S E D A R

Southeast Data, Assessment, and Review

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SEDAR 15
Stock Assessment Report 2 (SAR 2)
South Atlantic Greater Amberjack

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

SEDAR Offices
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Stock Assessment Report 2
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Section I. Introduction

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1. SEDAR Overview

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

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

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

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

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

SEDAR 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, 1993), in which "snapshot" analyses were conducted for a list of snapper-grouper species, including greater amberjack. 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. SPR was also estimated in this manner in the report by Potts and Brennan (1998). However, the only assessment conducted on this stock of greater amberjack was by Legault and Turner [**Evaluations of the Atlantic Greater Amberjack, *Seriola dumerili*, Stock Status**, July 1999, *Sustainable Fisheries Division Contribution* SFD-98/99-63]. Estimates of SPR found in the report by Potts and Brennan (2001) are from this assessment report. In 1999, alternative stock assessment methods (Delury depletion and ASPIC models) were applied to greater amberjack data from the Florida Atlantic coast (Nassau County to Miami) by the FL FWCC.

Summary from Legault and Turner: Stock assessments and projections of acceptable biological catches for Atlantic greater amberjack were conducted over a wide range of biological parameters due to insufficient knowledge about the true values. This approach is a different from previous assessments, which used only one estimate for stock assessment and did not compute maximum sustainable yields. Given the current limited knowledge of greater amberjack biology, and the fishery catches, in the Atlantic Ocean, the resulting ranges of possible stock status and future yields are large. If improvements in the understanding of greater amberjack biology and fishery statistics can be made, these wide ranges will narrow.

The stock assessments for Atlantic greater amberjack consisted of tuned virtual population analysis. The catch at age data used in the assessment are provided in Cummings (1999) and the tuning indices used are described in Cummings et al. (1999). A number of assessments were conducted using different indices, values for the natural mortality rate, and maturity ogives. Fecundity at age was set as the product of weight and maturity at age. A Monte Carlo/bootstrap approach was used to examine uncertainty within each assessment. The default control rule was used to evaluate the current stock status for each assessment. Each assessment was projected into the future to estimate acceptable biological catches (ABC) under two alternative fishing mortality rates which might be considered as proxies for F_{MSY} : (1) $F_{40\%SPR}$, the fishing mortality rate which generates a 40% static spawning potential ratio, and (2) $F_{0.1}$. Risk associated with selecting different ABC levels was examined across all combinations of assessments and projections.

3. Management Review

Table 1. General Management Information

Species	Greater Amberjack (*Seriola dumerili*)
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	Not overfishing
Current stock biomass status	Not overfished

Table 2a. Specific Management Criteria

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}	Not specified	F_{MSY}	UNK (SEDAR 15)
MSY	Yield at F_{MSY}	*	Yield at F_{MSY}	UNK (SEDAR 15)
F_{MSY}	$F_{30\%SPR}$	Not specified	F_{MSY}	UNK (SEDAR 15)
OY	Yield at F_{OY}	*	Yield at F_{OY}	UNK (SEDAR 15)
F_{OY}	$F_{40\%SPR}$	*	F_{OY} =65%, 75%, 85%F_{MSY}	UNK (SEDAR 15)
M	n/a	*	SEDAR 10	UNK (SEDAR 15)

*The 1998 assessment (Legault and Turner 1999) provided a range of values for M, F_{MSY}, and MSY using F_{MSY} proxies = $F_{40\%\ SPR}$ and $F_{0.1}$. See table 2b for the values.

Table 2b. Maximum sustainable yield medians and inner 50% from 400 Monte Carlo/bootstrap runs of 18 combinations of tuning indices used, M, F_{MSY} proxy, and maturity schedule (Legault and Turner 1999).

				MSY (million pounds)			
# Indices	M	F_{MSY} Proxy	Maturity Schedule	Median	Inner	50%	Range
one	0.2	$F_{40\%SPR}$	Early	12.50	10.48	-	15.38
one	0.2	$F_{40\%SPR}$	Late	11.51	9.65	-	14.14
one	0.2	$F_{0.1}$	N/A	10.67	8.95	-	13.12
one	0.25	$F_{40\%SPR}$	Early	15.54	12.61	-	18.98
one	0.25	$F_{40\%SPR}$	Late	14.07	11.42	-	17.18
one	0.25	$F_{0.1}$	N/A	12.48	10.14	-	15.24
one	0.3	$F_{40\%SPR}$	Early	19.53	15.78	-	23.95
one	0.3	$F_{40\%SPR}$	Late	17.42	14.08	-	21.36
one	0.3	$F_{0.1}$	N/A	14.70	11.90	-	18.02
four	0.2	$F_{40\%SPR}$	Early	4.43	4.13	-	4.78
four	0.2	$F_{40\%SPR}$	Late	4.09	3.82	-	4.42
four	0.2	$F_{0.1}$	N/A	3.79	3.54	-	4.09
four	0.25	$F_{40\%SPR}$	Early	4.94	4.58	-	5.37
four	0.25	$F_{40\%SPR}$	Late	4.48	4.16	-	4.88
four	0.25	$F_{0.1}$	N/A	4.00	3.71	-	4.34
four	0.3	$F_{40\%SPR}$	Early	5.80	5.33	-	6.36
four	0.3	$F_{40\%SPR}$	Late	5.18	4.77	-	5.68
four	0.3	$F_{0.1}$	N/A	4.42	4.07	-	4.84

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)	

*Based on information from Legault and Turner (1999), the stock is not overfished.

Table 4. Stock projection information

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

Quota Detail	Value
Current Quota Value	1,169,931 lb gutted weight
Next Scheduled Quota Change	Not Scheduled
Annual or averaged quota ?	Annual
If averaged, number of years to average	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 black sea bass 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 28” FL limit for greater amberjack (recreational only); 36” FL or 28” core length for greater amberjack (commercial only); bag limit 3 greater amberjack; spawning season closure – commercial harvest greater amberjack > 3 fish bag prohibited in April south of Cape Canaveral, FL.	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. One greater amberjack fish bag limit (recreational); in April, limit to 1/ person/day or 1/vessel/trip whichever is more restrictive (commercial, charter vessel/headboat); in April, no purchase or sale; quota = 1,169,931 lbs gutted weight, harvest prohibited after quota is met; trip limit = 1,000 lbs until quota reached; began fishing year May 1; prohibited coring. Imposed commercial trip limit for greater amberjack (1,000 lb).	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

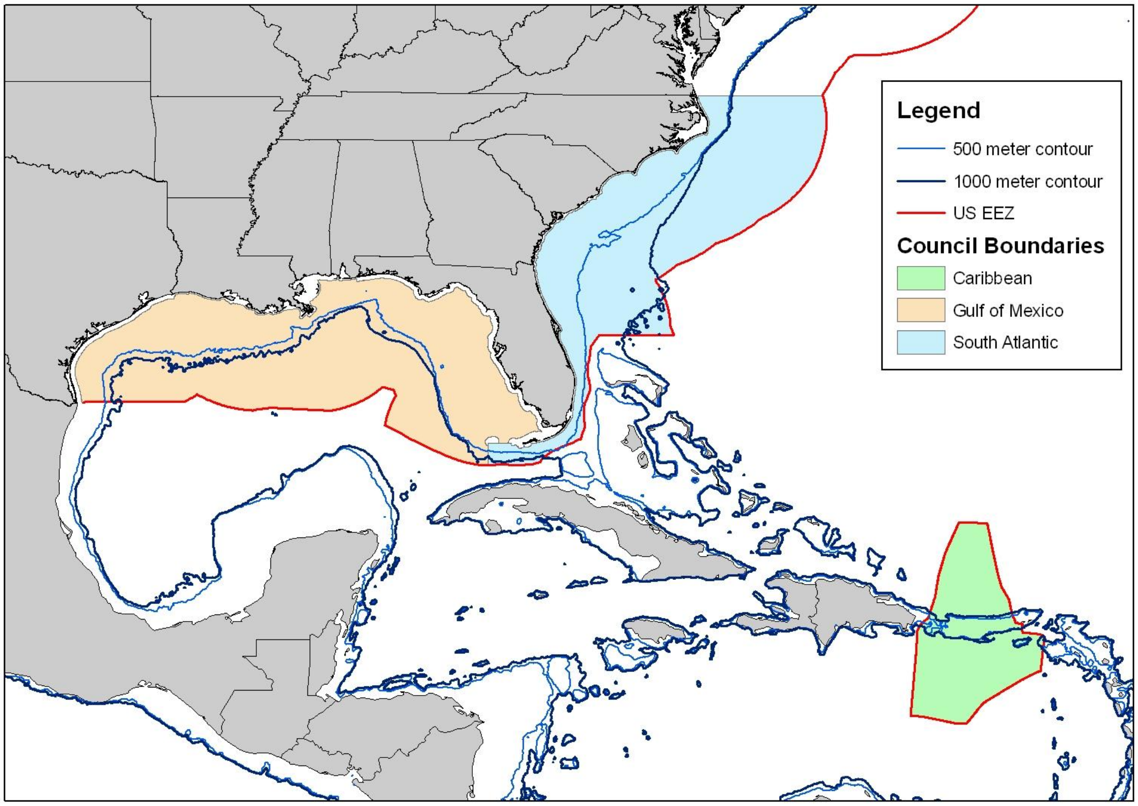
Commercial Fishery Regulations					Recreational Fishery Regulations		
Effective Date	Size Limit	Trip Limit	Season	Catch Limit	Size Limit	Possession Limit	Season
1/1/92	36” FL or 28” core length		Commercial harvest greater amberjack > 3 fish bag prohibited in April south of Cape Canaveral, FL.		28” FL	3 greater amberjack/person/day bag limit	
2/24/99	36” FL	1,000 lb trip limit until quota reached	In April, 1 greater amberjack/person/day or 1/person/trip whichever is more restrictive	Quota = 1,169,931 lb gutted weight (no harvest/sale/poss-ssion after met)	28” FL	1 greater amberjack/person/day	In April, 1 greater amberjack/day or 1/vessel/trip whichever is more restrictive (only for charter vessel/headboat)

References

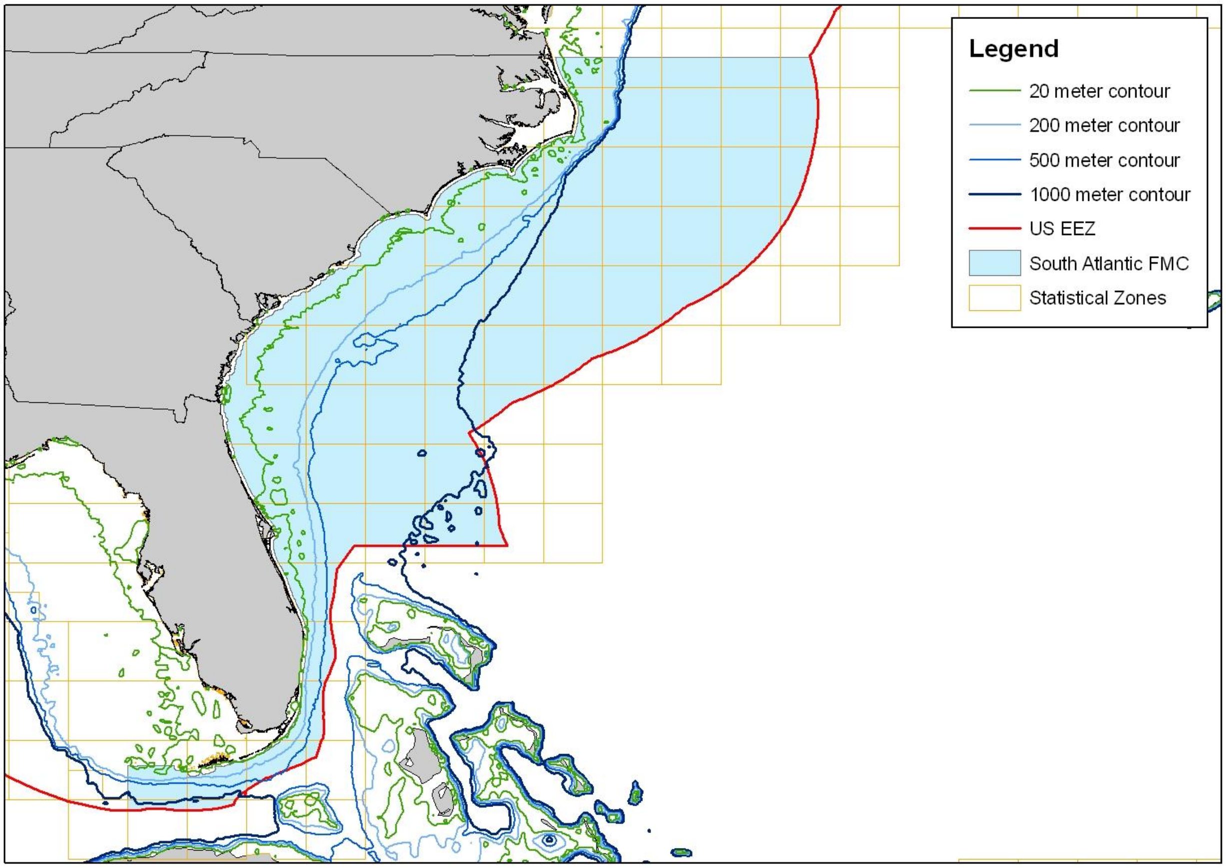
Legault, C.M. and S.C. Turner. 1999. Stock assessment analysis on Atlantic greater amberjack. Sustainable Fisheries Division Contribution SFD-98/99-63.

4. Southeast Region Maps

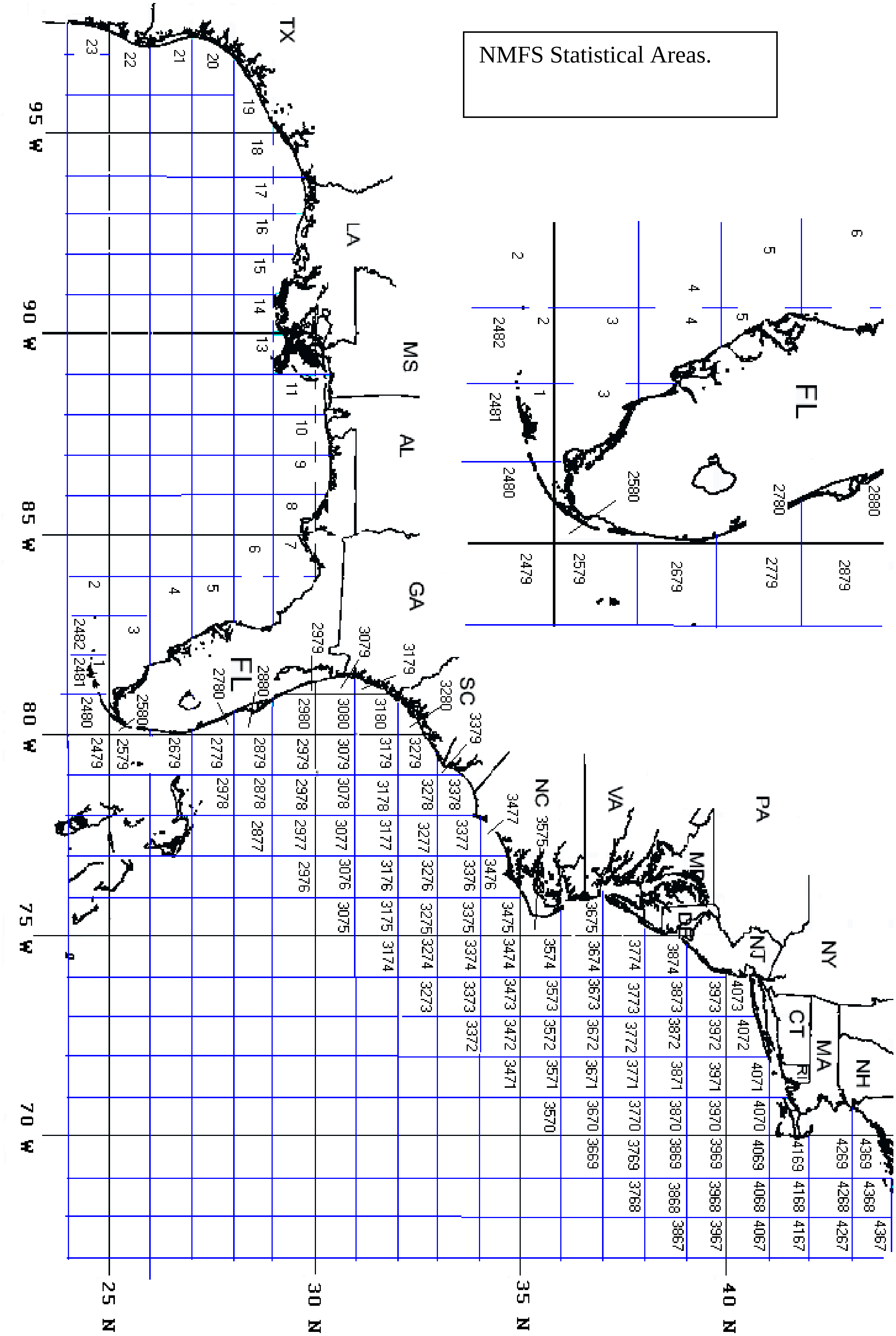
Southeast Region including Council and EEZ Boundaries



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



*U.S. GPO:200-656-



NMFS Statistical Areas.

5. Summary Report

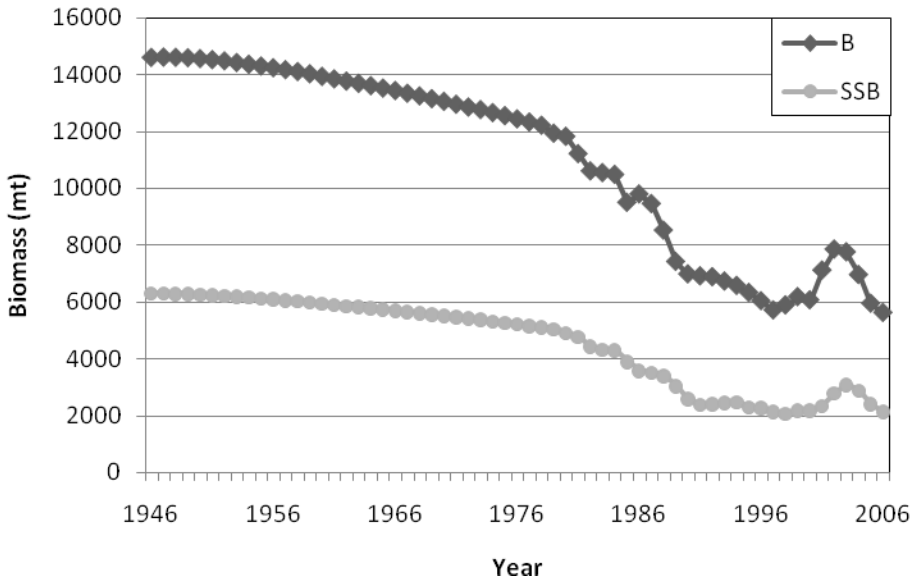
Stock Distribution and Identification

This assessment applies to greater amberjack within US waters of the South Atlantic from Monroe, FL (including the Gulf of Mexico) through Massachusetts.

Stock Status

The South Atlantic stock of greater amberjack was not overfished and was not experiencing overfishing in 2006.

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. 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 and commercial dive fisheries, logbook and port sampler data from the recreational headboat fishery, and MRFSS survey data of the rest of the recreational sector. Commercial longline and "other" landings were included with the hook and line landings for analysis. Landings given in the table are for years in which they were non-zero.

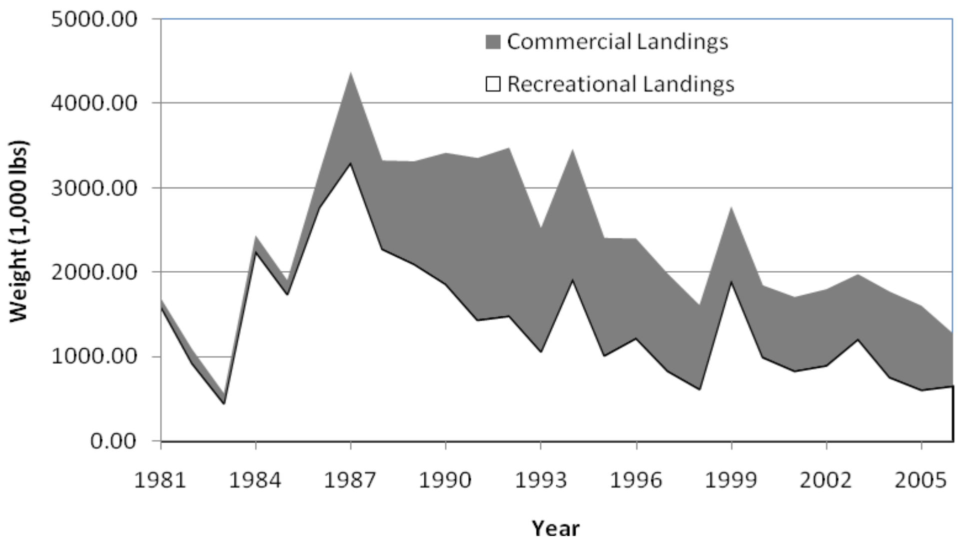
Table 1. Assessment Data Availability

Fishery	Landings	Estimated Discards	Indices
Commercial handline	1946-2006	1984-2006	1993-2006
Commercial dive	1986-2006	--	--
Headboat	1981-2006	--	1978-2006
Recreational (MRFSS)	1981-2006	1984-2006	--

Catch Trends

Greater amberjack were a recreationally-caught species until the late 1980's, when the commercial handline fishery began to target them. Since the early 1990's, landings have been fairly equal between the commercial and recreational sectors. Discards of greater amberjack are relatively low.

Figure 2. Landings by sector, 1981-2006. (Discards by weight were unavailable in this assessment).



Fishing Mortality Trends

The estimated time series of fishing mortality rate (*F*) shows a general increasing trend from the 1980s through the mid-1990s, and then a decline from the 1990s to the present value (around F = 0.23). Fishing mortality is compared to what the fishing mortality would be if the fishery were operating at maximum sustainable yield (F_{MSY}). This ratio (F/F_{MSY}) indicates that overfishing has not occurred over most of the assessment period, except in 1992, 1994, and 1999.

Figure 3. F/F_{MSY}

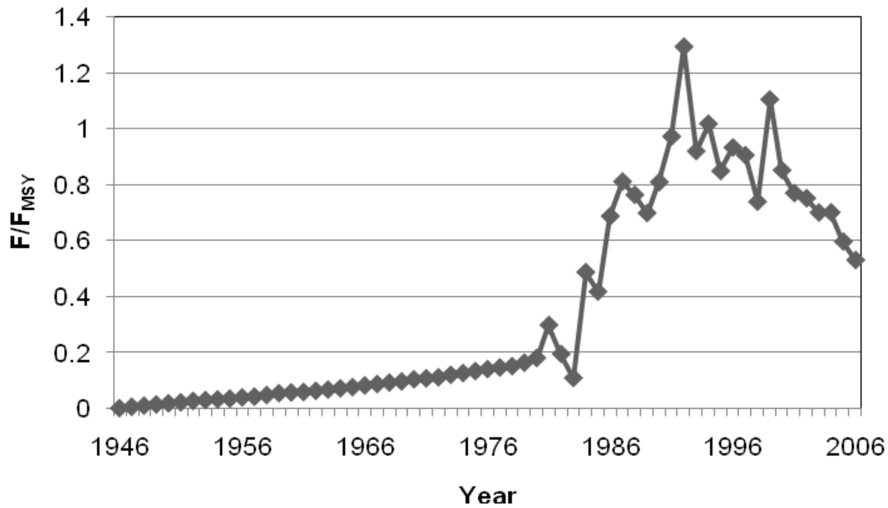
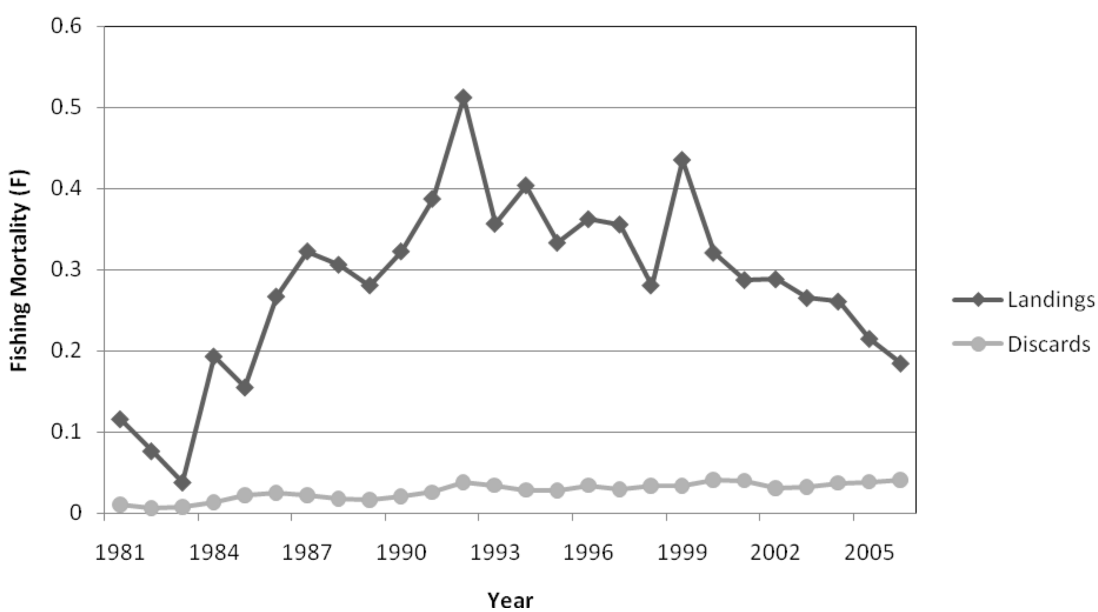


Figure 4. Fully recruited fishing mortality.



Minimum size limits have increased the age at full selection and the fishing mortality has reduced the number of older fish, suggesting that current landings are being supported by only 2 to 4 year classes in any given year.

Stock Abundance and Biomass Trends

Total estimated stock abundance averages 1.5 million fish and varies with a slightly decreasing trend. Abundance peaked with the strong 1986 year class, and again in 2001. Total abundance tapers off gradually thereafter to the estimate of slightly more than million fish in 2006 (see Figure 1).

Estimated spawning stock biomass has gradually and steadily decreased over the assessment period.

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 0.23 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

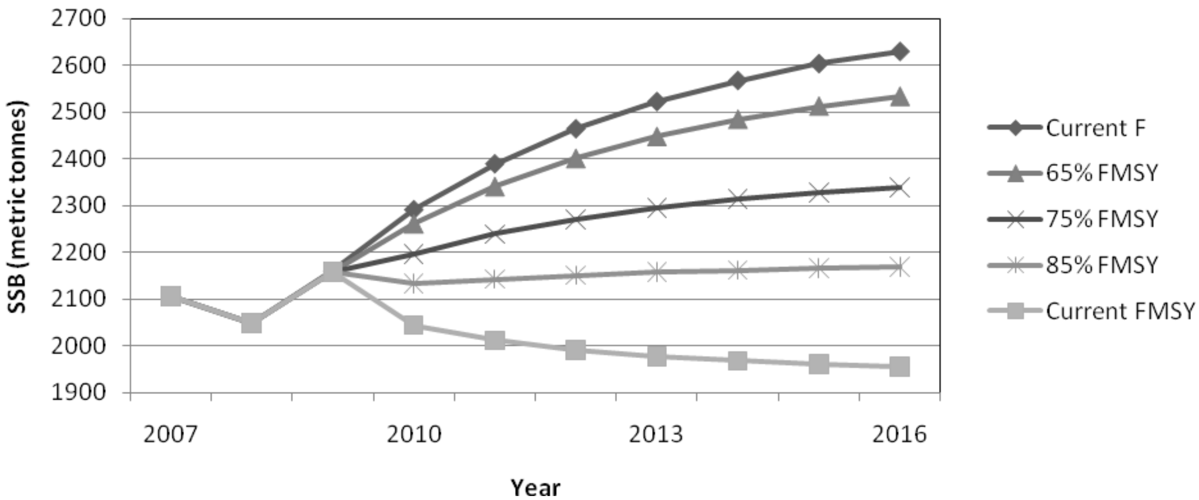
Quantity	Units	Estimate
MFMT (F_{MSY})	per year	0.424
$F_{30\%}$	per year	0.56
$F_{40\%}$	per year	0.342
F_{max}	per year	0.75
B_{MSY}	metric tonnes	5491
SSB_{MSY}	metric tonnes	1940
MSST	metric tonnes	1455
MSY	1000 lbs	2005
D_{MSY}	1000 fish	18
R_{MSY}	1000 fish	435
F_{2006}/F_{MSY}	–	0.531
SSB_{2006}/SSB_{MSY}	–	1.096
SSB_{2006}/MSST	–	1.461

Projections

Short term projections (2007 - 2016) were prepared to evaluate stock status over a range of future fishing mortalities (F_{MSY}, F_{OY}, $F_{current}$). These projections assumed that management changes could take place in 2009. 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. The fully selected fishing mortality rate in the initialization period was taken from the fully selected F during 2004–2006.

Projection results indicate spawning stock will remain above SSB_{MSY} and increase slightly from its current level through at least 2016 if fishing mortality and total removals are held at current conditions. Spawning stock biomass will decline to SSB_{MSY} levels by 2016 if mortality increases to F_{MSY}.

Figure 5. Projection results for Spawning Stock Biomass (in metric



tons).

Table 3. Landings and discards projected when ABC = 75% F_{MSY}. Landings are in metric tonnes and in thousands of pounds; discards are given in thousands of fish.

Year	L (mt)	L (1,000 lbs)	D (1,000 fish)
2007	747	1646	10
2008	650	1434	10
2009	777	1714	15
2010	806	1777	15
2011	833	1836	15
2012	848	1869	15
2013	859	1894	15
2014	868	1913	15
2015	874	1928	16
2016	879	1939	16

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.

Special Comments

The Peer Review Panel had no special comments on this assessment.

Table 4. Landings and discards for greater amberjack 1981-2006. Landings are in 1,000 lbs. whole weight, discards are thousands of fish.

Year	Recreational Landings 1,000 lbs.	Commercial Landings 1,000 lbs	Recreational Discards 1,000 fish	Commercial Discards 1,000 fish
1981	1611.71	86.99	5.46	0.00
1982	927.50	157.85	3.12	0.00
1983	451.98	111.04	3.91	0.00
1984	2254.34	182.94	6.34	0.00
1985	1746.49	157.10	9.75	0.00
1986	2770.13	397.06	10.85	0.00
1987	3308.15	1069.98	8.69	0.00
1988	2281.03	1043.37	6.66	0.00
1989	2103.88	1210.99	5.38	0.00
1990	1865.65	1549.50	6.80	0.00
1991	1440.55	1913.30	7.57	0.00
1992	1488.86	1987.71	8.46	1.15
1993	1067.10	1454.93	7.23	1.22
1994	1925.90	1537.24	4.90	1.71
1995	1019.18	1386.74	5.23	1.61
1996	1224.93	1172.92	5.30	2.02
1997	835.29	1145.28	5.52	2.11
1998	621.25	987.71	5.53	1.90
1999	1906.96	874.90	7.51	1.63
2000	998.29	845.19	8.36	1.73
2001	835.59	869.17	9.26	1.80
2002	901.00	895.99	9.60	1.64
2003	1212.86	762.77	10.64	1.37
2004	760.95	1008.03	10.29	1.18
2005	611.22	989.76	8.02	1.15
2006	657.22	613.61	7.65	1.30

Table 5. Benchmarks 1981-2006. The fishing mortality rate is full F, which includes the 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/FMSY	B	SSB	SSB/SSBMSY	SPR
1981	0.126	0.298	11203	4764	2.46	0.654
1982	0.082	0.194	10595	4425	2.28	0.722
1983	0.046	0.108	10536	4326	2.23	0.826
1984	0.207	0.487	10470	4301	2.22	0.536
1985	0.177	0.417	9491	3897	2.01	0.579
1986	0.292	0.688	9785	3582	1.85	0.463
1987	0.344	0.812	9447	3500	1.8	0.41
1988	0.324	0.764	8514	3398	1.75	0.427
1989	0.296	0.699	7413	3041	1.57	0.447
1990	0.343	0.81	6976	2575	1.33	0.409
1991	0.413	0.973	6904	2377	1.23	0.362
1992	0.549	1.295	6875	2399	1.24	0.329
1993	0.39	0.921	6722	2437	1.26	0.4
1994	0.432	1.019	6570	2467	1.27	0.364
1995	0.36	0.849	6321	2299	1.18	0.416
1996	0.396	0.934	6031	2263	1.17	0.383
1997	0.384	0.907	5706	2123	1.09	0.401
1998	0.314	0.74	5883	2071	1.07	0.447
1999	0.469	1.106	6173	2175	1.12	0.329
2000	0.361	0.852	6063	2168	1.12	0.401
2001	0.327	0.771	7109	2337	1.2	0.427
2002	0.319	0.752	7844	2796	1.44	0.432
2003	0.297	0.701	7749	3084	1.59	0.435
2004	0.297	0.701	6951	2862	1.48	0.44
2005	0.253	0.597	5942	2407	1.24	0.489
2006	0.225	0.531	5617	2126	1.1	0.504

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

Stock Assessment Improvement Program
Assessment Summary Form

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

FMP Common Name: Snapper-grouper

Stock: Greater amberjack (Seriola dumerili)

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 2

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}: 0.53

B/B_{MSY}: 1.1

B/B_{limit}: 1.46

Overfished?: No

Overfishing?: No

Basis for

F_{target}: ?

e.g., F_{OY}

F_{limit}: F at MSY

e.g., F_{MSY}

B_{MSY}: SSB at MSY

B_{limit}: MSST

e.g., MSST

Next Scheduled Assessment

Year: not scheduled

Month:

7. 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

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

Section II. Data Workshop Report

Contents

1. Introduction

1.1 Workshop Time and Place

The SEDAR 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

Group Membership
David Wyanski (SCDNR) – Leader
Chip Collier (NCDMF)
Stephanie McInerny (NMFS)
Paulette Mikell (SCDNR)
Jennifer Potts (NMFS)
Jessica Stephens (SCDNR)
Byron White (SCDNR)

This group's first task was to pull together the two greater amberjack age data sets supplied by SCDNR and NMFS-Beaufort. No formal exchange of samples was completed before the workshop, though an aging workshop was held prior to the age studies beginning. In the age database, increment counts had to be converted to calendar ages, which was to be completed after the workshop's conclusion. From the age data we were able to compute estimates of growth and natural mortality. Stock definition and discard mortality rates fell in line with the SEDAR9 (Gulf of Mexico greater amberjack).

2.2. Stock definition and description

2.2.1 .Otolith Chemistry

Otolith chemistry studies are not available for greater amberjack.

2.2.2. Population genetics

Genetic studies can provide estimates of connectivity among management units. Genetic variation has been observed between the South Atlantic, including the Florida Keys (SA), and GOM greater amberjack using mtDNA (Gold and Richardson 1998), with the break occurring somewhere along the southwest coast of Florida. Though data supports two separate stocks, Gold and Richardson (1998) report that the evidence is weak and needs further study. A new study is being conducted by Renshaw et al. (2007) to look at the utility of microsatellites to distinguish stocks of greater amberjack.

2.2.3. Larval transport and connectivity

It has been hypothesized that there are pathways for larval connectivity and transport from the Gulf to the Atlantic (Powles 1977), but oceanographic surface conditions do not favor transport in this direction during the spawning peak of greater amberjack in the Gulf (April to June off Louisiana; SEDAR9-SAR2). A two-dimensional model that utilizes wind stress data shows that the summer (April to September) months are characterized by continuous northwest flow with Ekman surface transport toward the northwest Florida coast (Fitzhugh et al. 2005). However, spawning in January to March could result in transport of larvae to the Atlantic because advection in the offshore direction from the West Florida Shelf would allow entrainment in the Loop Current, the Florida Current, and ultimately the Gulf Stream; therefore, eggs released along the West Florida Shelf could provide recruits to the Florida Keys and points to the north along the Atlantic coast.

Spawning of greater amberjack off the Florida Keys during the late winter and spring (February to May) occurs at a time when the alongshore currents flow eastward (Lee and Williams 1999), thereby providing the potential for transport of larvae to points north along the Atlantic coast.

There is some uncertainty about distinguishing the larvae of greater amberjack from those of other *Seriola* species because the only larval series description is based on lab-reared specimens from Pacific brood stock (Richards 2006).

Recommendation:
The DW is aware that oceanographic modeling efforts are advancing (3-D models), and recommends that larval transport and modeling efforts associated with development of an Integrated Coastal Ocean Observing System (ICOOS) be further supported.

2.2.4. Tagging

The DW reviewed the results of two greater amberjack tagging studies (McClellan and Cummings 1997; SEDAR15-RD02) and one greater amberjack data set (SC Marine Gamefish Tagging Program). The objective was to gauge the degree of exchange between Atlantic and Gulf stock units. Over 15,000 greater amberjack were tagged in the Gulf of Mexico and South Atlantic Bight, resulting in recaptures of approximately 2,000 fish. Movement of greater amberjack was dependent on tagging location. Fish tagged off Virginia through northeast Florida migrated south during the spring (McClellan and Cummings 1997; SEDAR15-RD02). Movement between the Atlantic and GOM was also detected in these studies, as well as movement from the Atlantic to the Bahamas and Caribbean. There were several fish tagged in the Atlantic that were recaptured from the Florida Keys, Bahamas, Cuba, Yucatan Peninsula, and Alabama (SEDAR15-RD02). Mixing rate from the SA to the GOM was 1.3% and from the GOM to the SA was 1.6% (McClellan and Cummings 1997), although a more recent study (unpublished) indicates a higher migration rate from the Atlantic to the GOM (SEDAR15-RD02). Additional analysis of the data is needed, as no estimate of migration rate was reported in the recent study.

Tagging data indicates that there are resident and migratory groups in the greater amberjack population off the Atlantic Coast. One group is resident off Florida (McCellan and Cummings 1997; SEDAR15-RD01). The second group is migratory and moves southward during the spawning season and northward afterward (Burch 1979; SEDAR15-RD02; SC Marine GameFish Tagging Program).

Recommendation:

Greater amberjack 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. However, it was acknowledged that this might change in future assessments. The management unit for greater amberjack was the Florida Keys to Virginia for the recreational fishery, and all of the Atlantic with a split in Monroe County for the commercial fishery to match the Gulf of Mexico (GOM) assessment.

2.3. Natural mortality

2.3.1. Juvenile (YOY)

Larval and juvenile greater amberjack are rarely encountered (n = 0 to 10 per year) in a nearshore (<30 ft) fishery-independent trawling program (SEAMAP) in the Atlantic. An estimated mortality rate for YOY greater amberjack was based on an age structured morality equation (Lorenzen 1996). Estimates of Z for juvenile greater amberjack (39-140 days old) was 0.0045 per day in the northwestern Gulf of Mexico (Wells and Rooker 2004a). Mortality rates for fish younger than in the study will be much higher and fish older than captured in the study will likely have lower mortality rates.

2.3.2. Sub-adult/Adult

Greater amberjack in the southeastern US live to be at least 17 years old (Manooch and Potts 1997; pers. comm. D. Murie, University of Florida – Gainesville), though neither age data set available for this assessment had fish that old (max age 13). The LH group felt that the samples in the age data were from a heavily exploited stock, and thus, using age 17 as the max age was more appropriate. Based on this information, the method of Hoenig (1983) resulted in M of 0.25. This point estimate of M was also used in the Gulf of Mexico greater amberjack SEDAR9.

The Lorenzen (1996) model, scaled to Hoenig, provides an age-specific estimate of natural mortality that ranges from 1.03 – 0.20 for fish age 0 to 13 (max age observed in the data available for this assessment and used to derive the growth parameters).

Issue: What max age to use.

Recommendations:
1. Use Hoenig point estimate for M and use max age of 17 years.
2. Use Lorenzen scaled M for ages 0 through 13.

2.4 Discard Mortality

Information on discard mortality rates of greater amberjack caught off the Atlantic coast of the southeastern U.S. is scarce. Data collected from surface observations of released undersized reef fish caught by headboat and commercial handline anglers fishing off Beaufort, NC, estimated maximum acute mortality of greater amberjack as 0.09 (0.91 as survival, n=11) for the headboat fishery and 0.08 (0.92 survival, n=12) for the commercial handline fishery (unpublished data, R. Dixon, NMFS, Beaufort, NC). In contrast, a NMFS Cooperative Research Program study involving SCDNR personnel and one local commercial fisherman reported 0.92 rate of mortality of undersized greater amberjack (n = 51). The report did state that the fish were not immediately released which would have contributed to the high rate of mortality (SEDAR15-RD07).

A pilot study, entitled "Headboat At-Sea Observer", conducted by Florida Wildlife Research Institute (FWRI) along Florida's east coast and Florida Keys, reported on the disposition of caught and released reef fish species (pers. comm., Beverly Sauls, FWRI). Observations on 76 greater amberjack caught and released suggest that this species had 100% survival after release. The depth range of capture of the fishing trips was recorded as 40 ft to 200 ft.

Two tagging studies of greater amberjack may give an indirect measure of release mortality. The first study took place in the Florida Keys (Burns et al., 2007), where 33 greater amberjack were tagged and two recaptured. The disposition of the fish was recorded for every fish caught and tagged. This study noted the fish were in "good" condition, which suggests that most would survive release. The second tagging study conducted by the SCDNR MARMAP group was able to tag 2,277 greater amberjack (SEDAR15-RD02). They noted that the fish were very hardy and there was no trend in recapture rate with depth. One fish was captured at a depth of 92 m, tagged and later recaptured.

Recommendation:
Due to the limited nature of the available data, the LH group recommends a release mortality rate of 0.2, with sensitivity runs in the range of 0.1 to 0.3. The discard mortality rate of 0.2 mirrors the rate used in the GOM greater amberjack assessment (SEDAR9-SAR2). We also felt that the acute mortality observed from headboats of 0.09 was the minimum value that could be used, and may actually be too low of an estimate.

2.5 Age Data

2.5.1. Age Structure Samples

Greater amberjack have been aged in four studies in the U.S. South Atlantic jurisdiction. The first study was conducted by Burch (1979) on fish collected in the Florida Keys from 1977-1978. Burch aged the fish using scales. The LH group decided not to consider this age data for inclusion in this assessment because of the issues inherent in aging reef fish with scales. The LH group did not have any confidence in the oldest ages reported by Burch, because scales tend to greatly underestimate ages of the fish compared to otoliths. Three more current studies using sectioned otoliths provided age data for consideration. Manooch and Potts (1997) reported on the age and growth of greater amberjack from the headboat and commercial fisheries operating from 1988 to 1994 (n=230). The maximum observed age was 17 years, which corresponds to the maximum age noted in an aging study on this species in the Gulf of Mexico (pers. comm., D. Murie, Univ. of Florida, Gainesville, FL). An age and growth study conducted by SCDNR (SEDAR15-RD01) on commercially and recreationally caught fish from 2000 to 2004 (n = 1,984) observed a maximum age of 13 years. An age and growth study conducted by NMFS Beaufort Lab (pers. comm. J. Potts, NMFS, SEFSC, Beaufort, NC) on commercially and recreationally caught fish from 1998 to 2006 (n = 1,576) observed a maximum age of 12 years. Manooch and Potts (1997) data was substantially different from that in the SCDNR and NMFS studies (Figure 2.1) in a comparison of mean fork length-at-increment count.

Recommendation:
The LH group recommends combining the SCDNR and NMFS age data sets (expressed as calendar age) for use in the assessment. (See Table 2.1 for sample size by fishery and year.) We felt that there was a change in methodology of assigning age to the otolith samples between the time of the Manooch and Potts (1997) and the current studies; therefore, the data from Manooch and Potts (1997) will not be included in the assessment.

2.5.2. Age Reader Precision

Personnel from the NMFS Beaufort Lab, SCDNR and D. Murie of UF – Gainseville participated in an aging workshop for greater amberjack in December 2006. SCDNR had finished its study; D. Murie's study was ongoing; and NMFS was just starting its current study. Determination of first increment was discussed, as well as interpretation of the rest of the increments on the otolith sections. Protocol for aging the fish was established. A formal exchange of 100 otoliths to determine the consistency of age estimates between the three laboratories is on-going.

2.6. Growth

Initial estimates of the von Bertalanffy growth parameters have been done based on fork length-at-increment counts from the SCDNR and NMFS data combined. Because 99.5% of the age samples were collected from fishery-dependent sources and subject to minimum size limits, the size of the fish at the youngest ages was thought to be skewed to the fastest growers. A methodology developed by Diaz et al. (2004) to estimate the von Bertalanffy growth parameters and correct for the skewed distribution of lengths-at-age for the youngest ages was used in SEDAR7 (Gulf of Mexico red snapper) and in SEDAR10 (Gulf of Mexico and Atlantic gag). We used that methodology as well as estimates from the uncorrected von Bertalanffy model inverse weighted by sample size at age and no weighting.

Recommendation:
The LH group recommends using the growth parameters estimated from the Diaz et al. (2004) methodology. The group felt that this growth model was the most appropriate biologically.

2.7. Reproduction

Harris et al. (SEDAR15-RD01) is the only available information on the reproductive biology of greater amberjack along the Atlantic coast of the southeastern U.S. Nearly all (99%) of the specimens for the study came from fishery-dependent sources, primarily commercial snapper reel, charter/party boats, and headboats in order of sample abundance. Information below on spawning seasonality, sexual maturity, sex ratio, and spawning frequency is based on the most accurate technique (histology) utilized to assess reproductive condition in fishes. Greater amberjack do not change sex during their lifetime (gonochorism).

2.7.1. Spawning Seasonality

Based on the occurrence of migratory nucleus (MN) oocytes and postovulatory follicles (POFs), spawning occurred from January through June, with peak spawning in April and May. Mean gonadosomatic index values also peaked in April and May. Although fish in spawning condition were captured from North Carolina through the Florida Keys, spawning appears to occur primarily off south Florida and the Florida Keys. Greater amberjack in spawning condition were sampled from a wide range of depths (45-122 m), although the bulk of samples were from the shelf break.

2.7.2. Sexual Maturity

Maturity ogives in tabular format are available in SEDAR15-RD01 (see Tables 3 and 4), a summary of which follows. The smallest mature male was 464 mm FL and the youngest was age 1; the size at 50% maturity was 644 mm FL (95% CI = 610-666), and the largest immature male was 755 mm FL, the oldest was age 5. All males were mature at 751-800 mm FL and age 6. The smallest mature female was 514 mm FL, and the youngest was age 1; the size at 50% maturity was 733 mm FL (95% CI = 719-745), and the largest immature female was 826 mm FL, the oldest was age 5. All females were mature by 851-900 mm FL and age 6. Age at 50% maturity for females was 1.3 yr (95% CI = 0.7-1.7). The gompertz equation (1-exp(-exp(a+b*age))) was used to estimate A_{50} for females (a= -1.2407; b= 0.6779); no estimate of A_{50} could be calculated for males owing to the low number of immature specimens.

2.7.3. Sex ratio

Tables with sex ratio by length class (mm FL) and age class are available in SEDAR15-RD01 (see Table 2). The overall male:female sex ratio for greater amberjack in these collections was **1:1.11**, significantly different from a 1:1 ratio ($0.01<P<0.025$), owing to females dominating the larger (>1100 mm FL) size classes. The female-skewed sex ratio probably reflects selectivity for larger fish in the commercial fishery due to size limit. Commercial fishermen involved in the study were permitted to land undersized specimens. If samples from charter/party boats and headboats are removed from the analysis, the sex ratio is more skewed toward females (**1:16**; see Figure 2.2 in this report). The sex ratio of the overall dataset was significantly biased toward females for only two age classes, and no obvious trends were evident in these data (SEDAR15-RD01; see Table 2).

2.7.4. Spawning Frequency

Spawning frequency and batch fecundity, necessary to estimate potential annual fecundity, were based on MN and hydrated oocytes, and spawning frequencies based on the occurrence of POFs were estimated for comparative purposes. Hydrated oocytes never represented more that 2% of the oocytes counted to estimate batch fecundity, as fishing generally occurred during morning hours, apparently several hours prior to the time of peak oocyte hydration. MN oocytes were predominant in the 31 specimens with oocytes sufficiently developed to clearly identify the batch to be released. The proportion of specimens with MN or hydrated oocytes among females with oocytes undergoing vitellogenesis was similar to the proportion with POFs < 24 hr old (0.213 vs. 0.241; SEDAR15-RD01, see Table 5). The average of the two proportions was 0.227, which corresponded to a spawning periodicity of approximately 5 days. With a spawning season of approximately 73 days off South Florida (27 February through 10 May), an individual female could spawn approximately 14 times.

2.7.5. Batch Fecundity

Statistically significant relationships were developed between batch fecundity and total length, fork length, and age (SEDAR15-RD01; see Table 6). Given the small sample sizes in late March ($19\text{-}28^{th}$) and early May (3^{rd}) and the similarity of the data from all months, data were combined to estimate the relationship between batch fecundity and fork length (SEDAR15-RD01; see Figure 12). Multiplying the estimated number of spawning events (14) by batch fecundity (BF) estimates (BF = 7.955*FL – 6,093,049) for greater amberjack 930-1296 mm FL produced estimates of potential annual fecundity that ranged from 18,271,400 to 59,032,800 oocytes. Relative to age, estimates of potential annual fecundity ranged from 25,472,100 to 47,194,300 oocytes for ages 3-7.

Recommendations:
The consensus of the workshop panel during plenary session on Friday (13 July 2007) was to recommend that the assessment be done with the assumption of a 1:1 sex ratio, owing to the sampling bias associated with commercial snapper reels. The Life History group also recommends that information on spawning seasonality and sexual maturity in SEDAR15-RD01 be utilized in the assessment, as this is the only information on the reproductive biology of greater amberjack along the Atlantic coast of the southeastern U.S. and it's based on the most accurate technique (histology) utilized to assess reproductive condition in fishes. Estimates of batch fecundity (vs. length and age) and spawning frequency are also available in SEDAR15-RD01.

2.8. Movements and migrations

The DW reviewed the results of two greater amberjack tagging studies (McClellan and Cummings 1997; SEDAR15-RD02) and one greater amberjack data set (SC Marine Gamefish Tagging Program). The objective was to gauge the degree of exchange between Atlantic and Gulf stock units. Over 15,000 greater amberjack were tagged in the Gulf of Mexico and South Atlantic Bight, resulting in recaptures of approximately 2,000 fish. Movement of greater amberjack was dependent on tagging location. Fish tagged off Virginia through northeast Florida migrated south during the spring (McClellan and Cummings 1997; SEDAR15-RD02). Movement between the Atlantic and GOM was also detected in these studies, as well as movement from the Atlantic to the Bahamas and Caribbean. There were several fish tagged in the Atlantic that were recaptured from the Florida Keys, Bahamas, Cuba, Yucatan Peninsula, and Alabama (SEDAR15-RD02). Mixing rate from the SA to the GOM was 1.3% and from the GOM to the SA was 1.6% (McClellan and Cummings 1997), although a more recent study (unpublished) indicates a higher migration rate from the Atlantic to the GOM (SEDAR15-RD02). Additional analysis of the data is needed, as no estimate of migration rate was reported in the recent study.

The mean distance traveled was dependent on the location of tagging. Fish tagged off Florida appeared to be a resident population with a high percentage of fish being recaptured in the same latitude (McCellan and Cummings 1997; SEDAR15-RD02) or same state of recapture (SC Marine Gamefish Tagging Program). Greater amberjack tagged off the Carolinas migrated a greater distance than those tagged off Florida (SEDAR15-RD02; SC Marine Gamefish Tagging Program). This migration may be related to the spawning season that occurs from January to June, but direct evidence to support this conclusion is limited. Greater amberjack were recaptured southward of tagging location from December to May (Burch 1979). As the spawning season ends, greater amberjack migrated northward. Additionally, the percentage of mature females with histological evidence of spawning during April and May, the peak spawning months, ranged from 77% off southeast Florida (24-25^{o} N) to 10% off Georgia and the Carolinas (31-34^{o} N) (SEDAR15-RD01).

Recommendation:
We agree with the decision in the current stock assessment to not account for migration between management units given the current state of knowledge. There is growing evidence that some level of stock exchange, probably small, is taking place between the US South Atlantic and the Gulf of Mexico. Additional analysis of the data in SEDAR15-RD02 and re-examination of the results of other tagging studies should be undertaken prior to future assessments of this species. In addition, research should be funded to use new technology such as satellite pop-up archival tags, otolith microchemistry and recent advances in genetics techniques to reinvestigate the mixing rate between the regions.

2.9. Habitat requirements

Throughout the Gulf of Mexico juvenile greater amberjack are commonly collected in association with pelagic *Sargassum* mats (Bortone et al. 1977). YOY greater amberjack (< 200 mm SL) are most common during May-June in offshore waters of the Gulf (Wells and Rooker 2004a). The sizes of individuals associated with *Sargassum* range from approximately 3-20 mm SL (age range: 40-150 d) (Wells and Rooker 2004b). Individuals larger than 30 mm TL are common in NOAA small pelagic trawl surveys (SEDAR9-

DW-22), as well as the headboat fishery along the Atlantic coast of the southeastern U.S. (Manooch and Potts 1997), suggesting a shift in habitat (pelagic to demersal) occurs at 5-6 months of age. After shifting to demersal habitats, sub-adults and adults congregate around reefs, rock outcrops, and wrecks. Since greater amberjack are only seasonally abundant in certain parts of their range, they likely utilize a variety of habitats and/or areas each year.

2.10. Meristic Conversions

Meristic relationships were calculated for greater amberjack for total length (TL), fork length (FL), standard length (SL), whole weight (WW) and gutted weight (GW), using combined data sets from various fishery-independent and fishery-dependent sources (Table 2.2). Fishery-independent data included total length, fork length, standard length, whole weight and gutted weight from the SCDNR MARMAP program. These same data were also available for fishery-dependent data from SCDNR and FWRI (less the gutted weight). In addition, NMFS headboat samples provided whole weight, total and fork lengths. All weights are shown in grams and all lengths in millimeters. Coefficients of determination were high for linear (length) and nonlinear (weight) regressions ($r^2 \geq 0.943$).

2.11. Comments on adequacy of data for assessment analyses

There are no direct estimates of natural and discard mortality. Both of these components of total mortality should have a range of values tested in the assessment to determine the effects of these parameters.

The age data is only from the most recent decade. During this time period, large minimum size limits were in place for both the recreational and commercial fisheries. The age composition data may be inadequate to characterize the fisheries prior to this time.

The remainder of the life-history data inputs for this assessment should be viewed as adequate to more than adequate.

2.12. Research recommendations

1) Use new technology such as satellite pop-up archival tags and recent advances in genetics techniques to reinvestigate the mixing rate between greater amberjack in the Gulf of Mexico and those in the waters along the Atlantic coast of the southeastern U.S. Such research will also provide insight into post-release survivorship, migratory patterns, and spawning locations.

2) 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 at SCDNR (Table 2.3). These classifications are currently used by MARMAP and NMFS Beaufort.

3) Conduct inter-lab comparison of age readings from test sets of otoliths in preparation for any future stock assessments.

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

5) Obtain better estimates of greater amberjack natural mortality and release mortality in commercial and recreational fisheries.

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

7) Investigate life history of larval/juvenile (age 0 and 1) greater amberjack, as little is known.

2.13. Itemized list of tasks for completion following workshop

1) Complete amberjack age composition: Potts; August 17, 2007 - done

2.14. Literature cited

Bortone, S. A., P. A. Hastings, and S. B. Collard. 1977. The pelagic-Sargassum ichthyofauna of the eastern Gulf of Mexico. Northeast Gulf Sci. 1:60-67.

Burch, R.K. 1979. The greater amberjack, *Seriola dumerili*: its biology and fishery off southeastern Florida. M.S. Thesis, University of Miami.

Burns, K. M., N. J. Brown-Peterson and D. R. Gregory, Jr. 2007. Combining a partnership among researchers, commercial, recreational and recreation-for-hire fishers with a cooperative tagging program to elucidate the life history and habitat utilization of select reef fish and coastal pelagic species in the Florida Keys. Mote Marine Laboratory Technical Report No. 1152.

Diaz, G.A., C.E. Porch, and M. Ortiz. 2004. Growth models for red snapper in US Gulf of Mexico Waters estimated from landings with minimum size limit restrictions. NMFS/SFD Contribution SFD-2004-038. SEDAR7-AW1.

Fitzhugh, G.R., C.C. Koenig, F.C. Coleman, C.B. Grimes, and W. Sturges III. 2005. Spatial and temporal patterns in fertilization and settlement of young gag (*Mycteroperca microlepis*) along the west Florida shelf. Bull. Mar. Sci. 77: 377-396.

Gold, J.R. and Richardson, L.R. 1998. Population structure in greater amberjack, Seriola dumerili, from the Gulf of Mexico and the western Atlantic Ocean. Fish. Bull. 96: 767-778.

Hoenig, J. M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82: 898-903.

Lee, T.N., and E. Williams. 1999. Mean distribution and seasonal variability of coastal currents and temperature in the Florida Keys with implications for larval recruitment. Bull. Mar. Sci. 64:35-56.

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

Manooch, C.S., III, and J.C. Potts. 1997. Age, growth and mortality of greater amberjack from the southeastern United States. Fish. Res. 30: 229-240.

McClellan, D.B., and N.J. Cummings. 1997. Preliminary analysis of tag and recapture data of the greater amberjack, *Seriola dumerili*, in the southeastern United States. Proc. 49th Annual Gulf and Carib. Fish. Inst., Christ Church, Barbados. November 1996. 49: 25-45.

Powles, H. 1977. Larval distributions and recruitment hypotheses for snappers and groupers of the South Atlantic Bight. Proc. Annual Conf. S.E. Assoc. Fish & Wildlife Agencies 31:362-371

Renshaw, M.A., J.C. Patton, C.E. Rexroad III, and J.R. Gold. 2007. Pcr primers for dinucleotide microsatellites in greater amberjack, *Seriola dumerili*. Conservation Genetics 8:1009-1011.

Richards, W.J. (Editor). 2006. Early stages of Atlantic fishes: an identification guide for the western central North Atlantic, Volume 2. CRC Press, Taylor & Francis Group, Boca Raton, 2640 p.

SEDAR9-SAR2. 2006. Stock Assessment Report 2, Gulf of Mexico greater amberjack.

SEDAR9-DW-22. Ingram, G.W., Jr. Data summary of gray triggerfish (*Balistes capriscus*),vermilion snapper (*Rhomboplites aurorubens*), and greater amberjack (*Seriola dumerili*) collected during small pelagic trawl surveys, 1988 – 1996.

SEDAR15-RD01. Harris, P.J., D.M. Wyanski, D.B. White, P.P. Mikell, and P.B. Eyo. In press. Age, growth, and reproduction of greater amberjack, *Seriola dumerili*, off the Atlantic coast of the southeastern United States. Trans. Amer. Fish. Soc.

SEDAR15-RD02. A Tag and Recapture study of greater amberjack, *Seriola dumerili*, from the Southeastern United States. MARMAP unpublished report.

SEDAR15-RD07. Harris, P. J., and J. A. Stephen. 2005. Characterization of commercial reef fish catch and bycatch off the southeast coast of the United States. Final Report, *CRP Grant No. NA03NMF4540416.*

Wells, R.J.D., and J.R. Rooker. 2004a. Distribution, age, and growth of young-of-the-year greater amberjack (*Seriola dumerili*) associated with pelagic *Sargassum*. Fish. Bull. 102:545-554.

Wells, R.J.D., and J.R. Rooker. 2004b. Spatial and temporal patterns of habitat use by fishes associated with *Sargassum* mats in the northwestern Gulf of Mexico. Bull. Mar. Sci. 74: 81-99.

2.15. Tables

Table 2.1. Sample size of aged fish by year, fishery, and gear: HL = commercial vertical hook and line; D = commercial divers/spears; CB = recreational charter boat; HB = recreational headboat; PR = recreational private boat.

	Commercial		Recreational			Fishery-Independent	
Year	**HL**	**D**	**CB**	**HB**	**PR**		**Grand Total**
1998	**37**						**37**
1999	**35**	**48**					**83**
2000	**154**	**21**		**7**		**10**	**192**
2001	**194**		**30**			**4**	**228**
2002	**817**		**228**	**5**	**5**	**3**	**1058**
2003	**426**		**554**	**47**	**10**		**1037**
2004	**36**		**377**	**3**	**1**		**417**
2005	**7**		**358**	**4**			**369**
2006			**133**	**6**			**139**
Grand Total	**1706**	**69**	**1680**	**72**	**16**	**17**	**3560**

Table 2.2. Length to length, weight to length, and gutted weight to whole weight conversions for greater amberjack. Units of length and weight are mm and g, respectively.

Conversion	Equation	N	r^2	a	a SE	b	b SE
TL – FL	FL = aTL + b	2881	0.987	0.08858	0.0022	-12.58	2.505
TL – SL	SL = aTL + b	1798	0.980	0.826	0.0027	-18.9706	3.032
FL – SL	SL = aFL + b	1811	0.986	0.9278	0.0026	-2.2515	2.495
TL – WW	$WT = a(TL)^b$	2798	0.953	0.00003	0.01504	2.815	0.000004
FL – WW	$WT = a(FL)^b$	2950	0.943	0.00003	0.000004	2.866	0.01622
WW – GW	GW = a(WW) + b	26	0.995	0.9209	0.0139	96.078	230.7086
WW – GW (no intercept)	WW = GW*C C = 1.079	26					

Table 2.3. Edge code and quality code developed by SCDNR to be incorporated into aging studies by both SCDNR and NMFS.

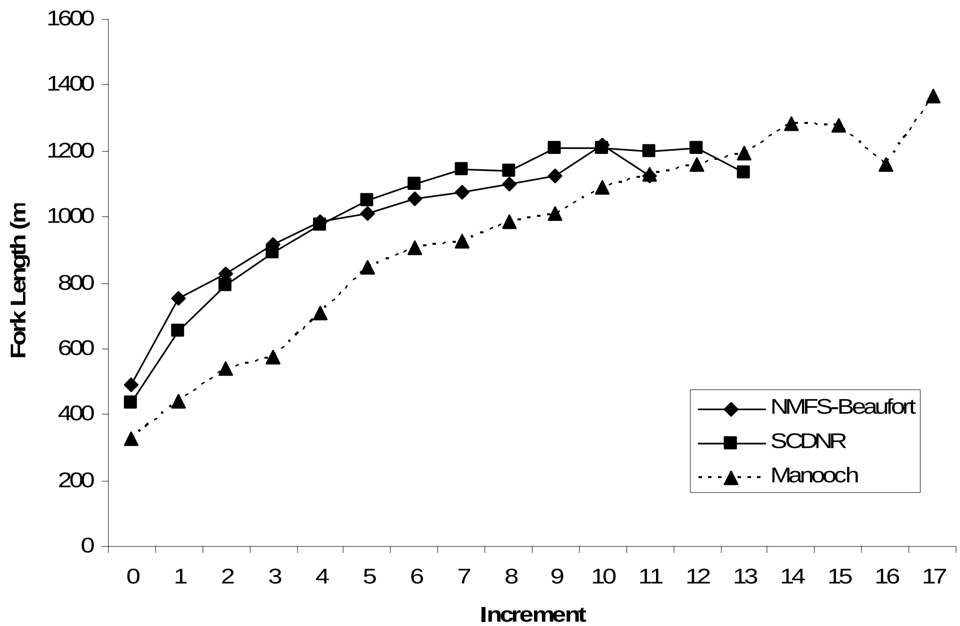
Quality Code	Action	Description
A	Omit otolith from analysis	Unreadable
B	Agreement on age may be difficult to reach. Omit from analysis.	Very difficult to read
C	Agreement after second reading is expected after some discussion.	Fair readability
D	Agreement after second reading is expected without much 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

2.16. Figures

Figure 2.1. a. Mean fork length (mm) at annual increment count in three studies of greater amberjack age and growth. (NMFS-Beaufort: J. Potts pers. comm.; SCDNR: P. Harris pers. comm.; Manooch: Manooch and Potts 1997). b. von Bertalanffy growth models calculated from observed length at annual increment count using the Diaz et al. model, the uncorrected model with no weighting and the uncorrected model with inverse weighting.

a.



b.

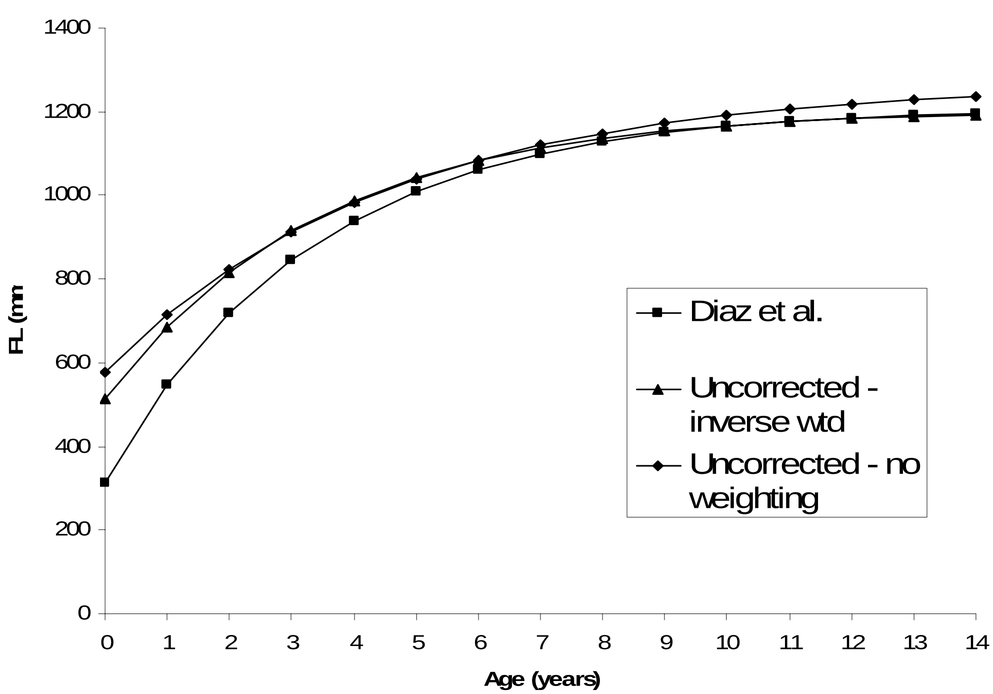
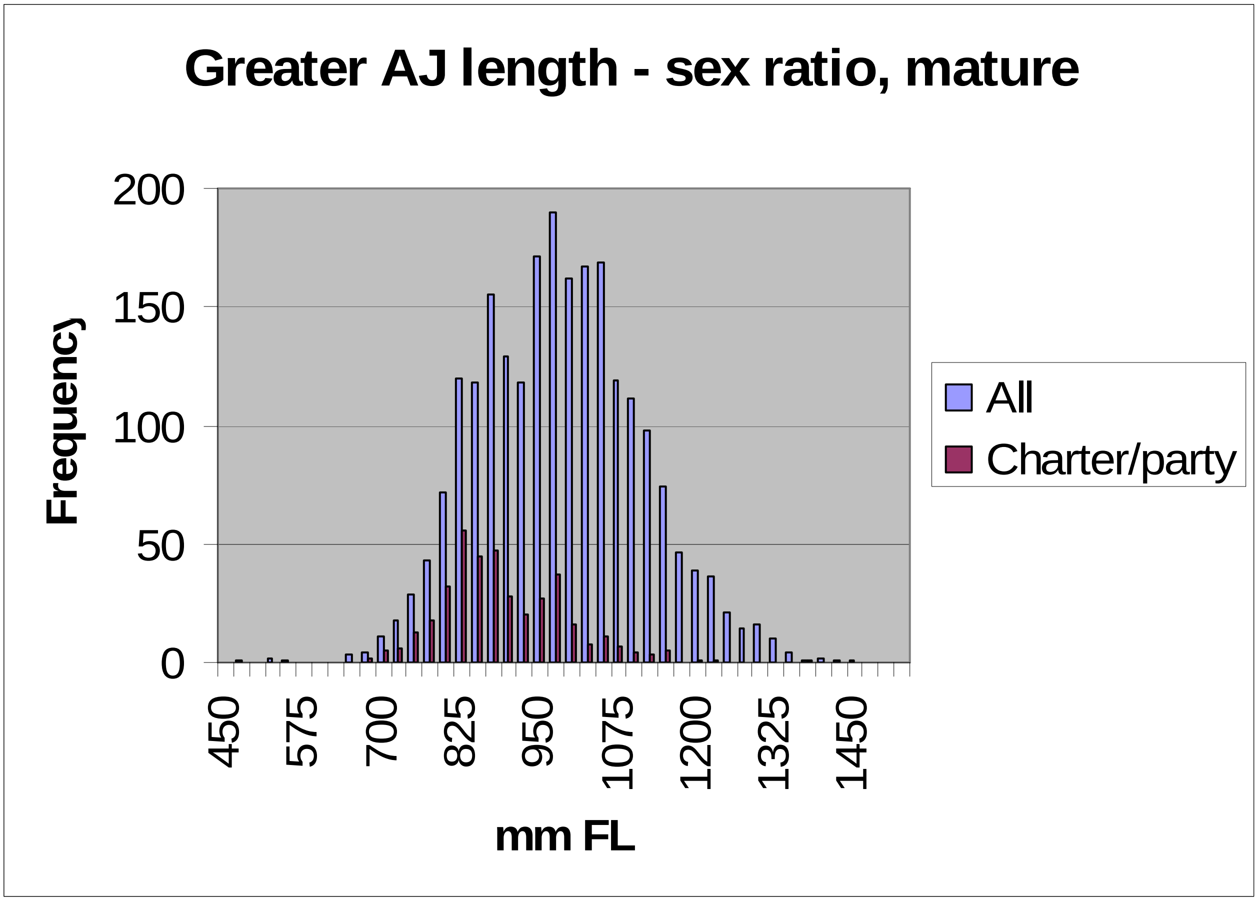


Figure 2.2. Fork length frequencies of sexually mature specimens utilized in SEDAR15-RD01 to estimate the population sex ratio of greater amberjack along the Atlantic coast of the southeastern U.S.



Appendix 1. Addendum to Growth (Section 2.6)

An error in the calculation of the greater amberjack growth model was found and addressed after the conclusion of the assessment workshop. In addition, fractional ages calculated from increment counts using the specie's assumed birthdate (April 1) and then adjusted for month of capture were available for use in growth analyses.

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 greater amberjack growth model.

A total of 625 samples were deleted to fix this error resulting in a revised greater amberjack von Bertalanffy model (L_∞ = 1194.0, k = 0.343, t_0 = -0.45; n = 2926) (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-age were visible for fish ages 1 – 7 years as well as fish 12 and 13 years of age (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-age for greater amberjack that were 7 years of age and younger and predicted slightly lower lengths-at-age for 12 and 13 year old fish.

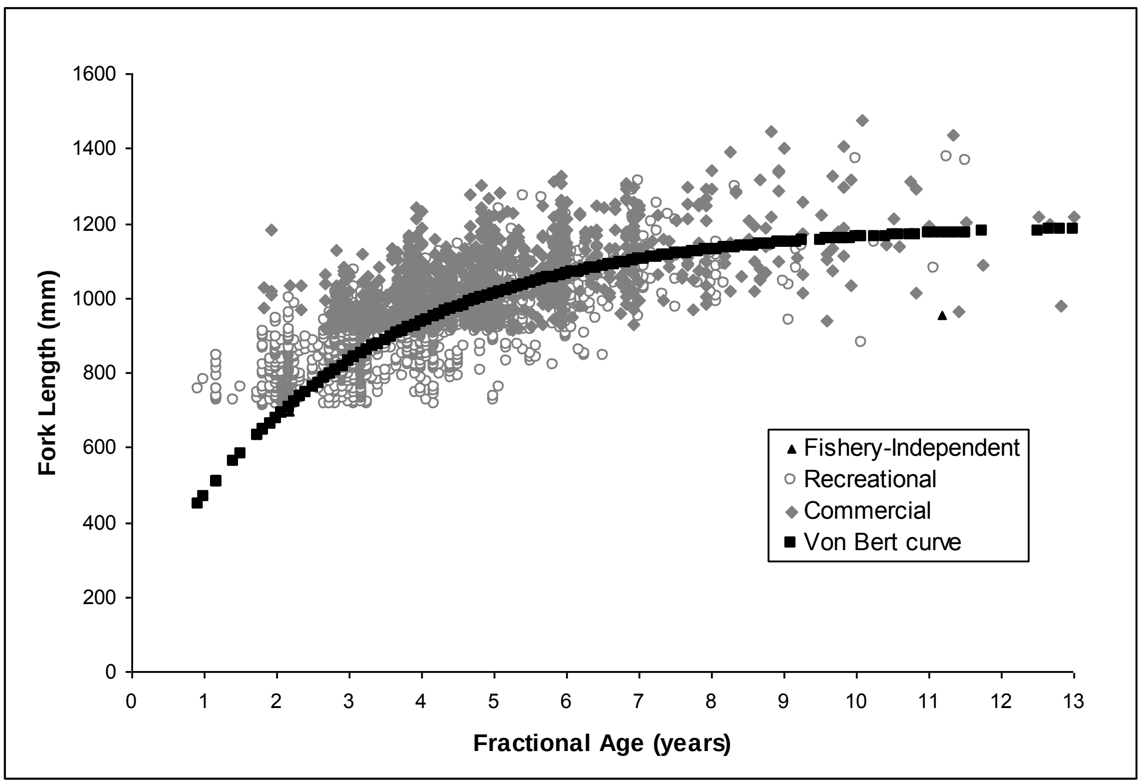


Figure A1.1. Revised von Bertalanffy model from greater amberjack fractional ages using Diaz et al. methodology with appropriate size limits in place.

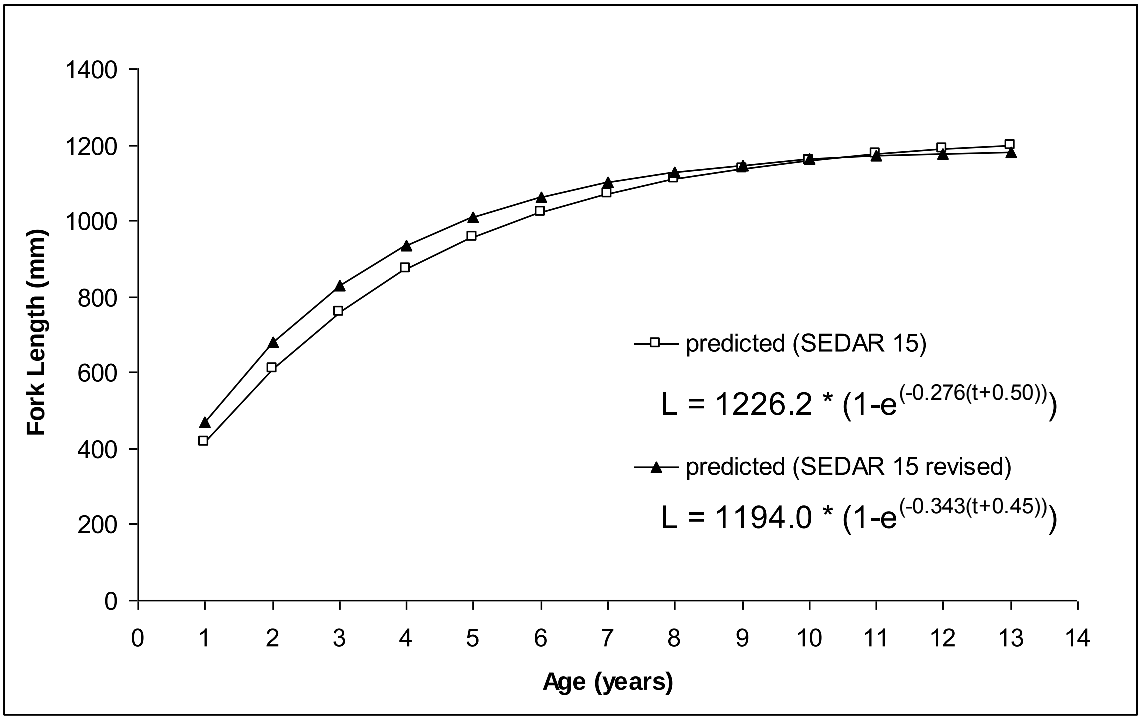


Figure A1.2. Comparison of original and revised greater amberjack von Bertalanffy growth models using Diaz et al. methodology.

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). Because the category amberjacks have not been identified to the species level until recently in the ALS, it was found necessary to use ancillary information for breaking out a portion of these landings as greater amberjack. Commercial landings for the U.S. South Atlantic greater amberjack 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 greater amberjack 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

3.2.1. Introduction

Gear Groupings: Prior to the DW the commercial working group settled on the following numerical gear codes for dividing greater amberjack commercial landings into five categories: handline (600-616, 660, 665), longline (675-677), diving (760, 941-943), and other gear types (remaining gear codes including small amount of unknown).

Stock Boundaries: 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). 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 (Virginia – Massachusetts). The earliest landings were in 1951 (1,346 pounds whole weight of unclassified amberjack). Positive annual reported landings were consistent through 2006, especially since 1985 (with exceptions only in 1987 and 1992). If we assume landings were truly 0 in those years none were reported for 1951-2006, then the average annual reported landings from Virginia through Massachusetts was 1,289 pounds (whole weight) of unclassified amberjack. To parallel the decision by the recreational working group, landings north of North Carolina are included in this assessment. Thus, the northern extent of this stock is Massachusetts (the northern most reported landings).

Weight Conversion: As in SEDAR 10 for South Atlantic gag, the Working Group decided to present all landings in gutted weight. The standard conversion of amberjacks for all south Atlantic states (North Carolina through Florida) from gutted weight to whole weight is by multiplying gutted weight by 1.04 to convert to whole weight. 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=26), the R^2 value was high (0.995) with no value having high leverage. The no-intercept regression estimate for slope is 1.079 (the ratio of means for whole weight to gutted weight) (see Table 2.2 in Section 2).

3.2.2. State-specific Landings

Adjustments to commercial landings in gutted weight were developed based on classified greater amberjack by the Working Group from each state by gear for 1962-2006:

Florida

Since the NMFS ALS showed considerably lower harvest than logbooks for the years 1994-1997, it was determined to use the Florida trip ticket data from 1986-2006 for commercial landings of Florida SA greater amberjack. Two issues arose with regard to greater amberjack landings from Florida South Atlantic waters. First, how much of total amberjack was greater amberjack? The Florida trip ticket identifies greater amberjack since 1986 while other identified amberjacks have been identified since the early 1990's. The thought was that the greater amberjack category was probably used for other identified amberjacks prior to that time, so greater amberjack harvest needed to be proportioned out from the total amberjack harvest. Florida does not have an unidentified amberjack category (NMFS ALS does), so only the greater amberjack and other identified amberjack categories were needed to determine the proportion of greater amberjack. This was done by using later years in which the probablility that other identified amberjacks would be lumped with greater amberjack was low due to market reasons and because the species codes for other identified amberjack species had been in use for some time. This was done to Monroe county and to Florida SA (without Monroe) amberjack landings separately (Table 3.1). Second, how to proportion South Atlantic and Gulf of Mexico landings in Monroe county (Florida Keys). This was done using proportions from the logbook data where fishers indicated waterbody codes that would allow separation of Gulf of Mexico and South Atlantic harvest.

For Monroe county, Florida trip ticket data from 1999-2006 were used to calculate an average proportion of greater amberjack to total amberjack. This average proportion was then applied to total amberjack harvest from 1986-1998 to calculate greater amberjack harvest for those years. The SA portion of Monroe county greater amberjack harvest was then determined by applying a proportion by year from the NMFS logbook landings where waterbody code indicated by the fisher identified where greater amberjack were caught. A proportion of Monroe South Atlantic to total Monroe for greater amberjack from logbooks was applied to the total Monroe county trip ticket landings by year from 1992-2006. The average proportion from those same years was then applied to the 1986-1991 trip ticket data to calculate total greater amberjack harvest from South Atlantic waters of Monroe county.

Greater amberjack harvest from the remaining Florida South Atlantic waters (without Monroe county) was determined by calculating an average proportion of greater amberjack to total amberjack from 1999-2006 Florida trip ticket data, then applying that average proportion to the 1986-1998 data. Upon completion, total Florida SA greater amberjack harvest was calculated by adding the Monroe SA totals to the non-Monroe Florid SA totals. Logbook data were then used to calculate proportions of Florida SA greater amberjack harvest by gear. This was done by dividing landings for each gear into total Florida SA landings, then applying those proportions to the Florida trip ticket SA landings by year from 1992-2006. The average proportion of logbook landings over all years by gear was then applied to trip ticket landings from 1986-1991.

Georgia.

Estimating the proportions for greater amberjack landings in GA for hook and line gear by using the TIP sample proportions revealed that the port agent sampling in GA from 1986 to 1994 was probably introducing a bias by sampling from sorted catch, while after this period a more reliable estimate was obtained by sampling unsorted catch. The difference in the proportions between the period from 1986 to 1994 differed significantly from those obtained for 1995 to 2006 (ANOVA, P = .007). During the period from 1986 to 1994 the proportions had $\bar{x} = 0.781$, s.d. = 0.165, while the period from 1995 to 2006 had $\bar{x} = 0.491$, s.d. = 0.214. We applied the mean proportion of 0.491 to hook and line landings prior to 1995 (Table 3.1).

Difference in GA TIP length proportions between time periods with differing sampling protocols.

Other gear types had a proportion of 1.0 for most years, so we applied this value across the diving, longlines trawl and other categories for all years with unclassified landings, with the exception of longlines in 1995, which had a proportion of 0.95.

South Carolina.

The South Carolina Department of Natural Resources (SCDNR) provided unclassified amberjack landings (pounds, gutted weight) from 1975 through 2006 by the agreed upon gear groupings. SC landings were 0 for amberjack landings for 1962-1974. Adjustment for unclassified amberjack was based on logbook data for 1992-2006. Ratios ranged from 18.7% in 1999 to 86.7% in 1995, and averaged 62.3% for this period. While annual values were applied for that year, the average values were applied historically; e.g., 1975-1991 (Table 3.1).

North Carolina

The North Carolina Division of Marine Fisheries (NCDMF) Trip Ticket Program (NCTTP) began on 1 January 1994. The NCTTP program has species codes for amberjacks, banded rudderfish and almaco jacks. However, a large portion of North Carolina's seafood dealers record all amberjacks (greater, lesser, banded rudderfish and almaco jacks) under the amberjack species codes without separating banded rudderfish and almaco jack. North Carolina biological sampling of amberjack species indicates that the relative proportion that greater amberjack composes the total landings of amberjack varies by district in North Carolina and by market grade (Table 3.1).

Greater amberjack landings were determined by using data from the biological database, regulation history and MRFSS data. The first step was to exclude all trips that realistically would not have landed any greater amberjack. These trips included all instances in which there was less than 20 pounds of amberjacks recorded. Twenty pounds was used as the cut off because this was close to the average weight of a 36" fish from NC MRFSS data and because 36" size limit has been in effect since the implementation of the NCTTP. So all trips with a recorded weight of less than 20 pounds were assumed to be another species of amberjack.

The second step took the average proportion of greater amberjack by year, district and market grade from the NCDMF biological database and applied that proportion by year, district and market grade to the NCTTP landings. If there was an instance where the NCTTP had landings of a market grade and district that was not accounted for in the biological database, then an average of that market grade by district over 1994 to 2006 from the biological database was used. To do this analysis, the proportion for the northern district was assumed to be the same as the central district because of very few sample sizes. Using these proportions, the greater amberjack landings for North Carolina from 1994 to 2006 were calculated.

Prior to 1994, all amberjacks were recorded under a single code. The amberjack fishery started to appear in NC in 1986. With this in mind, the average proportion of greater amberjack from 1994 to 2006 by gear type (as calculated above) was applied to the 1986 to 1993 NC amberjack landings by gear type. The total calculated greater amberjack landings were divided by the total landings of amberjack species including banded rudderfish and almaco jacks to calculate the average proportion of greater amberjacks to all amberjacks from 1994 to 2006. This was done to take into account that all amberjacks prior to 1994 were recorded as amberjack and were not separated out by species.

All amberjack landings prior to 1986 were assumed to be greater amberjacks because there was no market for the other amberjack species in that time frame. All landings were calculated in gutted weight.

Northern Region (Virginia-Massachusetts)

Three assumptions were made for these data. First, landings were assumed to be from the handlines gear (the dominant gear for the U.S. South Atlantic, representing 91.2% of the landings for 1962-2006). Second, we used the same gutted weight to whole conversion used by states to the south (1.04). Finally, the ratio for converting unclassified amberjack to greater amberjack was obtained from North Carolina biological sampling from there Middle and Northern Districts (see Table 3.1).

Historical Landings (1950-1961

Historical landings of unclassified amberjack were obtained for 1950-1961 from annual issues of *Fishery Statistics of the United States 19##* (U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries). These landings are reported consistently for the east coast of Florida back to 1950. Landings for Georgia through North Carolina are reported as zero for these years. With handlines as the dominant gear (representing 91.2% of the landings for 1962-2006), historical landings were assumed to be that gear. Conversion to gutted weight was based on standard conversion value of

1.04, and conversion to greater amberjack for the historic landings from Florida are based on the combined Florida proportion (Table 3.1).

3.2.3. Coastwide Summary

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

In recent years (since 2000), handlines represent about 92.1% compared with 7.5% for diving. Trivial amount of landings are associated with longline (0.3%), and other (<0.1%). Recent landings by state break out as follows: 83% from Florida, 4% from Georgia, 8% from South Carolina, 5% from North Carolina, and less than 0.1% from north of North Carolina (Virginia through Massachusetts).

To represent some of the uncertainty associated with converting unclassified amberjack to greater amberjack, greater amberjack landings were also calculated based on the mean ratios plus or minus one standard deviation (Table 3.1) multiplied by state-specific amberjack landings to obtain lower and upper bounds (Figure 3.5). The standard deviation of the conversion ratio was smallest for Florida (Table 3.1). The range represented by these lower and upper bounds is narrow, because standard deviation associated with proportion of greater amberjack was consistent from year to year since 1999 (low standard deviation) and greater amberjack landings from Florida dominate the coastwide landings (88% since 1962).

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 1.079 estimate above) from the TIP data for each state, gear, and year. These data were generally available from 1984 to 2006 for handlines (10,163 lengths). Data for the remaining gear types were sparse, with much more limited data from longlines (348), diving (664), and other (297) gear types available (see Table 3.4 for annual sample sizes by gear and state). Annual estimates of weight by gear, state and year are applied to landings in weight when sample size greater than or equal to 30 are available (Table 3.5). 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 3.6). 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. Greater amberjack landings in numbers are summarized by gear in Table 3.7 and in Figure 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 greater amberjack follows:

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

*Calculated discards=Mean greater amberjack 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 greater amberjack by handline vessels.

Calculated total discards for each region are provided in Table 3.8 for greater amberjack discarded from handline vessels. Prior to 1993, only 20% of Florida vessels were selected to report to the logbook program. The calculated discards for the region off Florida for 1992 were, therefore, expanded by a factor of five. Calculated discards for each region are summed by year to provide yearly total greater amberjack handline vessel discards in Table 3.9.

Mean cpue of discarded greater amberjack was determined for all trolling vessels reporting to the discard logbook program fishing in the south Atlantic during the years 2002-2006. Yearly total effort in hook hours of all vessels reported as fishing with trolling gear was then multiplied by the mean cpue of trolling vessel greater amberjack discards to calculate the yearly total greater amberjack discards from trolling vessels (Table 3.10).

The reason reported for discarding greater amberjack was due to regulatory restrictions in nearly all reports. Only in region 3 for greater amberjack handline vessels was an appreciable percentage (22.6%) of discards reported as due to market conditions.

The number of trips reporting greater amberjack in the US south Atlantic was very low and the number of individuals discarded was also low. Stratification of the available data was limited because of the small sample sizes and, therefore, likely does not capture much of the variation in numbers of discards within the greater amberjack. How that may affect the number of calculated discards (over or under estimate) is unknown. This is particularly true of the greater amberjack troll fishery. Discards from the dive fisheries for greater amberjack 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 unclassified amberjack sold in the South Atlantic states was calculated for the years 1962 through 2006 (Figure 3.7). Two values were calculated for each year. 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 $0.03 on average in 1962 to $0.74 per pound in 2000. In the most recent year, 2006, the price per pound paid to fishermen averaged $0.59 per pound. The price per pound varied somewhat from year to year, however between 1978 and 2000, the general trend was for increased price per pound. When the price per pound of greater amberjack was held to a constant 1962 dollar value, the trend remains, but is more subtle over time. From a low value of about $0.03 in 1962, the highest average value was $0.12 - $0.13 in the late 1990's and early 2000's. In the years between 2002 and 2006 the CPI adjusted price per pound remained essentially flat, hovering around $0.10 per pound.

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 FL in mm using conversions derived from the Life History Group except for core lengths, which were converted using the ratio of FL size limit to the core length size limit (36/28 = 1.29). We had no conversions for standard length, so these were deleted. Lengths greater than 1500 mm or less than 300 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. Core weight was converted using the conversion available from the ALS (1.41).

3.5.1 Sampling Intensity Length

Annual sample sizes are summarized in Table 3.4 by gear, and state for length data available for greater amberjack in the U.S. South Atlantic from the TIP data base.

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 weighting by the product of the landings in numbers and trip catch in numbers (for 1990-2006 in Figure 3.8). Annual length compositions for commercial longlines (for 1992-1994 and 1998-1999 in Figure 3.9), and commercial diving (for 1993-1995, 1999-2001 and 2003 in Figure 3.10) are also summarized using weighting by landings in numbers and by trip catch in numbers.

Sample size of greater amberjack ages are summarized by gear from commercial landings in the U.S. South Atlantic for 1998-2006 (Table 3.10). Age compositions were developed for handline (1998-2004; Figure 3.11) and diving (1999-2000; Figure 3.12) gear types. Weightings are by length compositions shown in Figures 3.8 and 3.10, 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 1990-2006. Florida and North Carolina sampling was consistent for this period. However, there were no length samples available from Georgia during 1995-2000, and South Carolina sampling only began in 1999 for greater amberjack. Useful length compositions are generally available for handlines for 1990-2006.

Much more limited length compositions are available for longlines (348 lengths) and diving (664) for the period 1984-2006. Annual length compositions for gear types other than handline were developed for longlines (1992-1994 and 1998-1999) and diving (1993-1995, 1999-2001, and 2003). Handline length compositions should be applied to be ‘other’ gear types to represent length compositions.

3.5 Research Recommendations for greater amberjack

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 handline 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 is a major issue with amberjack

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

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

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

North Carolina

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

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

NMFS SEFIN Annual Canvas Data for Florida

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

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

Table 3.1. Mean and standard deviation of annual conversion ratios developed to separate greater amberjack from unclassified amberjack by state for historical periods.

State	Source	Range of Years	Mean	Std Dev
North Carolina				
Southern Dist.	NC DMF	1994-2006	0.369	0.142
Mid/No Dist.	NC DMF	1994-2006	0.229	0.065
Handline	NC DMF	1994-2006	0.300	0.093
Longline	NC DMF	1994-2006	0.285	0.196
Diving	NC DMF	1994-2006	0.415	0.168
Other	NC DMF	1994-2006	0.205	0.113
South Carolina	Logbook	1992-2006	0.623	0.182
Georgia				
Handline	NMFS TIP	1995-2006	0.491	0.214
Longline	NMFS TIP		1.0	0.0
Diving	NMFS TIP		1.0	0.0
Other	NMFS TIP		1.0	0.0
Florida				
Monroe Cty	Logbook	1999-2006	0.940	0.026
Atlantic	Logbook	1999-2006	0.800	0.038
Combined	Logbook	1999-2006	0.870	0.032

Table 3.2. Greater amberjack landings (gutted weight in pounds) by gear from the U.S. South Atlantic, 1950-2006.

Year	Lines	Longline	Diving	Other	Total
1950	24260	0	0	0	24260
1951	21891	0	0	0	21891
1952	37707	0	0	0	37707
1953	30121	0	0	0	30121
1954	19659	0	0	0	19659
1955	8476	0	0	0	8476
1956	13042	0	0	0	13042
1957	2583	0	0	0	2583
1958	18074	0	0	0	18074
1959	41890	0	0	0	41890
1960	29462	0	0	0	29462
1961	4571	0	0	0	4571
1962	6495	0	0	0	6495
1963	6402	0	0	167	6569
1964	6714	0	0	0	6714
1965	7529	0	0	0	7529
1966	18488	0	0	0	18488
1967	19240	0	0	0	19240
1968	22887	0	0	0	22887
1969	15473	0	0	0	15473
1970	36923	0	0	0	36923
1971	22011	0	0	0	22011
1972	6547	0	0	3012	9559
1973	31736	0	0	6023	37759
1974	38028	0	0	2259	40286
1975	51336	0	0	0	51336
1976	58270	0	0	0	58270
1977	56444	0	0	91	56534
1978	35876	0	0	0	35876
1979	50719	0	0	891	51610
1980	39615	0	0	18535	58150
1981	50793	0	0	29823	80617
1982	124256	260	0	21776	146293
1983	93956	189	0	8762	102907
1984	164576	1170	0	3801	169548
1985	139561	1381	0	4657	145598
1986	317756	17256	28181	4794	367986
1987	899652	6331	84246	1407	991636
1988	879415	5195	79476	2898	966983
1989	1021518	6451	93351	1002	1122323

Table 3.2. (continued)

1990	1303580	13889	114386	4195	1436050
1991	1605478	11613	143766	12356	1773214
1992	1677790	14198	149301	892	1842181
1993	1246252	12061	89682	415	1348410
1994	1298388	6297	119400	601	1424687
1995	1169606	17916	97643	43	1285208
1996	990340	17342	79325	37	1087044
1997	928093	41427	91549	363	1061431
1998	821979	13150	80066	204	915398
1999	741955	1847	66915	128	810844
2000	673368	3175	106710	53	783307
2001	756903	2609	45152	871	805535
2002	751689	6304	72337	63	830393
2003	645974	2350	58438	159	706921
2004	876461	2546	55216	0	934223
2005	872910	357	43998	27	917292
2006	532002	185	36478	14	568680

Table 3.3. Greater amberjack landings (gutted weight in pounds) by region from the U.S. South Atlantic, 1950-2006.

Year	Florida	GA-NC	Total
1950	24260	0	24260
1951	21583	0	21583
1952	37310	0	37310
1953	29613	0	29613
1954	19659	0	19659
1955	7947	0	7947
1956	12799	0	12799
1957	1171	0	1171
1958	17986	0	17986
1959	41074	0	41074
1960	27940	0	27940
1961	4350	0	4350
1962	6274	0	6274
1963	6525	0	6525
1964	6692	0	6692
1965	7529	0	7529
1966	18488	0	18488
1967	19240	0	19240
1968	22503	141	22644
1969	14723	0	14723
1970	36724	0	36724
1971	21415	0	21415
1972	9537	0	9537
1973	37561	0	37561
1974	40154	0	40154
1975	51280	56	51336
1976	57972	298	58270
1977	55128	1407	56534
1978	35804	72	35876
1979	46679	4932	51610
1980	37704	20248	57952
1981	41681	38892	80572
1982	112959	33333	146293
1983	86136	16771	102907
1984	160034	9514	169548
1985	128483	16895	145378
1986	323338	44626	367964
1987	945176	46460	991636
1988	916384	50445	966829
1989	1034388	87913	1122300

Table 3.3. (continued)

1990	1330174	105832	1436006
1991	1613020	160183	1773203
1992	1708928	133253	1842181
1993	1118679	229289	1347968
1994	1205923	218576	1424499
1995	1093280	191274	1284554
1996	910829	176089	1086918
1997	828019	231941	1059960
1998	809260	105595	914855
1999	757905	52520	810425
2000	665365	115882	781247
2001	652277	152883	805160
2002	657624	172335	829959
2003	564026	142775	706802
2004	797488	136472	933960
2005	794594	122497	917091
2006	478668	89930	568599

Table 3.4. Sample size of greater amberjack collected for lengths by gear and state from the U.S. South Atlantic TIP data base, 1984-2006.

