S E D A R

Southeast Data, Assessment, and Review

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SEDAR 15
Stock Assessment Report 1 (SAR 1)
South Atlantic Red Snapper

February 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

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Stock Assessment Report 1
South Atlantic Red Snapper

Table of Contents

Section I. Introduction

Contents

Changes to the February 2008 Section I. Introduction
April 24, 2008

1. Page 14, Fishing Mortality Trends - Text on page 15 preceding Figure 4 was amended to reflect that F40% was the proxy value for the fishing limit recommended by the review panel. The resultant value of F/F40% (a mean near 14) was entered to replace the value of F/Fmsy (a mean near 9.1).
2. Page 15, Figure 4 – The graph depicting F/Fmsy was replaced with a graph depicting F/F40%, the proxy value recommended by the review panel.
3. Page 16, Table 2 – The value of SSB2006/SSBF40% was corrected from 0.027 to 0.025.
4. Page 20, Table 5 – The heading of the sixth column was changed from SSB/SSB40% to SSB/MSST40%. Column values did not change.
5. Page 21. Specific stock status data in the SAIP Form were amended to reflect changes 1-4 above. The B/Bmsy value of 0.027 was changed to 0.025, and the B/Blimit value of 0.029 was changed to 0.027.

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 15 was charged with assessing red snapper and greater amberjack in the US South Atlantic. This task was accomplished through workshops held between June 2007 and January 2008.

2. Assessment History

In the early 1990s, a series of unnumbered reports were prepared by the SAFMC Plan Development Team (1990) and later by the Beaufort Reeffish Team (1991, 1992), in which "snapshot" analyses were conducted for a list of snapper-grouper species, including red snapper. These analyses included the estimation of SPR (spawning potential ratio) based on a single year of data, and were intended to highlight species for future assessments. However, the only formal assessment conducted on this stock of red snapper was by Manooch et al. [**Population assessment of the red snapper from the southeastern United States**, *Fisheries Research* 38 (1998):19-32]. In that assessment, two age-structured models were used, an un-calibrated separable VPA (emphasized in the abstract below) and FADAPT. The results from this latter model were downplayed because the model was calibrated to a MARMAP chevron trap index, for which low sample size was of major concern. Prior to publication, a report of this assessment was prepared for the SAFMC and submitted on April 7, 1997. Estimates of SPR found in Potts and Brennan (1998, 2001) are taken from the assessment report to SAFMC. The most recent Gulf of Mexico red snapper assessment was conducted during the SEDAR 7 assessment process.

Abstract from Manooch et al: Changes in the age structure and population size of red snapper, *Lutjanus campechanus*, from North Carolina through the Florida Keys were examined using records of landings and size frequencies of fish from commercial, recreational, and headboat fisheries from 1986 to 1995. Population size in numbers at age was estimated for each year by applying separable virtual population analysis (SVPA) to the landings in numbers at age. SVPA was used to estimate annual, age-specific fishing mortality (F) for four levels of natural mortality (M=0.15, 0.20, 0.25, and 0.30). Although landings of red snapper for the three fisheries have declined, minimum fish size regulations have also resulted in an increase in the mean size of red snapper landed. Age at entry and age at full recruitment were age-1 for 1986-1991, compared with age-2 and age-6, respectively, for 1992-1995. Levels of mortality from fishing (F) ranged from 0.31 to 0.69 for the entire period. Spawning potential ratio (SPR) increased from 0.09 to 0.24 (M=0.25) from 1986 to 1995. The SPR level could be improved with a decrease in F, or an increase in age at entry to the fisheries. The latter could be enhanced now if fishermen, particularly recreational fishermen, comply with minimum size regulations.

3. Management Review

Table 1. General Management Information

Species	Red Snapper (*Lutjanus campechanus*)
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

The 1998 assessment (Manooch et. al 1998) provided the value of $F_{30\%SPR}$, $F_{40\%SPR}$ and M).

Criteria	Current		Proposed	
	Definition	Value	Definition	Value
MSST	[(1-M) or 0.5 whichever is greater]*B_{MSY}	Not specified	MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}	UNK (SEDAR 15)
MFMT	$F_{30\%SPR}$=F_{MSY}	F=0.40	F_{MSY}	UNK (SEDAR 15)
MSY	Yield at F_{MSY}	Not specified	Yield at F_{MSY}	UNK (SEDAR 15)
F_{MSY}	$F_{30\%SPR}$	F=0.40	F_{MSY}	UNK (SEDAR 15)
OY	Yield at F_{OY}	Not specified	Yield at F_{OY}	UNK (SEDAR 15)
F_{OY}	$F_{40\%SPR}$	F=0.26	F_{OY} =65%, 75%, 85% F_{MSY}	UNK (SEDAR 15)
M	n/a	0.25	SEDAR 10	UNK (SEDAR 15)

Table 3. Stock Rebuilding Information

If the stock is currently under a rebuilding plan, please provide the following details:

Rebuilding Parameter	Value
Rebuilding Plan Year 1	*
Generation Time (Years)	
Rebuilding Time (Years)	
Rebuilt Target Date	
Time to rebuild @ F=0 (Years)	

*In the past, red snapper was listed as overfished. As such, Amendment 4 (regulations effective January 1992) implemented a rebuilding plan ≤ 15 years beginning in 1991. Red snapper is currently listed as unknown in terms of an overfished status. The overfished determination of this stock has been changed to unknown to better reflect the current knowledge of its status. The previous pre-SFA determination of overfished for this stock was based on SPR, which is inadequate to determine the overfished status because it is not biomass-based and therefore does not meet criteria specified in the SFA. A biomass-based determination that is SFA compliant cannot be made at this time.

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 BMSY 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.

Table 5. Quota Calculation Details
If the stock is managed by quota, please provide the following information

Quota Detail	Value
Current Quota Value	N/A
Next Scheduled Quota Change	N/A
Annual or averaged quota ?	N/A
If averaged, number of years to average	N/A
Other?	N/A

Table 6. Regulatory and FMP History

Description of Action	FMP/Amendment	Effective Date
4” Trawl mesh size and 12” TL minimum size limit	Snapper Grouper FMP	8/31/1983
Prohibit trawls	Snapper Grouper Amend 1	1/12/1989
Required permit to fish for, land or sell snapper grouper species	Snapper Grouper Amend 3	1/31/1991
Prohibited gear: fish traps except bsb traps north of Cape Canaveral, FL; entanglement nets; longline gear inside 50 fathoms; bottom longlines to harvest wreckfish; powerheads and bangsticks in designated SMZs off S. Carolina. Established 20” TL minimum size and a 10 snapper/person/day bag limit, excluding vermilion snapper, and allowing no more than 2 red snappers.	Snapper Grouper Amend 4	1/1/1992
Oculina Experimental Closed Area.	Snapper Grouper Amend 6	6/27/1994
Limited entry program; transferable permits and 225 lb non-transferable permits.	Snapper Grouper Amend 8	12/14/1998
Vessels with longline gear aboard may only possess snowy grouper, warsaw grouper, yellowedge grouper, misty grouper, golden tilefish, blueline tilefish, and sand tilefish.	Snapper Grouper Amend 9	2/24/1999
Approved definitions for overfished and overfishing. MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}. MFMT = F_{MSY}	Snapper Grouper Amend 11	12/2/1999
Extended for an indefinite period the regulation prohibiting fishing for and possessing snapper grouper species within the *Oculina* Experimental Closed Area.	Snapper Grouper Amend 13A	4/26/2004

Table 7. Annual Regulatory Summary [1]

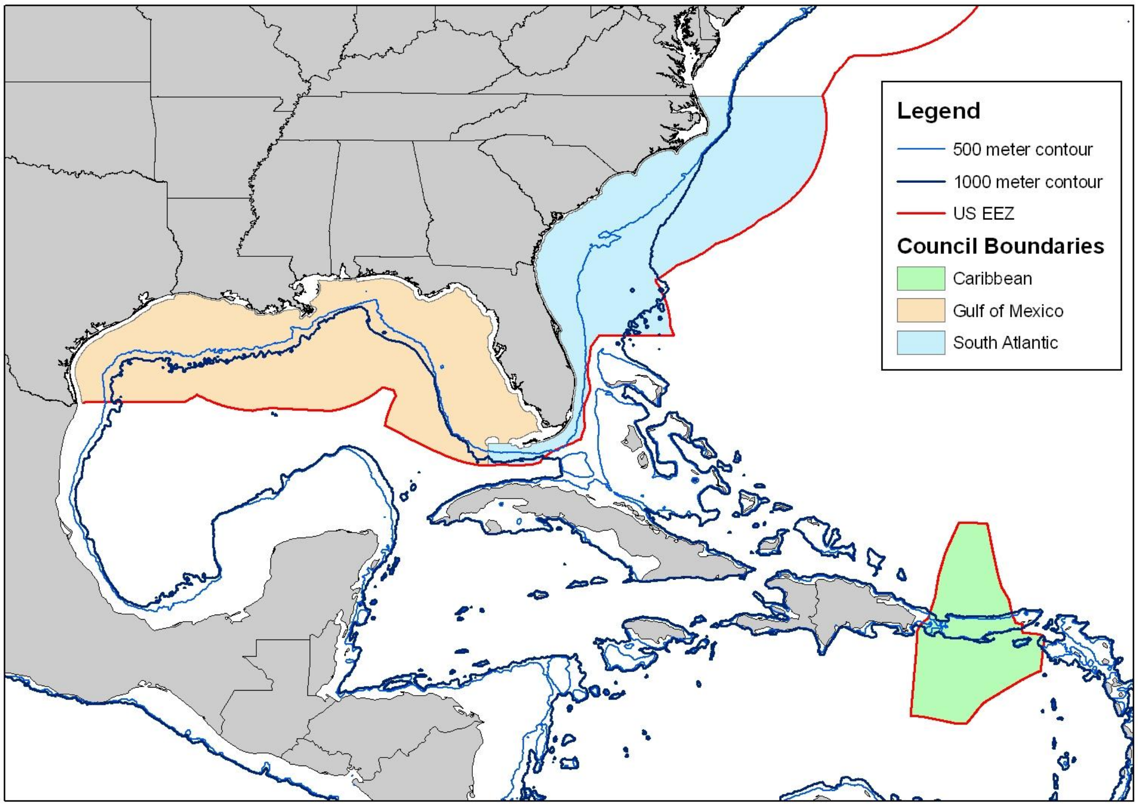
	Commercial Fishery Regulations				Recreational Fishery Regulations				
Effective Date	Size Limit	Trip Limit	Season	Catch Limit	Size Limit	Possession Limit	Season	Catch Target	Both/Other
8/31/1983	12" TL				12" TL				
1/1/1992	20" TL				20" TL				
1/1/1992						10 snapper/person/day bag limit, excluding vermilion snapper, and allowing no more than 2 red snappers.			

References

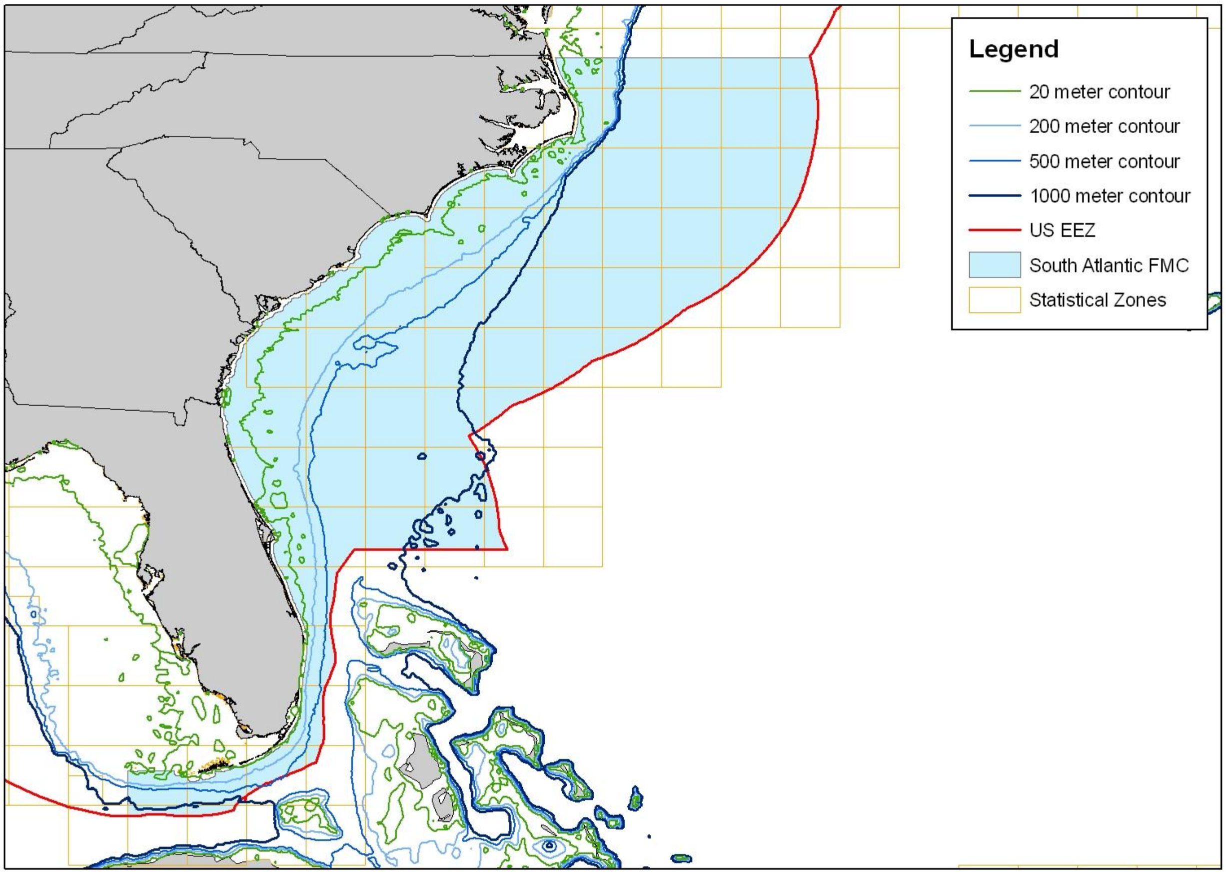
Manooch, C.S., III, J.C. Potts, D.S. Vaughan, and M.L. Burton. 1998. Population assessment of the red snapper from the southeastern United States. Fisheries Research. 38:19-32.

4. Southeast Region Maps

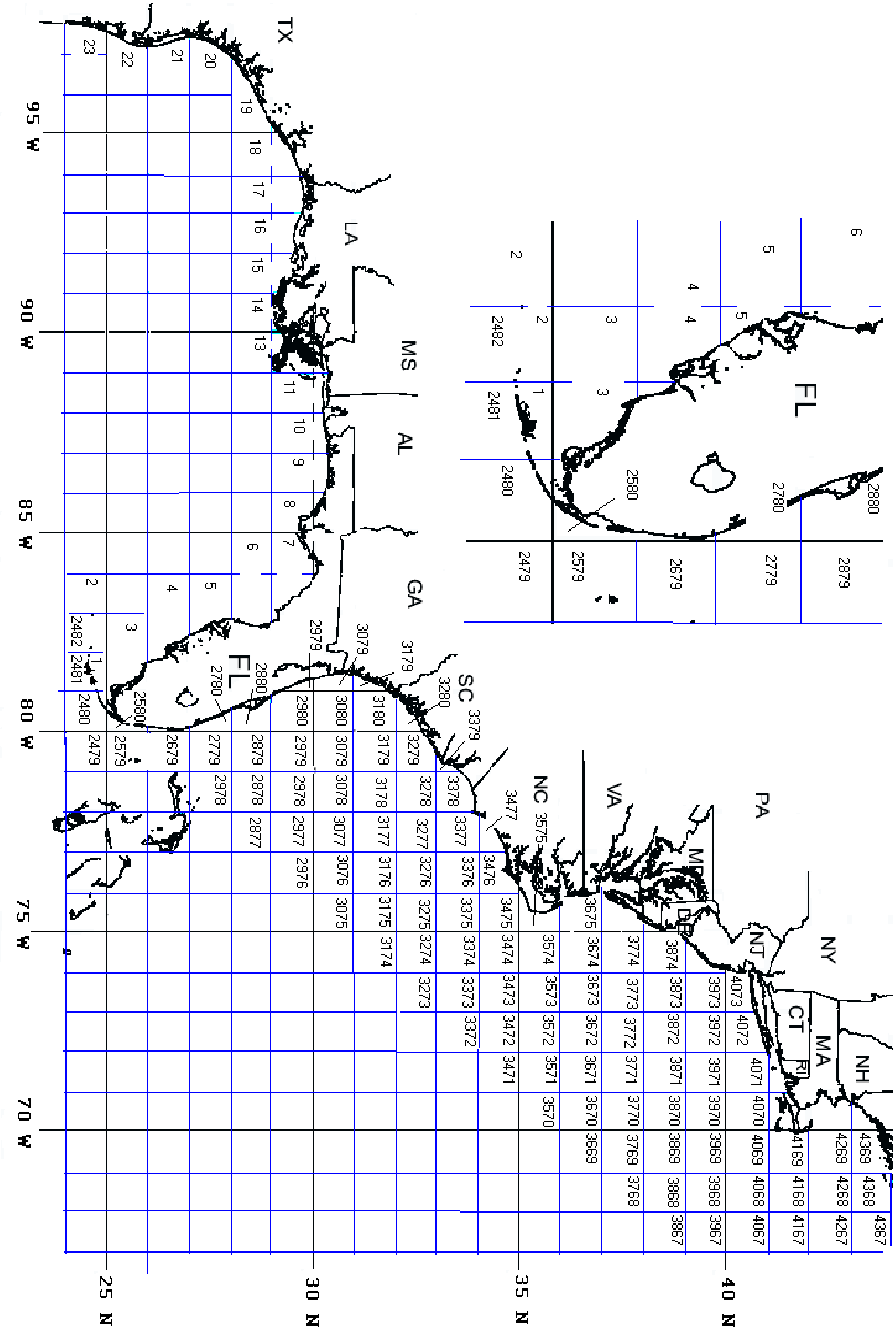
Southeast Region including Council and EEZ Boundaries



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



*U.S. GPO:200-656-



140

Statistical Grids and Codes

5. Summary Report

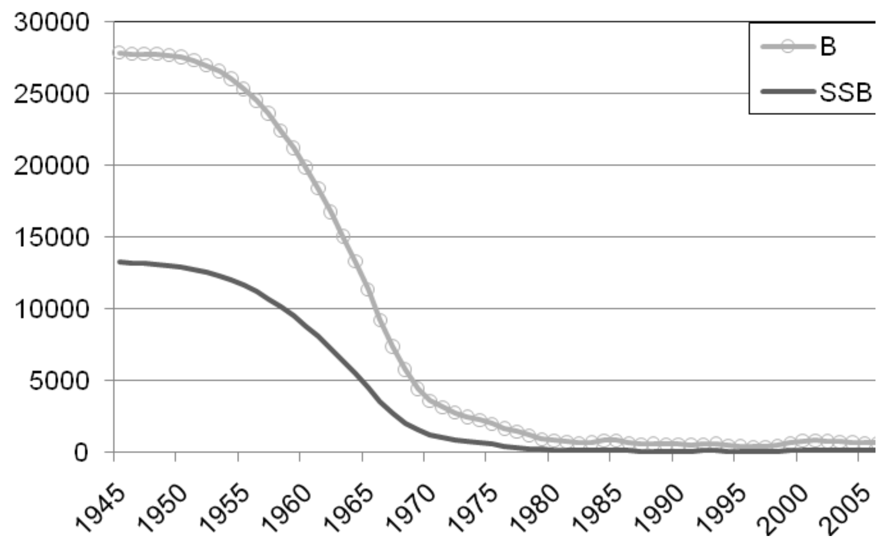
Stock Distribution and Identification

This assessment applies to the South Atlantic red snapper stock.

Stock Status

The assessment indicates that the stock has been overfished since 1960 and overfishing is currently occurring.

Figure 1. Biomass and Spawning Stock Biomass.



Assessment Methods

A statistical catch-at-age model (SCA) and a surplus-projection model (ASPIC) were considered in this assessment. A surplus-production model treats all fish in the population as having similar characteristics such as vulnerability to predation or to being caught in the fishery, and similar reproductive capacity. However, in fish populations natural mortality decreases with age, as fish become larger, and fecundity – reproductive capacity – increases with age. A catch-at-age model takes into account the changes in those characteristics with the age of the fish and it can account for recruitment variability and changes in selectivity due to regulations. Because of this enhanced ability to capture demographics, the catch-at-age model was chosen for evaluating stock status and providing management benchmarks and advice.

Assessment Data Summary

Data used for this assessment consist of records of commercial catch for the handline (hook-and-line) and dive fisheries, logbook data from the recreational headboat fishery, and MRFSS survey data of the rest of the recreational sector.

Table 1. Assessment Data Availability

Fishery	Landings	Estimated Discards	Indices
Commercial handline	1945-2006	1984-2006	1993-2006
Commercial dive	1984-2006	--	--
Headboat	1972-2006	1984-2006	1976-2006
Recreational (MRFSS)	1981-2006	1984-2006	1983-2006

A 12-inch length limit for red snapper was instituted in 1984, which is believed to have caused an increase in discarding. The dive fishery was assumed to generate no discards because of the selectivity of the method. Mortality rates used for discarded fish were 0.4 for the recreational fisheries and 0.9 for the commercial handline fishery. The higher mortality in the commercial fishery is due to the depth at which the fish are caught, and the effect of pressure changes as they are brought to the surface, and the length of time fish may be on deck before being returned to the water – the handling time of the fishery.

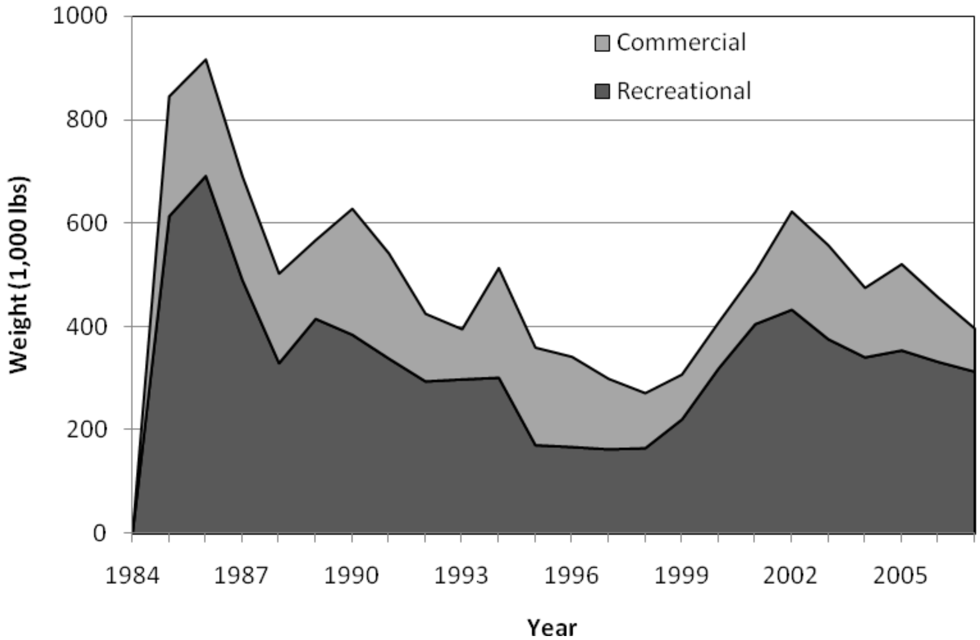
The base natural mortality (M) in the fishery was 0.078. This was assumed to be a constant over time, but varying with age because younger fish are much more vulnerable (for example, to predation) than larger, older fish.

Red snapper do not change sex over their lifetimes, and studies supported a constant 50:50 sex ratio for the population. The mean generation time of 20 years was estimated from data.

Catch Trends

The bulk of landings of red snapper come from the recreational fishery, which have exceeded the landings of the commercial fishery by 2-3 fold over the assessment period. Total landings were variable, with a downward trend through the 1990s.

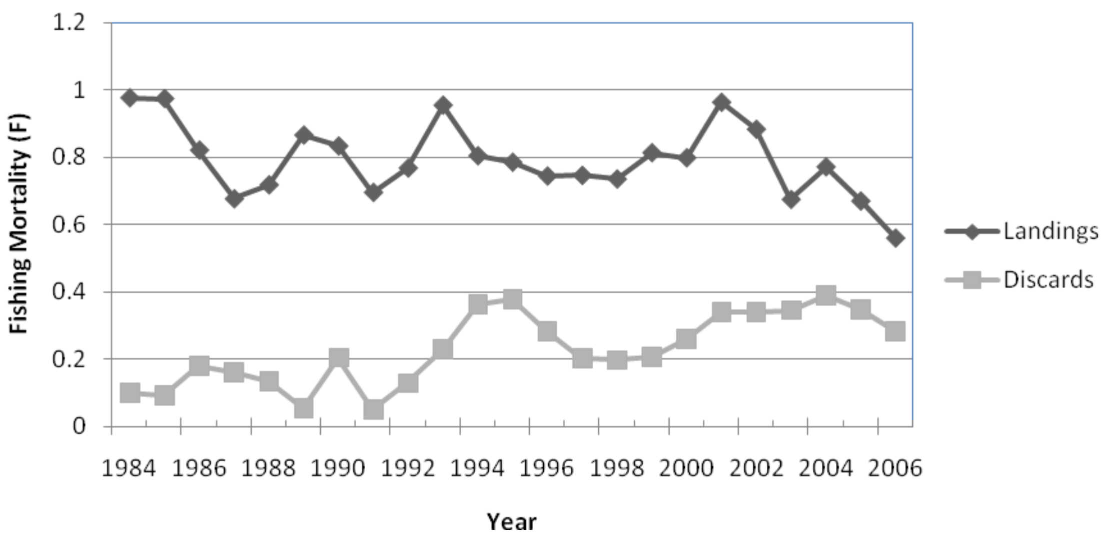
Figure 2. Landings by fishery sector, 1984-2006. (Discards by weight were unavailable in this assessment).



Fishing Mortality Trends

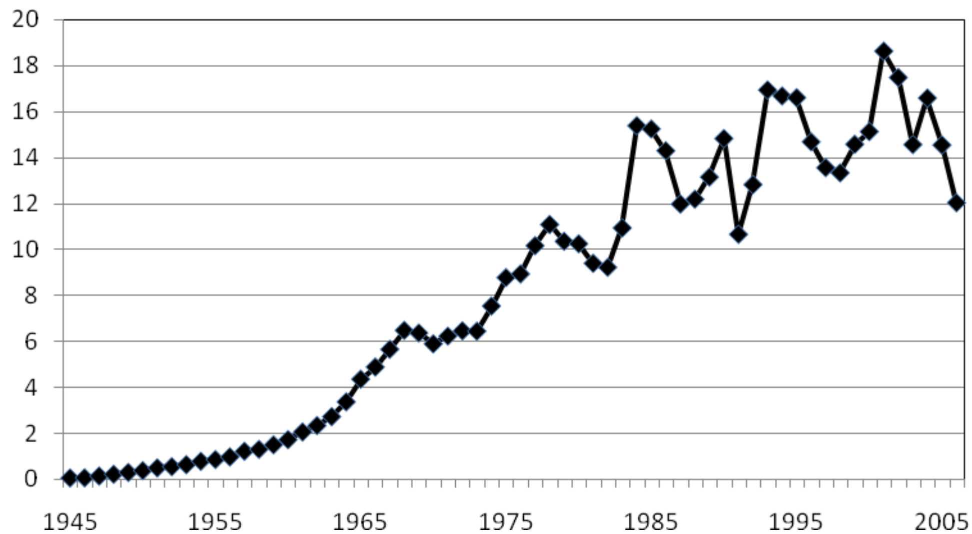
Fishing mortality can be evaluated by examining the time series of fully-recruited fishing mortality for both the landings and discards in the fishery. This is simply the sum of mortality by age in each component of the fishery.

Figure 3. Fully recruited fishing mortality.



The fishing mortality (F) is compared to what the fishing mortality would be if the fishery were operating at the proxy level for maximum fishing ($F_{40\%}$). The ratio of $F/F_{40\%}$ suggests a generally increasing trend from the 1950s through the mid-1980s, and since 1985 has fluctuated about a mean near 14. This indicates that overfishing has been occurring since 1960 at about 14 times the sustainable level, with the 2006 estimate of $F/F_{40\%}$ at 12.021.

Figure 4. $F/F_{40\%}$ The assessment review panel recommended the proxy value of F40% as the fishing limit, due to uncertainty in the assessment and the overfished/overfishing status of the stock.



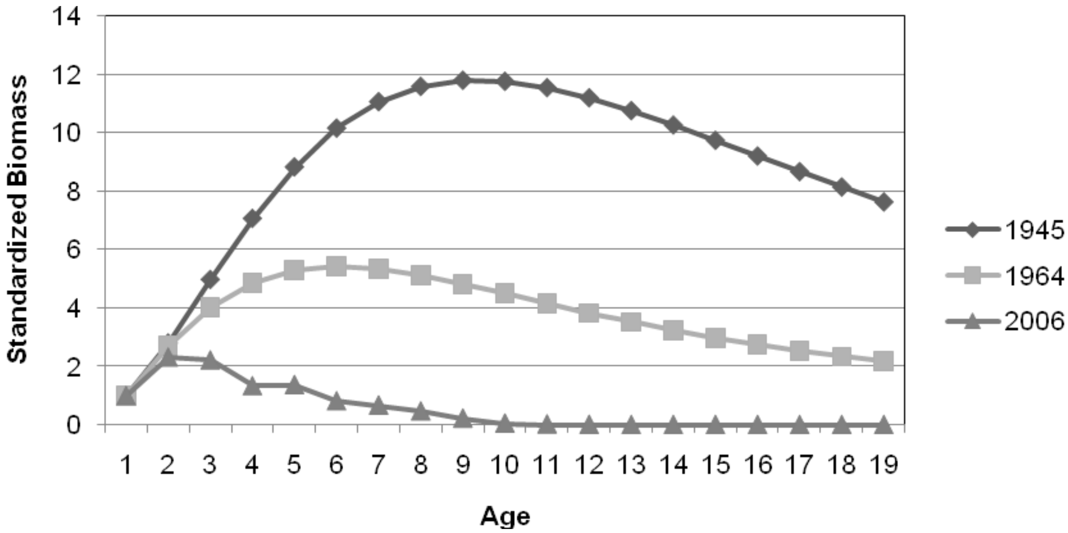
Stock Abundance and Biomass Trends

Estimated abundance-at-age shows truncation of the oldest ages from the 1950s into the 1980s; the age structure continues to be in a truncated condition. Fish of age 10 and above are practically non-existent in the population.

Estimated biomass-at-age follows a similar pattern of truncation as seen in the abundance data. Total biomass and spawning biomass show nearly identical trends—sharp decline during the 1950s and 1960s, continued decline during the 1970s, and stable but low levels since 1980.

Numbers of age-1 fish have declined during the same period, however notably strong year classes occurred in 1983 and 1984, and again in 1998 and 1999.

Figure 5. Age structure of the population (standardized to year-1 biomass).



Status Determination Criteria

The maximum fishing mortality threshold (MFMT) is defined by the Council as F_{MSY}, and the minimum stock size threshold (MSST) as $(1 - M)SSB_{MSY}$, where SSB refers to Spawning Stock Biomass, SSB_{MSY} is the level of SSB when the fishery is operating at maximum sustainable yield, and constant M is 0.078. Technically, "overfishing" is defined as occurring whenever F > MFMT and a stock is "overfished" when SSB < MSST. Current status of the stock and fishery are represented by the latest assessment year (2006).

Table 2. Status Summary Table (conditioned on the base run of the model).

Quantity	Units	Estimate
MFMT ($F_{40\%}$)	per year	0.07
$B_{40\%}$	mt	17347
$SSB_{F40\%}$	mt	7891
$MSST_{F40\%}$	mt	7275
$MSY_{F40\%}$	1000 lb	2314
$D_{F40\%}$	1000 fish	37
F_{MSY}	per year	0.112
$F_{2006}/F_{40\%}$	–	12.021
$SSB_{2006}/SSB_{F40\%}$	–	0.025

In addition to MSY-related benchmarks, proxies were computed based on per recruit analyses. These quantities may serve as proxies for F_{MSY}, if the spawner-recruit relationship cannot be estimated reliably. The proxies computed include F_{max}, $F_{30\%}$, and $F_{40\%}$, along with their associated yields. The value of F_{max} is defined as the level of fishing, F, that maximizes yield per recruit. $F_{30\%}$ and $F_{40\%}$ are the levels corresponding to 30% and 40% of the spawning potential ratio of the unfished stock. Uncertainty in the assessment led the review panel to choose $F_{40\%}$ as the MFMT value for red snapper.

Stock Status

Initial stock status was well above the maximum sustainable yield (MSY) benchmark, but declined sharply during the 1950s and 1960s. Declines slowed during the 1970s, and the stock has been stable at low levels since 1980. Based on the ratio of current estimated biomass to biomass at MSY, the stock is considered to be overfished. The benchmark history for period 1984-2006 is shown in Table 5.

Uncertainty

The effects of uncertainty in model structure were examined by comparing two structurally different assessment models—the catch-at-age model and a surplus-production model. For each model, uncertainty in data or assumptions was examined through sensitivity runs, which involve varying the value of a parameter and evaluating its impact on the model. Precision of benchmarks was computed by a parametric bootstrap procedure.

Projection methods

Projections were run to predict stock status in years after the assessment, 2007–2040. This 34 year time frame is the sum of mean generation time (20 years) and the number of years it would take for spawning biomass to reach SSB_{MSY} if no fishing occurred. The structure of the projection model was the same as that of the assessment model, and parameter estimates were those from the base run of the assessment model. Time-varying quantities, such as fishery selectivity curves, were fixed to reflect the most recent values of the assessment period, 2004-2006.

Table 3 shows the results of the 12 projection scenarios. What the discard-only projections show is that in order to rebuild the stock, the total catch (landings and discards) of red snapper will need to be reduced, not just the landings.

Special Comments

Reproduction in this model was calculated from mid-year spawning stock biomass (SSB), to reflect the actual timing of spawn. In most SEDAR models, the Jan. 1 SSB is assumed representative for purposes of calculating reproduction.

Table 3. Projection Scenarios (based on a reference run of the model). These are model projections based on the assumptions in the right hand column that provide an estimate of stock recovery dates.

Projection Scenario	**Projected Recovery Date**
$F = 0$	**2020**
$F = F_{current}$ (reflecting 2004-2006)	**0.3% of recovered value by 2040**
F_{MSY}	**97.5% of recovered value by 2040**
$F_{65\%MSY}$	**2025**
$F_{75\%MSY}$	**2027**
$F_{85\%MSY}$	**2030**
$F_{Rebuild}$ ($F_{Rebuild} = 0.109$, about 97% of F_{MSY})	**2040**
Discard Only Scenarios: All fish caught at rate F are discarded, and discard mortalities are applied	
$F = F_{current}$ (without Commercial Dive fishing) **Discard mortality: Com = 0.9, Rec = 0.4**	**15% of recovered value by 2040**
$F = F_{current}$ (without Commercial Dive fishing) **Discard mortality: Com = 0.8, Rec = 0.2**	**25% of recovered value by 2040**
$F = F_{current}$ (without Commercial Dive fishing) **Discard mortality: Com = 1.0, Rec = 0.6**	**9.8% of recovered value by 2040**
$F = F_{Rebuild}$ **Discard mortality: Com = 0.9, Rec = 0.4**	**2040**
$F = F_{Rebuild}$ **Discard mortality: Com = 0.7, Rec = 0.4**	**2040**

Table 4. Landings by fishery sector in thousands of pounds (whole weight), and discards in thousands of fish; 1984-2006.

Year	Recreational Landings	Commercial Landings	Recreational Discards	Commercial Discards
1984	613.78	231.76	46.81	6.76
1985	691.65	225.27	31.78	3.34
1986	490.21	200.71	28.69	6.37
1987	329.50	173.24	28.85	13.82
1988	415.23	152.30	29.96	6.83
1989	384.54	243.63	10.55	2.52
1990	338.44	203.35	17.94	27.47
1991	294.30	130.69	9.35	3.70
1992	298.22	96.96	21.30	16.46
1993	301.50	212.11	31.68	16.07
1994	171.01	188.58	32.13	22.01
1995	167.52	174.24	29.28	21.74
1996	163.08	136.15	15.62	29.03
1997	165.22	106.37	9.52	30.35
1998	220.80	86.73	37.71	22.97
1999	319.33	88.84	69.51	20.66
2000	405.01	100.57	96.28	19.63
2001	432.89	189.85	98.88	21.31
2002	375.73	181.68	82.74	19.92
2003	340.80	134.45	74.24	17.04
2004	354.23	166.69	80.43	14.23
2005	331.95	124.40	75.91	13.74
2006	313.10	83.17	63.65	15.22

Table 5. Benchmarks 1984-2006. The fishing mortality rate is full F, which includes discard mortalities. B is the total biomass at the start of the year, and SSB is the spawning biomass at midyear. B and SSB are in units mt (metric tonnes: 1,000 kg). SPR is static spawning potential ratio

Year	F	$F/F_{40\%}$	B	SSB	$SSB/SSB_{40\%}$	SPR
1984	1.076	15.376	839	180	0.025	0.011
1985	1.066	15.230	825	191	0.027	0.012
1986	1.000	14.284	663	173	0.024	0.013
1987	0.838	11.967	591	160	0.022	0.020
1988	0.852	12.176	616	163	0.023	0.018
1989	0.920	13.137	598	153	0.021	0.016
1990	1.037	14.815	553	141	0.020	0.014
1991	0.745	10.649	520	142	0.020	0.025
1992	0.897	12.807	575	169	0.024	0.033
1993	1.185	16.924	607	174	0.024	0.022
1994	1.166	16.664	509	158	0.022	0.026
1995	1.161	16.589	457	140	0.019	0.024
1996	1.027	14.669	413	123	0.017	0.028
1997	0.948	13.547	414	122	0.017	0.032
1998	0.932	13.321	504	138	0.019	0.030
1999	1.019	14.561	668	175	0.024	0.026
2000	1.058	15.113	814	224	0.031	0.025
2001	1.303	18.612	863	243	0.034	0.021
2002	1.223	17.465	797	235	0.033	0.023
2003	1.019	14.550	747	231	0.032	0.027
2004	1.160	16.574	720	215	0.030	0.022
2005	1.017	14.533	661	195	0.027	0.024
2006	0.841	12.021	644	194	0.027	0.030

1. 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: Red snapper (Lutjanus campechanus)
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: 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 = sesaonal 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 odels; 4 = size/age/stage-structured models; 5 = add ecosystem (multispecies, environment), spatial & seasonal analyses
- Frequency: 1
  0 = never; 1 = infrequent; 2 = frequent or recent (2-3 years); 3 = annual or more
- Year Reviewed: 2008
- Last Year of Data: 2006
  Used in the assessment
- Source: SEDAR 15 Stock Assessment Report 1
  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}: 12.02
- B/B_{MSY}: 0.025
- B/B_{limit}: 0.027
- Overfished?: Yes
- Overfishing?: Yes

Basis for
- F_{target}: ?
  e.g., F_{OY}
- F_{limit}: F40%
  e.g., F_{MSY}
- B_{MSY}: SSB at F40%
- B_{limit}: MSST
  e.g., MSST

Next Scheduled Assessment
- Year: not scheduled
- Month:

6. 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 maximises 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

Changes to the February 2008 Section II. Data Workshop Report
April 24, 2008

1. Pages 77-79, Figure 4.2 – Individual graphs and their year/sample size designations, which were improperly matched, were matched properly. Errant lines were removed from the individual graphs.
2. Page 82, paragraph 5.3.1.3 – The text was changed to clarify what commercial trips were used to determine effective effort. There were no changes in methods, and no new analyses were performed.
3. Page 85, paragraph 5.3.2.3 – The text was changed to clarify what headboat trips were used to determine effective effort. There were no changes in methods, and no new analyses were performed.
4. Page 116, Figure 5.9 – Errant blank spaces were removed to reveal state and county lines.
5. Page 118, Figure 5.11 – Errant lines were removed from the figure.

1. Introduction

1.1 Workshop Time and Place

The SEDAR 15 Data Workshop was held July 9 - 13, 2007 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); 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. Provide measures of population abundance that are appropriate for stock assessment. Document all programs used to develop indices, addressing program objectives, methods, coverage, sampling intensity, and other relevant characteristics. Provide maps of survey coverage. Consider relevant fishery dependent and independent data sources; develop values by appropriate strata (e.g., age, size, area, and fishery); provide measures of precision. Evaluate the degree to which available indices adequately 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 weight and number. Evaluate the adequacy of available data for accurately characterizing harvest and discard by species and fishery sector. Provide length and age distributions if feasible. Provide maps of fishery effort and harvest.

5. Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment. Include specific guidance on sampling intensity and coverage where possible.

6. Prepare complete documentation of workshop actions and decisions (Section II. of the SEDAR assessment report).

1.3 Participants

Workshop Panel

Alan Bianchi .... NCDMF
Ken Brennan ....NMFS SEFSC
Steve Brown .... FL FWC
Christine Burgess .... NCDMF
Julie Califf .... GA DNR
Rob Cheshire ....NMFS SEFSC
Chip Collier .... NCDMF
John Dean .... SAFMC SSC/Univ. of SC

David Gloeckner ....NMFS SEFSC
Jack Holland .... NCDMF
Stephanie McInerny ....NMFS SEFSC
Doug Mumford .... NCDMF
Jennifer Potts ....NMFS SEFSC
Marcel Reichert .... SC DNR
Jason Rueter .... NMFS SERO
Beverly Sauls .... FL FWC
Kyle Shertzer ....NMFS SEFSC
Tom Sminkey ....NMFS HQ
Doug Vaughan ....NMFS SEFSC
Byron White .... SC DNR
Geoff White ....ACCSP
David Wyanski .... SC DNR
Scott Zimmerman .... SAFMC AP
(FL Keys Comm. Fisherman's Assoc.)

Council Representation
Brian Cheuvront...SAFMC/NCDMF

Observers
Kevin Kolmos .... SC DNR
Mark Stratton .... SC DNR
Nate West .... SC DNR
Megan Westmeyer .... SC Aquarium
Gabe Ziskin .... MARMAP/C of C

Staff
John Carmichael..SEDAR/SAFMC
Rick DeVictor ....SAFMC
Patrick Gilles...NMFS SEFSC
Rachael Lindsay.. SEDAR

1.4 Workshop Documents

SEDAR15
South Atlantic Red Snapper & Greater Amberjack
Workshop Document List

Document #	Title	Authors
Documents Prepared for the Data Workshop		
SEDAR15-DW1	Discards of Greater Amberjack and Red Snapper Calculated for Vessels with Federal Fishing Permits in the US South Atlantic	McCarthy, K.

Documents Prepared for the Assessment Workshop		
SEDAR15-AW-1	SEDAR 15 Stock Assessment Model	Conn, P., K. Shertzer, and E. Williams
Documents Prepared for the Review Workshop		
SEDAR15-RW1		
SEDAR15-RW2		
Final Assessment Reports		
SEDAR15-AR1	Assessment of Red Snapper in the US South Atlantic	
SEDAR15-AR2	Assessment of Greater Amberjack in the US South Atlantic	
Reference Documents		
SEDAR15-RD01	Age, growth, and reproduction of greater amberjack, *Seriola dumerili*, off the Atlantic coast of the southeastern United States	Harris, P. , Wyanski, D., White, D. B.
SEDAR15-RD02 2007.	A Tag and Recapture study of greater amberjack, *Seriola dumerili*, from the Southeastern United States	MARMAP, SCDNR
SEDAR15-RD03	Stock Assessment Analyses on Atlantic Greater Amberjack	Legault, C., Turner, S.
SEDAR15-RD04	Age, Growth, And Reproduction Of The Red Snapper, *Lutjanus Campechanus,* From The Atlantic Waters Of The Southeastern U.S.	White, D. B., Palmer, S.
SEDAR15-RD05	Atlantic Greater Amberjack Abundance Indices From Commercial Handline and Recreational Charter, Private, and Headboat Fisheries through fishing year 1997	Cummings, N., Turner, S., McClellan, D. B., Legault, C.
SEDAR15-RD06 2007. MS Thesis, UNC Wilm. Dept. Biol. & Marine Biol.	Age and growth of red snapper, *Lutjanus Campechanus*, from the southeastern United States	McInerny, S.
SEDAR15-RD07 2005. CRP Grant # NA03NMF4540416.	Characterization of commercial reef fish catch and bycatch off the southeast coast of the United States.	Harris, P.J., and J.A. Stephen
SEDAR15-RD08	The 1960 Salt-Water Angling Survey, USFWS Circular 153	Clark, J. R.
SEDAR15-RD09	The 1965 Salt-Water Angling Survey, USFWS Resource Publication 67	Deuel, D. G. and J. R. Clark

SEDAR15-RD10	1970 Salt-Water Angling Survey, NMFS Current Fisheries Statistics Number 6200	Deuel, D. G.

2 Life History

2.1 Overview

State and federal biologists comprised the life history workgroup:

Chip Collier	NCDMF
Stephanie McInerny	NMFS, Beaufort
Paulette Mikell	SCDNR
Jennifer Potts	NMFS, Beaufort
Jessica Stephen	SCDNR
Byron White	SCDNR
David Wyanski	SCDNR - chair

This group's first task was to pull together the two red snapper age datasets supplied by SCDNR and NMFS-Beaufort. The primary issue faced in combining these datasets was not being able to convert increment counts in the SCDNR data to ages; no edge codes had been assigned. Upon examination of data from NMFS, it was determined that only 3% of the samples would be affected by not converting increment counts to age. A comparison of von Bertalanffy growth curves based on fractional age and increment count data from NMFS (corrected for size limits) revealed no difference in estimated theoretical growth (Figure 2.2); therefore, using increment counts for this assessment should not affect the overall result.

Another issue concerning the age data is determining the consistency of age estimates between laboratories (NMFS Beaufort and SCDNR). To do this, one reader from each laboratory examined a random subsample of 100 red snapper otoliths. An average percent error (APE) of 9.65 % was calculated from this exchange. For 95% of the samples exchanged, there was a difference of 0-2 increments between readers, suggesting similar otolith interpretation. Plots of total length at increment count were similar between laboratories (Figure 2.3).

A final issue facing the group was estimating discard mortality. A previous assessment of the red snapper population along the Atlantic coast used point estimates of 10% and 25% for release mortality based on observations by NMFS personnel. These estimates are low when compared to data in the recent red snapper assessment conducted in the Gulf of Mexico (SEDAR7). We also considered recent observer data collected from the headboat fishery on the Atlantic coast and commercial fisheries on the Atlantic coast and in the Gulf of Mexico. The decision was made to recommend the use of slightly higher point estimates of discard mortality in the commercial and recreational sectors (relative to those in SEDAR7) for the current assessment because depth data indicate that fishing occurs at greater depths in the Atlantic vs. Gulf of Mexico. Discard mortality was not estimated by depth zone because the model in the current assessment will likely not have a depth component.

2.2 Stock definition and description

Red snapper has been managed as separate Atlantic and Gulf stock units, and the SEDAR 15 workshop panel was instructed by the SAFMC to continue with the two US management units.

2.2.1 Otolith Chemistry

An otolith microchemistry study from the Gulf of Mexico region showed that Age 0 red snapper collected in three areas (north central, northwest, and southwest) can be classified to collection area with an accuracy of $\geq$87% based on the ratios of calcium to barium, cadmium, magnesium, and strontium (Patterson et al. 2001a). It may be possible to use this methodology to distinguish Gulf of Mexico and Atlantic coast fish.

2.2.2 Population genetics

There is no published evidence to date for separate Gulf of Mexico and Atlantic coast populations. A study by Garber et al. (2004) based on sequences from the control region of mtDNA concluded that red snapper constitute a single, panmictic population over the sampled range (Yucatan Peninsula, northern Gulf of Mexico, and the east coast of Florida). This question should be investigated again with the use of nuclear-DNA markers to search for inter- and intra-regional differences.

2.2.3 Demographic comparisons

Temporal differences in growth for Atlantic red snapper were recently investigated by NMFS (SEDAR15-RD06) and SCDNR (SEDAR15-RD04). Mean total length of red snapper collected off North Carolina and South Carolina were significantly larger than those sampled off the east coast of Florida ($P = 0.01$; SEDAR15-RD06). However, mean calendar age was also significantly larger for North and South Carolina red snapper ($P < 0.0001$), indicating that a possible reason for larger fish is simply the presence of older fish. To detect differences in red snapper growth between the Carolinas and Florida, length at age was compared. Data from both NMFS (SEDAR15-RD06) and SCDNR (SEDAR15-RD04) showed there were no significant differences in length at age between areas ($P > 0.05$).

2.2.4 Larval transport and connectivity

It has been hypothesized that there are pathways for larval connectivity and transport from the Gulf of Mexico to the Atlantic (Powles 1977), but oceanographic surface conditions on the west coast of Florida do not favor transport of eggs and larvae in this direction during the spawning peak of red snapper in the Gulf of Mexico (Jun - Aug; SEDAR7-DW-35). A two-dimensional model that utilizes wind stress data shows that the summer (Apr - Sep) months are characterized by continuous flow to the northwest with Ekman surface transport toward the northwest Florida coast (Fitzhugh et al. 2005). To evaluate transport below the surface, a three-dimensional model is necessary.

2.2.6 Tagging

There is no evidence in tagging studies for movement of red snapper between the Gulf of Mexico and the Atlantic coast (See **2.8. Movements and migrations**).

2.3 Natural mortality

2.3.1 Juvenile (YOY)

Juvenile red snapper are rarely encountered (n = 0 to 4 per year) in a nearshore (<30 ft) fishery-independent trawling program (SEAMAP) in the Atlantic. Little is known about the life history of larval and juvenile red snapper; therefore, no estimate of natural mortality is available.

2.3.2 Sub-adult/Adult

Natural mortality of red snapper was estimated using several methods. Initially, natural mortality (M) of red snapper was estimated to be 0.078 using the regression model reported by Hoenig (1983) for teleosts: $\ln(M) = 1.46-1.01*\ln(t_{max})$. Natural mortality from Hoenig's approach was 0.078 based on a maximum increment count of 53, since counts were not converted to calendar ages in the data workshop. The maximum calendar age of red snapper in the Gulf of Mexico is reported as 57 yr (Allman et al. 2002), which differs slightly from the maximum calendar age of 54 yr in the Atlantic (SEDAR15-RD06). Natural mortality was also estimated using a variety of models based on von Bertalanffy growth or reproductive parameters. Using these alternative models (Alverson and Carney 1975, Beverton 1992, Pauly 1980, and Ralston 1987), M ranged from 0.005 – 1.458 along the Atlantic coast. The Lorenzen (1996) model provides an age-specific estimate of natural mortality that ranges from 0.07 – 0.17 for fish with increment counts 2 to 53, with a higher estimate of 0.29 for fish with only 1 increment. Manooch et al. (1998) reported an estimate of M = 0.25, but the maximum age in their study was 25 yr.

Atypically low natural mortality estimates (M = 0.005) for Atlantic red snapper derived from the Alverson and Carney (1975) equation and uncommonly high estimates (M = 1.458) resulting from an equation by Beverton (1992) may be due to the unique life history of red snapper, as they mature at an early age but have the potential to live >50 yr. With respect to age at maturity relative to maximum age, red snapper do not follow the regression relationship previously established for some long-lived fishes (Beverton 1992).

Issue:
1.) Max age of red snapper in the Gulf is different than along the Atlantic coast.
2.) Natural mortality estimates using models based on growth and reproductive parameters were highly variable.

Recommendations:
1.) Use max age of 53 for this assessment since only increment counts are being used for age analysis and differences in estimates from models utilizing max age is minimal.
2.) Use Lorenzen age-specific model for estimates of natural mortality for Ages 1+.
3.) If desired, use a baseline estimate of 0.10 for the initial evaluations with a sensitivity analysis between 0.05 and 0.15. This baseline estimate matches the estimate used for Ages 2+ in SEDAR7 (Gulf of Mexico red snapper). A value of 0.6 was used for Age 1 in SEDAR7.

2.4 Discard Mortality

A previous assessment of the red snapper population along the Atlantic coast used release mortality rates of 10% and 25% based on observations by NMFS personnel (Manooch et al. 1998). These values are low estimates of discard mortality based on data in the recent red snapper assessment conducted in the Gulf of Mexico. We also considered recent observer data collected from the headboat fishery along the Atlantic coast and commercial fisheries along the Atlantic coast and in the Gulf of Mexico.

A study by Burns et al. (2004) conducted on headboats off Florida in the Atlantic and Gulf of Mexico found a release mortality of 64 % for red snapper. The majority of acute mortalities in this study (capture depth of 9–42 m) were attributed to hooking (49%), whereas barotrauma accounted for 13.5%. An earlier study by Burns et al. (2002), also conducted in the Atlantic and Gulf of Mexico, had similar results, as J-hook mortality accounted for 56% of the acute mortalities of red snapper on headboats. The effect of depth on discard mortality was analyzed using barometric chambers. Mortality due to barotrauma was not observed at depths of <20, 25, and 30 m (Burns et al. 2004). Mortality increased to 40% at 45 m and 45% at 60 m. These values were similar to those in other studies (Gitschlag and Renaud 1994; Koenig 2001). Patterson et al. (2001b) in the Gulf of Mexico estimated a discard mortality of 9% at 21 m, 14% at 27 m, and 18% at 32 m based on recaptures of tagged fish.

Higher release mortality was attributed to the commercial fishery in the Gulf of Mexico than to the recreational fishery due to different handling times and depths fished. Commercial fishermen have been observed to hold fish on deck until fishing at a site has ceased. After fishing activity has slackened, fishermen measure and release undersized fish. The prevalence of this practice in the commercial fishery is unknown, but higher mortality due to handling time (Koenig 2001 as cited in SEDAR7-RW) and the effect of hooking noted above may explain the high mortality (94% of 31 red snapper released) observed in a study of the discards of one commercial fisherman from the Atlantic coast (SEDAR15-RD07). Acute release morality in the commercial fishery ranged from 64-69% in the Gulf of Mexico (Baker et al. 2004; Neiland et al., in prep.) to 94% along the Atlantic coast (SEDAR15-RD07).

New data on red snapper release mortality is coming in from the headboat observers on the Atlantic coast. One of those studies is the "Headboat At-Sea Observer" pilot study in Florida (east coast and Florida Keys) conducted by conducted with federal funds by

Beverly Sauls (Florida Wildlife Research Institute). The release condition of fish is noted as: 1) released alive and swam down fast, 2) released alive and swam down slowly, 3) released alive and floated at the surface 4) released dead, or 5) predator attacked released fish. The observed release mortality for red snapper (n=1233) was very low (5%), as most fish swam down (condition 1 and 2) after being released. Similar results were noted in the headboat logbook reported by captains from Florida Keys to North Carolina in 2006 (1%, n =17,504). The MRFSS headboat observer data from north of Florida (unpublished data) had very few observations of red snapper and release condition was not recorded.

Recommendations:
The recommended discard mortality by depth (in parentheses) for red snapper in the Gulf of Mexico stock assessment (SEDAR7) was 15% at 20-40 m to 40% at >40 m in the recreational fishery and 71% at 55 m to 88% at 83 m in the commercial fishery. In the current assessment, point estimates were discussed for discard mortality because the model to be used will likely not have a depth component.

The Life History group recommends two values of discard mortality. For the recreational fisheries (MRFSS and Headboat), release mortality should be set at 40% (30 to 50% sensitivity range). For the commercial fishery, release mortality should be set at 90% (80 to 100% sensitivity range). Release mortality in the recreational fishery for red snapper is lower than that in the commercial fishery because the recreational fishery tends to fish in shallower waters. Actual locations of capture are not recorded, only minimum and maximum depths for the fishing trip. The mean minimum depth in the recreational (charter boat) fishery was 43 m (range 20 to 183 m). The mean maximum depth was 58 m (24 to 274 m). The commercial fishery had a mean minimum of 43 m (range 18 to 604 m). The mean maximum in the commercial fishery was 71 m (range 19 to 823 m). These depth data indicate that fishing occurs at greater depths in the Atlantic vs. Gulf of Mexico, thus the higher point estimates of discard mortality in the current assessment. In addition, the likelihood of longer handling times (i.e., time spent on deck) in the commercial fishery may increase release mortality.

2.5 Age Data

2.5.1 Age Structure Samples

Two sets of otolith-based age data were brought to the data workshop. Contributors included NMFS Beaufort and SCDNR (SEDAR15-RD04). NMFS data were collected from the U.S. South Atlantic commercial (n = 1,208) and recreational fisheries (n = 5,099) during 1977 – 2006 (Manooch and Potts 1997; SEDAR15-RD06). SCDNR data were collected from 1980 – 2006 and included samples from the U.S. South Atlantic commercial fishery (n = 612) as well as a fishery-independent survey (MARMAP; n = 405) (SEDAR15-RD04). The combined samples yielded a total of 7,324 red snapper age estimates. A brief characterization of sampling and related issues follows:

Issue:
Data from NMFS include increment counts converted to calendar age and fractional age using measures of otolith edge condition (edge code). Data from SCDNR include only increment counts without an edge code; therefore, counts cannot be converted to ages.

Recommendations:
1.) Combine data sets and perform age and growth analyses on only increment counts for both data sources. Upon examination of data from NMFS (SEDAR15-RD06), it was determined that only 3% of the samples would be affected by not converting to calendar age or fractional age, thus, using increment counts for this assessment should not affect the overall results of the analyses. To look for effects on growth estimates by using increment counts as opposed to calculated ages, separate size-limit corrected (Diaz et al. 2004) von Bertalanffy curves derived from fractional age (L_∞ = 896, k = 0.25, t_0 = -0.16) and increment count (L_∞ = 898, k = 0.24, t_0 = -0.23) were plotted using the NMFS data. The plot and parameter estimates revealed no difference in estimated theoretical growth between increment count and fractional age (Figure 2.1). In addition, the uncorrected von Bertalanffy curve from SEDAR15-RD04 based on increment counts from fishery-dependent samples (L_∞ = 899, k = 0.22, t_0 = -1.309) was plotted against an uncorrected curve using NMFS fractional age (L_∞ = 901, k = 0.22, t_0 = -0.92) data (SEDAR15-RD06) to further show no real difference in estimated theoretical growth (Figure 2.2).

2.) In future age assessments, ensure that all samples will be assigned an increment count as well as an edge code for more complete information from the sample. A classification of edge types has been developed by SCDNR denoting margin condition and quality of the sample that will be used by both laboratories (Table 2.1).

2.5.2 Age Reader Precision

A random subsample of 100 red snapper otoliths was exchanged between NMFS Beaufort and SCDNR to determine the consistency of age estimates between laboratories. An average percent error (APE) of 9.65 % was calculated from this exchange. For 95% of the samples exchanged, there was a difference of 0-2 increments between readers, suggesting similar otolith interpretation. The slight differences in increment count do not seem to affect the predicted growth of red snapper. Plots of total length at increment count were similar between laboratories (Figure 2.3). SCDNR data included smaller fish at several increments, most likely due to the addition of fishery-independent samples. The comparison of uncorrected growth curves from SEDAR15-RD06 samples and fishery-dependent data from SEDAR15-RD04 showed similar estimates of theoretical growth, also suggesting similar aging techniques (Figure 2.2).

Issue:
Differences in otolith interpretation can lead to incompatible datasets.

Recommendation:
To continue the exchange of calibration otoliths sets among state and federal agencies to maximize data comparability and for the purpose of quality control.

2.5.3 Age Patterns

Several strong year classes were evident for Atlantic red snapper between 1977 and 2006. These strong year classes were present in 1983, 1984, 1986 – 1989, 1991 – 1993, 1996, and 1999 – 2001. These cohorts could be followed through the fishery for as long as 5 – 8 yr, first appearing most commonly as age 2 and 3 fish. Moderate to strong year classes appeared to occur on average every 2 yr. Prior to 1983, large pulses of 2 and 3 year old red snapper were entering the fishery indicating possible strong year classes, but these cohorts could not be followed after age 3 (SEDAR15-RD06).

The maximum increment count in the dataset used for the current stock assessment is 53. An age validation study based on measurements of nuclear-bomb ^{14}C in otoliths confirmed that the longevity of red snapper in the Gulf of Mexico is at least 55 yr (Baker and Wilson 2001).

2.6 Growth

Several age and growth studies have been published on red snapper in the U.S. South Atlantic (Nelson and Manooch 1982; Manooch and Potts 1997; SEDAR15-RD04). The updated data set includes about 6400 newly processed samples (SEDAR15-RD06) along with samples from two out of the three previous aging studies (Manooch and Potts 1997; SEDAR15-RD04) providing a more complete analysis of red snapper age and growth along the Atlantic coast with increased spatial and temporal coverage. Data mentioned above from NMFS Beaufort and SCDNR were combined to develop an overall growth model for Atlantic red snapper.

Growth models can be influenced by the use of size-biased samples, for example, due to minimum size limits affecting fishery-dependent sampling. Thus, an overall, weighted von Bertalanffy growth model that corrects for size-selective data was used (L_∞ = 894, k = 0.25, t_0 = -0.01) (Diaz et al. 2004). Model fits used temporal specific size-limits (1983 to 1991, 12 inches total length (TL); 1992 to 2006, 20 inches TL). The model was fit to observed total lengths and increment counts.

Issues:
Size limit regulations for Atlantic red snapper changed within the study time period of 1977 to 2006 resulting in size-selective fishery-dependent samples (SEDAR15-RD06). The von Bertalanffy growth model may be influenced by size-selective sampling and may not appropriately represent the growth of the population.

Recommendations:
A modified von Bertalanffy growth model correcting for size limited data was used to represent growth of red snapper in the U. S. South Atlantic (Diaz et al. 2004). This model was previously used to estimate growth curves for Atlantic and Gulf of Mexico gag grouper (SEDAR 10) as well as Gulf of Mexico red snapper (SEDAR 7).

2.7 Reproduction

The study by White and Palmer (SEDAR15-RD04) represents the only available information on the reproductive biology of red snapper along the Atlantic coast of the southeastern U.S. Specimens were collected during 1979-2000 and the majority (64%) of the specimens for the study came from a fishery-dependent source, primarily commercial snapper reel catches. Additional fishery-independent data (MARMAP chevron trap) collected during 2001-2006 were added to the dataset prepared for the current stock assessment. All age-related results presented in this section were based on increment counts (not converted to calendar or fractional age). Information below on spawning seasonality, sexual maturity, and sex ratio is based on the most accurate technique (histology) utilized to assess reproductive condition in fishes. Red snapper do not change sex during their lifetime (gonochorism).

2.7.1 Spawning Seasonality

Based on the occurrence of hydrated oocytes and/or postovulatory follicles, spawning occurred from May through October and peaked during July through September. Mean values of a female gonadosomatic index peaked in June and July. Spawning females were captured in mid-shelf to shelf-break depths from Cape Fear, NC, to Cape Canaveral, FL.

2.7.2 Sexual Maturit*y*

Maturity ogives for age and TL are available in tabular format in SEDAR15-RD04 (see Table 8), a summary of which follows. The smallest mature male was 200 mm TL and the youngest was age 1; the size at 50% maturity was 223 mm TL (95% CI = 147-258), and the largest immature male was 378 mm TL, the oldest was age 4. All males were mature at 401-450 mm TL and age 5. The smallest mature female was 287 mm TL, and the youngest was age 2; the size at 50% maturity was 378 mm TL (95% CI = 364-389), and the largest immature female was 435 mm TL, the oldest was age 4. All females were mature by 451-500 mm TL and age 5. Age at 50% maturity (A_{50}) for females was 1.62 yr (logistic; 95% CI = 1.21-1.87).

An update of the maturity ogives can be found in the “Maturity” tab of the spreadsheet RSinput.xls. The logistic equation (1-1/(1+exp(a+b*age)) was used to estimate A_{50} for males (a=-0.78, b=1.728) and females (a=-2.93, b=1.759).
2.7.3. Sex ratio

Tables with sex ratio by length class (mm TL) are available in SEDAR15-RD04 (see Tables 6 and 7). The male:female sex ratios for all red snapper (including immature fish) in fishery-independent and fishery-dependent collections from 1979-2000 were **1:1.04** and **1:1.22**, respectively. Given the inclusion of immature fish in these sex ratios, the decision was made to re-analyze the data. Mature specimens from both sources, including the additional fishery-independent data collected during 2001-2006, comprised the new dataset. The sex ratio (**1:0.94**, n = 898) was not significantly different ($P > 0.05$)

from 1:1. An analysis of the two best years (1999-2000) of data produced the same result (**1:0.95**, n = 465). Commercial fishermen involved in the study were permitted to land undersized specimens. Updated sex ratio analyses can be found in the "Sex ratio" tab of the spreadsheet RSinput.xls.

2.7.4 Spawning Frequency

No information available for red snapper along the Atlantic coast of the U.S. Estimate is available from Gulf of Mexico (see Woods 2003; SEDAR7-DW-35).

2.7.5 Batch Fecundity

No information available for red snapper along the Atlantic coast of the U.S. Estimates of fecundity at age are available from Gulf of Mexico (see Woods 2003; SEDAR7-DW-35).

Recommendations:

2.8 Movements and migrations

Research on red snapper movements/migrations in Atlantic waters is limited. The limited data available indicate high site fidelity. In the largest study, Burns et al. (2004) tagged and released 5,272 red snapper in the Gulf of Mexico (from Naples, FL, to the eastern border of Texas) and Atlantic (from Cape Canaveral, FL, to Georgia) over a 13 yr period. Approximately 40% of these fish were tagged in the Atlantic. Forty-four percent of the specimens were recaptured within 1.9 km of the tagging site. Less than 10 of the 410 recapture events showed movement >100 miles and movement between the Gulf of Mexico and the Atlantic coast is not mentioned in the report.

The results of two smaller studies also indicate minimal movement in Atlantic red snapper. The SC Marine Gamefish Tagging Program reports 1,597 red snapper tagged with 171 recaptures. Ninety-three percent were recaptured within 2 km of the tagging site. SCDNR (MARMAP) data indicates 45 red snapper tagged with two recaptures, one of which was recaptured in same vicinity as tagged. The other recapture had no location data.

Numerous publications have reported on red snapper tagging and movements in the Gulf of Mexico (Fable 1980; Szedlmayer 1997; Watterson et al. 1998; Ingram and Patterson 2001; Patterson et al. 2001b; Patterson and Cowan 2003; Szedlmayer and Schropfer 2005; Schropfer and Szedlmayer 2006). Four studies from the Gulf of Mexico (Fable 1980; Szedlmayer 1997; Szedlmayer and Schropfer 2005; Schropfer and Szedlmayer 2006) found that red snapper have high site fidelity, moving less than 0.2 km to 1.6 km from the original location tagged. Four other publications (Watterson et al. 1998; Ingram and Patterson 2001; Patterson et al. 2001b; Patterson and Cowan 2003) found that red snapper have low site fidelity (24.8-46% site fidelity estimates) in the Gulf of Mexico.

However, three of those publications (Watterson et al. 1998; Ingram and Patterson 2001; Patterson et al. 2001b) state that the low fidelity was due to hurricanes. Watterson et al. (1998) reports that 80% of the recaptured red snapper that were not at liberty during Hurricane Opal were recaptured at their site of release. Red snapper that were at liberty during Hurricane Opal had a significantly higher likelihood ($P < 0.001$) of movement away from their site.

Recommendation:
Research on red snapper movements/migrations in Atlantic waters is limited. Available data and the results of studies in the Gulf of Mexico indicate high site fidelity. Tropical storms may cause greater than normal movement.

2.9 Meristics and conversion factors

Length/length, weight/length, and weight/weight relationships were calculated for red snapper for total length (TL), fork length (FL), standard length (SL), whole weight (WW) and gutted weight (GW), using various combined fishery-independent (SCDNR MARMAP program) and fishery-dependent (SCNDR and FWRI (less the gutted weight)) data sets (Table 2.2). In addition, NMFS headboat samples provided whole weight, total and fork lengths, while other NMFS samples provided whole weight and total length. All weights are shown in grams and all lengths in millimeters. Coefficients of determination were high for linear (length) and nonlinear (weight) regressions ($r^2 \geq 0.968$).

2.10 Comments on adequacy of data for assessment analyses

The data available for this assessment should be viewed as adequate to more than adequate. No information on Age 0 natural mortality, spawning frequency, and fecundity is available in the Atlantic, but these gaps should not affect the assessment.

2.11 Research recommendations

1) Use new technology such as recent advances in genetics techniques (microsatellite multiplex panels; see Saillant and Gold (2006)) to reinvestigate the stock structure and estimate the effective population size of red snapper in the Gulf of Mexico and along the Atlantic coast.

2) Obtain better estimates of red snapper natural mortality and release mortality in commercial and recreational fisheries.

3) Investigate life history of larval/juvenile (age 0 and 1) red snapper, as little is known.

4) All future age assessments (any species) 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 (Table 2.1). These classifications are currently used by MARMAP and NMFS Beaufort.

5) Continue to conduct inter-lab comparison of age readings from test sets of otoliths in preparation for any future stock assessments.

6) Obtain adequate data for gutted to whole weight conversions a priori (before stock assessment data workshop).

7) Strategies for collection of ageing parts vary for estimations of age composition and von Bertalanffy growth parameters. Typically, small specimens from fishery-independent sampling are needed to produce good estimates of von Bertalanffy parameters.

2.12 Itemized list of tasks for completion following workshop

1) Complete red snapper age composition: McInerny; August 17, 2007 - done

2.13 Literature cited

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2.14 Tables

Table 2.1. Edge code and quality code developed by SCDNR to be incorporated into aging studies by both SCDNR and NMFS.

Quality Code	Action	Description
A	Omit otolith from analysis	Unreadable
B	Agreement on age may be difficult to reach. Omit from analysis.	Very difficult to read
C	Agreement after second reading is expected after some discussion.	Fair readability
D	Agreement after second reading is expected without much discussion.	Good readability
E	Age estimates between readers should be the same.	Excellent readability

Edge Code	EdgeDescription	Translucent Width
1	Opaque Zone on the edge	None
2	Narrow translucent zone on the edge	Less than about 30% of previous increment
3	Medium translucent zone on the edge	About 30 - 60% of previous increment
4	Wide translucent zone on the edge	More than about 60% of previous increment

Table 2.2. Conversion equations for Atlantic red snapper using total length (TL), fork length (FL), standard length (SL), whole weight (WW) and gutted weight (GW).

Conversion	Equation	N	r^2	a	a SE	b	b SE
TL – FL	FL = aTL + b	2252	0.9948	0.9387	0.0013	-1.2893	0.7542
TL – SL	SL = aTL + b	1627	0.9905	0.8178	0.0019	-14.2895	1.091
FL – SL	SL = aFL + b	1597	0.9929	0.8679	0.0018	-12.1576	0.9431
TL – WW	$WT = a(TL)^b$	5312	0.9753	0.000007	0.0000003	3.104	0.007103
FL – WW	$WT = a(FL)^b$	1976	0.9681	0.000009	0.0000007	3.108	0.0127
WW – GW	GW = a(WW) + b	13	0.9996	0.9409	0.0059	-19.1681	25.4768
WW – GW (no intercept)	WW = GW*C C = 1.079	13					

2.15 Figures

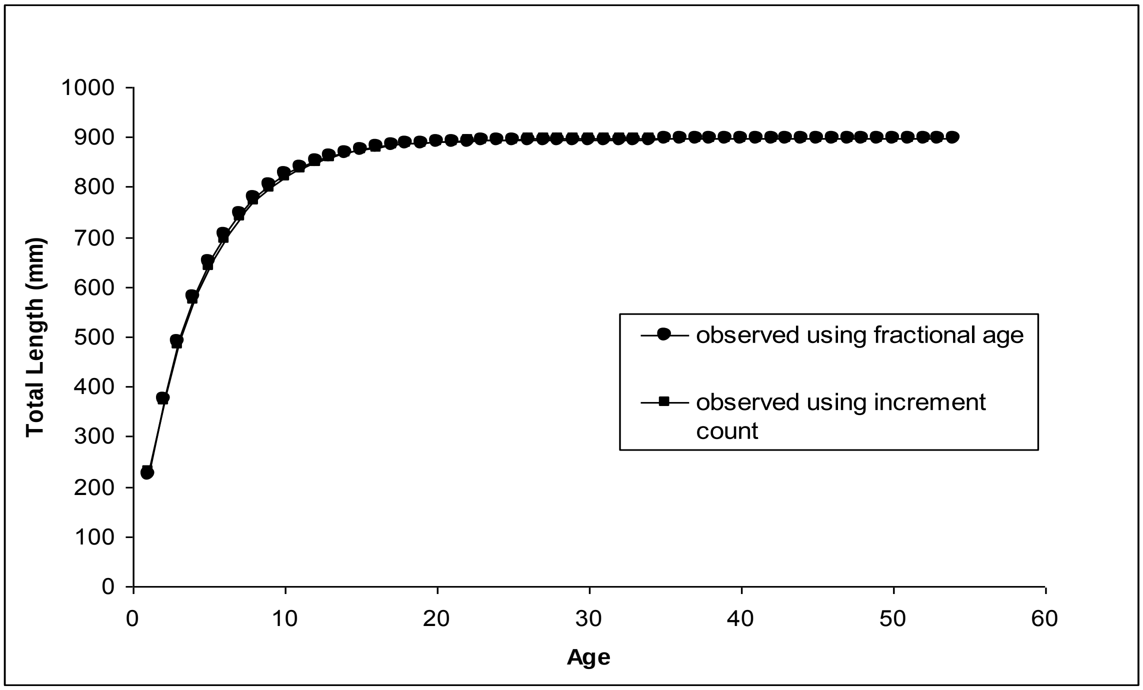

Figure 2.1. Comparison of size-limit corrected (Diaz et al. 2004) von Bertalanffy curves from NMFS red snapper data using fractional age and increment count.

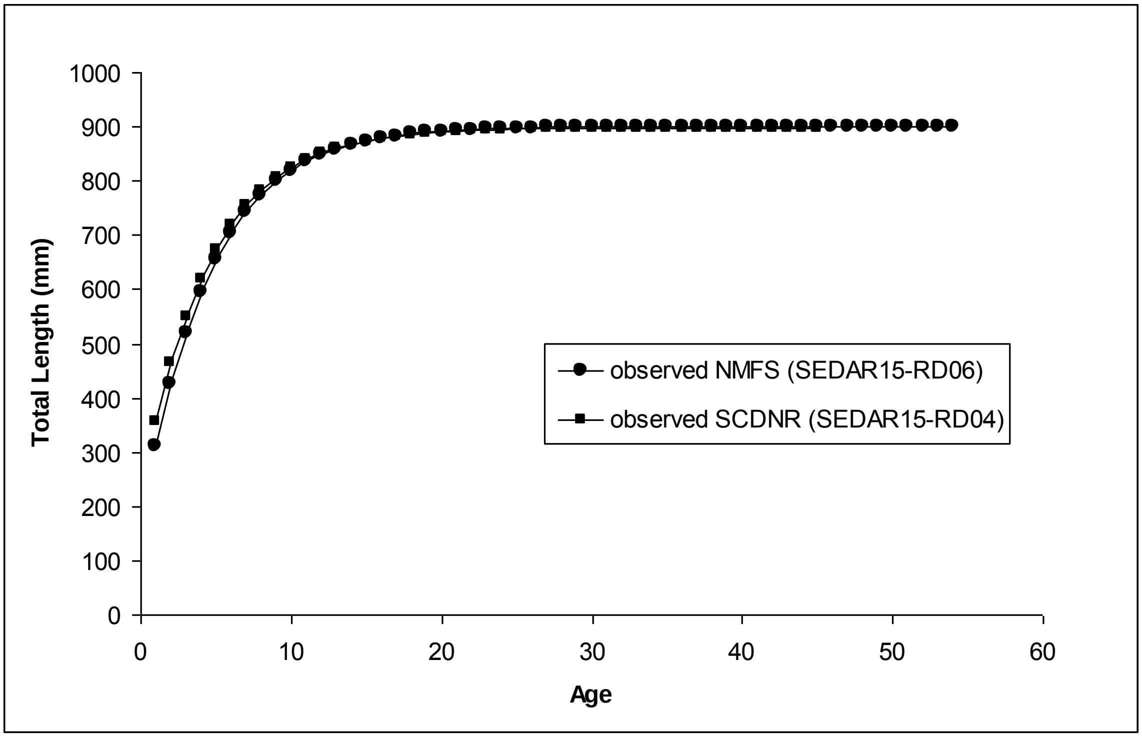

Figure 2.2. Comparison of uncorrected von Bertalanffy curves from NMFS fractional age data and SCDNR increment count data. All samples were from fishery-dependent sources.

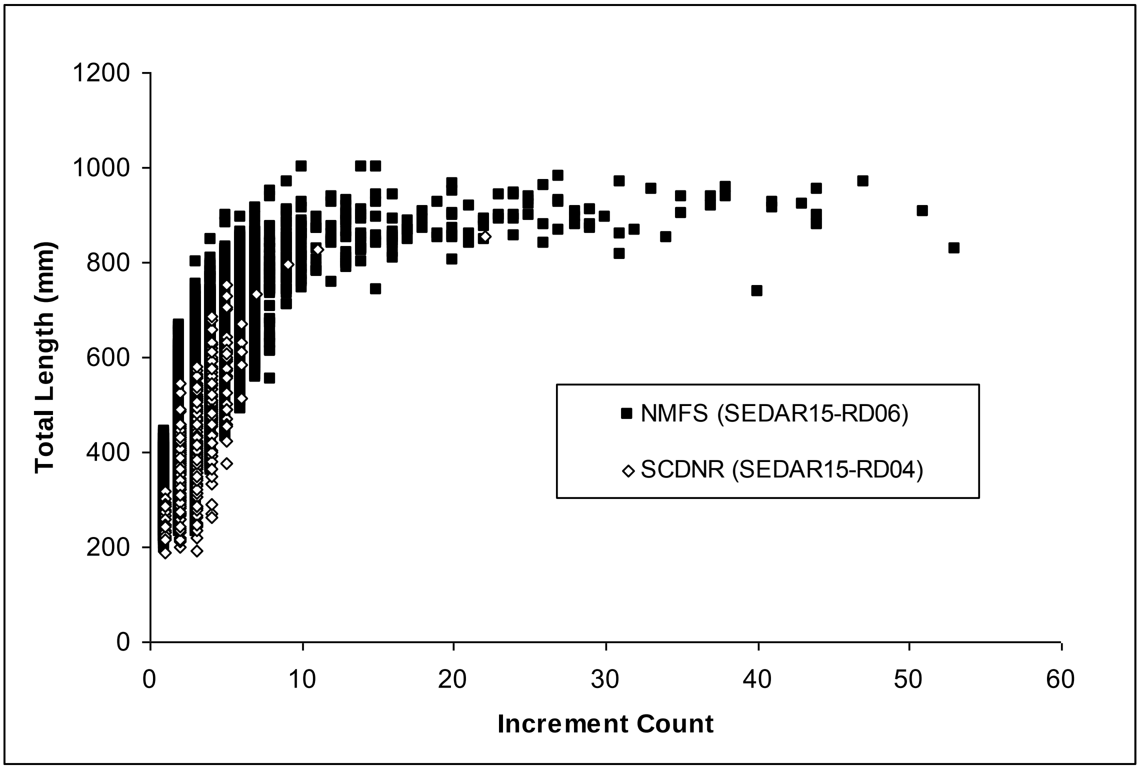

Figure 2.3. Red Snapper total length at increment comparison for all NMFS data vs. all SCDNR data.

Appendix 1. Addendum to Growth (Section 2.6)

Two errors in the calculation of the red snapper growth model were found and addressed after the conclusion of the assessment workshop.

Firstly, within the Diaz model used to calculate the von Bertalanffy curve, the fishery independent data from SCDNR were mistakenly treated as fishery dependent data so were, therefore, corrected for size limit effects. This data has been rectified. Secondly, within the SEDAR 7 document introducing the Diaz model (SEDAR7-AW-01), it states that observations below the minimum size limit assigned to them should be excluded from the analysis. This statement was overlooked and should have been taken into account when fitting the red snapper growth model.

Both errors have been fixed resulting in a revised red snapper growth model (L_∞ = 894.7, k = 0.235, t_0 = -0.48) (Figure A1.1). The revised model appears to fit the observed data well. Differences in parameter estimates between the original model and the revised model were minor. When the original and revised models were plotted together, differences in predicted length at increment count were visible for fish with 1 – 4 increments (Figure A1.2). When fish measuring under the minimum size limit (collected while regulations were in effect) were excluded from the model, the von Bertalanffy curve predicted higher lengths at increment counts 1 – 4.

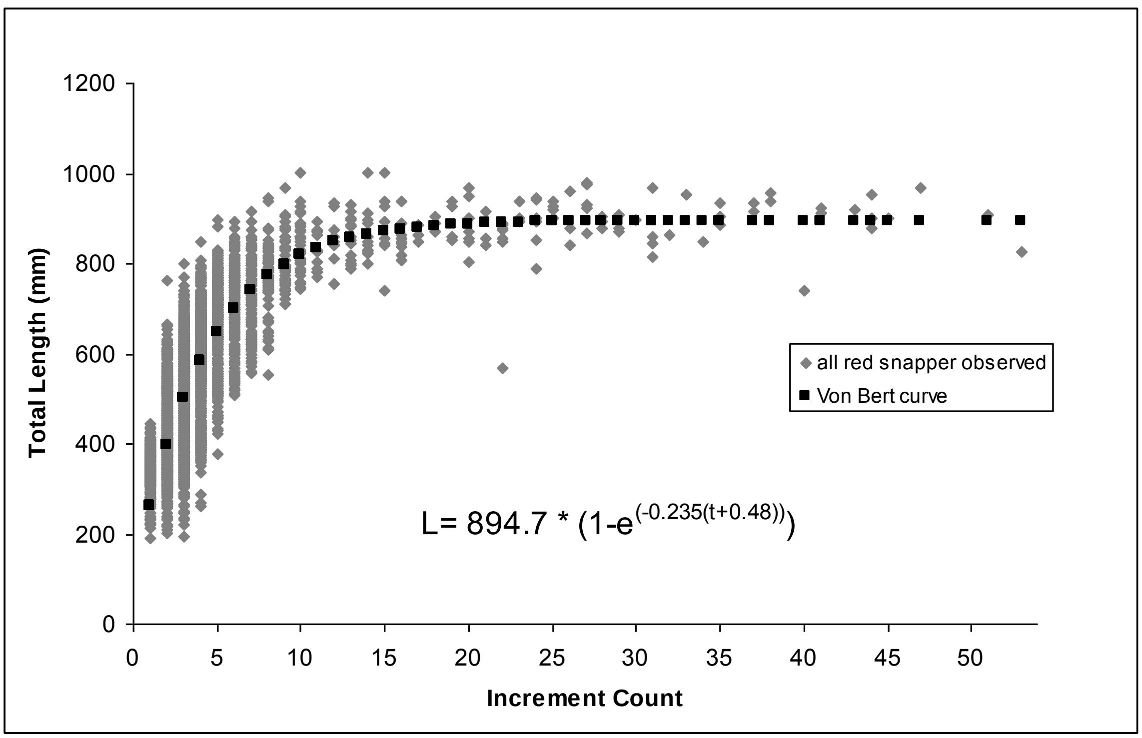

Figure A1.1. Revised von Bertalanffy model from all red snapper increment counts using Diaz et al. model with appropriate size limits in place.

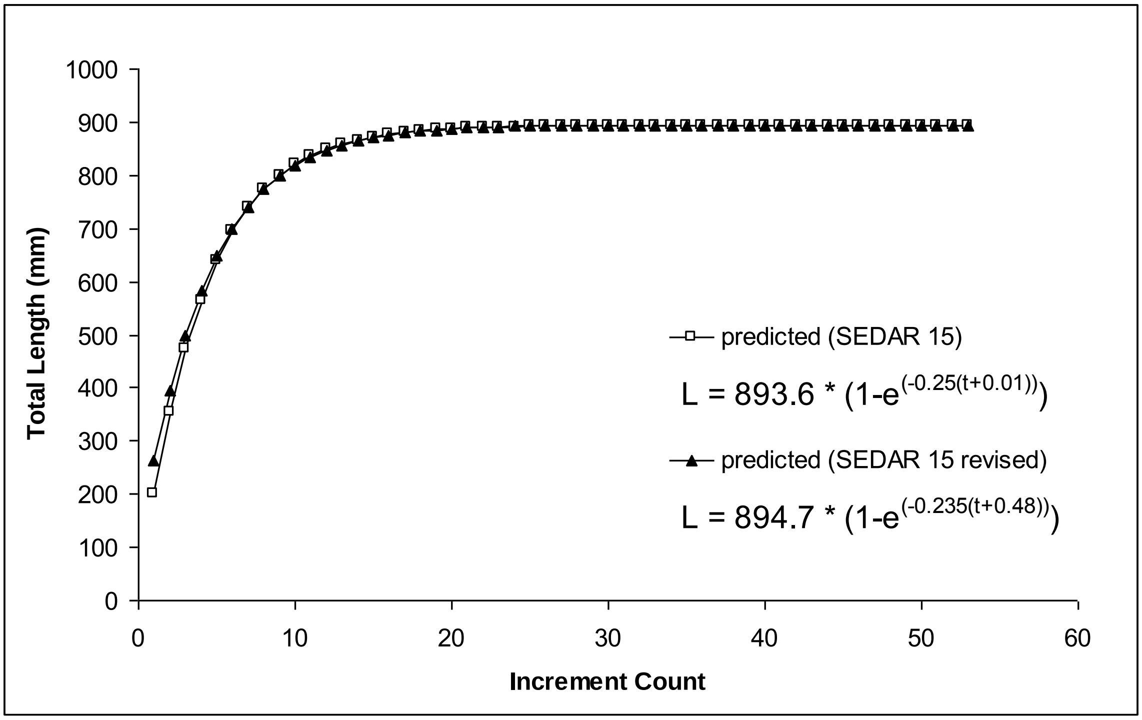

Figure A1.2. Von Bertalanffy Comparison of Original and Revised Diaz models for red snapper.

3 Commercial Fishery

3.1 Overview

A series of issues were discussed by the Commercial Working Group concerning stock boundaries both the southern boundary with the Gulf of Mexico and the northern boundary (north of North Carolina). No adjustments were deemed necessary for inclusion of unclassified snappers that would have been analogous to previous SEDAR assessments. Commercial landings for the U.S. South Atlantic red snapper stock were developed for the period 1900 through 2006. Estimated discards are presented for recent years (1992-2006) subsequent to the last change in minimum size limit for red snapper along the U.S. South Atlantic coast. Summaries of sampling intensity for lengths and age are presented, and length and age compositions by gear for which sample size was deemed minimally adequate. Several research recommendations are also given.

3.2 Commercial Landings

Prior to the DW the commercial working group settled on the following numerical gear codes for dividing red snapper commercial landings into five categories: handline (600-616, 660, 665), diving (760, 941-943), trawl (200-220), traps (325-390, and other gear types (remaining gear codes including small amount of unknown). Although reported separately here, the trawl and trap landings may ultimately be pooled with other gear types.

The first discussion by the working group concerned stock boundaries. In particular, Monroe County, Florida, is the focal point for the stock boundary between the U.S. South Atlantic and Gulf of Mexico waters. The Working Group decided to complement the recent Gulf of Mexico Greater Amberjack assessment (SEDAR 9), and parallel the decision made for the South Atlantic greater amberjack assessment also under consideration during SEDAR 15. In the SEDAR 9 Data Workshop report all Florida landings with water body codes 0010, 0019, and 7xxx and higher were considered South Atlantic catch. Also included were the small amount of landings from state 12 which represent Florida interior counties landed on Florida east coast. 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). For detailed description of the Accumulated Landing System (ALS), see addendum to this section.

For the years 1992-2004 water body and jurisdiction allocations are based on water body ratios as reported in the Fishery Logbook data and applied to the total landings reported in the ALS data set for Monroe County. The group consensus was data reported directly by fishermen in the logbook program versus data reported third person by dealers and associated staff submitted to the ALS would be more precise in assigning area of capture to catch.

Landings were obtained from the NMFS Northeast Regional Office from states north of North Carolina. The earliest landings were in 1970 (300 pounds, whole weight), positive landings were again obtained for 1987-1988, and continuously from 1993-2006 (with the exception of no landings reported for 2000). If we assume landings were truly 0 in those years none were reported for 1970-2006, then the average annual reported landings of red snapper from north of North Carolina was 83 pounds (whole weight). Based on this quantity, the working group decided to use the North Carolina-Virginia line as the northern boundary for purposes of this assessment.

As in SEDAR 10 for South Atlantic gag, the Working Group decided to present all landings in gutted weight. The standard conversion of snappers for Georgia and Florida from gutted weight to whole weight is by multiplying gutted weight by 1.11 to convert to whole weight. South Carolina uses a conversion close to 1.11 (i.e., 1.111…..), obtained by dividing gutted weight by 0.9. North Carolina uses a conversion of 1.08. With landings data inputted to model in gutted weight, any conversions from gutted back to whole weight will be based on recent data from the South Carolina MARMAP program. Although the sample size was small (N=13) the R^2 value was high (0.9996) with no value having high leverage. The no-intercept regression estimate for slope is 1.069 (the ratio of means for whole weight to gutted weight) (see Table 2.2 in Section 2).

Commercial landings in gutted weight were developed based on classified red snapper by the Working Group from each state by gear for 1962-2006.

Florida – the ALS data base was used to estimate landings by gear for 1962-2006. Water body codes as described above were used to proportion Florida Atlantic landings from Monroe County for 1962-1991; while the commercial logbook data were used for 1992-2006.

Georgia –GA DNR provided landings by gear back to 1989 (state reported landings were almost identical to ALS landings), and the ALS data base was used to extend landings back to 1962. Whole weight was converted to gutted weight by dividing by 1.11.

South Carolina – SC DNR provided landings by gear back to 1972 (state reported landings were very similar to ALS landings when adjusted to gutted weight), and the ALS data base was used to extend landings back to 1962.

North Carolina – NC DMF provided landings by gear back to 1950 in pounds gutted weight (NC data for 1950-1961 was used in preference to the historical landings data cited below). Again, landings estimates from the ALS were almost identical to that provided by NC DMF.

A summary of landings in gutted weight by gear are presented in Table 3.1 and Figure 3.3 for 1927-2006. Landings are also shown by state in Figure 3.4, but because of confidentiality issues, landings for Georgia through North Carolina are grouped together in Table 3.2.

In recent years (since 2000), handlines represent about 87.9% compared with almost 10.6% for diving. Trivial amount of landings are associated with trawls (0.2%), traps

(<0.1%), and other (1.2%). Recent landings by state break out as follows: 57% from Florida, 11% from Georgia, 22% from South Carolina, and 9% from North Carolina.

Next, historical landings of red snapper for 1927-1961 were obtained from: ***Historical Catch Statistics, Atlantic and Gulf Coast States, 1879-1989*** (US DOC/NOAA/NMFS, Current Statistics No. 9010, Historical Series Nos. 5-9). These landings are reported fairly consistently by state (North Carolina through east coast of Florida) back to 1927. With handlines as the dominant gear (representing 97% of the landings for 1962-2006), historical landings were assumed to be that gear (with the exception of small amounts of trawl landings in North Carolina reported for 1951-1952 and 1961). Conversion back to gutted weight was based on the respective state conversion values.

The decision was made by the Working Group to extend landings prior to 1927 back to 1900 by linear interpolation. Zero landings are assumed for 1900 and for purposes of the interpolation, the average of 1927-1931 is used for 1927. Additionally, several gaps in landings were found in the period 1927-1961. In particular, there were no reported landings for 1933, 1935, 1941-1944, and 1946-1949. Again, a linear interpolation was applied to these years, with the exception of 1941-1944. Landings for these years were assumed to have been 0. This was felt reasonable based on the low landings reported for 1940 leading up to WWII, and presumed reduction of effort immediately prior to and during WWII. Total red snapper landings in gutted weight for 1900-2006 are presented in Figure 3.5.

Commercial landings in weight were converted to commercial landings in numbers based on average weight (in whole weight, but converted to gutted weight based on 1.069 estimate above) from the TIP data for each state, gear, and year. These data was generally available from 1984 to 2004 for handlines (24,919 lengths). Data for the remaining gear types were sparse, with much more limited data from diving (640), trawls (301), traps (285), and other (1596) gear types available (annual sample sizes by gear and state in Table 3.3). Annual estimates of mean weight by gear, state and year are applied to the corresponding landings in weight when sample size greater than or equal to 30 are available (Table 3.4). When sample size do not meet this criterion, then averages across years or even across state and years (e.g., for trap and trawl) are used (Table 3.5). Because of a change in minimum size limits in 1992, mean weights from handlines are calculated before 1992 for any historical application, and for 1992 and later for any application for 1992 and later. Red snapper landings in numbers are summarized by gear in Table 3.6 and in Figures 3.6.

3.3 Commercial Discards

The report titled ‘Discards of Greater Amberjack and Red Snapper Calculated for Vessels with Federal Fishing Permits in the US South Atlantic’ was prepared by Kevin McCarthy (**SEDAR 15-DW01**). A brief summary of the results and discussion for red snapper follows:

Commercial discards of red snapper could only be calculated for handline vessels. Data for all other gear types was too limited for discard calculations. Significant differences among regions in cpue of handline vessel red snapper discards were identified in the GLM analysis. Mean red snapper cpue of all handline vessel trips reporting to the discard logbook program within each region, including those that did not have red snapper discards (zero discard trips), were used to calculate total discards:

*Calculated discards=Mean red snapper discard cpue*total effort per region*

Yearly total effort (hook hours) of all trips by handline vessels within each region was multiplied by the mean discard cpue from the appropriate region to calculate total discards of red snapper by handline vessels.

Calculated total discards for each region are provided in Table 3.7 for red snapper discarded from handline vessels, including effort in hook-hours. The calculated discards from each region were summed by year to provide yearly total red snapper handline vessel discards (Table 3.8). The reason reported for discarding red snapper was due to regulatory restrictions in nearly all reports.

The number of trips reporting red snapper in the US south Atlantic was very low and the number of individual red snapper discarded per trip was also low. Stratification of the available data was limited because of such small sample sizes and, therefore, likely does not capture much of the variation in numbers of discards within the red snapper fisheries. How that may affect the number of calculated discards (over or under estimate) is unknown. Discards from the dive fisheries for red snapper could not be calculated due to lack of discard reports from those fisheries. The methods used in prosecuting the dive fisheries, however, may limit the number of discards due to greater selectivity available to the dive fisher.

3.4. Commercial Price

Price per pound for red snapper sold in the South Atlantic states was calculated for the years 1962 through 2006. Two values were calculated for each year (Figure 3.7). The first values showed the actual price the fishermen received at the time of sale. The second value adjusted the amount using the Consumer Price Index (CPI) for each year using 1962 as base year to determine relative values for the price per pound. The CPI-calculated values held the value of one dollar constant throughout the time series. The actual price the fishermen received noted a general upwards trend from approximately $0.30 on average in 1962 to $3.28 per pound in 2006. There were sharp increases in the price per pound paid to fishermen for red snapper in the mid to late 1970's. When the price per pound of red snapper was held to a constant 1962 dollar value, the trend changes. From a low value of about $0.30 in 1962, the highest average value was $0.86 in 1978. In the last twenty years, the CPI adjusted price per pound has trended downward to where a pound of red snapper is worth just less than $0.50 in 2006.

3.5 Biological Sampling

Length frequency data were extracted from the TIP Online database. Data from the VA/NC line through Monroe County in FL were included in the extraction. Those data from Monroe County that were attributable to the Gulf were deleted from the data. All lengths were converted to TL in mm using conversions derived from the Life History Group. We had no conversions for standard length, so these were deleted. Lengths greater than 2000 mm were deleted, as the group felt that these extreme lengths may be errors and did not represent those lengths observed in the commercial fishery. Lengths were converted to cm and assigned to 1 cm length bins with a floor of 0.6 cm and a ceiling of 0.5 cm. Weights were converted to whole weight in grams using the length/weight relationship supplied by the Life History Group and then converted to whole weight in pounds. Mean weight were then calculated across year, state and gear. Landings data in gutted weight were converted to whole weight using the conversions supplied by the Life History Group.

3.5.1 Sampling Intensity Length

Annual sample sizes are summarized in Table 3.3 by gear, and state for length data available for red snapper in the U.S. South Atlantic from the TIP data base for 1984-2006.

3.5.2 Length/Age Distribution

Annual length compositions are created for each commercial gear using the following approach for weighting lengths across individual trips and by state:

- Trips: expand lengths by trip catch in numbers,
- State: expand lengths by landings in numbers.

Annual length compositions for commercial handlines are shown weighted by the product of the landings in numbers and trip catch in numbers (for 1984-2006 in Figure 3.8). Annual length compositions for commercial diving (for 1999-2001 and 2003 in Figure 3.9), trawls (for 1984, 1986-1988 in Figure 3.10) and traps (for 1991 in Figure 3.11) are also summarized using weighting by landings in numbers and by trip catch in numbers.

Sample size of red snapper ages are summarized by gear from commercial landings in the U.S. South Atlantic for 1980-2006 (Table 3.9). Length compositions were developed for handline (1988-2006, Fig. 3.12) and diving (2000, Fig. 3.13) gear types. Weighting is by length compositions shown in Figures 3.8 and 3.9, respectively. This 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

Generally sample sizes for length composition may be adequate for the handline component of the commercial fishery (Table 3.3). Overall 24,806 fish lengths were collected from handlines between 1984-2006. However, no lengths were collected from Florida in 1984 and 1987, and only 5 fish collected in 1988. Useful length compositions are generally available for handlines for 1985-1986 and 1989-2006.

Much more limited length compositions are available for diving (625 lengths), trawls (301 lengths), and traps (293 lengths) for the period 1984-2006. Annual length compositions for gear types other than handline were developed for diving (1999-2001 and 2003), trawls (1986-1988) and traps (1991). Handline length compositions should be applied to be ‘other’ gear types to represent length compositions.

3.6 Research Recommendations for red snapper

The following research recommendations were developed by the Working Group:

- 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 from Florida and 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 (not an issue with red snapper)

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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
=================
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
=======
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
=======
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. Red snapper landings (gutted weight in pounds) by gear from the U.S. South Atlantic, 1927-2006.

Year	Lines	Diving	Traps	Trawl	Other	Total
1927	111,737	0	0	0	0	111,737
1928	64,014	0	0	0	0	64,014
1929	60,736	0	0	0	0	60,736
1930	62,287	0	0	0	0	62,287
1931	102,753	0	0	0	0	102,753
1932	44,144	0	0	0	0	44,144
1933	90,541	0	0	0	0	90,541
1934	136,937	0	0	0	0	136,937
1935	131,532	0	0	0	0	131,532
1936	126,126	0	0	0	0	126,126
1937	189,189	0	0	0	0	189,189
1938	106,331	0	0	0	0	106,331
1939	88,338	0	0	0	0	88,338
1940	12,613	0	0	0	0	12,613
1941	0	0	0	0	0	0
1942	0	0	0	0	0	0
1943	0	0	0	0	0	0
1944	0	0	0	0	0	0
1945	225,325	0	0	0	0	225,325
1946	245,665	0	0	0	0	245,665
1947	266,004	0	0	0	0	266,004
1948	286,344	0	0	0	0	286,344
1949	306,683	0	0	0	0	306,683
1950	327,023	0	0	0	0	327,023
1951	459,459	0	0	6,944	0	466,404
1952	345,946	0	0	4,630	0	350,576
1953	363,964	0	0	0	0	363,964
1954	539,640	0	0	0	0	539,640
1955	448,649	0	0	0	0	448,649
1956	439,649	0	0	0	0	439,649
1957	788,605	0	0	0	0	788,605
1958	556,279	0	0	0	0	556,279
1959	597,126	0	0	0	0	597,126
1960	610,186	0	0	0	0	610,186
1961	717,251	0	0	3,426	0	720,676
1962	538,171	0	0	568	0	538,739
1963	409,000	0	0	0	1,217	410,218
1964	454,830	0	0	90	0	454,920
1965	534,515	0	0	0	0	534,515
1966	600,907	0	0	1,019	0	601,925
1967	788,331	0	648	185	0	789,164
1968	877,836	0	270	0	0	878,106
1969	558,477	0	10,981	370	1,712	571,540

Table 3.1. (continued)

1970	519,354	0	3,692	0	0	523,046
1971	447,962	0	0	0	0	447,962
1972	366,390	0	21,154	0	0	387,544
1973	312,838	0	4,978	389	0	318,205
1974	517,558	0	1,802	0	0	519,360
1975	608,586	0	0	320	0	608,906
1976	495,072	0	0	16,967	0	512,038
1977	520,564	0	0	21,226	0	541,790
1978	482,345	0	23,456	3,946	115	509,862
1979	344,070	0	4,626	7,461	0	356,157
1980	301,405	0	2,892	24,773	1,017	330,087
1981	292,104	0	7,710	24,847	70	324,731
1982	251,218	0	725	15,086	530	267,559
1983	261,566	0	147	7,652	1,872	271,237
1984	206,509	1,131	937	5,778	2,445	216,799
1985	202,434	2,126	2,288	3,736	146	210,730
1986	182,659	515	1,925	1,970	686	187,755
1987	157,903	389	580	743	2,441	162,056
1988	138,476	274	172	1,450	2,094	142,465
1989	225,156	1,026	266	0	1,456	227,904
1990	180,488	1,552	2,972	0	5,212	190,224
1991	110,158	4,926	4,991	3	2,174	122,252
1992	79,092	8,802	28	517	2,263	90,702
1993	192,483	5,372	246	94	228	198,422
1994	163,174	12,139	366	0	732	176,410
1995	152,926	9,504	369	24	168	162,991
1996	119,594	5,777	1,293	17	683	127,364
1997	88,457	7,004	1,003	2	3,035	99,501
1998	70,914	7,473	471	0	2,277	81,135
1999	72,740	9,244	199	0	919	83,102
2000	82,307	10,624	90	0	1,059	94,080
2001	158,072	18,685	205	5	628	177,595
2002	147,937	21,401	43	48	521	169,949
2003	107,093	16,157	454	0	2,063	125,768
2004	137,287	17,981	249	6	413	155,935
2005	103,555	8,804	599	0	3,408	116,366
2006	70,563	3,837	377	0	3,023	77,800

Table 3.2. Red snapper landings (gutted weight in pounds) by region from the U.S. South Atlantic, 1927-2006.

Year	Florida	GA-NC	Total
1927	53,153	58,584	111,737
1928	42,342	21,672	64,014
1929	17,117	43,619	60,736
1930	30,631	31,657	62,287
1931	100,901	1,852	102,753
1932	44,144	0	44,144
1933	90,541	0	90,541
1934	136,937	0	136,937
1935	131,532	0	131,532
1936	126,126	0	126,126
1937	189,189	0	189,189
1938	105,405	926	106,331
1939	86,486	1,852	88,338
1940	12,613	0	12,613
1941	0	0	0
1942	0	0	0
1943	0	0	0
1944	0	0	0
1945	221,622	3,704	225,325
1946	241,802	3,863	245,665
1947	261,982	4,022	266,004
1948	282,162	4,181	286,344
1949	302,342	4,341	306,683
1950	322,523	4,500	327,023
1951	459,459	6,944	466,404
1952	345,946	4,630	350,576
1953	362,162	1,802	363,964
1954	536,937	2,703	539,640
1955	448,649	0	448,649
1956	308,108	131,541	439,649
1957	579,279	209,326	788,605
1958	530,631	25,648	556,279
1959	566,667	30,459	597,126
1960	600,901	9,285	610,186
1961	610,811	109,866	720,676
1962	529,584	9,155	538,739
1963	406,379	3,839	410,218
1964	446,717	8,203	454,920
1965	519,844	14,670	534,515
1966	591,835	10,090	601,925
1967	733,301	55,863	789,164
1968	789,871	88,235	878,106
1969	544,517	27,023	571,540

Table 3.2. (continued)

1970	498,012	25,034	523,046
1971	391,932	56,029	447,962
1972	326,597	60,947	387,544
1973	284,717	33,488	318,205
1974	469,280	50,080	519,360
1975	576,252	32,654	608,906
1976	426,995	85,044	512,038
1977	409,869	131,921	541,790
1978	312,475	197,387	509,862
1979	206,477	149,680	356,157
1980	192,773	137,314	330,087
1981	166,062	158,669	324,731
1982	134,104	133,455	267,559
1983	141,099	130,138	271,237
1984	118,516	98,282	216,799
1985	127,659	83,071	210,730
1986	112,243	75,513	187,755
1987	105,465	56,591	162,056
1988	84,629	57,837	142,465
1989	98,692	129,212	227,904
1990	89,469	100,755	190,224
1991	61,923	60,329	122,252
1992	53,534	37,168	90,702
1993	74,326	124,096	198,422
1994	73,633	102,777	176,410
1995	96,745	66,246	162,991
1996	83,144	44,220	127,364
1997	73,618	25,884	99,501
1998	57,436	23,699	81,135
1999	44,352	38,750	83,102
2000	63,706	30,374	94,080
2001	104,467	73,128	177,595
2002	83,596	86,353	169,949
2003	66,078	59,689	125,768
2004	90,741	65,194	155,935
2005	65,890	50,475	116,366
2006	51,147	26,653	77,800

Table 3.3. Sample size of red snapper collected for lengths by gear and state from the U.S. South Atlantic TIP data base, 1984-2006.

	Handline					Diving				Trawl			Traps				Other					Grand
Year	**FL**	**GA**	**SC**	**NC**	**Total**	**FL**	**GA**	**SC**	**Total**	**GA**	**SC**	**Total**	**FL**	**SC**	**NC**	**Total**	**FL**	**GA**	**SC**	**NC**	**Total**	**Total**
1984		50	970	1069	2089				0		33	33			1	1			1	2	3	2126
1985	1250	203	1355	731	3539				0			0				0	14	33		14	61	3600
1986	170	144	272	660	1246				0		66	66				0	10			1	11	1323
1987		354	398	394	1146			2	2	49	15	64		2		2				90	90	1304
1988	5	233	176	207	621				0		138	138				0			1	17	18	777
1989	37	191	363	600	1191				0			0				0				10	10	1201
1990	204		148	435	787				0			0		6		6	18		12	5	35	828
1991	81	196	232	197	706				0			0		252	1	253	8	1		4	13	972
1992	180	110	144	78	512	4		5	9			0		9		9	12				12	542
1993	371	129	616	231	1348	8			8			0		5		5	31		25	1	57	1417
1994	217	77	417	456	1167	1	6		7			0		2		2	10			1	11	1187
1995	886	101	351	129	1467	25			25			0	1	3		4	44				44	1540
1996	426	105	282	58	871	21		7	28			0				0	18				18	917
1997	283	43	212	2	540	10			10			0				0	57				57	607
1998	166		228	22	416				0			0				0	84				84	500
1999	193		523	188	904	83			83			0		3		3	3				3	993
2000	323	65	434	59	881	129			129			0				0	14				14	1024
2001	581	93	454	280	1408	87			87			0				0		276			276	1771
2002	212	124	460	196	992	9			9			0				0					0	1001
2003	286	153	667	164	1270	210			210			0				0					0	1480
2004	35	214	456	90	795			8	8			0				0	566				566	1369
2005	45	94	377	102	618			3	3			0				0	180			1	181	802
2006	192	16	138	60	406	7		15	22			0				0	27		5		32	460
Total	6143	2695	9673	6408	24919	594	6	40	640	49	252	301	1	282	2	285	1096	310	44	146	1596	27741

Table 3.4. Mean gutted weight (pounds) of red snapper by state and gear from the U.S. South Atlantic TIP data base, 1984-2006.

	Handline				Diving			Trawl		Traps			Other			
Year	**FL**	**GA**	**SC**	**NC**	**FL**	**GA**	**SC**	**GA**	**SC**	**FL**	**SC**	**NC**	**FL**	**GA**	**SC**	**NC**
1984		4.25	4.47	6.42					2.06			1.21			3.50	26.42
1985	4.40	5.91	5.91	6.24									18.43	4.46		7.34
1986	5.77	9.27	5.97	5.79					7.09				14.19			5.71
1987		6.21	6.31	5.80			6.91	1.65	9.20		9.27					16.08
1988	14.82	6.65	6.18	4.18					3.36						2.85	19.02
1989	12.85	5.88	5.99	6.01												11.45
1990	5.22		3.61	6.19							9.41		22.83		11.02	6.72
1991	9.66	7.38	4.69	7.24							4.53	2.75	10.22	21.96		21.14
1992	12.71	10.61	7.76	9.68	8.66		11.57				6.55		15.31			
1993	14.08	8.51	5.78	6.51	14.79						5.42		14.68		5.28	6.91
1994	8.96	7.69	6.94	7.53	7.82	10.27					10.41		6.81			6.55
1995	9.14	8.23	8.51	10.60	16.12					22.77	9.58		13.43			
1996	9.93	8.39	10.19	8.08	10.50		13.53						14.43			
1997	10.91	12.64	11.65	15.86	11.17								12.72			
1998	9.75		10.99	7.10									9.45			
1999	9.14		8.19	6.07	11.49						5.46		11.99			
2000	8.66	7.78	9.58	9.30	7.87								12.01			
2001	8.24	7.55	7.80	6.73	8.94									2.17		
2002	9.26	6.75	7.55	7.35	10.97											
2003	10.43	8.44	8.47	10.18	9.48											
2004	11.03	10.17	10.02	13.39			10.29						8.36			
2005	11.71	9.90	11.27	13.36			8.90						6.01			12.32
2006	10.94	12.98	12.95	12.68	13.61		14.38						11.39		16.16	

Table 3.5. Sample size and weighted mean weight in pounds (whole weight) of red snapper averaged across years , and when necessary across states. Handlines and Other (Florida only) had sufficient sampling to split into two time periods based on change of minimum size limit in 1992.

Sample size:

Period	State	Handlines	Diving	Traps	Trawl	Other
<1992	FL	1747	594	285	301	50
	GA	1371	46	285	301	310
	SC	3914	46	285	301	44
	NC	4293	46	285	301	146
>=1992	FL	4396	594	285	301	1046
	GA	1324	46	285	301	310
	SC	5759	46	285	301	44
	NC	2115	46	285	301	146

Mean weights in pounds (whole weight):

Period	State	Handlines	Diving	Traps	Trawl	Other
<1992	FL	5.08	9.81	4.89	4.05	17.85
	GA	6.61	12.02	4.89	4.05	2.48
	SC	5.46	12.02	4.89	4.05	7.99
	NC	6.08	12.02	4.89	4.05	15.00
>=1992	FL	9.96	9.81	4.89	4.05	8.99
	GA	8.89	12.02	4.89	4.05	2.48
	SC	8.70	12.02	4.89	4.05	7.99
	NC	8.38	12.02	4.89	4.05	15.00

Table 3.6. Red snapper landings (in numbers) by gear from the U.S. South Atlantic, 1900-2006.

Year	Lines	Diving	Traps	Trawl	Other	Total
1900	0					0
1901	571					571
1902	1,142					1,142
1903	1,713					1,713
1904	2,284					2,284
1905	2,855					2,855
1906	3,427					3,427
1907	3,998					3,998
1908	4,569					4,569
1909	5,140					5,140
1910	5,711					5,711
1911	6,282					6,282
1912	6,853					6,853
1913	7,424					7,424
1914	7,995					7,995
1915	8,566					8,566
1916	9,138					9,138
1917	9,709					9,709
1918	10,280					10,280
1919	10,851					10,851
1920	11,422					11,422
1921	11,993					11,993
1922	12,564					12,564
1923	13,135					13,135
1924	13,706					13,706
1925	14,277					14,277
1926	14,848					14,848
1927	20,659					20,659
1928	12,432					12,432
1929	10,845					10,845
1930	11,623					11,623
1931	21,539					21,539
1932	9,281					9,281
1933	19,036					19,036
1934	28,790					28,790
1935	27,654					27,654
1936	26,517					26,517
1937	39,776					39,776
1938	22,323					22,323
1939	18,509					18,509

Table 3.6. (continued)

1940	2,652					2,652
1941	0					0
1942	0					0
1943	0					0
1944	0					0
1945	47,245					47,245
1946	51,534					51,534
1947	55,823					55,823
1948	60,112					60,112
1949	64,401					64,401
1950	68,750	0	0	0	0	68,750
1951	96,685	0	0	1,833	0	98,518
1952	72,798	0	0	1,222	0	74,020
1953	76,502	0	0	0	0	76,502
1954	113,426	0	0	0	0	113,426
1955	94,411	0	0	0	0	94,411
1956	88,180	0	0	0	0	88,180
1957	158,722	0	0	0	0	158,722
1958	116,172	0	0	0	0	116,172
1959	124,924	0	0	0	0	124,924
1960	128,016	0	0	0	0	128,016
1961	149,242	0	0	904	0	150,146
1962	113,050	0	0	150	0	113,200
1963	85,918	0	0	0	73	85,991
1964	95,574	0	0	24	0	95,598
1965	112,249	0	0	0	0	112,249
1966	126,135	0	0	269	0	126,404
1967	163,343	0	142	49	0	163,533
1968	182,126	0	59	0	0	182,185
1969	117,005	0	2,401	98	738	120,241
1970	108,541	0	807	0	0	109,348
1971	91,770	0	0	0	0	91,770
1972	75,361	0	4,625	0	0	79,985
1973	64,815	0	1,088	103	0	66,006
1974	106,939	0	394	0	0	107,333
1975	126,652	0	0	85	0	126,737
1976	101,734	0	0	4,478	0	106,213
1977	105,819	0	0	5,603	0	111,421
1978	95,304	0	5,128	1,042	8	101,481
1979	67,861	0	1,011	1,969	0	70,842

Table 3.6. (continued)

1980	59,974	0	632	6,539	66	67,211
1981	57,375	0	1,685	6,558	30	65,649
1982	49,541	0	159	3,982	71	53,753
1983	51,802	0	32	2,020	449	54,302
1984	44,831	117	205	2,573	469	48,195
1985	44,066	232	500	986	20	45,803
1986	32,078	54	421	339	56	32,948
1987	31,248	35	127	209	164	31,783
1988	27,694	24	38	461	153	28,370
1989	30,933	91	58	0	94	31,176
1990	39,924	169	650	0	648	41,390
1991	16,510	536	1,174	1	175	18,395
1992	8,083	946	6	136	264	9,436
1993	26,530	574	54	25	16	27,199
1994	22,364	1,311	80	0	86	23,841
1995	18,126	1,026	81	6	13	19,252
1996	13,297	626	283	5	68	14,278
1997	8,680	762	219	0	256	9,918
1998	7,804	814	103	0	258	8,979
1999	9,300	860	43	0	109	10,313
2000	10,007	1,443	20	0	126	11,596
2001	21,548	2,228	45	1	75	23,897
2002	19,783	2,323	9	13	68	22,196
2003	12,133	1,806	99	0	245	14,283
2004	13,637	1,944	54	2	53	15,690
2005	9,673	943	131	0	606	11,353
2006	6,679	411	82	0	359	7,531

Table 3.7. Calculated yearly total discards of red snapper by handline vessels for each region (regions: 1=2400 latitude to <3000 latitude; Region 2 = 3000 latitude to <3100 latitude; Region 3 = 3100 latitude to <3300 latitude; Region 4= 3300 latitude to <3700 latitude). Discards reported as number.

Year	Region	Mean Discards	Discard Standard Deviation	Total Effort (hook hours)	Calculated Discards
1992	1	0.01839	0.22306	89,479.0	8,227*
1992	2	0.03093	0.19870	85,821.0	2,655
1992	3	0.03171	0.17207	195,164.0	6,188
1992	4	0.00534	0.05003	228,924.0	1,222
1993	1	0.01839	0.22306	374,852.0	6,893
1993	2	0.03093	0.19870	86,341.5	2,671
1993	3	0.03171	0.17207	204,741.0	6,492
1993	4	0.00534	0.05003	337,962.4	1,804
1994	1	0.01839	0.22306	519,938.1	9,561
1994	2	0.03093	0.19870	94,936.5	2,937
1994	3	0.03171	0.17207	297,076.0	9,420
1994	4	0.00534	0.05003	476,132.2	2,542
1995	1	0.01839	0.22306	418,420.5	7,694
1995	2	0.03093	0.19870	156,294.0	4,835
1995	3	0.03171	0.17207	292,482.0	9,274
1995	4	0.00534	0.05003	440,122.0	2,349
1996	1	0.01839	0.22306	523,916.5	9,634
1996	2	0.03093	0.19870	230,232.0	7,122
1996	3	0.03171	0.17207	401,744.0	12,739
1996	4	0.00534	0.05003	516,895.8	2,759
1997	1	0.01839	0.22306	709,519.5	13,047
1997	2	0.03093	0.19870	206,871.0	6,400
1997	3	0.03171	0.17207	353,093.0	11,196
1997	4	0.00534	0.05003	577,396.0	3,082
1998	1	0.01839	0.22306	522,294.2	9,604
1998	2	0.03093	0.19870	126,665.0	3,918
1998	3	0.03171	0.17207	298,594.1	9,468
1998	4	0.00534	0.05003	474,546.6	2,533
1999	1	0.01839	0.22306	572,769.7	10,533
1999	2	0.03093	0.19870	118,819.0	3,676
1999	3	0.03171	0.17207	205,537.0	6,517
1999	4	0.00534	0.05003	418,476.3	2,234
2000	1	0.01839	0.22306	495,325.9	9,108
2000	2	0.03093	0.19870	100,503.1	3,109
2000	3	0.03171	0.17207	225,280.5	7,143
2000	4	0.00534	0.05003	458,840.3	2,449
2001	1	0.01839	0.22306	420,280.1	7,728
2001	2	0.03093	0.19870	90,989.0	2,815
2001	3	0.03171	0.17207	342,025.5	10,845
2001	4	0.00534	0.05003	429,314.1	2,292
2002	1	0.01839	0.22306	399,330.6	7,343
2002	2	0.03093	0.19870	107,208.5	3,316
2002	3	0.03171	0.17207	292,181.9	9,265
2002	4	0.00534	0.05003	413,752.3	2,209
2003	1	0.01839	0.22306	378,842.3	6,966
2003	2	0.03093	0.19870	90,086.0	2,787
2003	3	0.03171	0.17207	232,222.0	7,363
2003	4	0.00534	0.05003	341,045.0	1,821

Table 3.7. (continued)

Year	Region	Mean Discards	Discard Standard Deviation	Total Effort	Calculated Discards
2004	1	0.01839	0.22306	343,562.0	6,318
2004	2	0.03093	0.19870	78,631.0	2,432
2004	3	0.03171	0.17207	167,070.6	5,298
2004	4	0.00534	0.05003	330,764.0	1,766
2005	1	0.01839	0.22306	273,803.3	5,035
2005	2	0.03093	0.19870	70,031.0	2,166
2005	3	0.03171	0.17207	204,396.6	6,481
2005	4	0.00534	0.05003	297,695.0	1,589
2006	1	0.01839	0.22306	267,566.5	4,920
2006	2	0.03093	0.19870	75,894.0	2,348
2006	3	0.03171	0.17207	248,067.9	7,866
2006	4	0.00534	0.05003	333,484.5	1,780

*in 1992 only 20% of vessels in Florida were required to report to the logbook program, the calculated discards for areas off Florida (region 1) was expanded by a factor of five.

Table 3.8. Calculated yearly south Atlantic handline vessel red snapper discards. Discards are reported in number of fish.

Year	Calculated Discards
1992	18,292*
1993	17,860
1994	24,459
1995	24,153
1996	32,254
1997	33,725
1998	25,524
1999	22,959
2000	21,810
2001	23,680
2002	22,133
2003	18,937
2004	15,813
2005	15,272
2006	16,914

*in 1992 only 20% of vessels in Florida were required to report to the logbook program, the calculated discards for areas off Florida (region 1) was expanded by a factor of five.

Table 3.9. Sample size by gear of red snapper ages from commercial landings in the U.S. South Atlantic, 1980-2006

Year	Handline	Diving	Total Ages
1980	5		5
1981			0
1982			0
1983			0
1984			0
1985			0
1986			0
1987			0
1988	34		34
1989	7		7
1990	28		28
1991	22		22
1992	48		48
1993	37		37
1994	49		49
1995	24		24
1996	167		167
1997	182		182
1998	75		75
1999	147		147
2000	226	106	332
2001	144		144
2002	36		36
2003	51		51
2004	103		103
2005	140		140
2006	189		189
Grand Total	1714	106	1820

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

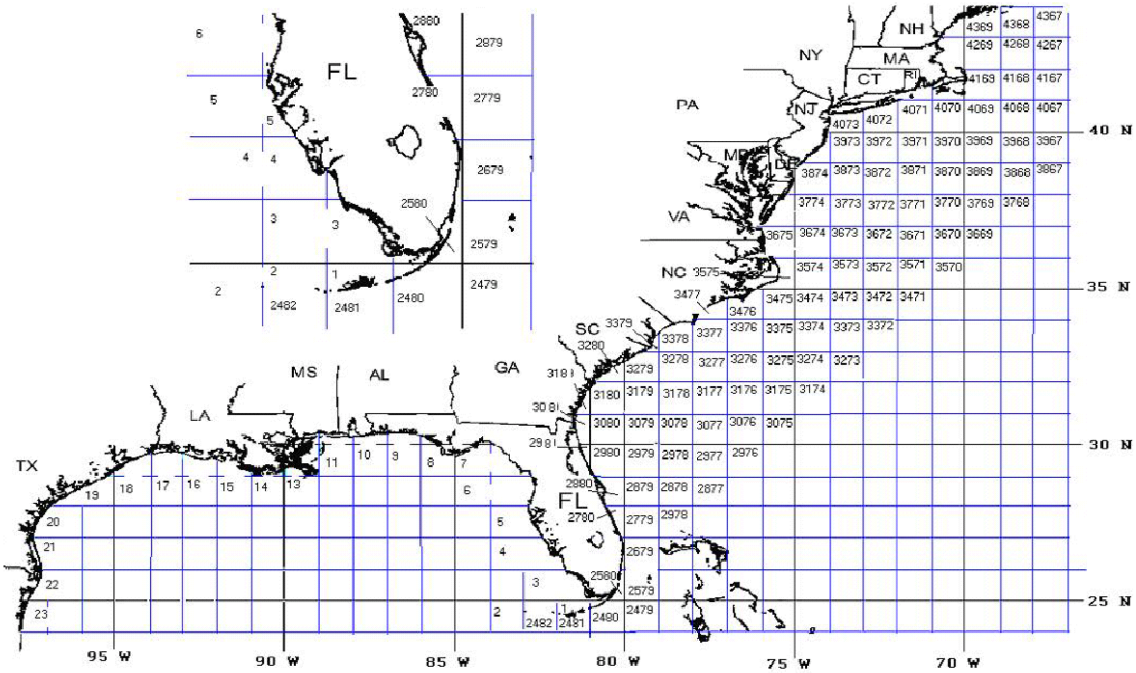


Figure 3.2. Map showing marine fisheries trip ticket fishing area code map for Florida.

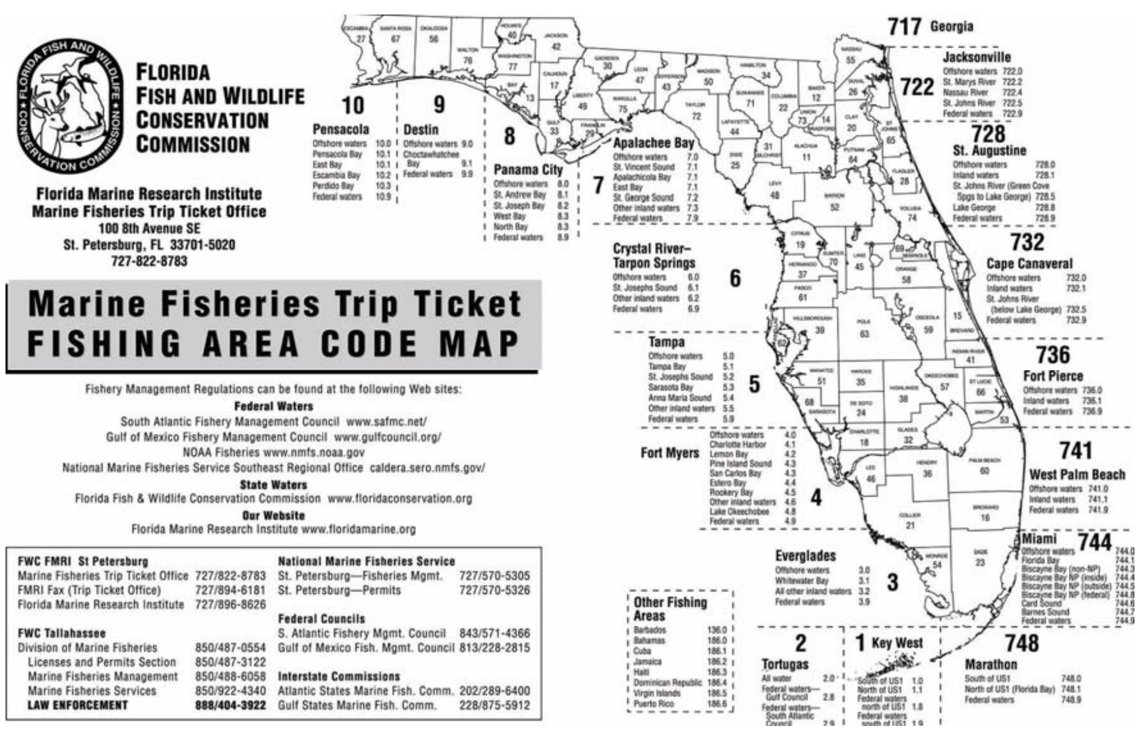


Figure 3.3. Red snapper landings by gear from the U.S. South Atlantic, 1927-2006.

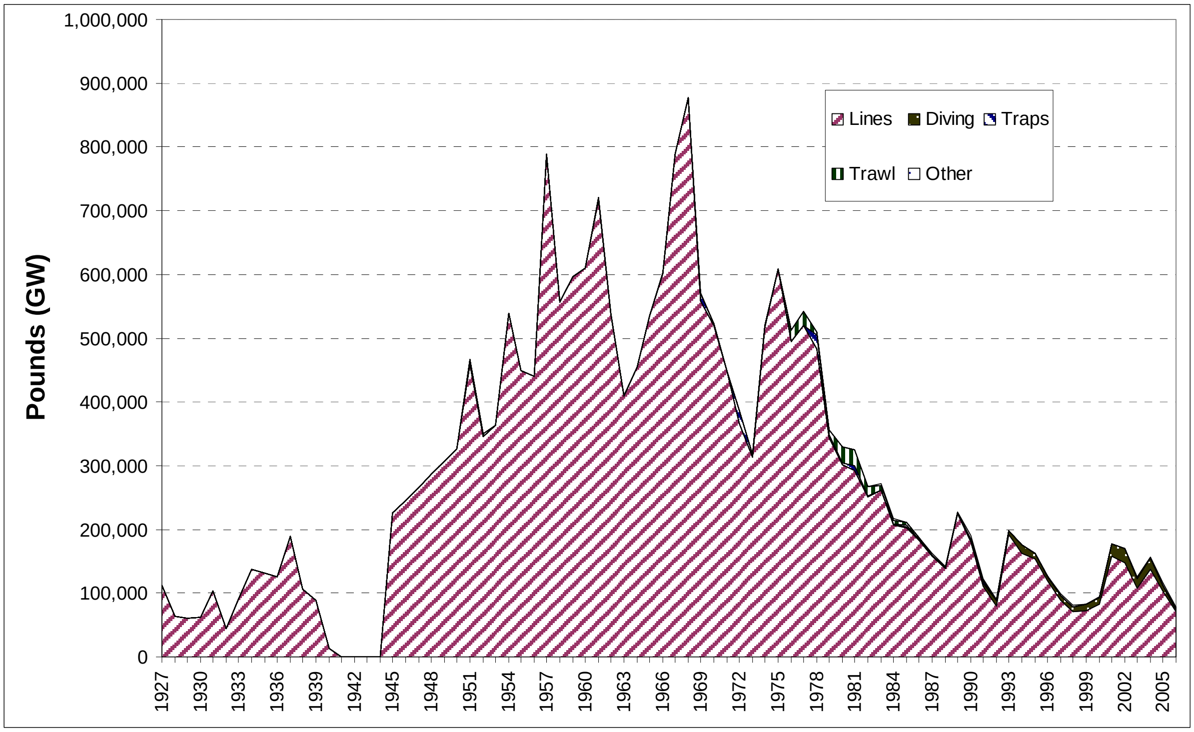


Figure 3.4. Red snapper landings by state from the U.S. South Atlantic, 1900-2006.

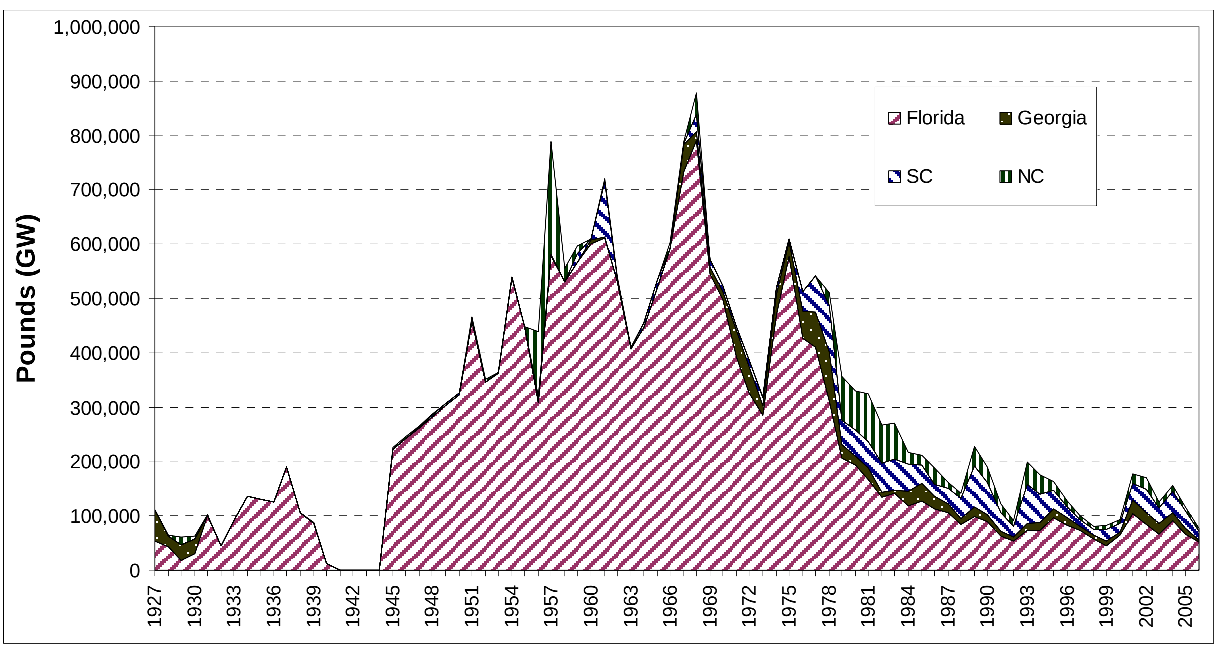


Figure 3.5. Red snapper landings from the U.S. South Atlantic, 1900-2006; with linear interpolation from 0 landings in 1900 to the average reported landings for 1927-1931 for 1927 when calculating the linear interpolations for 1901-1926.

