SEDAR 17 Stock Assessment Report: South Atlantic Vermilion Snapper

SEDAR55-RD02

7 August 2017

S E D A R

Southeast Data, Assessment, and Review

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SEDAR 17

Stock Assessment Report

South Atlantic Vermilion Snapper

November 19, 2008

SEDAR is a Cooperative Initiative of:

The Caribbean Fishery Management Council
The Gulf of Mexico Fishery Management Council
The South Atlantic Fishery Management Council
NOAA Fisheries Southeast Regional Office
NOAA Fisheries Southeast Fisheries Science Center
The Atlantic States Marine Fisheries Commission
The Gulf States Marine Fisheries Commission

SEDAR
The South Atlantic Fishery Management Council
4055 Faber Place #201
North Charleston, SC 29405
(843) 571-4366

Stock Assessment Report

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Section I. Introduction

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1. SEDAR Overview

SEDAR (Southeast Data, Assessment and Review) was initially developed by the Southeast Fisheries Science Center and the South Atlantic Fishery Management Council to improve the quality and reliability of stock assessments and to ensure a robust and independent peer review of stock assessment products. SEDAR was expanded in 2003 to address the assessment needs of all three Fishery Management Council in the Southeast Region (South Atlantic, Gulf of Mexico, and Caribbean) and to provide a platform for reviewing assessments developed through the Atlantic and Gulf States Marine Fisheries Commissions and state agencies within the southeast.

SEDAR strives to improve the quality of assessment advice provided for managing fisheries resources in the Southeast US by increasing and expanding participation in the assessment process, ensuring the assessment process is transparent and open, and providing a robust and independent review of assessment products. SEDAR is overseen by a Steering Committee composed of NOAA Fisheries representatives: Southeast Fisheries Science Center Director and the Southeast Regional Administrator; Regional Council representatives: the Executive Directors and Chairs of the South Atlantic, Gulf of Mexico, and Caribbean Fishery Management Councils; and Interstate Commissions: the Executive Directors of the Atlantic States and Gulf States Marine Fisheries Commissions.

SEDAR is organized around three workshops. First is the Data Workshop, during which fisheries, monitoring, and life history data are reviewed and compiled. Second is the Assessment workshop, during which assessment models are developed and population parameters are estimated using the information provided from the Data Workshop. Third and final is the Review Workshop, during which independent experts review the input data, assessment methods, and assessment products.

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

SEDAR Review Workshop Panels consist of a chair, a reviewer appointed by the Council, and 3 reviewers appointed by the Center for Independent Experts (CIE), an independent organization that provides independent, expert reviews of stock assessments and related work. The Review Workshop Chair is appointed by the SEFSC director and is usually selected from a NOAA Fisheries regional science center. Participating councils may appoint representatives of their SSC, Advisory, and other panels as observers to the review workshop.

SEDAR 17 was charged with assessing Spanish mackerel and vermilion snapper in the US South Atlantic. This task was accomplished through workshops held between May and October 2008.

2. Management Review

SEDAR 17
Management Information Worksheet
Vermilion Snapper

Details of specific regulatory requirements, including actual dates when actions went into effect, are critical to explaining catch trends and properly evaluating fishery-dependent CPUE. Current and proposed management specifications are critical to evaluating stock status as required in the SEDAR Terms of Reference. Information on current rebuilding plans is necessary to develop appropriate projections. Finally, several assumptions are necessary for developing accurate projections to evaluate impacts of changes in future fishing mortality.

Table 1. General Management Information

Species	Vermilion Snapper (*Rhomboplites aurorubens*)
Management Unit	Southeastern US
Management Unit Definition	All waters within South Atlantic Fishery Management Council Boundaries
Management Entity	South Atlantic Fishery Management Council
Management Contacts SERO / Council	Jack McGovern/Rick DeVictor
Current stock exploitation status	Overfishing
Current stock biomass status	Unknown

Table 2. Specific Management Criteria

Criteria	Current		Proposed in Amendment 16[1]		Results from SEDAR 17	
	Definition	Value	Definition	Value	Definition	Value
MSST	MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}	Unknown[2]	MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}	Unknown[2]	MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}	7.142×10^{12} eggs
MFMT	F_{MSY}	0.355[3]	F_{MSY}	0.355[3]	F_{MSY}	0.386
MSY	Yield at F_{MSY}	Not Specified	Yield at F_{MSY}	2,699,957 lbs whole weight[4]	Yield at F_{MSY}	1,665,000 pounds
F_{MSY}	F_{MAX}	0.355[3]	F_{MAX}	0.355[3]	F_{MAX}	0.386
OY	Yield at F_{OY}	Not Specified	Yield at F_{OY}	Option1[6]=(65%)(F_{MAX})= 547,887 lbs whole weight Option2[6]=(75%)(F_{MAX})= 628,459 lbs whole weight Option3[6] (85%)(F_{MAX})= 692,916 lbs whole weight	Yield at F_{OY}	Option1=(65%)(F_{MAX})= 1,559,000 lbs whole weight Option2=(75%)(F_{MAX})= 1,635,000 lbs whole weight Option3=(85%)(F_{MAX})= 1,656,000 lbs whole weight
F_{OY}	$F_{45\%SPR}$	0.25[5]	F_{OY} = 65%,75%, 85% F_{MAX}	0.23 (65% F_{MAX}); 0.27 (75%F_{MAX}); 0.30 (85%F_{MAX})	F_{OY} = 65%,75%, 85% F_{MSY}	0.251 (65% F_{MAX}); 0.289 (75%F_{MAX}); 0.328 (85%F_{MAX})
M	n/a	0.25	M	0.25	M	0.22

[1]The Council is developing Amendment 16 to the Snapper Grouper FMP that would end overfishing of vermilion snapper and establish management reference points. The Council is scheduled to approve submittal to the Secretary of Commerce at their September 2008 meeting.
[2]This value is unknown at this time given the high level of uncertainty with the biomass values.
[3]Source: Vermilion SEDAR Update 2007.
[4]The Council's SSC did not endorse the estimate of MSY at equilibrium from the vermilion snapper SEDAR Update (2007).
[5]Source: Powers 1999. The vermilion snapper SEDAR Update (2007) did not produce a F_{OY} value.
[6]Does not represent yield at equilibrium. OY values for 65%, 75%, and 85% of F_{MAX} were determined using the Baranov equation.

Table 3. Stock Rebuilding Information

The current stock biomass status is unknown; no rebuilding plan required.

Table 4. Stock projection information

(This provides the basic information necessary to bridge the gap between the terminal year of the assessment and the year in which any changes may take place or specific alternative exploitation rates should be evaluated.)

Requested Information	Value
First Year of Management	2009
Projection Criteria during interim years should be based on (e.g., exploitation or harvest)	Fixed Exploitation; Modified Exploitation; Fixed Harvest*
Projection criteria values for interim years should be determined from (e.g., terminal year, avg of X years)	Average of previous 3 years

*Fixed Exploitation would be $F=F_{MSY}$ (or $F<F_{MSY}$) that would rebuild overfished stock to B_{MSY} in the allowable timeframe. Modified Exploitation would be allow for adjustment in $F<=F_{MSY}$, which would allow for the largest landings that would rebuild the stock to B_{MSY} in the allowable timeframe. Fixed harvest would be maximum fixed harvest with $F<=F_{MSY}$ that would allow the stock to rebuild to B_{MSY} in the allowable timeframe.

First year of Management: Earliest year in which management changes resulting from this assessment are expected to become effective

interim years: those between the terminal assessment year and the first year that any management could realistically become effective.

Projection Criteria: The parameter which should be used to determine population removals, typically either an exploitation rate or an average landings value or a pre-specified landings target.

Table 5. Quota Calculation Details

Quota Detail	Value
Current Quota Value	Commercial quota set at 1,221,000 lbs whole weight (1,100,000 million lbs gutted weight)
Next Scheduled Quota Change	Through Amendment 16
Annual or averaged quota ?	annual
If averaged, number of years to average	n/a

How is the quota calculated - conditioned upon exploitation or average landings?
Quota specified in Amendment 13C is based on the average commercial catch during 1999-2003.

The quota specified in Amendment 16 would divide the total allowable catch (TAC) recommended by the SSC into a commercial and recreational portion based on the Council's preferred allocation alternative. The SSC specified a TAC based on the yield at F_{OY} of 628,459 lbs whole weight (566,179 lbs gutted weight). The Council's preferred allocation alternative would allocate 68% of the TAC to the commercial sector and 32% to the recreational sector resulting in a commercial quota of 427,352 lbs whole weight (385,002 lbs gutted weight).

Does the quota include bycatch/discard estimates? If so, what is the source of the bycatch/discard values? What are the bycatch/discard allowances?
The quota specified in Amendment 16 would be adjusted for an estimation of the expected dead discards after a quota is met. This estimate is the catch of vermilion snapper on trips targeting co-occurring species (incidental catch) and adjusted for the SEDAR accepted release mortality rate (dead discards). The source of data is the NMFS logbook.

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

- In determining incidental catch, a co-occurring species is targeted if at least 100 lbs whole weight is taken on a trip.
- After a quota is met or during a seasonal closure, if vermilion snapper makes up greater than 75% of the catch on a trip, the trip is not included in analyses.
- There will not be an increase in fishing effort before or after a seasonal closure.
- Some trips will not be taken after a quota is met. A range of 0 to 60% is used.
- Fishermen can avoid vermilion snapper to some degree by changing hook size, method of fishing, and location. A range of 0 to 60% is used.
- Dead discards determined by applying release mortality rate of 40% for commercially caught vermilion snapper.

Table 6. Federal Regulatory and FMP History

Description of Action	FMP/Amendment	Effective Date
4" trawl mesh size to achieve a 12" TL minimum size	Original FMP (SAFMC 1983)	8/31/83
Prohibit trawls	Amendment 1 (SAFMC 1988)	1/12/89
Prohibit fish traps, entanglement nets & longlines within 50 fathoms; bag limit of 10 vermilion per person per day; 10" TL recreational minimum size limit & 12" TL commercial minimum size limit	Amendment 4 (SAFMC 1991)	1/1/92
Oculina Experimental Closed Area	Amendment 6 (SAFMC 1993)	6/27/94
Limited entry program: transferable permits and 225-lb non-transferable permits	Amendment 8 (SAFMC 1997)	12/98
Recreational size limit increased to 11" TL; Vessels with longlines may only possess deepwater species	Amendment 9 (SAFMC 1998c)	2/24/99
Commercial quota set at 1.1 million lbs gutted weight; recreational size limit increased for 12" TL. After the commercial quota is met, all purchase and sale is prohibited and harvest and/or possession is limited to the bag limit.	Amendment 13C (SAFMC 2006)	10/23/06

Table 7. State Regulatory History – North Carolina and South Carolina

Description of Action	State	Effective Date
12 inch TL minimum size commercial	NC	5/24/99
11 inch TL minimum size recreational	NC	5/24/99
Creel limit: 10 fish per person per day if taken for recreational purposes	NC	5/24/99
Consistency with federal regulations	NC	2000-2007
Consistency with federal regulations	SC	1988-2007

Table 8. Annual Regulatory Summary

	Commercial Fishery Regulations		Recreational Fishery Regulations	
Effective Date	Size Limit	Quota	Size Limit	Possession Limit
1/1/92	12” TL		10” TL	10/person/day
2/24/99			11” TL	
10/23/06		1.1 million pounds (gutted weight)[1]	12” TL	

[1]After the commercial quota is met, all purchase and sale is prohibited and harvest and/or possession is limited to the bag limit.

References

Powers, J. 1999. Control parameters and alternatives for control rules for selected stocks under the jurisdiction of the South Atlantic Fishery Management Council. Southeast Fisheries Science Center.

SEDAR Update. 2006. Report of Stock Assessment: Vermillion Snapper. SEDAR Update Process #3. Assessment Workshop of April 2–4, 2007. Beaufort, North Carolina.

3. Assessment History

History of Vermilion Snapper Stock Assessments

The most recent assessment of the Atlantic stock of vermilion snapper was conducted through the SEDAR Update Process (SEDAR Update #3). A three-day SEDAR stock assessment workshop (AW) was convened at the NOAA Center for Coastal Fisheries and Habitat Research Beaufort, North Carolina, beginning on Monday, April 4, 2007 (Anonymous 2007). The workshop's objectives were to conduct an update assessment of the vermilion snapper (*Rhomboplites aurorubens*) off the southeastern U.S. and to conduct stock projections based on possible management scenarios. Participants in the update assessment included state and federal scientists, SAFMC AP and SSC members, and various observers. All decisions regarding stock assessment methods and acceptable data were made by consensus.

Available data on the species included all those utilized for the benchmark assessment (Anonymous 2003) conducted in 2002 – no additional data sources were identified during the scoping workshop (SW). These data were abundance indices, recorded landings, and samples of annual size compositions from indices and landings. Four abundance indices were used in the benchmark assessment: one from the NMFS headboat survey and three from the SC MARMAP fishery independent monitoring program. Landings data were available from all recreational and commercial fisheries.

As in the benchmark assessment, the update assessment used a statistical catch at length model. Benchmarks were based on proxies for MSY-related quantities. The AW provided the base run of the model, identical to that used in the benchmark assessment. This base run was used for the estimation of benchmarks and stock status. The ratio of fishing mortality in 2006 to F_{MAX} was 2.05, compared to 1.71 in the benchmark assessment, suggesting overfishing. Four projections were considered: $F=F_{MAX}$; $F=85\%F_{MAX}$; $F=75\%F_{MAX}$ and $F=65\%F_{MAX}$; the results of each were very similar.

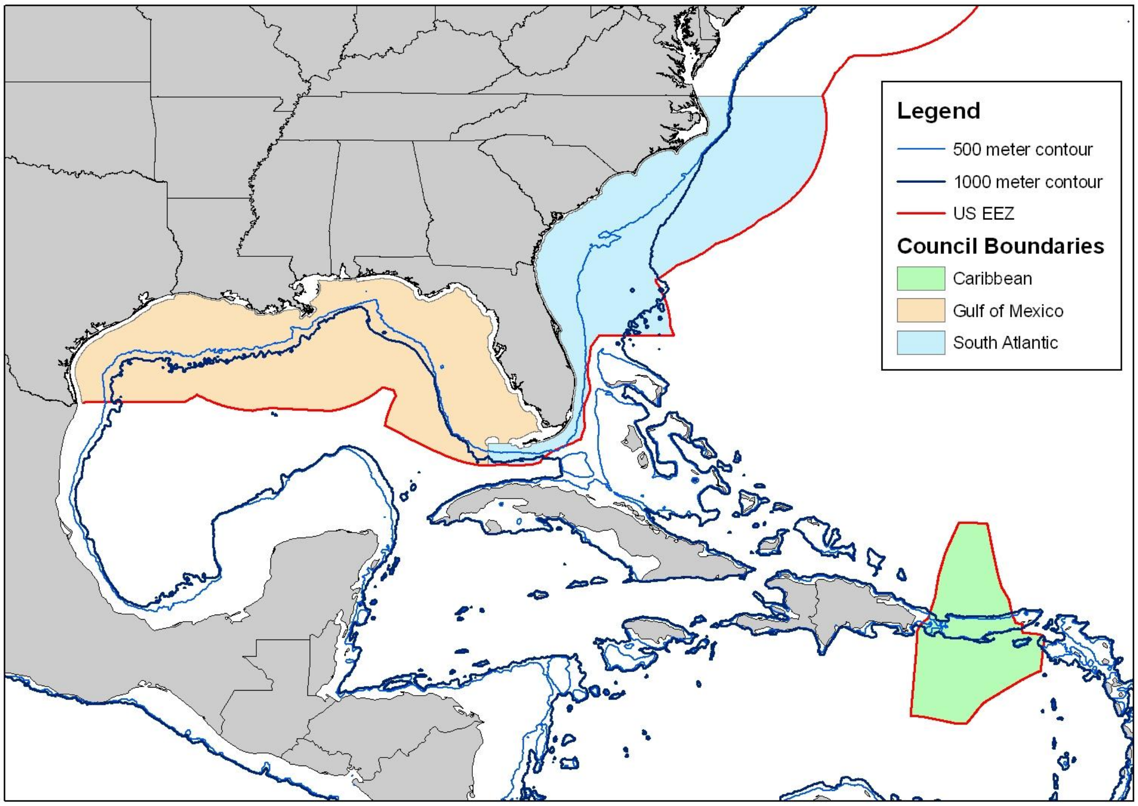
References (available from SEDAR website):

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

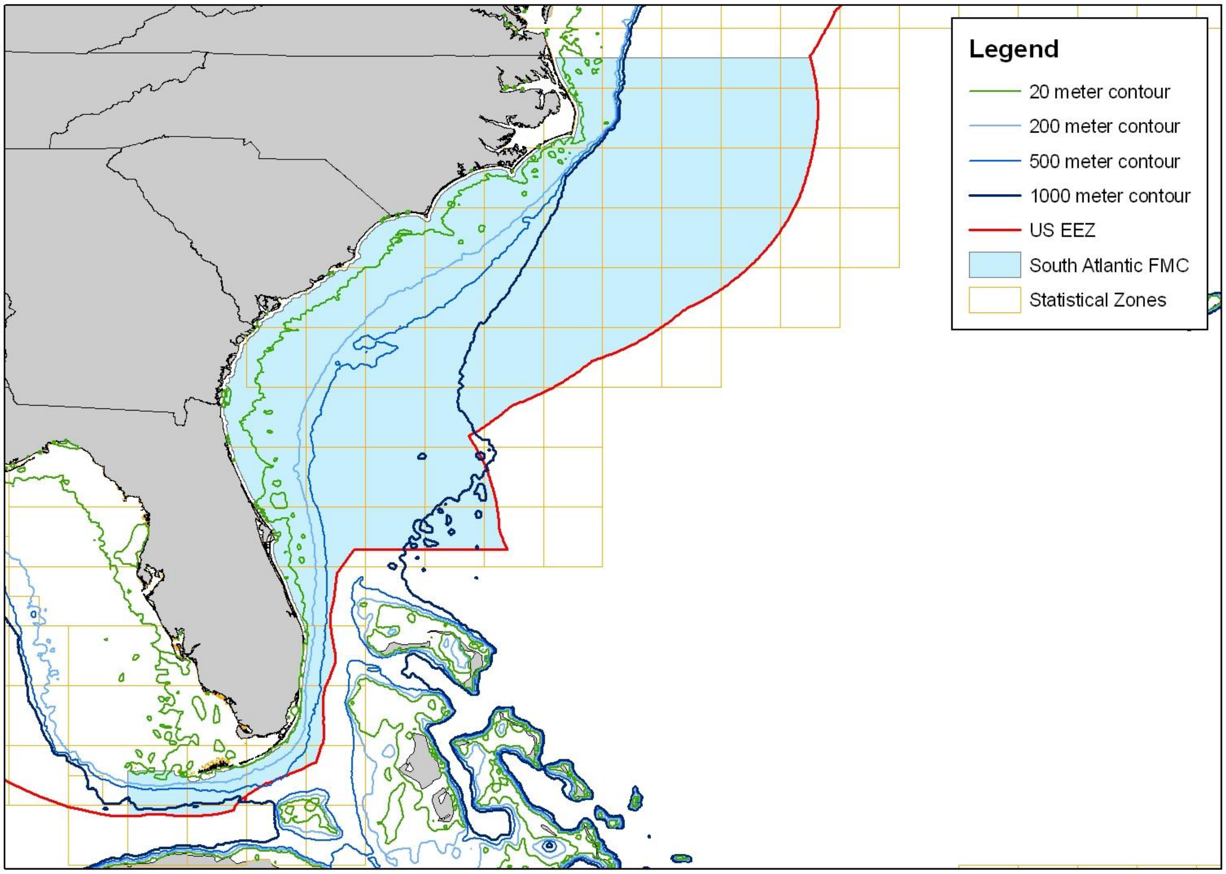
Anonymous. 2007. Report of Stock Assessment: Vermilion Snapper. SEDAR Update Process #3. Assessment Workshop of April 2-4, 2007. NOAA Fisheries, Sustainable Fisheries Branch, Beaufort, North Carolina, 43 pp.

4. Southeast Region Maps

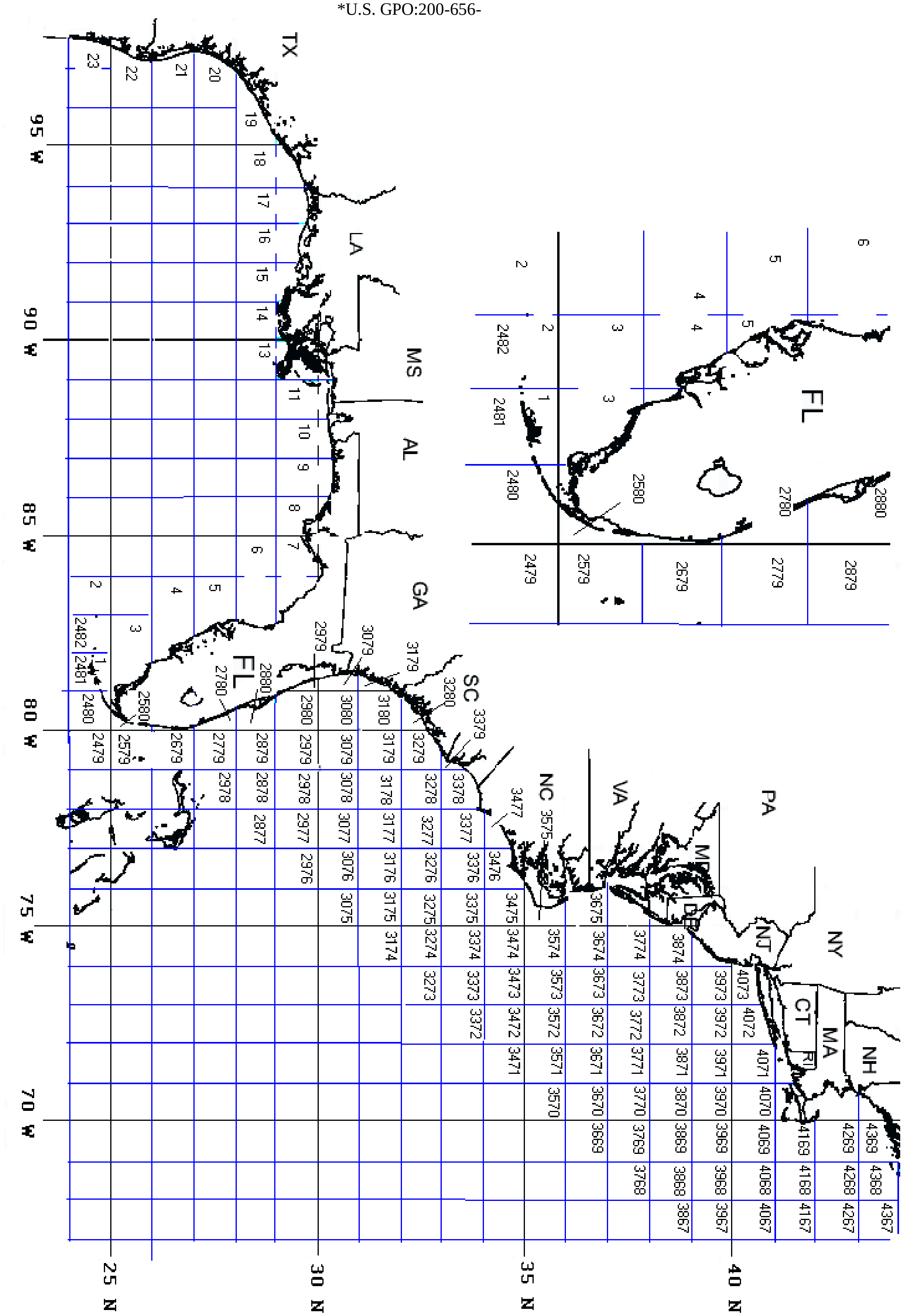
Southeast Region including Council and EEZ Boundaries



South Atlantic Council Boundaries, including contours, EEZ, and statistical area grid



*U.S. GPO:200-656-



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Statistical Grids and Codes

5. Summary Report

The Summary Report provides a broad but concise view of the salient aspects of the stock assessment. It recapitulates: (a) the information available to and prepared by the Data Workshop (DW); (b) the application of those data, development and execution of one or more assessment models, and identification of the most reliable model configuration as the base run by the Assessment Workshop (AW); and (c) the findings and advice determined during the Review Workshop (RW). All contents of the Summary Report are also elsewhere in the Stock Assessment Report (SAR).

5.1. Stock Distribution and Identification

Vermilion snapper have a broad geographic range extending from North Carolina to Sao Paulo, Brazil including the Gulf of Mexico. Although adult vermilion snapper have a relatively small home range based on mark recapture studies, genetic studies have only found weak evidence for genetic stock structure in this species.

Given the differences in the weight-length relationship, longevity, and weak genetic separation between the GOM and SA vermilion snapper, the DW Life History Work Group recommended keeping the GOM and SA management units separate for vermilion snapper. Recommendations for the AW were to keep the SA and GOM as separate stocks and use the jurisdiction set by the SAFMC (i.e., North Carolina through the east coast of Florida including Monroe County south of US 1 out to 83° West longitude).

5.2. Status of the Stock and Fishery

The base run of the catch-at-age model estimated the current stock status to be:

SSB_{2007}/SSB_{MSY} = 0.86 and

$SSB_{2007}/MSST$ = 1.10, both indicating the stock is not overfished.

It estimated the current fishery status in 2007 to be:

F_{2007}/F_{MSY} = 1.27, indicating the stock was subject to overfishing in 2007.

The SEDAR 17 Review Panel determined:

- The stock assessment as presented by the Assessment Workshop (AW) was accepted.
- It was concluded that the stock is not overfished.
- The determination was made that the stock is subject to overfishing. However, this conclusion is highly uncertain due to a lack of robustness to key model assumptions.

5.3. Assessment Methods

Three different model structures were applied: a statistical catch-at-age model, stock reduction analysis, and a surplus production model. In addition, catch curve analysis was used to examine mortality. The primary model was a statistical catch-at-age model implemented with the AD Model Builder software. In essence, a statistical catch-at-age model simulates a population forward in time while including fishing processes. Quantities to be estimated are systematically varied until characteristics of the simulated populations match available data on the real population. Statistical catch-at-age models share many attributes with ADAPT-style tuned and untuned VPAs.

Overall, the catch-at-age model 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 (See AW Figure 3.6 in Status Determination Criteria below). The model was configured to fit observed commercial and recreational landings closely. Fits to indices of abundance were reasonable. Observed fishery dependent indices were positively correlated, showing in general an increasing trend since the mid-1990s; predictions from recreational fisheries tracked this trend, but the commercial handline did not. That increasing trend was not apparent in the observed or predicted fishery independent chevron trap index.

A logistic surplus production model, implemented in ASPIC was used to estimate stock status. This approach was intended as a complement of the age-structured approach, and for additional verification that it was providing reasonable results.

After considering the results of several requested sensitivity runs, the Review Panel concluded that the assessment methods were adequate but not appropriate to fully address all terms of references. Rational and suggested improvements to the assessment methods used are covered under Section 2.1.8 of the RW Report.

5.4 . Assessment Data Sources

The catch-at-age model included data from five fisheries (1946–2007) on southeastern U.S. vermilion snapper: recreational headboat, general recreational, commercial historic trawl (1961–1962), commercial hook and line (handline), and commercial combined (recent trawl, trap, spears, longline, and other miscellaneous gears). The model was fit to data on annual landings, annual discard mortalities, annual length compositions of landings, annual age compositions of landings, annual length compositions of discards, three fishery dependent indices of abundance (commercial handline, general recreational, and headboat), and two fishery independent indices of abundance.

The fishery dependent data available to the AW are shown in Table 1. These data were employed to estimate values for years not available to during the 1946-2007 time series to be fit to the catch-at-age model.

Table 1. Fishery Dependent Assessment Data

Fishery, Index, or Survey	Period	Estimated Discards	Length Composition	Age Composition
Commercial combined*	1971-2007	--	1983-2007	--
Commercial handlines**	1958-2007	1992-2007	1983-2007	1992-2007
Historical trawl	1961-1962	--	--	--
MRFSS	1981-2007	1981-2007	1981-2007	2001-2007
Pre-MRFSS surveys	1960,1965,1970	--	--	--
Headboat survey	1972-2007	1999, 2004-2006	1972-2007	1975-2007
Headboat survey Discard Lengths	--	--	2004-2007	--

* Commercial combined includes recent trawl, traps, spears, longline, and other miscellaneous gears.
** Consists of manual and electric reels and 96 pounds of trawl in 1961

The 1960, 1965, and 1970 recreational landings estimates in number included headboat landings and the typical MRFSS fishing modes (shore, private vessel, charter vessel). Appropriate use of these values received considerable discussion during the AW. In particular, the AW panel was concerned about the potential for recall bias, as the salt-water angling survey was based on a 1-year recall. In general, such a long recall is likely to lead to overestimates of landings and effort. The AW panel had no information to estimate the amount of bias for SEDAR 17 species, but acknowledged that landings reported in the angling survey were likely biased high, and recommended reducing the 1960, 1965, and 1970 estimates to between 50% and 100% of the reported values. Thus, these estimates were reduced to 75% of the reported values for the base run of the assessment model. For sensitivity runs, values of 50%, 100%, and 125% were used. The Review Panel noted any additional information to substantiate these estimates, such as results from the Schlitz tagging programs of the 1960s, would be beneficial.

The model was fit to two fishery independent indices of abundance (MARMAP FL snapper trap 1983–1987; chevron trap 1990–2007) and to three fishery dependent indices of abundance (headboat 1976–2007; MRFSS 1987–2007; and commercial handline 1993–2007).

DW Table 5.1 displays the available catch and effort data sources considered for use in the assessment as indices of abundance. Both fishery dependent and fishery-independent sources are included. Note the final column indicates whether or not the source was recommended by the DW for use by the AW.

The Review Panel stated in its report that the DW provided adequate stock assessment data for use in the assessment. It considered that the best available data were made available to the AW and that appropriate life history parameters were supplied. Suggested improvements to the output of the DW are covered under Section 2.1.8 of its report.

Table 5.1. Vermilion snapper: A summary of catch-effort time series available for the SEDAR 17 data workshop.

Fishery Type	Data Source	Area	Years	Units	Standardization Method	Size Range	Issues	Use?
Recreational	Headboat	NC-FL	1976-2007	Number per angler-hr	Stephens and MacCall; delta-GLM	Same as fishery	Fishery dependent	Y
Commercial	Logbook - handline	NC-FL	1993-2007	Pounds per hook-hr	Stephens and MacCall; delta-GLM	Same as fishery	Fishery dependent	Y
Recreational	MRFSS	NC-FL	1987-2007	Number per angler-trip	Angler-trips included if species was targeted or caught (A+B1+B2); Nominal	Same as fishery	Fishery dependent	Y
Independent	MARMAP Chevron trap	NC-FL	1990-2007	Number per trap-hr	delta-GLM	Generally 15-40 cm	High variability	Y
Independent	MARMAP Florida trap	NC-FL	1983-1987	Number per trap-hr	delta-GLM	Generally 15-40 cm	High variability	Y
Independent	MARMAP Blackfish trap	NC-FL	1978-1987	Number per trap-hr	—	—	Low numbers of samples	N
Independent	MARMAP Hook and line	NC-FL	1979-1998	Number per hook-hr	—	—	Inconsistent sampling effort over time	N
Independent	MARMAP Short longline	NC-FL	1980-2007	Number per hook-hr	—	—	Very low sample sizes	N
Independent	MARMAP trawl	NC-FL	1980-1987		—	—	Low numbers of samples	N
Independent	SEAMAP	NC-FL	1990-2007	Number per hectare	—	—	Very low sample sizes	N
Independent	NMFS Northeast Groundfish Trawl	ME - Cape Hatteras	1972-2007	Number per trawl	—	—	Low sample sizes	N
Independent	Diver Reports (Reef.org)	NC-FL	1990-2007	—	—	—	Voluntary reporting	N
Recreational	NC Citation Program	NC	?-2007	—	—	—	Voluntary reporting, variable publicity, target species may not be included in program	N
Recreational	Online recreational trip reporting (myfish.com)	NC-FL	2007	—	—	—	Voluntary reporting, currently only on year of data available	N

5.5. Catch Trends

DW Figure 3.6 presents landings by commercial gear during 1958-2007. DW Table 3.2 shows commercial landings in pounds of whole weight by gear.

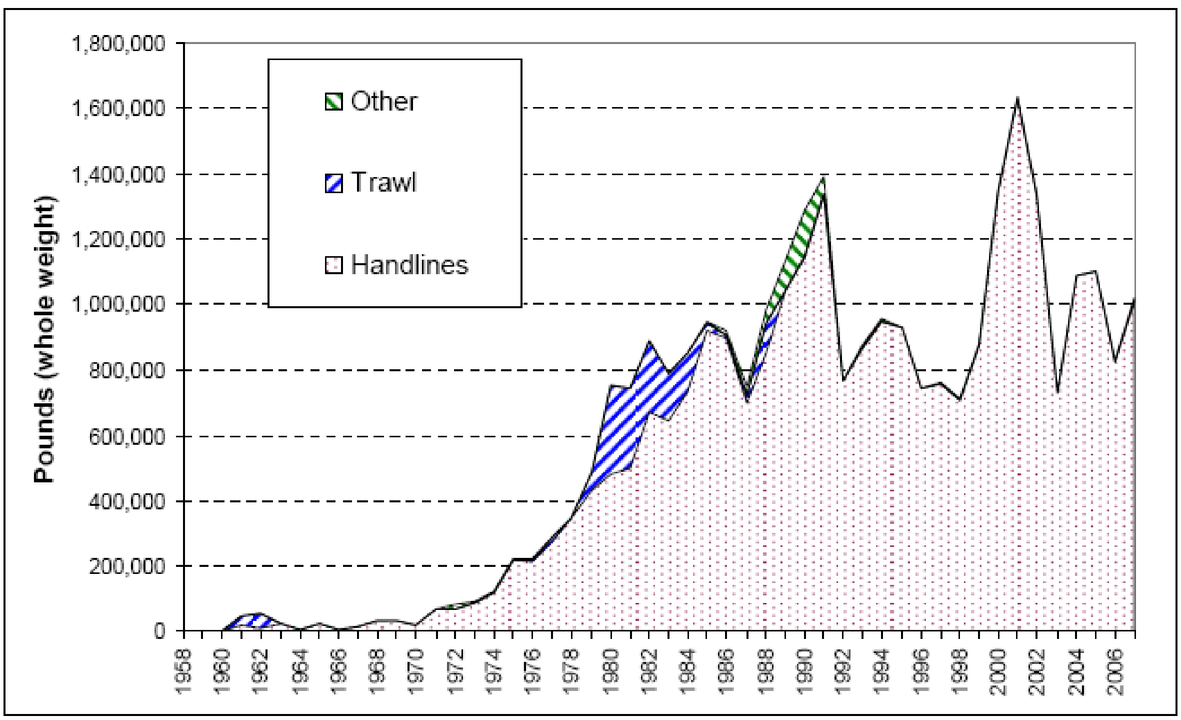


Figure 3.6. Vermilion snapper landings (pounds whole weight) by gear from the U.S. South Atlantic, 1958-2007. (see text for data sources).

Table 3.2. Vermilion snapper commercial landings (pounds whole weight) by gear for the US South Atlantic.

US South Atlantic - Gear				
Year	Handlines	Trawl	Other	Total
1958	194	0	0	194
1959	1,262	0	0	1,262
1960	1,747	0	0	1,747
1961	19,317	24,025	0	43,341
1962	10,822	42,582	0	53,405
1963	20,967	0	0	20,967
1964	6,792	0	0	6,792
1965	21,913	96	0	22,009
1966	3,397	0	0	3,397
1967	14,172	0	0	14,172
1968	31,936	0	0	31,936
1969	31,347	0	0	31,347
1970	19,511	0	0	19,511
1971	66,321	395	0	66,717
1972	68,794	0	11,790	80,584
1973	86,193	1,922	4,190	92,305
1974	119,387	0	2,728	122,115
1975	218,655	729	2,096	221,481
1976	212,410	7,144	378	219,931
1977	273,322	10,985	312	284,619
1978	345,076	1,047	0	346,122
1979	430,888	54,161	0	485,049
1980	482,636	268,613	0	751,249
1981	500,886	242,732	161	743,779
1982	672,796	215,630	36	888,462
1983	645,732	142,058	725	788,514
1984	734,077	117,694	262	852,032
1985	920,506	24,028	955	945,490
1986	896,379	10,587	13,390	920,356
1987	697,928	23,627	28,004	749,560
1988	854,227	89,294	42,243	985,765
1989	1,041,509	1,232	88,834	1,131,575
1990	1,141,190	4,613	144,100	1,289,902
1991	1,332,693	4,146	57,272	1,394,111
1992	764,936	33	244	765,214
1993	866,361	58	8,494	874,913
1994	948,426	0	9,734	958,160
1995	928,497	6	2,870	931,374
1996	743,692	40	1,354	745,087
1997	759,005	0	2,012	761,017
1998	708,112	1,101	1,293	710,506
1999	876,584	386	4,124	881,093

Table 3.2. (cont.)

2000	1,348,519	0	1,592	1,350,111
2001	1,633,594	0	3,230	1,636,824
2002	1,334,418	67	1,271	1,335,756
2003	727,859	0	6,970	734,829
2004	1,086,300	378	2,298	1,088,976
2005	1,100,916	2	869	1,101,787
2006	827,160	0	1,460	828,620
2007	1,012,612	0	7,693	1,020,305

Recreational headboat landings of vermilion snapper by state are shown in DW Table 4.8.2. Estimates of recreational discards of the headboat and general MRFSS recreational fisheries are presented in AW Figure 2.5.

Table 4.8.2. Total pounds of vermilion snapper landed by state in the South Atlantic headboat fishery 1981-2007

Year	NC	SC	GA\NEFL	SEFL	Grand Total
1981	81367	35071	85488	28059	229984
1982	123943	89066	97716	29115	339840
1983	93368	59097	96225	46694	295385
1984	47387	47944	121258	28375	244964
1985	53764	98190	156360	63853	372168
1986	55031	93358	145767	55159	349315
1987	39025	134761	154955	123200	451941
1988	46433	131111	150128	90965	418638
1989	41137	91577	105393	108433	346539
1990	108164	109316	81438	87856	386774
1991	128149	109386	65784	29985	333303
1992	95828	105671	20593	27505	249597
1993	73549	138415	16758	28478	257200
1994	92947	154310	13914	20477	281647
1995	92286	146054	10776	22743	271859
1996	77650	158325	10038	30295	276308
1997	85591	187511	15196	11615	299912
1998	70050	170842	23359	11240	275492
1999	86975	191435	46493	10830	335732
2000	102668	225250	64681	14188	406785
2001	109674	194077	73862	25007	402620
2002	82365	160671	59469	23941	326447
2003	59937	135208	57044	35255	287444
2004	96470	175888	54798	34406	361562
2005	111582	133264	56619	10512	311977
2006	128547	195696	71091	7017	402351
2007	138038	405324	67177	3225	613765
Grand Total	2321925	3876817	1922380	1008428	9129550

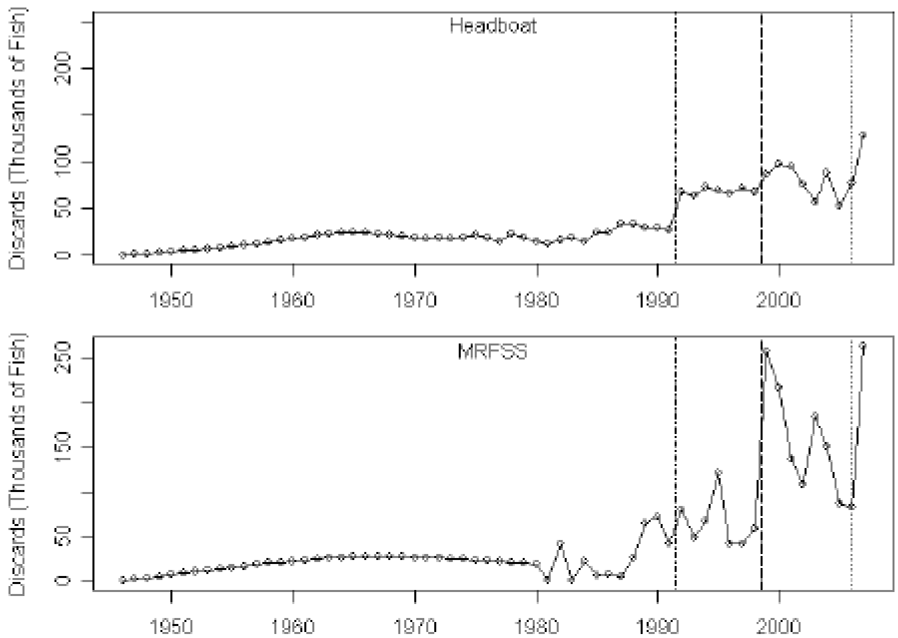


Figure 2.5. Recreational discard estimates in thousands of fish. Vertical lines represent size-limit changes for 1992 (dot-dash line), 1999 (dashed line), and during 2006 (dotted line).

5.6. Fishing Mortality Trends

The estimated time series of fishing mortality rate (*F*) shows a generally increasing trend from the 1950s through 1991, and has since been relatively stable around a mean near $F = 0.32$ (AW Figure 3.42). An uncharacteristically high estimate of *F* in 1991 is due to high F in the commercial handline and combined gears, both of which result from relatively high landings in that year combined with fewer available at the ages selected by gear. In the most recent years, the majority of full *F* was from commercial handline and headboat landings.

Estimated landings in pounds of whole weight by recreational and commercial fisheries modeled in the assessment are presented in AW Figure 3.44. Estimated discard mortalities from the general recreational, headboat, and commercial handline fisheries are displayed in AW Figure 3.45.

Figure 3.42. Estimated instantaneous fishing mortality rate (per year) by fishery. c.hal refers to commercial handline, c.htr to commercial historic trawl, c.cmb to commercial combined, hb to headboat, rec to general recreational, c.hal.D to commercial discard mortalities, hb.D to headboat discard mortalities, and rec.D to general recreational discard mortalities.

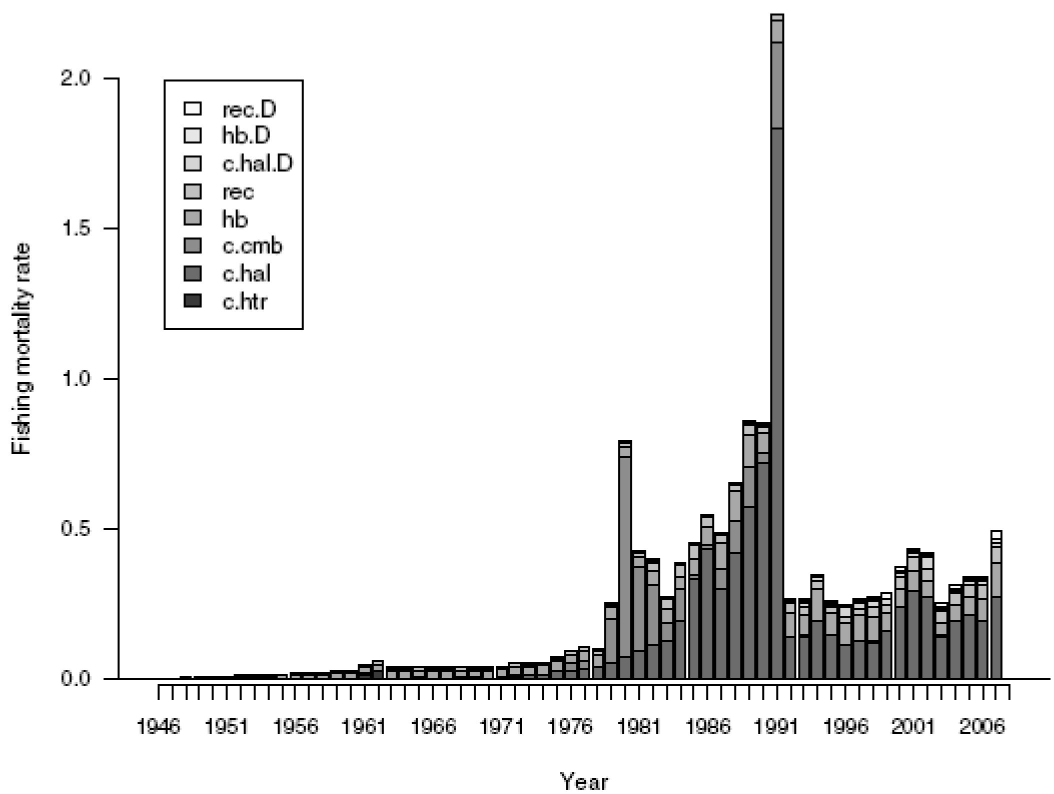


Figure 3.44. Estimated landings in whole weight by fishery from the catch-at-age model. c.hal refers to commercial handline, c.htr to commercial historic trawl, c.cmb to commercial combined, hb to headboat, rec to general recreational.

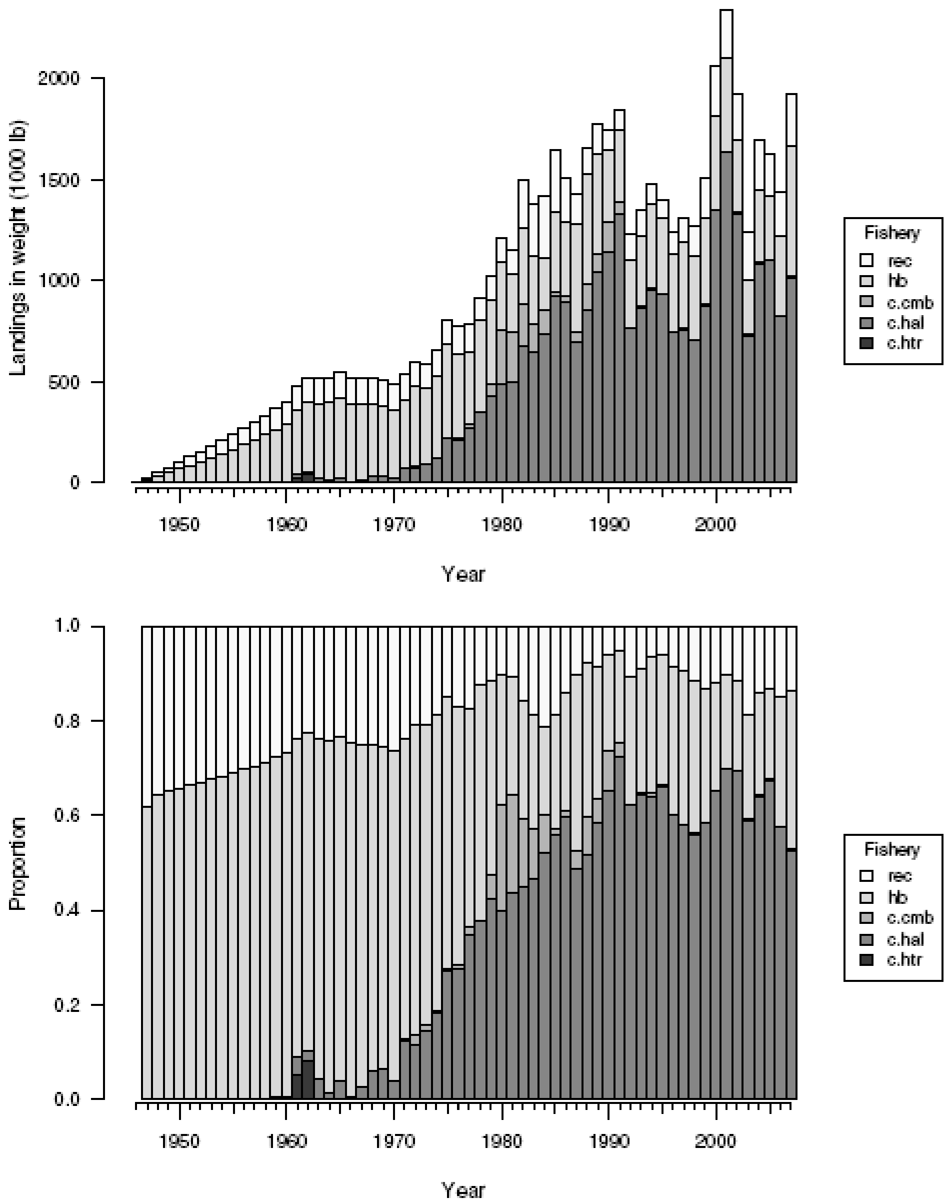
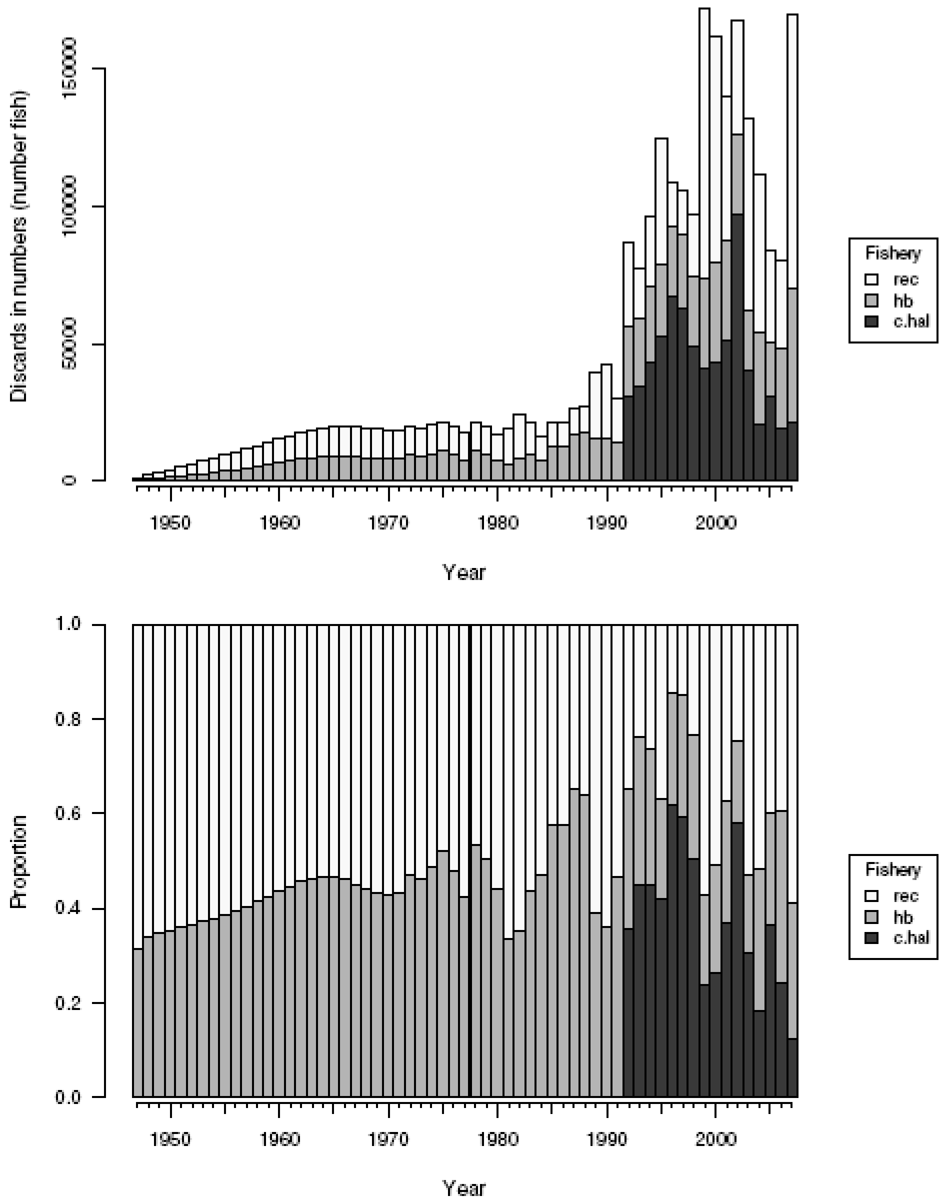


Figure 3.45. Estimated discard mortalities by fishery from the catch-at-age model. c.hal refers to commercial handline, hb to headboat, rec to general recreational.



5.7. Stock Abundance and Biomass Trends

Estimated abundance at age shows some truncation of the age structure, an expected consequence of fishing (AW Table 3.3). Annual numbers of recruits are shown in the age-1 column. Notably strong year classes were predicted to have occurred in 1978, 1990, and 1992. Years 2001 and 2002 were the most recent to have experienced stronger-than-expected recruitment.

Estimated biomass at age follows a similar pattern as abundance at age (AW Table 3.5). Total biomass and spawning biomass show nearly identical trends—gradual decline during the 1950s and 1960s, steep decline during the mid-1970s through 1980s, general increase during the 1990s, and then decline since 2000 (AW Figure 3.32).

A measure of the annual equilibrium spawners per recruit relative to the spawners per recruit in an unfished population is the static spawning potential ratio, and for vermilion snapper it is shown through time in AW Figure 3.48.

Figure 3.48. Estimated time series of static spawning potential ratio, the annual equilibrium spawners per recruit relative to that at the unfished level.

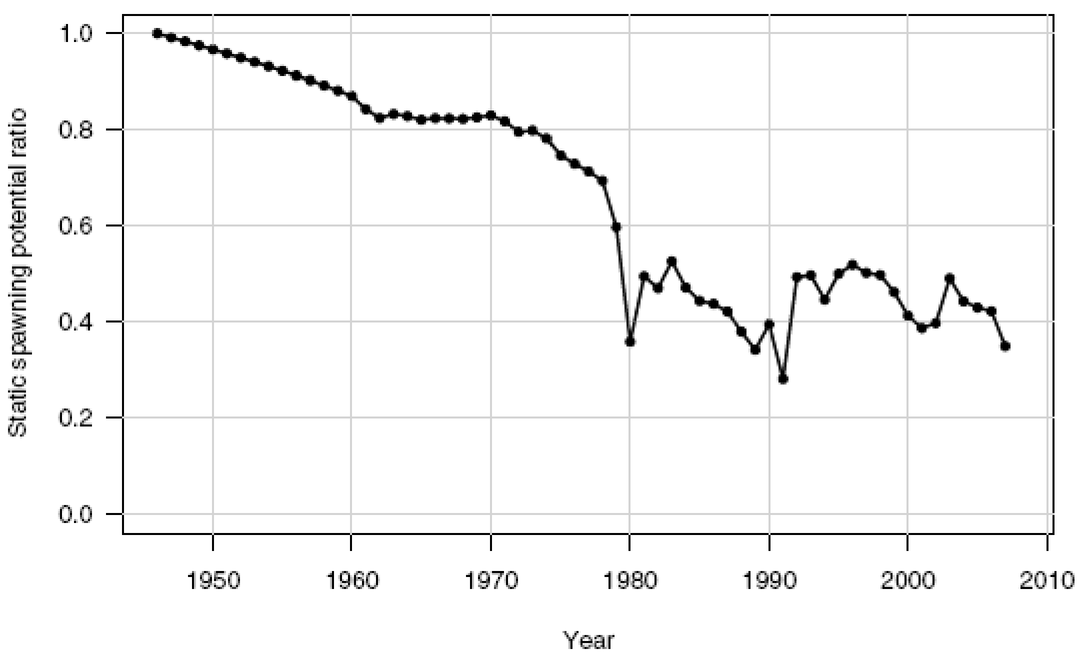
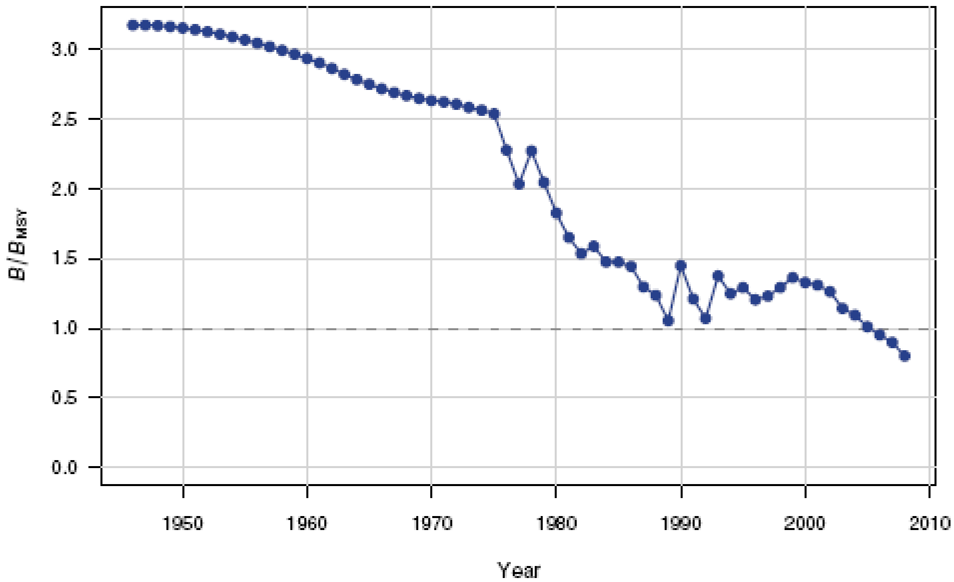


Figure 3.53. Estimated time series of biomass relative to MSY benchmarks. Top panel: B relative to B_{MSY}. Bottom panel: SSB relative to SSB_{MSY}.



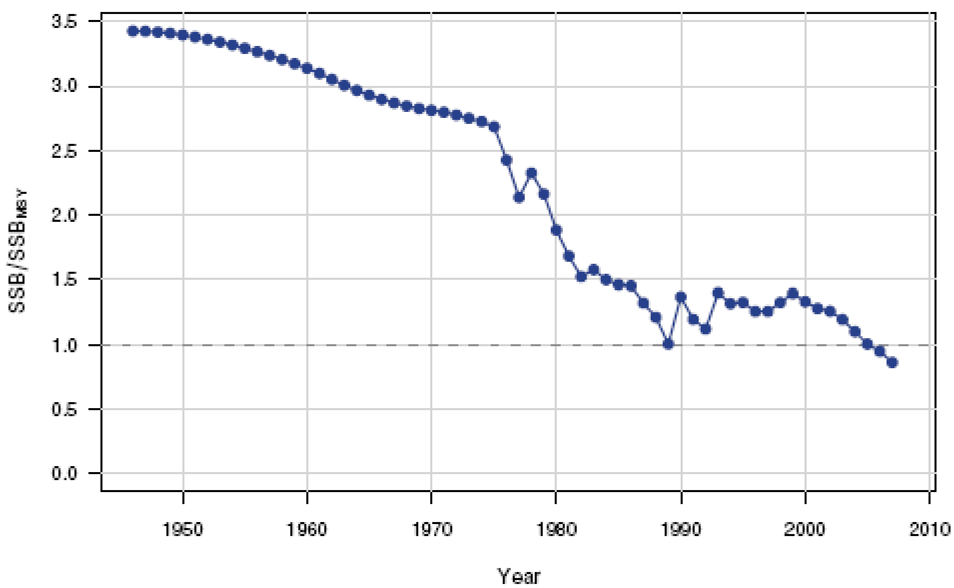


Table 3.3. Estimated abundance at age (1000 fish) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12
1946	6073.9	4318.9	3186.8	2413.3	1864.5	1462.3	1160.7	929.6	750.5	609.6	498.1	2317.1
1947	6073.9	4318.9	3186.8	2413.3	1864.5	1462.3	1160.7	929.6	750.5	609.6	498.1	2317.1
1948	6073.4	4316.2	3183.5	2410.3	1862.2	1460.4	1159.1	928.3	749.5	608.7	497.4	2314.0
1949	6071.8	4313.1	3178.2	2404.9	1857.5	1456.6	1156.0	925.8	747.4	607.1	496.0	2307.6
1950	6069.2	4309.2	3172.6	2397.9	1850.9	1451.0	1151.4	922.0	744.3	604.5	494.0	2298.0
1951	6065.8	4304.6	3166.4	2390.5	1843.1	1443.8	1145.4	917.1	740.2	601.2	491.2	2285.1
1952	6061.6	4299.3	3159.5	2382.7	1835.0	1435.7	1138.0	910.9	735.2	597.0	487.7	2268.9
1953	6056.7	4293.4	3152.1	2374.3	1826.4	1427.2	1129.9	903.7	729.1	592.0	483.6	2249.4
1954	6051.0	4286.7	3144.0	2365.3	1817.3	1418.3	1121.5	895.8	722.2	586.1	478.8	2226.6
1955	6044.6	4279.5	3135.3	2355.7	1807.6	1409.0	1112.7	887.6	714.7	579.6	473.3	2200.3
1956	6037.6	4271.6	3126.0	2345.6	1797.5	1399.2	1103.5	879.1	706.9	572.6	467.2	2170.7
1957	6029.9	4263.1	3116.0	2334.8	1786.7	1388.9	1093.8	870.3	698.9	565.3	460.7	2137.7
1958	6021.5	4253.9	3105.4	2323.4	1775.4	1378.0	1083.6	861.0	690.5	557.8	453.9	2101.7
1959	6012.5	4244.0	3094.1	2311.3	1763.4	1366.5	1073.0	851.2	681.7	550.0	447.0	2062.8
1960	6002.7	4233.4	3082.1	2298.5	1750.7	1354.3	1061.6	840.9	672.4	541.7	439.7	2021.1
1961	5992.2	4222.1	3069.2	2284.9	1737.3	1341.6	1049.7	830.1	662.7	533.1	432.1	1977.0
1962	5979.8	4149.7	3055.6	2270.5	1723.1	1326.6	1035.7	817.5	651.5	523.3	423.5	1927.5
1963	5965.2	4089.8	2997.7	2255.4	1708.3	1313.3	1022.3	805.1	640.5	513.5	414.9	1877.7
1964	5950.3	4181.8	2949.6	2208.3	1693.4	1298.2	1008.8	792.1	628.8	503.2	405.9	1825.2
1965	5937.2	4168.1	3012.3	2169.6	1655.5	1286.0	996.9	781.4	618.4	493.8	397.5	1775.5
1966	5924.6	4157.1	3000.3	2213.8	1624.9	1254.6	985.0	770.2	608.4	484.4	389.1	1724.9
1967	5913.3	4147.9	2991.9	2204.6	1657.8	1232.9	962.5	762.3	600.7	477.4	382.3	1680.7
1968	5903.8	4140.9	2986.3	2199.4	1651.6	1257.4	945.3	744.4	594.2	471.0	376.6	1639.2
1969	5895.3	4135.6	2982.8	2196.7	1648.8	1251.9	963.0	730.3	579.6	465.4	371.2	1600.0
1970	5888.3	4131.1	2980.6	2195.5	1647.9	1250.7	959.6	744.6	569.1	454.4	367.0	1565.8
1971	5883.1	4126.9	2978.2	2194.6	1647.6	1251.6	960.2	743.1	581.1	446.8	358.9	1537.8
1972	5877.7	4121.8	2974.6	2192.3	1646.6	1246.6	955.9	739.7	577.0	453.9	351.1	1501.2
1973	5869.5	4081.9	2962.7	2182.3	1638.8	1240.7	948.0	733.3	571.9	448.8	355.2	1459.8
1974	5860.3	4092.5	2936.3	2175.6	1633.0	1234.4	942.8	726.6	566.5	444.4	350.8	1429.1
1975	5850.3	4089.4	2938.3	2151.2	1623.9	1223.4	932.0	717.9	557.7	437.3	345.2	1392.5
1976	1079.2	4074.3	2927.5	2145.0	1599.5	1201.7	909.6	698.9	542.6	424.0	334.5	1338.6
1977	1400.4	734.0	2916.8	2137.0	1594.4	1183.3	893.2	681.9	528.0	412.4	324.1	1288.3
1978	11810.6	948.8	524.8	2126.6	1588.7	1173.0	872.9	664.6	511.3	398.3	312.9	1232.6
1979	1426.4	8215.4	671.8	378.6	1570.9	1153.1	851.6	639.2	490.5	379.7	297.5	1162.9
1980	1929.3	857.7	5861.4	488.3	280.0	1130.2	826.8	615.8	465.8	359.6	280.0	1084.7
1981	3503.2	686.4	612.8	4268.0	361.9	199.4	798.7	589.3	442.3	336.6	261.3	999.1
1982	4203.8	1839.5	487.5	443.6	3161.7	254.0	138.2	558.4	415.2	313.5	240.0	905.3
1983	8592.2	2358.1	1280.8	344.4	319.8	2126.1	167.7	92.0	374.5	280.1	212.8	783.0
1984	4021.6	5545.2	1644.6	905.9	247.9	212.5	1381.2	109.8	60.7	248.6	187.1	669.8
1985	6360.0	2467.3	3877.5	1165.9	651.5	156.5	128.9	844.8	67.7	37.6	155.0	538.1
1986	6094.4	4250.7	1694.9	2690.0	819.3	362.5	80.6	66.9	441.8	35.6	19.9	369.4
1987	2856.1	4100.3	2947.4	1189.6	1915.0	427.7	170.5	38.2	32.0	212.3	17.2	189.6
1988	4586.4	1803.1	2801.8	2031.5	830.1	1081.6	225.4	90.5	20.5	17.2	114.9	112.8
1989	2555.9	2767.9	1224.2	1916.7	1408.4	426.0	501.9	105.4	42.6	9.7	8.2	109.2
1990	15458.8	1488.7	1849.8	822.1	1306.6	634.8	166.7	197.9	41.9	17.0	3.9	47.5
1991	881.0	10207.5	1025.5	1290.7	586.8	554.4	225.3	59.7	71.4	15.2	6.2	18.9
1992	3514.5	450.1	7065.6	718.1	915.8	108.8	64.2	26.3	7.0	8.4	1.8	3.0
1993	10414.9	2499.0	329.2	4641.5	428.2	555.0	66.8	39.8	16.4	4.4	5.3	3.1
1994	1210.3	7405.6	1819.7	214.5	2796.9	262.6	345.1	41.9	25.2	10.5	2.8	5.4
1995	5797.7	860.6	5429.1	1140.6	118.7	1575.2	149.9	199.0	24.4	14.8	6.2	4.9
1996	2671.6	4122.5	626.7	3559.5	689.5	73.0	981.3	94.3	126.3	15.6	9.5	7.2
1997	5034.5	1899.7	3015.6	410.8	2199.1	434.1	46.6	634.0	61.5	82.9	10.3	11.1
1998	5966.5	3579.8	1388.3	1973.5	248.5	1353.7	270.9	29.4	403.3	39.4	53.5	13.9
1999	5990.5	4242.5	2614.5	903.9	1187.9	152.3	841.4	170.2	18.6	257.4	25.3	43.5
2000	4206.1	4259.6	2981.0	1604.6	537.6	719.7	93.6	522.6	106.7	11.8	163.5	44.0
2001	5845.2	2990.8	2994.6	1741.4	873.5	298.0	404.6	53.2	299.6	61.6	6.8	121.2
2002	5653.4	4156.3	2102.9	1685.0	888.4	453.8	157.0	215.4	28.6	162.1	33.5	70.3
2003	3054.7	4019.9	2947.5	1188.3	881.8	474.5	246.2	86.2	119.4	16.0	91.1	58.8
2004	3039.3	2172.1	2866.8	1859.1	727.3	549.3	299.7	157.1	55.5	77.4	10.4	98.4
2005	3370.9	2161.1	1531.7	1738.2	1068.3	425.2	325.6	179.4	94.9	33.7	47.4	67.1
2006	3678.7	2396.9	1531.0	913.6	973.2	608.8	245.7	190.1	105.7	56.3	20.1	68.8
2007	3272.1	2615.8	1677.7	900.9	510.2	553.1	350.8	143.1	111.6	62.5	33.5	53.3
2008	3178.8	2290.3	1701.1	907.6	446.3	256.4	281.0	179.7	73.8	58.0	32.6	45.6

Table 3.5. Estimated biomass at age (1000 lb) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12
1946	2019.3	2088.4	2072.1	1993.9	1876.2	1734.2	1580.7	1423.8	1270.8	1125.0	990.2	4912.7
1947	2019.3	2088.4	2072.1	1993.9	1876.2	1734.2	1580.7	1423.8	1270.8	1125.0	990.2	4912.7
1948	2019.1	2087.1	2069.9	1991.5	1873.8	1731.9	1578.6	1421.8	1269.0	1123.5	988.8	4906.0
1949	2018.6	2085.6	2066.5	1987.0	1869.1	1727.4	1574.4	1417.9	1265.5	1120.4	986.1	4892.5
1950	2017.8	2083.7	2062.9	1981.2	1862.5	1720.8	1568.1	1412.2	1260.3	1115.7	982.0	4872.1
1951	2016.6	2081.5	2058.8	1975.1	1854.6	1712.3	1559.8	1404.5	1253.4	1109.5	976.5	4844.8
1952	2015.2	2078.9	2054.3	1968.6	1846.4	1702.6	1549.9	1395.1	1244.7	1101.7	969.6	4810.5
1953	2013.6	2076.0	2049.5	1961.7	1837.8	1692.6	1538.8	1384.0	1234.5	1092.5	961.4	4769.2
1954	2011.7	2072.8	2044.2	1954.3	1828.6	1682.1	1527.3	1372.0	1222.7	1081.7	951.8	4720.7
1955	2009.6	2069.3	2038.6	1946.4	1818.9	1671.0	1515.4	1359.5	1210.1	1069.7	940.8	4665.1
1956	2007.2	2065.5	2032.5	1938.0	1808.7	1659.4	1502.8	1346.5	1197.0	1056.7	928.7	4602.2
1957	2004.7	2061.4	2026.1	1929.1	1797.9	1647.1	1489.6	1332.9	1183.3	1043.4	915.8	4532.4
1958	2001.9	2057.0	2019.2	1919.7	1786.5	1634.2	1475.8	1318.6	1169.1	1029.5	902.4	4455.9
1959	1998.9	2052.2	2011.8	1909.7	1774.4	1620.6	1461.3	1303.7	1154.2	1015.0	888.6	4373.4
1960	1995.7	2047.1	2004.0	1899.1	1761.7	1606.2	1445.8	1287.9	1138.5	999.8	874.1	4285.1
1961	1992.2	2041.6	1995.7	1887.8	1748.2	1591.0	1429.6	1271.3	1122.1	983.9	858.9	4191.5
1962	1988.0	2006.6	1986.8	1875.9	1733.9	1573.2	1410.4	1252.0	1103.2	965.7	841.8	4086.7
1963	1983.2	1977.6	1949.2	1863.5	1719.0	1557.5	1392.3	1233.0	1084.5	947.7	824.8	3981.1
1964	1978.2	2022.1	1917.9	1824.5	1704.0	1539.6	1373.9	1213.2	1064.6	928.7	806.9	3869.8
1965	1973.9	2015.5	1958.6	1792.6	1665.8	1525.1	1357.6	1196.7	1047.0	911.2	790.3	3764.2
1966	1969.7	2010.1	1950.8	1829.1	1635.1	1487.9	1341.5	1179.6	1030.2	894.0	773.5	3657.0
1967	1965.9	2005.7	1945.4	1821.5	1668.2	1462.1	1310.8	1167.5	1017.1	881.0	760.1	3563.4
1968	1962.8	2002.3	1941.7	1817.2	1661.9	1491.2	1287.4	1140.1	1006.0	869.3	748.6	3475.4
1969	1959.9	1999.8	1939.5	1814.9	1659.1	1484.7	1311.6	1118.5	981.4	859.0	737.9	3392.3
1970	1957.6	1997.6	1938.0	1814.0	1658.2	1483.3	1306.9	1140.4	963.6	838.6	729.7	3319.8
1971	1955.9	1995.5	1936.4	1813.2	1657.9	1484.3	1307.7	1138.1	984.0	824.6	713.5	3260.3
1972	1954.1	1993.1	1934.1	1811.4	1656.8	1478.4	1301.9	1133.0	977.0	837.8	698.0	3182.9
1973	1951.4	1973.8	1926.4	1803.0	1649.1	1471.4	1291.1	1123.1	968.4	828.2	706.1	3095.0
1974	1948.3	1978.9	1909.2	1797.5	1643.2	1464.0	1283.9	1112.9	959.1	820.2	697.4	3030.0
1975	1945.0	1977.4	1910.5	1777.3	1634.0	1450.9	1269.3	1099.6	944.3	807.1	686.2	2952.3
1976	358.8	1970.1	1903.5	1772.2	1609.5	1425.1	1238.8	1070.4	918.7	782.5	665.0	2838.0
1977	465.6	354.9	1896.5	1765.7	1604.4	1403.3	1216.4	1044.3	894.0	761.0	644.4	2731.5
1978	3926.5	458.8	341.2	1757.1	1598.6	1391.2	1188.8	1017.8	865.8	735.1	622.1	2613.2
1979	474.2	3972.5	436.8	312.8	1580.7	1367.5	1159.8	979.0	830.5	700.7	591.5	2465.5
1980	641.4	414.7	3811.1	403.4	281.7	1340.4	1126.0	943.1	788.7	663.6	556.6	2299.7
1981	1164.7	331.9	398.5	3526.4	364.2	236.5	1087.8	902.5	748.9	621.2	519.6	2118.2
1982	1397.6	889.5	317.0	366.5	3181.5	301.3	188.2	855.2	703.0	578.6	477.2	1919.5
1983	2856.5	1140.3	832.8	284.5	321.8	2521.4	228.4	140.9	634.1	517.0	423.1	1660.2
1984	1337.0	2681.4	1069.3	748.5	249.4	252.0	1881.0	168.2	102.8	458.9	371.9	1420.2
1985	2114.4	1193.1	2521.2	963.3	655.5	185.6	175.6	1293.8	114.6	69.4	308.2	1141.0
1986	2026.1	2055.4	1102.1	2222.5	824.4	429.9	109.8	102.5	748.1	65.7	39.6	783.2
1987	949.5	1982.7	1916.4	982.8	1927.0	507.2	232.2	58.6	54.1	391.8	34.2	402.1
1988	1524.8	871.9	1821.7	1678.5	835.2	1282.8	307.0	138.7	34.6	31.8	228.5	239.2
1989	849.7	1338.4	796.0	1583.6	1417.2	505.3	683.5	161.4	72.2	17.9	16.3	231.5
1990	5139.4	719.9	1202.8	679.3	1314.8	752.8	227.1	303.1	70.9	31.4	7.7	100.8
1991	292.9	4935.8	666.8	1066.4	590.4	657.5	306.8	91.4	120.8	28.0	12.4	40.1
1992	1168.4	217.6	4594.1	593.3	921.5	129.0	87.4	40.3	11.9	15.6	3.6	6.4
1993	3462.5	1208.4	214.1	3834.9	430.9	658.1	90.9	60.9	27.8	8.1	10.6	6.5
1994	402.4	3581.0	1183.2	177.2	2814.4	311.4	469.9	64.2	42.7	19.3	5.6	11.5
1995	1927.5	416.1	3530.1	942.4	119.5	1868.1	204.2	304.8	41.3	27.3	12.3	10.4
1996	888.2	1993.4	407.5	2941.0	693.8	86.6	1336.5	144.5	213.9	28.8	18.9	15.2
1997	1673.8	918.6	1960.8	339.4	2212.9	514.8	63.5	971.0	104.2	153.1	20.5	23.5
1998	1983.6	1731.0	902.7	1630.5	250.0	1605.4	369.0	45.0	682.9	72.7	106.3	29.4
1999	1991.6	2051.5	1699.9	746.8	1195.3	180.6	1145.9	260.6	31.6	475.0	50.3	92.2
2000	1398.4	2059.7	1938.3	1325.8	541.0	853.5	127.5	800.4	180.6	21.7	325.0	93.3
2001	1943.3	1446.2	1947.1	1438.8	878.9	353.4	551.0	81.4	507.2	113.6	13.6	256.9
2002	1879.5	2009.7	1367.3	1392.2	894.0	538.2	213.9	330.0	48.4	299.1	66.6	149.1
2003	1015.6	1943.8	1916.5	981.8	887.3	562.7	335.3	132.0	202.2	29.4	181.2	124.7
2004	1010.4	1050.3	1864.0	1536.0	731.8	651.5	408.1	240.6	94.0	142.8	20.7	208.7
2005	1120.7	1045.0	995.9	1436.2	1075.0	504.3	443.4	274.8	160.7	62.3	94.1	142.3
2006	1223.0	1159.0	995.5	754.8	979.2	722.0	334.7	291.2	179.0	103.9	40.0	145.9
2007	1087.8	1264.8	1090.8	744.4	513.4	656.0	477.8	219.1	189.0	115.3	66.6	113.1
2008	1056.8	1107.5	1106.1	749.9	449.1	304.1	382.7	275.3	125.0	107.0	64.9	96.8

Figure 3.32. Top panel: Estimated total biomass (metric tons) at start of year. Bottom panel: Estimated spawning biomass (10^{12} eggs) at midpoint of year.

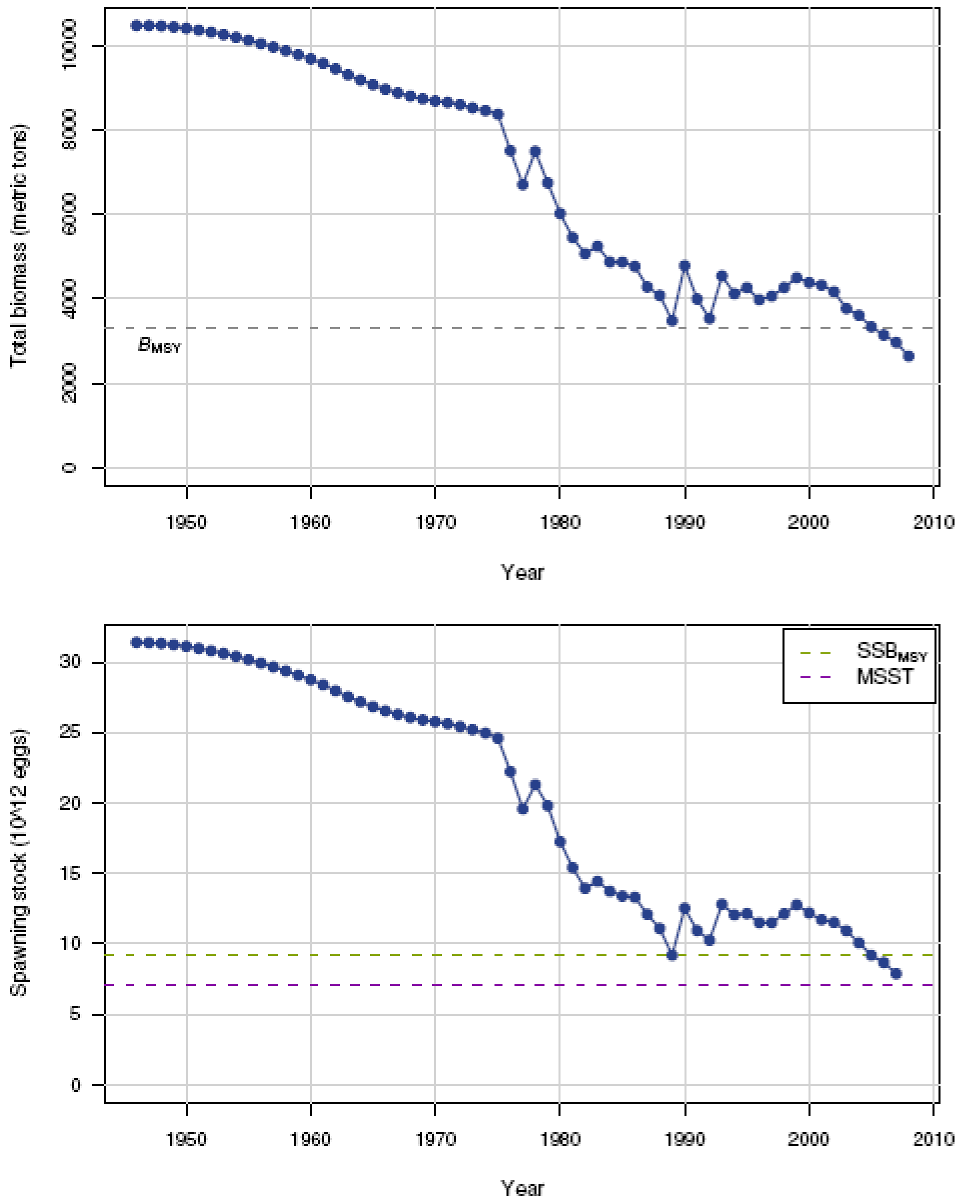
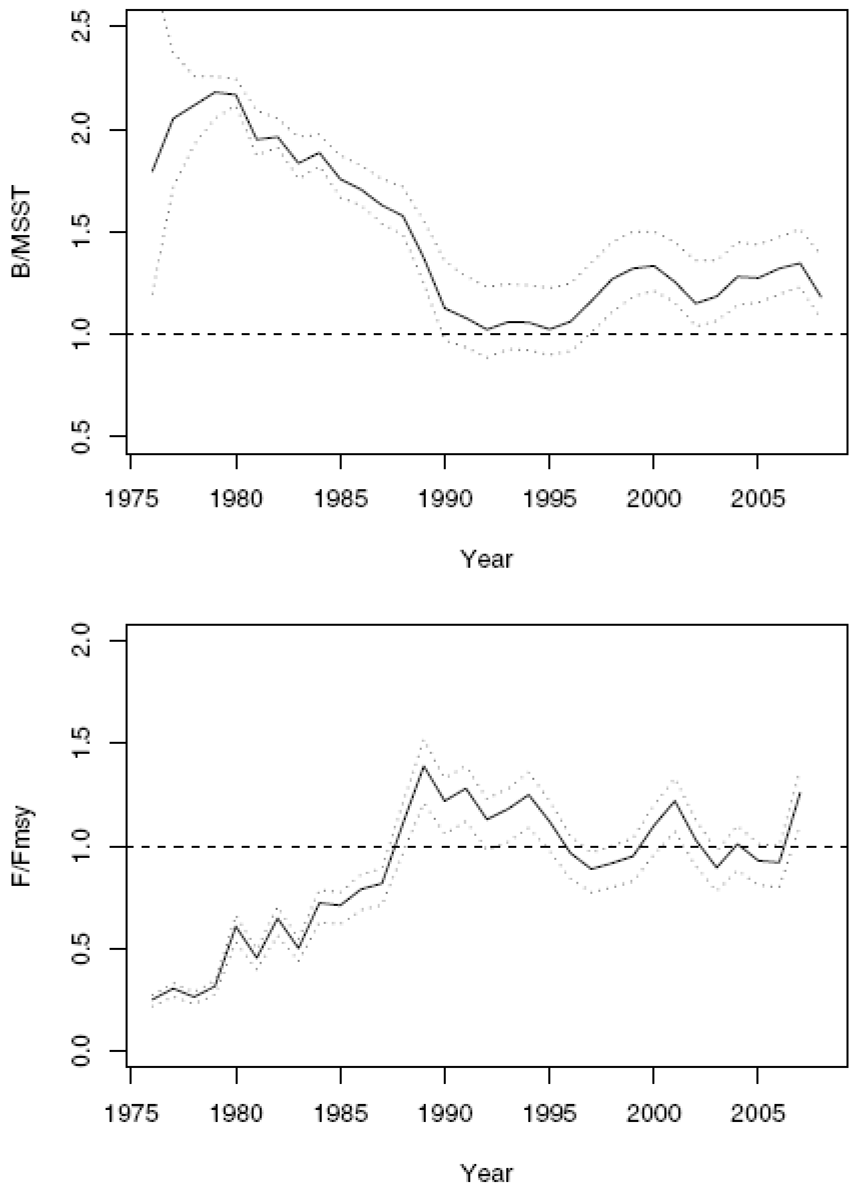


Figure 3.81. Base surplus production model estimates of biomass and fishing mortality rate relative to their thresholds. Dotted lines represent 80% approximate confidence limits from bootstrap analysis.



5.8. Status Determination Criteria

Biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the spawner-recruit curve with bias correction. 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. Uncertainty of benchmarks was computed through Monte Carlo/bootstrap analysis of the spawner-recruit curve.

Estimates of benchmarks are summarized in AW Table 3.16. Point estimates of MSY-related quantities were:

$F_{\text{MSY}} = 0.386/\text{yr}$,

MSY = 1665.27 klb

$B_{\text{MSY}} = 3299.78$ mt, and

$\text{SSB}_{\text{MSY}} = 9.16 \times 1012$ eggs.

Estimated time series of B/B_{MSY} and $\text{SSB}/\text{SSB}_{\text{MSY}}$ show similar patterns: initial status well above the MSY benchmark, general decline until 1990, followed by moderate increase until 1999, and then decline through the last assessment year (AW Figure 3.53 above, AW Table 3.6). Spawning biomass has remained above MSST throughout the time series, indicating that the stock is not overfished; however, the declining trend during the last decade may be of concern. Estimated age structure at the start of 2008 was similar to the equilibrium age structured expected at MSY.

As shown in AW Table 3.16, current stock status was estimated to be:

$\text{SSB}_{2007}/\text{SSB}_{\text{MSY}} = 0.86$ and

$\text{SSB}_{2007}/\text{MSST} = 1.10$.

The estimated time series of F/F_{MSY} shows a generally increasing trend until spiking in 1991. Since 1991, F/F_{MSY} has been relatively stable, with F generally less than F_{MSY} (AW Figure 3.55, AW Table 3.6). As shown in AW Table 3.16 current fishery status in the terminal year is estimated to be:

$F_{2007}/F_{\text{MSY}} = 1.27$, which indicates overfishing.

However, the geometric mean F from the last three years (F_{current} in projections) is approximately equal to F_{MSY} ($F_{\text{current}}/F_{\text{MSY}} = 0.997$).

Catch curve analysis suggested total mortality rate ranged from 0.2 to 1.4, with the bulk of the estimates between 0.4 and 0.7. Based on the constant estimate of natural mortality, $M = 0.22$, these values of Z suggest that fully selected fishing mortality rate is on the scale of $F = 0.18$ to $F = 0.48$, consistent with estimates from the catch-at-age model (AW Table 3.6).

In use of the stochastic stock reduction model, the posterior distribution of current F/F_{MSY} from the base run of the SRA indicated a high probability that overfishing is occurring. The posterior distribution of current SSB/MSST contained much uncertainty in stock status, but with a majority of the distribution indicating that the stock is not overfished. Sensitivity runs provided similar results. These runs suggest that overfishing is almost certainly occurring, and that higher precision in population growth rates imparts greater certainty that the stock is not overfished.

Estimates of annual biomass from the base surplus production model have been above MSST throughout the time series, while estimates of F have fluctuated around F_{MSY} since the late 1980s (See Aw Figure 3.81 above). The estimate of F_{2007}/F_{MSY} indicates overfishing in the terminal year. In general, the surplus production model provides indications of status similar to those of the age-structured model regarding 2007 status: the stock is not overfished, but overfishing may be occurring.

The Panel supports the estimates from the AW base model as follows:

Year :	2007
F:	0.49
F /F_{MSY}:	1.27
B (mt):	2966
B/$B_{unfished}$:	0.283
SSB/SSB_{MSY}:	0.861
SSB/MSST:	1.10

In agreeing with the AW on stock status, the Review Panel stated:

- The stock is not overfished. This conclusion is robust to most key model assumptions.
- The stock is subject to overfishing, but this conclusion is highly uncertain due to the lack of robustness to key model assumptions.

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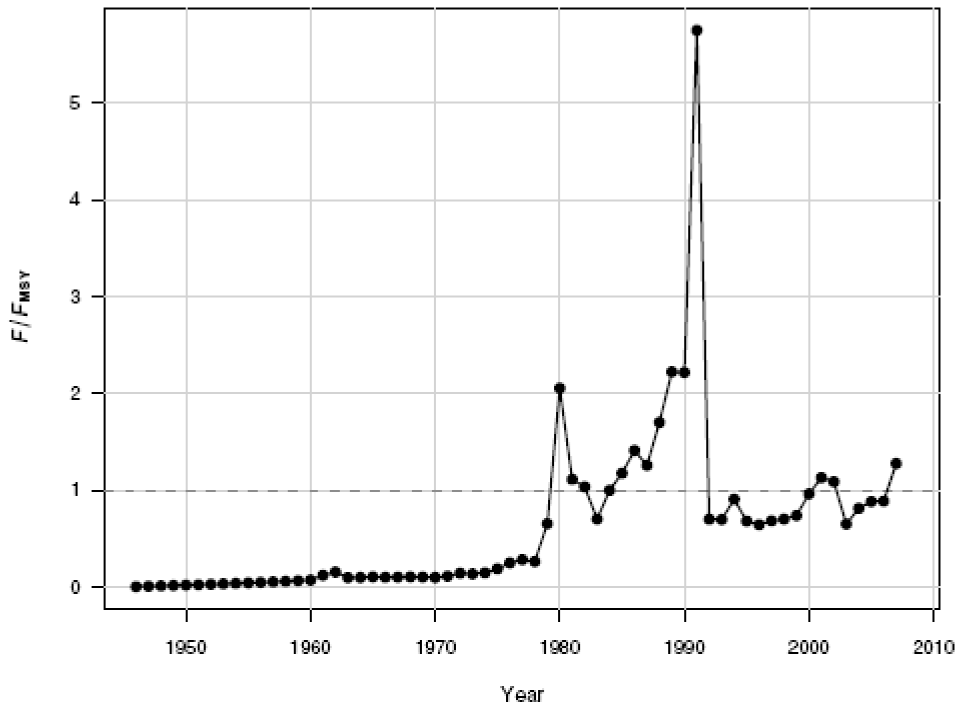
Table 3.16. Base run: Estimated status indicators, benchmarks, and related quantities from the catch-at-age model, conditional on estimated current selectivities averaged across fisheries. Precision is represented by 10^{th} and 90^{th} percentiles from bootstrap and Monte Carlo analysis of the spawner-recruit curve. 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 per year; status indicators are dimensionless; and biomass estimates are in units of metric tons, pounds, or eggs, as indicated. Symbols, abbreviations, and acronyms are listed in Appendix A.

Quantity	Units	Estimate	10^{th} Percentile	90^{th} Percentile
F_{MSY}	y^{-1}	0.386	0.199	0.792
$85\%F_{MSY}$	y^{-1}	0.328	–	–
$75\%F_{MSY}$	y^{-1}	0.289	–	–
$65\%F_{MSY}$	y^{-1}	0.251	–	–
B_{MSY}	mt	3300	2352	4525
SSB_{MSY}	10^{12} eggs	9.157	6.206	12.911
MSST	10^{12} eggs	7.142	4.840	10.071
MSY	1000 lb	1665	1216	2132
D_{MSY}	1000 fish	130	74	222
R_{MSY}	1000 fish	4466	3628	5401
Y at $85\%F_{MSY}$	1000 lb	1656	–	–
Y at $75\%F_{MSY}$	1000 lb	1635	–	–
Y at $65\%F_{MSY}$	1000 lb	1599	–	–
F_{2007}/F_{MSY}	–	1.274	0.620	2.464
SSB_{2007}/SSB_{MSY}	–	0.861	0.610	1.270
SSB_{2007}/MSST	–	1.103	0.782	1.628

Table 3.6. Estimated time series and status indicators. Fishing mortality rate is full F, which includes discard mortalities. Total biomass (B, mt) is at the start of the year, and spawning biomass (SSB, 10^{12} eggs) at the midpoint. The MSST is defined by $\text{MSST} = (1 - M)\text{SSB}_{\text{MSY}}$, *with constant* $M = 0.22$. *SPR is static spawning potential ratio.*

Year	F	F/F_{MSY}	B	B/B_{unfished}	SSB	$\text{SSB}/\text{SSB}_{\text{MSY}}$	SSB/MSST	SPR
1946	0.00000	0.00000	10472	1.000	31.39	3.428	4.39	1.000
1947	0.00151	0.00391	10472	1.000	31.37	3.426	4.39	0.992
1948	0.00303	0.00787	10460	0.999	31.31	3.420	4.38	0.983
1949	0.00458	0.01188	10438	0.997	31.23	3.410	4.37	0.975
1950	0.00616	0.01598	10405	0.994	31.11	3.397	4.36	0.967
1951	0.00779	0.02020	10363	0.990	30.97	3.382	4.34	0.958
1952	0.00947	0.02455	10314	0.985	30.80	3.363	4.31	0.950
1953	0.01121	0.02906	10256	0.979	30.61	3.342	4.29	0.941
1954	0.01302	0.03377	10192	0.973	30.40	3.319	4.26	0.932
1955	0.01492	0.03869	10122	0.967	30.17	3.294	4.22	0.922
1956	0.01691	0.04387	10045	0.959	29.92	3.267	4.19	0.913
1957	0.01902	0.04932	9963	0.951	29.65	3.238	4.15	0.903
1958	0.02126	0.05512	9875	0.943	29.37	3.207	4.11	0.893
1959	0.02370	0.06147	9781	0.934	29.06	3.174	4.07	0.882
1960	0.02625	0.06808	9682	0.925	28.75	3.139	4.02	0.870
1961	0.04488	0.11639	9577	0.915	28.38	3.099	3.97	0.843
1962	0.05819	0.15091	9446	0.902	27.95	3.053	3.91	0.825
1963	0.03584	0.09296	9305	0.889	27.53	3.007	3.85	0.833
1964	0.03639	0.09437	9182	0.877	27.17	2.967	3.80	0.829
1965	0.03894	0.10098	9071	0.866	26.83	2.930	3.76	0.821
1966	0.03736	0.09689	8962	0.856	26.53	2.897	3.71	0.824
1967	0.03794	0.09840	8876	0.848	26.28	2.870	3.68	0.824
1968	0.03893	0.10096	8801	0.840	26.06	2.846	3.65	0.823
1969	0.03812	0.09886	8736	0.834	25.89	2.827	3.62	0.826
1970	0.03653	0.09474	8685	0.829	25.76	2.813	3.61	0.831
1971	0.04189	0.10865	8651	0.826	25.62	2.798	3.59	0.818
1972	0.05341	0.13852	8599	0.821	25.42	2.776	3.56	0.796
1973	0.05071	0.13150	8522	0.814	25.20	2.751	3.53	0.799
1974	0.05524	0.14326	8457	0.808	24.96	2.725	3.49	0.783
1975	0.07092	0.18391	8371	0.799	24.59	2.685	3.44	0.747
1976	0.09456	0.24523	7508	0.717	22.22	2.427	3.11	0.730
1977	0.10748	0.27874	6705	0.640	19.57	2.138	2.74	0.714
1978	0.10002	0.25939	7492	0.715	21.30	2.326	2.98	0.694
1979	0.25070	0.65015	6746	0.644	19.80	2.162	2.77	0.598
1980	0.79152	2.05269	6019	0.575	17.25	1.883	2.41	0.359
1981	0.42802	1.11002	5452	0.521	15.41	1.682	2.16	0.495
1982	0.39806	1.03232	5069	0.484	13.94	1.523	1.95	0.471
1983	0.26958	0.69911	5244	0.501	14.43	1.576	2.02	0.527
1984	0.38435	0.99676	4872	0.465	13.72	1.499	1.92	0.472
1985	0.45257	1.17369	4870	0.465	13.38	1.462	1.87	0.444
1986	0.54316	1.40860	4767	0.455	13.30	1.453	1.86	0.438
1987	0.48371	1.25443	4281	0.409	12.10	1.321	1.69	0.422
1988	0.65521	1.69920	4080	0.390	11.09	1.211	1.55	0.380
1989	0.85703	2.22259	3480	0.332	9.19	1.004	1.29	0.342
1990	0.85451	2.21605	4785	0.457	12.53	1.368	1.75	0.396
1991	2.21780	5.75156	3996	0.382	10.94	1.195	1.53	0.282
1992	0.26870	0.69683	3533	0.337	10.26	1.120	1.44	0.494
1993	0.26776	0.69441	4542	0.434	12.81	1.399	1.79	0.498
1994	0.34871	0.90434	4120	0.393	12.05	1.316	1.69	0.447
1995	0.26140	0.67790	4266	0.407	12.14	1.326	1.70	0.501
1996	0.24724	0.64118	3977	0.380	11.50	1.256	1.61	0.519
1997	0.26263	0.68109	4062	0.388	11.50	1.256	1.61	0.502
1998	0.26954	0.69902	4268	0.408	12.13	1.325	1.70	0.498
1999	0.28359	0.73546	4500	0.430	12.77	1.394	1.79	0.463
2000	0.36984	0.95914	4384	0.419	12.19	1.331	1.71	0.414
2001	0.43468	1.12728	4323	0.413	11.71	1.279	1.64	0.388
2002	0.41858	1.08553	4168	0.398	11.52	1.258	1.61	0.398
2003	0.24965	0.64743	3770	0.360	10.93	1.193	1.53	0.491
2004	0.31232	0.80996	3610	0.345	10.07	1.100	1.41	0.443
2005	0.33925	0.87980	3336	0.319	9.18	1.003	1.29	0.430
2006	0.34099	0.88431	3143	0.300	8.67	0.947	1.21	0.423
2007	0.49122	1.27392	2966	0.283	7.88	0.861	1.10	0.350
2008	.	.	2642	0.252	.	.	.	.

Figure 3.55. Estimated time series of F relative to F_{MSY}.



5.9. Projections

Projections were run to predict stock status in years after the assessment, 2008–2018. This time frame of 11 years included one year (2008) at the current fishing rate and ten 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 base run.

A projection in which $F = F_{current}$, predicted the stock to remain near current levels, with modest increase. Similarly, other projections, with F at 65%, 75%, 85%, or 100% of F_{MSY}, predicted the stock to increase. In general, higher F resulted in larger annual and cumulative landings, but smaller biomass with a correspondingly smaller buffer from the MSST. As usual, projections should be interpreted in light of the model assumptions and key aspects of the data. Some major considerations are offered in the AW report.

5.10. Allowable Biological Catch (ABC) range

Acceptable biological catch (ABC) was computed using the probability based approach of Shertzer et al. (2008). In short, this approach solves for annual levels of projected landings that are consistent with a preset, acceptable probability of overfishing in each year. The method considers uncertainty in F_{MSY} and in annual fishing mortality. In this application, projections were run for five years past the end of the assessment, with the current fishing rate applied in 2008. No implementation uncertainty was included.

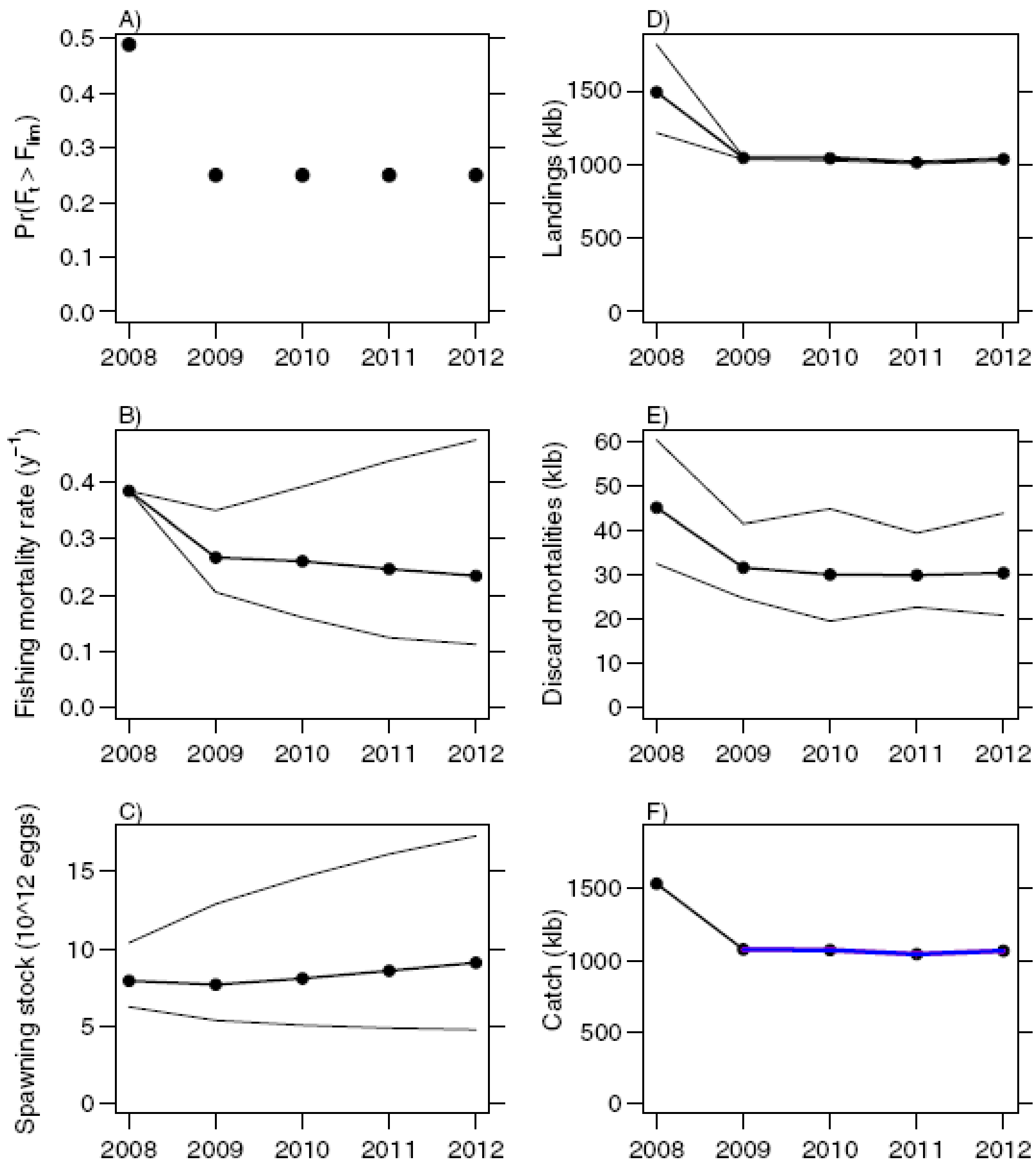
The distribution of F_{MSY} was used to compute annual ABC (landings plus discard mortalities in 1000 lb whole weight) for probabilities of 0.10, 0.20, 0.25, 0.30, 0.40, and 0.50. In general, the ABC increases with higher acceptable probability of overfishing, whereas stock size decreases. AW Table 3.19 and AW Figure 3.58 are shown with a probability of 0.25 by way of example.

Values of ABC were computed given uncertainties in F_{MSY}, current abundance at age (2008), and future recruitment. Uncertainty in management implementation was not considered. Thus, these ABC values should be considered as possible catch limits, and implementation uncertainty should be considered when setting annual catch targets (ACTs). The projection method applied here assumed that the catch taken from the stock was the ABC. If the projection had applied a catch level lower than the ABC, say at ACT < ABC, then the corresponding reduction in applied F would have resulted in higher stock sizes, and higher ABCs in subsequent years. In this sense, the values presented here are conservative.

Table 3.19. Acceptable biological catch (ABC), with annual probability of overfishing $P^* = 0.25$. F = fishing mortality rate, Pr(SSB > SSB_{MSY}) = proportion of replicates exceeding SSB_{MSY}, SSB = mid-year spawning stock (10^{12} eggs), R = recruits (1000 fish), D = discard mortalities (1000 lb whole weight), L = landings (1000 lb whole weight), and Sum L = cumulative landings. ABC (1000 lb whole weight) includes landings and discard mortalities. Annual ABCs are a single quantity among the 10000 replicate projections; other values presented are medians.

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(10^{12})	R(1000)	D(klb)	L(klb)	Sum L(klb)	ABC(klb)
2008	0.384	0.24	7.92	3194	45	1491	1491	-
2009	0.267	0.31	7.68	3152	32	1045	2536	1077
2010	0.26	0.38	8.07	3141	30	1042	3578	1072
2011	0.247	0.44	8.57	3180	30	1013	4592	1043
2012	0.234	0.49	9.1	3193	31	1036	5628	1067

Figure 3.58. Probability-based approach to computing acceptable biological catch (ABC), with annual probability of overfishing $P^* = 0.25$. The F in 2008 was set to $F = F_{current}$. Dotted solid lines correspond to median values, and thin lines to 10^{th} and 90^{th} percentiles of 10000 replicate projections. Spawning stock (SSB) is at mid-year, and catch (the ABC) includes landings plus discard mortalities.



5.11. Uncertainty

Sensitivity and retrospective analyses are useful for evaluating uncertainty in results of the base assessment model. Plotted in the AW report are time series of F/F_{MSY} and SSB/SSB_{MSY} for sensitivity to steepness, natural mortality, catchability, discard mortality rates, early recreational landings, commercial landings, and weighting of likelihood components. In general, results of sensitivity analyses were qualitatively the same as those of the base model run: the stock is not overfished but overfishing is occurring (AW Table 3.23). Retrospective analyses did not reveal any concerning trends.

In its report the Review Panel noted the methods used to characterize uncertainty were not considered entirely appropriate by the Panel. However, some guidance on the level of uncertainty can be obtained from the confidence intervals in the AW base model and the range of estimates from sensitivity runs. These results are likely to under-estimate the true level of uncertainty.

Table 3.23. Results from sensitivity runs of catch-at-age model. (A value of F_{MSY} = 5 indicates that equilibrium landings strictly increase over the explored range of F.)

Run	Description	F_{MSY}	SSB_{MSY} (10^{12} eggs)	MSY(klb)	F_{2007}/F_{MSY}	SSB_{2007}/SSB_{MSY}	SSB_{2007}/MSST	steep	R0(1000)
Base	—	0.386	9.16	1665	1.27	0.86	1.1	0.56	4326
S1	h estimated	5	3.6	2278	0.1	2.47	3.17	0.95	4340
S2	$h = 0.73$ ($F_{30\%}$)	0.666	7.36	1784	0.72	1.2	1.54	0.73	4660
S3	$h = 0.67$ ($F_{35\%}$)	0.521	8.16	1705	0.92	1.08	1.38	0.67	4789
S4	$h = 0.53$ ($F_{45\%}$)	0.307	10.55	1580	1.49	0.82	1.06	0.53	5217
S5	$h = 0.47$ ($F_{50\%}$)	0.236	12.3	1507	1.83	0.72	0.92	0.47	5496
S6	High M	0.719	8.36	1819	0.84	1.03	1.44	0.56	6686
S7	Low M	0.199	12.49	1466	2.5	0.55	0.66	0.56	3307
S8	q δ = 0.00	0.36	9.43	1666	1.07	1	1.29	0.56	4560
S9	q δ = 0.04	0.391	9.17	1696	1.44	0.77	0.99	0.56	4275
S10	High D mort	0.341	10.08	1601	1.39	0.87	1.11	0.56	5156
S11	Low D mort	0.354	9.6	1616	1.27	0.9	1.15	0.56	5015
S12	Rec L 0.5	0.336	10.04	1555	1.35	0.88	1.13	0.56	5074
S13	Rec L 1.0	0.349	9.88	1627	1.34	0.87	1.12	0.56	5124
S14	Rec L 1.25	0.339	10.32	1603	1.41	0.83	1.07	0.56	5229
S15	Low comm L	0.383	8.39	1529	1.34	0.85	1.09	0.56	3960
S16	High comm L	0.388	9.93	1804	1.22	0.87	1.12	0.56	4692
S17	HB index	0.38	9.64	1546	1.51	0.81	1.03	0.56	4737
S18	CVT index	0.417	8.77	1556	2.82	0.56	0.71	0.56	4145
S19	Low len comp	0.334	9.19	2005	1.22	0.9	1.15	0.56	4682
S20	Retro 2006	0.368	9.96	1583	0.96	0.87	1.12	0.56	4832
S21	Retro 2005	0.427	9.47	1741	0.84	0.89	1.15	0.56	3794
S22	Retro 2004	0.348	9.82	1485	1.2	0.92	1.18	0.56	5154
S23	Retro 2003	0.349	9.19	1564	0.94	0.83	1.06	0.56	4454

5.12. Special Comments

None

5.13. Sources of Information

All sources of Summary Report information are within the SEDAR 17 Vermilion Snapper Stock Assessment Report (SAR). Text is generally from the AW Report (SAR Section III), and the RW Report (SAR Section V). Sources of tables and figures are identified throughout the Summary Report.

6. SAIP Form (To be completed following the Review Workshop)

Stock Assessment Improvement Program
Assessment Summary Form

This form must be completed for each stock assessment once it has passed review or been rejected without anticipated revisions in the near future (<1 year). Please fill out all information to the best of your ability.

FMP Common Name Snapper-grouper
Stock Vermilion snapper
Level of Input Data for
Abundance 1
0 = none; 1 = fishery CPUE or imprecise survey with size composition; 2 = precise, frequent survey with age composition; 3 = survey with estimates of q; 4 = habitat-specific survey
Catch 2, 4
0 = none; 1 = landed catch; 2 = catch size composition; 3 = spatial patterns (logbooks); 4 = catch age composition; 5 = total catch by sector (observers)
Life History 2
0 = none; 1 = size; 2 = basic demographic parameters; 3 = seasonal or spatial information (mixing, migration); 4 = food habits data
Assessment Details
Area South Atlantic_
e.g., Gulf of Mexico, South Atlantic, Caribbean, Atlantic.
Level 4
0 = none; 1 = index only (commercial or research CPUE); 2 = simple life history equilibrium models; 3 = aggregated production models; 4 = size/age/stage-structured models; 5 = add ecosystem (multispecies, environment), spatial & seasonal analyses
Frequency 2
0 = never; 1 = infrequent; 2 = frequent or recent (2-3 years); 3 = annual or more
Year Reviewed 2008
Last Year of Data 2007
Used in the assessment
Source SEDAR 17
Citation
Review Result Accept
Accept, Reject, Remand, or Not reviewed
Assessment Type Benchmark
New, Benchmark, Update, or Carryover
Notes
Stock Status
F/F_{target} ?
F/F_{limit} 1.27
B/B_{MSY} 0.86
B/B_{limit} 1.10
Overfished? No
Overfishing? Yes
Basis for
F_{target} ?
e.g., F_{OY}
F_{limit} Fmsy, conditioned to equal F40%
e.g., F_{MSY}
B_{MSY} SSBmsy
B_{limit} MSST
e.g., MSST
Next Scheduled Assessment: Not yet scheduled

7. SEDAR Abbreviations

ABC	Allowable Biological Catch
ACCSP	Atlantic Coastal Cooperative Statistics Program
ADMB	AD Model Builder software program
ALS	Accumulated Landings System; SEFSC fisheries data collection program
ASMFC	Atlantic States Marine Fisheries Commission
B	stock biomass level
BAC	SAFMC SSC Bioassessment sub-Committee
B_{MSY}	value of B capable of producing MSY on a continuing basis
CFMC	Caribbean Fishery Management Council
CIE	Center for Independent Experts
CPUE	catch per unit of effort
GMFMC	Gulf of Mexico Fishery Management Council
F	fishing mortality (instantaneous)
FSAP	GMFMC Finfish Assessment Panel
F_{MSY}	fishing mortality to produce MSY under equilibrium conditions
F_{OY}	fishing mortality rate to produce Optimum Yield under equilibrium
F_{XX}% SPR	fishing mortality rate that will result in retaining XX% of the maximum spawning production under equilibrium conditions
F_{MAX}	fishing mortality that maximizes the average weight yield per fish recruited to the fishery
F_0,	a fishing mortality close to, but slightly less than, Fmax
FWRI	(State of) Florida Fisheries and Wildlife Research Institute
GLM	general linear model
GSMFC	Gulf States Marine Fisheries Commission
GULF FIN	GSMFC Fisheries Information Network
Lbar	mean length
M	natural mortality (instantaneous)
MFMT	maximum fishing mortality threshold, a value off above which overfishing is deemed to be occurring
MRFSS	Marine Recreational Fisheries Statistics Survey; combines a telephone survey of households to estimate number of trips with creel surveys to estimate catch and effort per trip
MSST	minimum stock size threshold, a value of B below which the stock is deemed to be overfished
MSY	maximum sustainable yield
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
OY	optimum yield
RVC	Reef Visual Census—a diver-operated survey of reef-fish numbers
SAFMC	South Atlantic Fishery Management Council
SAS	Statistical Analysis Software, SAS corporation.
SEDAR	Southeast Data, Assessment and Review
SEFSC	NOAA Fisheries Southeast Fisheries Science Center
SERO	NOAA Fisheries Southeast Regional Office
SFA	Sustainable Fisheries Act of 1996
SPR	spawning potential ratio, stock biomass relative to an unfished state of the stock

SEDAR Abbreviations – continued

SSB	Spawning Stock Biomass
SSC	Science and Statistics Committee
TIP	Trip Incident Program; biological data collection program of the SEFSC and Southeast States.
Z	total mortality, the sum of M and F

Section II. Data Workshop Report

Contents

1. Introduction

1.1 Workshop Time and Place

The SEDAR 17 Data Workshop was held May 19-23, 2008, in Charleston, SC.

1.2 Terms of Reference

1. Characterize stock structure and develop a unit stock definition. Provide a map of species and stock distribution.

2. Tabulate available life history information (e.g., age, growth, natural mortality, reproductive characteristics, discard mortality rates); provide appropriate models to describe growth, maturation, and fecundity by age, sex, or length as applicable. Evaluate the adequacy of available life-history information for conducting stock assessments and recommend life history information for use in population modeling.

3. Consider relevant fishery dependent and independent data sources to develop measures of population abundance. Document all programs used to develop indices; address program objectives, methods, coverage, sampling intensity, and other relevant characteristics. Provide maps of survey coverage. Develop values by appropriate strata (e.g., age, size, area, and fishery); provide measures of precision. Evaluate the degree to which available indices represent fishery and population conditions. Recommend which data sources should be considered in assessment modeling.

4. Characterize commercial and recreational catch, including both landings and discard removals, in pounds and number. Discuss the adequacy of available data for accurately characterizing harvest and discard by species and fishery sector. Provide length and age distributions of the catch. Provide maps of fishery effort and harvest.

5. Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment. Recommend sampling intensity by sector (fleet), area, and season.

6. Develop a spreadsheet of assessment model input data that incorporates the decisions and recommendations of the Data Workshop. Review and approve the contents of the input spreadsheet within 6 weeks prior to the Assessment Workshop.

7. Prepare complete documentation of workshop actions and decisions (Section II. of the SEDAR assessment report); prepare a list of tasks to be completed following the workshop, including deadlines and personnel assignments.

1.3 Participants

Appointee	Function	Affiliation
Coordination		
Dale Theiling	Chair and Chief Editor	SEDAR
Rachael Lindsay	Administrative Support	SEDAR
Data Management		
Rob Cheshire	Data Compiler	SEFSC
Commercial Statistics Workgroup		
Doug Vaughan	Leader and Editor	SEFSC
Kate Andrews	Data Provider and Rapporteur	SEFSC
Alan Bianchi	Data Provider	NC DMF
Steve Brown	Data Provider	FL FWC
Julie Califf	Data Provider	GA DNR
Jack Holland	Data Provider	NC DMF
Robert Wiggers	Data Provider	SC DNR
Geoff White	Data Provider	ACCSP
Dave Gloeckner	Data Provider	SEFSC/TIP
Kevin J. McCarthy	Data Provider	SEFSC/Logbooks
Recreational Statistics Workgroup		
Erik Williams	Leader, Rapporteur, and Editor	SEFSC
Doug Mumford	Data Provider	NC DMF
Robert Wiggers	Data Provider	SC DNR
Beverly Sauls	Data Provider	FL FWC
Tom Sminkey	Data Provider	MRFSS (MRIP)
Ken Brennan	Data Provider	SEFSC/Headboats
Life History Workgroup		
Jennifer Potts	Leader and Editor	SEFSC
Daniel Carr	Rapporteur	SEFSC
David Wyanski	Data Provider	SC DNR
Marcel Reichert	Data Provider	SC DNR
Doug DeVries	Data Provider	SEFSC
Chris Palmer	Data Provider	SEFSC
Stephanie McInerny	Data Provider	SEFSC
Indices Workgroup		
Kyle Shertzer	Leader and Editor	SEFSC
Helen Takade	Data Provider and Rapporteur	NC DMF
Rob Cheshire	Data Compiler	SEFSC
Elizabeth Wenner	Data Provider	SEAMAP
Pat Harris	Data Provider	MARMAP
Paul Conn	Data Provider	SEFSC
Geoff White	Data Provider	ACCSP
Kate Andrews	Data Provider	SEFSC

Analytical Team Representation

Kyle Shertzer	Vermilion Snapper Lead Analyst	SEFSC
Paul Conn	Spanish Mackerel Lead Analyst	SEFSC

Council Representation

Brian Chevront	Council Member	SAFMC
David Cupka	Council Member	SAFMC
Rick DeVictor	Vermilion Snapper Council Lead	SAFMC
Gregg Waugh	Spanish Mackerel Council Lead	SAFMC

Advisory Panel Representation

Ben Hartig	SAFMC AP Chair	FLA Commercial

Observers and Associates

Jeanne Boylan (SEAMAP)
Myra Brower (SAFMC)
Julie Defilippi (ACCSP)
Kim Iverson (SAFMC)
Bob Mahood (SAFMC)
Paulette Mikell (MARMAP)
Ernest Muhammad (SC DNR)
David Player (SC DNR)
Andi Stephens (SAFMC)
Jessica Stephen (MARMAP)
Elizabeth Vernon (SC DNR)

Acronyms
SEDAR 17 DW Attendance List

ACCSP	Atlantic Coastal Cooperative Statistics Program
AP	Advisory Panel
ASMFC	Atlantic States Marine Fisheries Commission
CCA	Coastal Conservation Association
CIE	Center for Independent Experts
FL FWC	Florida Fish and Wildlife Commission
FMP	Fishery Management Plan
GA DNR	Georgia Department of Natural Resources
MRFSS	Marine Recreational Fisheries Statistics System
MRIP	Marine Recreational Information Program
NC DMF	North Carolina Division of Marine Fisheries
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
SAFMC	South Atlantic Fishery Management Council
SEFSC	Southeast Fisheries Science Center, National Marine Fisheries Service
SC DNR	South Carolina Department of Natural Resources
SEDAR	Southeast Data, Assessment, and Review
SSC	Science & Statistics Committee, South Atlantic Fishery Management Council
TIP	Trip Interview Program, National Marine Fisheries Service

1.4 Workshop Documents

SEDAR 17
South Atlantic Vermilion Snapper and South Atlantic Spanish Mackerel
Data Workshop Document List

Document #	Title	Authors
Documents Prepared for the Data Workshop		
SEDAR17-DW01	South Atlantic Vermilion Snapper Management Information Worksheet	J. McGovern (SERO) R. DeVictor (SAFMC)
SEDAR17-DW02	South Atlantic Spanish Mackerel Management Information Worksheet	J. McGovern (SERO) R. DeVictor (SAFMC)
SEDAR17-DW03	South Atlantic Vermilion Snapper Assessment History	D. Vaughan (SEFSC)
SEDAR17-DW04	South Atlantic Spanish Mackerel Assessment History	D. Vaughan (SEFSC)
SEDAR17-DW05	South Atlantic Vermilion Snapper Commercial Chapter	D. Vaughan (SEFSC)
SEDAR17-DW06	South Atlantic Spanish Mackerel Commercial Chapter	D. Vaughan (SEFSC)
SEDAR17-DW07	A review of Spanish mackerel (*Scomberomorus maculatus)* age data, 1987-2007, Atlantic collections only, from the Panama City Laboratory, SEFSC, NOAA Fisheries Service	C. Palmer, D. DeVries, C. Fioramonti and L. Lombardi-Carlson (SEFSC)
SEDAR17-DW08	Vermilion Snapper Length Frequencies and Condition of Released Fish from At-Sea Headboat Observer Surveys in the South Atlantic, 2004 to 2007	B. Sauls, C. Wilson, D. Mumford, and K. Brennan (SEFSC)
SEDAR17-DW09	Development of Conversion Factors for Different Trap Types used by MARMAP since 1978.	P. Harris (MARMAP)
SEDAR17-DW10	Discards of Spanish Mackerel and Vermilion Snapper Calculated for Commercial Vessels with Federal Fishing Permits in the US South Atlantic	K. McCarthy (SEFSC)
SEDAR17-DW11	Standardized catch rates of vermilion snapper from the headboat sector: Sensitivity analysis of the 10-fish-per-angler bag limit	Sustainable Fisheries Branch (SEFSC)
SEDAR17-DW12	Estimation of Spanish mackerel and vermilion snapper bycatch in the shrimp trawl fishery in the South Atlantic (SA)	K. Andrews (SEFSC)
Documents Prepared for the Assessment Workshop		
SEDAR17-AW01	SEDAR 17 South Atlantic Vermilion Snapper Stock Assessment Model	To be prepared by SEDAR 17
SEDAR17-AW02	SEDAR 17 South Atlantic Spanish Mackerel Stock Assessment Model	To be prepared by SEDAR 17
Documents Prepared for the Review Workshop		

SEDAR17-RW01	SEDAR 17 South Atlantic Vermilion Snapper Document for Peer Review	To be prepared by SEDAR 17
SEDAR17-RW02	SEDAR 17 South Atlantic Spanish Mackerel Document for Peer Review	To be prepared by SEDAR 17
	Final Assessment Reports	
SEDAR17-AR01	Assessment of the Vermilion Snapper Stock in the US South Atlantic	To be prepared by SEDAR 17
SEDAR17-AR02	Assessment of the Spanish Mackerel Stock in the US South Atlantic	To be prepared by SEDAR 17
	Reference Documents	
SEDAR17-RD01	South Atlantic Vermilion Snapper Stock Assessment Report, SEDAR 2, 2003	SEDAR 2
SEDAR17-RD02	Update of the SEDAR 2 South Atlantic Vermilion Snapper Stock Assessment, 2007	SEDAR
SEDAR17-RD03	Fishery Management Plan for Spanish Mackerel, Atlantic States Marine Fisheries Commission, 1990	L. P. Mercer L. R. Phalen J. R. Maiolo
SEDAR17-RD04	Mitochondrial and nuclear DNA analysis of population subdivision among young-of-the-year Spanish mackerel (*Scomberomorus maculatus*) from the western Atlantic and Gulf of Mexico	V. P. Buonaccorsi E. Starkey J. E. Graves
SEDAR17-RD05	George Fishes MD TAFS 28 1-49	W. A. George
SEDAR17-RD06	Excerpt – Goode 1878 stats 7-1-99	Goode
SEDAR17-RD07	Excerpt – Henshall Comparative Excellence TAF 13 1-115	Henshall
SEDAR17-RD08	Stock Assessment Analyses on Spanish and King Mackerel Stocks, April 2003	Sustainable Fisheries Div, SEFSC
SEDAR17-RD09	Hooking Mortality of Reef Fishes in the Snapper-Grouper Commercial Fishery of the Southeastern United States	D.V. Guccione Jr.
SEDAR17-RD10	Effects of cryptic mortality and the hidden costs of using length limits in fishery management Lewis G Coggins Jr	L. G. Coggins Jr. and others
SEDAR17-RD11	Discard composition and release fate in the snapper and grouper commercial hook-and-line fishery in North Carolina, USA	P. J. Rudershausen and J. A. Buckel
SEDAR17-RD12	A multispecies approach to subsetting logbook data for purposes of estimating CPUE	A. Stephens and A. MacCall

SEDAR17-RD13	The 1960 Salt-Water Angling Survey, USFWS Circular 153	Clark, J. R.
SEDAR17-RD14	The 1965 Salt-Water Angling Survey, USFWS Resource Publication 67	Deuel, D. G. and J. R. Clark
SEDAR17-RD15	1970 Salt-Water Angling Survey, NMFS Current Fisheries Statistics Number 6200	Deuel, D. G.
SEDAR17-RD16	User's Guide: Delta-GLM function for the R Language /environment (Version 1.7.2, revised 07-06-2006)	Dick, E. J. SWFSC/NMFS
SEDAR17-RD17	Reproductive biology of Spanish mackerel, *Scomberomorus maculatus*, in the lower Chesapeake Bay. M.A. Thesis, Virginia Institute of Marine Science. (Selective pages)	Cooksey, C. L. 1996

SEDAR17 – South Atlantic Vermilion Snapper

II. Data Workshop Report

2. Life History

2.1. Overview – Members

Jennifer Potts – Group Leader
Daniel Carr
Chip Collier
Doug DeVries
Stephanie McInerny
Paulette Mikell
Chris Palmer
Marcel Reichert
Jessica Stephens
David Wyanski

2.2 Stock Definition and Description

Vermilion snapper have a broad geographic range extending from North Carolina to Sao Paulo, Brazil (Anderson, 2002). Although adult vermilion snapper have a relatively small home range based on mark recapture studies (Fable 1980), genetic studies have only found weak evidence for genetic stock structure in this species. This could be due to several factors including pelagic eggs mixing, insufficient time for genetic structure to be present, adults migrating among stocks, and hyper-variability of some genetic markers. The genetic reports range from no difference in the Gulf of Mexico (GOM) and US South Atlantic (SA) (Bagley et al. 1999) to minor differences among the two areas (Tringali and Higham, 2007). The weak genetic differences among the GOM and SA may be evidence of a strong barrier to connectivity among stocks (Tringali and Higham, 2007). Given the variability of the genetic studies, other indicators of stock structure were investigated.

Morphometric characteristics and life history traits are important components of stock assessments and can be used to detect the presence of different stocks (Swain et al. 2005). Mophometric characteristics include the weight-length relationship, fork length-total length relationship, and size-at-age. Life history traits include longevity, natural mortality, and maturity schedule. Both the morphometric characteristics and life history traits influence the predicted resiliency, growth, and recovery of a stock. Morphometrics and life history traits can be influenced by their environment and may vary from reef to reef. However, if there are significant differences among geographic regions, these traits should be considered in managing stocks.

Using the weight-length relationship for GOM vermilion snapper from SEDAR 9 Vermilion Snapper Data Workshop Report compared to the weight-length relationship for SA vermilion snapper, GOM vermilion snapper are predicted to be heavier than SA vermilion snapper for fish greater than 250 mm TL (10 inches).

Longevity estimates vary among the GOM and SA. GOM vermilion snapper reach a maximum age of 26 (SEDAR 9 Vermilion Snapper Data Workshop Report) and the SA vermilion snapper reach a maximum age of 19. This difference in maximum age may lead to differences in the natural mortality estimate if the estimate is based on Hoenig's (1983) natural mortality model.

Given the differences in the weight-length relationship, longevity, and weak genetic separation between the GOM and SA vermilion snapper, the Life History Work Group (LHWG) recommended keeping the GOM and SA management units separate for vermilion snapper. This is also consistent with SEDAR 15 for red snapper and greater amberjack. Additional studies should be undertaken to determine if phenotypic differences are persistent between the GOM and SA vermilion snapper stocks.

Recommendations for the AW:

1) Keep the SA and GOM as separate stocks and use the jurisdiction set by the SAFMC (i.e., North Carolina through the east coast of Florida including Monroe County south of US 1 out to 83^{o} West longitude).

2.3 Natural Mortality

Natural mortality is one of the hardest parameters of a stock assessment to determine. Many different estimators are available that rely on various age and theoretical growth parameters (Table 2.3.1). Due to the uncertainty and variability in the parameter estimates from the von Bertalanffy growth model, the LHWG recommend using the Hoenig estimator. Previous age and growth studies of vermilion snapper from the US South Atlantic found fish as old as 13 years. The current age and growth study found vermilion snapper as old as 19 years. The maximum age of the Gulf of Mexico stock was 26 years. The LHWG felt that the environment and fishing pressure are different enough between the two areas (GOM and SA) to expect differences in longevity and growth.

The LHWG felt that maximum age of 19 year old was reasonable for the SA stock, and the resulting Hoenig estimate of M was 0.22. For sensitivity analysis, the LHWG suggests a range of 0.16 – 0.28 to encompass estimates of M from the other methods of estimating M and from the Gulf of Mexico stock. The LHWG also presents the Lorenzen age based estimate of M using the von Bertalanffy parameters from all data combined, excluding the fishery-independent age 8+ fish and using the Diaz et al. correction methodology on the fishery-dependent data and age at the midpoint of the fishing year (Table 2.3.2).

Recommendations for the AW:

1) Model the natural mortality rate of vermilion snapper as a declining Lorenzen function of size.

2) The Lorenzen function should be scaled to an M of 0.22 - the Hoenig estimate of M based on a maximum age of 19 yr, with sensitivity runs between 0.16 and 0.28.

2.4 Discard Mortality

Since the last benchmark stock assessment on vermilion snapper in 2003, studies investigating release mortality on this species have increased. SEDAR 2 reported base estimates of 20 and 40 % release mortality for vermilion from recreational and commercial fisheries, respectively (SEDAR2_SAR2). These estimates were based on a 17 % release mortality reported during a venting study using fish released into cages (Collins et al. 1999) and 27 % mortality from unpublished data provided by Dixon and Huntsman (Dixon and Huntsman, unpub.) More recently, Guccione used a caging study to look at release mortality of several snapper/grouper species in the South Atlantic and reported 30 % mortality for vermilion snapper from a depth range of 34 to 55 meters (Guccione 2005). Caging studies can be useful for measuring delayed mortality for released species, but not predation. Burns et al. (2002) conducted a tag and recapture study to investigate mortality of various reef fishes from the Atlantic and Gulf of Mexico, however, only 6 of 825 vermilion were recaptured so there was not enough information available to calculate a release mortality estimate for this species.

Most release mortality estimates in recent years come from observing release condition of individual fish at the water's surface. Immediate mortality was calculated from both commercial and recreational fishing vessels. The At-Sea Headboat Observer Survey recorded release condition for 1,536 vermilion snapper caught by hook and line in east Florida from 2005 – 2007. Release mortality from this survey, 5.2 %, was the average percentage of dead discarded vermilion snapper across the 3 year study period. Discards were counted as "dead" if surface condition was recorded as poor, dead, or eaten (SEDAR17-DW08). The Commercial Logbook Program reported immediate release mortality rates for vermilion snapper for 5 regions between Florida and North Carolina (regions 1 -5) by randomly sampling commercial logbooks from 20 % of the currently fishing commercial vessels in the South Atlantic. Region 5 (North Carolina) had a release mortality rate of about 70 % which was uncharacteristically high compared to the other 4 regions. A release mortality of 20 % was calculated by averaging mortality rates from all regions (SEDAR17-DW10). Harris and Stephen (2004) looked at immediate mortality rates of vermilion snapper by accompanying one commercial fisherman for about 5 months. Data from this study can not estimate delayed mortality but it does include fish that were not immediately released by the fisherman. This estimate was 50 % mortality. Estimates of release mortality that include deck time are higher than other estimates observing immediate release condition. Also observed and recorded by Harris and Stephen (2004) were vermilion that were not released but kept as bait. Keeping vermilion as bait is not currently documented as a common practice of the commercial fishery, though the Snapper Grouper logbooks do have a category for fish "kept but not sold". The "kept" fish may be used for bait. The estimates of the number of fish "kept" cannot be used to characterize release mortality for the entire fishery. Instead, they need to be treated separately, but at the time of the data workshop, it was not decided how that should be handled.

The most recently published study on release mortality for snappers and groupers from the commercial fishery estimated immediate and delayed mortality rates. Immediate mortality for vermilion snapper was estimated to be 8.9 % (Rudershausen et al. 2007). This was calculated from discards observed by Rudershausen et al. (2007) from 2004 – 2006 along with additional discards recorded during another study currently in progress (Pers. Comm., Paul Rudershausen). Vermilion snapper used to estimate immediate mortality were captured between 29 – 57 meters. Delayed mortality estimates were calculated using a Monte Carlo simulation model that incorporated the percentage of observed gastric distention by depth as well as hooking mortality rates by body location. Hooking mortality rates were compiled from several previously published studies on various reef fish species. Delayed mortality for vermilion snapper caught from 25 – 75 meters was determined to be 38 %. This was the average delayed mortality from two depth ranges, 25 – 50 meters and 50 – 75 meters.

Recommendations for the AW:

1) The delayed mortality estimate from Rudershausen et al. (2007) of 38 % will be recommended as the base release mortality for both commercial and recreational fisheries. The discarded fish not counted as landings, but kept for some other reason need to be treated separately from the other discards. To be determined at the Assessment Workshop.

2) Sensitivity ranges of 20 – 50 % will be recommended as well, which were based on an average of the probability density distributions around the delayed mortality rate at each depth range, 25 – 50 and 50 – 75 meters.

2.5 Age

2.5.1. Aging procedures and error matrix

SEDAR 2 recommended that SCDNR and at the NOAA Beaufort Lab collaborate in providing an aging-error matrix for use in age- and length-structured assessment models. In 2008 the SCDNR and NOAA Beaufort laboratories held an ageing workshop and discussed methods and interpretation of otolith structures. The conclusion of this workshop was that both labs used the same methods (otoliths are aged sectioned) and interpret the otolith structures in similar ways. After the workshop otoliths of 583 vermilion snapper were read by both labs and the results compared. Each lab provided two readers and precision was calculated using average percent error (APE; Beamish and Fournier, 1981). Sixty percent of age readings were in agreement, and 95% were within ± 1 year. Average percent reader error (APE) was 8.32%. Production aging laboratories generally consider an APE ≤5% as a target for moderately long-lived species with relatively difficult to read otoliths (Morison et al., 1998; Campana, 2001). Amongst personnel aging vermilion snapper from the Gulf of Mexico, APE has been reported as high as 8.4% (Allman et al., 2001). Typically most of the disagreement between readers is due to difficulty establishing the first or core ring, which seems to be a common problem for many reef fish (Fowler 1995). Opaque zones near the core often make distinguishing the first annulus difficult. In the case of vermilion snapper, there was no bias in age reading for one lab or another (i.e., one lab did not consistently age the fish one more year than another lab). Aging error matrices are available in Table 2.5.1.1 based on the 583 samples read by both laboratories.

Recommendations for the AW:

1) NMFS Beaufort Lab and SCDNR personnel assigned ages to fish in a consistent manner and thus age data sets can be combined.

2) Aging error matrices can be used in the assessment model.

2.5.2. Availability and treatment of age data

The LH WG recommended using calendar age (not increment count) in the analyses. For all fish collected from January through August the age was the number of increments (count) +1 if the otolith had a wide translucent edge. In all other samples the age was equal to the number of increments (count).

Complete age data for fishery-independent (MARMAP) collections were available from 2002 through 2007. In 2000 and 2001, only part of the collected otolith samples were read, and from 1995 through 1999, no valid age readings are available. Prior to 1995 age readings are available, but samples were selected to construct an age/length key and not all samples were read.

Age data from fishery-dependent sources were collected since 1975. The earliest samples through 1991 were from the headboat fishery. Samples were from commercial and headboat fisheries from 1992 – 2002, and since then other recreational fishery samples from the east coast of Florida have been added to the collection (Table 2.5.2.1).

Recommendations for the AW:

1) The LH WG recommended for the fishery-independent source that only samples from 2002 through 2007 be used for age composition analysis.
2) All fishery-dependent age data can be used in the age composition analysis.
3) For comparison of size-at-age data, the LH WG recommends using the 2002-2007 fishing years due to the issues with the fishery-independent data and the most comprehensive fishery-dependent data is available.

4) The LH WG recommend using all data available to determine the von Bertalanffy growth parameters.

2.5.3. Variability in size at age

The size-at-age data for the 2002-2007 fishing years are presented as the median sizes (Figure 2.5.3.1; errors are plus/minus 1 quartile), due to the non-normal distribution of the length at each age of the fishery-dependent data because of the minimum size regulations. Overall, size-at-age in vermilion snapper is highly variable (Figure 2.5.3.2). Further analysis, separating sexes, and preliminary cohort analysis indicated that this high variability is real and a robust phenomenon. These findings are consistent with those reported by Allman et al. 2001 for vermilion snapper data from the Gulf of Mexico. The high variability in the size-at-age means that almost all age classes are subject to selection, because of legal limits. This selection may be a reason for the non-normality of the size-at-age data.

2.5.4. Differences in size at age between sexes

There were differences in size-at-age between males and females in some age classes (MARMAP 2007, data 2002-2007). However there is a large overlap due to the high variability in the size-at-age data in both males and females. The LH WG recommended sexes be combined in the size-at-age analysis. This recommendation was based on the inconsistency in the differences between age classes, the high variability in the data, and the fact that sex is not determined in fishery-dependent collections.

Recommendations for the AW:

All data should be combined for the assessment regardless of the sex.

2.5.5. Regional differences in size at age

Preliminary analysis indicated possible regional differences in size-at-age between NC-SC and samples collected further south (south of 31° latitude). Further investigations showed that the differences in size-at-age were only present in the recreational catches (Figure 2.5.5.1). The LH WG speculated that possible differences in fishing depths between regions may be a reason. Analysis of size-at-depth using the fishery-independent data showed some indications of an increase in size with depth, but the gear selection (small number of larger fish) and the high variability in the data prevent conclusive conclusions.

Recommendations for the AW:

The LH WG determined that the size-at-age data do not support the need for regional stock assessments.

2.6 Growth

Determining the theoretical growth of vermilion snapper has been difficult. The large variability in size-at-age, gear selectivity, location of catch and minimum size limit regulations have all influenced the von Bertalanffy growth parameters. There were also differences in size-at-age between fishery dependent (NMFS Beaufort) and fishery independent (MARMAP) data sets. These differences resulted in different von Bertalanffy growth parameters. The LF WG concluded that the fishery-independent data better represented the lower age classes, although the number of fish smaller than 250mm TL in the complete data set. Furthermore, the fishery-dependent data set included more larger, older fish. This may indicate that the MARMAP data set is subject to a gear selection in the larger size classes as seen in Figure 2.5.3.2, especially in age 8 and older. The LH WG recommended using a dome shape selectivity curve for the MARMAP data. The LH WG also recommended using the combined data sets of all years to characterize the growth of the vermilion snapper population in the SA (Table 2.6.1; Figure 2.6.1). To address the known effect of legal size limits for both the recreational catches (279 mm TL) and the commercial catches (305 mm TL) in the analysis of the von Bertalanffy parameters, the LH WG recommended to use the Diaz correction (Diaz et al. 2004) for the fishery-dependent data.

<u>Recommendations for the AW:</u>

All age data is to be used to estimate the von Bertalanffy growth model parameters. The Diaz et al. (2004) correction methodology will be applied to the fishery-dependent data affected by the minimum size regulations.

2.7 Reproduction

2.7.1 Spawning season

The spawning season of vermilion snapper is from April through September, peaking in June, July, and August (Cuellar et al. 1996, Mikell et al, 2008). Males appear to be reproductively active sooner and longer than the females.

2.7.2 Fecundity

There are no recent fecundity estimates available and the LH WG recommends using the data from Cuellar et al. (1996). The reported spawning periodicity for vermilion snapper off the southeastern United States is once every 5 to 5.5 days or 27 to 35 times per season (Cuellar et al. 1996, Mikell et al, 2008). The batch fecundity (BF or number of hydrated oocytes) is strongly related to fish length and is given by: $BF=0.0438*(\text{fork length in mm})^{2.508}$ (Cuellar et al. 1996). In comparison, Hood and Johnson(1999) reported that BF for the Gulf of Mexico vermilion snapper population was positively related to fish weight by: $BF=317*(\text{whole weight in gram})-3.162*10^4$.

Recommendations for the AW:

Annual fecundity should be used in the assessment model and is in the range of 27*BF to 35*BF.

2.7.3 Maturity schedules

Reproductive information for vermilion snapper is restricted to MARMAP data (reproductive data available through 2005). Only six of the 5,800 individuals collected between 1988 and 2005 and examined for reproductive stage were immature. These individuals ranged from 167 to 224 mm fork length. Almost all 1 year old males and females in the MARMAP data-set (1988-2005) are mature. These data are consistent with data from the Gulf of Mexico vermilion snapper where mature gonads were found in 69% of females at age 0, 84% at age 1, and 100% at all older ages (Hood and Johnson 1999).

The small number of immature fish prevented estimates of length and age at 50% maturity. Since no new data are available, the LF WG recommends using the maturity schedules based on what was provided for SEDAR2 (SEDAR2 2003, figure 5) for the current stock assessment: 0% at age-0, 80% at age-1, and 100% at age-2+.

Recommendations for the AW:

The maturity schedule for vermilion snapper is 0% at age-0, 80% at age-1, and 100% at age-2+.

2.7.4 Sex Ratio

The annual sex ratio data came from MARMAP data for years 1977 through 2006. The proportion of females in the data collected from 1977- 1987 was relatively constant around 62%. The proportion of females in the stock appeared to increase in 1988 and then hold relatively constant around 72% (Figure 2.7.4.1). It is difficult to determine whether this apparent shift in the proportion of females in the population is a real phenomenon or a result of gear selectivity. The MARMAP fishery-independent survey made a change in gear from a combination of trawls, “Antillean” traps, blackfish traps, fly nets and hook and line from 1977 – 1987 to chevron traps and hook and line since 1988.

Recommendations for the AW:

The LHWG recommends using the proportion from the 1988-2006 data, 72%, where the gear used by the MARMAP Survey was the most consistent.

2.8 Meristics and Conversion Factors

Several meristic conversion equations were generated for this assessment from fishery-dependent and fishery-independent data sources. The fishery-dependent sources included the Headboat Survey data and Florida's FWRI recreational fishery survey. The fishery-independent data came from MARMAP Survey. Total length – fork length linear conversion was based on 28,799 fish (Table 2.8.1a). The power function for whole weight – total length was based on 28,777 fish (Table 2.8.1b). Finally, the whole weight – gutted weight no intercept equation was based on 51 fish collected from Onslow Bay, NC (Table 2.8.1c).

Recommendations for the AW:

See Table 2.8.1

2.9 Life History Research Recommendations

As in previous assessments of reef fish in the US South Atlantic, studies on potential migration and stock structure of vermilion snapper between the Gulf of Mexico and SA need to be undertaken.

Estimates of mortality of fish are always difficult to quantify. Release mortality of undersized fish and fish exceeding the bag limit or trip limit should be easier to measure than natural mortality rates. More studies on release mortality are required and must include parameters such as disposition of the fish when released and time spent on deck before release. The level of use of undersized vermilion snapper as bait needs to be quantified and added as landings or some form of discard mortality, separate from the released fish.

Age and growth data need to be continually collected. The recreational component of the fishery is still not adequately sampled in the entire region, specifically north of Florida. We need the information to help determine area differences in age structure and growth. We also need sex specific data included with all biological samples. The MARMAP group needs to go back through their collections and fill in missing year's data as well as data for samples not selected for age-length keys prior to 1994. There needs to be a through investigation of how many age samples are enough for an assessment based on year, location, fishery and gear.

Further investigation into selectivity of gear and minimum size limit regulation impacts to the biological samples collected is required. Possible alternatives to the von Bertalanffy growth model need to be investigated, as well as the Diaz et al. methodology to correct for non-normal distribution of age samples due to size limits. More smaller fish, <200 mm TL, are needed to derive a better fit of the growth model at the youngest ages. Those fish are also needed for reproductive biology studies, as well as fish caught in the commercial and recreational fisheries.

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2.11 Tables

Table 2.3.1 Vermilion snapper natural mortality rates.
M: Natural mortality, k: VonBertalanffy growth parameter, T: temperature (°C), L_{inf}: Von Bertalanffy asymptotic length (mm), t_{max}: Maximum age, a_m: age at 50% maturity. FD: Fishery-Dependent data, FI: Fishery-Independent data. Maximum age = 19; Bottom water temperature = 25.09 °C; Age at 50% maturity = 1.

Data Source	L_∞ (mm)	k	Alverson & Carney	Hoenig	Pauly	Ralston	Jensen	Rule of thumb
All Years FD and FI data, FI ages 8+ excluded, t_0 unbound	**506**	**0.12**	**0.26**	**0.22**	**0.37**	**0.27**	**0.18**	**0.16**
2002-2007 FD and FI data, t_0 unbound	479.1	0.163	0.22	0.22	0.45	0.35	0.24	0.16
2002-2007 FD and FI data, t_0 = -1.00	413.6	0.291	0.12	0.22	0.69	0.62	0.44	0.16
2002-2007 FD data only, t_0 unbound,	454.4	0.225	0.17	0.22	0.57	0.48	0.34	0.16
2002-2007 FD data only, t_0 = -1.00	455.4	0.220	0.17	0.22	0.56	0.47	0.33	0.16
All Years FD data only, t_0 unbound,	550.6	0.131	0.25	0.22	0.38	0.29	0.20	0.16
All Years, FD data only, t_0 = -1.00	467.9	0.212	0.18	0.22	0.54	0.46	0.32	0.16
2002-2007 FI data only, t_0 unbound,	363.8	0.241	0.15	0.22	0.63	0.52	0.36	0.16
2002-2007 FI data only, t_0 = -1.00	333.7	0.465	0.05	0.22	1.00	0.98	0.70	0.16
All Years FI data only, t_0 unbound,	319.4	0.419	0.06	0.22	0.94	0.88	0.63	0.16
All Years, FI data only, t_0 = -1.00	312.4	0.567	0.03	0.22	1.16	1.19	0.85	0.16

Table 2.3.2 Vermilion snapper age specific natural mortality (Lorenzen) using the von Bertalanffy parameters from all years combined, excluding fishery-independent age 8+ fish with t_0 unbound, age at the midpoint of the fishing year, and scaled to M=0.22. Upper and Lower M are the 90% confidence intervals around the unscaled M.

Age	TL (mm)	W (grams)	M	Upper M	Lower M	Scaled M
0.5	192.9	92.4	0.93	1.40	0.58	0.36
1.5	228.3	150.8	0.80	1.24	0.49	0.31
2.5	259.7	219.3	0.71	1.12	0.43	0.28
3.5	287.6	294.9	0.65	1.04	0.39	0.26
4.5	312.3	374.8	0.61	0.98	0.35	0.24
5.5	334.2	456.4	0.57	0.93	0.33	0.22
6.5	353.6	537.9	0.54	0.89	0.31	0.21
7.5	370.8	617.7	0.52	0.86	0.30	0.20
8.5	386.1	694.7	0.50	0.84	0.29	0.20
9.5	399.7	768.0	0.49	0.81	0.28	0.19
10.5	411.7	837.1	0.47	0.80	0.27	0.19
11.5	422.4	901.7	0.46	0.78	0.26	0.18
12.5	431.8	961.7	0.45	0.77	0.25	0.18
13.5	440.2	1017.0	0.45	0.76	0.25	0.17
14.5	447.6	1067.8	0.44	0.75	0.25	0.17
15.5	454.2	1114.2	0.43	0.74	0.24	0.17
16.5	460.1	1156.4	0.43	0.73	0.24	0.17
17.5	465.3	1194.8	0.43	0.73	0.24	0.17
18.5	469.9	1229.5	0.42	0.72	0.23	0.17
19.5	474.0	1260.8	0.42	0.72	0.23	0.16

Table 2.5.1.1 Error matrix age readings of 583 vermilion snapper. Sectioned otoliths were read by SC-DNR (Marcel Reichert and Paulette Mikell) and a consensus reading was done on all otoliths that yielded differences in readings. NMSF Beaufort readers were Jennifer Potts and Stephanie McInerny and readings were analyzed separately (comparison SC v. NC, or combined and averaged (comparison NC v. SC).

SC-DNR (consensus reading)				
NS-Steph.	avg	sd	CV	n
0				
1	2.50	2.121	85%	2
2	2.42	0.827	34%	97
3	3.18	0.685	22%	220
4	3.89	0.687	18%	135
5	4.67	0.750	16%	78
6	5.61	0.567	10%	28
7	6.56	0.512	8%	16
8	6.00	0.000	0%	1
9	8.00	0.000	0%	3
10	8.67	0.577	7%	3
11				

SC-DNR (consensus reading)				
NS-Jen.	avg	sd	CV	n
0				
1	1.83	0.753	41%	6
2	2.39	0.626	26%	120
3	3.25	0.629	19%	195
4	3.99	0.643	16%	139
5	4.88	0.743	15%	77
6	5.73	0.944	16%	30
7	6.33	0.707	11%	9
8	6.50	2.121	33%	2
9	8.25	0.500	6%	4
10				
11	9.00	0.000	0%	1

SC age consensus	NC combined			
	avg	sd	CV	n
0				
1	1.92	0.669	35%	6
2	2.20	0.467	21%	86
3	3.04	0.640	21%	200
4	3.78	0.768	20%	160
5	4.59	0.948	21%	80
6	5.78	0.726	13%	36
7	6.72	0.461	7%	9
8	9.00	0.535	6%	4
9	10.00	0.816	8%	2
10				
11				

Table 2.5.2.1 Fishery-dependent vermilion snapper age samples available for the stock assessment by year, state and fishery. CB = Charter Boat; CM = Commercial; HB = Headboat; PR = Private Boat; RC = Recreational unknown type.

	Florida					Georgia		North Carolina			South Carolina	
Year	CB	CM	HB	PR	RC	CM	HB	CB	CM	HB	CM	HB
1975												1
1980			11									1
1981			112									
1982			38									
1983			2									
1986			89									
1987			7							1		
1988			2									
1991			10							136		20
1992		9								41	36	5
1993		74	1						94	42		5
1994		120	1						20	116	24	135
1995		263	117			3			50	50	1	24
1996			56							6		11
1997		55	6							7		1
1998		104	2									
1999		136										
2000		209										
2001	84	244	22									
2002	217	181	10									
2003	360	74	67	7				34	48	29		7
2004	102	159	299						353	29		3
2005	302	59	329	3	1				466	155	209	2
2006	230		487	2			8		461	51	484	51
2007	31	40	490				5		496	173	486	53
Total	1326	1727	2158	12	1	3	13	34	1988	836	1240	319

Table 2.6.1 Vermilion snapper von Bertalanffy growth parameters from combined data sources using the Diaz et al. (2004) correction methodology on the fishery-dependent data to account for size selectivity of fish due to minimum size regulations.

