	0	0	0
2032	0.413	0.03	84.79	570	248	1906	0	0	0
2033	0.413	0.04	85.9	570	249	1921	0	0	0
2034	0.413	0.04	86.86	570	249	1934	0	0	0
2035	0.413	0.04	87.7	571	250	1945	0	0	0
2036	0.413	0.05	88.42	571	250	1955	0	0	0
2037	0.413	0.05	89.06	571	251	1963	0	0	0
2038	0.413	0.06	89.61	571	251	1971	0	0	0
2039	0.413	0.06	90.09	571	251	1977	0	0	0
2040	0.413	0.06	90.5	571	252	1982	0	0	0
2041	0.413	0.07	90.86	572	252	1987	0	0	0
2042	0.413	0.07	91.18	572	252	1991	0	0	0
2043	0.413	0.07	91.45	572	252	1995	0	0	0
2044	0.413	0.07	91.68	572	252	1998	0	0	0
2045	0.413	0.07	91.88	572	252	2001	0	0	0

Table 3.22. Projection results under scenario 9—fishing mortality rate fixed at $F = F_{\text{rebuild}}$*, with rebuilding probability of 0.7 in 2044. F = fishing mortality rate (per year), Pr(*$\text{SSB} > \text{SSB}_{\text{MSY}}$*) = 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* $F_{\text{MSY}} = 0.24$ *(per yr),* $\text{SSB}_{\text{MSY}} = 112$ *(mt), and* MSY = 2192 *(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	0.413	0	8.06	396	111	530	0	0	0
2011	0.223	0	12.47	416	27	55	48	400	400
2012	0.223	0	16.86	465	32	68	65	538	938
2013	0.223	0	21.8	493	36	76	78	665	1603
2014	0.223	0	27.34	513	38	82	90	789	2392
2015	0.223	0	33.4	527	40	86	101	911	3303
2016	0.223	0	39.82	538	41	89	110	1028	4331
2017	0.223	0	46.45	546	42	91	118	1141	5471
2018	0.223	0	53.14	552	43	93	125	1247	6719
2019	0.223	0	59.73	557	43	94	131	1347	8066
2020	0.223	0.01	66.08	561	44	95	137	1440	9506
2021	0.223	0.02	72.1	564	44	96	141	1525	11,031
2022	0.223	0.03	77.74	566	44	96	145	1602	12,633
2023	0.223	0.05	82.95	568	45	97	149	1672	14,305
2024	0.223	0.09	87.72	570	45	97	152	1734	16,039
2025	0.223	0.13	92.05	571	45	97	155	1790	17,829
2026	0.223	0.18	95.95	572	45	98	157	1840	19,669
2027	0.223	0.23	99.44	573	45	98	159	1884	21,552
2028	0.223	0.28	102.55	573	45	98	161	1922	23,474
2029	0.223	0.33	105.31	574	45	98	162	1956	25,431
2030	0.223	0.38	107.74	575	45	98	164	1986	27,417
2031	0.223	0.43	109.88	575	45	98	165	2012	29,429
2032	0.223	0.47	111.76	575	45	98	166	2035	31,465
2033	0.223	0.5	113.4	576	45	98	167	2055	33,520
2034	0.223	0.54	114.84	576	45	98	168	2073	35,593
2035	0.223	0.57	116.1	576	45	98	168	2088	37,680
2036	0.223	0.59	117.19	576	45	98	169	2101	39,781
2037	0.223	0.61	118.14	576	45	98	169	2112	41,894
2038	0.223	0.63	118.97	577	45	99	170	2122	44,016
2039	0.223	0.64	119.69	577	45	99	170	2131	46,147
2040	0.223	0.66	120.32	577	45	99	170	2139	48,286
2041	0.223	0.67	120.87	577	45	99	171	2145	50,431
2042	0.223	0.68	121.34	577	45	99	171	2151	52,582
2043	0.223	0.69	121.75	577	45	99	171	2156	54,738
2044	0.223	0.7	122.11	577	45	99	171	2160	56,898
2045	0.223	0.7	122.42	577	45	99	172	2164	59,062

*Table 3.23. Projection results under scenario 11—fishing mortality rate fixed at $F = F_{\text{rebuild}}$, with rebuilding probability of 0.5 in 2019. 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} = 0.24 *(per yr),* SSB_{MSY} = 112 *(mt), and* MSY = 2192 *(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	0.413	0	8.06	396	111	530	0	0	0
2011	0.032	0	12.47	416	4	8	7	61	61
2012	0.032	0	19.42	465	5	11	11	90	151
2013	0.032	0	27.4	504	6	12	14	119	270
2014	0.032	0	37.3	527	6	13	17	150	419
2015	0.032	0	49.06	543	6	14	20	182	602
2016	0.032	0.01	62.5	554	7	14	22	216	818
2017	0.032	0.07	77.36	562	7	15	24	251	1069
2018	0.032	0.23	93.33	568	7	15	26	286	1354
2019	0.032	0.5	110.07	572	7	15	28	320	1674

Table 3.24. Input for Surplus–production model runs. Total removals in pounds including discards from historical time period (1950–1980) with alternate removal series in million pounds. Alternate series include a low recreational, high recreational, and adjusted Saltwater Angling Survey (SWAS) recreational estimate combined with commercial 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	Low Rec.	High Rec.	SWAS	Headboat	Headboat 2%catch inc.	Year	Proposed	Headboat	Headboat 2% catch. Inc.	Com. Logbook	Com. Logbook 2% catch. Inc.
1950	0.807	0.537	1.473	0.697			1981	1.011	2.07	1.87		
1951	1.014	0.710	1.739	0.941			1982	0.798	1.26	1.11		
1952	0.930	0.594	1.706	0.897			1983	0.566	0.81	0.70		
1953	1.000	0.622	1.843	0.995			1984	0.827	0.75	0.63		
1954	1.271	0.840	2.205	1.276			1985	0.965	1.15	0.94		
1955	1.254	0.763	2.288	1.260			1986	0.376	0.34	0.27		
1956	1.340	0.778	2.493	1.331			1987	0.438	0.40	0.31		
1957	1.826	1.192	3.101	1.800			1988	0.451	0.42	0.32		
1958	1.639	0.956	2.985	1.633			1989	0.585	0.61	0.45		
1959	1.727	1.009	3.113	1.763			1990	0.462	0.58	0.42		
1960	1.769	1.026	3.175	1.862			1991	0.385	0.75	0.52		
1961	1.895	1.144	3.291	1.900			1992	0.761	0.09	0.06		
1962	1.734	0.993	3.085	1.678			1993	0.466	0.19	0.13	1.14	0.75
1963	1.570	0.828	2.898	1.435			1994	0.497	0.30	0.19	0.91	0.58
1964	1.694	0.897	3.092	1.404			1995	0.358	0.40	0.25	0.92	0.57
1965	1.942	1.034	3.510	1.417			1996	0.310	0.46	0.28	0.57	0.34
1966	2.216	1.169	4.002	1.914			1997	0.330	0.52	0.30	0.57	0.33
1967	2.593	1.434	4.554	2.553			1998	0.282	0.29	0.16	0.63	0.35
1968	2.727	1.543	4.709	3.073			1999	0.459	0.42	0.23	0.76	0.41
1969	2.243	1.129	4.066	3.118			2000	0.835	0.54	0.28	0.75	0.39
1970	2.013	0.995	3.595	3.473			2001	0.758	1.01	0.50	1.22	0.61
1971	1.770	0.807	3.116	3.203			2002	0.738	1.16	0.56	1.37	0.66
1972	1.625	0.819	3.111	3.088			2003	0.568	0.85	0.39	1.11	0.51
1973	1.447	0.791	3.064	2.709			2004	0.696	1.35	0.60	1.44	0.63
1974	1.988	0.951	3.355	2.652			2005	0.542	1.17	0.49	1.23	0.52
1975	2.238	1.172	3.709	2.514			2006	0.473	0.70	0.28	0.61	0.24
1976	1.952	0.958	3.460	2.143	1.80	1.80	2007	0.813	0.55	0.21	0.66	0.25
1977	2.313	0.996	3.995	2.327	2.14	2.10	2008	1.362	2.49	0.90	1.20	0.43
1978	1.924	0.902	3.298	1.884	1.74	1.67	2009	1.525	2.95	1.00	1.92	0.65
1979	2.034	0.808	3.984	2.138	2.64	2.49						
1980	1.262	0.584	2.213	1.290	1.08	0.99						

Table 3.25. Red snapper– Surplus–production model runs with several removal series (SEDAR-24 DW proposed removals, removals with the low recreational estimates, high recreational estimates and adjusted saltwater angling survey estimates), model starting years, and with and without a 2% change in catchability from 1976–2003. Runs designated with "nc" did not converge, runs designated "Lmsy" had MSY estimates much larger than the highest landings and are considered unreasonable. Many fixed B1/k runs were evaluated but were limited due to time constraints.

Runs	Removals	Start Year	2% q increase	Estimated $B1/k$	Fixed $B1/k$ 0.2	0.4	0.6	0.8
1	DW proposed	1950	no	0.33	0.2	0.4	0.6	0.8
2	low recreational	1950	no	Lmsy	0.2	0.4	0.6	0.8
3	high recreational	1950	no	0.34	0.2	0.4	0.6	0.8
4	SWAS recreational	1950	no	Lmsy	nc	0.4	0.6	0.8
5	DW proposed	1962	no	0.35	Lmsy	0.4	0.6	0.8
6	DW proposed	1968	no	0.56	Lmsy	0.4	0.6	0.8
7	DW proposed	1976	no	Lmsy	Lmsy	0.4	0.6	0.8
Match to Base	DW proposed	1955	yes	0.32	0.2	0.4	0.6	0.8
9	low recreational	1955	yes	nc				
10	high recreational	1955	yes	Lmsy				
11	SWAS recreational	1955	yes	0.38			0.6	0.8
12	DW proposed	1962	yes	0.88		0.4	0.6	
13	DW proposed	1968	yes	0.41			0.6	nc
14	DW proposed	1976	yes	0.39			0.6	0.8

Table 3.26. Red snapper– Surplus–production model estimates of MSY in millions of pounds.

Runs	Removals	Start Year	2% q increase	Estimated $B1/k$	Fixed $B1/k$ 0.2	0.4	0.6	0.8
1	DW proposed	1950	no	1.771	1.967	1.73	1.766	1.760
2	low recreational	1950	no		1.153	0.980	0.974	0.972
3	high recreational	1950	no	3.083	3.636	3.011	2.907	2.839
4	SWAS recreational	1950	no			2.000	2.000	2.136
5	DW proposed	1962	no	2.100		1.986	1.772	1.665
6	DW proposed	1968	no	1.771		1.998	1.603	1.451
7	DW proposed	1976	no			1.639	1.234	1.092
Match to Base	DW proposed	1955	yes	1.980	2.538	1.862	1.784	1.699
9	low recreational	1955	yes					
10	high recreational	1955	yes					
11	SWAS recreational	1955	yes	2.216			2.112	2.137
12	DW proposed	1962	yes	1.633		1.971	1.731	
13	DW proposed	1968	yes	1.906			1.647	
14	DW proposed	1976	yes	1.672			1.29	1.151

Table 3.27. Red snapper– Surplus–production model estimates of F_{MSY}.

Runs	Removals	Start Year	2% q increase	Estimated $B1/k$	Fixed $B1/k$ 0.2	0.4	0.6	0.8
1	DW proposed	1950	no	0.221	0.199	0.204	0.249	0.249
2	low recreational	1950	no		0.231	0.302	0.305	0.306
3	high recreational	1950	no	0.169	0.164	0.169	0.168	0.162
4	SWAS recreational	1950	no			0.176	0.183	0.229
5	DW proposed	1962	no	0.205		0.203	0.232	0.222
6	DW proposed	1968	no	0.221		0.221	0.211	0.214
7	DW proposed	1976	no			0.261	0.246	0.265
Match to Base	DW proposed	1955	yes	0.209	0.201	0.227	0.246	0.208
9	low recreational	1955	yes					
10	high recreational	1955	yes					
11	SWAS recreational	1955	yes	0.241			0.214	0.229
12	DW proposed	1962	yes	0.218		0.186	0.204	
13	DW proposed	1968	yes	0.19			0.236	
14	DW proposed	1976	yes	0.268			0.276	0.299

Table 3.28. Red snapper– Surplus–production model estimates of B_{MSY}– million pounds.

Runs	Removals	Start Year	2% q increase	Estimated $B1/k$	Fixed $B1/k$ 0.2	0.4	0.6	0.8
1	DW proposed	1950	no	8.01	9.908	8.474	7.083	7.077
2	low recreational	1950	no		4.992	3.252	3.189	3.174
3	high recreational	1950	no	18.24	22.146	17.786	17.292	17.579
4	SWAS recreational	1950	no			11.382	10.955	9.321
5	DW proposed	1962	no	10.261		9.769	7.643	7.494
6	DW proposed	1968	no	8.01		9.051	7.592	6.785
7	DW proposed	1976	no			6.286	5.012	4.113
Match to Base	DW proposed	1955	yes	9.460	12.643	8.208	7.246	8.164
9	low recreational	1955	yes					
10	high recreational	1955	yes					
11	SWAS recreational	1955	yes	9.202			9.881	9.332
12	DW proposed	1962	yes	7.496		10.569	8.476	
13	DW proposed	1968	yes	10.018			6.969	
14	DW proposed	1976	yes	6.244			4.674	3.85

Table 3.29. Red snapper– Surplus–production model estimates of F_{2009}/F_{MSY}.

Runs	Removals	Start Year	2% q increase	Estimated $B1/k$	Fixed $B1/k$ 0.2	0.4	0.6	0.8
1	DW proposed	1950	no	2.31	2.35	2.33	2.27	2.28
2	low recreational	1950	no		2.6	2.64	2.64	2.65
3	high recreational	1950	no	2.21	2.21	2.2	2.2	2.24
4	SWAS recreational	1950	no			2.39	2.38	2.29
5	DW proposed	1962	no	2.28		2.28	2.29	2.28
6	DW proposed	1968	no	2.31		2.29	2.27	2.3
7	DW proposed	1976	no			2.27	2.31	2.31
Match to Base	DW proposed	1955	yes	3.67	3.67	3.59	3.5	3.7
9	low recreational	1955	yes					
10	high recreational	1955	yes					
11	SWAS recreational	1955	yes	3.47			3.67	3.57
12	DW proposed	1962	yes	3.65		3.81	3.72	
13	DW proposed	1968	yes	3.8			3.48	
14	DW proposed	1976	yes	3.45			3.37	3.41

Table 3.30. Red snapper– Surplus–production model estimates of B_{2010}/MSST.

Runs	Removals	Start Year	2% q increase	Estimated $B1/k$	Fixed $B1/k$ 0.2	0.4	0.6	0.8
1	DW proposed	1950	no	0.38	0.34	0.38	0.38	0.38
2	low recreational	1950	no		0.49	0.53	0.53	0.53
3	high recreational	1950	no	0.23	0.2	0.24	0.25	0.25
4	SWAS recreational	1950	no			0.32	0.33	0.32
5	DW proposed	1962	no	0.33		0.34	0.38	0.4
6	DW proposed	1968	no	0.38		0.34	0.42	0.46
7	DW proposed	1976	no			0.41	0.52	0.58
Match to Base	DW proposed	1955	yes	0.18	0.15	0.2	0.21	0.21
9	low recreational	1955	yes					
10	high recreational	1955	yes					
11	SWAS recreational	1955	yes	0.18			0.17	0.18
12	DW proposed	1962	yes	0.23		0.18	0.21	
13	DW proposed	1968	yes	0.19			0.23	
14	DW proposed	1976	yes	0.23			0.3	0.32

3.6 Figures

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

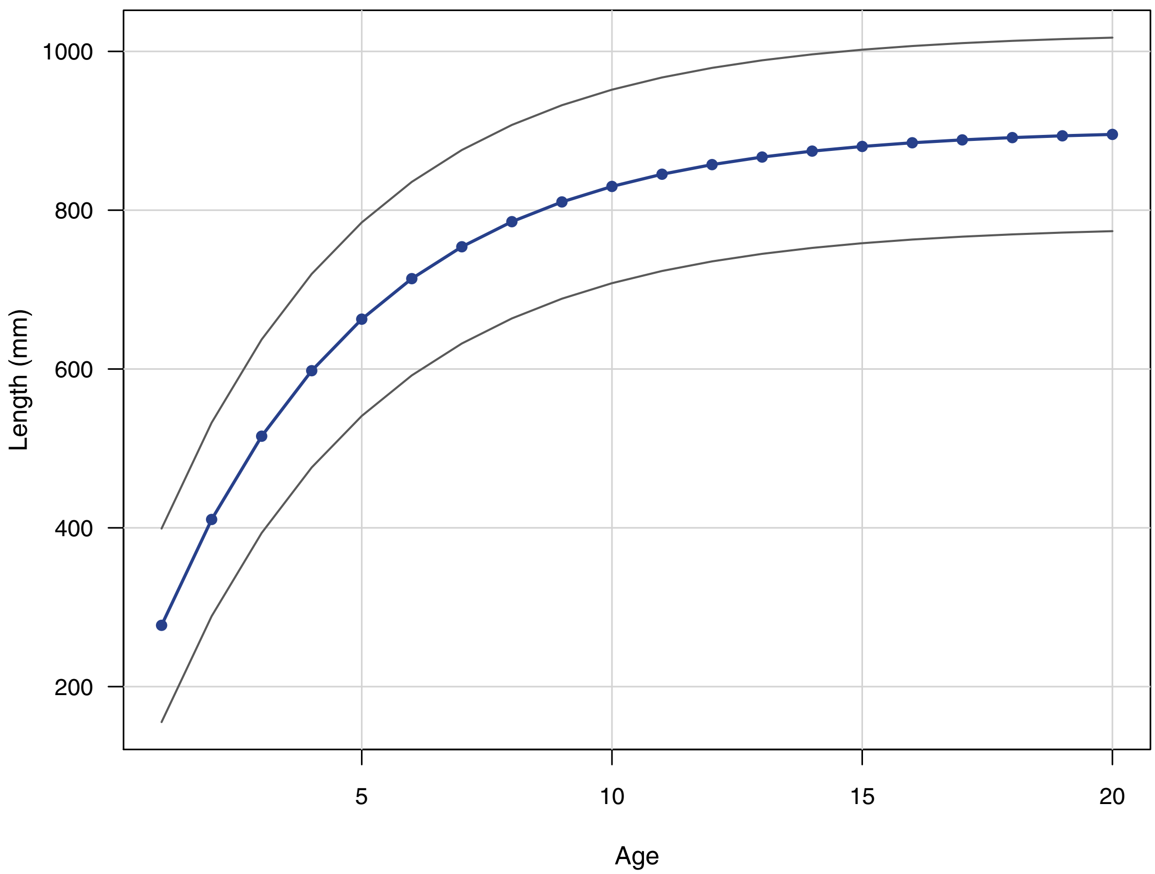


Figure 3.2. Standard errors of management quantities with increased number of Monte Carlo/bootstrap trials.

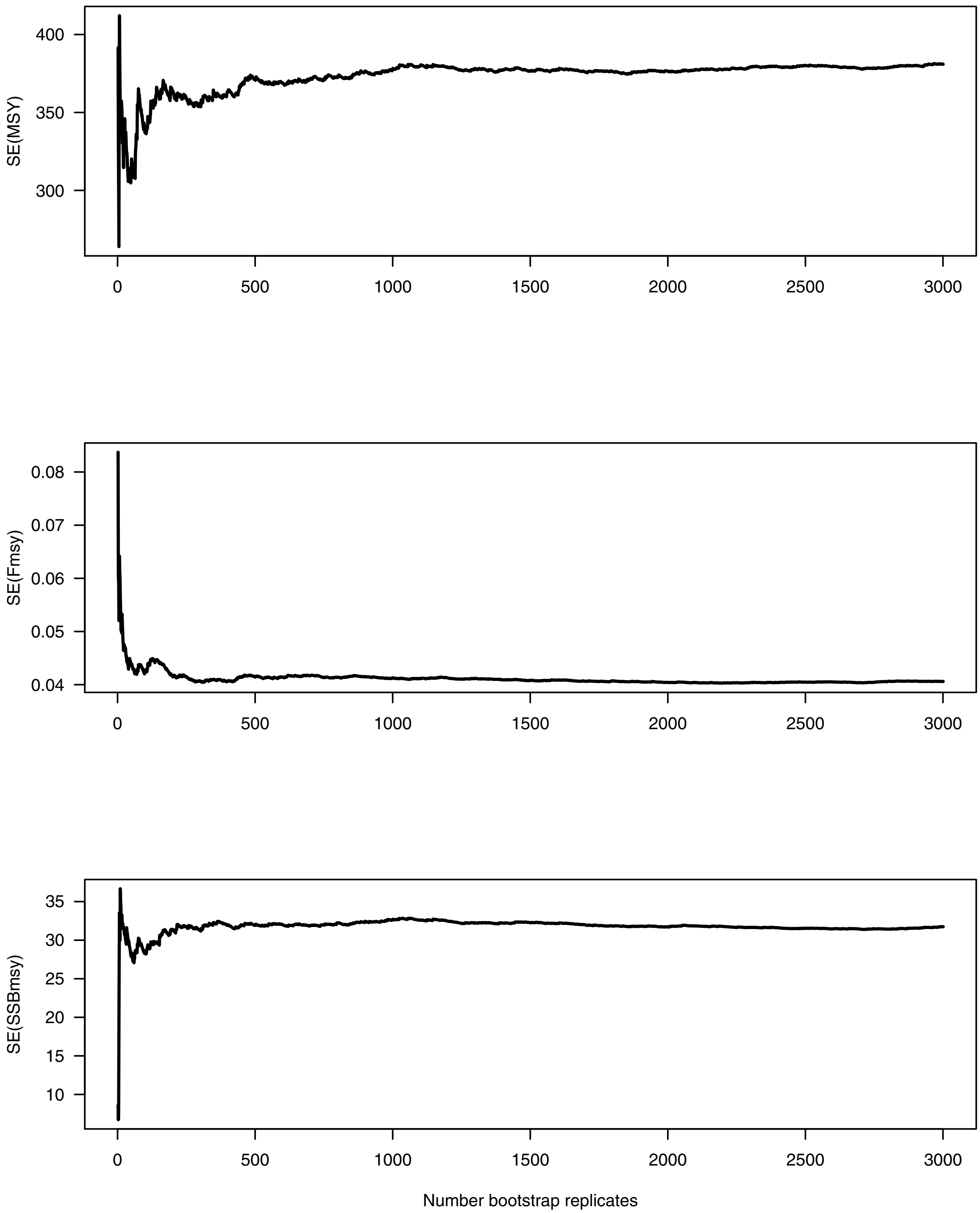


Figure 3.3. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, cl to commercial lines, cd to commercial dive, hb to for-hire, pvt to private recreational, 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.