	Handlines					Longlines					Diving				Other					Grand Total
Year	FL	GA	SC	NC	Total	FL	GA	SC	NC	Total	FL	GA	SC	Total	FL	GA	SC	NC	Total	
1984	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1985	1	0	0	23	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24
1986	1	14	0	7	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22
1987	0	16	0	23	39	0	0	0	0	0	0	0	0	0	4	4	0	0	8	47
1988	0	5	0	54	59	0	0	0	2	2	0	0	0	0	0	0	0	0	0	61
1989	0	9	0	14	23	0	0	0	6	6	0	0	0	0	0	0	0	0	0	29
1990	53	0	0	45	98	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98
1991	369	0	0	65	434	2	0	0	6	8	0	0	0	0	12	0	0	1	13	455
1992	475	53	0	19	547	25	0	0	0	25	9	0	0	9	5	0	0	0	5	586
1993	573	185	0	23	781	80	7	0	8	95	60	0	0	60	11	0	0	0	11	947
1994	309	143	0	64	516	11	21	0	6	38	14	29	0	43	0	0	0	0	0	597
1995	221	0	0	54	275	5	0	0	4	9	39	0	0	39	0	0	0	0	0	323
1996	223	0	0	27	250	5	0	0	0	5	0	0	0	0	4	0	0	0	4	259
1997	438	0	0	24	462	17	0	0	1	18	0	0	0	0	28	0	0	0	28	508
1998	422	0	0	30	452	47	0	0	0	47	0	0	0	0	106	0	0	0	106	605
1999	356	0	156	46	558	68	0	0	2	70	145	0	0	145	0	0	0	0	0	773
2000	668	0	339	98	1105	14	0	0	0	14	217	0	0	217	0	0	0	0	0	1336
2001	759	8	362	88	1217	5	0	0	0	5	38	0	0	38	0	0	0	0	0	1260
2002	640	21	262	124	1047	0	0	5	0	5	12	0	0	12	0	0	0	0	0	1064
2003	368	42	293	115	818	0	0	0	0	0	96	0	0	96	0	0	0	0	0	914
2004	528	52	155	121	856	0	0	0	0	0	0	0	0	0	59	0	0	0	59	915
2005	48	10	99	171	328	1	0	0	0	1	0	0	0	0	62	0	0	0	62	391
2006	75	5	54	117	251	0	0	0	0	0	4	0	1	5	0	0	1	0	1	257
Total	6527	563	1720	1353	10163	280	28	5	35	348	634	29	1	664	291	4	1	1	297	11472

Table 3.5. Mean gutted weight (pounds) of greater amberjack by state and gear from the U.S. South Atlantic TIP data base, 1984-2006.

	Handlines				Longlines				Diving			Other			
Year	FL	GA	SC	NC	FL	GA	SC	NC	FL	GA	SC	FL	GA	SC	NC
1984				8.82											
1985	29.42			11.71											
1986	18.09	17.34		23.03											
1987		23.30		7.89								2.06	40.87		
1988		24.00		14.12				7.85							
1989		19.50		26.81				9.73							
1990	23.62			15.42				0.00							
1991	42.47			10.47	32.33			39.42				29.88			9.58
1992	31.76	26.68		32.22	29.27				28.67			18.83			
1993	32.61	21.22		24.39	29.81	22.76		23.14	29.89			29.42			
1994	20.53	21.12		19.77	29.57	20.52		41.61	29.89	30.84					
1995	32.52			15.21	24.59			35.87	33.07						
1996	29.37			24.03	32.90							23.59			
1997	29.19			29.32	30.08			80.23				19.82			
1998	28.44			20.76	35.75							9.99			
1999	32.14		30.22	25.31	35.77			31.04	30.33						
2000	31.55		29.80	27.76	39.27				26.15						
2001	32.57	35.97	39.97	24.61	40.24				32.86						
2002	36.07	32.69	30.73	24.77			35.52		36.55						
2003	32.26	43.82	34.85	20.74					28.67						
2004	32.12	30.93	32.06	29.07								31.85			
2005	33.10	31.19	29.62	29.18	32.88							26.90			
2006	32.47	27.69	42.34	20.90					33.18		26.35			38.05	

Table 3.6. Sample size and weighted mean weight in pounds (whole weight) of greater amberjack averaged across years , and when necessary across states. Only handlines (except for South Carolina) had sufficient sampling to split into two time periods based on change of minimum size limit in 1992.

Sample size:

Period	State	Handlines	Longline	Diving	Other
<1992	FL	424	280	634	297
	GA	44	68	30	297
	SC	1720*	68	30	297
	NC	232	68	30	297
>=1992	FL	6103	280	634	297
	GA	519	68	30	297
	SC	1720	68	30	297
	NC	1121	68	30	297

*SC handline samples only after 1992.

Mean weights in pounds (whole weight):

Period	State	Handlines	Longline	Diving	Other
<1992	FL	40.03	32.86	29.03	21.05
	GA	20.71	26.45	30.69	21.05
	SC	33.57	26.45	30.69	21.05
	NC	13.5	26.45	30.69	21.05
>=1992	FL	31.43	32.86	29.03	21.05
	GA	25.5	26.45	30.69	21.05
	SC	33.57	26.45	30.69	21.05
	NC	24.7	26.45	30.69	21.05

Table 3.7. Greater amberjack landings (in numbers) by gear from the U.S. South Atlantic, 1950-2006.

Year	Handlines	Longline	Diving	Other	Total
1950	654	0	0	0	654
1951	606	0	0	0	606
1952	1,037	0	0	0	1,037
1953	839	0	0	0	839
1954	530	0	0	0	530
1955	257	0	0	0	257
1956	364	0	0	0	364
1957	144	0	0	0	144
1958	492	0	0	0	492
1959	1,172	0	0	0	1,172
1960	875	0	0	0	875
1961	135	0	0	0	135
1962	187	0	0	0	187
1963	175	0	0	9	183
1964	182	0	0	0	182
1965	203	0	0	0	203
1966	498	0	0	0	498
1967	519	0	0	0	519
1968	633	0	0	0	633
1969	457	0	0	0	457
1970	1,006	0	0	0	1,006
1971	625	0	0	0	625
1972	178	0	0	154	332
1973	866	0	0	309	1,175
1974	1,032	0	0	116	1,148
1975	1,384	0	0	0	1,384
1976	1,572	0	0	0	1,572
1977	1,555	0	0	5	1,559
1978	967	0	0	0	967
1979	1,571	0	0	46	1,617
1980	1,158	0	0	950	2,109
1981	1,821	0	0	1,529	3,350
1982	3,522	11	0	1,116	4,649
1983	2,816	8	0	449	3,273
1984	4,601	48	0	195	4,843
1985	4,305	56	0	239	4,600
1986	9,295	696	1,047	246	11,284
1987	24,983	236	3,125	72	28,417
1988	24,772	191	2,953	149	28,064
1989	28,883	239	3,461	51	32,634

Table 3.7. (continued)

1990	59,434	536	4,252	215	64,436
1991	44,559	436	5,333	633	50,962
1992	57,252	505	5,501	46	63,303
1993	41,911	466	3,207	21	45,605
1994	66,227	241	4,374	31	70,872
1995	40,545	720	3,211	2	44,478
1996	36,306	702	2,946	2	39,955
1997	34,442	1,679	3,401	19	39,541
1998	31,236	524	2,976	20	34,756
1999	25,217	57	2,380	7	27,661
2000	23,574	110	4,403	3	28,090
2001	25,346	87	1,485	45	26,963
2002	24,039	209	2,686	3	26,937
2003	21,508	78	2,195	8	23,790
2004	29,598	84	2,048	0	31,729
2005	29,100	12	1,632	1	30,745
2006	18,123	6	1,354	1	19,484

Table 3.8. Calculated yearly total discards of greater amberjack by handline vessels for each region (regions: 1=2400 latitude to <3100 latitude; Region 2 = 3100 latitude to <3300 latitude; Region 3 = 3300 latitude to <3700 latitude). Discards are reported in number of fish.

Year	Region	Mean Discards per Hook Hour	Discard Standard Deviation	Total Effort (Hook Hours)	Calculated Discards
1992	1	0.00196	0.03451	175,300.0	1,719*
1992	2	0.00931	0.03644	195,164.0	1,818
1992	3	0.00897	0.06350	228,924.0	2,053
1993	1	0.00196	0.03451	461,193.5	905
1993	2	0.00931	0.03644	204,741.0	1,907
1993	3	0.00897	0.06350	337,962.4	3,031
1994	1	0.00196	0.03451	614,874.6	1,206
1994	2	0.00931	0.03644	297,076.0	2,767
1994	3	0.00897	0.06350	476,132.2	4,270
1995	1	0.00196	0.03451	574,714.5	1,127
1995	2	0.00931	0.03644	292,482.0	2,724
1995	3	0.00897	0.06350	440,122.0	3,947
1996	1	0.00196	0.03451	754,148.5	1,479
1996	2	0.00931	0.03644	401,744.0	3,741
1996	3	0.00897	0.06350	516,895.8	4,635
1997	1	0.00196	0.03451	916,390.5	1,797
1997	2	0.00931	0.03644	353,093.0	3,288
1997	3	0.00897	0.06350	577,396.0	5,178
1998	1	0.00196	0.03451	648,959.2	1,273
1998	2	0.00931	0.03644	298,594.1	2,781
1998	3	0.00897	0.06350	474,546.6	4,255
1999	1	0.00196	0.03451	691,737.7	1,357
1999	2	0.00931	0.03644	205,537.0	1,914
1999	3	0.00897	0.06350	418,476.3	3,753
2000	1	0.00196	0.03451	596,641.0	1,170
2000	2	0.00931	0.03644	225,280.5	2,098
2000	3	0.00897	0.06350	458,840.3	4,115
2001	1	0.00196	0.03451	512,061.1	1,004
2001	2	0.00931	0.03644	342,025.5	3,185
2001	3	0.00897	0.06350	429,314.1	3,850
2002	1	0.00196	0.03451	507,699.1	996
2002	2	0.00931	0.03644	292,181.9	2,721
2002	3	0.00897	0.06350	413,752.3	3,710
2003	1	0.00196	0.03451	470,800.3	923
2003	2	0.00931	0.03644	232,222.0	2,163
2003	3	0.00897	0.06350	341,045.0	3,058
2004	1	0.00196	0.03451	423,793.0	831
2004	2	0.00931	0.03644	167,070.6	1,556
2004	3	0.00897	0.06350	330,764.0	2,966
2005	1	0.00196	0.03451	344,250.3	675
2005	2	0.00931	0.03644	204,396.6	1,904
2005	3	0.00897	0.06350	297,695.0	2,670
2006	1	0.00196	0.03451	345,692.5	678
2006	2	0.00931	0.03644	248,067.9	2,310
2006	3	0.00897	0.06350	333,484.5	2,990

*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. Calculated yearly south Atlantic handline vessel greater amberjack discards. Discards are reported in number of fish.

Year	Calculated Discards
1992	5,590*
1993	5,842
1994	8,242
1995	7,798
1996	9,856
1997	10,263
1998	8,309
1999	7,023
2000	7,383
2001	8,039
2002	7,427
2003	6,144
2004	5,353
2005	5,248
2006	5,979

*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 3.10. Yearly greater amberjack trolling vessel calculated discards. Discards are reported in number of fish.

Year	Mean Discards	Discard Standard Deviation	Total Effort (hook hours)	Calculated Discards
1992	0.00230	0.01305	70,263.5	161*
1993	0.00230	0.01305	101,504.5	233
1994	0.00230	0.01305	126,337.2	290
1995	0.00230	0.01305	113,356.5	260
1996	0.00230	0.01305	103,429.5	238
1997	0.00230	0.01305	132,169.0	304
1998	0.00230	0.01305	516,253.6	1,186
1999	0.00230	0.01305	493,706.2	1,134
2000	0.00230	0.01305	540,875.7	1,243
2001	0.00230	0.01305	414,732.5	953
2002	0.00230	0.01305	343,735.8	790
2003	0.00230	0.01305	304,693.1	700
2004	0.00230	0.01305	247,815.6	569
2005	0.00230	0.01305	220,684.3	507
2006	0.00230	0.01305	231,891.5	533

*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 3.11. Sample size by gear of greater amberjack ages from commercial landings in the U.S. South Atlantic, 1998-2006

Year	Handline	Longline	Diving	Total
1998	37	0	0	37
1999	35	0	48	83
2000	153	0	21	174
2001	193	1	0	194
2002	752	0	0	752
2003	424	0	0	424
2004	37	0	0	37
2005	6	1	0	7
2006	0	0	0	0

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

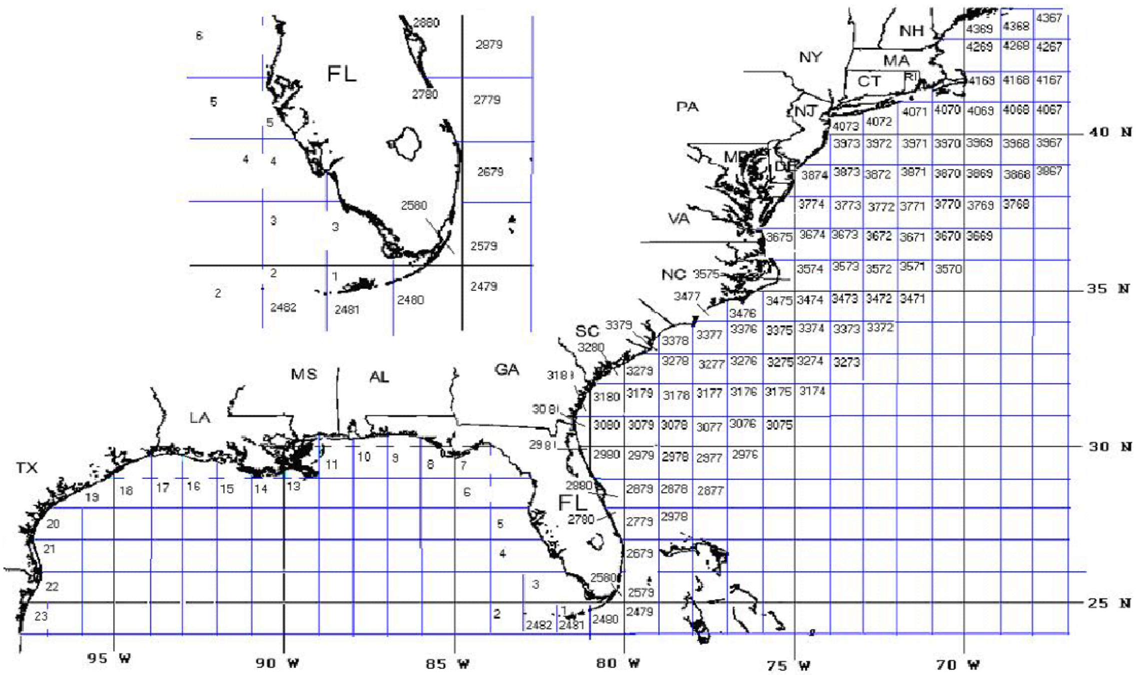


Figure 3.2. Map showing marine fisheries trip ticket fishing area code map for Florida.

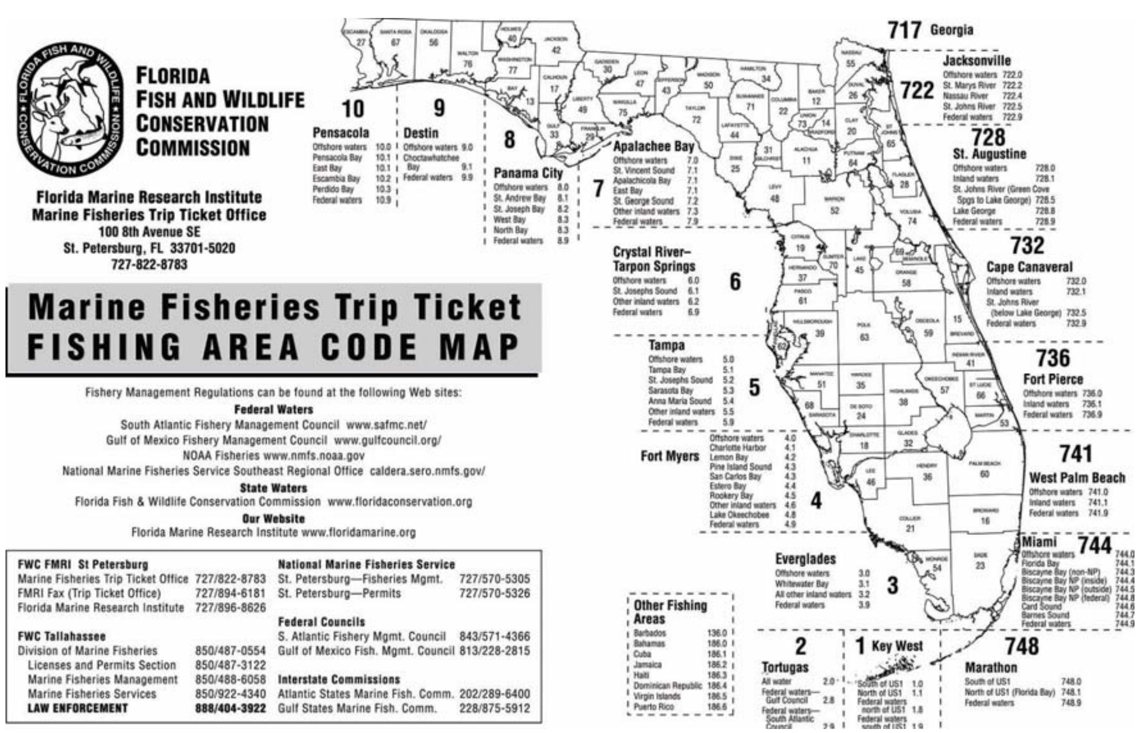


Figure 3.3. Greater amberjack landings by gear from the U.S. South Atlantic, 1950-2006.

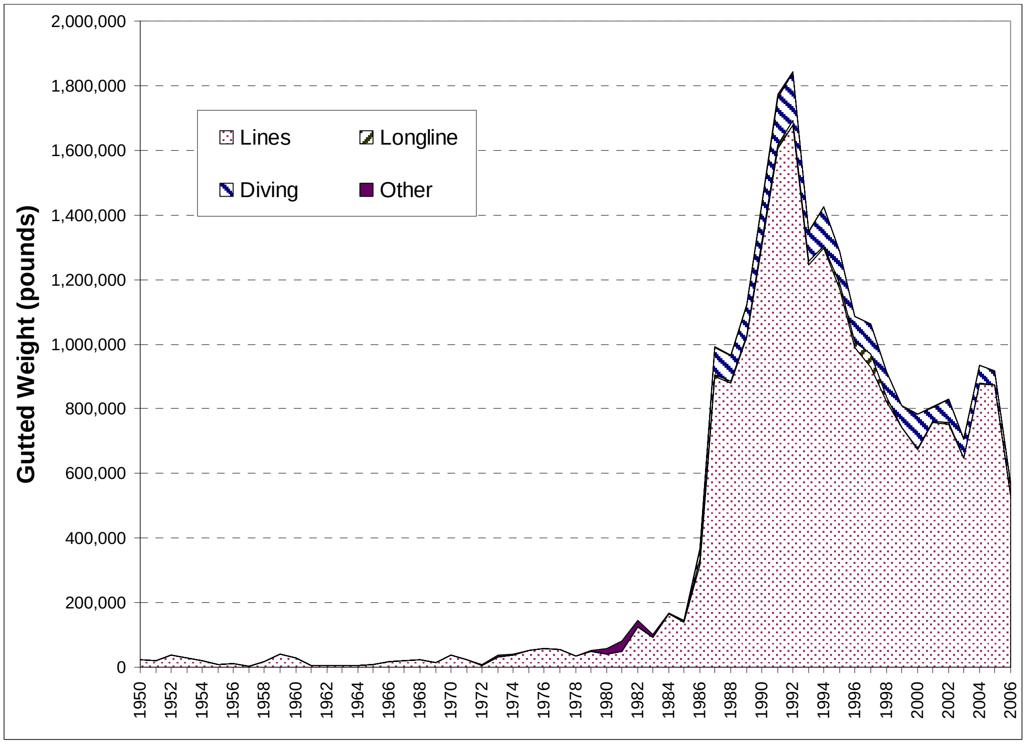


Figure 3.4. Greater amberjack landings by state from the U.S. South Atlantic, 1950-2006.

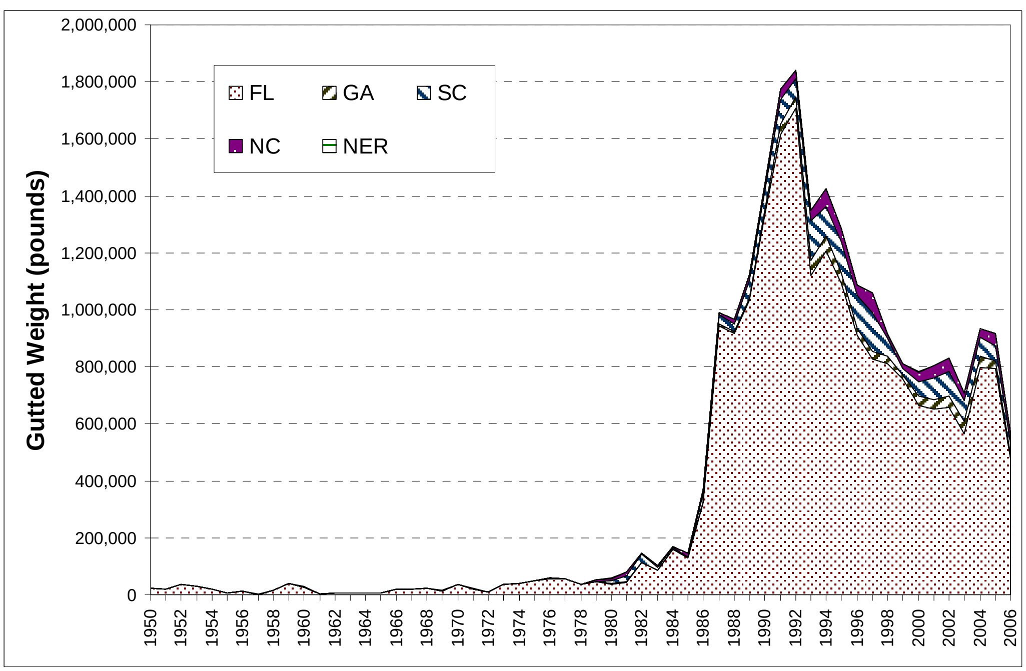


Figure 3.5. Range (upper and lower bound of greater amberjack landings from the U.S. South Atlantic, 1950-2006. Bounds are based on proportion of greater amberjack equal to mean proportion plus (upper) or minus (lower) one standard deviation applied to historical years by state and gear.

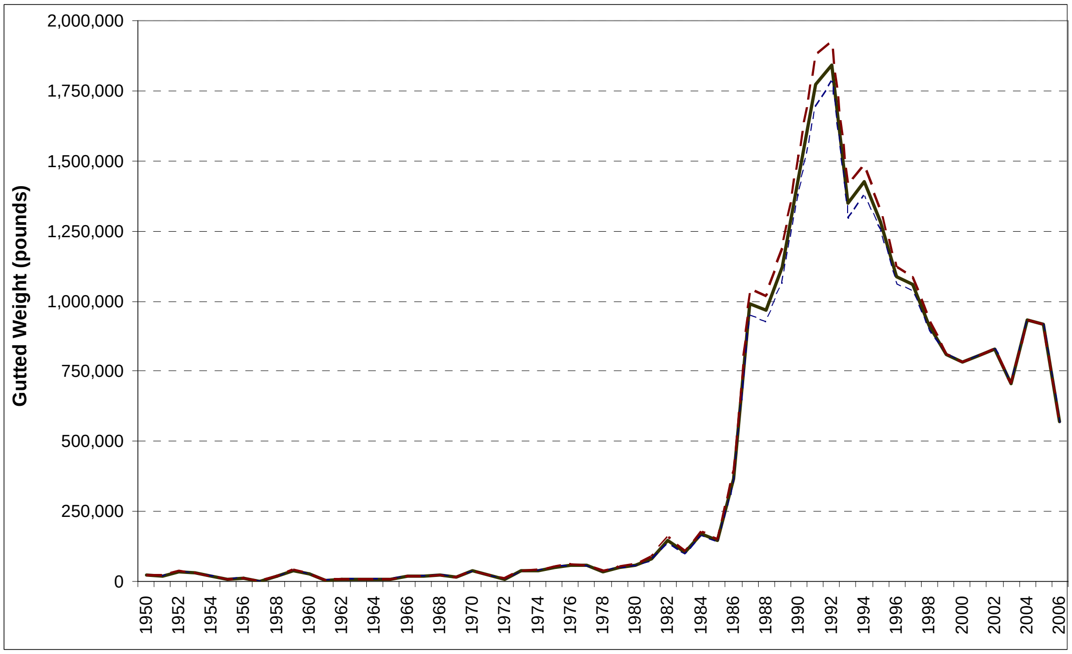


Figure 3.6. Greater amberjack landings in numbers by gear from the U.S. South Atlantic, 1950-2006.

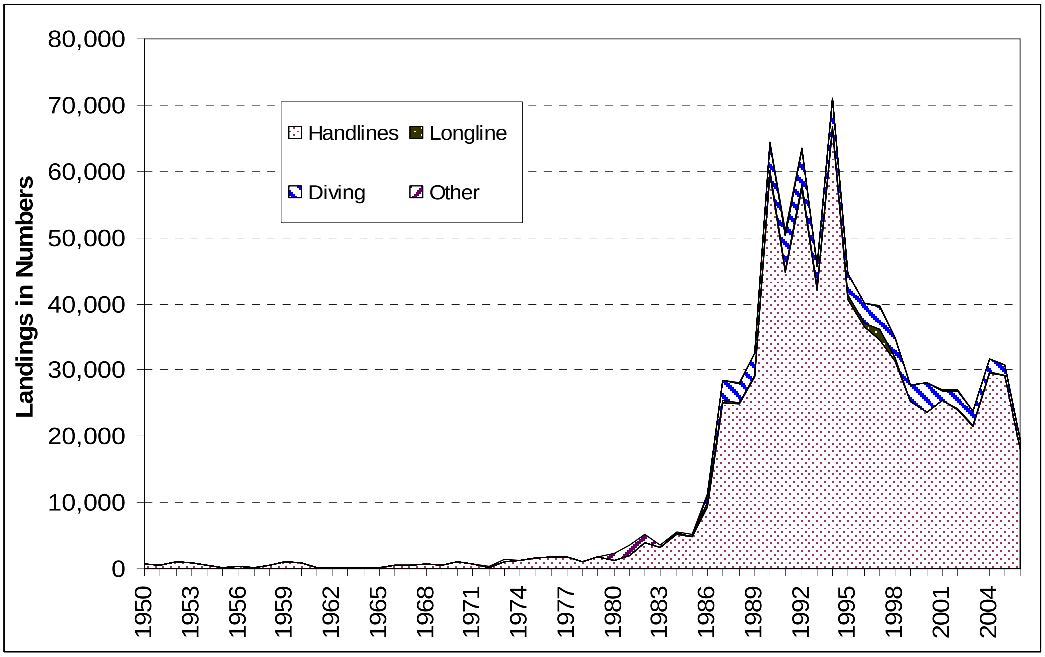


Figure 3.7. U.S. South Atlantic greater amberjack, price per pound, adjusted and unadjusted for inflation, 1962-2006. Price is adjusted by consumer price index (CPI) using 1962 as base year.

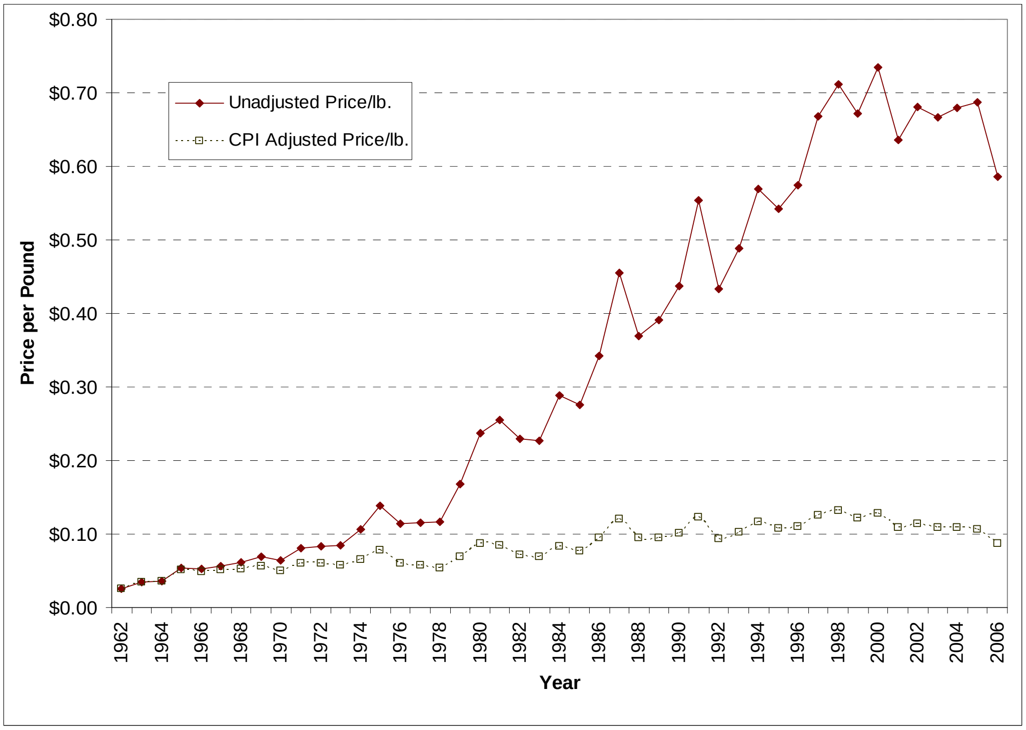


Figure 3.8. Length composition of greater amberjack grouper for commercial handline from TIP, 1987-2006. Weighting based on landings in numbers and trip catch in numbers. Sample size and year shown on each subplot.

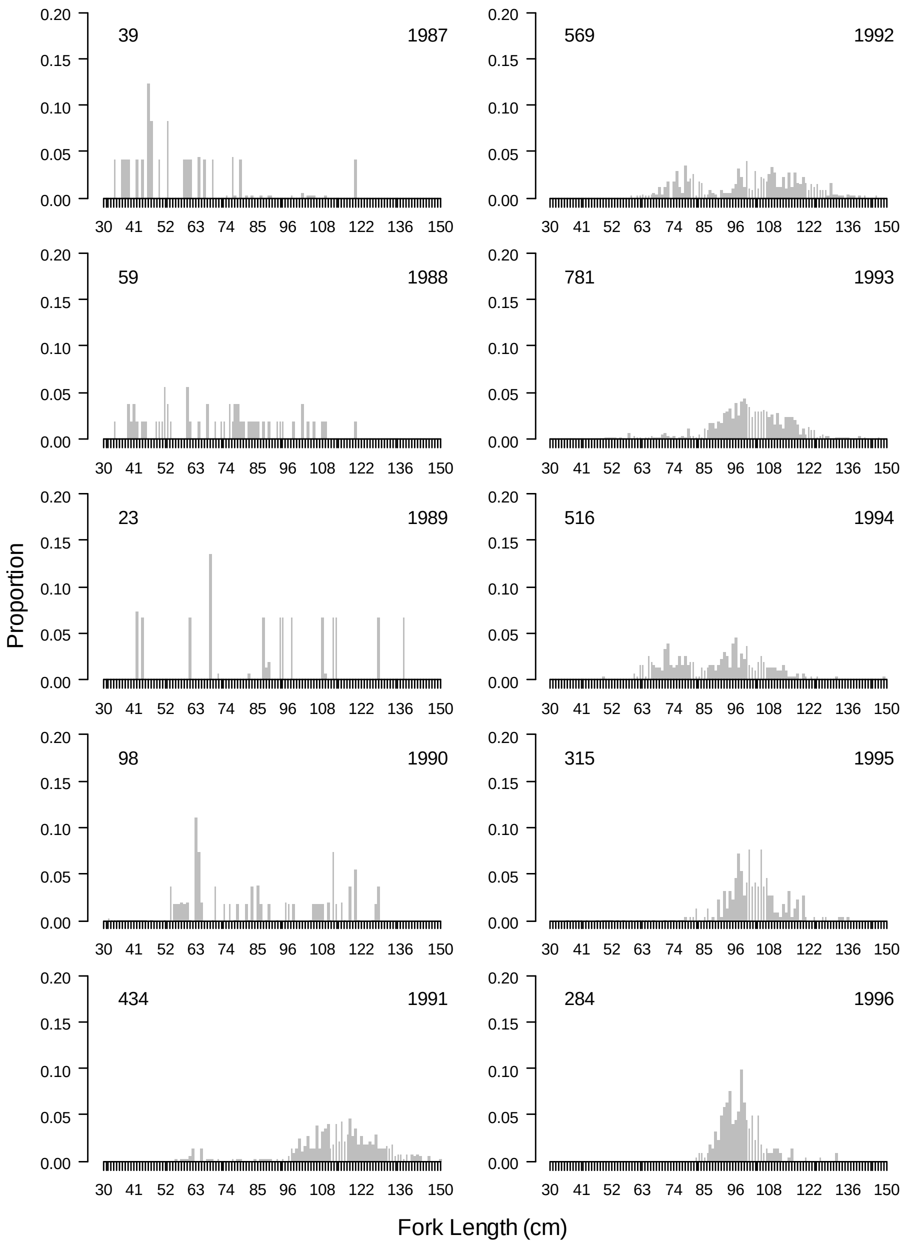


Figure 3.8. (continued)

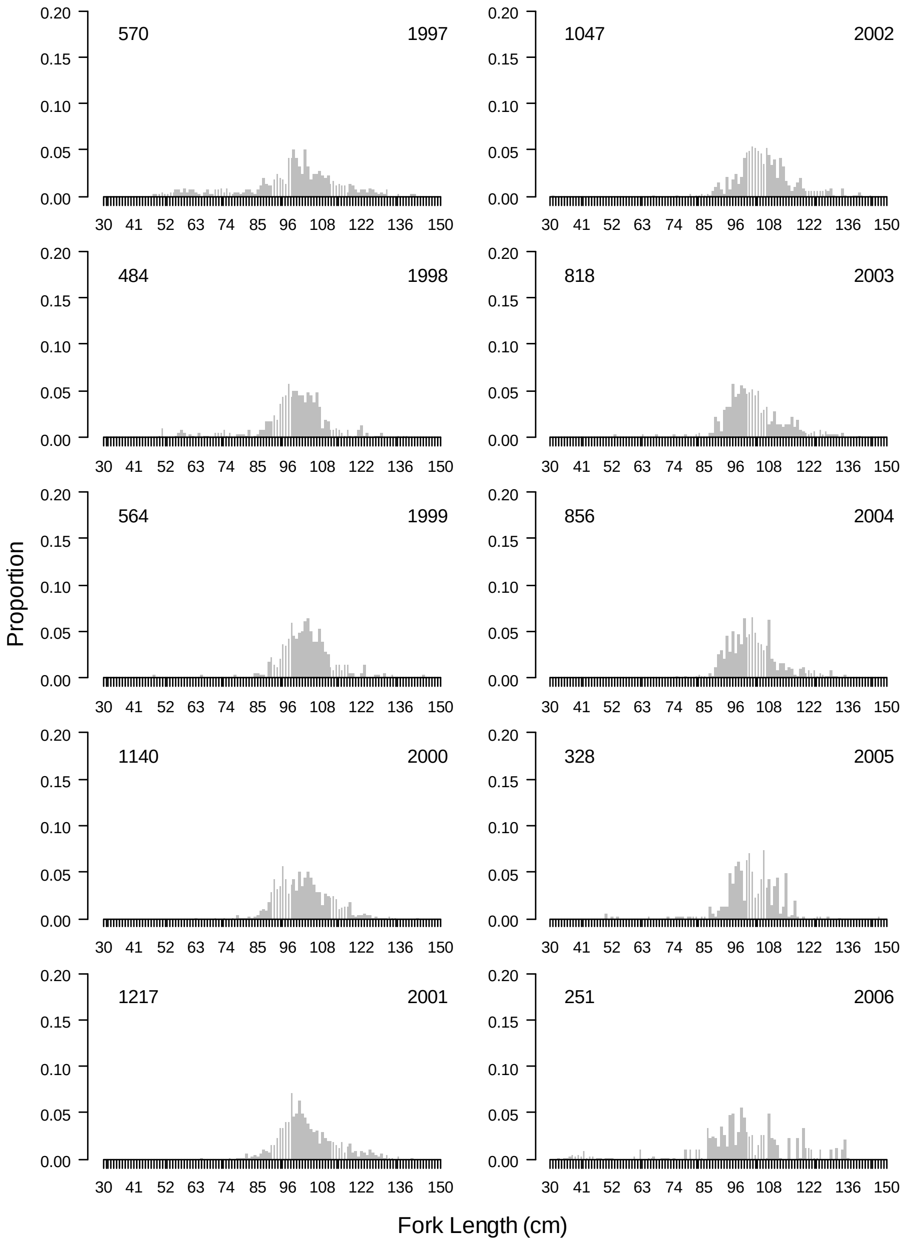


Figure 3.9. Length composition of greater amberjack for commercial longlines from TIP, 1992-1994, and 1998-1999. Weighting based on landings in numbers and trip catch in numbers. Sample size and year shown on each subplot.

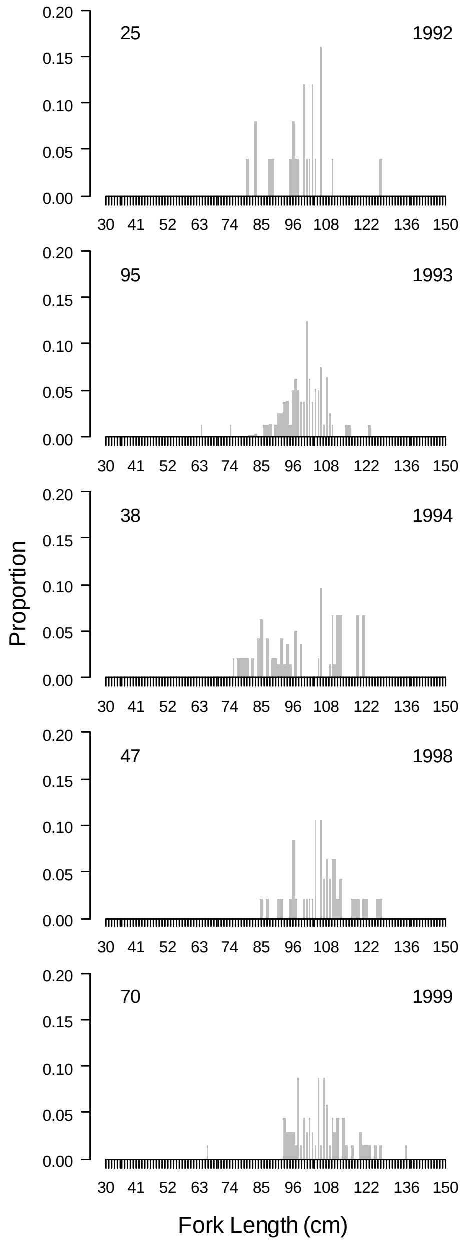


Figure 3.10. Length composition of greater amberjack for commercial diving from TIP,1993-1995, 1999-2001, and 2003. Weighting based on landings in numbers and trip catch in numbers. Sample size and year shown on each subplot.

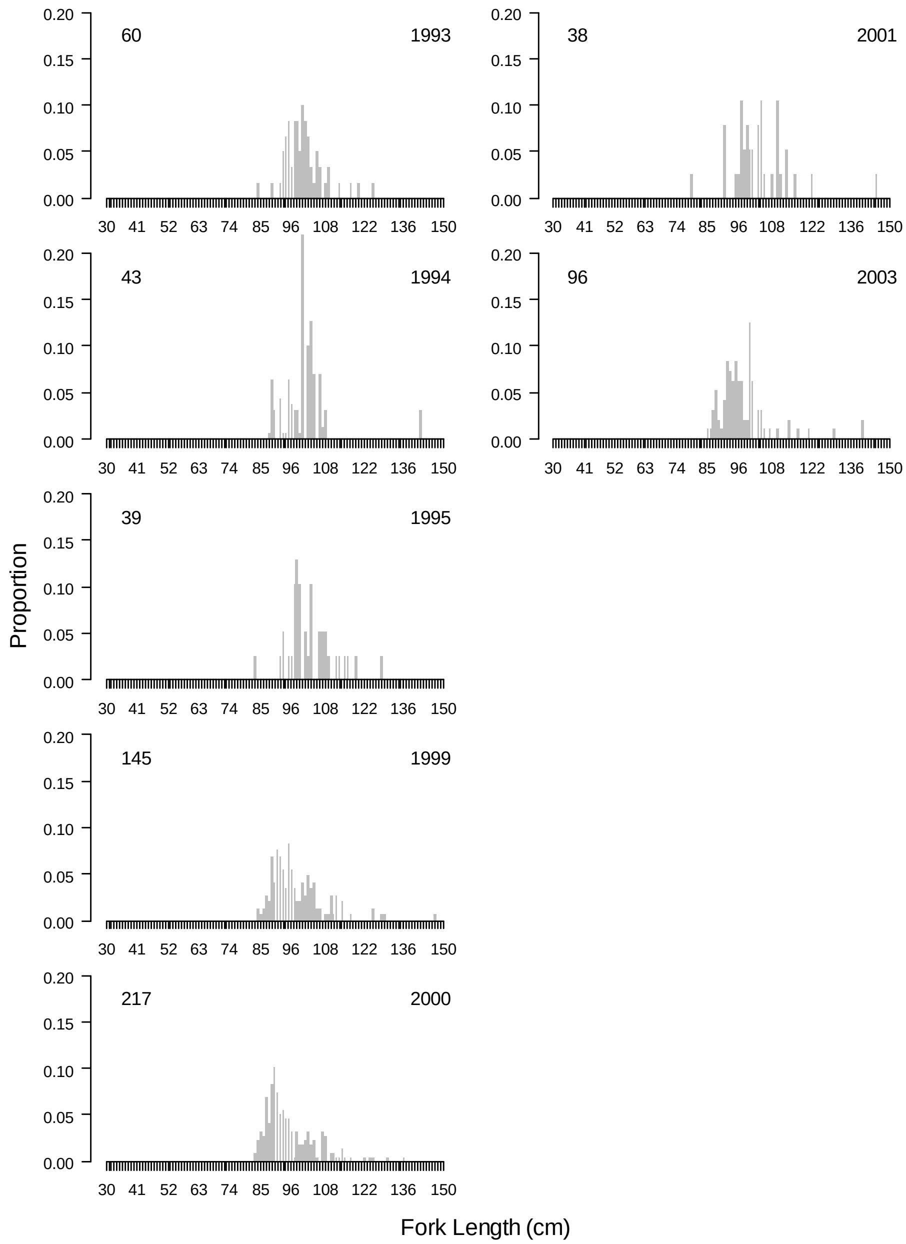


Figure 3.11. Age composition of greater amberjack for commercial handline from TIP, 1998-2004. Weighting based on corresponding length composition available for 1998-2004. Sample size and year shown on each subplot.

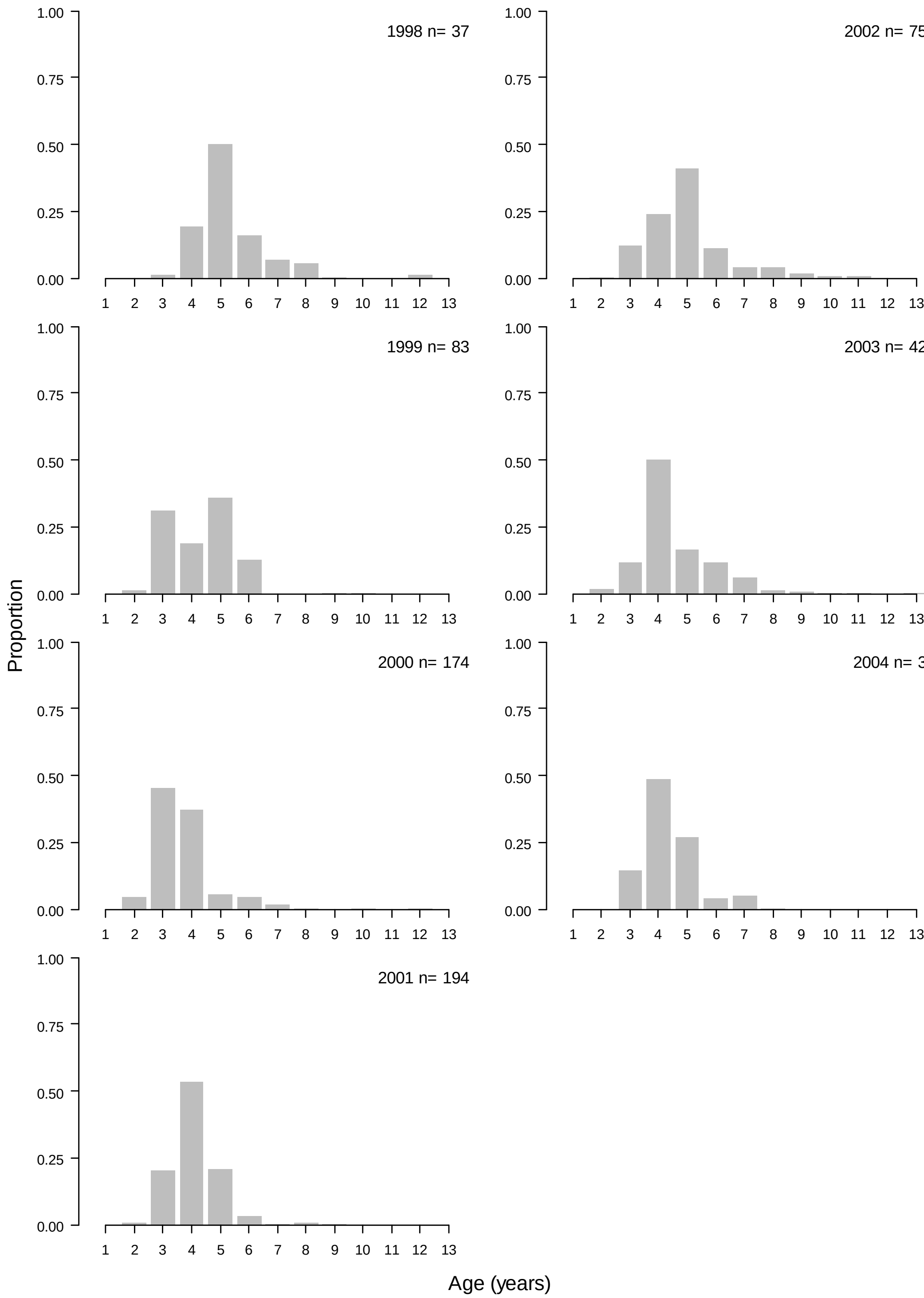
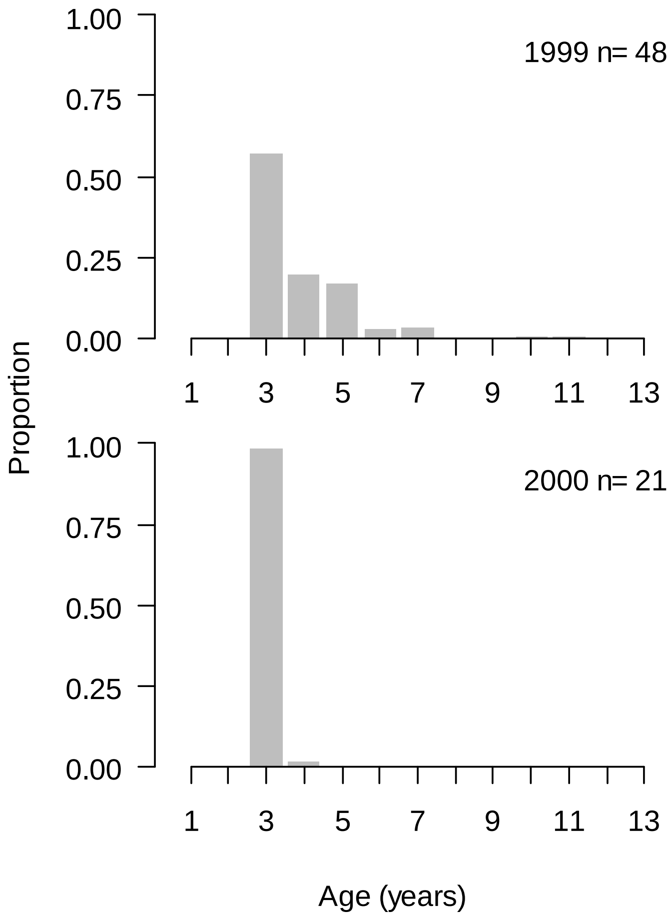


Figure 3.12. Age composition of greater amberjack for commercial diving from TIP, 1999-2000. Weighting based on corresponding length composition available for 1999. Sample size and year shown on each subplot.



4. Recreational Fishery (TOR 4, 5)

4.1. Overview

Members of the Recreational Fishery Working Group:
Ken Brennan - NMFS, Southeast Fisheries Science Center
Doug Mumford - NC Department of Environment and Natural Resources, Division of Marine Fisheries
Beverly Sauls (leader) - Florida Fish & Wildlife Conservation Commission, Fish & Wildlife Research Institute
Tom Sminkey - NMFS, Office of Science and Technology, Silver Spring, Maryland.

The group discussed the geographic range of recreational fisheries for greater amberjack. Greater amberjack recreational catches have been reported in the literature as far north as New York; however, no significant or reliable estimates of recreational catches for this species occur north of Virginia. Therefore, we considered the northern extent of the targeted recreational fishery for greater Amberjack to extend only through Virginia. The major portion of recreational fishing for this species in the Florida Keys occurs on the Atlantic side of the island chain and this area was defined as the southern boundary for targeted recreational fisheries for greater amberjack in the Atlantic.

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, resolution of species identification issues in the recreational fisheries, 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 Southeast Headboat 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 for greater amberjack from NC through FL are available beginning in 1981.

The Headboat Survey incorporates two components for estimating catch and effort. 1) Information about mean size of fishes landed are collected by port samplers during 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. 2) 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. 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 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 4.1 and 4.2), 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 continued to run concurrently with new FHS method through 2006.

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 greater amberjack weigh at least 50 pounds for harvested fish, or measure at least 50 inches for released fish.

Citation awards for greater amberjack in North Carolina are available from 1991 through 2006. More citations were awarded for greater amberjack during 2002 (997) than any other year (Table 4.3). Annual summaries from 1991-2006 along with individual citation records are available from 1996-2006. The datasets are in EXCEL format and can 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 919 greater amberjack have been tagged, resulting in 74 recaptures. Numbers of greater amberjack tagged each year and the size range of tagged fish are provide in Table 4.4.

4.3. Recreational Landings

Adjusted recreational landings, releases, and c.v.'s are summarized in Tables 4.1 and 4.2. Landings include shore, private boat, and charter modes estimated from the MRFSS, and headboat mode estimated from the headboat logbook survey. Adjustments were made to both data sets, as deemed appropriate by the workgroup, and those adjustments are described in detail in the following sections.

a. Species identification issues for greater amberjack

In the headboat survey, it was recognized that there was inaccurate reporting of greater amberjack and banded rudderfish. The two *Seriola* species are similar in appearance and are frequently misidentified. Beginning in 1981 through 1992, a special category for the two similar species, which were commonly referred to as "amberines", was added to the logbook reporting sheet for landed fish of either species that could not be distinguished. To account for the portion of greater amberjack reported in the "amberine" category, the workgroup reviewed headboat logbook landings data for greater amberjacks and banded rudderfish that were identifiable to the species level during the time period from 1992 to 1998 when regulated catch limits were consistent (28" fork length and 3 fish bag limit). These data were used to determine the relative proportions of the two species in the landings, and the ratio of greater amberjack to banded rudderfish was applied to amberine landings. The portion of amberines that was estimated to be greater amberjack was added to the greater amberjack landings. Annual landings for greater amberjack increased approximately 9% per year for the years 1981 to 1992 as a result of this adjustment.

In the MRFSS, all fish available during intercept surveys are identified to species (type A catch) by the field staff of the MRFSS program and identification is assumed to be correct to the species level. For any fish that can not be observed directly, the angler is asked to report fish they retained, either for consumption, use as bait, or other disposition to the interviewer (type B1 catch). If fish cannot be identified to species by anglers, then either a genus or family code can be used to identify the catch as either released catch or landed catch (these are classed as data types B2-released alive and B1-harvested, respectively). The workgroup reviewed estimated B1 landings for unobserved fish in the Jack Family and Amberjack Genus categories. The workgroup discussed the validity of applying a ratio from jack species that were observed directly by interviewers in the field to the harvest estimates for all unobserved jacks that could not be recorded to the species level. Because many small jack species harvested by recreational anglers are used as bait, and the majority of these fish are unobserved by interviewers and can not be identified to species, the group decided that before any ratio was applied to the Jack Family category, the portion of fish reported as disposition 4 (used for bait) should be removed. The remaining portion of Jack Family B1 landings were then portioned into greater amberjack and other jack species based on the relative proportions for jacks that were identified to species in the Type A catch (Table 4.5). The weight landed for all the unclassified landings, which are generally only a small proportion of the total annual landings of greater amberjack, was estimated using the average weight of the species-level landings data and expanded by the number landed within each category. For Amberjack Genus B1 landings, the landings observed A1 landings for all seriola species were used to calculate a proportion of Seriola landings that are greater amberjack. The proportion of Seriola type A landings that were greater amberjack was applied to Amberjack Genus B1 landings and added to the type A landings for greater amberjack (Table 4.5).

b. 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 substituted weight estimates were substituted and included in the annual weight estimates for Greater Amberjack. For the 1981 to 2006 time series, there were 34 missing cells for greater amberjack 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 in Virginia to Georgia due to low fishing activity during January and February. In east Florida, no landings estimates are available for Wave 1, 1981. We generated Wave 1 estimates for A+B1 and B2 catch for greater amberjack using the average portion of Wave 1 catch estimates to Waves 2-6 catch estimates for a four year prior (1983 to 1986). Estimates from 1982 were not included due to zero landings in several cells. The 1981 annual landings were increased by the mean value that Wave 1 contributed from the pooled years.

c. Headboat estimates in MRFSS

Any catch estimates from the MRFSS survey program that were classified as Headboat mode were excluded from the MRFSS landings throughout the time series. This fishery is monitored separately by the headboat logbook survey and was only rarely and sporadically sampled by the MRFSS. Headboat catch estimates are provided by the headboat logbook survey.

d. Monroe County, Florida

Landings were generated by assuming all greater amberjack caught and landed in Monroe county were from the Atlantic Ocean. The landings were broken out of the West Florida Annual Catch Estimates using a post-stratification technique. Estimated Landings were generated in numbers and pounds and added to the east coast greater amberjack landings estimates.

c. Back-Calculating Landings in Time

For stock assessment modelling 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 or headboat logbook survey were not available from 1962 to 1980.

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 across 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. Historic commercial landings were provided by the Commercial Fisheries Workgroup for 1945 to 2006. Commercial landings did not provide a good fit for greater amberjack recreational landings ($r^2 = 0.097$) and could not be used to regress recreational landings back in time. 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 amberjack catch estimates, since the recreational fishery is almost exclusively vessel based. The number of registered vessels in Florida steadily increased over time, and this trend did not correspond well with recreational amberjack harvest, which peaks in the 1980's, declines in the 1990's, and levels in recent years. 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. In the late 1800's and early 1900's, amberjack were known to recreational anglers in eastern Florida; however, the species were considered "barely edible" (Gregg 1902). Cummings and McClellan (1999) reviewed the early fishery in the south Atlantic and cited references indicating there was a small, incidental take in the recreational fishery as early as the 1950's and these fish were usually caught by anglers targeting other, more desirable species. Taylor (1951) noted in North Carolina that amberjack (*Seriola* species) were hard fighters with great strength, and among the most numerous and important game fishes in the state. Moe (1963) listed greater amberjack as an important fish to the offshore charter fishery in east Florida. An estimate by Ellis (1957) indicated that recreational catch exceeded commercial catch in the late 1950's. In the 1970's, greater amberjack became recognized as a good food-fish, as well as a game-fish. The recreational fishery in the 1970's was largely dominated by the charter sector, with some private boat fishing and a very small amount of headboat fishing. By the late 1970's, greater amberjack was becoming increasingly important as a recreational target species, and in southeast Florida the recreational fishery was thought to equal or exceed commercial landings (Berry and Burch, 1978). Many recreational anglers were reportedly selling their greater amberjack harvest, and this was unreported in the 1970's. Based on interviews with headboat captains (K. Brennan, personal comm.) and detailed historical reports from North Carolina, South Carolina and Florida, the workgroup decided that World War II would be an appropriate era to set the recreational harvest for this species to zero. Average landings estimates from the first three years of available data (1981-1983) were averaged and the average was divided by the number of years between 1946 and 1981 (40 years). Landings estimates for each year back from 1981 were incrementally declined backwards to zero in 1946.

d. Change in For-Hire Survey Methodology

The For-Hire Survey method was piloted in east Florida in 2000 and officially adopted in all the Atlantic coast states in 2003 as the new method for estimating charter mode effort and catch. The Coastal Household Telephone Survey continues to also generate estimates for charter mode fishing as a means of providing an uninterrupted time series. The new survey method has not been in use long enough on the Atlantic coast to compare with estimates from the Coastal Household Telephone Survey. In order to use the long-term time series for charter mode catch and effort from 1981 to 2006, we used Coastal Household Telephone Survey estimates for all years.

e. Shore estimates

Estimated shore landings for greater amberjack were a small portion of total recreational landings, and did not occur in most years. It is possible for pelagic species to come close to shore during upwelling events, particularly in southeast Florida where the Continental shelf is very narrow. Shore landings for greater amberjack were reviewed and the group decided to retain shore landing estimates in the total recreational landings.

f. Large Fish

The workgroup examined the potential effects of greater amberjack that were not weighed during MRFSS intercepts due to limitations of field staff or equipment, in particular for larger, heavier fish. Length/weight regressions for fish that were both weighed and measured were generated over three time periods, 1981-1992, 1993-1999, and 2000 to 2006. Weights for all fish that were measured but not weighed during MRFSS intercepts were filled in by using the weight conversion for the corresponding time period. For fish that were weighed during MRFSS intercepts, the weights were not changed. Landings were regenerated using the new average weights for all fish with either a measured or estimated weight. The impact on landings estimates by weight were small in both charter and private boat modes and only effected a few years. As a result, the workgroup determined that missing weights for large fish was not a concern and we did not adjust MRFSS landings estimates.

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. For greater amberjack, it was decided that the headboat fishery, which drift-fishes for greater amberjack, should not be compared to the charter fishery, which may fish differently (troll, bigger fish, more selective in what they keep). We applied the annual portion of landed and discarded fish in the MRFSS for all modes combined from 1981 to 2006 to annual headboat landings to get estimated headboat discards for greater amberjack. Released catch for years prior to 1981 were back calculated using the same methods as for harvest prior to 1981. Preliminary discard data from the Headboat Survey for 2006 were reviewed by workshop participants. Releases of greater amberjack from the Headboat Survey in 2006 were estimated to be 74% which is similar to 64% from the same year for the MRFSS At-Sea Headboat observations.

b. MRFSS discards

Anglers interviewed in the MRFSS intercept survey report any live fish they discarded during their fishing trip (type B2 catch). For unidentified fish in the Amberjack Genus category, it is not appropriate to assume that the same proportion of greater amberjack in the MRFSS landings estimates would apply to MRFSS released catch. The only available data on the released catch portion of Seriola species that are greater amberjack comes from at-sea headboat surveys. For fish in the Amberjack Genus category, we used the average from two recent years of headboat observer data from Florida to calculate a portion of discarded *Seriola* species that are greater amberjacks (Table 4.6). We applied this portion to MRFSS estimated Amberjack Genus B2 catch and added this to the MRFSS estimated Greater Amberjack B2 catch. We did not attempt to estimate the portion of unidentified jack releases that were greater amberjack.

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 aggregations 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. The annual numbers of greater amberjack measured in the MRFSS are given in Table 4.7.

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.

The 1984 length distribution revealed some data that, when investigated, proved to be erroneous in either length or weight. In wave 3, one interview contained observed, examined catch records for six greater amberjacks of lengths 1360 mm (3 fish), 1364 mm, 1368 mm, and 1380 mm. The five smallest of these fish had weight = 11.0 kg each, and the largest fish had a weight recorded as 11.2 kg. A regression equation produced using historic MRFSS data indicates the expected weights for these sizes should be ~30.5 kg. There were also two fish recorded as 199 and 200+ cm FL. These lengths are well above the reported maximum for the species and an error is assumed in either measuring the fish or transcribing the length data. Because it cannot be determined if these errors are in the length or weight measurements, both length and weight will be deleted. All of these eight fish lengths were deleted from the length frequency analysis, although the counts and landings estimates were not adjusted. Further, due to the small sample sizes in some cells (e.g., wave 3, private boat mode, federal waters; n=1, length=151 cm) the length data was pooled across boat modes (all for-hire and private boat mode lengths combined) before computation of weighting by mode and wave. All other years followed the standard protocols for pooling and weighting data by cell, then aggregating to produce the annual length frequency distribution.

b. Headboat Length Distributions

Lengths were collected from 1972-2006 by headboat dockside samplers. From 1972 to 1975, only North Carolina and South Carolina were sampled until 1976 when Georgia and the Northeast Coast of Florida were added to the headboat program. 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. Annual numbers of greater amberjack measured in the headboat survey are given in Table 4.8. The recreational 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 were not generated by the headboat program for any of the zones prior to 1981 and therefore the length compositions were not generated prior to 1981. The majority of fish sampled prior to 1991 were smaller than the 28 inch size limit imposed in 1992 (Figure 1). Outlier measurements for fish outside the maximum size range or too small to recruit to the recreational fishery were omitted. We are uncertain why the number of undersize fish sampled at the dock has increased since 2004. In the at-sea observer survey, biologists in Florida have observed that small greater amberjack are sometimes caught mixed within schools of banded rudderfish and the two species are not easily separated by the harvesters. This could explain many of the undersized amberjacks observed in dockside intercepts.

4.5.2. Adequacy for characterizing catch

Annual sample sizes for length frequency from the MRFSS and headboat surveys are less than 100 fish in many years, and this may not be adequate for use in catch-at-age models. Headboat length samples should not be pooled with MRFSS samples 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 yield 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. 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.

The South Carolina tagging program provides information on the area fished and size of greater amberjack 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 greater amberjack in the south Atlantic. There is currently no way to separate Monroe County landings by Atlantic and Gulf waters in either the MRFSS or FHS. Private boat estimates for Monroe County must be post-stratified from west Florida estimates. 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

Berry, F. and R. Burch. 1978. Aspects of the Amberjack Fisheries. Proc. Gulf and Carib. Fish. Inst. 31:179-194.

Cummings, N.J. and D.B. McClellan. 1999. Aspects of the Atlantic Greater Amberjack fishery through 1998. National Marine Fisheries Service, Southeast Science Center, Miami, FL. Sustainable Fisheries Division Contribution No. SFD 98/99-61. 156 pp.

Ellis, R.W. 1957. Catches of Fish by Charter Boats on Florida's East Coast. The Marine Laboratory, University of Miami. Special Service Bulletin No. 14, 6 pp.

Gregg, W.H. 1902. Where, When, and How to Catch Fish on the East Coast of Florida. The Matthews-Northrup Works, New York. 268 pp.

Taylor, H.F. 1951. Survey of Marine Fisheries of North Carolina. The Univ. of North Carolina Press, Chapel Hill. 555 pp.

Table 4.1. Greater Amberjack Recreational Landings and Discards

	Numbers of Fish in 1,000's										
	Landings			PSE	Discards			PSE	Landings+ Discards		
	Headboa	MRFSS	total	MRFSS	Headboa	MRFSS	total	MRFSS	Headboa	MRFSS	total
1962*	9.600	17.896	27.50	34.0	2.928	8.155	11.08	45	12.53	26.05	38.58
1963*	10.133	19.014	29.15	34.0	3.091	8.664	11.76	45	13.22	27.68	40.90
1964*	10.666	20.133	30.80	34.0	3.253	9.174	12.43	45	13.92	29.31	43.23
1965*	11.200	21.251	32.45	34.0	3.416	9.684	13.10	45	14.62	30.93	45.55
1966*	11.733	22.370	34.10	34.0	3.579	10.193	13.77	45	15.31	32.56	47.87
1967*	12.266	23.488	35.75	34.0	3.741	10.703	14.44	45	16.01	34.19	50.20
1968*	12.800	24.607	37.41	34.0	3.904	11.213	15.12	45	16.70	35.82	52.52
1969*	13.333	25.725	39.06	34.0	4.067	11.722	15.79	45	17.40	37.45	54.85
1970*	13.866	26.843	40.71	34.0	4.229	12.232	16.46	45	18.10	39.08	57.17
1971*	14.400	27.962	42.36	34.0	4.392	12.742	17.13	45	18.79	40.70	59.50
1972*	14.933	29.080	44.01	34.0	4.555	13.251	17.81	45	19.49	42.33	61.82
1973*	15.466	30.199	45.67	34.0	4.717	13.761	18.48	45	20.18	43.96	64.14
1974*	15.999	31.317	47.32	34.0	4.880	14.271	19.15	45	20.88	45.59	66.47
1975*	16.533	32.436	48.97	34.0	5.042	14.781	19.82	45	21.58	47.22	68.79
1976*	17.066	33.554	50.62	34.0	5.205	15.290	20.50	45	22.27	48.84	71.12
1977*	17.599	34.673	52.27	34.0	5.368	15.800	21.17	45	22.97	50.47	73.44
1978*	18.133	35.791	53.92	34.0	5.530	16.310	21.84	45	23.66	52.10	75.76
1979*	18.666	36.910	55.58	34.0	5.693	16.819	22.51	45	24.36	53.73	78.09
1980*	19.199	38.028	57.23	34.0	5.856	17.329	23.18	45	25.06	55.36	80.41
1981	16.747	53.957	70.70	37.3	4.657	20.785	25.44	45	21.40	74.74	96.15
1982	25.300	33.449	58.75	33.0	10.963	25.577	36.54	57.1	36.26	59.03	95.29
1983	17.151	26.679	43.83	31.8	3.490	5.625	9.11	67.6	20.64	32.30	52.94
1984	17.951	65.461	83.41	19.5	5.346	27.457	32.80	36.4	23.30	92.92	116.21
1985	10.697	69.361	80.06	21.7	5.049	62.006	67.06	32.6	15.75	131.37	147.11
1986	12.791	100.918	113.71	19.1	4.639	56.813	61.45	18.3	17.43	157.73	175.16
1987	17.260	95.689	112.95	32.3	5.465	43.941	49.41	23.9	22.72	139.63	162.36
1988	10.564	81.272	91.84	20.4	3.035	29.565	32.60	25.1	13.60	110.84	124.44
1989	11.636	80.487	92.12	31.3	2.873	26.383	29.26	19.4	14.51	106.87	121.38
1990	7.822	89.130	96.95	17.3	1.703	24.804	26.51	24.9	9.52	113.93	123.46
1991	8.709	68.618	77.33	15.3	3.707	50.849	54.56	21.7	12.42	119.47	131.88
1992	7.975	71.728	79.70	11.1	3.268	47.226	50.49	24.7	11.24	118.95	130.20
1993	7.066	47.751	54.82	16.2	3.348	37.408	40.76	17.4	10.41	85.16	95.57
1994	6.911	83.480	90.39	16.0	1.625	23.797	25.42	24.1	8.54	107.28	115.81
1995	4.615	39.944	44.56	20.1	1.083	12.223	13.31	27.9	5.70	52.17	57.87
1996	5.052	61.576	66.63	19.0	2.076	42.446	44.52	22.8	7.13	104.02	111.15
1997	2.812	39.208	42.02	21.8	1.228	24.883	26.11	31.3	4.04	64.09	68.13
1998	3.498	29.357	32.85	20.5	1.254	15.484	16.74	28	4.75	44.84	49.59
1999	4.733	86.268	91.00	12.2	1.834	42.527	44.36	24.6	6.57	128.79	135.36
2000	5.749	40.462	46.21	18.9	3.519	54.663	58.18	17.5	9.27	95.13	104.39
2001	4.872	48.192	53.06	14.2	2.201	28.169	30.37	18.2	7.07	76.36	83.43
2002	5.721	47.363	53.08	15.9	3.642	56.093	59.74	17.9	9.36	103.46	112.82
2003	7.150	54.430	61.58	11.4	4.040	59.776	63.82	15.7	11.19	114.21	125.40
2004	3.756	31.653	35.41	19.4	2.460	43.753	46.21	23.1	6.22	75.41	81.62
2005	2.858	25.215	28.07	14.5	1.954	50.862	52.82	25.3	4.81	76.08	80.89
2006	2.874	25.646	28.52	16.4	1.436	25.686	27.12	19.2	4.31	51.33	55.64

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

Table 4.2. Recreational landings in whole weight and average weight (estimated landings in number fish/estimated whole weight). PSE=percent standard error.

	Weight (pounds)			PSE	Average Weight (pounds)	
	Headboat	MRFSS	total	MRFSS	Headboat	MRFSS
1962*	85,888	386,125	472,013	30.8	8.947	21.576
1963*	90,659	410,258	500,917	30.8	8.947	21.576
1964*	95,431	434,391	529,822	30.8	8.947	21.576
1965*	100,202	458,524	558,726	30.8	8.947	21.576
1966*	104,974	482,657	587,630	30.8	8.947	21.576
1967*	109,745	506,789	616,535	30.8	8.947	21.576
1968*	114,517	530,922	645,439	30.8	8.947	21.576
1969*	119,288	555,055	674,344	30.8	8.947	21.576
1970*	124,060	579,188	703,248	30.8	8.947	21.576
1971*	128,832	603,321	732,152	30.8	8.947	21.576
1972*	133,603	627,454	761,057	30.8	8.947	21.576
1973*	138,375	651,586	789,961	30.8	8.947	21.576
1974*	143,146	675,719	818,865	30.8	8.947	21.576
1975*	147,918	699,852	847,770	30.8	8.947	21.576
1976*	152,689	723,985	876,674	30.8	8.947	21.576
1977*	157,461	748,118	905,579	30.8	8.947	21.576
1978*	162,232	772,251	934,483	30.8	8.947	21.576
1979*	167,004	796,383	963,387	30.8	8.947	21.576
1980*	171,775	820,516	992,292	30.8	8.947	21.576
1981	148,635	1,463,077	1,611,712	17.0	8.875	27.116
1982	261,456	666,042	927,497	48.3	10.334	19.912
1983	119,551	332,430	451,981	27.2	6.970	12.460
1984	269,762	1,984,578	2,254,340	21.1	15.028	30.317
1985	136,722	1,609,764	1,746,487	25.4	12.781	23.209
1986	152,716	2,617,411	2,770,127	17.4	11.939	25.936
1987	267,171	3,040,974	3,308,145	38.6	15.479	31.780
1988	179,806	2,101,223	2,281,029	23.4	17.021	25.854
1989	116,786	1,987,092	2,103,879	26.1	10.037	24.688
1990	117,780	1,747,865	1,865,646	21.6	15.058	19.610
1991	155,542	1,285,012	1,440,554	19.9	17.860	18.727
1992	158,204	1,330,652	1,488,856	13.3	19.838	18.551
1993	156,971	910,134	1,067,104	21.2	22.215	19.060
1994	120,578	1,805,323	1,925,901	18.9	17.447	21.626
1995	78,892	940,287	1,019,179	22.8	17.095	23.540
1996	92,674	1,132,253	1,224,927	18.0	18.344	18.388
1997	50,316	784,972	835,288	21.5	17.893	20.021
1998	53,697	567,549	621,246	24.5	15.351	19.333
1999	69,565	1,837,391	1,906,956	12.6	14.698	21.299
2000	129,946	868,340	998,287	22.7	22.603	21.461
2001	97,829	737,760	835,589	13.8	20.080	15.309
2002	87,143	813,852	900,996	15.6	15.232	17.183
2003	135,297	1,077,565	1,212,862	12.1	18.923	19.797
2004	82,616	678,338	760,954	19.4	21.996	21.431
2005	33,442	577,774	611,216	14.6	11.701	22.914
2006	39,782	617,433	657,216	18.8	13.842	24.075

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

Table 4.3. North Carolina Citation Results, 1991 through 2006.

Year	Greater Amberjack Harvest Citations	Greater Amberjack Release Citations	Total Amberjack Citations	Amberjack Percent Release Citation
1991	107	72	179	67.3
1992	188	144	332	76.6
1993	180	155	335	86.1
1994	215	186	401	91.2
1995	99	95	194	96.0
1996	174	144	318	82.8
1997	346	275	621	79.5
1998	281	267	548	95.0
1999	241	229	470	95.0
2000	224	179	403	79.9
2001	173	144	317	83.2
2002	516	481	997	93.2
2003	166	132	298	79.5
2004	175	147	322	84.0
2005	80	63	143	78.8
2006	69	45	114	75.0

Table 4.4. South Carolina Angler-Based Tagging Program, number of greater amberjack tagged and minimum and maximum size range.

Year	Number Measured	Range (inches)	Year	Number Measured	*Range (inches)*
1981	1	42	1995	49	*18-48*
1982	1	34	1996	92	*12.5-51*
1985	1	54	1997	71	*11.5-56*
1986	18	38-45	1998	69	*12-52*
1987	54	24-55	1999	91	*12-49*
1988	20	25-56	2000	51	*9-48*
1989	34	15-63	2001	39	*12-43*
1990	18	24-60	2002	24	*19-40*
1991	37	14-57	2003	22	*13-48*
1992	67	17-70	2004	9	*14-43.5*
1993	68	12-48	2005	4	*42-49*
1994	*34*	*11-48*	*2006*	*7*	*20-32*

Table 4.5. Additional greater amberjack (GAJ), in numbers of fish, added to known landings to account for greater amberjack in the Jack Family landings after fish used for bait were removed.

	Jack Family B1 Catch Estimate (numbers of fish)		Ratio from Observed Type A Fish		Additional GAJ Landings from Jack Family		Additional GAJ Landings from AJ Genus	
Year	Bait Included	Bait Removed	GAJ/All Jacks	GAJ/All Seriola	Number	Pounds	Number	Pounds
1981	4,752	76	0.0403	0.6258	3	88	0	0
1982	91,623	24,835	0.0214	0.8758	532	12,213	0	0
1983	106,374	51,494	0.0088	0.7215	455	6,313	1,082	12,517
1984	14,794	2,364	0.0359	0.7406	85	2,736	0	0
1985	11,510	3,737	0.0542	0.9811	203	4,224	0	0
1986	0	0	0.0281	0.4859	0	0	0	0
1987	2,832	1,047	0.1179	0.9934	123	4,179	193	6,476
1988	1,851	0	0.0393	0.2684	0	0	0	0
1989	6,168	4,782	0.0879	1.0000	420	10,689	0	0
1990	33,996	33,996	0.0621	1.0000	2,112	46,147	0	0
1991	1,296	1,296	0.0480	1.0000	62	1,080	0	0
1992	9,823	0	0.0656	0.9270	0	0	0	0
1993	4,831	3,380	0.0268	0.4579	91	2,143	0	0
1994	52,305	4,740	0.0582	0.8902	276	6,421	1,384	30,291
1995	12,612	3,267	0.0151	0.8698	49	1,115	87	1,967
1996	10,219	797	0.0282	0.9625	22	418	706	13,140
1997	19,494	855	0.0097	0.8135	8	157	1,681	25,678
1998	1,602	996	0.0180	0.8820	18	341	0	0
1999	20,034	1,514	0.0324	0.6807	49	1,082	15,083	311,401
2000	8,857	6,844	0.0150	0.5757	103	2,451	1,436	30,058
2001	84,424	26,616	0.0121	0.6089	322	5,633	1,977	24,307
2002	20,303	4,490	0.0125	0.8108	56	1,217	1,194	16,707
2003	71,745	49,836	0.0108	0.7524	536	12,113	504	9,497
2004	49,013	22,769	0.0082	0.3396	187	5,380	426	8,552
2005	106,768	24,623	0.0085	0.6705	210	5,297	2,341	61,798
2006	2,188	965	0.0111	0.4579	11	262	228	5,606

Table 4.6. At-Sea Headboat Surveys, 2005-2006. Numbers of all *Seriola* observed and identified to species, and the percent of *Seriola* that were greater amberjack.

		All Seriola Species		Percent GAJ	
YEAR	WAVE	Harvest	Release	Harvest	Release
2005	1	0	0		
2005	2	13	9	0.00	11.11
2005	3	51	33	1.96	0.00
2005	4	11	9	36.36	44.44
2005	5	210	29	8.10	27.59
2005	6	32	10	25.00	100.00
sum		317	90	9.46	25.56
2006	1	15	31	20.00	25.81
2006	2	897	5	0.11	100.00
2006	3	86	3	0.00	66.67
2006	4	760	31	0.92	100.00
2006	5	8	6	12.50	33.33
2006	6	11	9	9.09	66.67
sum		1777	85	0.73	63.53

Table 4.7. Greater amberjack annual sample sizes from Virginia, south Atlantic sub-region, and Florida Keys.

Year	Number of Lengths	Year	Number of Lengths
1981	33	1994	118
1982	12	1995	58
1983	24	1996	101
1984	82	1997	42
1985	53	1998	79
1986	71	1999	280
1987	83	2000	160
1988	59	2001	161
1989	109	2002	213
1990	77	2003	323
1991	77	2004	82
1992	71	2005	82
1993	94	2006	78

Table 4.8. Number of headboat biological samples in the in Southeast US Atlantic 1981- 2006.

Year	NC	SC	GA\FL	Total
1981	9	0	209	218
1982	15	0	83	98
1983	16	12	254	282
1984	12	31	188	231
1985	31	7	200	238
1986	33	4	211	248
1987	55	2	211	268
1988	52	33	59	144
1989	37	23	131	191
1990	18	20	81	119
1991	60	25	22	107
1992	28	24	78	130
1993	39	43	39	121
1994	22	46	56	124
1995	42	41	30	113
1996	37	33	13	83
1997	19	31	28	78
1998	14	30	57	101
1999	36	17	78	131
2000	43	13	32	88
2001	15	0	24	39
2002	15	23	110	148
2003	14	12	130	156
2004	27	0	41	68
2005	11	3	24	38
2006	22	34	28	84
Total	722	507	2,417	3,646

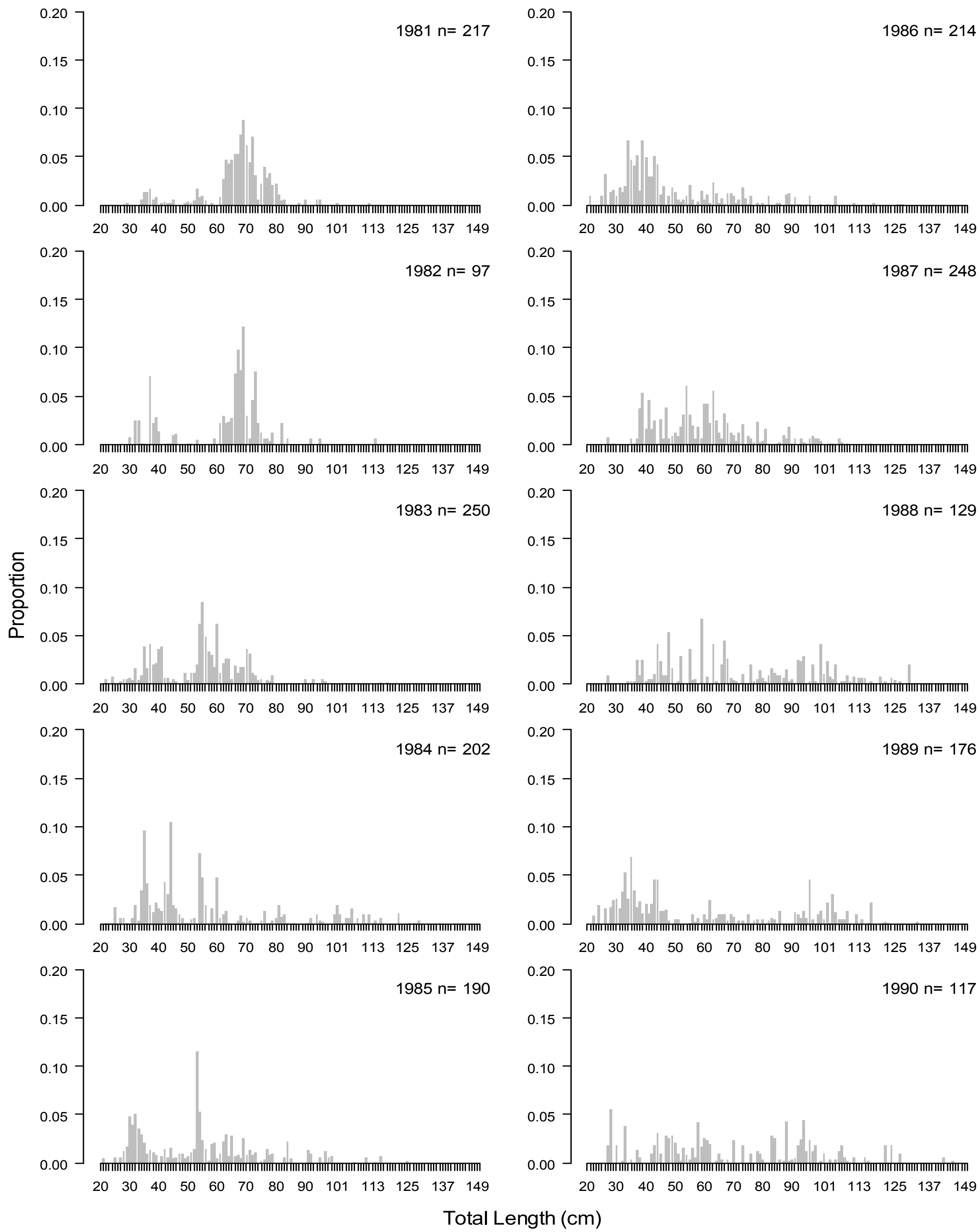


Figure 4.1. Catch weighted length frequencies of greater amberjack measured from headboat vessels from 1981-2006. The vertical line indicates a size limit of 28 inches implemented in January, 1992. It is included on all graphs as a reference value. The range of sizes from 20 to 130 cm excludes a small number of fish. The entire range of sizes will be provided to the assessment working group to determine an appropriate range of lengths for the model.

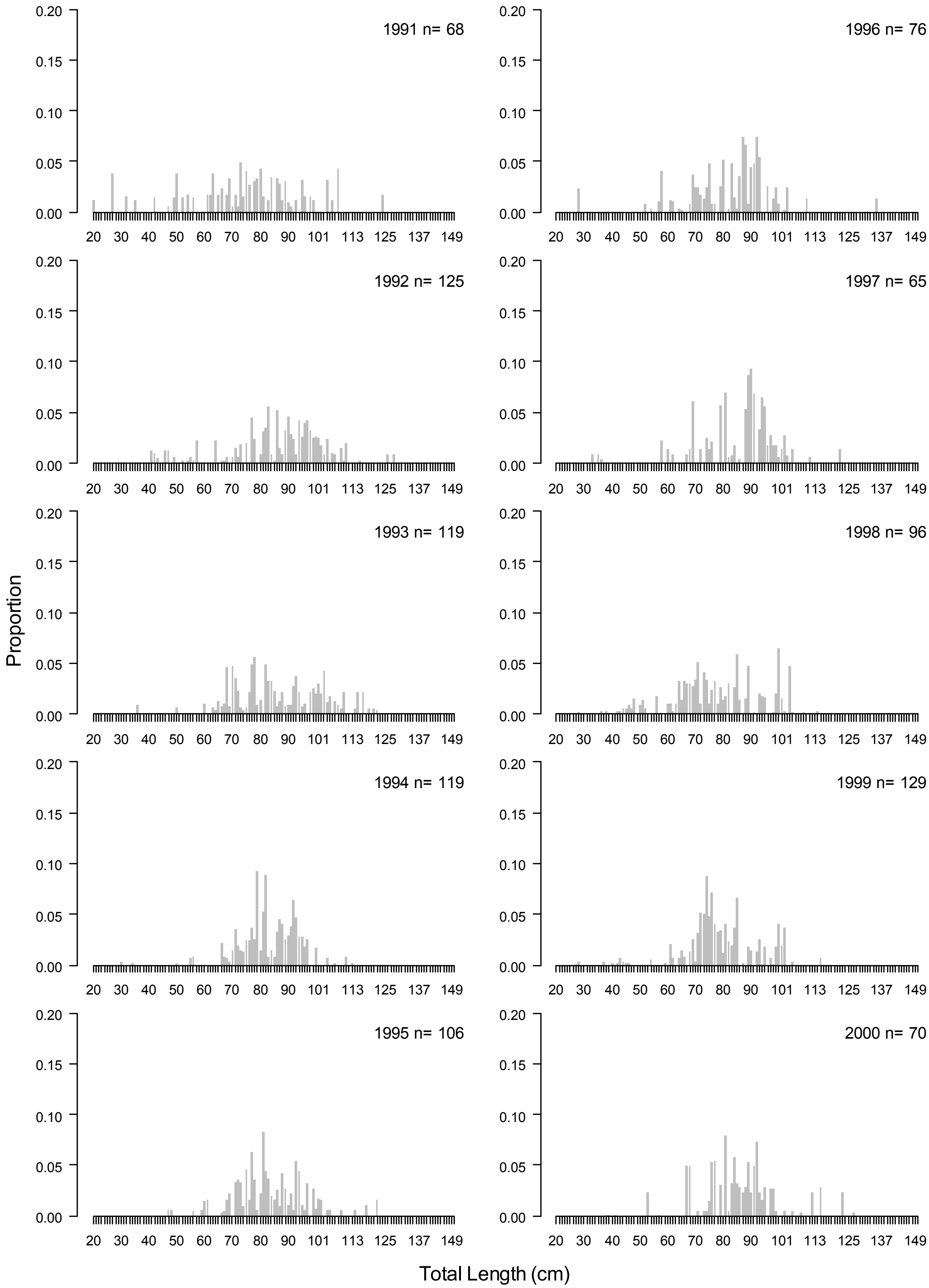


Figure 4.2. Continued

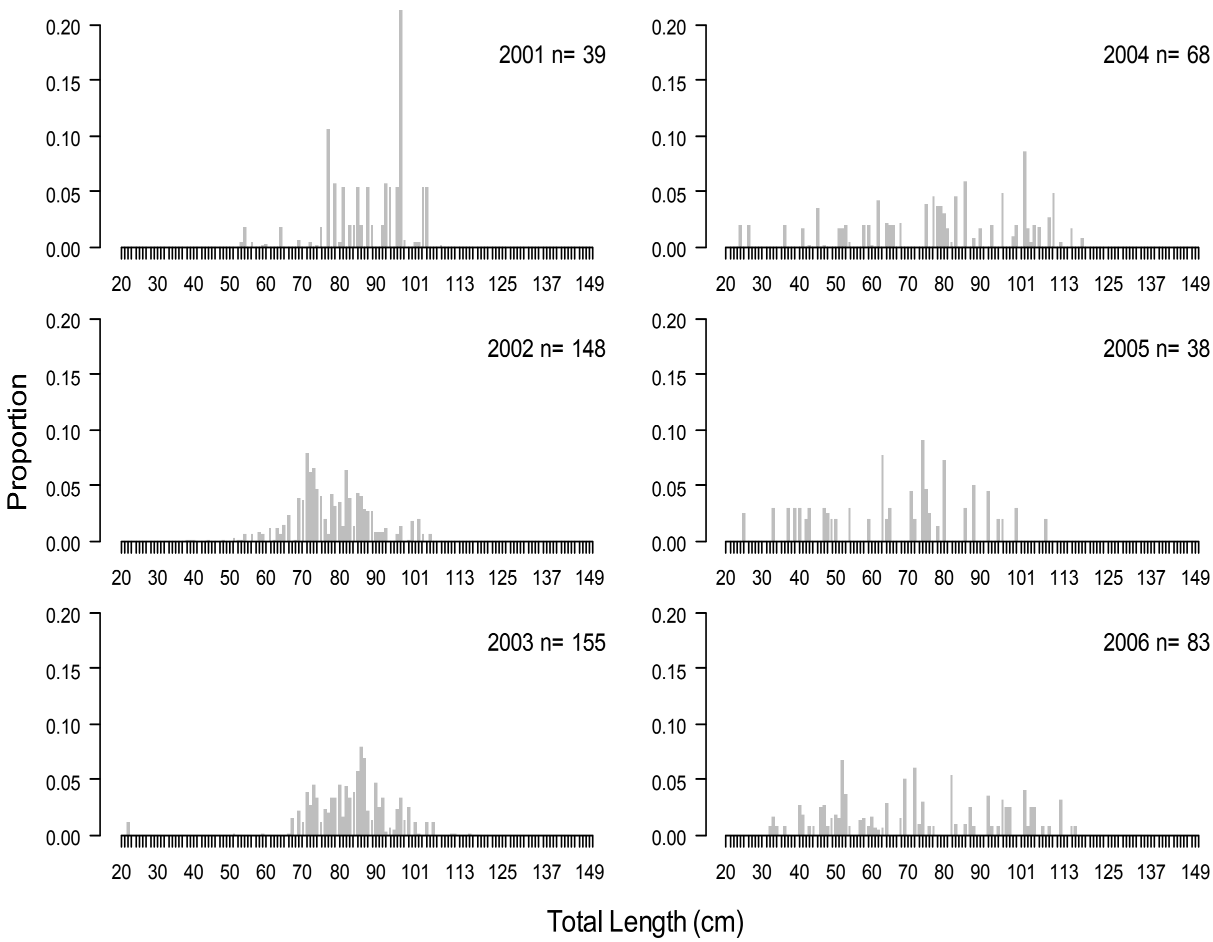


Figure 4.2. Continued

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

Greater amberjack have been sampled in low numbers by the MARMAP (Marine Resources Monitoring Assessment and Prediction) program with a variety of gear types since 1979 (gears detailed in previous working paper SEDAR10-DW-05), including chevron traps (1988–2006), hook and line (1979–2002), and short bottom longline (or vertical long line, 1980–2006). Although these three gear types and sampling methodologies are not specifically designed to sample greater amberjack 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 total number of greater amberjack collected in the traps between 1988 and 2006 was only 39 (2/yr, range 0-12), while in 8 of the 19 years no greater amberjacks were captured in the chevron traps at all. Because of the low catches and high variability, the DW did not recommend using MARMAP chevron trap samples to develop an index of abundance for greater amberjack 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 using 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 was placed on hook and line sampling during the 1990s and early 2000s so that more effort could be devoted to other sampling methods.

The total number of amberjacks caught between 1979 and 2002 was 39 (1.8/yr, range 0-20). Twenty of these fish were collected in a single year (1992), while 54% of the 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 greater amberjack. 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.

The total number of greater amberjacks caught in 1980-81, 1986-87, and between 1991 and 2006 was 74 (average of 4.4/yr, range 0-29). In 53% of the years no greater amberjack were collected and 48 of the total number of fish were collected in 1999 (19) and 2005 (29). 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 greater amberjack off the southeastern U.S.

5.2.2 Other fishery independent sources

Other existing data sets (i.e., SEAMAP survey, Univ. of SC/Baruch Institute low tide motile nekton survey) were considered for their potential as an index, but they sampled no or insufficient numbers of greater amberjack 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 92% 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).

Issue 4: Species to include in application of Stephens and MacCall (2004)
Option 1: Species in the snapper-grouper Fishery Management Plan.
Option 2: Option 1 plus pelagic species known to be caught alongside greater amberjack.
Decision: Option 1, because it is believed that catch of amberjack on trips targeting pelagic species is incidental. Thus, including pelagic species in the analysis would over-inflate effective effort toward amberjack.

Issue 5: Misidentification of greater amberjack with other amberjacks
Option 1: Use data as reported.
Option 2: Devise a correction method to achieve landings consistent with proportions of species as indicated by data from the Trip Interview Program (TIP). The method would need to be applied on a trip-by-trip basis.
Option 3: Exclude from the application of Stephens and MacCall (2004) those species that could be misidentified with greater amberjack (lesser amberjack, almaco jack, and banded rudderfish).
Decision: Option 3, because it minimizes any effect of misidentification (with the cost of removing possibly usable data). Option 2 was considered desirable, but could not meaningfully be achieved on a trip-by-trip basis.

Miscellaneous decisions

- A 36” FL or 28” core length size limit has been in place for the commercial fishery since 1992. The DW acknowledged that this issue could be handled by the assessment model through estimation of selectivity.
- In 1992, a bag limit of 3 greater amberjack during the month of April was implemented south of Cape Canaveral, FL. In 1999, the bag limit was reduced to 1 greater amberjack/person/day or 1/person/trip, whichever is more restrictive, during the month of April and was expanded geographically to include the entire management area. As a result, the DW decided to exclude the month of April from all years in the analysis.
- An annual commercial quota of 1,169,931 lb (gutted weight) has been in place since 1999. Analysis of the data showed that this quota was never reached between 1993 and 2006; therefore, it was decided to ignore any possible effect of the quota.
- A trip limit of 1,000 lb (gutted weight) has been in place for the commercial fishery since 1999. The proportion of trips exceeding 1,000 lb prior to 1999 was compared to those after 1999 for regions north and south of Cape Canaveral. Any effect of a trip limit appeared relatively small (Table 5.3); therefore, the DW decided to include all years from 1993 to 2006.

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 greater amberjack, approximately 92% 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 ~1% of handline records. Also excluded were records from April (as described above) and those 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 greater amberjack 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 appeared overly restrictive for the southern region (included only seven species) and was thus reduced to 1% for the southern region. A trip was then included if its associated probability of catching greater amberjack 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 28,269 trips, of which ~58% 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, month, and area×month as the factors other than year to be used in the binomial GLM (Table 5.4A), and it identified area, month, and area×month as factors to be used in the lognormal GLM (Table 5.4B).

5.3.1.4 Sampling Intensity

The numbers of positive trips by year and area are tabulated in Table 5.5. 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 5.6 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 clearly, problems remain, as demonstrated by the misidentification of other species (lesser amberjack, almaco jack, and banded rudderfish) as greater amberjack.

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 1978–2006.

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 either 1976 (sampling did not include southern Florida)

Option 3: Exclude early years; start the time series in 1978 (begins 100% coverage).
Decision: Option 3, because it provides full area coverage throughout the time series, including southern Florida where a substantial portion of the catch occurs.

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).

Issue 3: Species to include in application of Stephens and MacCall (2004)
Option 1: Species in the snapper-grouper Fishery Management Plan.
Option 2: Option 1 plus pelagic species known to be caught alongside greater amberjack.
Decision: Option 1, because it is believed that catch of amberjack on trips targeting pelagic species is incidental. Thus, including pelagic species in the analysis would over-inflate effective effort toward amberjack.

Issue 4: Misidentification of greater amberjack with other amberjacks
Option 1: Use data as reported.
Option 2: Devise a correction method to achieve landings consistent with proportions of species as indicated by TIP data. The method would need to be applied on a trip-by-trip basis.
Option 3: Exclude those species that could be misidentified with greater amberjack (lesser amberjack, almaco jack, and banded rudderfish).
Decision: Option 3, because it minimizes any effect of misidentification (with the cost of removing possibly usable data). Option 2 was considered desirable, but could not meaningfully be achieved on a trip-by-trip basis.

Miscellaneous decisions

- A 28” FL size limit has been in place for the recreational fishery since 1992. The DW acknowledged that size limits could be accounted for by the assessment model through estimation of selectivity.
- A bag limit of three greater amberjack/person/day was instituted for the recreational fishery in 1992. This bag limit was decreased to 1 greater amberjack/angler/day in 1999. Bag analysis showed that these limits had little effect on the headboat fishery (Table 5.7).
- Regulations were implemented in 1999 that restricted headboats to 1 greater amberjack/day or 1/vessel/trip during the month of April, whichever is more restrictive. The percentage of trips exceeding this limit was examined, and as a result, the DW decided to exclude the month of April from all years in the analysis.

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 1978–2006. Spatial coverage included the entire management area (Figure 5.5). Trips were trimmed from the analysis if the number of greater amberjack per angler was in the upper 1%, to exclude outliers suspected to be misreported or misrecorded. Also excluded were records from April (as described above) and those that did not report fields necessary to compute catch per unit effort.

Effective effort was based on those trips from areas where greater amberjack 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 of X=5% was applied to both regions. A trip was then included if its associated probability of catching greater amberjack 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 28,743 trips, of which ~19% 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 month, type, and area×type as the factors other than year to be used in the binomial GLM (Table 5.8A), and it identified area, month, and type as the factors to be used in the lognormal GLM (Table 5.8B).