Fishery-Dependent and Fishery-Independent data

Years	t_0	L_∞	K	t_0
All years, FI ages 8+ excluded	**unbound**	**506**	**0.12**	**-3.5**
2002-2007	t_0 unbound	479.1	0.163	-2.43
2002-2007	bound	413.6	0.291	-1.00

Fishery-Dependent data only

Years	t_0	L_∞	K	t_0
2002-2007	t_0 unbound	454.4	0.225	-0.98
2002-2007	bound	455.4	0.22	-1.00
All Years	t_0 unbound	550.6	0.131	-2.14
All Years	bound	467.9	0.212	-1.00

Fishery-Independent data only

Years	t_0	L_∞	K	t_0
2002-2007	t_0 unbound	363.8	0.241	-3.00
2002-2007	bound	333.7	0.465	-1.00
All Years	t_0 unbound	319.4	0.419	-1.74
All Years	bound	312.4	0.567	-1.00

Table 2.8.1 Vermilion snapper conversion equations for (a) length-length linear regression, (b) weight-length power function, and (c) whole weight-gutted weight no-intercept regression. TL = total length in mm; FL = fork length in mm; SL = standard length in mm; WW = whole weight in g; GW = gutted weight in g.

a.

Data Source	Dep. Var.	Ind. Var.	a	b	r^2	n	Dep. Var. Range	Ind. var. Range	Units
SA Headboat, State of FL recreational, and MARMAP fishery-independent	TL	FL	1.436	1.106	0.994	28,799	100-615	91-546	mm
	FL	TL	0.371	0.898	0.994	28,799	91-546	100-615	mm
	TL	SL	5.02	1.273	0.994	15,900	100-615	79-476	mm

b.

Data Source	Dep. Var.	Ind. Var.	a	b	r^2	n	Length Range	Weight Range	Units
SA Headboat, State of FL recreational, and MARMAP fishery-independent	WW	FL	2.5×10^{-5}	2.927	0.97	31,359	91-503	12-2,300	mm, g
	WW	TL	2.1×10^{-5}	2.907	0.96	28,777	100-560	12-2,300	mm, g

c.

Source	Equation	Units	n	r^2	slope	SE	Min WW	Max WW
Fishery-Independent collection	WW = slope*GW; no intercept	kg	51	0.998	1.068	0.006	0.15	2.10

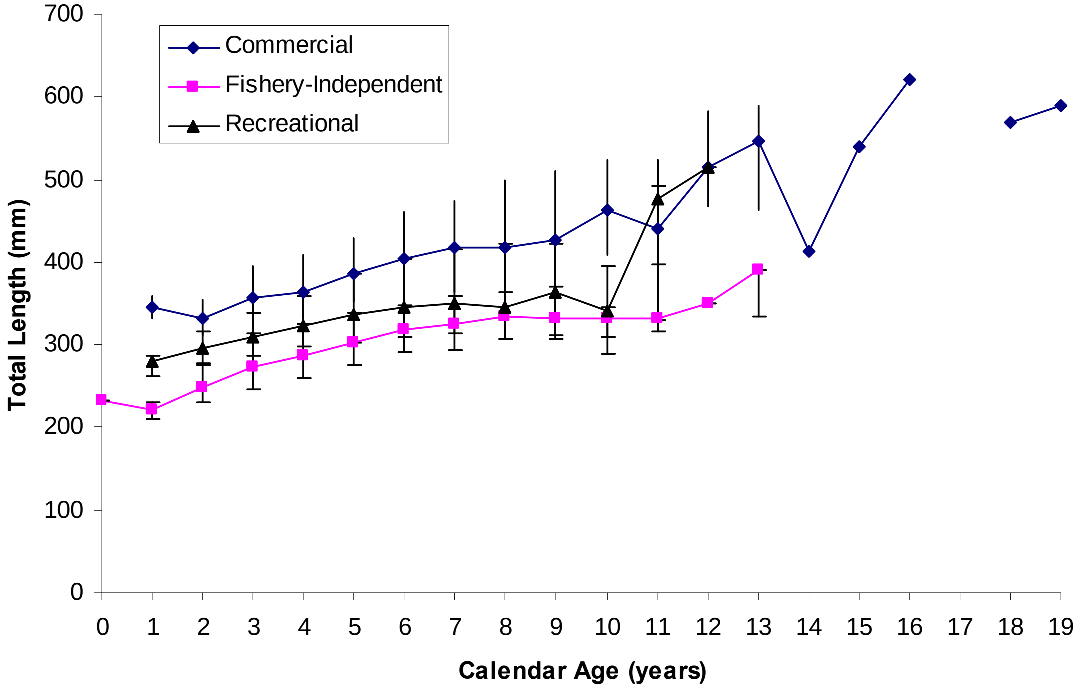

Figure 2.5.3.1 Vermilion Snapper 2002-2007 median size-at-age (errors are ± 1 quartile), for the US South Atlantic combined.

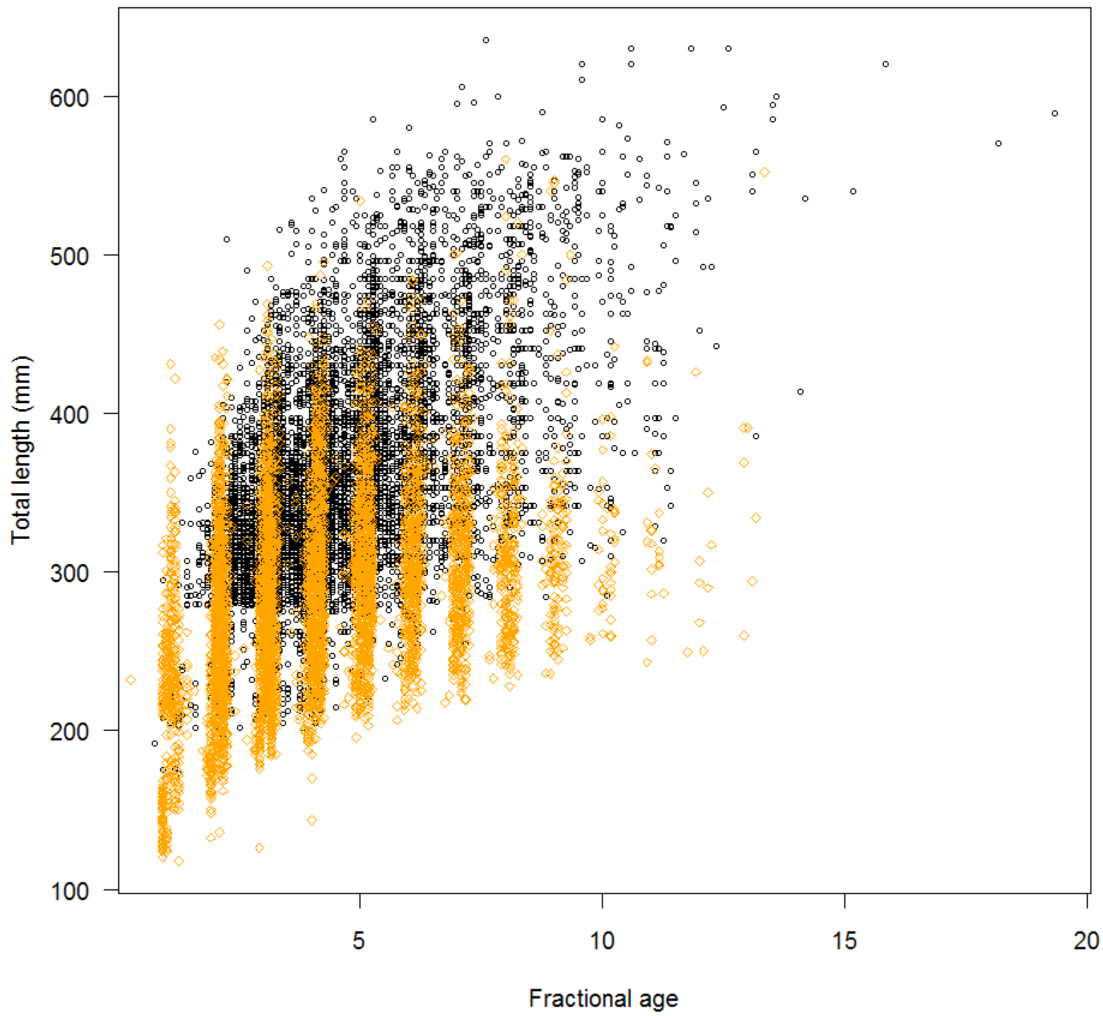

Figure 2.5.3.2 Vermilion snapper 2002-2007 size-at-age data for the US South Atlantic: Fishery-dependent v. fishery-independent.

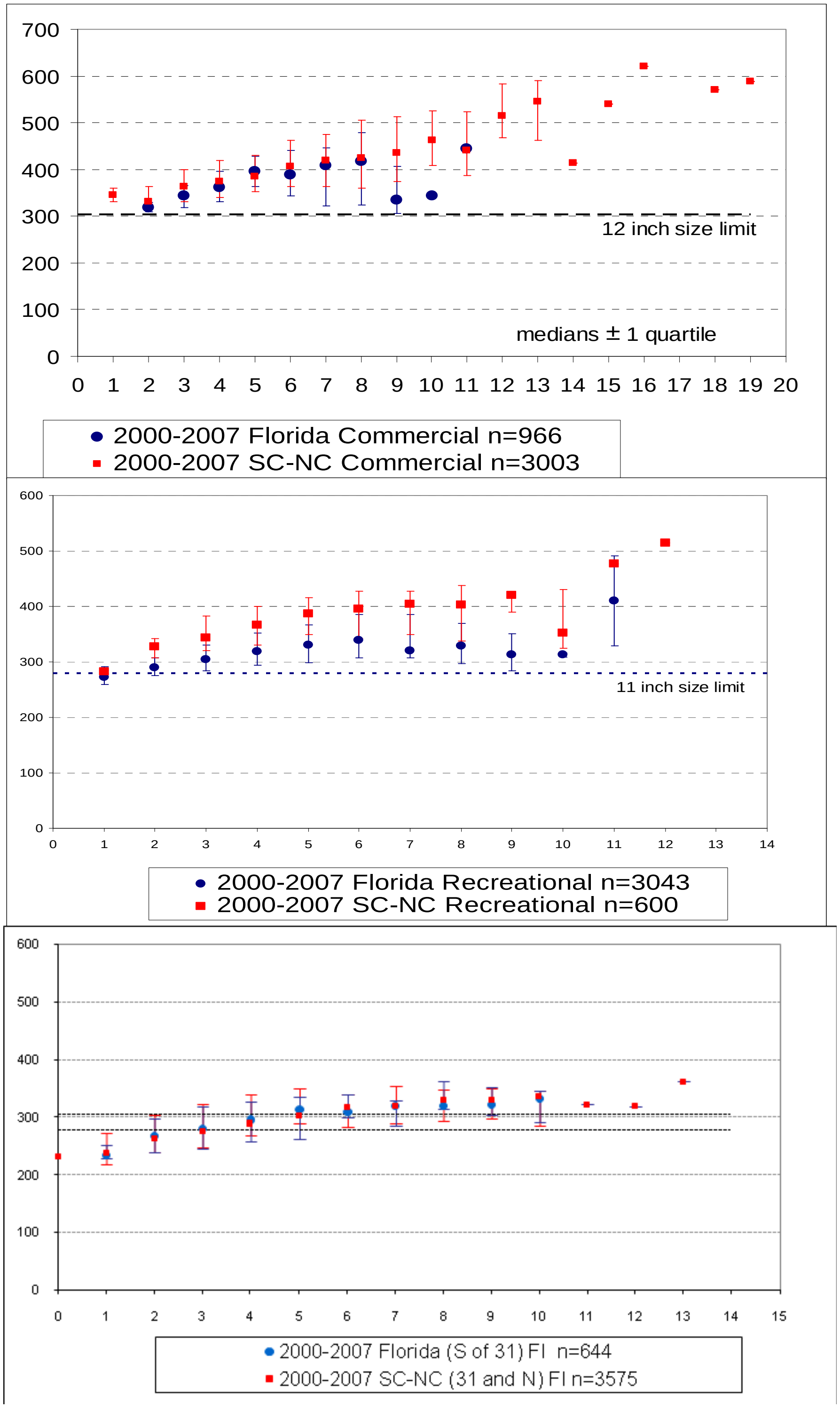

Figure 2.5.5.1 Median size (mm TL, y-axes) at age (year, x-axes) for vermilion snapper for NC/SC and Florida data. Data from 2000 through 2007. Error bars are ± 1 quartile. Horizontal dashed lines indicate the legal size limits (12 inches for commercial and 11 inches for recreational catches).

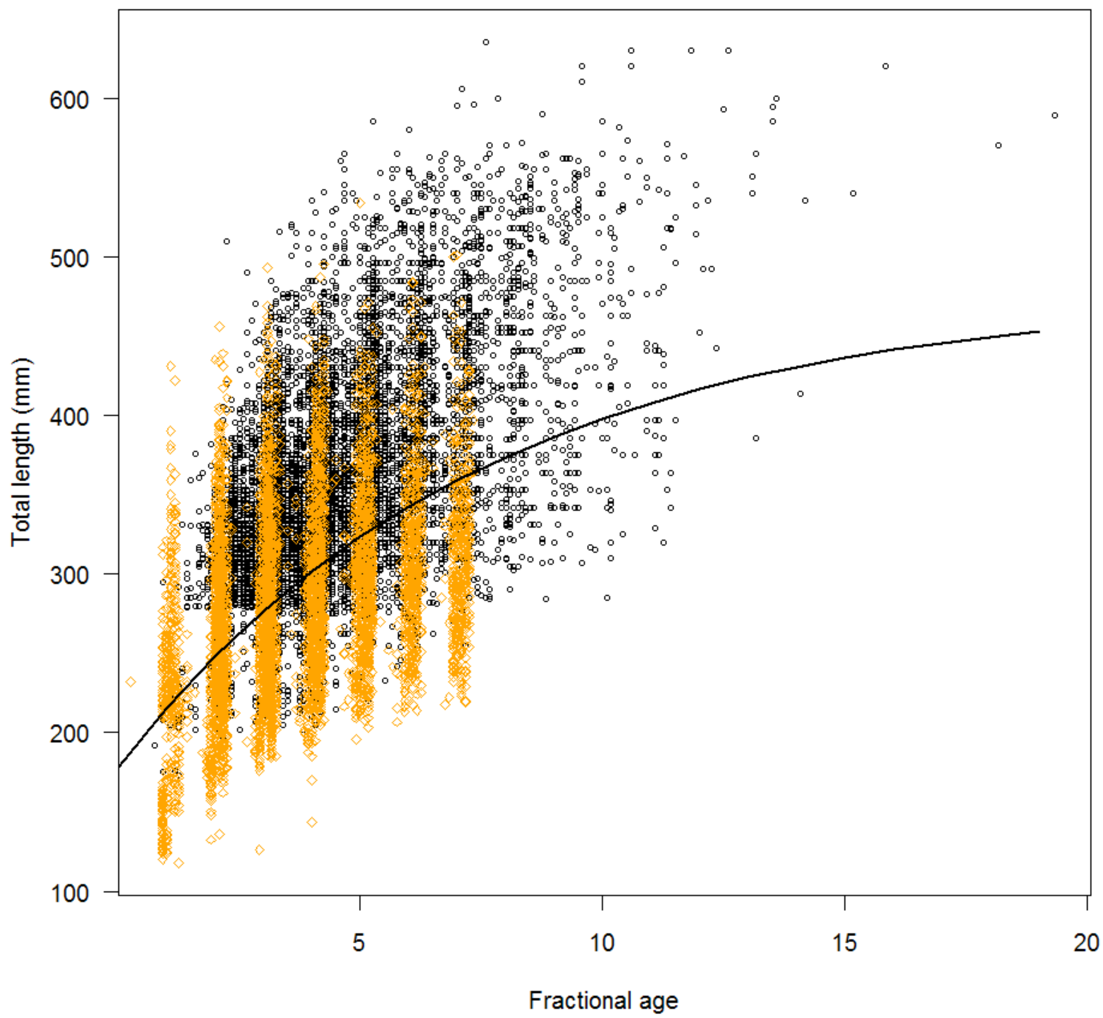

Figure 2.6.1 Vermilion snapper size-at-age data based on fractional age and the von Bertalanffy growth curve fit to the data. Data for age-8+ from the fishery-independent data has been eliminated due to dome selectivity of the MARMAP trap gear.

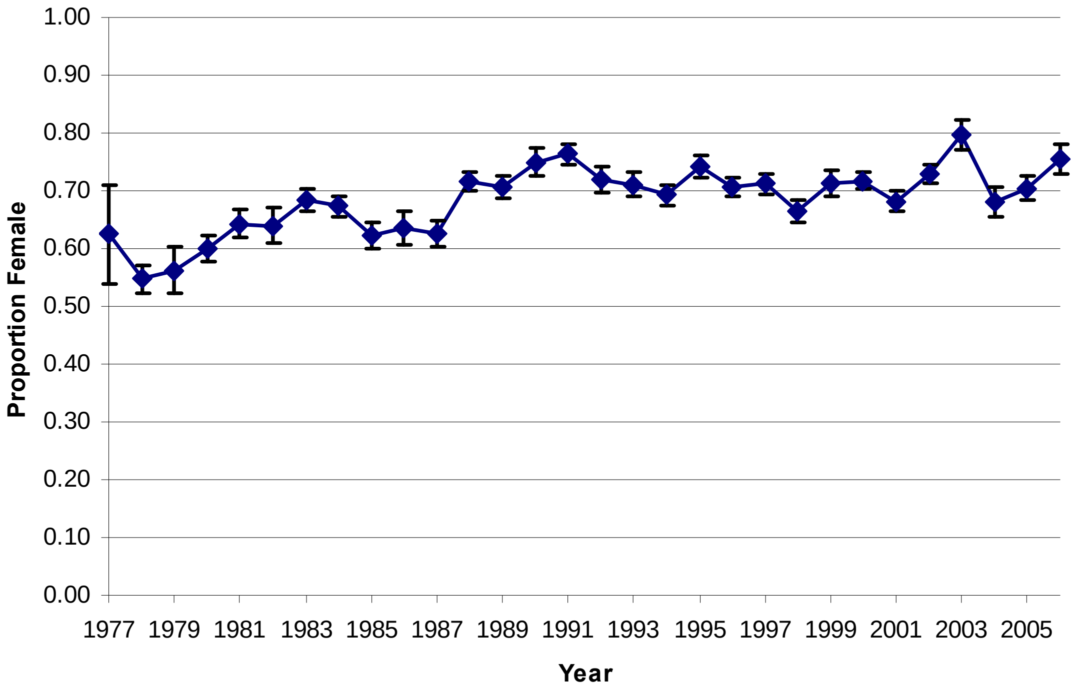

Figure 2.7.4.1 Proportion of female vermilion snapper in the US South Atlantic population.

3 Commercial Fishery

Chair: Douglas Vaughan (NMFS Beaufort); Rapporteur: Kate Andrews (NMFS Panama City); Members: Alan Bianchi (NC DMF), Jack Holland (NC DMF), Robert Wiggers (SC DNR), Julie Califf (GA DNR), Steve Brown (FL FWI), Dave Gloeckner (NMFS Beaufort), Kevin McCarthy (NMFS Miami), and Ben Hartig (FL Commercial Fisherman).

3.1 Overview

Historical commercial landings data for vermilion snapper were explored to address several issues. These issues included: (1) geographic stock boundaries, (2) historical perspective of landings data, (3) gear groupings for pooling landings, (4) mis-identification of species or need to expand unclassified snapper landings, (5) final presentation of landings by gear in pounds (whole weight) and in numbers based on state and federal data, (6) estimates of discards in numbers from commercial logbooks, (7) length and age compositions sampled from commercial fisheries, and (8) research needs.

3.2 Commercial Landings

3.2.1 NMFS Website and SAFIS for Commercial Landings

Initially, the NMFS website for commercial landings:

http://www.st.nmfs.noaa.gov/st1/commercial/landings/annual_landings.html

was queried on 12 March 2008 for all vermilion snapper landings along the Atlantic coast by state from 1950-2007. This query produced annual landings (available by gear) from 1958-2006 for Florida (east coast), Georgia, South Carolina, and North Carolina.

Additionally, we queried the Standard Atlantic Fisheries Information System (SAFIS, Internet based data entry system developed by the ACCSP) for commercial landings of vermilion snapper for Virginia and north. Only 75 pounds were reported as landed by bottom otter trawl from New York in 2005, otherwise no landings were available from Virginia and north that were identified as vermilion snapper. During the DW plenary, the need to query data bases for vermilion snapper landings north of the Virginia-North Carolina line for future assessments was emphasized.

Decision 1. Because essentially no vermilion snapper landings were reported north of North Carolina, the Workgroup recommended using the VA/NC line as the northern boundary for the South Atlantic vermilion snapper stock.

The NMFS website for commercial landings splits Florida into Florida East Coast (Atlantic) and Florida West Coast (Gulf of Mexico). Subsequent data bases post stratify

Monroe County (including the Keys) into Atlantic and Gulf of Mexico stocks. More detail is provided below.

The NMFS website contained landings back to 1950 for most species. Because the query showed no results for 1950-1957, the presumption is that none exist on this database. Other historical documents do not show commercial landings for vermilion snapper in the South Atlantic prior to 1958. Also, there were only small amounts of “snapper” (unclassified) on the NMFS website during the 1950s.

Decision 2. Because vermilion snapper landings were small prior to the 1970s, the Workgroup concluded that it was unnecessary to extend vermilion snapper landings prior to 1958 (earliest positive landings available), and therefore recommends that estimates of commercial landings be extended back to 1958.

These landings data were summarized by commercial gear, for initial exploration of which gears may be most important for landing vermilion snapper. Based on these data for 1958-2006, various line gears (handlines) accounted for 82.8% of the landings, combined gears for 12.0%, and otter trawls for another 4.5%. Miscellaneous gears made up the remainder (mostly pots & traps). This issue was further investigated with the SEFSC ALS database described next.

3.2.2 **Accumulated Landings System (ALS)**

Historical commercial landings (1962 to present) for the US South Atlantic are maintained as the Accumulated Landings System (ALS) in Miami by the SEFSC. For detailed description of the Accumulated Landing System (ALS), see addendum to this section. These data were made available by Josh Bennett (NMFS Miami). These data permit some refinement in setting the boundary for landings (catches) from Monroe County into South Atlantic and Gulf of Mexico stocks. We used the same approach as in SEDAR 15 for red snapper and greater amberjack. All Florida landings with water body codes 0010, 0019, and 7xxx were considered South Atlantic vermilion snapper regardless of Florida state code (10, 11, or 12). Also included were the undefined water-bodies (0000 and 9999) from ALS state 10 (Atlantic). See maps showing shrimp statistical areas for the Gulf of Mexico and U.S. Atlantic coasts (Figure 3.1) and Florida statistical areas (Figure 3.2).

Decision 3. The Workgroup decided to divide vermilion snapper into South Atlantic and Gulf of Mexico stocks by using the same approach as for the recent greater amberjack and red snapper assessments (SEDAR 15).

The ALS data were obtained from two databases. The primary database contains landings for all southern states by month and gear for 1962-2007. However, Florida data for the period 1977-1996 contains no gear information (gear is reported as code 999). To obtain gear-specific information for Florida for 1977-1996, one must refer to the other database (aka Florida General Canvass), which contains no corresponding monthly information (month = 13). The proportion of landings by gear from the Florida general canvass data base was applied to the unknown (gear = 999) landings from the primary data base to develop gear-specific landings from Florida for the period 1977-1996.

These data were summarized by gear code to assess the importance of different gears to the vermilion landings. Commercial landings for vermilion snapper were mostly from handlines (almost 98% by weight) based on the historical ALS data (1962-2007) for Atlantic Florida. Similarly, handlines were the dominant fishing gear for commercial landings from Georgia – North Carolina, accounting for over 93% by weight. However, there were historically important landings from trawls, or almost 6% of the commercial landings by weight from Georgia – North Carolina. These trawl landings were particularly important during the late 1970s and early 1980s (and were banned by Snapper-Grouper Amendment 1 in 1989, although trawl landings persist, perhaps as bycatch from other trawl fisheries).

Decision 4. The Workgroup recommended that landings by fishing gear be reduced to two categories, the dominant handline gear and historically important trawl gear. The small percentage from miscellaneous 'other' gears can be pooled with handlines.

The Workgroup was in general agreement with the SEDAR 2 Commercial Workgroup that mis-identification of vermilion snapper is minimal, and that, for instance, red snapper reported as vermilion snapper is unlikely. Also, mis-identification of vermilion snapper as red snapper was also thought to be minimal (after SEDAR 15 Commercial Workgroup).

Decision 5. The Workgroup concluded that mis-identification of vermilion snapper as another snapper or vice-versa was not a significant issue, and no corrections were necessary.

Vermilion snapper landings are variably recorded to species and as unclassified snappers. Reporting to species is more prevalent in recent years, and the proportion of total snapper landings reported as unclassified declines over time. After much discussion, the Workgroup agreed with the decision of the SEDAR 2 Commercial Workgroup. That is, unclassified snappers in Atlantic Florida were not though to include vermilion snappers. Unclassified snappers from Georgia were minimal (about 9000 lb in 1977 and 1978, otherwise generally less than 100 lb) and not thought to include vermilion snappers. However, unclassified snappers from South Carolina and North Carolina were thought to include vermilion snappers and were proportioned out as follows. Total vermillion landings are estimated for each state by year and gear reported to species (including vermilion snapper, but not red snapper). In general, the proportion of vermillion landings relative to the total snapper landings reported by species is used as a multiplier to estimate the proportion of vermillion landings in the unclassified category. For years in which there are no landings reported by species, the time series average percent vermillion is used to estimate the portion of vermillion snapper in the unclassified category. Further discussion relative to South and North Carolina will be found in section 3.2.3 under those state headings.

Decision 6. The Workgroup agreed that no treatment of unclassified snappers was required for Florida and Georgia, but was needed for South Carolina and North Carolina.

Vermilion snapper are typically landed in gutted form. The Workgroup agreed that to reduce confusion in reported landings between recreational and commercial fisheries, commercial landings should be reported in whole weight. Because vermilion snappers landings are originally obtained in gutted weight, and the conversion factors from gutted to whole weight vary by state, it was decided that the state landings would be transformed back to their original gutted weight, and then a single, biologically-based conversion factor would be applied to convert back to whole weight. In addition, a table is provided summarizing commercial landings by gear in gutted weight (pounds).

Decision 7. To reduce possible confusion with presentation of recreational landings, the Commercial Workgroup decided to present commercial landings as whole weight.

3.2.3 Commercial Landings Developed from State Databases

Commercial landings in whole weight were developed based on classified Vermilion snapper by the Working Group from each state by gear for 1958-2007.

Florida – Edited data from 1986-2007 were extracted and summarized by year, coast, area fished, county landed, and gear with whole pounds, gutted pounds, and number of trips from the Florida trip ticket database. Gears selected for summary were lines (rod & reel, long line, and electric reel combined), trawl, and other. Other gear consisted mostly of unclassified, dive and other net gears. Number of trips with other gear is noticeable from 1986-1992 because gear was not required on the trip ticket until late 1991. To fill in for missing gears for those years, we assigned gear to trips based on gears listed on the commercial fishers' annual license application. A hierarchy of these gear types, based on usage in later years, was used in combination with species composition on the trips to assign the most appropriate gear. Landings were then separated into Monroe county and Florida south Atlantic landings by year and gear.

Vermilion snapper data from NOAA Fisheries logbooks were extracted and summarized by year, state, coast, county and gear with gutted pounds, whole pounds, and number of trips. Gears were categorized as either as described above, as with trip tickets. Florida landings were separated into Florida Atlantic counties and Monroe county, and the proportion of Atlantic landings was calculated for Monroe county by year and gear. In addition, since logbook data did not start until 1990, and 1992 was selected as the first complete year, an annual average proportion of landings by gear from 1992-2007 was calculated to apply a proportion to pre-1992 data in the trip ticket landings.

The proportions calculated by year and gear for Atlantic landings from Monroe county were then applied to the Florida trip ticket landings from Monroe county by year and gear. Similarly, the annual average proportion from logbooks calculated from 1992-2007 was then applied to Monroe county Florida south Atlantic landings to each year, by gear, from 1986-1991. The proportioned landings for Monroe county were then added to the landings from the Atlantic counties by year and gear for final Florida SA landings by gear from 1986-2007.

Georgia – We are confident there is no misidentification of vermilion snapper by Georgia dealers and our dockside sampling has demonstrated that vermilion snapper are not sorted as unclassified snapper. As such, no adjustments were made to the data. Landings were provided for 1989 – 2007.

South Carolina – South Carolina commercial landings data were reported by coastal dealers starting in 1972 through mandatory monthly landings reports required from all SC licensed wholesale dealers. These reports were summaries which collected species, pounds landed, market category, catch disposition (gutted or whole), ex-vessel price and area fished. In September 2003, South Carolina began collecting trip level information through mandatory trip tickets, which captures detailed effort information along with fisherman and vessel identifiers. Commercial landings for vermilion snapper are reported in gutted pounds and separated by market category. Weights associated with each market category are combined to arrive at a cumulative total, and landings are converted to whole pounds using a conversion factor of 0.9 (e.g. divide gutted weight by 0.9). Canvas data are stored and extrapolated from an MS Access database for all landings, by species, by gear, back to 1972. In addition to vermilion snapper, landings that were reported as unclassified snapper (which were first reported as such in 1976) were also separated out by calendar year and gear (hand line, trawl, other) to determine the proportion of that catch estimated to be vermilion snapper. To arrive at a proportion, classified snapper landings (e.g. vermilion, silk, cubera, mango, mutton, yellowtail, dog, blackfin, and lane), excluding red snapper (since it was deemed in SEDAR 15 that red snapper were consistently reported as such), were combined into a total classified category by calendar year and gear type. Vermilion snapper landings (also separated by gear and year) were then divided by the total classified landings to determine the proportion of vermilion in the classified snapper landings. The proportion for each year, for each gear type, was then multiplied by the respective landing weights reported in the unclassified snapper category to estimate the weight of vermilion reported as unclassified snapper. The resulting weight was then added to the annual vermilion snapper landings in each respective gear and year category. South Carolina vermilion snappers landings are compared with and without including a portion of unclassified snappers (Figure 3.3).

North Carolina – The National Marine Fisheries Service prior to 1978 collected commercial landings data for North Carolina. Port agents would conduct monthly surveys of the state's major commercial seafood dealers to determine the commercial landings for the state. Starting in 1978, the North Carolina Division of Marine Fisheries entered into a cooperative program with the National Marine Fisheries Service to maintain the monthly surveys of North Carolina's major commercial seafood dealers and to obtain data from more dealers. The North Carolina Division of Marine Fisheries Trip Ticket Program (NCTTP) began on 1 January 1994. The NCTTP was initiated due to a decrease in cooperation in reporting under the voluntary NMFS/North Carolina Cooperative Statistics Program in place prior to 1994, as well as an increase in demand for complete and accurate trip-level commercial harvest statistics by fisheries managers. The detailed data obtained through the NCTTP allows for the calculation of effort (i.e. trips, licenses, participants, vessels) in a given fishery that was not available prior to 1994 and provides a much more detailed record of North Carolina's seafood harvest.

Annual landings of vermilion snapper were calculated for the SEDAR 17 Data Workshop for North Carolina. The annual landings cover the years from 1958 to 2007 to be consistent with other South Atlantic States, although North Carolina has no landings of vermilion snapper prior to 1971. Data used to calculate the landings for North Carolina include the North Carolina Trip Ticket Program (1994 to 2007), landings from the ALS (1962 to 1993), and landings from historical data (prior to 1961). Extrapolations of vermilion snapper from the unclassified landings of snapper were made from data prior 1993. All data collected from the North Carolina Trip Ticket Program was not changed or extrapolated. To calculate the amount of vermilion snapper in unclassified snapper landings, the proportion of vermilion snapper to other identified snappers was calculated from 1978 to 1991 by gear type. This calculation excluded landings of red snapper because it was assumed all red snapper were identified correctly and this logic is consistent with SEDAR 15. The calculated proportion was then applied to all unclassified landings of snapper to calculate a new adjusted landings total for vermilion snapper by gear type. North Carolina vermilion snappers landings are compared with and without including a portion of unclassified snappers (Figure 3.4).

Combined Landings in Weight – Annual landings in whole weight provided by the states were augmented with ALS landings back to 1962 as needed for years not covered by state landings. Landings prior to 1962 (1958-1961) were those downloaded from the NMFS website. Because individual states applied different gutted weight to whole weight conversions, it was decided that we should first convert the whole landings in whole weight back to their original gutted weight using the state-specific conversions. The state-specific gutted to whole weight conversions are as follows: Florida and Georgia multiply gutted weight by 1.11 to obtain whole weight, South Carolina divides gutted weight by 0.9 (quite similar to multiplying by 1.11), and North Carolina multiplies gutted weight by 1.08. The inverse of these processes was used in back transforming to gutted weight. Landings in gutted weight were then converted to whole weight by multiplying by the common biologically-based conversion factor (1.068, $r^2 = 0.994$; see Life History Section). Annual landings in whole weight are summarized by region (Table 3.1 and Figure 3.5) and by gear (Table 3.2 and Figure 3.6). Additionally, annual landings in gutted weight are summarized by gear in Table 3.2a.

A comparison was made of total commercial landings for US south Atlantic vermilion snappers between the recent updated assessment (to SEDAR 2) and the data presented here for SEDAR 17 for the period 1970-2007 (Figure 3.7). They match very closely. The largest deviation (23%) was in 1971 when landings were still low, but otherwise an average magnitude of 3.7% over the entire period 1970-2007, and 2.3% since 1990. Some of the differences are due to difference in defining the southern boundary with the Gulf of Mexico, some to ongoing corrections to data bases, and some to differences in proportioning unclassified snappers into vermilion snappers. Overall the differences are small.

Combined Landings in Numbers – Conversion of commercial landings in weight to numbers is based on mean weights obtained from TIP length sampling by state, gear and year. First sampled lengths are converted to weight using the weight length relation given in the Life History Section. When TIP length samples were inadequate (N<20) or non-existent, a weighted average of available weight was obtained by averaging across years, either prior to 1992 or 1992 and later (Table 3.3). The year 1992 was selected because of the implementation that year of a minimum size limit. Trawl data was so limited (and landings very small) after 1992, that only an overall mean was obtained. Landings in numbers are summarized by region (Table 3.4 and Figure 3.8) and by state (Table 3.5 and Figure 3.9).

Uncertainty in Commercial Landings – The Workgroup discussed the uncertainty that may be associated with estimates of commercial landings. In past assessments this discussion was framed about coefficients of variation (CV = standard deviation/mean) and how CVs may have varied over time. The CV was thought to have been high in the early years prior to the start of the ALS in 1962 (see Appendix on ALS). Meanwhile, the CV was thought to be relatively low in recent years, subsequent to North Carolina's trip ticket program in 1994. During the discussion, it was suggested that further improvements were associated with the transfer of responsibility for collection and processing to the SEFSC in 1978 and beginning of state-federal co-operation. Between the late 1978 and 1994, a series of improvements occurred, such as the Florida trip ticket in 1985/1986. Hence, a low CV of 10% was chosen for the recent period (1994-present), high CV of 40% for pre-ALS data, 30% for the early years of the ALS, and a linear interpolation from 30% to 10% form 1978-1994 (Figure 3.10). The Workgroup suggests that these CVs may serve as the basis for developing alternate landings streams for sensitivity model runs.

3.3. Commercial Price

Price per pound was estimated for vermilion snapper sold in the South Atlantic states from the ALS database for the years 1962 through 2006. The Producer Price Index (PPI) for "prepared fresh fish and other seafood" was obtained from the U.S. Bureau of Labor Statistics website (data.bls.gov), available since 1965. The PPI, like the CPI, is an index that reflects inflation. But the difference here is that the PPI reflects the costs associated with bringing the product to market. In other words, this PPI reflects more closely the changed in costs to fishermen and processors such as trip costs. Using 1965 as base year, observed price per pound was adjusted to obtain inflation-adjusted values for the price per pound. Unadjusted and adjusted price per pound are compared in Figure 3.11. The actual price the fishermen received noted a general upwards trend from approximately $0.23 on average in 1965 to $2.77 per pound in 2007.The PPI-calculated values held the value of one dollar constant throughout the time series, and show an actual decline over time. The PPI-adjusted value for 2007 was $0.19.

3.4. Commercial Discards

The report titled '***Discards of Spanish Mackerel and Vermilion Snapper Calculated for Commercial Vessels with Federal Fishing Permits in the US South Atlantic***' was prepared by Kevin McCarthy (**SEDAR 17-DW10**). A brief summary of the results and discussion for vermilion snapper follows:

Calculated total discards for each region are provided for vermilion snapper discarded from handline vessels. The calculated discards from each region were summed by year to provide yearly total vermilion snapper handline vessel discards (Table 3.6). Discards of vermilion snapper often exceeded 100,000 fish, although in recent years the number of discards has decreased to approximately 50,000 fish. There appears to be a trend among fishers in the south Atlantic to report “no discards” more frequently in recent years than during the first few years of the discard logbook program. The degree of impact of such reporting, resulting in more “no discard” trips, is unknown.

More than 85% of vermilion snapper released in regions 1-4 were reported as “alive” or “majority alive”. Discards in region 5, however, were frequently reported (70%) as majority dead. The reason reported for almost all (98-99%) vermilion snapper discards was regulations.

The number of trips reporting vermilion snapper in the US south Atlantic was very low and the number of individuals of those species reported as discarded was also low. Stratification of the available data was limited because of the small sample sizes and, therefore, likely does not capture much of the variation in numbers of discards within the vermilion snapper fisheries. How that may affect the number of calculated discards (over or under estimate) is unknown.

A minimum size limit of 12” TL was instituted in 1992 through Snapper-Grouper Amendment 4. Discussion by the Workgroup suggested that prior to 1992, discards were likely to be minimal. Expansion of estimates back to 1992 using logbook effort was accepted by the Workgroup as reasonable.

Decision 7. The Workgroup accepted these estimates of vermilion snapper discards in the handline fisheries for 1992-2007.

3.5 Biological Sampling

3.5.1 Length Distributions

Length samples have been collected by the Trip Interview Program (TIP) and several state agencies since 1981. These samples are collected by port agents at docks where commercial catches are landed throughout the US South Atlantic coasts. Trips are randomly sampled to obtain trip, effort, catch and length frequency information. Occasionally there has been quota sampling to obtain age structures on fish that are rare in the catch (extremely large and small fish). These non-random samples are identified in the data to allow removal from analyses were non-random samples are not appropriate.

Sample data were obtained from the TIP data set (NMFS/SEFSC), which contains information from commercial, recreational and research programs. The data used where a subset of this data set, which contained commercial samples that were identified as having no sampling bias (Table 3.7). These data were further limited to those that could be assigned a year, gear, state and area. Data that had unknown year sampled, gear used or sampling state were deleted from the file.

Sample data were joined with landings data by year, gear and state. Landings data were also limited to those data that could be assigned a year, gear, and state. Landings and sample data were assigned a state based on landing and sample location.

Length data were converted to cm total length and binned by one centimeter group with a floor of 0.5 cm and a ceiling of 0.4 cm. Length was converted to weight (whole weight in

Kg) using conversions provided by the life history group. The length data and landings data were broken into handline and trawl gears. Length compositions were weighted by expanding the number of lengths in each strata (gear, state, year) by the landings in numbers (relative frequency in stratum x landings in numbers for the stratum).

Annual length compositions of vermilion snapper for handline and trawl gears are summarized in Figures 3.12 – 3.13.

Market category comparison: It was suggested that we use market category to obtain size trends in landings data. To accomplish this task we would need to allocate landings by size based on market grade. As noted below, definition of market grade varied between states.

Landings are mostly available by market grade for vermilion snapper for 1994-2007 (Figure 3.14). Less than 1% were in the mixed grade for North Carolina, about 3% from South Carolina, less than 1% for Georgia, but about 60% from Florida. The mixed grade here includes both those landings designated as 'mixed' and those with no grade given. For purposes of this summary, categories for <1 pound (used by NC & GA) are referred to as Small, and categories for >2 pounds are referred to as large. The category for 1-2 pounds is referred to as Medium. Overall, 89% of the vermilion snapper landings were available by market grade (generally small, medium and large).

Of the 231,321 length samples obtained for vermilion snapper, only 81,194 had a market category assigned. It was felt that having only 35% of the samples with market grade was inadequate to allocate landings at size by market grade.

3.5.2 Age Distributions

Sample size of vermilion snapper ages are summarized by gear from commercial landings in the US Atlantic for 1992-2007 (Table 3.8). Age compositions were developed for handlines (1992-2007, Figure 3.15) gear types. Weighting is initially between states weight by state landings in numbers, and then by length composition shown in Figure 3.14. This latter weighting corrects for a potential sampling bias of age samples relative to length samples (see Section 3 in SEDAR10 for South Atlantic gag).

3.5.3 Adequacy for characterizing lengths and ages

Length sampling has been extensive for vermilion snapper from the handline fishery, with more than 231,000 fish sample for length. These samples are reasonably well distributed by state (10% from FL, 17% from GA, 50% from SC, and 23% from NC). An average of 9,377 fish sampled were available annually from 1984-2007. Samples were only available from North Carolina in 1983, and since 1984, state samples were lacking only in 1984 and 1987 from Florida, and 1990 from Georgia. Length sampling of vermilion snapper from trawls is much more limited, with a total of 2,218 fish lengths collected between 1984 and 1988 and in 1997. An additional 3,660 fish lengths were categorized as Other gear.

Of the 5,010 aged vermilion snapper, 4,985 of them are from the commercial handline fishery. Of the remain 25 ages, 8 were collected from "butterfly/wing net" gear, 6 from "diver" gear, and 11 from "trap" gear. The ages from handline gear are distributed among the states as follows: 1,727 from Atlantic Florida, 3 from Georgia, 1,276 from South Carolina, and 1,979 from North Carolina. Of particular concern was that all samples collected between 1997 and 2002 were from Atlantic Florida. Obviously, no post-stratification of samples by state is possible for these years. Any age composition for these years is representative of Florida alone, and not necessarily of the coastwide stock.

3.6 Research Recommendations for Vermilion snapper

- Still need observer coverage for the snapper-grouper fishery
  - 5-10% allocated by strata within states
  - possible to use exemption to bring in everything with no sale
  - get maximum information from fish
- Expand TIP sampling to better cover all statistical strata
  - Predominantly by H&L gear
  - In that sense, we have decent coverage for lengths
- Trade off with lengths versus ages, need for more ages (i.e., hard parts)
- Workshop to resolve historical commercial landings for a suite of snapper-grouper species
  - Monroe County (SA-GoM division)
  - Species identification (mis-identification and unclassified)

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Addendum to Commercial Landings (Section 3.2):

NMFS SEFIN Accumulated Landings (ALS)

Information on the quantity and value of seafood products caught by fishermen in the U.S. has been collected as early as the late1890s. Fairly serious collection activity began in the 1920s. The data set maintained by the Southeast Fisheries Science Center (SEFSC) in the SEFIN database management system is a continuous data set that begins in 1962.

In addition to the quantity and value, information on the gear used to catch the fish, the area where the fishing occurred and the distance from shore are also recorded. Because the quantity and value data are collected from seafood dealers, the information on gear and fishing location are estimated and added to the data by data collection specialists. In some states, this ancillary data are not available.

Commercial landings statistics have been collected and processed by various organizations during the 1962-to-present period that the SEFIN data set covers. During the 16 years from 1962 through 1978, these data were collected by port agents employed by the Federal government and stationed at major fishing ports in the southeast. The program was run from the Headquarters Office of the Bureau of Commercial Fisheries in Washington DC. Data collection procedures were established by Headquarters and the data were submitted to Washington for processing and computer storage. In 1978, the responsibility for collection and processing were transferred to the SEFSC.

In the early 1980s, the NMFS and the state fishery agencies within the Southeast began to develop a cooperative program for the collection and processing of commercial fisheries statistics. With the exception of two counties, one in Mississippi and one in Alabama, all of the general canvass statistics are collected by the fishery agency in the respective state and provided to the SEFSC under a comprehensive Cooperative Statistics Program (CSP).

The purpose of this documentation is to describe the current collection and processing procedures that are employed for the commercial fisheries statistics maintained in the SEFIN database.

1960 - Late 1980s
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Although the data processing and database management responsibility were transferred from the Headquarters in Washington DC to the SEFSC during this period, the data collection procedures remained essentially the same. Trained data collection personnel, referred to as fishery reporting specialists or port agents, were stationed at major fishing ports throughout the Southeast Region. The data collection procedures for commercial landings included two parts.

The primary task for the port agents was to visit all seafood dealers or fish houses within their assigned areas at least once a month to record the pounds and value for each species or product type that were purchased or handled by the dealer or fish house. The agents summed the landings and value data and submitted these data in monthly reports to their area supervisors. All of the monthly data were submitted in essentially the same form.

The second task was to estimate the quantity of fish that were caught by specific types of gear and the location of the fishing activity. Port agents provided this gear/area information for all of the landings data that they collected. The objective was to have gear and area information assigned to all monthly commercial landings data.

There are two problems with the commercial fishery statistics that were collected from seafood dealers. First, dealers do not always record the specific species that are caught and second, fish or shellfish are not always purchased at the same location where they are unloaded, i.e., landed.

Dealers have always recorded fishery products in ways that meet their needs, which sometimes make it ambiguous for scientific uses. Although the port agents can readily identify individual species, they usually were not at the fish house when fish were being unloaded and thus, could not observe and identify the fish.

The second problem is to identify where the fish were landed from the information recorded by the dealers on their sales receipts. The NMFS standard for fisheries statistics is to associate commercial statistics with the location where the product was first unloaded, i.e., landed, at a shore-based facility. Because some products are unloaded at a dock or fish house and purchased and transported to another dealer, the actual 'landing' location may not be apparent from the dealers' sales receipts. Historically, communications between individual port agents and the area supervisors were the primary source of information that was available to identify the actual unloading location.

Cooperative Statistics Program
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In the early 1980s, it became apparent that the collection of commercial fisheries statistics was an activity that was conducted by both the Federal government and individual state fishery agencies. Plans and negotiations were initiated to develop a program that would provide the fisheries statistics that are needed for management by both Federal and state agencies. By the mid- 1980s, formal cooperative agreements had been signed between the NMFS/SEFSC and each of the eight coastal states in the southeast, Puerto Rico and the US Virgin Islands.

Initially, the data collection procedures that were used by the states under the cooperative agreements were essentially the same as the historical NMFS procedures. As the states developed their data collection programs, many of them promulgated legislation that authorized their fishery agencies to collect fishery statistics. Many of the state statutes include mandatory data submission by seafood dealers.

Because the data collection procedures (regulations) are different for each state, the type and detail of data varies throughout the Region. The commercial landings database maintained in SEFIN contains a standard set of data that is consistent for all states in the Region.

A description of the data collection procedures and associated data submission requirements for each state follows.

Florida
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Prior to 1986, commercial landings statistics were collected by a combination of monthly mail submissions and port agent visits. These procedures provided quantity and value, but did not provide information on gear, area or distance from shore. Because of the large number of dealers, port agents were not able to provide the gear, area and distance information for monthly data. This information, however, is provided for annual summaries of the quantity and value and known as the Florida Annual Canvas data (see below).

Beginning in 1986, mandatory reporting by all seafood dealers was implemented by the State of Florida. The State requires that a report (ticket) be completed and submitted to the State for every trip. Dealers have to report the type of gear as well as the quantity (pounds) purchased for each species. Information on the area of catch can also be provided on the tickets for individual trips. As of 1986 the ALS system relies solely on the Florida trip ticket data to create the ALS landings data for all species other than shrimp.

Georgia
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Prior to 1977, the National Marine Fisheries Service collected commercial landings data Georgia. From 1977 to 2001 state port agents visited dealers and docks to collect the information on a regular basis. Compliance was mandatory for the fishing industry. To collect more timely and accurate data, Georgia initiated a trip ticket program in 1999, but the program was not fully implemented to allow complete coverage until 2001. All sales of seafood products landed in Georgia must be recorded on a trip ticket at the time of the sale. Both the seafood dealer and the seafood harvester are responsible for insuring the ticket is completed in full.

South Carolina
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Prior to 1972, commercial landings data were collected by various federal fisheries agents based in South Carolina, either U.S. Fish or Wildlife or National Marine Fisheries Service personnel. In 1972, South Carolina began collecting landings data from coastal dealers in cooperation with federal agents. Mandatory monthly landings reports on forms supplied by the Department are required from all licensed wholesale dealers in South Carolina. Until fall of 2003, those reports were summaries collecting species, pounds landed, disposition (gutted or whole) and market category, gear type and area fished; since September 2003, landings have been reported by a mandatory trip ticket system collecting landings by species, disposition and market category, pounds landed, ex-vessel prices with associated effort data to include gear type and amount, time fished, area fished, vessel and fisherman information.

South Carolina began collecting TIP length frequencies in 1983 as part of the Cooperative Statistics Program. Target species and length quotas were supplied by NMFS and sampling targets of 10% of monthly commercial trips by gear were set to collect those species and length frequencies. In 2005, South Carolina began collecting age structures (otoliths) in addition to length frequencies, using ACCSP funding to supplement CSP funding.

North Carolina

The National Marine Fisheries Service prior to 1978 collected commercial landings data for North Carolina. Port agents would conduct monthly surveys of the state's major commercial seafood dealers to determine the commercial landings for the state. Starting in 1978, the North Carolina Division of Marine Fisheries entered into a cooperative program with the National Marine Fisheries Service to maintain the monthly surveys of North Carolina's major commercial seafood dealers and to obtain data from more dealers.

The North Carolina Division of Marine Fisheries Trip Ticket Program (NCTTP) began on 1 January 1994. The NCTTP was initiated due to a decrease in cooperation in reporting under the voluntary NMFS/North Carolina Cooperative Statistics Program in place prior to 1994, as well as an increase in demand for complete and accurate trip-level commercial harvest statistics by fisheries managers. The detailed data obtained through the NCTTP allows for the calculation of effort (i.e. trips, licenses, participants, vessels) in a given fishery that was not available prior to 1994 and provides a much more detailed record of North Carolina's seafood harvest.

NMFS SEFIN Annual Canvas Data for Florida

The Florida Annual Data files from 1976 – 1996 represent annual landings by county (from dealer reports) which are broken out on a percentage estimate by species, gear, area of capture, and distance from shore. These estimates are submitted by Port agents, which were assigned responsibility for the particular county, from interviews and discussions from dealers and fishermen collected through out the year. The estimates are processed against the annual landings totals by county on a percentage basis to create the estimated proportions of catch by the gear, area and distance from shore. (The sum of percentages for a given Year, State, County, Species combination will equal 100.)

Area of capture considerations: ALS is considered to be a commercial landings data base which reports where the marine resource was landed. With the advent of some State trip ticket programs as the data source the definition is more loosely applied. As such one cannot assume reports from the ALS by State or county will accurately inform you of Gulf vs South Atlantic vs Foreign catch. To make that determination you must consider the area of capture.

Table 3.1. Vermilion snapper commercial landings (pounds whole weight) by region for the US South Atlantic.

US South Atlantic - Region			
Year	Florida	Georgia-North Carolina	Total
1958	194	0	194
1959	1,262	0	1,262
1960	1,747	0	1,747
1961	19,317	24,025	43,341
1962	5,921	46,416	52,337
1963	11,357	9,610	20,967
1964	6,504	288	6,792
1965	19,511	2,499	22,009
1966	3,397	0	3,397
1967	14,172	0	14,172
1968	31,936	0	31,936
1969	30,771	577	31,347
1970	19,511	0	19,511
1971	50,185	16,532	66,717
1972	65,910	14,674	80,584
1973	80,956	11,349	92,305
1974	99,399	22,716	122,115
1975	188,702	32,778	221,481
1976	147,060	72,871	219,931
1977	143,325	141,294	284,619
1978	111,621	234,501	346,122
1979	142,923	342,127	485,049
1980	104,167	639,606	743,774
1981	57,452	683,042	740,494
1982	59,883	821,176	881,059
1983	79,469	708,856	788,324
1984	91,272	740,104	831,376
1985	126,730	803,647	930,377
1986	97,309	811,742	909,051
1987	67,938	658,903	726,841
1988	86,039	858,204	944,243
1989	111,962	940,541	1,052,503
1990	177,766	1,000,215	1,177,981
1991	209,274	1,160,700	1,369,974
1992	175,165	589,924	765,089
1993	162,845	709,605	872,450
1994	214,948	734,453	949,400
1995	259,597	670,062	929,660
1996	185,076	559,338	744,414
1997	117,230	643,156	760,386
1998	93,005	615,773	708,778
1999	96,791	780,943	877,734

Table 3.1. (cont.)

2000	153,254	1,195,751	1,349,005
2001	186,992	1,446,927	1,633,919
2002	177,153	1,158,126	1,335,279
2003	112,461	615,698	728,160
2004	167,164	919,288	1,086,452
2005	146,429	955,259	1,101,688
2006	162,808	665,232	828,040
2007	176,641	838,906	1,015,547

Table 3.2. Vermilion snapper commercial landings (pounds whole weight) by gear for the US South Atlantic.

US South Atlantic - Gear				
Year	Handlines	Trawl	Other	Total
1958	194	0	0	194
1959	1,262	0	0	1,262
1960	1,747	0	0	1,747
1961	19,317	24,025	0	43,341
1962	10,822	42,582	0	53,405
1963	20,967	0	0	20,967
1964	6,792	0	0	6,792
1965	21,913	96	0	22,009
1966	3,397	0	0	3,397
1967	14,172	0	0	14,172
1968	31,936	0	0	31,936
1969	31,347	0	0	31,347
1970	19,511	0	0	19,511
1971	66,321	395	0	66,717
1972	68,794	0	11,790	80,584
1973	86,193	1,922	4,190	92,305
1974	119,387	0	2,728	122,115
1975	218,655	729	2,096	221,481
1976	212,410	7,144	378	219,931
1977	273,322	10,985	312	284,619
1978	345,076	1,047	0	346,122
1979	430,888	54,161	0	485,049
1980	482,636	268,613	0	751,249
1981	500,886	242,732	161	743,779
1982	672,796	215,630	36	888,462
1983	645,732	142,058	725	788,514
1984	734,077	117,694	262	852,032
1985	920,506	24,028	955	945,490
1986	896,379	10,587	13,390	920,356
1987	697,928	23,627	28,004	749,560
1988	854,227	89,294	42,243	985,765
1989	1,041,509	1,232	88,834	1,131,575
1990	1,141,190	4,613	144,100	1,289,902
1991	1,332,693	4,146	57,272	1,394,111
1992	764,936	33	244	765,214
1993	866,361	58	8,494	874,913
1994	948,426	0	9,734	958,160
1995	928,497	6	2,870	931,374
1996	743,692	40	1,354	745,087
1997	759,005	0	2,012	761,017
1998	708,112	1,101	1,293	710,506
1999	876,584	386	4,124	881,093

Table 3.2. (cont.)

2000	1,348,519	0	1,592	1,350,111
2001	1,633,594	0	3,230	1,636,824
2002	1,334,418	67	1,271	1,335,756
2003	727,859	0	6,970	734,829
2004	1,086,300	378	2,298	1,088,976
2005	1,100,916	2	869	1,101,787
2006	827,160	0	1,460	828,620
2007	1,012,612	0	7,693	1,020,305

Table 3.2a. Vermilion snapper commercial landings (pounds gutted weight) by gear for the US South Atlantic.

	US South Atlantic - Gear			
Year	Handlines	Trawl	Other	Total
1958	182	0	0	182
1959	1,182	0	0	1,182
1960	1,636	0	0	1,636
1961	18,091	22,500	0	40,591
1962	10,135	39,880	0	50,015
1963	19,636	0	0	19,636
1964	6,361	0	0	6,361
1965	20,523	90	0	20,613
1966	3,182	0	0	3,182
1967	13,273	0	0	13,273
1968	29,909	0	0	29,909
1969	29,358	0	0	29,358
1970	18,273	0	0	18,273
1971	62,113	370	0	62,483
1972	64,428	0	11,042	75,470
1973	80,723	1,800	3,924	86,447
1974	111,811	0	2,555	114,365
1975	204,780	683	1,963	207,425
1976	198,930	6,691	354	205,974
1977	255,977	10,288	292	266,557
1978	323,177	980	0	324,157
1979	403,544	50,724	0	454,268
1980	452,008	251,567	0	703,575
1981	469,100	227,328	151	696,579
1982	630,101	201,946	33	832,080
1983	604,754	133,043	679	738,475
1984	687,492	110,225	246	797,963
1985	862,091	22,504	895	885,489
1986	839,495	9,915	12,540	861,951
1987	653,638	22,128	26,227	701,993
1988	800,018	83,627	39,562	923,208
1989	975,415	1,153	83,196	1,059,765
1990	1,068,770	4,320	134,955	1,208,045
1991	1,248,121	3,883	53,637	1,305,641
1992	716,394	31	229	716,653
1993	811,382	54	7,955	819,391
1994	888,239	0	9,116	897,355
1995	869,575	6	2,688	872,269
1996	696,498	37	1,268	697,803
1997	710,839	0	1,884	712,723
1998	663,175	1,031	1,211	665,418
1999	820,956	361	3,862	825,179

Table 3.2a. (cont.)

2000	1,262,942	0	1,491	1,264,433
2001	1,529,926	0	3,025	1,532,952
2002	1,249,736	63	1,190	1,250,989
2003	681,669	0	6,528	688,197
2004	1,017,363	354	2,152	1,019,870
2005	1,031,052	2	814	1,031,867
2006	774,668	0	1,368	776,036
2007	948,352	0	7,204	955,556

Table 3.3. Mean weights (pounds) from TIP samples used to convert vermilion snapper commercial landings from pounds (whole weight) to numbers. Weights in shaded areas represent areas of insufficient (N<20) or no samples, and weighted means across years are used (split at 1992 with introduction of minimum size limit for vermilion snapper, except for trawl which had limited data mostly prior to 1992).

	Florida			Georgia			South Carolina			North Carolina		
Year	Handlines	Trawl	Other	Handlines	Trawl	Other	Handlines	Trawl	Other	Handlines	Trawl	Other
1958	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1959	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1960	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1961	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1962	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1963	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1964	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1965	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1966	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1967	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1968	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1969	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1970	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1971	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1972	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1973	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1974	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1975	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1976	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1977	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1978	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1979	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356

Table 3.3. (cont.)

1980	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1981	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1982	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.537	0.503	1.356
1983	1.138	0.736	1.468	1.036	0.227	1.111	1.069	0.503	0.745	1.967	0.503	1.356
1984	1.138	0.736	1.468	0.973	0.227	1.111	1.096	0.525	0.745	1.785	0.503	2.015
1985	1.173	0.736	1.468	1.070	0.227	1.111	1.161	0.503	0.745	1.800	0.503	1.753
1986	1.063	0.736	1.468	0.942	0.227	1.111	1.028	0.329	0.745	1.578	0.503	1.356
1987	1.138	0.736	1.468	1.081	0.227	1.111	1.055	0.288	1.700	1.360	0.503	1.534
1988	0.694	0.736	1.468	1.029	0.227	1.111	1.030	0.737	0.745	1.341	0.503	1.356
1989	0.840	0.736	1.468	1.320	0.227	1.111	1.100	0.503	0.745	1.396	0.503	1.356
1990	1.415	0.736	1.468	1.036	0.227	1.111	1.024	0.503	0.742	1.353	0.503	1.356
1991	1.171	0.736	1.468	1.066	0.227	1.111	1.008	0.503	0.704	1.510	0.503	0.857
1992	1.317	0.736	1.731	1.226	0.227	1.407	1.259	0.503	1.355	1.385	0.503	1.118
1993	1.275	0.736	1.402	1.328	0.227	1.407	1.466	0.503	1.074	1.562	0.503	1.387
1994	1.427	0.736	1.257	1.580	0.227	1.407	1.348	0.503	1.066	1.755	0.503	1.387
1995	1.231	0.736	1.305	1.319	0.227	1.407	1.283	0.503	0.987	1.568	0.503	1.755
1996	1.096	0.736	1.475	1.176	0.227	1.407	1.293	0.503	1.131	1.631	0.503	1.387
1997	0.925	0.736	1.177	1.433	0.227	1.407	1.332	0.503	1.131	1.814	0.503	1.387
1998	1.023	0.736	1.475	1.242	0.227	1.407	1.243	0.503	1.131	1.568	0.503	1.387
1999	1.231	0.736	1.927	1.185	0.227	1.407	1.339	0.503	1.105	1.738	0.503	1.387
2000	1.270	0.736	1.545	1.211	0.227	1.407	1.504	0.503	1.131	1.709	0.503	1.387
2001	1.192	0.736	0.992	1.198	0.227	1.407	1.768	0.503	1.131	1.723	0.503	1.387
2002	1.427	0.736	1.475	1.006	0.227	1.407	1.724	0.503	1.131	1.580	0.503	0.938
2003	1.345	0.736	1.385	1.155	0.227	1.407	1.440	0.503	1.131	1.734	0.503	0.798
2004	1.144	0.736	1.872	1.268	0.227	1.407	1.451	0.503	1.131	1.784	0.503	1.387
2005	1.965	0.736	1.475	1.241	0.227	1.407	1.558	0.503	1.131	1.905	0.503	1.387
2006	1.384	0.736	1.080	1.281	0.227	1.407	1.613	0.503	1.272	1.409	0.503	1.387
2007	1.429	0.736	1.554	1.251	0.227	1.407	1.700	0.503	1.131	1.624	0.503	1.387

Table 3.4. Vermilion snapper commercial landings (number of fish) by region for the US South Atlantic.

US South Atlantic - Region			
Year	Florida	Georgia-North Carolina	Total
1958	171	0	171
1959	1,109	0	1,109
1960	1,536	0	1,536
1961	16,981	47,796	64,776
1962	5,205	87,174	92,379
1963	9,984	8,988	18,971
1964	5,717	270	5,987
1965	17,151	2,438	19,589
1966	2,987	0	2,987
1967	12,458	0	12,458
1968	28,073	0	28,073
1969	27,049	539	27,589
1970	17,151	0	17,151
1971	44,115	13,994	58,110
1972	57,939	18,447	76,386
1973	71,165	12,207	83,371
1974	87,377	16,025	103,402
1975	165,880	22,763	188,643
1976	129,274	74,305	203,579
1977	125,991	136,598	262,589
1978	98,121	184,799	282,920
1979	125,637	308,054	433,691
1980	91,569	839,342	930,911
1981	50,503	863,351	913,854
1982	52,640	883,307	935,947
1983	69,858	674,836	744,694
1984	80,233	662,808	743,041
1985	108,053	572,795	680,848
1986	91,574	654,780	746,354
1987	59,721	617,793	677,515
1988	123,895	765,528	889,423
1989	133,295	749,411	882,705
1990	125,597	855,116	980,713
1991	178,767	974,169	1,152,935
1992	132,980	446,721	579,701
1993	127,701	474,905	602,606
1994	150,677	464,535	615,212
1995	210,940	467,120	678,060
1996	168,899	386,183	555,082
1997	126,742	409,674	536,416
1998	90,906	439,053	529,959
1999	78,599	519,176	597,775

Table 3.4. (cont.)

2000	120,687	790,029	910,717
2001	156,853	892,210	1,049,063
2002	124,177	788,125	912,302
2003	83,596	418,574	502,170
2004	146,174	608,877	755,051
2005	74,505	589,367	663,873
2006	117,622	458,079	575,701
2007	123,583	526,934	650,517

Table 3.5. Vermilion snapper commercial landings (number of fish) by gear for the US South Atlantic.

US South Atlantic - Gear				
Year	Handlines	Trawl	Other	Total
1958	171	0	0	171
1959	1,109	0	0	1,109
1960	1,536	0	0	1,536
1961	16,981	47,796	0	64,776
1962	9,789	84,041	0	93,830
1963	18,971	0	0	18,971
1964	5,987	0	0	5,987
1965	19,398	191	0	19,589
1966	2,987	0	0	2,987
1967	12,458	0	0	12,458
1968	28,073	0	0	28,073
1969	27,589	0	0	27,589
1970	17,151	0	0	17,151
1971	57,323	787	0	58,110
1972	60,636	0	15,750	76,386
1973	74,713	3,824	4,834	83,371
1974	100,945	0	2,457	103,402
1975	185,646	1,451	1,546	188,643
1976	189,088	14,212	278	203,579
1977	240,453	21,854	282	262,589
1978	280,838	2,082	0	282,920
1979	325,940	107,750	0	433,691
1980	357,195	583,869	0	941,063
1981	368,744	549,355	217	918,316
1982	498,435	447,518	48	946,001
1983	450,452	293,527	972	744,952
1984	537,073	233,668	352	771,094
1985	661,446	38,901	634	700,980
1986	707,569	36,310	10,713	754,591
1987	579,273	95,483	18,544	693,301
1988	767,280	121,199	29,802	918,282
1989	867,969	1,673	67,751	937,393
1990	932,265	6,264	121,533	1,060,062
1991	1,100,717	5,631	65,834	1,172,181
1992	579,589	45	165	579,800
1993	597,861	79	6,460	604,400
1994	614,384	0	7,798	622,182
1995	676,946	9	2,423	679,378
1996	554,515	54	996	555,565
1997	535,384	0	1,568	536,952
1998	529,449	1,496	934	531,879
1999	596,778	524	2,541	599,842

Table 3.5. (cont.)

2000	910,351	0	1,082	911,432
2001	1,048,806	0	3,186	1,051,991
2002	911,483	91	1,097	912,671
2003	501,902	0	5,086	506,987
2004	754,923	514	1,274	756,711
2005	663,194	3	744	663,941
2006	575,021	0	1,217	576,238
2007	647,950	0	5,628	653,578

Table 3.6. Calculated yearly south Atlantic handline vessel vermilion snapper discards by region and for US South Atlantic. Discards are reported in number of fish. Regions are defined as follows: 1 = 24^o to <30^o N latitude, 2 = 30^o to <32^o N latitude, 3 = 32^o to <33^o N latitude, 4 = 33^o to <34^o N latitude, 5 = 34^o to <37^o N latitude.

Sum of Calculated Discards	Region					
Year	1	2	3	4	5	Grand Total
1992	4425	29823	24284	14188	2304	75024
1993	3338	27587	31466	18447	3433	84271
1994	3849	28352	35991	33385	4030	105607
1995	4016	37900	48481	33685	3375	127457
1996	4749	60562	59739	34237	5058	164345
1997	5811	50786	58787	31345	5967	152696
1998	4746	33432	47262	29710	4653	119803
1999	4351	30868	33153	27830	3875	100077
2000	4365	28015	39264	29863	3275	104782
2001	3923	34586	55117	27503	3779	124908
2002	5614	12825	131925	79880	6776	237020
2003	9044	17251	16816	53702	1471	98284
2004	304	14685	5303	29467	3	49762
2005	5363	52768	4454	12104	256	74945
2006	133	19423	13950	13225	462	47193
2007	353	33982	4595	5279	7565	51774
Grand Total	64384	512845	610587	473850	56282	1717948

Table 3.7. Vermilion snapper lengths sampled from the commercial fishery and available in the TIP data base, 1983-2007.

	HANDLINE				TRAWL			
Year	FL	GA	NC	SC	FL	GA	NC	SC
1983	0	0	391	0	0	0	0	0
1984	0	1,242	4,797	1,937	0	0	0	196
1985	636	1,422	5,265	2,477	0	0	0	0
1986	43	1,281	4,954	1,610	0	0	0	650
1987	0	741	4,604	1,970	0	366	0	250
1988	175	795	3,223	1,384	0	0	0	692
1989	19	362	3,846	1,398	0	0	0	0
1990	192	0	4,348	1,467	0	0	0	0
1991	317	905	6,397	2,906	0	0	0	0
1992	1,416	819	2,859	1,067	0	0	0	0
1993	1,476	716	4,918	1,176	0	0	0	0
1994	457	767	5,374	890	0	0	0	0
1995	2,348	4,200	5,732	966	0	0	0	0
1996	776	1,402	2,519	2,021	0	0	0	0
1997	1,276	866	1,559	3,092	64	0	0	0
1998	1,782	233	1,557	3,072	0	0	0	0
1999	2,949	1,125	4,013	3,874	0	0	0	0
2000	4,219	2,115	7,815	4,563	0	0	0	0
2001	1,843	4,554	7,139	4,498	0	0	0	0
2002	709	3,377	4,560	3,378	0	0	0	0
2003	1,044	3,613	4,151	3,169	0	0	0	0
2004	94	5,837	5,334	2,193	0	0	0	0
2005	116	1,242	5,261	1,985	0	0	0	0
2006	987	1,529	7,562	1,046	0	0	0	0
2007	749	85	4,622	1,313	0	0	0	0

Table 3.8. Vermilion snapper ages sampled from the commercial handline fishery by state, 1992-2007. Excludes a total of 25 aged fish from miscellaneous gears (Other), sampled 2005-2007.

Year	Florida	Georgia	South Carolina	North Carolina	Total
1992	9		73		82
1993	74		15	94	183
1994	120		24	20	164
1995	263	3	1	50	317
1996					0
1997	55				55
1998	104				104
1999	136				136
2000	209				209
2001	244				244
2002	181				181
2003	74			48	122
2004	159			353	512
2005	59		209	459	727
2006			477	461	938
2007	40		477	494	1011
Total	1727	3	1276	1979	4985

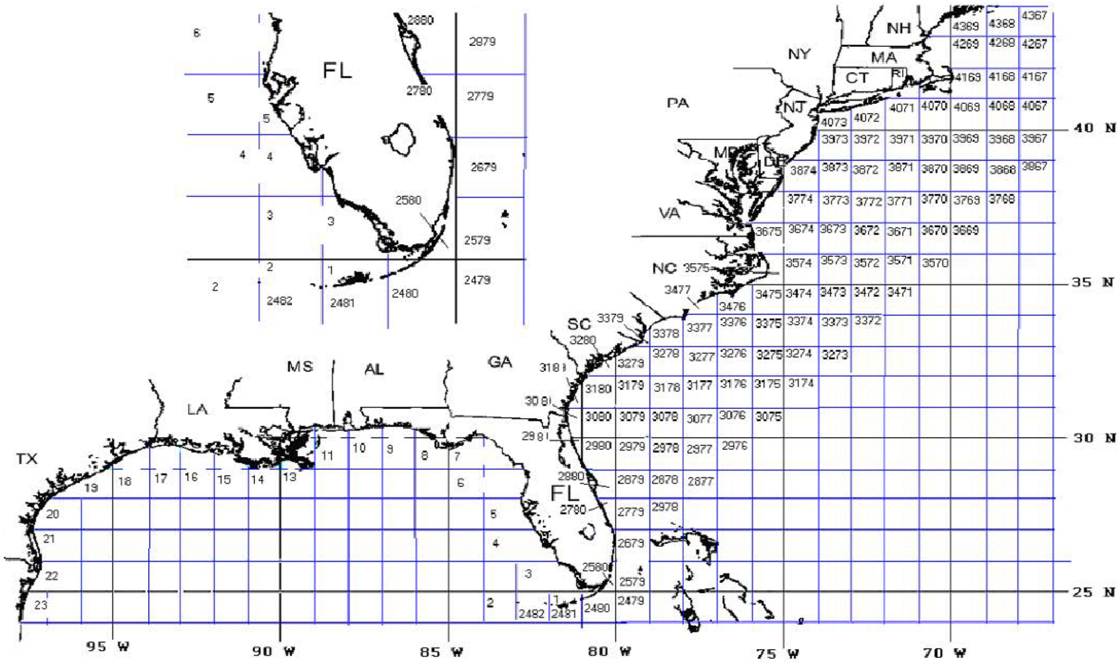


Figure 3.1. Map of U.S. Atlantic and Gulf coast with shrimp area designations.

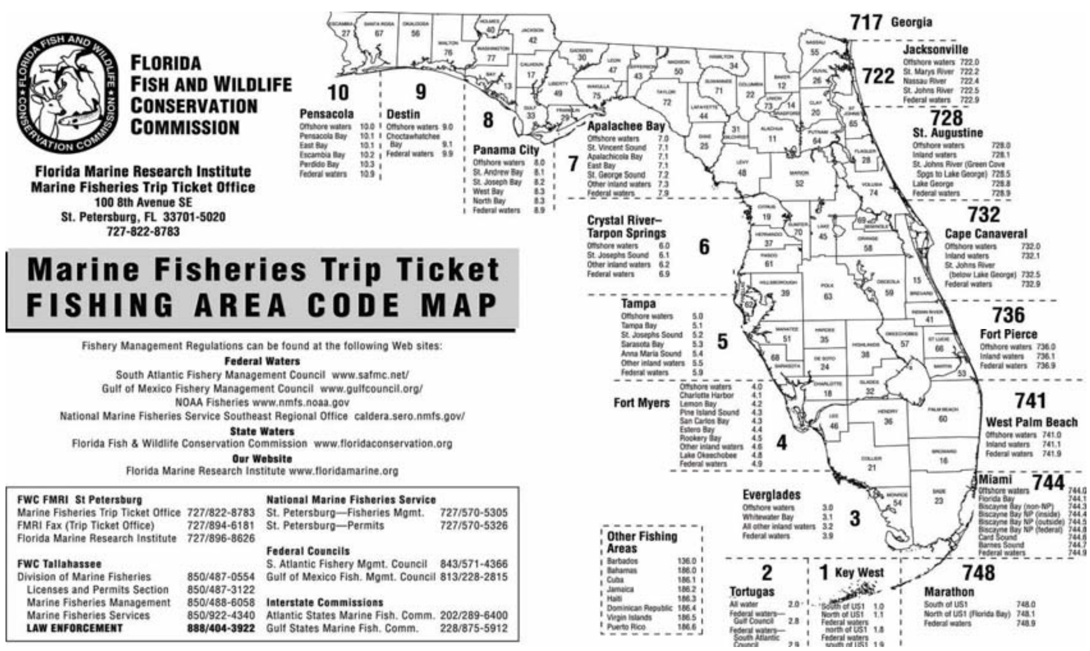


Figure 3.2. Map showing marine fisheries trip ticket fishing area code map for Florida.

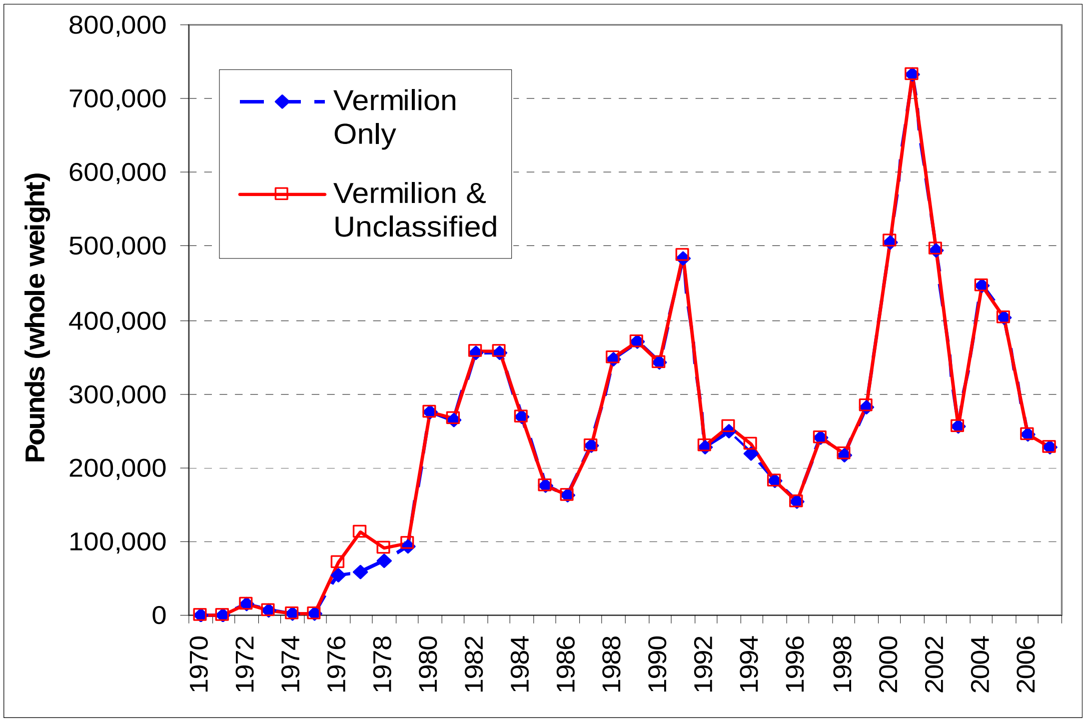


Figure 3.3. Comparison of South Carolina commercial landings for vermilion snapper with and without contribution from unclassified snappers.

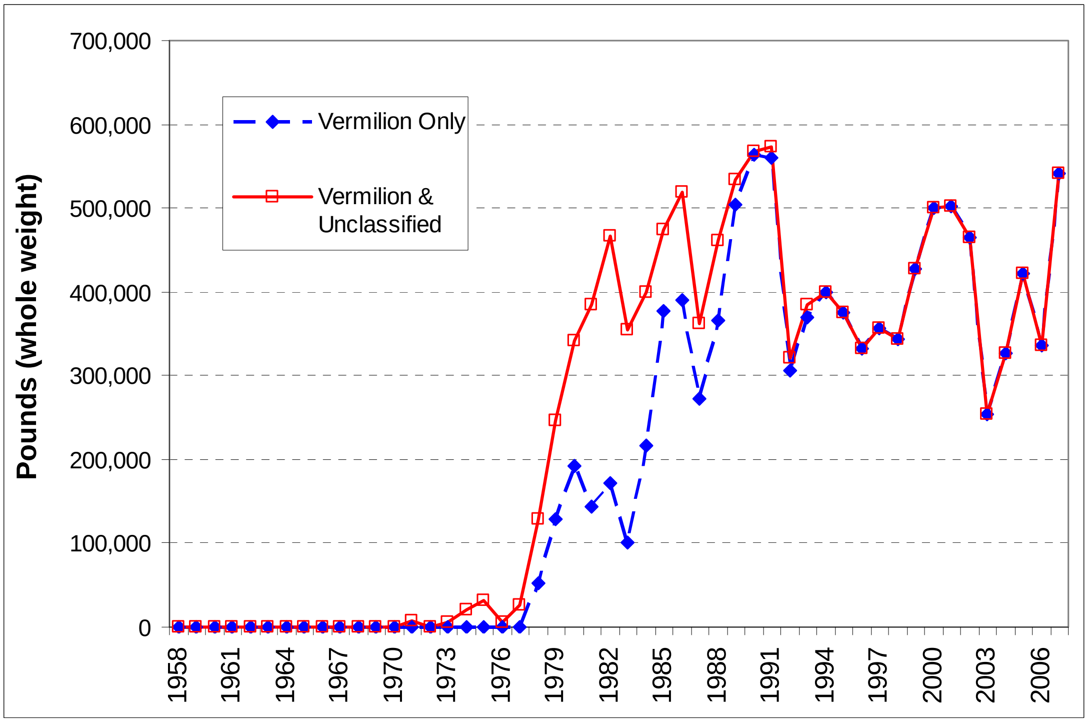


Figure 3.4. Comparison of North Carolina commercial landings for vermilion snapper with and without contribution from unclassified snappers.

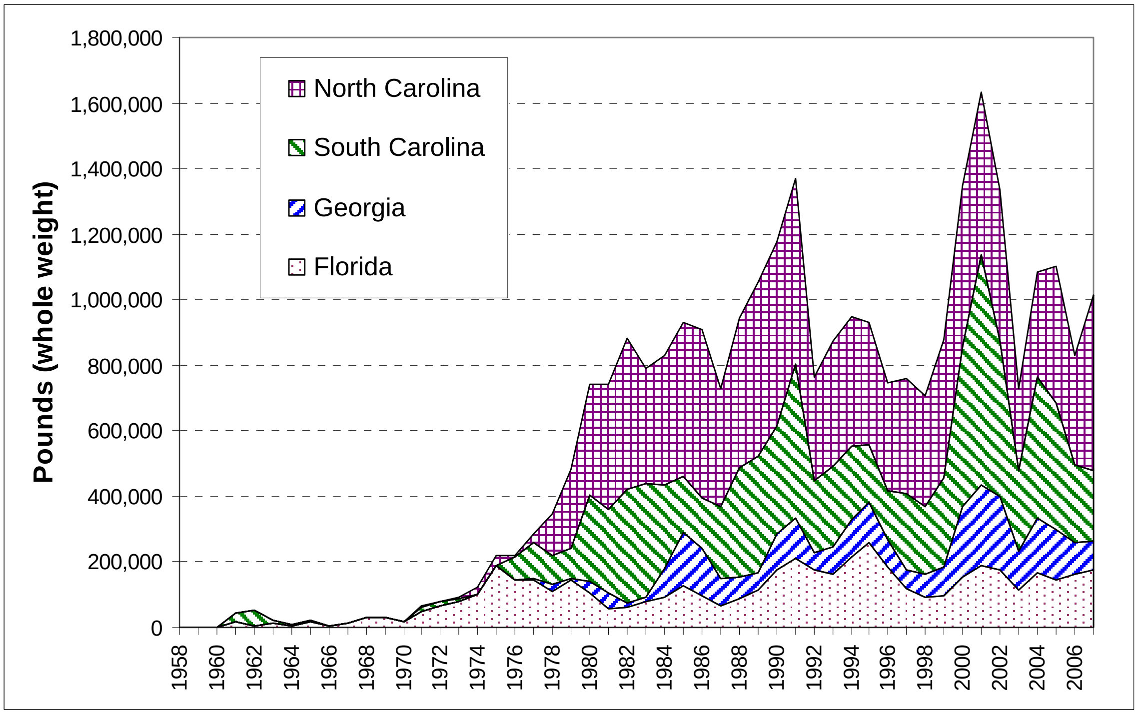


Figure 3.5. Vermilion snapper landings (pounds whole weight) by state from the U.S. South Atlantic, 1958-2007. (see text for data sources)

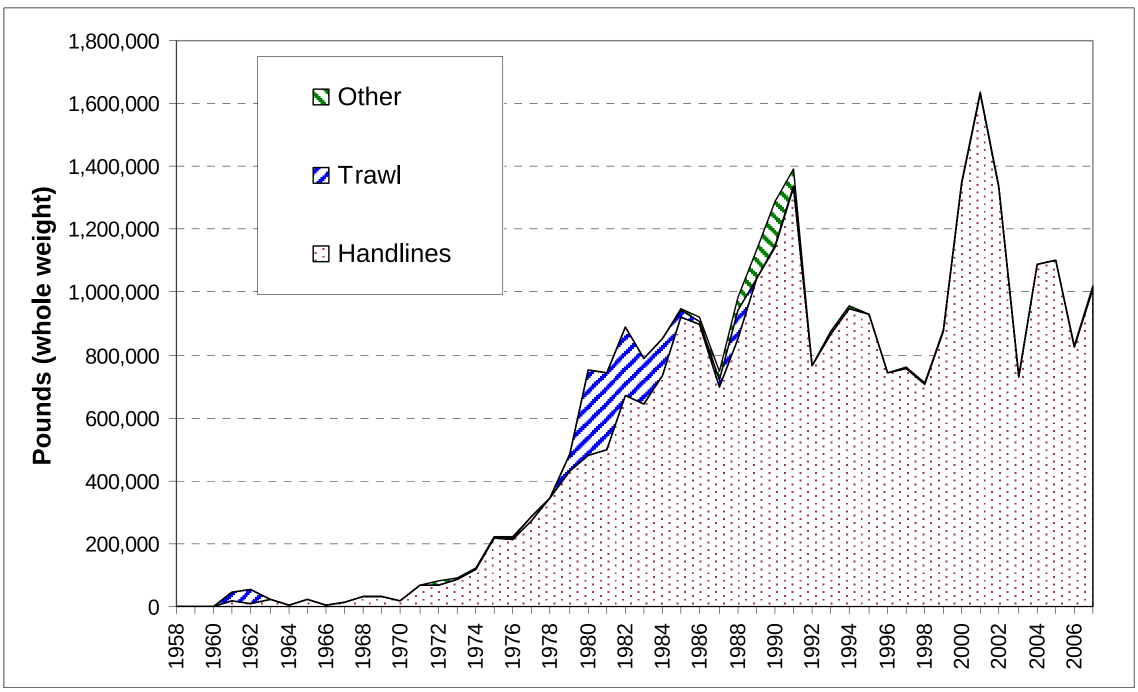


Figure 3.6. Vermilion snapper landings (pounds whole weight) by gear from the U.S. South Atlantic, 1958-2007. (see text for data sources).

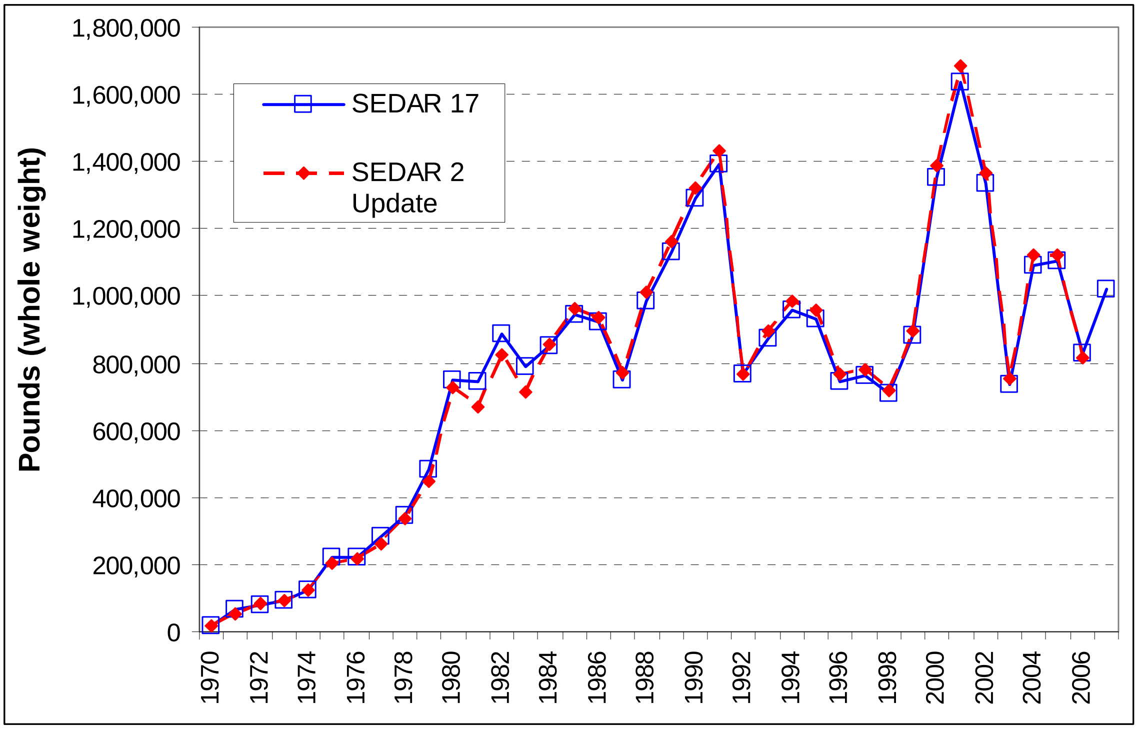


Figure 3.7. Vermilion snapper landings (pounds, whole weight) from the U.S. South Atlantic for 1970-2007, compared between the Update Assessment for SEDAR 2 and the current assessment (SEDAR 17).

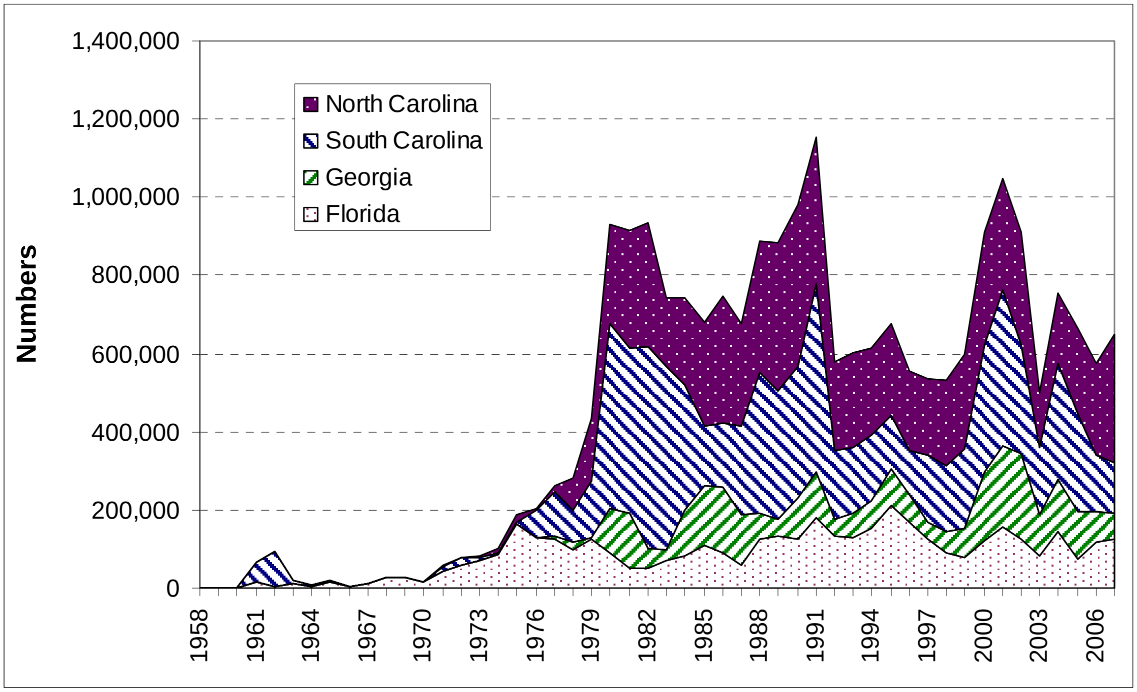


Figure 3.8. Vermilion snapper landings (number of fish) by state from the U.S. South Atlantic, 1958-2007. (see text for data sources)

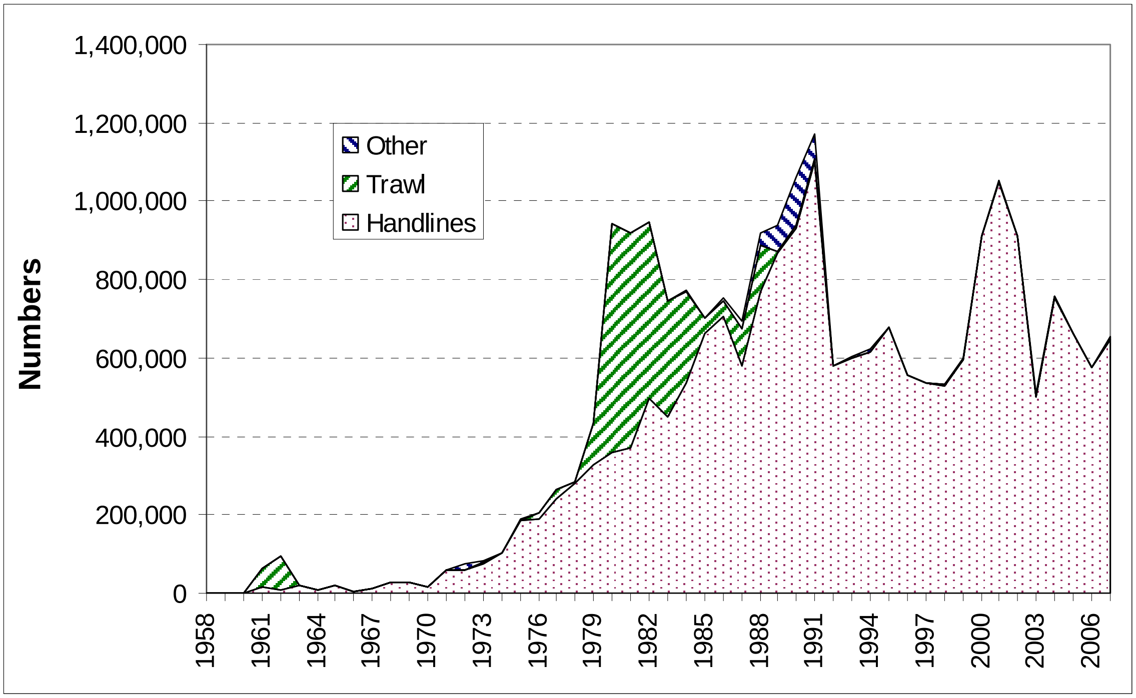


Figure 3.9. Vermilion snapper landings (number of fish) by gear from the U.S. South Atlantic, 1958-2007. (see text for data sources)

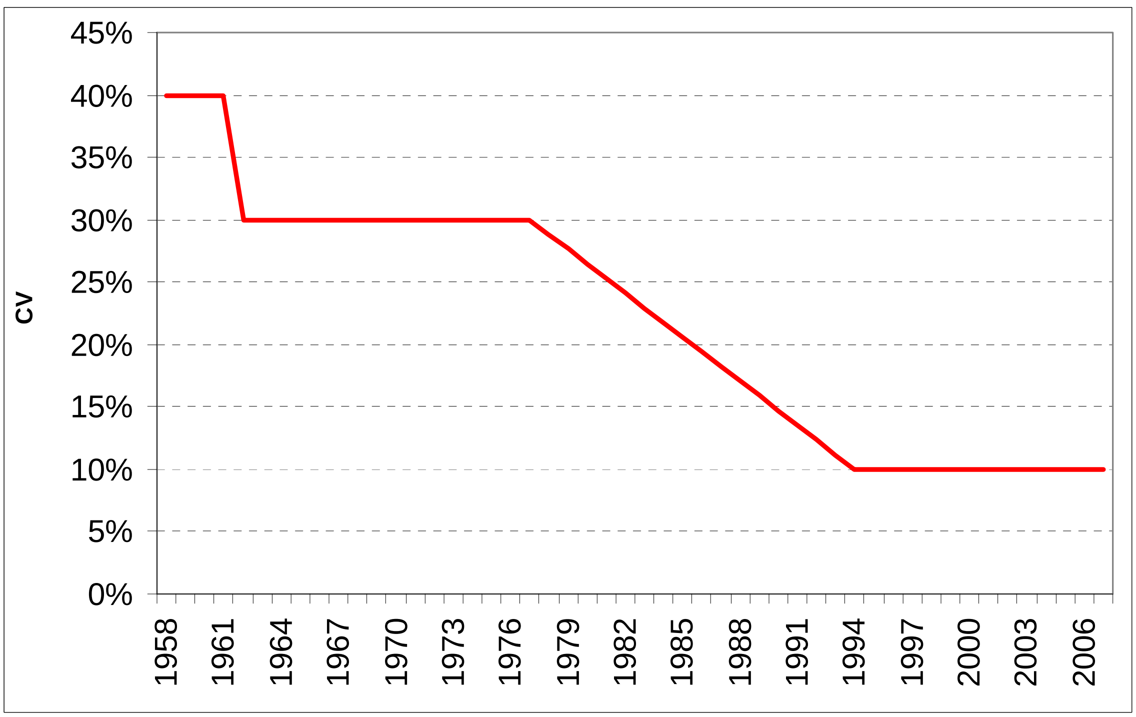


Figure 3.10. Coefficients of variation (CV) developed for reported commercial landings from 1958-2007 as developed by the Commercial Workgroup. The ALS was initiated in 1962, state-federal program began in late 1970s, and NC trip ticket began in 1994.

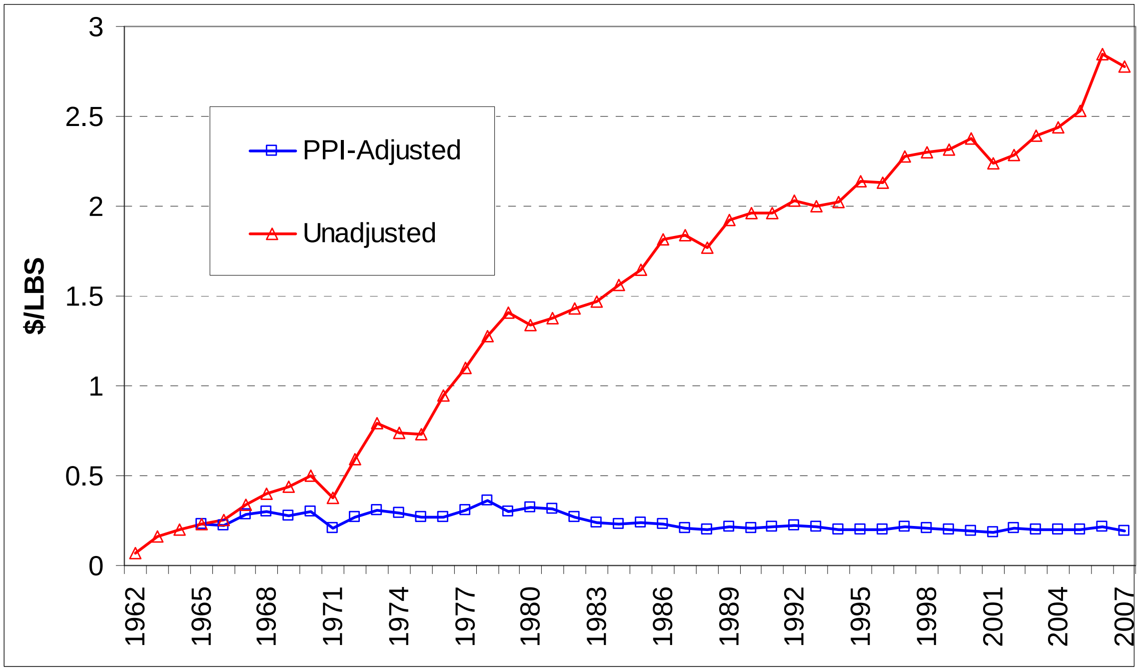


Figure 3.11. U.S. South Atlantic vermilion snapper, price per pound (whole weight), unadjusted and adjusted for inflation from the SEFSC ALS database, 1962-2007. Adjustment to price is by producer price index (PPI) using 1965 as base year.

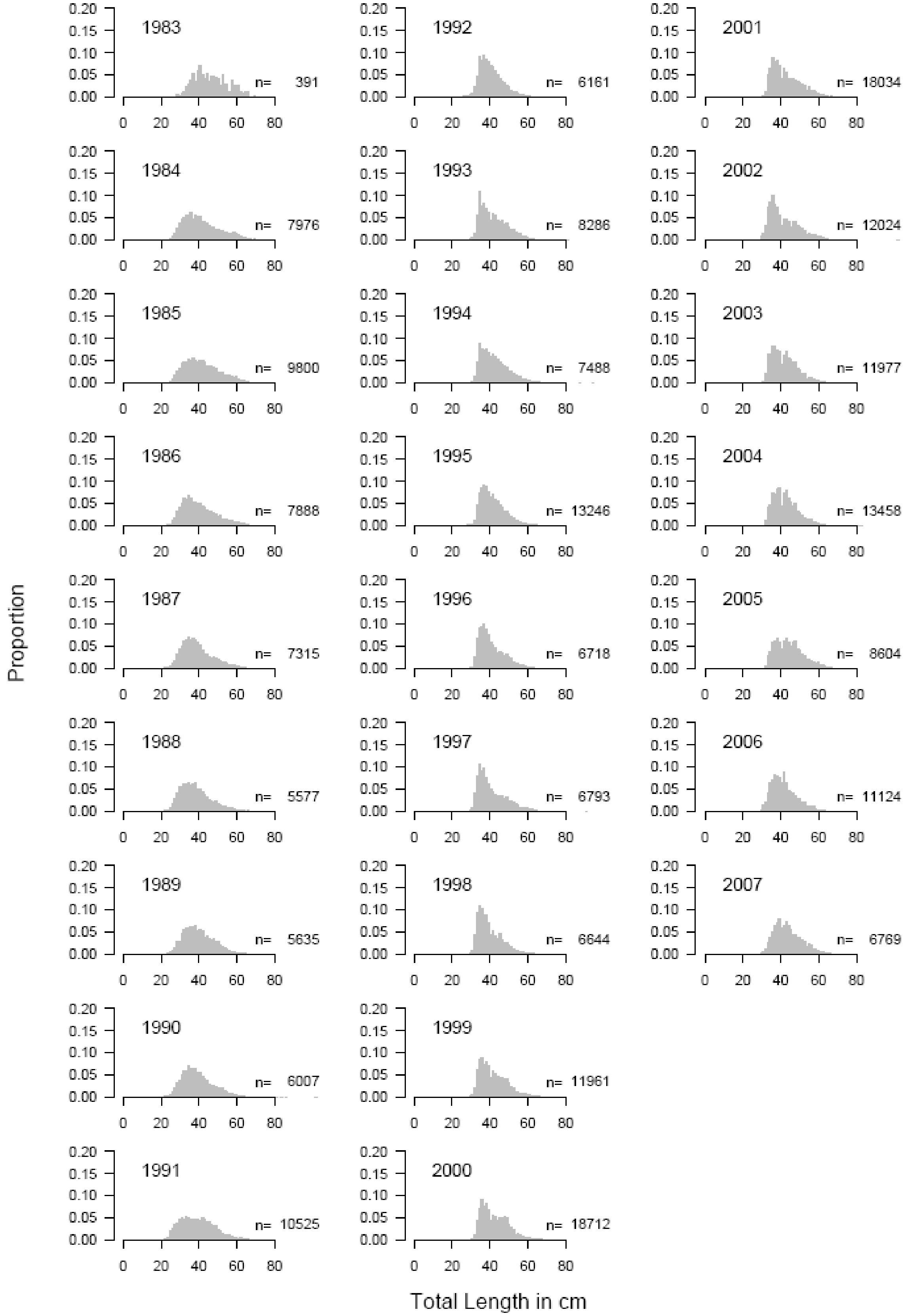


Figure 3.12. Vermilion snapper length frequencies (number at length, TL-cm) by year for commercial handline gear in the South Atlantic.

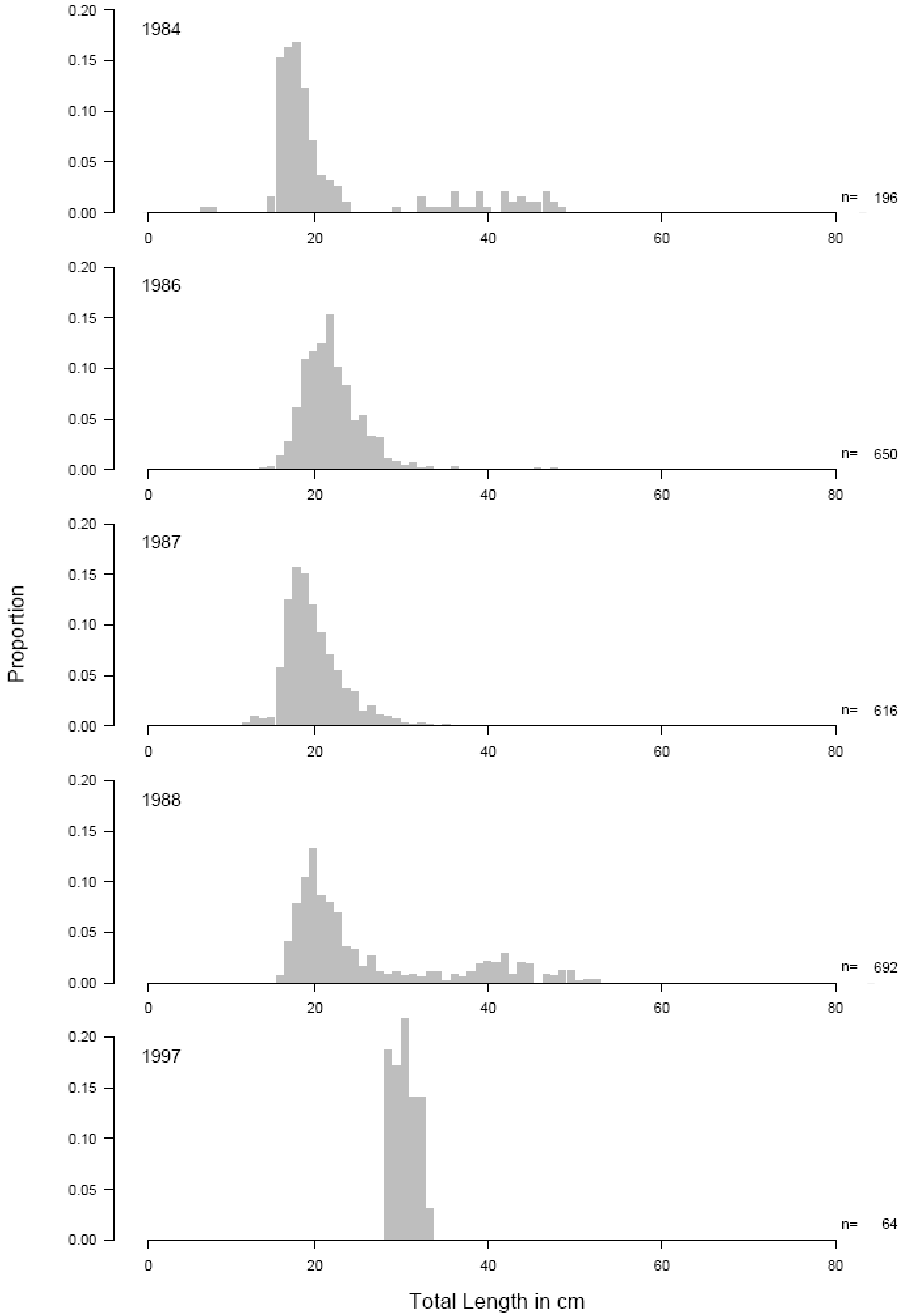


Figure 3.13. Vermilion snapper length frequencies (number at length, TL-cm) by year for commercial trawl gear in the South Atlantic.

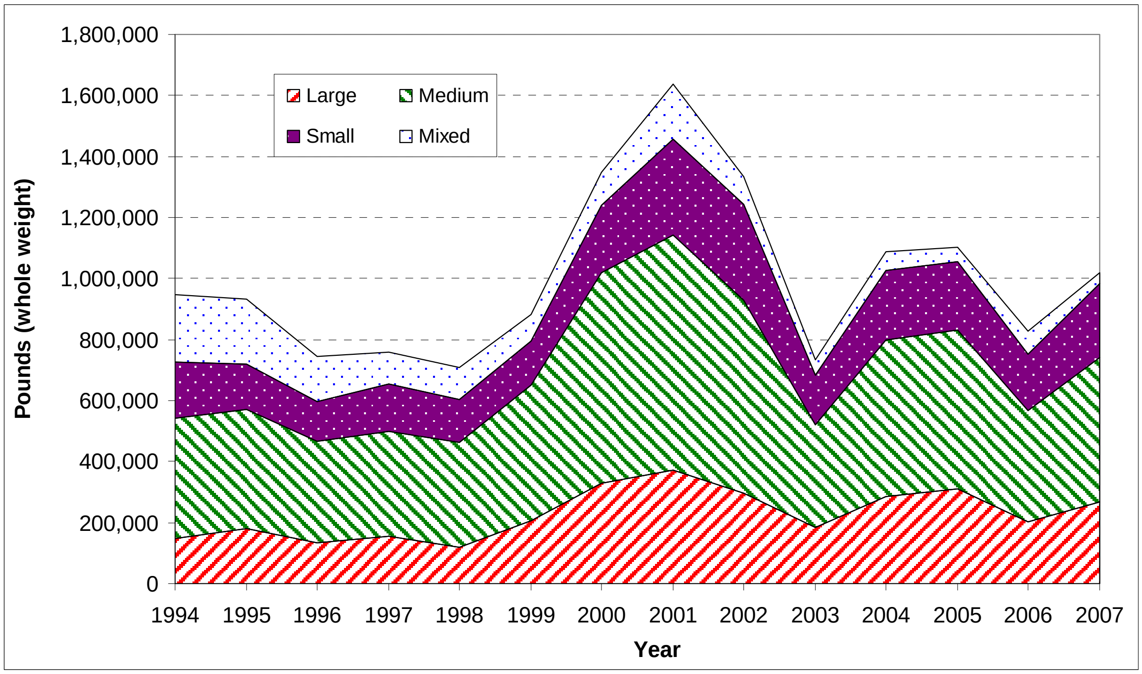


Figure 3.14. Commercial landings of vermilion snapper by market grade, 1994-2007.

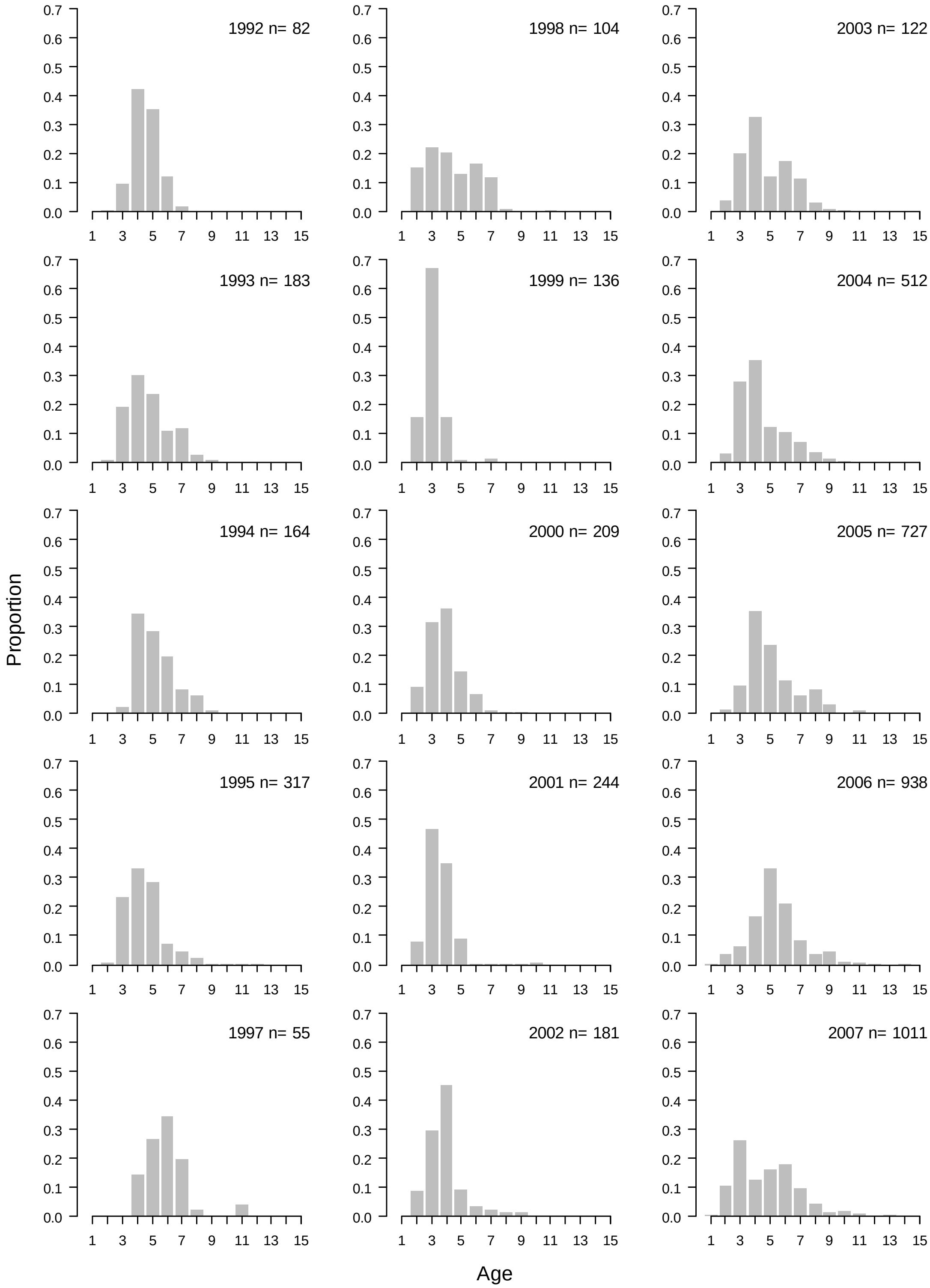


Figure 3.15. Vermilion snapper age frequencies by year for commercial handline gear in the South Atlantic.

Vermilion Snapper

4. Recreational Fishery Statistics

4.1 Overview - group membership, leader, and issues

Chair: Erik Williams (NMFS Beaufort); Members: Tom Sminkey (NMFS Silver Spring), Ken Brennan (NMFS Beaufort), Rob Cheshire (NMFS Beaufort), Beverly Sauls (FWRC).

Issues:

(1) Only one working paper for the recreational workgroup was submitted, reflecting the relatively small amount of pre-workshop work completed for this workgroup.

(2) At the time of the data workshop the 2007 headboat data had not been through a full set of quality assurance and quality control checks. Key entry was finalized just days prior to the DW.

(3) Historic data, does it accurately reflect catch levels of the species reported?

(4) Best use of at-sea headboat observer data.

(5) Use of Southeast Region Headboat Survey discard estimates.

4.2 Headboat Fishery

Historical accounts of headboat fishing in the South Atlantic for offshore snapper-grouper species date back to the years immediately following World War II. The headboat fishery is a readily identifiable segment of the recreational fishery, and is responsible for a significant percent of the recreational catch for some species, including vermilion snapper. Presently, the number of vessels in the headboat fleet fluctuates slightly from year to year as boats enter or leave the fishery, nonetheless, the relative size of the fleet is known, making it accessible to the Southeast Region Headboat Survey. The Southeast Region Headboat Survey included vessels only in North Carolina and South Carolina during the early part of the survey (1972-1975). The Survey expanded to northeast Florida in 1976, to southeast Florida in 1978, and finally to the Gulf of Mexico in 1986. From 1981-present the Survey included all headboats operating in the southeastern U.S. EEZ, encompassing the areas shown in Figure 4.9.1.

4.2.1 Headboat Landings

Vermilion snapper landings in numbers and weight were available from 1972 through the present from North Carolina and South Carolina. Landings from Georgia and the Atlantic coast of Florida, north of Cape Canaveral, were available starting in 1976, and are a major part of vermilion snapper headboat landings. Preliminary landings data were available for southeast Florida from 1978. Landings for 1976–1977 were estimated by regressing Georgia and north Florida observations against south Florida observations of landings in numbers and weight. Apparent errors in mean weights recorded for some months were corrected using the mean weights from adjacent months for the same area. Landings in numbers and weight are summarized by state (Table 4.8.1 and 4.8.2).

4.2.2 Headboat Discards

The logbook form was modified in 2004 to include a category to collect self-reported discards for each reported trip. This category is described on the form as the number of fish by species released alive and number released dead. Port agents instructed each captain on criteria for determining the condition of discarded fish. A fish is considered “released alive” if it is able to swim away on its own. If the fish floats off or is obviously dead or unable to swim, it is considered “released dead”. This self-reported data is currently unvalidated within the Headboat Survey. The recreational working group compared vermilion snapper discard data from the MRFSS At-Sea Observer program to the Headboat Survey logbook and determined that the logbook discard data was representative of the fishery (See SEDAR17-DW08).

4.2.3 Biological Sampling

Length and weight measurements from fishes taken by anglers on headboats are collected by port agents throughout the coverage area. Also, biological samples (scales, otoliths, spines, stomachs and gonads) are collected routinely. Length-weight data are used to compute average weights for each species and to compute age frequencies and mortality rates. This information combined with logbook data are used to calculate an estimate of total weight (kg) of reef fish landed in the headboat fishery.

4.2.3.1 Sampling Intensity Length/Age/Weight

The length composition from the headboat fishery was generated from 1972-2007. The sampling from 1972-1975 was in North Carolina and South Carolina. The Northern East coast of Florida was added for 1976-77. From 1978-2007 the sampling included all areas from NC to the Florida Keys (Table 4.8.3). Headboat at-sea observers collected length samples from 2003 to 2007 in North Carolina and South Carolina and in Florida from 2005-2007. The at-sea observer program collected length data on landed (Table 4.8.3) and discarded fish (Table 4.8.4).

4.2.3.2 Length – Age Distributions

The length composition from the headboat fishery was generated from 1972-2007. The DW participants recommend starting the series in 1976, the first year that the predominant fishing areas are fully covered. The 2003-2008 length distributions include the length data collected from the at-sea headboat observer program (See SEDAR 17-DW08). Values recorded in fork length were converted to total length using the conversion equation provided by the life history group. A length composition was generated for the landed and discarded fish from headboat survey. The headboat length composition associated with landings was weighted by the associated landings by region and period. The headboat areas were aggregated to regions of North Carolina, South Carolina, Georgia/North Florida, and South Florida (Florida break at Cape Canaveral). The periods consisted of January-May, June-August, and September –December. These periods were determined by the availability of monthly landings estimates from the early years of the headboat survey. The headboat length composition for discards was not weighted. Length composition values were stored in the VS_DW_summary.xls workbook and are plotted in Figure 4.9.2.

Lengths of discarded fish were collected by the MRFSS at-sea observer program from 2003 to 2007. Only North Carolina and South Carolina were sampled in 2003 and 2004. The 2005-2007 discard length data included all states from North Carolina to Florida (Table 4.8.4). Length composition values of headboat discards were stored in the VS_DW_summary.xls workbook and are plotted (Figure 4.9.3).

The headboat age samples were collected in Florida throughout the time series with high variability in sample size among years. Ages from North Carolina and South Carolina were available during the early 1990s and in years since about 2002. No samples were obtained from Georgia except in 2006 and 2007 where a few ages were obtained (Table 4.8.5). The headboat ages were weighted by the headboat length composition to overcome potential bias in selecting fish to age and to transfer the weighting given to the length composition based on landings to the age composition. The weighting value for each age record was the proportion from the length composition corresponding to the year and length (1 cm bins) of the aged fish. The weighting values were then summed by age and year to determine the age composition of the fishery. Each value was normalized to sum to 1 across years by dividing each value by the sum for that year. Headboat age composition values were stored in the VS_DW_summary.xls workbook and are plotted in Figure 4.9.4.

4.2.3.3 Adequacy for Characterizing Catch

Catch and effort data are reported on logbooks provided to all headboats in the Survey. These forms are completed by the captain or designated crew member after each trip and represent the total number and weight of all the species kept, along with the total number of fish discarded for each species. Each month port agents collect these logbook trip reports and check for accuracy and completeness. Although reporting via the logbooks is mandatory, compliance is low in some areas for recent years, especially South Florida. Landings for these non-reporting vessels were estimated from similar vessels adjusted using port sampler intercept data and estimates of the number of anglers.

4.2.3.4 Alternatives for Characterizing Discards

Based on the comparison of logbook data to the At-Sea Observer data, it was concluded that the logbook discard estimates for vermilion snapper would be used for the available years back to 2004 for the South Atlantic headboat fishery. For years prior to the addition of the discard category on the logbook form, the recreational workgroup suggests using the average for 2004-2006 to interpolate discards back to 1999 when the size limit was increased from 10" to 11". Further, the group recommends using the charter mode to calculate headboat discards for 1972-1998, since the discard rates from the longer time series of MRFSS reflect historic changes in discard rates. These rates include the impacts from changes in recreational size limits and bag limits for vermilion snapper over time.

4.2.4 Headboat Catch-at-Age/Length

Catch-at-age or length was not computed since age/length composition data is handled separately from catch estimates. For years in which adequate age/length sampling occurs, one could infer catch-at-age/length by multiplying the annual catch estimate by the annual age/length composition.

4.2.5 Headboat Effort

Headboat effort has changed only slightly in the past 10 years throughout the South Atlantic (Fig.4.9.5). The number of estimated trips in the headboat fishery has remained relatively constant during this period, with the only noticeable change occurring as effort peaked in GA and FL in 2000.

4.2.6 Comments on Adequacy of Headboat Data for Assessment Analyses

Catch and effort data are reported on logbooks provided to all headboats in the Survey. These forms are completed by the captain or designated crew member after each trip and represent the total number and weight of all the species kept, along with the total number of fish discarded for each species. Each month port agents collect these logbook trip reports and check for accuracy and completeness. Although reporting via the logbooks is mandatory, compliance is low in some areas for recent years, especially South Florida. No other data sources were available to provide information on the headboat fishery sector.

4.3 General Recreational Fishery (aka MRFSS)

4.3.1 General Recreational Landings

The report, SEDAR16-DW-21: Recreational Survey Data for King Mackerel in the Atlantic and Gulf of Mexico**,** was presented at the recent King Mackerel Data Workshop (Feb. 2008) and describes the methodology used to produce the recreational catch estimates based on the traditional MRFSS, the Charter Boat estimates produced by the For-Hire Survey method (FHS) from 2004-2007, and the ‘normalization’ of the pre-FHS estimates of Charter Boat effort and inclusion in the total annual landings estimates. Correction factors to adjust historical estimates in the Atlantic to those which would have been expected had the new methodology been used were not available prior to that meeting. This computational normalization was only modeled for the southeast states, NC to FL, and followed a similar method used in the Gulf of Mexico by Diaz and Phares (2006). Vermilion snapper was included in the southeast analyses and time-series of adjusted landings. It was determined that these statistics provided the best available estimates of recreational landings.

The fishing year for vermilion snapper in the southeast was the calendar year, and the range included in the landings was the southeast sub-region only (NC to Dade-Miami County on east coast of FL).

4.3.1.1 Historical Recreational Landings

The workgroup was tasked with collecting any and all recreational landings for years prior to the start of modern data collections. Catch estimates from the MRFSS are not available from pre-1981, and for headboat logbook estimates, vermilion snapper landings are not available pre-1972 from North Carolina to South Carolina, and pre-1980 for Georgia through Florida.

The workgroup considered several historic data sets. The U.S. Fish and Wildlife Service conducted salt-water angling surveys in 1960, 1965, and 1970 (Clark 1962; Deuel and Clark 1968; Deuel 1973). These surveys resulted in estimates of the number of anglers and the number and weight of fish caught by region for all recreational fishing, including headboats. The South Atlantic region was used for this assessment. In these surveys vermilion snapper are not reported at the species level, instead an unclassified snapper category is listed. Along with a snapper category in 1960, yellowtail snapper are reported separately, while in 1965 and 1970 both yellowtail snapper and red snapper are reported separately (Table 4.8.6).

Other data sources examined corroborate the estimates from the 1960, 1965, and 1970 salt-water angling surveys. Older reports from the state of Florida suggest the number of anglers estimated in these salt-water angling surveys is not too different (Ellis et al. 1958). Ellis et al. (1958) estimated 1,247,000 total number of salt and brackish water anglers in Florida in 1955, while the 1960 salt-water angling survey estimated 1,024,000 total anglers for the whole U.S. South Atlantic. Considering the Ellis et al. (1958) estimate includes the west coast of Florida, while the 1960 survey includes Georgia, South Carolina, and North Carolina, these estimates are not too different.

In order to estimate vermilion snapper landings from the snapper category in these surveys we analyzed recent catches of vermilion snapper in the headboat and general recreational fisheries. In the earliest years the ratio of headboat landings to all recreational landings (headboat plus general recreational) of vermilion snapper is high (Figure 4.9.6). The linear trend in this proportion suggests that the headboat fishery probably accounted for more than 95% of the historic recreational vermilion snapper landings. This high proportion fits with vermilion snapper being primarily an offshore fish species. The next step in breaking out the unclassified snapper category is to analyze the proportion of vermilion snapper relative to other snappers in the headboat fishery (Figure 4.9.7). We analyzed both the proportion of vermilion to all snappers minus yellowtail and the proportion of vermilion to all snappers minus yellowtail and red snapper.

The snapper data from the salt-water angling surveys for 1960 did not match the other years and therefore it was handled differently. For 1960 we chose to combine the unclassified snapper and yellowtail snapper estimates into an all snapper category; then applied the proportions for categories from the 1965 and 1970 surveys. This resulted in estimates for unclassified snappers, yellowtail snapper, and red snapper of 623, 11005, and 1036 (thousands), respectively. Applying the proportion of 0.75 vermilion to unclassified (minus yellowtail and red) from the headboat fishery yielded the final vermilion snapper estimates in Table 4.8.7.

The percent standard error (PSE) estimates in Table 4.8.7 were derived from a linear interpolation of tabled values provided in the U.S. Fish and Wildlife Service salt-water angling survey reports (Clark 1962; Deuel and Clark 1968; Deuel 1973). These PSE's are likely an underestimate of the true variance, since the vermilion snapper numbers were derived using a ratio of snappers, which itself has an unknown level of uncertainty not captured in the PSE values listed in Table 4.8.7.

4.3.2 General Recreational Discards

The access-point recreational fisheries surveys (angler intercept) ask anglers about any fish that were not landed or were landed, but not in the whole condition. Those fish that were not landed and were released alive were designated as discards and the raw reported data were expanded to the estimated totals following the same procedures as the landed fish (see landings & discards worksheet). No size data were available for this class of catch (except for those headboat-caught fish on trips with an observer/interviewer on board - these are included in the headboat mode section) so catches of discards are reported by number only.

4.3.3 Biological Sampling

The only biological data collected during the routine MRFSS/FHS surveys are length of fish and weight of landed fish. Both are collected opportunistically but field interviewers are instructed to measure and weigh up to fifteen fish of each available species from each angler interviewed. The individual fish are to be selected from the total landed catch at random to avoid any size-bias in the resultant sample. Fish are measured to the nearest mm fork length (center-line total length in non-forked fish) and weighed to the nearest 1/8 or ½ kg, depending on scale precision. Annual sample sizes of fish measured are included on the length-frequency worksheet. The worksheet required that vermilion snapper lengths be expressed in total length (TL) so the fork lengths (FL) obtained from the field were converted to TL using this equation (provided by the life history workgroup): TL = 1.436 + 1.106*(FL) and converting to cm.

4.3.3.1 Sampling Intensity Length/Age/Weight

See length frequency sample sizes on annual length-frequency worksheet.

4.3.3.2 Length – Age Distributions

The general recreational age composition was created using data from charter vessels and private vessels. The sampling was primarily from the charter vessel mode in Florida (See Tables 4.8.8 and 4.8.9). The recreational ages were weighted by the recreational length composition to overcome potential bias in selecting fish to age and to transfer the weighting given to the length composition based on landings to the age composition. The weighting value for each age record was the proportion from the length composition corresponding to the year and length (1 cm bins) of the aged fish. The weighting values were then summed by age and year to determine the age composition of the fishery. Each value was normalized to sum to 1 across years by dividing each value by the sum for that year. General recreational length and age composition values were stored in the VS_DW_summary.xls workbook and are plotted in Figures 4.9.8 and 4.9.9, respectively.

4.3.3.3 Adequacy for Characterizing Catch

Not addressed.

4.3.3.4 Alternatives for Characterizing Discards

Not addressed.

4.3.4 General Recreational Catch-at-Age/Length

Catch-at-age or length was not computed since age/length composition data is handled separately from catch estimates. For years in which adequate age/length sampling occurs, one could infer catch-at-age/length by multiplying the annual catch estimate by the annual age/length composition.

4.3.5 General Recreational Effort

Not addressed.

4.3.6 Comments on Adequacy of General Recreational Data for Assessment Analyses

Not addressed.

4.4 Recreational Workgroup Research Recommendations

There was insufficient time for this topic to be addressed by the workgroup during the data workshop.

4.5 Tasks for Completion following Data Workshop

Recreational workgroup things to be done post-DW:
(1) MRFSS landings for vermilion and Spanish from 1981-1985 (Tom Sminkey)
(2) Dig through some archives for more information on historic catch rates of Spanish mackerel (Beverly Sauls and Ken Brennan)
(3) Produce PSE's for historic and other landings time series (Erik Williams)
(4) Compute pre-2004 discards in headboat fishery from ratio of charter mode in MRFSS (Ken Brennan)
(5) Compile length composition data from headboat and MRFSS (Rob Cheshire)
(6) Submit all finalized data to Rob by June 13th (All)

4.8 Literature Cited

Clark, J.R. 1962. The 1960 Salt-Water Angling Survey. U.S. Department of the Interior, Bureau of Sport Fisheries and Wildlife, Circular 153, 36 pp.

Deuel, D.G. 1973. The 1970 Salt-Water Angling Survey. U.S. Department of Commerce, National Marine Fisheries Service, Current Fishery Statistics No. 6200, 54 pp.

Deuel, D.G. and J.R. Clark. 1968. The 1965 Salt-Water Angling Survey. U.S. Department of the Interior, Bureau of Sport Fisheries and Wildlife, Resource Publication 67, 51 pp.

Ellis, R.W., A. Rosen, and A.W. Moffett. 1958. A survey of the number of anglers and of their effort and expenditures in the coastal recreational fishery of Florida. State of Florida, Board of Conservation, Technical Series No. 24, 50 pp.

4.8 Tables

Table 4.8.1. Total number of vermilion snapper landed by state In the South Atlantic headboat fishery 1981-2007

Year	NC	SC	GA\NEFL	SEFL	Grand Total
1981	37829	25638	171029	36491	270987
1982	66210	104075	159093	32943	362321
1983	50194	73285	192548	83013	399040
1984	31146	60353	190516	42414	324429
1985	43907	106273	284923	94700	529803
1986	53796	114206	283153	81946	533101
1987	41904	176757	330108	182238	731007
1988	53807	169034	366423	151627	740891
1989	48541	140114	284303	188293	661251
1990	123396	167102	231284	134077	655859
1991	159682	174055	200209	66555	600501
1992	105240	147838	32112	60076	345266
1993	86532	171996	28722	39777	327027
1994	98288	216215	24549	30668	369720
1995	102328	199748	19386	33304	354766
1996	87806	198287	15481	38766	340340
1997	103135	218335	23309	19963	364742
1998	76576	210360	37375	17252	341563
1999	87368	213584	66945	14039	381936
2000	102653	207754	96240	21588	428235
2001	99609	195820	85421	38026	418876
2002	71370	154375	74893	34905	335543
2003	43295	114342	63643	30516	251796
2004	62042	143322	73902	49815	329081
2005	92257	101284	66101	15808	275450
2006	88192	166639	81529	8364	344724
2007	104710	323099	76126	4035	507970
Grand Total	2121813	4293890	3559323	1551199	11526225

Table 4.8.2. Total pounds of vermilion snapper landed by state in the South Atlantic headboat fishery 1981-2007

Year	NC	SC	GA\NEFL	SEFL	Grand Total
1981	81367	35071	85488	28059	229984
1982	123943	89066	97716	29115	339840
1983	93368	59097	96225	46694	295385
1984	47387	47944	121258	28375	244964
1985	53764	98190	156360	63853	372168
1986	55031	93358	145767	55159	349315
1987	39025	134761	154955	123200	451941
1988	46433	131111	150128	90965	418638
1989	41137	91577	105393	108433	346539
1990	108164	109316	81438	87856	386774
1991	128149	109386	65784	29985	333303
1992	95828	105671	20593	27505	249597
1993	73549	138415	16758	28478	257200
1994	92947	154310	13914	20477	281647
1995	92286	146054	10776	22743	271859
1996	77650	158325	10038	30295	276308
1997	85591	187511	15196	11615	299912
1998	70050	170842	23359	11240	275492
1999	86975	191435	46493	10830	335732
2000	102668	225250	64681	14188	406785
2001	109674	194077	73862	25007	402620
2002	82365	160671	59469	23941	326447
2003	59937	135208	57044	35255	287444
2004	96470	175888	54798	34406	361562
2005	111582	133264	56619	10512	311977
2006	128547	195696	71091	7017	402351
2007	138038	405324	67177	3225	613765
Grand Total	2321925	3876817	1922380	1008428	9129550

Table 4.8.3. Sample size of vermilion snapper measured for length in the headboat program. NC=North Carolina, SC=South Carolina, NF=Georgia/North Florida to Cape Canaveral, SF=South Florida from Cape Canaveral through the Florida Keys.

Year	NC	SC	NF	SF	Total
1972	796	344			1140
1973	329	251			580
1974	528	723			1251
1975	689	608			1297
1976	451	293	402		1146
1977	145	218	673		1036
1978	204	220	884	460	1768
1979	271	52	901	165	1389
1980	323	171	602	252	1348
1981	174	137	854	170	1335
1982	587	686	1334	170	2777
1983	863	587	1574	1458	4482
1984	543	1516	1918	568	4545
1985	818	627	3012	1437	5894
1986	1158	693	3213	1095	6159
1987	1262	1023	3106	936	6327
1988	1307	731	2193	528	4759
1989	993	925	2191	659	4768

Year	NC	SC	NF	SF	Total
1990	873	1222	2832	381	5308
1991	1065	944	1847	173	4029
1992	610	1752	301	160	2823
1993	649	2086	365	223	3323
1994	659	4121	417	527	5724
1995	736	3719	215	129	4799
1996	760	2736	300	62	3858
1997	843	2656	460	174	4133
1998	515	2478	899	347	4239
1999	1012	1665	1402	227	4306
2000	1373	1669	1229	198	4469
2001	1474		1531	382	3387
2002	496	492	2416	491	3895
2003	442	1108	1732	542	3824
2004	579	366	1315	1064	3324
2005	515	123	947	621	2206
2006	547	975	1151	536	3209
2007	642	1195	1049	1109	3995

Table 4.8.4. Sample size of length data from the headboat sector vermilion snapper discards.

Year	NC	SC	FL	Total
2003	23			23
2004	90	86		176
2005	202	191	259	652
2006	180	20	314	514
2007	55	43	755	853

Table 4.8.5. Sample size of vermilion snapper headboat age data by state.

Year	NC	SC	GA	FL
1975		1		
1980		1		11
1981				112
1982				38
1983				2
1986				89
1987	1			7
1988				2
1991	136	20		10
1992	41	5		
1993	42	5		1
1994	116	135		1
1995	50	24		117
1996	6	11		56
1997	7	1		6
1998				2
2001				22
2002				10
2003	29	7		67
2004	29	3		298
2005	155	1		329
2006	51	51	8	487
2007	173	53	5	490

Table 4.8.6. Estimates of the number of snapper caught (1000s) in the recreational fisheries in the U.S. South Atlantic from the U.S. Fish and Wildlife Service salt-water angling surveys conducted in 1960, 1965, and 1970.

Category	**1960**	**1965**	**1970**
Unclassified snapper	9,433	1,116	613
Yellowtail snapper	3,231	19,686	10,843
Red snapper		598	1,797

Table 4.8.7. Final estimates of vermilion snapper from recreational anglers.

Year	**Landings (1000s)**	**PSE**
1960	467	65%
1965	837	82%
1970	460	114%

Table 4.8.8. Sample size from vermilion snapper age data from each of the fishing modes (CB=charter, and PR=private).

Year	CB	PR	Total
2001	83		83
2002	217		217
2003	363	5	368
2004	102		102
2005	296	3	299
2006	228	2	230
2007	31		31

Table 4.8.9. Sample size of aged vermilion snapper by state from the general recreational sector.

Year	NC	FL	Total
2001		83	83
2002		217	217
2003	34	334	368
2004		102	102
2005		299	299
2006		230	230
2007		31	31

4.9 Figures

Figure 4.9.1. Reporting areas used in the Southeast Region Headboat Survey.

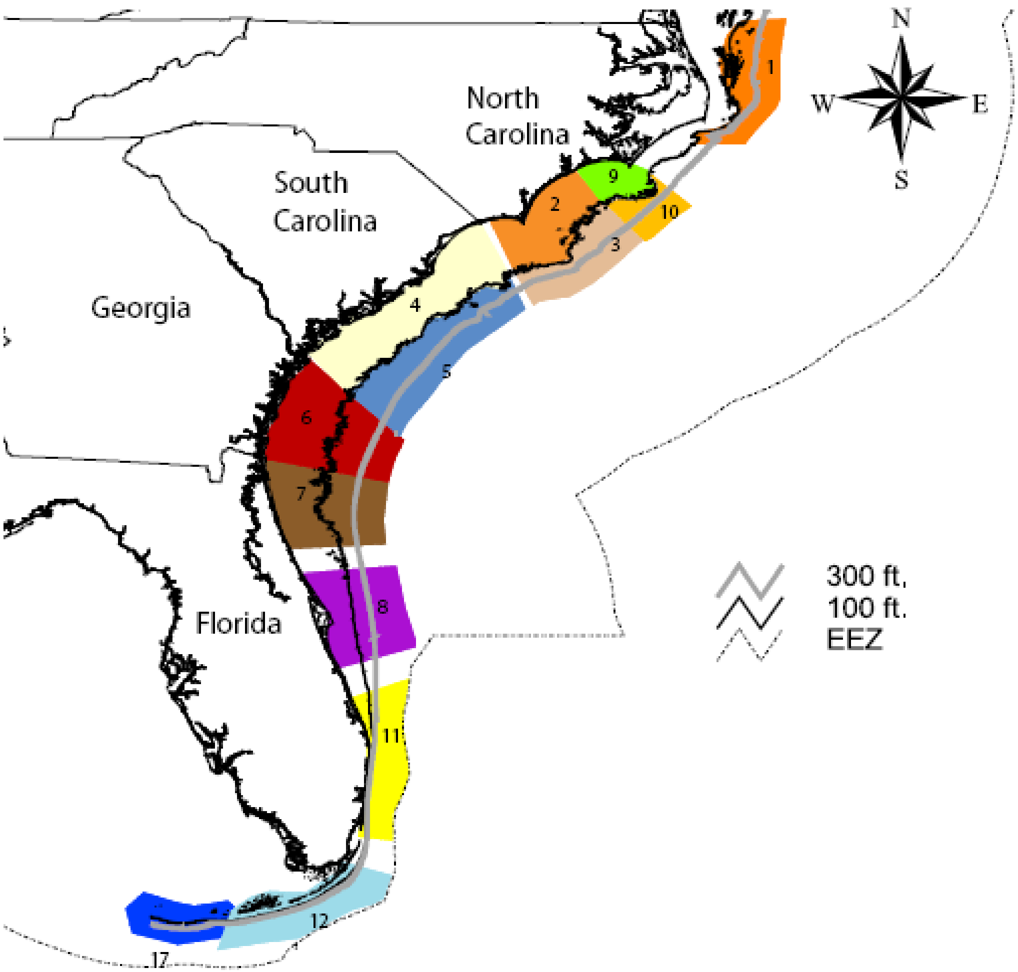


Figure 4.9.2. Vermilion snapper length composition from the headboat survey, data in 1 cm bins, total length. The dashed line represents the 1992 10 inch size limit, solid line represents the 1999 11 inch size limit and the dotted line represents the 2007 12 inch size limit.

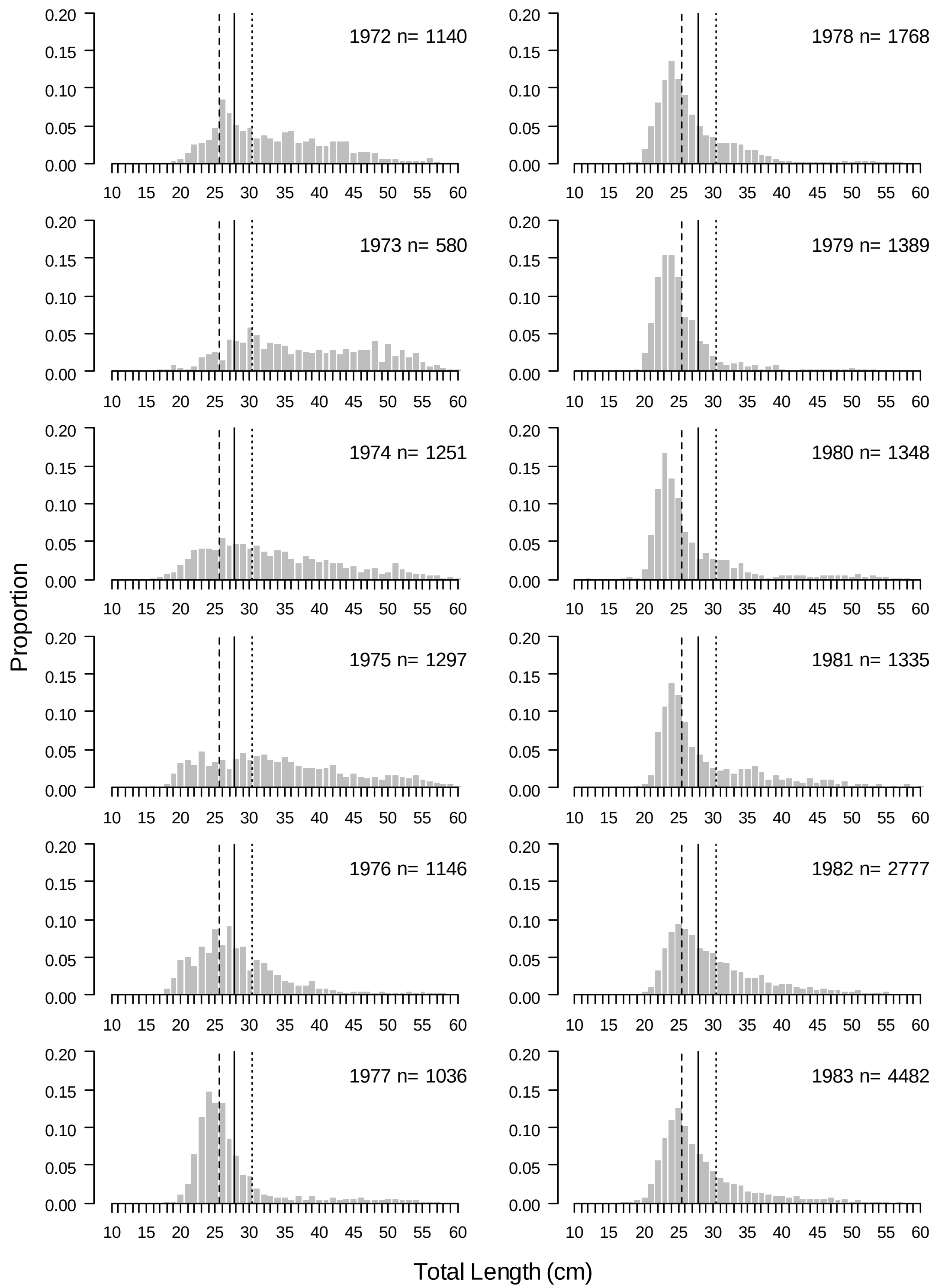


Figure 4.9.2. continued.

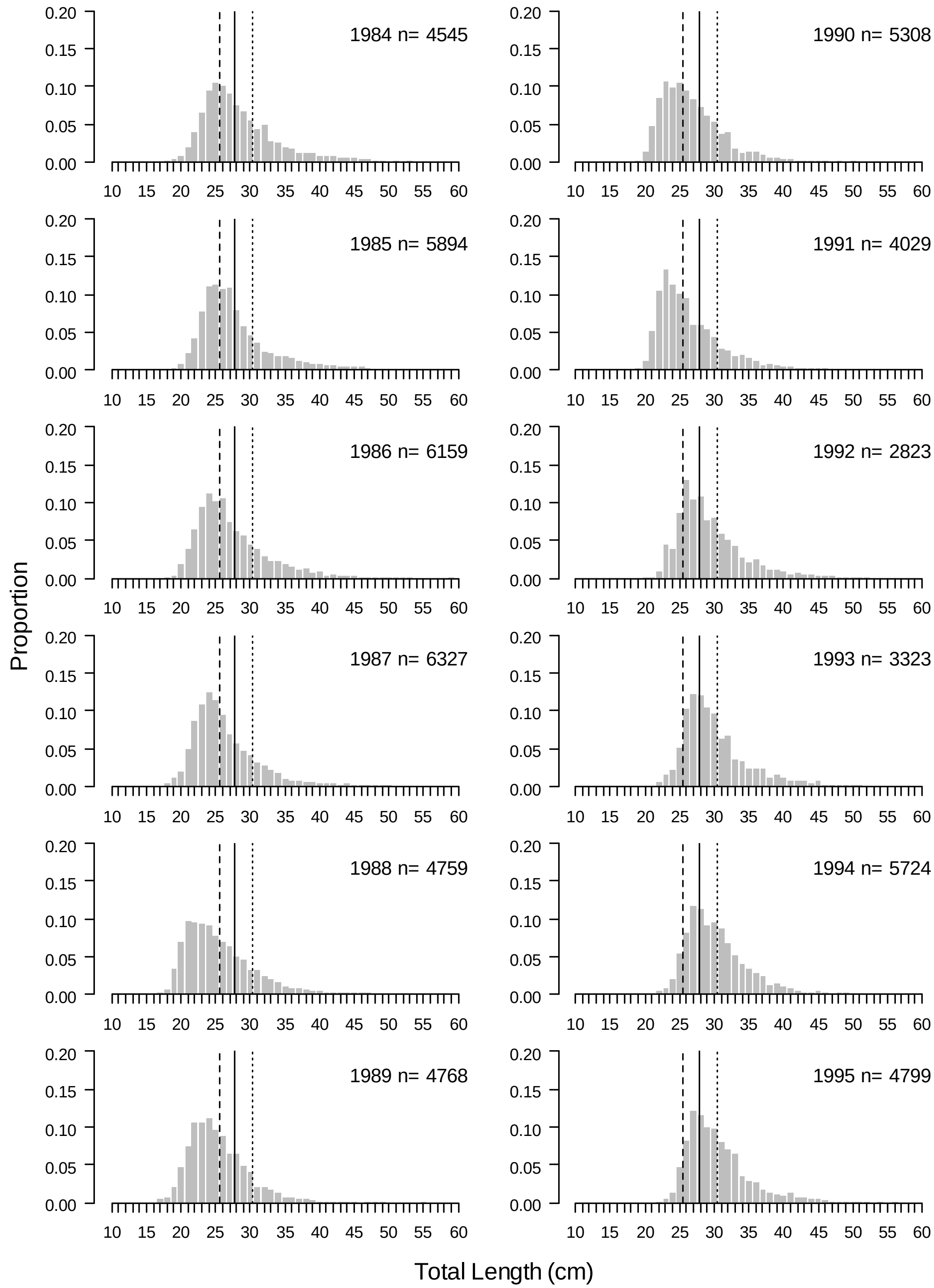


Figure 4.9.2. continued.

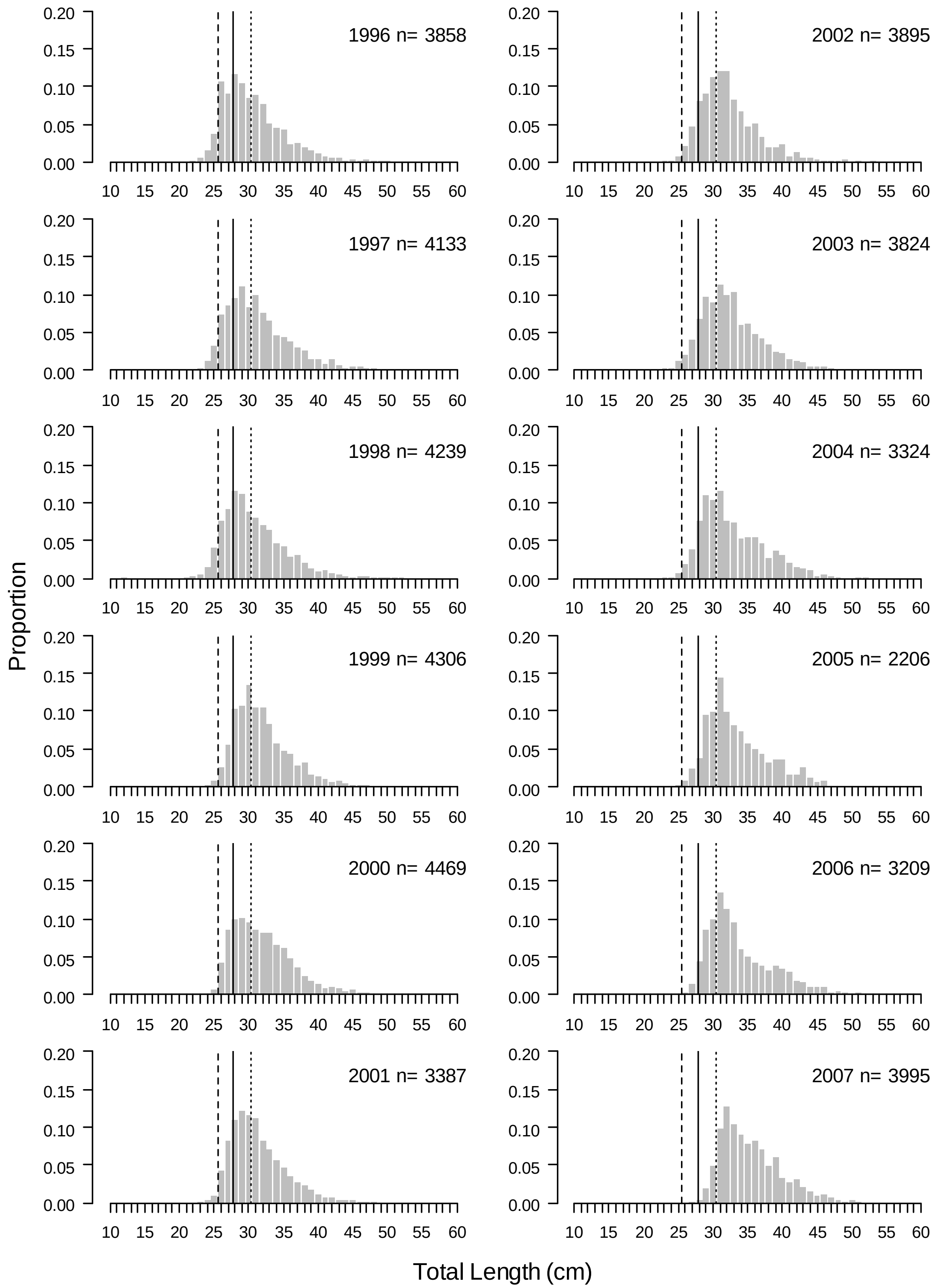


Figure 4.9.3. Vermilion snapper discard length composition from the headboat sector collected by the MRFSS headboat observer study. The, solid line represents the 1999 11 inch size limit and the dotted line represents the 2007 (Oct. 2006) 12 inch size limit.