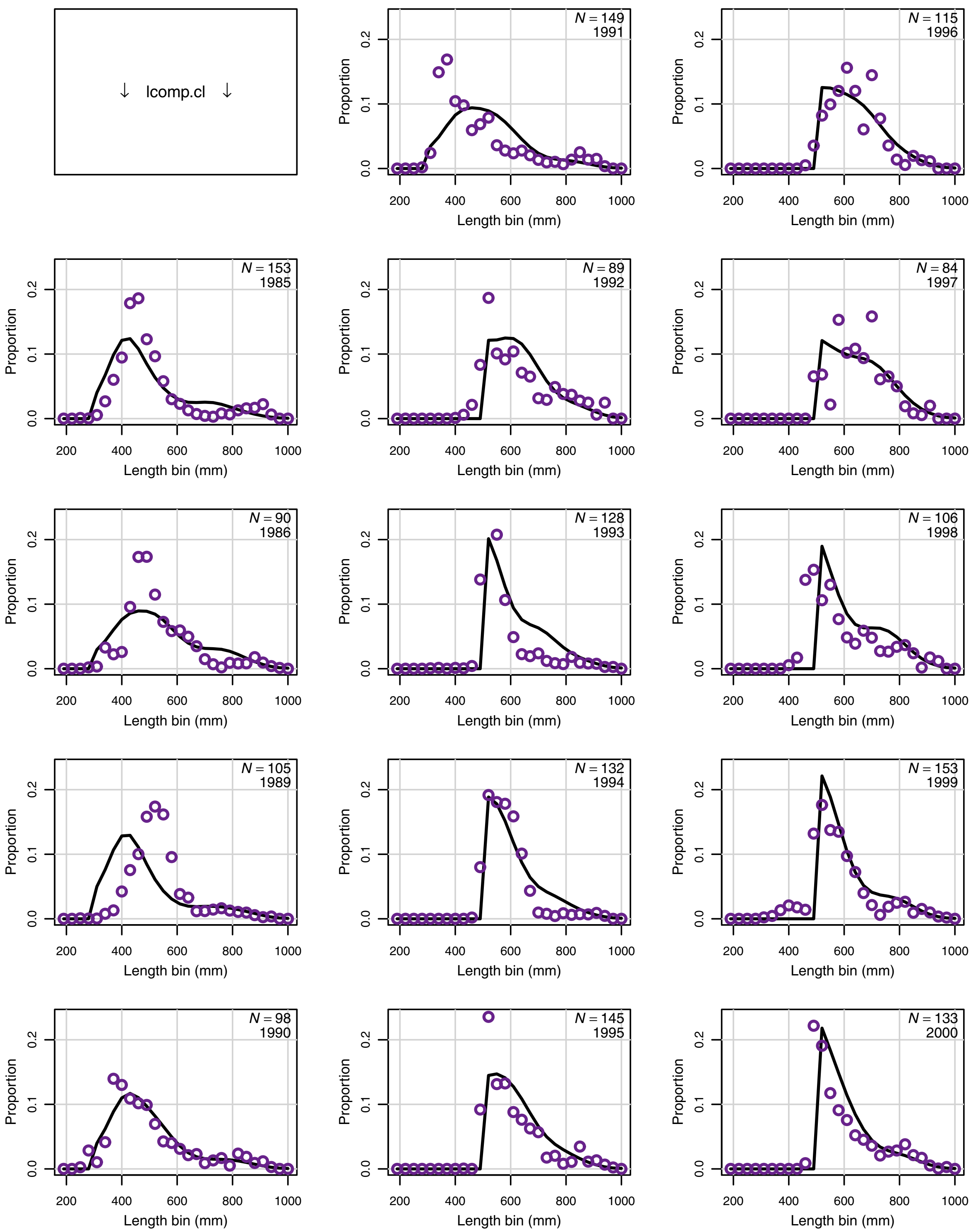


Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

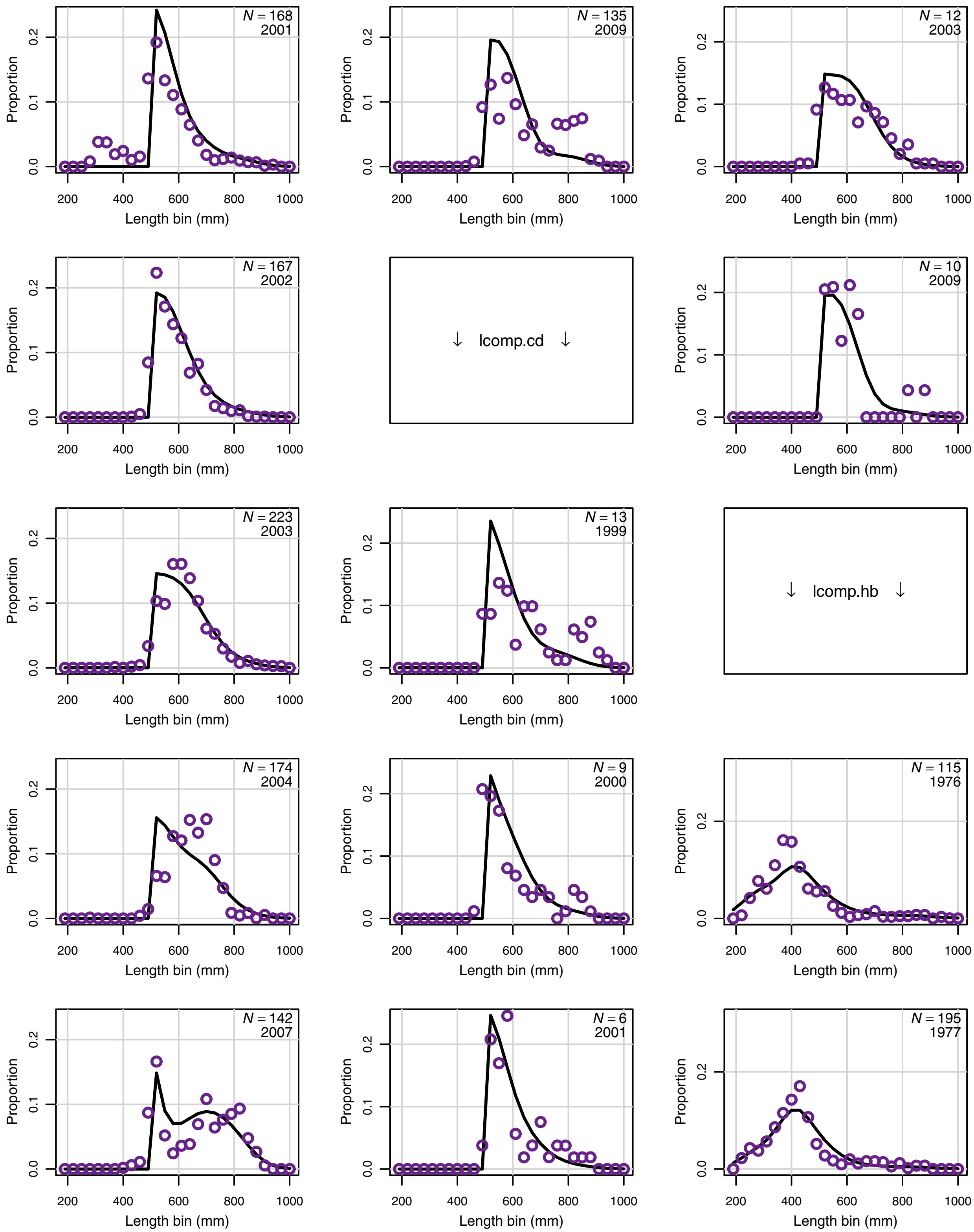


Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

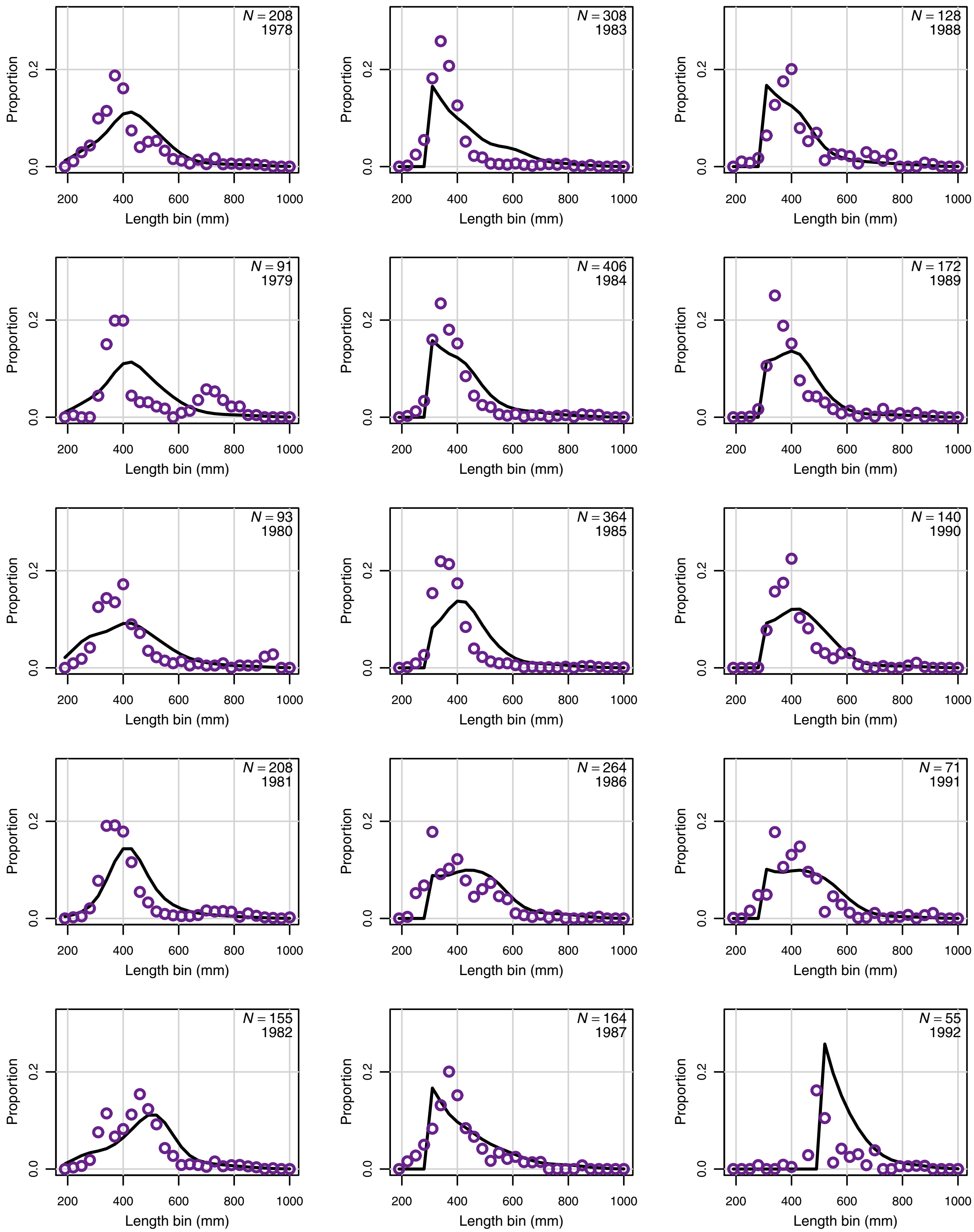


Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

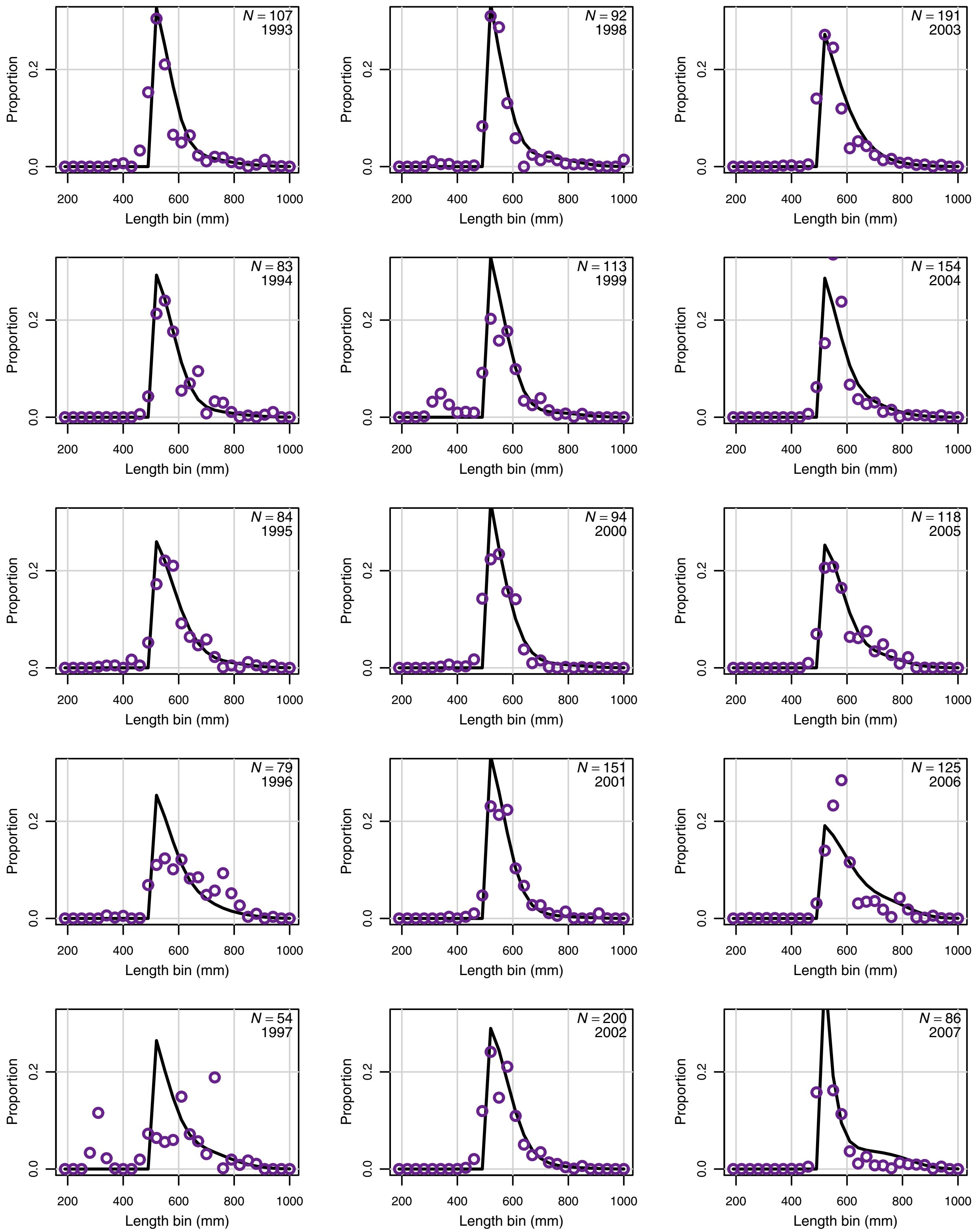


Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

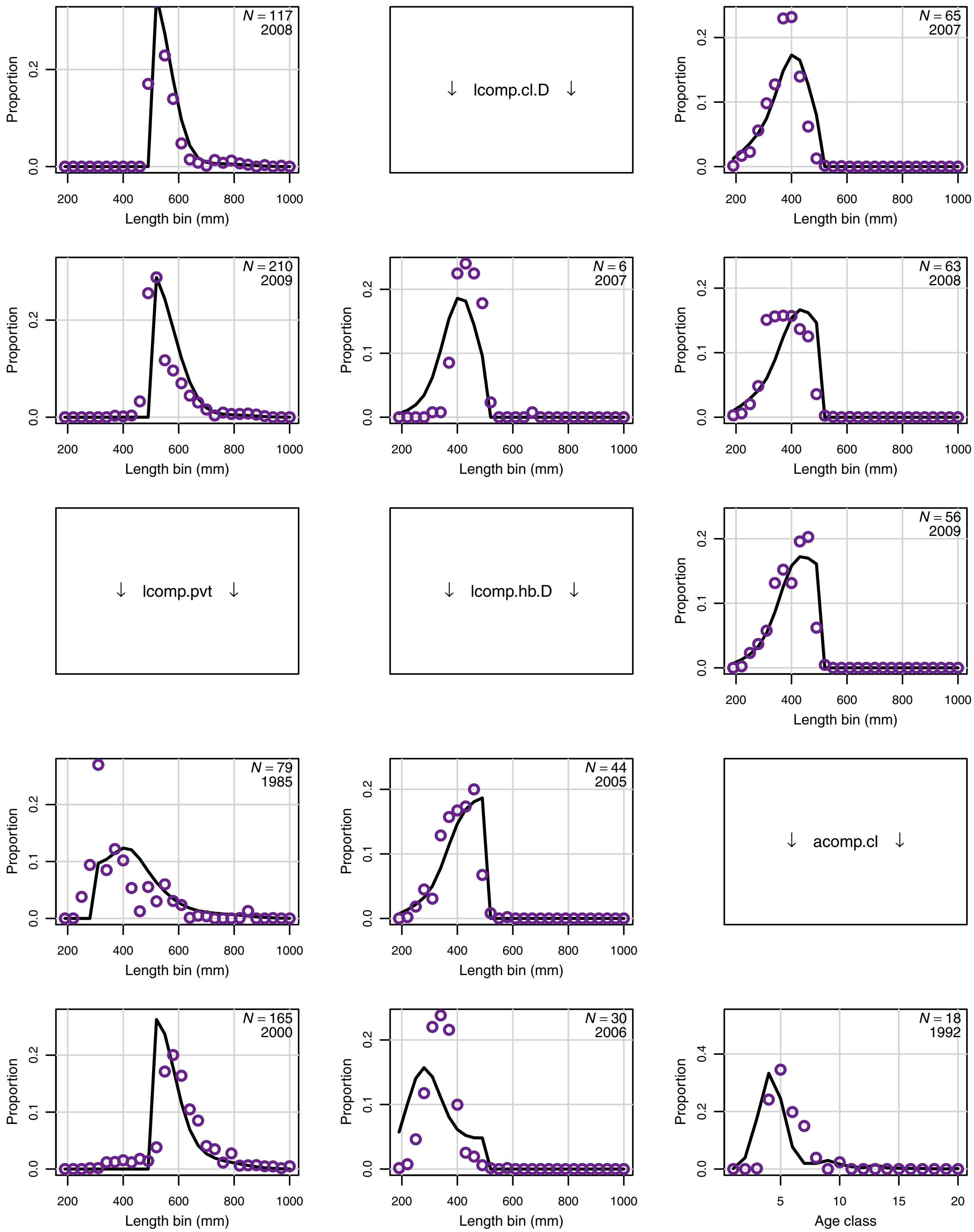


Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

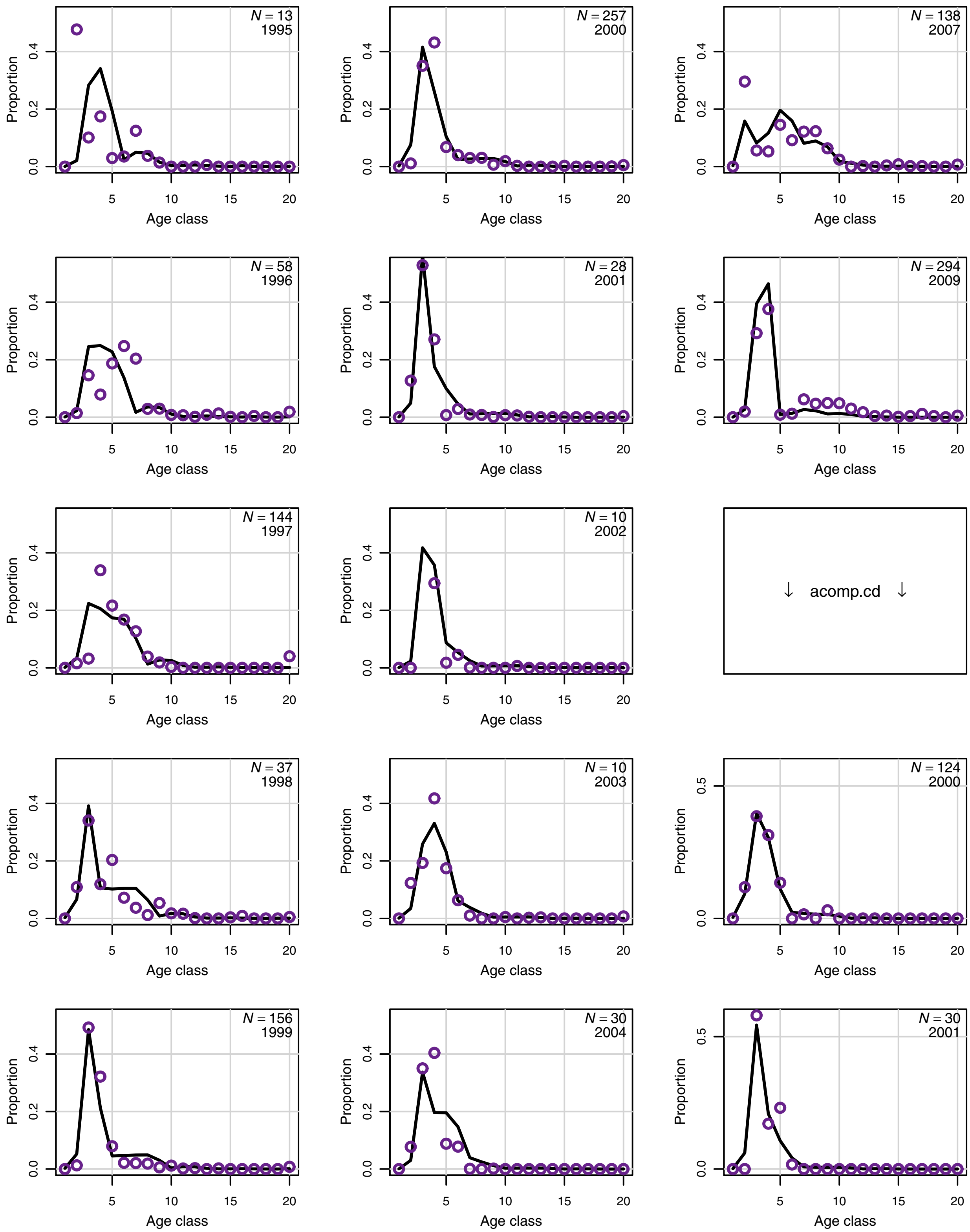


Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

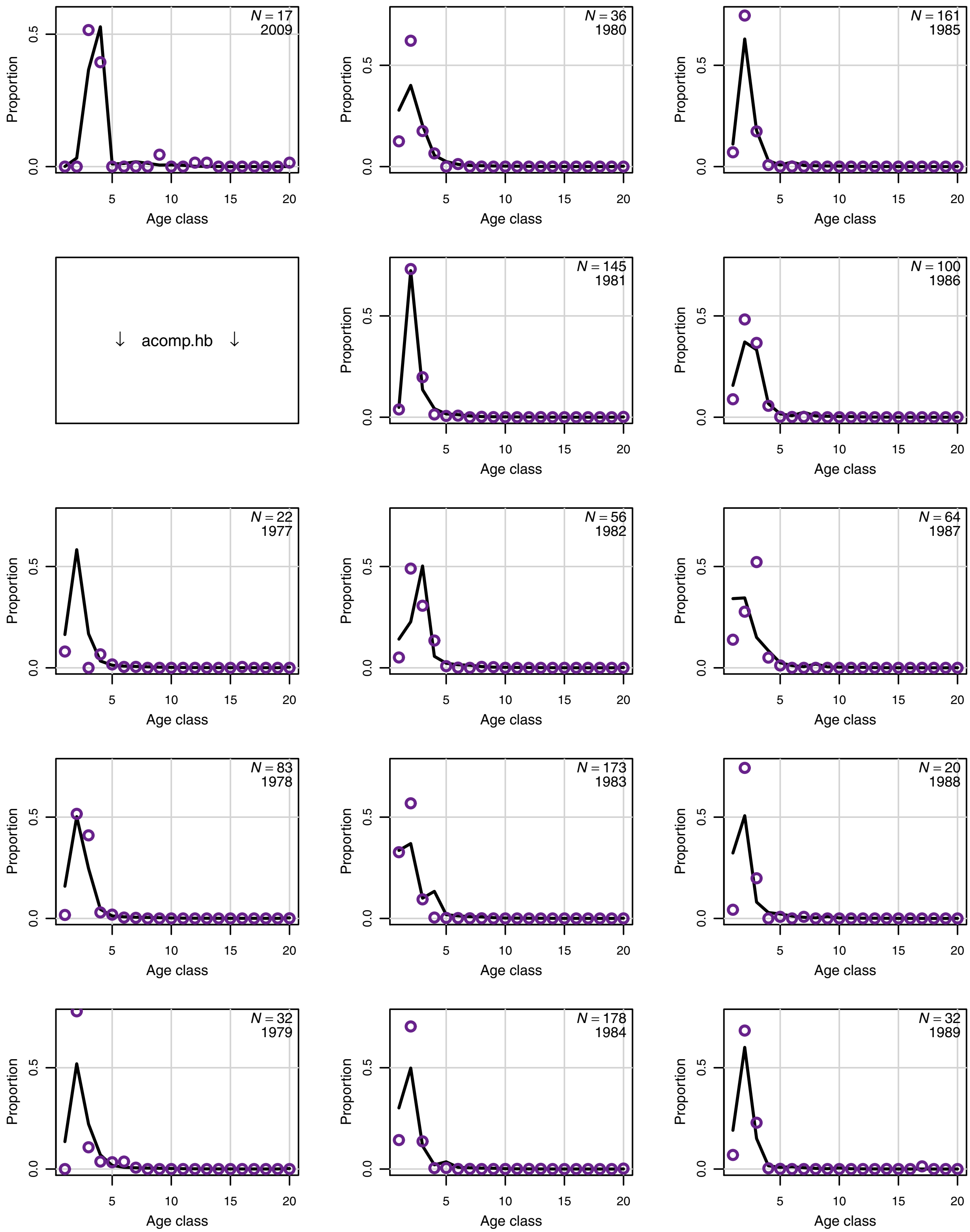


Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

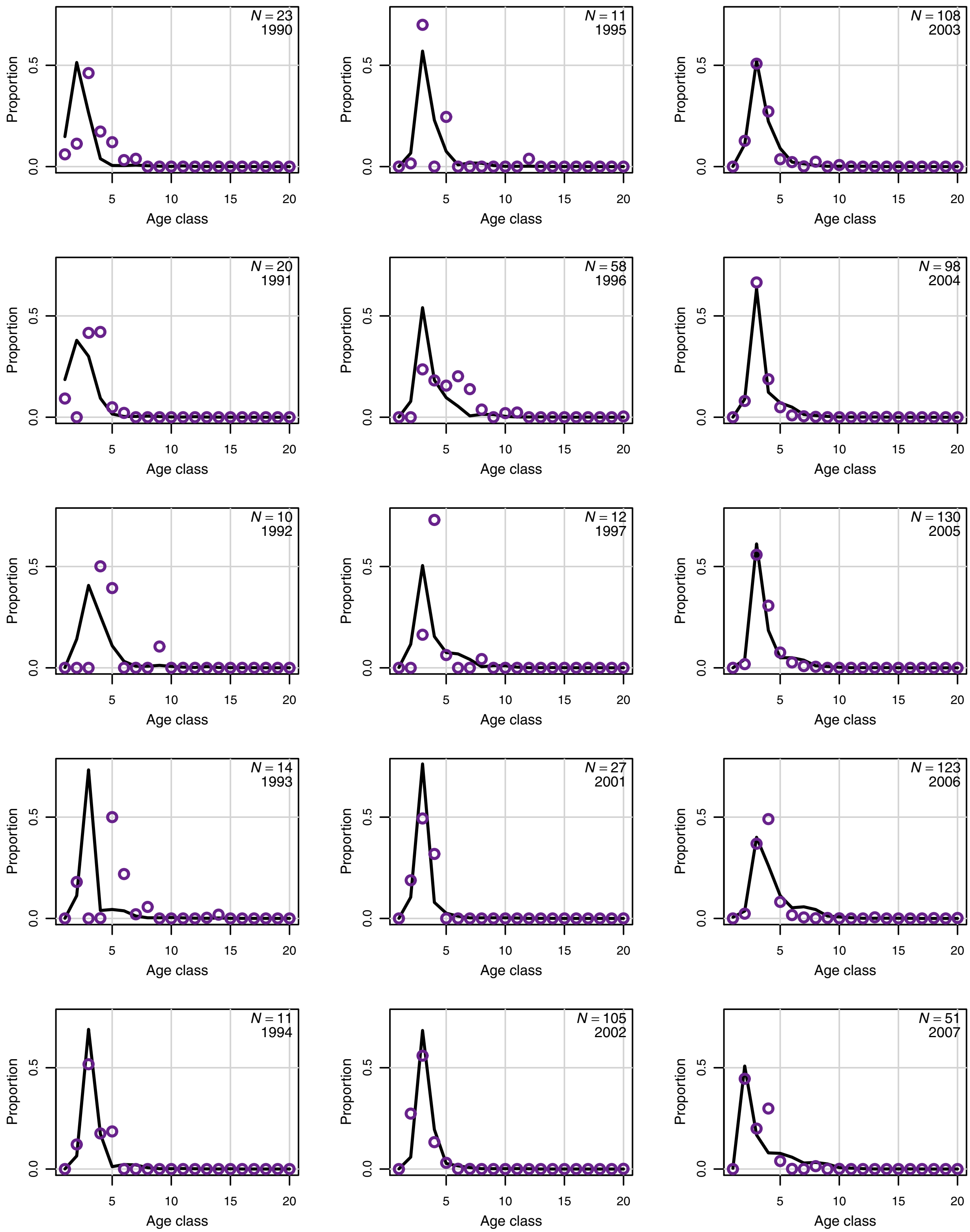


Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

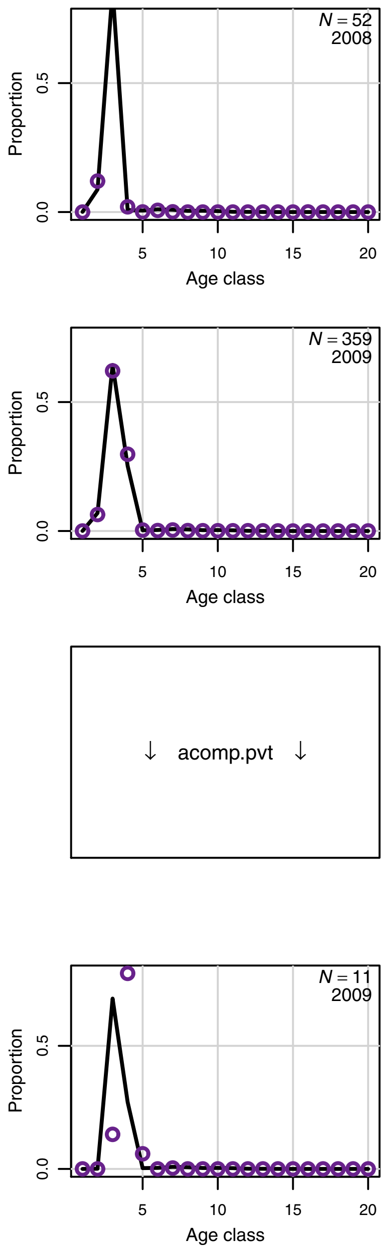


Figure 3.4. Top panel is a bubble plot of length composition residuals from commercial lines landings; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded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

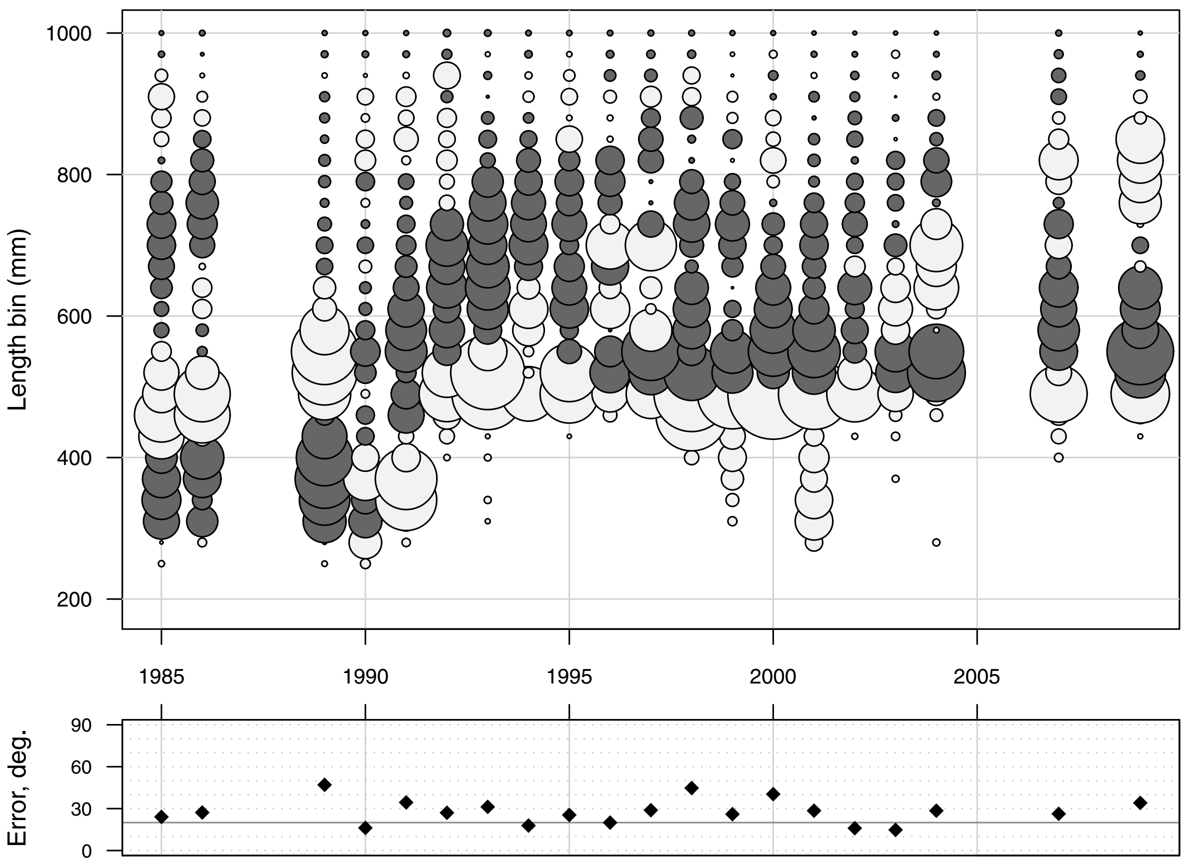


Figure 3.5. Top panel is a bubble plot of length composition residuals from commercial dive landings; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded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

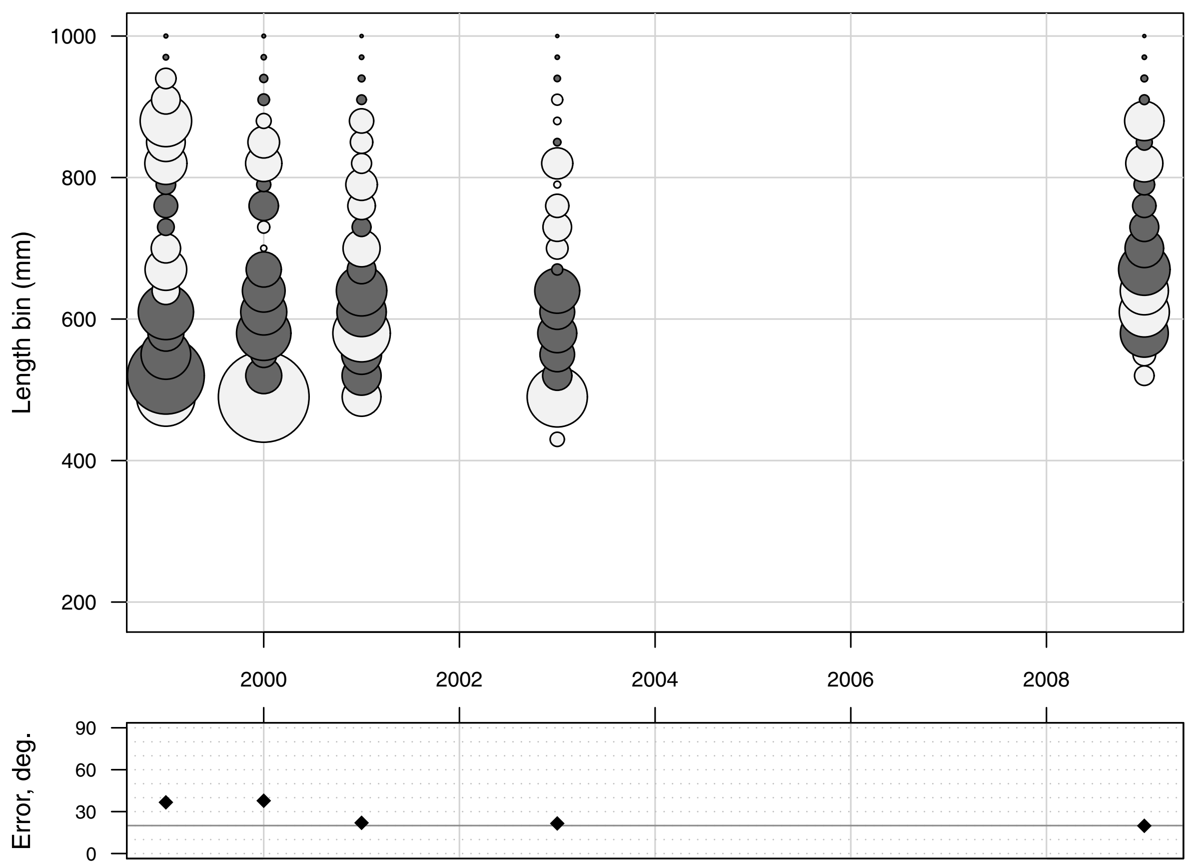


Figure 3.6. Top panel is a bubble plot of length composition residuals from for-hire landings; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between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

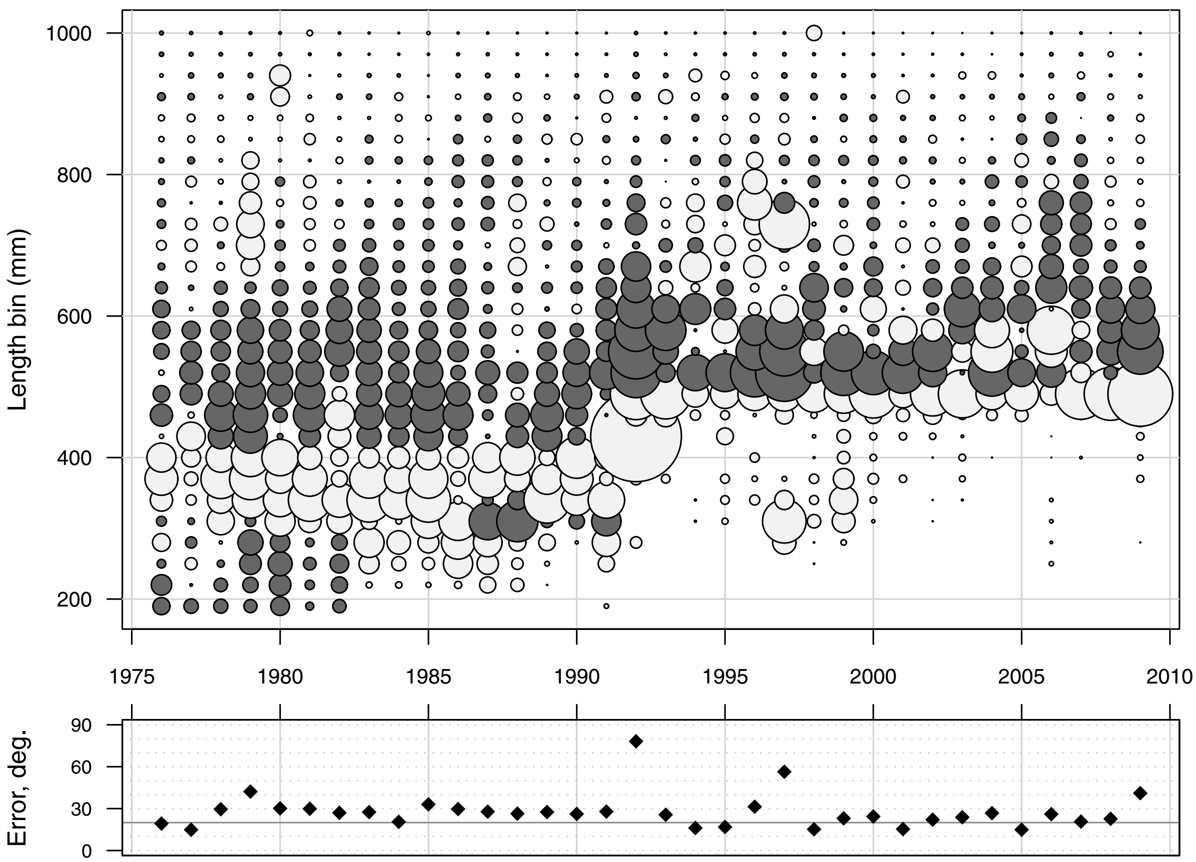


Figure 3.7. Top panel is a bubble plot of length composition residuals from private recreational landings; Dark represents overestimates and light underestimates. The two years shown represent length compositions pooled across years within the relevant time block of size-limit regulations. Bottom panel 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.

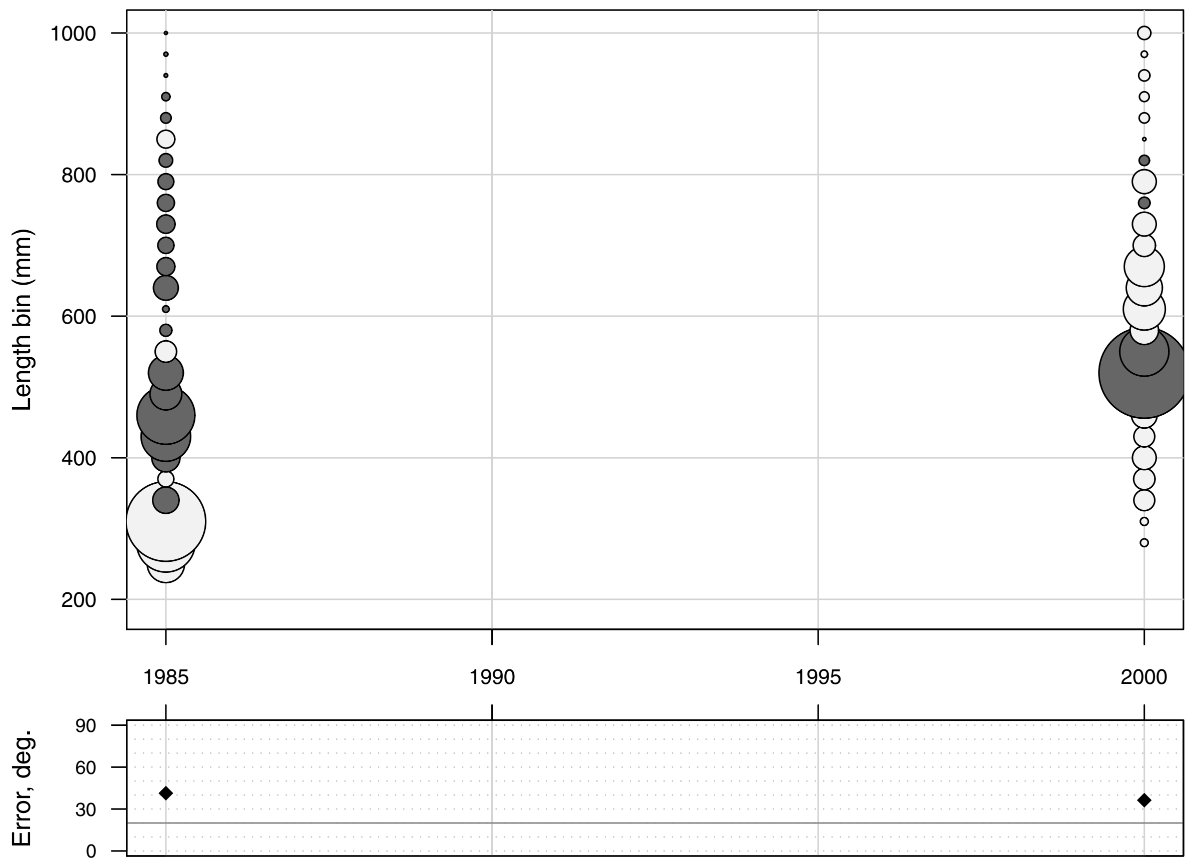


Figure 3.8. Top panel is a bubble plot of length composition residuals from commercial lines discards; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded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

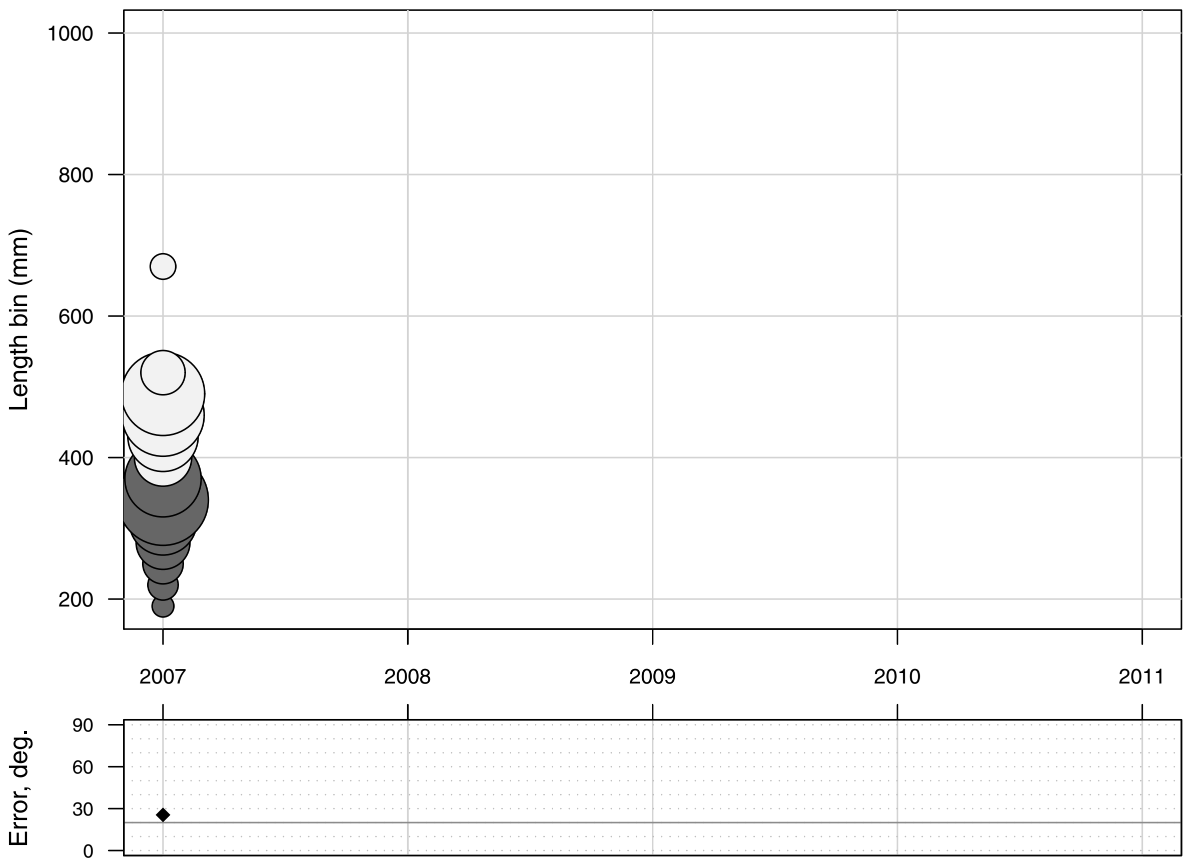


Figure 3.9. Top panel is a bubble plot of length composition residuals from for-hire discards; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between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

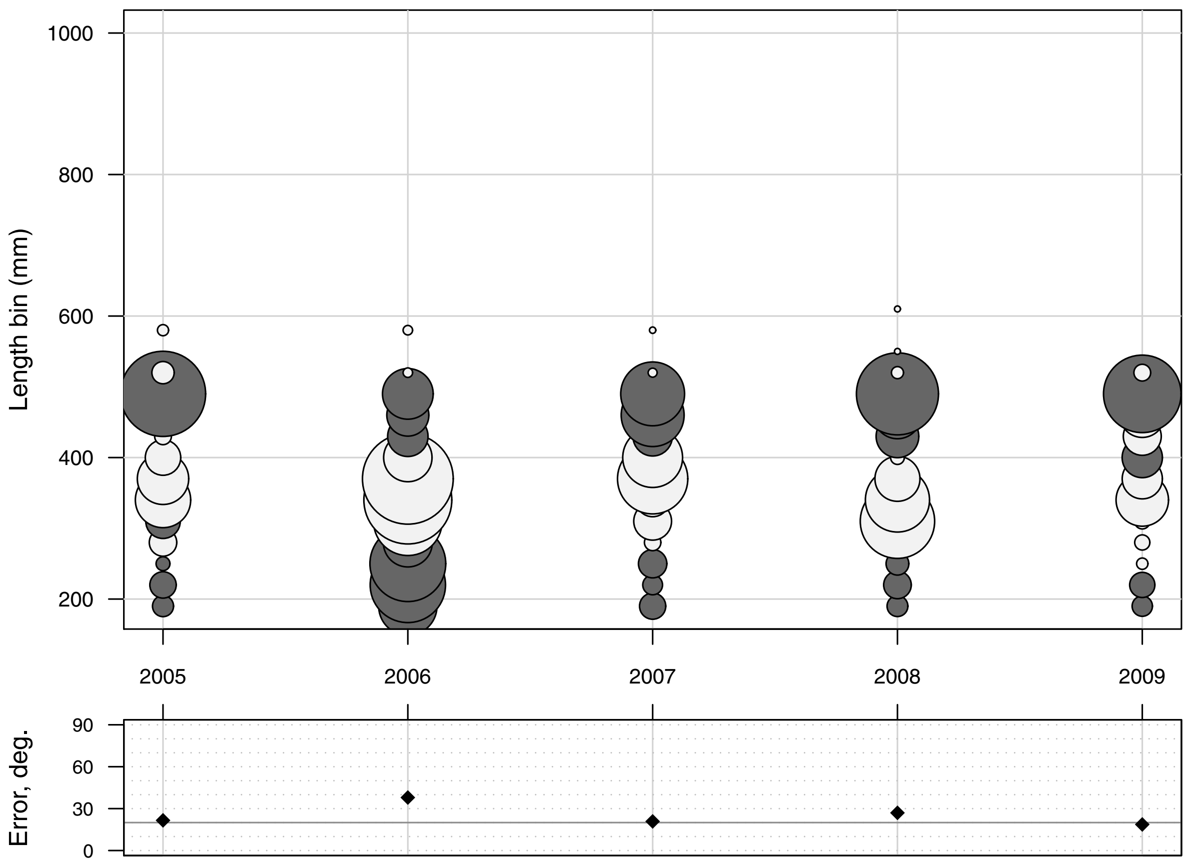


Figure 3.10. Top panel is a bubble plot of age composition residuals from commercial lines landings; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between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

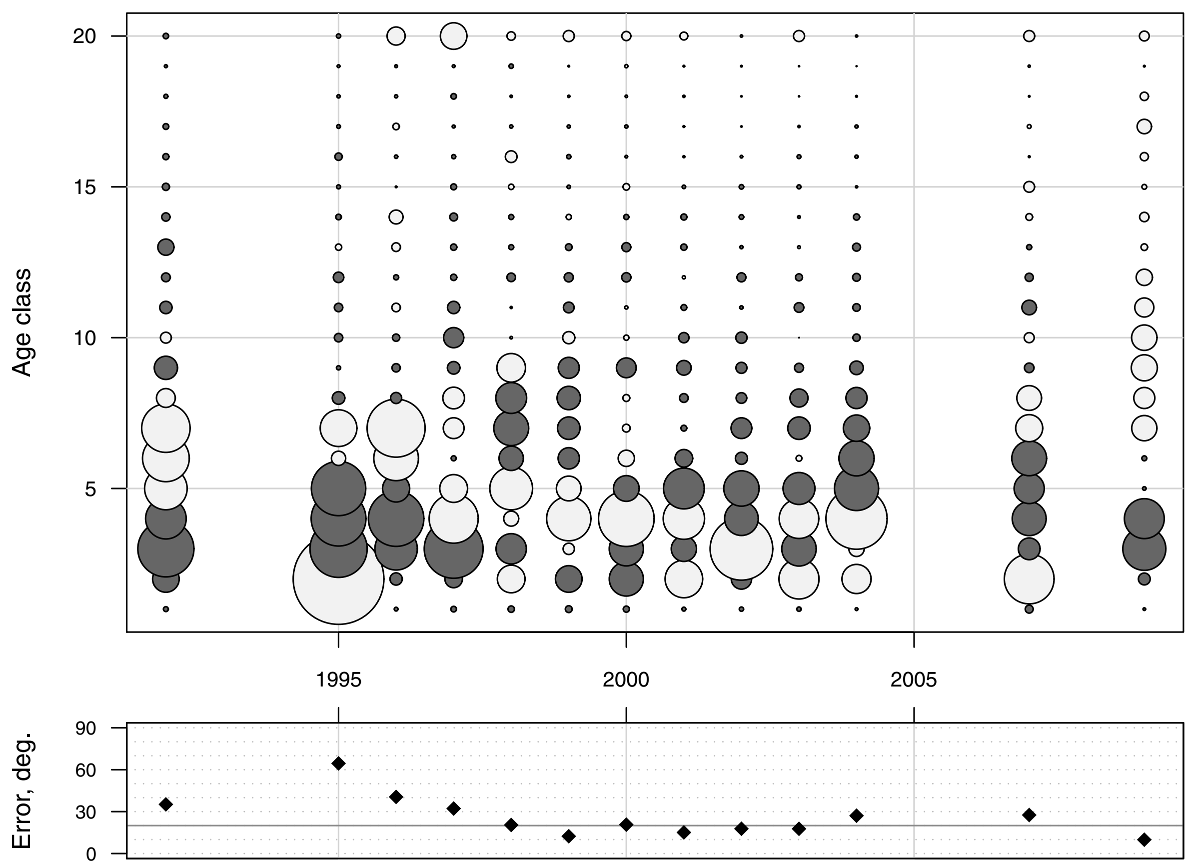


Figure 3.11. Top panel is a bubble plot of age composition residuals from commercial dive landings; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between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

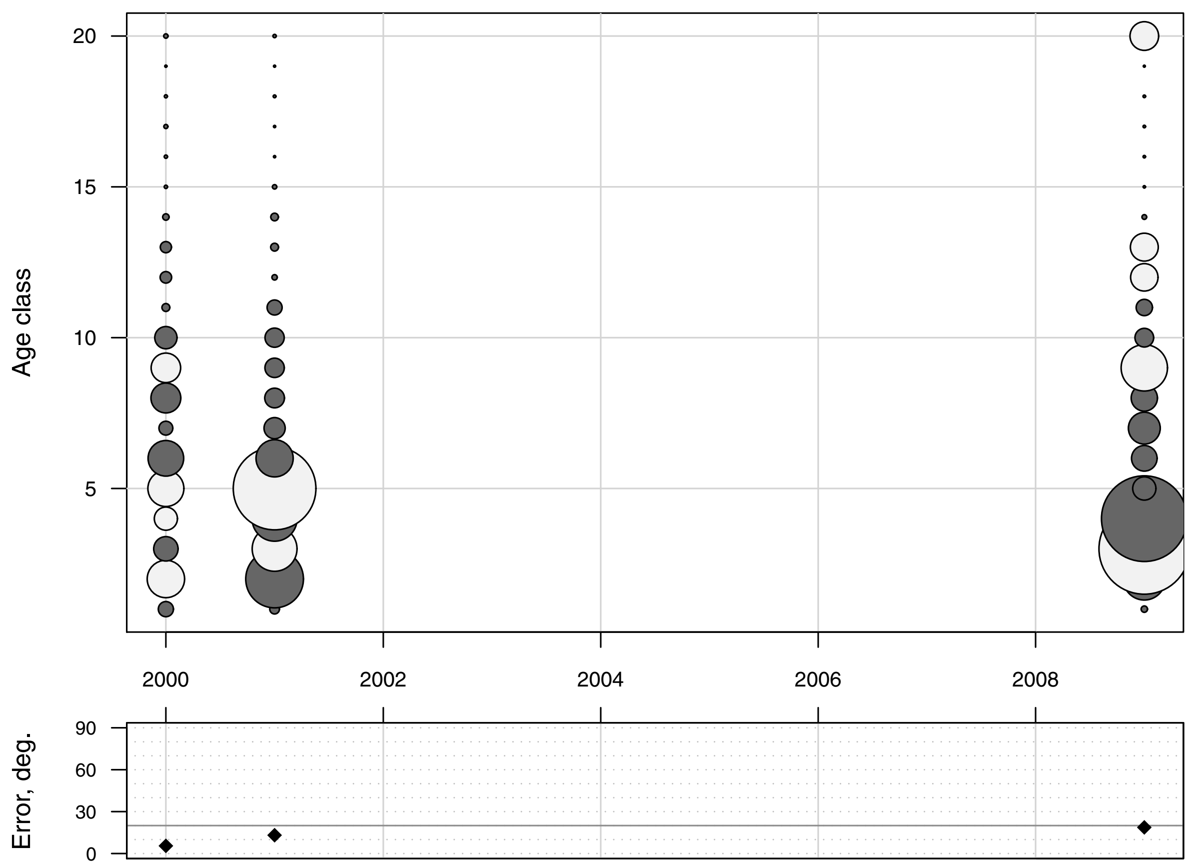


Figure 3.12. Top panel is a bubble plot of age composition residuals from for-hire landings; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0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

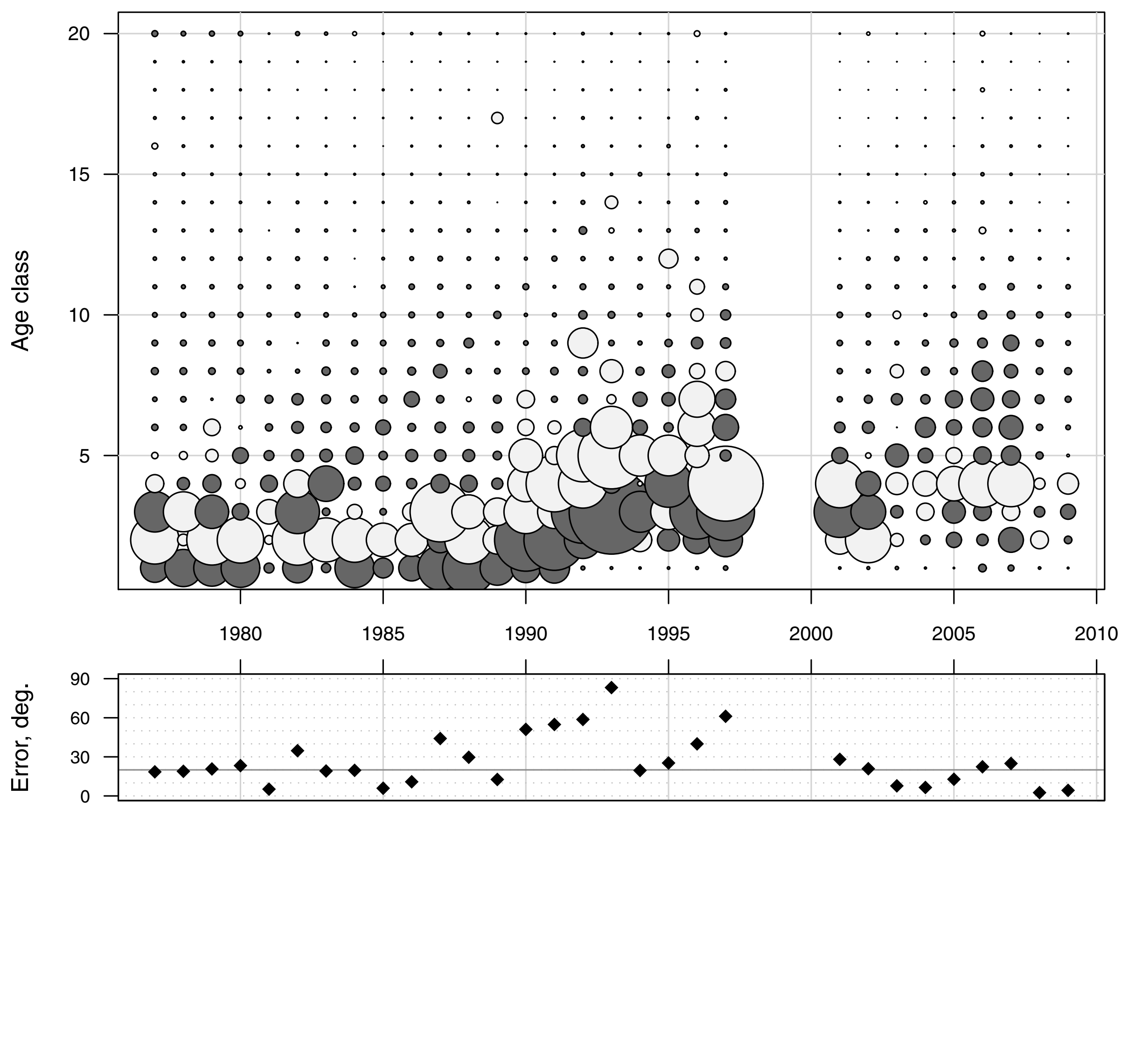


Figure 3.13. Top panel is a bubble plot of age composition residuals from private recreational landings; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded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

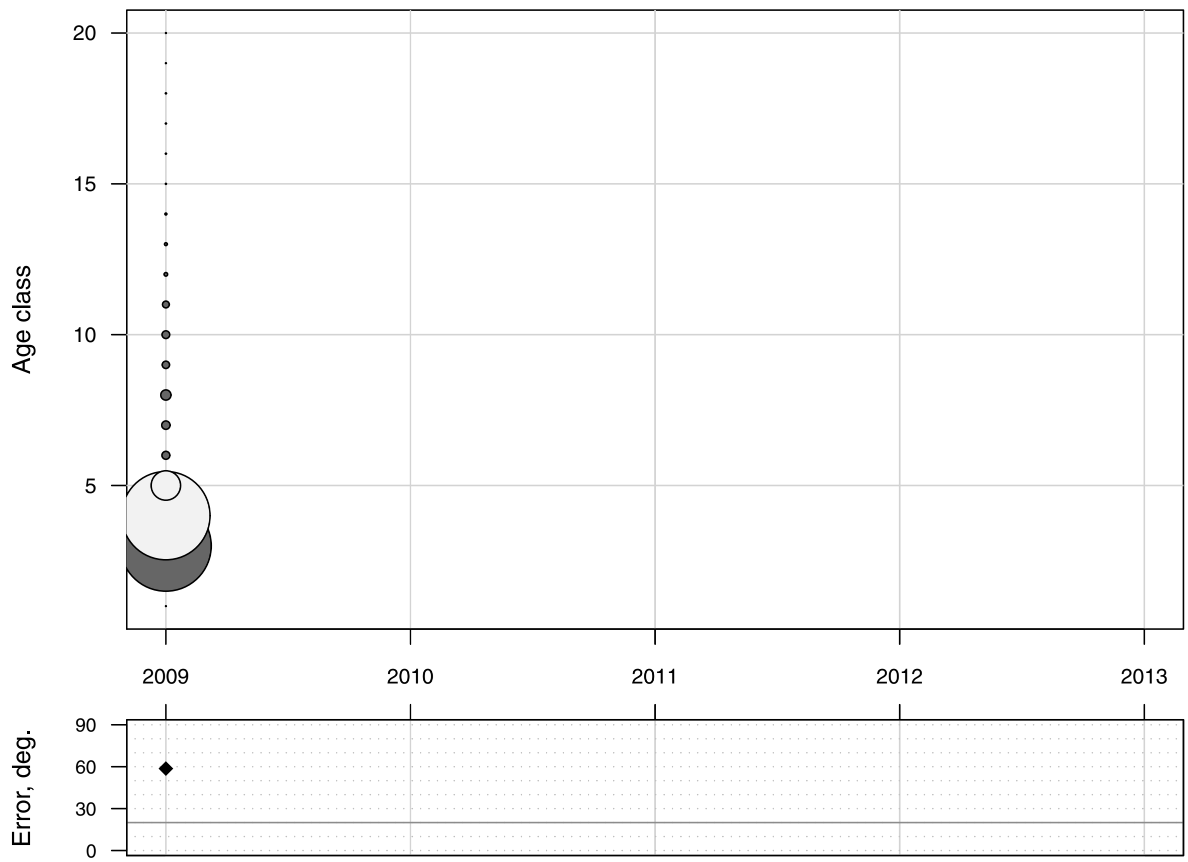


Figure 3.14. Observed (open circles) and estimated (line, solid circles) commercial lines landings (1000 lb whole weight).