5.3.2.4 Sampling Intensity

The numbers of positive trips by year and area are tabulated in Table 5.9. 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 5.10 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 greater amberjack. 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 greater amberjack 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 greater amberjack 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 of 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 1986, when the sample size increased substantially.
Option 3: Start the time series somewhere between 1982 and 1986.
Decision: Option 2. The DW decided to start the time series in 1986, when the sample size increased substantially with better distribution across states (Table 5.11). Prior to 1986, few greater amberjack trips were intercepted in NC or SC.

Miscellaneous decisions
- The group acknowledged the possibility that some greater amberjack were misreported as lesser amberjack, almaco jack, or banded rudderfish. MRFSS data were used as reported. It was assumed that if greater amberjack were misreported, the misreporting was not systematic, such that the greater amberjack reported could be considered a random sample of all greater amberjack caught.
- A 28” FL size limit has been in place for the recreational fishery since 1992. The DW acknowledged that this issue could be handled by the assessment model through estimation of selectivity.
- A bag limit of three greater amberjack/person/day was instituted for the recreational fishery in 1992. This bag limit was decreased to 1 greater amberjack/person/day in 1999. The effect of bag limits on recreational catch was not seen as an issue since estimates used in calculation of the index include discards (type B2).
- 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 greater amberjack to estimates of total marine recreational angler trips. Directed trips were defined as those trips where greater amberjack 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 5.11.

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 5.12 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 5.13.

5.5 RESEARCH RECOMMENDATIONS

1. Develop a method to correct for greater amberjack 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 greater amberjack population so off the southeastern U.S. Two ideas discussed were the following:
   - Adding gears to MARMAP that are more effective at catching greater amberjack
   - 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

ACCSP (Atlantic Coastal Cooperative Statistics Program). 2007. Recreational – Advanced Queries; generated by Geoff White; using ACCSP Data Warehouse [online application], Washington, D.C: Available at http://www.accsp.org/ → Data Center → Data Warehouse, accessed July 9, 2007.

Kaufman, L., Rousseeuw and P.J. 1990. Finding groups in data: an introduction to cluster analysis. John Wiley & Sons, Inc., New York, NY, 319 p.

Kruskal, J.B. 1964. Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. Psychometrika 29:1–27.

Lo, N.C., Jacobson, L.D., Squire, J.L. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49:2515-2526.

Maunder, M.N., Punt, A.E. 2004. Standardizing catch and effort data: a review of recent approaches. Fish. Res. 70:141-159.

McCune, B., Grace, J.B. 2002. Analysis of ecological communities. MjM Software Design, Gleneden Beach, Oregon. 300 p.

Rousseeuw, P.J. 1987. Silhouettes: a graphical aid to the interpretation and validation of cluster analysis. J. Comp. Appl. Math. 20:53–65.

SAFMC. 2006. SEDAR 10 Stock Assessment Report 1: South Atlantic Gag Grouper. (http://www.sefsc.noaa.gov/sedar/Sedar_Workshops.jsp?WorkshopNum=10)

Stephens, A., and A. MacCall. 2004. A multispecies approach to subsetting logbook data for purposes of estimating CPUE. Fish. Res. 70:299-310.

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	1978-2006	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	1986-2006	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 = 0 to 12 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 20 per year)	N
Independent	MARMAP Short longline	Atlantic	1980-2006	Number per hook-hr	Nominal	—	Low sample sizes; freq. annual zeros (n = 0 to 29 per year)	N
Independent	SEAMAP	Atlantic	1990-2006	Number per hectare	Nominal	—	Extremely low sample sizes; mostly annual zeros (n = 0 to 10 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 greater amberjack 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 unlikely that fishermen will list greater amberjack as a target species when only able to record a maximum of two species. Trips would be eliminated from the analysis if anglers fished in areas where greater amberjack 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 0-12 fish caught per year with the majority being zeros.
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 0-20 fish caught per year with the majority being 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 0-29 fish caught per year with the majority being 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 greater amberjack from program inception in 1990 to 2005

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 5.3. Proportion of greater amberjack trips exceeding 1000 lb (gutted weight), as reported in commercial logbook data. A 1000 lb trip limit was implemented in early 1999.

Year	North	South
1993	0.061	0.173
1994	0.067	0.159
1995	0.045	0.117
1996	0.067	0.083
1997	0.052	0.091
1998	0.064	0.099
1999	0.046	0.087
2000	0.033	0.054
2001	0.010	0.073
2002	0.010	0.089
2003	0.012	0.070
2004	0.002	0.157
2005	0.013	0.257
2006	0.003	0.256

Table 5.4A. Greater amberjack: 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	28255	38296.6	1.3554		-19148.3		
AREA	28251	37222.0	1.3175	2.79	-18611.0	1074.66	0.00000
MONTH	28245	37666.4	1.3336	1.61	-18833.2	630.22	0.00000

The explanatory factors in the base model are: YEAR AREA

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	28251	37222.0	1.3175		-18611.0		
MONTH	28241	36689.4	1.2992	1.40	-18344.7	532.59	0.00000

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

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	28241	36689.4	1.2992		-18344.7		
AREA*MONTH	28201	35830.0	1.2705	2.20	-17915.0	859.38	0.00000

Table 5.4B. Greater amberjack: 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	16440	96926.4	5.8958		-37936.8		
AREA	16436	31765.1	1.9327	67.22	-28758.9	18355.82	0.00000
MONTH	16430	81904.1	4.9850	15.45	-36551.4	2770.90	0.00000

The explanatory factors in the base model are: YEAR AREA

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	16436	31765.1	1.9327		-28758.9		
MONTH	16426	30915.1	1.8821	2.62	-28535.8	446.29	0.00000

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

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	16426	30915.1	1.8821		-28535.8		
AREA*MONTH	16386	29816.7	1.8196	3.32	-28238.2	595.25	0.00000

Table 5.5. Number of trips by year and area (GA=Georgia, NC=North Carolina, NF=north Florida, SC=South Carolina, SF=south Florida) that caught greater amberjack, as reported in commercial logbook data.

	Area					
Year	**GA**	**NC**	**NF**	**SC**	**SF**	**Total**
1992	43	65	122	127	253	610
1993	124	157	367	445	746	1839
1994	132	173	441	490	1074	2310
1995	138	205	396	638	1134	2511
1996	164	185	449	625	1285	2708
1997	120	248	361	685	1303	2717
1998	97	154	257	481	1070	2059
1999	77	177	226	328	1002	1810
2000	81	125	331	456	871	1864
2001	139	195	248	554	1023	2159
2002	138	173	212	481	1047	2051
2003	85	163	198	412	1018	1876
2004	109	112	151	453	1080	1905
2005	111	133	120	400	930	1694
2006	37	126	91	451	668	1373
Total	1595	2391	3970	7026	14504	29486

Table 5.6. CPUE of greater amberjack 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	12.277	0.859	0.849	0.754	0.955	1797	0.059
1994	15.268	1.069	0.904	0.817	0.999	2197	0.050
1995	13.298	0.931	1.048	0.956	1.150	2582	0.046
1996	11.534	0.807	0.947	0.861	1.041	2471	0.047
1997	12.535	0.877	0.907	0.824	0.998	2355	0.048
1998	12.760	0.893	0.935	0.836	1.045	2095	0.056
1999	10.952	0.767	0.740	0.656	0.835	1892	0.060
2000	9.506	0.665	0.904	0.805	1.015	1753	0.058
2001	11.443	0.801	0.979	0.883	1.086	2149	0.052
2002	12.737	0.892	1.024	0.924	1.135	2105	0.052
2003	13.288	0.930	1.009	0.902	1.128	1816	0.056
2004	20.584	1.441	1.427	1.283	1.587	1841	0.053
2005	24.433	1.710	1.301	1.160	1.460	1757	0.058
2006	19.387	1.357	1.026	0.903	1.165	1459	0.064

Table 5.7. Proportion of greater amberjack trips from the headboat fishery that exceeded one greater amberjack per angler. Starting in 1992, regulations included a bag limit of three greater amberjack per angler, and starting in 1999, one greater amberjack per angler.

Year	North of Canaveral	South of Canaveral
1973	0.015	
1974	0.000	
1975	0.013	
1976	0.012	
1977	0.010	
1978	0.006	0.000
1979	0.001	0.000
1980	0.031	0.018
1981	0.039	0.024
1982	0.029	0.019
1983	0.013	0.030
1984	0.008	0.015
1985	0.004	0.047
1986	0.016	0.011
1987	0.011	0.047
1988	0.006	0.022
1989	0.007	0.041
1990	0.002	0.003
1991	0.005	0.000
1992	0.009	0.015
1993	0.015	0.024
1994	0.019	0.009
1995	0.006	0.000
1996	0.010	0.000
1997	0.002	0.000
1998	0.005	0.014
1999	0.009	0.021
2000	0.013	0.000
2001	0.001	0.000
2002	0.012	0.000
2003	0.006	0.000
2004	0.013	0.000
2005	0.000	0.041
2006	0.004	0.015

Table 5.8A. Greater amberjack: 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	28714	27420.2	0.9549		-13710.1		
TYPE	28713	22839.5	0.7954	16.70	-11419.7	4580.77	0.00000
AREA	28711	25898.9	0.9021	5.54	-12949.5	1521.31	0.00000
MONTH	28704	26993.6	0.9404	1.52	-13496.8	426.66	0.00000

The explanatory factors in the base model are: YEAR TYPE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	28713	22839.5	0.7954		-11419.7		
MONTH	28703	22564.7	0.7861	1.17	-11282.3	274.81	0.00000
AREA	28710	22678.6	0.7899	0.69	-11339.3	160.88	0.00000

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

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	28703	22564.7	0.7861		-11282.3		
AREA	28700	22448.8	0.7822	0.50	-11224.4	115.90	0.00000

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

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	28703	22564.7	0.7861		-11282.3		
AREA*TYPE	28697	22070.1	0.7691	2.17	-11035.0	494.56	0.00000
AREA*MONTH	28671	22261.6	0.7764	1.23	-11130.8	303.08	0.00000
MONTH*TYPE	28693	22531.0	0.7852	0.11	-11265.5	33.61	0.00022

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

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	28697	22070.1	0.7691		-11035.0		
AREA*MONTH	28668	21892.2	0.7636	0.71	-10946.1	177.93	0.00000
MONTH*TYPE	28687	22062.1	0.7691	0.00	-11031.0	8.04	0.62492

Table 5.8B. Greater amberjack: 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	5513	6024.2	1.0927		-8094.9		
AREA	5510	5593.9	1.0152	7.09	-7889.6	410.65	0.00000
TYPE	5512	5719.0	1.0376	5.05	-7950.9	288.12	0.00000
MONTH	5503	5951.6	1.0815	1.02	-8061.4	67.12	0.00000

The explanatory factors in the base model are: YEAR AREA

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	5510	5593.9	1.0152		-7889.6		
TYPE	5509	5409.7	0.9820	3.28	-7796.8	185.58	0.00000
MONTH	5500	5527.3	1.0050	1.01	-7856.4	66.38	0.00000

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

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	5509	5409.7	0.9820		-7796.8		
MONTH	5499	5338.4	0.9708	1.14	-7760.0	73.55	0.00000

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

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	5499	5338.4	0.9708		-7760.0		
AREA*MONTH	5470	5285.1	0.9662	0.47	-7732.2	55.57	0.00212
AREA*TYPE	5496	5322.6	0.9684	0.24	-7751.8	16.47	0.00091
MONTH*TYPE	5489	5326.3	0.9704	0.04	-7753.8	12.52	0.25203

Table 5.9. Number of trips by year and area (NC=North Carolina, NF=Georgia and north Florida, SC=South Carolina, SF=south Florida) that caught greater amberjack, as reported in headboat data.

Year	Area				Total
	NC	NF	SC	SF	
1973	174	0	157	0	331
1974	2	0	20	0	22
1975	177	0	125	0	302
1976	163	340	160	0	663
1977	102	452	126	0	680
1978	173	700	207	61	1141
1979	108	593	107	316	1124
1980	59	819	192	444	1514
1981	92	468	35	553	1148
1982	188	506	202	475	1371
1983	181	572	267	669	1689
1984	73	525	263	480	1341
1985	54	538	312	446	1350
1986	113	862	290	570	1835
1987	204	842	395	535	1976
1988	144	518	373	366	1401
1989	40	312	192	436	980
1990	85	130	284	337	836
1991	138	179	319	206	842
1992	203	595	259	267	1324
1993	136	471	369	246	1222
1994	121	471	321	213	1126
1995	139	402	336	151	1028
1996	147	336	327	106	916
1997	71	106	265	72	514
1998	83	228	330	73	714
1999	75	410	310	48	843
2000	147	452	360	48	1007
2001	67	505	268	64	904
2002	46	557	294	39	936
2003	66	499	270	58	893
2004	127	271	312	66	776
2005	68	260	174	73	575
2006	72	205	209	68	554
Total	3838	14124	8430	7486	33878

Table 5.10. CPUE of greater amberjack 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
1978	0.0052	1.625	1.277	0.652	2.502	1037	0.346
1979	0.0034	1.072	1.228	0.581	2.594	925	0.387
1980	0.0038	1.206	1.362	0.618	3.001	1231	0.411
1981	0.0031	0.975	0.861	0.230	3.217	1046	0.738
1982	0.0037	1.163	1.243	0.544	2.840	1333	0.431
1983	0.0037	1.180	1.295	0.601	2.788	1410	0.398
1984	0.0028	0.871	1.085	0.439	2.678	1284	0.476
1985	0.0033	1.042	0.998	0.409	2.437	1418	0.470
1986	0.0043	1.352	1.498	0.752	2.984	1544	0.355
1987	0.0031	0.974	1.382	0.678	2.819	1512	0.368
1988	0.0028	0.878	0.965	0.370	2.513	1213	0.507
1989	0.0028	0.882	0.713	0.176	2.882	839	0.793
1990	0.0020	0.642	0.869	0.215	3.517	751	0.793
1991	0.0032	0.994	1.232	0.446	3.400	829	0.542
1992	0.0023	0.740	0.770	0.230	2.576	1014	0.663
1993	0.0020	0.631	0.619	0.161	2.384	1099	0.758
1994	0.0032	1.005	0.794	0.241	2.608	980	0.652
1995	0.0018	0.577	0.614	0.157	2.396	1082	0.768
1996	0.0029	0.911	0.919	0.300	2.818	983	0.607
1997	0.0014	0.433	0.544	0.099	2.980	690	1.029
1998	0.0019	0.592	0.511	0.110	2.383	959	0.899
1999	0.0033	1.024	0.860	0.257	2.883	788	0.665
2000	0.0044	1.375	1.056	0.321	3.474	635	0.652
2001	0.0032	1.002	0.904	0.283	2.885	803	0.633
2002	0.0056	1.772	1.712	0.732	4.003	742	0.445
2003	0.0055	1.723	1.676	0.630	4.459	583	0.520
2004	0.0029	0.910	0.805	0.199	3.258	684	0.794
2005	0.0024	0.751	0.578	0.106	3.143	712	1.024
2006	0.0022	0.697	0.631	0.120	3.307	617	0.994

Table 5.11. Number of intercepts from MRFSS that caught greater amberjack or reported greater amberjack as a targeted species. The index of abundance was computed for 1986–2006, because of total sample size and distribution across states.

Year	Total	NC	SC	GA	FL
1982	35	1	7	4	23
1983	51	2	4	0	45
1984	116	10	17	18	71
1985	92	4	12	19	57
1986	189	30	78	18	63
1987	275	139	46	44	46
1988	250	115	83	6	46
1989	291	141	75	1	74
1990	230	118	18	10	84
1991	259	161	16	6	76
1992	398	151	17	65	165
1993	195	132	18	0	45
1994	305	183	9	35	78
1995	157	117	1	6	33
1996	292	203	11	29	49
1997	169	79	32	22	36
1998	149	67	1	12	69
1999	449	29	1	10	409
2000	430	64	131	18	217
2001	486	84	8	9	385
2002	627	159	7	17	444
2003	675	107	28	61	479
2004	465	92	54	72	247
2005	248	30	24	23	171
2006	336	77	7	101	151

Table 5.12. CPUE of greater amberjack 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
1986	1.089	0.989	15.1
1987	1.328	1.206	23.6
1988	0.989	0.899	16.0
1989	1.176	1.069	25.0
1990	1.141	1.037	15.0
1991	1.322	1.201	13.6
1992	1.330	1.209	14.2
1993	1.295	1.176	12.1
1994	1.297	1.178	13.3
1995	0.969	0.881	17.0
1996	1.344	1.221	14.8
1997	1.137	1.033	17.9
1998	1.084	0.985	16.8
1999	0.960	0.872	11.9
2000	0.969	0.881	12.0
2001	0.896	0.814	17.6
2002	1.156	1.050	12.7
2003	1.138	1.034	9.6
2004	0.811	0.736	13.7
2005	0.883	0.802	14.4
2006	0.800	0.727	12.2

Table 5.13. Pearson correlation between indices. Values in parentheses are *p*-values from a *t*-test of H_0: $\rho = 0$. Values in brackets are correlations given a two-year shift in the commercial logbook index; two years is approximately the duration required for a greater amberjack to grow from the recreational size limit to the commercial size limit (28 inches to 36 inches FL).

	Headboat	MRFSS	Comm. logbook
Headboat	1.0	0.25 (0.28)	0.03 (0.92) [0.80]
MRFSS	—	1.0	–0.51 (0.06) [–0.10]
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).

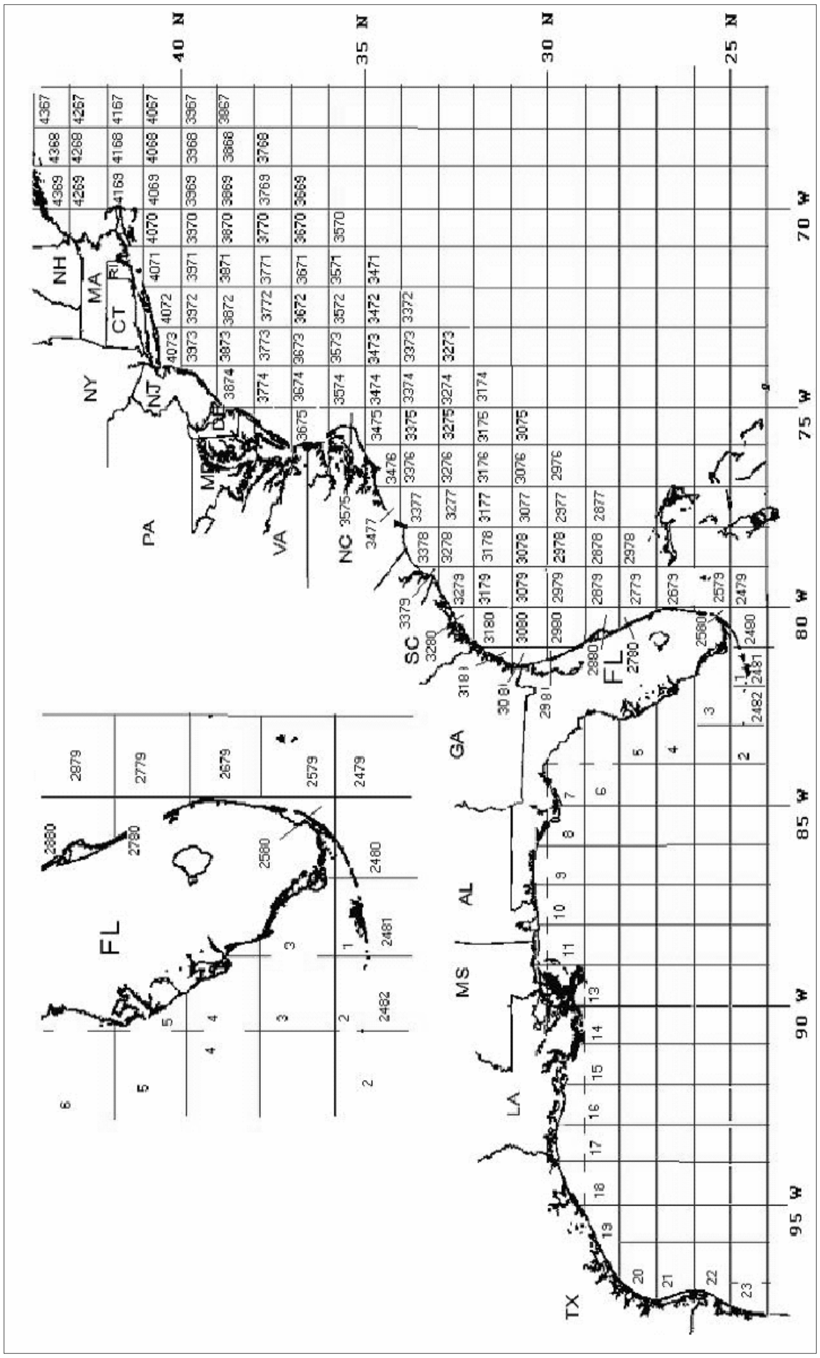


Figure 5.2A. Estimates of species-specific regression coefficients from Stephens and MacCall method applied to commercial logbook data from north of Cape Canaveral, as used to estimate each trip's probability of catching the focal species.

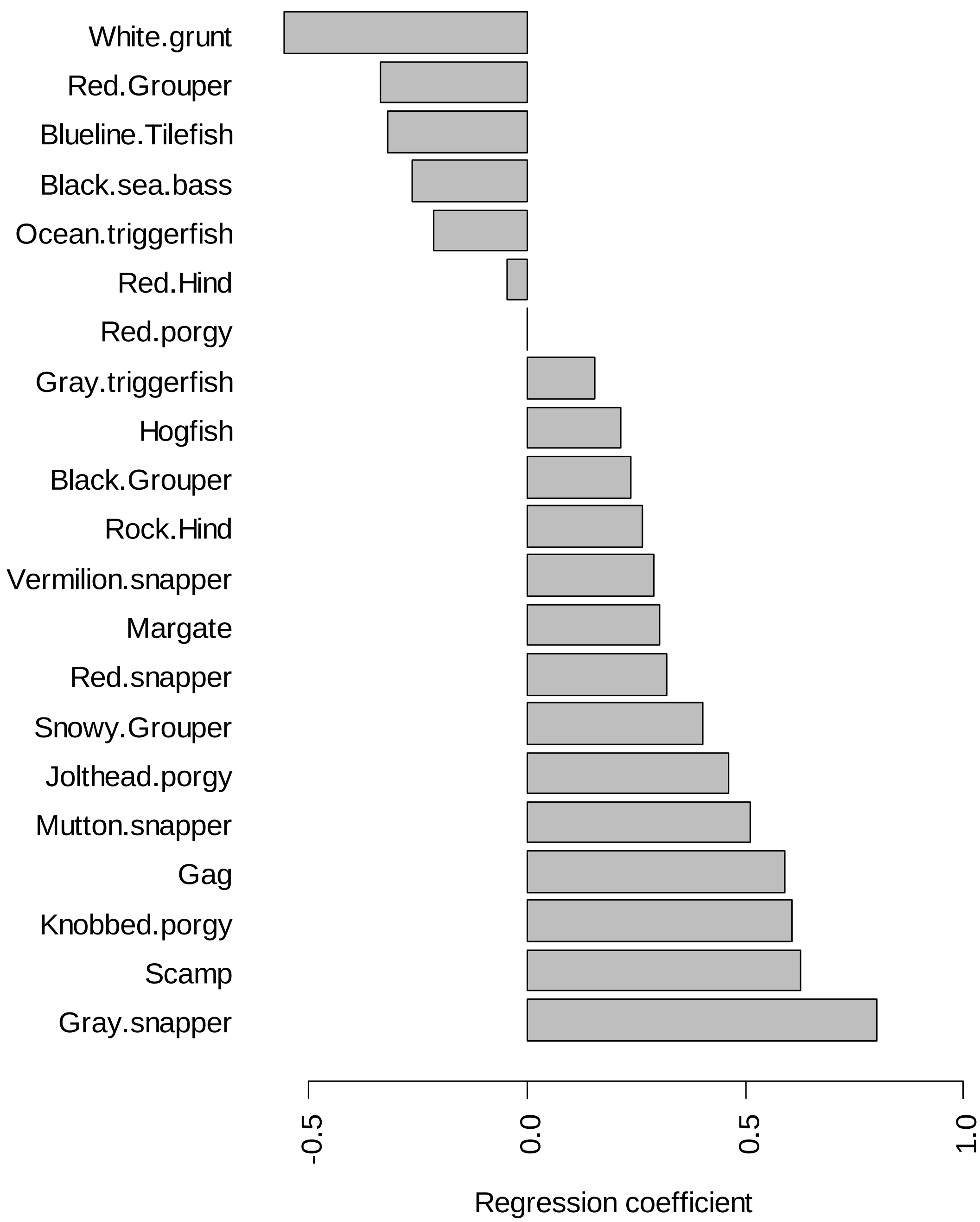


Figure 5.2B. Estimates of species-specific regression coefficients from Stephens and MacCall method applied to commercial logbook data from south of Cape Canaveral, as used to estimate each trip's probability of catching the focal species.

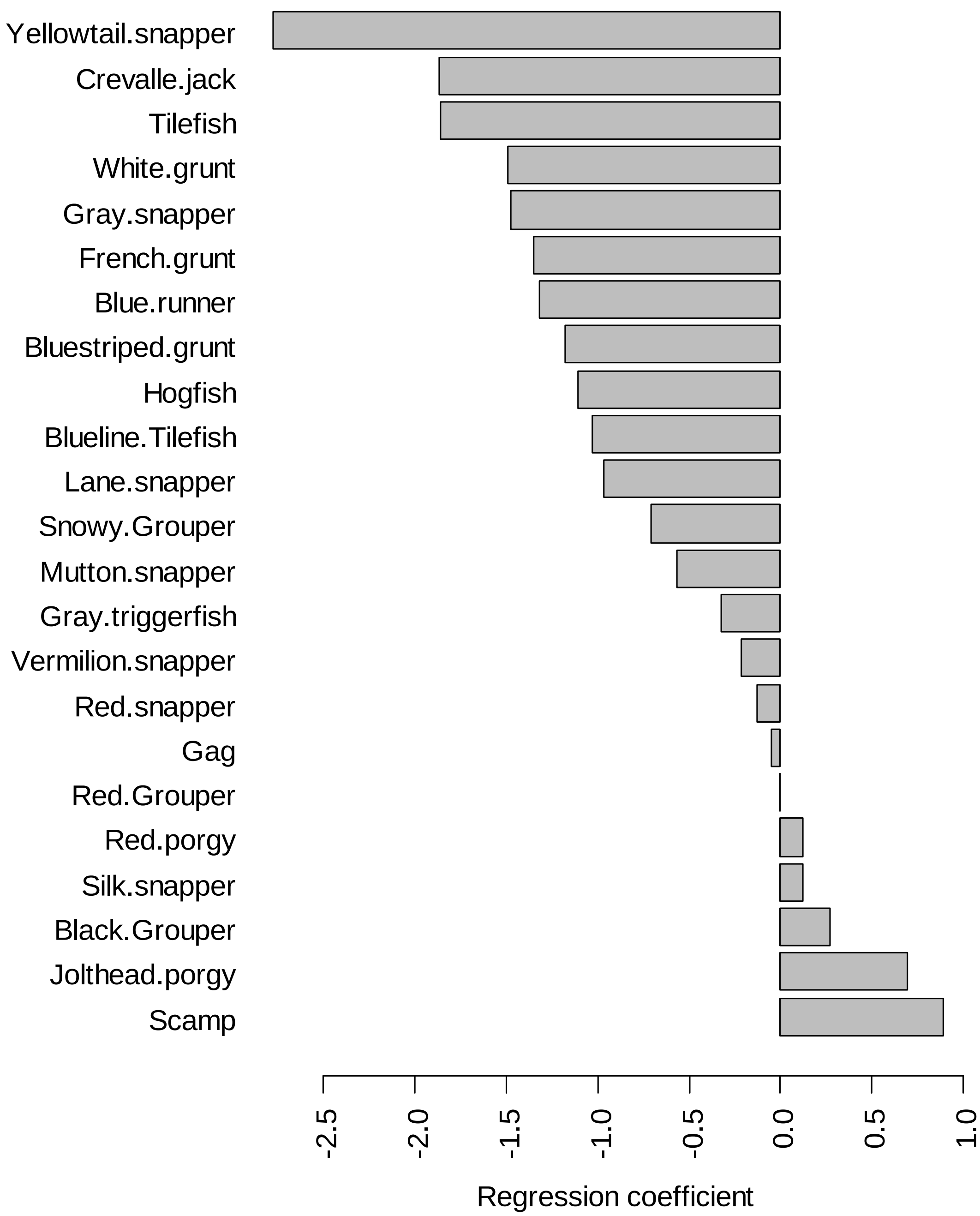


Figure 5.3A. Absolute difference between observed and predicted number of positive trips from Stephens and MacCall method applied to commercial logbook data from north of Cape Canaveral. Left and right panels differ only in the range of probabilities shown.

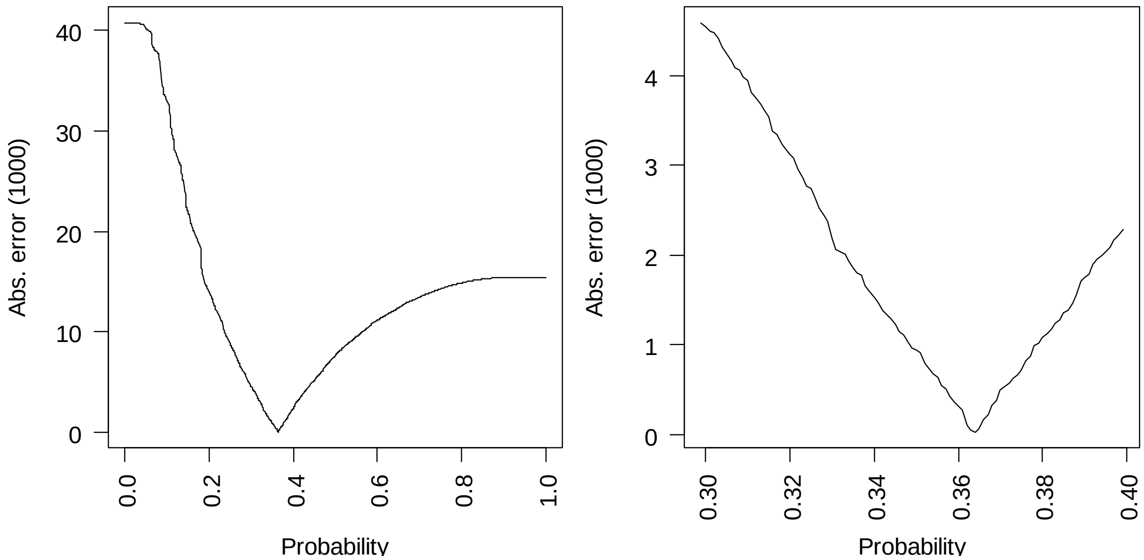


Figure 5.3B. Absolute difference between observed and predicted number of positive trips from Stephens and MacCall method applied to commercial logbook data from south of Cape Canaveral. Left and right panels differ only in the range of probabilities shown.

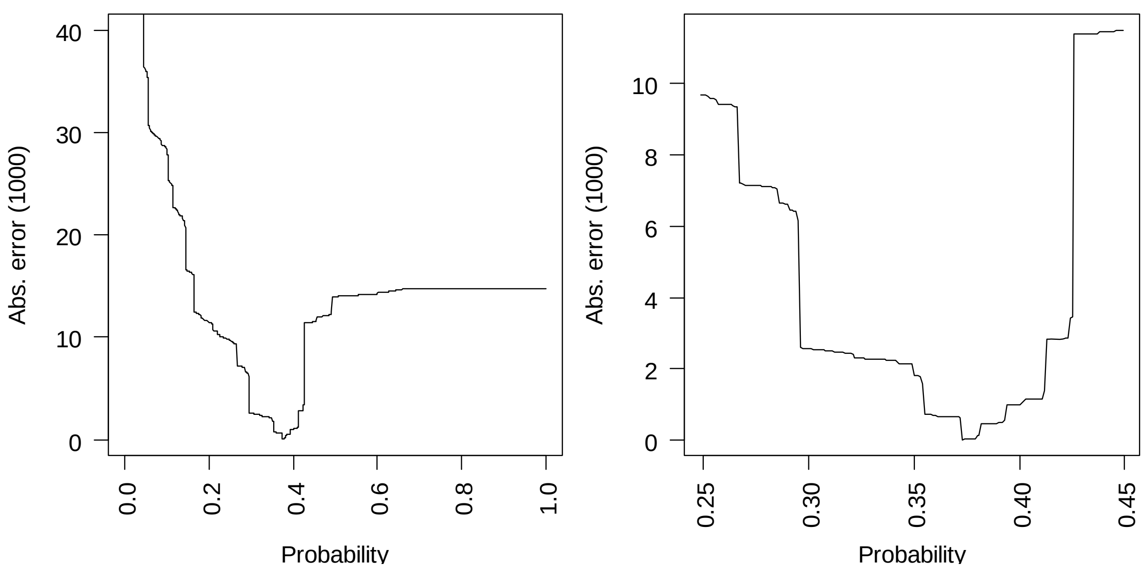


Figure 5.4. Greater amberjack: index of abundance from commercial logbook data.

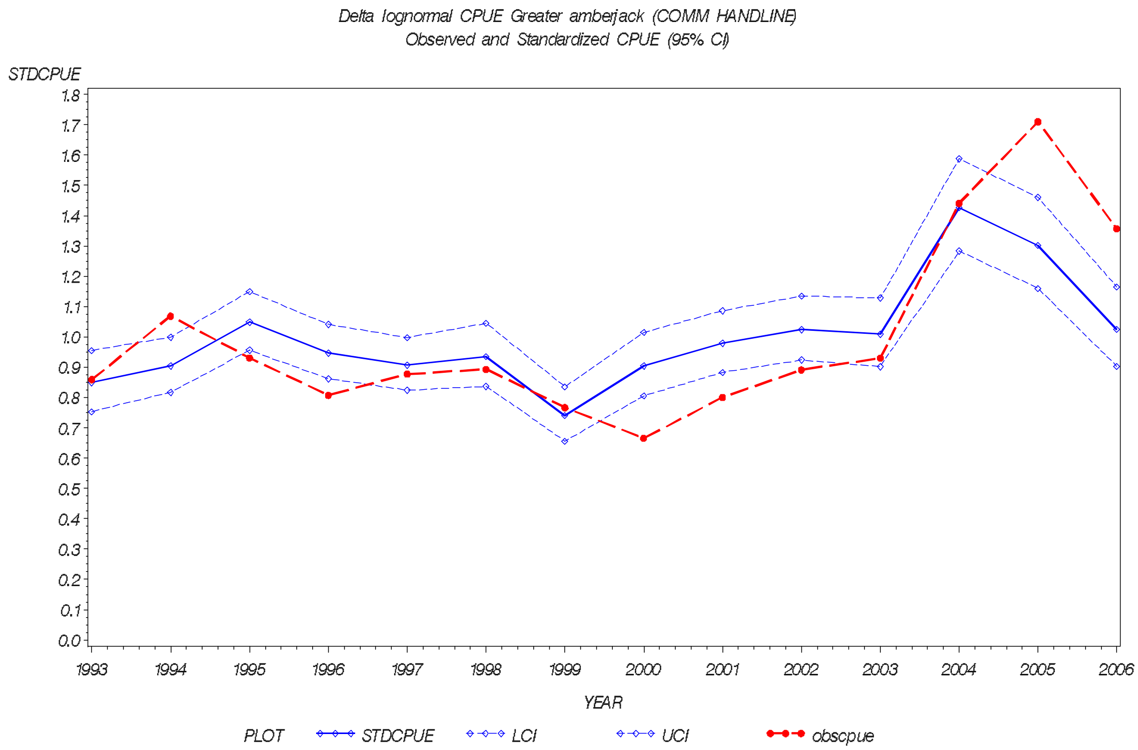


Figure 5.5. Areas from the headboat survey. Areas 11, 12, and 17 were considered southern Florida (break near Cape Canaveral).

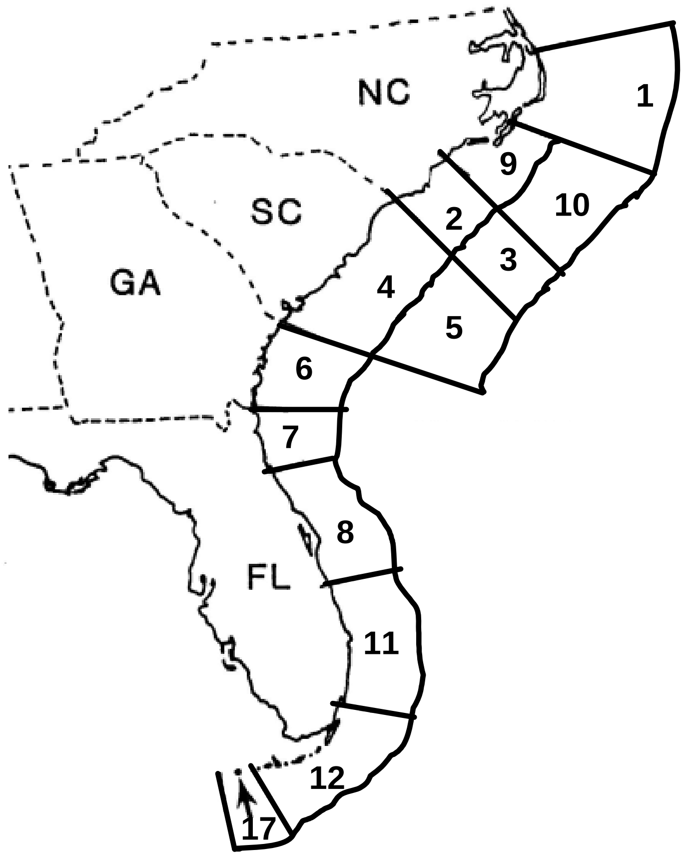


Figure 5.6A. Estimates of species-specific regression coefficients from Stephens and MacCall method applied to headboat data from areas in the northern region (excludes areas 11, 12, 17), as used to estimate each trip's probability of catching the focal species.

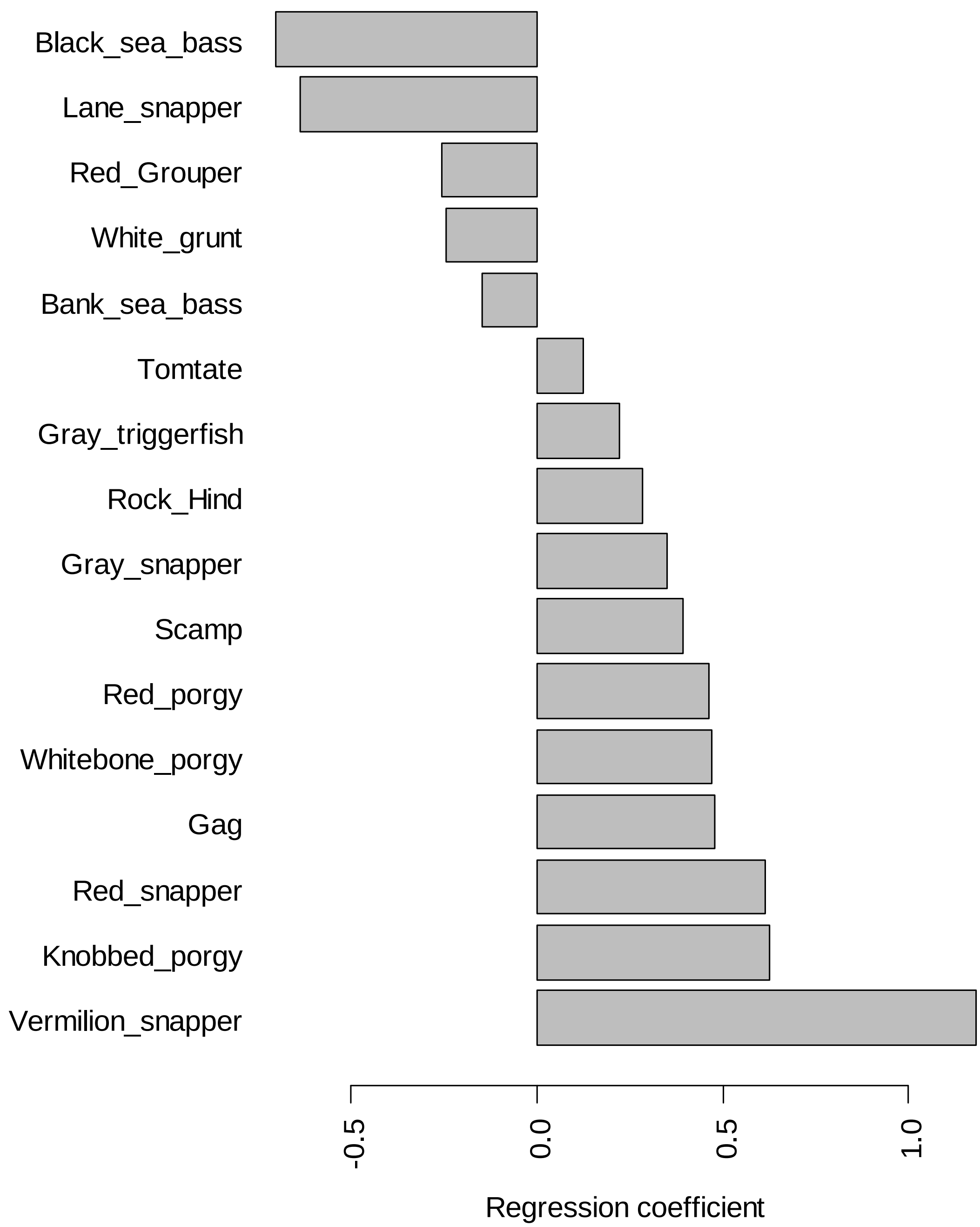


Figure 5.6B. Estimates of species-specific regression coefficients from Stephens and MacCall method applied to headboat data from areas in the southern region (areas 11, 12, 17), as used to estimate each trip's probability of catching the focal species.

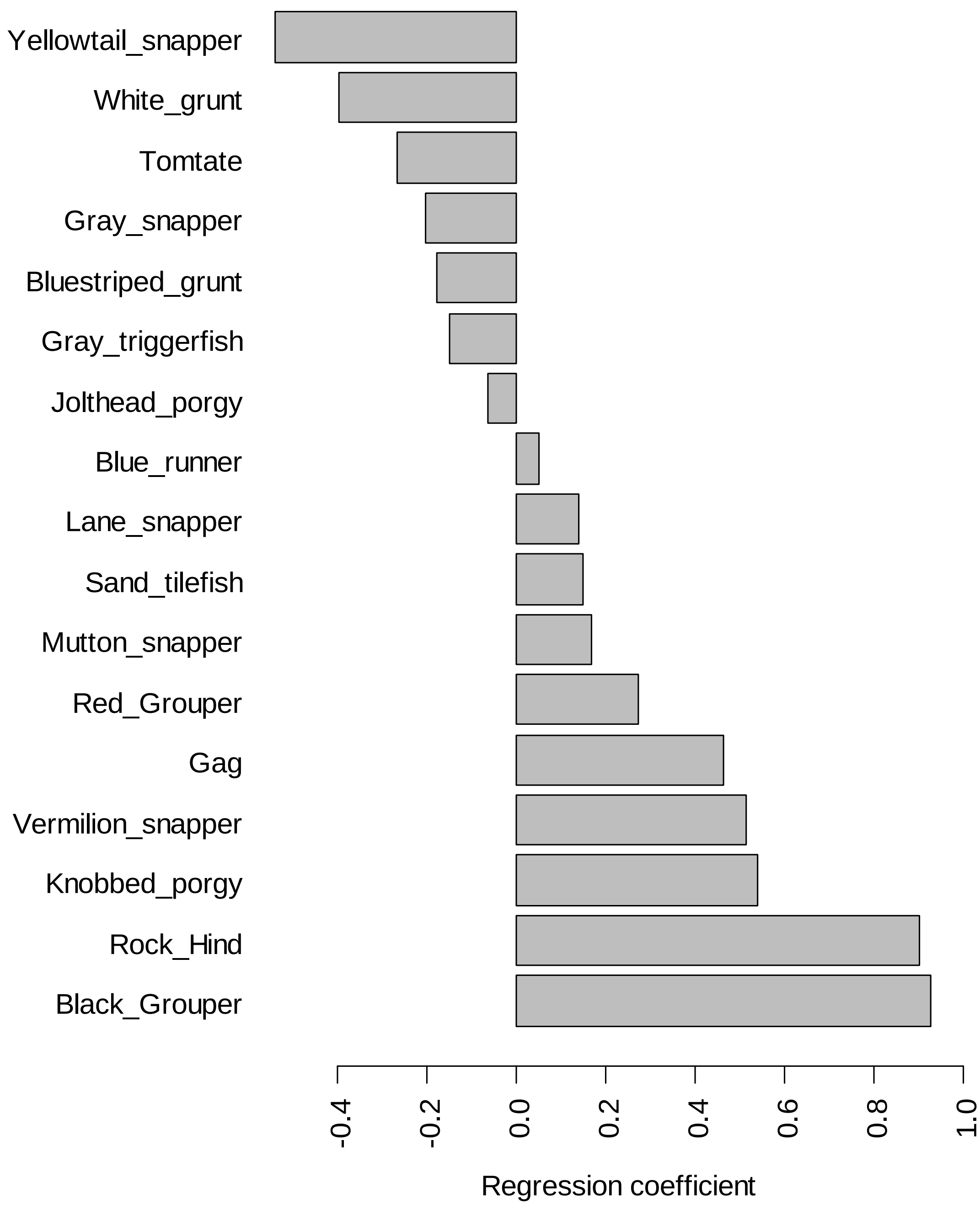


Figure 5.7A. Absolute difference between observed and predicted number of positive trips from Stephens and MacCall method applied to headboat data from the northern region (excludes areas 11, 12, 17). Left and right panels differ only in the range of probabilities shown.

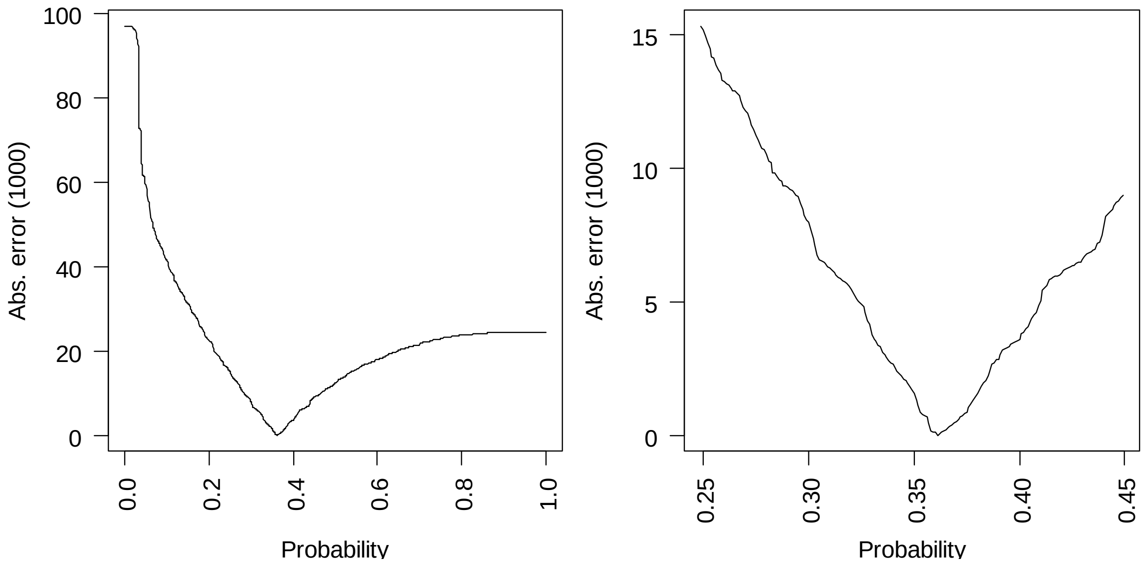


Figure 5.7B. Absolute difference between observed and predicted number of positive trips from Stephens and MacCall method applied to headboat data from the southern region (areas 11, 12, 17). Left and right panels differ only in the range of probabilities shown.

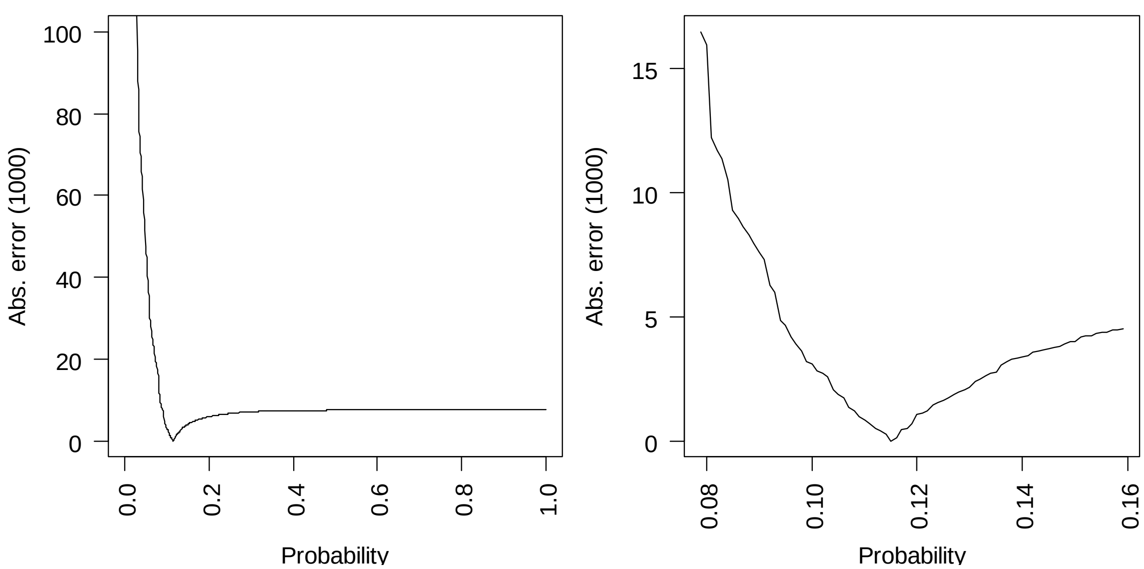


Figure 5.8. Greater amberjack: index of abundance from headboat data.

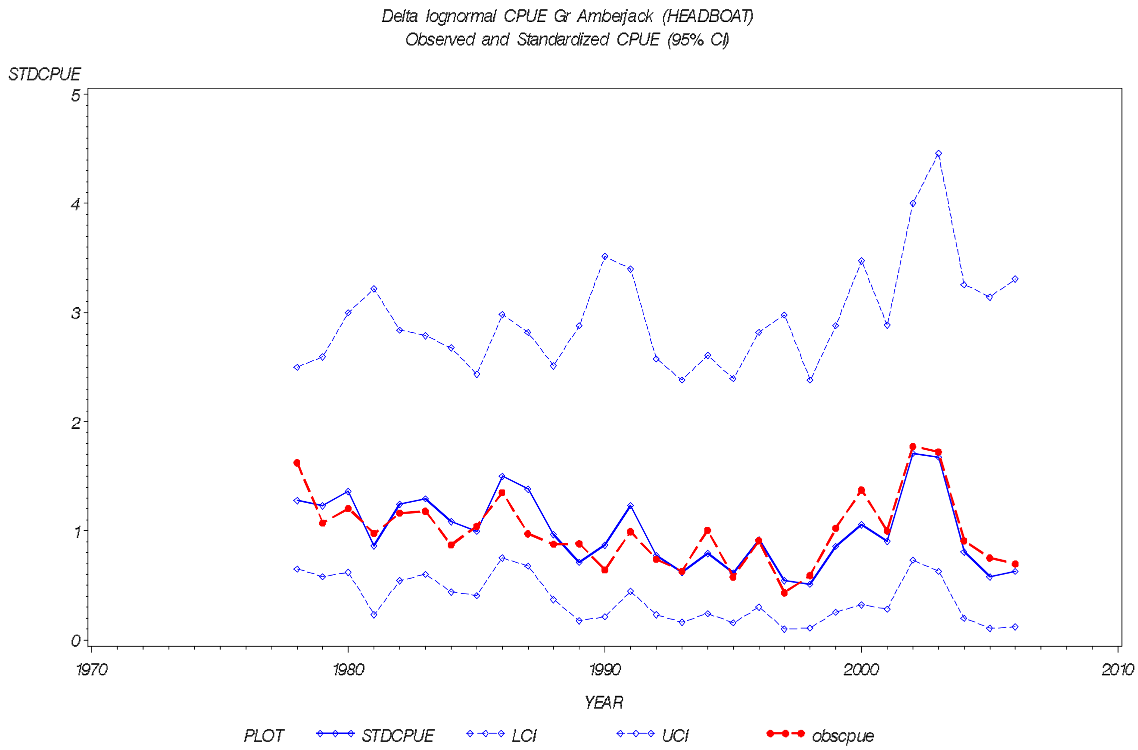


Figure 5.9. Counties sampled by the MRFSS, as used to compute the index of abundance, included those along the coast from Currituck County, NC through Miami-Dade County, FL.

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

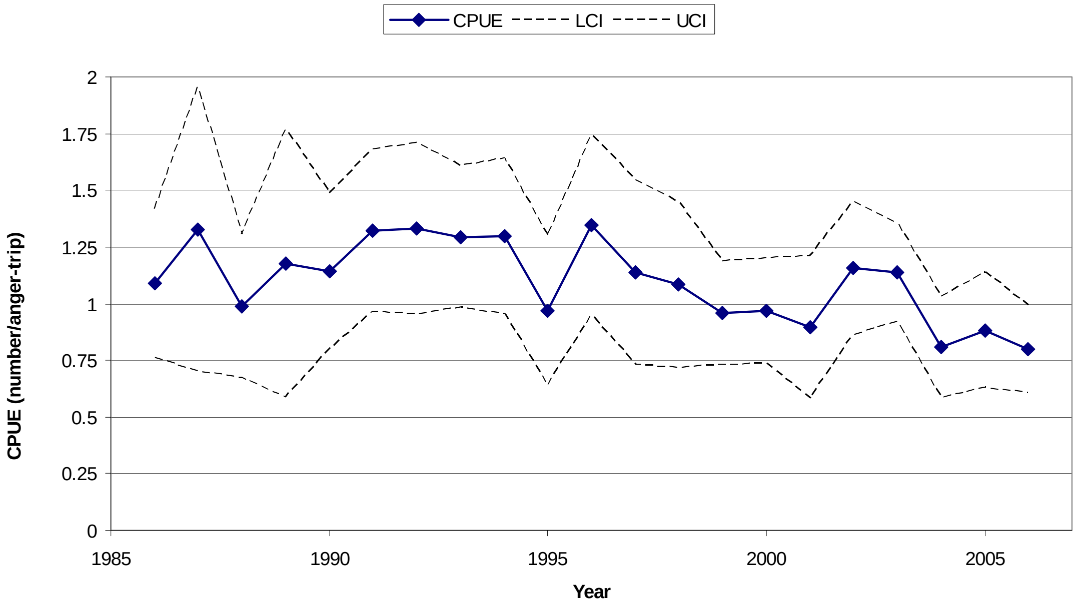
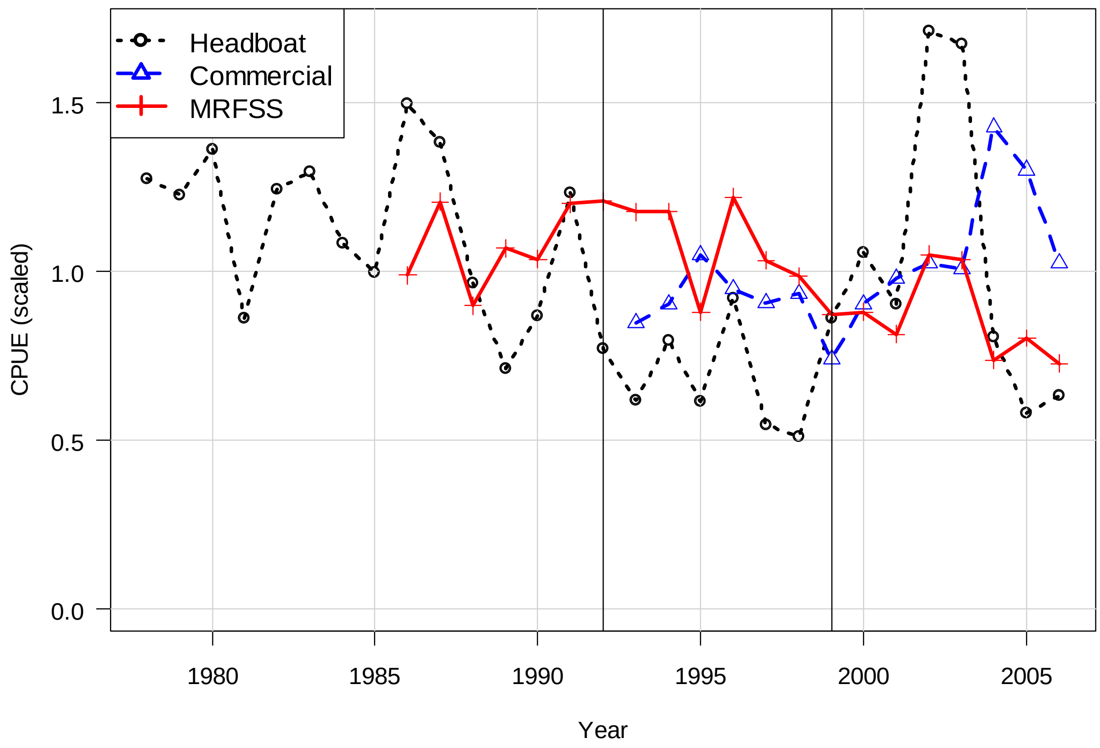


Figure 5.11. Greater amberjack: indices of abundance recommended for use in the assessment. Vertical lines represent years with new regulations. Each index is scaled to its mean.



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

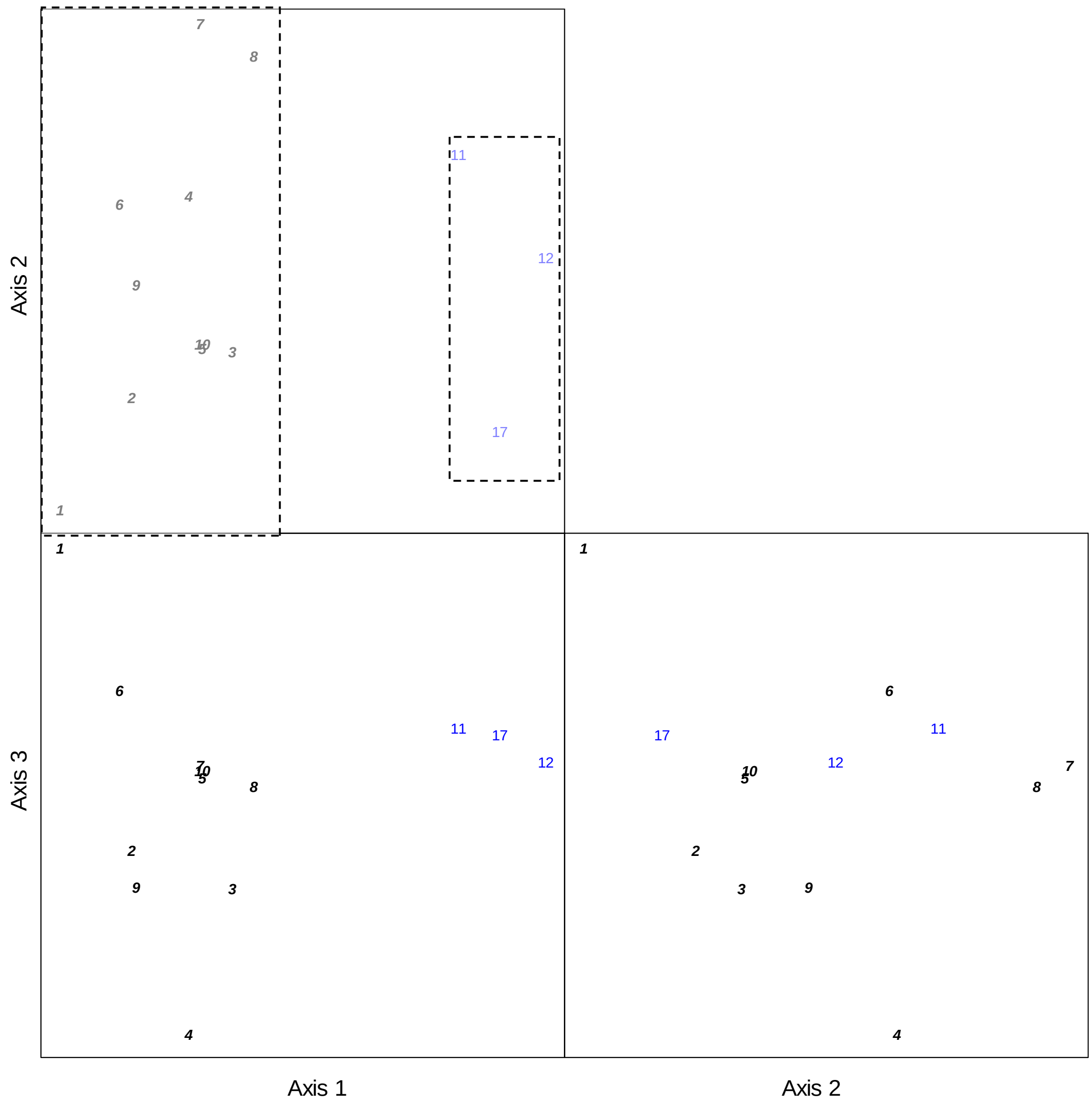
Appendix 5.2. Geographic areas with similarity in species landed.

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).

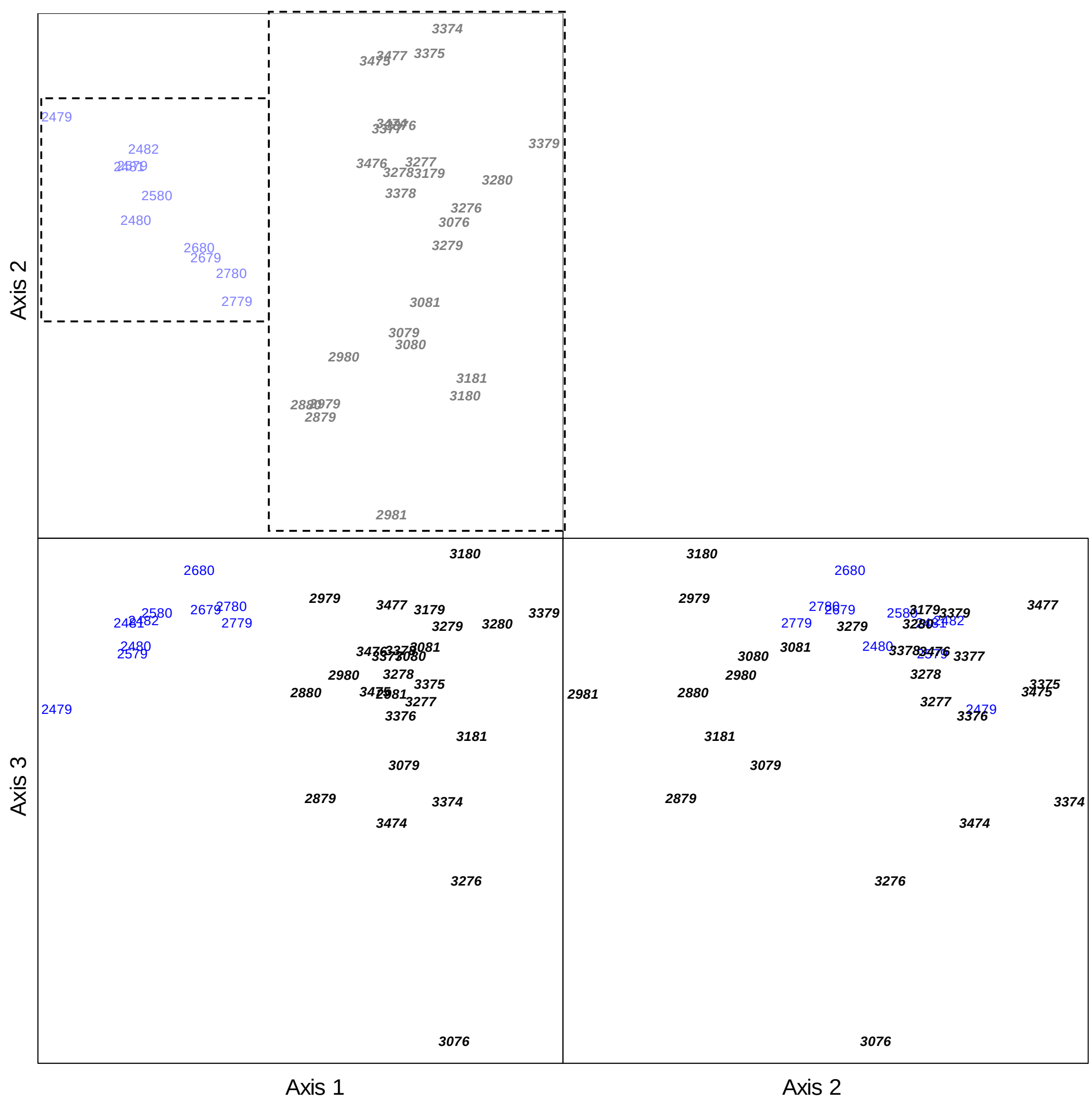
To compute dissimilarities, each data set (commercial logbook and headboat) was formatted as a matrix with rows representing geographic areas and columns representing species. Each element of the matrix quantified the relative frequency of species landed by geographic area. Thus, rows of the matrix summed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

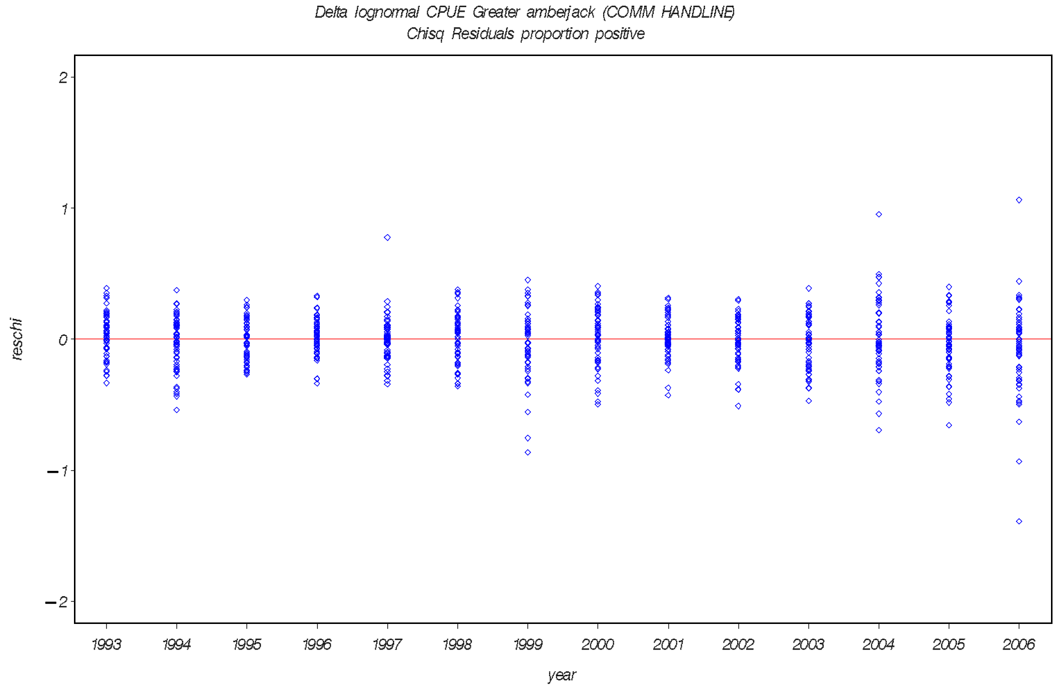


Appendix 5.2B. Nonmetric multidimensional scaling of areas from the commercial logbook data (handline). Rectangles in top left panel encapsulate areas with similar composition of landings, as identified by cluster analysis. Areas north of Cape Canaveral, FL are in bold font.

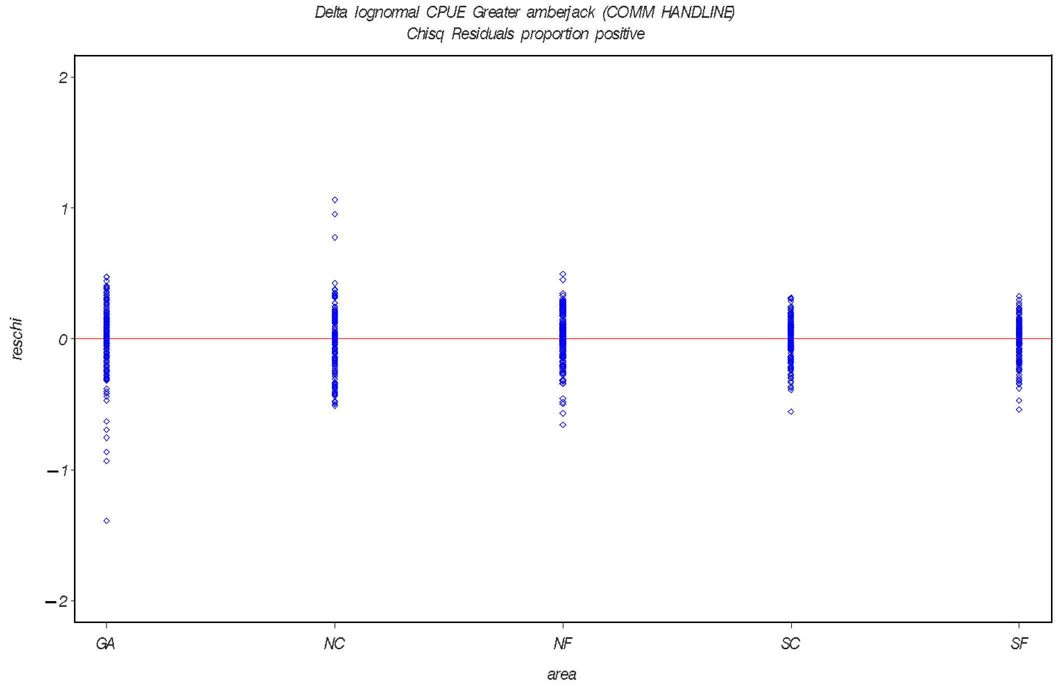


Appendix 5.3. Greater amberjack: diagnostics of delta-GLM fitted to commercial logbook data.

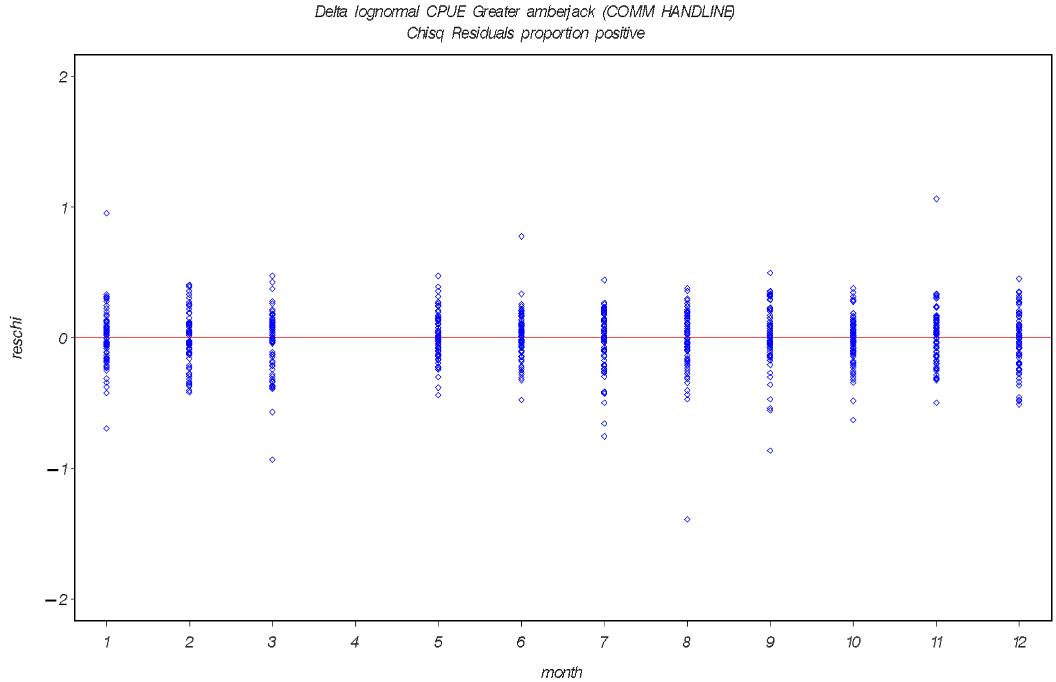
Appendix 5.3A.



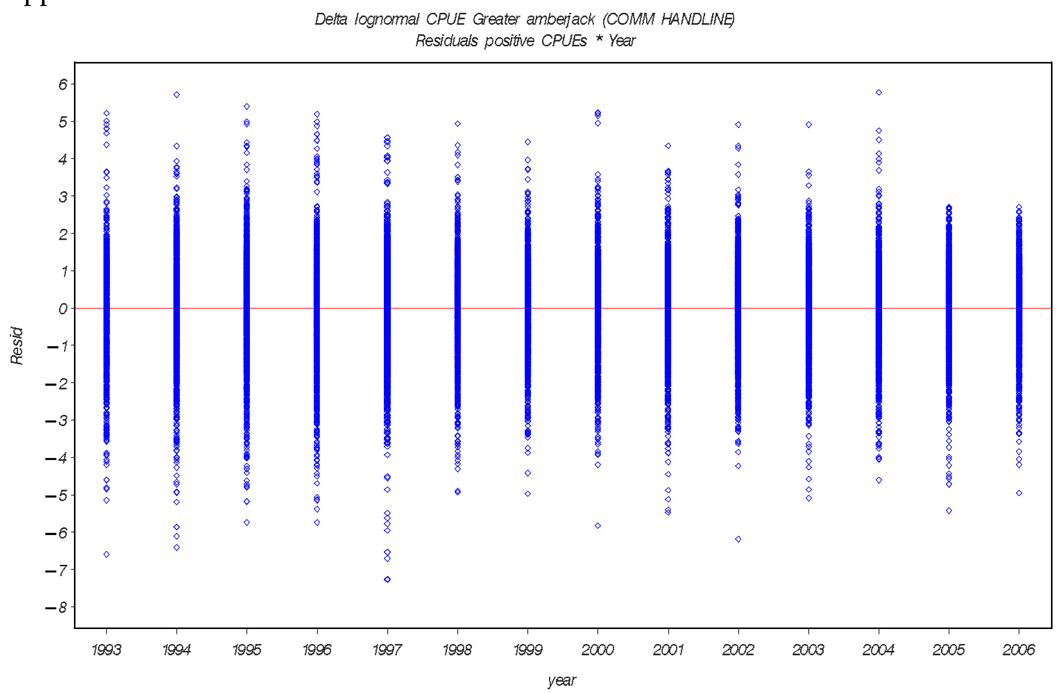
Appendix 5.3B.



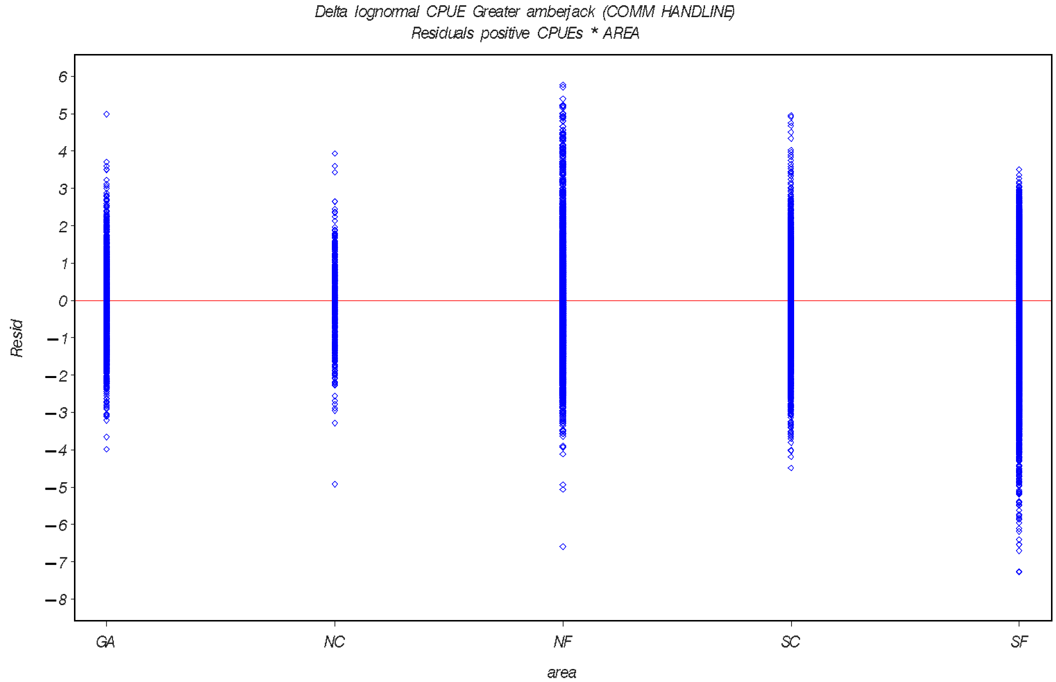
Appendix 5.3C.



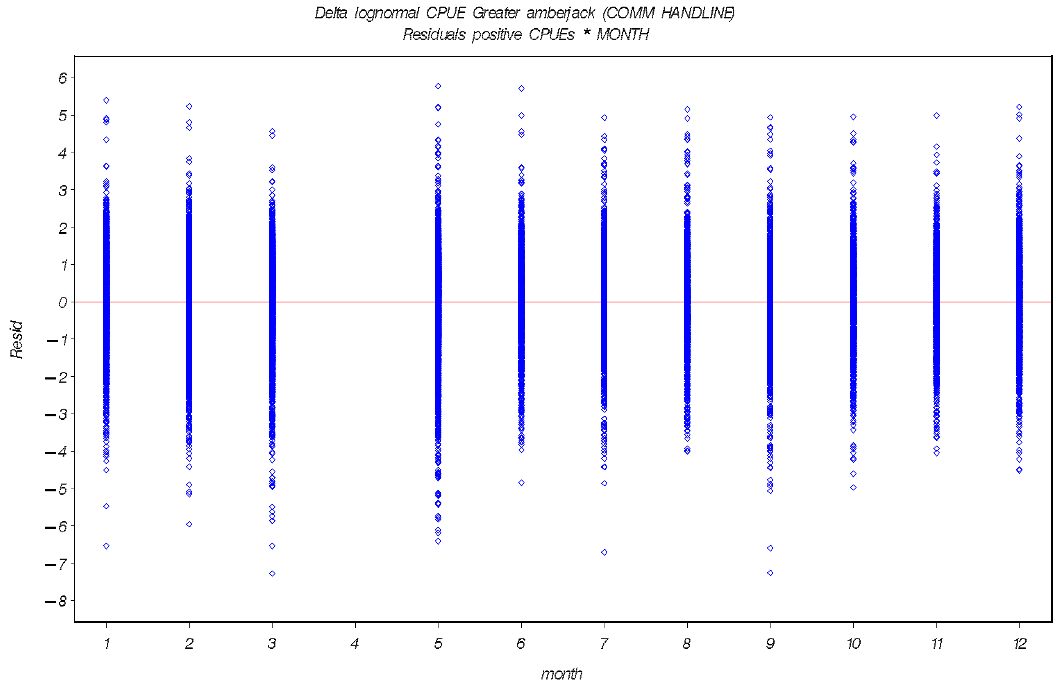
Appendix 5.3D.



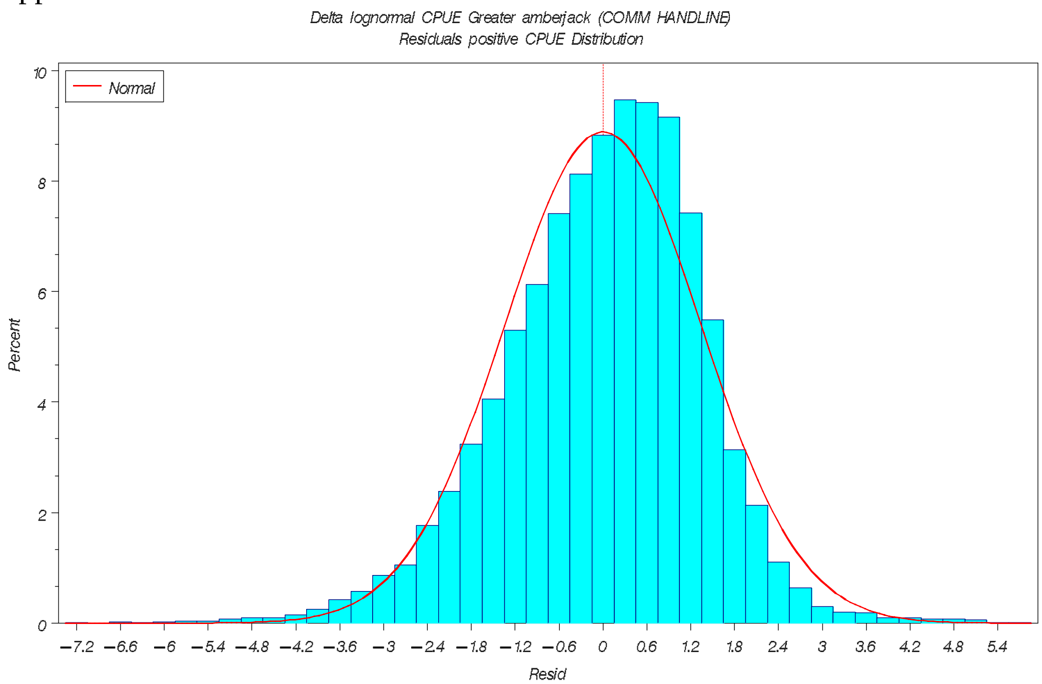
Appendix 5.3E.



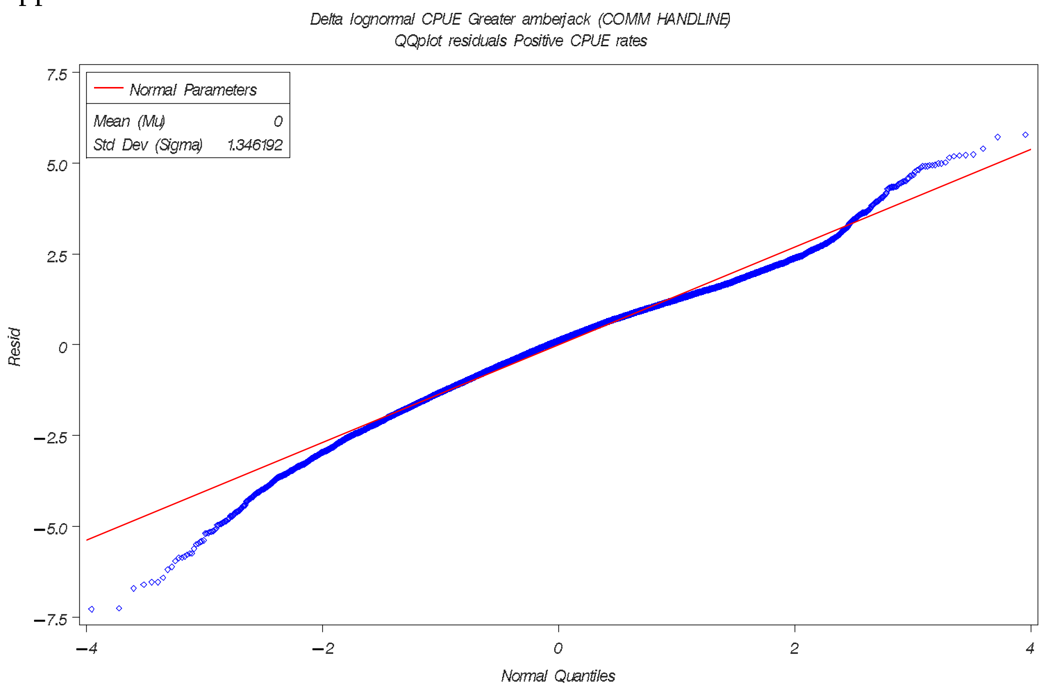
Appendix 5.3F.



Appendix 5.3G.

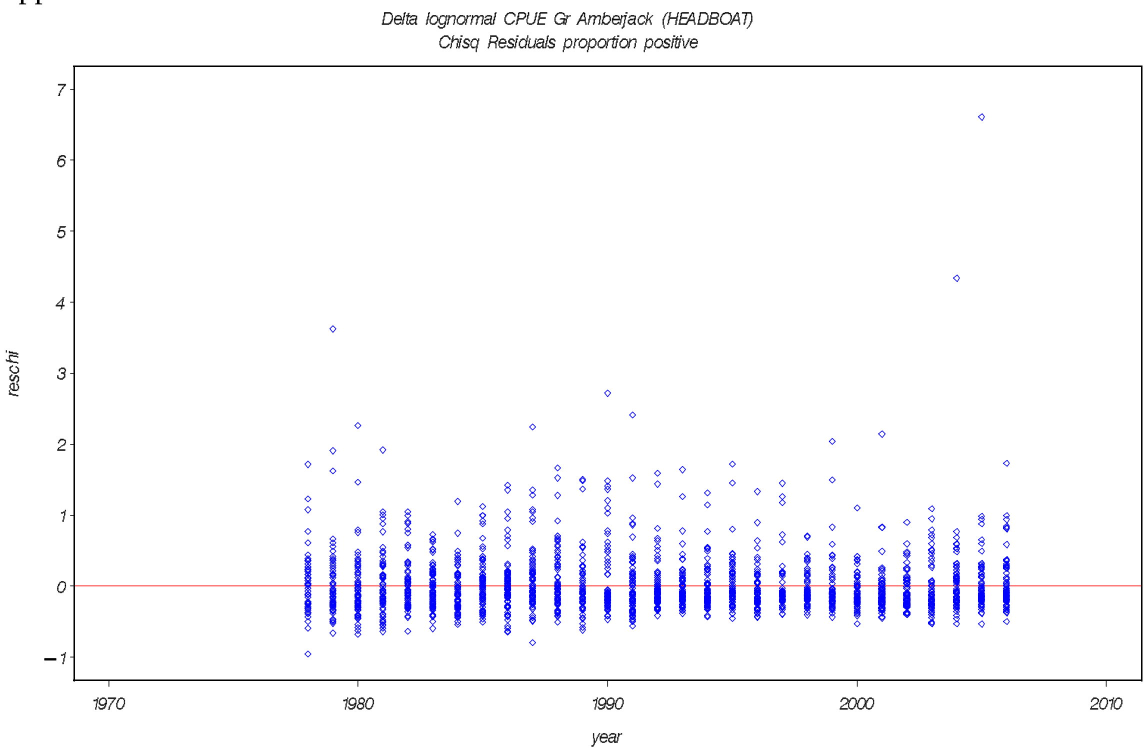


Appendix 5.3H.

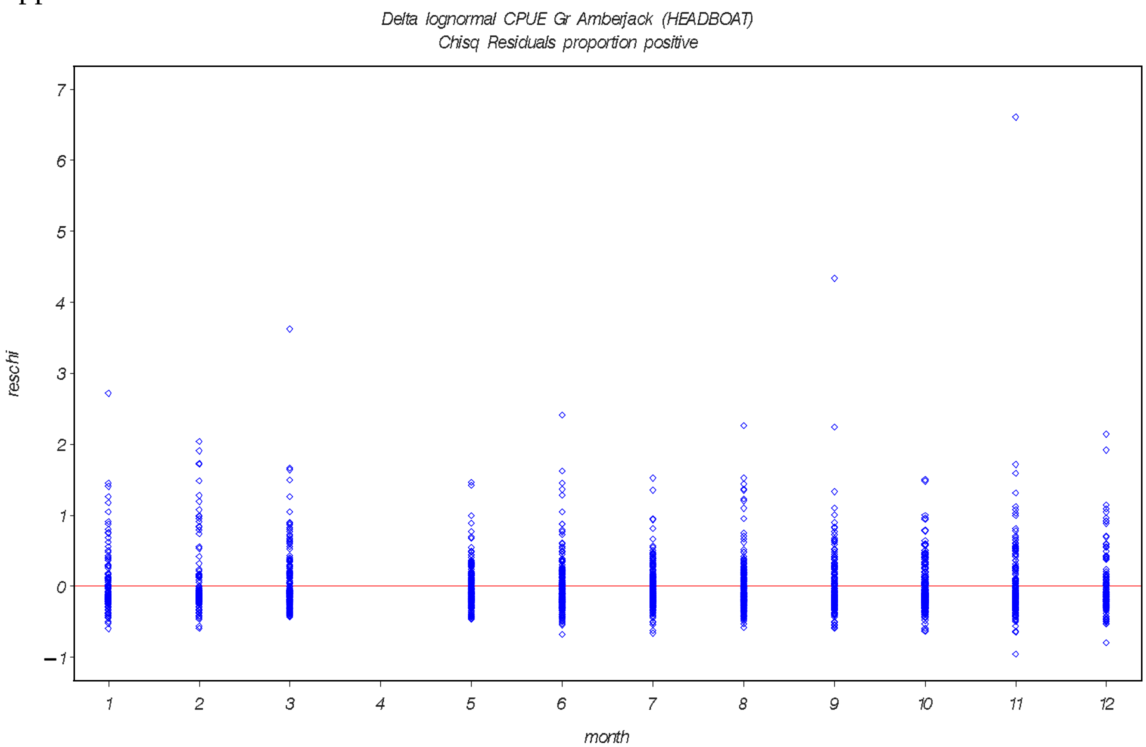


Appendix 5.4. Greater amberjack: diagnostics of delta-GLM fitted to headboat data

Appendix 5.4A.



Appendix 5.4B.