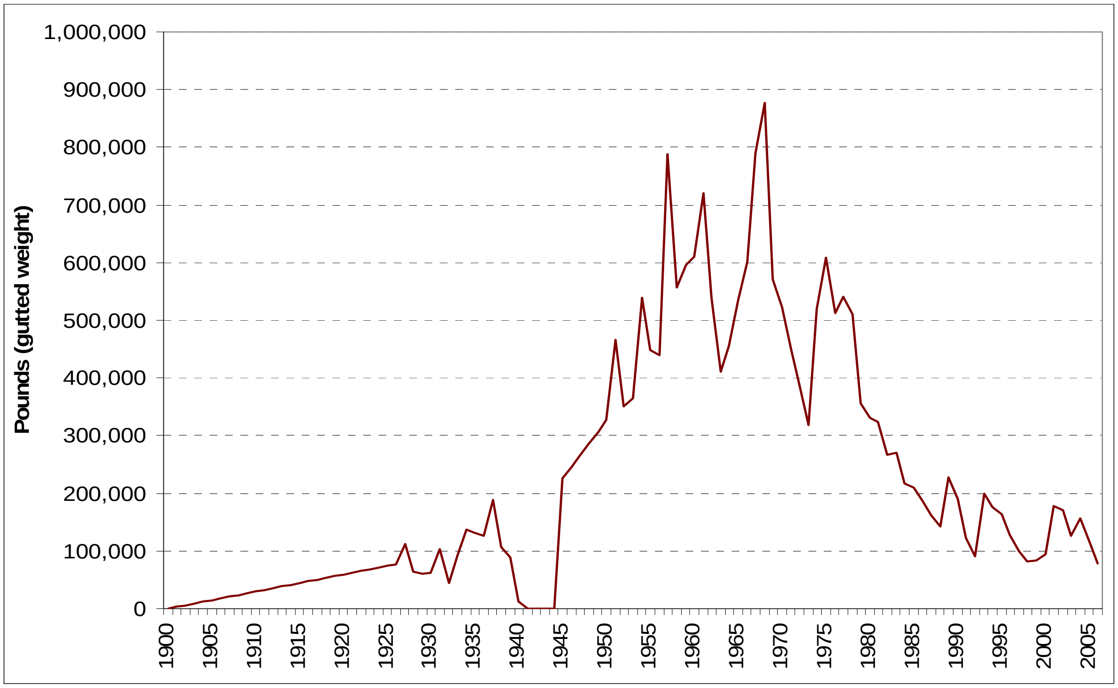


Figure 3.6. Red snapper landings in numbers by gear from the U.S. South Atlantic, 1900-2006.

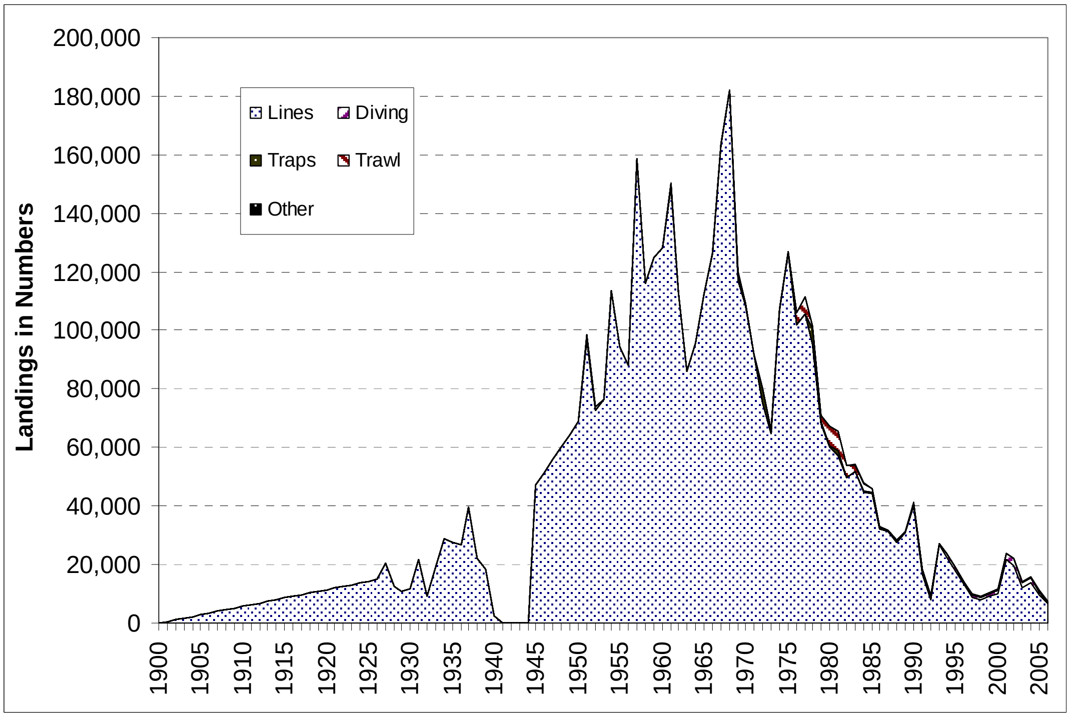


Figure 3.7. U.S. South Atlantic red snapper, price per pound, adjusted and unadjusted for inflation, 1962-2006. Price is adjusted by consumer price index (CPI) using 1962 as base year.

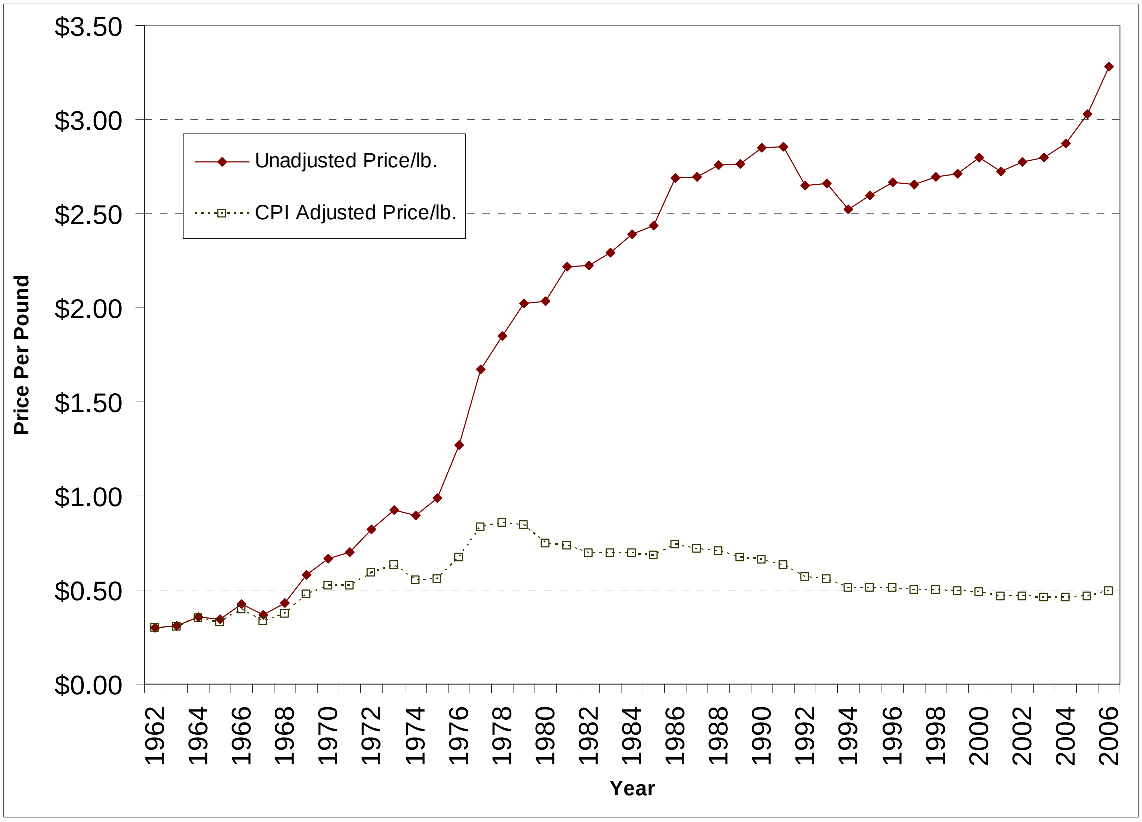


Figure 3.8. Annual length composition of red snapper for commercial handline from TIP, 1984-2006, and sample size. Weighting based on landings and trip catch in numbers. Sample size and year are shown on each subplot.

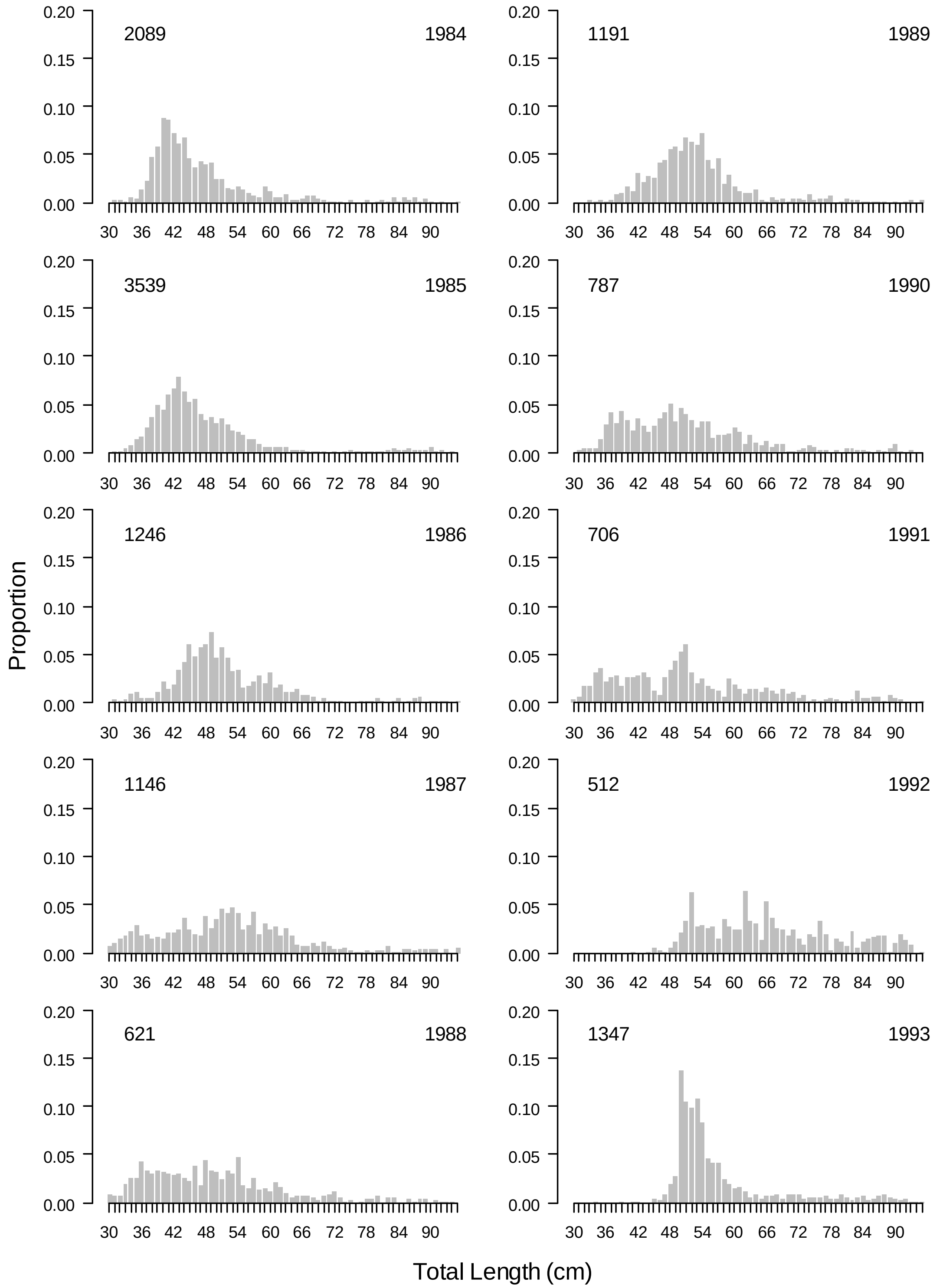


Figure 3.8. (continued)

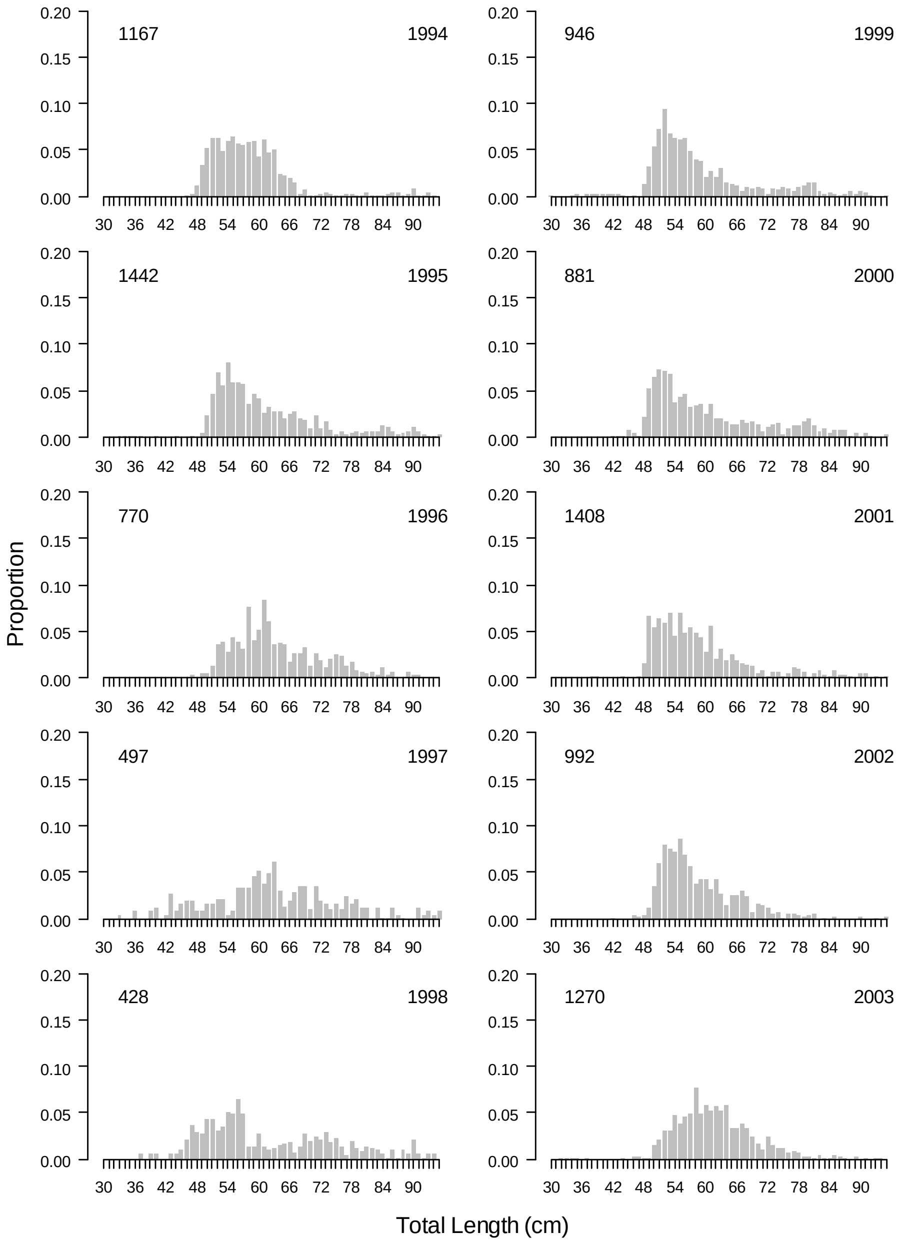


Figure 3.8. (continued)

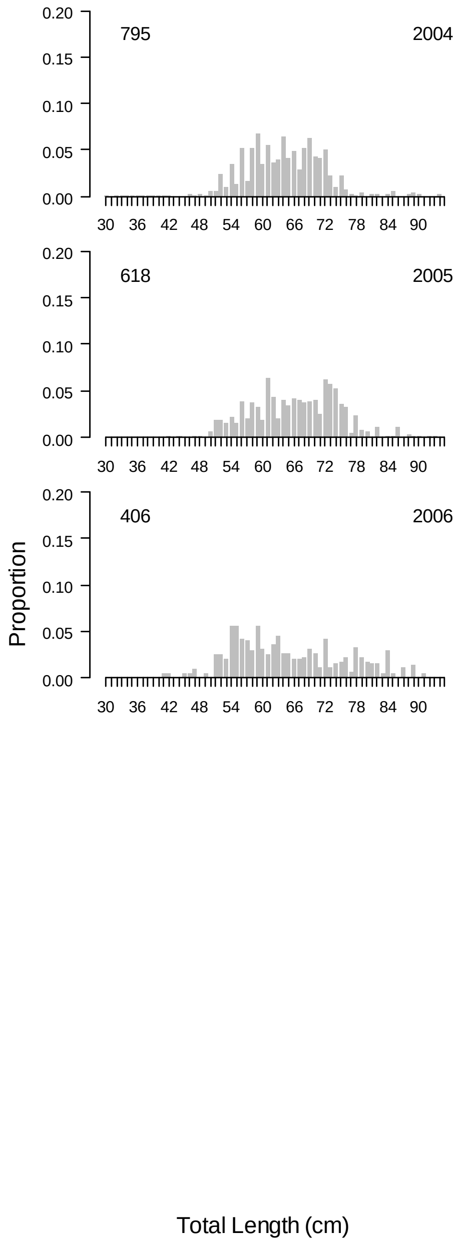


Figure 3.9. Length composition of red snapper for commercial diving from TIP, 1999-2001 and 2003. Weighting based on landings in numbers and trip catch in numbers. Sample size and year are shown on each subplot.

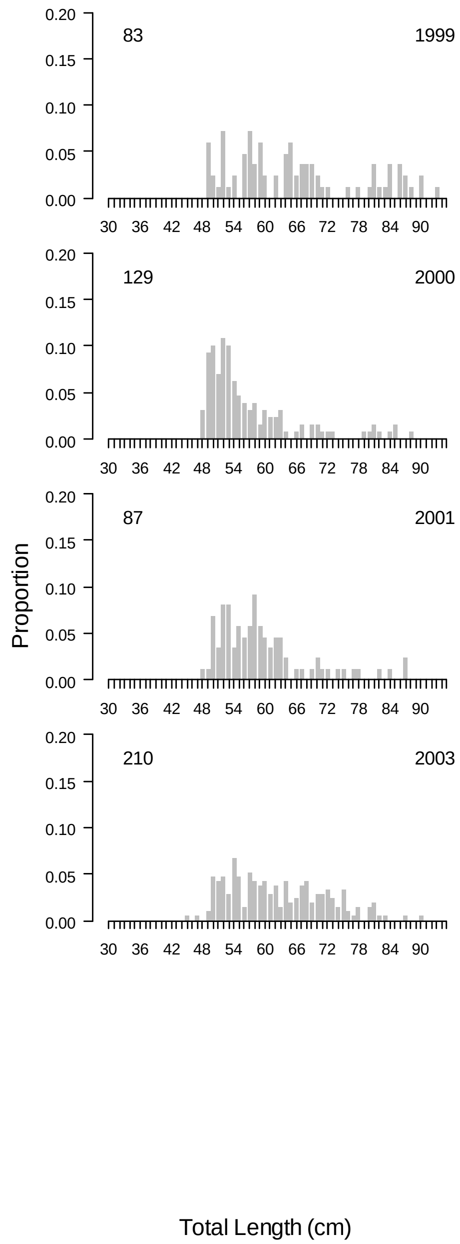


Figure 3.10. Length composition of red snapper for commercial trawls from TIP, 1984, 1986-1988. Weighting based on landings in numbers and trip catch in numbers. Sample size and year are shown on each subplot.

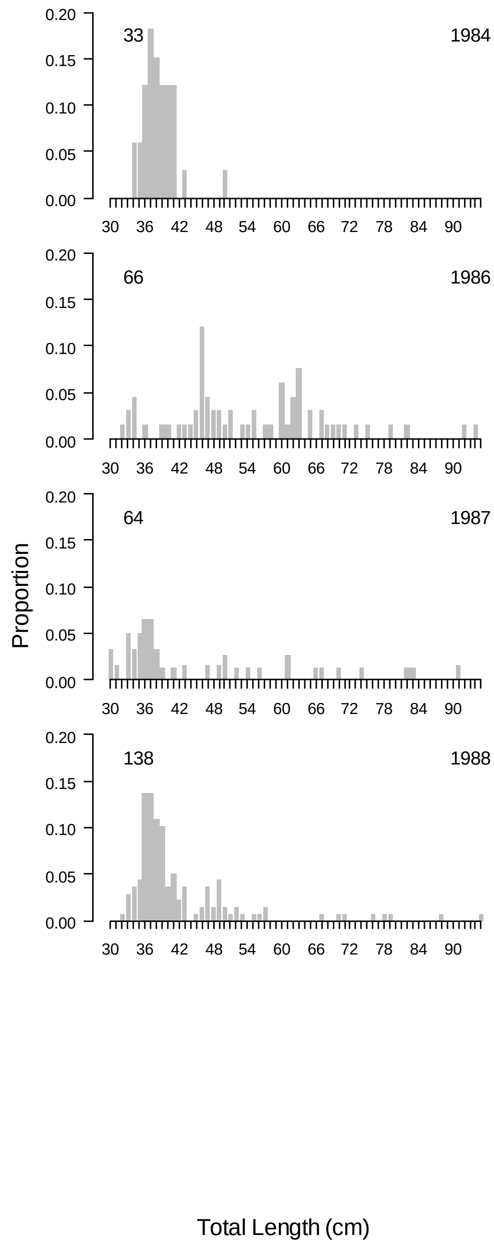


Figure 3.11. Length composition of red snapper for commercial traps from TIP, 1991. Weighting based on landings in numbers and trip catch in numbers. Sample size and year are shown on plot.

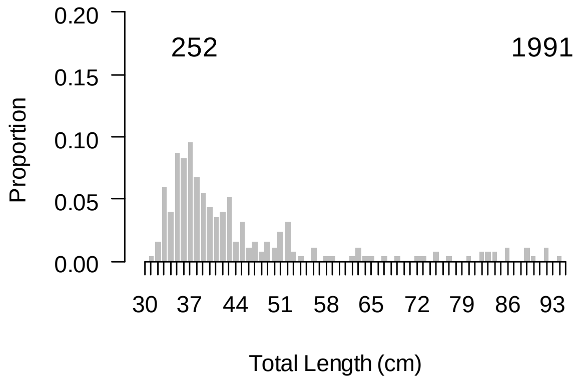


Figure 3.12. Age composition of red snapper for commercial handline from TIP, 1988-2006. Weighting based on corresponding length composition available for 1988-2006. Sample size and year are shown on each subplot.

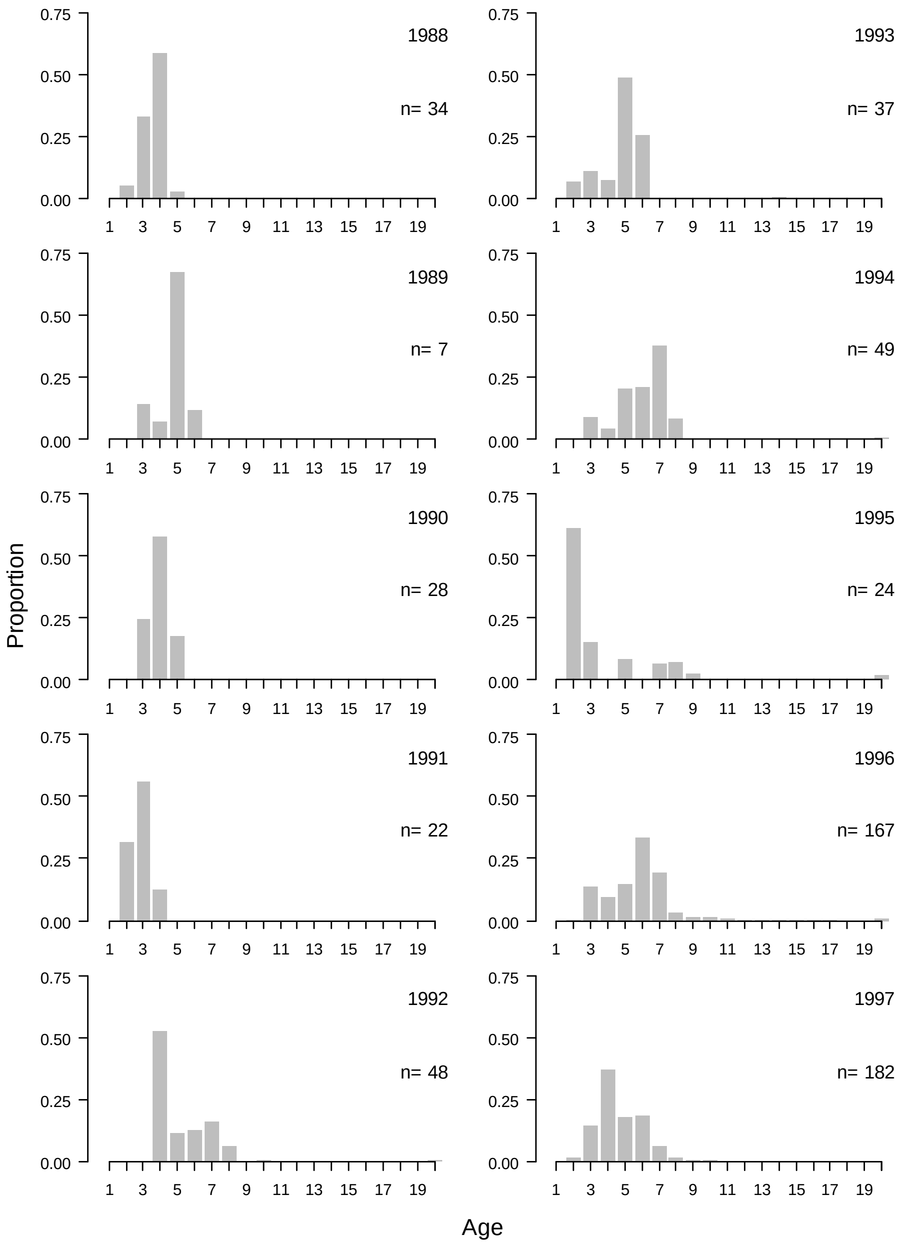


Figure 3.12. (continued)

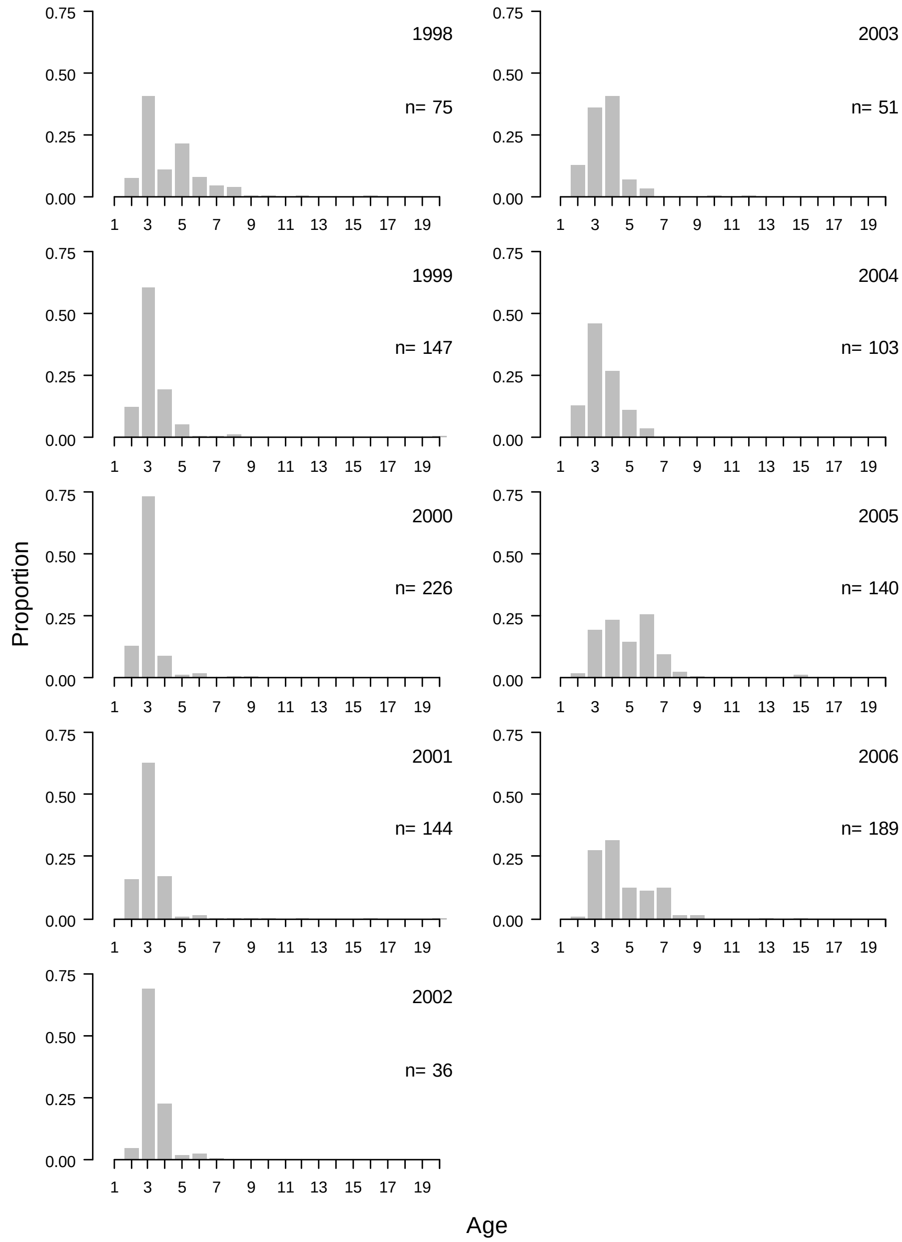
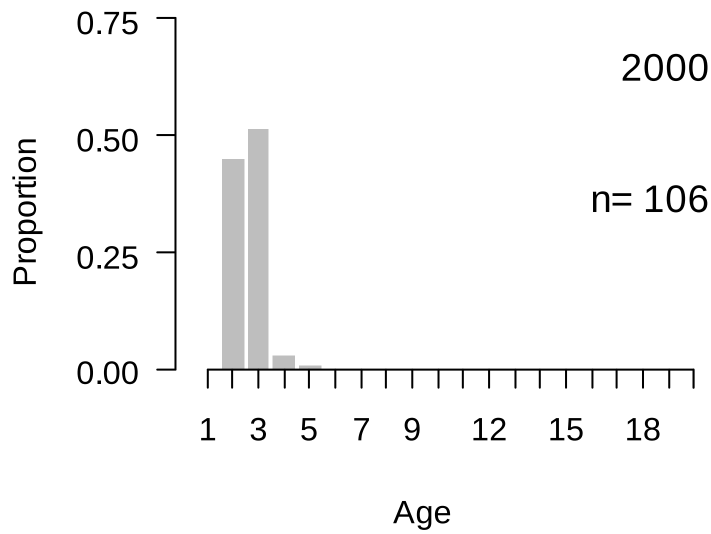


Figure 3.13. Age composition of red snapper for commercial handline from TIP, 2000. Weighting based on corresponding length composition available for 2000. Sample size and year are shown on plot.



4 Recreational Fishery (TOR 4, 5)

4.1 Overview

Members of the Recreational Fishery Working Group:

Ken Brennan, National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center
Doug Mumford, North Carolina Department of Environment and Natural Resources, Div of Marine Fisheries
Beverly Sauls (leader), Florida Fish & Wildlife Conservation Commission, Fish & Wildlife Research Institute
Tom Sminkey, NMFS, Office of Science and Technology.

The group discussed the geographic range of recreational fisheries for red snapper. North Carolina was considered to be the northern limit of the recreational fishery, and recreational catches north of Cape Hatteras are considered rare. The recreational fishery for red snapper tapers off in southeast Florida and a relatively small amount of fish in the recreational fishery come from areas around the Atlantic coast of the Florida Keys and Dry Tortugas, which is the southern boundary of the South Atlantic management area.

Major issues discussed by the group during the Data Workshop included issues with existing estimates of recreational landings and discards that needed resolution in order to construct a complete time series. Those issues addressed were sample size for weight estimates, back-calculation of estimates to 1962 as requested for the assessment model, missing estimates for discards in the headboat fishery, changes in survey methodologies over time, and the validity of shore catch estimates. In addition to historic data sets from the South Atlantic Headboat Logbook Survey and the Marine Recreational Fisheries Statistics Survey, several new and regional data sets were examined for their potential usefulness.

4.2 Sources of Recreational Fishery Dependent Data

NOAA Fisheries Service Southeast Region Headboat Survey

The Headboat Logbook Survey, conducted by the NMFS Beaufort Lab, provides a long time series of catch per unit effort, total effort, and estimated landings in number and weight (kg) from headboats in the Atlantic from North Carolina to Florida. Effort and harvest estimates are available for red snapper from NC and SC beginning in 1972, and estimates south of SC are available beginning in 1981. The Headboat Survey included only vessels from North Carolina and South Carolina from1972-1975. 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.

The Beaufort Headboat Logbook Survey incorporates two components for estimating catch and effort. 1) Information about total catch and effort are collected via the logbook, a form filled out by vessel personnel and containing total catch and effort data for individual trips. 2) Information about mean size of fishes landed are collected by port samplers during non-random dockside sampling, where fish are measured to the nearest mm and weighed to the nearest 0.01 kg. These data are used to generate mean weights for all species by area and month. Port samplers also collect otoliths for ageing studies during dockside sampling events. Data on discarded catch for either species were not requested on the logbook data sheet until 2004, when fields were added for number of fish released alive and number released dead. The logbook was designed to be a complete census of headboat fishing effort and catch; however, compliance with the mandatory reporting requirement has not been strictly enforced resulting in non-compliance in recent years, particularly for certain areas. Estimates of total effort and landings for non-reporting vessels are derived using data from comparable (geographically proximal, similar fishing characteristics) reporting vessels to estimate catch composition, and port agent summaries of total vessel activity information to estimate total effort by vessel by month. Correction factors derived from the ratio of total estimated effort/reported effort, on a by-month by-vessel basis, are applied to the reported landings to generate total estimated landings, by species by vessel by month. Lastly, estimated total landings in number are multiplied by the mean weight from the dockside sampling component, again by species by month, to estimate total landings in weight (kg).

Marine Recreational Fisheries Statistics Survey (MRFSS)

The Marine Recreational Fisheries Statistics Survey (MRFSS) provides a long time series of estimated catch per unit effort, total effort, landings, and discards for six two-month periods (waves) each year. The survey provides estimates for three recreational fishing modes: shore-based fishing (SH), private and rental boat fishing (PR), and for-hire charter and guide fishing (CH). When the survey first began in Wave 2, 1981, headboats were included in the for-hire mode, but were excluded after 1985 to avoid overlap with the Headboat Logbook Survey.

The MRFSS survey covers coastal Atlantic states from Maine to Florida. The state of Florida is sampled as two sub-regions. The east Florida sub-region includes counties adjacent to the Atlantic coast from Nassau County south through Miami-Dade County, and the west Florida sub-region includes Monroe County (Florida Keys) and counties adjacent to the Gulf of Mexico. Separate estimates are generated for each Florida subregion, and those estimates may be post-stratified into smaller regions based on proportional sampling.

The MRFSS design incorporates two complementary survey methods for estimating catch and effort. Catch data are collected through angler interviews during dockside intercept surveys. Effort data are collected in a random digit dialing telephone survey of coastal households. Catch rates from dockside intercept surveys are combined with estimates of effort from telephone interviews to estimate total landings and discards by wave, mode, and area fished (inland, state, and federal waters). Catch estimates from early years of the survey are highly variable with high percent standard errors (PSE's, shown in Tables 4.2 and 4.3), and sample size in the dockside intercept portion have been increased over time to improve precision of catch estimates. Full survey documentation and ongoing efforts to review and improve survey methods are available on the MRFSS website at: http://www.st.nmfs.gov/st1/recreational.

Survey methods for the for-hire fishing mode have seen the most improvement over time. Catch data were improved through increased sample quotas and state add-ons to the intercept portion of the survey. It was also recognized that the random household telephone survey was intercepting very few anglers in the for-hire fishing mode and the For-Hire Telephone Survey (FHS) was developed to estimate effort in the for-hire mode. The new method draws a random sample of known for-hire charter and guide vessels each week and vessel operators are called and asked directly to report their fishing activity. The FHS was piloted in east Florida in 2000 and officially adopted in all the Atlantic coast states in 2003. A further improvement in the FHS method was the pre-stratification of Florida into smaller sub-regions for estimating effort. The FHS subregions include three distinct regions bordering the Atlantic coast: Monroe County (sub-region 3), southeast Florida from Dade through Indian River Counties (sub-region 4), and northeast Florida from Martin through Nassau Counties (sub-region 5). The coastal household telephone survey method for the for-hire fishing mode continues to run concurrently with new FHS method.

Headboat At-Sea Observer Survey

An observer survey of the recreational headboat fishery was launched in NC and SC in 2004 and in FL in 2005 to collect more detailed information on recreational headboat catch, particularly for discarded fish. Headboat vessels are randomly selected throughout the year in each state, or each sub-region in Florida (defined the same as FHS sub-regions). Biologists board selected vessels with permission from the captain and observe anglers as they fish on the recreational trip. Data collected include number and species of fish landed and discarded, size of landed and discarded fish, and the release condition of discarded fish (FL only). Data are also collected on the length of the trip, area fished (inland, state, and federal waters) and, in Florida, the minimum and maximum depth fished. In the Florida Keys (sub-region 3) some vessels that run trips that span more than 24 hours are also sampled to collect information on trips that fish farther offshore and for longer durations, primarily in the vicinities of the Dry Tortugas and Florida Middle Grounds. While this data set is a short time series, it provides valuable quantitative information on the size distribution and release condition of fish discarded in the recreational fishery.

North Carolina Saltwater Fishing Tournament

The Official North Carolina Saltwater Fishing Tournament was designed to recognize outstanding angling achievement. Managed by the State of North Carolina, Department of Environment and Natural Resources' Division of Marine Fisheries, the program presents certificates suitable for framing to anglers who catch eligible fish at or over listed minimum weights. Applications are made through official weigh stations, located at many marinas, piers and tackle shops along the coast. Eligibility for an official citation requires that harvested red snapper weigh at least 10 pounds.

Citation awards for red snapper in North Carolina are available from 1991 through 2006. The number of annual citations awarded for red snapper ranged from a high of 72 during 2003 to only 9 fish recognized during 1997 (Table 4.4). Annual summaries from 1991-2006 along with individual citation records are available from 1996-2006. The datasets may be requested from workgroup member D. Mumford.

South Carolina's Angler-based Tagging Program

Since 1974, the South Carolina Marine Resources Division's Office of Fisheries Management has operated a tagging program that utilizes recreational anglers as a means for deploying external tags in marine game fish. The angler-based tagging program has proven to be a useful tool for promoting the conservation of marine game fish and increasing public resource awareness. In addition, the program has provided biologists with valuable data on movement and migration rates between stocks, growth rates, habitat utilization, and mortality associated with both fishing and natural events.

Select marine finfish species are targeted for tag and release based on their importance both recreationally and commercially to the State and South Atlantic region. The list of target species is further narrowed down based on the amount of historical data on that species with regards to seasonal movements, habitat requirements, growth rates and release mortality. Although red drum constitutes the majority of fish tagged and released by recreational anglers, program participants are encouraged to tag other eligible species where data gaps may exist. A total of 1,598 red snapper have been tagged, resulting in 172 recaptures. Numbers of red snapper tagged each year and the size range of tagged fish are provide in Table 4.5.

4.3 Recreational Landings

a. Missing cells in MRFSS estimates

The MRFSS calculates estimated landings in numbers and weight for each year, fishing mode, state, wave, and area fished (inshore, state waters, federal waters) combination, and each combination is referred to as a cell. Landings by weight are calculated by multiplying the average weight for all fish in a given cell by the estimated number of fish in the same cell. When no fish are weighed in a given cell, the estimated weight of fish landed is not generated for that cell. When there is an estimated number of fish landed, but no corresponding estimate for weight, that cell is referred to as a "missing cell". It is inaccurate to add cells together when there are missing weight estimates; therefore, weight estimates were filled in for missing cells by pooling cells and applying a pooled average weight to the number of fish in the cell with missing estimated weight. Weight landings were substituted in cells (Sub-reg, St, Year, Wave, Mode_fx, Area_x) that did not have >1 fish weighed. Average weight from sampled fish was calculated at the subregion, annual/wave level or higher, and applied to the number sampled in those cells that lacked sufficient sampled weights. The new weight estimates were substituted and included in the annual weight estimates for red snapper. For the 1981 to 2006 time series, there were 9 missing cells for red snapper landings estimates. Due to the high frequency of cells where there were zero estimated fish landed, cells had to be pooled for the entire year for all states combined (year, subregion).

Wave 1 estimates are not generated from Virginia to Georgia due to low fishing activity during January and February. In east Florida, no landings estimates are available for Wave 1, only for the year 1981. We generated Wave 1 estimates for A+B1 and B2 catch for red snapper using the average portion of Wave 1 catch estimates to Waves 2-6 catch estimates for the four year period from 1983 to 1986. The 1981 annual landings were increased by the mean value that Wave 1 contributed from the pooled years.

b. Headboat Estimates in MRFSS

Any catch estimates from the MRFSS survey program classified as Headboat mode were excluded from the landings. This fishery is monitored by the NMFS Southeast Headboat Program and was only rarely and sporadically sampled by the MRFSS.

c. Back-Calculating Landings in Time

For stock assessment modeling exercises, the workgroup was tasked with back-calculating recreational landings for years prior to the start of data collections extending backwards to 1962. Catch estimates from the MRFSS are not available from 1962 to 1980, and for headboat logbook estimates, red snapper landings estimates are not available from 1962 to 1971 from North Carolina to South Carolina, and from 1962 to 1980 for Georgia through Florida.

The workgroup considered several historic data sets for comparison with recreational trends as a possible means for regressing recreational statistics back in time. The U.S. Fish and Wildlife Survey of Fishing, Hunting, and Wildlife-Associated Recreation began in 1955 and is conducted approximately every 5 years. Due to several methodology changes over several time periods, the U.S. Fish and Wildlife Service does not recommend use of this data set as a continuous time series and this data set could not be used. A database of the number of registered recreational vessels in Florida was available for the time series 1964 to 2005. This database includes all registered fishing and nonfishing recreational vessels in freshwater and saltwater. The data set was considered as an index for comparison with recreational red snapper catch estimates, since the recreational fishery is exclusively vessel based. The number of registered vessels in Florida steadily increased over time, and this trend did not correspond well with recreational red snapper harvest, which peaks in the 1980's and appears to decline to a stable, but lower level in the 1990's and 2000's. Because the two trends do not track well, we did not attempt to use registered recreational vessels to regress recreational landings back in time.

In the absence of a good surrogate data set for recreational catch and harvest trends, the workgroup considered anecdotal accounts of the historic fishery and developments in technology in relation to fishing from recreational vessels. Red snapper is an offshore fishery and fishing occurs specifically on hard bottom and reef structure. The majority of private recreational boaters were not likely to venture far from sight of shore prior to the development of Loran A, which was first developed during WWII. After the war, Loran A became popular with commercial and recreational boaters as a means of navigation. However, it was not until the development of Loran C, with its longer range and accuracy, that Loran technology was particularly useful as a fishing aid. Prior to Loran C, it would be very difficult for recreational boaters to return to specific offshore fishing sites known to be productive for red snapper. The first receivers for Loran C were also cost prohibitive. In 1964, Raytheon offered a Loran C receiver for a retail cost of approximately $3,500. In 1979, SRD Labs came out with a smaller, more affordable receiver which they marketed for under $1,000 (www.rodgersmarine.com/history.com). While the for-hire sector may have had an interest and investment in expensive Loran C equipment as early as 1964, the private recreational sector would have been less likely to invest in Loran C technology for use in recreational fishing until at least 1979.

During the data workshop, the workgroup decided to set for-hire mode catch estimates to 0 in 1964, and private boat mode was estimated to be 0 in 1979 based on the limited technology for offshore fishing during those time periods. The workgroup reconsidered these start dates during the writing of this report, based on historic references which were not available during the data workshop. Historic accounts of recreational fisheries in Florida indicate that red snapper was not within reach of the recreational anglers in the early 1900's. Gregg (1902) noted that red snapper were caught on reefs ten miles from shore or more off the coast of east Florida and the species was described as "not exactly a sport fish". In Gregg's early accounts of Florida's recreational fishery, for-hire charters and guides were already catering to northern tourists who traveled by railroad to the east coast of Florida. Ellis (et. al 1958), documented a well established charter and party boat industry along the east coast of Florida (Ellis et al. 1958). The majority of charter and party vessels in the 1950's were located in the southeastern portion of the state; however, a small number of for-hire vessels were located in the north eastern counties from Indian River north where red snapper are more likely to be targeted. Rosen and Ellis (1961) surveyed coastal households in Florida and results indicate that private boat recreational anglers fished offshore for red snapper; however, the study did not specify if this fishing occurred in the Gulf of Mexico, Atlantic Ocean, or both. A later study of the developed offshore recreational fishery off eastern Florida indicates that small numbers of charter, party, and private vessels in the northeastern section of the state did venture offshore to catch red snapper prior to the introduction of Loran C recievers in 1964 (Moe 1963). In particular, red snapper were accessible to recreational anglers fishing outside Ponce de Leon Inlet in Volusia county.

The workgroup decided to extend landings back to 1946 for all modes (charter, headboat, and private boat) based on interviews with headboat captains (K. Brennan, personal communication) and historical reports from South Carolina and Florida for charter, headboat, and private boat modes. Moe (1963) noted, "The exploitation of the reef fishes on the offshore fishing grounds of Florida has increased tremendously since World War II." Based on this information, it is evident that fishing for offshore snapper-grouper species first developed sometime after World War II and that any recreational fishing was likely non-existent during the war years. It is also well documented that commercial fishing effort from large vessels was severely restricted during WWII.

Landings estimates from the first three years of available data (1981-1983 for MRFSS, 1972-1974 for headboats) were averaged and the average was divided by the number of years between zero landings and the average first catch estimates. Landings estimates for each year were incrementally declined backwards to zero in 1946. Red snapper headboat landings were limited to North Carolina and South Carolina from 1972-1980 and were estimated for specific reports and later digitized for assessment purposes. Trip reports for other areas began in 1976 and gradually increased so that all the currently sampled areas (NC to the Tortugas) were included by 1978. Landings for the non-coverage areas from 1972 -1980 were predicted by regressing landings of North Carolina and South Carolina catches combined against Georgia and Florida catches combined. The catch in numbers r2 value was 0.142 and was significant at $p<0.06$. The catch in weight r2 value was 0.046 and was not significant at $p<0.293$.

d. Change in Methodology for For-Hire Mode

The For-Hire Survey (FHS) method was piloted in east Florida in 2000 and officially adopted in 2003. In 2005, the For-Hire survey was implemented throughout all the south Atlantic states. The MRFSS coastal household telephone survey (CHTS) method for the for-hire fishing mode continues to run concurrently with the FHS method in all states. Because this new survey methodology has only been in place two full years throughout the south Atlantic region, there has been no evaluation of how the time series of landings estimates should be adjusted to account for the new survey method. Any difference between the two survey methods could cause a disjunct in the time series that may give a false signal of a change in landings. Therefore, we used MRFSS coastal household telephone survey estimates for all years and all states. The workgroup recommends that in the future, a comparison of the two methods be conducted before the next data workshop for this species so that CHTS estimates from earlier years can be adjusted and the new FHS estimates used for later years.

e. Shore Estimates

Because red snapper is an offshore species with a strong association with reefs and hard bottom, the group felt that it was implausible that this species would be landed from shore and shore landings for red snapper were omitted from total landings estimates. Several species of nearshore fish are often referred to as “red snapper”, which may explain the infrequent red snapper shore landing estimates in the MRFSS time series.

f. Monroe County

Monroe county landings estimates from the MRFSS are included in the total landings for the Gulf of Mexico. While Monroe County landings can be post-stratified, they can not be partitioned into fish from waters of the Atlantic Ocean or Gulf of Mexico. Because red snapper are less common on the extreme south Atlantic coast of Florida, Atlantic Coast landings from Monroe County likely contribute only a very small amount to recreational red snapper landings from the Atlantic. Because Gulf of Mexico red snapper could not be partitioned out of the Monroe County landings, the recreational workgroup decided not to include Monroe County MRFSS estimates. Headboat landings from Monroe County are seperated by area fished, and trips that occurred on the Atlantic side of Keys and Dry Tortugas were included in headboat landings.

4.4 Recreational Discards

a. Headboat discards

The collection of discard data began in 2004 in the Headboat Survey; however, discard estimates for 2004-2005 were unavailable for this assessment. Estimates from 2006 are preliminary and were only used for comparison purposes. Consequently, estimates of released (B2) fish from the MRFSS charter boat mode were used to estimate the proportion of released fish from the headboat fishery. The charter boat mode is thought to most closely approximate fishing practices followed by headboats. The ratio of released:retained (A+B1) fish in the charter boat mode from MRFSS were applied to the headboat catch in numbers, providing estimates of the number of released fish in the headboat fishery. The average of the ratio from 1981-1983 was applied for discards back to 1947, with 0 discards in 1946.

b. MRFSS discards

During the period of conduct of the MRFSS, the relationship between estimated live released fish (b2 record/estimates) and the landed fish (a+b1 record/estimates) changed dramatically by decade for red snapper. There is wide fluctuation in the number and proportion of discards in the 1980’s, suggesting either sample size issues or some real change in fishing behavior. During the 1980's (1982-1989) live discards were a low percentage of the annual total catch; during the 1990's this proportion more than doubled and during the period of 2000-2006 this proportion more than doubled again (Table 4.1). Regulatory changes during these time periods may account for some of the differences. In 1983, a 12" size limit was implemented, which was increased to 20" in 1992 along with implementation of a recreational bag limit of two fish per person. However, the effect of these regulatory changes is hard to discern due to low sampling levels during the 1980's and imprecise estimates. During three years from 1982 to 1991, there were zero discarded fish estimated, and the years with estimated discards have high PSE's. Stock assessment analysts may consider smoothing discard estimates by applying an average discard ratio to landings estimates. However, given changes in fishing regulations over the time periods, it may be that the fishery operated with virtually no fish released fish prior to 1992 and the wide variation in estimated discard numbers from year to year may be explained by the rarity of discard events in the sample. Therefore, it is recommended to use sensitivity runs to evaluate any potential effects of substitute estimation.

Because of the decadal differences in discard rates, the proportion of live discards to harvested fish from the 1980's were used when projecting backwards to provide a time series of live discard estimates. The average discard portion does not include 1981 estimates and proportions for projection because data was only collected in waves 2-6 and we already used proportional allocation to estimate the contribution of wave 1 fishing for that year (see Section 4.3.a). The adjusted values of landed fish for 1981 was straight-line reduced to 0 in the estimated first year of this fishery (1946). Then, from the proportional relationship of released fish to landed fish in the 1980's (0.365) and the estimated landed fish in 1981 (186,786) an estimate of the released fish in 1981 was computed (50.26 thousand fish). And, similar to the landings, this discard number was straight-line reduced to 0 in 1946. Estimates of released red snapper, in numbers of fish, and respective PSE's for charter mode and private boat mode are shown in Tables 4.2 and 4.3.

4.5 Biological Sampling

4.5.1 Sampling Intensity Length/Age/Weight

a. MRFSS Length Frequency Analysis

The MRFSS' angler intercept survey includes the collection of fish lengths from the harvested (landed, whole condition) catch. Up to 15 of each species landed per angler interviewed is measured to the nearest mm along a center line (defined as tip of snout to center of tail along a straight line, not curved over body). In those fish with a forked tail, this measure would typically be referred to as a fork length, and in those fish that do not have a forked tail it would typically be referred to as a total length with the exception of some fishes that have a single, or few, caudal fin rays that extend further, e.g., the black sea bass. The angler intercept survey is stratified by wave (2-month period), state, and fishing mode (shore, charter boat, party boat, private or rental boat) so simple agreggations of fish lengths across strata cannot be used to characterize a regional, annual length distribution of landed fish; a weighting scheme is needed to representatively include the distributions of each stratum value. Annual numbers of red snapper measured for length in MRFSS intercepts are summarized in Table 4.6.

The MRFSS' angler intercept length frequency analysis produces unbiased estimates of length-class frequencies for more than one strata by summing respectively weighted relative length-class frequencies across strata. The steps utilized are:

1) output a distribution of measured fish among state/mode/area/wave strata,

2) output a distribution of estimated catch among state/mode/area/wave strata,

3) calculate and output relative length-class frequencies for each state/mode/area/wave stratum,

4) calculate appropriate relative weighting factors to be applied to the length-class frequencies for each state/mode/area/wave stratum prior to pooling among strata,

5) sum across strata as defined, e.g., annual, sub-region length frequencies.

b. Headboat At-Sea Observer Survey Length Distributions

In 2005 and 2006, a total of 81 headboat trips were sampled by at-sea observers in northeast Florida. Red snapper was the number one target species for anglers who reported targeting a particular species of fish. Red snapper was also the third most abundant species in the observed discards. Lengths were collected during at-sea observer trips for both harvested and released (discarded) red snapper. A total of 148 harvested red snapper and 1,028 discarded red snapper were measured and the length frequency is plotted in Figure 1. Midline lengths were converted to total length using a length/weight regression equation from red snapper sampled in Florida recreational fishing surveys. These data are also available for trips sampled in South Carolina and North Carolina from 2004 to 2006, but were not summarized for this report. These data provide useful information on the proportion of discards to harvest and the size distribution. Size distribution of discarded fish in the recreational fishery is not collected in any other survey.

c. Headboat Logbook Survey Length Distributions

Lengths were collected from 1972-2006 by headboat dockside samplers. From 1972-1975, only North Carolina and South Carolina were sampled and Georgia and the northeast coast of Florida were sampled beginning in 1976. The headboat program sampled the entire range of Atlantic waters along the Southeast portion of the US from the NC-VA border through the Florida Keys beginning in 1978. Numbers of red snapper measured in headboat samples annually are summarized in Table 4.7.

The SEDAR 15 recreational data workgroup proposed using the lengths only from years where the entire range was sampled and to weight the length frequencies by landings. The landings were aggregated by year, zone, and season to generate weightings. The zones were delineated as North Carolina (NC), South Carolina (SC), Georgia-North Florida (GA-NFL, to Cape Canaveral), and South Florida (SFL). The seasons were January through May, June-August, and September-December. Landings estimates for NC and SC from 1978-80 were reported by year and zone only and therefore the weightings are by year and zone for those years. Landings estimates were not generated by the headboat program for GA-NFL or SFL prior to 1981. The landings were estimated for Georgia and Florida combined using a regression approach (see landings section). These combined landings from 1978-1980 were split between GA-NFL and SFL using the average proportion for each area from 1981-1985. GA-NFL accounted for 96.1% of the landings and SFL accounted for 3.9% of the landings. The 12 inch size limit implemented in 1983 had little influence on the size of fish landed from headboat vessels (Figure 2). The 20 inch size limit implemented in 1992 is apparent in the length compositions (Figure 2). A large number of undersize fish were reported in 1994; however, these fish were attributed to a single month and a single region. After reviewing original logbook data and associated collection numbers, it was determined an error occurred within the database. The records with conflicting fields were identified and the undersized fish from the region and month in question were removed from the data set. Length frequency distributions were recalculated and a new average weight was generated to produce a revised estimate for landings by weight for that year.

4.5.2 Adequacy for characterizing catch

Annual sample sizes for length frequency from the MRFSS are less than 100 fish in most years, and this may not be adequate for use in catch-at-age models. Headboat length samples add a substantial number to recreational length frequencies in most years, but the two samples should not be pooled without weighting to account for potential differences among modes and sample methods.

Opportunistic sampling of fish for biological data on age and growth of harvested fish during dockside interviews for catch data can never yeild sample sizes sufficient for catch at age models. Age information must be collected separate from MRFSS intercept surveys, and samples should be collected randomly using a survey sample design that results in representative, unbiased age samples from the recreational fishery. This will require dedicated funding for biological sampling, which has not been a high priority in the southeast. This workgroup recommends that a survey design with species specific annual goals by state or subregion (in Florida) and mode, and distributed throughout the fishing season, be a priority for funding in the southeast region. Setting minimum standards for numbers of otoliths by state, subregion, mode and wave is beyond the scope of this workgroup. However, a SEDAR workshop dedicated to this task with significant input from assessment scientists on minimum samples sizes needed for stock assessment model inputs would be a proper forum to guide funding initiatives in the southeast.

4.5.3 Alternatives for characterizing discards

The at-sea observer survey of headboat trips collects quality data on the species identification and size of discarded fish (Figure 1). The collection of release condition information should be expanded north of Florida, and the survey should also record more detailed area fished and depth information. The workgroup recommends that this new survey continue to add to the current time series for use in future assessment models. Currently for private boat and charter modes, discards are reported by recreational anglers; however, no information on size and limited information on release disposition are available. This method is subject to angler recall of both species identification and number of fish. Because the headboat fishery operates differently than the charter fishery, it may not be acceptable to apply the at-sea observer survey length frequencies to charter mode. Better information on the size, condition, and area fished are needed for charter mode and private boat mode, particularly for a species like red snapper where depth fished can have an impact on release mortality.

The South Carolina tagging program provides information on the area fished and size of red snapper caught and released by participants in the tagging program, and this data set could be useful for characterization of discards, though it is limited in geographic range. At the very least, this data set could be looked at for its potential expansion to other states and regions as a means of collecting more detailed information from private and charter anglers on discarded fish.

4.6 Research Recommendations

Six years of concurrent RDD and FHS effort estimates for east Florida need to be compared for adjusting effort estimates in for-hire mode for future assessments. This has been done in the Gulf for six years of concurrent data and resulted in significant changes to landings estimates for red snapper in the Gulf of Mexico assessment (SEDAR 7).

The PSE's for MRFSS estimates for reef-fish species continue to be high in the south Atlantic region, in spite of increased sample sizes implemented in recent years. The workgroup recommends evaluating recreational fishery survey data to study the relationship between sample size (both angler intercepts and effort interviews) and precision of annual catch estimates of reef-fish species at the sub-region and state levels to determine what sample sizes are needed to obtain minimum PSE levels of 20% or less.

Better geographic definition for estimated effort and catch are needed for red snapper in the south Atlantic. Red snapper are considered rare north of Cape Hatteras, NC. In Florida, red snapper are abundant in northeast Florida and less common in southeast Florida; however, private boat mode estimates are for the entire Florida east coast. The FHS stratifies east Florida into two subregions for better precision. Monroe County is a separate sub-region in the for-hire survey, but for private boat mode, MRFSS estimates effort and landings for the entire Gulf Coast of Florida, which included Monroe County. There is currently no way to separate Monroe County landings by Atlantic and Gulf waters in either the MRFSS or FHS. In addition to finer geographic scales, more detailed information on location of catch are needed from angler interviews. Currently, the MRFSS and FHS only delineate if fishing occurred in inland, state, or federal waters with no further detail on area fished or depth. These issues come up repeatedly in data work shops and stock assessments for other species, and a finer scale stratification for data collection and sample distribution with more detailed area fished information should be pursued in efforts to refine and improve recreational data collections at the national level, which are currently underway.

4.7 Literature Cited

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Table 4.1. Red Snapper Recreational Catch by Category for South Atlantic sub-region (Boat modes only). Released alive fish (b2) vs. landed fish (a+b1), charter boat and private/rental boat modes combined.

Year	Landings (a+b1)	Released Alive (b2)	b2/(a+b1)
1982	60,373	0	0.00
1983	165,962	40,044	0.24
1984	412,028	127,308	0.31
1985	527,138	90,290	0.17
1986	180,503	0	0.00
1987	63,252	106,728	1.69
1988	128,991	48,373	0.38
1989	149,915	20,038	0.13
1990	14,928	0	0.00
1991	46,276	35,993	0.78
1992	81,278	29,450	0.36
1993	16,323	70,507	4.32
1994	27,353	63,911	2.34
1995	14,010	50,872	3.63
1996	14,357	19,925	1.39
1997	34,327	13,742	0.40
1998	16,903	27,457	1.62
1999	58,182	179,665	3.09
2000	73,774	259,421	3.52
2001	50,814	208,885	4.11
2002	53,287	131,322	2.46
2003	35,662	159,177	4.46
2004	38,886	189,477	4.46
2005	33,708	123,059	4.87
2006	27,017	137,803	5.10
		Average proportion of b2/(a+b1):	
		All years	1.961
		1980's only	0.365
		1990's only	1.793
		2000's only	4.026

Table 4.2. Red snapper recreational landings and discards in numbers of fish. PSE=percent standard error.

	Number of Fish in 1000's											
	Landings			PSE	Discards			PSE	Landings+ Discards		
	Headboat	MRFSS	total	MRFSS	Headboat	MRFSS	total	MRFSS	Headboat	MRFSS	total
1962*	8.502	64.80	73.305	25.2	3.10	23.63	26.734	30.0	11.602	88.437	100.039
1963*	9.033	68.85	77.886	25.2	3.29	25.11	28.405	30.0	12.327	93.964	106.291
1964*	9.564	72.90	82.468	25.2	3.49	26.59	30.076	30.0	13.052	99.491	112.544
1965*	10.096	76.95	87.049	25.2	3.68	28.06	31.747	30.0	13.777	105.019	118.796
1966*	10.627	81.00	91.631	25.2	3.88	29.54	33.418	30.0	14.503	110.546	125.049
1967*	11.158	85.05	96.212	25.2	4.07	31.02	35.089	30.0	15.228	116.073	131.301
1968*	11.690	89.10	100.794	25.2	4.26	32.50	36.759	30.0	15.953	121.601	137.554
1969*	12.221	93.15	105.376	25.2	4.46	33.97	38.430	30.0	16.678	127.128	143.806
1970*	12.752	97.20	109.957	25.2	4.65	35.45	40.101	30.0	17.403	132.655	150.058
1971*	13.284	101.26	114.539	25.2	4.84	36.93	41.772	30.0	18.128	138.183	156.311
1972*	11.980	105.31	117.285	25.2	4.37	38.40	42.774	30.0	16.349	143.710	160.059
1973*	15.776	109.36	125.131	25.2	5.75	39.88	45.635	30.0	21.529	149.237	170.767
1974*	13.689	113.41	127.095	25.2	4.99	41.36	46.351	30.0	18.681	154.765	173.446
1975*	17.505	117.46	134.961	25.2	6.38	42.84	49.220	30.0	23.889	160.292	184.181
1976*	19.387	121.51	140.893	25.2	7.07	44.31	51.384	30.0	26.457	165.819	192.277
1977*	12.379	125.56	137.935	25.2	4.51	45.79	50.305	30.0	16.894	171.346	188.240
1978*	12.954	129.61	142.560	25.2	4.72	47.27	51.992	30.0	17.678	176.874	194.552
1979*	9.565	133.66	143.222	25.2	3.49	48.74	52.233	30.0	13.053	182.401	195.454
1980*	14.511	137.71	152.218	25.2	5.29	50.22	55.514	30.0	19.803	187.928	207.732
1981	35.719	186.52	222.234	25.1	0.38	2.00	2.383	100.0	36.102	188.515	224.617
1982	19.553	60.37	79.926	30.6	0.00	0.00	0.000	0.0	19.553	60.373	79.926
1983	30.698	165.96	196.660	19.8	7.41	40.04	47.451	38.0	38.105	206.006	244.111
1984	31.146	412.03	443.174	17.9	9.62	127.31	136.931	29.5	40.769	539.336	580.105
1985	50.336	527.14	577.475	19.0	8.62	90.29	98.912	43.9	58.958	617.429	676.387
1986	16.625	180.50	197.128	32.2	0.00	0.00	0.000	0.0	16.625	180.503	197.128
1987	24.996	63.25	88.247	19.7	42.18	106.73	148.906	57.8	67.174	169.979	237.153
1988	36.527	128.99	165.518	28.3	13.70	48.37	62.071	47.3	50.225	177.364	227.589
1989	23.453	149.92	173.368	19.9	3.13	20.04	23.173	41.9	26.588	169.953	196.541
1990	20.919	14.93	35.846	30.6	0.00	0.00	0.000	0.0	20.919	14.927	35.846
1991	13.857	46.28	60.133	33.1	10.78	35.99	46.771	51.5	24.635	82.269	106.904
1992	5.301	81.28	86.578	18.5	1.92	29.45	31.371	29.4	7.222	110.727	117.949
1993	7.347	16.32	23.670	21.8	31.74	70.51	102.242	28.4	39.082	86.830	125.912
1994	8.225	27.35	35.578	25.9	19.22	63.91	83.129	28.9	27.443	91.264	118.707
1995	8.826	14.01	22.837	29.7	32.05	50.87	82.918	20.2	40.872	64.883	105.755
1996	5.543	14.36	19.899	41.2	7.69	19.93	27.618	38.0	13.236	34.281	47.517
1997	5.770	34.33	40.097	48.5	2.31	13.74	16.052	26.9	8.080	48.069	56.149
1998	4.741	16.90	21.644	24.0	7.70	27.46	35.158	32.5	12.442	44.360	56.802
1999	6.836	58.18	65.017	20.9	21.11	179.67	200.775	15.9	27.946	237.846	265.792
2000	8.437	73.77	82.211	20.3	29.67	259.42	289.089	14.8	38.105	333.195	371.300
2001	12.028	50.81	62.842	16.6	49.44	208.89	258.329	13.8	61.472	259.699	321.171
2002	12.931	53.29	66.218	15.8	31.87	131.32	163.190	18.2	44.799	184.609	229.408
2003	5.706	35.66	41.367	16.5	25.47	159.18	184.646	16.2	31.175	194.838	226.013
2004	10.842	38.89	49.728	14.9	52.83	189.48	242.306	14.3	63.671	228.363	292.034
2005	8.907	33.71	42.615	18.2	32.52	123.06	155.576	13.4	41.424	156.767	198.191
2006	5.945	27.02	32.962	18.8	30.32	137.80	168.126	18.2	36.268	164.820	201.088

*Estimated landings are back-calculated using methods described in section 4.3

Table 4.3. Recreational landings in total pounds harvested and average weight of estimated landings (total estimated landings in number fish/total estimated weight). All weights are in whole weight. PSE=percent standard error.

	Landings (pounds)			PSE	Average Weight (pounds)	
	Headboat	MRFSS	total	MRFSS	Headboat	MRFSS
1962*	58,725	124,473	183,198	28.8	6.908	1.921
1963*	62,396	132,252	194,648	28.8	6.908	1.921
1964*	66,066	140,032	206,098	28.8	6.908	1.921
1965*	69,736	147,811	217,548	28.8	6.908	1.921
1966*	73,407	155,591	228,998	28.8	6.908	1.921
1967*	77,077	163,371	240,448	28.8	6.908	1.921
1968*	80,747	171,150	251,898	28.8	6.908	1.921
1969*	84,418	178,930	263,347	28.8	6.908	1.921
1970*	88,088	186,709	274,797	28.8	6.908	1.921
1971*	91,758	194,489	286,247	28.8	6.908	1.921
1972*	91,919	202,268	294,188	28.8	7.673	1.921
1973*	117,307	210,048	327,355	28.8	7.436	1.921
1974*	77,060	217,827	294,888	28.8	5.629	1.921
1975*	83,518	225,607	309,125	28.8	4.771	1.921
1976*	109,283	233,387	342,669	28.8	5.637	1.921
1977*	59,928	241,166	301,094	28.8	4.841	1.921
1978*	62,980	248,946	311,925	28.8	4.862	1.921
1979*	54,131	256,725	310,856	28.8	5.659	1.921
1980*	54,656	264,505	319,161	28.8	3.767	1.921
1981	116,586	435,918	552,505	32.5	3.264	2.337
1982	98,024	158,100	256,124	27.2	5.013	2.619
1983	74,004	199,496	273,500	26.6	2.411	1.202
1984	81,418	453,997	535,415	17.2	2.614	1.102
1985	132,084	1,335,524	1,467,608	29.1	2.624	2.534
1986	54,381	113,513	167,894	27.3	3.271	0.629
1987	81,840	133,676	215,516	20.0	3.274	2.113
1988	130,070	163,371	293,441	27.0	3.561	1.267
1989	70,796	247,981	318,777	30.1	3.019	1.654
1990	65,686	115,302	180,988	7.9	3.140	7.724
1991	72,030	131,515	203,545	34.2	5.198	2.842
1992	28,916	617,721	646,637	38.3	5.455	7.600
1993	42,718	135,919	178,637	27.4	5.814	8.327
1994	53,422	196,151	249,573	36.7	6.495	7.171
1995	57,474	66,005	123,479	28.0	6.512	4.711
1996	46,235	106,207	152,442	50.2	8.341	7.398
1997	51,205	88,905	140,110	43.6	8.874	2.590
1998	26,848	114,964	141,812	31.7	5.663	6.801
1999	43,559	169,434	212,993	17.9	6.372	2.912
2000	49,403	499,925	549,328	23.9	5.856	6.776
2001	68,385	343,118	411,503	19.1	5.685	6.752
2002	70,797	390,914	461,711	16.9	5.475	7.336
2003	41,354	277,329	318,683	18.0	7.247	7.777
2004	80,349	277,515	357,864	16.4	7.411	7.137
2005	58,696	245,372	304,068	17.3	6.590	7.279
2006	41,432	246,059	287,491	24.0	6.969	9.108

*Estimates back-calculated using methods in section 4.3

Table 4.4. North Carolina Citation Results, 1991 through 2006.

Year	Red Snapper Harvest Citations	Year	Red Snapper Harvest Citations
1991	21	1999	11
1992	23	2000	11
1993	24	2001	14
1994	14	2002	29
1995	10	2003	72
1996	17	2004	73
1997	9	2005	42
1998	12	2006	41

Table 4.5. South Carolina Angler-Based Tagging Program, number of fish tagged and minimum and maximum size range.

Year	Number Measured	Range (inches)	Year	Number Measured	*Range (inches)*
1990	1	10.5	1999	205	*6-29.8*
1991	2	11.5-14	2000	181	*10-22*
1992	52	13-20	2001	199	*11-33*
1993	133	10-20	2002	105	*13-29.5*
1994	102	6-19.5	2003	34	*12-19.5*
1995	79	11-20	2004	40	*14-30*
1996	56	9-24	2005	42	*14-20.5*
1997	91	11-21	2006	13	*13.5-19.5*
1998	*223*	*9-20.5*			

Table 4.6. Red Snapper - South Atlantic Sub-Region - Annual Sample Sizes

Year	Number of Lengths	Year	Number of Lengths
1981	44	1994	38
1982	29	1995	26
1983	161	1996	15
1984	370	1997	20
1985	249	1998	33
1986	226	1999	132
1987	63	2000	95
1988	87	2001	120
1989	59	2002	232
1990	18	2003	166
1991	16	2004	156
1992	17	2005	83
1993	23	2006	84

Table 4.7. Number of headboat biological samples of red snapper in the in Southeast US Atlantic 1972- 2006.

Year	NC	SC	GA\FL	Total
1972	20	30	N\A	50
1973	21	20	N\A	41
1974	29	66	N\A	95
1975	75	91	N\A	166
1976	145	51	302	498
1977	59	82	562	703
1978	50	45	621	716
1979	7	8	222	237
1980	10	14	233	257
1981	18	3	654	675
1982	30	6	421	457
1983	53	24	929	1,006
1984	48	103	1,170	1,321
1985	170	51	970	1,191
1986	51	30	353	434
1987	50	53	203	306
1988	64	43	100	207
1989	50	53	274	377
1990	35	43	356	434
1991	7	29	116	152
1992	20	25	28	73
1993	22	128	53	203
1994	14	46	59	119
1995	13	41	77	131
1996	7	107	54	168
1997	4	14	52	70
1998	11	33	109	153
1999	7	15	136	158
2000	7	9	104	120
2001	17	0	239	256
2002	8	12	340	360
2003	9	21	282	312
2004	5	10	292	307
2005	3	3	186	192
2006	4	9	149	162
Total	1,143	1318	9,646	12,107

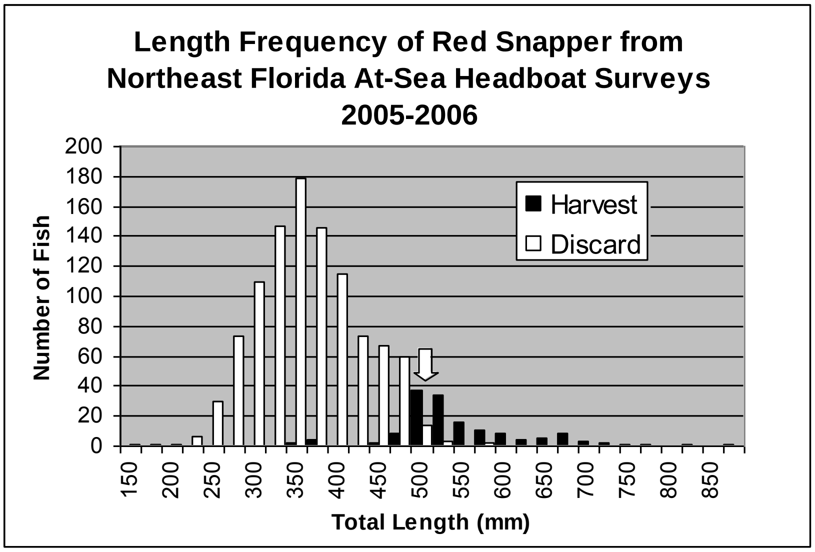

Figure 4.1. Length frequency of harvested and discarded red snapper from at-sea headboat observer trips in northeast Florida (Nassau through Brevard counties). The white arrow marks the size category where red snapper legally recruit to the 508 mm TL size limit. N = 148 harvested fish + 1,028 discarded fish.

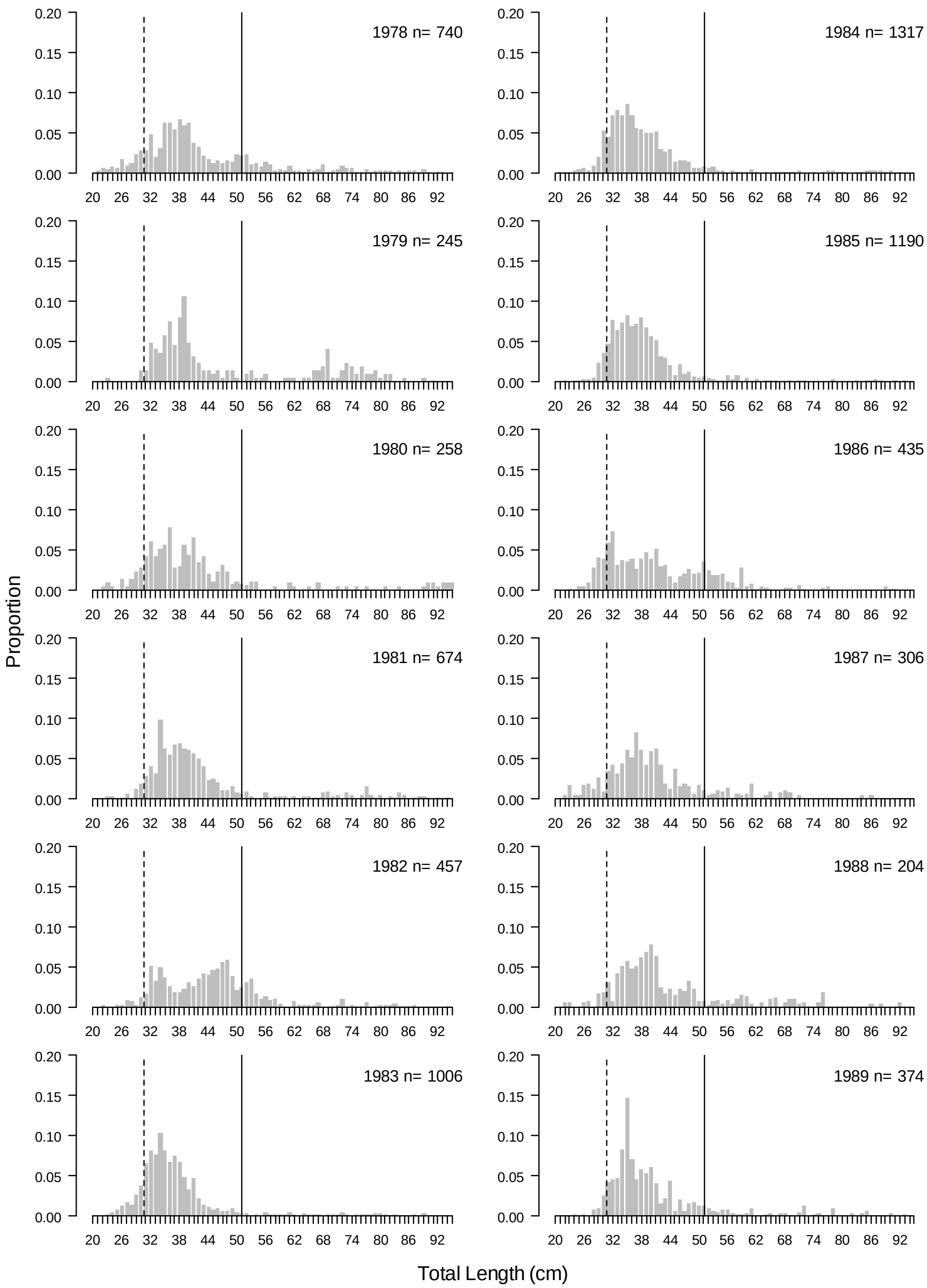

Figure 4.2. Catch weighted length frequencies of red snapper measured from headboat vessels from 1978-2006. Vertical lines indicate size limits of 12 (dashed) and 20 (solid) inches implemented in September, 1983 and January, 1992 respectively. They are included on all graphs as reference values. The range of sizes from 20 to 95 cm total length excludes a small number of larger size classes of fish for presentation purposes.

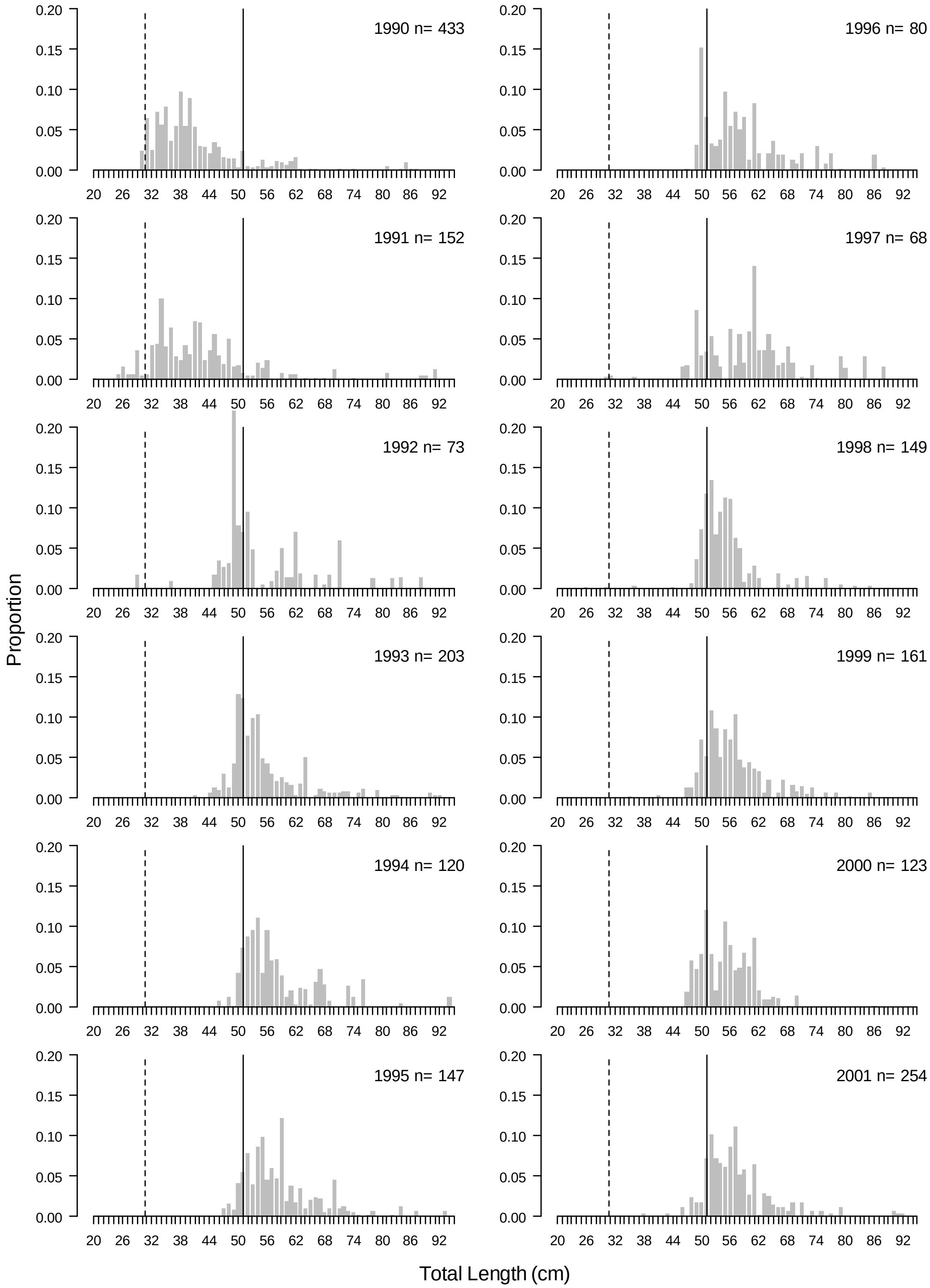

Figure 4.2 (continued)

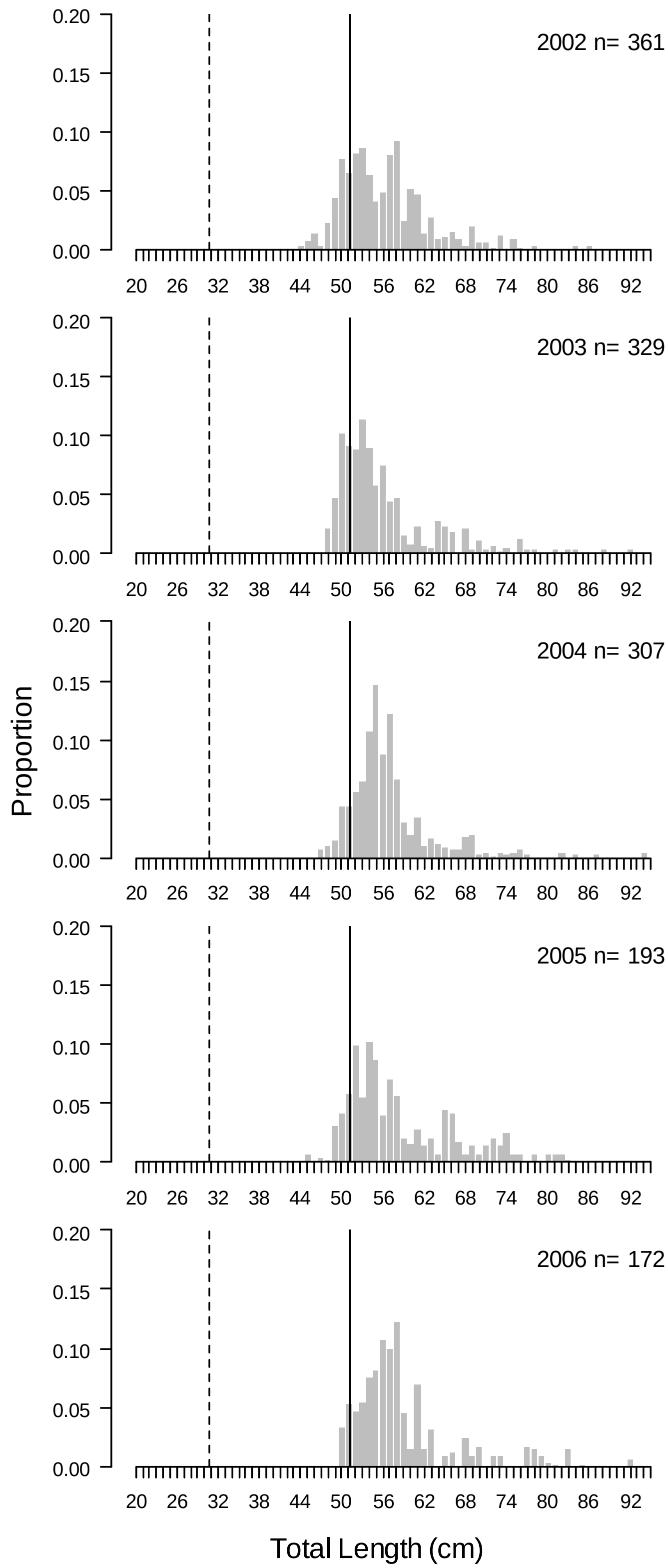

Figure 4.2 (continued)

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 dependent and fishery independent data. The DW recommended that three fishery dependent indices be used in the assessment: one from commercial logbook data, one from headboat data, and one from general recreational data (Table 5.1, 5.2). The DW did not recommend using any of the fishery independent indices because of inadequate sample sizes.

Membership of this DW working group included Christine Burgess, Rob Cheshire, Marcel Reichert, Kyle Shertzer (leader), and Geoff White.

5.2 FISHERY-INDEPENDENT INDICES

5.2.1 MARMAP

Red snapper have been sampled in low numbers by the MARMAP (Marine Resources Monitoring Assessment and Prediction) program with two gear types (gears detailed in previous working paper SEDAR10-DW-05): the chevron traps (1988–2006) and hook and line (1979–2002). Although these gear types and sampling methodology are not specifically designed to sample red snapper populations, the DW considered the data as a possible source to develop an index of abundance.

5.2.1.1 MARMAP Chevron trap:

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. During 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.

In spite of relatively extensive regional coverage, the average number of red snapper collected in the traps each year between 1988 and 2006 was only 18.5 (range 4–41, total 351). The average CPUE was 0.065 fish/trap/hr (range 0.432–0.008). Because of the low catches and the high variability in the data, the DW did not recommend using MARMAP chevron trap samples to develop an index of abundance for red snapper off the southeastern U.S.

5.2.1.2 MARMAP hook and line:

Hook and line stations were fished during dawn and dusk periods, one hour preceding and after actual sunrise and sunset. 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 2002. However, less emphasis has been placed on hook and line sampling during the 1990s and early 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 red snappers caught between 1979 and 2002 was 81 (3.7/yr), but 39 of these fish were collected in a single year (1982), while 41% of years sampled had zero catches. 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 red 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.

5.2.1.3 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.

Few (0–10 per year) red snapper were collected by MARMAP short bottom long line. Because of the low catches and high variability, the DW did not recommend using the MARMAP short bottom long line samples to develop an index of abundance for red snapper off the southeastern U.S.

5.2.2 Other fishery independent sources

Other existing data sets (SEAMAP survey, Univ. of SC/Baruch Institute low tide motile nekton survey) were considered for their potential as an index, but they sampled either no or insufficient numbers of red 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 vessels were required to submit logs. Using these data, an index of abundance was computed for 1993–2006.

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 98% of trips used handline.

Issue 2: Year selection
Option 1: Use all years of data (1992-2006)
Option 2: Only use data from 1993 to 2006
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 catch. This method would include trips with zero catch but positive effort.
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 some trips had zero catch but positive effort, and because regions north and south of Cape Canaveral were found to have differences in species assemblages (Appendix 5.2).

Miscellaneous decisions

- A 12" TL size limit was implemented in August of 1983. In 1992, the size limit was increased to 20" TL. The DW acknowledged that this issue could be handled by the assessment model through estimation of selectivity.
- Species included in the application of Stephens and MacCall (2004) were those in the snapper-grouper Fishery Management Plan.

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 1993–2006. Spatial coverage included the entire management area, from the Florida Keys through North Carolina (Figure 5.1). 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 red snapper, approximately 98% 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 3000 lb, 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 red 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 5.2A,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 X% of trips. A default value of X=5% was applied to the northern region, but this value was overly restrictive for the southern region (excluded the focal species) and was thus reduced to 1% for the southern region. A trip was then included if its associated probability of catching red snapper was higher than a threshold probability (Figure 5.3A,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 24,344 trips, of which ~61% were positive.

Standardized catch rates were estimated using a generalized linear model assuming delta-lognormal error structure (Lo et al., 1992; Maunder and Punt, 2004), in which the binomial distribution describes positive versus zero CPUE, and the normal distribution describes the log of positive CPUE. Explanatory variables considered, in addition to year (necessarily included), were month, geographic area, and a month×area interaction. 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). Interactions with year effects were not considered, because there was no *a priori* reason to expect them and because such effects may be inseparable from annual changes in abundance.

A forward stepwise approach was used to construct each GLM (binomial and lognormal). First a GLM was fit on year. These results reflect the distribution of the nominal data. Next, each main effect (area and month) was examined for its reduction in deviance per degree of freedom. The factor that caused the greatest reduction was added to the base model if it was significant based on a Chi-Square test ($\chi^2 \leq 0.05$) and if the reduction in deviance was greater than 1%. This model then became the base model. The process was repeated, adding main effects first and then two-way interaction terms, until no factor or interaction met the criteria for inclusion. The approach identified area as the only factor other than year to be used in the binomial GLM (Table 5.3A), and it identified area, month, and area×month as factors to be used in the lognormal GLM (Table 5.3B).

5.3.1.4 Sampling Intensity

The numbers of positive trips by year and area are tabulated in Table 5.4. 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 of residuals from the delta-GLM model fit are in Appendix 5.3. Table 5.5 shows nominal CPUE (pounds/hook-hr), standardized CPUE, confidence limits, coefficients of variation (CV), and annual sample sizes (number trips). Figure 5.4 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. 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 (e.g., vermilion snapper) as red 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 improved over time due to improved electronics. In addition, overall efficiency may have changed throughout the time series if fishermen of marginal skill have left 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 gag grouper assessment (SAFMC, 2006), and 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 1976–2006.

5.3.2.2 Issues discussed at the DW

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

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: Include all years (1973–2006)
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 that area contributed only a small proportion of red snapper catches.

Issue 2: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 catch. This method would include trips with zero catch but positive effort.
Option 3: Option 2, but apply method of Stephens and MacCall (2004) separately to regions north and south of Cape Canaveral
Decision: Option 3, because it is likely that some trips had zero catch but positive effort, and because regions north and south of Cape Canaveral were found to have differences in species assemblages (Appendix 5.2).

Miscellaneous decisions

- A 12” TL size limit was implemented in August of 1983. In 1992, the size limit was increased to 20” TL. The DW acknowledged that size limits could be accounted for by the assessment model through estimation of selectivity.
- A bag limit of 10 snapper/person/day, excluding vermilion snapper, and allowing no more than two red snappers, was instituted for the recreational fishery in 1992. Bag analysis showed that the limit of two red snapper per angler had little effect, if any, on the headboat fishery (Table 5.6).
- Species included in the application of Stephens and MacCall (2004) were those in the snapper-grouper Fishery Management Plan.

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 1976–2006. Spatial coverage included the entire management area (Figure 5.5). Trips were trimmed from the analysis if the number of red snapper per angler 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 red 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 X% of trips. A default value of X=5% was applied to the northern region, but this value was overly restrictive for the southern region (excluded the focal species) and was thus reduced to 1% for the southern region. A trip was then included if its associated probability of catching red snapper 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 42,802 trips, of which ~36% were positive.

Standardized catch rates were estimated using a generalized linear model assuming delta-lognormal error structure (Lo et al., 1992; Maunder and Punt, 2004), in which the binomial distribution describes positive versus zero CPUE, and the normal distribution describes the log of positive CPUE. Explanatory variables considered, in addition to year (necessarily included), were month, geographic area, month, trip type, and all possible interactions except those with year. Geographic areas reported in the headboat survey were pooled into larger areas (NC, SC, GA–north FL, and south FL) to provide adequate sample sizes for each level of this factor. Trip types were pooled into half-day trips (including three-quarter day) or full-day trips (including multi-day trips). Interactions with year effects were not considered, because there was no *a priori* reason to expect them and because such effects may be inseparable from annual changes in abundance.

A forward stepwise approach was used to construct each GLM (binomial and lognormal). First a GLM was fit on year. These results reflect the distribution of the nominal data. Next, each main effect (area, month, and trip duration) was examined for its reduction in deviance per degree of freedom. The factor that caused the greatest reduction was added to the base model if it was significant based on a Chi-Square test ($\chi^2 \leq 0.05$) and if the reduction in deviance was greater than 1%. This model then became the base model. The process was repeated, adding main effects first and then two-way interaction terms, until no factor or interaction met the criteria for inclusion. The approach identified area, month, type, and area×type as the factors other than year to be used in the binomial GLM (Table 5.7A), and it identified area, month, area×type as the factors to be used in the lognormal GLM (Table 5.7B).

5.3.2.4 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.

5.3.2.5 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 5.4. Table 5.9 shows nominal CPUE (number/hook-hr), standardized CPUE, confidence limits, coefficients of variation (CV), and annual sample sizes (number trips). Figure 5.8 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. 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 red 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 red snapper specifically.

The DW discussed a perceived shift in headboat effort during the 1980s, from full-day trips to half-day trips nearer shore. However, analysis of positive red snapper trips reveals that no such shift occurred during the 1980s. Half-day trips were initiated during the mid- to late-1970s, but have not increased since. Similar analyses of all headboat trips, by state and overall, revealed similar patterns. Furthermore, the DW noted that if there were a shift in trip type, it would be accounted for by the GLM, because trip type (half day, full day) was used as a factor.

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.

5.3.3 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). Using the MRFSS data from Currituck County, North Carolina through Miami-Dade County, Florida (Figure 5.9), an index of abundance was computed for 1986–2006.

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.

Decision: Option 2. MRFSS data contain information on targeting. This information identifies directed effort explicitly, whereas the method Stephens and MacCall (2004) does so implicitly.

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 1983, because of small sample size in 1982.
Decision: Option 2. The DW decided to start the time series in 1983, when the sample size increased substantially (Table 5.10).

Miscellaneous decisions
- The group acknowledged the possibility that some red snapper were misreported as other snappers. MRFSS data were used as reported. It was assumed that if red snapper were misreported, the misreporting was not systematic, such that the red snapper reported could be considered a random sample of all red snapper caught.
- A 12" TL size limit was implemented in August of 1983. In 1992, the size limit was increased to 20" TL. The DW acknowledged that size limits could be accounted for by the assessment model through estimation of selectivity.
- A bag limit of 10 snapper/person/day, excluding vermilion snapper, and allowing no more than two red snappers, was instituted for the recreational fishery in 1992. The DW believed that these limits were not likely to be reached in the recreational fishery and therefore would not influence an index of abundance derived from recreational fishery data.
- 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 red snapper to estimates of total marine recreational angler trips. Directed trips were defined as those trips where red 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. 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, 2007).

5.3.3.4 Sampling Intensity

Sampling intensity (number of intercepted angler-trips) by state is shown in Table 5.10.

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 5.11 shows nominal CPUE (number/angler-trip) and estimates of precision, as does Figure 5.10.

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 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

No fishery independent indices were recommended for use in the assessment. Three fishery dependent indices were recommended: commercial handline (logbook), headboat, and MRFSS (Tables 5.1, 5.2). The three indices are compared in Figure 5.11 and their correlations are in Table 5.12.

5.5 RESEARCH RECOMMENDATIONS

1. Develop a method to correct for red snapper that are misclassified or unclassified on a trip-by-trip basis.

2. Expand existing fishery independent sampling and/or development new fishery independent sampling of red snapper population so off the southeastern U.S. Two ideas discussed were the following:
   - Adding gears to MARMAP that are more effective at catching red snapper
   - Developing coast-wide sampling of larval and juvenile abundance

3. Examine how catchability has changed over time with increases in technology and potential changes in fishing practices. This is of particular importance when considering fishery dependent indices.

4. Investigate potential density-dependent changes in catchability.

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

6. Continue and expand the "Headboat at Sea Observer Survey". This survey collects discard information, which would provide for a more accurate index of abundance.

5.6 ITEMIZED LIST OF TASKS FOR COMPLETION FOLLOWING WORKSHOP

- Generate tables and figures
- Write chapter of DW report
- Submit data to Data Compiler

5.7 LITERATURE CITED

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5.8 TABLES

Table 5.1. A summary of catch-effort time series available for the SEDAR 15 data workshop.

Fishery Type	Data Source	Area	Years	Units	Standardization Method	Size Range	Issues	Use?
Recreational	Headboat	Atlantic	1976-2006	Number per angler-hr	Stephens and MacCall; delta-lognormal GLM	Same as fishery	Fishery dependent	Y
Commercial	Handline	Atlantic	1993-2006	Pounds per hook-hr	Stephens and MacCall; delta-lognormal GLM	Same as fishery	Fishery dependent	Y
Recreational	MRFSS	Atlantic	1983-2006	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	Atlantic	1988-2006	Number per trap-hr	Nominal	—	Low sample sizes; freq. annual zero (n = 4 to 41 per year)	N
Independent	MARMAP Hook and line	Atlantic	1979-2002	Number per hook-hr	Nominal	—	Low sample sizes; freq. annual zeros (n = 0 to 39 per year)	N
Independent	MARMAP Short longline	Atlantic	1980-2006	Number per hook-hr	Nominal	—	Low sample sizes; freq. annual zeros (n = 0 to 10 per year)	N
Independent	SEAMAP	Atlantic	1990-2006	Number per hectare	Nominal	—	Extremely low sample sizes; mostly annual zeros (n = 0 to 4 per year)	N
Independent	USC Baruch Institute nekton survey	South Carolina	—	—	—	—	n = 0	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, 14-year time series
Large sample size

Cons: Fishery dependent
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 fisherman 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 sample size
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 fisherman 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 red 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 red snapper when only able to record a maximum of two species. Trips would be eliminated from the analysis if anglers fished in areas where red 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

Fishery independent

MARMAP

Chevron Trap Index (*Not recommended for use*)

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

Cons: Low sample sizes. Only 4-41 fish caught per year.
High standard errors

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. Only 0-39 fish caught per year with frequent zeros.
Restricted depth coverage (midshelf sampled)
High standard errors
Ability of samplers may have changed over time
Level of effort has decreased over time

Short Bottom Longline Index (*Not recommended for use*)

Pros: Fishery independent

Cons: Low sample sizes. Only 0-10 fish caught per year with frequent zeros.

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)
Only captured 20 red snapper from program inception in 1990 to 2006

University of South Carolina Baruch Institute Low Tide Motile Nekton Survey (*Not Recommended for use*)

Pros: Fishery independent

Cons: Estuarine survey not likely to capture the focal species
Focal species not present in the database to date
Inadequate regional coverage

Table 5.3A. Red snapper: deviance analysis of the binomial sub-model of the delta-GLM applied to commercial logbook data.

The explanatory factors in the base model are: YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	24330	31919.7	1.3119		-15959.8		
AREA	24326	29688.5	1.2204	6.97	-14844.3	2231.14	0.00000
MONTH	24319	31682.8	1.3028	0.70	-15841.4	236.93	0.00000

The explanatory factors in the base model are: YEAR AREA

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	24326	29688.5	1.2204		-14844.3		
MONTH	24315	29479.3	1.2124	0.66	-14739.7	209.22	0.00000

The explanatory factors in the base model are: YEAR AREA

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	24326	29688.5	1.2204		-14844.3		
AREA*MONTH	24271	29410.8	1.2118	0.71	-14705.4	277.72	0.00000

Table 5.3B. Red snapper: deviance analysis of the lognormal sub-model of the delta-GLM applied to commercial logbook data.

The explanatory factors in the base model are: YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	14896	32597.9	2.1884		-26987.8		
AREA	14892	28575.5	1.9188	12.32	-26006.0	1963.61	0.00000
MONTH	14885	32082.1	2.1553	1.51	-26868.9	237.81	0.00000

The explanatory factors in the base model are: YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	14896	32597.9	2.1884		-26987.8		
MONTH	14885	32082.1	2.1553	1.51	-26868.9	237.81	0.00000

The explanatory factors in the base model are: YEAR MONTH

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	14885	32082.1	2.1553		-26868.9		
AREA*MONTH	14837	28163.7	1.8982	11.93	-25897.8	1942.24	0.00000

Table 5.4. Number of trips by year and area (GA=Georgia, NC=North Carolina, NF=north Florida, SC=South Carolina, SF=south Florida) that caught red snapper, as reported in commercial logbook data.

	Area					
Year	**GA**	**NC**	**NF**	**SC**	**SF**	**Total**
1992	51	130	149	267	77	674
1993	180	513	461	971	202	2327
1994	186	508	569	951	310	2524
1995	180	316	634	822	357	2309
1996	208	246	630	627	324	2035
1997	140	219	480	567	320	1726
1998	104	250	473	547	242	1616
1999	123	379	374	539	167	1582
2000	99	255	437	467	192	1450
2001	181	505	463	785	179	2113
2002	195	567	407	787	192	2148
2003	134	260	319	612	131	1456
2004	122	163	340	597	103	1325
2005	112	134	276	514	149	1185
2006	60	107	239	415	142	963
Total	2075	4552	6251	9468	3087	25433

Table 5.5. CPUE of red snapper off the southeastern U.S. based on handline gear reported in commercial logbooks. Columns are year, nominal CPUE (lb/hook-hr), nominal CPUE relative to its mean, standardized CPUE, lower (LCI) and upper (UCI) 95% confidence intervals of the standardized CPUE, annual sample size (N = number of positive and zero trips), and coefficient of variation (CV) of the standardized CPUE.

YEAR	Nominal CPUE	Relative nominal	Standardized CPUE	LCI	UCI	N	CV
1993	0.294	0.888	1.052	0.918	1.205	1862	0.068
1994	0.246	0.745	0.856	0.743	0.986	2058	0.071
1995	0.360	1.087	0.879	0.760	1.017	2293	0.073
1996	0.285	0.861	0.691	0.580	0.825	2104	0.088
1997	0.325	0.983	0.610	0.498	0.748	2013	0.102
1998	0.263	0.795	0.688	0.558	0.847	1782	0.105
1999	0.291	0.880	0.851	0.699	1.035	1596	0.098
2000	0.312	0.943	0.869	0.706	1.069	1571	0.104
2001	0.452	1.366	1.347	1.175	1.545	1869	0.068
2002	0.391	1.181	1.475	1.291	1.684	1758	0.066
2003	0.385	1.162	1.220	1.029	1.446	1446	0.085
2004	0.438	1.323	1.523	1.278	1.815	1369	0.088
2005	0.356	1.075	1.263	1.038	1.537	1354	0.098
2006	0.235	0.709	0.677	0.521	0.878	1269	0.131

Table 5.6. Proportion of red snapper trips from the headboat fishery that exceeded two red snapper per angler. Starting in 1992, regulations allowed no more than two red snapper per angler per trip.

Year	North of Canaveral	South of Canaveral
1973	0.000	
1974	0.003	
1975	0.005	
1976	0.066	
1977	0.041	
1978	0.048	0.000
1979	0.039	0.000
1980	0.018	0.000
1981	0.029	0.000
1982	0.007	0.000
1983	0.010	0.000
1984	0.021	0.014
1985	0.021	0.007
1986	0.001	0.000
1987	0.005	0.000
1988	0.008	0.033
1989	0.006	0.016
1990	0.006	0.030
1991	0.003	0.000
1992	0.007	0.000
1993	0.003	0.014
1994	0.004	0.011
1995	0.003	0.000
1996	0.002	0.000
1997	0.000	0.000
1998	0.000	0.053
1999	0.002	0.000
2000	0.003	0.000
2001	0.005	0.040
2002	0.011	0.091
2003	0.004	0.000
2004	0.003	0.000
2005	0.002	0.000
2006	0.006	0.000

Table 5.7A. Red snapper: deviance analysis of the binomial sub-model of the delta-GLM applied to headboat data.

The explanatory factors in the base model are: YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	42771	54586.9	1.2763		-27293.5		
AREA	42768	44162.1	1.0326	19.09	-22081.0	10424.83	0.00000
TYPE	42770	46083.3	1.0775	15.58	-23041.6	8503.63	0.00000
MONTH	42760	52140.4	1.2194	4.46	-26070.2	2446.56	0.00000

The explanatory factors in the base model are: YEAR AREA

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	42768	44162.1	1.0326		-22081.0		
TYPE	42767	38836.2	0.9081	12.06	-19418.1	5325.89	0.00000
MONTH	42757	43364.7	1.0142	1.78	-21682.4	797.38	0.00000

The explanatory factors in the base model are: YEAR AREA TYPE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	42767	38836.2	0.9081		-19418.1		
MONTH	42756	38271.1	0.8951	1.43	-19135.6	565.08	0.00000

The explanatory factors in the base model are: YEAR AREA TYPE MONTH

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	42756	38271.1	0.8951		-19135.6		
AREA*TYPE	42753	37187.5	0.8698	2.82	-18593.8	1083.58	0.00000
AREA*MONTH	42723	38117.7	0.8922	0.32	-19058.9	565.08	0.00000
MONTH*TYPE	42745	38181.7	0.8932	0.21	-19090.8	89.42	0.00000

The explanatory factors in the base model are: YEAR AREA TYPE MONTH AREA*TYPE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	42753	37187.5	0.8698		-18593.8		
AREA*MONTH	42720	37008.2	0.8663	0.41	-18504.1	1083.58	0.00000
MONTH*TYPE	42742	37130.0	0.8687	0.13	-18565.0	57.56	0.00000

Table 5.7B. Red snapper: deviance analysis of the lognormal sub-model of the delta-GLM applied to headboat data.

The explanatory factors in the base model are: YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	15255	20596.9	1.3502		-23969.1		
MONTH	15244	19252.1	1.2629	6.46	-23453.0	1032.09	0.00000
AREA	15252	19607.9	1.2856	4.78	-23593.0	752.20	0.00000
TYPE	15254	20546.3	1.3469	0.24	-23950.3	37.63	0.00000

The explanatory factors in the base model are: YEAR MONTH

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	15244	19252.1	1.2629		-23453.0		
AREA	15241	18506.8	1.2143	3.85	-23151.2	603.57	0.00000
TYPE	15243	19209.3	1.2602	0.22	-23436.0	34.06	0.00000

The explanatory factors in the base model are: YEAR MONTH AREA

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	15241	18506.8	1.2143		-23151.2		
TYPE	15240	18491.6	1.2134	0.08	-23145.0	12.56	0.00039

The explanatory factors in the base model are: YEAR MONTH AREA

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	15241	18506.8	1.2143		-23151.2		
AREA*TYPE	15237	18316.8	1.2021	1.00	-23072.4	157.69	0.00000
AREA*MONTH	15210	18374.4	1.2080	0.51	-23096.4	109.76	0.00000
MONTH*TYPE	15229	18410.5	1.2089	0.44	-23111.4	79.70	0.00000

The explanatory factors in the base model are: YEAR MONTH AREA AREA*TYPE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	15237	18316.8	1.2021		-23072.4		
AREA*MONTH	15206	18187.8	1.1961	0.50	-23018.3	108.11	0.00000
MONTH*TYPE	15226	18257.8	1.1991	0.25	-23047.7	49.34	0.00000

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

	Area				
Year	NC	NF	SC	SF	Total
1973	158	0	138	0	296
1974	163	0	202	0	365
1975	107	0	312	0	419
1976	101	593	284	0	978
1977	72	820	299	0	1191
1978	147	1267	316	15	1745
1979	121	1119	137	34	1411
1980	63	1248	192	59	1562
1981	111	1030	123	134	1398
1982	141	893	179	63	1276
1983	113	1183	239	92	1627
1984	72	1093	244	69	1478
1985	116	1306	322	140	1884
1986	103	1235	193	68	1599
1987	99	1324	261	61	1745
1988	145	1086	367	61	1659
1989	60	1059	223	64	1406
1990	33	987	272	33	1325
1991	83	754	211	20	1068
1992	127	536	211	60	934
1993	169	611	447	72	1299
1994	120	923	285	91	1419
1995	108	1117	206	81	1512
1996	81	896	153	25	1155
1997	31	518	80	19	648
1998	55	1022	164	19	1260
1999	105	1017	256	16	1394
2000	114	1086	211	29	1440
2001	181	1090	312	25	1608
2002	153	1041	327	11	1532
2003	83	937	209	7	1236
2004	65	1252	247	14	1578
2005	23	1200	147	27	1397
2006	19	1033	110	24	1186
Total	3442	31276	7879	1433	44030

Table 5.9. CPUE of red snapper off the southeastern U.S. based on headboat data. Columns are year, nominal CPUE (number/hook-hr), nominal CPUE relative to its mean, standardized CPUE, lower (LCI) and upper (UCI) 95% confidence intervals of the standardized CPUE, annual sample size (N = number of positive and zero trips), and coefficient of variation (CV) of the standardized CPUE.

YEAR	Nominal CPUE	Relative nominal	Standardized CPUE	LCI	UCI	N	CV
1976	0.0444	3.328	3.127	0.930	10.511	789	0.666
1977	0.0293	2.193	2.078	0.434	9.963	812	0.921
1978	0.0299	2.242	2.120	0.556	8.081	1419	0.751
1979	0.0276	2.067	2.138	0.537	8.504	1264	0.781
1980	0.0152	1.138	1.129	0.193	6.589	1333	1.085
1981	0.0258	1.934	2.777	0.782	9.866	998	0.703
1982	0.0110	0.823	1.044	0.164	6.629	1282	1.162
1983	0.0185	1.383	1.705	0.401	7.243	1450	0.829
1984	0.0214	1.606	1.554	0.332	7.276	1340	0.902
1985	0.0222	1.663	2.285	0.672	7.770	1643	0.674
1986	0.0072	0.539	0.511	0.059	4.442	2039	1.489
1987	0.0079	0.591	0.612	0.079	4.728	2048	1.357
1988	0.0091	0.678	0.563	0.069	4.580	1942	1.413
1989	0.0137	1.026	0.952	0.148	6.111	1301	1.171
1990	0.0112	0.838	0.987	0.161	6.031	1357	1.126
1991	0.0074	0.553	0.619	0.071	5.374	1384	1.489
1992	0.0025	0.186	0.081	0.003	2.546	2051	4.285
1993	0.0039	0.295	0.213	0.013	3.554	1862	2.498
1994	0.0047	0.353	0.225	0.014	3.732	1513	2.488
1995	0.0053	0.400	0.302	0.022	4.205	1395	2.157
1996	0.0037	0.277	0.202	0.010	4.075	1104	2.927
1997	0.0032	0.239	0.223	0.010	5.195	820	3.302
1998	0.0040	0.298	0.179	0.009	3.503	1465	2.847
1999	0.0060	0.446	0.293	0.021	4.018	1448	2.131
2000	0.0072	0.537	0.389	0.033	4.642	1270	1.911
2001	0.0135	1.010	0.822	0.125	5.400	1460	1.194
2002	0.0167	1.250	1.005	0.173	5.839	1350	1.081
2003	0.0098	0.734	0.518	0.050	5.365	973	1.708
2004	0.0131	0.981	0.969	0.161	5.824	1368	1.112
2005	0.0115	0.859	0.903	0.136	5.998	1190	1.204
2006	0.0071	0.531	0.473	0.043	5.224	1132	1.797

Table 5.10. Number of intercepts from MRFSS that caught red snapper or reported red snapper as a targeted species. The index of abundance was computed for 1983–2006, because of total sample size and distribution across states.

Year	Total	NC	SC	GA	FL
1982	48	0	14	0	34
1983	168	0	29	8	131
1984	398	15	81	7	295
1985	215	18	29	17	151
1986	154	4	4	11	135
1987	196	112	5	17	62
1988	279	134	7	8	130
1989	284	127	49	10	98
1990	114	82	5	0	27
1991	137	62	15	12	48
1992	278	63	0	93	122
1993	180	34	2	93	51
1994	257	76	6	95	80
1995	171	54	0	70	47
1996	98	15	6	53	24
1997	76	0	44	15	17
1998	131	7	23	46	55
1999	386	27	80	47	232
2000	508	16	110	40	342
2001	555	44	22	30	459
2002	567	61	19	23	464
2003	535	47	24	64	400
2004	554	9	38	181	326
2005	400	14	33	115	238
2006	493	25	32	164	272

Table 5.11. CPUE of red snapper off the southeastern U.S. based on MRFSS data. Relative CPUE is CPUE standardized to its mean.

YEAR	CPUE (number/ angler-trip)	Relative CPUE	PSE
1983	2.770	1.716	17.6
1984	2.533	1.569	15.3
1985	2.199	1.362	17.4
1986	1.154	0.715	32.2
1987	1.047	0.648	37.0
1988	1.137	0.704	24.9
1989	0.943	0.584	17.1
1990	0.323	0.200	29.9
1991	1.093	0.677	27.3
1992	1.723	1.067	15.2
1993	1.854	1.148	23.3
1994	1.201	0.744	20.9
1995	1.226	0.759	15.8
1996	1.073	0.665	28.0
1997	1.737	1.076	34.7
1998	1.295	0.802	21.5
1999	2.387	1.479	12.9
2000	2.163	1.340	12.2
2001	1.800	1.115	11.4
2002	1.604	0.994	13.7
2003	1.863	1.154	13.6
2004	2.088	1.294	11.7
2005	1.949	1.207	11.1
2006	1.585	0.982	15.5

Table 5.12. Pearson correlation between indices. Values in parentheses are *p*-values from a *t*-test of $H_0: \rho = 0$.

	Headboat	MRFSS	Comm. logbook
Headboat	1.0	0.39 (0.06)	0.88 (<0.001)
MRFSS	—	1.0	0.38 (0.18)
Comm. logbook	—	—	1.0

5.9 FIGURES

Figure 5.1. 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).

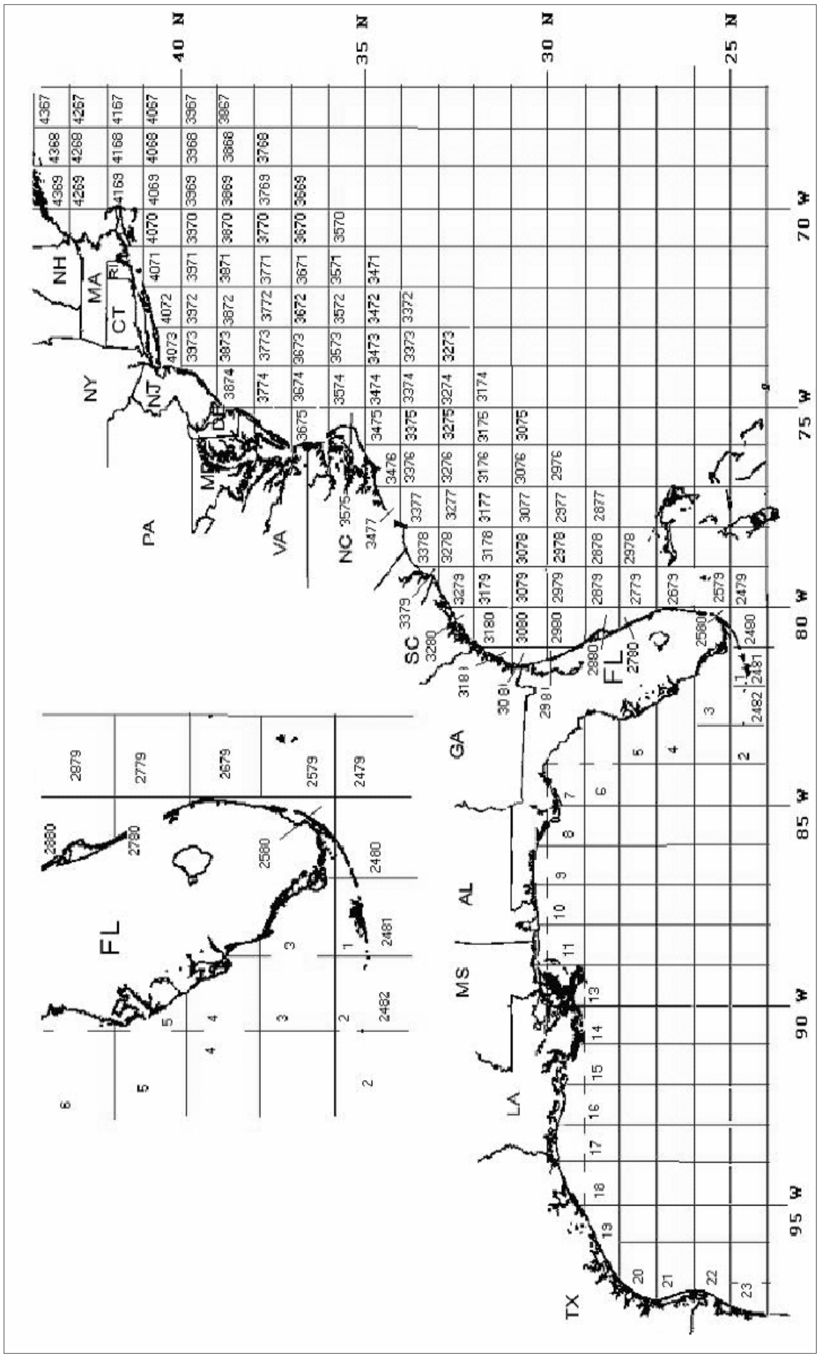


Figure 5.2A. Estimates of species-specific regression coefficients from Stephens and MacCall method applied to commercial logbook data from north of Cape Canaveral, as used to estimate each trip's probability of catching the focal species.

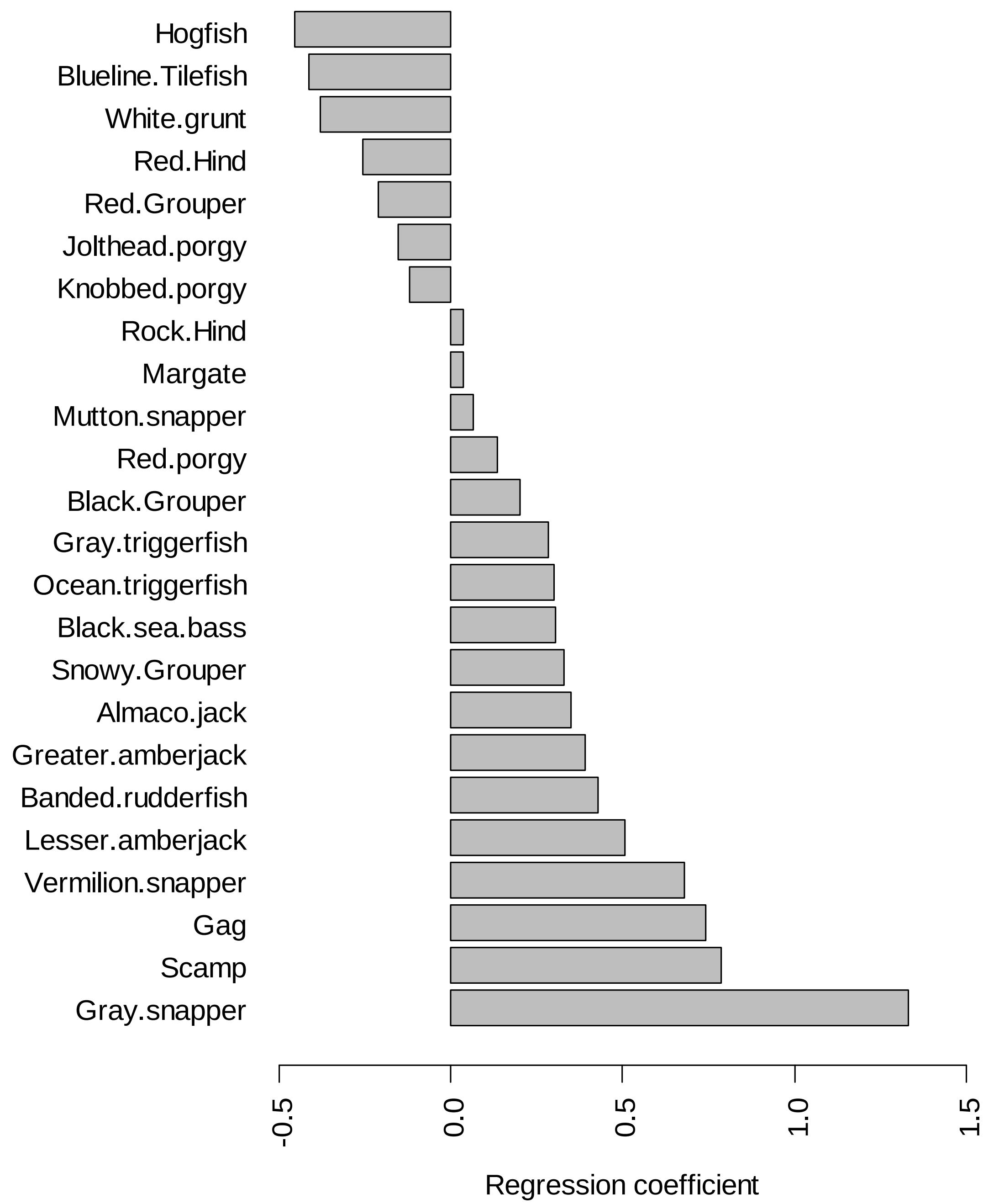


Figure 5.2B. Estimates of species-specific regression coefficients from Stephens and MacCall method applied to commercial logbook data from south of Cape Canaveral, as used to estimate each trip's probability of catching the focal species.

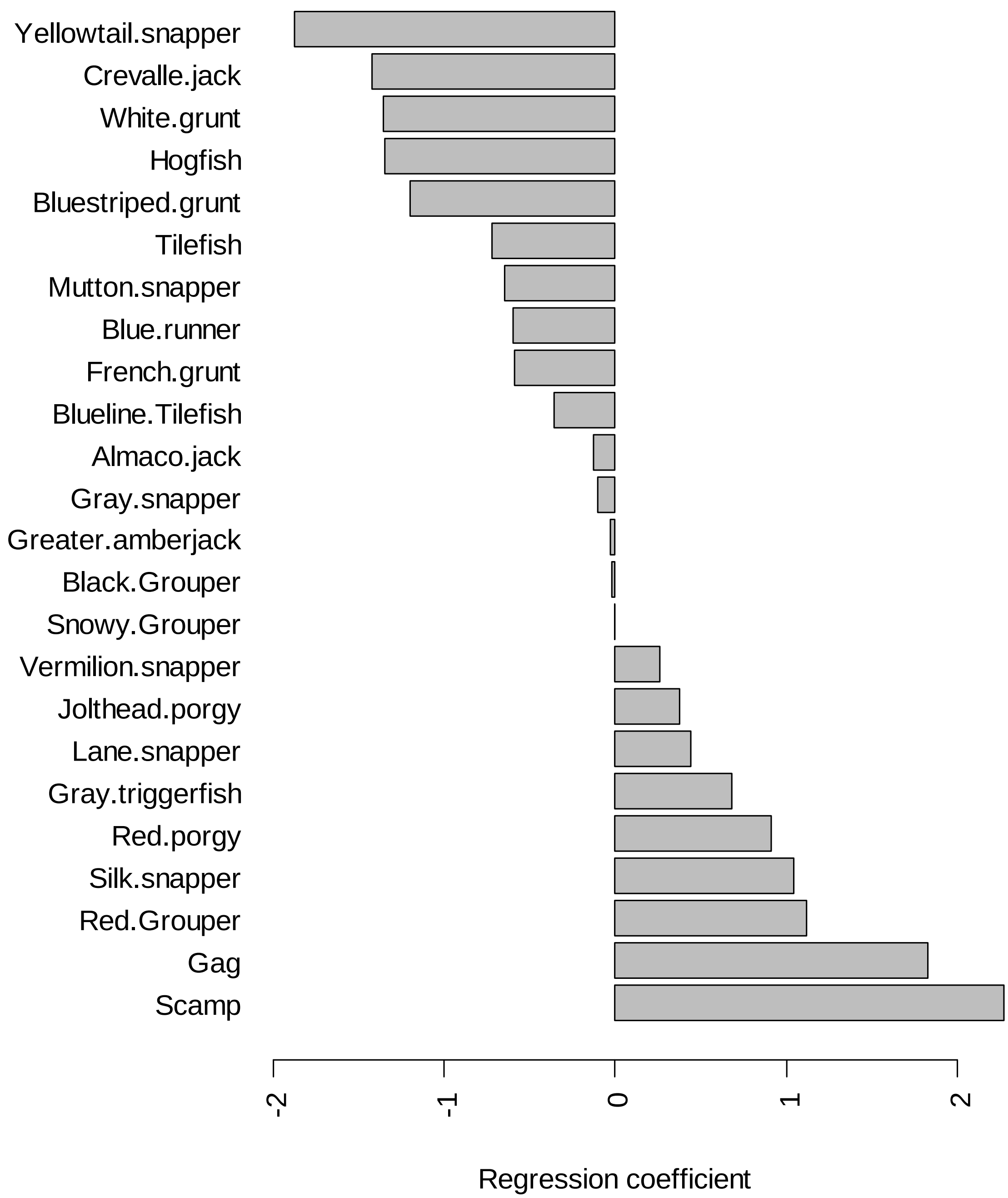


Figure 5.3A. Absolute difference between observed and predicted number of positive trips from Stephens and MacCall method applied to commercial logbook data from north of Cape Canaveral. Left and right panels differ only in the range of probabilities shown.

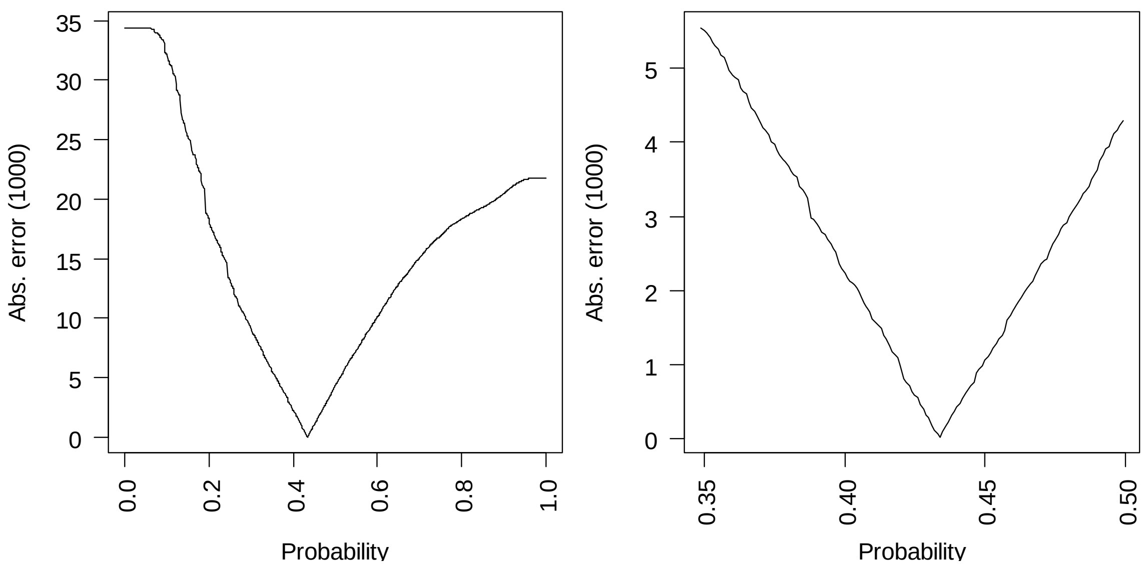


Figure 5.3B. Absolute difference between observed and predicted number of positive trips from Stephens and MacCall method applied to commercial logbook data from south of Cape Canaveral. Left and right panels differ only in the range of probabilities shown.

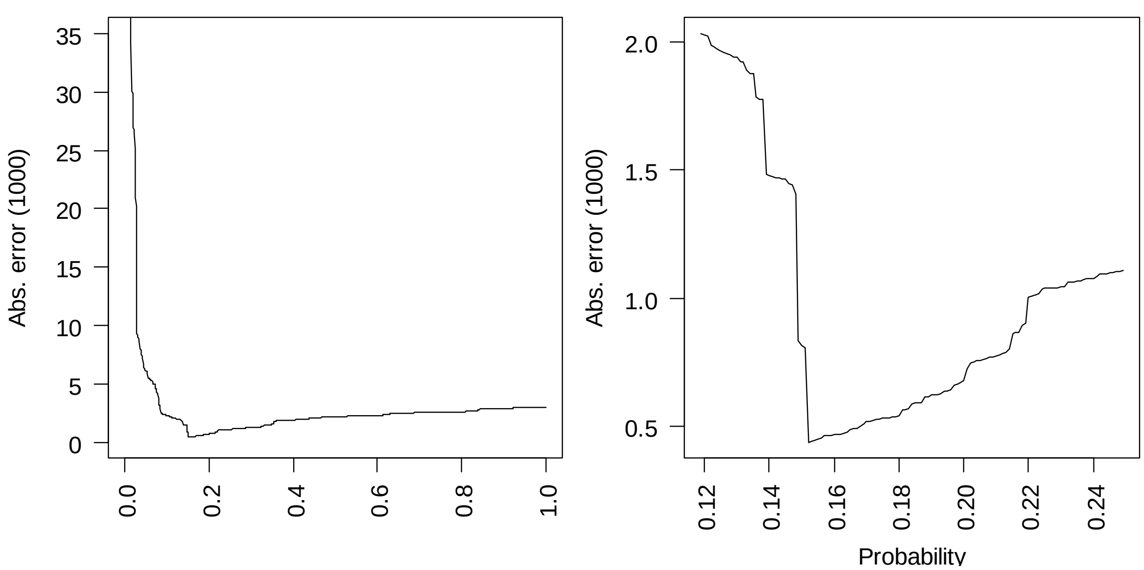


Figure 5.4. Red snapper: index of abundance from commercial logbook data.

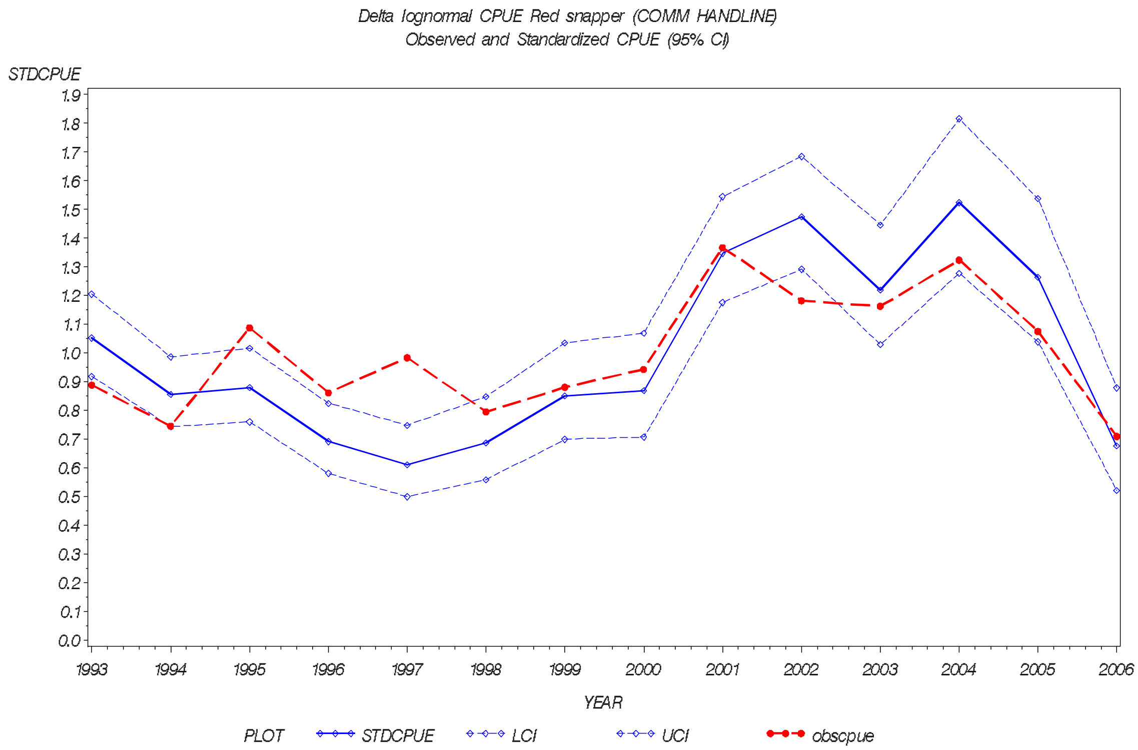


Figure 5.5. Areas from the headboat survey. Areas 11, 12, and 17 were considered southern Florida (break near Cape Canaveral).