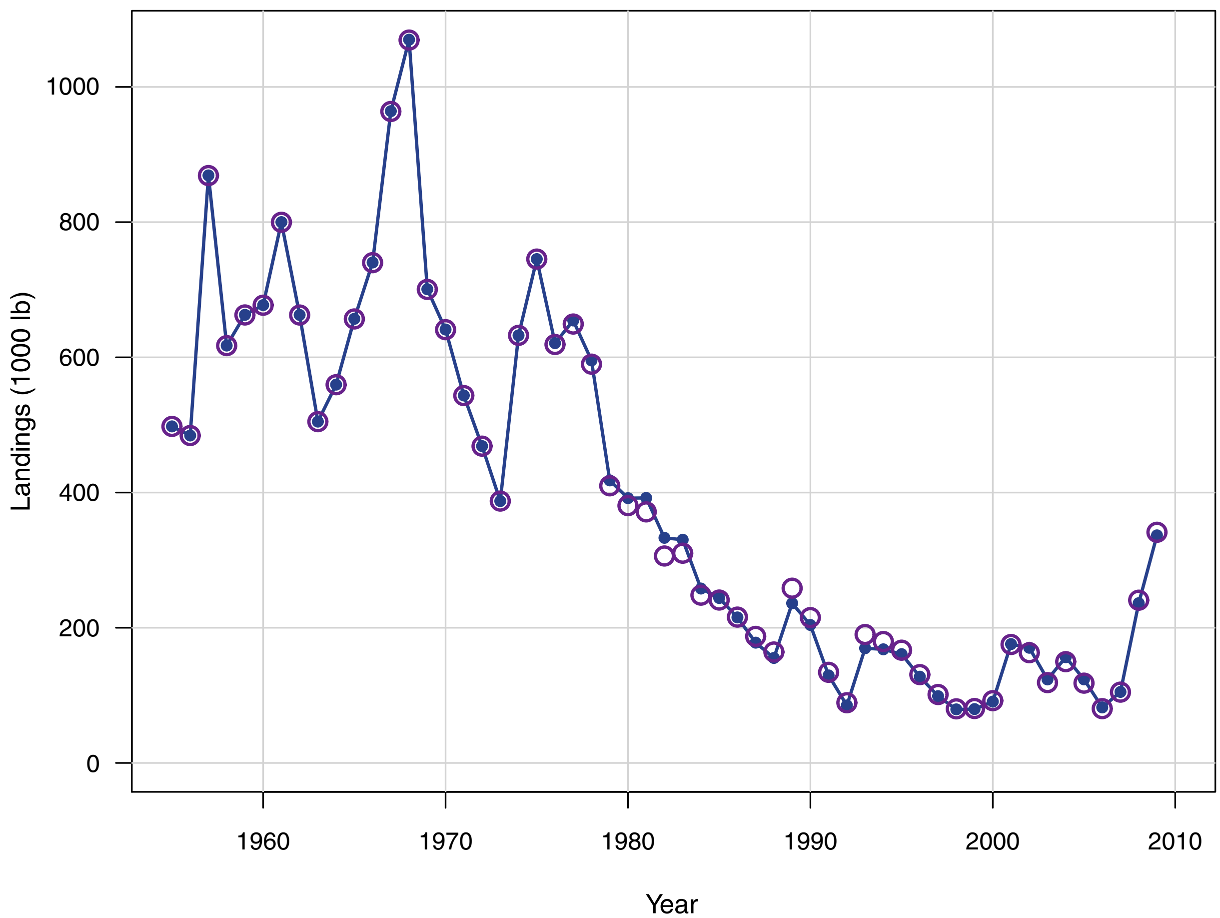


Figure 3.15. Observed (open circles) and estimated (line, solid circles) commercial dive (1000 lb whole weight).

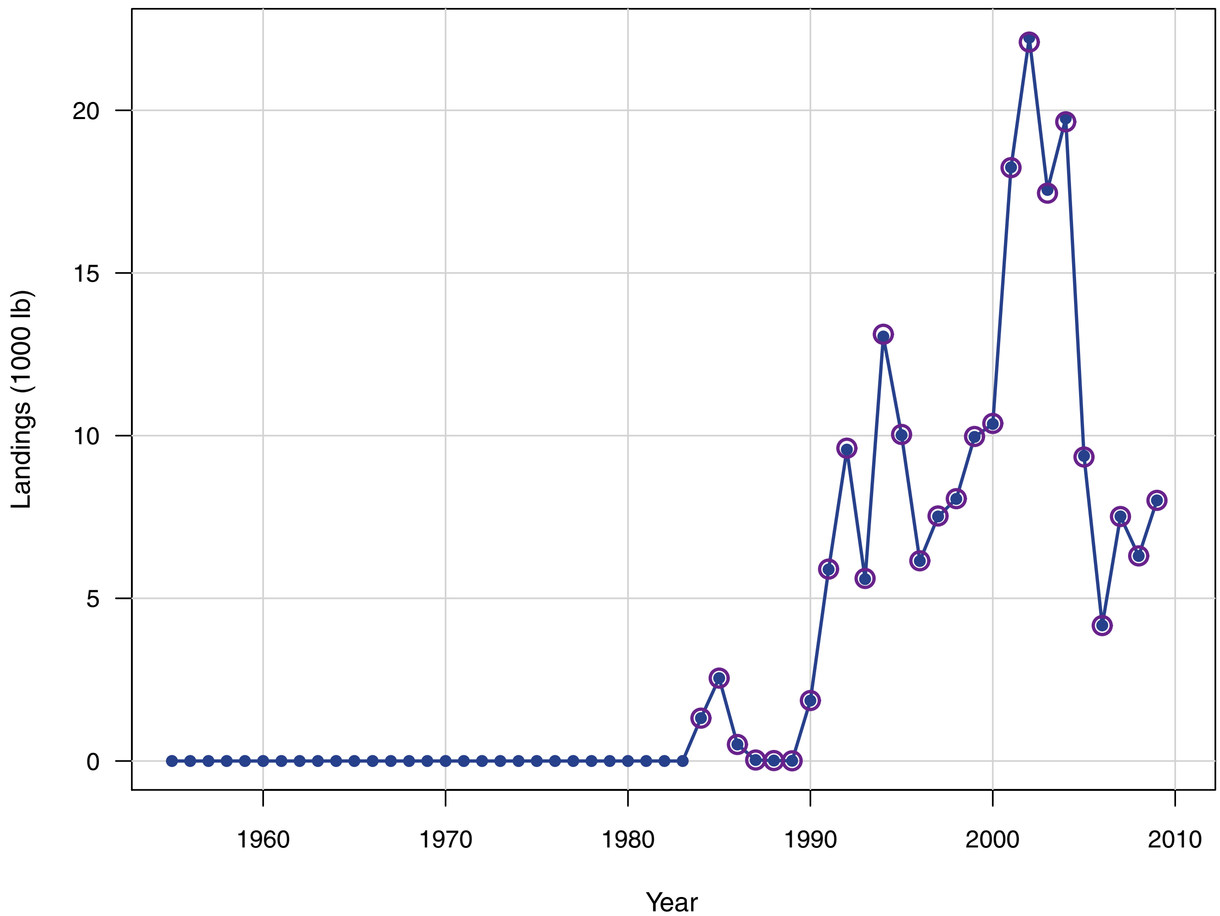


Figure 3.16. Observed (open circles) and estimated (line, solid circles) for-hire landings (1000 fish).

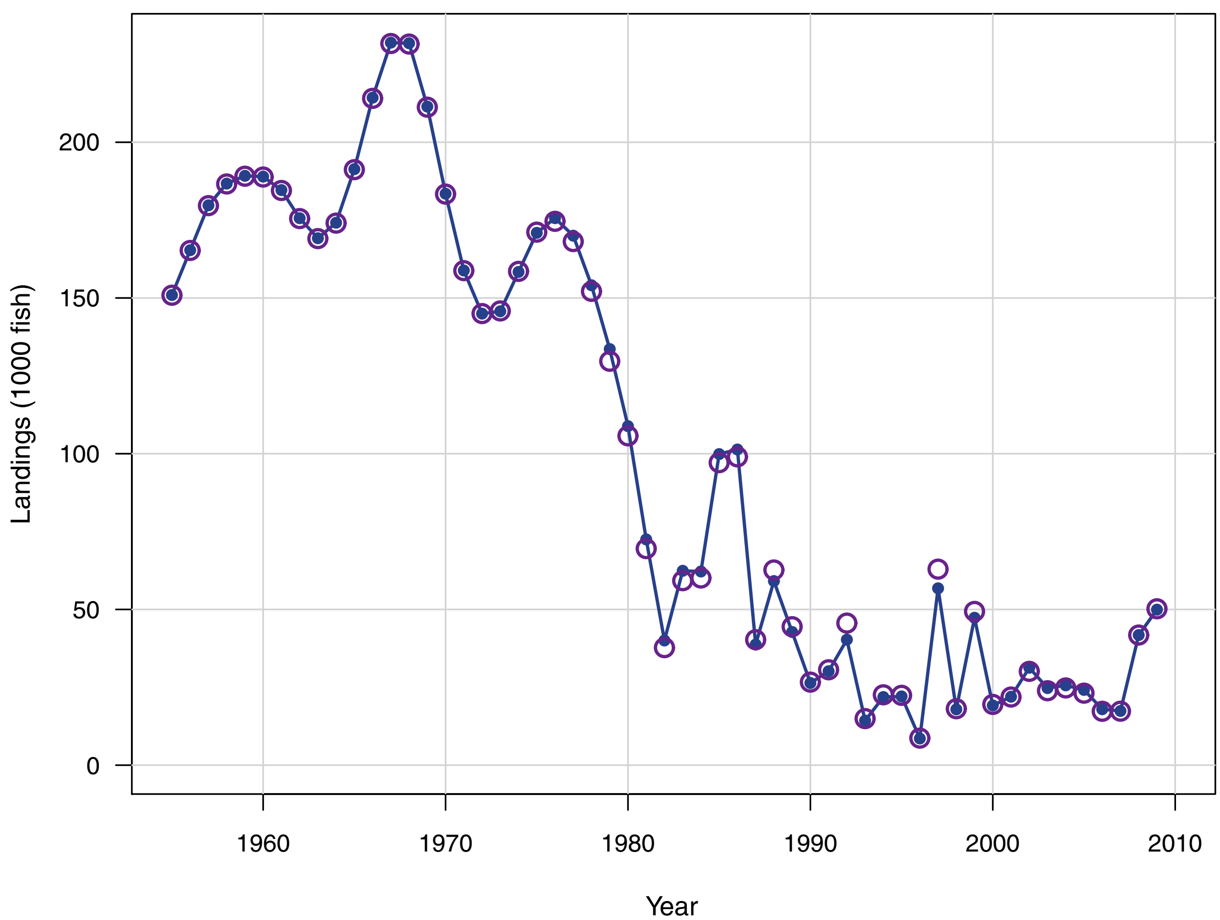


Figure 3.17. Observed (open circles) and estimated (line, solid circles) private recreational landings (1000 fish). In years without observations, values were predicted using average F (see §3.1.1.3 for details).

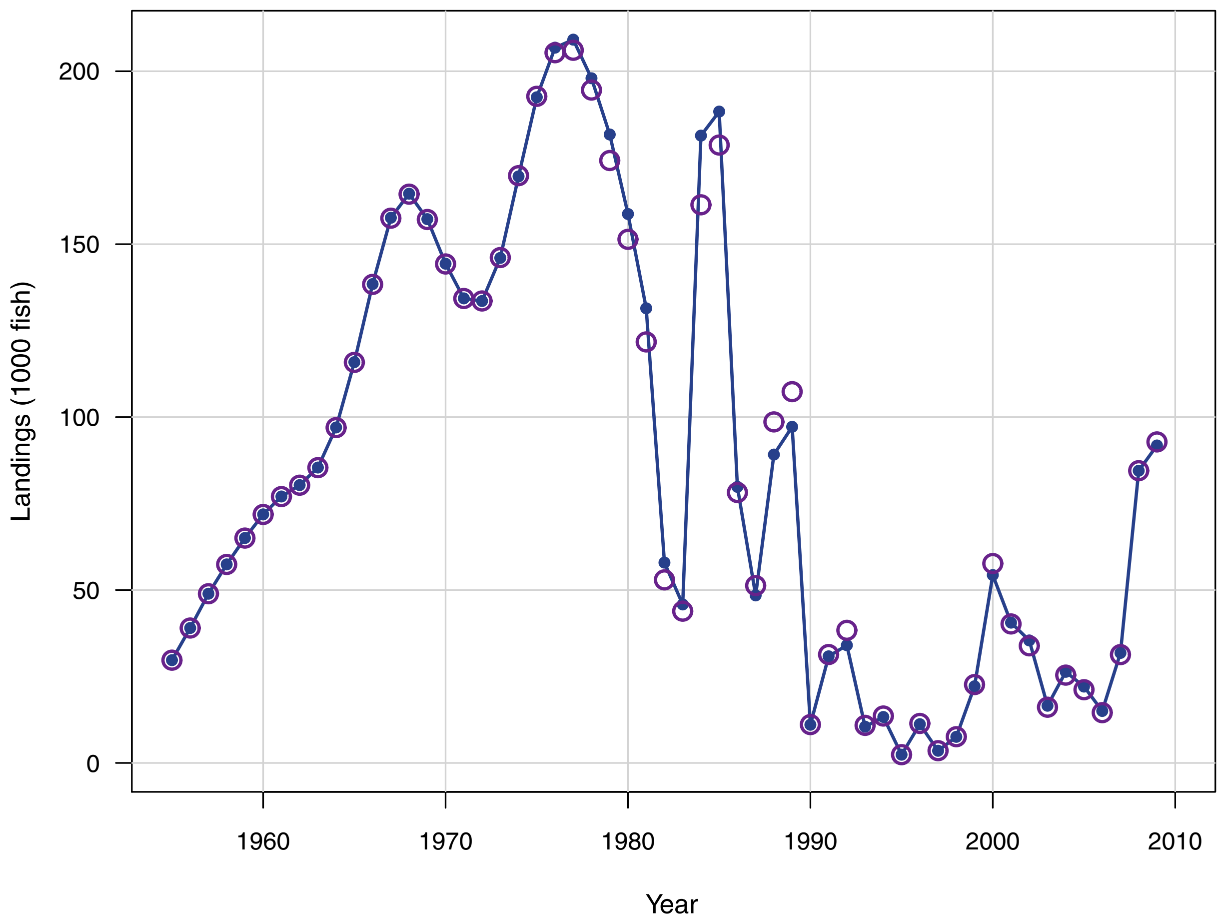


Figure 3.18. Observed (open circles) and estimated (line, solid circles) commercial lines discard mortalities (1000 dead fish).

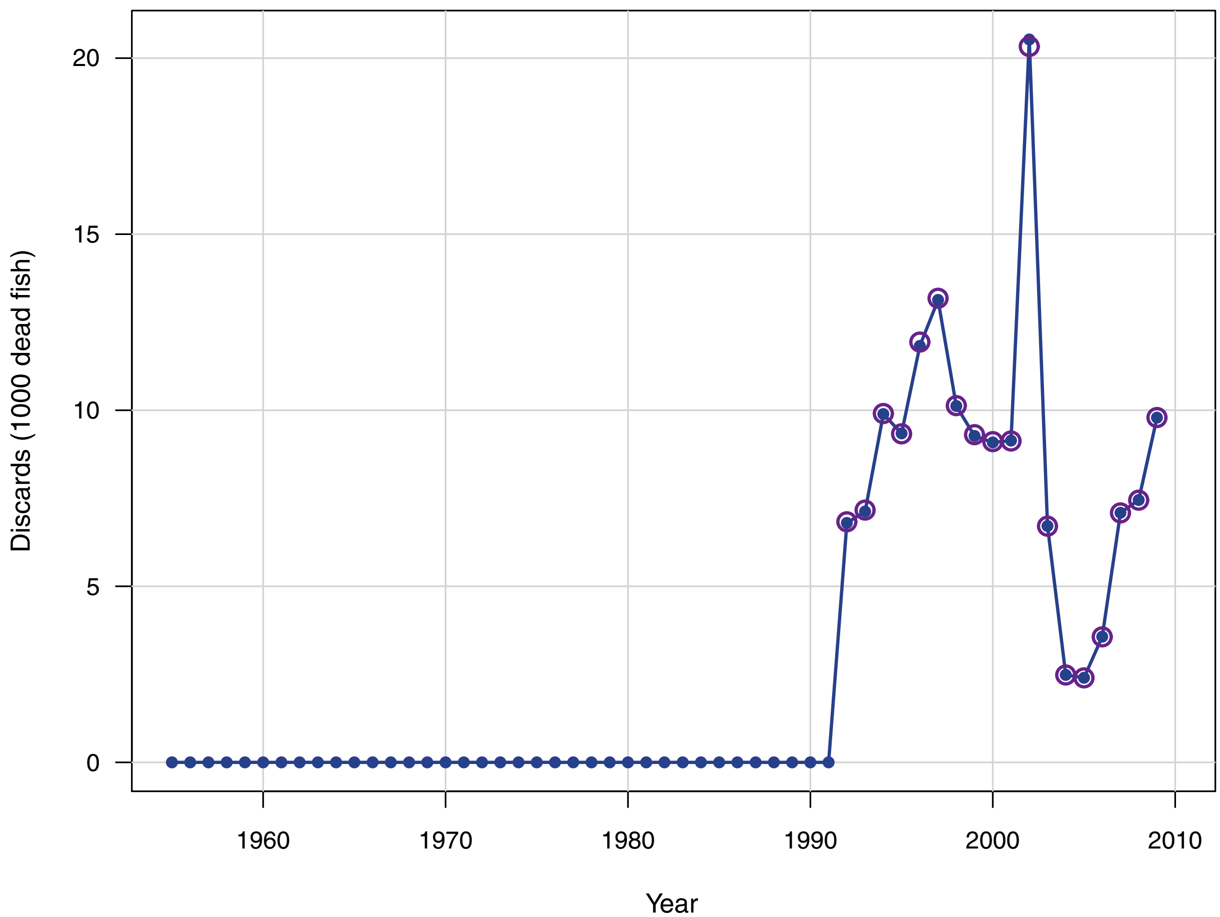


Figure 3.19. Observed (open circles) and estimated (line, solid circles) for-hire discard mortalities (1000 dead fish).

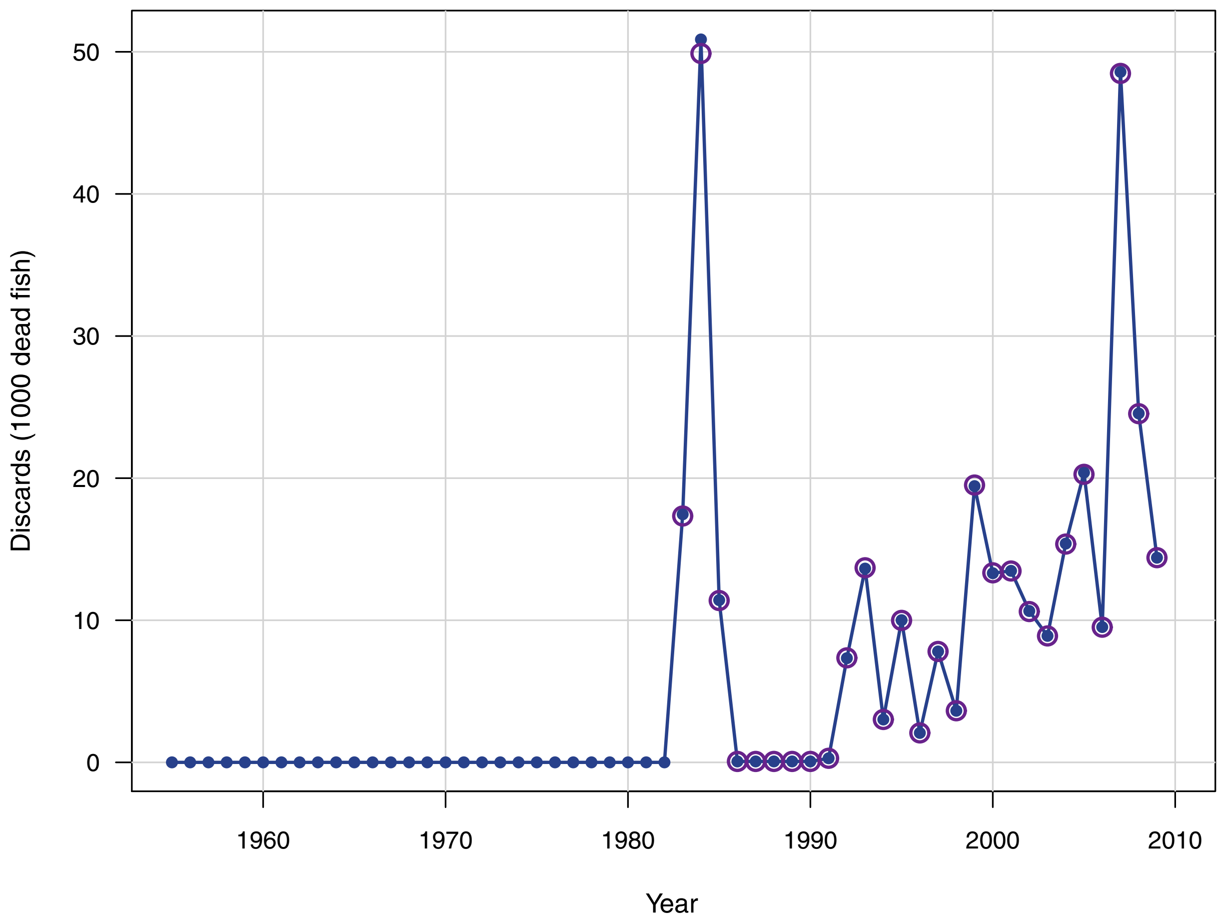


Figure 3.20. Observed (open circles) and estimated (line, solid circles) private recreational discard mortalities (1000 dead fish).

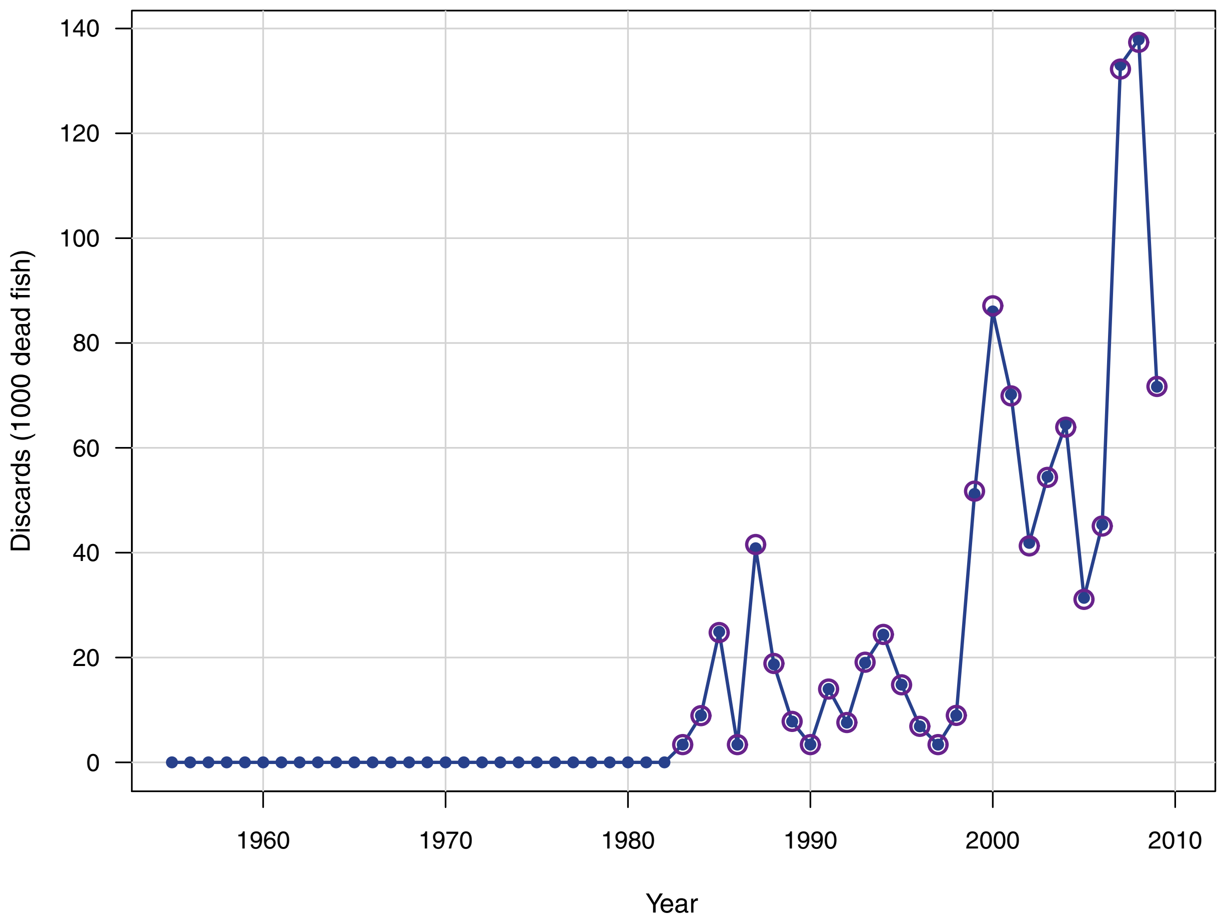


Figure 3.21. Observed (open circles) and estimated (line, solid circles) index of abundance from commercial lines.

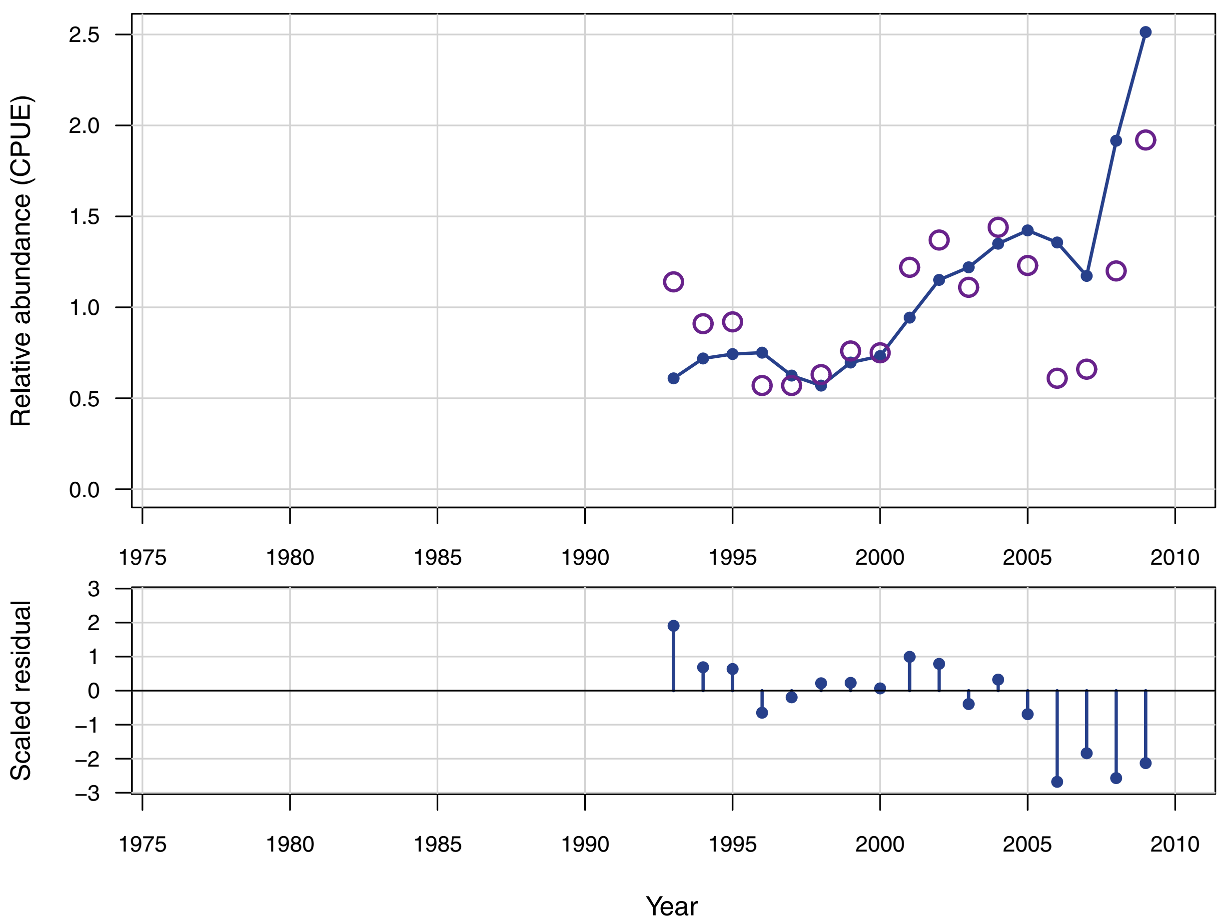


Figure 3.22. Observed (open circles) and estimated (line, solid circles) index of abundance from the for-hire (headboats) fleet.

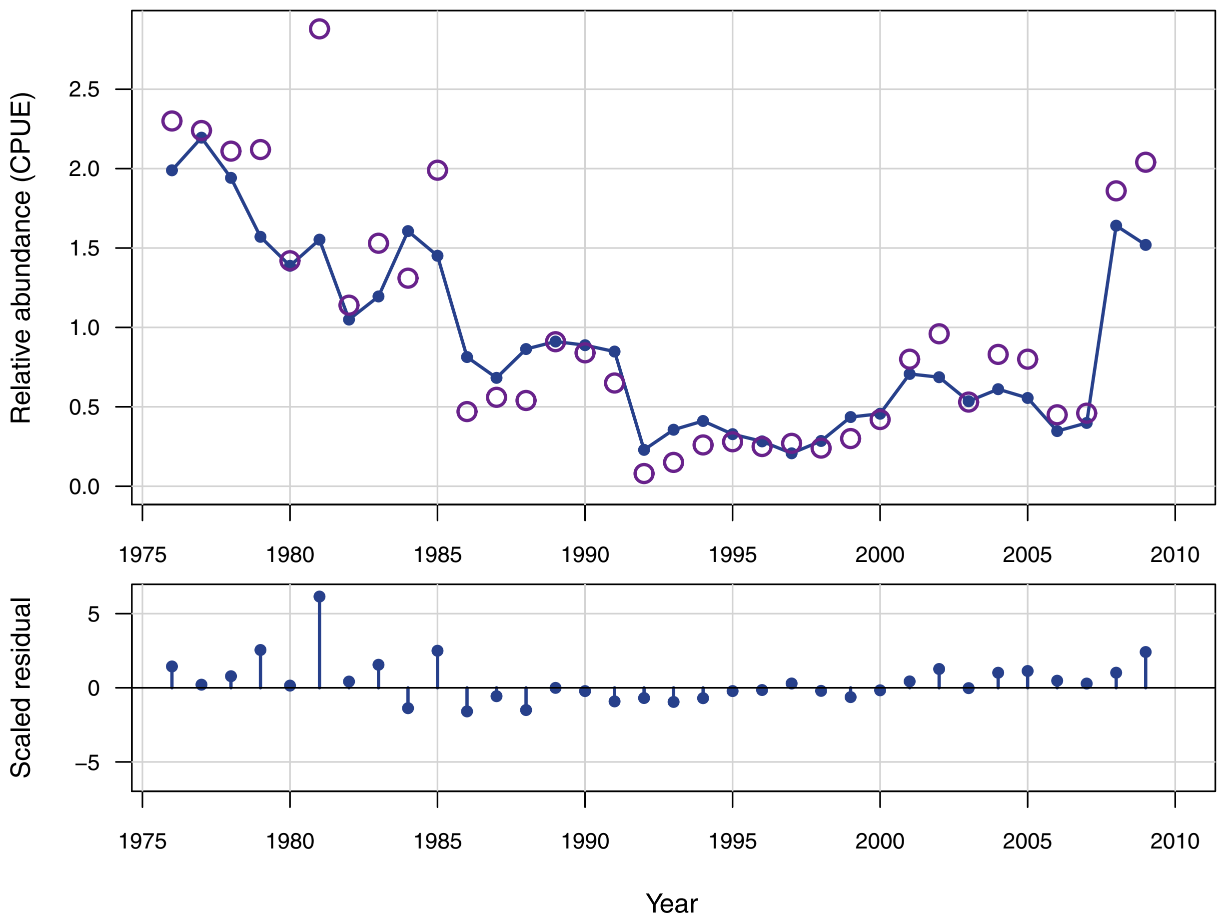


Figure 3.23. Observed (open circles) and estimated (line, solid circles) abundance from for-hire (headboat) discards.

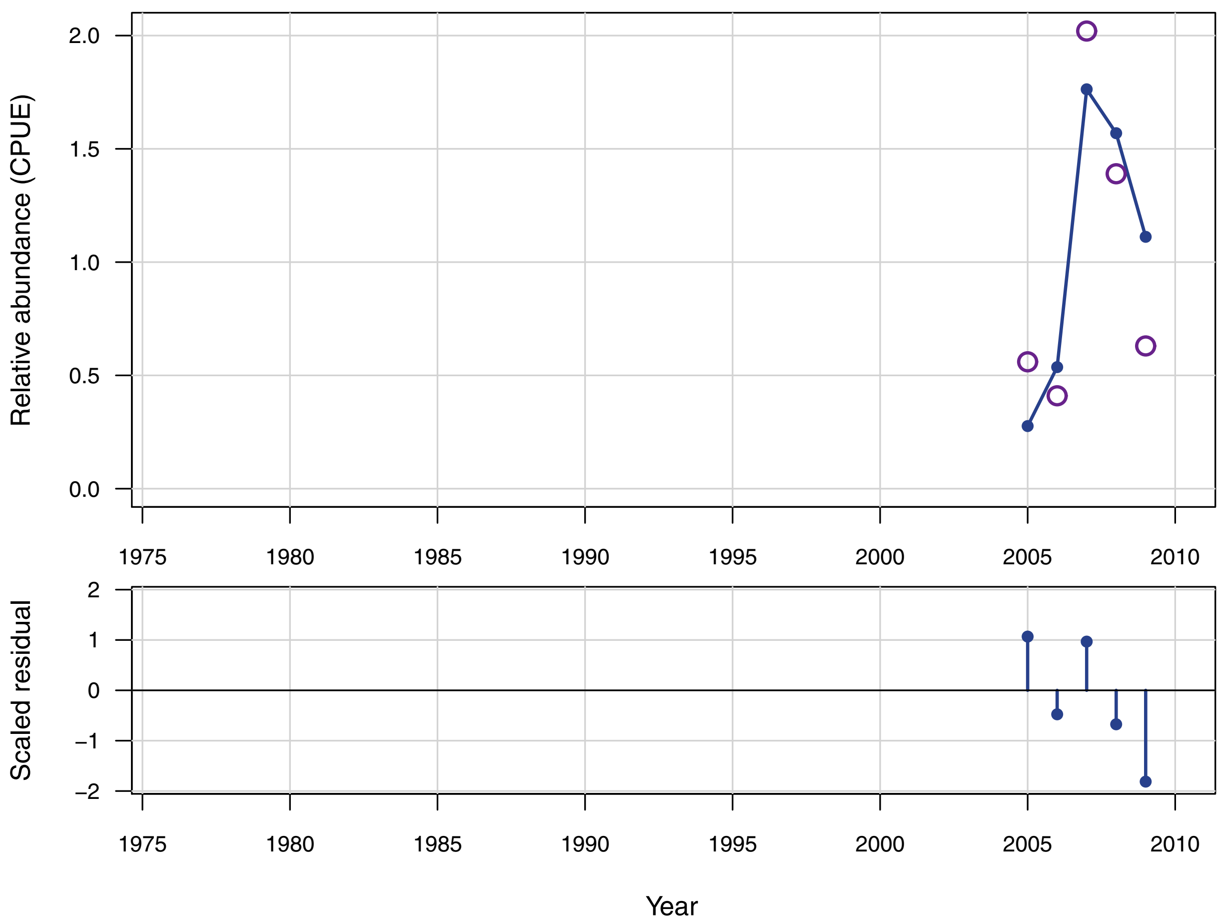


Figure 3.24. Estimated abundance at age at start of year.

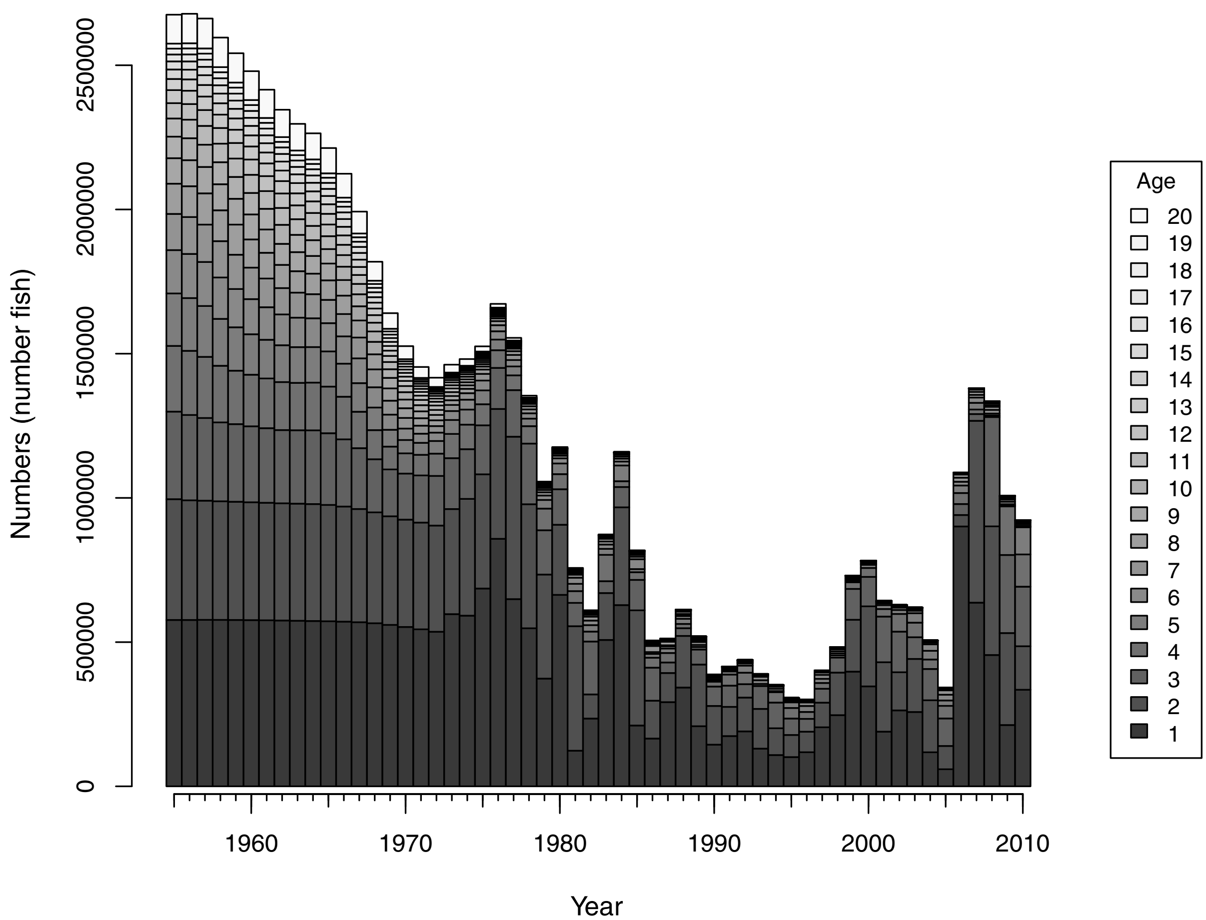


Figure 3.25. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates R_{MSY}. Bottom panel: log recruitment residuals.

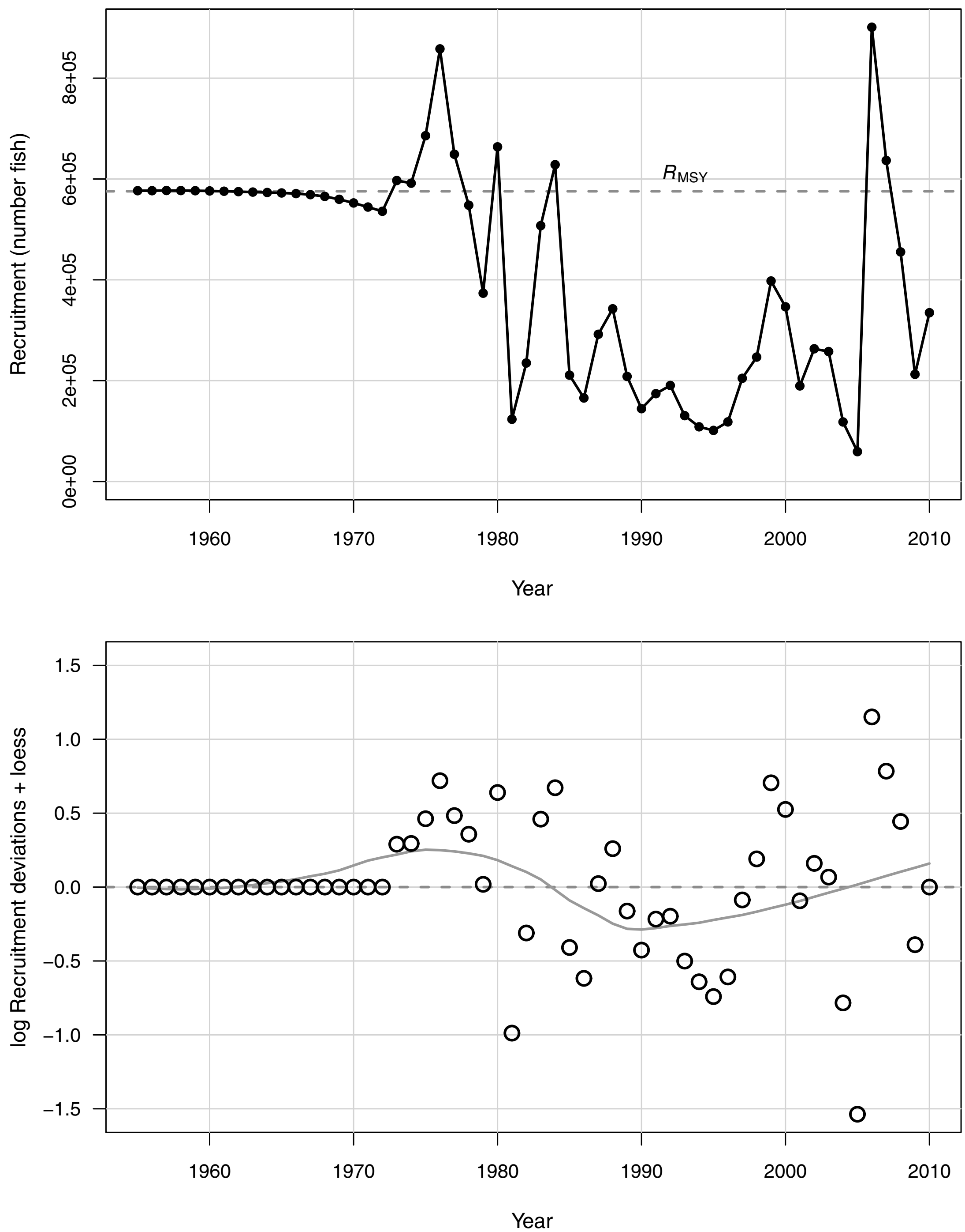


Figure 3.26. Estimated biomass at age at start of year.