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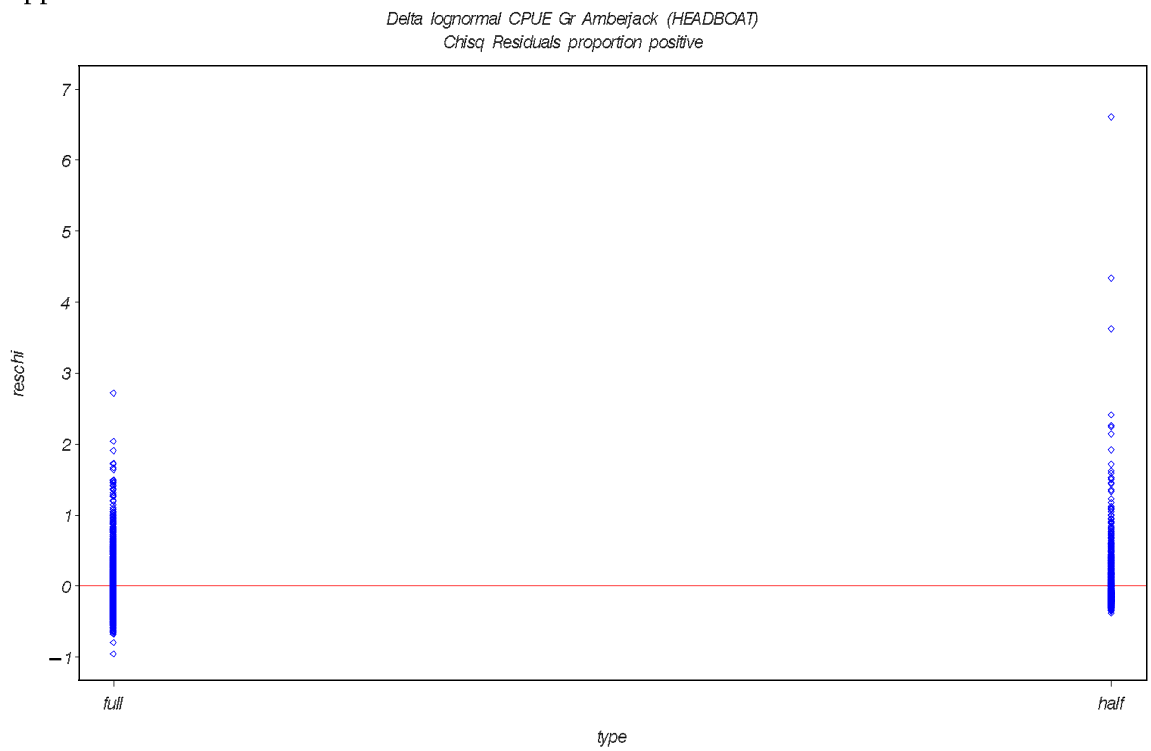

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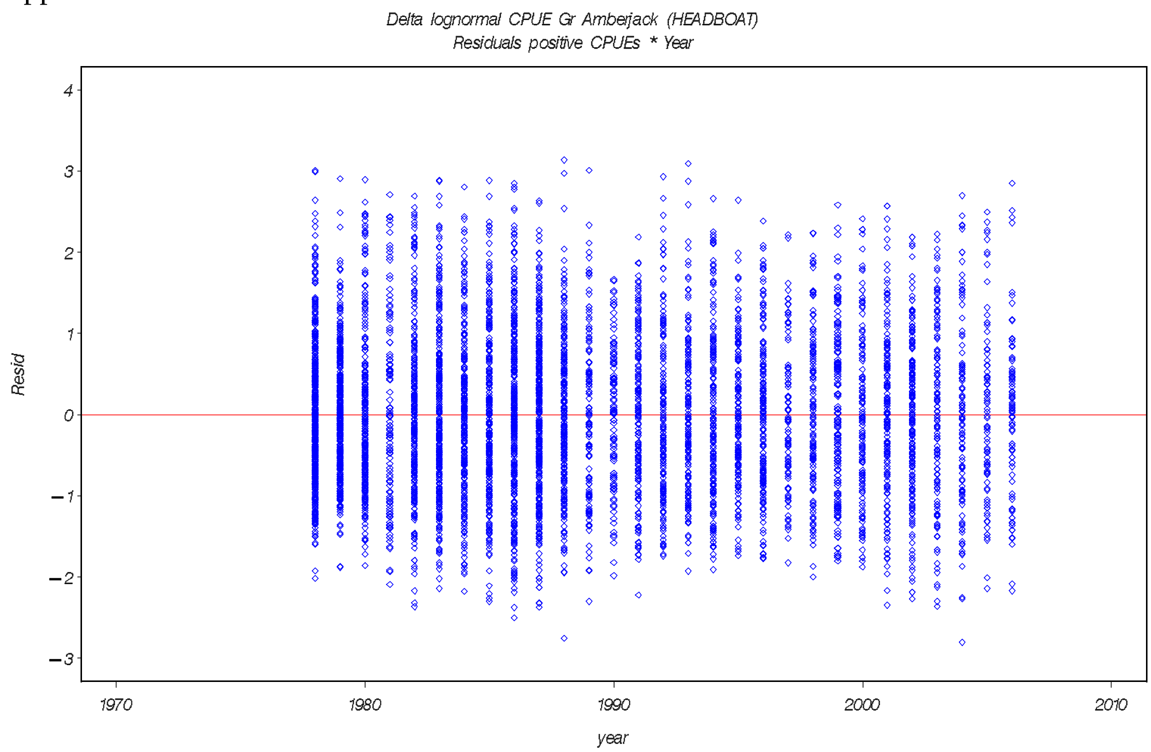

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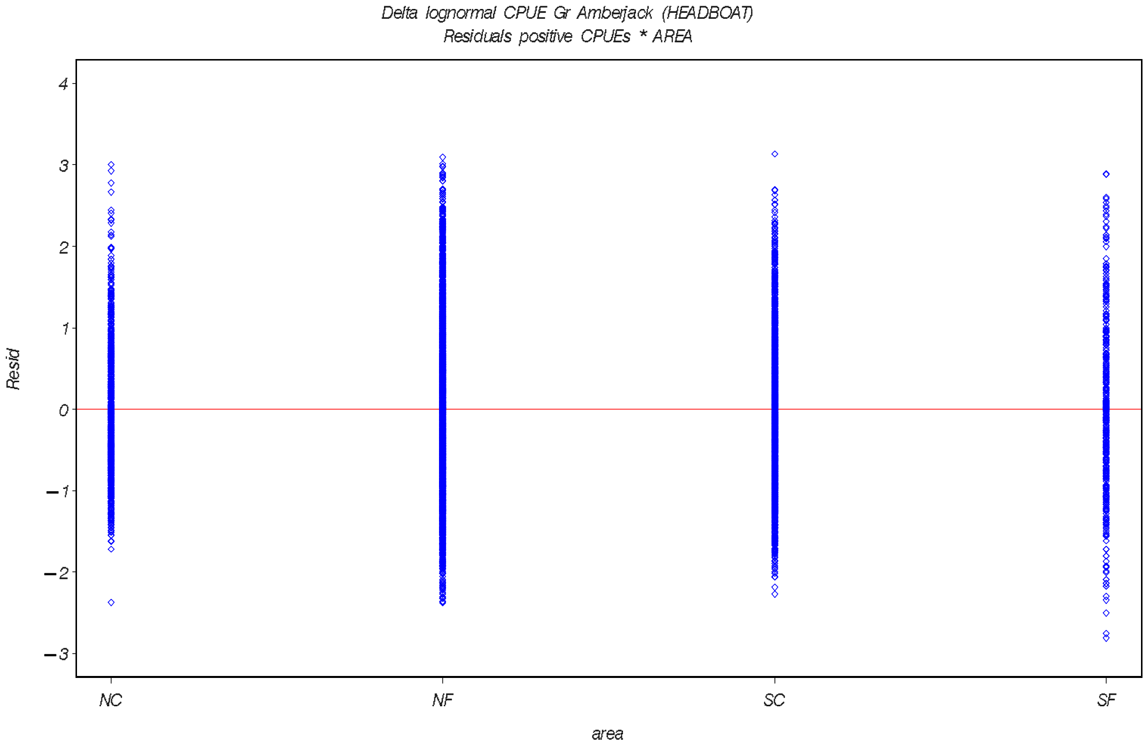

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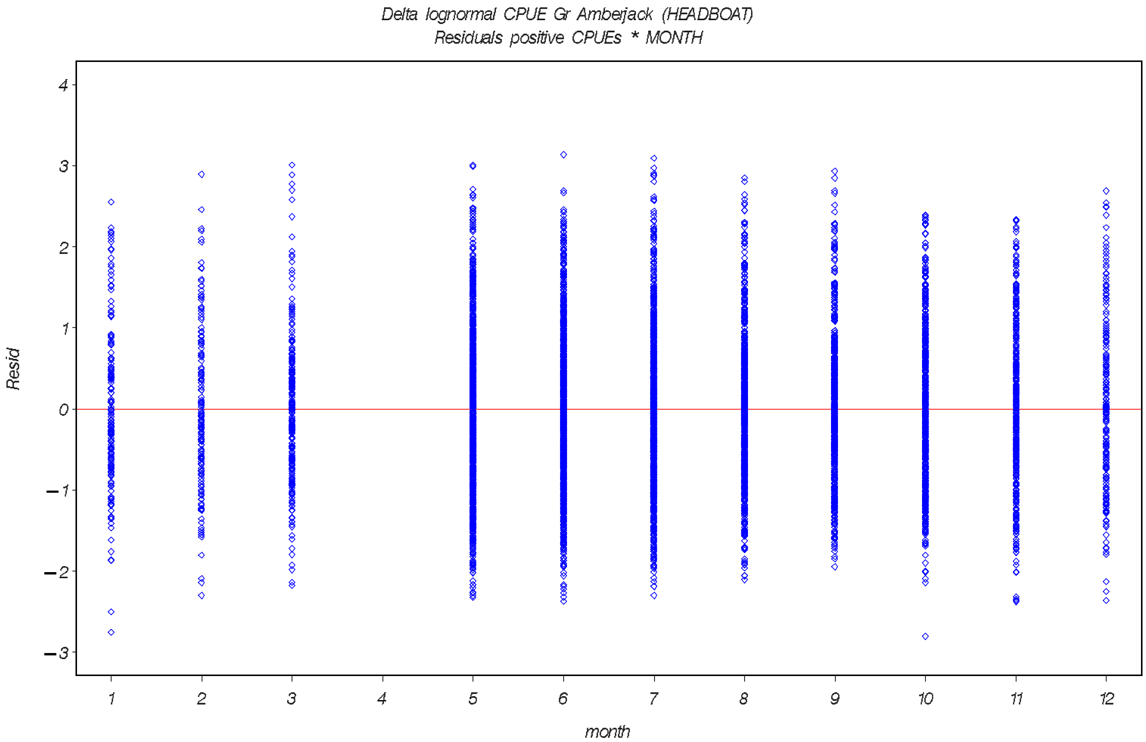

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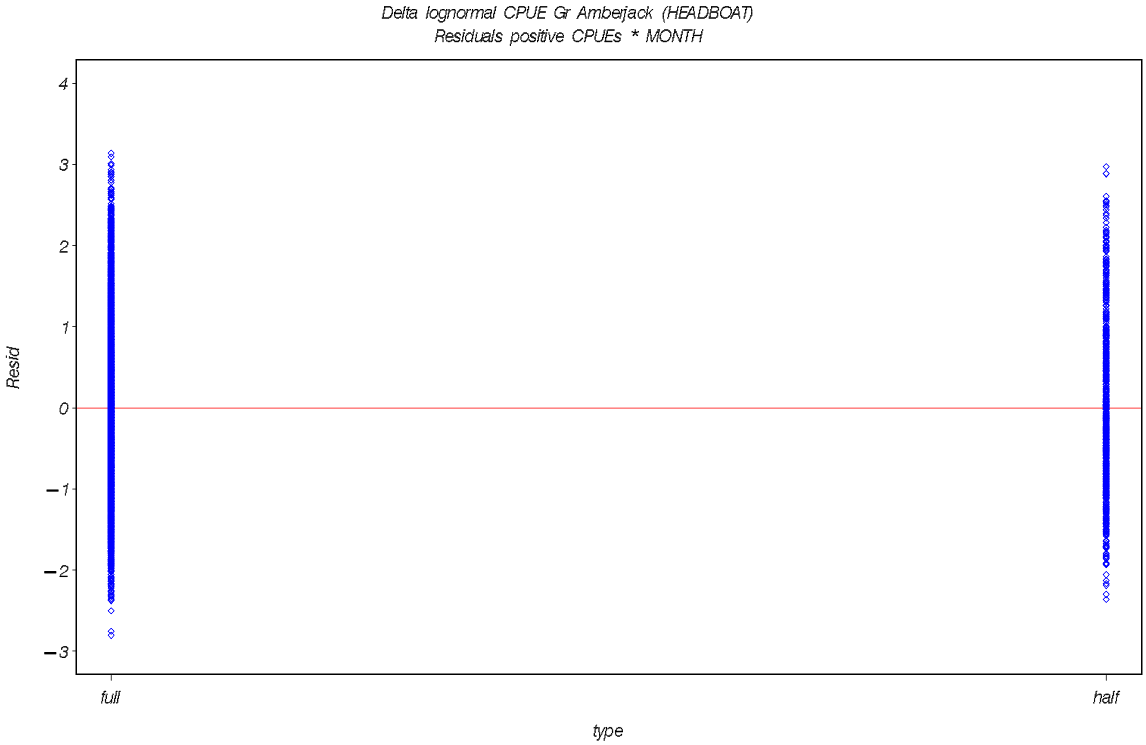
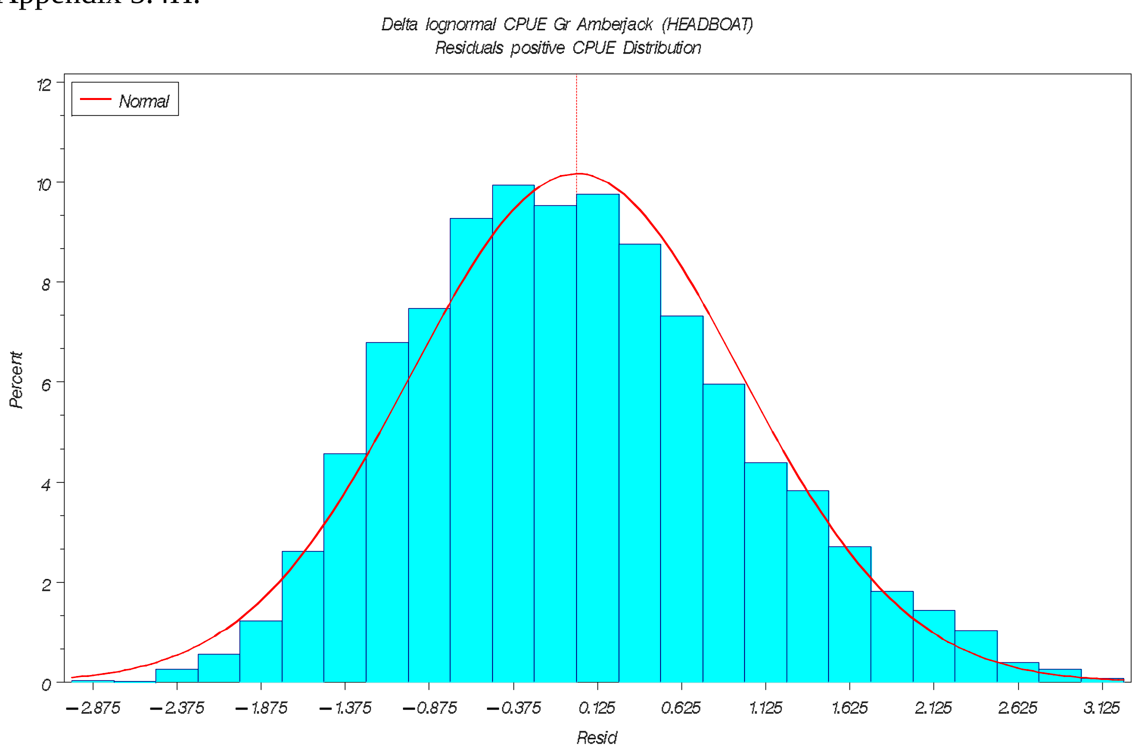
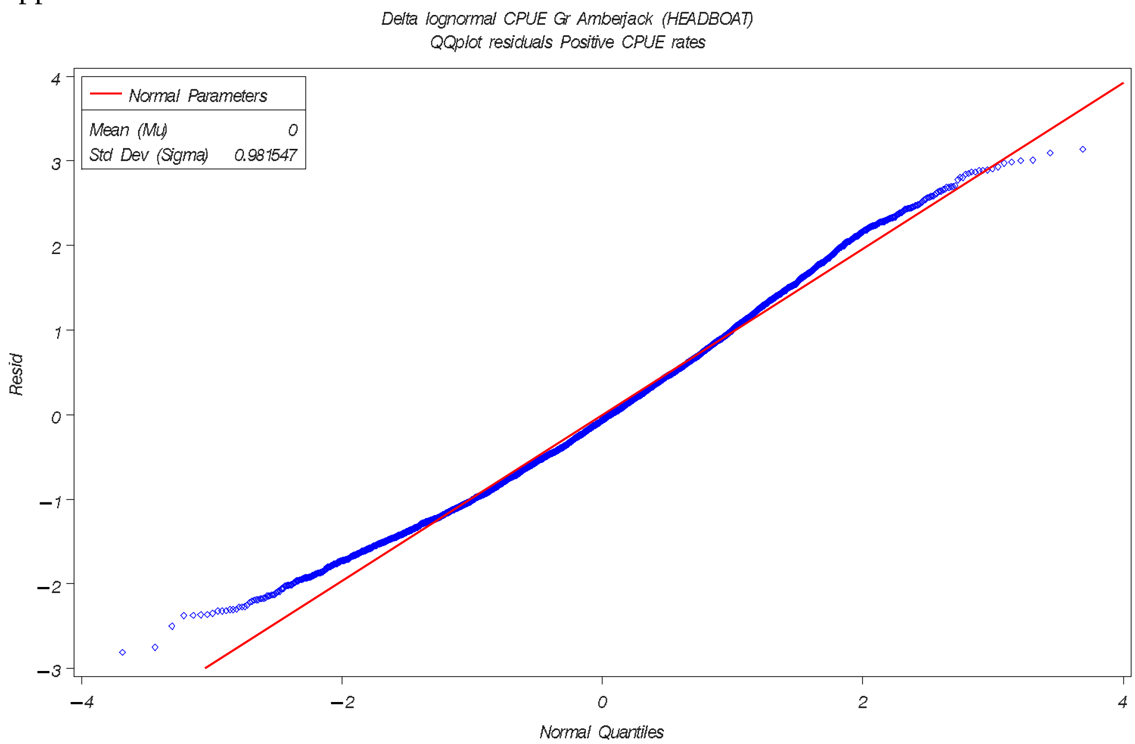


Appendix 5.4H.



Appendix 5.4I.



6 Submitted Comments

6.1 None were received.

Section III. Assessment Workshop Report

Contents

1. Workshop Proceedings

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.

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

1.2.1Discussion and Recommendations Regarding Data Modifications and Updates

(data mods detailed in section 2, this addresses any group discussion and recommendations)

<u>Data input and changes:</u>

The data workshop recommend the Lorenzen scaled M be based on a maximum age of 13, and used and age range of 0-13. This was changed to recognize a maximum age of 17, and the new scaled used an age range of 0-17 with scaled M (0.014). There was discussion if a maximum age of 13 and the corresponding age range be used, or should the maximum age of 17 be used with the corresponding age range.use age range to 13 or to 17? It was decided at the ages of 17 which had been known to the data workshop reflected the potential historic maximum age of the population, while the age of 13 may only reflect the current maximum age of the population. The decision was therefore made to change the maximum age to 17 and use the corresponding age range for both SCA and production models.

There was some discussion about the MRFSS data series – should it be smoothed as was done for red snapper? Discussion revolved around the reliability of amberjack data from MRFSS and the MRFSS sample size. Ultimately, it was decided the data series did not need to be smoothed because the PSE;s were around 20% which was considered acceptable.

The commercial catch data for longline and hook and line landings were merged, resulting in only two commercial gear types - diving and hook and line. The assessment workshop had no issues with this.

<u>Discards:</u>
The discards for all fisheries were smoothed using a 3-year moving average. This should be written up in the assessment report. The assessment workshop had no problem with this.

<u>Selectivity:</u>
The selectivity for the headboat fishery used same slope parameter for both time periods (pre 1992 and post 1992). This strategy was also applied to the commercial fishery.

<u>Length composition data:</u>
There was considerable discussion about the MRFSS length composition data – the mode of the length composition data for the two periods shifted wrong way as more small fish were measured after the imposition of the size limit than before. There was concern as to why this might be.

Although there were few small fish in early period for MRFSS, small fish were evident in the headboat length composition data for the first (pre 1992) period – why are these smaller fish not showing up in the MRFSS data set? It was discussed that the shift to smaller fish after 1992 is not incompatible with size limit – prior to the size limit fishermen may have kept few fish more or less randomly by size, whereas post size limit, they kept everything greater than the size limit. It was also suggested that this could be due to incorrect species ID, which may be more of a potential issue with MRFSS. It was further suggested that this could be an effect of increase in fishing mortality. It was decided by the group that there was no justification to change anything in the data set, and it was left as finalized by the data workshop.

<u>Age composition data:</u>
There was some discussion as to why the age composition data from the commercial diving data set were different to the age composition data from commercial hook and line data set – the length distributions were similar but the age distributions were slightly different. It was decided this could be due to variation in size at age, and was not an unreasonable assumption.

<u>Fishery dependent indices:</u>
The data workshop did a correlation between indices using a two year lag to allow for recreationally caught fish to grow to the size limit of the commercial fishery. This provided slightly better results for correlations between commercial and recreational indices. The data workshop made no recommendations as to how the lagged indices should be utilized in the assessment, and they were not utilized for either assessment model.

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.)

<u>SCA Model results:</u>
The spawning biomass was computed for March of the calendar year, to reflect spawning stock biomass just prior to the period of peak spawning in March and April.

Fishery dependent indices of biomass computed for July of each calendar year to represent the midpoint of fishery dependent indices.

The Lorenzen scaled natural mortality was computed using a maximum age of 13, and the age range modeled was ages 1-10+.

<u>Selectivity:</u>
All fisheries were assumed to have logistic selectivities that were estimated internally in the SCA model.

Discards:
The data workshop provided estimates (methodology) to estimate discards in the commercial hook and line fishery for period 1 (pre 1992). This was changed during the assessment workshop to zero discards from the commercial fishery for period 1. This decision was based on the pre 1992 length composition data which suggested there were no discards before the implementation of a minimum size limit in 1992.

The discards of the commercial diving sector were assumed to be zero.

The data workshop suggested discard selectivity from the headboat fishery for period 1 (pre 1992) should equal fishery selectivity and assumed discarded was personal decision of fishers. For period 2, (post 1992) discards were to be modeled using the difference between the two periods with a shared slope parameter across periods. This was changed during the assessment workshop. Based on discussions with headboat survey personnel (Mike Burton), who cited data from 1982-1987 showing no discards of amberjack during that period. Discards were therefore assumed to be zero for period 1. Discards for period 2 were calculated as suggested by the data workshop.

For MRFSS during periods 1 and 2, discard selectivity was assumed equal to fishery selectivity and were the personal choice of anglers. No changes to this during the assessment workshop.

The minimum sample size required for data to be used in the SCA model was increased from 12 to 21 to reflect approximately twice the number of age bins used in the SCA model. This caused an additional one year of data to be excluded from the model.

Likelihood weights:
First model runs started with all components weighted to one, which resulted in a poor fit to landings and unreasonable estimates of F. The weight on landings and discard components were increased to 10, which resulted in good fit, except last few years of recruitment estimates were too variable. A constraint on the last 3 yeas of recruitment deviations was added.

Model fit:
There was considerable discussion about the poor fits to the headboat and mrfss indices. It was suggested to try a run with increased weights for these indices, and to try a run with the MRFSS index dropped from the run. Other fits all appear to be acceptable and there was no discussion.

Model run with changes suggested above incorporated: Decreasing weight of mfrss index to zero did not impact model output. Increasing weight of headboat index to 10 (from 1) with MRFSS still at zero caused poorer fit of MRFSS landings, and negatively impacted the fit of the commercial hook and line index.

There was subsequent discussion as to whether the headboat or commercial index should be prioritized. The gear type of headboat was considered not the best for targeting amberjack, whereas the commercial fishery had some targeting, particularly of Florida. It was decided to drop MRFSS because of the negative correlation to the other indices and to follow advice of data workshop that it was the least reliable. It was asked if the headboat index should be split into two separate indices to reflect imposition of size limits in 92. It was decided this could not be done without a good *apriori* reason. It was decided to do a likliehood profile of the two remaining indices to see what the best weighting scheme should be to best capture the information within each index.

Headboat discard data supports assumptions by group that only small fish are discarded by headboats in period 2 (post 92), and further supported the assumption of no discards prior to 1992 in period 1.

The likelihood profiles were presented considering a range of weights for headboat index (1 to 10). As the weight of the headboat index increases, the fit to the commercial index got worse. Response to headboat fit showed a weight of 3 provided the best fit to the headboat index, while minimizing the negative impact on the commercial index, while the best overall fit was provided with a weight of 6 on the headboat index. So which to use? There was a suggestion to drop the commercial index altogether because the bulk of the commercial landings are taken off Florida, mainly from Monroe county, so the index might not be representative of the population in the region. It was decided to do run without the commercial index.

Dropping the commercial index did not result in a greatly improved fit. Decided to rerun likelihood profiles with increasing weights (up to 100), but without the commercial hal index.

Headboat landings were presented and the group concluded that the distribution of landings was relatively good across the entire region, with decent representation from all areas. This was thought to provide good support for the continued inclusion of the headboat index in the model.

Several iterations of likelihood profiles were presented considering different weighting schemes were presented and run, and several runs were made incorporating some of the suggested weights for the two included indices.

Finally, the weight of the headboat index was set at 100 and the commercial index at 300. This resulted in a good fit to both indices, and acceptable (not really different to earlier runs) fits to the age and length composition and landings data. An additional run with re-weighting the MRFSS index to attempt to reincorporate it into the model was run, but was not successful. Thus, the base run was decided on as the run with the headboat index weighted at 100 and the commercial index weighted at 300.

Production model:

The catch in number had to be converted to a catch in weight. The assessment workshop accepted the methodology presented to do this.

Indices were converted to weight and scaled, and catchability was changed by 2%/year. Again, the assessment workshop accepted the methodology presented to do this.

Discards:

It was decided that discards should be handled as was done for the SCA model.

Fit:
Used iterative reweightng of indices, and the fit was good. The results of B1/K was set to 0.85. The assessment workshop accepted the methodology presented to do this.

The assessment workshop agreed that there was no support to use the output of the surplus production model over the output of the SCA.

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

F_{curr} is slightly above F_{msy} in the projections because a 3-year moving average is used to calculate F_{curr}, even though F_{2006} is below F_{msy}. This is due to one data point from 2004 when F was high, and it drives the estimate of F_{curr} to slightly abobe F_{msy}. There was discussion whether F_{curr} should be calculated using a 5 year moving average, but the assessment workshop decided to leave keep using a 3-year average as F_{curr} as used for projections is not used to determine stock status.

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 – Part A (Provided by NMFS/SEFSC –Beaufort)

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

2.1 Growth, Maturity and Mortality

Corrected estimates of the von Bertalanffy growth parameters were estimated by the Life History Working Group (LHWG) as

$$FL\ (mm) = 1194.0\ (1 - \exp(-0.343(age + 0.45))),$$

and weight as a function of total length as

$$W\ (g) = 0.00003\ FL\ (mm)^{2.866}.$$

A short description of the corrections made estimating the von Bertalanffy growth parameters are presented in an appendix to the life history section of the DW. Estimates of female maturity at age were provided by the LHWG, and we assumed a female sex ratio of 0.5. Size (mid-year), sex ratio and female maturity at age are summarized for ages 1-10 in Table 2.1.

The LHWG recommended the Lorenzen (1996) approach to estimating age-varying M scaled to survival to a maximum age of 13 in the sampled data and scaled cumulative survival from 0 to 13 to 1.4% (Hewitt and Hoenig 2005). The Assessment Panel discussed whether the maximum age of 13 in the available aging data be used, or should the maximum age of 17 (also noted as such by the LHWG) be used; i.e., should a maximum age of 13 or 17 be used in calculating age-varying M? It was decided that the age of 17 better reflected the potential historic maximum age of the population, while the age of 13 may only reflect the current maximum age of the population. It was also decided to start the age range with age 1, in part, to parallel the approach used for red snapper and because age 0 is not modeled for either stock. So the age range of 1-17 was used to scale estimates of age-varying M. As recommended by the LHWG, upper and lower bounds for sensitivity runs of age-varying M were obtained by scaling the age-varying M to 1% and 5%, respectively. The various estimates of age-varying M are summarized in Table 2.2.

As recommended by the LHWG, discard mortality fractions were assumed constant at 0.2 for both MRFSS and headboat recreational fisheries, and for the commercial hook & line fishery

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 50 (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 8 yrs (rounded up from 7.9 yrs).

2.2 Recreational and Commercial Landings (Table 2.3)

Recreational landings were used as provided by the Recreational Working Group (RWG) for 1946-2006. The Assessment Panel discussed the necessity for smoothing the MRFSS A+B1 landings estimates, but decided not to do so because PSE's around 20% or below were deemed adequate. Trivial landings from commercial longlines and other gears were pooled with landings from commercial hook & line. Longlines and other gears comprised 1.5% of all commercial landings between 1962 and 2006 and only 0.3% since 2000. The Commercial Working Group (CWG) provided commercial landings back to 1950. To match the recreational landings time frame, commercial hook & line landings were linearly interpolated back to 0 in 1946. The mean commercial hook & line landings calculated for 1950-1952 was used in the interpolation for 1950.

Recreational MRFSS coefficients of variation (CV) were provided by the RWG using the MRFSS PSE's estimated for A+B1 fish. Annual CVs were assigned to headboat landings with a low value of 0.05 for 1981-2006, and twice that (0.1) for the earlier interpolated years, 1946-1980. Annual CVs were assigned to hook & line and diving gears, with high CV for earliest years (0.30) and low CV for recent years (0.1). A linear interpolation was made for intervening years (1985 to 1997).

2.3 Recreational and Commercial Discards (Table 2.4)

Because of concerns about the magnitude of the MRFSS PSE's for the B2 estimates (higher than the PSE's for A+B1), the Assessment Panel agreed to apply a 3-yr moving average to smooth MRFSS B2 estimates for the periods 1982-91 and 1992-2006 (separating the moving averages with the management change in 1992). The average ratio of B2/A+B1 for 1982-1991 (0.489) was used to extend MRFSS discard estimates from 1981 back to 1947. This was modified from that provided by the RWG, who averaged this ratio over 1982-1989. Because no management change occurred until 1992, it was believed there was no reason not to include 1990-1991 in this averaging (the difference being an average ratio of 0.49 for 1982-1991 and 0.50 for 1982-1989). This ratio increased to 0.85 following management imposed in 1992. Headboat landings were estimated within the model for 1992-2006, and assumed to be zero prior to 1992. Discard estimates for commercial trolling were pooled with discard estimates for commercial hook & line as provided by the Commercial Working Group (CWG). Discarding by commercial diving was assumed zero for the whole assessment period.

CV's for the recreational MRFSS discards were provided by the RWG (PSE estimates for B2 fish). CV's for commercial discard estimates were assumed twice that of the commercial landings.

2.4 Recreational and Commercial Length Compositions (Tables 2.5-2.8)

Commercial hook & line, commercial diving, headboat, and MRFSS length compositions were expressed as 5 cm intervals from 20-140 cm total length, with the largest interval (140 cm) a plus group. For most fisheries and years, there were no fish greater than 140 mm FL. Only 7 out of 20 years for MRFSS, 1 out of 26 years for headboat, 9 out of 20 years for commercial hook & line, and 3 out of 7 years for diving – overall 20 out of 79 years for all fisheries. In general, when there were fish lengths in excess of 140 mm FL, they made up fewer than 3%, with the exception of 4 years of MRFSS data that ranged from 3.9% in 2005 to 14.6% in 1989. Annual length compositions were retained for analysis when annual sample size was 21 or greater.

There was considerable discussion by the Assessment Panel about the MRFSS length composition data – the mode of the length composition data for the two periods shifted towards smaller fish after the imposition of the size limit. There was concern as to why this might be. Although there were few small fish in the early period for MRFSS, small fish were prevalent in the headboat length composition data for the first (pre 1992) period – why are these smaller fish not showing up as much in the MRFSS data set? It was discussed that the shift to smaller fish after 1992 is not incompatible with size limit – prior to the size limit, fishermen may have kept few fish more or less randomly by size, whereas post size limit, they kept everything greater than the size limit. It was also suggested that this could be due to incorrect species ID, which may be more of a potential issue with MRFSS. It was further suggested that this could be an effect of increase in fishing mortality. It was decided by the Assessment Panel that there was no justification to change anything in the data set, and it was left as finalized by the data workshop.

2.5 Recreational and Commercial Age Compositions (Tables 2.9-2.12)

Commercial hook & line, commercial diving, headboat, and MRFSS age compositions were expressed as ages from 1 to 10, with the oldest age (10) a plus group. Annual length and age compositions were retained for analysis when annual sample size was 21 or greater.

There was some discussion as to why the age composition data from commercial diving data was different compared to the age composition data from commercial hook & line data – the length distributions were similar but the age distributions were slightly different. It was decided this could be due to variation in size at age, and was not an unreasonable assumption.

2.6 Fishery-Dependent Indices (Table 2.13)

Fishery-dependent indices were provided by the Index Working Group with corresponding coefficients of variation (CV). Fishery dependent index CV's were then scaled to a maximum of 0.3

The Assessment Panel did a correlation between indices using a two year lag to allow for recreationally caught fish to grow to the size limit of the commercial fishery. The rationale is that following the imposition of minimum size limits in 1992 (28" FL for recreational and 36" FL for commercial). This provided slightly better results for correlations between commercial and recreational indices. The data workshop made no recommendations as to how the lagged indices should be utilized in the assessment, and they were not utilized for either assessment models (surplus production or age structured).

2.7 References

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

Hewitt, D.A., and J. M. Hoenig. 2005. Comparison of two approaches for estimating natural mortality based on longevity. Fish. Bull. 103:433-437.

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. Greater Amberjack: Size (mid-year), sex ratio and female maturity at age. Length is fork length, weight is whole weight.

Age	Length (mm)	Length (in)	Weight (kg)	Weight (lb)	Sex Ratio	Female Maturity
1	582.3	22.93	2.5	5.56	0.5	0.143
2	759.9	29.92	5.4	11.93	0.5	0.627
3	886.0	34.88	8.4	18.52	0.5	0.904
4	975.4	38.40	11.1	24.40	0.5	0.993
5	1038.9	40.90	13.3	29.24	0.5	0.994
6	1083.9	42.67	15.0	33.02	0.5	1.000
7	1115.9	43.93	16.3	35.89	0.5	1.000
8	1138.6	44.83	17.2	38.02	0.5	1.000
9	1154.7	45.46	18.0	39.58	0.5	1.000
10	1166.1	45.91	18.5	40.71	0.5	1.000

Table 2.2. Greater Amberjack: Estimates of natural mortality, M, based on Lorenzen (1996). These estimates are then scaled to cumulative survival for ages 1-17 (maximum age) to 1.4% (preferred) and range using 1% and 5%.

Age	M	Scaled M (0.014)	Upper (0.01)	Lower (0.05)
1	0.41	0.48	0.52	0.34
2	0.30	0.35	0.38	0.25
3	0.25	0.29	0.32	0.21
4	0.22	0.26	0.28	0.19
5	0.21	0.25	0.27	0.17
6	0.20	0.24	0.25	0.17
7	0.19	0.23	0.25	0.16
8	0.19	0.22	0.24	0.16
9	0.19	0.22	0.24	0.15
10	0.19	0.22	0.24	0.15
11	0.18	0.22	0.23	0.15
12	0.18	0.22	0.23	0.15
13	0.18	0.22	0.23	0.15
14	0.18	0.21	0.23	0.15
15	0.18	0.21	0.23	0.15
16	0.18	0.21	0.23	0.15
17	0.18	0.21	0.23	0.15

Table 2.3. Greater Amberjack: Landings and associated coefficient of variation (CV), 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
1946	0		0	0				
1947	7.54		14.31	24.13	0.30		0.10	0.31
1948	15.08		19.09	48.27	0.30		0.10	0.31
1949	22.62		23.86	72.40	0.30		0.10	0.31
1950	26.18		28.63	96.53	0.30		0.10	0.31
1951	23.62		33.40	120.66	0.30		0.10	0.31
1952	40.69		38.17	144.80	0.30		0.10	0.31
1953	32.50		42.94	168.93	0.30		0.10	0.31
1954	21.21		47.72	193.06	0.30		0.10	0.31
1955	9.15		52.49	217.20	0.30		0.10	0.31
1956	14.07		57.26	241.33	0.30		0.10	0.31
1957	2.79		62.03	265.46	0.30		0.10	0.31
1958	19.50		66.80	289.59	0.30		0.10	0.31
1959	45.20		71.57	313.73	0.30		0.10	0.31
1960	31.79		76.34	337.86	0.30		0.10	0.31
1961	4.93		81.12	361.99	0.30		0.10	0.31
1962	7.01		85.89	386.13	0.30		0.10	0.31
1963	7.09		90.66	410.26	0.30		0.10	0.31
1964	7.24		95.43	434.39	0.30		0.10	0.31
1965	8.12		100.20	458.52	0.30		0.10	0.31
1966	19.95		104.97	482.66	0.30		0.10	0.31
1967	20.76		109.75	506.79	0.30		0.10	0.31
1968	24.69		114.52	530.92	0.30		0.10	0.31
1969	16.70		119.29	555.06	0.30		0.10	0.31
1970	39.84		124.06	579.19	0.30		0.10	0.31
1971	23.75		128.83	603.32	0.30		0.10	0.31
1972	10.31		133.60	627.45	0.30		0.10	0.31
1973	40.74		138.37	651.59	0.30		0.10	0.31
1974	43.47		143.15	675.72	0.30		0.10	0.31
1975	55.39		147.92	699.85	0.30		0.10	0.31
1976	62.87		152.69	723.98	0.30		0.10	0.31
1977	61.00		157.46	748.12	0.30		0.10	0.31
1978	38.71		162.23	772.25	0.30		0.10	0.31
1979	55.69		167.00	796.38	0.30		0.10	0.31

Table 2.3. (cont.)

1980	62.74		171.78	820.52	0.30		0.10	0.31
1981	86.99		148.63	1463.08	0.30		0.05	0.17
1982	157.85		261.46	666.04	0.30		0.05	0.48
1983	111.04		119.55	332.43	0.30		0.05	0.27
1984	182.94		269.76	1984.58	0.30		0.05	0.21
1985	157.10		136.72	1609.76	0.29		0.05	0.25
1986	366.65	30.41	152.72	2617.41	0.27	0.27	0.05	0.17
1987	979.07	90.90	267.17	3040.97	0.26	0.26	0.05	0.39
1988	957.62	85.75	179.81	2101.22	0.24	0.24	0.05	0.23
1989	1110.26	100.73	116.79	1987.09	0.23	0.23	0.05	0.26
1990	1426.08	123.42	117.78	1747.87	0.21	0.21	0.05	0.22
1991	1758.17	155.12	155.54	1285.01	0.20	0.20	0.05	0.20
1992	1826.62	161.10	158.20	1330.65	0.19	0.19	0.05	0.13
1993	1358.17	96.77	156.97	910.13	0.17	0.17	0.05	0.21
1994	1408.40	128.83	120.58	1805.32	0.16	0.16	0.05	0.19
1995	1281.38	105.36	78.89	940.29	0.14	0.14	0.05	0.23
1996	1087.33	85.59	92.67	1132.25	0.13	0.13	0.05	0.18
1997	1046.50	98.78	50.32	784.97	0.11	0.11	0.05	0.22
1998	901.32	86.39	53.70	567.55	0.10	0.10	0.05	0.25
1999	802.70	72.20	69.57	1837.39	0.10	0.10	0.05	0.13
2000	730.05	115.14	129.95	868.34	0.10	0.10	0.05	0.23
2001	820.45	48.72	97.83	737.76	0.10	0.10	0.05	0.14
2002	817.94	78.05	87.14	813.85	0.10	0.10	0.05	0.16
2003	699.71	63.06	135.30	1077.57	0.10	0.10	0.05	0.12
2004	948.45	59.58	82.62	678.34	0.10	0.10	0.05	0.19
2005	942.28	47.47	33.44	577.77	0.10	0.10	0.05	0.15
2006	574.25	39.36	39.78	617.43	0.10	0.10	0.05	0.19

Table 2.4. Greater Amberjack: Discards and associated coefficients of variation (CV), as used in assessment (base). See model description for handling of headboat discards within the model structure.

	Discards in Numbers (1000)		Coefficient of Variation (CV)	
Year	Commercial Hook & Line	Recreational MRFSS	Commercial Hook & Line	Recreational MRFSS
1946		0		
1947		0.57		0.45
1948		1.13		0.45
1949		1.70		0.45
1950		2.26		0.45
1951		2.83		0.45
1952		3.39		0.45
1953		3.96		0.45
1954		4.52		0.45
1955		5.09		0.45
1956		5.65		0.45
1957		6.22		0.45
1958		6.78		0.45
1959		7.35		0.45
1960		7.92		0.45
1961		8.48		0.45
1962		9.05		0.45
1963		9.61		0.45
1964		10.18		0.45
1965		10.74		0.45
1966		11.31		0.45
1967		11.87		0.45
1968		12.44		0.45
1969		13.00		0.45
1970		13.57		0.45
1971		14.13		0.45
1972		14.70		0.45
1973		15.27		0.45
1974		15.83		0.45
1975		16.40		0.45
1976		16.96		0.45
1977		17.53		0.45
1978		18.09		0.45
1979		18.66		0.45

Table 2.4. (cont.)

1980		19.22		0.45
1981		27.28		0.45
1982		15.60		0.57
1983		19.55		0.68
1984		31.70		0.36
1985		48.76		0.33
1986		54.25		0.18
1987		43.44		0.24
1988		33.30		0.25
1989		26.92		0.19
1990		34.01		0.25
1991		37.83		0.22
1992	5.75	42.32	0.48	0.25
1993	6.08	36.14	0.44	0.17
1994	8.53	24.48	0.40	0.24
1995	8.06	26.16	0.36	0.28
1996	10.09	26.52	0.32	0.23
1997	10.57	27.60	0.28	0.31
1998	9.50	27.63	0.24	0.28
1999	8.16	37.56	0.20	0.25
2000	8.63	41.79	0.20	0.18
2001	8.99	46.31	0.20	0.18
2002	8.22	48.01	0.20	0.18
2003	6.84	53.21	0.20	0.16
2004	5.92	51.46	0.20	0.23
2005	5.76	40.10	0.20	0.25
2006	6.51	38.27	0.20	0.19

Table 2.5. Greater Amberjack: Length compositions from commercial hook & line (5-cm intervals FL).

Year	N	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140
1987	39	0.0000	0.0000	0.0000	0.0825	0.1238	0.2476	0.0413	0.0825	0.1238	0.0857	0.0413	0.0508	0.0445	0.0064	0.0064	0.0032	0.0064	0.0096	0.0032	0.0000	0.0413	0.0000	0.0000	0.0000	0.0000
1988	59	0.0000	0.0000	0.0000	0.0185	0.1110	0.0370	0.1110	0.0555	0.0740	0.0555	0.0370	0.1110	0.0925	0.0740	0.0375	0.0375	0.0557	0.0370	0.0370	0.0000	0.0185	0.0000	0.0000	0.0000	0.0000
1989	23	0.0000	0.0000	0.0000	0.0000	0.0737	0.0673	0.0000	0.0000	0.0673	0.0000	0.1410	0.0000	0.0064	0.0673	0.0321	0.2019	0.0000	0.0000	0.1410	0.0673	0.0000	0.0000	0.0673	0.0673	0.0000
1990	98	0.0000	0.0000	0.0018	0.0030	0.0047	0.0035	0.0006	0.0919	0.0569	0.2027	0.0373	0.0373	0.0373	0.0924	0.0196	0.0379	0.0184	0.0557	0.1120	0.0385	0.0930	0.0190	0.0367	0.0000	0.0000
1991	434	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0001	0.0029	0.0273	0.0164	0.0082	0.0028	0.0054	0.0082	0.0109	0.0217	0.0731	0.1056	0.1408	0.1570	0.1543	0.1083	0.0704	0.0433	0.0433
1992	569	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0063	0.0189	0.0526	0.0674	0.1032	0.0526	0.0253	0.0695	0.0947	0.1032	0.1116	0.1010	0.0800	0.0589	0.0358	0.0105	0.0084
1993	781	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0053	0.0036	0.0140	0.0089	0.0196	0.0108	0.0212	0.0439	0.0930	0.1466	0.1779	0.1495	0.1077	0.0989	0.0486	0.0278	0.0087	0.0070	0.0070
1994	516	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0034	0.0001	0.0259	0.0805	0.1067	0.0873	0.0842	0.0555	0.0941	0.1361	0.1163	0.0871	0.0581	0.0354	0.0161	0.0065	0.0032	0.0000	0.0032
1995	315	0.0000	0.0000	0.0000	0.0001	0.0002	0.0002	0.0004	0.0001	0.0002	0.0003	0.0001	0.0002	0.0272	0.0183	0.0633	0.1851	0.2350	0.2347	0.0767	0.0767	0.0543	0.0090	0.0045	0.0135	0.0000
1996	284	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0046	0.0494	0.1748	0.2778	0.2914	0.1121	0.0539	0.0179	0.0045	0.0045	0.0090	0.0000	0.0000
1997	570	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0137	0.0251	0.0320	0.0183	0.0274	0.0251	0.0251	0.0457	0.0799	0.1347	0.1986	0.1279	0.0959	0.0525	0.0434	0.0320	0.0160	0.0023	0.0046
1998	484	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0119	0.0071	0.0166	0.0095	0.0142	0.0142	0.0166	0.0190	0.0924	0.2227	0.2275	0.2109	0.0593	0.0308	0.0237	0.0095	0.0071	0.0047	0.0024
1999	564	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0000	0.0000	0.0028	0.0002	0.0030	0.0003	0.0169	0.0649	0.1913	0.2469	0.2463	0.1121	0.0646	0.0170	0.0169	0.0085	0.0029	0.0028
2000	1140	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0015	0.0016	0.0091	0.0273	0.1292	0.1980	0.2004	0.1877	0.1119	0.0703	0.0343	0.0180	0.0076	0.0015	0.0000
2001	1217	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0014	0.0118	0.0262	0.0720	0.2172	0.2517	0.1462	0.1094	0.0654	0.0444	0.0324	0.0149	0.0043	0.0014
2002	1047	0.0000	0.0000	0.0015	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0016	0.0002	0.0019	0.0051	0.0117	0.0410	0.0881	0.2150	0.2372	0.1818	0.0798	0.0575	0.0309	0.0247	0.0109	0.0108
2003	818	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0000	0.0026	0.0003	0.0028	0.0028	0.0030	0.0059	0.0109	0.0799	0.2125	0.2543	0.1833	0.0858	0.0691	0.0409	0.0213	0.0163	0.0058	0.0023
2004	856	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0019	0.0038	0.0132	0.0887	0.1968	0.2586	0.1869	0.1230	0.0473	0.0360	0.0246	0.0151	0.0038	0.0001
2005	328	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0080	0.0020	0.0000	0.0020	0.0020	0.0060	0.0080	0.0176	0.0448	0.2157	0.2533	0.1984	0.1418	0.0857	0.0050	0.0050	0.0020	0.0010	0.0020
2006	251	0.0000	0.0000	0.0000	0.0071	0.0227	0.0085	0.0057	0.0000	0.0138	0.0057	0.0043	0.0014	0.0329	0.0688	0.1240	0.1561	0.1792	0.0736	0.1097	0.0231	0.0816	0.0254	0.0231	0.0336	0.0000

Table 2.6. Greater Amberjack: Length compositions from commercial diving (5-cm intervals FL).

Year	N	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140
1993	60	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	0.0167	0.0333	0.3167	0.3833	0.1333	0.0500	0.0333	0.0167	0.0167	0.0000	0.0000	0.0000
1994	43	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	0.1443	0.1443	0.3715	0.2767	0.0316	0.0000	0.0000	0.0000	0.0000	0.0000	0.0316
1995	39	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	0.0256	0.0256	0.2051	0.3077	0.2051	0.1026	0.0769	0.0256	0.0000	0.0256	0.0000	0.0000
1999	145	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	0.0621	0.2759	0.2621	0.1586	0.1034	0.0759	0.0276	0.0000	0.0138	0.0138	0.0000	0.0069
2000	217	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	0.1613	0.3502	0.1843	0.1244	0.0783	0.0507	0.0277	0.0046	0.0092	0.0046	0.0046	0.0000
2001	38	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0263	0.0000	0.0790	0.1579	0.2368	0.2105	0.1579	0.0790	0.0263	0.0000	0.0000	0.0000	0.0263
2003	96	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	0.0521	0.2083	0.3438	0.2292	0.0833	0.0104	0.0313	0.0104	0.0000	0.0104	0.0000	0.0208

Table 2.7. Greater Amberjack: Length compositions from the headboat survey (5-cm intervals FL).

Year	N	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140
1981	217	0.0000	0.0000	0.0319	0.0973	0.0663	0.0236	0.0030	0.0055	0.0585	0.2436	0.2790	0.1238	0.0398	0.0063	0.0071	0.0067	0.0000	0.0000	0.0005	0.0067	0.0003	0.0000	0.0003	0.0000	0.0000
1982	97	0.0052	0.0126	0.0378	0.1090	0.1221	0.0170	0.0381	0.2490	0.1433	0.0894	0.1145	0.0225	0.0124	0.0004	0.0057	0.0142	0.0012	0.0000	0.0000	0.0026	0.0022	0.0009	0.0000	0.0000	0.0000
1983	250	0.0006	0.0232	0.0309	0.1939	0.1049	0.1790	0.0161	0.1398	0.0789	0.0158	0.0191	0.0169	0.0343	0.0110	0.0067	0.0149	0.0388	0.0258	0.0249	0.0092	0.0103	0.0011	0.0034	0.0006	0.0000
1984	202	0.0044	0.0120	0.1669	0.1100	0.0418	0.0420	0.0473	0.2079	0.0764	0.0806	0.0595	0.0307	0.0174	0.0319	0.0233	0.0172	0.0131	0.0004	0.0060	0.0083	0.0000	0.0028	0.0000	0.0000	0.0000
1985	190	0.0095	0.0411	0.0695	0.2250	0.1914	0.1224	0.0511	0.0427	0.0384	0.0466	0.0424	0.0366	0.0145	0.0042	0.0341	0.0114	0.0019	0.0095	0.0025	0.0000	0.0025	0.0013	0.0013	0.0000	0.0000
1986	214	0.0000	0.0078	0.0019	0.0132	0.1682	0.0969	0.0528	0.1494	0.1313	0.1301	0.0605	0.0391	0.0478	0.0133	0.0324	0.0252	0.0167	0.0105	0.0010	0.0007	0.0000	0.0008	0.0004	0.0000	0.0000
1987	248	0.0000	0.0084	0.0000	0.0326	0.0465	0.0923	0.1021	0.0458	0.0751	0.1097	0.0400	0.0332	0.0369	0.0513	0.0478	0.0754	0.0778	0.0362	0.0215	0.0226	0.0106	0.0139	0.0205	0.0000	0.0000
1988	129	0.0075	0.0344	0.1172	0.1980	0.0855	0.1296	0.0122	0.0115	0.0442	0.0369	0.0208	0.0150	0.0109	0.0225	0.0205	0.0729	0.0480	0.0514	0.0280	0.0270	0.0032	0.0012	0.0000	0.0020	0.0000
1989	176	0.0000	0.0179	0.0745	0.0543	0.0161	0.0867	0.0875	0.0496	0.1260	0.0160	0.0259	0.0281	0.0259	0.0593	0.0719	0.1176	0.0305	0.0361	0.0135	0.0084	0.0179	0.0281	0.0000	0.0000	0.0086
1990	117	0.0122	0.0377	0.0158	0.0122	0.0144	0.0062	0.0666	0.0315	0.0341	0.0785	0.0787	0.1329	0.1220	0.1071	0.0587	0.0596	0.0280	0.0438	0.0431	0.0000	0.0000	0.0170	0.0000	0.0000	0.0000
1991	68	0.0000	0.0000	0.0000	0.0000	0.0227	0.0311	0.0084	0.0335	0.0000	0.0267	0.0336	0.0831	0.0982	0.1334	0.1385	0.1597	0.1239	0.0501	0.0372	0.0027	0.0000	0.0085	0.0085	0.0000	0.0000
1992	125	0.0000	0.0000	0.0008	0.0092	0.0000	0.0000	0.0062	0.0000	0.0104	0.0409	0.1598	0.0859	0.1285	0.1086	0.0757	0.0777	0.1154	0.0844	0.0353	0.0471	0.0142	0.0000	0.0000	0.0000	0.0000
1993	119	0.0000	0.0000	0.0025	0.0013	0.0000	0.0000	0.0014	0.0145	0.0000	0.0299	0.0787	0.1133	0.2741	0.1077	0.1971	0.1450	0.0171	0.0086	0.0077	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000
1994	119	0.0000	0.0000	0.0000	0.0000	0.0000	0.0056	0.0056	0.0044	0.0359	0.0082	0.1070	0.1662	0.1908	0.1075	0.1072	0.1470	0.0660	0.0111	0.0056	0.0056	0.0266	0.0000	0.0000	0.0000	0.0000
1995	106	0.0000	0.0000	0.0234	0.0000	0.0000	0.0000	0.0083	0.0145	0.0627	0.0050	0.1105	0.1017	0.0804	0.1754	0.2405	0.0802	0.0474	0.0243	0.0128	0.0000	0.0000	0.0000	0.0000	0.0128	0.0000
1996	76	0.0000	0.0000	0.0000	0.0203	0.0000	0.0000	0.0000	0.0000	0.0445	0.0084	0.0882	0.0587	0.1321	0.0287	0.3008	0.1987	0.0798	0.0207	0.0057	0.0000	0.0134	0.0000	0.0000	0.0000	0.0000
1997	65	0.0000	0.0000	0.0014	0.0022	0.0054	0.0274	0.0423	0.0175	0.0225	0.1181	0.1530	0.1404	0.0968	0.0994	0.0635	0.0534	0.1041	0.0489	0.0014	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000
1998	96	0.0000	0.0012	0.0028	0.0028	0.0032	0.0128	0.0000	0.0062	0.0296	0.0292	0.1242	0.2978	0.1420	0.1243	0.0461	0.0517	0.1159	0.0028	0.0000	0.0072	0.0000	0.0000	0.0000	0.0000	0.0000
1999	129	0.0000	0.0000	0.0000	0.0000	0.0033	0.0000	0.0000	0.0243	0.0000	0.0496	0.0547	0.1325	0.1156	0.1747	0.2264	0.0938	0.0374	0.0051	0.0272	0.0283	0.0000	0.0272	0.0000	0.0000	0.0000
2000	70	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0257	0.0046	0.0174	0.0090	0.1255	0.1147	0.1135	0.0934	0.3755	0.0126	0.1063	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2001	39	0.0000	0.0000	0.0000	0.0000	0.0024	0.0007	0.0034	0.0134	0.0252	0.0551	0.2169	0.1772	0.1846	0.1616	0.0772	0.0313	0.0379	0.0132	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2002	148	0.0111	0.0000	0.0000	0.0000	0.0004	0.0000	0.0005	0.0000	0.0021	0.0160	0.0990	0.1319	0.1724	0.2779	0.1398	0.0706	0.0504	0.0228	0.0033	0.0020	0.0000	0.0000	0.0000	0.0000	0.0000
2003	155	0.0000	0.0384	0.0000	0.0192	0.0155	0.0383	0.0310	0.0229	0.0823	0.0595	0.0210	0.0842	0.1219	0.1034	0.0239	0.0677	0.1131	0.0556	0.0783	0.0155	0.0084	0.0000	0.0000	0.0000	0.0000
2004	68	0.0000	0.0247	0.0000	0.0614	0.0812	0.0614	0.0626	0.0307	0.0198	0.1288	0.0655	0.1615	0.0846	0.0307	0.0969	0.0397	0.0307	0.0000	0.0198	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2005	38	0.0000	0.0000	0.0080	0.0322	0.0451	0.0700	0.1239	0.0581	0.0526	0.0350	0.1249	0.0548	0.0540	0.0428	0.0420	0.0724	0.0648	0.0648	0.0389	0.0156	0.0000	0.0000	0.0000	0.0000	0.0000
2006	83	0.0025	0.0108	0.0313	0.0872	0.0764	0.0579	0.0263	0.0909	0.0695	0.1089	0.1346	0.0735	0.0621	0.0399	0.0360	0.0344	0.0238	0.0138	0.0084	0.0056	0.0029	0.0019	0.0012	0.0002	0.0002

Table 2.8. Greater Amberjack: Length compositions from the Marine Recreational Fisheries Statistics Survey (MRFSS) (5-cm intervals FL). Sample size of 12 in 1982 (highlighted in yellow) was set to zero (N<20 not used).

Year	N	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140
1981	33	0.0015	0.0472	0.0163	0.0037	0.0000	0.1245	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.4061	0.0330	0.2690	0.0989	0.0000	0.0000	0.0000	0.0000	0.0000
1982	12	0.0746	0.0249	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0689	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0298	0.0000	0.6325	0.1147	0.0249	0.0298	0.0000	0.0000	0.0000
1983	24	0.0000	0.0000	0.0000	0.0000	0.0648	0.1086	0.1574	0.0000	0.0000	0.0857	0.0835	0.0000	0.0000	0.0981	0.0752	0.0000	0.0104	0.0000	0.0000	0.3059	0.0000	0.0000	0.0000	0.0104	0.0000
1984	74	0.0000	0.0000	0.0000	0.0000	0.0000	0.0118	0.0104	0.0104	0.0104	0.0052	0.0290	0.1247	0.0052	0.0227	0.0867	0.0482	0.0499	0.0776	0.1348	0.0284	0.0721	0.0308	0.1800	0.0000	0.0617
1985	53	0.0000	0.0018	0.0000	0.0000	0.0000	0.0022	0.0129	0.0000	0.0129	0.0477	0.3038	0.0477	0.0000	0.0194	0.0823	0.0820	0.0157	0.0470	0.0258	0.1345	0.1029	0.0064	0.0550	0.0000	0.0000
1986	71	0.0000	0.0543	0.0424	0.0000	0.0000	0.0000	0.0000	0.0106	0.0729	0.1275	0.0775	0.0008	0.0364	0.0424	0.0767	0.0493	0.0156	0.1435	0.0511	0.0917	0.0283	0.0321	0.0141	0.0220	0.0110
1987	83	0.0000	0.0000	0.0000	0.0000	0.0085	0.0085	0.0009	0.0000	0.1172	0.0000	0.0802	0.0970	0.0673	0.0781	0.0509	0.0058	0.0813	0.0729	0.0983	0.0561	0.0190	0.1084	0.0031	0.0008	0.0460
1988	59	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000	0.0000	0.0712	0.0000	0.0000	0.0000	0.0025	0.0000	0.0000	0.0025	0.1859	0.3948	0.1321	0.1113	0.0336	0.0648	0.0000	0.0000	0.0000
1989	109	0.0000	0.0000	0.0044	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0462	0.0309	0.0666	0.0554	0.0483	0.1447	0.0627	0.1394	0.0155	0.0821	0.0506	0.0120	0.0922	0.1464
1990	77	0.0000	0.0000	0.0253	0.0084	0.0000	0.0009	0.0032	0.0599	0.0077	0.0069	0.0308	0.0020	0.0000	0.1586	0.0128	0.0461	0.1773	0.1451	0.1166	0.0783	0.0412	0.0015	0.0009	0.0000	0.0767
1991	77	0.0644	0.1089	0.0073	0.0000	0.0000	0.0000	0.0021	0.0000	0.0015	0.0000	0.0104	0.0065	0.2020	0.0180	0.0223	0.0259	0.1022	0.2541	0.0587	0.0829	0.0244	0.0000	0.0086	0.0000	0.0000
1992	71	0.0000	0.0137	0.0000	0.0000	0.0000	0.0000	0.0748	0.0370	0.0000	0.0000	0.0868	0.0302	0.0371	0.1053	0.0122	0.2040	0.1689	0.1495	0.0691	0.0114	0.0000	0.0000	0.0000	0.0000	0.0000
1993	94	0.0000	0.0000	0.1344	0.0548	0.0000	0.0129	0.0000	0.0000	0.0109	0.0101	0.0056	0.0516	0.0118	0.0071	0.0503	0.0789	0.2675	0.2170	0.0077	0.0324	0.0432	0.0000	0.0018	0.0021	0.0000
1994	118	0.0000	0.0000	0.0080	0.0000	0.0000	0.0068	0.0000	0.0000	0.0000	0.0012	0.0008	0.0461	0.0387	0.2452	0.0988	0.0855	0.1584	0.0735	0.1247	0.0294	0.0828	0.0000	0.0000	0.0000	0.0000
1995	58	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0064	0.0275	0.0038	0.0012	0.3126	0.1531	0.0626	0.0692	0.0901	0.0484	0.1044	0.0548	0.0522	0.0000	0.0000	0.0137
1996	101	0.0000	0.0000	0.0000	0.0000	0.0035	0.0000	0.0000	0.2363	0.1562	0.0000	0.0169	0.0106	0.0783	0.0420	0.0630	0.1207	0.1247	0.0514	0.0132	0.0471	0.0019	0.0255	0.0000	0.0087	0.0000
1997	42	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1166	0.0127	0.2721	0.0272	0.0540	0.1786	0.0268	0.1153	0.0850	0.1062	0.0000	0.0000	0.0056	0.0000	0.0000	0.0000
1998	79	0.0000	0.0000	0.0000	0.0000	0.0242	0.0242	0.0000	0.0000	0.0260	0.0000	0.0200	0.0907	0.1387	0.0580	0.0971	0.1611	0.1407	0.0968	0.0633	0.0396	0.0016	0.0016	0.0000	0.0000	0.0166
1999	280	0.0000	0.0000	0.0113	0.0000	0.0055	0.0000	0.0000	0.0000	0.0030	0.0024	0.0761	0.1433	0.1592	0.0714	0.0583	0.1294	0.1489	0.1002	0.0668	0.0121	0.0036	0.0026	0.0008	0.0052	0.0000
2000	160	0.0000	0.0000	0.0000	0.0000	0.0040	0.0000	0.0147	0.0364	0.0000	0.0000	0.0011	0.0279	0.0456	0.1798	0.1914	0.2268	0.1926	0.0347	0.0249	0.0157	0.0000	0.0046	0.0000	0.0000	0.0000
2001	161	0.0000	0.0867	0.0000	0.0000	0.0432	0.0565	0.0068	0.0106	0.0136	0.0490	0.1061	0.1079	0.0782	0.0322	0.0268	0.0843	0.1267	0.0834	0.0431	0.0198	0.0034	0.0134	0.0000	0.0000	0.0000
2002	213	0.0000	0.0000	0.0000	0.0000	0.0088	0.0000	0.0000	0.0000	0.0588	0.0221	0.0298	0.0592	0.0844	0.0912	0.3482	0.1075	0.0809	0.0461	0.0278	0.0149	0.0122	0.0081	0.0000	0.0000	0.0000
2003	323	0.0000	0.0000	0.0000	0.0030	0.0000	0.0000	0.0217	0.0000	0.0182	0.0000	0.0624	0.0671	0.0767	0.1311	0.2272	0.1217	0.1125	0.0863	0.0301	0.0300	0.0097	0.0023	0.0000	0.0000	0.0000
2004	82	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0115	0.0360	0.0159	0.1076	0.0875	0.1484	0.2301	0.1363	0.1309	0.0633	0.0078	0.0000	0.0247	0.0000	0.0000
2005	82	0.0000	0.0000	0.0000	0.0000	0.0000	0.0096	0.0000	0.0000	0.0000	0.0000	0.0259	0.1284	0.0887	0.0218	0.0998	0.1236	0.1623	0.1249	0.0657	0.0096	0.0421	0.0303	0.0286	0.0000	0.0387
2006	78	0.0000	0.0000	0.0000	0.0000	0.0000	0.0096	0.0000	0.0000	0.0289	0.0173	0.0332	0.0662	0.0806	0.0328	0.0336	0.3382	0.1236	0.2103	0.0166	0.0066	0.0066	0.0054	0.0000	0.0000	0.0000

Table 2.9. Greater Amberjack: Age compositions from commercial hook & line.

Year	N	1	2	3	4	5	6	7	8	9	10
1998	37	0.0000	0.0000	0.0127	0.1902	0.4992	0.1569	0.0697	0.0539	0.0048	0.0127
1999	83	0.0000	0.0120	0.3090	0.1895	0.3573	0.1243	0.0000	0.0000	0.0040	0.0040
2000	174	0.0000	0.0477	0.4519	0.3733	0.0543	0.0480	0.0188	0.0014	0.0000	0.0047
2001	194	0.0000	0.0076	0.2016	0.5348	0.2063	0.0313	0.0057	0.0085	0.0038	0.0005
2002	752	0.0000	0.0018	0.1233	0.2420	0.4087	0.1126	0.0415	0.0407	0.0161	0.0133
2003	424	0.0002	0.0160	0.1167	0.4996	0.1644	0.1185	0.0583	0.0115	0.0063	0.0086
2004	37	0.0000	0.0000	0.1445	0.4856	0.2707	0.0428	0.0511	0.0053	0.0000	0.0000

Table 2.10. Greater Amberjack: Age compositions from commercial diving.

Year	N	1	2	3	4	5	6	7	8	9	10
1999	48	0.0000	0.0000	0.5687	0.1949	0.1693	0.0288	0.0320	0.0000	0.0000	0.0064
2000	21	0.0000	0.0000	0.9828	0.0172	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 2.11. Greater Amberjack: Age compositions from the headboat survey.

Year	N	1	2	3	4	5	6	7	8	9	10
2003	47	0.0000	0.1915	0.6809	0.1064	0.0213	0.0000	0.0000	0.0000	0.0000	0.0000

Table 2.12. Greater Amberjack: Age compositions from the Marine Recreational Fisheries Statistics Survey (MRFSS).

Year	N	1	2	3	4	5	6	7	8	9	10
2001	30	0.0000	0.5667	0.2000	0.2333	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2002	233	0.0129	0.1931	0.4163	0.2446	0.0815	0.0258	0.0215	0.0000	0.0000	0.0043
2003	564	0.0213	0.1649	0.4947	0.2394	0.0337	0.0248	0.0148	0.0035	0.0035	0.0000
2004	378	0.0185	0.1270	0.1931	0.4418	0.1349	0.0503	0.0185	0.0053	0.0053	0.0052
2005	358	0.0028	0.2011	0.1397	0.2402	0.2514	0.1201	0.0196	0.0196	0.0000	0.0056
2006	133	0.0150	0.2030	0.1353	0.2707	0.1429	0.1053	0.0677	0.0301	0.0226	0.0075

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

	CPUE			Coefficient of Variation (CV)		
	Logbook	Recreational		Logbook	Recreational	
Year	Hook & Line	Headboat	MRFSS	Hook & Line	Headboat	MRFSS
1978		1.277			0.101	
1979		1.228			0.113	
1980		1.362			0.120	
1981		0.861			0.215	
1982		1.243			0.126	
1983		1.295			0.116	
1984		1.085			0.139	
1985		0.998			0.137	
1986		1.498	0.966		0.103	0.181
1987		1.382	1.178		0.107	0.283
1988		0.965	0.878		0.148	0.192
1989		0.713	1.044		0.231	0.300
1990		0.869	1.013		0.231	0.180
1991		1.232	1.173		0.158	0.163
1992		0.770	1.181		0.193	0.170
1993	0.849	0.619	1.149	0.278	0.221	0.144
1994	0.904	0.794	1.151	0.236	0.190	0.159
1995	1.048	0.614	0.860	0.216	0.224	0.204
1996	0.947	0.919	1.193	0.222	0.177	0.177
1997	0.907	0.544	1.009	0.224	0.300	0.215
1998	0.935	0.511	0.962	0.261	0.262	0.202
1999	0.740	0.860	0.852	0.283	0.194	0.143
2000	0.904	1.056	0.860	0.272	0.190	0.144
2001	0.979	0.904	0.795	0.243	0.184	0.211
2002	1.024	1.712	1.026	0.242	0.130	0.152
2003	1.009	1.676	1.010	0.263	0.152	0.115
2004	1.427	0.805	0.719	0.250	0.231	0.164
2005	1.301	0.578	0.783	0.270	0.298	0.173
2006	1.026	0.631	0.710	0.300	0.290	0.146

2 Data Review and Updates – Part B (Provided by MARMAP, SCDNR)

This material was provided by the Life History Workgroup following the Assessment Workshop. It was prepared by David Wyanski (MARMAP) and applies in part to red snapper (SAR 1) and amberjack (SAR 2).

<u>Length frequency of headboat discards</u>

The AW Panel requested that actual length frequency data on discards be provided to calculate an estimate of the mean whole weight of discards for comparison with an estimate calculated by utilizing length frequency data from the fishery that were collected prior to implementation of size limits. The actual discard length frequency data came from the "Headboat At-Sea Observer" pilot study in Florida (east coast and Florida Keys) conducted with federal funds by Beverly Sauls (Florida Wildlife Research Institute) in 2005-2006 (See Figures 1 and 2).

For greater amberjack, the estimate of mean whole weight from the pilot study was 3.6 lb versus 4.1 lb based on length data from the headboat fishery that were collected prior to implementation of the 71 cm FL (28 inch) size limit in 1992. For red snapper, the estimate of mean whole weight from the pilot study was 1.7 lb versus 1.6 lb based on length data from the headboat fishery that were collected prior to implementation of the 51 cm TL (20 inch) size limit in 1992.

<u>Depth distribution of red snapper</u>

Fishery-independent data from the MARMAP program at S. Carolina Dept. of Natural Resources were analyzed to examine the relationship between size of red snapper and water depth. There was interest within the AW panel in finding some information about the habitat of red snapper prior to full recruitment (i.e., ages 0-1) to the fishery. A two-way table of total length versus depth of collection revealed that 88% of the smallest (<20 cm TL; n = 98) fish are found at depths of 11-20 m, indicating that essential habitat for juvenile (ages 0-1) red snapper is likely in this depth range, perhaps in non-reef areas (Table 1). Additional research is required to describe the habitat of juveniles because MARMAP currently does minimal sampling at depths <20 m.

<u>Minor addition to section *2.5.3. Age Patterns* in Data Workshop report</u>

Add 1982 as strong year class.

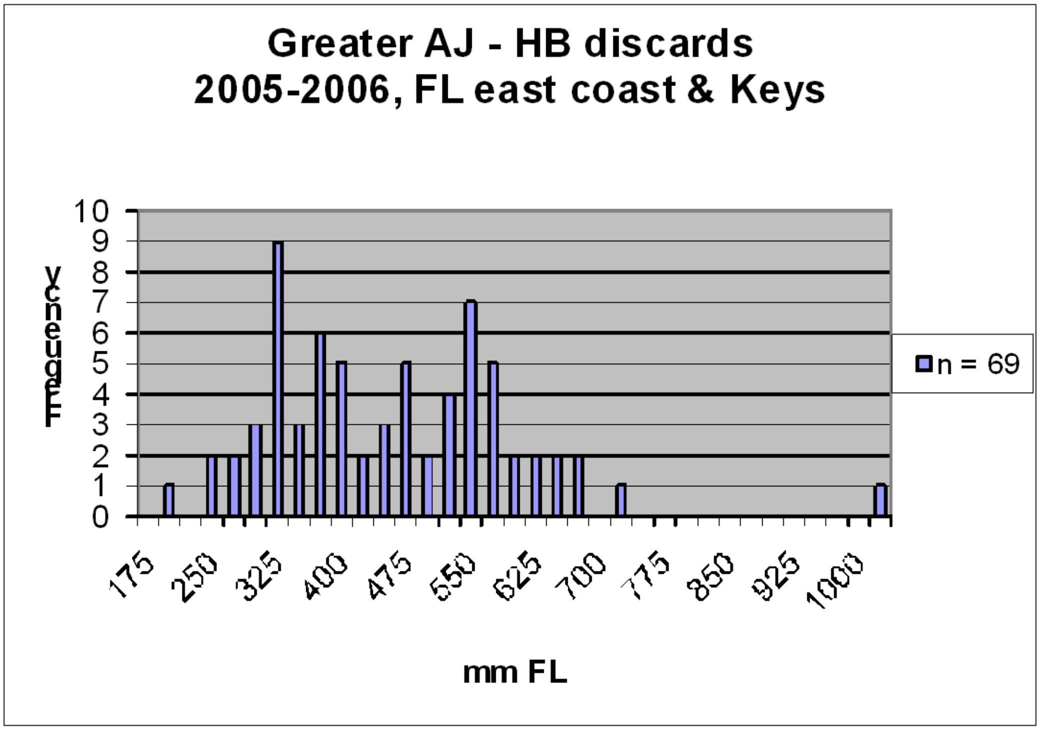


Figure 1. Length frequency of discarded greater amberjack that were measured during the "Headboat At-Sea Observer" pilot study in Florida (east coast and Florida Keys) conducted with federal funds by Beverly Sauls (Florida Wildlife Research Institute) in 2005-2006.

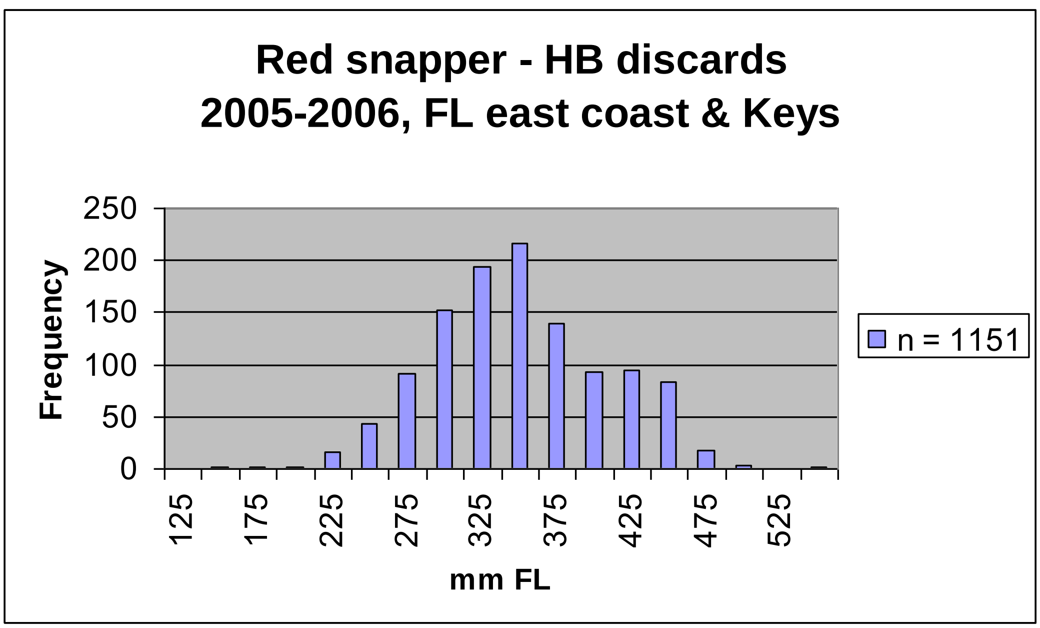


Figure 2. Length frequency of discarded red snapper that were measured during the "Headboat At-Sea Observer" pilot study in Florida (east coast and Florida Keys) conducted with federal funds by Beverly Sauls (Florida Wildlife Research Institute) in 2005-2006.

Percent		Depth (m)					
cm TL	**N**	**11-20**	**21-30**	**31-40**	**41-50**	**51-60**	**61-72**
2-10	31	100.00	0.00	0.00	0.00	0.00	0.00
11-20	67	82.09	10.45	0.00	5.97	0.00	1.49
21-30	97	9.28	45.36	21.65	23.71	0.00	0.00
31-40	132	0.00	53.79	21.21	21.97	0.76	2.27
41-50	184	0.54	28.26	32.07	16.30	16.30	6.52
51-60	73	0.00	8.22	26.03	23.29	32.88	9.59
61-70	30	0.00	6.67	36.67	20.00	36.67	0.00
71-80	6	0.00	33.33	16.67	16.67	16.67	16.67
81-92	5	0.00	40.00	20.00	0.00	20.00	20.00
Total	625						

Table 1. Percentage of red snapper captured in depth zones by total length interval. Data were collected during fishery-independent sampling by the MARMAP program at S. Carolina Dept. of Natural Resources. Primary gear types represented by the samples were chevron trap, Yankee trawl, and hook-and-line.

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 South Atlantic greater amberjack fisheries: commercial handline, commercial diving, general recreational (MRFSS), and headboat. These data included annual landings by fishery, annual discard mortalities by fishery (excluding commercial diving), annual length composition of landings by fishery in fork length, annual age composition of landings by fishery, and three fishery dependent indices of abundance (commercial handline, general recreational (MRFSS), and headboat). These data are tabulated in §III (2) of this report. The general recreational fishery has been sampled since 1981 by the MRFSS. 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 (0.2 deaths per released fish in the commercial sector and in the recreational sectors).

3.1.1.3 Model Configuration and Equations Model equations are detailed in Table 3.1 and AD Model Builder code for implementation in Appendix A. 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 re-scaled by a scalar multiple to provide a fraction of survivors at the oldest age consistent with the findings of Hoenig (1983).

Stock dynamics In the assessment model, new biomass was acquired through growth and recruitment while the population size of existing cohorts experienced exponential decay from fishing and natural mortality. The population was assumed closed to immigration and emigration (no net migration to or from the study area). The oldest age class 10+ allowed for the accumulation of fish (i.e., plus group). The initial stock biomass was assumed to be equal to the unfished (virgin) level in 1946, because minimal landings had occurred prior to the first year of the model.

Growth and maturity Mean size at age (fork length) was modeled with the von Bertalanffy equation and weight at age as a function of length. Mean size and maturity at age 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 the coefficient of variation (constant across ages) 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 corresponding to spawning peaks. For greater amberjack, peak spawning was considered to occur at the end of the first quarter 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 (1979–2006), 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 landings in pounds from four fisheries were modeled: commercial handline, commercial diving, headboat, and general recreational (MRFSS). Landings were modeled via the Baranov catch equation (Baranov 1918), in units of 1000 lb whole weight.

Discards Starting in 1992 with the implementation of size-limit regulations, time series of discard numbers (in units of 1000 fish) were modeled for each fishery except commercial diving. As with landings, discards were estimated via the Baranov catch equation (Baranov 1918), which required estimates of discard selectivities (described below) and release mortality rates. The assessment model fit discard estimates from the commercial (1992–2006) and general recreational (MRFSS, 1946–2006) fisheries. The headboat discards were modeled by applying the fishery landings F's to the discard selectivity (1992–2006), thus no fitting was required for these estimates.

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. All landings selectivities were estimated using 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 landed fish from each fishery was fixed within each period of size-limit regulations, but was permitted to vary among the two different periods (no regulations prior to 1992 and a 28 and 36 inch FL minimum size limit for recreational and commercial fisheries respectively beginning in 1992). 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.

Discard selectivity in the general recreational (MRFSS) fishery was assumed equal to the landings selectivity because there are no estimates of the size or age of these discards. For the headboat and commercial handline fisheries, discards were assumed to occur only after the implementation of the minimum size regulations. Discard selectivities for these fisheries were computed as the re–scaled difference between pre– and post–minimum size regulation fishery landings selectivities.

Indices of abundance The model was initially fit to three fishery dependent indices of abundance: headboat (1978–2006), MRFSS (1983–2006), and commercial handline (1993–2006). Predicted indices were computed from number at age at the midpoint of the year. The AW agreed that the MRFSS index was the least reliable and did not correlate well with the headboat and commercial handline indices, therefore it was dropped from the final base model run.

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 South Atlantic and Gulf of Mexico gag assessments. 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 recruitment 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 several 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 annual recruitment deviations (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 a largely unsolved problem in statistical catch-at-age modeling.

The number of likelihood 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 was done by group consensus and 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).

Much of the time during the AW was spent examining various weighting schemes. 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: Likelihood component weight for commercial handline abundance index =100
- S2: Likelihood component weight for commercial handline abundance index =300
- S3: Likelihood component weight for commercial handline abundance index =400
- S4: Likelihood component weight for commercial handline abundance index =500
- S5: Likelihood component weight for commercial handline abundance index =600
- S6: Likelihood component weight for commercial handline abundance index =700
- S7: Likelihood component weight for commercial handline abundance index =800
- S8: Likelihood component weight for commercial handline abundance index =900
- S9: Likelihood component weight for commercial handline abundance index =1000
- S10: Low M at age, computing by re-scaling the Lorenzen estimates to provide cumulative survival to the upper bound (5%) of Hoenig (1983)
- S11: High M at age, computing by re-scaling the Lorenzen estimates to provide cumulative survival to the lower bound (1%) of Hoenig (1983)
- S12: Slope of linear annual increase in catchability is 0.00 (i.e., constant catchability q)
- S13: Slope of linear annual increase in catchability is 0.04
- S14: Recruitment deviations begin in 1977
- S15: Recruitment deviations begin in 1981
- S16: MRFSS abundance index included
- S17: Retrospective analysis with terminal year of 2005
- S18: Retrospective analysis with terminal year of 2004
- S19: Retrospective analysis with terminal year of 2003
- S20: Retrospective analysis with terminal year of 2002
- S21: Retrospective analysis with terminal year of 2001

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, a total of 328 parameters.

3.1.1.5 **Benchmark/Refence Point Methods** In this assessment of greater amberjack, the quantities F_{MSY}, $\mathrm{SSB}_{\mathrm{MSY}}$, B_{MSY}, and MSY were estimated by the method of Shepherd (1982). In that method, the point of maximum yield is 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 0.25. 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 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 $n = 1,000$ 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 estimated in the assessment, as was the autocorrelation of residuals. The 10^{th} and 90^{th} percentiles from $n = 1,000$ projection replicates were used to quantify uncertainty in future time series.

3.1.1.7 **Projection methods** Ten–year projections were run to estimate stock status between the terminal year of the assessment and the beginning of year 2016. 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. Fully selected F was apportioned between landings and discard mortalities according to the selectivity curves averaged across fisheries, using geometric the mean F from the last three years of the assessment period (Table 3.2).

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, 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: $F = F_{\text{current}}$, defined as the geometric mean F of 2004–2006
- Scenario 2: $F = F_{\text{MSY}}$
- Scenario 3: $F = 65\%F_{\text{MSY}}$
- Scenario 4: $F = 75\%F_{\text{MSY}}$
- Scenario 5: $F = 85\%F_{\text{MSY}}$

3.1.2 Model 1 Results

3.1.2.1 Measures of Overall Model Fit Overall, the base run 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 (Figures 3.2–3.9).

The model fit observed commercial and recreational landings closely (Figures 3.10–3.13, Tables 3.3–3.4). In addition, it fit well to observed discards (Figures 3.14–3.15, Table 3.5).

Fits to indices of abundance were reasonable (Figures 3.16–3.17). The two indices were positively correlated. Both indices show a two year peak after 2001. The observed commercial handline index values show a peak in 2004–05, while the observed headboat index values show a peak in 2002–03. When the size at entry to the fishery is considered for the commercial handline (36 inch) and headboat (28 inch) the peaks agree, suggesting that both indices track abundance, albeit for different size classes.

3.1.2.2 Parameter Estimates Estimates of all 328 parameters from the catch-at-age model are shown in Appendix B. The coefficient of variation of length for the growth curve was estimated as cv=0.114 (Figure 3.18).

3.1.2.3 Stock Abundance and Recruitment Estimated abundance at age shows a marked reduction of the oldest ages during the 1980s and 1990s (Table 3.6 and Figure 3.19). Annual number of recruits is shown in Table 3.6 (age-1 column) and in Figure 3.20. Notable strength in year classes was predicted to have occurred in 1986 and 2001.

3.1.2.4 Stock Biomass (total and spawning stock) Estimated biomass at age follows a similar pattern of truncation as did abundance (Tables 3.7, 3.8 and Figure 3.21). Total biomass and spawning biomass show nearly identical trends— decline during the 1980s and 1990s, bump up in 2002–03, then back to levels close to MSY (Table 3.9, Figure 3.22).

3.1.2.5 **Fishery Selectivity** Estimated selectivities of landings from commercial handline shift toward older fish with implementation of minimum size regulation (Figures 3.23 and 3.24). In the most recent period, commercial handline fish were estimated to be almost fully selected by age 5 (Figure 3.24). Selectivity of landings from commercial diving estimated full selection at age 4 (Figure 3.25). Similar to commercial handline, landings from headboat fishery showed a shift toward older fish, with full selection at age 2 in the most recent period (Figures 3.26 and 3.27), as did landings from the general recreational fishery, with full selection at age 4 in the most recent period (Figures 3.28 and 3.29).

Estimated selectivities of discard mortality were treated differently for each fishery. The general recreational (MRFSS) discard selectivities were assumed equal to the fishery landings selectivities (Figures 3.30 and 3.31). The selectivities for commercial handline and headboat fisheries were computed from the change in minimum size regulations (Figures 3.32 and 3.33). Commercial handline discards are composed primarily of age 2–4 fish, while the headboat discards are entirely age 1 fish (Figures 3.32 and 3.33).

Average selectivities of landings and of discard mortalities were computed from F-weighted selectivities in the most recent period of regulations (Figures 3.34, 3.35, and 3.36). 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 3.2.

3.1.2.6 **Fishing Mortality** The estimated time series of fishing mortality rate (F) shows a generally increasing trend from the 1980s through the mid-1990s, and then a decline from the 1990s to the present values around $F = 0.23$ (Figure 3.37). In the most recent years, the majority of full F comprised commercial handline and general recreational (MRFSS) landings (Figure 3.37, Table 3.10).

Full F at age is shown in Table 3.9. In any given year, the maximum F at age may be less than that year's fully selected F. This inequality is due to the combination of two features of estimated selectivities: full selection occurs at different ages among gears and some sources of mortality (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 general recreational (MRFSS) and commercial handline sectors (Figures 3.38, 3.39, and 3.40). It is worth noting that minimum size limits have increased the age at full selection and the fishing mortality has reduced the number of older fish, suggesting that current landings are being supported by only 2 to 4 year classes in any given year.

3.1.2.7 **Stock-Recruitment Parameters** The estimated Beverton–Holt spawner-recruit curve is shown in Figure 3.41. Graphical analysis of the residuals indicates a balanced fit (Figure 3.42). Estimated parameters were as follows: steepness $\hat{h} = 0.74$, $\widehat{R_0} = 419797$ and first-order autocorrelation $\hat{\varrho} = 0.02$. Uncertainty in these parameters was estimated through bootstrap analysis of the spawner-recruit curve (Figures 3.43–3.45).

3.1.2.8 **Per–Recruit and Equilibrium Analyses** Static spawning potential ratio (static SPR) shows a trend of decrease from the beginning of the assessment period until the early 1990's, and since has remained relatively constant at levels around 40% to 50% (Figure 3.46, Table 3.11). 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 3.47), as were equilibrium landings, discards, spawning biomass, total biomass, and recruits (Figures 3.48–3.51). 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 $F_{\max} = 0.75$, $F_{30\%} = 0.56$, and $F_{40\%} = 0.34$ (Table 3.12). For this stock of greater amberjack, F_{MSY} corresponded to an F that provided 36% SPR (i.e., $F_{36\%}$), 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 3.41). This approach is consistent with methods used in rebuilding projections (i.e., fishing at F_{MSY} yields MSY from a stock SSB_{MSY}). Reference points estimated were F_{MSY}, MSY, B_{MSY}, SSB_{MSY} and R_{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 $F_{\text{MSY}} = 0.424$/yr, MSY = 2,005,000 lb, $B_{\text{MSY}} = 5,491$ mt, and $\text{SSB}_{\text{MSY}} = 1,940$ mt. Distributions of these benchmarks are shown in Figures 3.43 – 3.45.

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, decline during the 1980s and 1990s, and stable just above MSY since the 1990s (Figure 3.52, Table 3.11). Current stock status was estimated to be $\text{SSB}_{2006}/\text{SSB}_{\text{MSY}} = 1.096$ and $\text{SSB}_{2006}/\text{MSST} = 1.461$, indicating that the stock is not overfished (Table 3.12, Figure 3.53).

The estimated time series of F/F_{MSY} shows a generally increasing trend through the 1980s, steady around MSY in the 1990s, and a steady decline since 2000 (Figure 3.52, Table 3.11). The time series indicates that overfishing is not occurring with the current estimate at $F_{2006}/F_{\text{MSY}} = 0.531$ (Table 3.12, Figure 3.53).

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.

Retrospective analyses did not show any concerning trends, and in general, results of sensitivity analyses were similar to those of the base model run, particularly the qualitative results in the terminal that overfishing is not occurring and the stock is not overfished (Figures 3.54–3.58). Results from other sensitivity runs described in §3.1.1.3 are listed in Table 3.13. The re-scaling of M and changes in the q rate resulted in fairly predictable changes to population estimates. Other sensitivity runs show little change.

A sensitivity analysis for various weights (100–1000) applied to the commercial handline abundance index was conducted in order to determine the best value. The response of individual likelihood components to these weights are shown in Figures 3.59–3.64. For some components the fit is improved with an increasing weight for the commercial handline index, while others show a worse fit. The corresponding fits to the two abundance indices and recruitment estimates for each commercial handline index weight are shown in Figures 3.65–3.67. This sensitivity is one example of the process used during the AW to find weightings perceived to be optimal for all likelihood components. The base run model used a commercial handline index weight of 200, based primarily on the response of the unweighted likelihood fits shown in the first panel of Figure 3.59. Group consensus with regards to visual inspection of model fits was used to select final model weightings.

3.1.2.12 **Projections** As discussed in section §3.1.1.7 constant F rate population projections were conducted for F=F_{current}, $F = F_{\text{MSY}}$, $F = 65\%F_{\text{MSY}}$, $F = 75\%F_{\text{MSY}}$, $F = 85\%F_{\text{MSY}}$. The results are shown in Tables 3.14–3.18 and Figures 3.68–3.72.

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 (Quinn and Deriso 1999), 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 greater amberjack 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 estimating 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 handline (1993–2006), headboat survey (1978–2006), and MRFSS (1983–2006) programs.

All data were input into ASPIC in units of total whole weight. Conversions used to adapt the data provided by the DW into the form used in the surplus–production model are described below.

3.2.1.2.1 Landings The SEDAR 15 data workshop provided landings estimates for commercial and recreational sources from 1946–2006. Landings for 1946 were 0 and therefore were not included in the ASPIC analysis. Commercial landings were converted from gutted pounds to whole pounds using the conversion recommended by the SEDAR 15 Data Workshop. Landings for both headboat and MRFSS recreational data were provided in whole pounds and were not converted for the ASPIC model runs.

3.2.1.2.2 Dead Discards Discard estimates were provided in numbers for commercial and recreational data sources (See §III (2.3)). The following methods for converting number to weight as needed for input to the surplus–production model were based on analyses of changes in length compositions by fishery as well as discussion by the AW.

- **General recreational (MRFSS)(1946–2006)**
  Mean weights by year were calculated by dividing the landings in weight divided by the numbers. The mean weights by year were multiplied by the discarded greater amberjack numbers by year to get the weight of discards. This method was applied before and after regulations since there was no change in the size of landed fish before and after minimum size regulations were implemented in 1992.

- **Headboat and Commercial Handline(1992–2006)**
  The SEDAR 15 AW decided that headboat and commercial handline discards prior to 1992 were unlikely and no discards were estimated for those years. In 1992 the minimum size for greater amberjack was set at 28 inches FL for recreational fishing and 36 inches FL for commercial handline. These minimum size limits correspond to approximately 71 and 91 cm. The GAJ_DW_summary.xls workbook provides length composition data from commercial hook and line and headboat in 1 cm bins. The mean weight of fish discarded after the minimum size limit (1992) was then calculated by fishery as,

$$\frac{\sum_{1}^{r} P_i \, w_i}{\sum_{1}^{r} P_i} \tag{3}$$

  where (P_i) is the average proportion across years up to and including 1991 for each length bin(i) up to the minimum size limit (r) . The length–weight equation provided by the SEDAR 15 DW was used to estimate the weight in whole pounds at each length bin (w_i). The mean weight of discards for the headboat fishery (4.05 lb) and commercial handline fishery (7.40 lb) was then multiplied by the discards in numbers to give discards in pounds. The dead discards were calculated as discards times the discard mortality suggested by the SEDAR 15 DW of 0.2. The dead discards were combined with the total landings for input to the ASPIC model.

3.2.1.2.3 Relative abundance Estimates of relative abundance were provided by the SEDAR 15 DW for the headboat fishery, commercial handline (from logbooks), and general recreational fishery (MRFSS). The following manipulations were required to get the data in correct units and adjust for expected changes in catchability.

- **Changing catchability for all indices of abundance**
  The increase in catchability for all series of relative abundance was suggested to be 2% per year by the SEDAR 15 DW. We adjusted the relative abundance by dividing each years relative abundance value by an annual catchability factor (1.0 in 1978 to 1.56 in 2006, incremented by 0.02 each year).

- **Commercial Handline**
  The commercial handline index was provided in whole weight in pounds and did not require conversion of units. The commercial handline relative abundance values were adjusted for changes in catchability from 1993 to 2006.

- **Headboat and MRFSS**
  Headboat and MRFSS indices were provided in numbers and were converted to weight for the surplus–production model input. The mean weight by year was calculated by dividing the estimated landings in weight by the estimated landings in number. The indices in number per unit effort were then multiplied by the mean weight in that year to convert to pounds per unit effort. The indices were then rescaled to their mean and adjusted by the annual catchability factor.

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.

Mean weights for the recreational survey (MRFSS) and commercial handline fisheries remained fairly constant pre– and post–minimum size regulation (1992). However, headboat mean weights showed an increase after the implementation of the 28 inch FL size limit regulation (Figure 3.73). For this reason, the headboat index was split into time periods, before and after the 1992 size regulation.

The model would not converge to a reasonable result when allowed to estimate the ratio of initial biomass to carrying capacity (B_1/K) parameter in the model. Therefore we fixed a value of B_1/K=0.85 for the base run. B_1/K values of 0.75, 0.95, and 0.99 were also considered to examine sensitivity to this choice. The base model input file appears in Appendix C.

No projections were run using production model methods. Age-structured projections are considered more realistic and thus provide 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 3.74, 3.75, 3.76, and 3.77. In general, fits were adequate, including the noisy headboat index.

Fits from sensitivity runs were quite similar to those of the base production model (Figure 3.78). As described above, these sensitivity runs included variations in assumptions about B_1/K (B_1/K = 0.75, B_1/K = 0.95, or B_1/K = 0.99).

3.2.2.2 Parameter Estimates and Uncertainty

Parameter estimates from the base surplus production model are printed in Table 3.19, 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 3.79. Estimated relative biomass has dropped slightly below 1 since 2000. The estimate of F_{2006}/F_{MSY} does not indicate severe overfishing in the terminal year; however, estimated F has exceeded F_{MSY} since the mid–1980s.

Sensitivity analyses indicated that qualitative results were invariant to assumptions about starting biomass.

The results from both the surplus–production and age–structured models suggest fairly good agreement in their estimates of relative biomass and fishing mortality rate time series (Figure 3.80).

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 3.19.

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 the total effort weighted selectivity. If selectivity patterns change in the future or if the proportion of the total catch for each fishery changes, for example as a result of new management regulations, estimates of benchmarks would change as well.

The base run of the age-structured assessment model indicated that the stock is not overfished (SSB_{2006}/SSB_{MSY} = 1.096) and that overfishing is not occurring (F_{2006}/F_{MSY} = 0.531). These results were invariant to most of the different configurations used in sensitivity runs and retrospective analyses. The exception was in sensitivity runs with lower M values (re-scaled to 0.05 survivorship) and increased rate on the catchability coefficient (q rate = 0.04) applied to abundance indices. 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, projections and management benchmarks 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 projections, as well as the management benchmarks.
- 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, projections may be affected.

3.4 References

References

Baranov, F. I. 1918. On the question of teh biological basis of fisheries. Nauchnye Issledovaniya Ikhtiologicheskii Instituta Izvestiya **1**:81–128.

Burnham, K. P., D. R. Anderson, G. C. White, C. Brownie, and K. H. Pollock. 1987. Design and analysis methods for fish survival experiments based on release-recapture. American Fisheries Society Monograph **5**:1–437.

Clark, W. G. 2002. $F_{35\%}$ revisited ten years later. North American Journal of Fisheries Management **22**:251–257.

Deriso, R. B., T. J. Quinn, and P. R. Neal. 1985. Catch-age analysis with auxiliary information. Canadian Journal of Fisheries and Aquatic Sciences **42**:815–824.

Fournier, D., and C. P. Archibald. 1982. A general theory for analyzing catch at aage data. Canadian Journal of Fisheries and Aquatic Sciences **39**:1195–1207.

Hannesson, R. 2007. Growth accounting in a fishery. Journal of environmental economics and management **53**:364–376.

Hoenig, J. M. 1983. Empirical use of longevity data to estimate mortality rates. Fishery Bulletin **81**:898–903.

Jin, D., E. Thunberg, H. Kite-Powell, and K. Blake. 2002. Total factor productivity change in teh New England groundfish fishery: 1964–1993. Journal of Environmental Economics and Management **44**:540–556.

Lorenzen, K. 1996. The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural ecosystems and aquaculture. Journal of Fish Biology **49**:627–642.

Mace, P. M. 1994. Relationships between common biological reference points used as thresholds and targets of fisheries management strategies. Canadian Journal of Fisheries and Aquatic Sciences **51**:110–122.

Methot, R. M. 1989. Synthetic estimates of historical abundance and mortality for northern anchovy. American Fisheries Society Symposium **6**:66–82.

Otter Research, 2005. AD Model Builder Version 7.7.1. Otter Research, Ltd., Sidney, B.C., Canada.

Pella, J. J., and P. K. Tomlinson. 1969. A generalized stock production model. Bulletin of the Inter-American Tropical Tuna Commission **13**:419–496.

Prager, M. H. 1994. A suite of extensions to a nonequilibrium surplus-production model. Fishery Bulletin **92**:374–389.

Prager, M. H., 2005. User's Manual for ASPIC: A Stock-Production Model Incorporating Covariates (ver. 5) And Auxiliary Programs. National Marine Fishery Service, Beaufort Laboratory Document BL-2004-01, Beaufort, NC.

Quinn, T. J., and R. B. Deriso. 1999. Quantitative Fish Dynamics. Oxford University Press, New York, New York.

R Development Core Team, 2007. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. URL `http://www.R-project.org`.

Restrepo, V. R., G. G. Thompson, P. M. Mace, L. L. Gabriel, L. L. Wow, A. D. MacCall, R. D. Methot, J. E. Powers, B. L. Taylor, P. R. Wade, and J. F. Witzig, 1998. Technical guidance on the use of precautionary approahces to implementing Natinoal Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum-F/SPO-31.

Schaefer, M. B. 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. Bulletin of the Inter-American Tropical Tuna Commission **1**:27–56.

Schaefer, M. B. 1957. A study of the dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. Bulletin of the Inter-American Tropical Tuna Commission **2**:247–268.

Shepherd, J. G. 1982. A versatile new stock-recruitment relationship for fisheries, and the construction of sustainable yield curves. Journal du Conseil pour l'Exploration de la Mer **40**:67–75.

Williams, E. H., and K. W. Shertzer. 2003. Implications of life-history invariants for biological reference points used in fishery management. Canadian Journal of Fisheries and Aquatic Science **60**:710–720.