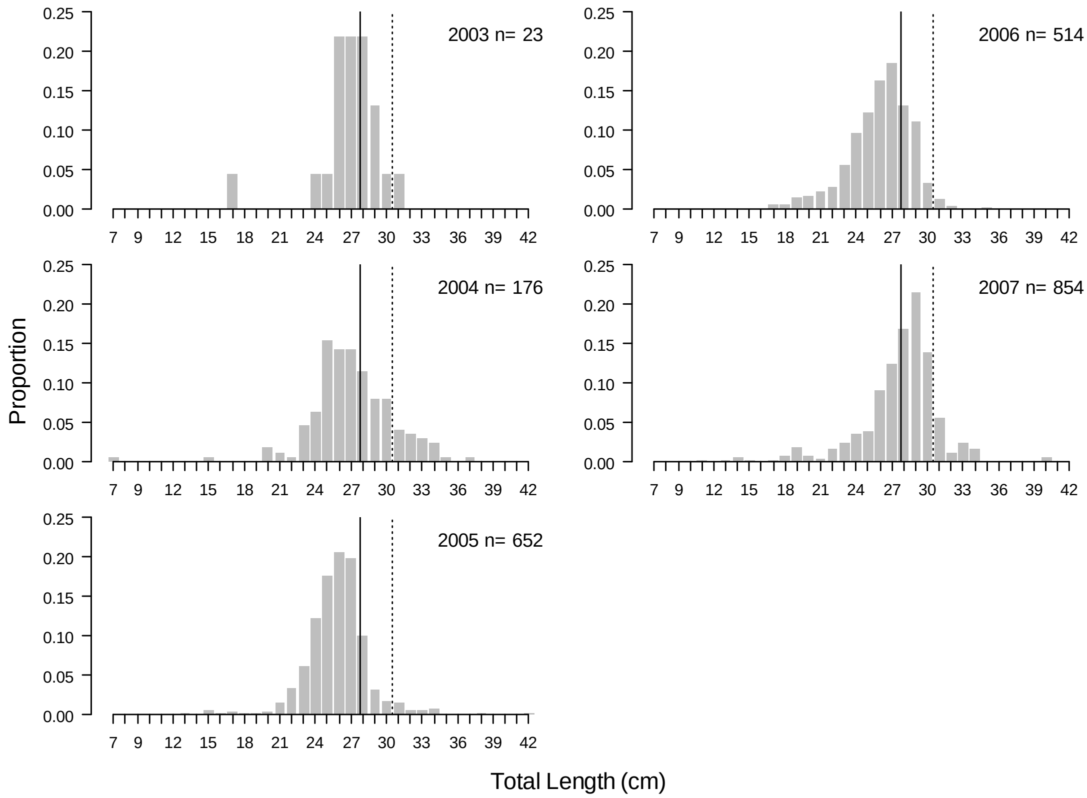


Figure 4.9.4. Age composition of vermilion snapper from the headboat fishery.

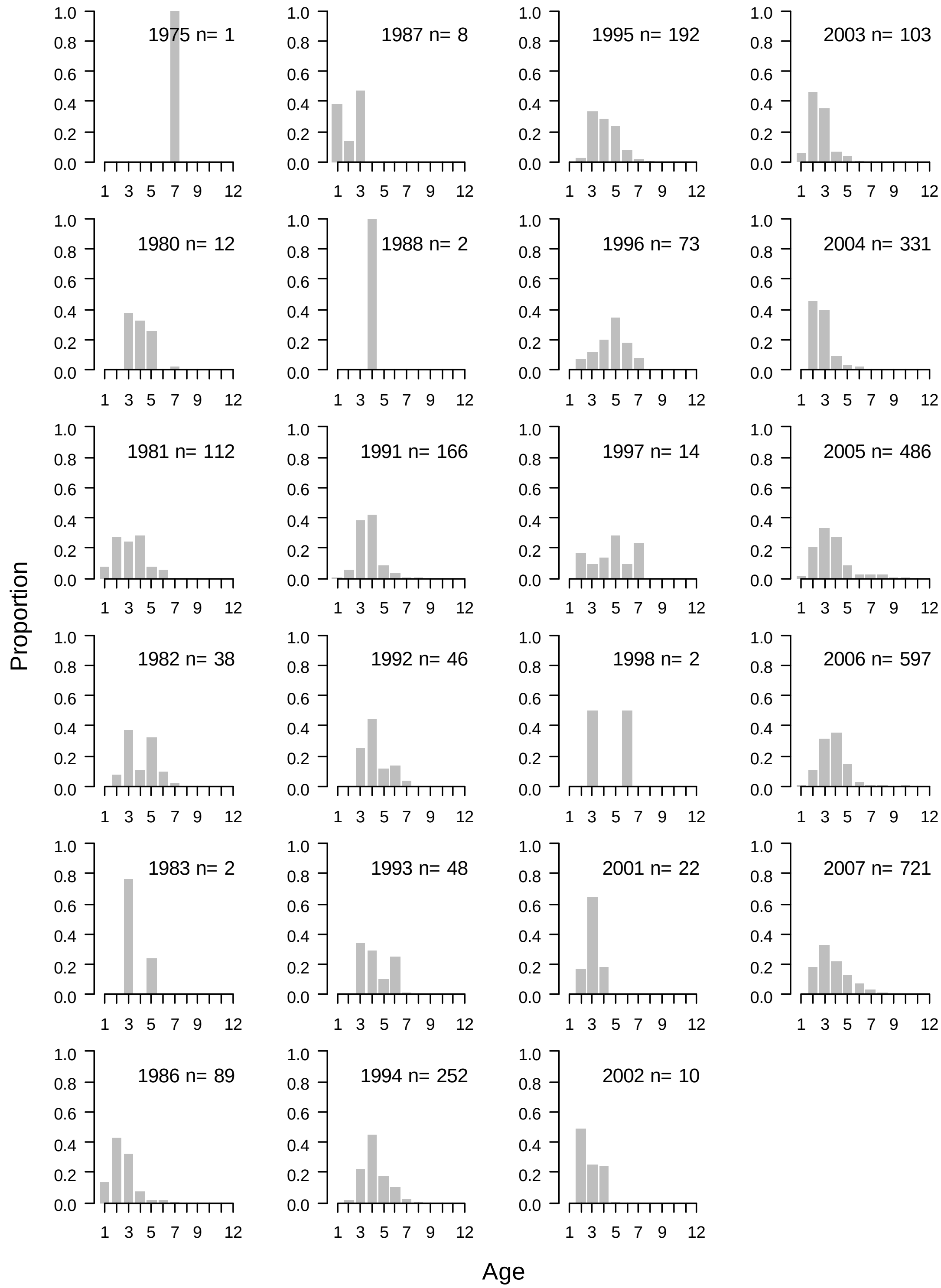


Figure 4.9.5. Number of headboat trips by region in the South Atlantic 1998-2007.

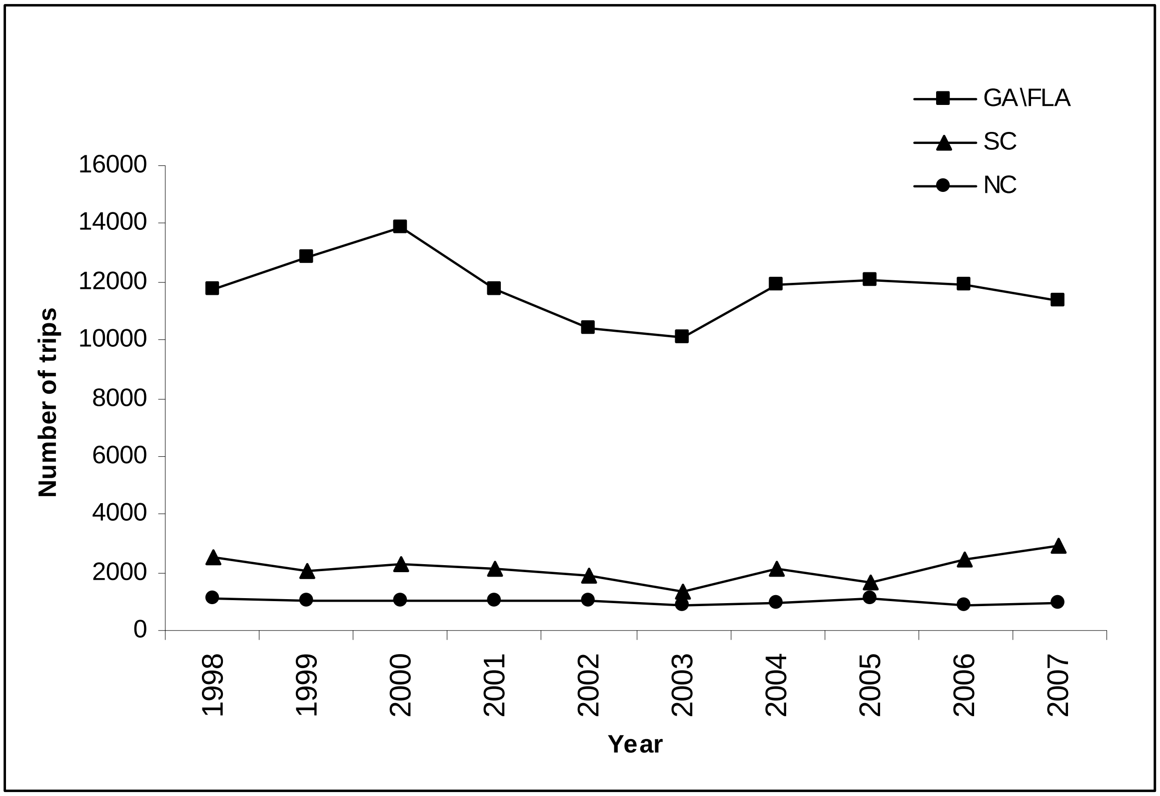


Figure 4.9.6. Proportion of headboat vermilion snapper landings relative to all recreational landings (headboat plus general recreational).

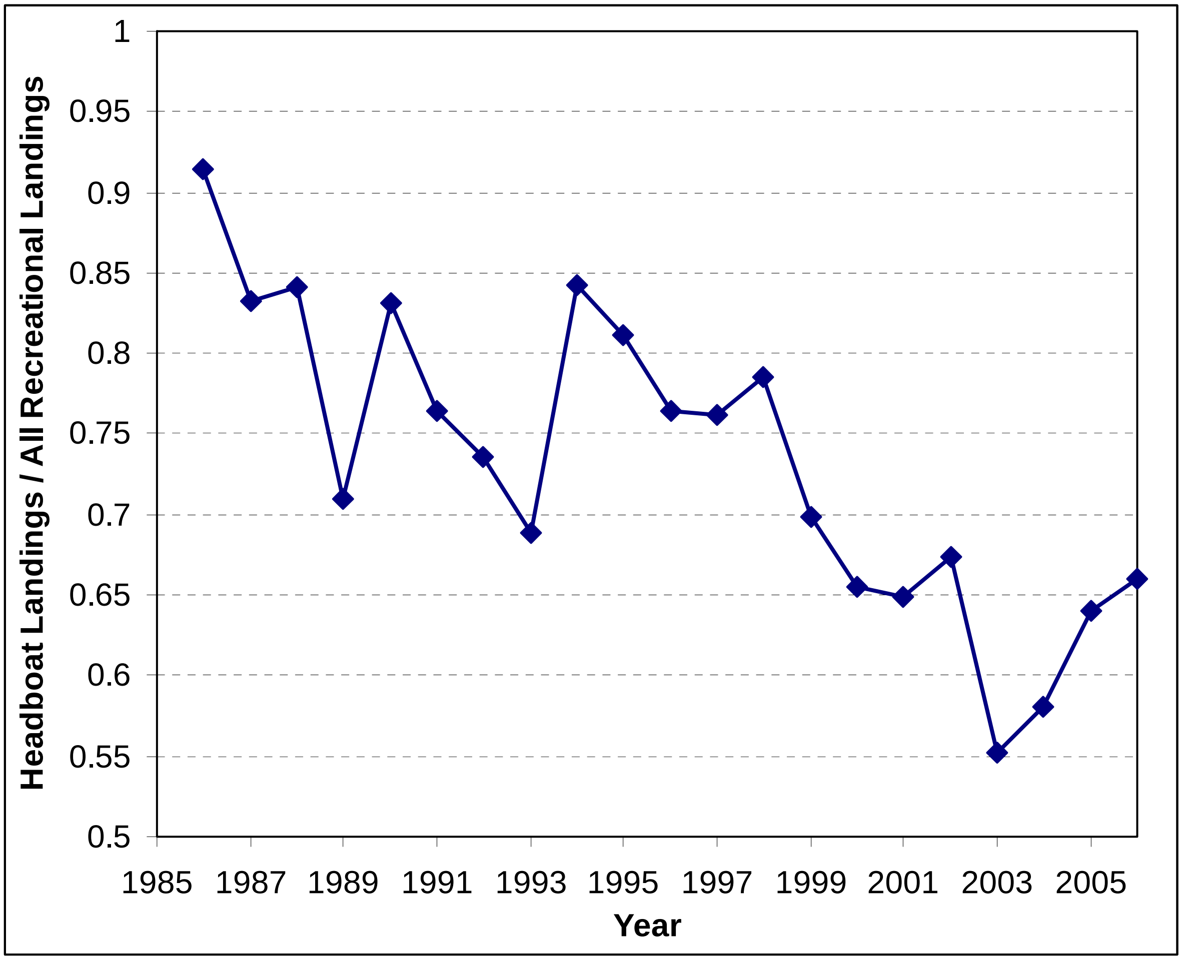


Figure 4.9.7. Proportion of headboat vermilion snapper landings relative to all snapper recreational landings minus yellowtail and red snapper.

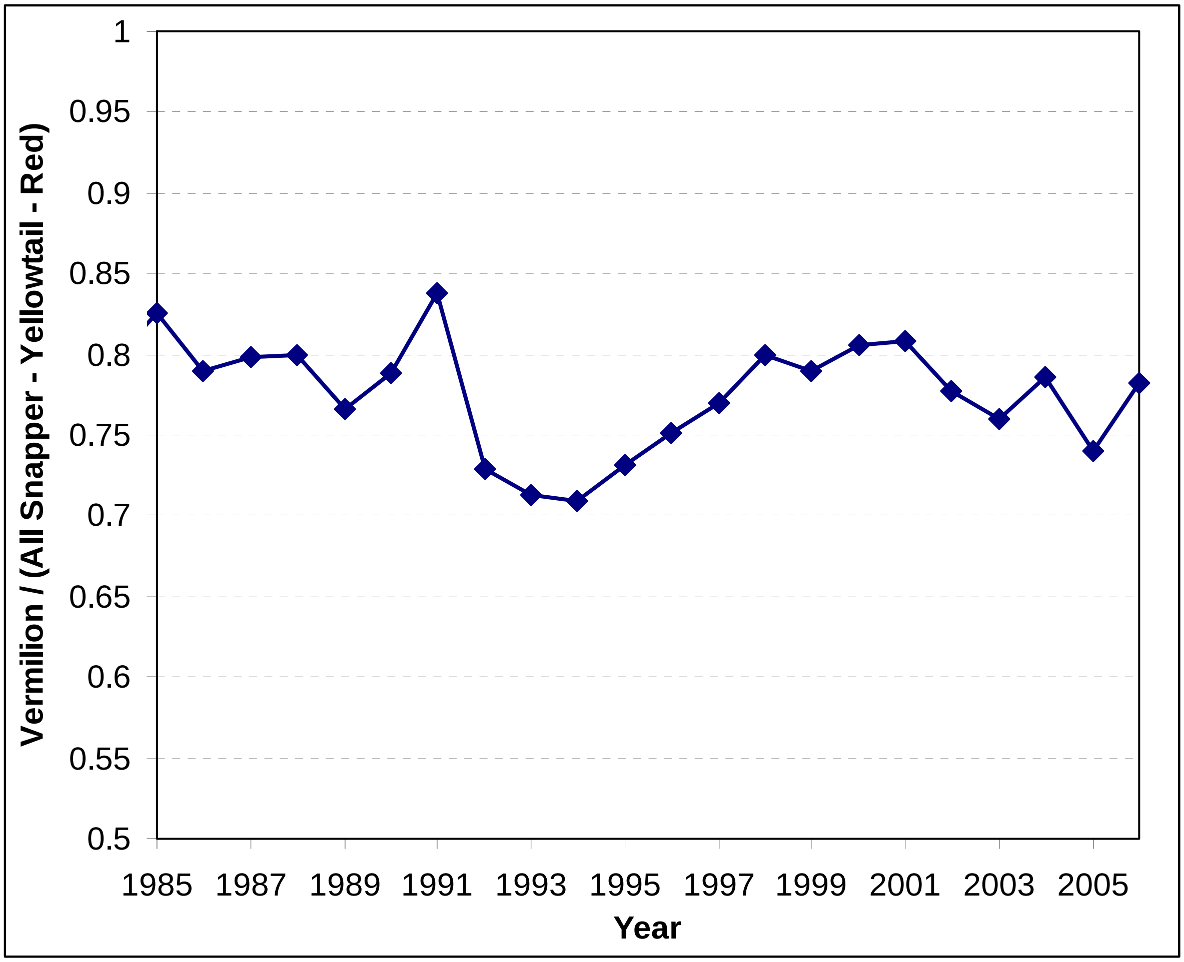


Figure 4.9.8. Vermilion snapper length composition from the general recreational sector provided by the MRFSS, 1 cm bins total length. The dashed line represents the 1992 10 inch size limit, solid line represents the 1999 11 inch size limit and the dotted line represents the 2007 12 inch size limit.

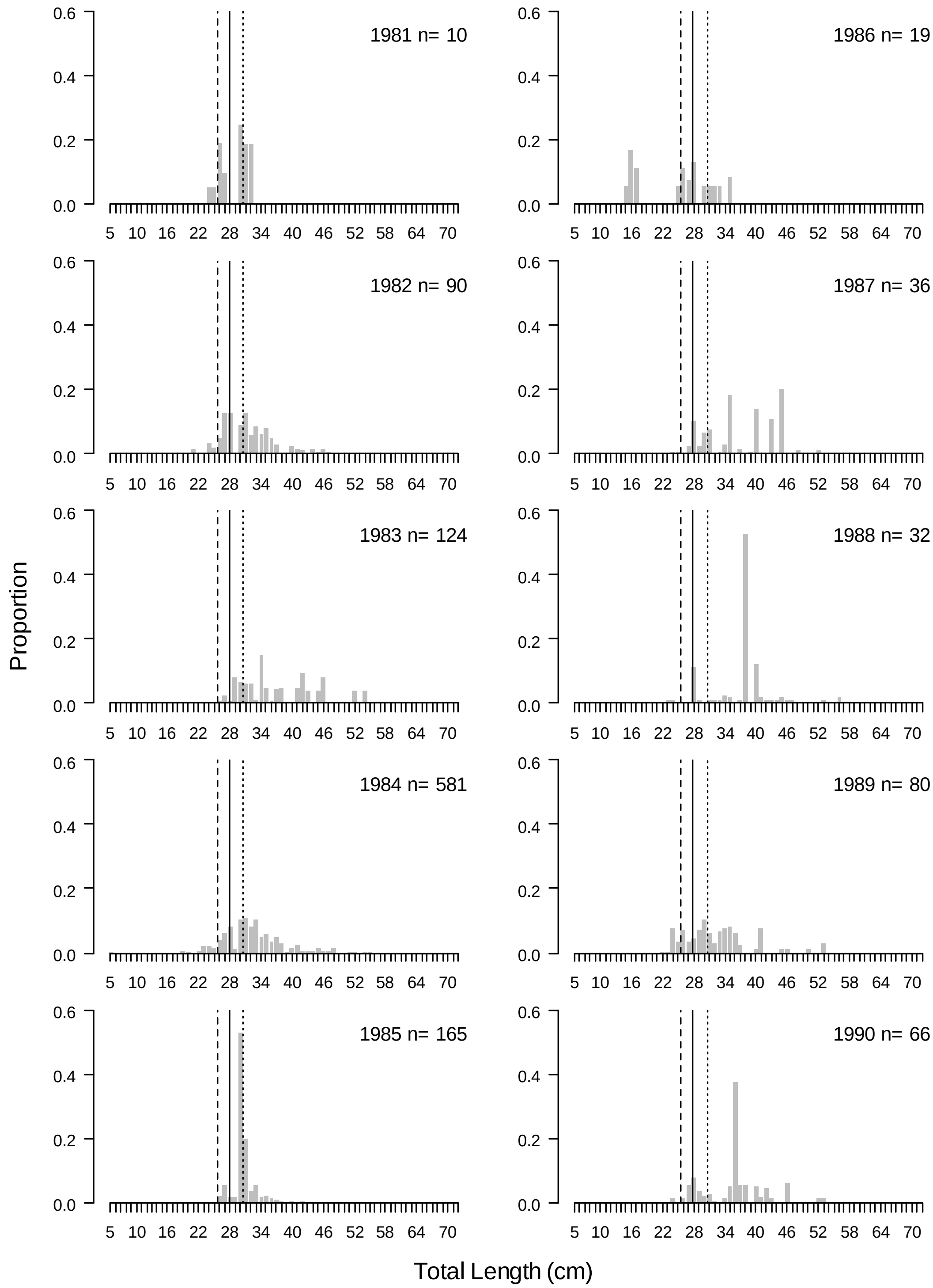


Figure 4.9.8. continued.

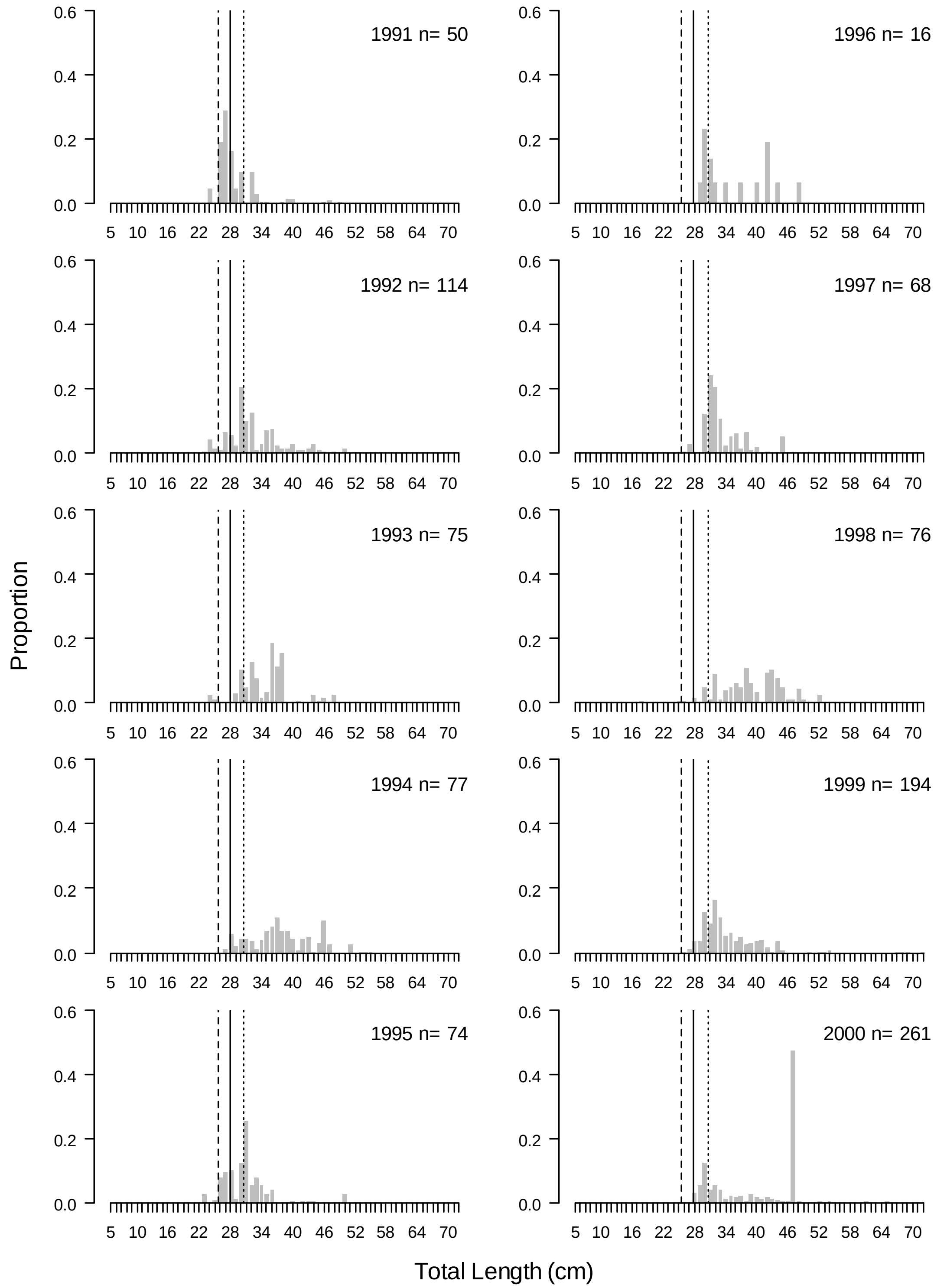


Figure 4.9.8. continued.

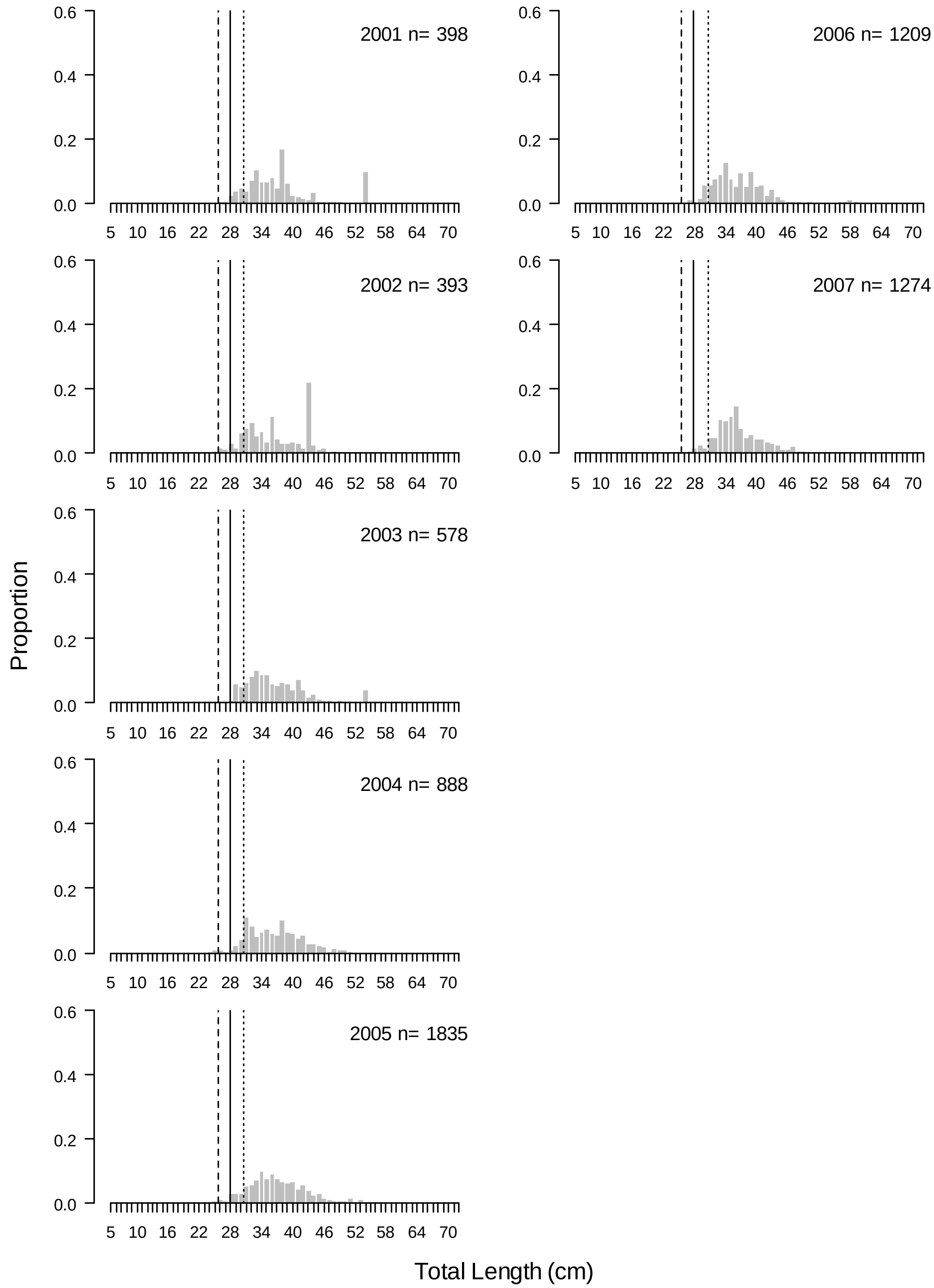
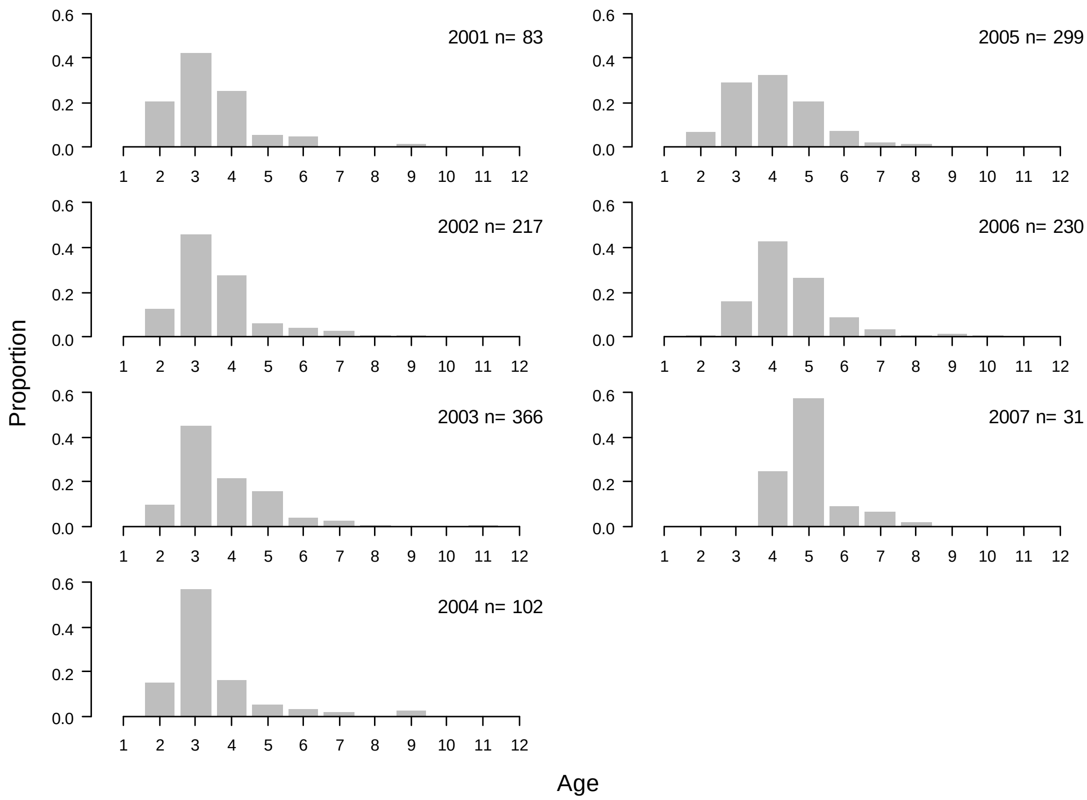


Figure 4.9.9. Age composition of vermilion snapper from the general recreation fishery. Private, charter modes are represented.



5. INDICATORS OF POPULATION ABUNDANCE

5.1 OVERVIEW

Several indices of abundance were considered for use in the assessment model. These indices are listed in Table 5.1, with pros and cons of each in Table 5.2. The possible indices came from fishery independent and fishery dependent data. The DW recommended the use of two fishery independent indices (one from MARMAP chevron traps and one from MARMAP Florida snapper traps) and three fishery dependent indices (one from commercial logbook data, one from headboat data, and one from general recreational data) (Table 5.1, 5.2).

Membership of this DW working group included Paul Conn, Julie DeFilippi, Pat Harris, Kyle Shertzer (leader), Helen Takada, Elizabeth Wenner, and Geoff White.

5.2 FISHERY INDEPENDENT INDICES

Vermilion snapper have been sampled by the MARMAP (Marine Resources Monitoring Assessment and Prediction) program using various gears (gears detailed in previous working paper SEDAR10-DW-05). Indices of abundance from two gear types were recommended for use in the assessment: chevron traps (1990–2007) and FL snapper traps (1983–1987). Other MARMAP gear types were considered, such as blackfish traps, hook & line, and vertical longlines, but were thought less likely to provide adequate indices for reasons described below.

In 1988 and 1989, FL snapper, blackfish, and chevron traps were fished synoptically for approximately 90 minutes from a 33.5 m research vessel that was anchored over randomly selected reef locations. Because of the proximity of the three types, and that hook and line sampling was occurring from the vessel at the same time the traps were deployed, the DW recommended that 1988 and 1989 be excluded from all fishery-independent indices developed.

In recent years, MARMAP has conducted a trap comparison study, which could allow for the possibility of extending the index from chevron traps back to years earlier than 1990. At this time, however, the working group considered that possibility to be premature, because the methods of data collection and analysis have not yet been adequately reviewed.

5.2.1 MARMAP CHEVRON TRAP

5.2.1.1 General description

Chevron traps were baited with cut clupeids and deployed at stations randomly selected by computer from a database of approximately 2,500 live bottom and shelf edge locations and buoyed ("soaked") for approximately 90 minutes. Beginning in the 1990s, additional sites were selected, based on scientific and commercial fisheries sources, off North Carolina and south Florida to facilitate expanding the overall sampling coverage. The site expansion has been ongoing, with a few new sites added each year.

As a result, the survey has relatively extensive regional coverage; the average number of vermilion snapper collected in the traps each year between 1990 and 2007 was 1,320.3 (range 152–3,138, total 26,406). The CPUE averaged 2.47 fish/trap-hr with much variation (CV=348%). The high variability in the data may in part be due to the schooling behavior of vermilion snapper, and it was suggested that the index could be standardized using a delta-GLM approach, as described below. The DW also noted positive correlation between the chevron trap index and mean summer bottom temperatures as recorded during MARMAP sampling, and it was recommended that the GLM approach include bottom temperature as a predictor variable.

5.2.1.2 Methods

The CPUE from MARMAP chevron trap data was computed in units of number fish caught per trap-hour. The duration of the time series was 1990–2007. Spatial coverage included areas from Florida through North Carolina (Figure 5.1).

Standardized catch rates were estimated using a delta-GLM error structure (Lo et al., 1992; Stefánsson, 1996; Maunder and Punt, 2004), in which the binomial distribution describes positive versus zero CPUE, and either a lognormal or gamma distribution describes the positive CPUE (software described in SEDAR17-RD16). Lognormal and gamma models were both fitted, and the error structure with the lowest AIC was selected. In this case, the lognormal model was selected (gamma AIC = 11262; lognormal AIC = 10894). Explanatory variables considered, in addition to year (necessarily included), were bottom temperature (continuous variable), season (categorical variable), latitude (categorical variable), and depth (continuous variable). Both model components (binomial and lognormal) included main effects only. Season comprised spring (May and earlier), summer (June-August), or autumn (September and later), with most sampling in the summer (~73% of records).

Measures of precision were computed by a jackknife routine and summarized by the resulting CV. The jackknife routine iteratively refitted the delta-GLM model N times (N is the total sample size), where each iteration removed a unique record.

5.3.1.3 Sampling Intensity

The numbers of chevron trap sets and positive sets (i.e., caught vermilion snapper) are tabulated in Table 5.3.

5.2.1.4 Size/Age Data

Length compositions of chevron trap catches were available for all years of sampling (Table 5.4A). In general, vermilion snapper caught in chevron traps were between 15 and 40 cm of length. The lack of larger fish suggests that selectivity of the gear is dome-shaped. Age compositions were available starting in 2002 (Table 5.4B). Prior to 2002, fish were not necessarily selected at random for ageing.

5.2.1.5 Catch Rates and Measures of Precision

Diagnostic plots from the delta-GLM model fit are in Appendix 5.3. Table 5.5 shows nominal CPUE (fish/trap-hr), standardized CPUE, coefficients of variation (CV), and annual sample sizes (number trips). Figure 5.2 shows standardized and nominal CPUE.

5.2.1.6 Comments on Adequacy for Assessment

The DW concluded that the geographic coverage and relative high catch rates justified using chevron trap CPUE as an index of abundance in the assessment. However, concern was raised that annual variation in the index was unrealistically large, particularly in the early part of the time series. These fluctuations may be due in part to the schooling behavior of vermilion snapper, rather than to actual changes in abundance. The scale of sampling intensity (hundreds of sets per year spanning the entire South Atlantic Bight) might not be large enough to adequately characterize relative abundance of a schooling fish. The DW was also concerned that catchability in chevron traps might be influenced by bottom temperature, and noted positive correlation between the nominal chevron trap index and mean summer bottom temperatures (Pearson $\rho = 0.55$; p-value = 0.02 from a *t*-test of H_0: $\rho = 0$). Although the delta-GLM represented an attempt to account for bottom temperature in the index, it may not have been able to do so adequately if annual variation in temperatures across trap locations was inseparable from year effects.

5.2.2 MARMAP FLORIDA SNAPPER TRAP

5.2.2.1 General Description

From 1978 to 1987, Florida snapper traps baited with cut clupeids were soaked for approximately two hours during daylight at 12 study areas with known live-bottom and/or rocky ridges distributed from Onlsow Bay, NC to Fernandina Beach, FL. The DW noted that although sampling locations were not selected equally across the management area, samples were collected from what is thought to be the center of distribution of vermilion in the SAB. The total number of vermilion snapper caught between 1980 and 1987 was 2,037 (254/yr; range 24-471), the bulk of these fish were collected during 1983 through 1987, when four sample areas cited on the shelf break off South Carolina were added. The CPUE averaged 0.78 fish/trap-hr with much variation (CV=343%). The high variability in the data may in part be due to the schooling behavior of vermilion snapper, and it was suggested that the index could be standardized using a delta-GLM approach, as described below.

5.2.2.2 Methods

The CPUE from MARMAP FL snapper trap data was computed in units of number fish caught per trap-hour. The duration of the time series was 1983–1987. Spatial coverage included areas from Florida through North Carolina (Figure 5.3).

Standardized catch rates were estimated using a delta-GLM error structure (Lo et al., 1992; Stefánsson, 1996; Maunder and Punt, 2004), in which the binomial distribution describes positive versus zero CPUE, and either a lognormal or gamma distribution describes the positive CPUE (software described in SEDAR17-RD16). Lognormal and gamma models were both fitted, and the error structure with the lowest AIC was selected. In this case, the lognormal model was selected (gamma AIC = 1309; lognormal AIC = 1239). Explanatory variables considered, in addition to year (necessarily included), were season (categorical variable) and depth (continuous variable). Both model components (binomial and lognormal) included main effects only. Season comprised spring (May and earlier) or summer (June-August, but with a single record from September), with most sampling in the summer (~59% of records). Bottom temperature was not included as an explanatory variable here (as it was with chevron traps) because it was not recorded for most records. Latitude was not included here because sampling at 33 degrees and north was only in relatively shallow waters where encounters of vermilion snapper were rare (Figure 5.3), and depth was already included.

Measures of precision were computed by a jackknife routine and summarized by the resulting CV. The jackknife routine iteratively refitted the delta-GLM model N times (N is the total sample size), where each iteration removed a unique record.

5.2.2.3 Sampling Intensity

The numbers of FL snapper trap sets and positive sets (i.e., caught vermilion snapper) are tabulated in Table 5.3.

5.2.2.4 Size/Age Data

Length compositions of FL snapper trap catches were available for all years of sampling (Table 5.4C). In general, vermilion snapper caught in FL snapper traps were between 15 and 40 cm of length. The lack of larger fish suggests that selectivity of the gear is dome-shaped. Fish were not selected at random for ageing, and thus no age compositions are available.

5.2.2.5 Catch Rates and Measures of Precision

Diagnostic plots from the delta-GLM model fit are in Appendix 5.4. Table 5.6 shows nominal CPUE (fish/trap-hr), standardized CPUE, coefficients of variation (CV), and annual sample sizes (number trips). Figure 5.4 shows standardized and nominal CPUE.

5.2.2.6 Comments on Adequacy for Assessment

The DW concluded that the geographic coverage and catch rates of the FL snapper trap were adequate to use the CPUE as an index of abundance in the assessment. However, concern was raised that annual variation in the index was quite large. These fluctuations may be due in part to the schooling behavior of vermilion snapper, rather than to actual changes in abundance. Schooling could affect sampling in several ways, for example, if probability of being caught in a trap (trap-oriented behavior) varies with some unmeasured variable(s) or if there is high variance in the probability of a school being sampled (effects of school and sampling locations relative to sampling intensity). The scale of sampling intensity (hundreds of sets per year) might not be large enough to adequately characterize relative abundance of a schooling fish.

5.2.3 OTHER DATA SOURCES CONSIDERED

5.2.3.1 MARMAP Blackfish Trap

From 1978 to 1987, blackfish traps baited with cut clupeids were soaked for approximately two hours during daylight at eight midshelf study areas with known live-bottom and/or rocky ridges distributed from Onlsow Bay, NC to Fernandina Beach, FL.

Although vermilion snapper were sampled by this gear type, it was utilized as a tool to sample black sea bass, and did not provide consistent samples of vermilion snapper. Furthermore, all sites sampled with blackfish traps were also sampled using Florida snapper traps (see above), which provide a better index of abundance for vermilion snapper. For these reasons, the DW did not recommend using the MARMAP blackfish trap samples to develop an index of abundance off the southeastern U.S.

5.2.3.2 MARMAP Hook and Line

Hook and line stations were fished primarily during dawn and dusk periods, one hour preceding and after actual sunrise and sunset, however some fishing was also conducted synoptically with trap sampling. Rods utilizing Electromate motors powered 6/0 Penn Senator reels and 36 kg test monofilament line were fished for 30 minutes by three anglers. The terminal tackle consisted of three 4/0 hooks on 23 kg monofilament leaders 0.25 m long and 0.3 m apart, weighted with 0.5 to 1 kg sinkers. The top and bottom hooks were baited with cut squid and the middle hook baited with cut cigar minnow (*Decapterus sp.*). The same method of sampling was used from 1978 to 2007. However, less emphasis has been placed on hook and line sampling during the 1990s and 2000s to put more effort on tagging of fish at night and running between chevron and long line stations to increase sample coverage.

The total number of vermilion snapper caught between 1979 and 2007 was 2,404 (85.8/yr; range 0-483), the bulk of these fish were collected during 1988 and 1989 (888, 37%) and sample size was less than 50 in all years except three. Changes in personnel and level of effort have changed over time, compromising the utility of the hook and line survey as an index. Much of the hook and line effort was conducted over mid-shelf depths, and as such may not provide an adequate representation of the complete range of vermilion snapper. As a result, the DW did not recommend using the MARMAP hook and line samples to develop an index of abundance off the southeastern U.S.

5.2.3.3 MARMAP Short Bottom Long Line (vertical long line)

The short bottom long line was deployed to catch grouper/snapper over high relief and rough bottom types at depths of 90 to 200 m. This bottom line consisted of 25.6 m of 6.4 mm solid braid dacron groundline dipped in green copper naphenate. The line is deployed by stretching the groundline along the vessel's gunwale with 11 kg weights attached at the ends of the line. Twenty gangions baited with whole squid were placed 1.2 m apart on the groundline which was then attached to an appropriate length of poly warp and buoyed to the surface with a Hi-Flyer. Sets are made for 90 minutes and the gear is retrieved using a pot hauler.

Only two vermilion snapper have ever been captured using this gear type, and the DW did not recommend using the MARMAP short bottom long line samples to develop an index of abundance for vermilion snapper off the southeastern U.S.

5.2.3.4 Miscellaneous Sources

Other sources of fishery independent data were considered for a possible index of abundance, including MARMAP trawls, SEAMAP, NMFS Northeast Groundfish Trawl, and diver reports (reef.org). These sources sampled either no or insufficient numbers of vermilion snapper to be useful as an index of abundance.

5.3 FISHERY DEPENDENT INDICES

5.3.1 COMMERCIAL LOGBOOK (HANDLINE)

5.3.1.1 General Description

The NMFS collects catch and effort data by trip from commercial fishermen who participate in fisheries managed by the SAFMC. For each fishing trip, data collected include date, gear, fishing area, days at sea, fishing effort, species caught, and weight of the catch (Appendix 5.1). The logbook program in the Atlantic started in 1992. In that year, logs were collected from a random sample representing 20% of vessels; starting in 1993, all commercial fishermen holding snapper-grouper permits were required to submit logs. Using these data, an index of abundance was computed for 1993–2007.

5.3.1.2 Issues Discussed at the DW

Issue 1: Gear selection
Option 1: Include all gear types
Option 2: Include only handlines (composed of handline and electric reels)
Decision: Option 2, because greater than 97% of trips used handline.

Issue 2: Year selection
Option 1: Use data starting in 1992
Option 2: Use data starting in 1993
Decision: Option 2, because 1992 included only 20% coverage of fishermen, whereas 1993 began 100% coverage.

Issue 3:Defining which trips constitute effort
Option 1: Include only positive trips
Option 2: Use method of Stephens and MacCall (2004) to define effort that could have caught the focal species based on the composition of other species in the landings. This method would include trips with effort but zero landings.
Option 3: Option 2, but apply Stephens and MacCall separately to regions north and south of Cape Canaveral
Decision: Option 3, because it is likely that not all effective effort was successful at landing vermilion snapper, and because regions north and south of Cape Canaveral were found to have differences in species assemblages (Appendix 5.2).

Miscellaneous decisions

- The DW acknowledged that changes in fishing regulations could affect the ability of fishery dependent CPUE to track abundance. For the commercial sector, a 12-inch TL size limit was implemented on January 1, 1992; this regulation was implemented prior to the logbook time series, and was therefore not a concern. A commercial quota of 1.1 million pounds gutted weight was implemented on October 23, 2006, but this quota was not reached and was therefore not a concern.
- Species considered for the application of Stephens and MacCall (2004) were those in the Snapper-Grouper Fishery Management Plan. Some of these species were excluded if rare or not important to the regression, as described below in the Methods.

5.3.1.3 Methods

The CPUE from commercial logbook data was computed in units of pounds caught per hook-hour. The duration of the time series was 1993–2007. Spatial coverage included the entire management area, from east of the Florida Keys through North Carolina (i.e., through 36° latitude) (Figure 5.5). Each record describes weight (total lb) of a single species caught on a single trip, along with descriptive information of the trip, such as effort, date, and area fished.

Of trips that caught vermilion snapper, greater than 97% used handline gear, defined here as gear with code H or E (Appendix 5.1). Thus, the analysis included handline gear only. Excluded were records suspected to be misreported or misrecorded, as in previous SEDAR assessments (e.g., SAFMC, 2006): The variable "effort" (hooks/line) was constrained to be between 1 and 40 (inclusive), the variable "numgear" (number of lines) to be between 1 and 10 (inclusive); the variable "crew" (number on boat) to be fewer than 13, the variable "totlbs" (weight of catch) to be less than the 99th percentile (2726 lb) of vermilion snapper landings, cpue of vermilion snapper to be less than its 99th percentile (6.379 lb/hook-hr), and hours fished to allow only positive values. These constraints removed fewer than 1% of handline records. Also excluded were records that did not report area fished, number of lines, number of hooks, time fished, or days at sea.

Effective effort was based on those trips from areas where vermilion snapper were available to be caught. Without fine-scale geographic information on fishing location, trips to be included in the analysis must be inferred. To do so, the method of Stephens and MacCall (2004) was applied. The method uses multiple logistic regression to estimate a probability for each trip that the focal species was caught, given other species caught on that trip. As mentioned previously, the method was applied separately to data from regions north and south of Cape Canaveral, because of differences in species assemblages (Figure 5.6A,B, Appendix 5.2). To avoid spurious correlations, species that were rarely caught were excluded from each regression: species were included as factors if caught in at least 1% of trips, with northern and southern regions considered separately. Model selection (i.e., choice of predictor species) was based on AIC using a backward stepwise algorithm (Venables and Ripley, 2002). The selected model (Table 5.7A,B) was used to compute for each trip a probability that vermilion snapper was caught, and a trip was then included if its associated probability was higher than a threshold probability (Figure 5.7A,B). The threshold was defined to be that which results in the same number of predicted and observed positive trips, as in Stephens and MacCall (2004). After applying Stephens and MacCall (2004) and the constraints described above, the resulting data set contained 29,338 trips, of which ~76% were positive.

Standardized catch rates were estimated using a delta-GLM error structure (Lo et al., 1992; Stefánsson, 1996; Maunder and Punt, 2004), in which the binomial distribution describes positive versus zero CPUE, and either a lognormal or gamma distribution describes the positive CPUE (software described in SEDAR17-RD16). Lognormal and gamma models were both fitted, and the error structure with the lowest AIC was selected. In this case, the gamma model was selected (gamma AIC = 75,018; lognormal AIC = 79,691). Explanatory variables considered, in addition to year (necessarily included), were month and geographic area. Both model components (binomial and gamma) included main effects only. Geographic areas reported in the logbooks were pooled into larger areas to provide adequate sample sizes for each level of this factor—NC (34°N ≤ latitude < 37°N), SC (32°N ≤ latitude < 34°N), GA (31°N ≤ latitude < 32°N), north FL (29°N ≤ latitude < 31°N), and south FL (latitude < 29°N).

Measures of precision were computed by a jackknife routine and summarized by the resulting CV. The jackknife routine iteratively refitted the delta-GLM model N times (N is the total sample size), where each iteration removed a unique record.

5.3.1.4 Sampling Intensity

The numbers of positive trips by year and area are tabulated in Table 5.8. The method of Stephens and MacCall (2004) does not necessarily select all positive trips.

5.3.1.5 Size/Age Data

Sizes and ages of fish represented by this index are the same as those of the commercial handline fishery (see chapter 3 of this DW report).

5.3.1.6 Catch Rates and Measures of Precision

Diagnostic plots from the delta-GLM model fit are in Appendix 5.5. Table 5.9 shows nominal CPUE (pounds/hook-hr), standardized CPUE, coefficients of variation (CV), and annual sample sizes (number trips selected by Stephens and MacCall method). Figure 5.8 shows standardized and nominal CPUE.

5.3.1.7 Comments on Adequacy for Assessment

The logbook index was recommended by the DW for use in the assessment. It had the advantages of wide geographic coverage and very large sample sizes, which could mitigate any effect of schooling on CPUE. The DW, however, did express several concerns about this data set (Table 5.2). It was pointed out that there are problems associated with any abundance index and that convincing counter-evidence needs to be presented to not use the logbook data.

Three concerns merit further description. First, commercial fishermen may target different species through time. If changes in targeting have occurred, effective effort can be difficult to estimate. However, the DW recognized that the method of Stephens and MacCall (2004), used here to identify trips for the analysis, can accommodate changes in targeting, as long as species assemblages are consistent.

Second, the data are self-reported and largely unverified. Some attempts at verification have found the data to be reliable, but problems likely remain, such as the possibility of misidentification of other species as vermilion snapper.

Third and probably foremost, the data are obtained from a directed fishery and therefore the index could contain problems associated with any fishery dependent index. Fishing efficiency of the fleet has likely increased over time due to improved electronics. In addition, overall efficiency may have changed throughout the time series if fishermen of marginal skill have left or entered the fishery at a greater rate than more successful fishermen. Also of concern is whether catch rates in a directed fishery are density-dependent. As fish abundance decreases, fishermen may maintain relatively high catch rates, and as fish abundance increases, catch rates may saturate.

The DW discussed how the assessment might attempt to account for changes in catchability over time. Constant catchability, though commonly assumed, would not be an appropriate assumption in this fishery, as the DW generally believed that catchability has increased with improvements in fishing gear and technology. The DW recommended that the base assessment model assume catchability increases by 2% per year, as was used in the SEDAR10 assessment of gag grouper (SAFMC, 2006) and SEDAR15 assessments of red snapper and greater amberjack (SAFMC, 2007a; SAFMC, 2007b). The DW further recommended that sensitivity runs consider increases of 0% (i.e., constant) and 4% per year.

5.3.2 RECREATIONAL HEADBOAT SURVEY

5.3.2.1 General Description

The headboat fishery is sampled separately from other recreational fisheries. The headboat fishery comprises large, for-hire vessels that generally charge a fee per angler and typically accommodate 20–60 passengers. Using the headboat data, an index of abundance was computed for 1976–2007.

5.3.2.2 Issues Discussed at the DW

<u>Issue 1: Include/exclude years prior to full area or vessel coverage</u>

Early years of headboat sampling did not have full area coverage. All headboats from North Carolina and South Carolina were sampled starting in 1973. Headboats from Georgia and northern Florida were sampled starting in 1976, and from southern Florida starting in 1978. All headboats across all areas were sampled starting in 1978.
Option 1: Use data starting in 1973
Option 2: Exclude early years; start the time series in 1976 (sampling did not include southern Florida)
Option 3: Exclude early years; start the time series in 1978 (begins 100% coverage).
Decision: Option 2, because most areas are represented throughout the time series; southern Florida is not represented in the first two years, but the delta-GLM model can account for predicted area effects.

<u>Issue 2:Defining which trips constitute effort</u>

Option 1: Include only positive trips
Option 2: Use method of Stephens and MacCall (2004) to define effort that could have caught the focal species based on the composition of other species in the landings. This method would include trips with effort but zero landings.
Option 3: Option 2, but apply Stephens and MacCall separately to regions north and south of Cape Canaveral
Decision: Option 3, because it is likely that not all effective effort was successful at landing vermilion snapper, and because regions north and south of Cape Canaveral were found to have differences in species assemblages (Appendix 5.2).

<u>Issue 3: Include/exclude years with 10 fish/angler bag limit</u>

Starting in 1992, with the implementation of a 10-fish bag limit, the percentage of headboat trips reporting greater than 10 vermilion snapper per angler remained low (Table 5.10), however the percentage of trips reporting exactly 10 vermilion snapper per angler rose from less than 2% annually to 7-11%. Concern was raised at the DW about whether a report of 10-fish per angler would accurately reflect the true number of vermilion snapper caught. Such a report might be an underestimate of the actual number caught for at least two reasons: 1) headboat operators may not wish to document in

writing a value that exceeds the regulation, and 2) vermilion snapper caught in excess of the bag limit would be released, if caught on headboat trips that were in compliance with regulations.
Option 1: End the time series in 1991.
Option 2: Use the entire time series of 1976-2007.
Decision: Option 2, because sensitivity analyses revealed that if reports of 10 fish per angler in 1992-2007 were erroneous, any effect on the index of abundance would be small (SEDAR17-DW11). The DW considered adjusting data at the trip level to account for such reports, but could only do so by making unverifiable assumptions, and thus decided to use the data as reported.

Miscellaneous decisions

- A 10-inch TL size limit was implemented on January 1, 1992, which was increased to 11 inches on February 24, 1999, and then again to 12 inches on October 23, 2006. The DW acknowledged that size limits could be accounted for by the assessment model through estimation of selectivity.
- Species considered for the application of Stephens and MacCall (2004) were those in the Snapper-Grouper Fishery Management Plan. Some of these species were excluded if rare or not important to the regression, as described below in the Methods.

5.3.2.3 Methods

The CPUE was computed in units of number of fish per hook-hour. The duration of the time series was 1976–2007. Spatial coverage included the entire management area (Figure 5.9). Few vessels have operated in Area 1 (NC outer banks) throughout the time series, and so any vessels sampled from that area were lumped with Area 10 (immediately south), and Area 1 was excluded from the analysis. Trips were trimmed from the analysis if the number of vermilion snapper landed was in the upper 1% or if CPUE was in the upper 1%, to exclude outliers suspected to be misreported or misrecorded. Also excluded were records that did not report fields necessary to compute catch per unit effort.

Effective effort was based on those trips from areas where vermilion snapper were available to be caught. Without fine-scale geographic information on fishing location, trips to be included in the analysis must be inferred. To do so, the method of Stephens and MacCall (2004) was applied. The method uses multiple logistic regression to estimate a probability for each trip that the focal species was caught, given other species caught on that trip. As mentioned previously, the method was applied separately to data from regions north and south of Cape Canaveral, because of differences in species assemblages (Figure 5.10A,B, Appendix 5.2). To avoid spurious correlations, species that were rarely caught were excluded from each regression: species were included as factors if caught in at least 1% of trips, with northern and southern regions considered separately. Model selection (i.e., choice of predictor species) was based on AIC using a backward stepwise algorithm (Venables and Ripley, 2002). The selected model (Table 5.11A,B) was used to compute for each trip a probability that vermilion snapper was caught, and a trip was then included if its associated probability was higher than a threshold probability (Figure 5.11A,B). The threshold was defined to be that which results in the same number of predicted and observed positive trips, as in Stephens and

MacCall (2004). After applying Stephens and MacCall (2004) and the constraints described above, the resulting data set contained 86,567 trips, of which ~42% caught vermilion snapper.

Standardized catch rates were estimated using a delta-GLM error structure (Lo et al., 1992; Stefánsson, 1996; Maunder and Punt, 2004), in which the binomial distribution describes positive versus zero CPUE, and either a lognormal or gamma distribution describes the positive CPUE (software described in SEDAR17-RD16). Lognormal and gamma models were both fitted, and the error structure with the lowest AIC was selected. In this case, the gamma model was selected (gamma AIC = –8052; lognormal AIC = –4103). Explanatory variables considered, in addition to year (necessarily included), were month, geographic area, and trip type (half-day or full-day trips). Both model components (binomial and gamma) included main effects only. Geographic areas reported were pooled into larger areas to provide adequate sample sizes for each level of this factor—NC, SC, GA and north FL combined, and south FL.

Measures of precision were computed by a jackknife routine and summarized by the resulting CV. The jackknife routine iteratively refitted the delta-GLM model N times (N is the total sample size), where each iteration removed a unique record.

5.3.2.4 Sampling Intensity

The numbers of positive trips by year and area are tabulated in Table 5.12. The method of Stephens and MacCall (2004) does not necessarily select all positive trips.

5.3.2.5 Size/Age Data

Sizes and ages of fish represented by this index are the same as those sampled by the headboat survey (see chapter 4 of this DW report).

5.3.2.6 Catch Rates and Measures of Precision

Diagnostic plots of residuals from the delta-GLM model fit are in Appendix 5.6. Table 5.13 shows nominal CPUE (fish/angler-hr), standardized CPUE, coefficients of variation (CV), and annual sample sizes (number trips selected by Stephens and MacCall method). Figure 5.12 shows standardized and nominal CPUE.

5.3.2.7 Comments on Adequacy for Assessment

The headboat index was recommended by the DW for use in the assessment. It had the advantages of wide geographic coverage and very large sample sizes, which could mitigate any effect of schooling on CPUE. However, the DW did discuss several concerns (Table 5.2). One concern was that this index may contain problems associated with fishery dependent indices, as described in section 5.3.1.7. The DW, however, did note that the headboat fishery is not a directed fishery for vermilion snapper. Rather, it more generally fishes a complex of snapper-grouper species, and does so with only limited search time. Thus, the headboat index may be a more reliable index of abundance than one developed from a fishery that targets vermilion snapper specifically.

The DW discussed how the assessment might attempt to account for changes in catchability over time. Constant catchability, though commonly assumed, would not be an appropriate assumption in this fishery, as the DW generally believed that catchability has increased with improvements in fishing gear and technology. The DW recommended that the base assessment model assume catchability increases by 2% per year, as was used in the SEDAR10 assessment of gag grouper (SAFMC, 2006) and SEDAR15 assessments of red snapper and greater amberjack (SAFMC, 2007a; SAFMC, 2007b). The DW further recommended that sensitivity runs consider increases of 0% (i.e., constant) and 4% per year.

5.3.3 RECREATIONAL INTERVIEWS

5.3.3.1 General Description

The general recreational fishery is sampled by the Marine Recreational Fisheries Statistics Survey (MRFSS). This general fishery includes all recreational fishing from shore, man-made structures, private boats, and charter boats (for-hire vessels that usually accommodate six or fewer anglers). Party boats were removed from this analysis because they are sampled by the headboat survey. Using the MRFSS data from the South Atlantic region, that is Currituck County, North Carolina through Miami-Dade County, Florida (Figure 5.13), an index of abundance was computed for 1987–2007.

5.3.3.2 Issues Discussed at DW

Issue 1: Trip selection

Option 1: Select angler-trips based on the method of Stephens and MacCall (2004)

Option 2: Use MRFSS data on effective effort to select angler-trips: Apply proportion of intercepted trips that were "directed" [i.e., targeted or caught (A1+B1+B2)] to estimates of total marine recreational angler-trips.

Option 3: Use MRFSS data on effective effort to select angler-trips: Apply proportion of intercepted trips that were "directed" [i.e., targeted or harvested (A1+B1 only)] to estimates of total marine recreational angler-trips.

Decision: Option 2 preferred. MRFSS data contain information on targeted species. Although this information may lead to underestimates of effective effort, it does identify effective effort explicitly, whereas the method of Stephens and MacCall (2004) does so implicitly. The DW noted that this index includes all catches (landings plus discards), and should be applied as such in the assessment model. Thus, to be of use, this index would require a selectivity curve of all catch (not just landings). If such a curve cannot be estimated reliably in the assessment model, a MRFSS index using landings only was also computed (option 3).

Issue 2: First year of time series

Option 1: Start the time series in 1982, the first year of data collection.

Option 2: Start the time series in 1987, because of increased sampling intensity starting in 1987, reflected in the increase in sample sizes.

Decision: Option 2. The DW decided to start the time series in 1987, when sampling intensity increased substantially (Table 5.14).

Miscellaneous decisions

- The group acknowledged the possibility that some vermilion snapper were misreported as other snappers, particularly red snapper. However, it was not feasible to identify which trips might have misreported, much less correct data at the level of trip, and thus MRFSS data were used as reported. It was assumed that if vermilion snapper were misreported, the misreporting was not systematic.

- A 10-inch TL size limit was implemented on January 1, 1992, which was increased to 11 inches on February 24, 1999, and then again to 12 inches on October 23, 2006. The DW acknowledged that size limits could be accounted for by the assessment model through estimation of selectivity.
- A bag limit of 10 vermilion snapper/person/day was instituted for the recreational fishery in 1992. The DW examined the occurrence of reaching and exceeding the bag limit and concluded that, because of low occurrence (generally <5% of trips per year), any influence on the index of abundance would be small (Table 5.15). Furthermore, it was believed that recreational fishermen would generally continue to fish after reaching the bag limit and would simply discard fish if necessary to remain in compliance, and therefore bag limits would have little or no influence on fishing behavior. In addition, the index includes discards, which would reduce further any possible influence.
- Estimates of CV of the catch per effort are not obtainable, but instead were represented by proportional standard error (PSE) of total catch.

5.3.3.3 Methods

The CPUE was computed in units of number fish per angler-trip. The method chosen produced unbiased estimates of "directed" angler trips by applying the proportion of intercepted trips that were "directed" toward vermilion snapper to estimates of total marine recreational angler trips. Directed trips were defined in two ways. First, directed trips were defined as those trips where vermilion snapper was listed as targeted (under the variables “prim1” or “prim2”) or caught (A1+B1+B2). Type B2 group catches (fish released alive) were assigned angler-trip values based on the leader with additional anglers acting as followers. Second, directed trips were defined as targeted (under the variables “prim1” or “prim2”) or harvested (A1+B1 only). The proportion of directed trips was calculated based on the count of directed trips relative to all samples taken in a year/state/wave/mode/area strata. That proportion was then applied to the effort estimate for the same strata and summed up to the year/region level. The MRFSS data used included those areas ranging from North Carolina to the east coast of Florida excluding Monroe County. The directed trip analysis was obtained from the Atlantic Coastal Cooperative Statistics Program website (ACCSP, 2008).

5.3.3.4 Sampling Intensity

Sampling intensity (number of intercepted angler-trips) by state is shown in Table 5.14.

5.3.3.5 Size/Age Data

Sizes and ages of fish represented by this index are the same as those of the recreational fishery as sampled by the MRFSS (see chapter 4 of this DW report).

5.3.3.6 Catch Rates and Measures of Precision

Table 5.16 shows nominal CPUE (number/angler-trip) and estimates of precision, as does Figure 5.14.

5.3.3.7 Comments on Adequacy for Assessment

The MRFSS index was recommended by the DW for use in the assessment. However, the DW did discuss several concerns (Table 5.2). One concern was that this index may contain problems associated with fishery dependent indices, as described in section 5.3.1.7. Another concern was the large uncertainty in MRFSS landings and effort estimates. The data were not collected with intention of providing an index of abundance.

The DW discussed how the assessment might attempt to account for changes in catchability over time. Constant catchability, though commonly assumed, would not be an appropriate assumption in this fishery, as the DW generally believed that catchability has increased with improvements in fishing gear and technology. The DW recommended that the base assessment model assume catchability increases by 2% per year, as was used in the SEDAR10 gag grouper assessment (SAFMC, 2006), and that sensitivity runs consider increases of 0% (i.e., constant) and 4% per year.

5.4 CONSENSUS RECOMMENDATIONS AND SURVEY EVALUATIONS

Two fishery independent indices were recommended for use in the assessment: MARMAP chevron trap and FL snapper trap. Three fishery dependent indices were recommended: commercial handline (logbook), headboat, and MRFSS (Tables 5.1, 5.2). The five indices are compared graphically in Figure 5.15 and their correlations in Table 5.17.

The DW spent considerable time discussing negative correlations between indices, in particular between indices from the headboat data and MARMAP chevron trap data. The headboat index suggests a generally increasing trend over the last 15 years, while the chevron trap index suggests a generally decreasing trend. Trends aside, the DW considered the headboat index to be more reliable, because of its large annual sample sizes (thousands of trips), wide geographic and depth coverage, and its generalist approach to fishing snapper-groupers (i.e., doesn’t specifically target vermilion snapper, but rather fishes a complex of species). The chevron trap data are collected from well-designed fishery independent sampling, but concern was raised that the annual sampling intensity (hundreds of sets) might not be sufficient to characterize reliably the overall abundance of a schooling fish such as vermilion snapper. Perhaps related, variability in early years of the index was not considered biologically plausible (e.g., 500% population increase in 1991, followed immediately by a 50% decrease). In addition, correlation between bottom temperature and chevron trap CPUE raised concern about a possible effect of temperature on catchability (Appendix 5.7); use of the delta-GLM represented an attempt to account for bottom temperature in the index, but may not have been able to do so adequately if annual variation in temperatures across trap locations was inseparable from year effects. Although not considered justification by the DW for favoring either index, the recent increasing trend of the headboat index was noted to be in better agreement with anecdotal reports from fishermen’ perception of the stock.

After considering pros and cons of each index (Table 5.2), the DW ranked the indices according to its perception of most (1) to least (5) reliable:

1. Headboat
2. MARMAP chevron trap
3. Commercial logbook
4. MARMAP FL snapper trap
5. MRFSS

The DW also noted that the diverging trends in indices, especially between headboat and chevron trap indices, would be difficult for an assessment model to fit simultaneously. Different runs of the assessment model might consider various schemes of preferential weighting of indices, or even various schemes of inclusion/exclusion of indices.

5.5 RESEARCH RECOMMENDATIONS

1. Expand fishery independent sampling to provide indices of abundance.

2. Examine variability in catchability

    - Environmental effects
    - Changes over time associated with increases in technology and potential changes in fishing practices. This is of particular importance when considering fishery dependent indices.
    - Potential density-dependent changes in catchability. This is of particular importance for schooling fishes.

3. Examine possible temporal changes in species assemblages. Such changes could influence how the Stephens and MacCall method is applied when determining effective effort.

4. Continue and expand fishery dependent at-sea-observer surveys. Such surveys collects discard information, which would provide for a more accurate index of abundance.

5. Review/analyze MARMAP trap comparison study.

5.6 ITEMIZED LIST OF TASKS FOR COMPLETION FOLLOWING WORKSHOP

- Standardize MARMAP indices
- Generate any remaining tables and figures
- Finish writing chapter of DW report
- Submit data to Data Compiler

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5.8 TABLES

Table 5.1. Vermilion snapper: A summary of catch-effort time series available for the SEDAR 17 data workshop.

Fishery Type	Data Source	Area	Years	Units	Standardization Method	Size Range	Issues	Use?
Recreational	Headboat	NC-FL	1976-2007	Number per angler-hr	Stephens and MacCall; delta-GLM	Same as fishery	Fishery dependent	Y
Commercial	Logbook - handline	NC-FL	1993-2007	Pounds per hook-hr	Stephens and MacCall; delta-GLM	Same as fishery	Fishery dependent	Y
Recreational	MRFSS	NC-FL	1987-2007	Number per angler-trip	Angler-trips included if species was targeted or caught (A+B1+B2); Nominal	Same as fishery	Fishery dependent	Y
Independent	MARMAP Chevron trap	NC-FL	1990-2007	Number per trap-hr	delta-GLM	Generally 15-40 cm	High variability	Y
Independent	MARMAP Florida trap	NC-FL	1983-1987	Number per trap-hr	delta-GLM	Generally 15-40 cm	High variability	Y
Independent	MARMAP Blackfish trap	NC-FL	1978-1987	Number per trap-hr	—	—	Low numbers of samples	N
Independent	MARMAP Hook and line	NC-FL	1979-1998	Number per hook-hr	—	—	Inconsistent sampling effort over time	N
Independent	MARMAP Short longline	NC-FL	1980-2007	Number per hook-hr	—	—	Very low sample sizes	N
Independent	MARMAP trawl	NC-FL	1980-1987		—	—	Low numbers of samples	N
Independent	SEAMAP	NC-FL	1990-2007	Number per hectare	—	—	Very low sample sizes	N
Independent	NMFS Northeast Groundfish Trawl	ME - Cape Hatteras	1972-2007	Number per trawl	—	—	Low sample sizes	N
Independent	Diver Reports (Reef.org)	NC-FL	1990-2007	—	—	—	Voluntary reporting	N
Recreational	NC Citation Program	NC	?-2007	—	—	—	Voluntary reporting, variable publicity, target species may not be included in program	N
Recreational	Online recreational trip reporting (myfish.com)	NC-FL	2007	—	—	—	Voluntary reporting, currently only on year of data available	N

Table 5.2. Issues with each data set considered for CPUE.

<u>Fishery dependent indices</u>

Commercial Logbook – Handline (*Recommended for use*)

Pros:
- Complete census
- Covers entire management area
- Continuous, 15-year time series
- Large annual sample size

Cons:
- Fishery dependent (targeting)
- Data are self-reported and largely unverified
- Little information on discard rates
- Catchability may vary over time and/or abundance

Issues Addressed:
- Possible shift in species preference [Stephens and MacCall (2004) approach]
- In some cases, self-reported landings have been compared to TIP data, and they appear reliable
- Increases in catchability over time (e.g., due to advances in technology or knowledge) can be addressed in the assessment model

Recreational Headboat (*Recommended for use*)

Pros:
- Complete census
- Covers entire management area
- Longest time series available
- Data are verified by port samplers
- Consistent sampling
- Large annual sample size
- Generally non-targeted for focal species

Cons:
- Fishery dependent
- Little information on discard rates
- Catchability may vary over time and/or abundance

Issues Addressed:
- Possible shift in species preference [Stephens and MacCall (2004) approach]
- The impression of some people that trip duration has shifted toward half-day trips is not consistent with the data (Exploratory data analysis reveals no such shift on vermilion snapper trips or on headboat trips overall. In addition, trip duration is accounted for as a factor in the GLM.)
- Increases in catchability over time (e.g., due to advances in technology or knowledge) can be addressed in the assessment model

MRFSS (*Recommended for use*)

Pros:
- Relatively long time series

Nearly complete area coverage (excluded Monroe County)
Only fishery dependent index to include discard information (A+B1+B2)

Cons: Fishery dependent
High uncertainty in MRFSS data
Targeted species (fields prim1 and prim2) are missing for many observations in the data set
When fishing a multispecies assemblage, such as the snapper-grouper complex, it is likely that fishermen would list target species other than vermilion snapper when only able to record a maximum of two species. Trips would be eliminated from the analysis if anglers fished in areas where vermilion snapper were likely to be present but were not actually caught, thus causing effort to be underestimated.

North Carolina Citation Program (*Not recommended for use*)

Pros: May correlate with changes in size over time

Cons: No measure of effort
Fishery dependent
Limited geographic coverage
Not designed to provide information on abundance
Dependent on fishermen to call in and report citations

Online Recreational Logbooks (www.myfish.com) (*Not recommended for use*)

Pros: Ancillary information collected (e.g., weather conditions)

Cons: Voluntary reporting
Fishery dependent
Not designed to provide information on abundance
Only one year (2007) not meaningful as an index

<u>Fishery independent</u>

MARMAP

Chevron Trap Index (*Recommended for use*)

Pros: Fishery independent random hard bottom survey
Adequate spatial coverage
Standardized sampling techniques

Cons: High variability
Unknown if sampling intensity (100s sets per year) is adequate to characterize region-wide abundance of a schooling fish

FL Snapper Trap Index (*Recommended for use*)

Pros: Fishery independent random hard bottom survey
Adequate spatial coverage, concentrated at center of species' range
Standardized sampling techniques

Cons: High variability

Unknown if sampling intensity (100s sets per year) is adequate to characterize region-wide abundance of a schooling fish
Short time series (5 years)

Blackfish Trap Index (*Not recommended for use*)
Pros: Fishery independent
Cons: Inadequate sample sizes
Sampled same sites as FL snapper traps, a better gear for vermilion snapper

Hook and Line Index (*Not recommended for use*)
Pros: Fishery independent random hard bottom survey
Adequate regional coverage
Standardized sampling techniques
Cons: Low sample sizes in most years
Restricted depth coverage (midshelf sampled)
High standard errors
Ability of samplers may have changed over time
Level of effort has decreased over time
Sampling conducted alongside trap surveys, so not independent of other gears. Intent was supplemental sampling of hard parts.

Short Bottom Longline Index (*Not recommended for use*)
Pros: Fishery independent
Cons: Inadequate sample sizes

Trawl (*Not recommended for use*)
Pros: Fishery independent
Cons: Inadequate sample sizes

SEAMAP Trawl Survey (*Not recommended for use*)
Pros: Stratified random sample design
Adequate regional coverage
Standardized sampling techniques
Cons: Limited depth coverage (shallow water survey)
Inadequate sample sizes

Diver Reports (www.reef.org) (*Not recommended for use*)
Pros: Trained divers
Visual account of species present
Cons: Not designed with objective of providing an index of abundance
Sample sizes off the southeastern U.S. (dives documenting vermilion snapper) reported on the website appear to be low

Table 5.3 Sampling intensity (number of trap sets and number of sets that caught vermilion snapper) of MARMAP gears Florida snapper trap and chevron trap.

	Florida snapper trap		Chevron trap	
Year	N sets	N positive	N sets	N positive
1983	165	47		
1984	259	62		
1985	260	66		
1986	228	67		
1987	346	61		
1988				
1989				
1990			274	77
1991			278	138
1992			293	102
1993			412	128
1994			410	174
1995			388	135
1996			519	168
1997			505	107
1998			485	112
1999			254	74
2000			328	108
2001			288	91
2002			292	116
2003			280	41
2004			327	73
2005			336	84
2006			349	58
2007			390	87

Table 5.4A Length compositions (cm) and sample sizes of vermilion snapper caught in MARMAP chevron traps.

LEN (cm)	N	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1990	830	0.000	0.000	0.000	0.006	0.134	0.280	0.195	0.133	0.101	0.059	0.031	0.019	0.014	0.010	0.002	0.005	0.001	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000
1991	3066	0.000	0.000	0.003	0.029	0.149	0.279	0.229	0.155	0.075	0.034	0.014	0.009	0.006	0.004	0.003	0.002	0.002	0.002	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000
1992	1514	0.000	0.000	0.000	0.010	0.123	0.247	0.316	0.146	0.077	0.033	0.015	0.007	0.011	0.007	0.003	0.002	0.001	0.001	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000
1993	1326	0.000	0.000	0.001	0.032	0.205	0.229	0.195	0.125	0.081	0.041	0.029	0.014	0.015	0.008	0.008	0.005	0.004	0.003	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000
1994	3350	0.000	0.000	0.000	0.008	0.091	0.202	0.236	0.147	0.105	0.068	0.042	0.028	0.023	0.013	0.011	0.008	0.005	0.004	0.002	0.002	0.001	0.001	0.001	0.001	0.000	0.000
1995	1786	0.000	0.003	0.006	0.068	0.158	0.174	0.157	0.146	0.091	0.055	0.041	0.032	0.026	0.015	0.012	0.006	0.005	0.003	0.001	0.002	0.001	0.000	0.000	0.000	0.000	0.000
1996	3162	0.000	0.000	0.003	0.015	0.040	0.129	0.174	0.160	0.130	0.109	0.072	0.046	0.030	0.021	0.017	0.016	0.009	0.009	0.004	0.003	0.004	0.003	0.002	0.002	0.000	0.001
1997	1805	0.000	0.000	0.000	0.001	0.012	0.078	0.139	0.168	0.178	0.123	0.085	0.063	0.041	0.037	0.020	0.017	0.016	0.008	0.004	0.004	0.004	0.001	0.001	0.001	0.001	0.001
1998	1249	0.000	0.000	0.001	0.002	0.023	0.075	0.083	0.123	0.118	0.131	0.112	0.087	0.074	0.058	0.046	0.021	0.014	0.014	0.008	0.003	0.001	0.003	0.001	0.000	0.001	0.000
1999	735	0.000	0.000	0.000	0.011	0.050	0.102	0.090	0.120	0.158	0.129	0.076	0.080	0.054	0.031	0.031	0.022	0.016	0.007	0.008	0.001	0.003	0.001	0.005	0.003	0.000	0.000
2000	1712	0.000	0.000	0.000	0.001	0.015	0.034	0.068	0.097	0.083	0.089	0.087	0.093	0.074	0.071	0.060	0.046	0.052	0.037	0.030	0.018	0.013	0.008	0.003	0.005	0.005	0.001
2001	1369	0.000	0.000	0.000	0.000	0.007	0.026	0.058	0.091	0.099	0.088	0.096	0.101	0.077	0.077	0.079	0.047	0.037	0.030	0.028	0.016	0.016	0.009	0.007	0.004	0.004	0.001
2002	1742	0.000	0.000	0.000	0.000	0.011	0.063	0.115	0.111	0.115	0.087	0.090	0.092	0.082	0.076	0.048	0.040	0.026	0.014	0.013	0.007	0.002	0.001	0.002	0.001	0.003	0.001
2003	245	0.000	0.000	0.000	0.000	0.020	0.049	0.033	0.114	0.131	0.078	0.078	0.069	0.057	0.073	0.082	0.086	0.033	0.037	0.024	0.008	0.004	0.000	0.008	0.004	0.004	0.004
2004	457	0.002	0.004	0.002	0.002	0.022	0.028	0.061	0.101	0.105	0.127	0.147	0.144	0.055	0.046	0.039	0.024	0.013	0.009	0.022	0.013	0.011	0.002	0.009	0.002	0.004	0.002
2005	772	0.000	0.000	0.000	0.001	0.000	0.026	0.073	0.105	0.131	0.115	0.093	0.076	0.054	0.052	0.067	0.047	0.030	0.027	0.030	0.019	0.013	0.010	0.004	0.006	0.006	0.008
2006	366	0.000	0.000	0.005	0.011	0.030	0.057	0.041	0.046	0.057	0.098	0.139	0.164	0.085	0.063	0.052	0.038	0.030	0.022	0.019	0.014	0.011	0.005	0.003	0.000	0.000	0.005
2007	1240	0.000	0.000	0.001	0.006	0.007	0.028	0.054	0.098	0.095	0.092	0.081	0.085	0.082	0.071	0.079	0.055	0.045	0.027	0.024	0.011	0.009	0.013	0.010	0.006	0.010	0.003

Table 5.4B Age compositions and sample sizes of vermilion snapper caught in MARMAP chevron traps.

Age	N	0	1	2	3	4	5	6	7	8	9	10	11	12+
2002	765	0.000	0.018	0.267	0.247	0.148	0.183	0.061	0.031	0.025	0.013	0.005	0.001	0.000
2003	215	0.000	0.051	0.284	0.288	0.172	0.070	0.102	0.009	0.014	0.000	0.000	0.005	0.005
2004	305	0.000	0.010	0.102	0.325	0.203	0.161	0.069	0.072	0.033	0.007	0.007	0.007	0.007
2005	482	0.002	0.012	0.193	0.216	0.272	0.141	0.075	0.031	0.044	0.004	0.004	0.004	0.002
2006	272	0.000	0.085	0.136	0.210	0.151	0.268	0.070	0.044	0.015	0.022	0.000	0.000	0.000
2007	536	0.000	0.009	0.485	0.104	0.088	0.088	0.138	0.052	0.019	0.006	0.007	0.004	0.000

Table 5.4C Length compositions (cm) and sample sizes of vermilion snapper caught in MARMAP FL snapper traps.

LEN (cm)	N	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1983	469	0.000	0.000	0.004	0.006	0.055	0.136	0.124	0.128	0.098	0.092	0.064	0.070	0.058	0.064	0.030	0.017	0.011	0.011	0.004	0.011	0.011	0.002	0.004	0.000	0.000	0.000
1984	354	0.000	0.000	0.000	0.017	0.051	0.167	0.164	0.172	0.136	0.110	0.085	0.040	0.014	0.011	0.008	0.003	0.000	0.006	0.006	0.003	0.000	0.000	0.000	0.000	0.006	0.000
1985	608	0.000	0.000	0.002	0.013	0.056	0.141	0.160	0.166	0.122	0.095	0.113	0.051	0.028	0.026	0.007	0.005	0.003	0.003	0.003	0.000	0.002	0.000	0.000	0.003	0.000	0.000
1986	471	0.000	0.000	0.006	0.034	0.100	0.231	0.172	0.157	0.098	0.051	0.059	0.032	0.017	0.011	0.004	0.017	0.004	0.002	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000
1987	290	0.000	0.003	0.007	0.062	0.121	0.193	0.186	0.138	0.103	0.066	0.024	0.024	0.021	0.007	0.010	0.017	0.007	0.000	0.003	0.000	0.003	0.003	0.000	0.000	0.000	0.000

Table 5.5. CPUE of vermilion snapper off the southeastern U.S. computed from MARMAP chevron traps. Columns are year, annual sample size (N = number of positive and zero trips), nominal CPUE (fish/trap-hr), nominal CPUE relative to its mean, standardized CPUE, and coefficient of variation (CV) of the standardized CPUE.

Year	N	Nominal CPUE	Relative nominal	Standardized CPUE	CV
1990	274	1.242	0.503	0.568	0.205
1991	278	6.962	2.819	2.541	0.175
1992	293	3.177	1.287	1.314	0.199
1993	412	1.975	0.800	1.052	0.173
1994	410	4.862	1.969	2.026	0.165
1995	388	2.774	1.123	1.069	0.177
1996	519	3.678	1.490	1.182	0.176
1997	505	1.978	0.801	0.695	0.196
1998	485	1.528	0.619	0.640	0.188
1999	254	1.710	0.693	0.883	0.212
2000	328	3.196	1.294	0.956	0.195
2001	288	2.684	1.087	0.994	0.205
2002	292	3.389	1.372	1.301	0.191
2003	280	0.504	0.204	0.605	0.262
2004	327	0.841	0.340	0.507	0.208
2005	336	1.215	0.492	0.532	0.189
2006	349	0.691	0.280	0.368	0.226
2007	390	2.042	0.827	0.769	0.203

Table 5.6. CPUE of vermilion snapper off the southeastern U.S. computed from MARMAP Florida snapper traps. Columns are year, annual sample size (N = number of positive and zero trips), nominal CPUE (fish/trap-hr), nominal CPUE relative to its mean, standardized CPUE, and coefficient of variation (CV) of the standardized CPUE.

Year	N	Nominal CPUE	Relative nominal	Standardized CPUE	CV
1983	165	1.118	1.338	1.330	0.239
1984	259	0.527	0.630	0.711	0.184
1985	260	0.942	1.127	1.179	0.195
1986	228	1.158	1.386	1.278	0.196
1987	346	0.433	0.519	0.501	0.189

Table 5.7A. Vermilion snapper: backward stepwise AIC applied to commercial logbook data from north of Cape Canaveral. Final model used for application of Stephens and MacCall.

```
Initial Model:
Vermilion.snapper ~ Speckled.hind + Rock.hind + Red.hind +
    Snowy.grouper +
    Red.grouper + Black.grouper + Gag + Scamp + Yellowfin.grouper +
    White.grunt + Margate + Black.margate + Bluestriped.grunt +
    French.grunt + Hogfish + Almaco.jack + Greater.amberjack +
    Lesser.amberjack + Banded.rudderfish + Red.porgy + Whitebone.porgy +
    Knobbed.porgy + Jolthead.porgy + Black.sea.bass + Silk.snapper +
    Gray.snapper + Mutton.snapper + Red.snapper + Yellowtail.snapper +
    Blueline.tilefish + Sand.tilefish +
    Gray.triggerfish +   Ocean.triggerfish + Queen.triggerfish

Final Model:
Vermilion.snapper ~ Speckled.hind + Rock.hind + Red.hind +
    Snowy.grouper + Red.grouper + Black.grouper +
    Gag + Scamp + Yellowfin.grouper +
    White.grunt + Margate + Black.margate + Bluestriped.grunt +
    French.grunt + Hogfish + Almaco.jack + Greater.amberjack +
    Lesser.amberjack + Banded.rudderfish + Red.porgy + Whitebone.porgy +
    Knobbed.porgy + Jolthead.porgy + Black.sea.bass + Silk.snapper +
    Gray.snapper + Mutton.snapper + Red.snapper + Yellowtail.snapper +
    Gray.triggerfish + Ocean.triggerfish + Queen.triggerfish
```

	Step	Df	Deviance	Resid. Df	Resid. Dev	AIC
1				59631	55410.98	55480.98
2	- Blueline.tilefish	1	0.3008467	59632	55411.28	55479.28
3	- Sand.tilefish	1	1.6760002	59633	55412.96	55478.96

Table 5.7B. Vermilion snapper: backward stepwise AIC applied to commercial logbook data from south of Cape Canaveral. Final model used for application of Stephens and MacCall.

```
Vermilion.snapper ~ Blue.runner + Crevalle.jack + Snowy.grouper +
    Red.grouper + Black.grouper + Gag + Scamp + White.grunt +
    Bluestriped.grunt + French.grunt + Hogfish + Almaco.jack +
    Greater.amberjack + Red.porgy + Jolthead.porgy + Silk.snapper +
    Gray.snapper + Lane.snapper + Mutton.snapper + Red.snapper +
    Yellowtail.snapper + Tilefish + Blueline.tilefish + Gray.triggerfish

Final Model:
Vermilion.snapper ~ Crevalle.jack + Snowy.grouper + Black.grouper +
    Gag + Scamp + White.grunt + French.grunt + Hogfish + Almaco.jack +
    Greater.amberjack + Red.porgy + Jolthead.porgy + Silk.snapper +
    Lane.snapper + Mutton.snapper + Red.snapper + Yellowtail.snapper +
    Gray.triggerfish
```

	Step	Df	Deviance	Resid. Df	Resid. Dev	AIC
1				139115	21454.93	21504.93
2	- Gray.snapper	1	0.05541852	139116	21454.98	21502.98
3	- Blueline.tilefish	1	0.06194497	139117	21455.04	21501.04
4	- Bluestriped.grunt	1	0.28023006	139118	21455.32	21499.32
5	- Red.grouper	1	0.30570823	139119	21455.63	21497.63
6	- Blue.runner	1	0.44765235	139120	21456.08	21496.08
7	- Tilefish	1	1.40189779	139121	21457.48	21495.48

Table 5.8. Number of trips by year and area (GA=Georgia, NC=North Carolina, NF=north Florida, SC=South Carolina, SF=south Florida) that caught vermilion snapper, as reported in commercial logbook data.

year	STATE					
Frequency	**GA**	**NC**	**NF**	**SC**	**SF**	**Total**
1993	186	640	442	1066	198	2532
1994	192	805	519	1250	133	2899
1995	175	891	616	1328	214	3224
1996	229	728	598	1175	194	2924
1997	159	841	490	1347	273	3110
1998	113	787	404	1323	222	2849
1999	117	727	335	1129	207	2515
2000	87	614	356	1121	216	2394
2001	149	582	371	1254	209	2565
2002	172	638	377	1133	217	2537
2003	117	417	293	958	224	2009
2004	98	332	297	931	176	1834
2005	98	382	234	970	193	1877
2006	68	395	215	1100	117	1895
2007	67	481	320	1179	123	2170
Total	2027	9260	5867	17264	2916	37334

Table 5.9. CPUE of vermilion snapper off the southeastern U.S. based on handline gear reported in commercial logbooks. Columns are year, annual sample size (N = number of positive and zero trips selected by the Stephens and MacCall method), nominal CPUE (lb/hook-hr), nominal CPUE relative to its mean, standardized CPUE, and coefficient of variation (CV) of the standardized CPUE.

Year	N	Nominal CPUE	Relative nominal	Standardized CPUE	CV
1993	2828	0.870	0.519	0.524	0.044
1994	3103	1.077	0.643	0.617	0.048
1995	3432	1.038	0.619	0.644	0.046
1996	3002	0.882	0.526	0.534	0.032
1997	3203	1.043	0.622	0.634	0.031
1998	2931	1.268	0.757	0.717	0.044
1999	2570	1.728	1.031	1.043	0.047
2000	2451	2.470	1.473	1.487	0.038
2001	2771	2.283	1.362	1.406	0.031
2002	2762	2.095	1.250	1.269	0.037
2003	2189	1.491	0.890	0.854	0.041
2004	2035	2.721	1.623	1.634	0.097
2005	1954	2.306	1.375	1.416	0.055
2006	1985	1.724	1.028	0.995	0.044
2007	2430	2.151	1.283	1.227	0.042

Table 5.10. Proportion of vermilion snapper trips from the headboat fishery that exceeded 10 vermilion snapper per angler. Starting in 1992, regulations allowed no more than 10 vermilion snapper per angler per day.

Proportion of trips with catch/angler>10 fish					
year	area				
Frequency	NC	NF	SC	SF	Total
1973	0.006	NA	0.117	NA	0.043
1974	0.005	NA	0.011	NA	0.008
1975	0.017	NA	0.034	NA	0.026
1976	0.003	0.060	0.014	NA	0.030
1977	0.021	0.054	0.003	NA	0.036
1978	0.000	0.069	0.026	0.000	0.047
1979	0.016	0.074	0.000	0.008	0.046
1980	0.020	0.049	0.006	0.002	0.025
1981	0.066	0.035	0.029	0.003	0.022
1982	0.056	0.019	0.041	0.004	0.020
1983	0.021	0.026	0.009	0.001	0.011
1984	0.019	0.019	0.044	0.002	0.014
1985	0.040	0.039	0.069	0.001	0.023
1986	0.038	0.047	0.073	0.002	0.029
1987	0.014	0.047	0.065	0.020	0.036
1988	0.038	0.083	0.069	0.009	0.050
1989	0.022	0.054	0.094	0.003	0.035
1990	0.085	0.044	0.068	0.002	0.028
1991	0.079	0.024	0.100	0.002	0.034
1992	0.015	0.000	0.056	0.002	0.011
1993	0.014	0.001	0.044	0.001	0.012
1994	0.039	0.006	0.106	0.000	0.036
1995	0.023	0.003	0.067	0.000	0.022
1996	0.034	0.003	0.079	0.000	0.030
1997	0.033	0.011	0.045	0.000	0.024
1998	0.049	0.023	0.060	0.000	0.034
1999	0.032	0.020	0.053	0.000	0.028
2000	0.023	0.085	0.049	0.000	0.052
2001	0.030	0.047	0.052	0.000	0.038
2002	0.031	0.091	0.043	0.000	0.058
2003	0.012	0.026	0.013	0.000	0.018
2004	0.030	0.044	0.014	0.000	0.028
2005	0.024	0.058	0.052	0.000	0.043
2006	0.016	0.045	0.017	0.000	0.032
2007	0.013	0.015	0.013	0.000	0.014
Total	0.026	0.041	0.048	0.004	0.029

Table 5.11A. Vermilion snapper: backward stepwise AIC applied to headboat data from north of Cape Canaveral. Final model used for application of Stephens and MacCall.

```
Initial Model:
Vermilion_snapper ~ Gag + Gray_triggerfish + Greater_amberjack +
    Knobbed_porgy + Red_porgy + Red_snapper + Speckled_Hind +
    White_grunt + Warsaw_Grouper + Black_sea_bass + Snowy_Grouper +
    Tomtate + Gray_snapper + Scamp + Red_Grouper + Whitebone_porgy +
    Lane_snapper + Atlantic_spadefish + Yellowtail_snapper +
    Rock_Hind + Longspine_porgy + Red_Hind + Mutton_snapper +
    Almaco_jack + Queen_triggerfish + Graysby + Jolthead_porgy +
    Cubera_snapper + Blue_runner + Scup + Bank_sea_bass
    + Banded_rudderfish

Final Model:
Vermilion_snapper ~ Gag + Gray_triggerfish + Greater_amberjack +
    Knobbed_porgy + Red_porgy + Red_snapper + Speckled_Hind +
    White_grunt + Warsaw_Grouper + Black_sea_bass + Snowy_Grouper +
    Tomtate + Gray_snapper + Scamp + Red_Grouper + Whitebone_porgy +
    Lane_snapper + Atlantic_spadefish + Yellowtail_snapper +
    Rock_Hind + Longspine_porgy + Red_Hind +
    Almaco_jack + Queen_triggerfish + Graysby +    Jolthead_porgy +
    Cubera_snapper + Blue_runner +
    Scup + Bank_sea_bass + Banded_rudderfish
```

	Step	Df	Deviance	Resid. Df	Resid. Dev	AIC
1				131975	127528.2	127594.2
2	- Mutton_snapper	1	1.107174	131976	127529.3	127593.3

Table 5.11B. Vermilion snapper: backward stepwise AIC applied to headboat data from south of Cape Canaveral. Final model used for application of Stephens and MacCall.

```
Initial Model:
Vermilion_snapper ~ Yellowtail_snapper + Black_Grouper +
    Mutton_snapper +
    Tomtate + White_grunt + Bluestriped_grunt + Gray_snapper +
    Gray_triggerfish + Red_Hind + Red_porgy + Hogfish + Jolthead_porgy +
    Lane_snapper + Red_Grouper + Knobbed_porgy + Whitebone_porgy +
    Margate + Red_snapper + Rock_Hind + Queen_triggerfish +
    Blue_runner +
    Gag + Porkfish + Scamp + Silk_snapper + Schoolmaster +
    Greater_amberjack +
    Black_sea_bass + Ocean_triggerfish + Graysby + Bar_jack +
    Blackfin_snapper + Sand_tilefish + French_grunt + Saucereye_porgy +
    Black_margate + Almaco_jack

Final Model:
Vermilion_snapper ~ Yellowtail_snapper + Black_Grouper +
    Mutton_snapper +
    Tomtate + White_grunt + Bluestriped_grunt + Gray_snapper +
    Gray_triggerfish + Red_Hind + Red_porgy + Hogfish + Jolthead_porgy +
    Lane_snapper + Red_Grouper + Knobbed_porgy + Whitebone_porgy +
    Red_snapper + Rock_Hind + Queen_triggerfish + Blue_runner +
    Gag + Porkfish + Scamp + Silk_snapper + Schoolmaster +
    Greater_amberjack +
    Black_sea_bass + Ocean_triggerfish + Bar_jack + Blackfin_snapper +
    Sand_tilefish + French_grunt + Saucereye_porgy + Black_margate +
    Almaco_jack


       Step Df  Deviance Resid. Df Resid. Dev      AIC
1                           145216   108825.0 108901.0
2 - Margate  1 0.1665179    145217   108825.2 108899.2
3 - Graysby  1 0.8435152    145218   108826.1 108898.1
```

Table 5.12. Number of trips by year and area (NC=North Carolina, NF=Georgia and north Florida, SC=South Carolina, SF=south Florida) that caught vermilion snapper, as reported in headboat data.

year	AREA				
Frequency	**NC**	**NF**	**SC**	**SF**	**Total**
1973	353	0	179	0	532
1974	420	0	453	0	873
1975	484	0	586	0	1070
1976	350	637	580	0	1567
1977	142	830	386	0	1358
1978	256	1400	392	231	2279
1979	243	1319	154	629	2345
1980	148	1458	363	1188	3157
1981	122	1139	208	1115	2584
1982	270	1063	462	1095	2890
1983	238	1316	546	2092	4192
1984	156	1295	405	1651	3507
1985	125	1295	480	2068	3968
1986	157	1891	490	2053	4591
1987	208	1832	651	2198	4889
1988	237	1643	710	1589	4179
1989	93	1396	351	1481	3321
1990	118	1085	428	1575	3206
1991	280	908	478	1078	2744
1992	476	1146	551	1394	3567
1993	414	1110	637	944	3105
1994	409	710	611	608	2338
1995	480	698	608	707	2493
1996	496	613	593	485	2187
1997	306	379	493	347	1525
1998	447	690	665	472	2274
1999	379	950	621	303	2253
2000	393	719	701	198	2011
2001	331	914	522	328	2095
2002	327	919	488	242	1976
2003	259	909	378	200	1746
2004	367	1171	492	402	2432
2005	253	924	329	276	1782
2006	247	1097	471	115	1930
2007	233	1061	520	51	1865
Total	10217	34517	16982	27115	88831

Table 5.13. CPUE of vermilion snapper off the southeastern U.S. based on headboat data. Columns are year, annual sample size (N = number of positive and zero trips selected by the Stephens and MacCall method), nominal CPUE (fish/angler-hr), nominal CPUE relative to its mean, standardized CPUE, and coefficient of variation (CV) of the standardized CPUE.

Year	N	Nominal CPUE	Relative nominal	Standardized CPUE	CV
1976	1536	0.233	1.512	1.252	0.038
1977	1790	0.215	1.391	1.064	0.041
1978	2678	0.281	1.819	1.639	0.032
1979	2484	0.212	1.377	1.569	0.036
1980	2908	0.112	0.728	0.899	0.042
1981	2501	0.112	0.724	1.027	0.044
1982	2610	0.098	0.633	0.882	0.042
1983	3412	0.133	0.859	1.319	0.031
1984	3052	0.123	0.797	1.090	0.035
1985	4048	0.139	0.903	1.319	0.032
1986	4879	0.120	0.781	1.081	0.030
1987	4714	0.155	1.006	1.340	0.030
1988	4062	0.181	1.172	1.431	0.028
1989	3082	0.141	0.914	1.140	0.038
1990	3170	0.137	0.890	1.147	0.036
1991	2861	0.143	0.926	1.066	0.038
1992	3776	0.085	0.548	0.498	0.046
1993	3069	0.090	0.585	0.500	0.047
1994	2802	0.107	0.693	0.497	0.050
1995	3080	0.098	0.635	0.536	0.050
1996	2403	0.123	0.796	0.586	0.049
1997	1702	0.146	0.944	0.826	0.053
1998	2679	0.138	0.895	0.688	0.045
1999	2153	0.156	1.014	0.803	0.045
2000	1923	0.205	1.330	0.991	0.046
2001	2127	0.196	1.268	1.063	0.043
2002	1861	0.220	1.426	1.171	0.043
2003	1734	0.141	0.915	0.744	0.055
2004	2285	0.179	1.160	1.033	0.039
2005	1718	0.168	1.086	0.941	0.049
2006	1706	0.183	1.189	0.990	0.043
2007	1762	0.168	1.088	0.866	0.046

Table 5.14. Number of intercepts from MRFSS that caught vermilion snapper or reported vermilion snapper as a targeted species. The index of abundance was computed for 1987–2007, because of sampling intensity and distribution across states.

Year	State	DIRECTED TRIPS (expanded by effort)	Effort Estimate of Trips	Number of Trips Sampled (Intercepted)	Number Interviewed Trips
1982	Total	72,956	626,128	535	60
	FL	18,478	531,881	436	16
	GA	15,054	17,370	15	13
	NC	—	—	—	—
	SC	39,424	76,877	84	31
1983	Total	78,041	1,390,161	1,249	70
	FL	31,642	949,983	1,085	54
	GA	—	—	—	—
	NC	44,593	420,445	66	7
	SC	1,806	19,734	98	9
1984	Total	70,773	949,090	1,920	247
	FL	41,016	832,356	1,503	133
	GA	—	—	—	—
	NC	—	—	—	—
	SC	29,757	116,735	417	114
1985	Total	126,123	1,485,633	1,191	149
	FL	98,704	1,400,108	876	100
	GA	1,746	14,000	152	18
	NC	—	—	—	—
	SC	25,673	71,525	163	31
1986	Total	26,582	1,155,202	893	38
	FL	23,650	1,124,305	688	15
	GA	2,219	14,152	158	21
	NC	—	—	—	—
	SC	713	16,745	47	2
1987	Total	28,495	1,139,553	3,343	84
	FL	20,074	789,663	437	10
	GA	1,309	19,099	102	7
	NC	4,622	277,392	2,216	42
	SC	2,490	53,398	588	25
1988	Total	47,852	1,793,350	4,015	205
	FL	16,410	1,310,818	1,046	13
	GA	2,127	9,355	18	4
	NC	16,570	261,348	1,992	123
	SC	12,745	211,829	959	65
1989	Total	79,130	2,808,512	5,279	330
	FL	43,873	2,330,680	1,358	24
	GA	1,470	3,551	21	9
	NC	14,865	317,954	3,165	199
	SC	18,922	156,327	735	98
1990	Total	27,109	2,087,368	4,883	209
	FL	17,328	1,776,909	1,262	13
	GA	NULL	NULL	24	10
	NC	8,981	305,980	3,470	169
	SC	800	4,479	127	17
1991	Total	37,607	2,031,971	5,022	189
	FL	23,676	1,694,569	1,307	18
	GA	1,888	7,821	40	14
	NC	6,971	293,822	3,534	138
	SC	5,072	35,758	141	19
1992	Total	38,266	2,069,799	6,889	550
	FL	9,511	1,569,660	2,535	24
	GA	4,791	33,993	427	156
	NC	13,302	379,307	3,667	343
	SC	10,662	86,838	260	27
1993	Total	39,485	3,274,350	7,184	234
	FL	22,267	3,008,535	4,077	32
	GA	5,049	10,483	151	76
	NC	7,572	232,347	2,926	120
	SC	4,597	22,985	30	6
1994	Total	49,054	3,172,651	8,865	391
	FL	26,512	2,770,811	3,524	33
	GA	5,718	17,343	153	64
	NC	15,242	362,345	5,146	291
	SC	1,582	22,152	42	3

1995	Total	54,522	2,183,356	6,370	277
	FL	19,521	1,760,623	2,095	24
	GA	12,530	20,991	152	89
	NC	10,310	360,390	4,052	145
	SC	12,161	41,352	71	19
1996	Total	23,406	920,519	5,247	211
	FL	2,276	618,908	848	3
	GA	10,264	38,424	214	71
	NC	5,599	215,816	4,037	115
	SC	5,267	47,371	148	22
1997	Total	46,284	2,276,859	7,364	195
	FL	19,293	1,720,971	2,284	29
	GA	3,041	15,624	150	45
	NC	8,482	391,861	4,452	63
	SC	15,468	148,403	478	58
1998	Total	41,649	2,353,929	7,867	244
	FL	21,065	2,001,378	4,094	47
	GA	3,011	7,120	188	86
	NC	2,485	167,772	2,998	43
	SC	15,088	177,659	587	68
1999	Total	88,295	2,766,720	9,306	374
	FL	69,561	2,584,012	6,875	205
	GA	1,334	4,510	95	24
	NC	4,734	114,714	2,001	71
	SC	12,666	63,484	335	74
2000	Total	101,621	3,595,061	10,057	445
	FL	84,290	3,064,243	6,445	209
	GA	341	1,136	59	20
	NC	2,096	306,378	2,438	27
	SC	14,894	223,304	1,115	189
2001	Total	84,451	3,573,380	11,004	531
	FL	65,819	2,981,819	7,433	290
	GA	1,178	1,610	89	65
	NC	6,112	489,397	3,130	67
	SC	11,342	100,553	352	109
2002	Total	74,484	3,169,187	10,973	544
	FL	57,739	2,769,278	7,951	346
	GA	2,581	65,313	285	48
	NC	10,088	277,150	2,578	113
	SC	4,076	57,447	159	37
2003	Total	83,679	3,628,516	9,593	629
	FL	67,580	3,429,850	7,884	353
	GA	3,535	5,341	295	195
	NC	3,837	148,819	1,274	38
	SC	8,727	44,506	140	43
2004	Total	86,556	4,077,753	10,784	759
	FL	48,795	3,500,173	7,712	272
	GA	10,264	25,719	446	268
	NC	17,878	525,124	2,320	88
	SC	9,619	26,738	306	131
2005	Total	66,098	4,100,802	9,302	391
	FL	45,771	3,628,854	7,228	176
	GA	6,153	11,829	227	109
	NC	11,467	443,517	1,554	50
	SC	2,707	16,602	293	56
2006	Total	71,845	4,481,283	11,222	570
	FL	55,108	4,243,957	8,796	222
	GA	7,802	12,084	352	229
	NC	3,689	198,347	1,754	42
	SC	5,246	26,893	320	77
2007	Total	145,460	6,799,736	11,046	560
	FL	91,245	5,912,142	8,053	283
	GA	8,985	26,089	161	75
	NC	13,494	671,083	2,393	91
	SC	31,736	190,422	439	111

Table 5.15. Proportion of vermilion snapper trips from MRFSS data that exceeded or equaled 10 vermilion snapper per angler. Starting in 1992, regulations allowed no more than 10 vermilion snapper per angler per day.

Year	Proportion trips >10 fish/angler	Proportion trips =10 fish/angler
1982	0.13	0.06
1983	0.17	0.00
1984	0.11	0.00
1985	0.13	0.14
1986	0.01	0.00
1987	0.06	0.01
1988	0.00	0.14
1989	0.06	0.08
1990	0.12	0.00
1991	0.16	0.00
1992	0.01	0.01
1993	0.05	0.04
1994	0.02	0.00
1995	0.00	0.00
1996	0.05	0.01
1997	0.01	0.01
1998	0.01	0.00
1999	0.00	0.01
2000	0.01	0.03
2001	0.06	0.04
2002	0.05	0.01
2003	0.03	0.04
2004	0.05	0.08
2005	0.04	0.05
2006	0.05	0.08
2007	0.01	0.01

Table 5.16. CPUE of vermilion snapper off the southeastern U.S. based on MRFSS data. Scaled CPUE is CPUE standardized to its mean. Totcatch CPUE is based on all catches (A+B1+B2 fish), and Harvest CPUE excludes fish discarded alive (excludes B2 fish).

Year	Totcatch CPUE	Scaled Totcatch CPUE	Total Catch PSE	Directed TotCatch Interviews	Harvest CPUE	Scaled Harvest CPUE	Harvest PSE	Directed Harvest Interviews
1987	4.57	1.17	36.2	84	4.53	1.47	37.1	81
1988	3.14	0.80	23.4	205	2.96	0.96	24.1	199
1989	3.71	0.95	19.7	330	3.41	1.11	23	313
1990	7.02	1.79	30.4	209	5.63	1.83	35	204
1991	5.67	1.45	24.7	189	5.59	1.81	29.5	183
1992	3.59	0.92	19.4	550	2.4	0.78	15.3	523
1993	3.52	0.90	17	234	3.05	0.99	19.5	220
1994	2.43	0.62	13.2	391	1.85	0.60	16.2	339
1995	3.13	0.80	23.6	277	1.36	0.44	18.5	236
1996	4.52	1.15	23.6	211	3.94	1.28	28.9	172
1997	2.56	0.65	18.1	195	2.05	0.67	17.8	186
1998	3.40	0.87	14.7	244	3.16	1.03	20.8	208
1999	4.30	1.10	11.2	374	2.27	0.74	15.9	295
2000	4.29	1.09	12.2	445	2.87	0.93	19.3	368
2001	4.04	1.03	11.1	531	3.25	1.06	15.3	450
2002	3.43	0.87	11.8	544	2.52	0.82	16.3	478
2003	4.12	1.05	12.6	629	2.61	0.85	16.6	537
2004	4.43	1.13	11.4	759	3.29	1.07	14.3	678
2005	3.60	0.92	12.2	391	2.88	0.93	16.1	348
2006	3.61	0.92	18.5	570	2.92	0.95	18.7	496
2007	3.29	0.84	9.7	560	2.15	0.70	12.9	469

Table 5.17. Pearson correlation between indices. Values in parentheses are *p*-values from a *t*-test of H_0: $\rho = 0$.

	Headboat	Commercial	MRFSS	Chevron trap	FL trap
Headboat	1	0.89 (<0.001)	0.35 (0.12)	-0.17 (0.49)	0.05 (0.93)
Commercial		1	0.36 (0.19)	-0.39 (0.15)	NA
MRFSS			1	0.03 (0.90)	NA
Chevron trap				1	NA
FL trap					1

5.9 FIGURES

Figure 5.1. Sampling locations of MARMAP chevron traps.

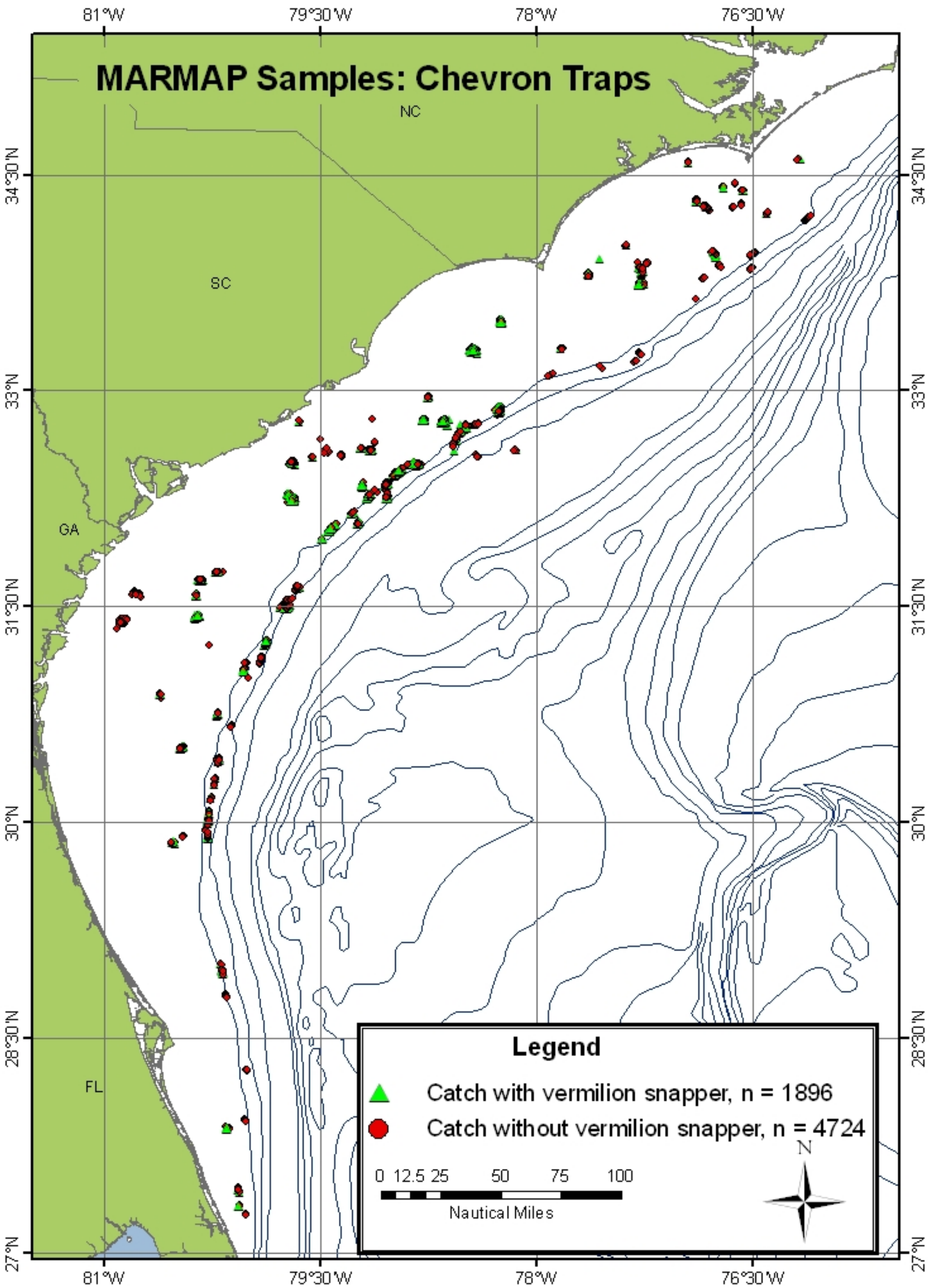


Figure 5.2. Vermilion snapper: index of abundance (plus/minus two SE) from MARMAP chevron trap data. Index is scaled to its mean.

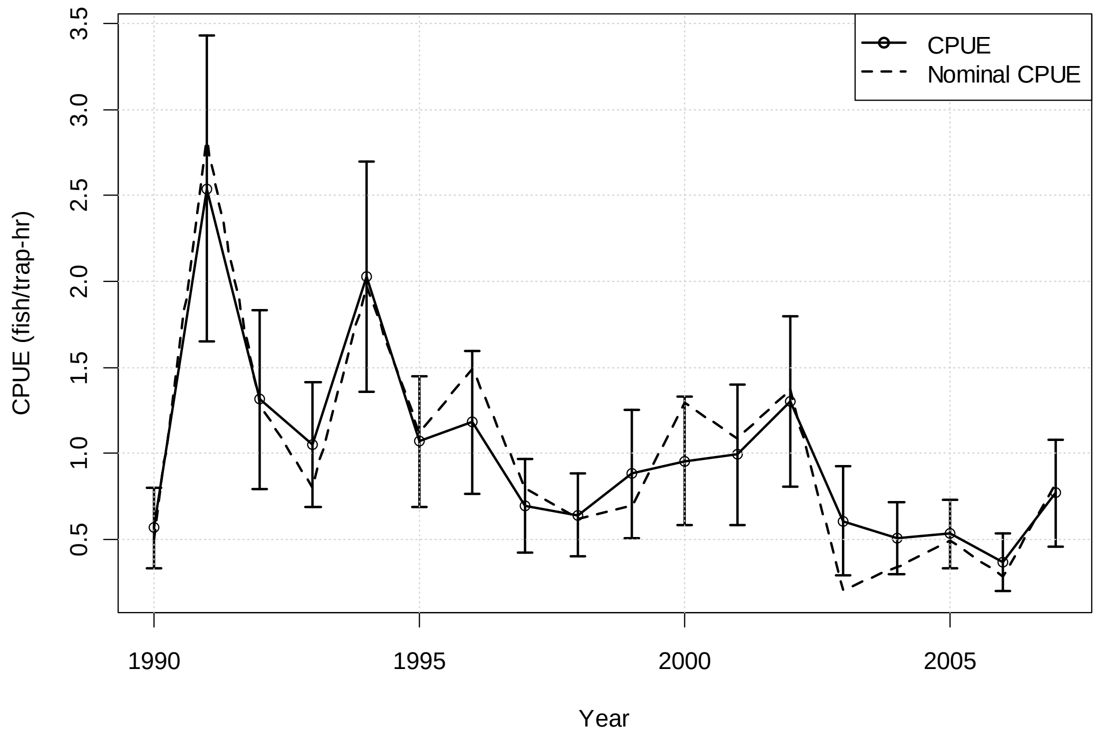


Figure 5.3. Sampling locations of MARMAP Florida snapper traps.

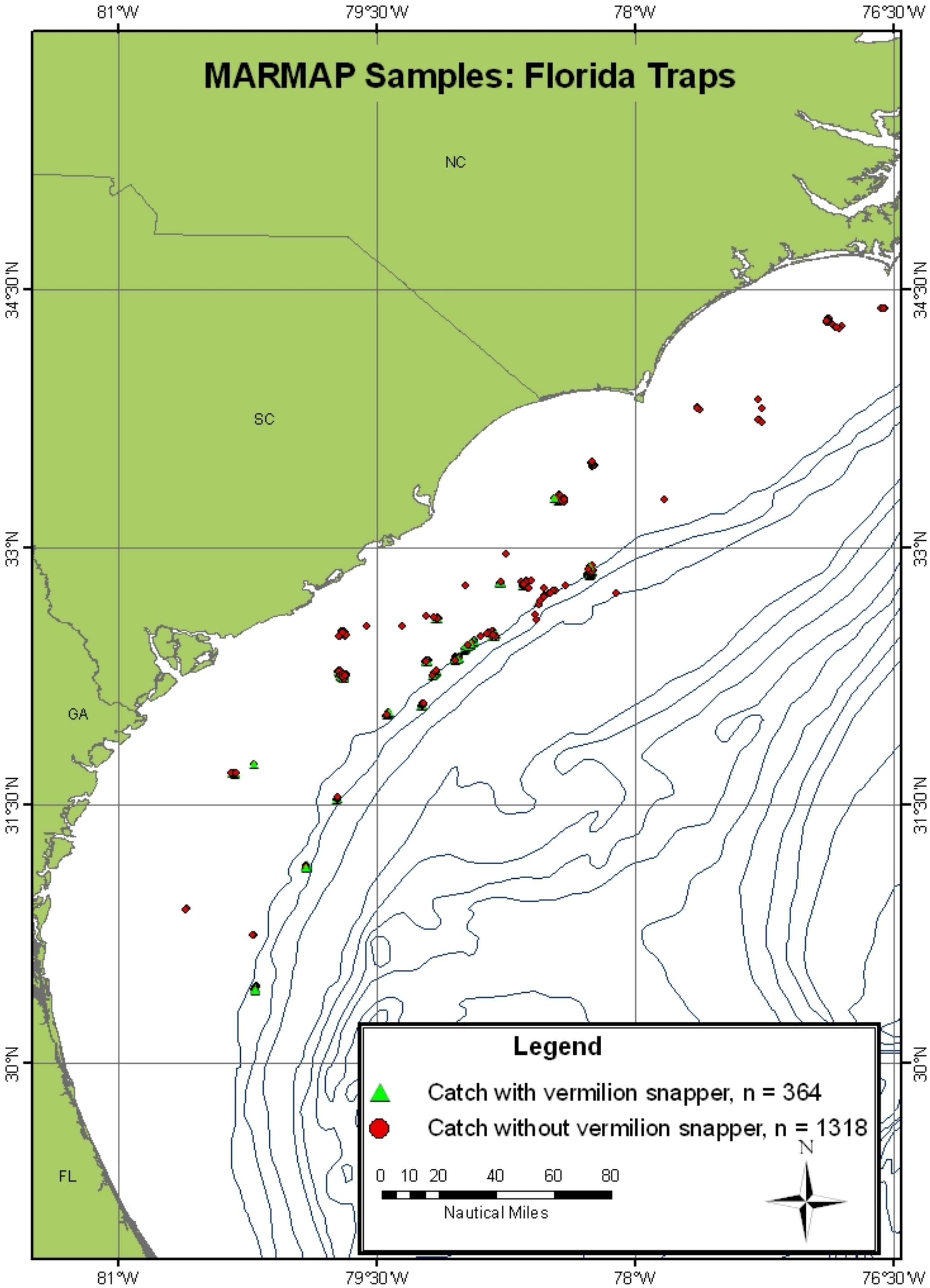


Figure 5.4. Vermilion snapper: index of abundance (plus/minus two SE) from MARMAP Florida snapper trap. Index is data scaled to its mean.

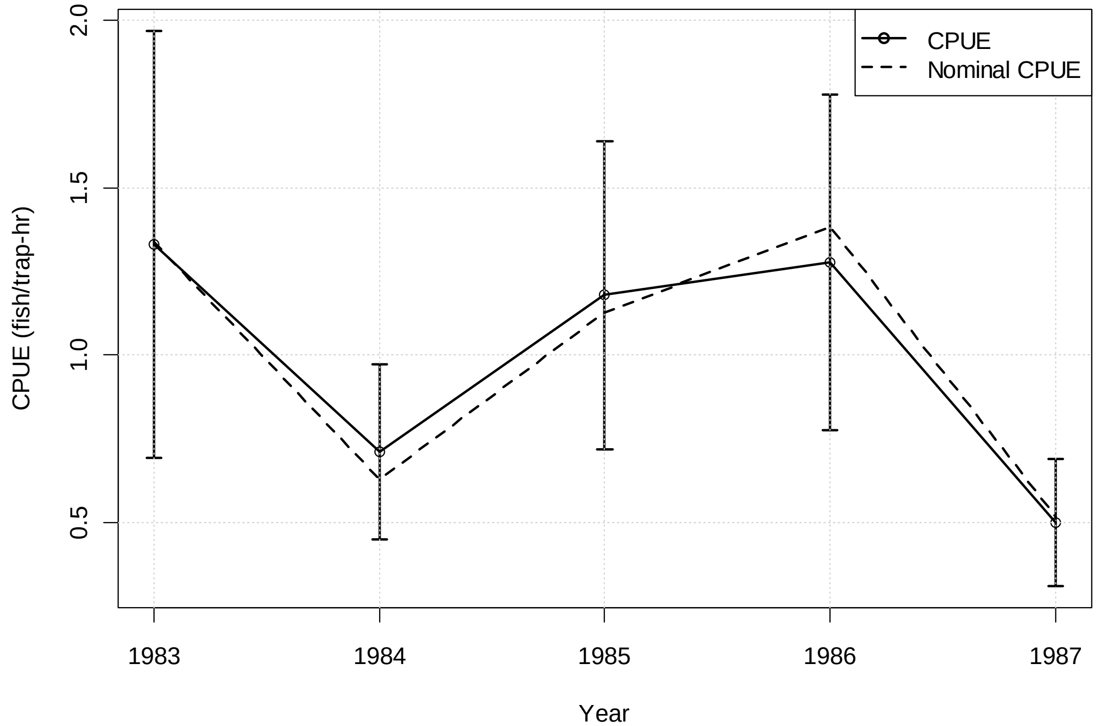


Figure 5.5. Areas reported in commercial logbooks. First two digits signify degrees latitude, second two degrees longitude. Areas were excluded from the analysis if north of 36 degrees latitude or if in the Gulf of Mexico (codes=1, 2, 3,…). Areas were considered southern Florida at 28 degrees latitude and south (break near Cape Canaveral).

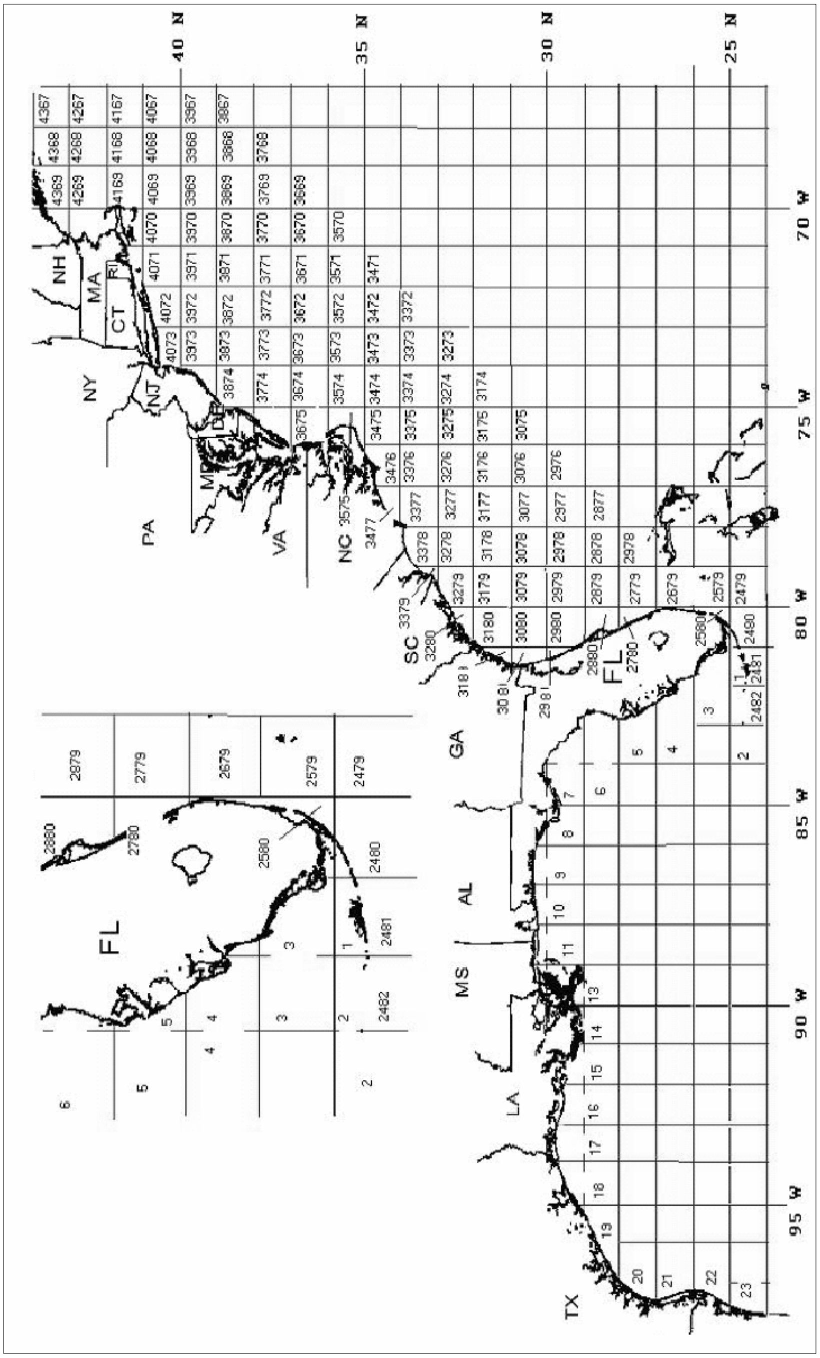


Figure 5.6A. Estimates of species-specific regression coefficients from Stephens and MacCall method applied to commercial logbook data from north of Cape Canaveral, as used to estimate each trip's probability of catching the focal species.

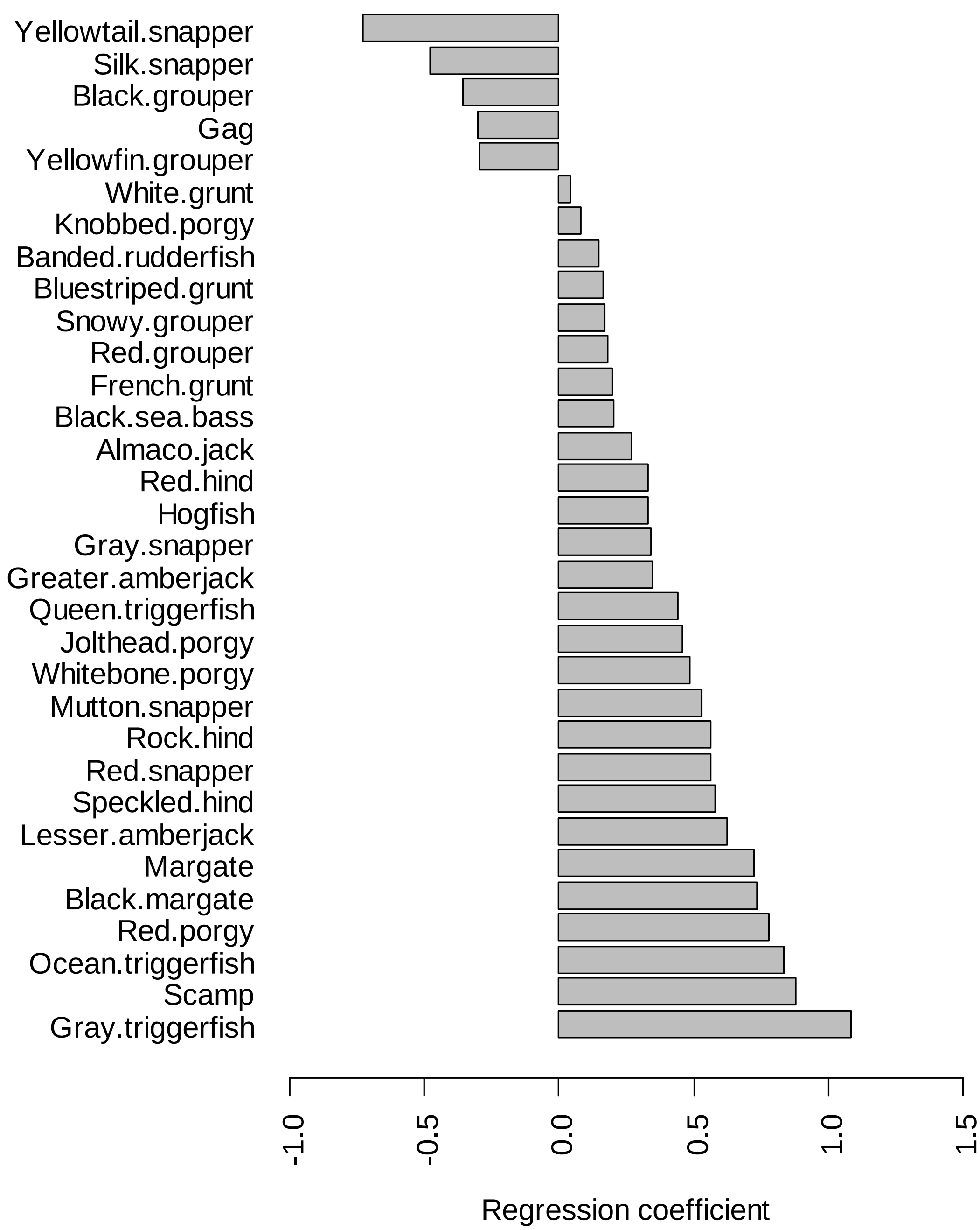


Figure 5.6B. Estimates of species-specific regression coefficients from Stephens and MacCall method applied to commercial logbook data from south of Cape Canaveral, as used to estimate each trip's probability of catching the focal species.

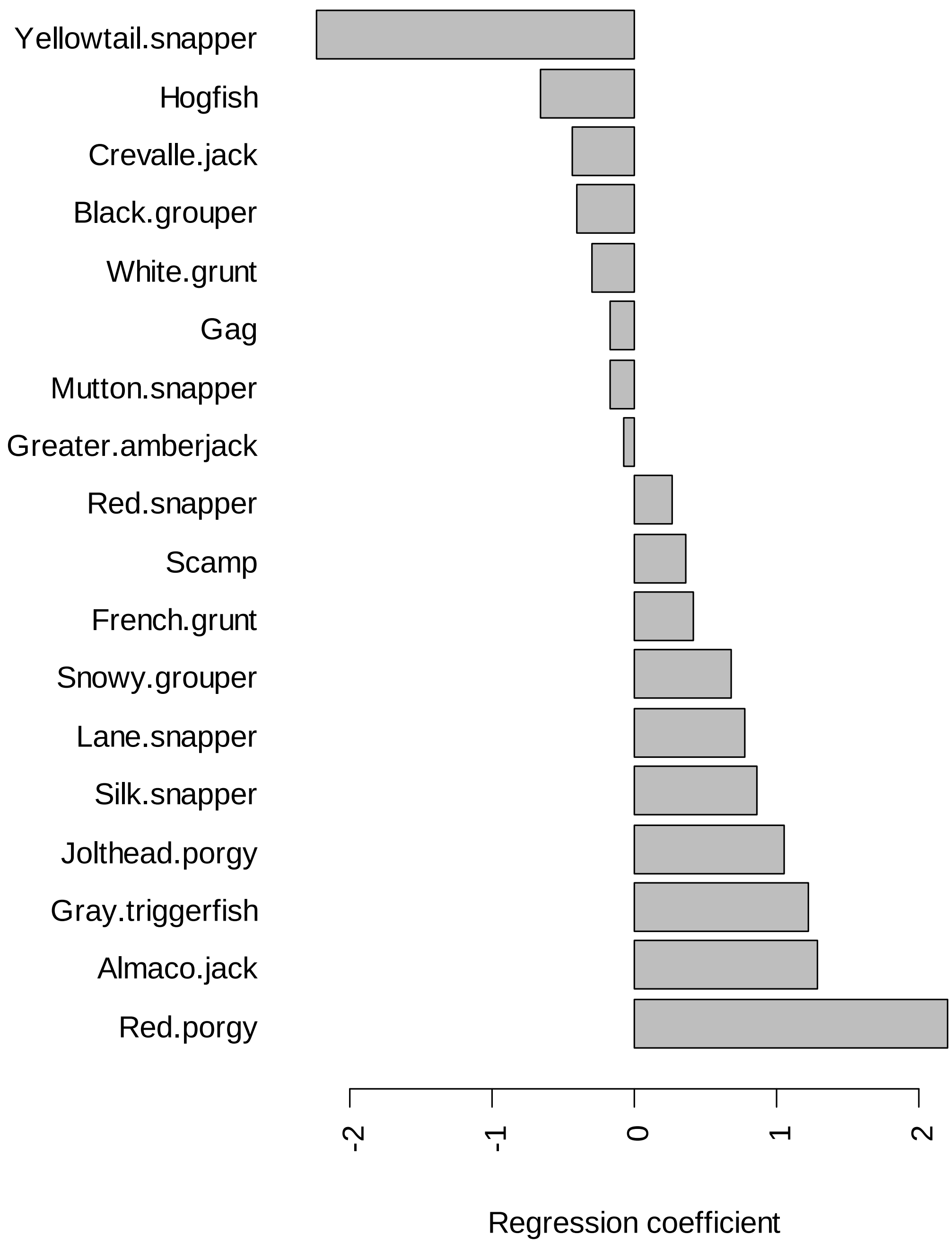


Figure 5.7A. Absolute difference between observed and predicted number of positive trips from Stephens and MacCall method applied to commercial logbook data from north of Cape Canaveral. Left and right panels differ only in the range of probabilities shown.

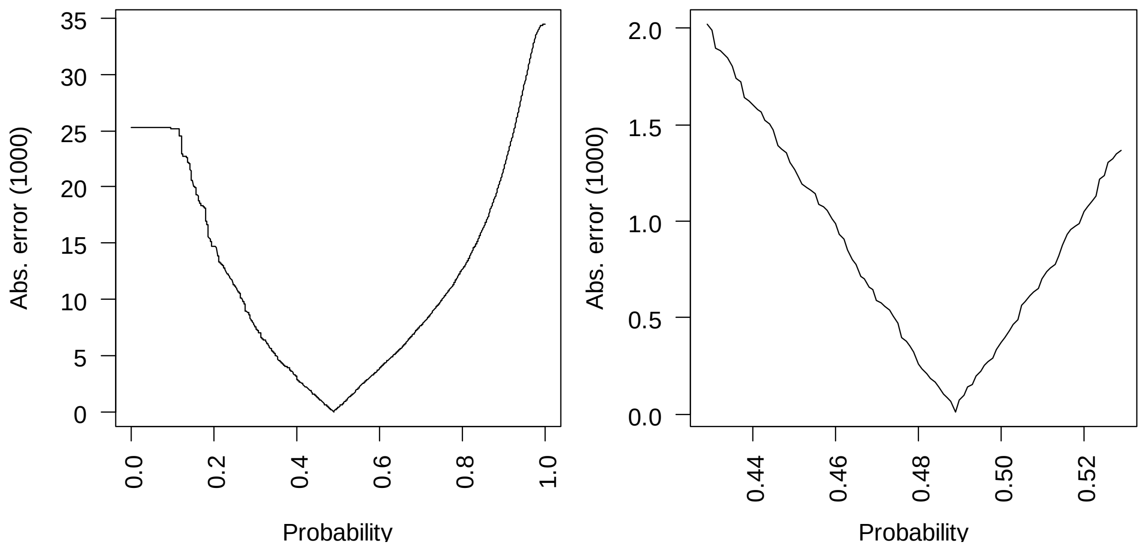


Figure 5.7B. Absolute difference between observed and predicted number of positive trips from Stephens and MacCall method applied to commercial logbook data from south of Cape Canaveral. Left and right panels differ only in the range of probabilities shown.

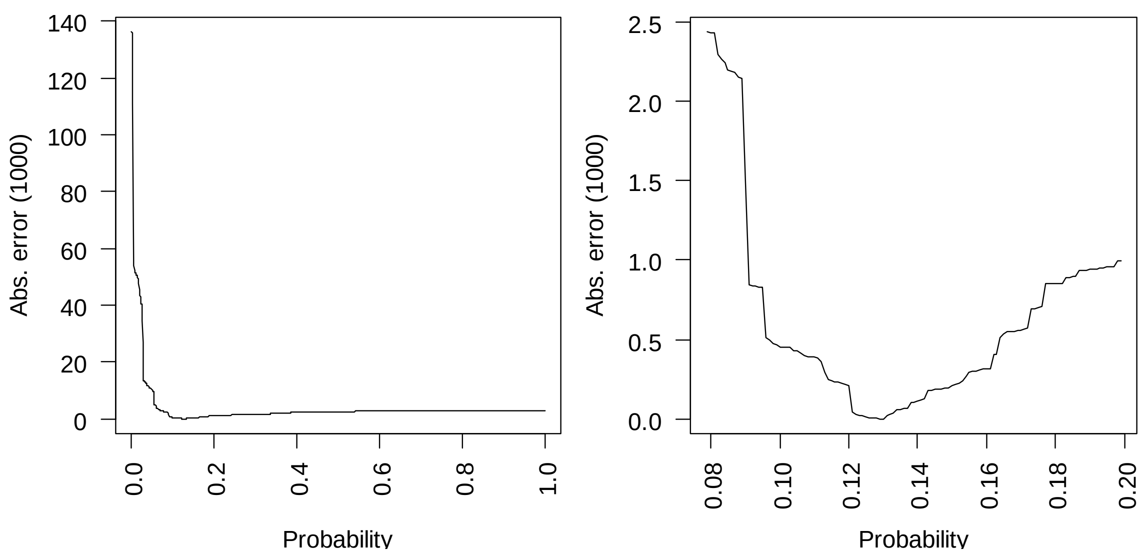


Figure 5.8. Vermilion snapper: index of abundance (plus/minus two SE) from commercial logbook data. Index is scaled to its mean.

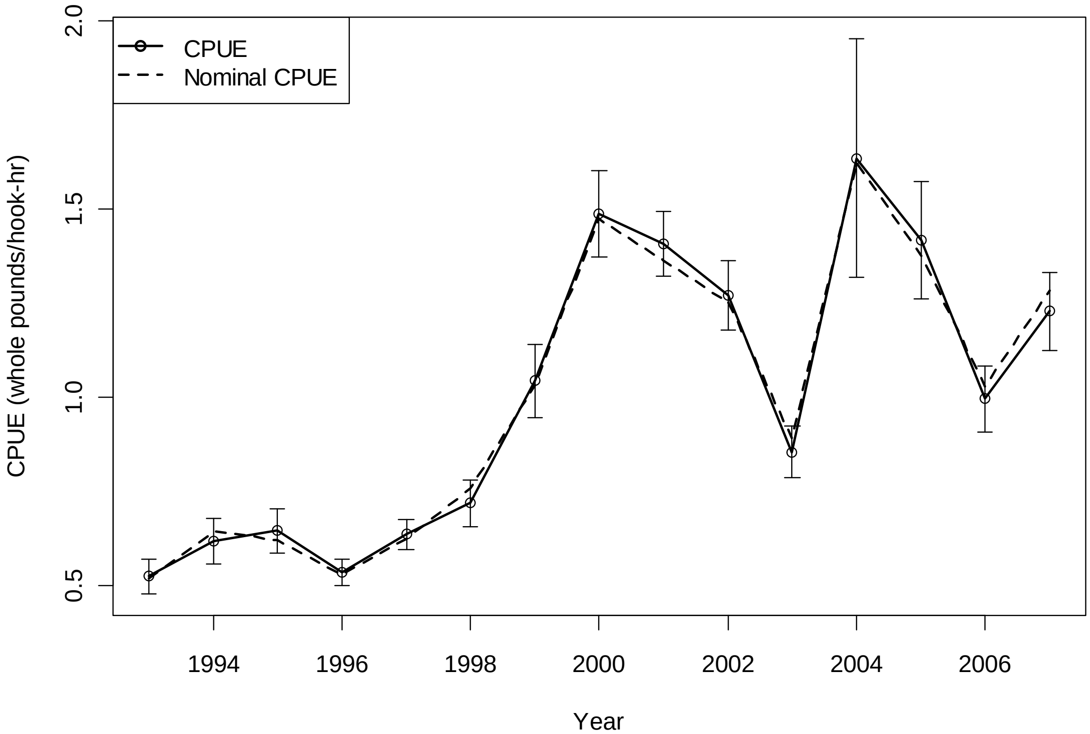


Figure 5.9. Areas from the headboat survey. Areas 11, 12, and 17 were considered southern Florida (break near Cape Canaveral).

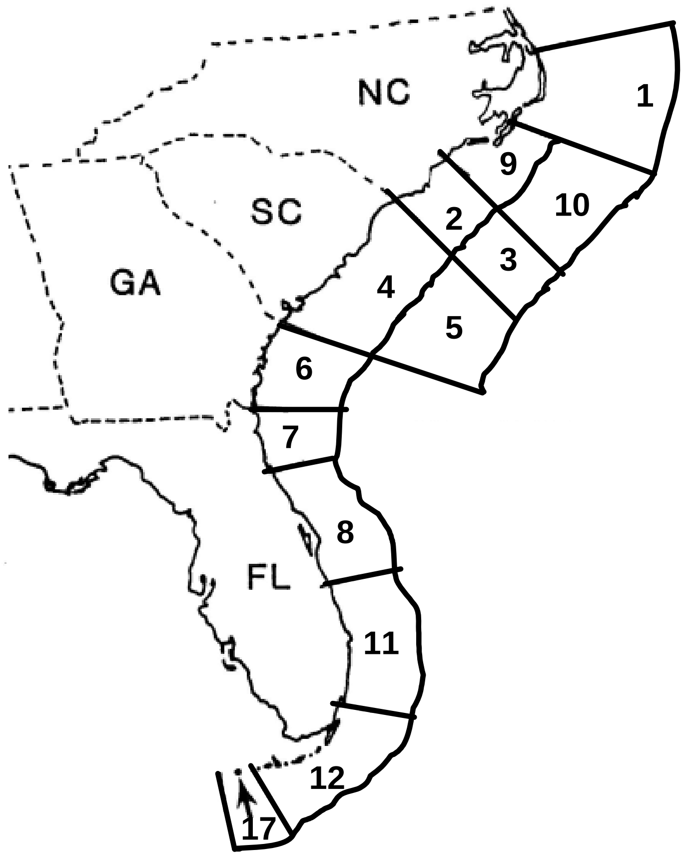


Figure 5.10A. Estimates of species-specific regression coefficients from Stephens and MacCall method applied to headboat data from areas in the northern region (excludes areas 11, 12, 17), as used to estimate each trip's probability of catching the focal species.

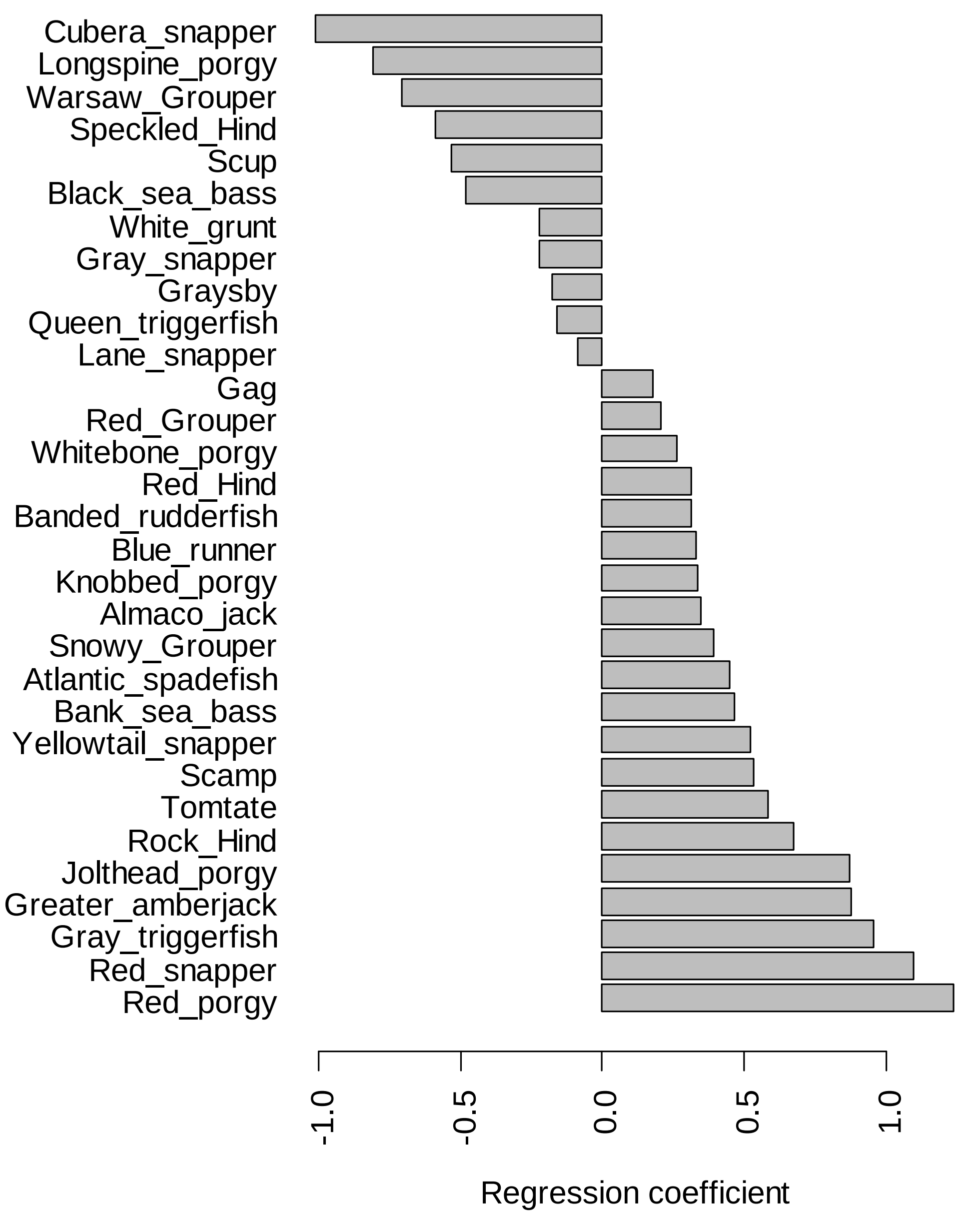


Figure 5.10B. Estimates of species-specific regression coefficients from Stephens and MacCall method applied to headboat data from areas in the southern region (areas 11, 12, 17), as used to estimate each trip's probability of catching the focal species.

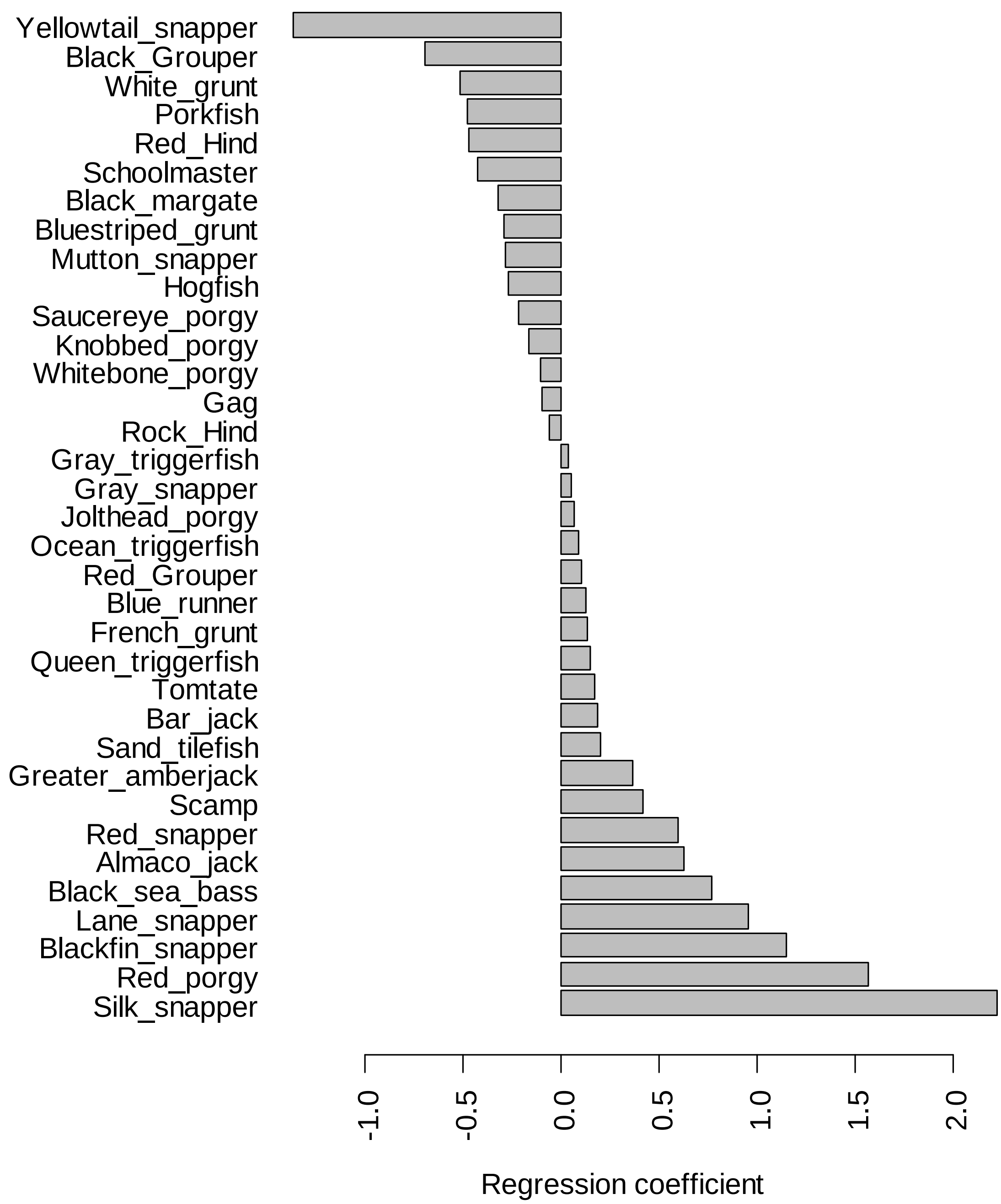


Figure 5.11A. Absolute difference between observed and predicted number of positive trips from Stephens and MacCall method applied to headboat data from the northern region (excludes areas 11, 12, 17). Left and right panels differ only in the range of probabilities shown.