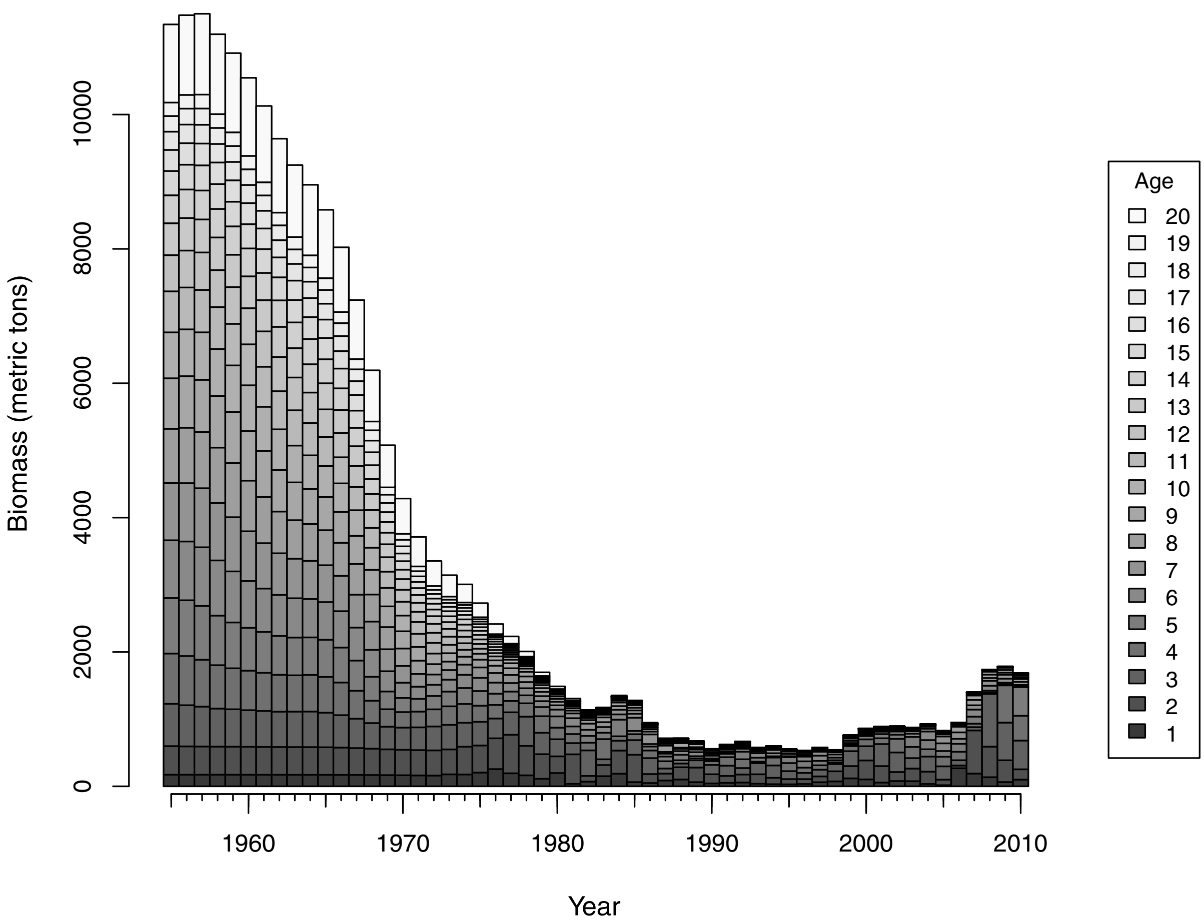
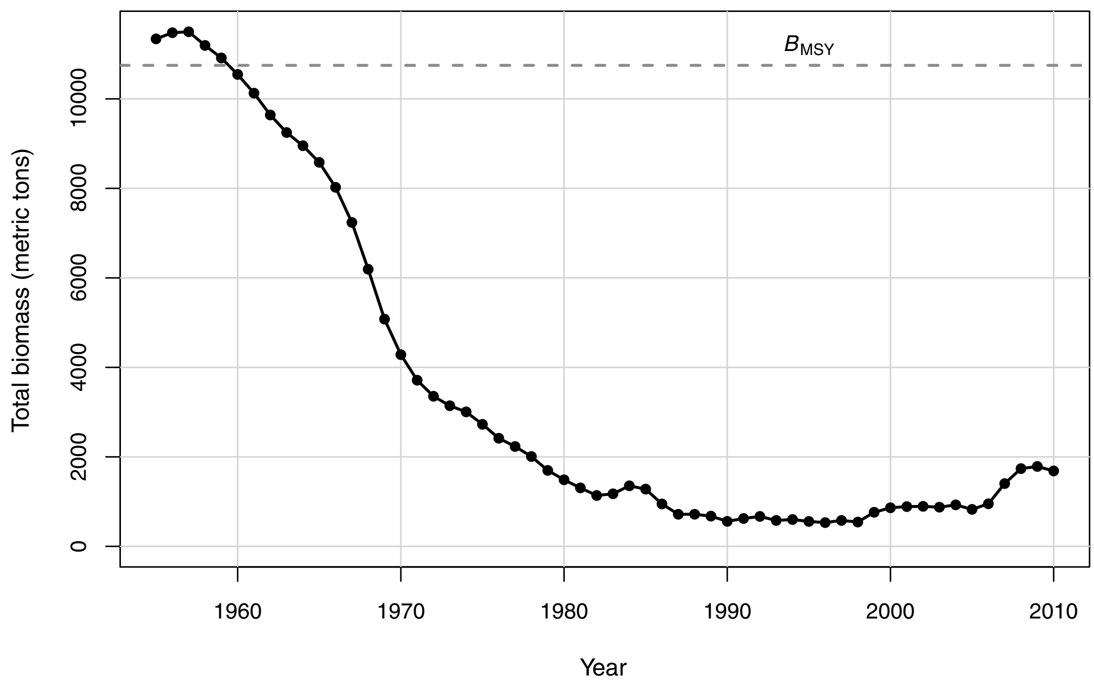


Figure 3.27. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates B_{MSY}. Bottom panel: Estimated spawning stock (gonad biomass of mature females) at time of peak spawning.



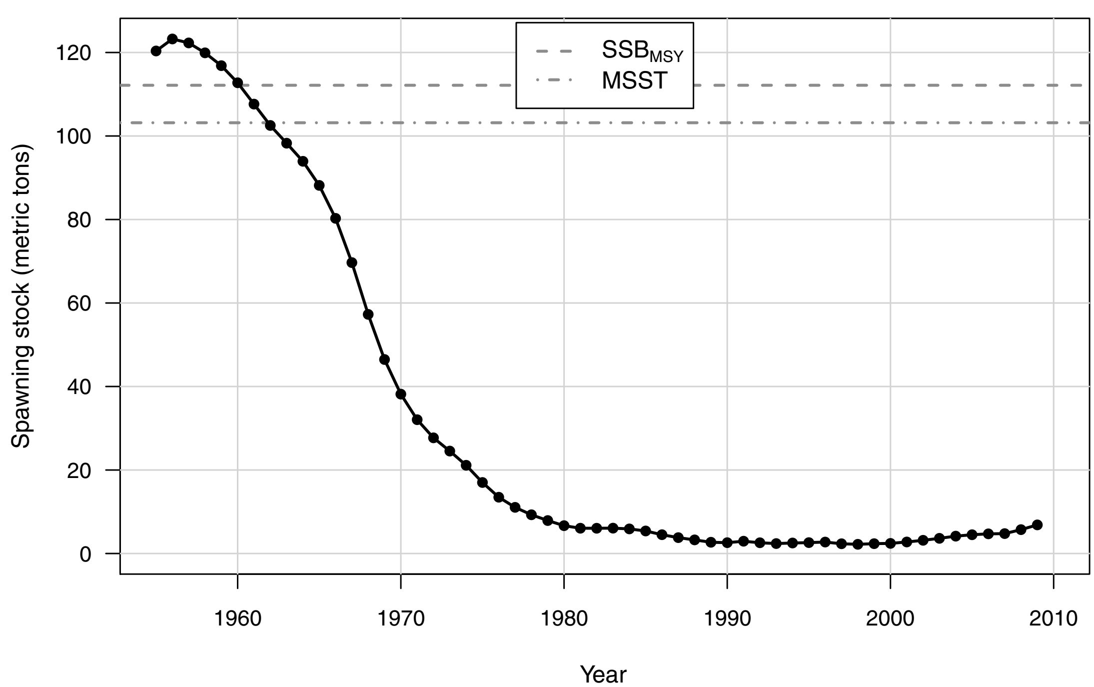


Figure 3.28. Selectivities of commercial fleets. Top panel: commercial lines, 1955–1991. Middle panel: commercial lines, 1992–2009. Bottom panel: commercial dive.

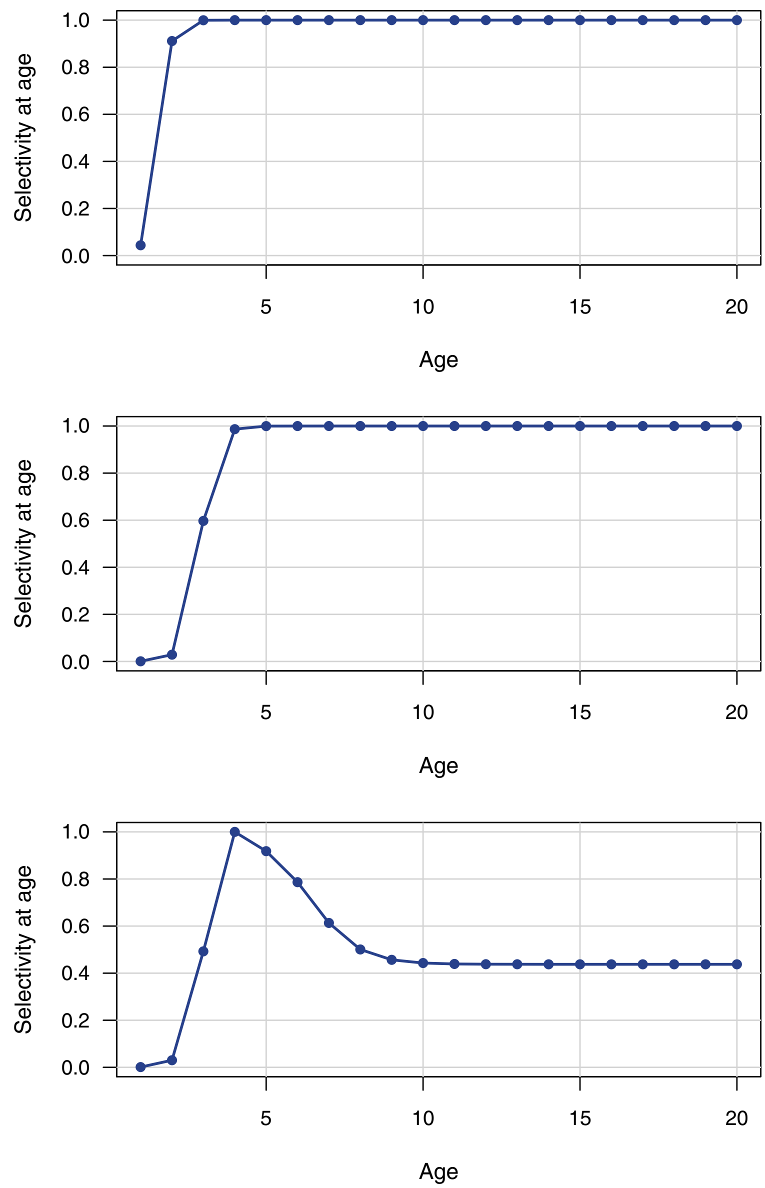


Figure 3.29. Selectivities of the for-hire fleet. Top panel: 1955–1983. Middle panel: 1983–1991. Bottom panel: 1992–2009.

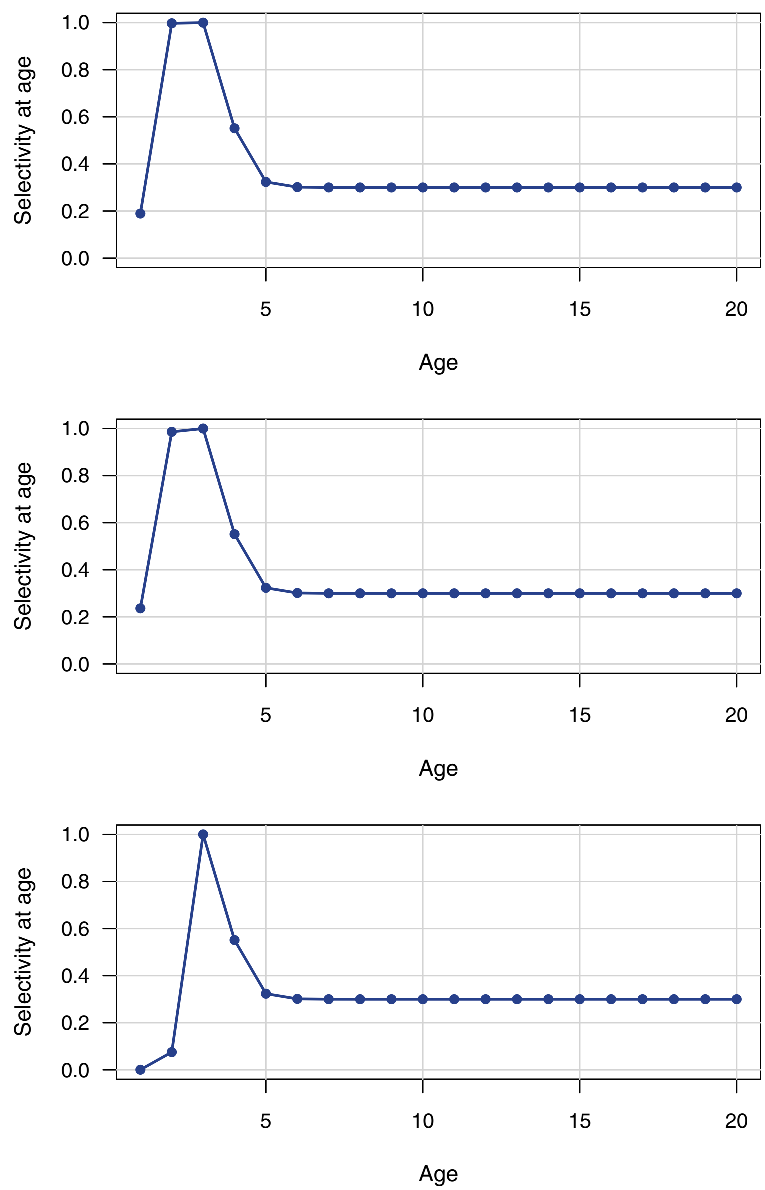


Figure 3.30. Selectivities of the private recreational fleet. Top panel: 1955–1983. Bottom panel: 1992–2009.

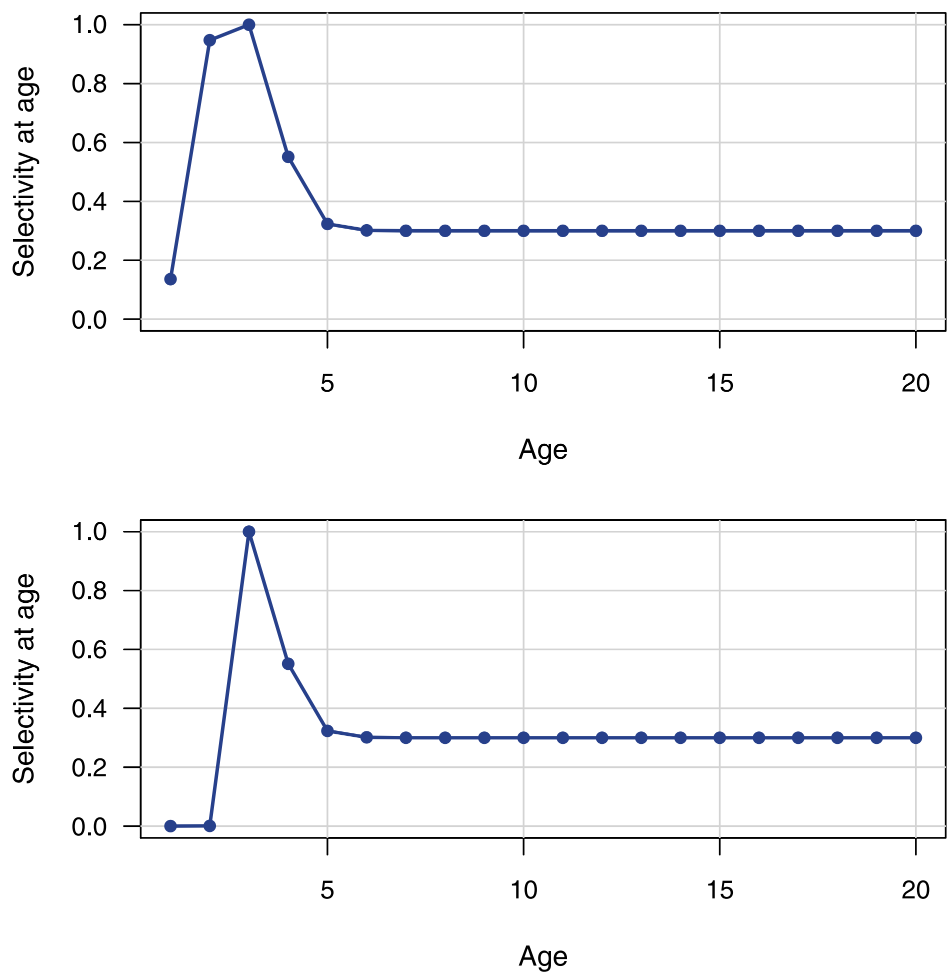


Figure 3.31. Selectivities of discard mortalities. Top panel: commercial lines, 1992–2009. Middle panel: recreational (for-hire and private), 1983–1991. Bottom panel: recreational (for-hire and private), 1992–2009.

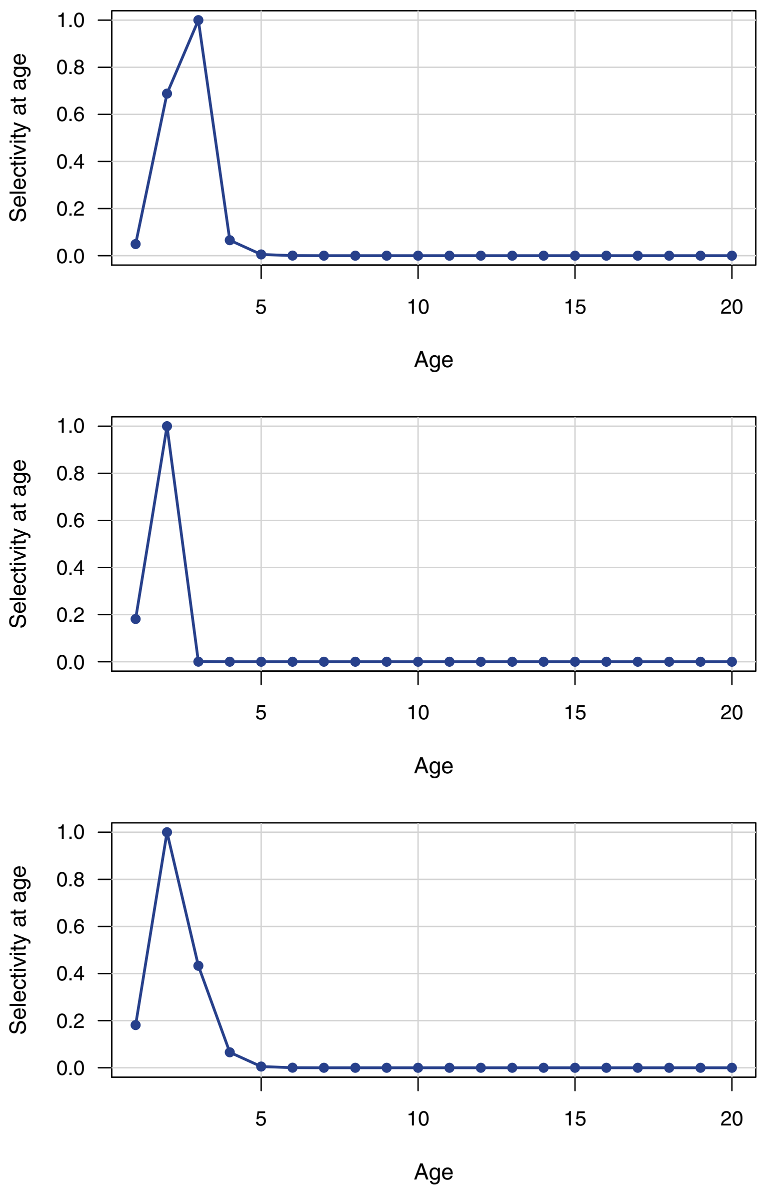


Figure 3.32. Average selectivities from the terminal assessment year (2009, 20-inch limit), weighted by geometric mean Fs from the last three assessment years, and used in computation of benchmarks and central-tendency projections. Top panel: average selectivity applied to landings. Middle panel: average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

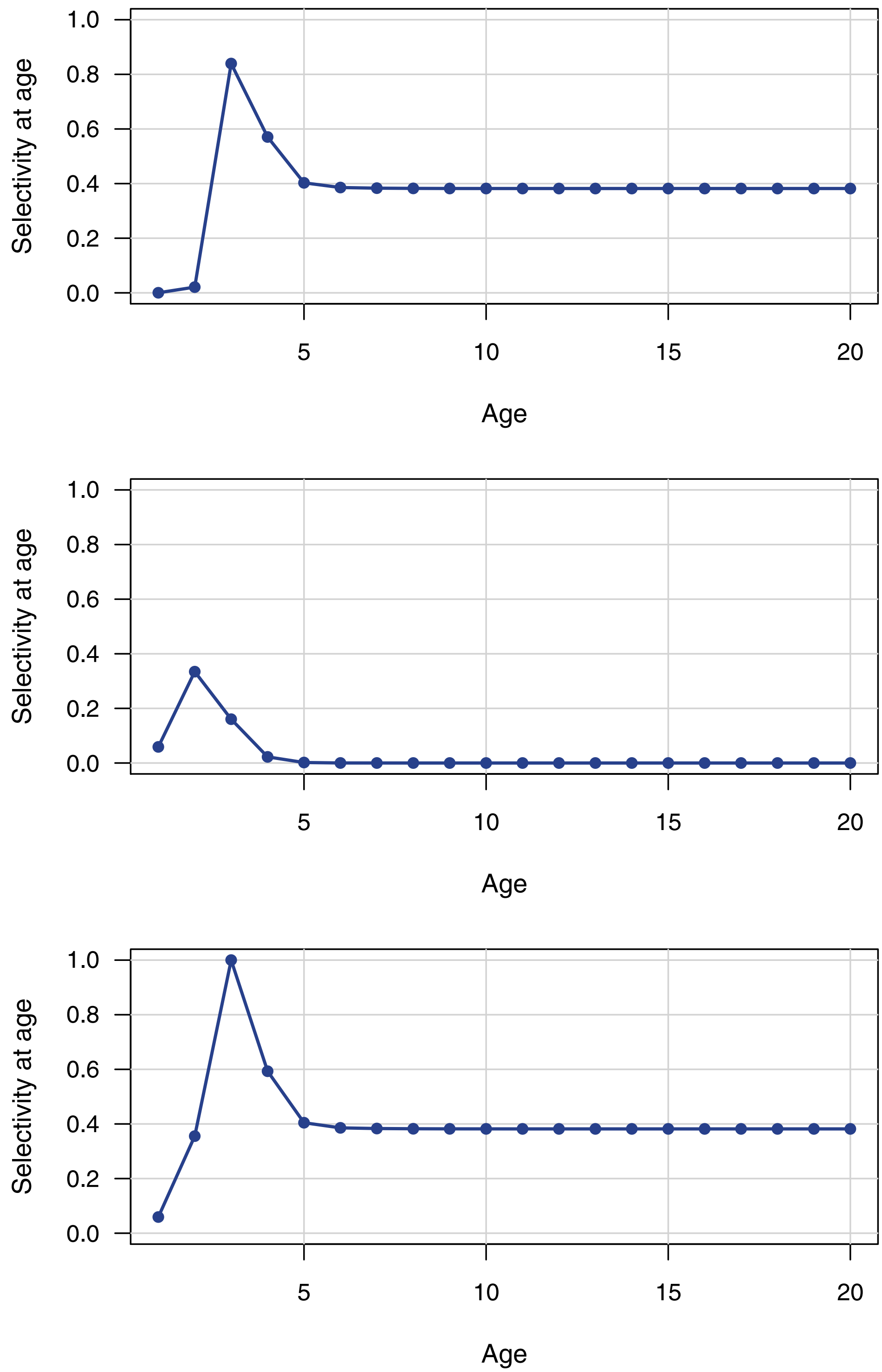


Figure 3.33. Estimated fully selected fishing mortality rate (per year) by fishery. cl refers to commercial lines, cd to commercial dive, hb to for-hire, pvt to private recreational, cl.D to commercial discard mortalities, hb.D to for-hire discard mortalities, and pvt.D to private recreational discard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

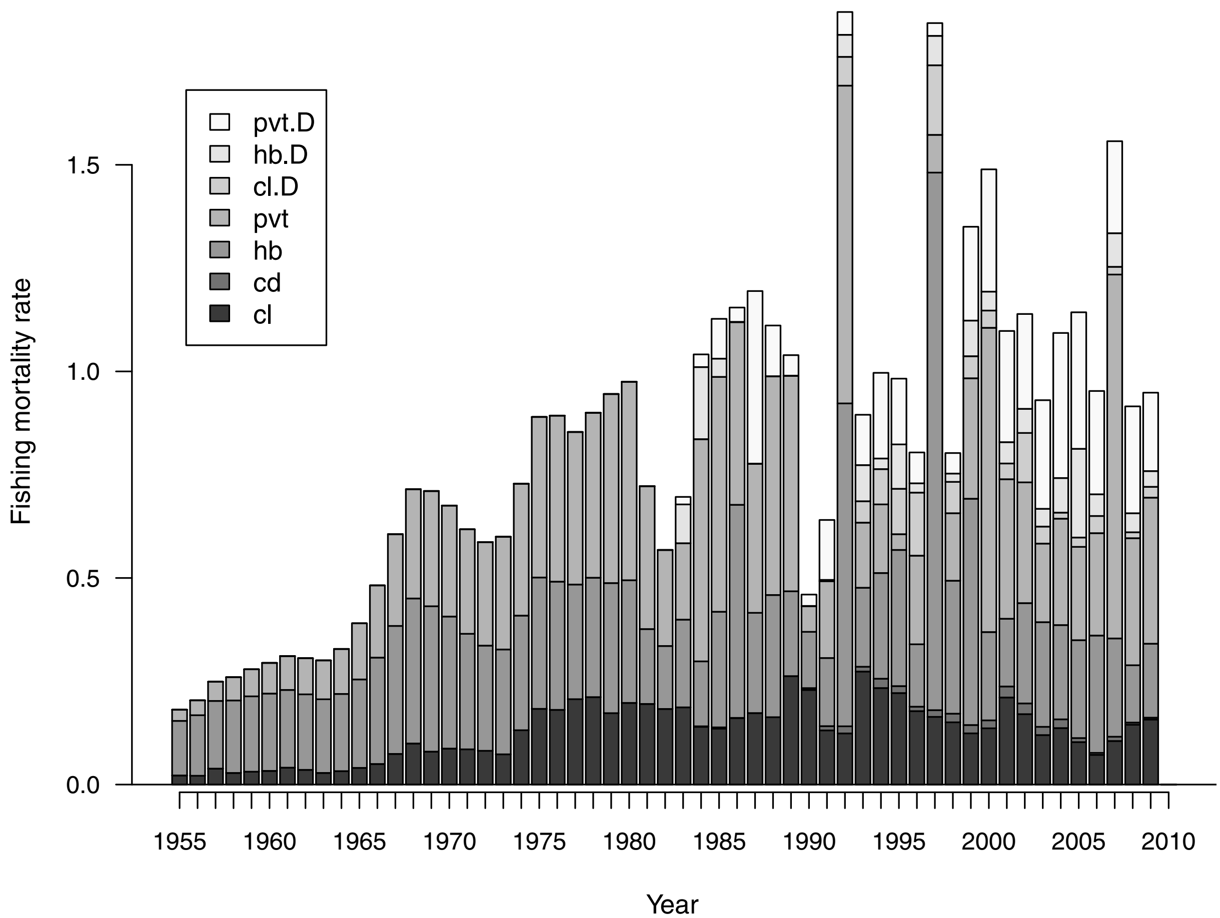


Figure 3.34. Estimated landings in numbers by fishery from the catch-age model. cl refers to commercial lines, cd to commercial dive, hb to for-hire, pvt to private recreational.

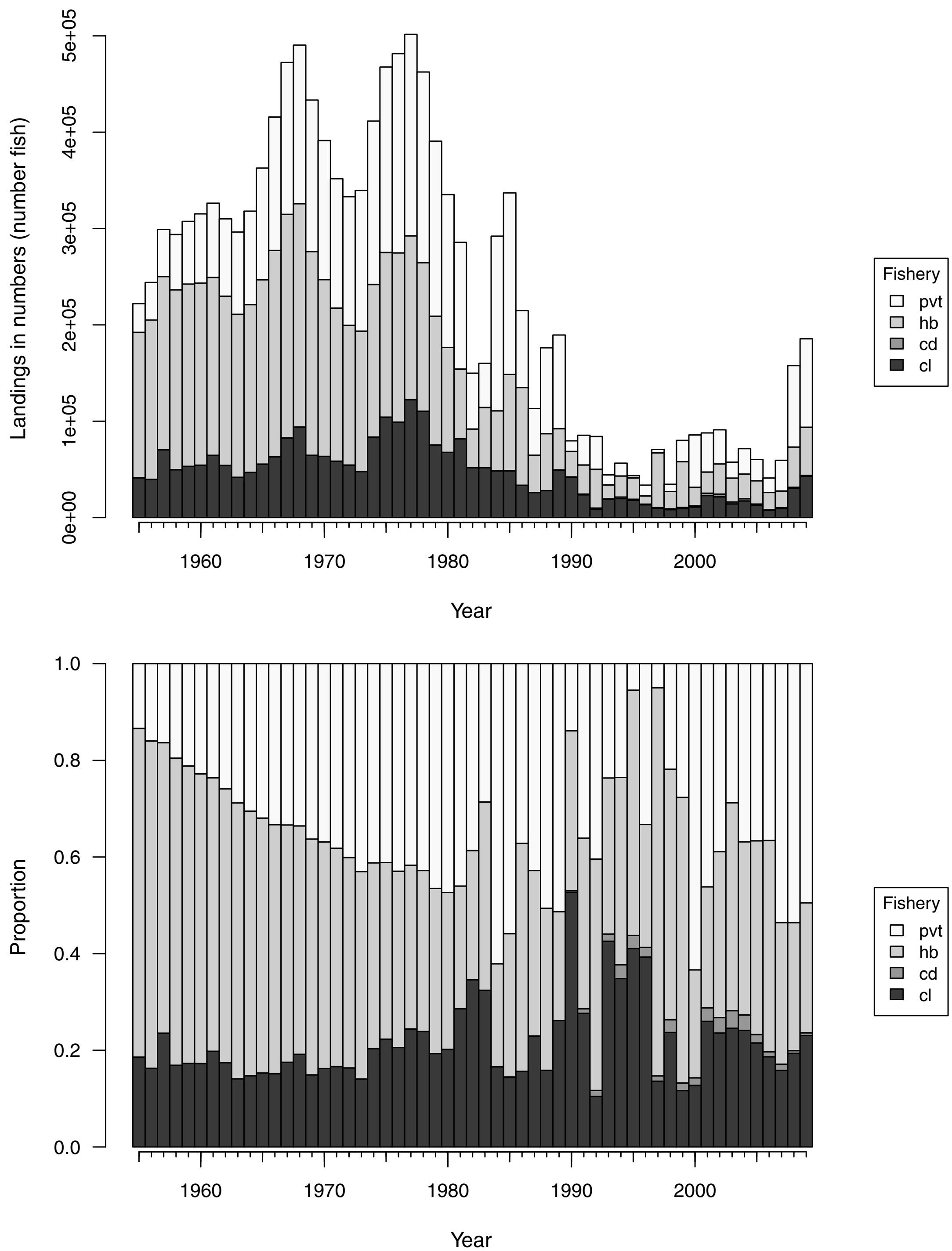


Figure 3.35. Estimated landings in whole weight by fishery from the catch-age model. cl refers to commercial lines, cd to commercial dive, hb to for-hire, pvt to private recreational.

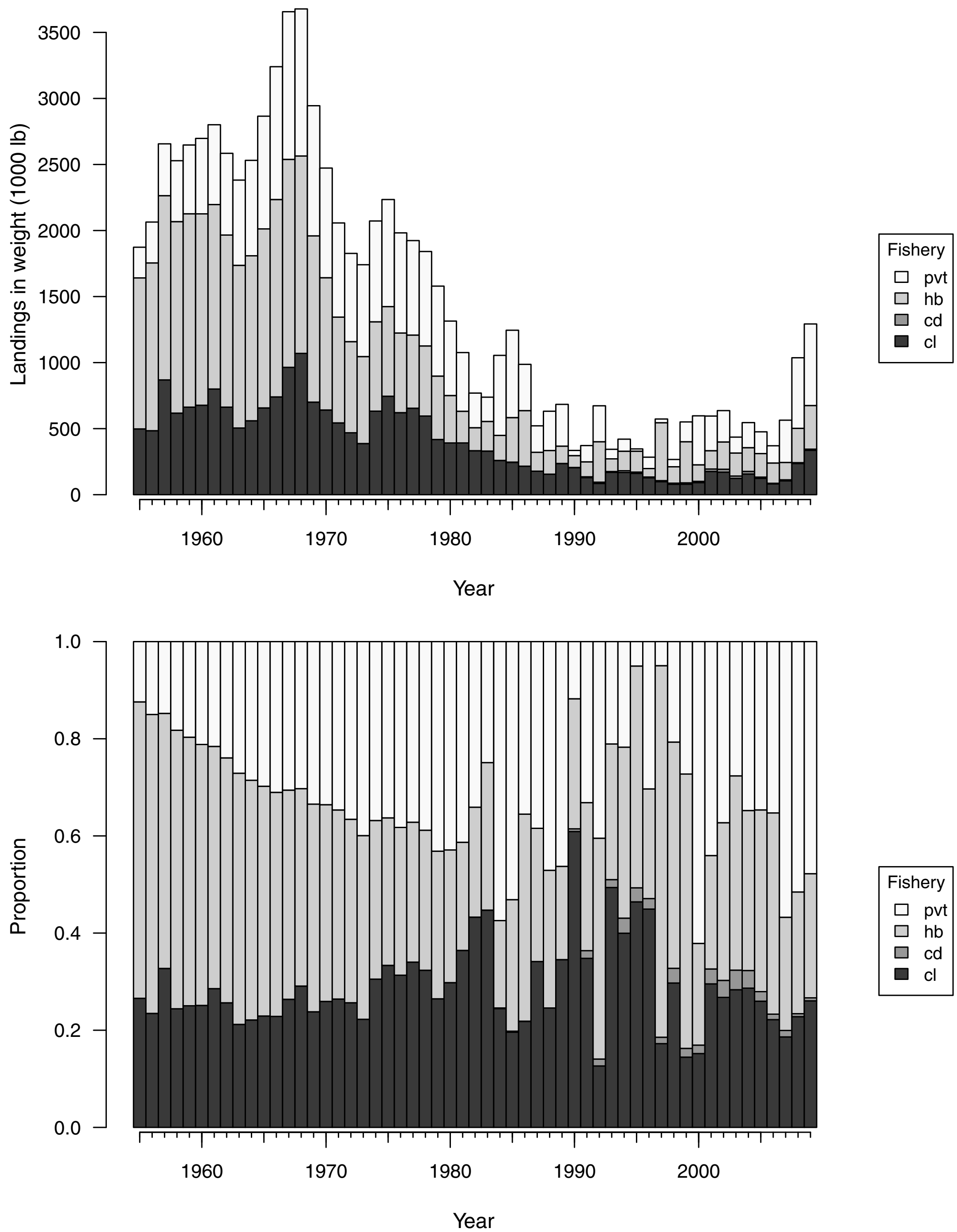


Figure 3.36. Estimated discard mortalities by fishery from the catch-age model. cl refers to commercial lines, hb to for-hire, pvt to private recreational.

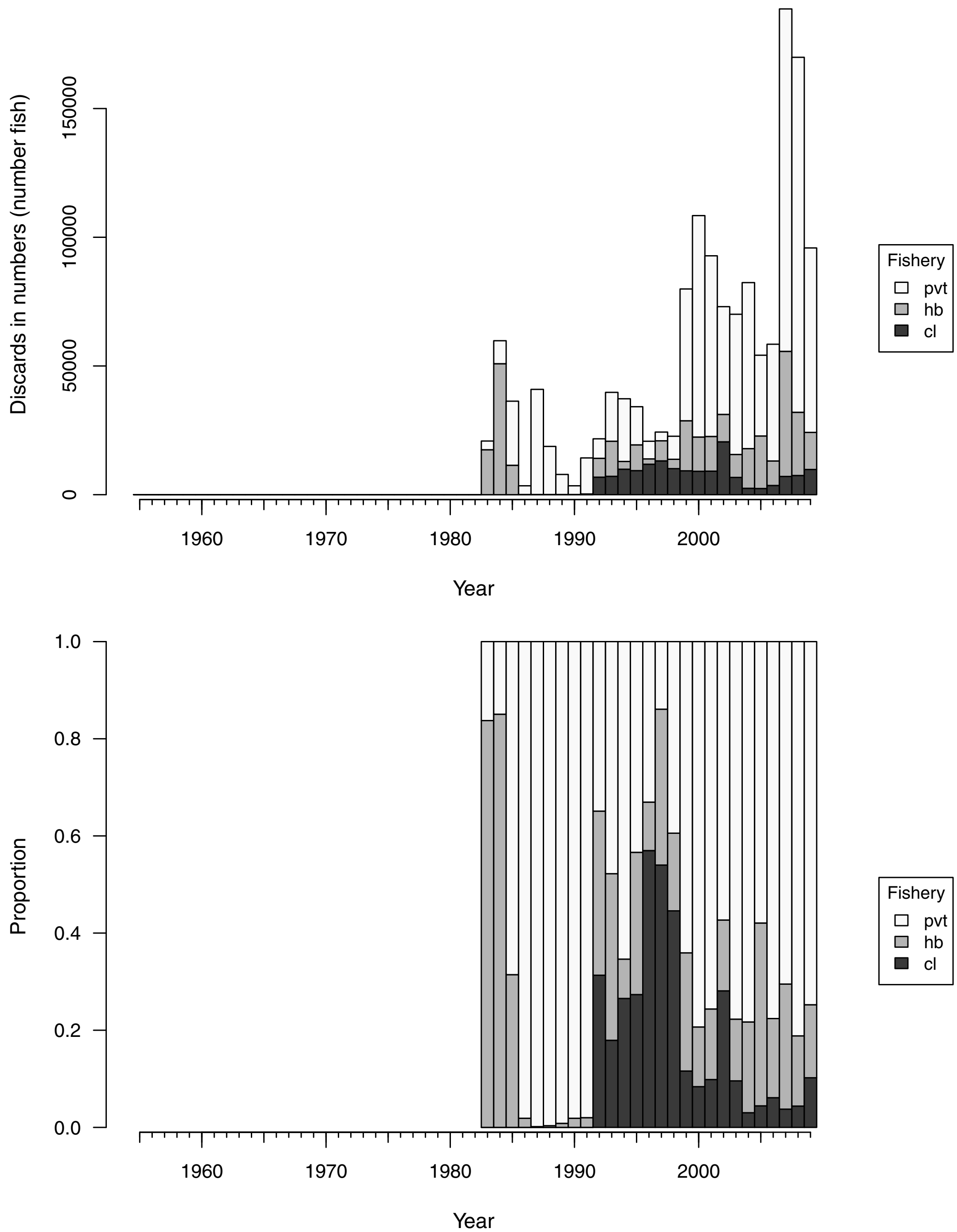


Figure 3.37. Top panel: Beverton–Holt spawner-recruit curves, with and without lognormal bias correction. Years within panel indicate year of recruitment generated from spawning biomass one year prior. Bottom panel: log of recruits (number age-1 fish) per spawner (mature female gonad weight) as a function of spawners.