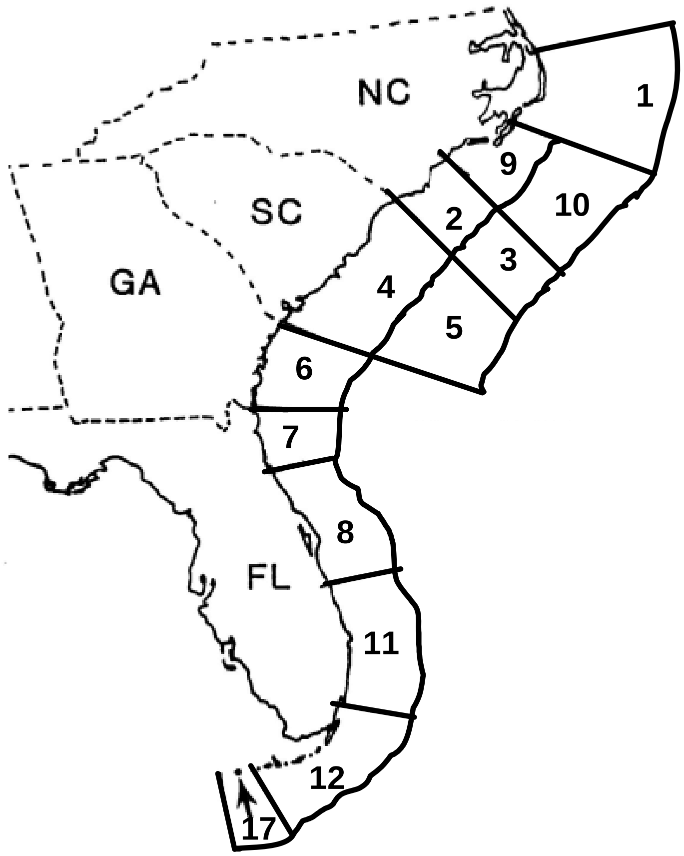


Figure 5.6A. Estimates of species-specific regression coefficients from Stephens and MacCall method applied to headboat data from areas in the northern region (excludes areas 11, 12, 17), as used to estimate each trip's probability of catching the focal species.

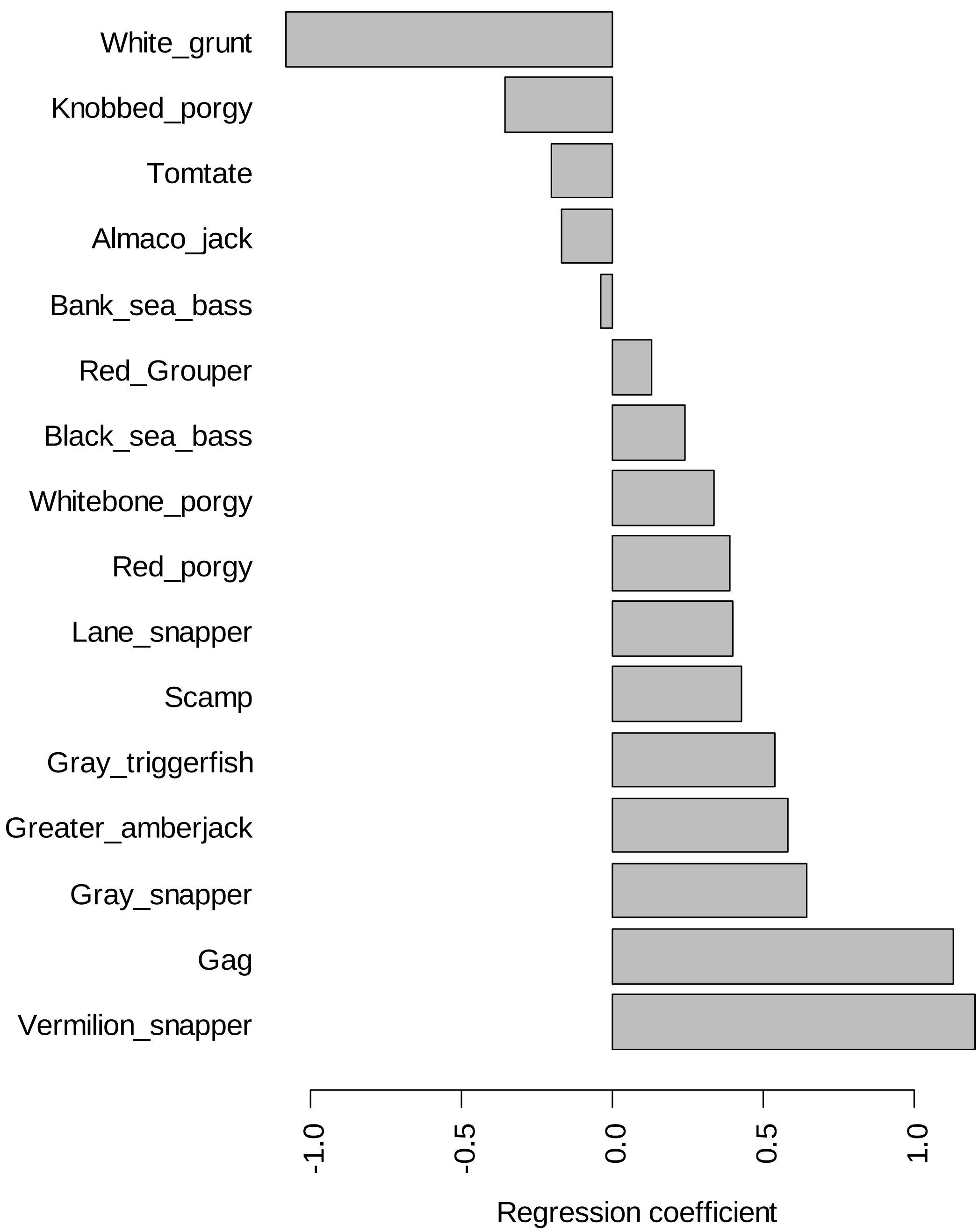


Figure 5.6B. Estimates of species-specific regression coefficients from Stephens and MacCall method applied to headboat data from areas in the southern region (areas 11, 12, 17), as used to estimate each trip's probability of catching the focal species.

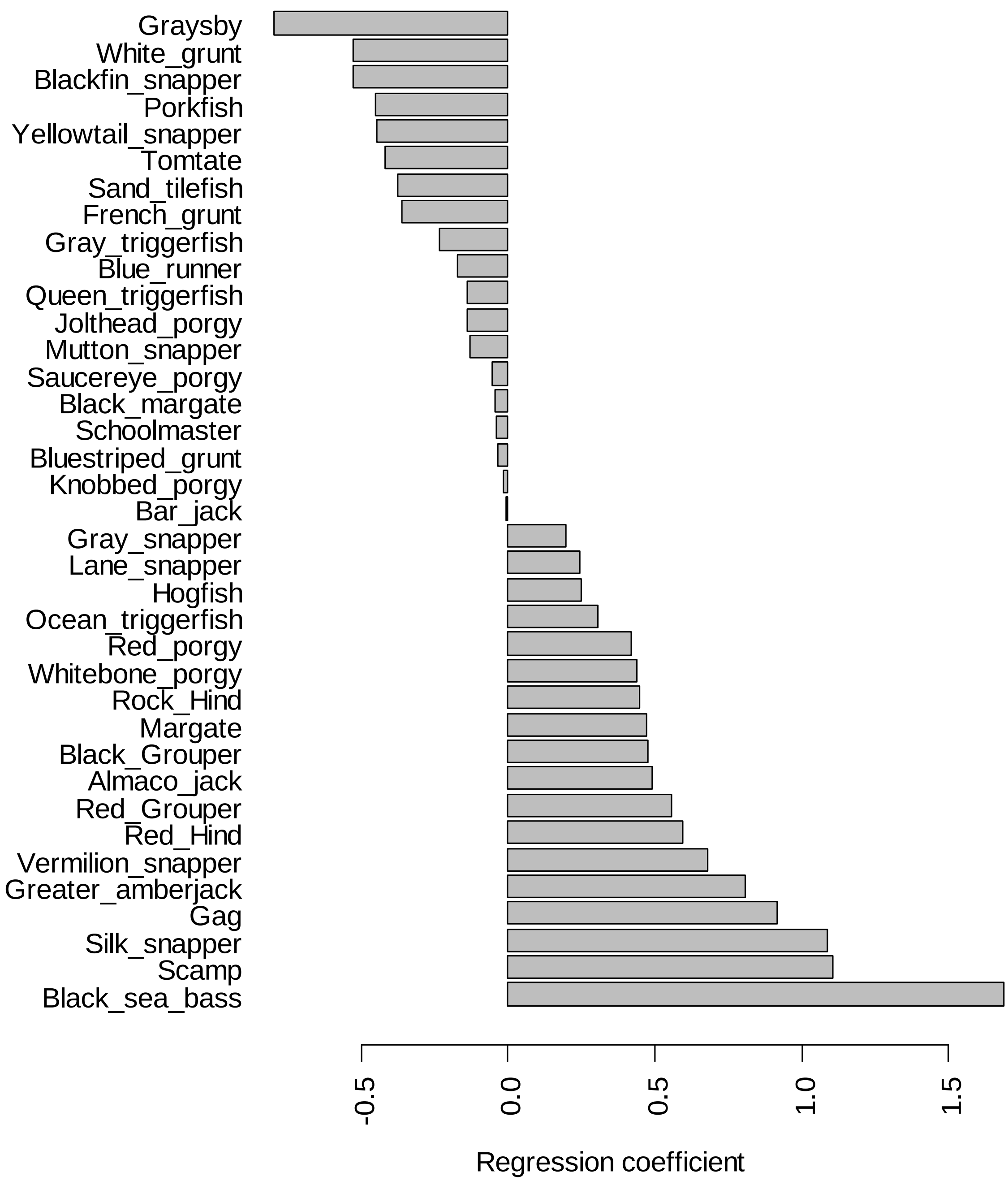


Figure 5.7A. Absolute difference between observed and predicted number of positive trips from Stephens and MacCall method applied to headboat data from the northern region (excludes areas 11, 12, 17). Left and right panels differ only in the range of probabilities shown.

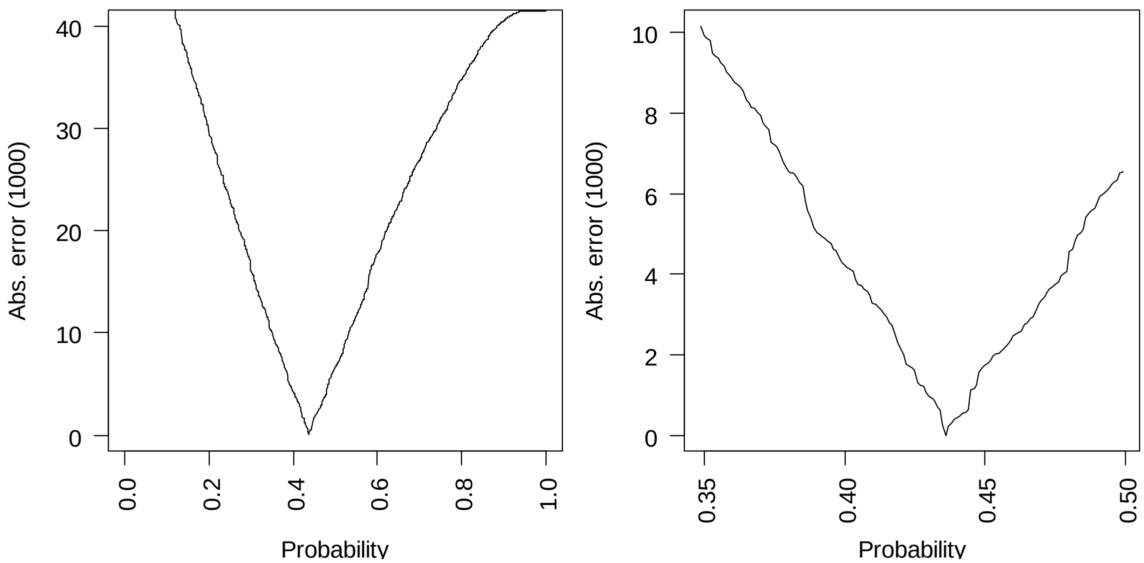


Figure 5.7B. Absolute difference between observed and predicted number of positive trips from Stephens and MacCall method applied to headboat data from the southern region (areas 11, 12, 17). Left and right panels differ only in the range of probabilities shown.

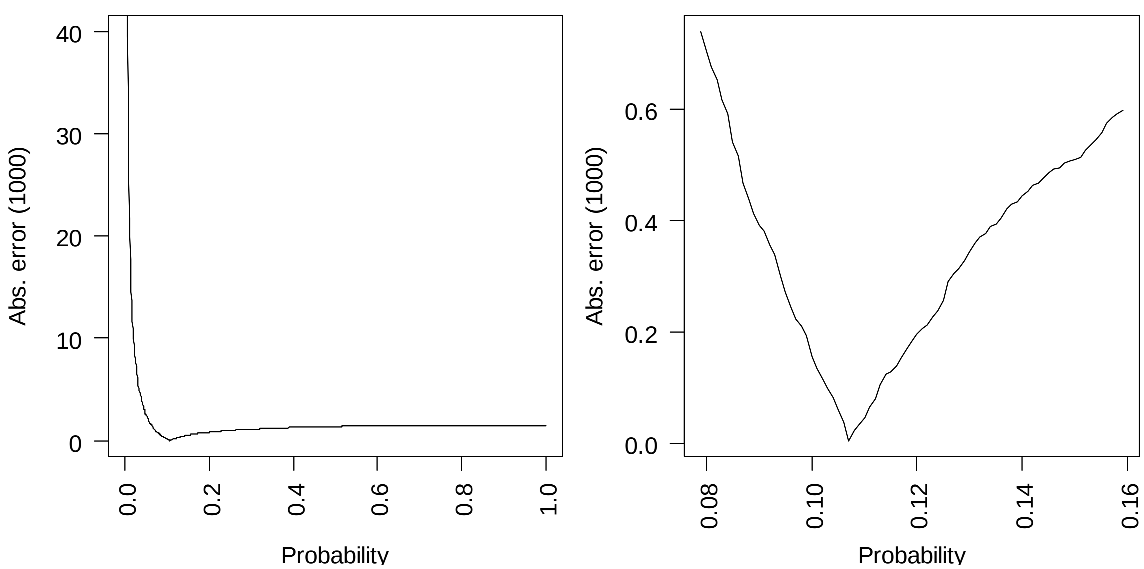


Figure 5.8. Red snapper: index of abundance from headboat data.

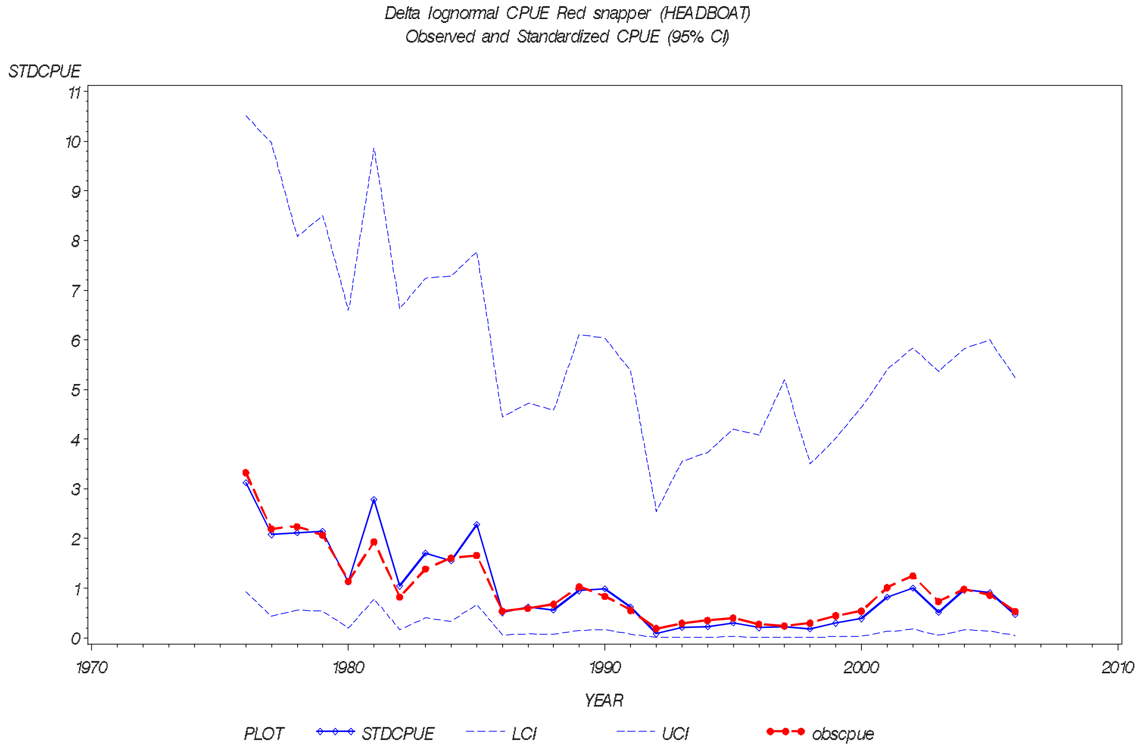


Figure 5.9. Counties sampled by the MRFSS, as used to compute the index of abundance, included those along the coast from Currituck County, NC through Miami-Dade County, FL.

Figure 5.10. Red snapper: index of abundance from MRFSS data. Lower/upper confidence intervals are minus/plus two standard errors.

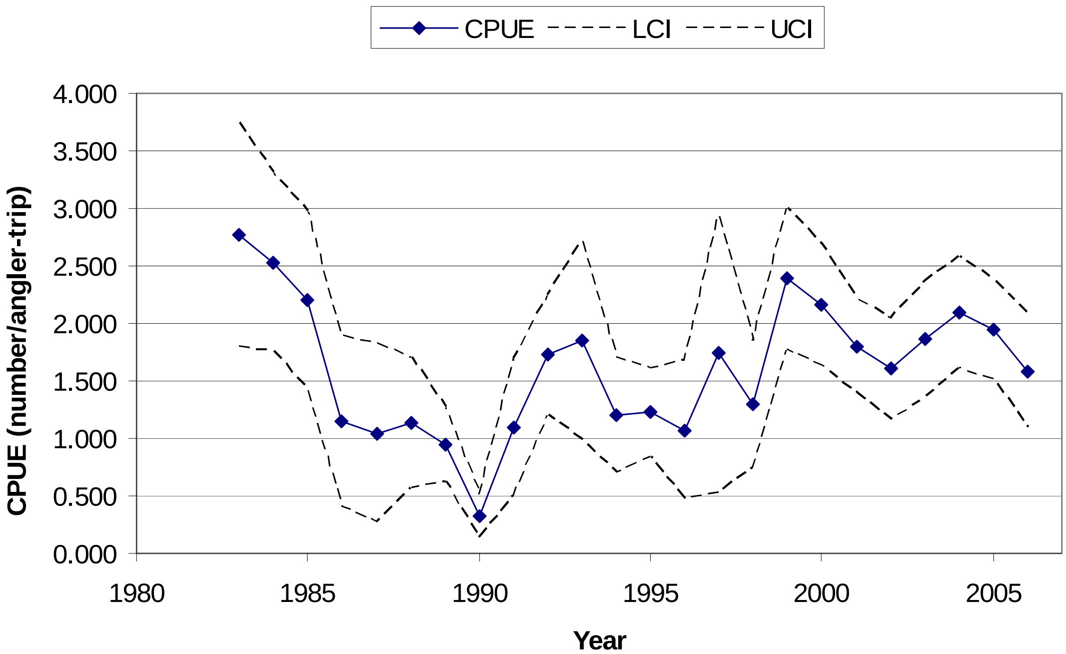
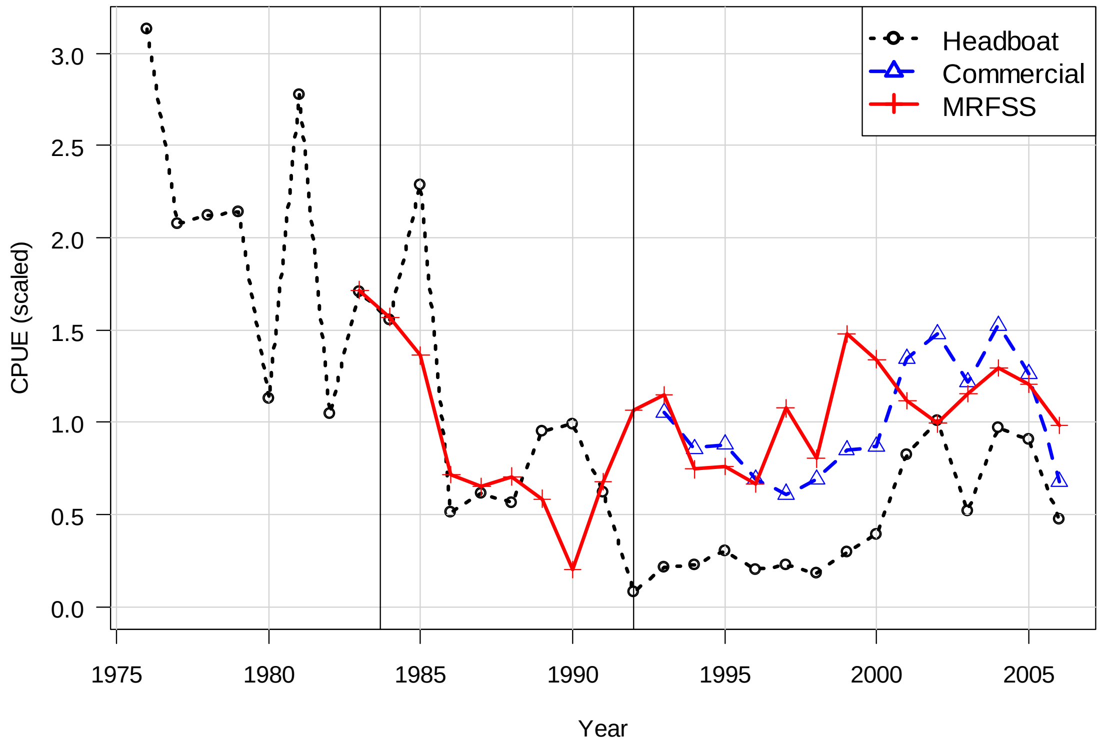


Figure 5.11. Red snapper: indices of abundance recommended for use in the assessment. Vertical lines represent years with new regulations. Each index is scaled to its mean.



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

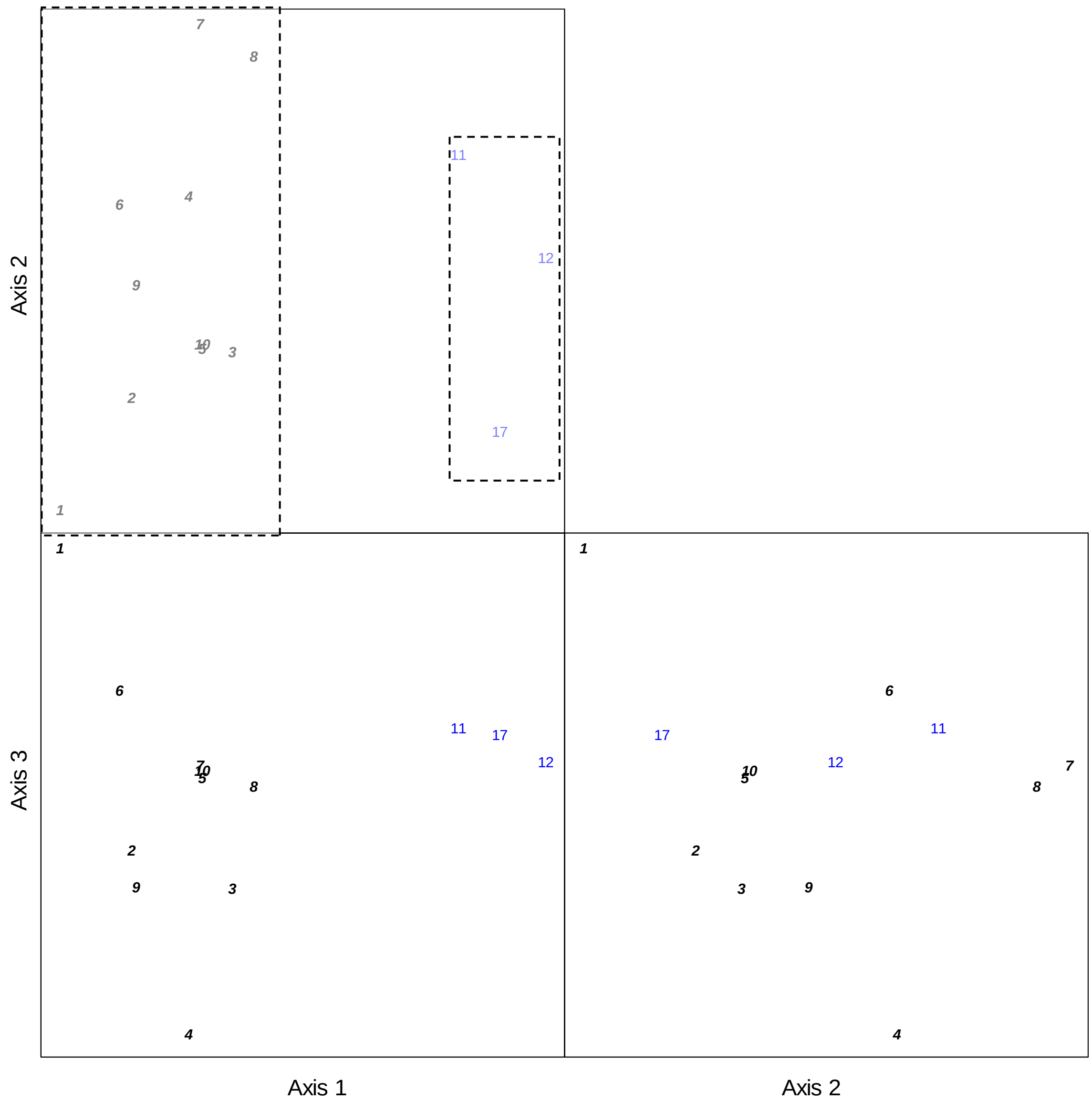
Appendix 5.2. Geographic areas with similarity in species landed.

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).

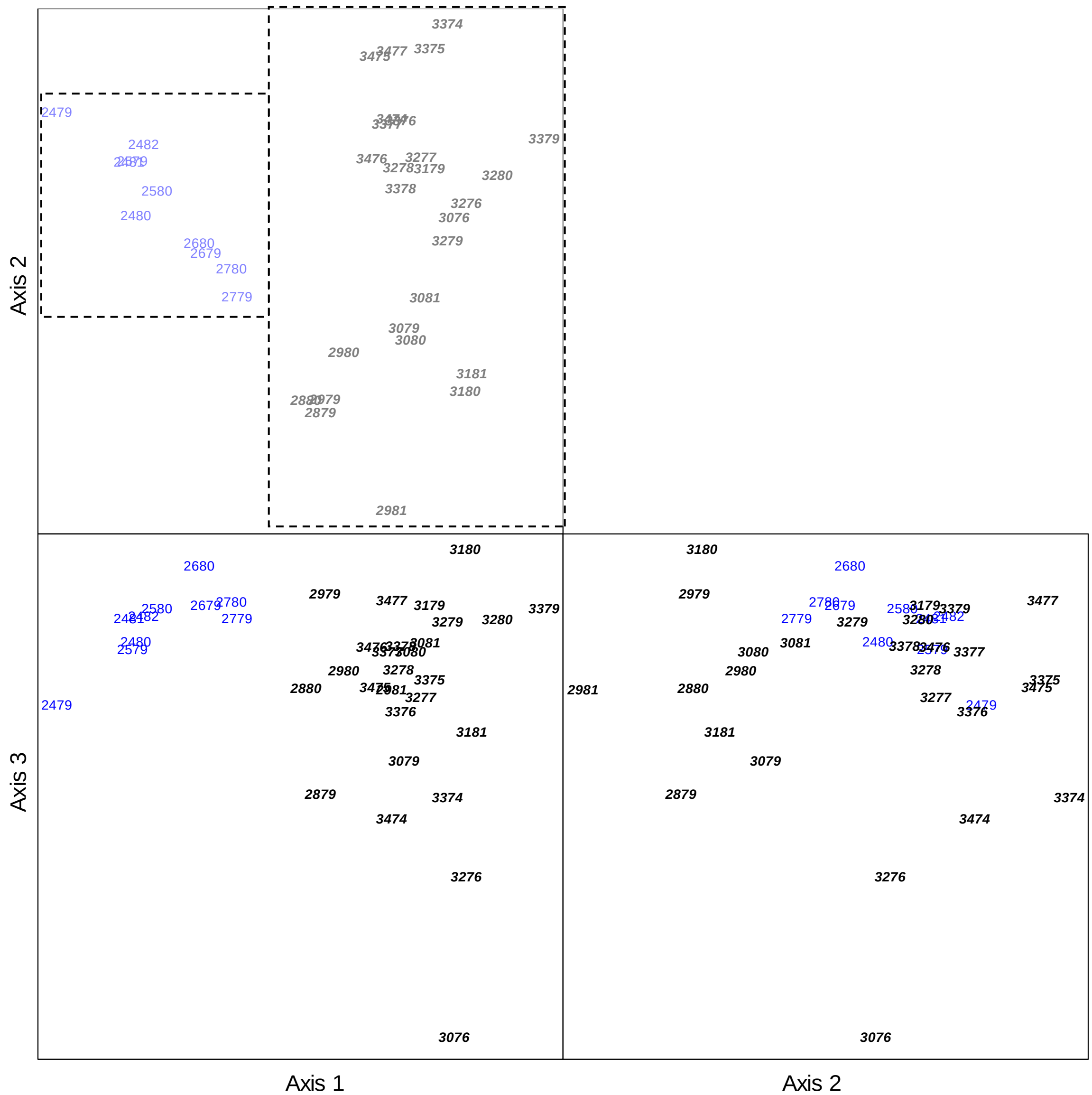
To compute dissimilarities, each data set (commercial logbook and headboat) was formatted as a matrix with rows representing geographic areas and columns representing species. Each element of the matrix quantified the relative frequency of species landed by geographic area. Thus, rows of the matrix summed 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 5.2A. 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 font.

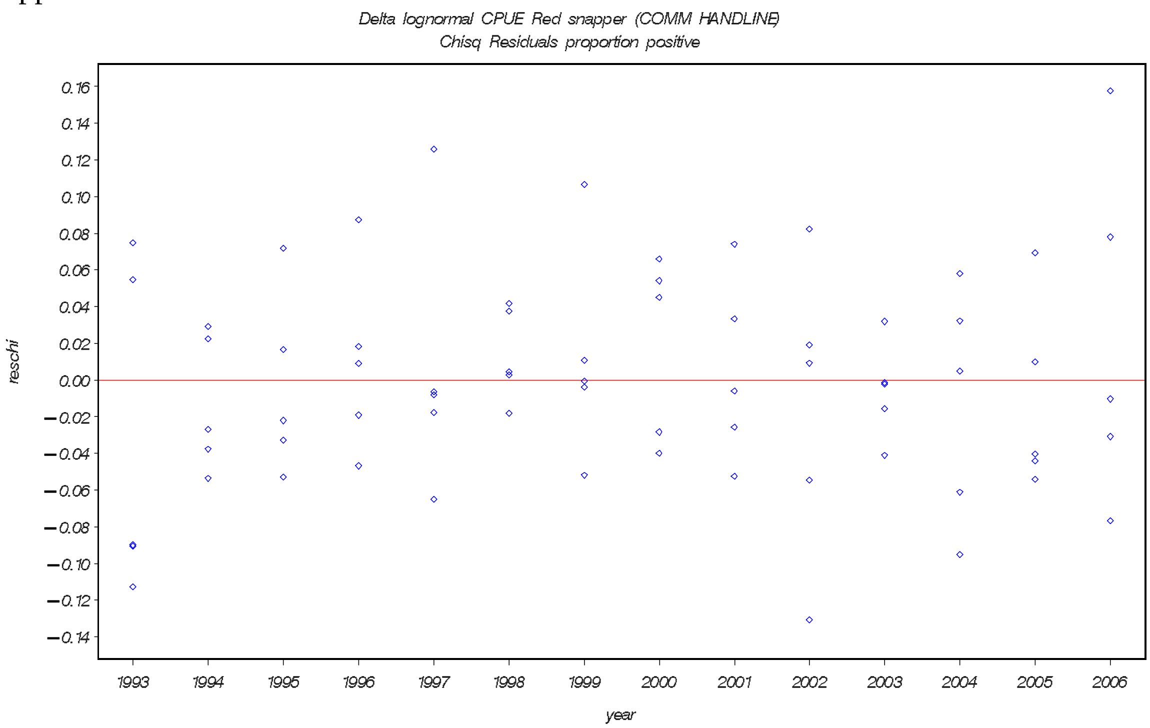


Appendix 5.2B. Nonmetric multidimensional scaling of areas from the commercial logbook data (handline). Rectangles in top left panel encapsulate areas with similar composition of landings, as identified by cluster analysis. Areas north of Cape Canaveral, FL are in bold font.

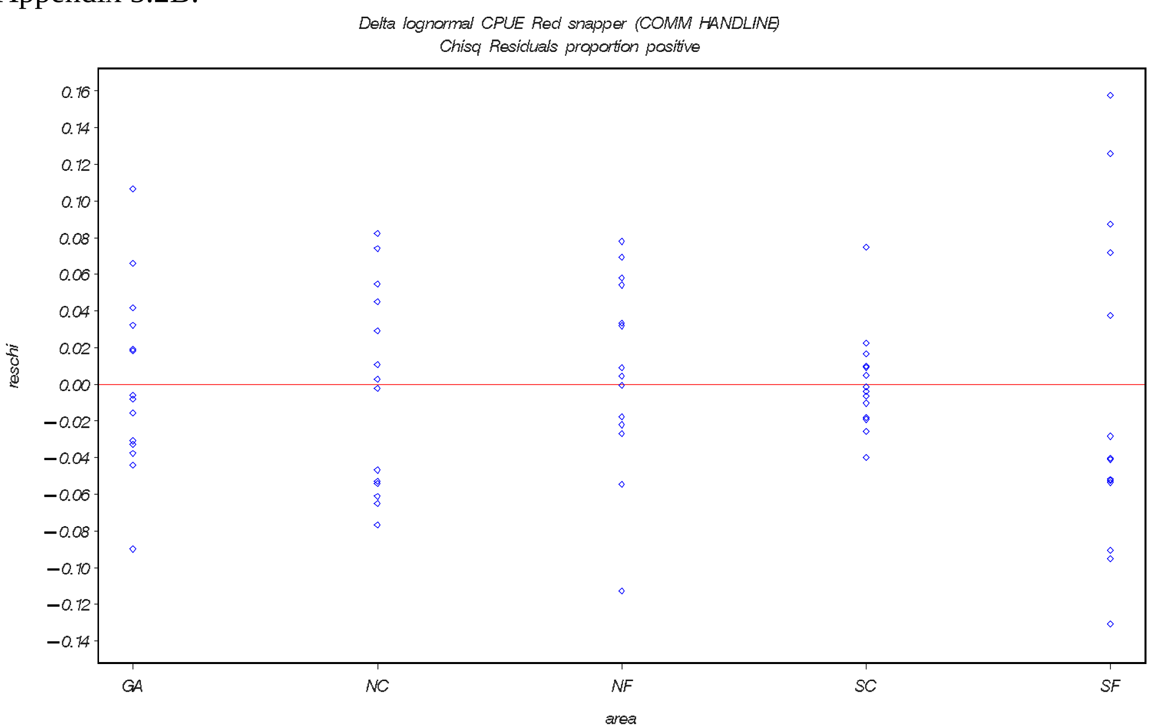


Appendix 5.2. Red snapper: diagnostics of delta-GLM fitted to commercial logbook data.

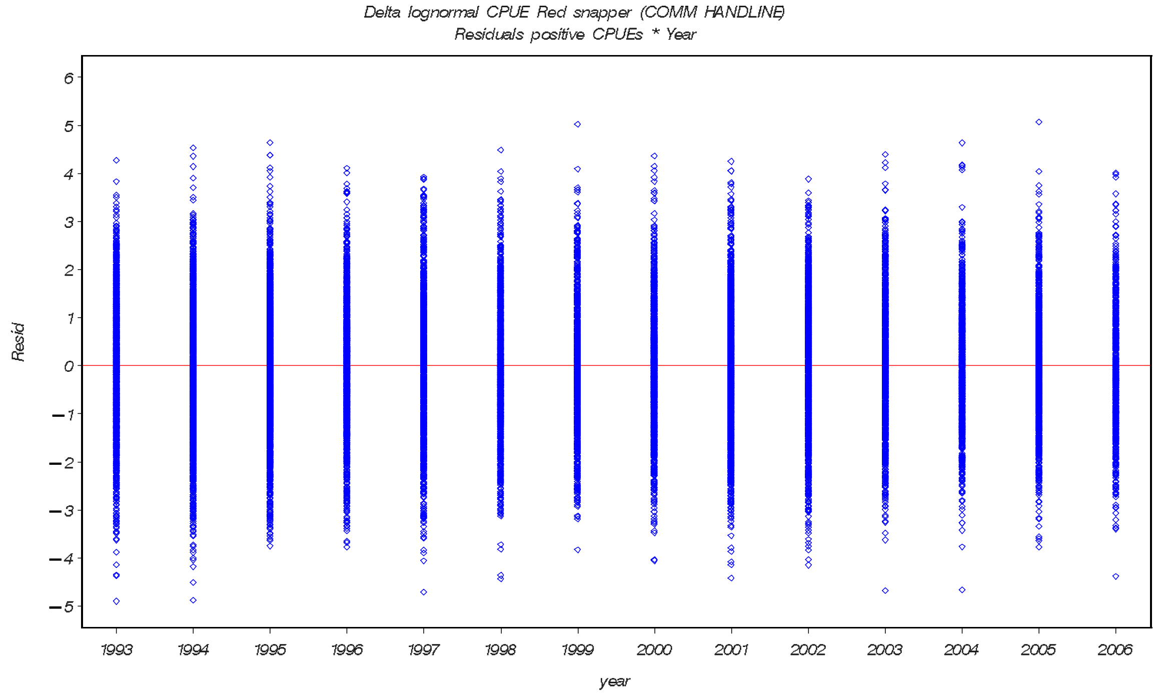
Appendix 5.2A.



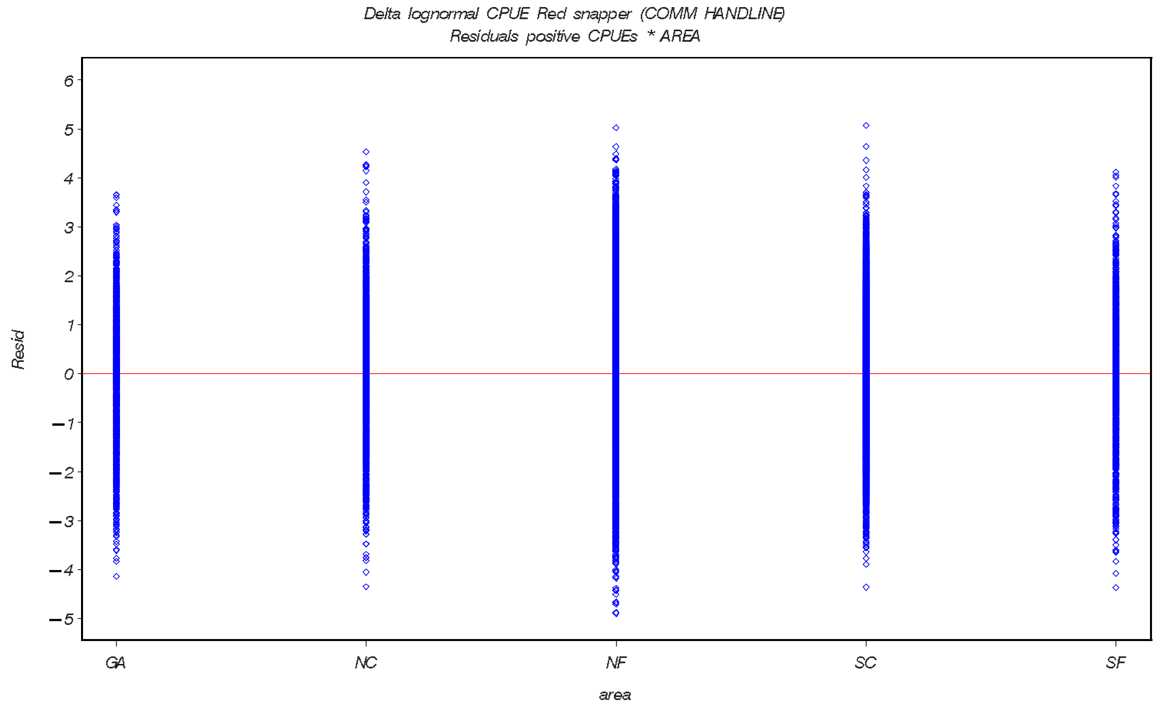
Appendix 5.2B.



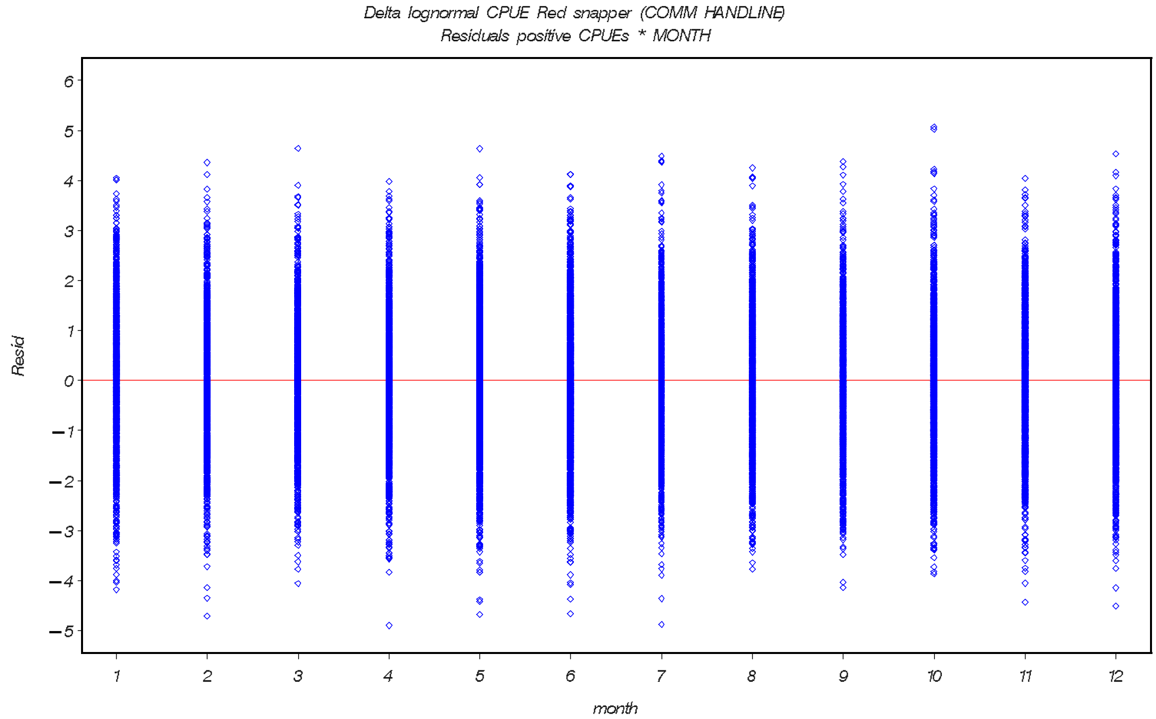
Appendix 5.2C.



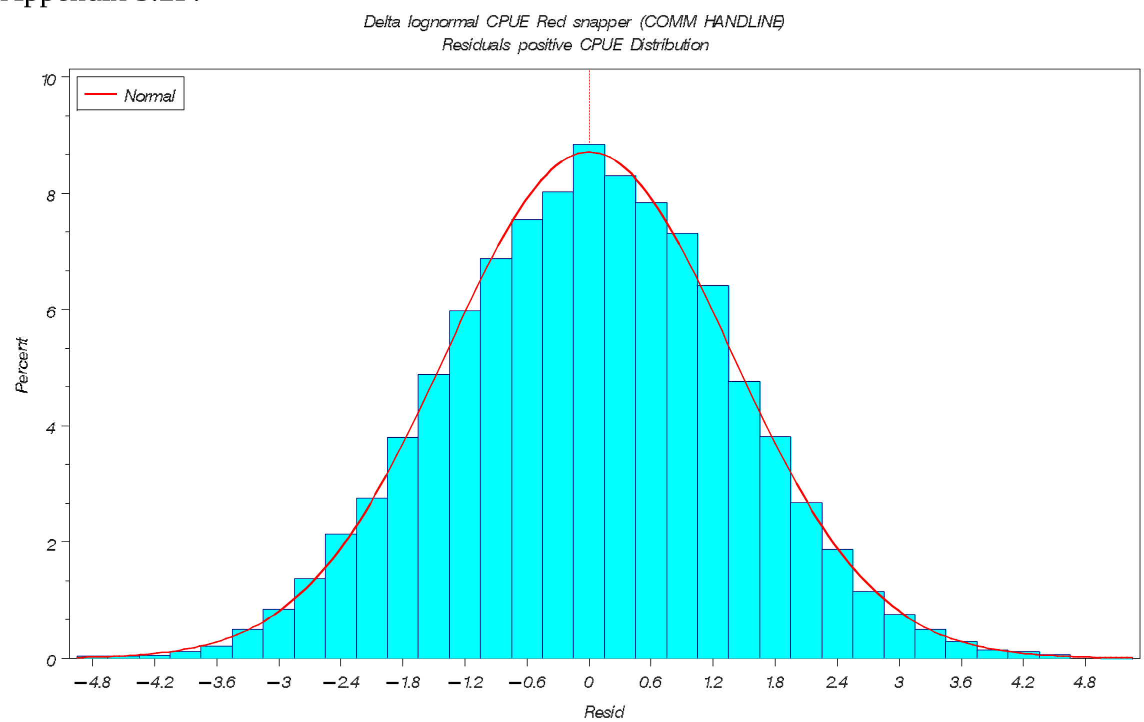
Appendix 5.2D.



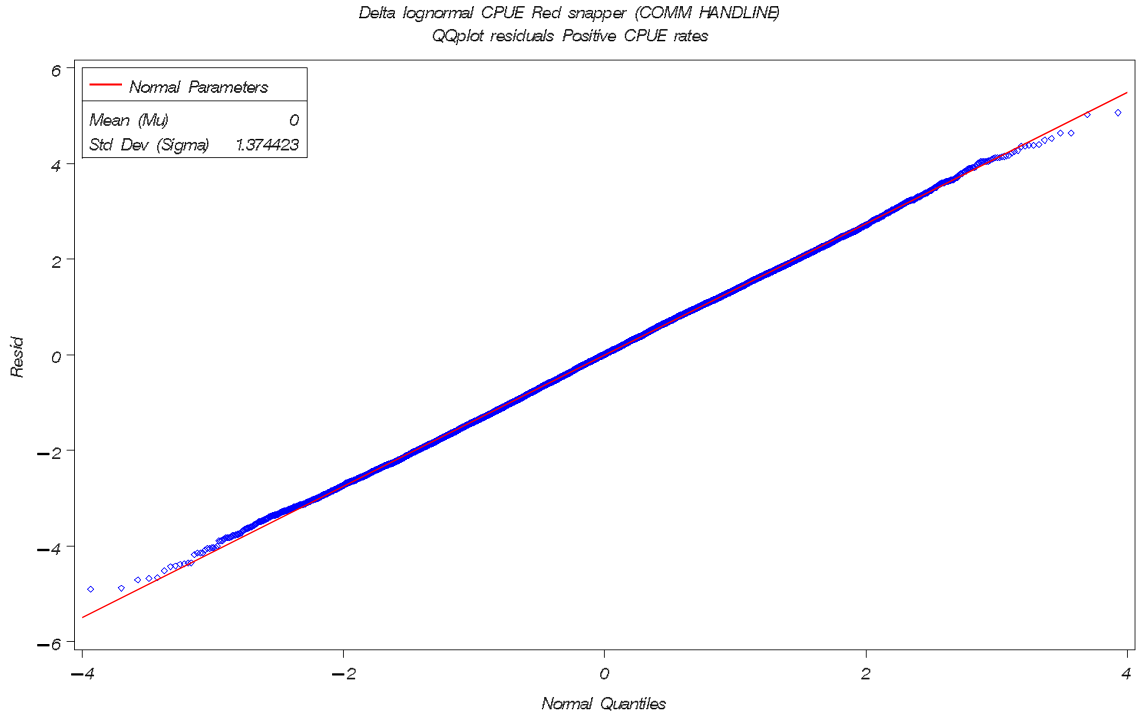
Appendix 5.2E.



Appendix 5.2F.

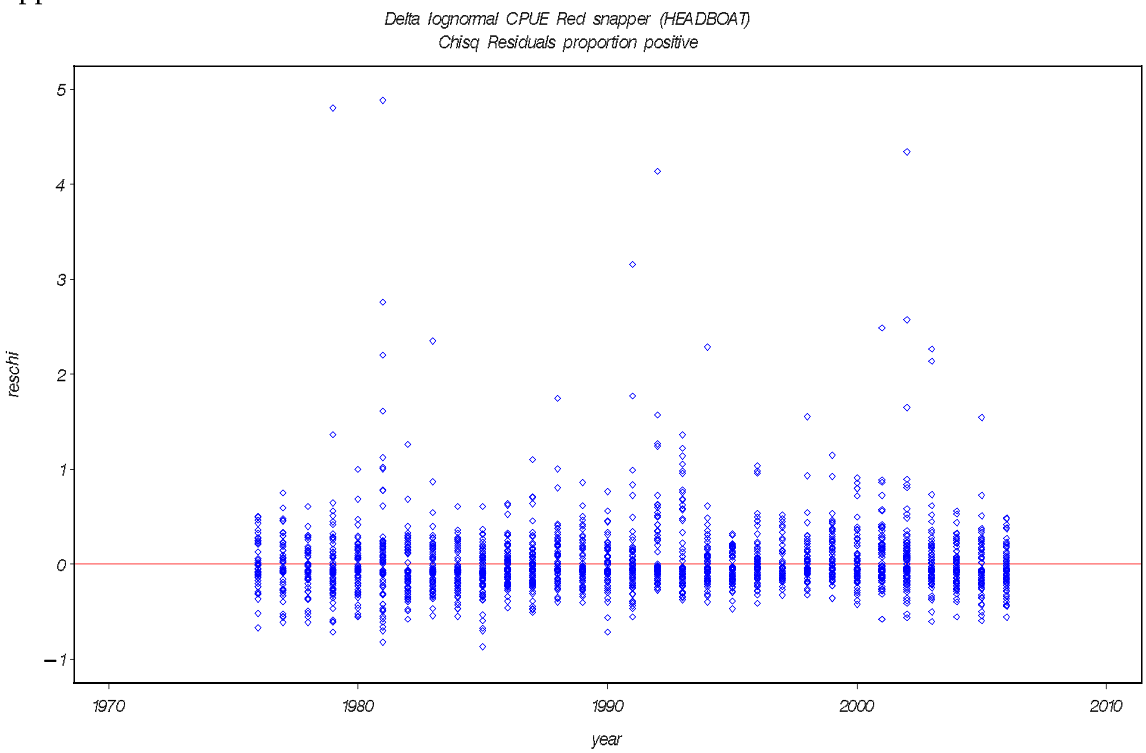


Appendix 5.2G.

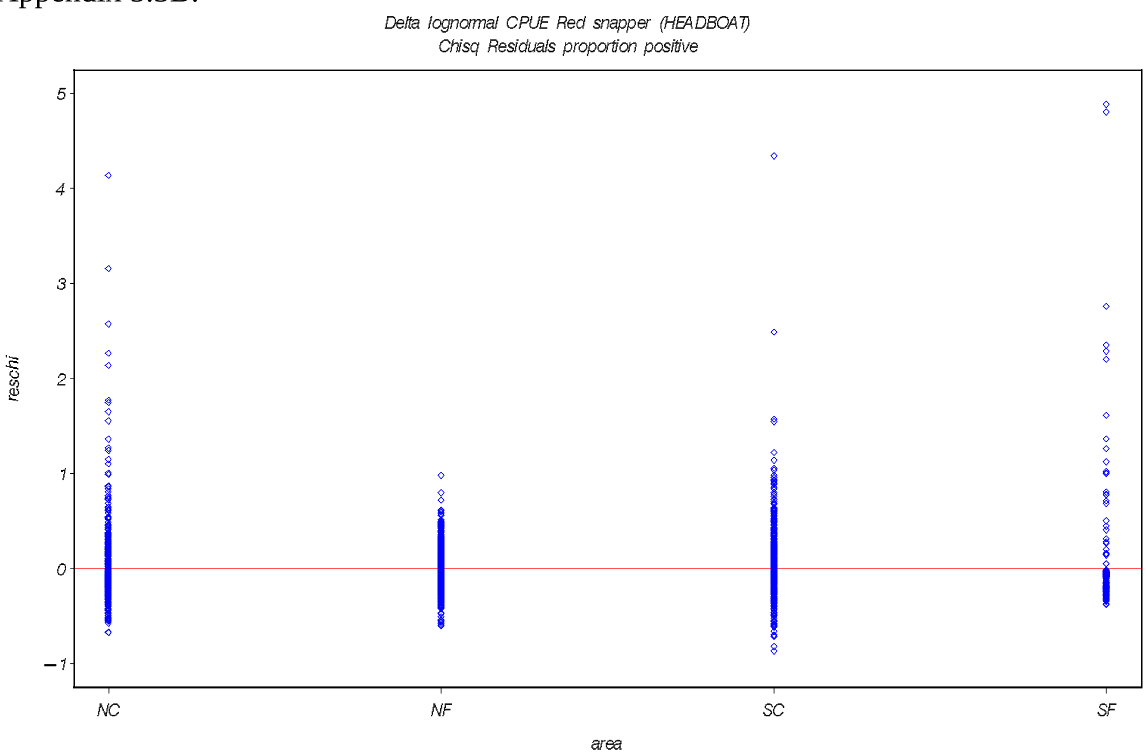


Appendix 5.3. Red snapper: diagnostics of delta-GLM fitted to headboat data

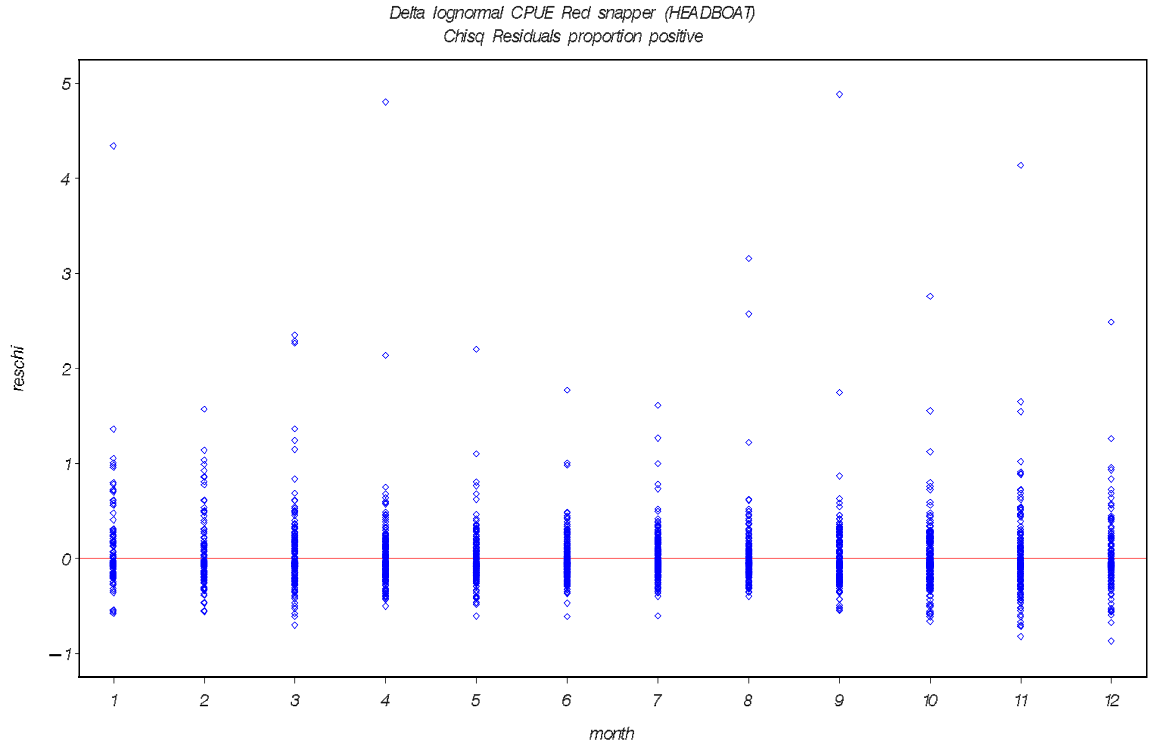
Appendix 5.3A.



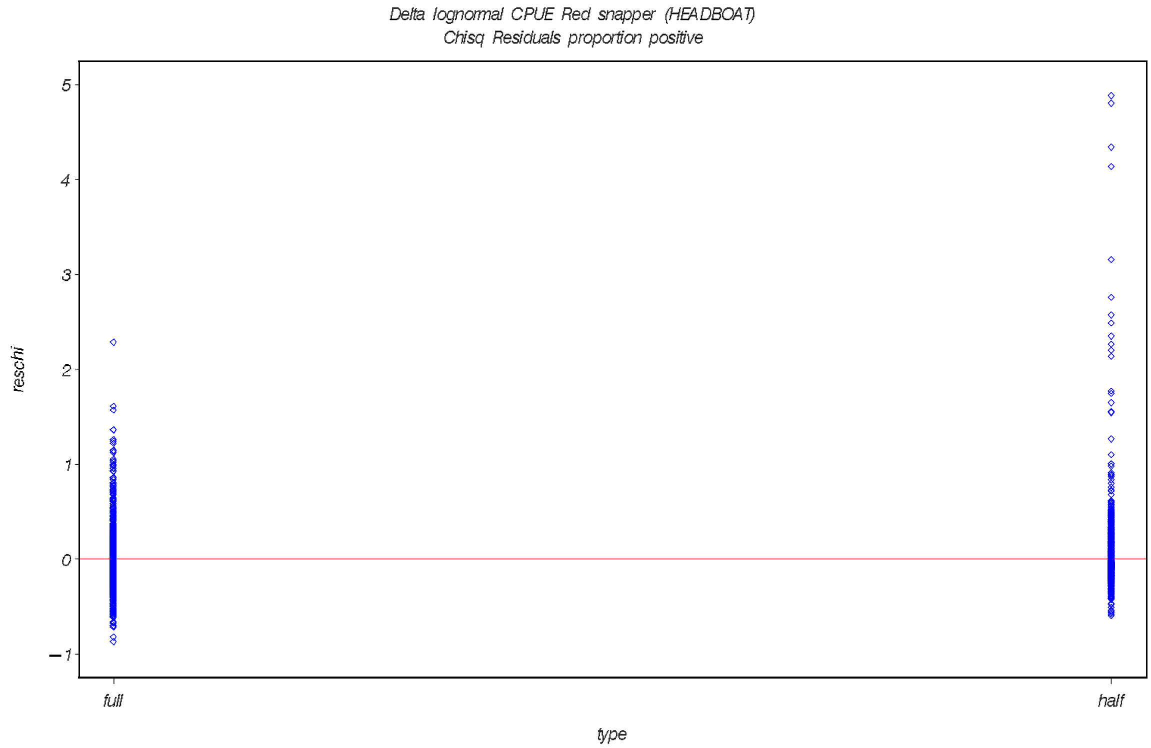
Appendix 5.3B.



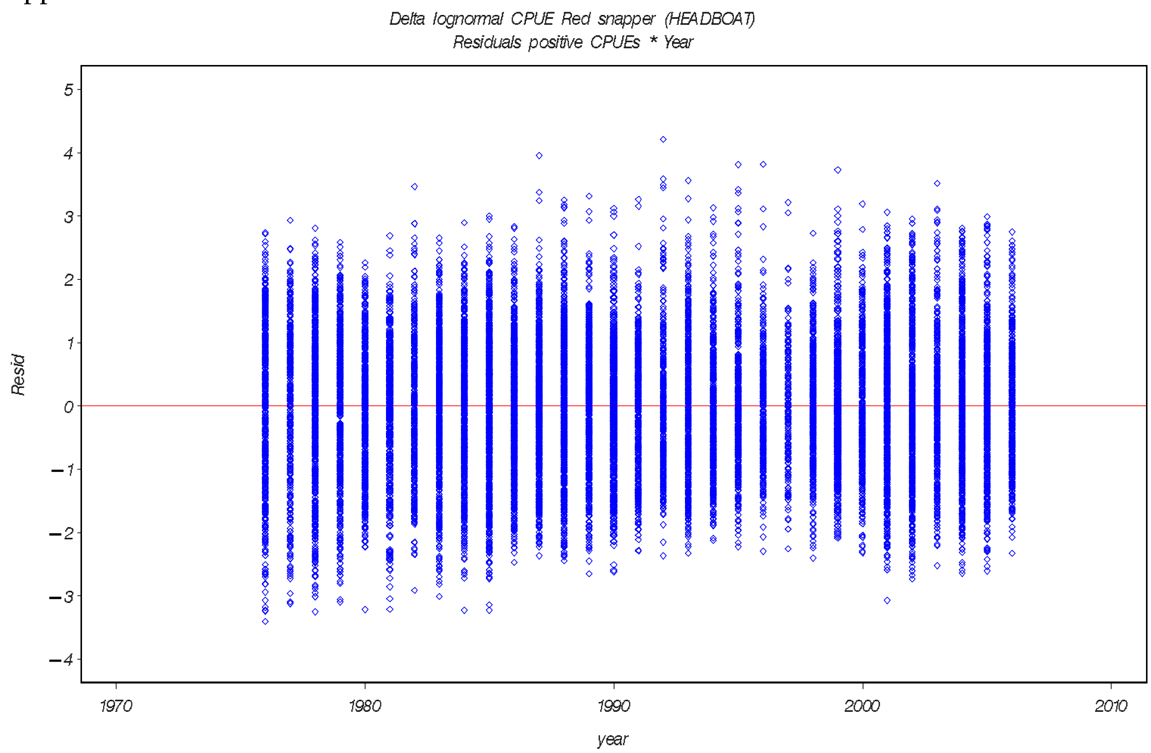
Appendix 5.3C.



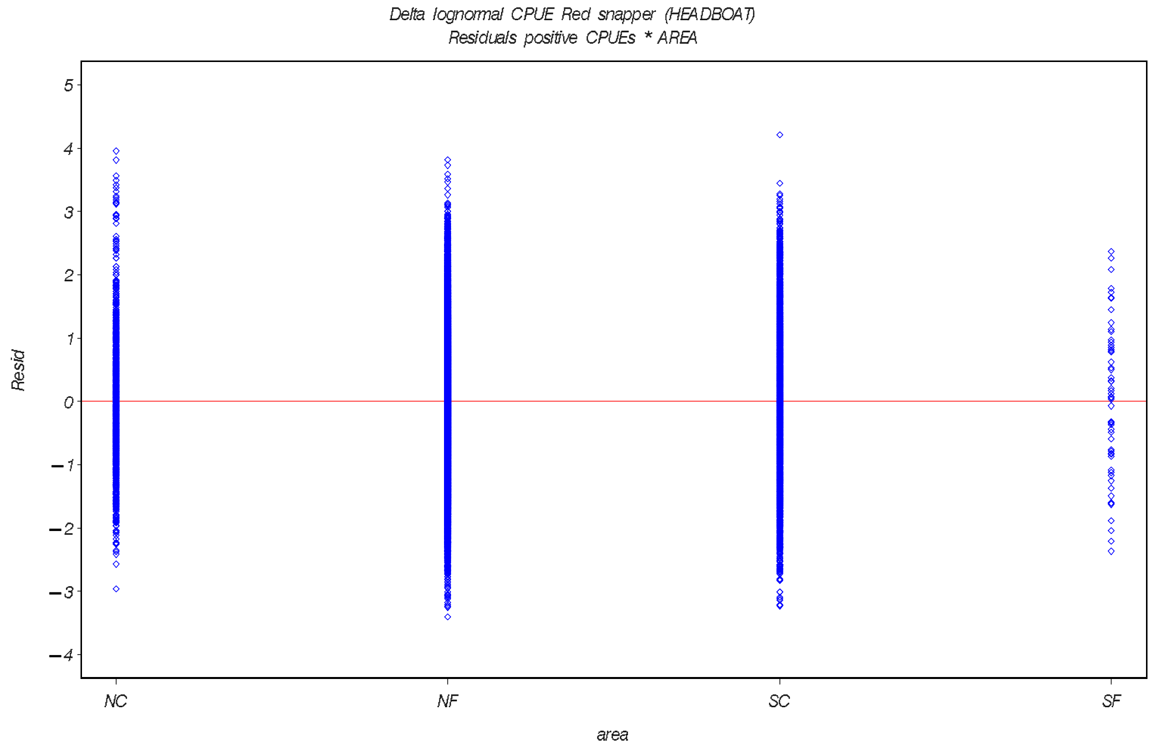
Appendix 5.3D.



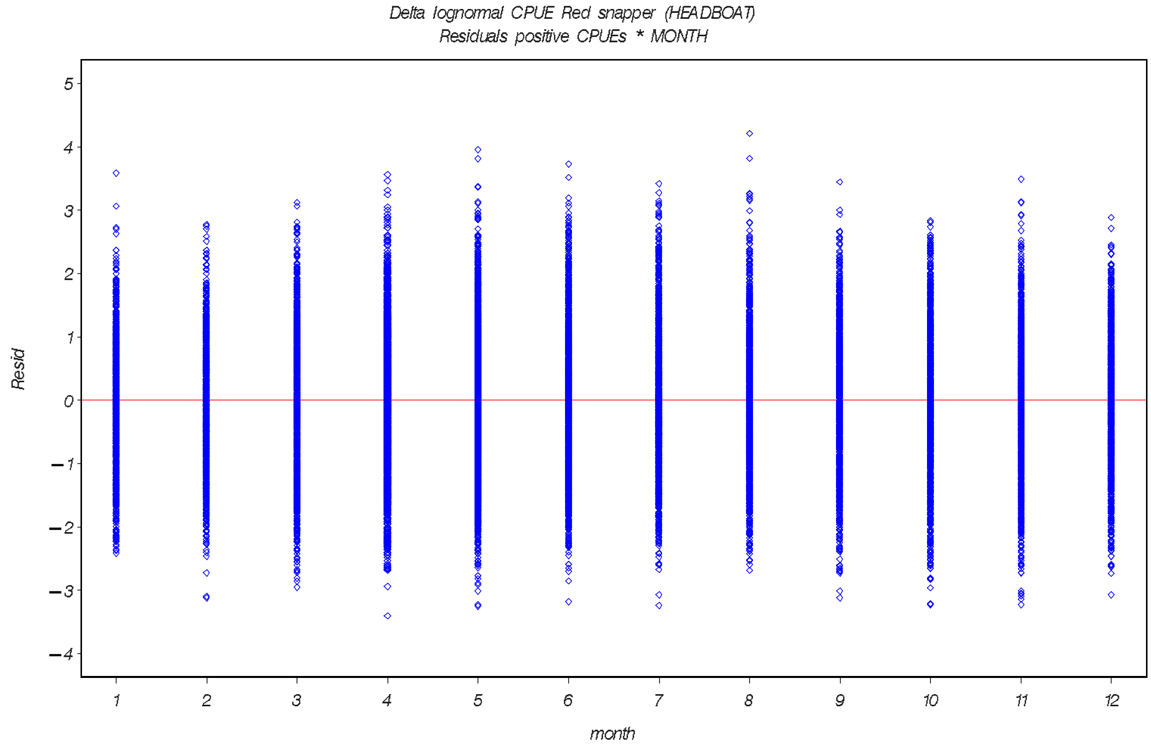
Appendix 5.3E.



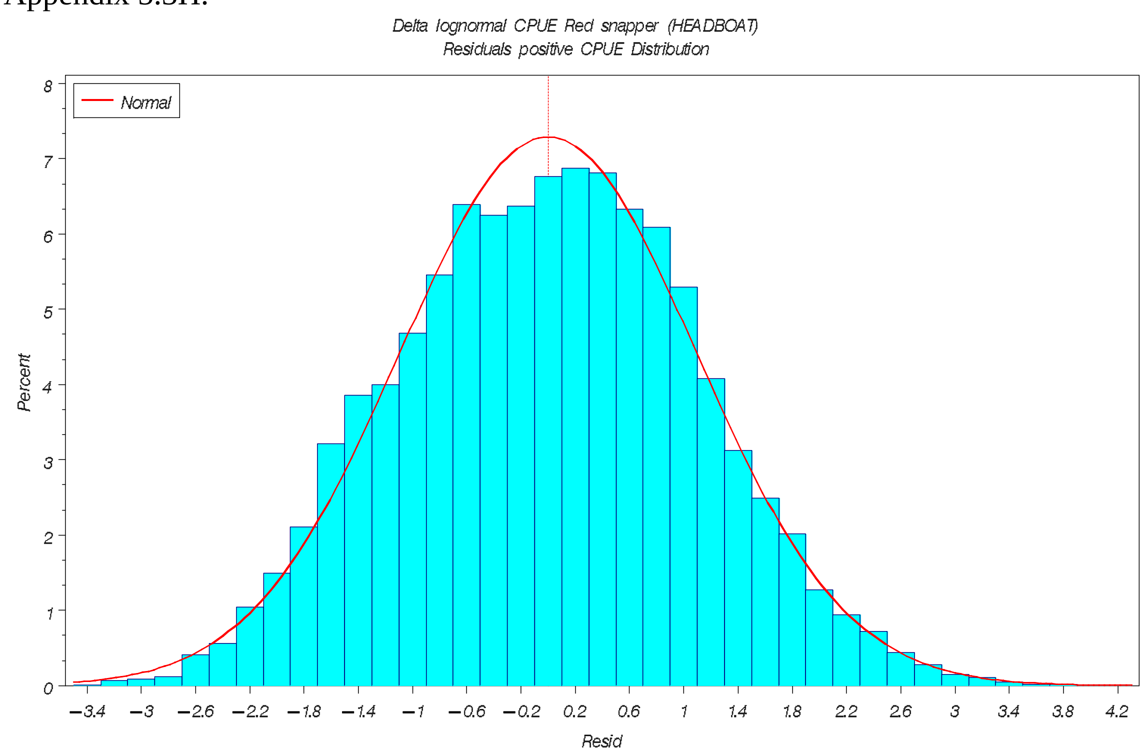
Appendix 5.3F.



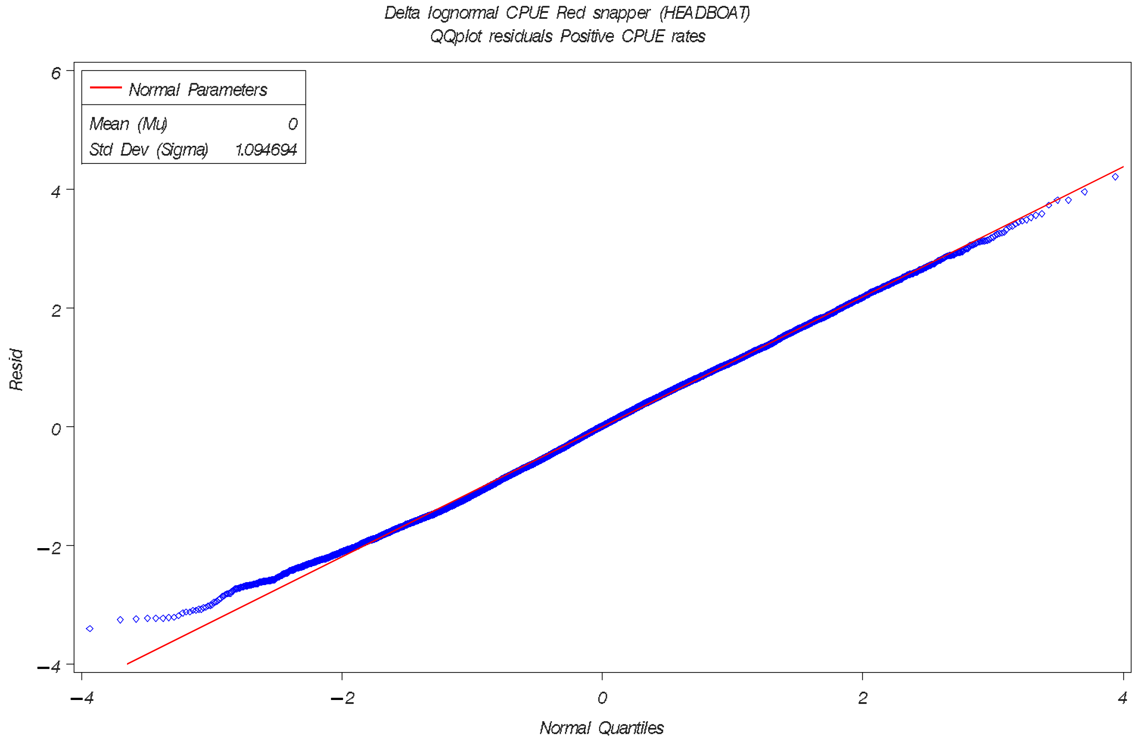
Appendix 5.3G.



Appendix 5.3H.



Appendix 5.3I.



6 Submitted Comments

6.1 None were received.

Section III. Assessment Workshop Report

Contents

1. Workshop Proceeding

1.1 Introduction

1.1.1 Workshop Time and Place

The SEDAR 15 Assessment Workshop was held October 22-26, 2007 in Beaufort, NC.

1.1.2 Terms of Reference

1. Review any changes in data following the data workshop and any analyses suggested by the data workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.
2. Develop population assessment models that are compatible with available data and recommend which model and configuration is deemed most reliable or useful for providing advice. Document all input data, assumptions, and equations.
3. Provide estimates of stock population parameters (fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, etc); include appropriate and representative measures of precision for parameter estimates.
4. Characterize uncertainty in the assessment and estimated values, considering components such as input data, modeling approach, and model configuration. Provide appropriate measures of model performance, reliability, and 'goodness of fit'.
5. Provide yield-per-recruit, spawner-per-recruit, and stock-recruitment evaluations.
6. Provide estimates for SFA criteria. This may include evaluating existing SFA benchmarks or estimating alternative SFA benchmarks (SFA benchmarks include MSY, Fmsy, Bmsy, MSST, and MFMT); recommend proxy values where necessary.
7. Provide declarations of stock status relative to SFA benchmarks.
8. Estimate an Allowable Biological Catch (ABC) range.
9. Project future stock conditions (biomass, abundance, and exploitation) and develop rebuilding schedules if warranted; include estimated generation time. Stock projections shall be developed in accordance with the following:
   A) If stock is overfished:
      F=0, F=current, F=Fmsy, Ftarget (OY),
      F=Frebuild (max that rebuild in allowed time)
   B) If stock is overfishing
      F=Fcurrent, F=Fmsy, F= Ftarget (OY)
   C) If stock is neither overfished nor overfishing
      F=Fcurrent, F=Fmsy, F=Ftarget (OY)
10. Evaluate the results of past management actions and, if appropriate, probable impacts of current management actions with emphasis on determining progress toward stated management goals.
11. Review the research recommendations provided by the Data Worskhop. Provide additional recommendations for future research and data collection (field and assessment) with a focus on those items which will improve future assessment efforts. Provide details regarding sampling design, sampling strata and sampling intensity that

will facilitate collection of data that will resolve identified deficiencies and impediments in the current assessment.

12. Provide complete model output values and population estimates in an accessible and formatted excel file.
13. Complete the Assessment Workshop Report (Section III of the SEDAR Stock Assessment Report) and prepare a first draft of the Advisory Report.

1.1.3 Participants

Workshop Panel

Jeff Buckel .... SAFMC SSC/NCSU
Brian Cheuvront.. SAFMC/NC DMF
Rob Cheshire .... NMFS SEFSC
Chip Collier... NC DMF
Paul Conn.. NMFS SEFSC
Pat Harris .... SAFMC SSC/SC DNR
Jack McGovern .... NMFS SERO
Marcel Reichert.. SC DNR
Kyle Shertzer .... NMFS SEFSC
Andi Stephens .... SAFMC
Doug Vaughan .... NMFS SEFSC
Erik Williams .... NMFS SEFSC
David Wyanski... SC DNR

Observers

Alan Bianchi .... NC DMF
Ken Brennan .... NMFS SEFSC
Jeff Burton .... NMFS SEFSC
Stephanie McInerny .... NMFS SEFSC
Paulette Mikell .... SC DNR
Mike Prager... NMFS SEFSC
Jennifer Potts... NMFS SEFSC
Jessica Stephen... SC DNR
Helen Takade .... NC DMF
Jim Waters .... NMFS SEFSC

Staff

John Carmichael.. SAFMC
Julie Neer .... SEDAR
Rachael Lindsay.. SEDAR
Dale Theiling .... SEDAR

1.1.4 Workshop Documents

Documents prepared for the SEDAR 15 assessment workshop:

SEDAR15-AW-1	SEDAR 15 Stock Assessment Model	Conn, P., K. Shertzer, and E. Williams

1.2 Panel Recommendations and Consensus Statements

1.2.1 Discussion and Recommendations Regarding Data Modifications and Updates

Data modifications are detailed in section 2 and address any group discussion and recommendations.

Modeling Periods

There were three modeling periods. These were based on changes in regulations, time series of landings data, and behavior of model.

1946-1984 – Period 1
1984-1991 – Period 2
1992-present – Period 3

Landings data went back as far as 1901. However, the model did not give reasonable results with a 1901 start. It was sensitive to many small configuration changes. The start of 1946 seemed to provide needed stability. The assessment group supports 1946 start date as that is when landings begin after no landings data during WW2. There were regulation changes between period 1 and 2 and between period 2 and 3.

Sample size for age and length data

The decision of sample size for annual age and length composition data was a balance between too little data and noise and including all data that might be informative. As a compromise between these two, a minimum sample size of 40 was used.

Age-classes

Analysis showed the model insensitive to various choices of age-class saturation (plus-group age). Life history characteristics saturate by age 20, therefore age 20 was chosen as the plus-group.

Changes to timing in catch at age model

Annual SSB was estimated mid-year because peak spawning occurs in May-July. This was a change from prior modeling where SSB was estimated at beginning of year. Total biomass and abundance are estimated at start of year.

Stock Recruitment

There was concern that spikes in recruitment from initial runs were anomalies. However, these strong year classes were present in age composition data. Landing spikes are driving recruitment.

First year of recruitment deviations (from constraint to S-R curve) is now an input parameter to the model (i.e., can be chosen). Equivalent to an age structured production model when constrained to stock recruitment model. When not constrained, deviations used to model recruitment variation. As a potential attempt to fit length composition of headboat data (see below) the recruit residuals were started earlier (1971?); ealier start dates of recruitment residuals provided better fits to length composition data but S-R relationships were poor. The base model has recruitment residuals beginning in 1974; sensitivities will be 1972 and 1976.

Smoothing of MRFSS catch to calculate landings (1992-2006)

The PSE's for MRFSS landings data were often above 20% suggesting that annual estimates were not reliable. For the surplus production model (see section below), there were two changes made to the MRFSS landings data to reduce large interannual variability in individual fish weight and numbers landed. First, the annual mean weight of individual fish was smoothed using LOESS techniques (weight is smoothed by the square root of sample-size). Second, the mean number of red snapper landed per year was smoothed using a three year running average. The catch at age model only used the smoothing data on mean fish size initially but then changed to same landings data as used in production model. The assessment text should clearly and repeatedly state that smoothed MRFSS date were used; all figure legends should reflect that. The text should also be clear on why MRFSS data were smoothed.

Fishery selectivities

The fishery selectivity functions vary by period and sector to deal with regulation changes in three different fisheries. The length composition from each fishery and time period was used for fishery selectivities. However, the recreational and headboat fishery selectivities in period 2 were determined using a logistic function fit using a slope parameter from a pdf from the VBGF model and minimum size limit.

The length compositions from MRFSS show a large number of illegal fish. This was discussed and it was determined that it was not a sample size issue because the minimum sample size was 40 per year.

Discards and discard selectivity

The calculation of discards in the assessment differed from the data workshop. Discards of red snapper in MRFSS (B2's) had high year-to-year variability. Therefore, a three year running average was used on discards for both the catch at age model and the production model. The recreational discards pre-1984 were modeled initially but then assumed no discard in later runs (see Discussion below). Headboat discards were estimated using the landings/discards ratio from MRFSS for 1984-2006. Commercial discards 1992-2006 from logbooks (hook and line fishery); discards for previous periods assumed to be same landings/discards ratio. Discards for diving fishery not estimated (assumed not to exist).

How much discarding under the 12" size? There was some indication 12" did little (len comp, but little prior to size change). Could simplify and use 2 periods. That model was not pursued.

There were no data to estimate selectivity functions for discards and the complement of the logistic selectivity for the fishery was first chosen to model discard selectivity. Discussion focused on likelihood that there probably was no discarding of any red snapper in period 1 because there were no size regulations. All concluded that this was valid assumption for commercial and recreational fishery.

One problem with discard selectivities that was discussed had to do with too high of discards on large fish. Discussion about whether or not to use probability size approach for selectivity (e.g., use age and growth data and pdf's to determine probability of age-2 being below size limit). Decision not to use that approach alone but to use estimated slopes from that approach but still let data drive how selection function moves from left to right in model. Vbgf – pdf used to calculate slope of logistic fnct…then use that slope instead of knife edge.

Period 1 (pre-1984): no discard

Periods 2 (HB and MRFSS): a50 = a(size limit) based on length composition and slope determined from probability density function and VBGF. This approach used for headboat and MRFSS only

Period 2 & 3 Commercial and Period 3 (HB and MRFSS): fishery selectivity based on length composition

Discard mortality

The discard mortality for the commercial fishery was assumed to be 0.9 and for the recreational fishery, 0.4. There was discussion that the commercial discard mortality was too high. The Gulf of Mexico red snapper model used 0.7-0.8. It was decided that a sensitivity run with a commercial discard of 0.7 should be examined. Cited deeper water as reason why discard mortality might be higher in US South Atlantic. Also, habit of commercial fishers leaving fish on deck was cited as reason for higher discard mortality overall. Is it critical? Maybe, but discards not overly high so expectation is that results will not be sensitive. Noted the diff with gulf, but that is inadequate justification. No advisors here to discuss, and would be affected by mortality. Should we consider using another?

Multiple independent sensitivity runs were recommended: Commercial of 0.7, 0.8, 0.9, and 1.0 and recreational of 0.2, 0.4, and 0.6.

Likelihood weightings

Range from 1 to 1000….

1.2.2 Discussion and Critique of Each Model Considered

Address all models, note Preferred Model &Configuration, summarize Model Issues Discussed and group consensus on issues.

(Model is detailed by analyst in later section. Brief overview here, detail is on the issues and recommendations to resolve issues.)

Surplus production model-ASPIC runs

Smoothing of landings data as described in CAA model section. Another issue that had to be dealt with was that not all discards die. The calculation of dead discards was accepted by group.

Two assumption groups examined:

Assumption group 1: discards negligible before 1984; mean discard weight equal to mean weight of individual fish in landings, (not preferred due to large fish being discarded).

Assumption group 2: decompose total selectivity into gear and fisherman selectivity; Assume knife edge gear selectivity at age1; Assume fisherman selectivity due entirely to size limits; Assume age specific M and constant F0 of 0.2

B1/K (equivalent to B0/K below)=0.9 because goes back to 1901 when virgin fishery

Sensitivity analyses examined changes in B1/K and smoothed vs not smoothed MRFSS data.

Status shows 27 out of last 30 yrs have F higher than Fmsy but not in last year. B lower than Bmsy for majority of recent years.

Caveat- discard mortality makes up large proportion and lots of small fish. The numbers of fish are not accounted for explicitly in model. These are better accounted for in an age-structured model. Initial ASPIC results were viewed with skepticism because it was viewed as overly optimistic.

There were new ASPIC runs using the updated landings data (see discussion regarding updated landings data below). With new data, ASPIC predicted that the F/Fmsy and B/Bmsy from ASPIC are similar to CAA model output though B/Bmsy was not quite as bad. Fits to headboat indices using new landings data are better than initial ASPIC runs.

Catch-at-age model

The catch-at-age model gave a poor fit to the 1978 – 1983 headboat length composition data. The problem has to do with large number of year classes that have similar size range – confidence limits bound mean of ~700mm. The model forces many of older fish into that length range. The removal of those predicted lengths during 1978-1983 requires either truncated age classes from poor recruitment or removing those larger fish using high fishing mortality prior to the 1978-1983 period.

The first attempt to fix this problem examined changes to selectivity patterns on larger fish early in the time series and then allowing selectivity parameter to change annually. This did not provide a better fit to headboat length composition and was not retained in subsequent model runs.

It was determined that the large number of recruits that were artificially put into system with stock recruitment function during 50s and 60s was carrying through into predicted length composition during 1978-1983. To reduce this problem, recruitment deviations were begun at earlier year (1971) in model. Although this solution fixed the problem it may be doing so at expense of missing a much higher F in the early years of modeling period. Discussion also focused on fact that the observed recruitment pattern may not be defensible.

Next attempt at fitting headboat length compostion data focused on getting rid of larger fish using increased selectivities in period 1. Assume in period 1 all selectivities are same across fisheries and allow selectivities to change linearly (a50) each year shifting towards left and getting steaper. This effectively kills off the larger fish earlier. Also fix slope of parameter in period 2. See Fishery selectivity section for discussion of this approach. These changes in the fishery selectivity functions did not improve fits to the headboat length composition.
The modifications of period 1 selectivities was dropped.

The following model runs went back to modifications of stock recruitment function to reduce recruitment of fish during early period. The initial period of poor stock recruitment fits were argued to be a "burn in" period and there was discussion that this might be defensible given that it includes 1950s and 1960s. If the "burn in" period was dropped from S/R curve it looks good and would be defensible. Is this satisfactory? It was decided that this approach was not satisfactory because of possibly missing high fishing mortality during early period that was documented in literature.

The landings data from period 1 were re-visited. A new approach of estimating MRFSS landings from 1946 to 1980 was attempted using ratio of commercial to recreational from later periods and applying that during period 1. These new MRFSS estimates did not fix the headboat length composition fits; the increased recreational landings in period 1 was not enough to remove large fish predictions in the 1978-1983 headboat fishery. Another approach allowed bias estimation of those earlier landings which did fix headboat length fits. Discussion then focused on whether or not the recreational landings (MRFSS + HB) are too low given USFWS reports and bias estimation results. Data from these reports were not included in data workshop because MRFSS? USFW? deemed these data untrustworthy. However, the assessment group felt that creel surveys from the 1960s and 1970s could be considered trustworthy. Recreational landings from these reports were much higher (order of magnitude) than linear interpolation approach (from 1946 to 1980), ratio, and bias estimation? approach. The next step was to linear interpolate between red snapper landings data from USFW reports; observed data for 1955, 1960, and 1965 was interpolated through from 1945 to 1980. Results were similar and a bias parameter on those new landings data. The base run used these linear interpolations on the 1945 to 1980 for recreational landings (headboat and private); this allowed improvement of fits to headboat length compositions. Anchor point years for linear interpolation of recreational landings are 1946, 1960, 1965, 1970, and 1981. There are no head boat landings before 1972 in base run.

The biomass of the stock is below 5% of virgin biomass at terminal year in base run but also when setting recruitment at low levels in period 1. The assessment group felt that high fishing mortality based on survey from sportfishing report was more realistic and defensible than low recruitment during period 1 and poor fit of S/R relationship.

The influence of B1/K on base model was examined. Examination of likelihoods to examine fits and nothing really stood out as best B1/K. Examination of status indicators B/Bo, F/Fmsy, and SSB/SSBmsy did not support any single value of B1/K. Since there are fishery landings prior to 1946, it was assumed that the stock was below a B1/K of 1.0 but probably not below 0.5; an initial stock status of 0.75 was chosen.

The B/Bo values (in period 3) and the model fits to indices were not influenced by variation in B1/K ranging from 0.5 to 1.0.

Projections using a 20 year generation time. Given generation time and rule of rebuilding the rebuilding time for red snapper will be 30 years or 2039?

Red snapper projections with generation time of 20 years. F=0 shows rebuilt in 11 years at 2021. However, this is highly unrealistic because F will not be 0 even if a moratorium because of discard mortality.

For projections at Fmsy, population would be rebuilt by ~ 2040.

For projections at 0.75Foy, population can rebuild by 2039 if assume discards don't get any worse and recruitment stays same.

There were multiple sensitivity analyses (changes in M scaling, q values, steepness, discard mortality of recreational and commercial sectors, and B1/K) and all results for F/Fmsy and SSB/SSBmsy were similar. Population is so low that results in terminal years are all low even though there are relative differences. The data workshop landings and the base run (USFW) landings give similar results for period 3; however, the time that overfishing started changes from 1960s (USFW) to 19770s? for DW landings. Changes in values of steepness also changed patterns through time as well but end result same.

Retrospective analyses will be done week following assessment workshop along with projections dealing with new discards given that what is in fishery now is predominantly bycatch (likely no directed fishing for red snapper). Problem is that what they land now is an indirect fishery….how to estimate a discard F??? Use all current landings and assume they would be discarded? Take discard selectivity and fishery selectivity and add together to get new selectivity and then take all landings currently and assume that will still happen. Given discard mortalities the best we can do is to reduce F by ~50%? Fishing mortality from diving would go completely (no discards).

1.2.3 Recommended Parameter Estimates

1.2.4 Evaluation of uncertainty and model precision

There was discussion of how to determine precision for parameter estimates in CAA model. There is no easy way to do this. Traditional precision measures are not appropriate in likelihood/weighting framework. On the question of quantifying uncertainty in parameter estimates, the preference of workshop participants was to consider different weightings of likelihood components in an attempt to provide the best overall fit to trusted data sources. One consequence of this decision was that traditional likelihood-based methods (involving the Hessian or profile likelihood, for instance) no longer provided unbiased measures of precision. In particular, likelihood weights greater than 1.0 typically result in overestimates of precision (i.e., understatements of uncertainty). Because weights on certain likelihood components were substantially higher than 1.0 workshop participants thus agreed that it would be misleading to provide standard errors along with parameter estimates.

Another possibility for quantifying uncertainty is to compare results of different analyses where model structure is allowed to vary. Sensitivity runs, for instance, could be used to evaluate the variability in parameter estimates resulting from different assumptions. Unfortunately, model averaging (cf. Burnham and Anderson 2002) could not be employed in a formal sense because likelihood weights often changed between simulation runs. Nevertheless, comparison of parameter estimates between runs provided a useful characterization of uncertainty.

Literature Cited

Burnham, K. P. and D. R. Anderson. 2002. Model Selection and Multimodel Inference: A Practical Information-theoretic Approach, 2nd Edition. Springer-Verlag: New York.

1.2.5 Discussion of YPR, SPR, Stock-Recruitment

1.2.6 Recommended SFA parameters and Management Criteria (Provide Table - existing ests of past criteria, current ests of past criteria, currents ests of proposed/requested criteria.)

1.2.7 Status of Stock Declarations

1.2.8 Recommended ABC

1.2.9 Discussion of Stock Projections

1.2.10 Management Evaluation

Effectiveness/impacts of past management actions
- *Have size, bag, harvest limits etc. affected the stock? achieved objectives?*
- *evaluation of rebuilding strategy (if implemented)*

Possible impacts of proposed management actions

- *Optional. Special Comments, Advice if particular regulations are pending*

1.2.11 Statements addressing any additional Terms of Reference not covered above (optional)

1.2.12 Research Recommendations

2 Data Input and Changes

Processing of data for the assessment is described in the SEDAR 15 Red Snapper Data Workshop Report. This section describes additional manipulations to the data output for use in the ADMB age structured model.

2.1 Growth, Maturity, and Mortality

Corrected von Bertalanffy growth function (VBGF) was estimated by the Life History Working Group (LHWG), and presented in life history section in Data Workshop (DW) report as

$$TL\ (mm) = 894.7\ (1 - \exp(-0.235(age + 0.48))),$$

and weight as a function of total length as

$$W\ (g) = 0.000007\ TL\ (mm)^{3.104}.$$

Female maturity at age was estimated from the fitted logistic equation provided in Life History section:

$$\Pr\{\text{female mature}\} = 1 - (1/(1 + \exp(-2.9282 + 1.7594\ age))),$$

and we assumed a sex ratio of 0.5. Size (mid-year), sex ratio and female maturity at age are summarized for ages 1-20 in Table 2.1

We used estimates of age-varying M based on the approach of Lorenzen (1996) scaled to cumulative mortality of 1.4% for ages 1-53 as provided by the LHWG (using corrected growth parameters). They also recommended using upper and lower estimates (for sensitivity runs) of age-varying M by scaling the Lorenzen estimates of M to 1 and 5%. The various estimates of age-varying M are summarized in Table 2.2.

Discard mortality fractions were assumed constant at 0.4 for the recreational fisheries (headboat and MRFSS) and 0.9 for the commercial fishery (hook & line). Additional sensitivity model runs were made for commercial release mortalities of 0.7, 0.8 and 1.0 (0.7 was used for Gulf of Mexico red snapper). The LHWG believed that commercial release mortality would be higher in the US south Atlantic than in the Gulf of Mexico because of generally deeper water.

Generation time (G) was estimated 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 1 fish at age 1 and decrementing based on natural mortality only, and b_x is per capita birth rate of females at age. Because female biomass is used as a proxy for female reproduction in our model, we substitute the product of $m_x w_x$ for b_x in this equation, where m_x is proportion of females mature at age and w_x is expected weight (of females) at age. This weighted average of age for mature female biomass yields an estimate of 20 yrs (rounded up from 19.5 yrs).

2.2 Recreational and Commercial Landings (Table 2.3)

The Recreational Working Group (RWG) provided MRFSS and headboat landings for 1946-2006. A linear interpolation was applied to MRFSS landings assuming 0 in 1946 to the beginning of MRFSS landings estimates (A+B1) in 1981. Similarly, a linear interpolation was applied to headboat landings assuming 0 in 1946 to the beginning of headboat landings estimates in 1972. Concerns about the high PSE's for the MRFSS landings estimates led the Assessment Panel to consider using a 3-yr moving average to smooth MRFSS landings estimates in numbers provided by the RWG for 1981-2006. In addition, loess smoothing (weighted by inverse sample size) was applied to annual mean weights of fish (catch in weight/catch in numbers). MRFSS harvest in weight was calculated from the product of the smoothed estimated harvest in numbers times the smoothed mean weight of fish.

The RWG applied a linear interpolation from 0 in 1946 to estimated values in 1981 for MRFSS and 1972 for headboat. During the Assessment Workshop, preliminary model runs suggested significantly higher landings in the early period (1946-1980) than reflected in the landings. Although the RWG dismissed estimates from the Salt-Water Angling reports (Clark 1962, Deuel and Clark 1968, Deuel 1973), the Assessment Panel agreed that these estimates were at least as reasonable as the linear interpolation to zero in 1946 used by the RWG. Therefore, recreational landings were interpolated between zero in 1946 to 1981 with intermediate landings estimates used for 1960 (Clark 1962), 1965 (Deuel and Clark 1968), and 1970 (Deuel 1973). In general, these values were assumed to include headboat landings for these years. Thus, when interpolating between 1970 and 1981, the headboat landings were subtracted for 1972-1980 (and listed separately for headboat). Headboat landings prior to 1972 were assumed zero (i.e., included in the MRFSS landings). Recreational landings (MRFSS and headboat) as estimated by the two approaches are compared in Figure 2.1.

Commercial fisheries were reduced to two gears, commercial hook & line and diving. Trivial landings from commercial trawls, traps and other gears (2% for 1962-2006, and 1.2% since 2000) were pooled with landings from commercial hook & line. Commercial landings were developed back to 1927 from historical records with some interpolation for missing years by the Commercial Working Group. Additionally a linear interpolation was used assuming 0 landings in 1900 to estimate values for 1900-1927.

The MRFSS PSE for A+B1 was used as the CV for estimates of MRFSS landings. Annual CV's were assigned to headboat landings with 0.1 used for 1972-1980 and 0.05 for 1981-2006. Annual CVs were assigned to hook & line and diving gears, with high CV for earliest years (0.30) and low CV for recent years (0.05). A linear interpolation was made for intervening years (1927 to 1962).

2.4 Recreational and Commercial Discards (Table 2.4)

Because of high PSE's associated with the MRFSS B2 estimates, the Assessment Panel applied a 3-yr moving average to these B2 estimates for 1984-91, and 1992-2006 (separating these moving averages with change in management). To estimate headboat discards, the Assessment Panel applied the annual MRFSS ratio of B2/A+B1 to headboat landings to estimate headboat discards for 1984-2006. Furthermore, we set headboat discard coefficient of variation (CV) to MRFSS B2 PSE.

Estimates of commercial hook & line discards were available for 1992-2006 from the Commercial Working Group (CWG). The average discarding rate (discards/harvest) for commercial hook & line was compared to that for MRFSS (B2/A+B1) for the period 1992-2006 (59%). MRFSS discarding rate (reduced by 59%) was applied to commercial harvest for 1984-1991 to obtain commercial discard estimates for these years. CV's for commercial discard estimates was assumed twice those of the commercial landings.

2.5 Recreational and Commercial Length and Age Compositions (Tables 2.5-2.12)

MRFSS, headboat, commercial hook & line, and commercial diving length compositions were expressed as 3 cm intervals from 19-100 cm total length, with the largest interval (100 cm) a plus group. Ages from 20-53 were pooled into a 20+ category for data from these fisheries. Annual length and age compositions were retained for analysis when sample size was 40 or larger.

2.6 Indices (Table 2.13)

Three fishery-dependent CPUE's were provided by the Index Working Group (IWG). CV's associated with the fishery dependent indices were scaled to a maximum of 0.3

References:

Clark, J. 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. 1970 Salt-Water Angling Survey. U.S. Department of Commerce, NOAA, *Current Fishery Statistics* No. 6200, 54 p.

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 p.

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

Lorenzen, K. 1996. The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural ecosystems and aquaculture. Fish. Biol. 49:627-647.

Table 2.1. Red Snapper: Size (mid-year), sex ratio and female maturity at age. Length is total length, weight is whole weight.

Age	Length (mm)	Length (in)	Weight (kg)	Weight (lb)	Sex Ratio	Female Maturity
1	332.9	13.11	0.5	1.04	0.5	0.237
2	450.5	17.74	1.2	2.66	0.5	0.644
3	543.6	21.40	2.2	4.77	0.5	0.913
4	617.1	24.30	3.2	7.07	0.5	0.984
5	675.2	26.58	4.2	9.36	0.5	0.997
6	721.2	28.39	5.2	11.48	0.5	1.000
7	757.5	29.82	6.1	13.37	0.5	1.000
8	786.3	30.96	6.8	15.01	0.5	1.000
9	809.0	31.85	7.4	16.39	0.5	1.000
10	826.9	32.56	8.0	17.55	0.5	1.000
11	841.1	33.11	8.4	18.50	0.5	1.000
12	852.3	33.56	8.7	19.28	0.5	1.000
13	861.2	33.91	9.0	19.91	0.5	1.000
14	868.2	34.18	9.3	20.41	0.5	1.000
15	873.8	34.40	9.4	20.82	0.5	1.000
16	878.2	34.57	9.6	21.15	0.5	1.000
17	881.6	34.71	9.7	21.41	0.5	1.000
18	884.4	34.82	9.8	21.62	0.5	1.000
19	886.5	34.90	9.9	21.78	0.5	1.000
20	888.2	34.97	9.9	21.91	0.5	1.000

Table 2.2. Estimates of natural mortality, M, for red snapper based on Lorenzen (1996). These estimates are then scaled to cumulative survival for ages 1-53 (maximum age) to 1.4% (preferred) and range using 1% and 5%. Ages 1-20 used in the statistical catch-at-age model.

Age	M	Scaled M (0.014)	Upper (0.01)	Lower (0.05)
1	0.71	0.23	0.16	0.25
2	0.48	0.16	0.11	0.17
3	0.38	0.13	0.09	0.14
4	0.33	0.11	0.08	0.12
5	0.30	0.10	0.07	0.11
6	0.28	0.09	0.06	0.10
7	0.26	0.09	0.06	0.09
8	0.25	0.08	0.06	0.09
9	0.25	0.08	0.06	0.09
10	0.24	0.08	0.06	0.08
11	0.24	0.08	0.05	0.08
12	0.23	0.08	0.05	0.08
13	0.23	0.08	0.05	0.08
14	0.23	0.07	0.05	0.08
15	0.23	0.07	0.05	0.08
16	0.23	0.07	0.05	0.08
17	0.22	0.07	0.05	0.08
18	0.22	0.07	0.05	0.08
19	0.22	0.07	0.05	0.08
20	0.22	0.07	0.05	0.08
21	0.22	0.07	0.05	0.08
22	0.22	0.07	0.05	0.08
23	0.22	0.07	0.05	0.08
24	0.22	0.07	0.05	0.08
25	0.22	0.07	0.05	0.08
26	0.22	0.07	0.05	0.08
27	0.22	0.07	0.05	0.08
28	0.22	0.07	0.05	0.08
29	0.22	0.07	0.05	0.08
30	0.22	0.07	0.05	0.08
31	0.22	0.07	0.05	0.08
32	0.22	0.07	0.05	0.08
33	0.22	0.07	0.05	0.08
34	0.22	0.07	0.05	0.08
35	0.22	0.07	0.05	0.08
36	0.22	0.07	0.05	0.08
37	0.22	0.07	0.05	0.08
38	0.22	0.07	0.05	0.08
39	0.22	0.07	0.05	0.08

Table 2.2. (cont.)

40	0.22	0.07	0.05	0.08
41	0.22	0.07	0.05	0.08
42	0.22	0.07	0.05	0.08
43	0.22	0.07	0.05	0.08
44	0.22	0.07	0.05	0.08
45	0.22	0.07	0.05	0.08
46	0.22	0.07	0.05	0.08
47	0.22	0.07	0.05	0.08
48	0.22	0.07	0.05	0.08
49	0.22	0.07	0.05	0.08
50	0.22	0.07	0.05	0.08
51	0.22	0.07	0.05	0.08
52	0.22	0.07	0.05	0.08
53	0.22	0.07	0.05	0.08

Table 2.3. Red snapper: Landings and associated coefficient of variation, as used in the assessment (base).

	Landings in Whole Weight (1000 pounds)				Coefficient of Variation (CV)			
	Commercial		Recreational		Commercial		Recreational	
Year	Hook & Line	Diving	Headboat	MRFSS	Hook & Line	Diving	Headboat	MRFSS
1945	240.9				0.17			
1946	262.6				0.16			
1947	284.4			292.4	0.16			0.29
1948	306.1			584.9	0.15			0.29
1949	327.8			877.3	0.14			0.29
1950	349.6			1169.8	0.14			0.29
1951	498.6			1462.2	0.13			0.29
1952	374.8			1754.7	0.12			0.29
1953	389.1			2047.1	0.12			0.29
1954	576.9			2339.6	0.11			0.29
1955	479.6			2632.0	0.10			0.29
1956	470.0			2924.4	0.10			0.29
1957	843.0			3216.9	0.09			0.29
1958	594.7			3509.3	0.08			0.29
1959	638.3			3801.8	0.08			0.29
1960	652.3			4094.2	0.07			0.29
1961	770.4			4411.8	0.06			0.29
1962	575.9			4729.3	0.05			0.29
1963	438.5			5046.9	0.05			0.29
1964	486.3			5364.4	0.05			0.29
1965	571.4			5682.0	0.05			0.29
1966	643.5			4933.2	0.05			0.29
1967	843.6			4184.4	0.05			0.29
1968	938.7			3435.6	0.05			0.29
1969	611.0			2686.8	0.05			0.29
1970	559.1			1938.0	0.05			0.29
1971	478.9			1787.3	0.05			0.29
1972	414.3		91.9	1544.7	0.05		0.10	0.29
1973	340.2		117.3	1368.6	0.05		0.10	0.29
1974	555.2		77.1	1258.2	0.05		0.10	0.29
1975	650.9		83.5	1101.0	0.05		0.10	0.29
1976	547.4		109.3	924.6	0.05		0.10	0.29
1977	579.2		59.9	823.2	0.05		0.10	0.29
1978	545.0		63.0	669.5	0.05		0.10	0.29
1979	380.7		54.1	527.7	0.05		0.10	0.29

Table 2.3. (cont.)

1980	352.9		54.7	376.5	0.05		0.10	0.29
1981	347.1		116.6	280.4	0.05		0.05	0.33
1982	286.0		98.0	246.3	0.05		0.05	0.27
1983	290.0		74.0	329.8	0.05		0.05	0.27
1984	230.5	1.2	81.4	532.4	0.05	0.05	0.05	0.17
1985	223.0	2.3	132.1	559.6	0.05	0.05	0.05	0.29
1986	200.2	0.6	54.4	435.8	0.05	0.05	0.05	0.27
1987	172.8	0.4	81.8	247.7	0.05	0.05	0.05	0.20
1988	152.0	0.3	130.1	285.2	0.05	0.05	0.05	0.27
1989	242.5	1.1	70.8	313.7	0.05	0.05	0.05	0.30
1990	201.7	1.7	65.7	272.8	0.05	0.05	0.05	0.08
1991	125.4	5.3	72.0	222.3	0.05	0.05	0.05	0.34
1992	87.6	9.4	28.9	269.3	0.05	0.05	0.05	0.38
1993	206.4	5.7	42.7	258.8	0.05	0.05	0.05	0.27
1994	175.6	13.0	53.4	117.6	0.05	0.05	0.05	0.37
1995	164.1	10.2	57.5	110.0	0.05	0.05	0.05	0.28
1996	130.0	6.2	46.2	116.8	0.05	0.05	0.05	0.50
1997	98.9	7.5	51.2	114.0	0.05	0.05	0.05	0.44
1998	78.7	8.0	26.8	193.9	0.05	0.05	0.05	0.32
1999	79.0	9.9	43.6	275.8	0.05	0.05	0.05	0.18
2000	89.2	11.4	49.4	355.6	0.05	0.05	0.05	0.24
2001	169.9	20.0	68.4	364.5	0.05	0.05	0.05	0.19
2002	158.8	22.9	70.8	304.9	0.05	0.05	0.05	0.17
2003	117.2	17.3	41.4	299.4	0.05	0.05	0.05	0.18
2004	147.5	19.2	80.3	273.9	0.05	0.05	0.05	0.16
2005	115.0	9.4	58.7	273.3	0.05	0.05	0.05	0.17
2006	79.1	4.1	41.4	271.7	0.05	0.05	0.05	0.24

Table 2.4. Red snapper: Discards and associated coefficients of variation, as used in assessment (base).

	Discards in Numbers (1000)			Coefficient of Variation (CV)		
	Commercial	Recreational		Commercial	Recreational	
Year	Hook & Line	Headboat	MRFSS	Hook & Line	Headboat	MRFSS
1984	7.5	8.2	108.8	0.30	0.30	0.30
1985	3.7	6.9	72.5	0.44	0.44	0.44
1986	7.1	6.0	65.7	0.51	0.51	0.51
1987	15.4	20.4	51.7	0.58	0.58	0.58
1988	7.6	16.5	58.4	0.47	0.47	0.47
1989	2.8	3.6	22.8	0.42	0.42	0.42
1990	30.5	26.2	18.7	0.47	0.47	0.47
1991	4.1	5.4	18.0	0.52	0.52	0.52
1992	18.3	3.3	50.0	0.10	0.29	0.29
1993	17.9	24.6	54.6	0.10	0.28	0.28
1994	24.5	18.6	61.8	0.10	0.29	0.29
1995	24.2	28.3	44.9	0.10	0.20	0.20
1996	32.3	10.9	28.2	0.10	0.38	0.38
1997	33.7	3.4	20.4	0.10	0.27	0.27
1998	25.5	20.6	73.6	0.10	0.33	0.33
1999	23.0	18.3	155.5	0.10	0.16	0.16
2000	21.8	24.7	216.0	0.10	0.15	0.15
2001	23.7	47.3	199.9	0.10	0.14	0.14
2002	22.1	40.4	166.5	0.10	0.18	0.18
2003	18.9	25.6	160.0	0.10	0.16	0.16
2004	15.8	43.8	157.2	0.10	0.14	0.14
2005	15.3	39.7	150.1	0.10	0.13	0.13
2006	16.9	28.7	130.4	0.10	0.18	0.18

Table 2.5. Red snapper: Length compositions from commercial hook & line.

Year	N	19	22	25	28	31	34	37	40	43	46	49	52	55	58	61	64	67	70	73	76	79	82	85	88	91	94	97	100
1984	2089	0.0000	0.0000	0.0000	0.0001	0.0058	0.0107	0.0853	0.2344	0.2018	0.1251	0.1059	0.0535	0.0397	0.0301	0.0242	0.0135	0.0200	0.0084	0.0024	0.0022	0.0044	0.0086	0.0095	0.0111	0.0022	0.0011	0.0000	0.0000
1985	3539	0.0000	0.0000	0.0006	0.0000	0.0033	0.0257	0.0809	0.1554	0.2088	0.1479	0.1023	0.0886	0.0556	0.0296	0.0187	0.0124	0.0056	0.0035	0.0034	0.0061	0.0063	0.0108	0.0101	0.0106	0.0108	0.0030	0.0000	0.0000
1986	1246	0.0000	0.0000	0.0000	0.0024	0.0059	0.0244	0.0151	0.0486	0.0970	0.1673	0.1801	0.1363	0.0680	0.0696	0.0671	0.0366	0.0224	0.0085	0.0030	0.0036	0.0096	0.0049	0.0082	0.0123	0.0040	0.0052	0.0001	0.0000
1987	1146	0.0000	0.0000	0.0000	0.0034	0.0316	0.0694	0.0520	0.0514	0.0808	0.0610	0.0973	0.1328	0.0922	0.0915	0.0680	0.0519	0.0244	0.0254	0.0122	0.0045	0.0058	0.0097	0.0078	0.0092	0.0084	0.0060	0.0033	0.0000
1988	621	0.0000	0.0000	0.0000	0.0107	0.0232	0.0716	0.1065	0.0958	0.0865	0.0795	0.1086	0.0890	0.0824	0.0550	0.0501	0.0235	0.0211	0.0209	0.0187	0.0051	0.0173	0.0119	0.0047	0.0101	0.0048	0.0029	0.0000	0.0000
1989	1191	0.0000	0.0009	0.0000	0.0002	0.0002	0.0072	0.0128	0.0388	0.0784	0.1111	0.1670	0.1918	0.1517	0.0955	0.0399	0.0267	0.0109	0.0100	0.0145	0.0120	0.0087	0.0081	0.0035	0.0025	0.0030	0.0031	0.0017	0.0000
1990	787	0.0000	0.0000	0.0000	0.0000	0.0072	0.0239	0.1023	0.1007	0.0852	0.1057	0.1304	0.1007	0.0821	0.0566	0.0565	0.0389	0.0289	0.0120	0.0149	0.0117	0.0039	0.0119	0.0042	0.0092	0.0100	0.0029	0.0000	0.0000
1991	706	0.0000	0.0000	0.0000	0.0035	0.0271	0.0857	0.0776	0.0721	0.0858	0.0474	0.1304	0.1124	0.0569	0.0459	0.0438	0.0400	0.0386	0.0356	0.0145	0.0103	0.0100	0.0170	0.0171	0.0158	0.0100	0.0013	0.0000	0.0013
1992	512	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0003	0.0087	0.0371	0.1223	0.0808	0.0769	0.1117	0.0766	0.1163	0.0655	0.0431	0.0679	0.0273	0.0349	0.0423	0.0362	0.0430	0.0086	0.0002	0.0000
1993	1347	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0024	0.0012	0.0156	0.1845	0.3117	0.1707	0.0848	0.0440	0.0184	0.0238	0.0232	0.0177	0.0174	0.0178	0.0150	0.0137	0.0223	0.0105	0.0036	0.0012	0.0000
1994	1167	0.0069	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0047	0.0980	0.1765	0.1832	0.1736	0.1520	0.0974	0.0381	0.0096	0.0098	0.0047	0.0056	0.0057	0.0093	0.0089	0.0110	0.0050	0.0000	0.0000
1995	1442	0.0000	0.0000	0.0000	0.0011	0.0000	0.0045	0.0034	0.0011	0.0011	0.0011	0.0289	0.1720	0.1978	0.1399	0.1000	0.0760	0.0720	0.0514	0.0333	0.0117	0.0148	0.0172	0.0295	0.0149	0.0204	0.0068	0.0011	0.0000
1996	770	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0031	0.0096	0.0886	0.1105	0.1475	0.1978	0.1098	0.0709	0.0710	0.0503	0.0606	0.0322	0.0150	0.0209	0.0062	0.0060	0.0000	0.0000	0.0000
1997	497	0.0000	0.0000	0.0000	0.0000	0.0000	0.0039	0.0079	0.0197	0.0394	0.0551	0.0329	0.0573	0.0455	0.1106	0.1382	0.1035	0.0828	0.0796	0.0449	0.0518	0.0504	0.0239	0.0125	0.0044	0.0160	0.0118	0.0079	0.0000
1998	428	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0051	0.0101	0.0102	0.0672	0.0990	0.1076	0.1645	0.0750	0.0505	0.0426	0.0402	0.0725	0.0674	0.0400	0.0402	0.0367	0.0173	0.0166	0.0274	0.0101	0.0000	0.0000
1999	946	0.0000	0.0000	0.0000	0.0000	0.0009	0.0027	0.0060	0.0087	0.0057	0.0012	0.0997	0.2341	0.1889	0.1278	0.0693	0.0583	0.0277	0.0295	0.0192	0.0257	0.0376	0.0245	0.0080	0.0116	0.0113	0.0014	0.0003	0.0000
2000	881	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0060	0.0139	0.1394	0.2118	0.1251	0.1022	0.0808	0.0515	0.0473	0.0375	0.0385	0.0259	0.0490	0.0287	0.0202	0.0145	0.0048	0.0020	0.0008	0.0000
2001	1408	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0016	0.0016	0.0018	0.1383	0.1935	0.1637	0.1469	0.1047	0.0748	0.0477	0.0249	0.0165	0.0189	0.0168	0.0165	0.0127	0.0049	0.0094	0.0016	0.0000	0.0016
2002	992	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0061	0.0504	0.2146	0.2269	0.1373	0.1180	0.0669	0.0807	0.0386	0.0229	0.0126	0.0106	0.0068	0.0017	0.0000	0.0016	0.0032	0.0000	0.0000
2003	1270	0.0000	0.0000	0.0000	0.0000	0.0006	0.0014	0.0014	0.0004	0.0011	0.0042	0.0166	0.0832	0.1314	0.1739	0.1678	0.1436	0.1067	0.0523	0.0510	0.0286	0.0113	0.0076	0.0091	0.0039	0.0010	0.0029	0.0000	0.0000
2004	795	0.0000	0.0000	0.0000	0.0000	0.0013	0.0018	0.0028	0.0021	0.0010	0.0028	0.0092	0.0405	0.1022	0.1362	0.1270	0.1453	0.1314	0.1491	0.0844	0.0336	0.0059	0.0048	0.0084	0.0061	0.0021	0.0021	0.0000	0.0000
2005	618	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0037	0.0014	0.0087	0.0536	0.0752	0.0896	0.1260	0.0954	0.1199	0.1042	0.1728	0.0728	0.0377	0.0112	0.0163	0.0053	0.0037	0.0023	0.0001	0.0000
2006	406	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0050	0.0050	0.0200	0.0050	0.0711	0.1539	0.1281	0.0928	0.0982	0.0622	0.0693	0.0692	0.0462	0.0719	0.0363	0.0350	0.0258	0.0050	0.0000	0.0000	0.0000

Table 2.6. Red snapper: Length compositions from commercial diving.

Year	N	19	22	25	28	31	34	37	40	43	46	49	52	55	58	61	64	67	70	73	76	79	82	85	88	91	94	97	100
1999	83	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0843	0.0964	0.0723	0.1687	0.0482	0.1084	0.0964	0.0723	0.0120	0.0120	0.0241	0.0602	0.0723	0.0361	0.0241	0.0120	0.0000	0.0000
2000	129	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2248	0.2791	0.1473	0.0853	0.0775	0.0388	0.0233	0.0388	0.0155	0.0000	0.0155	0.0233	0.0233	0.0078	0.0000	0.0000	0.0000	0.0000
2001	87	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0920	0.1954	0.1379	0.2069	0.1264	0.0690	0.0230	0.0460	0.0230	0.0230	0.0115	0.0115	0.0115	0.0230	0.0000	0.0000	0.0000	0.0000
2003	210	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0095	0.0571	0.1190	0.1286	0.1333	0.1095	0.0762	0.1048	0.0762	0.0714	0.0476	0.0286	0.0286	0.0000	0.0048	0.0048	0.0000	0.0000	0.0000

Table 2.7. Red snapper: Length compositions from the headboat survey.

Year	N	19	22	25	28	31	34	37	40	43	46	49	52	55	58	61	64	67	70	73	76	79	82	85	88	91	94	97	100
1978	740	0.0000	0.0112	0.0298	0.0445	0.1022	0.1129	0.1834	0.1574	0.0702	0.0397	0.0523	0.0545	0.0322	0.0159	0.0128	0.0066	0.0161	0.0062	0.0184	0.0053	0.0079	0.0046	0.0067	0.0054	0.0032	0.0004	0.0000	0.0001
1979	245	0.0000	0.0044	0.0000	0.0002	0.0748	0.1320	0.1982	0.1852	0.0495	0.0268	0.0308	0.0220	0.0180	0.0000	0.0140	0.0088	0.0440	0.0484	0.0533	0.0356	0.0264	0.0181	0.0048	0.0044	0.0002	0.0000	0.0000	0.0000
1980	258	0.0000	0.0138	0.0184	0.0417	0.1292	0.1476	0.1348	0.1627	0.0950	0.0637	0.0413	0.0239	0.0106	0.0050	0.0140	0.0050	0.0092	0.0046	0.0048	0.0094	0.0004	0.0050	0.0046	0.0046	0.0230	0.0276	0.0000	0.0000
1981	674	0.0000	0.0033	0.0033	0.0179	0.0856	0.1917	0.1895	0.1782	0.1122	0.0537	0.0330	0.0167	0.0070	0.0064	0.0049	0.0049	0.0093	0.0166	0.0119	0.0200	0.0093	0.0033	0.0106	0.0055	0.0022	0.0011	0.0000	0.0022
1982	457	0.0000	0.0032	0.0065	0.0202	0.0806	0.1180	0.0642	0.0807	0.1186	0.1516	0.1190	0.0919	0.0415	0.0256	0.0067	0.0099	0.0083	0.0047	0.0156	0.0090	0.0047	0.0117	0.0023	0.0036	0.0002	0.0017	0.0000	0.0000
1983	1006	0.0000	0.0015	0.0249	0.0561	0.1829	0.2600	0.2079	0.1265	0.0463	0.0232	0.0196	0.0049	0.0052	0.0040	0.0065	0.0038	0.0018	0.0038	0.0052	0.0039	0.0060	0.0017	0.0001	0.0032	0.0000	0.0000	0.0008	0.0000
1984	1317	0.0000	0.0026	0.0120	0.0320	0.1692	0.2333	0.1806	0.1500	0.0833	0.0420	0.0252	0.0200	0.0053	0.0031	0.0068	0.0009	0.0047	0.0039	0.0008	0.0039	0.0035	0.0008	0.0063	0.0063	0.0035	0.0000	0.0000	0.0000
1985	1190	0.0000	0.0014	0.0050	0.0307	0.1576	0.2172	0.2185	0.1747	0.0794	0.0369	0.0230	0.0130	0.0095	0.0095	0.0061	0.0018	0.0005	0.0010	0.0014	0.0001	0.0023	0.0004	0.0029	0.0041	0.0015	0.0005	0.0000	0.0008
1986	435	0.0017	0.0017	0.0080	0.0753	0.1715	0.1029	0.1032	0.1364	0.0768	0.0463	0.0670	0.0778	0.0487	0.0391	0.0113	0.0073	0.0029	0.0082	0.0017	0.0065	0.0000	0.0000	0.0000	0.0035	0.0022	0.0000	0.0000	0.0000
1987	306	0.0000	0.0200	0.0241	0.0550	0.0839	0.1351	0.1941	0.1627	0.0730	0.0711	0.0380	0.0212	0.0335	0.0127	0.0253	0.0136	0.0178	0.0109	0.0000	0.0000	0.0000	0.0000	0.0077	0.0000	0.0000	0.0000	0.0000	0.0000
1988	204	0.0000	0.0106	0.0065	0.0233	0.0573	0.1501	0.1599	0.2108	0.0636	0.0591	0.0634	0.0172	0.0223	0.0292	0.0177	0.0178	0.0186	0.0258	0.0082	0.0249	0.0000	0.0000	0.0041	0.0041	0.0053	0.0000	0.0000	0.0000
1989	374	0.0000	0.0001	0.0014	0.0168	0.1105	0.2745	0.1737	0.1522	0.0807	0.0312	0.0428	0.0261	0.0198	0.0048	0.0116	0.0035	0.0054	0.0042	0.0133	0.0031	0.0085	0.0031	0.0092	0.0000	0.0031	0.0005	0.0000	0.0000
1990	433	0.0000	0.0000	0.0000	0.0000	0.1091	0.2043	0.1864	0.1937	0.0765	0.0759	0.0297	0.0291	0.0188	0.0228	0.0306	0.0018	0.0014	0.0014	0.0014	0.0000	0.0000	0.0037	0.0118	0.0014	0.0000	0.0000	0.0000	0.0000
1991	152	0.0013	0.0000	0.0201	0.0462	0.0503	0.1830	0.1153	0.1448	0.1278	0.1027	0.0808	0.0140	0.0545	0.0070	0.0111	0.0013	0.0018	0.0117	0.0004	0.0000	0.0000	0.0075	0.0000	0.0070	0.0115	0.0000	0.0000	0.0000
1992	73	0.0000	0.0000	0.0000	0.0167	0.0000	0.0000	0.0092	0.0000	0.0000	0.0762	0.3357	0.2137	0.0042	0.0804	0.0971	0.0181	0.0210	0.0759	0.0000	0.0000	0.0120	0.0120	0.0139	0.0139	0.0000	0.0000	0.0000	0.0000
1993	203	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0024	0.0052	0.0496	0.1810	0.2957	0.1923	0.0740	0.0363	0.0659	0.0223	0.0163	0.0156	0.0152	0.0095	0.0067	0.0000	0.0000	0.0119	0.0000	0.0000	0.0000
1994	524	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0066	0.0549	0.2554	0.2474	0.1550	0.0333	0.0473	0.1044	0.0079	0.0378	0.0345	0.0000	0.0000	0.0039	0.0000	0.0000	0.0116	0.0000	0.0000
1995	147	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0096	0.0629	0.1714	0.2283	0.2275	0.0729	0.0620	0.0493	0.0628	0.0222	0.0011	0.0052	0.0005	0.0128	0.0056	0.0000	0.0056	0.0000	0.0000
1996	80	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.1822	0.1266	0.1862	0.1851	0.1142	0.0541	0.0355	0.0382	0.0285	0.0262	0.0013	0.0000	0.0178	0.0028	0.0000	0.0000	0.0000	0.0000
1997	68	0.0000	0.0000	0.0000	0.0000	0.0066	0.0000	0.0022	0.0000	0.0000	0.0308	0.1146	0.1152	0.0759	0.0918	0.2348	0.1279	0.0757	0.0222	0.0185	0.0000	0.0417	0.0000	0.0279	0.0144	0.0000	0.0000	0.0000	0.0000
1998	149	0.0000	0.0000	0.0003	0.0000	0.0004	0.0001	0.0028	0.0003	0.0008	0.0000	0.1144	0.3183	0.3179	0.1195	0.0567	0.0000	0.0214	0.0117	0.0143	0.0117	0.0041	0.0027	0.0027	0.0000	0.0000	0.0000	0.0000	0.0000
1999	161	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0024	0.0000	0.0114	0.1144	0.2431	0.2047	0.1850	0.1103	0.0278	0.0275	0.0370	0.0163	0.0061	0.0053	0.0013	0.0061	0.0000	0.0000	0.0000	0.0000	0.0000
2000	123	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000	0.0185	0.1679	0.2035	0.2394	0.1609	0.1539	0.0297	0.0107	0.0137	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000
2001	254	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0000	0.0035	0.0106	0.0555	0.2450	0.2111	0.2185	0.0909	0.0658	0.0270	0.0326	0.0054	0.0089	0.0109	0.0000	0.0000	0.0000	0.0107	0.0000	0.0000	0.0000
2002	361	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0001	0.0026	0.0245	0.1438	0.2319	0.1518	0.1951	0.1116	0.0460	0.0276	0.0312	0.0137	0.0103	0.0034	0.0000	0.0065	0.0000	0.0000	0.0000	0.0000	0.0000
2003	329	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1701	0.2933	0.2221	0.1076	0.0376	0.0565	0.0404	0.0188	0.0140	0.0169	0.0037	0.0072	0.0043	0.0037	0.0037	0.0000	0.0000	0.0000
2004	307	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0071	0.0696	0.1634	0.3416	0.2188	0.0648	0.0370	0.0331	0.0264	0.0082	0.0150	0.0000	0.0039	0.0036	0.0035	0.0000	0.0039	0.0000	0.0000
2005	193	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0104	0.0752	0.2107	0.2269	0.1460	0.0578	0.0713	0.0655	0.0345	0.0586	0.0138	0.0142	0.0152	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2006	172	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0323	0.1533	0.2634	0.2681	0.0993	0.0399	0.0352	0.0253	0.0177	0.0169	0.0260	0.0155	0.0010	0.0000	0.0060	0.0000	0.0000	0.0000

Table 2.8. Red snapper: Length compositions from the Marine Recreational Fisheries Statistical Survey (MRFSS).

Year	N	19	22	25	28	31	34	37	40	43	46	49	52	55	58	61	64	67	70	73	76	79	82	85	88	91	94	97	100
1981	44	0.0000	0.0042	0.2369	0.1142	0.1044	0.0000	0.0902	0.1515	0.0148	0.1419	0.0210	0.0210	0.0790	0.0210	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1983	161	0.1298	0.1543	0.1235	0.1226	0.0783	0.1382	0.1088	0.0359	0.0119	0.0082	0.0305	0.0291	0.0000	0.0000	0.0270	0.0013	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1984	370	0.0202	0.0909	0.1885	0.2526	0.1979	0.0905	0.0116	0.0302	0.0864	0.0167	0.0020	0.0056	0.0021	0.0040	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1985	249	0.0229	0.1517	0.0981	0.0823	0.0682	0.0365	0.0267	0.0373	0.1188	0.0007	0.1741	0.0820	0.0880	0.0023	0.0053	0.0000	0.0000	0.0053	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1986	226	0.0137	0.4728	0.0942	0.1833	0.1084	0.0839	0.0000	0.0117	0.0320	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1987	63	0.0000	0.1753	0.0000	0.1151	0.0897	0.1638	0.1737	0.0057	0.0190	0.1357	0.0536	0.0487	0.0000	0.0173	0.0023	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1988	87	0.0000	0.0000	0.8122	0.0722	0.0000	0.1156	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1989	59	0.1287	0.1827	0.1338	0.0708	0.1037	0.1406	0.0730	0.0230	0.0257	0.0395	0.0011	0.0000	0.0314	0.0267	0.0193	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1999	132	0.0000	0.0000	0.0372	0.2508	0.1659	0.0887	0.0602	0.0272	0.0062	0.0419	0.0962	0.0115	0.0564	0.0577	0.0081	0.0343	0.0205	0.0081	0.0043	0.0081	0.0000	0.0000	0.0166	0.0000	0.0000	0.0000	0.0000	0.0000
2000	95	0.0000	0.0000	0.0000	0.0117	0.0209	0.0092	0.0116	0.0000	0.0044	0.0557	0.3529	0.1898	0.1086	0.0364	0.0724	0.0282	0.0124	0.0724	0.0065	0.0039	0.0000	0.0029	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2001	120	0.0000	0.0000	0.0000	0.0000	0.0207	0.0000	0.0250	0.0207	0.0323	0.0557	0.2868	0.2028	0.0756	0.1209	0.0415	0.0330	0.0000	0.0259	0.0043	0.0021	0.0201	0.0302	0.0025	0.0000	0.0000	0.0000	0.0000	0.0000
2002	232	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0003	0.0092	0.0630	0.0991	0.2623	0.1365	0.1142	0.1107	0.1068	0.0620	0.0160	0.0100	0.0057	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000
2003	166	0.0000	0.0000	0.0000	0.0000	0.1273	0.0565	0.0095	0.0496	0.0218	0.0306	0.1296	0.0686	0.0751	0.0321	0.1326	0.0592	0.0783	0.0738	0.0391	0.0043	0.0000	0.0000	0.0106	0.0000	0.0017	0.0000	0.0000	0.0000
2004	156	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0184	0.0594	0.0416	0.1492	0.2301	0.1117	0.1273	0.0969	0.0669	0.0189	0.0239	0.0287	0.0118	0.0053	0.0022	0.0035	0.0043	0.0000	0.0000	0.0000	0.0000
2005	83	0.0000	0.0000	0.0000	0.0000	0.0000	0.0449	0.0200	0.0000	0.0240	0.0231	0.1909	0.2898	0.0662	0.0594	0.0353	0.0216	0.1158	0.0447	0.0282	0.0108	0.0232	0.0000	0.0019	0.0000	0.0000	0.0000	0.0000	0.0000
2006	84	0.0000	0.0247	0.0123	0.0062	0.0062	0.0000	0.0000	0.0000	0.0000	0.0132	0.1886	0.2338	0.0948	0.0193	0.0639	0.0301	0.0000	0.1133	0.0541	0.0108	0.0372	0.0000	0.0265	0.0217	0.0217	0.0000	0.0000	0.0217

Table 2.9. Red snapper: Age compositions from commercial hook & line.

Year	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1992	48	0.0000	0.0000	0.0003	0.5245	0.1156	0.1288	0.1627	0.0625	0.0000	0.0057	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1994	49	0.0000	0.0000	0.0858	0.0404	0.2011	0.2104	0.3775	0.0827	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0022
1996	167	0.0000	0.0008	0.1367	0.0950	0.1504	0.3314	0.1966	0.0302	0.0167	0.0139	0.0114	0.0022	0.0033	0.0038	0.0022	0.0011	0.0011	0.0000	0.0000	0.0032
1997	182	0.0000	0.0146	0.1450	0.3713	0.1777	0.1843	0.0638	0.0166	0.0048	0.0026	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0195
1998	75	0.0000	0.0724	0.4058	0.1118	0.2132	0.0803	0.0471	0.0412	0.0062	0.0070	0.0000	0.0029	0.0000	0.0000	0.0000	0.0029	0.0000	0.0000	0.0000	0.0091
1999	147	0.0000	0.1233	0.6037	0.1903	0.0538	0.0051	0.0068	0.0095	0.0015	0.0015	0.0009	0.0022	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008
2000	226	0.0000	0.1265	0.7345	0.0861	0.0114	0.0170	0.0038	0.0088	0.0061	0.0038	0.0000	0.0000	0.0000	0.0000	0.0010	0.0000	0.0000	0.0000	0.0000	0.0011
2001	144	0.0000	0.1590	0.6282	0.1716	0.0109	0.0160	0.0025	0.0013	0.0020	0.0035	0.0000	0.0010	0.0000	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0034
2003	51	0.0000	0.1281	0.3602	0.4029	0.0671	0.0346	0.0013	0.0000	0.0000	0.0021	0.0000	0.0026	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012
2004	103	0.0000	0.1282	0.4560	0.2686	0.1099	0.0335	0.0008	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0008
2005	140	0.0000	0.0205	0.1922	0.2365	0.1484	0.2563	0.0918	0.0227	0.0092	0.0000	0.0000	0.0000	0.0000	0.0031	0.0154	0.0034	0.0000	0.0006	0.0000	0.0001
2006	189	0.0000	0.0104	0.2738	0.3144	0.1251	0.1124	0.1255	0.0142	0.0172	0.0000	0.0000	0.0000	0.0040	0.0000	0.0028	0.0000	0.0000	0.0000	0.0000	0.0000

Table 2.10. Red snapper: Age compositions from commercial diving.