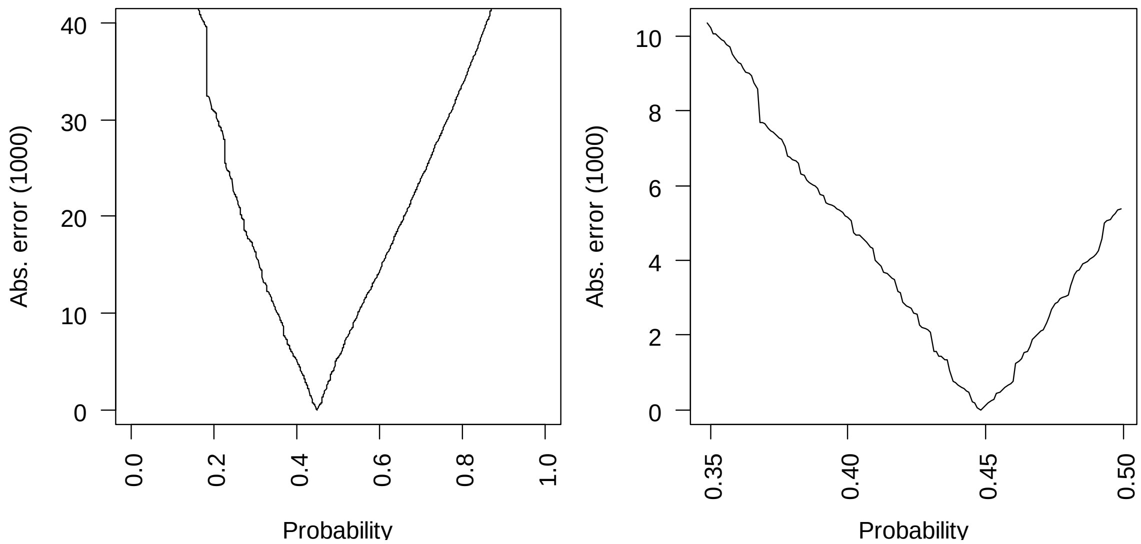


Figure 5.11B. Absolute difference between observed and predicted number of positive trips from Stephens and MacCall method applied to headboat data from the southern region (areas 11, 12, 17). Left and right panels differ only in the range of probabilities shown.

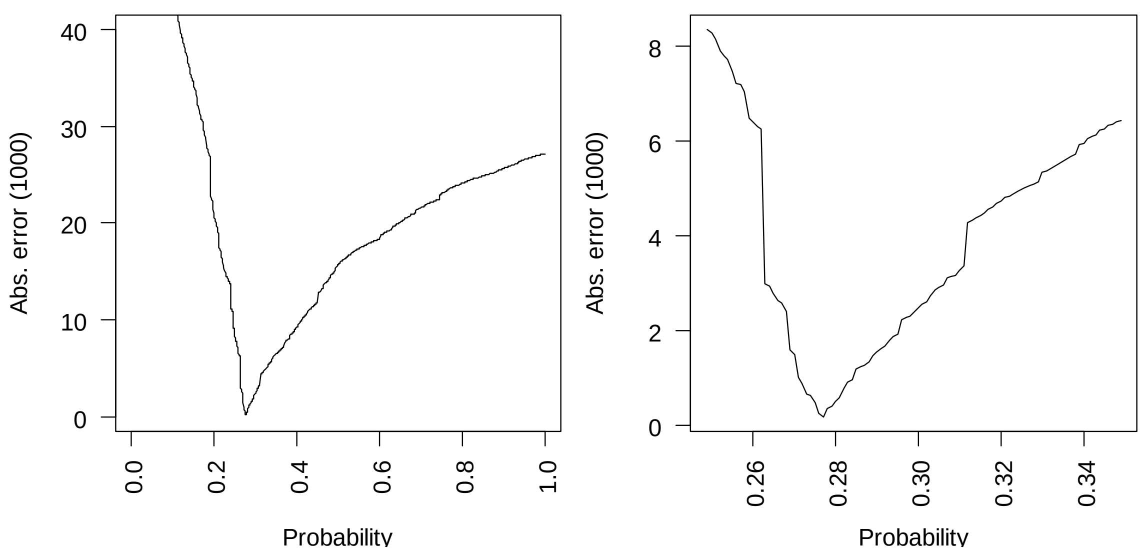


Figure 5.12. Vermilion snapper: index of abundance (plus/minus two SE) from headboat data. Index is scaled to its mean.

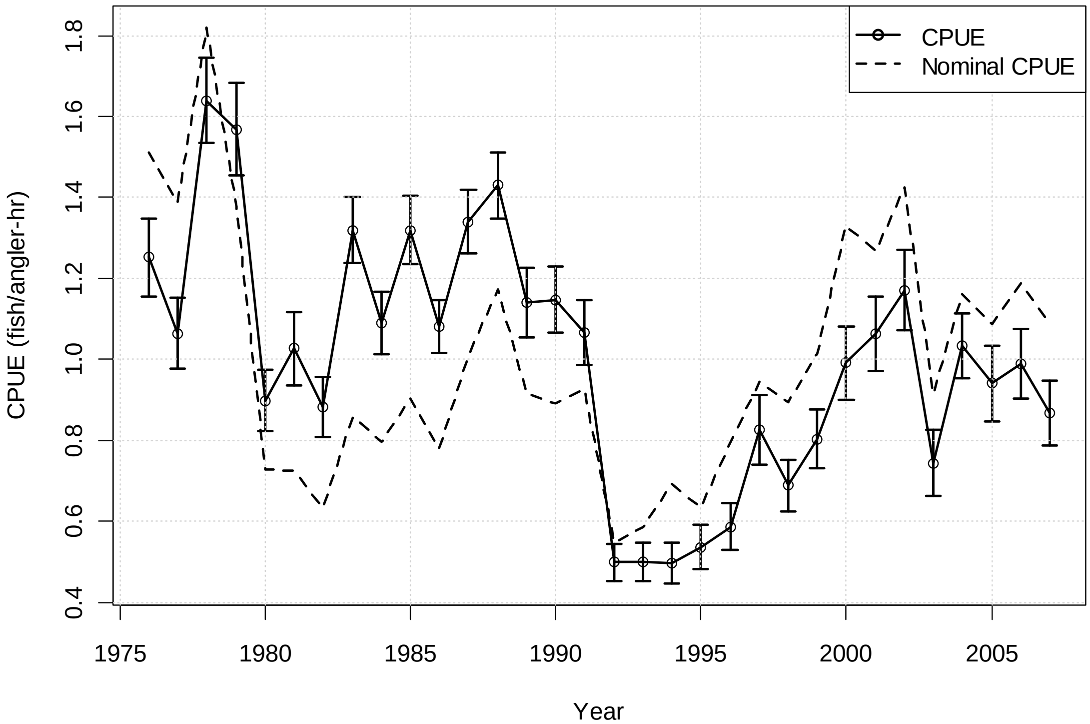


Figure 5.13. Counties sampled by the MRFSS, as used to compute the index of abundance, included those along the coast from Currituck County, NC through Miami-Dade County, FL.

Figure 5.14. Vermilion snapper: index of abundance (plus/minus two SE) from MRFSS data. Index from total catch (closed diamonds, solid line) is scaled to its mean, as is the index from harvest only (open squares, dotted line).

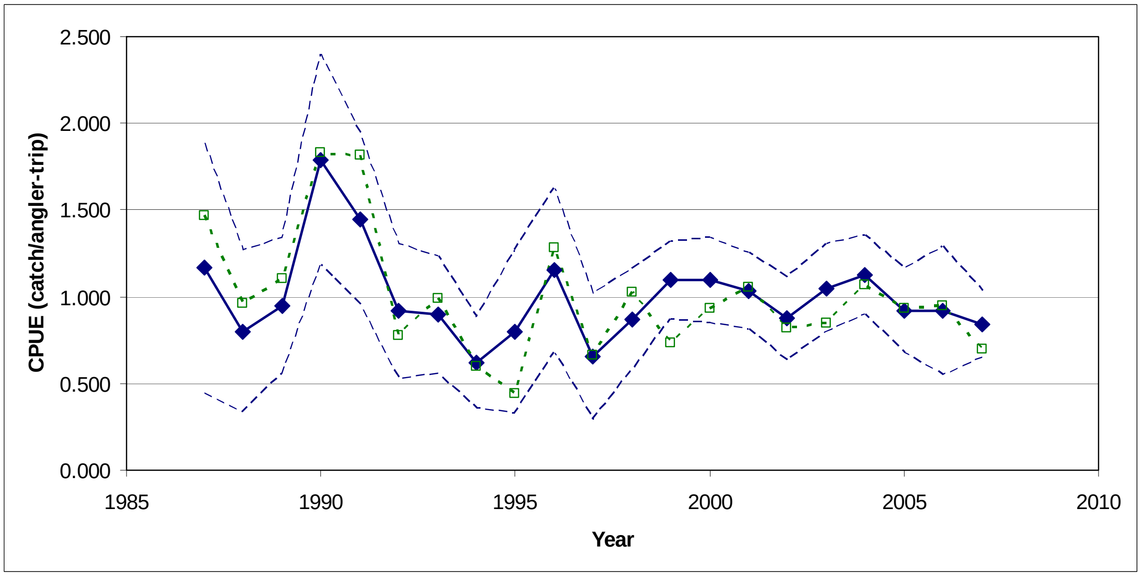
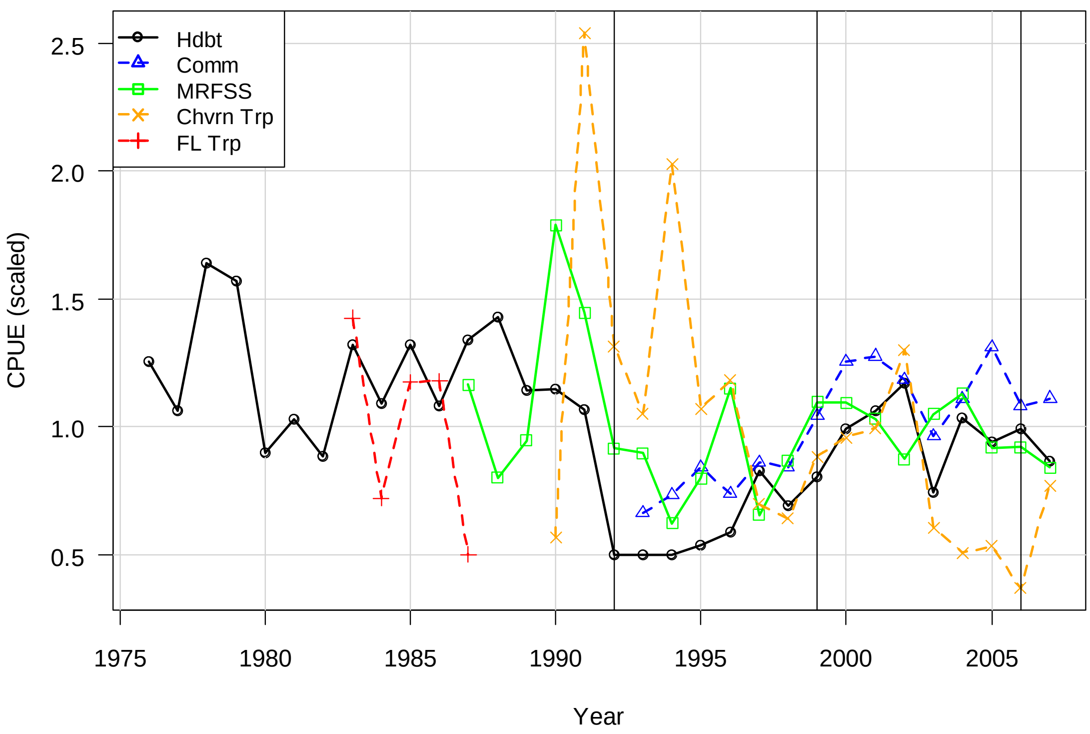


Figure 5.15. Vermilion snapper: indices of abundance recommended for use in the assessment. Vertical lines represent years with new recreational regulations. Each index is scaled to its mean.



5.10 APPENDICES

Appendix 5.1: Information contained in the commercial logbook data set (all variables are numeric unless otherwise noted):

schedule: this is a unique identifier for each fishing trip and is a character variable
species: a character variable to define the species
gear: a character variable, the gear type, multiple gear types may be used in a single trip, L = longline, H = handline, E = electric reels, B = bouy gear, GN = gill net, P = diver using power head gear, S = diver using spear gun, T = trap, TR = trolling
area: area fished, in the south Atlantic these codes have four digits- the first two are degrees of latitude and the second two are the degrees of longitude
conversion: conversion factor for calculating total pounds (totlbs) from gutted weight
gutted: gutted weight of catch for a particular species, trip, gear, and area
whole: whole weight of catch for a particular species, trip, gear, and area
totlbs: a derived variable that sums the gutted (with conversion factor) and whole weights, this is the total weight in pounds of the catch for a particular species, trip, gear, and area
length: length of longline (in miles) or gill net (in yards)
mesh1 – mesh4: mesh size of traps or nets
numgear: the amount of a gear used, number of lines (handlines, electric reels), number of sets (longlines), number of divers, number of traps, number of gill nets
fished: hours fished on a trip, this is problematic for longline data as discussed later
effort: like numgear, the data contained in this field depends upon gear type; number of hooks/line for handlines, electric reels, and trolling; number of hooks per longline for longlines; number of traps pulled for traps; depth of the net for gill nets, this field is blank for divers
source: a character variable, this identifies the database that the record was extracted from, sg = snapper grouper, grf = gulf reef fish, all records should have this source code
tif_no: a character variable, trip identifier, not all records will have a tif_no
vesid: a character variable, a unique identifier for each vessel
started: numeric (mmddyy8) variable, date the trip started
landed: numeric (mmddyy8) variable, date the vessel returned to port
unload: numeric (mmddyy8) variable, date the catch was unloaded
received: numeric (mmddyy8) variable, date the logbook form was received from the fisherman
opened: numeric (mmddyy8) variable, date the logbook form was opened and given a schedule number
away: number of days at sea, this value should equal (landed-started+1)
crew: number of crew members, including the captain

dealer: character variable, identifier for the dealer who bought the catch, in some cases there may be multiple dealers for a trip
state: character variable, the state in which the catch was sold
county: character variable, the county in which the catch was sold
area1 – area3: areas fished, if the trip included catch from multiple areas, those areas will be listed here
trip_ticke: character variable, trip ticket number, a unique identifier for each trip not all trips have this identifier

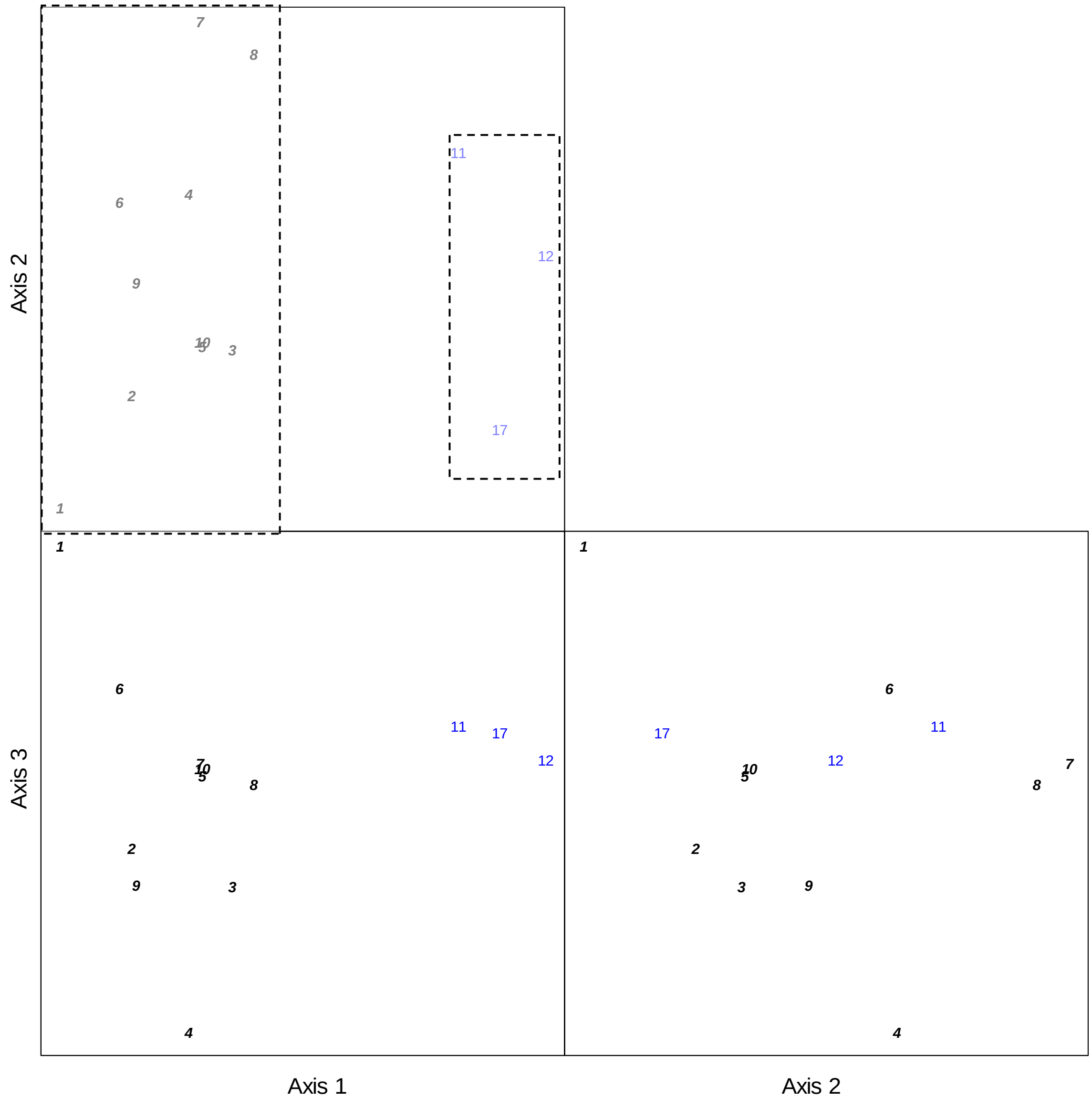
Appendix 5.2. Geographic areas with similarity in species landed.

This appendix describes multivariate statistical analyses used to identify geographic areas with similarity in species landed. Two techniques were applied—ordination and cluster analysis. Both require use of a measure of dissimilarity (distance) among areas. These analyses used the Sørenson (also called Bray-Curtis) measure of distance, a common measure in ecological studies (McCune and Grace, 2002).

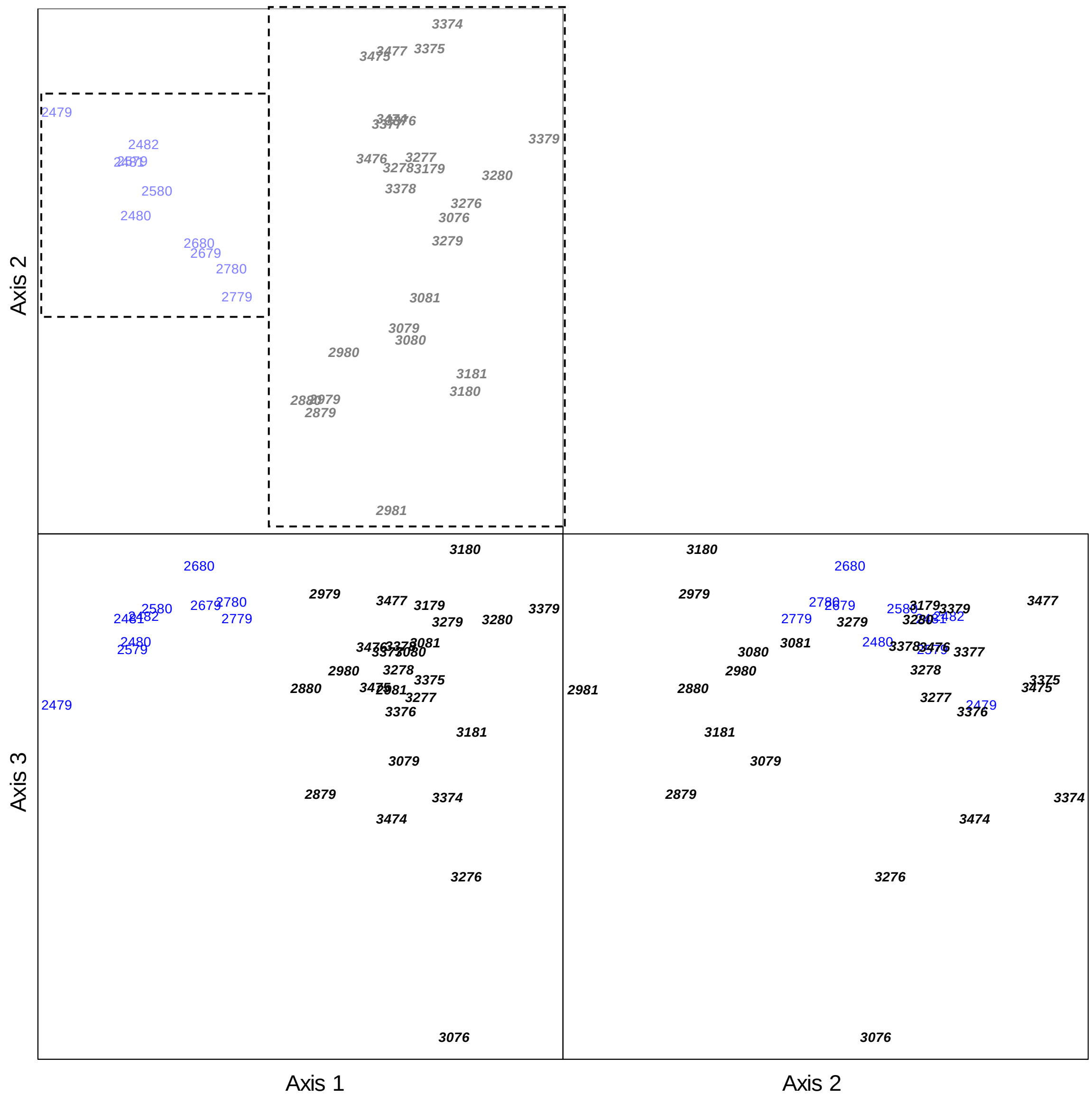
To compute dissimilarities, each data set (commercial logbook and headboat) was formatted as a matrix with rows representing geographic areas and columns representing species. Each element of the matrix quantified the relative frequency of species landed by geographic area. Thus, rows of the matrix summed to one. Geographic areas with a trivial number of records (<0.01%) were removed from the analysis, which left 292,316 records of area-species in the recreational (headboat) data set and 239,991 in the commercial data set. The resulting frequencies were then transformed using the arcsine squareroot transformation, as is appropriate for proportion data (McCune and Grace, 2002). After transformation, a matrix of dissimilarities between areas was computed using the Sørenson measure of distance.

To quantify similarity of areas based on their catch compositions, the ordination method of nonmetric multidimensional scaling (NMDS) was applied to the matrix of dissimilarities (Kruskal, 1964). In addition to ordination, nonhierarchical cluster analysis was applied in order to partition the geographic areas. This cluster analysis used the method of *k*-medoids, a more robust version of the classical method of *k*-means (Kaufman and Rousseeuw, 1990). As with any nonhierarchical method, the number of clusters *k* must be specified *a priori*. This study applied a range of values and selected the *k* most concordant with the data, as indicated by highest average silhouette width (Rousseeuw, 1987). In both commercial logbook and headboat data sets, optimal $k = 2$, with division between areas near Cape Canaveral, FL (Appendix 5.2A,B).

Appendix 5.2 Figure A. Nonmetric multidimensional scaling of areas from the headboat data. Rectangles in top left panel encapsulate areas with similar composition of landings, as identified by *k*-medoid cluster analysis. Areas north of Cape Canaveral, FL are in bold, black font.

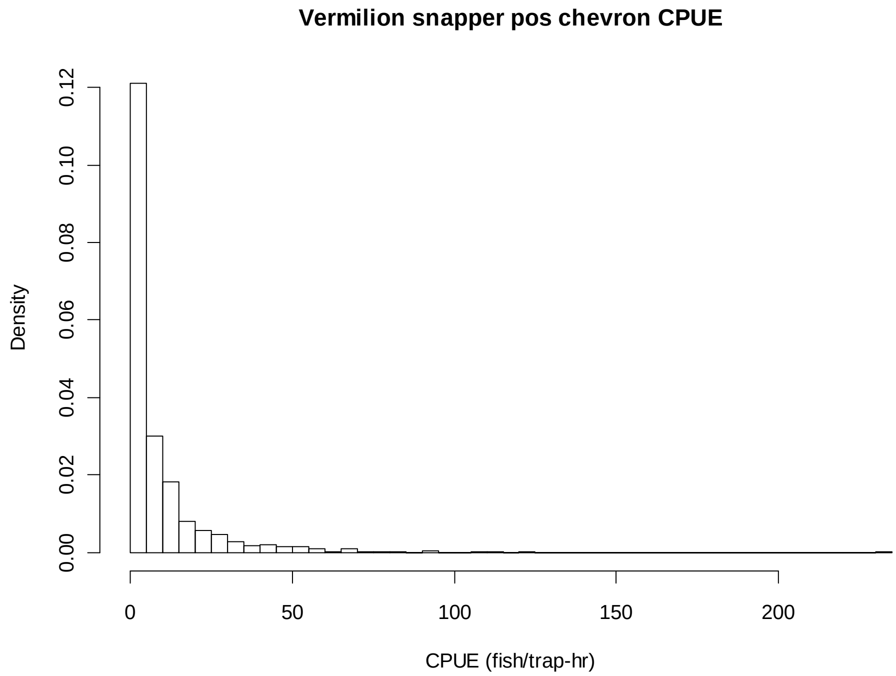


Appendix 5.2 Figure B. Nonmetric multidimensional scaling of areas from the commercial logbook data (handline). Rectangles in top left panel encapsulate areas with similar composition of landings, as identified by cluster analysis. Areas north of Cape Canaveral, FL are in bold, black font.

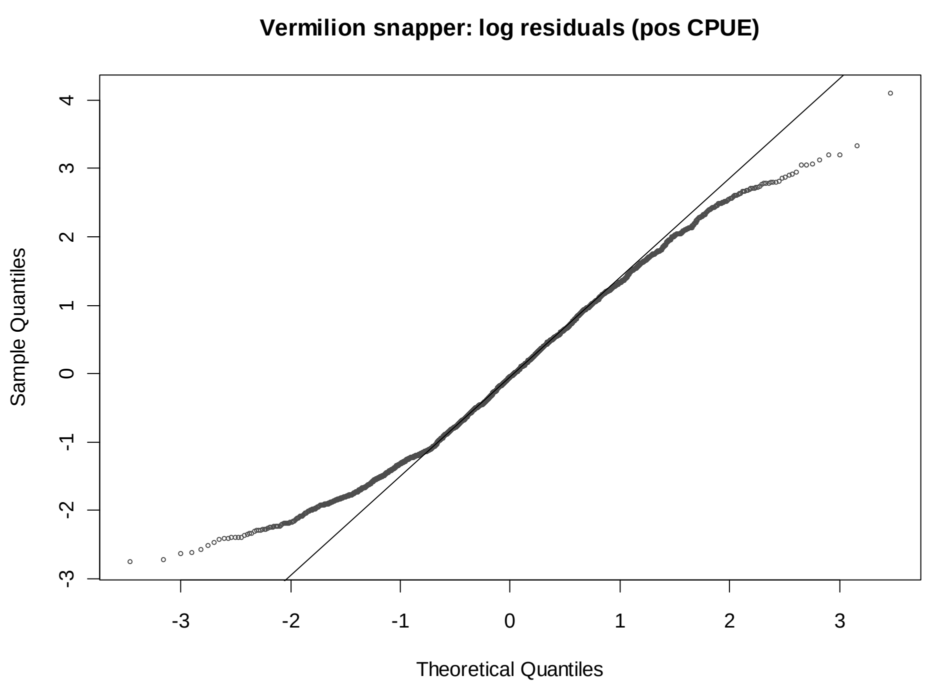


Appendix 5.3. Vermilion snapper: diagnostics of delta-GLM fitted to MARMAP chevron trap data.

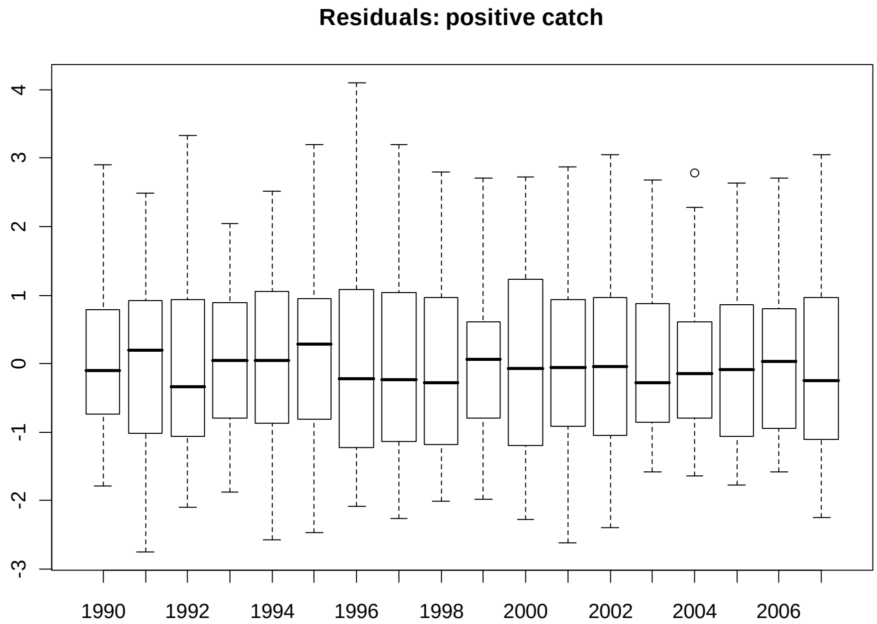
Appendix 5.3 Figure A.



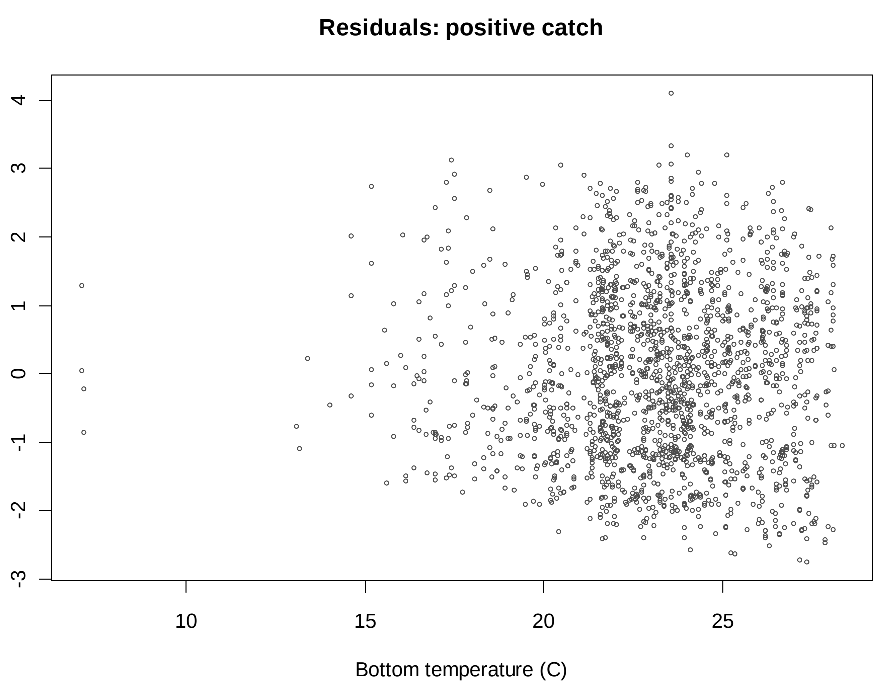
Appendix 5.3 Figure B.



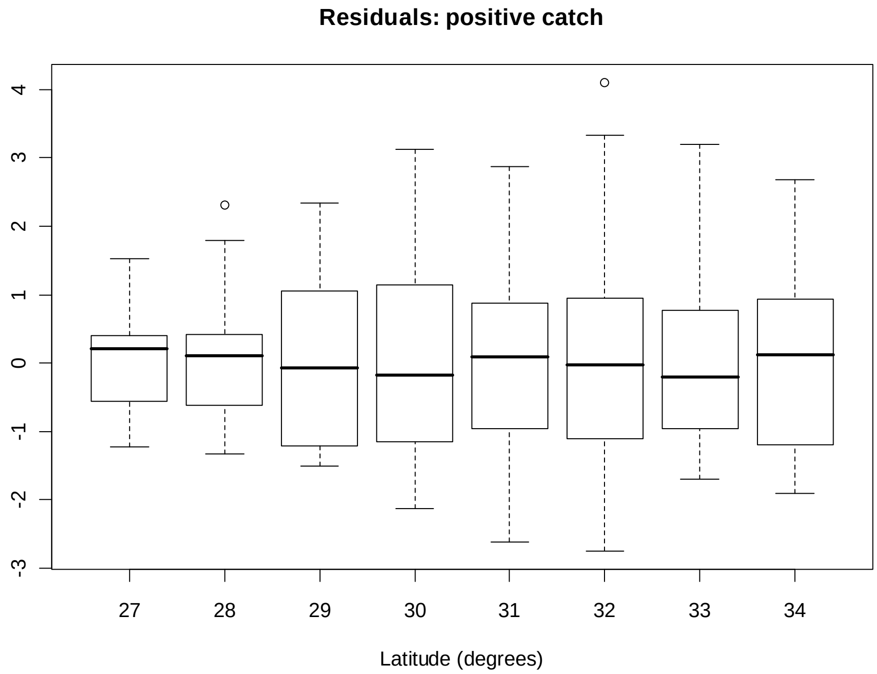
Appendix 5.3 Figure C.



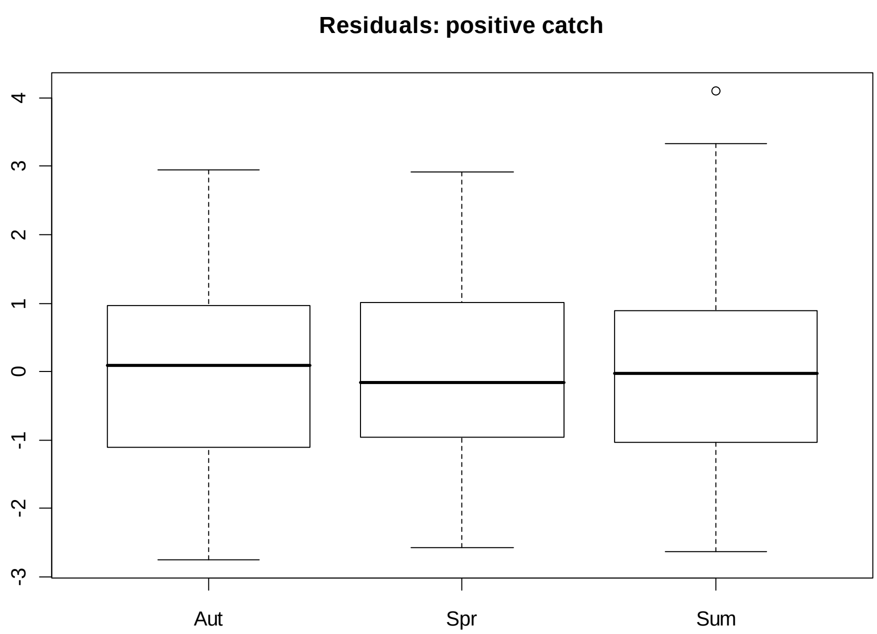
Appendix 5.3 Figure D.



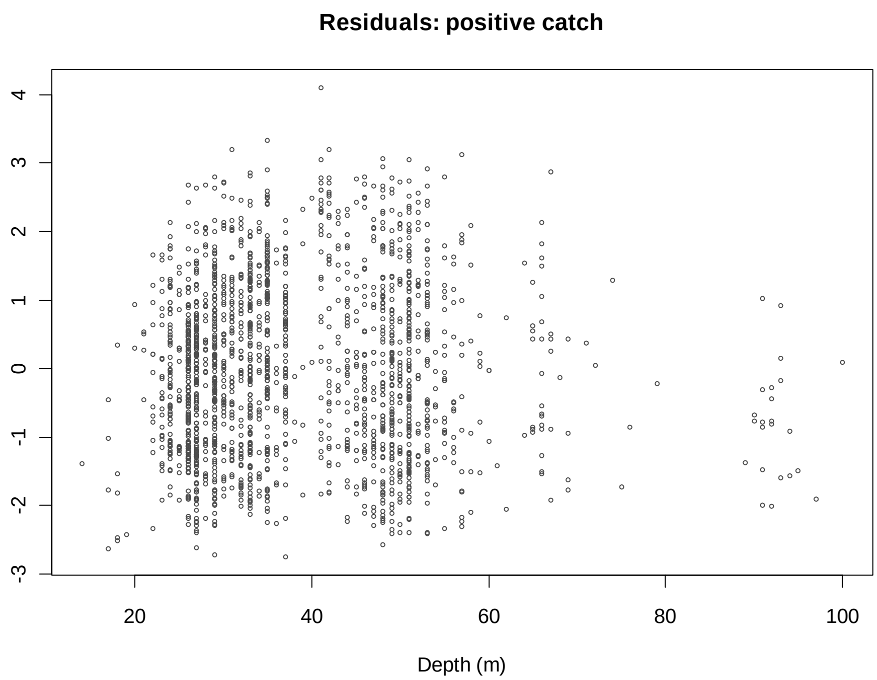
Appendix 5.3 Figure E.



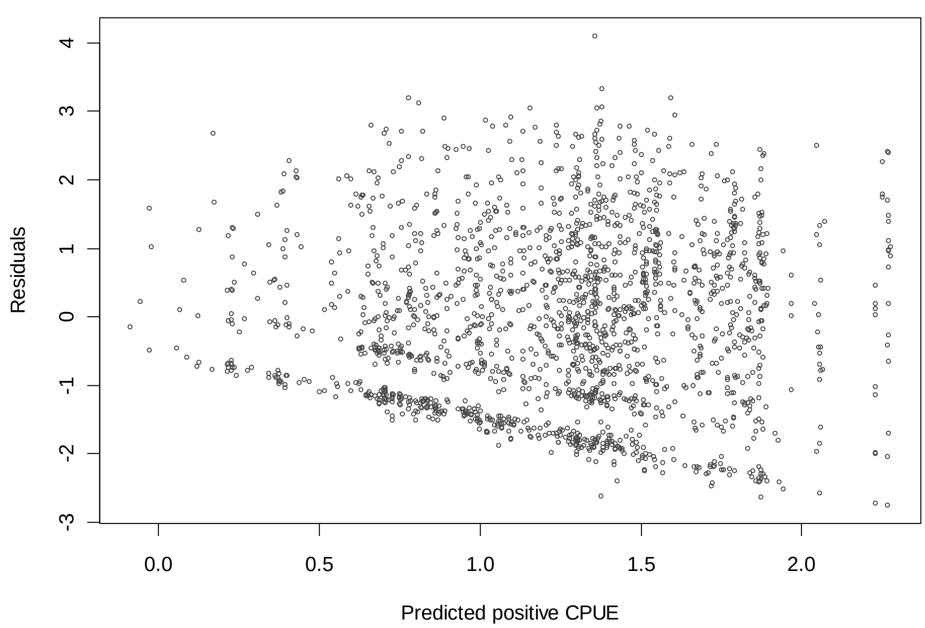
Appendix 5.3 Figure F.



Appendix 5.3 Figure G.

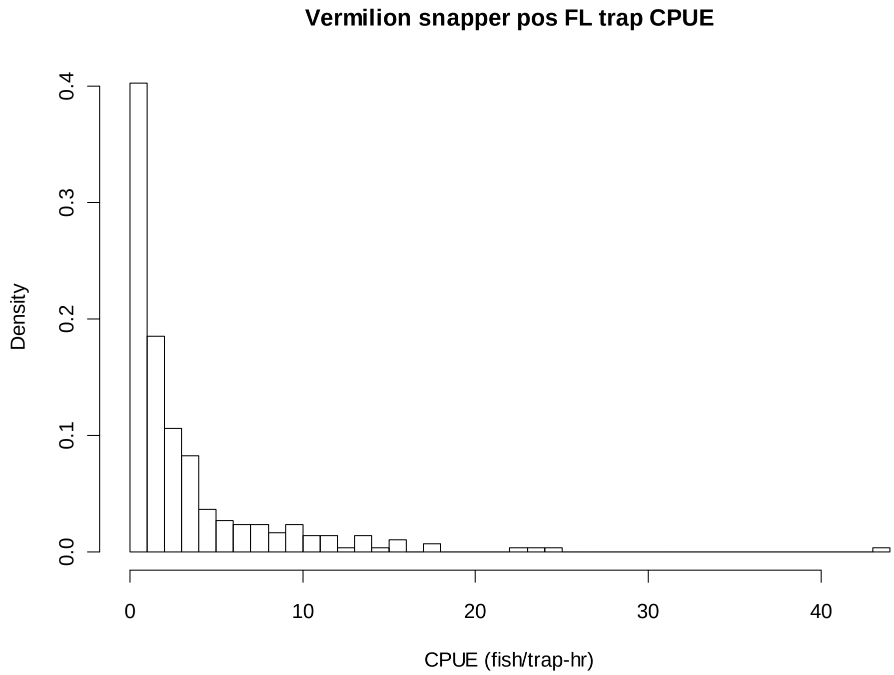


Appendix 5.3 Figure H.

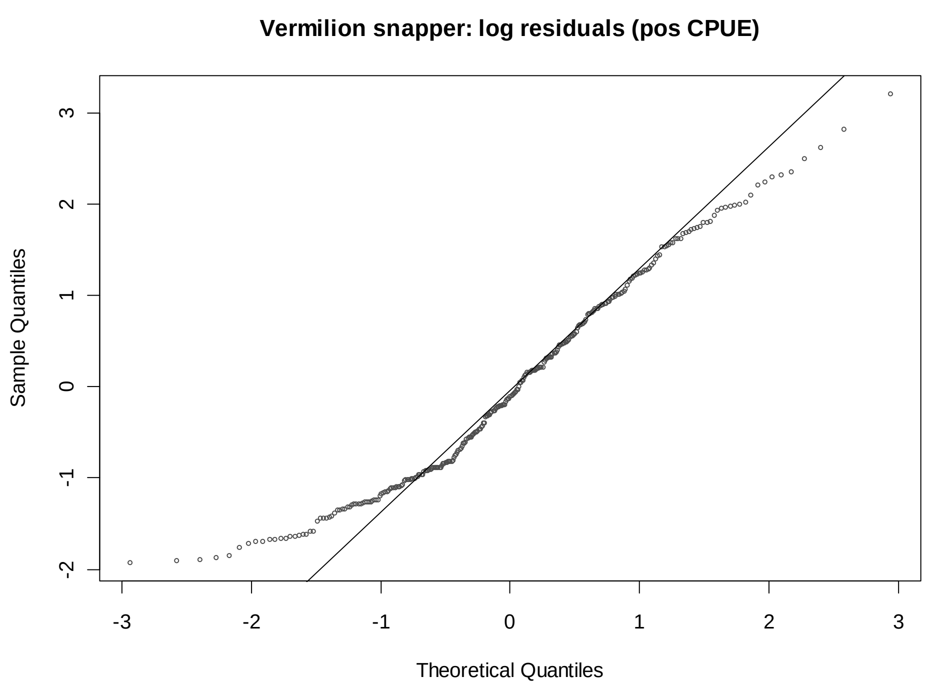


Appendix 5.4. Vermilion snapper: diagnostics of delta-GLM fitted to MARMAP Florida snapper trap data.

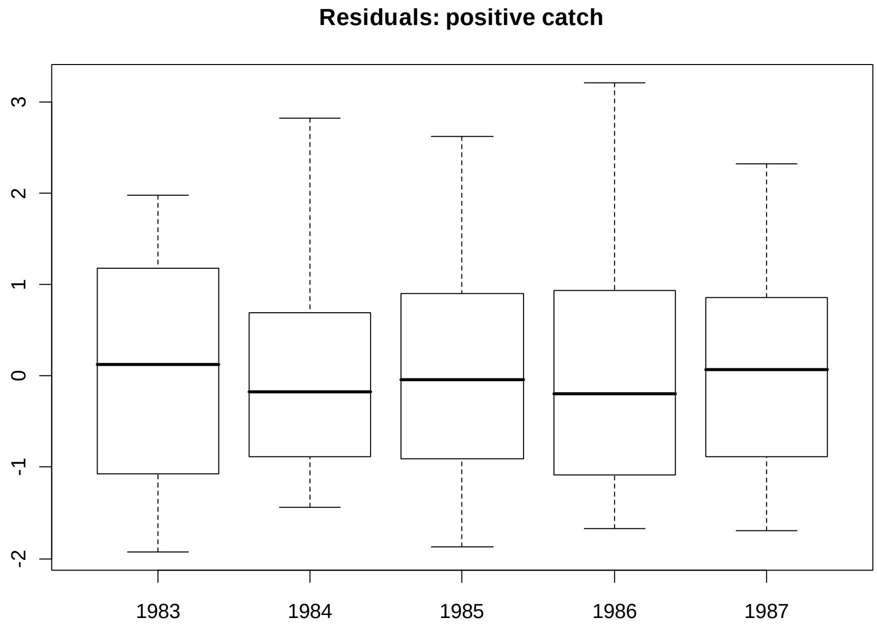
Appendix 5.4 Figure A.



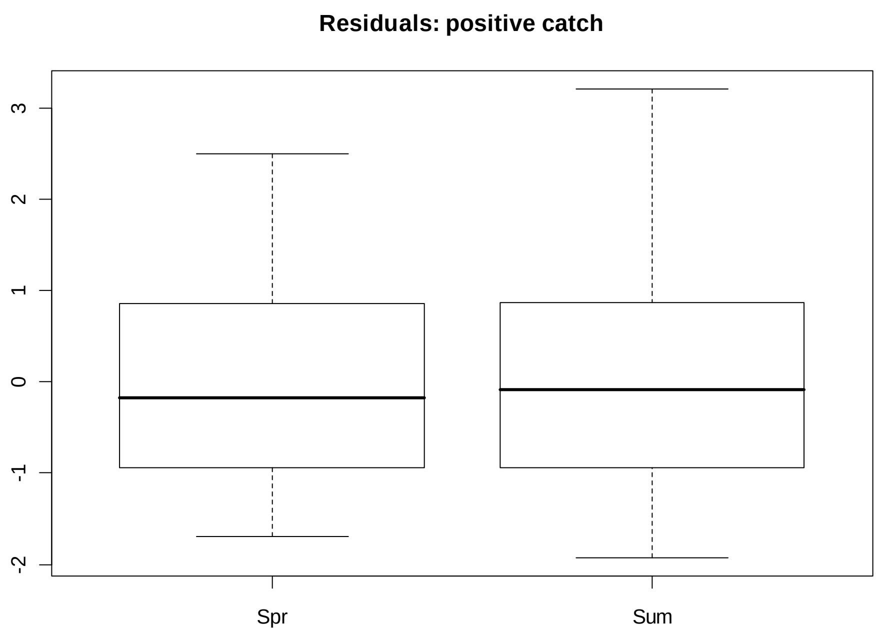
Appendix 5.4 Figure B.



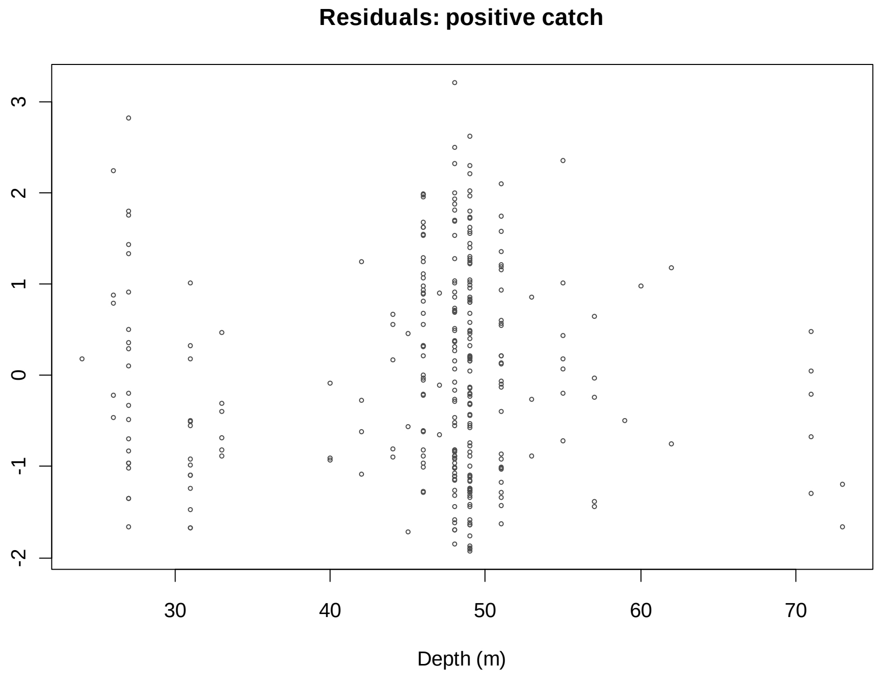
Appendix 5.4 Figure C.



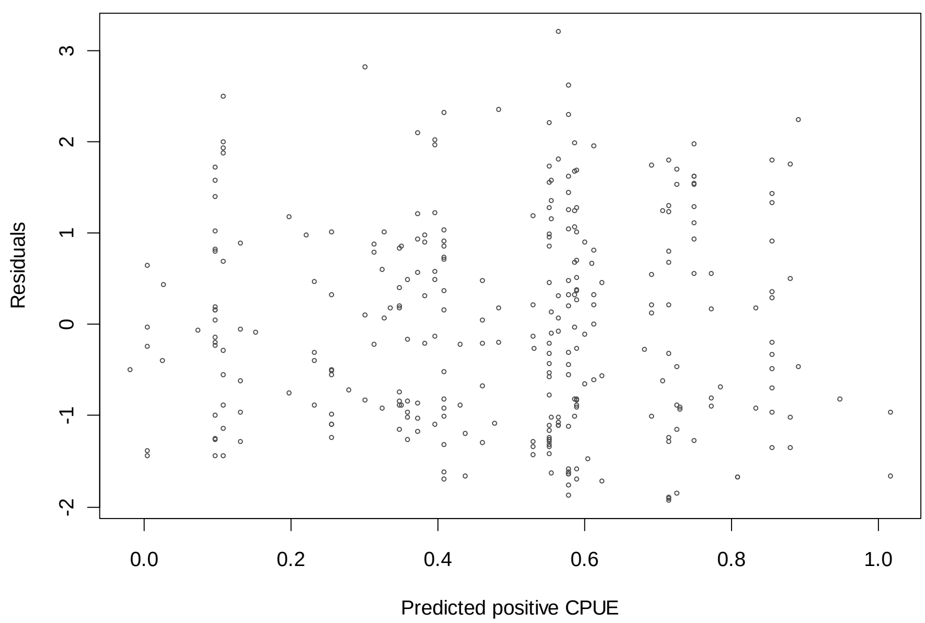
Appendix 5.4 Figure D.



Appendix 5.4 Figure E.

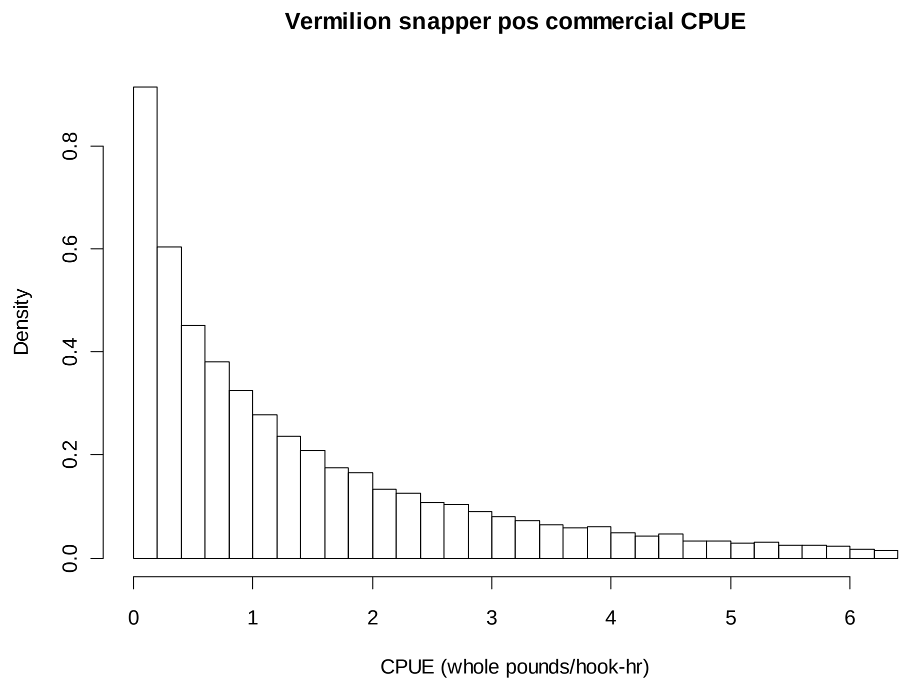


Appendix 5.4 Figure F.

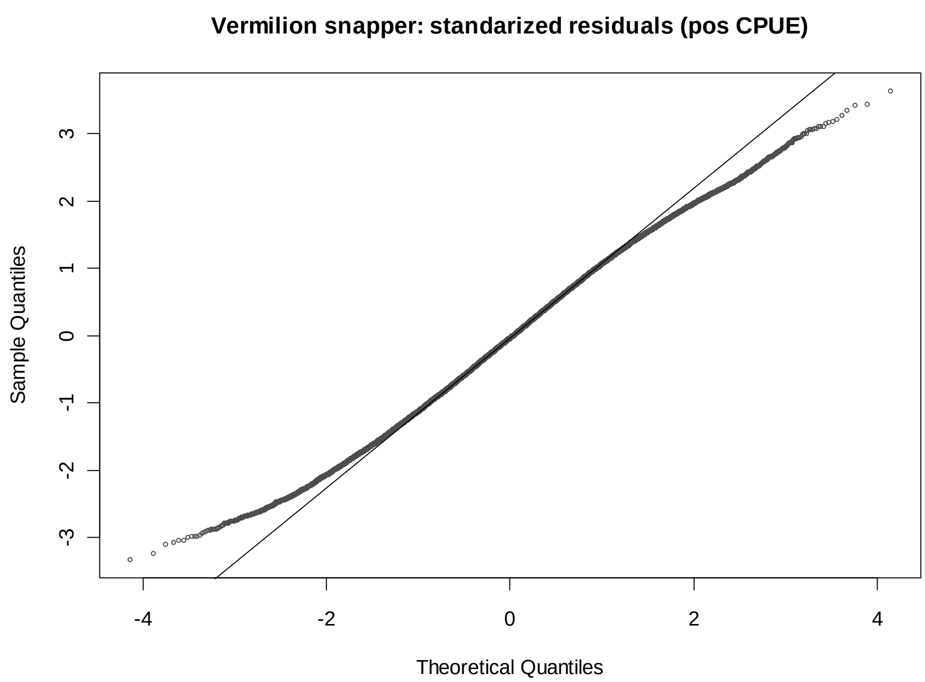


Appendix 5.5. Vermilion snapper: diagnostics of delta-GLM fitted to commercial logbook data. Gamma model residuals were standardized using method of Dunn and Smyth (1996).

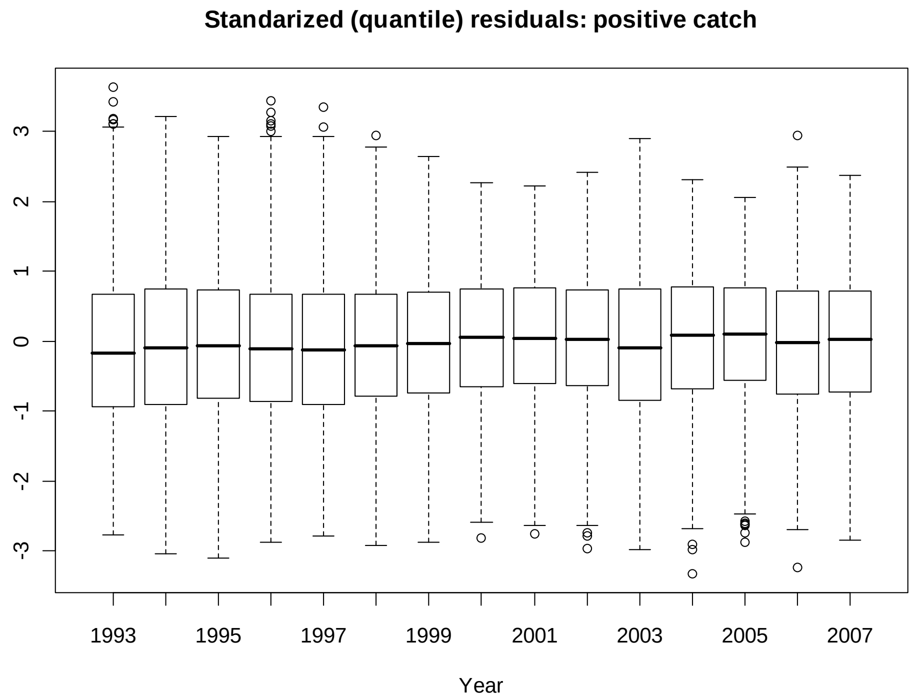
Appendix 5.5 Figure A.



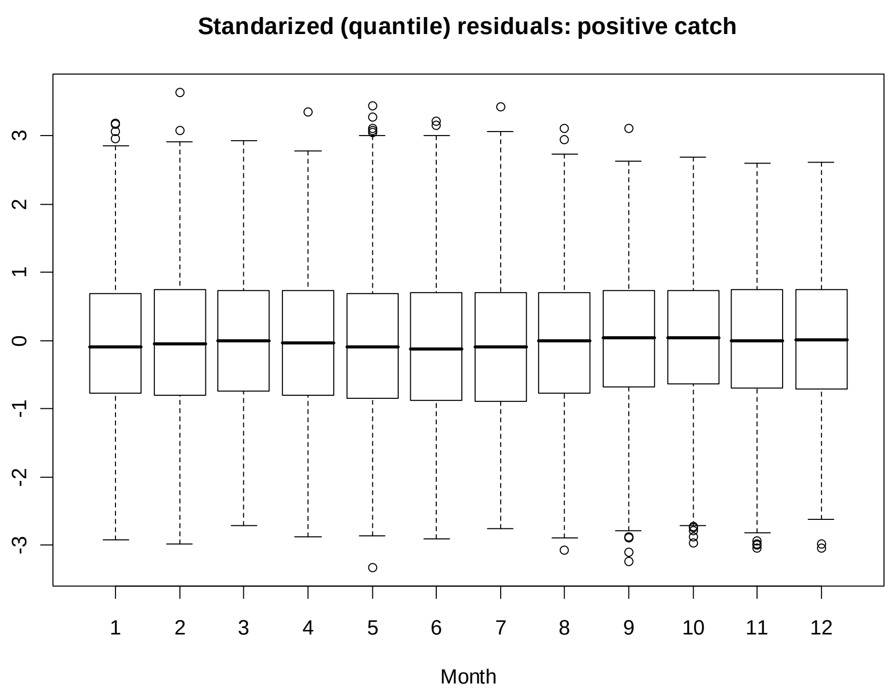
Appendix 5.5 Figure B.



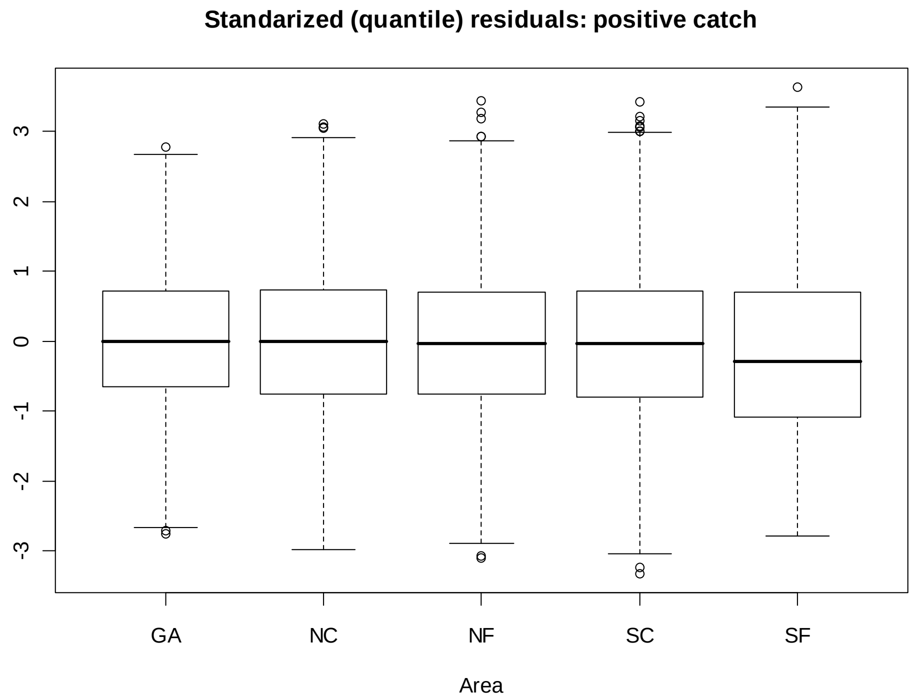
Appendix 5.5 Figure C.



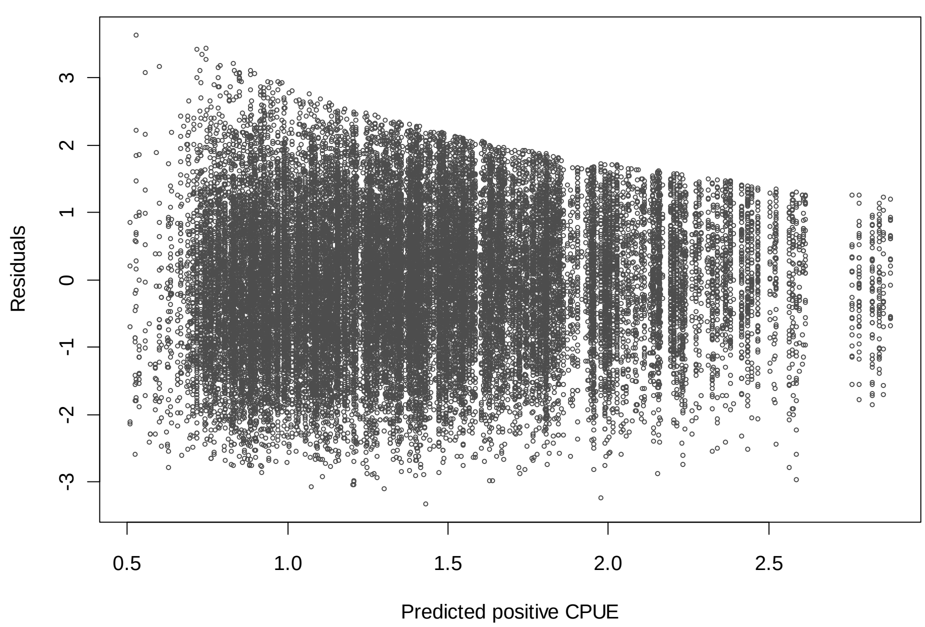
Appendix 5.5 Figure D.



Appendix 5.5 Figure E.

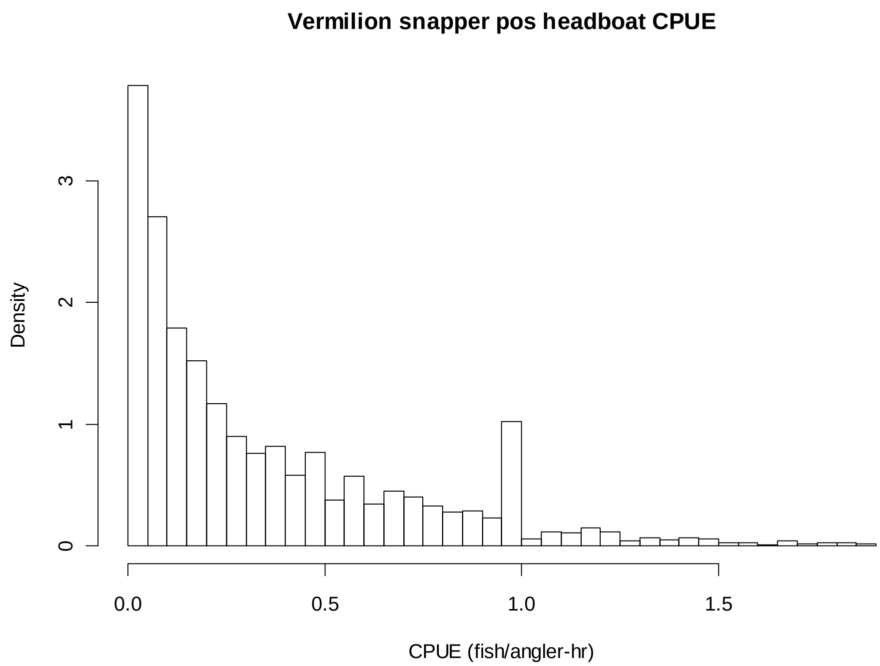


Appendix 5.5 Figure F.

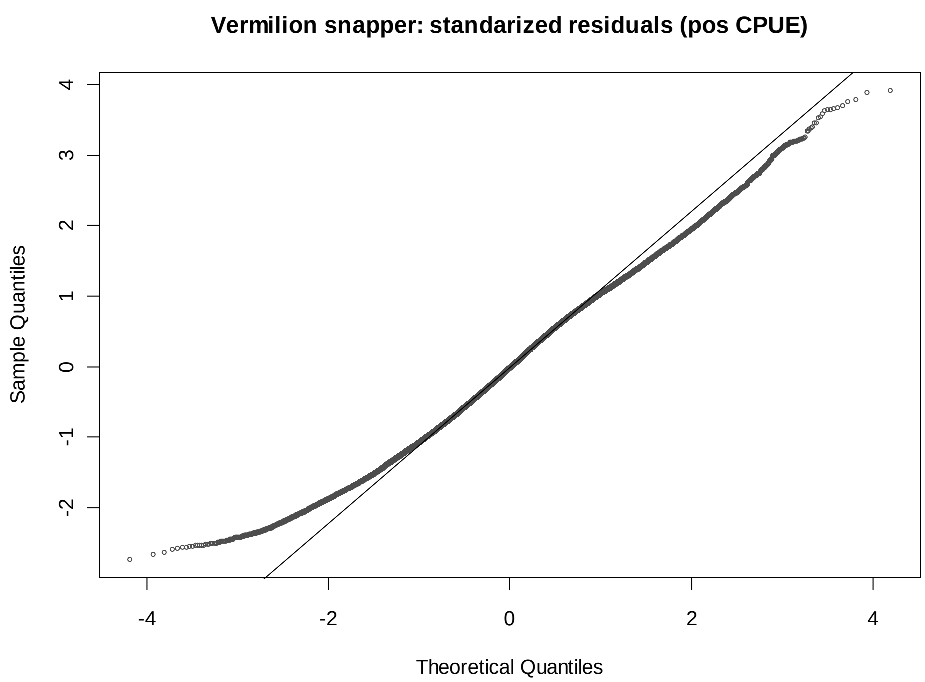


Appendix 5.6. Vermilion snapper: diagnostics of delta-GLM fitted to headboat data. Gamma model residuals were standardized using method of Dunn and Smyth (1996).

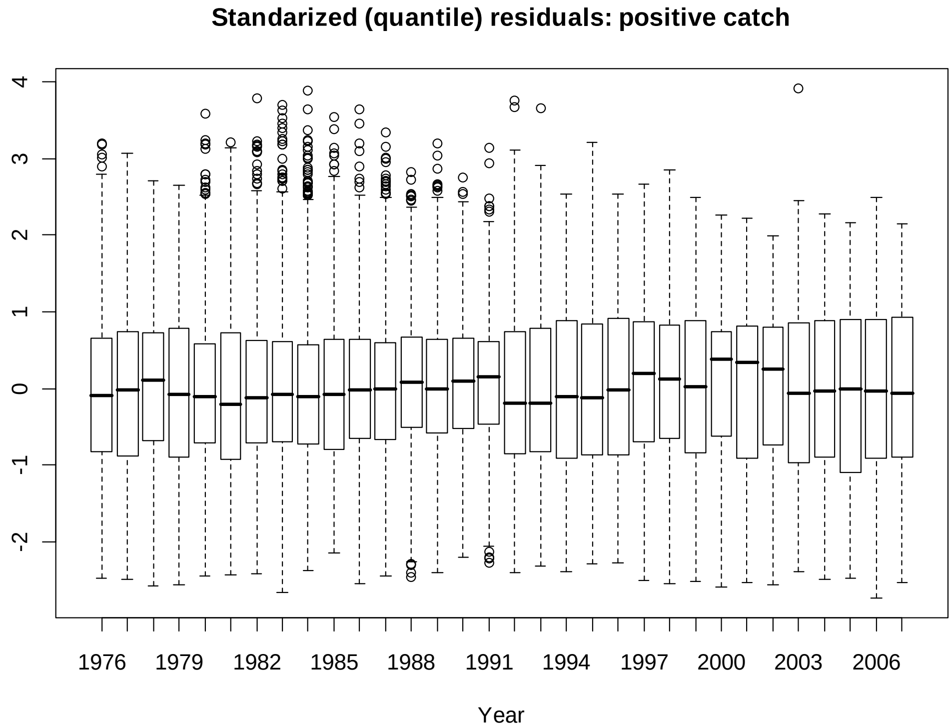
Appendix 5.6 Figure A.



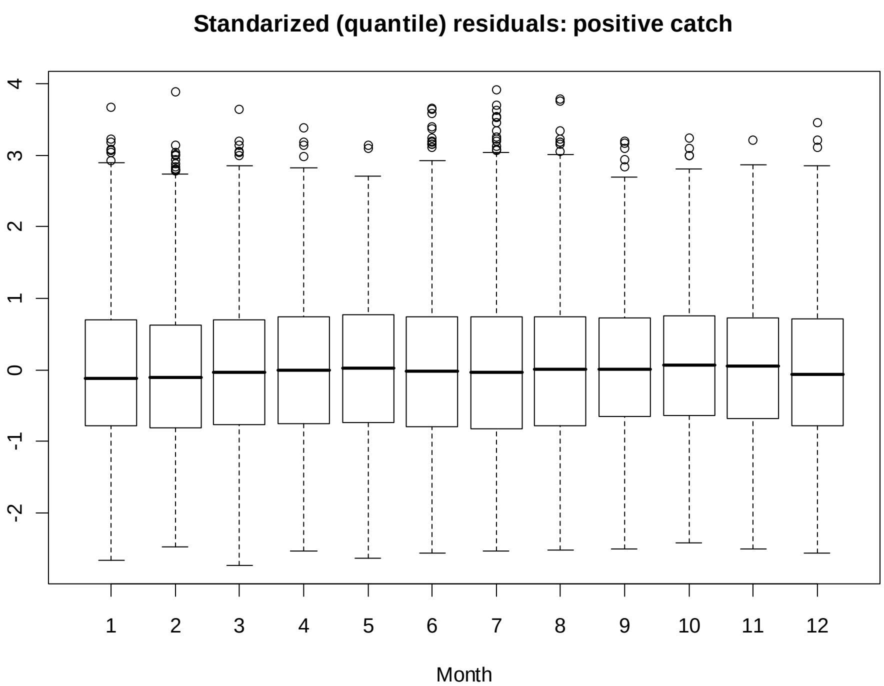
Appendix 5.6 Figure B.



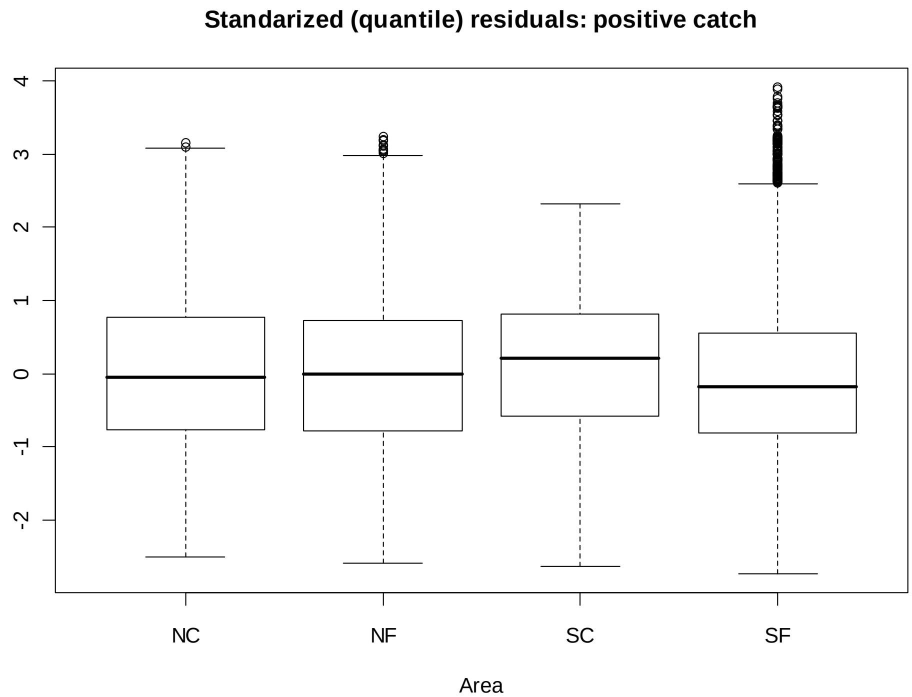
Appendix 5.6 Figure C.



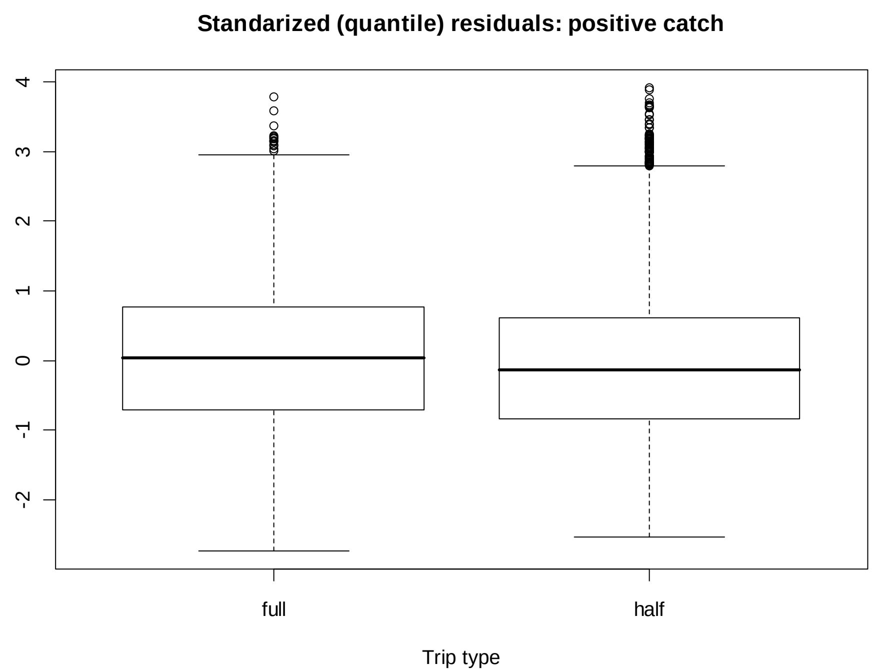
Appendix 5.6 Figure D.



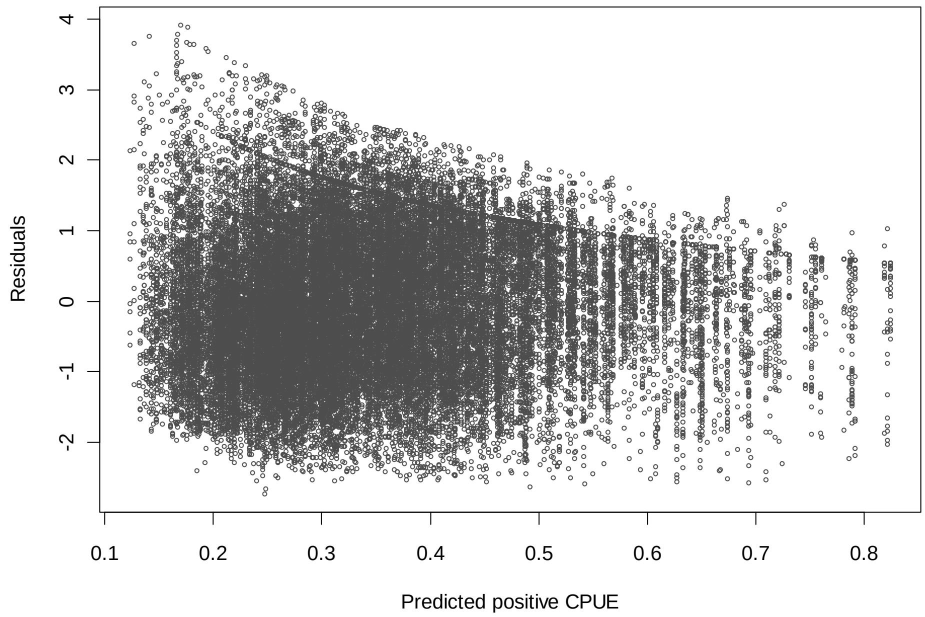
Appendix 5.6 Figure E.



Appendix 5.6 Figure F.

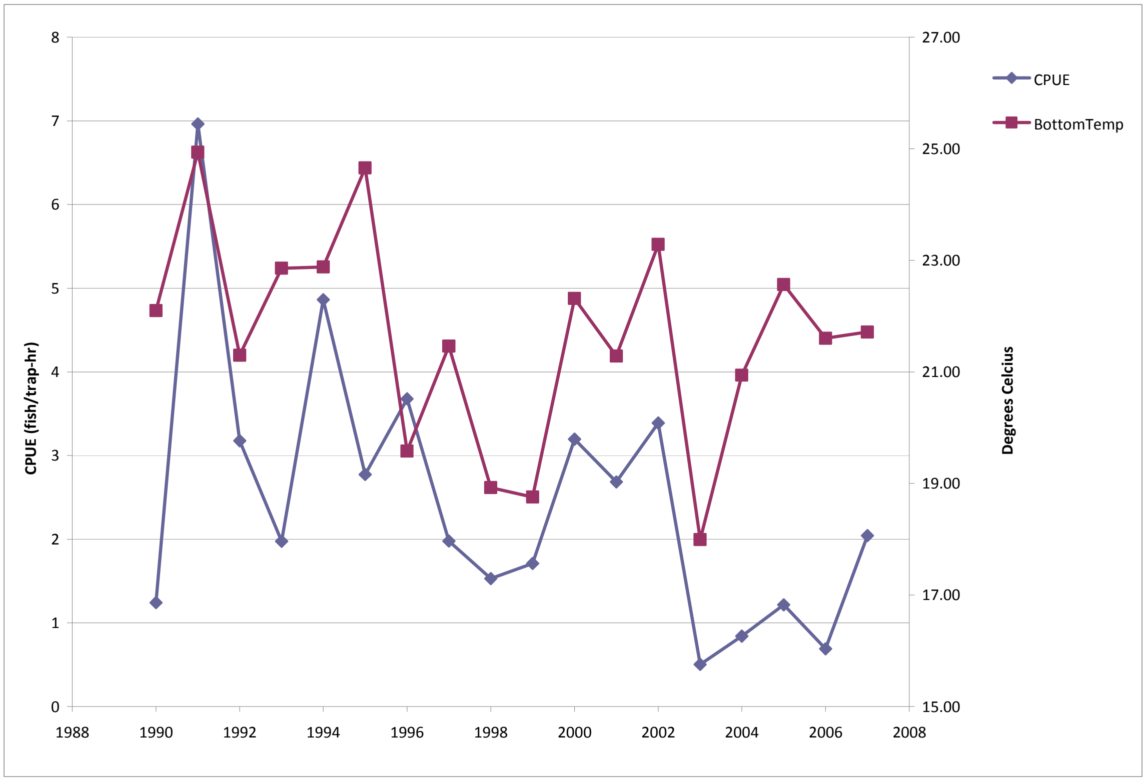


Appendix 5.6 Figure G.



Appendix 5.7. MARMAP chevron trap nominal CPUE and bottom temperature (Pearson $\rho = 0.55$; p-value = 0.02 from a *t*-test of H_0: $\rho = 0$).

Appendix 5.7 Figure A.



6. Submitted Comments

Section III. Assessment Workshop Report

Contents

1. Workshop Proceeding

1.1 Introduction

1.1.1 Workshop Time and Place

The SEDAR 17 Assessment Workshop was held August 25-29, 2008 in Beaufort, NC.

1.1.2 Terms of Reference

1. Review any changes in data following the data workshop, any analyses suggested by the data workshop, and provide estimated values for any required data in DW TOR 4 that are not available from observations. 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. Document model code in an AW working paper.
3. Provide estimates of stock population parameters (fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, discard removals, etc) by age and other relevant categorizations (i.e., fleet or sector); include representative measures of precision for parameter estimates.
4. Characterize uncertainty in the assessment and estimated values, considering components such as input data sources, data assumptions, 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 MSA National Standards. This may include: evaluating existing SFA benchmarks, estimating alternative SFA benchmarks, and recommending proxy values.
7. Provide declarations of stock status relative to SFA benchmarks; recommend alternative SFA benchmarks if necessary.
8. Project future stock conditions. Provide estimates of exploitation, stock abundance and yield (discards and directed harvest) in pounds and numbers for a minimum of 10 years into the future. Fully document all projection assumptions (e.g., recruitment, selectivity, discard mortality). Develop rebuilding schedules if warranted; include estimated generation time. Stock projections shall be developed in accordance with the following:
    - A) If stock is overfished:
        - F=0, F=current, F=Fmsy, Ftarget (OY),
        - F=Frebuild (max that rebuild in allowed time)
    - B) If stock is overfishing
        - F=Fcurrent, F=Fmsy, F= Ftarget (OY)
    - C) If stock is neither overfished nor overfishing
        - F=Fcurrent, F=Fmsy, F=Ftarget (OY)

9. Evaluate the impacts of past and current management actions on the stock, with emphasis on determining progress toward stated management goals and identifying possible unintended fishery or population effects.
10. Consider the data workshop research recommendations. Provide additional recommendations for future research and data collection (field and assessment); be as specific in describing sampling design and sampling intensity.
11. Prepare an accessible, documented, labeled, and formatted spreadsheet containing all model parameter estimates and all relevant population information resulting from model estimates and any projection and simulation exercises. Include all data included in assessment report tables, all data that support assessment workshop figures, and those tables required for the summary report.
12. Complete the Assessment Workshop Report (Section III of the SEDAR Stock Assessment Report), prepare a first draft of the Advisory Report, and develop a list of tasks to be completed following the workshop.
13. Perform a probabilistic analysis of proposed reference points and provide the probability of overfishing at various harvest or exploitation levels. (Added 7-2-08)

1.1.3 Participants

Appointee	Function	Affiliation
Coordination		
Dale Theiling	Chair	SEDAR
Rachael Lindsay	Administrative Support	SEDAR
Science and Statistics Committee Representation		
Marcel Reichert	Stock Leader & Proceedings Editor - Vermilion Snapper	SC DNR/MARMAP
Scott Crosson	Stock Leader & Proceedings Editor - Spanish Mackerel	NC DMF
Rapporteur		
Rick DeVictor	Rapporteur	SAFMC
Analytical Team		
Kyle Shertzer	Lead Analyst and Model Editor - Vermilion Snapper	SEFSC Beaufort
Paul Conn	Lead Analyst and Model Editor - Spanish Mackerel	SEFSC Beaufort
Doug Vaughan	Analyst	SEFSC Beaufort
Erik Williams	Analyst	SEFSC Beaufort
Rob Cheshire	Team Member	SEFSC Beaufort
Data Workgroup Leaders		
Doug Vaughan	Commercial Data Presenter	SEFSC Beaufort
Erik Williams	Recreational Data Presenter	SEFSC Beaufort
Jennifer Potts	Life History Data Presenter	SEFSC Beaufort
Kyle Shertzer	Indices Data Presenter	SEFSC Beaufort

Council Representation

Brian Cheuvront	Council Member	NC DMF
Rick DeVictor	Council Staff – Stocks Lead	SAFMC
Andi Stephens	Council Staff - Fishery Biologist	SAFMC

Advisory Panel Representation

Ben Hartig	Mackerel AP Chair	Florida Commercial

Appointed Observers

Jessica Stephen	Observer	SC DNR/MARMAP
Jack McGovern	Observer	SERO

Observers

Jim Waters	Observer	SEFSC Beaufort
Jim Thorson	Observer	Virginia Tech

1.1.4 Workshop Documents

Documents prepared for and by the SEDAR 17 data and assessment workshops:

Document #	Title	Authors
Documents Prepared for the Data Workshop		
SEDAR17-DW01	South Atlantic Vermilion Snapper Management Information Worksheet	J. McGovern (SERO) R. DeVictor (SAFMC)
SEDAR17-DW02	South Atlantic Spanish Mackerel Management Information Worksheet	J. McGovern (SERO) R. DeVictor (SAFMC)
SEDAR17-DW03	South Atlantic Vermilion Snapper Assessment History	D. Vaughan (SEFSC)
SEDAR17-DW04	South Atlantic Spanish Mackerel Assessment History	D. Vaughan (SEFSC)
SEDAR17-DW05	South Atlantic Vermilion Snapper Commercial Chapter	D. Vaughan (SEFSC)
SEDAR17-DW06	South Atlantic Spanish Mackerel Commercial Chapter	D. Vaughan (SEFSC)
SEDAR17-DW07	A review of Spanish mackerel (*Scomberomorus maculatus)* age data, 1987-2007, Atlantic collections only, from the Panama City Laboratory, SEFSC, NOAA Fisheries Service	C. Palmer, D. DeVries, C. Fioramonti and L. Lombardi-Carlson (SEFSC)
SEDAR17-DW08	Vermilion Snapper Length Frequencies and Condition of Released Fish from At-Sea Headboat Observer Surveys in the South Atlantic, 2004 to 2007	B. Sauls, C. Wilson, D. Mumford, and K. Brennan (SEFSC)
SEDAR17-DW09	Development of Conversion Factors for Different Trap Types used by MARMAP since 1978.	P. Harris (MARMAP)
SEDAR17-DW10	Discards of Spanish Mackerel and Vermilion Snapper Calculated for Commercial Vessels with Federal Fishing Permits in the US South Atlantic	K. McCarthy (SEFSC)
SEDAR17-DW11	Standardized catch rates of vermilion snapper from the headboat sector: Sensitivity analysis of the 10-fish-per-angler bag limit	Sustainable Fisheries Branch (SEFSC)
SEDAR17-DW12	Estimation of Spanish mackerel and vermilion snapper	K. Andrews (SEFSC)

	bycatch in the shrimp trawl fishery in the South Atlantic (SA)	
	Documents Prepared for the Assessment Workshop	
SEDAR17-AW01	SEDAR 17 South Atlantic Vermilion Snapper Stock Assessment Model	To be prepared by SEDAR 17
SEDAR17-AW02	SEDAR 17 South Atlantic Spanish Mackerel Stock Assessment Model	To be prepared by SEDAR 17
SEDAR17-AW03	Development of an aging error matrix for the vermilion snapper catch-at-age stock assessment model	E. Williams (SEFSC)
SEDAR17-AW04	Catch curve analysis of age composition data for Spanish mackerel	E. Williams (SEFSC)
SEDAR17-AW05	Catch curve analysis of age composition data for vermilion snapper	E. Williams (SEFSC)
SEDAR17-AW06	Methods for combining multiple indices into one, with application to south Atlantic (U.S.) Spanish mackerel	P. Conn (SEFSC)
SEDAR17-AW07	Extrapolation of Spanish mackerel bycatch by commercial shrimp trawl fisheries	P. Conn (SEFSC)
SEDAR17-AW08	A Bayesian approach to stochastic stock reduction analysis, with application to south Atlantic Spanish mackerel	P. Conn (SEFSC)
SEDAR17-AW09	Surplus–production Model Results of Vermilion Snapper off the Southeastern United States	R. Cheshire (SEFSC)
SEDAR17-AW10	Surplus–production Model Results of Spanish Mackerel off the Southeastern United States	R. Cheshire (SEFSC)
SEDAR17-AW11	AD Model Builder code to implement catch-age assessment model of vermilion snapper	K. Shertzer (SEFSC)
SEDAR17-AW12	AD Model Builder code to implement catch-age assessment model of Spanish mackerel	P. Conn (SEFSC)
SEDAR17-AW13	ASCII file populated by results of VS base catch-age model	K. Shertzer (SEFSC)
	Documents Prepared for the Review Workshop	
SEDAR17-RW01	SEDAR 17 South Atlantic Vermilion Snapper Document for Peer Review	To be prepared by SEDAR 17
SEDAR17-RW02	SEDAR 17 South Atlantic Spanish Mackerel Document for Peer Review	To be prepared by SEDAR 17
	Final Assessment Reports	
SEDAR17-AR01	Assessment of the Vermilion Snapper Stock in the US South Atlantic	To be prepared by SEDAR 17

SEDAR17-AR02	Assessment of the Spanish Mackerel Stock in the US South Atlantic	To be prepared by SEDAR 17
Reference Documents		
SEDAR17-RD01	South Atlantic Vermilion Snapper Stock Assessment Report, SEDAR 2, 2003	SEDAR 2
SEDAR17-RD02	Update of the SEDAR 2 South Atlantic Vermilion Snapper Stock Assessment, 2007	SEDAR
SEDAR17-RD03	Fishery Management Plan for Spanish Mackerel, Atlantic States Marine Fisheries Commission, 1990	L. P. Mercer L. R. Phalen J. R. Maiolo
SEDAR17-RD04	Mitochondrial and nuclear DNA analysis of population subdivision among young-of-the-year Spanish mackerel (*Scomberomorus maculatus*) from the western Atlantic and Gulf of Mexico	V. P. Buonaccorsi E. Starkey J. E. Graves
SEDAR17-RD05	George Fishes MD TAFS 28 1-49	W. A. George
SEDAR17-RD06	Excerpt – Goode 1878 stats 7-1-99	Goode
SEDAR17-RD07	Excerpt – Henshall Comparative Excellence TAF 13 1-115	Henshall
SEDAR17-RD08	Stock Assessment Analyses on Spanish and King Mackerel Stocks, April 2003	Sustainable Fisheries Div, SEFSC
SEDAR17-RD09	Hooking Mortality of Reef Fishes in the Snapper-Grouper Commercial Fishery of the Southeastern United States	D.V. Guccione Jr.
SEDAR17-RD10	Effects of cryptic mortality and the hidden costs of using length limits in fishery management Lewis G Coggins Jr	L. G. Coggins Jr. and others
SEDAR17-RD11	Discard composition and release fate in the snapper and grouper commercial hook-and-line fishery in North Carolina, USA	P. J. Rudershausen and J. A. Buckel
SEDAR17-RD12	A multispecies approach to subsetting logbook data for purposes of estimating CPUE	A. Stephens and A. MacCall
SEDAR17-RD13	The 1960 Salt-Water Angling Survey, USFWS Circular 153	J. R. Clark
SEDAR17-RD14	The 1965 Salt-Water Angling Survey, USFWS Resource Publication 67	D. G. Deuel and J. R. Clark
SEDAR17-RD15	1970 Salt-Water Angling Survey, NMFS Current Fisheries Statistics Number 6200	D. G. Deuel
SEDAR17-RD16	User’s Guide: Delta-GLM function for the R Language /environment (Version 1.7.2, revised 07-06-2006)	E. J. Dick (SWFSC/NMFS)
SEDAR17-RD17	Reproductive biology of Spanish mackerel, *Scomberomorus maculatus*, in the lower Chesapeake Bay. M.A. Thesis, Virginia Institute of Marine Science. (Selective pages)	C. L. Cooksey
SEDAR17-RD18	The summer flounder chronicles: Science, politics, and litigation, 1975–2000	M. Terceiro

SEDAR17-RD19	Use of Angler Diaries to Examine Biases Associated with 12-Month Recall on Mail Questionnaires	N. Connelly and T. Brown
SEDAR17-RD20	Comparing 1994 Angler Catch and Harvest Rates from On-Site and Mail Surveys on Selected Maine Lakes	B. Roach
SEDAR17-RD21	Response Errors in Canadian Waterfowl Surveys	A. Sen
SEDAR17-RD22	Exaggeration of Walleye Catches by Alberta Anglers	M. Sullivan
SEDAR17-RD23	Effects of Recall Bias and Non-response Bias on Self-Report Estimates of Angling Participation	M. A. Tarrant and M. J. Manfredo
SEDAR17-RD24	Influence of Survey Method on Estimates of Statewide Fishing Activity	T. Thompson
SEDAR 17-RD25	Final Amendment 6 to the Fishery Management Plan for the Shrimp Fishery of the South Atlantic Region	SAFMC, 2004

1.2 Panel Recommendations and Comments

The following consensus comments and recommendations were made by the assessment panel in response to the Assessment Workshop Terms of Reference. Specifics of those terms reported by the analysts and accepted by the panel are discussed in detail in Chapters 2 and Chapter 3. Those earning panel discussion follow.

1. Review any changes in data following the data workshop, any analyses suggested by the data workshop, and provide estimated values for any required data in DW TOR 4 that are not available from observations. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.

Changes in the data made since the DW (see Chapter 2 of AW report) were adopted by the AW, most importantly: new length data on commercial discards, new discard mortality to reflect fish kept as bait, trawl data in later period grouped with "other" for modeling purposes, adjusted MARMAP age compositions, and the treatment of the recreational landing for 1960, '65, and '70 (RD13, RD14, and RD15).

Other data discussions were:

- weighing age compositions by state of depth strata: no strong data to support this and this was also discussed, and rejected, by the DW.
- The proposed smoothing approach for the MRFSS data was approved.
- The AW agreed that the best available data are used in the assessment.
- The change as a result of the adjusted MARMAP age composition data was mostly that it provided a more stable estimate of the dome shaped selectivity of the chevron trap.

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. Document model code in an AW working paper.

After the initial runs, it was discovered that steepness was running into its upper bounds. The Assessment Workshop panel discussed the possibility of fixing steepness at a value that provides consistency between Fmsy and a proxy, most notably the proxy used in SEDAR 15 (red snapper). In that assessment, F40% was used as a proxy for Fmsy, as suggested by Mace (1994). For this assessment, the Assessment Workshop panel decided upon a steepness value of 0.56 corresponding to F40%. The Panel discussed using a different proxy for vermilion snapper due to differences in life-history traits between the two species. It was ultimately decided to use the same proxy for the base run as there is no documented link between steepness and life-history traits, and to examine effects of this decision through sensitivity runs.

The panel agreed on a base run and 23 sensitivity runs (see chapter 3 for list of model runs).

The model code was documented by the modelers in an AW working paper (AW11) to be provided following the workshop.

10. Consider the data workshop research recommendations. Provide additional recommendations for future research and data collection (field and assessment); be as specific in describing sampling design and sampling intensity.

Review of Data Workshop Recommendations

All Data workshop research recommendations were discussed and there were only slight changes in the recommendations by the AW panel. The collection and processing of hard parts for each of the species should be specified in terms of numbers, locations, season, fisheries, etc. as to make most efficient use of limited resources.

AW Research Recommendations

- Better description (numbers, sizes, etc.) of fish kept for bait in the headboat fishery.
- Investigate catchability issues. This recommendation will be addressed at the Catchability Workshop.

Other Recommendations of the Assessment Panel

Comprehensive Data and Assessment Archive: A goal of the SEDAR process, as stated in several workshop Terms of Reference, is to properly document all aspects of the data employed in the assessments, the assessments themselves, and the peer review of assessment details and results. While the various workshop reports and data workbooks compile much of the information, concern has been expressed that a full compilation of data manipulations, and programs used to generate the final data used in the assessment is not available following a SEDAR cycle. The concept of a SEDAR Comprehensive Data and Assessment Workshops Archive was proposed by the SEDAR 17 Data Compiler during preparations for the DW. Though the idea was not advanced from the DW as a formal recommendation it was generally taken favorably. An archive could serve as: a single reference for anyone wishing to dig deeper into how data were processed, a reference for future assessments, a backup of final data processing programs or spreadsheets for those who develop them, and continuity in cases of personnel changes for future assessments and updates. When discussed at the AW it was recognized implementation of an archive could have benefits and costs, but that it would require more attention than SEDAR 17 AW participants could give it, and all SEDAR cooperators were not present. The AW recommends that a SEDAR-wide workgroup be convened to identify the pros and cons of a Comprehensive Data and Assessment Archive for each future SEDAR.

Independent Expert on Assessment Panel: The assessment panel recommends that for future SEDAR assessment workshops, a scientist experienced in assessment methods and modeling (such as a CIE reviewer, or a NMFS or state person from outside the region) be provided as a workshop panelist. An independent expert can participate in discussing technical details of the methods used for SEDAR assessments, and assist in decisions related to model configuration during the workshop. In particular, the analysts believe that an independent analyst could contribute fresh information to improve the assessments.

Review and Qualification of Historic Recreational Angler Survey Reports: Pre-MRFSS catch and related effort data from south Atlantic recreational fisheries are very scarce, but are considered valuable to stock assessments, where available. Two reports of the U. S. Fish and Wildlife Service (SEDAR 17-RD13 and SEDAR 17-RD14) and one of the NMFS (SEDAR 17-RD15) characterize south Atlantic salt-water angling effort and success based on recall surveys conducted in 1960, 1965, and 1970, respectively. These references have been viewed in various ways in previous stock assessments performed through

the SEDAR process. In SEDAR 2 for South Atlantic black sea bass, these data were not used explicitly in the age-structured modeling, however, with assumptions, were used to extend the time frame for application of the production modeling approach. In SEDAR 15 for South Atlantic red snapper these data were employed by the assessment panel at face value for the three survey years and to interpolate recreational landings before, between, and after survey years. In SEDAR 15 for South Atlantic greater amberjack the review panel agreed with the assessment panel that the survey estimates of recreational landings of "jacks" not be included in the assessment due in part to species identification concerns. For the present assessment the assessment panel has employed the survey data for both stocks under assessment, but considers recall bias on the part of persons surveyed to be a significant factor. Thus they chose to reduce the weight of the estimates in its base runs and explore the effect on the model through sensitivity runs.
A guiding principal of the SEDAR process is consistency in the identification and utilization of data that characterize fishery stocks under assessment and the fisheries that affect the stocks. Because the three pre-MRFSS saltwater angling survey reports have proven of value, and likely will be referenced in future stock assessments, the AW recommends they be reviewed by a group of fishery professionals. The group should include persons knowledgeable in survey design, data collection, and application of survey data to fishery stock assessments. The group's function would be to qualify the three surveys, and others which the group may identify, and provide guidelines that further consistency in their utilization in future stock assessment conducted under the SEDAR process. The review of these reports could be coupled with a review and qualification of commercial and other data to standardize their use in stock assessments, as recommended in the SEDAR 17 data workshop reports.

Avoid Brief Workshop Interims: The panel made a recommendation against scheduling abbreviated SEDAR stock assessments. AW participants felt that an abbreviated schedule could compromise the quality of the assessment.

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

The spreadsheet developed to meet this term was prepared by the analysts as AW13.

2. Data Input and Changes

Processing of data for the assessment is described in the SEDAR 17 Vermilion Snapper Data Workshop Report. This section describes additional processing of the data for use in the assessment models.

2.1 Life History

2.1.1 Modifications to Natural Mortality

Lorenzen (1996) estimates of age-specific natural mortality were rescaled to the Hoenig estimate of M=0.22 using ages 1+, such that both estimates provided the same proportion (0.015) surviving through the oldest age observed (Table 2.1). For sensitivity runs of the assessment model, upper and lower bounds were similarly rescaled to M=0.28 and M=0.16, providing 0.005 and 0.048 proportion surviving through the oldest age, respectively.

2.1.2 Generation Time

If a stock rebuilding plan becomes necessary, generation time (G) would be used in computing the rebuilding time frame. Generation time was estimated here from Eq. 3.4 in Gotelli (1998, p. 57):

$$G = \Sigma\, l_x b_x x / \Sigma\, l_x b_x,$$

where summation was over ages x = 1 through 100 (by which age the numerator and denominator were both essentially zero), l_x is the number of fish at age starting with one fish at age-1 and decrementing based on natural mortality only, and b_x is per capita birth rate of mature females at age ($b_x = m_x f_x$, where m_x is proportion of females mature at age and f_x is expected fecundity at age. This weighted average age of mature female fecundity (i.e., generation time) yields an estimate of 8.1 yrs.

2.1.3 Age Reading Error

An age-reading error matrix was developed for use in the assessment, as described in the document SEDAR17-AW03. The matrix (Table 2.2) is used to convert modeled ages for matching observed (i.e., read with error) age compositions.

2.2 Commercial Fishery

2.2.1 Commercial Landings

Commercial landings were further subdivided into one of three components. The primary gear was handline, which included manual and electric reels (also, 96 lb of trawl landings from 1965 were lumped into handline). The secondary gear was a combined gear category, which consisted mostly of trawl landings during the 1970s and 1980s, and mostly of "other" landings during 1989–2007 ("other" included trawl, trap, spears, longline, and other miscellaneous gears). Historical trawl was separated as its own two-year time series (1961-1962), as it was then the overall dominant gear and to distinguish it from the more recent trawl fishery (Table 2.3).

For the statistical catch-age model, the decision was made to fit landings exactly when possible; to facilitate this, a common coefficient of variation of 0.05 was assigned to all landings time series (Table 2.3). This approach followed suggestions by the SEDAR 15 Review Workshop, where it was argued that possible deviations from observed landings be considered in sensitivity analysis by running the model with alternative landings time series.

2.2.2 Commercial Length and Age Compositions

Commercial length compositions were updated to have a minimum of 15 cm total length (TL) and a maximum of 60 cm TL (with 60 cm treated as a plus group) for input into the assessment model, with 1cm bins. Age compositions were updated to range from ages 1 to 12 (with 12 treated as a plus group).

2.2.3 Commercial Discards

Estimates of commercial discards for vermilion snapper can be found in SEDAR 17-DW10 (*Discards of Spanish Mackerel and Vermilion Snapper Calculated for Commercial Vessels with Federal Fishing Permits in the US South Atlantic*) for the period 1992-2007. Extension of commercial discards prior to 1992 (implementation of 12-inch TL size limit) was deemed unnecessary, although some unknown small amount may have been kept for bait. However, information provided in the above report was used to develop a rough estimate of the proportion "discards" that were released (mostly alive) versus those kept for bait. This estimate (5.35%) of vermilion snapper kept for bait (but listed as discards) was developed directly from Table 5 of SEDAR 17-DW10. The terminology here is a bit misleading, because clearly fish kept for bait are not released and have a mortality rate of 100%. Thus, in the assessment, "release" mortality of commercial discards was adjusted upward to account for fish kept as bait, by using commercial discard mortality rate of 41%, rather than 38% from the DW report. The value of 41% was computed as the weighted average 5.35×100% + (100-5.35) ×38%.

Subsequent to the SEDAR 17 DW, observer data became available from the South Atlantic commercial handline fishery. These data are collected through a MARFIN project by the Gulf and South Atlantic Fishery Foundation and the data set is maintained by the Galveston Laboratory of the NMFS-SEFSC. To date, data have been collect since 28 December 2006 and are available through February 2008. Of 5,507 vermilion snapper whose lengths were measured, 298 were released alive, 97 were kept for bait, 5,108 were kept (i.e., landed), and 3 were of unknown fate. The length distributions of the 298 fish released alive and of the 97 kept for bait were quite similar (Figure 2.1). Thus, these

298+97 fish were combined to describe the length distribution of vermilion snapper caught or kept for bait by the commercial handline fishery.

2.3 Recreational Fishery

2.3.1 Recreational Landings

The 1960, 1965, and 1970 recreational landings estimates (Clark, 1962; Deuel and Clark, 1968; Deuel, 1973) in number included headboat landings and the typical MRFSS fishing modes (shore, private vessel, charter vessel). Appropriate use of these values received considerable discussion during the SEDAR 17 AW. In particular, the AW panel was concerned about the potential for recall bias, as the salt-water angling survey was based on a 1-year recall. In general, such a long recall is likely to lead to overestimates of landings and effort (Thompson and Hubert, 1990; Tarrant et al., 1993; Connelly and Brown, 1995). At least one author has suggested that landings reported in these salt-water angling surveys could be biased high by as much as 100% (Terceiro, 2002). The AW panel had no information to estimate the amount of bias for SEDAR 17 species, but acknowledged that landings reported in the angling survey were likely biased high, and recommended reducing the 1960, 1965, and 1970 estimates to between 50% and 100% of the reported values. Thus, these estimates were reduced to 75% of the reported values for the base run of the assessment model. For sensitivity runs, values of 50%, 100%, and 125% were used.

Because the salt-water angling survey included headboat and other recreational sources, values from the survey were partitioned into headboat and general recreational landings for use in the assessment, using the average ratio of annual headboat to total landings from 1986-2007 (Figure 4.9.6 of the SEDAR17 DW report). The average ratio of annual headboat to total recreational landings was 0.73, and this value was used to estimate headboat landings as a portion of the salt-water angling survey estimates for 1960, 1965, and 1970. These values were then multiplied by 0.75 to adjust for recall bias (or multiplied by 0.5, 1.0, or 1.25 for sensitivity runs). The “predict” function applied to the output of the “smooth.spline” function within the R software package was used to generate point estimates of smoothed landings for 1946-1971. The 1946 landings were assumed to be 0 and the1972 headboat survey landings estimate was used as the upper anchor point. The smoothing parameter (spar) option was set to 0.25 in the smooth.spline function. The predicted values for 1947-1971 were combined with the headboat survey estimates (1972-2007) to generate the times series of headboat landings from 1947-2007 (Table 2.4, Figure 2.2).

The MRFSS landings portion of the salt-water angling survey was 0.27 (one minus the headboat portion). The 1960, 1965, and 1970 salt-water angling survey estimates were adjusted by 0.27 to give the MRFSS proportion of landings, and these values were then multiplied by 0.75 to adjust for recall bias (or multiplied by 0.5, 1.0, or 1.25 for sensitivity runs). The MRFSS landings were erratic in the early years of the survey (1981-86) and the estimated PSE values were high in the early years also. To account for what appears to be sampling error, the entire time series of MRFSS landings was smoothed, weighted by the inverse of the PSE of MRFSS landings in numbers squared multiplied by 100. Squaring the PSE more dramatically decreases the weight given to larger PSE values while multiplying by 100 shifts the relationship between PSE and weight so that all PSE values less than 10 get full weight (Figure 2.3). The salt-water angling PSE estimates were the highest in the time series. The "predict" function applied to the output of the "smooth.spline" function within the R software package with the smoothing factor (spar) set to 0.35 was used to generate 1) smoothed point estimates of MRFSS landings in pounds for years where data was available (1960, 1965, 1970, 1981-2007) 2) point estimates of smoothed landings for missing years from 1946-1980 (Figure 2.4). This was a two step smoothing function determining the 1981-2007 prediction first and then the 1946-1980 with the predicted landings from 1981, the first year of predicted data in the first series, serving as the anchor point for the second step of smoothing and predicting landings. These two time series of smoothed landings were then combined to generate the input for the assessment model (Table 2.4).

For the statistical catch-age model, the decision was made to fit landings exactly when possible; to facilitate this, a common coefficient of variation of 0.05 was assigned to all landings time series (Table 2.4). This approach followed suggestions by the SEDAR 15 Review Workshop, where it was argued that possible deviations from observed landings be considered in sensitivity analysis by running the model with alternative landings time series.

2.3.2 Recreational Length and Age Compositions

Recreational length compositions were truncated to start at 15 cm (146mm-155mm) TL and pool the values greater than 60 cm into the 60 cm bin (596-605mm) creating a 60 plus group. The annual compositions were renormalized to sum to 1. However the sample sizes were not adjusted for truncating. There were relatively few fish in these bins and determining the number of fish in each bin is complicated by the weighting of the length composition. The 1972-1975 compositions for headboat were dropped because of incomplete coverage.

The recreational age compositions contain no updates since the DW.

2.3.3 Recreational Discards

Discards were estimated in numbers from headboat (2004-2007) and MRFSS (1981-2007) were available from the DW. Because MRFSS data indicated that discards occurred prior to size-limit regulations, discard estimates of recreational fisheries were extended back to the starting year (1947), as described below.

The discard ratio for MRFSS (discards in number/landings in number) was computed for 1981-2007 and extended back to 1946 as the average annual discard ratio for the years prior to size limit regulations (1981-1991). In a few years of MRFSS discards (1981, 1983, 1985-1987), discards were zero or near zero, and in those cases were replaced with the average of the two surrounding years. Headboat discard ratios for 1999-2003 were computed as the average discard ratio from the years available within the same management period (2004-2006). Discard ratios for 1992-1998 were computed as the 1999 discard ratio estimate from headboat multiplied by the ratio of the average annual MRFSS discard ratio (1992-1998) to the average annual MRFSS discard ratio (1999-2006). The headboat discard ratio prior to size limit regulations were determined by multiplying the 1992 discard ratio by the ratio of the average annual MRFSS discard ratio (1981-1991) to the average annual MRFSS discard ratio (1992-1998). I

The missing years of discards in thousands of fish for both recreational data sources were computed as the final time series of landings in thousands of fish multiplied by the annual discard ratio. Figure 2.5 and Table 2.4 show the series of discard estimates in numbers for 1947-2007.

2.4 Indices of abundance

2.4.1 MARMAP Chevron Trap Length and Age Compositions

Composition data from fishery independent sampling are included in the catch-age assessment for a single purpose—to allow estimation of the gear's selectivity (which itself is used for matching the index of abundance). Because the model is age-structured, selectivity is treated as a function of age. As such, age composition data are more valuable than length composition data for estimating selectivity. Thus, MARMAP chevron trap length compositions were not included as a data source for fitting the assessment model. Instead, selectivity of MARMAP chevron traps was estimated solely from the age composition data.

During the assessment workshop, MARMAP age compositions were re-calculated because of the non-random nature of the MARMAP sub-sampling regime, which was not accounted for in the data provided during the data workshop. The MARMAP methodology between 2002 and 2007 (age composition data included for this stock assessment) included sub-sampling the catch for age composition by latitude degrees and cm length class. The sub-sampling methodology for all latitudes except 32° N involved retaining the first 15 fish per cm class per latitude for age growth and reproductive analysis. Sub-sampling within the 32° N latitudes was different due to a higher sampling effort in this latitude and consisted of retaining the first 5 fish per cm bin per trip (5-6 trips/year; each trip was 2-9 days). Once a sub-sample (15 or 5, depending on latitude) was met within a cm size class, no further fish were retained for that size class. From 2002 to 2007, this sub-sampling regime resulted in MARMAP retaining between 44-94% of the total number of vermilion snapper collected (Table 2.5).

The following was done to correct for the sub-sampling regime: Within each sub-sampling combination (year/latitude/cm or year/latitude/cm/trip), the number of fish captured per length class and the number of fish sub-sampled were summarized and used to calculate a proportion for each sub-sampling combination. After determining the proportion for each sub-sampling combination, the number of each age fish within each combination was calculated. This value was then adjusted using the proportion for each category for an estimate of the number of fish each age. These values were then used to create a new age composition for each year.

2.4.2 Annual CVs

As in previous SEDAR assessments, annual CVs of each index of abundance were rescaled to a maximum of 0.3. The reasons for rescaling are two-fold. First, CVs of the various indices were not all estimated by the same methods, and are thus not comparable across indices. Second, rescaling allows external weights of the different indices to have more interpretable control of model fits, while still allowing CVs to affect relative influence of data points within a time series.

2.4.3 Combining Indices

The various indices used in the statistical catch-age model were combined into a single index for use in the production and stock-reduction models. For this analysis, the headboat index was divided into two periods, 1976–1991 and 1992–2007, because of a possible effect on CPUE of the 10-inch recreational size limit implemented in 1992. The method used to combine indices was the same as that used for Spanish mackerel, as described in SEDAR17-AW06. In brief, the method assumes that observed indices are sampled from a common population trend, subject to process and sampling error. The underlying trend is estimated through Bayesian analysis of a hierarchical model (Figures 2.6, 2.7), and that estimated trend serves as the combined index.

The statistical catch-age model applied a linearly increasing catchability of 2% per year to fishery dependent indices. Production and stock-reduction models did not model increasing catchability explicitly, but rather included it implicitly by adjusting the combined index of abundance with a linear decrease of 2% per year (Table 2.6, Figure 2.8).

2.5 Total removals

Although the catch-age assessment modeled landings and discards by fishery, the surplus production model and stock reduction analysis utilized a single time series of total removals. This single time series combined landings and discards in pounds of whole weight.

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Table 2.1 Estimates of age-specific natural mortality from Lorenzen, scaled to the Hoenig estimate of M=0.22, as well lower (M=0.16) and upper (M=0.28) bounds.

Age	Lorenzen M	Scaled M (M=0.22)	Scaled M (M=0.16)	Scaled M (M=0.28)
1	0.799	0.341	0.248	0.434
2	0.713	0.304	0.221	0.387
3	0.651	0.278	0.202	0.354
4	0.605	0.258	0.188	0.329
5	0.570	0.243	0.177	0.310
6	0.542	0.231	0.168	0.295
7	0.520	0.222	0.161	0.282
8	0.502	0.214	0.156	0.272
9	0.486	0.208	0.151	0.264
10	0.474	0.202	0.147	0.257
11	0.463	0.198	0.144	0.252
12	0.454	0.194	0.141	0.247
13	0.446	0.191	0.139	0.243
14	0.440	0.188	0.137	0.239
15	0.434	0.185	0.135	0.236
16	0.429	0.183	0.133	0.233
17	0.425	0.181	0.132	0.231
18	0.421	0.180	0.131	0.229
19	0.418	0.178	0.130	0.227

Table 2.2 Age-reading error matrix.

	True Age												
Pred Age	1	2	3	4	5	6	7	8	9	10	11	12	
1	0.671	0.231	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
2	0.301	0.516	0.227	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
3	0.027	0.231	0.505	0.227	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
4	0.000	0.021	0.227	0.505	0.227	0.020	0.000	0.000	0.000	0.000	0.000	0.000	
5	0.000	0.000	0.020	0.227	0.505	0.227	0.020	0.000	0.000	0.000	0.000	0.000	
6	0.000	0.000	0.000	0.020	0.227	0.505	0.227	0.020	0.000	0.000	0.000	0.000	
7	0.000	0.000	0.000	0.000	0.020	0.227	0.505	0.227	0.020	0.000	0.000	0.000	
8	0.000	0.000	0.000	0.000	0.000	0.020	0.227	0.505	0.227	0.020	0.000	0.000	
9	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.227	0.505	0.227	0.020	0.000	
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.227	0.505	0.225	0.020	
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.227	0.501	0.223	
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.021	0.253	0.756	Plus group

Table 2.3 Commercial landings and discards as used in the catch-age assessment model. The H. Trawl category is historical trawl, and the Combined category includes trawl landings since 1970.

Landings							Discards	
	1000 lb whole weight			CV's			1000 fish	CV
Year	Handline	H. Trawl	Combined	Handline	H. Trawl	Combined	Handline	Handline
1958	0.1941	0.0000	0.0000	0.05	0.00	0.00	0	0
1959	1.2619	0.0000	0.0000	0.05	0.00	0.00	0	0
1960	1.7472	0.0000	0.0000	0.05	0.00	0.00	0	0
1961	19.3167	24.0246	0.0000	0.05	0.05	0.00	0	0
1962	10.8222	42.5823	0.0000	0.05	0.05	0.00	0	0
1963	20.9669	0.0000	0.0000	0.05	0.00	0.00	0	0
1964	6.7919	0.0000	0.0000	0.05	0.00	0.00	0	0
1965	22.0094	0.0000	0.0000	0.05	0.00	0.00	0	0
1966	3.3974	0.0000	0.0000	0.05	0.00	0.00	0	0
1967	14.1721	0.0000	0.0000	0.05	0.00	0.00	0	0
1968	31.9357	0.0000	0.0000	0.05	0.00	0.00	0	0
1969	31.3475	0.0000	0.0000	0.05	0.00	0.00	0	0
1970	19.5109	0.0000	0.0000	0.05	0.00	0.00	0	0
1971	66.3214	0.0000	0.3955	0.05	0.00	0.05	0	0
1972	68.7938	0.0000	11.7898	0.05	0.00	0.05	0	0
1973	86.1925	0.0000	6.1121	0.05	0.00	0.05	0	0
1974	119.3868	0.0000	2.7278	0.05	0.00	0.05	0	0
1975	218.6555	0.0000	2.8250	0.05	0.00	0.05	0	0
1976	212.4096	0.0000	7.5215	0.05	0.00	0.05	0	0
1977	273.3219	0.0000	11.2970	0.05	0.00	0.05	0	0
1978	345.0756	0.0000	1.0465	0.05	0.00	0.05	0	0
1979	430.8881	0.0000	54.1611	0.05	0.00	0.05	0	0
1980	482.6361	0.0000	268.6132	0.05	0.00	0.05	0	0
1981	500.8858	0.0000	242.8936	0.05	0.00	0.05	0	0
1982	672.7962	0.0000	215.6655	0.05	0.00	0.05	0	0
1983	645.7321	0.0000	142.7823	0.05	0.00	0.05	0	0
1984	734.0766	0.0000	117.9559	0.05	0.00	0.05	0	0
1985	920.5064	0.0000	24.9836	0.05	0.00	0.05	0	0
1986	896.3793	0.0000	23.9772	0.05	0.00	0.05	0	0
1987	697.9285	0.0000	51.6314	0.05	0.00	0.05	0	0
1988	854.2274	0.0000	131.5371	0.05	0.00	0.05	0	0
1989	1041.5094	0.0000	90.0653	0.05	0.00	0.05	0	0
1990	1141.1896	0.0000	148.7127	0.05	0.00	0.05	0	0
1991	1332.6934	0.0000	61.4177	0.05	0.00	0.05	0	0
1992	764.9364	0.0000	0.2775	0.05	0.00	0.05	75.0240	0.05
1993	866.3612	0.0000	8.5520	0.05	0.00	0.05	84.2710	0.05
1994	948.4258	0.0000	9.7341	0.05	0.00	0.05	105.6070	0.05
1995	928.4970	0.0000	2.8768	0.05	0.00	0.05	127.4570	0.05
1996	743.6924	0.0000	1.3942	0.05	0.00	0.05	164.3450	0.05
1997	759.0050	0.0000	2.0116	0.05	0.00	0.05	152.6960	0.05
1998	708.1121	0.0000	2.3942	0.05	0.00	0.05	119.8030	0.05
1999	876.5837	0.0000	4.5096	0.05	0.00	0.05	100.0770	0.05
2000	1348.5193	0.0000	1.5921	0.05	0.00	0.05	104.7820	0.05
2001	1633.5940	0.0000	3.2303	0.05	0.00	0.05	124.9080	0.05
2002	1334.4184	0.0000	1.3379	0.05	0.00	0.05	237.0200	0.05
2003	727.8589	0.0000	6.9700	0.05	0.00	0.05	98.2840	0.05
2004	1086.2997	0.0000	2.6764	0.05	0.00	0.05	49.7620	0.05
2005	1100.9156	0.0000	0.8709	0.05	0.00	0.05	74.9450	0.05
2006	827.1596	0.0000	1.4604	0.05	0.00	0.05	47.1930	0.05
2007	1012.6122	0.0000	7.6927	0.05	0.00	0.05	51.7740	0.05

Table 2.4 Recreational landings and discards as used in the catch-age assessment model. The General category is general recreational, sampled by the MRFSS starting in 1981.

	Number (1000 fish)							
Year	Landings		CV's		Discards		CV's	
Year	Headboat	General	Headboat	General	Headboat	General	Headboat	General
1946	0.000	0.000	0.05	0.05	0.000	0.000	0.05	0.05
1947	14.632	9.013	0.05	0.05	0.903	1.953	0.05	0.05
1948	30.581	17.077	0.05	0.05	1.887	3.701	0.05	0.05
1949	46.801	25.099	0.05	0.05	2.888	5.439	0.05	0.05
1950	63.431	33.059	0.05	0.05	3.915	7.165	0.05	0.05
1951	80.610	40.935	0.05	0.05	4.975	8.871	0.05	0.05
1952	98.478	48.707	0.05	0.05	6.078	10.556	0.05	0.05
1953	117.175	56.352	0.05	0.05	7.231	12.213	0.05	0.05
1954	136.839	63.851	0.05	0.05	8.445	13.838	0.05	0.05
1955	157.611	71.182	0.05	0.05	9.727	15.426	0.05	0.05
1956	179.629	78.325	0.05	0.05	11.086	16.974	0.05	0.05
1957	203.033	85.257	0.05	0.05	12.530	18.477	0.05	0.05
1958	227.963	91.959	0.05	0.05	14.069	19.929	0.05	0.05
1959	254.558	98.409	0.05	0.05	15.710	21.327	0.05	0.05
1960	282.957	104.587	0.05	0.05	17.463	22.666	0.05	0.05
1961	312.783	110.447	0.05	0.05	19.303	23.936	0.05	0.05
1962	341.589	115.852	0.05	0.05	21.081	25.107	0.05	0.05
1963	366.412	120.640	0.05	0.05	22.613	26.145	0.05	0.05
1964	384.289	124.651	0.05	0.05	23.716	27.014	0.05	0.05
1965	392.256	127.722	0.05	0.05	24.208	27.680	0.05	0.05
1966	388.652	129.749	0.05	0.05	23.986	28.119	0.05	0.05
1967	377.023	130.858	0.05	0.05	23.268	28.359	0.05	0.05
1968	362.218	131.230	0.05	0.05	22.354	28.440	0.05	0.05
1969	349.083	131.049	0.05	0.05	21.544	28.401	0.05	0.05
1970	342.467	130.497	0.05	0.05	21.135	28.281	0.05	0.05
1971	345.461	129.728	0.05	0.05	21.320	28.114	0.05	0.05
1972	402.814	128.788	0.05	0.05	24.860	27.911	0.05	0.05
1973	383.908	127.693	0.05	0.05	23.693	27.673	0.05	0.05
1974	421.690	126.461	0.05	0.05	26.025	27.406	0.05	0.05
1975	477.319	125.109	0.05	0.05	29.458	27.113	0.05	0.05
1976	399.737	123.653	0.05	0.05	24.670	26.798	0.05	0.05
1977	317.303	122.112	0.05	0.05	19.582	26.464	0.05	0.05
1978	487.529	120.503	0.05	0.05	30.088	26.115	0.05	0.05
1979	425.382	118.841	0.05	0.05	26.252	25.755	0.05	0.05
1980	322.990	117.146	0.05	0.05	19.933	25.388	0.05	0.05
1981	270.987	115.008	0.05	0.05	16.724	33.350	0.05	0.05
1982	362.321	230.532	0.05	0.05	22.361	41.312	0.05	0.05
1983	399.040	304.266	0.05	0.05	24.627	31.903	0.05	0.05
1984	324.429	366.589	0.05	0.05	20.022	22.494	0.05	0.05
1985	529.803	420.894	0.05	0.05	32.697	24.091	0.05	0.05
1986	533.101	307.370	0.05	0.05	32.900	24.091	0.05	0.05
1987	731.007	202.196	0.05	0.05	45.114	24.091	0.05	0.05
1988	740.891	179.117	0.05	0.05	45.724	25.687	0.05	0.05

1989	661.251	202.690	0.05	0.05	40.809	63.855	0.05	0.05
1990	655.859	190.929	0.05	0.05	40.476	71.476	0.05	0.05
1991	600.501	164.798	0.05	0.05	37.060	42.392	0.05	0.05
1992	345.266	136.442	0.05	0.05	67.499	79.547	0.05	0.05
1993	327.027	116.230	0.05	0.05	63.934	48.160	0.05	0.05
1994	369.720	85.881	0.05	0.05	72.280	66.768	0.05	0.05
1995	354.766	81.076	0.05	0.05	69.357	121.089	0.05	0.05
1996	340.340	93.301	0.05	0.05	66.536	41.777	0.05	0.05
1997	364.742	104.549	0.05	0.05	71.307	41.445	0.05	0.05
1998	341.563	120.203	0.05	0.05	66.775	59.409	0.05	0.05
1999	381.936	165.514	0.05	0.05	86.492	257.553	0.05	0.05
2000	428.235	209.669	0.05	0.05	96.977	215.610	0.05	0.05
2001	418.876	212.669	0.05	0.05	94.858	137.247	0.05	0.05
2002	335.543	191.314	0.05	0.05	75.986	108.259	0.05	0.05
2003	251.796	204.084	0.05	0.05	57.021	183.324	0.05	0.05
2004	329.081	212.034	0.05	0.05	87.969	150.603	0.05	0.05
2005	275.450	180.800	0.05	0.05	52.502	87.678	0.05	0.05
2006	344.724	180.756	0.05	0.05	76.340	83.166	0.05	0.05
2007	507.970	213.288	0.05	0.05	127.773	262.351	0.05	0.05

Table 2.5. Sub-sampling of fish for ageing from MARMAP chevron traps.

Year	Captured	Sub-sampled	Percentage
2002	1742	780	45%
2003	245	230	94%
2004	362	317	88%
2005	746	505	68%
2006	363	276	76%
2007	1221	541	44%

Table 2.6. Combined index of abundance for vermilion snapper off the southeastern U.S. Estimated values are those from Bayesian analysis. Adjusted values are the estimated values decreased linearly by 2% per year, as used in the production and stock-reduction assessment models to account for increased catchability.

Year	Estimated	Adjusted
1976	1.100	1.100
1977	0.894	0.876
1978	1.355	1.302
1979	1.291	1.218
1980	0.860	0.796
1981	1.180	1.073
1982	1.145	1.022
1983	1.364	1.196
1984	1.009	0.870
1985	1.229	1.042
1986	1.023	0.852
1987	0.910	0.746
1988	0.769	0.621
1989	0.654	0.519
1990	0.856	0.668
1991	0.839	0.645
1992	0.602	0.456
1993	0.639	0.477
1994	0.652	0.480
1995	0.717	0.520
1996	0.730	0.522
1997	0.843	0.594
1998	0.784	0.544
1999	0.992	0.679
2000	1.226	0.828
2001	1.265	0.843
2002	1.249	0.822
2003	1.019	0.661
2004	1.207	0.773
2005	1.268	0.803
2006	1.167	0.729
2007	1.162	0.718

Table 2.7 Total removals in whole weight, as used in surplus production model and stock reduction analysis.

Year	Landings (lb)
1946	0
1947	17824
1948	35917.8
1949	54183.3
1950	72709.2
1951	91584.3
1952	110897.4
1953	130737.4
1954	151192.9
1955	172352.8
1956	194306
1957	217141.1
1958	241128.7
1959	266994.2
1960	293462.5
1961	359261.9
1962	394420.3
1963	386316.1
1964	389508.4
1965	412072.8
1966	393472.3
1967	395670
1968	401468.8
1969	390915.6
1970	374442.7
1971	420318.6
1972	480034.6
1973	465084.7
1974	526169.6
1975	683473.2
1976	583413.6
1977	563384.5
1978	726839.3
1979	811080.7
1980	1020397.1
1981	1027764.3
1982	1392755.9
1983	1263343.9
1984	1322975.3
1985	1557867.9
1986	1417236.3
1987	1284662.3
1988	1448930.6
1989	1520240.9
1990	1715555.5
1991	1736478.6

1992	1080203.1
1993	1179459.8
1994	1258760.2
1995	1226414.1
1996	1060844.2
1997	1110000.7
1998	1050848.2
1999	1358523.3
2000	1916342.8
2001	2172376.2
2002	1789221.8
2003	1245288.6
2004	1648408.8
2005	1568545
2006	1410770.2
2007	1897131.9

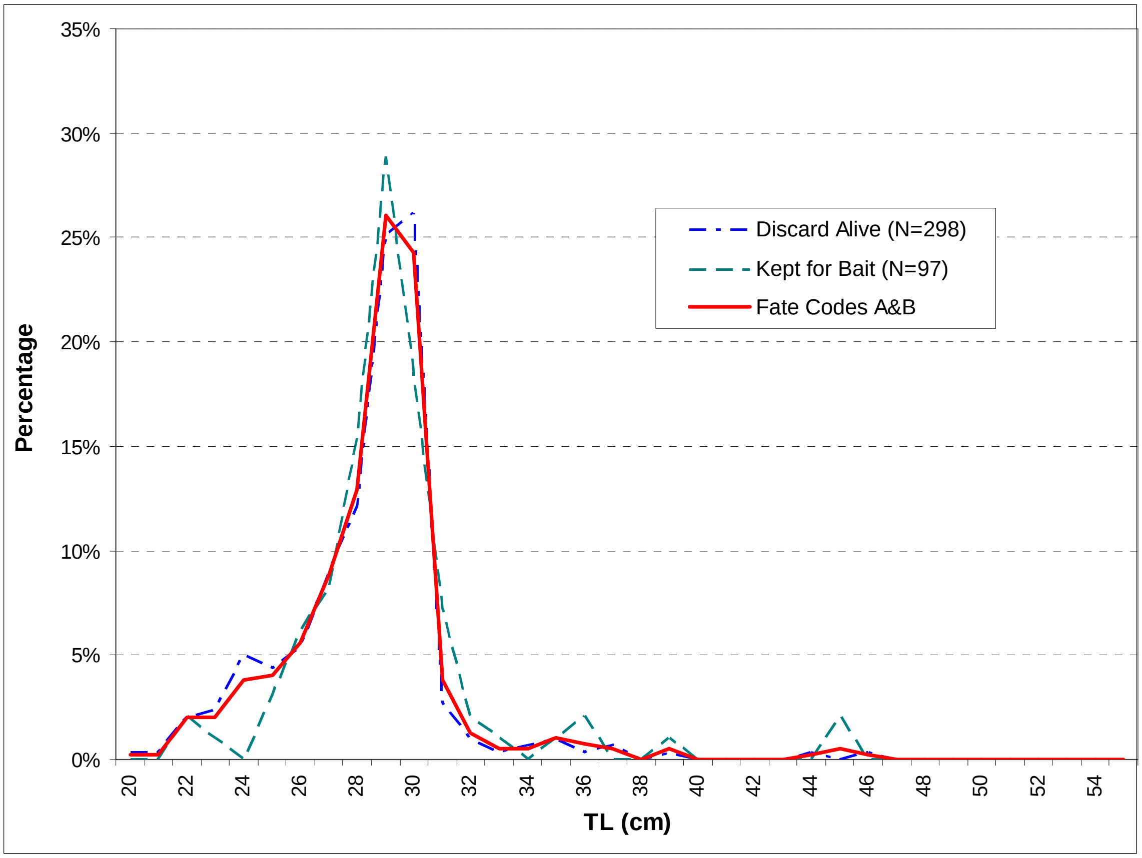

Figure 2.1. Length compositions of vermilion snapper released alive or kept for bait from observer coverage of the South Atlantic bandit rig fishery between December 28, 2006 and February 20, 2008 (MARFIN project of Gulf and South Atlantic Fishery Foundation).

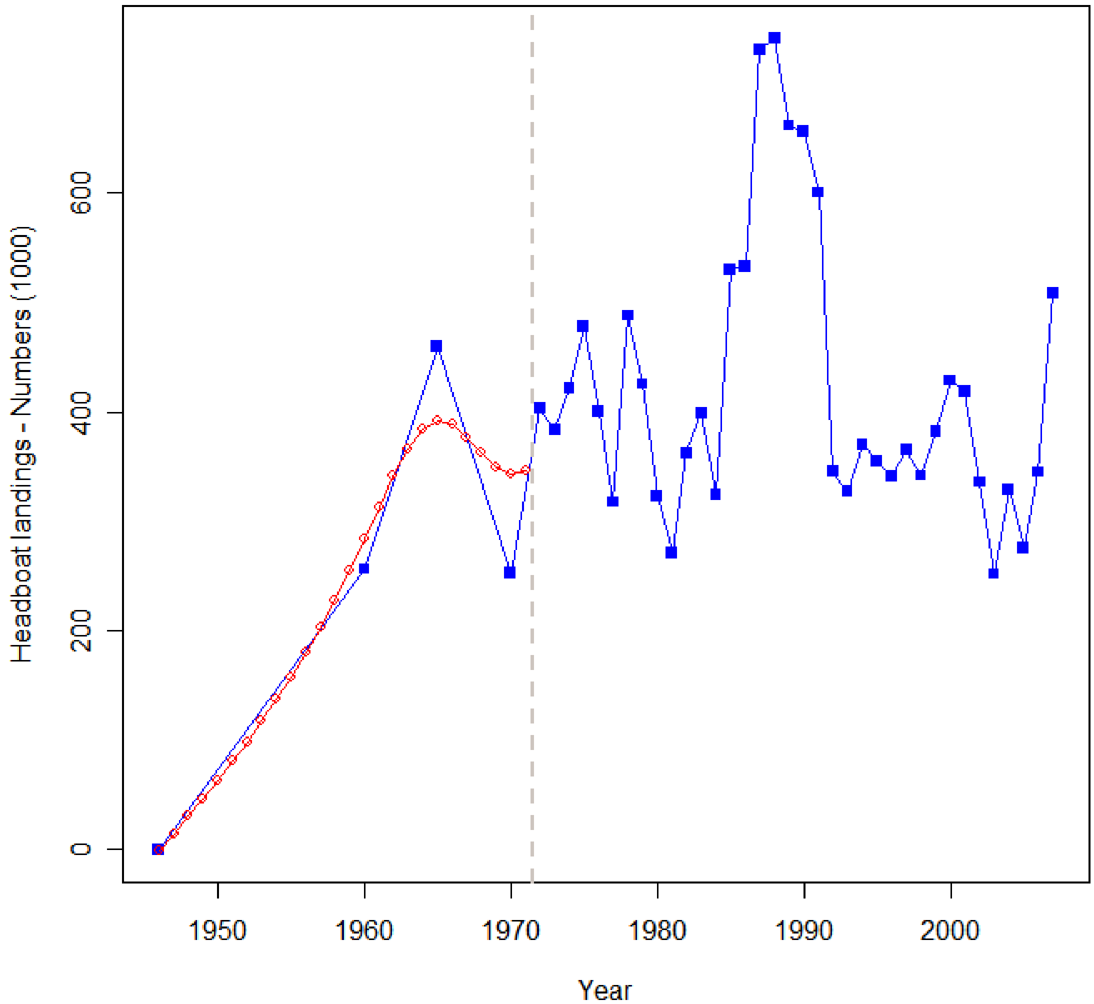

Figure 2.2. Smoothed and predicted headboat landings (open red circles) and estimated headboat landings (closed blue squares) in thousands of fish. Vertical line represents split between the series. The predicted values to the left of the vertical dashed line (open red circles) was combined with the headboat survey estimates to the right to give the assessment model input.

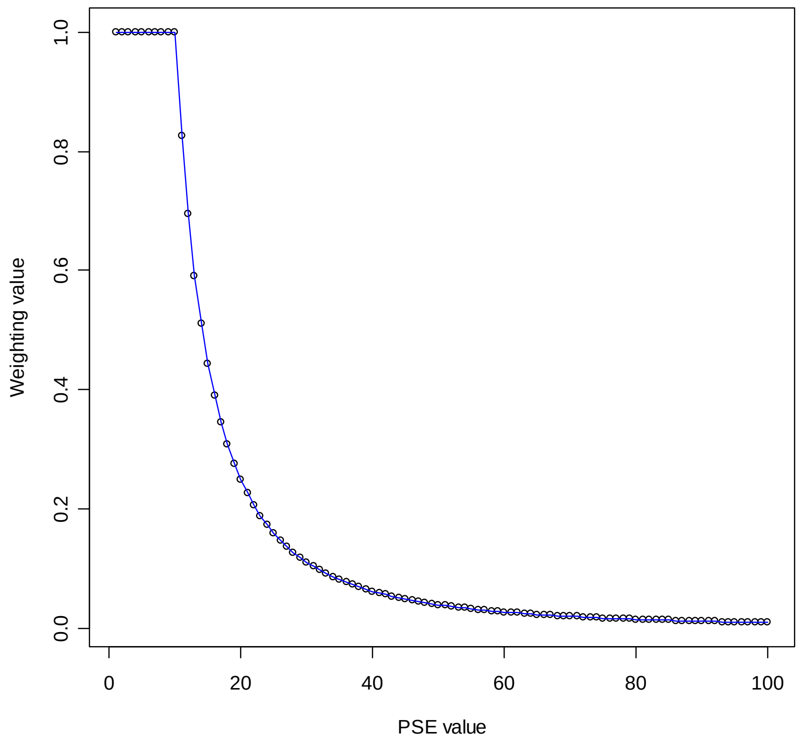

Figure 2.3. Relationship between the MRFSS PSE estimates and the weighting applied to the smoothing function.

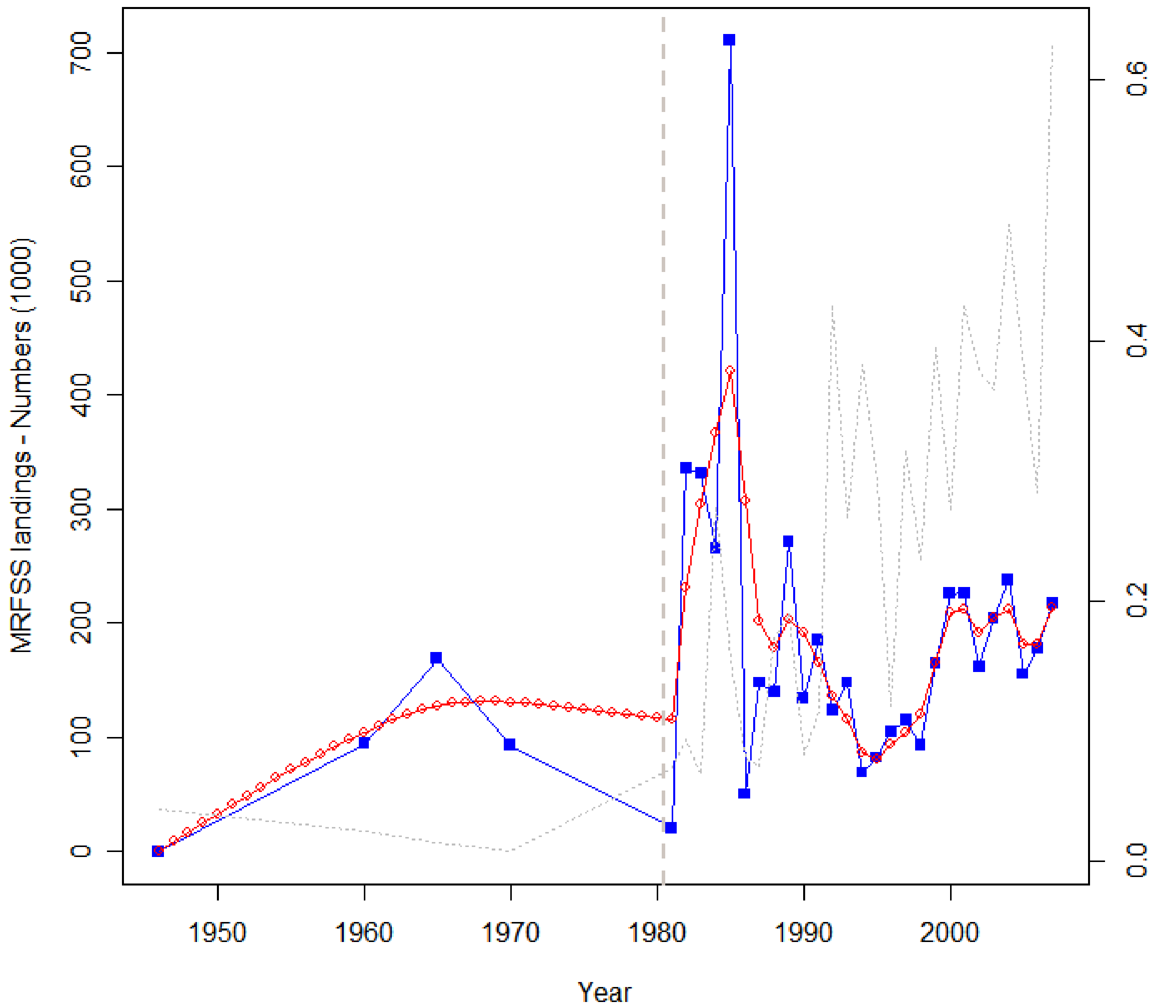

Figure 2.4. Smoothed MRFSS landings (open red circles) and estimated MRFSS landings (closed blue squares) in thousands of fish corresponding to the left axis. Weighting values (light gray dotted line) are plotted and correspond with the right axis. Vertical dashed line represents split between the two smoothing processes. The entire smoothed MRFSS landings series (open red circles) was used as input to the assessment model.

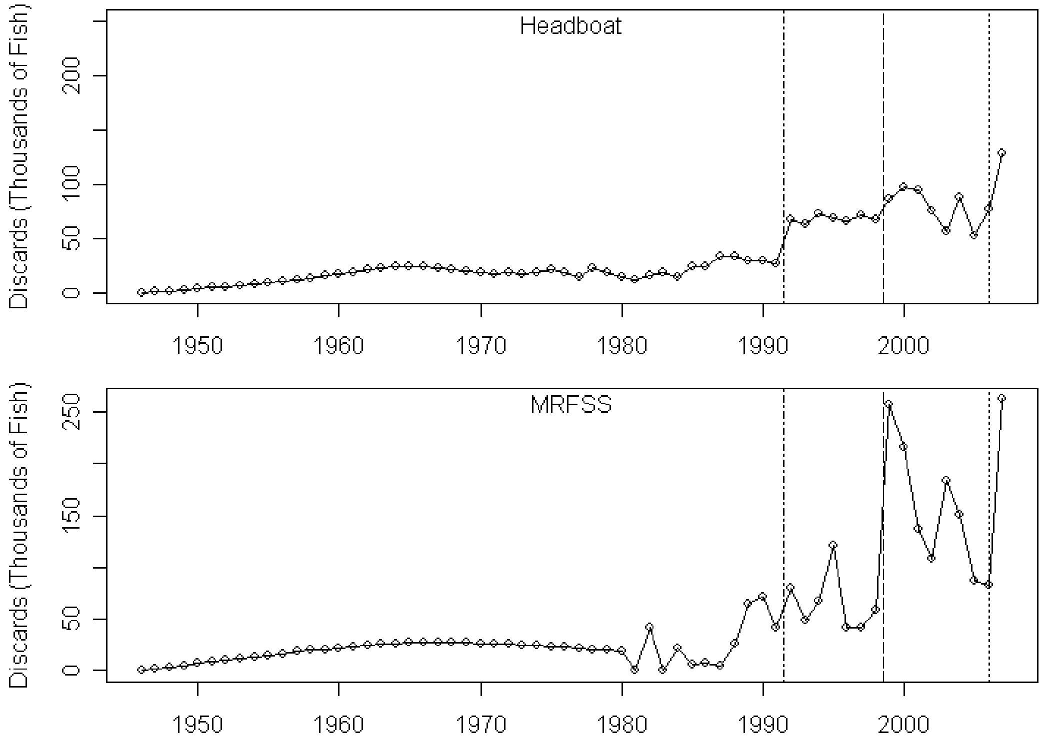

Figure 2.5. Recreational discard estimates in thousands of fish. Vertical lines represent size-limit changes for 1992 (dot-dash line), 1999 (dashed line), and during 2006 (dotted line).

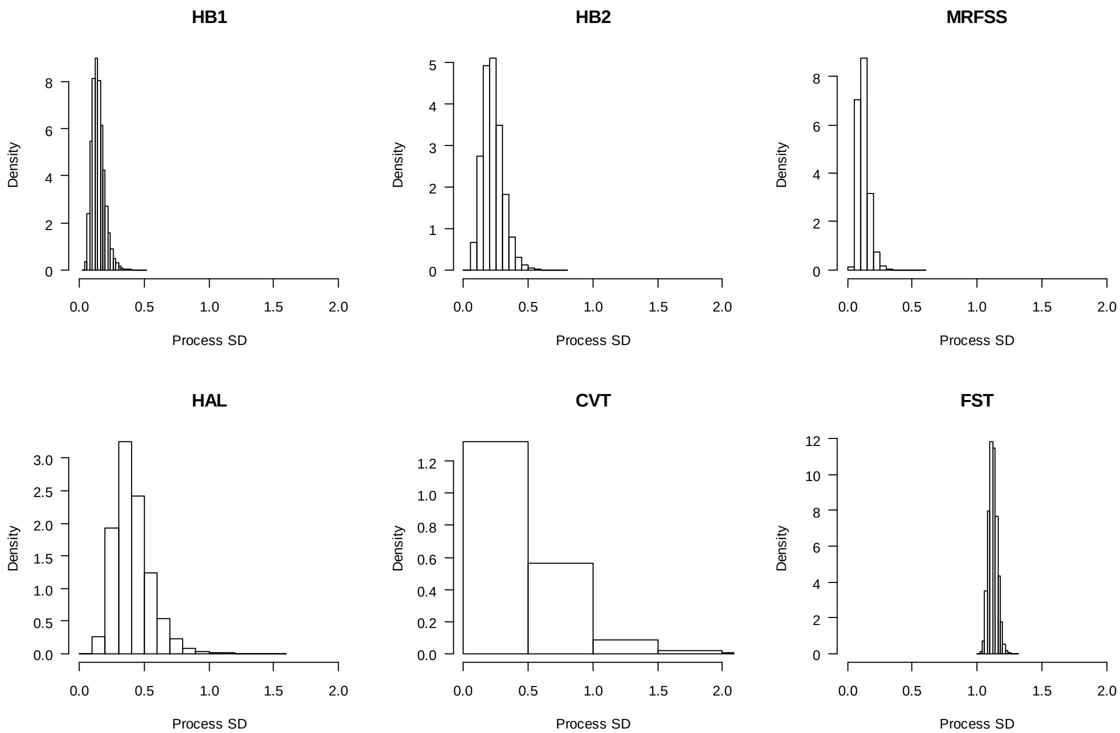

Figure 2.6. Estimated posterior distributions of process errors from the various indices of abundance (HB1=1976–1991 headboat; HB2=1992–2007 headboat; MRFSS=MRFSS; HAL=commercial handline; CVT=MARMAP chevron trap; and FST=MARMAP Florida snapper trap). Large process errors are indicative of an index that may not track well the underlying abundance.

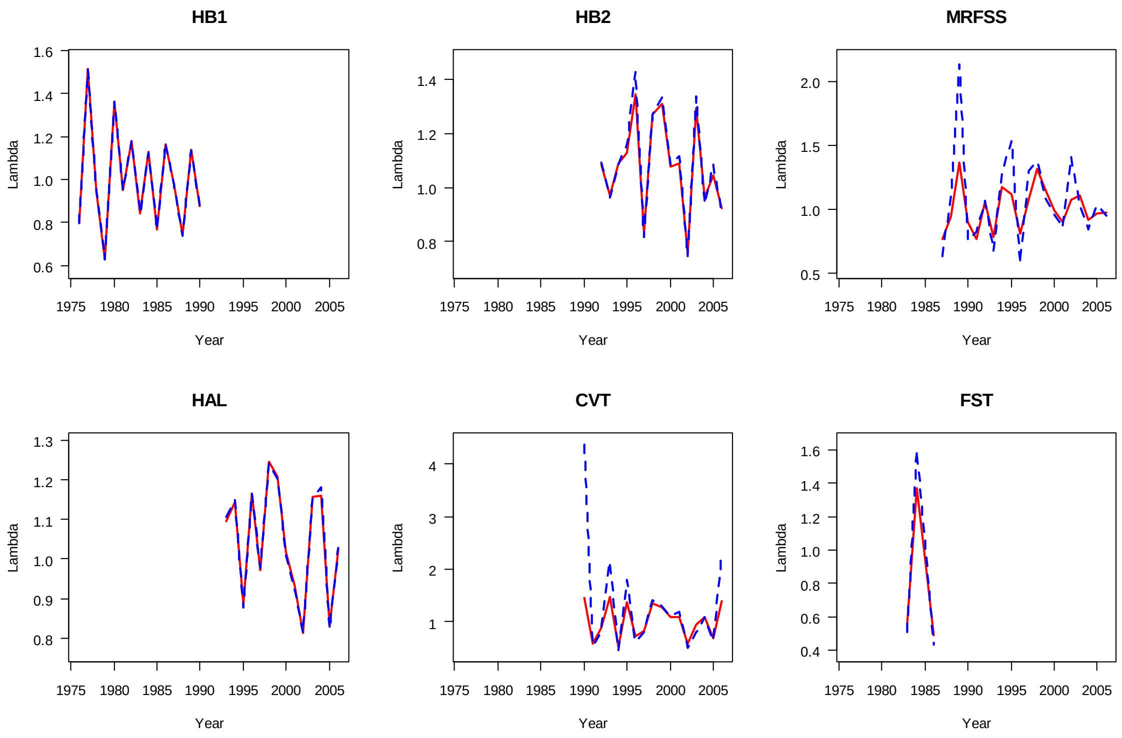

Figure 2.7. Estimated latent population growth rates (i.e., Lambda; solid lines) and those calculated from the indices produced by the SEDAR 17 DW (dashed lines). Latent time series include process error, but have sampling error removed.