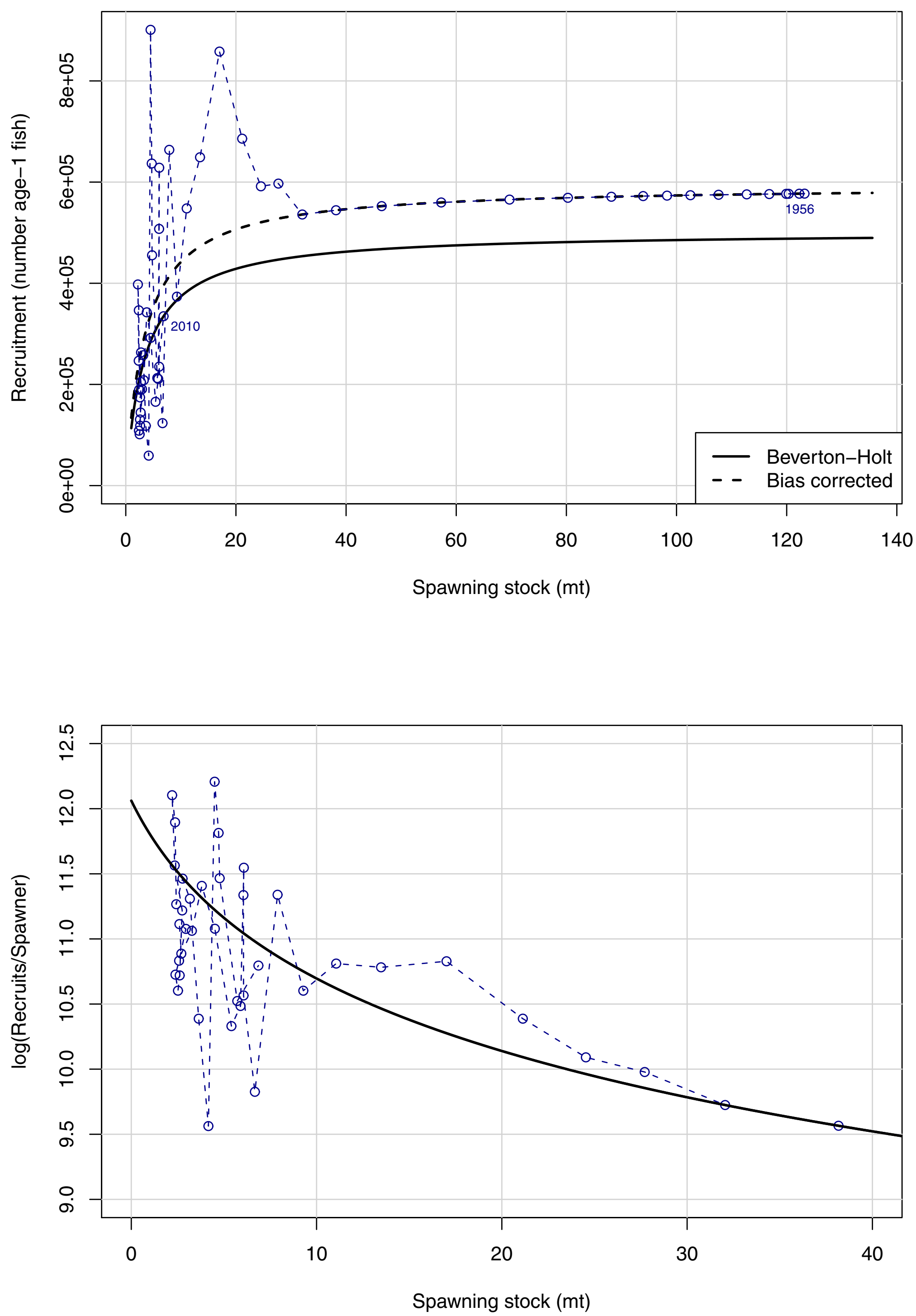


Figure 3.38. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-1 fish), steepness, unfished spawners per recruit, and standard deviation of recruitment residuals in log space. Vertical lines represent point estimates or values from the base run of the Beaufort Assessment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

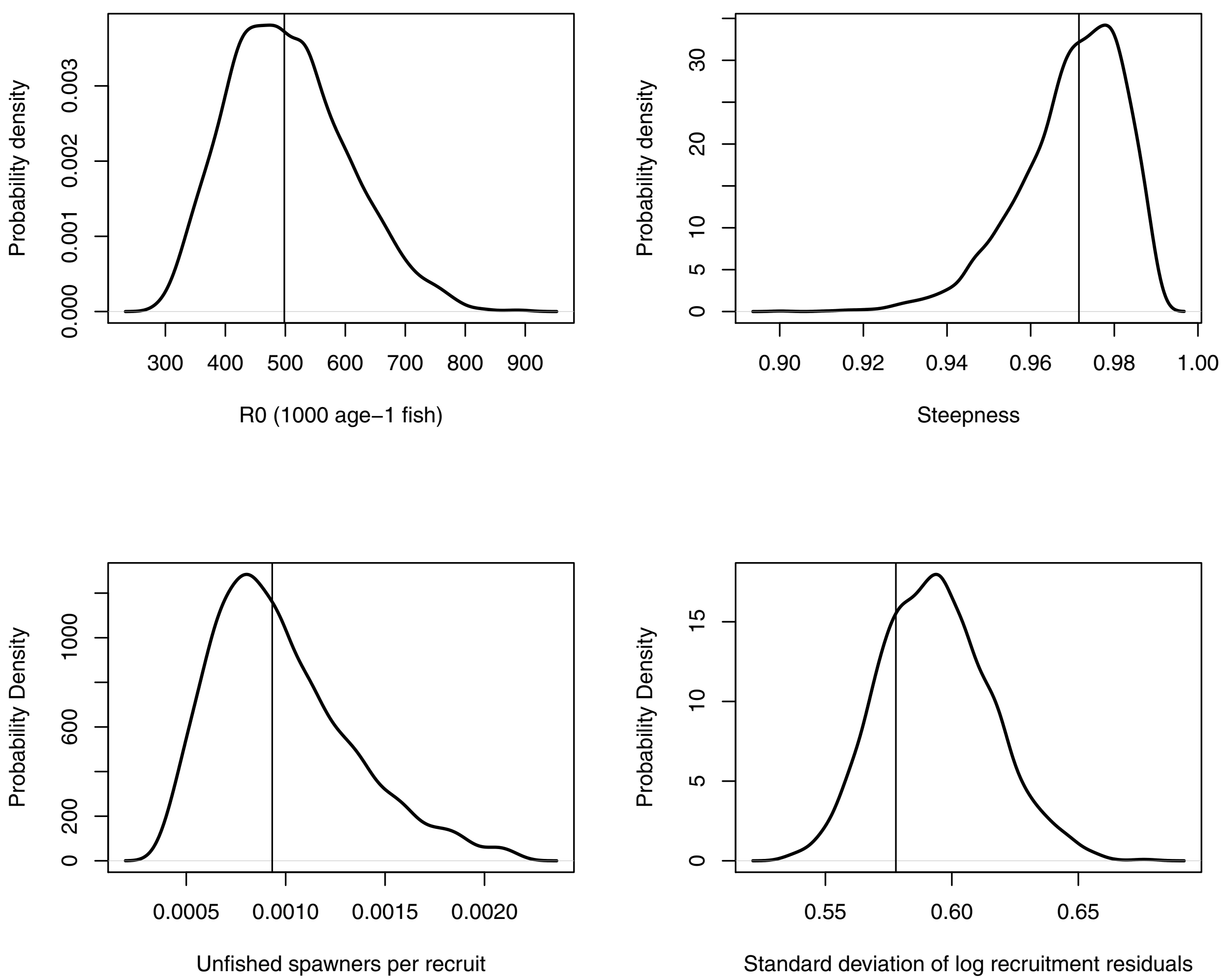


Figure 3.39. Estimated time series of static spawning potential ratio, the annual equilibrium spawners per recruit relative to that at the unfished level.

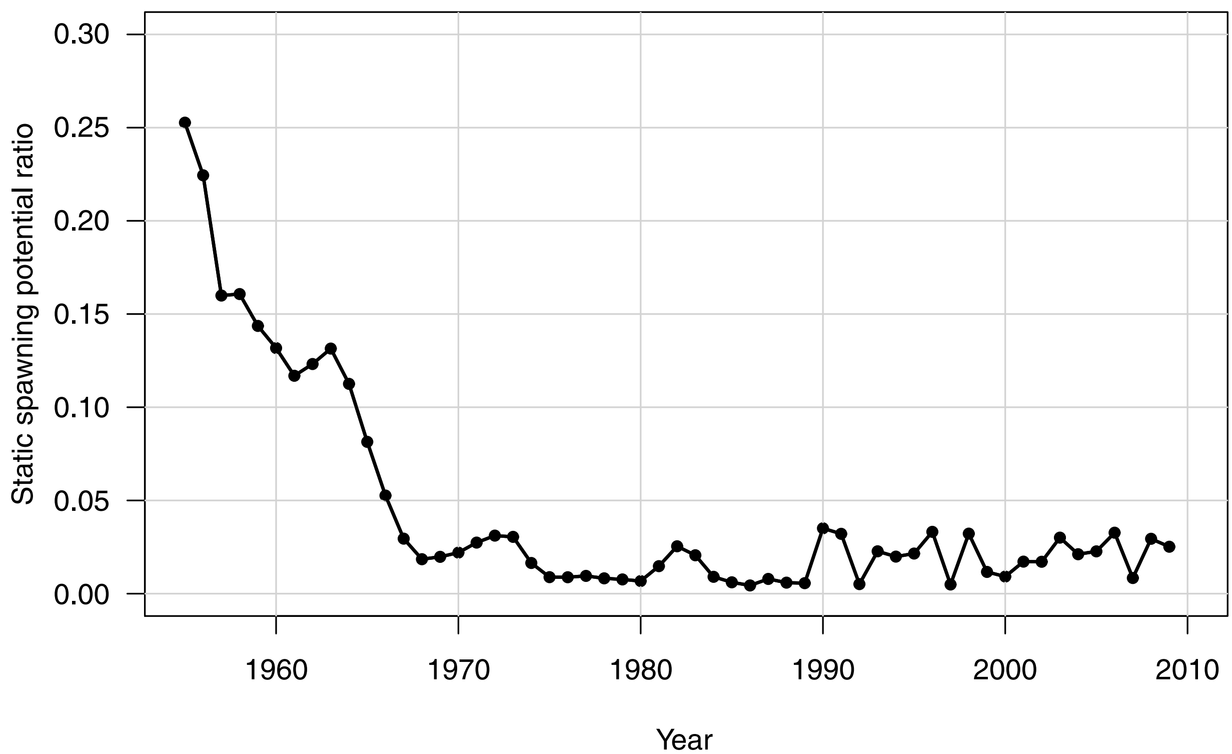


Figure 3.40. Top panel: yield per recruit. Bottom panel: spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the y% levels provide $F_{y\%}$. Both curves are based on average selectivity from the end of the assessment period.

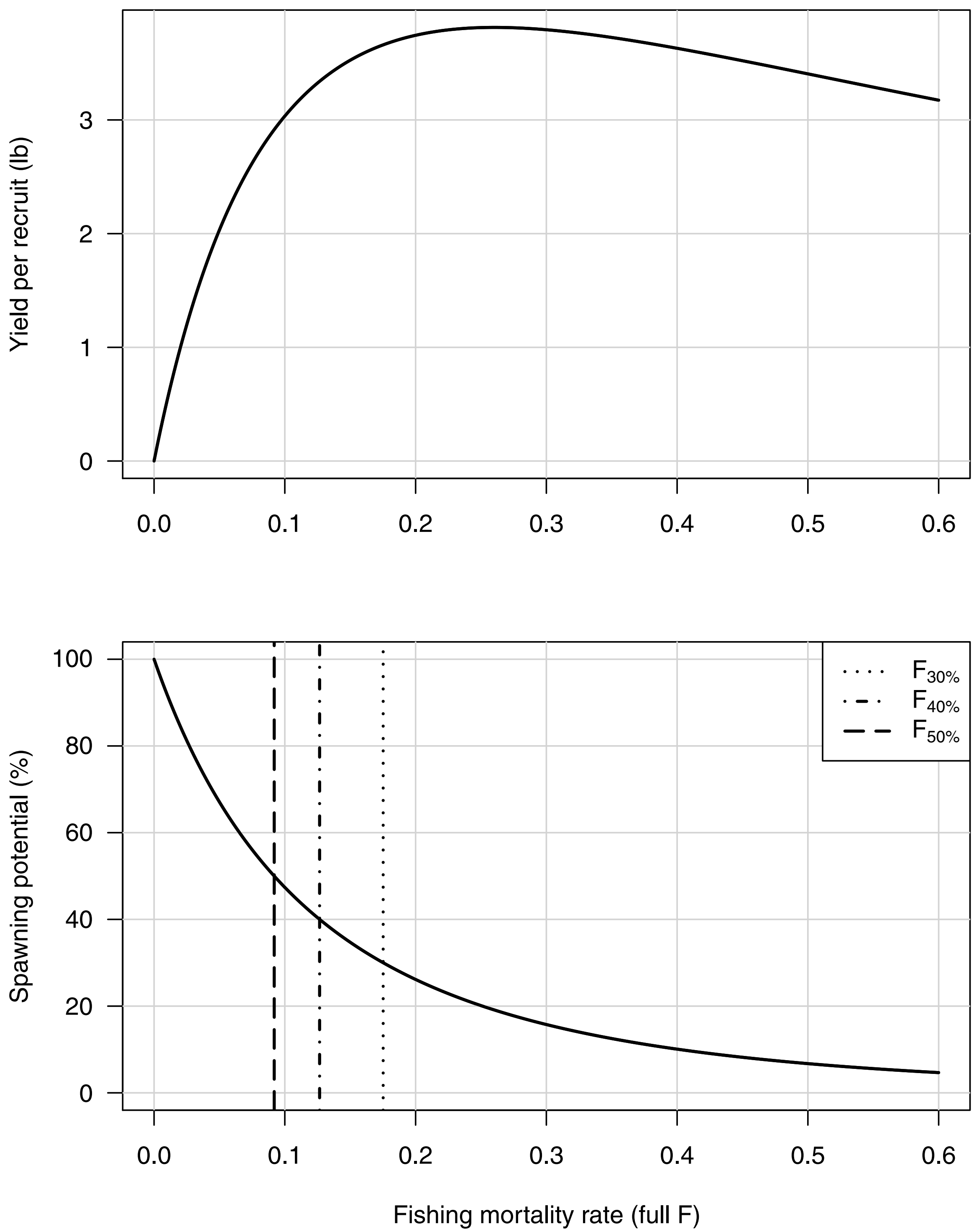


Figure 3.41. Top panel: equilibrium landings. The peak occurs where fishing rate is $F_{MSY} = 0.24$ *and equilibrium landings are* MSY = 2192 *(1000 lb). Bottom panel: equilibrium spawning biomass. Both curves are based on average selectivity from the end of the assessment period.*

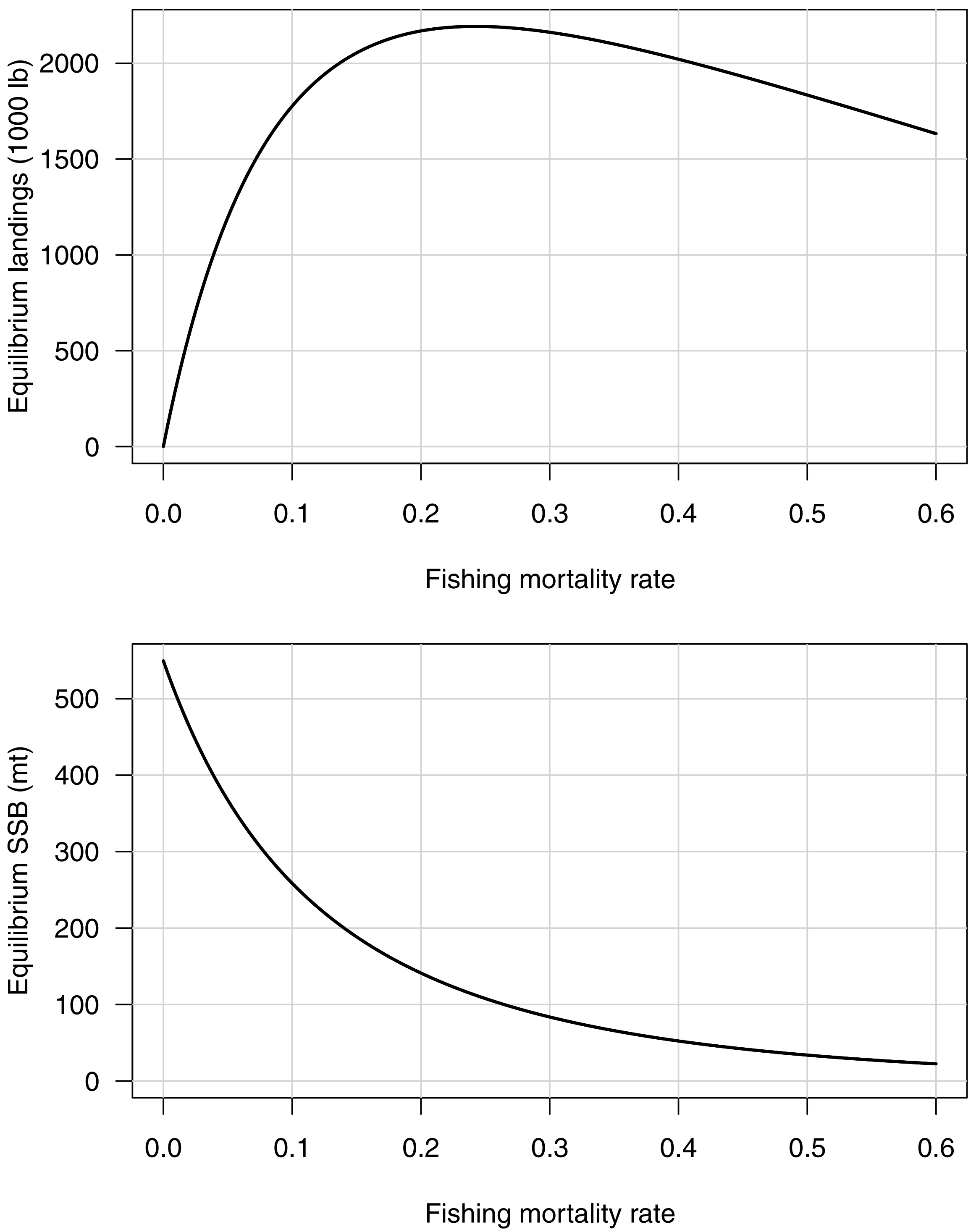


Figure 3.42. Top panel: equilibrium landings as a function of equilibrium biomass, which itself is a function of fishing mortality rate. The peak occurs where equilibrium biomass is $B_{MSY} = 10750$ *mt and equilibrium landings are* MSY = 2192 *(1000 lb). Bottom panel: equilibrium discard mortality as a function of equilibrium biomass.*

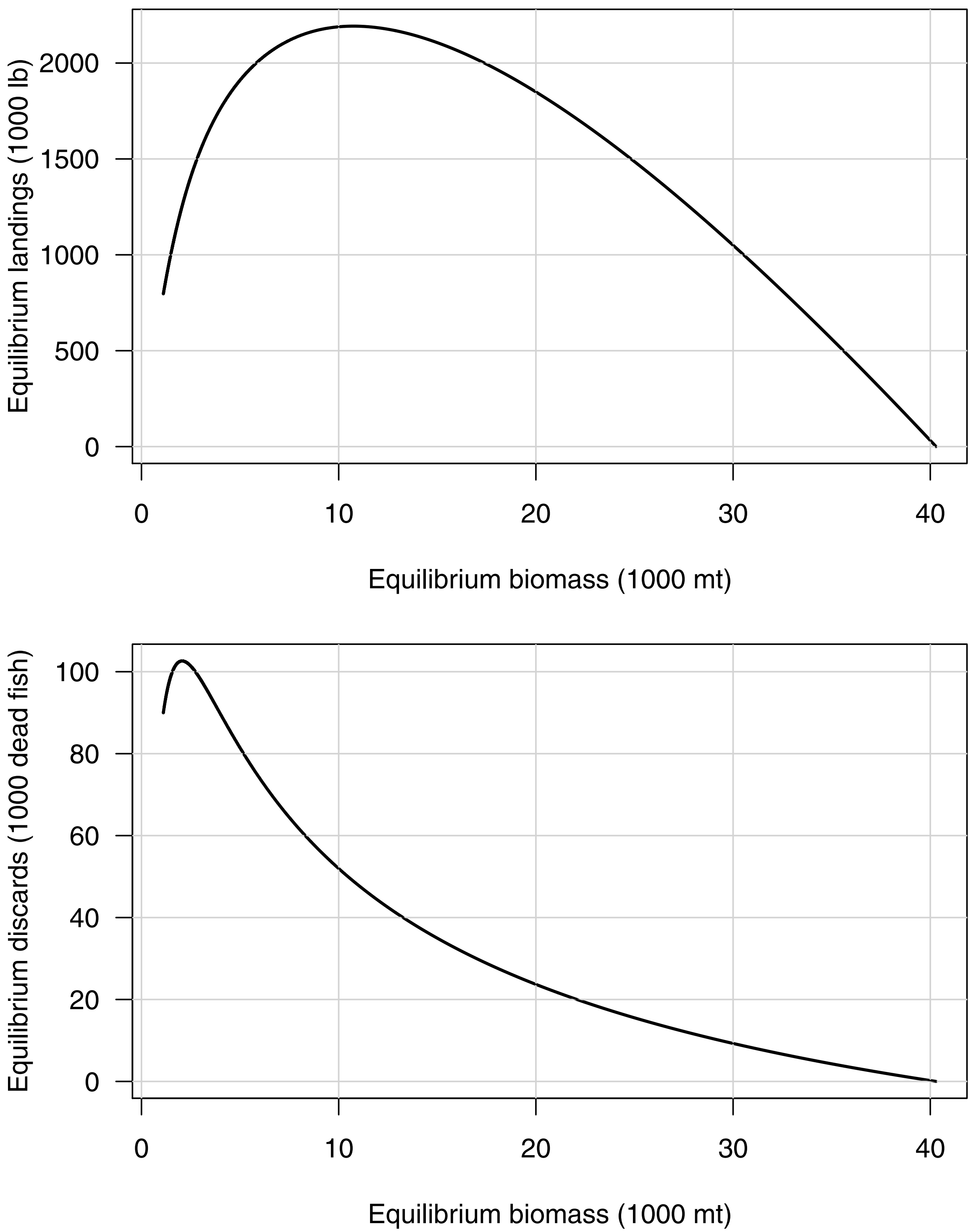


Figure 3.43. Probability densities of MSY*-related benchmarks from MCB analysis of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.*

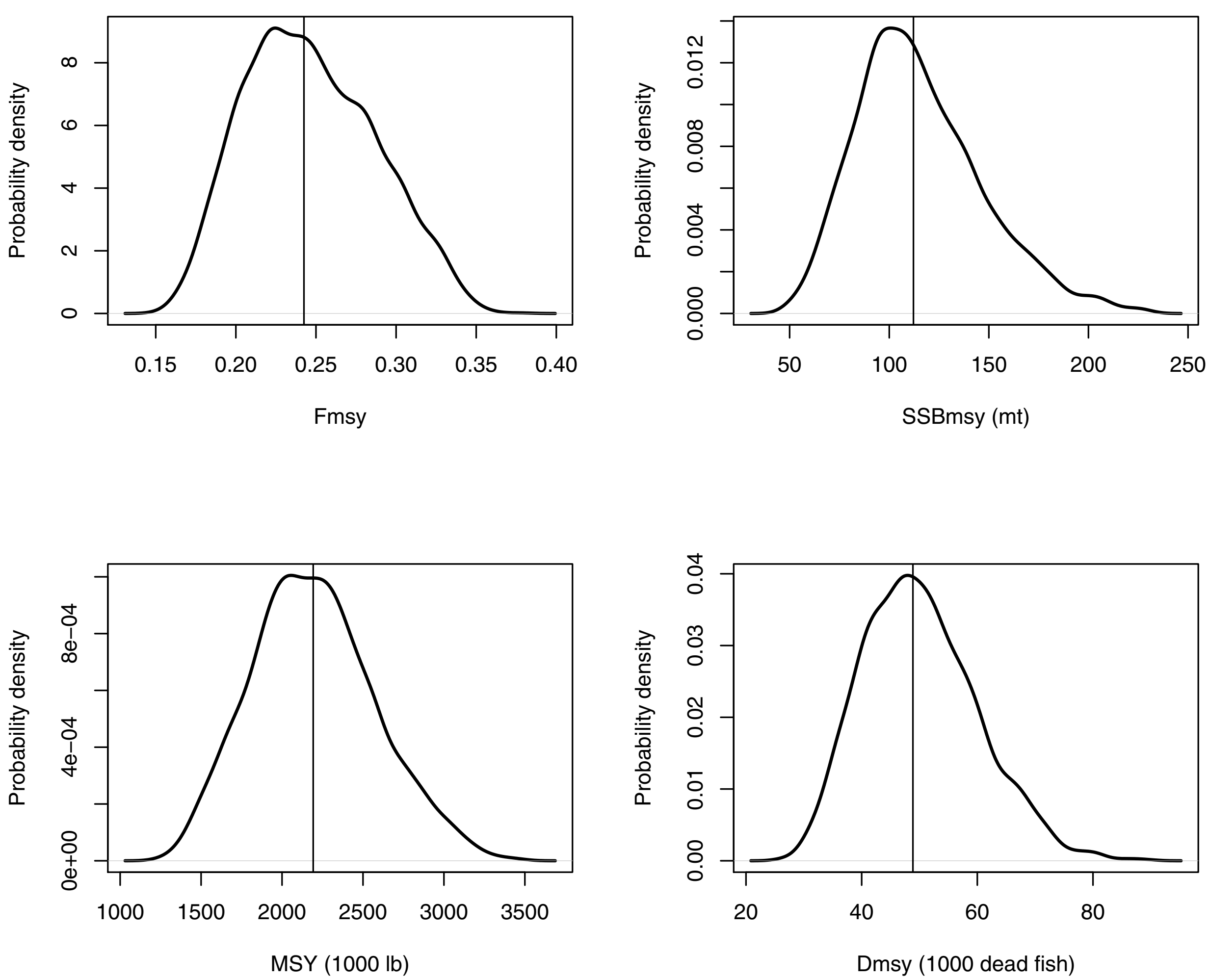
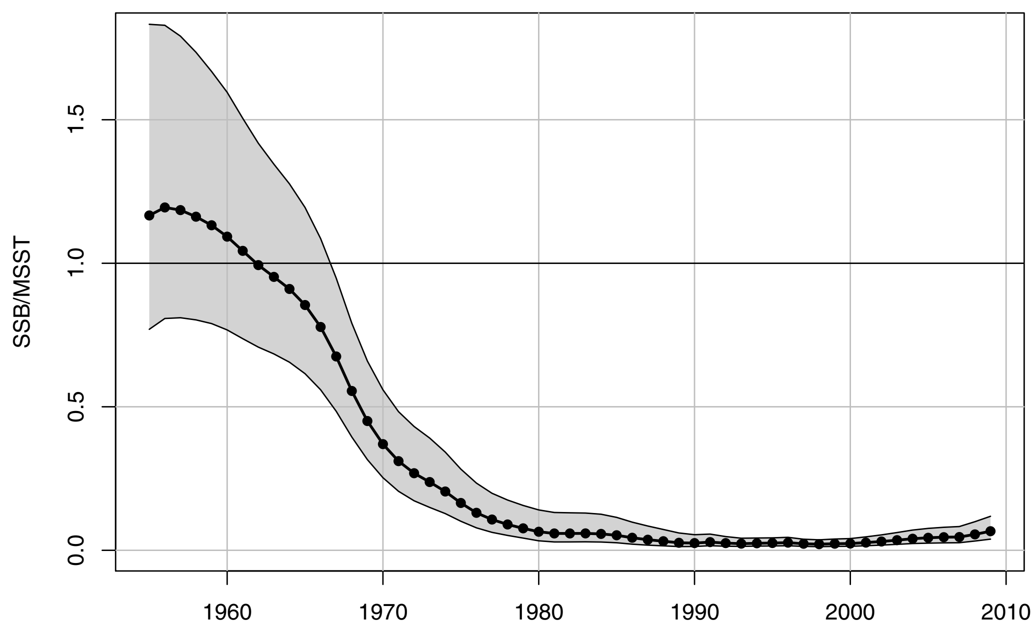


*Figure 3.44. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; gray error bands indicate 5^{th} and 95^{th} percentiles of the MCB trials. Top panel: spawning biomass relative to the minimum stock size threshold (*MSST*). Bottom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



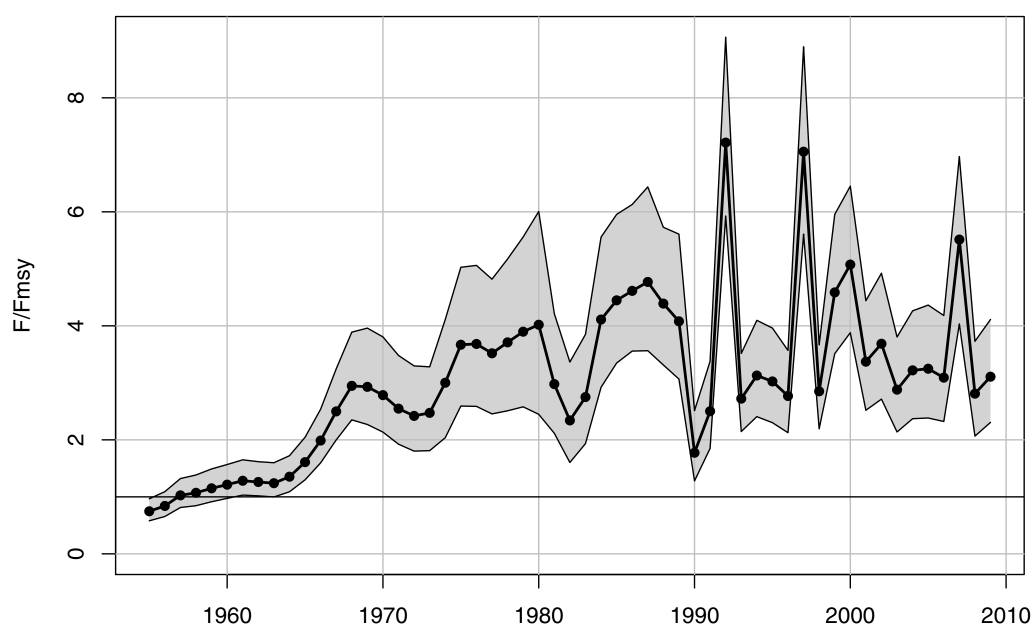
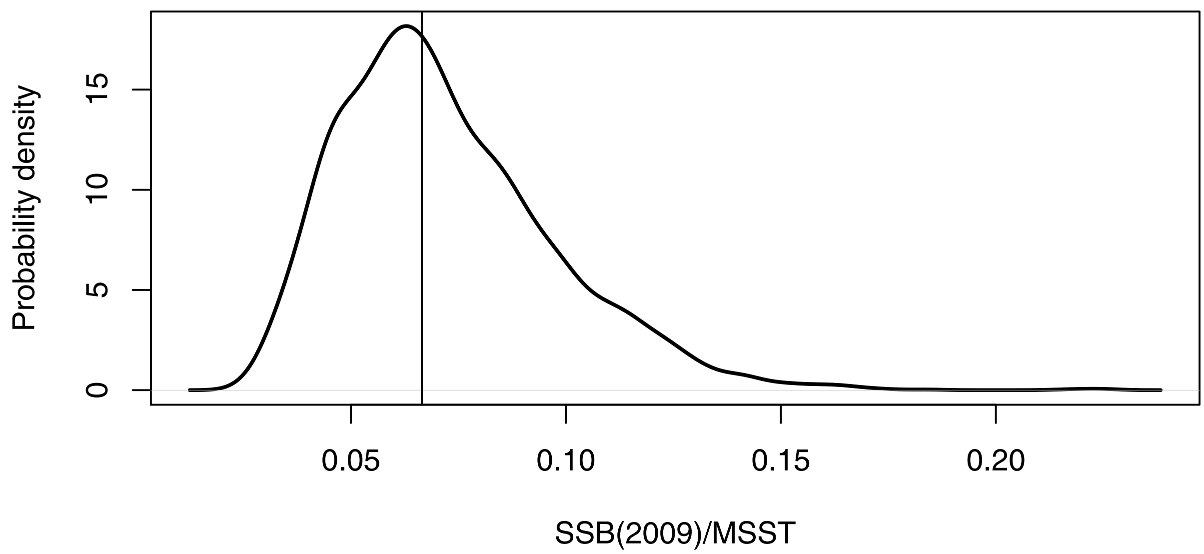


Figure 3.45. Probability densities of terminal status estimates from MCB analysis of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.



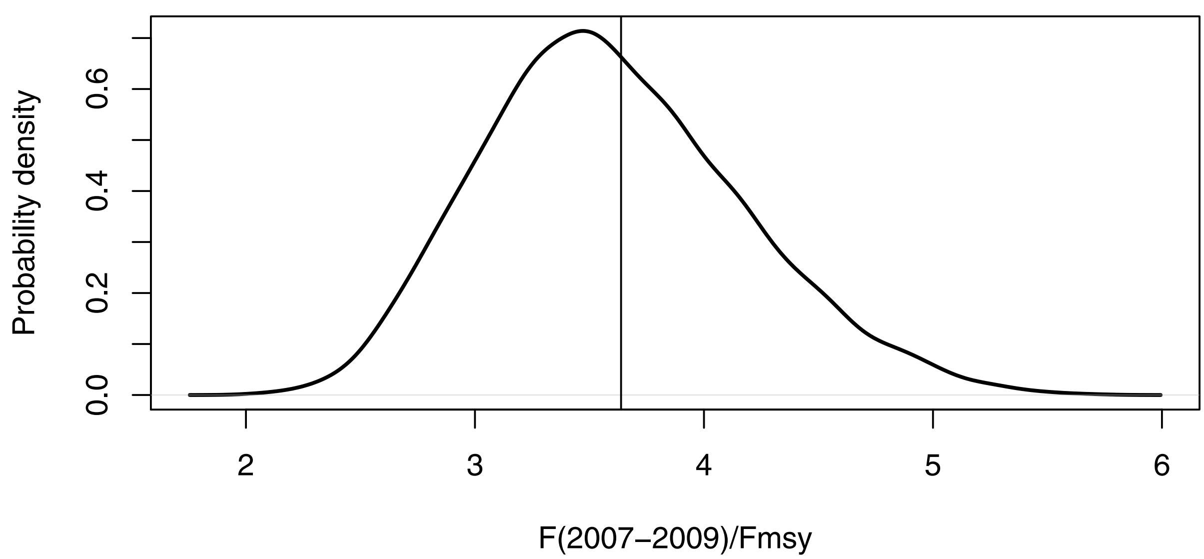


Figure 3.46. Phase plot of terminal status estimates from MCB analysis of the Beaufort Assessment Model. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by 5^{th} *and* 95^{th} *percentiles.*

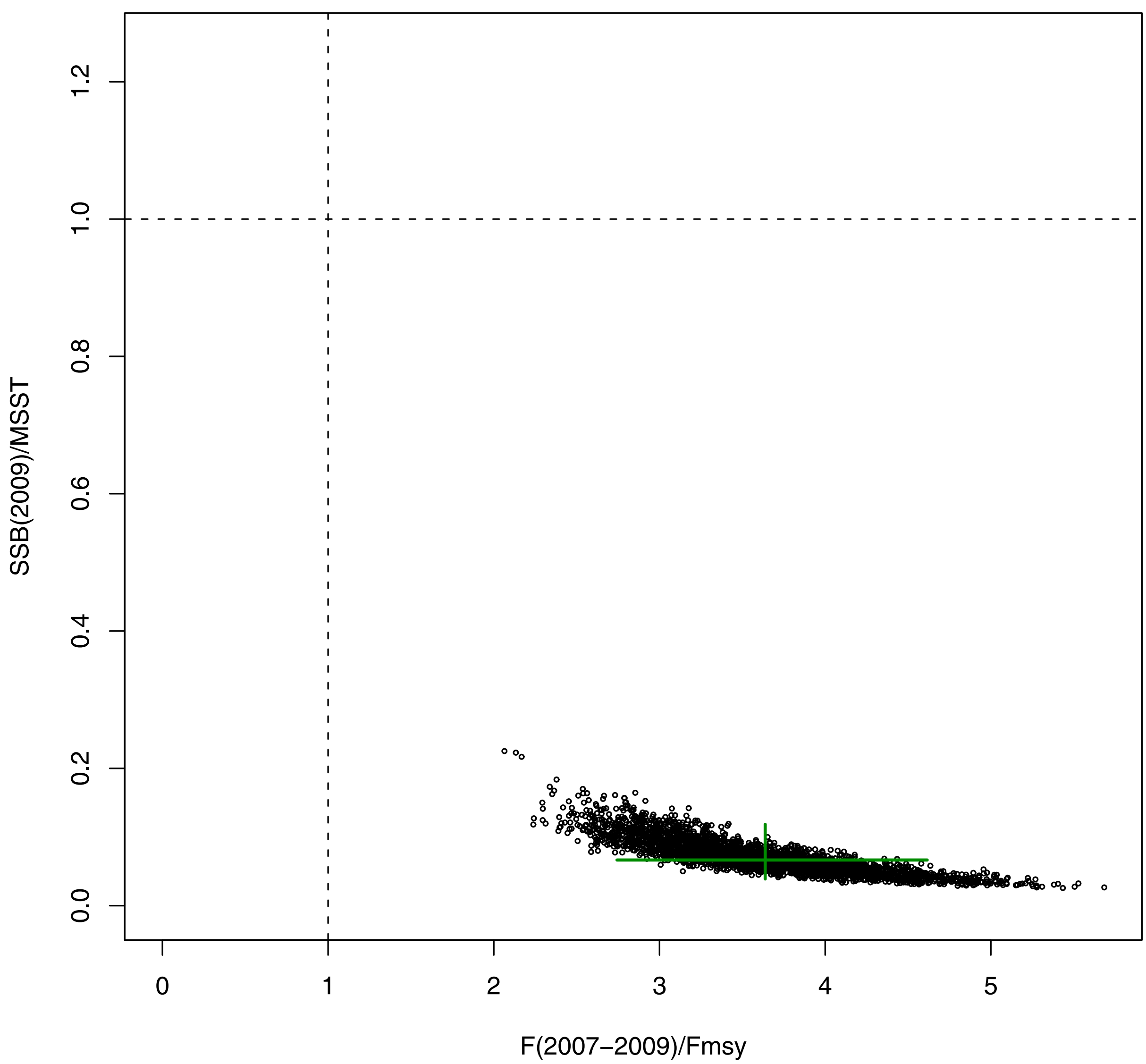


Figure 3.47. Age structure relative to the equilibrium expected at MSY*.*

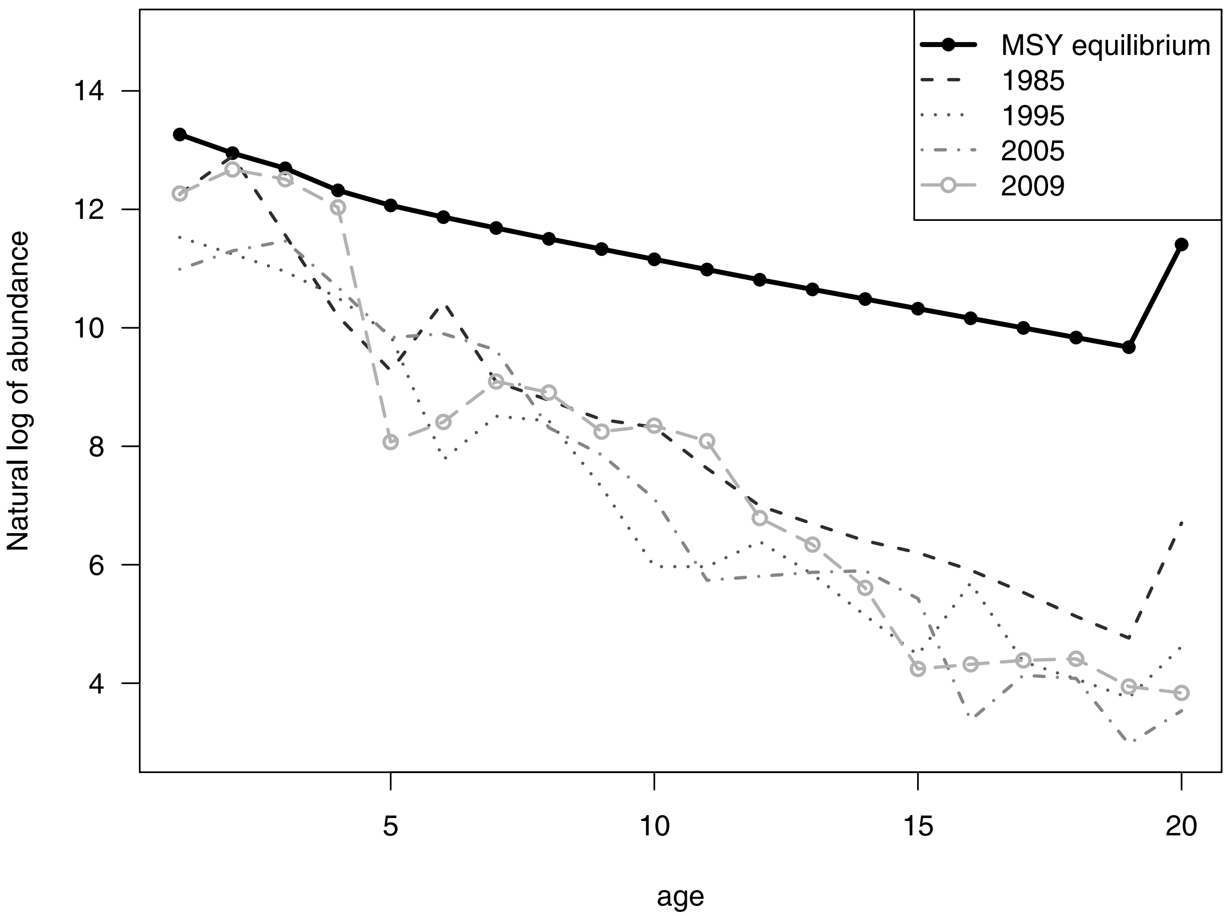


Figure 3.48. Sensitivity to changes in natural mortality (sensitivity runs S1 and S2). Top panel: Ratio of F to F_{MSY}. *Bottom panel: Ratio of* SSB *to* MSST.

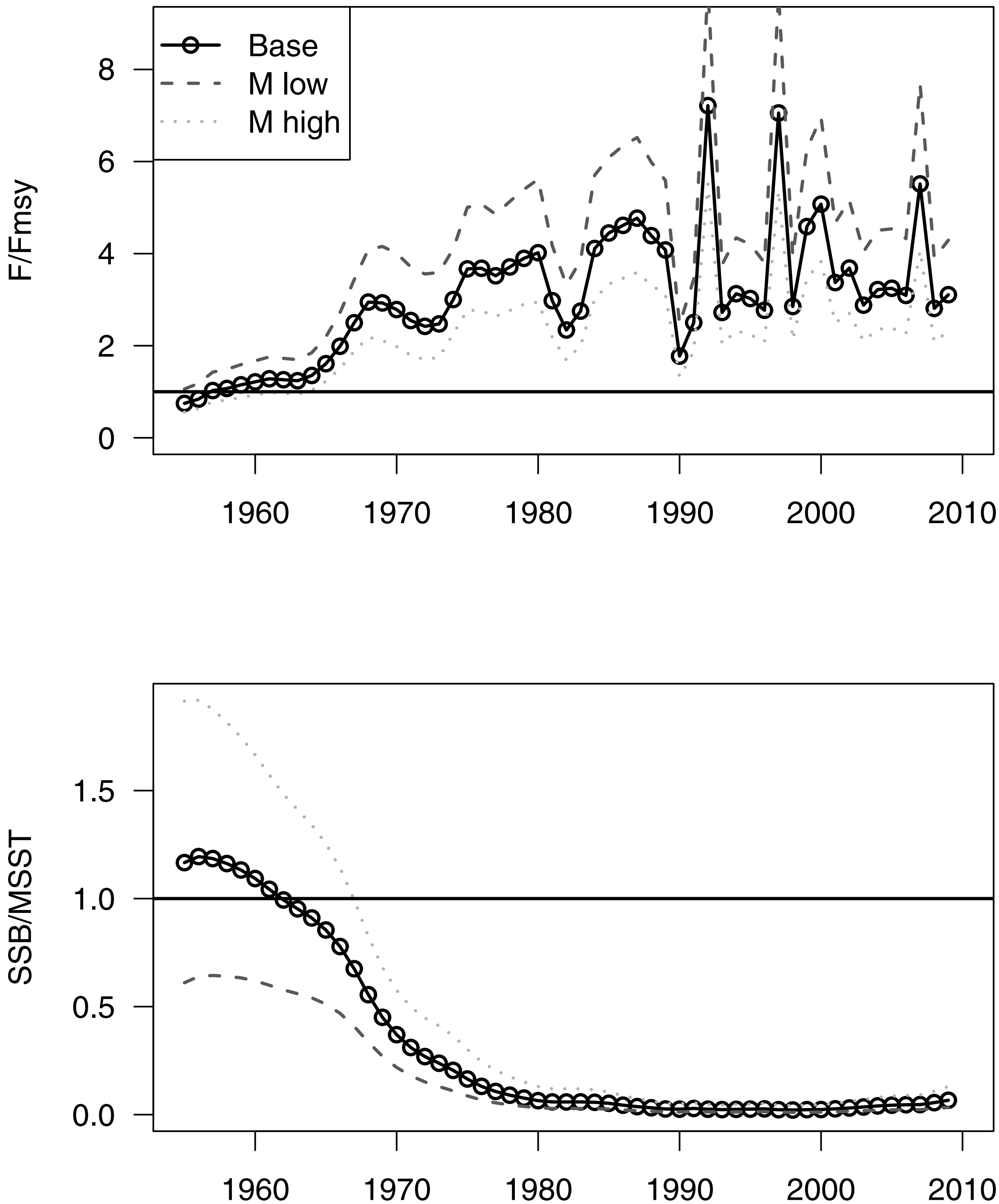


Figure 3.49. Sensitivity to discard mortality rates (sensitivity runs S3 and S4). Top panel:Ratio of F to F_{MSY}. *Bottom panel:Ratio of* SSB *to* MSST.