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	$y = \{1946 \ldots 2006\}$
Index of ages	a	$a = \{1 \ldots A\}$, where $A = 10^+$
Index of size-limit periods	r	$r = \{1 \ldots 2\}$ where 1 = 1946 − 1991 (no size limit), 2 = 1992 − 2006 (28-inch and 36-inch limits for recreational and commercial, respectively)
Index of length bins	l	$l = \{1 \ldots 25\}$
Length bins	l'	$l' = \{200, 250, \ldots, 1400\}$, with values as midpoints and bin size of 50 mm
Index of fisheries	f	$f = \{1 \ldots 4\}$ where 1=commercial handline, 2=commercial diving, 3=recreational headboat, 4=general recreational (MRFSS)
Index of CPUE	u	$u = \{1 \ldots 2\}$ where 1 = commercial logbook, 2 = headboat
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	Mean of observations
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
Observed abundance indices	$U_{u,y}$	$u = 1$, commercial logbook, $y = \{1993 \ldots 2006\}$ $u = 2$, headboat, $y = \{1978 \ldots 2006\}$

Table 3.1. (continued)

Quantity	Symbol	Description or definition
CVs of abundance indices	$c^U_{u,y}$	$u = \{1 \ldots 2\}$ as above. Annual values estimated from delta-lognormal GLM for commercial and headboat. 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 $f = 1, 4$.
Discard mortality rate	δ_f	Proportion discards by fishery f that die. Base-model values from the DW were 0.2 for all fisheries.
Observed discard mortalities	$D_{f,y}$	$D_{f,y} = \delta_f D'_{f,y}$ for $f = 1, 4$
CVs of dead discards	$c^D_{f,y}$	Annual values estimated (for MRFSS) or assumed
Population Model		
Mean length at age	l_a	$l_a = L_\infty(1 - \exp[-K(a - t_0)])$ 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	$s_{f,a,r}$	$s_{f,a,r} = \frac{1}{1+\exp[-\hat{\eta}_{1,f,r}(a - \hat{\alpha}_{1,f,r})]}$: for $f = 1, 2, 3, 4$; $r = 1, 2$ where $\hat{\eta}_{1,f,r}$ and $\hat{\alpha}_{1,f,r}$ are fishery-specific parameters estimated for each regulation period. Selectivity of commercial diving is assumed constant across regulation periods. Curves were rescaled, if necessary, to have a maximum of one.
Discard selectivity	$s'_{f,a,r}$	$s'_{f,a,r} = \begin{cases} s_{f,a,2} - s_{f,a,1} & : \text{for } f = 1, 3;\ r = 2 \\ s_{f,a,r} & : \text{for } f = 4;\ r = 1, 2 \end{cases}$ Curves were rescaled, if necessary, to have a maximum of one.
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, but for headboat, was assumed equal to $\hat{F}_{f,y}$.
Total fishing mortality rate	F_y	$F_y = \sum_f \left(\hat{F}_{f,y} + \hat{F}^D_{f,y}\right)$
Total mortality rate	$Z_{a,y}$	$Z_{a,y} = M_a + \sum_{f=1}^{4} F_{f,a,y} + \sum_{f=1,3,4} F^D_{f,a,y}$

Table 3.1. (continued)

Quantity	Symbol	Description or definition
Abundance at age	$N_{a,y}$	$N_{1,1946} = \gamma \hat{R}_0$ $N_{a+1,1946} = N_{a,1946} \exp(-M_a) \quad \forall a \in (1 \ldots A-1)$ $N_{A,1946} = N_{A-1,1946} \frac{\exp(-M_{A-1})}{1-\exp(-M_A)}$ $N_{0,y+1} = \begin{cases} \frac{0.8\hat{R}_0 \hat{h} S_y}{0.2\phi_0 \hat{R}_0(1-\hat{h})+(\hat{h}-0.2)S_y} \varsigma & \text{for } y+1 < 1979 \\ \frac{0.8\hat{R}_0 \hat{h} S_y}{0.2\phi_0 \hat{R}_0(1-\hat{h})+(\hat{h}-0.2)S_y} \exp(\hat{R}_{y+1}) & \text{for } y+1 \geq 1979 \end{cases}$ $N_{a+1,y+1} = N_{a,y} \exp(-Z_{a,y}) \quad \forall a \in (1 \ldots A-1)$ $N_{A,y} = N_{A-1,y-1} \frac{\exp(-Z_{A-1,y-1})}{1-\exp(-Z_{A,y-1})}$ where 1946 is the initialization year and $\gamma = 1$ scales the initial abundance 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 $y \geq 1979$ and are zero otherwise. Bias correction $\varrho = \exp(\sigma^2/2)$, where σ^2 is the variance of recruitment deviations during 1979–2003. 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 end of 1st quarter $N''_{a,y} = N_{a,y} \exp(-Z_{a,y}/4)$
Unfished abundance at age per recruit at time of spawning	NPR_a	$NPR_1 = 1 \exp(-M_1/4)$ $NPR_{a+1} = NPR_a \exp[-(3M_a/4 + M_{a+1}/4)] \quad \forall a \in (1 \ldots A-1)$ $NPR_A = \frac{NPR_A}{1-\exp(-M_A)}$
Unfished mature biomass per recruit	ϕ_0	$\phi_0 = \sum_a NPR_a w_a \rho_{a,y} m_a$
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		

Table 3.1. (continued)

Quantity	Symbol	Description or definition
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. Bins are 50 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
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 $\omega_3 = 15$ 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	$\Lambda_4 = \omega_4 \sum_{f} \sum_{y} \frac{\left[\log\left((\delta_f D_{f,y}+x)/(\check{D}_{f,y}+x)\right)\right]^2}{2(c^D_{f,y})^2} \quad \text{for } f = 1,4$ where $\omega_4 = 15$ 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 $\omega_{5,1} = 200$ and $\omega_{5,(2,3)} = 100$ are preset weights for $u = 1,2$ and x =1e-5 is an arbitrary value to avoid log zero or division by zero
Constraint on recruitment deviations	Λ_6	$\Lambda_6 = \omega_6 \left[R^2_{1979} + \sum_{y>1979} (R_y - \hat{\varrho} R_{y-1})^2 \right]$ where R_y are recruitment deviations in log space, $\omega_6 = 1$ is a preset weight and $\hat{\varrho}$ is the estimated first-order autocorrelation
Additional constraint on recruitment deviations	Λ_7	$\Lambda_7 = \omega_7 \left(\sum_{y \geq 2004} R^2_y \right)$ where $\omega_7 = 10$ is a preset weight
Constraint on F_y	Λ_8	$\Lambda_8 = \omega_8 \sum_{y} I_y (F_y - \Psi)^2$ where $\omega_8 = 1$ 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. Greater amberjack: Model estimated selectivity at age by fishery (only 1992–2006 estimates indicated).

Age	Length (mm)	Length (in)	c.hal	c.dv	hb	mrfss	D.c.hal	D.hb	D.mrfss	L.avg	D.avg	L.avg+D.avg
1	467.9	18.4	0.0002	0.0000	0.0419	0.0316	0.0074	0.9986	0.0316	0.0126	0.0257	0.0383
2	678.7	26.7	0.0042	0.0000	0.9990	0.2930	0.1504	0.0029	0.2930	0.1320	0.0288	0.1607
3	828.3	32.6	0.0864	0.2443	1.0000	0.8403	0.9984	0.0000	0.8403	0.3798	0.0964	0.4762
4	934.5	36.8	0.6813	0.9999	1.0000	0.9853	0.4808	0.0000	0.9853	0.7507	0.0958	0.8465
5	1009.9	39.8	0.9797	1.0000	1.0000	0.9988	0.0311	0.0000	0.9988	0.9043	0.0858	0.9901
6	1063.3	41.9	0.9991	1.0000	1.0000	0.9999	0.0014	0.0000	0.9999	0.9144	0.0851	0.9995
7	1101.3	43.4	1.0000	1.0000	1.0000	1.0000	0.0001	0.0000	1.0000	0.9149	0.0851	1.0000
8	1128.2	44.4	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	0.9149	0.0851	1.0000
9	1147.3	45.2	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	0.9149	0.0851	1.0000
10	1160.9	45.7	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	0.9149	0.0851	1.0000

Table 3.3. Greater amberjack– Base run: Model estimated time series of landings in number for each fishery.

Year	C.HAL	C.Diving	Headboat	MRFSS	Total
1946	0	0	0	0	0
1947	262	0	733	822	1817
1948	525	0	980	1645	3150
1949	789	0	1226	2470	4485
1950	914	0	1474	3297	5685
1951	825	0	1722	4126	6673
1952	1423	0	1972	4956	8351
1953	1138	0	2222	5789	9149
1954	744	0	2474	6624	9842
1955	321	0	2727	7461	10509
1956	494	0	2981	8300	11775
1957	98	0	3236	9141	12475
1958	687	0	3493	9986	14166
1959	1594	0	3753	10836	16183
1960	1123	0	4016	11690	16829
1961	174	0	4279	12547	17000
1962	248	0	4543	13406	18197
1963	251	0	4808	14270	19329
1964	257	0	5076	15136	20469
1965	289	0	5346	16007	21642
1966	711	0	5618	16883	23212
1967	741	0	5893	17765	24399
1968	884	0	6171	18652	25707
1969	599	0	6450	19544	26593
1970	1431	0	6733	20443	28607
1971	855	0	7018	21349	29222
1972	372	0	7304	22260	29936
1973	1472	0	7593	23177	32242
1974	1574	0	7886	24105	33565
1975	2011	0	8184	25043	35238
1976	2288	0	8485	25992	36765
1977	2225	0	8789	26946	37960
1978	1416	0	9096	28128	38640
1979	2045	0	8930	29589	40564
1980	2308	0	9905	32648	44861
1981	3184	0	7363	54204	64751
1982	5870	0	14917	27010	47797
1983	3966	0	7228	12388	23582
1984	6953	0	14617	77993	99563
1985	6009	0	7945	58880	72834
1986	13256	1049	12215	96312	122832
1987	36542	3094	19420	82882	141938
1988	39520	3270	10932	74477	128199
1989	39526	3890	6571	58199	108186
1990	43118	4359	9116	54069	110662
1991	53452	5188	13673	46641	118954
1992	47825	5998	10463	64406	128692
1993	43386	4012	9874	40126	97398
1994	45416	5206	7379	68835	126836
1995	43527	4210	4403	39337	91477
1996	39582	3325	5818	54194	102919
1997	38863	3911	2755	41037	86566
1998	34330	3396	3246	28664	69636
1999	28580	2761	4612	90512	126465
2000	27372	4728	7992	46112	86204
2001	32963	1990	6375	42327	83655
2002	32988	3150	6270	53056	95464
2003	29530	2701	8016	69622	109869
2004	42291	2461	4007	52325	101084
2005	37253	1760	1536	26742	67291
2006	19427	1348	1960	27597	50332

Table 3.4. Greater amberjack– Base run: Model estimated time series of landings in gutted weight (klb) for each fishery.

Year	C.HAL	C.Diving	Headboat	MRFSS	Total
1946	0	0	0	0	0
1947	8	0	14	24	46
1948	15	0	19	48	82
1949	23	0	24	72	119
1950	26	0	29	97	152
1951	24	0	33	121	178
1952	41	0	38	145	224
1953	33	0	43	169	245
1954	21	0	48	193	262
1955	9	0	52	217	278
1956	14	0	57	241	312
1957	3	0	62	265	330
1958	20	0	67	290	377
1959	45	0	72	314	431
1960	32	0	76	338	446
1961	5	0	81	362	448
1962	7	0	86	386	479
1963	7	0	91	410	508
1964	7	0	95	434	536
1965	8	0	100	459	567
1966	20	0	105	483	608
1967	21	0	110	507	638
1968	25	0	115	531	671
1969	17	0	119	555	691
1970	40	0	124	580	744
1971	24	0	129	604	757
1972	10	0	134	628	772
1973	41	0	138	653	832
1974	43	0	143	677	863
1975	55	0	148	702	905
1976	63	0	153	726	942
1977	61	0	157	751	969
1978	39	0	162	782	983
1979	56	0	167	828	1051
1980	63	0	172	905	1140
1981	88	0	149	1537	1774
1982	160	0	262	754	1176
1983	112	0	120	341	573
1984	186	0	270	2156	2612
1985	157	0	137	1588	1882
1986	354	30	153	2376	2913
1987	892	90	267	1947	3196
1988	872	85	180	1745	2882
1989	943	99	117	1428	2587
1990	1112	120	118	1296	2646
1991	1322	150	155	1030	2657
1992	1376	156	158	1187	2877
1993	1111	95	157	747	2110
1994	1166	126	120	1342	2754
1995	1149	104	79	796	2128
1996	1065	85	93	1090	2333
1997	1067	99	50	832	2048
1998	917	87	54	582	1640
1999	795	72	70	1712	2649
2000	726	115	130	870	1841
2001	854	49	98	790	1791
2002	876	79	87	937	1979
2003	760	63	136	1326	2285
2004	1084	60	83	1158	2385
2005	1039	48	33	653	1773
2006	587	39	40	665	1331

Table 3.5. Greater amberjack– Base run: Model estimated time series of dead discards in number for each fishery.

Year	C.HAL	Headboat	MRFSS	Total
1947	0	0	113	113
1948	0	0	226	226
1949	0	0	339	339
1950	0	0	452	452
1951	0	0	565	565
1952	0	0	678	678
1953	0	0	792	792
1954	0	0	905	905
1955	0	0	1018	1018
1956	0	0	1131	1131
1957	0	0	1244	1244
1958	0	0	1357	1357
1959	0	0	1470	1470
1960	0	0	1583	1583
1961	0	0	1696	1696
1962	0	0	1809	1809
1963	0	0	1922	1922
1964	0	0	2036	2036
1965	0	0	2149	2149
1966	0	0	2262	2262
1967	0	0	2375	2375
1968	0	0	2488	2488
1969	0	0	2601	2601
1970	0	0	2715	2715
1971	0	0	2828	2828
1972	0	0	2941	2941
1973	0	0	3055	3055
1974	0	0	3168	3168
1975	0	0	3282	3282
1976	0	0	3395	3395
1977	0	0	3509	3509
1978	0	0	3630	3630
1979	0	0	3772	3772
1980	0	0	3943	3943
1981	0	0	5656	5656
1982	0	0	3184	3184
1983	0	0	4132	4132
1984	0	0	6470	6470
1985	0	0	9716	9716
1986	0	0	10722	10722
1987	0	0	8536	8536
1988	0	0	6536	6536
1989	0	0	5295	5295
1990	0	0	6486	6486
1991	0	0	7262	7262
1992	1128	5620	8056	14804
1993	1190	5929	7062	14181
1994	1662	2242	4735	8639
1995	1596	4048	5066	10710
1996	2009	1331	5272	8612
1997	2123	2033	5615	9771
1998	1894	3055	5562	10511
1999	1623	2065	7348	11036
2000	1726	6143	8359	16228
2001	1809	8086	9515	19410
2002	1650	2065	9943	13658
2003	1381	1099	11259	13739
2004	1197	1067	12302	14566
2005	1157	717	9087	10961
2006	1303	1758	7825	10886

Table 3.6. Greater amberjack: Estimated abundance at age (1000s) at start of year

Year	1	2	3	4	5	6	7	8	9	10
1946	499.3	307.9	217.1	161.9	124.3	97.1	76.7	61.0	48.8	199.4
1947	506.2	307.9	217.1	161.9	124.3	97.1	76.7	61.0	48.8	199.4
1948	506.2	312.0	217.0	161.7	124.1	97.0	76.6	60.9	48.7	198.9
1949	506.2	311.9	219.8	161.5	123.8	96.7	76.3	60.7	48.5	198.2
1950	506.1	311.8	219.6	163.4	123.5	96.3	75.9	60.4	48.2	197.0
1951	506.0	311.7	219.5	163.2	124.9	95.9	75.5	60.0	47.9	195.6
1952	505.9	311.6	219.3	163.0	124.6	96.8	75.1	59.6	47.5	193.9
1953	505.7	311.5	219.1	162.7	124.2	96.4	75.7	59.1	47.1	191.8
1954	505.6	311.3	219.0	162.5	123.9	96.1	75.3	59.5	46.7	189.6
1955	505.4	311.1	218.8	162.3	123.7	95.7	74.9	59.1	46.9	187.3
1956	505.2	310.9	218.6	162.1	123.5	95.5	74.6	58.8	46.6	185.5
1957	505.0	310.8	218.3	161.8	123.2	95.2	74.3	58.4	46.2	183.4
1958	504.8	310.6	218.1	161.6	122.9	94.9	74.0	58.1	45.9	181.3
1959	504.6	310.4	217.9	161.3	122.5	94.5	73.6	57.7	45.6	179.0
1960	504.3	310.2	217.6	160.8	122.0	94.0	73.1	57.3	45.1	176.3
1961	504.0	309.9	217.4	160.6	121.6	93.5	72.6	56.8	44.7	173.7
1962	503.8	309.7	217.2	160.5	121.4	93.2	72.2	56.4	44.3	171.2
1963	503.5	309.4	216.9	160.2	121.2	92.9	71.8	56.0	43.9	168.7
1964	503.3	309.2	216.6	159.8	120.8	92.5	71.5	55.6	43.5	166.0
1965	503.0	308.9	216.3	159.5	120.4	92.1	71.1	55.2	43.1	163.4
1966	502.7	308.7	216.1	159.2	120.0	91.7	70.7	54.8	42.8	160.7
1967	502.4	308.4	215.8	158.8	119.6	91.2	70.2	54.4	42.4	157.9
1968	502.1	308.1	215.5	158.4	119.1	90.7	69.6	53.9	41.9	155.1
1969	501.7	307.9	215.2	158.1	118.7	90.2	69.1	53.4	41.4	152.2
1970	501.4	307.6	214.9	157.8	118.3	89.7	68.6	52.9	41.0	149.4
1971	501.0	307.3	214.5	157.3	117.8	89.2	68.1	52.3	40.5	146.4
1972	500.7	307.0	214.2	157.0	117.4	88.7	67.6	51.8	40.0	143.5
1973	500.3	306.6	213.9	156.7	117.0	88.3	67.1	51.4	39.6	140.6
1974	500.0	306.3	213.5	156.1	116.5	87.8	66.6	50.8	39.1	137.6
1975	499.5	306.0	213.2	155.7	115.9	87.2	66.0	50.3	38.6	134.6
1976	499.1	305.6	212.8	155.2	115.3	86.5	65.4	49.7	38.0	131.5
1977	498.7	305.3	212.4	154.7	114.7	85.8	64.7	49.1	37.5	128.3
1978	498.2	304.9	212.0	154.3	114.2	85.2	64.1	48.5	36.9	125.2
1979	367.7	304.5	211.6	153.9	113.8	84.7	63.5	47.9	36.4	122.2
1980	605.9	224.6	211.1	153.3	113.1	84.1	62.8	47.2	35.8	118.9
1981	125.6	369.8	155.5	152.5	112.2	83.1	61.9	46.4	35.0	115.1
1982	622.7	76.5	254.2	110.5	108.4	79.2	58.5	43.6	32.7	106.3
1983	543.7	378.6	52.7	182.2	80.2	79.0	57.9	42.9	32.1	102.9
1984	226.5	333.0	263.9	38.4	135.5	60.3	59.8	44.1	32.8	103.6
1985	469.7	136.5	224.8	181.2	25.9	89.6	39.4	39.0	28.7	89.2
1986	1053.6	284.9	93.1	156.6	124.8	17.6	60.2	26.4	26.2	79.4
1987	377.3	634.7	190.9	62.0	100.2	77.0	10.6	36.1	15.8	63.4
1988	190.3	226.2	420.9	121.8	37.4	58.4	44.1	6.0	20.5	45.1
1989	227.1	114.5	151.0	271.9	74.7	22.2	34.1	25.6	3.5	38.2
1990	714.0	137.3	77.0	98.3	168.9	45.3	13.3	20.3	15.2	24.9
1991	630.0	431.1	91.8	48.7	58.4	97.8	25.9	7.6	11.6	22.9
1992	474.6	379.4	285.8	55.3	26.9	31.5	52.1	13.7	4.0	18.3
1993	507.1	286.6	250.5	175.6	27.7	12.5	14.7	24.4	6.5	10.6
1994	249.9	306.8	192.9	164.1	100.3	15.0	6.8	8.0	13.4	9.4
1995	621.1	151.5	203.4	120.0	89.2	52.0	7.8	3.6	4.2	12.1
1996	180.0	378.4	102.4	133.4	69.7	49.6	29.1	4.4	2.0	9.3
1997	450.7	109.4	252.1	64.4	74.8	37.6	26.9	15.9	2.4	6.3
1998	638.8	275.2	73.8	163.3	36.6	40.5	20.5	14.8	8.8	4.8
1999	359.3	390.2	187.1	49.0	98.3	21.4	23.8	12.1	8.8	8.1
2000	557.6	218.1	253.0	108.8	25.3	49.0	10.7	12.0	6.2	8.6
2001	1054.1	337.4	145.6	161.8	62.7	14.1	27.5	6.1	6.8	8.4
2002	387.4	640.9	227.0	94.8	96.1	36.1	8.2	16.1	3.6	9.0
2003	136.4	236.3	432.7	148.5	56.4	55.4	21.0	4.8	9.4	7.4
2004	190.5	82.9	158.3	280.1	89.5	33.3	33.0	12.6	2.9	10.2
2005	267.7	116.1	55.8	103.0	169.0	52.7	19.8	19.7	7.5	7.9
2006	498.0	164.0	79.2	37.3	64.8	104.3	32.8	12.4	12.4	9.8
2007	372.2	304.6	111.3	52.5	23.9	41.2	66.9	21.2	8.0	14.5

Table 3.7. Greater amberjack: Estimated biomass at age (mt)

Year	1	2	3	4	5	6	7	8	9	10
1946	673.1	1205.4	1504.6	1585.2	1520.2	1377.1	1202.7	1025.3	860.0	3634.3
1947	682.4	1205.4	1504.6	1585.2	1520.2	1377.1	1202.7	1025.3	860.0	3634.3
1948	682.4	1221.5	1503.4	1583.4	1517.9	1374.5	1200.3	1023.2	858.1	3626.6
1949	682.4	1221.2	1522.9	1580.9	1514.2	1370.3	1196.0	1019.4	854.8	3612.4
1950	682.3	1220.9	1521.9	1600.0	1510.0	1365.0	1190.4	1014.0	850.1	3591.8
1951	682.1	1220.4	1520.9	1597.8	1526.6	1359.3	1183.9	1007.6	844.3	3565.6
1952	682.0	1219.9	1519.8	1595.8	1523.3	1372.7	1177.5	1000.7	837.8	3534.9
1953	681.8	1219.4	1518.5	1592.9	1518.8	1367.0	1186.6	993.1	830.2	3497.1
1954	681.6	1218.8	1517.2	1590.9	1515.0	1361.8	1180.4	999.6	822.9	3456.7
1955	681.3	1218.1	1515.9	1589.1	1512.3	1357.3	1174.7	993.3	827.4	3414.8
1956	681.1	1217.4	1514.5	1587.2	1509.9	1353.8	1169.7	987.5	821.3	3381.6
1957	680.8	1216.6	1513.0	1584.5	1506.3	1349.6	1164.8	981.6	815.0	3344.2
1958	680.5	1215.9	1511.5	1582.4	1502.9	1345.3	1159.9	976.3	809.2	3305.7
1959	680.3	1215.1	1509.9	1578.9	1498.3	1339.4	1153.6	970.0	803.0	3262.7
1960	679.9	1214.3	1508.0	1574.8	1491.8	1331.9	1145.5	962.0	795.5	3214.5
1961	679.5	1213.4	1506.4	1572.4	1487.1	1325.1	1137.9	954.2	788.0	3166.9
1962	679.2	1212.4	1504.8	1571.0	1485.0	1320.6	1131.5	947.3	781.1	3121.6
1963	678.8	1211.4	1502.9	1568.0	1481.8	1316.6	1125.7	940.3	774.1	3074.7
1964	678.5	1210.5	1501.0	1564.8	1477.3	1311.9	1120.5	933.8	767.0	3026.7
1965	678.1	1209.5	1499.1	1561.7	1472.6	1305.9	1114.5	927.8	760.3	2977.9
1966	677.7	1208.5	1497.2	1558.5	1467.8	1299.7	1107.5	921.1	753.9	2928.7
1967	677.3	1207.5	1495.2	1554.6	1462.3	1292.8	1099.6	913.1	746.6	2878.2
1968	676.9	1206.4	1493.2	1551.2	1456.8	1285.7	1091.7	904.8	738.6	2827.2
1969	676.4	1205.3	1491.0	1547.6	1451.5	1278.6	1083.5	896.3	730.3	2775.1
1970	675.9	1204.2	1488.9	1544.5	1446.8	1272.2	1075.8	888.1	722.2	2723.5
1971	675.5	1203.0	1486.5	1539.8	1440.4	1264.5	1067.2	879.0	713.3	2668.5
1972	675.0	1201.8	1484.4	1536.8	1435.0	1257.6	1059.3	870.7	705.0	2615.4
1973	674.5	1200.5	1482.2	1533.8	1431.2	1251.5	1052.1	863.1	697.3	2563.9
1974	674.0	1199.2	1479.5	1528.5	1424.3	1244.0	1043.3	854.0	688.5	2508.8
1975	673.4	1198.0	1477.1	1524.1	1417.1	1235.5	1034.5	844.7	679.5	2453.5
1976	672.9	1196.6	1474.6	1519.4	1410.0	1226.0	1024.5	835.1	670.1	2396.9
1977	672.3	1195.1	1471.9	1514.8	1402.9	1216.9	1013.8	824.6	660.6	2339.6
1978	671.6	1193.6	1469.2	1510.5	1396.5	1208.3	1003.9	814.0	650.6	2282.9
1979	495.8	1192.1	1466.4	1507.2	1391.5	1201.1	995.2	804.7	641.1	2228.0
1980	816.8	879.4	1462.9	1500.8	1383.4	1191.5	984.4	793.5	630.3	2167.6
1981	169.3	1447.9	1077.7	1493.0	1371.5	1177.8	970.2	779.5	617.2	2098.9
1982	839.5	299.4	1761.7	1081.7	1325.6	1122.8	916.5	732.1	577.2	1938.6
1983	733.0	1482.4	364.9	1783.7	980.3	1120.4	908.2	721.2	566.0	1876.0
1984	305.3	1303.9	1828.4	376.2	1657.3	854.3	937.5	740.4	578.0	1888.7
1985	633.2	534.6	1557.9	1773.7	317.1	1270.6	617.4	654.6	506.5	1625.6
1986	1420.4	1115.6	645.0	1533.3	1525.7	249.2	943.9	443.7	461.1	1447.2
1987	508.7	2484.8	1322.8	606.8	1224.7	1091.3	166.6	606.9	279.0	1155.4
1988	256.5	885.6	2916.7	1192.9	457.1	828.3	690.9	101.5	362.0	822.7
1989	306.1	448.3	1046.3	2662.3	913.3	314.8	534.6	429.7	61.8	695.9
1990	962.6	537.5	533.6	962.5	2065.5	641.8	208.2	341.4	268.7	454.2
1991	849.4	1687.9	636.3	476.4	714.4	1386.5	405.2	126.9	203.7	417.3
1992	639.8	1485.5	1980.8	541.4	329.5	446.9	816.3	230.3	70.6	334.0
1993	683.6	1121.9	1736.1	1719.3	338.4	176.8	229.8	409.6	113.7	192.5
1994	336.9	1201.3	1336.5	1606.7	1226.2	212.4	106.5	135.1	236.9	171.7
1995	837.3	593.0	1409.3	1174.9	1090.7	737.4	122.6	60.0	74.9	221.1
1996	242.7	1481.3	709.8	1306.2	852.5	702.6	456.2	74.0	35.6	169.8
1997	607.7	428.2	1746.7	630.9	914.0	532.5	421.6	267.2	42.7	114.1
1998	861.1	1077.4	511.5	1598.4	447.8	574.4	321.3	248.3	154.8	87.8
1999	484.4	1527.6	1296.5	479.4	1202.6	302.8	373.3	203.8	154.9	148.0
2000	751.8	854.0	1753.0	1065.5	308.9	694.3	168.0	202.1	108.5	157.1
2001	1421.1	1321.1	1008.8	1584.4	766.5	199.6	431.2	101.8	120.5	153.8
2002	522.3	2509.3	1573.0	927.7	1175.3	511.4	128.0	269.9	62.7	164.1
2003	183.9	925.2	2998.7	1454.1	689.8	786.0	328.7	80.3	166.5	135.3
2004	256.9	324.4	1097.0	2742.4	1094.3	471.7	516.9	211.0	50.7	185.9
2005	360.9	454.7	386.4	1008.6	2066.5	747.2	309.7	331.2	133.0	143.9
2006	671.4	642.1	548.7	365.5	792.0	1478.0	514.0	208.0	218.8	178.0
2007	501.8	1192.5	771.2	514.3	291.7	583.6	1048.4	355.9	141.7	263.6

Table 3.8. Greater amberjack: Estimated biomass at age (1000 lb)

Year	1	2	3	4	5	6	7	8	9	10
1946	1484.0	2657.5	3317.0	3494.8	3351.5	3035.9	2651.4	2260.4	1895.9	8012.2
1947	1504.5	2657.5	3317.0	3494.8	3351.5	3035.9	2651.4	2260.4	1895.9	8012.2
1948	1504.5	2693.0	3314.5	3490.7	3346.3	3030.3	2646.1	2255.7	1891.9	7995.2
1949	1504.4	2692.4	3357.5	3485.2	3338.3	3021.0	2636.8	2247.3	1884.6	7964.0
1950	1504.2	2691.5	3355.3	3527.5	3329.0	3009.2	2624.4	2235.5	1874.2	7918.7
1951	1503.9	2690.6	3352.9	3522.6	3365.7	2996.7	2610.1	2221.3	1861.3	7860.8
1952	1503.5	2689.5	3350.5	3518.2	3358.2	3026.4	2595.9	2206.3	1846.9	7793.1
1953	1503.1	2688.3	3347.6	3511.6	3348.4	3013.8	2616.0	2189.4	1830.3	7709.9
1954	1502.6	2686.9	3344.9	3507.2	3340.1	3002.2	2602.3	2203.8	1814.1	7620.8
1955	1502.1	2685.4	3342.0	3503.3	3334.2	2992.3	2589.8	2189.9	1824.1	7528.4
1956	1501.5	2683.8	3338.9	3499.3	3328.8	2984.7	2578.8	2177.1	1810.6	7455.2
1957	1501.0	2682.2	3335.5	3493.2	3320.9	2975.4	2567.9	2164.0	1796.8	7372.8
1958	1500.3	2680.6	3332.3	3488.5	3313.3	2965.9	2557.2	2152.5	1784.0	7287.8
1959	1499.7	2678.9	3328.7	3481.0	3303.1	2953.0	2543.3	2138.5	1770.2	7192.9
1960	1498.9	2677.0	3324.7	3471.9	3288.8	2936.4	2525.3	2120.9	1753.8	7086.8
1961	1498.1	2675.0	3321.1	3466.7	3278.5	2921.2	2508.6	2103.6	1737.3	6981.8
1962	1497.3	2672.8	3317.5	3463.4	3273.8	2911.4	2494.5	2088.5	1722.1	6881.9
1963	1496.5	2670.7	3313.2	3456.8	3266.7	2902.7	2481.8	2073.0	1706.6	6778.5
1964	1495.7	2668.7	3309.1	3449.8	3256.9	2892.2	2470.2	2058.7	1690.8	6672.8
1965	1494.9	2666.5	3305.0	3442.8	3246.5	2879.1	2457.0	2045.4	1676.1	6565.2
1966	1494.1	2664.4	3300.8	3435.9	3236.0	2865.4	2441.5	2030.7	1662.1	6456.8
1967	1493.2	2662.1	3296.3	3427.4	3223.8	2850.0	2424.2	2013.0	1646.0	6345.2
1968	1492.2	2659.7	3291.9	3419.9	3211.7	2834.6	2406.7	1994.7	1628.3	6233.0
1969	1491.2	2657.2	3287.2	3411.9	3200.0	2818.8	2388.7	1976.0	1610.0	6118.1
1970	1490.2	2654.7	3282.5	3405.1	3189.6	2804.8	2371.7	1958.0	1592.2	6004.4
1971	1489.2	2652.1	3277.3	3394.6	3175.5	2787.7	2352.7	1937.9	1572.5	5883.1
1972	1488.0	2649.4	3272.5	3388.0	3163.7	2772.6	2335.4	1919.6	1554.2	5766.0
1973	1487.0	2646.6	3267.6	3381.5	3155.2	2759.2	2319.5	1902.7	1537.2	5652.5
1974	1485.9	2643.9	3261.8	3369.7	3140.1	2742.6	2300.0	1882.7	1517.9	5530.9
1975	1484.7	2641.1	3256.4	3360.1	3124.1	2723.8	2280.8	1862.3	1498.1	5409.1
1976	1483.4	2638.0	3250.8	3349.8	3108.6	2702.8	2258.6	1841.2	1477.3	5284.3
1977	1482.1	2634.8	3244.9	3339.6	3092.9	2682.7	2235.1	1818.0	1456.3	5158.0
1978	1480.7	2631.5	3238.9	3330.2	3078.7	2663.7	2213.3	1794.6	1434.4	5032.9
1979	1093.0	2628.1	3232.9	3322.7	3067.7	2648.1	2194.0	1774.0	1413.3	4912.0
1980	1800.7	1938.8	3225.2	3308.7	3049.9	2626.9	2170.3	1749.4	1389.6	4778.7
1981	373.3	3192.1	2375.9	3291.6	3023.6	2596.6	2138.8	1718.5	1360.7	4627.2
1982	1850.8	660.0	3884.0	2384.7	2922.4	2475.3	2020.6	1614.0	1272.4	4273.8
1983	1616.0	3268.1	804.6	3932.4	2161.1	2470.0	2002.2	1589.9	1247.7	4135.8
1984	673.1	2874.5	4031.0	829.3	3653.7	1883.4	2066.9	1632.4	1274.3	4163.8
1985	1396.1	1178.5	3434.5	3910.2	699.2	2801.1	1361.2	1443.2	1116.6	3583.8
1986	3131.5	2459.5	1422.1	3380.4	3363.6	549.4	2080.8	978.1	1016.5	3190.6
1987	1121.4	5478.0	2916.3	1337.8	2700.0	2405.8	367.2	1337.9	615.1	2547.2
1988	565.5	1952.5	6430.3	2629.9	1007.8	1826.0	1523.2	223.9	798.1	1813.8
1989	674.9	988.4	2306.6	5869.3	2013.5	694.1	1178.6	947.3	136.3	1534.2
1990	2122.2	1185.0	1176.4	2121.9	4553.7	1415.0	459.1	752.6	592.4	1001.3
1991	1872.5	3721.2	1402.7	1050.3	1575.0	3056.6	893.4	279.7	449.1	920.0
1992	1410.5	3275.0	4366.8	1193.6	726.4	985.2	1799.6	507.8	155.7	736.4
1993	1507.0	2473.4	3827.3	3790.3	746.0	389.8	506.6	903.0	250.7	424.4
1994	742.7	2648.5	2946.6	3542.1	2703.4	468.3	234.8	297.8	522.3	378.6
1995	1845.9	1307.4	3107.0	2590.2	2404.6	1625.7	270.4	132.3	165.1	487.4
1996	535.0	3265.8	1564.9	2879.8	1879.3	1549.0	1005.7	163.2	78.6	374.4
1997	1339.7	944.0	3850.9	1390.9	2015.1	1174.0	929.6	589.0	94.1	251.5
1998	1898.5	2375.4	1127.8	3523.9	987.2	1266.4	708.4	547.4	341.2	193.5
1999	1068.0	3367.8	2858.2	1056.8	2651.2	667.5	822.9	449.3	341.6	326.3
2000	1657.4	1882.6	3864.7	2349.1	681.1	1530.7	370.3	445.6	239.3	346.4
2001	3132.9	2912.4	2223.9	3493.1	1689.7	440.1	950.7	224.5	265.7	339.1
2002	1151.5	5532.1	3467.9	2045.2	2591.1	1127.3	282.2	595.0	138.2	361.8
2003	405.4	2039.8	6611.0	3205.8	1520.8	1732.8	724.6	177.0	367.2	298.3
2004	566.3	715.2	2418.6	6045.9	2412.5	1039.9	1139.5	465.1	111.8	409.8
2005	795.7	1002.4	851.8	2223.6	4555.9	1647.3	682.8	730.2	293.2	317.3
2006	1480.2	1415.6	1209.8	805.8	1746.2	3258.4	1133.2	458.5	482.4	392.4
2007	1106.2	2629.1	1700.3	1133.9	643.0	1286.6	2311.3	784.6	312.3	581.0

Table 3.9. Greater amberjack: Estimated instantaneous fishing mortality rate (per yr) at age, including discard mortality

Year	1	2	3	4	5	6	7	8	9	10
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002
1948	0.001	0.001	0.002	0.003	0.003	0.004	0.004	0.004	0.004	0.004
1949	0.001	0.002	0.003	0.004	0.005	0.005	0.006	0.006	0.006	0.006
1950	0.001	0.002	0.004	0.005	0.006	0.007	0.007	0.007	0.007	0.007
1951	0.001	0.002	0.004	0.006	0.007	0.008	0.009	0.009	0.009	0.009
1952	0.002	0.003	0.005	0.008	0.009	0.010	0.011	0.011	0.011	0.011
1953	0.002	0.003	0.006	0.008	0.010	0.011	0.012	0.012	0.012	0.012
1954	0.002	0.004	0.006	0.009	0.011	0.012	0.013	0.013	0.013	0.013
1955	0.002	0.004	0.006	0.009	0.012	0.013	0.014	0.014	0.014	0.014
1956	0.002	0.004	0.007	0.010	0.013	0.015	0.016	0.016	0.016	0.016
1957	0.003	0.005	0.007	0.011	0.014	0.016	0.017	0.017	0.017	0.017
1958	0.003	0.005	0.009	0.013	0.016	0.018	0.019	0.020	0.020	0.020
1959	0.003	0.006	0.010	0.015	0.019	0.021	0.022	0.022	0.023	0.023
1960	0.003	0.006	0.010	0.015	0.020	0.022	0.023	0.024	0.024	0.024
1961	0.004	0.006	0.010	0.015	0.020	0.023	0.024	0.024	0.024	0.024
1962	0.004	0.007	0.011	0.017	0.021	0.024	0.026	0.026	0.026	0.026
1963	0.004	0.007	0.012	0.018	0.023	0.026	0.027	0.028	0.028	0.028
1964	0.004	0.008	0.013	0.019	0.024	0.028	0.029	0.030	0.030	0.030
1965	0.005	0.008	0.013	0.020	0.026	0.029	0.031	0.032	0.032	0.032
1966	0.005	0.009	0.015	0.022	0.028	0.032	0.033	0.034	0.034	0.035
1967	0.005	0.009	0.015	0.023	0.030	0.034	0.035	0.036	0.036	0.037
1968	0.006	0.010	0.016	0.025	0.032	0.036	0.038	0.038	0.039	0.039
1969	0.006	0.010	0.017	0.026	0.033	0.037	0.039	0.040	0.040	0.041
1970	0.006	0.011	0.019	0.028	0.036	0.040	0.042	0.043	0.044	0.044
1971	0.007	0.011	0.019	0.029	0.037	0.042	0.044	0.045	0.045	0.045
1972	0.007	0.012	0.019	0.029	0.038	0.043	0.045	0.046	0.047	0.047
1973	0.007	0.013	0.021	0.032	0.041	0.047	0.049	0.050	0.050	0.051
1974	0.007	0.013	0.023	0.034	0.043	0.049	0.052	0.053	0.053	0.053
1975	0.008	0.014	0.024	0.036	0.046	0.052	0.055	0.056	0.056	0.056
1976	0.008	0.015	0.025	0.038	0.048	0.055	0.057	0.059	0.059	0.059
1977	0.009	0.015	0.026	0.040	0.050	0.057	0.060	0.061	0.062	0.062
1978	0.009	0.016	0.027	0.040	0.052	0.059	0.062	0.063	0.064	0.064
1979	0.009	0.017	0.029	0.044	0.056	0.064	0.067	0.068	0.069	0.069
1980	0.010	0.018	0.032	0.048	0.062	0.070	0.074	0.075	0.076	0.076
1981	0.013	0.025	0.049	0.077	0.101	0.115	0.122	0.125	0.126	0.126
1982	0.014	0.024	0.040	0.057	0.069	0.077	0.080	0.082	0.082	0.082
1983	0.007	0.012	0.022	0.032	0.039	0.043	0.045	0.045	0.046	0.046
1984	0.023	0.044	0.083	0.129	0.167	0.189	0.200	0.204	0.206	0.206
1985	0.016	0.034	0.068	0.109	0.142	0.162	0.171	0.175	0.176	0.177
1986	0.023	0.051	0.113	0.183	0.236	0.268	0.282	0.288	0.290	0.291
1987	0.028	0.061	0.156	0.241	0.292	0.322	0.335	0.341	0.343	0.344
1988	0.024	0.055	0.143	0.225	0.274	0.302	0.315	0.321	0.323	0.324
1989	0.020	0.048	0.136	0.212	0.254	0.278	0.289	0.294	0.295	0.296
1990	0.021	0.053	0.166	0.256	0.300	0.324	0.336	0.340	0.342	0.343
1991	0.024	0.062	0.214	0.327	0.370	0.394	0.405	0.410	0.412	0.412
1992	0.021	0.066	0.194	0.428	0.524	0.530	0.530	0.530	0.530	0.530
1993	0.019	0.047	0.130	0.296	0.367	0.371	0.372	0.372	0.372	0.372
1994	0.017	0.062	0.181	0.346	0.410	0.414	0.414	0.414	0.414	0.414
1995	0.012	0.042	0.128	0.279	0.341	0.345	0.345	0.345	0.345	0.345
1996	0.015	0.057	0.170	0.315	0.372	0.375	0.375	0.375	0.375	0.375
1997	0.010	0.044	0.141	0.301	0.366	0.370	0.370	0.370	0.370	0.370
1998	0.009	0.037	0.117	0.243	0.292	0.296	0.296	0.296	0.296	0.296
1999	0.016	0.084	0.248	0.397	0.450	0.454	0.454	0.454	0.454	0.454
2000	0.019	0.055	0.153	0.288	0.338	0.341	0.341	0.341	0.341	0.341
2001	0.014	0.047	0.136	0.257	0.306	0.309	0.309	0.309	0.309	0.309
2002	0.011	0.044	0.131	0.254	0.303	0.307	0.307	0.307	0.307	0.307
2003	0.015	0.051	0.142	0.242	0.281	0.284	0.284	0.284	0.284	0.284
2004	0.012	0.047	0.136	0.241	0.283	0.285	0.285	0.285	0.285	0.285
2005	0.007	0.034	0.108	0.200	0.236	0.239	0.239	0.239	0.239	0.239
2006	0.008	0.038	0.117	0.184	0.207	0.208	0.208	0.208	0.208	0.208

Table 3.10. Greater amberjack: Estimated time series of fishing mortality rate by year for commercial handline F.c.hal, commercial diving (F.c.dv), headboat(F.hb), recreational survey(F.mrfss),commercial handline discards(F.c.hal.D), headboat discards(F.hb.D), recreational survey discards(F.mrfss.D), and full F (F.full) .

Year	F.c.hal	F.c.dv	F.hb	F.mrfss	F.c.hal.D	F.hb.D	F.mrfss.D	F.full
1946	0.000	0.000	0.000	0.000	.	.	.	0.000
1947	0.000	0.000	0.001	0.001	.	.	0.000	0.002
1948	0.001	0.000	0.001	0.002	.	.	0.000	0.004
1949	0.001	0.000	0.001	0.003	.	.	0.000	0.006
1950	0.001	0.000	0.001	0.005	.	.	0.001	0.007
1951	0.001	0.000	0.001	0.006	.	.	0.001	0.009
1952	0.002	0.000	0.001	0.007	.	.	0.001	0.011
1953	0.001	0.000	0.002	0.008	.	.	0.001	0.012
1954	0.001	0.000	0.002	0.009	.	.	0.001	0.013
1955	0.000	0.000	0.002	0.011	.	.	0.001	0.014
1956	0.001	0.000	0.002	0.012	.	.	0.002	0.016
1957	0.000	0.000	0.002	0.013	.	.	0.002	0.017
1958	0.001	0.000	0.002	0.015	.	.	0.002	0.020
1959	0.002	0.000	0.003	0.016	.	.	0.002	0.023
1960	0.001	0.000	0.003	0.017	.	.	0.002	0.024
1961	0.000	0.000	0.003	0.019	.	.	0.003	0.025
1962	0.000	0.000	0.003	0.020	.	.	0.003	0.026
1963	0.000	0.000	0.003	0.022	.	.	0.003	0.028
1964	0.000	0.000	0.004	0.023	.	.	0.003	0.030
1965	0.000	0.000	0.004	0.025	.	.	0.003	0.032
1966	0.001	0.000	0.004	0.026	.	.	0.003	0.035
1967	0.001	0.000	0.004	0.028	.	.	0.004	0.037
1968	0.001	0.000	0.005	0.029	.	.	0.004	0.039
1969	0.001	0.000	0.005	0.031	.	.	0.004	0.041
1970	0.002	0.000	0.005	0.033	.	.	0.004	0.044
1971	0.001	0.000	0.005	0.034	.	.	0.005	0.045
1972	0.001	0.000	0.006	0.036	.	.	0.005	0.047
1973	0.002	0.000	0.006	0.038	.	.	0.005	0.051
1974	0.002	0.000	0.006	0.040	.	.	0.005	0.053
1975	0.003	0.000	0.006	0.042	.	.	0.005	0.056
1976	0.003	0.000	0.007	0.044	.	.	0.006	0.059
1977	0.003	0.000	0.007	0.046	.	.	0.006	0.062
1978	0.002	0.000	0.007	0.048	.	.	0.006	0.064
1979	0.003	0.000	0.007	0.052	.	.	0.007	0.069
1980	0.003	0.000	0.008	0.058	.	.	0.007	0.076
1981	0.005	0.000	0.007	0.103	.	.	0.011	0.126
1982	0.009	0.000	0.013	0.053	.	.	0.006	0.082
1983	0.007	0.000	0.006	0.025	.	.	0.008	0.046
1984	0.012	0.000	0.014	0.166	.	.	0.014	0.207
1985	0.011	0.000	0.008	0.136	.	.	0.022	0.177
1986	0.028	0.003	0.009	0.226	.	.	0.025	0.292
1987	0.083	0.010	0.016	0.213	.	.	0.022	0.344
1988	0.076	0.010	0.012	0.208	.	.	0.018	0.324
1989	0.085	0.010	0.009	0.177	.	.	0.016	0.296
1990	0.122	0.014	0.010	0.176	.	.	0.021	0.343
1991	0.184	0.024	0.014	0.166	.	.	0.026	0.413
1992	0.318	0.030	0.015	0.148	0.004	0.015	0.019	0.549
1993	0.238	0.016	0.015	0.088	0.004	0.015	0.015	0.390
1994	0.217	0.019	0.011	0.156	0.007	0.011	0.011	0.432
1995	0.213	0.016	0.008	0.096	0.007	0.008	0.012	0.360
1996	0.199	0.014	0.009	0.140	0.011	0.009	0.014	0.396
1997	0.224	0.018	0.006	0.108	0.009	0.006	0.015	0.384
1998	0.180	0.014	0.006	0.080	0.012	0.006	0.016	0.314
1999	0.177	0.014	0.007	0.236	0.008	0.007	0.019	0.469
2000	0.171	0.022	0.014	0.114	0.006	0.014	0.021	0.361
2001	0.170	0.008	0.010	0.099	0.008	0.010	0.022	0.327
2002	0.167	0.013	0.007	0.101	0.005	0.007	0.019	0.319
2003	0.128	0.008	0.010	0.118	0.003	0.010	0.019	0.297
2004	0.140	0.006	0.007	0.107	0.005	0.007	0.025	0.297
2005	0.134	0.006	0.003	0.071	0.011	0.003	0.024	0.253
2006	0.090	0.006	0.004	0.084	0.012	0.004	0.024	0.225

Table 3.11. Greater amberjack: 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; units for B and SSB are whole wieght– mt. SPR is static spawning potential ratio.

Year	F	F/F_{MSY}	B	B/B_{unfished}	SSB	$\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$	SPR
1946	0.000	0.000	14588	1.189	6297	3.25	1.000
1947	0.002	0.005	14597	1.190	6295	3.24	0.990
1948	0.004	0.009	14591	1.190	6287	3.24	0.982
1949	0.006	0.014	14575	1.188	6276	3.24	0.974
1950	0.007	0.017	14546	1.186	6260	3.23	0.967
1951	0.009	0.021	14509	1.183	6241	3.22	0.961
1952	0.011	0.026	14464	1.179	6217	3.20	0.952
1953	0.012	0.029	14405	1.175	6188	3.19	0.947
1954	0.013	0.032	14345	1.170	6159	3.17	0.943
1955	0.014	0.034	14284	1.165	6129	3.16	0.939
1956	0.016	0.039	14224	1.160	6099	3.14	0.931
1957	0.017	0.041	14156	1.154	6066	3.13	0.927
1958	0.020	0.047	14090	1.149	6032	3.11	0.918
1959	0.023	0.054	14011	1.142	5992	3.09	0.907
1960	0.024	0.056	13918	1.135	5947	3.07	0.903
1961	0.025	0.058	13831	1.128	5906	3.04	0.901
1962	0.026	0.062	13754	1.121	5868	3.02	0.894
1963	0.028	0.067	13674	1.115	5829	3.00	0.888
1964	0.030	0.071	13592	1.108	5788	2.98	0.881
1965	0.032	0.076	13507	1.101	5747	2.96	0.875
1966	0.035	0.082	13421	1.094	5704	2.94	0.866
1967	0.037	0.086	13327	1.087	5658	2.92	0.860
1968	0.039	0.092	13232	1.079	5612	2.89	0.852
1969	0.041	0.096	13136	1.071	5565	2.87	0.847
1970	0.044	0.104	13042	1.063	5518	2.84	0.836
1971	0.045	0.107	12938	1.055	5468	2.82	0.832
1972	0.047	0.111	12841	1.047	5422	2.79	0.828
1973	0.051	0.120	12750	1.040	5376	2.77	0.816
1974	0.053	0.126	12644	1.031	5324	2.74	0.809
1975	0.056	0.133	12538	1.022	5272	2.72	0.800
1976	0.059	0.140	12426	1.013	5217	2.69	0.791
1977	0.062	0.146	12313	1.004	5163	2.66	0.784
1978	0.064	0.151	12201	0.995	5110	2.63	0.780
1979	0.069	0.163	11923	0.972	5046	2.60	0.766
1980	0.076	0.180	11811	0.963	4914	2.53	0.749
1981	0.126	0.298	11203	0.913	4764	2.46	0.654
1982	0.082	0.194	10595	0.864	4425	2.28	0.722
1983	0.046	0.108	10536	0.859	4326	2.23	0.826
1984	0.207	0.487	10470	0.854	4301	2.22	0.536
1985	0.177	0.417	9491	0.774	3897	2.01	0.579
1986	0.292	0.688	9785	0.798	3582	1.85	0.463
1987	0.344	0.812	9447	0.770	3500	1.80	0.410
1988	0.324	0.764	8514	0.694	3398	1.75	0.427
1989	0.296	0.699	7413	0.604	3041	1.57	0.447
1990	0.343	0.810	6976	0.569	2575	1.33	0.409
1991	0.413	0.973	6904	0.563	2377	1.23	0.362
1992	0.549	1.295	6875	0.561	2399	1.24	0.329
1993	0.390	0.921	6722	0.548	2437	1.26	0.400
1994	0.432	1.019	6570	0.536	2467	1.27	0.364
1995	0.360	0.849	6321	0.515	2299	1.18	0.416
1996	0.396	0.934	6031	0.492	2263	1.17	0.383
1997	0.384	0.907	5706	0.465	2123	1.09	0.401
1998	0.314	0.740	5883	0.480	2071	1.07	0.447
1999	0.469	1.106	6173	0.503	2175	1.12	0.329
2000	0.361	0.852	6063	0.494	2168	1.12	0.401
2001	0.327	0.771	7109	0.580	2337	1.20	0.427
2002	0.319	0.752	7844	0.640	2796	1.44	0.432
2003	0.297	0.701	7749	0.632	3084	1.59	0.435
2004	0.297	0.701	6951	0.567	2862	1.48	0.440
2005	0.253	0.597	5942	0.484	2407	1.24	0.489
2006	0.225	0.531	5617	0.458	2126	1.10	0.504

Table 3.12. Greater amberjack—Base run: Estimated status indicators, benchmarks, and related quantities from the catch-at-age model, conditional on estimated current selectivities and ratios of F among fisheries. Precision is represented by 10th and 90th percentiles of 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 D.

Quantity	Units	Estimate	10th Percentile	90th Percentile
F_{MSY}	y^{-1}	0.424	0.201	0.666
$85\%F_{MSY}$	y^{-1}	0.360	–	–
$75\%F_{MSY}$	y^{-1}	0.318	–	–
$65\%F_{MSY}$	y^{-1}	0.276	–	–
$F_{30\%}$	y^{-1}	0.560	–	–
$F_{40\%}$	y^{-1}	0.342	–	–
F_{max}	y^{-1}	0.750	–	–
B_{MSY}	metric tons	5491	4664	7306
SSB_{MSY}	metric tons	1940	1535	2768
MSST	metric tons	1455	–	–
MSY	1000 lbs	2005	1479	2403
D_{MSY}	1000s	18	10	28
R_{MSY}	1000s	435	373	508
Y at $85\%F_{MSY}$	1000 lb	1993	–	–
Y at $75\%F_{MSY}$	1000 lb	1968	–	–
Y at $65\%F_{MSY}$	1000 lb	1925	–	–
Y at $F_{30\%}$	1000 lb	1970	–	–
Y at $F_{40\%}$	1000 lb	1984	–	–
Y at F_{max}	1000 lb	1110	–	–
F_{2006}/F_{MSY}	–	0.531	0.338	1.117
SSB_{2006}/SSB_{MSY}	–	1.096	0.768	1.385
$SSB_{2006}/MSST$	–	1.461	1.024	1.847

Table 3.13. Greater amberjack—Base run: Status indicators from sensitivity runs of catch-at-age model. Included are estimates of stock-recruit parameters, steepness (h) and virgin recruitment (R_0, in units of 1000 fish). Sensitivity runs are described with more detail in section §3.1.1.3. Symbols, abbreviations, and acronyms are listed in Appendix D.

Description	R0	steep	autocorr	SSB0 (mt)	MSY (1000 pounds)	Dmsy (1000 pounds)	Fmsy	F(2006)/ Fmsy	SSBmsy (mt)	SSB(2006)/ SSBmsy	F40%	F30%	Fmax
Base Run	**419797**	**0.74**	**0.02**	**5294**	**2005**	**18.3**	**0.42**	**0.53**	**1940**	**1.10**	**0.34**	**0.56**	**0.75**
M Re-Scaled (0.05)	219505	0.95	0.02	5462	1836	12.2	0.47	0.88	1607	0.77	0.24	0.38	0.53
M Re-Scaled (0.01)	516395	0.62	0.04	5562	1998	18.1	0.35	0.54	2266	1.12	0.37	0.62	0.81
q Rate = 0.0	457462	0.95	0.14	5770	2474	30.8	0.85	0.14	1641	2.45	0.39	0.64	0.96
q Rate = 0.04	451555	0.55	0.03	5695	1749	11.9	0.34	1.17	2406	0.61	0.45	0.76	1.16
Start Yr R-devs = 1977	416162	0.95	0.00	5249	2331	27.1	0.93	0.22	1503	1.72	0.42	0.68	1.05
Start Yr R-devs = 1981	416747	0.79	0.09	5256	2062	19.3	0.60	0.38	1779	1.27	0.41	0.68	1.03
MRFSS CPUE Added	550717	0.55	0.08	6946	2058	19.8	0.22	0.56	3062	1.13	0.28	0.42	0.55

Table 3.14. Greater amberjack—Base run : Projection results under current F (starting in 2009) (fishing mortality rate fixed at the current value in 2007-2008). SSB = spawning stock biomass, R = recruits, F = fishing mortality rate, L = landings, Sum L = cumulative landings, and D = dead discards. For reference, relevant estimated benchmarks are listed in table 3.12.

Year	SSB(klb)	R(1000s)	F(/yr)	L(mt)	L(klb)	D(1000s)
2007	2106	498	0.26	747	1646	10
2008	2048	442	0.26	650	1434	10
2009	2159	440	0.26	643	1417	12
2010	2291	444	0.26	693	1529	13
2011	2389	449	0.26	738	1628	13
2012	2464	452	0.26	767	1692	13
2013	2522	454	0.26	789	1740	13
2014	2567	456	0.26	807	1779	13
2015	2603	458	0.26	820	1808	14
2016	2629	459	0.26	830	1831	14

Table 3.15. Greater amberjack—Base run : Projection results under current Fmsy (starting in 2009) (fishing mortality rate fixed at the current value in 2007-2008). SSB = spawning stock biomass, R = recruits, F = fishing mortality rate, L = landings, Sum L = cumulative landings, and D = dead discards. For reference, relevant estimated benchmarks are listed in table 3.12.

Year	SSB(klb)	R(1000s)	F(/yr)	L(mt)	L(klb)	D(1000s)
2007	2106	498	0.26	747	1646	10
2008	2048	442	0.26	650	1434	10
2009	2159	440	0.42	996	2196	19
2010	2044	444	0.42	965	2127	19
2011	2011	439	0.42	950	2095	19
2012	1990	438	0.42	937	2066	19
2013	1977	437	0.42	930	2050	19
2014	1967	436	0.42	925	2039	18
2015	1960	436	0.42	921	2030	18
2016	1954	436	0.42	918	2023	18

Table 3.16. Greater amberjack—Base run : Projection results under 65% of Fmsy (starting in 2009) (fishing mortality rate fixed at the current value in 2007-2008). SSB = spawning stock biomass, R = recruits, F = fishing mortality rate, L = landings, Sum L = cumulative landings, and D = dead discards. For reference, relevant estimated benchmarks are listed in table 3.12.

Year	SSB(klb)	R(1000s)	F(/yr)	L(mt)	L(klb)	D(1000s)
2007	2106	498	0.26	747	1646	10
2008	2048	442	0.26	650	1434	10
2009	2159	440	0.28	685	1510	13
2010	2261	444	0.28	730	1609	13
2011	2341	448	0.28	770	1697	14
2012	2401	451	0.28	795	1752	14
2013	2448	453	0.28	814	1794	14
2014	2485	454	0.28	828	1826	14
2015	2513	455	0.28	840	1851	14
2016	2534	456	0.28	848	1870	14

Table 3.17. Greater amberjack—Base run : Projection results under 75% of Fmsy (starting in 2009) (fishing mortality rate fixed at the current value in 2007-2008). SSB = spawning stock biomass, R = recruits, F = fishing mortality rate, L = landings, Sum L = cumulative landings, and D = dead discards. For reference, relevant estimated benchmarks are listed in table 3.12.

Year	SSB(klb)	R(1000s)	F(/yr)	L(mt)	L(klb)	D(1000s)
2007	2106	498	0.26	747	1646	10
2008	2048	442	0.26	650	1434	10
2009	2159	440	0.32	777	1714	15
2010	2196	444	0.32	806	1777	15
2011	2239	445	0.32	833	1836	15
2012	2270	447	0.32	848	1869	15
2013	2295	448	0.32	859	1894	15
2014	2314	449	0.32	868	1913	15
2015	2328	450	0.32	874	1928	16
2016	2339	450	0.32	879	1939	16

Table 3.18. Greater amberjack—Base run : Projection results under 85% of Fmsy (starting in 2009) (fishing mortality rate fixed at the current value in 2007-2008). SSB = spawning stock biomass, R = recruits, F = fishing mortality rate, L = landings, Sum L = cumulative landings, and D = dead discards. For reference, relevant estimated benchmarks are listed in table 3.12.

Year	SSB(klb)	R(1000s)	F(/yr)	L(mt)	L(klb)	D(1000s)
2007	2106	498	0.26	747	1646	10
2008	2048	442	0.26	650	1434	10
2009	2159	440	0.36	867	1911	16
2010	2133	444	0.36	875	1928	17
2011	2143	443	0.36	886	1954	17
2012	2151	443	0.36	890	1962	17
2013	2158	444	0.36	894	1970	17
2014	2163	444	0.36	897	1977	17
2015	2167	444	0.36	899	1981	17
2016	2170	444	0.36	900	1985	17

Table 3.19. Greater amberjack- Surplus-production run: Parameter estimates from the surplus-production model ASPIC with bias-corrected bootstrap analysis estimates of the 50 and 80% confidence limits.

Parameter	Estimate	80% Lower	80% Upper	50% Lower	50% Upper
B1/K	8.500E-01	8.500E-01	8.500E-01	8.500E-01	8.500E-01
K	7.909E+07	4.942E+07	2.045E+08	6.580E+07	1.465E+08
MSY	1.505E+06	6.862E+04	1.922E+06	4.688E+05	1.618E+06
Y(2007)	1.492E+06	1.957E+05	1.903E+06	5.839E+05	1.645E+06
Y@Fmsy	1.368E+06	3.755E+05	1.926E+06	8.011E+05	1.598E+06
Bmsy	3.954E+07	2.471E+07	1.023E+08	3.290E+07	7.323E+07
Fmsy	3.805E-02	1.631E-03	7.172E-02	6.828E-03	4.596E-02
B/Bmsy	9.090E-01	7.447E-01	1.213E+00	8.155E-01	1.066E+00
F/Fmsy	1.074E+00	7.653E-01	3.812E+00	9.242E-01	1.788E+00
Y/MSY	9.917E-01	9.648E-01	1.000E+00	9.890E-01	9.997E-01

3.4.2 Figures

Figure 3.1. Greater amberjack– Base run: Estimated (line) and observed (circles) annual length compositions (lcomp) and age compositions (acomp) from commercial handline (c.hal), commercial diving (c.dv), headboat (hb) and MRFSS (mrfss) sectors. After each series of annual plots, the ratio of observed sample size (N) and multinomial effective sample sizes, based on the observed and model estimated compositions are shown.

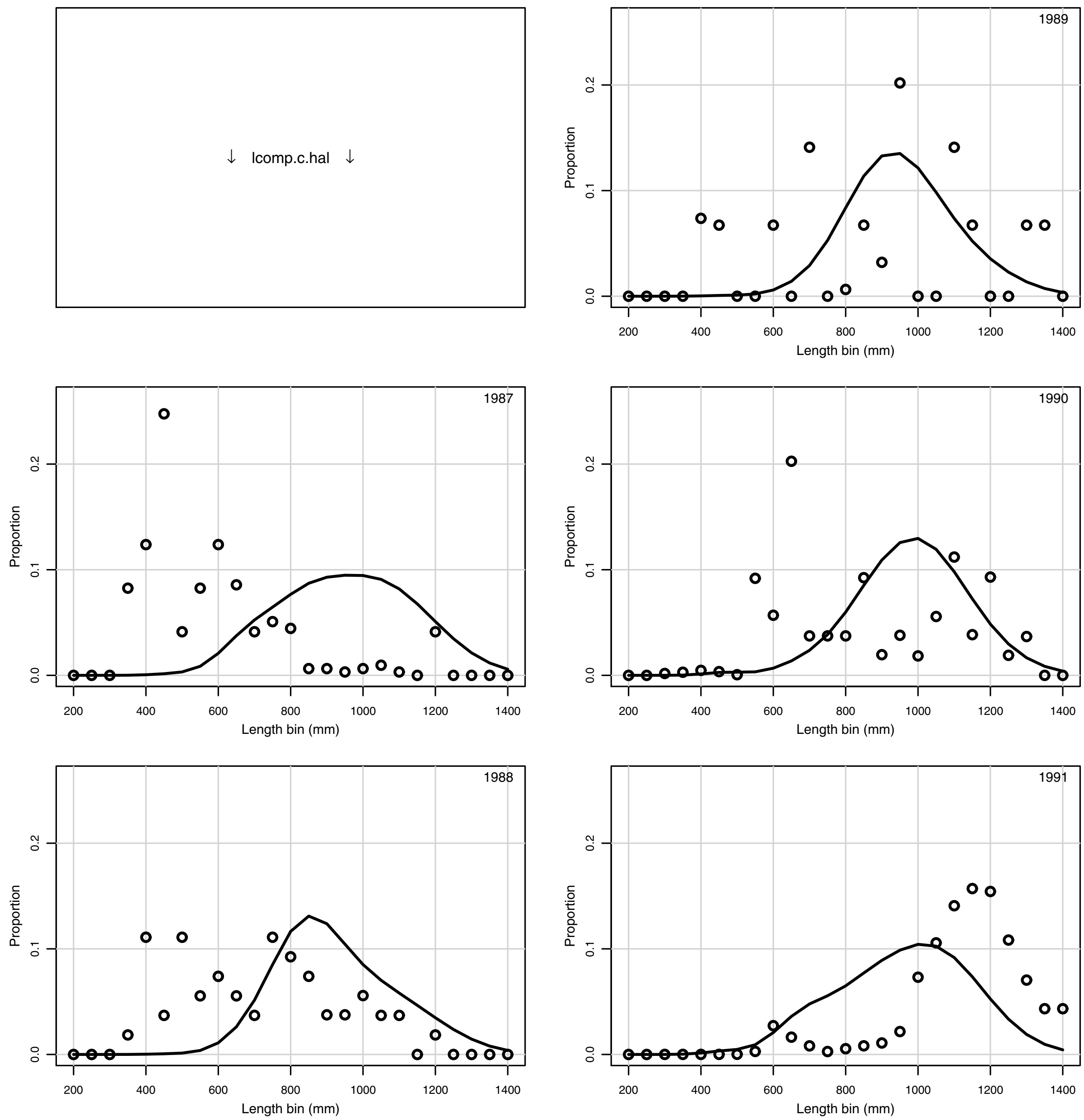
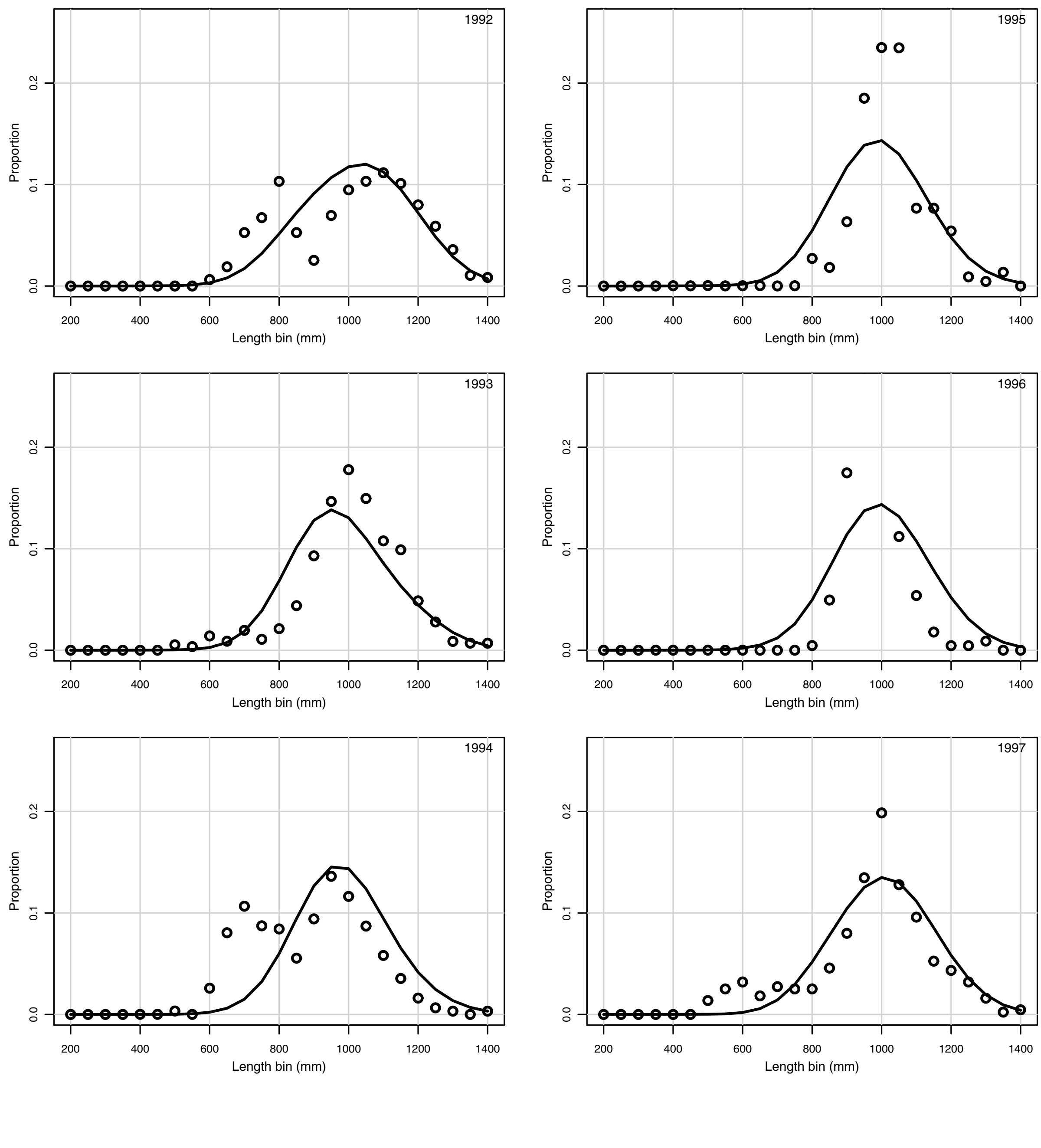


Figure 3.1. (Continued) Greater amberjack– Base run: Estimated (line) and observed (circles) annual length compositions (lcomp) and age compositions (acomp) from commercial handline (c.hal), commercial diving (c.dv), headboat (hb) and MRFSS (mrfss) sectors. After each series of annual plots, the ratio of observed sample size (N) and multinomial effective sample sizes, based on the observed and model estimated compositions are shown.



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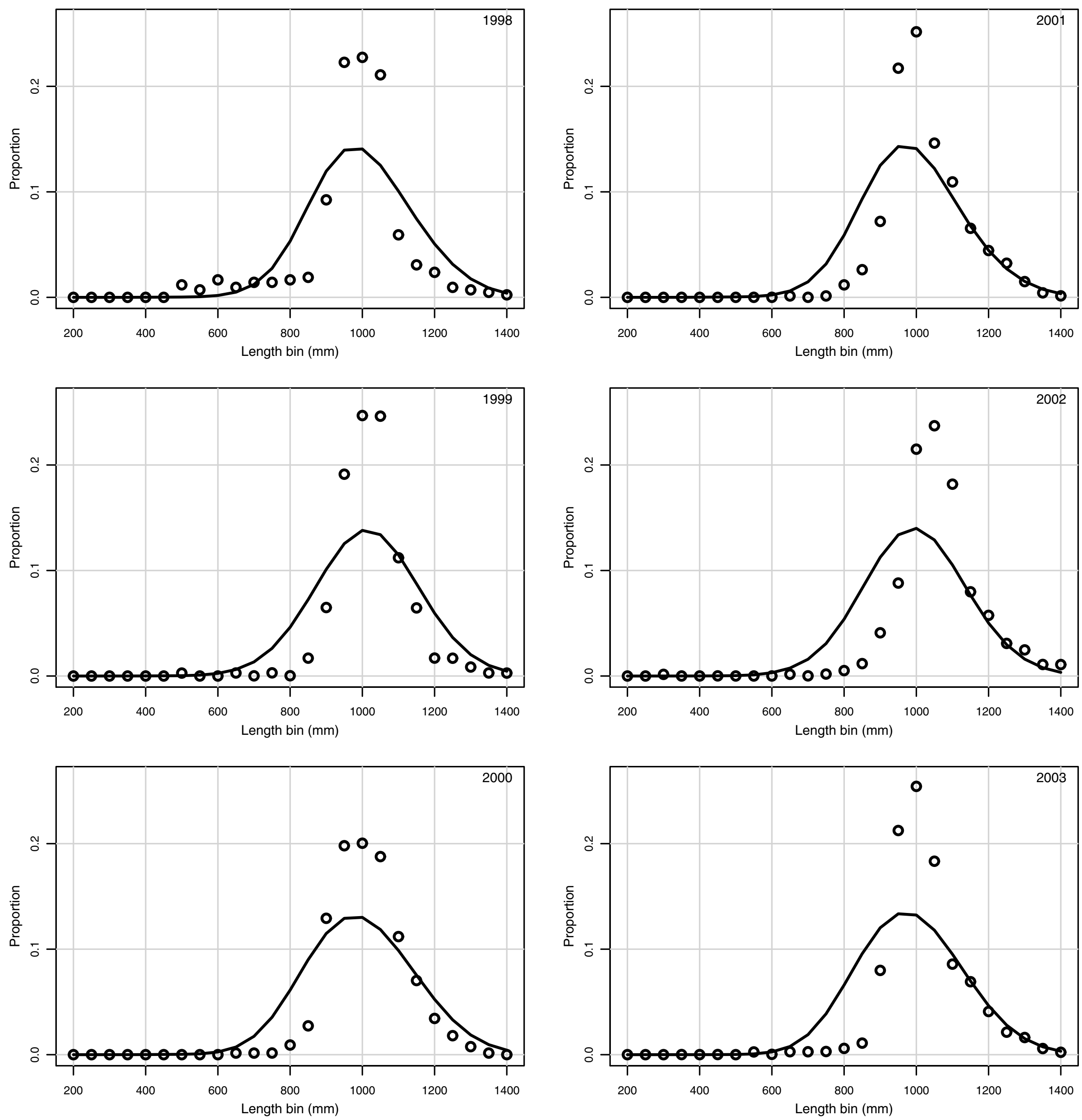

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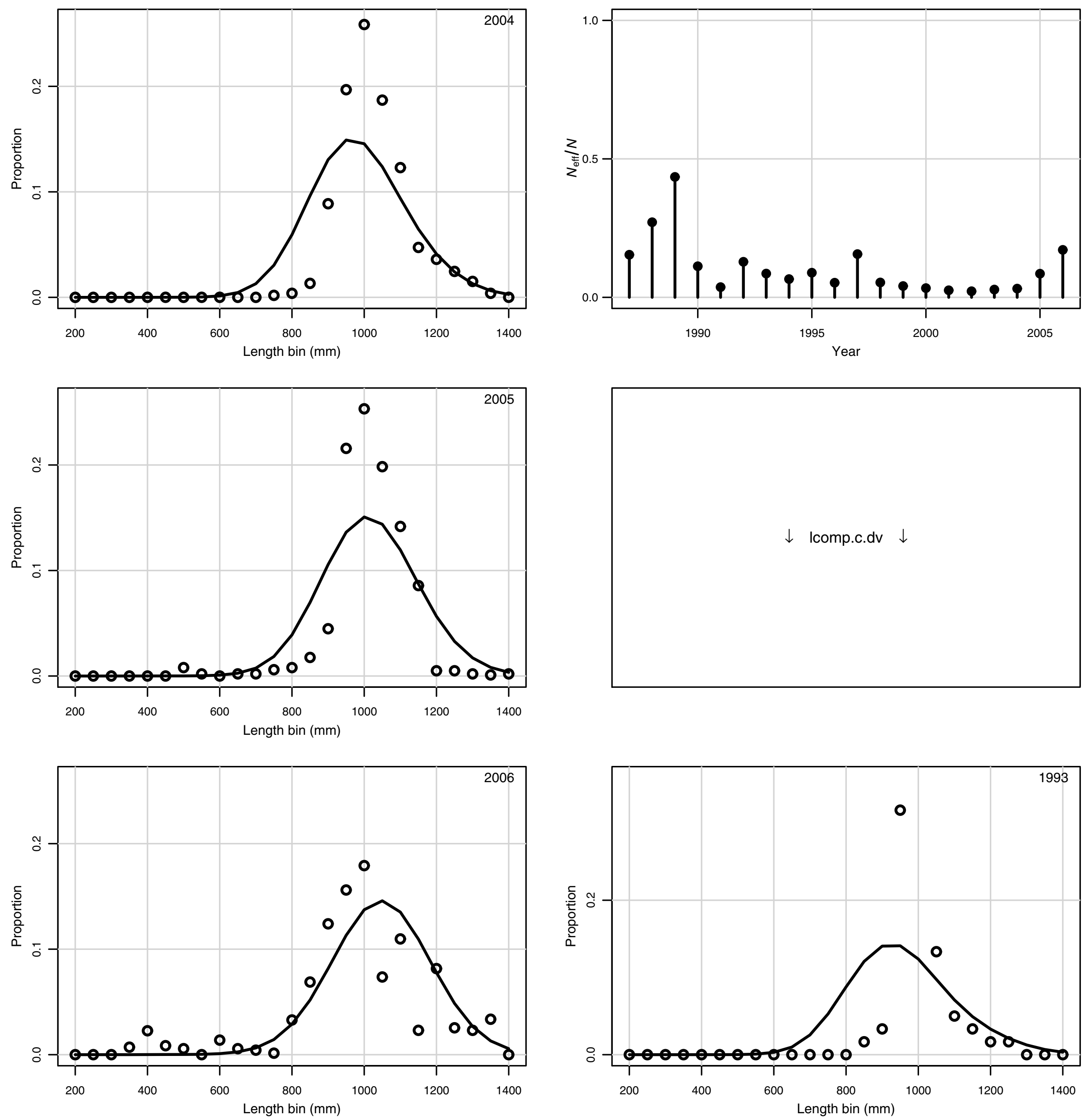

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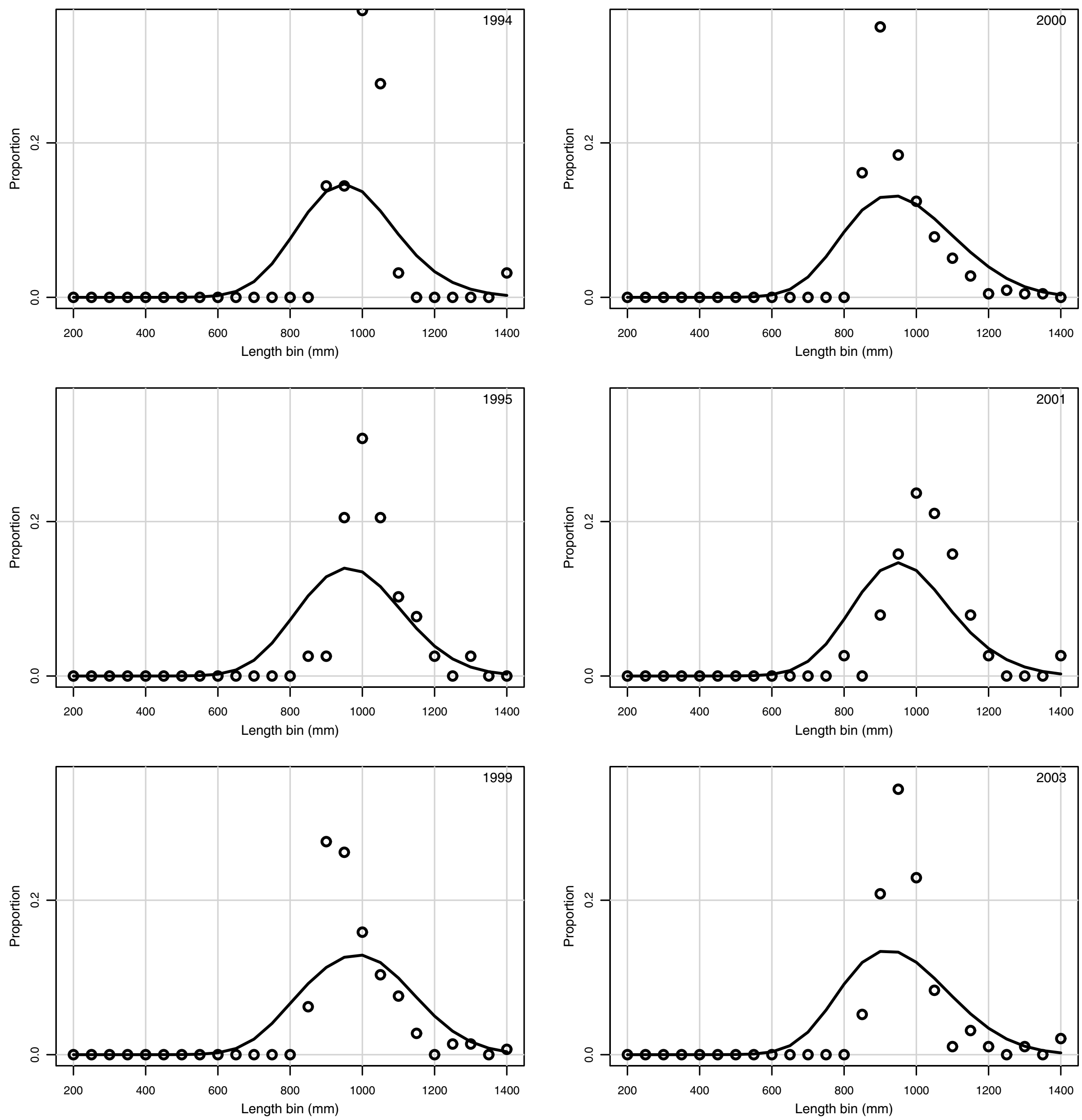

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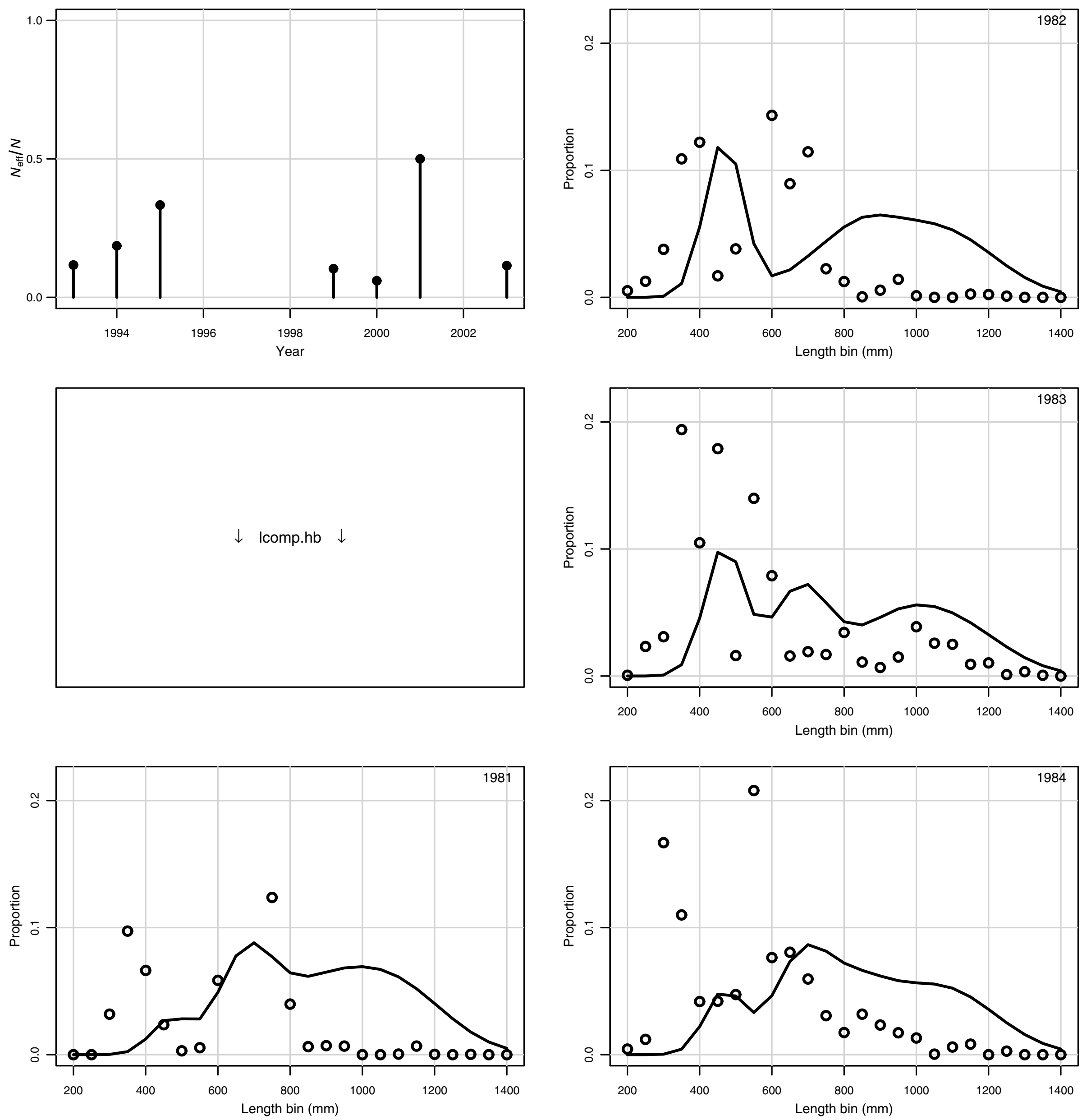

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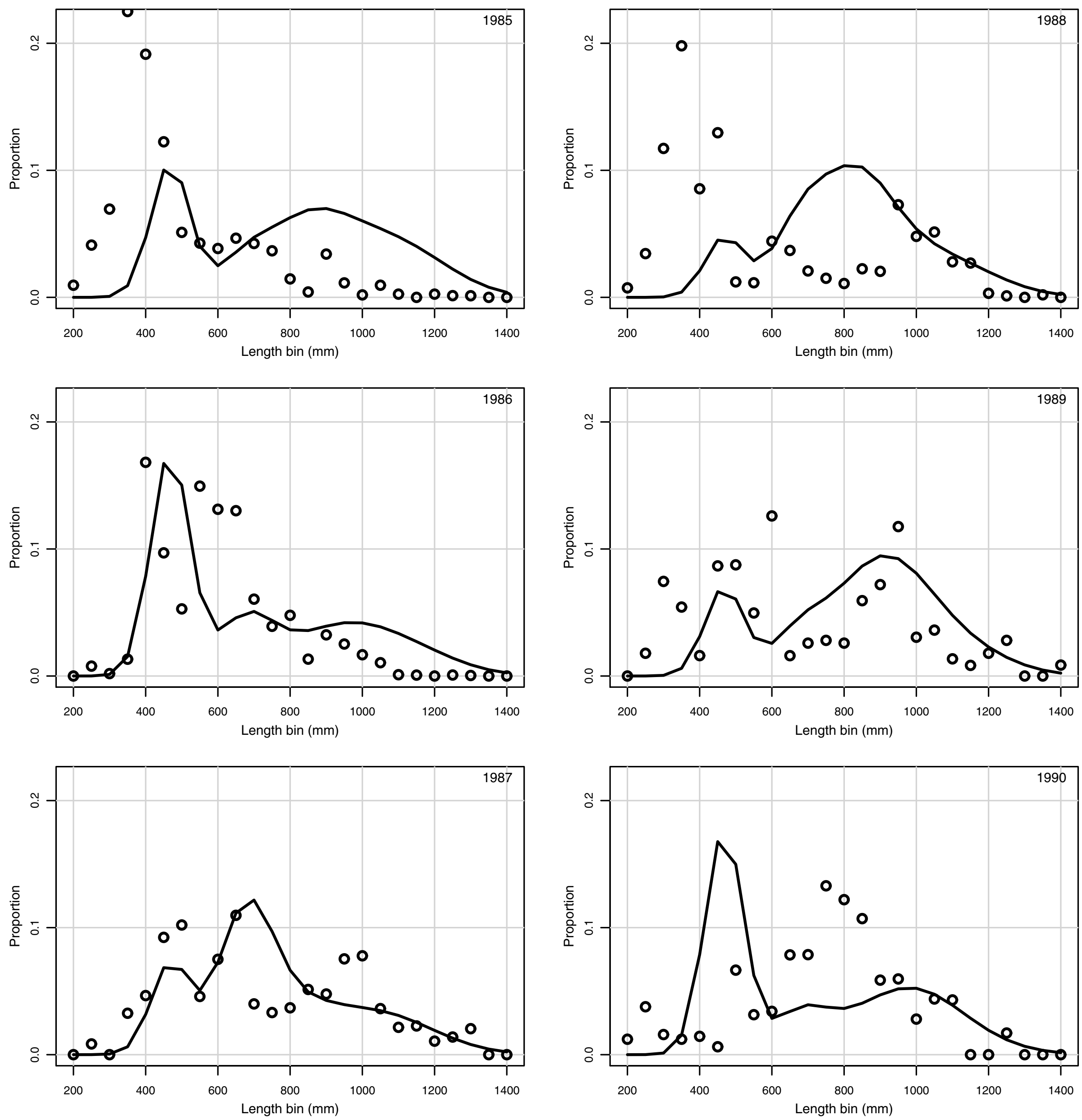

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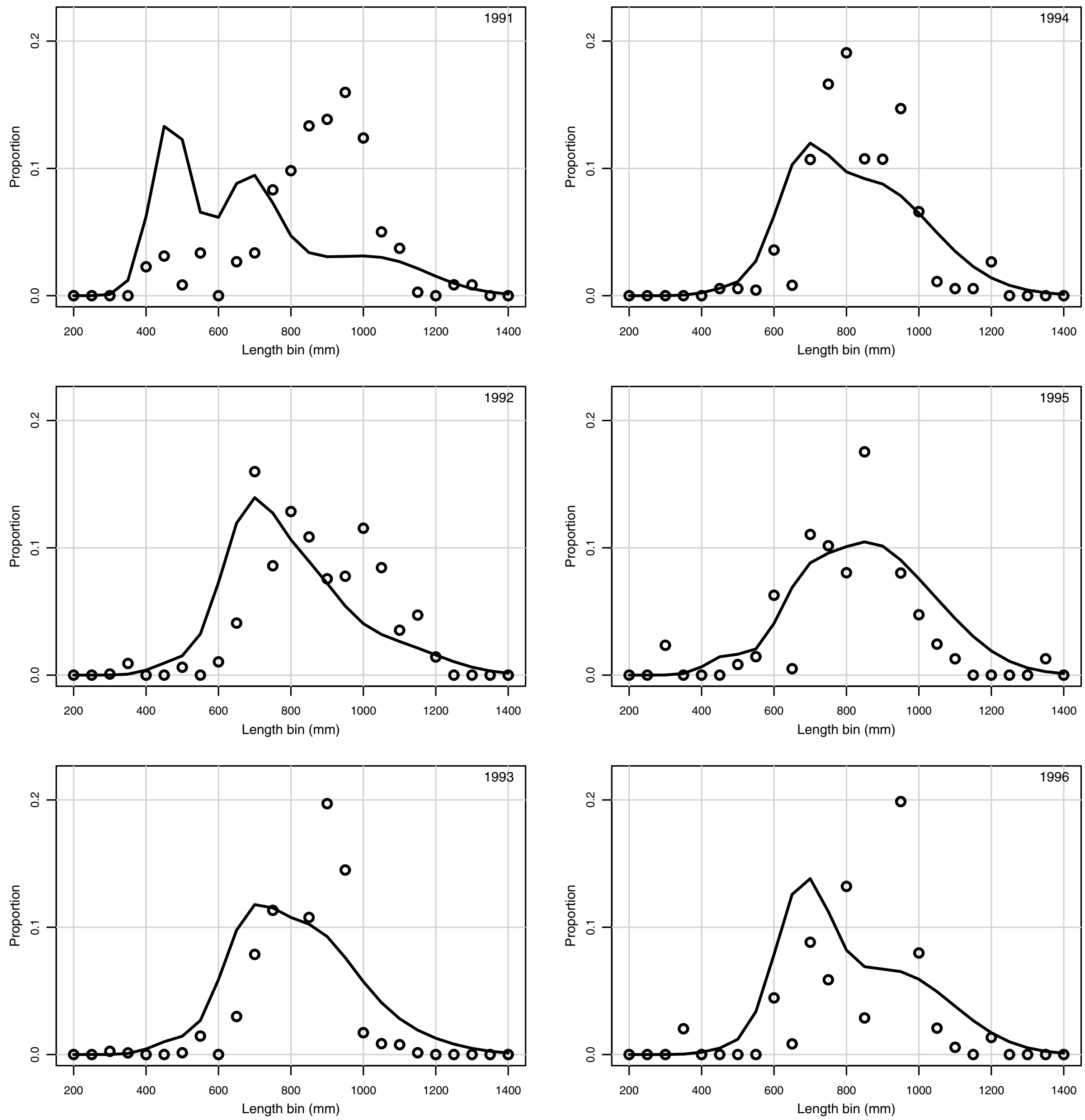
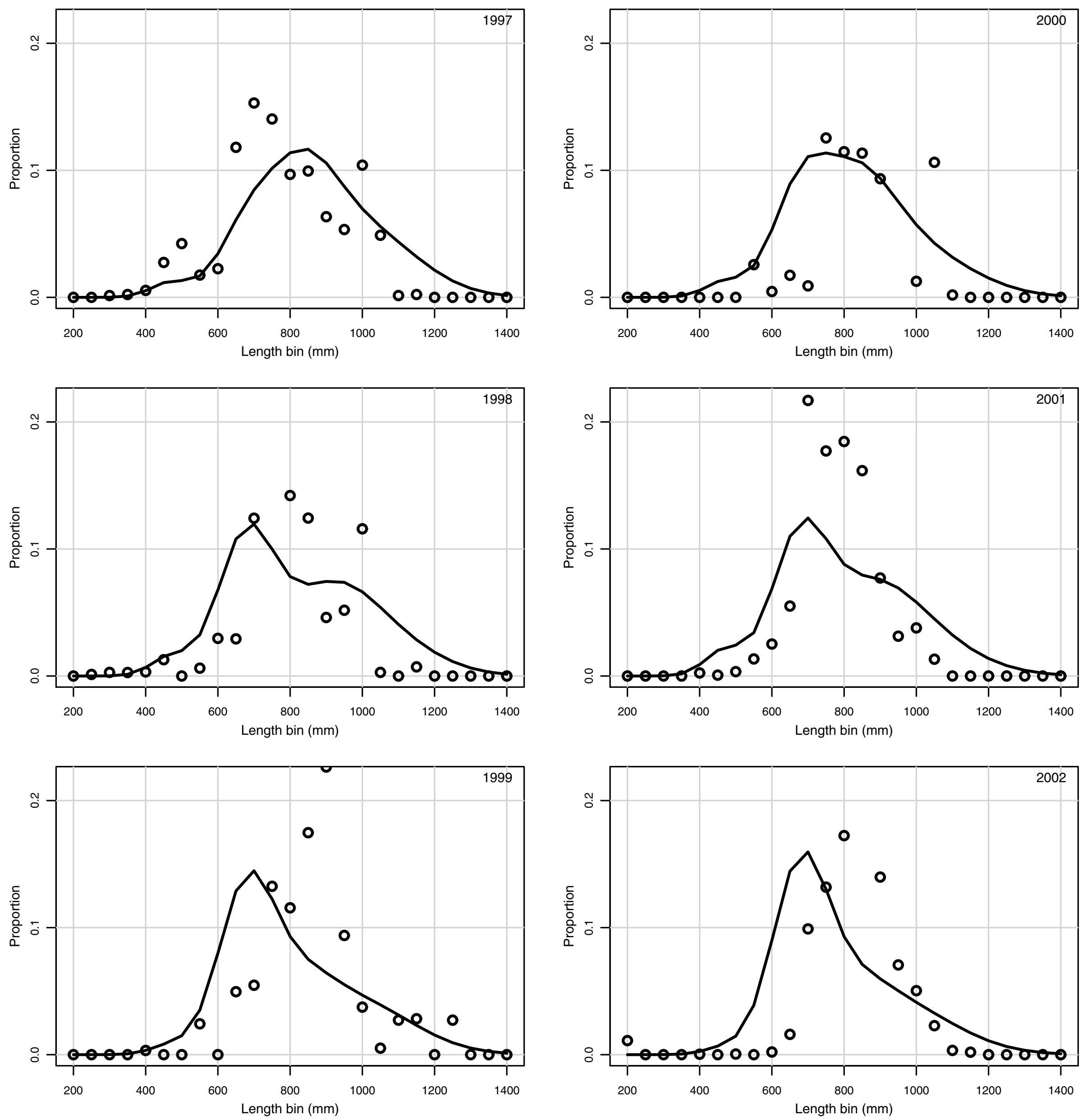


Figure 3.1. (Continued) Greater amberjack– Base run: Estimated (line) and observed (circles) annual length compositions (lcomp) and age compositions (acomp) from commercial handline (c.hal), commercial diving (c.dv), headboat (hb) and MRFSS (mrfss) sectors. After each series of annual plots, the ratio of observed sample size (N) and multinomial effective sample sizes, based on the observed and model estimated compositions are shown.