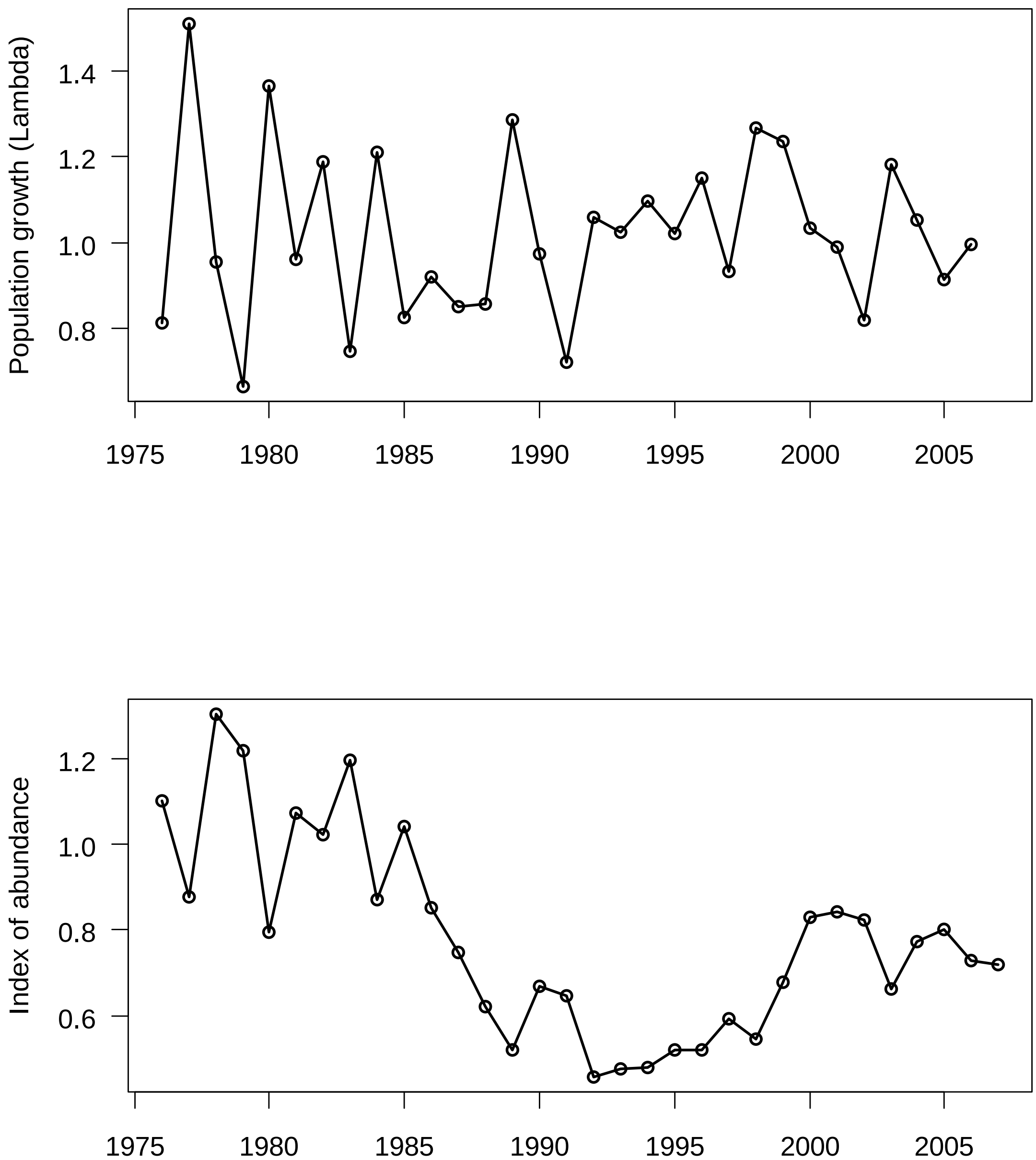

Figure 2.8. Top panel: Estimated population growth rate from the combined index of vermilion snapper abundance. Bottom panel: corresponding index of abundance adjusted to reflect linearly increasing catchability of 2% per year.

3 Stock Assessment Models and Results

Three different model structures were applied in this assessment of vermilion snapper: a statistical catch-at-age model, stock reduction analysis, and a surplus production model. In addition, catch curve analysis was used to examine mortality. The catch-at-age model was considered to be the primary assessment model. Abbreviations used in this report are defined in Appendix A.

3.1 Model 1: Catch-at-age Model

3.1.1 Model 1 Methods

3.1.1.1 **Overview** The primary model in this assessment was a statistical catch-at-age model (Quinn and Deriso 1999), implemented with the AD Model Builder software (Otter Research 2005). In essence, a statistical catch-at-age model simulates a population forward in time while including fishing processes. Quantities to be estimated are systematically varied until characteristics of the simulated populations match available data on the real population. Statistical catch-at-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) in his stock-synthesis model. The catch-at-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, and red snapper.

3.1.1.2 **Data Sources** The catch-at-age model included data from five fisheries (1946–2007) on southeastern U.S. vermilion snapper: recreational headboat, general recreational, commercial historic trawl (1961–1962), commercial hook and line (handline), and commercial combined (recent trawl, trap, spears, longline, and other miscellaneous gears). The model was fit to data on annual landings (in whole weight for commercial fisheries, in numbers for recreational fisheries), annual discard mortalities (in numbers for commercial handline and recreational fisheries), annual length compositions of landings, annual age compositions of landings, annual length compositions of discards, three fishery dependent indices of abundance (commercial handline, general recreational, and headboat), and two fishery independent indices of abundance. Data used in the model are tabulated in the DW report and in §III(2) of this report.

The general recreational fishery has been sampled since 1981 by the MRFSS, but for previous years, landings values were obtained by interpolating data reported in saltwater angling surveys (Clark 1962; Deuel and Clark 1968; Deuel 1973), adjusted to account for recall bias (§III(2)). Starting with the headboat survey in 1972, headboat landings were separated from the general recreational fishery. Data on annual discard mortalities, as fit by the model, were computed by multiplying total discards (tabulated in §III(2)) by the fishery-specific release mortality rates of 0.41 in the commercial sector and 0.38 in the recreational (§III(2)).

3.1.1.3 **Model Configuration and Equations** Model equations are detailed in Table 3.1, and AD Model Builder code for implementation is supplied in SEDAR-17-AW11. 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 (1.5%) of fish surviving through the oldest observed age (19 years) as would occur with constant $M = 0.22$ from the DW. This fraction is consistent with the findings of Hoenig (1983) and discussed in Hewitt and Hoenig (2005). Similar rescaling was used in sensitivity analyses with $M = 0.16$ and $M = 0.28$, which corresponded to 4.8% and 0.5% surviving through the oldest observed age, respectively.

Stock dynamics In the assessment model, new biomass was acquired through growth and recruitment, while abundance of existing cohorts experienced exponential decay from fishing and natural mortality. The population was assumed closed to immigration and emigration. The model included age classes $1 - 12^+$, where the oldest age class 12^+ allowed for the accumulation of fish (i.e., plus group). The initial stock (in 1946) was assumed to be at the unfished (virgin) biomass and age structure.

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) and fork length (FL) were modeled as functions of total length (Table 3.2, Figure 3.1). Parameters of growth and conversions (TL-WW, TL-FL) 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 CV estimated by the assessment model ($\widehat{\text{CV}} = 21.39\%$). 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, and 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 may differ from that in the population at large.

Maturity and fecundity Maturity at age of females was modeled as 80% at age 1 and 100% at ages 2^+. For spawning females, annual egg production was computed as eggs spawned per batch, a function of fork length, multiplied by the number of batches per year. Maturity and fecundity parameters were provided by the DW and treated as input to the assessment model.

Spawning biomass Spawning biomass was modeled as the population egg production, assuming a sex ratio of 71.5% female, as estimated by the DW. Spawning biomass was computed each year from number at age when spawning peaks. For vermilion snapper, peak spawning was considered to occur at the midpoint of the year.

Recruitment Recruitment was predicted from spawning biomass (population egg production) using a Beverton–Holt spawner-recruit model. As described below in the section "Configuration of base run," the assessment model was unable to estimate steepness (h) reliably, where h is a key parameter of the spawner-recruit model. Thus, steepness was fixed at $h = 0.56$ in the base run of the assessment model, a value chosen to correspond to the F_{MSY} proxy, $F_{40\%}$. In years when composition data could provide information on year-class strength, estimated recruitment was conditioned on the Beverton–Holt model with autocorrelated residuals (1976–2007). In years prior, recruitment followed the Beverton–Holt model precisely, similar to an age-structured production model.

Landings Time series of landing from five fisheries were modeled: commercial handline, commercial historic trawl, commercial combined, headboat, and general recreational (MRFSS). Time series spanned 1946–2007, with the exception of commercial historical trawl, which spanned 1961–1962. 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 fisheries, and 1000 fish for recreational).

Discards Commercial handline discard mortalities were modeled starting in 1992 with the implementation of the 12-inch size-limit regulation. Headboat and general recreational discard mortalities were modeled for the entire time series (1946–2007), because MRFSS data indicated that recreational discards occurred prior to 1992 when size limits were implemented. As with landings, discard mortalities (in units of 1000 fish) were modeled with the Baranov catch equation (Baranov 1918), which required estimates of discard selectivities (described below) and release mortality rates. In the base model, headboat and recreational release mortality rates were 0.38, and commercial release mortality rates were 0.41, slightly higher to account for some fish reported as discards but actually used as bait (§III(2)).

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.

Selectivities In most cases, selectivities were estimated using a parametric approach. For the dominant fisheries, selectivities were estimated as a two-parameter logistic model. This parametric approach reduces the number of estimated parameters and imposes theoretical structure on the estimates. Critical to estimating selectivity parameters are age and size composition data.

Selectivity of each fishery was fixed within each period of size-limit regulations, but was permitted to vary among periods. Commercial fisheries experienced two periods of size-limit regulations (no limit prior to 1992, 12-inch limit during 1992–2007), and recreational fisheries experienced four periods (no limit prior to 1992, 10-inch limit during 1992–1998, 11-inch limit during 1999–2006, and 12-inch limit in 2007). Ideally, a model would have sufficient age composition data from each fishery over time to estimate 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 MRFSS collected little age or length composition data on vermilion snapper until recently, headboat and general recreational fisheries were assumed to have the same selectivities in recreational regulation periods 1 and 2. Commercial combined only had length composition data from the mid-1980s; because of the small size of these fish, it was assumed that this gear caught only age-1 fish in commercial period 1. In period 2, with no composition data to estimate selectivity of commercial combined, this selectivity was assumed to be the same as that of commercial handline. Along with this change in shape between commercial period 1 and 2 came a change in types of gears that comprised commercial combined (mostly targeted trawl in period 1, mostly bycatch trawl, spears, trap, and longline in period 2). Similar to commercial combined in period 1, MARMAP FL snapper trap was assumed to catch only age-1 fish, because length compositions contained relatively small fish and no age compositions were available. MARMAP chevron trap had age composition data and was estimated to be dome-shaped, using a double logistic model. Preliminary fits of the assessment model consistently estimated some selectivities to be knife-edge, and thus in those cases, the slope parameter was fixed to provide that desired shape, to reduce the number of estimated parameters (this was done for MARMAP chevron trap, commercial handline in commercial period 2, headboat and general recreational in recreational periods 2 and 3, and headboat in recreational period 4).

Selectivities of discards were partially estimated, assuming that discards consisted primarily of undersized fish, as implied by observed length compositions of discards. The general approach taken for discard selectivities was that the value for age-1 fish was fixed at zero, for age-2 fish was estimated, for age-3 fish was assumed full selection, and for ages-4^+ was fixed at the age-specific probability of being below the size limit given a normal distribution of size at age. Given available data on discards, some additional assumptions were necessary: Headboat and general recreational were assumed to have the same discard selectivities. Selectivity of age-2 fish in recreational period 2 was assumed to be the same as the estimate from period 3, because no length composition data were available before period 3. Recreational discard selectivity in period 1 was assumed to be the same as that during period 2.

Indices of abundance The model was fit to two fishery independent indices of abundance (MARMAP FL snapper trap 1983–1987; chevron trap 1990–2007) and to three fishery dependent indices of abundance (headboat 1976–2007; MRFSS 1987–2007; and commercial handline 1993–2007). Predicted indices were computed from numbers at age at the midpoint of the year or, in the case of commercial handline, weight at age.

The DW and AW agreed that catchability of fishery dependent sources has likely increased over time as a result of technological improvements. To reflect such changes, catchability was assumed to increase linearly with a slope of 2% per year (0% or 4% in sensitivity runs). This slope and range (0–4%) was used in SEDAR10 assessments of gag grouper and in SEDAR15 assessments of red snapper and greater amberjack. The lower bound of the range was chosen to represent the status quo assumption of constant catchability; the range itself is consistent with increases in total factor productivity estimated for New England groundfish (4.4%) and for Norwegian stocks (1.7–4.3%) (Jin et al. 2002; Hannesson 2007).

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, as described in §3.1.1.7. Computed benchmarks included MSY, fishing mortality rate at MSY (F_{MSY}), and spawning biomass (population egg production) at MSY (SSB_{MSY}). 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. In addition, because steepness (h) could not be estimated reliably, h was fixed at a value such that $F_{40\%}$ is a proxy for F_{MSY}.

Fitting criterion The fitting criterion was a 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, and only from years that met a minimum sample size criterion ($n \geq 400$ for length compositions of landings, $n \geq 170$ for length compositions of discards, $n \geq 45$ for age compositions).

The total likelihood also included a penalty term to discourage large deviation from zero in recruitment residuals during the last three assessment years. In addition, a least-squares penalty term was applied to log deviations of annual recruitment (allowing for autocorrelation), permitting estimation of the Beverton–Holt spawner-recruit parameters internal to the assessment model.

Likelihood component weights The influence of each dataset on the overall model fit was determined by the specification of the error terms in each likelihood component. In the case of lognormal likelihoods, error was quantified by the inverse of the annual coefficient of variation, and for the multinomial components, by the annual sample sizes (§III(2)). These terms determine the influence of each year of data relative to other years of the same data source. However, the relative influence of different datasets is typically treated by re-weighting each likelihood component, including penalty terms. An objective determination of these weights is largely an unsolved problem in statistical catch-at-age modeling.

The number of weights to be examined were reduced by grouping likelihood components based on their type, scale, and method of collection. For example, the five time series of landings were grouped, so that a single weight was applied to all five. Other data sources were grouped similarly. This led to five component weights on datasets that required specification: length compositions (ω_1), age compositions (ω_2), landings (ω_3), discards (ω_4), and indices (ω_5).

Configuration of base run The selection of likelihood component weights for the base run model involved an iterative process of model fitting, examination of the fit, and adjustment of the weights. The performance of individual model runs was evaluated based on a balance between biological realism and reasonable fits to the observed datasets, including consideration of overdispersion, model mis-specification (e.g. runs of residuals), and general reliability of the data sources (i.e. understanding of information content). Likelihood component weights applied in the base model (Table 3.1) were selected by the AW using the following procedure:

1. Set weight on landings (ω_3) and discards (ω_4) to $\omega_3 = \omega_4 = 1000$, so as to match these time series closely. (Uncertainty in landings and discards time series is evaluated through sensitivity runs.) Set remaining weights to one.
2. Fit the assessment model using the weights described above, but with the weight on length compositions set to a value from the vector, $\omega_1 \in \{0.001, 0.005, 0.01, 0.05, 0.1, 0.2, 0.4, 0.6, 0.8, 1.0\}$. Examine any trade-offs among fits to data sources, and select a value for ω_1.
3. Fit the assessment model using the weights selected in step 2, but with the weight on indices set to a value from the vector, $\omega_5 \in \{1, 5, 10, 50, 100, 200, 300, 400, 500, 1000\}$. Examine any trade-offs among fits to data sources, and select a value for ω_5.

In the above procedure, fits are pivoted on age composition data, for which the weight remains at $\omega_2 = 1$.

As the weight on length composition components increased, fits to length composition data were improved, as expected, but fits to age composition data and indices were degraded (Figure 3.2). Based on these trade-offs and on a desire to emphasize indices and age compositions over length compositions, the AW selected a weight of $\omega_1 = 0.01$ for length compositions. A similar examination of the weight on indices (Figure 3.3) led the AW to select $\omega_5 = 100$, which provided a relatively good fit to indices without much compromise in length and age compositions.

Across model configurations, estimates of steepness (h), a key parameter of the spawner-recruit relationship, hit the upper allowable bound of 0.95 (Figures 3.2, 3.3). A likelihood profile on steepness revealed little distinction across the range of $h \in (0.45, 0.95)$, suggesting that the data provided insufficient information for the model to estimate this parameter (Figure 3.4). Thus, the AW fixed steepness so as to be consistent with $F_{40\%}$ as a proxy for F_{MSY}. Some studies have found that $F_{40\%}$ is too high across many life-history strategies (Williams and Shertzer 2003) and can lead to undesirably low levels of biomass and recruitment (Clark 2002). However, this was not believed to be the case for vermilion snapper because of their rapid maturation (80% mature by age-1). The value of $F_{40\%}$ was recommended for red snapper by the SEDAR15 review panel, and has been suggested as a reasonable proxy for F_{MSY} (Mace 1994).

Because reference points $F_{40\%}$ and F_{MSY} are conditional on estimates of selectivity curves, the value of steepness was calculated in an iterative manner. First, the assessment model was fitted with steepness estimated to provide initial estimates of selectivity curves. Given those estimated selectivities, the value of steepness was computed (h_{try}) such that $F_{40\%} = F_{\text{MSY}}$. The assessment model was then fitted again, but with steepness fixed at h_{try}. Again, based on the estimates of selectivity curves, a new value of steepness was computed such that $F_{40\%} = F_{\text{MSY}}$. This process was repeated until h_{try} converged (which required two or fewer iterations). For the base run of the assessment, the value consistent with $F_{40\%} = F_{\text{MSY}}$ is $h = 0.56$ (Figure 3.5). Uncertainty in this choice of proxy was evaluated through sensitivity analyses (described below).

Sensitivity analyses Sensitivity of results to the base configuration was examined through sensitivity and retrospective analyses. These runs vary from the base run as follows:

- S1: Steepness (h) estimated
- S2: Steepness $h = 0.73$, consistent with $F_{\text{MSY}} = F_{30\%}$
- S3: Steepness $h = 0.67$, consistent with $F_{\text{MSY}} = F_{35\%}$
- S4: Steepness $h = 0.53$, consistent with $F_{\text{MSY}} = F_{45\%}$
- S5: Steepness $h = 0.47$, consistent with $F_{\text{MSY}} = F_{50\%}$
- S6: High M at age (Lorenzen estimates rescaled to constant $M = 0.28$ so as to provide the same cumulative survival of 0.5% through the oldest observed age)
- S7: Low M at age (Lorenzen estimates rescaled to constant $M = 0.16$ so as to provide the same cumulative survival of 4.8% through the oldest observed age)
- S8: Constant catchability applied to fishery dependent indices
- S9: Linearly increasing catchability with slope of 0.04 applied to fishery dependent indices
- S10: High discard mortality rates (0.53 for commercial, 0.5 for recreational)
- S11: Low discard mortality rates (0.24 for commercial, 0.2 for recreational)
- S12: 1960, 1965, and 1970 recreational landings from the salt-water angling reports scaled by 0.5
- S13: 1960, 1965, and 1970 recreational landings from the salt-water angling reports scaled by 1.0
- S14: 1960, 1965, and 1970 recreational landings from the salt-water angling reports scaled by 1.25
- S15: Commercial landings decreased by 1 standard deviation, based on CVs from the DW
- S16: Commercial landings increased by 1 standard deviation, based on CVs from the DW
- S17: All indices but headboat downweighted to $\omega_5 = 1$
- S18: All indices but MARMAP chevron trap downweighted to $\omega_5 = 1$
- S19: Length composition data downweighted to $\omega_1 = 0.0001$
- S20: Retrospective run with data through 2006
- S21: Retrospective run with data through 2005
- S22: Retrospective run with data through 2004
- S23: Retrospective run with data through 2003

Model testing To ensure that the assessment model produces viable estimates (i.e., that all model parameters are identifiable), test data were generated with known parameter values and then analyzed with the assessment model. For simplicity, a stripped down version of the model (Table 3.1) was considered, but this version nevertheless retained all essential components. In particular, a simulation model was used to generate data from one fishery and included likelihood contributions of landings, CPUE, and age composition. Selectivity at age remained the same over time, and all likelihood weights were set equal to one. The simulation model [written in R; R Development Core Team (2007)] was programmed independently of the assessment model [written in AD Model Builder; Otter Research (2005)].

Parameter identification was determined using the "analytical-numeric" approach of Burnham et al. (1987). Deterministic expected value data were generated from input parameter values, without any process or sampling error. These data were then analyzed with the assessment model in attempt to obtain the exact parameters that generated the data.

In this test, all model parameters were estimated exactly. This result provided evidence that all parameters could be properly identified. It further suggested that the assessment model has been implemented correctly and can provide an accurate assessment. As an additional measure of quality control, the input file used by the assessment model was reviewed for accuracy by multiple analysts.

3.1.1.4 **Parameters Estimated** The model estimated annual fishing mortality rates of each fishery, selectivity parameters of fisheries and fishery independent indices of abundance, Beverton–Holt parameters including autocorrelation, annual recruitment deviations, catchability coefficients associated with indices, and CV of size at age. Estimated parameters are identified in Table 3.1.

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-17-AW05. In short, catch curves were analyzed by linear regression of the log-transformed proportions at age. Proportions at age were represented by both true and synthetic cohorts. For both, catch curve analysis requires the assumptions that mortality and catchability remain constant with age. An additional assumption for synthetic cohorts is constant recruitment. These assumptions are rarely met, if ever, by fish populations. Thus, the application of catch curve analysis here is for diagnostic purposes, primarily to ensure that catch-age estimates of mortality were within a reasonable range.

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 represents SPR that would be achieved under an equilibrium age structure at the current F (hence the term *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 F from the last three years (2005–2007).

3.1.1.7 **Benchmark/Reference Point Methods** In this assessment of vermilion snapper, the quantities F_{MSY}, SSB_{MSY}, B_{MSY}, and MSY were estimated by the method of Shepherd (1982). In that method, the point of maximum yield is 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,

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

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 (2005–2007).

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 0.22. Overfishing is defined as $F >$ MFMT and overfished as SSB < MSST. Current status of the stock and fishery are represented by the latest assessment year (2007).

3.1.1.8 **Uncertainty and Measures of Precision** Uncertainty has many sources and was examined in several ways. The effects of uncertainty in model structure were examined by applying three assessment models—the catch-at-age model, stock-reduction analysis, and a surplus-production model—with quite different mechanistic structures. For each model, uncertainty in data or assumptions was examined through sensitivity runs.

Precision of benchmarks from the catch-at-age model was computed external to the assessment through a bootstrap/Monte Carlo approach. First, the variance–covariance matrix (Σ) of the spawner-recruit parameters was estimated by parametric bootstrap. This bootstrap procedure generated lognormal recruitment deviations, with variance and autocorrelation as estimated by the assessment model, and then re-estimated parameters of the spawner-recruit curve. The re-estimation was iterated $n = 10000$ times; iterations in which steepness hit a bound were discarded and a 1% trim was applied to all estimated parameters before computing Σ. Second, distributions of benchmarks were computed based on $n = 100000$ Monte Carlo iterations, in which spawner-recruit parameters were drawn from a multivariate normal distribution, with mean equal to the point estimates and Σ from the parametric bootstrap. For presentation, the 10^{th} and 90^{th} percentiles of each benchmark were used to indicate uncertainty.

3.1.1.9 **Acceptable Biological Catch** Acceptable biological catch (ABC) was computed using the probability-based approach of Shertzer et al. (2008). In short, this approach solves for annual levels of projected landings that are consistent with a preset, acceptable probability of overfishing ($P^\star$) in each year. The method considers uncertainty in F_{MSY}, computed as in §3.1.1.8, and described by the probability density function, $\phi_{F_{\text{MSY}}}$. It also considers uncertainty in annual fishing mortality, computed by stochastic projection (§3.1.1.10), and described by the probability density function, ϕ_{F_t}. Given the distributions $\phi_{F_{\text{MSY}}}$ and ϕ_{F_t}, the probability of overfishing associated with catch C can be computed as,

$$\Pr(F_t > F_{\text{MSY}}) = \int_0^\infty \left[\int_F^\infty \phi_{F_t}(\theta)\, d\theta \right] \phi_{F_{\text{MSY}}}(F)\, dF \qquad (2)$$

where θ is a dummy integration variable. The value of C is then adjusted until the distribution of F_t is positioned to achieve $\Pr(F_t > F_{\text{MSY}}) = P^\star$. This value of C is that year's ABC.

In this application, projections were run for five years past the end of the assessment, with the current fishing rate applied in 2008. No implementation uncertainty was included. Values of $P^\star$considered were $P^\star = \{0.1, 0.2, 0.25, 0.3, 0.4, 0.5\}$.

3.1.1.10 **Projection Methods** Projections were run to predict stock status in years after the assessment, 2008–2018. This time frame of 11 years included one year (2008) at the current fishing rate and ten 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 base run. 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.

Initialization of projections In projections, any change in fishing effort was assumed to start in 2009, which is the earliest year management regulations could be implemented. Because the assessment period ended in 2007, the projections required a one-year initialization period (2008). Point estimates of initial abundance at age in the projection (start of 2008), other than at age 1, were taken to be the 2007 estimates from the assessment, discounted by 2007 natural and fishing mortalities. The initial abundance at age 1 was computed using the estimated spawner-recruit model and the 2007 estimate of SSB. The fully selected fishing mortality rate applied in the initialization period, $F = F_{\text{current}}$, was taken to be the geometric mean of fully selected F during 2005–2007.

Annual predictions of SSB (mid-year), F, recruits, landings, and discards were represented by deterministic projections. 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 Monte Carlo simulations.

Stochasticity of projections Projections used a Monte Carlo procedure to generate stochasticity in the spawner-recruit relationship and in the initial number at age. The Beverton–Holt model (without bias correction), fit by the assessment, 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 with first-order autocorrelation,

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

Here ϵ_y was drawn from a normal distribution with mean $\hat{\varrho}\epsilon_{y-1}$ and standard deviation $\hat{\sigma}$, where $\hat{\varrho}$ and $\hat{\sigma}$ are estimates of autocorrelation and standard deviation from the assessment model (Table 3.1). Similarly, distribution of the initial number at age N_a was modeled as lognormal, centered on the point estimates and with standard deviation $\hat{\sigma}$. Deviations of initial N_a were truncated to fall within one standard deviation (in log space) of the point estimates.

The Monte Carlo procedure generated 2000 replicate projections, each with a different stream of stochastic recruitments, and each with a different annual estimate of SSB, F, recruitment, landings, and discards. Precision of projections was represented graphically by the 10^{th} and 90^{th} percentiles of the 2000 stochastic projections.

Projection scenarios Five constant-F projection scenarios were considered:

- Scenario 1: $F = F_{\text{current}}$, defined as the geometric mean F of 2005–2007
- Scenario 2: $F = 65\%F_{\text{MSY}}$
- Scenario 3: $F = 75\%F_{\text{MSY}}$
- Scenario 4: $F = 85\%F_{\text{MSY}}$
- Scenario 5: $F = F_{\text{MSY}}$

3.1.2 Model 1 Results

3.1.2.1 Measures of Overall Model Fit Overall, the catch-at-age model 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 3.6). Residuals of these fits, by year and fishery, are summarized with bubble plots; differences between annual observed and predicted vectors are summarized with angular deviation (Figure 3.7–3.17). Angular deviation is defined as the arc cosine of the dot product of two vectors.

The model was configured to fit observed commercial and recreational landings closely (Figures 3.18–3.22), as well as observed discards (Figures 3.23–3.25).

Fits to indices of abundance were reasonable (Figures 3.26–3.30). Observed fishery dependent indices were positively correlated, showing in general an increasing trend since the mid-1990s; predictions from recreational fisheries tracked this trend, but the commercial handline did not. That increasing trend was not apparent in the observed or predicted fishery independent chevron trap index.

3.1.2.2 Parameter Estimates Estimates of all parameters from the catch-at-age model are shown in Appendix B.

3.1.2.3 Stock Abundance and Recruitment Estimated abundance at age shows some truncation of the age structure, an expected consequence of fishing (Table 3.3). Annual number of recruits is shown in Table 3.3 (age-1 column) and in Figure 3.31. Notably strong year classes were predicted to have occurred in 1978, 1990, and 1992. Years 2001 and 2002 were the most recent to have experienced stronger-than-expected recruitment.

3.1.2.4 Total and Spawning Biomass Estimated biomass at age follows a similar pattern as abundance at age (Tables 3.4,3.5). Total biomass and spawning biomass show nearly identical trends—gradual decline during the 1950s and 1960s, steep decline during the mid-1970s through 1980s, general increase during the 1990s, and then decline since 2000 (Figure 3.32; Table 3.6).

3.1.2.5 Fishery Selectivity Estimated selectivities of landings from commercial handline are shown in Figure 3.33. In the most recent period, fish were estimated to be fully selected by age 4. Selectivity of landings from commercial historic trawl was assumed the same as that of commercial combined gear in the first period of commercial regulations, which consisted mostly of trawl (Figure 3.34, 3.35). This selectivity was not estimated, but fixed to be only of age-1 fish, based on observed length distributions (Figure 3.6). Selectivity of commercial combined in the second commercial period was assumed to be the same as commercial handline. Selectivities from the headboat fishery for each period of regulations are shown in Figure 3.36, and those of the general recreational fishery in Figure 3.37.

By design, estimated selectivities of discard mortalities were similar across the commercial handline, headboat, and general recreational fisheries (Figure 3.38 – Figure 3.40), with the exception that selectivity of age-2 fish was estimated to be 0.0 in commercial discards, and 1.0 in headboat and general recreational discards.

Average selectivities of landings and of discard mortalities were computed from F-weighted selectivities in the most recent period of regulations (Figure 3.41). These average selectivities were used to compute benchmarks and projections. All selectivities from the most recent period, including average selectivities, are presented in Table 3.7.

3.1.2.6 **Fishing Mortality** The estimated time series of fishing mortality rate (F) shows a generally increasing trend from the 1950s through 1991, and has since been relatively stable around a mean near $\bar{F} = 0.32$ (Figure 3.42). An uncharacteristically high estimate of F in 1991 comprised mostly F from the commercial combined gear, which was high in that year because the gear, with selectivity assumed to be only of age-1 fish, targeted an unusually small class of recruits (Figure 3.31). In the most recent years, the majority of full F was from commercial handline and headboat landings (Figure 3.42, Table 3.8).

Full F at age is shown in Table 3.9. In any given year, the maximum F at age may be less than that year's fully selected F. 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 3.10 shows total landings at age in numbers, and Table 3.11 in 1000 lb. Since the mid-1980s, estimated landings by sector have been dominated by commercial handline and headboat (Figures 3.43, 3.44; Tables 3.12, 3.13).

Estimated discard mortalities show much variability since size limits were implemented in 1992, but occur on a smaller scale than landings (Figure 3.45; Tables 3.14, 3.15)

3.1.2.7 **Catch Curve Analysis** Catch curve analysis suggested total mortality rate ($Z = F + M$) ranged from 0.2 to 1.4, with the bulk of the estimates between 0.4 and 0.7 (SEDAR-17-AW05). Based on the constant estimate of natural mortality, $M = 0.22$, these values of Z suggest that fully selected fishing mortality rate is on the scale of $F = 0.18$ to $F = 0.48$, consistent with estimates from the catch-at-age model (Table 3.6).

3.1.2.8 **Stock-Recruitment Parameters** The estimated Beverton–Holt spawner-recruit curve, with steepness fixed at $h = 0.56$, is shown in Figure 3.46. The effect of density dependence on recruitment appears weak over the range of spawners in the assessment, as depicted graphically by estimated recruits per spawner as a function of spawners (Figure 3.46). Beverton–Holt parameters were as follows: steepness $h = 0.56$, $\widehat{R_0} = 4325709$, first-order autocorrelation $\hat{\varrho} = 1.33\text{E}{-7}$, and bias correction $\hat{\varsigma} = 1.32$. Uncertainty in these parameters was estimated through bootstrap analysis of the spawner-recruit curve (Figure 3.47).

3.1.2.9 **Per Recruit and Equilibrium Analyses** Static spawning potential ratio (static SPR) shows a trend of decrease from the beginning of the assessment period until the late 1980s, and since has remained relatively constant around a mean of 44% (Figure 3.48, Table 3.6).

Yield per recruit and spawning potential ratio were computed as functions of F (Figure 3.49). 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 (2005–2007). By definition, the F that maximizes yield per recruit is F_{max}; here, the curve is strictly increasing throughout the range of F considered (0.0 to 3.0, but only displayed up to $F = 1.0$). Thus $F_{\text{max}} > 3.0$, if it exists at all, and should not be regarded as a possible proxy benchmark. By design, the F that provides 40% SPR (i.e., $F_{40\%}$) corresponds to F_{MSY}.

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of F (Figures 3.50). 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 3.51).

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 3.46). 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—$F_{OY} = 65\%F_{MSY}$, $F_{OY} = 75\%F_{MSY}$, and $F_{OY} = 85\%F_{MSY}$—and for each, the corresponding yield was computed. Uncertainty of benchmarks was computed through Monte Carlo/bootstrap analysis of the spawner-recruit curve, as described in §3.1.1.8.

Estimates of benchmarks are summarized in Table 3.16. Point estimates of MSY-related quantities were F_{MSY} = 0.386/yr, MSY = 1665.27 klb, B_{MSY} = 3299.78 mt, and $SSB_{MSY} = 9.16 \times 10^{12}$ eggs. Distributions of these benchmarks are shown in Figure 3.52.

3.1.2.11 **Status of the Stock and Fishery** Estimated time series of B/B_{MSY} and SSB/SSB_{MSY} show similar patterns: initial status well above the MSY benchmark, general decline until 1990, followed by moderate increase until 1999, and then decline through the last assessment year (Figure 3.53, Table 3.6). Spawning biomass has remained above MSST throughout the time series, indicating that the stock is not overfished; however, the declining trend during the last decade may be of concern. Estimated age structure at the start of 2008 was similar to the equilibrium age structured expected at MSY (Figure 3.54). Current stock status was estimated to be $SSB_{2007}/SSB_{MSY} = 0.86$ and $SSB_{2007}/MSST = 1.10$ (Table 3.16).

The estimated time series of F/F_{MSY} shows a generally increasing trend until spiking in 1991. This spike is due to an uncharacteristically high estimate of F from the commercial combined gear, which was high in that year because the gear, with selectivity assumed to be only of age-1 fish, targeted an unusually small class of recruits (Figure 3.31). Since 1991, F/F_{MSY} has been relatively stable, with F generally less than F_{MSY} (Figure 3.55, Table 3.6). Current fishery status in the terminal year is estimated to be $F_{2007}/F_{MSY} = 1.27$, which indicates overfishing (Table 3.16). However, the geometric mean F from the last three years ($F_{current}$ in projections) is approximately equal to F_{MSY} ($F_{current}/F_{MSY} = 0.997$).

3.1.2.12 **Acceptable Biological Catch** The distribution of F_{MSY} in Figure 3.52 was used to compute annual ABC (landings plus discard mortalities in 1000 lb whole weight). In general, the ABC increases with higher acceptable probability of overfishing ($P^\star$), whereas stock size decreases (Figures 3.56–3.61, Tables 3.17–3.22).

Values of ABC were computed given uncertainties in F_{MSY}, current abundance at age (2008), and future recruitment. Uncertainty in management implementation was not considered. Thus, these ABC values should be considered as possible catch limits, and implementation uncertainty should be considered when setting annual catch targets (ACTs).

The projection method applied here assumed that the catch taken from the stock was the ABC. If the projection had applied a catch level lower than the ABC, say at ACT < ABC, then the corresponding reduction in applied F would have resulted in higher stock sizes, and higher ABCs in subsequent years. In this sense, the values presented here are conservative.

3.1.2.13 **Sensitivity and Retrospective Analyses** Sensitivity and retrospective analyses, as described in §3.1.1.3, are useful for evaluating uncertainty in results of the base assessment model. Plotted are time series of F/F_{MSY} and $\text{SSB}/\text{SSB}_{\text{MSY}}$ for sensitivity to steepness (Figure 3.62), natural mortality (Figure 3.63), catchability (Figure 3.64), discard mortality rates (Figure 3.65), early recreational landings (Figure 3.66), commercial landings (Figure 3.67), and weighting of likelihood components (Figure 3.68). In general, results of sensitivity analyses were qualitatively the same as those of the base model run: the stock is not overfished but overfishing is occurring (Table 3.23). Retrospective analyses did not reveal any concerning trends (Figure 3.69).

3.1.2.14 **Projections** Projection scenario 1, in which $F = F_{\text{current}}$, predicted the stock to remain near current levels, with modest increase (Figure 3.70, Table 3.24). Recent F, taken as the mean of the last three years, was nearly equal to the estimate of F_{MSY} ($F_{\text{current}} \approx F_{\text{MSY}}$).

Similarly, other projections, with F at 65%, 75%, 85%, or 100% of F_{MSY}, predicted the stock to increase (Figures 3.71–3.74, Tables 3.25–3.28). In general, higher F resulted in larger annual and cumulative landings, but smaller biomass with a correspondingly smaller buffer from the MSST.

These projections and those used to compute ABCs both applied F_{current} in 2008. However, tables associated with the two types of analysis do not necessarily report the same 2008 values of projected quantities (e.g., landings). This is because projection tables (Tables 3.24–3.28) report expected values from deterministic runs; the ABC projections contained no deterministic component, and thus ABC tables (Tables 3.17–3.22) report median values.

3.2 Model 2: Stock Reduction Analysis

3.2.1 Model 2 Methods

3.2.1.1 **Overview** Stochastic stock reduction analysis (SRA), as applied in this assessment, models an age-structured population by fitting to age-aggregated data. Its purpose here was to provide results using an assessment model of intermediate complexity between the fully age-structured catch-at-age model and fully age-aggregated surplus production model. The SRA approach works by initializing a stock at a range of values for biomass and productivity, and projecting the stock forward under stochastic recruitment (Walters et al. 2006). The method then examines the likelihood of each of the stock trajectories, given the history of exploitation and fits to observed data. In this manner, one can estimate plausible values of virgin recruitment (R_0) and steepness (h) of the spawner-recruit curve, along with management quantities.

3.2.1.2 **Data Sources** The SRA model was fit using a single time series of removals (1946–2007) and a single index of abundance (1976–2007). Total removals, including landings and dead discards, were extended back to 1946 when the stock was considered to be in an unfished condition (Table 2.7 of §III(2)).

Landings The SEDAR-17 DW provided estimates of commercial landings in pounds (whole weight) and recreational landings in numbers of fish. For use in SRA, all landings were combined into a single time series in units of pounds. Thus, headboat and recreational landings were converted to pounds, which was accomplished by multiplying landings in numbers by the average annual mean weight from the headboat fishery. MRFSS mean weights were highly variable and were thus not used for this conversion.

Dead Discards Estimates of total discard (alive and dead) were provided in numbers for commercial and recreational data sources. These estimates were converted to numbers of dead discards by applying the discard mortality rates suggested by the DW. These values were then converted to units of pounds, as described in SEDAR-17-AW09. The dead discards in weight were combined with the total landings for input to the SRA model.

Index of abundance Estimates of relative abundance were provided by the SEDAR-17 DW using data from the headboat program, commercial logbooks, MRFSS, and MARMAP chevron traps and Florida traps. These five indices were combined into one index of catch per effort as described in §III(2), following the methods of SEDAR-17-AW06.

The SEDAR-17 DW believed that catchability has almost certainly increased over time, and suggested that this increase be accounted for by assuming linear change with slope of 2% per year. However, the SRA applied here does not estimate catchability. Thus, to account for the linear increase, the index of abundance was adjusted by dividing each year's relative abundance value by an annual catchability factor (1.0 in 1976 to 1.62 in 2007, incremented by 0.02 each year) (Table 2.6 of §III(2)).

Rather than fitting to values of the index (U_t), inference was based on gradient matching (Ellner et al. 2002), that is, based on fitting $\lambda_t = U_{t+1}/U_t$, the finite rate of population change. The quantity λ_t is dimensionless, which removes the need to estimate a catchability parameter q (SEDAR-17-AW08).

3.2.1.3 Model Configuration and Equations

Model equations and estimation procedures are described in SEDAR-17-AW08. This section provides a synopsis of the methods and describes specifics of this application to vermilion snapper.

In stochastic SRA, uncertainty in population dynamics of each stock trajectory is described by the parameter vector $\boldsymbol{\theta}$,

$$\boldsymbol{\theta} = \{R_0, h, \sigma_R, \epsilon_1, \epsilon_2, \ldots, \epsilon_Y\} \quad (4)$$

where R_0 is average recruitment of an unexploited population, h is steepness, σ_R is the standard deviation of recruitment deviations around the spawner-recruit function, and ϵ_t is the annual recruitment deviation in year t, generated here for 1975–2007. The inclusion of uncertainty in the ϵ_t parameters is the fundamental difference between deterministic and stochastic SRA, and it is considered essential for adequately assessing population viability of a stock over the history of exploitation (McAllister et al. 1994).

In addition to the estimated parameters of the stochastic SRA, the model requires additional information to define the stock. This model input is assumed to be without error. For vermilion snapper, it is summarized by $\boldsymbol{\phi}$,

$$\boldsymbol{\phi} = \{\boldsymbol{M}, \boldsymbol{m}, \boldsymbol{\rho}, \boldsymbol{\mathcal{F}}, \boldsymbol{w}, \boldsymbol{s}\} \quad (5)$$

which represents age-specific vectors of natural mortality, maturity of females, sex ratio, annual fecundity, weight, and combined selectivity of the fishing gears, respectively. Here, life-history vectors were the same as those provided by the DW and used in the catch-at-age model (note, $\boldsymbol{\rho}$ is considered constant across ages). Selectivity was assumed to be equal to the combined selectivity estimated by the catch-at-age model, rescaled to provide a maximum of one: $\mathbf{s} = \{0.04, 0.24, 0.72, 0.98, 0.99, 0.99, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0\}$.

Because of the large number of latent recruitment deviations in stochastic SRAs, classical maximum likelihood inference is problematic. An alternative, used here, is Bayesian inference. In this application, prior distributions on parameters R_0, h, and σ_R were specified as uniform: $R_0 \sim \text{U}(5.0\text{E}6, 1.5\text{E}7)$, $h \sim \text{U}(0.3, 0.9)$, and $\sigma_R \sim \text{U}(0.3, 0.7)$. In addition, lower and upper bounds on F, $F_L = 0.05$ and $F_U = 1.0$, were implemented to avoid stock abundance from becoming unrealistically low or high. The bounds were based loosely on estimates from catch curve analysis (SEDAR-17-AW05). The lower bound restriction was not applied near the start of the simulation (prior to 1960), when low F is expected given the conjunction of relatively low landings and relatively high stock size.

Posterior inference was based on sequential importance sampling (SIS), which has history in Bayesian fishery applications (e.g. McAllister et al. 1994; McAllister and Ianelli 1997; Newman and Lindley 2006). SIS involves sampling the initial state vector $\boldsymbol{\theta}$ a large number of times (say n_p) from assumed prior distributions of parameters. Each sample, termed a "particle," is passed through the population model. The probability of retaining a particle then depends on the fit to data, and those particles surviving this process contribute to inference about the parameters.

Many algorithms exist for performing SIS, ranging in levels of complexity. The one used here, known as the bootstrap particle filter (Gordon et al. 1993), is of moderate complexity. This algorithm, adapted for stochastic SRA (SEDAR-17-AW08), proceeds as follows:

1. Randomly sample n_p values from prior distributions for R_0, h, and σ_R. The ith draw from each distribution is associated with particle i.
2. Initialize population vector (number at age) of each particle in year $t = 1$.
3. For each particle, generate a recruitment deviation $\epsilon_t \sim \text{lognormal}(0, \sigma_R)$. Propagate the population forward one time step.
4. Assign a weight w_p to each particle. Weight $w_p = 0$ if landings exceed abundance or if any $F_t \notin [F_L, F_U]$, and $w_p = \text{L}(\lambda_t|\boldsymbol{\theta})$ otherwise. $\text{L}(\lambda_t|\boldsymbol{\theta})$ gives the likelihood for the observed values of population change.
5. Resample the particles with replacement, where the probability of selecting particle p is given by $w_p / \sum_p w_p$. Increment year, $t = t + 1$
6. Repeat steps 3 to 5 until the end of the study.

The collection of particles in the final sample then provides an approximation to the posterior distributions of model parameters and management quantities.

For the above procedure, one must specify a likelihood function for the observed values of population change (λ_t). Here, a normal likelihood was applied. To define that likelihood, the standard deviation of population growth was assumed to be constant through time at one of three values: $\sigma_\lambda = 0.05$, $\sigma_\lambda = 0.2$, or $\sigma_\lambda = 0.35$. The central value of $\sigma_\lambda = 0.2$ is presented as the base run of stochastic SRA.

3.2.2 Model 2 Results

3.2.2.1 Model Fit In stochastic SRA, thousands of particles were fit to the population growth rate (λ_t). Several representative fits from the base run are shown in Figure 3.75, along with corresponding trajectories of spawning biomass.

3.2.2.2 **Parameter Estimates and Uncertainty** Posterior distributions of parameter estimates are shown in Figure 3.76. When interpreting these estimates, one should bear in mind that stochastic SRA is likely to impart some bias on estimated parameters (SEDAR-17-AW08). Bias occurs because one possible outcome of a stochastic stock trajectory is extinction, which is more probable for low values of $R0$ and h, and high values of σ_R. The surviving particles available to be sampled for posterior distributions would tend to have parameter values that minimized the random chance of extinction, potentially imparting bias on estimates (high for $R0$ and h, low for σ_R).

3.2.2.3 **Status of the Stock and Fishery** The posterior distribution of current F/F_{MSY} from the base run of the SRA indicated a high probability that overfishing is occurring (Figure 3.77). The posterior distribution of current SSB/MSST contained much uncertainty in stock status, but with a majority of the distribution indicating that the stock is not overfished (Figure 3.77). Sensitivity runs provided similar results (Figures 3.78, 3.79). These runs suggest that overfishing is almost certainly occurring, and that higher precision in population growth rates (smaller σ_λ) imparts greater certainty that the stock is not overfished.

3.3 Model 3: Surplus Production Model

3.3.1 Model 3 Methods

3.3.1.1 **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 to the data, decomposing population change into a number of 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 vermilion snapper off the southeastern U.S. While primary assessment of the stock was performed via the age-structured model, the surplus production approach was intended as a complement, and for additional verification that the age-structured approach was providing reasonable results.

3.3.1.2 **Data Sources** The surplus-production model was fit using a single time series of removals (Table 2.7 of §III(2)), which included landings and dead discards, and a single index of abundance (Table 2.6 of §III(2)). Both time series were of duration 1976–2007.

Landings The SEDAR-17 DW provided estimates of commercial landings in pounds (whole weight) and recreational landings in numbers of fish. For use in the production model, all landings were combined into a single time series in units of pounds. Thus, headboat and recreational landings were converted to pounds, which was accomplished by multiplying landings in numbers by the average annual mean weight from the headboat fishery. MRFSS mean weights were highly variable and were thus not used for this conversion.

Dead Discards Estimates of total discards (alive and dead) were provided in numbers for commercial and recreational data sources. These estimates were converted to numbers of dead discards by applying the discard mortality rates suggested by the DW. These values were then converted to units of pounds, as described in

SEDAR-17-AW09. The dead discards in weight were combined with the total landings for input to the ASPIC model (Table 2.7 of §III(2)).

Index of abundance Estimates of relative abundance were provided by the SEDAR-17 DW using data from the headboat program, commercial logbooks, MRFSS, and MARMAP chevron traps and Florida traps. These five indices were combined into one index of catch per effort as described in §III(2), following the methods described in SEDAR-17-AW06.

The SEDAR-17 DW believed that catchability has almost certainly increased over time, and suggested that this increase be accounted for by assuming linear change with slope of 2% per year. However, ASPIC estimates constant catchability. Thus, to account for the linear increase, the index of abundance was adjusted by dividing each year's relative abundance value by an annual catchability factor (1.0 in 1976 to 1.62 in 2007, incremented by 0.02 each year) (Table 2.6 of §III(2)).

The data input file of the base production model run is provided in Appendix C.

3.3.1.3 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). Modeling was conditioned on effort.

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

$$\frac{dB_t}{dt} = rB_t - \frac{r}{K}B_t^2, \tag{6}$$

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

$$\frac{dB_t}{dt} = (r - F_t)B_t - \frac{r}{K}B_t^2. \tag{7}$$

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.

A base run of ASPIC was configured to estimate B_1/K by minimizing sum of squared errors. Two sensitivity runs were configured with the initial biomass ratio fixed at either $B_1/K = 0.5$ or $B_1/K = 0.9$, and a third sensitivity run used a different objective function that minimized the least absolute value of errors. This objective function is less affected by outliers than sum of squared errors.

3.3.2 Model 3 Results

3.3.2.1 Model Fit

Fits to indices from the base and sensitivity runs of the surplus production model are shown in Figure 3.80. In general, fits were adequate, although the model underpredicted relative abundance near the end of the time series.

The base run estimated B_1/K at 0.700 in 1976, which falls within the range of values expected. Combining the indices allowed the model to fit the data without the added difficulty of resolving conflicts among the indices. The lack of fit to the more recent part of the CPUE time series may be due in part to an effect of regulations on CPUE.

3.3.2.2 Parameter Estimates and Uncertainty

Parameter estimates and MSY benchmarks from the base surplus production model run are tabulated in Appendix D, along with estimates of bias and precision.

3.3.2.3 Status of the Stock and Fishery

Estimates of annual biomass from the base production model have been above MSST throughout the time series, while estimates of F have fluctuated around F_{MSY} since the late 1980s (Figure 3.81). The estimate of F_{2007}/F_{MSY} indicates overfishing in the terminal year. In general, the surplus production model provides indications of status similar to those of the age-structured model regarding 2007 status: the stock is not overfished, but overfishing may be occurring (Figure 3.82).

Sensitivity analyses of the production model provided qualitatively similar results as the base run (Table 3.29).

3.4 Discussion

3.4.1 Comments on Assessment Results

Estimated benchmarks play a central role in this assessment. Values of SSB_{MSY} and F_{MSY} are used to gauge status of the stock and fishery, and in cases where rebuilding projections are necessary, SSB reaching SSB_{MSY} is the criterion that defines a successfully rebuilt stock. Computation of benchmarks is conditional on selectivity. If selectivity patterns change in the future, for example as a result of new management regulations, estimates of benchmarks would likely change as well.

The base run of the age-structured assessment model indicated that the stock is not overfished ($\text{SSB}_{2007}/\text{MSST} = 1.10$), but that overfishing is occurring ($F_{2007}/F_{\text{MSY}} = 1.27$). These results did not appear to contain much retrospective error, and were consistent with most, but not all, of the 23 configurations used in sensitivity runs. In addition, the same qualitative findings resulted from the stochastic stock reduction analysis and the surplus production model, both of which had quite different model structure than that of the catch-at-age assessment.

Although the assessment estimated that overfishing was occurring in 2007, the estimate of $F_{\text{current}} = 0.384$ (mean of last three years) was approximately equal to $F_{\text{MSY}} = 0.386$.

Although the stock was estimated not to be overfished, it may become so if the recent trend of stock decline continues. Projections predict this trend to reverse, but with much uncertainty.

3.4.2 **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:

- Initial abundance at age of the projections were centered on point estimates from the assessment. If those estimates are inaccurate, rebuilding will likely be affected.
- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect projection results.
- The projections assumed no change in the selectivity applied to discards. As stock increase generally begins with the smallest size classes, management action may be needed to meet that assumption.
- 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.

3.5 References

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3.5.1 Tables

Table 3.1. General definitions, input data, population model, and negative log-likelihood components of the statistical catch-at-age model. Hat notation ($\hat{*}$) indicates parameters estimated by the assessment model, and breve notation ($\breve{*}$) indicates estimated quantities whose fit to data forms the objective function.

Quantity	Symbol	Description or definition
General Definitions		
Index of years	y	$y \in \{1946 \ldots 2007\}$
Index of ages	a	$a \in \{1 \ldots A\}$, where $A = 12^+$
Index of size-limit periods	r	$r \in \{1 \ldots 4\}$ where 1 = 1946 – 1991 (no size limit), 2 = 1992 – 1998 (12-inch commercial limit, 10-inch rec limit), 3 = 1999 – 2006 (12-inch commercial limit, 11-inch rec limit), and 4 = 2007 (12-inch limit)
Index of length bins	l	$l \in \{1 \ldots 46\}$
Length bins	l'	$l' \in \{150, 160, \ldots, 600\}$, with values as midpoints and bin size of 10 mm. Largest size treated as a plus group.
Index of fisheries	f	$f \in \{1 \ldots 5\}$ where 1=commercial handline, 2=commercial historic trawl, 3=commercial other, 4=recreational headboat, 5=general recreational (MRFSS)
Index of discards	d	$d \in \{1 \ldots 3\}$ where 1=commercial handline, 2=recreational headboat, 3=general recreational (MRFSS)
Index of CPUE	u	$u \in \{1 \ldots 5\}$ where 1 = commercial handline, 2 = headboat, 3 = MRFSS, 4 = MARMAP FL snapper trap, 5 = MARMAP chevron trap
Input Data		
Proportion female at age	$\rho_{a,y}$	Assumed constant across ages and years
Proportion females mature at age	m_a	Values are 0.8 at age 1 and 1.0 at ages 2^+
Observed length compositions	$p^{\lambda}_{(f,d,u),l,y}$	Proportional contribution of length bin l in year y to fishery f, d (landings or discards) or index u
Observed age compositions	$p^{\alpha}_{(f,u),a,y}$	Proportional contribution of age class a in year y to fishery f or index u.
Ageing error matrix	$\mathcal{E}$	Estimated from multiple readers ageing the same otoliths.
Length comp. sample sizes	$n^{\lambda}_{(f,d,u),y}$	Number of length samples collected in year y from fishery f, discards d, or index u

Table 3.1. (continued)

Quantity	Symbol	Description or definition
Age comp. sample sizes	$n^{\alpha}_{(f,u),y}$	Number of age samples collected in year y from fishery f or index u
Observed fishery landings	$L_{f,y}$	Reported landings in year y from fishery f. Commercial L in whole weight, and rec L in numbers of fish.
CVs of landings	$c^{L}_{f,y}$	Assumed 0.05
Observed abundance indices	$U_{u,y}$	$u = 1$, commercial handline (weight), $y \in \{1993 \ldots 2007\}$ $u = 2$, headboat (numbers), $y \in \{1976 \ldots 2007\}$ $u = 3$, MRFSS (numbers), $y \in \{1987 \ldots 2007\}$ $u = 4$, MARMAP FL trap (numbers), $y \in \{1983 \ldots 1987\}$ $u = 5$, MARMAP chevron trap (numbers), $y \in \{1990 \ldots 2007\}$
CVs of abundance indices	$c^{U}_{u,y}$	$u = \{1 \ldots 5\}$ as above. Annual values estimated from delta-lognormal GLM for $u = 1, 2, 4, 5$, as PSEs for $u = 3$ (MRFSS). Each time series rescaled to a maximum of 0.3
Natural mortality rate	M_a	Function of weight at age (w_a): $M_a = \alpha w_a^{\beta}$, with estimates of α and β from Lorenzen (1996). Lorenzen M_a then rescaled based on Hoenig estimate.
Observed total discards	$D'_{d,y}$	Discards (1000 fish) in year y from fishery d.
Discard mortality rate	δ_d	Proportion discards by fishery d that die. Base values were 0.41 for commercial, 0.38 for headboat and MRFSS.
Observed discard mortalities	$D_{d,y}$	$D_{d,y} = \delta_d D'_{d,y}$
CVs of dead discards	$c^{D}_{d,y}$	Assumed 0.05
Population Model		
Mean length at age	l_a	Total length (midyear); $l_a = L_{\infty}(1 - \exp[-K(a - t_0 + 0.5)])$ where K, L_{∞}, and t_0 are parameters estimated by the DW
Mean fork length at age	ℓ_a	$\ell_a = \theta_1 + \theta_2 l_a$ where θ_1 and θ_2 are parameters from the DW
Annual fecundity at age	$\mathcal{F}_a$	$\mathcal{F}_a = \theta_3 \theta_4 \ell_a^{\theta_5}$ where θ_3 is batches per year of a mature female, and θ_4 and θ_5 are parameters describing eggs per batch
CV of l_a	$\hat{c}^{\lambda}_a$	Estimated variation of growth, assumed constant across ages.
Age–length conversion of population	$\psi^{u}_{a,l}$	$\psi^{u}_{a,l} = \frac{1}{\sqrt{2\pi}(\hat{c}^{\lambda}_a l_a)} \frac{\exp\left[-(l'_l - l_a)^2\right]}{\left(2(\hat{c}^{\lambda}_a l_a)^2\right)}$, the Gaussian density function. Matrix ψ^u is rescaled to sum to one within ages, with the largest size a plus group. This matrix is constant across years and is used only to match length comps of fishery independent indices.

Table 3.1. (continued)

Quantity	Symbol	Description or definition
Age–length conversion of landings	$\psi^L_{f,a,l,y}$	$\psi^L_{f,a,l,y} = \begin{cases} \frac{1}{\sqrt{2\pi}(\hat{c}^{\lambda}_a l_a)} \frac{\exp\left[-(l'_l - l_a)^2\right]}{\left(2(\hat{c}^{\lambda}_a l_a)^2\right)} & : l_a \geq l_{\text{limit}} \\ 0 & : \text{otherwise} \end{cases}$ where l_{limit} is the size limit for fishery f in year y (and would be treated as 0 prior to regulations). Annual matrices $\psi^L_{f,\cdot,\cdot,y}$ are rescaled to sum to one within ages, with the largest size a plus group.
Age–length conversion of discards	$\psi^D_{d,a,l,y}$	$\psi^D_{d,a,l,y} = \begin{cases} \frac{1}{\sqrt{2\pi}(\hat{c}^{\lambda}_a l_a)} \frac{\exp\left[-(l'_l - l_a)^2\right]}{\left(2(\hat{c}^{\lambda}_a l_a)^2\right)} & : l_a < l_{\text{limit}} \\ 0 & : \text{otherwise} \end{cases}$ where l_{limit} is the size limit for fishery d in year y (and would be treated as ∞ prior to regulations). Annual matrices $\psi^D_{d,\cdot,\cdot,y}$ are rescaled to sum to one within ages, with the largest size a plus group.
Mean length at age of landings and discards	$\xi^{L,D}_{(f,d),a,y}$	Mean length at age from $\psi^L_{f,\cdot,\cdot,y}$ for landings or $\psi^D_{d,\cdot,\cdot,y}$ for discards
Individual weight at age of population	w_a	Computed from length at age by $w_a = \theta_6 l_a^{\theta_7}$ where θ_6 and θ_7 are parameters from the DW
Individual weight at age of landings and discards	$w^{L,D}_{(f,d),a,y}$	Computed from length at age by $w^{L,D}_{(f,d),a,y} = \theta_6(\xi^{L,D}_{(f,d),a,y})^{\theta_7}$
Fishery and index selectivities	$s_{(f,u),a,r}$	$s_{f,a,r} = \begin{cases} \frac{1}{1+\exp\left[-\hat{\eta}_{1,f,r}(a-\hat{\alpha}_{1,f,r})\right]} & : f = 1,4,5 \\ \left(\frac{1}{\max s_{(f,u),a,r}}\right)\left(\frac{1}{1+\exp\left[-\hat{\eta}_{1,(f,u),r}(a-\hat{\alpha}_{1,(f,u),r})\right]}\right) \left(1 - \frac{1}{1+\exp\left[-\hat{\eta}_{2,(f,u),r}(a-[\hat{\alpha}_{1,(f,u),r}+\hat{\alpha}_{2,(f,u),r}])\right]}\right) & : f = 2,3 \end{cases}$ where $\hat{\eta}_{1,(f,u),r}$, $\hat{\eta}_{2,(f,u),r}$, $\hat{\alpha}_{1,(f,u),r}$, and $\hat{\alpha}_{2,(f,u)),r}$ are estimated parameters. Not all parameters were estimated for each fishery (or index) and each period of regulations; some parameters were fixed as described in the text. In the case of commercial fisheries where the size limit did not change after 1992, a single selectivity for each fishery was used for $r = 2,3,4$. In cases where knife-edge selection was applied, $\eta_{1,f,r} = 12$, where 12 is an arbitrary value to achieve the desired shape.

Table 3.1. (continued)

Quantity	Symbol	Description or definition
Discard selectivity	$s'_{d,a,r}$	$s'_{d,1,r}$ assumed zero; $s'_{d,2,r}$ estimated; $s'_{d,3,r} = 1$; $s'_{d,4^+,r}$ set equal to the age-specific probability of total length below the size limit in period r. Recreational fisheries ($d = 2, 3$) assumed to have the same discard selectivity. Recreational discard selectivity in period $r = 1$ assumed the same as that in $r = 2$. Recreational selectivity of age-2 in $r = 2$ set equal to the estimated parameter from $r = 3$.
Fishing mortality rate of landings	$F_{f,a,y}$	$F_{f,a,y} = s_{f,a,y}\hat{F}_{f,y}$ where $\hat{F}_{f,y}$ is an estimated fully selected fishing mortality rate by fishery and $s_{f,a,y} = s_{f,a,r}$ for y in the years represented by r
Fishing mortality rate of discards	$F^D_{d,a,y}$	$F^D_{d,a,y} = s'_{d,a,r}\hat{F}^D_{d,y}$ where $\hat{F}^D_{d,y}$ is an estimated fully selected fishing mortality rate of discards by fishery
Total fishing mortality rate	F_y	$F_y = \sum_f \hat{F}_{f,y} + \sum_d \hat{F}^D_{d,y}$
Total mortality rate	$Z_{a,y}$	$Z_{a,y} = M_a + \sum_f F_{f,a,y} + \sum_d F^D_{d,a,y}$
Abundance at age	$N_{a,y}$	$N_{1,1946} = \frac{\hat{R}_0\left(\varsigma 0.8\hat{h} - 0.2(1-\hat{h})\right)}{h-0.2}$ $N_{a+1,1946} = N_{a,1946}\exp(-M_a) \quad \forall a \in (1\ldots A-1)$ $N_{A,1946} = N_{A-1,1946}\frac{\exp(-M_{A-1})}{1-\exp(-M_A)}$ $N_{1,y+1} = \begin{cases} \frac{0.8\hat{R}_0\hat{h}S_y}{0.2\phi_0\hat{R}_0(1-\hat{h})+(\hat{h}-0.2)S_y}\varsigma & \text{for } y+1 < 1976 \\ \frac{0.8\hat{R}_0\hat{h}S_y}{0.2\phi_0\hat{R}_0(1-\hat{h})+(\hat{h}-0.2)S_y}\exp(\hat{R}_{y+1}) & \text{for } y+1 \geq 1976 \end{cases}$ $N_{a+1,y+1} = N_{a,y}\exp(-Z_{a,y}) \quad \forall a \in (1\ldots A-1)$ $N_{A,y} = N_{A-1,y-1}\frac{\exp(-Z_{A-1,y-1})}{1-\exp(-Z_{A,y-1})}$ where 1946 is the initialization year starting with a virgin population. Parameters $\hat{R}_0$ (asymptotic maximum recruitment) and $\hat{h}$ (steepness) are estimated parameters of the spawner-recruit curve, and $\hat{R}_y$ are estimated annual recruitment deviations in log space for $y \geq 1976$ and are zero otherwise. Bias correction $\varsigma = \exp(\sigma^2/2)$, where σ^2 is the variance of recruitment deviations during 1976–2004. Quantities ϕ_0 and S_y are described below.
Abundance at age (mid-year)	$N'_{a,y}$	Used to match indices of abundance $N'_{a,y} = N_{a,y}\exp(-Z_{a,y}/2)$
Abundance at age at time of spawning	$N''_{a,y}$	Assumed mid-year to correspond with peak spawning $N''_{a,y} = N'_{a,y}$
Unfished abundance at age per recruit at time of spawning	NPR_a	$NPR_1 = 1 \times \exp(-M_1/2)$ $NPR_{a+1} = NPR_a \exp[-(M_a + M_{a+1})/2] \quad \forall a \in (1\ldots A-1)$ $NPR_A = \frac{NPR_{A-1}\exp[-(M_{A-1}+M_A)/2]}{1-\exp(-M_A)}$
Unfished spawning biomass per recruit	ϕ_0	$\phi_0 = \sum_a NPR_a \mathcal{F}_a \rho_{a,y} m_a$

Table 3.1. (continued)

Quantity	Symbol	Description or definition
Spawning biomass	S_y	$S_y = \sum_a N''_{a,y} \mathcal{F}_a \rho_{a,y} m_a$ Also referred to as spawning stock biomass (SSB), here in units of population fecundity (eggs).
Population biomass	B_y	$B_y = \sum_a N_{a,y} w_a$
Landing at age in numbers	$L'_{f,a,y}$	$L'_{f,a,y} = \frac{F_{f,a,y}}{Z_{a,y}} N_{a,y}[1-\exp(-Z_{a,y})]$
Landing at age in weight	$L''_{f,a,y}$	$L''_{f,a,y} = w^L_{f,a,y} L'_{f,a,y}$
Discard mortalities at age in numbers	$D'_{d,a,y}$	$D'_{d,a,y} = \frac{F^D_{d,a,y}}{Z_{a,y}} N_{a,y}[1-\exp(-Z_{a,y})]$
Discard mortalities at age in weight	$D''_{d,a,y}$	$D''_{d,a,y} = w^D_{d,a,y} D'_{d,a,y}$
Predicted landings	$\check{L}_{f,y}$	$\check{L}_{f,y} = \begin{cases} \sum_a L''_{f,a,y} & : f = 1,2,3 \\ \sum_a L'_{f,a,y} & : f = 4,5 \end{cases}$
Predicted discard mortalities	$\check{D}_{d,y}$	$\check{D}_{d,y} = \sum_a D'_{d,a,y}$
Predicted length compositions of fishery independent data	$\check{p}^{\lambda}_{u,l,y}$	$\check{p}^{\lambda}_{u,l,y} = \frac{\sum_a \psi_{a,l} s_{u,a,y} N'_{a,y}}{\sum_a s_{u,a,y} N'_{a,y}}$
Predicted length compositions of landings	$\check{p}^{\lambda}_{f,l,y}$	$\check{p}^{\lambda}_{f,l,y} = \frac{\sum_a \psi^L_{f,a,l,y} L'_{f,a,y}}{\sum_a L'_{f,a,y}}$
Predicted length compositions of discards	$\check{p}^{\lambda}_{d,l,y}$	$\check{p}^{\lambda}_{d,l,y} = \frac{\sum_a \psi^D_{d,a,l,y} D'_{d,a,y}}{\sum_a D'_{d,a,y}}$
Predicted age compositions	$\check{p}^{\alpha}_{(f,u),a,y}$	$\check{p}^{\alpha}_{(f,u),a,y} = \frac{\mathcal{E} L'_{(f,u),a,y}}{\sum_a L'_{(f,u),a,y}}$
Predicted CPUE	$\check{U}_{u,y}$	$\check{U}_{u,y} = \begin{cases} \hat{q}_u \sum_a w^L_{f=u,a,y} N'_{a,y} s_{u,a,r} & : u = 1 \\ \hat{q}_u \sum_a N'_{a,y} s_{u,a,r} & : u = 2,3,4,5 \end{cases}$ where $\hat{q}_u$ is the estimated catchability coefficient of index u and $s_{u,a,r}$ is the selectivity of the relevant fishery in the year corresponding to y
Objective Function		
Multinomial length compositions	Λ_1	$\Lambda_1 = -\omega_1 \sum_{f,d,u} \sum_y \left[n^{\lambda}_{(f,d,u),y} \sum_l (p^{\lambda}_{(f,d,u),l,y} + x) \log \left(\frac{(\check{p}^{\lambda}_{(f,d,u),l,y} + x)}{(p^{\lambda}_{(f,d,u),l,y} + x)} \right) \right]$ where ω_1 is a preset weight and x =1e-5 is an arbitrary value to avoid log zero. The denominator of the log is a scaling term. Bins are 10 mm wide.

Table 3.1. (continued)

Quantity	Symbol	Description or definition
Multinomial age compositions	Λ_2	$\Lambda_2 = -\omega_2 \sum_{f,u} \sum_{y} \left[n^{\alpha}_{(f,u),y} \sum_{a} (p^{\alpha}_{(f,u),a,y} + x) \log \left(\frac{(\breve{p}^{\alpha}_{(f,u),a,y} + x)}{(p^{\alpha}_{(f,u),a,y} + x)} \right) \right]$ where ω_2 is a preset weight and x =1e-5 is an arbitrary value to avoid log zero. The denominator of the log is a scaling term.
Lognormal landings	Λ_3	$\Lambda_3 = \omega_3 \sum_{f} \sum_{y} \frac{\left[\log\left((L_{f,y}+x)/(\breve{L}_{f,y}+x)\right)\right]^2}{2(c^L_{f,y})^2}$ where ω_3 is a preset weight and x =1e-5 is an arbitrary value to avoid log zero or division by zero. Here, input CVs are treated as standard deviations.
Lognormal discard mortalities	Λ_4	$\Lambda_4 = \omega_4 \sum_{d} \sum_{y} \frac{\left[\log\left((\delta_d D_{d,y}+x)/(\breve{D}_{d,y}+x)\right)\right]^2}{2(c^D_{d,y})^2}$ where ω_4 is a preset weight and x =1e-5 is an arbitrary value to avoid log zero or division by zero. Here, input CVs are treated as standard deviations.
Lognormal CPUE	Λ_5	$\Lambda_5 = \sum_{u} \omega_5 \sum_{y} \frac{\left[\log\left((U_{u,y}+x)/(\breve{U}_{u,y}+x)\right)\right]^2}{2(c^U_{u,y})^2}$ where ω_5 is a preset weight and x =1e-5 is an arbitrary value to avoid log zero or division by zero. Here, input CVs are treated as standard deviations.
Constraint on recruitment deviations	Λ_6	$\Lambda_6 = \omega_6 \left[R^2_{1976} + \sum_{y>1976} (R_y - \hat{\varrho} R_{y-1})^2 \right]$ where R_y are recruitment deviations in log space, $\omega_6 = 1$ is a preset weight and $\hat{\varrho}$ is the estimated first-order autocorrelation
Additional constraint on recruitment deviations	Λ_7	$\Lambda_7 = \omega_7 \left(\sum_{y \geq 2005} R^2_y \right)$ where $\omega_7 = 1000$ is a preset weight
Total objective function	Λ	$\Lambda = \sum_{i=1}^{7} \Lambda_i$ Objective function minimized by the assessment model

Table 3.2. Average size at age (mid-year) of population

Age	Total length (mm)	Total length (in)	CV length	Whole weight (kg)	Whole weight (lb)
1	228.3	9.0	0.21	0.15	0.33
2	259.7	10.2	0.21	0.22	0.48
3	287.6	11.3	0.21	0.29	0.65
4	312.3	12.3	0.21	0.37	0.83
5	334.2	13.2	0.21	0.46	1.01
6	353.6	13.9	0.21	0.54	1.19
7	370.8	14.6	0.21	0.62	1.36
8	386.1	15.2	0.21	0.69	1.53
9	399.7	15.7	0.21	0.77	1.69
10	411.7	16.2	0.21	0.84	1.85
11	422.4	16.6	0.21	0.90	1.99
12	431.8	17.0	0.21	0.96	2.12

Table 3.3. Estimated abundance at age (1000 fish) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12
1946	6073.9	4318.9	3186.8	2413.3	1864.5	1462.3	1160.7	929.6	750.5	609.6	498.1	2317.1
1947	6073.9	4318.9	3186.8	2413.3	1864.5	1462.3	1160.7	929.6	750.5	609.6	498.1	2317.1
1948	6073.4	4316.2	3183.5	2410.3	1862.2	1460.4	1159.1	928.3	749.5	608.7	497.4	2314.0
1949	6071.8	4313.1	3178.2	2404.9	1857.5	1456.6	1156.0	925.8	747.4	607.1	496.0	2307.6
1950	6069.2	4309.2	3172.6	2397.9	1850.9	1451.0	1151.4	922.0	744.3	604.5	494.0	2298.0
1951	6065.8	4304.6	3166.4	2390.5	1843.1	1443.8	1145.4	917.1	740.2	601.2	491.2	2285.1
1952	6061.6	4299.3	3159.5	2382.7	1835.0	1435.7	1138.0	910.9	735.2	597.0	487.7	2268.9
1953	6056.7	4293.4	3152.1	2374.3	1826.4	1427.2	1129.9	903.7	729.1	592.0	483.6	2249.4
1954	6051.0	4286.7	3144.0	2365.3	1817.3	1418.3	1121.5	895.8	722.2	586.1	478.8	2226.6
1955	6044.6	4279.5	3135.3	2355.7	1807.6	1409.0	1112.7	887.6	714.7	579.6	473.3	2200.3
1956	6037.6	4271.6	3126.0	2345.6	1797.5	1399.2	1103.5	879.1	706.9	572.6	467.2	2170.7
1957	6029.9	4263.1	3116.0	2334.8	1786.7	1388.9	1093.8	870.3	698.9	565.3	460.7	2137.7
1958	6021.5	4253.9	3105.4	2323.4	1775.4	1378.0	1083.6	861.0	690.5	557.8	453.9	2101.7
1959	6012.5	4244.0	3094.1	2311.3	1763.4	1366.5	1073.0	851.2	681.7	550.0	447.0	2062.8
1960	6002.7	4233.4	3082.1	2298.5	1750.7	1354.3	1061.6	840.9	672.4	541.7	439.7	2021.1
1961	5992.2	4222.1	3069.2	2284.9	1737.3	1341.6	1049.7	830.1	662.7	533.1	432.1	1977.0
1962	5979.8	4149.7	3055.6	2270.5	1723.1	1326.6	1035.7	817.5	651.5	523.3	423.5	1927.5
1963	5965.2	4089.8	2997.7	2255.4	1708.3	1313.3	1022.3	805.1	640.5	513.5	414.9	1877.7
1964	5950.3	4181.8	2949.6	2208.3	1693.4	1298.2	1008.8	792.1	628.8	503.2	405.9	1825.2
1965	5937.2	4168.1	3012.3	2169.6	1655.5	1286.0	996.9	781.4	618.4	493.8	397.5	1775.5
1966	5924.6	4157.1	3000.3	2213.8	1624.9	1254.6	985.0	770.2	608.4	484.4	389.1	1724.9
1967	5913.3	4147.9	2991.9	2204.6	1657.8	1232.9	962.5	762.3	600.7	477.4	382.3	1680.7
1968	5903.8	4140.9	2986.3	2199.4	1651.6	1257.4	945.3	744.4	594.2	471.0	376.6	1639.2
1969	5895.3	4135.6	2982.8	2196.7	1648.8	1251.9	963.0	730.3	579.6	465.4	371.2	1600.0
1970	5888.3	4131.1	2980.6	2195.5	1647.9	1250.7	959.6	744.6	569.1	454.4	367.0	1565.8
1971	5883.1	4126.9	2978.2	2194.6	1647.6	1251.6	960.2	743.1	581.1	446.8	358.9	1537.8
1972	5877.7	4121.8	2974.6	2192.3	1646.6	1246.6	955.9	739.7	577.0	453.9	351.1	1501.2
1973	5869.5	4081.9	2962.7	2182.3	1638.8	1240.7	948.0	733.3	571.9	448.8	355.2	1459.8
1974	5860.3	4092.5	2936.3	2175.6	1633.0	1234.4	942.8	726.6	566.5	444.4	350.8	1429.1
1975	5850.3	4089.4	2938.3	2151.2	1623.9	1223.4	932.0	717.9	557.7	437.3	345.2	1392.5
1976	1079.2	4074.3	2927.5	2145.0	1599.5	1201.7	909.6	698.9	542.6	424.0	334.5	1338.6
1977	1400.4	734.0	2916.8	2137.0	1594.4	1183.3	893.2	681.9	528.0	412.4	324.1	1288.3
1978	11810.6	948.8	524.8	2126.6	1588.7	1173.0	872.9	664.6	511.3	398.3	312.9	1232.6
1979	1426.4	8215.4	671.8	378.6	1570.9	1153.1	851.6	639.2	490.5	379.7	297.5	1162.9
1980	1929.3	857.7	5861.4	488.3	280.0	1130.2	826.8	615.8	465.8	359.6	280.0	1084.7
1981	3503.2	686.4	612.8	4268.0	361.9	199.4	798.7	589.3	442.3	336.6	261.3	999.1
1982	4203.8	1839.5	487.5	443.6	3161.7	254.0	138.2	558.4	415.2	313.5	240.0	905.3
1983	8592.2	2358.1	1280.8	344.4	319.8	2126.1	167.7	92.0	374.5	280.1	212.8	783.0
1984	4021.6	5545.2	1644.6	905.9	247.9	212.5	1381.2	109.8	60.7	248.6	187.1	669.8
1985	6360.0	2467.3	3877.5	1165.9	651.5	156.5	128.9	844.8	67.7	37.6	155.0	538.1
1986	6094.4	4250.7	1694.9	2690.0	819.3	362.5	80.6	66.9	441.8	35.6	19.9	369.4
1987	2856.1	4100.3	2947.4	1189.6	1915.0	427.7	170.5	38.2	32.0	212.3	17.2	189.6
1988	4586.4	1803.1	2801.8	2031.5	830.1	1081.6	225.4	90.5	20.5	17.2	114.9	112.8
1989	2555.9	2767.9	1224.2	1916.7	1408.4	426.0	501.9	105.4	42.6	9.7	8.2	109.2
1990	15458.8	1488.7	1849.8	822.1	1306.6	634.8	166.7	197.9	41.9	17.0	3.9	47.5
1991	881.0	10207.5	1025.5	1290.7	586.8	554.4	225.3	59.7	71.4	15.2	6.2	18.9
1992	3514.5	450.1	7065.6	718.1	915.8	108.8	64.2	26.3	7.0	8.4	1.8	3.0
1993	10414.9	2499.0	329.2	4641.5	428.2	555.0	66.8	39.8	16.4	4.4	5.3	3.1
1994	1210.3	7405.6	1819.7	214.5	2796.9	262.6	345.1	41.9	25.2	10.5	2.8	5.4
1995	5797.7	860.6	5429.1	1140.6	118.7	1575.2	149.9	199.0	24.4	14.8	6.2	4.9
1996	2671.6	4122.5	626.7	3559.5	689.5	73.0	981.3	94.3	126.3	15.6	9.5	7.2
1997	5034.5	1899.7	3015.6	410.8	2199.1	434.1	46.6	634.0	61.5	82.9	10.3	11.1
1998	5966.5	3579.8	1388.3	1973.5	248.5	1353.7	270.9	29.4	403.3	39.4	53.5	13.9
1999	5990.5	4242.5	2614.5	903.9	1187.9	152.3	841.4	170.2	18.6	257.4	25.3	43.5
2000	4206.1	4259.6	2981.0	1604.6	537.6	719.7	93.6	522.6	106.7	11.8	163.5	44.0
2001	5845.2	2990.8	2994.6	1741.4	873.5	298.0	404.6	53.2	299.6	61.6	6.8	121.2
2002	5653.4	4156.3	2102.9	1685.0	888.4	453.8	157.0	215.4	28.6	162.1	33.5	70.3
2003	3054.7	4019.9	2947.5	1188.3	881.8	474.5	246.2	86.2	119.4	16.0	91.1	58.8
2004	3039.3	2172.1	2866.8	1859.1	727.3	549.3	299.7	157.1	55.5	77.4	10.4	98.4
2005	3370.9	2161.1	1531.7	1738.2	1068.3	425.2	325.6	179.4	94.9	33.7	47.4	67.1
2006	3678.7	2396.9	1531.0	913.6	973.2	608.8	245.7	190.1	105.7	56.3	20.1	68.8
2007	3272.1	2615.8	1677.7	900.9	510.2	553.1	350.8	143.1	111.6	62.5	33.5	53.3
2008	3178.8	2290.3	1701.1	907.6	446.3	256.4	281.0	179.7	73.8	58.0	32.6	45.6

Table 3.4. Estimated biomass at age (mt) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12
1946	916.0	947.3	939.9	904.4	851.0	786.6	717.0	645.8	576.4	510.3	449.1	2228.4
1947	916.0	947.3	939.9	904.4	851.0	786.6	717.0	645.8	576.4	510.3	449.1	2228.4
1948	915.9	946.7	938.9	903.3	850.0	785.6	716.0	644.9	575.6	509.6	448.5	2225.3
1949	915.6	946.0	937.4	901.3	847.8	783.6	714.1	643.2	574.0	508.2	447.3	2219.2
1950	915.2	945.2	935.7	898.6	844.8	780.5	711.3	640.5	571.7	506.1	445.4	2210.0
1951	914.7	944.2	933.9	895.9	841.2	776.7	707.5	637.1	568.5	503.3	442.9	2197.6
1952	914.1	943.0	931.8	893.0	837.5	772.3	703.0	632.8	564.6	499.7	439.8	2182.0
1953	913.3	941.7	929.6	889.8	833.6	767.7	698.0	627.8	559.9	495.5	436.1	2163.3
1954	912.5	940.2	927.3	886.4	829.4	763.0	692.8	622.3	554.6	490.7	431.7	2141.3
1955	911.5	938.6	924.7	882.9	825.1	758.0	687.4	616.7	548.9	485.2	426.7	2116.0
1956	910.5	936.9	921.9	879.1	820.4	752.7	681.7	610.8	542.9	479.3	421.3	2087.5
1957	909.3	935.0	919.0	875.0	815.5	747.1	675.7	604.6	536.7	473.3	415.4	2055.8
1958	908.1	933.0	915.9	870.8	810.3	741.3	669.4	598.1	530.3	467.0	409.3	2021.2
1959	906.7	930.9	912.6	866.2	804.9	735.1	662.8	591.4	523.5	460.4	403.0	1983.7
1960	905.2	928.5	909.0	861.4	799.1	728.5	655.8	584.2	516.4	453.5	396.5	1943.7
1961	903.6	926.0	905.2	856.3	793.0	721.7	648.5	576.7	509.0	446.3	389.6	1901.2
1962	901.8	910.2	901.2	850.9	786.5	713.6	639.8	567.9	500.4	438.0	381.8	1853.7
1963	899.6	897.0	884.1	845.2	779.7	706.4	631.5	559.3	491.9	429.9	374.1	1805.8
1964	897.3	917.2	869.9	827.6	772.9	698.4	623.2	550.3	482.9	421.2	366.0	1755.3
1965	895.3	914.2	888.4	813.1	755.6	691.8	615.8	542.8	474.9	413.3	358.5	1707.4
1966	893.4	911.8	884.9	829.7	741.7	674.9	608.5	535.1	467.3	405.5	350.9	1658.8
1967	891.7	909.8	882.4	826.2	756.7	663.2	594.6	529.6	461.3	399.6	344.8	1616.3
1968	890.3	908.2	880.8	824.2	753.8	676.4	583.9	517.1	456.3	394.3	339.6	1576.4
1969	889.0	907.1	879.7	823.2	752.6	673.5	594.9	507.3	445.2	389.6	334.7	1538.7
1970	888.0	906.1	879.1	822.8	752.2	672.8	592.8	517.3	437.1	380.4	331.0	1505.8
1971	887.2	905.2	878.4	822.5	752.0	673.3	593.1	516.2	446.3	374.0	323.6	1478.8
1972	886.4	904.0	877.3	821.6	751.5	670.6	590.5	513.9	443.2	380.0	316.6	1443.7
1973	885.1	895.3	873.8	817.8	748.0	667.4	585.6	509.4	439.2	375.7	320.3	1403.9
1974	883.7	897.6	866.0	815.3	745.3	664.0	582.4	504.8	435.0	372.0	316.3	1374.4
1975	882.2	896.9	866.6	806.2	741.2	658.1	575.7	498.8	428.3	366.1	311.3	1339.1
1976	162.7	893.6	863.4	803.9	730.1	646.4	561.9	485.5	416.7	354.9	301.6	1287.3
1977	211.2	161.0	860.3	800.9	727.8	636.5	551.7	473.7	405.5	345.2	292.3	1239.0
1978	1781.0	208.1	154.8	797.0	725.1	631.0	539.2	461.7	392.7	333.4	282.2	1185.3
1979	215.1	1801.9	198.1	141.9	717.0	620.3	526.1	444.1	376.7	317.8	268.3	1118.3
1980	290.9	188.1	1728.7	183.0	127.8	608.0	510.7	427.8	357.8	301.0	252.5	1043.1
1981	528.3	150.6	180.7	1599.5	165.2	107.3	493.4	409.4	339.7	281.8	235.7	960.8
1982	633.9	403.5	143.8	166.2	1443.1	136.7	85.4	387.9	318.9	262.5	216.4	870.7
1983	1295.7	517.2	377.8	129.1	146.0	1143.7	103.6	63.9	287.6	234.5	191.9	753.0
1984	606.5	1216.3	485.0	339.5	113.1	114.3	853.2	76.3	46.6	208.1	168.7	644.2
1985	959.1	541.2	1143.6	437.0	297.4	84.2	79.6	586.9	52.0	31.5	139.8	517.5
1986	919.0	932.3	499.9	1008.1	373.9	195.0	49.8	46.5	339.3	29.8	18.0	355.3
1987	430.7	899.3	869.3	445.8	874.1	230.1	105.3	26.6	24.6	177.7	15.5	182.4
1988	691.6	395.5	826.3	761.3	378.9	581.9	139.2	62.9	15.7	14.4	103.6	108.5
1989	385.4	607.1	361.0	718.3	642.8	229.2	310.0	73.2	32.8	8.1	7.4	105.0
1990	2331.2	326.5	545.6	308.1	596.4	341.5	103.0	137.5	32.1	14.3	3.5	45.7
1991	132.9	2238.8	302.5	483.7	267.8	298.2	139.2	41.5	54.8	12.7	5.6	18.2
1992	530.0	98.7	2083.8	269.1	418.0	58.5	39.7	18.3	5.4	7.1	1.6	2.9
1993	1570.6	548.1	97.1	1739.5	195.4	298.5	41.3	27.6	12.6	3.7	4.8	3.0
1994	182.5	1624.3	536.7	80.4	1276.6	141.3	213.2	29.1	19.4	8.8	2.6	5.2
1995	874.3	188.8	1601.2	427.5	54.2	847.3	92.6	138.3	18.7	12.4	5.6	4.7
1996	402.9	904.2	184.8	1334.0	314.7	39.3	606.2	65.5	97.0	13.1	8.6	6.9
1997	759.2	416.7	889.4	154.0	1003.7	233.5	28.8	440.4	47.2	69.4	9.3	10.7
1998	899.7	785.2	409.5	739.6	113.4	728.2	167.4	20.4	309.8	33.0	48.2	13.3
1999	903.4	930.5	771.1	338.8	542.2	81.9	519.8	118.2	14.3	215.4	22.8	41.8
2000	634.3	934.3	879.2	601.4	245.4	387.1	57.8	363.1	81.9	9.8	147.4	42.3
2001	881.5	656.0	883.2	652.6	398.7	160.3	249.9	36.9	230.1	51.5	6.2	116.5
2002	852.5	911.6	620.2	631.5	405.5	244.1	97.0	149.7	21.9	135.7	30.2	67.6
2003	460.6	881.7	869.3	445.3	402.5	255.2	152.1	59.9	91.7	13.4	82.2	56.6
2004	458.3	476.4	845.5	696.7	331.9	295.5	185.1	109.2	42.6	64.8	9.4	94.7
2005	508.3	474.0	451.8	651.4	487.6	228.8	201.1	124.7	72.9	28.2	42.7	64.6
2006	554.7	525.7	451.5	342.4	444.2	327.5	151.8	132.1	81.2	47.1	18.2	66.2
2007	493.4	573.7	494.8	337.6	232.9	297.5	216.7	99.4	85.7	52.3	30.2	51.3
2008	479.4	502.3	501.7	340.1	203.7	137.9	173.6	124.9	56.7	48.5	29.4	43.9

Table 3.5. Estimated biomass at age (1000 lb) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12
1946	2019.3	2088.4	2072.1	1993.9	1876.2	1734.2	1580.7	1423.8	1270.8	1125.0	990.2	4912.7
1947	2019.3	2088.4	2072.1	1993.9	1876.2	1734.2	1580.7	1423.8	1270.8	1125.0	990.2	4912.7
1948	2019.1	2087.1	2069.9	1991.5	1873.8	1731.9	1578.6	1421.8	1269.0	1123.5	988.8	4906.0
1949	2018.6	2085.6	2066.5	1987.0	1869.1	1727.4	1574.4	1417.9	1265.5	1120.4	986.1	4892.5
1950	2017.8	2083.7	2062.9	1981.2	1862.5	1720.8	1568.1	1412.2	1260.3	1115.7	982.0	4872.1
1951	2016.6	2081.5	2058.8	1975.1	1854.6	1712.3	1559.8	1404.5	1253.4	1109.5	976.5	4844.8
1952	2015.2	2078.9	2054.3	1968.6	1846.4	1702.6	1549.9	1395.1	1244.7	1101.7	969.6	4810.5
1953	2013.6	2076.0	2049.5	1961.7	1837.8	1692.6	1538.8	1384.0	1234.5	1092.5	961.4	4769.2
1954	2011.7	2072.8	2044.2	1954.3	1828.6	1682.1	1527.3	1372.0	1222.7	1081.7	951.8	4720.7
1955	2009.6	2069.3	2038.6	1946.4	1818.9	1671.0	1515.4	1359.5	1210.1	1069.7	940.8	4665.1
1956	2007.2	2065.5	2032.5	1938.0	1808.7	1659.4	1502.8	1346.5	1197.0	1056.7	928.7	4602.2
1957	2004.7	2061.4	2026.1	1929.1	1797.9	1647.1	1489.6	1332.9	1183.3	1043.4	915.8	4532.4
1958	2001.9	2057.0	2019.2	1919.7	1786.5	1634.2	1475.8	1318.6	1169.1	1029.5	902.4	4455.9
1959	1998.9	2052.2	2011.8	1909.7	1774.4	1620.6	1461.3	1303.7	1154.2	1015.0	888.6	4373.4
1960	1995.7	2047.1	2004.0	1899.1	1761.7	1606.2	1445.8	1287.9	1138.5	999.8	874.1	4285.1
1961	1992.2	2041.6	1995.7	1887.8	1748.2	1591.0	1429.6	1271.3	1122.1	983.9	858.9	4191.5
1962	1988.0	2006.6	1986.8	1875.9	1733.9	1573.2	1410.4	1252.0	1103.2	965.7	841.8	4086.7
1963	1983.2	1977.6	1949.2	1863.5	1719.0	1557.5	1392.3	1233.0	1084.5	947.7	824.8	3981.1
1964	1978.2	2022.1	1917.9	1824.5	1704.0	1539.6	1373.9	1213.2	1064.6	928.7	806.9	3869.8
1965	1973.9	2015.5	1958.6	1792.6	1665.8	1525.1	1357.6	1196.7	1047.0	911.2	790.3	3764.2
1966	1969.7	2010.1	1950.8	1829.1	1635.1	1487.9	1341.5	1179.6	1030.2	894.0	773.5	3657.0
1967	1965.9	2005.7	1945.4	1821.5	1668.2	1462.1	1310.8	1167.5	1017.1	881.0	760.1	3563.4
1968	1962.8	2002.3	1941.7	1817.2	1661.9	1491.2	1287.4	1140.1	1006.0	869.3	748.6	3475.4
1969	1959.9	1999.8	1939.5	1814.9	1659.1	1484.7	1311.6	1118.5	981.4	859.0	737.9	3392.3
1970	1957.6	1997.6	1938.0	1814.0	1658.2	1483.3	1306.9	1140.4	963.6	838.6	729.7	3319.8
1971	1955.9	1995.5	1936.4	1813.2	1657.9	1484.3	1307.7	1138.1	984.0	824.6	713.5	3260.3
1972	1954.1	1993.1	1934.1	1811.4	1656.8	1478.4	1301.9	1133.0	977.0	837.8	698.0	3182.9
1973	1951.4	1973.8	1926.4	1803.0	1649.1	1471.4	1291.1	1123.1	968.4	828.2	706.1	3095.0
1974	1948.3	1978.9	1909.2	1797.5	1643.2	1464.0	1283.9	1112.9	959.1	820.2	697.4	3030.0
1975	1945.0	1977.4	1910.5	1777.3	1634.0	1450.9	1269.3	1099.6	944.3	807.1	686.2	2952.3
1976	358.8	1970.1	1903.5	1772.2	1609.5	1425.1	1238.8	1070.4	918.7	782.5	665.0	2838.0
1977	465.6	354.9	1896.5	1765.7	1604.4	1403.3	1216.4	1044.3	894.0	761.0	644.4	2731.5
1978	3926.5	458.8	341.2	1757.1	1598.6	1391.2	1188.8	1017.8	865.8	735.1	622.1	2613.2
1979	474.2	3972.5	436.8	312.8	1580.7	1367.5	1159.8	979.0	830.5	700.7	591.5	2465.5
1980	641.4	414.7	3811.1	403.4	281.7	1340.4	1126.0	943.1	788.7	663.6	556.6	2299.7
1981	1164.7	331.9	398.5	3526.4	364.2	236.5	1087.8	902.5	748.9	621.2	519.6	2118.2
1982	1397.6	889.5	317.0	366.5	3181.5	301.3	188.2	855.2	703.0	578.6	477.2	1919.5
1983	2856.5	1140.3	832.8	284.5	321.8	2521.4	228.4	140.9	634.1	517.0	423.1	1660.2
1984	1337.0	2681.4	1069.3	748.5	249.4	252.0	1881.0	168.2	102.8	458.9	371.9	1420.2
1985	2114.4	1193.1	2521.2	963.3	655.5	185.6	175.6	1293.8	114.6	69.4	308.2	1141.0
1986	2026.1	2055.4	1102.1	2222.5	824.4	429.9	109.8	102.5	748.1	65.7	39.6	783.2
1987	949.5	1982.7	1916.4	982.8	1927.0	507.2	232.2	58.6	54.1	391.8	34.2	402.1
1988	1524.8	871.9	1821.7	1678.5	835.2	1282.8	307.0	138.7	34.6	31.8	228.5	239.2
1989	849.7	1338.4	796.0	1583.6	1417.2	505.3	683.5	161.4	72.2	17.9	16.3	231.5
1990	5139.4	719.9	1202.8	679.3	1314.8	752.8	227.1	303.1	70.9	31.4	7.7	100.8
1991	292.9	4935.8	666.8	1066.4	590.4	657.5	306.8	91.4	120.8	28.0	12.4	40.1
1992	1168.4	217.6	4594.1	593.3	921.5	129.0	87.4	40.3	11.9	15.6	3.6	6.4
1993	3462.5	1208.4	214.1	3834.9	430.9	658.1	90.9	60.9	27.8	8.1	10.6	6.5
1994	402.4	3581.0	1183.2	177.2	2814.4	311.4	469.9	64.2	42.7	19.3	5.6	11.5
1995	1927.5	416.1	3530.1	942.4	119.5	1868.1	204.2	304.8	41.3	27.3	12.3	10.4
1996	888.2	1993.4	407.5	2941.0	693.8	86.6	1336.5	144.5	213.9	28.8	18.9	15.2
1997	1673.8	918.6	1960.8	339.4	2212.9	514.8	63.5	971.0	104.2	153.1	20.5	23.5
1998	1983.6	1731.0	902.7	1630.5	250.0	1605.4	369.0	45.0	682.9	72.7	106.3	29.4
1999	1991.6	2051.5	1699.9	746.8	1195.3	180.6	1145.9	260.6	31.6	475.0	50.3	92.2
2000	1398.4	2059.7	1938.3	1325.8	541.0	853.5	127.5	800.4	180.6	21.7	325.0	93.3
2001	1943.3	1446.2	1947.1	1438.8	878.9	353.4	551.0	81.4	507.2	113.6	13.6	256.9
2002	1879.5	2009.7	1367.3	1392.2	894.0	538.2	213.9	330.0	48.4	299.1	66.6	149.1
2003	1015.6	1943.8	1916.5	981.8	887.3	562.7	335.3	132.0	202.2	29.4	181.2	124.7
2004	1010.4	1050.3	1864.0	1536.0	731.8	651.5	408.1	240.6	94.0	142.8	20.7	208.7
2005	1120.7	1045.0	995.9	1436.2	1075.0	504.3	443.4	274.8	160.7	62.3	94.1	142.3
2006	1223.0	1159.0	995.5	754.8	979.2	722.0	334.7	291.2	179.0	103.9	40.0	145.9
2007	1087.8	1264.8	1090.8	744.4	513.4	656.0	477.8	219.1	189.0	115.3	66.6	113.1
2008	1056.8	1107.5	1106.1	749.9	449.1	304.1	382.7	275.3	125.0	107.0	64.9	96.8

Table 3.6. Estimated time series and status indicators. Fishing mortality rate is full F, which includes discard mortalities. Total biomass (B, mt) is at the start of the year, and spawning biomass (SSB, 10^{12} eggs) at the midpoint. The MSST *is defined by* $\text{MSST} = (1 - M)\text{SSB}_{\text{MSY}}$*, with constant* $M = 0.22$*. SPR is static spawning potential ratio.*

Year	F	F/F_{MSY}	B	B/B_{unfished}	SSB	$\text{SSB}/\text{SSB}_{\text{MSY}}$	SSB/MSST	SPR
1946	0.00000	0.00000	10472	1.000	31.39	3.428	4.39	1.000
1947	0.00151	0.00391	10472	1.000	31.37	3.426	4.39	0.992
1948	0.00303	0.00787	10460	0.999	31.31	3.420	4.38	0.983
1949	0.00458	0.01188	10438	0.997	31.23	3.410	4.37	0.975
1950	0.00616	0.01598	10405	0.994	31.11	3.397	4.36	0.967
1951	0.00779	0.02020	10363	0.990	30.97	3.382	4.34	0.958
1952	0.00947	0.02455	10314	0.985	30.80	3.363	4.31	0.950
1953	0.01121	0.02906	10256	0.979	30.61	3.342	4.29	0.941
1954	0.01302	0.03377	10192	0.973	30.40	3.319	4.26	0.932
1955	0.01492	0.03869	10122	0.967	30.17	3.294	4.22	0.922
1956	0.01691	0.04387	10045	0.959	29.92	3.267	4.19	0.913
1957	0.01902	0.04932	9963	0.951	29.65	3.238	4.15	0.903
1958	0.02126	0.05512	9875	0.943	29.37	3.207	4.11	0.893
1959	0.02370	0.06147	9781	0.934	29.06	3.174	4.07	0.882
1960	0.02625	0.06808	9682	0.925	28.75	3.139	4.02	0.870
1961	0.04488	0.11639	9577	0.915	28.38	3.099	3.97	0.843
1962	0.05819	0.15091	9446	0.902	27.95	3.053	3.91	0.825
1963	0.03584	0.09296	9305	0.889	27.53	3.007	3.85	0.833
1964	0.03639	0.09437	9182	0.877	27.17	2.967	3.80	0.829
1965	0.03894	0.10098	9071	0.866	26.83	2.930	3.76	0.821
1966	0.03736	0.09689	8962	0.856	26.53	2.897	3.71	0.824
1967	0.03794	0.09840	8876	0.848	26.28	2.870	3.68	0.824
1968	0.03893	0.10096	8801	0.840	26.06	2.846	3.65	0.823
1969	0.03812	0.09886	8736	0.834	25.89	2.827	3.62	0.826
1970	0.03653	0.09474	8685	0.829	25.76	2.813	3.61	0.831
1971	0.04189	0.10865	8651	0.826	25.62	2.798	3.59	0.818
1972	0.05341	0.13852	8599	0.821	25.42	2.776	3.56	0.796
1973	0.05071	0.13150	8522	0.814	25.20	2.751	3.53	0.799
1974	0.05524	0.14326	8457	0.808	24.96	2.725	3.49	0.783
1975	0.07092	0.18391	8371	0.799	24.59	2.685	3.44	0.747
1976	0.09456	0.24523	7508	0.717	22.22	2.427	3.11	0.730
1977	0.10748	0.27874	6705	0.640	19.57	2.138	2.74	0.714
1978	0.10002	0.25939	7492	0.715	21.30	2.326	2.98	0.694
1979	0.25070	0.65015	6746	0.644	19.80	2.162	2.77	0.598
1980	0.79152	2.05269	6019	0.575	17.25	1.883	2.41	0.359
1981	0.42802	1.11002	5452	0.521	15.41	1.682	2.16	0.495
1982	0.39806	1.03232	5069	0.484	13.94	1.523	1.95	0.471
1983	0.26958	0.69911	5244	0.501	14.43	1.576	2.02	0.527
1984	0.38435	0.99676	4872	0.465	13.72	1.499	1.92	0.472
1985	0.45257	1.17369	4870	0.465	13.38	1.462	1.87	0.444
1986	0.54316	1.40860	4767	0.455	13.30	1.453	1.86	0.438
1987	0.48371	1.25443	4281	0.409	12.10	1.321	1.69	0.422
1988	0.65521	1.69920	4080	0.390	11.09	1.211	1.55	0.380
1989	0.85703	2.22259	3480	0.332	9.19	1.004	1.29	0.342
1990	0.85451	2.21605	4785	0.457	12.53	1.368	1.75	0.396
1991	2.21780	5.75156	3996	0.382	10.94	1.195	1.53	0.282
1992	0.26870	0.69683	3533	0.337	10.26	1.120	1.44	0.494
1993	0.26776	0.69441	4542	0.434	12.81	1.399	1.79	0.498
1994	0.34871	0.90434	4120	0.393	12.05	1.316	1.69	0.447
1995	0.26140	0.67790	4266	0.407	12.14	1.326	1.70	0.501
1996	0.24724	0.64118	3977	0.380	11.50	1.256	1.61	0.519
1997	0.26263	0.68109	4062	0.388	11.50	1.256	1.61	0.502
1998	0.26954	0.69902	4268	0.408	12.13	1.325	1.70	0.498
1999	0.28359	0.73546	4500	0.430	12.77	1.394	1.79	0.463
2000	0.36984	0.95914	4384	0.419	12.19	1.331	1.71	0.414
2001	0.43468	1.12728	4323	0.413	11.71	1.279	1.64	0.388
2002	0.41858	1.08553	4168	0.398	11.52	1.258	1.61	0.398
2003	0.24965	0.64743	3770	0.360	10.93	1.193	1.53	0.491
2004	0.31232	0.80996	3610	0.345	10.07	1.100	1.41	0.443
2005	0.33925	0.87980	3336	0.319	9.18	1.003	1.29	0.430
2006	0.34099	0.88431	3143	0.300	8.67	0.947	1.21	0.423
2007	0.49122	1.27392	2966	0.283	7.88	0.861	1.10	0.350
2008	.	.	2642	0.252	.	.	.	.

Table 3.7. Selectivity at age for commercial handline (c.hal), commercial historic trawl (c.htr), commercial combined (c.cmb), headboat (hb), general recreational (rec), commercial handline discard mortalities (D.c.hal), headboat discard mortalities (D.hb), general recreational discard mortalities (D.rec), 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)	c.hal	c.htr	c.cmb	hb	rec	D.c.hal	D.hb	D.rec	L.avg	D.avg	L.avg+D.avg
1	228.3	9.0	0.0000	1	0.0000	0.0000	0.2793	0.000	0.000	0.000	0.0355	0.0000	0.0000
2	259.7	10.2	0.0000	0	0.0000	0.5934	0.3904	0.000	1.000	1.000	0.1706	0.0533	0.0000
3	287.6	11.3	0.5334	0	0.5334	1.0000	0.5147	1.000	1.000	1.000	0.5817	0.0834	0.5334
4	312.3	12.3	1.0000	0	1.0000	1.0000	0.6379	0.455	0.455	0.455	0.8707	0.0379	1.0000
5	334.2	13.2	1.0000	0	1.0000	1.0000	0.7462	0.343	0.343	0.343	0.8844	0.0286	1.0000
6	353.6	13.9	1.0000	0	1.0000	1.0000	0.8319	0.264	0.264	0.264	0.8953	0.0220	1.0000
7	370.8	14.6	1.0000	0	1.0000	1.0000	0.8941	0.207	0.207	0.207	0.9032	0.0173	1.0000
8	386.1	15.2	1.0000	0	1.0000	1.0000	0.9366	0.168	0.168	0.168	0.9086	0.0140	1.0000
9	399.7	15.7	1.0000	0	1.0000	1.0000	0.9644	0.139	0.139	0.139	0.9121	0.0116	1.0000
10	411.7	16.2	1.0000	0	1.0000	1.0000	0.9821	0.117	0.117	0.117	0.9144	0.0098	1.0000
11	422.4	16.6	1.0000	0	1.0000	1.0000	0.9932	0.101	0.101	0.101	0.9158	0.0084	1.0000
12	431.8	17.0	1.0000	0	1.0000	1.0000	1.0000	0.089	0.089	0.089	0.9166	0.0074	1.0000

Table 3.8. Estimated time series of fishing mortality rate for commercial handline (F.c.hal), commercial historic trawl (F.c.htr), commercial combined (F.c.cmb), headboat (F.hb), general recreational (F.rec), commercial handline discard mortalities (F.c.hal.D), headboat discard mortalities (F.hb.D), general recreational discard mortalities (F.mrfss.D), and full F (F.full).

Year	F.c.hal	F.c.htr	F.c.cmb	F.hb	F.rec	F.c.hal.D	F.hb.D	F.rec.D	F.full
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.002
1948	0.000	0.000	0.000	0.002	0.001	0.000	0.000	0.000	0.003
1949	0.000	0.000	0.000	0.003	0.001	0.000	0.000	0.000	0.005
1950	0.000	0.000	0.000	0.004	0.002	0.000	0.000	0.000	0.006
1951	0.000	0.000	0.000	0.005	0.002	0.000	0.000	0.000	0.008
1952	0.000	0.000	0.000	0.006	0.003	0.000	0.000	0.001	0.009
1953	0.000	0.000	0.000	0.007	0.003	0.000	0.000	0.001	0.011
1954	0.000	0.000	0.000	0.008	0.004	0.000	0.000	0.001	0.013
1955	0.000	0.000	0.000	0.009	0.004	0.000	0.001	0.001	0.015
1956	0.000	0.000	0.000	0.011	0.005	0.000	0.001	0.001	0.017
1957	0.000	0.000	0.000	0.012	0.005	0.000	0.001	0.001	0.019
1958	0.000	0.000	0.000	0.014	0.006	0.000	0.001	0.001	0.021
1959	0.000	0.000	0.000	0.016	0.006	0.000	0.001	0.001	0.024
1960	0.000	0.000	0.000	0.018	0.006	0.000	0.001	0.001	0.026
1961	0.002	0.014	0.000	0.020	0.007	0.000	0.001	0.001	0.045
1962	0.001	0.026	0.000	0.022	0.007	0.000	0.001	0.001	0.058
1963	0.002	0.000	0.000	0.024	0.008	0.000	0.001	0.001	0.036
1964	0.001	0.000	0.000	0.025	0.008	0.000	0.001	0.001	0.036
1965	0.002	0.000	0.000	0.026	0.008	0.000	0.001	0.001	0.039
1966	0.000	0.000	0.000	0.026	0.009	0.000	0.001	0.002	0.037
1967	0.001	0.000	0.000	0.025	0.009	0.000	0.001	0.002	0.038
1968	0.003	0.000	0.000	0.024	0.009	0.000	0.001	0.002	0.039
1969	0.003	0.000	0.000	0.023	0.009	0.000	0.001	0.002	0.038
1970	0.002	0.000	0.000	0.023	0.009	0.000	0.001	0.002	0.037
1971	0.007	0.000	0.000	0.023	0.009	0.000	0.001	0.002	0.042
1972	0.007	0.000	0.007	0.027	0.009	0.000	0.001	0.002	0.053
1973	0.009	0.000	0.004	0.026	0.009	0.000	0.001	0.002	0.051
1974	0.013	0.000	0.002	0.029	0.009	0.000	0.001	0.002	0.055
1975	0.024	0.000	0.002	0.033	0.009	0.000	0.002	0.002	0.071
1976	0.024	0.000	0.025	0.032	0.010	0.000	0.001	0.001	0.095
1977	0.032	0.000	0.029	0.030	0.012	0.000	0.002	0.003	0.107
1978	0.042	0.000	0.000	0.038	0.009	0.000	0.006	0.005	0.100
1979	0.054	0.000	0.146	0.038	0.011	0.000	0.001	0.001	0.251
1980	0.071	0.000	0.672	0.033	0.012	0.000	0.001	0.002	0.792
1981	0.091	0.000	0.283	0.031	0.013	0.000	0.003	0.006	0.428
1982	0.110	0.000	0.203	0.046	0.029	0.000	0.003	0.006	0.398
1983	0.124	0.000	0.062	0.044	0.034	0.000	0.003	0.004	0.270
1984	0.191	0.000	0.112	0.037	0.042	0.000	0.001	0.001	0.384
1985	0.329	0.000	0.014	0.058	0.046	0.000	0.002	0.002	0.453
1986	0.435	0.000	0.014	0.057	0.033	0.000	0.002	0.002	0.543
1987	0.299	0.000	0.068	0.088	0.024	0.000	0.003	0.001	0.484
1988	0.420	0.000	0.110	0.096	0.023	0.000	0.004	0.002	0.655
1989	0.572	0.000	0.137	0.105	0.032	0.000	0.004	0.006	0.857
1990	0.720	0.000	0.035	0.066	0.019	0.000	0.005	0.009	0.855
1991	1.833	0.000	0.288	0.074	0.020	0.000	0.001	0.002	2.218
1992	0.139	0.000	0.000	0.083	0.033	0.005	0.004	0.005	0.269
1993	0.142	0.000	0.001	0.070	0.025	0.016	0.008	0.006	0.268
1994	0.192	0.000	0.002	0.106	0.025	0.018	0.003	0.003	0.349
1995	0.144	0.000	0.000	0.076	0.017	0.010	0.005	0.008	0.261
1996	0.115	0.000	0.000	0.073	0.020	0.031	0.005	0.003	0.247
1997	0.124	0.000	0.000	0.086	0.025	0.018	0.006	0.004	0.263
1998	0.122	0.000	0.000	0.085	0.030	0.021	0.005	0.005	0.270
1999	0.157	0.000	0.001	0.059	0.032	0.014	0.005	0.016	0.284
2000	0.236	0.000	0.000	0.063	0.039	0.013	0.006	0.013	0.370
2001	0.294	0.000	0.001	0.067	0.041	0.016	0.007	0.010	0.435
2002	0.269	0.000	0.000	0.057	0.042	0.038	0.005	0.007	0.419
2003	0.142	0.000	0.001	0.039	0.040	0.013	0.003	0.011	0.250
2004	0.192	0.000	0.000	0.055	0.040	0.006	0.007	0.012	0.312
2005	0.215	0.000	0.000	0.055	0.042	0.014	0.005	0.009	0.339
2006	0.190	0.000	0.000	0.076	0.048	0.010	0.008	0.008	0.341
2007	0.271	0.000	0.002	0.113	0.056	0.011	0.012	0.025	0.491

Table 3.9. 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
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1948	0.001	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
1949	0.002	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
1950	0.003	0.004	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.006
1951	0.003	0.005	0.006	0.006	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
1952	0.004	0.006	0.008	0.008	0.008	0.009	0.009	0.009	0.009	0.009	0.009	0.009
1953	0.005	0.008	0.009	0.009	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
1954	0.005	0.009	0.011	0.011	0.011	0.012	0.012	0.012	0.012	0.012	0.012	0.012
1955	0.006	0.010	0.012	0.012	0.013	0.013	0.014	0.014	0.014	0.014	0.014	0.014
1956	0.007	0.011	0.014	0.014	0.015	0.015	0.015	0.015	0.016	0.016	0.016	0.016
1957	0.008	0.013	0.016	0.016	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
1958	0.009	0.014	0.017	0.018	0.019	0.019	0.019	0.019	0.020	0.020	0.020	0.020
1959	0.010	0.016	0.019	0.020	0.021	0.021	0.022	0.022	0.022	0.022	0.022	0.022
1960	0.011	0.018	0.021	0.022	0.023	0.024	0.024	0.024	0.024	0.024	0.024	0.024
1961	0.026	0.019	0.023	0.024	0.027	0.028	0.028	0.028	0.028	0.028	0.028	0.028
1962	0.039	0.021	0.026	0.027	0.029	0.030	0.030	0.030	0.030	0.030	0.030	0.030
1963	0.014	0.023	0.028	0.029	0.031	0.033	0.033	0.033	0.033	0.033	0.033	0.033
1964	0.015	0.024	0.029	0.030	0.032	0.033	0.033	0.034	0.034	0.034	0.034	0.034
1965	0.015	0.025	0.030	0.031	0.034	0.036	0.036	0.036	0.036	0.036	0.036	0.036
1966	0.016	0.025	0.030	0.031	0.033	0.034	0.034	0.035	0.035	0.035	0.035	0.035
1967	0.015	0.025	0.030	0.031	0.033	0.035	0.035	0.035	0.035	0.035	0.035	0.035
1968	0.015	0.024	0.029	0.030	0.034	0.036	0.036	0.036	0.036	0.036	0.036	0.036
1969	0.015	0.023	0.028	0.029	0.033	0.035	0.035	0.035	0.035	0.035	0.035	0.035
1970	0.014	0.023	0.028	0.029	0.032	0.033	0.034	0.034	0.034	0.034	0.034	0.034
1971	0.015	0.023	0.028	0.029	0.036	0.038	0.039	0.039	0.039	0.039	0.039	0.039
1972	0.024	0.026	0.032	0.033	0.040	0.043	0.043	0.043	0.043	0.043	0.043	0.043
1973	0.020	0.025	0.031	0.032	0.040	0.044	0.044	0.044	0.044	0.044	0.044	0.044
1974	0.019	0.027	0.033	0.034	0.046	0.050	0.050	0.051	0.051	0.051	0.051	0.051
1975	0.021	0.030	0.037	0.038	0.058	0.065	0.066	0.066	0.066	0.066	0.066	0.066
1976	0.044	0.030	0.037	0.039	0.058	0.066	0.066	0.066	0.066	0.067	0.067	0.067
1977	0.048	0.031	0.038	0.039	0.064	0.073	0.074	0.074	0.074	0.074	0.074	0.074
1978	0.022	0.041	0.049	0.045	0.077	0.089	0.090	0.090	0.090	0.090	0.090	0.090
1979	0.168	0.034	0.041	0.044	0.086	0.102	0.102	0.102	0.103	0.103	0.103	0.103
1980	0.692	0.032	0.039	0.041	0.096	0.116	0.117	0.117	0.117	0.117	0.117	0.117
1981	0.303	0.038	0.045	0.042	0.111	0.136	0.136	0.136	0.136	0.136	0.136	0.136
1982	0.237	0.058	0.070	0.069	0.154	0.184	0.185	0.185	0.185	0.185	0.185	0.185
1983	0.097	0.056	0.068	0.071	0.166	0.200	0.201	0.202	0.202	0.202	0.202	0.202
1984	0.148	0.054	0.066	0.072	0.217	0.269	0.270	0.270	0.270	0.270	0.270	0.270
1985	0.062	0.071	0.088	0.095	0.343	0.432	0.434	0.434	0.434	0.434	0.434	0.435
1986	0.055	0.062	0.076	0.082	0.407	0.523	0.524	0.525	0.525	0.525	0.525	0.525
1987	0.119	0.077	0.094	0.102	0.328	0.410	0.411	0.411	0.412	0.412	0.412	0.412
1988	0.164	0.083	0.102	0.108	0.424	0.537	0.538	0.539	0.539	0.539	0.539	0.539
1989	0.199	0.099	0.120	0.125	0.554	0.707	0.709	0.709	0.710	0.710	0.710	0.710
1990	0.074	0.069	0.082	0.079	0.614	0.805	0.806	0.806	0.806	0.806	0.806	0.806
1991	0.331	0.064	0.078	0.085	1.442	1.925	1.926	1.926	1.927	1.927	1.927	1.927
1992	0.000	0.009	0.142	0.259	0.258	0.257	0.257	0.256	0.256	0.256	0.256	0.256
1993	0.000	0.013	0.150	0.249	0.246	0.244	0.243	0.242	0.242	0.241	0.241	0.240
1994	0.000	0.006	0.189	0.334	0.331	0.329	0.328	0.327	0.327	0.326	0.326	0.326
1995	0.000	0.013	0.144	0.245	0.243	0.242	0.241	0.241	0.240	0.240	0.240	0.240
1996	0.000	0.009	0.144	0.224	0.220	0.217	0.215	0.214	0.213	0.212	0.211	0.211
1997	0.000	0.010	0.146	0.245	0.242	0.240	0.239	0.238	0.238	0.237	0.237	0.237
1998	0.000	0.010	0.151	0.250	0.247	0.244	0.243	0.242	0.241	0.241	0.240	0.240
1999	0.000	0.049	0.210	0.262	0.258	0.256	0.254	0.253	0.252	0.252	0.251	0.251
2000	0.000	0.048	0.260	0.350	0.347	0.345	0.344	0.343	0.342	0.341	0.341	0.341
2001	0.000	0.048	0.297	0.415	0.412	0.410	0.408	0.407	0.406	0.406	0.405	0.405
2002	0.000	0.040	0.293	0.390	0.384	0.381	0.378	0.376	0.375	0.374	0.373	0.372
2003	0.000	0.034	0.183	0.233	0.230	0.228	0.227	0.226	0.226	0.225	0.225	0.225
2004	0.000	0.045	0.222	0.296	0.294	0.292	0.291	0.290	0.290	0.289	0.289	0.289
2005	0.000	0.041	0.239	0.322	0.319	0.317	0.316	0.315	0.314	0.314	0.314	0.313
2006	0.000	0.053	0.252	0.324	0.322	0.320	0.319	0.318	0.318	0.317	0.317	0.317
2007	0.016	0.126	0.336	0.444	0.445	0.446	0.447	0.447	0.448	0.447	0.447	0.447

Table 3.10. Estimated total landings at age in numbers (1000 fish)

Year	1	2	3	4	5	6	7	8	9	10	11	12
1946	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1947	3.2	3.3	3.0	2.6	2.1	1.7	1.4	1.1	0.9	0.8	0.6	2.9
1948	6.4	6.6	6.1	5.2	4.3	3.5	2.8	2.3	1.9	1.5	1.2	5.8
1949	9.7	10.0	9.2	7.9	6.5	5.3	4.3	3.4	2.8	2.3	1.9	8.7
1950	13.1	13.4	12.4	10.6	8.7	7.1	5.7	4.6	3.7	3.1	2.5	11.7
1951	16.5	16.9	15.6	13.3	11.0	8.9	7.2	5.8	4.7	3.8	3.1	14.7
1952	20.0	20.5	18.9	16.2	13.3	10.7	8.7	7.0	5.7	4.6	3.8	17.7
1953	23.7	24.3	22.4	19.1	15.7	12.6	10.2	8.2	6.7	5.4	4.5	20.8
1954	27.6	28.2	25.9	22.1	18.1	14.6	11.8	9.5	7.7	6.3	5.1	23.9
1955	31.6	32.3	29.6	25.2	20.6	16.6	13.4	10.8	8.7	7.1	5.8	27.1
1956	35.8	36.5	33.5	28.5	23.3	18.7	15.0	12.1	9.8	8.0	6.5	30.3
1957	40.2	41.0	37.6	31.9	26.0	20.9	16.8	13.5	10.9	8.8	7.2	33.5
1958	44.9	45.7	41.8	35.5	28.9	23.2	18.6	14.9	12.0	9.7	7.9	36.9
1959	49.8	50.7	46.3	39.2	32.0	25.7	20.5	16.4	13.2	10.7	8.7	40.4
1960	55.1	56.0	51.1	43.1	35.2	28.2	22.5	18.0	14.5	11.7	9.5	43.8
1961	132.5	61.6	56.1	47.3	40.2	32.6	25.9	20.7	16.6	13.4	10.9	50.0
1962	193.5	66.3	61.1	51.4	42.7	34.2	27.2	21.6	17.3	14.0	11.3	51.8
1963	71.2	70.4	64.5	55.0	46.5	37.5	29.7	23.6	18.9	15.2	12.3	55.8
1964	75.0	75.9	67.0	56.8	47.1	37.5	29.6	23.5	18.8	15.1	12.2	54.9
1965	77.1	78.0	70.5	57.5	49.0	39.9	31.4	24.9	19.8	15.9	12.8	57.3
1966	77.3	78.2	70.6	59.0	46.5	37.2	29.7	23.4	18.6	14.9	12.0	53.3
1967	76.1	76.9	69.4	57.9	47.9	37.2	29.5	23.6	18.7	14.9	12.0	52.8
1968	74.3	75.0	67.7	56.5	48.6	39.1	29.8	23.7	19.0	15.1	12.1	53.0
1969	72.5	73.3	66.1	55.2	47.5	38.1	29.8	22.8	18.2	14.7	11.7	50.6
1970	71.6	72.3	65.3	54.5	45.7	36.4	28.4	22.2	17.1	13.7	11.1	47.4
1971	73.3	72.9	65.8	54.9	51.1	41.9	32.6	25.5	20.0	15.5	12.4	53.4
1972	116.2	81.8	73.8	61.6	56.8	46.3	36.1	28.1	22.1	17.4	13.5	57.9
1973	96.6	78.5	71.3	59.5	57.1	47.0	36.4	28.4	22.3	17.5	13.9	57.3
1974	92.6	84.9	76.2	63.9	64.4	53.5	41.4	32.2	25.2	19.9	15.7	64.2
1975	102.0	94.2	84.6	70.1	80.8	68.9	53.1	41.2	32.2	25.3	20.0	81.0
1976	39.8	94.7	85.1	70.6	80.1	68.0	52.1	40.4	31.5	24.7	19.5	78.3
1977	56.1	16.9	83.8	69.6	86.9	74.3	56.7	43.6	33.9	26.6	20.9	83.4
1978	217.8	24.7	17.1	78.6	103.4	88.6	66.6	51.1	39.5	30.8	24.3	95.9
1979	187.4	217.3	22.2	14.2	115.0	99.5	74.2	56.1	43.2	33.5	26.3	103.2
1980	832.8	21.4	182.9	17.3	22.8	110.7	81.7	61.2	46.5	36.0	28.1	109.0
1981	783.1	16.8	18.7	148.2	33.4	22.5	90.8	67.4	50.8	38.8	30.2	115.5
1982	757.1	74.5	24.6	25.4	398.1	38.1	20.9	85.1	63.5	48.1	36.9	139.5
1983	674.3	99.1	67.1	20.4	43.4	344.9	27.4	15.1	61.9	46.4	35.3	130.3
1984	469.4	238.7	88.3	55.0	43.0	44.9	294.0	23.5	13.0	53.5	40.4	144.8
1985	324.3	139.2	272.2	92.5	169.0	49.4	41.0	269.7	21.7	12.1	49.9	173.6
1986	278.3	207.4	103.0	184.8	244.9	133.1	29.8	24.8	164.3	13.3	7.4	138.3
1987	272.3	247.7	221.5	100.9	478.1	129.2	51.9	11.7	9.8	65.3	5.3	58.6
1988	590.7	115.1	222.4	182.2	256.3	404.9	84.9	34.3	7.8	6.5	43.8	43.1
1989	393.8	201.6	110.7	196.0	536.4	195.2	231.2	48.8	19.8	4.5	3.8	51.0
1990	937.0	68.4	105.9	53.4	537.4	317.6	83.8	99.9	21.2	8.6	2.0	24.2
1991	212.2	519.0	64.9	92.4	408.9	437.6	178.4	47.4	56.8	12.1	5.0	15.1
1992	0.0	0.0	741.7	143.0	183.7	22.0	13.0	5.4	1.4	1.7	0.4	0.6
1993	0.0	0.0	32.4	869.2	80.8	105.4	12.7	7.6	3.2	0.9	1.0	0.6
1994	0.0	0.0	239.1	52.5	689.5	65.1	86.0	10.5	6.3	2.6	0.7	1.4
1995	0.0	0.0	536.1	213.6	22.4	299.0	28.6	38.1	4.7	2.8	1.2	0.9
1996	0.0	0.0	53.6	587.3	114.8	12.2	165.3	16.0	21.4	2.7	1.6	1.2
1997	0.0	0.0	290.0	75.8	408.8	81.2	8.8	119.7	11.6	15.7	2.0	2.1
1998	0.0	0.0	134.8	368.0	46.7	256.2	51.5	5.6	77.3	7.6	10.3	2.7
1999	0.0	99.6	362.3	175.2	232.3	30.0	166.4	33.8	3.7	51.4	5.1	8.7
2000	0.0	108.3	526.1	406.9	137.4	185.1	24.2	135.6	27.8	3.1	42.8	11.5
2001	0.0	80.8	603.7	510.4	258.1	88.6	120.9	15.9	90.1	18.6	2.1	36.7
2002	0.0	96.8	388.9	457.0	243.2	125.1	43.5	60.0	8.0	45.4	9.4	19.8
2003	0.0	67.1	368.2	209.1	156.4	84.7	44.2	15.5	21.6	2.9	16.5	10.7
2004	0.0	48.3	444.9	410.0	161.7	122.9	67.3	35.4	12.6	17.6	2.4	22.4
2005	0.0	48.4	252.4	410.7	254.5	101.9	78.4	43.4	23.0	8.2	11.5	16.4
2006	0.0	73.6	268.7	218.0	234.1	147.4	59.8	46.4	25.9	13.8	5.0	17.0
2007	43.4	189.7	361.0	273.4	158.1	174.1	111.8	46.0	36.1	20.3	10.9	17.4

Table 3.11. Estimated total landings at age in whole weight (1000 lb)

Year	1	2	3	4	5	6	7	8	9	10	11	12
1946	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1947	1.1	1.6	2.0	2.1	2.2	2.1	1.9	1.7	1.6	1.4	1.2	6.1
1948	2.1	3.2	4.0	4.3	4.3	4.1	3.8	3.5	3.1	2.8	2.5	12.2
1949	3.2	4.8	6.0	6.5	6.5	6.3	5.8	5.3	4.7	4.2	3.7	18.5
1950	4.3	6.5	8.0	8.8	8.8	8.4	7.8	7.1	6.3	5.6	5.0	24.7
1951	5.5	8.2	10.1	11.0	11.0	10.5	9.8	8.9	8.0	7.1	6.3	31.1
1952	6.7	9.9	12.3	13.4	13.4	12.7	11.8	10.7	9.6	8.6	7.5	37.5
1953	7.9	11.7	14.5	15.8	15.8	15.0	13.9	12.6	11.3	10.0	8.9	44.1
1954	9.2	13.6	16.9	18.3	18.2	17.3	16.0	14.5	13.0	11.6	10.2	50.7
1955	10.5	15.6	19.3	20.8	20.8	19.7	18.2	16.5	14.8	13.1	11.5	57.4
1956	11.9	17.7	21.8	23.5	23.4	22.2	20.5	18.5	16.6	14.7	12.9	64.2
1957	13.4	19.8	24.4	26.3	26.2	24.8	22.8	20.6	18.4	16.3	14.3	71.1
1958	14.9	22.1	27.2	29.3	29.1	27.5	25.3	22.8	20.3	18.0	15.8	78.2
1959	16.6	24.5	30.1	32.4	32.2	30.5	27.9	25.2	22.4	19.8	17.4	85.6
1960	18.3	27.1	33.2	35.6	35.4	33.4	30.6	27.5	24.5	21.6	18.9	92.9
1961	44.1	29.8	36.5	39.1	40.5	38.6	35.3	31.7	28.1	24.8	21.7	105.9
1962	64.3	32.0	39.7	42.5	42.9	40.6	37.0	33.1	29.4	25.8	22.6	109.7
1963	23.7	34.0	42.0	45.4	46.8	44.4	40.4	36.1	31.9	28.0	24.4	118.2
1964	24.9	36.7	43.5	46.9	47.4	44.5	40.4	36.0	31.7	27.8	24.2	116.4
1965	25.6	37.7	45.8	47.5	49.3	47.3	42.8	38.1	33.5	29.3	25.5	121.5
1966	25.7	37.8	45.9	48.7	46.8	44.1	40.4	35.9	31.5	27.5	23.8	112.9
1967	25.3	37.2	45.1	47.9	48.2	44.1	40.2	36.1	31.7	27.5	23.8	111.9
1968	24.7	36.3	44.0	46.7	48.9	46.3	40.6	36.3	32.2	28.0	24.1	112.3
1969	24.1	35.4	43.0	45.6	47.8	45.2	40.5	34.9	30.8	27.0	23.3	107.3
1970	23.8	35.0	42.5	45.0	46.0	43.1	38.6	34.0	28.9	25.3	22.0	100.4
1971	24.4	35.2	42.8	45.4	51.4	49.7	44.4	39.0	33.9	28.5	24.7	113.3
1972	38.6	39.5	48.0	50.9	57.2	54.9	49.1	43.1	37.4	32.2	26.9	122.7
1973	32.1	38.0	46.4	49.2	57.4	55.7	49.6	43.5	37.7	32.4	27.7	121.6
1974	30.8	41.1	49.5	52.8	64.8	63.5	56.4	49.3	42.7	36.7	31.2	136.0
1975	33.9	45.5	55.0	58.0	81.3	81.7	72.3	63.1	54.5	46.7	39.8	171.7
1976	13.2	45.8	55.3	58.3	80.6	80.7	71.0	61.8	53.3	45.6	38.8	166.0
1977	18.6	8.2	54.5	57.5	87.5	88.1	77.2	66.7	57.4	49.0	41.6	176.7
1978	72.4	12.0	11.1	64.9	104.0	105.0	90.7	78.2	66.8	56.9	48.3	203.3
1979	62.3	105.1	14.4	11.7	115.7	118.0	101.1	85.9	73.1	61.9	52.4	218.7
1980	276.9	10.4	118.9	14.3	22.9	131.2	111.2	93.7	78.7	66.4	55.8	231.1
1981	260.3	8.1	12.2	122.4	33.6	26.7	123.7	103.2	86.0	71.5	60.0	244.9
1982	251.7	36.0	16.0	21.0	400.5	45.2	28.5	130.3	107.5	88.8	73.4	295.8
1983	224.2	47.9	43.6	16.9	43.6	409.0	37.4	23.2	104.8	85.7	70.3	276.3
1984	156.1	115.4	57.4	45.4	43.2	53.2	400.4	36.0	22.1	98.8	80.3	307.1
1985	107.8	67.3	177.0	76.4	170.0	58.6	55.8	413.1	36.7	22.3	99.2	368.0
1986	92.5	100.3	67.0	152.7	246.4	157.8	40.5	38.0	278.3	24.5	14.8	293.2
1987	90.5	119.8	144.0	83.4	481.1	153.2	70.6	17.9	16.6	120.5	10.5	124.2
1988	196.4	55.7	144.6	150.5	257.9	480.2	115.6	52.5	13.1	12.1	87.1	91.4
1989	130.9	97.5	72.0	162.0	539.7	231.5	314.9	74.7	33.5	8.3	7.6	108.1
1990	311.5	33.1	68.9	44.1	540.7	376.7	114.2	153.0	35.9	16.0	3.9	51.3
1991	70.5	251.0	42.2	76.3	411.5	519.0	243.0	72.6	96.2	22.3	9.9	32.1
1992	0.0	0.0	759.2	164.3	237.7	31.7	20.8	9.3	2.7	3.5	0.8	1.4
1993	0.0	0.0	33.7	1010.4	105.6	153.5	20.5	13.4	6.0	1.7	2.2	1.4
1994	0.0	0.0	248.0	61.0	900.2	94.8	138.1	18.4	12.0	5.4	1.5	3.1
1995	0.0	0.0	557.0	248.5	29.3	435.6	46.0	66.9	8.9	5.8	2.6	2.2
1996	0.0	0.0	55.0	676.0	148.7	17.7	264.1	27.9	40.5	5.4	3.5	2.8
1997	0.0	0.0	295.6	86.7	527.3	117.0	14.0	208.4	22.0	31.8	4.2	4.8
1998	0.0	0.0	136.9	420.1	60.1	368.4	81.9	9.8	145.5	15.3	22.1	6.1
1999	0.0	83.8	378.5	210.4	311.4	44.6	272.2	60.2	7.1	105.8	11.0	20.0
2000	0.0	91.2	556.4	492.7	185.6	277.1	39.8	242.8	53.6	6.3	93.6	26.6
2001	0.0	68.0	642.7	621.0	350.0	133.1	199.3	28.6	174.4	38.4	4.5	84.6
2002	0.0	81.5	413.9	556.0	329.7	187.8	71.7	107.6	15.4	93.8	20.6	45.6
2003	0.0	56.5	385.4	251.4	210.0	126.1	72.3	27.7	41.5	5.9	36.1	24.6
2004	0.0	40.7	468.1	494.8	217.7	183.4	110.5	63.3	24.2	36.2	5.2	51.6
2005	0.0	40.7	266.5	497.0	343.5	152.5	128.9	77.6	44.4	16.9	25.2	37.7
2006	0.0	61.9	279.3	260.7	312.9	218.6	97.5	82.6	49.7	28.4	10.8	38.9
2007	40.7	194.7	409.8	344.5	220.7	268.0	188.2	84.0	70.9	42.6	24.2	40.6

Table 3.12. Estimated time series of landings in numbers (1000 fish) for commercial handline (L.c.hal), commercial historic trawl (L.c.htr), commercial combined (L.c.cmb), headboat (L.hb), and general recreational (L.rec)

Year	L.c.hal	L.c.htr	L.c.cmb	L.hb	L.rec	Total
1946	.	.	.	.	.	0.00
1947	.	.	.	14.63	9.01	23.64
1948	.	.	.	30.58	17.08	47.66
1949	.	.	.	46.80	25.10	71.90
1950	.	.	.	63.43	33.06	96.49
1951	.	.	.	80.61	40.94	121.55
1952	.	.	.	98.48	48.71	147.19
1953	.	.	.	117.17	56.35	173.53
1954	.	.	.	136.84	63.85	200.69
1955	.	.	.	157.61	71.18	228.79
1956	.	.	.	179.63	78.33	257.95
1957	.	.	.	203.03	85.26	288.29
1958	0.12	.	.	227.96	91.96	320.05
1959	0.80	.	.	254.56	98.41	353.77
1960	1.11	.	.	282.96	104.59	388.65
1961	12.27	72.26	.	312.78	110.45	507.76
1962	6.88	128.08	.	341.59	115.85	592.41
1963	13.36	.	.	366.41	120.64	500.41
1964	4.34	.	.	384.29	124.65	513.28
1965	14.07	.	.	392.26	127.72	534.05
1966	2.17	.	.	388.65	129.75	520.58
1967	9.09	.	.	377.03	130.86	516.97
1968	20.54	.	.	362.22	131.23	513.99
1969	20.21	.	.	349.09	131.05	500.35
1970	12.61	.	.	342.47	130.50	485.58
1971	42.94	.	1.19	345.46	129.73	519.32
1972	44.62	.	35.46	402.82	128.79	611.69
1973	56.00	.	18.38	383.91	127.69	586.00
1974	77.70	.	8.20	421.70	126.46	634.06
1975	142.57	.	8.50	477.33	125.11	753.51
1976	138.81	.	22.62	399.75	123.65	684.83
1977	179.16	.	33.98	317.30	122.11	652.56
1978	227.08	.	3.15	487.53	120.50	838.27
1979	284.91	.	162.91	425.40	118.84	992.06
1980	302.17	.	807.92	323.00	117.15	1550.24
1981	299.57	.	730.59	270.99	115.01	1416.16
1982	470.34	.	648.69	362.32	230.53	1711.88
1983	432.87	.	429.47	399.04	304.27	1565.65
1984	462.66	.	354.80	324.43	366.59	1508.48
1985	588.64	.	75.15	529.81	420.90	1614.50
1986	616.82	.	72.12	533.11	307.37	1529.42
1987	563.66	.	155.30	731.01	202.20	1652.17
1988	676.25	.	395.65	740.93	179.12	1991.95
1989	857.94	.	270.91	661.30	202.69	1992.84
1990	965.34	.	447.31	655.87	190.93	2259.45
1991	1099.73	.	184.74	600.51	164.80	2049.79
1992	630.92	.	0.23	345.31	136.45	1112.91
1993	664.01	.	6.55	327.10	116.24	1113.90
1994	690.94	.	7.09	369.81	85.89	1153.72
1995	709.36	.	2.20	354.82	81.08	1147.45
1996	541.44	.	1.01	340.37	93.30	976.13
1997	544.98	.	1.44	364.74	104.55	1015.71
1998	497.30	.	1.68	341.52	120.20	960.70
1999	617.92	.	3.18	381.90	165.51	1168.50
2000	969.82	.	1.15	428.21	209.66	1608.83
2001	1192.07	.	2.36	418.85	212.66	1825.94
2002	969.13	.	0.97	335.55	191.31	1496.96
2003	536.00	.	5.13	251.79	204.08	997.01
2004	802.40	.	1.98	329.03	212.01	1345.42
2005	792.05	.	0.63	275.39	180.77	1248.84
2006	583.16	.	1.03	344.65	180.73	1109.57
2007	715.47	.	5.44	507.90	213.28	1442.08

Table 3.13. Estimated time series of landings in whole weight (1000 lb) for commercial handline (L.c.hal), commercial historic trawl (L.c.htr), commercial combined (L.c.cmb), headboat (L.hb), and general recreational (L.rec)

Year	L.c.hal	L.c.htr	L.c.cmb	L.hb	L.rec	Total
1946	.	.	.	.	.	0.00
1947	.	.	.	15.39	9.48	24.86
1948	.	.	.	32.15	17.95	50.10
1949	.	.	.	49.17	26.37	75.55
1950	.	.	.	66.59	34.71	101.30
1951	.	.	.	84.54	42.93	127.47
1952	.	.	.	103.13	51.01	154.14
1953	.	.	.	122.51	58.92	181.42
1954	.	.	.	142.78	66.62	209.41
1955	.	.	.	164.09	74.11	238.20
1956	.	.	.	186.54	81.34	267.88
1957	.	.	.	210.27	88.29	298.56
1958	0.19	.	.	235.37	94.95	330.52
1959	1.26	.	.	261.98	101.28	364.51
1960	1.75	.	.	290.18	107.25	399.18
1961	19.32	24.02	.	319.70	112.89	475.93
1962	10.82	42.58	.	348.21	118.10	519.71
1963	20.97	.	.	371.98	122.47	515.42
1964	6.79	.	.	387.90	125.82	520.52
1965	22.01	.	.	393.73	128.20	543.94
1966	3.40	.	.	388.10	129.56	521.06
1967	14.17	.	.	374.80	130.09	519.06
1968	31.94	.	.	358.58	129.91	520.43
1969	31.35	.	.	344.31	129.26	504.91
1970	19.51	.	.	336.81	128.34	484.67
1971	66.32	.	0.40	338.84	127.24	532.79
1972	68.79	.	11.79	394.01	125.97	600.57
1973	86.19	.	6.11	374.44	124.54	591.29
1974	119.39	.	2.73	409.81	122.90	654.82
1975	218.66	.	2.83	461.27	120.90	803.65
1976	212.41	.	7.52	420.44	130.06	770.43
1977	273.32	.	11.30	359.92	138.51	783.05
1978	345.08	.	1.05	455.09	112.49	913.70
1979	430.90	.	54.16	418.33	116.87	1020.26
1980	482.65	.	268.60	337.83	122.53	1211.62
1981	500.89	.	242.89	287.08	121.84	1152.70
1982	672.80	.	215.66	370.57	235.78	1494.81
1983	645.73	.	142.78	337.17	257.09	1382.77
1984	734.10	.	117.96	264.47	298.84	1415.37
1985	920.56	.	24.98	393.85	312.88	1652.28
1986	896.44	.	23.98	371.45	214.16	1506.03
1987	697.95	.	51.63	534.82	147.93	1432.33
1988	854.32	.	131.54	540.56	130.68	1657.09
1989	1041.69	.	90.07	496.66	152.23	1780.65
1990	1141.48	.	148.71	355.50	103.49	1749.18
1991	1332.96	.	61.42	354.75	97.35	1846.48
1992	765.13	.	0.28	334.06	132.00	1231.46
1993	866.76	.	8.55	348.97	124.01	1348.29
1994	948.85	.	9.73	425.20	98.75	1482.54
1995	928.76	.	2.88	383.51	87.64	1402.78
1996	743.79	.	1.39	389.47	106.76	1241.42
1997	759.00	.	2.01	428.11	122.71	1311.83
1998	707.98	.	2.39	411.02	144.66	1266.05
1999	876.43	.	4.51	426.84	197.42	1505.20
2000	1348.32	.	1.59	471.04	244.69	2065.64
2001	1633.32	.	3.23	462.68	245.36	2344.59
2002	1334.41	.	1.34	365.34	222.55	1923.64
2003	727.85	.	6.97	270.74	231.91	1237.48
2004	1085.87	.	2.68	364.57	242.48	1695.60
2005	1100.16	.	0.87	314.54	215.36	1630.93
2006	826.78	.	1.46	394.63	218.45	1441.33
2007	1012.35	.	7.69	644.65	264.27	1928.96

Table 3.14. Estimated time series of dead discards in numbers (1000 fish) for commercial handline (D.c.hal), headboat (D.hb), and general recreational (D.rec)

Year	D.c.hal	D.hb	D.rec	Total
1946	.	.	.	0.00
1947	.	0.34	0.74	1.09
1948	.	0.72	1.41	2.12
1949	.	1.10	2.07	3.16
1950	.	1.49	2.72	4.21
1951	.	1.89	3.37	5.26
1952	.	2.31	4.01	6.32
1953	.	2.75	4.64	7.39
1954	.	3.21	5.26	8.47
1955	.	3.70	5.86	9.56
1956	.	4.21	6.45	10.66
1957	.	4.76	7.02	11.78
1958	.	5.35	7.57	12.92
1959	.	5.97	8.10	14.07
1960	.	6.64	8.61	15.25
1961	.	7.34	9.10	16.43
1962	.	8.01	9.54	17.55
1963	.	8.59	9.94	18.53
1964	.	9.01	10.27	19.28
1965	.	9.20	10.52	19.72
1966	.	9.11	10.69	19.80
1967	.	8.84	10.78	19.62
1968	.	8.49	10.81	19.30
1969	.	8.19	10.79	18.98
1970	.	8.03	10.75	18.78
1971	.	8.10	10.68	18.78
1972	.	9.45	10.61	20.05
1973	.	9.00	10.52	19.52
1974	.	9.89	10.41	20.30
1975	.	11.19	10.30	21.50
1976	.	9.37	10.18	19.56
1977	.	7.44	10.06	17.50
1978	.	11.43	9.92	21.36
1979	.	9.98	9.79	19.76
1980	.	7.57	9.65	17.22
1981	.	6.36	12.67	19.03
1982	.	8.50	15.70	24.20
1983	.	9.36	12.12	21.48
1984	.	7.61	8.55	16.16
1985	.	12.42	9.15	21.58
1986	.	12.50	9.15	21.66
1987	.	17.14	9.15	26.30
1988	.	17.38	9.76	27.14
1989	.	15.51	24.26	39.77
1990	.	15.38	27.16	42.54
1991	.	14.08	16.11	30.19
1992	30.76	25.65	30.23	86.64
1993	34.55	24.30	18.30	77.15
1994	43.30	27.47	25.37	96.14
1995	52.26	26.36	46.01	124.63
1996	67.38	25.28	15.88	108.54
1997	62.61	27.10	15.75	105.45
1998	49.12	25.37	22.58	97.07
1999	41.03	32.87	97.87	171.77
2000	42.96	36.85	81.93	161.74
2001	51.21	36.05	52.15	139.41
2002	97.18	28.87	41.14	167.19
2003	40.30	21.67	69.66	131.63
2004	20.40	33.43	57.23	111.06
2005	30.73	19.95	33.32	83.99
2006	19.35	29.01	31.60	79.96
2007	21.23	48.55	99.69	169.47

Table 3.15. Estimated time series of dead discards in whole weight (1000 lb) for commercial handline (D.c.hal), headboat (D.hb), and general recreational (D.rec)

Year	D.c.hal	D.hb	D.rec	Total
1946	.	.	.	0.00
1947	.	0.10	0.47	0.57
1948	.	0.21	0.89	1.10
1949	.	0.32	1.31	1.63
1950	.	0.43	1.72	2.15
1951	.	0.55	2.13	2.68
1952	.	0.67	2.53	3.21
1953	.	0.80	2.93	3.73
1954	.	0.93	3.32	4.25
1955	.	1.07	3.70	4.77
1956	.	1.22	4.07	5.29
1957	.	1.38	4.42	5.81
1958	.	1.55	4.77	6.32
1959	.	1.74	5.09	6.83
1960	.	1.93	5.41	7.34
1961	.	2.13	5.71	7.84
1962	.	2.33	5.99	8.32
1963	.	2.50	6.24	8.73
1964	.	2.62	6.41	9.03
1965	.	2.67	6.56	9.24
1966	.	2.65	6.66	9.31
1967	.	2.57	6.71	9.28
1968	.	2.47	6.73	9.20
1969	.	2.38	6.72	9.09
1970	.	2.33	6.69	9.02
1971	.	2.35	6.64	9.00
1972	.	2.74	6.59	9.34
1973	.	2.62	6.54	9.15
1974	.	2.87	6.47	9.34
1975	.	3.25	6.39	9.64
1976	.	2.72	6.30	9.02
1977	.	2.20	7.18	9.38
1978	.	3.37	7.48	10.85
1979	.	2.85	5.30	8.15
1980	.	2.23	6.44	8.67
1981	.	1.88	9.45	11.33
1982	.	2.47	10.16	12.63
1983	.	2.71	7.37	10.08
1984	.	2.18	4.71	6.90
1985	.	3.62	5.60	9.22
1986	.	3.61	5.23	8.84
1987	.	4.96	5.34	10.30
1988	.	5.08	6.12	11.20
1989	.	4.49	14.26	18.75
1990	.	4.48	16.75	21.23
1991	.	4.01	8.23	12.24
1992	13.58	7.57	26.34	47.49
1993	16.00	7.03	15.20	38.22
1994	19.68	7.87	19.94	47.49
1995	23.23	7.76	40.13	71.12
1996	31.15	7.27	12.83	51.24
1997	28.18	7.91	13.43	49.51
1998	22.42	7.32	18.40	48.14
1999	18.47	11.22	90.22	119.91
2000	19.28	12.60	75.55	107.42
2001	22.98	12.40	48.83	84.21
2002	43.85	9.84	37.68	91.37
2003	18.05	7.41	64.15	89.62
2004	9.16	11.57	54.44	75.17
2005	13.97	6.87	31.66	52.51
2006	8.78	9.95	29.63	48.35
2007	9.57	20.49	111.79	141.85

Table 3.16. Base run: Estimated status indicators, benchmarks, and related quantities from the catch-at-age model, conditional on estimated current selectivities averaged across fisheries. Precision is represented by 10^{th} and 90^{th} percentiles from bootstrap and Monte Carlo analysis of the spawner-recruit curve. 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 per year; status indicators are dimensionless; and biomass estimates are in units of metric tons, pounds, or eggs, as indicated. Symbols, abbreviations, and acronyms are listed in Appendix A.

Quantity	Units	Estimate	10^{th} Percentile	90^{th} Percentile
F_{MSY}	y^{-1}	0.386	0.199	0.792
85%F_{MSY}	y^{-1}	0.328	–	–
75%F_{MSY}	y^{-1}	0.289	–	–
65%F_{MSY}	y^{-1}	0.251	–	–
B_{MSY}	mt	3300	2352	4525
SSB_{MSY}	10^{12} eggs	9.157	6.206	12.911
MSST	10^{12} eggs	7.142	4.840	10.071
MSY	1000 lb	1665	1216	2132
D_{MSY}	1000 fish	130	74	222
R_{MSY}	1000 fish	4466	3628	5401
Y at 85%F_{MSY}	1000 lb	1656	–	–
Y at 75%F_{MSY}	1000 lb	1635	–	–
Y at 65%F_{MSY}	1000 lb	1599	–	–
F_{2007}/F_{MSY}	–	1.274	0.620	2.464
SSB_{2007}/SSB_{MSY}	–	0.861	0.610	1.270
SSB_{2007}/MSST	–	1.103	0.782	1.628

Table 3.17. Acceptable biological catch (ABC), with annual probability of overfishing $P^\star = 0.1$. F = fishing mortality rate, Pr(SSB > SSB_{MSY}) = proportion of replicates exceeding SSB_{MSY}, SSB = mid-year spawning stock (10^{12} eggs), R = recruits (1000 fish), D = discard mortalities (1000 lb whole weight), L = landings (1000 lb whole weight), and Sum L = cumulative landings. ABC (1000 lb whole weight) includes landings and discard mortalities. Annual ABCs are a single quantity among the 10000 replicate projections; other values presented are medians.