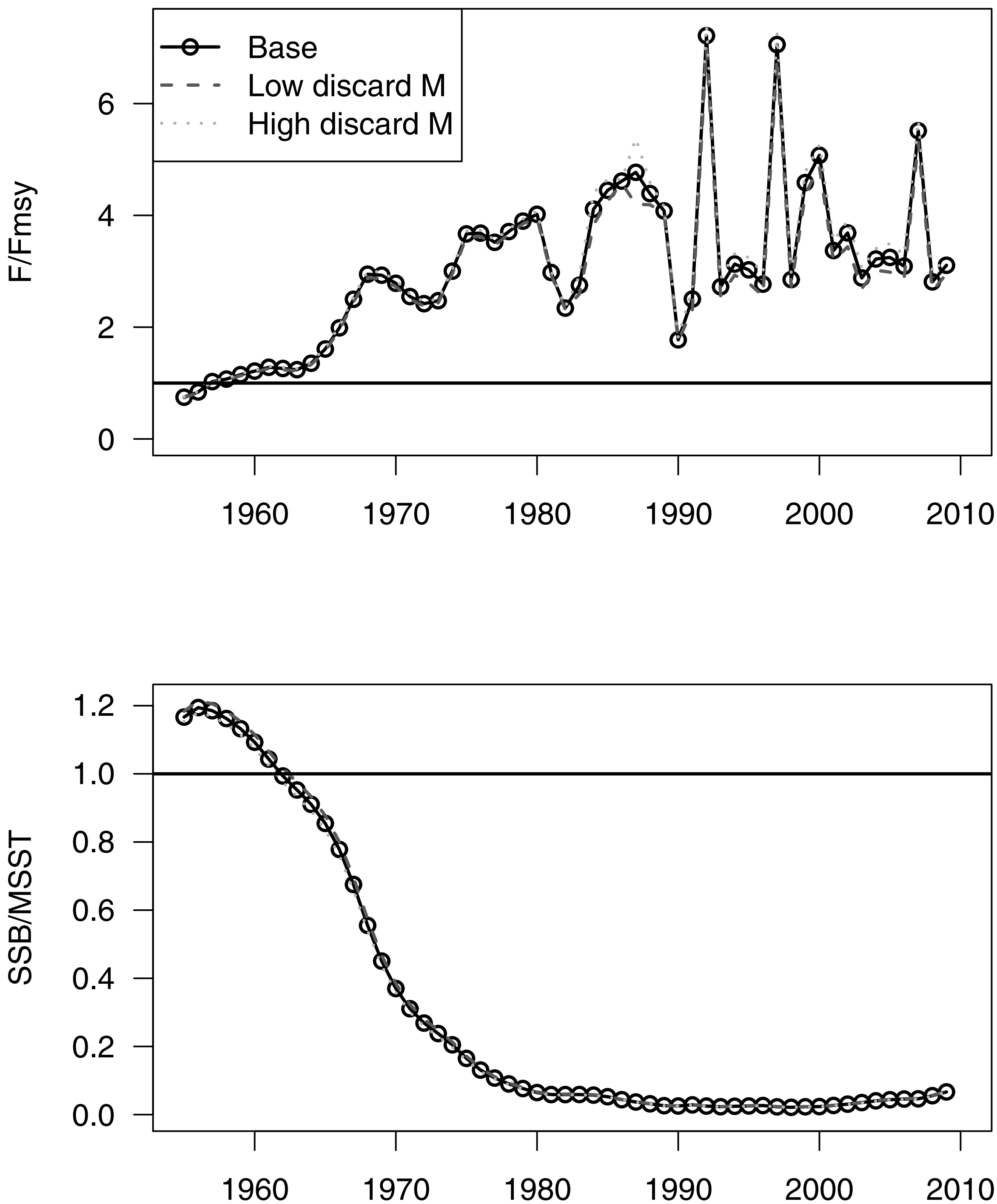


Figure 3.50. Sensitivity to catchability assumptions (sensitivity runs S5–S7). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* MSST.

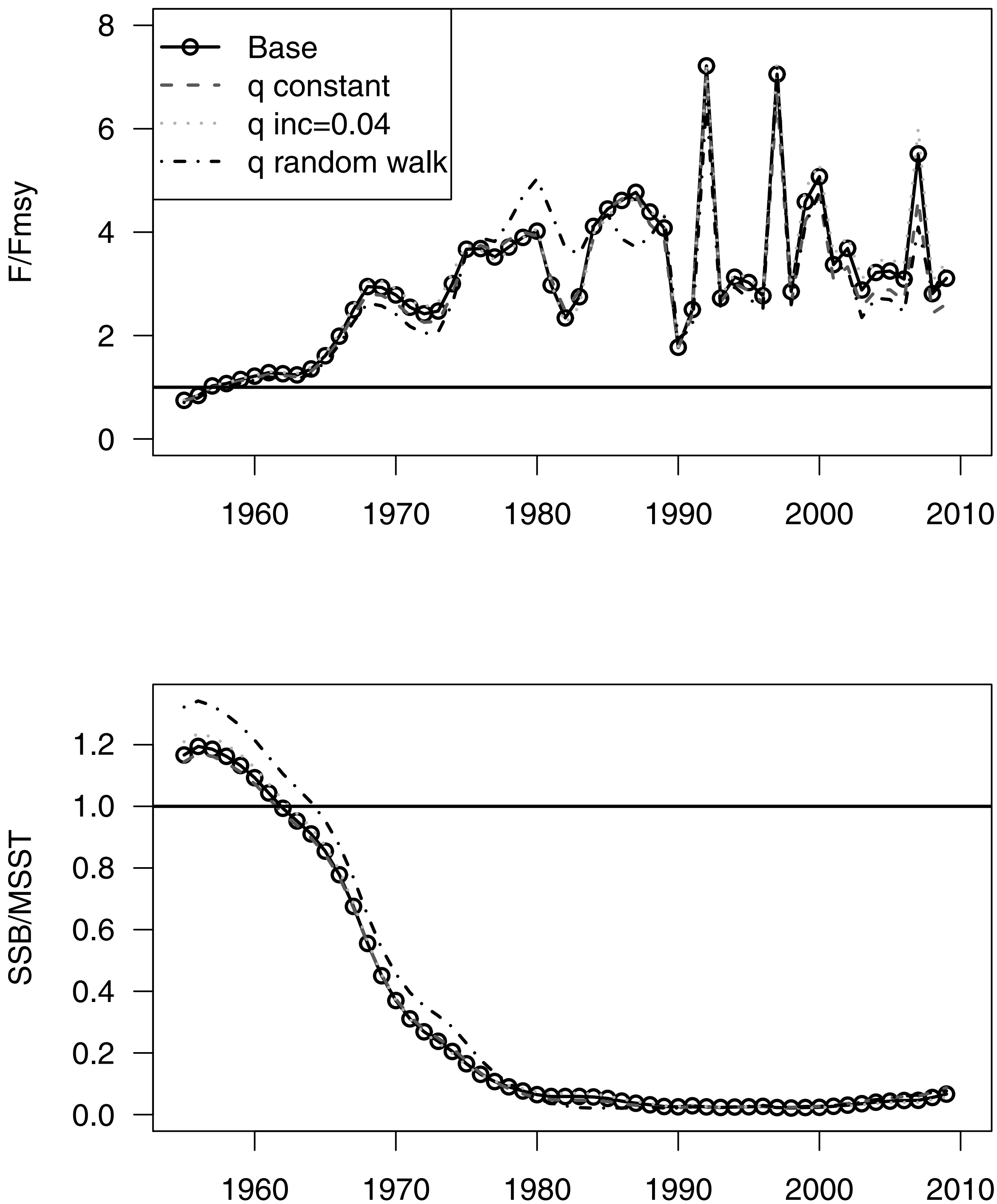


Figure 3.51. Sensitivity to ageing error (sensitivity run S8). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* MSST.

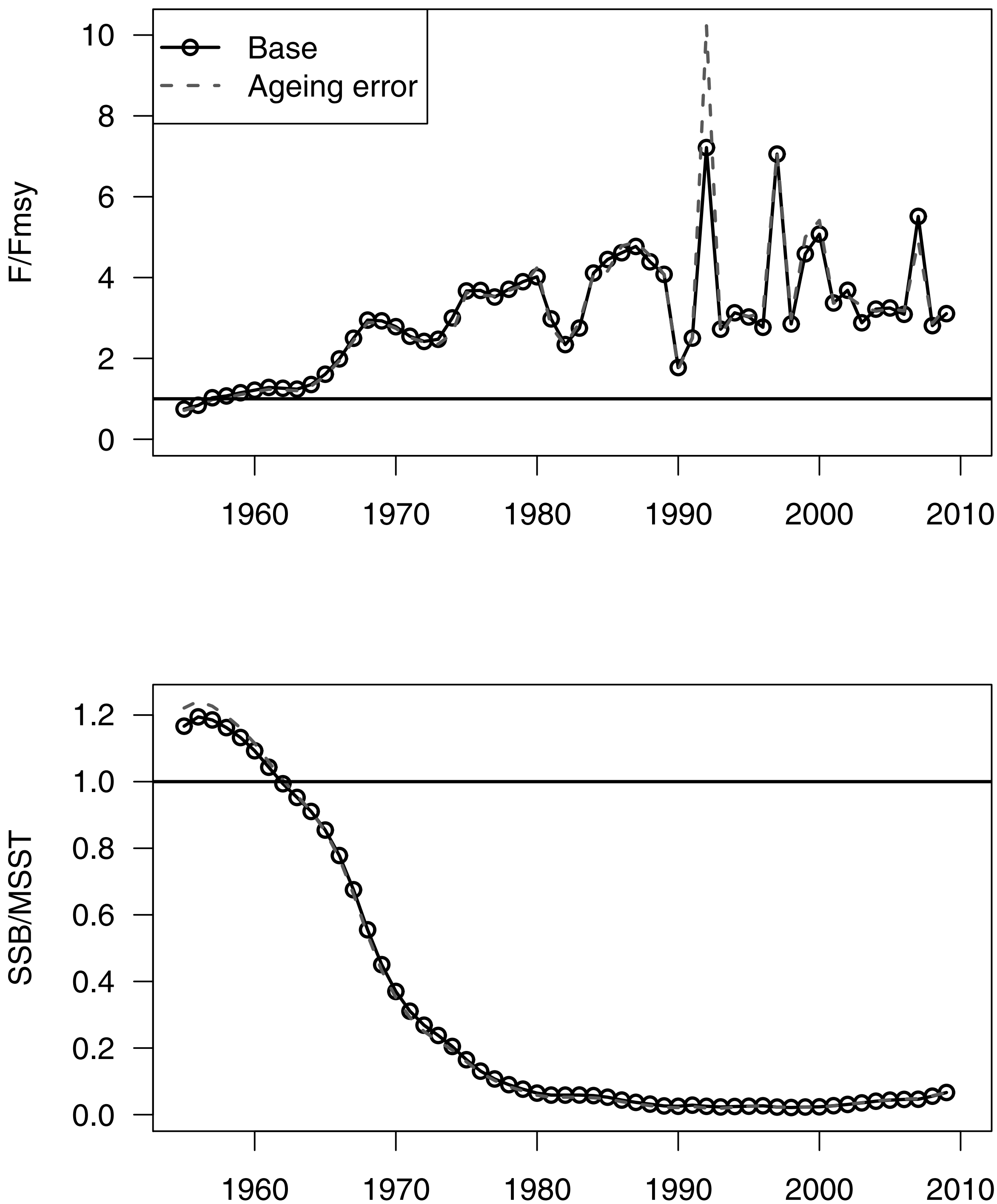


Figure 3.52. Comparison to continuity assumptions (sensitivity run S9). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* MSST.

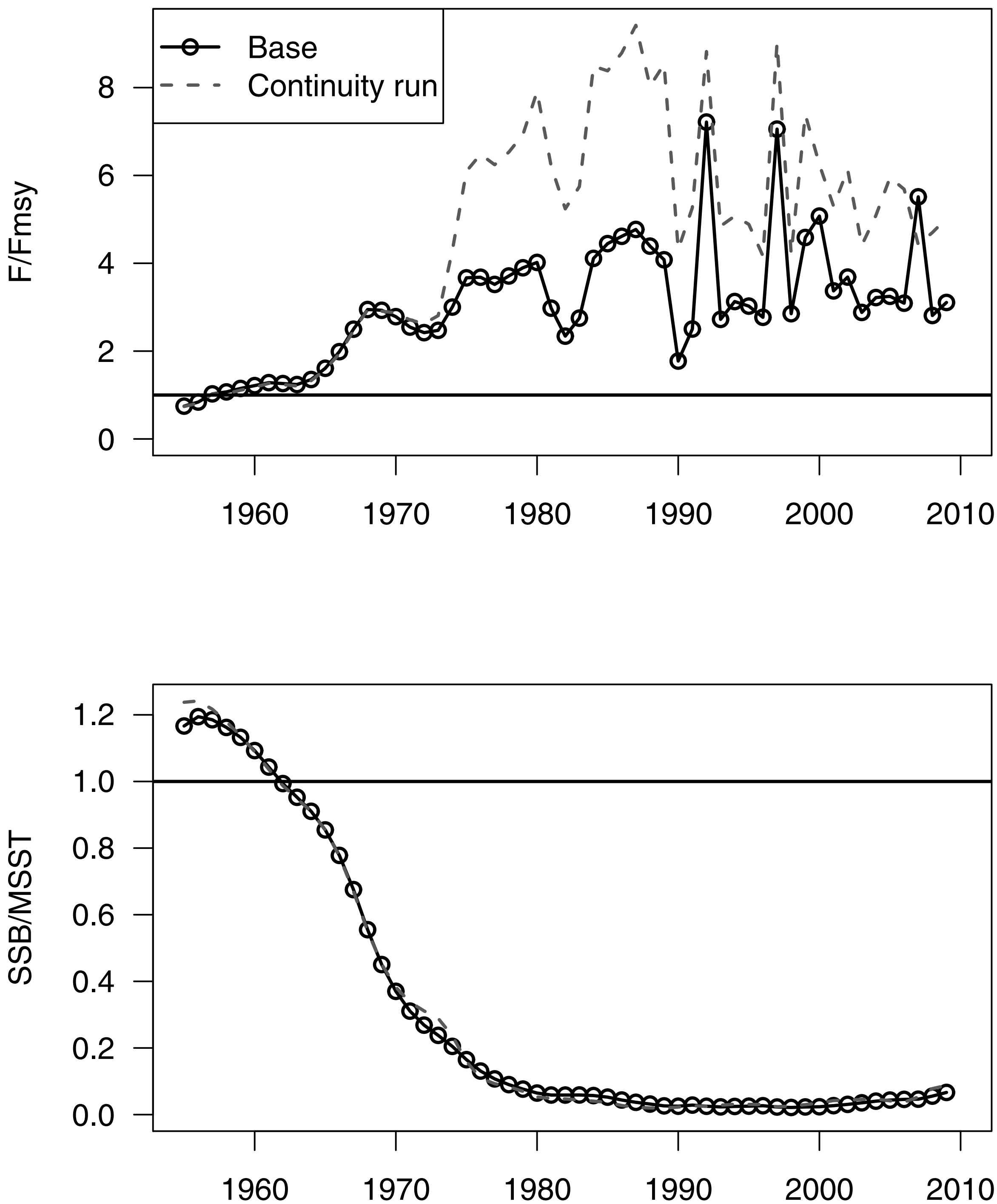


Figure 3.53. Sensitivity to starting year of the assessment model (sensitivity run S10). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* MSST.

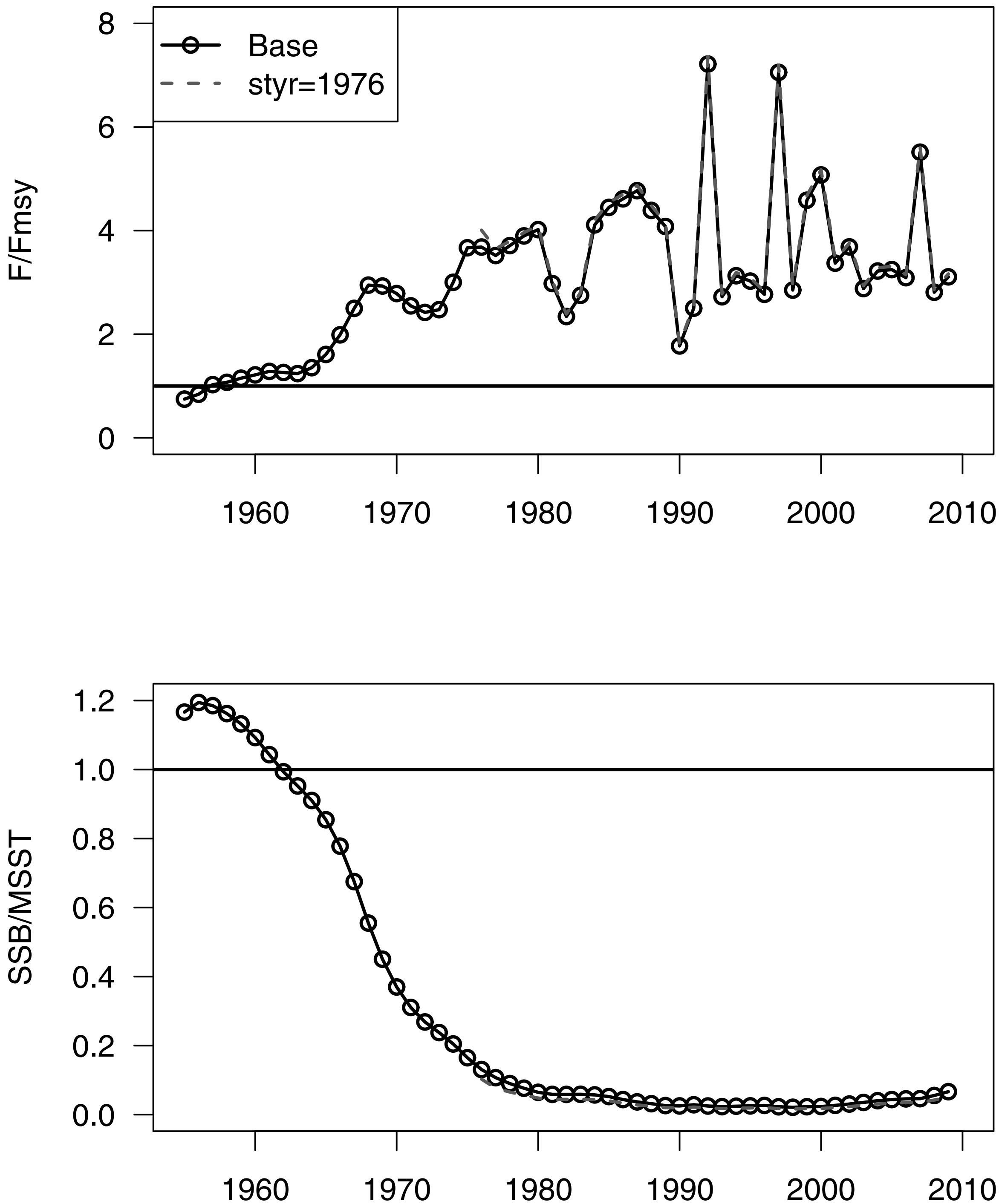


Figure 3.54. Sensitivity to landings streams (sensitivity runs S11–S14). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* MSST.

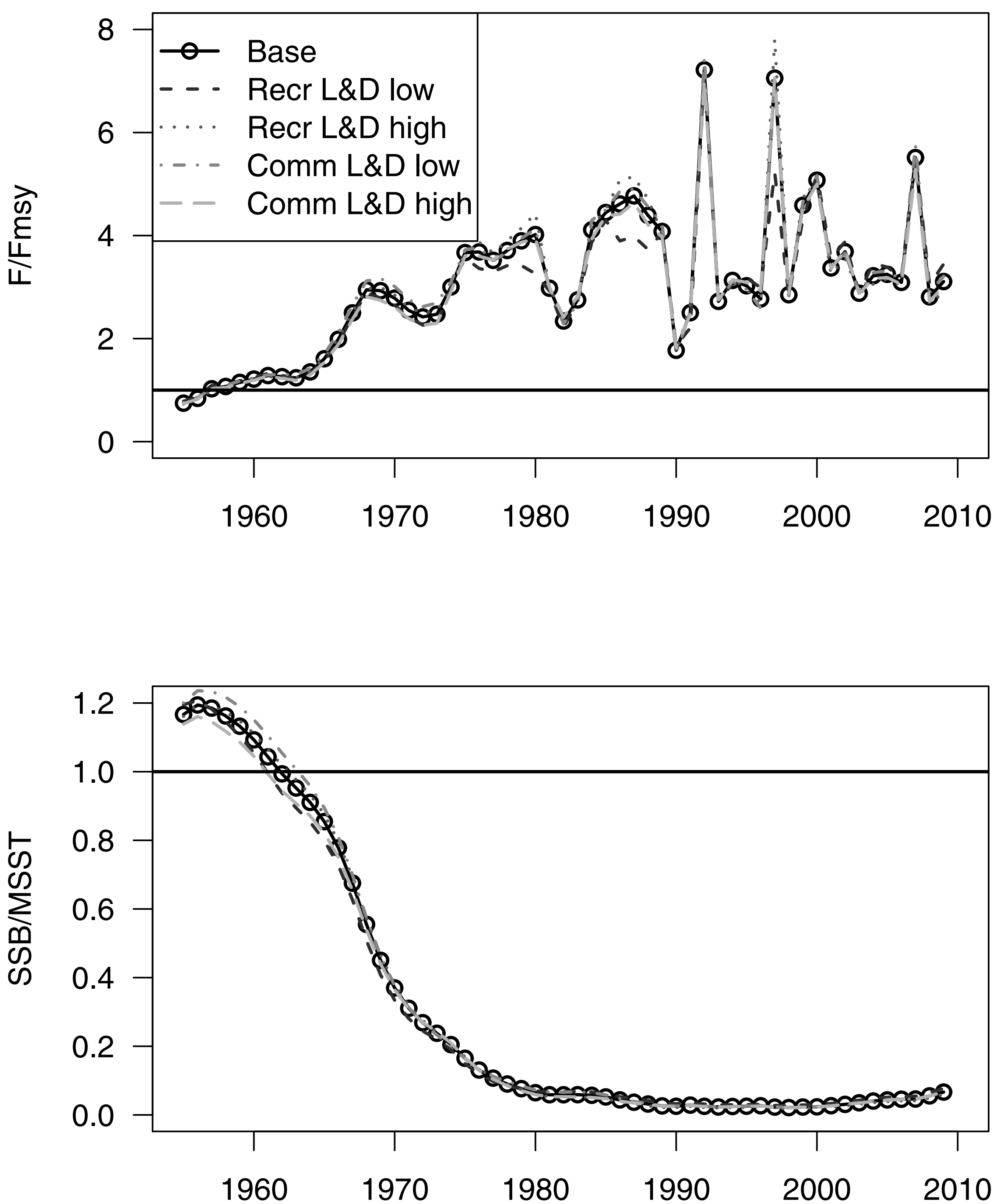


Figure 3.55. Sensitivity to component weights of data sources (sensitivity runs S15–S22). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* MSST.

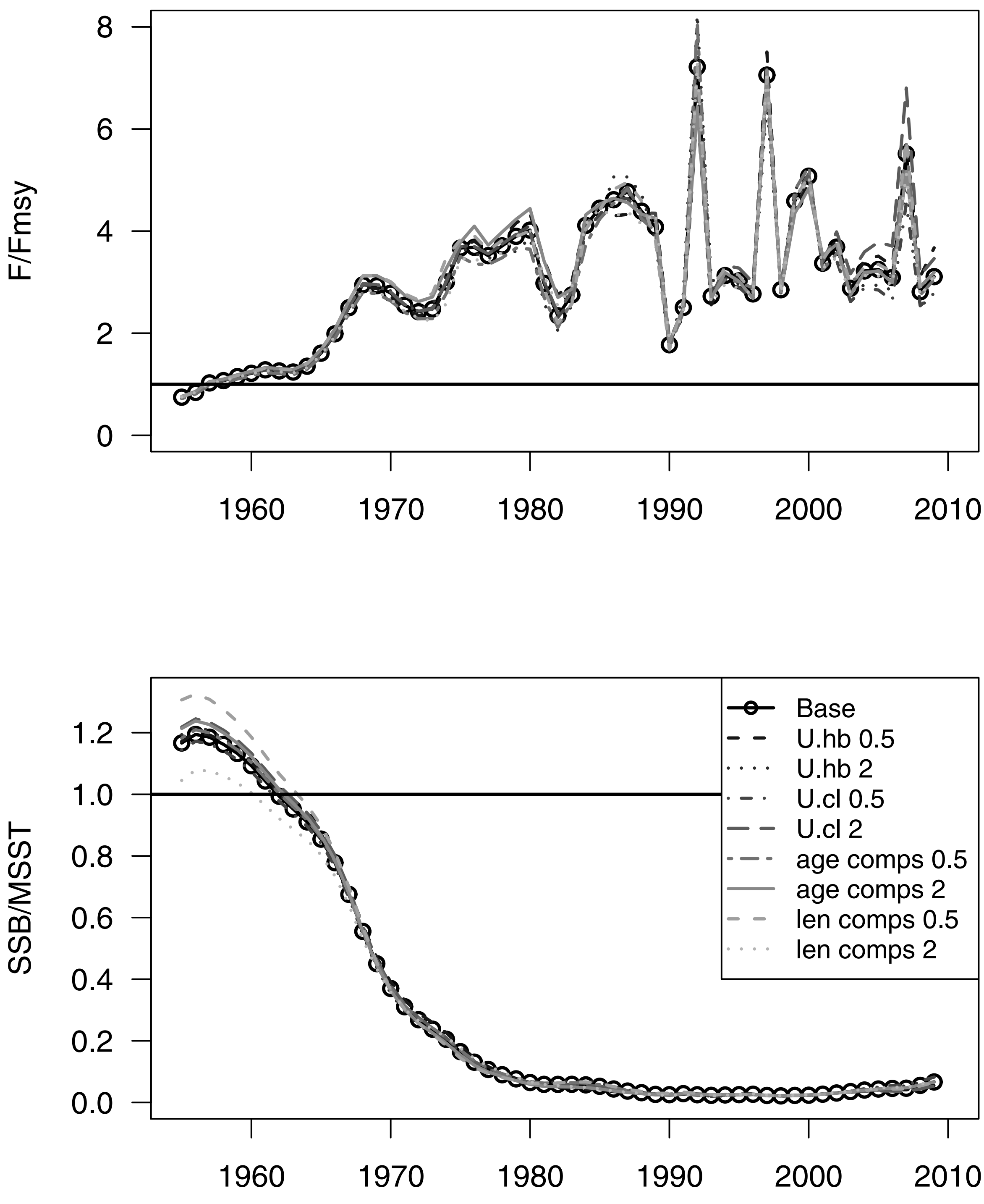


Figure 3.56. Sensitivity to selectivity patterns (sensitivity runs S23–S30). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* MSST.

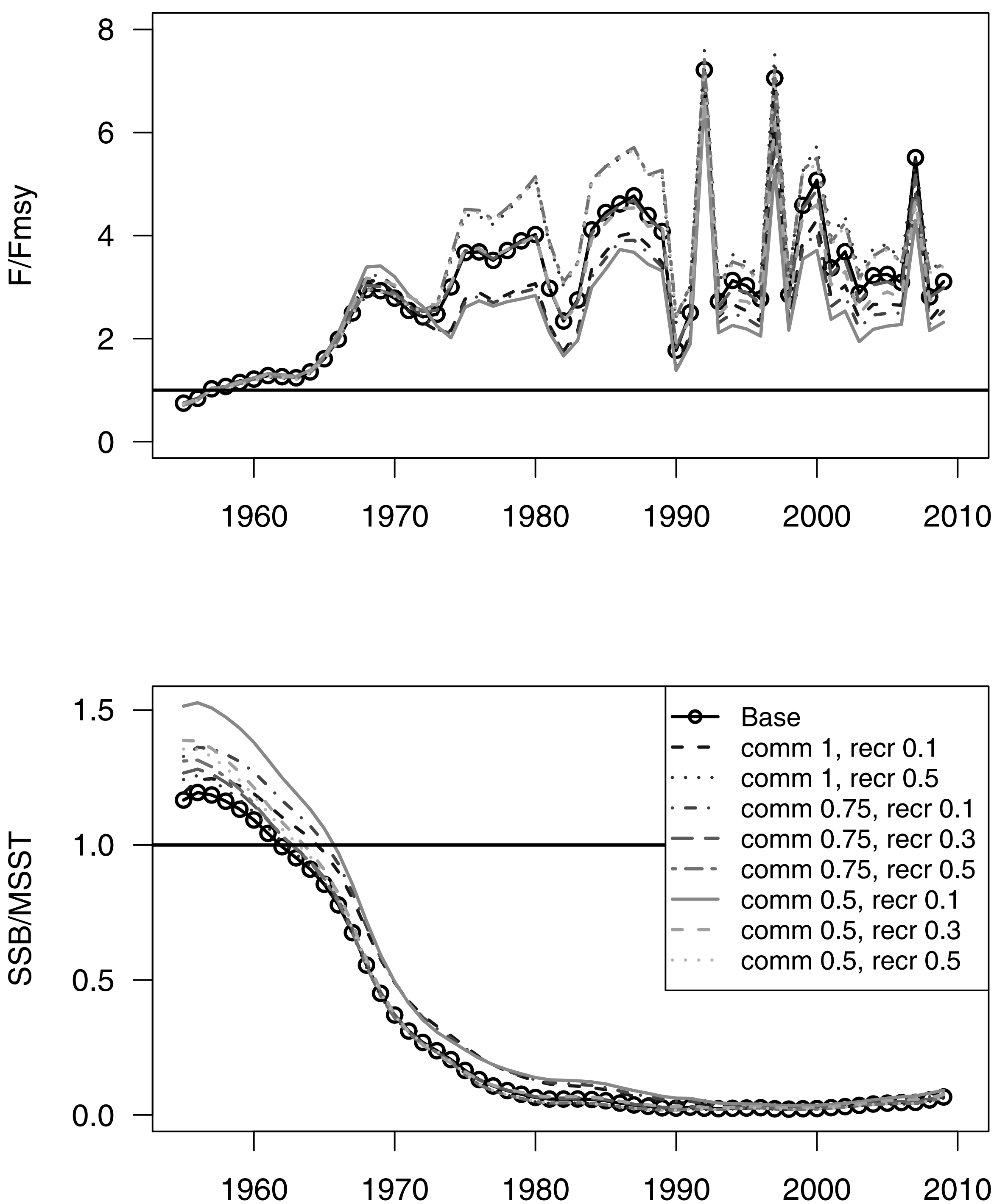


Figure 3.57. Sensitivity to compound extremes (sensitivity runs S31 and S32). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* MSST.

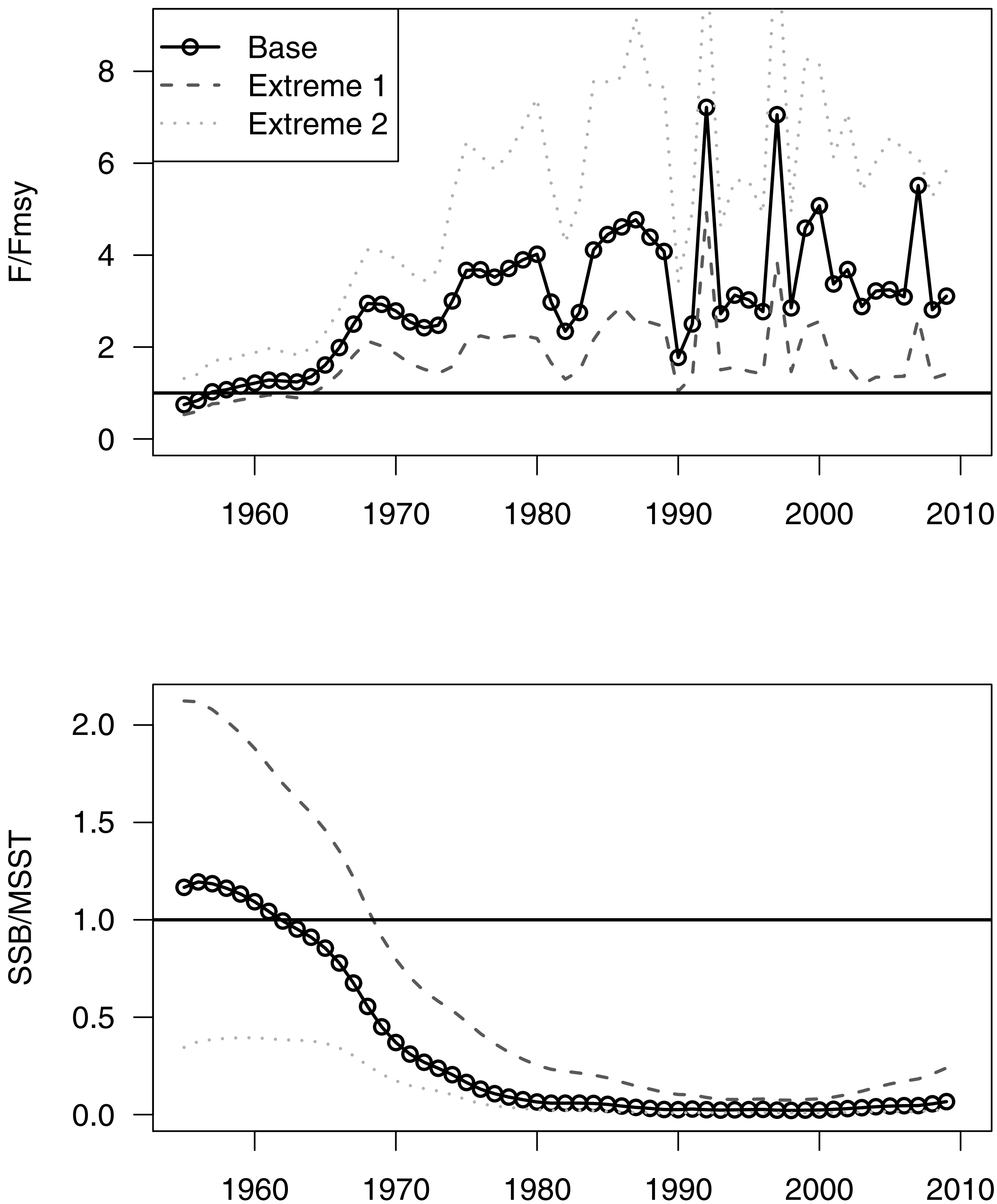


Figure 3.58. Retrospective analyses. Sensitivity to terminal year of data (sensitivity runs S33–S36). Top panel: Fishing mortality rate. Bottom panel: Spawning biomass.

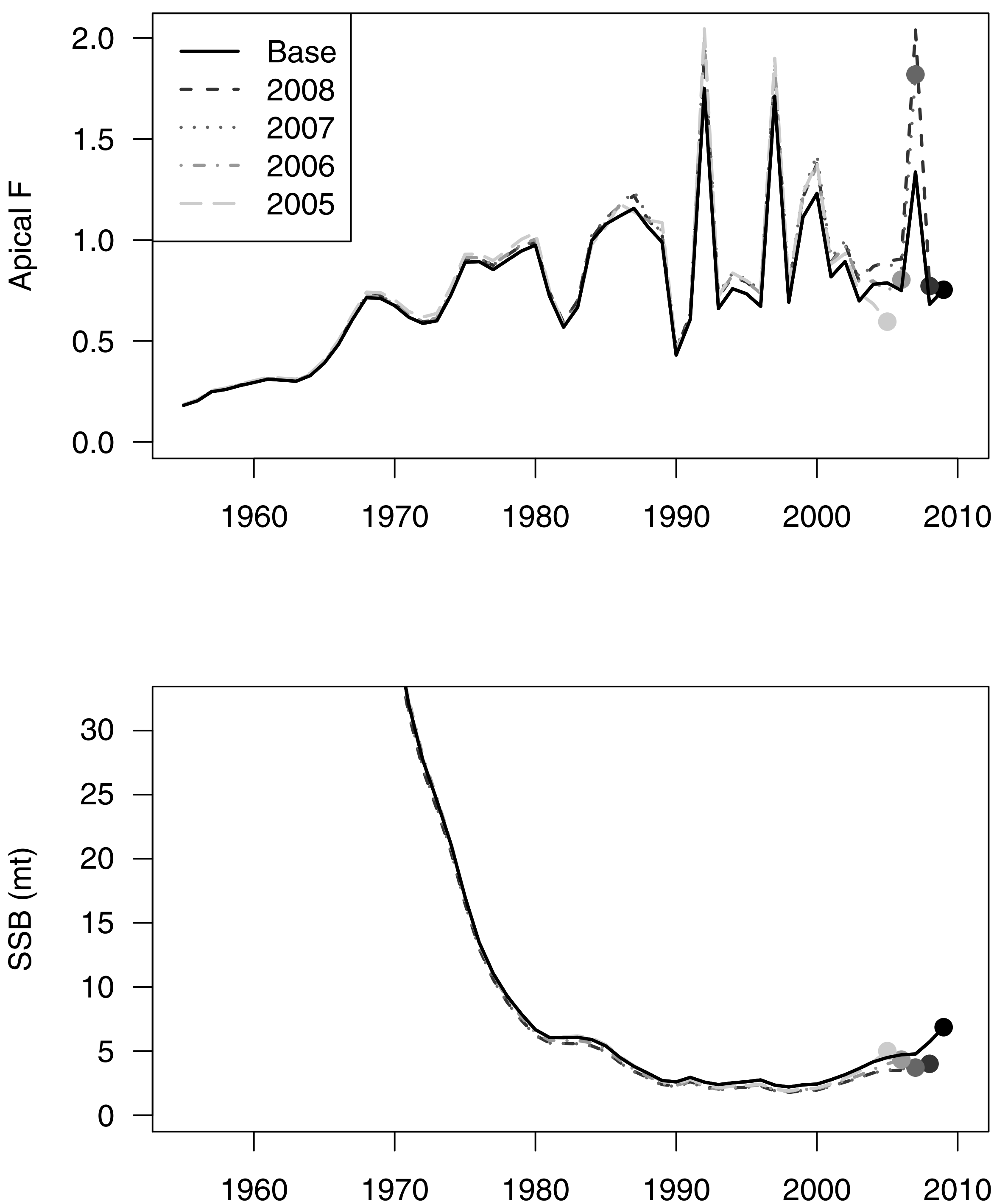


Figure 3.59. Phase plot of terminal status estimates from sensitivity runs of the Beaufort Assessment Model.