Year	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2000	106	0.0000	0.4481	0.5120	0.0306	0.0080	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 2.11. Red snapper: Age compositions from the headboat survey.

Year	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	72	0.0417	0.5278	0.1667	0.1667	0.0139	0.0417	0.0278	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0139	0.0000	0.0000	0.0000	0.0000
1978	279	0.0215	0.4050	0.5054	0.0323	0.0179	0.0072	0.0072	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0072
1979	47	0.0000	0.6170	0.1702	0.0426	0.0851	0.0426	0.0426	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1980	94	0.1809	0.5106	0.2340	0.0319	0.0000	0.0213	0.0000	0.0213	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1981	415	0.0265	0.7012	0.1855	0.0337	0.0169	0.0120	0.0048	0.0048	0.0048	0.0000	0.0000	0.0000	0.0024	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0072
1982	134	0.0448	0.4030	0.4030	0.0672	0.0299	0.0075	0.0075	0.0075	0.0075	0.0075	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0075	0.0000	0.0075
1983	754	0.3939	0.4655	0.0942	0.0186	0.0093	0.0066	0.0040	0.0027	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0027
1984	619	0.1599	0.6656	0.1018	0.0178	0.0162	0.0065	0.0048	0.0016	0.0016	0.0032	0.0048	0.0000	0.0032	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0128
1985	511	0.0431	0.7652	0.1605	0.0137	0.0020	0.0039	0.0000	0.0020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0020	0.0000	0.0020	0.0020	0.0039
1986	192	0.0521	0.4531	0.4115	0.0573	0.0104	0.0052	0.0052	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0052
1987	93	0.1613	0.2473	0.5054	0.0645	0.0215	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1989	57	0.0877	0.4035	0.3860	0.0702	0.0175	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0175	0.0000	0.0000	0.0000	0.0175	0.0000	0.0000	0.0000
1996	124	0.0000	0.0081	0.2742	0.1210	0.1048	0.2419	0.1129	0.0323	0.0242	0.0161	0.0242	0.0081	0.0000	0.0081	0.0000	0.0000	0.0000	0.0000	0.0000	0.0243

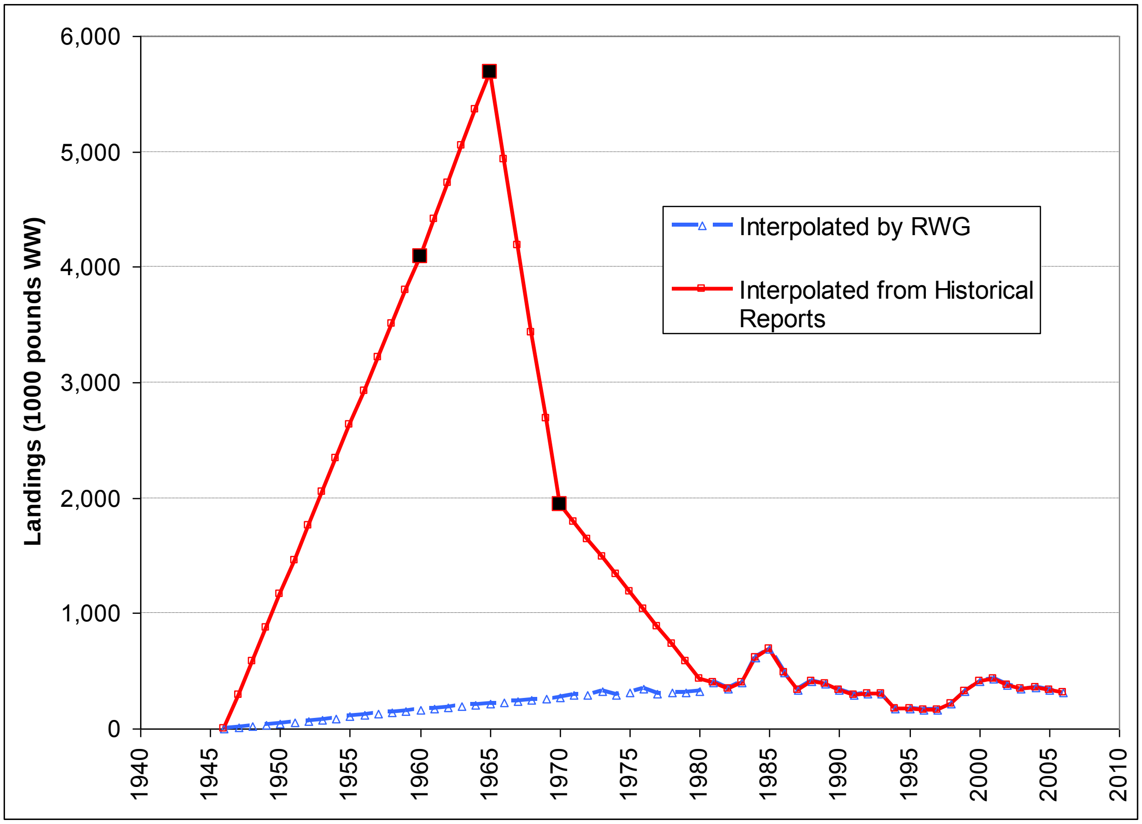
Table 2.12. Red snapper: Age compositions from the Marine Recreational Fisheries Statistical Survey (MRFSS).

Year	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2001	75	0.0000	0.2533	0.5067	0.1600	0.0267	0.0267	0.0133	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0133
2002	386	0.0000	0.2409	0.5492	0.1192	0.0440	0.0207	0.0078	0.0078	0.0026	0.0026	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0052
2003	389	0.0000	0.2314	0.3650	0.2622	0.0771	0.0129	0.0103	0.0026	0.0129	0.0129	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0026	0.0000	0.0000	0.0104
2004	311	0.0000	0.2797	0.3859	0.1640	0.0900	0.0354	0.0032	0.0032	0.0064	0.0064	0.0000	0.0000	0.0096	0.0032	0.0000	0.0000	0.0000	0.0000	0.0000	0.0128
2005	256	0.0000	0.1055	0.4570	0.2500	0.1328	0.0273	0.0078	0.0000	0.0000	0.0000	0.0039	0.0039	0.0000	0.0078	0.0000	0.0000	0.0000	0.0000	0.0000	0.0039

Table 2.13. Red snapper: Indices of abundance and coefficients of variation, as used in assessment (base).

	Catch per Unit Effort (CPUE)			Coefficient of Variation (CV)		
	Logbook (Pounds WW)	Recreational (Numbers)		Commercial	Recreational	
Year	Hook & Line	Headboat	MRFSS	Hook & Line	Headboat	MRFSS
1976		3.13			0.05	
1977		2.08			0.06	
1978		2.12			0.05	
1979		2.14			0.05	
1980		1.13			0.08	
1981		2.78			0.05	
1982		1.04			0.08	
1983		1.70	1.72		0.06	0.14
1984		1.55	1.57		0.06	0.12
1985		2.29	1.36		0.05	0.14
1986		0.51	0.72		0.10	0.26
1987		0.61	0.65		0.10	0.30
1988		0.56	0.70		0.10	0.20
1989		0.95	0.58		0.08	0.14
1990		0.99	0.20		0.08	0.24
1991		0.62	0.68		0.10	0.22
1992		0.08	1.07		0.30	0.12
1993	1.05	0.21	1.15	0.16	0.17	0.19
1994	0.86	0.22	0.74	0.16	0.17	0.17
1995	0.88	0.30	0.76	0.17	0.15	0.13
1996	0.69	0.20	0.66	0.20	0.20	0.23
1997	0.61	0.22	1.08	0.23	0.23	0.28
1998	0.69	0.18	0.80	0.24	0.20	0.17
1999	0.85	0.29	1.48	0.22	0.15	0.10
2000	0.87	0.39	1.34	0.24	0.13	0.10
2001	1.35	0.82	1.12	0.16	0.08	0.09
2002	1.48	1.01	0.99	0.15	0.08	0.11
2003	1.22	0.52	1.15	0.19	0.12	0.11
2004	1.52	0.97	1.29	0.20	0.08	0.09
2005	1.26	0.90	1.21	0.22	0.08	0.09
2006	0.68	0.47	0.98	0.30	0.13	0.13

Figure 2.1. Comparison of red snapper recreational landings, including the original interpolated values provided by the Recreational Working Group (RWG) and the interpolation from historical reports by the Assessment Panel. Solid squares represent landings reported in Salt-Water Angling Surveys (Clark, 1962; Deuel and Clark, 1968; Deuel, 1973).



3 Stock Assessment Models and Results

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 red porgy, black sea bass, tilefish, snowy grouper, and gag grouper.

3.1.1.2 **Data Sources** The catch-at-age model was fit to data from each of the four primary fisheries on southeastern U.S. red snapper: commercial hook and line, commercial diving, general recreational, and headboat. These data included annual landings in whole weight by fishery, annual discard mortalities by fishery (excluding commercial diving), annual length composition of landings by fishery, annual age composition of landings by fishery, and three fishery dependent indices of abundance (commercial hook and line, general recreational, and headboat). These data are tabulated 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). 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 (0.9 deaths per released fish in the commercial sector and 0.4 in the recreational).

3.1.1.3 **Model Configuration and Equations** Model equations are detailed in Table 3.1 and AD Model Builder code for implementation in Appendices B and C. A general description of the assessment model follows:

Natural mortality rate The natural mortality rate (M) was assumed constant over time, but variable 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 by a scalar multiple to provide a fraction (1.4%) of survivors at the oldest age consistent with the findings of Hoenig (1983) and discussed in Hewitt and Hoenig (2005).

Stock dynamics In the assessment model, new biomass was acquired through growth and recruitment, while abundance of existing cohorts experienced exponential decay from fishing and natural mortality. The population was assumed closed to immigration and emigration. The oldest age class 20+ allowed for the accumulation of fish (i.e., plus group). The initial stock biomass was assumed to be less than the unfished (virgin) level, because moderate landings had occurred prior to the first year of the model. Initial biomass and abundance assumed the unfished age structure but with number at age discounted by a fixed proportion.

Growth and maturity Mean size at age (total length) was modeled with the von Bertalanffy equation, and weight at age (whole weight) as a function of length. Maturity at age of females was modeled with a logistic equation. Parameters of growth, length-weight conversion, and maturity were estimated by the DW and were treated as input to the assessment model. For fitting size composition data, the distribution of size at age was assumed normal with CV estimated by the assessment model.

Spawning biomass Spawning biomass (in units of mt) was modeled as the mature female biomass, assuming a 50 : 50 sex ratio. It was computed each year from number at age when spawning peaks. For red snapper, peak spawning was considered to occur at the midpoint of the year.

Recruitment Recruitment was predicted from spawning biomass using a Beverton–Holt spawner-recruit model. In years when composition data could provide information on year-class strength (1974–2006), estimated recruitment was conditioned on the Beverton–Holt model with autocorrelated residuals. In years prior, recruitment followed the Beverton–Holt model precisely (similar to an age-structured production model).

Landings Time series of landing from four fisheries were modeled: commercial handline, commercial diving, headboat, and general recreational (MRFSS). Prior to 1972, the headboat fishery was considered part of the general recreational fishery. Landings were modeled via the Baranov catch equation (Baranov 1918), in units of 1000 lb whole weight.

Discards Starting in 1984 with the implementation of size-limit regulations, time series of discard mortalities (in units of 1000 fish) were modeled for each fishery except commercial diving. As with landings, discard mortalities were modeled via the Baranov catch equation (Baranov 1918), which required estimates of discard selectivities (described below) and release mortality rates.

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 Selectivities were estimated using a parametric approach. For landings from commercial diving, selectivity was estimated as a double-logistic (dome-shaped) model; for landings from the other three fisheries, selectivities were estimated as a 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 the three different periods (no regulations prior to 1984, 12-inch limit during 1984–1991, and 20-inch limit during 1992–2006). The exception was commercial diving, which had composition data only in the most recent period, and thus selectivity for this fishery was assumed constant through time. In the first period, composition data were not collected from commercial fisheries and were sparse from MRFSS; in this period, most composition data were collected by the headboat sampling program. Thus, selectivity in the first period was assumed the same for commercial hook and line, headboat, and general recreational fisheries. In addition, the slope of selectivity of the general recreational fishery in the second period of regulations was not estimated, but was fixed at a value to approximate knife-edge selection.

Selectivities of discards could not be estimated directly, because composition data (both age and length) of discards were lacking. Instead, selectivities of discards were computed in three stages: First, a vector of selectivity at age was computed as one minus a logistic model, with that model's slope parameter set at the estimate from the fishery and the 50% selection parameter set at the age corresponding to the size limit. Second, the vector was rescaled to have a maximum value of one for ages 2+. Third, a value of discard selectivity at age 1 was assumed to be 0.5 (0.25 or 0.75 in sensitivity runs). This method assumed that discards consisted primarily of undersized fish, and that age-1 fish were partially vulnerable to fishing gear.

Indices of abundance The model was fit to three fishery dependent indices of abundance: headboat (1976–2006), MRFSS (1983–2006), and commercial handline (1993–2006). Predicted indices were computed from number at age at the midpoint of the year.

The DW and AW agreed that catchability has likely increased over time as a result of technological progress. To reflect such improvements, 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 stocks in the U.S. Atlantic and Gulf of Mexico. The lower bound of the range was chosen to represent the status quo assumption of constant catchability; the range itself is consistent with productivity increases 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 §3.1.1.5. Computed benchmarks included MSY, fishing mortality rate at MSY (F_{MSY}), and total mature biomass at MSY ($\mathrm{SSB}_{\mathrm{MSY}}$). 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.

Fitting criterion The fitting criterion was a maximum likelihood approach in which observed landings were fit closely, and the observed length and age compositions, abundance indices, and discards were fit to the degree that they were compatible. Landings, discards, and index data were fit using a lognormal likelihood. Composition data were fit using a multinomial likelihood.

The total likelihood also included penalty terms to discourage (1) fully selected F greater than 3.0 in any year and (2) 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 components can only be 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 four time series of landings data were grouped, so that a single weight was applied to all four landings components. Similarly the discard components were grouped, the index components were grouped, the age composition components were grouped, and the length composition components were grouped. Groups were separated only if necessary based on examination of initial model runs.

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 an individual model run 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 used in the base model are listed in Table 3.1.

Configuration of base run and sensitivity analyses A base model run was configured as described above and in Table 3.1. Sensitivity of results to the base configuration was examined through sensitivity and retrospective analyses. These runs vary from the base run as follows:

- S1: Low M at age, computing by rescaling the Lorenzen estimates to provide cumulative survival to the upper bound (5%) of Hoenig (1983)
- S2: High M at age, computing by rescaling the Lorenzen estimates to provide cumulative survival to the lower bound (1%) of Hoenig (1983)
- S3: Slope of linear annual increase in catchability is 0.00 (i.e., constant catchability q)
- S4: Slope of linear annual increase in catchability is 0.04
- S5: Recruitment deviations begin in 1972
- S6: Recruitment deviations begin in 1976
- S7: Low values of recreational landings prior to 1981, as provided by the DW
- S8: Recreational landings prior to 1981 as in the base run, but scaled by an estimated parameter of multiplicative bias
- S9: Commercial release mortality rate of 0.7
- S10: Commercial release mortality rate of 0.8
- S11: Commercial release mortality rate of 1.0
- S12: Recreational release mortality rate of 0.2
- S13: Recreational release mortality rate of 0.6
- S14: Selectivity of age-1 discards assumed to be 0.25
- S15: Selectivity of age-1 discards assumed to be 0.75
- S16: Steepness fixed at 0.8
- S17: Steepness fixed at 0.6
- S18: Retrospective analysis with terminal year of 2005
- S19: Retrospective analysis with terminal year of 2004
- S20: Retrospective analysis with terminal year of 2003
- S21: Retrospective analysis with terminal year of 2002
- S22: Retrospective analysis with terminal year of 2001
- S23: Initial biomass relative to carrying capacity $B_1/K = 0.95$
- S24: Initial biomass relative to carrying capacity $B_1/K = 0.90$
- S25: Initial biomass relative to carrying capacity $B_1/K = 0.85$
- S26: Initial biomass relative to carrying capacity $B_1/K = 0.80$

- S27: Initial biomass relative to carrying capacity $B_1/K = 0.70$
- S28: Initial biomass relative to carrying capacity $B_1/K = 0.65$
- S29: Initial biomass relative to carrying capacity $B_1/K = 0.60$
- S30: Initial biomass relative to carrying capacity $B_1/K = 0.55$
- S31: Initial biomass relative to carrying capacity $B_1/K = 0.50$

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). Expected value data were generated deterministically from input parameter values, without any process or sampling error. These data were then analyzed via 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 provides evidence that all parameters could be properly identified. It further suggests that the assessment model is 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 each fishery in each period of fishing regulations, Beverton–Holt parameters including autocorrelation, annual recruitment deviations, catchability coefficients associated with abundance indices, and CV of size at age. Estimated parameters are identified in Table 3.1.

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

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,

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

where R_0 is virgin recruitment, h is steepness, and Φ_F is spawning potential ratio given growth, maturity, and total mortality at age (including natural, fishing, and discard mortality rates). The R_{eq} and mortality schedule imply an equilibrium age structure and an average sustainable yield (ASY). The estimate of F_{MSY} is the F giving the highest ASY (excluding discards), and the estimate of MSY is that ASY. The estimate of $\mathrm{SSB}_{\mathrm{MSY}}$ 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 the effort-weighted selectivities at age estimated over the last three years (2004–2006), a period of unchanged regulations.

The maximum fishing mortality threshold (MFMT) is defined by the SAFMC as F_{MSY}, and the minimum stock size threshold (MSST) as $(1-M)\mathrm{SSB}_{\mathrm{MSY}}$ (Restrepo et al. 1998), with constant M defined here as 0.078. 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 (2006).

In addition to the MSY-related benchmarks, proxies were computed based on per recruit analyses. These proxies include F_{max}, $F_{30\%}$, and $F_{40\%}$, along with their associated yields. The value of F_{max} is defined as the F that maximizes yield per recruit; the values of $F_{30\%}$ and $F_{40\%}$ as those Fs corresponding to 30% and 40% spawning potential ratio (i.e., spawners per recruit relative to that at the unfished level). These quantities may serve as proxies for F_{MSY}, if the spawner-recruit relationship cannot be estimated reliably. Mace (1994) recommended $F_{40\%}$ as a proxy; however, later studies have found that $F_{40\%}$ is too high across many life-history strategies (Williams and Shertzer 2003) and can lead to undesirably low levels of biomass and recruitment (Clark 2002).

3.1.1.6 Uncertainty and Measures of Precision

The effects of uncertainty in model structure was examined by applying two assessment models—the catch-at-age model and a surplus-production model—with quite different mechanistic structure. For each model, uncertainty in data or assumptions was examined through sensitivity runs.

Precision of benchmarks was computed by parametric bootstrap. The bootstrap procedure generated lognormal recruitment deviations, with variance and autocorrelation as estimated by the assessment model. It then re-estimated the Beverton–Holt spawner-recruit curve and its associated MSY benchmarks. The procedure was iterated $n = 1000$ times, and the 10^{th} and 90^{th} percentiles of each benchmark were used to indicate uncertainty.

Uncertainty in the projections was computed through Monte Carlo simulations, with time series of future recruitments determined by random lognormal deviation (described in §3.1.1.7). The variance of this distribution was that estimated in the assessment, as was the autocorrelation of residuals. The 10^{th} and 90^{th} percentiles from $n = 1000$ projection replicates were used to quantify uncertainty in future time series.

3.1.1.7 Projection methods

Projections were run to predict stock status in years after the assessment, 2007–2040. This time frame of 34 years reflects the sum of mean generation time (20 years, §III(2)) and the number of years for spawning biomass to reach $\mathrm{SSB}_{\mathrm{MSY}}$ under $F = 0$. 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 2006, the projections required a two-year initialization period (2007–2008). The initial abundance at age in the projection (start of 2007), other than at age 0, was taken to be the 2006 estimates from the assessment, discounted by 2006 natural and fishing mortalities. The initial abundance at age 0 was computed using the estimated spawner-recruit model and the 2006 estimate of SSB. The fully selected fishing mortality rate in the initialization period was taken to be the geometric mean of fully selected F during 2004–2006.

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. 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,

$$R_y = \bar{R}_y \exp(\epsilon_y). \tag{2}$$

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).

The Monte Carlo procedure generated 1000 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 by the 10^{th} and 90^{th} percentiles of the 1000 stochastic projections.

Projection scenarios Several constant-F projection scenarios were considered:

- Scenario 1: $F = 0$
- Scenario 2: $F = F_{\text{current}}$, defined as the geometric mean F of 2004–2006
- Scenario 3: $F = F_{\text{MSY}}$
- Scenario 4: $F = 65\%F_{\text{MSY}}$
- Scenario 5: $F = 75\%F_{\text{MSY}}$
- Scenario 6: $F = 85\%F_{\text{MSY}}$
- Scenario 7: $F = F_{\text{rebuild}}$, defined as the maximum F that allows rebuilding by the recovery time horizon

In addition, several discard-only projections were considered. These projections were structured as described above, with two exceptions: (1) commercial diving was excluded and (2) fishery-specific values of F that would have went toward landings were discounted by the release mortality rate. This approach, in which all fish caught were modeled as released, treats the fishery as consisting of bycatch associated with targeting other species. A tacit assumption is that any individual fish could be caught only once per year. The discard-only projections included the following scenarios:

- Scenario 8: $F = F_{\text{current}}$, but all fish caught were released and subjected to release mortality rates of 0.9 in the commercial sector and 0.4 in the headboat and recreational sectors
- Scenario 9: $F = F_{\text{current}}$, but all fish caught were released and subjected to release mortality rates of 0.8 in the commercial sector and 0.2 in the headboat and recreational sector
- Scenario 10: $F = F_{\text{current}}$, but all fish caught were released and subjected to release mortality rates of 1.0 in the commercial sector and 0.6 in the recreational sector
- Scenario 11: $F = F_{\text{rebuild}}$, given that all fish caught were released and subjected to release mortality rates of 0.9 in the commercial sector and 0.4 in the headboat and recreational sector
- Scenario 12: $F = F_{\text{rebuild}}$, given that all fish caught were released and subjected to release mortality rates of 0.7 in the commercial sector and 0.4 in the headboat and recreational sector

When interpreting the discard-only projections, one should keep in mind that the distribution of full F among the various fisheries is different from that in the assessment, which may lead to some inconsistency between projections and benchmarks from the assessment (e.g., fishing at F_{MSY} may lead to an equilibrium stock size other than SSB_{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 3.1). 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 3.2–3.9). 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 3.10–3.13). In addition, it fit well to observed discards (Figures 3.14–3.16).

Fits to indices of abundance were reasonable (Figures 3.17–3.19). The three indices were positively correlated. Since the mid-1990s, indices showed an increasing trend in general, but during the last three years, a decreasing trend.

3.1.2.2 Parameter Estimates Estimates of all parameters from the catch-at-age model are shown in Appendix D. The estimated coefficient of variation of length at age was $\widehat{\text{CV}} = 11.57\%$ (Figure 3.20).

3.1.2.3 Stock Abundance and Recruitment Estimated abundance at age shows truncation of the oldest ages during the 1950s and 1960s, from which the stock has not yet recovered (Table 3.2). Annual number of recruits is shown in Table 3.2 (age-1 column) and in Figure 3.21. Notable strength in year classes was predicted to have occurred in 1983 and 1984, and again in 1998 and 1999.

3.1.2.4 Stock Biomass (total and spawning stock) Estimated biomass at age follows a similar pattern of truncation as did abundance (Tables 3.3,3.4). Total biomass and spawning biomass show nearly identical trends—sharp decline during the 1950s and 1960s, continued decline during the 1970s, and stable but low levels since 1980 (Figure 3.22, Table 3.5).

3.1.2.5 **Fishery Selectivity** Estimated selectivities of landings from commercial handline shift toward older fish with implementation of each new minimum size regulation (12 inches in 1984 and then 20 inches in 1992) (Figure 3.23). In the most recent period, fish were estimated to be almost fully selected by age 4. Selectivity of landings from commercial diving was estimated to be dome-shaped with a peak at age 9 and 10 (Figure 3.24). Similar to commercial handline, landings from headboat fishery showed a shift toward older fish, with full selection at age 4 in the most recent period (Figure 3.25), as did landings from the general recreational fishery, with full selection at age 3 in the most recent period (Figure 3.26).

Estimated selectivities of discard mortalities were similar across the commercial handline, headboat, and general recreational fisheries (Figure 3.27 – Figure 3.29). These selectivities included age-1 and age-2 fish in the period 1984–1991, when the 12-inch size limit was in place. They additionally included age-3 fish in the period 1992–2006, when the 20-inch size limit was in place.

Average selectivities of landings and of discard mortalities were computed from F-weighted selectivities in the most recent period of regulations (Figure 3.30). These average selectivities were used to compute benchmarks and in projections. All selectivities from the most recent period, including average selectivities, are presented in Table 3.6.

3.1.2.6 **Fishing Mortality** The estimated time series of fishing mortality rate (F) shows a generally increasing trend from the 1950s through the mid-1980s, and since 1985 has fluctuated around a mean near $F = 1.02$ (Figure 3.31). In the most recent years, the majority of full F comprised commercial handline landings, general recreational landings, and general recreational discard mortalities (Figure 3.31, Table 3.7).

Full F at age is shown in Table 3.8. 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 (commercial diving, discards) have dome-shaped selectivity.

Throughout most of the assessment period, estimated landings and discard mortalities in number of fish have been dominated by the recreational sector (Figures 3.32, 3.33). Table 3.9 shows total landings at age in numbers, Table 3.10 in metric tons, and Table 3.11 in 1000 lb.

3.1.2.7 **Stock-Recruitment Parameters** The estimated Beverton–Holt spawner-recruit curve is shown in Figure 3.34. Variability about the curve was estimated only at low levels of spawning biomass, because composition data required for estimating recruitment deviations became available only after the stock was depleted. The effect of density dependence on recruitment can be examined graphically via the estimated recruits per spawner as a function of spawners (Figure 3.35). Estimated parameters were as follows: steepness $\hat{h} = 0.95$, $\widehat{R_0} = 604909.7$, first-order autocorrelation $\hat{\varrho} = 0.33$, and bias correction $\hat{\varsigma} = 1.1$. Uncertainty in these parameters was estimated through bootstrap analysis of the spawner-recruit curve (Figure 3.36).

3.1.2.8 **Per Recruit and Equilibrium Analyses** Static spawning potential ratio (static SPR) shows a trend of marked decrease from the beginning of the assessment period until the late 1970's, and since has remained relatively constant at levels between 1% and 3% (Figure 3.37, Table 3.5). 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 (Figure 3.38), as were equilibrium landings and spawning biomass (Figures 3.39). Equilibrium landings and discards were also computed as functions of biomass B, which itself is a function of F (Figure 3.40). As in computation of MSY-related benchmarks, per recruit analyses applied the most recent selectivity patterns averaged across fisheries, weighted by F from the last three years (2004–2006). Per-recruit estimates were $F_{\max} = 0.12$, $F_{30\%} = 0.10$, and $F_{40\%} = 0.07$ (Figure 3.38, Table 3.12). For this stock of red snapper, F_{MSY} corresponded to an F that provided 28% SPR (i.e., $F_{28\%}$), but of course, a proxy is unnecessary if F_{MSY} is estimated directly.

3.1.2.9 **Benchmarks / Reference Points / ABC values** As described in §3.1.1.5, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the estimated spawner-recruit curve with bias correction (Figure 3.34). 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 bootstrap analysis of the spawner-recruit curve, as described in §3.1.1.6.

Estimates of benchmarks are summarized in Table 3.12. Point estimates of MSY-related quantities were $F_{\text{MSY}} = 0.112/\text{yr}$, MSY = 2,318,939 lb, $B_{\text{MSY}} = 11,734$ mt, and $\text{SSB}_{\text{MSY}} = 5184$ mt. Distributions of these benchmarks are shown in Figure 3.41.

3.1.2.10 **Status of the Stock and Fishery** Estimated time series of B/B_{MSY} and $\text{SSB}/\text{SSB}_{\text{MSY}}$ show similar patterns: initial status well above the MSY benchmark, steep decline during the 1950s and 1960s, continued but less steep decline during the 1970s, and stable at low levels since 1980 (Figure 3.42, Table 3.5). Current stock status was estimated to be $\text{SSB}_{2006}/\text{SSB}_{\text{MSY}} = 0.037$ and $\text{SSB}_{2006}/\text{MSST} = 0.041$, indicating that the stock is overfished (Table 3.12).

The estimated time series of F/F_{MSY} shows a generally increasing trend from the 1950s through the mid-1980s, and since 1985 has fluctuated about a mean near 9.1 (Figure 3.43, Table 3.5). The time series indicates that overfishing has been occurring since 1960, with the current estimate at $F_{2006}/F_{\text{MSY}} = 7.513$ (Table 3.12).

3.1.2.11 **Evaluation of Uncertainty** Uncertainty in results of the base assessment model was evaluated through sensitivity and retrospective analyses, as described in §3.1.1.3. Plotted are time series of F/F_{MSY} and $\text{SSB}/\text{SSB}_{\text{MSY}}$ for sensitivity to natural mortality (Figure 3.44), increase in catchability (Figure 3.45), starting year of recruitment deviations (Figure 3.46), recreational landings prior to 1981 (Figure 3.47), discard mortality rates (Figure 3.48), discard selectivity of age-1 fish (Figure 3.49), steepness (Figure 3.50), retrospective error (Figure 3.51), and initial biomass relative to carrying capacity (Figure 3.52). Retrospective analyses did not show any concerning trends, and in general, results of sensitivity analyses were qualitatively the same as those of the base model run: the stock is overfished and is experiencing overfishing (Table 3.13).

3.1.2.12 **Projections** Projection scenario 1, in which $F = 0$, predicted the stock to recover to the level of SSB_{MSY} in 2020 (Figure 3.53, Table 3.14). That duration plus the 20-year generation time (§III(2)) defined the rebuilding time frame such that recovery occurs by the end of year 2040. Thus, all projections were run through the year 2040.

Projection scenario 2, in which $F = F_{current}$, predicted the stock to decline even lower than estimates from the end of the assessment (Figure 3.54, Table 3.15). If F is reduced to F_{MSY}, as in scenario 3, the stock was predicted to begin recovery, but not to the level of SSB_{MSY} within the rebuilding time frame (Figure 3.55, Table 3.16). If F is reduced to 65%, 75%, or 85% of F_{MSY}, as in scenarios 4, 5, or 6 respectively, the stock was predicted to recover in time. (Figures 3.56–3.58, Tables 3.17– 3.19). The maximum F that allowed rebuilding within the time frame was $F_{rebuild} = 0.109$, about 97 % of F_{MSY} (Figure 3.59, Table 3.20).

Discard-only projections predicted that, under $F = F_{current}$ (minus commercial diving), disallowing the retention of red snapper would not be sufficient to rebuild the stock, whether discard mortality rates were those used in the assessment (scenario 8, Figure 3.60, Table 3.21), lower than those used in the assessment (scenario 9, Figure 3.61, Table 3.22), or higher than those used in the assessment (scenario 10, Figure 3.62, Table 3.23). These results suggest that to rebuild the stock, total catches of red snapper will need to be reduced, not just landings. In discard-only projections, the maximum fishing rate that allowed rebuilding within the time frame was $F_{rebuild} = 0.262$ if discard mortality rates were those used in the base assessment model (scenario 11, Figure 3.63, Table 3.24), and it was $F_{rebuild} = 0.286$ if the commercial discard mortality rate was 0.7 (scenario 12, Figure 3.64, Table 3.25). The fact that these values of $F_{rebuild}$exceed F_{MSY} reflects the difference between selectivity curves used in the discard-only projection and in computation of MSY.

3.2 Model 2: Production model

3.2.1 Model 2 Methods

3.2.1.1 **Overview** Assessments based on age or length structure are often favored because they incorporate more data on the structure of the population. However, these approaches typically involve fitting a large number of parameters 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 red 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.

3.2.1.2 **Data Sources** Data included total landings in weight and three abundance indices, also computed on a weight basis. The three indices were from the commercial logbook (1993–2006), headboat survey (1976–2006), and MRFSS (1983–2006) programs.

All data were input into ASPIC in units of total whole weight. To make the conversion for headboat and recreational fisheries, mean weight per fish was computed for each year. Initial inspection of annual samples of the weight distribution in each fishery indicated substantial variation in mean weight per landed fish from year to year (Figure 3.65, Figure 3.66). Much of this variation is likely an artifact of the sampling process (annual sample sizes ranged from 15 to 370 for the MRFSS survey and 68 to 1370 for headboat surveys). Thus annual mean weights per landed fish were smoothed using local polynomial regression (Cleveland et al. 1992). Fitting was based on weighted least squares, where (statistical) weights for each observation were set to the square root of sample size. All fitting was performed with the function *loess* in the statistical programming language *R* (R Development Core Team 2007). The change in size-limit regulations in 1992 resulted in higher weight per landed fish; however, no change points were considered because of low sample sizes. Nevertheless, modeled weights tracked observed weights (Figure 3.65, Figure 3.66). Although there was a clear case for smoothing annual estimates of mean weight per fish, considerable variability was still evident in estimates of MRFSS landings. Thus estimates of MRFSS landings in numbers were smoothed as well, which was accomplished with a three year moving average (Fig. 3.67). For MRFSS, these smoothed landings in numbers were then multiplied by the smoothed mean weights to compute landings in weight.

Several changes were made to landings to better conform to assumptions made by the primary age-structured assessment model. The beginning of the time series was set to 1946, with extra recreational landings included from 1946 to 1980 to reflect the lack of data on these substantial fisheries (§III(2)). In particular, saltwater angling surveys indicated that recreational landings amounted to 4.1 million lb in 1960 (Clark 1962), 5.7 million lb in 1965 (Deuel and Clark 1968), and 1.9 million lb in 1970 (Deuel 1973).

To include discard mortalities with total removals, total discards in number were multiplied by the discard mortality rate and were then converted to whole weight in pounds. As with the age-structured analysis, discard mortality of 0.4 and 0.9 were applied to recreational fisheries (i.e., headboat and MRFSS) and to the commercial hook and line fishery, respectively (SEDAR 2007). To arrive at a figure in whole pounds, it was necessary to estimate the mean weight of discarded fish. Two scenarios were considered. In the first ("Assumption 1"), the mean weight of discards prior to 1992 (when a 20-inch size limit began) was set to the mean weight of landed fish for each fishery. The implicit assumption here is that the probability a fish was discarded before 1992 did not depend on size. Starting in 1992, it was assumed that all discards were due to the size limit, and the mean weight of discards was set to the mean weight of fish less than 20 inches landed prior to 1992 (Figure 3.68). Discards before 1984 were assumed to be negligible.

The second possibility for mean weight of discarded fish ("Assumption 2") involved decomposition of selectivity into two components reflecting gear selectivity and selectivity of fishermen (i.e., fish kept given caught). Here, selectivity of gear was assumed knife-edge, with 100% selectivity starting at 1 year of age (and 0% before age 1). Next, selectivity of fishermen after this age was assumed due to regulations. For the period starting in 1992, this entailed assuming that fishermen released fish < 20 inches, and for previous years, that fishermen released fish < 12 inches (a 12 inch total length regulation was instituted the year discard estimates became available). Discards before 1984 were assumed to be negligible. Using this approach, it was possible to calculate an average weight for fish in the population by applying a preset level of mortality to gauge the relative frequency of different ages in the population that were subject to discarding. The mean weight associated with this age distribution could then be applied to each time period. The age distribution was computed from the total mortality rates, which included age-specific (Lorenzen) natural mortality rates, as suggested by the SEDAR-15 DW, and a fishing mortality rate of 0.2 (initial ASPIC runs indicated a level of F_{MSY} near 0.2). Estimated age-length relationships indicated that red snapper reach 12 inches of length at an age of 1.26 and reach 20 inches at age 3.11. Numerical integration was then used to calculate a mean weight for fish caught between ages 1.0 and 1.26 for years prior to 1992 and between ages 1.0 and 3.11 for years starting in 1992, assuming that mortality events were piecewise exponentially distributed. Calculated in this manner, the mean total weight for discards was 0.62 lb for 1984–1991 and 1.54 lb for 1992–2006.

One final adjustment was made to index data prior to analysis. To reflect improvements in technology and the ability of fishermen to locate and catch fish, a 2% increase in catchability (q) was assumed for each year starting in 1980. This increase was incorporated by dividing catch per unit effort (CPUE_t) in each fishery by a linearly increasing function, so that

$$\mathrm{CPUE}_t^* = \frac{\mathrm{CPUE_t}}{1 + (t - 1979) \times .02} \tag{3}$$

for every year starting in 1980 ($\mathrm{CPUE}_t^* = \mathrm{CPUE}_t$ for $t < 1980$). The revised index CPUE_t^* was then used in analysis.

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

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

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

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

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

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

Fitting was achieved through maximum likelihood, conditional on the statistical weights and constraints applied. Nonparametric confidence intervals on parameters were estimated through bootstrapping.

To configure a base run of ASPIC, Assumption 2 of mean discard weight (described above) was used, as it was considered the more plausible scenario. However, a sensitivity run used Assumption 1, and another sensitivity run ignored discards entirely.

Three options for the ratio of initial biomass to carrying capacity (B_1/K) were considered. The first option was to estimate it as a parameter in the model; however, using this approach parameter estimates exceeded 1.0. As this result was somewhat implausible, base run estimates of this ratio were fixed to 0.95. A fixed value of $B_1/K = 0.75$, as used in the age-structure model, was also considered to examine sensitivity to this choice. The base model input file appears in Appendix E.

No projections were run using production model methods. Age-structured projections are considered more realistic and thus a better guide for management.

3.2.2 Model 2 Results

3.2.2.1 Model Fit Fits to indices from the base production model are shown in Figures 3.69, 3.70, and 3.71. In general, fits were adequate, although the model predicted that abundance declined earlier than was indicated by the headboat index.

Fits from sensitivity runs were quite similar to those of the base production model (Figures not shown). As described above, these sensitivity runs included variations in assumptions about B_1/K ($B_1/K = 0.75$ or B_1/K estimated) and about discards (no discards or Assumption 1 for mean discard weight).

3.2.2.2 Parameter Estimates and Uncertainty Parameter estimates from the base surplus production model are printed in Table 3.26, along with estimates of bias and precision. These estimates of uncertainty were obtained through nonparametric bootstrapping, as implemented in ASPIC.

3.2.2.3 Stock Abundance and Fishing Mortality Rate Estimates of biomass relative to B_{MSY} and fishing mortality rate relative to F_{MSY} from the production model are shown in Figure 3.72. Estimates of annual biomass have been well below B_{MSY} since the mid-1960s, with possibly some small amount of recovery since implementation of current size limits in 1992. The estimate of F_{2006}/F_{MSY} does not indicate severe overfishing in the terminal year; however, estimates of annual F have exceeded F_{MSY} substantially and regularly over the last half century. In general, the surplus production model indicates conclusions similar to those of the age-structured model regarding 2006 stock status: the stock is overfished and overfishing is occurring.

Sensitivity analyses indicated that qualitative results were invariant to assumptions about starting biomass and discards. All runs produced estimates of current stock status where B_{2006}/B_{MSY} was in the range 0.14–0.18, with estimates of $F/F_{\text{MSY}} > 1$ for nearly all of the last 50 years.

3.2.2.4 Benchmarks, uncertainty Estimates of MSY and related quantities from the surplus production model, together with estimates of uncertainty derived through the bootstrap, are given in Table 3.26.

3.3 Discussion

3.3.1 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. In rebuilding projections, 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 overfished ($\text{SSB}_{2006}/\text{SSB}_{\text{MSY}} = 0.037$) and that overfishing is occurring ($F_{2006}/F_{\text{MSY}} = 7.513$). These results were invariant to the 31 different configurations used in sensitivity runs and retrospective analyses. In addition, the same qualitative findings resulted from the age-aggregated surplus production model and its various sensitivity runs.

3.3.2 Comments on Projections

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

- Initial abundance at age of the projections were based on 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 rebuilding.
- The projections assumed no change in the selectivity applied to discards. As recovery 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. The assessment results suggest that recruitment may be characterized by runs of high or low values, possibly due in part to environmental conditions. If so, rebuilding may be affected.
- Discard-only projections tacitly assumed that any individual fish would be caught only once per year. To the extent that this assumption is violated, discard-only projections may overestimate the velocity of recovery.
- Discard-only projections allocated sources of mortality in different proportions than those used in computing MSY-related benchmarks. Thus discard-only projections are not consistent with benchmarks, in the sense that fishing at F_{MSY} may lead to an equilibrium stock size other than $\mathrm{SSB}_{\mathrm{MSY}}$.

3.4 References

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3.4.1 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	$y \in \{1945 \ldots 2006\}$
Index of ages	a	$a \in \{1 \ldots A\}$, where $A = 20^+$
Index of size-limit periods	r	$r \in \{1 \ldots 3\}$ where 1 = 1945 – 1983 (no size limit), 2 = 1984 – 1991 (12-inch limit), and 3 = 1992 – 2006 (20-inch limit)
Index of length bins	l	$l \in \{1 \ldots 28\}$
Length bins	l'	$l' \in \{190, 220, \ldots, 1000\}$, with values as midpoints and bin size of 30 mm
Index of fisheries	f	$f \in \{1 \ldots 4\}$ where 1=commercial handline, 2=commercial diving, 3=recreational headboat, 4=general recreational (MRFSS)
Index of CPUE	u	$u \in \{1 \ldots 3\}$ where 1 = commercial logbook, 2 = headboat, 3 = MRFSS
Input Data		
Proportion female at age	$\rho_{a,y}$	Constant across ages and years assuming a 50:50 sex ratio
Proportion females mature at age	m_a	Estimated by logistic regression
Observed length compositions	$p^{\lambda}_{(f,u),l,y}$	Proportional contribution of length bin l in year y to fishery f 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
Length comp. sample sizes	$n^{\lambda}_{(f,u),y}$	Number of length samples collected in year y from fishery f or index u
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 (1000 lb whole weight) in year y from fishery f
CVs of landings	$c^{L}_{f,y}$	Annual values estimated for MRFSS; for other sectors, based on understanding of historical accuracy of data

Table 3.1. (continued)

Quantity	Symbol	Description or definition
Observed abundance indices	$U_{u,y}$	$u = 1$, commercial logbook, $y \in \{1993 \ldots 2006\}$ $u = 2$, headboat, $y \in \{1976 \ldots 2006\}$ $u = 3$, MRFSS, $y \in \{1983 \ldots 2006\}$
CVs of abundance indices	$c^U_{u,y}$	$u = \{1 \ldots 3\}$ as above. Annual values estimated from delta-lognormal GLM for commercial and headboat, as PSEs for 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	$D'_{f,y}$	Discards (1000 fish) in year y from fishery $f = 1, 3, 4$.
Discard mortality rate	δ_f	Proportion discards by fishery f that die. Base-model values from the DW were 0.9 for commercial, 0.4 for headboat and MRFSS.
Observed discard mortalities	$D_{f,y}$	$D_{f,y} = \delta_f D'_{f,y}$ for $f = 1, 3, 4$
CVs of dead discards	$c^D_{f,y}$	Annual values estimated (for MRFSS) or assumed
Population Model		
Mean length at age	l_a	Total length; $l_a = L_\infty(1 - \exp[-K(a - t_0)])$ where K, L_∞, and t_0 are parameters estimated by the DW.
CV of l_a	$\hat{c}^{\lambda}_a$	Estimated variation of growth, assumed constant across ages.
Age–length conversion	$\psi_{a,l}$	$\psi_{a,l} = \frac{1}{\sqrt{2\pi}(\hat{c}^{\lambda}_a l_a)} \frac{\exp\left[-(l'_l - l_a)^2\right]}{\left(2(\hat{c}^{\lambda}_a l_a)^2\right)}$, the Gaussian density function. Matrix $\psi_{a,l}$ is rescaled to sum to one across ages.
Individual weight at age	w_a	Computed from length at age by $w_a = \theta_1 l_a^{\theta_2}$ where θ_1 and θ_2 are parameters estimated by the DW
Fishery selectivity	$s_{f,a,r}$	$s_{f,a,r} = \begin{cases} \frac{1}{1+\exp[-\hat{\eta}_{1,f,r}(a-\hat{\alpha}_{1,f,r})]} & : \text{for } f = 1,3,4 \\ \left(\frac{1}{\max s_{f,a,r}}\right)\left(\frac{1}{1+\exp[-\hat{\eta}_{1,f,r}(a-\hat{\alpha}_{1,f,r})]}\right)\left(1 - \frac{1}{1+\exp[-\hat{\eta}_{2,f,r}(a-[\hat{\alpha}_{1,f,r}+\hat{\alpha}_{2,f,r}])]}\right) & : \text{for } f = 2 \end{cases}$ where $\hat{\eta}_{1,f,r}$, $\hat{\eta}_{2,f,r}$, $\hat{\alpha}_{1,f,r}$, and $\hat{\alpha}_{2,f,r}$ are fishery-specific parameters estimated for each regulation period, with the exception of the no-size-limit period ($r = 1$) in which a single selectivity curve was assumed to apply across fisheries. Also, the slope of MRFSS selectivity in period 2 was fixed to approximate a knife-edge curve ($\eta_{1,4,2} = 10.4$). Selectivity of commercial diving is assumed constant across regulation periods. Curves were rescaled, if necessary, to have a maximum of one.

Table 3.1. (continued)

Quantity	Symbol	Description or definition
Discard selectivity	$s'_{f,a,r}$	$s'_{f,a,r} = 1 - \frac{1}{1+\exp[-\hat{\eta}_{1,f,r}(a-\alpha_{1,f,r})]}$: for $f = 1,3,4$; $r = 2,3$ where $\hat{\eta}_{1,f,r}$ is the slope estimated for the fishery selectivity and $\alpha_{1,f,r}$ is fixed at the age corresponding to the size limit. $s'_{f,2+,r}$ rescaled to a maximum of one, then $s'_{f,1,r}$ fixed at 0.5 (0.25 or 0.75 in sensitivity runs).
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	$F^D_{f,a,y}$	$F^D_{f,a,y} = s'_{f,a,r}\hat{F}^D_{f,y}$ where $\hat{F}^D_{f,y}$ is an estimated fully selected fishing mortality rate of discards by fishery
Total fishing mortality rate	F_y	$F_y = \sum_f \left(\hat{F}_{f,y} + \hat{F}^D_{f,y}\right)$
Total mortality rate	$Z_{a,y}$	$Z_{a,y} = M_a + \sum_{f=1}^{4} F_{f,a,y} + \sum_{f=1,3,4} F^D_{f,a,y}$
Abundance at age	$N_{a,y}$	$N_{1,1945} = \gamma\hat{R}_0$ $N_{a+1,1945} = N_{a,1945}\exp(-M_a) \quad \forall a \in (1\ldots A-1)$ $N_{A,1945} = N_{A-1,1945}\frac{\exp(-M_{A-1})}{1-\exp(-M_A)}$ $N_{0,y+1} = \begin{cases} \frac{0.8\hat{R}_0\hat{h}S_y}{0.2\phi_0\hat{R}_0(1-\hat{h})+(\hat{h}-0.2)S_y}\varsigma & \text{for } y+1 < 1974 \\ \frac{0.8\hat{R}_0\hat{h}S_y}{0.2\phi_0\hat{R}_0(1-\hat{h})+(\hat{h}-0.2)S_y}\exp(\hat{R}_{y+1}) & \text{for } y+1 \geq 1974 \end{cases}$ $N_{a+1,y+1} = N_{a,y}\exp(-Z_{a,y}) \quad \forall a \in (1\ldots A-1)$ $N_{A,y} = N_{A-1,y-1}\frac{\exp(-Z_{A-1,y-1})}{1-\exp(-Z_{A,y-1})}$ where 1945 is the initialization year and γ scales the initial abundance relative to the unfished level. Parameters $\hat{R}_0$ (unfished 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 $y \geq 1974$ and are zero otherwise. Bias correction $\varrho = \exp(\sigma^2/2)$, where σ^2 is the variance of recruitment deviations during 1974–2003. 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 $N''_{a,y} = N'_{a,y}$
Unfished abundance at age per recruit at time of spawning	NPR_a	$NPR_1 = 1\exp(-M_1/2)$ $NPR_{a+1} = NPR_a\exp[-(M_a + M_{a+1})/2] \quad \forall a \in (1\ldots A-1)$ $NPR_A = \frac{NPR_{A-1}\exp[-(M_{A-1}+M_A)/2]}{1-\exp(-M_A)}$
Unfished mature biomass per recruit	ϕ_0	$\phi_0 = \sum_a NPR_a w_a \rho_{a,y} m_a$

Table 3.1. (continued)

Quantity	Symbol	Description or definition
Mature biomass	S_y	$S_y = \sum_a N''_{a,y} w_a \rho_{a,y} m_a$ Also referred to as spawning stock biomass (SSB)
Population biomass	B_y	$B_y = \sum_a N_{a,y} w_a$
Landed catch at age	$C_{f,a,y}$	$C_{f,a,y} = \frac{F_{f,a,y}}{Z_{a,y}} N_{a,y}[1 - \exp(-Z_{a,y})]$
Discard mortalities at age	$C^D_{f,a,y}$	$C^D_{f,a,y} = \frac{F^D_{f,a,y}}{Z_{a,y}} N_{a,y}[1 - \exp(-Z_{a,y})]$
Predicted landings	$\check{L}_{f,y}$	$\check{L}_{f,y} = \sum_a C_{f,a,y} w_a$
Predicted discard mortalities	$\check{D}_{f,y}$	$\check{D}_{f,y} = \sum_a C^D_{f,a,y}$
Predicted length compositions	$\check{p}^\lambda_{(f,u),l,y}$	$\check{p}^\lambda_{(f,u),l,y} = \frac{\psi_{a,l} C_{(f,u),a,y}}{\sum_a C_{(f,u),a,y}}$
Predicted age compositions	$\check{p}^\alpha_{(f,u),a,y}$	$\check{p}^\alpha_{(f,u),a,y} = \frac{C_{(f,u),a,y}}{\sum_a C_{(f,u),a,y}}$
Predicted CPUE	$\check{U}_{u,y}$	$\check{U}_{u,y} = \hat{q}_u \sum_a N'_{a,y} s_{u,a,r}$ 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
Negative Log-Likelihood		
Multinomial length compositions	Λ_1	$\Lambda_1 = -\omega_1 \sum_{f,u} \sum_y \left[n^\lambda_{(f,u),y} \sum_l (p^\lambda_{(f,u),l,y} + x) \log \left(\frac{(\check{p}^\lambda_{(f,u),l,y} + x)}{(p^\lambda_{(f,u),l,y} + x)} \right) \right]$ where $\omega_1 = 1$ 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 30 mm wide.
Multinomial age compositions	Λ_2	$\Lambda_2 = -\omega_2 \sum_{f,u} \sum_y \left[n^\alpha_{(f,u),y} \sum_a (p^\alpha_{(f,u),a,y} + x) \log \left(\frac{(\check{p}^\alpha_{(f,u),a,y} + x)}{(p^\alpha_{(f,u),a,y} + x)} \right) \right]$ where $\omega_2 = 1$ 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.
Lognormal landings	Λ_3	$\Lambda_3 = \omega_3 \sum_f \sum_y \frac{\left[\log\left((L_{f,y} + x)/(\check{L}_{f,y} + x)\right)\right]^2}{2(c^L_{f,y})^2}$ where $\omega_3 = 1000$ is a preset weight and x =1e-5 is an arbitrary value to avoid log zero or division by zero
Lognormal discard mortalities	Λ_4	$\Lambda_4 = \omega_4 \sum_f \sum_y \frac{\left[\log\left((\delta_f D_{f,y} + x)/(\check{D}_{f,y} + x)\right)\right]^2}{2(c^D_{f,y})^2}$ for $f = 1, 3, 4$ where $\omega_4 = 1000$ is a preset weight and x =1e-5 is an arbitrary value to avoid log zero or division by zero
Lognormal CPUE	Λ_5	$\Lambda_5 = \sum_u \omega_{5,u} \sum_y \frac{\left[\log\left((U_{u,y} + x)/(\check{U}_{u,y} + x)\right)\right]^2}{2(c^U_{u,y})^2}$ where $\omega_{5,1} = 100$ and $\omega_{5,(2,3)} = 10$ are preset weights for $u = 1, 2, 3$ and x =1e-5 is an arbitrary value to avoid log zero or division by zero

Table 3.1. (continued)

Quantity	Symbol	Description or definition
Constraint on recruitment deviations	Λ_6	$\Lambda_6 = \omega_6 \left[R_{1974}^2 + \sum_{y>1974} (R_y - \hat{\varrho} R_{y-1})^2 \right]$ where R_y are recruitment deviations in log space, $\omega_6 = 100$ is a preset weight and $\hat{\varrho}$ is the estimated first-order autocorrelation
Additional constraint on recruitment deviations	Λ_7	$\Lambda_7 = \omega_7 \left(\sum_{y \geq 2004} R_y^2 \right)$ where $\omega_7 = 1000$ is a preset weight
Constraint on F_y	Λ_8	$\Lambda_8 = \omega_8 \sum_y I_y (F_y - \Psi)^2$ where $\omega_8 = 1000$ is a preset weight, $\Psi = 3.0$ is the max unconstrained F_y, and $I_y = \begin{cases} 1 & : \text{if } F_y > \Psi \\ 0 & : \text{otherwise} \end{cases}$
Total likelihood	Λ	$\Lambda = \sum_{i=1}^{8} \Lambda_i$ Objective function minimized by the assessment model

Table 3.2. Red snapper: Estimated abundance at age (1000 fish) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1945	453.7	360.3	308.1	271.8	243.8	221.1	201.8	185.1	170.3	157.2	145.3	134.5	124.6	115.6	107.3	99.6	92.5	86.0	79.9	1058.2
1946	661.8	360.0	306.8	270.7	242.8	220.1	201.0	184.3	169.6	156.5	144.7	133.9	124.1	115.1	106.8	99.2	92.2	85.6	79.6	1053.9
1947	661.7	525.1	306.4	269.5	241.7	219.2	200.1	183.5	168.9	155.8	144.0	133.3	123.6	114.6	106.4	98.8	91.8	85.3	79.2	1049.1
1948	661.7	524.4	444.5	267.7	239.4	217.0	198.1	181.7	167.2	154.3	142.6	132.0	122.4	113.5	105.3	97.8	90.8	84.4	78.5	1038.8
1949	661.6	523.7	441.6	386.2	236.5	213.7	195.1	178.9	164.7	151.9	140.5	130.0	120.5	111.7	103.7	96.3	89.5	83.1	77.3	1023.0
1950	661.5	523.1	438.6	381.5	339.3	210.0	191.0	175.2	161.3	148.8	137.6	127.3	118.0	109.4	101.6	94.3	87.6	81.4	75.7	1001.9
1951	661.4	522.4	435.5	376.8	333.3	299.6	186.6	170.6	157.1	144.9	133.9	124.0	114.9	106.6	98.9	91.9	85.3	79.3	73.7	975.6
1952	661.3	521.4	431.4	371.1	326.5	291.9	264.1	165.4	151.7	140.0	129.4	119.8	111.0	102.9	95.5	88.7	82.4	76.6	71.2	942.4
1953	661.1	520.9	429.1	366.3	320.5	284.9	256.4	233.2	146.5	134.7	124.5	115.3	106.8	99.1	92.0	85.4	79.3	73.7	68.5	907.1
1954	660.9	520.0	426.0	362.0	314.3	277.9	248.7	225.0	205.3	129.3	119.1	110.3	102.2	94.8	88.0	81.7	75.9	70.5	65.5	867.6
1955	660.6	518.7	421.0	355.8	307.5	269.8	240.2	216.0	196.0	179.3	113.1	104.4	96.7	89.7	83.3	77.3	71.8	66.8	62.0	821.4
1956	660.2	517.8	417.6	349.7	300.5	262.5	231.9	207.4	187.2	170.3	156.1	98.6	91.1	84.5	78.4	72.8	67.6	62.9	58.4	773.4
1957	659.7	516.6	413.6	344.1	293.1	254.5	223.9	198.7	178.3	161.4	147.1	135.0	85.4	78.9	73.3	68.0	63.2	58.7	54.6	722.6
1958	659.0	514.3	405.6	335.0	283.5	244.0	213.4	188.6	167.9	151.1	137.0	125.0	114.9	72.7	67.3	62.5	58.0	53.9	50.1	663.5
1959	658.2	513.1	401.4	326.6	274.4	234.6	203.3	178.7	158.4	141.5	127.5	115.8	105.8	97.3	61.6	57.0	53.0	49.2	45.8	605.7
1960	657.2	510.9	395.0	318.9	263.9	224.0	192.9	167.9	148.1	131.6	117.7	106.3	96.6	88.3	81.3	51.5	47.7	44.3	41.2	545.4
1961	656.0	508.4	387.2	308.9	253.5	212.0	181.2	156.8	137.0	121.1	107.8	96.6	87.3	79.4	72.7	66.9	42.4	39.3	36.5	483.4
1962	654.4	504.9	376.5	295.8	240.0	199.0	167.6	143.9	125.0	109.4	96.9	86.4	77.5	70.1	63.8	58.4	53.8	34.1	31.6	418.6
1963	652.3	501.5	366.6	282.0	225.3	184.7	154.3	130.5	112.5	97.9	85.9	76.2	68.0	61.1	55.3	50.3	46.1	42.5	26.9	355.5
1964	649.7	497.0	354.4	267.3	209.1	168.8	139.4	117.0	99.3	85.8	74.8	65.7	58.3	52.1	46.8	42.4	38.6	35.4	32.6	293.8
1965	646.0	490.2	335.8	247.0	189.5	149.8	121.8	101.0	85.1	72.4	62.7	54.7	48.1	42.8	38.2	34.4	31.1	28.4	26.0	239.8
1966	640.3	480.1	309.0	218.4	163.4	126.6	100.8	82.3	68.5	57.9	49.3	42.8	37.4	32.9	29.3	26.2	23.5	21.3	19.4	182.2
1967	632.2	472.1	291.8	193.7	139.3	105.3	82.2	65.7	53.9	44.9	38.0	32.5	28.2	24.6	21.7	19.3	17.3	15.5	14.1	133.3
1968	621.0	460.6	271.8	173.3	117.1	85.0	64.7	50.7	40.7	33.5	28.0	23.7	20.3	17.6	15.4	13.6	12.1	10.8	9.7	92.3
1969	605.4	446.8	250.3	152.4	98.8	67.4	49.3	37.7	29.7	23.9	19.7	16.5	14.0	11.9	10.4	9.1	8.0	7.1	6.4	60.3
1970	586.8	436.3	244.7	141.5	87.6	57.4	39.4	29.0	22.2	17.5	14.1	11.7	9.8	8.3	7.1	6.2	5.4	4.8	4.2	39.7
1971	569.8	426.0	247.1	143.0	84.1	52.6	34.7	24.0	17.7	13.6	10.7	8.7	7.2	6.0	5.1	4.4	3.8	3.3	2.9	27.1
1972	555.0	411.6	235.6	141.0	83.0	49.3	31.1	20.6	14.3	10.5	8.1	6.4	5.2	4.3	3.6	3.1	2.6	2.3	2.0	18.0
1973	540.4	399.4	224.0	132.3	80.5	47.9	28.6	18.1	12.1	8.4	6.2	4.8	3.8	3.1	2.5	2.1	1.8	1.6	1.4	11.9
1974	478.7	389.0	217.6	125.9	75.6	46.5	27.8	16.7	10.6	7.1	4.9	3.7	2.8	2.2	1.8	1.5	1.3	1.1	0.9	7.8
1975	595.1	338.9	196.3	113.3	66.7	40.5	25.1	15.1	9.1	5.8	3.9	2.7	2.0	1.5	1.2	1.0	0.8	0.7	0.6	4.8
1976	427.8	413.4	156.9	93.8	55.0	32.7	20.0	12.4	7.5	4.5	2.9	1.9	1.4	1.0	0.8	0.6	0.5	0.4	0.3	2.7
1977	448.2	296.5	189.3	74.1	45.0	26.7	16.0	9.8	6.1	3.7	2.2	1.4	1.0	0.7	0.5	0.4	0.3	0.2	0.2	1.5
1978	387.3	304.9	124.6	82.0	32.7	20.1	12.0	7.2	4.4	2.8	1.7	1.0	0.7	0.4	0.3	0.2	0.2	0.1	0.1	0.8
1979	234.2	259.8	120.1	50.6	33.9	13.6	8.4	5.1	3.1	1.9	1.2	0.7	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.4
1980	513.6	158.8	107.7	51.3	22.0	14.9	6.0	3.7	2.3	1.4	0.8	0.5	0.3	0.2	0.1	0.1	0.1	0.0	0.0	0.2
1981	142.6	348.9	66.3	46.4	22.5	9.7	6.6	2.7	1.7	1.0	0.6	0.4	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.1
1982	279.9	98.1	154.6	30.3	21.6	10.6	4.6	3.2	1.3	0.8	0.5	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.1
1983	545.9	193.1	44.0	71.6	14.3	10.3	5.1	2.2	1.5	0.6	0.4	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
1984	750.1	367.0	76.9	18.1	29.9	6.0	4.4	2.2	1.0	0.7	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0

Table 3.2. (continued)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1985	212.8	462.5	137.4	25.9	6.2	10.3	2.1	1.5	0.8	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	282.8	131.9	172.6	47.4	9.1	2.2	3.7	0.7	0.5	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	359.5	169.9	49.9	67.7	18.9	3.7	0.9	1.5	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988	277.1	234.0	75.7	22.5	31.1	8.8	1.7	0.4	0.7	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989	279.5	180.7	100.2	32.7	9.9	13.8	3.9	0.8	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	251.3	186.5	80.9	37.8	12.6	3.8	5.4	1.5	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991	339.5	156.1	73.3	31.9	15.1	5.1	1.6	2.2	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1992	164.1	234.4	79.8	35.1	15.5	7.4	2.5	0.7	1.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1993	126.8	121.2	140.8	42.4	16.8	7.4	3.5	1.1	0.3	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1994	127.7	89.1	66.6	66.3	16.1	6.3	2.8	1.3	0.4	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1995	126.6	84.2	47.4	34.6	32.2	7.8	3.0	1.3	0.6	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	178.9	82.9	43.9	23.9	16.3	15.1	3.6	1.4	0.6	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1997	184.4	122.7	46.3	22.8	11.1	7.5	7.0	1.6	0.6	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1998	405.2	131.6	74.5	25.4	10.7	5.2	3.5	3.2	0.7	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	437.3	289.4	74.6	38.2	12.1	5.1	2.5	1.6	1.5	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	350.3	310.6	158.7	36.5	17.3	5.5	2.3	1.1	0.7	0.6	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	265.8	242.3	162.4	76.4	17.1	8.1	2.5	1.0	0.5	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	294.3	176.6	118.5	73.9	33.5	7.4	3.5	1.0	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	202.6	195.7	88.7	56.9	35.4	16.0	3.5	1.5	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2004	257.2	134.5	98.0	44.2	30.5	19.0	8.5	1.8	0.8	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2005	266.9	167.0	64.6	45.8	21.3	14.7	9.1	3.9	0.8	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006	268.8	176.8	81.8	30.5	22.6	10.6	7.3	4.4	1.9	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2007	276.0	184.1	92.6	41.3	16.1	12.0	5.6	3.9	2.4	1.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3.3. Red snapper: Estimated biomass at age (mt) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1945	102.9	289.8	513.8	729.1	910.0	1047.0	1139.9	1193.8	1215.4	1211.8	1189.4	1153.5	1108.6	1057.8	1003.9	948.7	893.5	839.3	786.8	10487.5
1946	150.1	289.6	511.7	726.1	906.3	1042.7	1135.2	1188.9	1210.4	1206.8	1184.5	1148.8	1104.0	1053.5	999.8	944.8	889.9	835.9	783.6	10444.5
1947	150.1	422.4	511.0	722.8	902.2	1038.0	1130.1	1183.5	1205.0	1201.4	1179.2	1143.7	1099.1	1048.8	995.3	940.6	885.9	832.2	780.1	10397.7
1948	150.1	421.8	741.3	718.0	893.4	1027.8	1119.0	1171.9	1193.1	1189.6	1167.6	1132.4	1088.3	1038.5	985.5	931.3	877.2	824.0	772.4	10295.3
1949	150.1	421.3	736.4	1035.9	882.6	1012.2	1102.0	1154.0	1174.9	1171.5	1149.8	1115.2	1071.7	1022.6	970.5	917.1	863.8	811.4	760.6	10138.6
1950	150.1	420.8	731.4	1023.3	1266.4	994.4	1079.2	1130.2	1150.7	1147.3	1126.1	1092.1	1049.6	1001.5	950.5	898.2	846.0	794.7	744.9	9929.1
1951	150.1	420.2	726.3	1010.7	1243.9	1418.8	1054.3	1100.6	1120.5	1117.2	1096.6	1063.5	1022.1	975.3	925.6	874.7	823.8	773.9	725.4	9669.2
1952	150.0	419.4	719.5	995.6	1218.6	1382.4	1492.1	1066.6	1082.4	1079.2	1059.3	1027.3	987.3	942.1	894.1	844.9	795.8	747.5	700.7	9340.0
1953	150.0	419.0	715.6	982.7	1196.1	1349.4	1448.6	1504.1	1045.2	1038.7	1019.5	988.8	950.3	906.8	860.6	813.2	765.9	719.5	674.4	8989.8
1954	149.9	418.3	710.3	971.1	1173.2	1316.1	1405.2	1451.0	1464.6	996.7	975.1	945.7	908.9	867.3	823.1	777.8	732.6	688.1	645.1	8598.2
1955	149.9	417.2	702.0	954.3	1147.7	1277.9	1356.7	1393.3	1398.6	1382.6	926.2	895.4	860.5	821.1	779.3	736.4	693.6	651.5	610.7	8140.7
1956	149.8	416.5	696.4	938.0	1121.7	1243.3	1310.1	1337.8	1335.6	1313.1	1277.8	845.8	810.3	773.2	733.8	693.4	653.1	613.5	575.1	7665.3
1957	149.7	415.5	689.7	923.1	1093.8	1205.6	1264.6	1281.7	1272.5	1244.1	1204.0	1157.7	759.4	722.3	685.5	647.8	610.1	573.1	537.2	7161.1
1958	149.5	413.7	676.4	898.8	1058.1	1155.5	1205.3	1216.1	1198.3	1165.0	1121.3	1072.3	1021.7	665.4	629.5	594.9	560.3	526.3	493.3	6575.9
1959	149.3	412.8	669.4	876.2	1024.2	1111.4	1148.5	1152.3	1130.3	1090.7	1043.9	992.8	940.8	890.0	576.5	543.1	511.5	480.5	450.4	6003.2
1960	149.1	411.0	658.8	855.3	984.8	1061.0	1089.5	1083.0	1056.4	1014.8	963.9	911.6	859.1	808.3	760.5	490.5	460.5	432.6	405.5	5405.4
1961	148.8	409.0	645.7	828.5	946.3	1004.2	1023.8	1011.3	977.3	933.5	882.8	828.6	776.5	726.6	679.9	637.0	409.5	383.4	359.4	4790.9
1962	148.5	406.2	627.8	793.5	895.6	942.8	946.8	928.5	891.6	843.8	793.4	741.4	689.6	641.6	597.1	556.4	519.5	333.1	311.2	4148.7
1963	148.0	403.4	611.4	756.5	841.0	874.9	871.6	842.0	802.7	754.8	703.3	653.5	605.0	558.8	517.1	479.2	445.0	414.4	265.2	3522.9
1964	147.4	399.8	591.0	716.9	780.3	799.6	787.2	754.3	708.4	661.4	612.3	563.7	519.0	477.1	438.2	403.8	373.0	345.4	321.0	2912.1
1965	146.5	394.3	560.0	662.7	707.1	709.4	687.9	651.4	606.8	558.1	512.9	469.2	428.0	391.3	357.8	327.2	300.5	276.8	255.9	2376.8
1966	145.3	386.2	515.3	585.8	609.8	599.8	569.4	531.1	489.0	446.1	403.9	366.8	332.5	301.1	273.8	249.3	227.2	208.1	191.3	1805.9
1967	143.4	379.8	486.5	519.7	519.8	498.7	464.1	423.8	384.3	346.5	311.2	278.4	250.5	225.5	203.1	183.9	166.9	151.7	138.7	1320.7
1968	140.9	370.5	453.3	464.9	436.9	402.7	365.6	327.3	290.6	258.0	229.0	203.2	180.2	161.0	144.1	129.3	116.6	105.6	95.8	914.3
1969	137.3	359.4	417.4	408.8	368.8	319.4	278.6	243.3	211.8	184.1	161.0	141.2	124.1	109.3	97.1	86.5	77.4	69.6	62.9	597.2
1970	133.1	351.0	408.1	379.5	326.9	271.8	222.8	186.9	158.7	135.3	115.8	100.0	86.9	75.9	66.4	58.8	52.2	46.6	41.8	393.4
1971	129.3	342.7	412.1	383.6	313.7	249.1	196.0	154.5	126.0	104.8	87.9	74.4	63.7	54.9	47.7	41.6	36.7	32.5	28.9	268.2
1972	125.9	331.1	392.9	378.2	309.7	233.4	175.4	132.8	101.8	81.3	66.5	55.2	46.2	39.3	33.7	29.2	25.3	22.3	19.7	178.8
1973	122.6	321.3	373.5	354.8	300.4	226.7	161.7	116.9	86.0	64.6	50.8	41.1	33.7	28.1	23.7	20.3	17.5	15.1	13.3	117.5
1974	108.6	312.9	362.9	337.7	282.3	220.3	157.3	107.9	75.9	54.7	40.4	31.4	25.2	20.5	17.0	14.3	12.2	10.5	9.0	77.6
1975	135.0	272.7	327.4	304.0	248.8	191.7	141.6	97.3	64.9	44.6	31.7	23.1	17.8	14.2	11.5	9.5	7.9	6.7	5.8	47.6
1976	97.1	332.6	261.6	251.5	205.4	155.0	113.0	80.3	53.6	35.0	23.7	16.6	12.0	9.2	7.3	5.9	4.8	4.0	3.4	26.9
1977	101.7	238.5	315.6	198.7	168.1	126.5	90.3	63.3	43.7	28.6	18.4	12.3	8.6	6.1	4.7	3.7	3.0	2.4	2.0	15.1
1978	87.9	245.2	207.7	220.0	121.9	95.0	67.7	46.5	31.7	21.4	13.8	8.8	5.8	4.0	2.9	2.2	1.7	1.4	1.1	7.8
1979	53.1	209.0	200.2	135.7	126.5	64.6	47.6	32.6	21.8	14.5	9.7	6.2	3.9	2.6	1.8	1.2	0.9	0.7	0.6	3.8
1980	116.5	127.8	179.5	137.7	82.1	70.5	34.1	24.2	16.1	10.5	6.9	4.6	2.9	1.8	1.2	0.8	0.6	0.4	0.3	2.0
1981	32.3	280.7	110.6	124.4	83.9	46.1	37.5	17.4	12.0	7.8	5.0	3.3	2.1	1.3	0.8	0.5	0.4	0.3	0.2	1.1
1982	63.5	78.9	257.9	81.4	80.5	50.1	26.0	20.4	9.2	6.2	4.0	2.5	1.6	1.1	0.7	0.4	0.3	0.2	0.1	0.6
1983	123.8	155.4	73.4	192.0	53.3	48.6	28.6	14.3	10.9	4.8	3.2	2.0	1.3	0.8	0.5	0.3	0.2	0.1	0.1	0.4
1984	170.2	295.2	128.2	48.5	111.6	28.5	24.6	13.9	6.8	5.0	2.2	1.4	0.9	0.6	0.4	0.2	0.1	0.1	0.1	0.2
1985	48.3	372.0	229.1	69.5	23.1	49.0	11.8	9.8	5.4	2.5	1.9	0.8	0.5	0.3	0.2	0.1	0.1	0.1	0.0	0.1
1986	64.2	106.1	287.8	127.0	33.9	10.4	20.7	4.8	3.8	2.0	0.9	0.7	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0
1987	81.6	136.7	83.2	181.6	70.5	17.3	5.0	9.6	2.1	1.7	0.9	0.4	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0
1988	62.9	188.2	126.2	60.5	116.1	41.5	9.6	2.7	5.0	1.1	0.8	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
1989	63.4	145.3	167.1	87.8	37.0	65.5	22.2	4.9	1.3	2.4	0.5	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
1990	57.0	150.1	134.9	101.5	46.9	18.2	30.4	9.9	2.1	0.6	1.0	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1991	77.0	125.6	122.3	85.5	56.5	24.0	8.8	14.1	4.4	0.9	0.2	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1992	37.2	188.5	133.0	94.1	57.7	35.0	14.0	4.8	7.3	2.2	0.5	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1993	28.8	97.5	234.9	113.6	62.6	34.9	19.8	7.4	2.4	3.4	1.0	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1994	29.0	71.7	111.1	177.8	60.0	30.0	15.7	8.4	3.0	0.9	1.3	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1995	28.7	67.7	79.1	92.8	120.2	36.8	17.0	8.2	4.0	1.3	0.4	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	40.6	66.7	73.2	64.0	60.7	71.5	20.4	8.8	4.0	1.8	0.6	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1997	41.8	98.7	77.2	61.2	41.3	35.7	39.5	10.6	4.4	1.9	0.9	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1998	91.9	105.9	124.2	68.1	40.0	24.6	19.9	20.7	5.3	2.1	0.9	0.4	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
1999	99.2	232.8	124.4	102.5	45.2	24.3	14.0	10.6	10.4	2.5	1.0	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
2000	79.5	249.8	264.7	97.8	64.7	26.0	13.0	7.0	5.0	4.6	1.1	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
2001	60.3	194.9	270.8	204.9	63.8	38.5	14.4	6.7	3.4	2.2	2.0	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
2002	66.8	142.0	197.6	198.2	125.1	35.3	19.6	6.7	2.8	1.3	0.8	0.8	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
2003	46.0	157.4	147.8	152.7	132.2	75.6	19.6	9.9	3.0	1.2	0.5	0.4	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0
2004	58.4	108.2	163.5	118.6	113.8	90.0	47.8	11.5	5.4	1.5	0.6	0.3	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0
2005	60.5	134.3	107.7	122.9	79.6	69.7	51.2	25.4	5.7	2.5	0.7	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
2006	61.0	142.2	136.5	81.9	84.2	50.1	41.1	28.6	13.5	2.9	1.2	0.4	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
2007	62.6	148.1	154.3	110.7	60.1	56.9	31.9	25.0	16.8	7.7	1.6	0.7	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0

Table 3.4. Red snapper: Estimated biomass at age (1000 lb) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1945	226.9	639.0	1132.7	1607.3	2006.3	2308.2	2513.1	2631.8	2679.4	2671.5	2622.2	2543.1	2444.0	2332.1	2213.3	2091.5	1969.9	1850.4	1734.6	23120.9
1946	331.0	638.4	1128.1	1600.7	1998.1	2298.7	2502.8	2621.0	2668.5	2660.6	2611.4	2532.7	2434.0	2322.6	2204.2	2083.0	1961.8	1842.9	1727.5	23026.2
1947	330.9	931.2	1126.6	1593.5	1989.1	2288.4	2491.5	2609.3	2656.5	2648.6	2599.7	2521.4	2423.1	2312.2	2194.3	2073.6	1953.0	1834.6	1719.7	22923.0
1948	330.9	930.0	1634.4	1582.9	1969.5	2265.9	2467.0	2583.6	2630.3	2622.6	2574.1	2496.5	2399.2	2289.4	2172.7	2053.2	1933.8	1816.5	1702.8	22697.3
1949	330.9	928.8	1623.4	2283.9	1945.8	2231.4	2429.4	2544.2	2590.3	2582.6	2534.9	2458.5	2362.7	2254.5	2139.7	2022.0	1904.4	1788.9	1676.9	22351.7
1950	330.9	927.6	1612.4	2256.0	2791.9	2192.3	2379.3	2491.7	2536.8	2529.3	2482.6	2407.7	2313.9	2208.0	2095.5	1980.2	1865.0	1751.9	1642.3	21890.0
1951	330.8	926.4	1601.3	2228.1	2742.3	3128.0	2324.4	2426.5	2470.4	2463.1	2417.6	2344.7	2253.3	2150.2	2040.6	1928.4	1816.2	1706.1	1599.3	21317.0
1952	330.7	924.6	1586.2	2194.8	2686.5	3047.6	3289.6	2351.4	2386.3	2379.2	2335.3	2264.9	2176.6	2077.0	1971.1	1862.7	1754.4	1648.0	1544.8	20591.1
1953	330.6	923.7	1577.5	2166.4	2636.9	2974.9	3193.6	3315.9	2304.2	2290.0	2247.7	2180.0	2095.0	1999.1	1897.2	1792.8	1688.6	1586.2	1486.9	19819.1
1954	330.5	922.2	1566.0	2141.0	2586.4	2901.6	3097.8	3198.9	3228.8	2197.3	2149.8	2085.0	2003.7	1912.0	1814.6	1714.7	1615.0	1517.1	1422.1	18955.7
1955	330.4	919.8	1547.7	2104.0	2530.3	2817.3	2991.0	3071.6	3083.5	3048.0	2042.0	1974.1	1897.1	1810.3	1718.0	1623.5	1529.1	1436.4	1346.5	17947.3
1956	330.2	918.3	1535.2	2067.9	2472.9	2741.0	2888.2	2949.4	2944.6	2894.8	2817.0	1864.8	1786.3	1704.6	1617.7	1528.7	1439.8	1352.5	1267.8	16899.2
1957	329.9	916.1	1520.6	2035.2	2411.4	2657.8	2788.0	2825.7	2805.3	2742.7	2654.4	2552.4	1674.2	1592.4	1511.3	1428.1	1345.1	1263.5	1184.4	15787.4
1958	329.6	912.0	1491.2	1981.4	2332.8	2547.5	2657.2	2681.1	2641.8	2568.4	2472.1	2364.1	2252.4	1467.0	1387.8	1311.4	1235.2	1160.3	1087.6	14497.3
1959	329.2	910.0	1475.9	1931.8	2257.9	2450.1	2532.1	2540.5	2492.0	2404.6	2301.5	2188.8	2074.1	1962.2	1271.0	1197.2	1127.6	1059.2	992.9	13234.9
1960	328.7	906.1	1452.4	1885.7	2171.2	2339.0	2401.9	2387.7	2328.9	2237.2	2125.1	2009.8	1894.0	1782.0	1676.7	1081.5	1015.3	953.7	894.0	11916.8
1961	328.1	901.7	1423.6	1826.6	2086.2	2213.9	2257.1	2229.4	2154.5	2058.0	1946.2	1826.8	1711.9	1601.8	1499.0	1404.4	902.8	845.3	792.4	10562.1
1962	327.3	895.4	1384.0	1749.3	1974.4	2078.4	2087.3	2046.9	1965.6	1860.2	1749.2	1634.5	1520.3	1414.6	1316.5	1226.6	1145.4	734.4	686.2	9146.4
1963	326.3	889.4	1347.8	1667.7	1854.2	1928.9	1921.6	1856.2	1769.6	1664.1	1550.5	1440.6	1333.9	1231.8	1140.0	1056.4	981.0	913.6	584.6	7766.8
1964	324.9	881.4	1302.9	1580.6	1720.4	1762.9	1735.5	1663.0	1561.8	1458.1	1349.9	1242.7	1144.1	1051.9	966.1	890.3	822.2	761.6	707.8	6420.0
1965	323.1	869.3	1234.5	1460.9	1558.9	1563.9	1516.6	1436.1	1337.8	1230.4	1130.9	1034.5	943.7	862.7	788.8	721.4	662.5	610.3	564.1	5240.0
1966	320.3	851.4	1136.1	1291.6	1344.5	1322.3	1255.4	1171.0	1078.0	983.5	890.4	808.6	733.0	663.9	603.6	549.6	500.9	458.9	421.8	3981.3
1967	316.2	837.2	1072.6	1145.8	1145.9	1099.4	1023.2	934.4	847.3	763.9	686.1	613.8	552.3	497.1	447.8	405.4	367.9	334.5	305.7	2911.6
1968	310.6	816.9	999.4	1025.0	963.1	887.7	806.0	721.6	640.6	568.9	504.9	448.1	397.2	354.9	317.7	285.0	257.1	232.7	211.1	2015.7
1969	302.8	792.3	920.2	901.2	813.1	704.2	614.2	536.4	466.9	405.9	354.9	311.2	273.7	240.9	214.1	190.8	170.6	153.5	138.6	1316.6
1970	293.5	773.8	899.8	836.5	720.7	599.3	491.2	412.1	349.9	298.2	255.2	220.5	191.6	167.3	146.5	129.6	115.1	102.6	92.2	867.4
1971	285.0	755.5	908.4	845.6	691.6	549.1	432.1	340.7	277.9	231.0	193.9	164.0	140.3	121.1	105.2	91.7	80.8	71.6	63.7	591.3
1972	277.6	729.9	866.3	833.8	682.8	514.7	386.7	292.7	224.3	179.2	146.7	121.6	101.9	86.6	74.3	64.3	55.8	49.1	43.4	394.2
1973	270.3	708.3	823.4	782.3	662.4	499.9	356.6	257.7	189.7	142.4	111.9	90.5	74.4	61.9	52.3	44.7	38.5	33.4	29.3	259.1
1974	239.4	689.9	800.1	744.6	622.3	485.6	346.8	238.0	167.2	120.5	89.0	69.2	55.4	45.2	37.4	31.5	26.8	23.1	19.9	171.0
1975	297.6	601.1	721.9	670.2	548.6	422.6	312.1	214.4	143.0	98.4	69.8	51.0	39.2	31.2	25.3	20.9	17.5	14.9	12.8	104.9
1976	214.0	733.2	576.8	554.5	452.8	341.6	249.0	176.9	118.2	77.2	52.3	36.7	26.5	20.3	16.0	13.0	10.6	8.9	7.5	59.2
1977	224.2	525.9	695.8	438.2	370.5	278.9	199.1	139.6	96.4	63.1	40.6	27.2	18.9	13.5	10.3	8.1	6.5	5.4	4.5	33.3
1978	193.7	540.7	457.9	485.0	268.7	209.4	149.2	102.5	69.8	47.2	30.4	19.3	12.8	8.8	6.3	4.8	3.8	3.0	2.5	17.3
1979	117.1	460.7	441.4	299.2	278.8	142.4	105.0	71.9	48.0	32.1	21.4	13.6	8.6	5.6	3.9	2.7	2.1	1.6	1.3	8.5
1980	256.9	281.7	395.8	303.6	181.0	155.5	75.1	53.3	35.5	23.2	15.3	10.0	6.3	4.0	2.6	1.8	1.3	0.9	0.7	4.4
1981	71.3	618.8	243.8	274.3	185.1	101.7	82.7	38.4	26.5	17.3	11.1	7.2	4.7	2.9	1.8	1.2	0.8	0.6	0.4	2.3
1982	140.0	174.0	568.5	179.3	177.5	110.4	57.4	44.9	20.3	13.7	8.8	5.6	3.6	2.3	1.5	0.9	0.6	0.4	0.3	1.3
1983	273.0	342.5	161.8	423.3	117.5	107.1	63.0	31.5	24.0	10.6	7.1	4.5	2.8	1.8	1.2	0.7	0.4	0.3	0.2	0.8
1984	375.2	650.8	282.6	106.9	245.9	62.9	54.3	30.7	14.9	11.1	4.8	3.2	2.0	1.3	0.8	0.5	0.3	0.2	0.1	0.4
1985	106.4	820.1	505.1	153.3	51.0	108.0	26.1	21.6	11.8	5.6	4.1	1.8	1.2	0.7	0.5	0.3	0.2	0.1	0.1	0.2
1986	141.5	233.9	634.5	280.1	74.7	22.9	45.7	10.5	8.4	4.5	2.1	1.5	0.7	0.4	0.3	0.2	0.1	0.1	0.0	0.1
1987	179.8	301.4	183.4	400.3	155.4	38.2	11.0	21.2	4.7	3.7	1.9	0.9	0.7	0.3	0.2	0.1	0.1	0.0	0.0	0.1
1988	138.6	415.0	278.2	133.3	255.9	91.5	21.3	5.9	11.0	2.4	1.8	1.0	0.4	0.3	0.1	0.1	0.1	0.0	0.0	0.0
1989	139.8	320.4	368.5	193.6	81.6	144.4	48.8	10.9	2.9	5.4	1.2	0.9	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0
1990	125.7	330.8	297.4	223.8	103.4	40.1	67.0	21.7	4.7	1.2	2.2	0.5	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0
1991	169.8	276.9	269.5	188.4	124.6	53.0	19.4	31.0	9.7	2.0	0.5	0.9	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0
1992	82.1	415.7	293.2	207.4	127.2	77.2	30.8	10.7	16.1	4.8	1.0	0.3	0.5	0.1	0.1	0.0	0.0	0.0	0.0	0.0
1993	63.4	214.9	517.8	250.5	138.0	77.0	43.5	16.2	5.2	7.5	2.2	0.5	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0
1994	63.9	158.0	244.9	392.0	132.3	66.0	34.5	18.5	6.5	2.0	2.8	0.8	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
1995	63.3	149.3	174.3	204.5	265.0	81.0	37.5	18.1	8.9	2.9	0.9	1.3	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1996	89.5	147.0	161.5	141.2	133.9	157.6	44.9	19.4	8.8	4.0	1.3	0.4	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0
1997	92.2	217.6	170.3	135.0	91.1	78.8	87.0	23.4	9.6	4.2	1.9	0.6	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0
1998	202.7	233.5	273.8	150.1	88.3	54.3	43.9	45.7	11.6	4.6	1.9	0.9	0.3	0.1	0.2	0.0	0.0	0.0	0.0	0.0
1999	218.7	513.1	274.3	226.1	99.7	53.5	30.8	23.4	23.0	5.6	2.1	0.9	0.4	0.2	0.0	0.1	0.0	0.0	0.0	0.0
2000	175.2	550.8	583.6	215.7	142.7	57.4	28.7	15.4	11.0	10.2	2.4	1.0	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0
2001	132.9	429.6	596.9	451.6	140.7	84.9	31.7	14.8	7.4	4.9	4.5	1.1	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0
2002	147.2	313.2	435.7	436.9	275.9	77.8	43.1	14.7	6.2	2.8	1.9	1.8	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0
2003	101.3	347.1	325.9	336.6	291.5	166.7	43.2	21.8	6.7	2.6	1.1	0.8	0.9	0.2	0.1	0.1	0.0	0.0	0.0	0.0
2004	128.7	238.5	360.4	261.5	250.8	198.3	105.3	25.4	11.9	3.4	1.3	0.6	0.4	0.5	0.1	0.1	0.0	0.0	0.0	0.0
2005	133.5	296.1	237.3	270.9	175.6	153.6	112.9	55.9	12.5	5.5	1.5	0.6	0.3	0.2	0.2	0.1	0.0	0.0	0.0	0.0
2006	134.5	313.6	300.9	180.5	185.7	110.4	90.6	63.2	29.7	6.4	2.8	0.8	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0
2007	138.1	326.5	340.3	244.0	132.6	125.4	70.3	55.2	37.1	17.0	3.6	1.5	0.4	0.2	0.1	0.1	0.1	0.0	0.0	0.0

Table 3.5. Red snapper: Estimated time series and status indicators. Fishing mortality rate is full F, which includes discard mortalities. Total biomass (B) is at the start of the year, and spawning biomass (SSB) at the midpoint; B and SSB are in units mt. SPR is static spawning potential ratio.

Year	F	F/F_{MSY}	B	$B/B_{unfished}$	SSB	SSB/SSB_{MSY}	SPR
1945	0.00411	0.0367	27823	0.7500	13256	2.5572	0.6345
1946	0.00449	0.0401	27757	0.7482	13178	2.5420	0.6320
1947	0.00989	0.0883	27769	0.7486	13124	2.5316	0.5983
1948	0.01534	0.1370	27739	0.7477	13062	2.5196	0.5666
1949	0.02087	0.1864	27662	0.7457	12985	2.5048	0.5365
1950	0.02652	0.2368	27526	0.7420	12882	2.4849	0.5077
1951	0.03464	0.3093	27313	0.7363	12727	2.4552	0.4698
1952	0.03822	0.3412	26945	0.7263	12531	2.4172	0.4542
1953	0.04454	0.3977	26538	0.7154	12300	2.3726	0.4282
1954	0.05467	0.4881	26018	0.7014	11994	2.3137	0.3904
1955	0.06017	0.5373	25296	0.6819	11625	2.2424	0.3716
1956	0.06805	0.6076	24503	0.6605	11211	2.1627	0.3467
1957	0.08525	0.7612	23599	0.6361	10699	2.0638	0.2995
1958	0.09111	0.8135	22398	0.6038	10117	1.9516	0.2854
1959	0.10490	0.9366	21198	0.5714	9500	1.8327	0.2554
1960	0.12068	1.0775	19862	0.5354	8822	1.7018	0.2260
1961	0.14391	1.2849	18403	0.4961	8069	1.5565	0.1905
1962	0.16350	1.4599	16757	0.4517	7262	1.4009	0.1662
1963	0.19066	1.7024	15071	0.4063	6429	1.2402	0.1391
1964	0.23552	2.1029	13312	0.3588	5537	1.0681	0.1063
1965	0.30478	2.7213	11381	0.3068	4555	0.8786	0.0740
1966	0.34145	3.0486	9238	0.2490	3608	0.6960	0.0624
1967	0.39542	3.5305	7397	0.1994	2790	0.5381	0.0496
1968	0.45333	4.0476	5790	0.1561	2098	0.4048	0.0397
1969	0.44525	3.9755	4455	0.1201	1598	0.3083	0.0409
1970	0.41206	3.6791	3612	0.0974	1298	0.2504	0.0464
1971	0.43564	3.8897	3148	0.0849	1106	0.2133	0.0424
1972	0.45193	4.0351	2779	0.0749	959	0.1850	0.0399
1973	0.45059	4.0231	2490	0.0671	852	0.1643	0.0401
1974	0.52713	4.7065	2278	0.0614	748	0.1443	0.0309
1975	0.61378	5.4801	2004	0.0540	620	0.1196	0.0237
1976	0.62480	5.5786	1699	0.0458	514	0.0992	0.0230
1977	0.71077	6.3462	1451	0.0391	419	0.0809	0.0183
1978	0.77541	6.9233	1194	0.0322	329	0.0634	0.0157
1979	0.72426	6.4666	937	0.0253	265	0.0511	0.0177
1980	0.71660	6.3982	820	0.0221	223	0.0430	0.0181
1981	0.65715	5.8674	768	0.0207	215	0.0414	0.0211
1982	0.64484	5.7575	685	0.0185	201	0.0388	0.0218
1983	0.76482	6.8288	714	0.0192	181	0.0350	0.0161
1984	1.07634	9.6102	839	0.0226	180	0.0347	0.0114
1985	1.06609	9.5187	825	0.0222	191	0.0368	0.0116
1986	0.99991	8.9278	663	0.0179	173	0.0335	0.0131
1987	0.83766	7.4791	591	0.0159	160	0.0309	0.0196
1988	0.85233	7.6101	616	0.0166	163	0.0313	0.0178
1989	0.91956	8.2104	598	0.0161	153	0.0295	0.0159
1990	1.03705	9.2594	553	0.0149	141	0.0271	0.0140
1991	0.74542	6.6555	520	0.0140	142	0.0275	0.0254
1992	0.89651	8.0045	575	0.0155	169	0.0326	0.0329
1993	1.18468	10.5775	607	0.0164	174	0.0336	0.0223
1994	1.16646	10.4148	509	0.0137	158	0.0305	0.0262
1995	1.16125	10.3683	457	0.0123	140	0.0269	0.0244
1996	1.02684	9.1683	413	0.0111	123	0.0237	0.0276
1997	0.94830	8.4670	414	0.0112	122	0.0234	0.0324
1998	0.93248	8.3257	504	0.0136	138	0.0266	0.0296
1999	1.01926	9.1005	668	0.0180	175	0.0338	0.0263
2000	1.05793	9.4458	814	0.0219	224	0.0432	0.0250
2001	1.30281	11.6322	863	0.0233	243	0.0468	0.0205
2002	1.22252	10.9154	797	0.0215	235	0.0452	0.0234
2003	1.01853	9.0941	747	0.0201	231	0.0446	0.0273
2004	1.16021	10.3590	720	0.0194	215	0.0414	0.0220
2005	1.01732	9.0832	661	0.0178	195	0.0376	0.0238
2006	0.84145	7.5130	644	0.0174	194	0.0373	0.0298
2007	.	.	677	0.0182	.	.	.

Table 3.6. Red snapper: Selectivity at age estimated for the period 1992–2006

Age	Length (mm)	Length (in)	c.hal	c.dv	hb	rec	D.c.hal	D.hb	D.rec	L.avg	D.avg	L.avg+D.avg
1	262.8	10.3	0.0001	0.0051	0.0000	0.0210	0.5000	0.5000	0.5000	0.0105	0.2613	0.2718
2	395.2	15.6	0.0052	0.0110	0.0000	0.6546	1.0000	1.0000	1.0000	0.3115	0.5226	0.8341
3	499.8	19.7	0.2815	0.0238	0.4162	0.9941	0.6009	0.7159	0.6035	0.6088	0.3249	0.9337
4	582.5	22.9	0.9672	0.0510	1.0000	0.9999	0.0193	0.0001	0.0168	0.8886	0.0075	0.8962
5	647.9	25.5	0.9996	0.1075	1.0000	1.0000	0.0003	0.0000	0.0002	0.9038	0.0001	0.9039
6	699.6	27.5	1.0000	0.2202	1.0000	1.0000	0.0000	0.0000	0.0000	0.9161	0.0000	0.9161
7	740.4	29.2	1.0000	0.4234	1.0000	1.0000	0.0000	0.0000	0.0000	0.9380	0.0000	0.9380
8	772.7	30.4	1.0000	0.7225	1.0000	1.0000	0.0000	0.0000	0.0000	0.9701	0.0000	0.9701
9	798.3	31.4	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.0000	1.0000	0.0000	1.0000
10	818.5	32.2	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.0000	1.0000	0.0000	1.0000
11	834.4	32.9	1.0000	0.6657	1.0000	1.0000	0.0000	0.0000	0.0000	0.9640	0.0000	0.9640
12	847.1	33.3	1.0000	0.3115	1.0000	1.0000	0.0000	0.0000	0.0000	0.9259	0.0000	0.9259
13	857.0	33.7	1.0000	0.1188	1.0000	1.0000	0.0000	0.0000	0.0000	0.9052	0.0000	0.9052
14	864.9	34.1	1.0000	0.0414	1.0000	1.0000	0.0000	0.0000	0.0000	0.8968	0.0000	0.8968
15	871.2	34.3	1.0000	0.0139	1.0000	1.0000	0.0000	0.0000	0.0000	0.8939	0.0000	0.8939
16	876.1	34.5	1.0000	0.0046	1.0000	1.0000	0.0000	0.0000	0.0000	0.8929	0.0000	0.8929
17	880.0	34.6	1.0000	0.0015	1.0000	1.0000	0.0000	0.0000	0.0000	0.8926	0.0000	0.8926
18	883.1	34.8	1.0000	0.0005	1.0000	1.0000	0.0000	0.0000	0.0000	0.8924	0.0000	0.8924
19	885.5	34.9	1.0000	0.0002	1.0000	1.0000	0.0000	0.0000	0.0000	0.8924	0.0000	0.8924
20	887.4	34.9	1.0000	0.0001	1.0000	1.0000	0.0000	0.0000	0.0000	0.8924	0.0000	0.8924

Table 3.7. Red snapper: Estimated time series of fishing mortality rate for commercial handline (F.c.hal), commercial diving (F.c.dv), headboat (F.hb), general recreational (F.rec),commercial handline discards (F.c.hal.D), headboat discards (F.hb.D), general recreational discards (F.mrfss.D), and full F (F.full).

Year	F.c.hal	F.c.dv	F.hb	F.rec	F.c.hal.D	F.hb.D	F.rec.D	F.full
1945	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.004
1946	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.004
1947	0.005	0.000	0.000	0.005	0.000	0.000	0.000	0.010
1948	0.005	0.000	0.000	0.010	0.000	0.000	0.000	0.015
1949	0.006	0.000	0.000	0.015	0.000	0.000	0.000	0.021
1950	0.006	0.000	0.000	0.020	0.000	0.000	0.000	0.027
1951	0.009	0.000	0.000	0.026	0.000	0.000	0.000	0.035
1952	0.007	0.000	0.000	0.031	0.000	0.000	0.000	0.038
1953	0.007	0.000	0.000	0.037	0.000	0.000	0.000	0.045
1954	0.011	0.000	0.000	0.044	0.000	0.000	0.000	0.055
1955	0.009	0.000	0.000	0.051	0.000	0.000	0.000	0.060
1956	0.009	0.000	0.000	0.059	0.000	0.000	0.000	0.068
1957	0.018	0.000	0.000	0.068	0.000	0.000	0.000	0.085
1958	0.013	0.000	0.000	0.078	0.000	0.000	0.000	0.091
1959	0.015	0.000	0.000	0.090	0.000	0.000	0.000	0.105
1960	0.017	0.000	0.000	0.104	0.000	0.000	0.000	0.121
1961	0.021	0.000	0.000	0.123	0.000	0.000	0.000	0.144
1962	0.018	0.000	0.000	0.146	0.000	0.000	0.000	0.164
1963	0.015	0.000	0.000	0.175	0.000	0.000	0.000	0.191
1964	0.020	0.000	0.000	0.216	0.000	0.000	0.000	0.236
1965	0.028	0.000	0.000	0.277	0.000	0.000	0.000	0.305
1966	0.039	0.000	0.000	0.302	0.000	0.000	0.000	0.341
1967	0.066	0.000	0.000	0.329	0.000	0.000	0.000	0.395
1968	0.097	0.000	0.000	0.356	0.000	0.000	0.000	0.453
1969	0.082	0.000	0.000	0.363	0.000	0.000	0.000	0.445
1970	0.092	0.000	0.000	0.320	0.000	0.000	0.000	0.412
1971	0.092	0.000	0.000	0.344	0.000	0.000	0.000	0.436
1972	0.091	0.000	0.020	0.340	0.000	0.000	0.000	0.452
1973	0.084	0.000	0.029	0.338	0.000	0.000	0.000	0.451
1974	0.155	0.000	0.021	0.351	0.000	0.000	0.000	0.527
1975	0.218	0.000	0.028	0.368	0.000	0.000	0.000	0.614
1976	0.216	0.000	0.043	0.366	0.000	0.000	0.000	0.625
1977	0.280	0.000	0.029	0.402	0.000	0.000	0.000	0.711
1978	0.330	0.000	0.038	0.407	0.000	0.000	0.000	0.775
1979	0.284	0.000	0.040	0.399	0.000	0.000	0.000	0.724
1980	0.321	0.000	0.050	0.346	0.000	0.000	0.000	0.717
1981	0.305	0.000	0.102	0.250	0.000	0.000	0.000	0.657
1982	0.290	0.000	0.099	0.255	0.000	0.000	0.000	0.645
1983	0.318	0.000	0.081	0.366	0.000	0.000	0.000	0.765
1984	0.357	0.014	0.087	0.517	0.013	0.006	0.082	1.076
1985	0.307	0.034	0.123	0.509	0.009	0.007	0.077	1.066
1986	0.264	0.010	0.063	0.484	0.033	0.012	0.135	1.000
1987	0.269	0.007	0.104	0.295	0.053	0.031	0.078	0.838
1988	0.236	0.005	0.156	0.320	0.025	0.024	0.086	0.852
1989	0.387	0.017	0.091	0.371	0.011	0.006	0.038	0.920
1990	0.352	0.027	0.091	0.362	0.124	0.047	0.034	1.037
1991	0.222	0.084	0.102	0.286	0.014	0.008	0.028	0.745
1992	0.223	0.140	0.068	0.336	0.057	0.004	0.069	0.897
1993	0.465	0.085	0.086	0.317	0.079	0.046	0.107	1.185
1994	0.347	0.194	0.099	0.164	0.148	0.048	0.166	1.166
1995	0.353	0.140	0.118	0.174	0.162	0.082	0.133	1.161
1996	0.335	0.081	0.114	0.213	0.185	0.027	0.072	1.027
1997	0.294	0.097	0.144	0.209	0.155	0.007	0.042	0.948
1998	0.234	0.105	0.073	0.322	0.075	0.027	0.096	0.932
1999	0.212	0.134	0.108	0.358	0.047	0.017	0.143	1.019
2000	0.197	0.154	0.097	0.349	0.044	0.022	0.195	1.058
2001	0.278	0.256	0.101	0.326	0.061	0.052	0.228	1.303
2002	0.232	0.267	0.096	0.287	0.066	0.052	0.222	1.223
2003	0.166	0.166	0.056	0.286	0.065	0.038	0.242	1.019
2004	0.219	0.157	0.113	0.282	0.059	0.070	0.260	1.160
2005	0.189	0.072	0.092	0.315	0.054	0.061	0.234	1.017
2006	0.142	0.030	0.070	0.316	0.055	0.040	0.188	0.841

Table 3.8. Red snapper: Estimated instantaneous fishing mortality rate (per yr) at age, including discard mortality

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1945	0.001	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
1946	0.001	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
1947	0.002	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
1948	0.003	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
1949	0.005	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021
1950	0.006	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027
1951	0.008	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
1952	0.008	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038
1953	0.010	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
1954	0.012	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055
1955	0.013	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060
1956	0.015	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
1957	0.019	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085
1958	0.020	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091
1959	0.023	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105
1960	0.026	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121
1961	0.031	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144
1962	0.036	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164
1963	0.042	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191
1964	0.051	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236
1965	0.066	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305
1966	0.074	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341
1967	0.086	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395	0.395
1968	0.099	0.453	0.453	0.453	0.453	0.453	0.453	0.453	0.453	0.453	0.453	0.453	0.453	0.453	0.453	0.453	0.453	0.453	0.453	0.453
1969	0.097	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445
1970	0.090	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412
1971	0.095	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436
1972	0.099	0.452	0.452	0.452	0.452	0.452	0.452	0.452	0.452	0.452	0.452	0.452	0.452	0.452	0.452	0.452	0.452	0.452	0.452	0.452
1973	0.098	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451
1974	0.115	0.527	0.527	0.527	0.527	0.527	0.527	0.527	0.527	0.527	0.527	0.527	0.527	0.527	0.527	0.527	0.527	0.527	0.527	0.527
1975	0.134	0.614	0.614	0.614	0.614	0.614	0.614	0.614	0.614	0.614	0.614	0.614	0.614	0.614	0.614	0.614	0.614	0.614	0.614	0.614
1976	0.136	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625
1977	0.155	0.711	0.711	0.711	0.711	0.711	0.711	0.711	0.711	0.711	0.711	0.711	0.711	0.711	0.711	0.711	0.711	0.711	0.711	0.711
1978	0.169	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
1979	0.158	0.724	0.724	0.724	0.724	0.724	0.724	0.724	0.724	0.724	0.724	0.724	0.724	0.724	0.724	0.724	0.724	0.724	0.724	0.724
1980	0.156	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717
1981	0.143	0.657	0.657	0.657	0.657	0.657	0.657	0.657	0.657	0.657	0.657	0.657	0.657	0.657	0.657	0.657	0.657	0.657	0.657	0.657
1982	0.141	0.645	0.645	0.645	0.645	0.645	0.645	0.645	0.645	0.645	0.645	0.645	0.645	0.645	0.645	0.645	0.645	0.645	0.645	0.645
1983	0.167	0.765	0.765	0.765	0.765	0.765	0.765	0.765	0.765	0.765	0.765	0.765	0.765	0.765	0.765	0.765	0.765	0.765	0.765	0.765
1984	0.253	0.826	0.962	0.962	0.963	0.964	0.967	0.972	0.975	0.975	0.971	0.966	0.963	0.962	0.961	0.961	0.961	0.961	0.961	0.961

Table 3.8. (continued)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1985	0.248	0.829	0.940	0.941	0.943	0.946	0.953	0.964	0.973	0.973	0.962	0.950	0.943	0.940	0.939	0.939	0.939	0.939	0.939	0.939
1986	0.279	0.816	0.811	0.811	0.811	0.813	0.815	0.817	0.820	0.820	0.817	0.813	0.812	0.811	0.811	0.811	0.810	0.810	0.810	0.810
1987	0.199	0.652	0.669	0.669	0.669	0.670	0.672	0.674	0.676	0.676	0.673	0.671	0.669	0.669	0.669	0.669	0.669	0.669	0.669	0.669
1988	0.197	0.691	0.713	0.713	0.713	0.713	0.714	0.716	0.717	0.717	0.715	0.714	0.713	0.713	0.712	0.712	0.712	0.712	0.712	0.712
1989	0.174	0.647	0.849	0.849	0.850	0.852	0.855	0.860	0.865	0.865	0.859	0.853	0.850	0.849	0.849	0.848	0.848	0.848	0.848	0.848
1990	0.246	0.777	0.806	0.807	0.809	0.812	0.817	0.825	0.832	0.832	0.823	0.814	0.809	0.807	0.806	0.806	0.806	0.806	0.806	0.806
1991	0.140	0.515	0.612	0.614	0.619	0.629	0.646	0.671	0.694	0.694	0.666	0.636	0.620	0.614	0.611	0.610	0.610	0.610	0.610	0.610
1992	0.073	0.353	0.507	0.629	0.642	0.658	0.686	0.728	0.767	0.767	0.720	0.670	0.644	0.633	0.629	0.628	0.627	0.627	0.627	0.627
1993	0.123	0.442	0.628	0.861	0.877	0.887	0.904	0.930	0.954	0.954	0.925	0.895	0.878	0.872	0.869	0.869	0.868	0.868	0.868	0.868
1994	0.186	0.474	0.530	0.613	0.630	0.652	0.691	0.750	0.803	0.803	0.739	0.670	0.632	0.617	0.612	0.610	0.610	0.609	0.609	0.609
1995	0.193	0.494	0.561	0.645	0.659	0.675	0.704	0.745	0.784	0.784	0.738	0.688	0.661	0.650	0.646	0.645	0.645	0.645	0.645	0.645
1996	0.147	0.426	0.529	0.660	0.670	0.680	0.696	0.721	0.743	0.743	0.716	0.687	0.671	0.665	0.663	0.662	0.662	0.662	0.662	0.662
1997	0.107	0.343	0.476	0.647	0.658	0.669	0.689	0.718	0.745	0.745	0.713	0.678	0.659	0.652	0.649	0.648	0.648	0.648	0.648	0.648
1998	0.106	0.411	0.542	0.630	0.641	0.653	0.674	0.705	0.734	0.734	0.699	0.662	0.642	0.634	0.631	0.630	0.630	0.630	0.630	0.630
1999	0.112	0.444	0.590	0.681	0.693	0.708	0.735	0.775	0.812	0.812	0.768	0.720	0.694	0.684	0.680	0.679	0.679	0.678	0.678	0.678
2000	0.138	0.492	0.606	0.649	0.660	0.677	0.708	0.755	0.797	0.797	0.746	0.691	0.662	0.650	0.645	0.644	0.644	0.643	0.643	0.643
2001	0.178	0.558	0.662	0.715	0.733	0.762	0.814	0.891	0.962	0.962	0.876	0.786	0.736	0.716	0.709	0.707	0.706	0.706	0.706	0.706
2002	0.178	0.532	0.608	0.626	0.644	0.674	0.728	0.808	0.882	0.882	0.793	0.698	0.647	0.626	0.619	0.616	0.616	0.615	0.615	0.615
2003	0.179	0.535	0.570	0.516	0.525	0.544	0.578	0.628	0.674	0.674	0.618	0.559	0.527	0.514	0.510	0.508	0.508	0.508	0.508	0.508
2004	0.202	0.577	0.636	0.620	0.630	0.648	0.680	0.727	0.770	0.770	0.718	0.662	0.632	0.620	0.616	0.614	0.614	0.614	0.614	0.614
2005	0.181	0.557	0.624	0.599	0.605	0.613	0.627	0.649	0.669	0.669	0.645	0.619	0.606	0.600	0.598	0.597	0.597	0.597	0.597	0.597
2006	0.148	0.491	0.559	0.530	0.532	0.536	0.542	0.551	0.559	0.559	0.549	0.538	0.533	0.530	0.530	0.529	0.529	0.529	0.529	0.529

Table 3.9. Red snapper: Landings at age (1000 fish), as estimated by the assessment model

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1945	0.4	1.4	1.2	1.1	1.0	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3	4.2
1946	0.6	1.5	1.3	1.1	1.0	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	4.6
1947	1.3	4.8	2.8	2.5	2.3	2.1	1.9	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.0	0.9	0.9	0.8	0.8	10.0
1948	2.0	7.4	6.4	3.9	3.5	3.2	2.9	2.7	2.4	2.3	2.1	1.9	1.8	1.7	1.5	1.4	1.3	1.2	1.2	15.3
1949	2.7	10.0	8.6	7.6	4.7	4.2	3.9	3.5	3.3	3.0	2.8	2.6	2.4	2.2	2.1	1.9	1.8	1.7	1.5	20.4
1950	3.4	12.7	10.8	9.5	8.5	5.3	4.8	4.4	4.1	3.7	3.5	3.2	3.0	2.8	2.6	2.4	2.2	2.1	1.9	25.3
1951	4.4	16.5	13.9	12.2	10.8	9.8	6.1	5.6	5.1	4.7	4.4	4.1	3.8	3.5	3.2	3.0	2.8	2.6	2.4	32.0
1952	4.9	18.1	15.2	13.2	11.7	10.5	9.5	6.0	5.5	5.0	4.7	4.3	4.0	3.7	3.5	3.2	3.0	2.8	2.6	34.1
1953	5.7	21.0	17.6	15.1	13.3	11.9	10.7	9.8	6.1	5.6	5.2	4.8	4.5	4.2	3.9	3.6	3.3	3.1	2.9	38.1
1954	7.0	25.6	21.3	18.3	15.9	14.1	12.7	11.5	10.5	6.6	6.1	5.7	5.2	4.9	4.5	4.2	3.9	3.6	3.4	44.5
1955	7.7	28.1	23.1	19.7	17.1	15.1	13.4	12.1	11.0	10.1	6.4	5.9	5.4	5.1	4.7	4.4	4.0	3.8	3.5	46.3
1956	8.7	31.6	25.8	21.8	18.8	16.5	14.6	13.1	11.8	10.8	9.9	6.2	5.8	5.4	5.0	4.6	4.3	4.0	3.7	49.1
1957	10.9	39.1	31.8	26.7	22.8	19.9	17.5	15.6	14.0	12.7	11.6	10.6	6.7	6.2	5.8	5.4	5.0	4.6	4.3	57.0
1958	11.6	41.5	33.2	27.7	23.5	20.3	17.8	15.8	14.1	12.7	11.5	10.5	9.6	6.1	5.6	5.2	4.9	4.5	4.2	55.8
1959	13.3	47.4	37.6	30.9	26.1	22.4	19.4	17.1	15.2	13.6	12.2	11.1	10.2	9.3	5.9	5.5	5.1	4.7	4.4	58.2
1960	15.2	53.8	42.3	34.4	28.6	24.4	21.0	18.3	16.2	14.4	12.9	11.6	10.6	9.7	8.9	5.6	5.2	4.9	4.5	59.8
1961	18.1	63.2	48.9	39.3	32.4	27.2	23.3	20.2	17.7	15.6	13.9	12.5	11.3	10.3	9.4	8.7	5.5	5.1	4.7	62.5
1962	20.5	70.6	53.5	42.3	34.5	28.7	24.2	20.9	18.1	15.9	14.1	12.6	11.3	10.2	9.3	8.5	7.8	5.0	4.6	61.0
1963	23.7	80.8	59.9	46.5	37.3	30.7	25.7	21.8	18.8	16.4	14.4	12.7	11.4	10.2	9.3	8.4	7.7	7.1	4.5	59.6
1964	29.1	96.8	70.1	53.3	41.9	33.9	28.1	23.6	20.0	17.3	15.1	13.3	11.8	10.6	9.5	8.6	7.8	7.2	6.6	59.6
1965	37.1	119.7	83.2	61.7	47.5	37.7	30.7	25.5	21.5	18.3	15.9	13.9	12.2	10.8	9.7	8.7	7.9	7.2	6.6	60.9
1966	41.1	129.1	84.3	60.1	45.1	35.1	28.0	22.9	19.1	16.1	13.8	11.9	10.4	9.2	8.2	7.3	6.6	6.0	5.4	50.9
1967	46.7	143.5	89.9	60.2	43.5	33.0	25.8	20.7	16.9	14.2	12.0	10.2	8.9	7.8	6.8	6.1	5.5	4.9	4.4	42.1
1968	52.3	156.3	93.6	60.1	40.8	29.7	22.7	17.8	14.3	11.8	9.8	8.3	7.1	6.2	5.4	4.8	4.3	3.8	3.4	32.5
1969	50.1	149.5	84.9	52.1	33.9	23.2	17.0	13.0	10.3	8.3	6.8	5.7	4.8	4.1	3.6	3.2	2.8	2.5	2.2	20.9
1970	45.1	137.1	78.0	45.4	28.3	18.6	12.8	9.4	7.2	5.7	4.6	3.8	3.2	2.7	2.3	2.0	1.8	1.6	1.4	13.0
1971	46.2	140.0	82.4	48.0	28.4	17.8	11.8	8.1	6.0	4.6	3.7	3.0	2.4	2.0	1.7	1.5	1.3	1.1	1.0	9.2
1972	46.6	139.3	80.9	48.8	28.8	17.2	10.9	7.2	5.0	3.7	2.9	2.3	1.8	1.5	1.3	1.1	0.9	0.8	0.7	6.3
1973	45.2	134.9	76.7	45.7	27.9	16.7	10.0	6.3	4.2	2.9	2.2	1.7	1.3	1.1	0.9	0.7	0.6	0.5	0.5	4.2
1974	46.5	148.5	84.3	49.1	29.6	18.3	11.0	6.6	4.2	2.8	2.0	1.4	1.1	0.9	0.7	0.6	0.5	0.4	0.4	3.1
1975	66.7	145.1	85.2	49.5	29.3	17.8	11.1	6.7	4.0	2.6	1.7	1.2	0.9	0.7	0.5	0.4	0.4	0.3	0.3	2.1
1976	48.8	179.2	69.0	41.5	24.5	14.6	8.9	5.6	3.4	2.0	1.3	0.9	0.6	0.5	0.3	0.3	0.2	0.2	0.2	1.2
1977	57.6	140.9	91.2	35.9	21.9	13.1	7.8	4.8	3.0	1.8	1.1	0.7	0.5	0.3	0.2	0.2	0.2	0.1	0.1	0.8
1978	54.0	153.8	63.7	42.2	16.9	10.4	6.2	3.7	2.3	1.4	0.9	0.5	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.4
1979	30.6	125.1	58.6	24.9	16.7	6.8	4.2	2.5	1.5	0.9	0.6	0.4	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.2
1980	66.5	75.9	52.1	25.0	10.8	7.3	3.0	1.8	1.1	0.7	0.4	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.1
1981	17.0	156.9	30.2	21.3	10.4	4.5	3.1	1.3	0.8	0.5	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1982	32.9	43.5	69.5	13.7	9.8	4.8	2.1	1.4	0.6	0.4	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1983	75.1	96.5	22.3	36.5	7.3	5.3	2.6	1.1	0.8	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984	120.6	169.4	45.1	10.7	17.7	3.6	2.6	1.3	0.6	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3.9. (continued)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1985	34.1	216.5	79.4	15.1	3.6	6.1	1.2	0.9	0.5	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	41.9	53.6	90.9	25.1	4.8	1.2	2.0	0.4	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	34.4	57.1	23.0	31.5	8.8	1.7	0.4	0.7	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988	29.2	87.7	36.5	11.0	15.2	4.3	0.8	0.2	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989	33.7	73.6	54.4	17.9	5.4	7.6	2.2	0.4	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	28.6	69.4	42.4	20.0	6.7	2.1	2.9	0.8	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991	32.5	52.8	31.7	13.9	6.7	2.3	0.7	1.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1992	1.1	40.9	25.3	15.5	7.0	3.4	1.2	0.4	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1993	0.8	19.2	47.9	23.3	9.4	4.2	2.0	0.7	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1994	0.5	7.3	15.0	28.7	7.2	2.9	1.3	0.7	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1995	0.5	7.3	11.1	15.5	14.9	3.7	1.5	0.6	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	0.7	8.9	11.4	10.9	7.6	7.2	1.7	0.7	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1997	0.8	13.5	12.3	10.3	5.1	3.5	3.3	0.8	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1998	2.5	21.4	22.8	11.3	4.9	2.4	1.7	1.6	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	3.0	51.5	24.7	17.9	5.8	2.5	1.2	0.9	0.8	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	2.4	52.9	50.3	16.5	8.0	2.6	1.1	0.6	0.4	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	1.8	37.7	50.7	36.9	8.5	4.2	1.4	0.6	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	1.8	24.5	33.3	32.5	15.2	3.5	1.7	0.6	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	1.1	26.8	22.9	21.6	13.8	6.4	1.5	0.7	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2004	1.4	17.8	26.9	19.3	13.6	8.7	4.0	0.9	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2005	1.5	24.9	18.5	19.5	9.3	6.5	4.1	1.8	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006	1.5	27.1	22.8	11.9	8.9	4.2	2.9	1.8	0.8	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3.10. Red snapper: Landings at age (mt, whole weight), as estimated by the assessment model

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1945	0.1	1.1	2.0	2.8	3.6	4.1	4.5	4.7	4.8	4.8	4.7	4.6	4.4	4.2	4.0	3.7	3.5	3.3	3.1	41.4
1946	0.1	1.2	2.2	3.1	3.9	4.5	4.9	5.1	5.2	5.2	5.1	5.0	4.8	4.6	4.3	4.1	3.8	3.6	3.4	45.2
1947	0.3	3.8	4.7	6.7	8.5	9.8	10.7	11.2	11.4	11.4	11.2	10.8	10.4	9.9	9.4	8.9	8.4	7.9	7.4	98.7
1948	0.4	5.9	10.6	10.4	13.0	15.0	16.3	17.1	17.5	17.4	17.1	16.6	16.0	15.2	14.5	13.7	12.9	12.1	11.3	151.2
1949	0.6	8.1	14.3	20.3	17.4	20.0	21.8	22.9	23.3	23.3	22.9	22.2	21.3	20.4	19.3	18.3	17.2	16.2	15.2	202.0
1950	0.8	10.2	18.0	25.4	31.6	24.9	27.1	28.4	28.9	28.9	28.4	27.5	26.5	25.3	24.0	22.7	21.4	20.1	18.8	250.7
1951	1.0	13.3	23.3	32.6	40.4	46.2	34.4	36.0	36.7	36.6	35.9	34.9	33.5	32.0	30.4	28.7	27.1	25.4	23.8	317.6
1952	1.1	14.6	25.4	35.4	43.5	49.6	53.6	38.4	39.0	38.9	38.2	37.1	35.7	34.0	32.3	30.5	28.8	27.0	25.3	337.8
1953	1.3	16.9	29.3	40.6	49.6	56.2	60.5	62.9	43.8	43.5	42.8	41.5	39.9	38.1	36.1	34.2	32.2	30.2	28.3	377.8
1954	1.6	20.6	35.5	49.0	59.5	66.9	71.6	74.1	74.9	51.0	49.9	48.5	46.6	44.5	42.2	39.9	37.6	35.3	33.1	441.3
1955	1.7	22.6	38.6	52.8	63.9	71.4	75.9	78.1	78.5	77.7	52.1	50.4	48.4	46.2	43.9	41.5	39.1	36.7	34.4	458.7
1956	2.0	25.4	43.1	58.5	70.3	78.2	82.6	84.5	84.5	83.1	80.9	53.6	51.4	49.0	46.5	44.0	41.4	38.9	36.5	486.6
1957	2.5	31.5	53.0	71.5	85.2	94.2	99.1	100.6	100.0	97.8	94.7	91.1	59.8	56.9	54.0	51.1	48.1	45.2	42.4	564.7
1958	2.6	33.4	55.4	74.2	87.8	96.2	100.6	101.7	100.3	97.6	94.0	90.0	85.8	55.9	52.9	50.0	47.1	44.2	41.5	552.6
1959	3.0	38.1	62.7	82.8	97.2	105.9	109.7	110.2	108.2	104.5	100.1	95.3	90.3	85.5	55.4	52.2	49.1	46.2	43.3	577.0
1960	3.5	43.3	70.5	92.3	106.7	115.4	118.8	118.3	115.5	111.0	105.5	99.9	94.2	88.6	83.4	53.8	50.5	47.5	44.5	593.1
1961	4.1	50.8	81.5	105.4	121.0	128.8	131.6	130.2	126.0	120.4	114.0	107.0	100.3	93.9	87.9	82.4	53.0	49.6	46.5	619.9
1962	4.6	56.8	89.1	113.6	128.8	136.1	137.0	134.5	129.4	122.5	115.3	107.8	100.3	93.4	86.9	81.0	75.6	48.5	45.3	604.1
1963	5.4	65.0	99.9	124.7	139.3	145.4	145.1	140.4	134.0	126.2	117.6	109.4	101.3	93.6	86.6	80.3	74.6	69.4	44.4	590.5
1964	6.6	77.9	116.8	142.9	156.3	160.7	158.5	152.1	143.1	133.7	123.8	114.1	105.1	96.6	88.8	81.8	75.6	70.0	65.1	590.2
1965	8.4	96.3	138.7	165.4	177.4	178.5	173.5	164.6	153.5	141.3	129.9	118.9	108.5	99.2	90.8	83.0	76.3	70.3	64.9	603.4
1966	9.3	103.9	140.6	161.1	168.5	166.2	158.2	147.8	136.2	124.4	112.7	102.4	92.8	84.1	76.5	69.7	63.5	58.2	53.5	504.9
1967	10.6	115.4	150.0	161.4	162.2	156.1	145.6	133.2	120.9	109.1	98.1	87.8	79.0	71.1	64.1	58.0	52.7	47.9	43.8	417.0
1968	11.9	125.7	156.0	161.2	152.2	140.8	128.1	114.8	102.1	90.7	80.6	71.5	63.4	56.7	50.8	45.5	41.1	37.2	33.8	322.3
1969	11.4	120.2	141.6	139.8	126.7	110.1	96.2	84.2	73.3	63.8	55.8	49.0	43.1	37.9	33.7	30.1	26.9	24.2	21.8	207.5
1970	10.2	110.3	130.1	121.9	105.5	88.0	72.3	60.8	51.6	44.1	37.7	32.6	28.3	24.8	21.7	19.2	17.0	15.2	13.7	128.5
1971	10.5	112.7	137.4	128.9	105.9	84.4	66.5	52.5	42.9	35.7	30.0	25.4	21.7	18.7	16.3	14.2	12.5	11.1	9.9	91.6
1972	10.6	112.1	134.9	130.9	107.7	81.4	61.3	46.5	35.7	28.5	23.4	19.4	16.2	13.8	11.8	10.2	8.9	7.8	6.9	62.9
1973	10.3	108.5	127.9	122.5	104.2	78.9	56.4	40.8	30.1	22.6	17.8	14.4	11.8	9.8	8.3	7.1	6.1	5.3	4.7	41.2
1974	10.6	119.5	140.5	131.7	110.6	86.6	62.0	42.6	30.0	21.6	16.0	12.4	10.0	8.1	6.7	5.7	4.8	4.1	3.6	30.7
1975	15.1	116.7	142.1	132.9	109.3	84.4	62.5	43.0	28.7	19.8	14.0	10.3	7.9	6.3	5.1	4.2	3.5	3.0	2.6	21.1
1976	11.1	144.2	115.0	111.4	91.4	69.1	50.5	35.9	24.0	15.7	10.6	7.5	5.4	4.1	3.3	2.6	2.2	1.8	1.5	12.1
1977	13.1	113.4	152.0	96.4	81.9	61.8	44.2	31.1	21.5	14.1	9.0	6.1	4.2	3.0	2.3	1.8	1.5	1.2	1.0	7.4
1978	12.2	123.7	106.2	113.3	63.0	49.3	35.2	24.2	16.5	11.2	7.2	4.6	3.0	2.1	1.5	1.1	0.9	0.7	0.6	4.1
1979	7.0	100.6	97.7	66.7	62.4	32.0	23.6	16.2	10.8	7.2	4.8	3.1	1.9	1.3	0.9	0.6	0.5	0.4	0.3	1.9
1980	15.1	61.1	87.0	67.2	40.2	34.7	16.8	11.9	8.0	5.2	3.4	2.3	1.4	0.9	0.6	0.4	0.3	0.2	0.2	1.0
1981	3.9	126.2	50.4	57.1	38.7	21.3	17.4	8.1	5.6	3.6	2.3	1.5	1.0	0.6	0.4	0.3	0.2	0.1	0.1	0.5
1982	7.5	35.0	116.0	36.9	36.6	22.8	11.9	9.3	4.2	2.9	1.8	1.2	0.8	0.5	0.3	0.2	0.1	0.1	0.1	0.3
1983	17.0	77.6	37.2	97.9	27.3	25.0	14.7	7.4	5.6	2.5	1.7	1.1	0.7	0.4	0.3	0.2	0.1	0.1	0.0	0.2
1984	27.4	136.3	75.1	28.6	66.2	17.0	14.7	8.4	4.1	3.0	1.3	0.9	0.5	0.3	0.2	0.1	0.1	0.1	0.0	0.1

Table 3.10. (continued)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1985	7.7	174.2	132.5	40.5	13.5	28.9	7.0	5.9	3.2	1.5	1.1	0.5	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.1
1986	9.5	43.1	151.5	67.4	18.1	5.5	11.1	2.6	2.1	1.1	0.5	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
1987	7.8	46.0	38.4	84.4	32.9	8.1	2.4	4.5	1.0	0.8	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1988	6.6	70.6	60.9	29.4	56.7	20.3	4.7	1.3	2.5	0.5	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1989	7.6	59.2	90.6	48.0	20.3	36.1	12.3	2.8	0.7	1.4	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1990	6.5	55.8	70.8	53.7	24.9	9.7	16.4	5.3	1.2	0.3	0.5	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991	7.4	42.4	52.9	37.4	25.0	10.8	4.0	6.6	2.1	0.4	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1992	0.3	32.9	42.3	41.7	26.2	16.2	6.7	2.4	3.8	1.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1993	0.2	15.5	79.8	62.4	35.1	19.8	11.3	4.3	1.4	2.0	0.6	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1994	0.1	5.9	24.9	77.0	26.8	13.8	7.5	4.3	1.6	0.5	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1995	0.1	5.8	18.6	41.7	55.6	17.3	8.3	4.2	2.1	0.7	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	0.2	7.2	19.1	29.3	28.4	33.9	9.8	4.4	2.0	0.9	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1997	0.2	10.8	20.5	27.6	19.1	16.7	18.9	5.3	2.2	1.0	0.4	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1998	0.6	17.2	38.0	30.2	18.1	11.3	9.4	10.1	2.7	1.0	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	0.7	41.4	41.2	48.1	21.7	11.8	7.0	5.5	5.6	1.4	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.5	42.5	83.9	44.2	29.9	12.3	6.4	3.6	2.6	2.5	0.6	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	0.4	30.3	84.5	99.1	31.8	19.7	7.7	3.8	2.0	1.3	1.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	0.4	19.7	55.6	87.2	56.9	16.6	9.7	3.6	1.6	0.7	0.4	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	0.3	21.6	38.1	58.0	51.7	30.5	8.3	4.4	1.4	0.5	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2004	0.3	14.4	44.9	51.8	50.9	41.2	22.7	5.7	2.8	0.8	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
2005	0.3	20.0	30.8	52.3	34.6	30.7	23.0	11.7	2.7	1.2	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006	0.3	21.8	38.0	31.8	33.2	19.9	16.5	11.7	5.6	1.2	0.5	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3.11. Red snapper: Landings at age (1000 lb, whole weight), as estimated by the assessment model

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1945	0.2	2.4	4.4	6.2	7.8	9.0	9.9	10.3	10.5	10.5	10.3	10.0	9.6	9.2	8.7	8.3	7.8	7.3	6.9	91.4
1946	0.3	2.6	4.8	6.8	8.5	9.8	10.7	11.3	11.5	11.5	11.3	10.9	10.5	10.0	9.5	9.0	8.5	8.0	7.5	99.6
1947	0.6	8.5	10.4	14.9	18.7	21.5	23.5	24.7	25.1	25.1	24.6	23.9	23.0	21.9	20.8	19.7	18.5	17.4	16.3	217.7
1948	1.0	13.1	23.4	22.8	28.6	33.0	36.0	37.8	38.5	38.4	37.7	36.6	35.2	33.6	31.9	30.1	28.4	26.7	25.0	333.3
1949	1.3	17.8	31.5	44.7	38.3	44.1	48.1	50.4	51.4	51.3	50.4	48.9	47.0	44.9	42.6	40.3	37.9	35.6	33.4	445.4
1950	1.7	22.5	39.7	56.0	69.6	54.9	59.7	62.6	63.8	63.7	62.5	60.7	58.4	55.7	52.9	50.0	47.1	44.2	41.5	552.7
1951	2.2	29.2	51.3	71.9	89.0	101.8	75.8	79.3	80.8	80.7	79.2	76.9	73.9	70.6	67.0	63.3	59.6	56.0	52.5	700.2
1952	2.5	32.1	55.9	78.0	96.0	109.2	118.2	84.6	86.0	85.8	84.3	81.8	78.6	75.1	71.3	67.3	63.4	59.6	55.9	744.8
1953	2.9	37.3	64.6	89.5	109.5	123.9	133.3	138.7	96.5	96.0	94.3	91.5	87.9	83.9	79.7	75.3	70.9	66.6	62.5	832.9
1954	3.5	45.4	78.3	108.0	131.1	147.6	157.9	163.4	165.1	112.5	110.1	106.8	102.7	98.1	93.1	88.0	82.9	77.9	73.0	972.9
1955	3.8	49.8	85.0	116.5	140.8	157.3	167.4	172.2	173.1	171.3	114.8	111.0	106.8	101.9	96.7	91.4	86.1	80.9	75.9	1011.2
1956	4.3	56.0	95.0	129.0	155.0	172.4	182.1	186.3	186.2	183.2	178.4	118.2	113.3	108.1	102.6	97.0	91.4	85.8	80.5	1072.7
1957	5.4	69.4	116.9	157.7	187.8	207.7	218.4	221.7	220.4	215.7	208.9	200.9	131.9	125.5	119.1	112.6	106.0	99.6	93.4	1244.9
1958	5.8	73.6	122.2	163.6	193.6	212.2	221.8	224.2	221.2	215.2	207.3	198.3	189.0	123.2	116.5	110.2	103.8	97.5	91.4	1218.2
1959	6.7	84.0	138.3	182.5	214.4	233.4	241.8	243.0	238.6	230.5	220.7	210.0	199.1	188.4	122.1	115.0	108.3	101.8	95.4	1272.0
1960	7.6	95.5	155.4	203.4	235.3	254.4	261.8	260.7	254.6	244.8	232.7	220.2	207.6	195.4	183.9	118.6	111.4	104.6	98.1	1307.6
1961	9.1	112.1	179.6	232.3	266.7	283.9	290.1	287.0	277.7	265.5	251.3	236.0	221.2	207.1	193.8	181.6	116.8	109.4	102.5	1366.6
1962	10.2	125.3	196.5	250.4	284.1	300.0	302.0	296.6	285.2	270.1	254.2	237.6	221.1	205.8	191.6	178.5	166.7	106.9	99.9	1331.9
1963	11.9	143.3	220.3	274.8	307.1	320.5	320.0	309.6	295.5	278.2	259.3	241.1	223.3	206.3	191.0	177.0	164.4	153.1	98.0	1301.8
1964	14.5	171.7	257.6	315.0	344.5	354.2	349.5	335.4	315.4	294.7	273.0	251.5	231.6	213.0	195.7	180.4	166.6	154.3	143.4	1301.2
1965	18.6	212.2	305.8	364.7	391.1	393.6	382.5	362.8	338.4	311.5	286.5	262.2	239.3	218.8	200.1	183.0	168.1	154.9	143.2	1330.2
1966	20.5	229.0	310.0	355.1	371.5	366.5	348.7	325.8	300.3	274.2	248.4	225.7	204.7	185.4	168.6	153.6	140.0	128.3	117.9	1113.0
1967	23.4	254.4	330.6	355.9	357.6	344.2	321.1	293.7	266.6	240.6	216.2	193.5	174.2	156.8	141.3	128.0	116.1	105.6	96.5	919.3
1968	26.2	277.2	344.0	355.5	335.6	310.3	282.4	253.2	225.0	200.0	177.6	157.7	139.9	125.0	111.9	100.4	90.6	82.0	74.4	710.5
1969	25.1	265.1	312.2	308.1	279.3	242.7	212.1	185.5	161.7	140.7	123.1	108.0	95.0	83.6	74.3	66.3	59.3	53.3	48.2	457.5
1970	22.6	243.2	286.8	268.7	232.6	194.0	159.4	133.9	113.8	97.1	83.2	71.9	62.5	54.6	47.8	42.3	37.6	33.5	30.1	283.2
1971	23.1	248.4	302.9	284.1	233.5	186.0	146.7	115.8	94.6	78.7	66.1	55.9	47.9	41.3	35.9	31.3	27.6	24.5	21.8	201.9
1972	23.3	247.1	297.4	288.5	237.3	179.5	135.1	102.5	78.6	62.9	51.5	42.7	35.8	30.4	26.1	22.6	19.6	17.3	15.3	138.6
1973	22.6	239.2	282.0	270.0	229.7	173.9	124.3	90.0	66.3	49.8	39.2	31.7	26.1	21.7	18.3	15.7	13.5	11.7	10.3	90.9
1974	23.3	263.4	309.8	290.5	243.9	190.9	136.6	93.9	66.1	47.6	35.2	27.4	22.0	17.9	14.8	12.5	10.6	9.1	7.9	67.8
1975	33.4	257.2	313.2	292.9	240.9	186.1	137.8	94.8	63.3	43.6	30.9	22.6	17.4	13.9	11.2	9.3	7.8	6.6	5.7	46.6
1976	24.4	317.9	253.5	245.5	201.4	152.4	111.4	79.2	53.0	34.6	23.5	16.5	11.9	9.1	7.2	5.8	4.8	4.0	3.4	26.6
1977	28.8	249.9	335.1	212.6	180.6	136.3	97.5	68.5	47.4	31.0	19.9	13.4	9.3	6.7	5.1	4.0	3.2	2.6	2.2	16.4
1978	27.0	272.7	234.0	249.7	138.9	108.6	77.5	53.3	36.4	24.6	15.9	10.1	6.7	4.6	3.3	2.5	2.0	1.6	1.3	9.0
1979	15.3	221.8	215.4	147.1	137.7	70.5	52.1	35.8	23.9	16.0	10.6	6.8	4.3	2.8	1.9	1.4	1.0	0.8	0.6	4.2
1980	33.3	134.6	191.7	148.1	88.7	76.4	37.0	26.3	17.5	11.5	7.5	5.0	3.1	2.0	1.3	0.9	0.6	0.5	0.4	2.2
1981	8.5	278.2	111.1	126.0	85.4	47.1	38.3	17.8	12.3	8.0	5.2	3.4	2.2	1.4	0.9	0.6	0.4	0.3	0.2	1.1
1982	16.4	77.2	255.6	81.2	80.8	50.4	26.3	20.6	9.3	6.3	4.0	2.6	1.7	1.1	0.7	0.4	0.3	0.2	0.1	0.6
1983	37.6	171.2	82.0	215.9	60.2	55.1	32.5	16.3	12.4	5.5	3.6	2.3	1.5	0.9	0.6	0.4	0.2	0.1	0.1	0.4
1984	60.3	300.5	165.7	63.1	145.9	37.5	32.5	18.4	9.0	6.7	2.9	1.9	1.2	0.8	0.5	0.3	0.2	0.1	0.1	0.3

Table 3.11. (continued)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1985	17.0	383.9	292.0	89.3	29.9	63.6	15.5	12.9	7.1	3.4	2.5	1.1	0.7	0.4	0.3	0.2	0.1	0.1	0.0	0.1
1986	21.0	95.1	334.0	148.5	39.8	12.2	24.5	5.7	4.5	2.4	1.1	0.8	0.4	0.2	0.1	0.1	0.1	0.0	0.0	0.1
1987	17.2	101.3	84.6	186.1	72.6	17.9	5.2	10.0	2.2	1.7	0.9	0.4	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0
1988	14.6	155.6	134.2	64.8	125.0	44.9	10.5	2.9	5.4	1.2	0.9	0.5	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0
1989	16.9	130.5	199.8	105.8	44.8	79.6	27.1	6.1	1.6	3.0	0.6	0.5	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
1990	14.3	123.1	156.0	118.3	55.0	21.4	36.1	11.8	2.6	0.7	1.2	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1991	16.3	93.6	116.7	82.4	55.1	23.7	8.9	14.6	4.7	1.0	0.2	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1992	0.6	72.6	93.2	91.9	57.7	35.7	14.7	5.3	8.3	2.5	0.5	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1993	0.4	34.1	176.0	137.5	77.3	43.6	25.0	9.5	3.1	4.4	1.3	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1994	0.2	13.0	55.0	169.7	59.2	30.4	16.6	9.4	3.5	1.1	1.4	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1995	0.2	12.9	40.9	91.9	122.5	38.2	18.2	9.2	4.7	1.5	0.4	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	0.4	15.8	42.1	64.5	62.6	74.7	21.7	9.6	4.4	2.0	0.6	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1997	0.4	23.9	45.2	60.9	42.1	36.9	41.7	11.6	4.9	2.1	0.9	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1998	1.3	38.0	83.8	66.6	40.0	25.0	20.7	22.3	5.8	2.3	0.9	0.4	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
1999	1.5	91.4	90.8	106.0	47.7	26.1	15.4	12.2	12.4	3.0	1.1	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
2000	1.2	93.8	184.9	97.5	66.0	27.1	14.0	7.9	5.8	5.4	1.2	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
2001	0.9	66.8	186.2	218.4	70.1	43.5	17.0	8.4	4.4	3.0	2.5	0.6	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
2002	0.9	43.4	122.6	192.2	125.4	36.6	21.5	7.9	3.5	1.6	1.0	0.9	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
2003	0.6	47.6	84.1	127.8	113.9	67.1	18.2	9.8	3.2	1.2	0.5	0.3	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0
2004	0.7	31.7	99.0	114.1	112.3	90.9	50.0	12.6	6.1	1.8	0.6	0.3	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0
2005	0.8	44.1	68.0	115.4	76.3	67.6	50.7	25.7	5.9	2.6	0.7	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
2006	0.8	48.0	83.8	70.1	73.3	43.9	36.4	25.8	12.3	2.6	1.1	0.3	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0

Table 3.12. Red snapper: 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 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 mt or pounds, as indicated. Symbols, abbreviations, and acronyms are listed in Appendix A.