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(10^{12})	R(1000)	D(klb)	L(klb)	Sum L(klb)	ABC(klb)
2008	0.384	0.24	7.92	3194	45	1491	1491	–
2009	0.192	0.32	7.85	3152	23	772	2263	795
2010	0.184	0.43	8.53	3173	22	794	3057	816
2011	0.171	0.51	9.29	3266	22	786	3843	808
2012	0.161	0.59	10.06	3304	22	812	4655	834

Table 3.18. Acceptable biological catch (ABC), with annual probability of overfishing $P^\star = 0.2$. F = fishing mortality rate, Pr(SSB > SSB_{MSY}) = proportion of replicates exceeding SSB_{MSY}, SSB = mid-year spawning stock (10^{12} eggs), R = recruits (1000 fish), D = discard mortalities (1000 lb whole weight), L = landings (1000 lb whole weight), and Sum L = cumulative landings. ABC (1000 lb whole weight) includes landings and discard mortalities. Annual ABCs are a single quantity among the 10000 replicate projections; other values presented are medians.

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(10^{12})	R(1000)	D(klb)	L(klb)	Sum L(klb)	ABC(klb)
2008	0.384	0.24	7.92	3194	45	1491	1491	–
2009	0.243	0.31	7.73	3152	29	961	2452	990
2010	0.236	0.4	8.21	3149	28	967	3419	995
2011	0.222	0.47	8.79	3209	28	945	4365	973
2012	0.209	0.52	9.39	3227	28	966	5331	994

Table 3.19. Acceptable biological catch (ABC), with annual probability of overfishing $P^\star = 0.25$. F = fishing mortality rate, Pr(SSB > SSB_{MSY}) = proportion of replicates exceeding SSB_{MSY}, SSB = mid-year spawning stock (10^{12} eggs), R = recruits (1000 fish), D = discard mortalities (1000 lb whole weight), L = landings (1000 lb whole weight), and Sum L = cumulative landings. ABC (1000 lb whole weight) includes landings and discard mortalities. Annual ABCs are a single quantity among the 10000 replicate projections; other values presented are medians.

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(10^{12})	R(1000)	D(klb)	L(klb)	Sum L(klb)	ABC(klb)
2008	0.384	0.24	7.92	3194	45	1491	1491	–
2009	0.267	0.31	7.68	3152	32	1045	2536	1077
2010	0.26	0.38	8.07	3141	30	1042	3578	1072
2011	0.247	0.44	8.57	3180	30	1013	4592	1043
2012	0.234	0.49	9.1	3193	31	1036	5628	1067

Table 3.20. Acceptable biological catch (ABC), with annual probability of overfishing $P^\star = 0.3$. F = fishing mortality rate, Pr(SSB > SSB_{MSY}) = proportion of replicates exceeding SSB_{MSY}, SSB = mid-year spawning stock (10^{12} eggs), R = recruits (1000 fish), D = discard mortalities (1000 lb whole weight), L = landings (1000 lb whole weight), and Sum L = cumulative landings. ABC (1000 lb whole weight) includes landings and discard mortalities. Annual ABCs are a single quantity among the 10000 replicate projections; other values presented are medians.

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(10^{12})	R(1000)	D(klb)	L(klb)	Sum L(klb)	ABC(klb)
2008	0.384	0.24	7.92	3194	45	1491	1491	–
2009	0.29	0.3	7.63	3152	34	1126	2618	1160
2010	0.285	0.37	7.94	3132	33	1113	3731	1146
2011	0.272	0.42	8.37	3150	33	1079	4810	1112
2012	0.259	0.47	8.82	3154	33	1100	5911	1134

Table 3.21. Acceptable biological catch (ABC), with annual probability of overfishing $P^\star = 0.4$. F = fishing mortality rate, Pr(SSB > SSB_{MSY}) = proportion of replicates exceeding SSB_{MSY}, SSB = mid-year spawning stock (10^{12} eggs), R = recruits (1000 fish), D = discard mortalities (1000 lb whole weight), L = landings (1000 lb whole weight), and Sum L = cumulative landings. ABC (1000 lb whole weight) includes landings and discard mortalities. Annual ABCs are a single quantity among the 10000 replicate projections; other values presented are medians.

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(10^{12})	R(1000)	D(klb)	L(klb)	Sum L(klb)	ABC(klb)
2008	0.384	0.24	7.92	3194	45	1491	1491	–
2009	0.338	0.29	7.52	3152	39	1289	2780	1328
2010	0.336	0.35	7.67	3109	37	1254	4034	1291
2011	0.326	0.39	7.94	3094	38	1209	5243	1246
2012	0.315	0.42	8.27	3082	39	1225	6468	1264

Table 3.22. Acceptable biological catch (ABC), with annual probability of overfishing $P^\star = 0.5$. F = fishing mortality rate, Pr(SSB > SSB_{MSY}) = proportion of replicates exceeding SSB_{MSY}, SSB = mid-year spawning stock (10^{12} eggs), R = recruits (1000 fish), D = discard mortalities (1000 lb whole weight), L = landings (1000 lb whole weight), and Sum L = cumulative landings. ABC (1000 lb whole weight) includes landings and discard mortalities. Annual ABCs are a single quantity among the 10000 replicate projections; other values presented are medians.

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(10^{12})	R(1000)	D(klb)	L(klb)	Sum L(klb)	ABC(klb)
2008	0.384	0.24	7.92	3194	45	1491	1491	–
2009	0.39	0.28	7.41	3152	45	1461	2952	1505
2010	0.395	0.32	7.39	3087	43	1400	4352	1442
2011	0.394	0.35	7.5	3038	44	1347	5699	1391
2012	0.387	0.38	7.67	2988	46	1357	7055	1402

Table 3.23. Results from sensitivity runs of catch-at-age model. (A value of F_{MSY} = 5 indicates that equilibrium landings strictly increase over the explored range of F.)

Run	Description	F_{MSY}	SSB_{MSY} (10^{12} eggs)	MSY(klb)	F_{2007}/F_{MSY}	SSB_{2007}/SSB_{MSY}	SSB_{2007}/MSST	steep	R0(1000)
Base	—	0.386	9.16	1665	1.27	0.86	1.1	0.56	4326
S1	*h* estimated	5	3.6	2278	0.1	2.47	3.17	0.95	4340
S2	$h = 0.73$ ($F_{30\%}$)	0.666	7.36	1784	0.72	1.2	1.54	0.73	4660
S3	$h = 0.67$ ($F_{35\%}$)	0.521	8.16	1705	0.92	1.08	1.38	0.67	4789
S4	$h = 0.53$ ($F_{45\%}$)	0.307	10.55	1580	1.49	0.82	1.06	0.53	5217
S5	$h = 0.47$ ($F_{50\%}$)	0.236	12.3	1507	1.83	0.72	0.92	0.47	5496
S6	High M	0.719	8.36	1819	0.84	1.03	1.44	0.56	6686
S7	Low M	0.199	12.49	1466	2.5	0.55	0.66	0.56	3307
S8	q $\delta = 0.00$	0.36	9.43	1666	1.07	1	1.29	0.56	4560
S9	q $\delta = 0.04$	0.391	9.17	1696	1.44	0.77	0.99	0.56	4275
S10	High D mort	0.341	10.08	1601	1.39	0.87	1.11	0.56	5156
S11	Low D mort	0.354	9.6	1616	1.27	0.9	1.15	0.56	5015
S12	Rec L 0.5	0.336	10.04	1555	1.35	0.88	1.13	0.56	5074
S13	Rec L 1.0	0.349	9.88	1627	1.34	0.87	1.12	0.56	5124
S14	Rec L 1.25	0.339	10.32	1603	1.41	0.83	1.07	0.56	5229
S15	Low comm L	0.383	8.39	1529	1.34	0.85	1.09	0.56	3960
S16	High comm L	0.388	9.93	1804	1.22	0.87	1.12	0.56	4692
S17	HB index	0.38	9.64	1546	1.51	0.81	1.03	0.56	4737
S18	CVT index	0.417	8.77	1556	2.82	0.56	0.71	0.56	4145
S19	Low len comp	0.334	9.19	2005	1.22	0.9	1.15	0.56	4682
S20	Retro 2006	0.368	9.96	1583	0.96	0.87	1.12	0.56	4832
S21	Retro 2005	0.427	9.47	1741	0.84	0.89	1.15	0.56	3794
S22	Retro 2004	0.348	9.82	1485	1.2	0.92	1.18	0.56	5154
S23	Retro 2003	0.349	9.19	1564	0.94	0.83	1.06	0.56	4454

Table 3.24. Projection results under scenario 1—fishing mortality rate fixed at $F = F_{current}$. *F = fishing mortality rate (per year), Pr(*SSB > SSB_{MSY}*) = proportion of replicates exceeding* SSB_{MSY}, *SSB = mid-year spawning stock (*10^{12} *eggs), R = recruits (1000 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} = 0.386, SSB_{MSY} = 9.16, R_{MSY} = 4466, MSY = 1665.27, *and* D_{MSY} = 130, *each in the same units as the relevant time series. Expected values presented are from deterministic projections.*

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(10^{12})	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2008	0.384	0.25	7.7	4211	99	42	1055	1390	1390
2009	0.384	0.29	7.92	4170	107	46	1058	1372	2762
2010	0.384	0.31	8.15	4219	117	50	1109	1417	4179
2011	0.384	0.33	8.34	4268	120	51	1159	1472	5651
2012	0.384	0.34	8.51	4309	122	52	1191	1511	7162
2013	0.384	0.34	8.64	4342	123	53	1214	1542	8704
2014	0.384	0.35	8.75	4368	125	53	1233	1566	10,271
2015	0.384	0.36	8.83	4389	126	54	1247	1587	11,857
2016	0.384	0.36	8.9	4406	126	54	1258	1603	13,460
2017	0.384	0.36	8.96	4419	127	54	1267	1616	15,075
2018	0.384	0.37	9.01	4430	128	55	1274	1626	16,701

Table 3.25. Projection results under scenario 2—fishing mortality rate fixed at $F = 0.65F_{MSY}$. F = fishing mortality rate (per year), Pr(SSB > SSB_{MSY}) = proportion of replicates exceeding SSB_{MSY}, SSB = mid-year spawning stock (10^{12} eggs), R = recruits (1000 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 $F_{MSY} = 0.386$, $SSB_{MSY} = 9.16$, $R_{MSY} = 4466$, MSY = 1665.27, and $D_{MSY} = 130$, each in the same units as the relevant time series. Expected values presented are from deterministic projections.

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(10^{12})	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2008	0.384	0.25	7.7	4211	99	42	1055	1390	1390
2009	0.251	0.29	7.92	4170	72	31	720	937	2326
2010	0.251	0.38	8.83	4219	81	35	806	1041	3367
2011	0.251	0.44	9.4	4405	84	36	880	1138	4506
2012	0.251	0.49	9.9	4510	88	38	934	1213	5719
2013	0.251	0.53	10.32	4594	91	39	979	1278	6997
2014	0.251	0.56	10.68	4663	93	40	1018	1334	8331
2015	0.251	0.59	10.99	4718	95	41	1050	1382	9713
2016	0.251	0.6	11.24	4763	96	41	1076	1422	11,135
2017	0.251	0.62	11.45	4799	98	42	1097	1455	12,591
2018	0.251	0.65	11.62	4828	99	42	1115	1482	14,073

Table 3.26. Projection results under scenario 3—fishing mortality rate fixed at $F = 0.75F_{MSY}$. *F = fishing mortality rate (per year), Pr(*SSB > SSB_{MSY}*) = proportion of replicates exceeding* SSB_{MSY}, *SSB = mid-year spawning stock (*10^{12} *eggs), R = recruits (1000 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* $F_{MSY} = 0.386$, $SSB_{MSY} = 9.16$, $R_{MSY} = 4466$, MSY = 1665.27, *and* $D_{MSY} = 130$, *each in the same units as the relevant time series. Expected values presented are from deterministic projections.*

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(10^{12})	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2008	0.384	0.25	7.7	4211	99	42	1055	1390	1390
2009	0.289	0.29	7.92	4170	82	35	821	1066	2456
2010	0.289	0.35	8.62	4219	92	39	901	1160	3616
2011	0.289	0.4	9.07	4365	95	41	971	1249	4865
2012	0.289	0.44	9.46	4450	98	42	1020	1316	6181
2013	0.289	0.47	9.78	4520	101	43	1060	1372	7553
2014	0.289	0.49	10.05	4575	103	44	1094	1421	8973
2015	0.289	0.52	10.28	4620	105	45	1121	1461	10,434
2016	0.289	0.52	10.46	4656	106	46	1144	1494	11,929
2017	0.289	0.54	10.62	4685	107	46	1162	1522	13,450
2018	0.289	0.56	10.74	4708	108	46	1176	1544	14,994

Table 3.27. Projection results under scenario 4—fishing mortality rate fixed at $F = 0.85F_{MSY}$. F = fishing mortality rate (per year), Pr(SSB > SSB_{MSY}) = proportion of replicates exceeding SSB_{MSY}, SSB = mid-year spawning stock (10^{12} eggs), R = recruits (1000 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 $F_{MSY} = 0.386$, $SSB_{MSY} = 9.16$, $R_{MSY} = 4466$, MSY = 1665.27, and $D_{MSY} = 130$, each in the same units as the relevant time series. Expected values presented are from deterministic projections.

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(10^{12})	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2008	0.384	0.25	7.7	4211	99	42	1055	1390	1390
2009	0.328	0.29	7.92	4170	93	39	919	1193	2583
2010	0.328	0.33	8.42	4219	103	44	989	1270	3852
2011	0.328	0.37	8.76	4326	105	45	1053	1347	5200
2012	0.328	0.4	9.05	4392	108	46	1095	1404	6603
2013	0.328	0.42	9.29	4446	111	47	1130	1450	8054
2014	0.328	0.43	9.48	4490	112	48	1158	1490	9544
2015	0.328	0.45	9.65	4525	114	49	1180	1522	11,066
2016	0.328	0.45	9.78	4552	115	49	1198	1548	12,614
2017	0.328	0.46	9.89	4575	116	50	1212	1570	14,184
2018	0.328	0.47	9.97	4593	117	50	1224	1587	15,771

Table 3.28. Projection results under scenario 5—fishing mortality rate fixed at $F = F_{MSY}$. F = fishing mortality rate (per year), Pr(SSB > SSB_{MSY}) = proportion of replicates exceeding SSB_{MSY}, SSB = mid-year spawning stock (10^{12} eggs), R = recruits (1000 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} = 0.386, SSB_{MSY} = 9.16, R_{MSY} = 4466, MSY = 1665.27, and D_{MSY} = 130, each in the same units as the relevant time series. Expected values presented are from deterministic projections.

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(10^{12})	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2008	0.384	0.25	7.7	4211	99	42	1055	1390	1390
2009	0.386	0.29	7.92	4170	107	46	1061	1376	2766
2010	0.386	0.31	8.14	4219	117	50	1111	1419	4185
2011	0.386	0.33	8.34	4267	120	51	1161	1475	5660
2012	0.386	0.34	8.5	4308	122	52	1193	1513	7173
2013	0.386	0.34	8.63	4340	124	53	1216	1543	8716
2014	0.386	0.35	8.73	4366	125	53	1234	1568	10,284
2015	0.386	0.36	8.82	4386	126	54	1248	1588	11,872
2016	0.386	0.36	8.89	4403	127	54	1259	1603	13,475
2017	0.386	0.36	8.94	4416	127	54	1268	1616	15,091
2018	0.386	0.37	8.99	4427	128	55	1275	1626	16,718

Table 3.29. Parameter, benchmark, and status estimates from base and sensitivity runs of the surplus production model applied to vermilion snapper. Runs are defined by the objective function (LS=Least Squares, LAV=Least Absolute Values) and by B_1/K fixed or estimated.

Run	Obj. Fcn.	B_1/K	K (lb)	r	MSY (lb)	F_{MSY}	B_{MSY} (lb)	B/MSST	F/F_{MSY}
B1K0.5	LS	0.50 (fixed)	4.69E+06	1.22	1.43E+06	0.61	2.34E+06	1.12	1.31
base	LS	0.70 (est.)	5.16E+06	1.10	1.42E+06	0.55	2.58E+06	1.18	1.26
B1K0.9	LS	0.90 (fixed)	5.17E+06	1.10	1.42E+06	0.55	2.59E+06	1.23	1.21
LAV	LAV	0.71 (est.)	4.82E+06	1.17	1.41E+06	0.58	2.41E+06	1.07	1.36

3.5.2 Figures

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

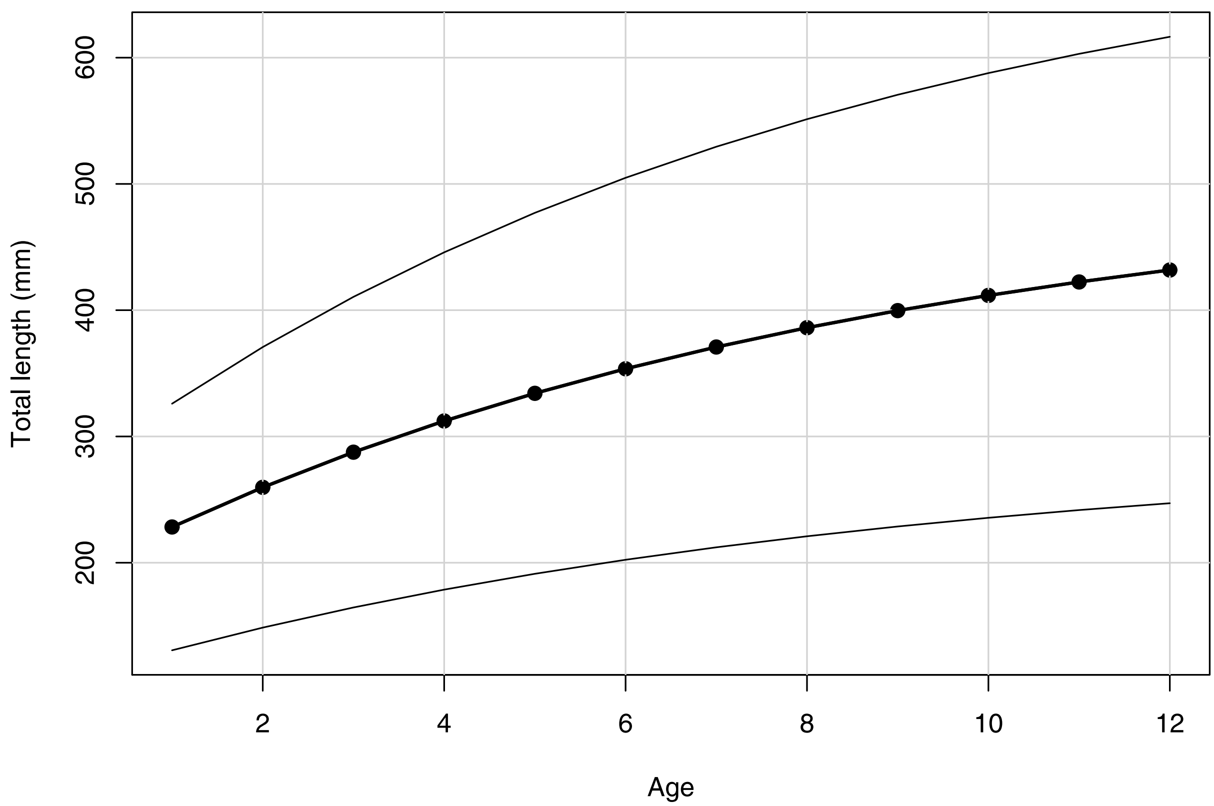


Figure 3.2. Exploration of model fits given changes in likelihood weight on length compositions. Relative likelihood contributions are based on unweighted likelihoods; a smaller value implies a better fit. Top panel: Length comps vs age comps. Middle panel: Length comps vs indices. Bottom panel: Estimates of steepness.

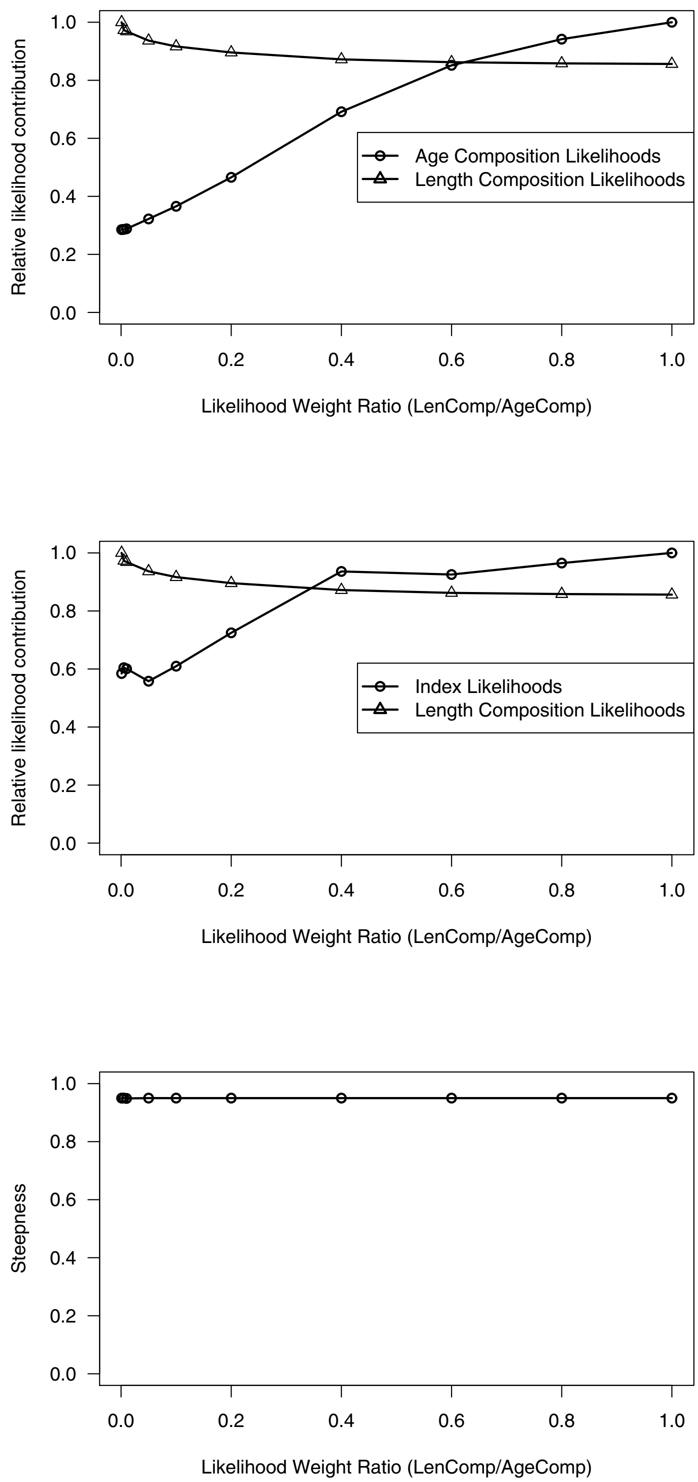


Figure 3.3. Exploration of model fits given changes in likelihood weight on indices. Relative likelihood contributions are based on unweighted likelihoods; a smaller value implies a better fit. Top panel: Indices vs age comps. Middle panel: Indices vs length comps. Bottom panel: Estimates of steepness.

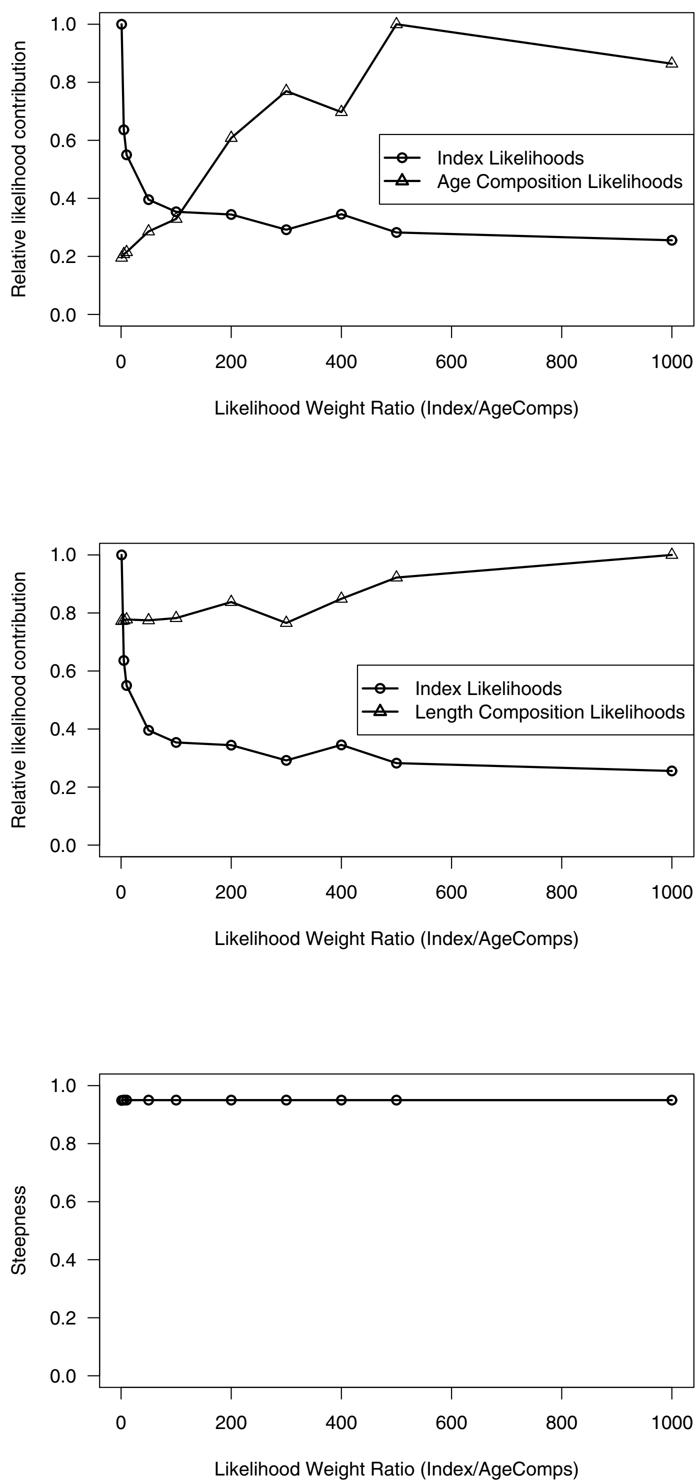


Figure 3.4. Likelihood profile on steepness. Top panels are relative weighted likelihoods; bottom panels are relative unweighted. Right-hand panels are the same as left-hand panels, except for the y-axis scale. A smaller relative likelihood value implies a better fit.

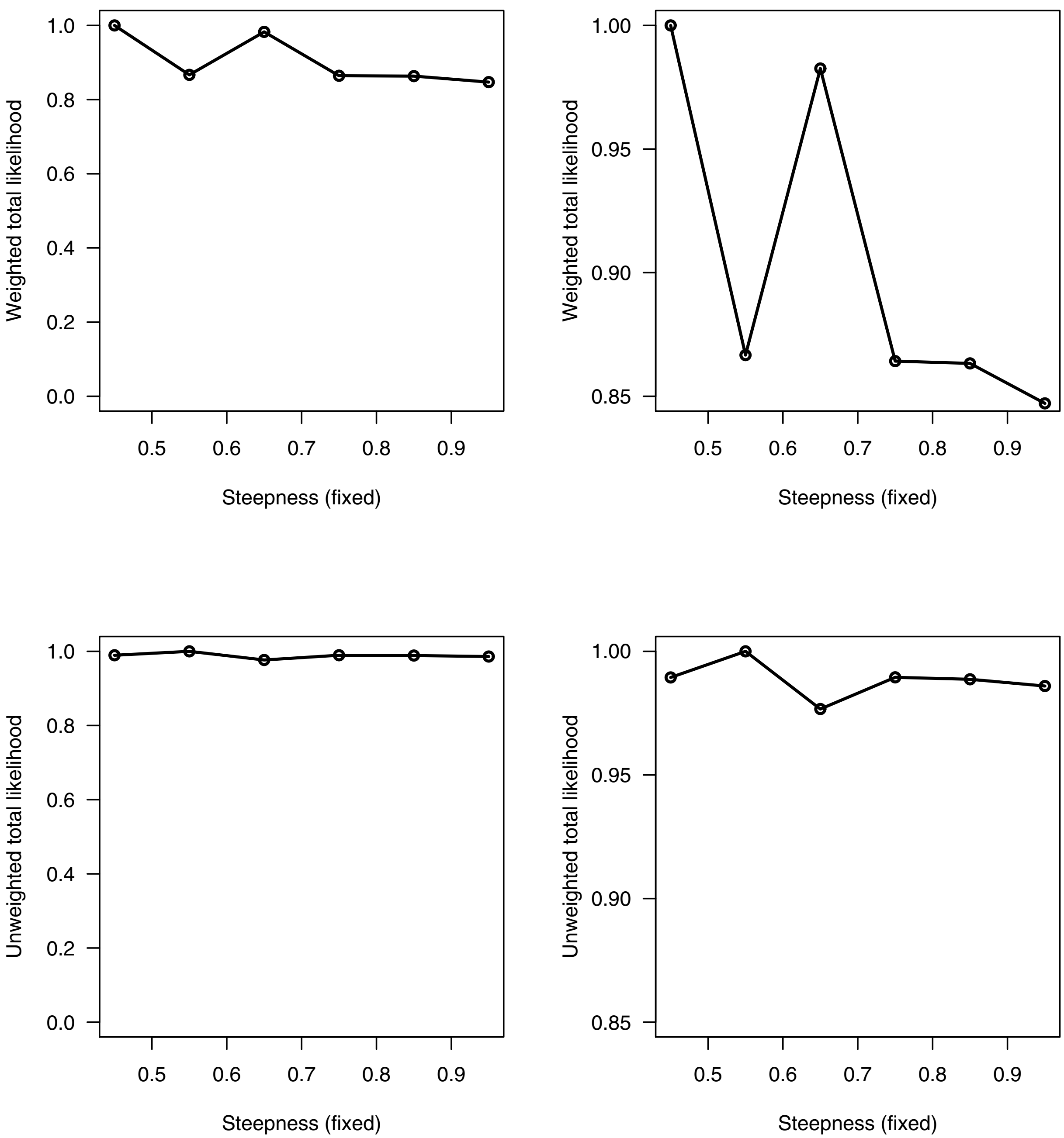


Figure 3.5. Steepness ($h = 0.56$) consistent with $F_{40\%} = F_{MSY}$.

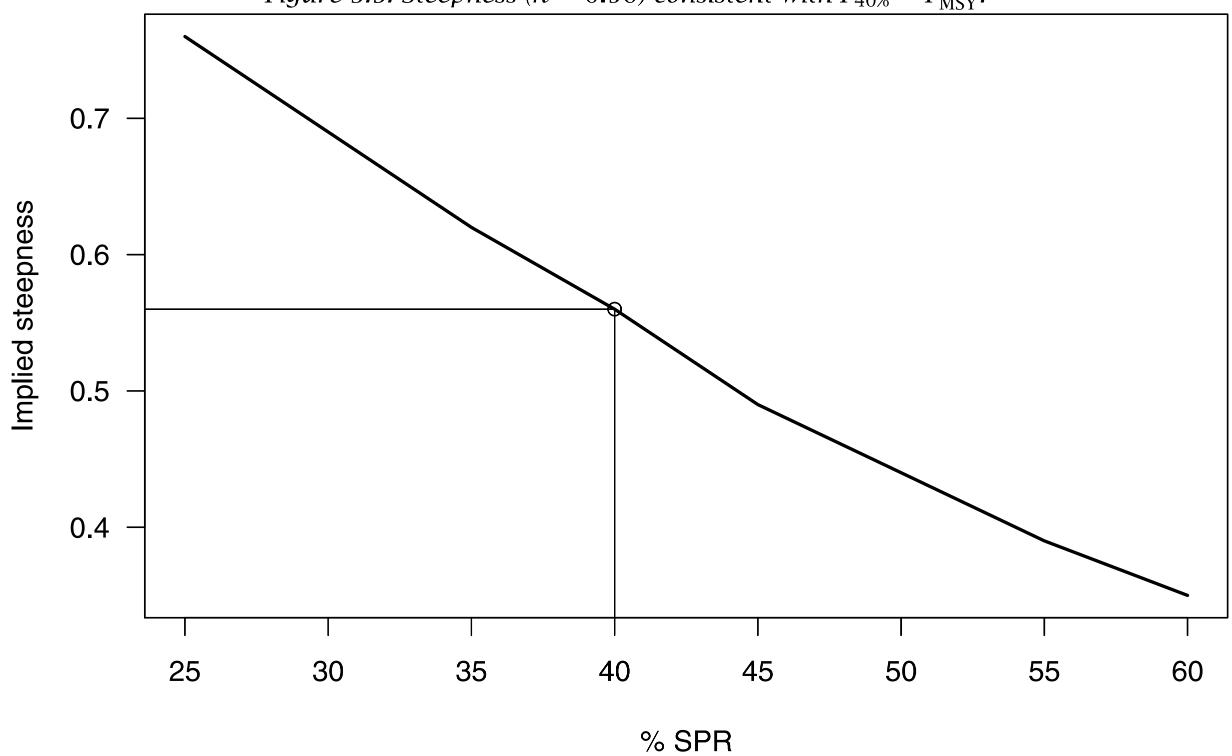


Figure 3.6. Observed (open circles) and estimated (solid line) annual length and age compositions by fishery. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, fst to FL snapper trap, cvt to chevron trap, c.hal to commercial handline, c.cmb to commercial combined, hb to headboat, and rec to general recreational (MRFSS). N = −99999 indicates that sample size was below the cutoff for use in fitting.

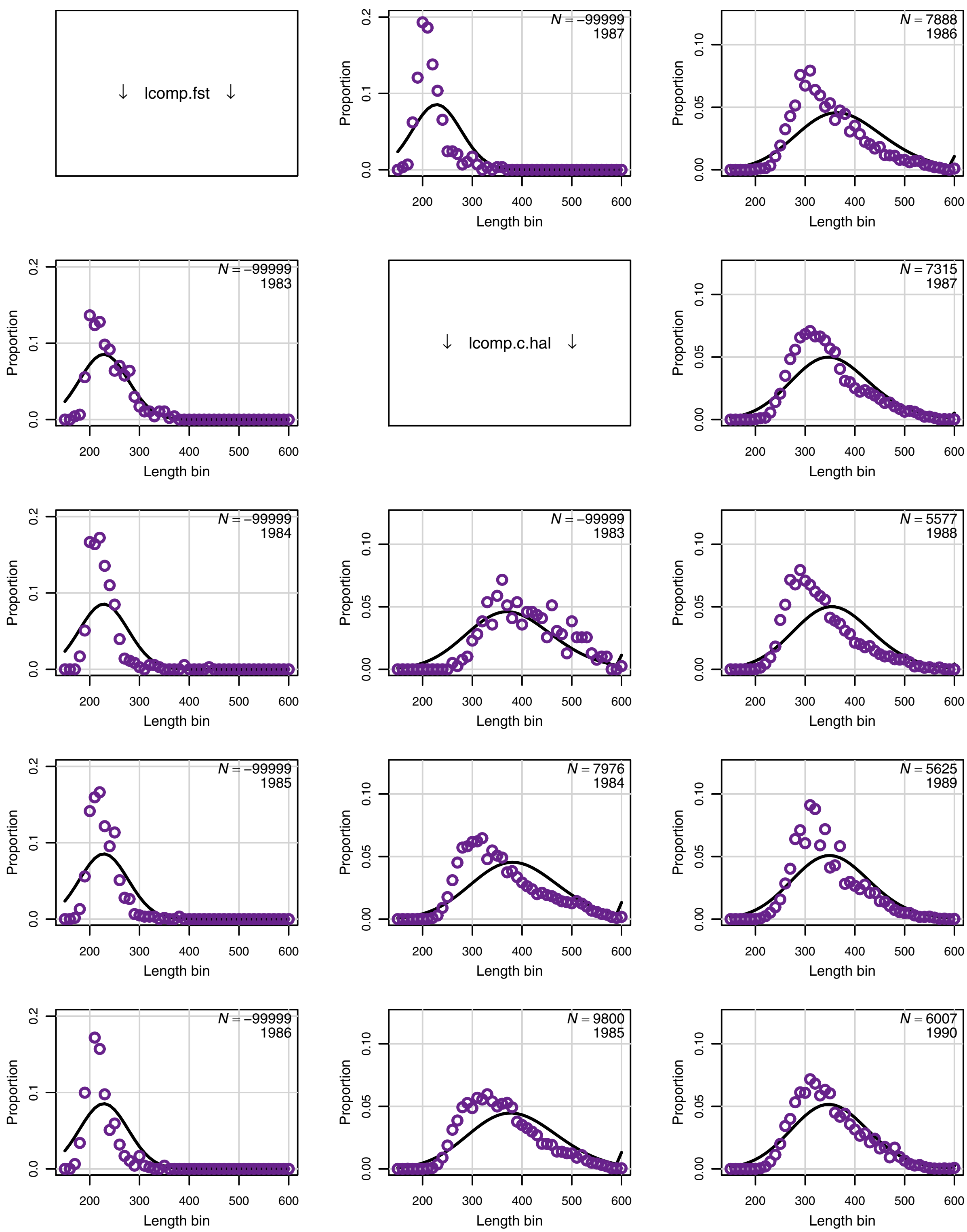


Figure 3.6. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fishery.

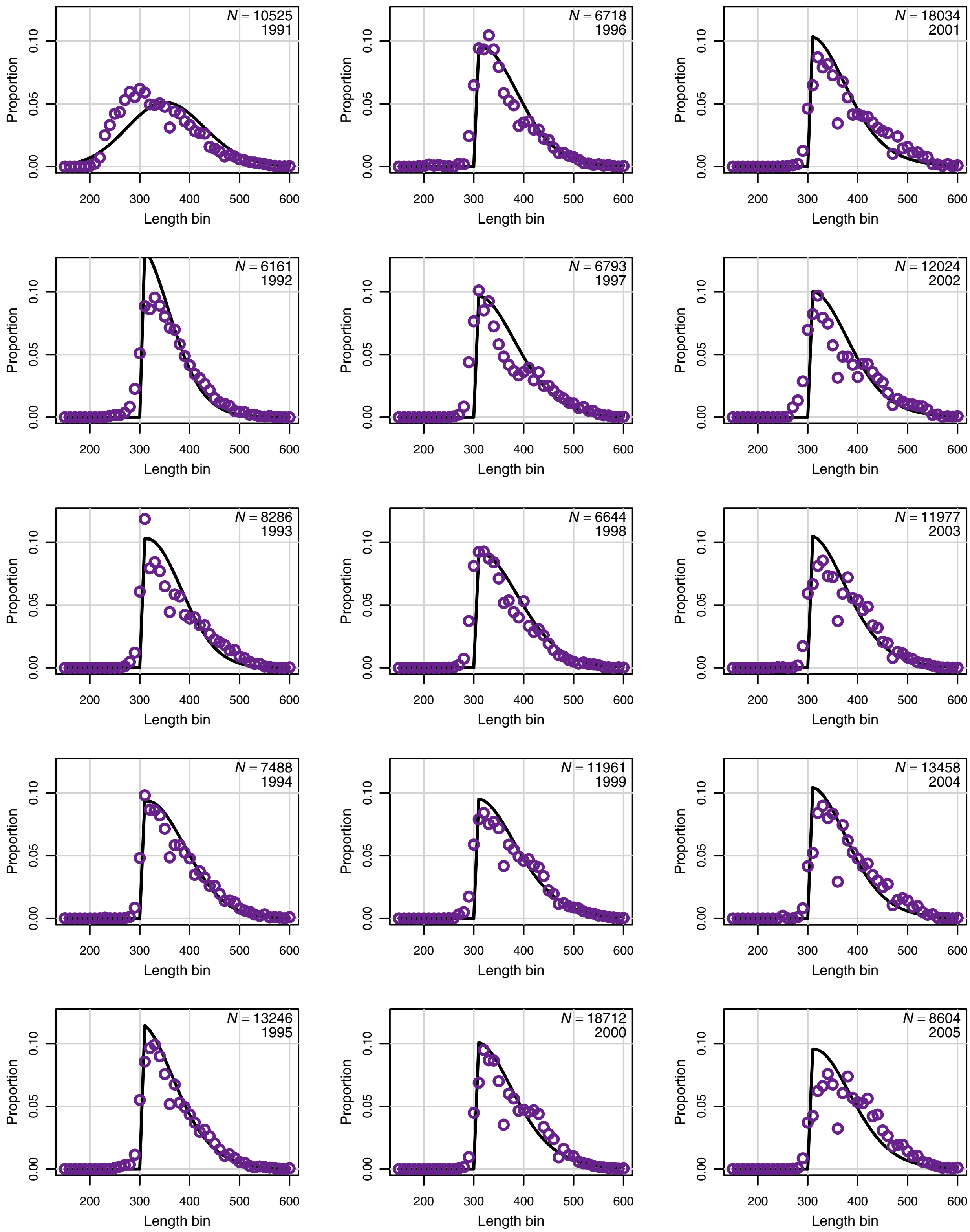


Figure 3.6. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fishery.

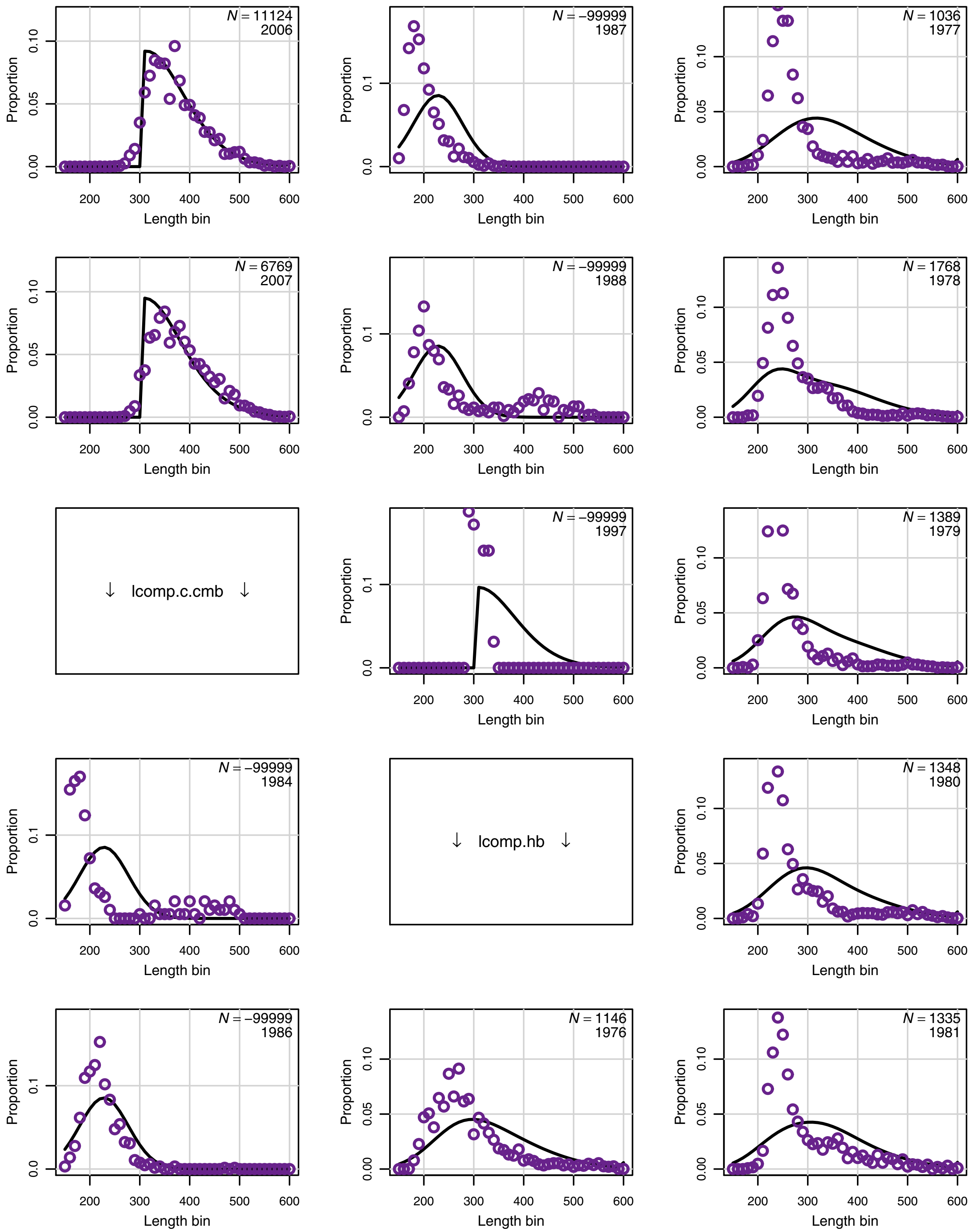


Figure 3.6. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fishery.

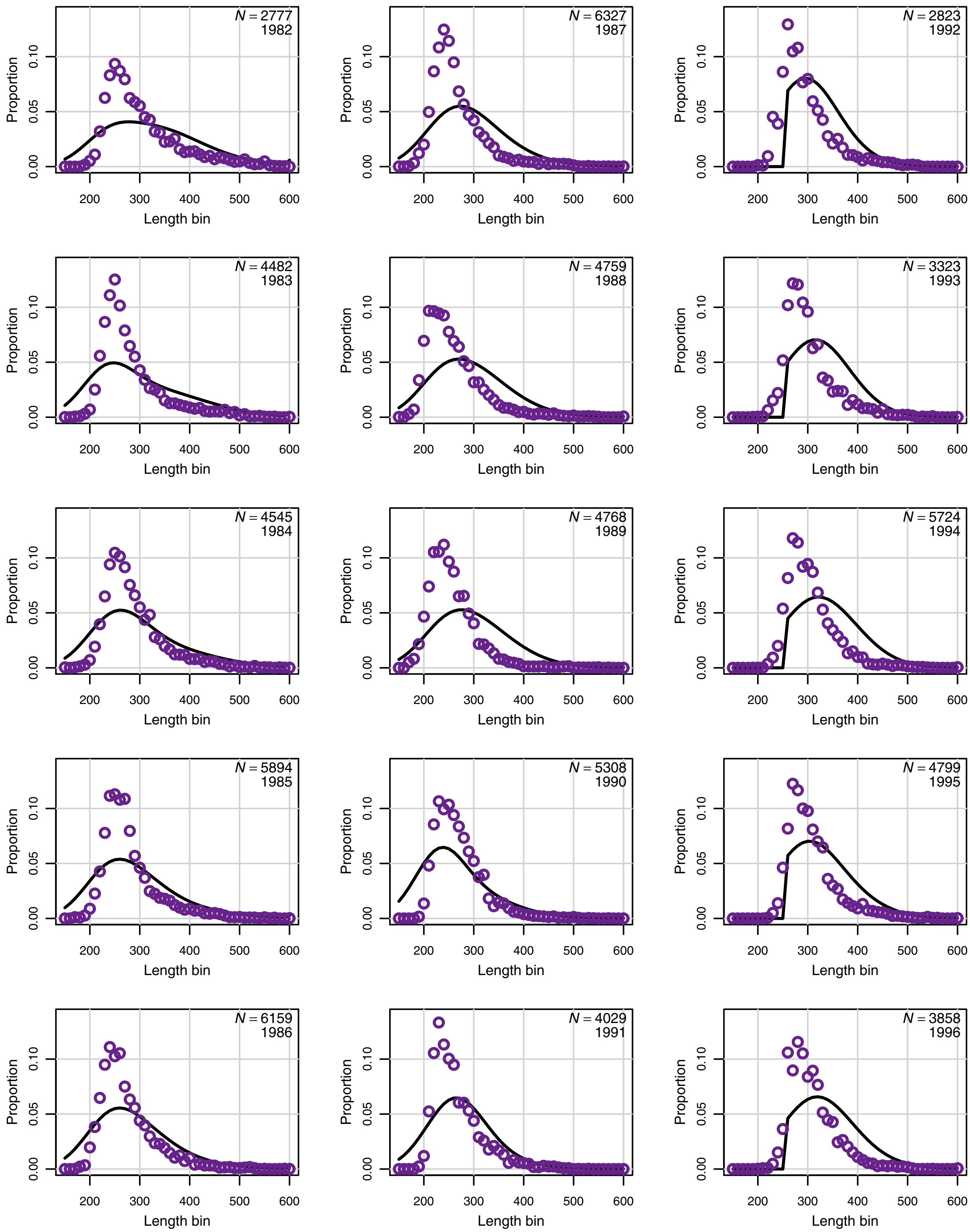


Figure 3.6. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fishery.

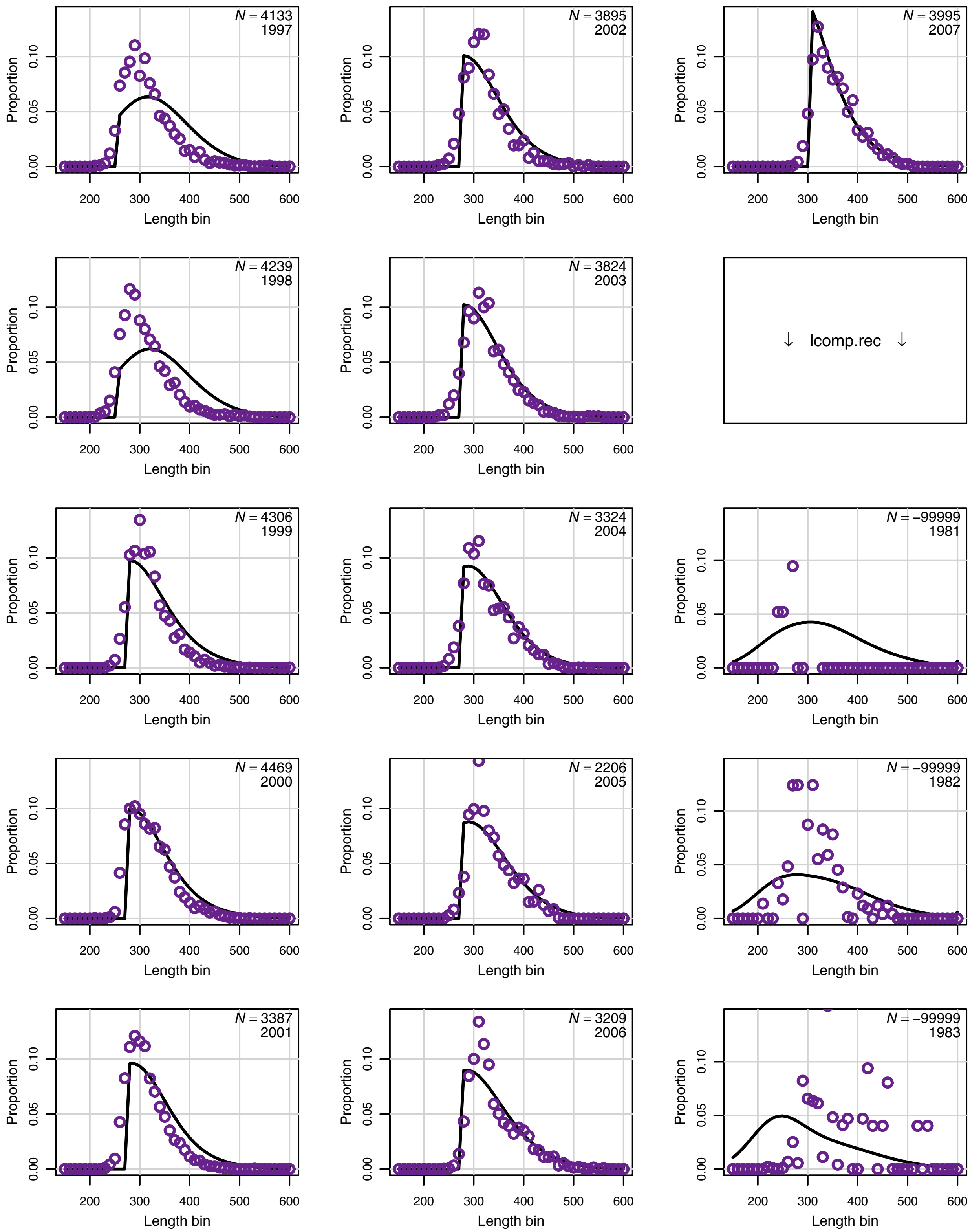


Figure 3.6. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fishery.

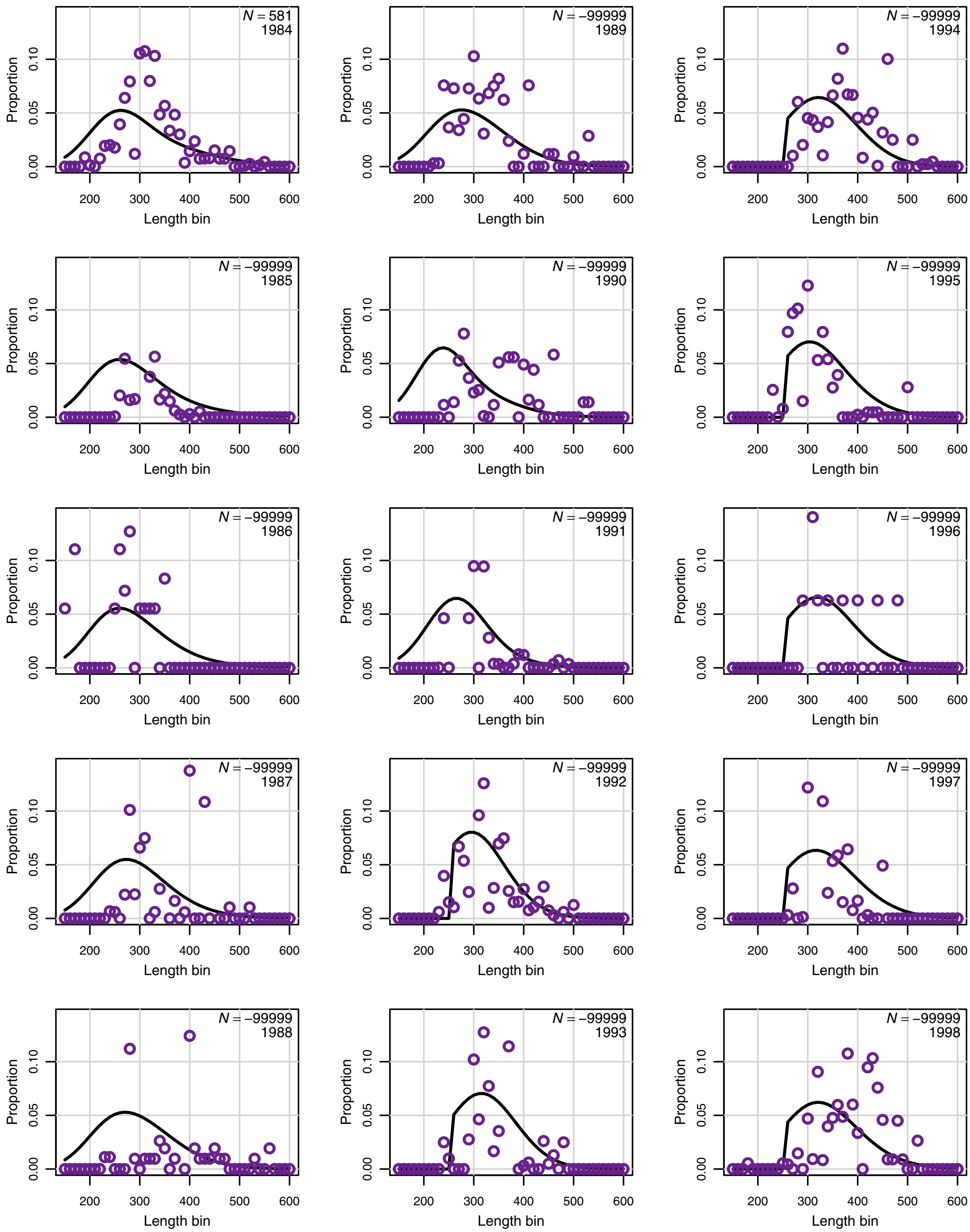


Figure 3.6. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fishery.

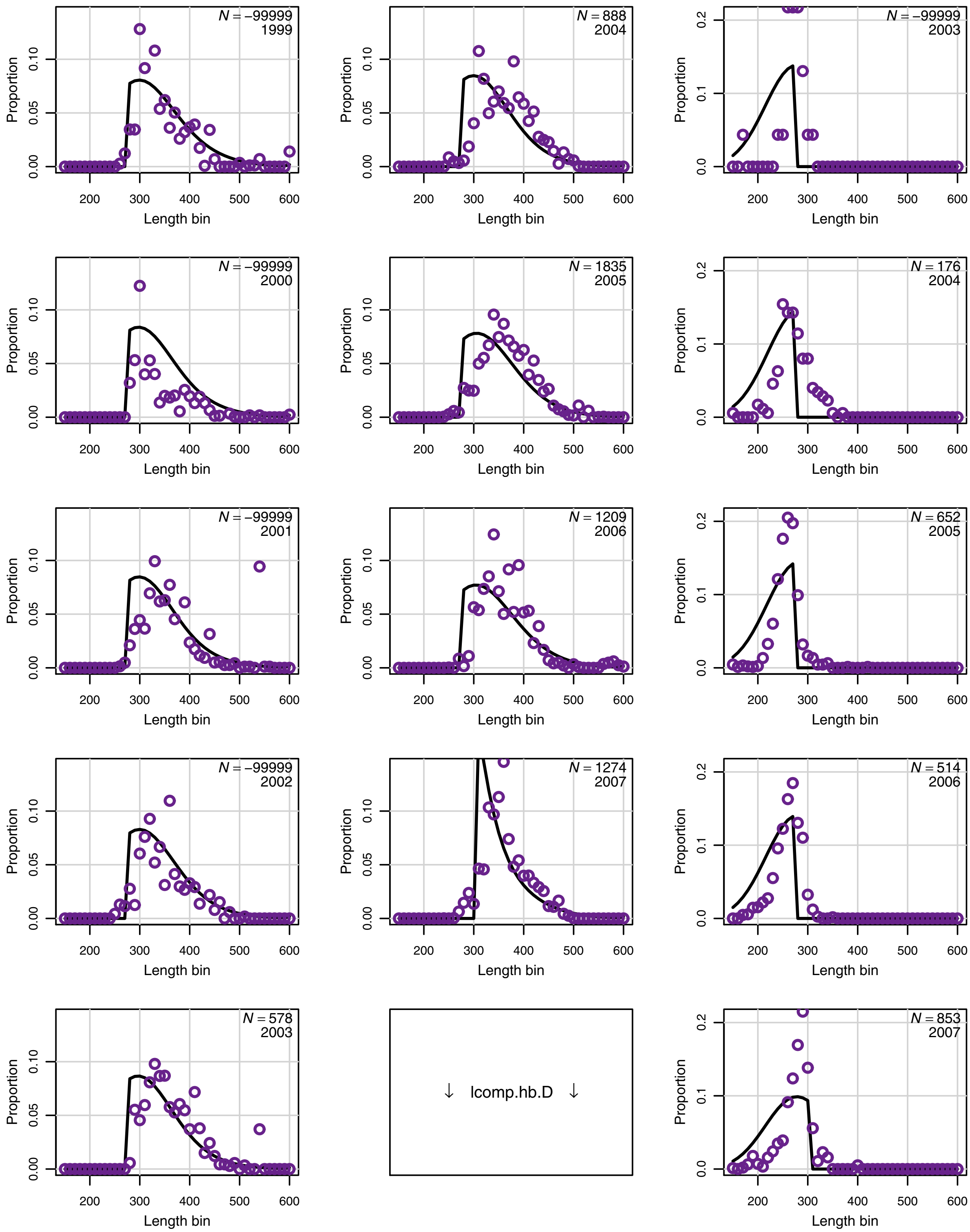


Figure 3.6. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fishery.

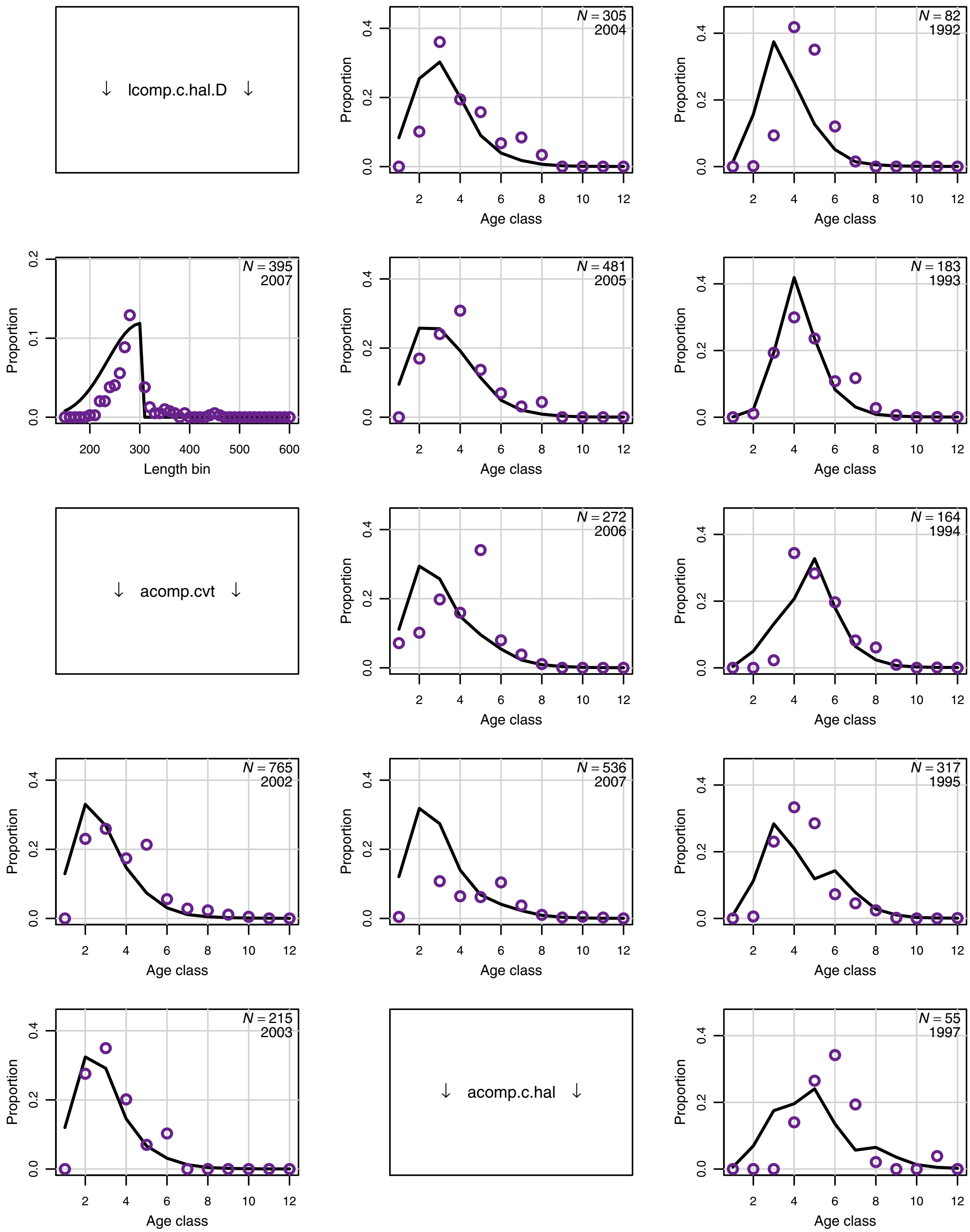


Figure 3.6. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fishery.

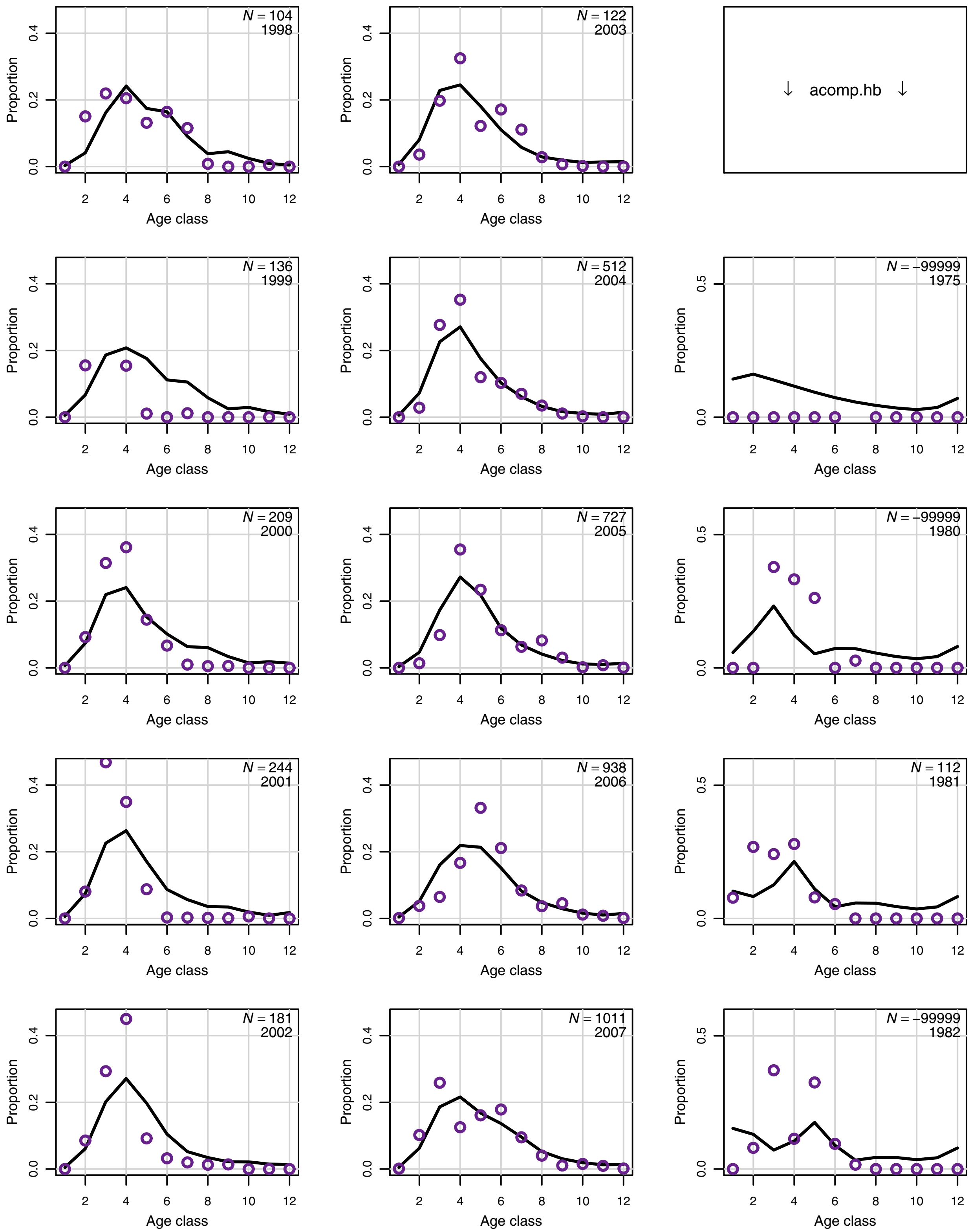


Figure 3.6. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fishery.

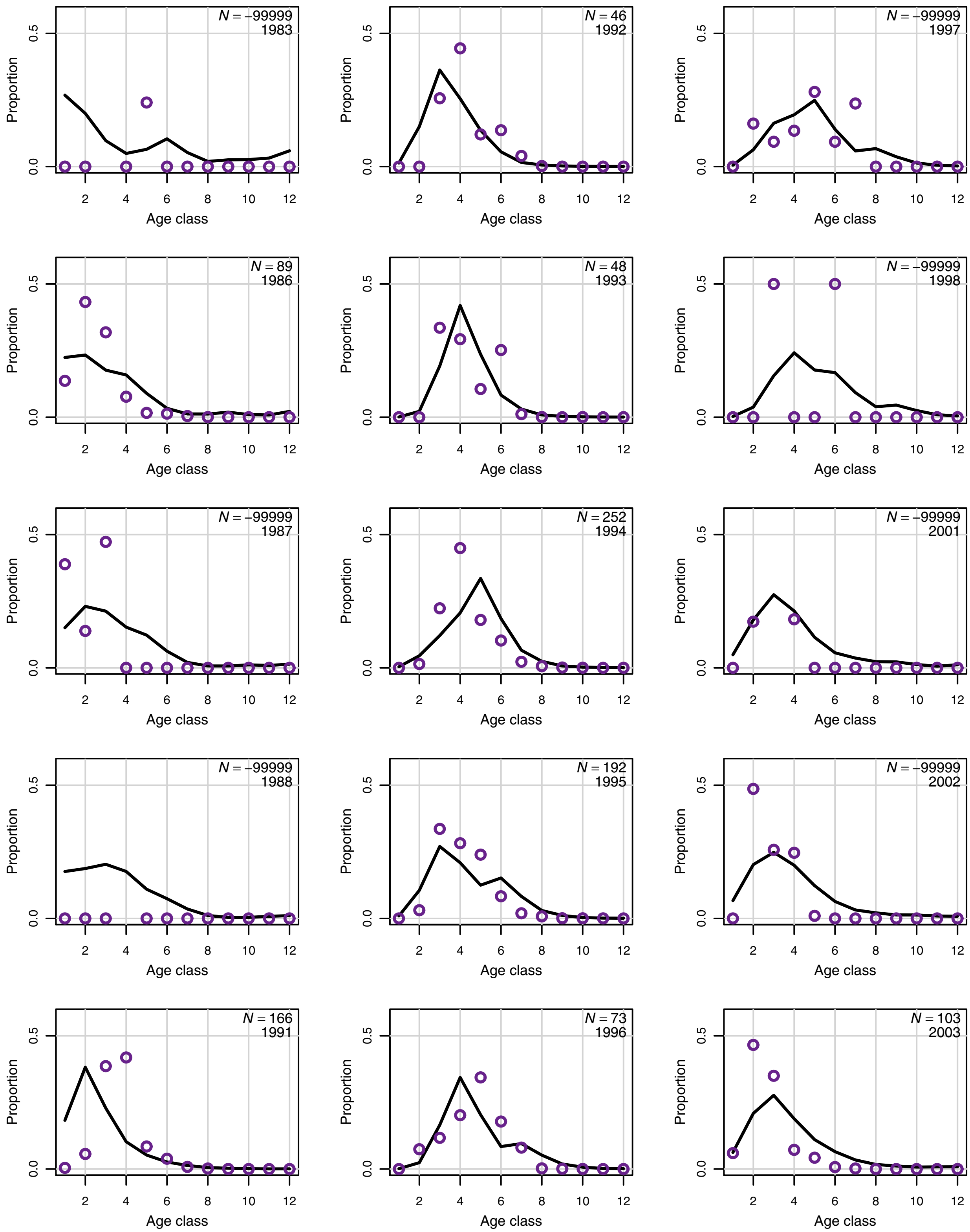


Figure 3.6. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fishery.

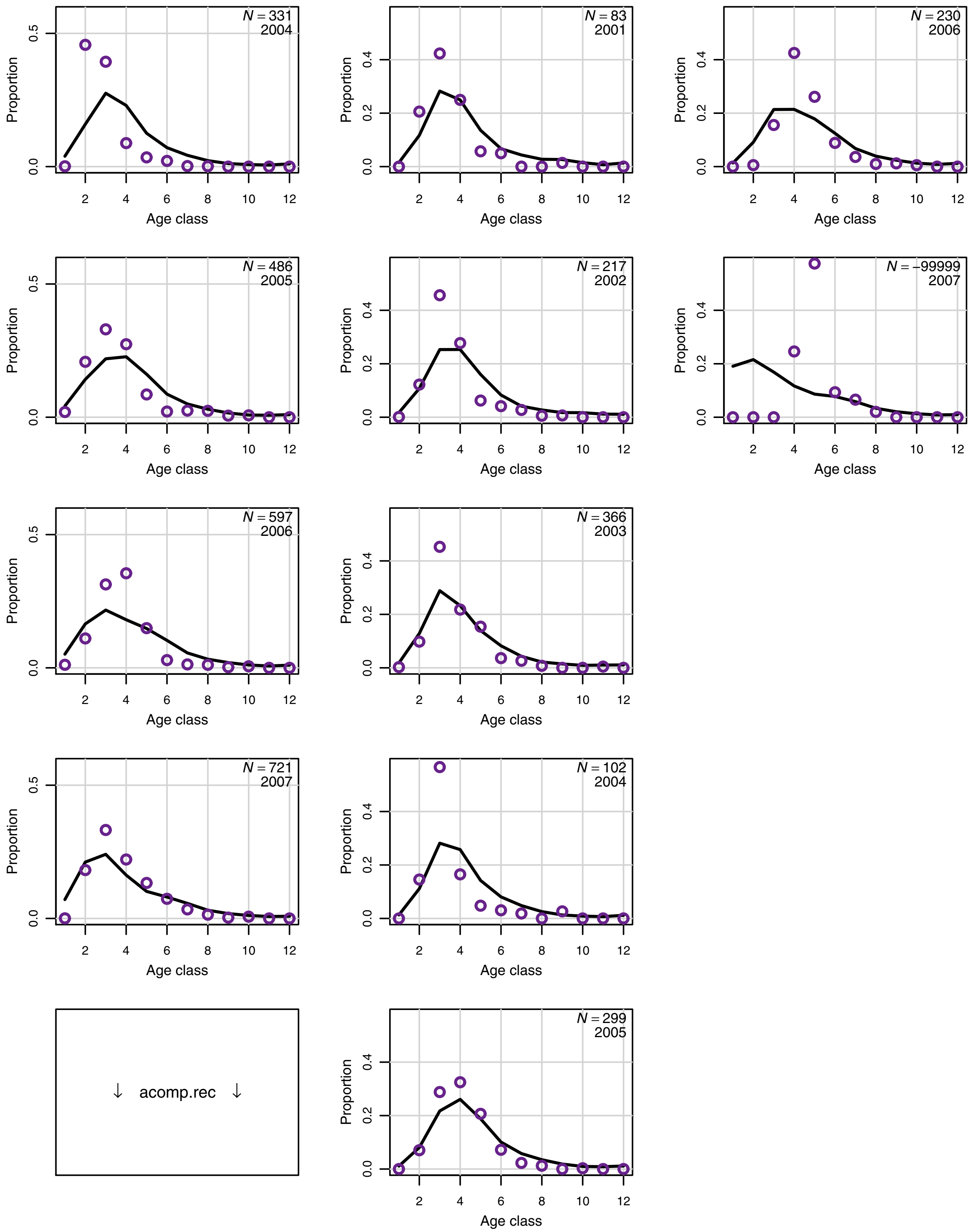


Figure 3.7. Top panel is a bubble plot of length composition residuals from MARMAP Florida snapper trap; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

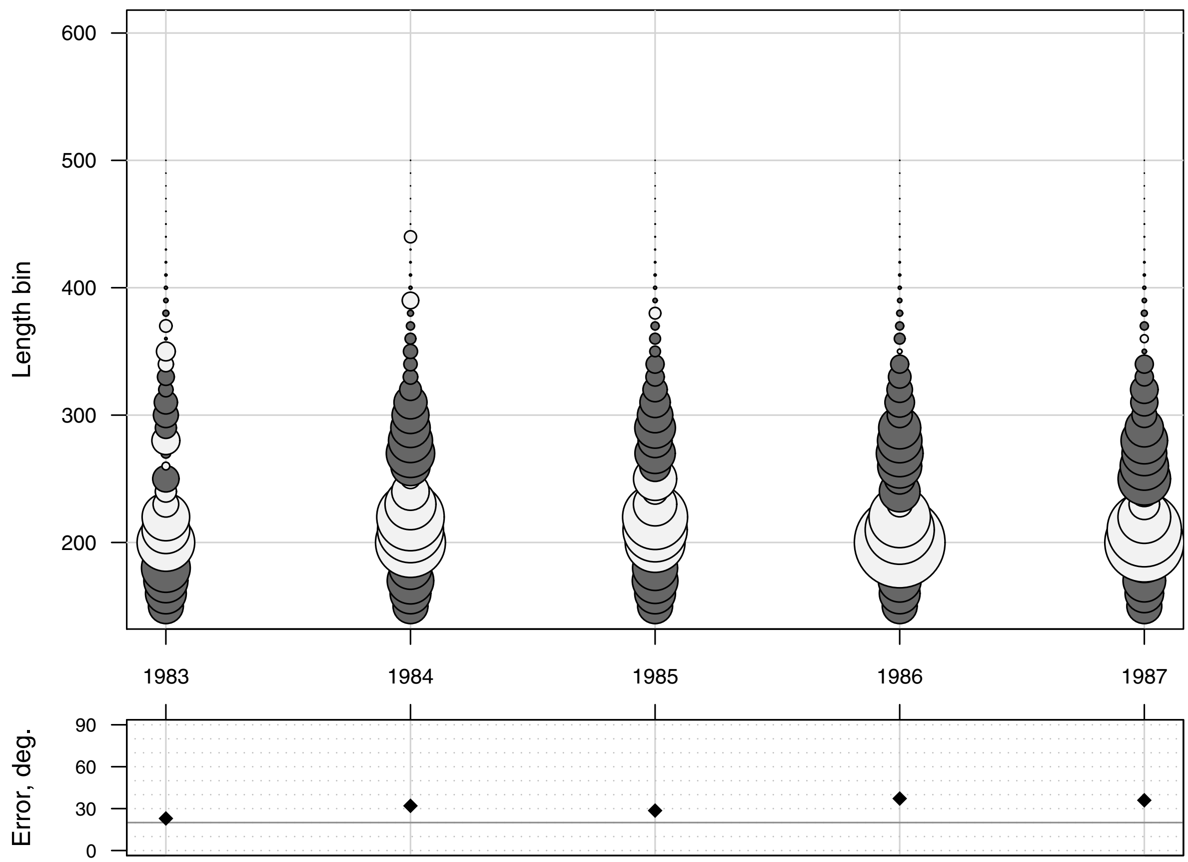


Figure 3.8. Top panel is a bubble plot of length composition residuals from the commercial handline fishery; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded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

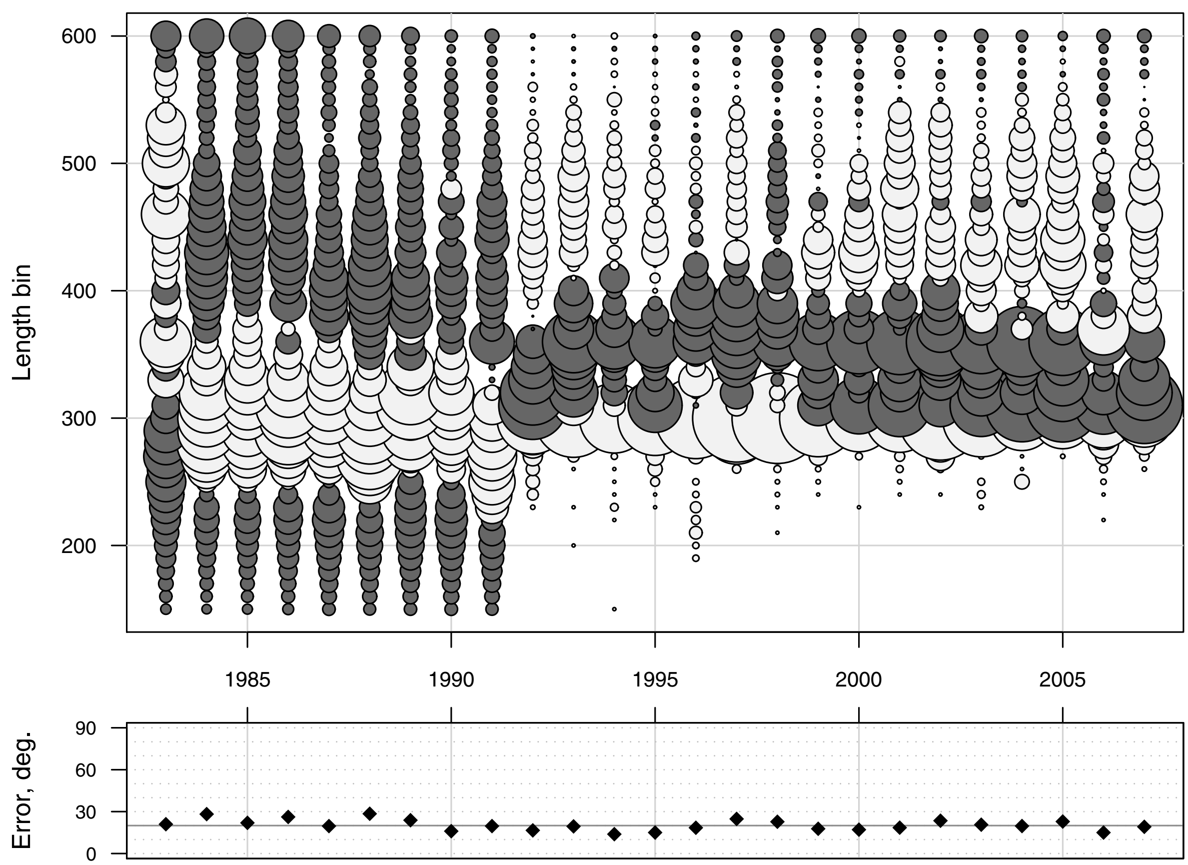


Figure 3.9. Top panel is a bubble plot of length composition residuals from the commercial combined fishery; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded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

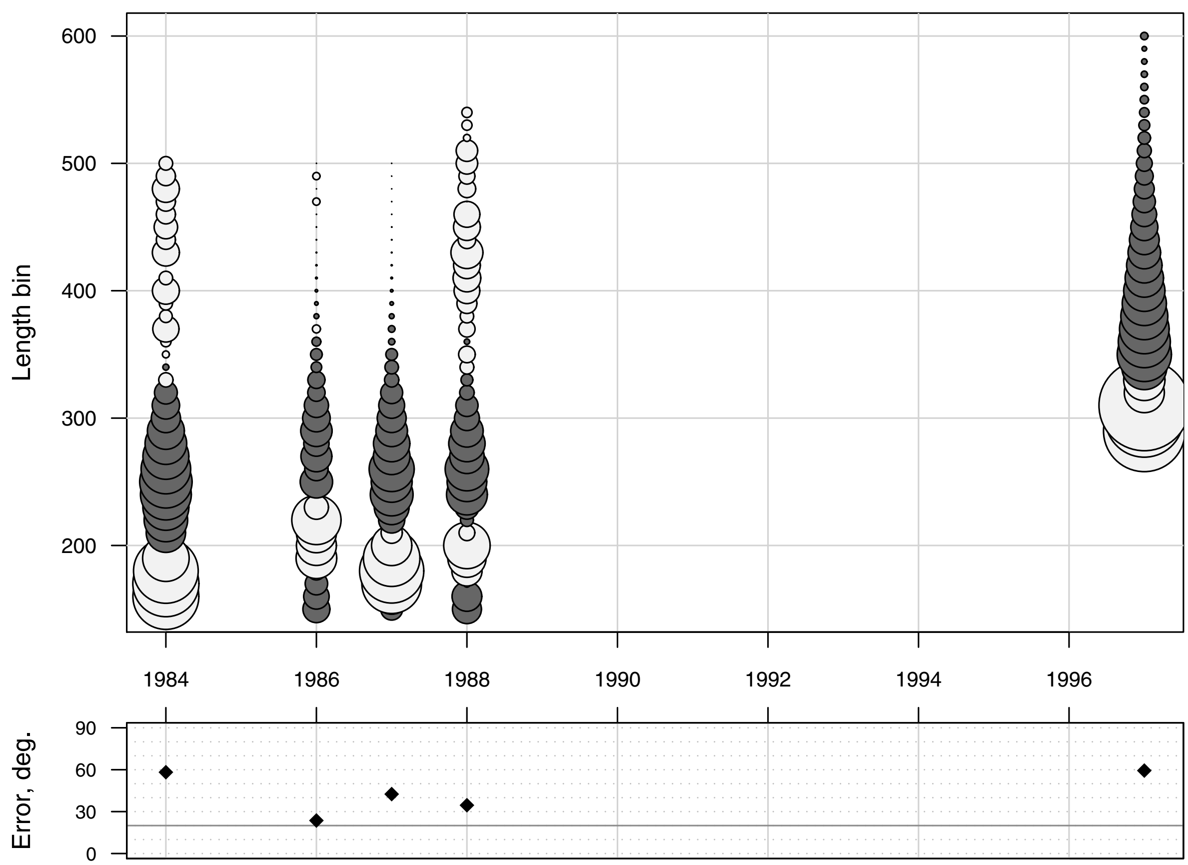


Figure 3.10. Top panel is a bubble plot of length composition residuals from the headboat fishery; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between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

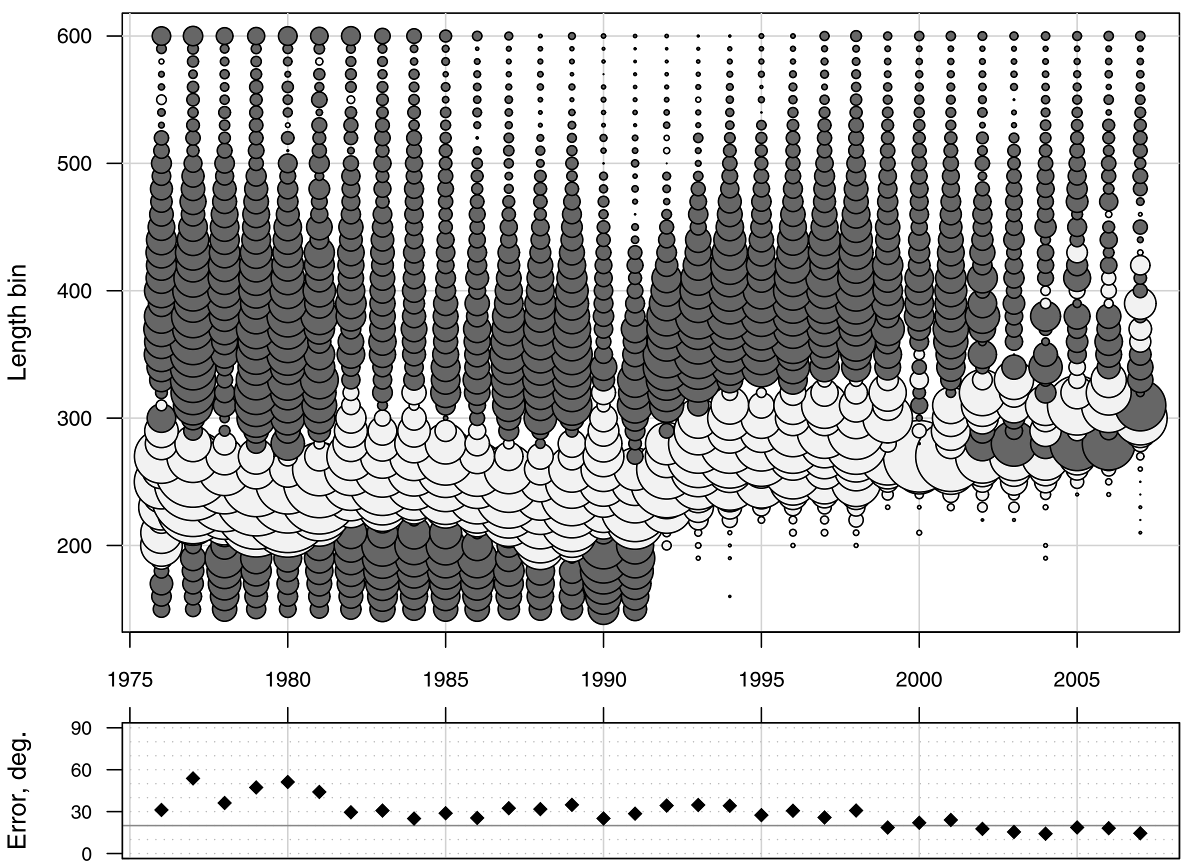


Figure 3.11. Top panel is a bubble plot of length composition residuals from the recreational fishery (MRFSS); Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is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

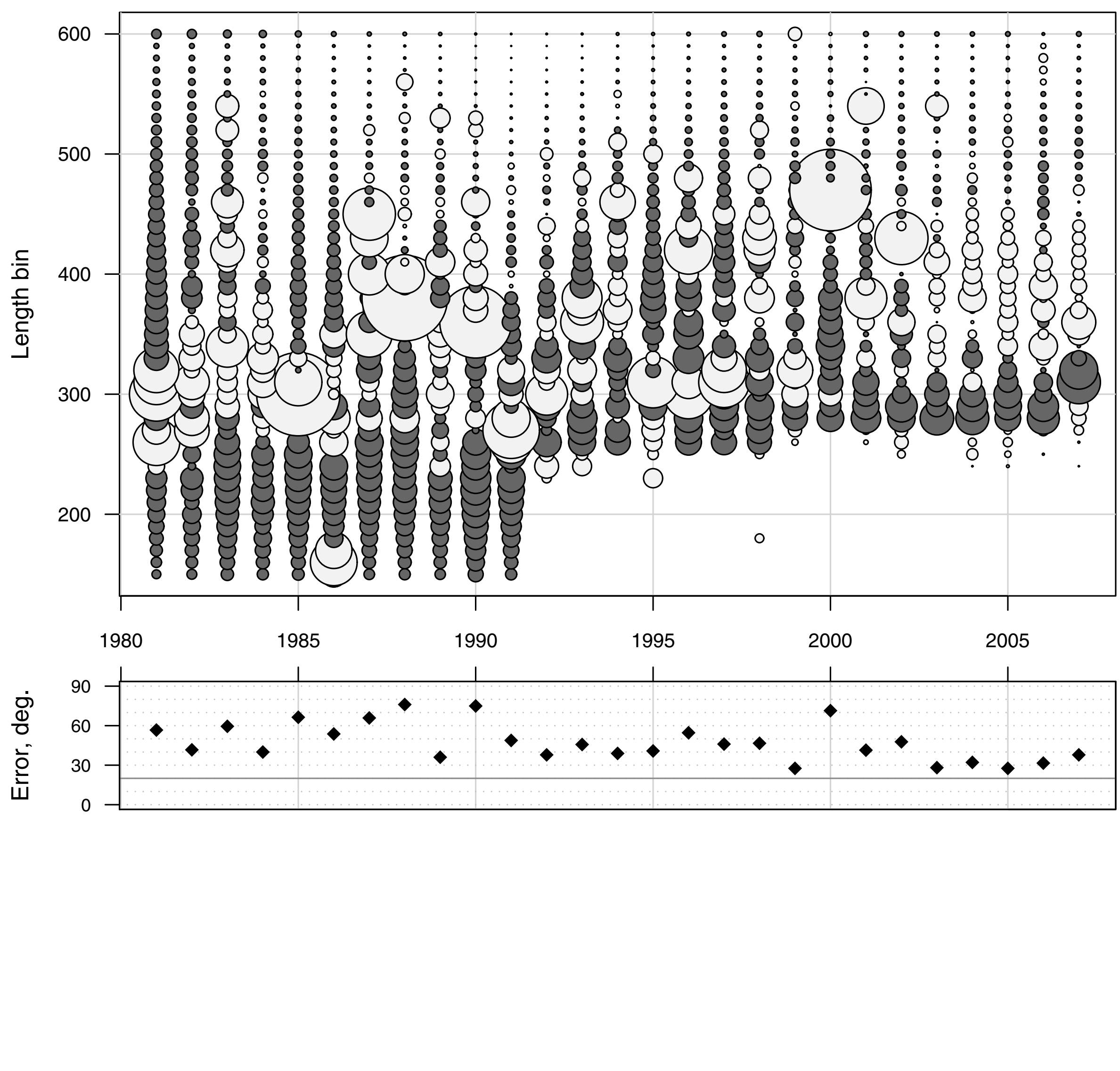


Figure 3.12. Top panel is a bubble plot of length composition residuals from headboat discards; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between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

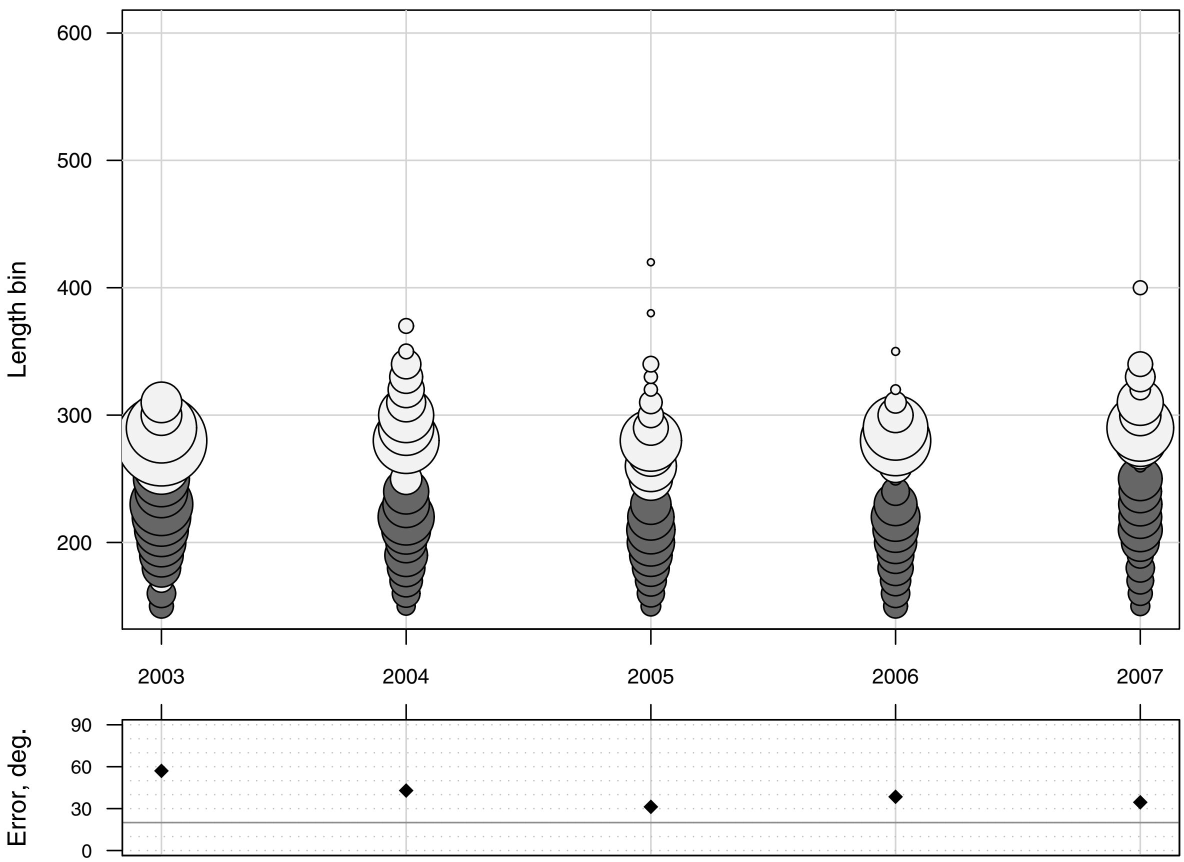


Figure 3.13. Top panel is a bubble plot of length composition residuals from commercial handline discards; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded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

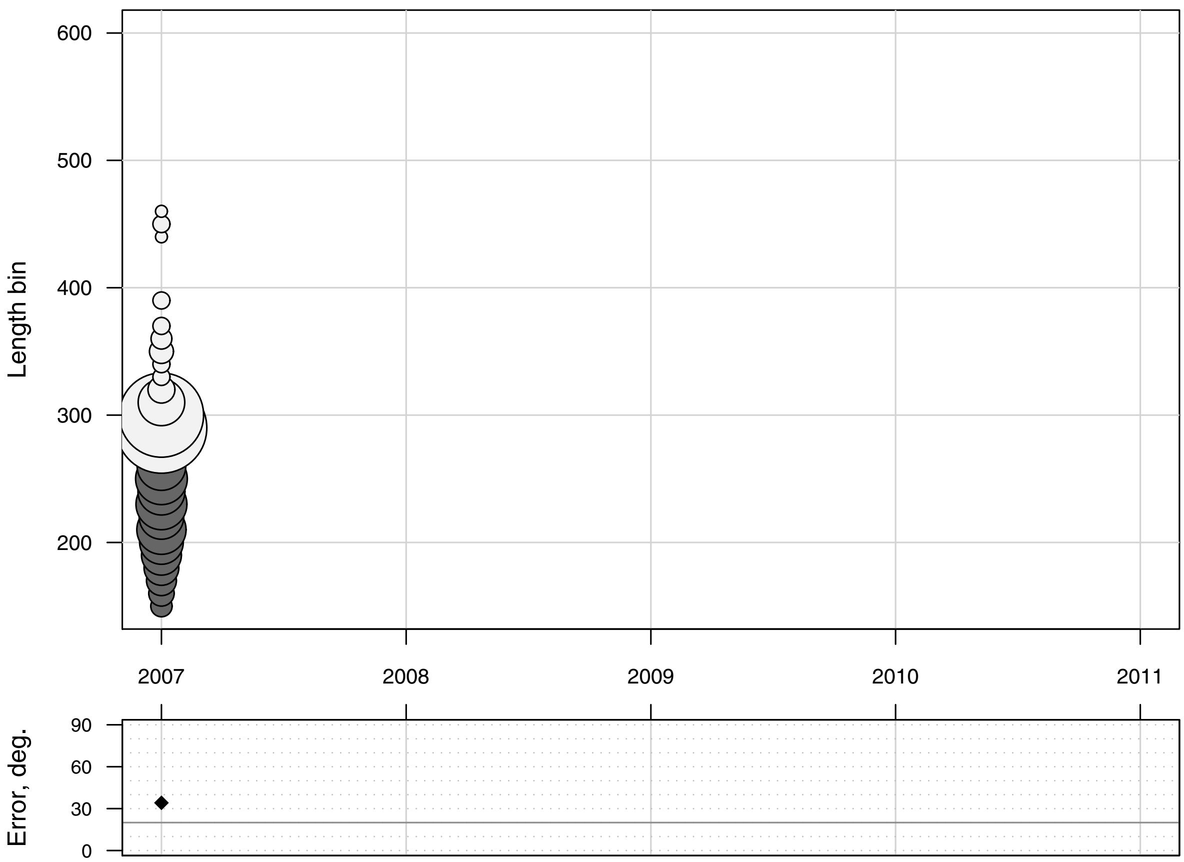


Figure 3.14. Top panel is a bubble plot of age composition residuals from MARMAP chevron trap; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

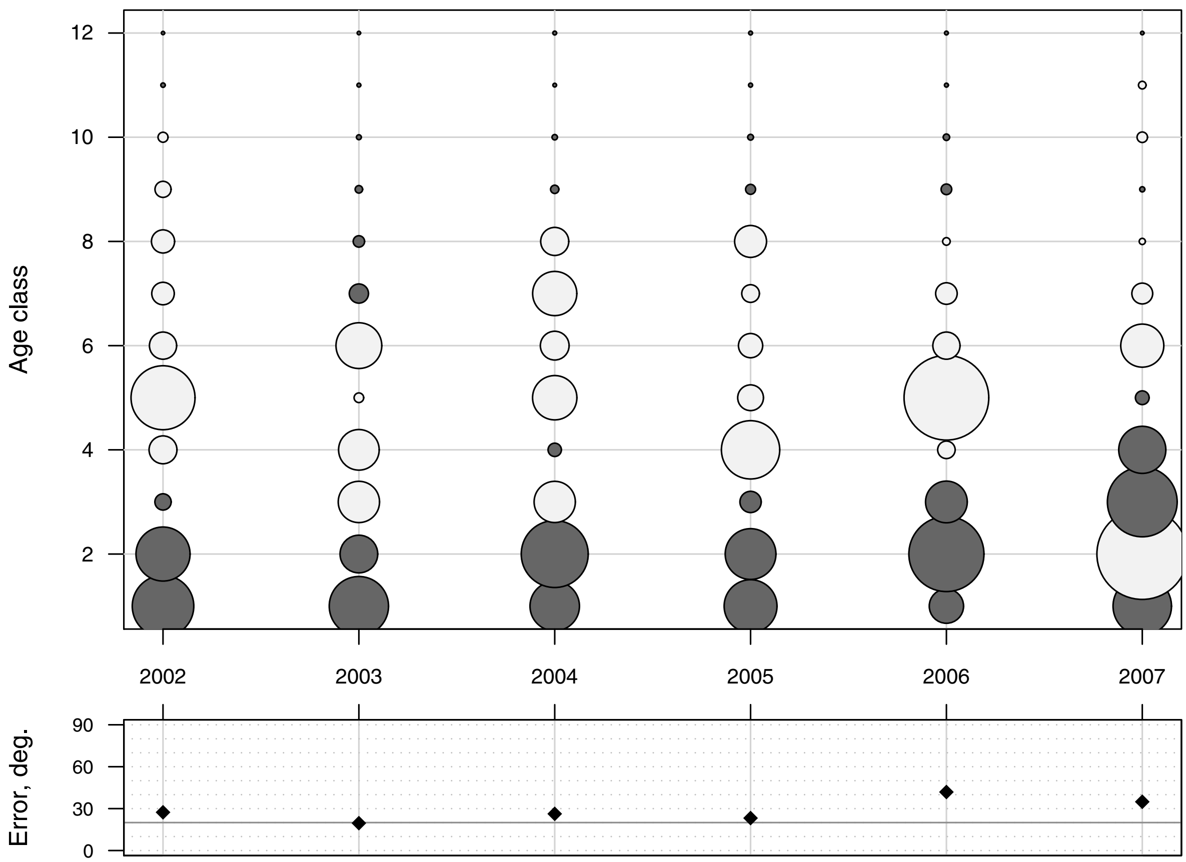


Figure 3.15. Top panel is a bubble plot of age composition residuals from the commercial handline fishery; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

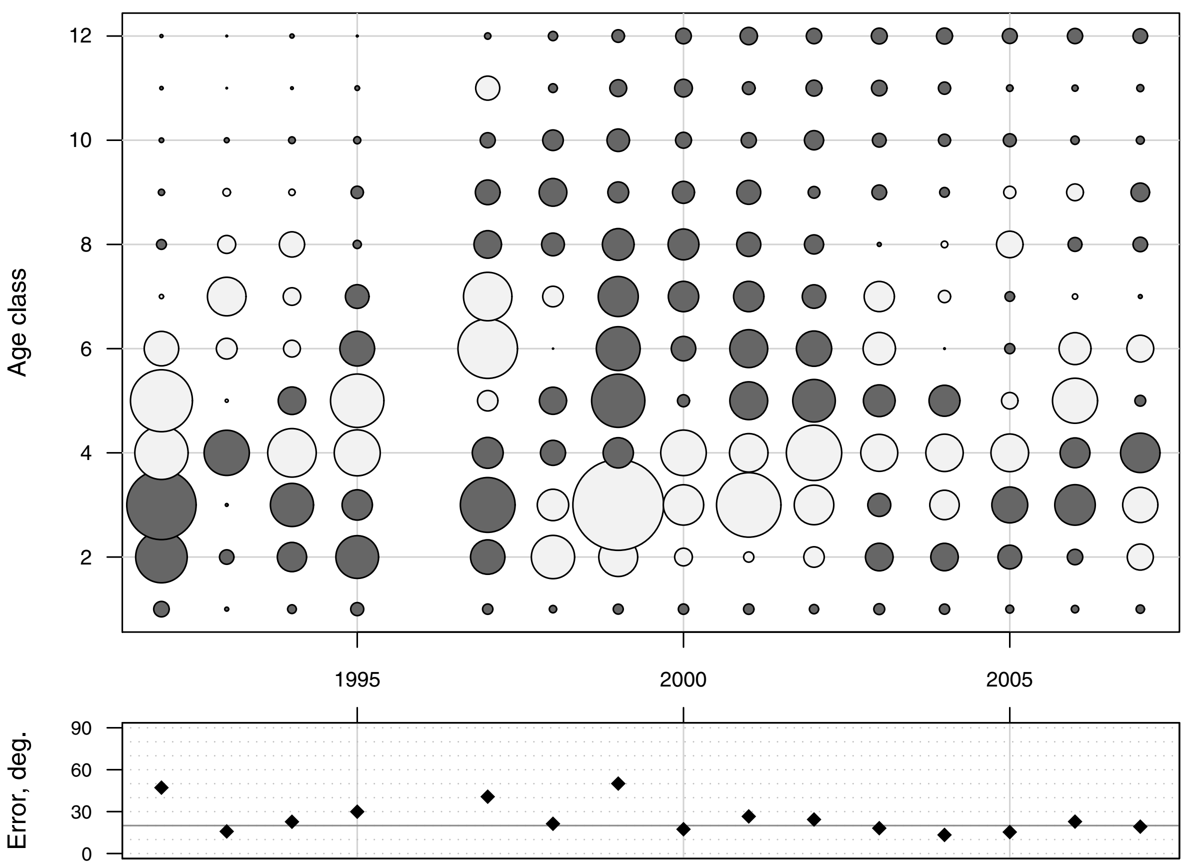


Figure 3.16. Top panel is a bubble plot of age composition residuals from the headboat fishery; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

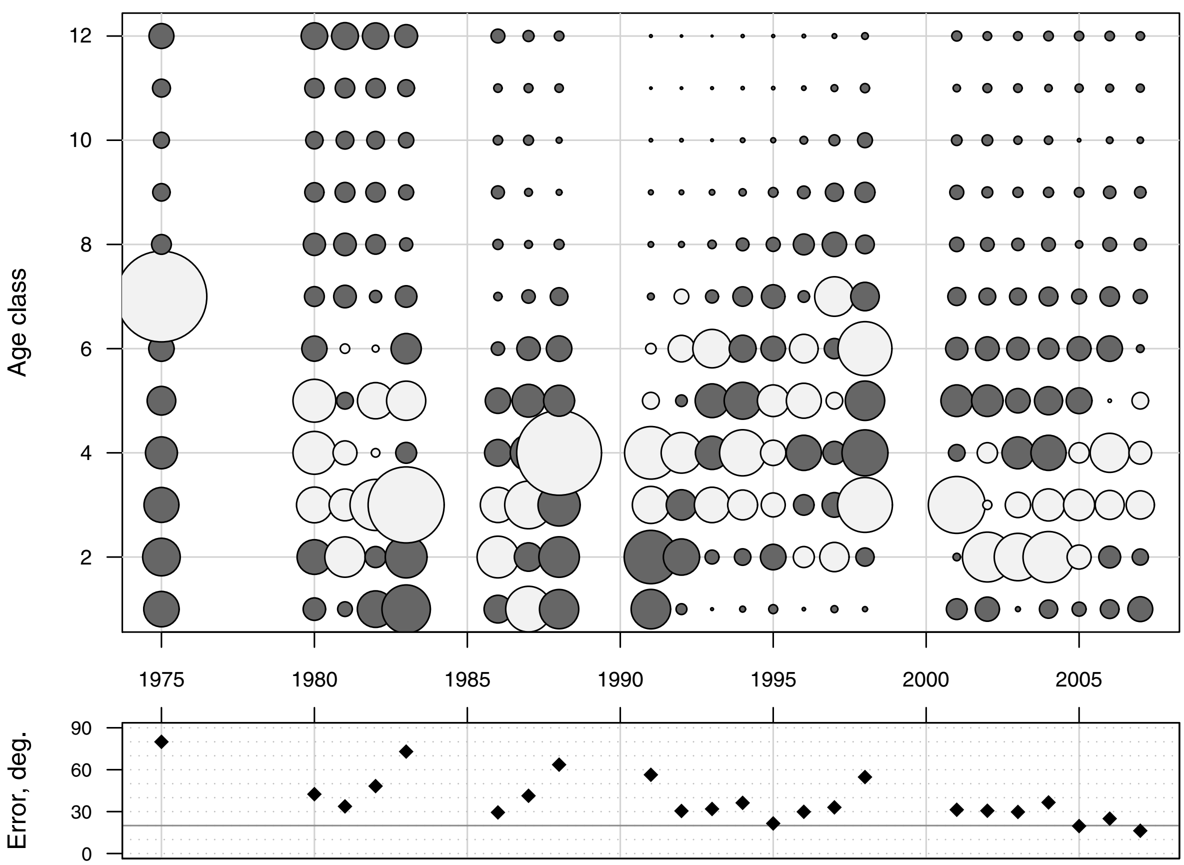


Figure 3.17. Top panel is a bubble plot of age composition residuals from the recreational fishery (MRFSS); Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

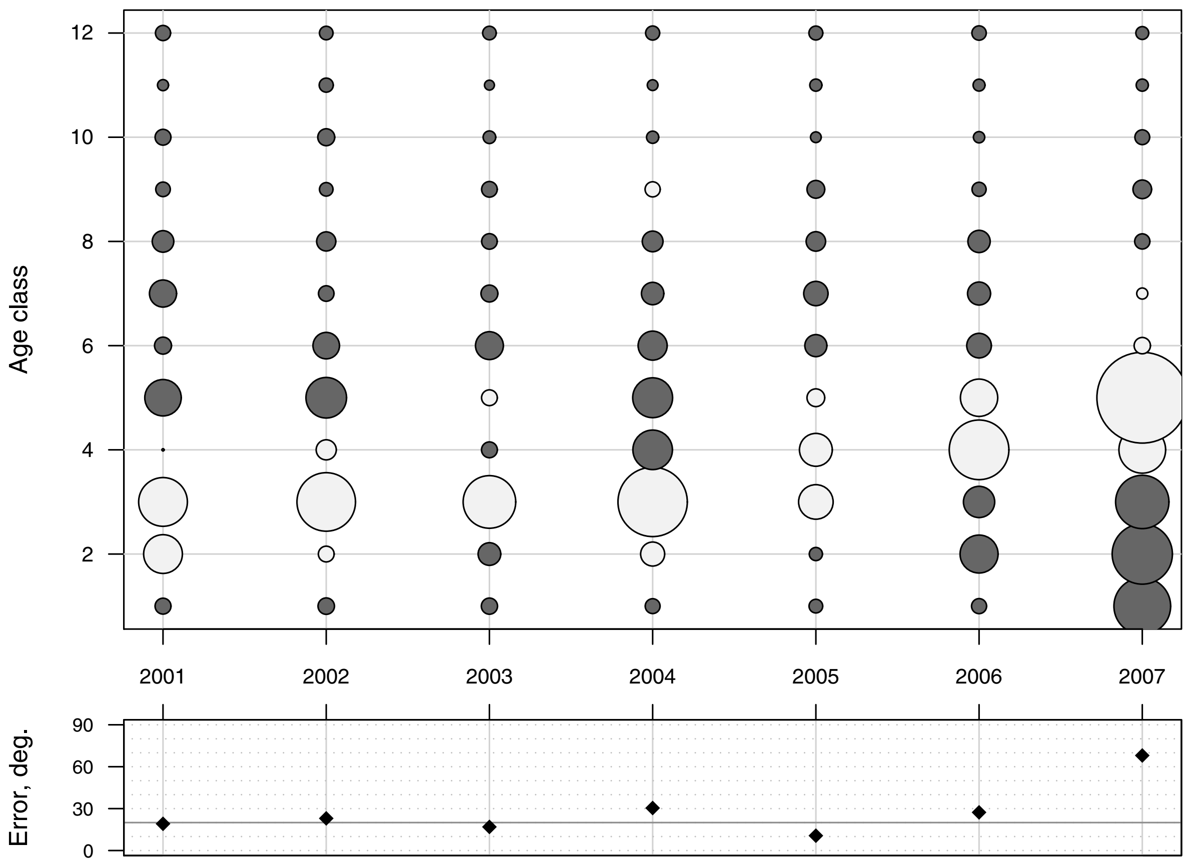


Figure 3.18. Observed (open circles) and estimated (solid line, circles) commercial handline landings (1000 lb whole weight). Open and solid circles are indistinguishable.

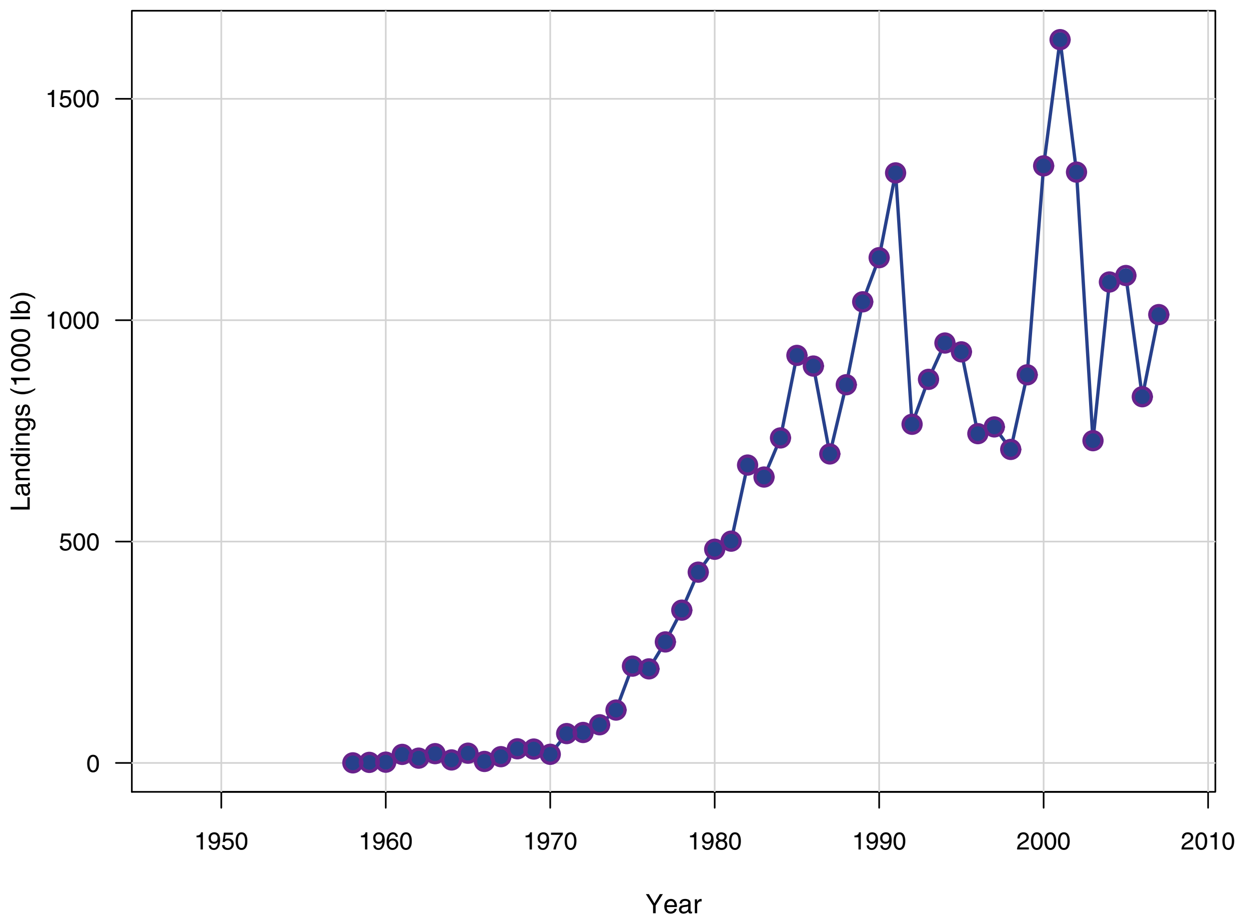


Figure 3.19. Observed (open circles) and estimated (solid line, circles) commercial historic trawl (1000 lb whole weight). Open and solid circles are indistinguishable.

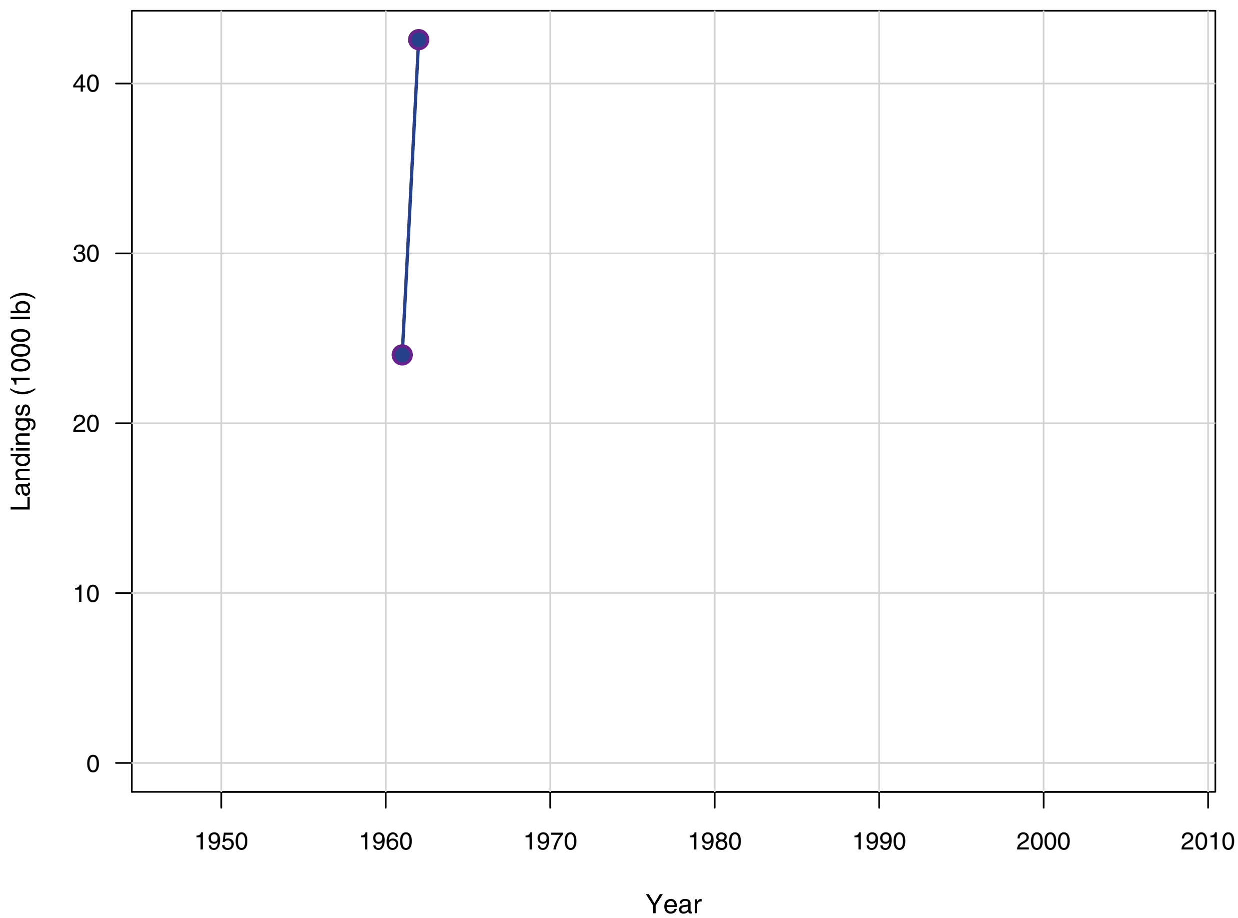


Figure 3.20. Observed (open circles) and estimated (solid line, circles) commercial combined gears (1000 lb whole weight). Open and solid circles are indistinguishable.

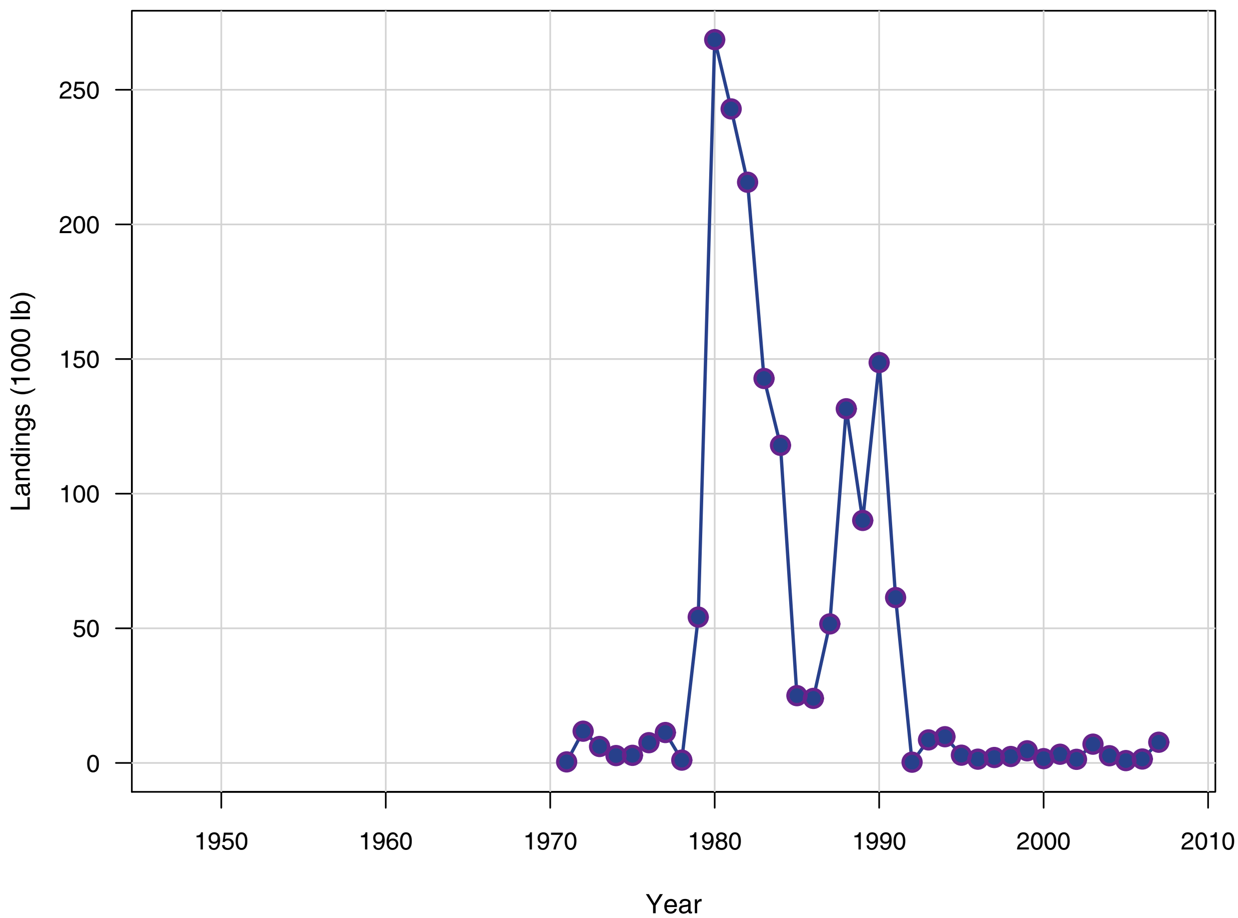


Figure 3.21. Observed (open circles) and estimated (solid line, circles) headboat landings (1000 fish). Open and solid circles are indistinguishable.

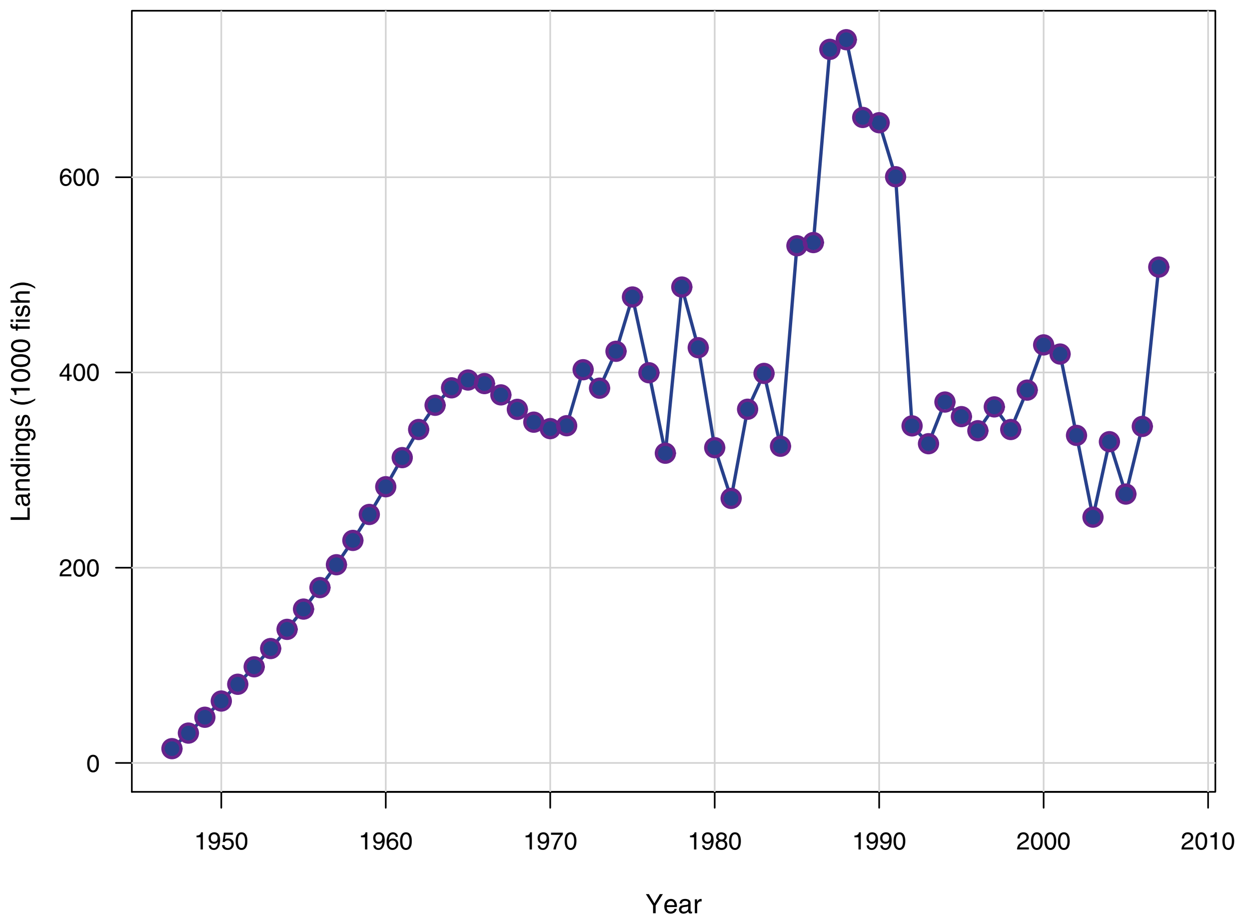


Figure 3.22. Observed (open circles) and estimated (solid line, circles) general recreational landings (1000 fish). Open and solid circles are indistinguishable.

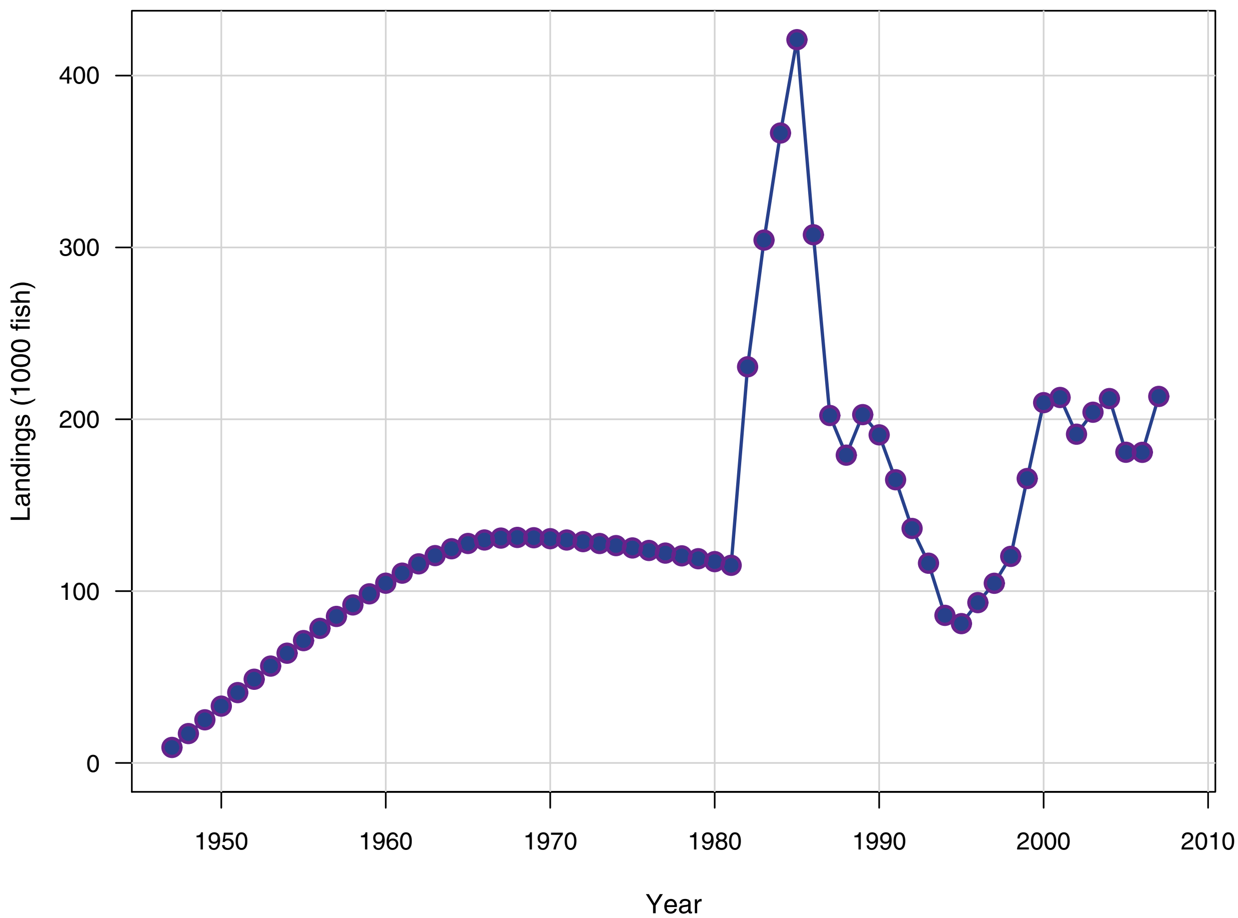


Figure 3.23. Observed (open circles) and estimated (solid line, circles) commercial handline discard mortalities. Open and solid circles are indistinguishable.

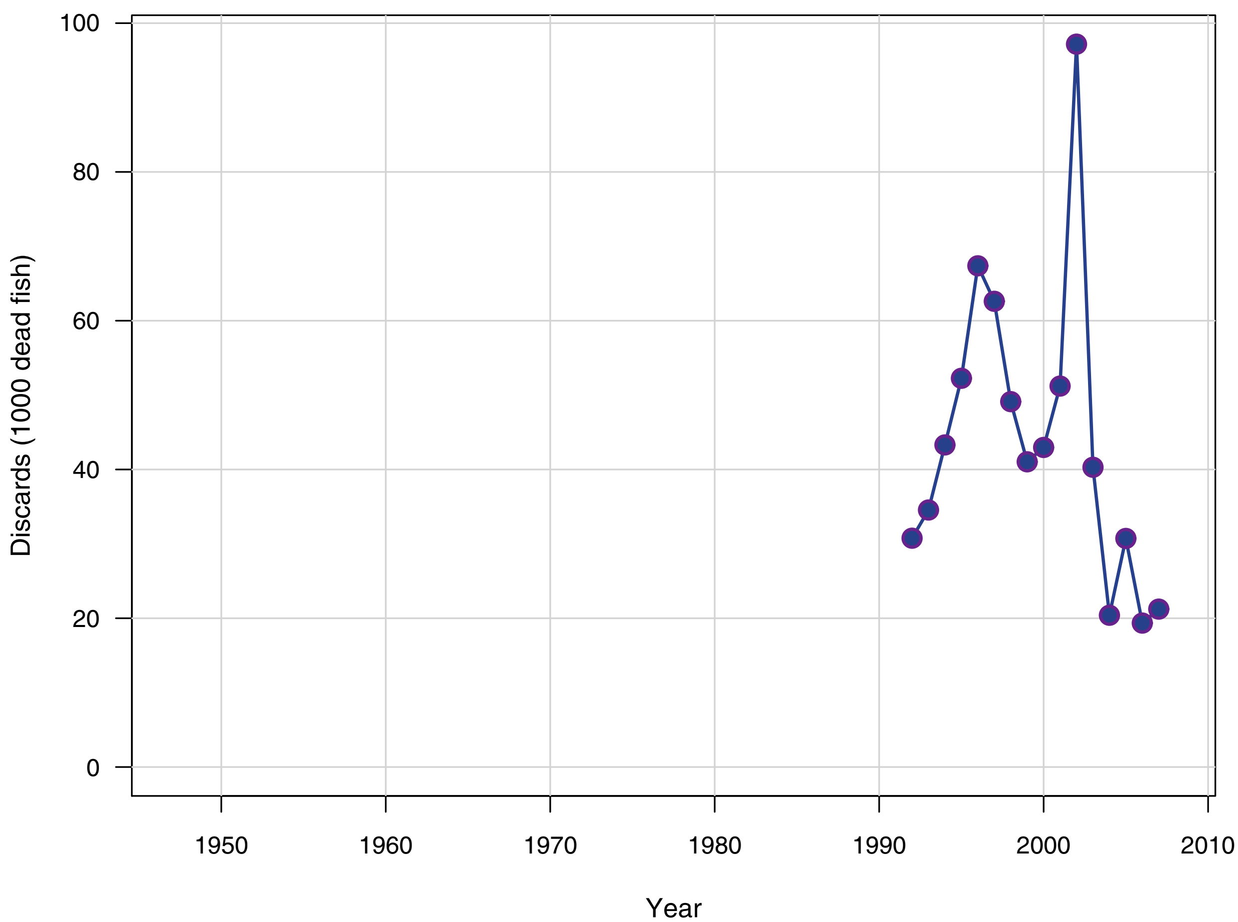


Figure 3.24. Observed (open circles) and estimated (solid line, circles) headboat discard mortalities. Open and solid circles are indistinguishable.

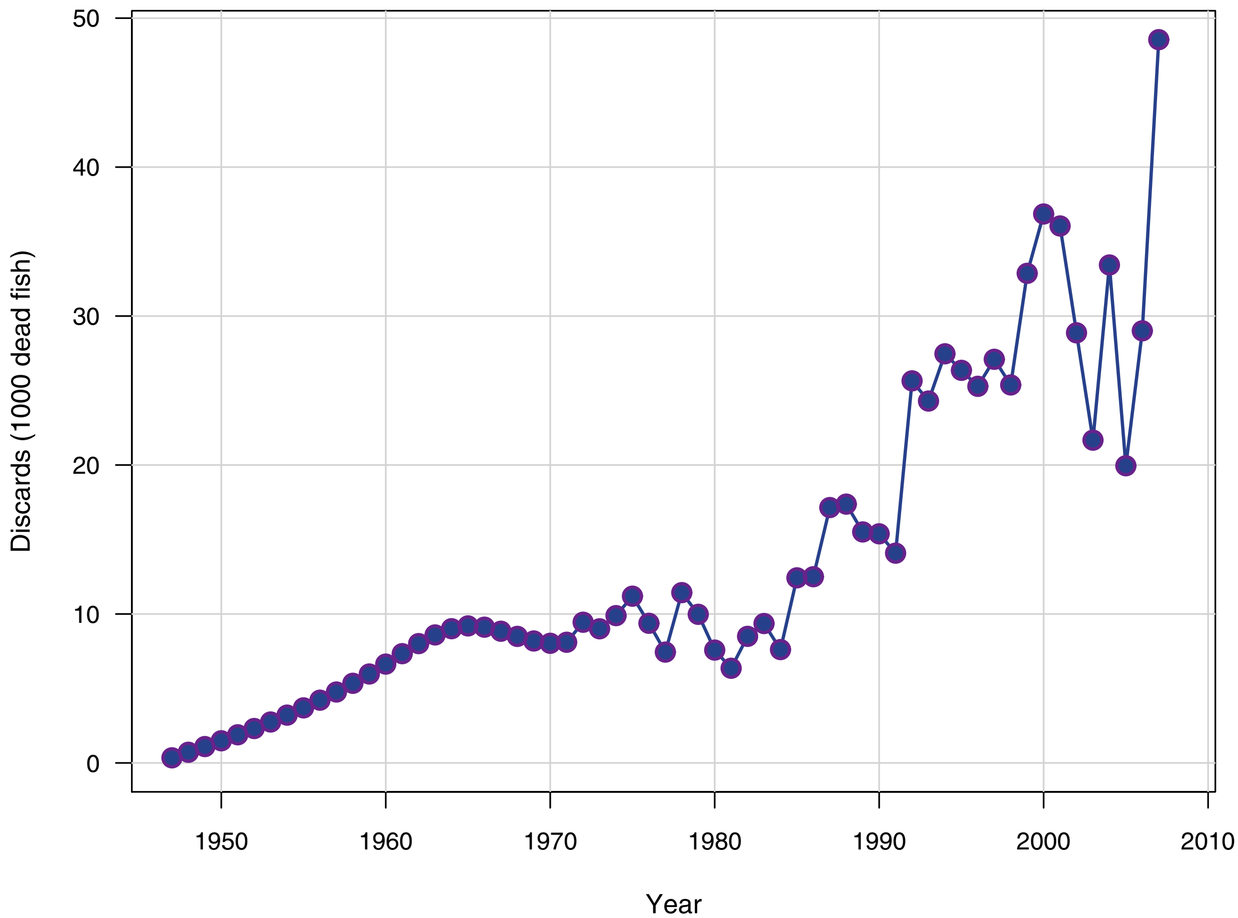


Figure 3.25. Observed (open circles) and estimated (solid line, circles) general recreational discard mortalities. Open and solid circles are indistinguishable.

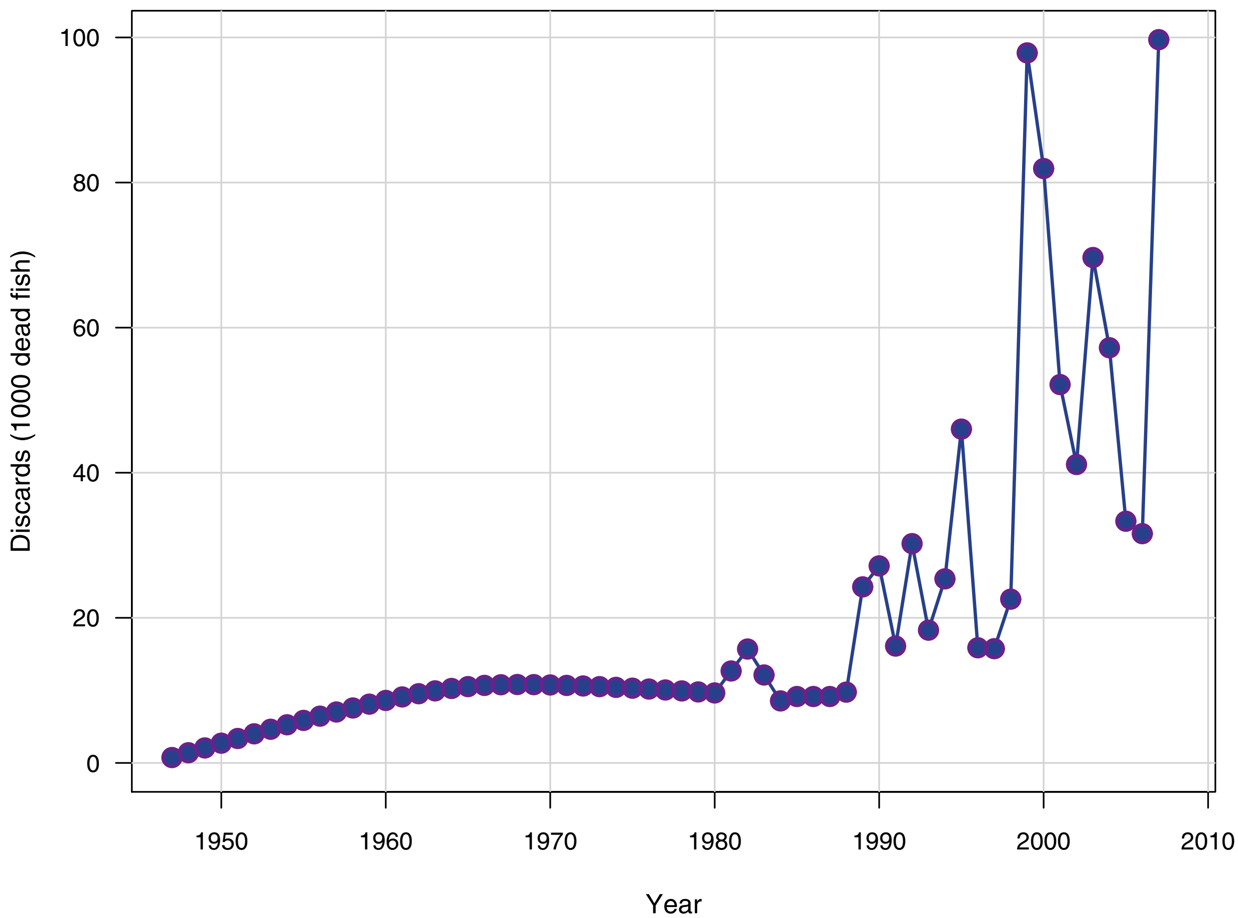


Figure 3.26. Observed (open circles) and estimated (solid line, circles) index of abundance from MARMAP Florida snapper trap.

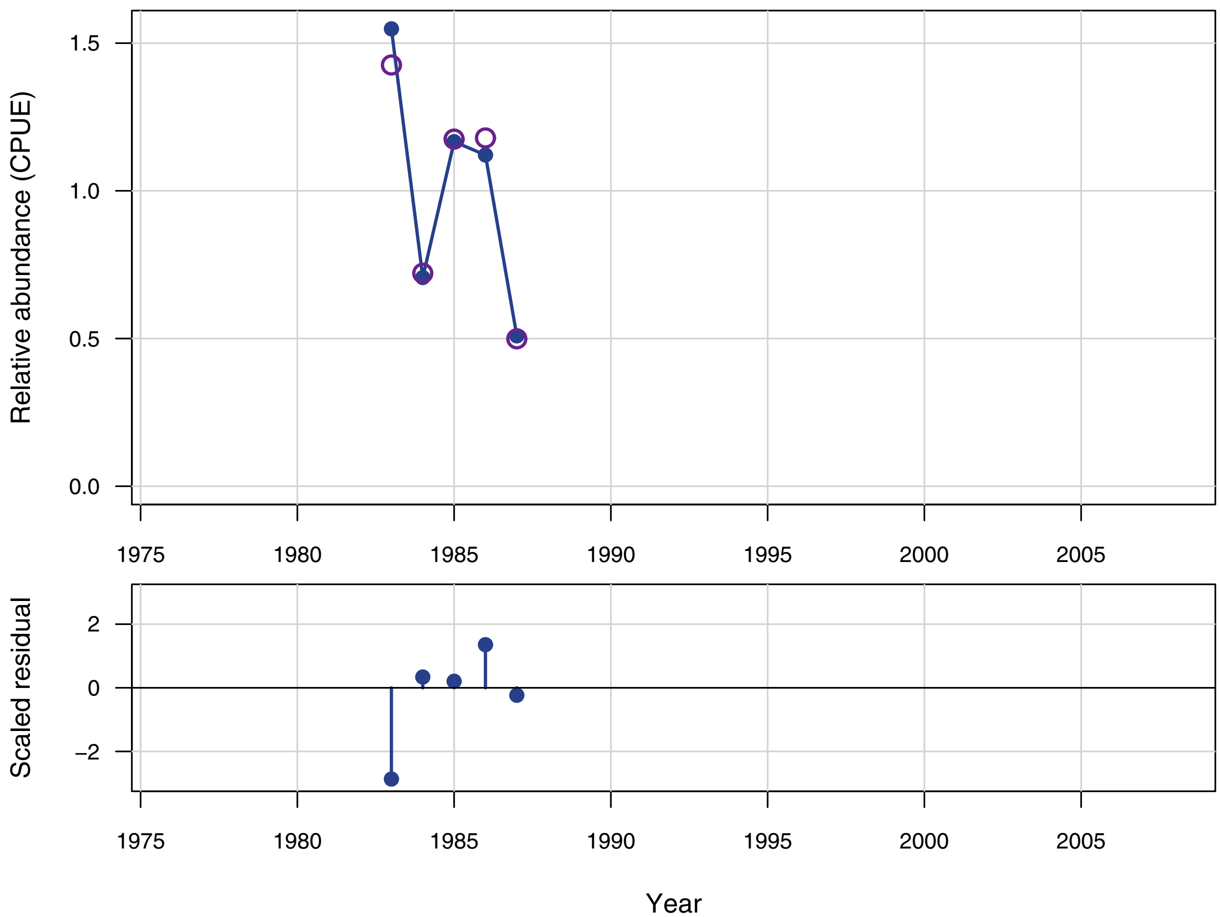


Figure 3.27. Observed (open circles) and estimated (solid line, circles) index of abundance from MARMAP chevron trap.

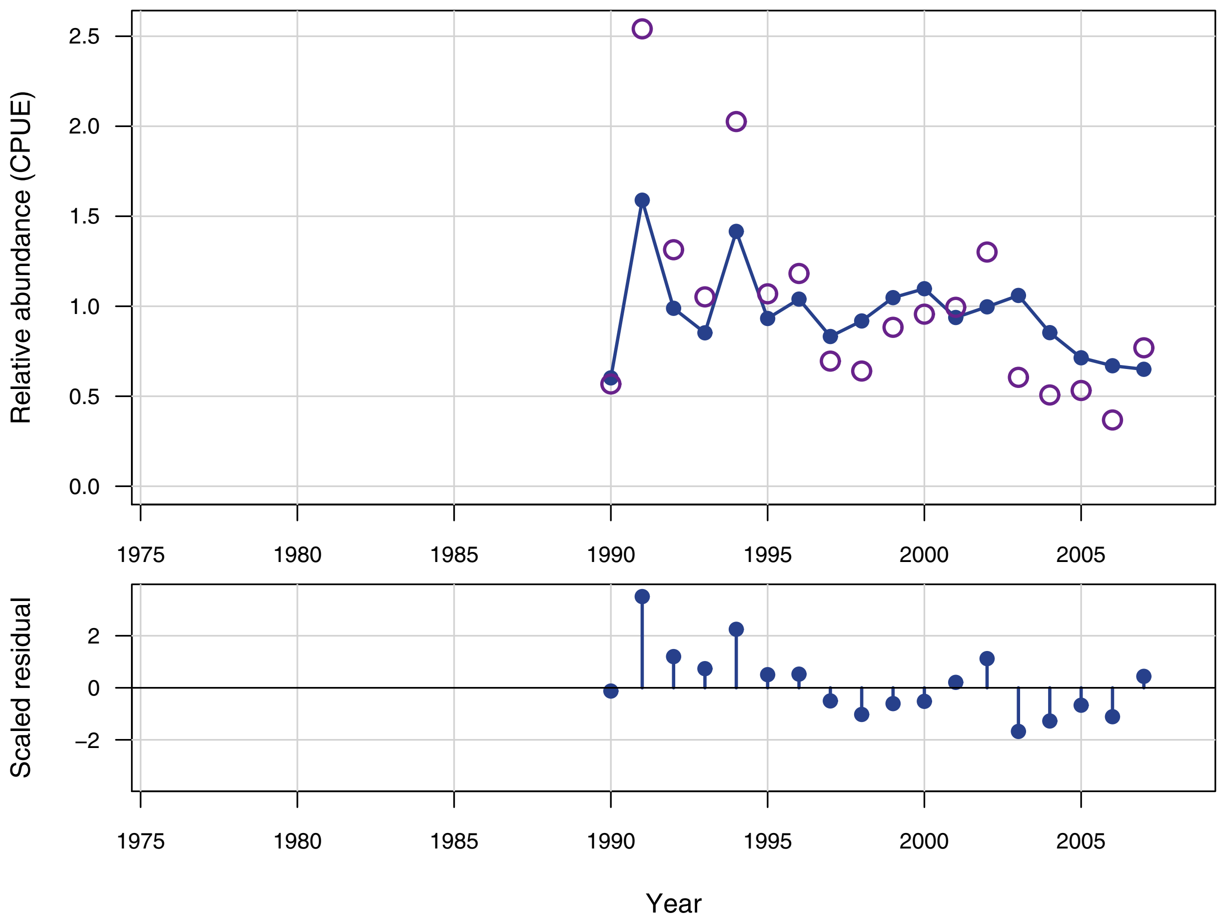


Figure 3.28. Observed (open circles) and estimated (solid line, circles) index of abundance from commercial handline.