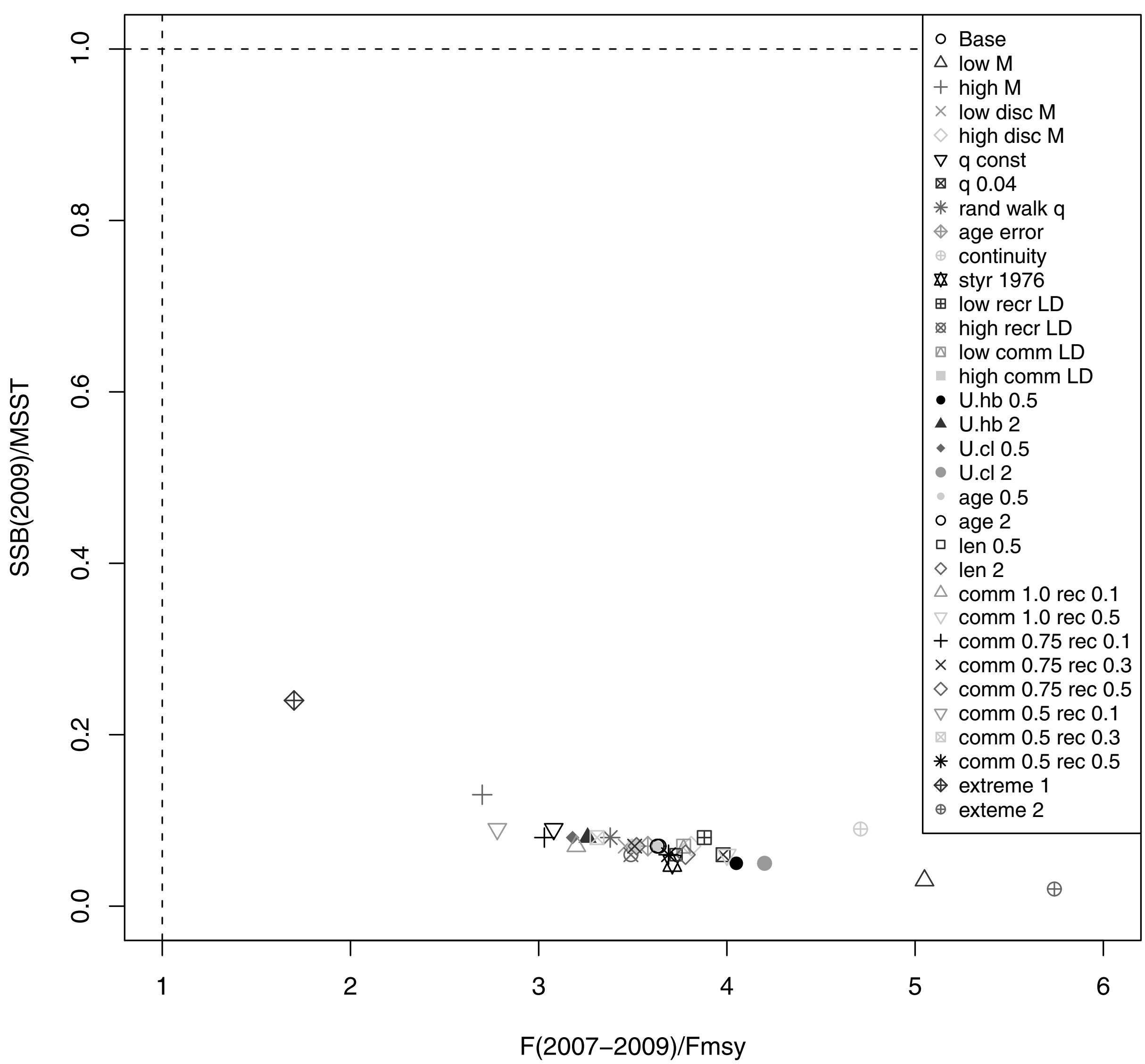


Figure 3.60. Projection results under scenario 1—fishing mortality rate fixed at F = 0. Curve represents the proportion of projection replicates for which SSB(mid-year) has reached at least SSB_{MSY} = 112*.*

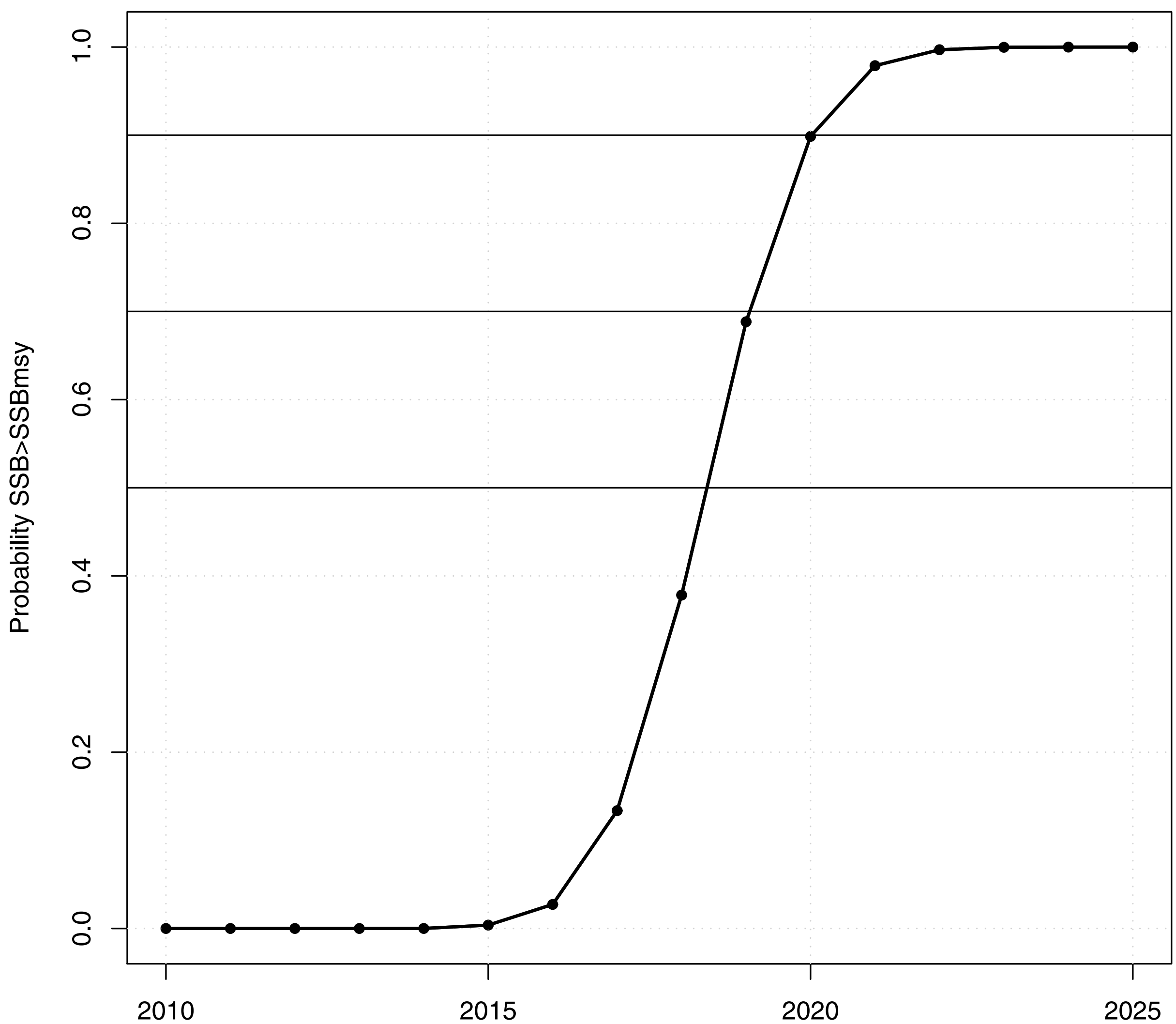


Figure 3.61. Projection results under scenario 2—fishing mortality rate fixed at $F = F_{\text{current}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

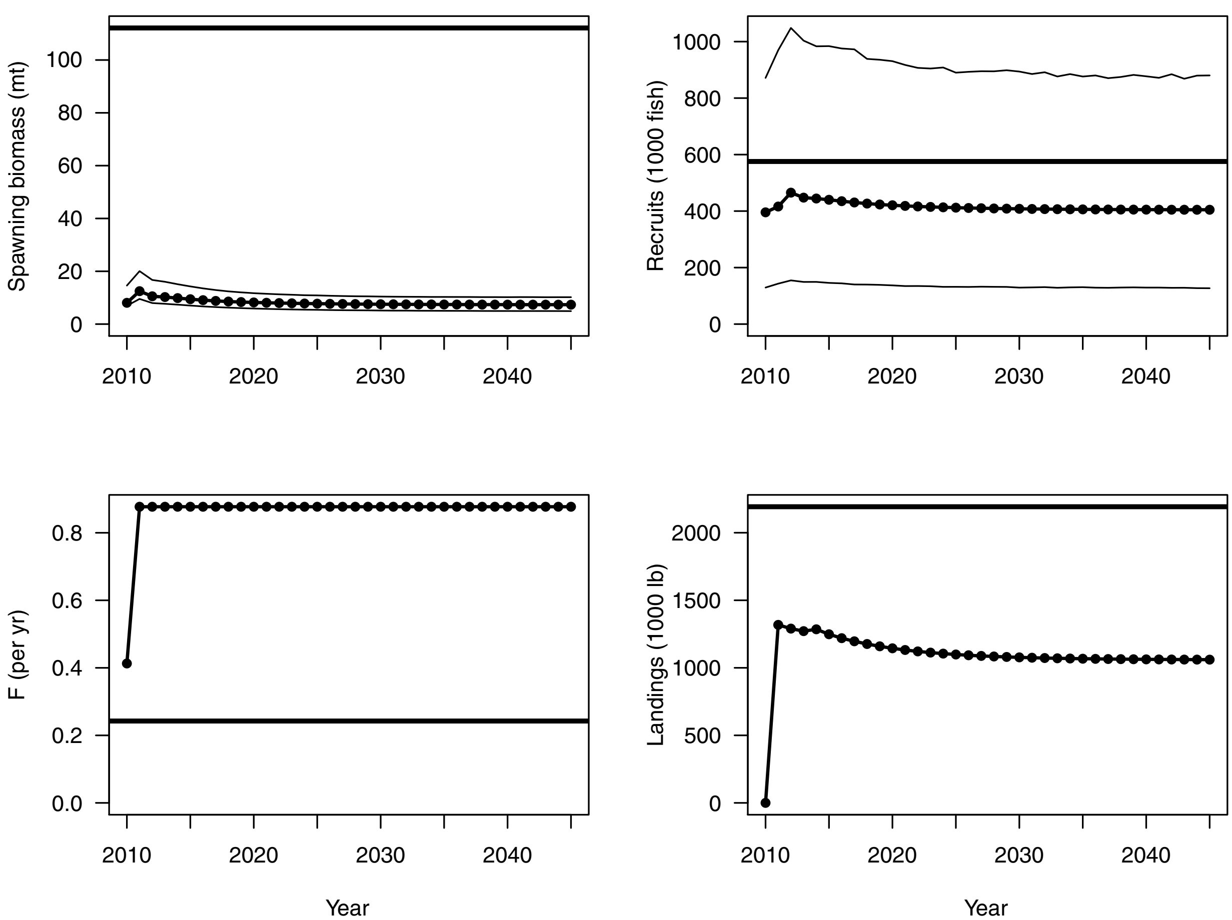


Figure 3.62. Projection results under scenario 3—fishing mortality rate fixed at $F = 65\% F_{MSY}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

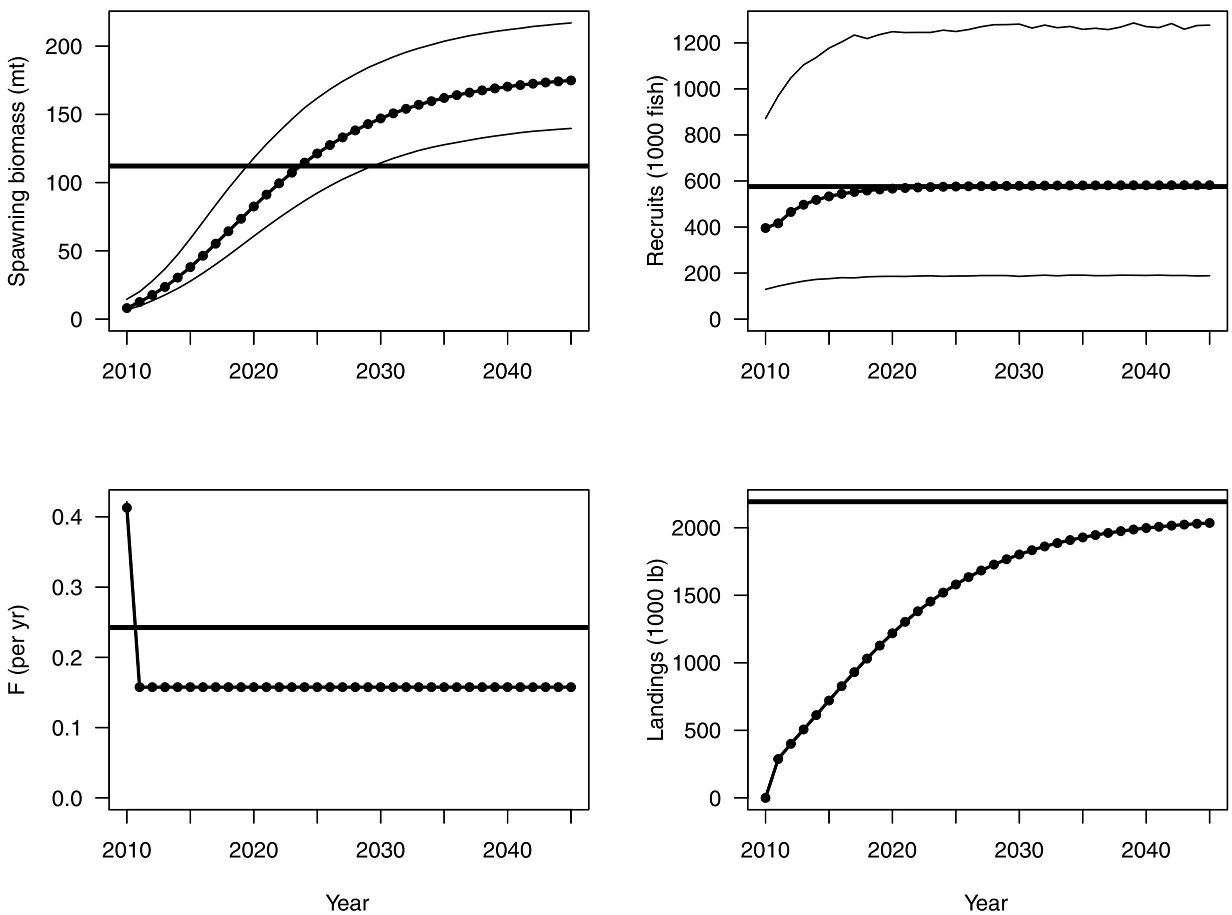


Figure 3.63. Projection results under scenario 4—fishing mortality rate fixed at $F = 75\%F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

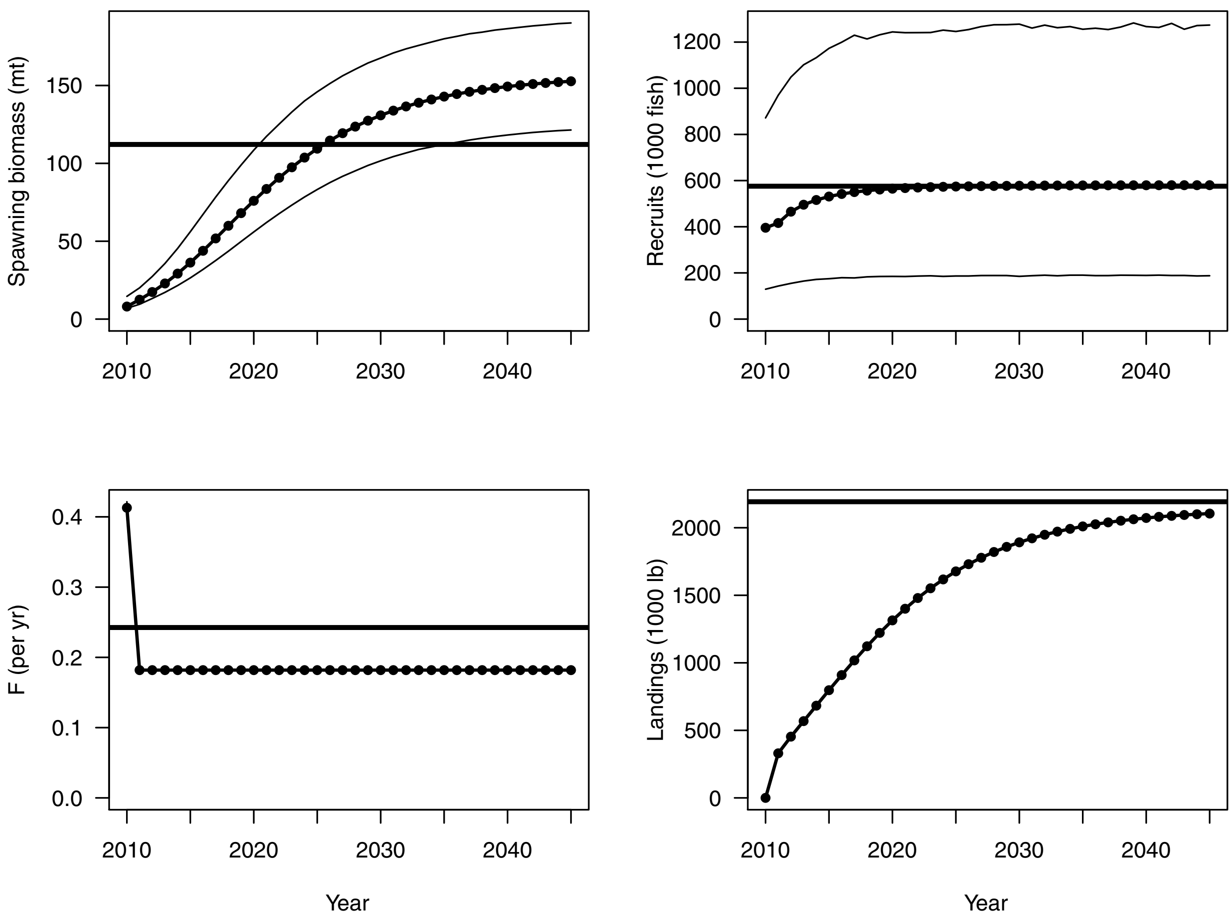


Figure 3.64. Projection results under scenario 5—fishing mortality rate fixed at $F = 85\%F_{\mathrm{MSY}}$*. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to* 5^{th} *and* 95^{th} *percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

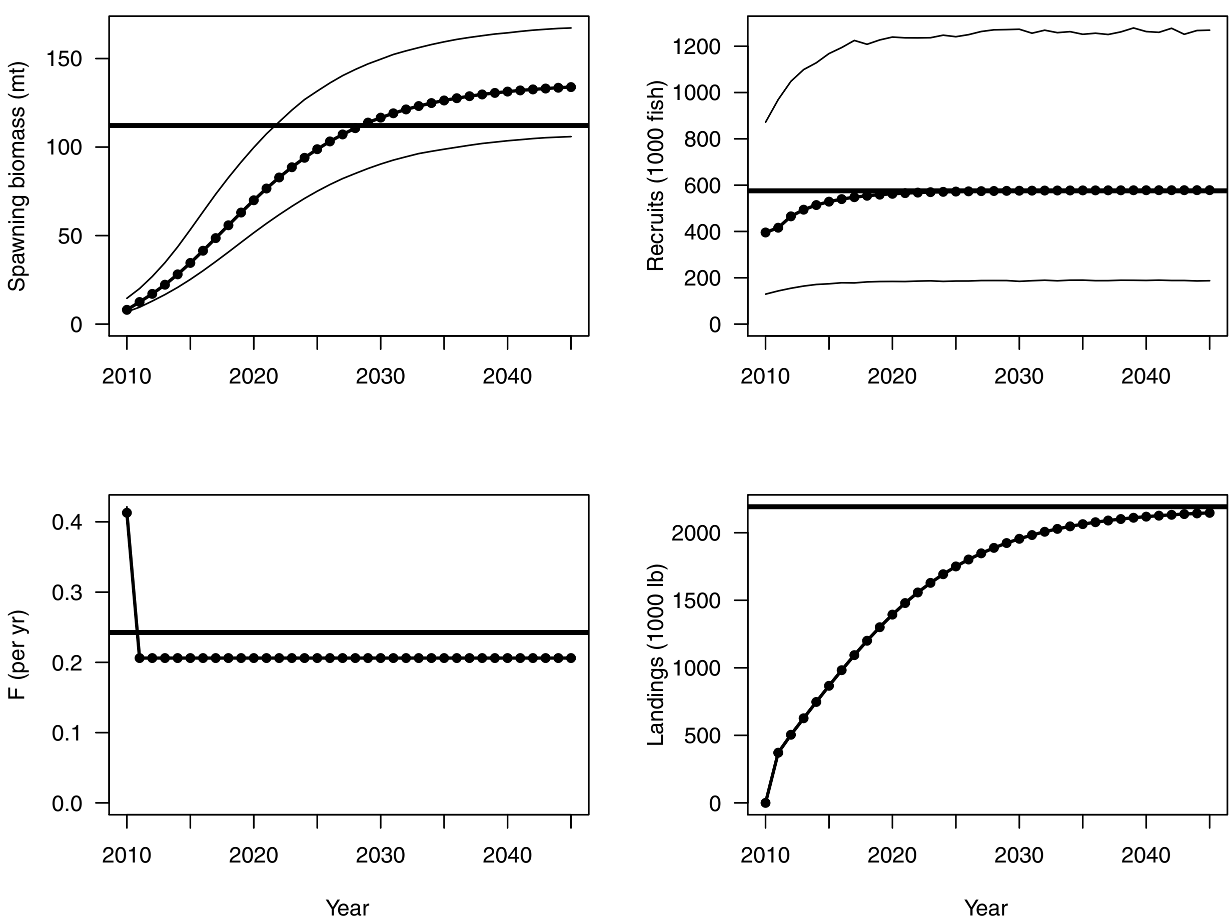


Figure 3.65. Projection results under scenario 6—fishing mortality rate fixed at $F = F_{\text{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

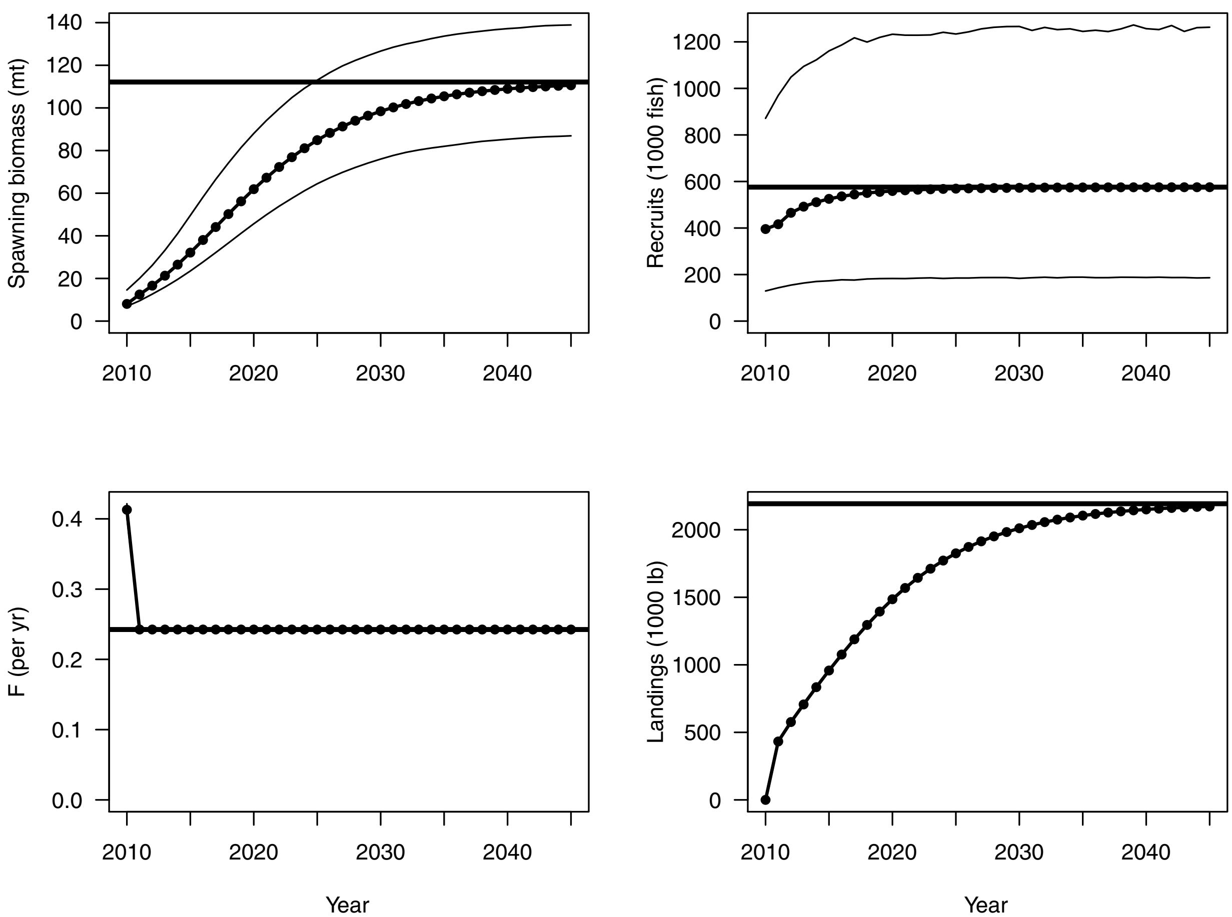


Figure 3.66. Projection results under scenario 7—moratorium projection (all potential landings converted to discards). Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} *and* 95^{th} *percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

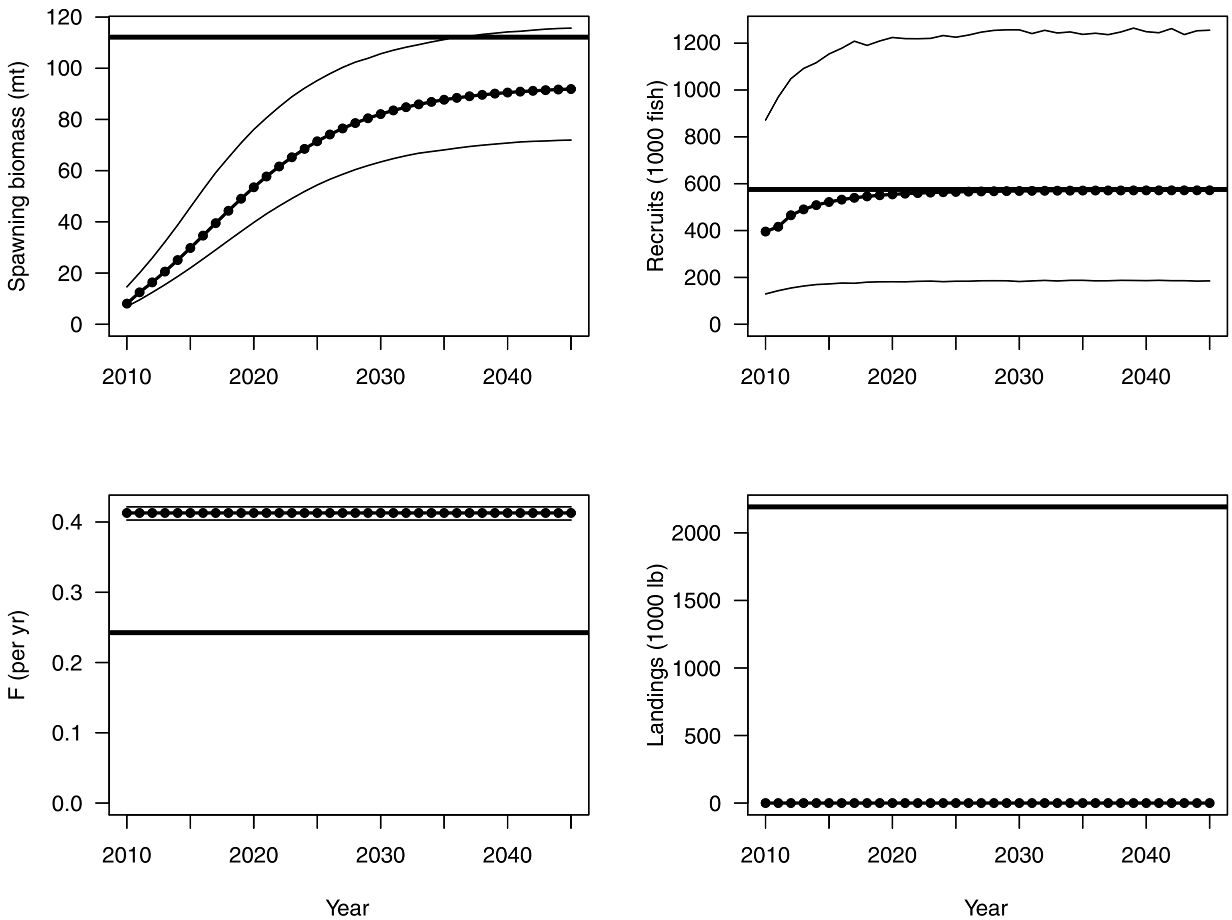


Figure 3.67. Projection results under scenario 9—fishing mortality rate fixed at $F = F_{\text{rebuild}}$, with rebuilding probability of 0.70 in 2044. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

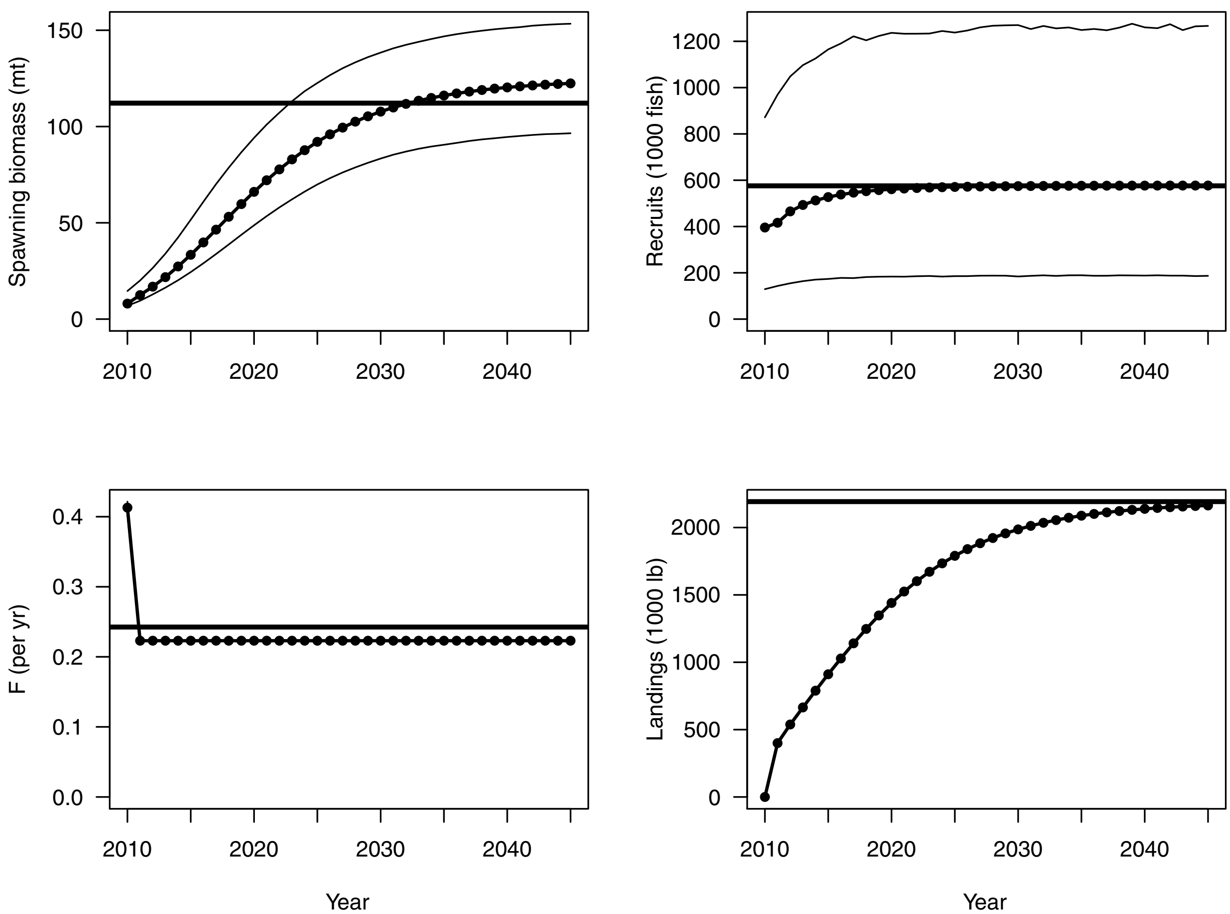


Figure 3.68. Projection results under scenario 11—fishing mortality rate fixed at $F = F_{\text{rebuild}}$, with rebuilding probability of 0.50 in 2019. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY-related quantities. Spawning stock (SSB) is at mid-year.

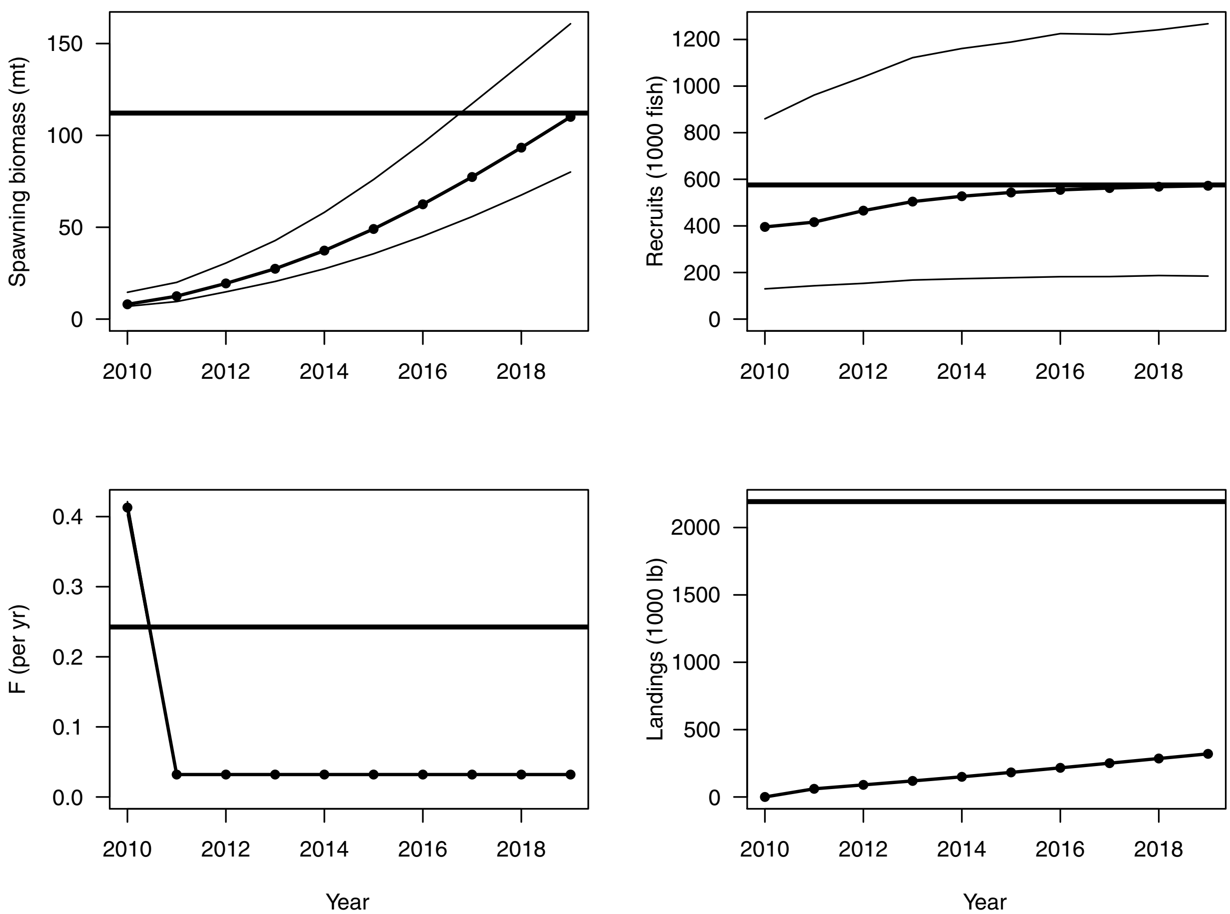


Figure 3.69. Red Snapper in Atlantic: Fit of production model to the headboat index with and without a 2% catchability increase since 1976 saturating in 2003. The initial biomass relative to the carrying capacity B1/k was estimated and fixed at a range of values.

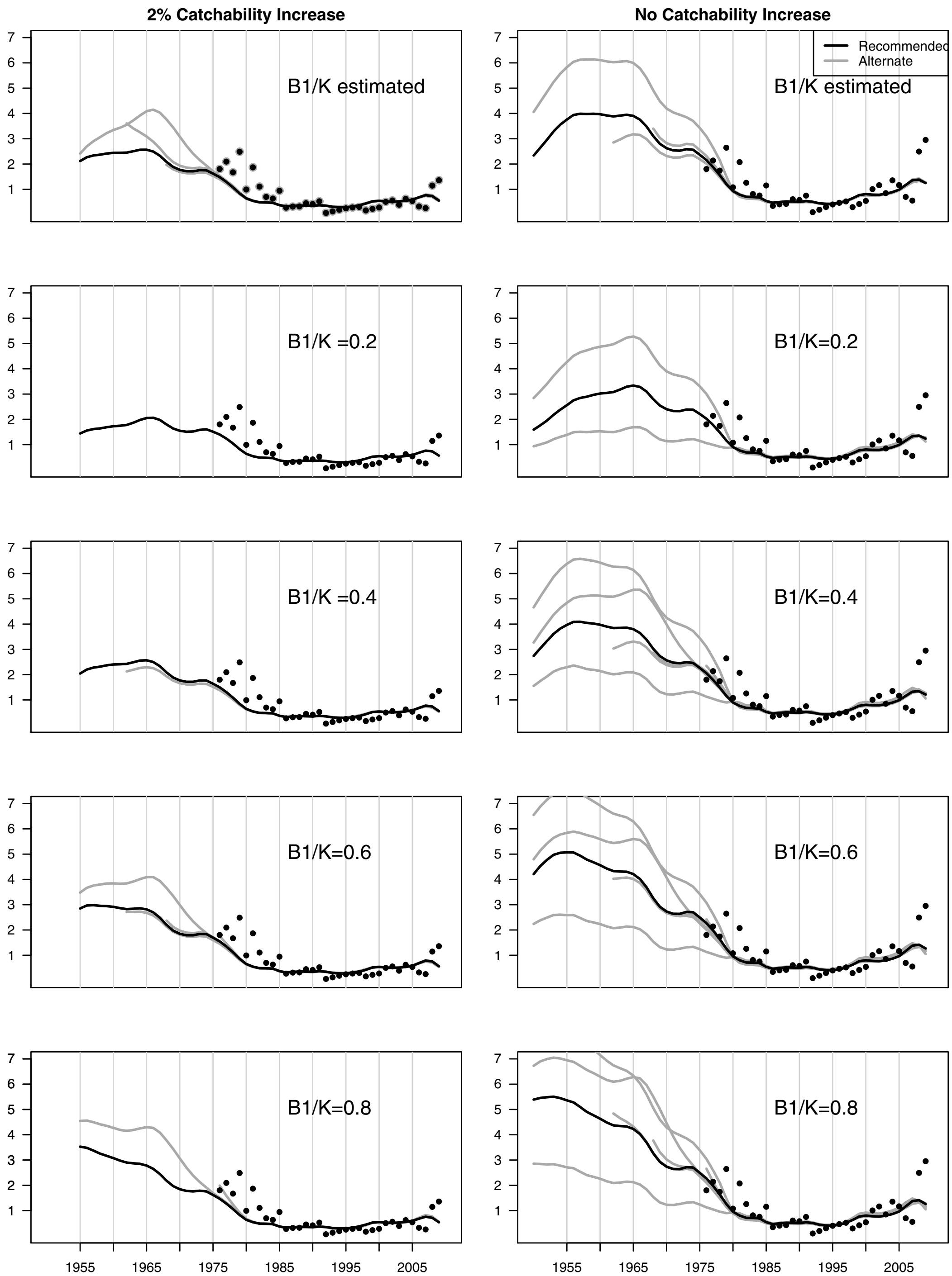


Figure 3.70. Red Snapper in Atlantic: Fit of production model to the commercial lines index with and without a 2% catchability increase since 1976 saturating in 2003. The initial biomass relative to the carrying capacity $B1/k$ was estimated and fixed at a range of values.

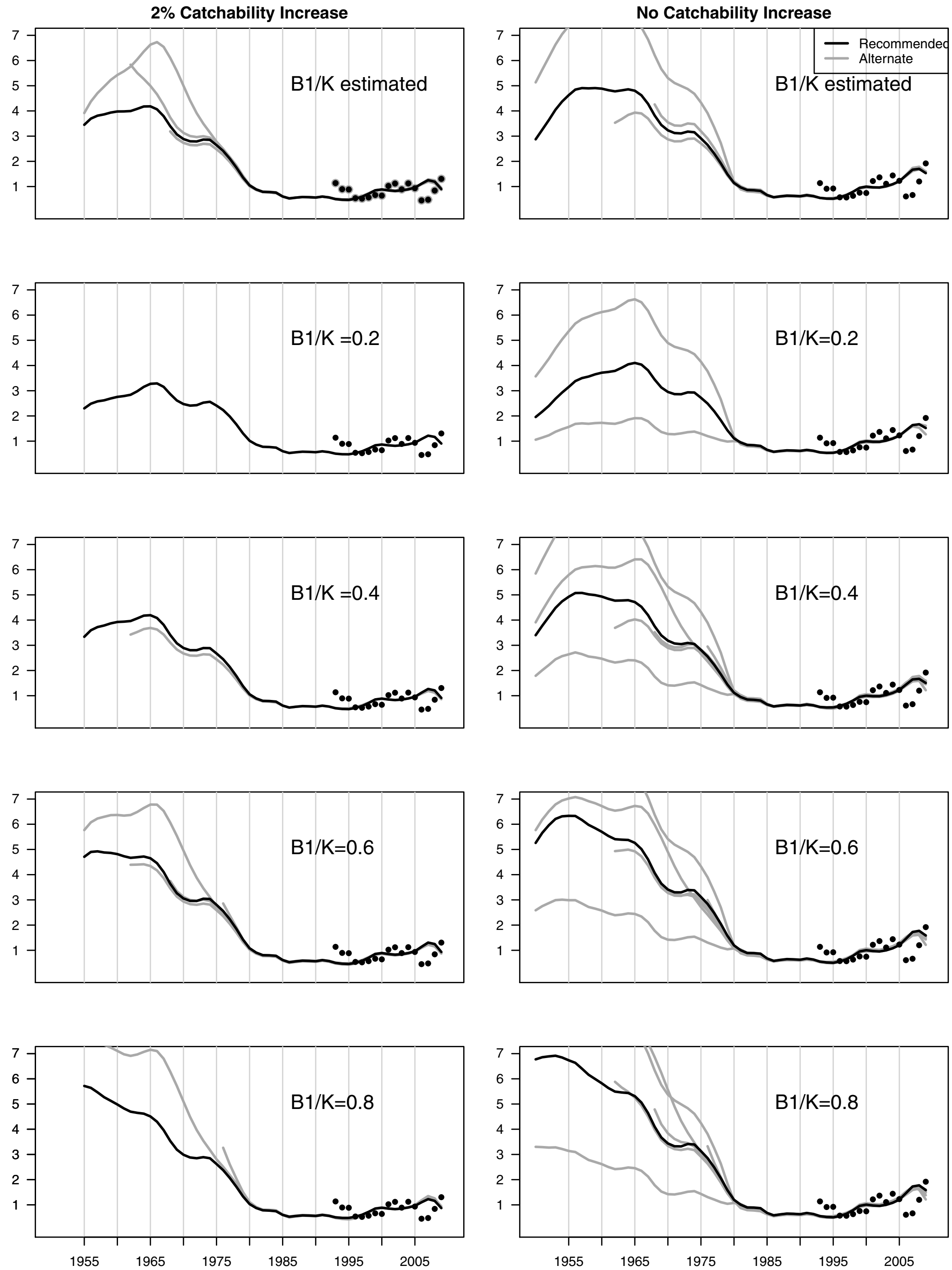


Figure 3.71. Red Snapper in Atlantic: Production model estimates of relative biomass, B/MSST. The runs were made with and without a 2% catchability increase since 1976 saturating in 2003. The initial biomass relative to the carrying capacity B1/k was estimated and fixed at a range of values.

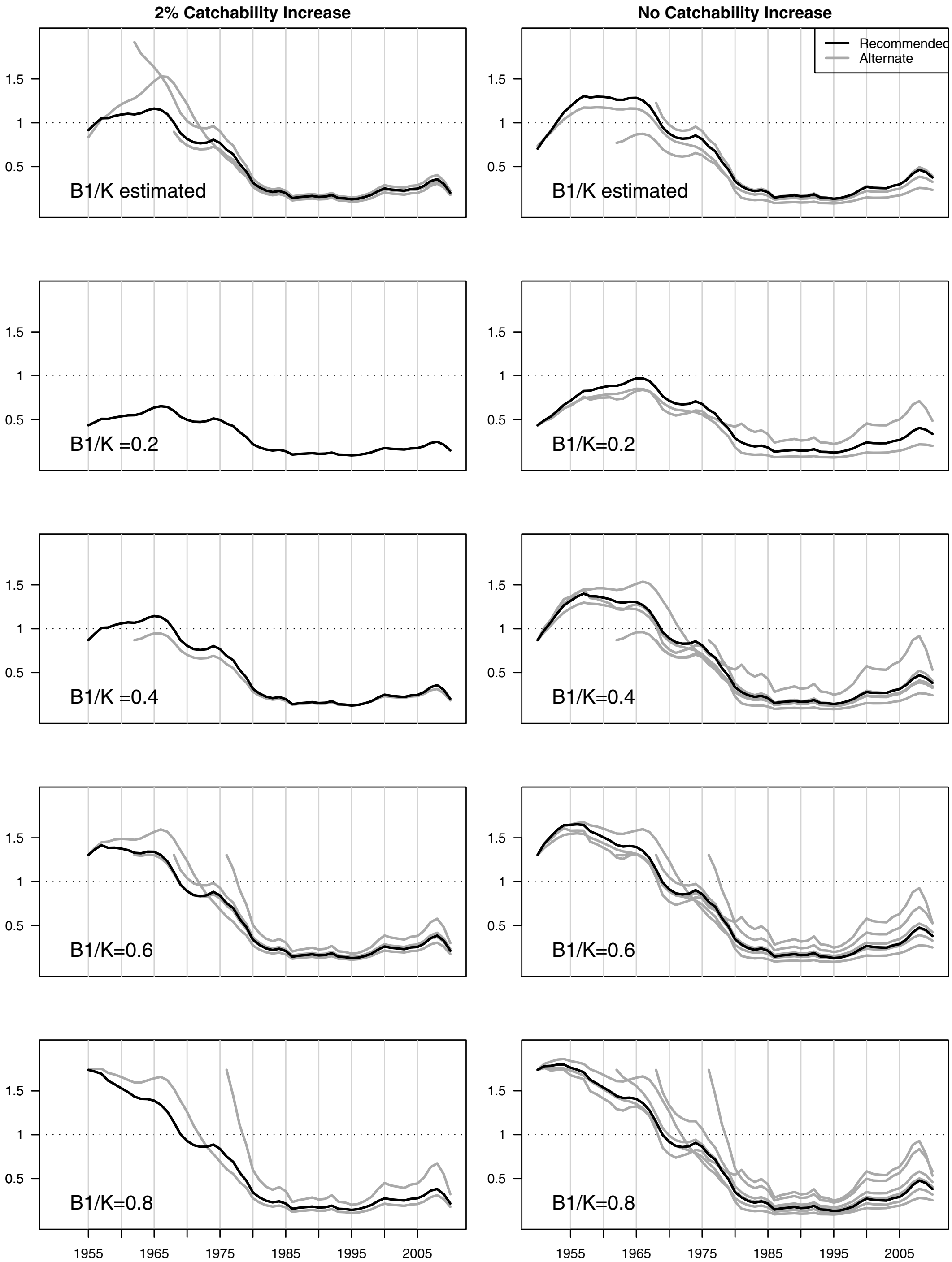


Figure 3.72. Red Snapper in Atlantic: Production model estimates of relative fishing mortality rate. The runs were made with and without a 2% catchability increase since 1976 saturating in 2003. The initial biomass relative to the carrying capacity B1/k was estimated and fixed at a range of values.