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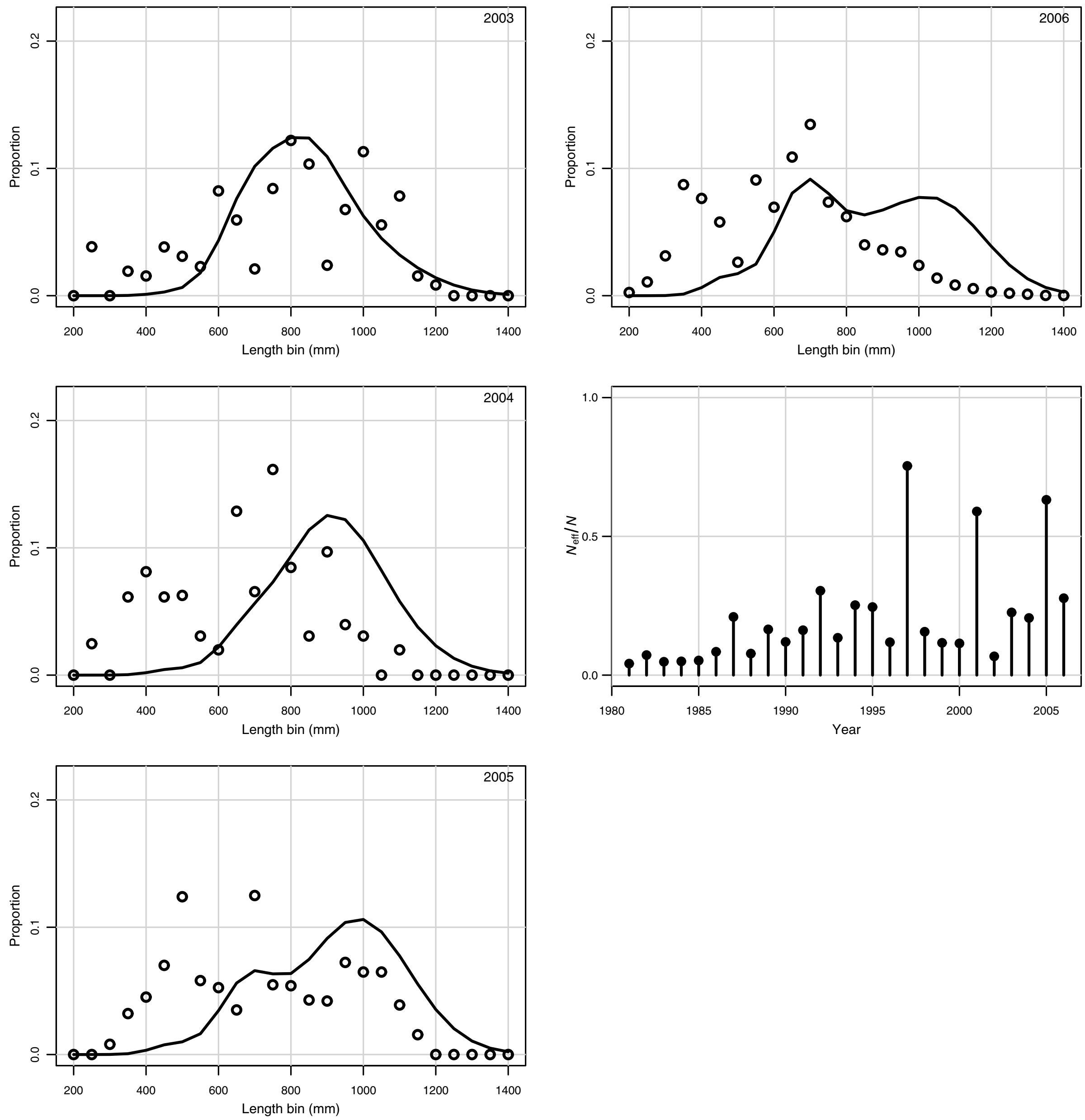

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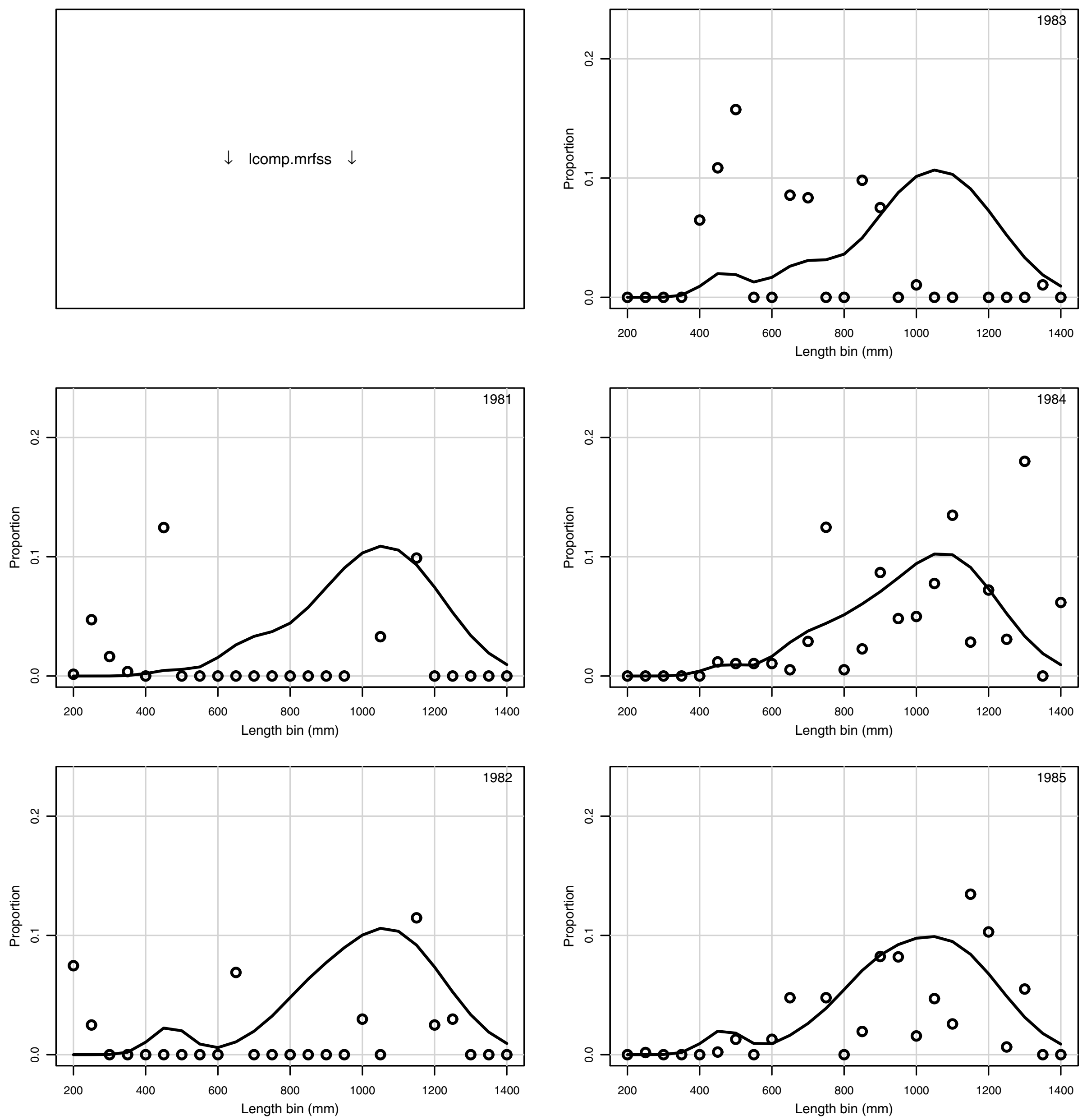
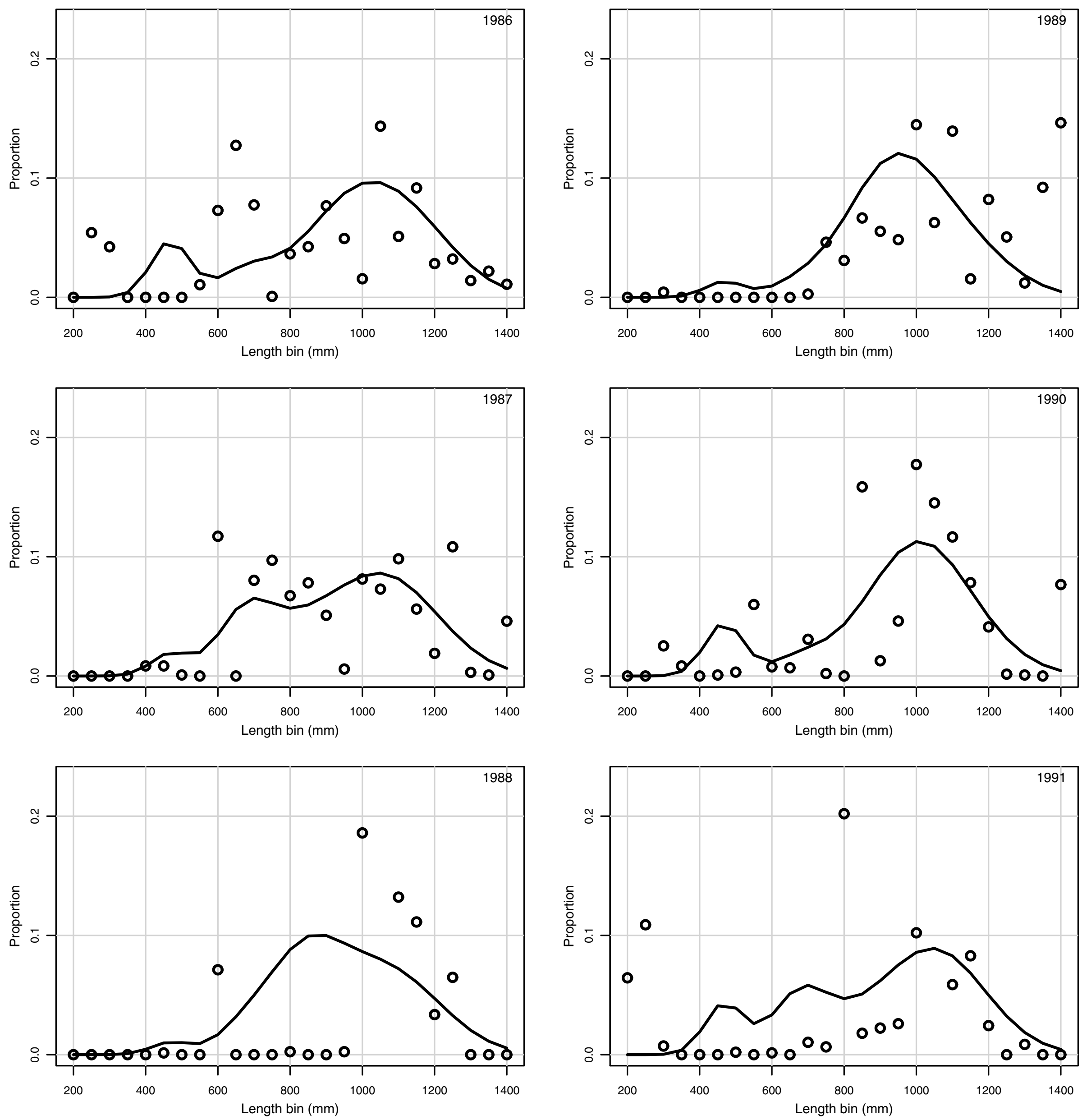


Figure 3.1. (Continued) Greater amberjack– Base run: Estimated (line) and observed (circles) annual length compositions (lcomp) and age compositions (acomp) from commercial handline (c.hal), commercial diving (c.dv), headboat (hb) and MRFSS (mrfss) sectors. After each series of annual plots, the ratio of observed sample size (N) and multinomial effective sample sizes, based on the observed and model estimated compositions are shown.



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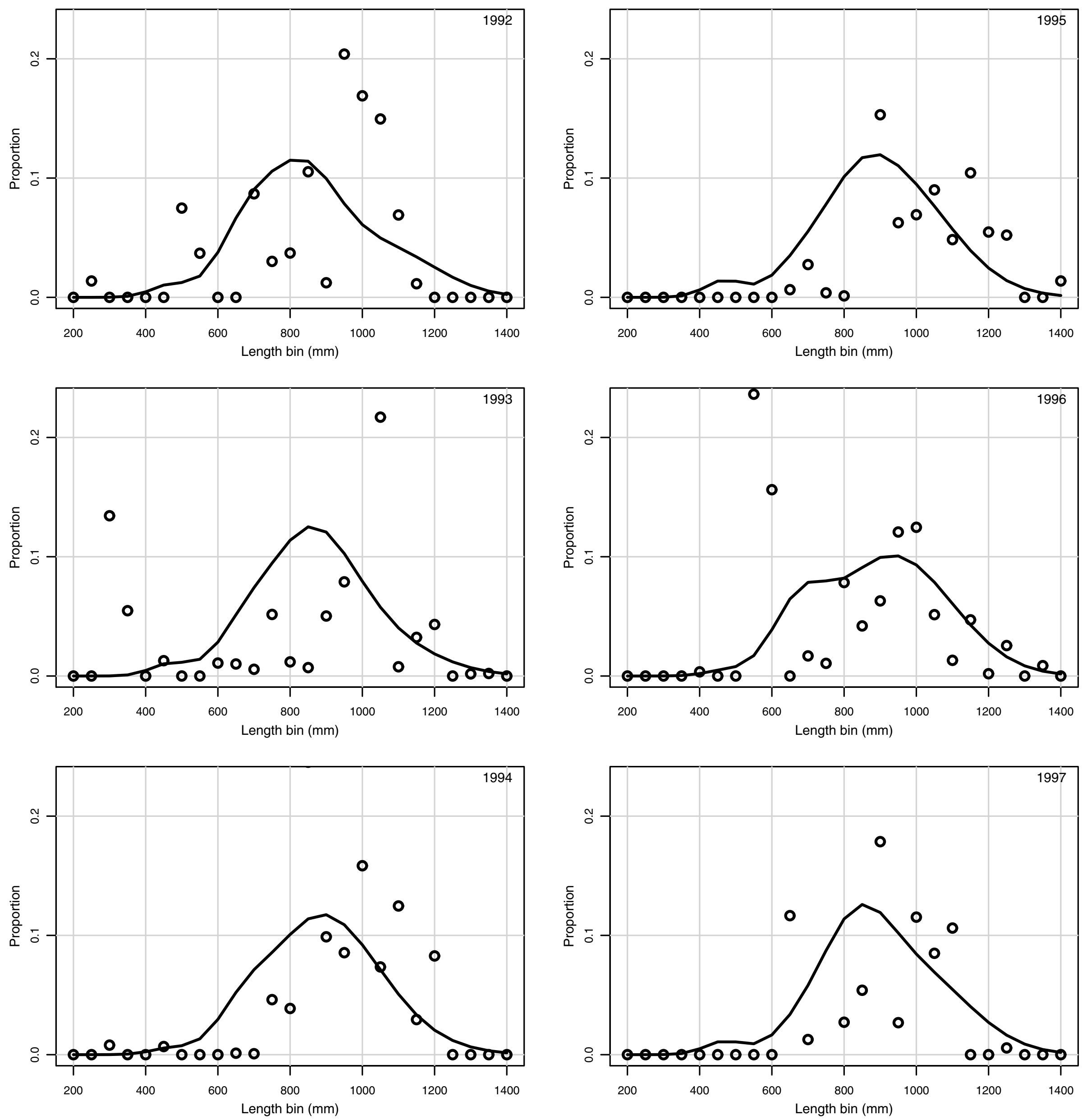

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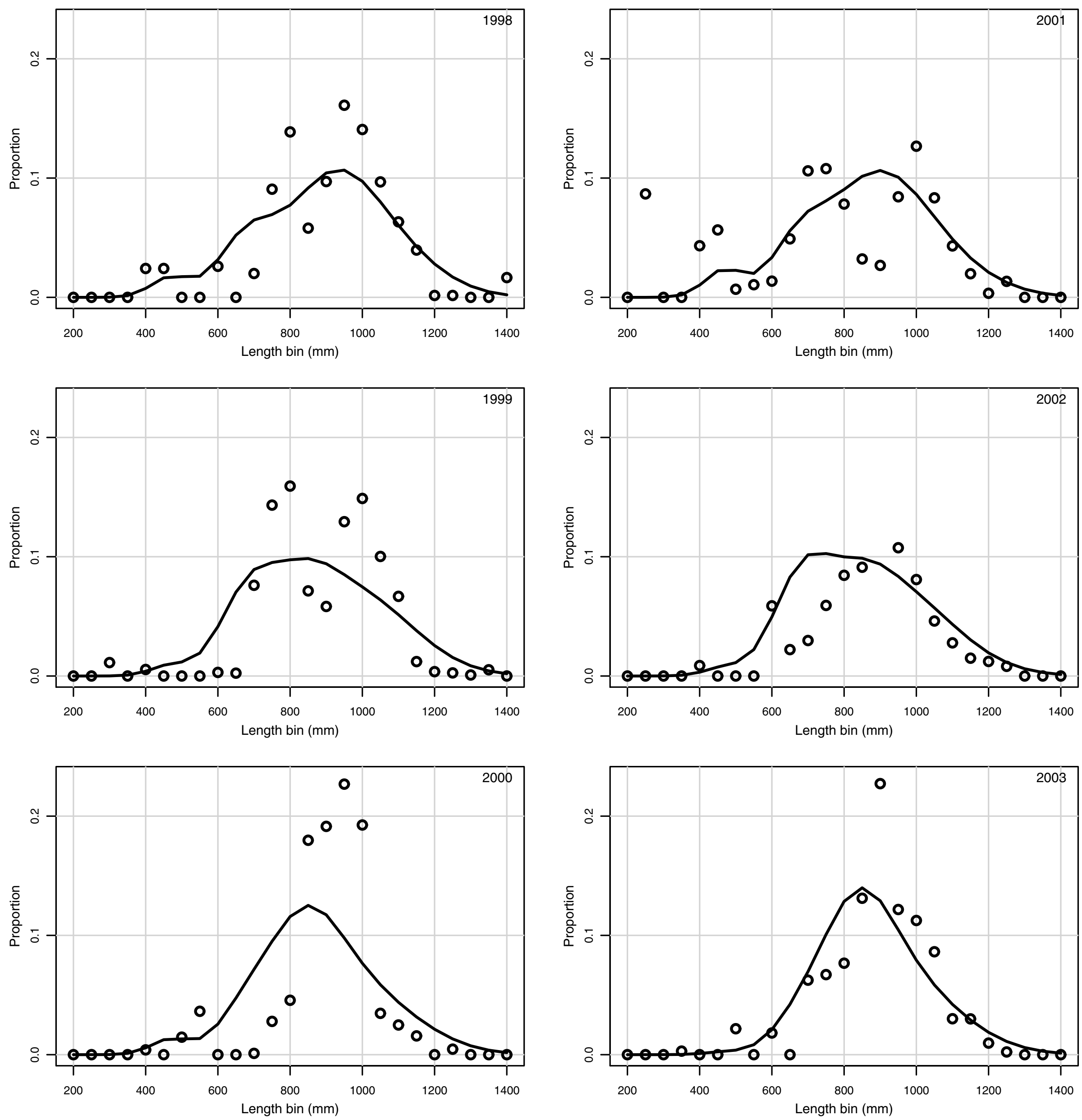
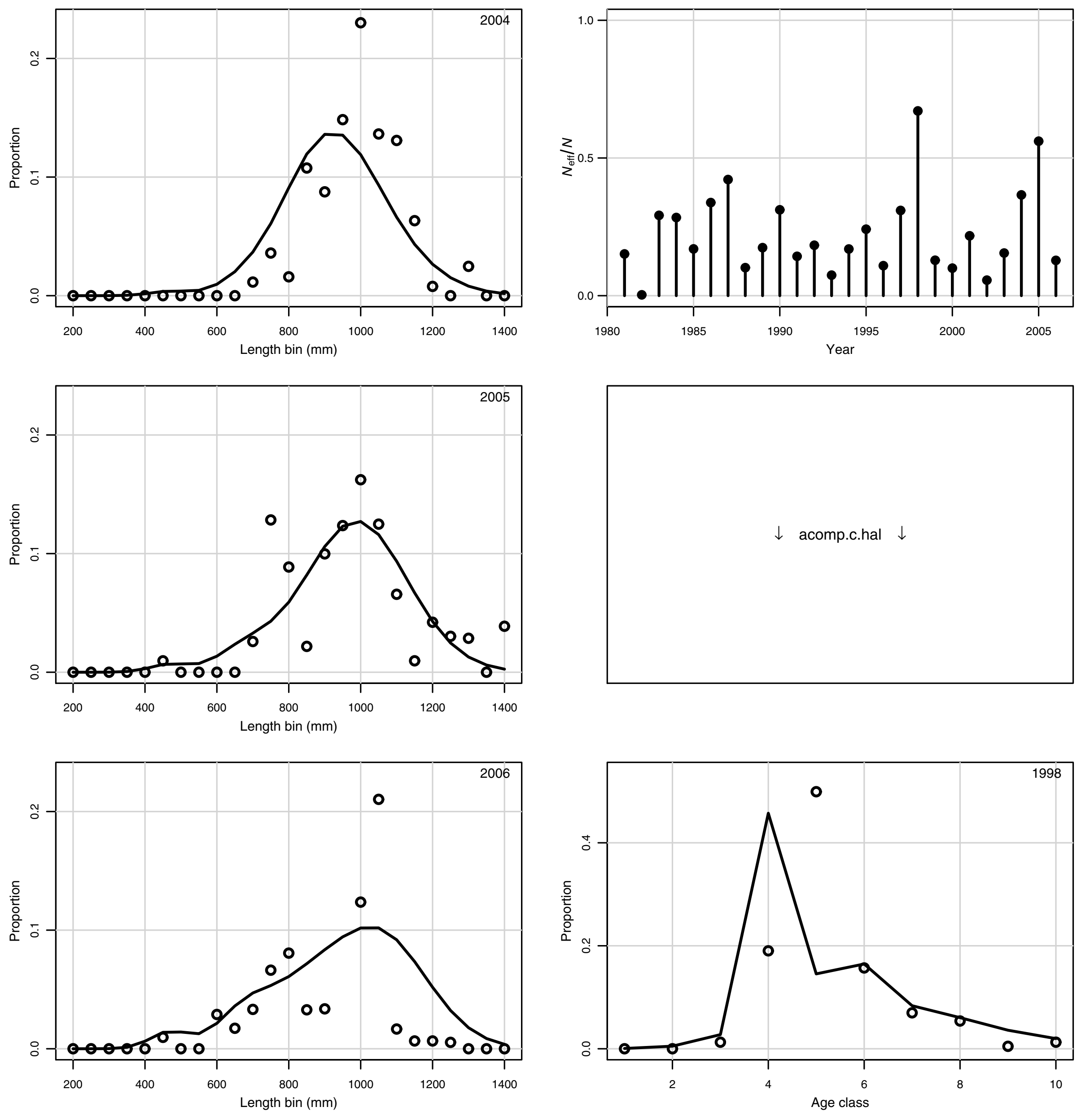


Figure 3.1. (Continued) Greater amberjack– Base run: Estimated (line) and observed (circles) annual length compositions (lcomp) and age compositions (acomp) from commercial handline (c.hal), commercial diving (c.dv), headboat (hb) and MRFSS (mrfss) sectors. After each series of annual plots, the ratio of observed sample size (N) and multinomial effective sample sizes, based on the observed and model estimated compositions are shown.



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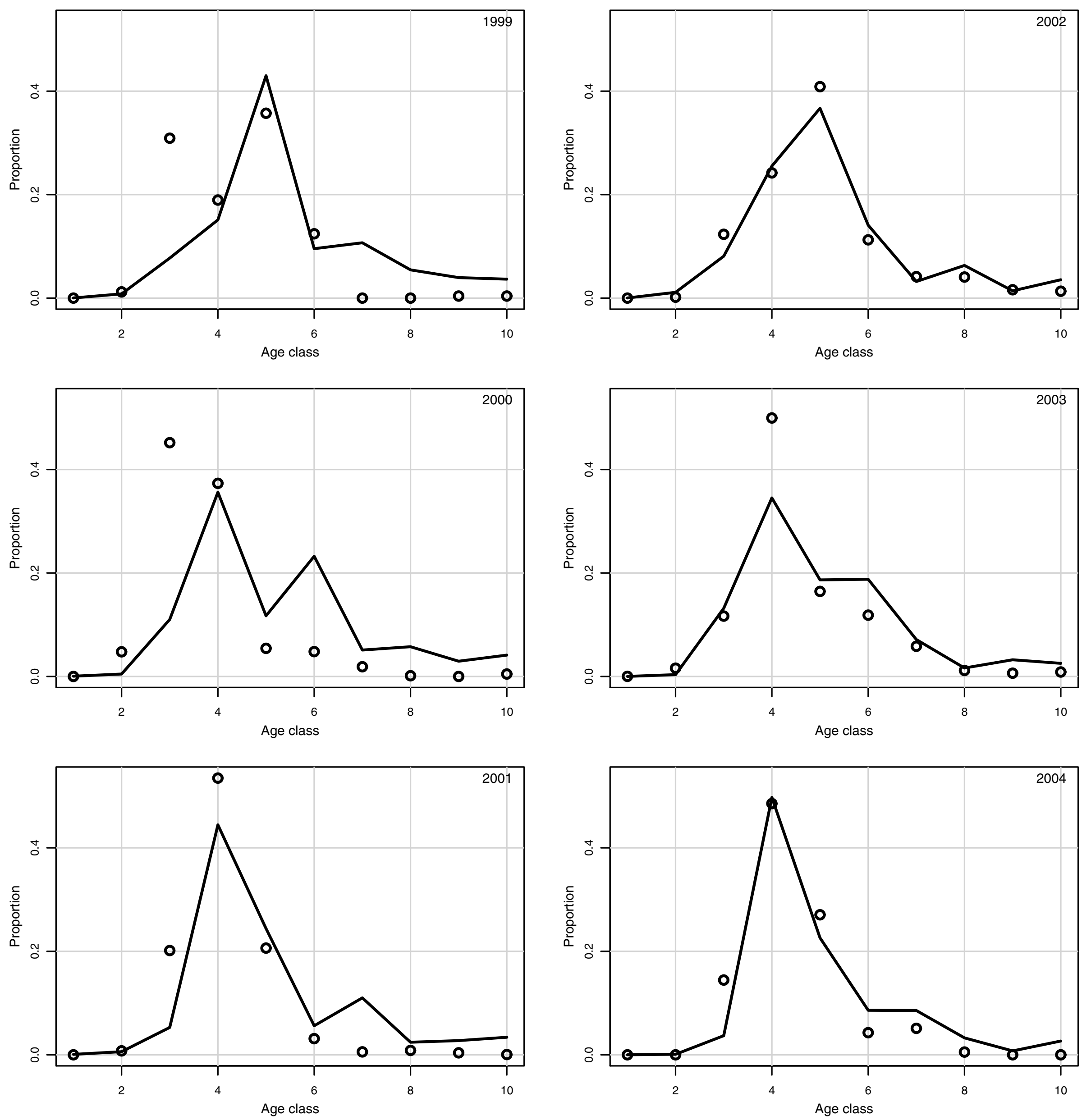


Figure 3.1. (Continued) Greater amberjack– Base run: Estimated (line) and observed (circles) annual length compositions (lcomp) and age compositions (acomp) from commercial handline (c.hal), commercial diving (c.dv), headboat (hb) and MRFSS (mrfss) sectors. After each series of annual plots, the ratio of observed sample size (N) and multinomial effective sample sizes, based on the observed and model estimated compositions are shown.

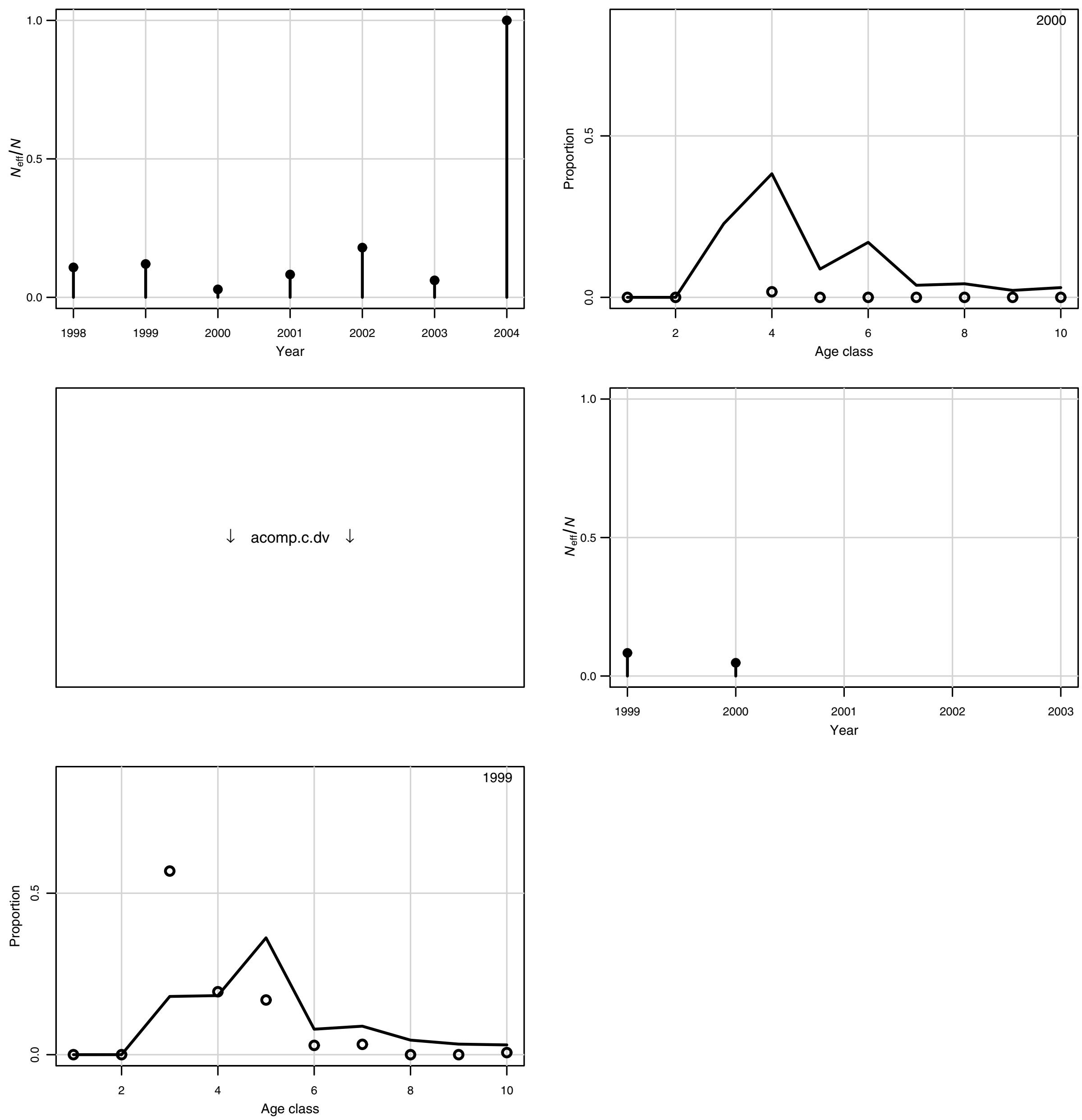


Figure 3.1. (Continued) Greater amberjack– Base run: Estimated (line) and observed (circles) annual length compositions (lcomp) and age compositions (acomp) from commercial handline (c.hal), commercial diving (c.dv), headboat (hb) and MRFSS (mrfss) sectors. After each series of annual plots, the ratio of observed sample size (N) and multinomial effective sample sizes, based on the observed and model estimated compositions are shown.

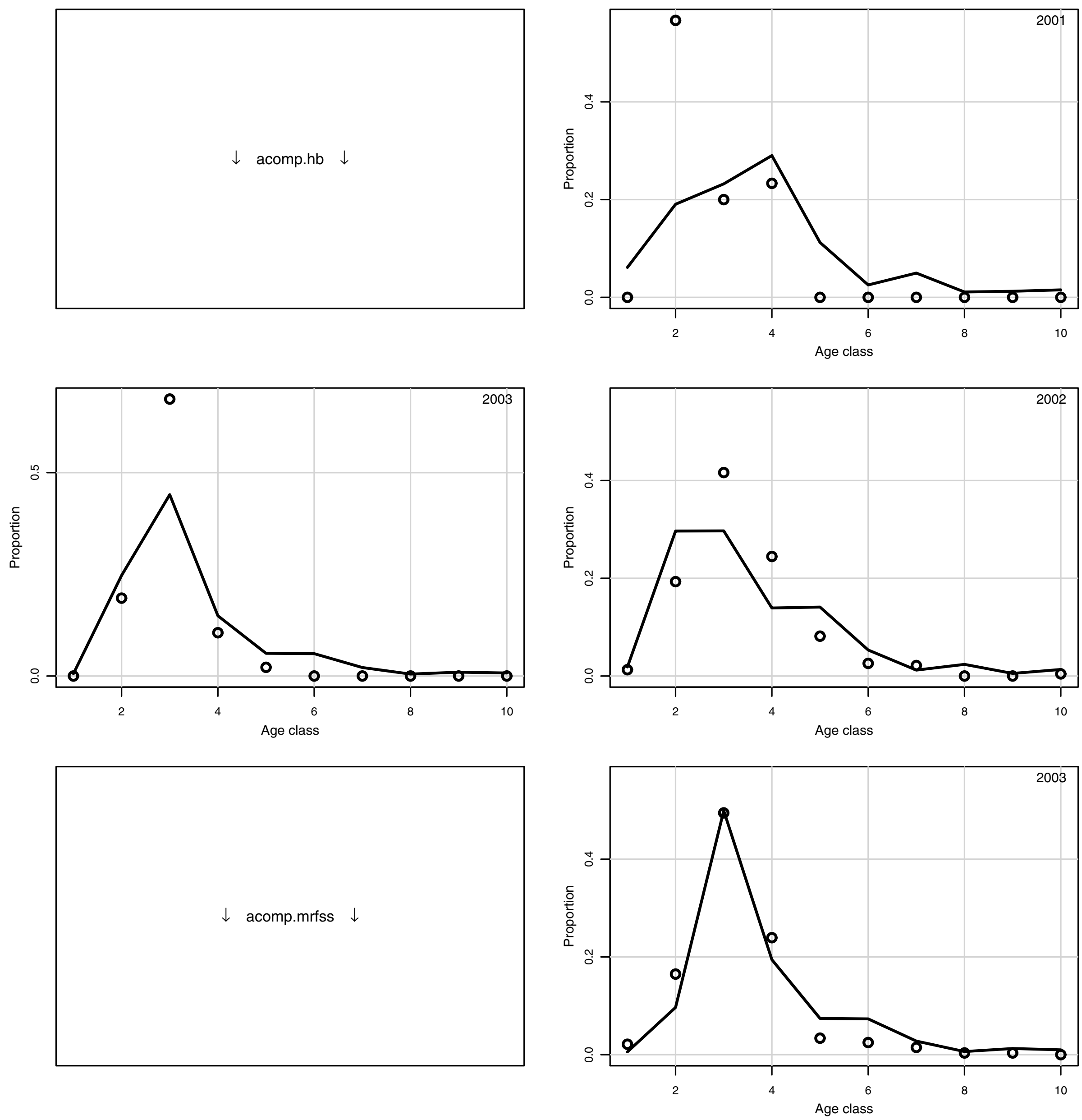


Figure 3.1. (Continued) Greater amberjack– Base run: Estimated (line) and observed (circles) annual length compositions (lcomp) and age compositions (acomp) from commercial handline (c.hal), commercial diving (c.dv), headboat (hb) and MRFSS (mrfss) sectors. After each series of annual plots, the ratio of observed sample size (N) and multinomial effective sample sizes, based on the observed and model estimated compositions are shown.

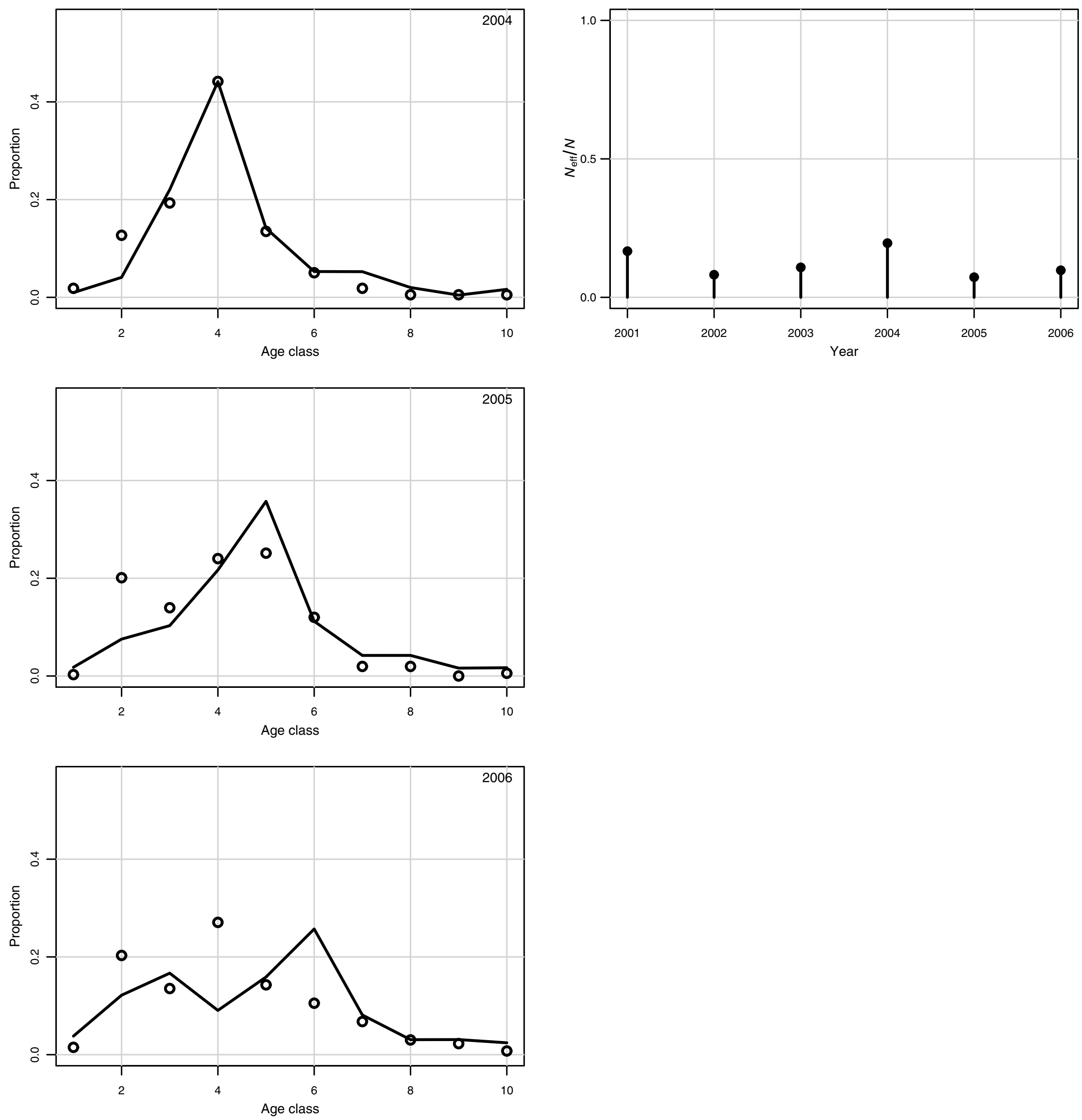


Figure 3.2. Greater amberjack– Base run: Bubble plot of length composition residuals from the commercial handline fishery; Dark bubbles are overestimates and light bubbles are underestimates. Area of the bubbles correspond to magnitude of the residuals. Error is bounded between 0^o *and* 90^o*, with* 0^o *indicating a perfect fit.*

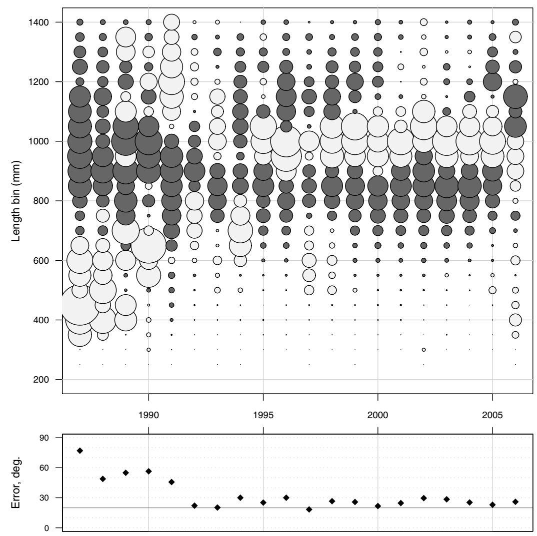


Figure 3.3. Greater amberjack– Base run: Bubble plot of length composition residuals from the commercial diving fishery; Dark bubbles are overestimates and light bubbles are underestimates. Area of the bubbles correspond to magnitude of the residuals. Error is bounded between 0^o *and* 90^o*, with* 0^o *indicating a perfect fit.*

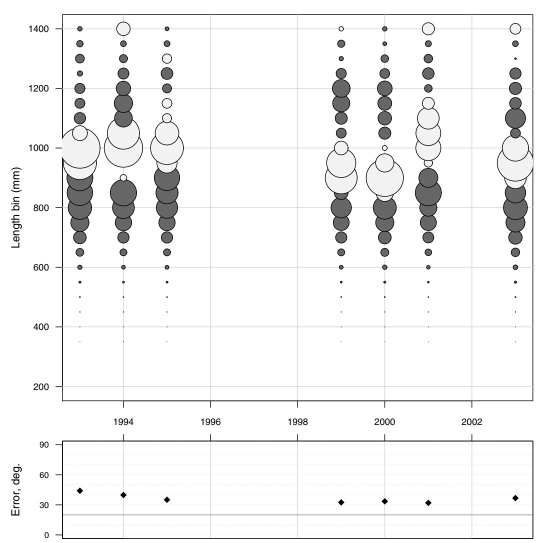


Figure 3.4. Greater amberjack– Base run: Bubble plot of length composition residuals from the headboat fishery; Dark bubbles are overestimates and light bubbles are underestimates. Area of the bubbles correspond to magnitude of the residuals. Error is bounded between 0^o *and* 90^o, *with* 0^o *indicating a perfect fit.*

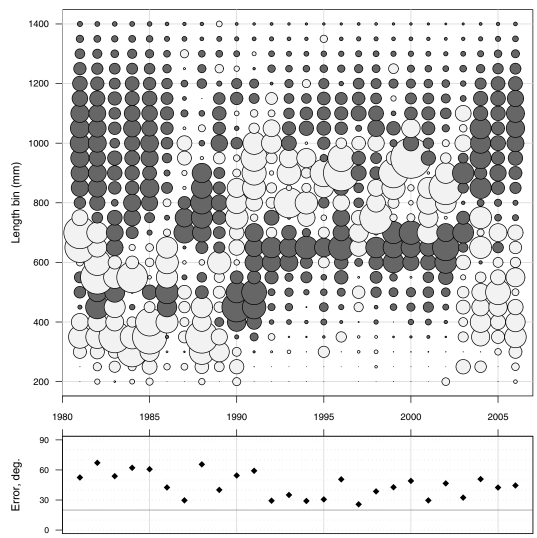


Figure 3.5. Greater amberjack– Base run: Bubble plot of length composition residuals from the recreational survey; Dark bubbles are overestimates and light bubbles are underestimates. Area of the bubbles correspond to magnitude of the residuals. Error is bounded between 0^o *and* 90^o, *with* 0^o *indicating a perfect fit.*

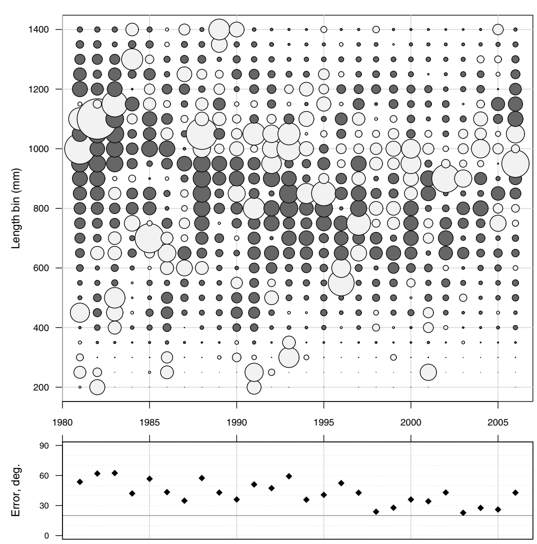


Figure 3.6. Greater amberjack– Base run: Bubble plot of age composition residuals from the commercial handline fishery; Dark bubbles are overestimates and light bubbles are underestimates. Area of the bubbles correspond to magnitude of the residuals.

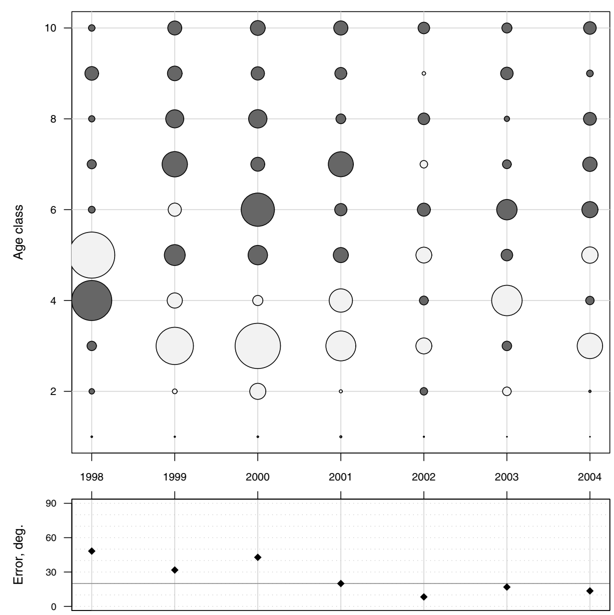


Figure 3.7. Greater amberjack– Base run: Bubble plot of age composition residuals from the commercial diving fishery; Dark bubbles are overestimates and light bubbles are underestimates. Area of the bubbles correspond to magnitude of the residuals.

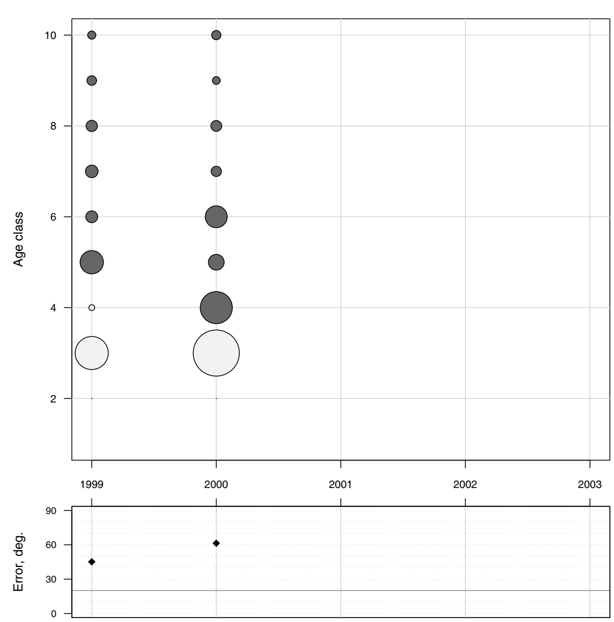


Figure 3.8. Greater amberjack– Base run: Bubble plot of age composition residuals from the headboat fishery; Dark bubbles are overestimates and light bubbles are underestimates. Area of the bubbles correspond to magnitude of the residuals.

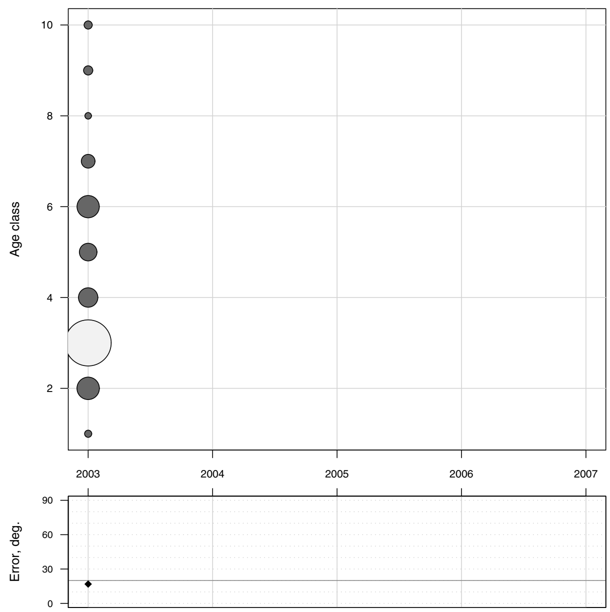


Figure 3.9. Greater amberjack– Base run: Bubble plot of age composition residuals from the recreational survey; Dark bubbles are overestimates and light bubbles are underestimates. Area of the bubbles correspond to magnitude of the residuals.

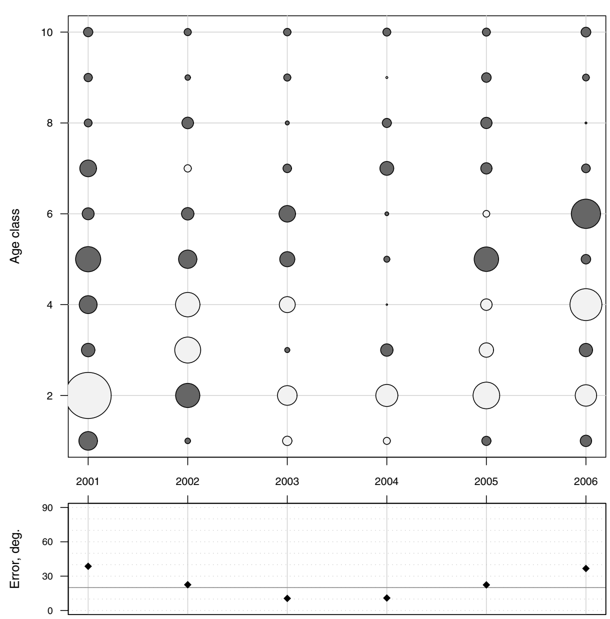


Figure 3.10. Greater amberjack– Base run: Commercial handline landings (klb) from the assessment model, estimated (line, filled circles) and observed (open circles).

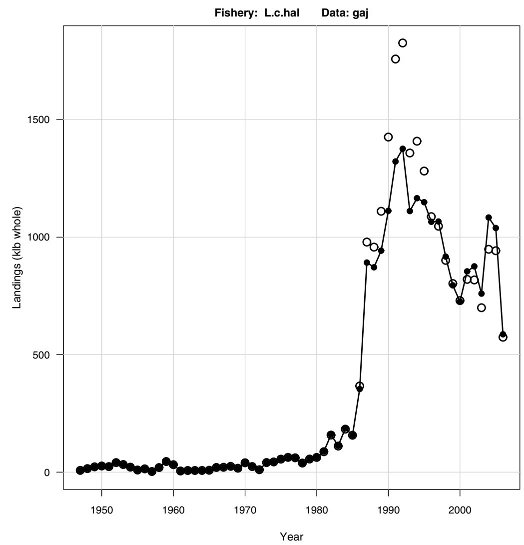


Figure 3.11. Greater amberjack– Base run: Commercial diving landings (klb) from the assessment model, estimated (line, filled circles) and observed (open circles).

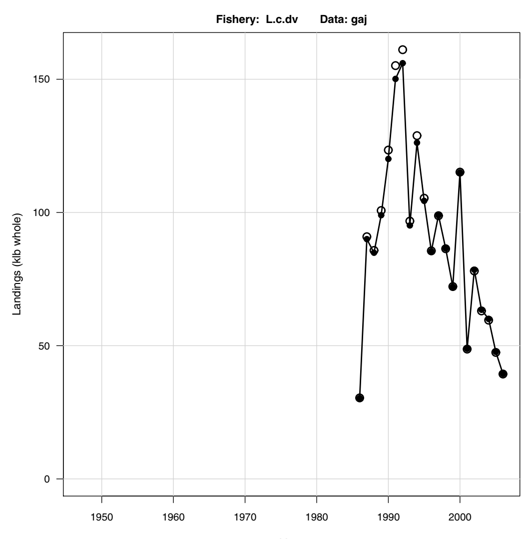


Figure 3.12. Greater amberjack– Base run: Headboat landings (klb) from the assessment model, estimated (line, filled circles) and observed (open circles).

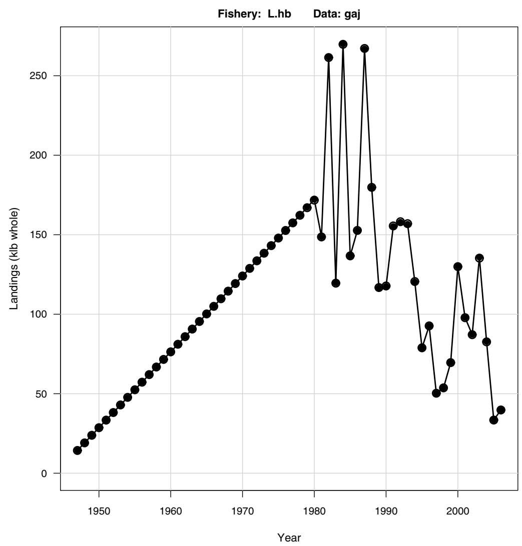


Figure 3.13. Greater amberjack– Base run: Recreational survey landings (klb) from the assessment model, estimated (line, filled circles) and observed (open circles).

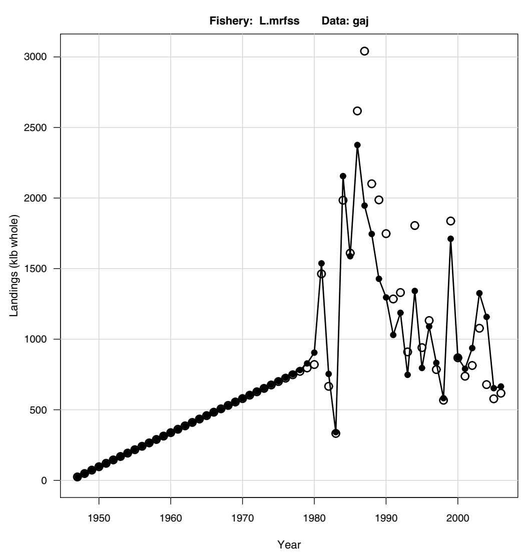


Figure 3.14. Greater amberjack Base run:– Discard mortalities (1000s fish) from the commercial handline fishery, estimated (line, filled circles) and observed (open circles).

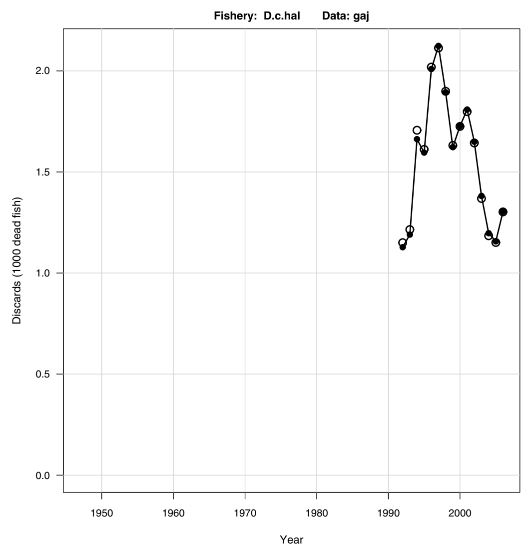


Figure 3.15. Greater amberjack Base run:– Discard mortalities (1000s fish) from the recreational survey, estimated (line, filled circles) and observed (open circles).

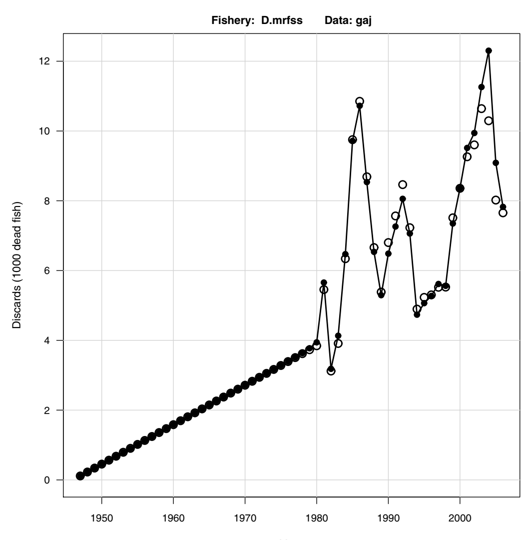


Figure 3.16. Greater amberjack– Base run: Fit to commercial handline index of abundance, estimated (line, solid circle) and observed (open circles) with scaled residuals in bottom panel.

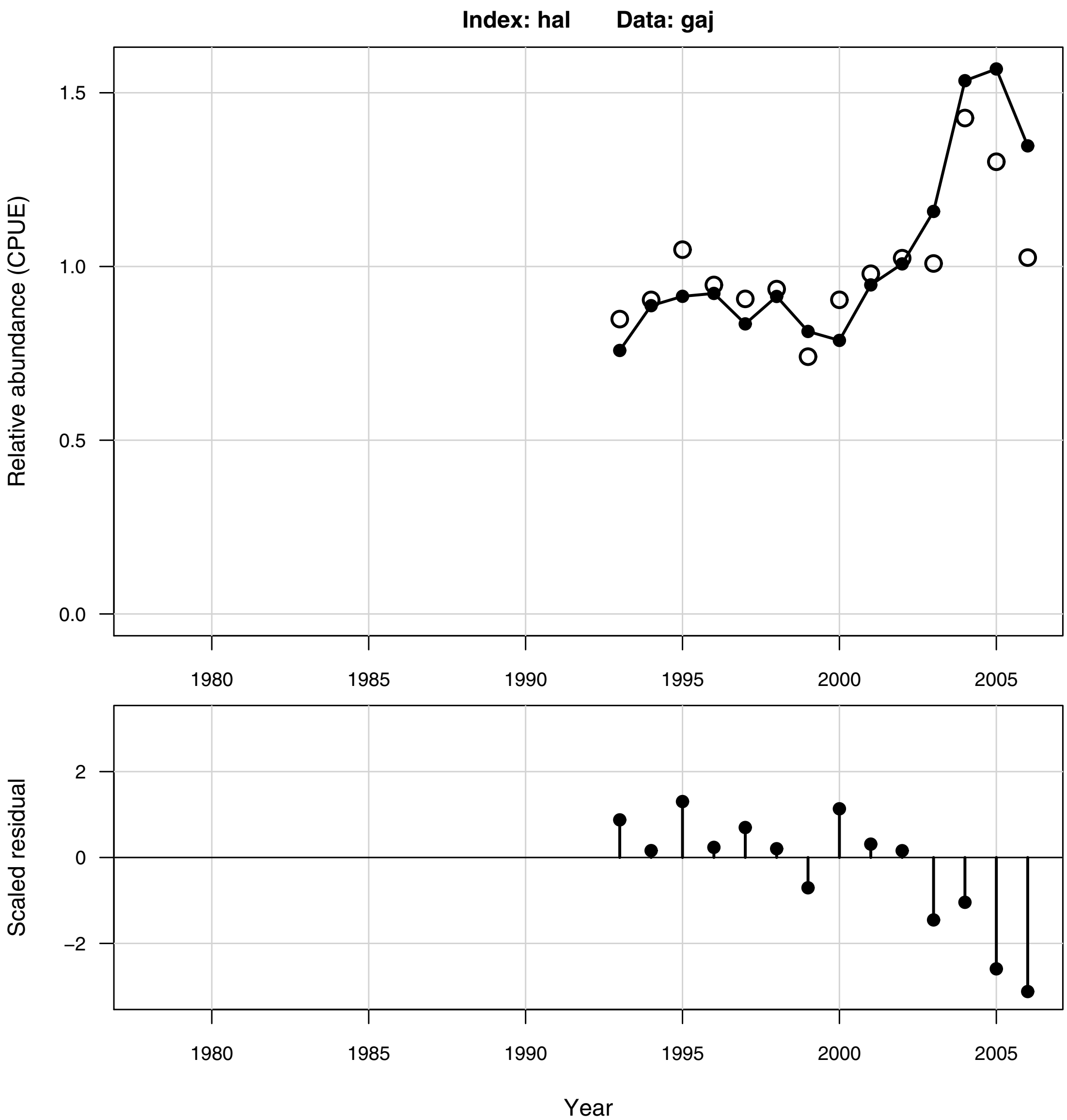


Figure 3.17. Greater amberjack– Base run: Fit to headboat index of abundance, estimated (line, solid circle) and observed (open circles) with scaled residuals in bottom panel.

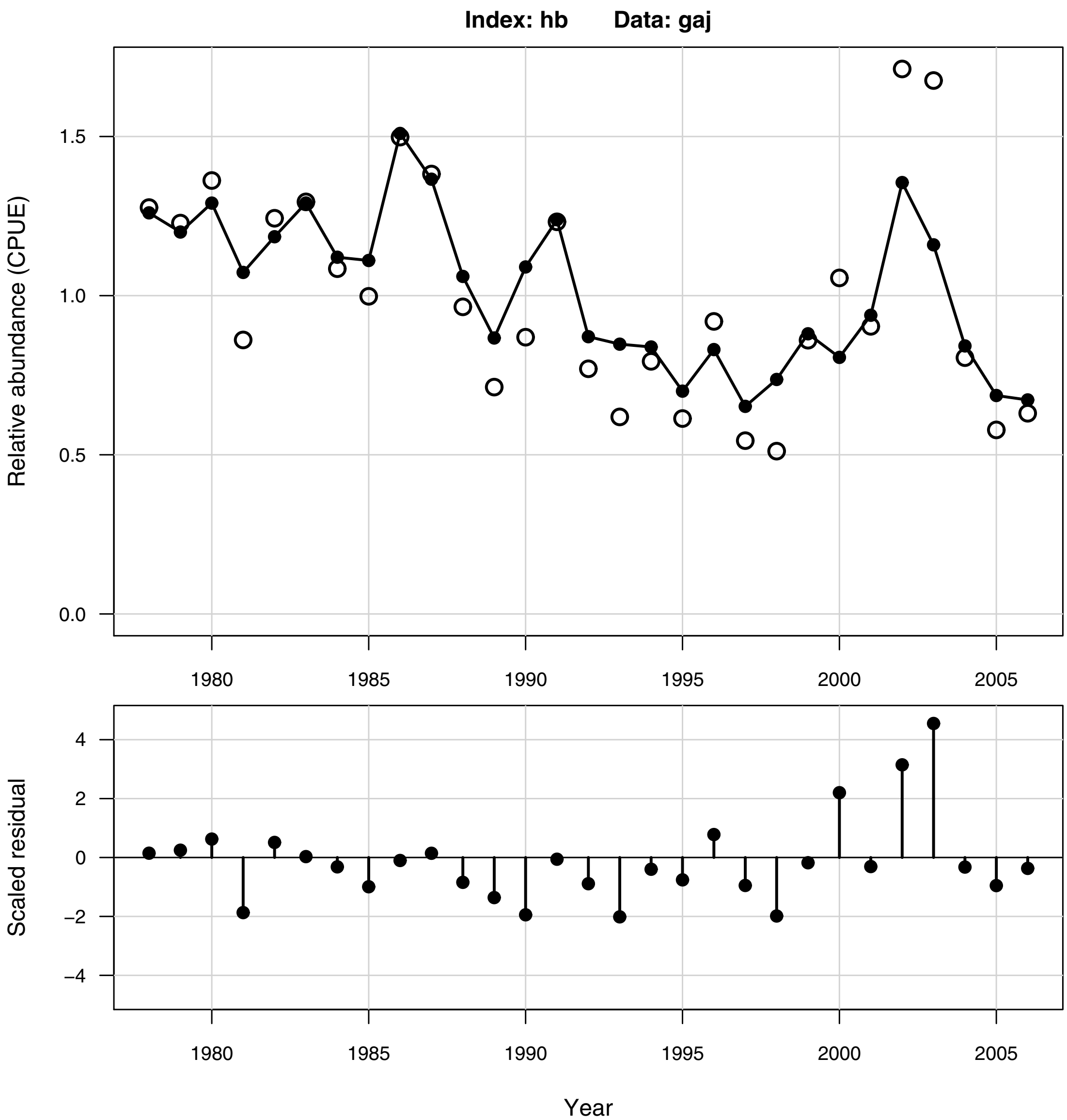


Figure 3.18. Greater amberjack– Base run: Mean length (mm) at age (midyear) of greater amberjack, estimated internally by the assessment model assuming von Bertalanffy growth. Thin lines represent 95% confidence intervals from estimated CV parameters.

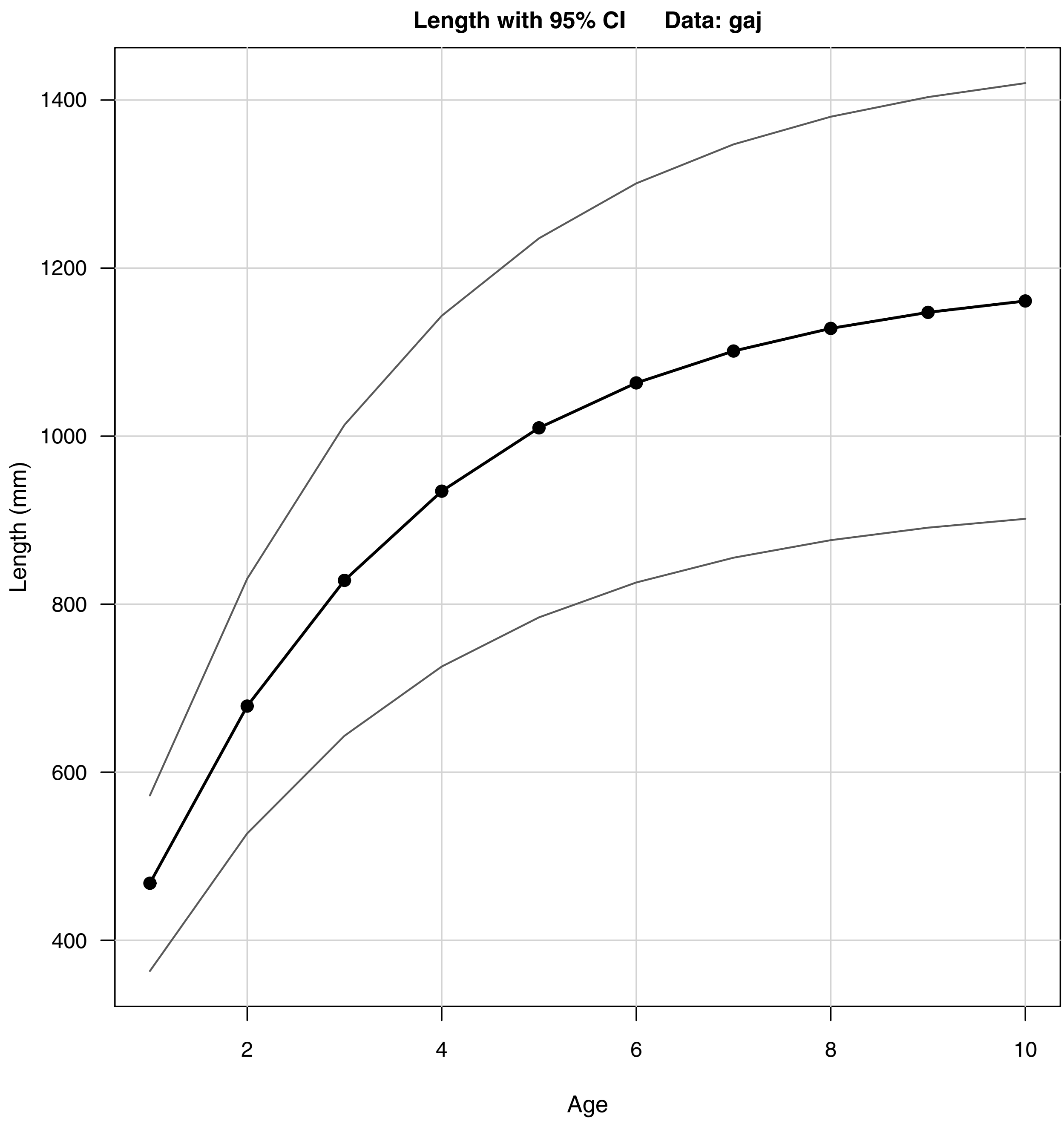


Figure 3.19. Greater amberjack– Base run: Estimated numbers of fish at age from the stock assessment model.

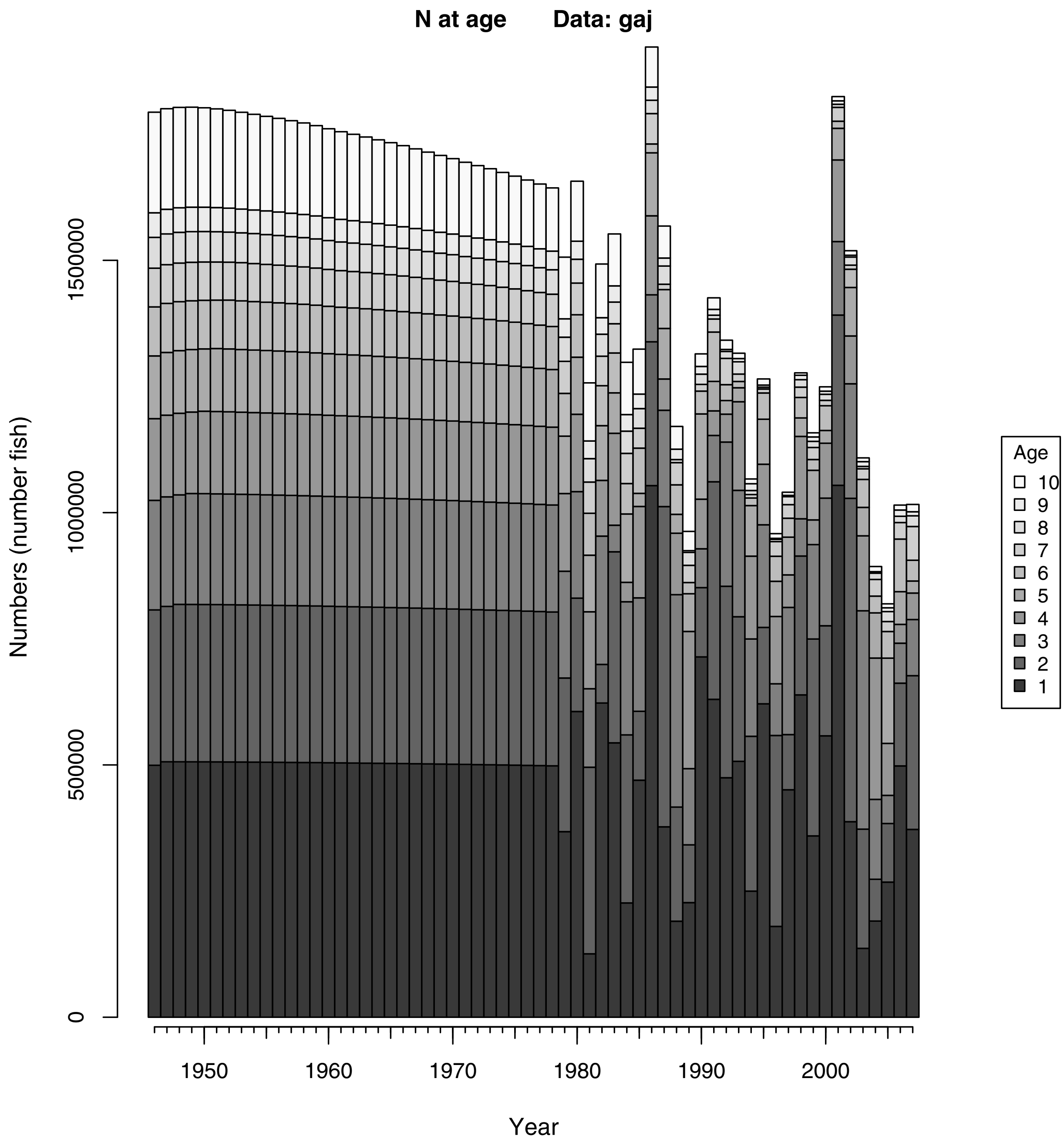


Figure 3.20. Greater amberjack Base run: Estimated time series of number of recruits with dashed line at $\hat{R}_{\text{msy}}$.

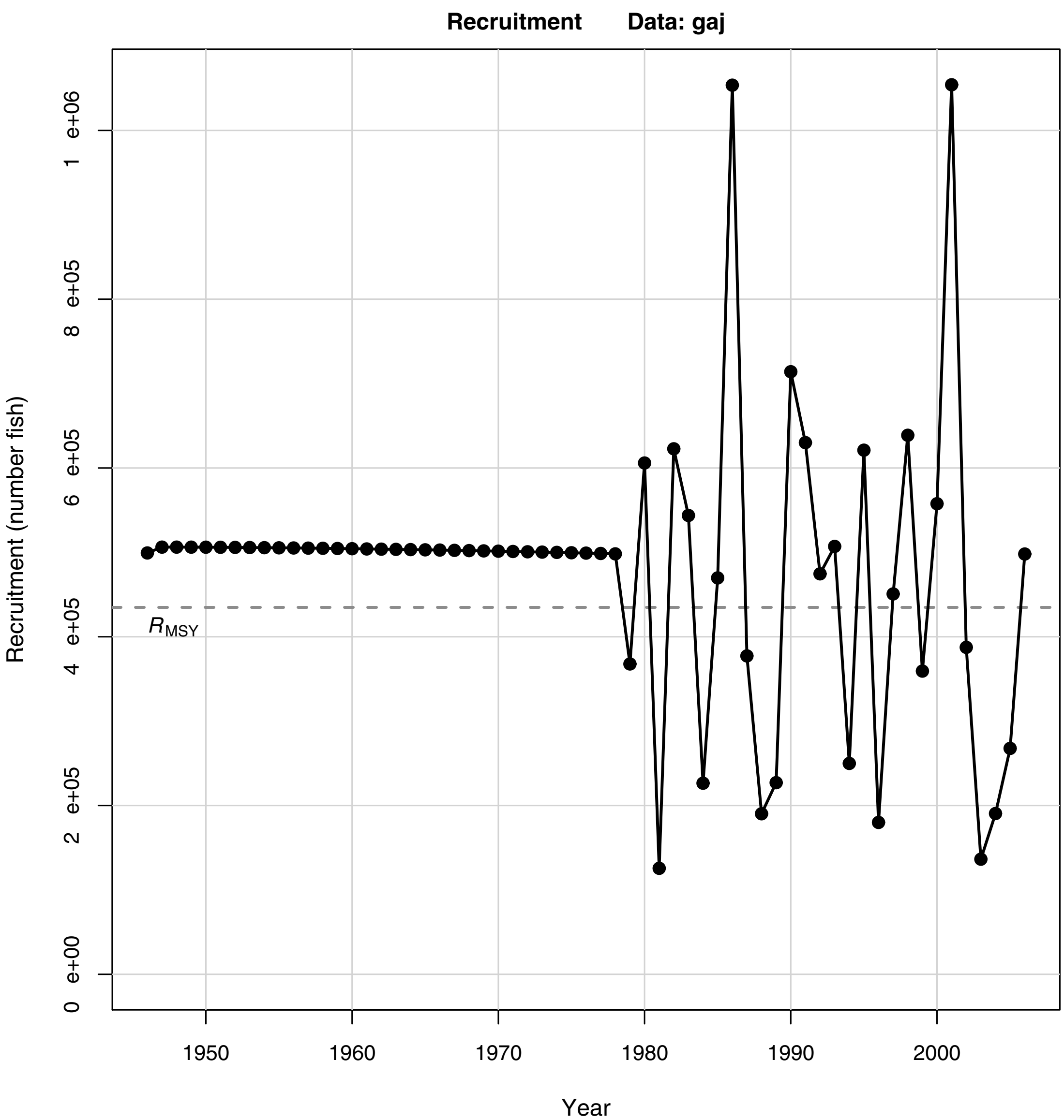


Figure 3.21. Greater amberjack– Base run: Estimated biomass at age in metric tons from the stock assessment model.

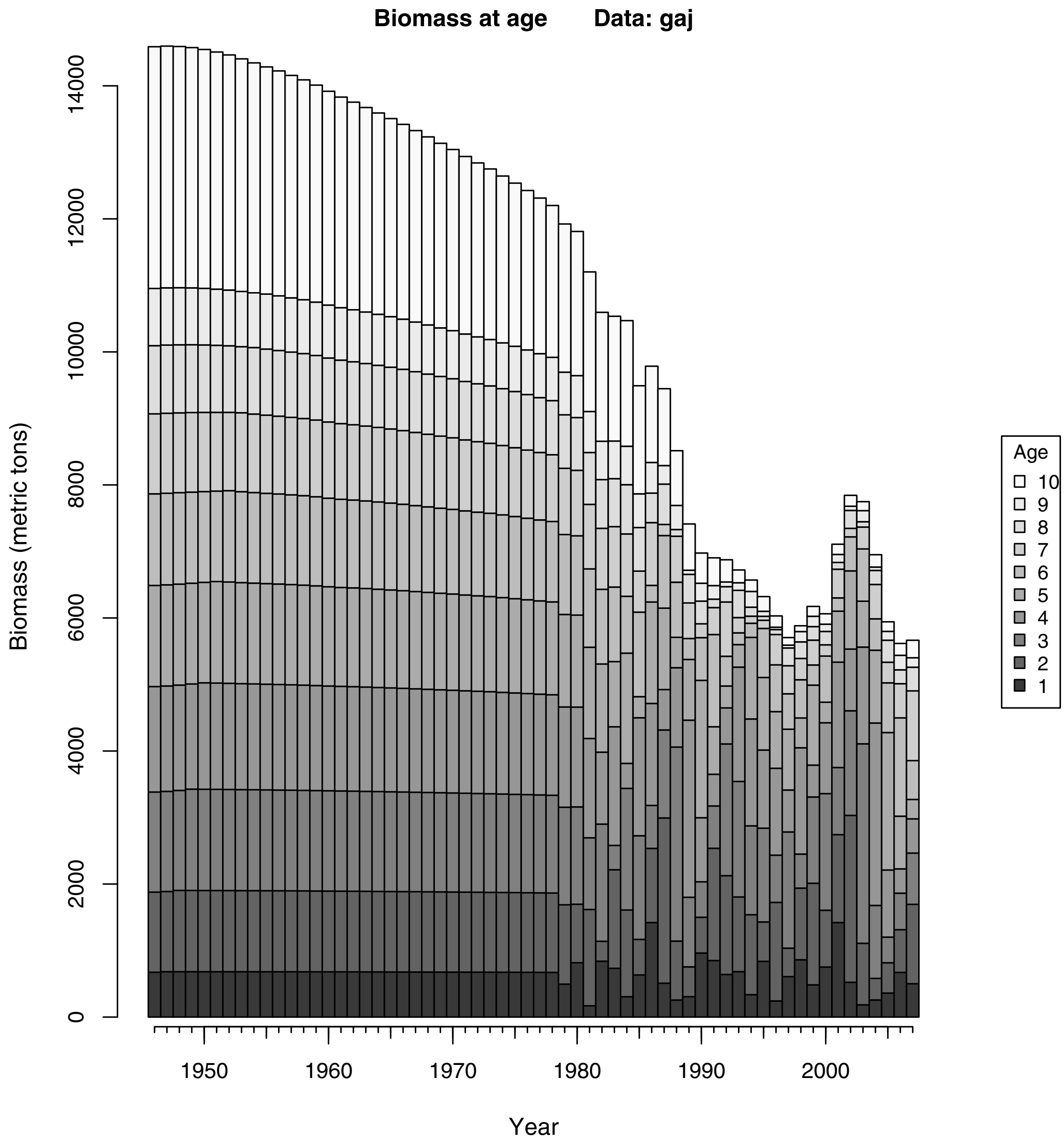


Figure 3.22. Greater amberjack– Base run: Estimated biomass time series. Top panel, total biomass and bottom panel, spawning stock biomass (male mature biomass + female mature biomass). The solid horizontal line represents the level corresponding to MSY *and the horizontal dashed lines represent the 10th and 90th percentiles of the* MSY *level.*

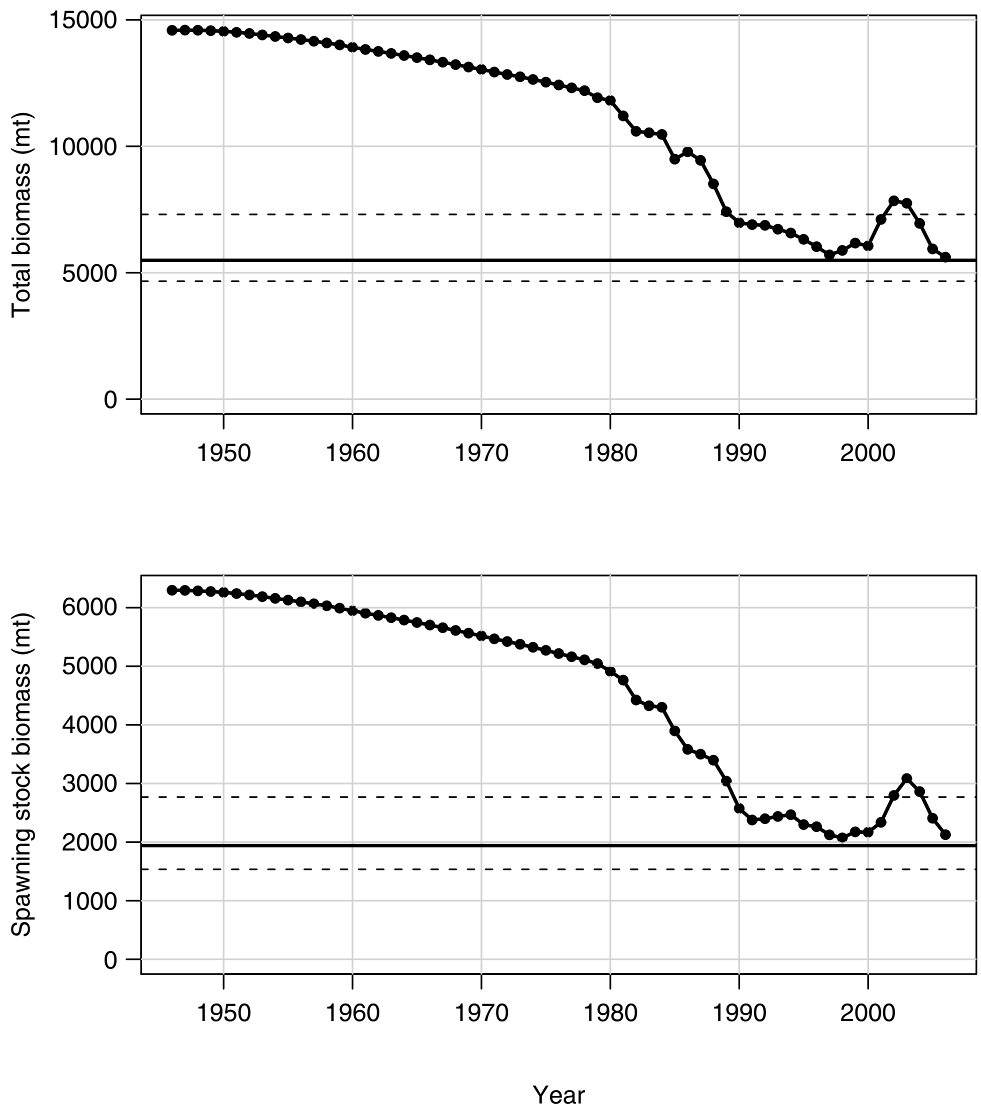


Figure 3.23. Greater amberjack– Base run: Estimated selectivity of commercial handline fishery through 1991.

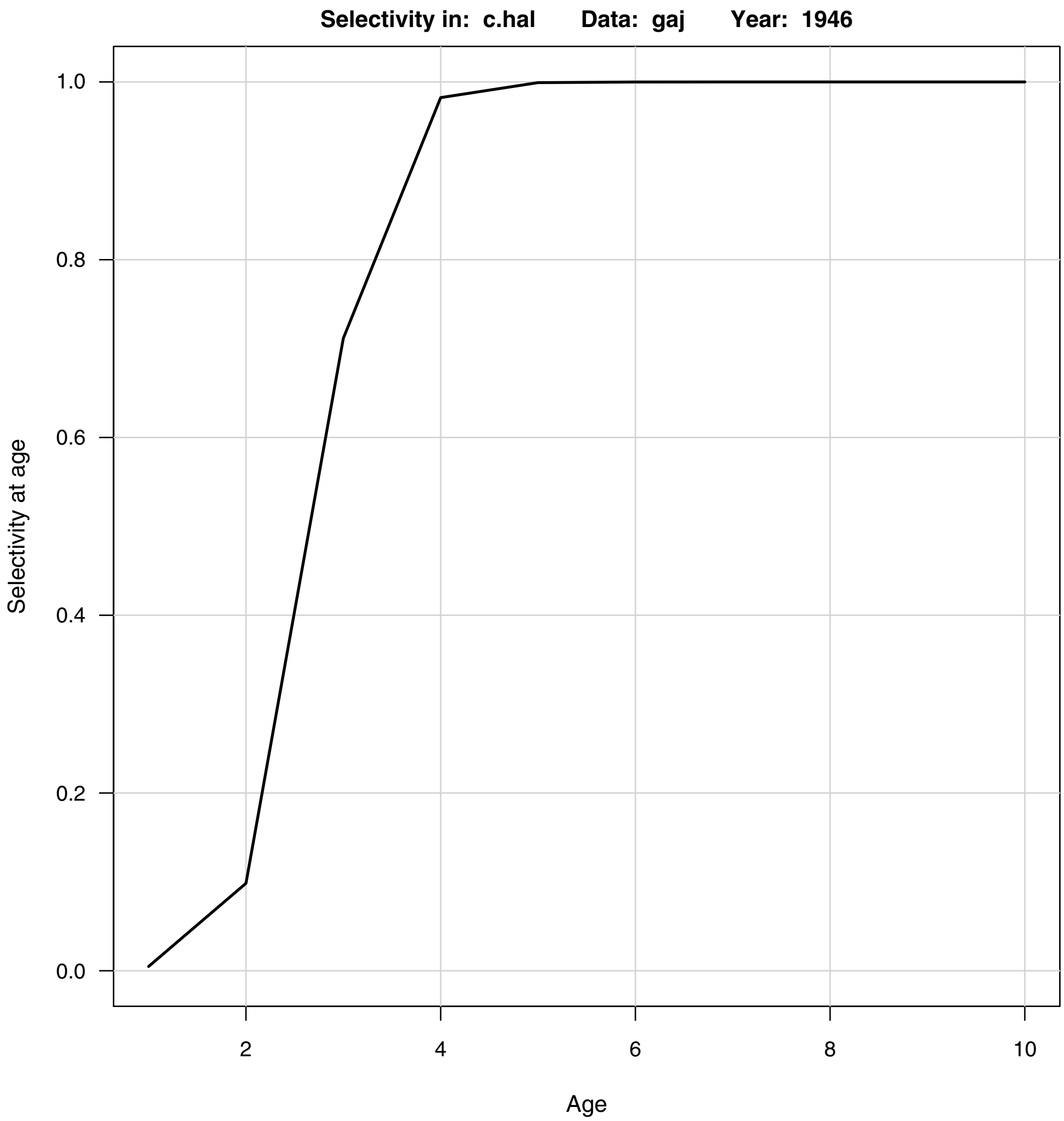


Figure 3.24. Greater amberjack– Base run: Estimated selectivity of commercial handline fishery from 1992 to 2006.

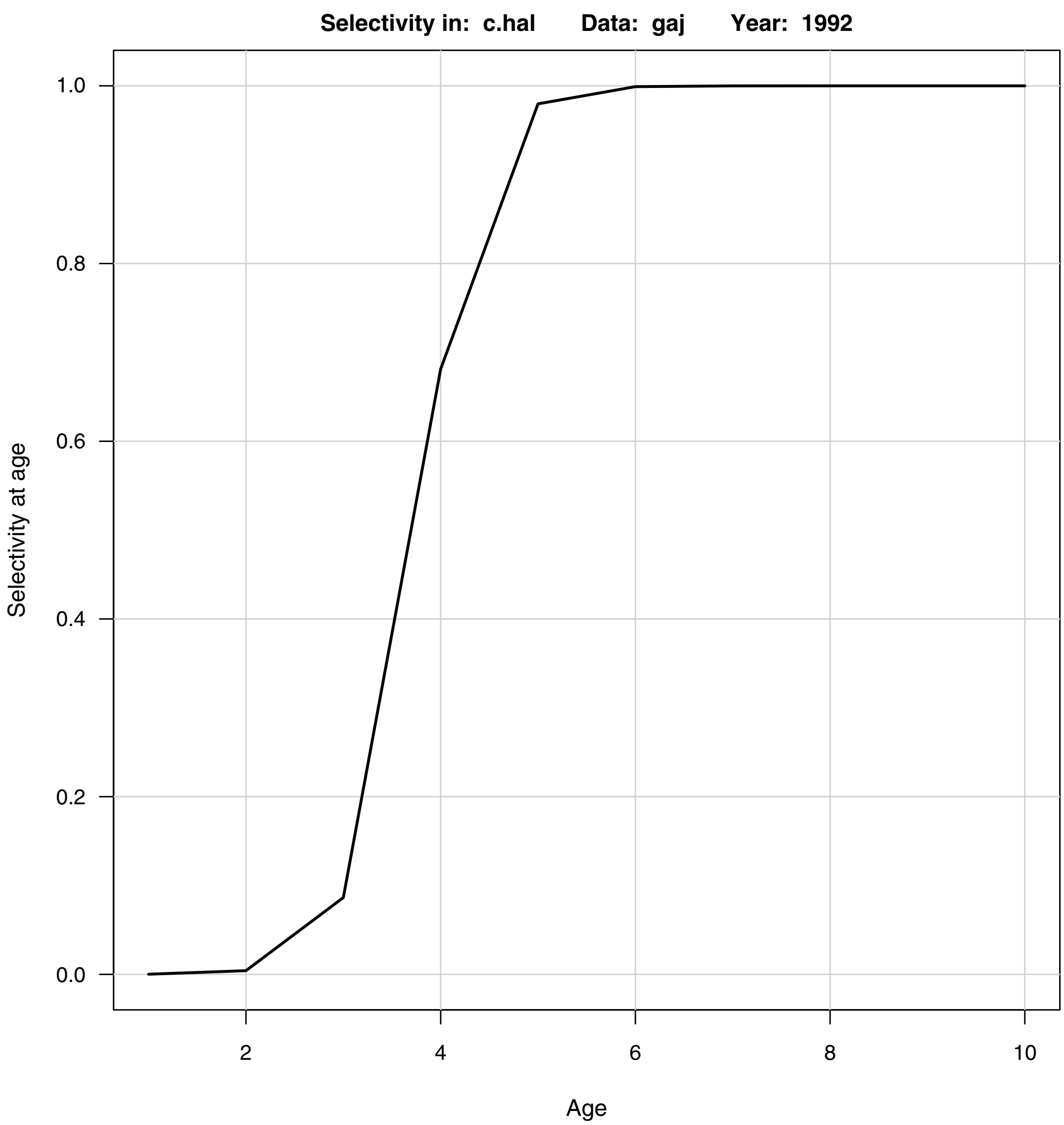


Figure 3.25. Greater amberjack– Base run: Estimated selectivity of commercial diving fishery from 1946-2006.

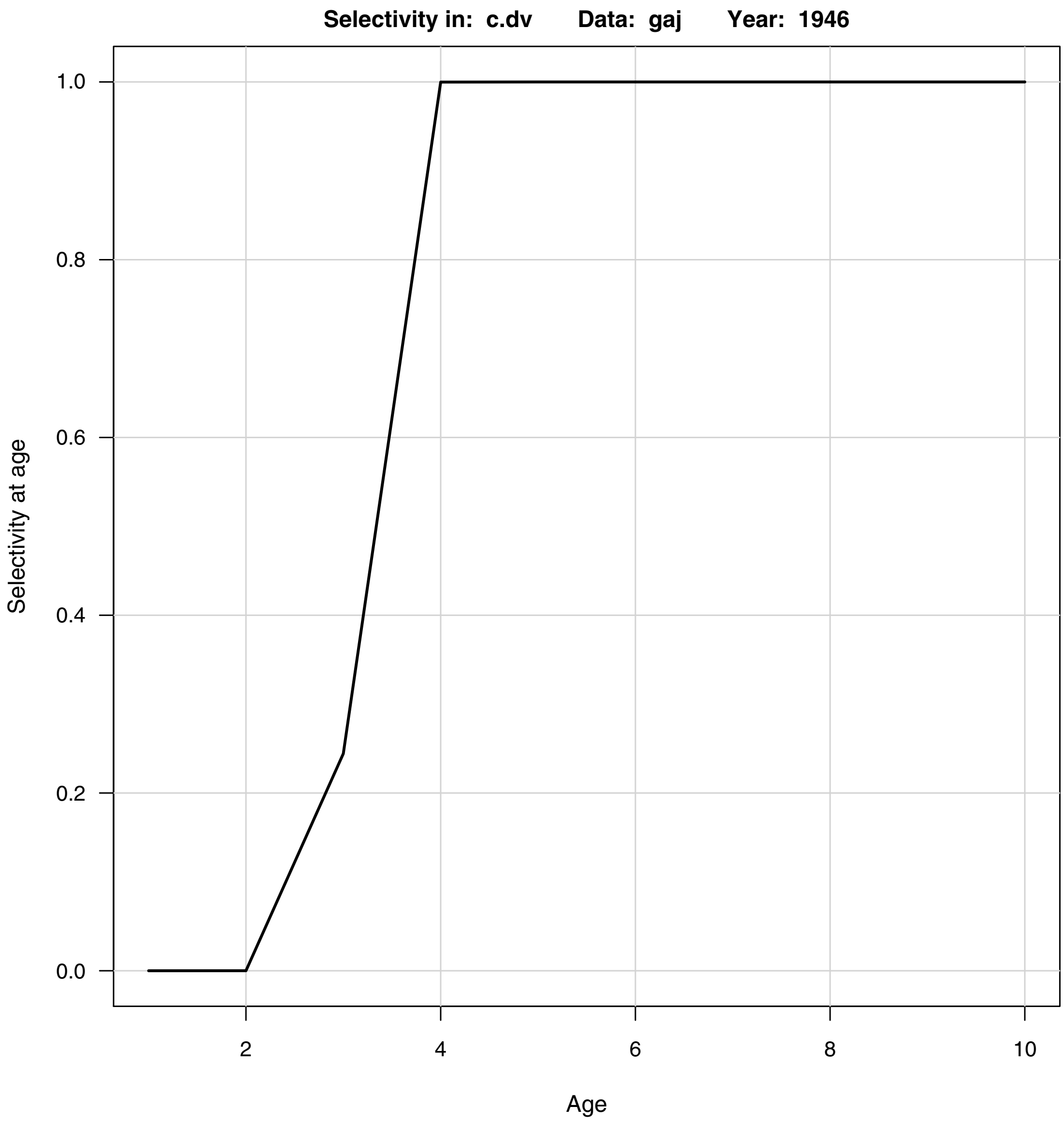


Figure 3.26. Greater amberjack– Base run: Estimated selectivity of headboat fishery through 1991.

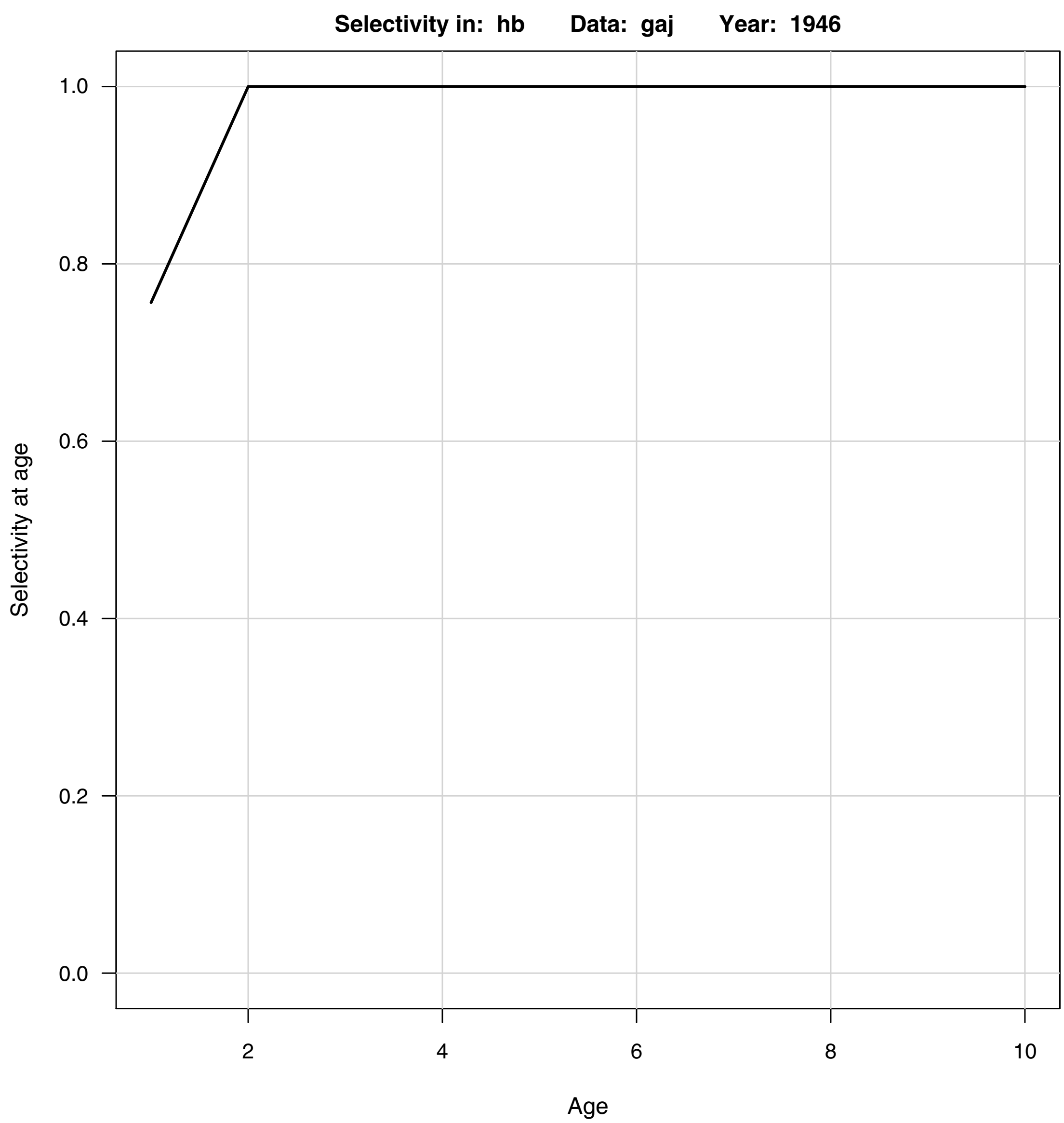


Figure 3.27. Greater amberjack– Base run: Estimated selectivity of headboat fishery from 1992 to 2006.