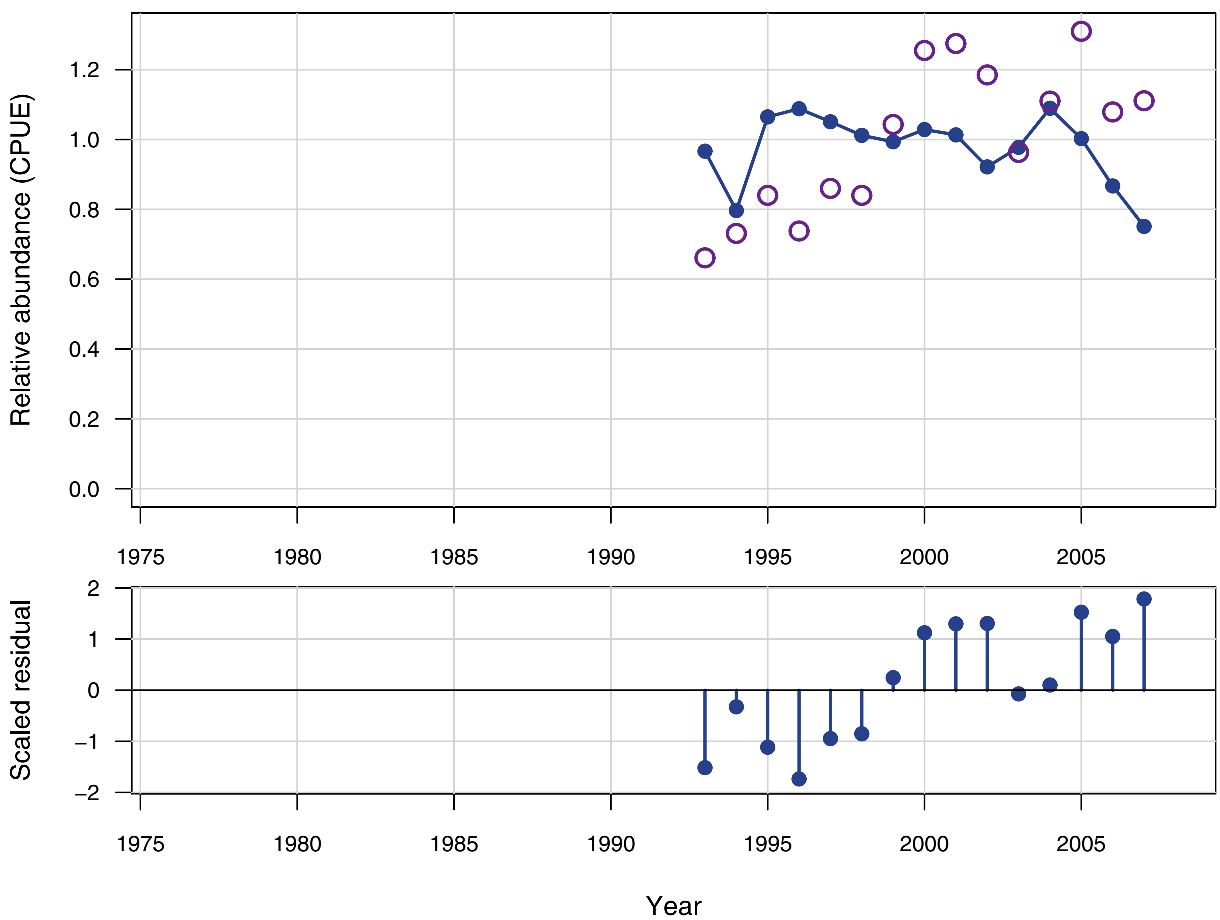


Figure 3.29. Observed (open circles) and estimated (solid line, circles) index of abundance from headboat.

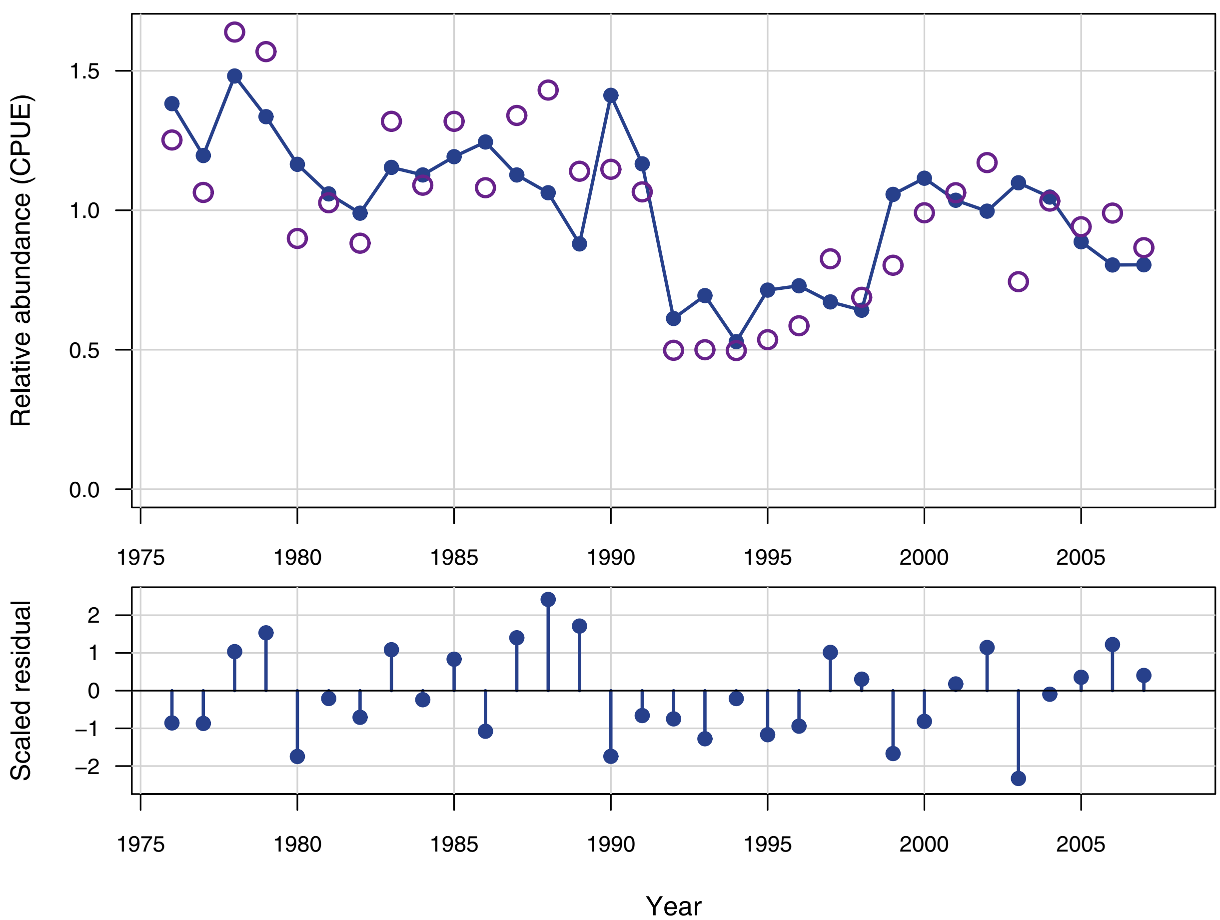


Figure 3.30. Observed (open circles) and estimated (solid line, circles) abundance from general recreational (MRFSS).

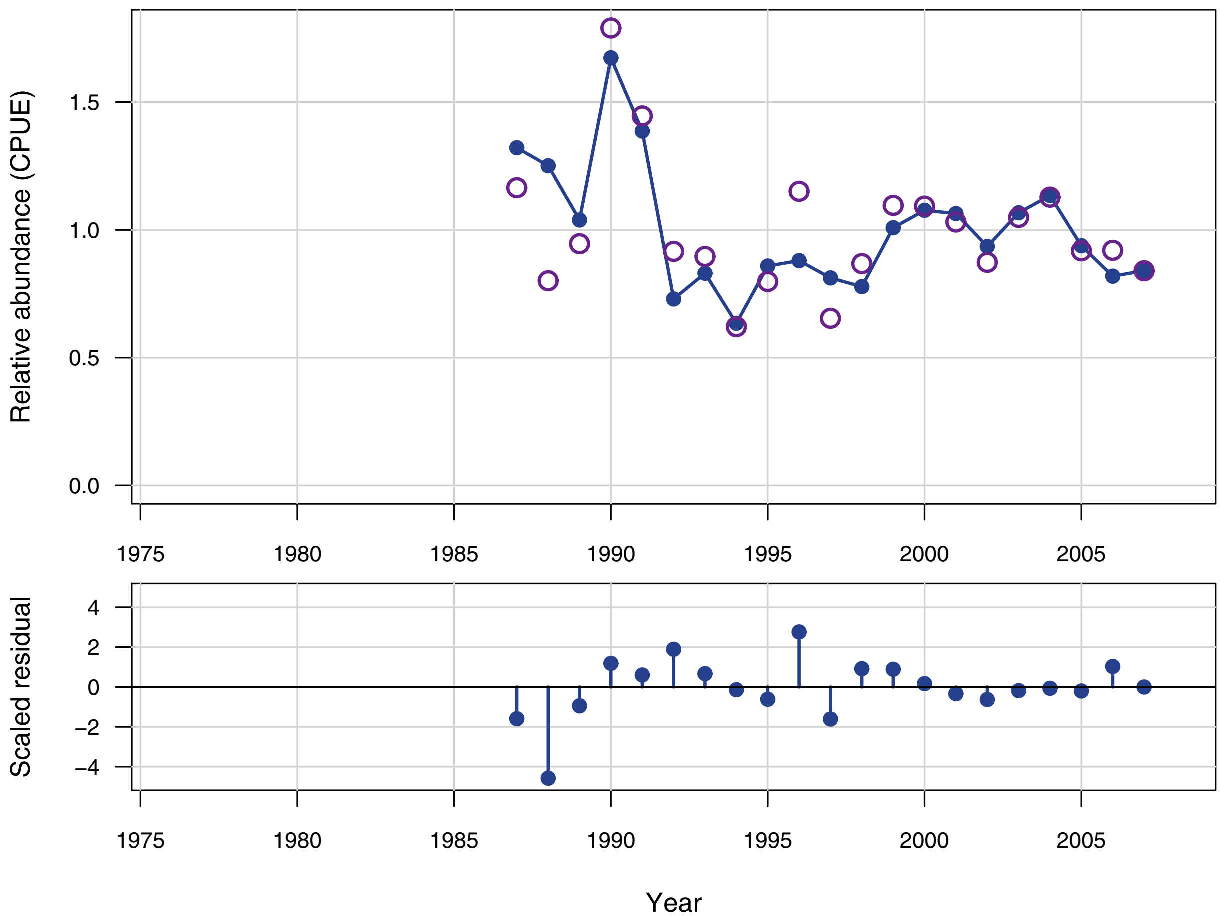


Figure 3.31. Top panel: Estimated recruitment of age-1 fish. Bottom panel: log recruitment residuals.

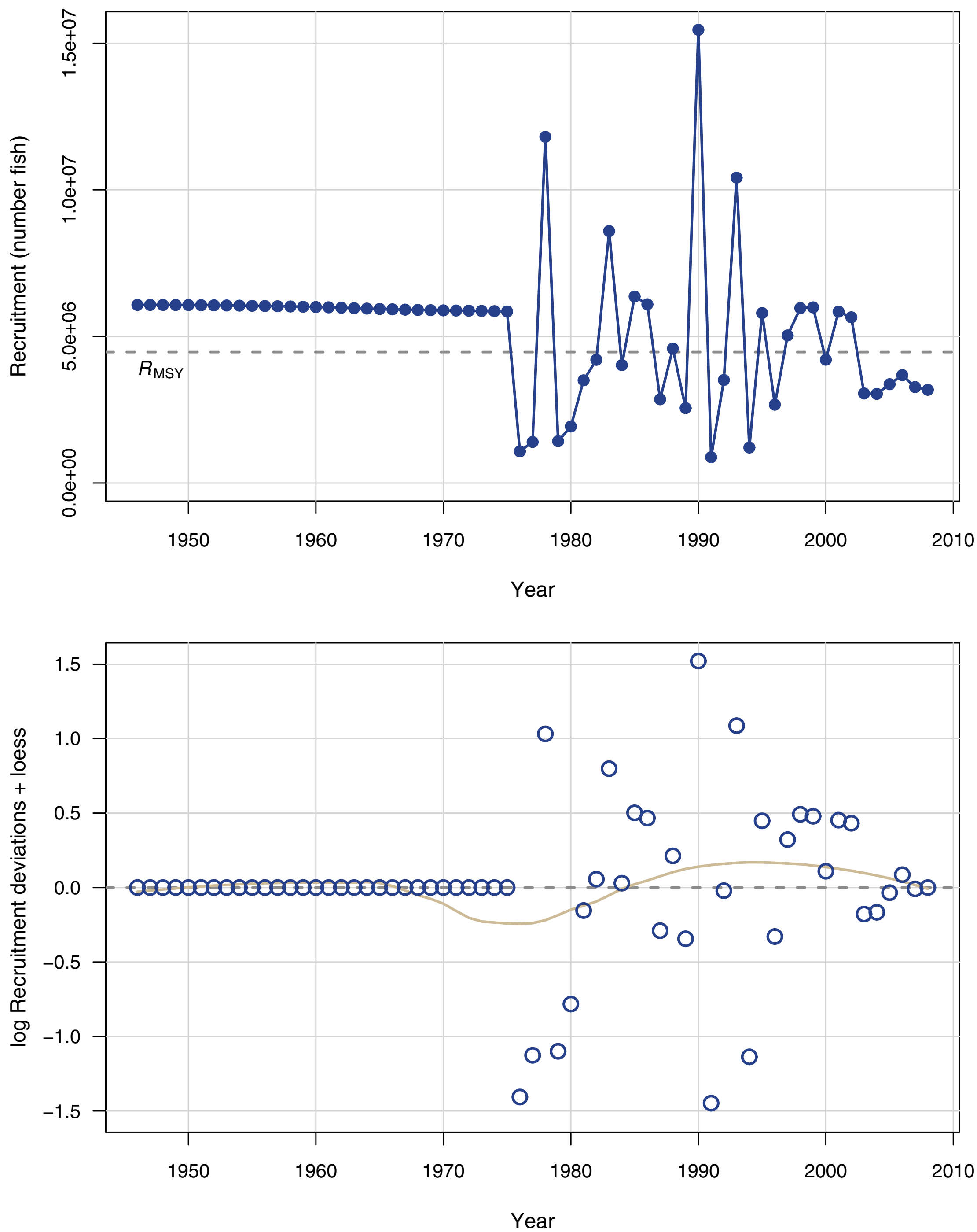


Figure 3.32. Top panel: Estimated total biomass (metric tons) at start of year. Bottom panel: Estimated spawning biomass (10^{12} eggs) at midpoint of year.

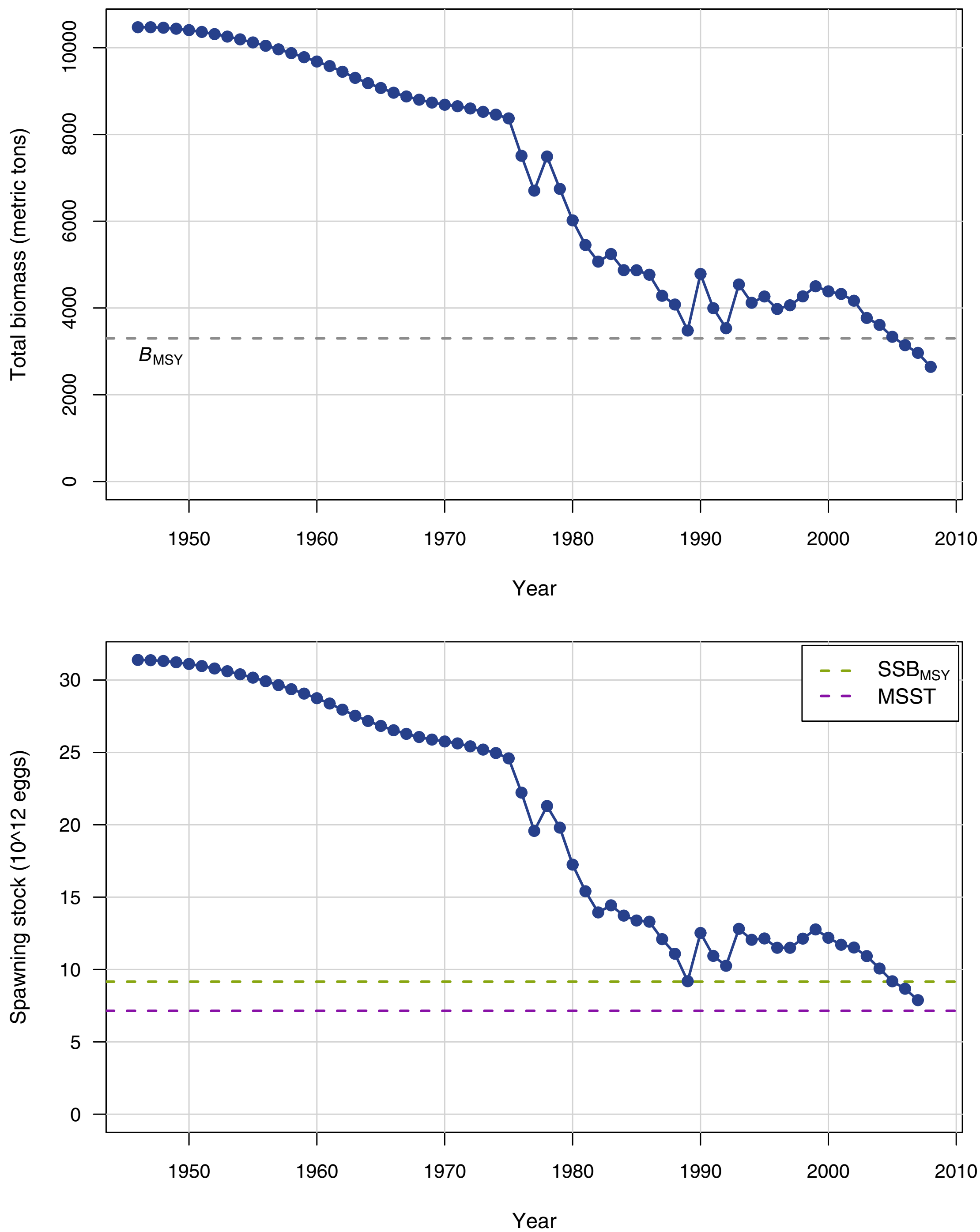


Figure 3.33. Estimated selectivities of commercial handline. Top panel: commercial period 1 (prior to 1992, no regulations). Bottom panel: period 2 (1992–2007, 12-inch limit).

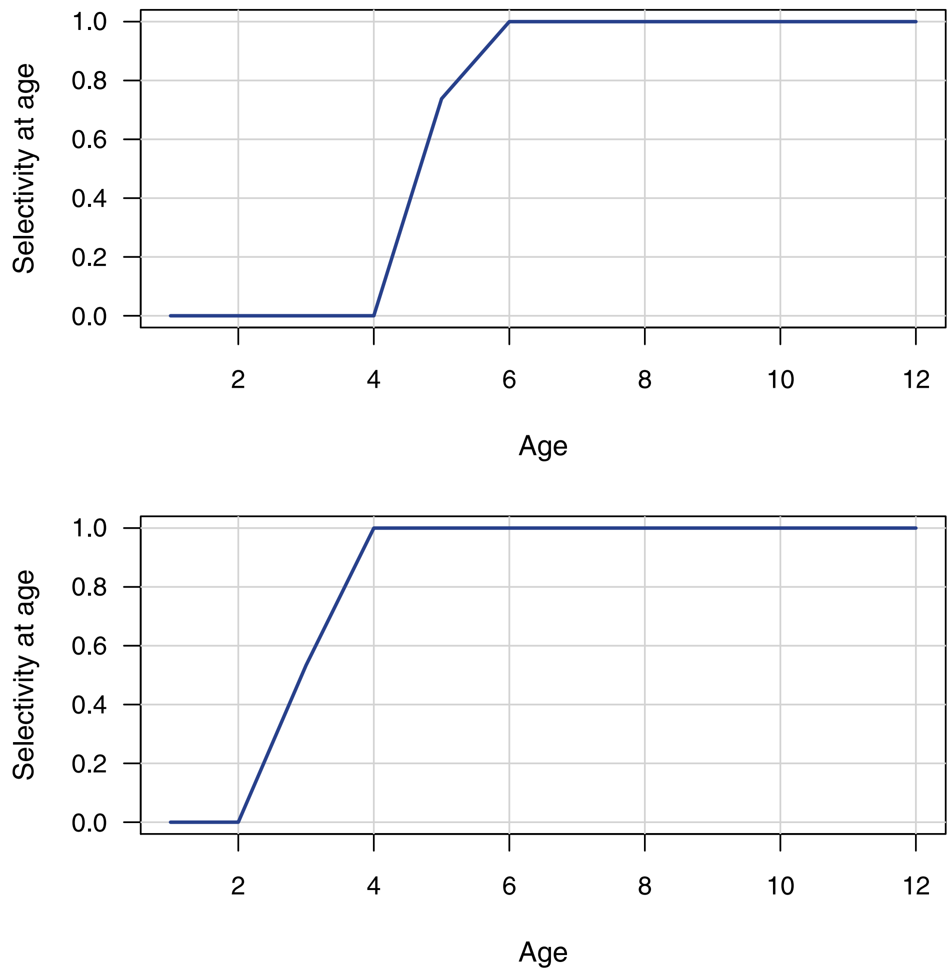


Figure 3.34. Selectivity of commercial historic trawl (1961, 1962).

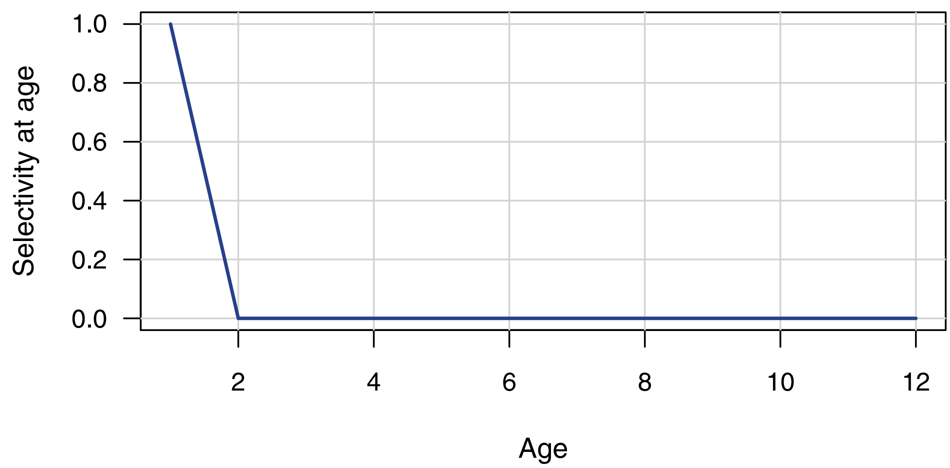


Figure 3.35. Selectivities of commercial combined gears. Top panel: commercial period 1 (prior to 1992, no regulations). Bottom panel: period 2 (1992–2007, 12-inch limit).

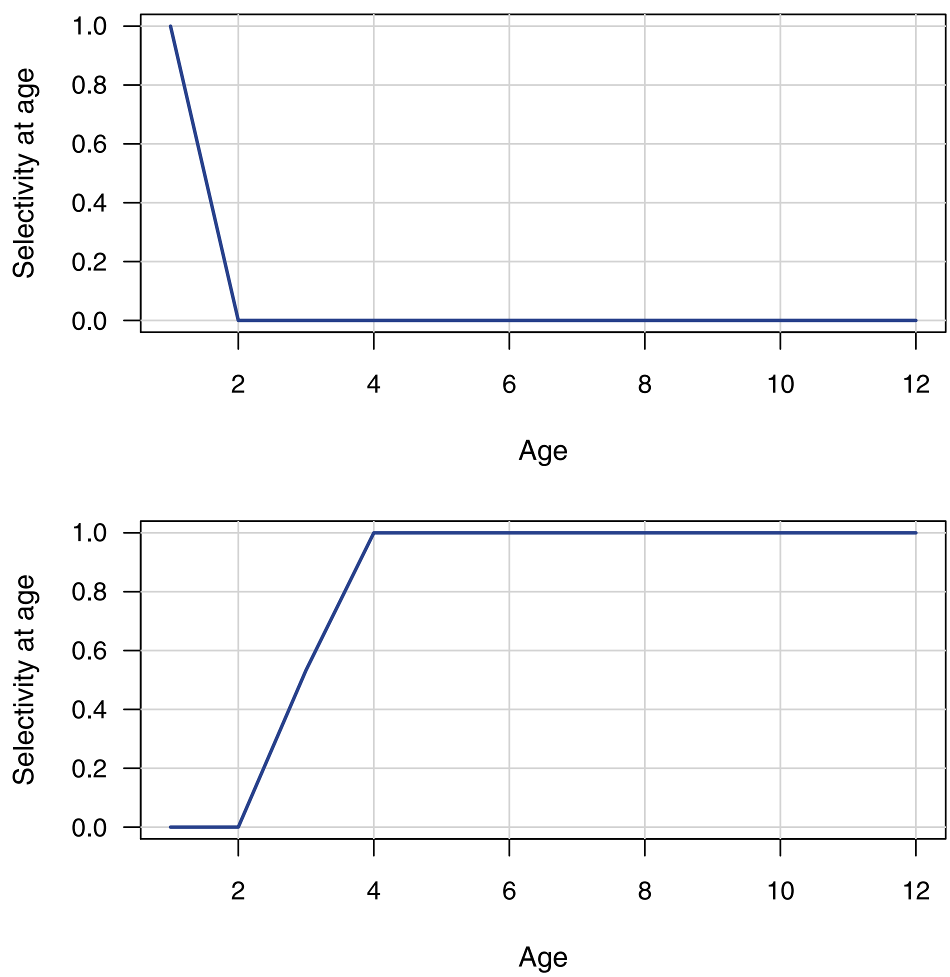


Figure 3.36. Estimated selectivities of the headboat fishery. Top panel: recreational period 1 (prior to 1992, no regulations). Second panel: period 2 (1992–1998, 10-inch limit). Third panel: period 3 (1999–2006, 11-inch limit). Bottom panel: period 4 (2007, 12-inch limit).

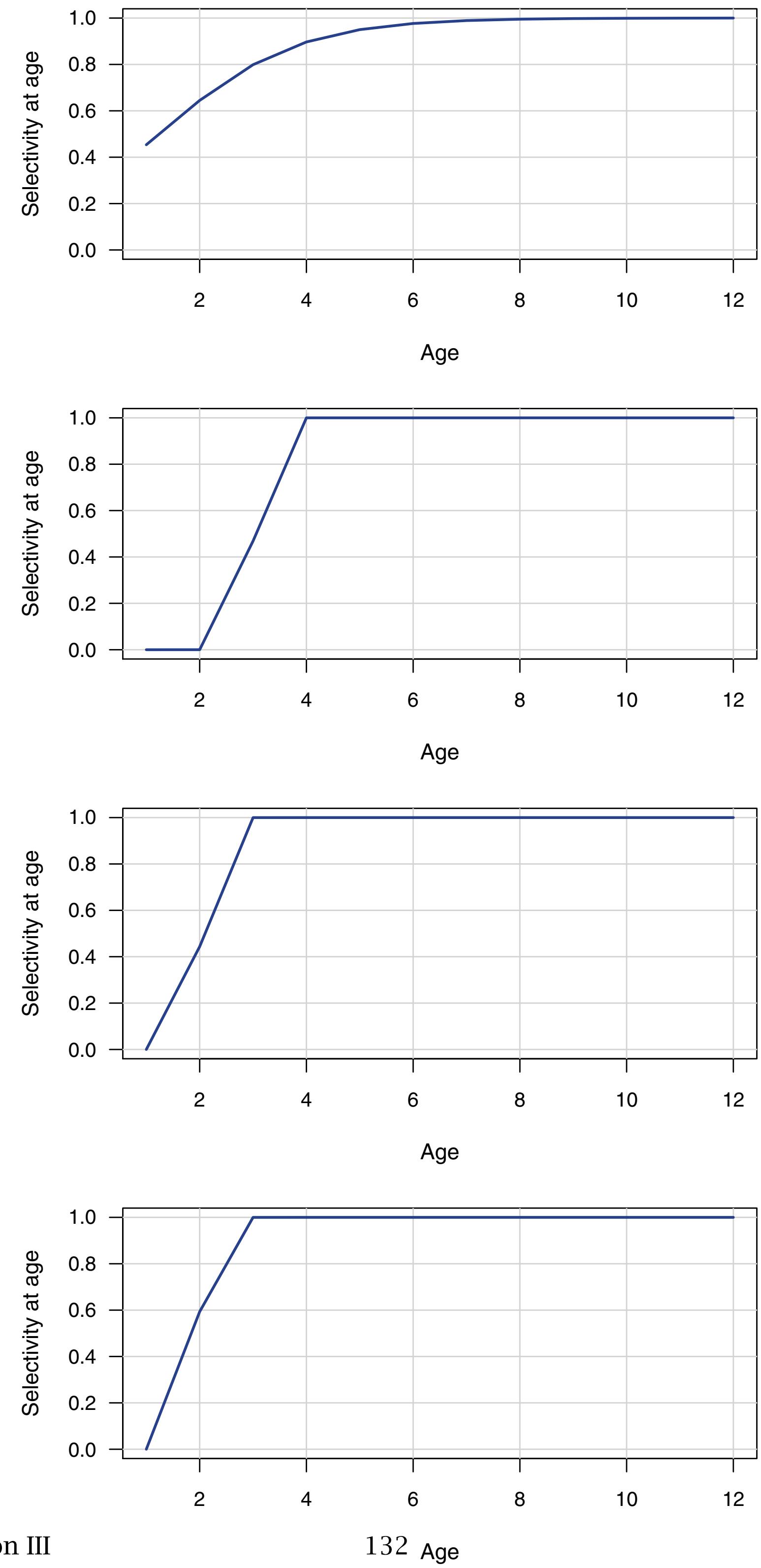


Figure 3.37. Estimated selectivities of the general recreational fishery. Top panel: recreational period 1 (prior to 1992, no regulations). Second panel: period 2 (1992–1998, 10-inch limit). Third panel: period 3 (1999–2006, 11-inch limit). Bottom panel: period 4 (2007, 12-inch limit).

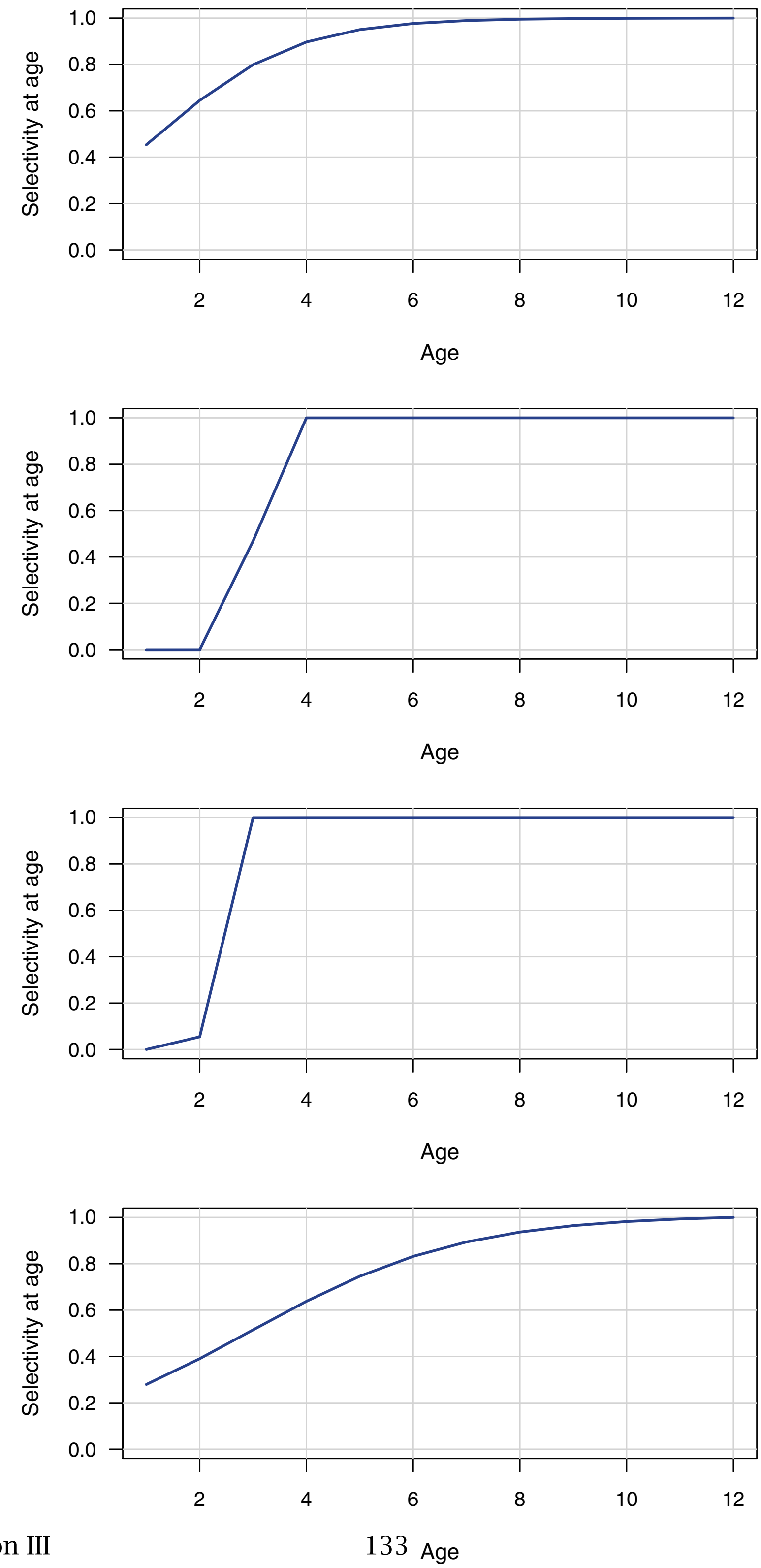


Figure 3.38. Estimated selectivity of discard mortalities from commercial handline during 1992–2007 (12-inch limit). Prior to this period, commercial discards were assumed to be zero.

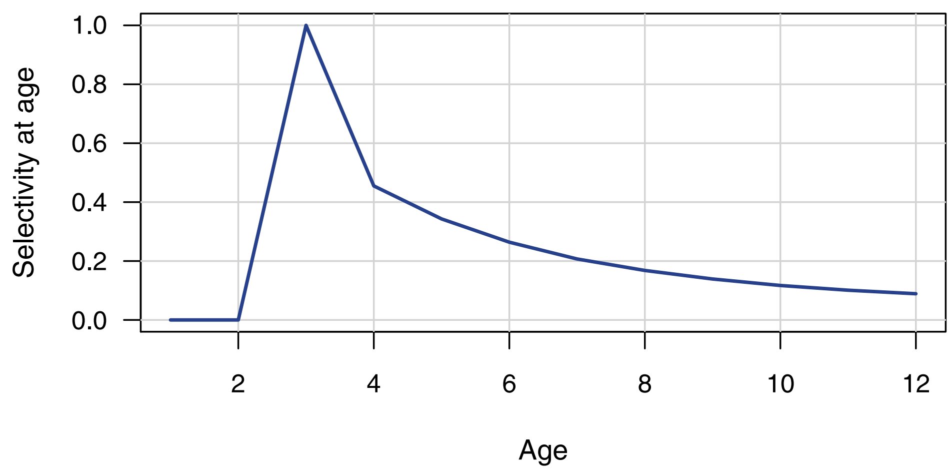


Figure 3.39. Estimated selectivities of discard mortalities from the headboat fishery. The selectivity in recreational period 1 (prior to 1992, no regulations) was assumed equal to that of period 2. Top panel: recreational period 2 (1992–1998, 10-inch limit). Middle panel: period 3 (1999–2006, 11-inch limit). Bottom panel: period 4 (2007, 12-inch limit).

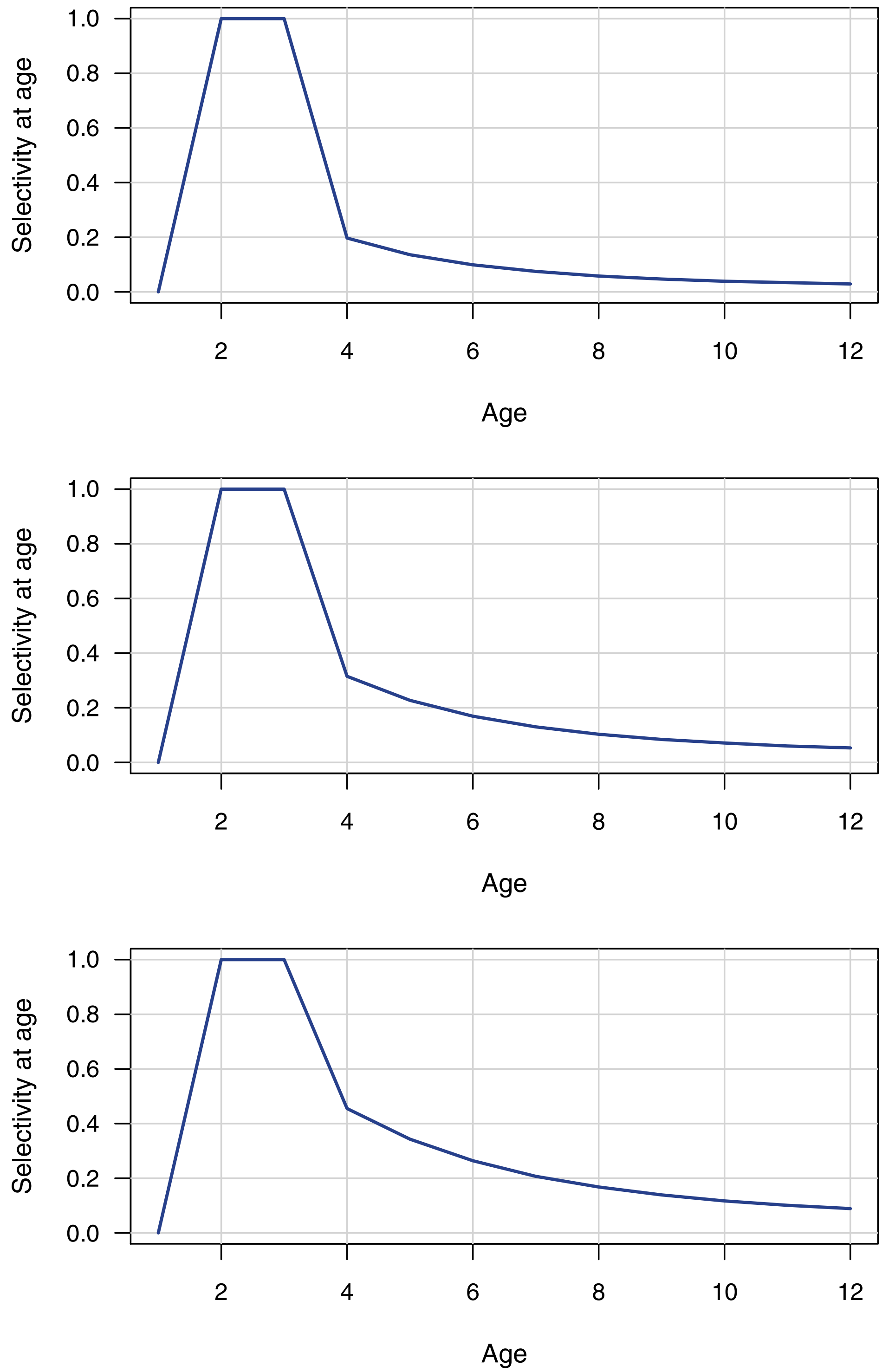


Figure 3.40. Estimated selectivities of discard mortalities from the headboat fishery. The selectivity in recreational period 1 (prior to 1992, no regulations) was assumed equal to that of period 2. Top panel: recreational period 2 (1992–1998, 10-inch limit). Middle panel: period 3 (1999–2006, 11-inch limit). Bottom panel: period 4 (2007, 12-inch limit).

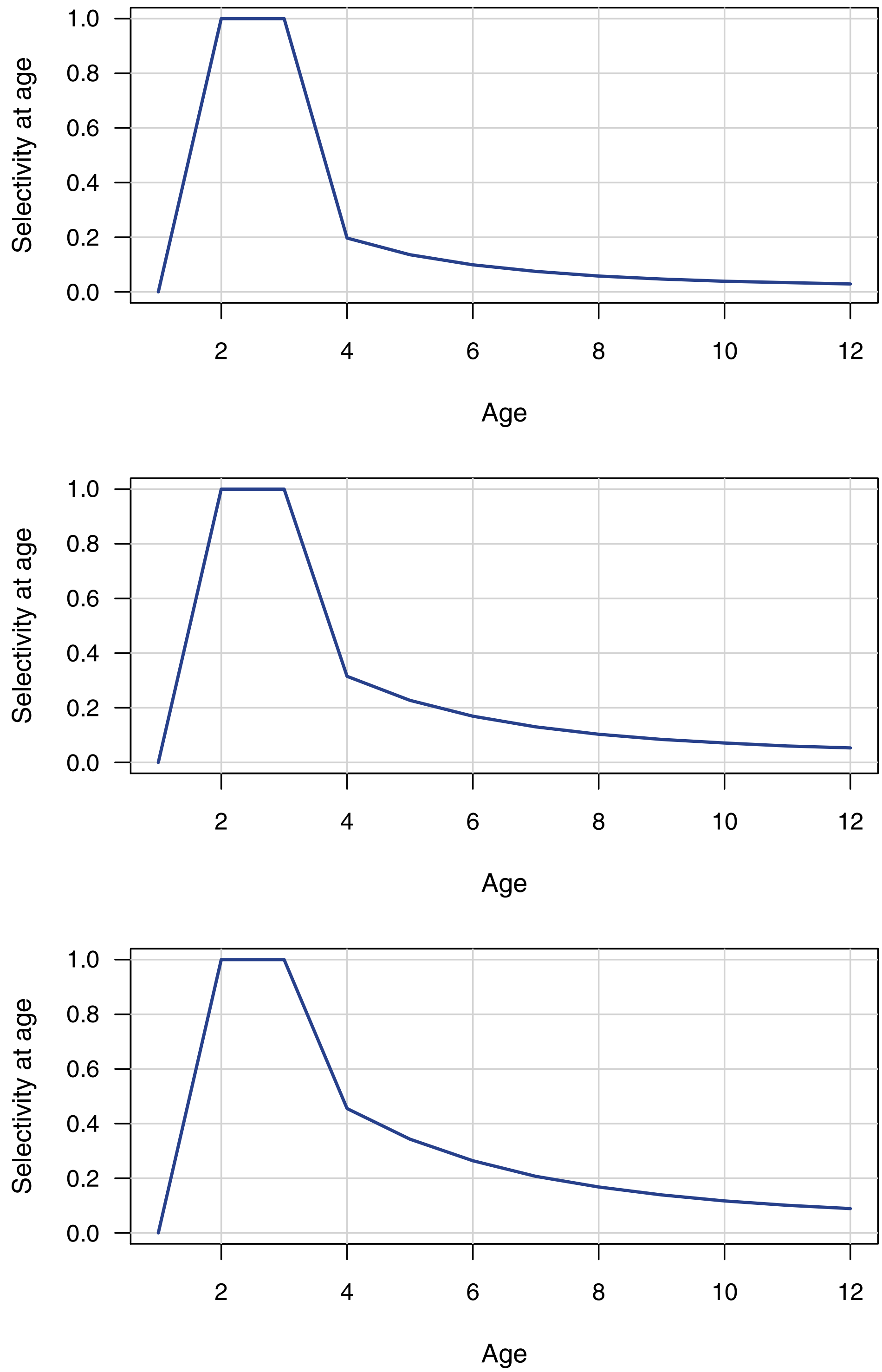


Figure 3.41. Average selectivities from the terminal assessment year (2007, 12-inch limit), weighted by geometric mean Fs from the last three assessment years, and used in computation of benchmarks and projections. Top panel: average selectivity applied to landings. Middle panel: average selectivity applied to discard mortalities. Bottom panel: total average selectivity.

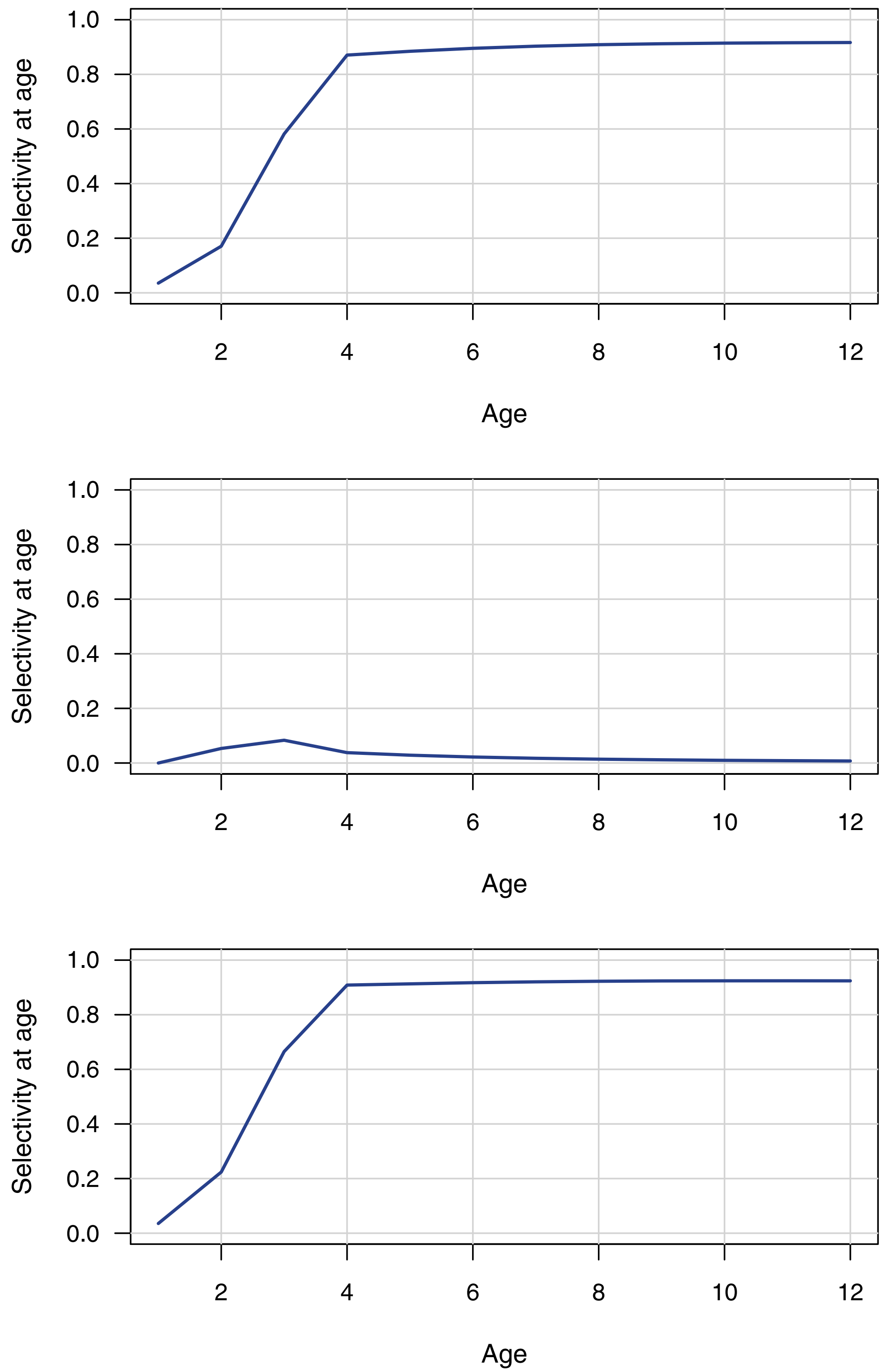


Figure 3.42. Estimated instantaneous fishing mortality rate (per year) by fishery. c.hal refers to commercial handline, c.htr to commercial historic trawl, c.cmb to commercial combined, hb to headboat, rec to general recreational, c.hal.D to commercial discard mortalities, hb.D to headboat discard mortalities, and rec.D to general recreational discard mortalities.

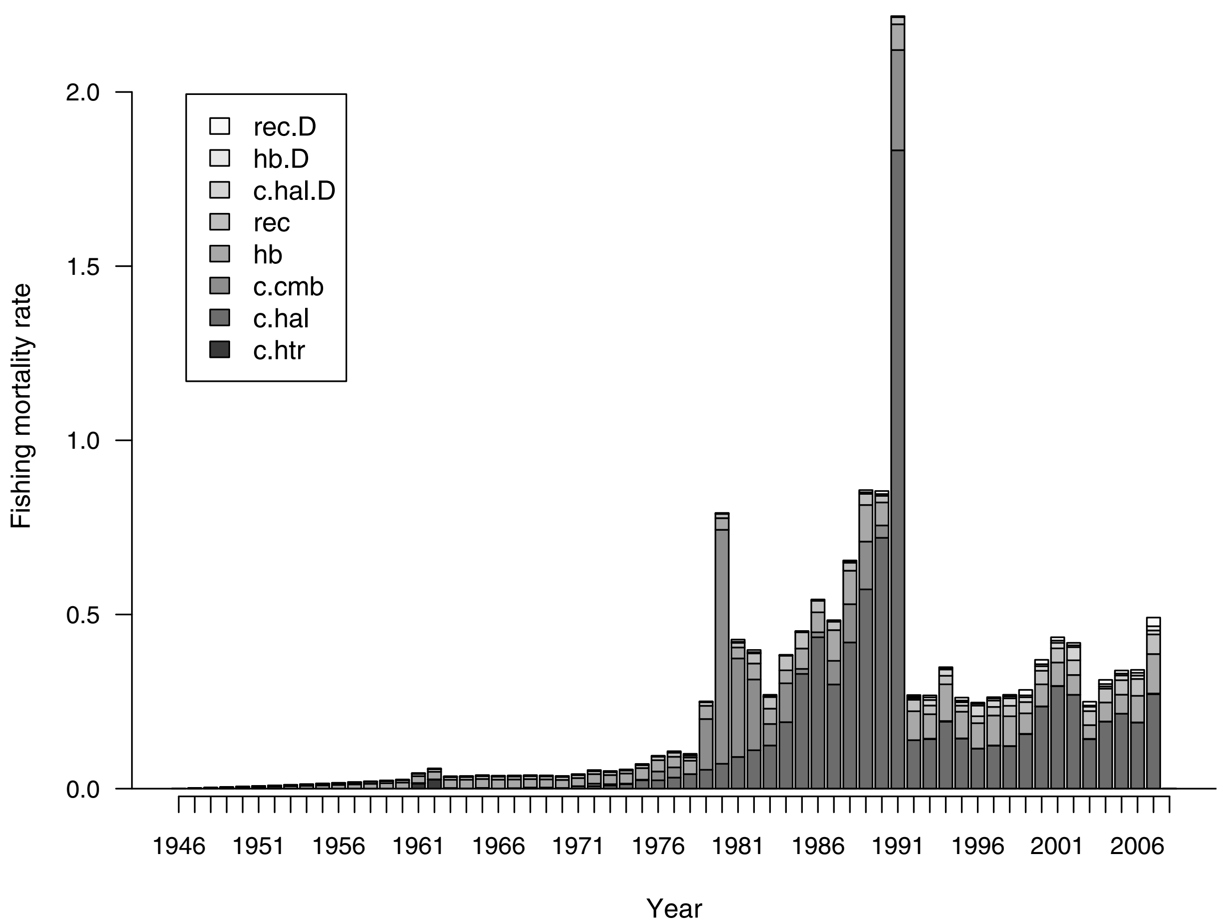


Figure 3.43. Estimated landings in numbers by fishery from the catch-at-age model. c.hal refers to commercial handline, c.htr to commercial historic trawl, c.cmb to commercial combined, hb to headboat, rec to general recreational.

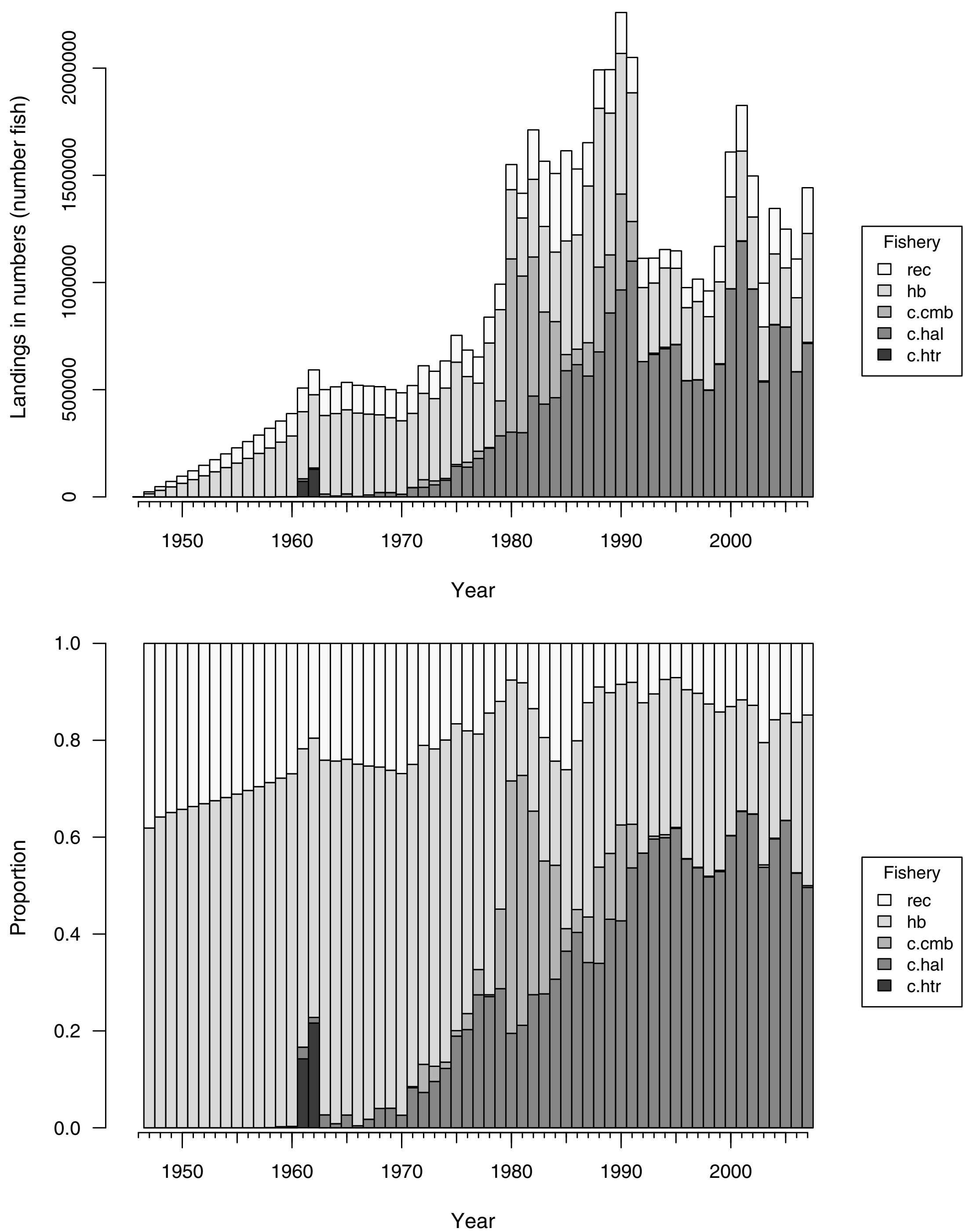


Figure 3.44. Estimated landings in whole weight by fishery from the catch-at-age model. c.hal refers to commercial handline, c.htr to commercial historic trawl, c.cmb to commercial combined, hb to headboat, rec to general recreational.

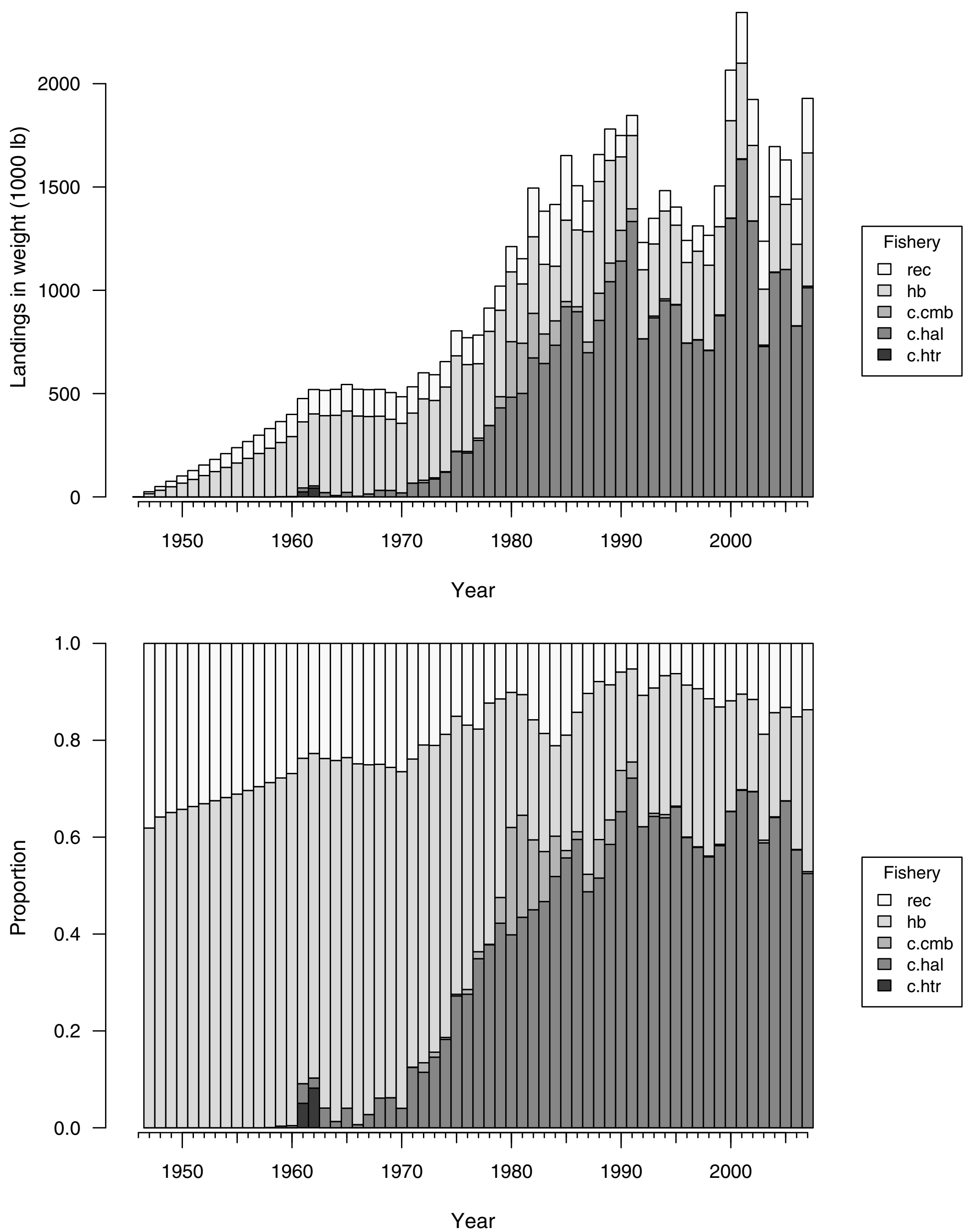


Figure 3.45. Estimated discard mortalities by fishery from the catch-at-age model. c.hal refers to commercial handline, hb to headboat, rec to general recreational.

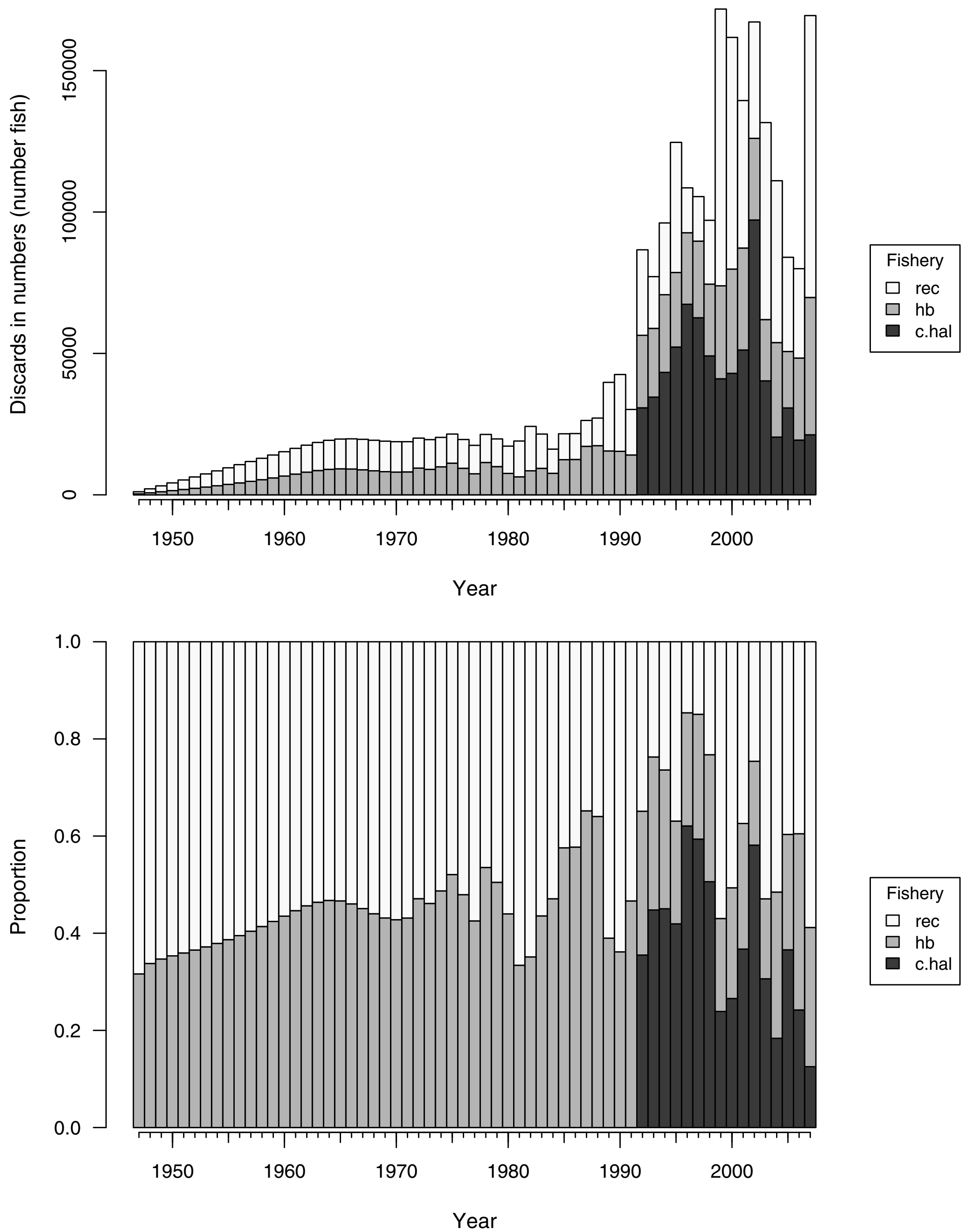
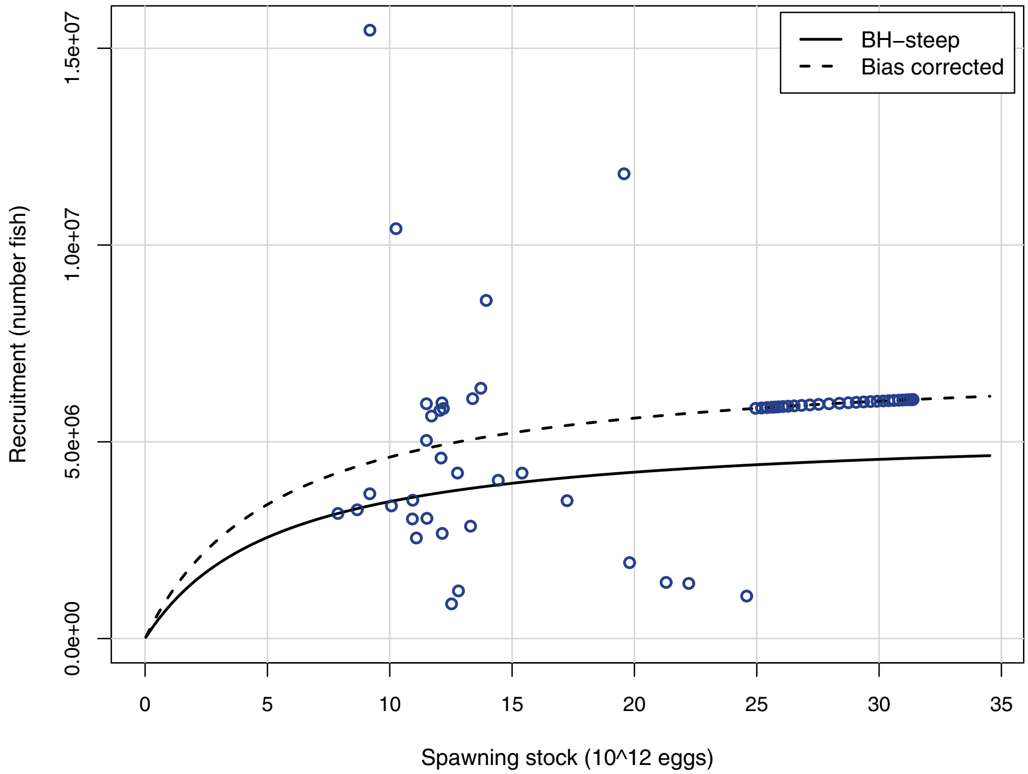


Figure 3.46. Top panel: Beverton–Holt spawner-recruit curves, with and without lognormal bias correction. Bottom panel: log of recruits (number fish) per spawner (10^{12} eggs) as a function of spawners.



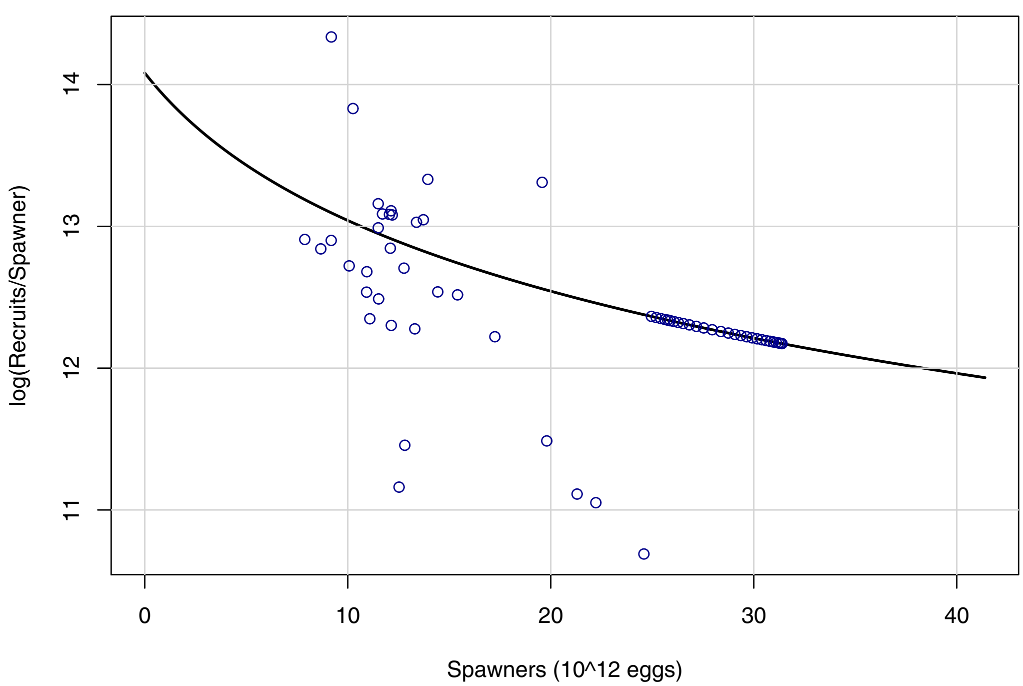


Figure 3.47. Probability densities of spawner-recruit parameters R0 (unfished recruitment), steepness, autocorrelation, and lognormal bias correction. Vertical lines represent point estimates from the assessment model.

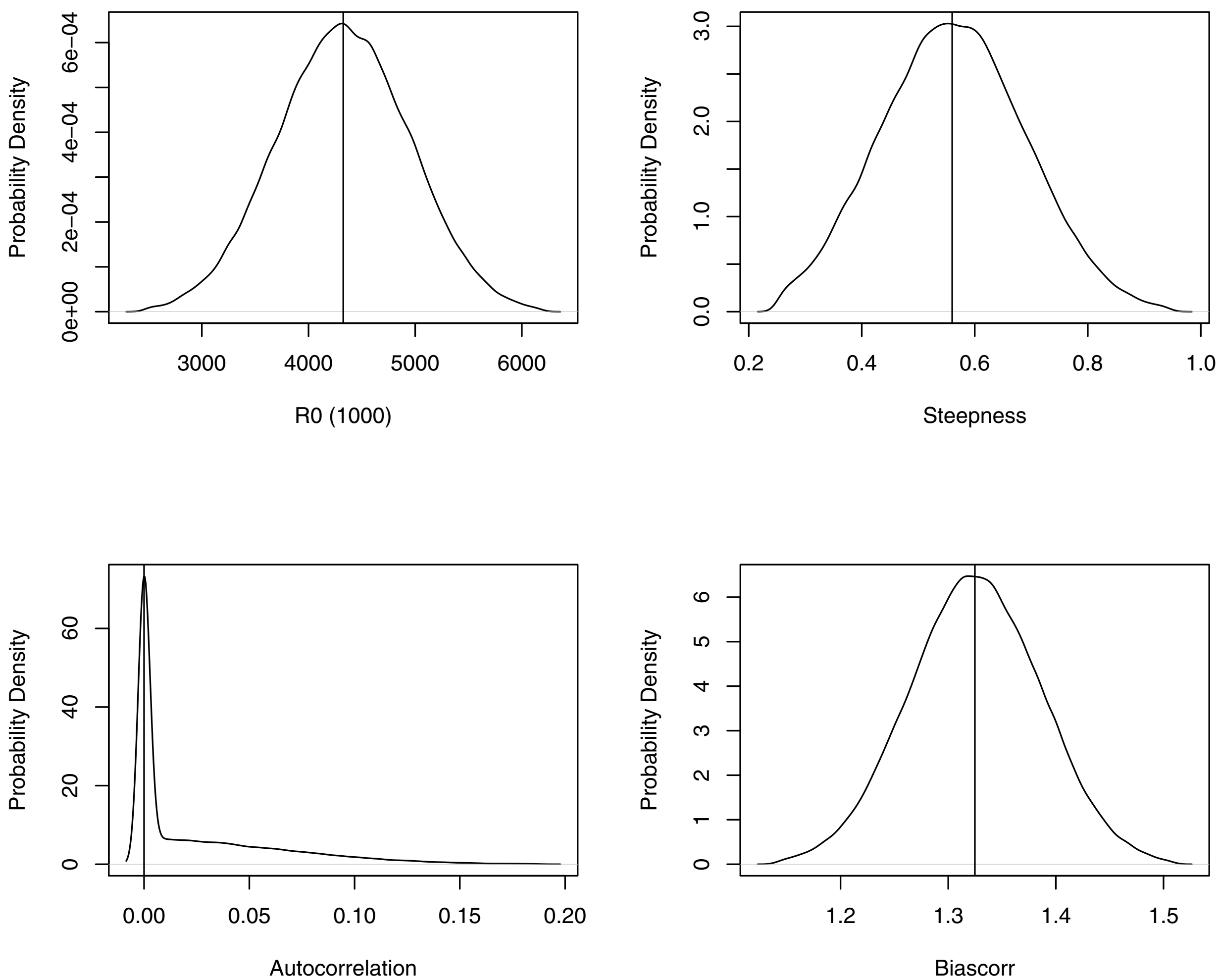


Figure 3.48. Estimated time series of static spawning potential ratio, the annual equilibrium spawners per recruit relative to that at the unfished level.

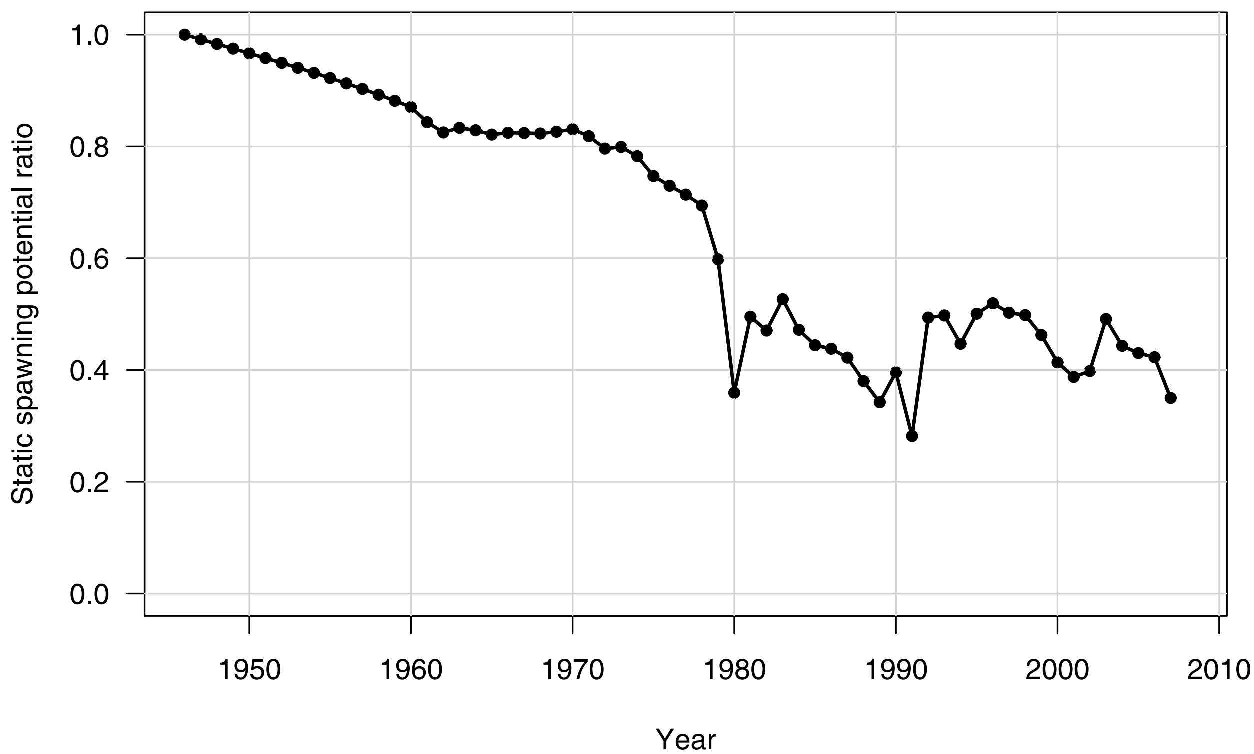


Figure 3.49. Top panel: yield per recruit. Bottom panel: spawning potential ratio (egg production per recruit relative to that at the unfished level), from which the y% levels provide $F_{y\%}$. Both curves are based on average selectivity from the end of the assessment period.

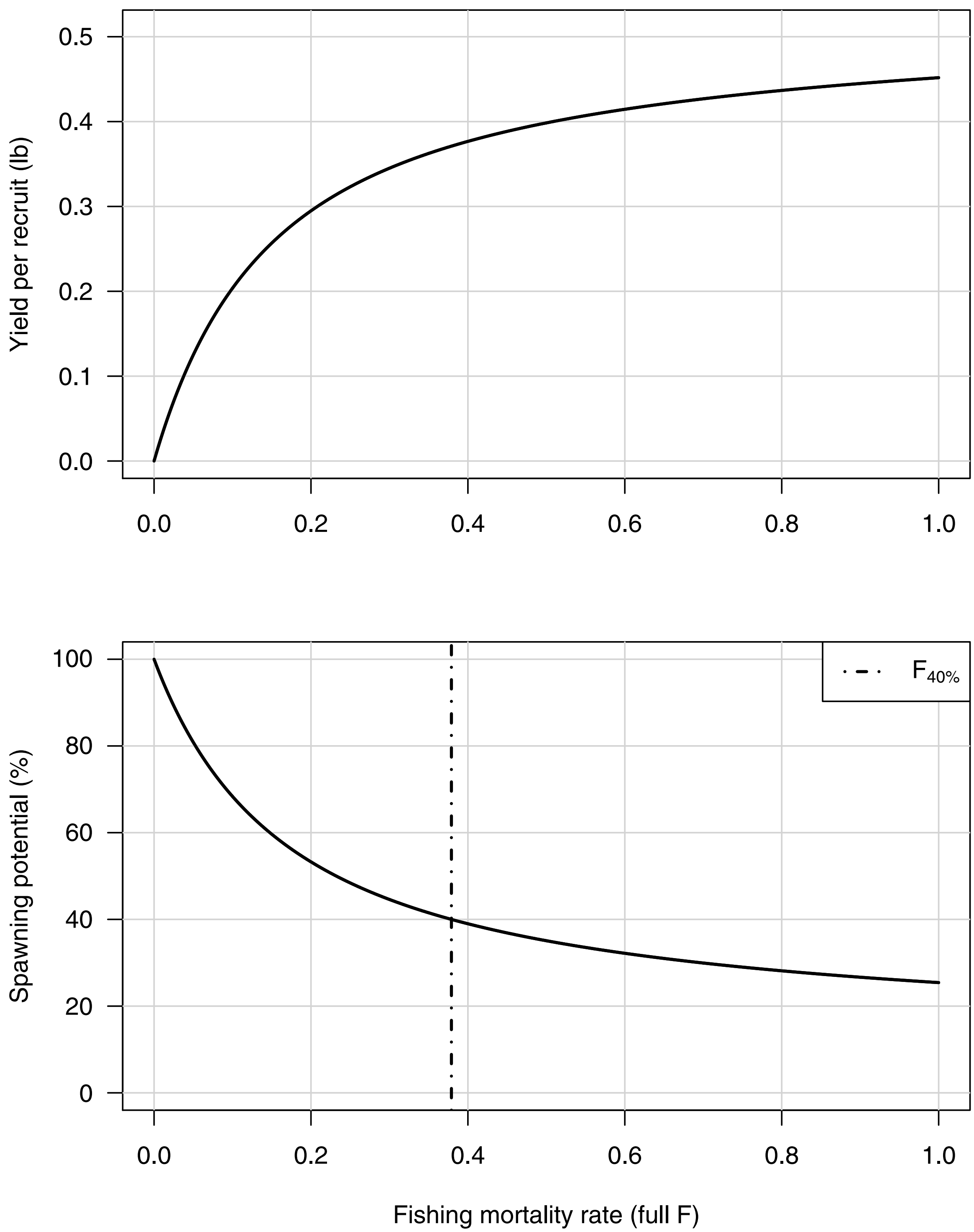


Figure 3.50. Top panel: equilibrium landings. The peak occurs where fishing rate is $F_{MSY} = 0.386$ *and equilibrium landings are* MSY = 1665.27 1000 *lb. Bottom panel: equilibrium spawning biomass. Both curves are based on average selectivity from the end of the assessment period.*

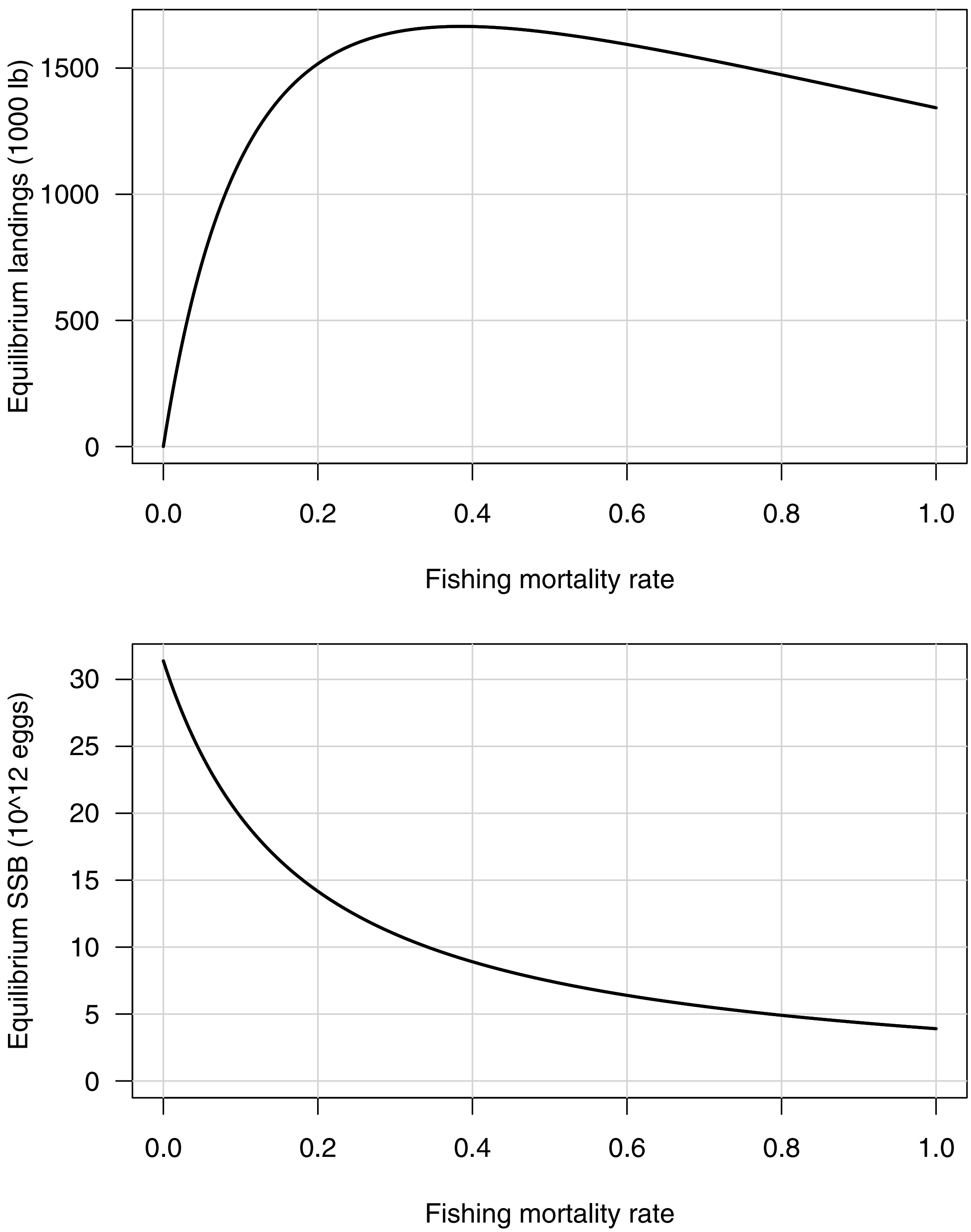


Figure 3.51. Top panel: equilibrium landings as a function of equilibrium biomass, which itself is a function of fishing mortality rate. The peak occurs where equilibrium biomass is B_{MSY} = 3299.78 *mt and equilibrium landings are* MSY = 1665.27 1000 *lb. Bottom panel: equilibrium discard mortality as a function of equilibrium biomass.*

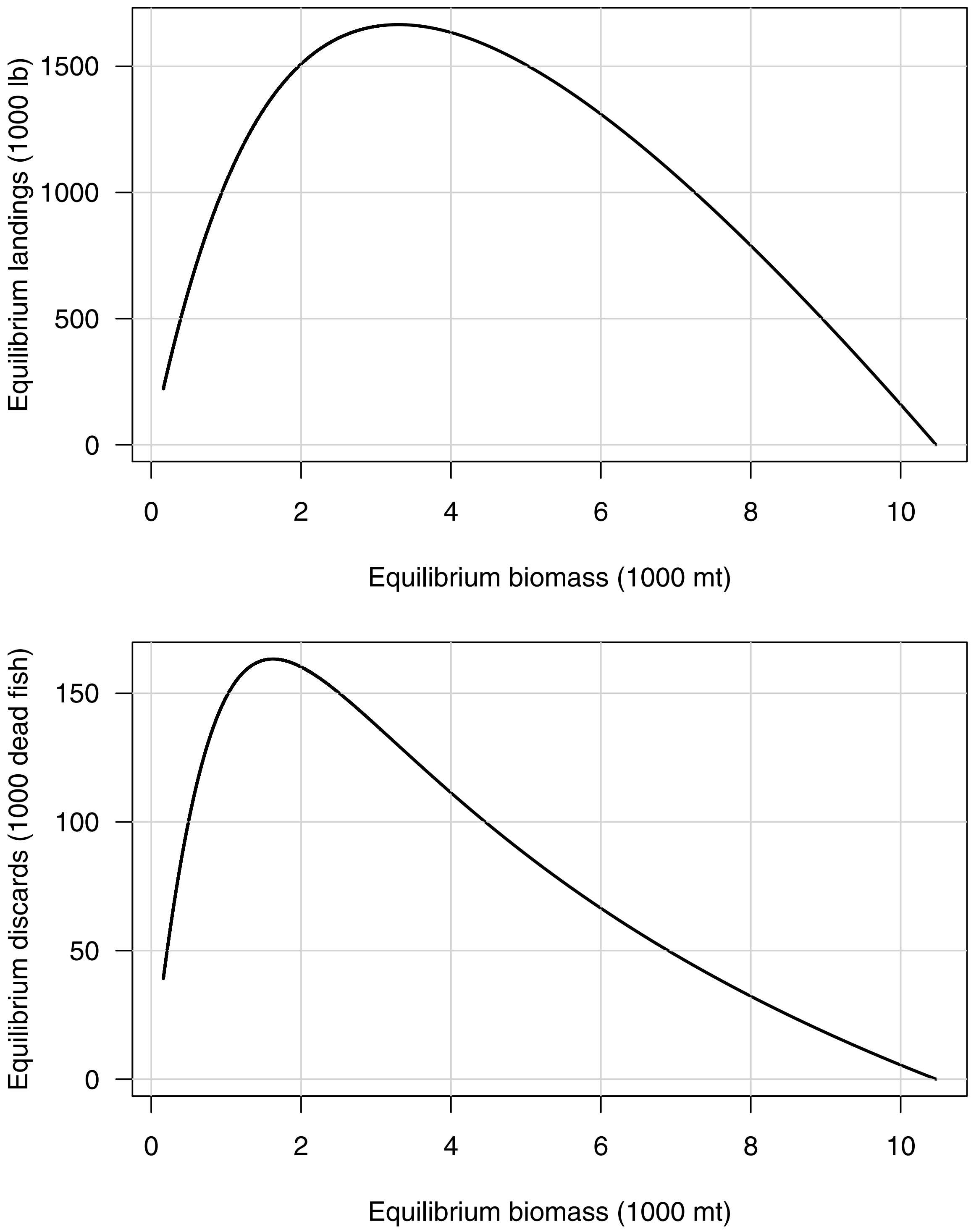


Figure 3.52. Probability densities of MSY*-related benchmarks. Vertical lines represent point estimates.*

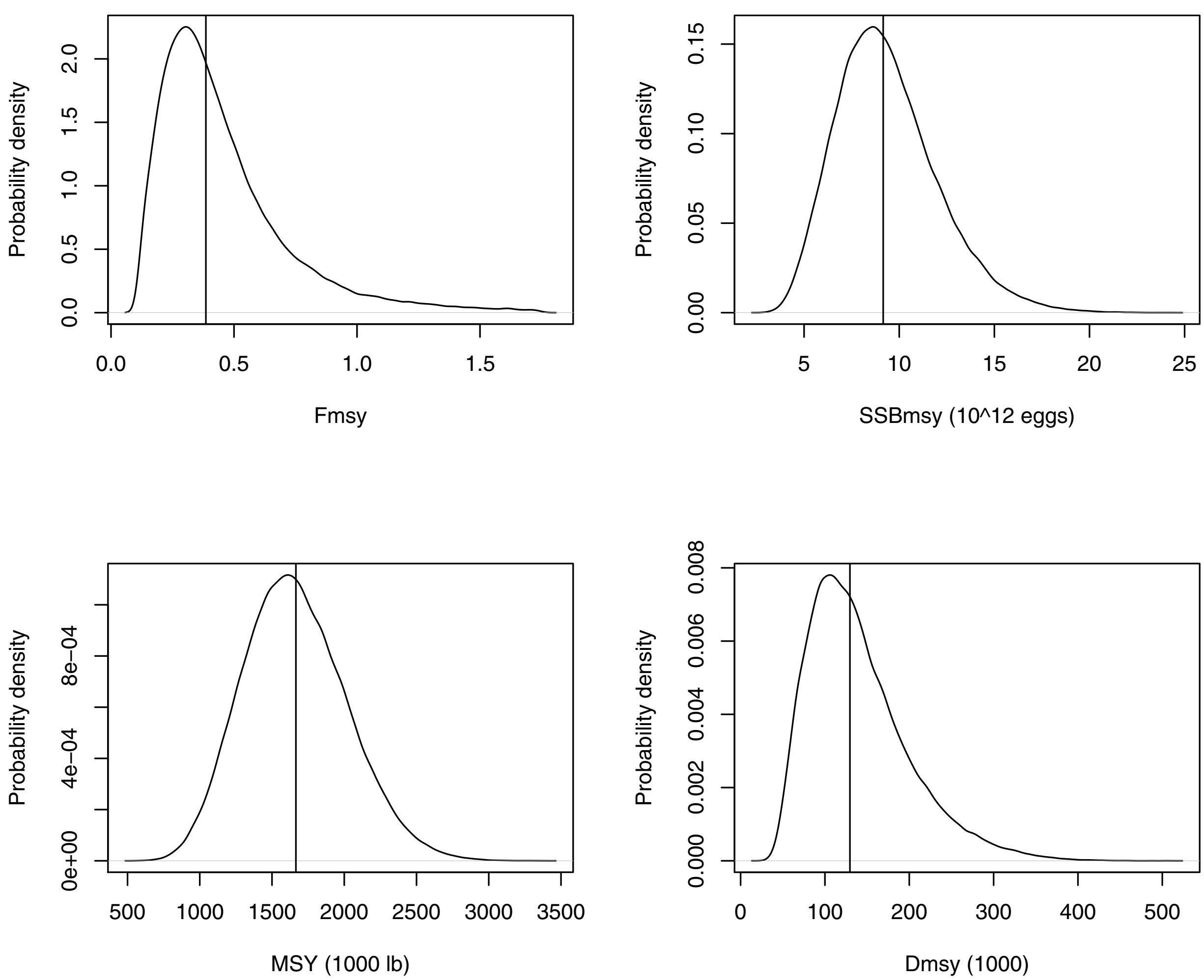


Figure 3.53. Estimated time series of biomass relative to MSY *benchmarks. Top panel: B relative to* B_{MSY}*. Bottom panel:* SSB *relative to* SSB_{MSY}*.*

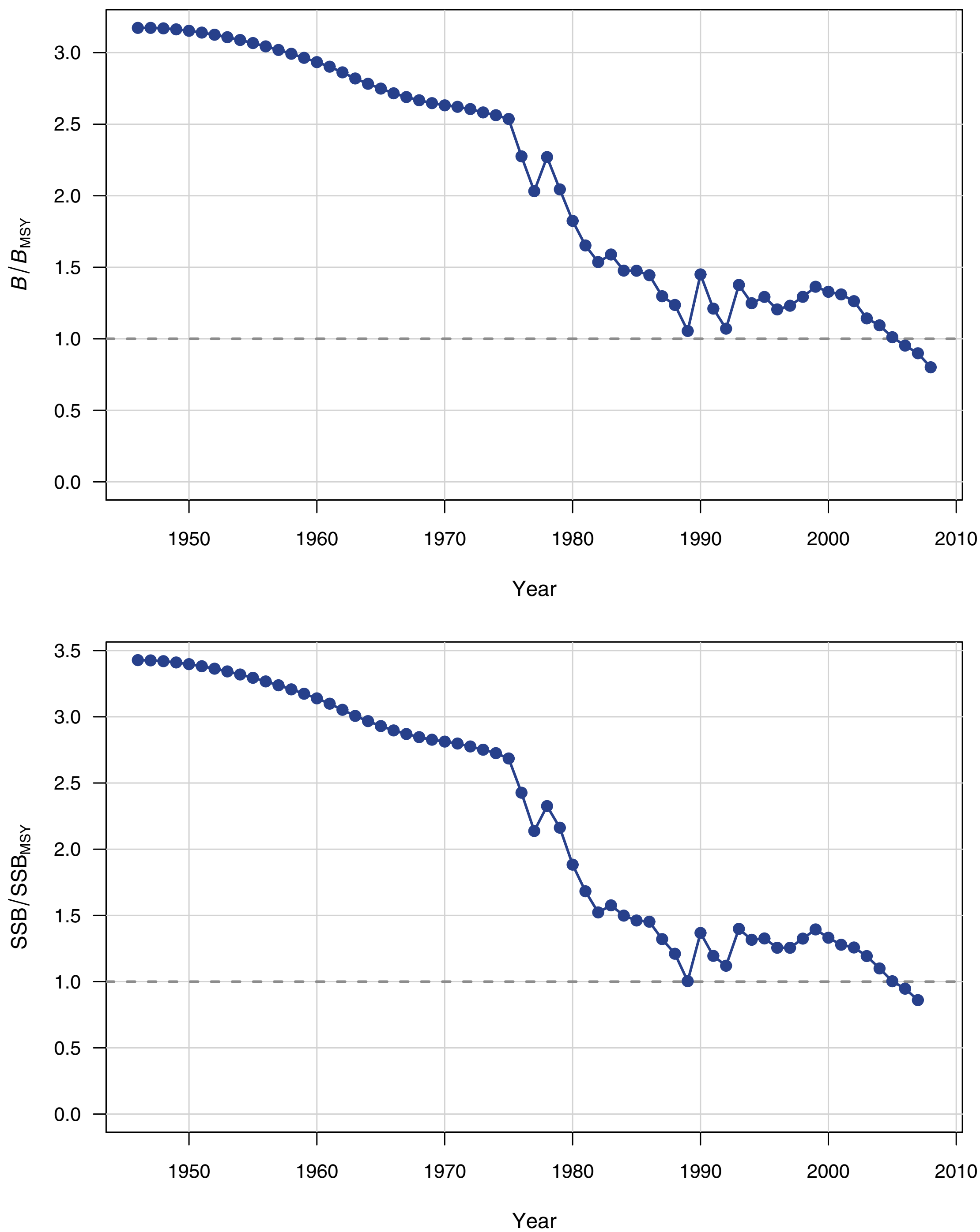


Figure 3.54. Age structure relative to the equilibrium expected at MSY*.*

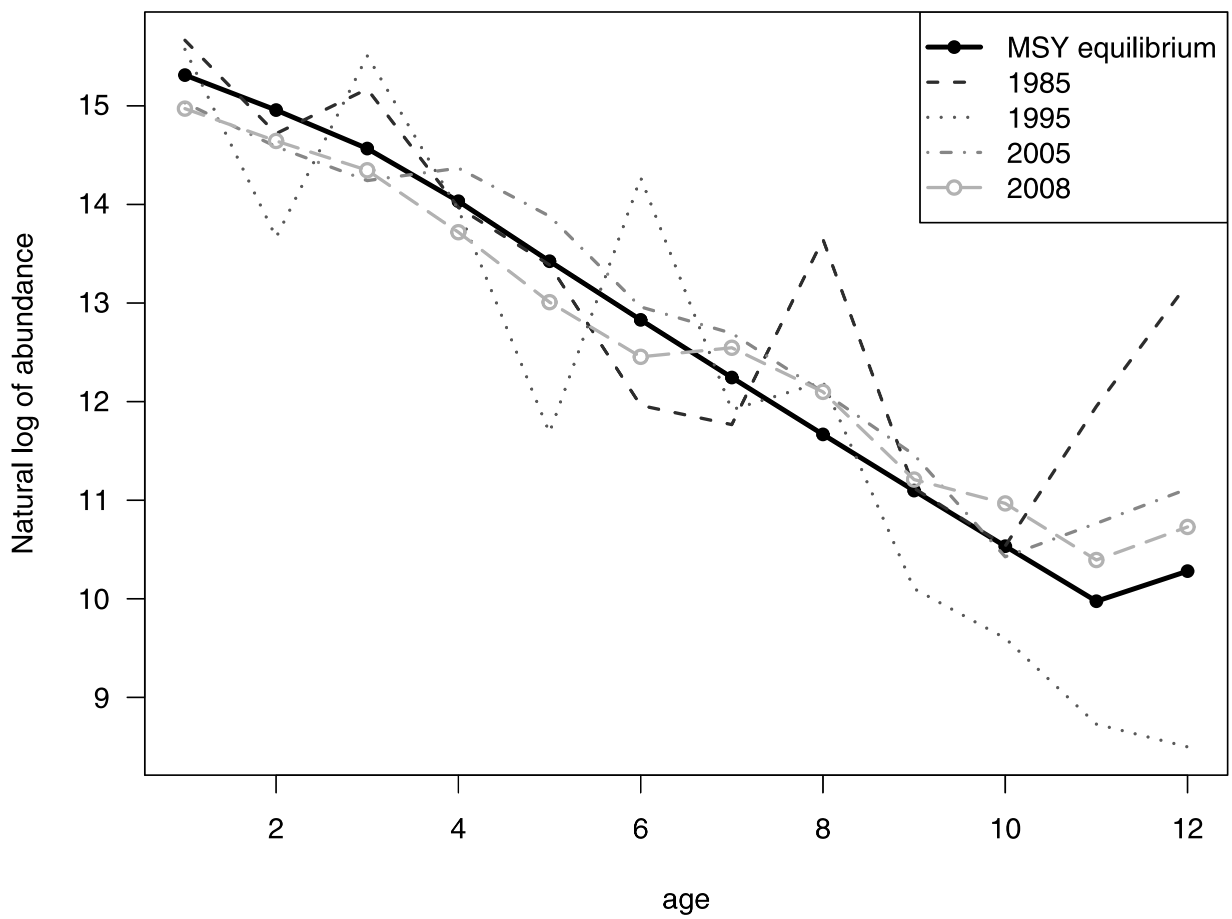


Figure 3.55. Estimated time series of F relative to F_{MSY}.

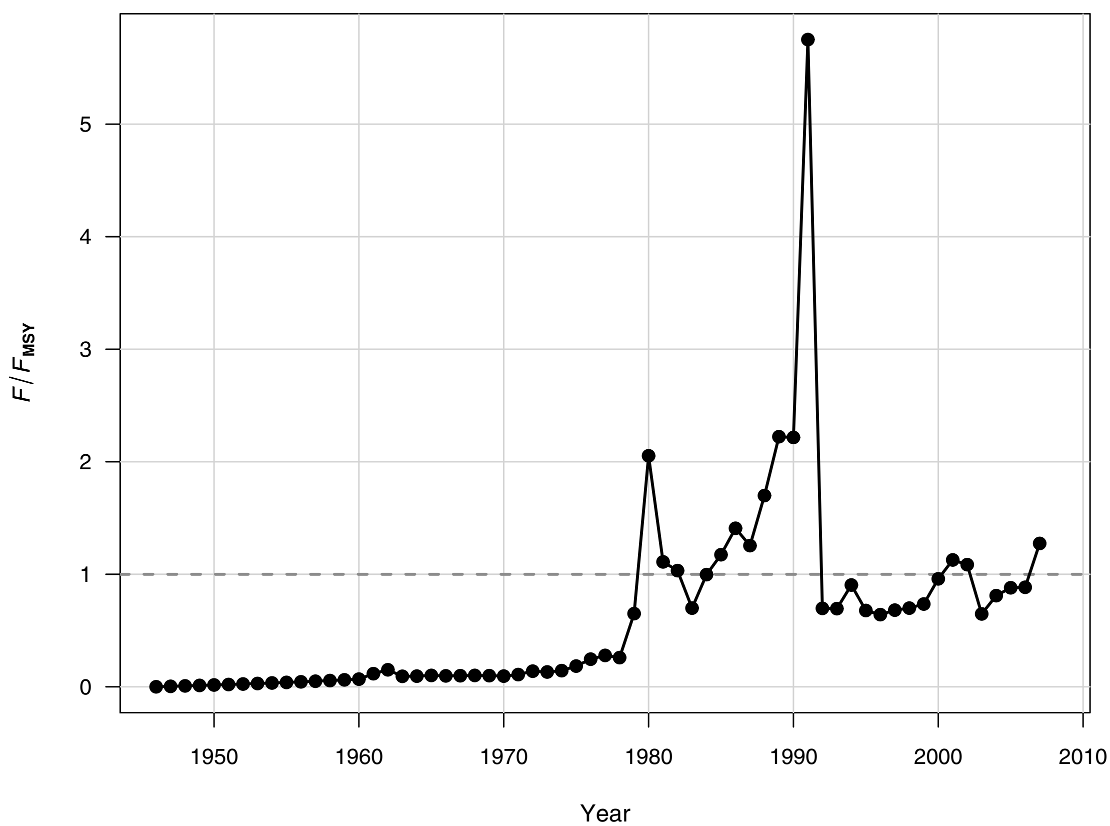


Figure 3.56. Probability-based approach to computing acceptable biological catch (ABC), with annual probability of overfishing $P^\star = 0.1$. The F in 2008 was set to $F = F_{\text{current}}$. Dotted solid lines correspond to median values, and thin lines to 10^{th} and 90^{th} percentiles of 10000 replicate projections. Spawning stock (SSB) is at mid-year, and catch (the ABC) includes landings plus discard mortalities.

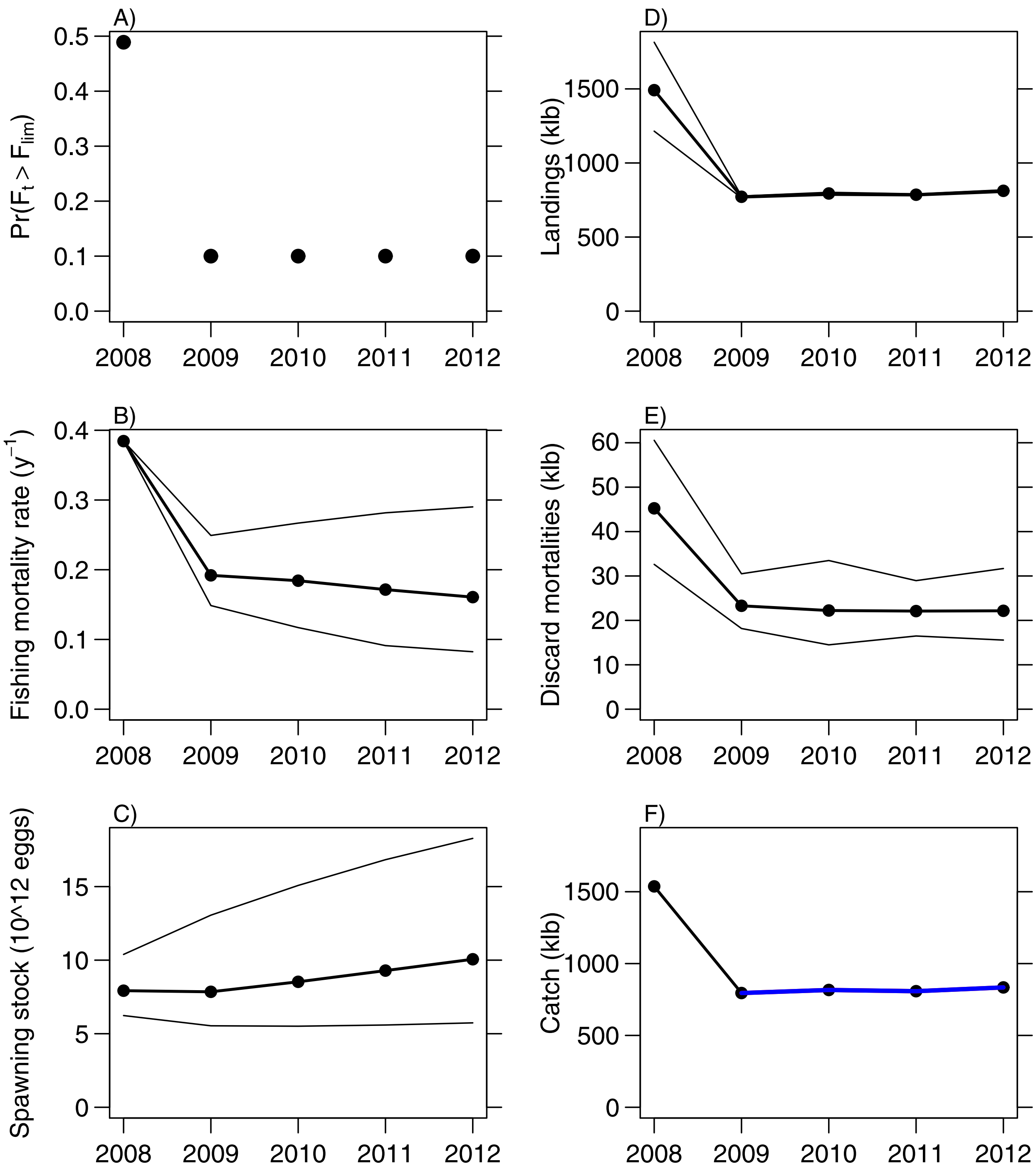


Figure 3.57. Probability-based approach to computing acceptable biological catch (ABC), with annual probability of overfishing $P^{\star} = 0.2$. The F in 2008 was set to $F = F_{\text{current}}$. Dotted solid lines correspond to median values, and thin lines to 10^{th} and 90^{th} percentiles of 10000 replicate projections. Spawning stock (SSB) is at mid-year, and catch (the ABC) includes landings plus discard mortalities.

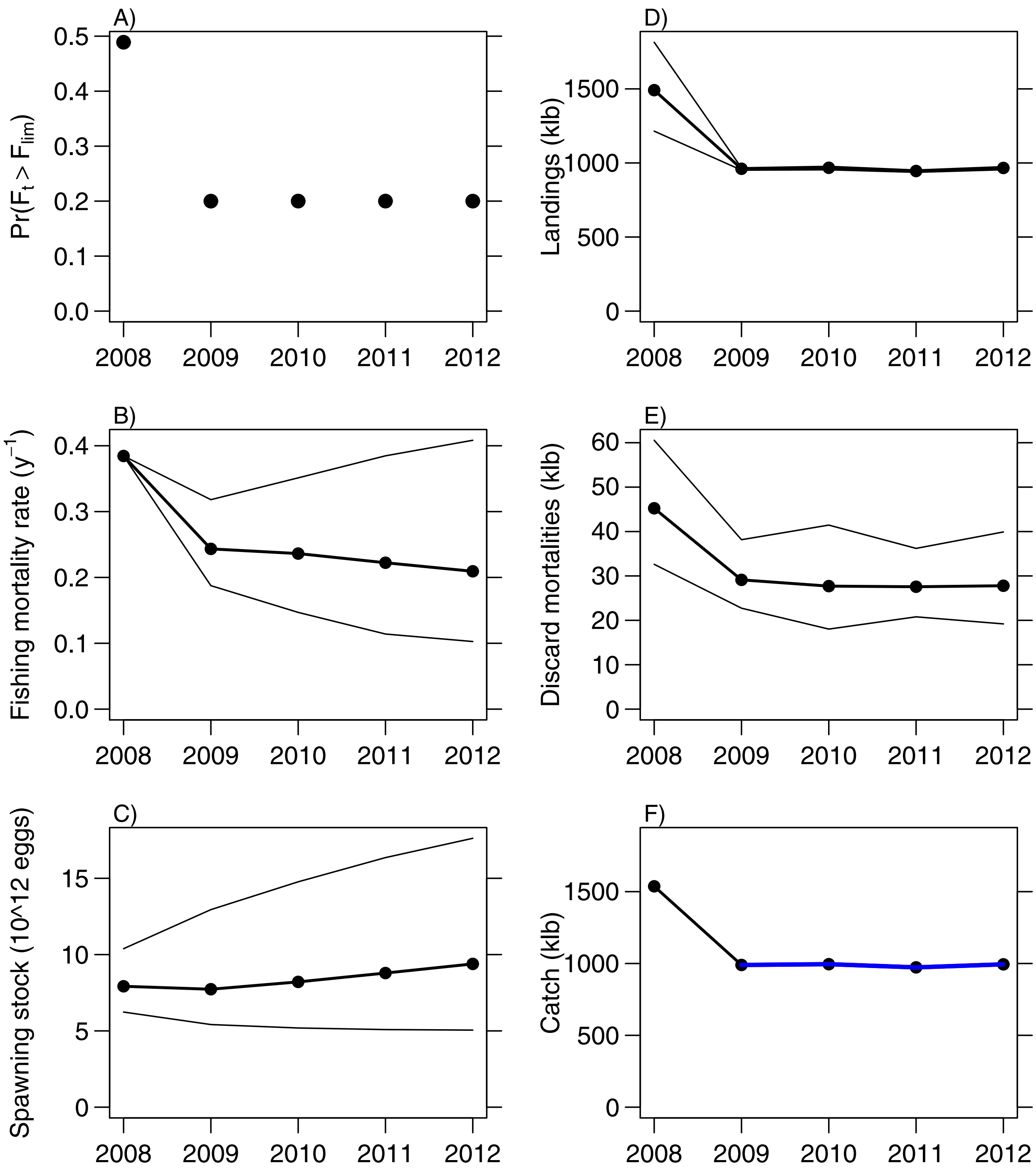


Figure 3.58. Probability-based approach to computing acceptable biological catch (ABC), with annual probability of overfishing $P^\star = 0.25$. The F in 2008 was set to $F = F_{\text{current}}$. Dotted solid lines correspond to median values, and thin lines to 10^{th} and 90^{th} percentiles of 10000 replicate projections. Spawning stock (SSB) is at mid-year, and catch (the ABC) includes landings plus discard mortalities.

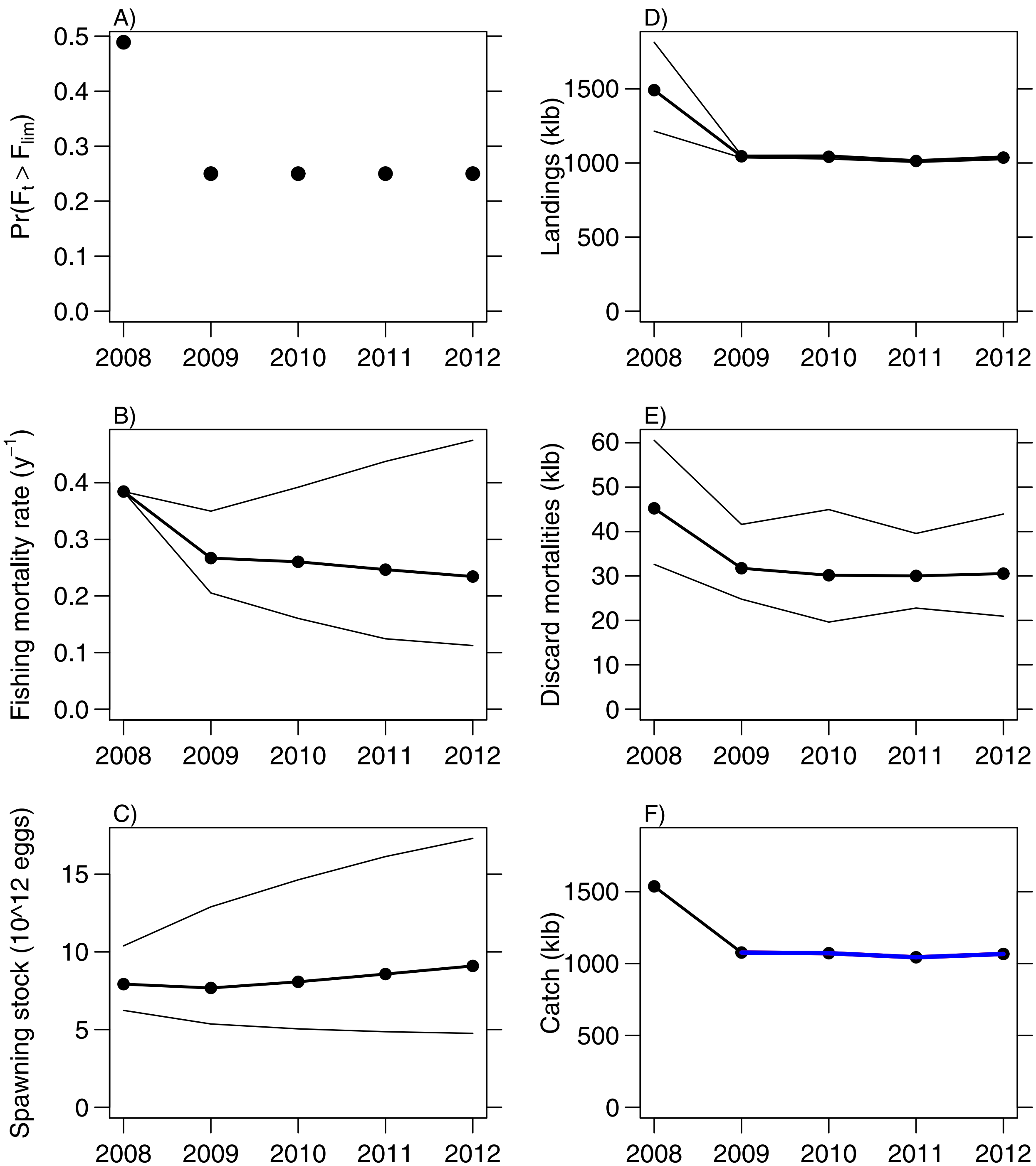


Figure 3.59. Probability-based approach to computing acceptable biological catch (ABC), with annual probability of overfishing $P^{\star} = 0.3$. The F in 2008 was set to $F = F_{\text{current}}$. Dotted solid lines correspond to median values, and thin lines to 10^{th} and 90^{th} percentiles of 10000 replicate projections. Spawning stock (SSB) is at mid-year, and catch (the ABC) includes landings plus discard mortalities.

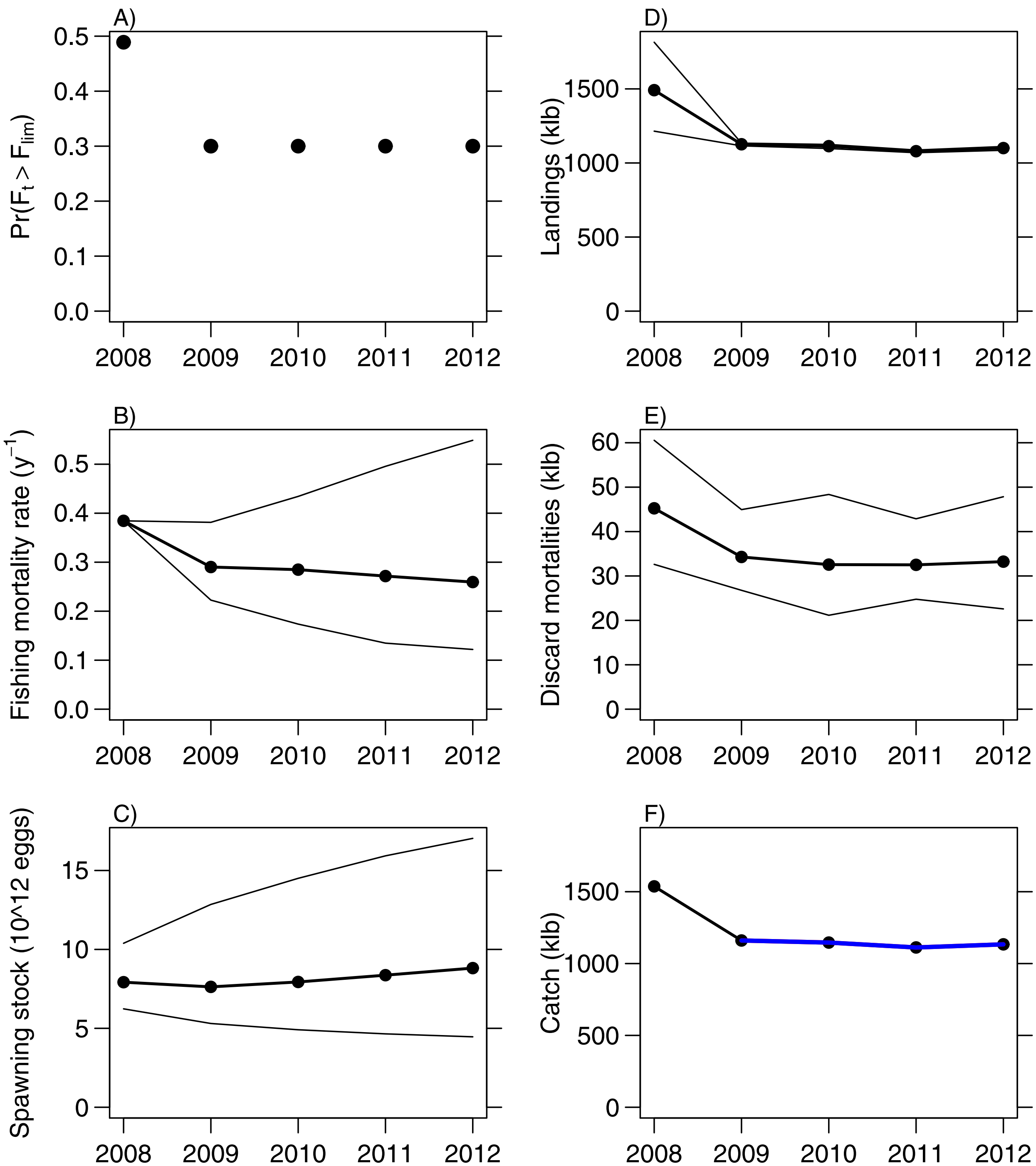


Figure 3.60. Probability-based approach to computing acceptable biological catch (ABC), with annual probability of overfishing $P^{\star} = 0.4$. The F in 2008 was set to $F = F_{\text{current}}$. Dotted solid lines correspond to median values, and thin lines to 10^{th} and 90^{th} percentiles of 10000 replicate projections. Spawning stock (SSB) is at mid-year, and catch (the ABC) includes landings plus discard mortalities.

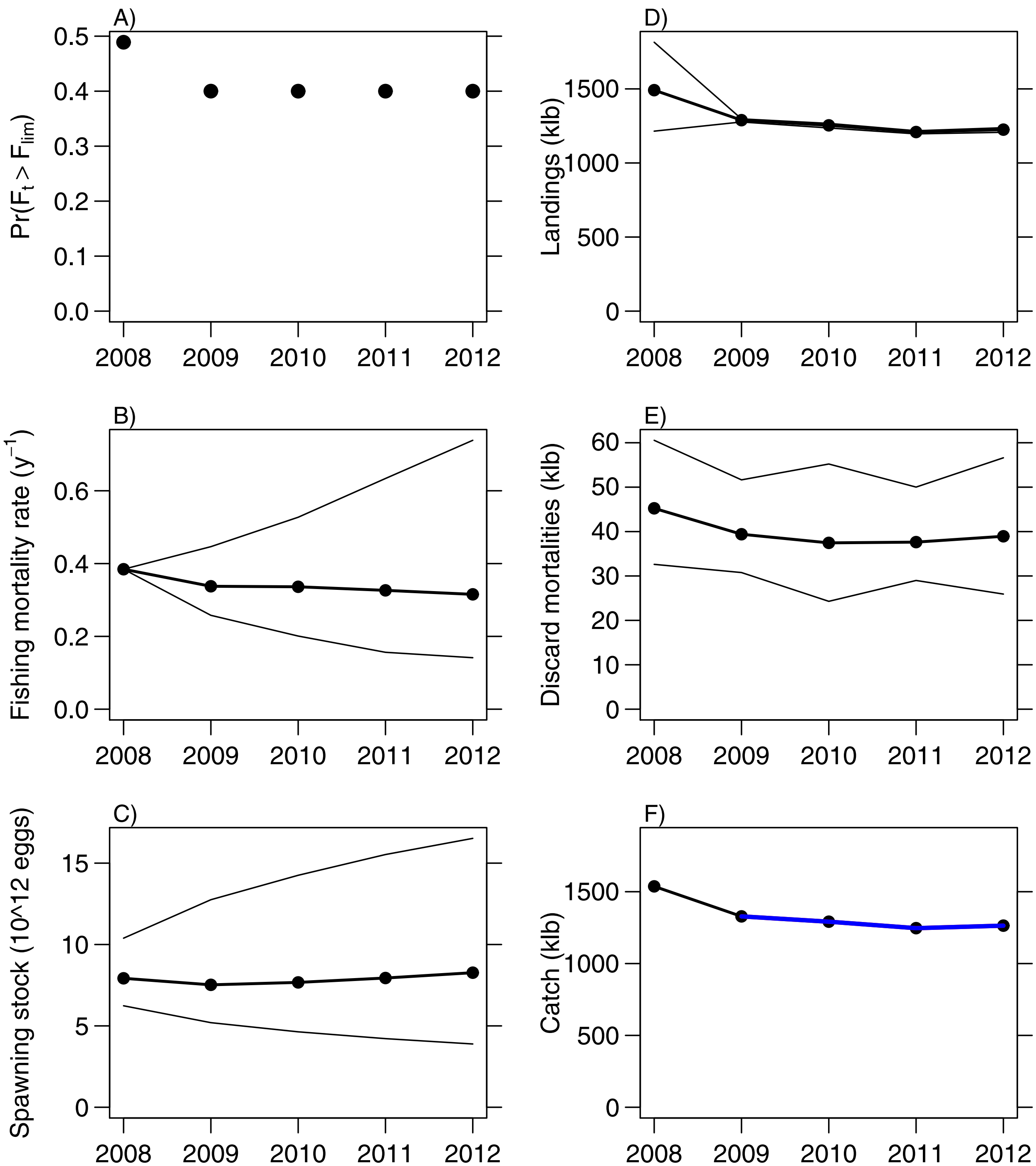


Figure 3.61. Probability-based approach to computing acceptable biological catch (ABC), with annual probability of overfishing $P^\star = 0.5$. The F in 2008 was set to $F = F_{\mathrm{current}}$. Dotted solid lines correspond to median values, and thin lines to 10^{th} and 90^{th} percentiles of 10000 replicate projections. Spawning stock (SSB) is at mid-year, and catch (the ABC) includes landings plus discard mortalities.

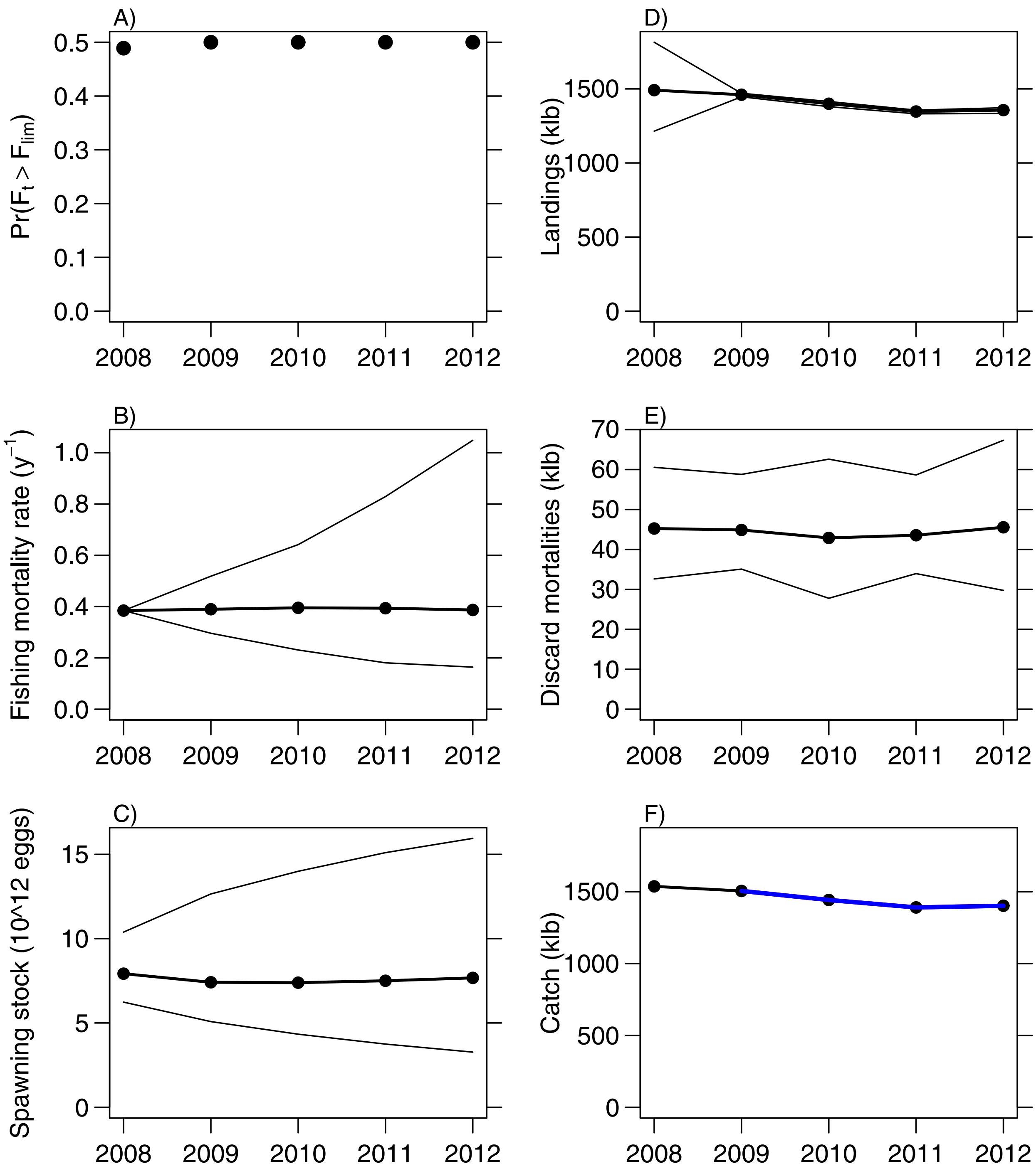


Figure 3.62. Sensitivity to changes in steepness, either estimated or consistent with $F_{MSY} = F_{x\%}$ *(sensitivity runs S1 – S5). Top panel: Ratio of* F *to* F_{MSY}*. Bottom panel: Ratio of* SSB *to* SSB_{MSY}*.*

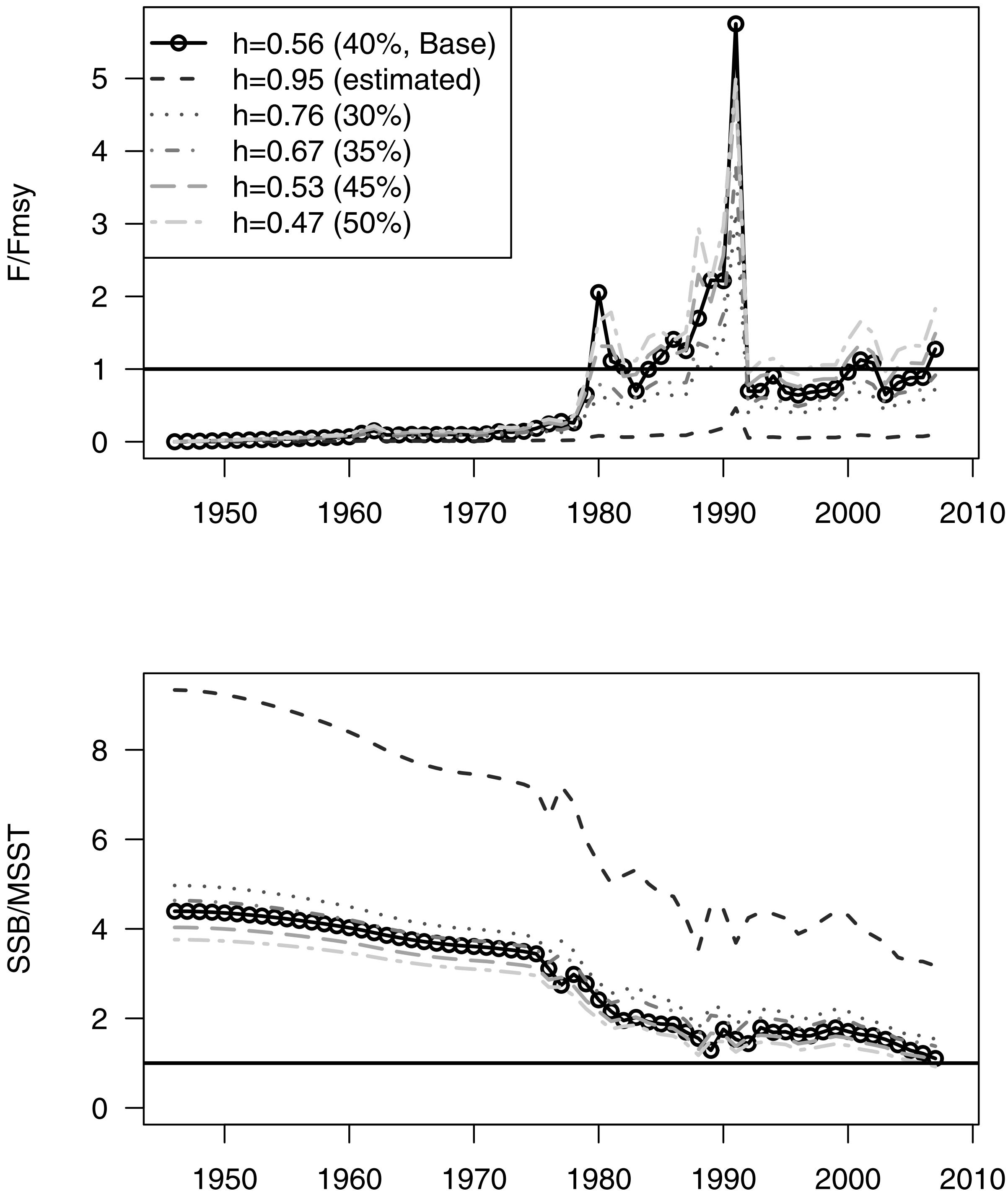


Figure 3.63. Sensitivity to changes in natural mortality (sensitivity runs S6 and S7). Top panel: Ratio of F to F_{MSY}. *Bottom panel: Ratio of* SSB *to* SSB_{MSY}.

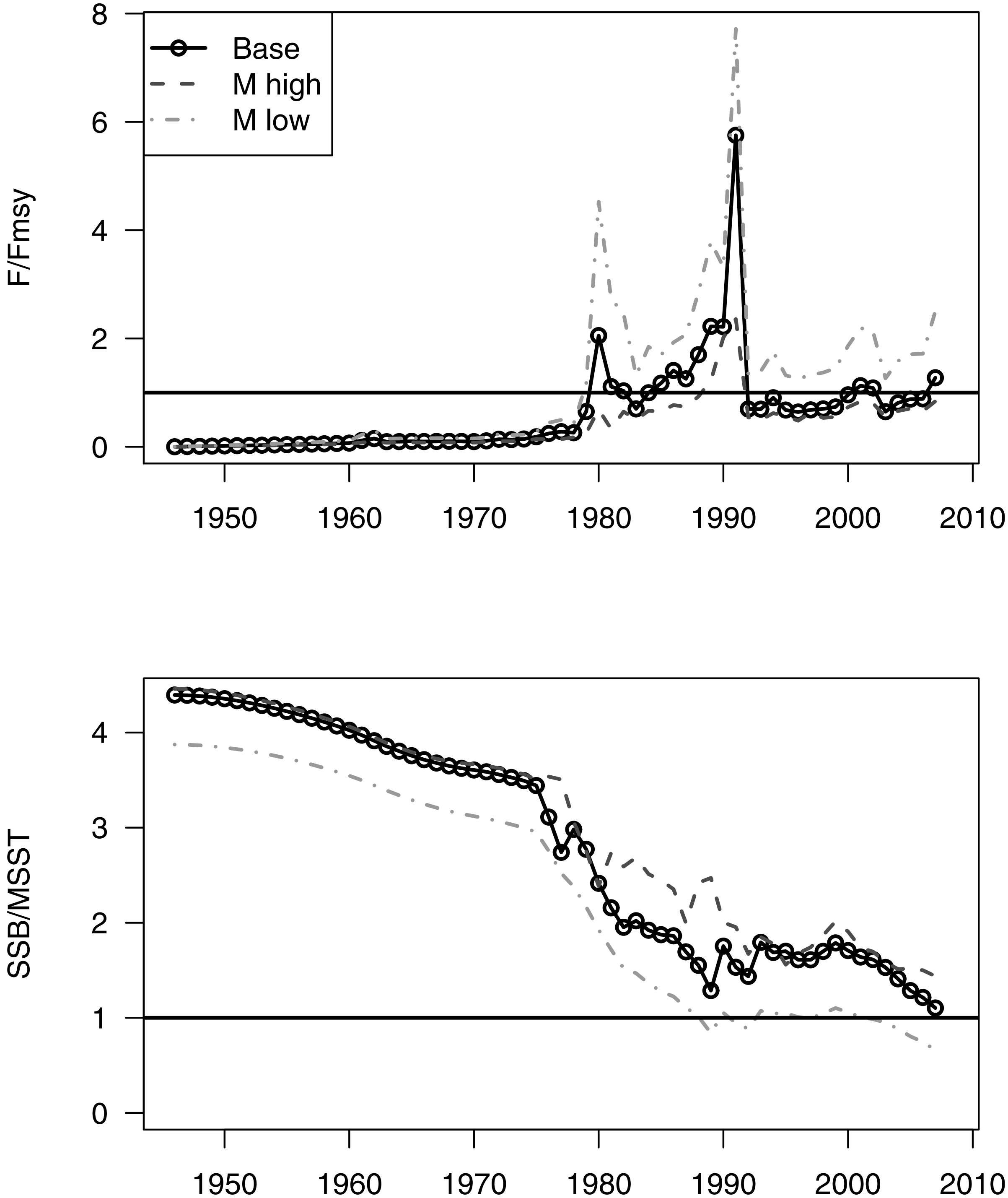


Figure 3.64. Sensitivity to changes in catchability (sensitivity runs S8 and S9). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* SSB_{MSY}*.*

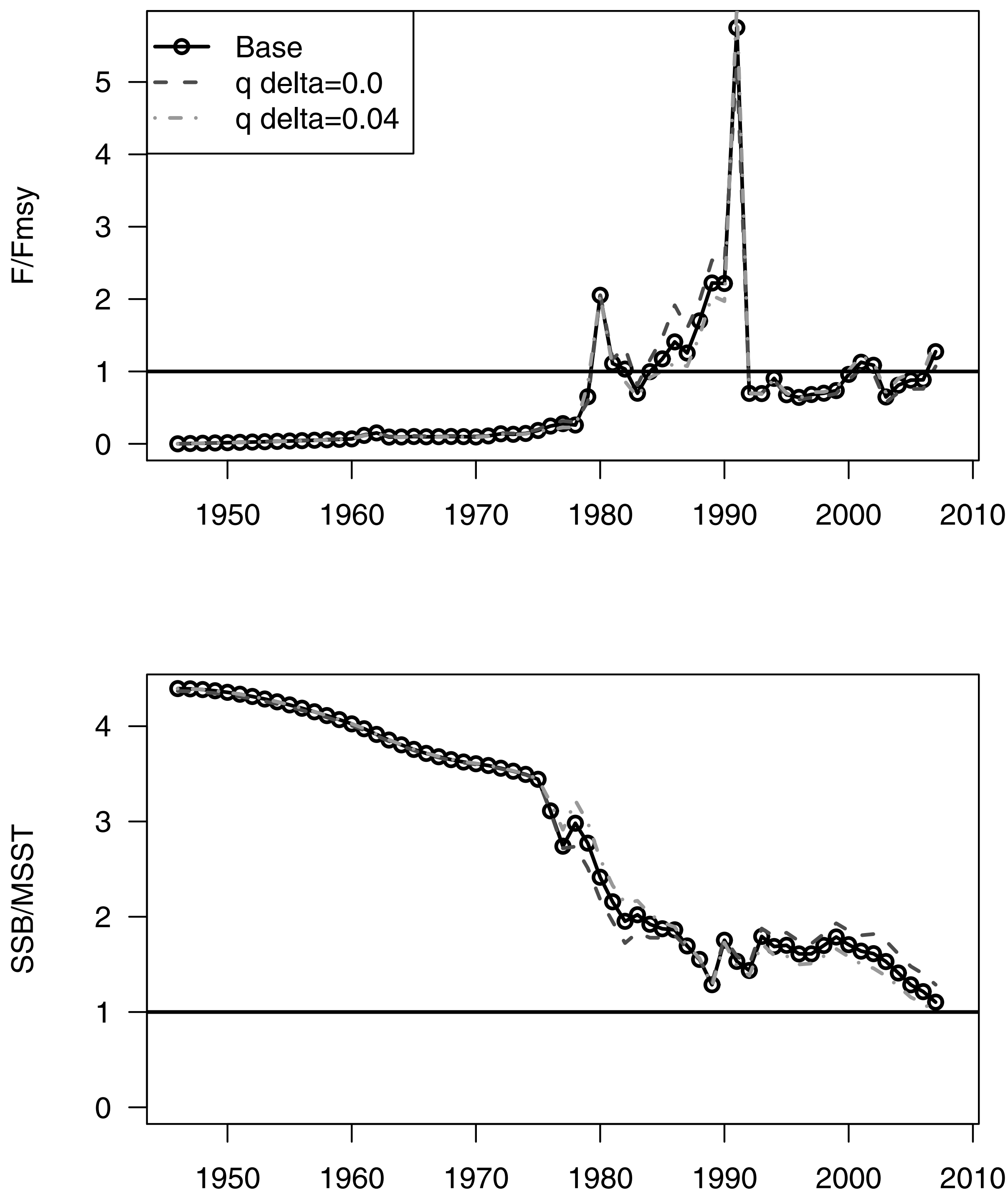


Figure 3.65. Sensitivity to discard mortality rates (sensitivity runs S10 and S11). Top panel:Ratio of F *to* F_{MSY}. *Bottom panel:Ratio of* SSB *to* SSB_{MSY}.

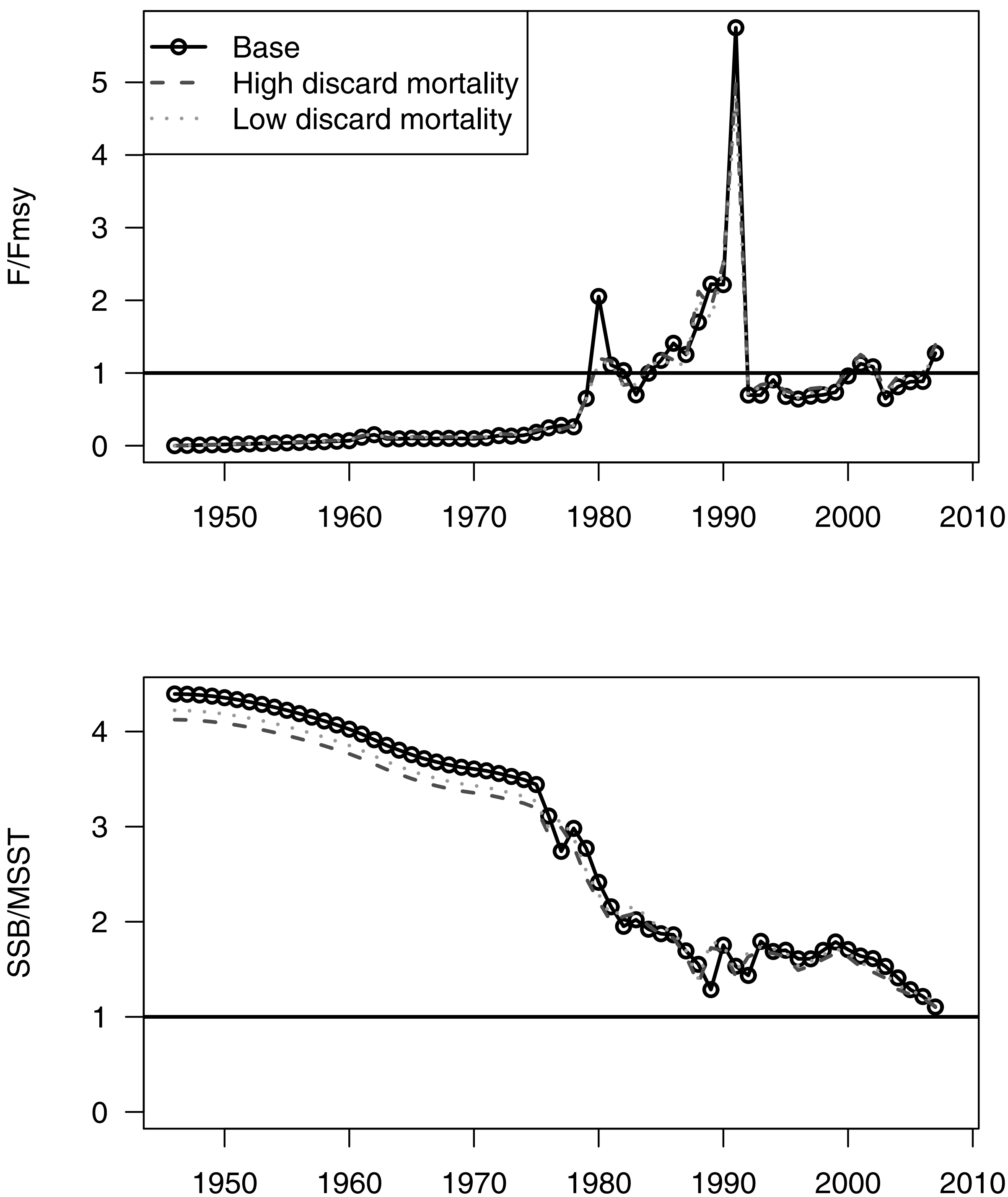
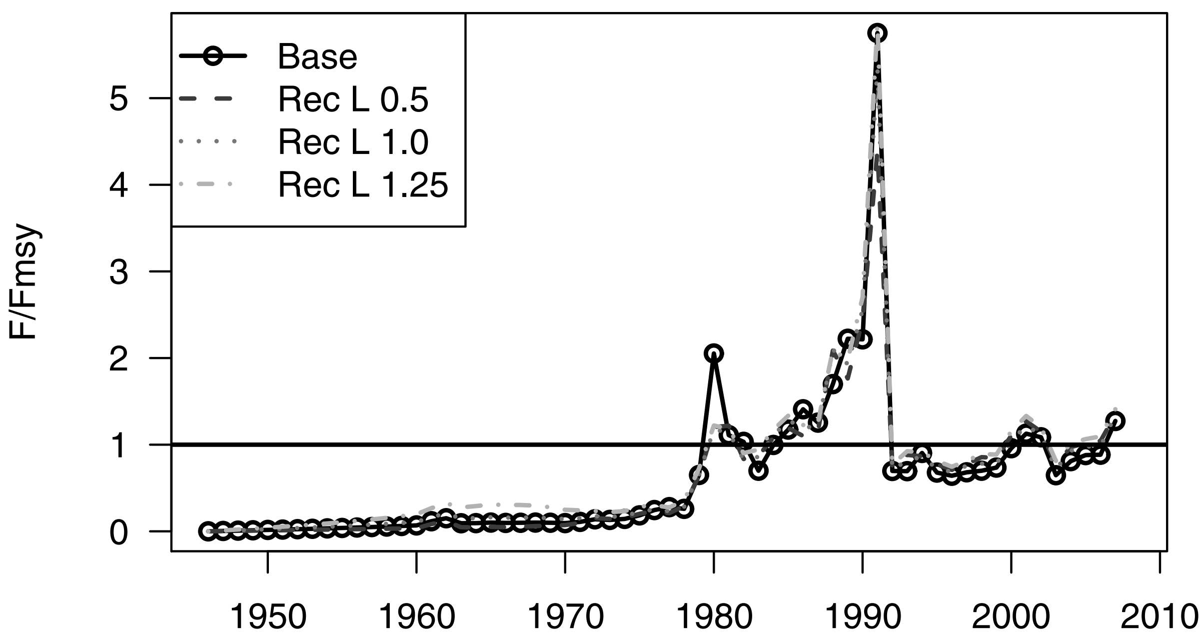


Figure 3.66. Sensitivity to early recreational landings (sensitivity runs S12 – S14). Top panel: Ratio of F to F_{MSY}. *Bottom panel: Ratio of* SSB *to* SSB_{MSY}.



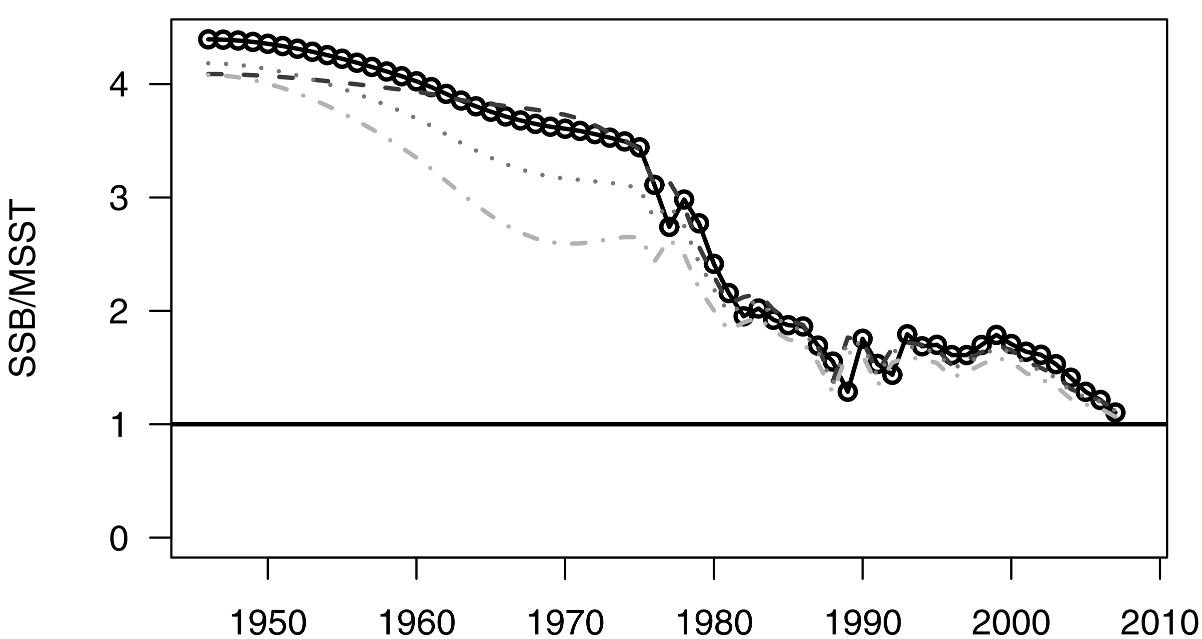


Figure 3.67. Sensitivity to commercial landings (sensitivity runs S15 and S16). Top panel: Ratio of F to F_{MSY}. *Bottom panel: Ratio of* SSB *to* SSB_{MSY}.

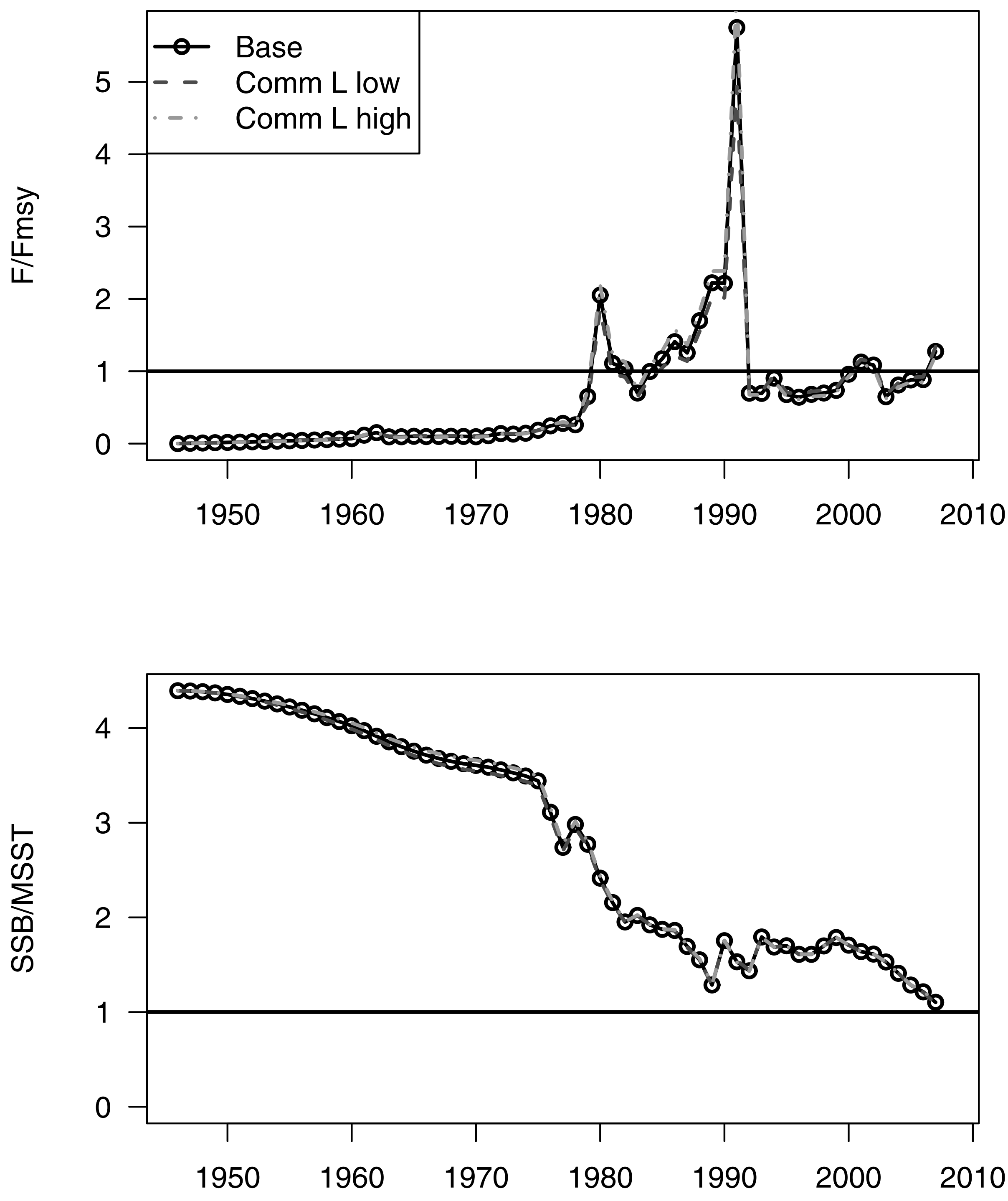


Figure 3.68. Sensitivity to likelihood weights (sensitivity runs S17 – S19). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* SSB_{MSY}.