Quantity	Units	Estimate	10^{th} Percentile	90^{th} Percentile
F_{MSY}	y^{-1}	0.112	0.110	0.113
$85\%F_{MSY}$	y^{-1}	0.095	–	–
$75\%F_{MSY}$	y^{-1}	0.084	–	–
$65\%F_{MSY}$	y^{-1}	0.073	–	–
$F_{30\%}$	y^{-1}	0.100	–	–
$F_{40\%}$	y^{-1}	0.070	–	–
F_{max}	y^{-1}	0.120	–	–
B_{MSY}	mt	11734	10539	14174
SSB_{MSY}	mt	5184	4655	6267
MSST	mt	4779	4301	5791
MSY	1000 lb	2319	2072	2785
D_{MSY}	1000 fish	55	49	66
R_{MSY}	1000 fish	644	576	774
Y at $85\%F_{MSY}$	1000 lb	2300	–	–
Y at $75\%F_{MSY}$	1000 lb	2263	–	–
Y at $65\%F_{MSY}$	1000 lb	2200	–	–
Y at $F_{30\%}$	1000 lb	2310	–	–
Y at $F_{40\%}$	1000 lb	2177	–	–
Y at F_{max}	1000 lb	2316	–	–
F_{2006}/F_{MSY}	–	7.513	7.446	7.650
SSB_{2006}/SSB_{MSY}	–	0.037	0.031	0.042
$SSB_{2006}/MSST$	–	0.041	0.033	0.045

Table 3.13. Red snapper: Results from sensitivity runs of catch-at-age model.

Run	Description	F_{MSY}	SSB_{MSY} (mt)	MSY (1000 lb)	F_{2006}/F_{MSY}	SSB_{2006}/SSB_{MSY}	steep	R0(1000)
Base	—	0.112	5184	2319	7.51	0.04	0.95	605
S1	Low M	0.097	6112	1977	10.36	0.03	0.95	377
S2	High M	0.112	5089	2362	7.25	0.04	0.95	673
S3	q slope 0.0	0.111	5304	2226	5.72	0.05	0.95	603
S4	q slope 0.04	0.107	5174	2355	9.20	0.03	0.95	606
S5	Rec dev 1972	0.106	5203	2299	7.82	0.04	0.95	608
S6	Rec dev 1976	0.106	5209	2302	7.79	0.04	0.95	602
S7	Low recr L	0.143	1729	559	11.09	0.11	0.95	152
S8	Bias recr L est	0.104	9024	3927	7.72	0.02	0.94	1034
S9	Comm D mort 0.7	0.105	5180	2316	7.72	0.04	0.95	603
S10	Comm D mort 0.8	0.106	5186	2302	7.70	0.04	0.95	604
S11	Comm D mort 1.0	0.106	5238	2289	7.79	0.04	0.95	606
S12	Recr D mort 0.2	0.115	4978	2424	6.01	0.04	0.95	601
S13	Recr D mort 0.6	0.113	5417	2176	8.51	0.04	0.95	607
S14	D sel age 1 0.25	0.113	5201	2295	7.94	0.04	0.95	605
S15	D sel age 1 0.75	0.128	5157	2381	6.65	0.04	0.95	605
S16	steep=0.8	0.131	7648	2056	9.59	0.03	0.80	562
S17	steep=0.6	0.118	10554	1624	7.09	0.05	0.60	441
S18	Retro 2005	0.107	4812	2107	7.74	0.04	0.95	559
S19	Retro 2004	0.106	4936	2150	7.80	0.04	0.95	569
S20	Retro 2003	0.106	5020	2194	7.78	0.04	0.95	581
S21	Retro 2002	0.106	5109	2241	7.76	0.04	0.95	592
S22	Retro 2001	0.105	5367	2333	7.82	0.04	0.95	619
S23	B1/K=0.95	0.105	5463	2401	7.79	0.04	0.95	633
S24	B1/K=0.90	0.109	5588	2492	7.64	0.03	0.95	649
S25	B1/K=0.85	0.105	5706	2528	7.75	0.03	0.95	664
S26	B1/K=0.80	0.105	5851	2600	7.74	0.03	0.95	682
S27	B1/K=0.70	0.104	5211	2326	7.34	0.05	0.95	606
S28	B1/K=0.65	0.106	5197	2325	8.05	0.05	0.95	605
S29	B1/K=0.60	0.132	5070	2415	8.23	0.04	0.95	604
S30	B1/K=0.55	0.104	5239	2325	9.21	0.05	0.95	600
S31	B1/K=0.50	0.176	4870	2571	12.84	0.04	0.94	601

*Table 3.14. Red snapper: Projection results under scenario 1—fishing mortality rate fixed at $F = 0$. F = fishing mortality rate (per year), SSB = mid-year spawning stock biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000 fish). For reference, estimated benchmarks are* $F_{MSY} = 0.112$, $SSB_{MSY} = 5184$, $R_{MSY} = 644$, MSY = 2319, *and* $D_{MSY} = 55$, *each in the same units as the relevant time series.*

Year	F(per yr)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	D(1000)
2007	0.998	161	269	562	562	130
2008	0.998	125	273	420	982	123
2009	0.000	106	233	0	982	0
2010	0.000	304	208	0	982	0
2011	0.000	498	379	0	982	0
2012	0.000	755	457	0	982	0
2013	0.000	1100	513	0	982	0
2014	0.000	1537	554	0	982	0
2015	0.000	2060	584	0	982	0
2016	0.000	2657	604	0	982	0
2017	0.000	3313	619	0	982	0
2018	0.000	4013	629	0	982	0
2019	0.000	4742	636	0	982	0
2020	0.000	5486	642	0	982	0
2021	0.000	6233	646	0	982	0
2022	0.000	6973	649	0	982	0
2023	0.000	7697	651	0	982	0
2024	0.000	8401	654	0	982	0
2025	0.000	9080	655	0	982	0
2026	0.000	9731	656	0	982	0
2027	0.000	10,351	658	0	982	0
2028	0.000	10,940	659	0	982	0
2029	0.000	11,497	659	0	982	0
2030	0.000	12,023	660	0	982	0
2031	0.000	12,518	661	0	982	0
2032	0.000	12,982	661	0	982	0
2033	0.000	13,417	662	0	982	0
2034	0.000	13,824	662	0	982	0
2035	0.000	14,205	662	0	982	0
2036	0.000	14,561	663	0	982	0
2037	0.000	14,893	663	0	982	0
2038	0.000	15,203	663	0	982	0
2039	0.000	15,492	663	0	982	0
2040	0.000	15,762	663	0	982	0

*Table 3.15. Red snapper: Projection results under scenario 2—fishing mortality rate fixed at $F = F_{\text{current}}$. F = fishing mortality rate (per year), SSB = mid-year spawning stock biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000 fish). For reference, estimated benchmarks are* $F_{\text{MSY}} = 0.112$, $\text{SSB}_{\text{MSY}} = 5184$, $R_{\text{MSY}} = 644$, MSY = 2319, *and* $D_{\text{MSY}} = 55$, *each in the same units as the relevant time series.*

Year	F(per yr)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	D(1000)
2007	0.998	161	269	562	562	130
2008	0.998	125	273	420	982	123
2009	0.998	106	233	343	1325	115
2010	0.998	93	208	299	1624	102
2011	0.998	83	190	265	1889	91
2012	0.998	74	175	237	2126	83
2013	0.998	67	161	214	2340	77
2014	0.998	61	149	195	2535	71
2015	0.998	56	139	178	2714	66
2016	0.998	52	130	165	2878	61
2017	0.998	48	122	152	3030	57
2018	0.998	45	115	142	3172	54
2019	0.998	42	108	133	3305	51
2020	0.998	40	102	124	3429	48
2021	0.998	37	97	117	3546	45
2022	0.998	35	92	110	3656	43
2023	0.998	33	88	104	3761	41
2024	0.998	32	83	99	3859	39
2025	0.998	30	80	94	3953	37
2026	0.998	29	76	89	4043	35
2027	0.998	27	73	85	4128	34
2028	0.998	26	70	81	4209	32
2029	0.998	25	67	78	4287	31
2030	0.998	24	65	75	4362	30
2031	0.998	23	62	72	4433	29
2032	0.998	22	60	69	4502	28
2033	0.998	21	58	66	4568	27
2034	0.998	21	56	64	4632	26
2035	0.998	20	54	61	4693	25
2036	0.998	19	52	59	4752	24
2037	0.998	18	50	57	4809	23
2038	0.998	18	49	55	4864	22
2039	0.998	17	47	53	4917	22
2040	0.998	17	46	51	4968	21

*Table 3.16. Red snapper: Projection results under scenario 3—fishing mortality rate fixed at $F = F_{MSY}$. F = fishing mortality rate (per year), SSB = mid-year spawning stock biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000 fish). For reference, estimated benchmarks are* $F_{MSY} = 0.112$, $SSB_{MSY} = 5184$, $R_{MSY} = 644$, MSY = 2319, *and* $D_{MSY} = 55$, *each in the same units as the relevant time series.*

Year	F(per yr)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	D(1000)
2007	0.998	161	269	562	562	130
2008	0.998	125	273	420	982	123
2009	0.112	106	233	55	1037	17
2010	0.112	265	208	99	1136	19
2011	0.112	401	356	158	1294	22
2012	0.112	568	424	229	1523	29
2013	0.112	778	476	315	1838	36
2014	0.112	1029	517	425	2264	41
2015	0.112	1312	548	552	2816	44
2016	0.112	1615	571	690	3505	47
2017	0.112	1928	588	833	4338	49
2018	0.112	2240	600	976	5314	50
2019	0.112	2544	609	1117	6431	51
2020	0.112	2832	616	1252	7682	52
2021	0.112	3102	622	1377	9060	53
2022	0.112	3350	626	1492	10,552	53
2023	0.112	3575	629	1596	12,148	54
2024	0.112	3778	632	1689	13,837	54
2025	0.112	3959	634	1771	15,608	54
2026	0.112	4120	636	1844	17,451	54
2027	0.112	4262	637	1908	19,359	54
2028	0.112	4387	638	1964	21,323	54
2029	0.112	4495	639	2012	23,335	55
2030	0.112	4590	640	2055	25,390	55
2031	0.112	4673	641	2092	27,481	55
2032	0.112	4744	641	2123	29,605	55
2033	0.112	4806	642	2151	31,756	55
2034	0.112	4859	642	2175	33,930	55
2035	0.112	4905	642	2195	36,126	55
2036	0.112	4945	643	2213	38,338	55
2037	0.112	4979	643	2228	40,566	55
2038	0.112	5008	643	2241	42,807	55
2039	0.112	5033	643	2252	45,059	55
2040	0.112	5055	643	2262	47,320	55

*Table 3.17. Red snapper: Projection results under scenario 4—fishing mortality rate fixed at F = 65%F_{MSY}. F = fishing mortality rate (per year), SSB = mid-year spawning stock biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000 fish). For reference, estimated benchmarks are* F_{MSY} = 0.112, $\mathrm{SSB}_{\mathrm{MSY}}$ = 5184, R_{MSY} = 644, MSY = 2319, *and* D_{MSY} = 55, *each in the same units as the relevant time series.*

Year	F(per yr)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	D(1000)
2007	0.998	161	269	562	562	130
2008	0.998	125	273	420	982	123
2009	0.073	106	233	37	1018	11
2010	0.073	278	208	67	1086	13
2011	0.073	432	364	111	1197	15
2012	0.073	627	436	165	1362	20
2013	0.073	878	489	232	1595	25
2014	0.073	1183	531	320	1915	28
2015	0.073	1533	561	423	2337	30
2016	0.073	1916	584	537	2874	32
2017	0.073	2320	600	657	3531	33
2018	0.073	2732	611	781	4312	34
2019	0.073	3142	620	905	5217	35
2020	0.073	3540	626	1026	6242	35
2021	0.073	3921	631	1141	7384	36
2022	0.073	4279	635	1249	8633	36
2023	0.073	4613	638	1349	9982	36
2024	0.073	4922	641	1440	11,422	37
2025	0.073	5204	643	1523	12,945	37
2026	0.073	5460	644	1598	14,544	37
2027	0.073	5692	646	1666	16,210	37
2028	0.073	5901	647	1727	17,937	37
2029	0.073	6089	648	1781	19,718	37
2030	0.073	6256	648	1830	21,547	37
2031	0.073	6406	649	1873	23,420	37
2032	0.073	6538	650	1911	25,331	37
2033	0.073	6656	650	1945	27,276	37
2034	0.073	6760	650	1975	29,251	37
2035	0.073	6853	651	2002	31,253	37
2036	0.073	6934	651	2025	33,278	37
2037	0.073	7006	651	2046	35,324	37
2038	0.073	7069	652	2064	37,389	37
2039	0.073	7125	652	2080	39,469	37
2040	0.073	7175	652	2095	41,563	37

Table 3.18. Red snapper: Projection results under scenario 5—fishing mortality rate fixed at F = 75%F_{MSY}. F = fishing mortality rate (per year), SSB = mid-year spawning stock biomass (mt)*, R = recruits (1000 fish), L = landings (1000* lb *whole weight), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000 fish). For reference, estimated benchmarks are* F_{MSY} = 0.112, SSB_{MSY} = 5184, R_{MSY} = 644, MSY = 2319, *and* D_{MSY} = 55, *each in the same units as the relevant time series.*

Year	F(per yr)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	D(1000)
2007	0.998	161	269	562	562	130
2008	0.998	125	273	420	982	123
2009	0.084	106	233	42	1024	13
2010	0.084	274	208	77	1100	14
2011	0.084	423	362	126	1226	17
2012	0.084	609	432	185	1411	23
2013	0.084	848	485	259	1670	28
2014	0.084	1136	527	354	2024	32
2015	0.084	1466	558	465	2489	34
2016	0.084	1824	580	588	3077	36
2017	0.084	2199	596	717	3794	38
2018	0.084	2580	608	849	4643	39
2019	0.084	2956	617	979	5622	40
2020	0.084	3319	624	1107	6729	40
2021	0.084	3663	629	1228	7957	41
2022	0.084	3985	633	1339	9296	41
2023	0.084	4283	636	1442	10,738	41
2024	0.084	4556	638	1535	12,274	42
2025	0.084	4804	640	1620	13,893	42
2026	0.084	5028	642	1695	15,589	42
2027	0.084	5229	643	1763	17,352	42
2028	0.084	5409	644	1824	19,176	42
2029	0.084	5569	645	1877	21,053	42
2030	0.084	5711	646	1925	22,977	42
2031	0.084	5836	647	1966	24,944	42
2032	0.084	5947	647	2003	26,947	42
2033	0.084	6044	648	2036	28,983	42
2034	0.084	6130	648	2064	31,047	42
2035	0.084	6205	649	2089	33,137	42
2036	0.084	6271	649	2111	35,248	42
2037	0.084	6329	649	2131	37,378	42
2038	0.084	6379	649	2147	39,526	42
2039	0.084	6423	650	2162	41,688	43
2040	0.084	6462	650	2175	43,863	43

Table 3.19. Red snapper: Projection results under scenario 6—fishing mortality rate fixed at F = 85%F_{MSY}. F = fishing mortality rate (per year), SSB = mid-year spawning stock biomass (mt)*, R = recruits (1000 fish), L = landings (1000* lb *whole weight), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000 fish). For reference, estimated benchmarks are* F_{MSY} = 0.112, SSB_{MSY} = 5184, R_{MSY} = 644, MSY = 2319, *and* D_{MSY} = 55*, each in the same units as the relevant time series.*

Year	F(per yr)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	D(1000)
2007	0.998	161	269	562	562	130
2008	0.998	125	273	420	982	123
2009	0.095	106	233	47	1029	14
2010	0.095	271	208	86	1115	16
2011	0.095	414	360	139	1254	19
2012	0.095	592	429	204	1458	25
2013	0.095	819	481	283	1740	31
2014	0.095	1092	523	385	2125	35
2015	0.095	1402	554	503	2628	38
2016	0.095	1737	576	633	3261	41
2017	0.095	2086	593	769	4030	42
2018	0.095	2437	605	906	4936	44
2019	0.095	2782	614	1042	5979	45
2020	0.095	3113	621	1174	7152	45
2021	0.095	3425	626	1298	8450	46
2022	0.095	3715	630	1412	9862	46
2023	0.095	3981	633	1516	11,378	46
2024	0.095	4223	636	1610	12,988	47
2025	0.095	4442	638	1694	14,682	47
2026	0.095	4638	640	1769	16,451	47
2027	0.095	4812	641	1836	18,287	47
2028	0.095	4967	642	1895	20,182	47
2029	0.095	5104	643	1947	22,128	47
2030	0.095	5224	644	1993	24,121	47
2031	0.095	5330	644	2033	26,154	47
2032	0.095	5423	645	2068	28,222	47
2033	0.095	5504	645	2098	30,320	47
2034	0.095	5574	646	2125	32,445	47
2035	0.095	5636	646	2148	34,593	48
2036	0.095	5690	646	2168	36,762	48
2037	0.095	5736	647	2186	38,948	48
2038	0.095	5777	647	2201	41,149	48
2039	0.095	5812	647	2215	43,364	48
2040	0.095	5842	647	2226	45,590	48

Table 3.20. Red snapper: Projection results under scenario 7—fishing mortality rate fixed at $F = F_{\text{rebuild}}$. F = fishing mortality rate (per year), SSB = mid-year spawning stock biomass (mt)*, R = recruits (1000 fish), L = landings (1000* lb *whole weight), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000 fish). For reference, estimated benchmarks are* $F_{\text{MSY}} = 0.112$, $\text{SSB}_{\text{MSY}} = 5184$, $R_{\text{MSY}} = 644$, MSY = 2319, *and* $D_{\text{MSY}} = 55$*, each in the same units as the relevant time series.*

Year	F(per yr)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	D(1000)
2007	0.998	161	269	562	562	130
2008	0.998	125	273	420	982	123
2009	0.109	106	233	54	1036	16
2010	0.109	266	208	96	1132	18
2011	0.109	403	357	155	1287	22
2012	0.109	572	425	225	1512	29
2013	0.109	785	477	310	1821	35
2014	0.109	1040	518	419	2240	40
2015	0.109	1328	549	544	2784	43
2016	0.109	1636	572	680	3465	46
2017	0.109	1955	589	822	4287	48
2018	0.109	2274	601	965	5252	49
2019	0.109	2584	610	1105	6357	50
2020	0.109	2880	617	1240	7596	51
2021	0.109	3157	622	1365	8962	51
2022	0.109	3412	627	1480	10,442	52
2023	0.109	3644	630	1584	12,026	52
2024	0.109	3853	633	1677	13,703	53
2025	0.109	4041	635	1760	15,463	53
2026	0.109	4207	636	1833	17,296	53
2027	0.109	4354	638	1898	19,194	53
2028	0.109	4484	639	1954	21,148	53
2029	0.109	4597	640	2004	23,152	53
2030	0.109	4696	641	2047	25,198	53
2031	0.109	4782	641	2084	27,282	53
2032	0.109	4857	642	2117	29,399	53
2033	0.109	4922	642	2145	31,544	54
2034	0.109	4978	643	2169	33,712	54
2035	0.109	5026	643	2190	35,902	54
2036	0.109	5068	643	2208	38,110	54
2037	0.109	5104	644	2223	40,334	54
2038	0.109	5135	644	2237	42,570	54
2039	0.109	5161	644	2248	44,819	54
2040	0.109	5184	644	2258	47,077	54

*Table 3.21. Red snapper: Projection results under scenario 8—Discard-only projection with fishing rate fixed at $F = F_{current}$ minus commercial diving, and with release mortality rates of 0.9 in the commercial sector and 0.4 in the headboat and general recreational sectors. F = fishing rate (per year), Fmort = fishing rate leading to discard mortality (a portion of F), SSB = mid-year spawning stock biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight), and D = discard mortalities (1000 fish). For reference, the target for rebuilding is* SSB_{MSY} = 5184.

Year	F(per yr)	Fmort (per yr)	SSB(mt)	R(1000)	L(1000 lb)	D(1000)
2007	0.998	0.998	161	269	562	130
2008	0.998	0.998	125	273	420	123
2009	0.927	0.668	106	233	0	117
2010	0.927	0.668	181	208	0	126
2011	0.927	0.668	220	292	0	139
2012	0.927	0.668	260	325	0	164
2013	0.927	0.668	304	353	0	186
2014	0.927	0.668	350	379	0	206
2015	0.927	0.668	397	402	0	224
2016	0.927	0.668	442	422	0	240
2017	0.927	0.668	485	439	0	255
2018	0.927	0.668	525	453	0	267
2019	0.927	0.668	562	464	0	278
2020	0.927	0.668	595	474	0	287
2021	0.927	0.668	624	482	0	295
2022	0.927	0.668	649	488	0	302
2023	0.927	0.668	671	494	0	307
2024	0.927	0.668	690	498	0	312
2025	0.927	0.668	706	502	0	316
2026	0.927	0.668	720	505	0	319
2027	0.927	0.668	731	507	0	322
2028	0.927	0.668	741	509	0	324
2029	0.927	0.668	749	511	0	326
2030	0.927	0.668	755	512	0	327
2031	0.927	0.668	761	513	0	328
2032	0.927	0.668	765	514	0	329
2033	0.927	0.668	769	515	0	330
2034	0.927	0.668	772	515	0	331
2035	0.927	0.668	775	516	0	331
2036	0.927	0.668	777	516	0	332
2037	0.927	0.668	779	516	0	332
2038	0.927	0.668	780	517	0	332
2039	0.927	0.668	781	517	0	333
2040	0.927	0.668	782	517	0	333

*Table 3.22. Red snapper: Projection results under scenario 9—Discard-only projection with fishing rate fixed at $F = F_{current}$ minus commercial diving, and with release mortality rates of 0.8 in the commercial sector and 0.2 in the headboat and general recreational sectors. F = fishing rate (per year), Fmort = fishing rate leading to discard mortality (a portion of F), SSB = mid-year spawning stock biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight), and D = discard mortalities (1000 fish). For reference, the target for rebuilding is* SSB_{MSY} = 5184.

Year	F(per yr)	Fmort (per yr)	SSB(mt)	R(1000)	L(1000 lb)	D(1000)
2007	0.998	0.998	161	269	562	130
2008	0.998	0.998	125	273	420	123
2009	0.927	0.570	106	233	0	106
2010	0.927	0.570	199	208	0	114
2011	0.927	0.570	256	308	0	130
2012	0.927	0.570	317	350	0	159
2013	0.927	0.570	387	386	0	185
2014	0.927	0.570	462	418	0	207
2015	0.927	0.570	540	446	0	228
2016	0.927	0.570	619	468	0	247
2017	0.927	0.570	696	487	0	263
2018	0.927	0.570	770	503	0	278
2019	0.927	0.570	839	515	0	290
2020	0.927	0.570	902	526	0	300
2021	0.927	0.570	959	534	0	309
2022	0.927	0.570	1010	540	0	316
2023	0.927	0.570	1055	546	0	322
2024	0.927	0.570	1094	550	0	328
2025	0.927	0.570	1128	554	0	332
2026	0.927	0.570	1157	557	0	335
2027	0.927	0.570	1182	559	0	338
2028	0.927	0.570	1202	561	0	341
2029	0.927	0.570	1220	563	0	343
2030	0.927	0.570	1235	564	0	345
2031	0.927	0.570	1247	565	0	346
2032	0.927	0.570	1258	566	0	347
2033	0.927	0.570	1266	567	0	348
2034	0.927	0.570	1273	568	0	349
2035	0.927	0.570	1279	568	0	349
2036	0.927	0.570	1284	569	0	350
2037	0.927	0.570	1288	569	0	350
2038	0.927	0.570	1292	569	0	351
2039	0.927	0.570	1295	569	0	351
2040	0.927	0.570	1297	570	0	351

*Table 3.23. Red snapper: Projection results under scenario 10—Discard-only projection with fishing rate fixed at $F = F_{\text{current}}$ minus commercial diving, and with release mortality rates of 1.0 in the commercial sector and 0.6 in the headboat and general recreational sectors. F = fishing rate (per year), Fmort = fishing rate leading to discard mortality (a portion of F), SSB = mid-year spawning stock biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight), and D = discard mortalities (1000 fish). For reference, the target for rebuilding is* $SSB_{MSY} = 5184$.

Year	F(per yr)	Fmort (per yr)	SSB(mt)	R(1000)	L(1000 lb)	D(1000)
2007	0.998	0.998	161	269	562	130
2008	0.998	0.998	125	273	420	123
2009	0.927	0.767	106	233	0	127
2010	0.927	0.767	164	208	0	135
2011	0.927	0.767	190	276	0	145
2012	0.927	0.767	215	300	0	165
2013	0.927	0.767	242	321	0	183
2014	0.927	0.767	270	341	0	198
2015	0.927	0.767	297	359	0	213
2016	0.927	0.767	323	375	0	226
2017	0.927	0.767	347	389	0	237
2018	0.927	0.767	369	401	0	248
2019	0.927	0.767	389	410	0	257
2020	0.927	0.767	406	419	0	264
2021	0.927	0.767	422	426	0	271
2022	0.927	0.767	435	432	0	276
2023	0.927	0.767	447	437	0	281
2024	0.927	0.767	457	441	0	285
2025	0.927	0.767	466	444	0	288
2026	0.927	0.767	473	447	0	291
2027	0.927	0.767	479	449	0	293
2028	0.927	0.767	484	451	0	295
2029	0.927	0.767	488	453	0	297
2030	0.927	0.767	492	454	0	298
2031	0.927	0.767	495	455	0	299
2032	0.927	0.767	497	456	0	300
2033	0.927	0.767	499	457	0	301
2034	0.927	0.767	501	457	0	302
2035	0.927	0.767	502	458	0	302
2036	0.927	0.767	504	458	0	303
2037	0.927	0.767	505	458	0	303
2038	0.927	0.767	505	459	0	303
2039	0.927	0.767	506	459	0	303
2040	0.927	0.767	507	459	0	304

Table 3.24. Red snapper: Projection results under scenario 11—Discard-only projection with fishing rate fixed at $F = F_{\text{rebuild}}$, given release mortality rates of 0.9 in the commercial sector and 0.4 in the headboat and general recreational sectors. F = fishing rate (per year), Fmort = fishing rate leading to discard mortality (a portion of F), SSB = mid-year spawning stock biomass (mt), R = recruits (1000 fish), L = landings (1000 lb whole weight), and D = discard mortalities (1000 fish). For reference, the target for rebuilding is $\text{SSB}_{\text{MSY}} = 5184$.

Year	F(per yr)	Fmort (per yr)	SSB(mt)	R(1000)	L(1000 lb)	D(1000)
2007	0.998	0.998	161	269	562	130
2008	0.998	0.998	125	273	420	123
2009	0.262	0.189	106	233	0	37
2010	0.262	0.189	262	208	0	47
2011	0.262	0.189	394	354	0	59
2012	0.262	0.189	556	421	0	78
2013	0.262	0.189	760	473	0	99
2014	0.262	0.189	1003	514	0	117
2015	0.262	0.189	1278	545	0	135
2016	0.262	0.189	1575	568	0	151
2017	0.262	0.189	1884	586	0	166
2018	0.262	0.189	2195	598	0	179
2019	0.262	0.189	2501	608	0	190
2020	0.262	0.189	2794	615	0	200
2021	0.262	0.189	3071	621	0	209
2022	0.262	0.189	3329	625	0	217
2023	0.262	0.189	3565	629	0	223
2024	0.262	0.189	3781	632	0	229
2025	0.262	0.189	3975	634	0	234
2026	0.262	0.189	4148	636	0	238
2027	0.262	0.189	4303	637	0	242
2028	0.262	0.189	4440	638	0	245
2029	0.262	0.189	4560	640	0	248
2030	0.262	0.189	4666	640	0	250
2031	0.262	0.189	4759	641	0	252
2032	0.262	0.189	4839	642	0	254
2033	0.262	0.189	4910	642	0	256
2034	0.262	0.189	4971	643	0	257
2035	0.262	0.189	5024	643	0	258
2036	0.262	0.189	5070	643	0	259
2037	0.262	0.189	5110	644	0	260
2038	0.262	0.189	5145	644	0	261
2039	0.262	0.189	5174	644	0	261
2040	0.262	0.189	5200	644	0	262

Table 3.25. Red snapper: Projection results under scenario 12—Discard-only projection with fishing rate fixed at $F = F_{\text{rebuild}}$, given release mortality rates of 0.7 in the commercial sector and 0.4 in the headboat and general recreational sectors. F = fishing rate (per year), Fmort = fishing rate leading to discard mortality (a portion of F), SSB = mid-year spawning stock biomass (mt)*, R = recruits (1000 fish), L = landings (1000* lb *whole weight), and D = discard mortalities (1000 fish). For reference, the target for rebuilding is* $\text{SSB}_{\text{MSY}} = 5184$.

Year	F(per yr)	Fmort (per yr)	SSB(mt)	R(1000)	L(1000 lb)	D(1000)
2007	0.998	0.998	161	269	562	130
2008	0.998	0.998	125	273	420	123
2009	0.286	0.195	106	233	0	40
2010	0.286	0.195	261	208	0	50
2011	0.286	0.195	390	353	0	62
2012	0.286	0.195	550	420	0	82
2013	0.286	0.195	751	471	0	103
2014	0.286	0.195	990	512	0	122
2015	0.286	0.195	1260	544	0	139
2016	0.286	0.195	1552	567	0	155
2017	0.286	0.195	1856	585	0	170
2018	0.286	0.195	2163	597	0	183
2019	0.286	0.195	2465	607	0	194
2020	0.286	0.195	2756	615	0	204
2021	0.286	0.195	3032	620	0	212
2022	0.286	0.195	3289	625	0	220
2023	0.286	0.195	3525	628	0	226
2024	0.286	0.195	3741	631	0	232
2025	0.286	0.195	3936	634	0	237
2026	0.286	0.195	4111	635	0	241
2027	0.286	0.195	4267	637	0	245
2028	0.286	0.195	4406	638	0	248
2029	0.286	0.195	4528	639	0	250
2030	0.286	0.195	4636	640	0	253
2031	0.286	0.195	4730	641	0	255
2032	0.286	0.195	4813	642	0	257
2033	0.286	0.195	4885	642	0	258
2034	0.286	0.195	4948	642	0	260
2035	0.286	0.195	5003	643	0	261
2036	0.286	0.195	5051	643	0	262
2037	0.286	0.195	5092	643	0	263
2038	0.286	0.195	5128	644	0	263
2039	0.286	0.195	5159	644	0	264
2040	0.286	0.195	5186	644	0	265

Table 3.26. Parameter estimates from fit of surplus production model applied to red snapper, including bootstrap estimates of bias and uncertainty.

ESTIMATES FROM BOOTSTRAPPED ANALYSIS

Param name	Point estimate	Estimated bias in pt estimate	Estimated relative bias	Bias-corrected approximate confidence limits 80% lower	80% upper	50% lower	50% upper
B1/K	9.500E-01	-5.440E-15	0.00%	9.500E-01	9.500E-01	9.500E-01	9.500E-01
K	4.495E+07	4.455E+06	9.91%	4.235E+07	5.182E+07	4.235E+07	4.588E+07
q(1)	2.215E-07	-2.345E-08	-10.58%	1.574E-07	2.900E-07	2.044E-07	2.599E-07
q(2)	2.455E-07	-2.882E-08	-11.74%	1.843E-07	3.636E-07	2.284E-07	3.150E-07
q(3)	2.370E-07	-2.621E-08	-11.06%	1.785E-07	3.131E-07	2.155E-07	2.849E-07
MSY	3.342E+06	-2.028E+05	-6.07%	2.997E+06	3.476E+06	3.295E+06	3.476E+06
Ye(2007)	1.065E+06	3.844E+04	3.61%	7.266E+05	1.465E+06	8.866E+05	1.277E+06
Y.@Fmsy	5.836E+05	4.367E+04	7.48%	3.836E+05	8.455E+05	4.718E+05	7.122E+05
Bmsy	2.247E+07	2.228E+06	9.91%	2.117E+07	2.591E+07	2.117E+07	2.294E+07
Fmsy	1.487E-01	-1.500E-02	-10.09%	1.157E-01	1.642E-01	1.437E-01	1.642E-01
fmsy(1)	6.713E+05	3.458E+04	5.15%	5.457E+05	7.760E+05	5.966E+05	7.186E+05
fmsy(2)	6.059E+05	6.129E+04	10.12%	4.403E+05	7.689E+05	5.012E+05	6.729E+05
fmsy(3)	6.275E+05	4.253E+04	6.78%	5.003E+05	7.406E+05	5.457E+05	6.756E+05
B./Bmsy	1.746E-01	3.238E-02	18.54%	9.938E-02	2.418E-01	1.268E-01	1.983E-01
F./Fmsy	1.077E+00	2.464E-02	2.29%	7.586E-01	1.606E+00	8.974E-01	1.322E+00
Ye./MSY	3.187E-01	4.194E-02	13.16%	1.889E-01	4.252E-01	2.375E-01	3.573E-01
q2/q1	1.108E+00	-3.390E-03	-0.31%	8.411E-01	1.497E+00	9.725E-01	1.328E+00
q3/q1	1.070E+00	6.407E-03	0.60%	8.472E-01	1.340E+00	9.426E-01	1.210E+00

3.4.2 Figures

Figure 3.1. Red snapper: 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, c.hal to commercial handline, c.dv to commercial diving, hb to headboat, and rec to general recreational (MRFSS).

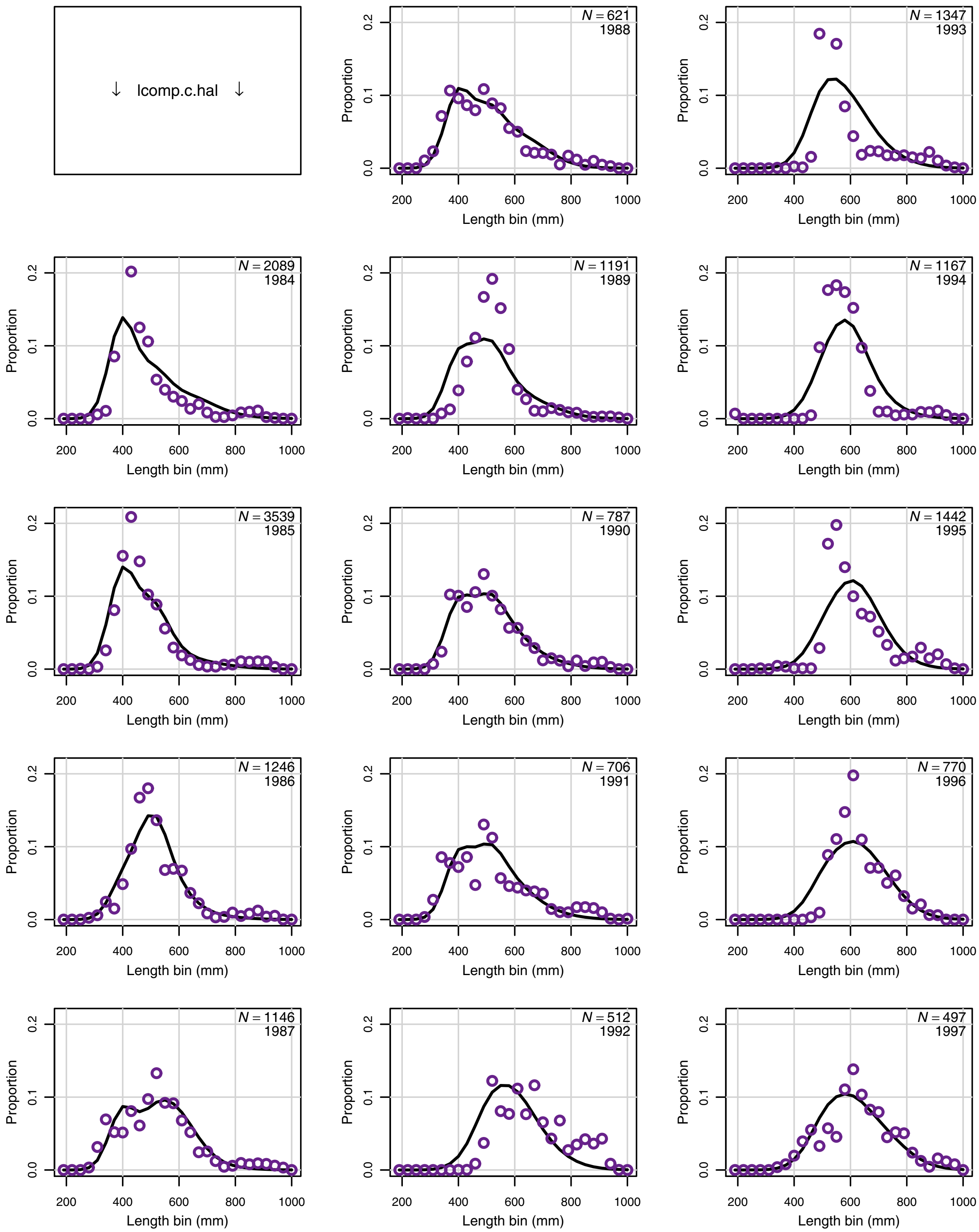


Figure 3.1. (cont.) Red snapper: Observed (open circles) and estimated (solid line) annual length and age compositions by fishery.

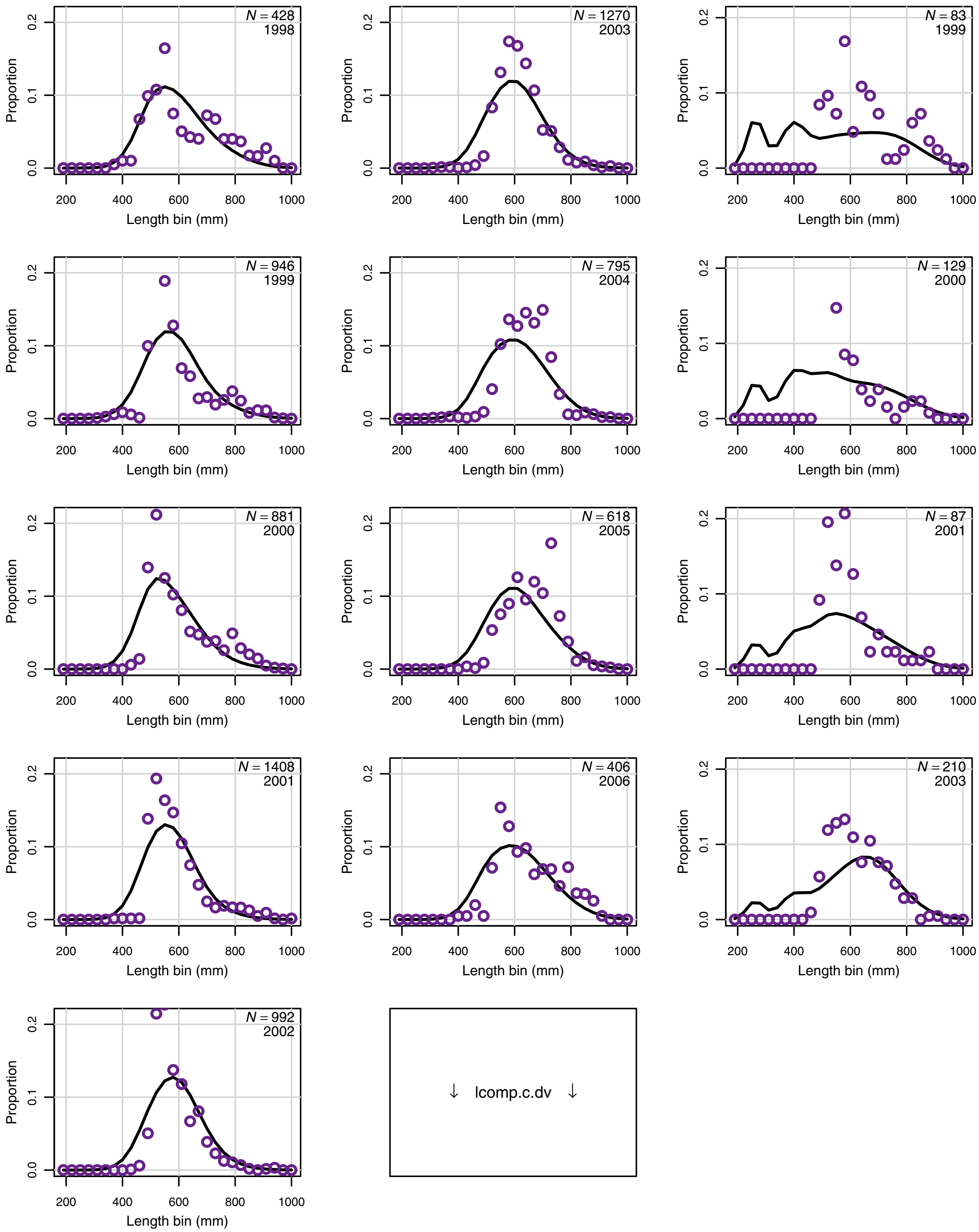


Figure 3.1. (cont.) Red snapper: Observed (open circles) and estimated (solid line) annual length and age compositions by fishery.

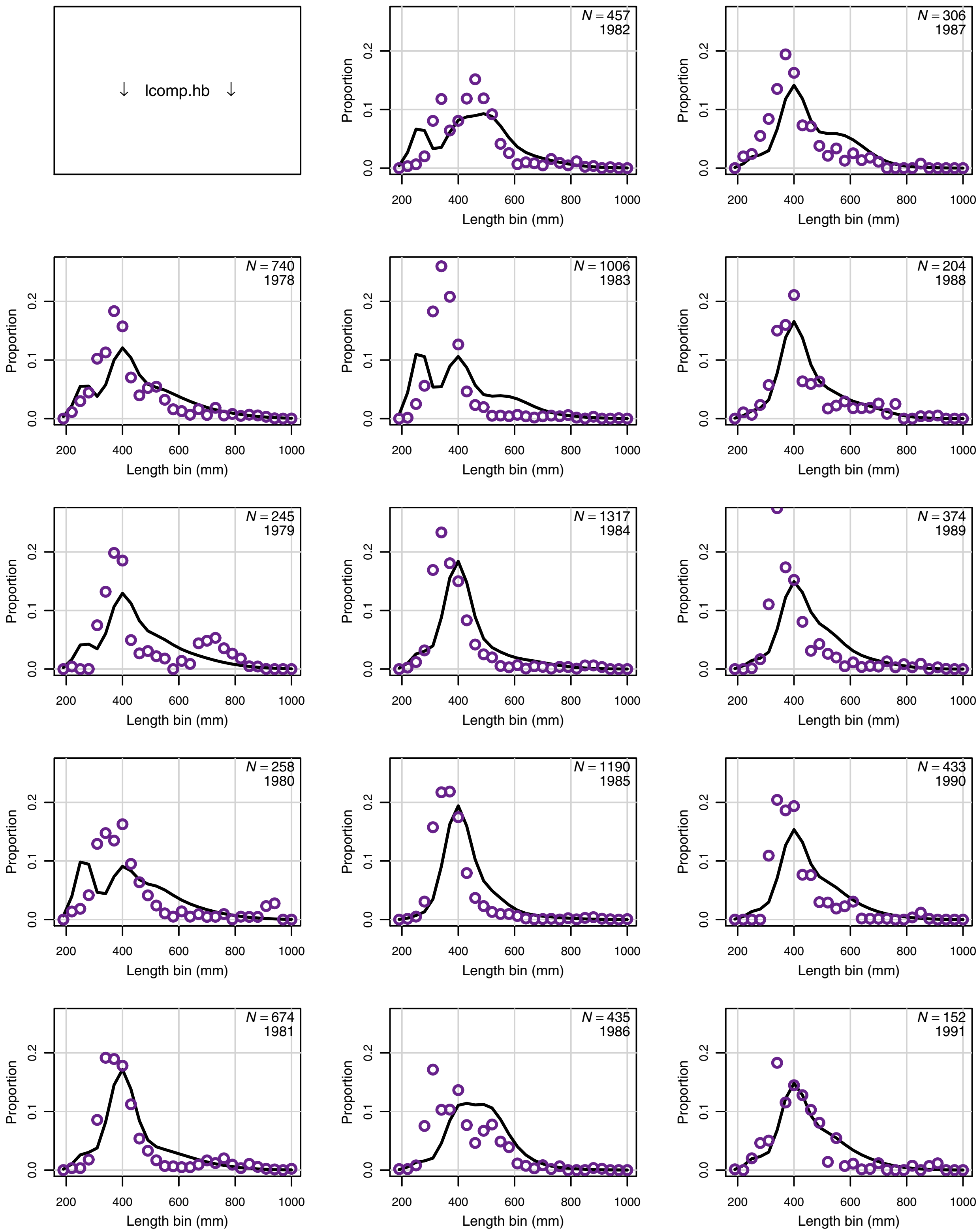


Figure 3.1. (cont.) Red snapper: Observed (open circles) and estimated (solid line) annual length and age compositions by fishery.

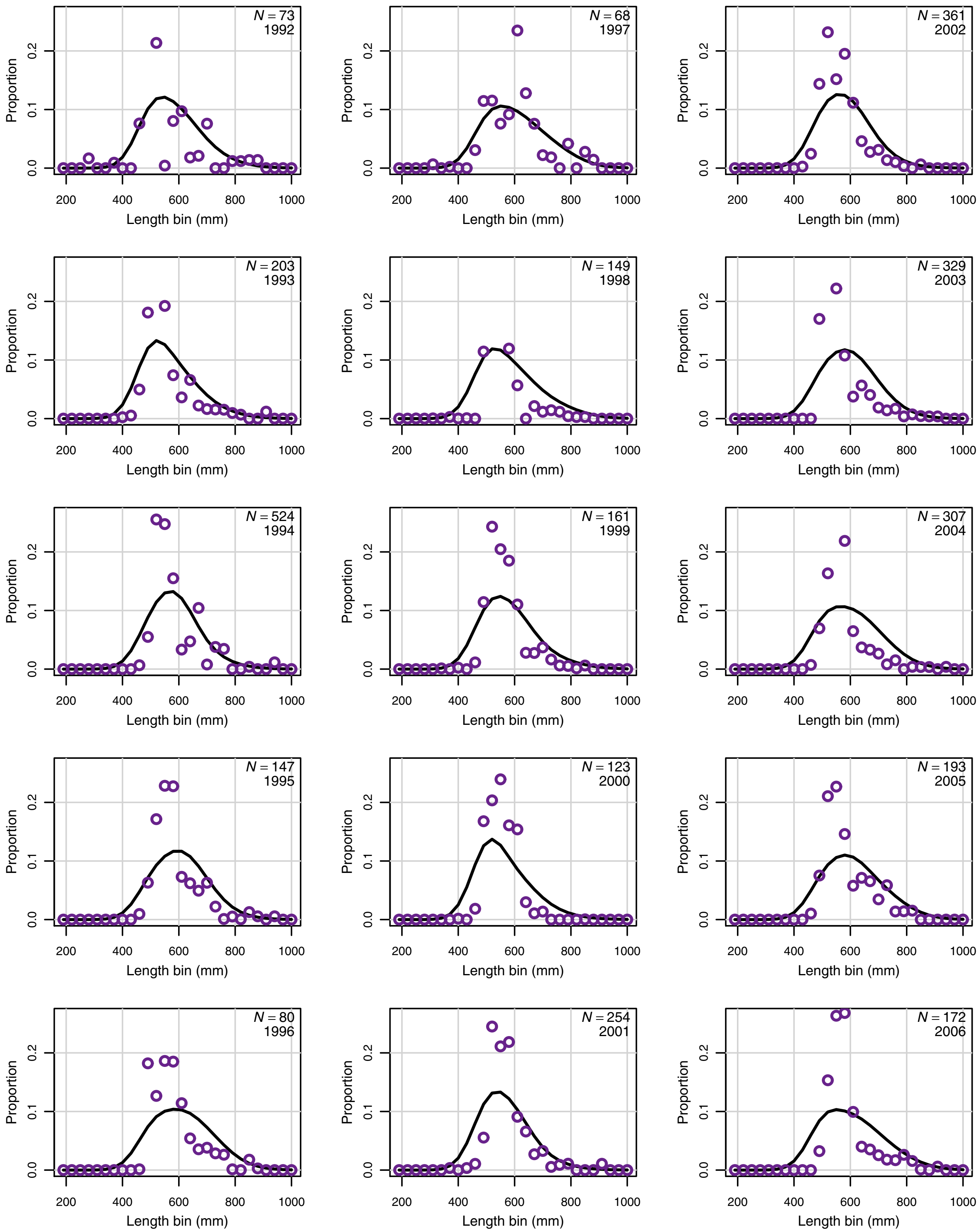


Figure 3.1. (cont.) Red snapper: Observed (open circles) and estimated (solid line) annual length and age compositions by fishery.

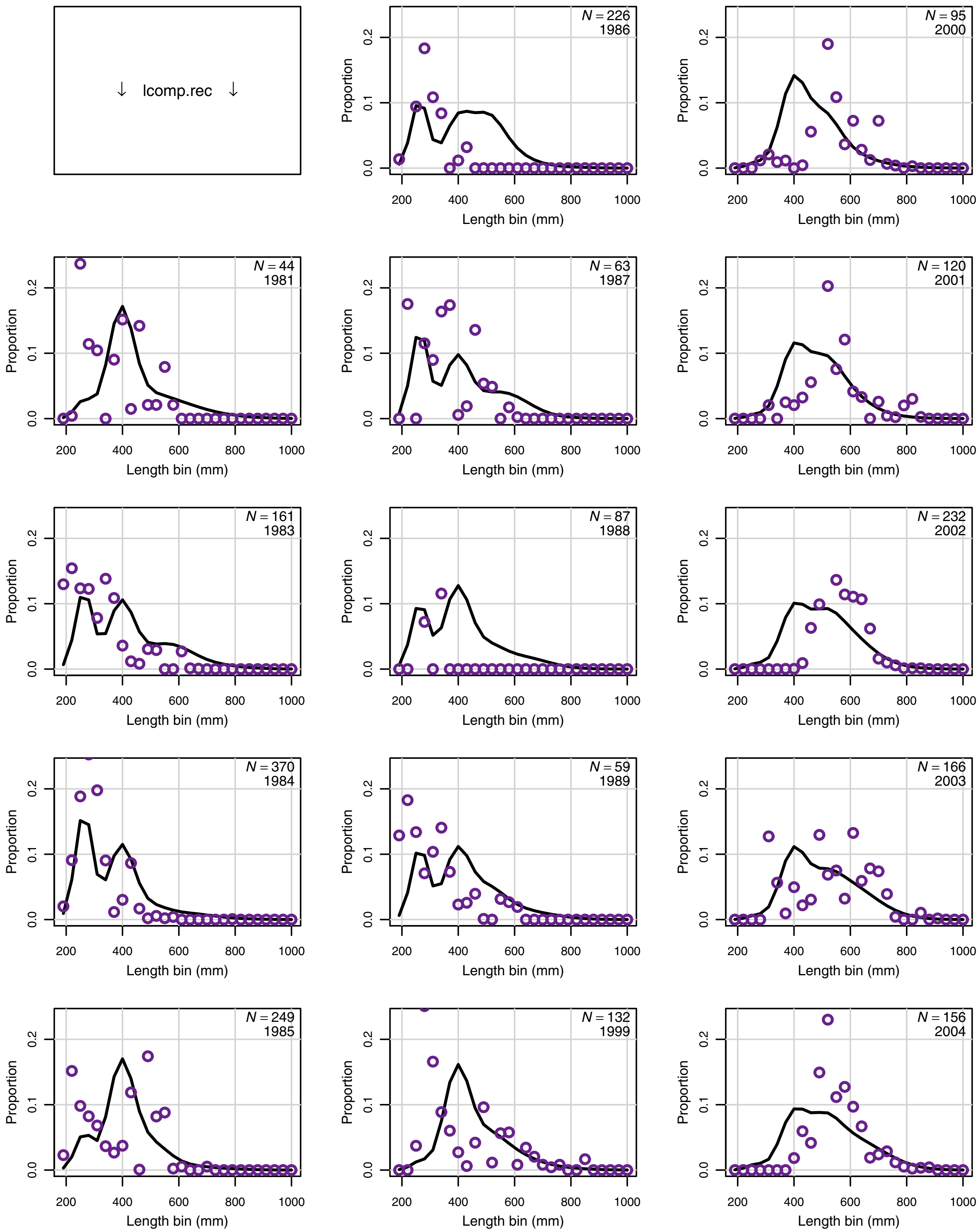


Figure 3.1. (cont.) Red snapper: Observed (open circles) and estimated (solid line) annual length and age compositions by fishery.

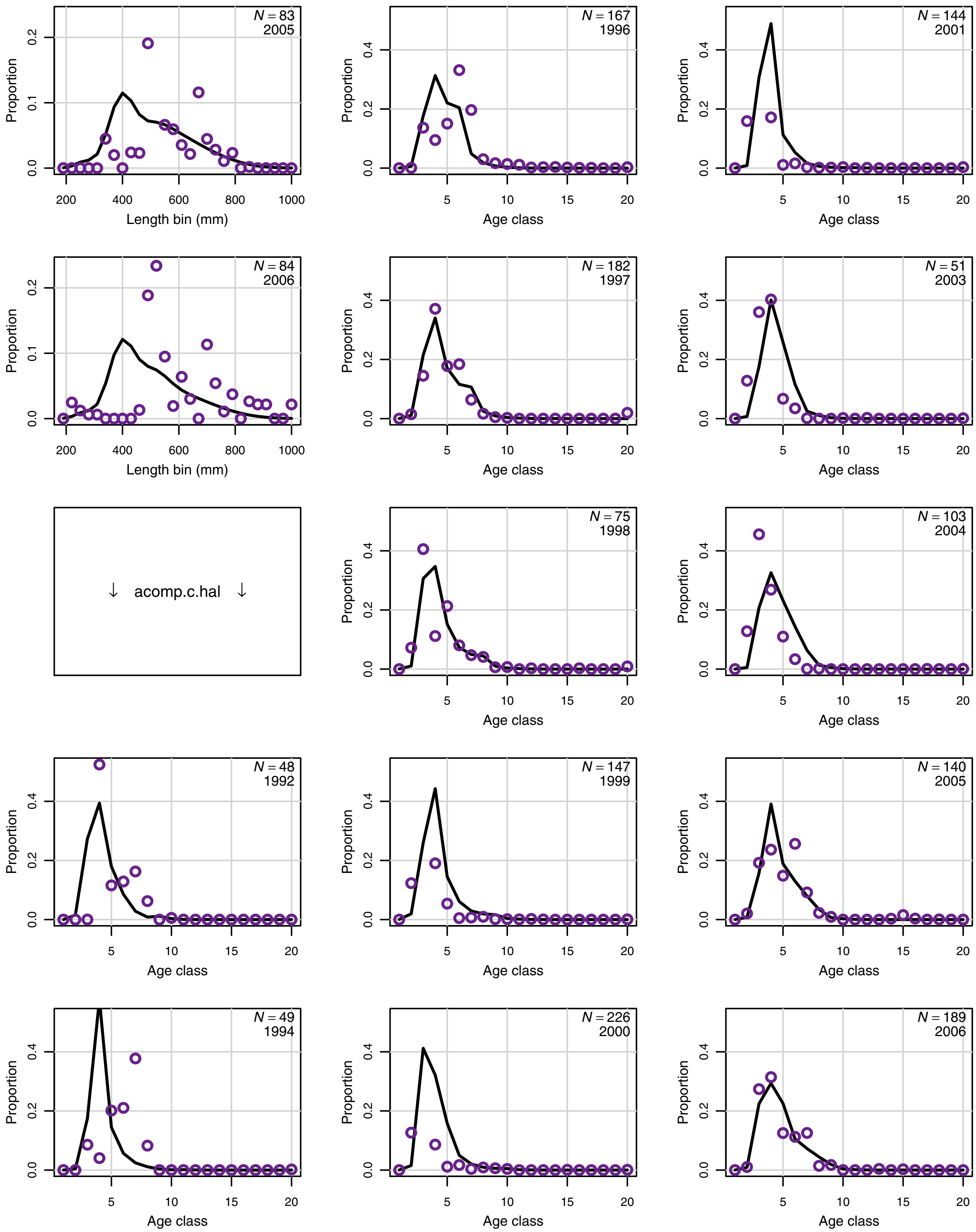


Figure 3.1. (cont.) Red snapper: Observed (open circles) and estimated (solid line) annual length and age compositions by fishery.

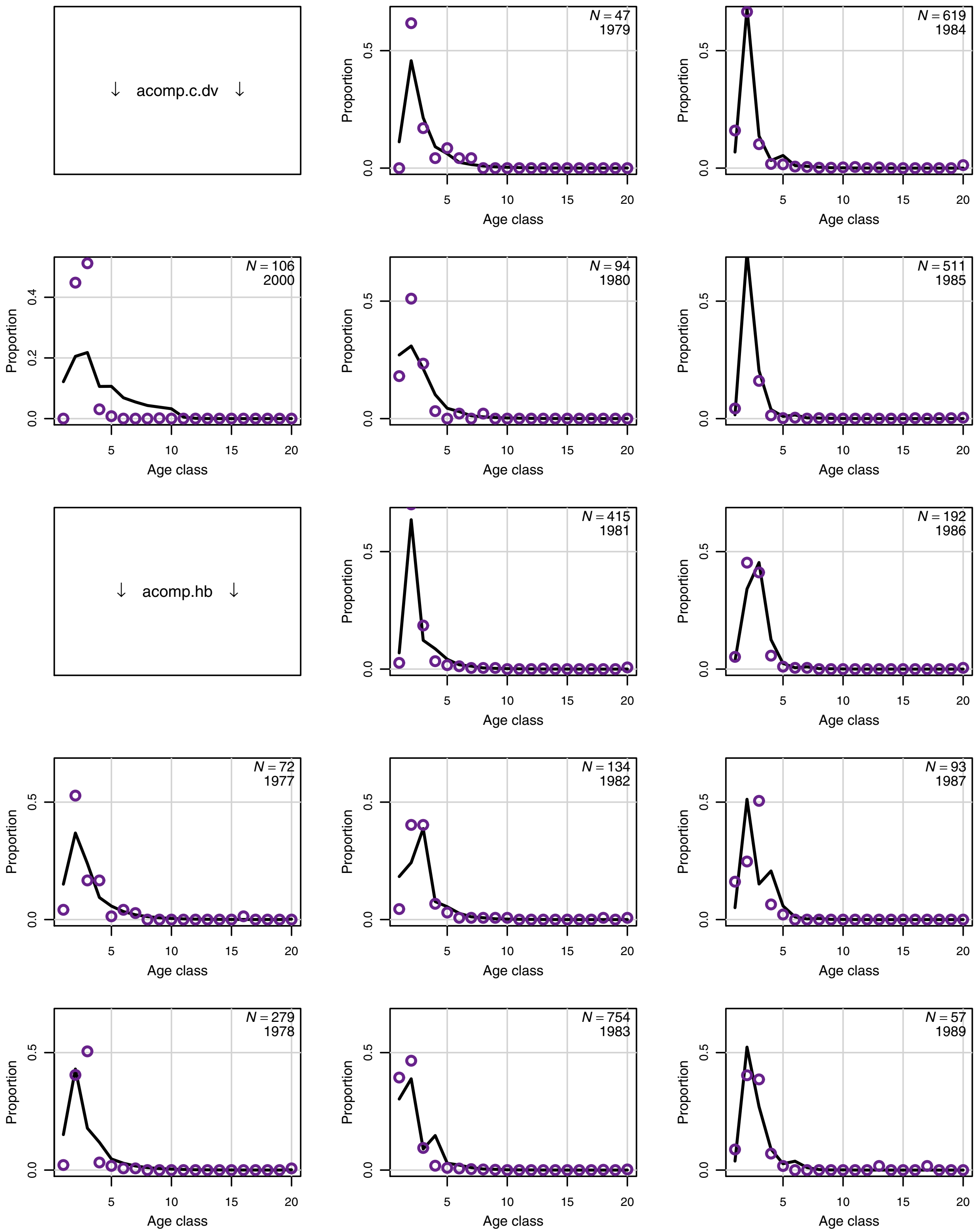


Figure 3.1. (cont.) Red snapper: Observed (open circles) and estimated (solid line) annual length and age compositions by fishery.

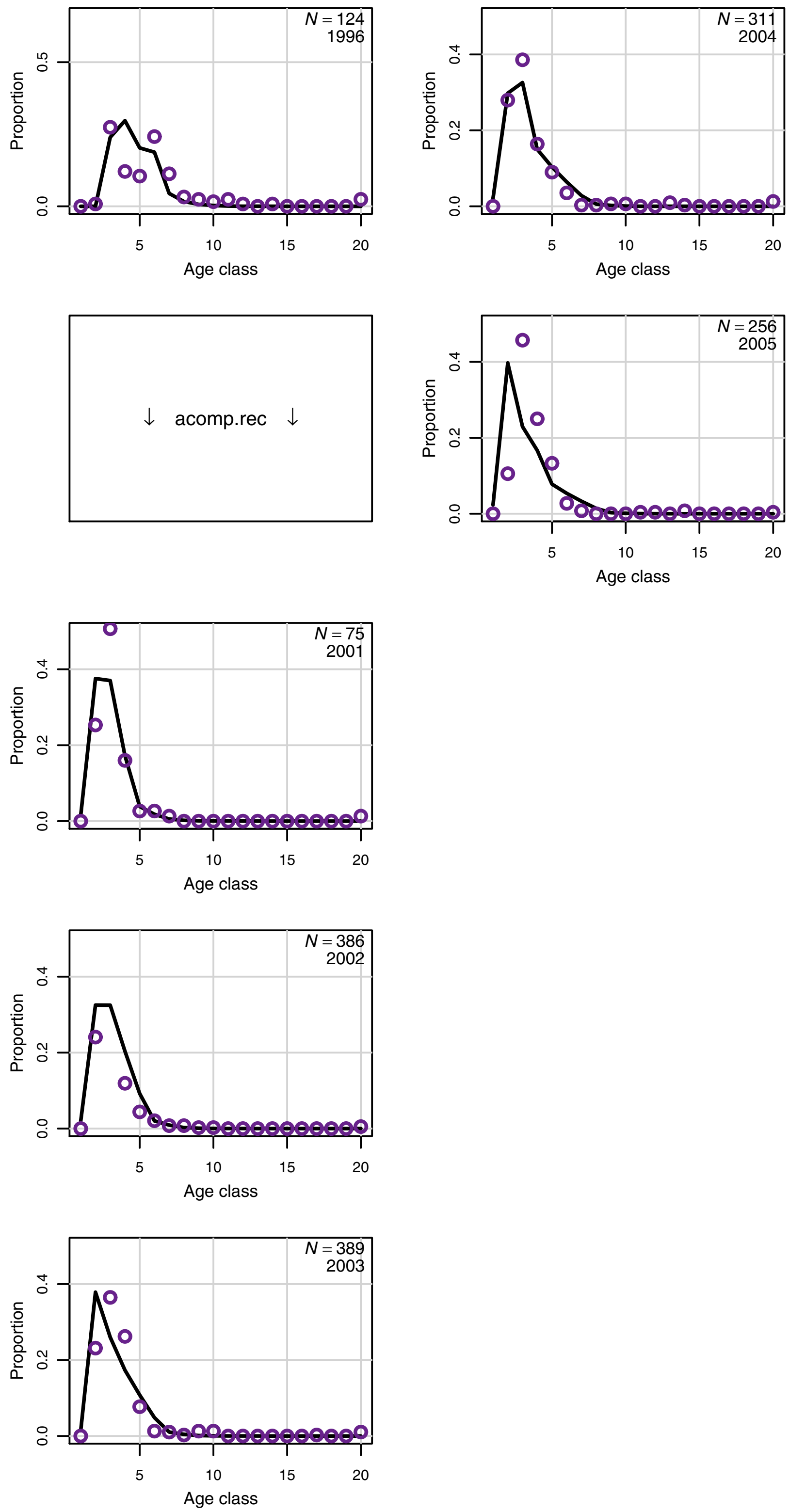


Figure 3.2. Red snapper: Top panel is a bubble plot of length composition residuals from the commercial handline fishery; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

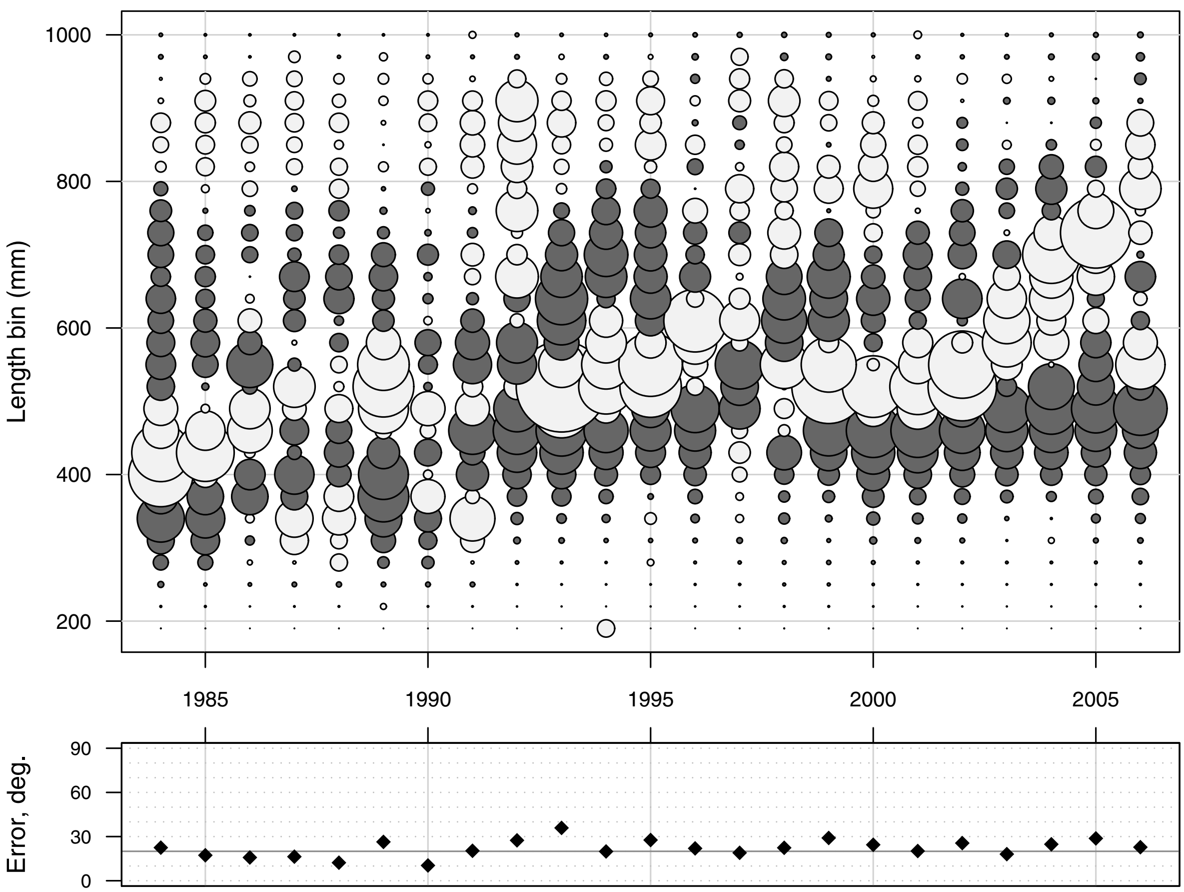


Figure 3.3. Red snapper: Top panel is a bubble plot of length composition residuals from the commercial diving fishery; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees.
Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

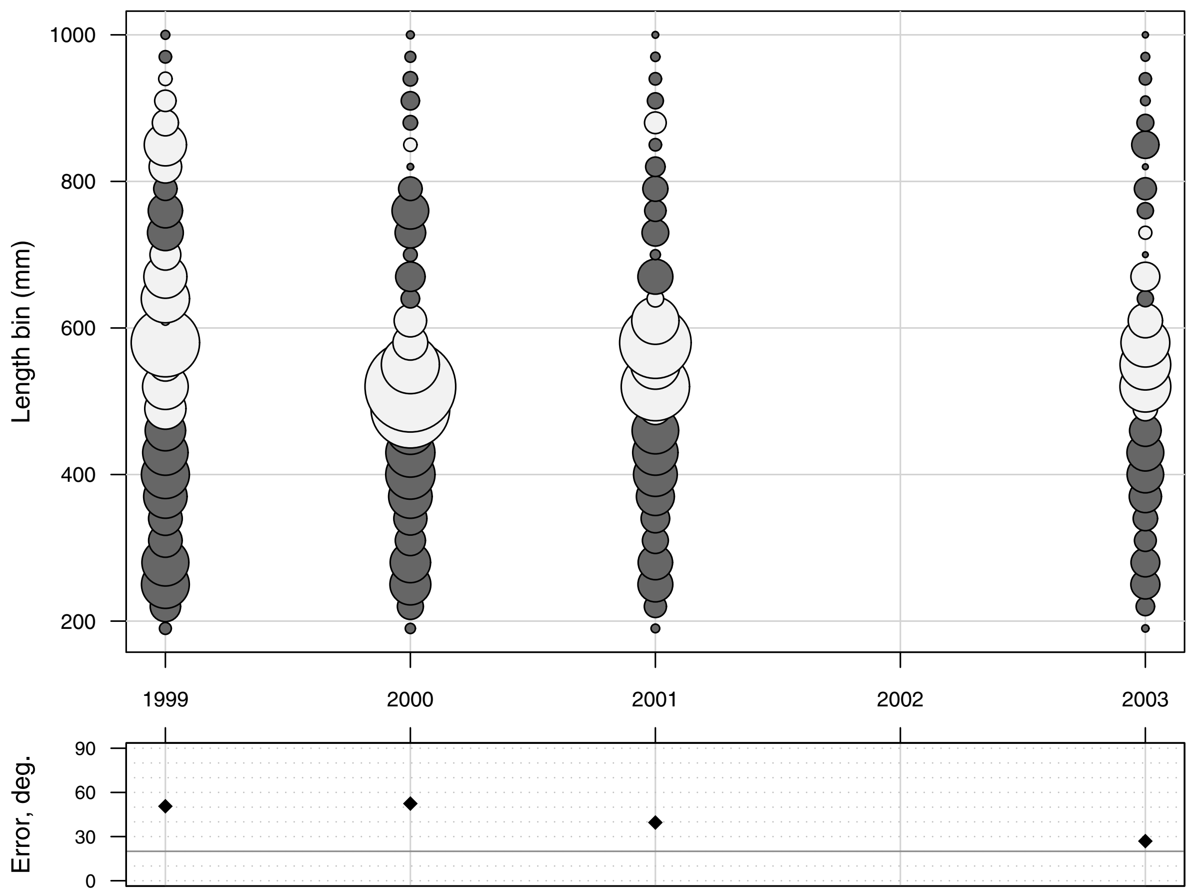


Figure 3.4. Red snapper: Top panel is a bubble plot of length composition residuals from the headboat fishery; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees.
Error is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

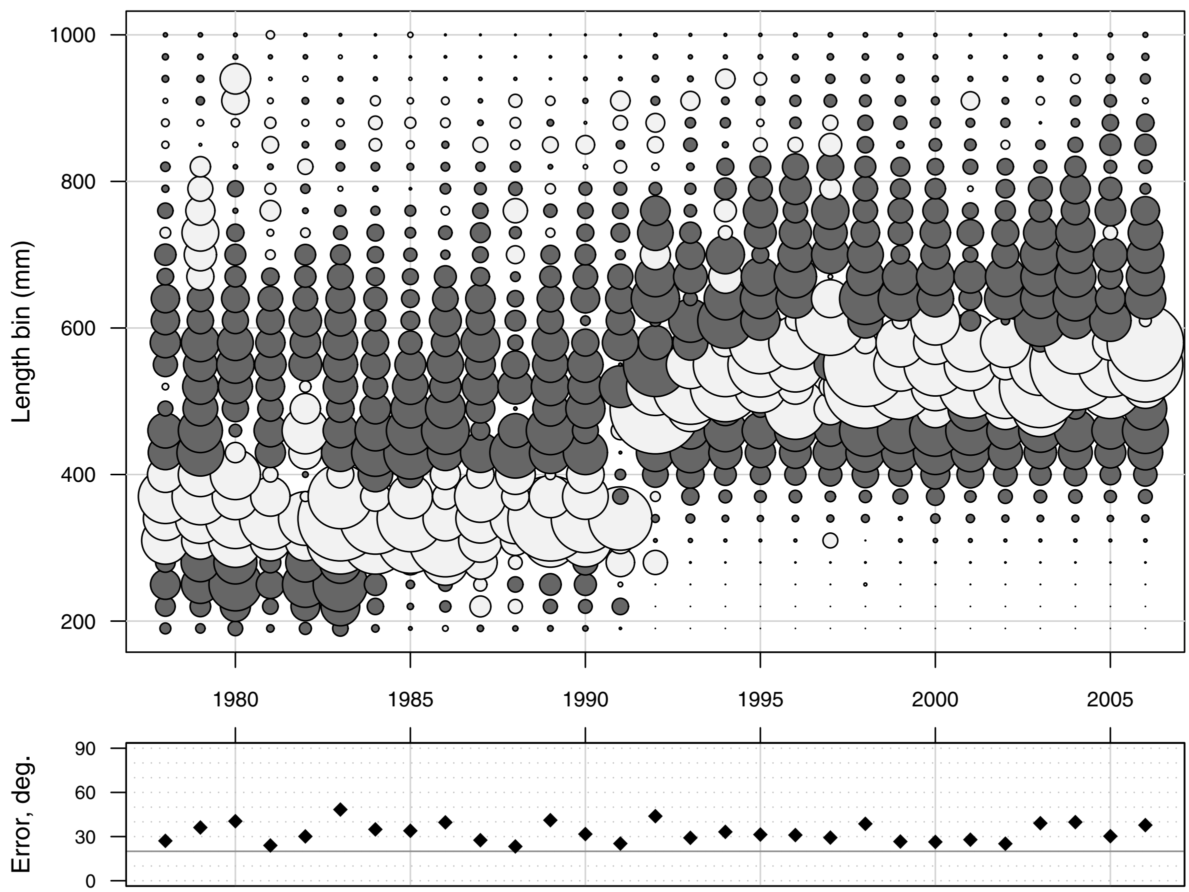


Figure 3.5. Red snapper: Top panel is a bubble plot of length composition residuals from the recreational fishery (MRFSS); Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees.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

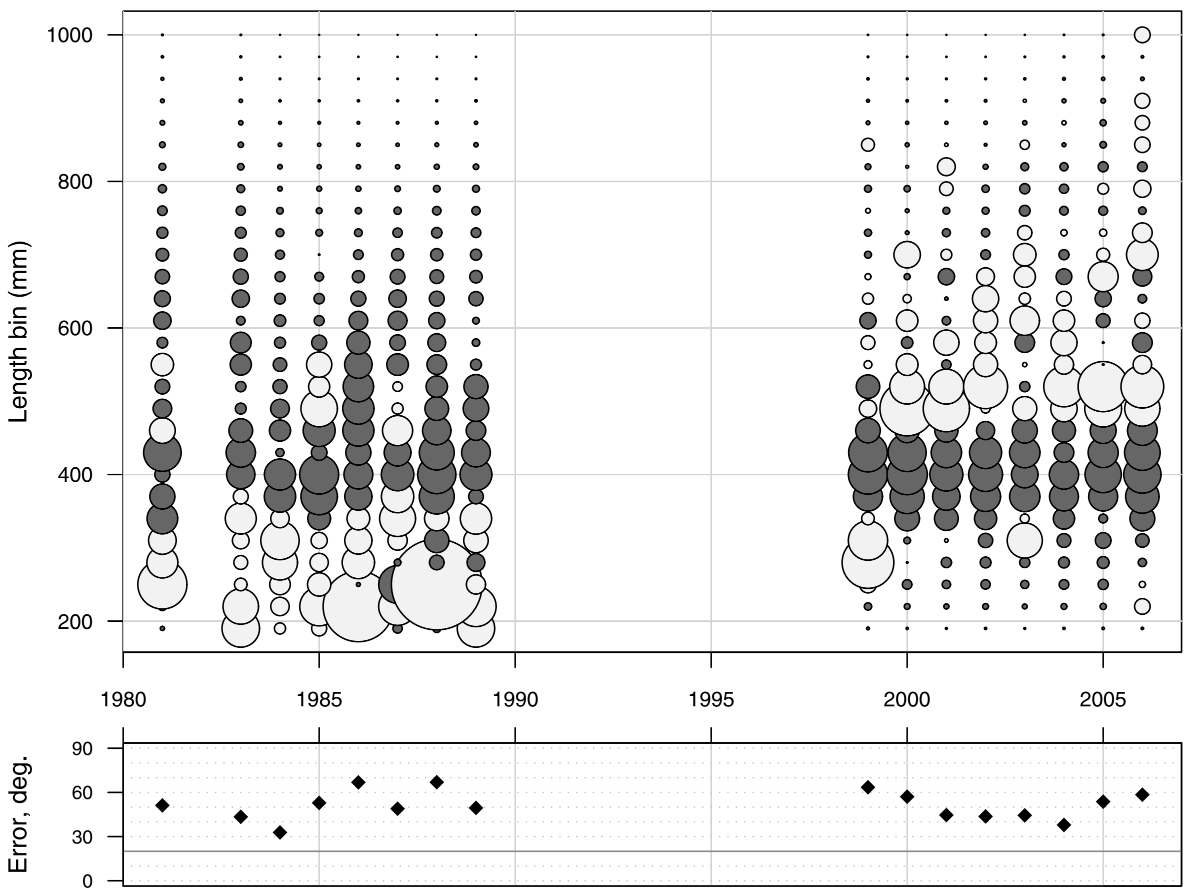


Figure 3.6. Red snapper: Top panel is a bubble plot of age composition residuals from the commercial handline fishery; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees.
Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

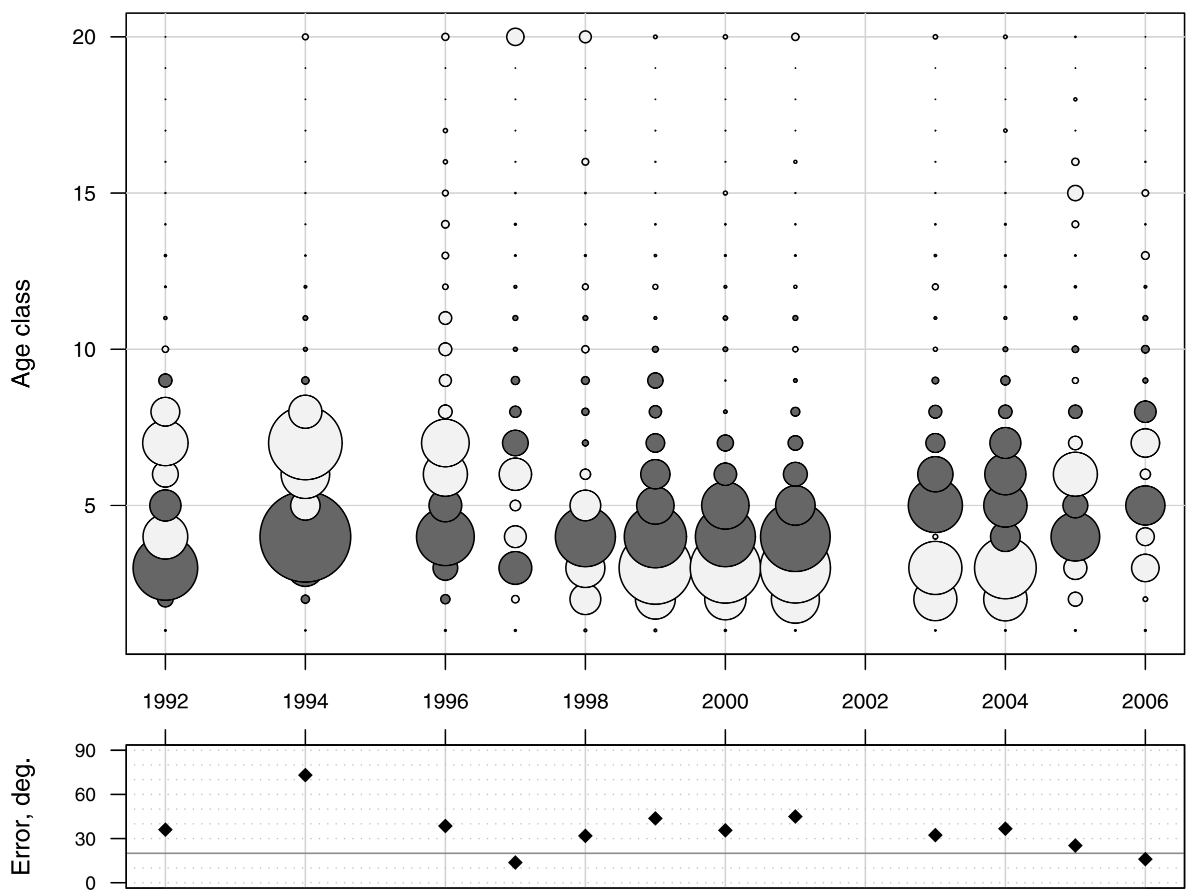


Figure 3.7. Red snapper: Top panel is a bubble plot of age composition residuals from the commercial diving fishery; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees.
Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

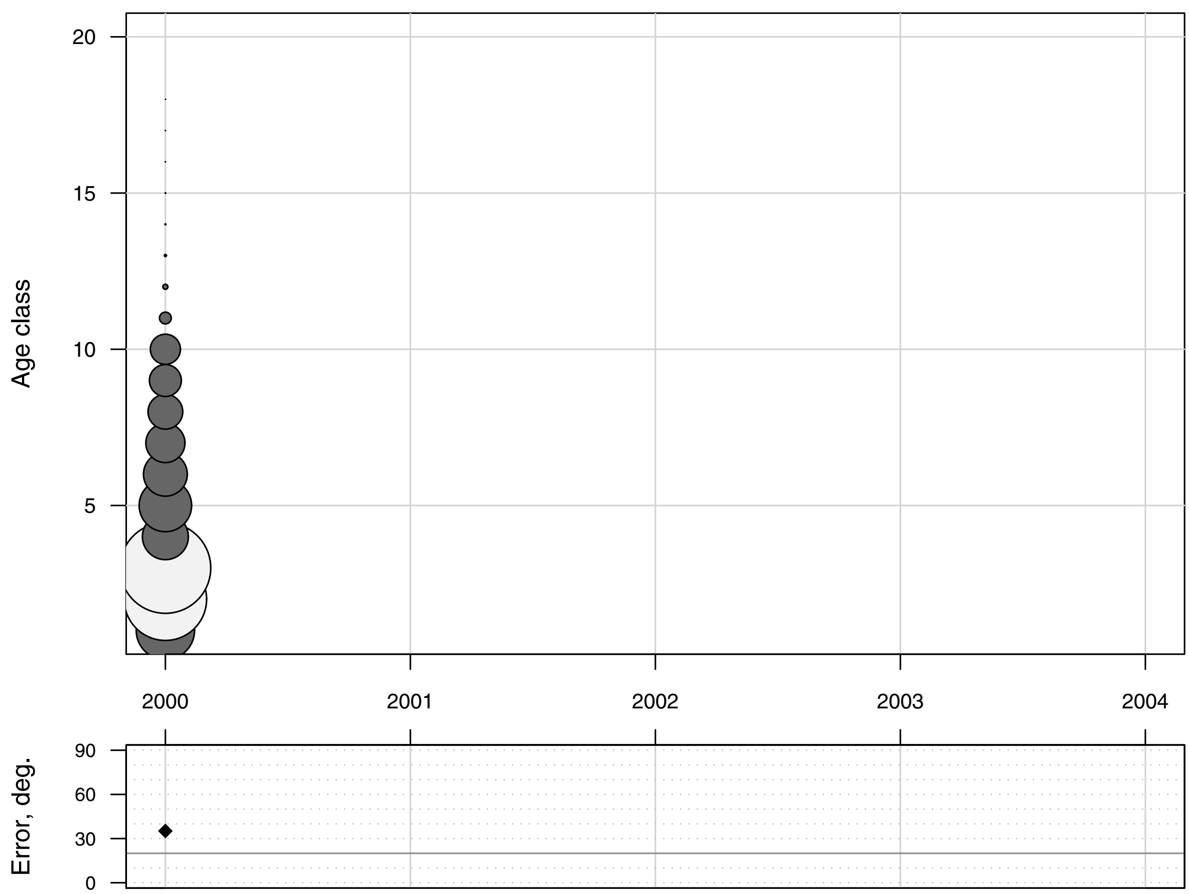


Figure 3.8. Red snapper: Top panel is a bubble plot of age composition residuals from the headboat fishery; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees.
Error is bounded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

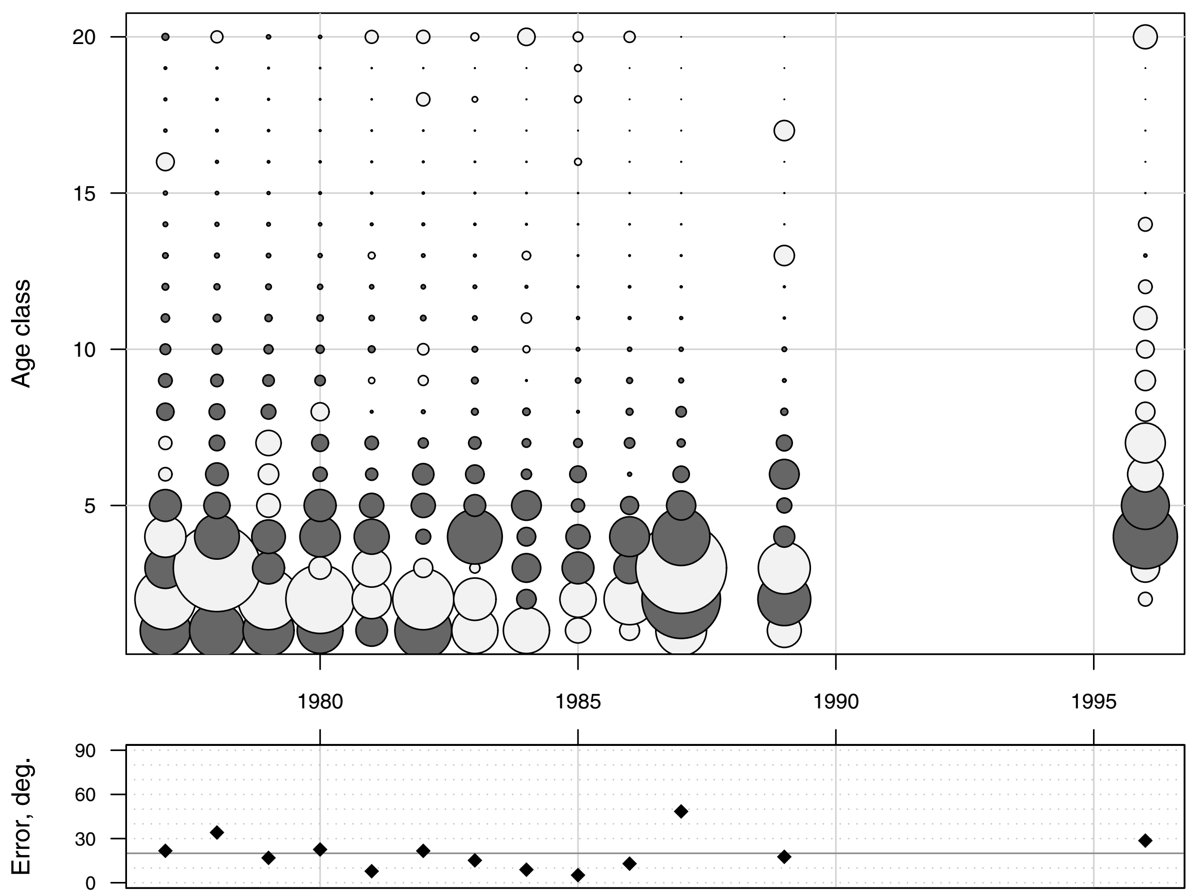


Figure 3.9. Red snapper: Top panel is a bubble plot of age composition residuals from the recreational fishery (MRFSS); Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees.
Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

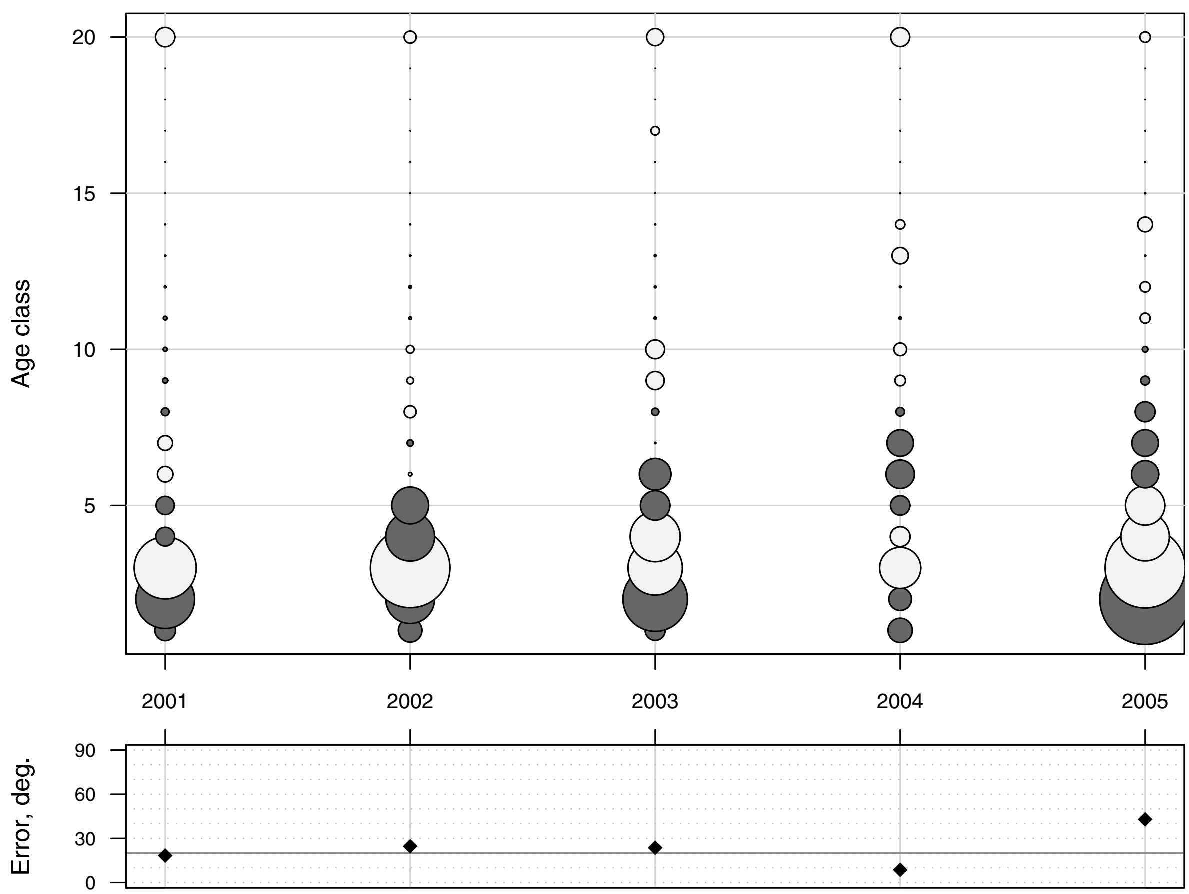


Figure 3.10. Red snapper: Observed (open circles) and estimated (solid line, circles) commercial handline landings (whole weight). Open and closed circles are indistinguishable.

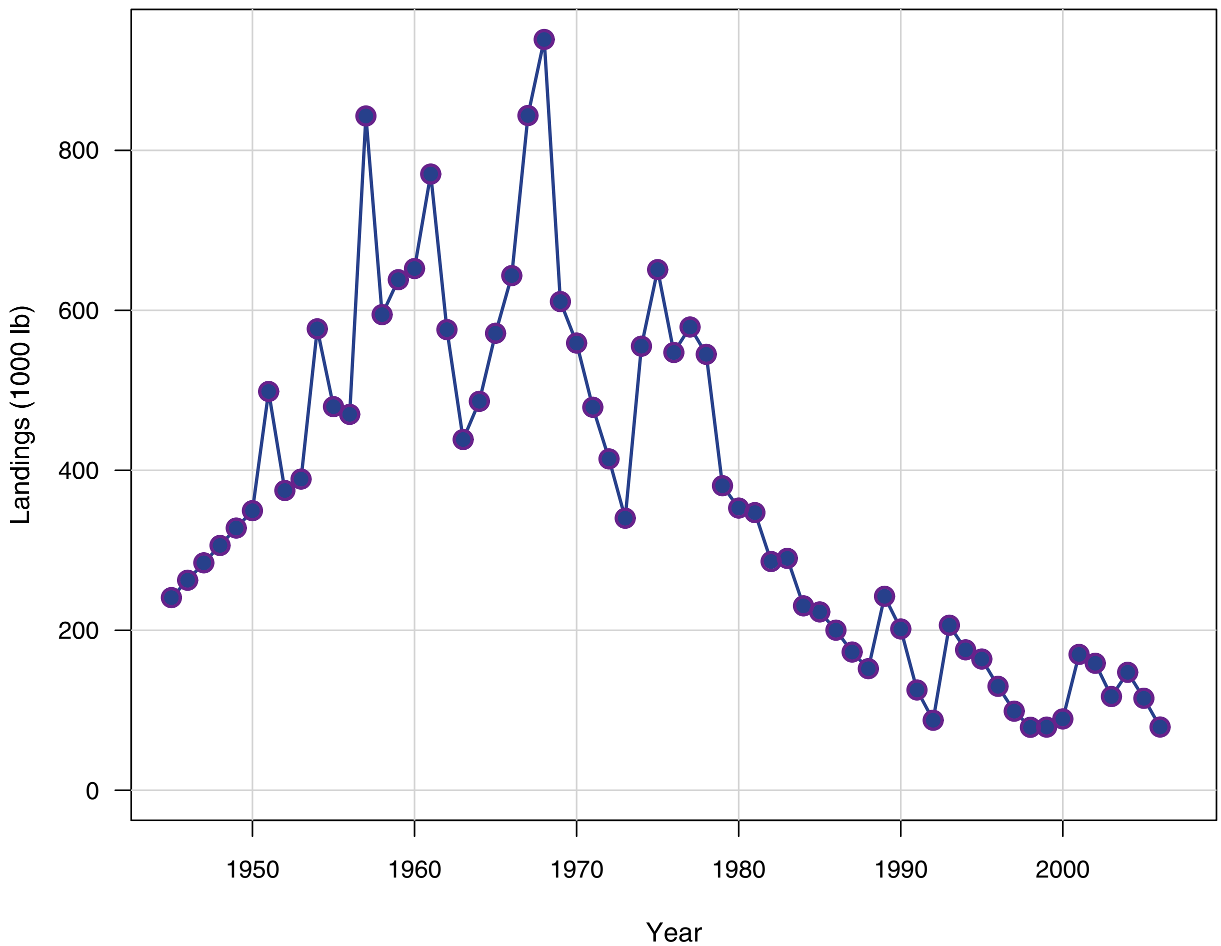


Figure 3.11. Red snapper: Observed (open circles) and estimated (solid line, circles) commercial diving landings (whole weight). Open and closed circles are indistinguishable.

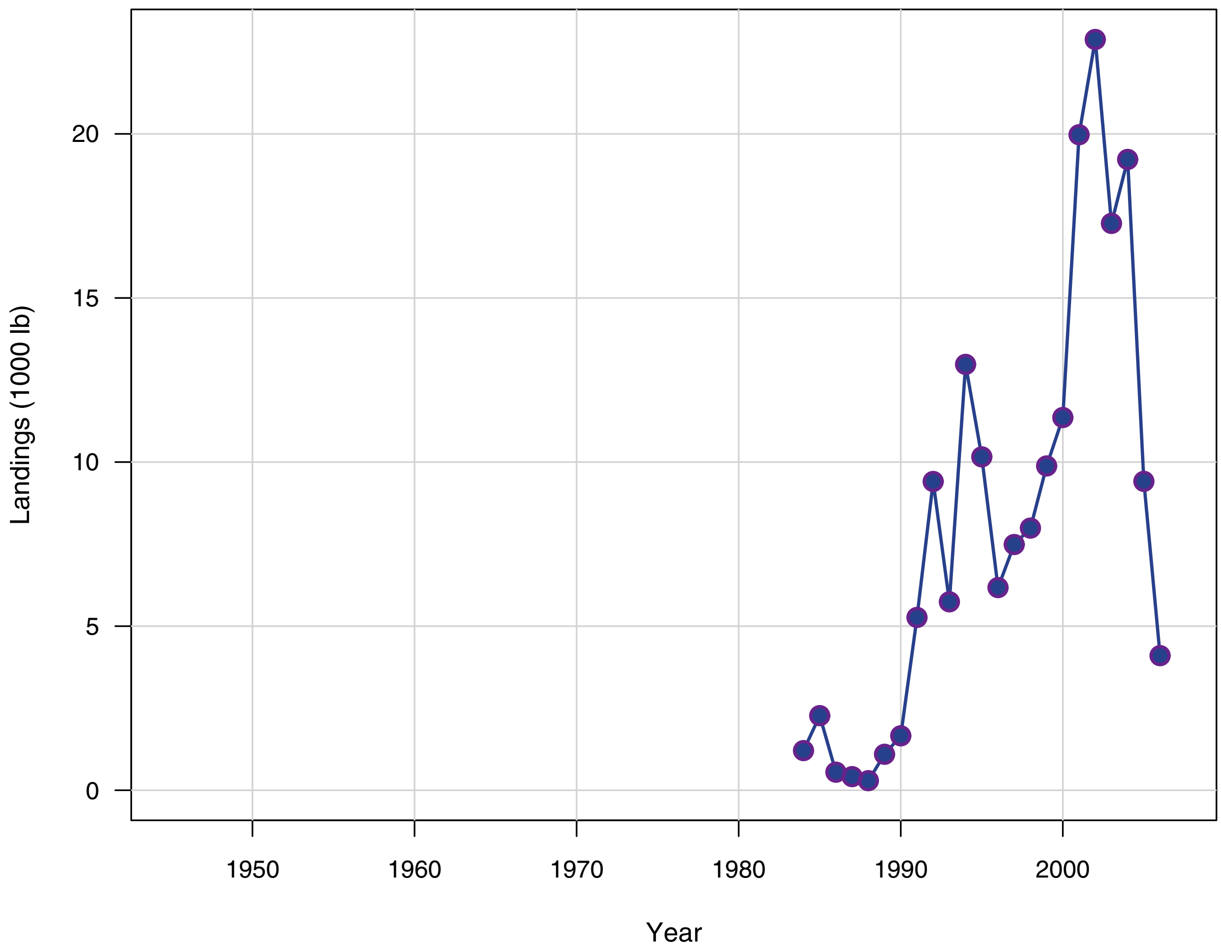


Figure 3.12. Red snapper: Observed (open circles) and estimated (solid line, circles) headboat landings (whole weight). Open and closed circles are indistinguishable.

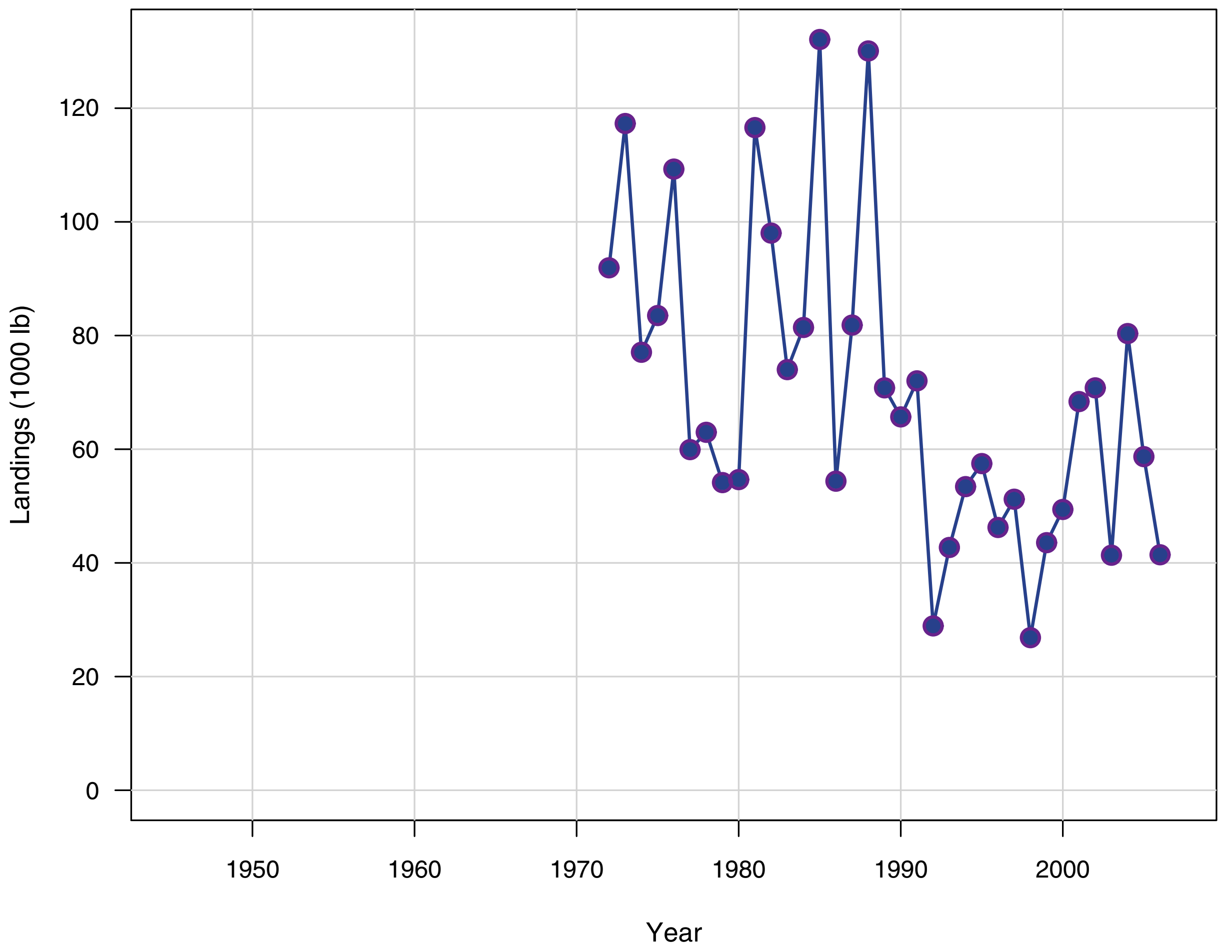


Figure 3.13. Red snapper: Observed (open circles) and estimated (solid line, circles) general recreational landings (whole weight). Open and closed circles are indistinguishable.

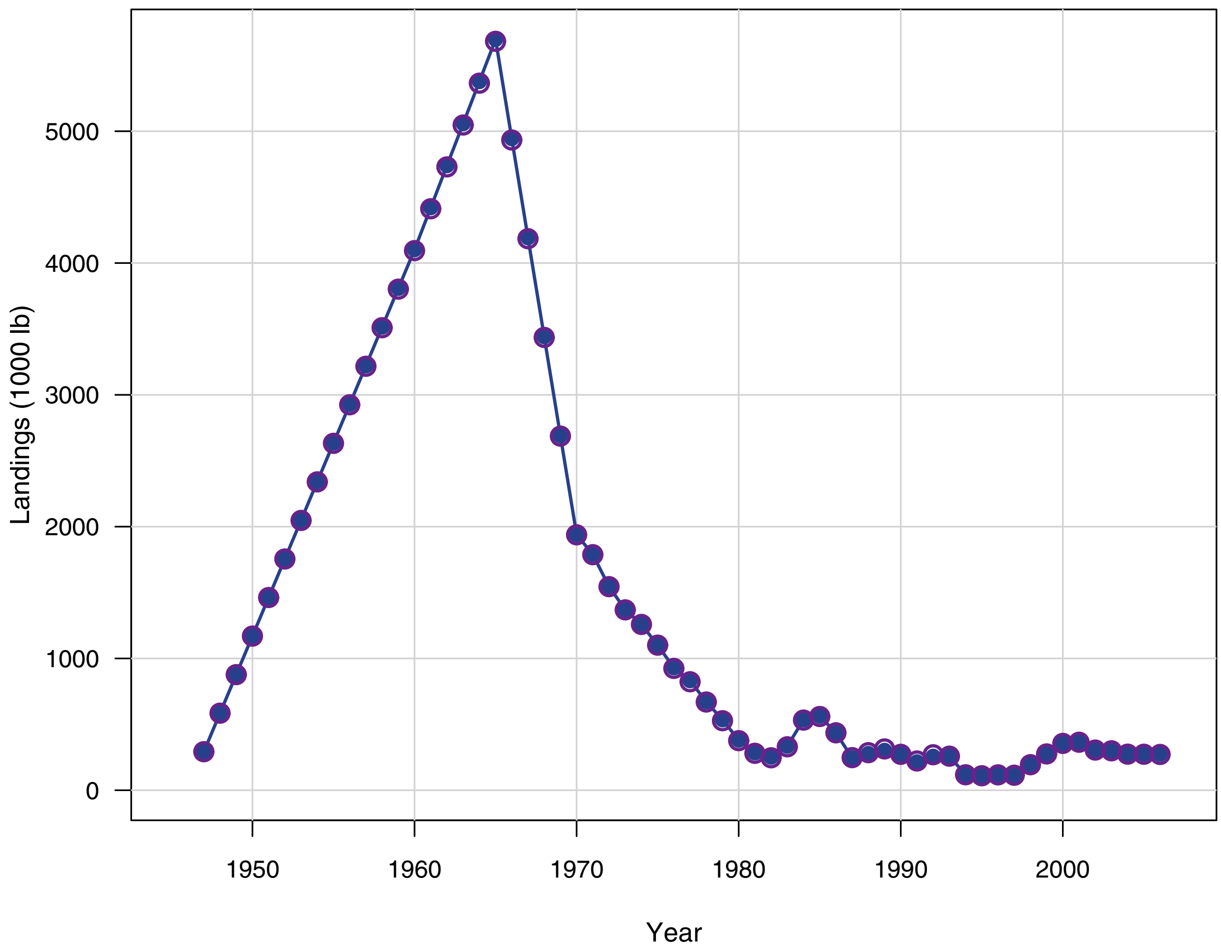


Figure 3.14. Red snapper: Observed (open circles) and estimated (solid line, circles) commercial handline discard mortalities. Open and closed circles are indistinguishable.

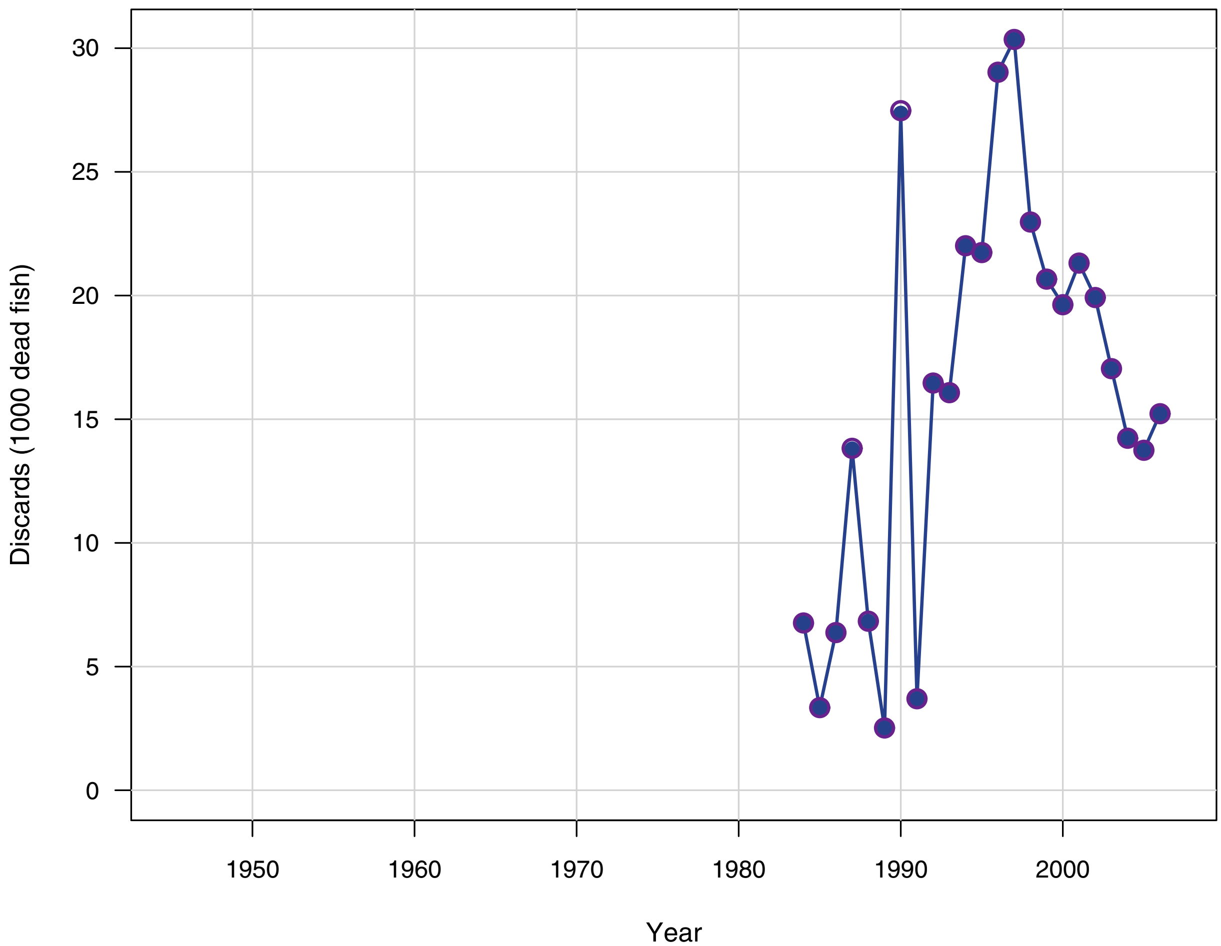


Figure 3.15. Red snapper: Observed (open circles) and estimated (solid line, circles) headboat discard mortalities. Open and closed circles are indistinguishable.

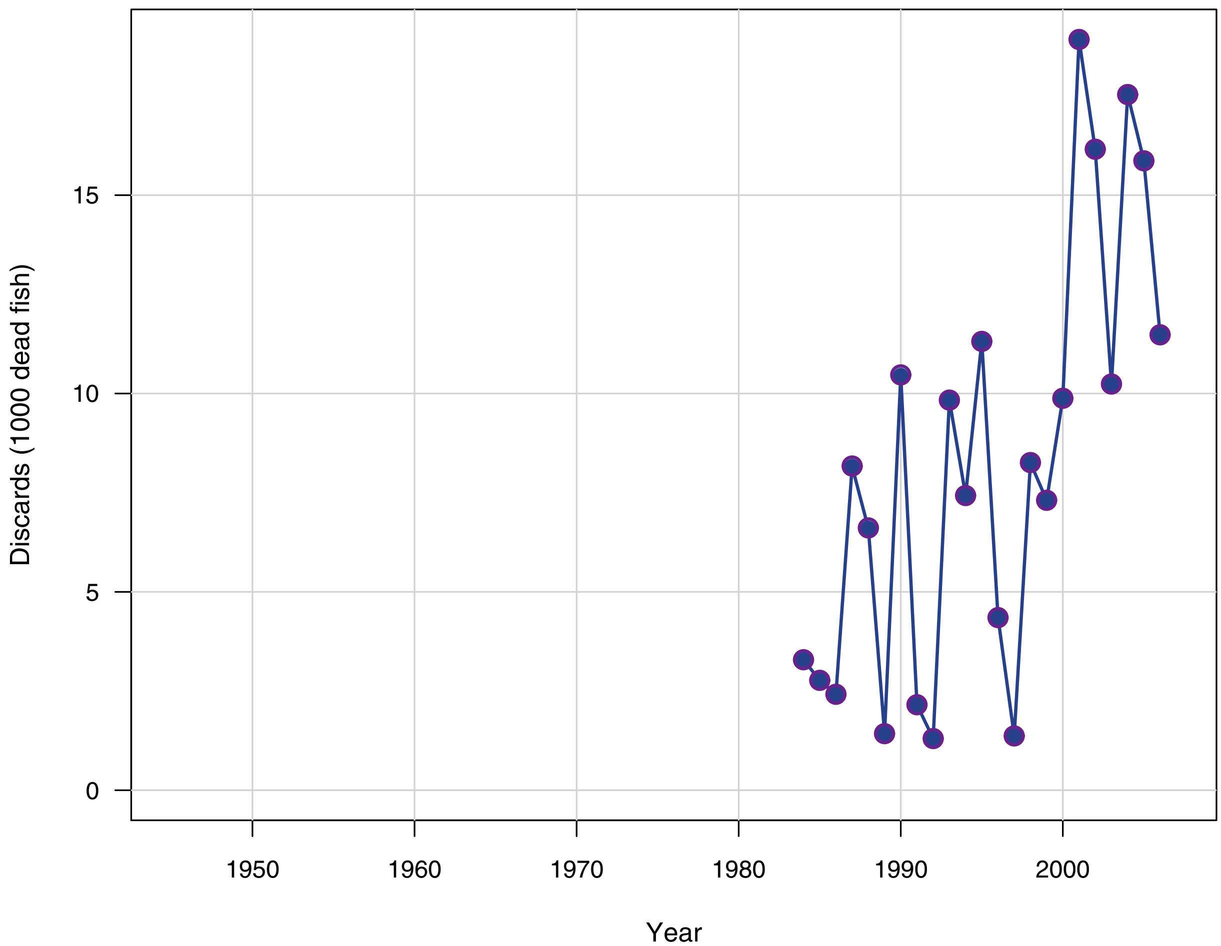


Figure 3.16. Red snapper: Observed (open circles) and estimated (solid line, circles) general recreational discard mortalities. Open and closed circles are indistinguishable.

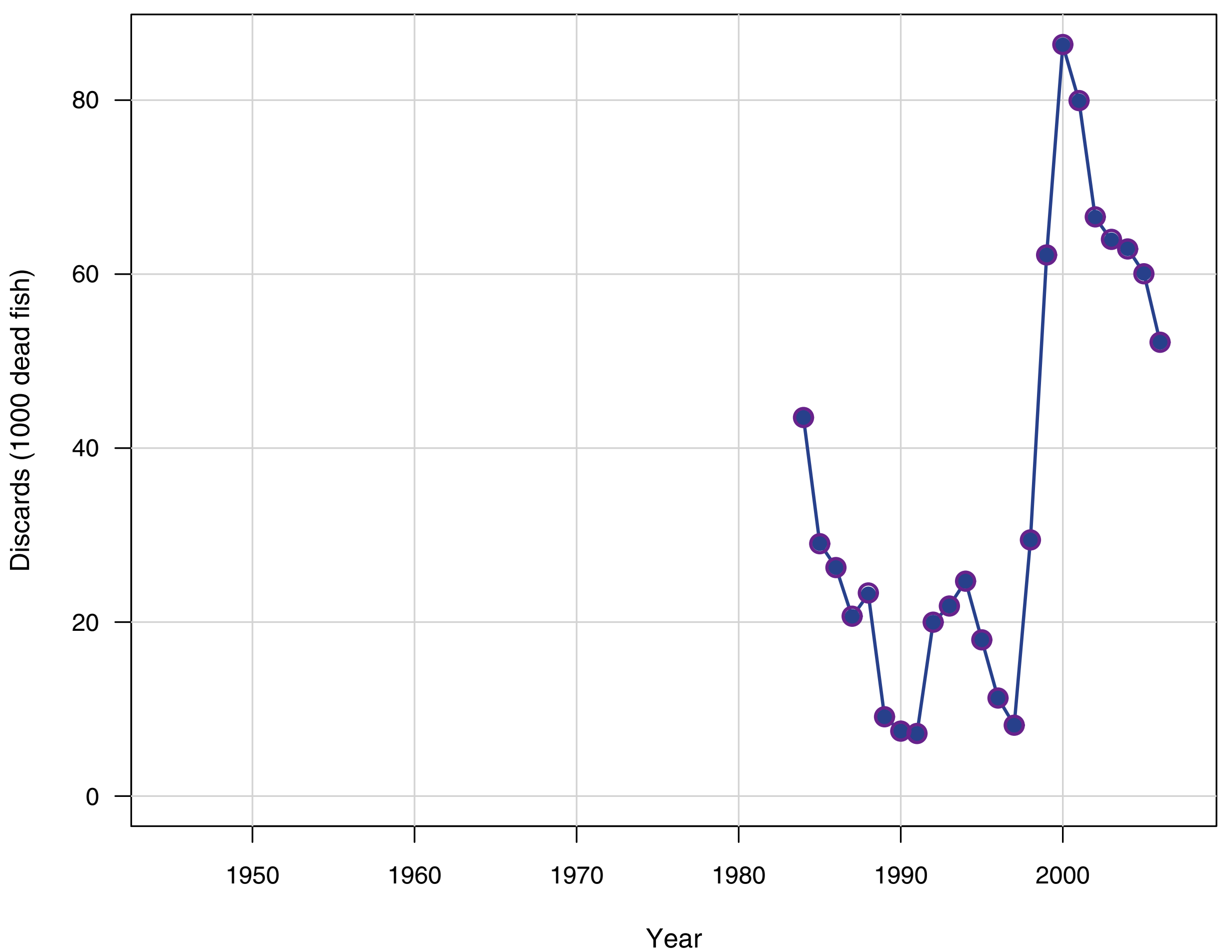


Figure 3.17. Red snapper: Fit of index of abundance from commercial handline; Observed (open circles) and estimated (solid line, circles).

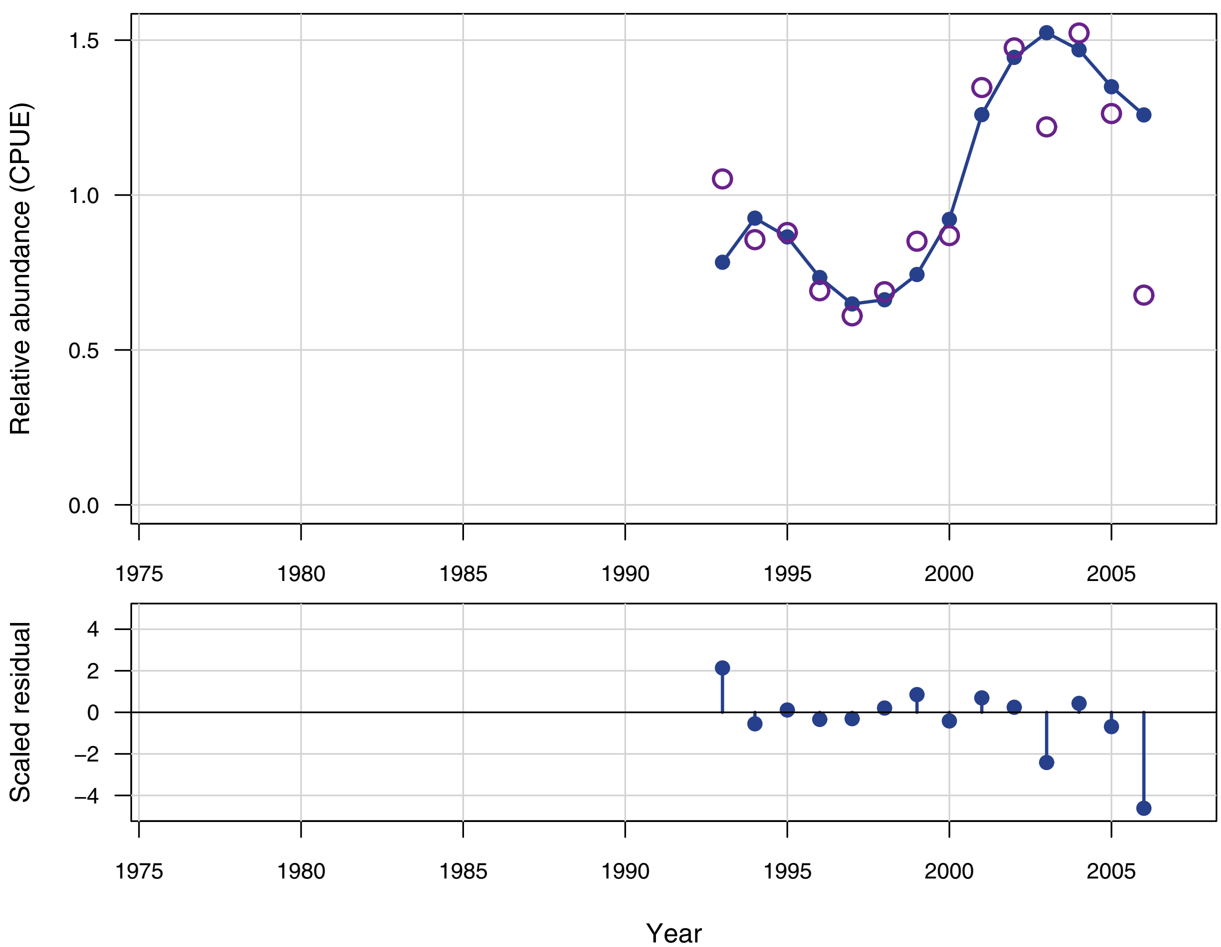


Figure 3.18. Red snapper: Fit of index of abundance from headboat; Observed (open circles) and estimated (solid line, circles).

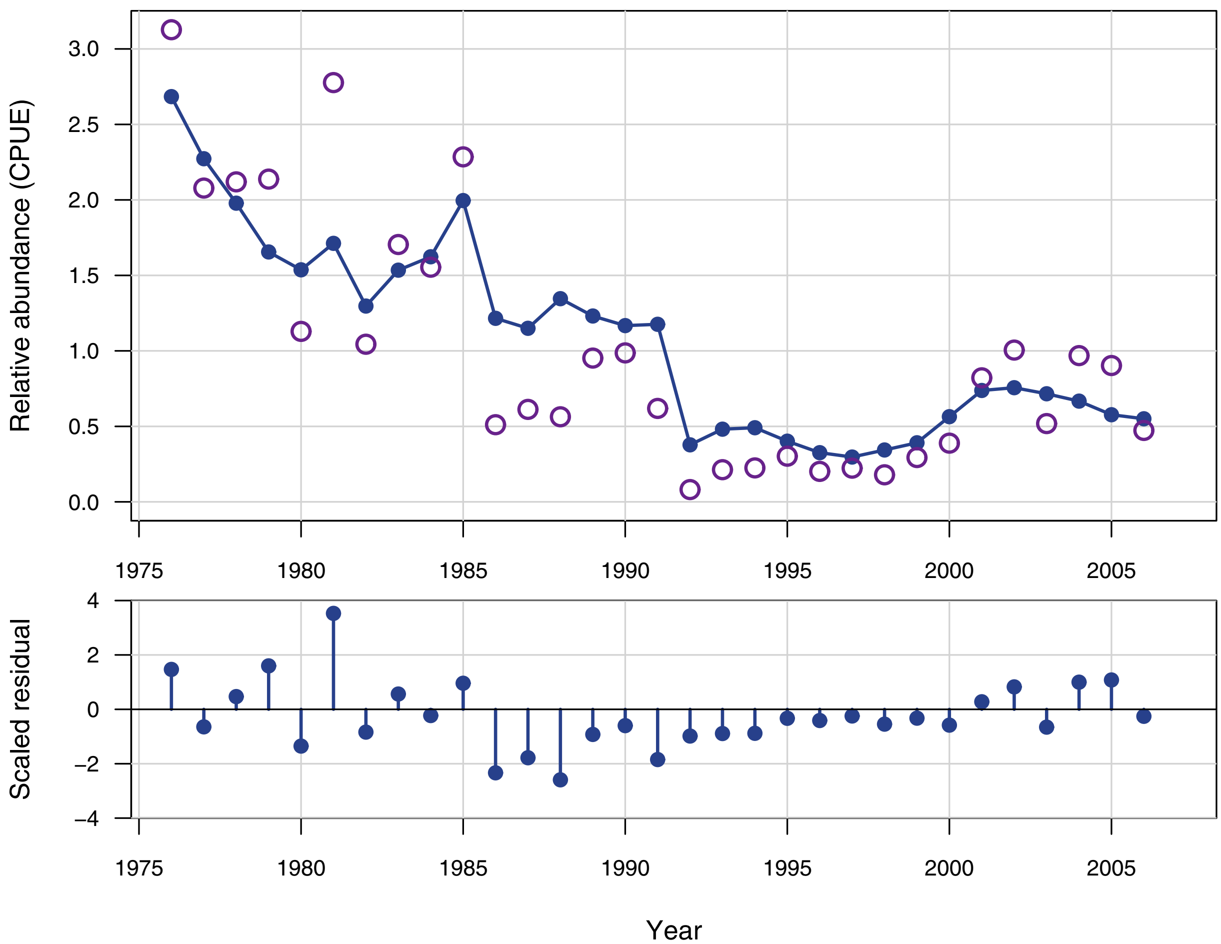


Figure 3.19. Red snapper: Fit of index of abundance from general recreational (MRFSS); Observed (open circles) and estimated (solid line, circles).