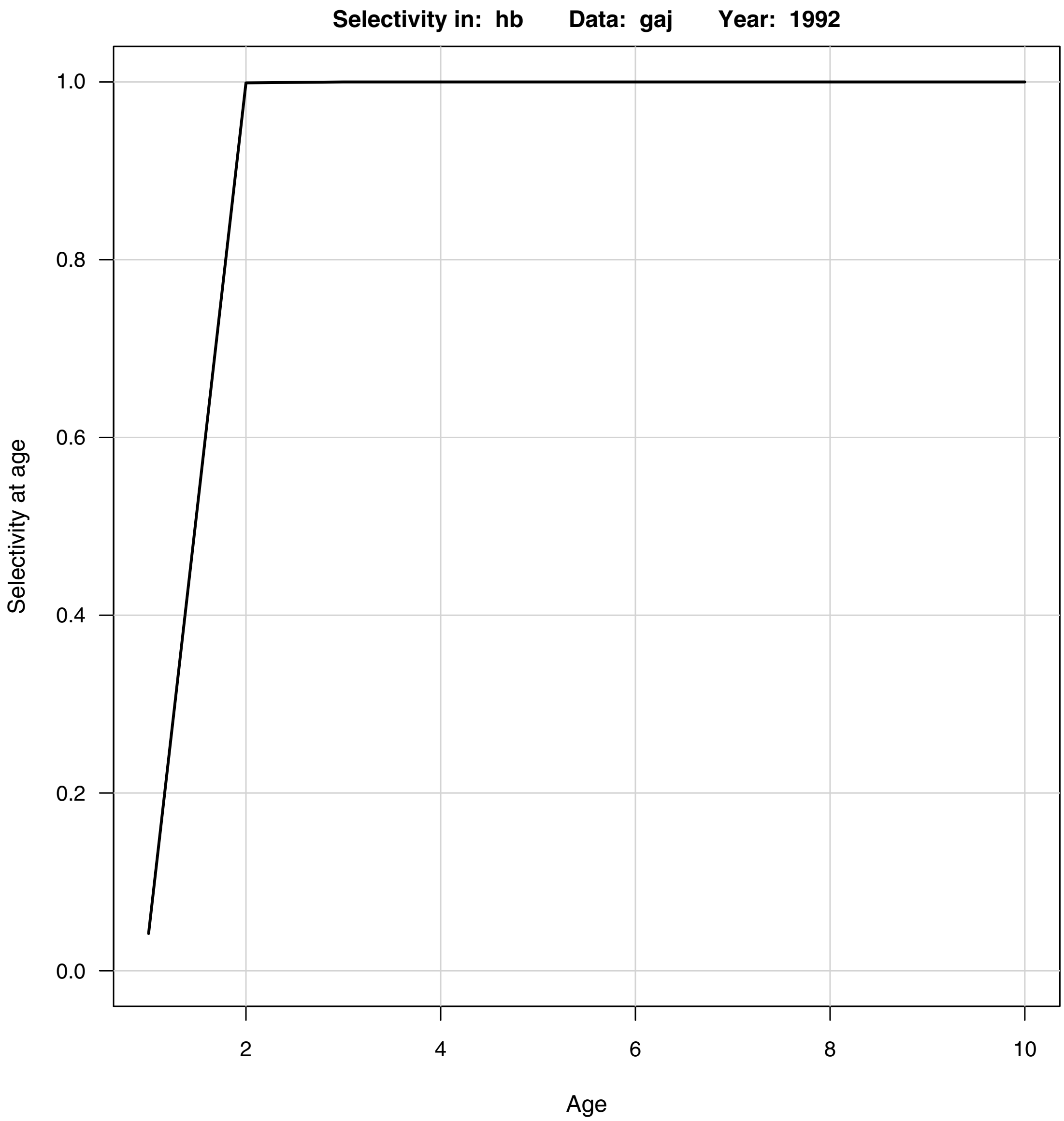


Figure 3.28. Greater amberjack– Base run: Estimated selectivity of the recreational (MRFSS) fishery through 1991.

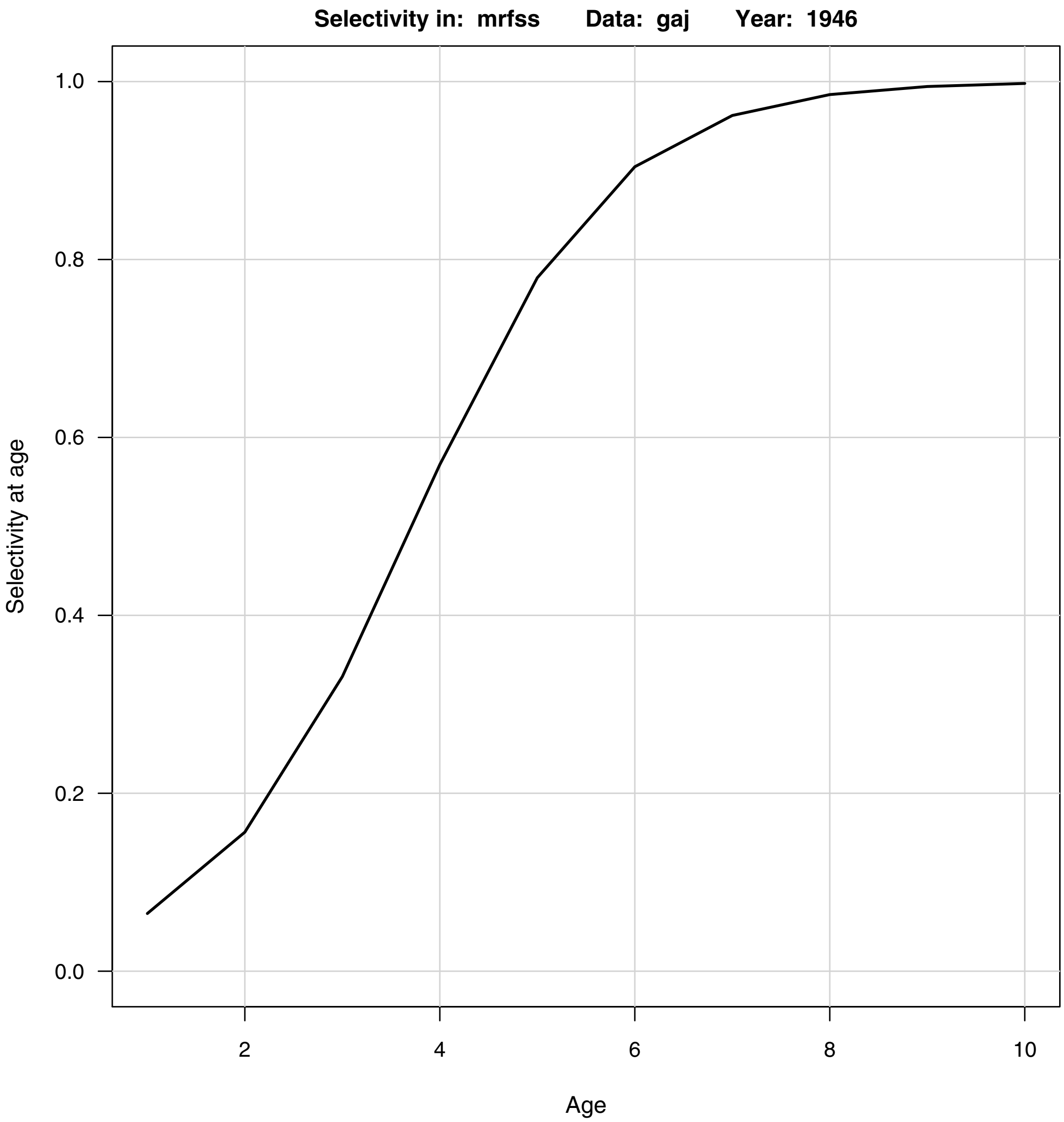


Figure 3.29. Greater amberjack– Base run: Estimated selectivity of recreational (MRFSS) fishery from 1992 to 2006.

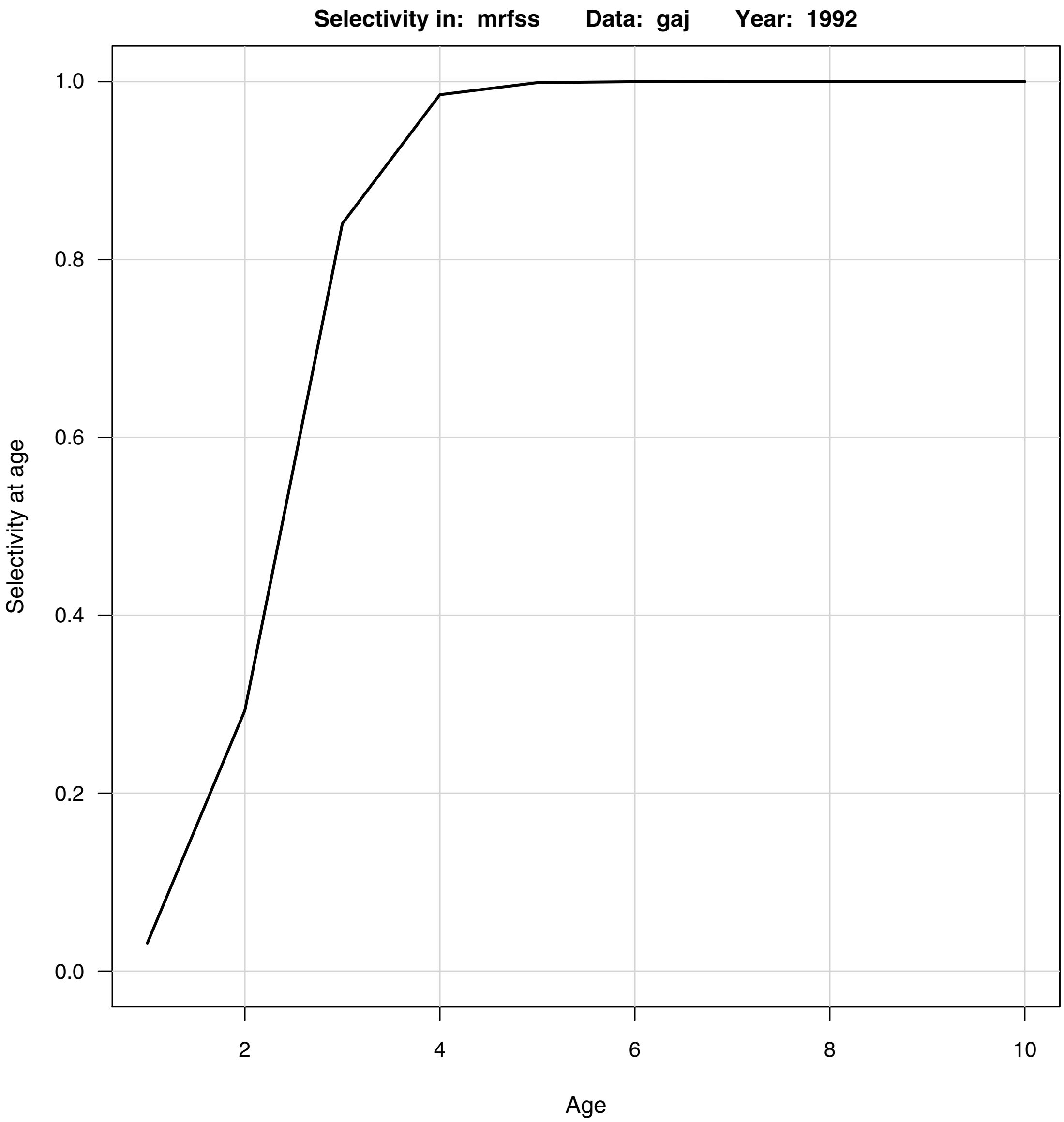


Figure 3.30. Greater amberjack– Base run: Estimated selectivity applied to discard rates in 1947–1991 for the recreational (MRFSS) fishery.

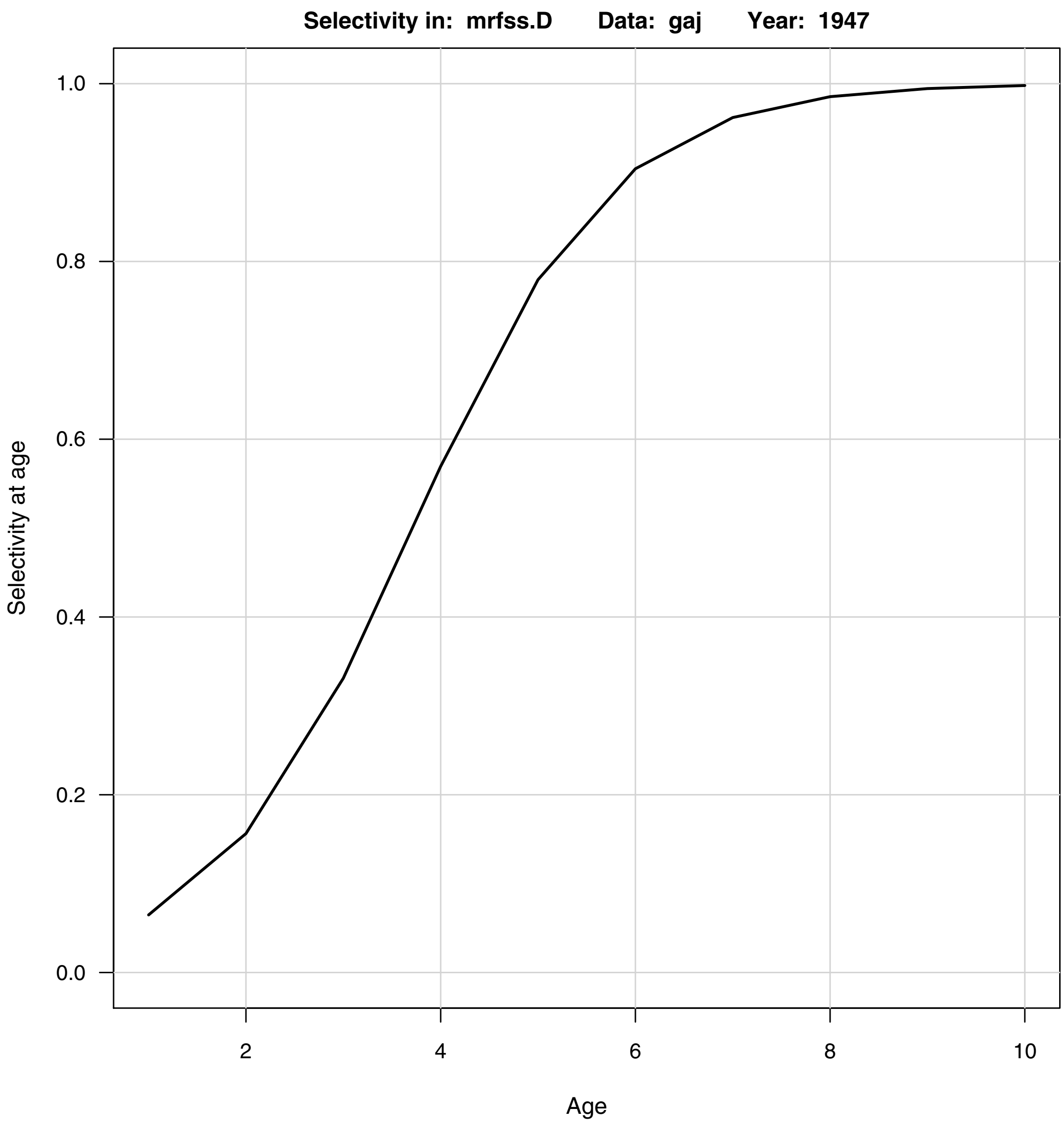


Figure 3.31. Greater amberjack– Base run: Estimated selectivity applied to discard rates in 1992–2006 for the recreational (MRFSS) fishery.

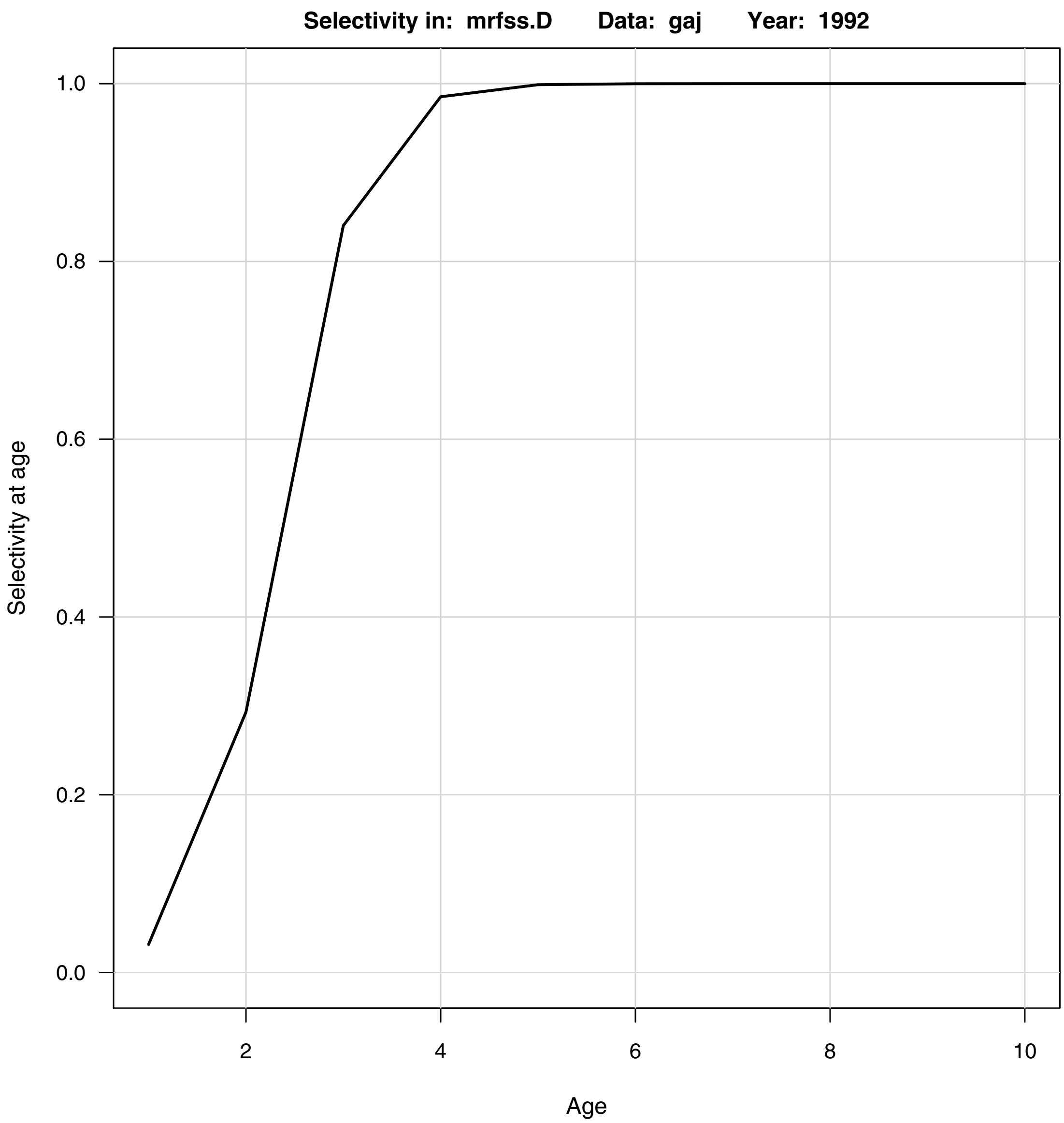


Figure 3.32. Greater amberjack– Base run: Estimated selectivity applied to discard rates in 1992–2006 for the commercial handline fishery.

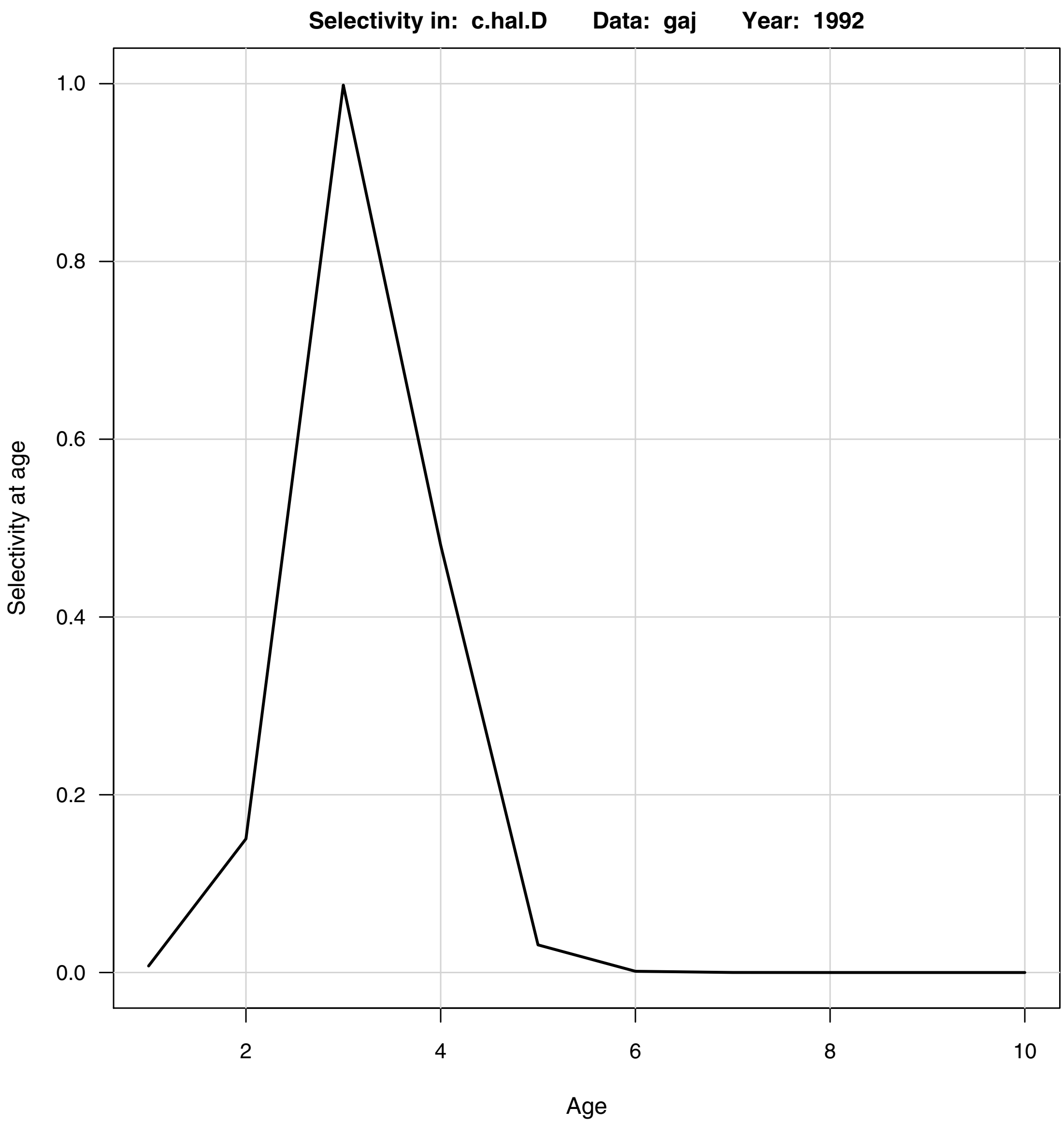


Figure 3.33. Greater amberjack– Base run: Estimated selectivity applied to discard rates in 1992–2006 for the headboat fishery.

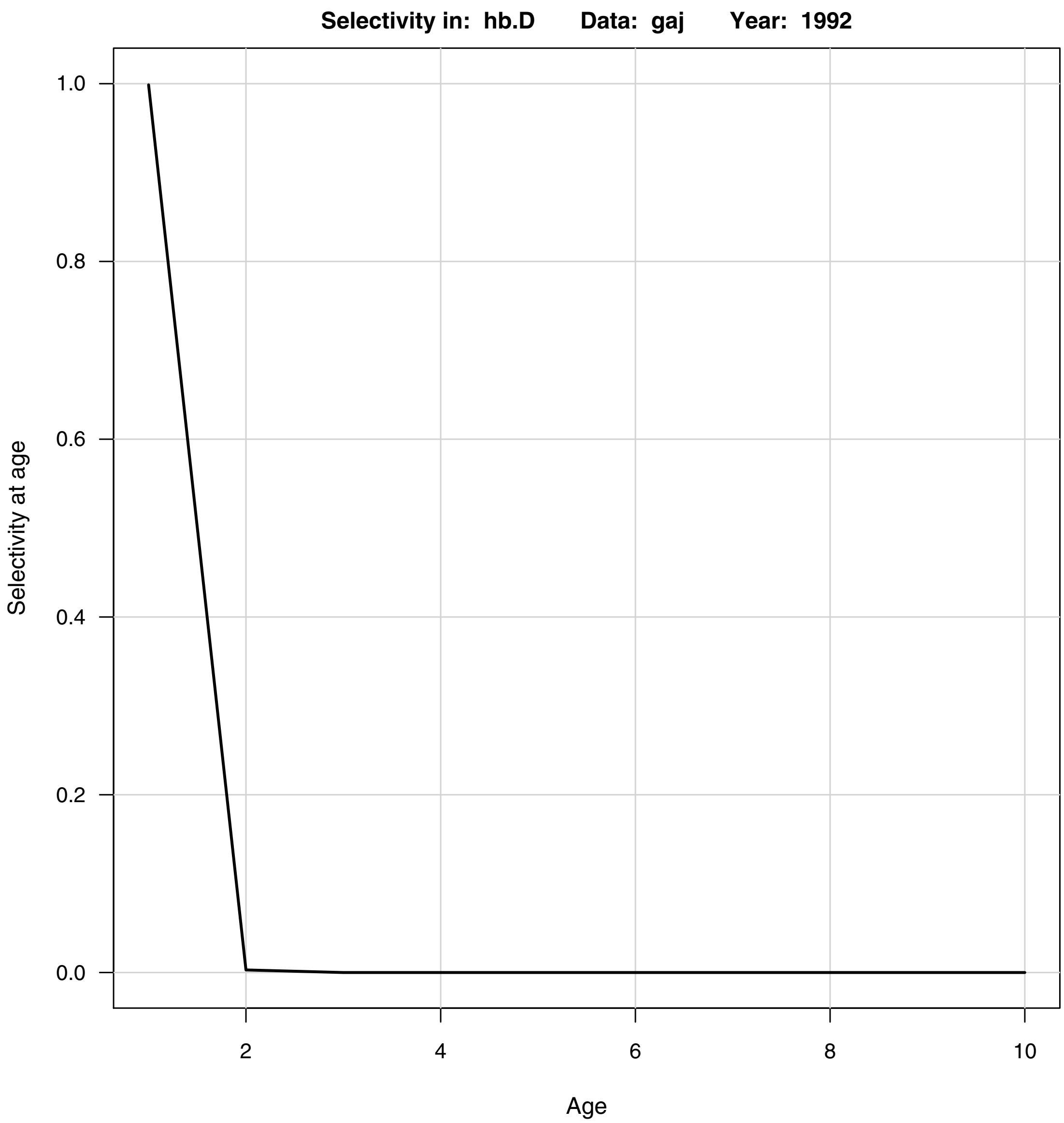


Figure 3.34. Greater amberjack– Base run: Estimated selectivity for landed fish used in MSY calculations computed from the 3-year geometric mean weighted fishing mortality rates (F) for all fishery gear types.

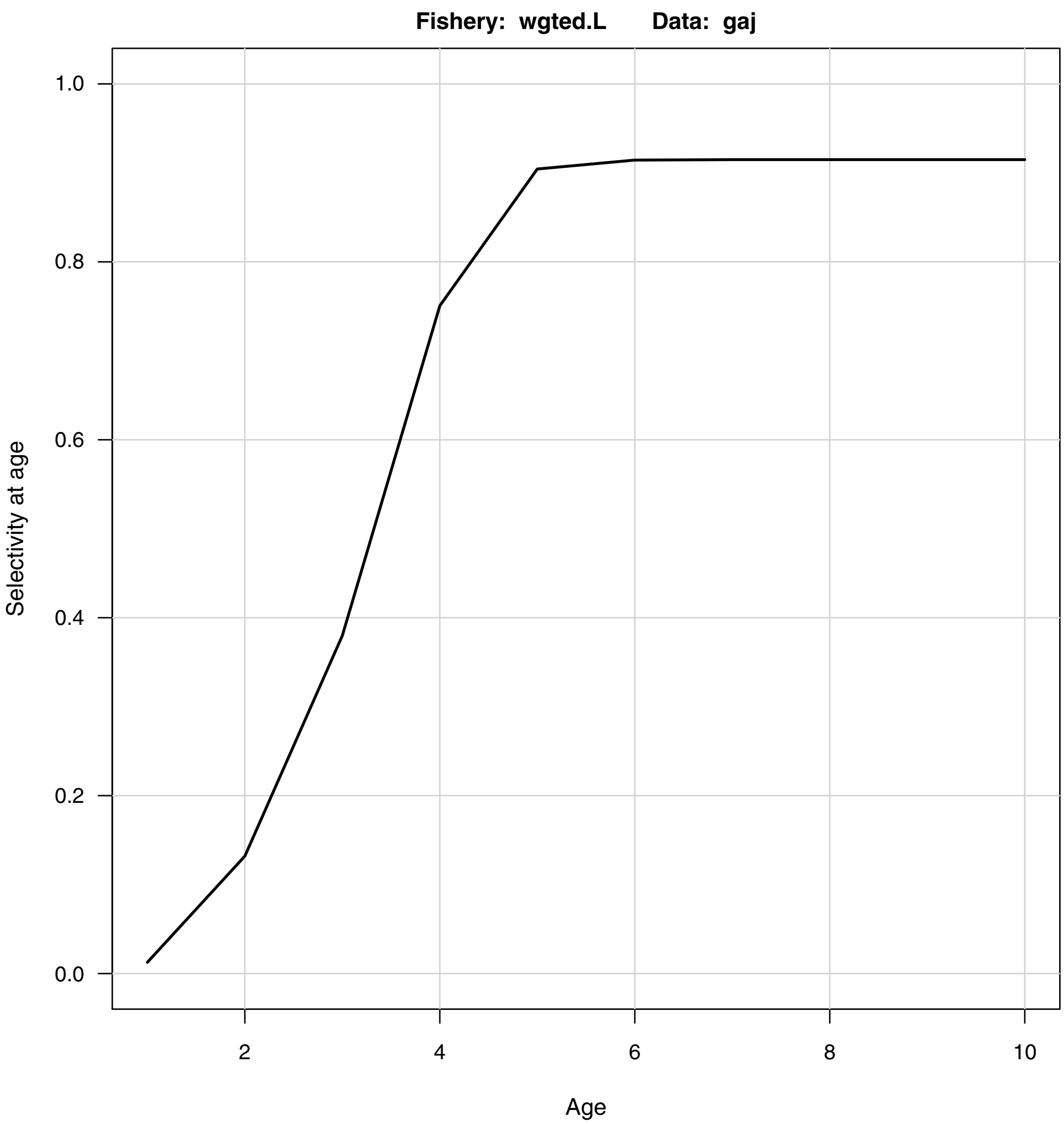


Figure 3.35. Greater amberjack– Base run: Estimated selectivity for discarded fish used in MSY calculations computed from the 3-year geometric mean weighted fishing mortality rates (F) for all fishery gear types.

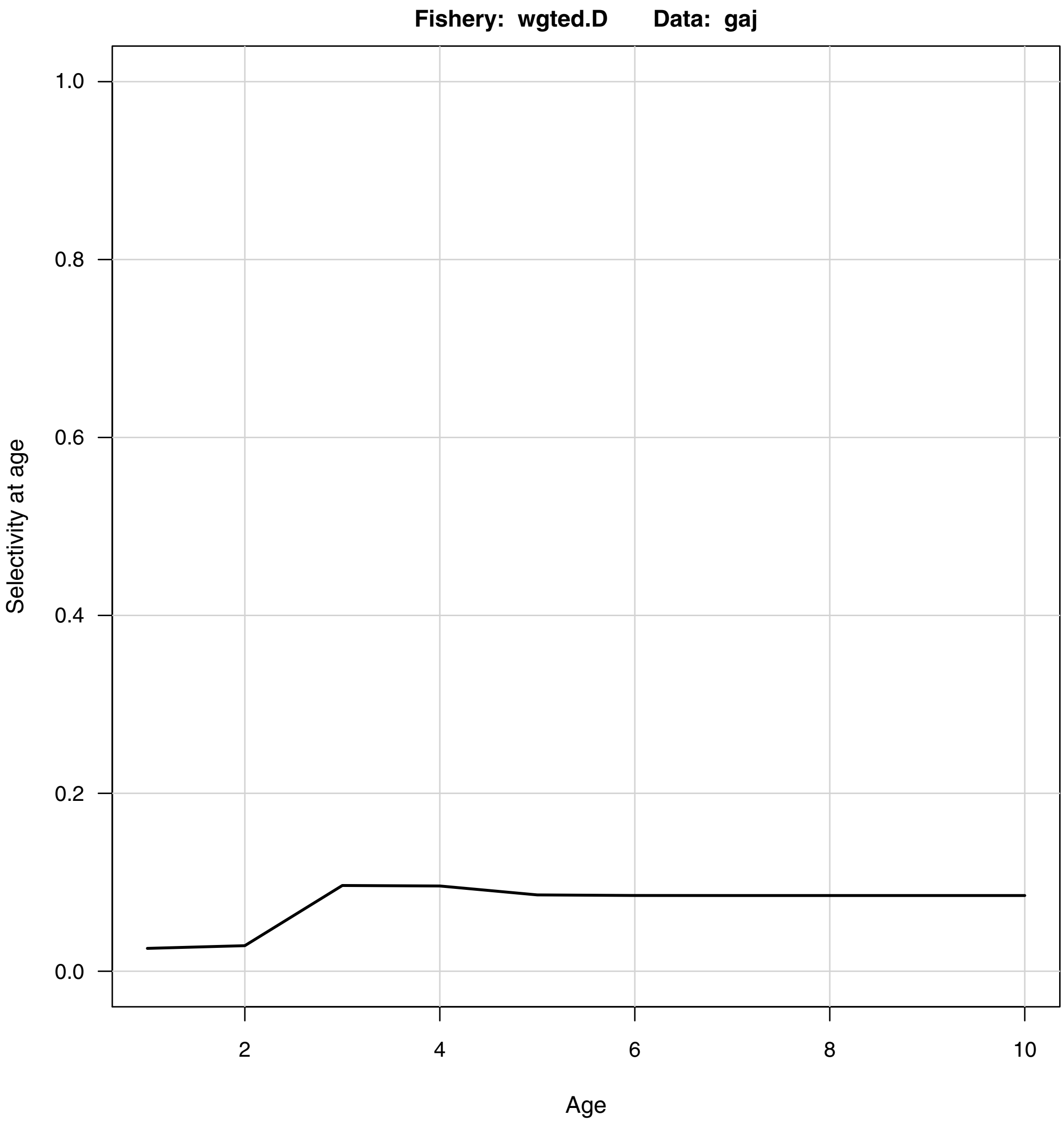


Figure 3.36. Greater amberjack– Base run: Estimated selectivity for landed and discarded fish used in MSY calculations computed from the 3-year geometric mean weighted fishing mortality rates (F) for all fishery gear types.

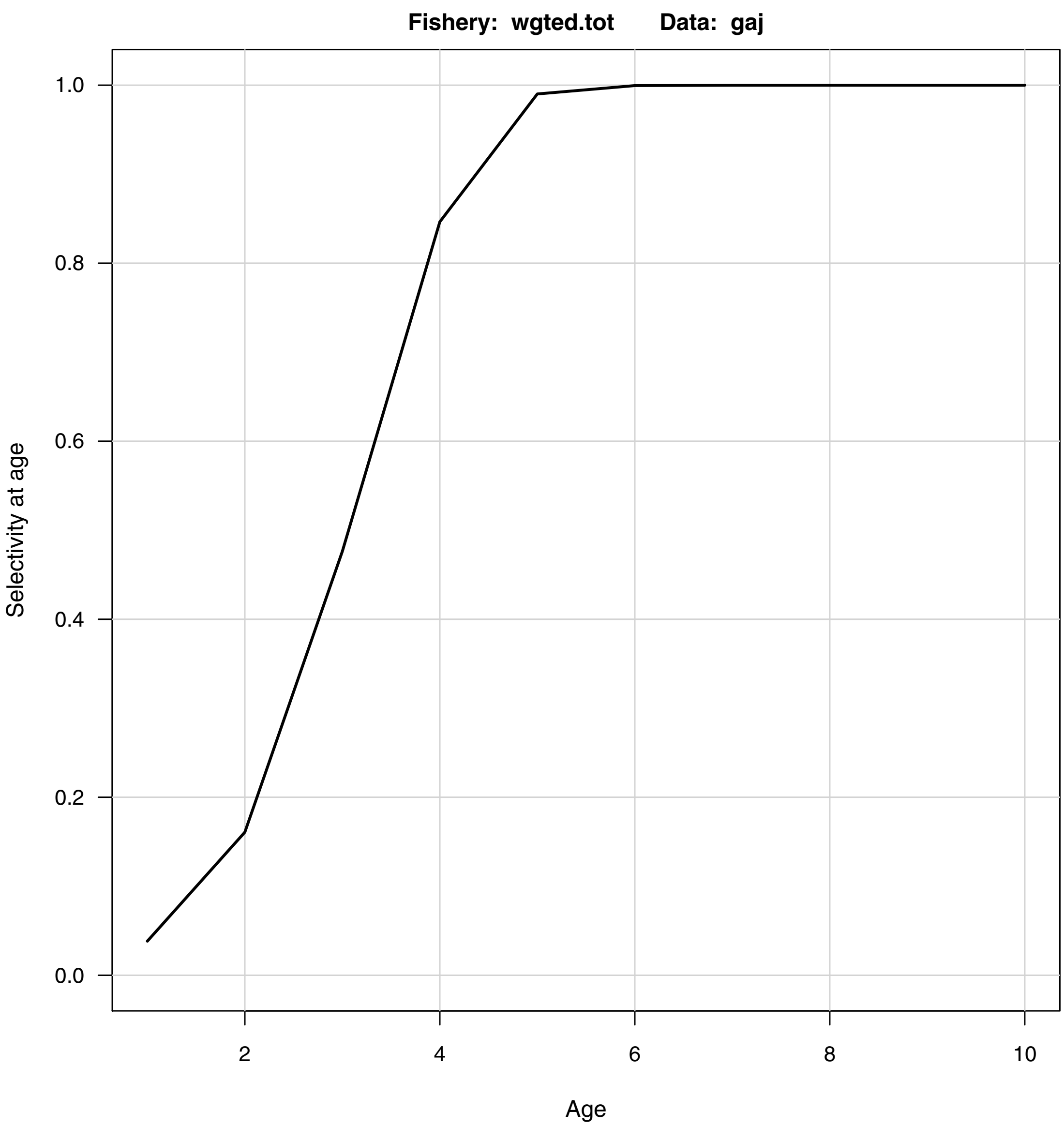


Figure 3.37. Greater amberjack– Base run: Stacked bar plot of fully selected fishing mortality (F) and discard rates by fishery. General recreational discards (mrfss.D), headboat discards (hb.D), commercial handline discards (c.hal.D), general recreational F (mrfss), headboat F (hb), commercial diving F (c.dv), commercial handline F (c.hal).

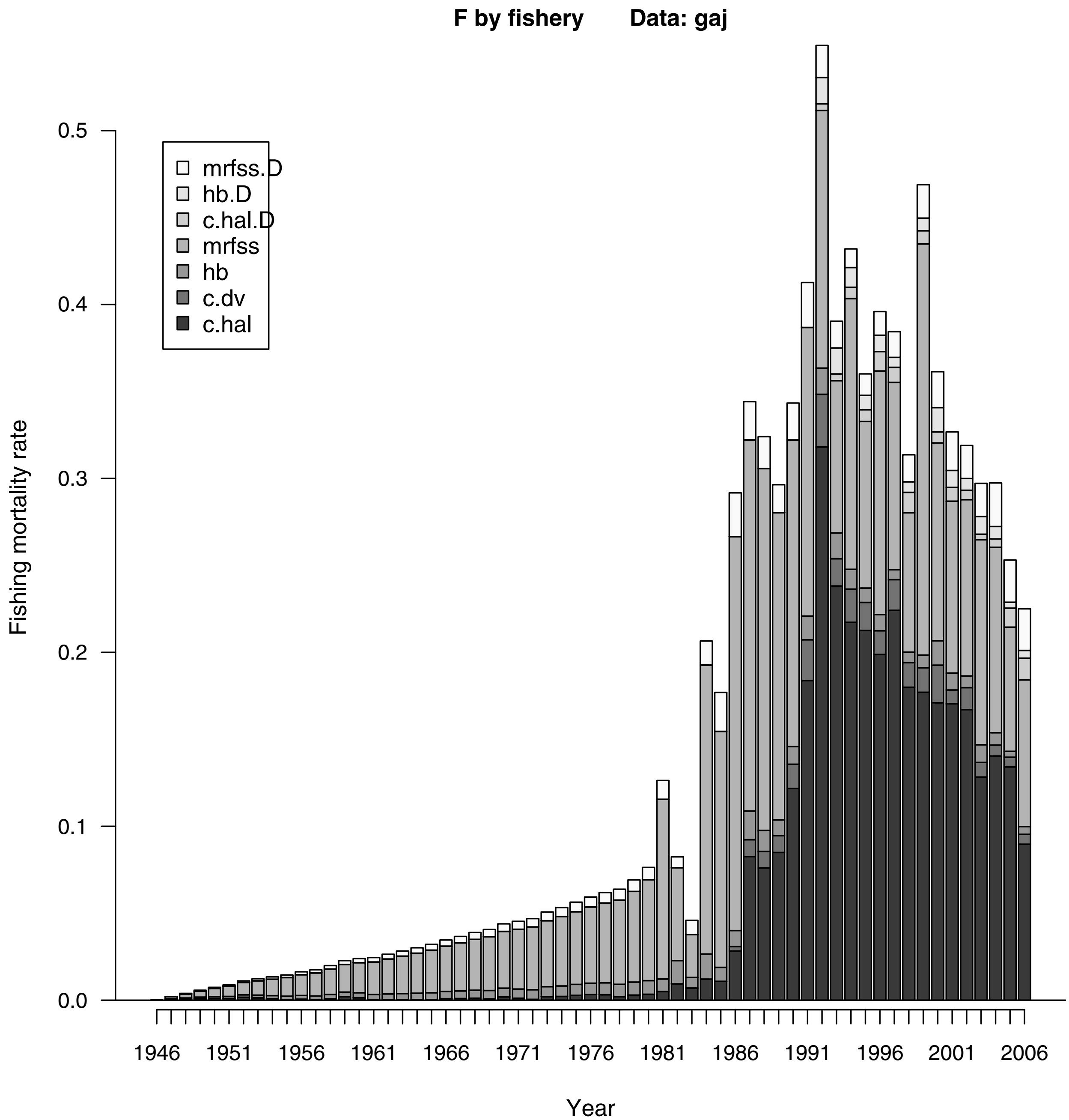


Figure 3.38. Greater amberjack– Base run: Estimated catch in numbers by fishery from the stock assessment model. General recreational (mrfss), headboat (hb),commercial diving (c.dv), and commercial handline (c.hal).

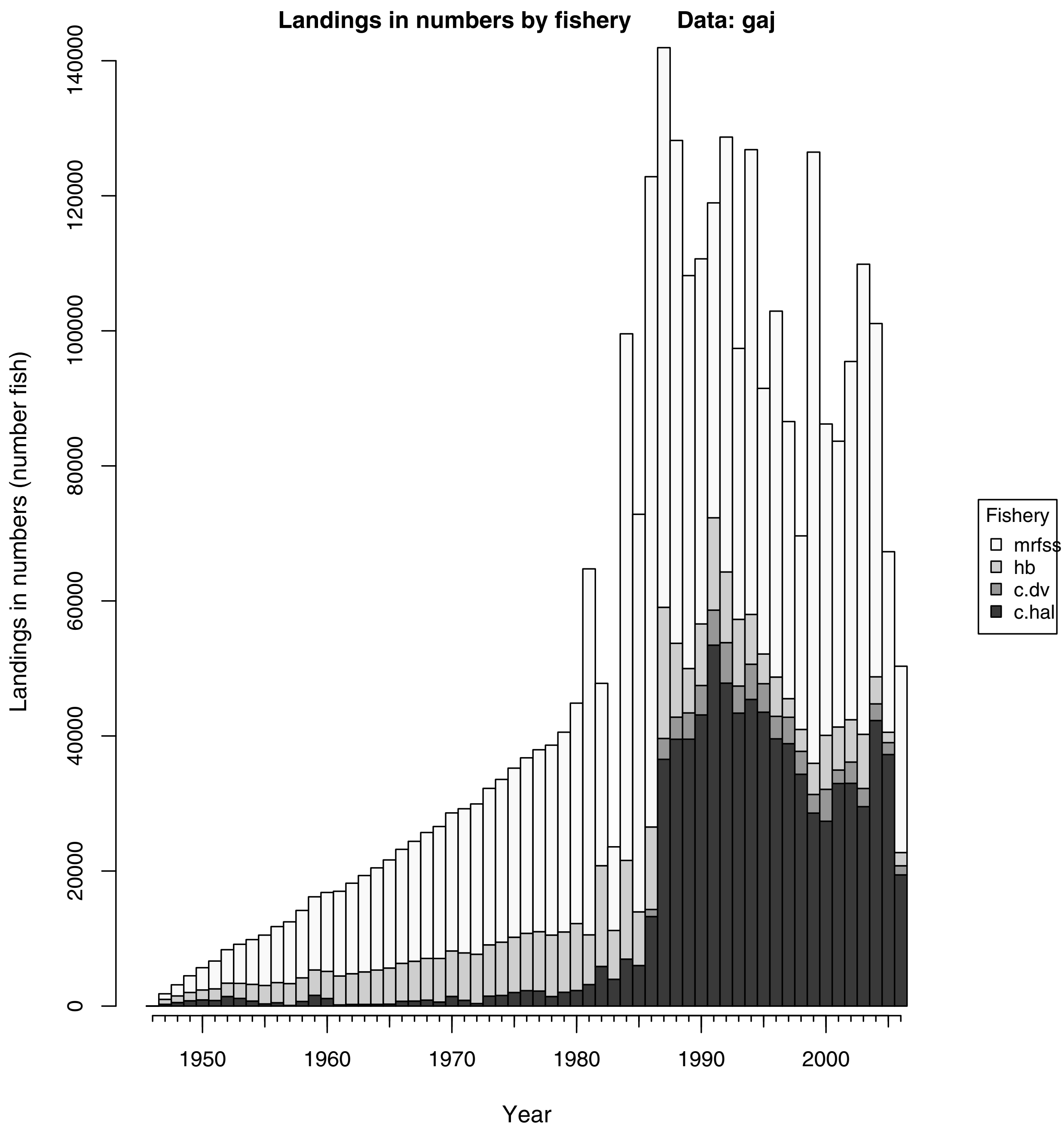


Figure 3.39. Greater amberjack– Base run: Estimated landings in metric tons by fishery from the stock assessment model. General recreational (mrfss), headboat (hb),commercial diving (c.dv), and commercial handline (c.hal).

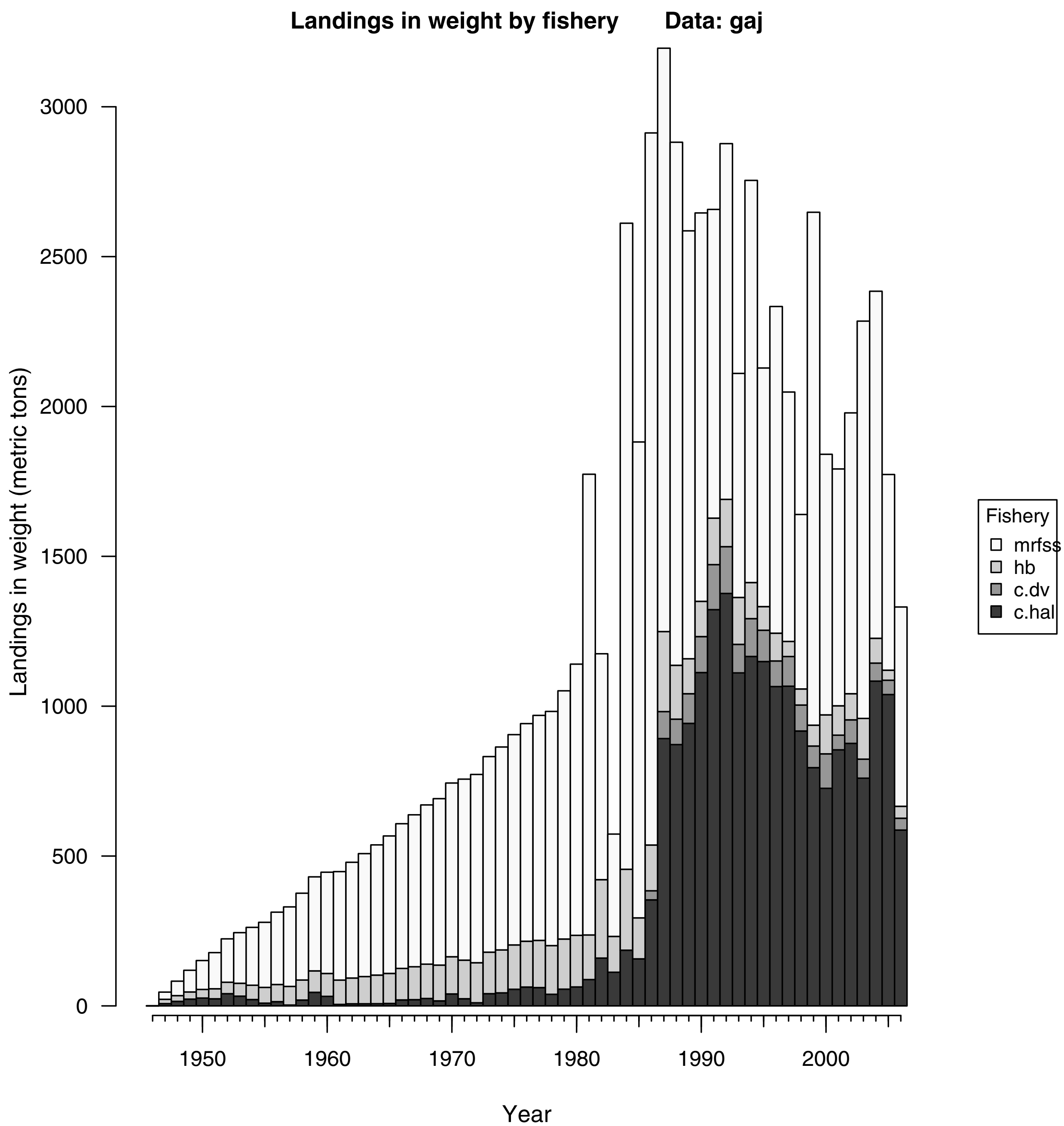


Figure 3.40. Greater amberjack– Base run: Estimated discards in numbers by fishery from the stock assessment model. General recreational (mrfss), headboat (hb) and commercial handline (c.hal).

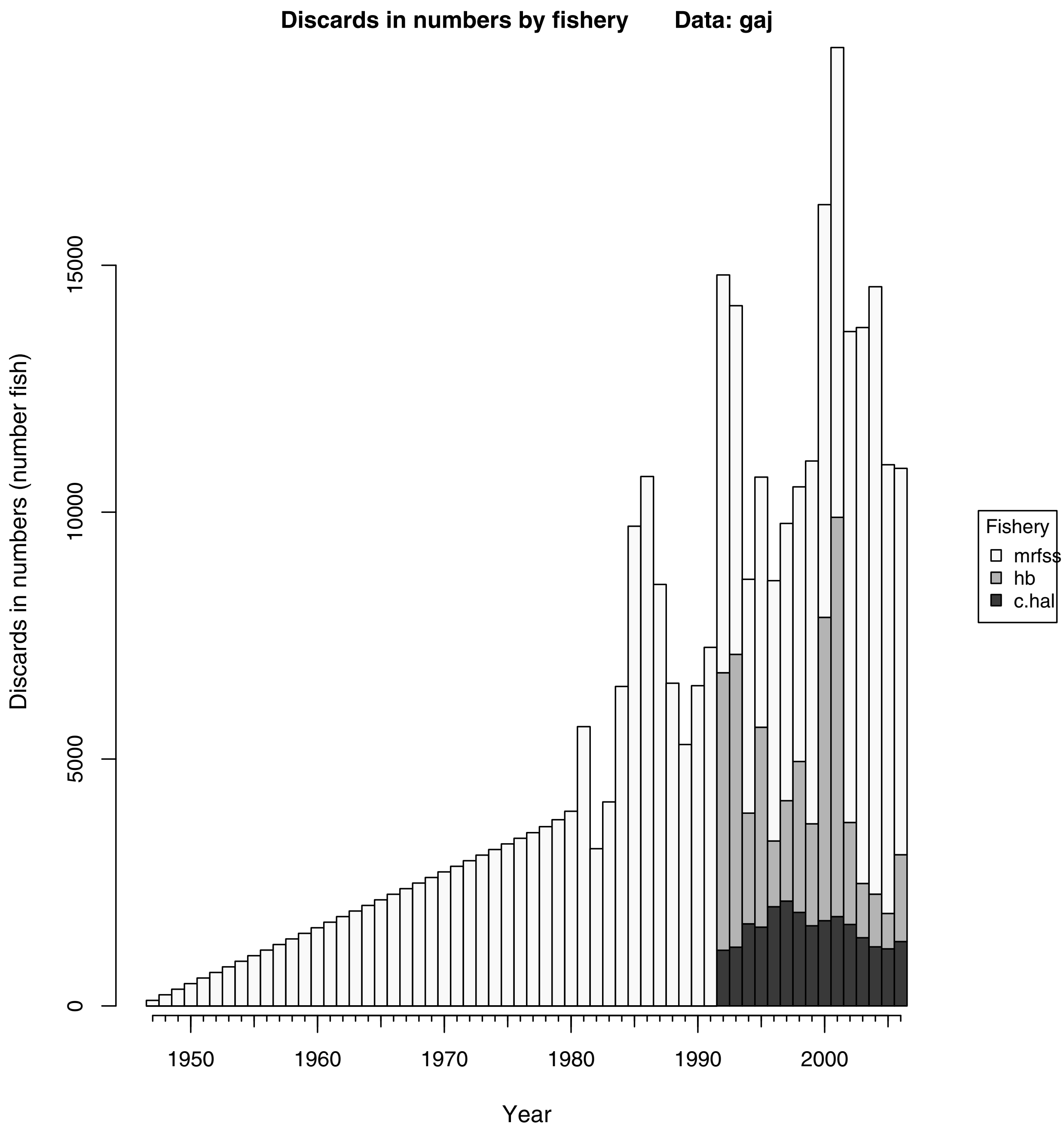


Figure 3.41. Greater amberjack– Base run: Estimated stock-recruitment relationship of greater amberjack. Circles represent estimated recruitment values from 1947-2006; Solid curve is estimated relationship; Dashed curve is estimated relationship with lognormal bias correction, from which benchmarks are derived.

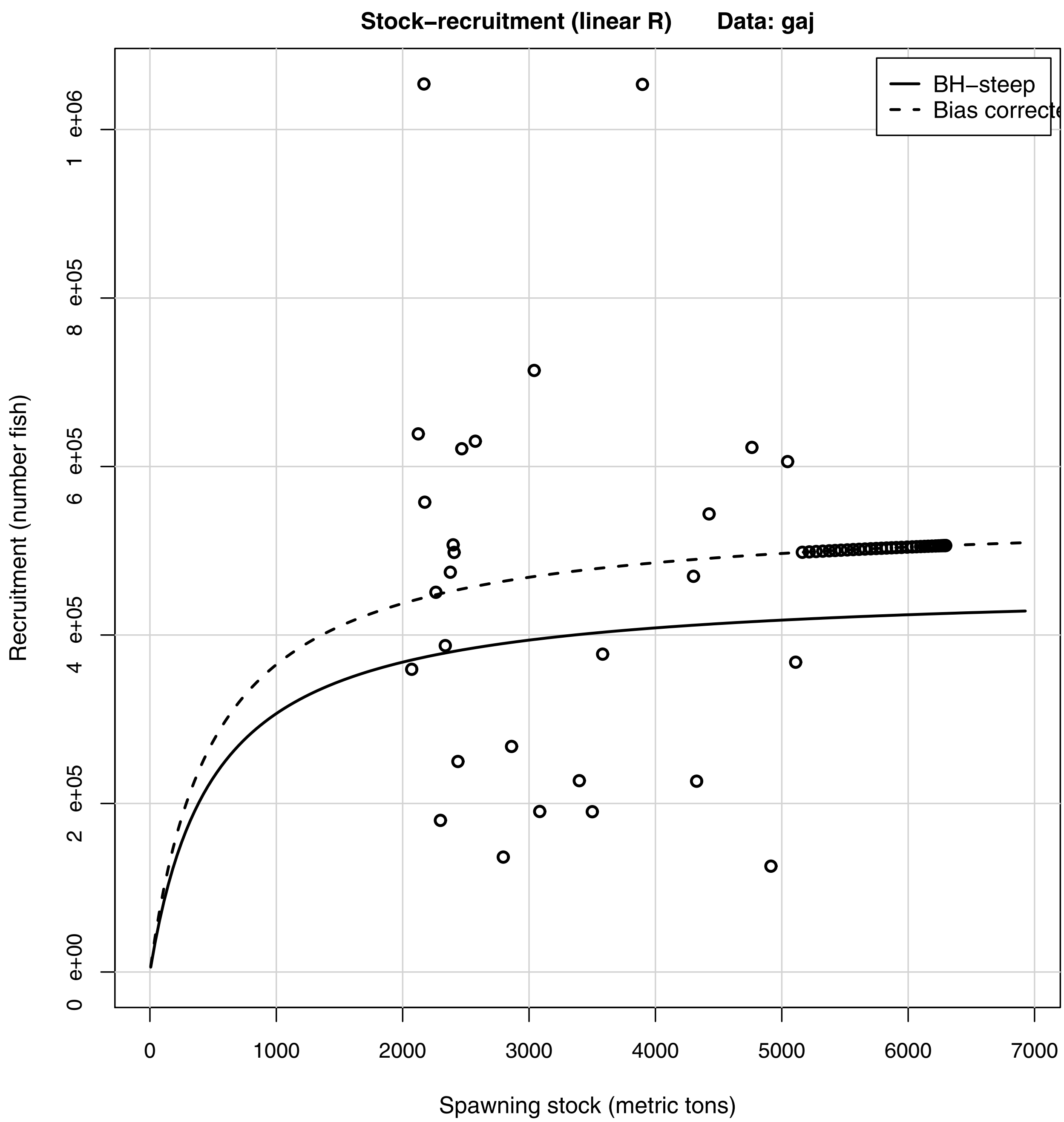


Figure 3.42. Greater amberjack Base run: Estimated time series of Log of recruitment residuals with dashed line at zero, the value indicating no deviation from the estimated stock-recruit curve. Solid line shows loess fit to residuals.

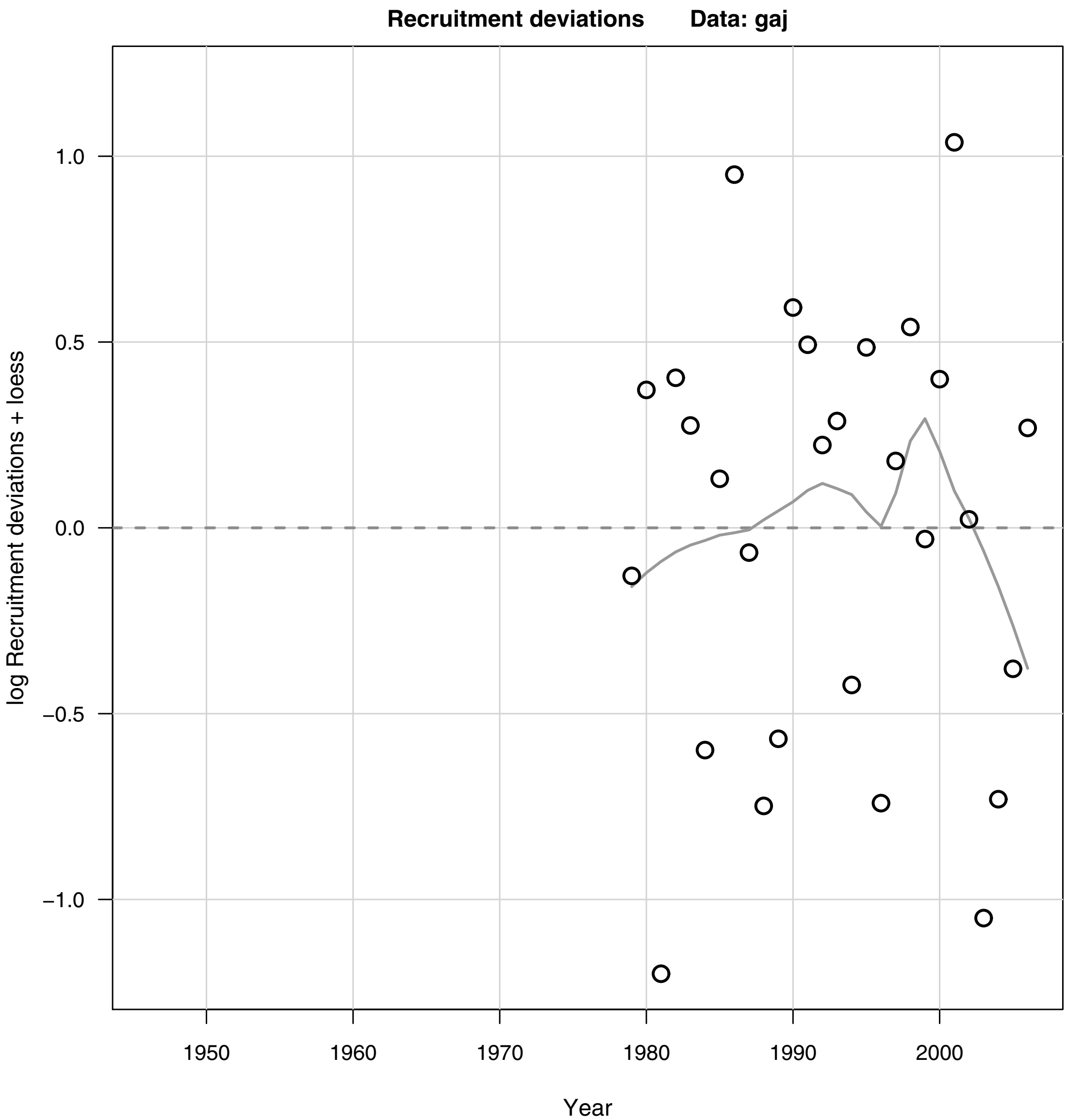


Figure 3.43. Greater amberjack– Base run: Probability density of stock-recruit parameters R0 (virgin recruitment) and steepness, recruitment autocorrelation, and fishing mortality rate at MSY (Fmsy). Vertical line represents base run estimate.

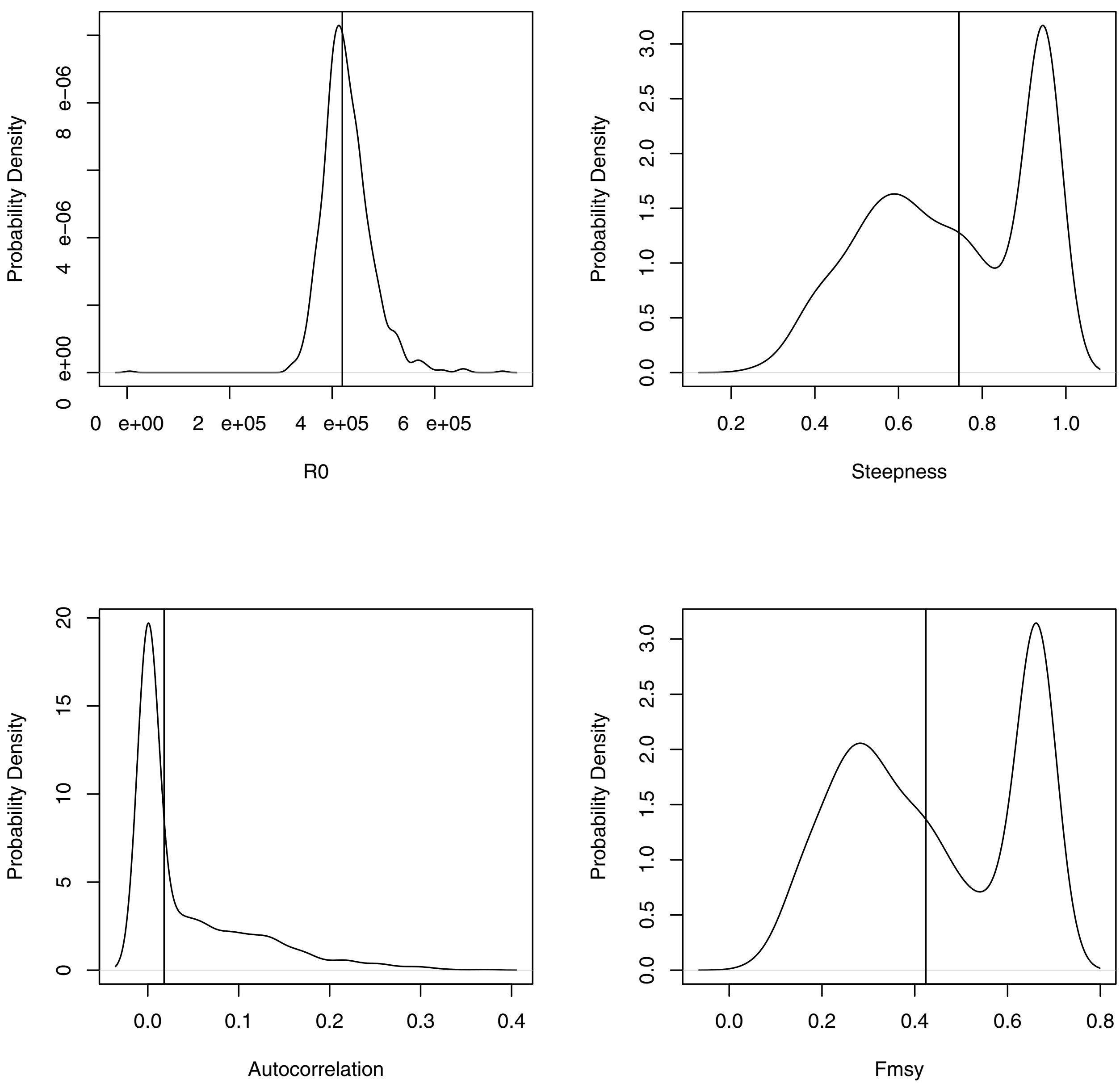


Figure 3.44. Greater amberjack– Base run: Probability density of MSY , Discards at MSY (Dmsy), SSB at MSY (SSBmsy) and total biomass at MSY (Bmsy). Vertical line represents base run estimate.

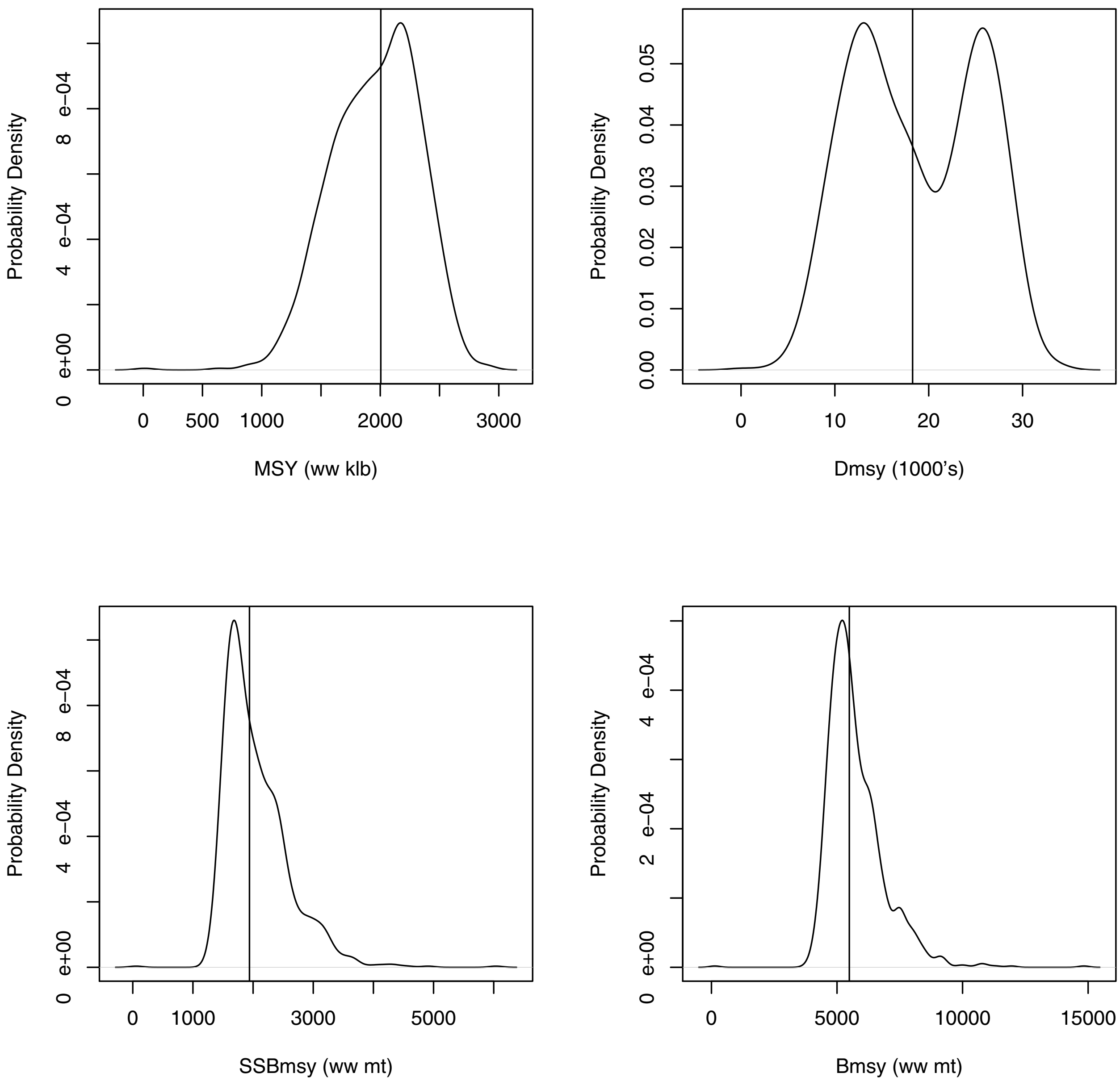


Figure 3.45. Greater amberjack– Base run: Probability density of R at MSY (Rmsy). Vertical line represents base run estimate.

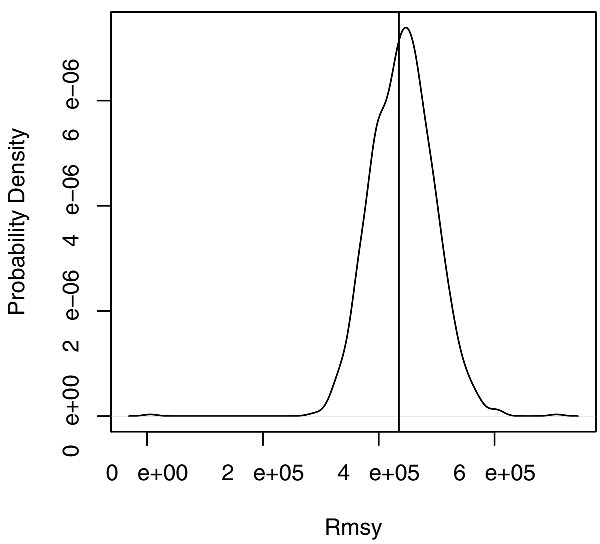


Figure 3.46. Greater amberjack– Base run: Estimated time series of static spawning potential ratio (SPR) using fully selected fishing mortality rates.

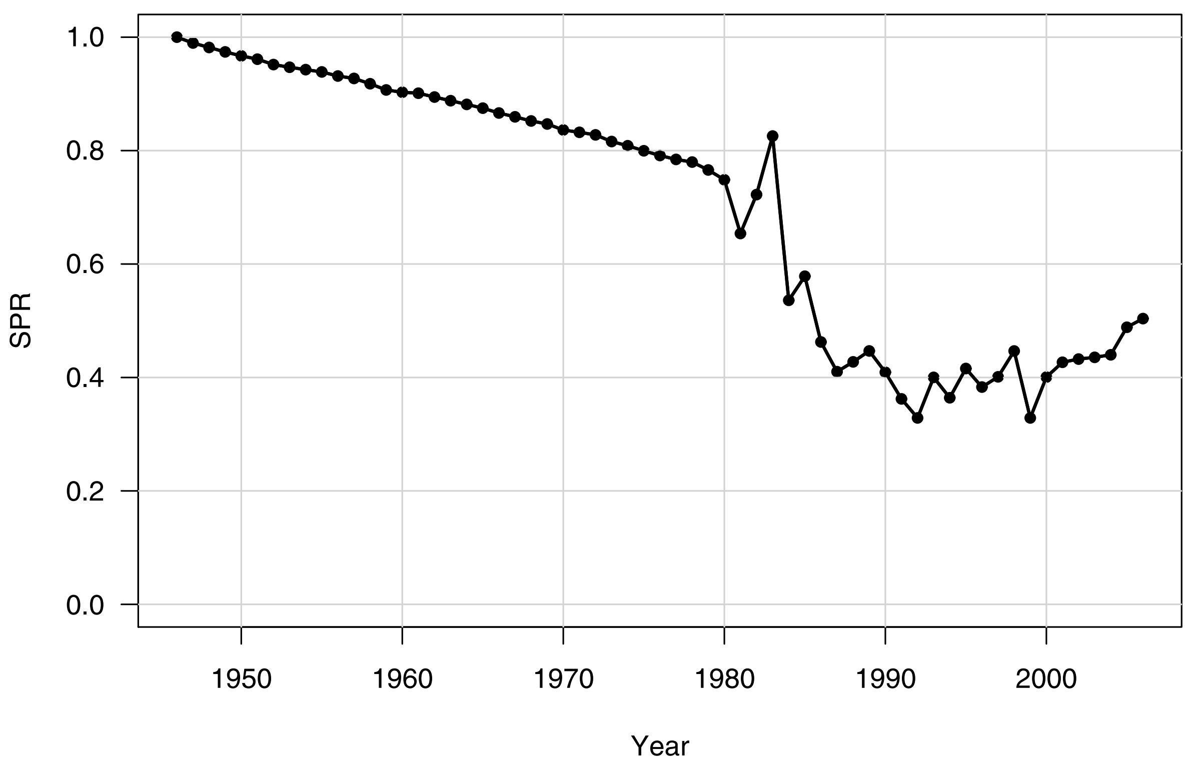


Figure 3.47. Greater amberjack– Base run: Estimated yield (top panel) and spawning stock biomass (SSB) per recruit (%SPR)(bottom panel) as functions of fully selected fishing mortality rate. Vertical lines represent $F_{30\%}$, $F_{40\%}$, F_{MSY} and F_{max}.

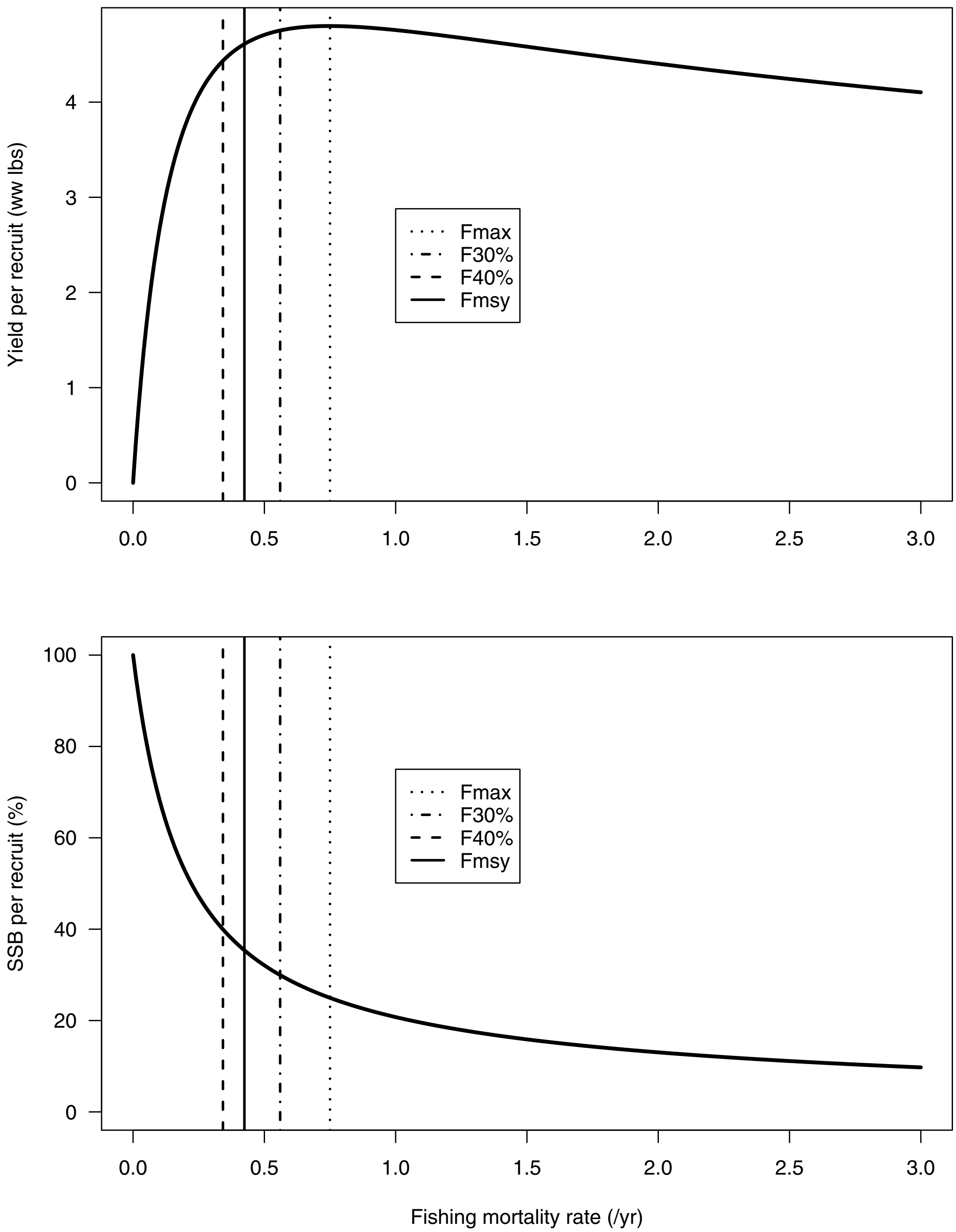


Figure 3.48. Greater amberjack– Base run: Equilibrium landings(top panel) and discards (bottom panel), as expected from the estimated stock-recruit curve with bias correction. Vertical lines represent $F_{30\%}$, $F_{40\%}$,F_{MSY}, and F_{max}.

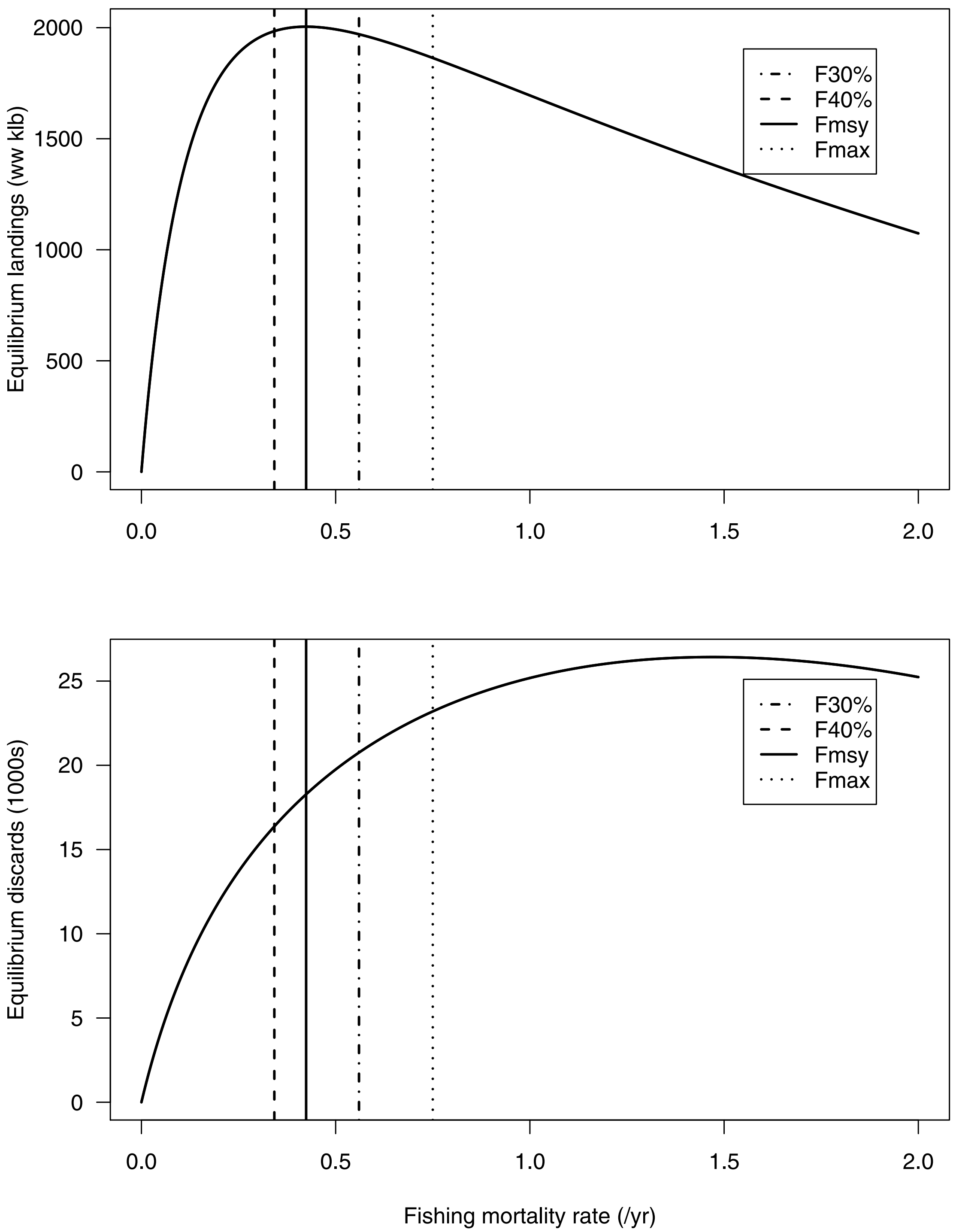


Figure 3.49. Greater amberjack– Base run: Equilibrium landings(top panel) and discards (bottom panel) at total biomass (mt), as expected from the estimated stock-recruit curve with bias correction.

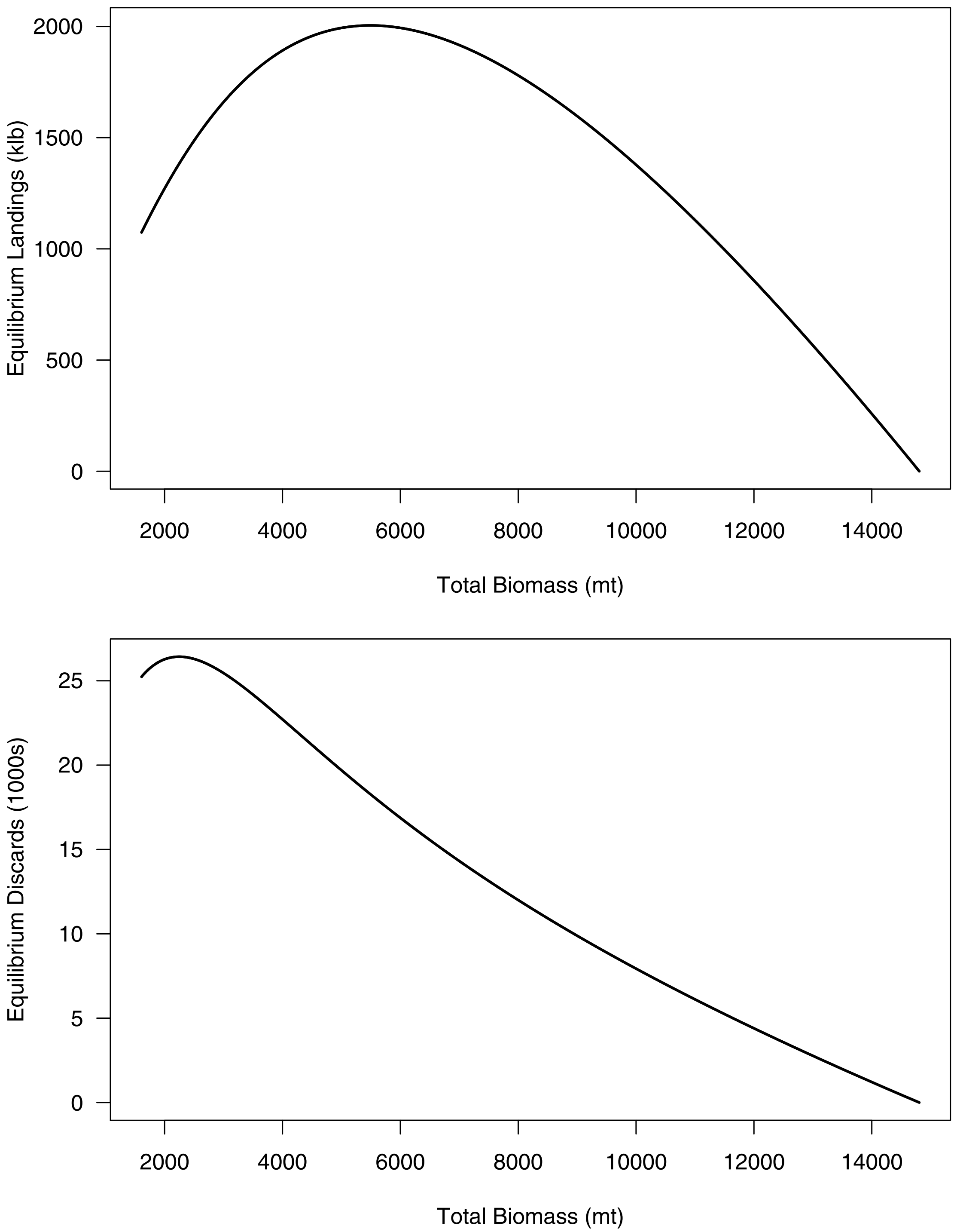


Figure 3.50. Greater amberjack– Base run: Equilibrium SSB *(top panel) and biomass (bottom panel), as expected from the estimated stock-recruit curve with bias correction. Vertical lines represent* $F_{30\%}$, $F_{40\%}$, F_{MSY}, *and* F_{max}.

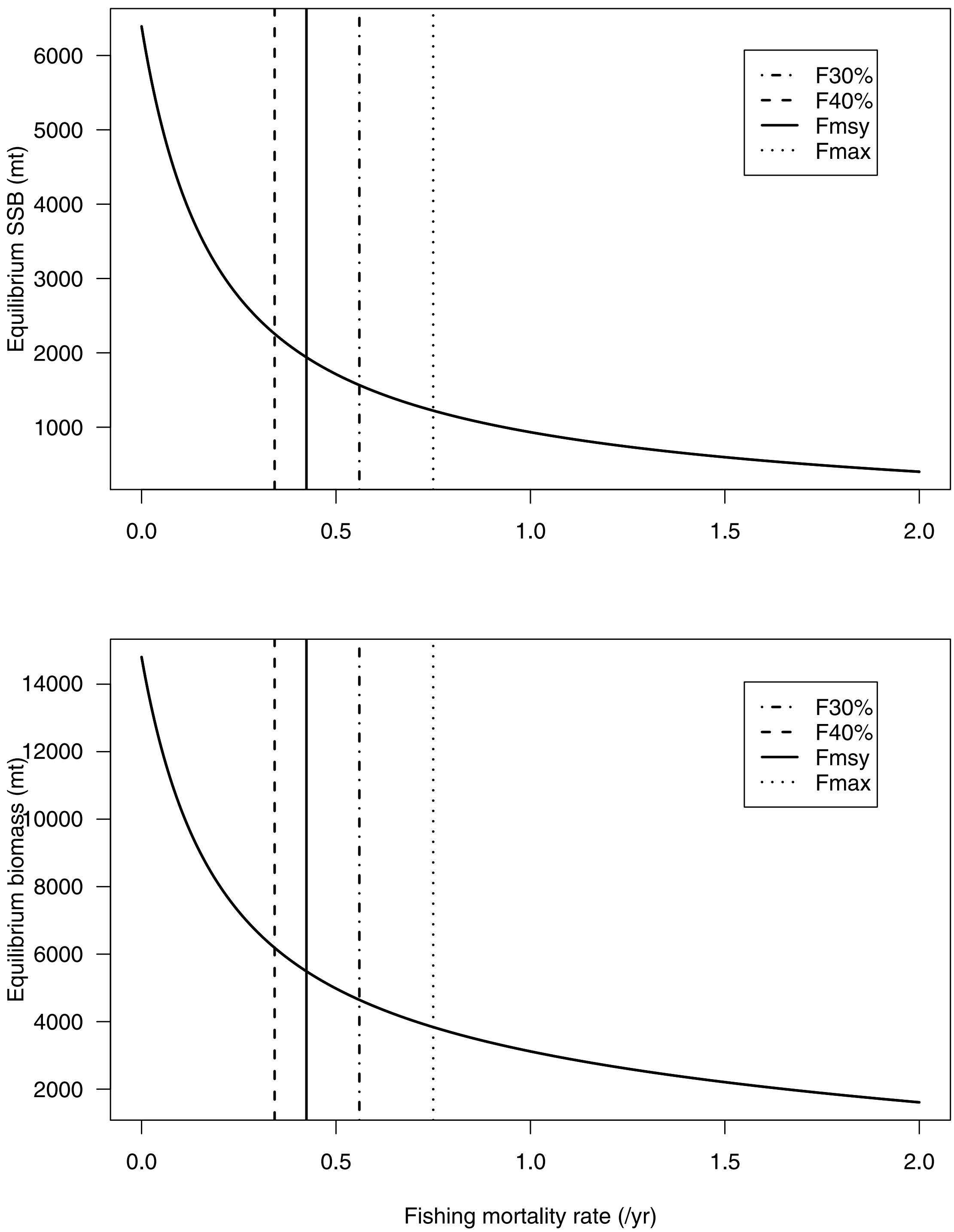


Figure 3.51. Greater amberjack– Base run: Estimated recruits as expected from the estimated stock-recruit curve with bias correction. Vertical lines represent $F_{30\%}$, $F_{40\%}$, F_{MSY} and F_{max}.

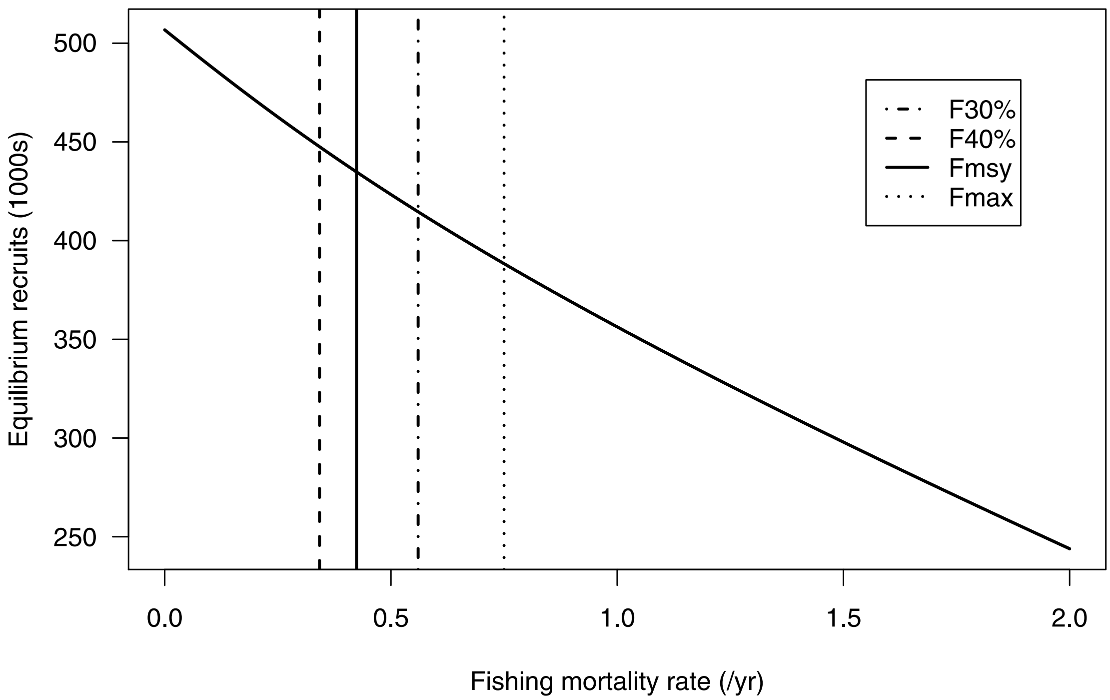
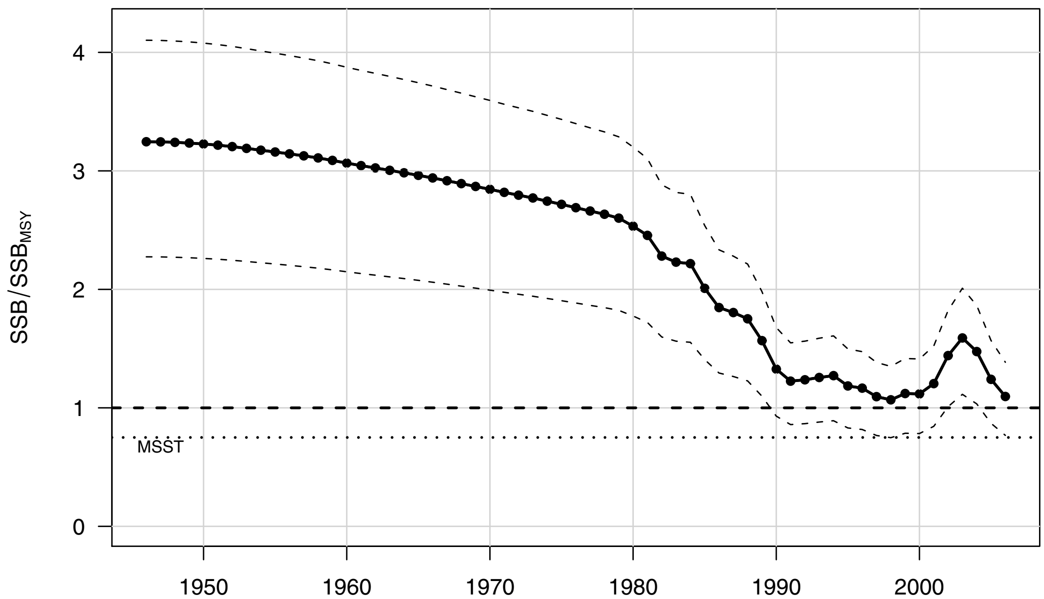


Figure 3.52. Greater amberjack– Base run: Estimated biomass time series, relative to MSY *benchmarks, of SSB relative to* $\mathrm{SSB_{MSY}}$ *(top panel) and fishing mortality rate (F) relative to* F_{MSY} *(bottom panel). In each panel, a dashed horizontal line at one indicates where an estimated time series would equal its related benchmark; a dotted horizontal line at* $1 - M$ *indicates where estimated* SSB *would equal* MSST *(top panel only); thin dashed lines indicate 90% range of uncertainty from 1000 bootstrap estimates of stock-recruit curve.*



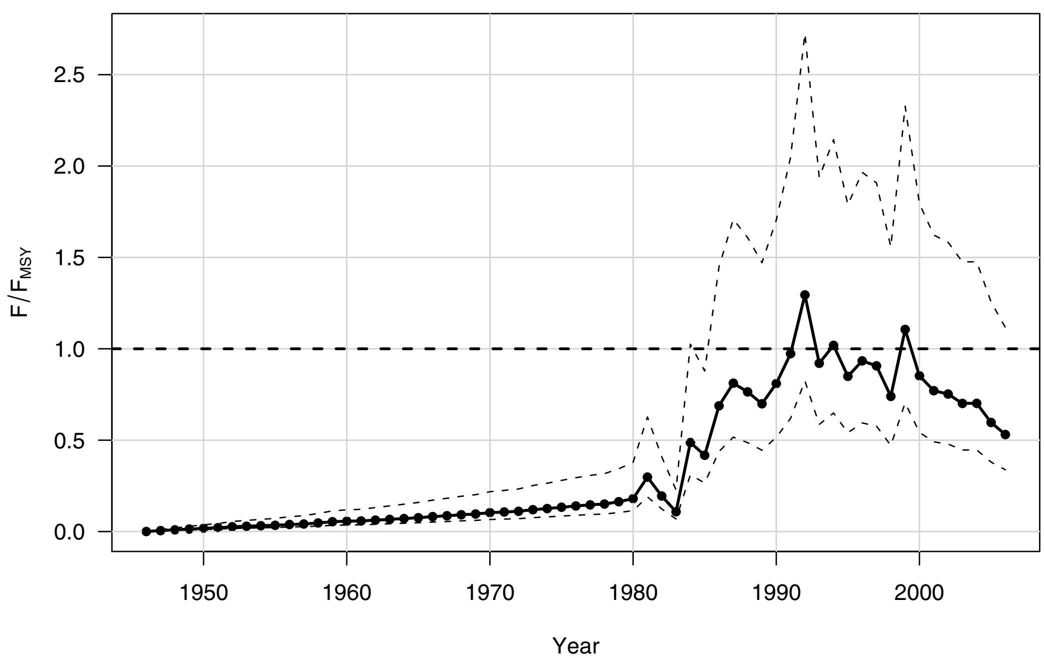


Figure 3.53. Greater amberjack– Base run: Phaseplot with population estimates for the last 10 years (two-digit year indicated inside circles). solid horizontal and vertical lines correspond to the MSY *values* (F_{MSY} *and* SSB_{MSY}). *Dashed vertical line corresponds to* MSST.