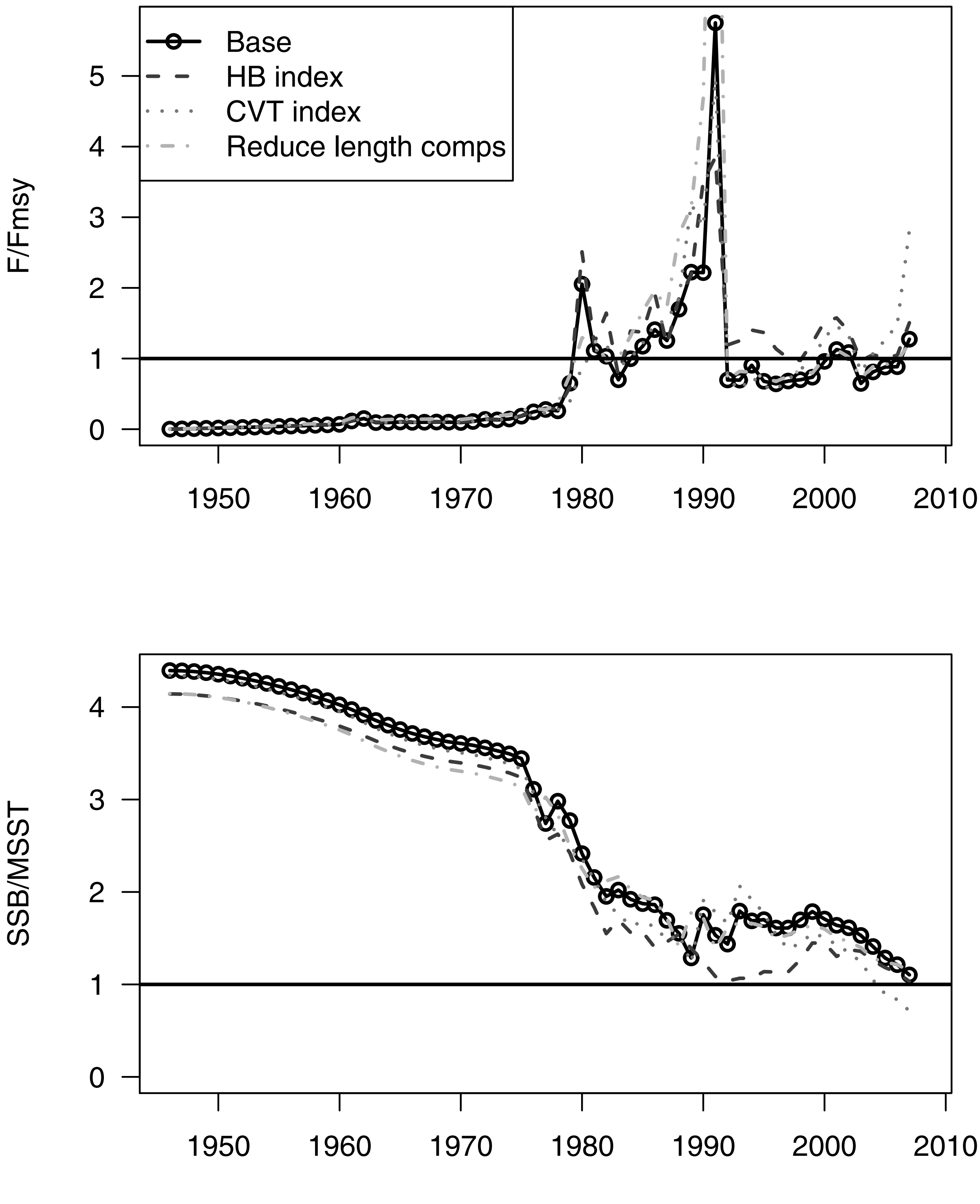


Figure 3.69. Retrospective analyses. Sensitivity to terminal year of data (sensitivity runs S20–S23). Top panel: Fishing mortality rate. Bottom panel: Spawning stock.

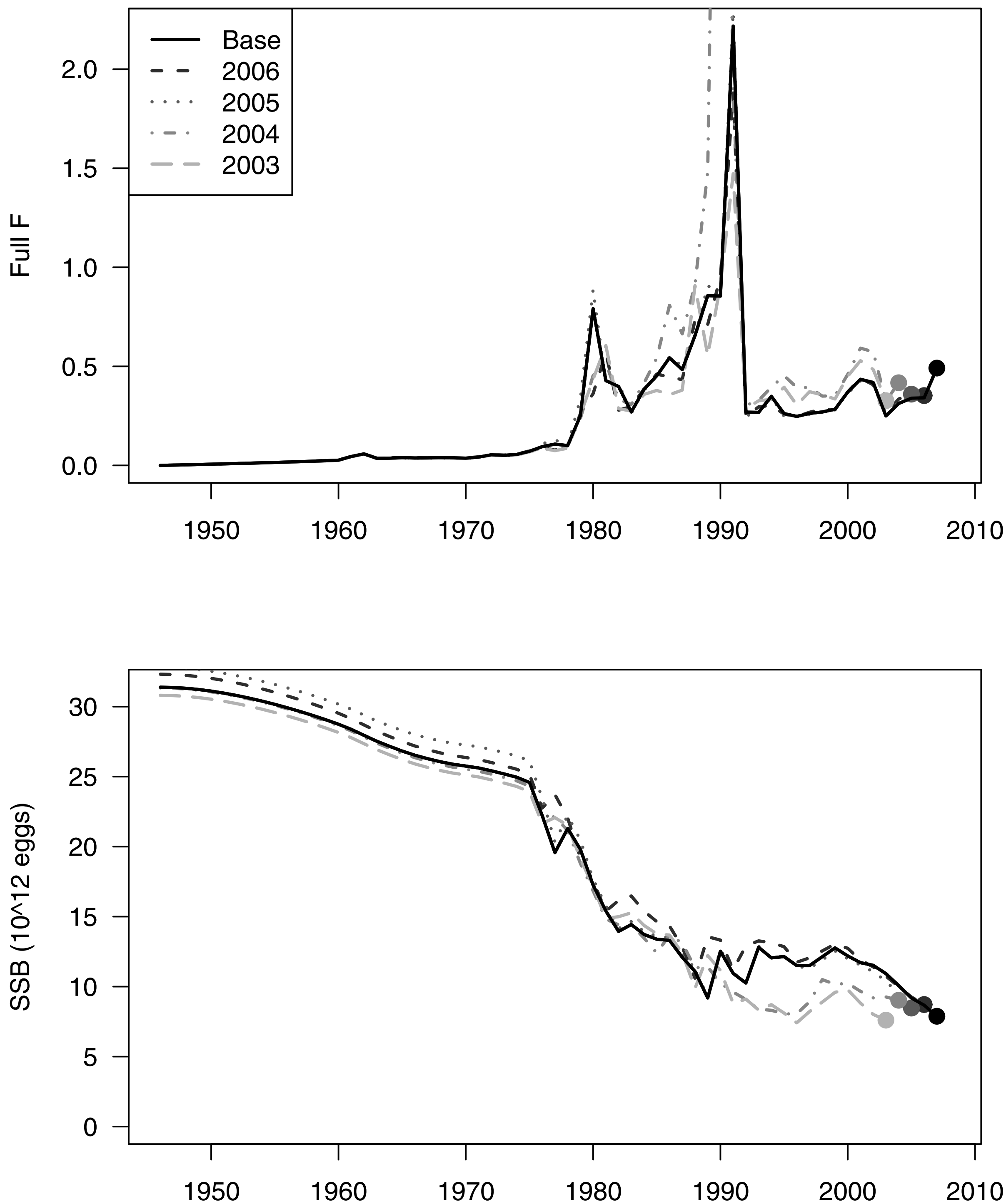


Figure 3.70. Projection results under scenario 1—fishing mortality rate fixed at $F = F_{\text{current}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 2000 replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

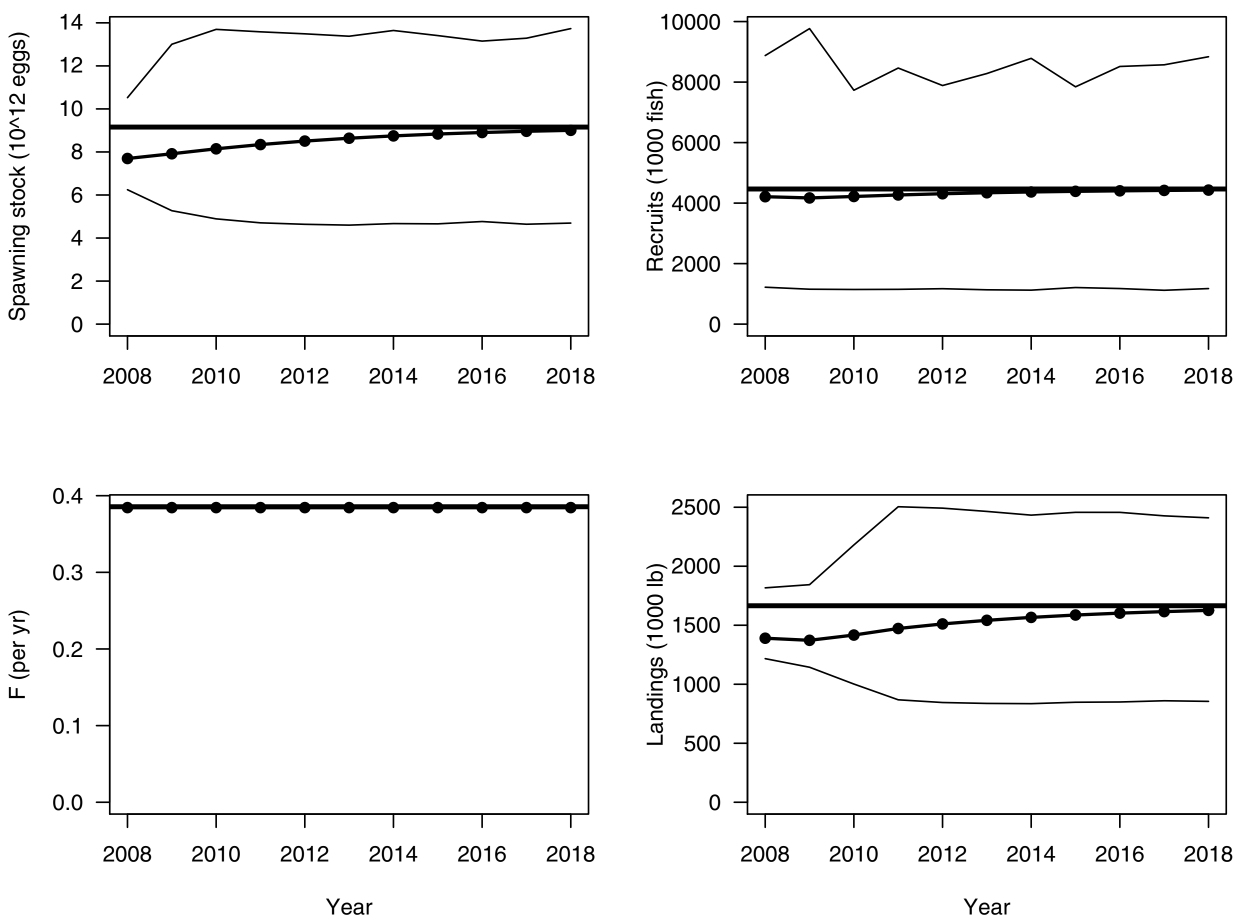


Figure 3.71. Projection results under scenario 2—fishing mortality rate fixed at $F = 65\%F_{\mathrm{MSY}}$*. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to* 10^{th} *and* 90^{th} *percentiles of 2000 replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

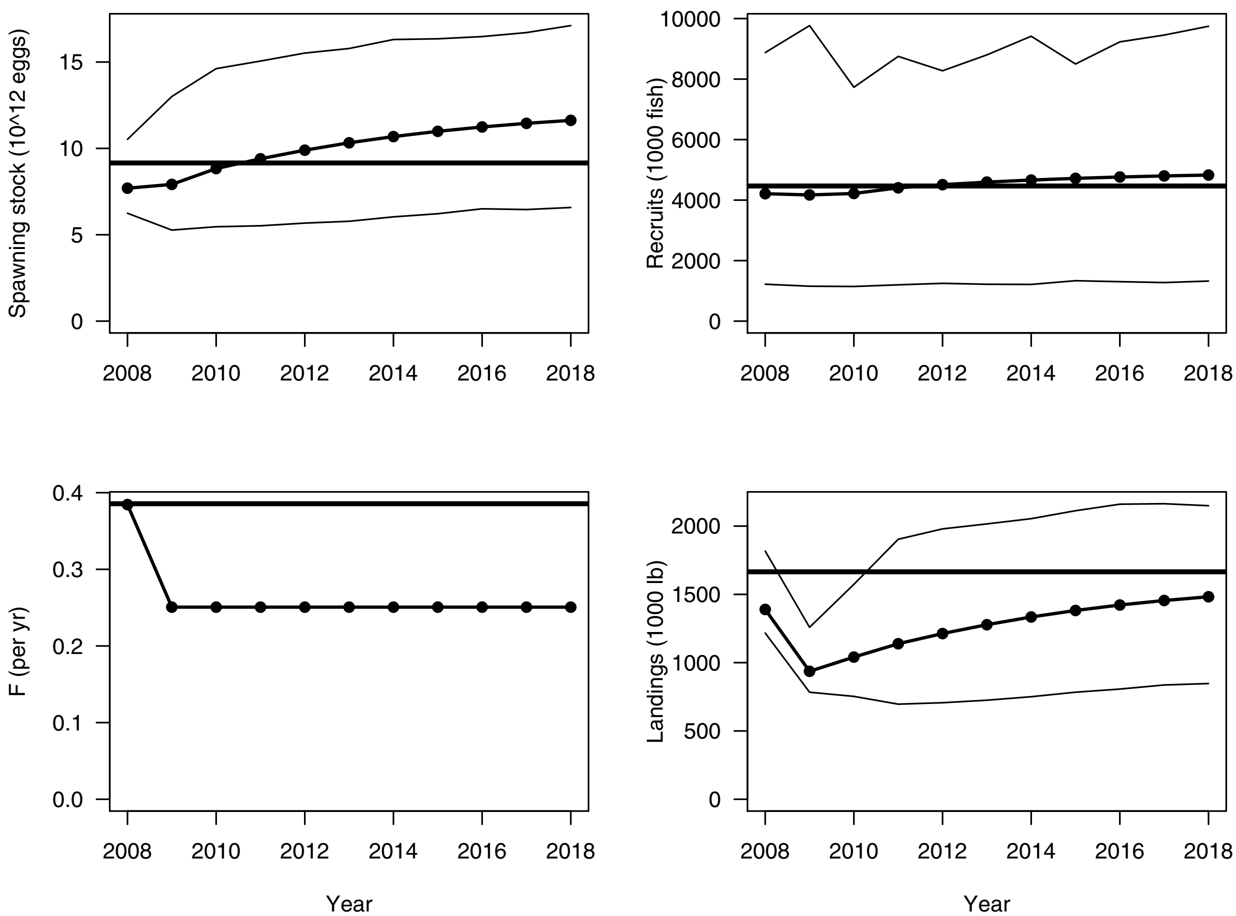


Figure 3.72. Projection results under scenario 3—fishing mortality rate fixed at $F = 75\%F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 2000 replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

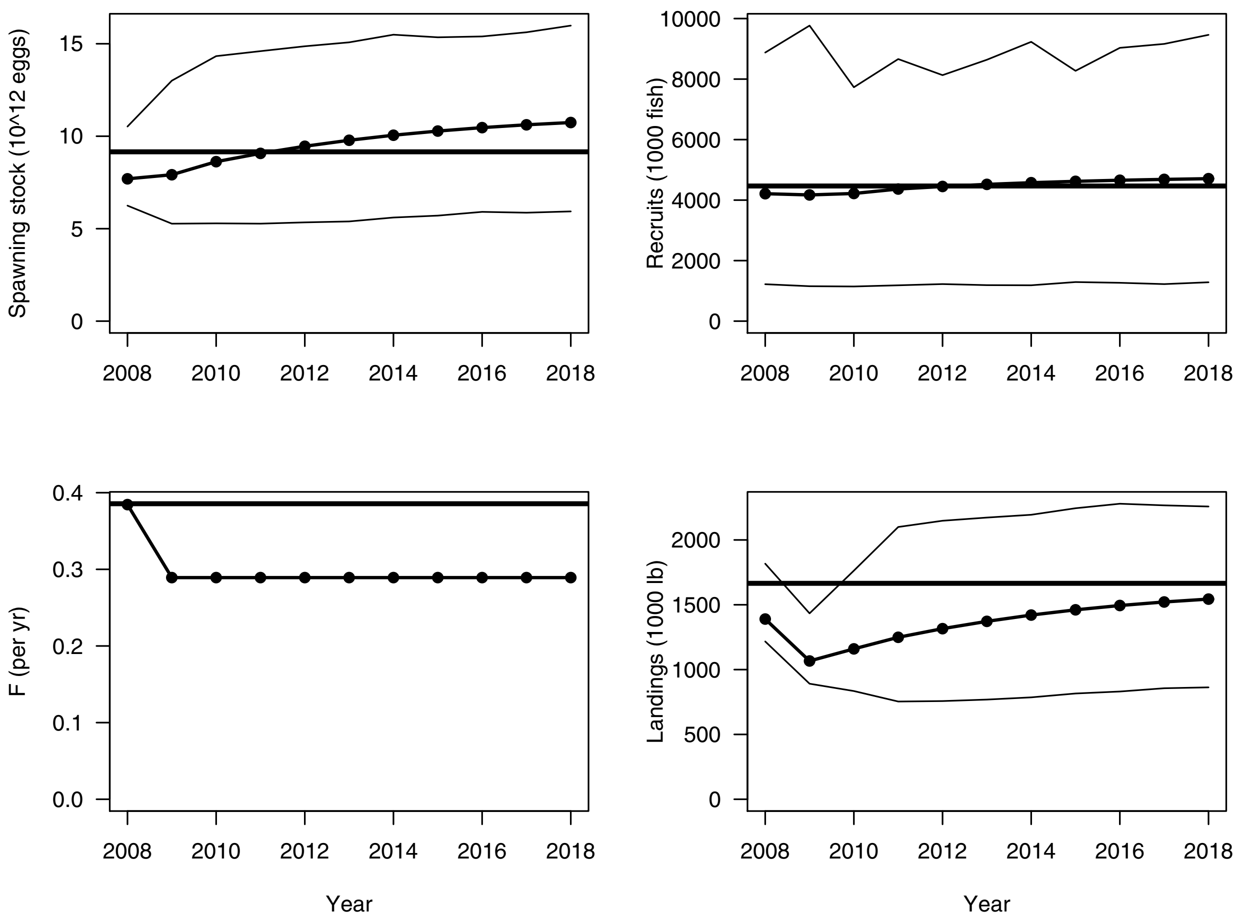


Figure 3.73. Projection results under scenario 4—fishing mortality rate fixed at $F = 85\%F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 2000 replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

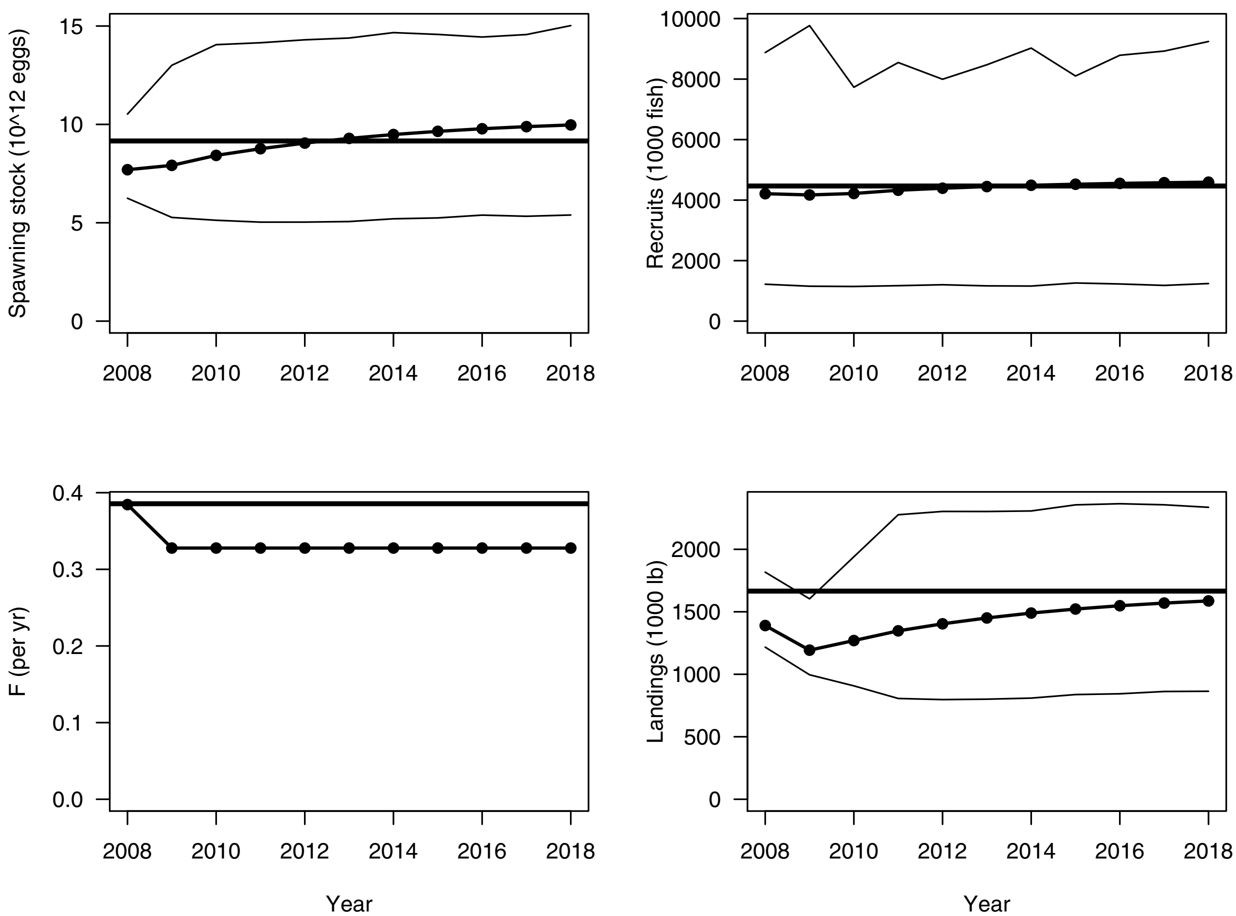


Figure 3.74. Projection results under scenario 5—fishing mortality rate fixed at $F = F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 2000 replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

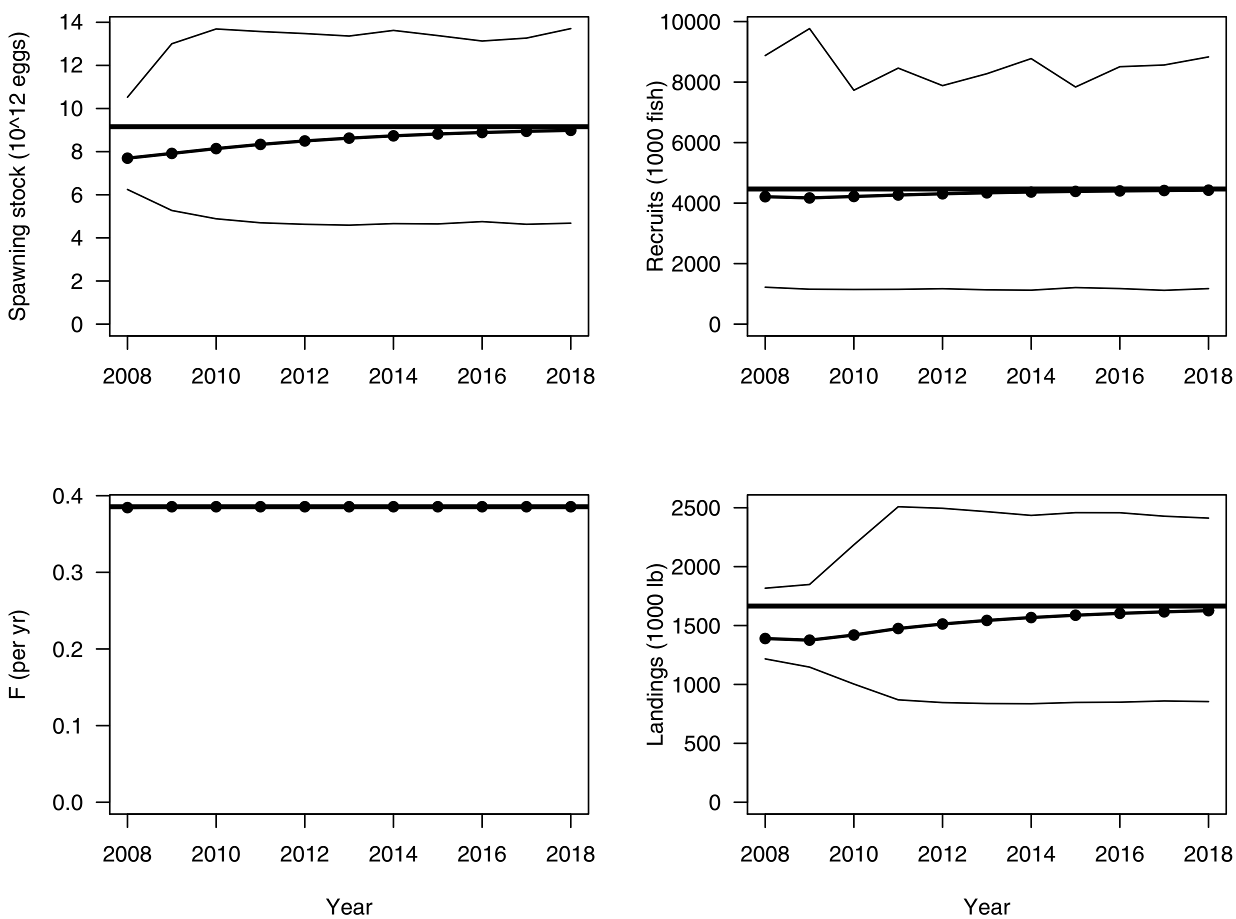


Figure 3.75. Stock reduction analysis time series (30 randomly selected "particles"). Top panel: spawning biomass relative to the unfished level. Bottom panel: observed (open circles) and predicted (lines) population growth rates.

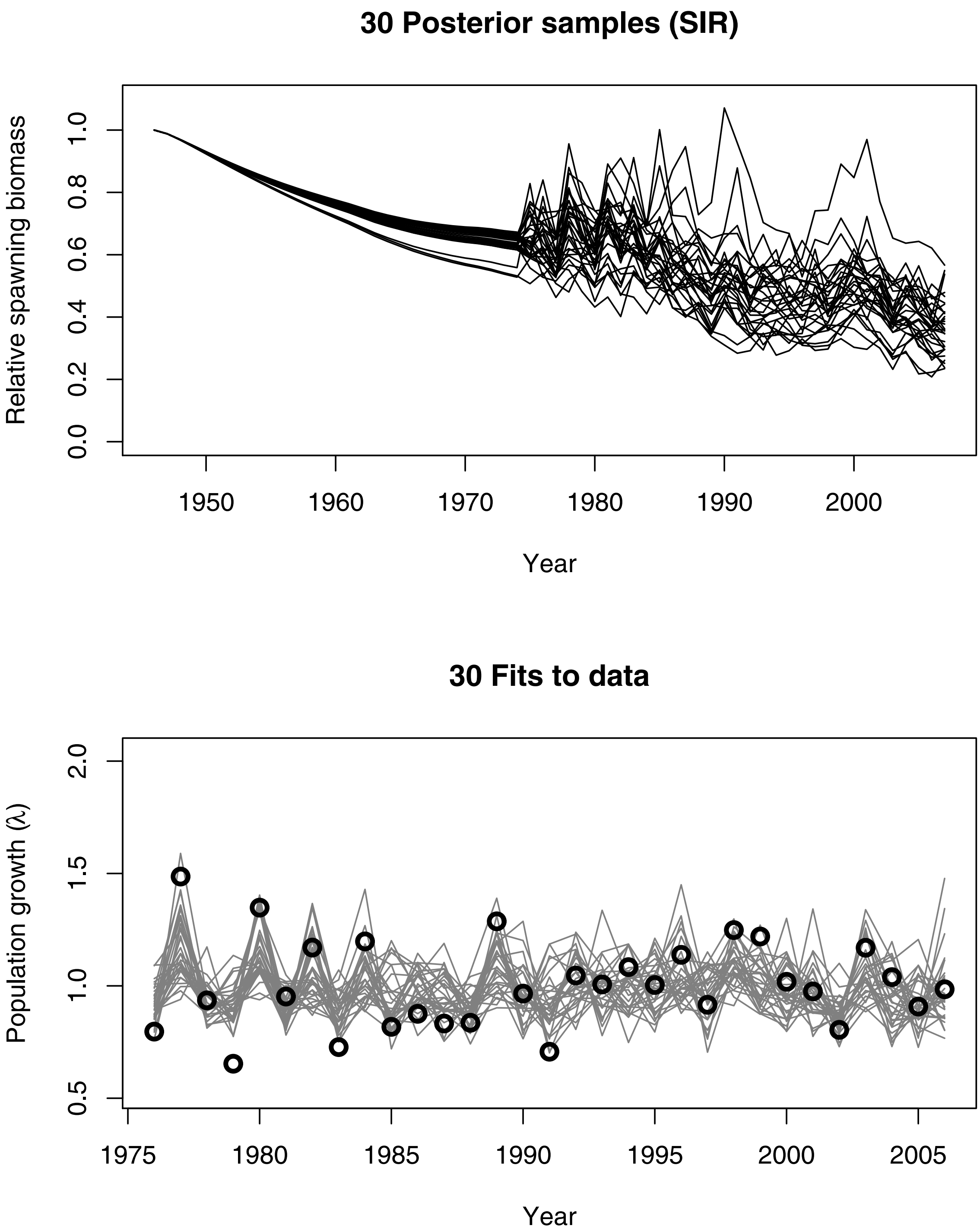


Figure 3.76. Posterior distributions of parameters estimated by stock reduction analysis.

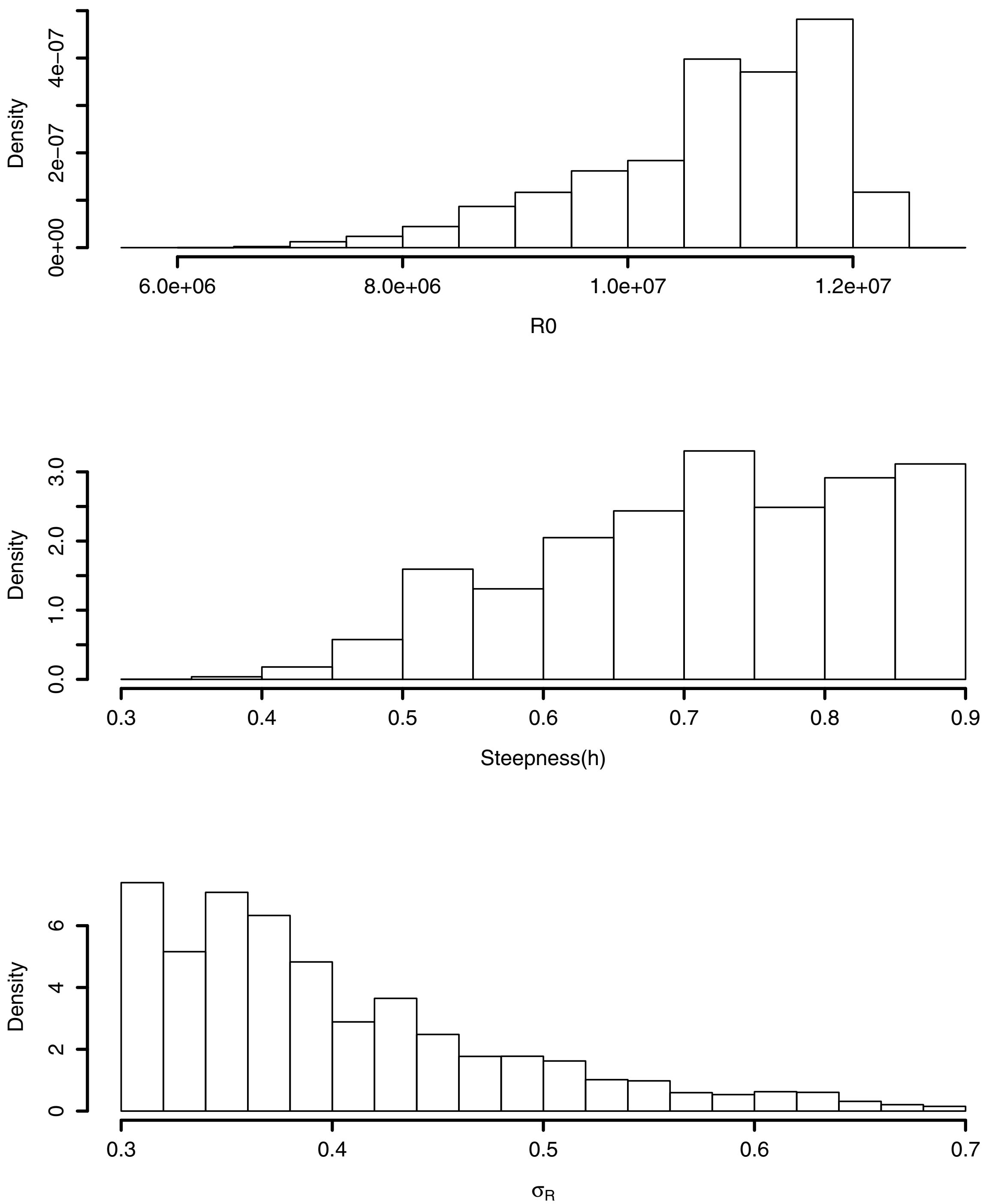


Figure 3.77. Posterior distributions of current (2007) fishery status and stock status from the base run of stock reduction analysis with $\sigma_\lambda = 0.2$.

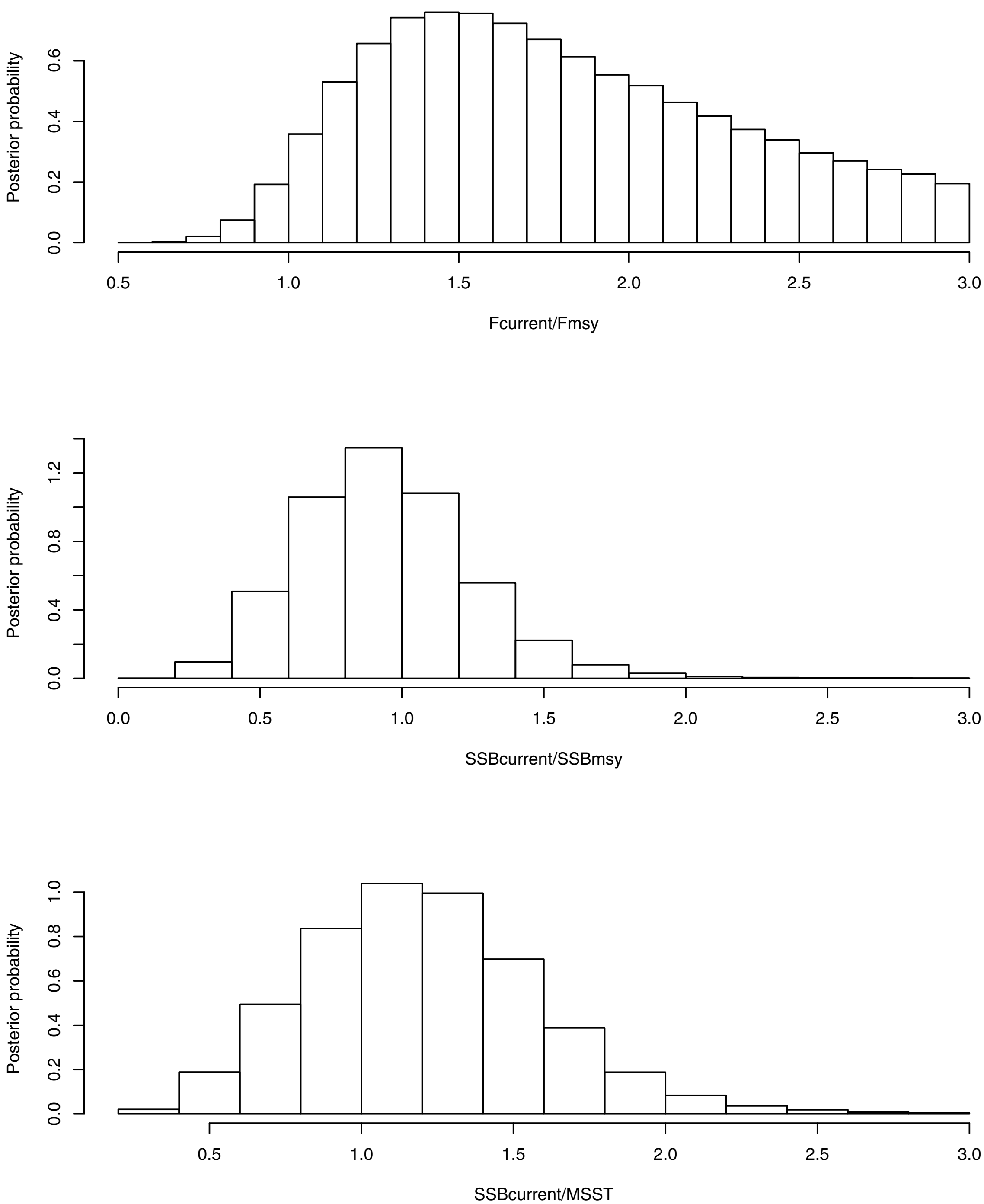


Figure 3.78. Posterior distributions of current (2007) fishery status and stock status from the sensitivity run of stock reduction analysis with $\sigma_\lambda = 0.05$.

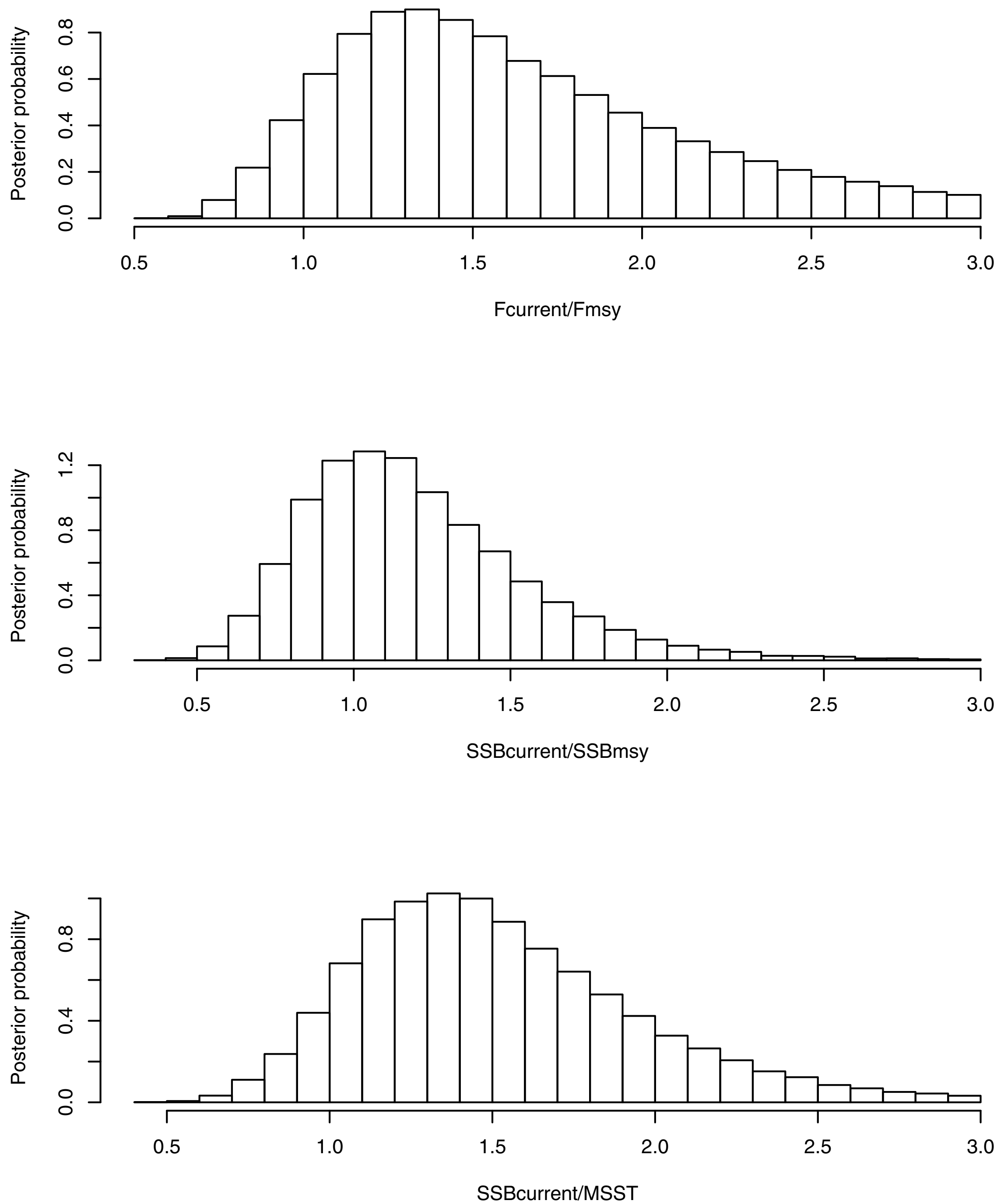


Figure 3.79. Posterior distributions of current (2007) fishery status and stock status from the sensitivity run of stock reduction analysis with $\sigma_\lambda = 0.35$.

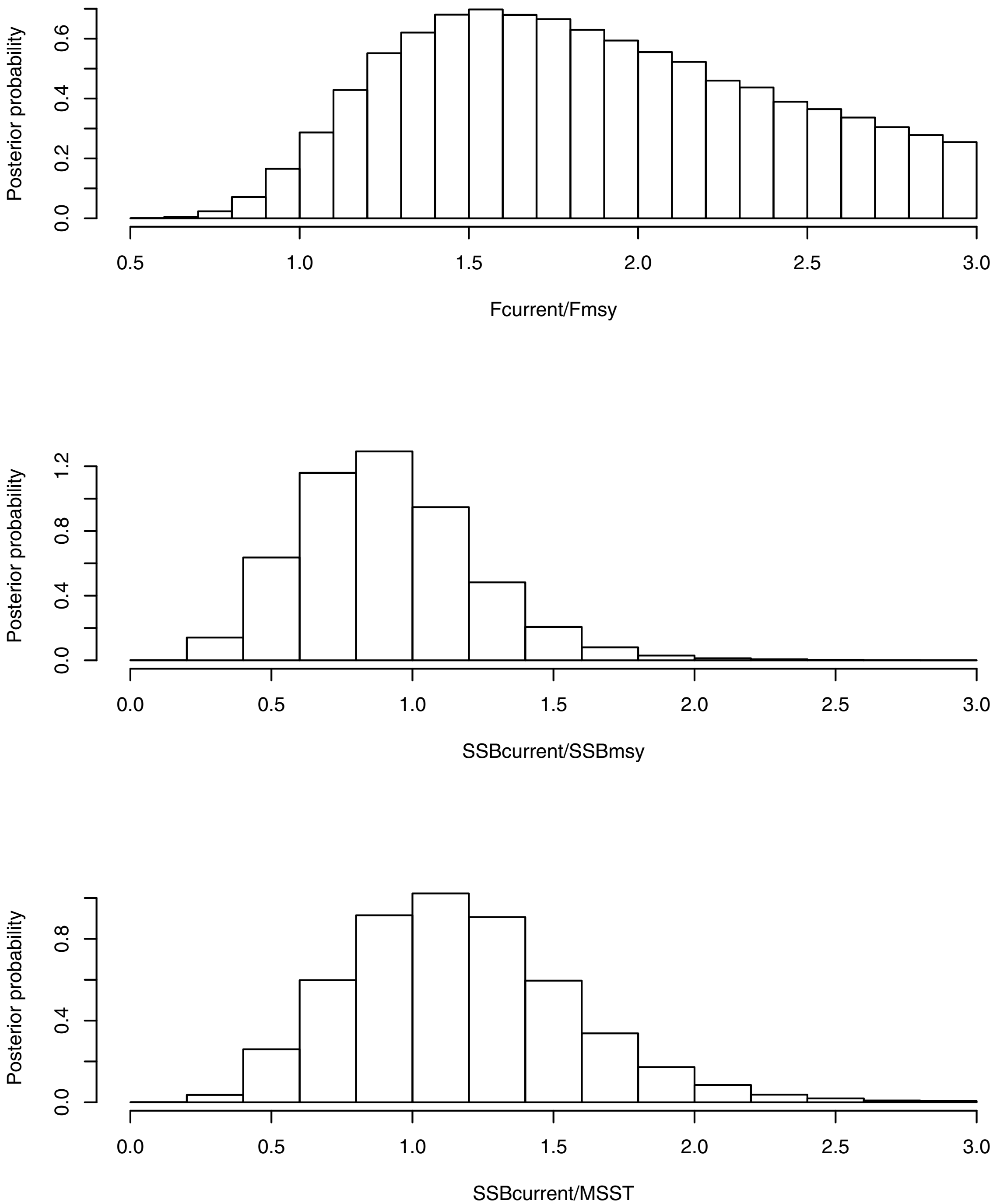


Figure 3.80. Surplus production model fits to the combined index: Observed (solid circles) and predicted CPUE (lines).

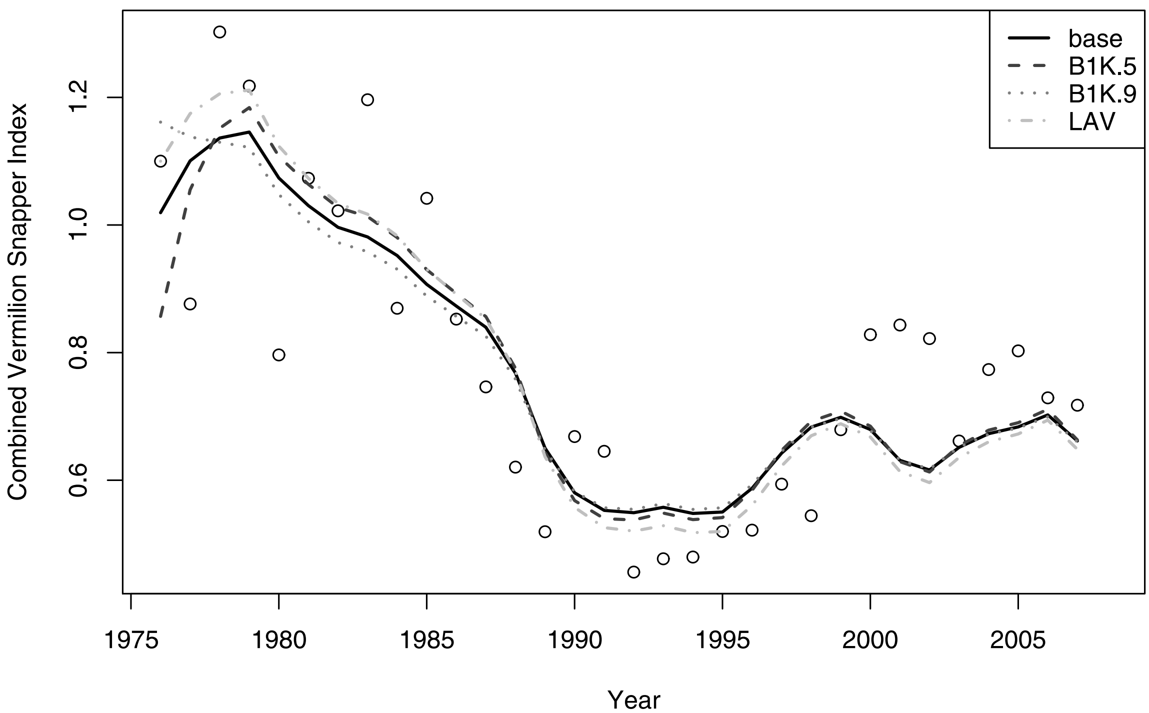


Figure 3.81. Base surplus production model estimates of biomass and fishing mortality rate relative to their thresholds. Dotted lines represent 80% approximate confidence limits from bootstrap analysis.

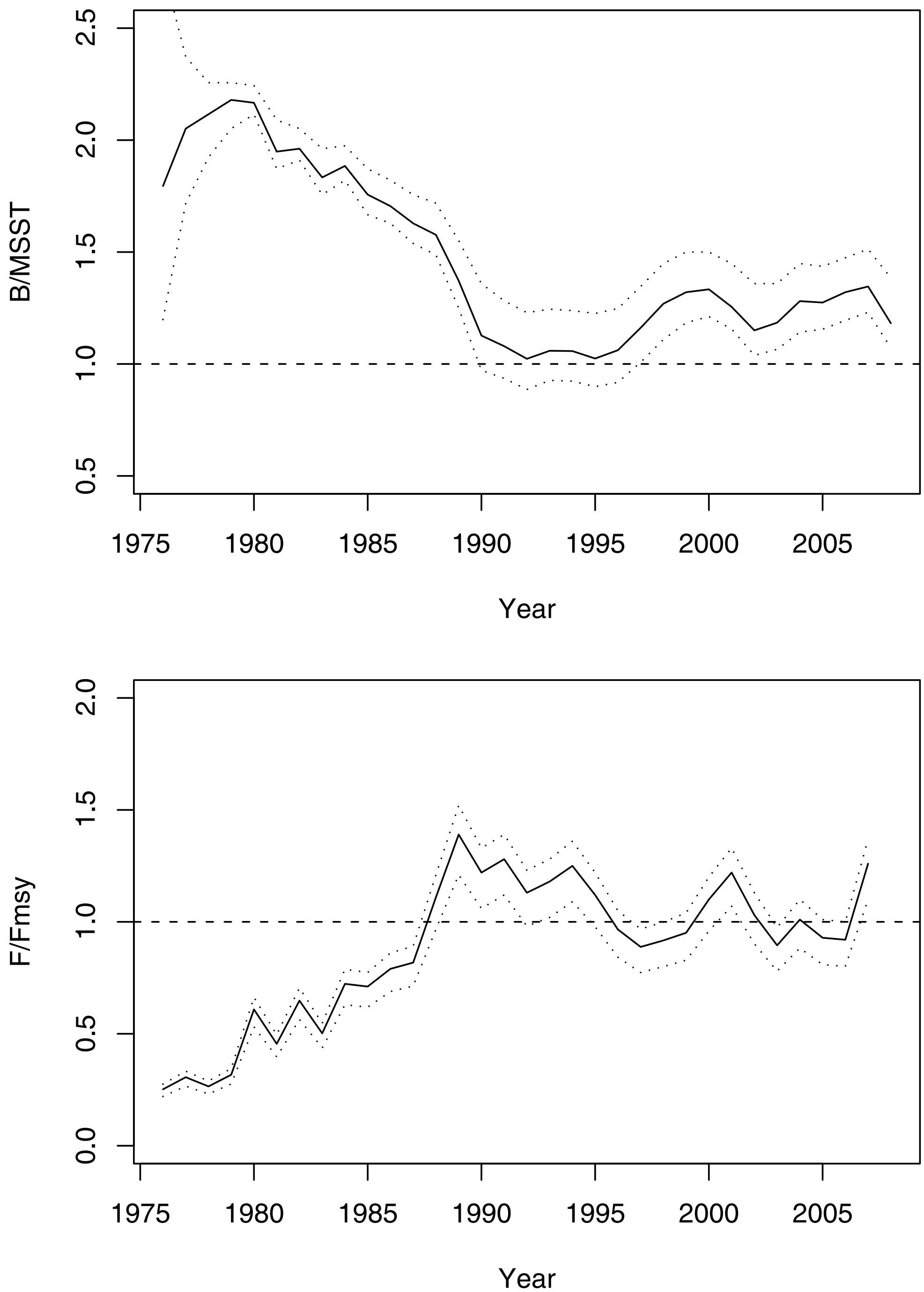
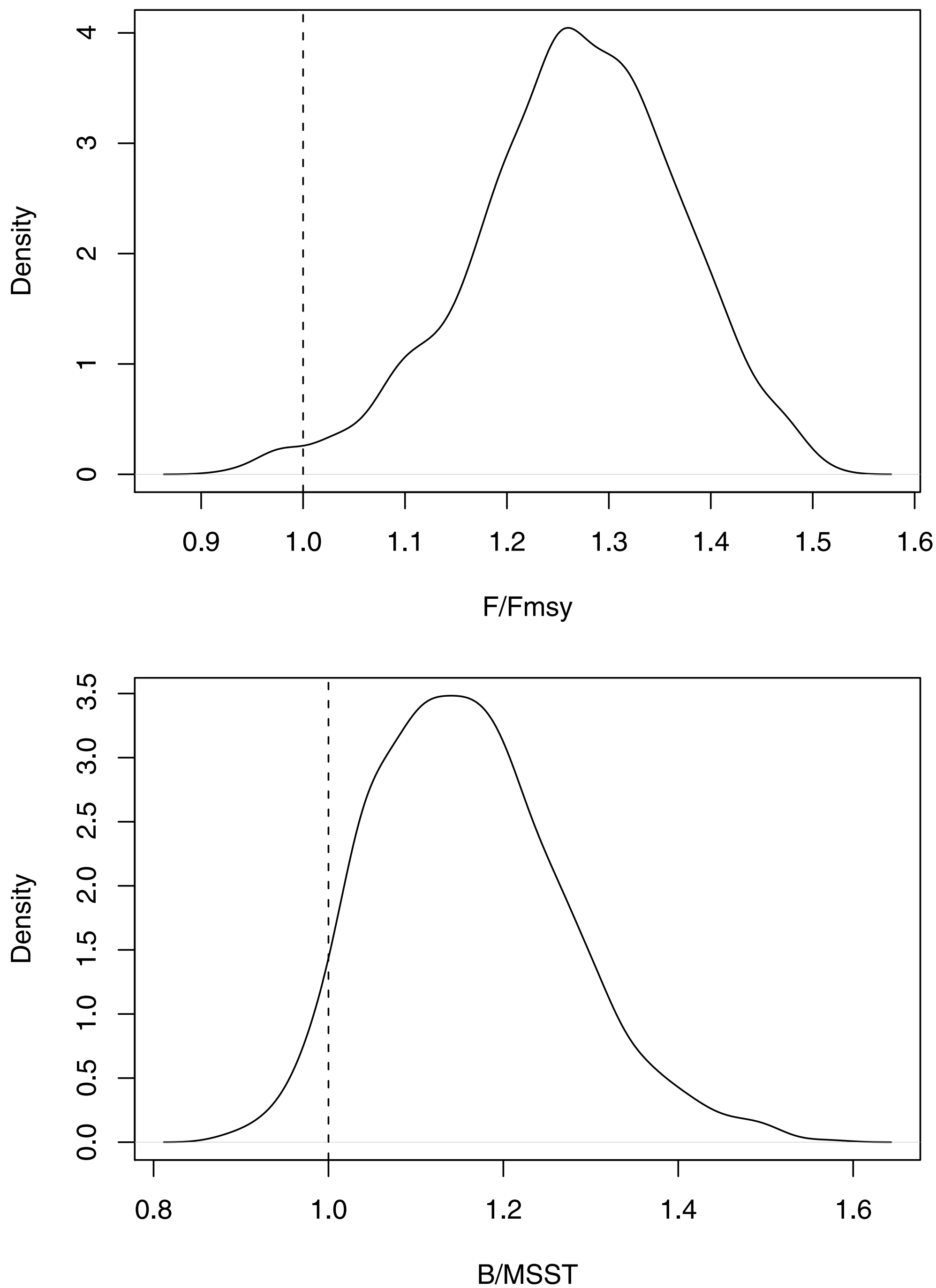


Figure 3.82. Bootstrap distributions of current (2007) fishery status and stock status from the base surplus production model.



Appendix A Abbreviations and symbols

Table A.1. Acronyms, abbreviations, and mathematical symbols used in this report

Symbol	Meaning
ABC	Acceptable Biological Catch
AW	Assessment Workshop (here, for vermilion snapper)
ASY	Average Sustainable Yield
B	Total biomass of stock, conventionally on January 1r
CPUE	Catch per unit effort; used after adjustment as an index of abundance
CV	Coefficient of variation
DW	Data Workshop (here, for vermilion 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 vermilion snapper as $(1 - M)\text{SSB}_{\text{MSY}} = 0.7\text{SSB}_{\text{MSY}}$.
MSY	Maximum sustainable yield (per year)
mt	Metric ton(s). One mt is 1000 kg, or about 2205 lb.
N	Number of fish in a stock, conventionally on January 1
NC	State of North Carolina
NMFS	National Marine Fisheries Service, same as "NOAA Fisheries Service"
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
OY	Optimum yield; SFA specifies that OY ≤ MSY.
PSE	Proportional standard error
R	Recruitment
SAFMC	South Atlantic Fishery Management Council (also, Council)
SC	State of South Carolina
SCDNR	Department of Natural Resources of SC
SEDAR	SouthEast Data Assessment and Review process
SFA	Sustainable Fisheries Act; the Magnuson–Stevens Act, as amended
SL	Standard length (of a fish)
SPR	Spawning potential ratio
SRA	Stock reduction analysis
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 AD Model Builder implementation of catch-at-age assessment model

```
# Number of parameters = 414  Objective function value = 8525.07  Maximum gradient component = 0.0228749
# log_len_cv:
-1.54233885366
# log_R0:
15.2800867133
# log_dev_N_rec:
 -1.40634287477 -1.12666817699 1.03194081817 -1.09971373649 -0.782387203161 -0.154325867076 0.0563106492503
  0.798286918891 0.0294935454967 0.501948793732 0.466460372812 -0.289658080219 0.212608992613 -0.344143125230
   1.52157171742 -1.44785929172 -0.0212248615813 1.08706124949 -1.13710430828 0.448106443969 -0.329011242489
    0.321824430476 0.491690732315 0.478728361275 0.109543620858 0.452681398800 0.432028018035 -0.178328571078
     -0.166055636905 -0.0345397312634 0.0861921958435 -0.00911555220090
# R_autocorr:
1.32794094110e-07
# selpar_L50_CVT:
1.61406419623
# selpar_L502_CVT:
3.22300170419
# selpar_slope2_CVT:
0.467978570967
# selpar_L50_cHAL1:
4.91377149116
# selpar_slope_cHAL1:
11.9995144747
# selpar_L50_cHAL2:
2.98884095859
# selpar_Age2_cHAL_D2:
9.44191325125e-08
# selpar_L50_HB1:
1.23819387272
# selpar_slope_HB1:
0.782700146897
# selpar_L50_HB2:
3.01042514578
# selpar_L50_HB3:
2.01880799602
# selpar_L50_HB4:
1.96848916245
# selpar_Age2_HB_D3:
0.999999869946
# selpar_Age2_HB_D4:
0.999999660158
# selpar_L50_MRFSS3:
2.23763584185
# selpar_L50_MRFSS4:
2.92567213513
# selpar_slope_MRFSS4:
0.500000013609
# log_q_FST:
-15.3102640838
# log_q_CVT:
-15.6913353996
# log_q_HAL:
-8.73989410747
# log_q_HB:
-16.0011315319
# log_q_MRFSS:
-15.6427535345
# log_avg_F_cHAL:
-3.46785794414
# log_F_dev_cHAL:
 -7.55456073244 -5.66798754609 -5.32693357914 -2.90651536051 -3.46710074695 -2.78617842577 -3.89378701940
  -2.69735325493 -4.54504931614 -3.10098761598 -2.27485513164 -2.28168397506 -2.74711850741 -1.51475876054
   -1.46644514444 -1.22834684570 -0.888190913510 -0.260136239106 -0.260724185940 0.0196388916920 0.287479725052
```

```
    0.552920882479 0.828052116302 1.07054717705 1.26353690694 1.37993153021 1.81182002971 2.35760468813
     2.63453393325 2.26082704356 2.59963725859 2.90941758879 3.13955474580 4.07355888859 1.49596665817
      1.51640790275 1.81768939978 1.52951909085 1.30468718940 1.37836128690 1.36439293779 1.61374932061
       2.02394026493 2.24503405175 2.15572777794 1.51398700128 1.81975113679 1.93111797656 1.80664964820 2.16267025085
# log_avg_F_cCMB:
-5.39889151444
# log_F_dev_cCMB:
 -2.93468035022 0.465214433886 -0.192223467491 -0.997808490391 -0.960163393675 1.72047858823 1.86854332882
  -2.65515548909 3.47276476692 5.00101866142 4.13617270728 3.80527593059 2.61382443250 3.20535145860
   1.15529184514 1.15373317962 2.70822869447 3.19046926624 3.41260801587 2.05656234198 4.15383871276
    -4.49497285351 -1.17114690952 -0.830883823937 -2.31661555412 -3.04372128320 -2.62366869710 -2.39394599279
     -1.72486869292 -2.78658349048 -2.04972348928 -2.81837863975 -1.20346371011 -2.25487958009 -3.27929068712
      -2.60115030484 -0.786051464688
# log_avg_F_cHTR:
-3.94965845415
# log_F_dev_cHTR:
 -0.290138314171 0.290138314171
# log_avg_F_HB:
-3.55838977968
# log_F_dev_HB:
 -3.51997788676 -2.78121766442 -2.35320523914 -2.04588998067 -1.80226261312 -1.59747291777 -1.41848636968
  -1.25766143586 -1.11013280897 -0.972661447445 -0.842976925591 -0.719441111979 -0.600831273462 -0.486236937338
   -0.375328659608 -0.274009702360 -0.191265913800 -0.133659176617 -0.103889661678 -0.105065125862
    -0.128865479927 -0.163269541047 -0.195676162003 -0.211624291516 -0.199442186497 -0.0397778504718
     -0.0808317839303 0.0203062889240 0.155574287233 0.128206836569 0.0615699545307 0.296049006970
      0.282186097155 0.160537682866 0.0991260021748 0.473744249869 0.435075059627 0.268996022156
       0.719097368920 0.698924014870 1.13053946988 1.21649701022 1.30502371230 0.841653049547 0.953809860790
        1.06964748028 0.902627743562 1.30963196832 0.987165061023 0.938064288393 1.10407954863 1.09722428968
         0.724348382632 0.796481733155 0.858699031970 0.690076020148 0.323311551855 0.649003086484 0.649070324397
          0.984691683161 1.38012197924
# log_avg_F_MRFSS:
-4.43503606832
# log_F_dev_MRFSS:
 -3.12787453529 -2.48721776374 -2.09963554545 -1.82090259686 -1.60325366539 -1.42483715058 -1.27389104188
  -1.14326816318 -1.02837679985 -0.926042321721 -0.834029461009 -0.750636028937 -0.674582353704 -0.604867550909
   -0.539657861951 -0.478660219893 -0.425569690859 -0.382893074285 -0.349305718716 -0.325505508299
    -0.310417145280 -0.301922862612 -0.298773582963 -0.299808985778 -0.302242643891 -0.303449007018
     -0.304970480300 -0.307398536634 -0.306799346870 -0.168488757691 -0.0167052711279 -0.224984278037
      -0.116392743703 0.0229659995104 0.118699613344 0.898251577223 1.04056249797 1.26781806298 1.36561499335
       1.02490694588 0.721993289068 0.673287858091 0.999165553610 0.484244634366 0.537396001841 1.01779584773
        0.744656689189 0.726309909801 0.387628887177 0.520533780863 0.731197143207 0.929600889275 1.00585184991
         1.18990168994 1.22892708785 1.26852271755 1.22250516631 1.21198756137 1.25658007618 1.40653852616 1.55991584465
# log_avg_F_cHAL_D:
-4.26775030998
# log_F_dev_cHAL_D:
 -1.05589304924 0.124570248828 0.263107009610 -0.343322382257 0.783741288718 0.272020231363 0.426608539064
  -0.00223718447193 -0.0574827663670 0.118575232005 0.996845518207 -0.109946621838 -0.818690472286 -0.0303484995084
   -0.354835939753 -0.212711152068
# log_avg_F_HB_D:
-6.42440235899
# log_F_dev_HB_D:
 -3.57214302183 -2.83371542076 -2.40627844550 -2.09988762281 -1.85787260086 -1.65497114649 -1.47838168073
  -1.32006292929 -1.17537480816 -1.04099884804 -0.914707456208 -0.794747952728 -0.680032212620 -0.569555236015
   -0.464320616398 -0.363655934392 -0.276940522727 -0.231833503301 -0.214643882518 -0.220673326226
    -0.248577720024 -0.286857293745 -0.322577793092 -0.340847916479 -0.330942421318 -0.174400615042 -0.215669715979
     -0.118031221842 0.00922643884273 -0.163296942958 0.150713020218 1.23055081800 -0.268596299701 -0.268475139655
      0.658139399487 0.741978138464 0.532138626653 -0.305145097511 0.306699355354 0.324426059541 0.514452809682
       0.903742245148 0.924734467108 1.11518549782 -0.109466337218 0.908327398268 1.53652721855 0.727370762823
        1.08363816055 1.18683017757 1.32063615691 1.20817476883 1.18166517329 1.24761651556 1.40574513053
         1.12788159347 0.745428182318 1.45857664039 1.19066702130 1.56948690134 2.01312300414
# log_avg_F_MRFSS_D:
-6.16461811390
# log_F_dev_MRFSS_D:
 -3.06052788912 -2.41988487813 -2.03303169004 -1.75527913438 -1.53929468468 -1.36273666431 -1.21404230280
  -1.08600328851 -0.974010173436 -0.874783375175 -0.786090746162 -0.706330025969 -0.634140023384 -0.568557821986
   -0.508981771833 -0.448665636481 -0.391591750010 -0.361412410878 -0.340401137899 -0.321482371804 -0.310496520078
    -0.305850167277 -0.306034982518 -0.309372327760 -0.314104519193 -0.318424031383 -0.320176339642 -0.326111090116
     -0.333510055473 -0.340341826763 0.192103339170 0.829150001021 -0.547493949198 -0.286359286591 1.08856812673
      1.09602829818 0.531210959122 -0.448512392628 -0.258529997277 -0.246992546750 -0.372685751402 0.0673191901560
       1.11266295012 1.42405381767 -0.234829080509 0.812780034844 0.993418903015 0.388262597765 1.38111762080
        0.461647881302 0.518225550091 0.831508115634 2.01304233409 1.78682345825 1.51536060372 1.22207533828
```

```
1.65347433969 1.73644463882 1.44369575121 1.39534325159 2.47275554028
```

Appendix C ASPIC Input: Computer input file to run base production model.

```
bot                          Run Mode
'SAFMC Vermilion Snapper SEDAR 17 (2007) Landings and Combined Indices'
LOGISTIC EFT SSE       Modeltype, conditioning, loss fn
112                          Verbosity
1000                          N Bootstraps
1  100000                     Monte Carlo
1d-8                         Conv (fit)
3d-8  6                      Conv (restart), N restarts
1d-4  20                      Conv (F), steps/yr for generalized
8d0                           Max F allowed
0d0                           Weight for B1>K
1                           Number of series
1.0d0                   Series weights
0.5d0                        B1/K guess
2.0e6                        MSY guess
2.0e7                        K guess
5d-8                         q guess
1 1 1 1                    Estimate flags
2e4  2e7                     MSY bounds
1e6  1e9                     K bounds
82184571                     Random seed
32                         Number of years
"Combined Index (1976-2007), Total Ldgs whole pounds"
"CC"

1976 1.100024 583414
1977 0.876247059 563384
1978 1.302483654 726839
1979 1.21780283 811081
1980 0.79635963 1020397
1981 1.073162727 1027764
1982 1.022236607 1392756
1983 1.196282456 1263344
1984 0.869518103 1322975
1985 1.041830508 1557868
1986 0.852481667 1417236
1987 0.746255246 1284662
1988 0.620532419 1448931
1989 0.519260159 1520241
1990 0.668441719 1715556
1991 0.645261923 1736479
1992 0.456011061 1080203
1993 0.476882015 1179460
1994 0.479594779 1258760
1995 0.519694928 1226414
1996 0.521738143 1060844
1997 0.59382993 1110001
1998 0.544400417 1050848
1999 0.679140342 1358523
2000 0.828120946 1916343
2001 0.843245333 2172376
2002 0.821976974 1789222
2003 0.66145     1245289
2004 0.773426282 1648409
2005 0.802713924 1568545
2006 0.729148125 1410770
2007 0.717541358 1897132
```

```
Note: Source of data is file "SM_AW_input.xls" dated 14 aug 2008, prepared by RTC
This input file prepared by RTC, 14 AUG 2008 using the combined index per Paul Conn
```

Appendix D ASPIC Output: Base production model.

```
SAFMC Vermilion Snapper SEDAR 17 (2007) Landings and Combined Indices                                             Page 1
                                                                                      Wednesday, 27 Aug 2008 at 14:40:50
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 5.30)
                                                                                                        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                              EFT conditioning
           Mike.Prager@noaa.gov                                                                      SSE optimization

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

CONTROL PARAMETERS (FROM INPUT FILE)                    Input file: e:\sedar17-vs-aspic\vs2008_b1k_est_eft_2pct.inp
------------------------------------------------------------------------------------------------------------------------
Operation of ASPIC:  Fit logistic (Schaefer) model by direct optimization.
Number of years analyzed:                     32        Number of bootstrap trials:                          0
Number of data series:                         1        Bounds on MSY (min, max):       2.000E+04     2.000E+07
Objective function:                Least squares        Bounds on K (min, max):         1.000E+06     1.000E+09
Relative conv. criterion (simplex):    1.000E-08        Monte Carlo search mode, trials:        1        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:                N/A


PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS)                                              error code   0
------------------------------------------------------------------------------------------------------------------------
Normal convergence
Number of restarts required for convergence:      8


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(0)   Penalty for B1 > K                     0.000E+00      1          N/A    0.000E+00          N/A
Loss(1)   Combined Index (1950-2006), Total Ldgs 8.052E-01     32    2.684E-02    1.000E+00    1.000E+00        0.704
.................................................................................................
TOTAL OBJECTIVE FUNCTION, MSE, RMSE:          8.05173422E-01         2.876E-02    1.696E-01
Estimated contrast index (ideal = 1.0):               0.4523         C* = (Bmax-Bmin)/K
Estimated nearness index (ideal = 1.0):               1.0000         N* = 1 - |min(B-Bmsy)|/K


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

B1/K      Starting relative biomass (in 1976)    6.996E-01        5.000E-01    7.912E-01            1            1
MSY       Maximum sustainable yield              1.421E+06        2.000E+06    1.125E+06            1            1
K         Maximum population size                5.160E+06        2.000E+07    6.752E+06            1            1
phi       Shape of production curve (Bmsy/K)     0.5000           0.5000            ----            0            1

--------- Catchability Coefficients by Data Series ---------------
q(1)      Combined Index (1950-2006), Total Ldgs 2.618E-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              1.421E+06                        ----                     ----
Bmsy      Stock biomass giving MSY               2.580E+06                         K/2         K*n**(1/(1-n))
Fmsy      Fishing mortality rate at MSY          5.509E-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(2008)/Bmsy	9.224E-01	----	----
F./Fmsy	Ratio: F(2007)/Fmsy	1.257E+00	----	----
Fmsy/F.	Ratio: Fmsy/F(2007)	7.958E-01	----	----
Y.(Fmsy)	Approx. yield available at Fmsy in 2008	1.311E+06	MSY*B./Bmsy	MSY*B./Bmsy
	...as proportion of MSY	9.224E-01	----	----
Ye.	Equilibrium yield available in 2008	1.413E+06	4*MSY*(B/K-(B/K)**2)	g*MSY*(B/K-(B/K)**n)
	...as proportion of MSY	9.940E-01	----	----

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

fmsy(1)	Combined Index (1950-2006), Total Ldgs	2.104E+06	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	1976	0.139	3.610E+06	3.893E+06	5.834E+05	5.406E+05	1.048E+06	2.521E-01	1.399E+00
2	1977	0.168	4.117E+06	4.203E+06	5.634E+05	7.076E+05	8.579E+05	3.056E-01	1.596E+00
3	1978	0.146	4.268E+06	4.340E+06	7.268E+05	6.341E+05	7.594E+05	2.652E-01	1.654E+00
4	1979	0.174	4.393E+06	4.375E+06	8.111E+05	7.630E+05	7.325E+05	3.165E-01	1.703E+00
5	1980	0.335	4.363E+06	4.100E+06	1.020E+06	1.376E+06	9.240E+05	6.090E-01	1.691E+00
6	1981	0.251	3.911E+06	3.935E+06	1.028E+06	9.867E+05	1.029E+06	4.551E-01	1.516E+00
7	1982	0.357	3.953E+06	3.805E+06	1.393E+06	1.358E+06	1.099E+06	6.475E-01	1.532E+00
8	1983	0.277	3.695E+06	3.748E+06	1.263E+06	1.036E+06	1.130E+06	5.019E-01	1.432E+00
9	1984	0.398	3.788E+06	3.636E+06	1.323E+06	1.449E+06	1.182E+06	7.231E-01	1.468E+00
10	1985	0.392	3.521E+06	3.464E+06	1.558E+06	1.356E+06	1.254E+06	7.107E-01	1.365E+00
11	1986	0.435	3.419E+06	3.334E+06	1.417E+06	1.451E+06	1.299E+06	7.901E-01	1.325E+00
12	1987	0.451	3.268E+06	3.207E+06	1.285E+06	1.446E+06	1.337E+06	8.181E-01	1.267E+00
13	1988	0.611	3.159E+06	2.933E+06	1.449E+06	1.793E+06	1.392E+06	1.110E+00	1.225E+00
14	1989	0.767	2.758E+06	2.484E+06	1.520E+06	1.904E+06	1.415E+06	1.391E+00	1.069E+00
15	1990	0.672	2.269E+06	2.216E+06	1.716E+06	1.489E+06	1.393E+06	1.220E+00	8.794E-01
16	1991	0.705	2.172E+06	2.111E+06	1.736E+06	1.487E+06	1.374E+06	1.279E+00	8.420E-01
17	1992	0.620	2.059E+06	2.097E+06	1.080E+06	1.301E+06	1.372E+06	1.126E+00	7.981E-01
18	1993	0.648	2.130E+06	2.129E+06	1.179E+06	1.379E+06	1.378E+06	1.175E+00	8.256E-01
19	1994	0.687	2.129E+06	2.093E+06	1.259E+06	1.438E+06	1.371E+06	1.247E+00	8.252E-01
20	1995	0.618	2.062E+06	2.101E+06	1.226E+06	1.298E+06	1.372E+06	1.122E+00	7.991E-01
21	1996	0.532	2.136E+06	2.243E+06	1.061E+06	1.194E+06	1.396E+06	9.663E-01	8.278E-01
22	1997	0.489	2.338E+06	2.454E+06	1.110E+06	1.201E+06	1.417E+06	8.884E-01	9.062E-01
23	1998	0.505	2.554E+06	2.609E+06	1.051E+06	1.319E+06	1.421E+06	9.174E-01	9.900E-01
24	1999	0.524	2.656E+06	2.668E+06	1.359E+06	1.398E+06	1.420E+06	9.507E-01	1.030E+00
25	2000	0.606	2.678E+06	2.595E+06	1.916E+06	1.572E+06	1.421E+06	1.100E+00	1.038E+00
26	2001	0.675	2.527E+06	2.411E+06	2.172E+06	1.626E+06	1.414E+06	1.224E+00	9.794E-01
27	2002	0.570	2.315E+06	2.353E+06	1.789E+06	1.341E+06	1.410E+06	1.034E+00	8.974E-01
28	2003	0.493	2.385E+06	2.488E+06	1.245E+06	1.227E+06	1.419E+06	8.947E-01	9.243E-01
29	2004	0.558	2.577E+06	2.570E+06	1.648E+06	1.434E+06	1.421E+06	1.013E+00	9.989E-01
30	2005	0.512	2.564E+06	2.611E+06	1.569E+06	1.336E+06	1.421E+06	9.287E-01	9.939E-01
31	2006	0.507	2.650E+06	2.682E+06	1.411E+06	1.359E+06	1.419E+06	9.195E-01	1.027E+00
32	2007	0.692	2.710E+06	2.526E+06	1.897E+06	1.749E+06	1.419E+06	1.257E+00	1.050E+00
33	2008		2.380E+06						9.224E-01

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RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED) Combined Index (1950-2006), Total Ldgs w

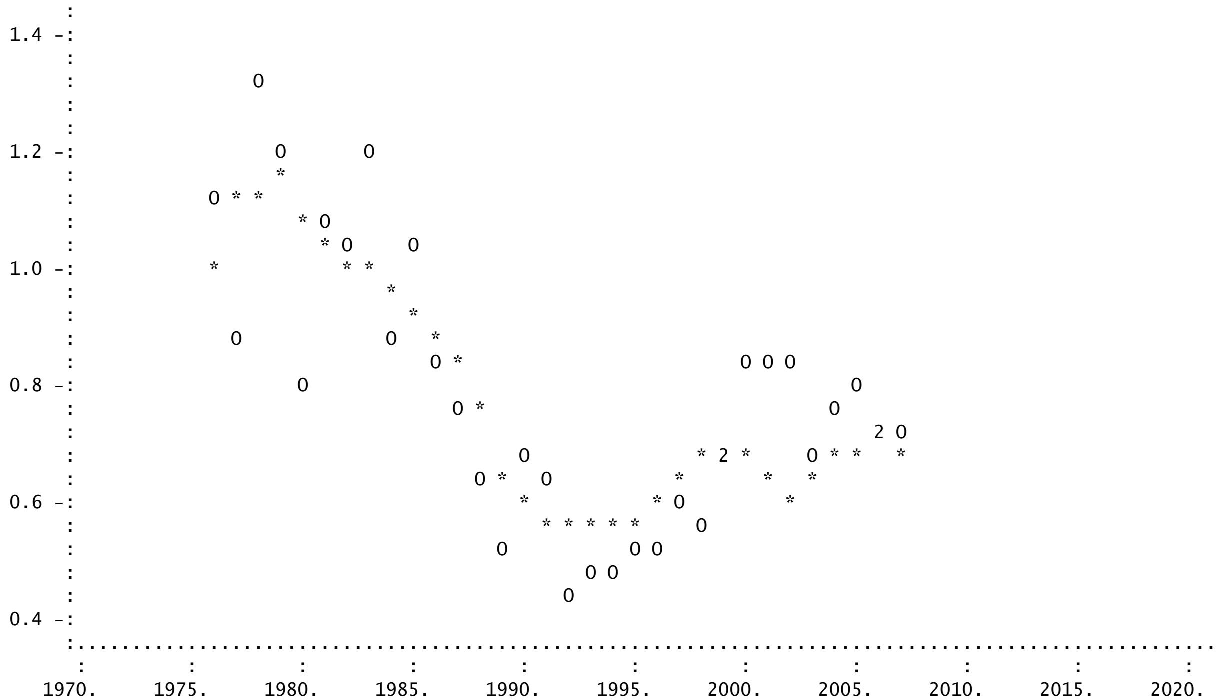
Data type CC: CPUE-catch series Series weight: 1.000

Obs	Year	Observed CPUE	Estimated CPUE	Estim F	Observed yield	Model yield	Resid in log yield	Statist weight
1	1976	1.100E+00	1.019E+00	0.1389	5.834E+05	5.406E+05	0.07623	1.000E+00
2	1977	8.762E-01	1.101E+00	0.1683	5.634E+05	7.076E+05	-0.22794	1.000E+00
3	1978	1.302E+00	1.136E+00	0.1461	7.268E+05	6.341E+05	0.13650	1.000E+00
4	1979	1.218E+00	1.146E+00	0.1744	8.111E+05	7.630E+05	0.06106	1.000E+00
5	1980	7.964E-01	1.074E+00	0.3355	1.020E+06	1.376E+06	-0.29871	1.000E+00
6	1981	1.073E+00	1.030E+00	0.2508	1.028E+06	9.867E+05	0.04073	1.000E+00
7	1982	1.022E+00	9.964E-01	0.3567	1.393E+06	1.358E+06	0.02561	1.000E+00

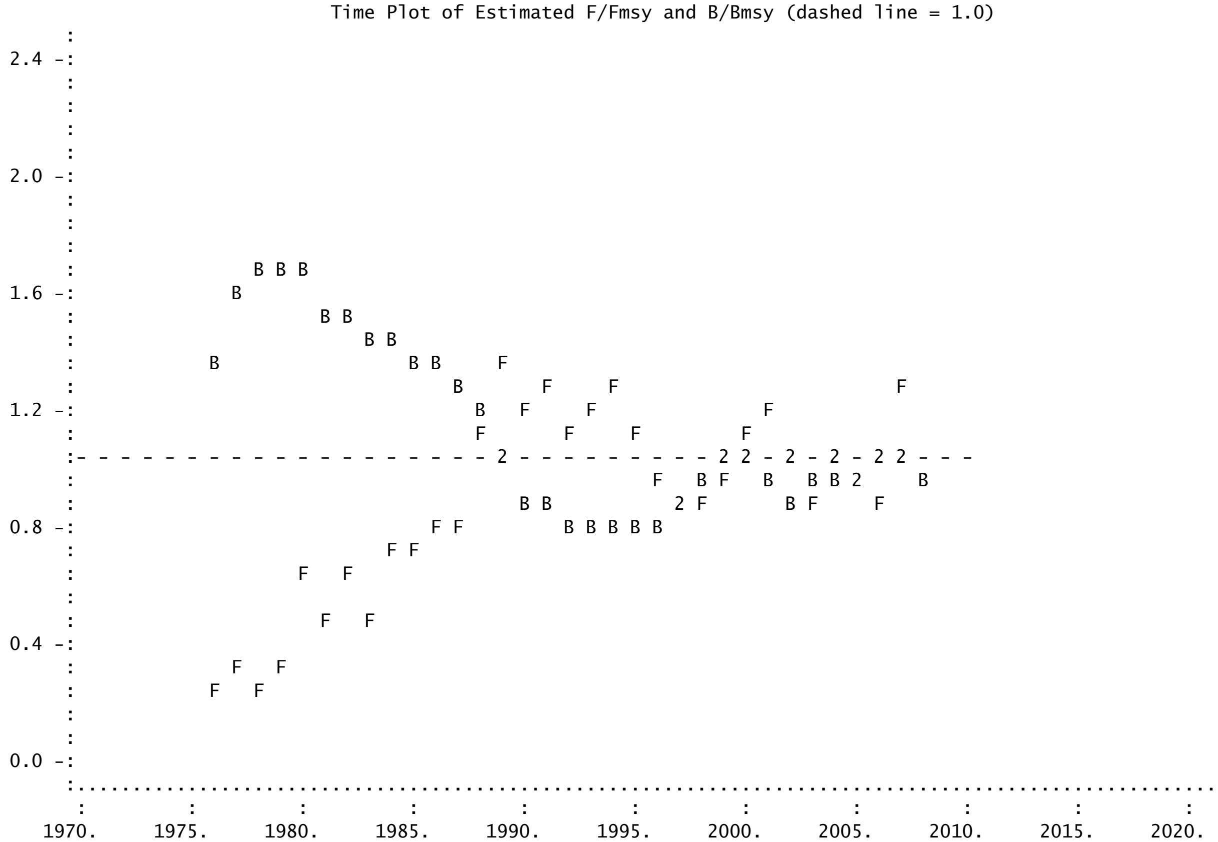
8	1983	1.196E+00	9.813E-01	0.2765	1.263E+06	1.036E+06	0.19810	1.000E+00
9	1984	8.695E-01	9.521E-01	0.3984	1.323E+06	1.449E+06	-0.09074	1.000E+00
10	1985	1.042E+00	9.070E-01	0.3915	1.558E+06	1.356E+06	0.13860	1.000E+00
11	1986	8.525E-01	8.730E-01	0.4353	1.417E+06	1.451E+06	-0.02374	1.000E+00
12	1987	7.463E-01	8.397E-01	0.4507	1.285E+06	1.446E+06	-0.11796	1.000E+00
13	1988	6.205E-01	7.680E-01	0.6114	1.449E+06	1.793E+06	-0.21321	1.000E+00
14	1989	5.193E-01	6.504E-01	0.7666	1.520E+06	1.904E+06	-0.22514	1.000E+00
15	1990	6.684E-01	5.804E-01	0.6720	1.716E+06	1.489E+06	0.14131	1.000E+00
16	1991	6.453E-01	5.527E-01	0.7046	1.736E+06	1.487E+06	0.15477	1.000E+00
17	1992	4.560E-01	5.491E-01	0.6202	1.080E+06	1.301E+06	-0.18571	1.000E+00
18	1993	4.769E-01	5.576E-01	0.6476	1.179E+06	1.379E+06	-0.15632	1.000E+00
19	1994	4.796E-01	5.479E-01	0.6872	1.259E+06	1.438E+06	-0.13319	1.000E+00
20	1995	5.197E-01	5.502E-01	0.6179	1.226E+06	1.298E+06	-0.05695	1.000E+00
21	1996	5.217E-01	5.874E-01	0.5324	1.061E+06	1.194E+06	-0.11847	1.000E+00
22	1997	5.938E-01	6.425E-01	0.4894	1.110E+06	1.201E+06	-0.07873	1.000E+00
23	1998	5.444E-01	6.833E-01	0.5054	1.051E+06	1.319E+06	-0.22718	1.000E+00
24	1999	6.791E-01	6.986E-01	0.5238	1.359E+06	1.398E+06	-0.02831	1.000E+00
25	2000	8.281E-01	6.794E-01	0.6059	1.916E+06	1.572E+06	0.19789	1.000E+00
26	2001	8.432E-01	6.312E-01	0.6745	2.172E+06	1.626E+06	0.28969	1.000E+00
27	2002	8.220E-01	6.160E-01	0.5699	1.789E+06	1.341E+06	0.28842	1.000E+00
28	2003	6.614E-01	6.515E-01	0.4930	1.245E+06	1.227E+06	0.01519	1.000E+00
29	2004	7.734E-01	6.729E-01	0.5581	1.648E+06	1.434E+06	0.13919	1.000E+00
30	2005	8.027E-01	6.835E-01	0.5116	1.569E+06	1.336E+06	0.16071	1.000E+00
31	2006	7.291E-01	7.023E-01	0.5066	1.411E+06	1.359E+06	0.03746	1.000E+00
32	2007	7.175E-01	6.615E-01	0.6923	1.897E+06	1.749E+06	0.08135	1.000E+00

```
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 1
                    -1       -0.75     -0.5      -0.25       0       0.25      0.5       0.75       1
                     |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    -------------------------------------------------------------------------------------
1976     0.0762                                              |===
1977    -0.2279                                     =========|
1978     0.1365                                              |=====
1979     0.0611                                              |==
1980    -0.2987                                  ============|
1981     0.0407                                              |==
1982     0.0256                                              |=
1983     0.1981                                              |========
1984    -0.0907                                          ====|
1985     0.1386                                              |======
1986    -0.0237                                             =|
1987    -0.1180                                         =====|
1988    -0.2132                                     =========|
1989    -0.2251                                     =========|
1990     0.1413                                              |======
1991     0.1548                                              |======
1992    -0.1857                                       =======|
1993    -0.1563                                        ======|
1994    -0.1332                                         =====|
1995    -0.0569                                            ==|
1996    -0.1185                                         =====|
1997    -0.0787                                           ===|
1998    -0.2272                                     =========|
1999    -0.0283                                             =|
2000     0.1979                                              |========
2001     0.2897                                              |============
2002     0.2884                                              |============
2003     0.0152                                              |=
2004     0.1392                                              |======
2005     0.1607                                              |======
2006     0.0375                                              |=
2007     0.0813                                              |===
                   -------------------------------------------------------------------------------------
SAFMC Vermilion Snapper SEDAR 17 (2007) Landings and Combined Indices                                       Page  4

                Observed (O) and Estimated (*) CPUE for Data Series # 1 -- Combined Index (1950-2006), Total Ldgs w
           :
      1.6 -:
           :
           :
           :
```



Time Plot of Estimated F/Fmsy and B/Bmsy (dashed line = 1.0)



Elapsed time: 0 hours, 0 minutes, 3 seconds.

4 Submitted Comments

4.1 None were received

Section II. Research Recommendations

Contents

1. Data Workshop

1.1 Recommendations of the Life History Work Group

1. Ages provided for future assessments should be advanced when appropriate (i.e., during months when annuli are being formed) so fish can be assigned to the correct year class. If advanced ages cannot be provided, data should include assessment of otolith edge type. Classification schemes for edge type and quality of the otolith/section have been developed by the MARMAP program at SCDNR and are currently used by MARMAP and NMFS Beaufort.

2. Conduct inter-lab comparisons of age readings from test sets of otoliths in preparation for any future stock assessments.

3. Obtain adequate data to determine gutted to whole weight relationships.

4. To ensure more accurate estimates of t0, increase efforts to collect age 0 specimens for use in estimating von Bertalanffy (VB) growth parameters.

1.2 Recommendations of the Commercial Work Group

1. Expand TIP sampling to better cover all statistical strata
   - Predominantly from Florida and by gillnet & castnet gears
   - In that sense, we have decent coverage for lengths

2. Trade off with lengths versus ages, need for more ages (i.e.,hard parts)

3. Need to address issue of fish retained for bait (undersized) or used for food by crew.(how to capture in landings)

1.3 Recommendations of the Recreational Work Group

There was insufficient time for this topic to be addressed by the workgroup during the data workshop.

1.4 Recommendations of the Indices Work Group

1. Investigate whether catchability varies as a function of fish density and/or environmental conditions.

2. Investigate how temporal changes in migratory patterns may influence indices of abundance (for fishery dependent and fishery independent indices).

3. Investigate the possibility of using models that allow catchability to follow a random walk.

2. Assessment Workshop

2.1 Recommendations of the Assessment Panel

Comprehensive Data and Assessment Archive: A goal of the SEDAR process, as stated in several workshop Terms of Reference, is to properly document all aspects of the data employed in the assessments, the assessments themselves, and the peer review of assessment details and results. While the various workshop reports and data workbooks compile much of the information, concern has been expressed that a full compilation of data manipulations, and programs used to generate the final data used in the assessment is not available following a SEDAR cycle. The concept of a SEDAR Comprehensive Data and Assessment Workshops Archive was proposed by the SEDAR 17 Data Compiler during preparations for the DW. Though the idea was not advanced from the DW as a formal recommendation it was generally taken favorably. An archive could serve as: a single reference for anyone wishing to dig deeper into how data were processed, a reference for future assessments, a backup of final data processing programs or spreadsheets for those who develop them, and continuity in cases of personnel changes for future assessments and updates. When discussed at the AW it was recognized implementation of an archive could have benefits and costs, but that it would require more attention than SEDAR 17 AW participants could give it, and all SEDAR cooperators were not present. The AW recommends that a SEDAR-wide workgroup be convened to identify the pros and cons of a Comprehensive Data and Assessment Archive for each future SEDAR.

Independent Expert on Assessment Panel: The assessment panel recommends that for future SEDAR assessment workshops, a scientist experienced in assessment methods and modeling (such as a CIE reviewer, or a NMFS or state person from outside the region) be provided as a workshop panelist. An independent expert can participate in discussing technical details of the methods used for SEDAR assessments, and assist in decisions related to model configuration during the workshop. In particular, the analysts believe that an independent analyst could contribute fresh information to improve the assessments.

Review and Qualification of Historic Recreational Angler Survey Reports: Pre-MRFSS catch and related effort data from south Atlantic recreational fisheries are very scarce, but are considered valuable to stock assessments, where available. Two reports of the U. S. Fish and Wildlife Service (SEDAR 17-RD13 and SEDAR 17-RD14) and one of the NMFS (SEDAR 17-RD15) characterize south Atlantic salt-water angling effort and success based on recall surveys conducted in 1960, 1965, and 1970, respectively. These references have been viewed in various ways in previous stock assessments performed through the SEDAR process. In SEDAR 2 for South Atlantic black sea bass, these data were not used explicitly in the age-structured modeling, however, with assumptions, were used to extend the time frame for application of the production modeling approach. In SEDAR 15 for South Atlantic red snapper these data were employed by the assessment panel at face value for the three survey years and to interpolate recreational landings before, between, and after survey years. In SEDAR 15 for South Atlantic greater amberjack the review panel agreed with the assessment panel that the survey estimates of recreational landings of “jacks” not be included in the assessment due in part to species identification concerns. For the present assessment the assessment panel has employed the survey data for both stocks under assessment, but considers recall bias on the part of persons surveyed to be a significant factor. Thus they chose to reduce the weight of the estimates in its base runs and explore the effect on the model through sensitivity runs.

A guiding principal of the SEDAR process is consistency in the identification and utilization of data that characterize fishery stocks under assessment and the fisheries that affect the stocks. Because the three pre-MRFSS saltwater angling survey reports have proven of value, and likely will be referenced in future stock assessments, the AW recommends they be reviewed by a group of fishery professionals. The group should include persons knowledgeable in survey design, data collection, and application of survey data to fishery stock assessments. The group's function would be to qualify the three surveys, and others which the group may identify, and provide guidelines that further consistency in their utilization in future stock assessment conducted under the SEDAR process. The review of these reports could be coupled with a review and qualification of commercial and other data to standardize their use in stock assessments, as recommended in the SEDAR 17 data workshop reports.

Avoid Brief Workshop Interims: The panel made a recommendation against scheduling abbreviated SEDAR stock assessments. AW participants felt that an abbreviated schedule could compromise the quality of the assessment.

3. Review Workshop

3.1 Research Recommendations of the Review Panel

The numerous research recommendations from the DW and AW were not explicitly discussed at the RW. Individual panelists reviewed the recommendations and were in broad agreement with the suggestions. However, there is a clear need for the recommendations to be prioritized. Also, the Panel recommended that a proper statistical framework be used for the catch-at-age models. This would allow alternative parameterizations to be evaluated in terms of AIC or some other statistical criteria, and the calculation of standardized residuals (which allows the appropriateness of relative data weightings to be judged).

The AW base model estimates that over-fishing is occurring and that stock size is close to the over-fished threshold. This suggests that the next assessment should be sooner than the normal timeframe for assessment updates.

Section V. Review Workshop Report

Contents

1. Introduction

1.1. Workshop Time and Place

The SEDAR 17 Review Workshop was held at the Hampton Inn in Savannah, Georgia on October 20 through October 24, 2008.

1.2. Terms of Reference

1. Evaluate the adequacy, appropriateness, and application of data used in the assessment*.
2. Evaluate the adequacy, appropriateness, and application of methods used to assess the stock*.
3. Recommend appropriate estimates of stock abundance, biomass, and exploitation*.
4. Evaluate the methods used to estimate population benchmarks and management parameters (*e.g., MSY, Fmsy, Bmsy, MSST, MFMT, or their proxies*); provide estimated values for management benchmarks, a range of ABC, and declarations of stock status*.
5. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status; recommend appropriate estimates of future stock condition* (e.g., exploitation, abundance, biomass).
6. Evaluate the adequacy, appropriateness, and application of methods used to characterize uncertainty in estimated parameters. Provide measures of uncertainty for estimated parameters*. Ensure that the implications of uncertainty in technical conclusions are clearly stated.
7. Ensure that stock assessment results are clearly and accurately presented in the Stock Assessment Report and Advisory Report and that reported results are consistent with Review Panel recommendations**.
8. Evaluate the SEDAR Process. Identify any Terms of Reference which were inadequately addressed by the Data or Assessment Workshops; identify any additional information or assistance which will improve Review Workshops; suggest improvements or identify aspects requiring clarification.
9. Review the research recommendations provided by the Data and Assessment workshops and make any additional recommendations warranted. Clearly indicate the research and monitoring needs that may appreciably improve the reliability of future assessments. Recommend an appropriate interval for the next assessment.
10. Prepare a Peer Review Consensus Summary summarizing the Panel's evaluation of the stock assessment and addressing each Term of Reference. Develop a list of tasks to be completed following the workshop. Complete and submit the Consensus Report within 3 weeks of workshop conclusion.

* The review panel may request additional sensitivity analyses, evaluation of alternative assumptions, and correction of errors identified in the assessments provided by the assessment workshop panel; the review panel may not request a new assessment. Additional details regarding the latitude given the review panel to deviate from assessments provided by the assessment workshop panel are provided in the *SEDAR Guidelines* and the *SEDAR Review Panel Overview and Instructions*.

** The panel shall ensure that corrected estimates are provided by addenda to the assessment report in the event corrections are made in the assessment, alternative model configurations are recommended, or additional analyses are prepared as a result of review panel findings regarding the TORs above.

1.3. List of Participants

SEDAR 17

Stock Assessment Peer Review Workshop
October 20-24, 2008
Savannah, GA

Appointee	Function	Affiliation
Independent Review Panel		
Mr. Gary Shepherd	Chair and Reviewer	NOAA/NMFS
Dr. Noel Cadigan	Reviewer	CIE
Mr. Patrick Cordue	Reviewer	CIE
Dr. Beatriz Roel	Reviewer	CIE
Rapporteur		
Dr. Andi Stephens	Rapporteur - Vermilion Snapper	SEDAR
Presenters and Analytical Team		
Dr. Kyle Shertzer	Lead Analyst and Data Presenter - Vermilion Snapper	SEFSC
Dr. Paul Conn	Lead Analyst and Data Presenter - Spanish Mackerel	SEFSC
Appointed Observers		
Duane Harris	Council Chairman	SAFMC
George Geiger	Council Member	SAFMC
Rick DeVictor	Council Staff Lead – Vermilion Snapper	SAFMC
Gregg Waugh	Council Staff Lead - Spanish Mackerel	SAFMC
Dr. Marcel Reichert	Stock Leader – Vermilion Snapper	SAFMC SSC
Dr. Andi Stephens	Fishery Biologist	SAFMC
Dr. Scott Crosson	Stock Leader – Spanish Mackerel	SAFMC SSC
Ben Hartig	Mackerel AP Chair	Florida Commercial
Coordination		
Dale Theiling	Coordinator	SEDAR
Rachael Lindsay	Administrative Support	SEDAR
Tyree Davis	Information Technology Support	SEFSC

Acronyms

AP	Advisory Panel
CIE	Center for Independent Experts
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
SAFMC	South Atlantic Fishery Management Council
SEDAR	Southeast Data, Assessment, and Review
SEFSC	Southeast Fisheries Science Center
SERO	Southeast Regional Office
SSC	Scientific and Statistical Committee

1.4. List of Review Workshop Working Papers & Documents

SEDAR 17
South Atlantic Vermilion Snapper and South Atlantic Spanish Mackerel
Workshop Document List

Document #	Title	Authors
Documents Prepared for the Data Workshop		
SEDAR17-DW01	South Atlantic Vermilion Snapper Management Information Worksheet	J. McGovern (SERO) R. DeVictor (SAFMC)
SEDAR17-DW02	South Atlantic Spanish Mackerel Management Information Worksheet	J. McGovern (SERO) R. DeVictor (SAFMC)
SEDAR17-DW03	South Atlantic Vermilion Snapper Assessment History	D. Vaughan (SEFSC)
SEDAR17-DW04	South Atlantic Spanish Mackerel Assessment History	D. Vaughan (SEFSC)
SEDAR17-DW05	South Atlantic Vermilion Snapper Commercial Chapter	D. Vaughan (SEFSC)
SEDAR17-DW06	South Atlantic Spanish Mackerel Commercial Chapter	D. Vaughan (SEFSC)
SEDAR17-DW07	A review of Spanish mackerel (*Scomberomorus maculatus)* age data, 1987-2007, Atlantic collections only, from the Panama City Laboratory, SEFSC, NOAA Fisheries Service	C. Palmer, D. DeVries, C. Fioramonti and L. Lombardi-Carlson (SEFSC)
SEDAR17-DW08	Vermilion Snapper Length Frequencies and Condition of Released Fish from At-Sea Headboat Observer Surveys in the South Atlantic, 2004 to	B. Sauls, C. Wilson, D. Mumford, and K. Brennan (SEFSC)

	2007	
SEDAR17-DW09	Development of Conversion Factors for Different Trap Types used by MARMAP since 1978.	P. Harris (MARMAP)
SEDAR17-DW10	Discards of Spanish Mackerel and Vermilion Snapper Calculated for Commercial Vessels with Federal Fishing Permits in the US South Atlantic	K. McCarthy (SEFSC)
SEDAR17-DW11	Standardized catch rates of vermilion snapper from the headboat sector: Sensitivity analysis of the 10-fish-per-angler bag limit	Sustainable Fisheries Branch (SEFSC)
SEDAR17-DW12	Estimation of Spanish mackerel and vermilion snapper bycatch in the shrimp trawl fishery in the South Atlantic (SA)	K. Andrews (SEFSC)
	Documents Prepared for the Assessment Workshop	
SEDAR17-AW01	SEDAR 17 South Atlantic Vermilion Snapper Stock Assessment Model	SEDAR 17
SEDAR17-AW02	SEDAR 17 South Atlantic Spanish Mackerel Stock Assessment Model	SEDAR 17
SEDAR17-AW03	Development of an aging error matrix for the vermilion snapper catch-at-age stock assessment model	E. Williams (SEFSC)
SEDAR17-AW04	Catch curve analysis of age composition data for Spanish mackerel	E. Williams (SEFSC)
SEDAR17-AW05	Catch curve analysis of age composition data for vermilion snapper	E. Williams (SEFSC)
SEDAR17-AW06	Methods for combining multiple indices into one, with application to south Atlantic (U.S.) Spanish mackerel	P. Conn (SEFSC)
SEDAR17-AW07	Extrapolation of Spanish mackerel bycatch by commercial shrimp trawl fisheries	P. Conn (SEFSC)
SEDAR17-AW08	A Bayesian approach to stochastic stock reduction analysis, with application to south Atlantic Spanish mackerel	P. Conn (SEFSC)
SEDAR17-AW09	Preliminary Surplus–production Model Results of Vermilion Snapper off the Southeastern United States	R. Cheshire (SEFSC)
SEDAR17-AW10	Preliminary Surplus–production Model Results of Spanish Mackerel off the Southeastern United States	R. Cheshire (SEFSC)
SEDAR17-AW11	AD Model Builder code to implement catch-age assessment model of vermilion snapper	K. Shertzer (SEFSC)
SEDAR17-AW12	AD Model Builder code to implement catch-age assessment model of Spanish mackerel	P. Conn (SEFSC)
SEDAR17-AW13	ASCII file populated by results of VS base catch-age model	K. Shertzer (SEFSC)

Documents Prepared for the Review Workshop		
SEDAR17-RW01	SEDAR 17 South Atlantic Vermilion Snapper Document for Peer Review	SEDAR 17
SEDAR17-RW02	SEDAR 17 South Atlantic Spanish Mackerel Document for Peer Review	SEDAR 17
Final Assessment Reports		
SEDAR17-AR01	Assessment of the Vermilion Snapper Stock in the US South Atlantic	SEDAR 17
SEDAR17-AR02	Assessment of the Spanish Mackerel Stock in the US South Atlantic	SEDAR 17
Reference Documents		
SEDAR17-RD01	South Atlantic Vermilion Snapper Stock Assessment Report, SEDAR 2, 2003	SEDAR 2
SEDAR17-RD02	Update of the SEDAR 2 South Atlantic Vermilion Snapper Stock Assessment, 2007	SEDAR
SEDAR17-RD03	Fishery Management Plan for Spanish Mackerel, Atlantic States Marine Fisheries Commission, 1990	L. P. Mercer L. R. Phalen J. R. Maiolo
SEDAR17-RD04	Mitochondrial and nuclear DNA analysis of population subdivision among young-of-the-year Spanish mackerel (*Scomberomorus maculatus*) from the western Atlantic and Gulf of Mexico	V. P. Buonaccorsi E. Starkey J. E. Graves
SEDAR17-RD05	George Fishes MD TAFS 28 1-49	W. A. George
SEDAR17-RD06	Excerpt – Goode 1878 stats 7-1-99	Goode
SEDAR17-RD07	Excerpt – Henshall Comparative Excellence TAF 13 1-115	Henshall
SEDAR17-RD08	Stock Assessment Analyses on Spanish and King Mackerel Stocks, April 2003	Sustainable Fisheries Div, SEFSC
SEDAR17-RD09	Hooking Mortality of Reef Fishes in the Snapper-Grouper Commercial Fishery of the Southeastern United States	D.V. Guccione Jr.
SEDAR17-RD10	Effects of cryptic mortality and the hidden costs of using length limits in fishery management Lewis G Coggins Jr	L. G. Coggins Jr. and others
SEDAR17-RD11	Discard composition and release fate in the snapper and grouper commercial hook-and-line fishery in North Carolina, USA	P. J. Rudershausen and J. A. Buckel
SEDAR17-RD12	A multispecies approach to subsetting logbook data for purposes of estimating CPUE	A. Stephens and A. MacCall

SEDAR17-RD13	The 1960 Salt-Water Angling Survey, USFWS Circular 153	J. R. Clark
SEDAR17-RD14	The 1965 Salt-Water Angling Survey, USFWS Resource Publication 67	D. G. Deuel and J. R. Clark. 1968
SEDAR17-RD15	1970 Salt-Water Angling Survey, NMFS Current Fisheries Statistics Number 6200	D. G. Deuel. 1973
SEDAR17-RD16	User's Guide: Delta-GLM function for the R Language /environment (Version 1.7.2, revised 07-06-2006)	E. J. Dick (SWFSC/NMFS). 2006
SEDAR17-RD17	Reproductive biology of Spanish mackerel, *Scomberomorus maculatus*, in the lower Chesapeake Bay. M.A. Thesis, Virginia Institute of Marine Science. (Selective pages)	C. L. Cooksey. 1996
SEDAR17-RD18	The summer flounder chronicles: Science, politics, and litigation, 1975–2000	M. Terceiro. 2002
SEDAR17-RD19	Use of Angler Diaries to Examine Biases Associated with 12-Month Recall on Mail Questionnaires	N. Connelly and T. Brown. 1995
SEDAR17-RD20	Comparing 1994 Angler Catch and Harvest Rates from On-Site and Mail Surveys on Selected Maine Lakes	B. Roach. 1999
SEDAR17-RD21	Response Errors in Canadian Waterfowl Surveys	A. Sen. 1973
SEDAR17-RD22	Exaggeration of Walleye Catches by Alberta Anglers	M. Sullivan. 2003
SEDAR17-RD23	Effects of Recall Bias and Non-response Bias on Self-Report Estimates of Angling Participation	M. A. Tarrant and M. J. Manfredo. 1993
SEDAR17-RD24	Influence of Survey Method on Estimates of Statewide Fishing Activity	T. Thompson. 1990
SEDAR 17-RD25	Final Amendment 6 to the Fishery Management Plan for the Shrimp Fishery of the South Atlantic Region	SAFMC. 2004
SEDAR 17-RD26	SEDAR 17-RD26 SA Gag Stock Assessment Report SEDAR 10 updated	SEDAR. 2006
SEDAR 17-RD27	Effect of Some Variations in Sampling Practices on Len Freq Dist of Gag	CHING-PING CHIH. 2006
SEDAR 17-RD28	Fluctuations in Abundance of Spanish Mackerel in Chesapeake Bay and the Mid-Atlantic Region. North Am. J. Fisheries Management. 12:450-458.	M. E. Chittenden, Jr, L. R. Barbieri and C. M. Jones. 1993.
SEDAR 17-RD29	Returns from 1965 Schlitz Tagging Program w Cumulative Analysis of Previous Results	D. Beaumariage. 1969
SEDAR 17-RD30	Spatial and temporal occurrence of Spanish Mackerel in Chesapeake Bay, Fishery Bulletin	Chittenden, M.E. Jr, L. R. Barbieri and C. M. Jones. 1993.

2. Consensus Report

Summary

- The stock assessment as presented by the Assessment Workshop (AW) was accepted.
- It was concluded that the stock is not overfished.
- The determination was made that the stock is subject to overfishing. However, this conclusion is highly uncertain due to a lack of robustness to key model assumptions.

2.1 Terms of Reference.

2.1.1 Evaluate the adequacy, appropriateness, and application of data used in the assessment

The Data Workshop provided adequate stock assessment data for use in the assessment. The Panel considered that the best available data were made available to the assessment workshop and that appropriate life history parameters were supplied. Suggested improvements to the output of the data workshop are covered under Section 2.1.8.

Summary of Panel Discussions

It was noted that the reconstruction of the early recreational catch history (31 year period, 1950-1980) was based on just three highly uncertain survey estimates in 1960, 1965 and 1970.

The Review Workshop (RW) concluded that the number of trips sampled should be used for multinomial sample sizes in the statistical catch at age model, rather than the number of fish measured.

The abundance indices, and the method of combining several indices, were discussed in detail. The Chevron trap time series, although very noisy, stood out as the only series showing a declining trend. The other indices, all fishery dependent, showed broad agreement, and were negatively correlated with the fishery independent trap indices. It was suggested that the trap time series might be expected to be the least biased of the available indices. However, it was noted that bias could occur in the trap series due to a range of factors (which may not have been accounted for in the general linear model (GLM) that was used to derive the indices).

The headboat time series was considered by the AW to be the preferred abundance timeseries. The Panel did note a pattern in the difference between the un-standardized headboat indices and the standardized time series: the standardization increased the indices prior to 1992 and decreased them from 1992 onwards. This was hypothesized to be related to regulation changes in 1992. It was noted that a new selectivity was estimated for this series after 1992 but that catchability was assumed to remain unchanged.

It was noted that the method of combining several indices made two assumptions which were less than ideal. However, the combined time series was not used in the base model.

The application of an annual 2% (additive) increase in gear efficiency for the catch per unit of effort (CPUE) indices was discussed. Although the percentage is somewhat arbitrary, it was noted that sensitivity runs at 0% and 4% had been performed.

2.1.2 Evaluate the adequacy, appropriateness, and application of methods used to assess the stock.

The AW presented results from four assessment methods. The primary assessment method used a "statistical catch-at-age" model (SCA), and the supporting methods were: a novel stock reduction method (SRA); a non-equilibrium production model (ASPIC); and catch curve analysis (as a diagnostic for the SCA). After considering the results of several requested sensitivity runs, the Panel concluded that the assessment methods were adequate but not appropriate to fully address all terms of references. Rational and suggested improvements to the assessment methods used are covered under Section 2.1.8.

Summary of Panel Discussions

The main issues discussed related to the SCA method: fitting the early (and uncertain) catch history exactly, the assumed stock-recruitment relationship, estimated selectivities, the method of calculating a total F across fisheries, and the relative weights applied to likelihood components (catch, length frequencies, age frequencies, abundance indices). Several requests for analyses with regards to these issues were completed (*see* Section 2.2).

There was concern from some members of the Panel that the catch histories were being fitted exactly even though much of the pre-MRFSS landings data was very uncertain. All Panel members agreed that there was inadequate information in the data supplied to the model to reliably estimate early catches. The main concern was that the uncertainty in catches was not being propagated through to the final assessment results.

The steepness of the assumed Beverton-Holt stock-recruitment relationship had originally been estimated in the model at 0.95 – the upper bound placed on the parameter. In subsequent runs it had been fixed at 0.56 on the basis that this value corresponded to $F_{MSY} = F_{40\%}$. Panel members had mixed views on the value of steepness used. There was no support from the model estimates of spawning stock size and associated recruitment for such a value; nor any recommendations from the life-history group of the data workshop on a plausible range. It was agreed that a range of steepness values should be used in sensitivity runs (*see* Section 2.2).

Much discussion centered on the peaked nature of the age-based selectivities for the Chevron trap series, and the fisheries, given the very wide distribution of lengths at age (e.g., a 25cm fish could be aged from 1 to 10 years). The Data Workshop (DW) had expected very flat selectivities to be estimated, but this was not the case. For example, the Chevron trap selectivity was close to zero at age 1, but substantially higher at ages 2 and 3 years. The age frequencies also showed a similar pattern. It appears that availability (to the traps and the fisheries) is partly determined by age (e.g., fish aged 1 year may not be in the area/habitat where the Chevron traps are deployed).

The calculation of the total *F* across fisheries was an issue. The AW summed the fully selected *F*s for each fishery to derive the fully-recruited *F* over all fisheries. In the terminal year this was done in conjunction with an *F*-averaged selectivity that was not rescaled to have maximum of 1. This approach allowed valid comparisons of the total *F* with the calculated F_{MSY} but made comparisons with catch-curve estimates of *F* problematic. At the Panel's request, total *F*s were computed from age based Fs summed across fisheries. These were presented and compared to catch curve estimates.

The relative weighting of data sets is always an important issue for statistical models. In the SCA model, likelihood components are weighted by specified multipliers. The AW had applied a subjective, albeit, systematic, method for determining the multipliers. From a likelihood profile over virgin recruitment (R_0) it appeared that the biomass signal was being determined mainly by the age frequency data, and secondarily by the abundance indices (*see* Section 2.2). Three new runs were requested to investigate the sensitivity of the assessment results to the index likelihood-multiplier (included in a suite of new runs – *see* below).

The Panel was concerned that the base run in the SCA model did not provide a reliable assessment of stock status. Although many sensitivity runs had been performed by the AW the Panel did not believe that the full range of uncertainties had been explored. A set of sensitivity runs was requested to explore the effect on over-fished and over-fishing stock status determination. The dimensions of uncertainties were: steepness, landings history, abundance likelihood-multiplier, and natural mortality. Because of a high degree of sensitivity in the MSY benchmarks to the specified value of steepness, the results of the runs were also considered in relationship to $F_{40\%}$ and the MSST associated with $B_{40\%}$ (*see* Section 2.2).

The results of the sensitivity analysis supported the conclusion from the AW base model that the stock was not over-fished. However, the sensitivities runs also showed that the conclusion from the AW base model that over-fishing was occurring, was not robust to key model assumptions.

2.1.3 Recommend appropriate estimates of stock abundance, biomass, and exploitation.

The Panel supports the estimates from the AW base model. Estimates for 2007 are given below (*see* Table 3.6 of the AW report).

Year	*F*	F/F_{MSY}	*B* (mt)	B/B_{unfished}	SSB/SSB_{MSY}	*SSB/MSST*
2007	0.49	1.27	2966	0.283	0.861	1.10

2.1.4 Evaluate the methods used to estimate population benchmarks and management parameters (e.g., MSY, Fmsy, Bmsy, MSST, MFMT, or their proxies); provide estimated values for management benchmarks, a range of ABC, and declarations of stock status.

The method of Shepherd (1982) was used to determine F_{MSY} and associated benchmarks and management thresholds. This is a traditional and defensible approach. However, the results from the method depend on biological and fishery parameters which may be poorly determined. Particularly in this stock assessment, the value of steepness is highly uncertain and, as a consequence, so are the estimated benchmarks. In these circumstances it may be more prudent to use proxies for F_{MSY} and B_{MSY} rather than values calculated from an assumed level of steepness. However, B_{MSY} and its proxies are sensitive to uncertainty in landings.

Despite the above comments, the Panel supports the estimates from the AW base model (*see* Table 3.16 of the AW report for estimated benchmarks; *see* Tables 3.17–3.22 for a range of ABC depending on the level of risk management wishes to adopt).
Declaration of stock status:

- The stock is not overfished. This conclusion is robust to most key model assumptions.
- The stock is subject to overfishing, but this conclusion is highly uncertain due to the lack of robustness to key model assumptions.

2.1.5 Evaluate the adequacy, appropriateness, and application of the methods used to project future population status; recommend appropriate estimates of future stock condition (e.g., exploitation, abundance, biomass).

The projection method uses estimated numbers at age as a starting point and projects forwards using stochastic recruitment. However, the average projection trajectory is defined to be deterministic (to ensure that the average trajectory is consistent with the deterministic benchmarks). This is an adequate approach for short term projections (1-3 years). However, any projection results should be treated with caution because of the uncertainty in base model results.

Estimates of future stock condition are contained in Tables 3.24 to 3.28 of the AW report.

2.1.6 Evaluate the adequacy, appropriateness, and application of methods used to characterize uncertainty in estimated parameters. Provide measures of uncertainty for estimated parameters. Ensure that the implications of uncertainty in technical conclusions are clearly stated.

The methods used to characterize uncertainty were not considered entirely appropriate by the Panel. However, some guidance on the level of uncertainty can be obtained from the confidence intervals in the AW base model (Table 3.16 in the AW report) and the range of estimates from sensitivity runs (*see* Table 2.2.1 of this report). These results are likely to under-estimate the true level of uncertainty.

<u>Summary of Panel Discussions</u>

The Panel noted that the AW had made a genuine effort to quantify uncertainty, in terms of: parameter estimates, through a partial bootstrap; robustness, with sensitivity runs; model structure by using alternative methods. However, the Panel considered that the AW had not used the best available methods.

Identified problems included:

- bootstrap with just stochastic recruitment ignores important components of uncertainty (and provides only a tenuous link between the variance of input data and the variance of parameter estimates)
- sensitivity runs to a questionable base model – so poorly "centered"
- sensitivity runs are a subjective quantification of uncertainty
- the results of the SRA model were counter-intuitive when compared with SCA model results (much higher estimated R_0 but a similar stock status)
- the uncertainty in the landings data prior to 1981 was not adequately propagated.

See Section 2.1.8 for suggested improved methods.

2.1.7 Ensure that stock assessment results are clearly and accurately presented in the Stock Assessment Report and Advisory Report and that reported results are consistent with Review Panel recommendations.

This was completed after a draft Advisory report was received from the SEDAR Coordinator.

2.1.8 Evaluate the SEDAR Process. Identify any Terms of Reference which were inadequately addressed by the Data or Assessment Workshops; identify any additional information or assistance which will improve Review Workshops; suggest improvements or identify aspects requiring clarification.

I. Terms of Reference of Data Workshop

1. Characterize stock structure and develop a unit stock definition. Provide a map of species and stock distribution.

The DW defined the stock structure of vermilion snapper and a justification for the delineation. A map of the geographic distribution of snapper catches would have been helpful for understanding the fisheries.

2. Tabulate available life history information (e.g., age, growth, natural mortality, *reproductive characteristics, discard mortality rates); provide appropriate models to describe growth, maturation, and fecundity by age, sex, or length as applicable. Evaluate the adequacy of available life-history information for conducting stock assessments and recommend life history information for use in population modeling.*

Life history information, based on empirical data as well as literature references, was compiled as required by the term of reference. Future consideration should be given to estimating growth (simultaneously with other parameters) within the SCA model (with the inclusion of conditional age at length data). In addition the DW should provide guidance for analysts regarding the steepness parameter for stock-recruitment, based on their knowledge of the biology of the species. The high variability in the length at age should be further explored with regards to geographic variation in growth rates. In addition, distribution of fish by age should be examined for implications in fisheries selectivity (e.g. are age 1 fish inshore, older fish vulnerable to the fishery further offshore).

3. Consider relevant fishery dependent and independent data sources to develop measures of population abundance. Document all programs used to develop indices; address program objectives, methods, coverage, sampling intensity, and other relevant characteristics. Provide maps of survey coverage. Develop values by appropriate strata (e.g., age, size, area, and fishery); provide measures of precision. Evaluate the degree to which available indices represent fishery and population conditions. Recommend which data sources should be considered in assessment modeling.

Available fishery independent and dependent data were developed as measures of abundance and reasonably well documented. The addition of simple ANOVA output tables from the GLM analysis would provide reviewers with additional diagnostic information. Consideration should also be given to use of a stepwise regression as a method for determining the relevance of ancillary variables. Potential environmental/oceanographic explanatory variables should also be considered.

4. Characterize commercial and recreational catch, including both landings and discard removals, in pounds and number. Discuss the adequacy of available data for accurately characterizing harvest and discard by species and fishery sector. Provide length and age distributions of the catch. Provide maps of fishery effort and harvest.

Recreational landings prior to the initiation of the MRFSS program were inferred from three surveys of recreational landings in 1960, 1965 and 1970. Any additional information to substantiate these estimates, such as results from the Schlitz tagging programs of the 1960s, would be beneficial.

The use of length and age data in the SCA model requires that such data are representative of the catch. The assumption is that these data were collected randomly from all fisheries sampled, but no information to substantiate this assumption is provided. If landings are sorted into market category and sampling done randomly within a category, then weighting by proportion of each category would be required. Whether this was done, or necessary, was not well documented.

Although not required by the model used in the assessment, development of a catch at age matrix could provide a useful tool for evaluation. With such information, cohort strength, changes in selectivity, etc. could be examined for comparison to model results. Additionally, maps of fishing effort and catch as requested in the term of reference would have been helpful.

5. Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment. Recommend sampling intensity by sector (fleet), area, and season.

Useful recommendations were provided by the DW.

6. Develop a spreadsheet of assessment model input data that incorporates the decisions and recommendations of the Data Workshop. Review and approve the contents of the input spreadsheet within 6 weeks prior to the Assessment Workshop.

Completed as required.

7. Prepare complete documentation of workshop actions and decisions (Section II. of the SEDAR assessment report); prepare a list of tasks to be completed following the workshop, including deadlines and personnel assignments.

Completed as required.

II. Terms of Reference of Assessment Workshop

1. Review any changes in data following the data workshop, any analyses suggested by the data workshop, and provide estimated values for any required data in DW TOR 4 that are not available from observations. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.

Completed as required.

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. Document model code in an AW working paper.

Model code was provided. Population models were developed to characterize the stock status as a basis for providing management advice. Documentation of the input, assumptions and equations were either provided with the results or in references from previous analyzes. However, in the SCA model, the use of specified multipliers for each likelihood component undermines the statistical nature of the model. Standardized residuals cannot be calculated when the multipliers are not equal to 1. Therefore, the internal statistical consistency of the model cannot be verified – and data weightings are subjective. It is recommended that base models use multipliers of 1 (and weights be adjusted, if necessary, using effective sample sizes and CVs).

3. Provide estimates of stock population parameters (fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, discard removals, etc) by age and other relevant categorizations (i.e., fleet or sector); include representative measures of precision for parameter estimates.

Appropriate measures of population parameters were provided by the AW. Additional clarification concerning the summation of fishing mortality across gear types with different selectivities would be helpful.

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

Uncertainty in the base model results were provided as partial-bootstrap distributions of critical parameters (using the uncertainty in recruitment deviations). Robustness to model assumptions was evaluated with sensitivity runs. Alternative estimation models were also used. The AW made a genuine attempt to quantify estimation and model uncertainty. However, they failed to capture an appropriate level of uncertainty.

The base model had subjective weights for the different data sources. Therefore, it is not necessarily a good base about which to test sensitivities to model assumptions. Also, the bootstrap distributions do not include the full scope of observation error in the input data – indeed, there is only a tenuous link between the variance assumptions of the input data and the variance of parameter estimates. Research into better methods to include the uncertainty in landings history is recommended.

It is also recommended that managers specify exactly what measures of uncertainty they require and for which parameters or management variables.

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

Appropriate information was provided by the AW. However, as noted the DW should consider making recommendations for appropriate steepness parameters.

6. Provide estimates for SFA criteria consistent with applicable FMPs, proposed FMPs and Amendments, other ongoing or proposed management programs, and MSA National Standards. This may include: evaluating existing SFA benchmarks, estimating alternative SFA benchmarks, and recommending proxy values.

A proxy value for Fmsy of F40% was recommended by the AW.

7. Provide declarations of stock status relative to SFA benchmarks; recommend alternative SFA benchmarks if necessary.

Estimates for vermilion snapper were provided as required.

8. Project future stock conditions. Provide estimates of exploitation, stock abundance and yield (discards and directed harvest) in pounds and numbers for a minimum of 10 years into the future. Fully document all projection assumptions (e.g., recruitment, selectivity, discard mortality). Develop rebuilding schedules if warranted; include estimated generation time. Stock projections shall be developed in accordance with the following:
A) If stock is overfished:
F=0, F=current, F=Fmsy, Ftarget (OY),
F=Frebuild (max that rebuild in allowed time)
B) If stock is overfishing
F=Fcurrent, F=Fmsy, F= Ftarget (OY)
C) If stock is neither overfished nor overfishing
F=Fcurrent, F=Fmsy, F=Ftarget (OY)

Projections were made as required by the ToR.

9. Evaluate the impacts of past and current management actions on the stock, with emphasis on determining progress toward stated management goals and identifying possible unintended fishery or population effects.

Impacts from past management actions were not considered explicitly, however the time series of model results reflect past management actions.

10. Consider the data workshop research recommendations. Provide additional recommendations for future research and data collection (field and assessment); be as specific in describing sampling design and sampling intensity.

Specific recommendations for changes or addition of data collection were not provided by the assessment workshop.

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

Completed as required.

12. Complete the Assessment Workshop Report (Section III of the SEDAR Stock Assessment Report), prepare a first draft of the Advisory Report, and develop a list of tasks to be completed following the workshop.

Completed as required.

13. Perform a probabilistic analysis of proposed reference points and provide the probability of overfishing at various harvest or exploitation levels. (Added 7-2-08)

Completed as required.

2.1.9 Review the research recommendations provided by the Data and Assessment workshops and make any additional recommendations warranted. Clearly indicate the research and monitoring needs that may appreciably improve the reliability of future assessments. Recommend an appropriate interval for the next assessment.

The numerous research recommendations from the DW and AW were not explicitly discussed at the RW. Individual panelists reviewed the recommendations and were in broad agreement with the suggestions. However, there is a clear need for the recommendations to be prioritized. Also, the Panel recommended that a proper statistical framework be used for the catch-at-age models. This would allow alternative parameterizations to be evaluated in terms of AIC or some other statistical criteria, and the calculation of standardized residuals (which allows the appropriateness of relative data weightings to be judged).

The AW base model estimates that over-fishing is occurring and that stock size is close to the over-fished threshold. This suggests that the next assessment should be sooner than the normal timeframe for assessment updates.

2.1.10 Prepare a Peer Review Consensus Summary summarizing the Panel's evaluation of the stock assessment and addressing each Term of Reference. Develop a list of tasks to be completed following the workshop. Complete and submit the Consensus Report within 3 weeks of workshop conclusion.

Completed as required.

2.2 Further Analyses and Evaluations

Two main analyses were requested by the Panel. A likelihood profile over virgin recruitment and a set of sensitivity runs.

The likelihood profile over virgin recruitment for the different data types showed that the estimate resulted from a trade-off between the biomass indices and the age frequency data (Figure 2.2.1). The age-frequency was dominant, but the length frequency data showed little contrast over the range of values considered (Figure 2.2.1). The latter result was encouraging, as in general there is little real information on biomass contained within length frequencies (because of confounding with selectivities and errors in growth parameters).

The main diagnostic that the Panel used for the acceptability of the base model was its robustness to key model assumptions. Fifteen sensitivity runs were considered, with regard to steepness, the landings history, the weight on the biomass indices, and natural mortality (Table 2.2.1). Estimated levels of virgin recruitment and MSY are sensitive to the assumed landings history, but F_{MSY} is not (Table 2.2.1). However, F_{MSY} is very sensitive to the assumed levels of steepness and natural mortality (Table 2.2.1). The conclusion that the stock is not over-fished is robust to all assumptions considered except a low natural mortality and two landing scenarios explored under steepness =0.5 (Figure 2.2.2). The conclusion with regard to over-fishing is not robust when considered against the MSY based benchmark (Figure 2.2.2). However, the estimated terminal *F* is relatively robust to most assumptions except the abundance-indices weight (Figure 2.2.3).

Table 2.2.1: Estimated MSY-based benchmarks and stock status relative to the benchmarks for the set of sensitivity runs considered by the RW. Base, low, and high landings (L) were crossed with three values of steepness (h, S1-S9). Increased multipliers of the index likelihood were considered (S10-S12), as well as alternative values of M (S13-S14), and an intermediate level of low landings (S15).

label	description	Fmsy	SSBmsy	MSY	F/Fmsy	SSB/SSBmsy	SSB/MSST	h	R0(1000)
Base	h=0.56 base L	0.386	9.16	1665	1.27	0.86	1.1	0.56	4326
RW-S1	h=0.5 L-2SE	0.27	8.04	1108	1.65	0.82	1.04	0.5	3769
RW-S2	h=0.5 base L	0.264	11.6	1499	1.67	0.76	0.97	0.5	5367
RW-S3	h=0.5 L+2SE	0.27	14.72	1984	1.64	0.75	0.96	0.5	6928
RW-S4	h=0.7 L-2SE	0.711	4.81	1353	0.72	1.2	1.54	0.7	2877
RW-S5	h=0.7 base L	0.654	7.29	1820	0.74	1.2	1.53	0.7	4701
RW-S6	h=0.7 L+2SE	0.653	9.43	2326	0.73	1.18	1.51	0.7	6048
RW-S7	h=0.9 L-2SE	3.938	2.44	1644	0.13	2.39	3.06	0.9	2727
RW-S8	h=0.9 base L	2.144	4.84	2169	0.23	1.83	2.35	0.9	4392
RW-S9	h=0.9 L+2SE	2.153	6.17	2761	0.23	1.83	2.35	0.9	5620
RW-S10	Index 200	0.446	9.63	1705	1.09	0.91	1.16	0.56	4383
RW-S11	Index 500	0.35	10.76	1828	0.88	1.05	1.35	0.56	4993
RW-S12	Index 1000	0.304	9.75	2148	0.92	1.09	1.4	0.56	5014
RW-S13	high M	0.719	8.36	1819	0.84	1.03	1.44	0.56	6686
RW-S14	low M	0.199	12.49	1466	2.5	0.55	0.66	0.56	3307
RW-S15	h=0.56 L-1SE	0.386	7.82	1431	1.29	0.87	1.12	0.56	3703

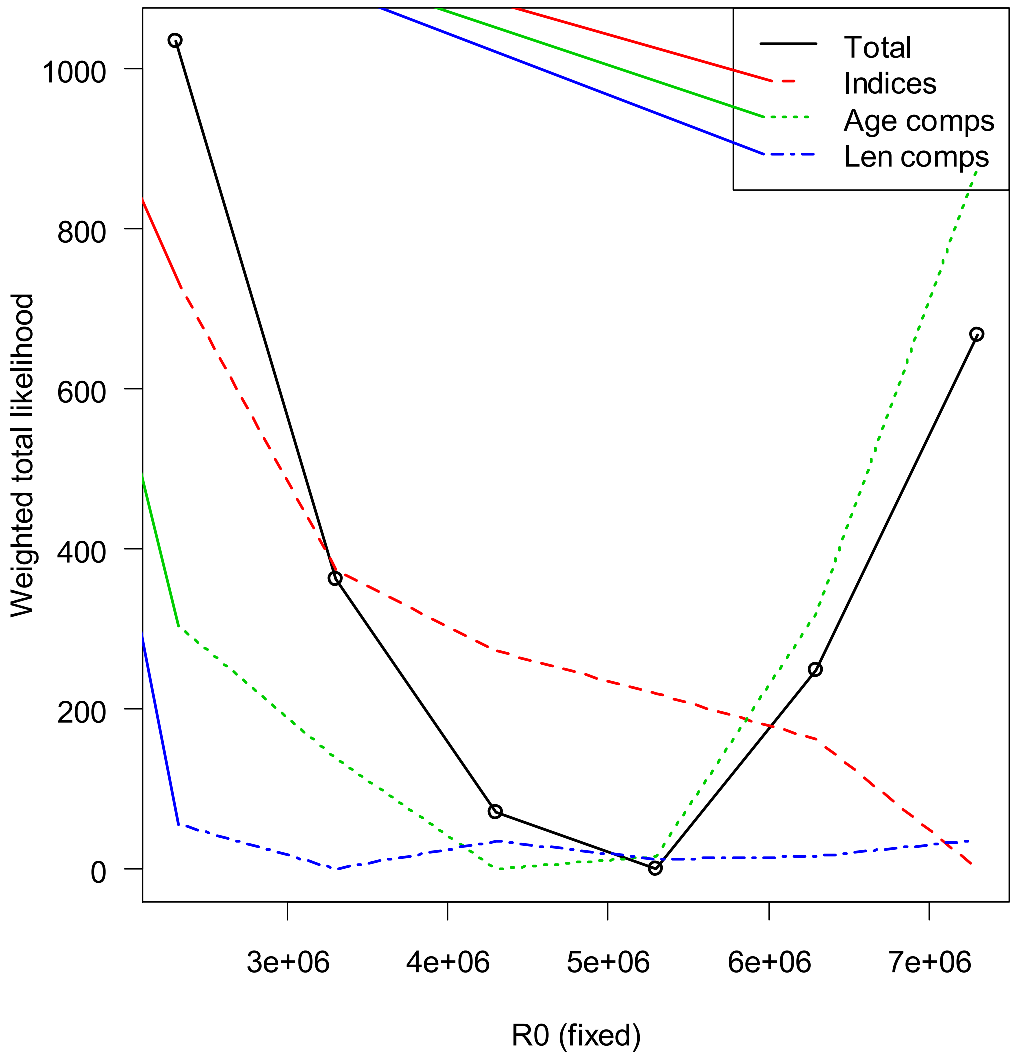


Figure 2.2.1: Likelihood profile across virgin recruitment (R_0) for each data type. The weighted negative log-likelihood is shown for each data type (referenced to zero by subtracting the minimum value for each data type over the R_0 range).

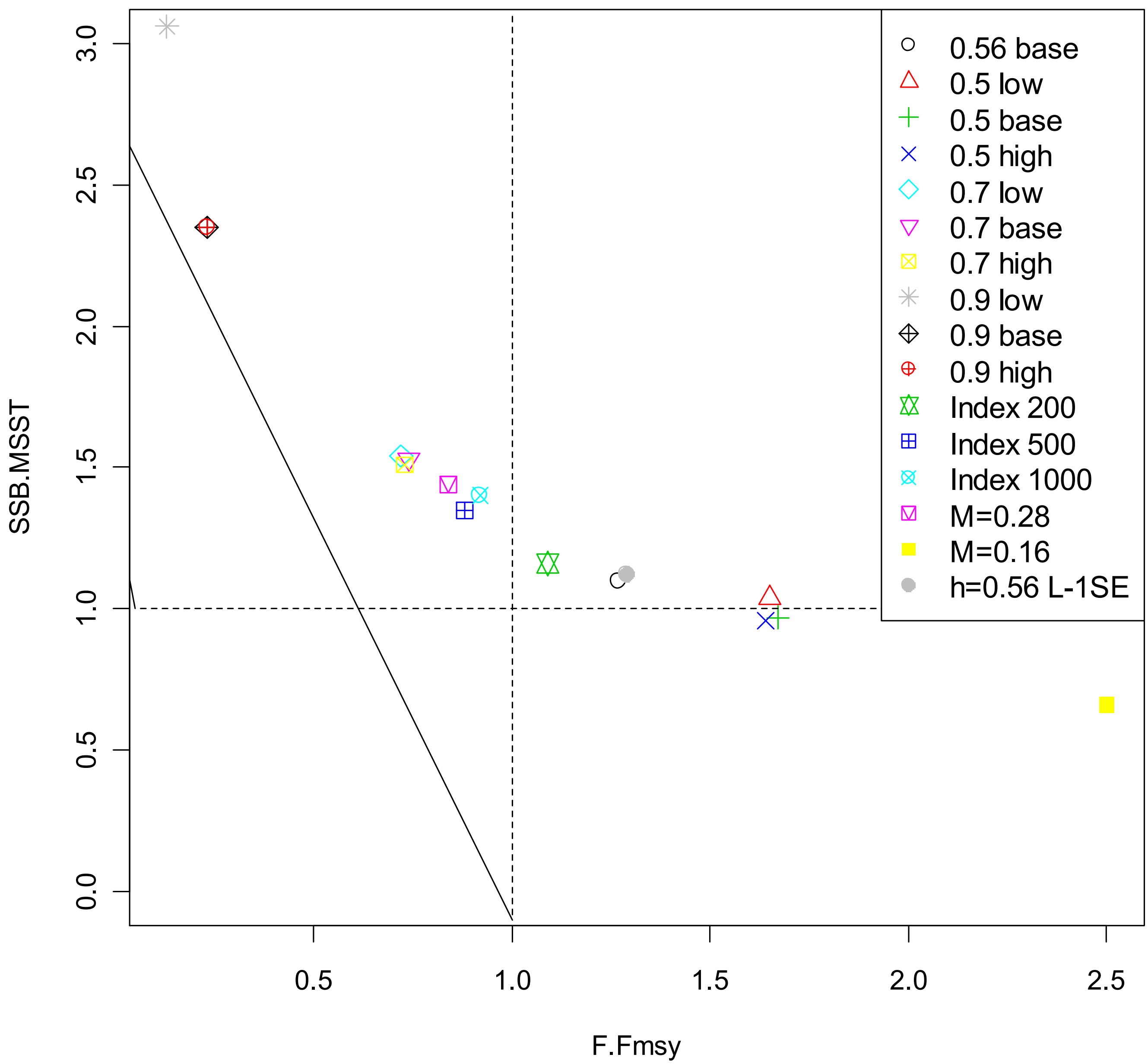


Figure 2.2.2: Estimated stock status relative to the MSY-based benchmarks for the set of sensitivities runs considered by the RW (see Table 2.2.1).

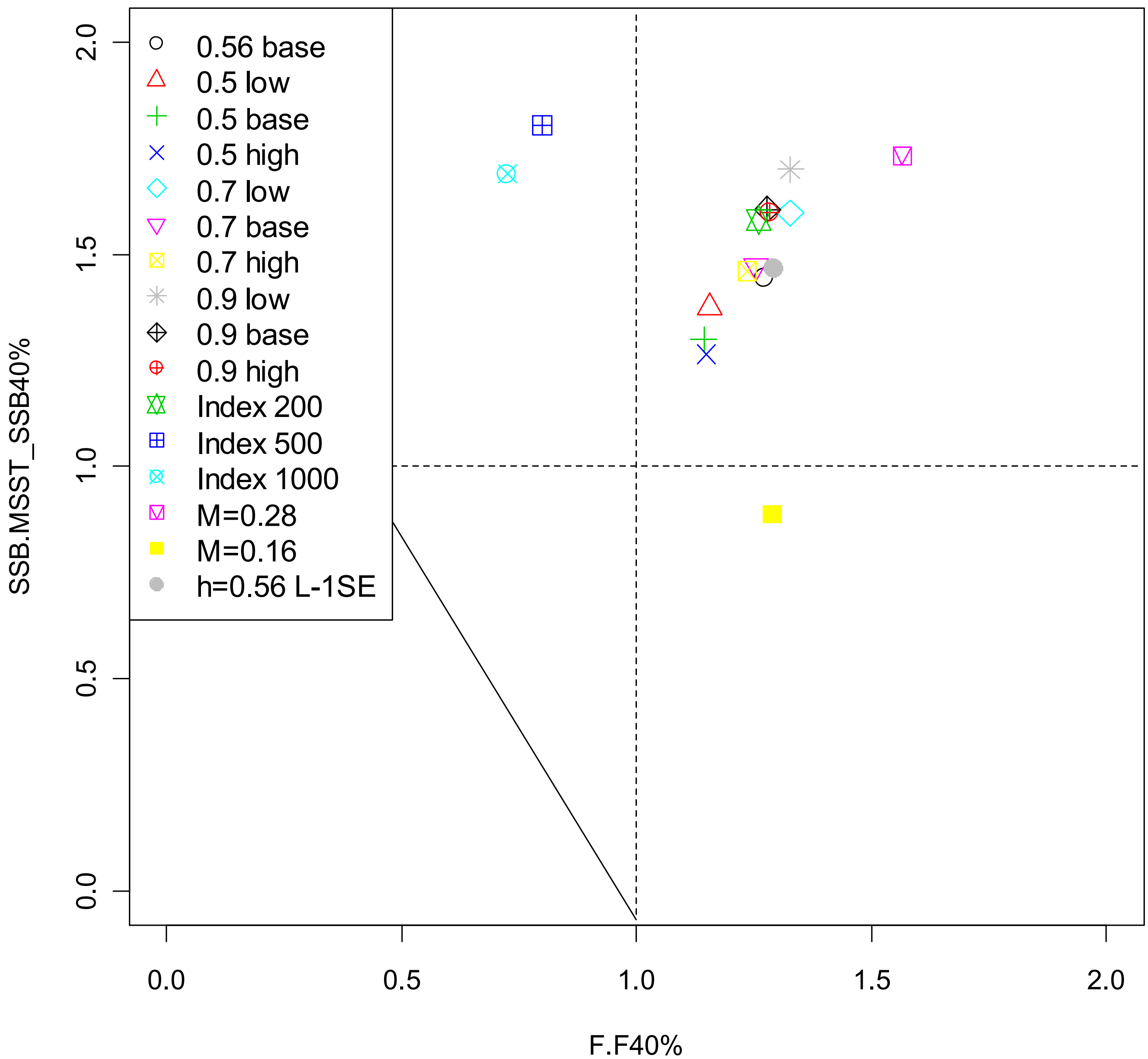


Figure 2.2.3: Estimated stock status relative to proxy-based benchmarks for the set of sensitivities runs considered by the RW (see Table 2.2.1).

2.3 Additional Comments

This assessment was reviewed in conjunction with a Spanish mackerel assessment which used very similar assessment methods applied to similar types of data. However, while the vermillion snapper assessment was mainly accepted by the Panel, the Spanish mackerel assessment was only partially accepted. There was discussion on whether the contrary outcomes constituted a "logical flaw" – how could the same methods, with similar data lead to acceptance for one, but rejection for the other?

This issue was never fully resolved, but the argument in support of “logical consistency” was that the two assessments were sufficiently different, in terms of overall quality, that one could be accepted while the other was mainly rejected. The Spanish mackerel assessment contained similar problems as the snapper assessment, but had additional problems (i.e. significant but highly uncertain estimates of historic recreational catch and by-catch in the shrimp fishery; questionable use of a combined abundance time series in the base model; substantial but potentially inappropriate biomass signal from the length frequency data) which contributed to the determination that it was not fully acceptable.

The Panel thanks the AW representatives for their excellent presentations and hard work before and during the RW. The table and figures referenced under Section 2.2 were produced by the AW representatives.

2.4 Recommendations for Future Workshops

The TOR for the DW and AW are comprehensive in terms of what is needed to perform a stock assessment. However, they are somewhat lacking in what is required to review a stock assessment. There appears to be no requirement for executive summaries to be produced for any aspect of the data preparation or assessment. The DW and AW reports could have been greatly improved with the inclusion of executive summaries aimed at reviewers who may be unfamiliar with the particular fisheries and data sets.

2.5 Reviewer Statements *Each individual reviewer should provide a statement attesting whether or not the contents of the Consensus Report provide an accurate and complete summary of their views on the issues covered in the review. Reviewers may also make any additional individual comments or suggestions desired.*

Gary Shepherd- Review Panel Chair: The SEDAR 17 review was based on assessment results provided by the Data Workshop and Assessment Workshop. Although the Review Panel has made recommendations for additional information in future reports, the extensive data and analyzes in the documents represented a tremendous effort by the two groups, which was appreciated. In addition, I would like to acknowledge the professionalism and patience by the assessment team in providing additional analyzes as requested by the Review Panel. The conclusions of the review panel as presented in the summary report accurately represent my own conclusion regarding the assessment of vermilion snapper.

Noel Cadigan, CIE Reviewer. I agree that the content of this summary report reflects the consensus of the SEDAR 17 Review Workshop

Beatriz Roel – CIE Reviewer. The SEDAR 17 review process was undertaken on the basis of the documentation made available to the Panel and the presentations made by the Assessment Team. The documentation was comprehensive and the AT presentations were of high standard. The interaction between the Review Panel, the Assessment Team

and other participants was facilitated by a relaxed atmosphere and I would like to thank participants and organizers for a productive and pleasant meeting.
The contents of the Consensus Report provide an accurate and complete summary of my views on the issues covered in the review.

Patrick Cordue - CIE reviewer: The content of this report represents the consensus view of the four Panel members. A full summary of my individual views is contained in my CIE report. My general conclusions and views are consistent with those in the consensus report. However, my CIE report contains technical criticisms and recommendations which are not included in the consensus report.

3. Submitted Comments

None were received.

Section VI. Addenda

Contents

1. Revisions and Corrections

1.1. Correction to Table 3.1 of the Data Workshop Report

In the original Table 3.1 of the Data Workshop Report, the column labeled “Florida” included landings only from handline gear. The corrected table is below, in which the “Florida” column includes landings from all gears in units of pounds whole weight.

1.2. Correction to Table 3.4 of the Data Workshop Report

In the original Table 3.4 of the Data Workshop Report, the column labeled “Florida” included landings only from handline gear. The corrected table is below, in which the “Florida” column includes landings from all gears in units of number fish.

1.3. Revision to text in the Assessment Workshop Report

Section 3.1.2.6. The second sentence of the first paragraph should read:
An uncharacteristically high estimate of total *F* in 1991 is due to high *F*’s in the commercial handline and combined gears, both of which result from relatively high landings in that year combined with fewer fish available at the ages selected by each gear.

Section 3.1.2.11. The second sentence of the second paragraph should read:
This spike is due to an uncharacteristically high estimate of *F* from the commercial handline and combined gears, both of which result from relatively high landings in that year combined with fewer fish available at the ages selected by each gear.

Table 3.1 (corrected). Vermilion snapper commercial landings (pounds whole weight) by region for the US South Atlantic.

US South Atlantic – Region			
Year	Florida	Georgia-North Carolina	Total
1958	194	0	194
1959	1,262	0	1,262
1960	1,747	0	1,747
1961	19,317	24,025	43,341
1962	6,989	46,416	53,405
1963	11,357	9,610	20,967
1964	6,504	288	6,792
1965	19,511	2,499	22,009
1966	3,397	0	3,397
1967	14,172	0	14,172
1968	31,936	0	31,936
1969	30,771	577	31,347
1970	19,511	0	19,511
1971	50,185	16,532	66,717
1972	65,910	14,674	80,584
1973	80,956	11,349	92,305
1974	99,399	22,716	122,115
1975	188,702	32,778	221,481
1976	147,060	72,871	219,931
1977	143,325	141,294	284,619
1978	111,621	234,501	346,122
1979	142,923	342,127	485,049
1980	111,643	639,606	751,249
1981	60,737	683,042	743,779
1982	67,285	821,176	888,462
1983	79,659	708,856	788,514
1984	111,928	740,104	852,032
1985	141,843	803,647	945,490
1986	108,615	811,742	920,356
1987	90,657	658,903	749,560
1988	127,561	858,204	985,765
1989	191,034	940,541	1,131,575
1990	289,687	1,000,215	1,289,902
1991	233,411	1,160,700	1,394,111
1992	175,290	589,924	765,214
1993	165,308	709,605	874,913
1994	223,707	734,453	958,160
1995	261,311	670,062	931,374
1996	185,749	559,338	745,087
1997	117,860	643,156	761,017
1998	94,734	615,773	710,506
1999	100,151	780,943	881,093

Table 3.1. (cont.)

2000	154,361	1,195,751	1,350,111
2001	189,897	1,446,927	1,636,824
2002	177,630	1,158,126	1,335,756
2003	119,131	615,698	734,829
2004	169,688	919,288	1,088,976
2005	146,527	955,259	1,101,787
2006	163,388	665,232	828,620
2007	181,399	838,906	1,020,305

Table 3.4 (corrected). Vermilion snapper commercial landings (number of fish) by region for the US South Atlantic.

US South Atlantic - Region			
Year	Florida	Georgia-North Carolina	Total
1958	171	0	171
1959	1,109	0	1,109
1960	1,536	0	1,536
1961	16,981	47,796	64,776
1962	6,655	87,174	93,830
1963	9,984	8,988	18,971
1964	5,717	270	5,987
1965	17,151	2,438	19,589
1966	2,987	0	2,987
1967	12,458	0	12,458
1968	28,073	0	28,073
1969	27,049	539	27,589
1970	17,151	0	17,151
1971	44,115	13,994	58,110
1972	57,939	18,447	76,386
1973	71,165	12,207	83,371
1974	87,377	16,025	103,402
1975	165,880	22,763	188,643
1976	129,274	74,305	203,579
1977	125,991	136,598	262,589
1978	98,121	184,799	282,920
1979	125,637	308,054	433,691
1980	101,721	839,342	941,063
1981	54,965	863,351	918,316
1982	62,694	883,307	946,001
1983	70,116	674,836	744,952
1984	108,286	662,808	771,094
1985	128,185	572,795	700,980
1986	99,811	654,780	754,591
1987	75,507	617,793	693,301
1988	152,754	765,528	918,282
1989	187,982	749,411	937,393
1990	204,946	855,116	1,060,062
1991	198,013	974,169	1,172,181
1992	133,078	446,721	579,800
1993	129,495	474,905	604,400
1994	157,648	464,535	622,182
1995	212,258	467,120	679,378
1996	169,382	386,183	555,565
1997	127,277	409,674	536,952
1998	92,826	439,053	531,879
1999	80,666	519,176	599,842

Table 3.4. (cont.)

2000	121,403	790,029	911,432
2001	159,781	892,210	1,051,991
2002	124,546	788,125	912,671
2003	88,413	418,574	506,987
2004	147,834	608,877	756,711
2005	74,573	589,367	663,941
2006	118,159	458,079	576,238
2007	126,644	526,934	653,578

2. Additional Documentation of the Final Review Model Configuration

None