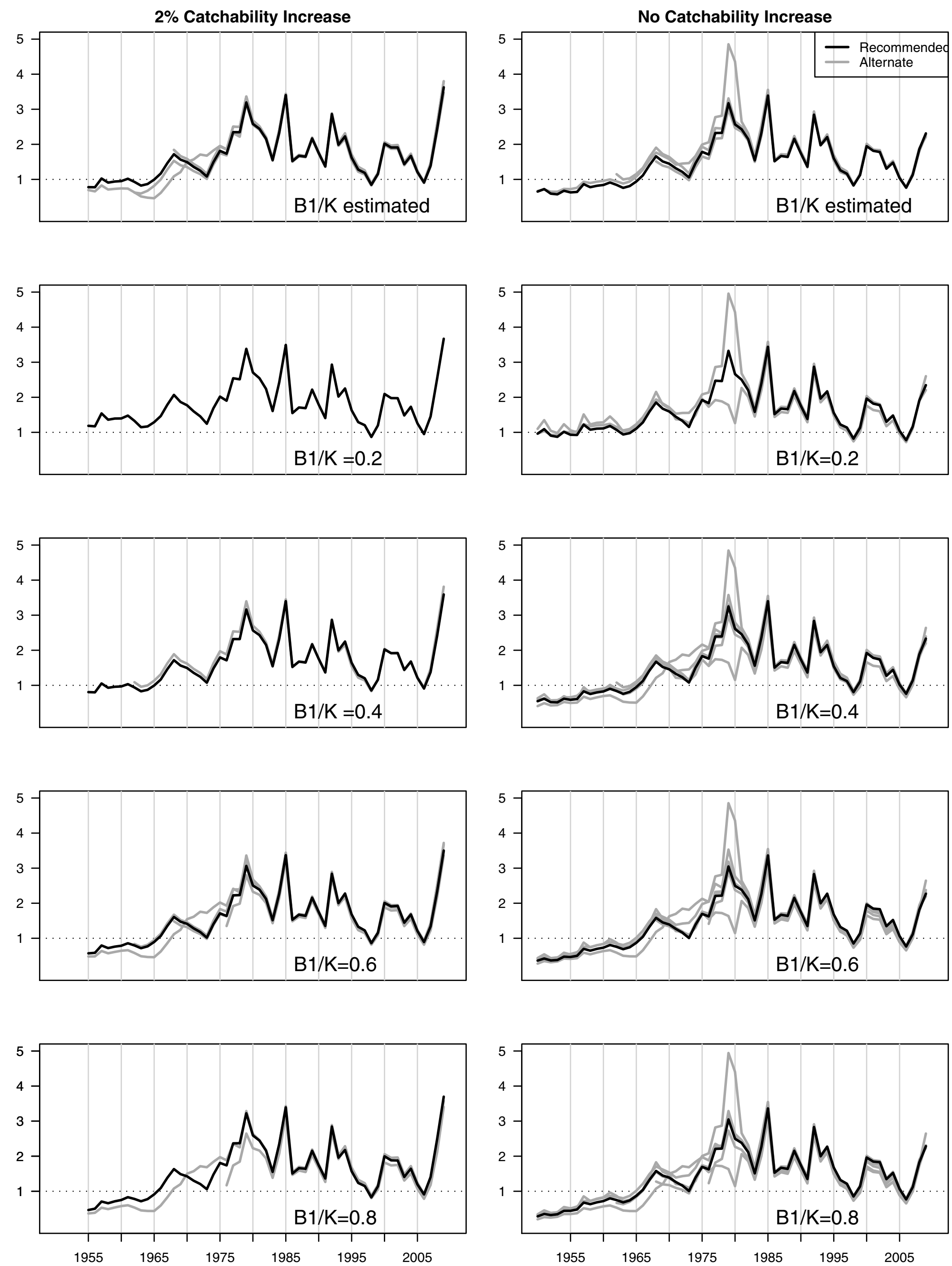


Figure 3.73. Red Snapper in Atlantic: Production model kernel density plots of relative biomass and relative fishing rate from 960 bootstrap runs of the model configured to match the input to the age structured model with B1/k estimated.

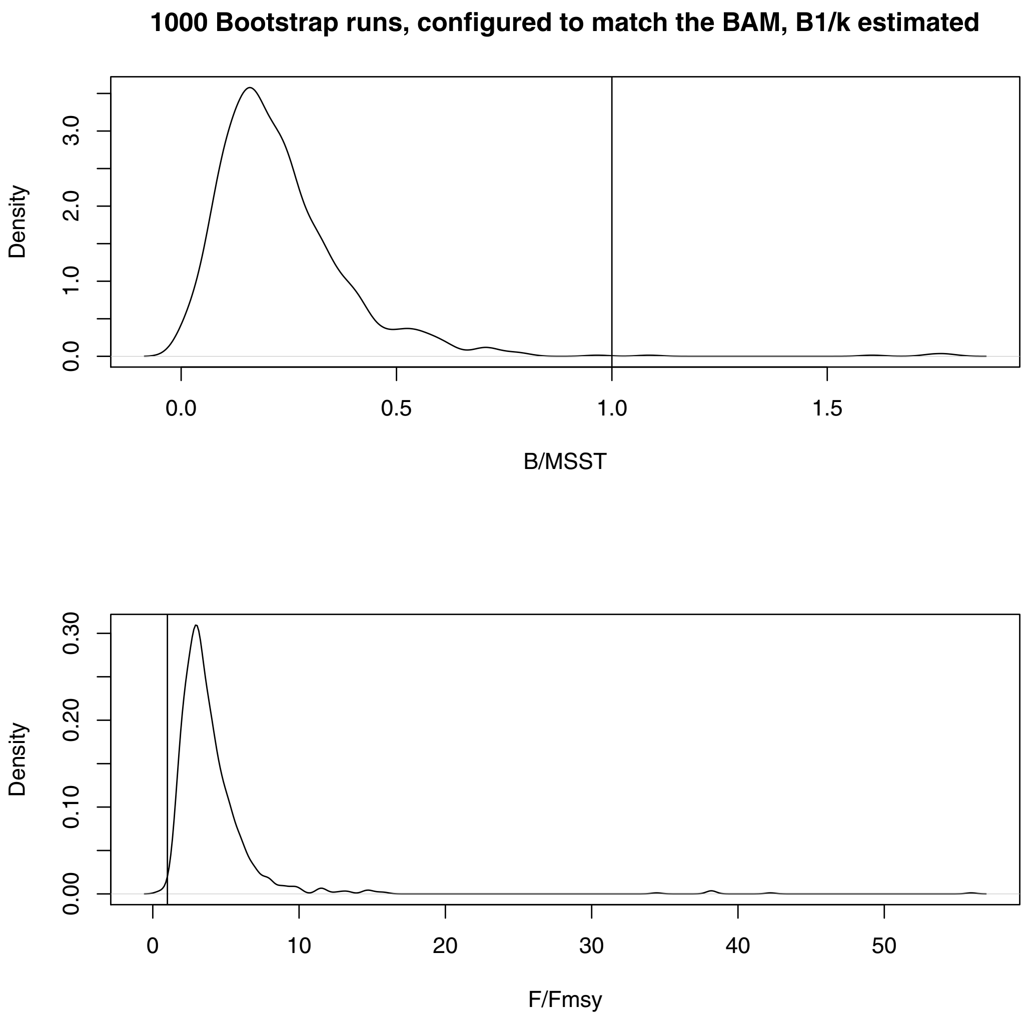
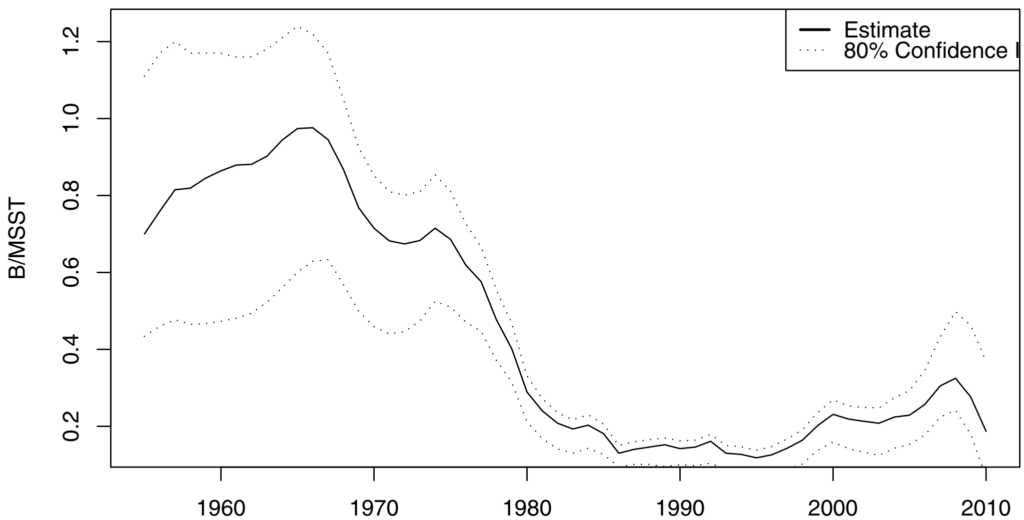
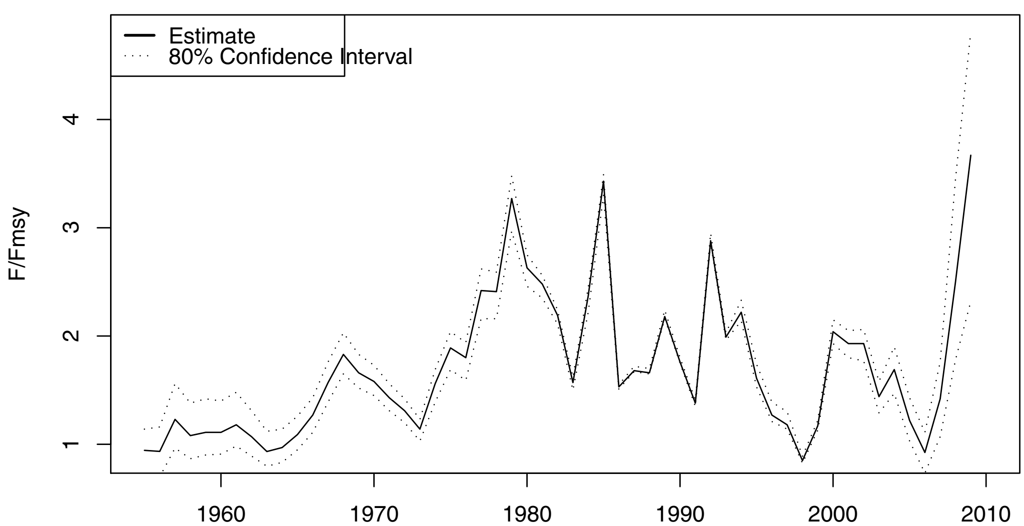


Figure 3.74. Red Snapper in Atlantic: Production model time series plots of relative fishing rate and relative biomass from 960 bootstrap runs of the model configured to match the input to the age structured model with $B1/k$ *estimated.*





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 $(1 - M)\text{SSB}_{MSY} = 0.7\text{SSB}_{MSY}$.
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

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# Number of parameters = 341  Objective function value = 8803.92  Maximum gradient component = 7.82158e-05
# len_sd_val:
62.1739656172
# log_R0:
13.1190137910
# steep:
0.971542695316
# rec_sigma:
0.550608462688
# log_rec_dev:
 0.289966339531 0.295040266690 0.462316219626 0.719561565737 0.483442233820 0.357575647936
 0.0185408565987 0.639775967877 -0.988107251728 -0.310583765476 0.459521922872 0.671910403650
 -0.408871339301 -0.617576564635 0.0233647707307 0.259771013276 -0.162318854410 -0.426537302662
 -0.216723126502 -0.197334557123 -0.500795960728 -0.640847153619 -0.740910150534
 -0.608118813019 -0.0871771640455 0.190656178889 0.705278520674 0.525370576364
 -0.0929449857930 0.160339851000 0.0675242045289 -0.783646851600 -1.53681671954
 1.15112550534 0.784251902679 0.443833809405 -0.389857196516
# R_autocorr:
0.00000000000
# selpar_L50_cL2:
1.56993220797
# selpar_slope_cL2:
5.41405190827
# selpar_L50_cL3:
2.89975804541
# selpar_slope_cL3:
3.91642748811
# selpar_L502_cL:
8.00000000000
# selpar_slope2_cL:
1.00000000000
# selpar_min_cL:
0.500000000000
# selpar_Age1_cL_D3_logit:
-2.95886192771
# selpar_Age2_cL_D3_logit:
0.791379063303
# selpar_L50_cD3:
3.00854906162
# selpar_slope_cD3:
3.43961794021
# selpar_L502_cD:
6.38314900713
# selpar_slope2_cD:
1.28018789398
# selpar_min_cD:
0.437597689631
# selpar_L50_HB1:
1.19665963336
# selpar_slope_HB1:
7.39777597838
# selpar_L50_HB2:
1.21576215229
# selpar_slope_HB2:
5.43785033263
# selpar_L50_HB3:
2.49303883337
# selpar_slope_HB3:
5.08756028871
# selpar_L502_HB:
3.79179572603
# selpar_slope2_HB:
2.78336393366
# selpar_min_HB:
0.300000000000
# selpar_Age1_HB_D3_logit:
```

```
-1.50716863151
# selpar_L50_PVT2:
1.39021077897
# selpar_slope_PVT2:
4.74102175514
# selpar_L50_PVT3:
4.66795292916
# selpar_slope_PVT3:
2.68627785077
# selpar_L502_HB:
3.79179572603
# selpar_slope2_HB:
2.78336393366
# selpar_min_HB:
0.300000000000
# log_q_cL:
-6.91087207539
# log_q_HB:
-12.5270724835
# log_q_HBD:
-13.1545856055
# q_rate:
0.0200000000000
# q_DD_beta:
0.00000000000
# q_RW_log_dev_cL:
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000
# q_RW_log_dev_HB:
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000
# q_RW_log_dev_HBD:
 0.00000000000 0.00000000000 0.00000000000 0.00000000000
# log_avg_F_cL:
-2.25395301716
# log_F_dev_cL:
 -1.56090614880 -1.59715307262 -1.00135832801 -1.31743964390 -1.21637579903
 -1.15642211886 -0.943030820702 -1.08306021798 -1.31523404077 -1.17252749704
 -0.954686546598 -0.746741408918 -0.347202366970 -0.0545942846822 -0.275580183614
 -0.186982723907 -0.207728584138 -0.250457111620 -0.360634447675 0.225014067247
 0.557048040248 0.543627820764 0.677413357073 0.701120691854 0.498923565688 0.632816189034
 0.619780955235 0.555522082198 0.576721439792 0.285429284397 0.255097662843 0.425653222784
 0.499578635172 0.440295042733 0.916214272190 0.779767895216 0.222036036221 0.164599698128
 0.957427320662 0.799913225387 0.746523219706 0.526424534919 0.445158799032 0.361468664640
 0.166133435933 0.260043442347 0.696825374588 0.484544327589 0.131990746905 0.264081778880
 -0.0216568487061 -0.378704931036 0.00368856500702 0.322261240355 0.405332490811
# log_avg_F_cD:
-5.31969616941
# log_F_dev_cD:
 -1.29871357898 -0.512156770461 -1.98068857497 -4.59871446630 -5.20469504922 -5.76303091987
 -0.0933058397821 0.740158630364 1.25698783416 0.868123946623 1.52854232277 1.23609412143
 0.778628442636 1.19725009794 1.44773647685 1.41427600427 1.37084946079 1.69534841945
 1.66885518349 1.40186976919 1.46111719080 0.698900965084 -0.0182624520624 0.754461000193
 0.0515630205289 -0.101195234934
# log_avg_F_HB:
-1.41049285287
# log_F_dev_HB:
 -0.614016511088 -0.509631887378 -0.398149423733 -0.329994235352 -0.290854066706 -0.265327437399
 -0.260337816184 -0.288784642696 -0.314249916490 -0.267111438386 -0.131327690354 0.0537692932699
 0.238589112694 0.363567628565 0.366019817166 0.269634007399 0.135981813400 0.0422397618960
 0.0390127736378 0.128313512541 0.264492862565 0.240292839193 0.128379198045 0.169034738887
 0.254616252138 0.195934926750 -0.297498906183 -0.470728939324 -0.139387508959 -0.440048109886
 0.136821371184 0.748353443613 -0.00618000081424 0.192072664981 -0.172480522989 -0.583113315989
 -0.391413594766 1.16407563659 -0.244171930160 0.0472392162121 0.300577228155 -0.479084712162
 1.67371898871 0.276769407022 0.808469473170 -0.132956232702 -0.397920306407 -0.00514980619927
 0.0374108375243 -0.0670115705722 -0.0298706812492 0.151449231734 -0.0254959599676
```

```
 -0.564630492138 -0.309908380817
# log_avg_F_PVT:
-1.55225410872
# log_F_dev_PVT:
 -2.05832981789 -1.77261147990 -1.51759884751 -1.32667768573 -1.17514711119 -1.04746942187
 -0.948806866358 -0.884318160781 -0.810622513312 -0.664702664110 -0.444066387315 -0.191853951818
 0.0473693004688 0.221747064683 0.275352118645 0.238147097968 0.177472603682 0.168762549327
 0.253545004320 0.410376312535 0.606955666654 0.640816090997 0.555843318957 0.634052063709
 0.770428143026 0.818844141125 0.490643968106 0.0930298984019 -0.135346445926 0.932159945966
 0.987522589180 0.736175741840 0.532099416040 0.915875733910 0.901329079928 -1.22586970020
 -0.129407027557 1.28962910823 -0.295149670059 -0.242947697372 -1.71568167961 0.0126600110579
 -0.841077319283 -0.259422344584 0.319763525646 1.24637136249 0.466511826865 0.322092684546
 -0.107201602297 0.195688163718 0.0645315508658 0.157537957944 1.42533111361
 0.372940807682 0.512702432545
# F_init_ratio:
0.157678466915
# log_avg_F_cL_D:
-3.01569371075
# log_F_dev_cL_D:
 0.353148058022 0.0554898618258 0.555062880122 0.807385674279 1.13589400017 1.23489556557
 0.437439486262 0.0873623206375 -0.160611604588 -0.251031747329 0.892306591013 -0.173720937807
 -1.20819998690 -0.773654849586 -0.166640270635 -0.964943703206 -1.23047055879 -0.629710779060
# log_avg_F_HB_D:
-3.80374694581
# log_F_dev_HB_D:
 1.43845010763 2.05751383000 0.683833963958 -3.51516334311 -3.51565806108 -3.95894546295
 -3.99152464524 -3.74497843873 -2.01796652641 0.873357390461 1.36738084336 0.141795482549
 1.57307593525 0.0114384274700 1.16194577718 -0.102132963322 1.35253369491 0.720461411547
 0.841005257248 0.963221874719 0.656392806137 1.32396764035 2.26531919251 0.856922074979
 1.29451491642 0.725805229538 0.537433584639
# log_avg_F_PVT_D:
-2.11305516124
# log_F_dev_PVT_D:
 -1.89137498544 -1.37187985313 -0.227014101385 -1.24915180417 1.24018700061 0.0150204492568
 -0.891876522509 -1.47852214567 0.182790799070 -0.784265695998 0.00812623634908 0.539852802678
 0.275655777743 -0.481288118205 -1.36407885339 -0.890035120694 0.630454340063 0.895691187563
 0.800496395916 0.641485939122 0.777390065766 1.06621715523 1.00584312194 0.727091614722
 0.611103660163 0.760796054822 0.451284599565
```

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
                                                                                Wednesday, 25 Aug 2010 at 12:14:51
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 5.31)
                                                                                                  FIT 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: w:\... 24\assessment\aspic\inc catchability\rs2010_103ic.inp
------------------------------------------------------------------------------------------------------------------------
Operation of ASPIC:  Fit logistic (Schaefer) model by direct optimization.
Number of years analyzed:                      55          Number of bootstrap trials:                             0
Number of data series:                          2          Bounds on MSY (min, max):       8.000E+03     1.000E+07
Objective function:                 Least squares          Bounds on K (min, max):         1.000E+07     2.000E+08
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
Number of restarts required for convergence:    116


CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
------------------------------------------------------------------------------------------------------------------------
                                       |
 1  Headboat Index (1976-2009), Tota...|   1.000
                                       |      34
                                       |
 2  Commercial                         |   0.531   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  1.450E+01     34     4.530E-01    1.000E+00    7.920E-01        0.363
Loss(2)   Commercial                              3.801E+00     17     2.534E-01    1.000E+00    1.416E+00       -1.051
.............................................................................................
TOTAL OBJECTIVE FUNCTION, MSE, RMSE:          1.82985252E+01           3.978E-01    6.307E-01
Estimated contrast index (ideal = 1.0):              0.3943           C* = (Bmax-Bmin)/K
Estimated nearness index (ideal = 1.0):              0.9488           N* = 1 - |min(B-Bmsy)|/K
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MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
------------------------------------------------------------------------------------------------------------------------
Parameter                                          Estimate     User/pgm guess    2nd guess    Estimated   User guess

B1/K      Starting relative biomass (in 1955)     3.219E-01          5.000E-01    7.071E-01            1            1
MSY       Maximum sustainable yield               1.980E+06          1.500E+06    1.041E+06            1            1
K         Maximum population size                 1.892E+07          3.000E+07    4.800E+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	2.778E-07	5.000E-08	4.750E-06	1	1
q(2)	Commercial	4.514E-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	1.980E+06	----	----
Bmsy	Stock biomass giving MSY	9.460E+06	K/2	K*n**(1/(1-n))
Fmsy	Fishing mortality rate at MSY	2.093E-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	1.716E-01	----	----
F./Fmsy	Ratio: F(2009)/Fmsy	3.668E+00	----	----
Fmsy/F.	Ratio: Fmsy/F(2009)	2.726E-01	----	----
Y.(Fmsy)	Approx. yield available at Fmsy in 2010	3.398E+05	MSY*B./Bmsy	MSY*B./Bmsy
	...as proportion of MSY	1.716E-01	----	----
Ye.	Equilibrium yield available in 2010	6.213E+05	4*MSY*(B/K-(B/K)**2)	g*MSY*(B/K-(B/K)**n)
	...as proportion of MSY	3.137E-01	----	----
---------	Fishing effort rate at MSY in units of each CE or CC series ---------			
fmsy(1)	Headboat Index (1976-2009), Total Ldgs	7.536E+05	Fmsy/q(1)	Fmsy/q(1)

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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	0.197	6.091E+06	6.349E+06	1.254E+06	1.254E+06	1.766E+06	9.435E-01	6.438E-01
2	1956	0.196	6.602E+06	6.850E+06	1.340E+06	1.340E+06	1.829E+06	9.341E-01	6.979E-01
3	1957	0.257	7.092E+06	7.108E+06	1.826E+06	1.826E+06	1.858E+06	1.227E+00	7.497E-01
4	1958	0.226	7.124E+06	7.243E+06	1.639E+06	1.639E+06	1.871E+06	1.081E+00	7.531E-01
5	1959	0.232	7.356E+06	7.440E+06	1.727E+06	1.727E+06	1.890E+06	1.109E+00	7.776E-01
6	1960	0.233	7.520E+06	7.588E+06	1.769E+06	1.769E+06	1.903E+06	1.113E+00	7.949E-01
7	1961	0.247	7.654E+06	7.661E+06	1.895E+06	1.895E+06	1.909E+06	1.182E+00	8.091E-01
8	1962	0.223	7.668E+06	7.761E+06	1.734E+06	1.734E+06	1.916E+06	1.067E+00	8.105E-01
9	1963	0.195	7.850E+06	8.037E+06	1.570E+06	1.570E+06	1.935E+06	9.333E-01	8.298E-01
10	1964	0.203	8.215E+06	8.348E+06	1.694E+06	1.694E+06	1.953E+06	9.695E-01	8.684E-01
11	1965	0.229	8.474E+06	8.483E+06	1.942E+06	1.942E+06	1.959E+06	1.094E+00	8.958E-01
12	1966	0.265	8.491E+06	8.355E+06	2.216E+06	2.216E+06	1.953E+06	1.267E+00	8.975E-01
13	1967	0.329	8.228E+06	7.879E+06	2.593E+06	2.593E+06	1.924E+06	1.572E+00	8.698E-01
14	1968	0.384	7.559E+06	7.103E+06	2.727E+06	2.727E+06	1.856E+06	1.834E+00	7.990E-01
15	1969	0.348	6.688E+06	6.447E+06	2.243E+06	2.243E+06	1.779E+06	1.662E+00	7.069E-01
16	1970	0.331	6.224E+06	6.077E+06	2.013E+06	2.013E+06	1.727E+06	1.582E+00	6.579E-01
17	1971	0.300	5.938E+06	5.902E+06	1.770E+06	1.770E+06	1.700E+06	1.433E+00	6.277E-01
18	1972	0.275	5.867E+06	5.906E+06	1.625E+06	1.625E+06	1.701E+06	1.314E+00	6.202E-01
19	1973	0.238	5.943E+06	6.086E+06	1.447E+06	1.447E+06	1.728E+06	1.136E+00	6.283E-01
20	1974	0.326	6.225E+06	6.092E+06	1.988E+06	1.988E+06	1.729E+06	1.559E+00	6.580E-01
21	1975	0.395	5.966E+06	5.667E+06	2.238E+06	2.238E+06	1.661E+06	1.887E+00	6.307E-01
22	1976	0.376	5.389E+06	5.196E+06	1.952E+06	1.952E+06	1.578E+06	1.795E+00	5.697E-01
23	1977	0.507	5.015E+06	4.561E+06	2.313E+06	2.313E+06	1.448E+06	2.423E+00	5.301E-01
24	1978	0.505	4.150E+06	3.810E+06	1.924E+06	1.924E+06	1.273E+06	2.412E+00	4.386E-01
25	1979	0.684	3.499E+06	2.973E+06	2.034E+06	2.034E+06	1.047E+06	3.270E+00	3.698E-01
26	1980	0.550	2.512E+06	2.294E+06	1.262E+06	1.262E+06	8.437E+05	2.629E+00	2.655E-01
27	1981	0.519	2.093E+06	1.949E+06	1.011E+06	1.011E+06	7.317E+05	2.479E+00	2.212E-01
28	1982	0.458	1.813E+06	1.744E+06	7.985E+05	7.985E+05	6.629E+05	2.187E+00	1.917E-01
29	1983	0.329	1.678E+06	1.722E+06	5.661E+05	5.661E+05	6.554E+05	1.570E+00	1.774E-01
30	1984	0.495	1.767E+06	1.670E+06	8.272E+05	8.272E+05	6.373E+05	2.366E+00	1.868E-01
31	1985	0.718	1.577E+06	1.343E+06	9.647E+05	9.647E+05	5.219E+05	3.432E+00	1.667E-01
32	1986	0.319	1.135E+06	1.177E+06	3.761E+05	3.761E+05	4.622E+05	1.526E+00	1.199E-01

33	1987	0.352	1.221E+06	1.245E+06	4.383E+05	4.383E+05	4.869E+05	1.682E+00	1.290E-01
34	1988	0.348	1.269E+06	1.297E+06	4.506E+05	4.506E+05	5.056E+05	1.660E+00	1.342E-01
35	1989	0.457	1.324E+06	1.281E+06	5.852E+05	5.852E+05	4.999E+05	2.182E+00	1.400E-01
36	1990	0.369	1.239E+06	1.253E+06	4.620E+05	4.620E+05	4.898E+05	1.762E+00	1.310E-01
37	1991	0.289	1.267E+06	1.333E+06	3.851E+05	3.851E+05	5.186E+05	1.381E+00	1.339E-01
38	1992	0.603	1.400E+06	1.261E+06	7.607E+05	7.607E+05	4.924E+05	2.883E+00	1.480E-01
39	1993	0.417	1.132E+06	1.119E+06	4.663E+05	4.663E+05	4.407E+05	1.991E+00	1.196E-01
40	1994	0.465	1.106E+06	1.068E+06	4.969E+05	4.969E+05	4.220E+05	2.222E+00	1.169E-01
41	1995	0.337	1.031E+06	1.062E+06	3.580E+05	3.580E+05	4.197E+05	1.610E+00	1.090E-01
42	1996	0.266	1.093E+06	1.166E+06	3.102E+05	3.102E+05	4.579E+05	1.271E+00	1.156E-01
43	1997	0.247	1.241E+06	1.334E+06	3.298E+05	3.298E+05	5.189E+05	1.181E+00	1.312E-01
44	1998	0.178	1.430E+06	1.589E+06	2.822E+05	2.822E+05	6.091E+05	8.485E-01	1.512E-01
45	1999	0.244	1.757E+06	1.880E+06	4.593E+05	4.593E+05	7.086E+05	1.167E+00	1.857E-01
46	2000	0.427	2.006E+06	1.955E+06	8.350E+05	8.350E+05	7.338E+05	2.041E+00	2.121E-01
47	2001	0.403	1.905E+06	1.880E+06	7.581E+05	7.581E+05	7.089E+05	1.926E+00	2.014E-01
48	2002	0.403	1.856E+06	1.833E+06	7.384E+05	7.384E+05	6.930E+05	1.925E+00	1.962E-01
49	2003	0.302	1.810E+06	1.880E+06	5.682E+05	5.682E+05	7.089E+05	1.443E+00	1.914E-01
50	2004	0.353	1.951E+06	1.973E+06	6.959E+05	6.959E+05	7.399E+05	1.685E+00	2.063E-01
51	2005	0.256	1.995E+06	2.116E+06	5.418E+05	5.418E+05	7.867E+05	1.223E+00	2.109E-01
52	2006	0.193	2.240E+06	2.445E+06	4.731E+05	4.731E+05	8.910E+05	9.243E-01	2.368E-01
53	2007	0.297	2.658E+06	2.742E+06	8.135E+05	8.135E+05	9.815E+05	1.417E+00	2.810E-01
54	2008	0.522	2.826E+06	2.608E+06	1.362E+06	1.362E+06	9.410E+05	2.495E+00	2.987E-01
55	2009	0.768	2.405E+06	1.986E+06	1.525E+06	1.525E+06	7.430E+05	3.668E+00	2.542E-01
56	2010		1.623E+06						1.716E-01

SAFMC Red Snapper (2010) Landings and Indices Page 4

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

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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	*	1.764E+00	0.1975	1.254E+06	1.254E+06	0.00000	1.000E+00
2	1956	*	1.903E+00	0.1955	1.340E+06	1.340E+06	0.00000	1.000E+00
3	1957	*	1.975E+00	0.2569	1.826E+06	1.826E+06	0.00000	1.000E+00
4	1958	*	2.012E+00	0.2263	1.639E+06	1.639E+06	0.00000	1.000E+00
5	1959	*	2.067E+00	0.2321	1.727E+06	1.727E+06	0.00000	1.000E+00
6	1960	*	2.108E+00	0.2331	1.769E+06	1.769E+06	0.00000	1.000E+00
7	1961	*	2.128E+00	0.2473	1.895E+06	1.895E+06	0.00000	1.000E+00
8	1962	*	2.156E+00	0.2234	1.734E+06	1.734E+06	0.00000	1.000E+00
9	1963	*	2.232E+00	0.1954	1.570E+06	1.570E+06	0.00000	1.000E+00
10	1964	*	2.319E+00	0.2029	1.694E+06	1.694E+06	0.00000	1.000E+00
11	1965	*	2.356E+00	0.2290	1.942E+06	1.942E+06	0.00000	1.000E+00
12	1966	*	2.321E+00	0.2652	2.216E+06	2.216E+06	0.00000	1.000E+00
13	1967	*	2.189E+00	0.3291	2.593E+06	2.593E+06	0.00000	1.000E+00
14	1968	*	1.973E+00	0.3840	2.727E+06	2.727E+06	0.00000	1.000E+00
15	1969	*	1.791E+00	0.3479	2.243E+06	2.243E+06	0.00000	1.000E+00
16	1970	*	1.688E+00	0.3312	2.013E+06	2.013E+06	0.00000	1.000E+00
17	1971	*	1.639E+00	0.3000	1.770E+06	1.770E+06	0.00000	1.000E+00
18	1972	*	1.641E+00	0.2751	1.625E+06	1.625E+06	0.00000	1.000E+00
19	1973	*	1.691E+00	0.2377	1.447E+06	1.447E+06	0.00000	1.000E+00
20	1974	*	1.692E+00	0.3263	1.988E+06	1.988E+06	0.00000	1.000E+00
21	1975	*	1.574E+00	0.3950	2.238E+06	2.238E+06	0.00000	1.000E+00
22	1976	1.801E+00	1.443E+00	0.3757	1.952E+06	1.952E+06	-0.22131	1.000E+00
23	1977	2.095E+00	1.267E+00	0.5071	2.313E+06	2.313E+06	-0.50302	1.000E+00
24	1978	1.671E+00	1.058E+00	0.5049	1.924E+06	1.924E+06	-0.45683	1.000E+00
25	1979	2.486E+00	8.257E-01	0.6844	2.034E+06	2.034E+06	-1.10217	1.000E+00
26	1980	9.914E-01	6.372E-01	0.5502	1.262E+06	1.262E+06	-0.44199	1.000E+00
27	1981	1.867E+00	5.413E-01	0.5188	1.011E+06	1.011E+06	-1.23815	1.000E+00
28	1982	1.107E+00	4.845E-01	0.4577	7.985E+05	7.985E+05	-0.82589	1.000E+00
29	1983	6.977E-01	4.785E-01	0.3287	5.661E+05	5.661E+05	-0.37723	1.000E+00
30	1984	6.327E-01	4.639E-01	0.4953	8.272E+05	8.272E+05	-0.31040	1.000E+00
31	1985	9.436E-01	3.730E-01	0.7184	9.647E+05	9.647E+05	-0.92819	1.000E+00
32	1986	2.734E-01	3.270E-01	0.3195	3.761E+05	3.761E+05	0.17891	1.000E+00
33	1987	3.145E-01	3.458E-01	0.3521	4.383E+05	4.383E+05	0.09476	1.000E+00
34	1988	3.214E-01	3.602E-01	0.3475	4.506E+05	4.506E+05	0.11391	1.000E+00
35	1989	4.488E-01	3.558E-01	0.4568	5.852E+05	5.852E+05	-0.23226	1.000E+00
36	1990	4.166E-01	3.480E-01	0.3688	4.620E+05	4.620E+05	-0.17986	1.000E+00
37	1991	5.245E-01	3.702E-01	0.2890	3.851E+05	3.851E+05	-0.34851	1.000E+00

38	1992	6.395E-02	3.502E-01	0.6034	7.607E+05	7.607E+05	1.70023	1.000E+00
39	1993	1.271E-01	3.108E-01	0.4167	4.663E+05	4.663E+05	0.89417	1.000E+00
40	1994	1.912E-01	2.967E-01	0.4651	4.969E+05	4.969E+05	0.43976	1.000E+00
41	1995	2.471E-01	2.950E-01	0.3370	3.580E+05	3.580E+05	0.17743	1.000E+00
42	1996	2.790E-01	3.238E-01	0.2661	3.102E+05	3.102E+05	0.14914	1.000E+00
43	1997	3.010E-01	3.705E-01	0.2473	3.298E+05	3.298E+05	0.20751	1.000E+00
44	1998	1.645E-01	4.413E-01	0.1776	2.822E+05	2.822E+05	0.98695	1.000E+00
45	1999	2.260E-01	5.221E-01	0.2443	4.593E+05	4.593E+05	0.83745	1.000E+00
46	2000	2.805E-01	5.430E-01	0.4271	8.350E+05	8.350E+05	0.66048	1.000E+00
47	2001	5.031E-01	5.222E-01	0.4032	7.581E+05	7.581E+05	0.03731	1.000E+00
48	2002	5.578E-01	5.091E-01	0.4029	7.384E+05	7.384E+05	-0.09142	1.000E+00
49	2003	3.895E-01	5.223E-01	0.3022	5.682E+05	5.682E+05	0.29332	1.000E+00
50	2004	6.227E-01	5.481E-01	0.3527	6.959E+05	6.959E+05	-0.12758	1.000E+00
51	2005	5.363E-01	5.878E-01	0.2560	5.418E+05	5.418E+05	0.09171	1.000E+00
52	2006	3.206E-01	6.791E-01	0.1935	4.731E+05	4.731E+05	0.75057	1.000E+00
53	2007	2.545E-01	7.617E-01	0.2967	8.135E+05	8.135E+05	1.09622	1.000E+00
54	2008	1.146E+00	7.244E-01	0.5223	1.362E+06	1.362E+06	-0.45892	1.000E+00
55	2009	1.358E+00	5.516E-01	0.7678	1.525E+06	1.525E+06	-0.90081	1.000E+00

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	--	*	2.866E+00	0.00000	1.000E+00
2	1956	0.000E+00	0.000E+00	--	*	3.092E+00	0.00000	1.000E+00
3	1957	0.000E+00	0.000E+00	--	*	3.209E+00	0.00000	1.000E+00
4	1958	0.000E+00	0.000E+00	--	*	3.269E+00	0.00000	1.000E+00
5	1959	0.000E+00	0.000E+00	--	*	3.358E+00	0.00000	1.000E+00
6	1960	0.000E+00	0.000E+00	--	*	3.425E+00	0.00000	1.000E+00
7	1961	0.000E+00	0.000E+00	--	*	3.458E+00	0.00000	1.000E+00
8	1962	0.000E+00	0.000E+00	--	*	3.503E+00	0.00000	1.000E+00
9	1963	0.000E+00	0.000E+00	--	*	3.628E+00	0.00000	1.000E+00
10	1964	0.000E+00	0.000E+00	--	*	3.768E+00	0.00000	1.000E+00
11	1965	0.000E+00	0.000E+00	--	*	3.829E+00	0.00000	1.000E+00
12	1966	0.000E+00	0.000E+00	--	*	3.771E+00	0.00000	1.000E+00
13	1967	0.000E+00	0.000E+00	--	*	3.556E+00	0.00000	1.000E+00
14	1968	0.000E+00	0.000E+00	--	*	3.206E+00	0.00000	1.000E+00
15	1969	0.000E+00	0.000E+00	--	*	2.910E+00	0.00000	1.000E+00
16	1970	0.000E+00	0.000E+00	--	*	2.743E+00	0.00000	1.000E+00
17	1971	0.000E+00	0.000E+00	--	*	2.664E+00	0.00000	1.000E+00
18	1972	0.000E+00	0.000E+00	--	*	2.666E+00	0.00000	1.000E+00
19	1973	0.000E+00	0.000E+00	--	*	2.747E+00	0.00000	1.000E+00
20	1974	0.000E+00	0.000E+00	--	*	2.750E+00	0.00000	1.000E+00
21	1975	0.000E+00	0.000E+00	--	*	2.558E+00	0.00000	1.000E+00
22	1976	0.000E+00	0.000E+00	--	*	2.345E+00	0.00000	1.000E+00
23	1977	0.000E+00	0.000E+00	--	*	2.059E+00	0.00000	1.000E+00
24	1978	0.000E+00	0.000E+00	--	*	1.720E+00	0.00000	1.000E+00
25	1979	0.000E+00	0.000E+00	--	*	1.342E+00	0.00000	1.000E+00
26	1980	0.000E+00	0.000E+00	--	*	1.036E+00	0.00000	1.000E+00
27	1981	0.000E+00	0.000E+00	--	*	8.797E-01	0.00000	1.000E+00
28	1982	0.000E+00	0.000E+00	--	*	7.874E-01	0.00000	1.000E+00
29	1983	0.000E+00	0.000E+00	--	*	7.775E-01	0.00000	1.000E+00
30	1984	0.000E+00	0.000E+00	--	*	7.538E-01	0.00000	1.000E+00
31	1985	0.000E+00	0.000E+00	--	*	6.061E-01	0.00000	1.000E+00
32	1986	0.000E+00	0.000E+00	--	*	5.314E-01	0.00000	1.000E+00
33	1987	0.000E+00	0.000E+00	--	*	5.619E-01	0.00000	1.000E+00
34	1988	0.000E+00	0.000E+00	--	*	5.853E-01	0.00000	1.000E+00
35	1989	0.000E+00	0.000E+00	--	*	5.782E-01	0.00000	1.000E+00
36	1990	0.000E+00	0.000E+00	--	*	5.655E-01	0.00000	1.000E+00
37	1991	0.000E+00	0.000E+00	--	*	6.015E-01	0.00000	1.000E+00
38	1992	0.000E+00	0.000E+00	--	*	5.690E-01	0.00000	1.000E+00
39	1993	1.000E+00	1.000E+00	--	1.137E+00	5.051E-01	0.81143	1.000E+00
40	1994	1.000E+00	1.000E+00	--	8.957E-01	4.822E-01	0.61926	1.000E+00
41	1995	1.000E+00	1.000E+00	--	8.851E-01	4.794E-01	0.61314	1.000E+00
42	1996	1.000E+00	1.000E+00	--	5.386E-01	5.262E-01	0.02330	1.000E+00
43	1997	1.000E+00	1.000E+00	--	5.216E-01	6.020E-01	-0.14328	1.000E+00

44	1998	1.000E+00	1.000E+00	--	5.688E-01	7.172E-01	-0.23176	1.000E+00
45	1999	1.000E+00	1.000E+00	--	6.653E-01	8.484E-01	-0.24320	1.000E+00
46	2000	1.000E+00	1.000E+00	--	6.407E-01	8.824E-01	-0.32005	1.000E+00
47	2001	1.000E+00	1.000E+00	--	1.023E+00	8.487E-01	0.18696	1.000E+00
48	2002	1.000E+00	1.000E+00	--	1.119E+00	8.273E-01	0.30227	1.000E+00
49	2003	1.000E+00	1.000E+00	--	8.888E-01	8.488E-01	0.04609	1.000E+00
50	2004	1.000E+00	1.000E+00	--	1.123E+00	8.907E-01	0.23193	1.000E+00
51	2005	1.000E+00	1.000E+00	--	9.333E-01	9.552E-01	-0.02324	1.000E+00
52	2006	1.000E+00	1.000E+00	--	4.499E-01	1.104E+00	-0.89728	1.000E+00
53	2007	1.000E+00	1.000E+00	--	4.781E-01	1.238E+00	-0.95124	1.000E+00
54	2008	1.000E+00	1.000E+00	--	8.407E-01	1.177E+00	-0.33661	1.000E+00
55	2009	1.000E+00	1.000E+00	--	1.304E+00	8.963E-01	0.37506	1.000E+00