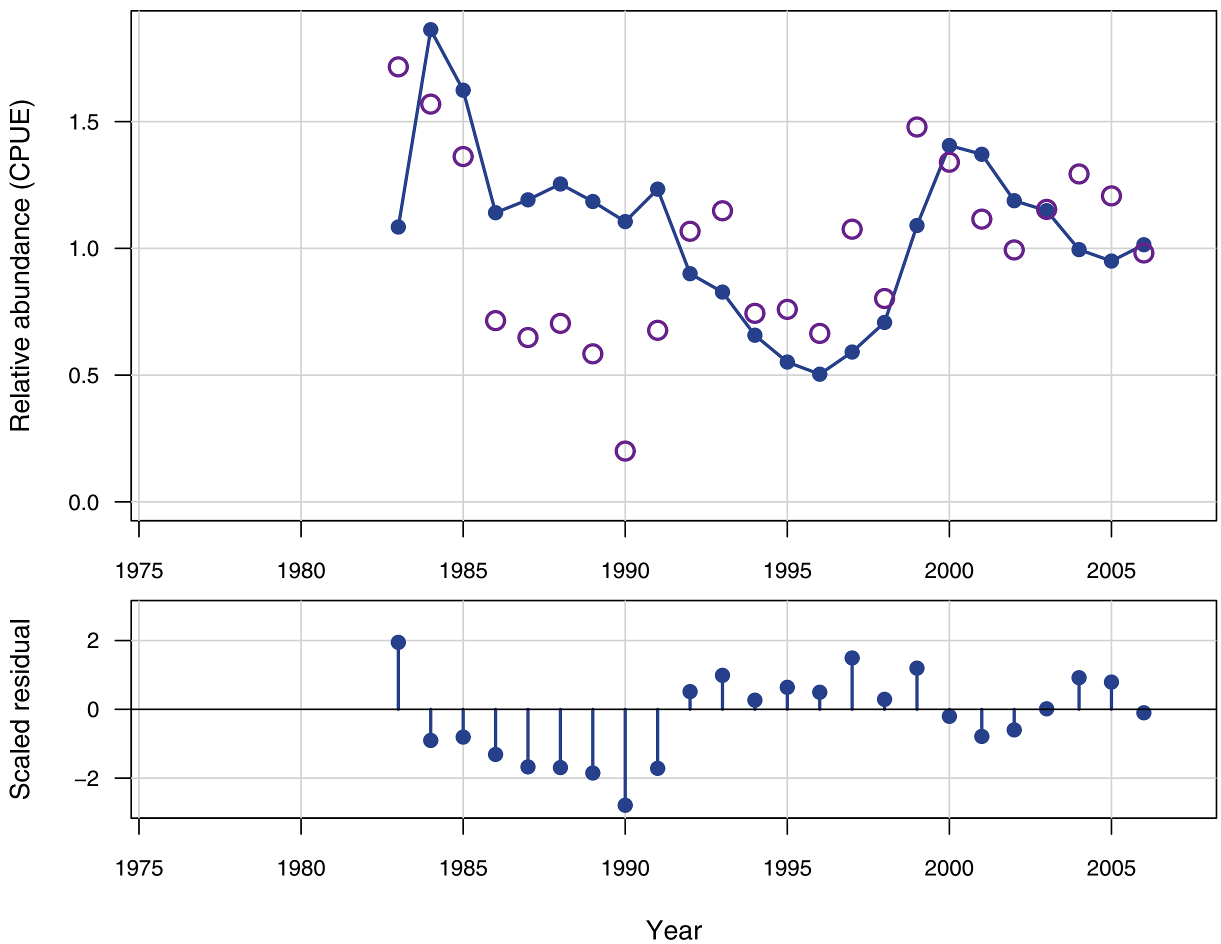


Figure 3.20. Red snapper: Mean length at age (mm) and estimated 95% confidence interval.

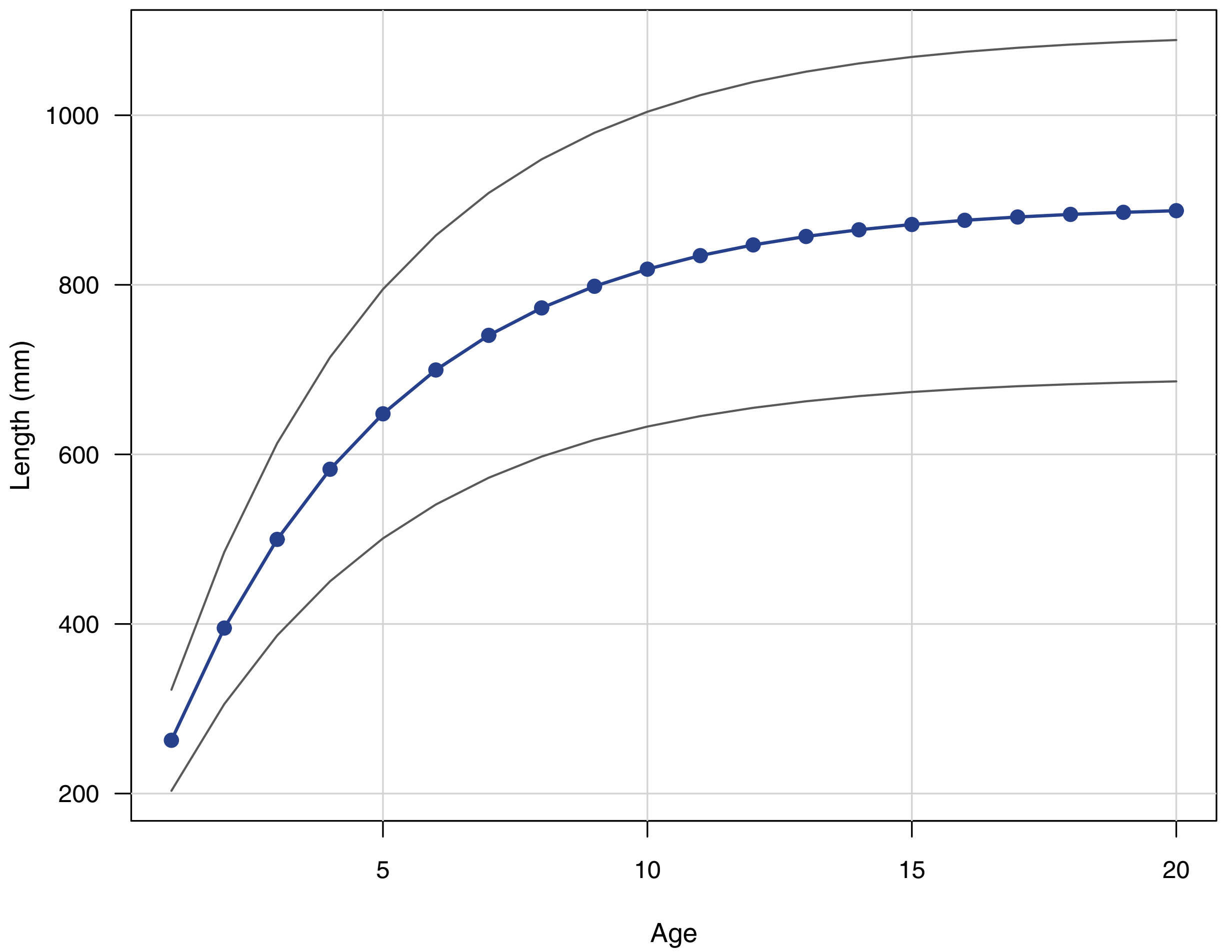


Figure 3.21. Red snapper: Top panel – Estimated recruitment of age-1 fish. Bottom panel – log recruitment residuals.

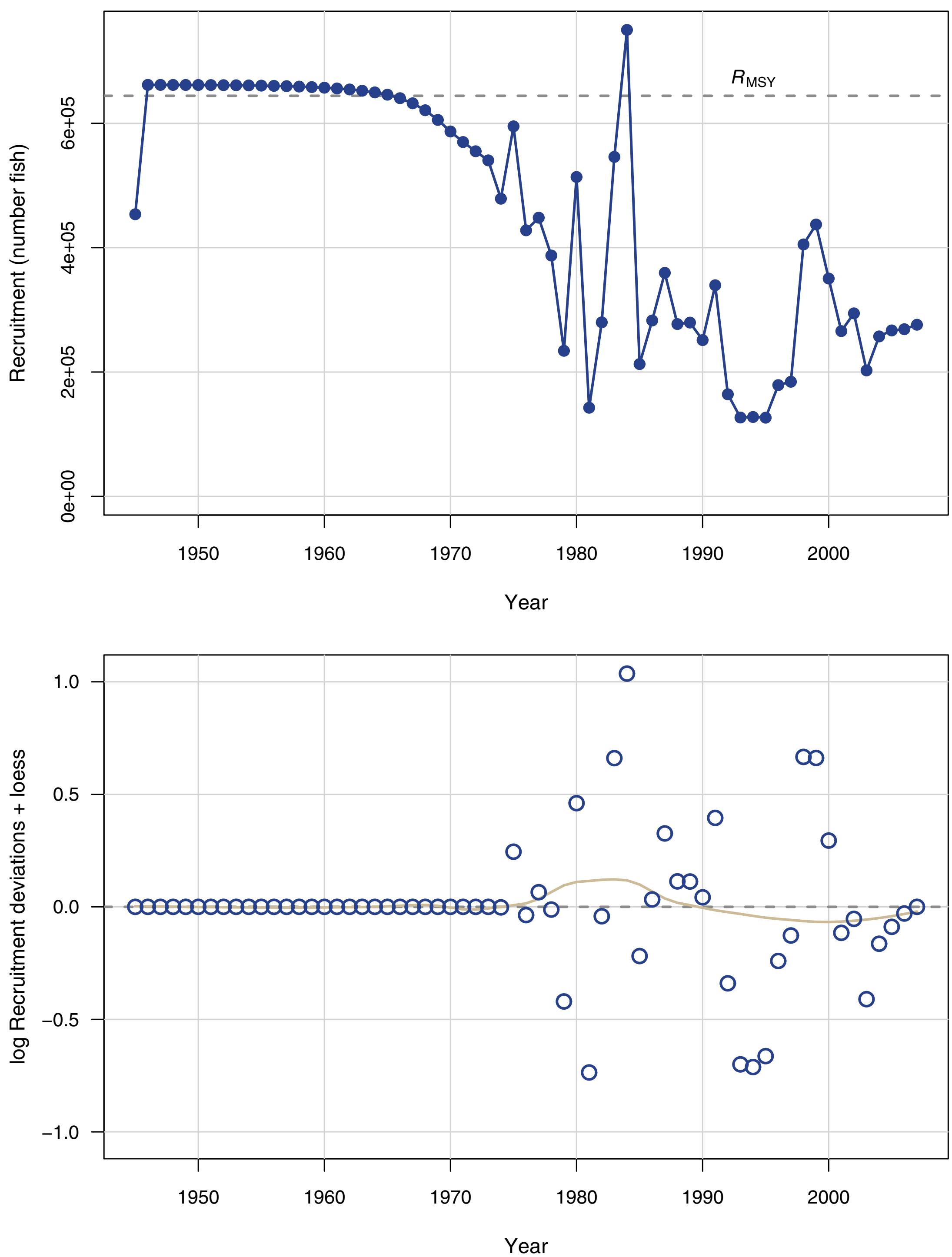


Figure 3.22. Red snapper: Top panel – Estimated total biomass (metric tons) at start of year. Bottom panel – Estimated spawning biomass (metric tons) at midpoint of year.

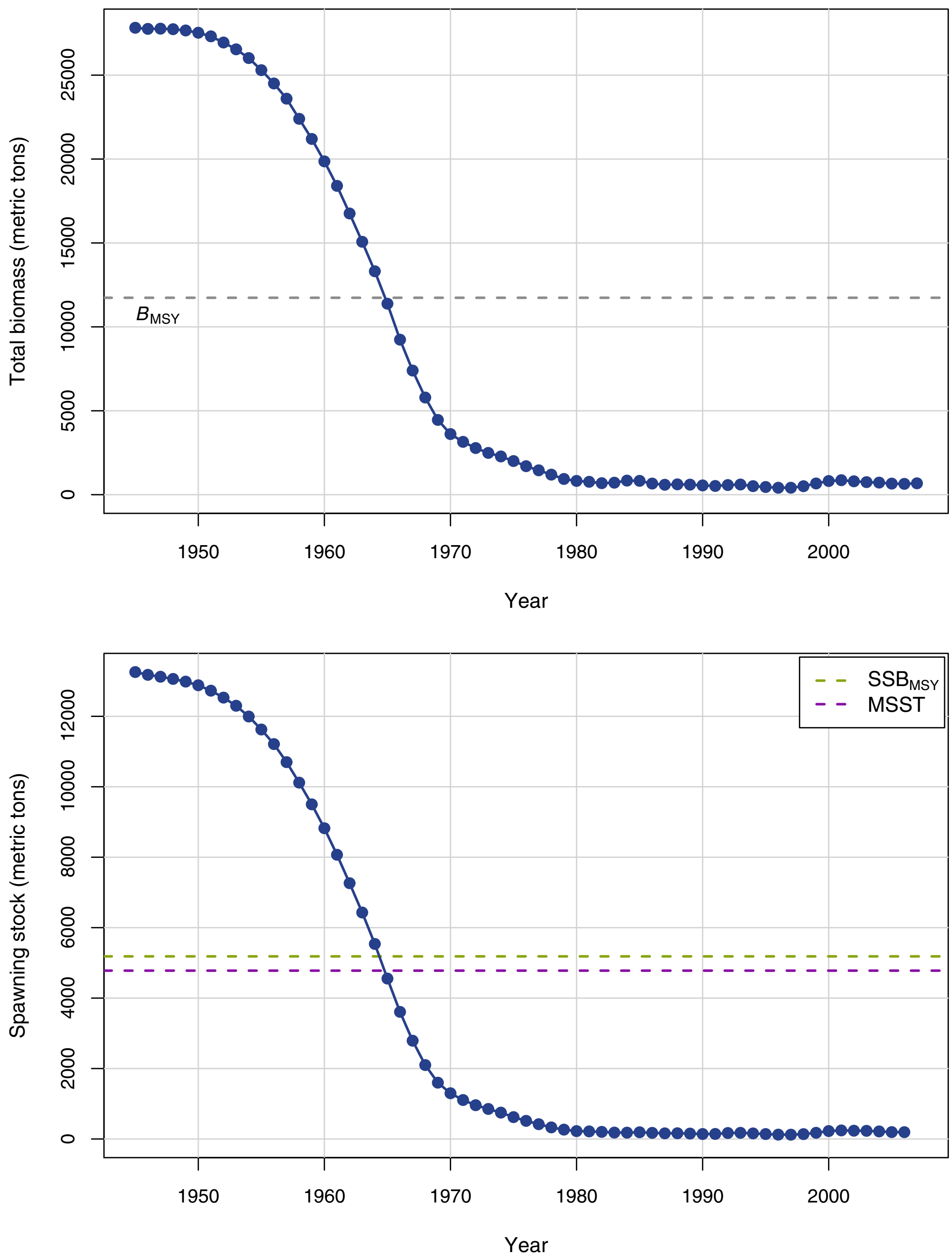


Figure 3.23. Red snapper: Estimated selectivities of commercial handline. Top panel – period 1 (prior to 1984, no regulations). Middle panel – period 2 (1984–1991, 12-inch limit). Bottom panel – period 3 (1992–2006, 20-inch limit).

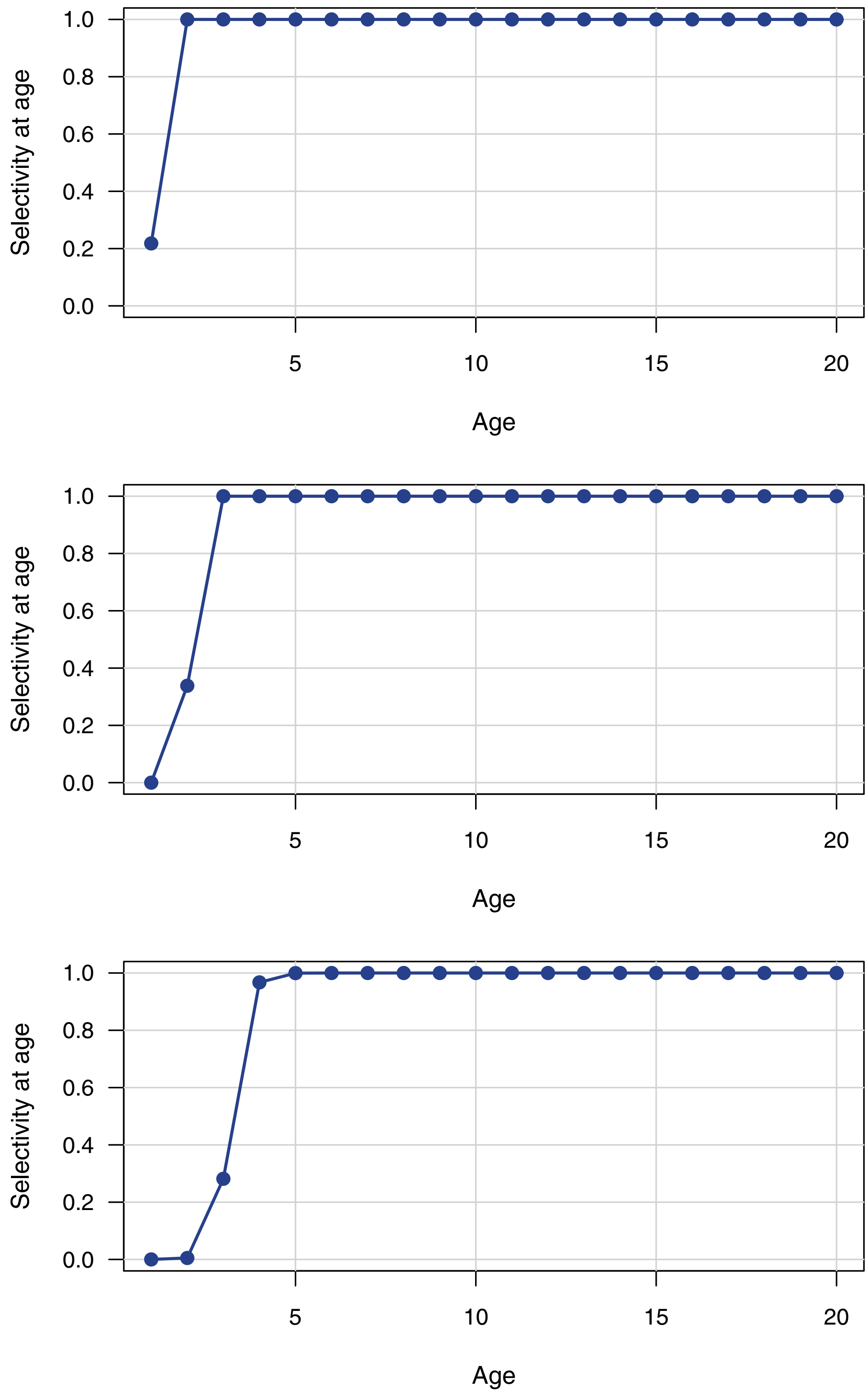


Figure 3.24. Red snapper: Estimated selectivity of commercial diving, assumed constant through time.

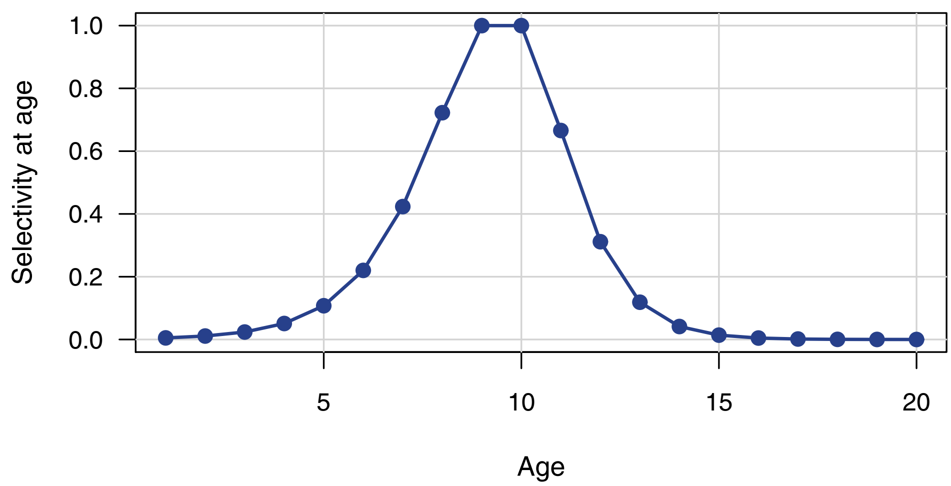


Figure 3.25. Red snapper: Estimated selectivities of the headboat fishery. Top panel – period 1 (prior to 1984, no regulations). Middle panel – period 2 (1984–1991, 12-inch limit). Bottom panel – period 3 (1992–2006, 20-inch limit).

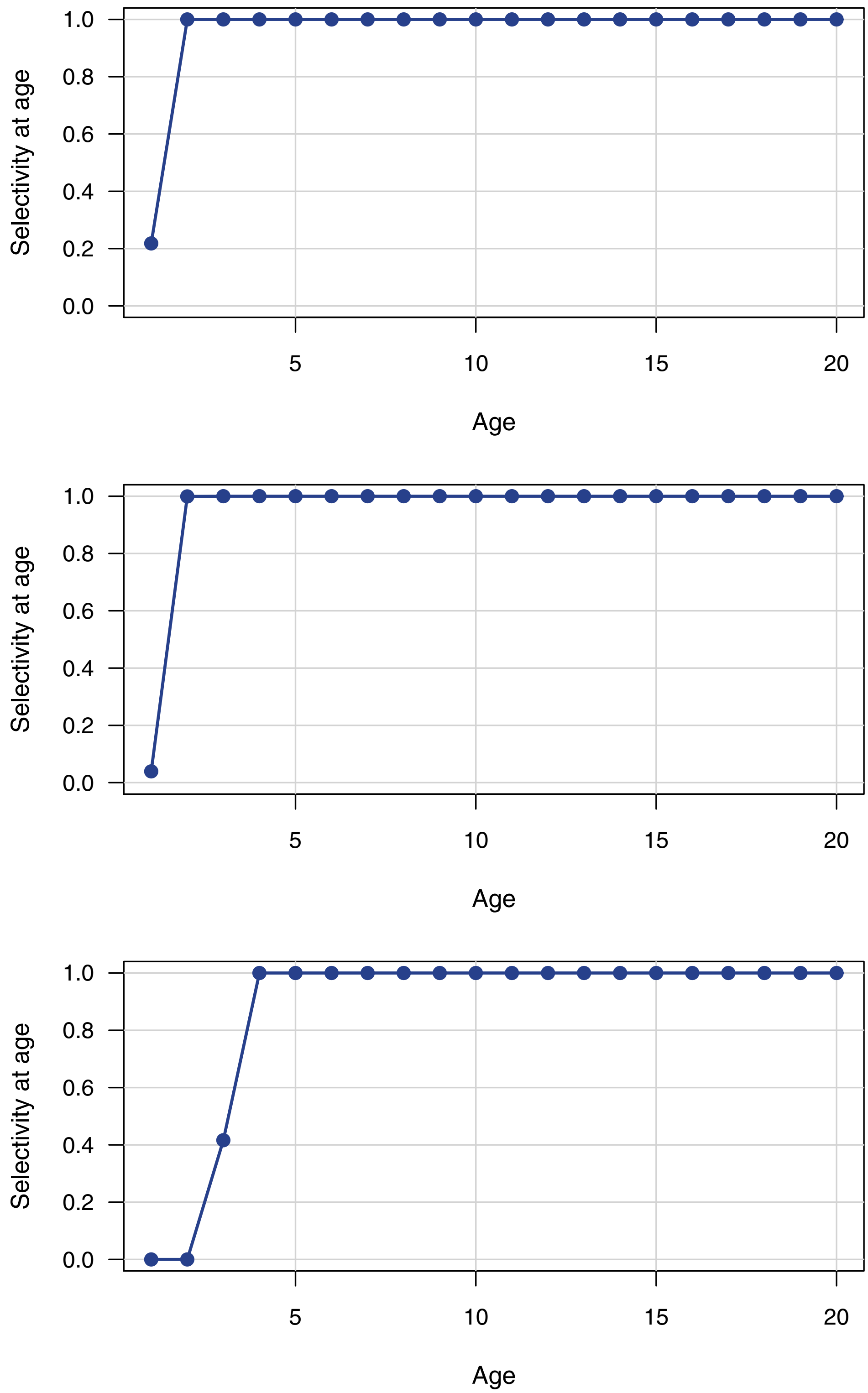


Figure 3.26. Red snapper: Estimated selectivities of the general recreational fishery. Top panel – period 1 (prior to 1984, no regulations). Middle panel – period 2 (1984–1991, 12-inch limit). Bottom panel – period 3 (1992–2006, 20-inch limit).

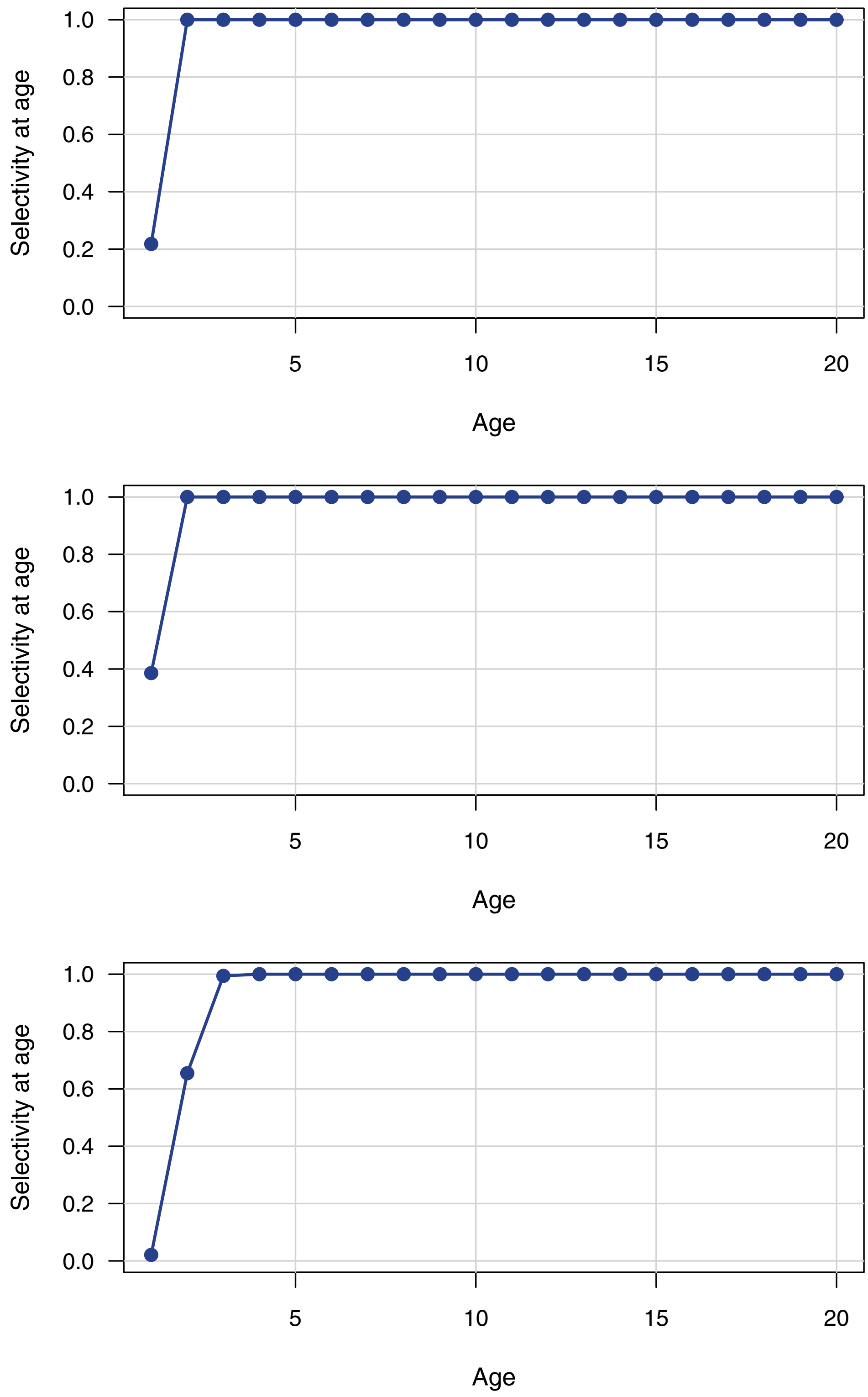


Figure 3.27. Red snapper: Estimated selectivities of discard mortalities from commercial handline. Discards were assumed negligible in period 1, the years prior to implementation of regulations. Top panel – period 2 (1984–1991, 12-inch limit). Bottom panel – period 3 (1992–2006, 20-inch limit).

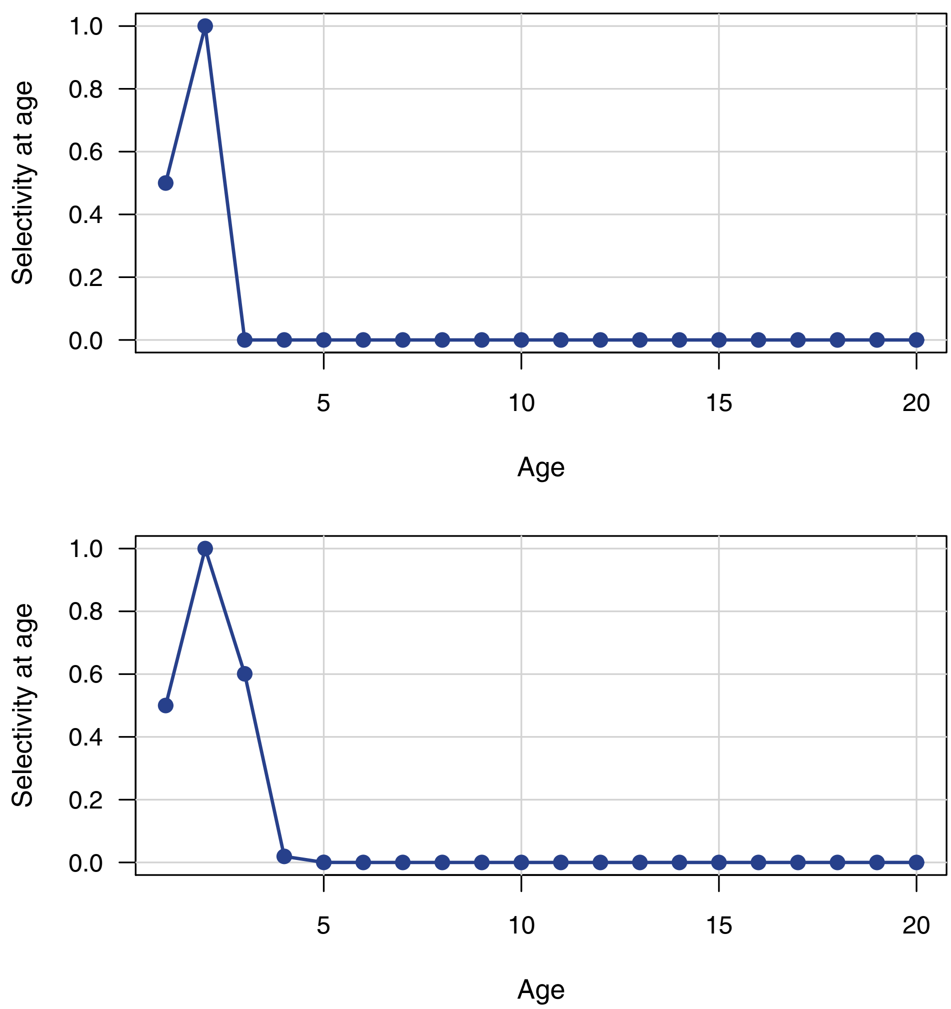


Figure 3.28. Red snapper: Estimated selectivities of discard mortalities from the headboat fishery. Discards were assumed negligible in period 1, the years prior to implementation of regulations. Top panel – period 2 (1984–1991, 12-inch limit). Bottom panel – period 3 (1992–2006, 20-inch limit).

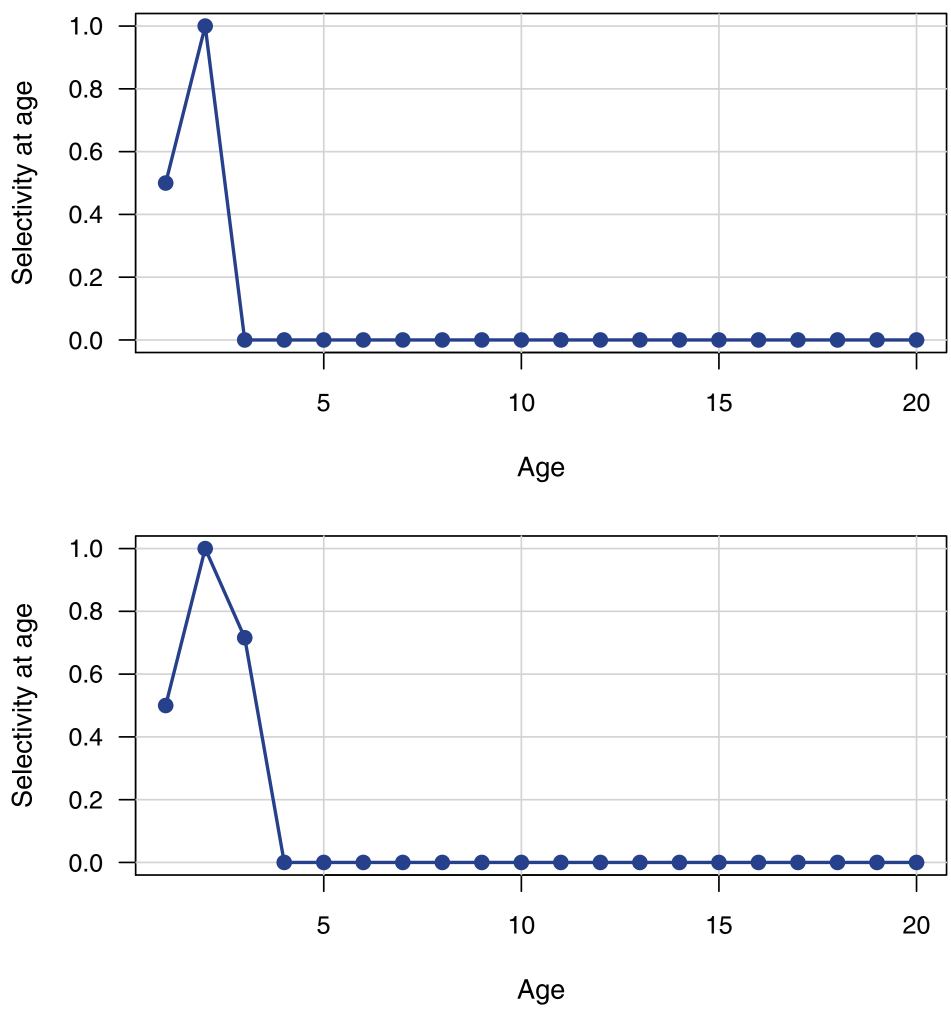


Figure 3.29. Red snapper: Estimated selectivities of discard mortalities from the general recreational fishery. Discards were assumed negligible in period 1, the years prior to implementation of regulations. Top panel – period 2 (1984–1991, 12-inch limit). Bottom panel – period 3 (1992–2006, 20-inch limit).

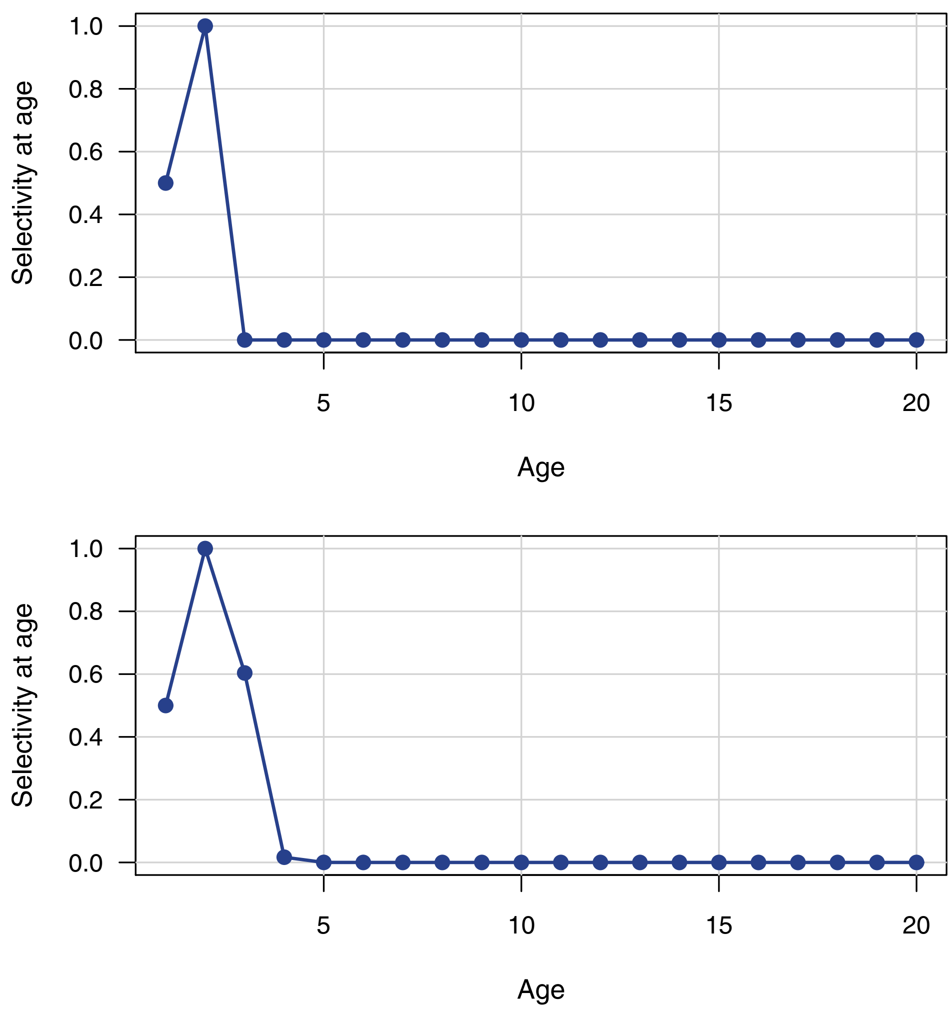


Figure 3.30. Red snapper: Average selectivities from period 3 (1992–2006, 20-inch limit), weighted by geometric mean Fs from the last three assessment years. and used in computation of benchmarks and projections. Top panel – Average selectivity applied to landings. Middle panel – Average selectivity applied to discard mortalities. Bottom panel – Total average selectivity.

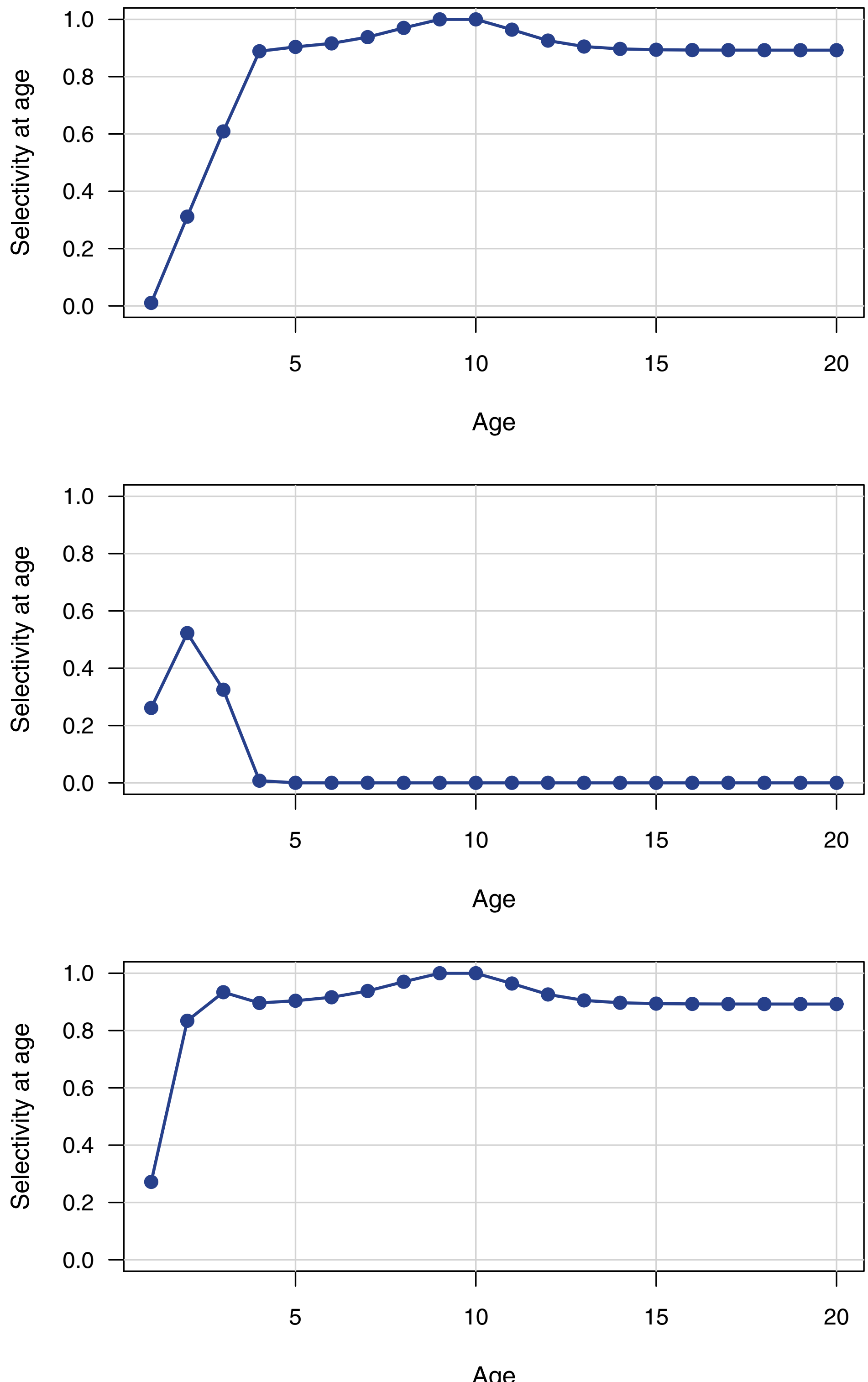


Figure 3.31. Red snapper: Estimated instantaneous fishing mortality rate (per year) by fishery. c.hal refers to commercial handline, c.dv to commercial diving, hb to headboat, rec to general recreational, c.hal.D to commercial discard mortalities, c.hb.D to headboat discard mortalities, and rec.D to general recreational discard mortalities.

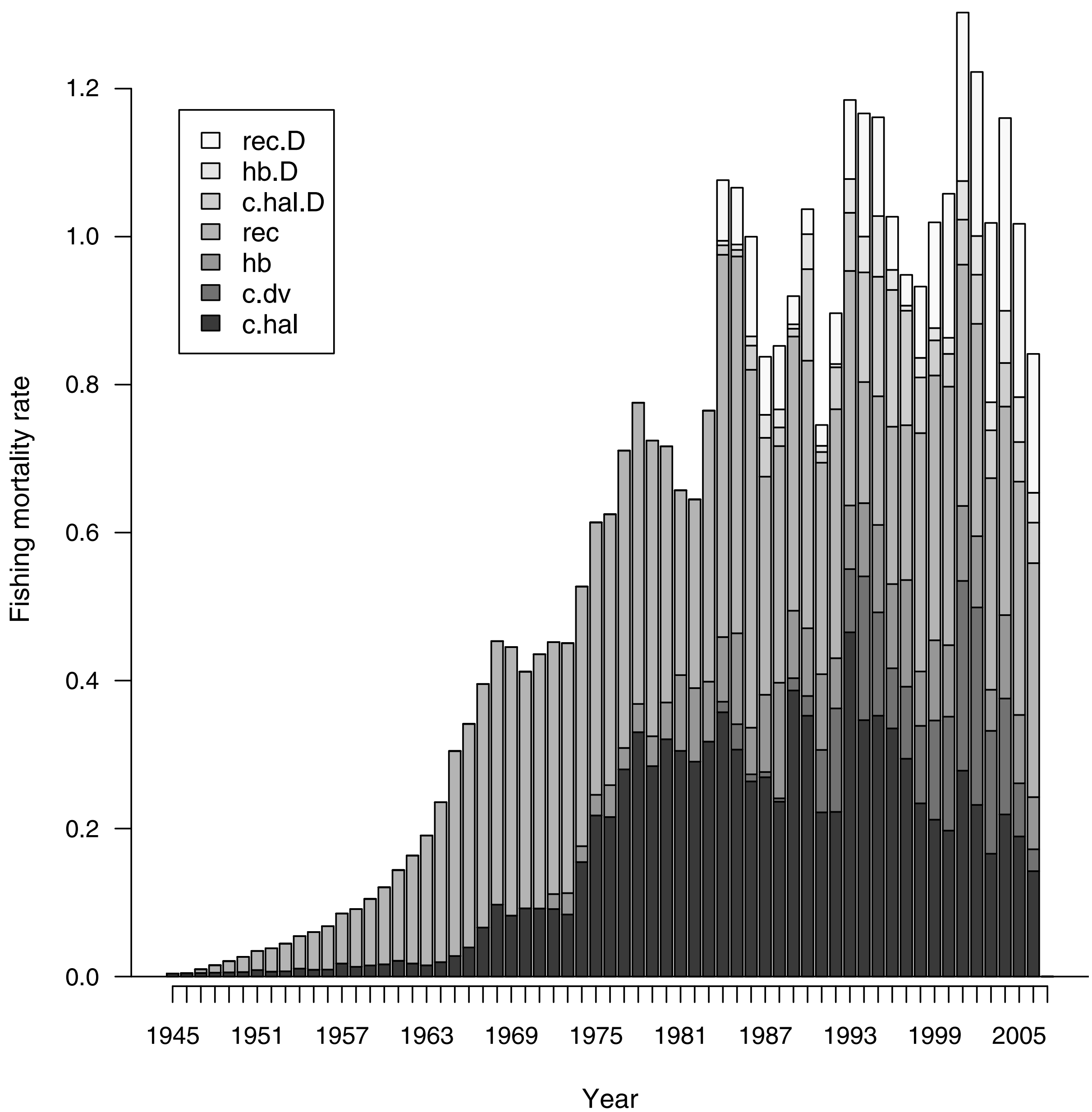
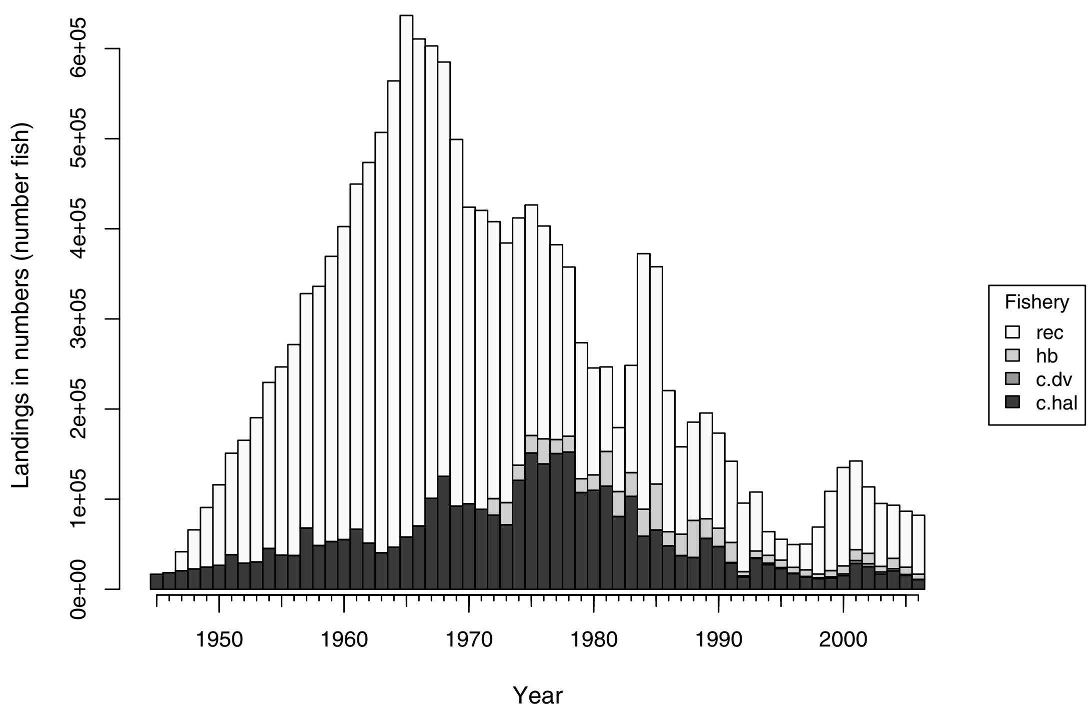


Figure 3.32. Red snapper: Estimated landings by fishery from the catch-at-age model. c.hal refers to commercial handline, c.dv to commercial diving, hb to headboat, rec to general recreational.



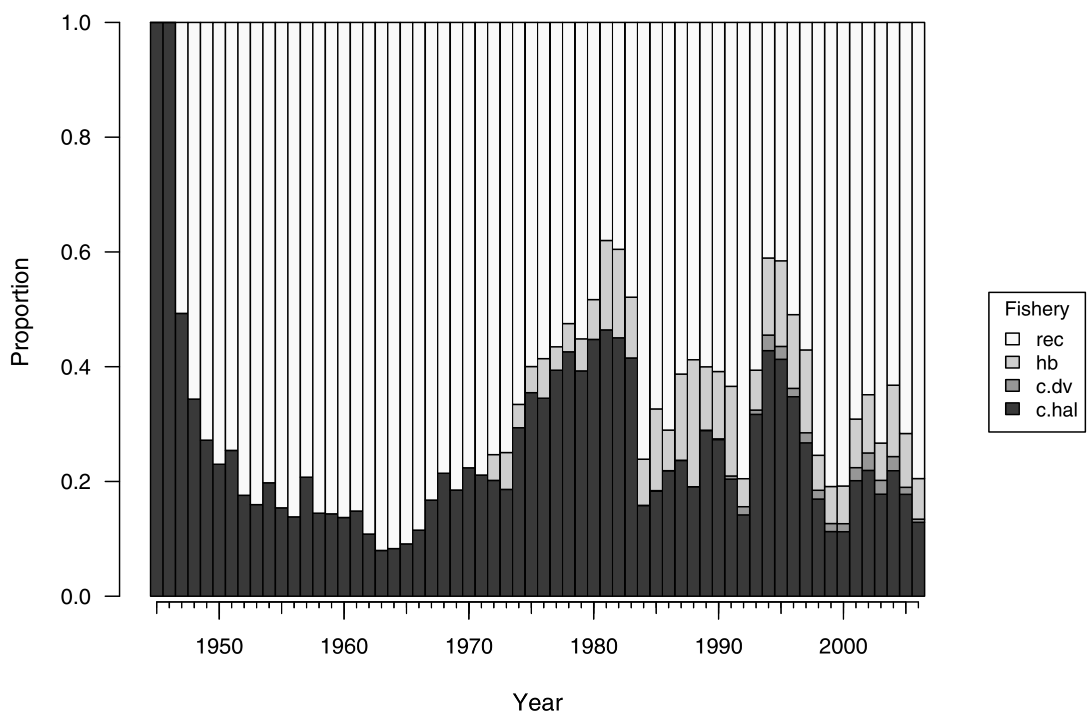


Figure 3.33. Red snapper: Estimated discard mortalities by fishery from the catch-at-age model. c.hal refers discard mortalities from commercial handline, hb from headboat, rec from general recreational.

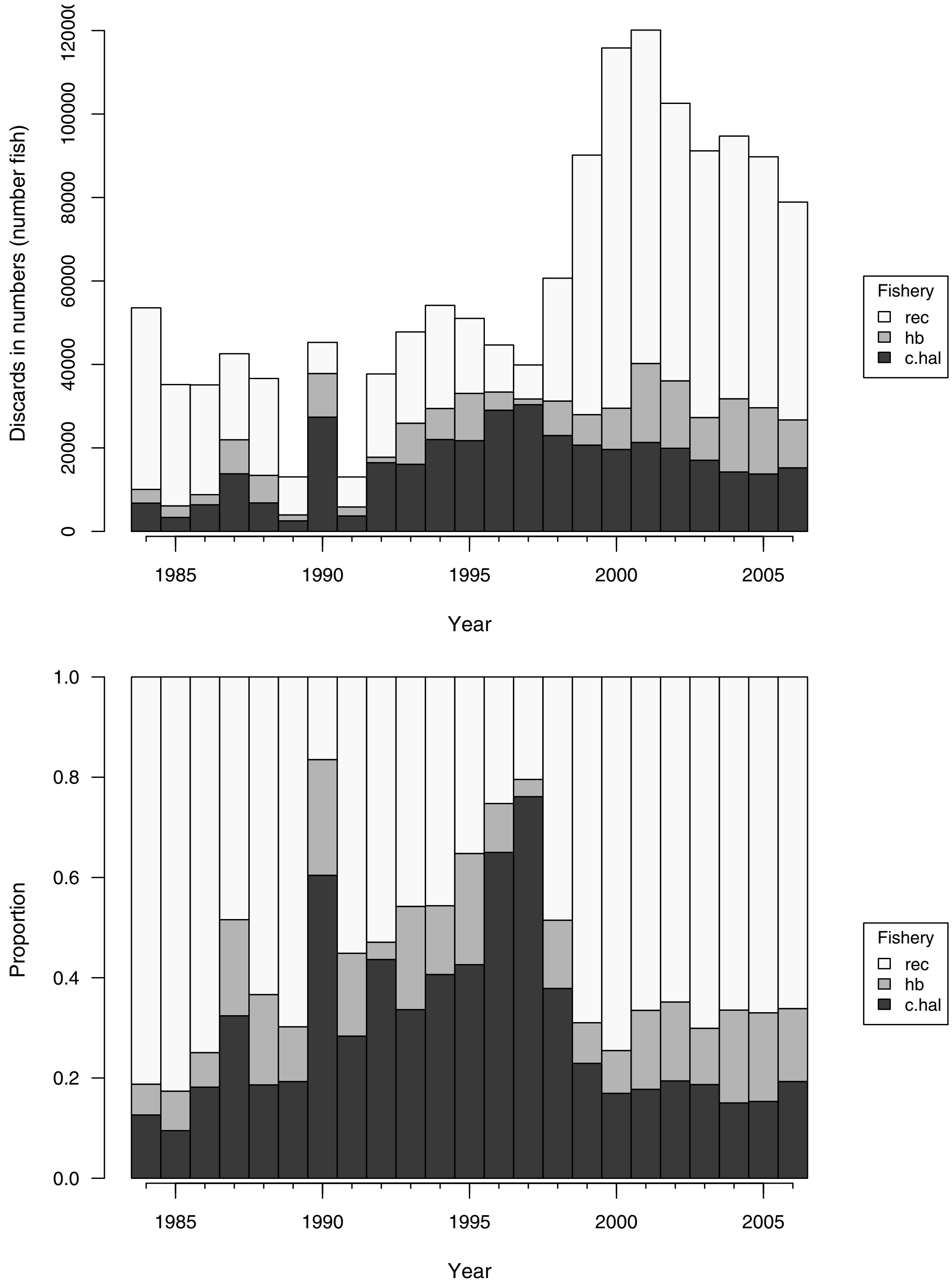


Figure 3.34. Red snapper: Estimated Beverton–Holt spawner-recruit curves, with and without lognormal bias correction.

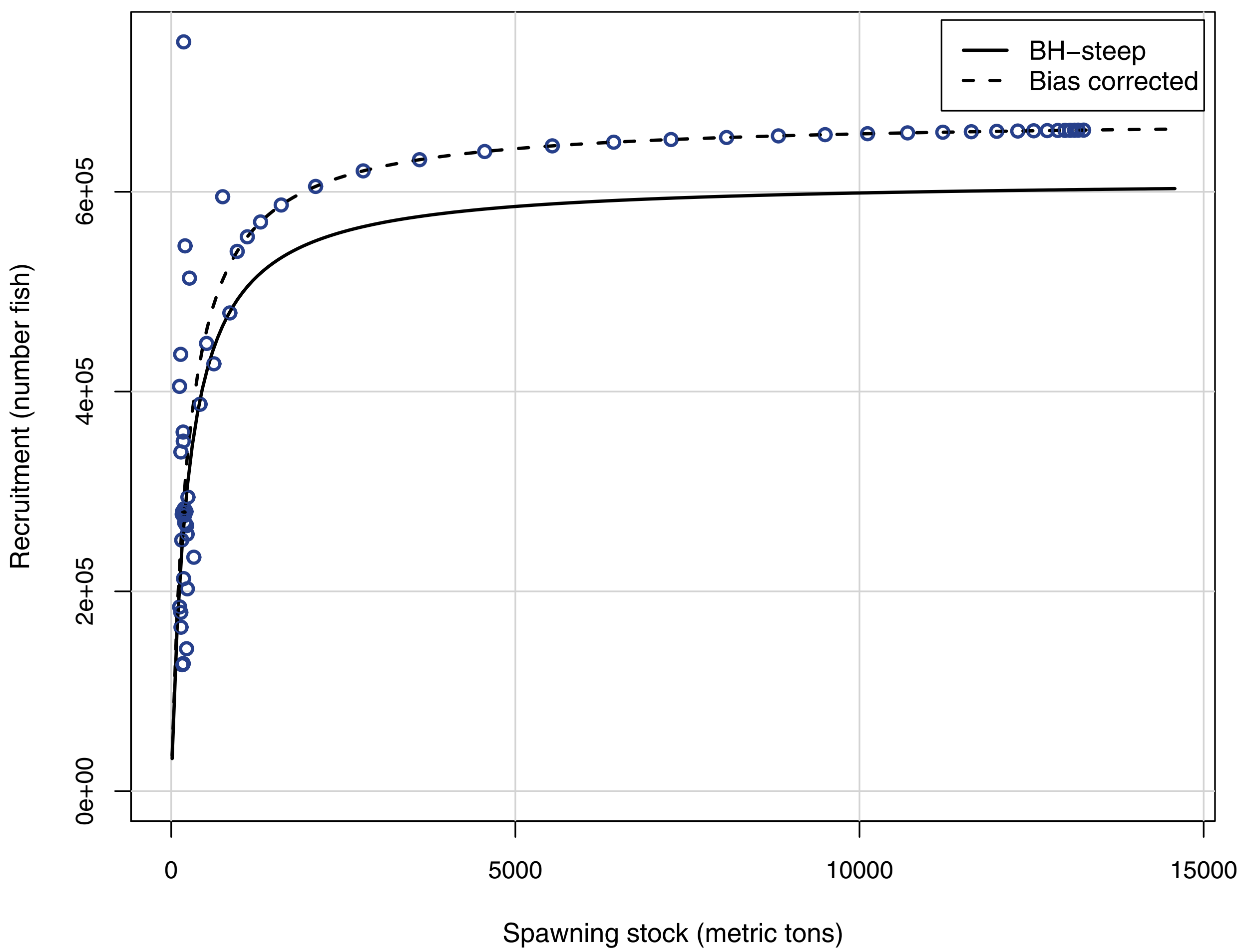
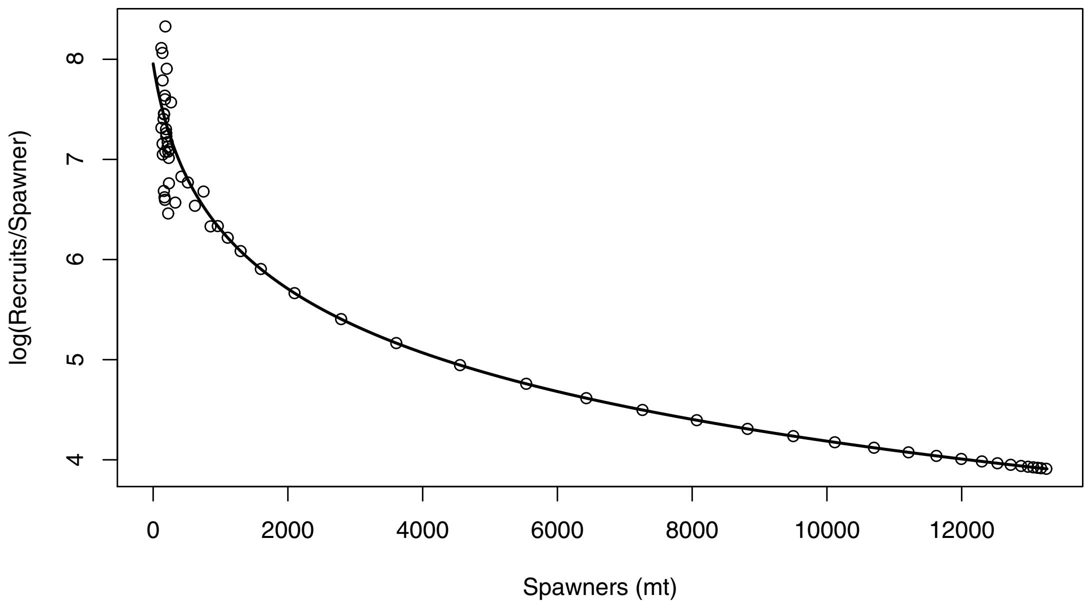


Figure 3.35. Red snapper: Top panel – Log of recruits (number fish) per spawner (mt) as a function of spawners. Bottom panel – Same as top panel, but over a narrower range.



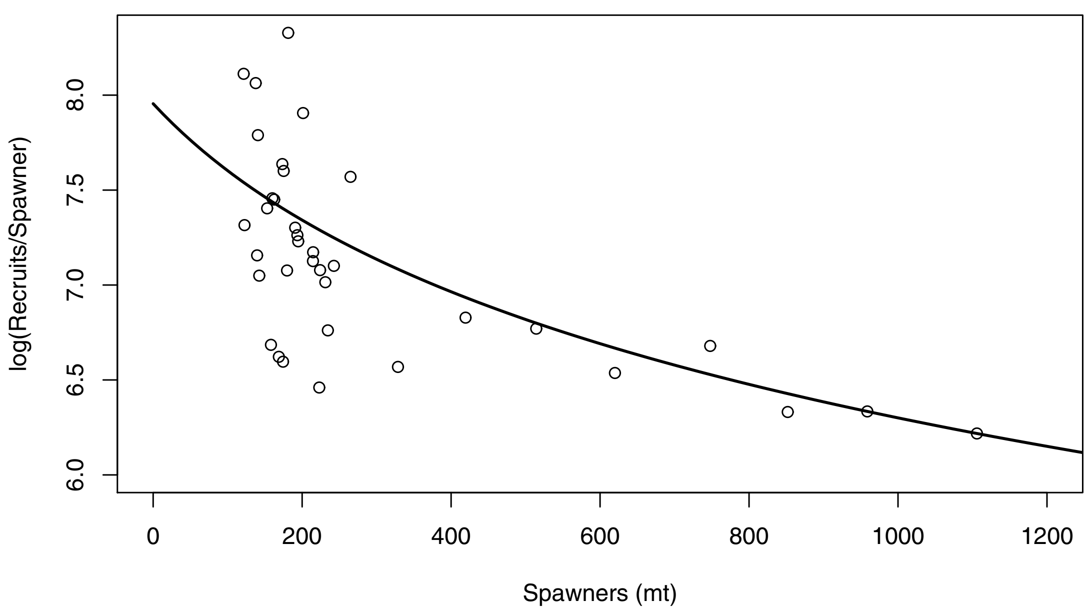


Figure 3.36. Red snapper: Probability densities of spawner-recruit parameters R0 (unfished recruitment), steepness, autocorrelation, and lognormal bias correction. Vertical lines represent point estimates from the assessment model.

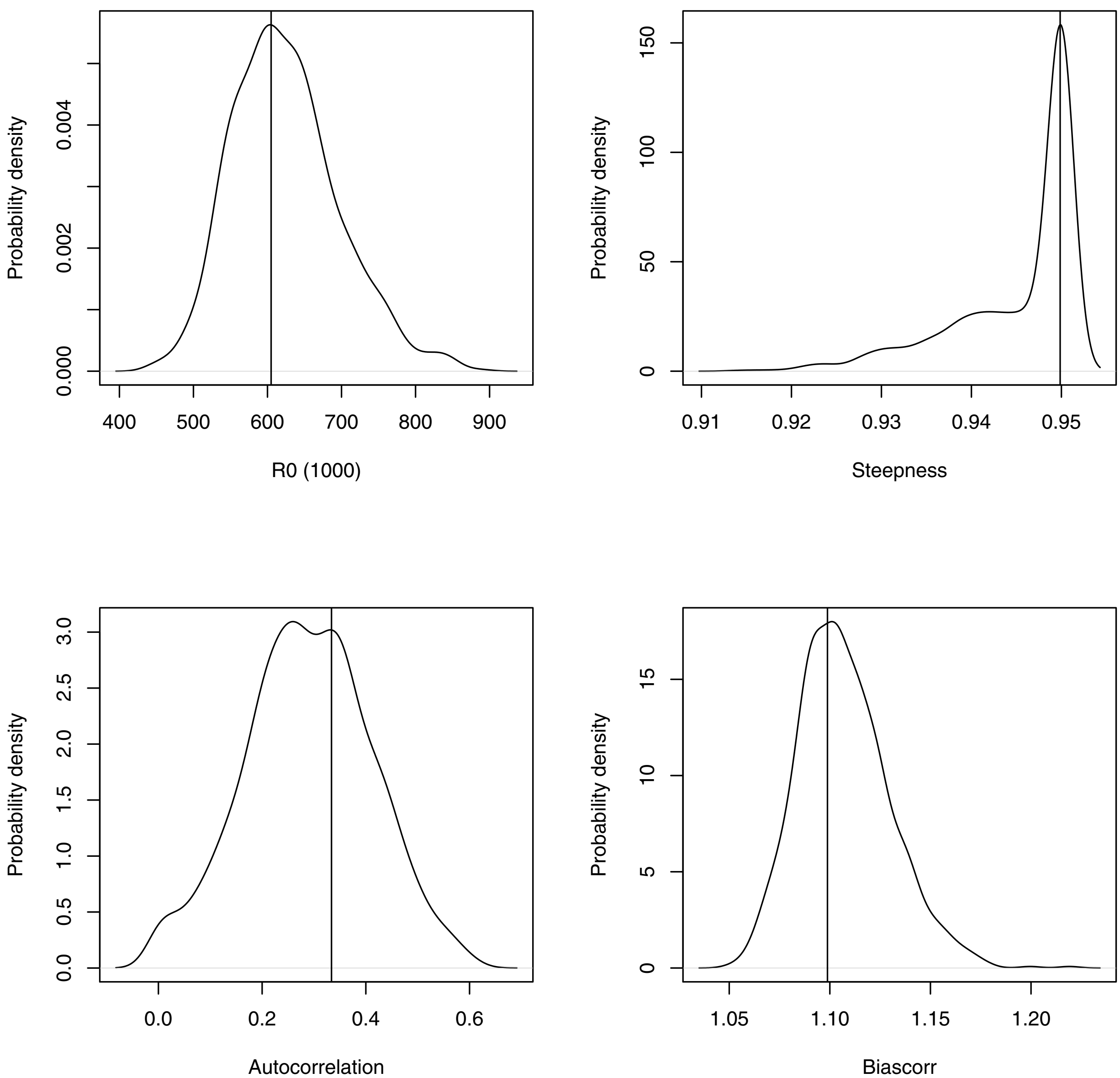


Figure 3.37. Red snapper: Estimated time series of static spawning potential ratio, the annual equilibrium spawners per recruit relative to that at the unfished level.

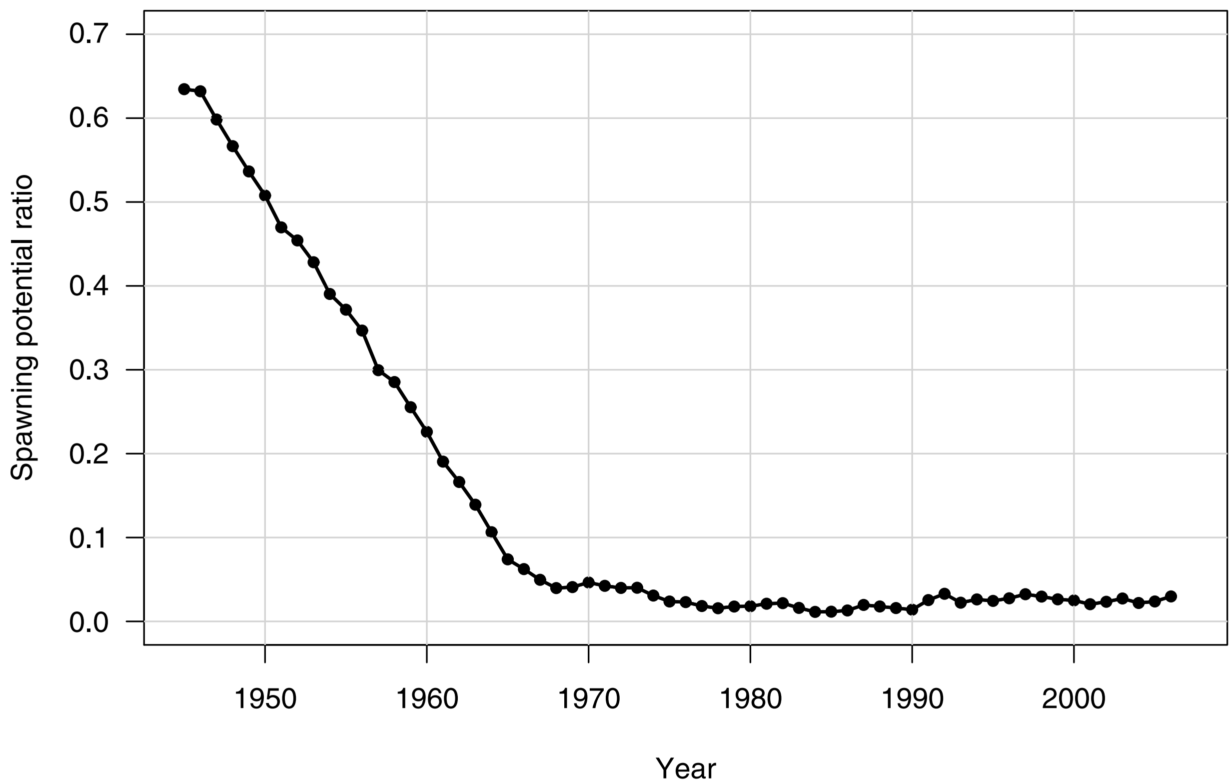


Figure 3.38. Red snapper: Top panel – Yield per recruit, from which the maximum provides F_{max}. Bottom panel – Spawning potential ratio (spawners per recruit relative to that at the unfished level), from which the 30% and 40% levels provide $F_{30\%}$ and $F_{40\%}$. Both curves are based on average selectivity from the end of the assessment period.

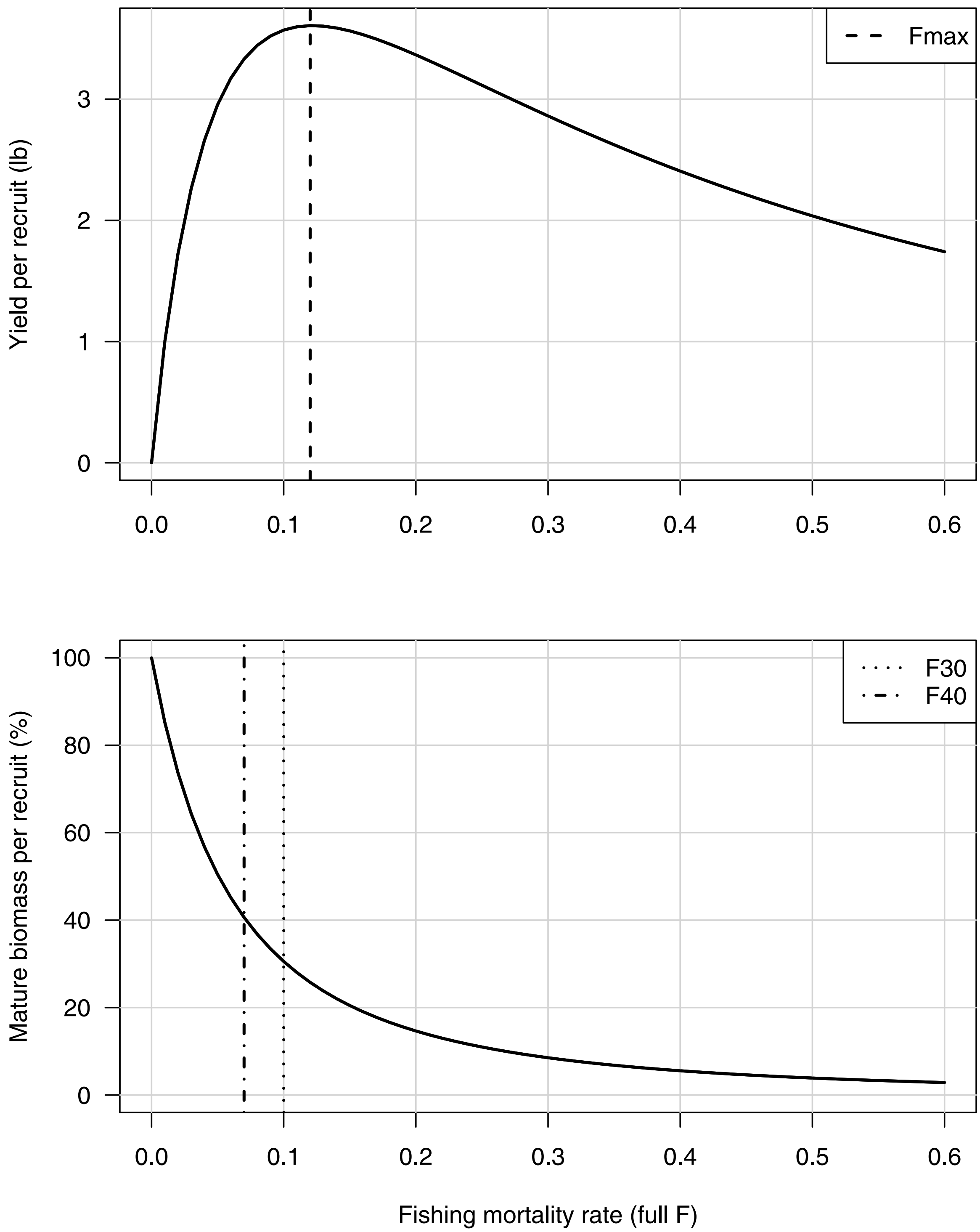


Figure 3.39. Red snapper: Top panel – Equilibrium landings. Bottom panel – Equilibrium spawning biomass. Both curves are based on average selectivity from the end of the assessment period.

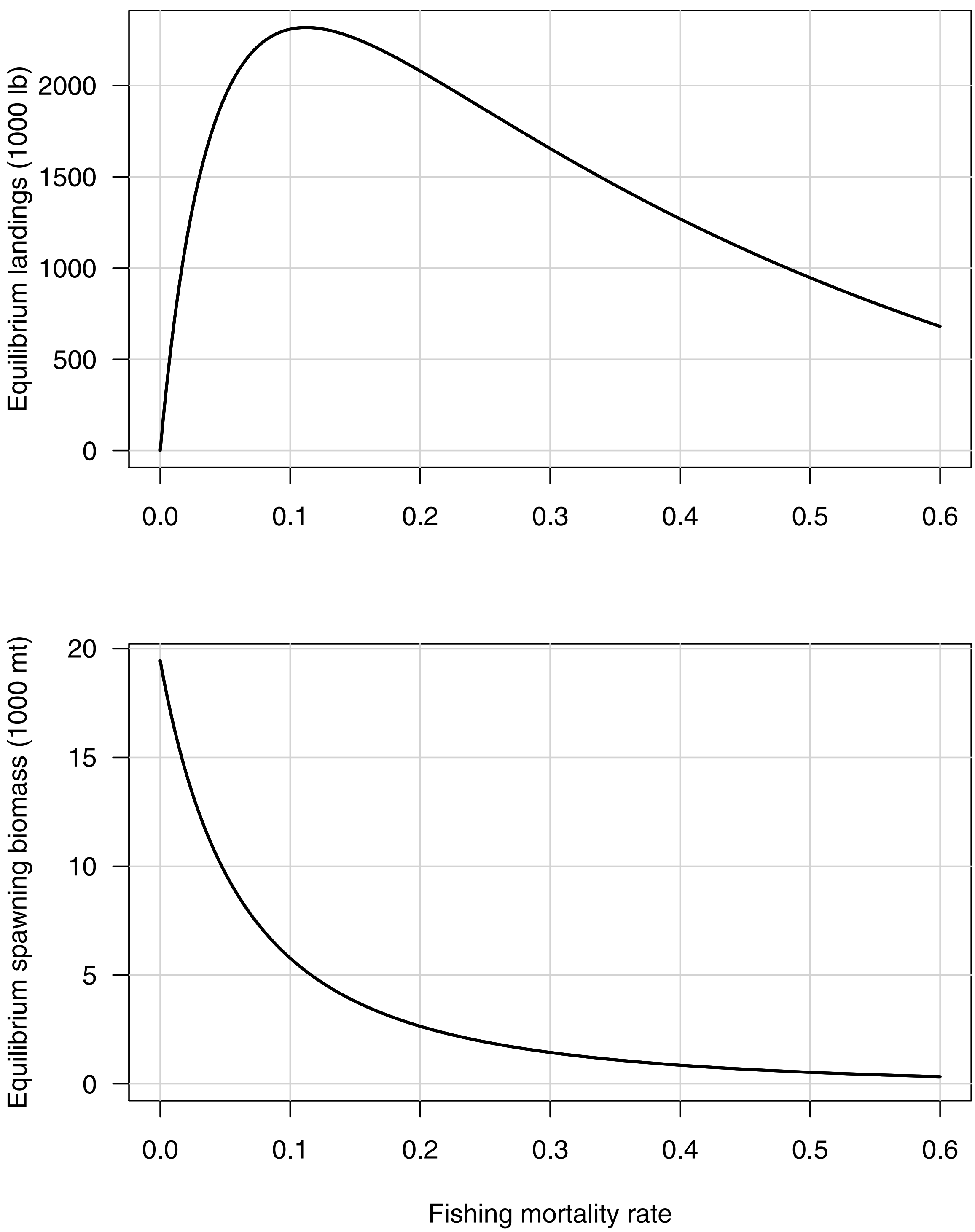


Figure 3.40. Red snapper: Top panel – Equilibrium landings as a function of equilibrium biomass, which itself is a function of fishing mortality rate. The peak occurs where equilibrium biomass is B_{MSY} = 11.734 1000 *mt and equilibrium landings are* MSY = 2319 1000 *lb. Bottom panel – Equilibrium discard mortality as a function of equilibrium biomass.*

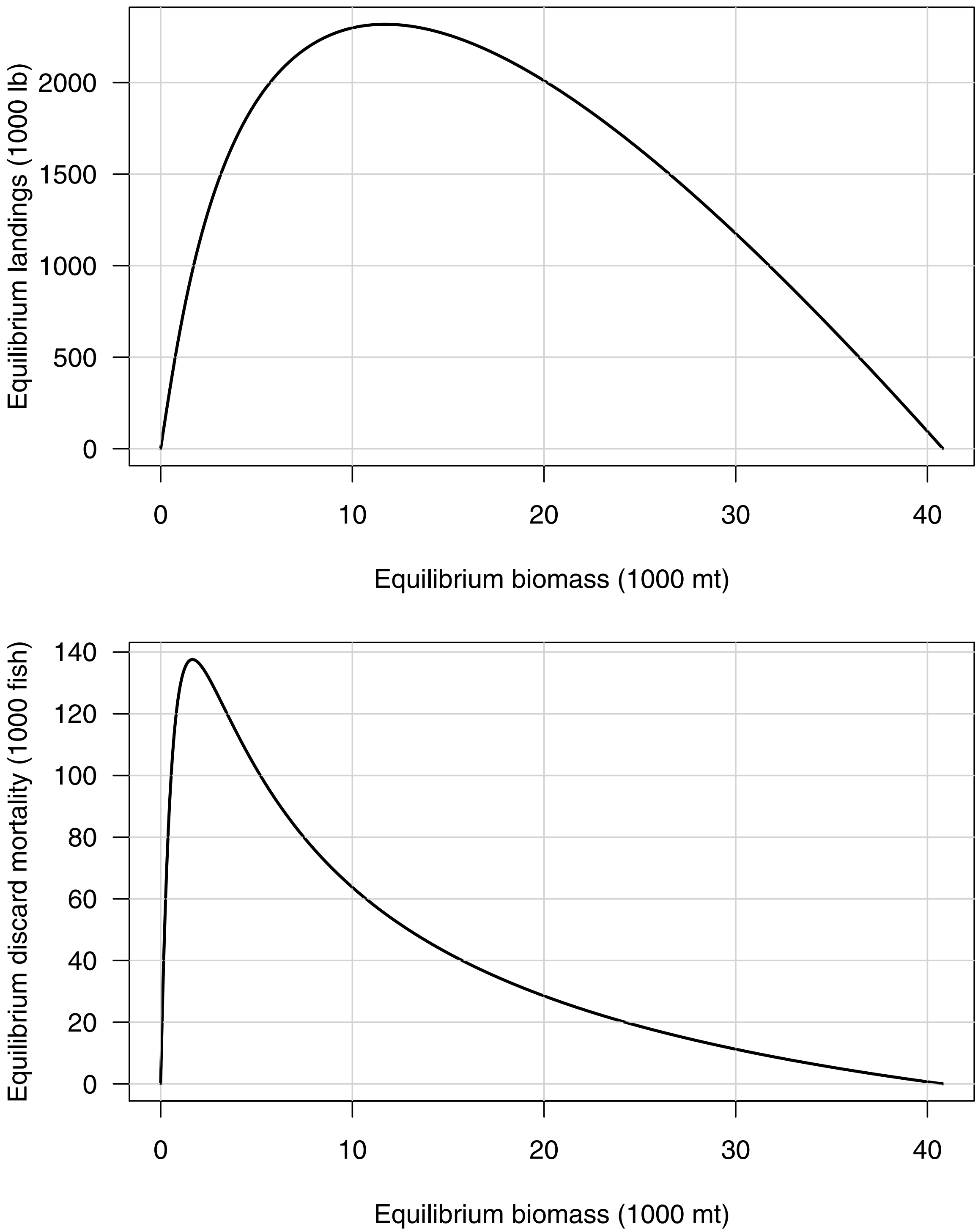


Figure 3.41. Red snapper: Probability densities of MSY*-related benchmarks. Vertical lines represent point estimates.*

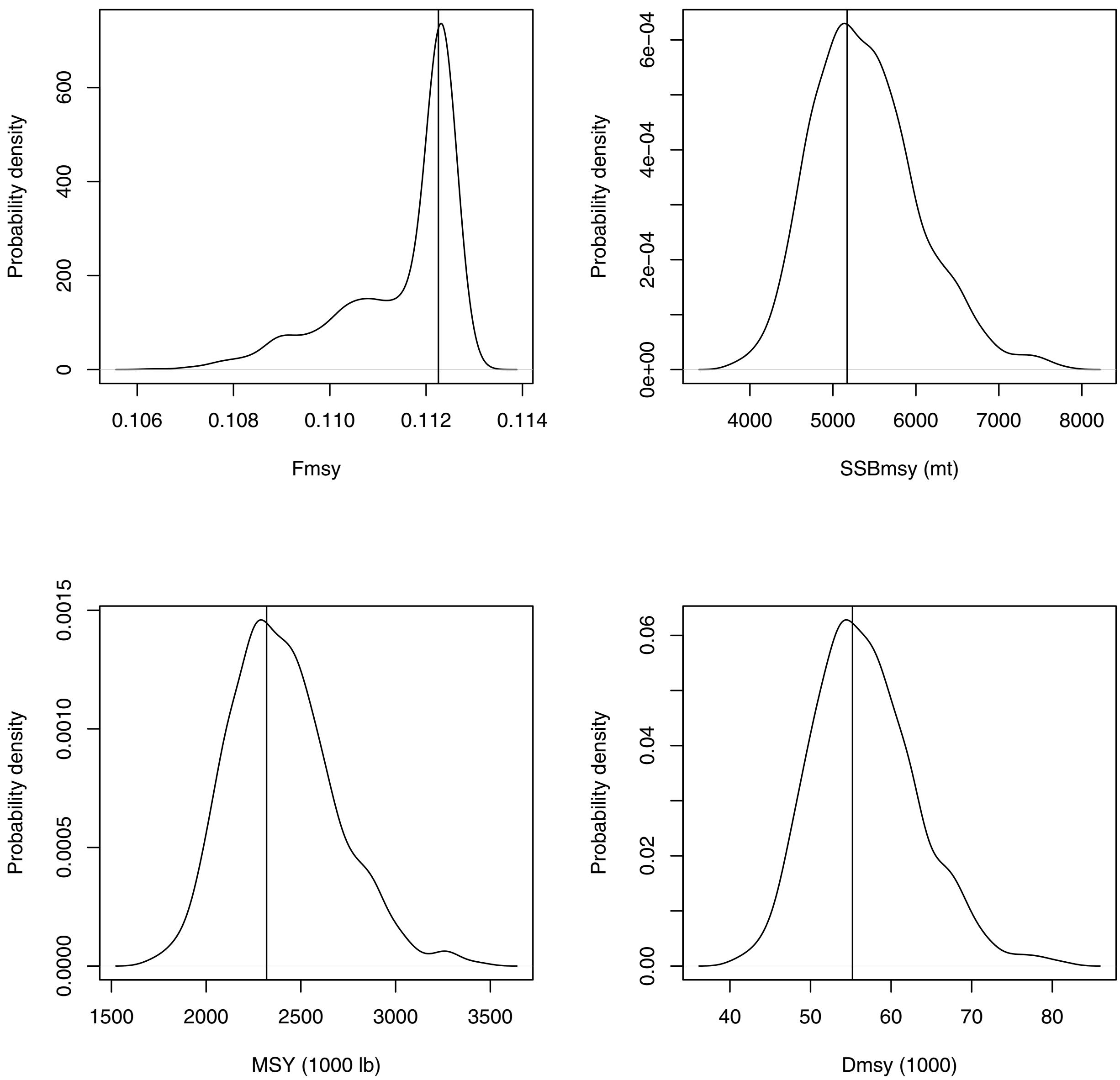


Figure 3.42. Red snapper: Estimated time series of biomass relative to MSY *benchmarks. Top panel – B relative to* B_{MSY}*. Bottom panel –* SSB *relative to* $\mathrm{SSB}_{\mathrm{MSY}}$*.*

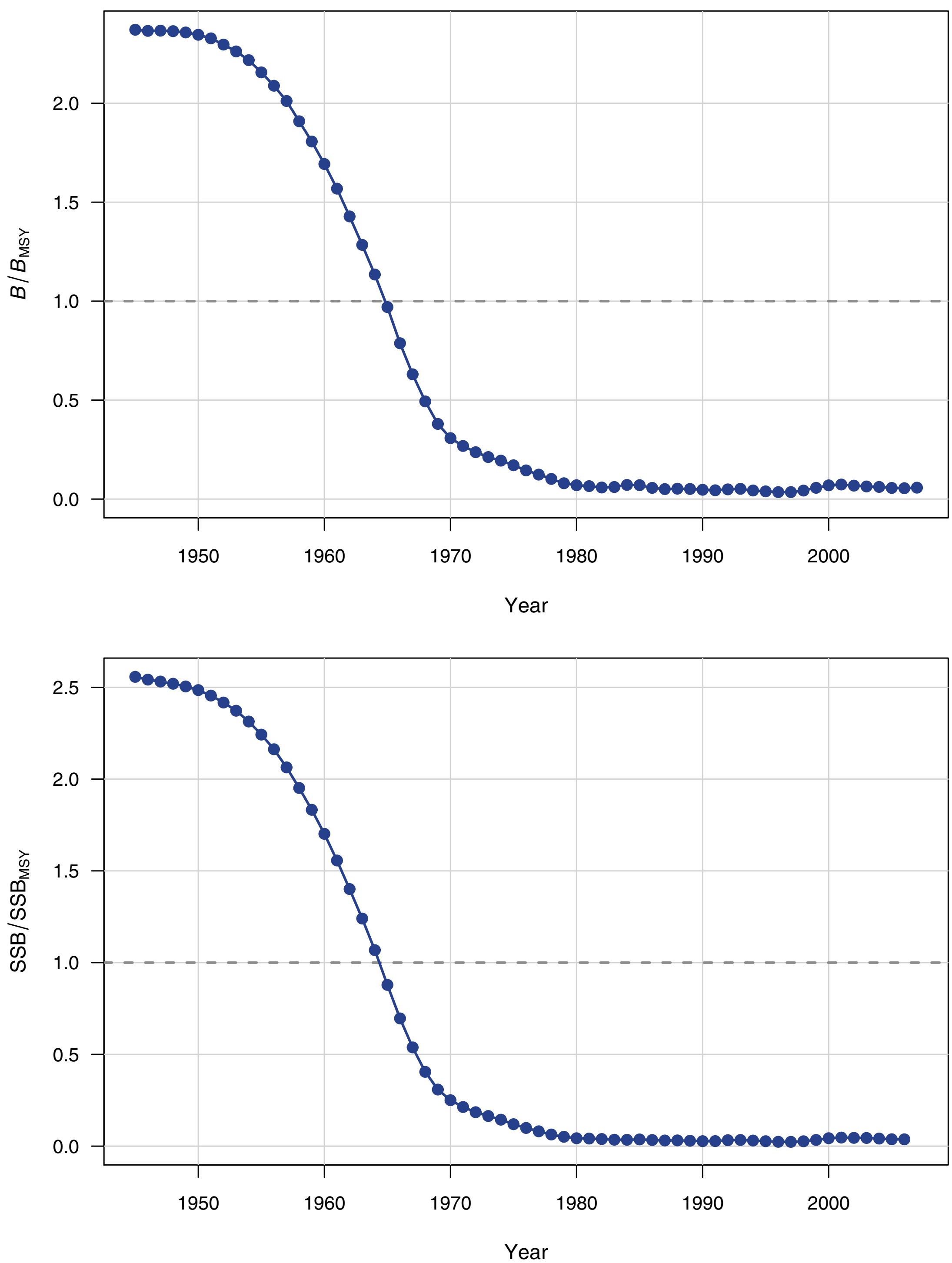


Figure 3.43. Red snapper: Estimated time series of F relative to F_{MSY}.

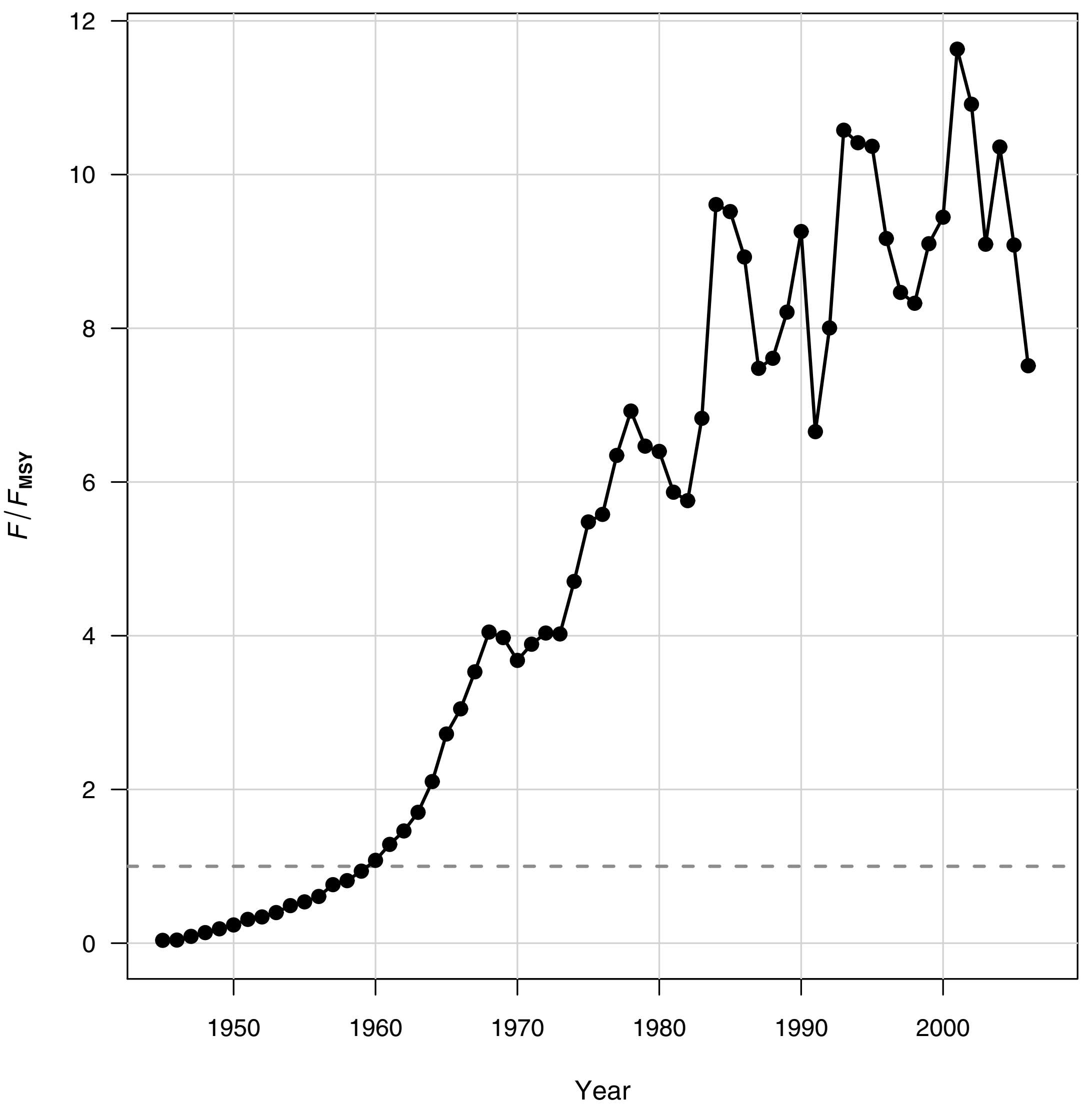


Figure 3.44. Red snapper: Sensitivity of results to natural mortality (sensitivity runs S1 and S2). Top panel – Ratio of F to F_{MSY}. Bottom panel – Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

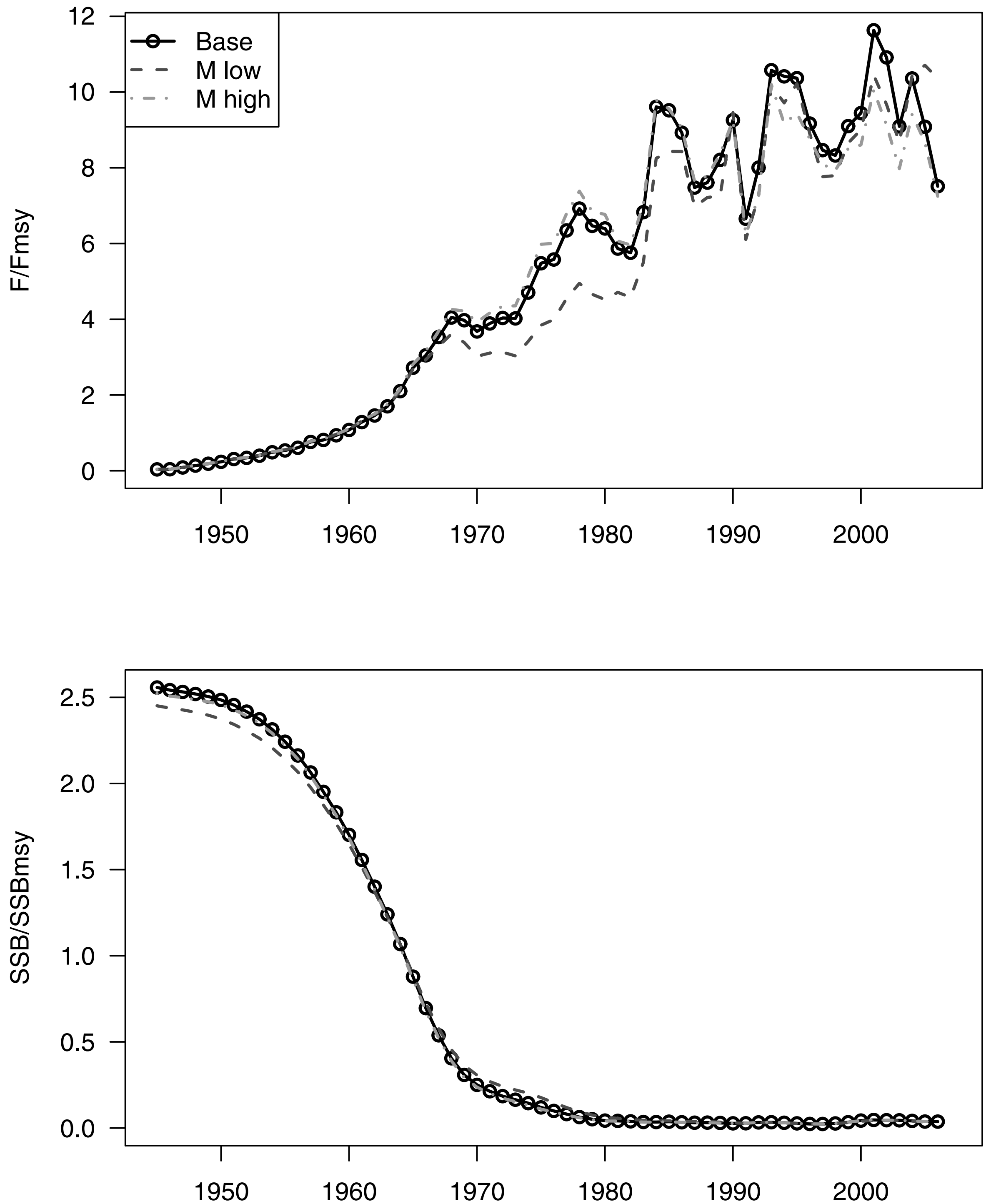


Figure 3.45. Red snapper: Sensitivity of results to increase in catchability (sensitivity runs S3 and S4). Top panel – Ratio of F to F_{MSY}. Bottom panel – Ratio of SSB *to* SSB_{MSY}.

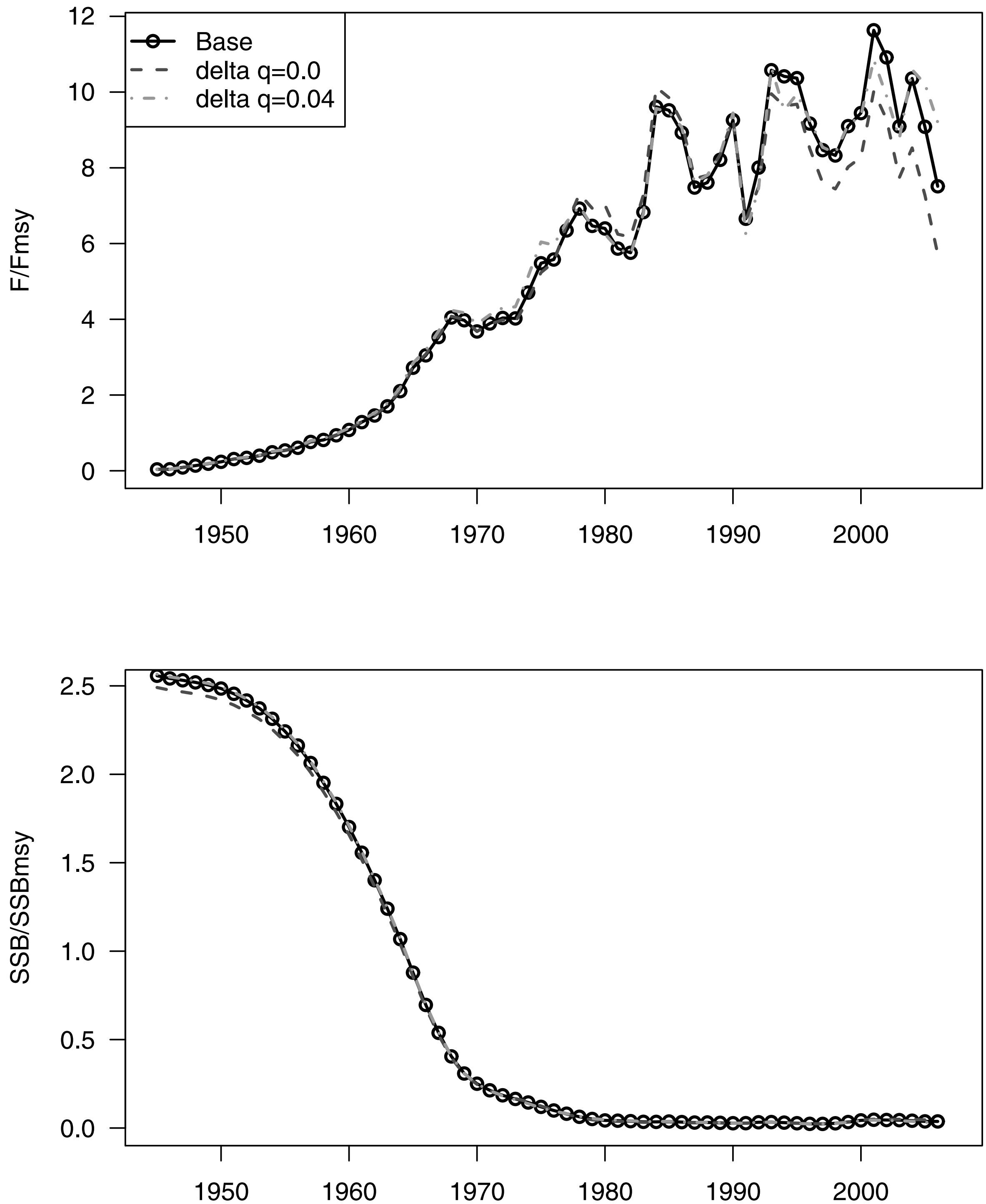


Figure 3.46. Red snapper: Sensitivity of results to starting year of recruitment deviations (sensitivity runs S5 and S6). Top panel – Ratio of F to F_{MSY}. Bottom panel – Ratio of SSB to SSB_{MSY}.

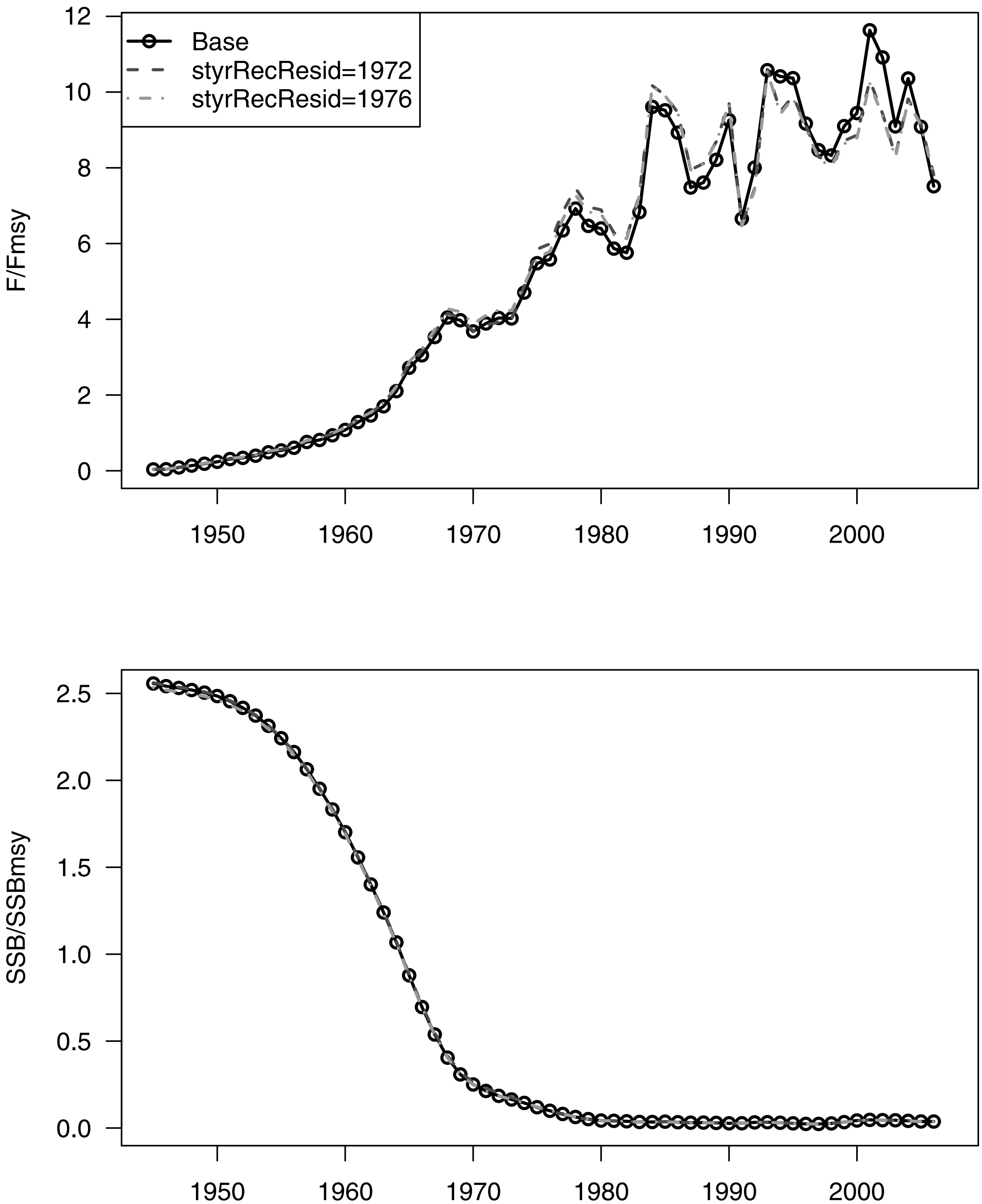


Figure 3.47. Red snapper: Sensitivity of results to recreational landings prior to 1981 (sensitivity runs S7 and S8). Top panel – Ratio of F to F_{MSY}. Bottom panel – Ratio of SSB *to* SSB_{MSY}.

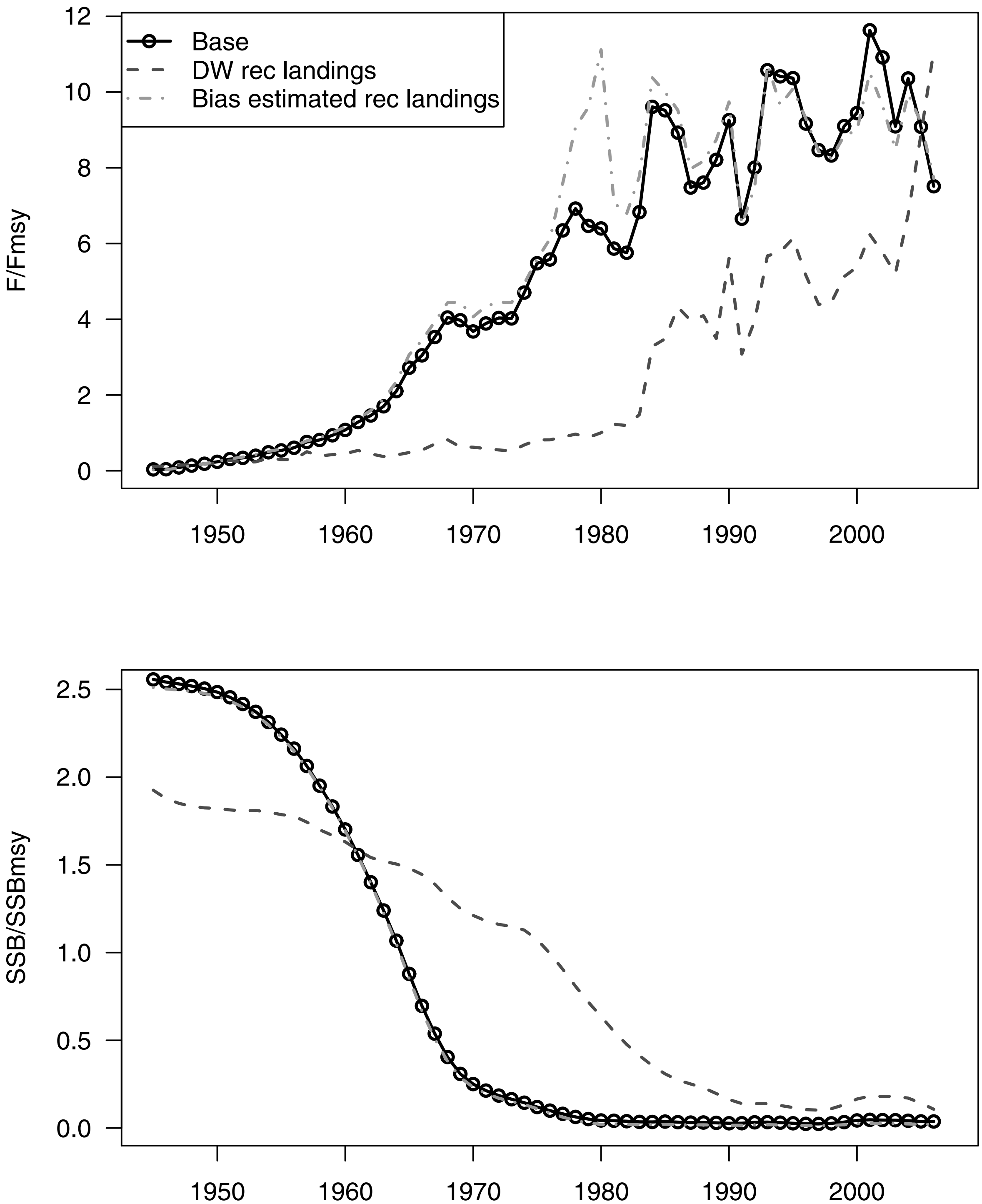


Figure 3.48. Red snapper: Sensitivity of results to discard mortality rates (sensitivity runs S9–S13). Top panel – Ratio of F to F_{MSY}. Bottom panel – Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

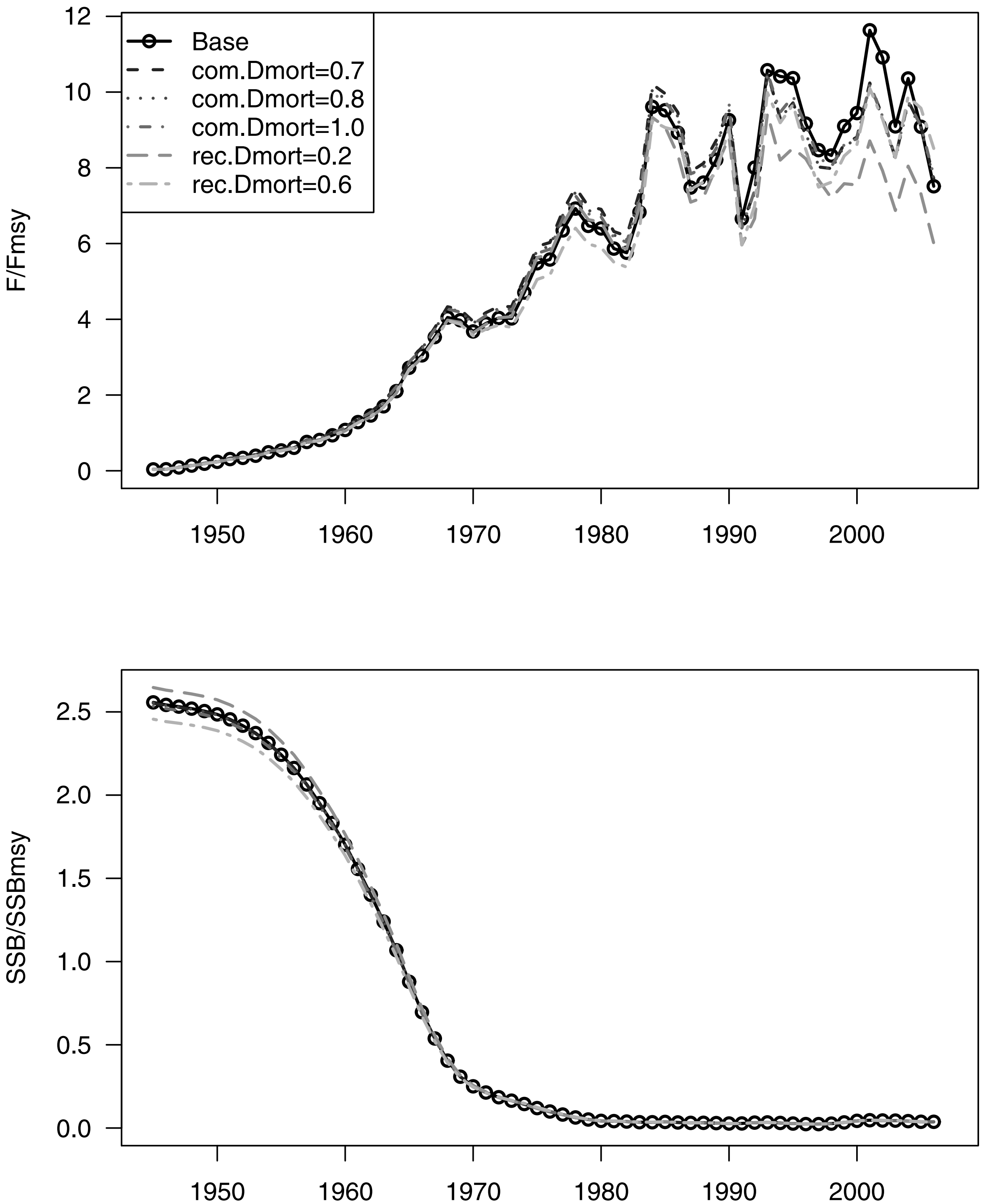


Figure 3.49. Red snapper: Sensitivity of results to discard selectivity of age-1 fish (sensitivity runs S14 and S15). Top panel – Ratio of F to F_{MSY}. Bottom panel – Ratio of SSB *to* SSB_{MSY}.

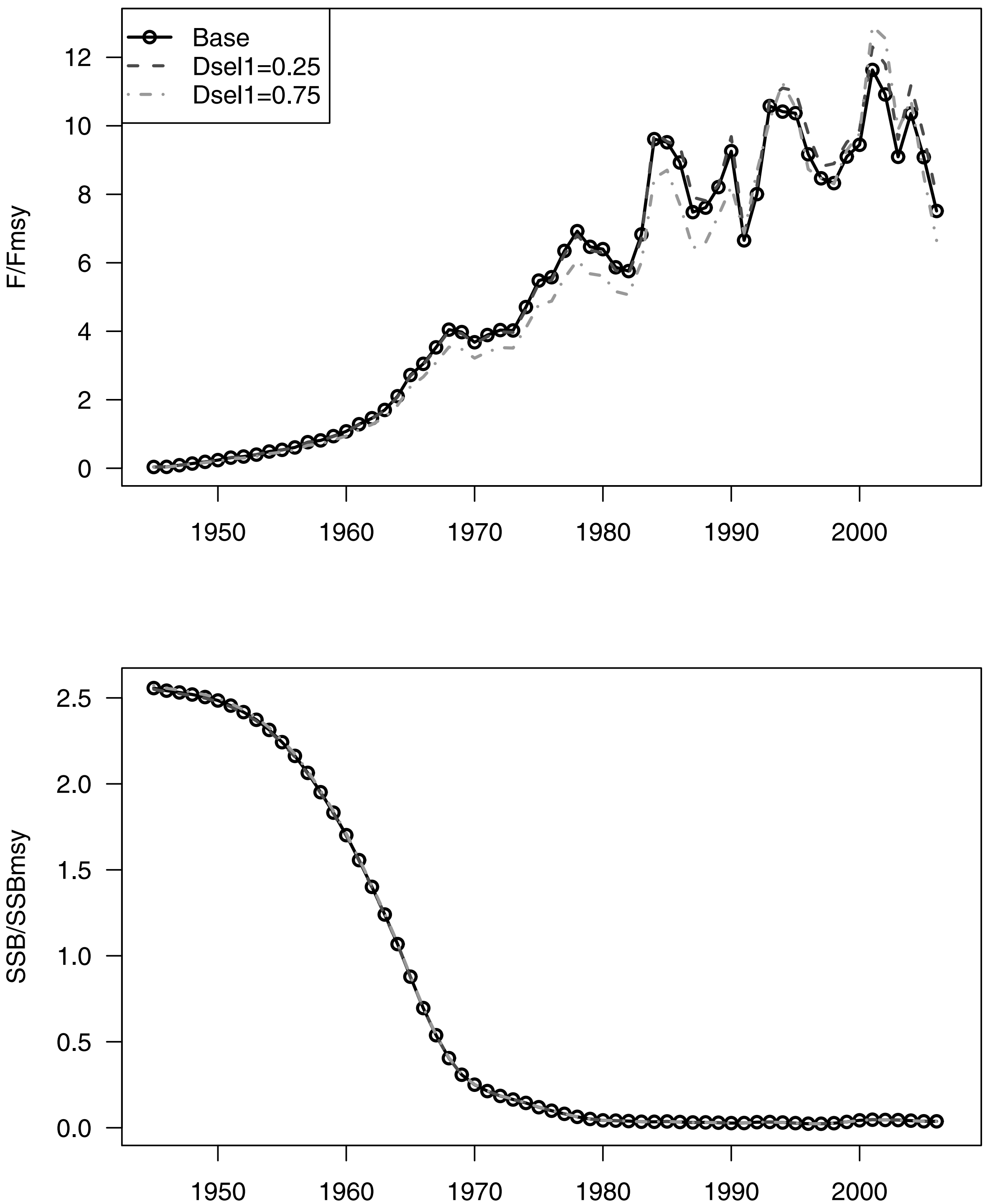


Figure 3.50. Red snapper: Sensitivity of results to steepness (sensitivity runs S16 and S17). Top panel – Ratio of F to F_{MSY}. Bottom panel – Ratio of SSB to SSB_{MSY}.

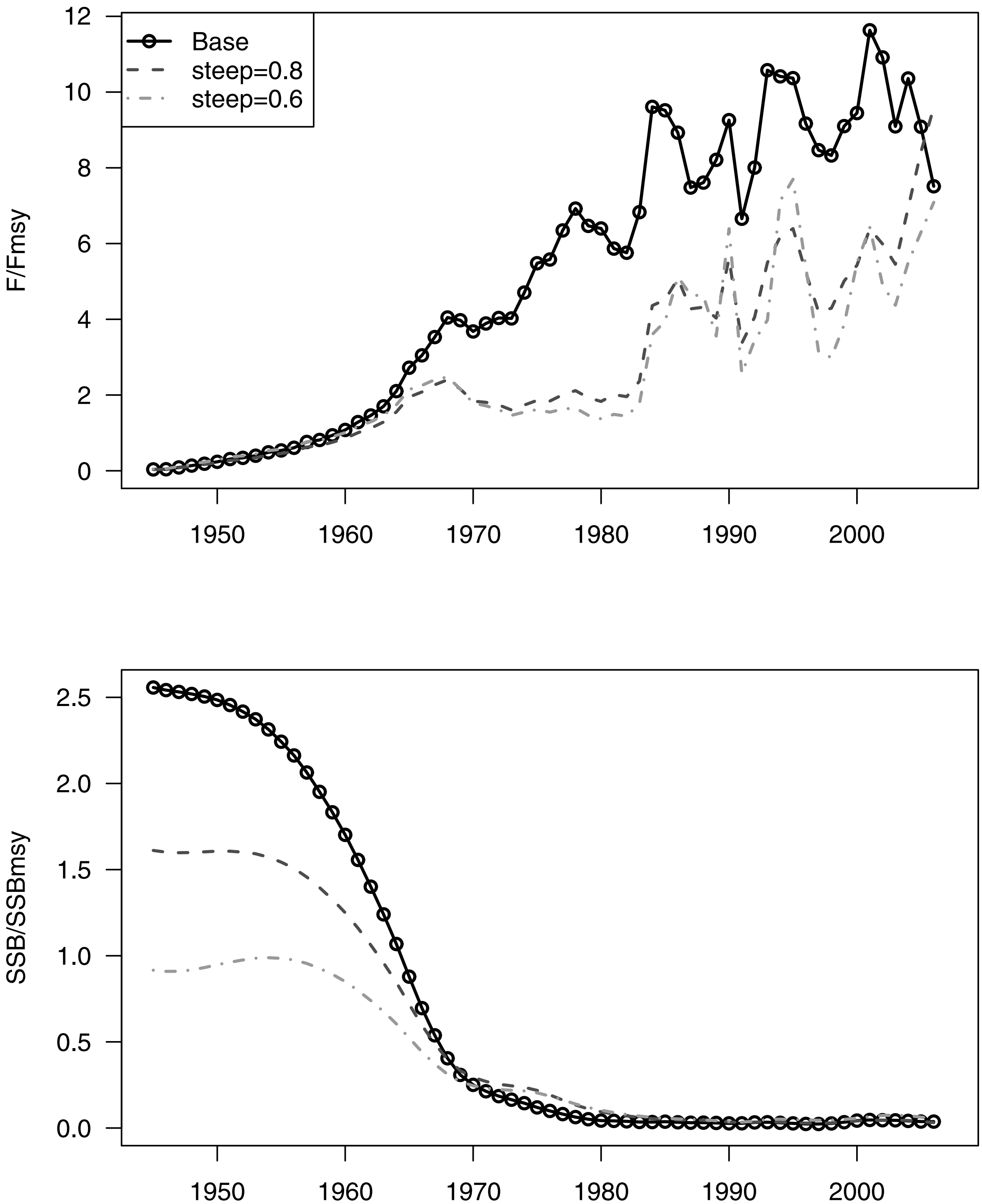


Figure 3.51. Red snapper: Retrospective analysis. Sensitivity of results to terminal year of data (sensitivity runs S18–S22). Top panel – Ratio of F to F_{MSY}. *Bottom panel – Ratio of* SSB *to* SSB_{MSY}.

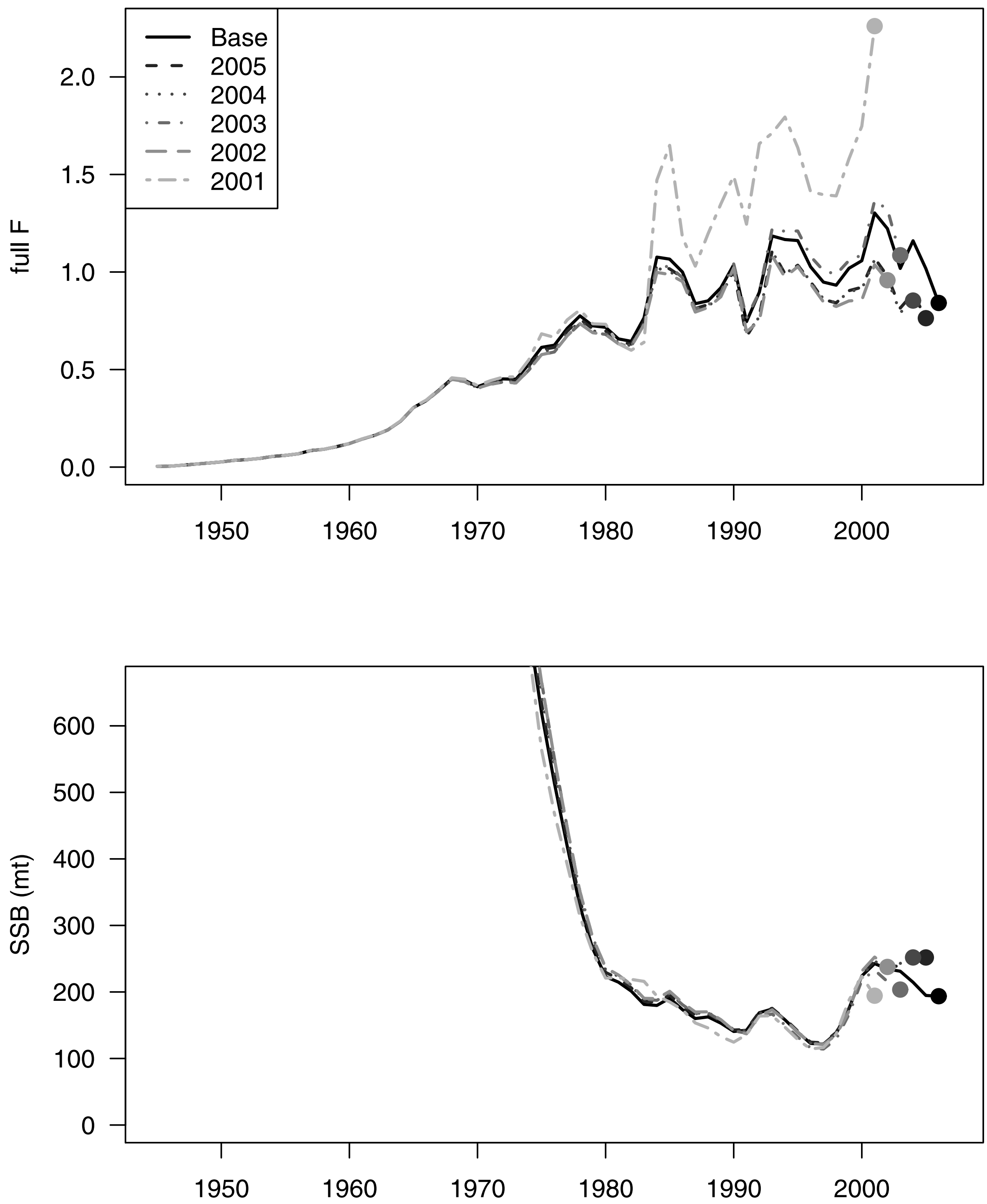


Figure 3.52. Red snapper: Sensitivity of results to initial stock status B1/K (sensitivity runs S23–S31). Top panel – Ratio of F to F_{MSY}. Bottom panel – Ratio of SSB to SSB_{MSY}.

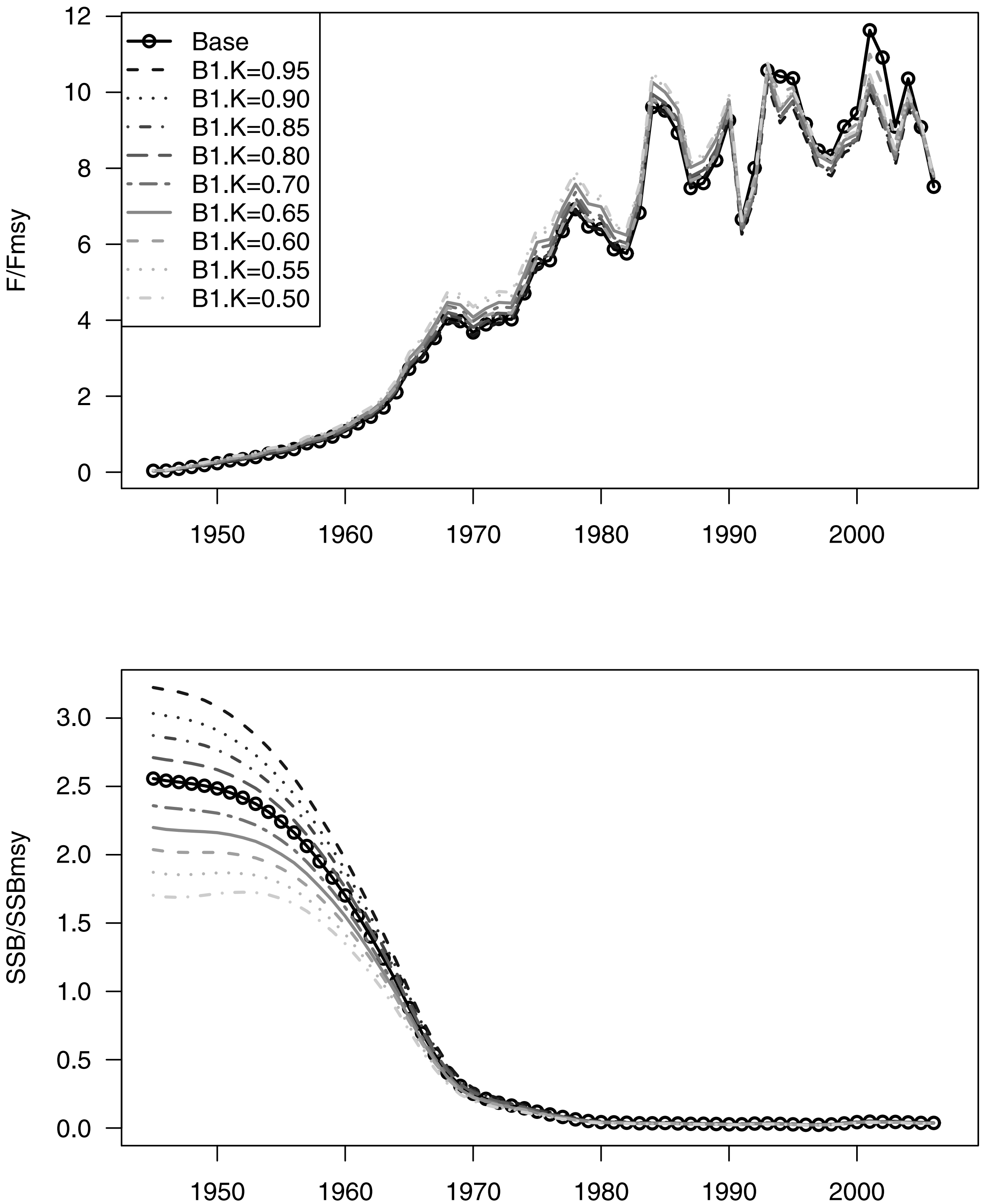


Figure 3.53. Red snapper: Projection results under scenario 1—fishing mortality rate fixed at $F = 0$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 1000 replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock biomass (SSB) is at mid-year.*

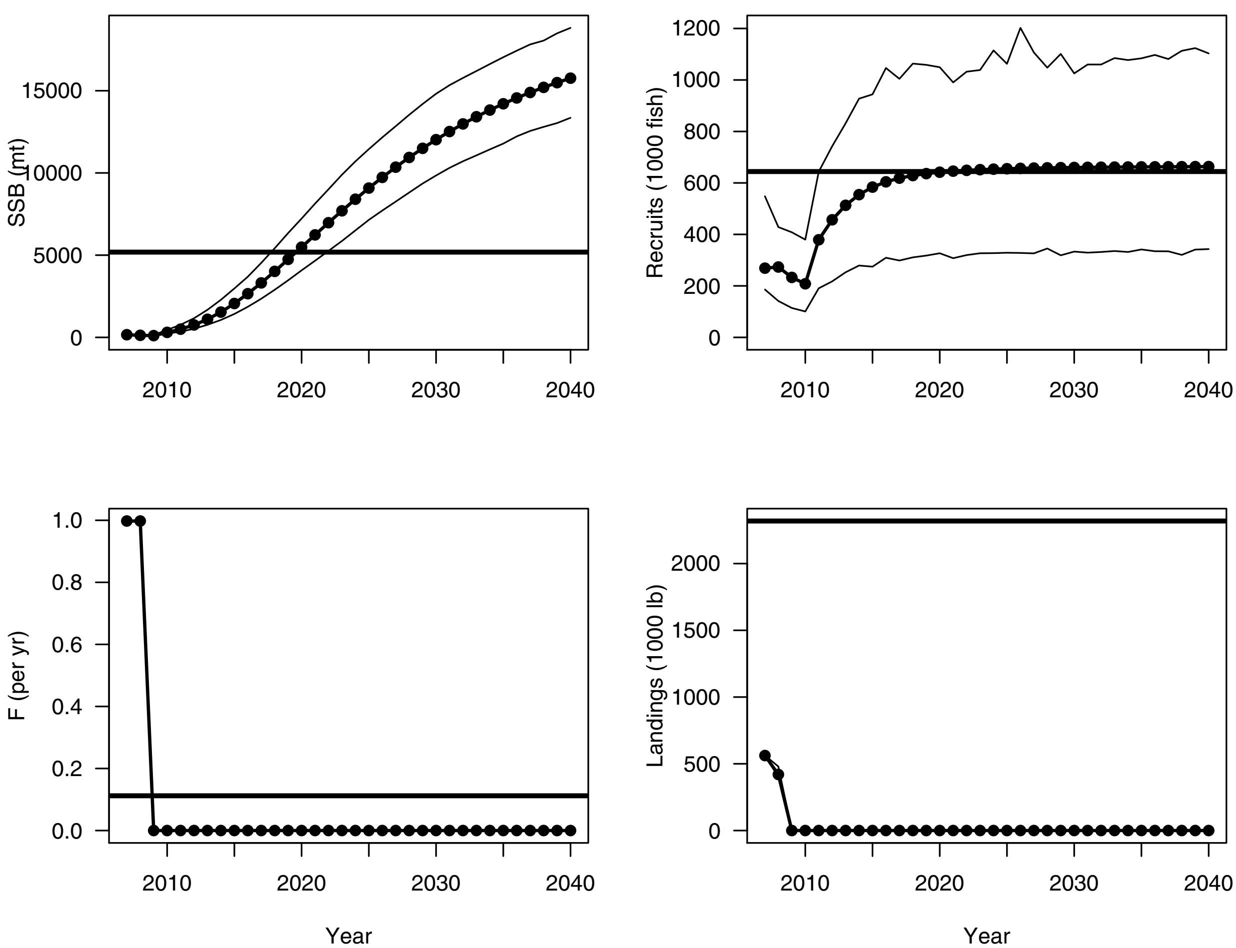


Figure 3.54. Red snapper: Projection results under scenario 2—fishing mortality rate fixed at $F = F_{\text{current}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 1000 replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock biomass (SSB) is at mid-year.*

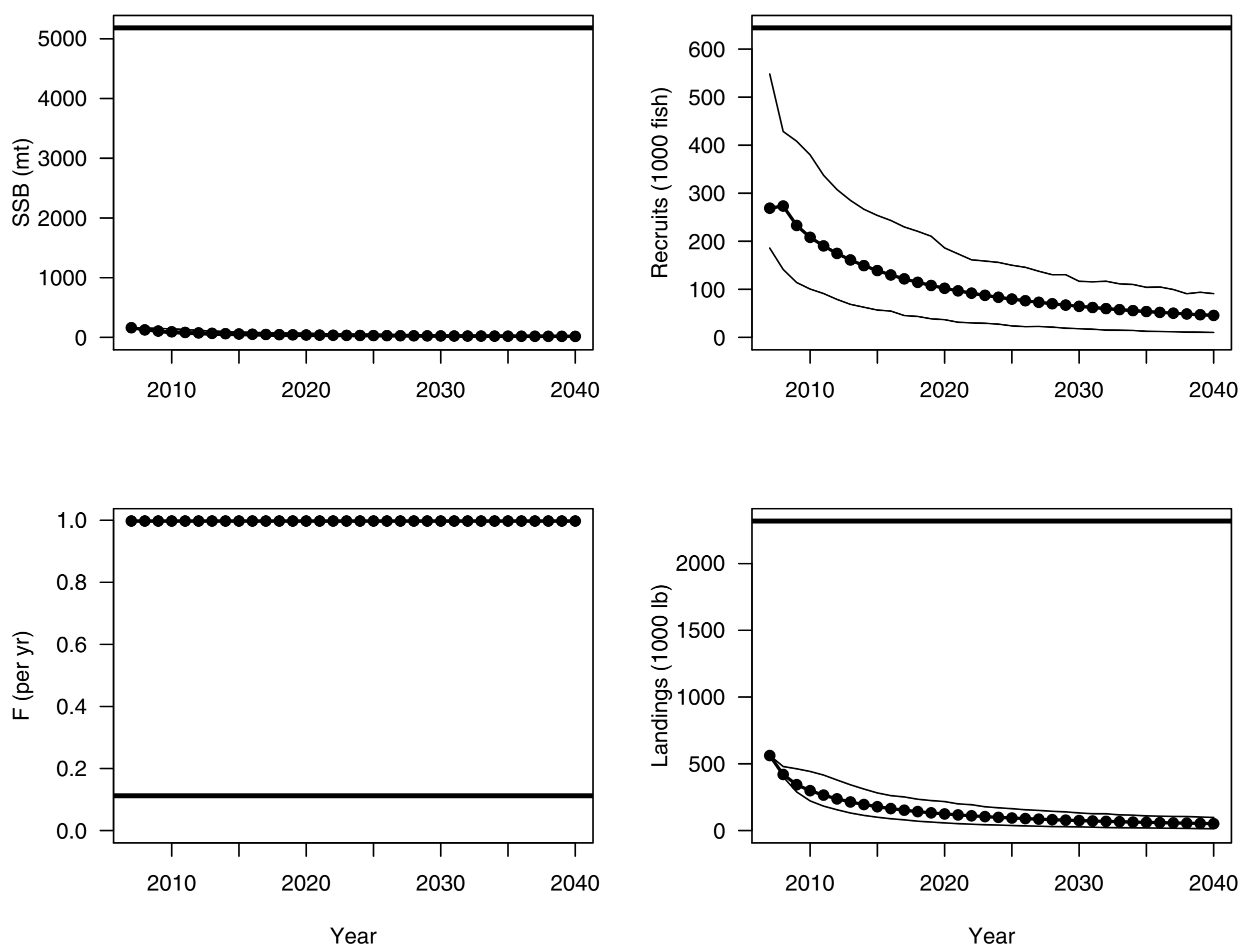


Figure 3.55. Red snapper: Projection results under scenario 3—fishing mortality rate fixed at $F = F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 1000 replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock biomass (SSB) is at mid-year.*

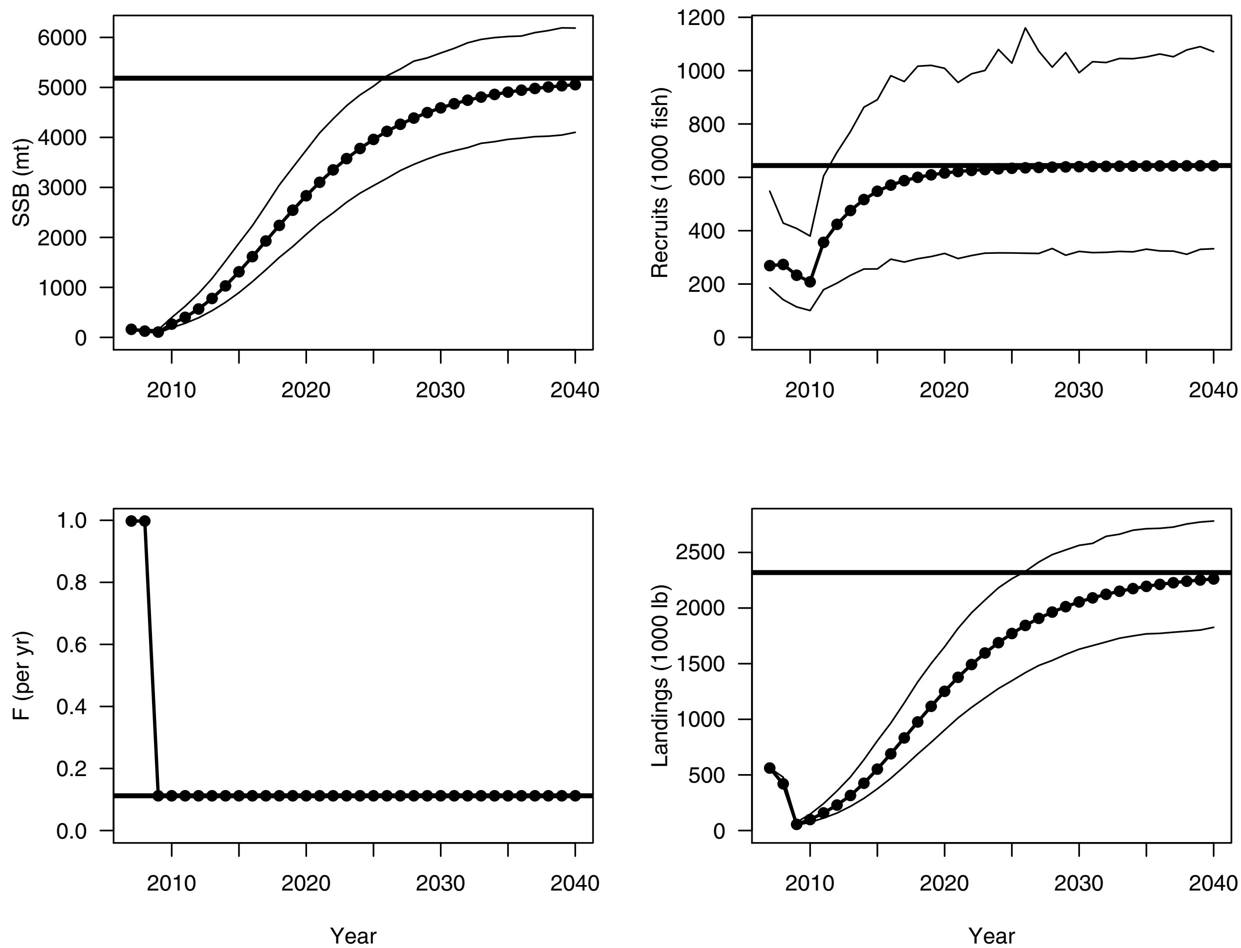


Figure 3.56. Red snapper: Projection results under scenario 4—fishing mortality rate fixed at $F = 65\%F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 1000 replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock biomass (SSB) is at mid-year.*

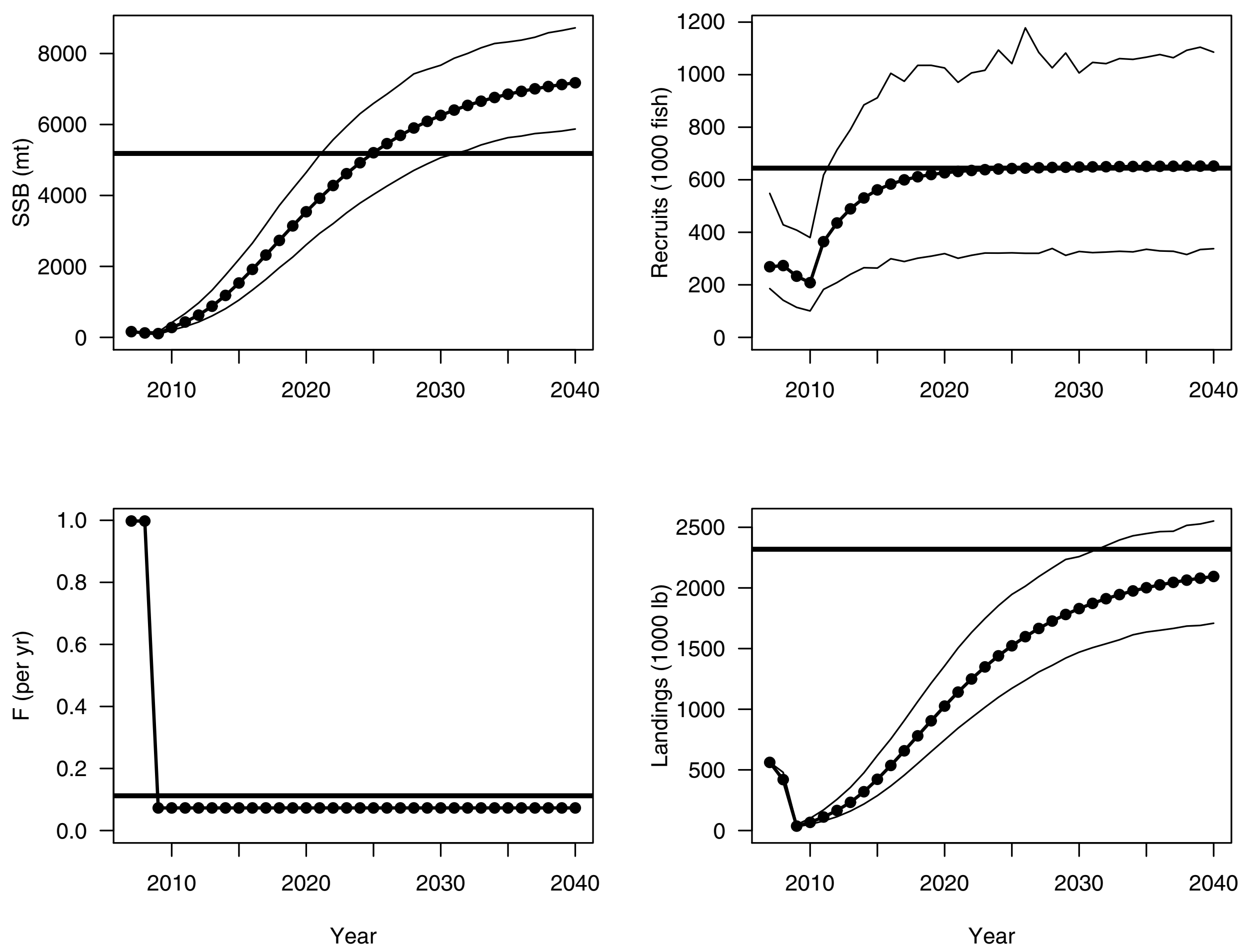


Figure 3.57. Red snapper: Projection results under scenario 5—fishing mortality rate fixed at $F = 75\%F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 1000 replicate projections. Horizontal lines mark MSY-related quantities. Spawning stock biomass (SSB) is at mid-year.

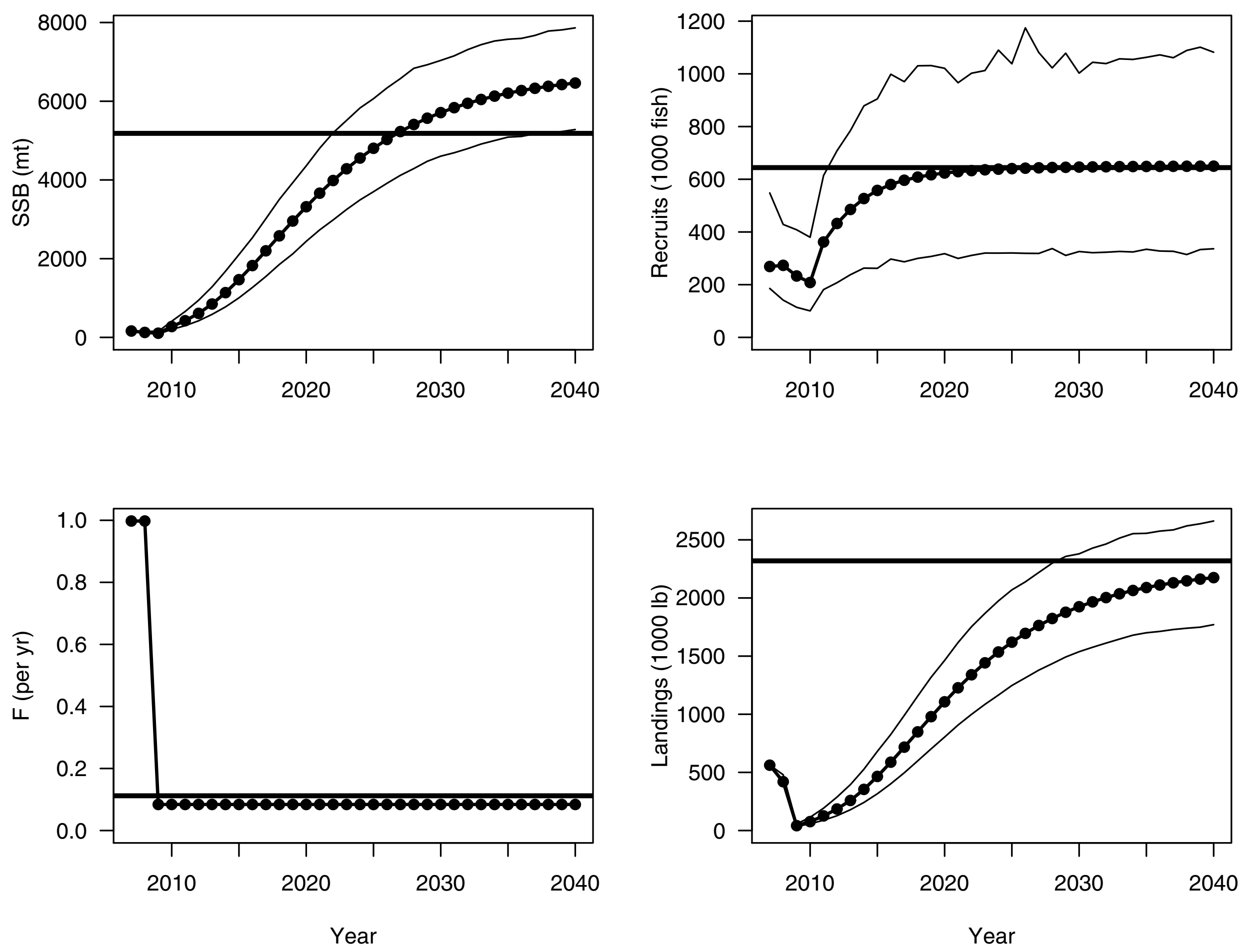


Figure 3.58. Red snapper: Projection results under scenario 6—fishing mortality rate fixed at $F = 85\%F_{MSY}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 1000 replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock biomass (SSB) is at mid-year.*

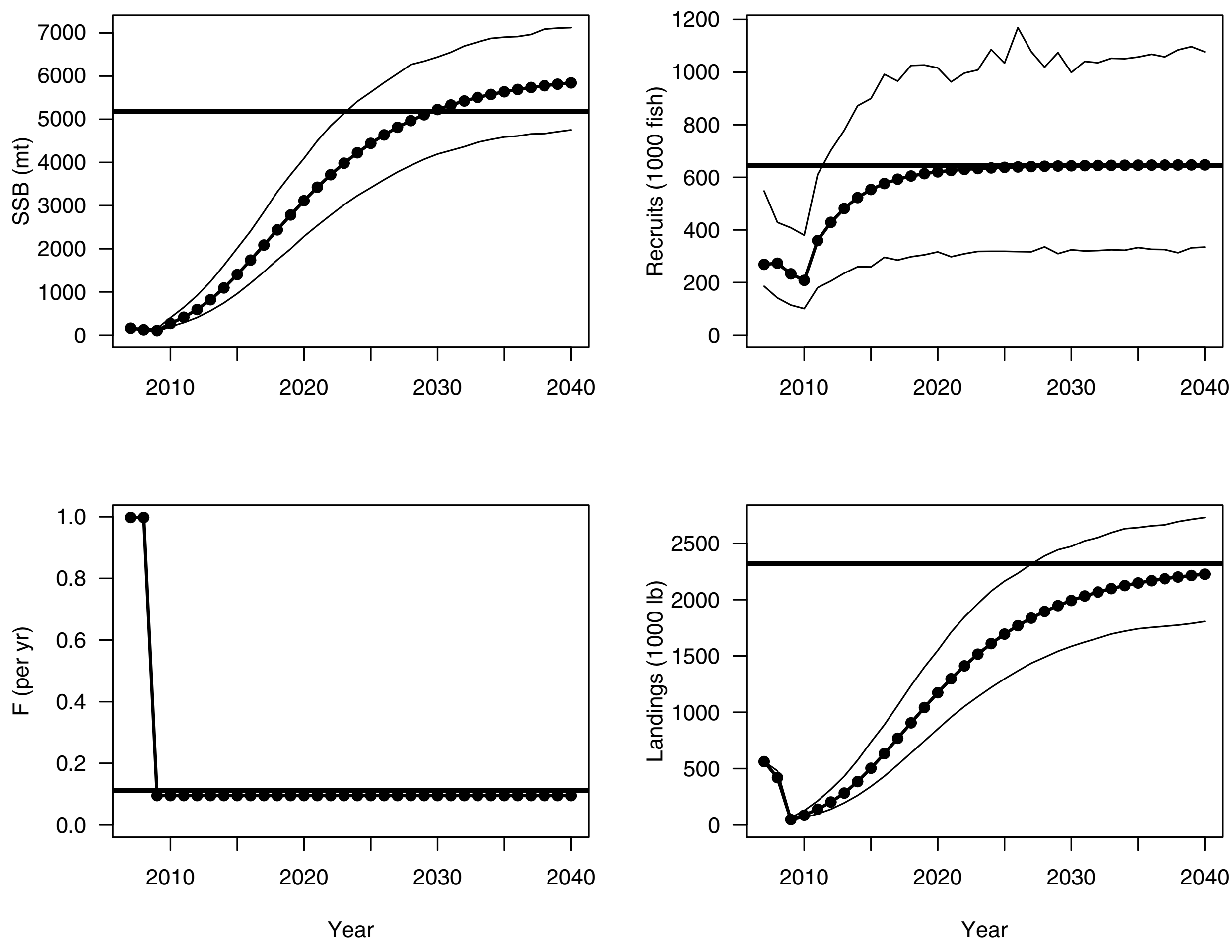


Figure 3.59. Red snapper: Projection results under scenario 7—fishing mortality rate fixed at $F = F_{\text{rebuild}}$*. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to* 10^{th} *and* 90^{th} *percentiles of 1000 replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock biomass (SSB) is at mid-year.*

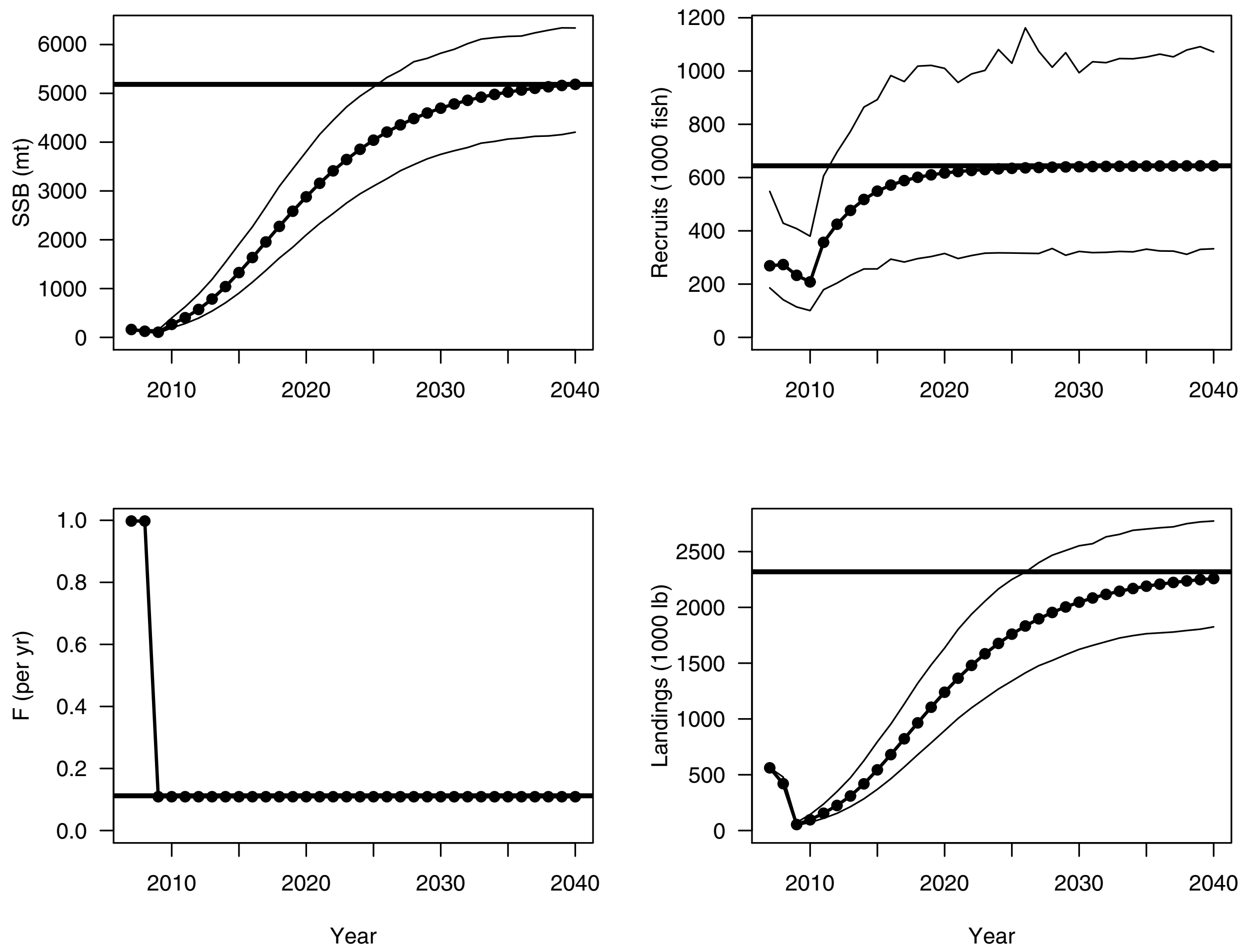


Figure 3.60. Red snapper: Projection results under scenario 8—Discard-only projection with fishing mortality rate fixed at $F = F_{\text{current}}$ minus commercial diving, and with release mortality rates of 0.9 in the commercial sector and 0.4 in the headboat and general recreational sectors. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 1000 replicate projections. Spawning stock biomass (SSB) is at mid-year. In the SSB *panel, solid horizontal line marks* SSB_{MSY}*, the rebuilding target. In the F panel, the dashed horizontal line marks the fishing rate applied, of which only a portion (dotted solid line) leads to discard mortality. Spawning stock biomass (SSB) is at mid-year.*

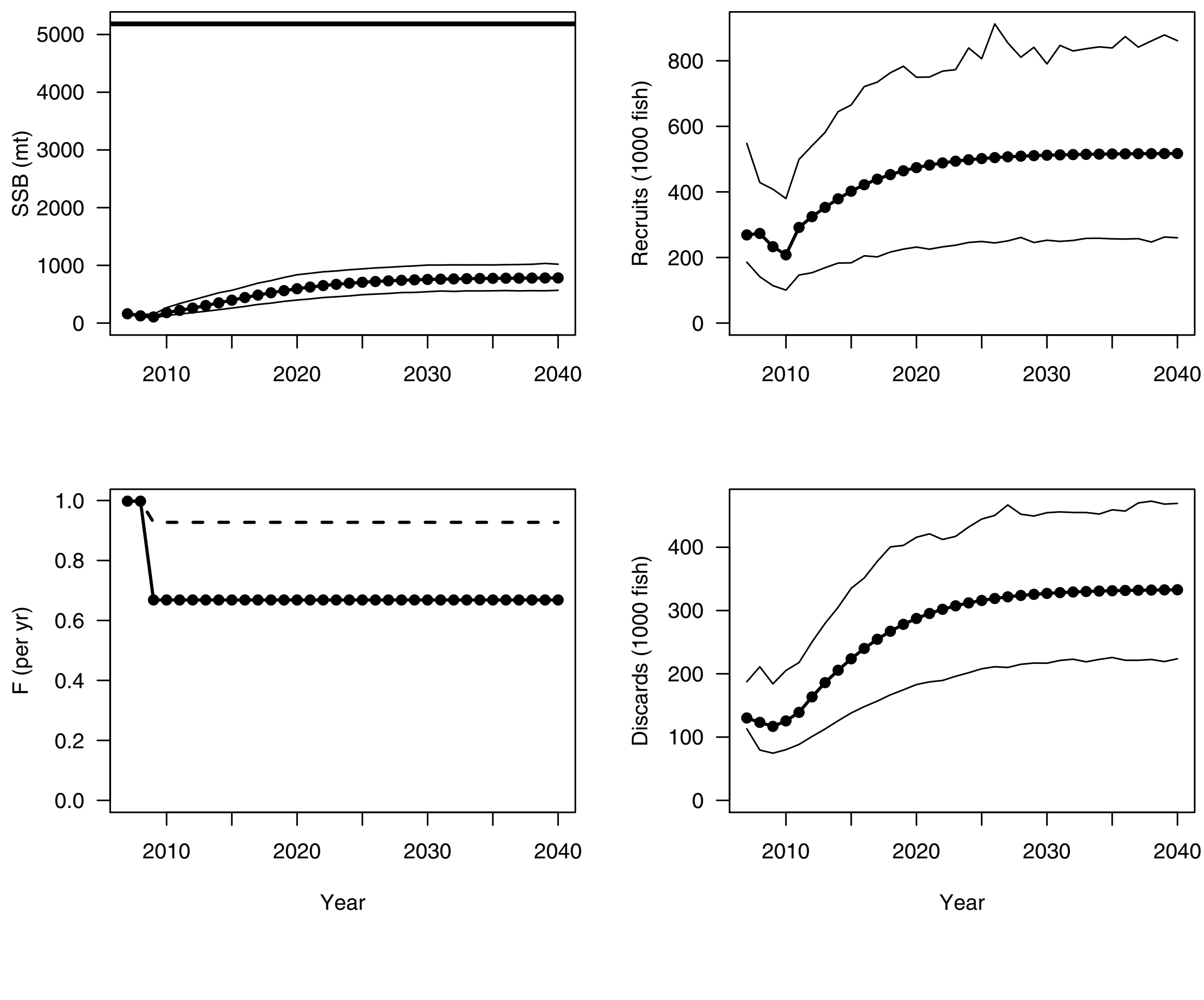


Figure 3.61. Red snapper: Projection results under scenario 9—Discard-only projection with fishing mortality rate fixed at $F = F_{\text{current}}$ minus commercial diving, and with release mortality rates of 0.8 in the commercial sector and 0.2 in the headboat and general recreational sectors. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 1000 replicate projections. Spawning stock biomass (SSB) is at mid-year. In the SSB *panel, solid horizontal line marks* SSB_{MSY}, *the rebuilding target. In the F panel, the dashed horizontal line marks the fishing rate applied, of which only a portion (dotted solid line) leads to discard mortality.*

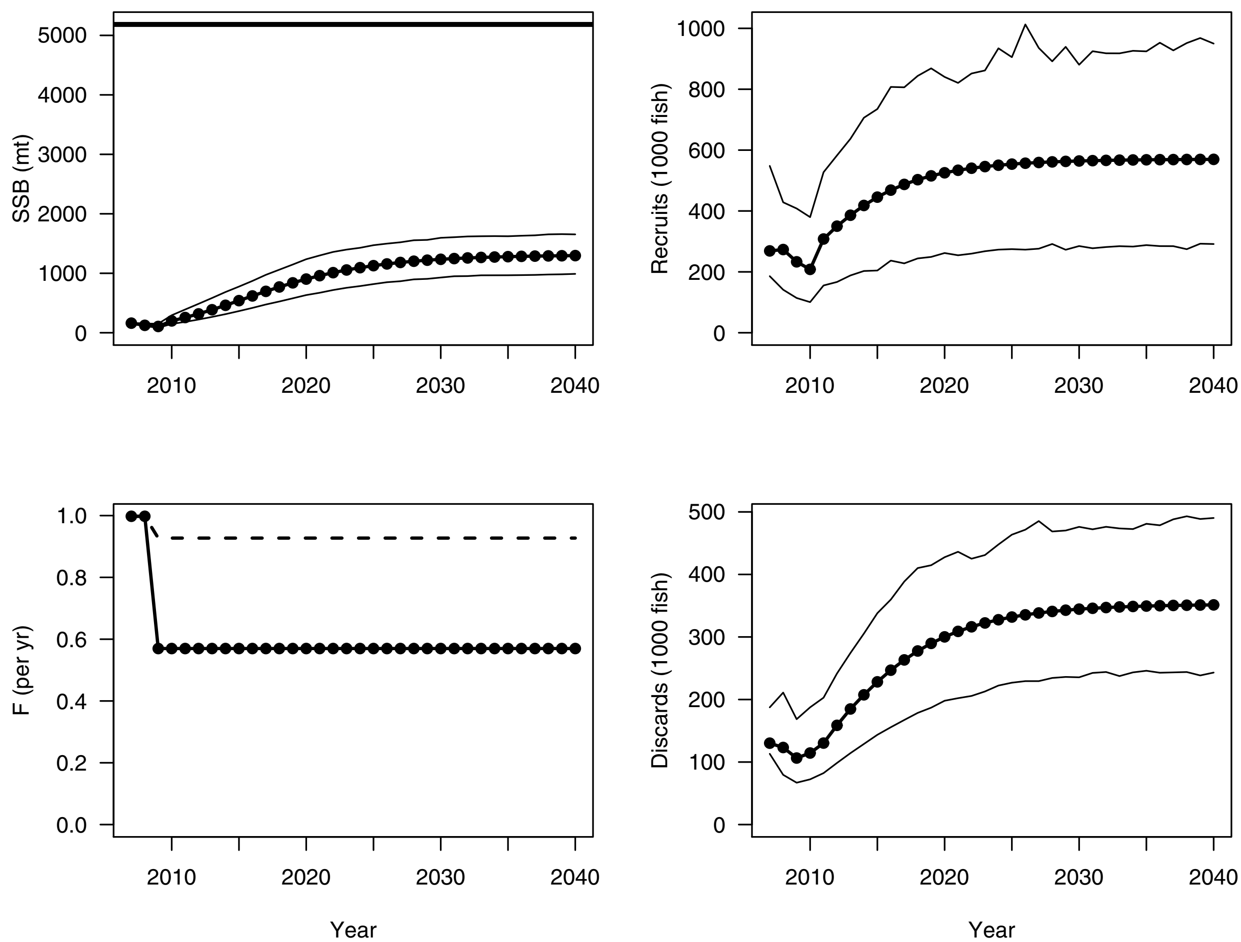


Figure 3.62. Red snapper: Projection results under scenario 10—Discard-only projection with fishing mortality rate fixed at $F = F_{\text{current}}$ minus commercial diving, and with release mortality rates of 1.0 in the commercial sector and 0.6 in the headboat and general recreational sectors. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 1000 replicate projections. Spawning stock biomass (SSB) is at mid-year. In the SSB *panel, solid horizontal line marks* SSB_{MSY}*, the rebuilding target. In the F panel, the dashed horizontal line marks the fishing rate applied, of which only a portion (dotted solid line) leads to discard mortality.*

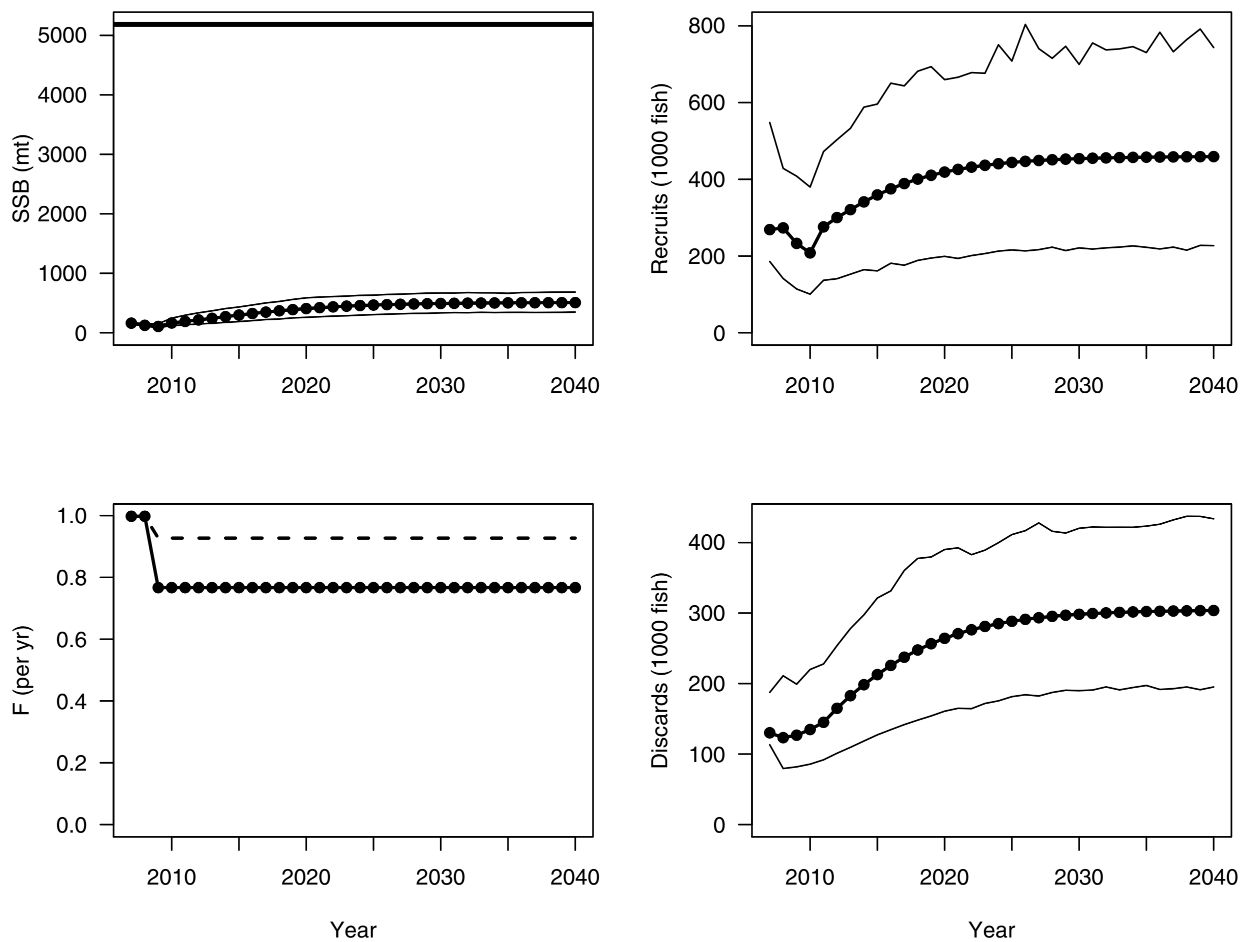


Figure 3.63. Red snapper: Projection results under scenario 11—Discard-only projection with fishing mortality rate fixed at $F = F_{\text{rebuild}}$, given release mortality rates of 0.9 in the commercial sector and 0.4 in the headboat and general recreational sectors. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 1000 replicate projections. Spawning stock biomass (SSB) is at mid-year. In the SSB *panel, solid horizontal line marks* SSB_{MSY}*, the rebuilding target. In the F panel, the dashed horizontal line marks the fishing rate applied, of which only a portion (dotted solid line) leads to discard mortality.*

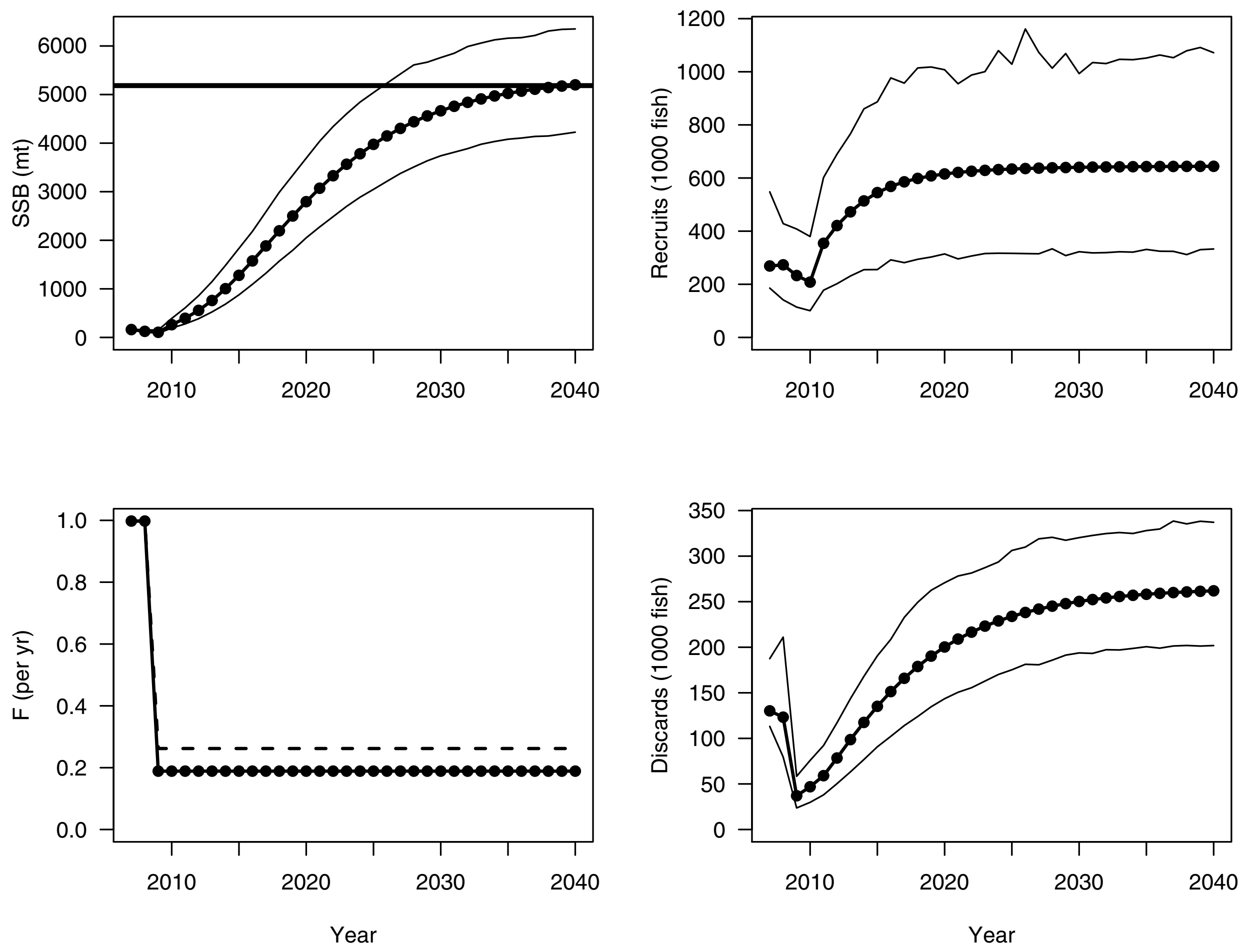


Figure 3.64. Red snapper: Projection results under scenario 12—Discard-only projection with fishing mortality rate fixed at $F = F_{\text{rebuild}}$, given release mortality rates of 0.7 in the commercial sector and 0.4 in the headboat and general recreational sectors. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 1000 replicate projections. Spawning stock biomass (SSB) is at mid-year. In the SSB panel, solid horizontal line marks SSB_{MSY}, the rebuilding target. In the F panel, the dashed horizontal line marks the fishing rate applied, of which only a portion (dotted solid line) leads to discard mortality.

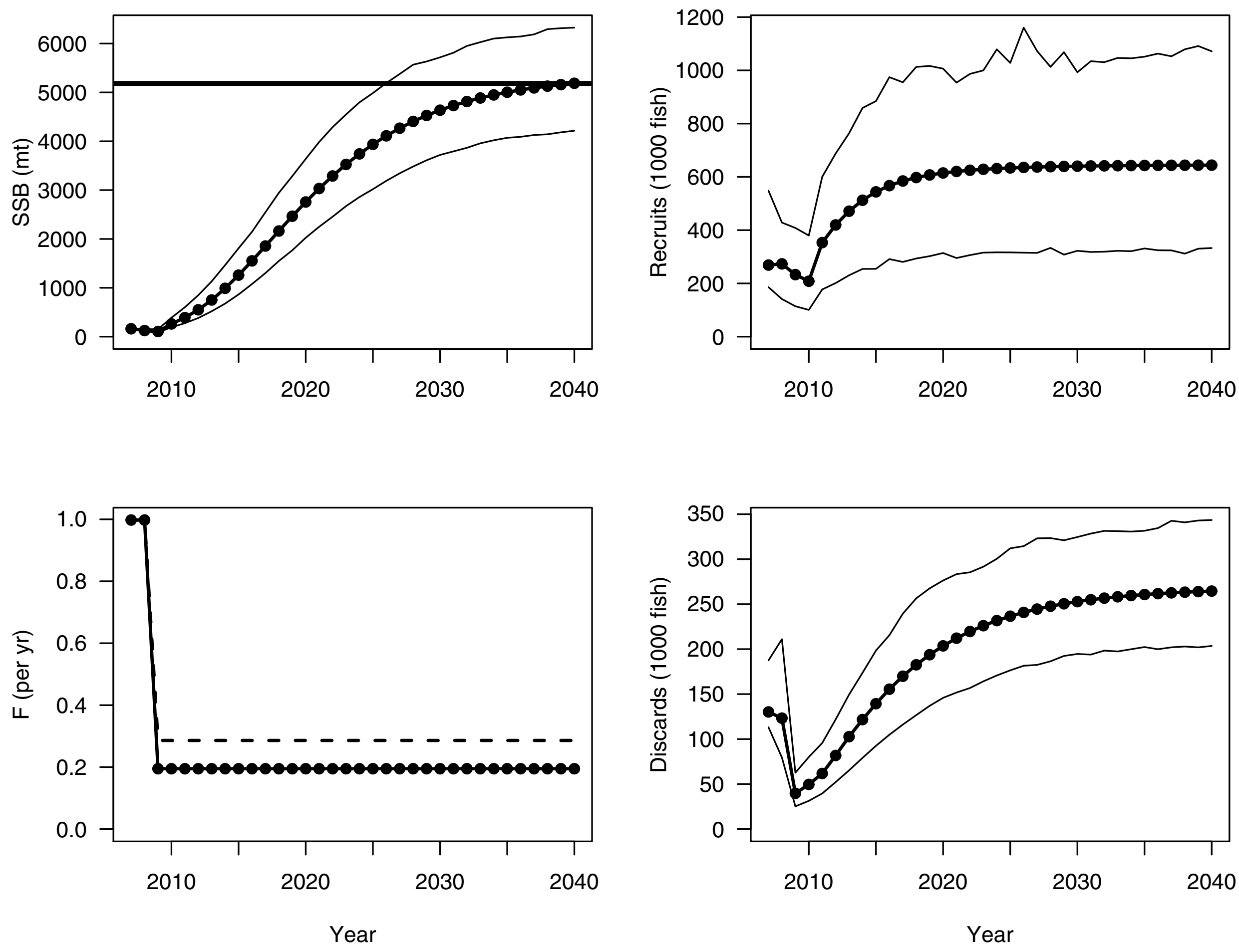


Figure 3.65. Observed (open circles) versus modeled (solid line) weight per landed fish in the headboat fishery for each calendar year. Sample sizes ranged from 68 to 1370 per year.

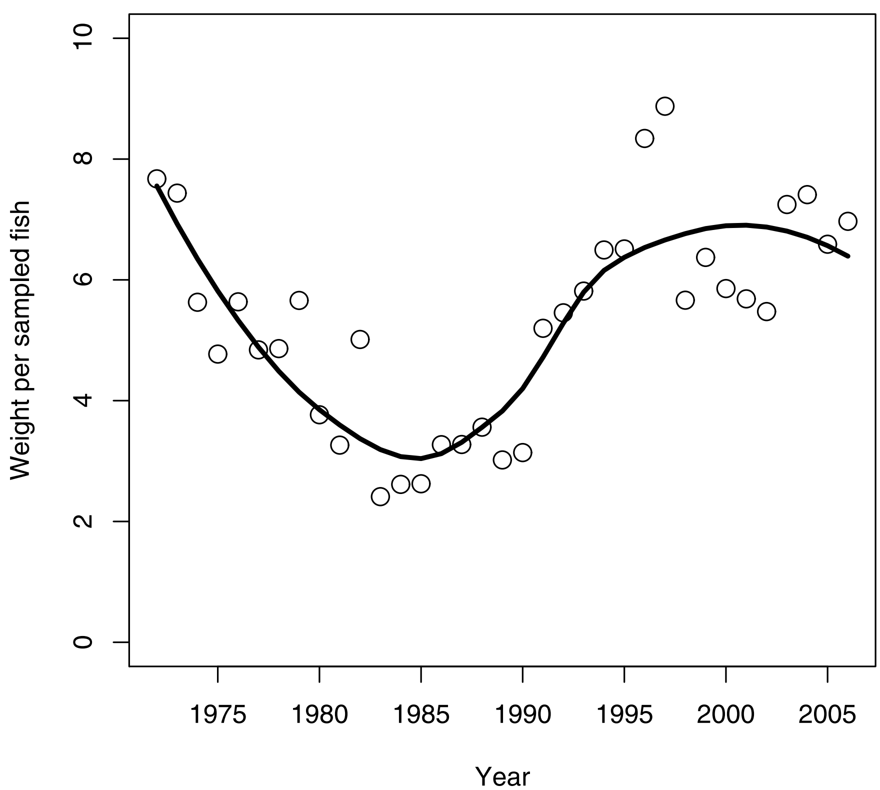


Figure 3.66. Observed (open circles) versus modeled (solid line) weight per landed fish for the MRFSS survey in each calendar year. Sample sizes ranged from 15 to 370 per annum.

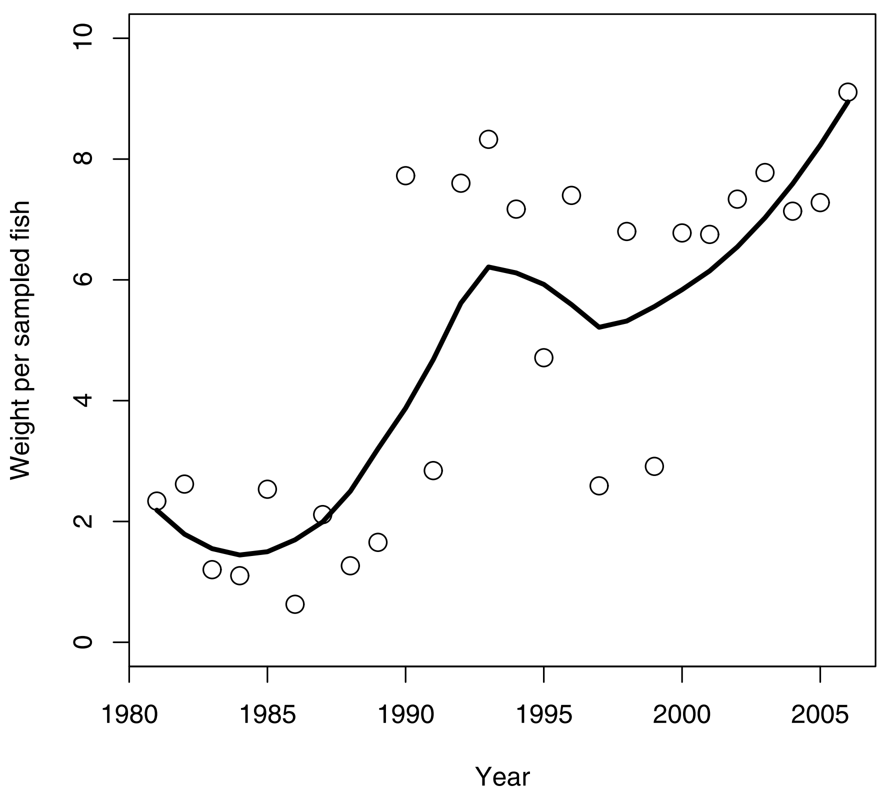


Figure 3.67. MRFSS landings in total weight using raw numbers of fish (solid line) and three year running averages of numbers of landed fish. Both approaches use smoothed annual estimates of mean fish weight.

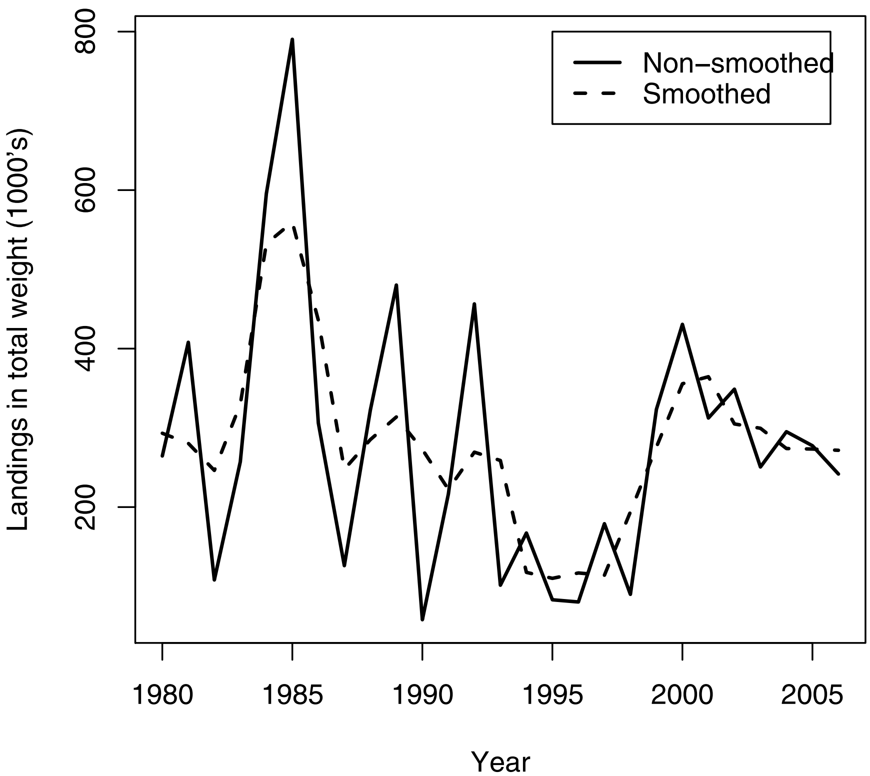


Figure 3.68. Assumptions about annual mean discard weight per fish, as used in fits of surplus production model.

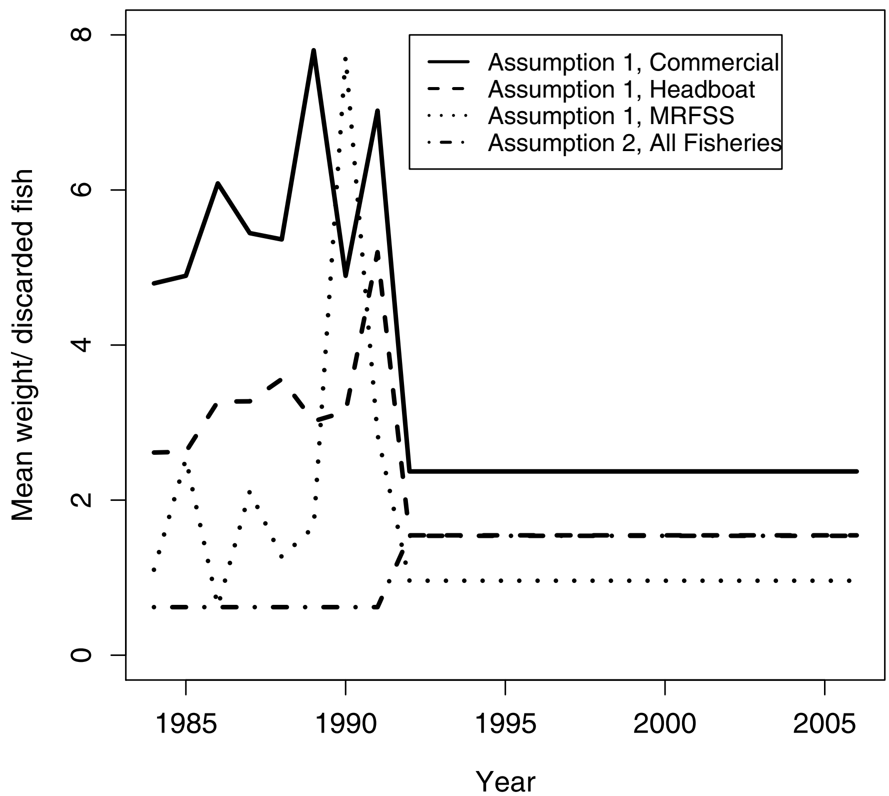


Figure 3.69. Surplus production model fit to headboat index: Observed (solid circles) and predicted CPUE (open squares)

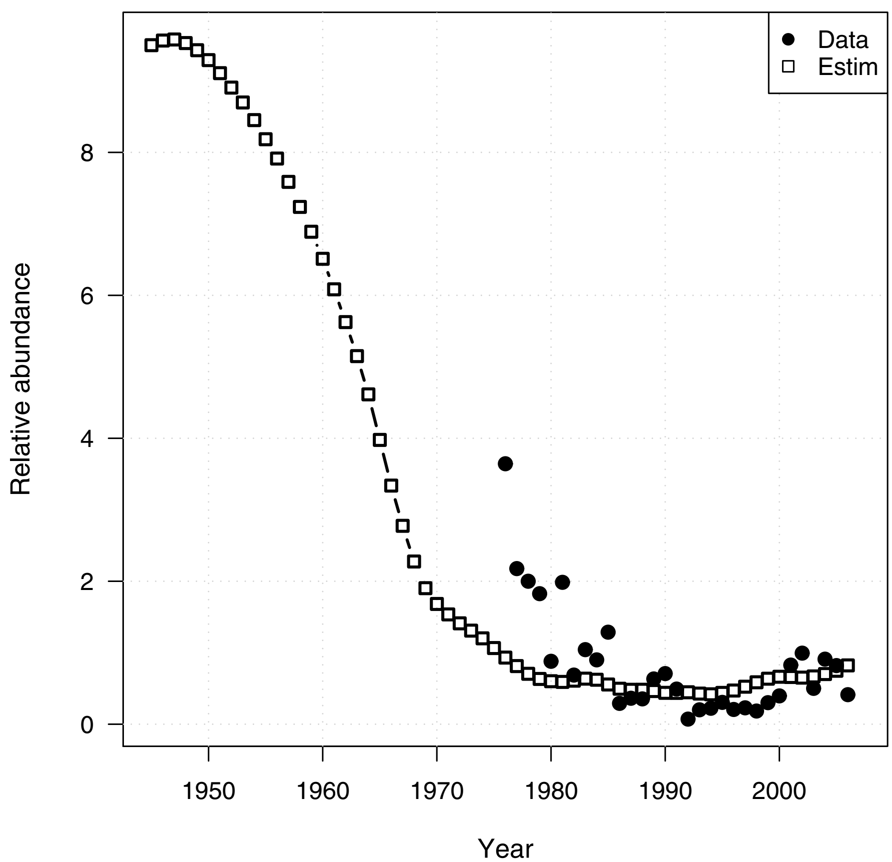


Figure 3.70. Surplus production model fit to commercial index: Observed (solid circles) and predicted CPUE (open squares)

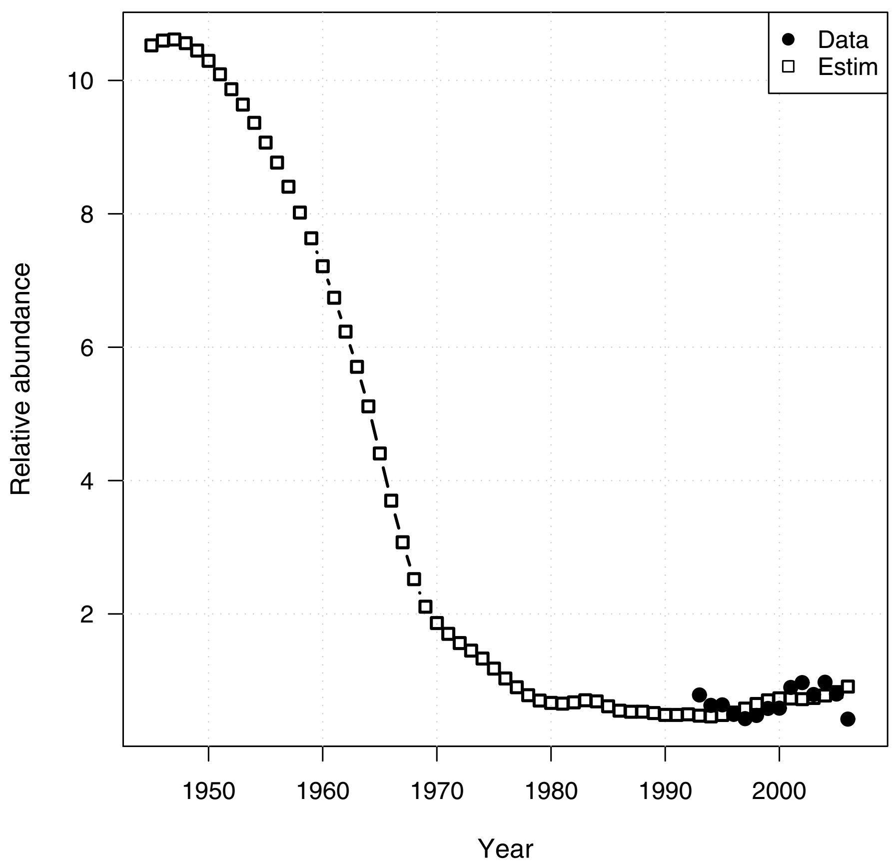


Figure 3.71. Surplus production model fit to MRFSS index: Observed (solid circles) and predicted CPUE (open squares)

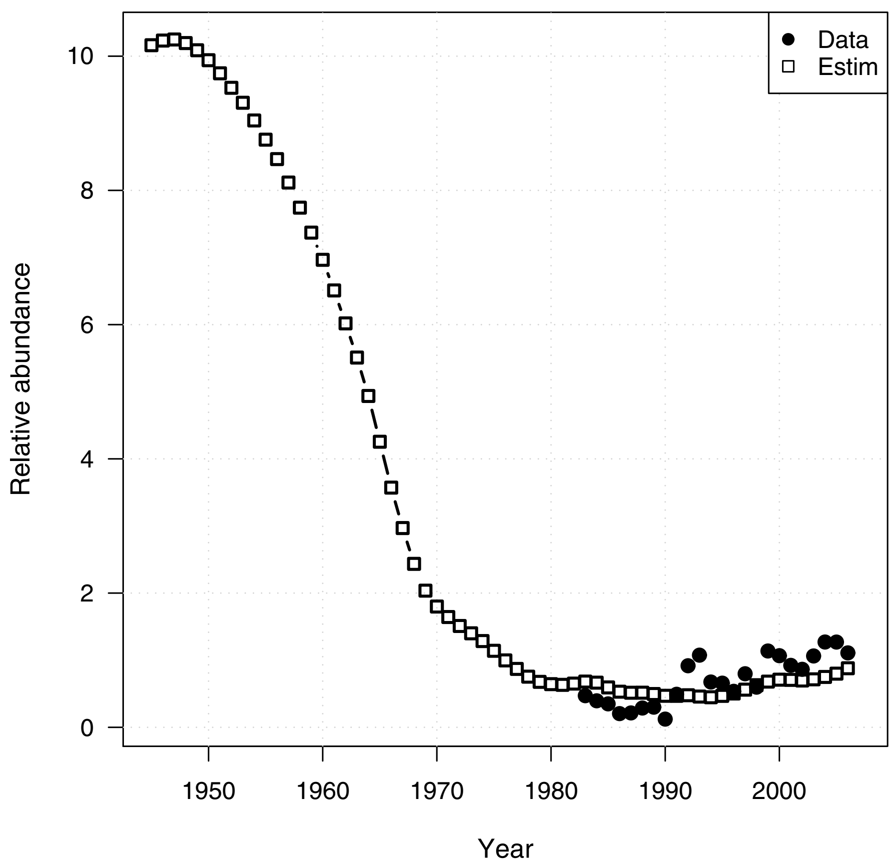
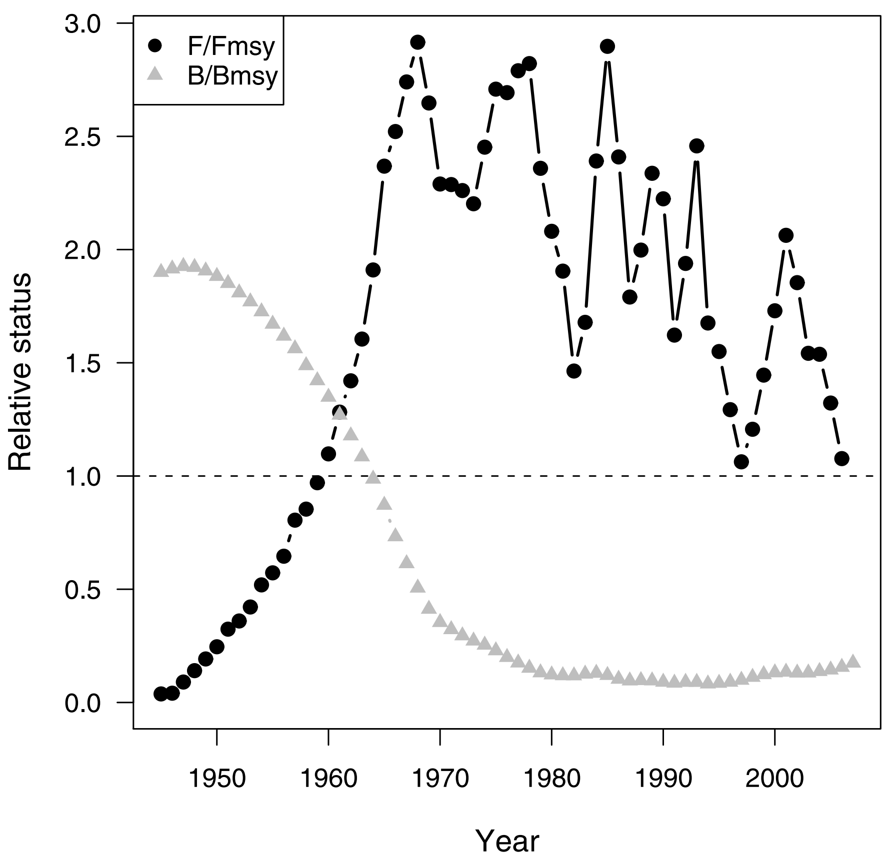


Figure 3.72. Surplus production model estimates of fishing mortality rate and biomass relative to their MSY *benchmarks.*



Appendix A Abbreviations and symbols

Table A.1. Acronyms, abbreviations, and mathematical symbols used in this report

Symbol	Meaning
AW	Assessment Workshop (here, for red 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 red snapper)
E	Exploitation rate; fraction of the biomass taken by fishing per year
E_{MSY}	Exploitation rate at which MSY can be attained
F	Instantaneous rate of fishing mortality
F_{MSY}	Fishing mortality rate at which MSY can be attained
FL	State of Florida
GA	State of Georgia
GLM	Generalized linear model
K	Average size of stock when not exploited by man; carrying capacity
kg	Kilogram(s); 1 kg is about 2.2 lb.
klb	Thousand pounds; thousands of pounds
lb	Pound(s); 1 lb is about 0.454 kg
m	Meter(s); 1 m is about 3.28 feet.
M	Instantaneous rate of natural (non-fishing) mortality
MARMAP	Marine Resources Monitoring, Assessment, and Prediction Program, a fishery-independent data collection program of SCDNR
MFMT	Maximum fishing-mortality threshold; a limit reference point used in U.S. fishery management; often based on F_{MSY}
mm	Millimeter(s); 1 inch = 25.4 mm
MRFSS	Marine Recreational Fisheries Statistics Survey, a data-collection program of NMFS
MSST	Minimum stock-size threshold; a limit reference point used in U.S. fishery management. The SAFMC has defined MSST for red snapper as $(1-M)\mathrm{SSB}_{\mathrm{MSY}} = 0.7\mathrm{SSB}_{\mathrm{MSY}}$.
MSY	Maximum sustainable yield (per year)
mt	Metric ton(s). One mt is 1000 kg, or about 2205 lb.
N	Number of fish in a stock, conventionally on January 1
NC	State of North Carolina
NMFS	National Marine Fisheries Service, same as “NOAA Fisheries Service”
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
OY	Optimum yield; SFA specifies that OY ≤ 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
SSB	Spawning stock biomass; mature biomass of males and females
$\mathrm{SSB}_{\mathrm{MSY}}$	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 model characterized by computations backward in time; may use abundance indices to influence the estimates
yr	Year(s)

Appendix B AD Model Builder implementation of catch-at-age assessment model

```
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##
//##  SEDAR15 Assessment: Red Snapper, October 2007
//##
//##  Kyle Shertzer, NMFS, Beaufort Lab
//##  Kyle.Shertzer@noaa.gov
//##
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>

DATA_SECTION
//Create ascii file for output
//!!CLASS ofstream report1("rsresults.rep",ios::out);  //create file for output

!!cout << "Starting Red Snapper Assessment Model" << endl;

// Starting and ending year of the model (year data starts)
init_int styr;
init_int endyr;

//Starting year to estimate recruitment deviation from S-R curve
init_int styr_rec_dev;

//3 periods: until ’91 no size regs, 1992-98 12inch TL, 1999-04 14inch TL
init_int endyr_period1;
init_int endyr_period2;


//Total number of ages
init_int nages;

// Vector of ages for age bins
init_ivector agebins(1,nages);

//number assessment years
//int styrR;
number nyrs;
number nyrs_rec;
//this section MUST BE INDENTED!!!
 LOCAL_CALCS
   nyrs=endyr-styr+1.;
   nyrs_rec=endyr-styr_rec_dev+1.;
 END_CALCS

//Total number of length bins for each matrix
init_int nlenbins;

// Vector of lengths for length bins (mm)(midpoint)
init_ivector lenbins(1,nlenbins);

//discard mortality constants
init_number set_Dmort_commHAL;
init_number set_Dmort_HB;
init_number set_Dmort_MRFSS;

//Total number of iterations for spr calcs
init_int n_iter_spr;
//Total number of iterations for msy calcs
init_int n_iter_msy;
//starting index of ages for exploitation rate: if model has age-0s, ages of E are (value-1) to oldest
init_int set_E_age_st;
//bias correction (set to 1.0 for no bias correction or 0.0 to compute from rec variance)
init_number set_BiasCor;
// Von Bert parameters
init_number set_Linf;
init_number set_K;
init_number set_t0;
```

```
//CV of length at age
init_number set_len_cv;

//length(mm)-weight(whole weigt in g) relationship: W=aL^b
init_number wgtpar_a;
init_number wgtpar_b;
//weight-weight relationship:whole weight to gutted weight -- gutted=a*whole
init_number wgtpar_whole2gutted

//Female maturity and proportion female at age
init_vector maturity_f_obs(1,nages);            //total maturity of females
init_vector prop_f_obs(1,nages);                //proportion female at age

//##############################################################################
//###################Commercial Hook and Line fishery ########################
//CPUE
init_int styr_HAL_cpue;
init_int endyr_HAL_cpue;
init_vector obs_HAL_cpue(styr_HAL_cpue,endyr_HAL_cpue);//Observed CPUE
init_vector HAL_cpue_cv(styr_HAL_cpue,endyr_HAL_cpue); //CV of cpue

// Landings - after WW II (1000 lb whole weight)
init_int styr_commHAL_L_2;
init_int endyr_commHAL_L_2;
init_vector obs_commHAL_L_2(styr_commHAL_L_2,endyr_commHAL_L_2); //vector of observed landings by year
init_vector commHAL_L_cv_2(styr_commHAL_L_2,endyr_commHAL_L_2);    //vector of CV of landings by year

// Discards (1000s)
init_int styr_commHAL_D;
init_int endyr_commHAL_D;
init_vector obs_commHAL_released(styr_commHAL_D,endyr_commHAL_D); //vector of observed releases by year, multiplied by discard mortalit
init_vector commHAL_D_cv(styr_commHAL_D,endyr_commHAL_D);    //vector of CV of discards by year

// Length Compositions (30mm bins)
init_int styr_commHAL_lenc;
init_int endyr_commHAL_lenc;
init_vector nsamp_commHAL_lenc(styr_commHAL_lenc,endyr_commHAL_lenc);
init_matrix obs_commHAL_lenc(styr_commHAL_lenc,endyr_commHAL_lenc,1,nlenbins);
// Age Compositions
init_int nyr_commHAL_agec;
init_ivector yrs_commHAL_agec(1,nyr_commHAL_agec);
init_vector nsamp_commHAL_agec(1,nyr_commHAL_agec);
init_matrix obs_commHAL_agec(1,nyr_commHAL_agec,1,nages);

//##############################################################################
//##############################Commercial Diving fishery ########################
// Landings (1000 lb whole weight)
init_int styr_commDV_L;
init_int endyr_commDV_L;
init_vector obs_commDV_L(styr_commDV_L,endyr_commDV_L);
init_vector commDV_L_cv(styr_commDV_L,endyr_commDV_L);    //vector of CV of landings by year
// Length Compositions (30mm bins)
init_int nyr_commDV_lenc;
init_ivector yrs_commDV_lenc(1,nyr_commDV_lenc);
init_vector nsamp_commDV_lenc(1,nyr_commDV_lenc);
init_matrix obs_commDV_lenc(1,nyr_commDV_lenc,1,nlenbins);
// Age Compositions
init_int nyr_commDV_agec;
init_ivector yrs_commDV_agec(1,nyr_commDV_agec);
init_vector nsamp_commDV_agec(1,nyr_commDV_agec);
init_matrix obs_commDV_agec(1,nyr_commDV_agec,1,nages);

//##############################################################################
//################################Headboat fishery ########################################
//CPUE
init_int styr_HB_cpue;
init_int endyr_HB_cpue;
init_vector obs_HB_cpue(styr_HB_cpue,endyr_HB_cpue);//Observed CPUE
init_vector HB_cpue_cv(styr_HB_cpue,endyr_HB_cpue); //CV of cpue
// Landings (1000 lb whole weight)
init_int styr_HB_L;
```

```
init_int endyr_HB_L;
init_vector obs_HB_L(styr_HB_L,endyr_HB_L);
init_vector HB_L_cv(styr_HB_L,endyr_HB_L);
// Discards (1000s)
init_int styr_HB_D;
init_int endyr_HB_D;
init_vector obs_HB_released(styr_HB_D,endyr_HB_D); //vector of observed releases by year, multiplied by discard mortality for fitting
init_vector HB_D_cv(styr_HB_D,endyr_HB_D);    //vector of CV of discards by year
// Length Compositions (10mm bins)
init_int styr_HB_lenc;
init_int endyr_HB_lenc;
init_vector nsamp_HB_lenc(styr_HB_lenc,endyr_HB_lenc);
init_matrix obs_HB_lenc(styr_HB_lenc,endyr_HB_lenc,1,nlenbins);
// Age compositions
init_int nyr_HB_agec;
init_ivector yrs_HB_agec(1,nyr_HB_agec);
init_vector nsamp_HB_agec(1,nyr_HB_agec);
init_matrix obs_HB_agec(1,nyr_HB_agec,1,nages);

//#############################################################################
//############################MRFSS landings #################################
//CPUE
init_int styr_MRFSS_cpue;
init_int endyr_MRFSS_cpue;
init_vector obs_MRFSS_cpue(styr_MRFSS_cpue,endyr_MRFSS_cpue);//Observed CPUE
init_vector MRFSS_cpue_cv(styr_MRFSS_cpue,endyr_MRFSS_cpue); //CV of cpue
// Landings (1000 lb whole weight)
init_int styr_MRFSS_L;
init_int endyr_MRFSS_L;
init_vector obs_MRFSS_L(styr_MRFSS_L,endyr_MRFSS_L);
init_vector MRFSS_L_cv(styr_MRFSS_L,endyr_MRFSS_L);
// Discards (1000s)
init_int styr_MRFSS_D;
init_int endyr_MRFSS_D;
init_vector obs_MRFSS_released(styr_MRFSS_D,endyr_MRFSS_D); //vector of observed releases by year, multiplied by discard mortality for
init_vector MRFSS_D_cv(styr_MRFSS_D,endyr_MRFSS_D);    //vector of CV of discards by year
// Length Compositions (30mm bins)
init_int nyr_MRFSS_lenc;
init_ivector yrs_MRFSS_lenc(1,nyr_MRFSS_lenc);
init_vector nsamp_MRFSS_lenc(1,nyr_MRFSS_lenc);
init_matrix obs_MRFSS_lenc(1,nyr_MRFSS_lenc,1,nlenbins);
// Age Compositions
init_int styr_MRFSS_agec;
init_int endyr_MRFSS_agec;
init_vector nsamp_MRFSS_agec(styr_MRFSS_agec,endyr_MRFSS_agec);
init_matrix obs_MRFSS_agec(styr_MRFSS_agec,endyr_MRFSS_agec,1,nages);

//#############################################################################
//##################Parameter values and initial guesses #################################
//--weights for likelihood components-------------------------------------------------------------------------------
init_number set_w_L;
init_number set_w_D;
init_number set_w_lc;
init_number set_w_ac;
init_number set_w_I_HAL;
init_number set_w_I_HB;
init_number set_w_I_MRFSS;
init_number set_w_R;
init_number set_w_R_init;
init_number set_w_R_end;
init_number set_w_F;
init_number set_w_B1dB0;         // weight on B1/B0
init_number set_w_fullF;         //penalty for any fullF>5
init_number set_w_cvlen_dev;         //penalty on cv deviations at age
init_number set_w_cvlen_diff;       //penalty on first difference of cv deviations at age

//Initial guess for commercial landings bias parameter
init_number set_L_early_bias;
//Initial guess for rate of increase on q
init_number set_q_rate;
//Initial guesses or fixed values
```

```
init_number set_steep;
//init_number set_M;
init_vector set_M(1,nages); //age-dependent: used in model
init_number set_M_constant; //age-independent: used only for MSST

//--index catchability------------------------------------------------------------------------------------------------------
init_number set_logq_HAL;     //catchability coefficient (log) for commercial logbook CPUE index
init_number set_logq_HB;      //catchability coefficient (log) for the headboat index
init_number set_logq_MRFSS;   //catchability coefficient (log) for MRFSS CPUE index

//--F's--------------------------------
init_number set_log_avg_F_commHAL_2;
init_number set_log_avg_F_commDV;
init_number set_log_avg_F_HB;
init_number set_log_avg_F_MRFSS;

//--discard F's-----------------------
init_number set_log_avg_F_commHAL_D;
init_number set_log_avg_F_HB_D;
init_number set_log_avg_F_MRFSS_D;

//Set some more initial guesses of estimated parameters
init_number set_log_R0;
init_number set_R1_mult;
init_number set_B1dB0;
init_number set_R_autocorr;

//Initial guesses of estimated selectivity parameters
init_number set_selpar_L50_commHAL1;
init_number set_selpar_slope_commHAL1;
init_number set_selpar_L502_commHAL1;
init_number set_selpar_slope2_commHAL1;
init_number set_selpar_L50_commHAL2;
init_number set_selpar_slope_commHAL2;
init_number set_selpar_L502_commHAL2;
init_number set_selpar_slope2_commHAL2;
init_number set_selpar_L50_commHAL3;
init_number set_selpar_slope_commHAL3;
init_number set_selpar_L502_commHAL3;
init_number set_selpar_slope2_commHAL3;

init_number set_selpar_L50_commDV1;
init_number set_selpar_L502_commDV1;
init_number set_selpar_slope_commDV1;
init_number set_selpar_slope2_commDV1;
//init_number set_selpar_L50_commDV2;
//init_number set_selpar_L502_commDV2;
//init_number set_selpar_slope_commDV2;
//init_number set_selpar_slope2_commDV2;

init_number set_selpar_L50_HB1;
init_number set_selpar_slope_HB1;
init_number set_selpar_L502_HB1;
init_number set_selpar_slope2_HB1;
init_number set_selpar_L50_HB2;
init_number set_selpar_slope_HB2;
init_number set_selpar_L502_HB2;
init_number set_selpar_slope2_HB2;
init_number set_selpar_L50_HB3;
init_number set_selpar_slope_HB3;
init_number set_selpar_L502_HB3;
init_number set_selpar_slope2_HB3;

init_number set_selpar_L50_MRFSS1;
init_number set_selpar_slope_MRFSS1;
init_number set_selpar_L502_MRFSS1;
init_number set_selpar_slope2_MRFSS1;
init_number set_selpar_L50_MRFSS2;
init_number set_selpar_slope_MRFSS2;
init_number set_selpar_L502_MRFSS2;
init_number set_selpar_slope2_MRFSS2;
```

```
init_number set_selpar_L50_MRFSS3;
init_number set_selpar_slope_MRFSS3;
init_number set_selpar_L502_MRFSS3;
init_number set_selpar_slope2_MRFSS3;

init_number set_selpar_commHAL_D_age1;
init_number set_selpar_HB_D_age1;
init_number set_selpar_MRFSS_D_age1;

// #######Indices for year(iyear), age(iage),length(ilen) ###############
int iyear;
int iage;
int ilen;
int E_age_st;   //starting age for exploitation rate: (value-1) to oldest

init_number end_of_data_file;
//this section MUST BE INDENTED!!!
 LOCAL_CALCS
   if(end_of_data_file!=999)
   {
     for(iyear=1; iyear<=100; iyear++)
     {
       cout << "*** WARNING: Data File NOT READ CORRECTLY ****" << endl;
       cout << "" <<endl;
     }
   }
   else
   {
    cout << "Data File read correctly" << endl;
   }
 END_CALCS


//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
PARAMETER_SECTION
//--------------Growth--------------------------------------------------------------------------

  //init_bounded_number Linf(600,1400,2);
  //init_bounded_number K(0.05,0.6,2);
  //init_bounded_number t0(-2.0,0.0,2);
  number Linf;
  number K;
  number t0;
  vector wgt_g(1,nages);        //whole wgt in g
  vector wgt_kg(1,nages);       //whole wgt in kg
  vector wgt(1,nages);          //whole wgt in mt
  vector wgt_klb(1,nages);      //whole wgt in 1000 lb
  vector meanlen(1,nages);        //mean length at age
  number sqrt2pi;
  number g2mt;                    //conversion of grams to metric tons
  number g2kg;                      //conversion of grams to kg
  number mt2klb;                  //conversion of metric tons to 1000 lb

  matrix lenprob(1,nages,1,nlenbins);           //distn of size at age (age-length key, 30 mm bins)
  init_bounded_number log_len_cv(-5,-0.3,3);
  //init_bounded_number log_len_cv(-4.6,-0.7,2) //cv expressed in log-space, bounds correspond to 0.01, 0.5
  //init_bounded_dev_vector log_len_cv_dev(1,nages,-2,2,3)
  vector len_cv(1,nages);

//----Predicted length and age compositions
  matrix pred_commHAL_lenc(styr_commHAL_lenc,endyr_commHAL_lenc,1,nlenbins);
  matrix pred_commDV_lenc(1,nyr_commDV_lenc,1,nlenbins);
  matrix pred_HB_lenc(styr_HB_lenc,endyr_HB_lenc,1,nlenbins);
  matrix pred_MRFSS_lenc(1,nyr_MRFSS_lenc,1,nlenbins);

  matrix pred_commHAL_agec(1,nyr_commHAL_agec,1,nages);
  matrix pred_commDV_agec(1,nyr_commDV_agec,1,nages);
  matrix pred_HB_agec(1,nyr_HB_agec,1,nages);
  matrix pred_MRFSS_agec(styr_MRFSS_agec,endyr_MRFSS_agec,1,nages);
```

```
  //nsamp_X_allyr vectors used only for R output of comps with nonconsecutive yrs
  vector nsamp_commDV_lenc_allyr(styr,endyr);
  vector nsamp_MRFSS_lenc_allyr(styr,endyr);
  vector nsamp_commHAL_agec_allyr(styr,endyr);
  vector nsamp_commDV_agec_allyr(styr,endyr);
  vector nsamp_HB_agec_allyr(styr,endyr);

//-----Population------------------------------------------------------------------------------------
  matrix N(styr,endyr+1,1,nages);           //Population numbers by year and age at start of yr
  matrix N_mdyr(styr,endyr,1,nages);        //Population numbers by year and age at mdpt of yr: used for comps and SSB
  matrix B(styr,endyr+1,1,nages);           //Population biomass by year and age
  vector totB(styr,endyr+1);                //Total biomass by year
  //init_bounded_number log_R1(5,20,1);       //log(Recruits) in styr
  sdreport_vector SSB(styr,endyr);       //Spawning biomass by year
  sdreport_vector rec(styr,endyr+1);       //Recruits by year
  vector prop_f(1,nages);                   //Proportion female by age
  vector maturity_f(1,nages);               //Proportion of female mature at age
  vector reprod(1,nages);

//---Stock-Recruit Function (Beverton-Holt, steepness parameterization)----------
  init_bounded_number log_R0(5,20,1);       //log(virgin Recruitment)
  sdreport_number R0;
  init_bounded_number steep(0.25,0.95,3);     //steepness
  //number steep;  //uncomment to fix steepness, comment line directly above
  init_bounded_dev_vector log_dev_N_rec(styr_rec_dev,endyr,-3,3,2); //log recruitment deviations
  vector log_dev_R(styr,endyr+1);           //used in output. equals zero except for yrs in log_dev_N_rec
  number var_rec_dev;                       //variance of log recruitment deviations.
                                              //Estimate from yrs with unconstrainted S-R(XXXX-XXXX)
  number BiasCor;                           //Bias correction in equilibrium recruits
  init_bounded_number R_autocorr(0,1.0,3);  //autocorrelation in SR
  //number R_autocorr
  sdreport_number R_autocorr_sd;
  sdreport_number steep_sd;                 //steepness for stdev report
  number S0;                                //equal to spr_F0*R0 = virgin SSB
  number B0;                                //equal to bpr_F0*R0 = virgin B
  number B1dB0;                             //B1dB0 computed and used in constraint
  //init_bounded_number R1_mult(0.05,1.0,1);   //R(styr)=R1_mult*R0
  number R1_mult;                           //equals B1dB0 under assumption of virgin age structure
  number R1;                                //Recruits in styr

  sdreport_number S1S0;                     //SSB(styr) / virgin SSB
  sdreport_number popstatus;                //SSB(endyr) / virgin SSB

//---Selectivity-------------------------------------------------------------------------

  //Commercial hook and line
  matrix sel_commHAL(styr,endyr,1,nages);
  //init_bounded_number selpar_slope_commHAL1(0.5,12.0,1); //period 1
  //init_bounded_number selpar_L50_commHAL1(0.1,10.,1);
  //init_bounded_number selpar_slope2_commHAL1(0.0,12.0,3); //period 1
  //init_bounded_number selpar_L502_commHAL1(1.0,15.0,3);
  number selpar_slope_commHAL1; //period 1 is assumed same as HB and MRFSS
  number selpar_L50_commHAL1;
  number selpar_slope2_commHAL1; //period 1
  number selpar_L502_commHAL1;
  init_bounded_number selpar_slope_commHAL2(0.5,12.0,1); //period 2
  init_bounded_number selpar_L50_commHAL2(0.1,10.,1);
  //init_bounded_number selpar_slope2_commHAL2(0.0,12.0,3); //period 2
  //init_bounded_number selpar_L502_commHAL2(1.0,15.0,3);
  number selpar_slope2_commHAL2; //period 2
  number selpar_L502_commHAL2;
  init_bounded_number selpar_slope_commHAL3(0.5,12.0,1); //period 3
  init_bounded_number selpar_L50_commHAL3(0.1,10.,1);
  //init_bounded_number selpar_slope2_commHAL3(0.0,12.0,3); //period 3
  //init_bounded_number selpar_L502_commHAL3(1.0,15.0,3);
  number selpar_slope2_commHAL3; //period 3
  number selpar_L502_commHAL3;
  //init_bounded_dev_vector selpar_L50_commHAL_dev(styr_commHAL_lenc,endyr_period1,-5,5,3);
  vector sel_commHAL_1(1,nages); //sel in period 1
  vector sel_commHAL_2(1,nages); //sel in period 2
  vector sel_commHAL_3(1,nages); //sel in period 3
```

```
//Commercial diving
matrix sel_commDV(styr,endyr,1,nages);           //time invariant
init_bounded_number selpar_slope_commDV1(0.5,12.0,1);
init_bounded_number selpar_L50_commDV1(0.1,10.,1);
init_bounded_number selpar_slope2_commDV1(0.1,12.0,3);
init_bounded_number selpar_L502_commDV1(1.0,20.0,3);
vector sel_commDV_vec(1,nages); //sel vector

//Headboat: logistic, parameters allowed to vary with period defined by size restrictions
matrix sel_HB(styr,endyr,1,nages);
init_bounded_number selpar_slope_HB1(0.5,12.0,1); //period 1
init_bounded_number selpar_L50_HB1(0.1,10.0,1);
//init_bounded_number selpar_slope2_HB1(0.1,12.0,3); //period 1
//init_bounded_number selpar_L502_HB1(1.0,20.0,3);
number selpar_slope2_HB1;
number selpar_L502_HB1;
number selpar_slope_HB2;//period 2
//init_bounded_number selpar_slope_HB2(0.5,12.0,1);
init_bounded_number selpar_L50_HB2(0.1,10.,1);
//init_bounded_number selpar_slope2_HB2(0.1,12.0,3); //period 2
//init_bounded_number selpar_L502_HB2(1.0,20.0,3);
number selpar_slope2_HB2;
number selpar_L502_HB2;
init_bounded_number selpar_slope_HB3(0.5,12.0,1); //period 3
init_bounded_number selpar_L50_HB3(0.1,10.,1);
//init_bounded_number selpar_slope2_HB3(0.1,12.0,3); //period 3
//init_bounded_number selpar_L502_HB3(1.0,20.0,3);
number selpar_slope2_HB3;
number selpar_L502_HB3;
//init_bounded_dev_vector selpar_L50_HB_dev(styr_HB_lenc,endyr_period1,-5,5,3);
vector sel_HB_1(1,nages); //sel in period 1
vector sel_HB_2(1,nages); //sel in period 2
vector sel_HB_3(1,nages); //sel in period 3


//MRFSS:
matrix sel_MRFSS(styr,endyr,1,nages);
//init_bounded_number selpar_slope_MRFSS1(0.5,9.0,1); //period 1
//init_bounded_number selpar_L50_MRFSS1(0.1,10.0,1);
//init_bounded_number selpar_slope2_MRFSS1(0.0,12.0,3); //period 1
//init_bounded_number selpar_L502_MRFSS1(1.0,15.0,3);
number selpar_slope_MRFSS1; //period 1 selectivity for MRFSS is same as HB
number selpar_L50_MRFSS1;
number selpar_slope2_MRFSS1;
number selpar_L502_MRFSS1;
number selpar_slope_MRFSS2; //period 2
//init_bounded_number selpar_slope_MRFSS2(0.5,12.0,1); //period 2
init_bounded_number selpar_L50_MRFSS2(0.1,10.,1);
//init_bounded_number selpar_slope2_MRFSS2(0.1,12.0,3); //period 2
//init_bounded_number selpar_L502_MRFSS2(1.0,20.0,3);
number selpar_slope2_MRFSS2;
number selpar_L502_MRFSS2;
init_bounded_number selpar_slope_MRFSS3(0.5,12.0,1); //period 3
init_bounded_number selpar_L50_MRFSS3(0.1,10.,1);
//init_bounded_number selpar_slope2_MRFSS3(0.1,12.0,3); //period 3
//init_bounded_number selpar_L502_MRFSS3(1.0,20.0,3);
number selpar_slope2_MRFSS3;
number selpar_L502_MRFSS3;
//init_bounded_dev_vector selpar_L50_MRFSS_dev(1981,endyr_period1,-5,5,3);
vector sel_MRFSS_2(1,nages); //sel in period 2; period 1 same as HB
vector sel_MRFSS_3(1,nages); //sel in period 3


//effort-weighted, recent selectivities
vector sel_wgted_L(1,nages);  //toward landings
vector sel_wgted_D(1,nages);  //toward discards
vector sel_wgted_tot(1,nages);//toward Z, landings plus deads discards
number max_sel_wgted_tot;
```

```
//-------CPUE Predictions--------------------------------
  vector pred_HAL_cpue(styr_HAL_cpue,endyr_HAL_cpue);          //predicted HAL U (pounds/hook-hour)
  matrix N_HAL(styr_HAL_cpue,endyr_HAL_cpue,1,nages);          //used to compute HAL index
  vector pred_HB_cpue(styr_HB_cpue,endyr_HB_cpue);             //predicted HB U (number/angler-day)
  matrix N_HB(styr_HB_cpue,endyr_HB_cpue,1,nages);             //used to compute HB index
  vector pred_MRFSS_cpue(styr_MRFSS_cpue,endyr_MRFSS_cpue);    //predicted MRFSS U (number/1000 hook-hours)
  matrix N_MRFSS(styr_MRFSS_cpue,endyr_MRFSS_cpue,1,nages);    //used to compute MRFSS index

//---Catchability (CPUE q's)----------------------------------------------------------
  init_bounded_number log_q_HAL(-20,-5,1);
  init_bounded_number log_q_HB(-20,-5,1);
  init_bounded_number log_q_MRFSS(-20,-5,1);
  //init_bounded_number q_rate(-0.1,0.1,-3);
  number q_rate;

//---Landings Bias--------------------------------------------------------------------
  //init_bounded_number L_early_bias(0.1,10.0,3);
  number L_early_bias;
  number L_commHAL_bias;
//---C is landings in (numbers), L is landings in wgt (mt)------------------------------------------------
  matrix C_commHAL(styr,endyr,1,nages);                //landings (numbers) at age
  matrix L_commHAL(styr,endyr,1,nages);                //landings (mt) at age
  matrix L_commHAL_klb(styr,endyr,1,nages);            //landings (1000 lb whole weight) at age
  vector pred_commHAL_L_2(styr_commHAL_L_2,endyr_commHAL_L_2); //post-WWII yearly landings summed over ages

  matrix C_commDV(styr,endyr,1,nages);                //landings (numbers) at age
  matrix L_commDV(styr,endyr,1,nages);                //landings (mt) at age
  matrix L_commDV_klb(styr,endyr,1,nages);            //landings (1000 lb whole weight) at age
  vector pred_commDV_L(styr_commDV_L,endyr_commDV_L);  //yearly landings (klb) summed over ages

  matrix C_HB(styr,endyr,1,nages);                    //landings (numbers) at age
  matrix L_HB(styr,endyr,1,nages);                    //landings (mt) at age
  matrix L_HB_klb(styr,endyr,1,nages);            //landings (1000 lb whole weight) at age
  vector pred_HB_L(styr_HB_L,endyr_HB_L);              //yearly landings (klb) summed over ages

  matrix C_MRFSS(styr,endyr,1,nages);                 //landings (numbers) at age
  matrix L_MRFSS(styr,endyr,1,nages);                 //landings (mt) at age
  matrix L_MRFSS_klb(styr,endyr,1,nages);             //landings (1000 lb whole weight) at age
  vector pred_MRFSS_L(styr_MRFSS_L,endyr_MRFSS_L);     //yearly landings (klb) summed over ages

  matrix C_total(styr,endyr,1,nages);                 //catch in number
  matrix L_total(styr,endyr,1,nages);                 //landings in mt
  vector L_total_yr(styr,endyr);                      //total landings (mt) by yr summed over ages

//---Discards (number dead fish) ----------------------------------------------------
  matrix C_commHAL_D(styr_commHAL_D,endyr_commHAL_D,1,nages);//discards (numbers) at age
  vector pred_commHAL_D(styr_commHAL_D,endyr_commHAL_D);     //yearly discards summed over ages
  vector obs_commHAL_D(styr_commHAL_D,endyr_commHAL_D);      //observed releases multiplied by discard mortality
  matrix early_C_commHAL_D(styr,styr_commHAL_D-1,1,nages);//discards (numbers) at age pre-data
  vector early_pred_commHAL_D(styr,styr_commHAL_D-1);     //yearly discards summed over ages pre-data


  matrix C_HB_D(styr_HB_D,endyr_HB_D,1,nages);           //discards (numbers) at age
  vector pred_HB_D(styr_HB_D,endyr_HB_D);                //yearly discards summed over ages
  vector obs_HB_D(styr_HB_D,endyr_HB_D);                 //observed releases multiplied by discard mortality
  matrix early_C_HB_D(styr,styr_HB_D-1,1,nages);//discards (numbers) at age pre-data
  vector early_pred_HB_D(styr,styr_HB_D-1);     //yearly discards summed over ages pre-data

  matrix C_MRFSS_D(styr_HB_D,endyr_MRFSS_D,1,nages);     //discards (numbers) at age
  vector pred_MRFSS_D(styr_MRFSS_D,endyr_MRFSS_D);          //yearly discards summed over ages
  vector obs_MRFSS_D(styr_MRFSS_D,endyr_MRFSS_D);        //observed releases multiplied by discard mortality
  matrix early_C_MRFSS_D(styr,styr_MRFSS_D-1,1,nages);//discards (numbers) at age pre-data
  vector early_pred_MRFSS_D(styr,styr_MRFSS_D-1);     //yearly discards summed over ages pre-data


//---MSY calcs-------------------------------------------------------------------------

  number F_commHAL_prop;  //proportion of F_full attributable to hal, last three yrs
  number F_commDV_prop;   //proportion of F_full attributable to diving, last three yrs
  number F_HB_prop;       //proportion of F_full attributable to headboat, last three yrs
  number F_MRFSS_prop;    //proportion of F_full attributable to MRFSS, last three yrs
```

```
  number F_commHAL_D_prop;//proportion of F_full attributable to hal discards, last three yrs
  number F_HB_D_prop;     //proportion of F_full attributable to headboat discards, last three yrs
  number F_MRFSS_D_prop;  //proportion of F_full attributable to MRFSS discards, last three yrs
  number F_temp_sum;      //sum of geom mean full Fs in last yrs, used to compute F_fishery_prop

  number SSB_msy_out;           //SSB at msy
  number F_msy_out;             //F at msy
  number msy_out;               //max sustainable yield
  number B_msy_out;             //total biomass at MSY
  number E_msy_out;             //exploitation rate at MSY (ages E_age_st plus)
  number R_msy_out;             //equilibrium recruitment at F=Fmsy
  number D_msy_out;             //equilibrium dead discards at F=Fmsy
  number spr_msy_out;           //spr at F=Fmsy

  vector N_age_msy(1,nages);         //numbers at age for MSY calculations: beginning of yr
  vector N_age_msy_mdyr(1,nages);    //numbers at age for MSY calculations: mdpt of yr
  vector C_age_msy(1,nages);         //catch at age for MSY calculations
  vector Z_age_msy(1,nages);         //total mortality at age for MSY calculations
  vector D_age_msy(1,nages);         //discard mortality (dead discards) at age for MSY calculations
  vector F_L_age_msy(1,nages);       //fishing mortality (landings, not discards) at age for MSY calculations
  vector F_D_age_msy(1,nages);
  vector F_msy(1,n_iter_msy);        //values of full F to be used in per-recruit and equilibrium calculations
  vector spr_msy(1,n_iter_msy);      //reproductive capacity-per-recruit values corresponding to F values in F_msy
  vector R_eq(1,n_iter_msy);     //equilibrium recruitment values corresponding to F values in F_msy
  vector L_eq(1,n_iter_msy);     //equilibrium landings(mt) values corresponding to F values in F_msy
  vector SSB_eq(1,n_iter_msy);   //equilibrium reproductive capacity values corresponding to F values in F_msy
  vector B_eq(1,n_iter_msy);     //equilibrium biomass values corresponding to F values in F_msy
  vector E_eq(1,n_iter_msy);     //equilibrium exploitation rates corresponding to F values in F_msy
  vector D_eq(1,n_iter_msy);     //equilibrium discards (1000s) corresponding to F values in F_msy

  vector FdF_msy(styr,endyr);
  vector EdE_msy(styr,endyr);
  vector SdSSB_msy(styr,endyr);
  number SdSSB_msy_end;
  number FdF_msy_end;
  number EdE_msy_end;

//--------Mortality------------------------------------------------------------------
  vector M(1,nages);                            //age-dependent natural mortality
  number M_constant;                            //age-indpendent: used only for MSST
  matrix F(styr,endyr,1,nages);
  vector fullF(styr,endyr);                      //Fishing mortality rate by year
  vector E(styr,endyr);                          //Exploitation rate by year
  sdreport_vector fullF_sd(styr,endyr);
  sdreport_vector E_sd(styr,endyr);
  matrix Z(styr,endyr,1,nages);

  init_bounded_number log_avg_F_commHAL_2(-10,0,1); //post-WW2
  init_bounded_dev_vector log_F_dev_commHAL_2(styr_commHAL_L_2,endyr_commHAL_L_2,-10,5,1);
  matrix F_commHAL(styr,endyr,1,nages);
  vector F_commHAL_out(styr,endyr_commHAL_L_2); //used for intermediate calculations in fcn get_mortality
  //number log_F_init_commHAL;

  init_bounded_number log_avg_F_commDV(-10,0,1);
  init_bounded_dev_vector log_F_dev_commDV(styr_commDV_L,endyr_commDV_L,-10,5,2);
  matrix F_commDV(styr,endyr,1,nages);
  vector F_commDV_out(styr,endyr_commDV_L); //used for intermediate calculations in fcn get_mortality
  //number log_F_init_commDV;

  init_bounded_number log_avg_F_HB(-10,0,1);
  init_bounded_dev_vector log_F_dev_HB(styr_HB_L,endyr_HB_L,-10,5,2);
  matrix F_HB(styr,endyr,1,nages);
  vector F_HB_out(styr,endyr_HB_L);        //used for intermediate calculations in fcn get_mortality
  //number log_F_init_HB;

  init_bounded_number log_avg_F_MRFSS(-10,0,1);
  init_bounded_dev_vector log_F_dev_MRFSS(styr_MRFSS_L,endyr_MRFSS_L,-10,5,2);
  matrix F_MRFSS(styr,endyr,1,nages);
  vector F_MRFSS_out(styr,endyr_MRFSS_L); //used for intermediate calculations in fcn get_mortality
  //number log_F_init_MRFSS;
```

```
//--Discard mortality stuff------------------------------------------------------------------------------
  init_bounded_number log_avg_F_commHAL_D(-10,0,1);
  init_bounded_dev_vector log_F_dev_commHAL_D(styr_commHAL_D,endyr_commHAL_D,-10,5,2);
  matrix F_commHAL_D(styr,endyr,1,nages);
  vector F_commHAL_D_out(styr,endyr); //used for intermediate calculations in fcn get_mortality
  number F_commHAL_D_ratio;  //ratio of average discard F to fishery F, for projection discards back before data
  matrix sel_commHAL_D(styr,endyr,1,nages);
  vector sel_commHAL_D_dum(1,nages); //logistic version of sel for computing discard sel
  number selpar_commHAL_D_age1;      //discard selectivity of age

  init_bounded_number log_avg_F_HB_D(-10,0,1);
  init_bounded_dev_vector log_F_dev_HB_D(styr_HB_D,endyr_HB_D,-10,5,2);
  matrix F_HB_D(styr,endyr,1,nages);
  vector F_HB_D_out(styr,endyr); //used for intermediate calculations in fcn get_mortality
  number F_HB_D_ratio;  //ratio of average discard F to fishery F, for projection discards back before data
  matrix sel_HB_D(styr,endyr,1,nages);
  vector sel_HB_D_dum(1,nages); //logistic version of sel for computing discard sel
  number selpar_HB_D_age1;      //discard selectivity of age 1

  init_bounded_number log_avg_F_MRFSS_D(-10,0,1);
  init_bounded_dev_vector log_F_dev_MRFSS_D(styr_MRFSS_D,endyr_MRFSS_D,-10,5,2);
  matrix F_MRFSS_D(styr,endyr,1,nages);
  vector F_MRFSS_D_out(styr,endyr); //used for intermediate calculations in fcn get_mortality
  number F_MRFSS_D_ratio;  //ratio of average discard F to fishery F, for projection discards back before data
  matrix sel_MRFSS_D(styr,endyr,1,nages);
  vector sel_MRFSS_D_dum(1,nages); //logistic version of sel for computing discard sel
  number selpar_MRFSS_D_age1;      //discard selectivity of age 1

  number selpar_L50_D_2; //age at 50% discard sel assumed equal to age at size limit (12in=304.8mm)
  number selpar_L50_D_3; //age at 50% discard sel assumed equal to age at size limit (20in=508mm)


  number Dmort_commHAL;
  number Dmort_HB;
  number Dmort_MRFSS;

////---Per-recruit stuff---------------------------------------------------------------------------------
  vector N_age_spr(1,nages);         //numbers at age for SPR calculations: beginning of year
  vector N_age_spr_mdyr(1,nages);    //numbers at age for SPR calculations: midyear
  vector C_age_spr(1,nages);         //catch at age for SPR calculations
  vector Z_age_spr(1,nages);         //total mortality at age for SPR calculations
  vector spr_static(styr,endyr);    //vector of static SPR values by year
  vector F_L_age_spr(1,nages);       //fishing mortality (landings, not discards) at age for SPR calculations
  vector F_spr(1,n_iter_spr);        //values of full F to be used in per-recruit and equilibrium calculations
  vector spr_spr(1,n_iter_spr);      //reporductive capacity-per-recruit values corresponding to F values in F_spr
  vector L_spr(1,n_iter_spr);        //landings(mt)-per-recruit values corresponding to F values in F_spr
  vector E_spr(1,n_iter_spr);        //exploitation rate values corresponding to F values in F_spr

  vector N_spr_F0(1,nages);          //Used to compute spr at F=0: midpt of year
  vector N_bpr_F0(1,nages);          //Used to compute bpr at F=0: start of year
  number spr_F0;                     //Spawning biomass per recruit at F=0
  number bpr_F0;                     //Biomass per recruit at F=0

//-------Objective function components-----------------------------------------------------------------------
  number w_L;
  number w_D;
  number w_lc;
  number w_ac;
  number w_I_HAL;
  number w_I_HB;
  number w_I_MRFSS;
  number w_R;
  number w_R_init;
  number w_R_end;
  number w_F;
  number w_B1dB0;
  number w_fullF;
  number w_cvlen_dev;
  number w_cvlen_diff;

  number f_HAL_cpue;
```

```
  number f_HB_cpue;
  number f_MRFSS_cpue;

  number f_commHAL_L_2;
  number f_commDV_L;
  number f_HB_L;
  number f_MRFSS_L;

  number f_commHAL_D;
  number f_HB_D;
  number f_MRFSS_D;

  number f_commHAL_lenc;
  number f_commDV_lenc;
  number f_HB_lenc;
  number f_MRFSS_lenc;

  number f_commHAL_agec;
  number f_commDV_agec;
  number f_HB_agec;
  number f_MRFSS_agec;

  number f_N_dev;               //weight on recruitment deviations to fit S-R curve
  number f_N_dev_early;         //extra weight against deviations before styr
  number f_N_dev_end;         //extra constraint on last 3 years of recruitment variability
  number f_Fend_constraint;     //penalty for F deviation in last 5 years
  number f_B1dB0_constraint;    //penalty to fix B(styr)/K
  number f_fullF_constraint;    //penalty for fullF>5
  number f_cvlen_dev_constraint; //deviation penalty on cv's of length at age
  number f_cvlen_diff_constraint;//first diff penalty on cv's of length at age

  objective_function_value fval;
  number fval_unwgt;


//--Dummy arrays for output convenience  --------------------------
  vector xdum(styr,endyr);
  vector xdum2(styr,endyr+1);
//--Other dummy variables ----
  number sel_diff_dum;
  number zero_dum;
  number dzero_dum;

  //init_number x_dum; //used only during model development. can be removed.

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
INITIALIZATION_SECTION


//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
GLOBALS_SECTION
  #include "admodel.h"          // Include AD class definitions
  #include "admb2r.cpp"    // Include S-compatible output functions (needs preceding)

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
RUNTIME_SECTION
 maximum_function_evaluations 500, 2000, 10000;
 convergence_criteria 1e-1, 1e-2, 1e-4;

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
PRELIMINARY_CALCS_SECTION

// Set values of fixed parameters or set initial guess of estimated parameters
  Dmort_commHAL=set_Dmort_commHAL;
  Dmort_HB=set_Dmort_HB;
  Dmort_MRFSS=set_Dmort_MRFSS;

  obs_commHAL_D=Dmort_commHAL*obs_commHAL_released;
```

```
obs_HB_D=Dmort_HB*obs_HB_released;
obs_MRFSS_D=Dmort_MRFSS*obs_MRFSS_released;

E_age_st=set_E_age_st;   //E computed over ages E_age_st +   [E_age_st-1+ if model starts with age 0]

Linf=set_Linf;
K=set_K;
t0=set_t0;

selpar_L50_D_2=t0-log(1.0-304.8/Linf)/K; //age at size limit: 304.8 = limit in mm
selpar_L50_D_3=t0-log(1.0-508./Linf)/K;  //age at size limit: 508 = limit in mm

M=set_M;
M_constant=set_M_constant;
steep=set_steep;
log_dev_N_rec=0.0;
R_autocorr=set_R_autocorr;

log_q_HAL=set_logq_HAL;
log_q_HB=set_logq_HB;
log_q_MRFSS=set_logq_MRFSS;
q_rate=set_q_rate;

L_early_bias=set_L_early_bias;
L_commHAL_bias=1.0;

w_L=set_w_L;
w_D=set_w_D;
w_lc=set_w_lc;
w_ac=set_w_ac;
w_I_HAL=set_w_I_HAL;
w_I_HB=set_w_I_HB;
w_I_MRFSS=set_w_I_MRFSS;
w_R=set_w_R;
w_R_init=set_w_R_init;
w_R_end=set_w_R_end;
w_F=set_w_F;
w_B1dB0=set_w_B1dB0;
w_fullF=set_w_fullF;
w_cvlen_dev=set_w_cvlen_dev;
w_cvlen_diff=set_w_cvlen_diff;

log_avg_F_commHAL_2=set_log_avg_F_commHAL_2;
log_avg_F_commDV=set_log_avg_F_commDV;
log_avg_F_HB=set_log_avg_F_HB;
log_avg_F_MRFSS=set_log_avg_F_MRFSS;

log_avg_F_commHAL_D=set_log_avg_F_commHAL_D;
log_avg_F_HB_D=set_log_avg_F_HB_D;
log_avg_F_MRFSS_D=set_log_avg_F_MRFSS_D;

log_len_cv=log(set_len_cv);
log_R0=set_log_R0;
R1_mult=set_R1_mult;
B1dB0=set_B1dB0;

selpar_L50_commHAL1=set_selpar_L50_commHAL1;
selpar_slope_commHAL1=set_selpar_slope_commHAL1;
selpar_L502_commHAL1=set_selpar_L502_commHAL1;
selpar_slope2_commHAL1=set_selpar_slope2_commHAL1;
selpar_L50_commHAL2=set_selpar_L50_commHAL2;
selpar_slope_commHAL2=set_selpar_slope_commHAL2;
selpar_L502_commHAL2=set_selpar_L502_commHAL2;
selpar_slope2_commHAL2=set_selpar_slope2_commHAL2;
selpar_L50_commHAL3=set_selpar_L50_commHAL3;
selpar_slope_commHAL3=set_selpar_slope_commHAL3;
selpar_L502_commHAL3=set_selpar_L502_commHAL3;
selpar_slope2_commHAL3=set_selpar_slope2_commHAL3;

selpar_L50_commDV1=set_selpar_L50_commDV1;
selpar_L502_commDV1=set_selpar_L502_commDV1;
```

```
  selpar_slope_commDV1=set_selpar_slope_commDV1;
  selpar_slope2_commDV1=set_selpar_slope2_commDV1;
  //selpar_L50_commDV2=set_selpar_L50_commDV2;
  //selpar_L502_commDV2=set_selpar_L502_commDV2;
  //selpar_slope_commDV2=set_selpar_slope_commDV2;
  //selpar_slope2_commDV2=set_selpar_slope2_commDV2;

  selpar_L50_HB1=set_selpar_L50_HB1;
  selpar_slope_HB1=set_selpar_slope_HB1;
  selpar_L502_HB1=set_selpar_L502_HB1;
  selpar_slope2_HB1=set_selpar_slope2_HB1;
  selpar_L50_HB2=set_selpar_L50_HB2;
  selpar_slope_HB2=set_selpar_slope_HB2;
  selpar_L502_HB2=set_selpar_L502_HB2;
  selpar_slope2_HB2=set_selpar_slope2_HB2;
  selpar_L50_HB3=set_selpar_L50_HB3;
  selpar_slope_HB3=set_selpar_slope_HB3;
  selpar_L502_HB3=set_selpar_L502_HB3;
  selpar_slope2_HB3=set_selpar_slope2_HB3;

  selpar_L50_MRFSS1=set_selpar_L50_MRFSS1;
  selpar_slope_MRFSS1=set_selpar_slope_MRFSS1;
  selpar_L502_MRFSS1=set_selpar_L502_MRFSS1;
  selpar_slope2_MRFSS1=set_selpar_slope2_MRFSS1;
  selpar_L50_MRFSS2=set_selpar_L50_MRFSS2;
  selpar_slope_MRFSS2=set_selpar_slope_MRFSS2;
  selpar_L502_MRFSS2=set_selpar_L502_MRFSS2;
  selpar_slope2_MRFSS2=set_selpar_slope2_MRFSS2;
  selpar_L50_MRFSS3=set_selpar_L50_MRFSS3;
  selpar_slope_MRFSS3=set_selpar_slope_MRFSS3;
  selpar_L502_MRFSS3=set_selpar_L502_MRFSS3;
  selpar_slope2_MRFSS3=set_selpar_slope2_MRFSS3;

  selpar_commHAL_D_age1=set_selpar_commHAL_D_age1;
  selpar_HB_D_age1=set_selpar_HB_D_age1;
  selpar_MRFSS_D_age1=set_selpar_MRFSS_D_age1;

 sqrt2pi=sqrt(2.*3.14159265);
 g2mt=0.000001;         //conversion of grams to metric tons
 g2kg=0.001;         //conversion of grams to kg
 mt2klb=2.20462;        //converstion of metric tons to 1000 lb
 //df=0.001; //difference for msy derivative approximations
 zero_dum=0.0;

 //additive constant to prevent division by zero
 dzero_dum=0.00001;

 SSB_msy_out=0.0;

 maturity_f=maturity_f_obs;
 prop_f=prop_f_obs;

////Fill in maturity matrix for calculations for styr to styr
//    for(iyear=styr; iyear<=styr-1; iyear++)
//      {
//         maturity_f(iyear)=maturity_f_obs;
//         maturity_m(iyear)=maturity_m_obs;
//         prop_m(iyear)=prop_m_obs(styr);
//         prop_f(iyear)=1.0-prop_m_obs(styr);
//      }
//    for (iyear=styr;iyear<=endyr;iyear++)
//      {
//         maturity_f(iyear)=maturity_f_obs;
//         maturity_m(iyear)=maturity_m_obs;
//         prop_m(iyear)=prop_m_obs(iyear);
//         prop_f(iyear)=1.0-prop_m_obs(iyear);
//      }

//Fill in sample sizes of comps sampled in nonconsec yrs.
//Used only for output in R object
     nsamp_commDV_lenc_allyr=missing; //"missing" defined in admb2r.cpp
```

```
      nsamp_MRFSS_lenc_allyr=missing;
      nsamp_commHAL_agec_allyr=missing;
      nsamp_commDV_agec_allyr=missing;
      nsamp_HB_agec_allyr=missing;
      for (iyear=1; iyear<=nyr_commDV_lenc; iyear++)
         {
          nsamp_commDV_lenc_allyr(yrs_commDV_lenc(iyear))=nsamp_commDV_lenc(iyear);
         }
      for (iyear=1; iyear<=nyr_MRFSS_lenc; iyear++)
         {
          nsamp_MRFSS_lenc_allyr(yrs_MRFSS_lenc(iyear))=nsamp_MRFSS_lenc(iyear);
         }
      for (iyear=1; iyear<=nyr_commHAL_agec; iyear++)
         {
          nsamp_commHAL_agec_allyr(yrs_commHAL_agec(iyear))=nsamp_commHAL_agec(iyear);
         }
      for (iyear=1; iyear<=nyr_commDV_agec; iyear++)
         {
          nsamp_commDV_agec_allyr(yrs_commDV_agec(iyear))=nsamp_commDV_agec(iyear);
         }
      for (iyear=1; iyear<=nyr_HB_agec; iyear++)
         {
          nsamp_HB_agec_allyr(yrs_HB_agec(iyear))=nsamp_HB_agec(iyear);
         }



//fill in F's, Catch matrices, and log rec dev with zero's
  F_commHAL.initialize();
  C_commHAL.initialize();
  F_commDV.initialize();
  C_commDV.initialize();
  F_HB.initialize();
  C_HB.initialize();
  F_MRFSS.initialize();
  C_MRFSS.initialize();

  F_commHAL_D.initialize();
  F_HB_D.initialize();
  F_MRFSS_D.initialize();

  sel_commHAL_D.initialize();
  sel_HB_D.initialize();
  sel_MRFSS_D.initialize();

  log_dev_R.initialize();

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
TOP_OF_MAIN_SECTION
  arrmblsize=20000000;
  gradient_structure::set_MAX_NVAR_OFFSET(1600);
  gradient_structure::set_GRADSTACK_BUFFER_SIZE(2000000);
  gradient_structure::set_CMPDIF_BUFFER_SIZE(2000000);
  gradient_structure::set_NUM_DEPENDENT_VARIABLES(500);


//>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
PROCEDURE_SECTION

 R0=mfexp(log_R0);

 //cout<<"start"<<endl;
 get_length_and_weight_at_age();
 //cout << "got length and weight transitions" <<endl;
 get_reprod();
 get_length_at_age_dist();
 //cout<< "got predicted length at age distribution"<<endl;
 get_spr_F0();
 //cout << "got F0 spr" << endl;
```

```
 get_selectivity();
 //cout << "got selectivity" << endl;
 get_mortality();
 //cout << "got mortalities" << endl;
 get_bias_corr();
 //cout<< "got recruitment bias correction" << endl;
 get_numbers_at_age();
 //cout << "got numbers at age" << endl;
 get_landings_numbers();
 //cout << "got catch at age" << endl;
 get_landings_wgt();
 //cout << "got landings" << endl;
 get_dead_discards();
 //cout << "got discards" << endl;
 get_indices();
 //cout << "got indices" << endl;
 get_length_comps();
 //cout<< "got length comps"<< endl;
 get_age_comps();
 //cout<< "got age comps"<< endl;

 evaluate_objective_function();
 //cout << "objective function calculations complete" << endl;

FUNCTION get_length_and_weight_at_age
  //compute mean length (mm) and weight (whole and gutted) at age
    meanlen=Linf*(1.0-mfexp(-K*(agebins-t0)));   //length in mm
    wgt_g=wgtpar_a*pow(meanlen,wgtpar_b);        //wgt in grams
    wgt_kg=g2kg*wgt_g;                           //wgt in grams
    wgt=g2mt*wgt_g;     //mt of whole wgt: g2mt converts g to mt
    wgt_klb=mt2klb*wgt;                          //1000 lb of whole wgt


FUNCTION get_reprod

   //product of stuff going into reproductive capacity calcs
   reprod=elem_prod(elem_prod(prop_f,maturity_f),wgt);

FUNCTION get_length_at_age_dist
  //compute matrix of length at age, based on the normal distribution
  for (iage=1;iage<=nages;iage++)
  {
    //len_cv(iage)=mfexp(log_len_cv+log_len_cv_dev(iage));
    len_cv(iage)=mfexp(log_len_cv);
    for (ilen=1;ilen<=nlenbins;ilen++)
    {
      lenprob(iage,ilen)=(mfexp(-(square(lenbins(ilen)-meanlen(iage))/
      (2.*square(len_cv(iage)*meanlen(iage)))))/(sqrt2pi*len_cv(iage)*meanlen(iage)));
    }
    lenprob(iage)/=sum(lenprob(iage)); //standardize to account for truncated normal (i.e., no sizes<0)

  }

FUNCTION get_spr_F0
  //at mdyr, apply half this yr's mortality, half next yr's
  N_spr_F0(1)=1.0*mfexp(-1.0*M(1)/2.0);//at start of yr
  N_bpr_F0(1)=1.0;
  for (iage=2; iage<=nages; iage++)
  {
    //N_spr_F0(iage)=N_spr_F0(iage-1)*mfexp(-1.0*(M(iage-1));
    N_spr_F0(iage)=N_spr_F0(iage-1)*mfexp(-1.0*(M(iage-1)/2.0 + M(iage)/2.0));
    N_bpr_F0(iage)=N_bpr_F0(iage-1)*mfexp(-1.0*(M(iage-1)));
  }
  N_spr_F0(nages)=N_spr_F0(nages)/(1.0-mfexp(-1.0*M(nages))); //plus group (sum of geometric series)
  N_bpr_F0(nages)=N_bpr_F0(nages)/(1.0-mfexp(-1.0*M(nages)));

  spr_F0=sum(elem_prod(N_spr_F0,reprod));
  bpr_F0=sum(elem_prod(N_bpr_F0,wgt));


FUNCTION get_selectivity
```

```
// ------- compute landings selectivities by period
  selpar_L50_commHAL1=selpar_L50_HB1;
  selpar_slope_commHAL1=selpar_slope_HB1;

  for (iage=1; iage<=nages; iage++)
  {
     //sel_commHAL_1(iage)=1./(1.+mfexp(-1.*selpar_slope_commHAL1*(double(agebins(iage))-selpar_L50_commHAL1))); //logistic
     sel_commHAL_1(iage)=(1./(1.+mfexp(-1.*selpar_slope_commHAL1*(double(agebins(iage))-
                        selpar_L50_commHAL1))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_commHAL1*
                        (double(agebins(iage))-(selpar_L50_commHAL1+selpar_L502_commHAL1)))))); //double logistic

     //sel_commHAL_2(iage)=1./(1.+mfexp(-1.*selpar_slope_commHAL2*(double(agebins(iage))-selpar_L50_commHAL2))); //logistic
     sel_commHAL_2(iage)=(1./(1.+mfexp(-1.*selpar_slope_commHAL2*(double(agebins(iage))-
                        selpar_L50_commHAL2))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_commHAL2*
                        (double(agebins(iage))-(selpar_L50_commHAL2+selpar_L502_commHAL2)))))); //double logistic

     //sel_commHAL_3(iage)=1./(1.+mfexp(-1.*selpar_slope_commHAL3*(double(agebins(iage))-selpar_L50_commHAL3))); //logistic
     sel_commHAL_3(iage)=(1./(1.+mfexp(-1.*selpar_slope_commHAL3*(double(agebins(iage))-
                        selpar_L50_commHAL3))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_commHAL3*
                        (double(agebins(iage))-(selpar_L50_commHAL3+selpar_L502_commHAL3)))))); //double logistic

     sel_commDV_vec(iage)=(1./(1.+mfexp(-1.*selpar_slope_commDV1*(double(agebins(iage))-
                        selpar_L50_commDV1))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_commDV1*
                        (double(agebins(iage))-(selpar_L50_commDV1+selpar_L502_commDV1)))))); //double logistic

     //sel_HB_1(iage)=1./(1.+mfexp(-1.*selpar_slope_HB1*(double(agebins(iage))-selpar_L50_HB1))); //logistic
     sel_HB_1(iage)=(1./(1.+mfexp(-1.*selpar_slope_HB1*(double(agebins(iage))-
                        selpar_L50_HB1))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_HB1*
                        (double(agebins(iage))-(selpar_L50_HB1+selpar_L502_HB1)))))); //double logistic
     //sel_HB_2(iage)=1./(1.+mfexp(-1.*selpar_slope_HB2*(double(agebins(iage))-selpar_L50_HB2))); //logistic
     sel_HB_2(iage)=(1./(1.+mfexp(-1.*selpar_slope_HB2*(double(agebins(iage))-
                        selpar_L50_HB2))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_HB2*
                        (double(agebins(iage))-(selpar_L50_HB2+selpar_L502_HB2)))))); //double logistic
     //sel_HB_3(iage)=1./(1.+mfexp(-1.*selpar_slope_HB3*(double(agebins(iage))-selpar_L50_HB3))); //logistic
     sel_HB_3(iage)=(1./(1.+mfexp(-1.*selpar_slope_HB3*(double(agebins(iage))-
                        selpar_L50_HB3))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_HB3*
                        (double(agebins(iage))-(selpar_L50_HB3+selpar_L502_HB3)))))); //double logistic
     //sel_MRFSS_2(iage)=1./(1.+mfexp(-1.*selpar_slope_MRFSS2*(double(agebins(iage))-selpar_L50_MRFSS2))); //logistic
     sel_MRFSS_2(iage)=(1./(1.+mfexp(-1.*selpar_slope_MRFSS2*(double(agebins(iage))-
                        selpar_L50_MRFSS2))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_MRFSS2*
                        (double(agebins(iage))-(selpar_L50_MRFSS2+selpar_L502_MRFSS2)))))); //double logistic
     //sel_MRFSS_3(iage)=1./(1.+mfexp(-1.*selpar_slope_MRFSS3*(double(agebins(iage))-selpar_L50_MRFSS3))); //logistic
     sel_MRFSS_3(iage)=(1./(1.+mfexp(-1.*selpar_slope_MRFSS3*(double(agebins(iage))-
                        selpar_L50_MRFSS3))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_MRFSS3*
                        (double(agebins(iage))-(selpar_L50_MRFSS3+selpar_L502_MRFSS3)))))); //double logistic

  }
  sel_commHAL_1=sel_commHAL_1/max(sel_commHAL_1); //re-normalize double logistic
  sel_commHAL_2=sel_commHAL_2/max(sel_commHAL_2); //re-normalize double logistic
  sel_commHAL_3=sel_commHAL_3/max(sel_commHAL_3); //re-normalize double logistic
  sel_commDV_vec=sel_commDV_vec/max(sel_commDV_vec); //re-normalize double logistic
  sel_HB_1=sel_HB_1/max(sel_HB_1); //re-normalize double logistic
  sel_HB_2=sel_HB_2/max(sel_HB_2); //re-normalize double logistic
  sel_HB_3=sel_HB_3/max(sel_HB_3); //re-normalize double logistic
  sel_MRFSS_2=sel_MRFSS_2/max(sel_MRFSS_2); //re-normalize double logistic
  sel_MRFSS_3=sel_MRFSS_3/max(sel_MRFSS_3); //re-normalize double logistic

//-----------fill in years--------------------------------------------

  for (iyear=styr; iyear<=endyr_period1; iyear++)
  //period1 HAL sel assumes HB sel but shifted by that difference in L50 from period2
  {
     sel_commHAL(iyear)=sel_commHAL_1;
     sel_commDV(iyear)=sel_commDV_vec;
     sel_HB(iyear)=sel_HB_1;
     sel_MRFSS(iyear)=sel_HB(iyear); //early period MRFSS same as HB

//     if (iyear>=styr_HB_lenc)  //selectivity in some early HB years varies
//     {
//       for (iage=1; iage<=nages; iage++)
```

```
//       {
//         //sel_HB(iyear,iage)=1./(1.+mfexp(-1.*selpar_slope_HB1*(double(agebins(iage))
//         //     -(selpar_L50_HB1+selpar_L50_HB_dev(iyear))))); //logistic
//         sel_HB(iyear,iage)=(1./(1.+mfexp(-1.*selpar_slope_HB1*(double(agebins(iage))-
//                       (selpar_L50_HB1+selpar_L50_HB_dev(iyear))))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_HB1*
//                       (double(agebins(iage))-(selpar_L50_HB1+selpar_L502_HB1)))))); //double logistic
//       }
//       sel_HB(iyear)=sel_HB(iyear)/max(sel_HB(iyear)); //re-normalize double logistic
//     }
//     sel_MRFSS(iyear)=sel_HB(iyear); //early period MRFSS same as HB
  }


  for (iyear=endyr_period1+1; iyear<=endyr_period2; iyear++)
  {
     sel_commHAL(iyear)=sel_commHAL_2;
     sel_commDV(iyear)=sel_commDV_vec;
     sel_HB(iyear)=sel_HB_2;
     sel_MRFSS(iyear)=sel_MRFSS_2;
  }

  for (iyear=endyr_period2+1; iyear<=endyr; iyear++)
  {
     sel_commHAL(iyear)=sel_commHAL_3;
     sel_commDV(iyear)=sel_commDV_vec;
     sel_HB(iyear)=sel_HB_3;
     sel_MRFSS(iyear)=sel_MRFSS_3;
  }


//---Discard selectivities---------------------------------
//---------------------------------------------------------

//period 1 (pre data)
//  for (iage=1; iage<=nages; iage++)
//  {
//   sel_commHAL_D_dum(iage)=1./(1.+mfexp(-1.*selpar_slope_commHAL1*
//                     (double(agebins(iage))-selpar_L50_commHAL1)));
//   sel_HB_D_dum(iage)=1./(1.+mfexp(-1.*selpar_slope_HB1*
//                     (double(agebins(iage))-selpar_L50_HB1)));
//   sel_MRFSS_D_dum(iage)=1./(1.+mfexp(-1.*selpar_slope_MRFSS1*
//                     (double(agebins(iage))-selpar_L50_MRFSS1)));
//   }
//
//  for (iyear=styr;iyear<styr_commHAL_D;iyear++)
//    {
//     sel_commHAL_D(iyear)=1.0-sel_commHAL_D_dum;
//     sel_commHAL_D(iyear)=(sel_commHAL_D(iyear))/(max(sel_commHAL_D(iyear)));
//     sel_commHAL_D(iyear,1)=selpar_commHAL_D_age1;
//     sel_commHAL_D(iyear)=(sel_commHAL_D(iyear))/(max(sel_commHAL_D(iyear)));
//    }
//
//  for (iyear=styr;iyear<styr_HB_D;iyear++)
//    {
//     sel_HB_D(iyear)=1.0-sel_HB_D_dum;
//     sel_HB_D(iyear)=(sel_HB_D(iyear))/(max(sel_HB_D(iyear)));
//     sel_HB_D(iyear,1)=selpar_HB_D_age1;
//     sel_HB_D(iyear)=(sel_HB_D(iyear))/(max(sel_HB_D(iyear)));
//    }
//  for (iyear=styr;iyear<styr_MRFSS_D;iyear++)
//    {
//     sel_MRFSS_D(iyear)=1.0-sel_MRFSS_D_dum;
//     sel_MRFSS_D(iyear)=(sel_MRFSS_D(iyear))/(max(sel_MRFSS_D(iyear)));
//     sel_MRFSS_D(iyear,1)=selpar_MRFSS_D_age1;
//     sel_MRFSS_D(iyear)=(sel_MRFSS_D(iyear))/(max(sel_MRFSS_D(iyear)));
//    }

//period 2
  for (iage=1; iage<=nages; iage++)
  {
   sel_commHAL_D_dum(iage)=1./(1.+mfexp(-1.*selpar_slope_commHAL2*
```

```
                     (double(agebins(iage))-selpar_L50_D_2)));
   sel_HB_D_dum(iage)=1./(1.+mfexp(-1.*selpar_slope_HB2*
                     (double(agebins(iage))-selpar_L50_D_2)));
   sel_MRFSS_D_dum(iage)=1./(1.+mfexp(-1.*selpar_slope_MRFSS2*
                     (double(agebins(iage))-selpar_L50_D_2)));
   }

  for (iyear=styr_commHAL_D;iyear<=endyr_period2;iyear++)
    {
     sel_commHAL_D(iyear)=1.0-sel_commHAL_D_dum;
     sel_commHAL_D(iyear)(2,nages)=(sel_commHAL_D(iyear)(2,nages))/(max(sel_commHAL_D(iyear)(2,nages)));
     sel_commHAL_D(iyear,1)=selpar_commHAL_D_age1;
     //sel_commHAL_D(iyear)=(sel_commHAL_D(iyear))/(max(sel_commHAL_D(iyear)));
    }

  for (iyear=styr_HB_D;iyear<=endyr_period2;iyear++)
    {
     sel_HB_D(iyear)=1.0-sel_HB_D_dum;
     sel_HB_D(iyear)(2,nages)=(sel_HB_D(iyear)(2,nages))/(max(sel_HB_D(iyear)(2,nages)));
     sel_HB_D(iyear,1)=selpar_HB_D_age1;
     //sel_HB_D(iyear)=(sel_HB_D(iyear))/(max(sel_HB_D(iyear)));
    }
  for (iyear=styr_MRFSS_D;iyear<=endyr_period2;iyear++)
    {
     sel_MRFSS_D(iyear)=1.0-sel_MRFSS_D_dum;
     sel_MRFSS_D(iyear)(2,nages)=(sel_MRFSS_D(iyear)(2,nages))/(max(sel_MRFSS_D(iyear)(2,nages)));
     sel_MRFSS_D(iyear,1)=selpar_MRFSS_D_age1;
     //sel_MRFSS_D(iyear)=(sel_MRFSS_D(iyear))/(max(sel_MRFSS_D(iyear)));
    }

//period 3
  for (iage=1; iage<=nages; iage++)
  {
   sel_commHAL_D_dum(iage)=1./(1.+mfexp(-1.*selpar_slope_commHAL3*
                     (double(agebins(iage))-selpar_L50_D_3)));
   sel_HB_D_dum(iage)=1./(1.+mfexp(-1.*selpar_slope_HB3*
                     (double(agebins(iage))-selpar_L50_D_3)));
   sel_MRFSS_D_dum(iage)=1./(1.+mfexp(-1.*selpar_slope_MRFSS3*
                     (double(agebins(iage))-selpar_L50_D_3)));
   }
  for (iyear=endyr_period2+1;iyear<=endyr_commHAL_D;iyear++)
    {
     sel_commHAL_D(iyear)=1.0-sel_commHAL_D_dum;
     sel_commHAL_D(iyear)(2,nages)=(sel_commHAL_D(iyear)(2,nages))/(max(sel_commHAL_D(iyear)(2,nages)));
     sel_commHAL_D(iyear,1)=selpar_commHAL_D_age1;
     //sel_commHAL_D(iyear)=(sel_commHAL_D(iyear))/(max(sel_commHAL_D(iyear)));
    }
  for (iyear=endyr_period2+1;iyear<=endyr_HB_D;iyear++)
    {
     sel_HB_D(iyear)=1.0-sel_HB_D_dum;
     sel_HB_D(iyear)(2,nages)=(sel_HB_D(iyear)(2,nages))/(max(sel_HB_D(iyear)(2,nages)));
     sel_HB_D(iyear,1)=selpar_HB_D_age1;
     //sel_HB_D(iyear)=(sel_HB_D(iyear))/(max(sel_HB_D(iyear)));
    }
  for (iyear=endyr_period2+1;iyear<=endyr_MRFSS_D;iyear++)
    {
     sel_MRFSS_D(iyear)=1.0-sel_MRFSS_D_dum;
     sel_MRFSS_D(iyear)(2,nages)=(sel_MRFSS_D(iyear)(2,nages))/(max(sel_MRFSS_D(iyear)(2,nages)));
     sel_MRFSS_D(iyear,1)=selpar_MRFSS_D_age1;
     //sel_MRFSS_D(iyear)=(sel_MRFSS_D(iyear))/(max(sel_MRFSS_D(iyear)));

    }



FUNCTION get_mortality
  fullF=0.0;
  ////initialization F is avg of first 3 yrs of observed landings
  //log_F_init_commHAL=sum(log_F_dev_commHAL(styr_commHAL_L,(styr_commHAL_L+2)))/3.0;
  //log_F_init_commDV=sum(log_F_dev_commDV(styr_commDV_L,(styr_commDV_L+2)))/3.0;
```

```
  //log_F_init_HB=sum(log_F_dev_HB(styr_HB_L,(styr_HB_L+2)))/3.0;
  //log_F_init_MRFSS=sum(log_F_dev_MRFSS(styr_MRFSS_L,(styr_MRFSS_L+2)))/3.0;

//  F_commHAL_D_ratio=(sum(mfexp(log_avg_F_commHAL_D+log_F_dev_commHAL_D(styr_commHAL_D,(styr_commHAL_D+7)))))/8.0)/
//            (sum(mfexp(log_avg_F_commHAL_2+log_F_dev_commHAL_2(styr_commHAL_D,(styr_commHAL_D+7)))))/8.0);
//  F_HB_D_ratio=(sum(mfexp(log_avg_F_HB_D+log_F_dev_HB_D(styr_HB_D,(styr_HB_D+7)))))/8.0)/
//            (sum(mfexp(log_avg_F_HB+log_F_dev_HB(styr_HB_D,(styr_HB_D+7)))))/8.0);
//  F_MRFSS_D_ratio=(sum(mfexp(log_avg_F_MRFSS_D+log_F_dev_MRFSS_D(styr_MRFSS_D,(styr_MRFSS_D+7)))))/8.0)/
//            (sum(mfexp(log_avg_F_MRFSS+log_F_dev_MRFSS(styr_MRFSS_D,(styr_MRFSS_D+7)))))/8.0);


  for (iyear=styr; iyear<=endyr; iyear++)
  {
    if(iyear<styr_commHAL_L_2)
    {
      F_commHAL_out(iyear)=0.0;//mfexp(log_avg_F_commHAL+log_F_init_commHAL);
    }
    else
    {
      F_commHAL_out(iyear)=mfexp(log_avg_F_commHAL_2+log_F_dev_commHAL_2(iyear));
    }
    F_commHAL(iyear)=sel_commHAL(iyear)*F_commHAL_out(iyear);

    fullF(iyear)+=F_commHAL_out(iyear);

    if(iyear<styr_commDV_L)
    {
      F_commDV_out(iyear)=0.0;//mfexp(log_avg_F_commDV+log_F_init_commDV);
    }
    else
    {
      F_commDV_out(iyear)=mfexp(log_avg_F_commDV+log_F_dev_commDV(iyear));
    }
    F_commDV(iyear)=sel_commDV(iyear)*F_commDV_out(iyear);
    fullF(iyear)+=F_commDV_out(iyear);

    if(iyear<styr_HB_L)
    {
      F_HB_out(iyear)=0.0;//mfexp(log_avg_F_HB+log_F_init_HB);
    }
    else
    {
      F_HB_out(iyear)=mfexp(log_avg_F_HB+log_F_dev_HB(iyear));
    }
    F_HB(iyear)=sel_HB(iyear)*F_HB_out(iyear);

    fullF(iyear)+=F_HB_out(iyear);

    if(iyear<styr_MRFSS_L)
    {
      F_MRFSS_out(iyear)=0.0;//mfexp(log_avg_F_MRFSS+log_F_init_MRFSS);
    }
    else
    {
      F_MRFSS_out(iyear)=mfexp(log_avg_F_MRFSS+log_F_dev_MRFSS(iyear));
    }
    F_MRFSS(iyear)=sel_MRFSS(iyear)*F_MRFSS_out(iyear);

    fullF(iyear)+=F_MRFSS_out(iyear);



    //discards
    if(iyear>=styr_commHAL_D)
    {
      F_commHAL_D_out(iyear)=mfexp(log_avg_F_commHAL_D+log_F_dev_commHAL_D(iyear));
      F_commHAL_D(iyear)=sel_commHAL_D(iyear)*F_commHAL_D_out(iyear);
      fullF(iyear)+=F_commHAL_D_out(iyear);
    }
//    else
//    {
```

```
//      F_commHAL_D_out(iyear)=F_commHAL_D_ratio*F_commHAL_out(iyear);
//      F_commHAL_D(iyear)=sel_commHAL_D(iyear)*F_commHAL_D_out(iyear);
//      fullF(iyear)+=F_commHAL_D_out(iyear);
//    }

    if(iyear>=styr_HB_D)
    {
      F_HB_D_out(iyear)=mfexp(log_avg_F_HB_D+log_F_dev_HB_D(iyear));
      F_HB_D(iyear)=sel_HB_D(iyear)*F_HB_D_out(iyear);
      fullF(iyear)+=F_HB_D_out(iyear);
    }
//    else
//    {
//      F_HB_D_out(iyear)=F_HB_D_ratio*F_HB_out(iyear);
//      F_HB_D(iyear)=sel_HB_D(iyear)*F_HB_D_out(iyear);
//      fullF(iyear)+=F_HB_D_out(iyear);
//    }

    if(iyear>=styr_MRFSS_D)
    {
      F_MRFSS_D_out(iyear)=mfexp(log_avg_F_MRFSS_D+log_F_dev_MRFSS_D(iyear));
      F_MRFSS_D(iyear)=sel_MRFSS_D(iyear)*F_MRFSS_D_out(iyear);
      fullF(iyear)+=F_MRFSS_D_out(iyear);
    }

//    else
//    {
//      F_MRFSS_D_out(iyear)=F_MRFSS_D_ratio*F_MRFSS_out(iyear);
//      F_MRFSS_D(iyear)=sel_MRFSS_D(iyear)*F_MRFSS_D_out(iyear);
//      fullF(iyear)+=F_MRFSS_D_out(iyear);
//    }

    F(iyear)=F_commHAL(iyear); //first in additive series (NO +=)
    F(iyear)+=F_commDV(iyear);
    F(iyear)+=F_HB(iyear);
    F(iyear)+=F_MRFSS(iyear);

    F(iyear)+=F_commHAL_D(iyear);
    F(iyear)+=F_HB_D(iyear);
    F(iyear)+=F_MRFSS_D(iyear);

    Z(iyear)=M+F(iyear);
  }

FUNCTION get_bias_corr
  var_rec_dev=norm2(log_dev_N_rec(styr_rec_dev,(endyr-2))-sum(log_dev_N_rec(styr_rec_dev,(endyr-2)))
              /(nyrs_rec-2.0))/(nyrs_rec-3.0); //sample variance from yrs styr_rec_dev-2004
  if (set_BiasCor <= 0.0) {BiasCor=mfexp(var_rec_dev/2.0);}   //bias correction
  else {BiasCor=set_BiasCor;}


FUNCTION get_numbers_at_age
//Initial age
  S0=spr_F0*R0;
  B0=bpr_F0*R0;
  R1_mult=B1dB0;
  R1=R1_mult*mfexp(log(((0.8*R0*steep*S0)/
     (0.2*R0*spr_F0*(1.0-steep)+(steep-0.2)*S0))+dzero_dum));

  //Assume equilibrium age structure for first year
  N(styr,1)=R1;
  N_mdyr(styr,1)=N(styr,1)*mfexp(-1.*M(1)/2.0);
  for (iage=2; iage<=nages; iage++)
  {
    N(styr,iage)=N(styr,iage-1)*mfexp(-1.*M(iage-1));
    N_mdyr(styr,iage)=N(styr,iage)*mfexp(-1.*M(iage)/2.0);
  }
  //plus group calculation
  N(styr,nages)=N(styr,nages)/(1.-mfexp(-1.*M(nages)));
  N_mdyr(styr,nages)=N_mdyr(styr,nages)/(1.-mfexp(-1.*M(nages)));
```

```
  SSB(styr)=sum(elem_prod(N_mdyr(styr),reprod));
  B(styr)=elem_prod(N(styr),wgt);
  totB(styr)=sum(B(styr));

//Rest of years
  for (iyear=styr; iyear<endyr; iyear++)
  {
    if(iyear<(styr_rec_dev-1)) //recruitment follows S-R curve exactly
    {
        //add 0.00001 to avoid log(zero)
        N(iyear+1,1)=BiasCor*mfexp(log(((0.8*R0*steep*SSB(iyear))/(0.2*R0*spr_F0*
            (1.0-steep)+(steep-0.2)*SSB(iyear)))+dzero_dum));
        N(iyear+1)(2,nages)=++elem_prod(N(iyear)(1,nages-1),(mfexp(-1.*Z(iyear)(1,nages-1))));
        N(iyear+1,nages)+=N(iyear,nages)*mfexp(-1.*Z(iyear,nages));//plus group
        N_mdyr(iyear+1)(1,nages)=elem_prod(N(iyear+1)(1,nages),(mfexp(-1.*(Z(iyear+1)(1,nages))/2.0))); //mdyr
        SSB(iyear+1)=sum(elem_prod(N_mdyr(iyear+1),reprod));
        B(iyear+1)=elem_prod(N(iyear+1),wgt);
        totB(iyear+1)=sum(B(iyear+1));
    }
    else   //recruitment follows S-R curve with lognormal deviation
    {
        //add 0.00001 to avoid log(zero)
        N(iyear+1,1)=mfexp(log(((0.8*R0*steep*SSB(iyear))/(0.2*R0*spr_F0*
            (1.0-steep)+(steep-0.2)*SSB(iyear)))+dzero_dum)+log_dev_N_rec(iyear+1));
        N(iyear+1)(2,nages)=++elem_prod(N(iyear)(1,nages-1),(mfexp(-1.*Z(iyear)(1,nages-1))));
        N(iyear+1,nages)+=N(iyear,nages)*mfexp(-1.*Z(iyear,nages));//plus group
        N_mdyr(iyear+1)(1,nages)=elem_prod(N(iyear+1)(1,nages),(mfexp(-1.*(Z(iyear+1)(1,nages))/2.0))); //mdyr
        SSB(iyear+1)=sum(elem_prod(N_mdyr(iyear+1),reprod));
        B(iyear+1)=elem_prod(N(iyear+1),wgt);
        totB(iyear+1)=sum(B(iyear+1));
    }
  }


    //last year (projection) has no recruitment variability
    N(endyr+1,1)=mfexp(log(((0.8*R0*steep*SSB(endyr))/(0.2*R0*spr_F0*
                 (1.0-steep)+(steep-0.2)*SSB(endyr)))+dzero_dum));
    N(endyr+1)(2,nages)=++elem_prod(N(endyr)(1,nages-1),(mfexp(-1.*Z(endyr)(1,nages-1))));
    N(endyr+1,nages)+=N(endyr,nages)*mfexp(-1.*Z(endyr,nages));//plus group
    //SSB(endyr+1)=sum(elem_prod(N(endyr+1),reprod));
    B(endyr+1)=elem_prod(N(endyr+1),wgt);
    totB(endyr+1)=sum(B(endyr+1));

//Recruitment time series
  rec=column(N,1);

//Benchmark parameters
  S1S0=SSB(styr)/S0;
  popstatus=SSB(endyr)/S0;


FUNCTION get_landings_numbers //Baranov catch eqn
  for (iyear=styr; iyear<=endyr; iyear++)
  {
    for (iage=1; iage<=nages; iage++)
    {
      C_commHAL(iyear,iage)=N(iyear,iage)*F_commHAL(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
      C_commDV(iyear,iage)=N(iyear,iage)*F_commDV(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
      C_HB(iyear,iage)=N(iyear,iage)*F_HB(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
      C_MRFSS(iyear,iage)=N(iyear,iage)*F_MRFSS(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
    }
  }


FUNCTION get_landings_wgt

//---Predicted landings------------------------
```

```
  for (iyear=styr; iyear<=endyr; iyear++)
  {
    L_commHAL(iyear)=elem_prod(C_commHAL(iyear),wgt); //in mt
    L_commDV(iyear)=elem_prod(C_commDV(iyear),wgt);   //in mt
    L_HB(iyear)=elem_prod(C_HB(iyear),wgt);           //in mt
    L_MRFSS(iyear)=elem_prod(C_MRFSS(iyear),wgt);     //in mt

    L_commHAL_klb(iyear)=elem_prod(C_commHAL(iyear),wgt_klb); //in 1000 lb
    L_commDV_klb(iyear)=elem_prod(C_commDV(iyear),wgt_klb);   //in 1000 lb
    L_HB_klb(iyear)=elem_prod(C_HB(iyear),wgt_klb);           //in 1000 lb
    L_MRFSS_klb(iyear)=elem_prod(C_MRFSS(iyear),wgt_klb);     //in 1000 lb
  }


  for (iyear=styr_commHAL_L_2; iyear<=endyr_commHAL_L_2; iyear++)
    {
     pred_commHAL_L_2(iyear)=sum(L_commHAL_klb(iyear));
    }
  for (iyear=styr_commDV_L; iyear<=endyr_commDV_L; iyear++)
    {
     pred_commDV_L(iyear)=sum(L_commDV_klb(iyear));
    }
  for (iyear=styr_HB_L; iyear<=endyr_HB_L; iyear++)
    {
     pred_HB_L(iyear)=sum(L_HB_klb(iyear));
    }
  for (iyear=styr_MRFSS_L; iyear<=endyr_MRFSS_L; iyear++)
    {
     pred_MRFSS_L(iyear)=sum(L_MRFSS_klb(iyear));
    }

FUNCTION get_dead_discards //Baranov catch eqn
  //dead discards at age (number fish)
//  for (iyear=styr; iyear<styr_commHAL_D; iyear++)
//  {
//    for (iage=1; iage<=nages; iage++)
//    {
//      early_C_commHAL_D(iyear,iage)=N(iyear,iage)*F_commHAL_D(iyear,iage)*
//        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
//    }
//    early_pred_commHAL_D(iyear)=sum(early_C_commHAL_D(iyear))/1000.0; //pred annual dead discards in 1000s
//  }
  for (iyear=styr_commHAL_D; iyear<=endyr_commHAL_D; iyear++)
  {
    for (iage=1; iage<=nages; iage++)
    {
      C_commHAL_D(iyear,iage)=N(iyear,iage)*F_commHAL_D(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
    }
    pred_commHAL_D(iyear)=sum(C_commHAL_D(iyear))/1000.0; //pred annual dead discards in 1000s
  }

//  for (iyear=styr; iyear<styr_HB_D; iyear++)
//  {
//    for (iage=1; iage<=nages; iage++)
//    {
//      early_C_HB_D(iyear,iage)=N(iyear,iage)*F_HB_D(iyear,iage)*
//        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
//    }
//    early_pred_HB_D(iyear)=sum(early_C_HB_D(iyear))/1000.0; //pred annual dead discards in 1000s
//  }
  for (iyear=styr_HB_D; iyear<=endyr_HB_D; iyear++)
  {
    for (iage=1; iage<=nages; iage++)
    {
      C_HB_D(iyear,iage)=N(iyear,iage)*F_HB_D(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
    }
    pred_HB_D(iyear)=sum(C_HB_D(iyear))/1000.0; //pred annual dead discards in 1000s
  }
```

```
//  for (iyear=styr; iyear<styr_MRFSS_D; iyear++)
//  {
//    for (iage=1; iage<=nages; iage++)
//    {
//      early_C_MRFSS_D(iyear,iage)=N(iyear,iage)*F_MRFSS_D(iyear,iage)*
//        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
//    }
//    early_pred_MRFSS_D(iyear)=sum(early_C_MRFSS_D(iyear))/1000.0; //pred annual dead discards in 1000s
//  }
  for (iyear=styr_MRFSS_D; iyear<=endyr_MRFSS_D; iyear++)
  {
    for (iage=1; iage<=nages; iage++)
    {
      C_MRFSS_D(iyear,iage)=N(iyear,iage)*F_MRFSS_D(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
    }
    pred_MRFSS_D(iyear)=sum(C_MRFSS_D(iyear))/1000.0; //pred annual dead discards in 1000s
  }



FUNCTION get_indices
//---Predicted CPUEs------------------------
 //Hook and line Logbook cpue
  for (iyear=styr_HAL_cpue; iyear<=endyr_HAL_cpue; iyear++)
  {   //index in whole wgt (lb) units, wgt_klb in 1000 lb, but the multiplier (1000) is absorbed by q
      N_HAL(iyear)=elem_prod(elem_prod(N_mdyr(iyear),sel_commHAL(iyear)),wgt_klb);
      pred_HAL_cpue(iyear)=mfexp(log_q_HAL)*(1+(iyear-styr_HAL_cpue)*q_rate)*sum(N_HAL(iyear));
      //pred_HAL_cpue(iyear)=mfexp(log_q_HAL)*sum(N_HAL(iyear));
  }
 //Headboat cpue
  for (iyear=styr_HB_cpue; iyear<=endyr_HB_cpue; iyear++)
  {   //index in number units
      N_HB(iyear)=elem_prod(N_mdyr(iyear),sel_HB(iyear));
      pred_HB_cpue(iyear)=mfexp(log_q_HB)*(1+(iyear-styr_HB_cpue)*q_rate)*sum(N_HB(iyear));
      //pred_HB_cpue(iyear)=mfexp(log_q_HB)*sum(N_HB(iyear));
  }
  //MRFSS cpue
  for (iyear=styr_MRFSS_cpue; iyear<=endyr_MRFSS_cpue; iyear++)
  {   //index in number units
      N_MRFSS(iyear)=elem_prod(N_mdyr(iyear),sel_MRFSS(iyear));
      pred_MRFSS_cpue(iyear)=mfexp(log_q_MRFSS)*(1+(iyear-styr_MRFSS_cpue)*q_rate)*sum(N_MRFSS(iyear));
      //pred_MRFSS_cpue(iyear)=mfexp(log_q_MRFSS)*sum(N_MRFSS(iyear));
  }


FUNCTION get_length_comps
 //Commercial
  for (iyear=styr_commHAL_lenc;iyear<=endyr_commHAL_lenc;iyear++)
  {
    pred_commHAL_lenc(iyear)=(C_commHAL(iyear)*lenprob)/sum(C_commHAL(iyear));
  }
  for (iyear=1;iyear<=nyr_commDV_lenc;iyear++)
  {
    pred_commDV_lenc(iyear)=(C_commDV(yrs_commDV_lenc(iyear))*lenprob)
                              /sum(C_commDV(yrs_commDV_lenc(iyear)));
  }
 //Headboat
  for (iyear=styr_HB_lenc;iyear<=endyr_HB_lenc;iyear++)
  {
    pred_HB_lenc(iyear)=(C_HB(iyear)*lenprob)/sum(C_HB(iyear));
  }
 //MRFSS
  for (iyear=1;iyear<=nyr_MRFSS_lenc;iyear++)
  {
    pred_MRFSS_lenc(iyear)=(C_MRFSS(yrs_MRFSS_lenc(iyear))*lenprob)
                              /sum(C_MRFSS(yrs_MRFSS_lenc(iyear)));
  }

FUNCTION get_age_comps
 //Commercial
```

```
  for (iyear=1;iyear<=nyr_commHAL_agec;iyear++)
  {
    pred_commHAL_agec(iyear)=C_commHAL(yrs_commHAL_agec(iyear))/
                             sum(C_commHAL(yrs_commHAL_agec(iyear)));
  }
  for (iyear=1;iyear<=nyr_commDV_agec;iyear++)
  {
    pred_commDV_agec(iyear)=C_commDV(yrs_commDV_agec(iyear))/
                             sum(C_commDV(yrs_commDV_agec(iyear)));
  }
 //Headboat
  for (iyear=1;iyear<=nyr_HB_agec;iyear++)
  {
    pred_HB_agec(iyear)=C_HB(yrs_HB_agec(iyear))/
                             sum(C_HB(yrs_HB_agec(iyear)));
  }
 //MRFSS
  for (iyear=styr_MRFSS_agec;iyear<=endyr_MRFSS_agec;iyear++)
  {
    pred_MRFSS_agec(iyear)=C_MRFSS(iyear)/sum(C_MRFSS(iyear));
  }

//-----------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_sel_weighted_current
  F_temp_sum=0.0;
  F_temp_sum+=mfexp((3.0*log_avg_F_commHAL_2+sum(log_F_dev_commHAL_2(endyr-2,endyr)))/3.0);
  F_temp_sum+=mfexp((3.0*log_avg_F_commDV+sum(log_F_dev_commDV(endyr-2,endyr)))/3.0);
  F_temp_sum+=mfexp((3.0*log_avg_F_HB+sum(log_F_dev_HB(endyr-2,endyr)))/3.0);
  F_temp_sum+=mfexp((3.0*log_avg_F_MRFSS+sum(log_F_dev_MRFSS(endyr-2,endyr)))/3.0);
  F_temp_sum+=mfexp((3.0*log_avg_F_commHAL_D+sum(log_F_dev_commHAL_D(endyr-2,endyr)))/3.0);
  F_temp_sum+=mfexp((3.0*log_avg_F_HB_D+sum(log_F_dev_HB_D(endyr-2,endyr)))/3.0);
  F_temp_sum+=mfexp((3.0*log_avg_F_MRFSS_D+sum(log_F_dev_MRFSS_D(endyr-2,endyr)))/3.0);

  F_commHAL_prop=mfexp((3.0*log_avg_F_commHAL_2+sum(log_F_dev_commHAL_2(endyr-2,endyr)))/3.0)/F_temp_sum;
  F_commDV_prop=mfexp((3.0*log_avg_F_commDV+sum(log_F_dev_commDV(endyr-2,endyr)))/3.0)/F_temp_sum;
  F_HB_prop=mfexp((3.0*log_avg_F_HB+sum(log_F_dev_HB(endyr-2,endyr)))/3.0)/F_temp_sum;
  F_MRFSS_prop=mfexp((3.0*log_avg_F_MRFSS+sum(log_F_dev_MRFSS(endyr-2,endyr)))/3.0)/F_temp_sum;
  F_commHAL_D_prop=mfexp((3.0*log_avg_F_commHAL_D+sum(log_F_dev_commHAL_D(endyr-2,endyr)))/3.0)/F_temp_sum;
  F_HB_D_prop=mfexp((3.0*log_avg_F_HB_D+sum(log_F_dev_HB_D(endyr-2,endyr)))/3.0)/F_temp_sum;
  F_MRFSS_D_prop=mfexp((3.0*log_avg_F_MRFSS_D+sum(log_F_dev_MRFSS_D(endyr-2,endyr)))/3.0)/F_temp_sum;

  sel_wgted_L=F_commHAL_prop*sel_commHAL(endyr)+
              F_commDV_prop*sel_commDV(endyr)+
              F_HB_prop*sel_HB(endyr)+
              F_MRFSS_prop*sel_MRFSS(endyr);

  sel_wgted_D=F_commHAL_D_prop*sel_commHAL_D(endyr)+
                F_HB_D_prop*sel_HB_D(endyr)+
                F_MRFSS_D_prop*sel_MRFSS_D(endyr);

  sel_wgted_tot=sel_wgted_L+sel_wgted_D;

  max_sel_wgted_tot=max(sel_wgted_tot);
  sel_wgted_tot/=max_sel_wgted_tot;
  sel_wgted_L/=max_sel_wgted_tot; //landings sel bumped up by same amount as total sel
  sel_wgted_D/=max_sel_wgted_tot;



FUNCTION get_msy

  //fill in Fs for per-recruit stuff
  F_msy.fill_seqadd(0,.001);


  //compute values as functions of F
  for(int ff=1; ff<=n_iter_msy; ff++)
  {
    //uses fishery-weighted F's
    Z_age_msy=0.0;
    F_L_age_msy=0.0;
```

```
    F_D_age_msy=0.0;

    F_L_age_msy=F_msy(ff)*sel_wgted_L;
    F_D_age_msy=F_msy(ff)*sel_wgted_D;
    Z_age_msy=M+F_L_age_msy+F_D_age_msy;

    N_age_msy(1)=1.0;
    for (iage=2; iage<=nages; iage++)
    {
      N_age_msy(iage)=N_age_msy(iage-1)*mfexp(-1.*Z_age_msy(iage-1));
    }
    N_age_msy(nages)=N_age_msy(nages)/(1.0-mfexp(-1.*Z_age_msy(nages)));
    N_age_msy_mdyr(1,(nages-1))=elem_prod(N_age_msy(1,(nages-1)),
                                mfexp((-1.*Z_age_msy(1,(nages-1)))/2.0));
    N_age_msy_mdyr(nages)=(N_age_msy_mdyr(nages-1)*
                         (mfexp(-1.*(Z_age_msy(nages-1)/2 + Z_age_msy(nages)/2) )))
                         /(1.0-mfexp(-1.*Z_age_msy(nages)));

    spr_msy(ff)=sum(elem_prod(N_age_msy_mdyr,reprod));


    //Compute equilibrium values of R (including bias correction), SSB and Yield at each F
    R_eq(ff)=(R0/((5.0*steep-1.0)*spr_msy(ff)))*
                 (BiasCor*4.0*steep*spr_msy(ff)-spr_F0*(1.0-steep));
    if (R_eq(ff)<dzero_dum) {R_eq(ff)=dzero_dum;}
    N_age_msy*=R_eq(ff);
    N_age_msy_mdyr*=R_eq(ff);

    for (iage=1; iage<=nages; iage++)
    {
      C_age_msy(iage)=N_age_msy(iage)*(F_L_age_msy(iage)/Z_age_msy(iage))*
                      (1.-mfexp(-1.*Z_age_msy(iage)));
      D_age_msy(iage)=N_age_msy(iage)*(F_D_age_msy(iage)/Z_age_msy(iage))*
                      (1.-mfexp(-1.0*Z_age_msy(iage)));
    }


    SSB_eq(ff)=sum(elem_prod(N_age_msy_mdyr,reprod));
    B_eq(ff)=sum(elem_prod(N_age_msy,wgt));
    L_eq(ff)=sum(elem_prod(C_age_msy,wgt));
    E_eq(ff)=sum(C_age_msy(E_age_st,nages))/sum(N_age_msy(E_age_st,nages));
    D_eq(ff)=sum(D_age_msy)/1000.0;
  }

  msy_out=max(L_eq);

  for(ff=1; ff<=n_iter_msy; ff++)
  {
   if(L_eq(ff) == msy_out)
      {
        SSB_msy_out=SSB_eq(ff);
        B_msy_out=B_eq(ff);
        R_msy_out=R_eq(ff);
        D_msy_out=D_eq(ff);
        E_msy_out=E_eq(ff);
        F_msy_out=F_msy(ff);
        spr_msy_out=spr_msy(ff);
      }
  }

//-----------------------------------------------------------------------------------------------------------------------
FUNCTION get_miscellaneous_stuff

  //compute total catch-at-age and landings
  C_total=(C_HB+C_MRFSS+C_commHAL+C_commDV); //catch in number fish
  L_total=L_HB+L_MRFSS+L_commHAL+L_commDV;   //landings in mt whole weight

  //compute exploitation rate of age E_age_st +
  for(iyear=styr; iyear<=endyr; iyear++)
  {
    E(iyear)=(sum(C_total(iyear)(E_age_st,nages)))/sum(N(iyear)(E_age_st,nages)); //catch in 1000s
```

```
    L_total_yr(iyear)=sum(L_total(iyear));
  }

  steep_sd=steep;
  fullF_sd=fullF;
  E_sd=E;

  if(E_msy_out>0)
    {
      EdE_msy=E/E_msy_out;
      EdE_msy_end=EdE_msy(endyr);
    }
  if(F_msy_out>0)
    {
      FdF_msy=fullF/F_msy_out;
      FdF_msy_end=FdF_msy(endyr);
    }
  if(SSB_msy_out>0)
    {
      SdSSB_msy=SSB/SSB_msy_out;
      SdSSB_msy_end=SdSSB_msy(endyr);
    }

   //fill in log recruitment deviations for yrs they are nonzero
   for(iyear=styr_rec_dev; iyear<=endyr; iyear++)
   {
    log_dev_R(iyear)=log_dev_N_rec(iyear);
   }

//-----------------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_per_recruit_stuff

  //static per-recruit stuff

  for(iyear=styr; iyear<=endyr; iyear++)
  {
    N_age_spr(1)=1.0;
    for(iage=2; iage<=nages; iage++)
    {
      N_age_spr(iage)=N_age_spr(iage-1)*mfexp(-1.*Z(iyear,iage-1));
    }
    N_age_spr(nages)=N_age_spr(nages)/(1.0-mfexp(-1.*Z(iyear,nages)));
    N_age_spr_mdyr(1,(nages-1))=elem_prod(N_age_spr(1,(nages-1)),
                                mfexp(-1.*Z(iyear)(1,(nages-1))/2.0));
    N_age_spr_mdyr(nages)=(N_age_spr_mdyr(nages-1)*
                          (mfexp(-1.*(Z(iyear)(nages-1)/2.0 + Z(iyear)(nages)/2.0) )))
                          /(1.0-mfexp(-1.*Z_age_msy(nages)));
    spr_static(iyear)=sum(elem_prod(N_age_spr_mdyr,reprod))/spr_F0;
  }

  //fill in Fs for per-recruit stuff
  F_spr.fill_seqadd(0,.01);
  //compute SSB/R and YPR as functions of F
  for(int ff=1; ff<=n_iter_spr; ff++)
  {
    //uses fishery-weighted F's, same as in MSY calculations
    Z_age_spr=0.0;
    F_L_age_spr=0.0;

    F_L_age_spr=F_spr(ff)*sel_wgted_L;

    Z_age_spr=M+F_L_age_spr+F_spr(ff)*sel_wgted_D;

    N_age_spr(1)=1.0;
    for (iage=2; iage<=nages; iage++)
    {
      N_age_spr(iage)=N_age_spr(iage-1)*mfexp(-1.*Z_age_spr(iage-1));
    }
    N_age_spr(nages)=N_age_spr(nages)/(1-mfexp(-1.*Z_age_spr(nages)));
    N_age_spr_mdyr(1,(nages-1))=elem_prod(N_age_spr(1,(nages-1)),
                                   mfexp((-1.*Z_age_spr(1,(nages-1)))/2.0));
```

```
    N_age_spr_mdyr(nages)=(N_age_spr_mdyr(nages-1)*
                          (mfexp(-1.*(Z_age_spr(nages-1)/2 + Z_age_spr(nages)/2) )))
                          /(1.0-mfexp(-1.*Z_age_spr(nages)));

    spr_spr(ff)=sum(elem_prod(N_age_spr_mdyr,reprod));
    L_spr(ff)=0.0;
    for (iage=1; iage<=nages; iage++)
    {
      C_age_spr(iage)=N_age_spr(iage)*(F_L_age_spr(iage)/Z_age_spr(iage))*
                      (1.-mfexp(-1.*Z_age_spr(iage)));
      L_spr(ff)+=C_age_spr(iage)*wgt(iage);
    }
    E_spr(ff)=sum(C_age_spr(E_age_st,nages))/sum(N_age_spr(E_age_st,nages));

  }

//----------------------------------------------------------------------------------------------------------------------------------


FUNCTION evaluate_objective_function
  fval=0.0;
  fval_unwgt=0.0;

//---likelihoods---------------------------
  //fval=square(x_dum-3.0);

//---Indices-------------------------------
  f_HAL_cpue=0.0;
  for (iyear=styr_HAL_cpue; iyear<=endyr_HAL_cpue; iyear++)
  {
    f_HAL_cpue+=square(log((pred_HAL_cpue(iyear)+dzero_dum)/
        (obs_HAL_cpue(iyear)+dzero_dum)))/(2.0*square(HAL_cpue_cv(iyear)));
  }
  fval+=w_I_HAL*f_HAL_cpue;
  fval_unwgt+=f_HAL_cpue;

  f_HB_cpue=0.0;
  for (iyear=styr_HB_cpue; iyear<=endyr_HB_cpue; iyear++)
  {
    f_HB_cpue+=square(log((pred_HB_cpue(iyear)+dzero_dum)/
        (obs_HB_cpue(iyear)+dzero_dum)))/(2.0*square(HB_cpue_cv(iyear)));
  }
  fval+=w_I_HB*f_HB_cpue;
  fval_unwgt+=f_HB_cpue;

  f_MRFSS_cpue=0.0;
  for (iyear=styr_MRFSS_cpue; iyear<=endyr_MRFSS_cpue; iyear++)
  {
    f_MRFSS_cpue+=square(log((pred_MRFSS_cpue(iyear)+dzero_dum)/
        (obs_MRFSS_cpue(iyear)+dzero_dum)))/(2.0*square(MRFSS_cpue_cv(iyear)));
  }
  fval+=w_I_MRFSS*f_MRFSS_cpue;
  fval_unwgt+=f_MRFSS_cpue;


//---Landings-------------------------------

  f_commHAL_L_2=0.0; //in 1000s gutted pounds
  for (iyear=styr_commHAL_L_2; iyear<=endyr_commHAL_L_2; iyear++)
  {
      f_commHAL_L_2+=square(log((pred_commHAL_L_2(iyear)+dzero_dum)/
        (obs_commHAL_L_2(iyear)+dzero_dum)))/(2.0*square(commHAL_L_cv_2(iyear)));
  }
  fval+=w_L*f_commHAL_L_2;
  fval_unwgt+=f_commHAL_L_2;

  f_commDV_L=0.0; //in 1000s gutted pounds
  for (iyear=styr_commDV_L; iyear<=endyr_commDV_L; iyear++)
  {
    f_commDV_L+=square(log((pred_commDV_L(iyear)+dzero_dum)/
        (obs_commDV_L(iyear)+dzero_dum)))/(2.0*square(commDV_L_cv(iyear)));
```

```
  }
  fval+=w_L*f_commDV_L;
  fval_unwgt+=f_commDV_L;

  f_HB_L=0.0; //in 1000s
  for (iyear=styr_HB_L; iyear<=endyr_HB_L; iyear++)
  {
    f_HB_L+=square(log((pred_HB_L(iyear)+dzero_dum)/
        (obs_HB_L(iyear)+dzero_dum)))/(2.0*square(HB_L_cv(iyear)));
  }
  fval+=w_L*f_HB_L;
  fval_unwgt+=f_HB_L;

  f_MRFSS_L=0.0; //in 1000s
  for (iyear=styr_MRFSS_L; iyear<=1980; iyear++)
  {
    f_MRFSS_L+=square(log((pred_MRFSS_L(iyear)+dzero_dum)/
        (L_early_bias*obs_MRFSS_L(iyear)+dzero_dum)))/(2.0*square(MRFSS_L_cv(iyear)));
  }
  for (iyear=1981; iyear<=endyr_MRFSS_L; iyear++)
  {
    f_MRFSS_L+=square(log((pred_MRFSS_L(iyear)+dzero_dum)/
        (obs_MRFSS_L(iyear)+dzero_dum)))/(2.0*square(MRFSS_L_cv(iyear)));
  }
  fval+=w_L*f_MRFSS_L;
  fval_unwgt+=f_MRFSS_L;


//---Discards-------------------------------
  f_commHAL_D=0.0; //in 1000s
  for (iyear=styr_commHAL_D; iyear<=endyr_commHAL_D; iyear++)
  {
    f_commHAL_D+=square(log((pred_commHAL_D(iyear)+dzero_dum)/
        (obs_commHAL_D(iyear)+dzero_dum)))/(2.0*square(commHAL_D_cv(iyear)));
  }
  fval+=w_D*f_commHAL_D;
  fval_unwgt+=f_commHAL_D;


  f_HB_D=0.0; //in 1000s
  for (iyear=styr_HB_D; iyear<=endyr_HB_D; iyear++)
  {
    f_HB_D+=square(log((pred_HB_D(iyear)+dzero_dum)/
        (obs_HB_D(iyear)+dzero_dum)))/(2.0*square(HB_D_cv(iyear)));
  }
  fval+=w_D*f_HB_D;
  fval_unwgt+=f_HB_D;

  f_MRFSS_D=0.0; //in 1000s
  for (iyear=styr_MRFSS_D; iyear<=endyr_MRFSS_D; iyear++)
  {
    f_MRFSS_D+=square(log((pred_MRFSS_D(iyear)+dzero_dum)/
        (obs_MRFSS_D(iyear)+dzero_dum)))/(2.0*square(MRFSS_D_cv(iyear)));
  }
  fval+=w_D*f_MRFSS_D;
  fval_unwgt+=f_MRFSS_D;


//---Length comps-------------------------------
  f_commHAL_lenc=0.0;
  for (iyear=styr_commHAL_lenc; iyear<=endyr_commHAL_lenc; iyear++)
  {
    f_commHAL_lenc-=nsamp_commHAL_lenc(iyear)*
        sum( elem_prod((obs_commHAL_lenc(iyear)+dzero_dum),
            log(elem_div((pred_commHAL_lenc(iyear)+dzero_dum),
               (obs_commHAL_lenc(iyear)+dzero_dum)))));
  }
  fval+=w_lc*f_commHAL_lenc;
  fval_unwgt+=f_commHAL_lenc;

  f_commDV_lenc=0.;
```

```
  for (iyear=1; iyear<=nyr_commDV_lenc; iyear++)
  {
    f_commDV_lenc-=nsamp_commDV_lenc(iyear)*
         sum(elem_prod((obs_commDV_lenc(iyear)+dzero_dum),
             log(elem_div((pred_commDV_lenc(iyear)+dzero_dum),
                (obs_commDV_lenc(iyear)+dzero_dum)))));
  }
  fval+=w_lc*f_commDV_lenc;
  fval_unwgt+=f_commDV_lenc;

  f_HB_lenc=0.0;
  for (iyear=styr_HB_lenc; iyear<=endyr_HB_lenc; iyear++)
  {
    f_HB_lenc-=nsamp_HB_lenc(iyear)*
        sum( elem_prod((obs_HB_lenc(iyear)+dzero_dum),
            log(elem_div((pred_HB_lenc(iyear)+dzero_dum),
               (obs_HB_lenc(iyear)+dzero_dum)))));
  }
  fval+=w_lc*f_HB_lenc;
  fval_unwgt+=f_HB_lenc;

  f_MRFSS_lenc=0.;
  for (iyear=1; iyear<=nyr_MRFSS_lenc; iyear++)
  {
    f_MRFSS_lenc-=nsamp_MRFSS_lenc(iyear)*
         sum(elem_prod((obs_MRFSS_lenc(iyear)+dzero_dum),
             log(elem_div((pred_MRFSS_lenc(iyear)+dzero_dum),
                (obs_MRFSS_lenc(iyear)+dzero_dum)))));
  }
  fval+=w_lc*f_MRFSS_lenc;
  fval_unwgt+=f_MRFSS_lenc;


//---Age comps-------------------------------
  f_commHAL_agec=0.0;
  for (iyear=1; iyear<=nyr_commHAL_agec; iyear++)
  {
    f_commHAL_agec-=nsamp_commHAL_agec(iyear)*
            sum(elem_prod((obs_commHAL_agec(iyear)+dzero_dum),
               log(elem_div((pred_commHAL_agec(iyear)+dzero_dum),
                  (obs_commHAL_agec(iyear)+dzero_dum)))));
  }
  fval+=w_ac*f_commHAL_agec;
  fval_unwgt+=f_commHAL_agec;

  f_commDV_agec=0.0;
  for (iyear=1; iyear<=nyr_commDV_agec; iyear++)
  {
    f_commDV_agec-=nsamp_commDV_agec(iyear)*
            sum(elem_prod((obs_commDV_agec(iyear)+dzero_dum),
                log(elem_div((pred_commDV_agec(iyear)+dzero_dum),
                   (obs_commDV_agec(iyear)+dzero_dum)))));
  }
  fval+=w_ac*f_commDV_agec;
  fval_unwgt+=f_commDV_agec;

  f_HB_agec=0.0;
  for (iyear=1; iyear<=nyr_HB_agec; iyear++)
  {
    f_HB_agec-=nsamp_HB_agec(iyear)*
            sum(elem_prod((obs_HB_agec(iyear)+dzero_dum),
                log(elem_div((pred_HB_agec(iyear)+dzero_dum),
                   (obs_HB_agec(iyear)+dzero_dum)))));
  }
  fval+=w_ac*f_HB_agec;
  fval_unwgt+=f_HB_agec;

  f_MRFSS_agec=0.0;
  for (iyear=styr_MRFSS_agec; iyear<=endyr_MRFSS_agec; iyear++)
  {
    f_MRFSS_agec-=nsamp_MRFSS_agec(iyear)*
```

```
        sum(elem_prod((obs_MRFSS_agec(iyear)+dzero_dum),
            log(elem_div((pred_MRFSS_agec(iyear)+dzero_dum),
                (obs_MRFSS_agec(iyear)+dzero_dum)))));
  }
  fval+=w_ac*f_MRFSS_agec;
  fval_unwgt+=f_MRFSS_agec;


//-----------Constraints and penalties--------------------------------
  f_N_dev=0.0;
  //f_N_dev=norm2(log_dev_N_rec);
  f_N_dev=pow(log_dev_N_rec(styr_rec_dev),2);
  for(iyear=(styr_rec_dev+1); iyear<=endyr; iyear++)
  {
    f_N_dev+=pow(log_dev_N_rec(iyear)-R_autocorr*log_dev_N_rec(iyear-1),2);
  }
  fval+=w_R*f_N_dev;

//  f_N_dev_early=0.0;
//  f_N_dev_early=norm2(log_dev_N_rec(styr_rec_dev,(styr_rec_dev+5)));
//  fval+=w_R_init*f_N_dev_early;

  f_N_dev_end=0.0; //last 3 yrs
    f_N_dev_end=norm2(log_dev_N_rec(endyr-2,endyr));
  fval+=w_R_end*f_N_dev_end;

//  f_B1dB0_constraint=0.0;
//    f_B1dB0_constraint=square(totB(styr)/B0-B1dB0);
//  fval+=w_B1dB0*f_B1dB0_constraint;

  f_Fend_constraint=0.0; //last 3 yrs
  f_Fend_constraint=norm2(first_difference(fullF(endyr-2,endyr)));
  fval+=w_F*f_Fend_constraint;

  f_fullF_constraint=0.0;
  for (iyear=styr; iyear<=endyr; iyear++)
    {
     if (fullF(iyear)>3.0)
     {
     f_fullF_constraint+=square(fullF(iyear)-3.0);
     }
    }
  fval+=w_fullF*f_fullF_constraint;

//  f_cvlen_diff_constraint=0.0;
//    f_cvlen_diff_constraint=norm2(first_difference(log_len_cv_dev));
//  fval+=w_cvlen_diff*f_cvlen_diff_constraint;
//
//  f_cvlen_dev_constraint=0.0;
//    f_cvlen_dev_constraint=norm2(log_len_cv_dev);
//  fval+=w_cvlen_dev*f_cvlen_dev_constraint;

  //cout << "fval = " << fval << "  fval_unwgt = " << fval_unwgt << endl;


REPORT_SECTION
  //cout<<"start report"<<endl;
  get_sel_weighted_current();
  //cout<<"got sel weighted"<<endl;
  get_msy();
  //cout<<"got msy"<<endl;
  get_miscellaneous_stuff();
  //cout<<"got misc stuff"<<endl;
  get_per_recruit_stuff();
  //cout<<"got per recruit"<<endl;
  cout << "BC Fmsy=" << F_msy_out<< "   BC SSBmsy=" << SSB_msy_out <<endl;
  cout<<"Pop status="<<SSB(endyr)/SSB_msy_out<<endl;
  cout << "var_rec_resid="<<var_rec_dev<<endl;
  //cout << "x_dum="<<x_dum<<endl;

  report << "TotalLikelihood " << fval << endl;
```

```
  report<<" "<<endl;

  report << "Bias-corrected (BC) MSY stuff" << endl;
  report << "BC Fmsy " << F_msy_out << endl;
  report << "BC Emsy " << E_msy_out << endl;
  report << "BC SSBmsy " << SSB_msy_out << endl;
  report << "BC Rmsy " << R_msy_out << endl;
  report << "BC Bmsy " << B_msy_out << endl;
  report << "BC MSY " << msy_out << endl;
  report << "BC F/Fmsy " << fullF/F_msy_out << endl;
  report << "BC E/Emsy " << E/E_msy_out << endl;
  report << "BC SSB/SSBmsy " << SSB/SSB_msy_out << endl;
  report << "BC B/Bmsy " << totB/B_msy_out << endl;
  report << "BC Yield/MSY " << L_total_yr/msy_out <<endl;
  report << "BC F(2006)/Fmsy " << fullF(endyr)/F_msy_out << endl;
  report << "BC E(2006)/Emsy " << E(endyr)/E_msy_out << endl;
  report << "BC SSB(2006)/SSBmsy " << SSB(endyr)/SSB_msy_out << endl;
  report << "BC Predicted Landings(2006)/MSY " << L_total_yr(endyr)/msy_out <<endl;
  report  << " "<<endl;

  report << "Mortality and growth" << endl;
  report << "M "<<M<<endl;
  report << "Linf="<<Linf << "   K=" <<K<<"   t0="<< t0<<endl;
  report << "mean length " << meanlen << endl;
    report << "cv length " << len_cv << endl;
  report << "wgt " << wgt << endl;
  report<<" "<<endl;

  report << "Stock-Recruit " << endl;
  report << "R0= " << R0 << endl;
  report << "Steepness= " << steep << endl;
  report << "spr_F0= " << spr_F0 << endl;
  report << "Recruits(R) " << rec << endl;
  report << "VirginSSB " << S0 << endl;
  report << "SSB(styr)/VirginSSB " << S1S0 << endl;
  report << "SSB(2006)/VirginSSB " << popstatus << endl;
  report << "SSB " << SSB << endl;
  report << "Biomass " << totB << endl;
  report << "log recruit deviations (styr_rec_dev-2003)   " << log_dev_N_rec(styr_rec_dev,2003) <<endl;
  report << "variance of log rec dev (select yrs)  "<<var_rec_dev<<endl;
  report<<" "<<endl;

  report << "Exploitation rate (1901-2006)" << endl;
 report << E << endl;
 report << "Fully-selected F (1901-2006)" << endl;
 report << fullF << endl;
 report << "Headboat F" << endl;
 report << F_HB_out << endl;
 report << "MRFSS F" << endl;
 report << F_MRFSS_out << endl;
 report << "commHAL F" << endl;
 report << F_commHAL_out << endl;
 report << "commDV F" << endl;
 report << F_commDV_out << endl;
  report<<" "<<endl;
 report << "Headboat selectivity" << endl;
 report << sel_HB << endl;
 report << "Headboat DISCARD selectivity" << endl;
 report << sel_HB_D << endl;
 report << "MRFSS selectivity" << endl;
 report << sel_MRFSS << endl;
 report << "MRFSS DISCARD selectivity" << endl;
 report << sel_MRFSS_D << endl;
 report << "commHAL selectivity" << endl;
 report << sel_commHAL << endl;
 report << "commHAL DISCARD selectivity" << endl;
 report << sel_commHAL_D << endl;
 report << "commDV selectivity" << endl;
 report << sel_commDV << endl;

 report << "log_q_HAL "<<log_q_HAL<<endl;
```

```
report << "Obs  HAL U"<<obs_HAL_cpue << endl;
report << "pred HAL U"<<pred_HAL_cpue << endl;
report << "log_q_HB "<<log_q_HB<<endl;
report << "Obs  HB U"<<obs_HB_cpue << endl;
report << "pred HB U"<<pred_HB_cpue << endl;
report << "log_q_MRFSS "<<log_q_MRFSS<<endl;
report << "Obs  MRFSS U"<<obs_MRFSS_cpue << endl;
report << "pred MRFSS U"<<pred_MRFSS_cpue << endl;

report << "Obs  HB landings (1000s)"<<obs_HB_L << endl;
report << "pred HB landings (1000s)"<<pred_HB_L << endl;
report << "Obs  MRFSS landings (1000s)"<<obs_MRFSS_L << endl;
report << "pred MRFSS landings (1000s)"<<pred_MRFSS_L << endl;
report << "Obs  commHAL landings--postWWII (1000 lb)"<<obs_commHAL_L_2 << endl;
report << "pred commHAL landings--postWWII (1000 lb)"<<pred_commHAL_L_2 << endl;
report << "Obs  commDV landings (1000 lb)"<<obs_commDV_L << endl;
report << "pred commDV landings (1000 lb)"<<pred_commDV_L << endl;

#include "rs_make_Robject6.cxx"   // write the S-compatible report
```

Appendix C Data input file for AD Model Builder implementation of catch-at-age assessment model

```
##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
##  Data Input File
##  SEDAR15 Assessment: Red Snapper
##
##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>

#starting and ending year of model
1945
2006
#Starting year to estimate recruitment deviation from S-R curve
1974
#3 periods of size regs: 1901-83 no restrictions, 1984-91 12inch TL, 1992-06 20inch TL
#ending years of regulation period
1983
1991
##Number of ages (16 classes is 1,...15,20+)
20
##vector of agebins, last is a plus group
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
#number length bins
28
#Vector of length bins (mm)(midpoint of bin)
190 220 250 280 310 340 370 400 430 460 490 520 550 580 610 640 670 700 730 760 790 820 850 880 910 940 970 1000
#discard mortality constant
0.9  #comm HAL
0.4 #headboat
0.4 #MRFSS
#number of iterations in spr calculations (max F examined is (value-1)/100
101
#number of iterations in msy calculations (max F examined is (value-1)/1000
1001
#starting age for exploitation rate
2
#multiplicative bias correction (may set to 1.0 for none or negative to compute from rec variance)
-1.0
#starting values for VonBert params (Linf, K, t0), units in mm TL
894.7
0.235
-0.48
#starting value of constant cv of length at age
0.1
#length-weight (whole wgt) coefficients a and b, W=aL^b, (W=g, L=mm)
7.0E-06
3.104
#weight-weight conversion (gutted wgt=a*whole weight)
0.935
#time-variant vector of % maturity-at-age for females (ages 1-20)
0.2371 0.6435 0.9129 0.9838 0.9972 0.9995 0.9999 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000
 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000
#time-variant vector of proportion female (ages 1-16)
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
##################Commercial Hook and Line fishery landings#######################
#Commercial Hook and Line CPUE Index from Logbook
#Starting and ending years of CPUE index
1993
2006
#Observed CPUE and assumed CVs
1.0520 0.8560 0.8790 0.6910 0.6100 0.6880 0.8510 0.8690 1.3470 1.4750 1.2200 1.5230 1.2630 0.6770
0.1557 0.1626 0.1672 0.2015 0.2336 0.2405 0.2244 0.2382 0.1557 0.1511 0.1947 0.2015 0.2244 0.3000
#Commercial Hook and Line fishery landings
#Starting and ending years of post-WW2 landings time series, respectively
1945
2006
#Observed landings (1000 lb whole weight) and assumed CVs of post-WW2 period
```

```
240.8728 262.6156 284.3585 306.1014 327.8442 349.5871 498.5858 374.7653 389.0775 576.8748 479.6054 469.9846
 843.0190 594.6620 638.3276 652.2887 770.4032 575.9120 438.5230 486.3098 571.3961 643.4580 843.6164 938.6953
 610.9764 559.1361 478.8710 414.2849 340.1609 555.1961 650.9209 547.3689 579.1734 545.0425 380.7316 352.8625
 347.1376 286.0204 289.9523 230.5490 222.9973 200.1596 172.8222 152.0031 242.5327 201.6904 125.4217 87.5517
 206.3708 175.6062 164.0779 129.9766 98.8793 78.7447 78.9544 89.2141 169.8753 158.7980 117.1732 147.4730
 114.9833 79.0658
0.1716 0.1649 0.1581 0.1514 0.1446 0.1378 0.1311 0.1243 0.1176 0.1108 0.1041 0.0973 0.0905 0.0838 0.0770 0.0703
 0.0635 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500
 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500
 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500  0.0500
#Starting and ending years of discards time series, respectively
1984
2006
#Observed discards (1000s) and assumed CVs
7.5139 3.7113 7.0833 15.3593 7.5931 2.7985 30.5268 4.1107 18.2920 17.8600 24.4590 24.1530 32.2540 33.7250 25.5240
 22.9590 21.8100 23.6800 22.1330 18.9370 15.8130 15.2720 16.9140
0.2950 0.4390 0.5085 0.5780 0.4730 0.4190 0.4670 0.5150 0.1000 0.1000 0.1000 0.1000 0.1000 0.1000 0.1000
 0.1000 0.1000 0.1000 0.1000 0.1000 0.1000 0.1000 0.1000
#Starting and ending years of commercial hook and line length composition sample data
1984
2006
#sample size of commercial length comp data by year
2089 3539 1246 1146 621 1191 787 706 512 1347 1167 1442 770 497 428 946 881 1408 992 1270 795 618 406
#commercial length composition samples (year,lengthbin 30mm)
0.000000 0.000000 0.000000 0.000085 0.005792 0.010724 0.085283 0.234352 0.201790 0.125118 0.105871 0.053530
 0.039652 0.030128 0.024232 0.013502 0.020044 0.008436 0.002390 0.002178 0.004441 0.008564 0.009484
 0.011112 0.002179 0.001068 0.000042 0.000000
0.000000 0.000000 0.000563 0.000022 0.003253 0.025697 0.080921 0.155433 0.208769 0.147857 0.102327 0.088617
 0.055563 0.029593 0.018731 0.012442 0.005598 0.003519 0.003433 0.006096 0.006265 0.010781 0.010070
 0.010632 0.010780 0.003039 0.000000 0.000000
0.000000 0.000000 0.000000 0.002393 0.005895 0.024398 0.015051 0.048590 0.096989 0.167292 0.180142 0.136277
 0.067977 0.069566 0.067135 0.036575 0.022352 0.008465 0.003032 0.003615 0.009620 0.004854 0.008176
 0.012306 0.003963 0.005229 0.000109 0.000000
0.000000 0.000000 0.000000 0.003384 0.031572 0.069420 0.051955 0.051438 0.080792 0.061041 0.097334 0.132811
 0.092176 0.091513 0.067967 0.051861 0.024362 0.025431 0.012224 0.004491 0.005817 0.009671 0.007848
 0.009161 0.008391 0.006024 0.003317 0.000000
0.000000 0.000000 0.000000 0.010683 0.023213 0.071614 0.106530 0.095847 0.086477 0.079517 0.108594 0.089006
 0.082381 0.055006 0.050058 0.023540 0.021137 0.020883 0.018697 0.005139 0.017254 0.011850 0.004735
  0.010103 0.004848 0.002886 0.000000 0.000000
0.000000 0.000867 0.000000 0.000187 0.000187 0.007207 0.012757 0.038788 0.078355 0.111119 0.167015 0.191779
 0.151687 0.095468 0.039852 0.026702 0.010875 0.010038 0.014467 0.011981 0.008732 0.008127 0.003508
 0.002457 0.002976 0.003132 0.001734 0.000000
0.000000 0.000000 0.000000 0.000000 0.007187 0.023912 0.102282 0.100680 0.085245 0.105668 0.130364 0.100741
 0.082120 0.056583 0.056537 0.038945 0.028926 0.012038 0.014916 0.011652 0.003930 0.011868 0.004248
 0.009206 0.010019 0.002940 0.000000 0.000000
0.000000 0.000000 0.000000 0.003520 0.027120 0.085704 0.077641 0.072089 0.085789 0.047421 0.130354 0.112361
 0.056871 0.045916 0.043770 0.039953 0.038645 0.035647 0.014464 0.010264 0.010016 0.017017 0.017070
 0.015797 0.010011 0.001280 0.000000 0.001280
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000290 0.000290 0.008668 0.037135 0.122303
 0.080777 0.076936 0.111687 0.076600 0.116283 0.065519 0.043128 0.067884 0.027342 0.034881 0.042259
 0.036182 0.042980 0.008633 0.000223 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000580 0.000000 0.002365 0.001205 0.015594 0.184521 0.311655
 0.170655 0.084795 0.044039 0.018417 0.023796 0.023166 0.017725 0.017425 0.017792 0.015009 0.013663
 0.022304 0.010493 0.003640 0.001160 0.000000
0.006945 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.004728 0.097994 0.176468
 0.183151 0.173631 0.152049 0.097401 0.038121 0.009582 0.009817 0.004657 0.005623 0.005676 0.009250
 0.008946 0.010995 0.004964 0.000000 0.000000
0.000000 0.000000 0.000000 0.001129 0.000000 0.004517 0.003388 0.001129 0.001138 0.001138 0.028890 0.172011
 0.197772 0.139872 0.099993 0.076049 0.071969 0.051428 0.033255 0.011662 0.014816 0.017221 0.029455
 0.014914 0.020352 0.006777 0.001129 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.003139 0.009558 0.088592
 0.110470 0.147492 0.197828 0.109826 0.070920 0.071033 0.050255 0.060613 0.032182 0.015004 0.020857
 0.006221 0.006009 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.003936 0.007872 0.019681 0.039361 0.055107 0.032942 0.057294
 0.045514 0.110641 0.138206 0.103492 0.082770 0.079551 0.044944 0.051828 0.050376 0.023864 0.012532
 0.004418 0.015986 0.011808 0.007872 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.005062 0.010124 0.010157 0.067217 0.099009 0.107634
 0.164492 0.074950 0.050489 0.042590 0.040164 0.072483 0.067393 0.040024 0.040156 0.036661 0.017283
 0.016584 0.027406 0.010124 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000903 0.002710 0.006022 0.008735 0.005721 0.001204 0.099701 0.234114
 0.188871 0.127762 0.069294 0.058252 0.027671 0.029490 0.019167 0.025684 0.037589 0.024522 0.008000
```

```
 0.011553 0.011313 0.001419 0.000301 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.005970 0.013930 0.139393 0.211793
 0.125071 0.102238 0.080784 0.051535 0.047280 0.037462 0.038489 0.025883 0.049038 0.028726 0.020208
 0.014541 0.004849 0.001990 0.000818 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.001565 0.001565 0.001565 0.001817 0.138333 0.193514
 0.163702 0.146912 0.104656 0.074774 0.047701 0.024903 0.016542 0.018905 0.016780 0.016541 0.012668
 0.004947 0.009388 0.001611 0.000046 0.001565
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000868 0.006073 0.050424 0.214597
 0.226914 0.137309 0.118036 0.066931 0.080746 0.038634 0.022889 0.012568 0.010613 0.006841 0.001735
 0.000000 0.001617 0.003205 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000612 0.001429 0.001448 0.000408 0.001077 0.004177 0.016606 0.083204
 0.131355 0.173907 0.167763 0.143618 0.106735 0.052261 0.050997 0.028555 0.011270 0.007622 0.009124
 0.003939 0.001007 0.002883 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.001293 0.001810 0.002844 0.002069 0.001034 0.002808 0.009172 0.040471
 0.102190 0.136158 0.127005 0.145269 0.131415 0.149071 0.084374 0.033646 0.005910 0.004825 0.008410
 0.006119 0.002057 0.002056 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.003711 0.001399 0.008714 0.053582
 0.075220 0.089623 0.126035 0.095390 0.119910 0.104244 0.172768 0.072808 0.037749 0.011172 0.016287
 0.005316 0.003711 0.002312 0.000052 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.004988 0.004988 0.019953 0.004988 0.071136
 0.153878 0.128064 0.092837 0.098221 0.062168 0.069339 0.069226 0.046206 0.071914 0.036278 0.034978
 0.025816 0.005018 0.000000 0.000000 0.000000
#Number and vector of years of age compositions for hook and line fishery
12
1992 1994 1996 1997 1998 1999 2000 2001 2003 2004 2005 2006
#sample sizes of age comps by year (minimum sample size of 45)
48 49 167 182 75 147 226 144 51 103 140 189
#age composition samples (year,age)
0.0000 0.0000 0.0003 0.5245 0.1156 0.1288 0.1627 0.0625 0.0000 0.0057 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000
0.0000 0.0000 0.0858 0.0404 0.2011 0.2104 0.3775 0.0827 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0022
0.0000 0.0008 0.1367 0.0950 0.1504 0.3314 0.1966 0.0302 0.0167 0.0139 0.0114 0.0022 0.0033 0.0038 0.0022 0.0011 0.0011
 0.0000 0.0000 0.0032
0.0000 0.0146 0.1450 0.3713 0.1777 0.1843 0.0638 0.0166 0.0048 0.0026 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0195
0.0000 0.0724 0.4058 0.1118 0.2132 0.0803 0.0471 0.0412 0.0062 0.0070 0.0000 0.0029 0.0000 0.0000 0.0000 0.0029 0.0000
 0.0000 0.0000 0.0091
0.0000 0.1233 0.6037 0.1903 0.0538 0.0051 0.0068 0.0095 0.0015 0.0015 0.0009 0.0022 0.0006 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0008
0.0000 0.1265 0.7345 0.0861 0.0114 0.0170 0.0038 0.0088 0.0061 0.0038 0.0000 0.0000 0.0000 0.0000 0.0010 0.0000 0.0000
 0.0000 0.0000 0.0011
0.0000 0.1590 0.6282 0.1716 0.0109 0.0160 0.0025 0.0013 0.0020 0.0035 0.0000 0.0010 0.0000 0.0000 0.0000 0.0006 0.0000
 0.0000 0.0000 0.0034
0.0000 0.1281 0.3602 0.4029 0.0671 0.0346 0.0013 0.0000 0.0000 0.0021 0.0000 0.0026 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0012
0.0000 0.1282 0.4560 0.2686 0.1099 0.0335 0.0008 0.0015 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0007
 0.0000 0.0000 0.0008
0.0000 0.0205 0.1922 0.2365 0.1484 0.2563 0.0918 0.0227 0.0092 0.0000 0.0000 0.0000 0.0000 0.0031 0.0154 0.0034 0.0000
 0.0006 0.0000 0.0001
0.0000 0.0104 0.2738 0.3144 0.1251 0.1124 0.1255 0.0142 0.0172 0.0000 0.0000 0.0000 0.0040 0.0000 0.0028 0.0000 0.0000
 0.0000 0.0000 0.0000
##############################Commercial Diving fishery landings################################################
#Starting and ending years of landings time series, respectively
1984
2006
#Observed landings (1000 lb whole weight)  and CV's
1.2088 2.2732 0.5509 0.4157 0.2925 1.0968 1.6589 5.2658 9.4090 5.7426 12.9764 10.1594 6.1755 7.4878 7.9886 9.8820
 11.3574 19.9740 22.8772 17.2723 19.2213 9.4119 4.1019
0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500
 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500
#Number and vector of years of length compositions (comm diving)
4
1999 2000 2001 2003
#sample sizes of length comp data by year
83 129 87 210
#commercial diving length comp samples (year,age) (30mm length bins)
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.084337 0.096385
 0.072289 0.168675 0.048192 0.108434 0.096386 0.072289 0.012048 0.012048 0.024096 0.060241 0.072290
 0.036144 0.024096 0.012048 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.224806 0.279069
```

```
 0.147288 0.085272 0.077520 0.038760 0.023256 0.038760 0.015504 0.000000 0.015504 0.023256 0.023256
 0.007752 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.091954 0.195403
 0.137931 0.206896 0.126437 0.068966 0.022988 0.045977 0.022988 0.022988 0.011494 0.011494 0.011494
 0.022989 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.009524 0.057143 0.119047
 0.128572 0.133333 0.109523 0.076191 0.104762 0.076190 0.071429 0.047619 0.028572 0.028572 0.000000
 0.004762 0.004762 0.000000 0.000000 0.000000
#Number and vector of years of age compositions (comm diving)
1
2000
#sample sizes of age comp data by year
106
#commercial diving age comp samples (year,age) (30mm length bins)
0.0000 0.4481 0.5120 0.0306 0.0080 0.0000 0.0000 0.0000 0.0013 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000

#####################################Headboat landings#######################################
#Starting and ending years for CPUE index
1976
2006
#Observed CPUE values (numbers) and CVs,
3.1273 2.0784 2.1197 2.1377 1.1290 2.7770 1.0440 1.7046 1.5543 2.2851 0.5111 0.6124 0.5635 0.9523 0.9867 0.6188 0.0814
 0.2131 0.2249 0.3025 0.2018 0.2232 0.1793 0.2935 0.3888 0.8216 1.0053 0.5184 0.9687 0.9029 0.4730
0.0466 0.0645 0.0526 0.0547 0.0760 0.0492 0.0813 0.0580 0.0632 0.0472 0.1043 0.0950 0.0989 0.0820 0.0789 0.1042 0.3000
 0.1749 0.1742 0.1510 0.2049 0.2312 0.1993 0.1492 0.1338 0.0836 0.0757 0.1196 0.0778 0.0843 0.1258
#Starting and ending years for landings time series
1972
2006
#Headboat landings vector (1000 lb whole weight) and CV’s
91.9195 117.3068 77.0601 83.5177 109.2828 59.9280 62.9797 54.1306 54.6560 116.5865 98.0245 74.0044 81.4175 132.0839
 54.3806  81.8396 130.0701 70.7963 65.6860 72.0302 28.9160 42.7177 53.4220 57.4743 46.2349 51.2053 26.8480 43.5588
 49.4030 68.3849 70.7972  41.3535 80.3494 58.6955 41.4320
0.1000 0.1000 0.1000 0.1000 0.1000 0.1000 0.1000 0.1000 0.1000 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500
 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500 0.0500
 0.0500 0.0500 0.0500 0.0500
#Starting and ending years of discards time series, respectively
1984
2006
#Observed discards (1000s) and assumed CVs
8.2243 6.9261 6.0487 20.4313 16.5317 3.5675 26.1743 5.3889 3.2597 24.5857 18.5721 28.2857 10.8805 3.4248 20.6495 18.2722
 24.7013 47.3119 40.3947 25.5998 43.8402 39.6659 28.7009
0.2950 0.4390 0.5085 0.5780 0.4730 0.4190 0.4670 0.5150 0.2940 0.2840 0.2890 0.2020 0.3800 0.2690 0.3250 0.1590 0.1480
 0.1380 0.1820 0.1620 0.1430 0.1340 0.1820
#Starting and ending year of headboat length composition data
1978
2006
#sample sizes of length comp data by year
740 245 258 674 457 1006 1317 1190 435 306 204 374 433 152 73 203 524 147 80 68 149 161 123 254 361 329 307 193 172
#HB recreational length comp samples (year,lengthbin)
0.000000 0.011192 0.029757 0.044504 0.102228 0.112909 0.183413 0.157412 0.070186 0.039671 0.052280 0.054473
 0.032152 0.015917 0.012819 0.006614 0.016111 0.006229 0.018435 0.005275 0.007924 0.004634 0.006693
 0.005423 0.003199 0.000403 0.000000 0.000147
0.000000 0.004401 0.000000 0.000180 0.074823 0.132041 0.198242 0.185218 0.049501 0.026770 0.030810 0.022007
 0.017967 0.000000 0.014044 0.008803 0.044014 0.048415 0.053294 0.035573 0.026408 0.018083 0.004763
 0.004401 0.000239 0.000000 0.000000 0.000000
0.000000 0.013821 0.018428 0.041652 0.129184 0.147611 0.134841 0.162672 0.094989 0.063692 0.041322 0.023945
 0.010642 0.004978 0.014003 0.004985 0.009214 0.004607 0.004796 0.009396 0.000363 0.004970 0.004607
 0.004607 0.023035 0.027642 0.000000 0.000000
0.000000 0.003285 0.003285 0.017868 0.085598 0.191654 0.189528 0.178150 0.112231 0.053740 0.033016 0.016669
 0.006955 0.006425 0.004908 0.004866 0.009277 0.016554 0.011926 0.020010 0.009277 0.003285 0.010567
 0.005471 0.002182 0.001091 0.000000 0.002182
0.000000 0.003244 0.006487 0.020157 0.080609 0.117952 0.064175 0.080709 0.118593 0.151585 0.119034 0.091946
 0.041488 0.025608 0.006705 0.009949 0.008289 0.004682 0.015604 0.008998 0.004746 0.011713 0.002257
 0.003623 0.000190 0.001656 0.000000 0.000000
0.000000 0.001518 0.024907 0.056075 0.182923 0.259970 0.207947 0.126528 0.046318 0.023201 0.019594 0.004893
 0.005247 0.004045 0.006513 0.003835 0.001814 0.003782 0.005154 0.003915 0.006001 0.001668 0.000117
 0.003245 0.000031 0.000000 0.000759 0.000000
0.000000 0.002567 0.012035 0.031952 0.169169 0.233278 0.180632 0.149956 0.083270 0.041962 0.025230 0.019959
 0.005345 0.003129 0.006809 0.000918 0.004749 0.003878 0.000786 0.003947 0.003502 0.000804 0.006273
 0.006341 0.003508 0.000000 0.000000 0.000000
```

```
0.000000 0.001374 0.005049 0.030662 0.157596 0.217217 0.218549 0.174736 0.079380 0.036921 0.023019 0.013005
 0.009546 0.009494 0.006095 0.001822 0.000505 0.000954 0.001374 0.000126 0.002328 0.000415 0.002874
 0.004122 0.001500 0.000505 0.000000 0.000828
0.001689 0.001689 0.008009 0.075292 0.171497 0.102916 0.103201 0.136420 0.076763 0.046258 0.067023 0.077775
 0.048677 0.039086 0.011287 0.007304 0.002941 0.008237 0.001689 0.006548 0.000000 0.000000 0.000000
 0.003474 0.002226 0.000000 0.000000 0.000000
0.000000 0.020030 0.024141 0.055009 0.083918 0.135126 0.194120 0.162665 0.073043 0.071123 0.038037 0.021156
 0.033534 0.012724 0.025297 0.013556 0.017831 0.010946 0.000000 0.000000 0.000000 0.000000 0.007744
 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.010641 0.006539 0.023320 0.057288 0.150149 0.159890 0.210842 0.063596 0.059081 0.063369 0.017175
 0.022272 0.029238 0.017745 0.017758 0.018587 0.025845 0.008176 0.024936 0.000000 0.000000 0.004116
 0.004116 0.005321 0.000000 0.000000 0.000000
0.000000 0.000062 0.001397 0.016816 0.110482 0.274537 0.173677 0.152228 0.080688 0.031175 0.042780 0.026141
 0.019826 0.004837 0.011557 0.003524 0.005395 0.004243 0.013270 0.003071 0.008485 0.003071 0.009214
 0.000000 0.003071 0.000452 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.109130 0.204279 0.186408 0.193689 0.076475 0.075931 0.029714 0.029096
 0.018826 0.022760 0.030595 0.001776 0.001440 0.001444 0.001444 0.000000 0.000000 0.003743 0.011810
 0.001440 0.000000 0.000000 0.000000 0.000000
0.001304 0.000000 0.020080 0.046160 0.050278 0.183048 0.115281 0.144787 0.127764 0.102726 0.080835 0.013956
 0.054539 0.006956 0.011053 0.001304 0.001835 0.011671 0.000405 0.000000 0.000000 0.007474 0.000000
 0.007000 0.011545 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.016674 0.000000 0.000000 0.009215 0.000000 0.000000 0.076216 0.335667 0.213706
 0.004226 0.080442 0.097116 0.018099 0.020976 0.075885 0.000000 0.000000 0.012015 0.012015 0.013874
 0.013874 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.002393 0.005187 0.049647 0.180985 0.295728
 0.192317 0.074039 0.036253 0.065912 0.022315 0.016307 0.015594 0.015160 0.009534 0.006721 0.000000
 0.000000 0.011908 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.006602 0.054936 0.255356
 0.247441 0.155006 0.033299 0.047331 0.104350 0.007875 0.037809 0.034508 0.000000 0.000000 0.003938
 0.000000 0.000000 0.011550 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.009608 0.062942 0.171435
 0.228337 0.227544 0.072940 0.062006 0.049309 0.062812 0.022220 0.001079 0.005240 0.000540 0.012781
 0.005604 0.000000 0.005604 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.001338 0.182169 0.126638
 0.186246 0.185110 0.114190 0.054069 0.035506 0.038152 0.028520 0.026155 0.001338 0.000000 0.017753
 0.002816 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.006552 0.000000 0.002184 0.000000 0.000000 0.030757 0.114563 0.115212
 0.075882 0.091838 0.234829 0.127920 0.075701 0.022183 0.018465 0.000000 0.041713 0.000000 0.027851
 0.014350 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000253 0.000000 0.000379 0.000126 0.002800 0.000253 0.000772 0.000000 0.114421 0.318315
 0.317866 0.119523 0.056733 0.000000 0.021398 0.011664 0.014338 0.011664 0.004148 0.002674 0.002674
 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.001251 0.000000 0.002389 0.000000 0.011424 0.114412 0.243072
 0.204686 0.185032 0.110314 0.027806 0.027478 0.037045 0.016337 0.006080 0.005344 0.001251 0.006080
 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.001538 0.000000 0.018463 0.167852 0.203492
 0.239393 0.160860 0.153910 0.029702 0.010665 0.013676 0.000000 0.000000 0.000000 0.000000 0.000447
 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.003479 0.000000 0.003479 0.010598 0.055454 0.244992
 0.211144 0.218545 0.090924 0.065779 0.027040 0.032611 0.005435 0.008914 0.010870 0.000000 0.000000
 0.000000 0.010734 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000064 0.000064 0.000000 0.000064 0.002568 0.024455 0.143824 0.231925
 0.151848 0.195072 0.111591 0.046002 0.027558 0.031172 0.013662 0.010260 0.003402 0.000000 0.006469
 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.170145 0.293279
 0.222072 0.107563 0.037570 0.056529 0.040391 0.018838 0.014042 0.016901 0.003735 0.007188 0.004278
 0.003735 0.003735 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000045 0.000000 0.007128 0.069609 0.163440
 0.341638 0.218792 0.064774 0.037034 0.033085 0.026396 0.008172 0.015035 0.000000 0.003888 0.003564
 0.003512 0.000000 0.003888 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.010350 0.075201 0.210663
 0.226903 0.146013 0.057810 0.071272 0.065479 0.034519 0.058648 0.013783 0.014157 0.015201 0.000000
 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000020 0.000020 0.000000 0.032339 0.153295
 0.263444 0.268072 0.099291 0.039919 0.035151 0.025342 0.017735 0.016894 0.026023 0.015487 0.001020
 0.000000 0.005951 0.000000 0.000000 0.000000
#Number and vector of years of age compositions (headboat)
13
1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1989 1996
#sample sizes of age comp data by year
72 279 47 94 415 134 754 619 511 192 93 57 124
```

```
#headboat age comp samples (year,age)
0.0417 0.5278 0.1667 0.1667 0.0139 0.0417 0.0278 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0139
 0.0000 0.0000 0.0000 0.0000
0.0215 0.4050 0.5054 0.0323 0.0179 0.0072 0.0072 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0072
0.0000 0.6170 0.1702 0.0426 0.0851 0.0426 0.0426 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0000
0.1809 0.5106 0.2340 0.0319 0.0000 0.0213 0.0000 0.0213 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0000
0.0265 0.7012 0.1855 0.0337 0.0169 0.0120 0.0048 0.0048 0.0048 0.0000 0.0000 0.0000 0.0024 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0072
0.0448 0.4030 0.4030 0.0672 0.0299 0.0075 0.0075 0.0075 0.0075 0.0075 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0075 0.0000 0.0075
0.3939 0.4655 0.0942 0.0186 0.0093 0.0066 0.0040 0.0027 0.0013 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0013 0.0000 0.0027
0.1599 0.6656 0.1018 0.0178 0.0162 0.0065 0.0048 0.0016 0.0016 0.0032 0.0048 0.0000 0.0032 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0128
0.0431 0.7652 0.1605 0.0137 0.0020 0.0039 0.0000 0.0020 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0020
 0.0000 0.0020 0.0020 0.0039
0.0521 0.4531 0.4115 0.0573 0.0104 0.0052 0.0052 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0052
0.1613 0.2473 0.5054 0.0645 0.0215 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0000
0.0877 0.4035 0.3860 0.0702 0.0175 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0175 0.0000 0.0000 0.0000
 0.0175 0.0000 0.0000 0.0000
0.0000 0.0081 0.2742 0.1210 0.1048 0.2419 0.1129 0.0323 0.0242 0.0161 0.0242 0.0081 0.0000 0.0081 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0243

##################################MRFSS landings  ################################
#Recreational MRFSS CPUE Index
#Starting and ending years of CPUE index
1983
2006
#Observed CPUE and assumed CVs
1.7160 1.5691 1.3622 0.7150 0.6482 0.7041 0.5839 0.2003 0.6767 1.0674 1.1483 0.7437 0.7593 0.6646 1.0756 0.8021
 1.4787 1.3397 1.1153 0.9938 1.1537 1.2935 1.2070 0.9818
0.1426 0.1244 0.1414 0.2612 0.3000 0.2020 0.1386 0.2421 0.2215 0.1233 0.1887 0.1698 0.1282 0.2270 0.2812 0.1746
 0.1046 0.0989 0.0928 0.1111 0.1104 0.0945 0.0896 0.1258
#Recreational Charter+Private boat landings
#Starting and ending years for landings time series
1947
2006
#MRFSS landings vector (1000 lb whole weight)
292.4449 584.8897 877.3346 1169.7795 1462.2243 1754.6692 2047.1141 2339.5589 2632.0038 2924.4487 3216.8935
 3509.3384 3801.7832 4094.2281 4411.7825 4729.3369 5046.8912 5364.4456 5682.0000 4933.2000 4184.4000
 3435.6000 2686.8000 1938.0000 1787.3110 1544.7025 1368.6262 1258.1839 1101.0373 924.5833 823.2490 669.5083
 527.6684 376.4540 280.4210 246.2609 329.7836 532.3594 559.5652 435.8287 247.6627 285.1564 313.7427
 272.7566 222.2649 269.3082 258.7844 117.5910 110.0483 116.8490 114.0103 193.9496 275.7707 355.6031
 364.5065 304.9288 299.4494 273.8766 273.2545 271.6663
0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877
 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877 0.2877
 0.2877 0.2877 0.3250 0.2720 0.2660 0.1720 0.2910 0.2730 0.2000 0.2700 0.3010 0.0790 0.3420 0.3830 0.2740 0.3670
 0.2800 0.5020 0.4360 0.3170 0.1790 0.2390 0.1910 0.1690 0.1800 0.1640 0.1730 0.2400
#Starting and ending years of discards time series, respectively
1984
2006
#Observed discards (1000s) and assumed CVs
108.7990 72.5327 65.6727 51.7003 58.3797 22.8037 18.6770 17.9965 49.9785 54.6227 61.7633 44.9027 28.1797 20.3747 73.6213
 155.5143  215.9903 199.8760 166.4613 159.9920 157.2377 150.1130 130.4310
0.2950 0.4390 0.5085 0.5780 0.4730 0.4190 0.4670 0.5150 0.2940 0.2840 0.2890 0.2020 0.3800 0.2690 0.3250 0.1590
 0.1480 0.1380 0.1820 0.1620 0.1430 0.1340 0.1820
#Number and vector of years of length compositions (mrfss)
16
1981 1983 1984 1985 1986 1987 1988 1989 1999 2000 2001 2002 2003 2004 2005 2006
#sample sizes of length comp data by year
44 161 370 249 226 63 87 59 132 95 120 232 166 156 83 84
#mrfss length comp samples (year,age) (30mm length bins)
0.000000 0.004157 0.236882 0.114186 0.104372 0.000000 0.090207 0.151488 0.014833 0.141937 0.020970
 0.020970 0.079028 0.020970 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.129796 0.154287 0.123536 0.122646 0.078259 0.138223 0.108759 0.035931 0.011872 0.008151 0.030527
```

```
 0.029117 0.000000 0.000000 0.027014 0.001255 0.000627 0.000000 0.000000 0.000000 0.000000
 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.020221 0.090890 0.188465 0.252555 0.197856 0.090460 0.011589 0.030233 0.086400 0.016738 0.002021
 0.005644 0.002095 0.004029 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000804
 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.022865 0.151662 0.098149 0.082313 0.068166 0.036538 0.026657 0.037257 0.118753 0.000710 0.174114
 0.081986 0.087967 0.002268 0.005297 0.000000 0.000000 0.005297 0.000000 0.000000 0.000000
 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.013735 0.472811 0.094212 0.183259 0.108405 0.083864 0.000000 0.011697 0.032017 0.000000 0.000000
 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.175341 0.000000 0.115138 0.089666 0.163768 0.173663 0.005704 0.019016 0.135747 0.053603
 0.048733 0.000000 0.017294 0.002327 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.812215 0.072169 0.000000 0.115615 0.000000 0.000000 0.000000 0.000000 0.000000
 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.128728 0.182724 0.133831 0.070753 0.103667 0.140636 0.073020 0.023029 0.025690 0.039460 0.001089
 0.000000 0.031447 0.026650 0.019275 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.037173 0.250817 0.165887 0.088738 0.060234 0.027233 0.006234 0.041877 0.096174
 0.011463 0.056369 0.057686 0.008136 0.034289 0.020465 0.008136 0.004321 0.008136 0.000000
 0.000000 0.016632 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.011685 0.020914 0.009220 0.011587 0.000000 0.004419 0.055707 0.352879
 0.189844 0.108603 0.036373 0.072400 0.028172 0.012449 0.072400 0.006509 0.003898 0.000000
 0.002938 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.020654 0.000000 0.025002 0.020654 0.032271 0.055661 0.286802
 0.202812 0.075627 0.120878 0.041450 0.033019 0.000000 0.025898 0.004285 0.002143 0.020122
 0.030176 0.002546 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000314 0.000314 0.009179 0.063032 0.099141
 0.262279 0.136474 0.114177 0.110730 0.106753 0.061971 0.015982 0.010021 0.005715 0.001306
 0.001306 0.001306 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.127279 0.056475 0.009475 0.049574 0.021806 0.030561 0.129571
 0.068645 0.075096 0.032077 0.132556 0.059181 0.078273 0.073809 0.039091 0.004265 0.000000
 0.000000 0.010550 0.000000 0.001716 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.018412 0.059403 0.041620 0.149247
 0.230105 0.111686 0.127270 0.096927 0.066860 0.018885 0.023925 0.028698 0.011801 0.005256
 0.002187 0.003457 0.004260 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.044904 0.020009 0.000000 0.023988 0.023130 0.190900
 0.289755 0.066240 0.059448 0.035328 0.021633 0.115822 0.044680 0.028232 0.010841 0.023232
 0.000000 0.001857 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.024675 0.012337 0.006169 0.006169 0.000000 0.000000 0.000000 0.000000 0.013208 0.188583
 0.233792 0.094847 0.019260 0.063917 0.030058 0.000000 0.113346 0.054149 0.010798 0.037220
 0.000000 0.026461 0.021671 0.021671 0.000000 0.000000 0.021671
#Starting and ending year of mrfss age composition data
2001
2005
#sample sizes of mrfss age comp data by year
75 386 389 311 256
#mrfss age comps (year,lengthbin)
0.0000 0.2533 0.5067 0.1600 0.0267 0.0267 0.0133 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0133
0.0000 0.2409 0.5492 0.1192 0.0440 0.0207 0.0078 0.0078 0.0026 0.0026 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0052
0.0000 0.2314 0.3650 0.2622 0.0771 0.0129 0.0103 0.0026 0.0129 0.0129 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0026 0.0000 0.0000 0.0104
0.0000 0.2797 0.3859 0.1640 0.0900 0.0354 0.0032 0.0032 0.0064 0.0064 0.0000 0.0000 0.0096 0.0032 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0128
0.0000 0.1055 0.4570 0.2500 0.1328 0.0273 0.0078 0.0000 0.0000 0.0000 0.0039 0.0039 0.0000 0.0078 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0039
###############Likelihood Component Weighting######################################################################
#Weights in objective fcn
1000.0  #landings
1000.0  #discards
1.0  #length comps
1.0  #age comps
100.0  #HAL cpue index
10.0  #HB cpue index
10.0     #MRFSS cpue index
100.0 #S-R residuals
0.0  #constrain first several years of recruitment variability
```

```
1000.0 #additional constraint on variability of recruitment in last three yrs
0.0  #constrain variability of F in last three years
0.0  #constraint B1/B0
1000.0   #penalty if F exceeds 3.0
0.0  #penalty on deviation in CV at age
0.0     #penalty on first difference in CV at age

################Parameter values and initial guesses##############################################################################
#bias adjustment (multiplier) for MRFSS landings
1.0
#annual rate of increase on all fishery dependent q's
0.02
#steepness (fixed or initial guess)
0.75
#natural mortality at age
0.2304 0.1566 0.1254 0.1085 0.0981 0.0912 0.0864 0.0830 0.0805 0.0786 0.0772 0.0761 0.0753
 0.0746 0.0741 0.0737 0.0734 0.0732 0.0730 0.0728

#age-independent natural mortality (used only to compute MSST=(1-M)SSBmsy)
0.0781
#log catchabilities (initial guesses)
-6.0    #commHAL
-12.0   #HB
-12.0   #MRFSS
#log mean F's (initial guesses)
-2.0   #commHAL post-WWII
-3.0   #commDV
-3.0   #HB
-2.0   #MRFSS
#log mean F's for discards (initial guesses)
-3.0   #commHAL discards
-3.0   #HB discards
-2.0   #MRFSS discards
#log_R0 - log virgin recruitment
12.0
#R1_mult: R(styr)=R1_mult*R1.  R1=R0 if S1dS0=1
1.0
#B1/B0 constraint
0.75
# R autocorrelation
0.0
#Selectivity parameters.
#Initial guess must be within boundaries.
  #init_bounded_number selpar_slope_commDV1(0.5,12.0,1);
  #init_bounded_number selpar_L50_commDV1(0.1,10.,1);
  #init_bounded_number selpar_slope2_commDV1(0.1,12.0,3);
  #init_bounded_number selpar_L502_commDV1(1.0,20.0,3);

2.0 #selpar_L50_commHAL1  b1
2.0 #selpar_slope_commHAL1 b3
10.0 #selpar_L502_commHAL1  b1
0.0 #selpar_slope2_commHAL1 b3
2.0 #selpar_L50_commHAL2  b1
2.0 #selpar_slope_commHAL2 b3
10.0 #selpar_L502_commHAL2  b1
0.0 #selpar_slope2_commHAL2 b3
4.0 #selpar_L50_commHAL3  b1
2.0 #selpar_slope_commHAL3 b3
10.0 #selpar_L502_commHAL3  b1
0.0 #selpar_slope2_commHAL3 b3

3.0 #selpar_L50_commDV1 b1
10.0 #selpar_L502_commDV1 b2
2.0 #selpar_slope_commDV1 b3
1.0 #selpar_slope2_commDV1 b4

2.0 #selpar_L50_HB1 b1
3.0 #selpar_slope_HB1      b3
10.0 #selpar_L502_HB1  b1
0.0 #selpar_slope2_HB1 b3
2.0 #selpar_L50_HB2  b1
```

```
10.4 #selpar_slope_HB2      b3
10.0 #selpar_L502_HB2  b1
0.0 #selpar_slope2_HB2 b3
4.0 #selpar_L50_HB3  b1
3.0 #selpar_slope_HB3      b3
10.0 #selpar_L502_HB3  b1
0.0 #selpar_slope2_HB3 b3

2.0 #selpar_L50_MRFSS1 b1
3.0 #selpar_slope_MRFSS1      b3
10.0 #selpar_L502_MRFSS1  b1
0.0 #selpar_slope2_MRFSS1 b3
2.0 #selpar_L50_MRFSS2  b1
10.4 #selpar_slope_MRFSS2      b3
10.0 #selpar_L502_MRFSS2  b1
0.0 #selpar_slope2_MRFSS2 b3
4.0 #selpar_L50_MRFSS3  b1
3.0 #selpar_slope_MRFSS3      b3
10.0 #selpar_L502_MRFSS3  b1
0.0 #selpar_slope2_MRFSS3 b3

0.5 #commHAL discard selectivity of age 1: value prior to standardizing to one
0.5 #HB discard selectivity of age 1: value prior to standardizing to one
0.5 #MRFSS discard selectivity of age 1: value prior to standardizing to one

999 #end of data file flag
```

Appendix D Parameter estimates from AD Model Builder implementation of catch-at-age assessment model

```
# Number of parameters = 312  Objective function value = 16451.9  Maximum gradient component = 19726.1
# log_len_cv:
-2.15648784892
# log_R0:
13.3128344188
# steep:
0.949859882180
# log_dev_N_rec:
 -0.00235346720443 0.244971211035 -0.0366583783528 0.0650572572250 -0.0121136773153
 -0.420479893992 0.460766239921 -0.735971495785 -0.0418362285841 0.660835931526
 1.03648952870 -0.218685360548 0.0327555292295 0.326270090336 0.113052702574
 0.112544052963 0.0423009815001 0.395298770412 -0.339795984693 -0.700001570534
 -0.711967228540 -0.663401142407 -0.240517559991 -0.127310978501 0.666264673458
 0.661635094279 0.294547815266 -0.115521156760 -0.0535322293854 -0.410272657978
 -0.163958690852 -0.0888654462297 -0.0295467307694
# R_autocorr:
0.333753438920
# selpar_slope_commHAL2:
11.9984819496
# selpar_L50_commHAL2:
2.05591477850
# selpar_slope_commHAL3:
4.32167562058
# selpar_L50_commHAL3:
3.21678138968
# selpar_slope_commDV1:
0.773690913760
# selpar_L50_commDV1:
8.91928060462
# selpar_slope2_commDV1:
1.11324247999
# selpar_L502_commDV1:
1.48787259102
# selpar_slope_HB1:
11.9984058155
# selpar_L50_HB1:
1.10646231368
# selpar_L50_HB2:
1.30701823180
# selpar_slope_HB3:
10.3201958594
# selpar_L50_HB3:
3.03280141155
# selpar_L50_MRFSS2:
1.04472365415
# selpar_slope_MRFSS3:
4.48100106675
# selpar_L50_MRFSS3:
1.85736444315
# log_q_HAL:
-6.30344972238
# log_q_HB:
-12.3683685103
# log_q_MRFSS:
-12.5847492845
# log_avg_F_commHAL_2:
-2.59687803490
# log_F_dev_commHAL_2:
 -2.89864906942 -2.80830940126 -2.72635828847 -2.64869598225 -2.57441499487 -2.50232821790
 -2.13537277774 -2.40537359876 -2.34945034707 -1.93070589814 -2.08433639889 -2.06871567073
 -1.43815596788 -1.73172165630 -1.59871303392 -1.50383337177 -1.24929851283 -1.43633547050
 -1.58880274736 -1.33867627982 -0.986321252602 -0.639056871022 -0.117493767719
 0.265575609897 0.100857422982 0.213104090311 0.210893560976 0.202611290208 0.118674198424
 0.730935182130 1.07230051834 1.06270783029 1.32385732621 1.48902126813 1.33941528847
```

```
 1.45979487253 1.40942765223 1.36035600380 1.44978388893 1.56741923740 1.41497557107
 1.26400203746 1.28523132671 1.15445475167 1.64660457913 1.55416107275 1.09152538162
 1.09428764801 1.83170179112 1.53713585012 1.55423599341 1.50427098073 1.37399863361
 1.14479239156 1.04596737485 0.973633208325 1.31759667576 1.13578043737 0.801114133997
 1.07838414224 0.932563255756 0.647967098714
# log_avg_F_commDV:
-2.79620224579
# log_F_dev_commDV:
 -1.45960851069 -0.574516136348 -1.85139425956 -2.15659488794 -2.60673599875 -1.29785259977
 -0.826310068805 0.323460161585 0.828783329469 0.336050195635 1.15755035615 0.827872178035
 0.286208237289 0.467339918017 0.540313138558 0.786575090210 0.925107801059 1.43539961130
 1.47513952348 1.00105845493 0.942742869352 0.163049347689 -0.723637750897
# log_avg_F_HB:
-2.63465473348
# log_F_dev_HB:
 -1.26525519814 -0.908175089712 -1.20602780830 -0.943249974923 -0.510718510463
 -0.906945550769 -0.631297216274 -0.573630022233 -0.367573838887 0.355846551406
 0.326767813116 0.121636984852 0.197763920371 0.537842162609 -0.128832518450
 0.375241249298 0.778192070065 0.239027233044 0.243087608479 0.355048314005
 -0.0546865382767 0.180907280030 0.322173223678 0.498525331402 0.461482412236
 0.697386302348 0.0225669157434 0.412721969873 0.298437299631 0.345493238302
 0.294415731400 -0.255919396890 0.452239052873 0.253076033109 -0.0175670345521
# log_avg_F_MRFSS:
-1.70225344506
# log_F_dev_MRFSS:
 -3.59288730447 -2.89568011761 -2.48447219329 -2.18882381546 -1.95365678321
 -1.75574421696 -1.58302857850 -1.42447866054 -1.27551806764 -1.13412806714
 -0.992414031727 -0.849805104974 -0.707453851783 -0.559941950366 -0.396959387259
 -0.223359719540 -0.0381383359997 0.169727903754 0.418498923911 0.505332275144
 0.591081132131 0.669881784364 0.688459341524 0.562361689325 0.634107384519
 0.624750712891 0.616834148442 0.655005445702 0.702931495383 0.697438730532
 0.790503291153 0.803280676084 0.784606846687 0.641434154951 0.314943889533
 0.335675638532 0.697792447244 1.04189689670 1.02750657537 0.975911982446
 0.480605526705 0.562270375804 0.709494329038 0.685200969027 0.449789153396
 0.612966518713 0.553316540652 -0.107701870929 -0.0469192860845 0.154233300344
 0.137926270955 0.569636376303 0.674660774115 0.650551139644 0.581787648393
 0.453814585040 0.450313261331 0.435766342964 0.547898618414 0.550916246314
# log_avg_F_commHAL_D:
-2.97348527107
# log_F_dev_commHAL_D:
 -1.38998894022 -1.75687712426 -0.447513066639 0.0267971589529 -0.706703801841
 -1.58012319512 0.883652830166 -1.26281962918 0.102974461750 0.429759451573
 1.06406381592 1.15047093498 1.28522749429 1.10775528579 0.385791245350
 -0.0741569384813 -0.143537396604 0.172729609305 0.261476950021 0.234652923259
 0.141866805017 0.0462990647262 0.0682020612505
# log_avg_F_HB_D:
-3.76334013483
# log_F_dev_HB_D:
 -1.32071332223 -1.15408594337 -0.626702673318 0.291965617274 0.0503101427666
 -1.35826077377 0.711152683668 -1.01270400205 -1.66435725268 0.677136694330
 0.736582581445 1.26209162287 0.156288242317 -1.21913936928 0.133612221606
 -0.336360852546 -0.0677889929106 0.810343088306 0.813490429198 0.490560081798
 1.11097893068 0.962221549644 0.553379296250
# log_avg_F_MRFSS_D:
-2.24501469505
# log_F_dev_MRFSS_D:
 -0.256856309739 -0.322049075516 0.240913059127 -0.299914836616 -0.210750145174
 -1.02269191415 -1.14424230999 -1.32662189322 -0.433135371522 0.00830769935766
 0.451389600002 0.231302928222 -0.389182192329 -0.935813878376 -0.0949354168395
 0.299073387956 0.608752165218 0.765256439660 0.738499726078 0.827810499761
 0.899811230571 0.793397628835 0.571678978685
```

Appendix E ASPIC Input: Computer input file to run base production model.

```
FIT                           Run Mode
"SAFMC Red Snapper SEDAR 15 (2007), increasing q 2%/yr from 1980"
LOGISTIC YLD SSE              Modeltype, conditioning, loss fn
112                           Verbosity
600                           N Bootstraps
1  10000                      Monte Carlo
1d-8                          Conv (fit)
3d-8  8                       Conv (restart), N restarts
1d-4  6                       Conv (F), steps/yr for generalized
4                             Max F allowed
1                             Weight for B1>K
3                             Number of series
1d0 1d0 1d0                   Series weights  (HB, CHL, MRFSS)
0.95d0                         B1/K guess
2000000.0                         MSY guess
12000000.0                        K guess
5d-8 5d-8 5d-8                q guess
0 1 1 1 1 1                   Estimate flags
100000.0  4000000.0                 MSY bounds
5000000.0  150000000.0               K bounds
82184571                      Random seed
62                            Number of years
"Headboat Index (1976-2006)"
"CC"
1945 -1    240873
1946 -1    262616
1947 -1    580474
1948 -1    898332
1949 -1    1216190
1950 -1    1534048
1951 -1    1979162
1952 -1    2151457
1953 -1    2461884
1954 -1    2945796
1955 -1    3144642
1956 -1    3431137
1957 -1    4100286
1958 -1    4148044
1959 -1    4487825
1960 -1    4797902
1961 -1    5237241
1962 -1    5363974
1963 -1    5547810
1964 -1    5916822
1965 -1    6323133
1966 -1    5650065
1967 -1    5105093
1968 -1    4455043
1969 -1    3382194
1970 -1    2585224
1971 -1    2357941
1972 -1    2141321
1973 -1    1935262
1974 -1    1977250
1975 -1    1937189
1976 3.644 1684470
1977 2.177 1522785
1978 2.000 1335616
1979 1.826 1002098
1980 0.880 839788
1981 1.985 756045
1982 0.687 598187
1983 1.043 717653
1984 0.900 998100
1985 1.287 1080462
1986 0.291 802000
```

```
1987 0.363 578701
1988 0.354 646530
1989 0.633 727421
1990 0.708 655137
1991 0.491 477087
1992 0.071 581258
1993 0.201 706321
1994 0.223 470761
1995 0.305 455372
1996 0.206 408605
1997 0.229 374022
1998 0.184 474887
1999 0.301 617465
2000 0.396 770263
2001 0.827 914602
2002 0.994 810991
2003 0.501 691860
2004 0.910 723824
2005 0.820 663114
2006 0.413 594536
"Commercial Logbook Index"
"I1"
1945   -1
1946   -1
1947   -1
1948   -1
1949   -1
1950   -1
1951   -1
1952   -1
1953   -1
1954   -1
1955   -1
1956   -1
1957   -1
1958   -1
1959   -1
1960   -1
1961   -1
1962   -1
1963   -1
1964   -1
1965   -1
1966   -1
1967   -1
1968   -1
1969   -1
1970   -1
1971   -1
1972   -1
1973   -1
1974   -1
1975   -1
1976   -1
1977   -1
1978   -1
1979   -1
1980   -1
1981   -1
1982   -1
1983   -1
1984   -1
1985   -1
1986   -1
1987   -1
1988   -1
1989   -1
1990   -1
1991   -1
1992   -1
1993   0.785
```

```
1994   0.629
1995   0.637
1996   0.494
1997   0.430
1998   0.478
1999   0.583
2000   0.587
2001   0.898
2002   0.970
2003   0.792
2004   0.976
2005   0.799
2006   0.423
"MRFSS Index"
"I1"
1945   -1
1946   -1
1947   -1
1948   -1
1949   -1
1950   -1
1951   -1
1952   -1
1953   -1
1954   -1
1955   -1
1956   -1
1957   -1
1958   -1
1959   -1
1960   -1
1961   -1
1962   -1
1963   -1
1964   -1
1965   -1
1966   -1
1967   -1
1968   -1
1969   -1
1970   -1
1971   -1
1972   -1
1973   -1
1974   -1
1975   -1
1976   -1
1977   -1
1978   -1
1979   -1
1980   -1
1981   -1
1982   -1
1983  0.471
1984  0.395
1985  0.349
1986  0.204
1987  0.214
1988  0.287
1989  0.300
1990  0.122
1991  0.492
1992  0.917
1993  1.075
1994  0.675
1995  0.658
1996  0.536
1997  0.798
1998  0.598
1999  1.137
2000  1.067
```

```
2001  0.923
2002  0.864
2003  1.063
2004  1.271
2005  1.270
2006  1.109
Note:
This input file prepared by PBC, 15 Nov 2007
```

4 Submitted Comments

4.1 None were received

Section IV. Review Workshop Report

Contents

1. Introduction

1.1. Workshop Time and Place

The SEDAR 15 Review Workshop was held at the Brownstone Holiday Inn in Raleigh, North Carolina on January 28 through February 1, 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. Prepare an Advisory Report summarizing key assessment results. (Reports to be drafted by the Panel during the review workshop with a final report due two weeks after the workshop ends.)

* 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 15 Review Workshop
January 28-February 1, 2008
Raleigh, NC

NAME	Affiliation
Workshop Panel	
Kevin Friedland, Chair	NMFS NEFSC
Robin Cook	CIE
Vivian Haist	CIE
Joe Hightower	USGS
Graham Pilling	CIE
Presenters	
Kyle Shertzer	NMFS SEFSC
Doug Vaughan	NMFS SEFSC
Erik Williams	NMFS SEFSC
Robert Muller	FL FWC
Appointed Observers	
Jeff Buckel	SAFMC SSC/NCSU
Brian Cheuvront	SAFMC/NC DMF
Rob Cheshire	NMFS SEFSC
Paul Conn	NMFS SEFSC
Doug Gregory	GMFMC SSC
Tony Iarocci	SAFMC
Joe O'Hop	FL FWC
Observers	
Mac Currin	SAFMC
Mike Waine	NCSU
Will Smith	NCSU
Staff	
John Carmichael	SAFMC
Tyree Davis	NMFS SEFSC
Rachael Lindsay	SEDAR

Andi Stephens ....SAFMC
Dale Theiling .... SEDAR

1.4. List of Review Workshop Working Papers & Documents

SEDAR15
South Atlantic Red Snapper & Greater Amberjack
Workshop Document List

Document #	Title	Authors
Documents Prepared for the Data Workshop		
SEDAR15-DW1	Discards of Greater Amberjack and Red Snapper Calculated for Vessels with Federal Fishing Permits in the US South Atlantic	McCarthy, K.
Documents Prepared for the Assessment Workshop		
SEDAR15-AW-1	SEDAR 15 Stock Assessment Model - Statistical Catch-at-Age Model	Conn, P., K. Shertzer, and E. Williams
Documents Prepared for the Review Workshop		
SEDAR15-RW1	SEDAR 15 SAR1 (Red Snapper) Peer Review Document	SEDAR 15
SEDAR15-RW2	SEDAR 15 SAR2 (South Atlantic Greater Amberjack) Peer Review Document	SEDAR 15
SEDAR 15-RW3	SEDAR 15 SAR3 (South Atlantic and Florida Mutton Snapper) Peer Review Document	SEDAR 15 (Florida Fish & Wildlife Research Institute)
Final Assessment Reports		
SEDAR15-AR1	Assessment of Red Snapper in the US South Atlantic	
SEDAR15-AR2	Assessment of Greater Amberjack in the US South Atlantic	
Reference Documents		
SEDAR15-RD01	Age, growth, and reproduction of greater amberjack, *Seriola dumerili*, off the Atlantic coast of the southeastern United States	Harris, P. , Wyanski, D., White, D. B.
SEDAR15-RD02 2007.	A Tag and Recapture study of greater amberjack, *Seriola dumerili*, from the Southeastern United States	MARMAP, SCDNR
SEDAR15-RD03	Stock Assessment Analyses on Atlantic Greater Amberjack	Legault, C., Turner, S.
SEDAR15-RD04	Age, Growth, And Reproduction Of The Red Snapper, *Lutjanus Campechanus*, From The Atlantic Waters Of The Southeastern U.S.	White, D. B., Palmer, S.
SEDAR15-RD05	Atlantic Greater Amberjack Abundance Indices	Cummings, N.,

	From Commercial Handline and Recreational Charter, Private, and Headboat Fisheries through fishing year 1997	Turner, S., McClellan, D. B., Legault, C.
SEDAR15-RD06 2007. MS Thesis, UNC Wilm. Dept. Biol. & Marine Biol.	Age and growth of red snapper, *Lutjanus Campechanus*, from the southeastern United States	McInerny, S.
SEDAR15-RD07 2005. CRP Grant # NA03NMF4540416.	Characterization of commercial reef fish catch and bycatch off the southeast coast of the United States.	Harris, P.J., and J.A. Stephen
SEDAR15-RD08	The 1960 Salt-Water Angling Survey, USFWS Circular 153	Clark, J. R.
SEDAR15-RD09	The 1965 Salt-Water Angling Survey, USFWS Resource Publication 67	Deuel, D. G. and J. R. Clark
SEDAR15-RD10	1970 Salt-Water Angling Survey, NMFS Current Fisheries Statistics Number 6200	Deuel, D. G.

2. Consensus Report

2.1. Statements addressing each Term of Reference

1. **Evaluate the adequacy, appropriateness, and application of data used in the assessment.**

Data used in the assessment consisted of landings from three fleets segments, three fishery dependent abundance indices, age composition data and length frequency data. All these data are subject to a relatively high degree of uncertainty. In relation to landings, the Assessment Workshop (AW) decided to use estimates of catch in 1960, 1965 and 1970 derived from a saltwater angling survey that had been rejected by the Data Workshop (DW). These values suggest that catches before the 1980s were of an order of magnitude higher than DW values. The review panel discussed this at some length and felt that on balance it was appropriate to include these values. There was some anecdotal evidence to support the apparently unexpectedly high values.

Sample sizes for the age and length frequency data are very small in relation to the landings and therefore may not reflect actual age and length compositions with any precision. Age data are available only for more recent years and suggest that most fish in the catches are around age 3. The size composition data change in response to management regulations on minimum landing size.

The abundance indices are a crucial element of the available data but will, of course, be subject to bias associated with changes in technology and non-random sampling by commercial and recreational fisheries. In the model, values of abundance index catchability were assumed to increase by 2% per year. The indices all relate to the more recent period of the assessment and there is therefore almost no data other than catch for the period up to the 1980s. There is some correlation between the series, which provides some support for the view that they are measuring a common signal in the stock over time. It would be highly desirable to invest in a fishery independent abundance index to improve future assessments (see term of reference 9).

Red snapper has an unusual life history pattern in that they are apparently long lived (maximum age over 50) while maturing as early as age 1. This leads to low estimates of age specific natural mortality, yet the assessment seems to suggest the stock is highly productive and contributes to a very high estimate of the steepness of the stock recruitment function. The panel felt that the steepness estimate was unreliable. The life history attributes would merit further investigation to confirm their unusual characteristics.

Notwithstanding the limitations of available data, the panel felt that the data had been used appropriately and that it provided an adequate basis on which to conduct an assessment. The uncertainties in the data limit the robustness of the conclusions that can be derived from the assessment.

2. **Evaluate the adequacy, appropriateness, and application of methods used to assess the stock.**

Two assessment methods were used. The principal method was an age structure model (SCA) constructed within a stock synthetic framework using AD model builder. The second was a much simpler surplus production model using ASPIC software, which makes no explicit assumptions about age structure. Both of these approaches are well established and appropriate for the data available and for the estimation of the management indicators.

The SCA model is a complex model based on maximizing a quasi-likelihood function. In order to fit the model, a large number of assumptions are required that relate to fishery selectivity, discard selectivity and survival, stock recruitment function, natural mortality by age, and other less critical factors. The panel was generally satisfied that the assumptions made were appropriate, but while they are reasonable, it must be remembered that many are best guesses and are not currently verifiable.

One of the main points of discussion was centered on the relative weights given to the various likelihood components in the objective function. These had been arrived at through trial and error by fitting the model, examining the model fit, adjusting the weights and then refitting the model until a satisfactory fit had been achieved. The panel was concerned that the criteria for judging goodness-of-fit were subject to individual interpretation and may not be repeatable. The need to find a more systematic method to select the weights was stressed, but the panel accepted the values used in the assessment on the basis that most information on the stock trajectory lay in the landings data.

The ASPIC model was used to investigate a different model interpretation of the data and provides a valuable alternative to exploring the uncertainty in population estimates. It gave qualitatively similar results to the SCA model providing some reassurance that the perceived stock decline is real and not an artifact of the assumptions on natural mortality and stock recruitment. There still remains the possibility that poorly estimated recreational catches in the early period exaggerate the perceived steep population decline.

The panel asked for a simple catch curve analysis to be undertaken on the age compositions. This analysis supported the Z estimates emerging from the SCA model (see section 2.3).

3. **Recommend appropriate estimates of stock abundance, biomass, and exploitation.**

The SCA model was advocated as the basis for estimates of abundance, biomass and exploitation. There are substantial uncertainties in the model results and the AW provides sensitivity runs to illustrate the possible range of uncertainty. Clearly, all the runs show the same qualitative results and indicate that the stock status is overfished and suffering from overfishing. However, there is no unique ‘best estimate model run’ that stands out as superior to other runs. Recognizing the need to use a reference run to characterize the stock and its status, the panel suggests using the SCA base run for estimates of stock abundance, biomass and exploitation. The values need to be interpreted as one realization of a number of equally plausible runs and are conditioned on the particular assumptions made about the data and the population dynamics model. Alternative assumptions could yield equally plausible but different values as may arise in future assessments.

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 most important aspect of population benchmarks and management parameters is to be able to judge relative position of the current stock to the benchmarks. In this context, absolute values of F_{msy}, SSB_{msy} are less important than the ratios $F_{current}/F_{msy}$ and $SSB_{current}/SSB_{msy}$. In all the model sensitivity runs and the ASPIC model, the ratios estimated the stock to be overfished and experiencing overfishing, despite the absolute values of the individual quantities varying substantially. The conclusion of the status of the stock therefore appears quite robust to a wide range of model configurations and the panel felt this was the appropriate classification.

One of the principal difficulties with the SCA model estimate of the stock recruitment parameters is that the steepness estimate appears unrealistically high. In addition, there are no data in the assessment to adequately define the asymptote of the Beverton-Holt function and hence estimates of MSY indicators cannot be considered reliable. It may be preferable, as indicated above, to use the ratio indicators to evaluate stock status or use SPR proxies. The panel suggested that $F_{40\%}$ and $SSB_{40\%}$ proxies may be used as limit indicators.

Given the choice of the base SCA run as the reference case, the panel suggests that if managers wish to use specific benchmark values they consider the estimates conditioned on this run. The values are given in Table 1. It should be borne in mind that these values will likely change at a future assessment given their sensitivity to equally plausible model configurations.

Table 1. Management quantities based on $F_{40\%}$, a proxy for F_{MSY}

Quantity	Units	Estimate
$F_{40\%}$	y^{-1}	0.07
$B_{F40\%}$	mt	17347
$SSB_{F40\%}$	mt	7891
$MSST_{F40\%}$	mt	7275
$MSY_{F40\%}$	1000 lb	2314
$D_{F40\%}$	1000 fish	37
R_0 (bias corrected)	1000 fish	664.7
$F_{2006}/F_{40\%}$	–	12.021
$SSB_{2006}/SSB_{F40\%}$	–	0.025
$SSB_{2006}/MSST_{F40\%}$	–	0.027

Note: Biomass and discard estimates corresponding to $F_{40\%}$ assume equilibrium recruitment of bias-corrected R_0, as estimated by the base assessment model. MSST=(1-M)SSB, with M equal to the Hoenig estimate (=0.078).

The Review Panel (RP) noted that its instructions specified that it "…shall not provide specific management advice. Such advice will be provided by existing Council Committees, such as the Science and Statistical Committee and Advisory Panels, following completion of the assessment." Given these guidelines, the RP could not provide ABCs and felt that it was an inappropriate task for a review panel. The RP could review the methodology used by others to arrive at an ABC if provided.

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).**

Projections conducted by the AW are conditional on the base run. They include stochasticity only in the stock recruitment model and this generally will underestimate the overall uncertainty in future projections. This problem is in part due to the restricted uncertainty incorporated into the stock-recruitment model and the assumption of fixed values for all other quantities. In particular, the assumption of a fixed initial population size limits the range of likely uncertainty on future stock development. The panel therefore felt that the projections presented should be interpreted more in qualitative terms and that the uncertainty envelope presented (10^{th} and 90^{th} percentiles) does not provide likely probabilities. However, the relative change in rebuilding time compared to baseline for a given F scenario is likely to be a more reliable indicator of the value of a chosen management regime. What is clear is that rebuilding will not occur at current F and that rebuilding times are long, generally on the order of decades.

Interpretation of rebuilding times needs to be considered in the context of the very low current stock size. It is possible that stock dynamics at these apparently depleted levels may not be the same as the assumed stock recruitment relationship, which has been estimated for the whole historical time period.

The panel discussed the value of projections made beyond 5-10 years. Clearly the uncertainty increases rapidly with time as the currently measured stock is replaced by model values into the future. Realistically, the projections beyond the range of the predominant age groups in the stock are highly uncertain. In this assessment, the best that can be concluded is that rebuilding times will be very long.

An important aspect of the projection scenarios is the modeling of discards, which consider incidental bycatch which might arise in the absence of directed fishing. This provides a valuable metric to judge the efficacy of management measures that are unable to prevent all catches of red snapper.

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.**

Uncertainty in the assessment has been characterized mainly by the use of sensitivity runs. These examine the change in the assessment when certain assumptions are varied. A large number of sensitivity runs were performed, which the panel considered. It was felt that these offered a useful insight into the robustness of the assessment. None of the runs altered the perception of the stock status. Estimates of F_{msy} were very consistent at around $F \approx 0.1$ while SSB_{msy} varied between 3189-10554mt.

The panel suggested a subset of the sensitivity runs, plus two additional runs to examine the effect of the recreational fishery catch, as a summary of the uncertainty in the assessment. The results are given in Table 2.

Table 2. Results of sensitivity runs characterizing the uncertainty in the assessment.

Run	Description	F_{msy}	SSB_{msy} (mt)	MSY (1000 lb)	F_{2006}/F_{msy}	SSB_{2006}/SSB_{msy}	steep	R0 (1000)
Base		0.112	5184	2319	7.51	0.04	0.95	605
S1	Low M	0.097	6112	1977	10.36	0.03	0.95	377
S2	High M	0.112	5089	2362	7.25	0.04	0.95	673
S16	steep=0.8	0.131	7648	2056	9.59	0.03	0.8	562
S17	steep=0.6	0.118	10554	1624	7.09	0.05	0.6	441
S32	0.5 Early rec L	0.112	3189	1314	8.3	0.06	0.95	356
S33	1.5 Early rec L	0.104	7419	3283	7.73	0.03	0.94	858
S34	Finit=0.05	0.106	5431	2416	7.71	0.04	0.95	635
S35	Finit=0.10	0.105	6069	2696	7.74	0.03	0.95	706
S36	Finit=0.15	0.104	6600	2912	7.83	0.03	0.95	764
	Surplus production	0.149	2247	3342	1.077	0.17		

As might be expected, the uncertainty described above is conditioned on the structural assumptions in the model and will only give a partial impression of overall uncertainty. The AW also ran a surplus production model, which gives a further insight into uncertainty. This analysis suggests that F is closer to MSY (Table 2). The analysis provides confidence intervals on the estimates of benchmarks that are similar to the range in the SCA sensitivity runs.

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.**

The RP ensured that the stock assessment results were clearly and accurately presented in the SEDAR Summary Report for Red Snapper and that the results were consistent with the RP 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.**

The RP had no specific comments about the SEDAR process in regard to the review process for red snapper. However, the RP discussed issues of relevance to the overall SEDAR review process.

The review panel appreciated the standardized layout of the data and assessment workshop reports, which greatly aided the reviewers in assimilating information on the different stocks.

Panel members noted that the documents had been received approximately one week before the review panel convened, rather than the two weeks stipulated in the Terms of Reference. This delay hampered a more thorough review by the panel members, although this was mitigated by the thorough presentations provided by the stock experts.

The review panel thanked the rapporteurs for their assistance in developing the consensus summary reports, and noted that their contribution was invaluable and critical in preparing reports prior to the closure of the Review Workshop. The panel suggested that the process could further be improved by SEDAR helping to prepare the rapporteurs for this task with a more detailed guide on how to prepare a rapporteur's report.

The panel suggested that a fisherman-friendly one-page summary of the review proceedings be prepared for the Council. This could subsequently be disseminated at the docks to inform fishermen of the review workshop activities and findings.

The international members of the review panel appreciated the presentation of a short summary of US management regulations and benchmarks, which was a useful reminder of the legislative framework in which the review panel operated.

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 RP supports the recommendations of data workshop. Of the recommendations provided in the report, the most critical priority for stock assessment is establishment of a fishery independent index. This could best be accomplished by adding gears to the MARMAP survey that are more effective at catching red snapper.

Other important recommendations are:

- Quantifying release mortality and length/age structure of discards, for instance by expanding the “Headboat at Sea Observer Survey.”
- Using consistent otolith ageing assumptions.
- Assessing the degree to which catchability has changed over time.
- Improving data collection protocols.

The recommendation to analyze stock structure using microsatellite genetic techniques, while good science, is probably less important to improving the current assessment.

The panel felt that the procedure for choosing the weights in the likelihood function might be improved and recommends that a more rigorous protocol be investigated to avoid criticism of subjectivity.

Bayesian methods should be considered for inference on uncertainty. These methods would allow priors on steepness, natural mortality, and other parameters to be chosen in order to quantify uncertainty in stock status and benchmarks. These additional procedures will require adequate time being afforded to assessment scientists to develop the appropriate tools.

In order to be able to measure an improvement in the stock, the next assessment would need to be conducted some years (5 perhaps) after any new management measures are introduced. This implies an interval of about 6-7 years before the next assessment. If managers are particularly concerned about the status of the stock, then a shorter interval of 3 years might be considered to check whether any further deterioration has occurred, but this would not be a sufficiently long time interval to be able to detect the efficacy of management measures.

10. Prepare a Peer Review Consensus Summary summarizing the Panel’s evaluation of the stock assessment and addressing each Term of Reference. Prepare an Advisory Report summarizing key assessment results.

The RP prepared a Review Panel Consensus Summary and provided comments on the SEDAR Summary Report for Red Snapper.

Reviewer Statements

The panel attests that the Review Panel Consensus Summary for red snapper provides and accurate and complete summary of the issues discussed during the review.

2.2. Panel Comments on the SEDAR Process

See term of reference 8

2.3. Summary Results of Analytical Requests

The panel was concerned about the influence of the very large recreational catch in the early years on the assessment. The sensitivity run (S7), which used a low estimate of recreational landings, was considered too extreme; the panel requested additional runs that examined the sensitivity of ±50% of the landings. The results did not alter the perceived state of the stock and are given in Table 2.

A simple catch curve analysis using commercial handline and headboat age compositions to estimate Z was requested. Z was primarily estimated between 0.5 and 2.0 over the period 1975-2006, and was on the same scale as mortality estimates produced by the statistical catch-at-age model (Figure 1). This gives extra credence to the results of the catch-at-age model.

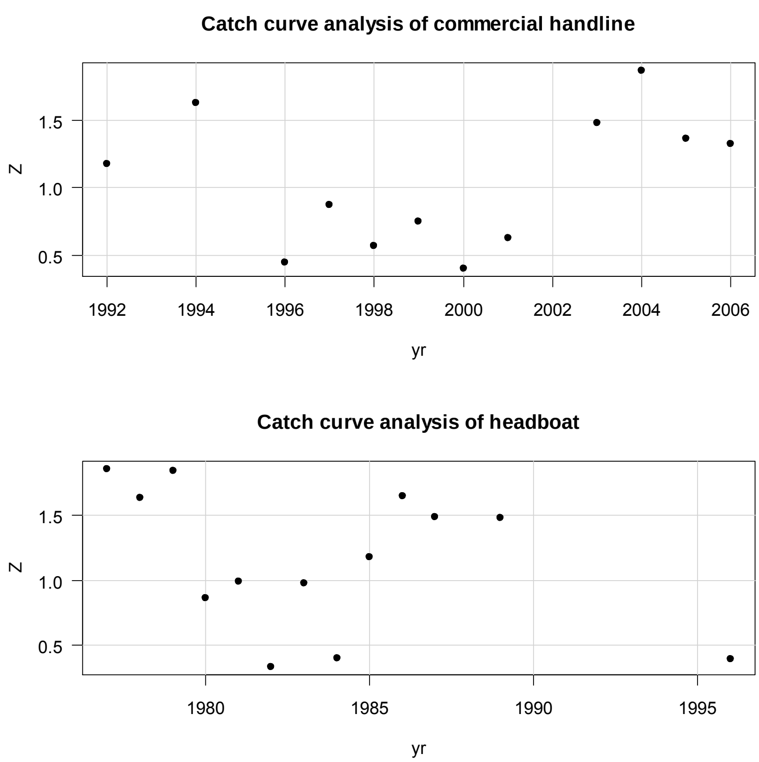


Figure 1. Results of catch curve analysis. Estimates of Z are consistent with the SCA model.

A set of runs examining the assumption of initial stock depletion was requested. These considered initial depletion of 5, 10 and 15 percent. Results were largely similar to previous runs and are summarized in Table 2.

3. Submitted Comments

Comments were received in the following memorandum from Captain Bill Kelly addressed to SAFMC member Captain Tony Iarocci. The four-page memorandum was discussed at the review workshop. Comments of the review panel follow the memorandum.

To: Capt. Tony Iarocci

From: Capt. Bill Kelly

Date: January 29, 2008

Subj: Stock Assessment Comments On Greater Amberjack, Mutton Snapper And Red Snapper.

Comments:

Tony,

Here is a cross section of comments I received from charter boat captains in Miami down through the Islamorada area.

Capt. Jimbo Thomas Thomas Flyer Bayside Marina

Jimbo and his brother Rick are lifetime 20+ year charter fishermen in Miami. Greater Amberjack are done, gone, non-existent off the Miami area. He would support a complete spawning closure, an additional one month closure to match the commercial fishery, reduced bag, slot and increase in minimum size to match commercial fishery.

Mutton snapper are plentiful in shallow on the patch reefs but all are under minimum size. They no longer catch muttons in 100 to 150 feet of water. The few they do catch are out deep on wrecks in 200 to 250 feet of water and they are usually big fish of 12-18 pounds. However, the numbers seem to be dwindling.

Red snapper are not abundant off the Miami area and he might catch three or four a year deep dropping.

Jimbo sees law enforcement as a serious issue off the mainland says for the most part it is non-existent as well.

Jimbo holds Restricted Species Endorsement, Federal Kingfish License, Unlimited Reef Fish Permit.

Capt. Bouncer Smith Bouncer's Dusky Miami Beach Marina

Lifetime charter boat fisherman off South Florida. He does not sell fish but respects the right of charter fishermen with permits to sell their catch and said many will not survive the economic turn-down if that aspect is taken away from them.

Greater Amberjack are severely depleted. In days gone by you could catch them until the customers couldn't wind anymore. Now you might catch one in a hard day of trying. Bouncer would support a full spawning closure, an additional one month closure to match the commercial fishery and reduced bag limits. He also favors a narrower slot favoring the bigger fish.

With regard to mutton snapper Bouncer agrees there are lots of little ones on the patches but no more 10-15 pounders and only scattered action on the deeper wrecks for fish of 15 pounds when they used to catch them to 20. Bouncer would support spawning closure, reduced bag limits, increase in size limits.

Red snapper are not a part of his directed fishery although he has caught more in recent years than ever amounting to perhaps 8 to 9 fish per year.

Bouncer also talked about the shortage of law enforcement in the area. He said his boat has been stopped once in the last two years and Susan Cocking of the Miami Herald was on board doing an article. Considering the number of days he spends on the water as one of the top fishing guides in South Florida he actually felt he should have been stopped and inspected more times.

Capt. Chuck Schimmelan Dee Cee Holiday Isle Marina

Chuck is a thirty year charter boat fishermen out of Holiday Isle Marina in Islamorada. Chuck sees a major decline in Greater Amberjack and drop in weight from an average of 60 pounds to 40. They can still be caught with some regularity at the Islamorada Hump but not in numbers of the past. He would support a full spawning closure, increase in the recreational closed sees to match the commercial fleet and increase in minimum size to match commercials.

Mutton snapper seem to be holding their own and fishing is neither up nor down. He would support a spawning closure.

Red Snapper are not part of his fishery.

Capt. Greg Pope Tag 'Em Holiday Isle Marina

Greg sees the Greater Amberjack population as down with fish averaging about 35 pounds down from the 50"s & 60"s of years gone by. He targets commercial fishermen as the cause of their depletion. He would support a full spawning closure, additional closure to match the commercial fishery and an increase in minimum size.

Mutton snapper seem to be holding their own according to Greg with fair numbers of 7-8 pounders on the patch reefs and along the reef line in 80 to 100 feet of water.

Red snapper are not part of his fishery.

Capt. Steve Leopold Yabba Dabba Do Holiday Isle Marina

Steve does not target a lot of amberjack but from his experience the fish seem to average about 35-40 pounds. He would support a spawning closure and increased closure to match the commercial fishery as well as an increase in minimum size.

Steve has found mutton snapper fishing about the same with no significant changes. There seem to be a fair amount of fish on the patch reefs of Hawk Channel and along the reef line. He would support a spawning closure.

Red snapper are not part of his fishery.

Capt. Rob Dixon Challenger Whale Harbor Marina

Greater amberjack are not a big part of his fishery but he sees an average of about 30 pounds per fish and says they are in decline. He would support spawning closure, increased in minimum size, changes in bag limits, etc. to correct the reduction in numbers. Feels commercial fishermen have a lot to do with the reduced stocks.

Mutton snapper seem to be about the same with no significant changes. He would support a spawning closure.

Red Snapper are not part of his fishery.

Rob does sell fish and said it is an important part of his business and vital to his overall income.

Capt. Robert Morrison Miller Time Whale Harbor Marina

Does not target greater amberjack but says stocks are on the decline and fish now run 30-40 pounds compared to 50-60 in past years. He would support a spawning closure, increase in size limits, closure to match the commercial fishery.

Mutton snapper action to the south and west of Islamorada is on the decline. He attributes part of it to commercial divers and states he sees significant numbers of speared fish at local fish houses.

Red snapper are not part of his fishery.

Capt. Randy Towe Quit Yer Bitchin' Private Dock

Randy has been fishing in the Keys for close to thirty years. Greater amberjack are not a part of his fishery.

Mutton snapper fishing for Randy has been fair and he sees signs of improvement. Randy fishes both sides of the islands and this year his anglers are catching and releasing record numbers of mutton snapper back in Florida

Bay. The action happens while targeting Spanish and king mackerel in water 10-12 feet deep and he usually catches and releases as many as 25 juvenile muttons while mackerel fishing. Randy would support spawning closures.

Red snapper are not part of his fishery.

Capt. Alex Adler Kalex Bud N Mary's Marina
Alex is a thirty year fisherman in the Islamorada. He sells fish and it constitutes a significant portion of his income. Alex feels greater amberjack stocks have been decimated primarily by commercial fishermen and would endorse any efforts to help rebuild the stock including a complete closoure, spawning closure, etc.

Mutton snapper are also in short supply according to Alex and the impact on these stocks over the past few years has been significant. He is gravely concerned there are no longer any spawning stocks in the area between Islamroada and Marathon. He would support spawning closures, reduced bag and increased size limit to improve stocks.

Red snapper are not part of his fishery.

Alex felt law enforcement was an issue, especially with regard to private boats.

Capt. Bill Kelly OH-MI Private Dock
Bill has been a fishing guide in Islamorada for the past 31 years. Although he no longer targets greater amberjack he has seen the average fish go from 60 to 30 pounds and in the past two years back up to 35. Bill feels the burden lies equally on recreational and commercial fishermen and recreational anglers should at least have to raise their minimum size limit of 28" to 32" to match the commercial sector and the recreational closure should match the commercial fishery. He also supports spawning closures.

Mutton snapper are not as prevalent as they used to be although this year seemed to be better than last and there were a lot of juvenile fish on the patch reefs of hawk channel which is good for recruitment. He would support spawning closures.

Red snapper are not part of his fishery.

Law enforcement is an issue and Bill would like to see more of it, especially on recreational boats for undersized fish and bag limit violations.

The review panel discussed a submission from Captain Bill Kelly that presented the opinions of a number of fishermen from Miami down through the Islamorada area on the status of greater amberjack and mutton snapper resources (few of the fishers had red snapper in their fisheries). The panel welcomed the document and noted a number of points.

There was considerable consistency between the opinions of the fishermen on declines in greater amberjack average catch weights, from 50-60 lbs to around 30 lbs. It was noted that this decline was fully consistent with the model results, reflecting the fishing of stock from a relatively unexploited state to one near MSY.

The panel recognized the valuable contribution that fishermen can provide, including expert opinion and data collection. Undertaking co-operative approaches to survey resources in a structured way, providing information that might otherwise be unavailable to stock assessments, are extremely worthwhile, and the panel supported efforts to expand these activities.

Section V. Addenda and Post-Review Updates

Contents

1 Revisions or Corrections

1.1 Other than changes to the Stock Assessment Models and Review component of the review workshop report discussed in (2) below, no revisions or corrections wee made.

2 Added Documentation of Final Review Model Configuration

The following changes were made to the Stock Assessment Models and Review component of the review workshop report and are shown in the Stock Assessment Report:

1) A figure of size at age (figure 3.20) is added. This figure was shown during the review workshop in the assessment presentation, but not previously in the document for peer review.

2) Units of measure have been stated in several locations of the text, specifically landings in 1000 lb whole weight, discards in 1000 dead fish, and spawning biomass in mt.

3) There is a correction of the description of how stochastic recruitment was modeled in projections (i.e., lognormal recruitment deviations were applied to the spawner-recruit curve without bias correction). The methods were applied correctly, but the description in the report for peer review was inaccurate, as discussed during the review.