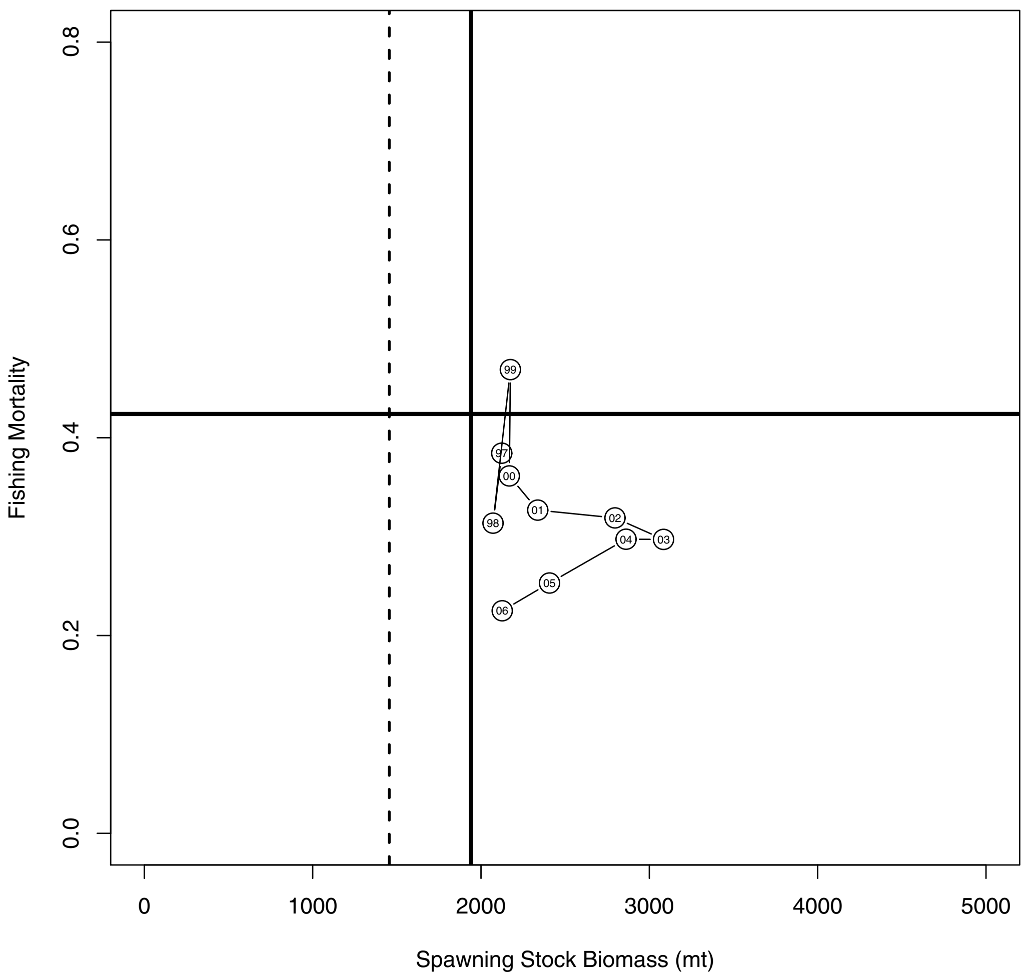


Figure 3.54. Greater amberjack– Base run: Estimates of fishing mortality rate from a retrospective analysis back to 2001. Ending year of model run is indicated by open circle in last year.

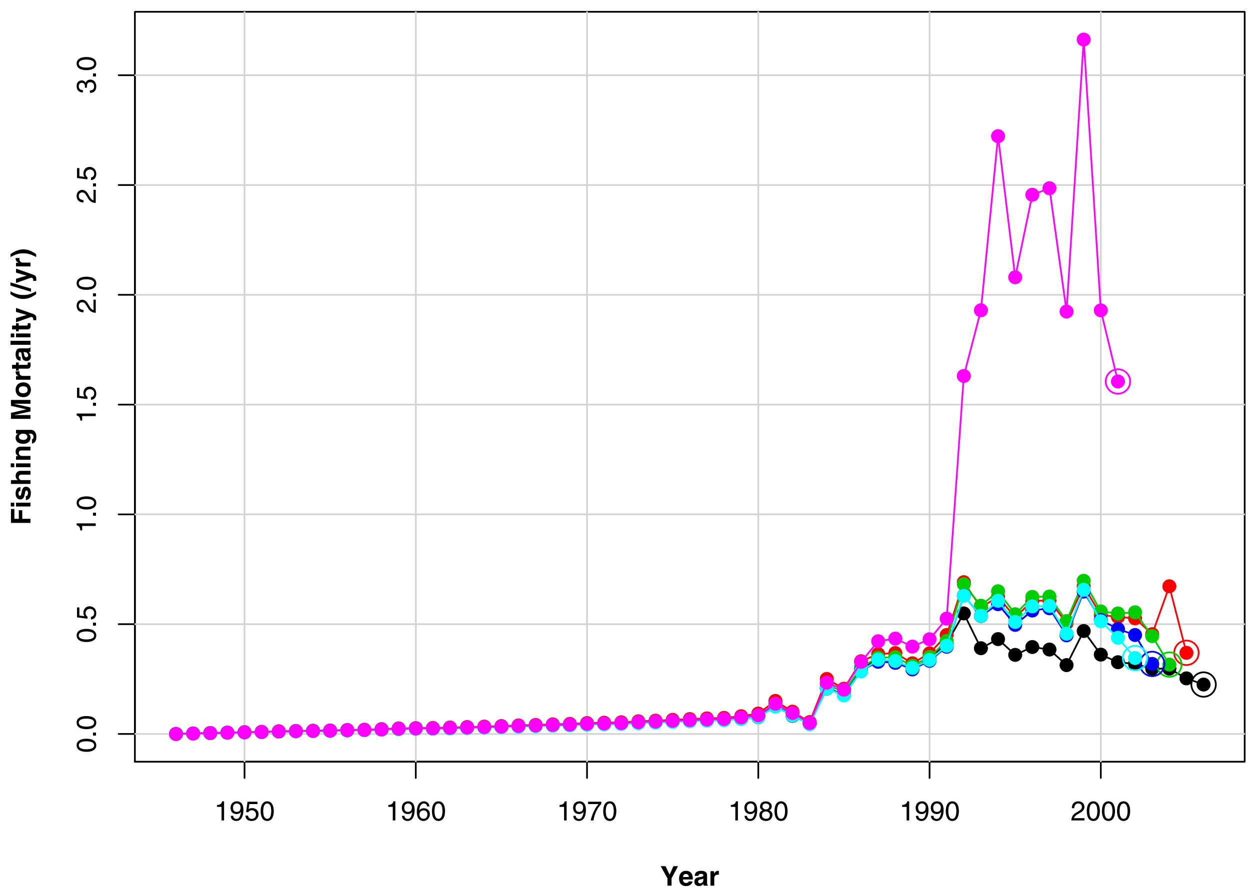


Figure 3.55. Greater amberjack– Base run: Estimates of fishing mortality rate (F) relative to the fishing mortality rate at MSY (Fmsy)from a retrospective analysis back to 2001. Ending year of model run is indicated by open circle in last year.

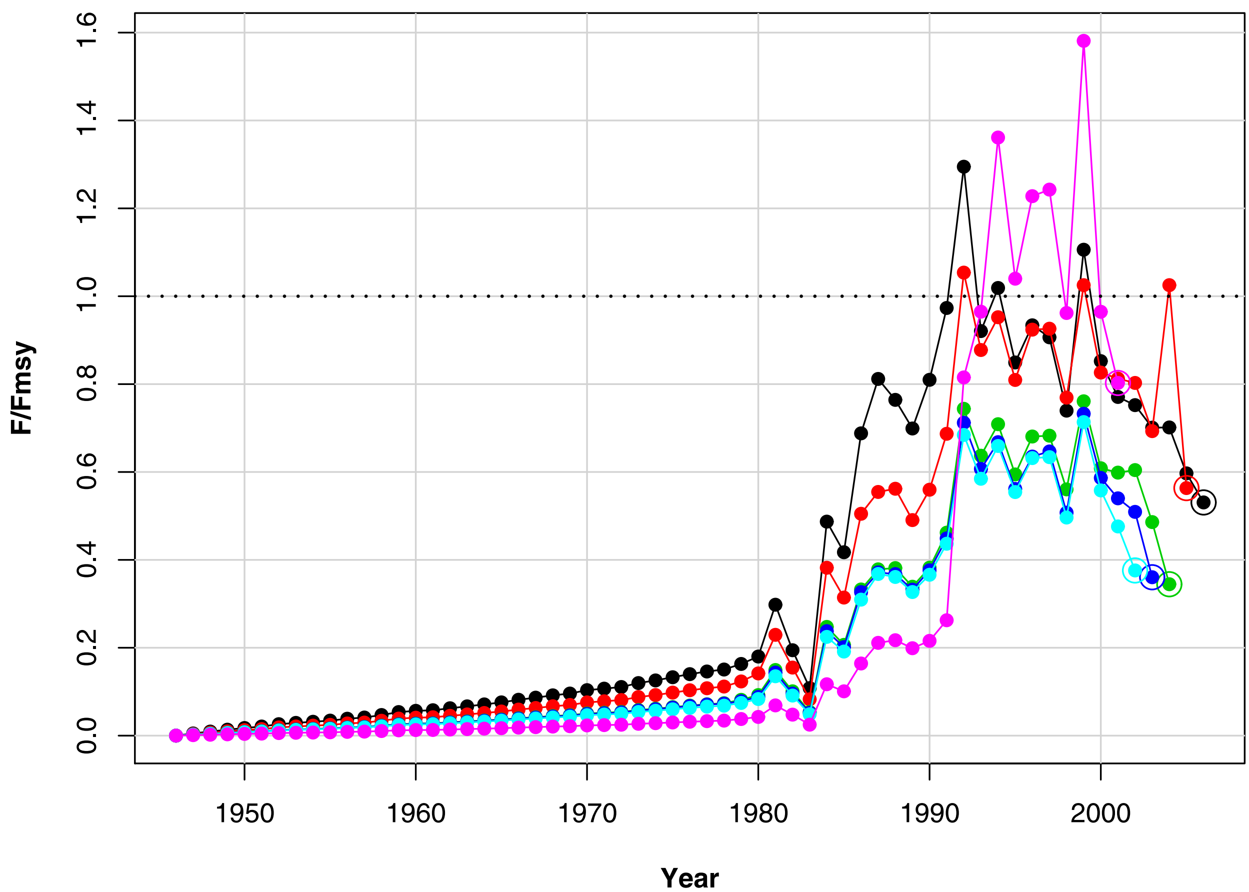


Figure 3.56. Greater amberjack– Base run: Estimates of spawning stock biomass (klb) from a retrospective analysis back to 2001. Ending year of model run is indicated by open circle in last year.

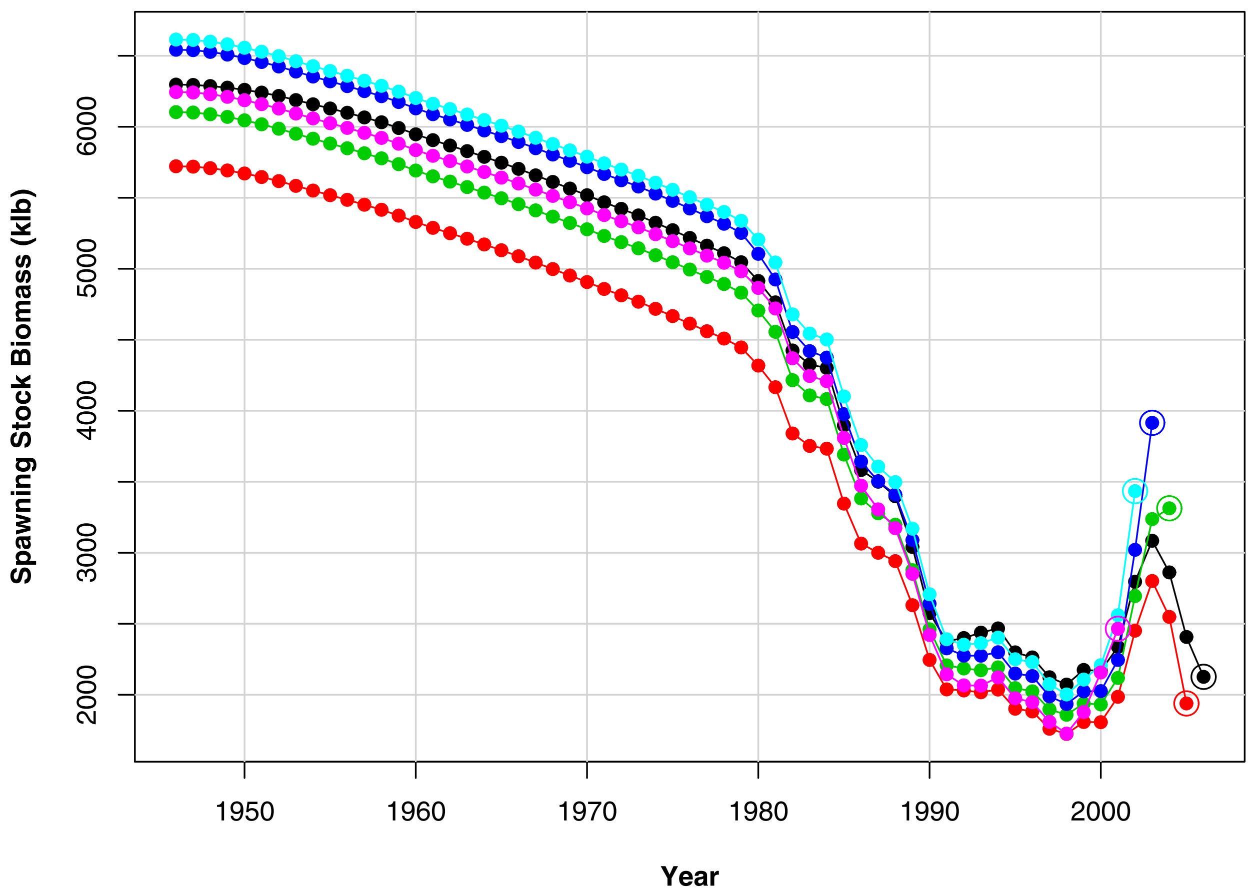


Figure 3.57. Greater amberjack– Base run: Estimates of spawning stock biomass (klb) relative to spawning stock biomass at MSY (SSBmsy)from a retrospective analysis back to 2001. Ending year of model run is indicated by open circle in last year.

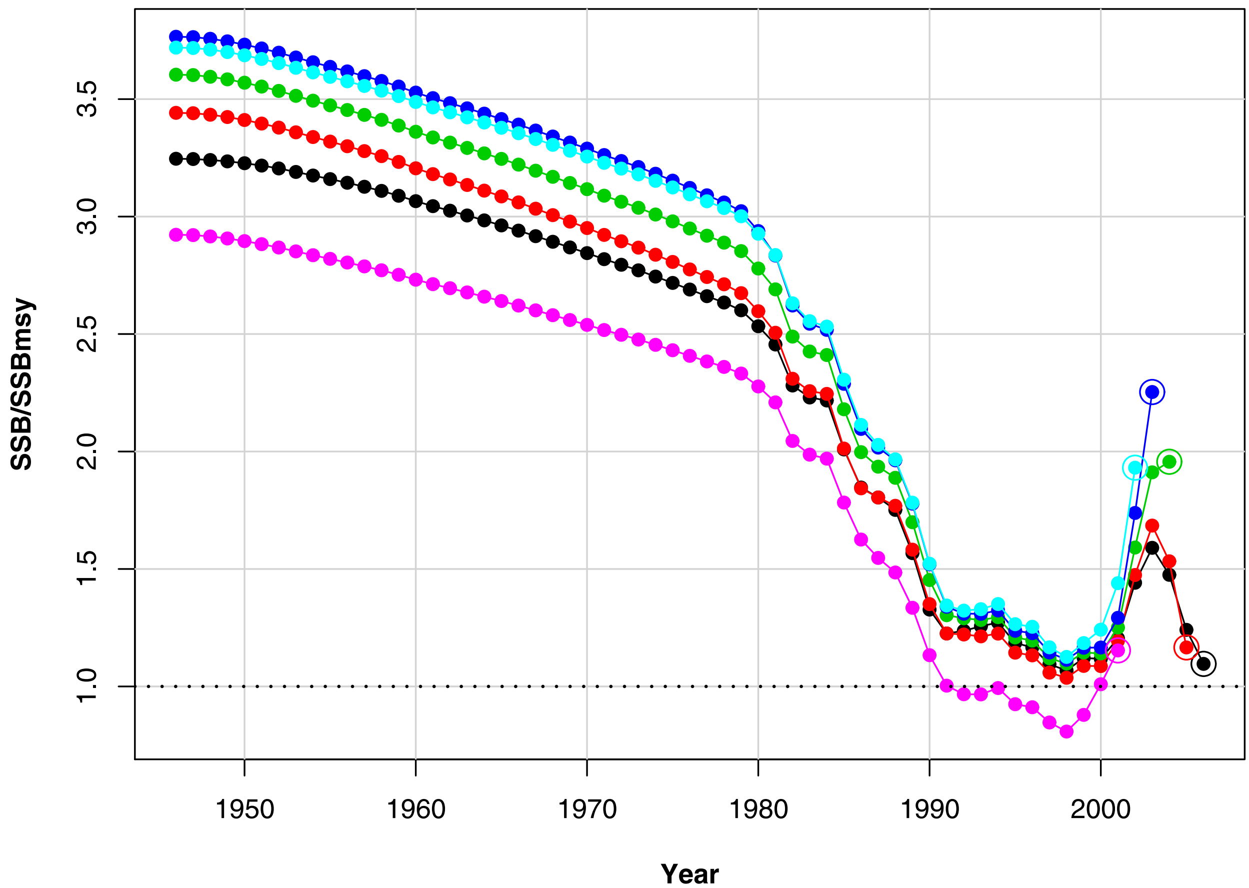


Figure 3.58. Greater amberjack– Base run: Estimates of recruits (1000s) from a retrospective analysis back to 2001. Ending year of model run is indicated by open circle in last year.

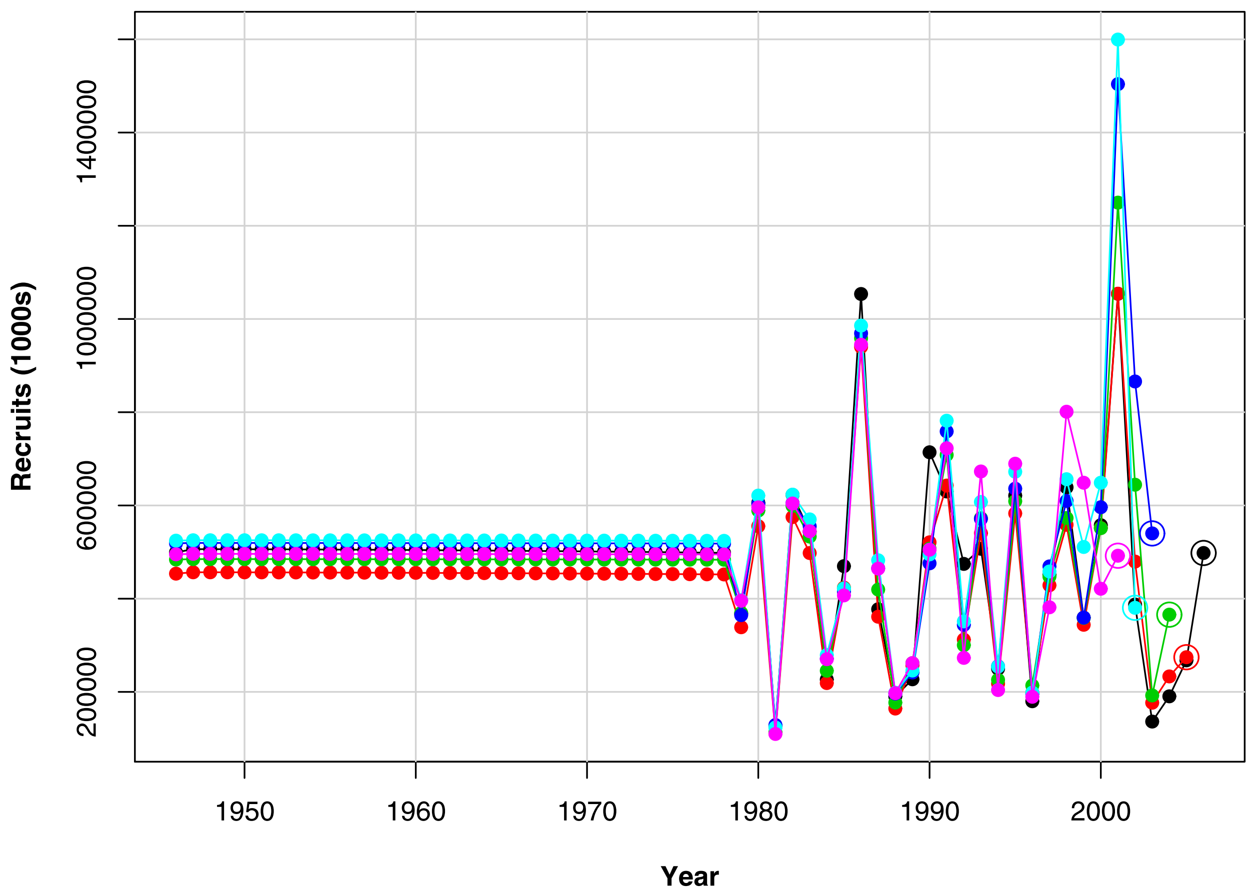


Figure 3.59. Greater amberjack– Base run: Sensitivity of the unweighted total likelihood component (lk.unwgt.data), the total likelihood component (lk.total), the commercial handline index likelihood component (lk.U.hal), and the headboat index likelihood component (lk.U.hb) to changes in the weight (100–1000) applied to the commercial handline index likelihood component.

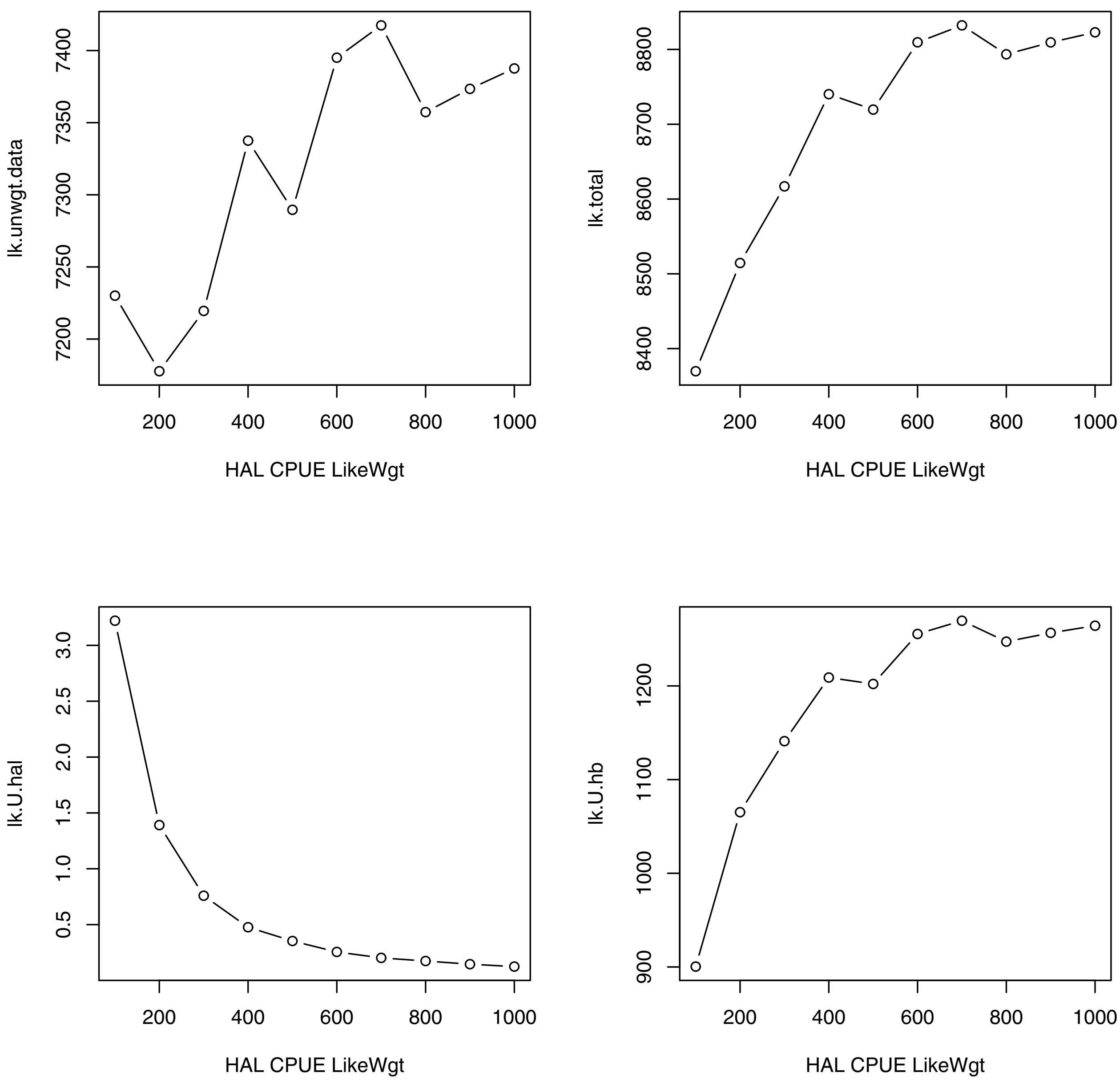


Figure 3.60. Greater amberjack– Base run: Sensitivity of the recreational index likelihood component (lk.U.mrfss), the commercial handline landings (lkL.c.hal), the commercial diving landings likelihood component (lk.L.c.dv), and the headboat landings likelihood component (lk.L.hb) to changes in the weight (100–1000) applied to the commercial handline index likelihood component.

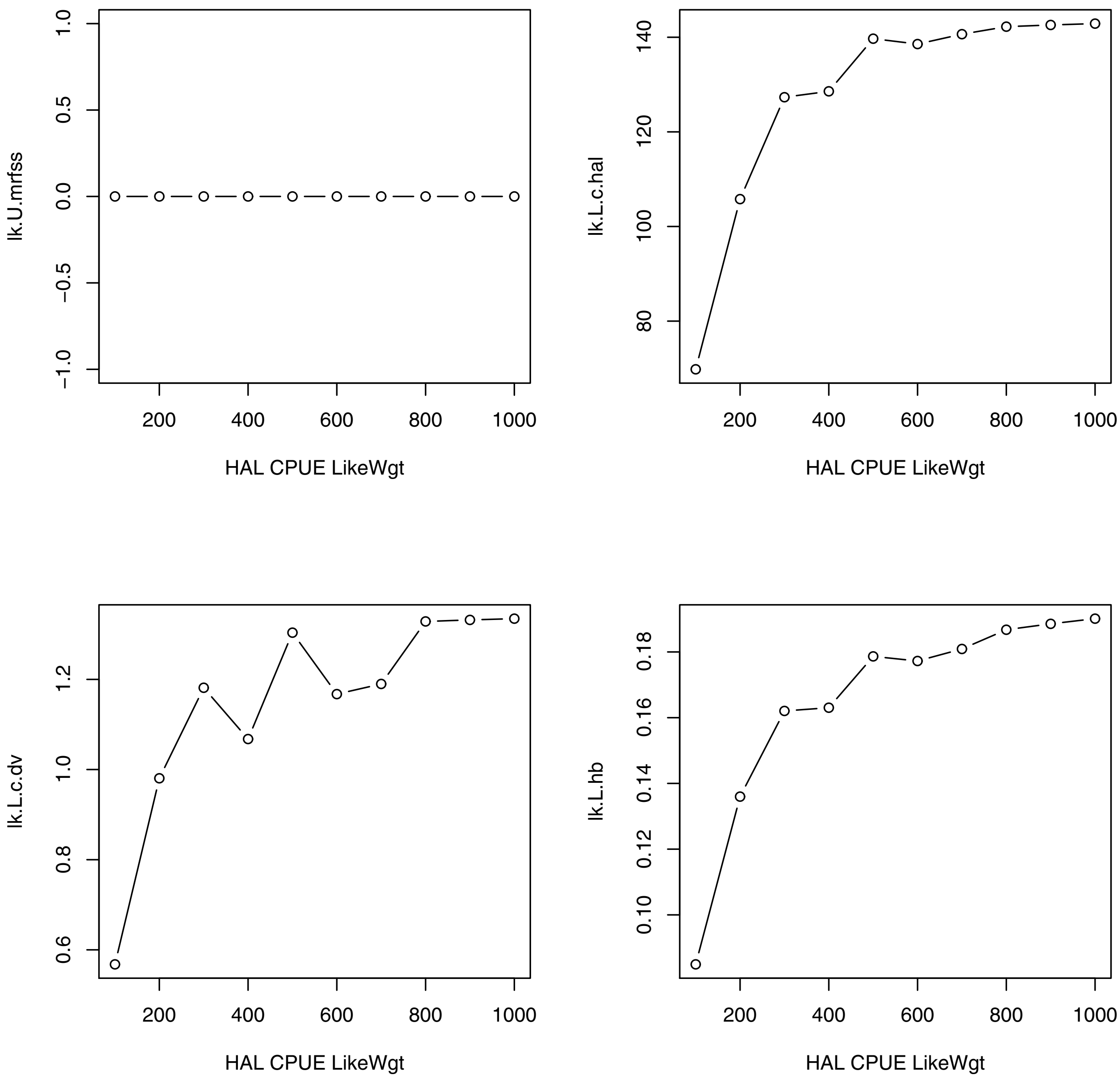


Figure 3.61. Greater amberjack– Base run: Sensitivity of the recreational landings likelihood component (lk.L.mfrss), the commercial handline discard likelihood component (lk.D.c.hal), the headboat discard likelihood component (lk.D.hb), and the recreational discard likelihood component (lk.D.mrfss) to changes in the weight (100–1000) applied to the commercial handline index likelihood component.

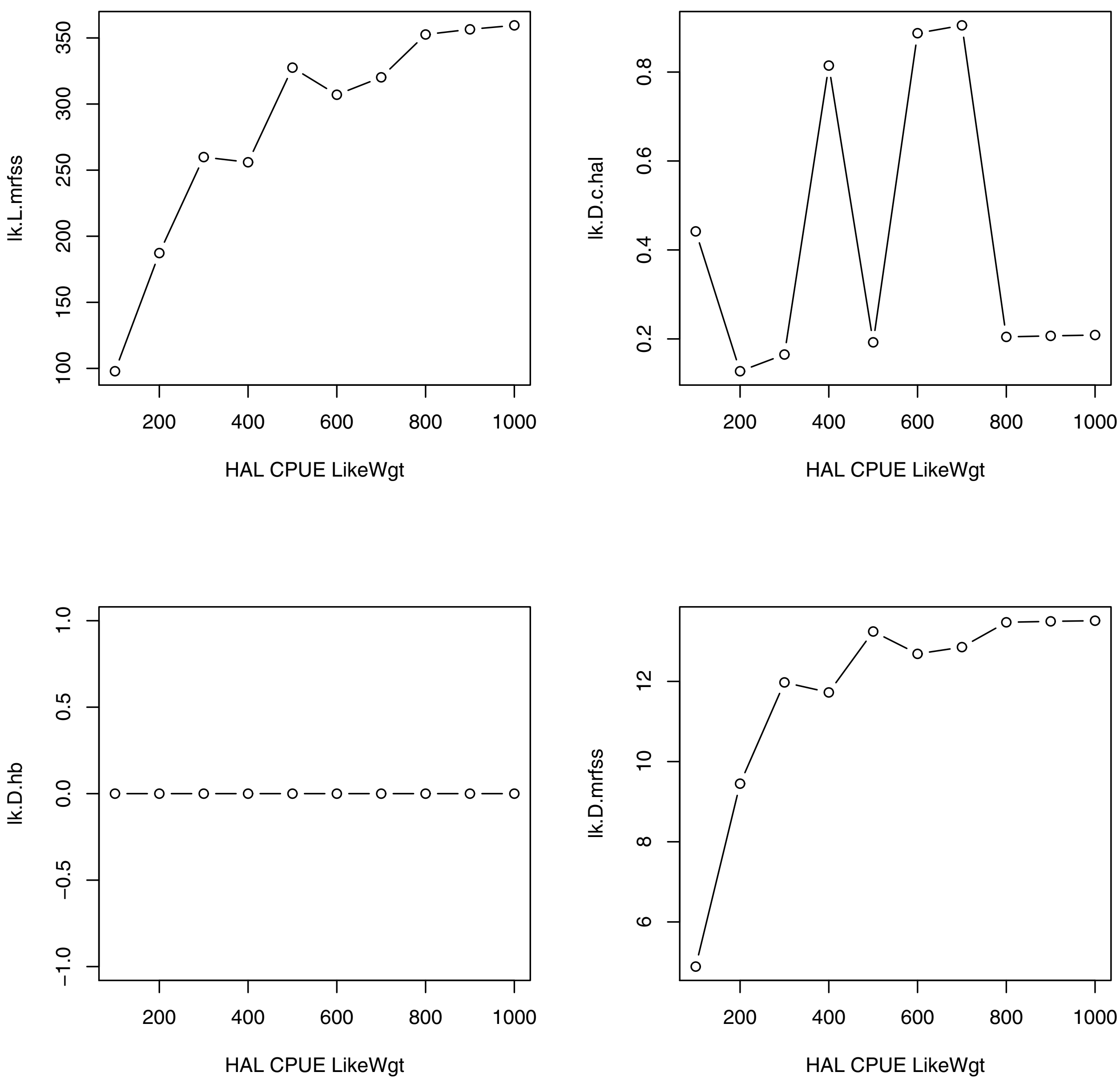


Figure 3.62. Greater amberjack– Base run: Sensitivity of the commercial length composition likelihood component (lk.lenc.c.hal), the commercial diving likelihood component (lk.lenc.c.dv), the headboat length composition likelihood component (lk.lenc.hb), and the recreational length composition likelihood component (lk.lenc.mrfss) to changes in the weight (100–1000) applied to the commercial handline index likelihood component.

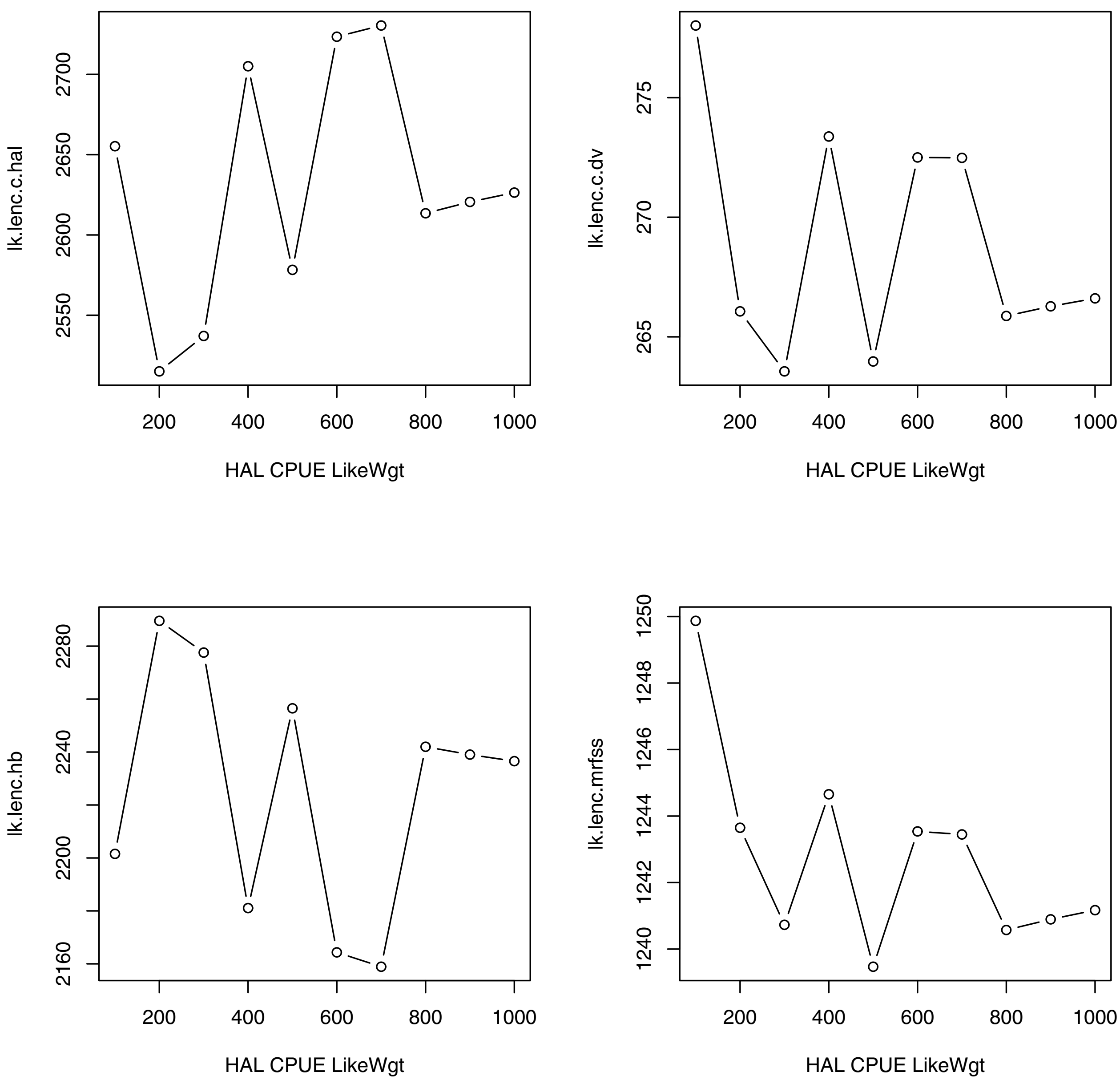


Figure 3.63. Greater amberjack– Base run: Sensitivity of the commercial age composition likelihood component (lk.agec.c.hal), the commercial age composition likelihood component (lk.agec.c.dv), the headboat age composition likelihood component (lk.agec.hb), and the recreational age composition likelihood component (lk.agec.mrfss) to changes in the weight (100–1000) applied to the commercial handline index likelihood component.

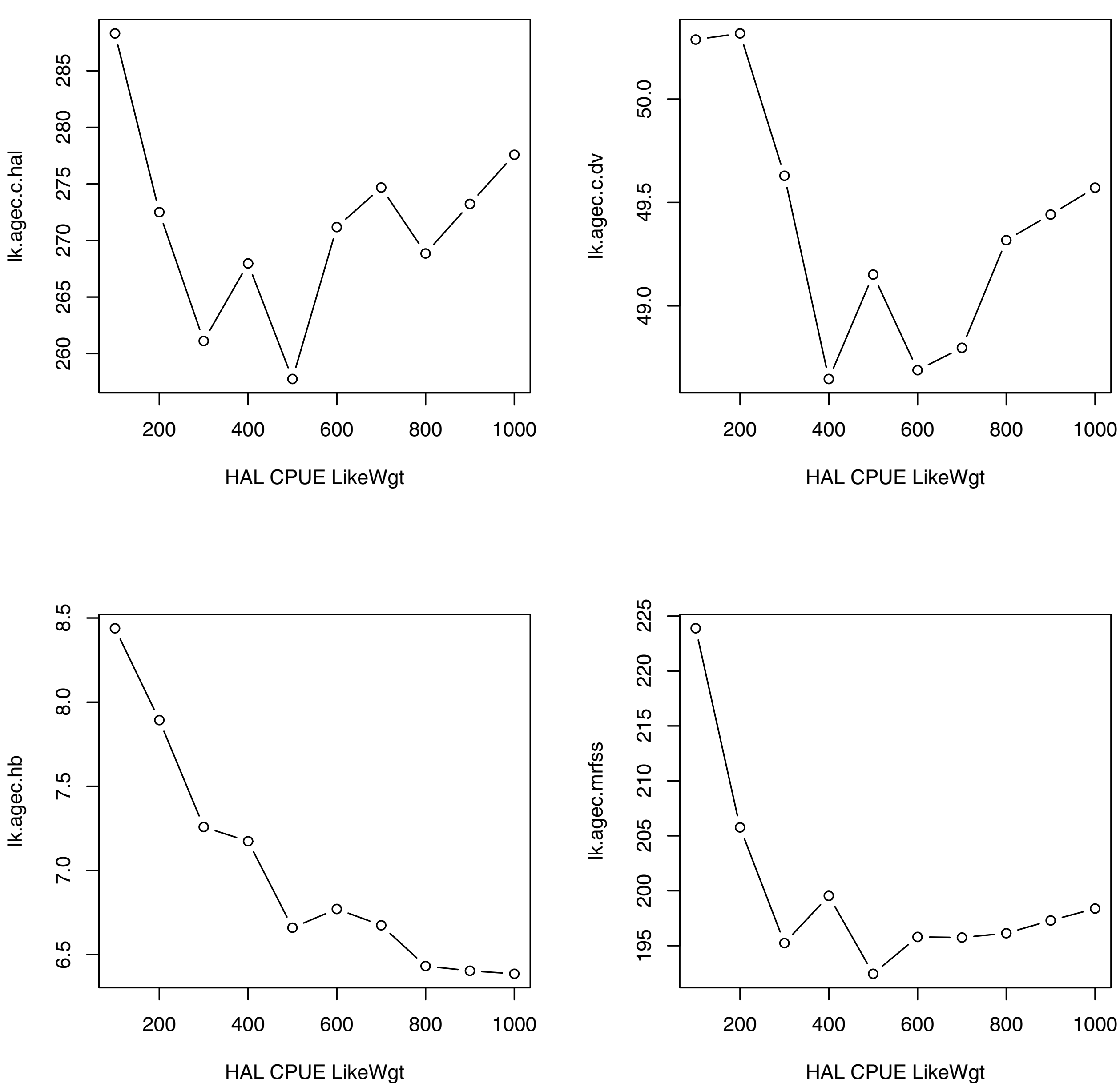


Figure 3.64. Greater amberjack– Base run: Sensitivity of the stock recruitment fit likelihood component (lk.SRfit) to changes in the weight (100–1000) applied to the commercial handline index likelihood component.

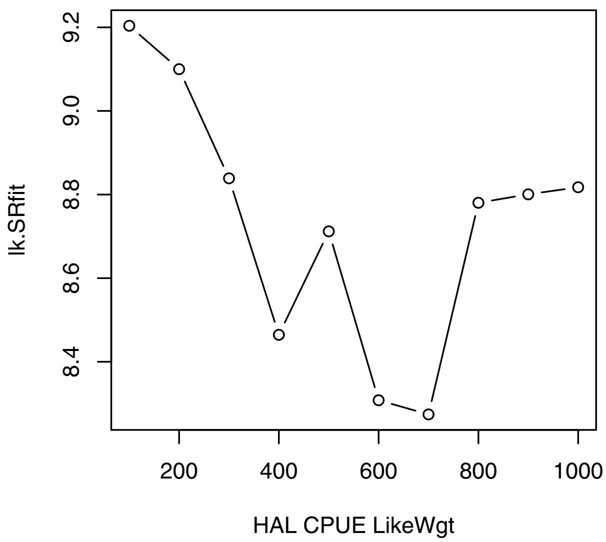


Figure 3.65. Greater amberjack- Recruitment estimates from sensitivity analysis for various weights (100-1000) applied to the commercial handline index likelihood component.

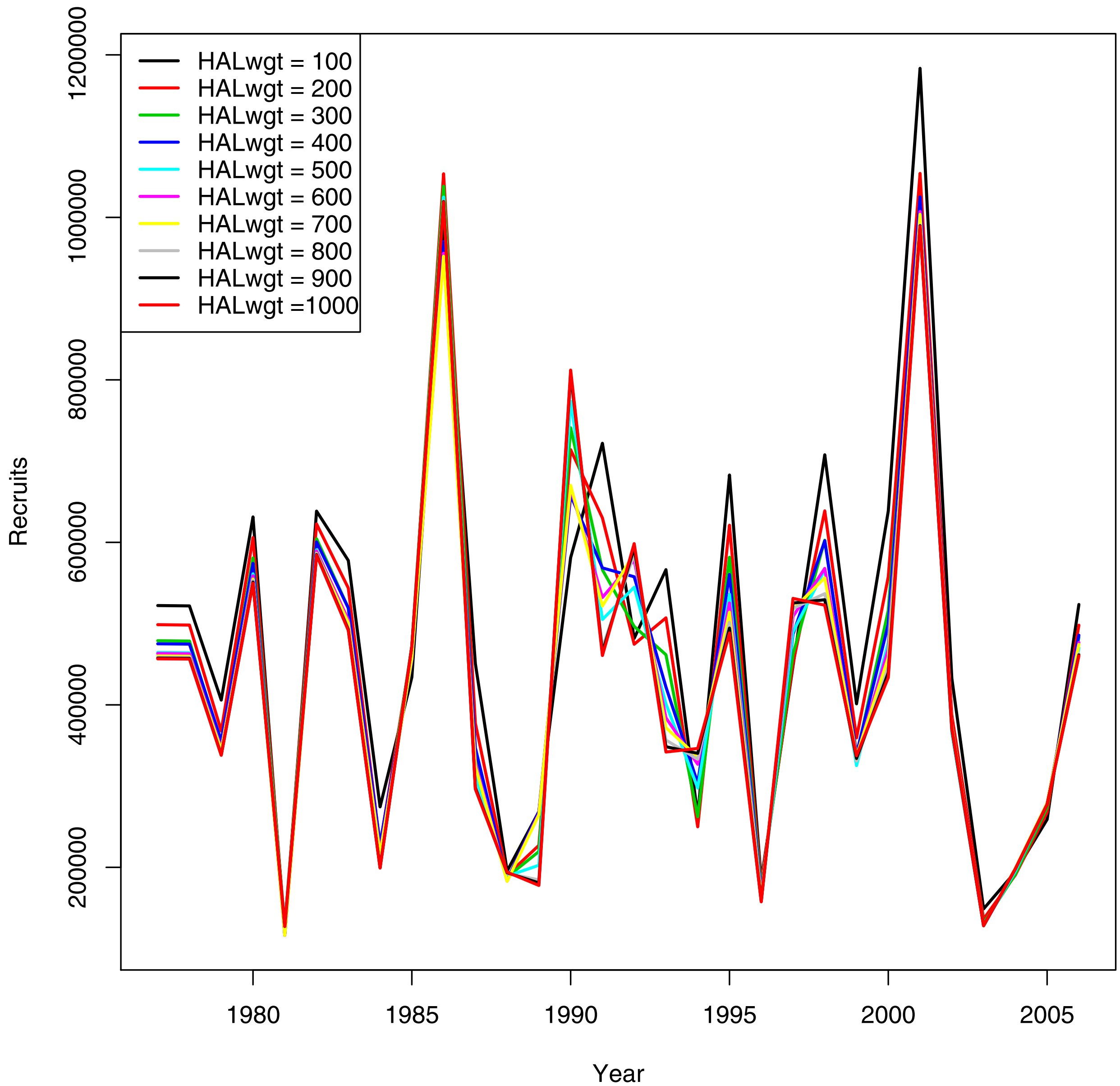


Figure 3.66. Greater amberjack- Fits to the commercial handline index (U.hal) for various weights (100-1000) applied to the commercial handline index likelihood component. Circles represent observed values of index.

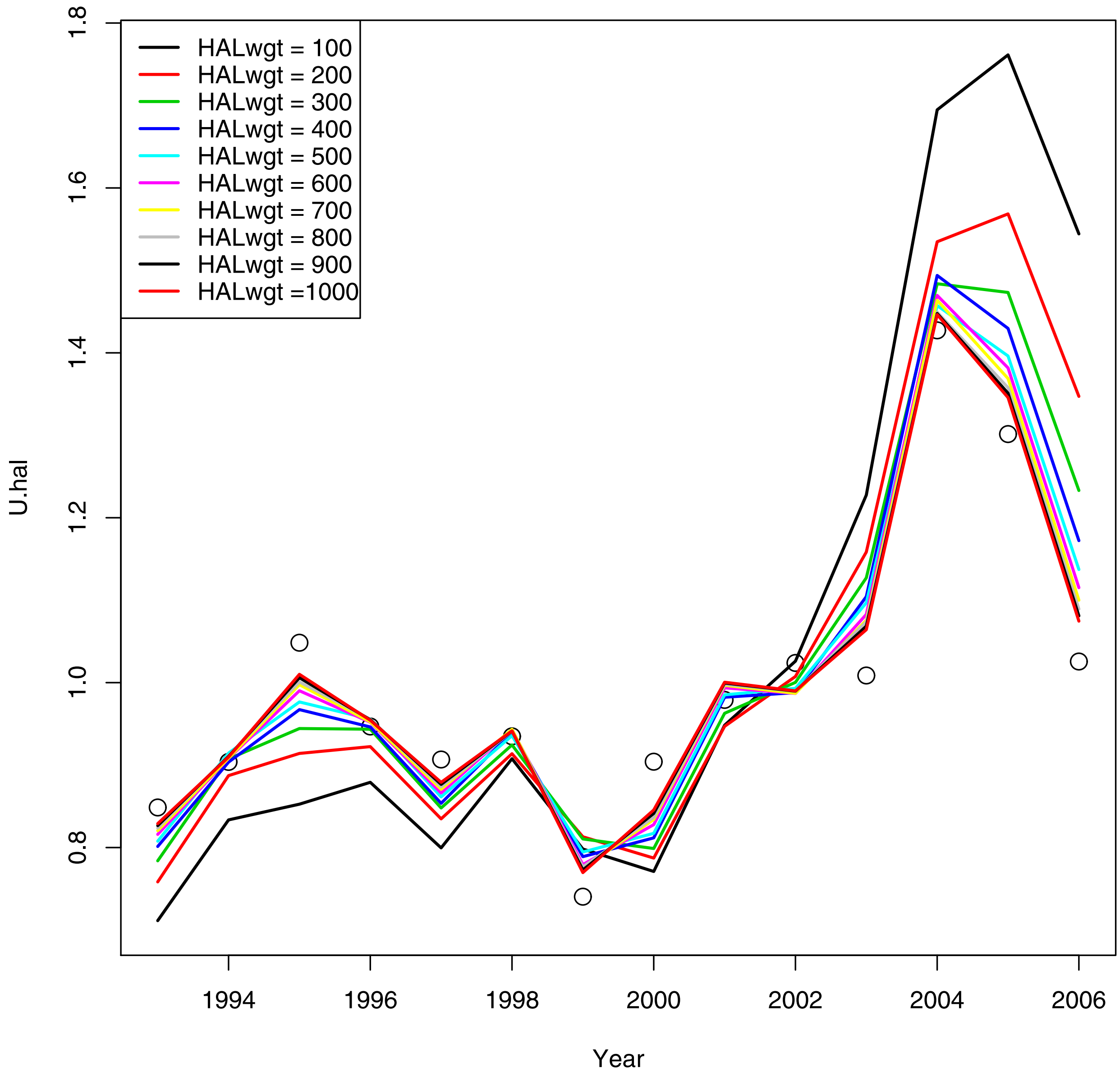


Figure 3.67. Greater amberjack– Fits to the headboat index (U.hb) for various weights (100–1000) applied to the commercial handline index likelihood component. Circles represent observed values of index.

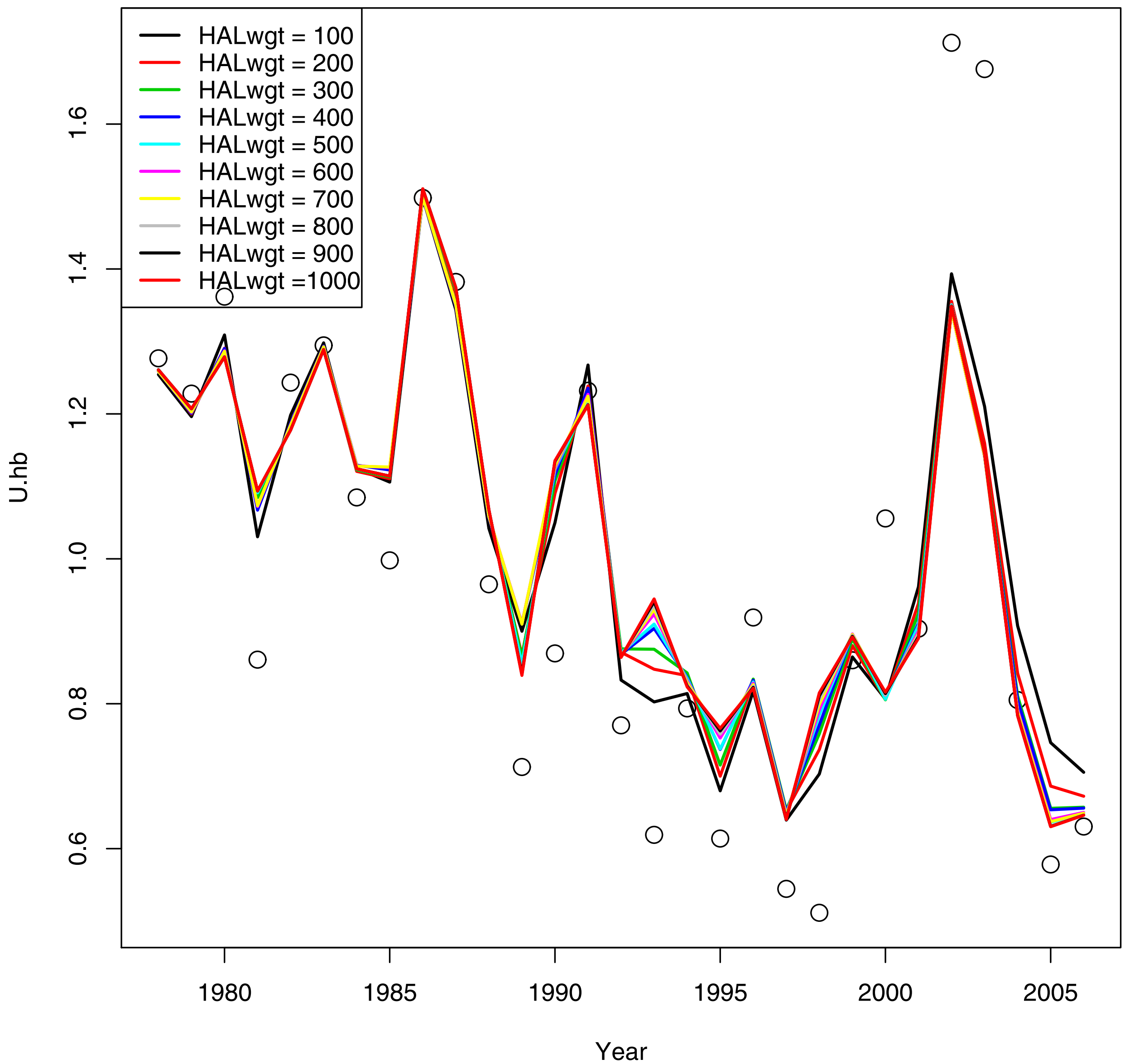


Figure 3.68. Greater amberjack– Base run: Projections under current fishing mortality rate for all years. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY}; B) Recruits, horizontal line is R_{MSY}; C) Fishing mortality rate, horizontal line is F_{MSY}; and D) Landings, horizontal line is MSY.

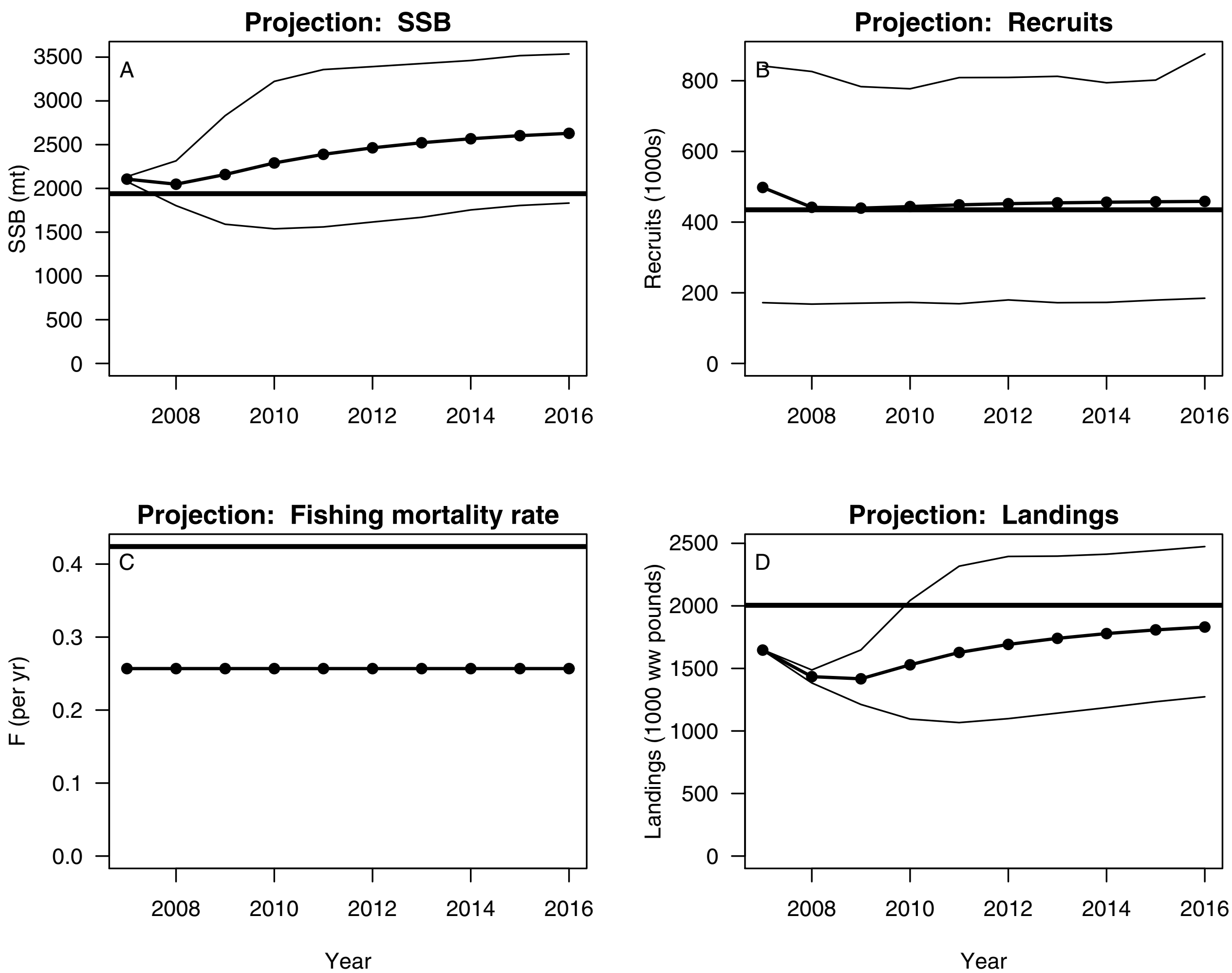


Figure 3.69. Greater amberjack– Base run: Projections under current fishing mortality rate in 2007-2008 and F_{MSY} in 2009-2016. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY}; B) Recruits, horizontal line is R_{MSY}; C) Fishing mortality rate, horizontal line is F_{MSY}; and D) Landings, horizontal line is MSY.

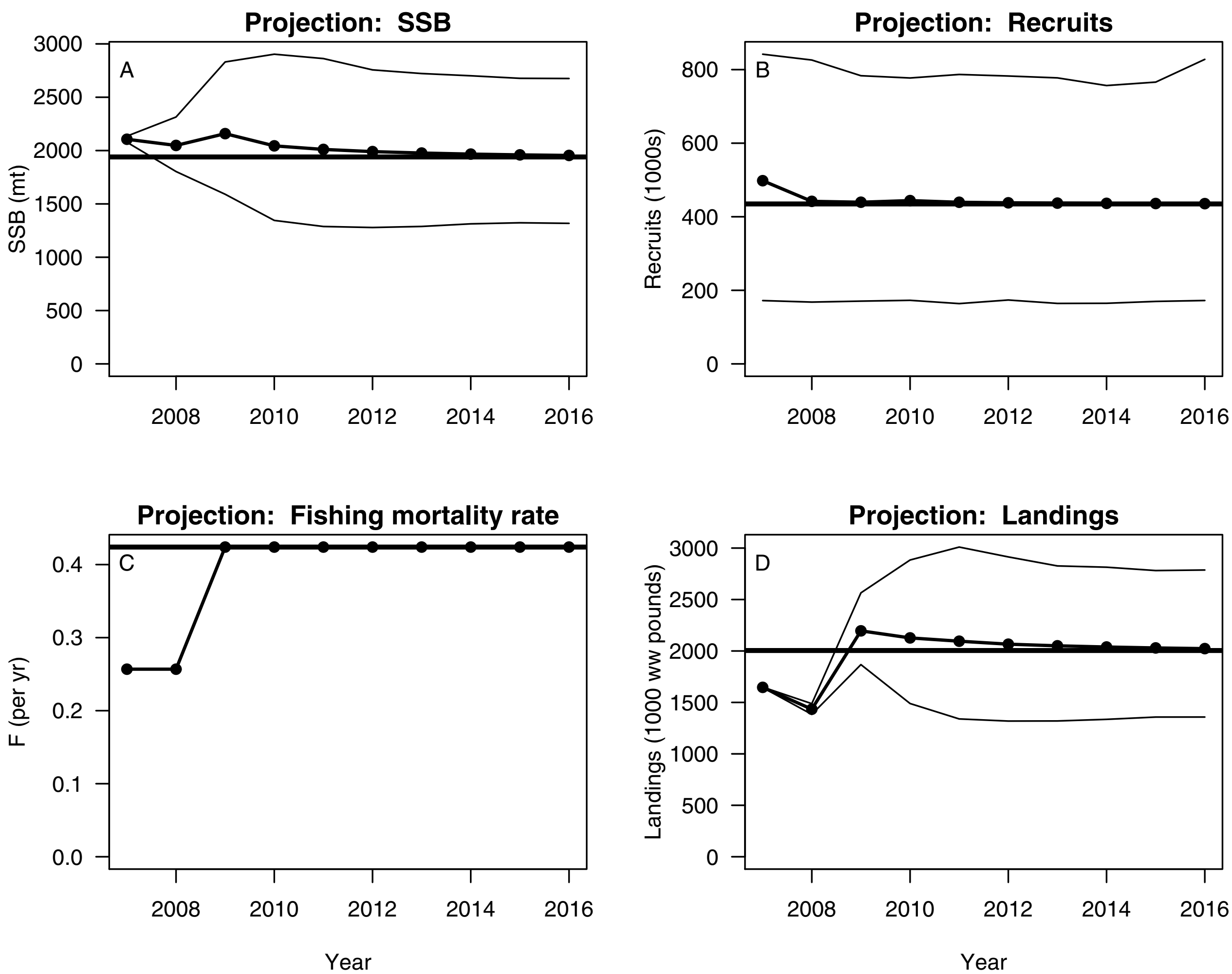


Figure 3.70. Greater amberjack– Base run: Projections under current fishing mortality rate in 2007-2008 and 85% of F_{MSY} in 2009-2016. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY}; B) Recruits, horizontal line is R_{MSY}; C) Fishing mortality rate, horizontal line is F_{MSY}; and D) Landings, horizontal line is MSY.

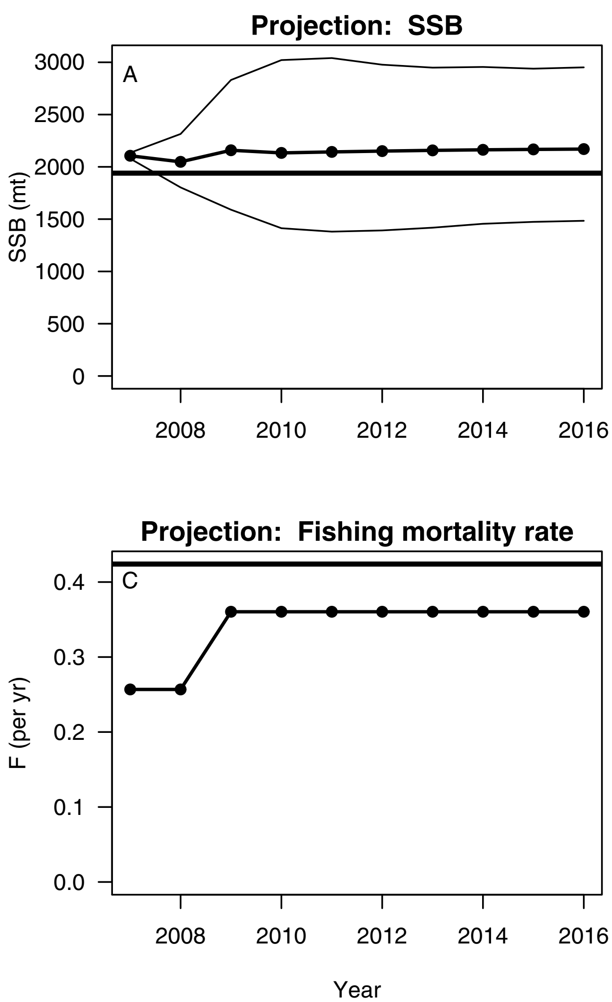


Figure 3.71. Greater amberjack– Base run: Projections under current fishing mortality rate in 2007-2008 and 75% of F_{MSY} in 2009-2016. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY}; B) Recruits, horizontal line is R_{MSY}; C) Fishing mortality rate, horizontal line is F_{MSY}; and D) Landings, horizontal line is MSY.

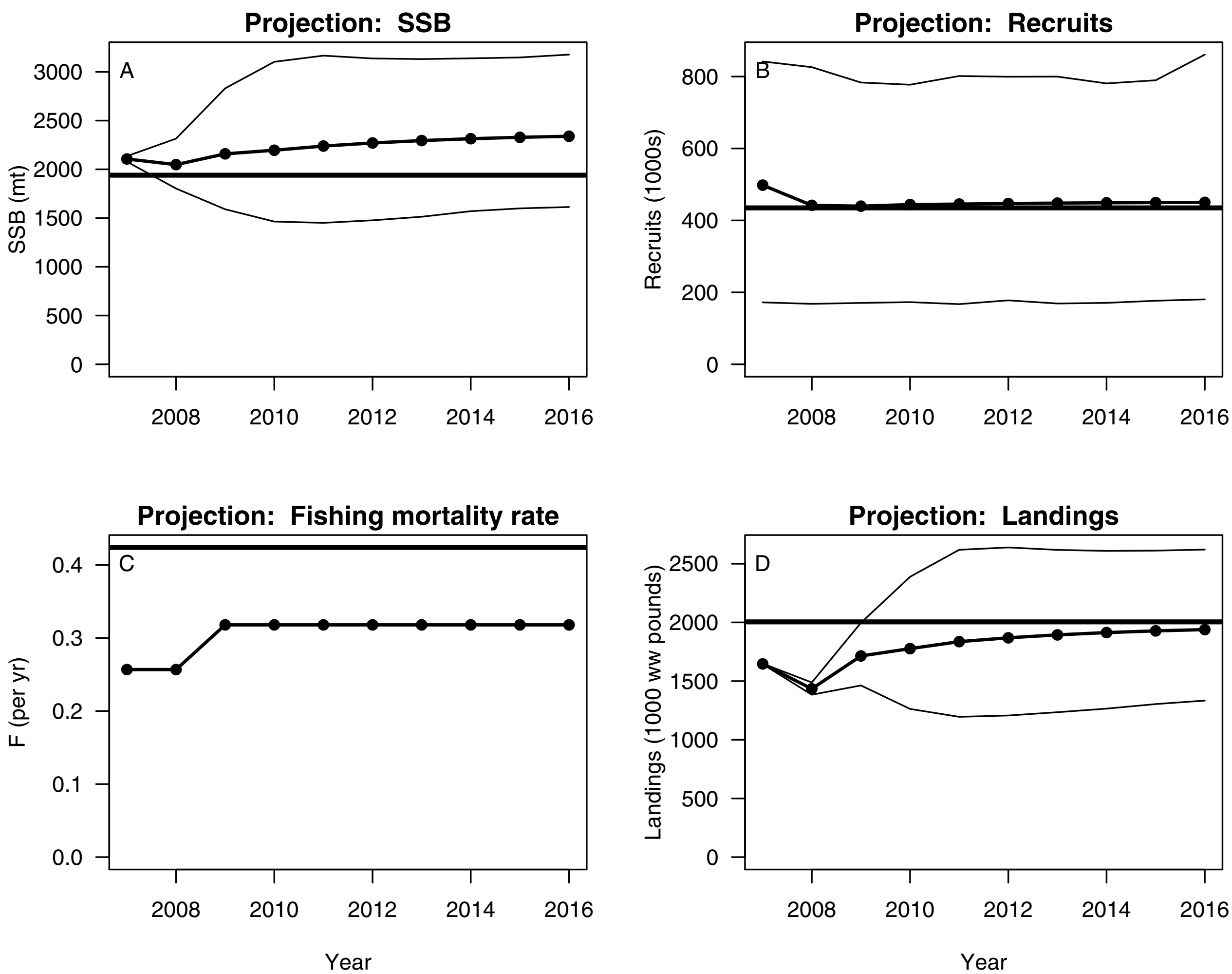


Figure 3.72. Greater amberjack– Base run: Projections under current fishing mortality rate in 2007-2008 and 65% of F_{MSY} *in 2009-2016. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is* SSB_{MSY}*; B) Recruits, horizontal line is* R_{MSY}*; C) Fishing mortality rate, horizontal line is* F_{MSY}*; and D) Landings, horizontal line is MSY.*

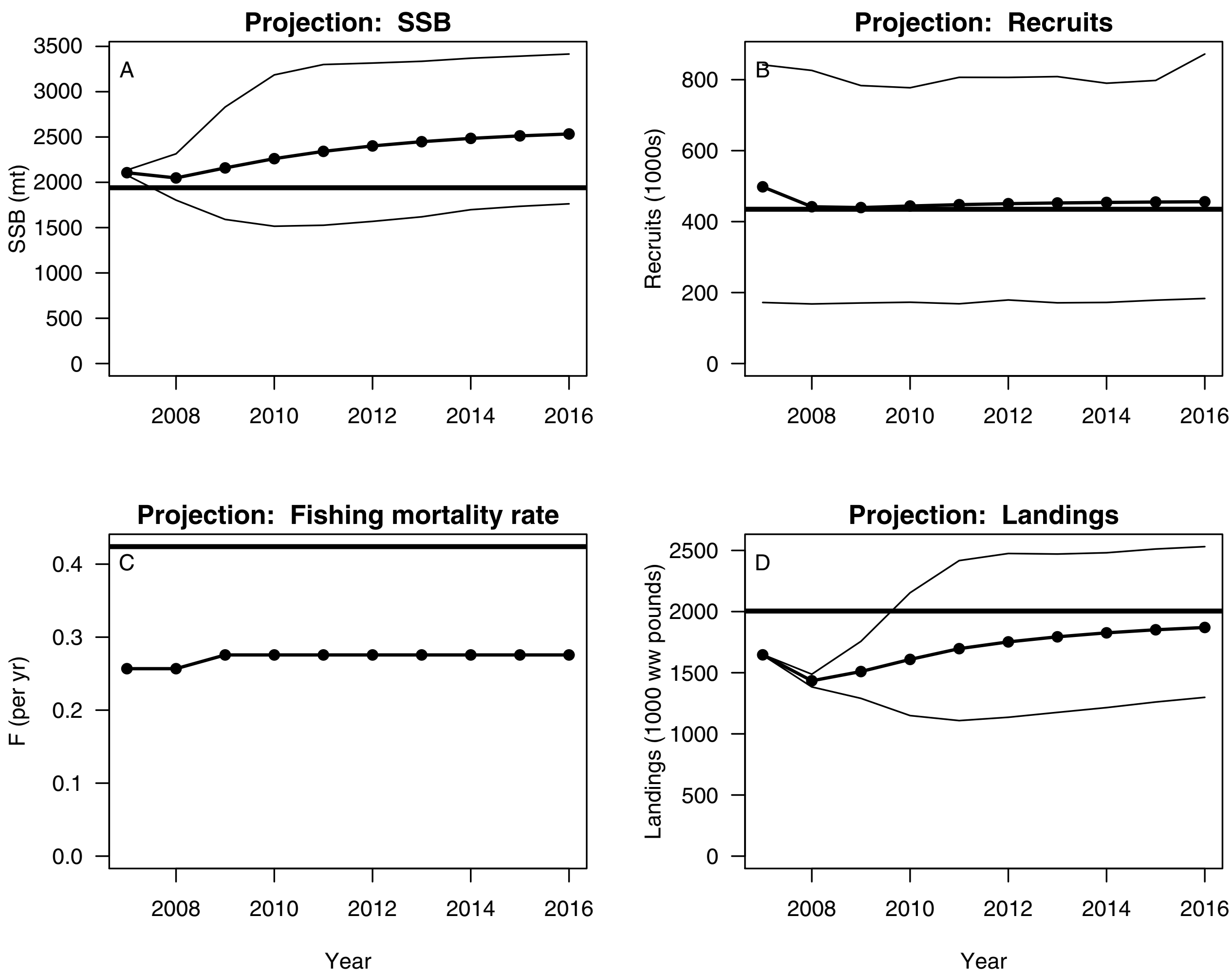


Figure 3.73. Greater amberjack– Base run: Mean weight of headboat landings computed by dividing headboat landings in weight by landings in number.

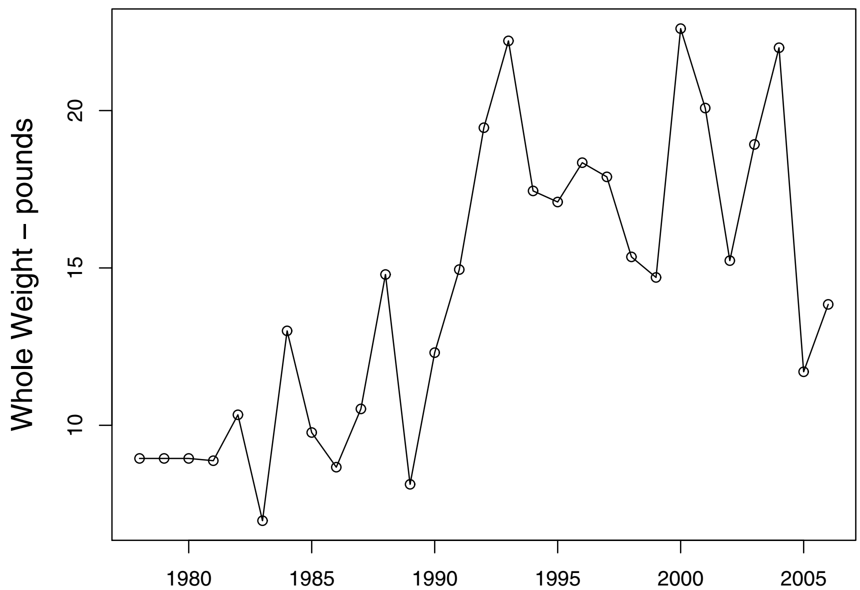


Figure 3.74. Greater amberjack– Base run – Surplus-production model: Fit of production model to headboat index from period 1 (1978 – 1991).

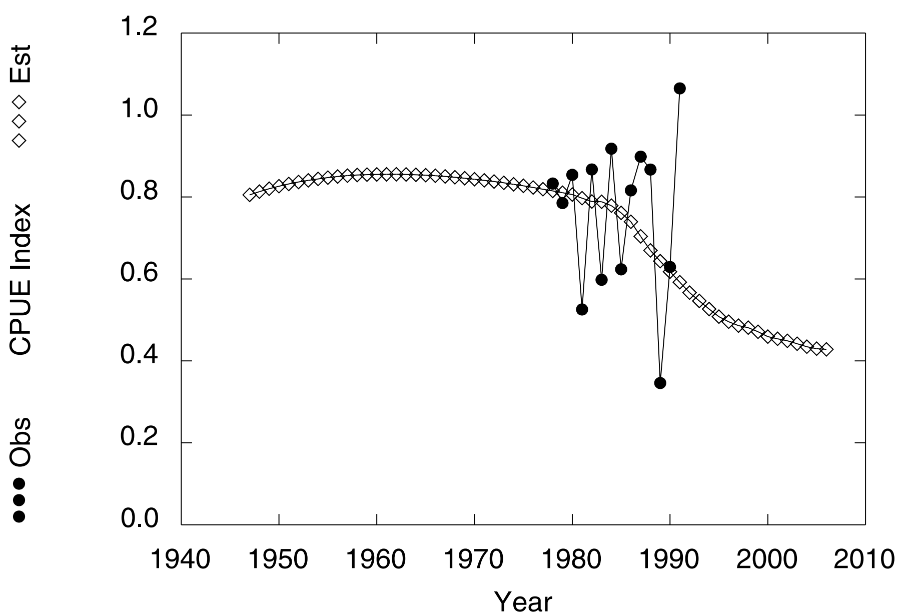


Figure 3.75. Greater amberjack– Base run – Surplus-production model: Fit of production model to headboat index from period 2 (1992 – 2006).

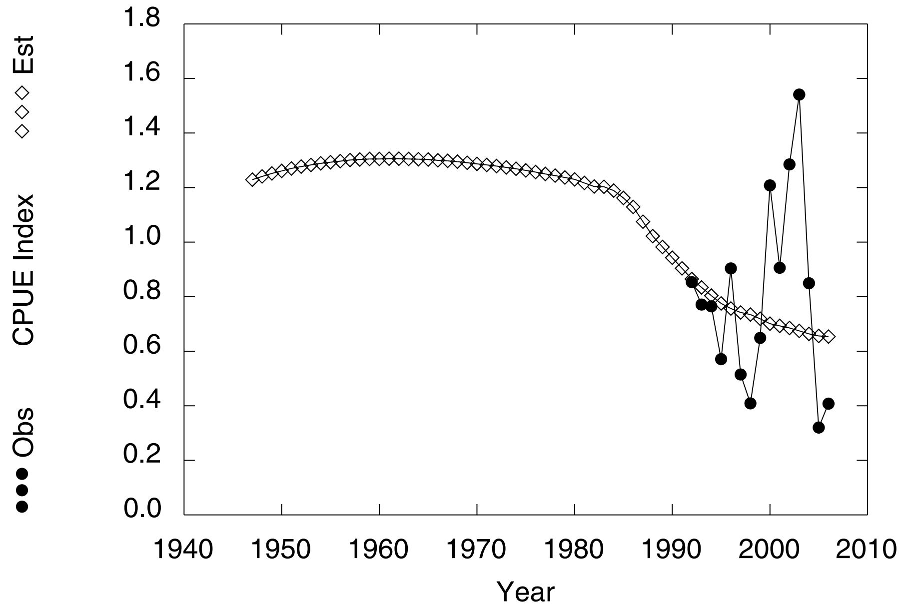


Figure 3.76. Greater amberjack– Base run – Surplus-production model: Fit of production model to recreational index (MRFSS).

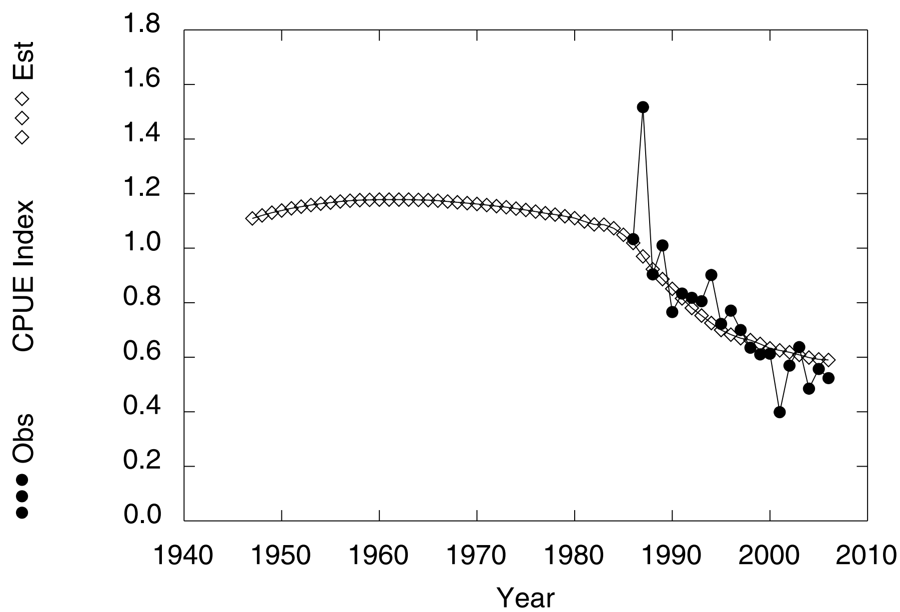


Figure 3.77. Greater amberjack– Base run – Surplus-production model: Fit of production model to commercial handline index.

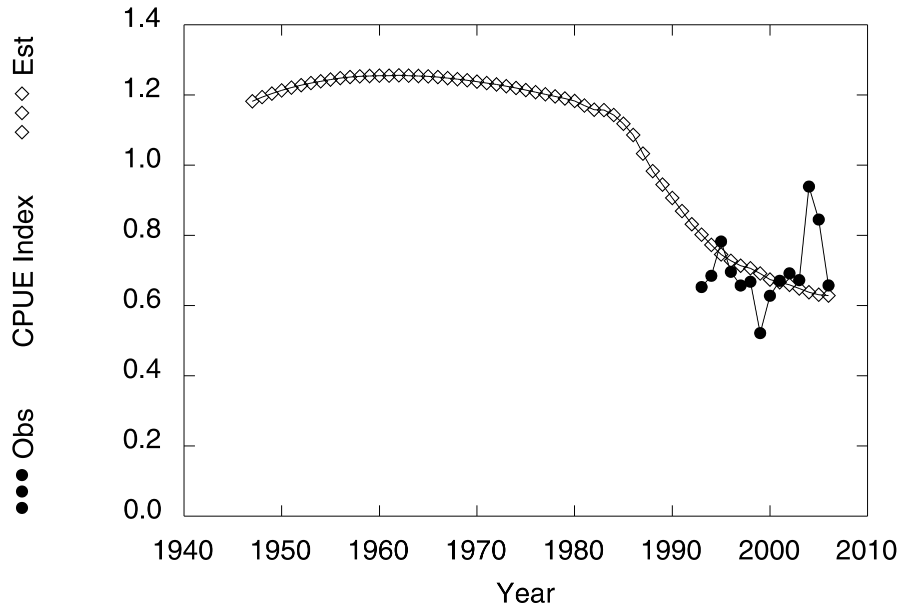


Figure 3.78. Greater amberjack- Sensitivity runs: Relative fishing mortality F/F_{MSY} and biomass B/B_{MSY} from the surplus-production model sensitivity runs with B1/K set to 0.75, 0.95, and 0.99. The base run plot with B1/K set to 0.85 is shown as the solid line.

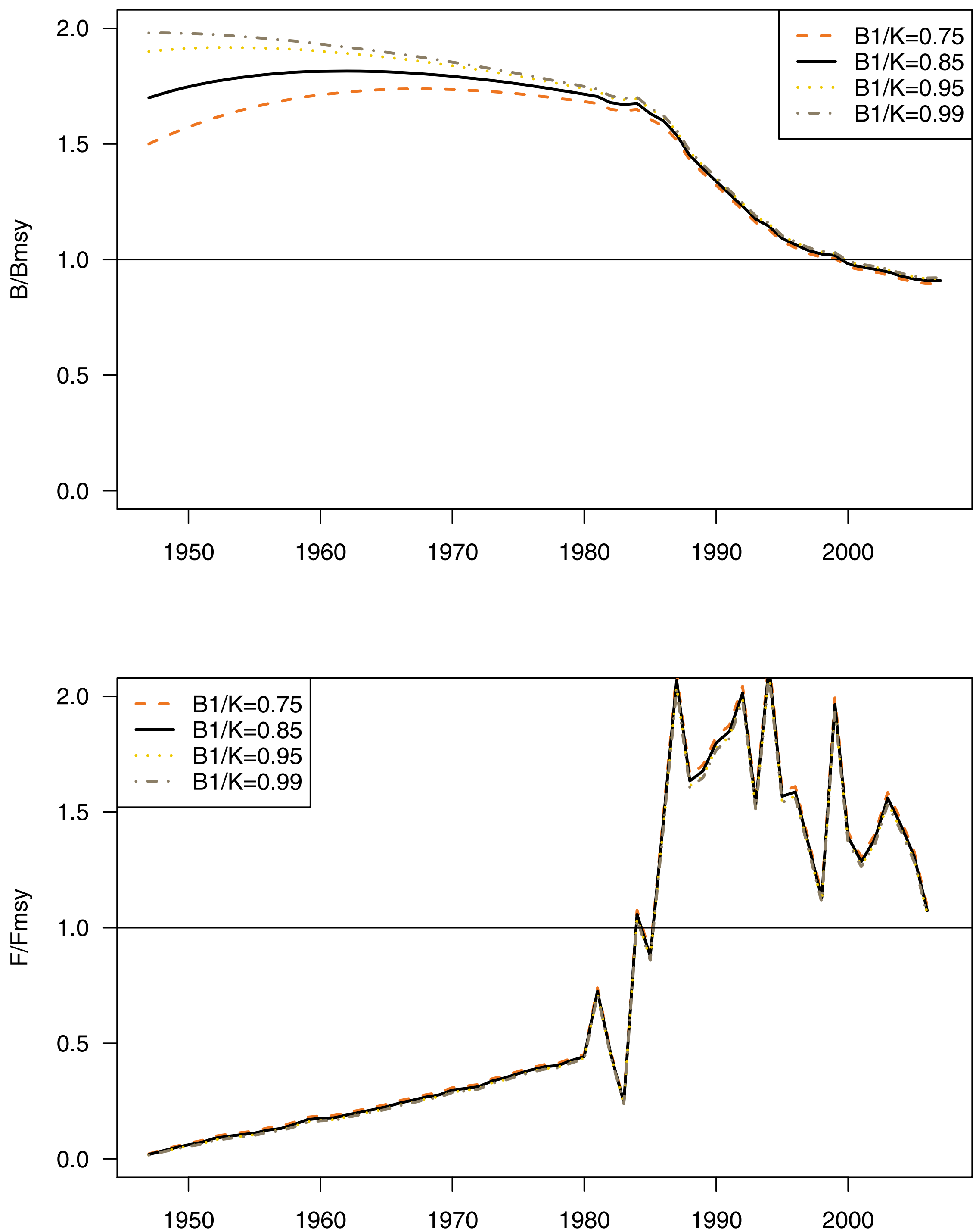


Figure 3.79. Greater amberjack– Base run – Surplus-production model: Production model estimates ratio of the fishing mortality rate to fishing mortality rate at MSY (F/Fmsy) ratio and the biomass to biomass at MSY ratio (B/Bmsy).

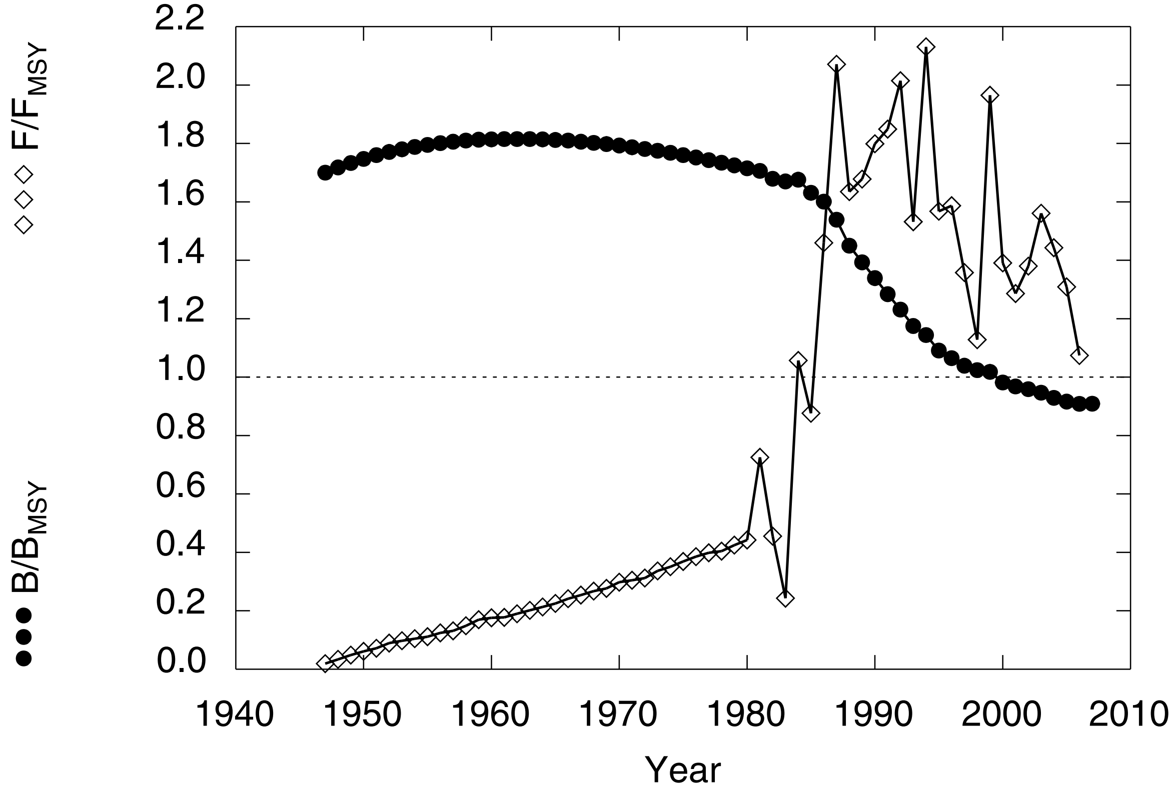
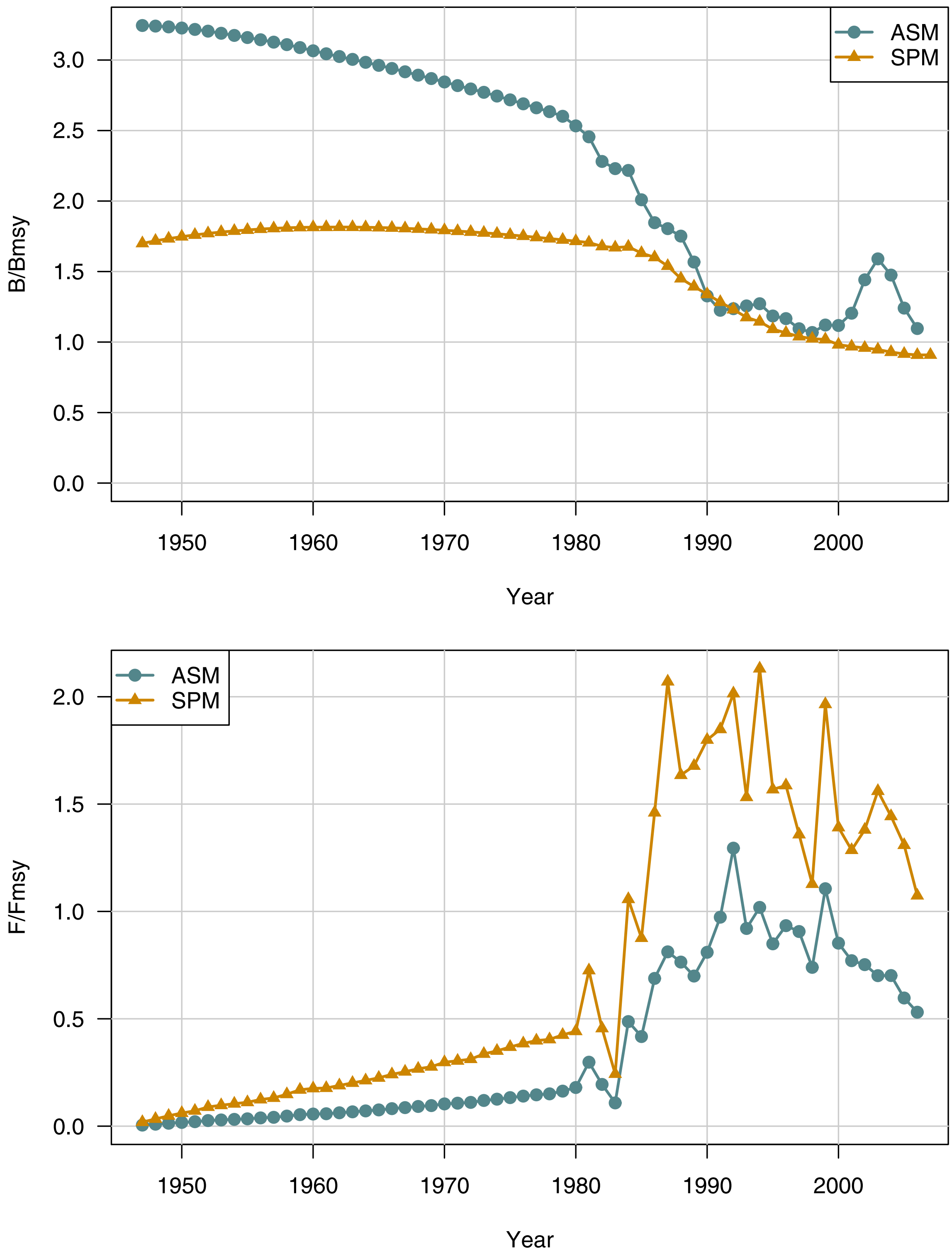


Figure 3.80. Greater amberjack– Age structured model (ASM) – Surplus-production model (SPM) comparison: Age structured and surplus production model estimated ratio of the biomass to biomass at MSY ratio (B/B_{MSY} – upper panel) and the fishing mortality rate to fishing mortality rate at MSY *ratio (F/F_{MSY} - lower panel).*



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

```
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##
//##  SEDAR15 Assessment: Greater Amberjack, October 2007
//##
//##  NMFS, Beaufort Lab
//##
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>

DATA_SECTION
!!cout << "Starting The Great Greater Amberjack Assessment Model" << endl;

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

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

//Total number of ages
init_int nages;

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

//number of assessment and recruitment years
number nyrs;
number nyrsR;
//this section MUST BE INDENTED!!!
 LOCAL_CALCS
   nyrs=endyr-styr+1;
   nyrsR=endyr-styrR+1;
 END_CALCS

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

!!cout << "nlenbins = " << nlenbins << endl;

// 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;

!!cout << "set_len_cv = " << set_len_cv << endl;

//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_w2g

//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

!!cout << "prop_f_obs = " << prop_f_obs << endl;

//#############################################################################
//##################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 (1000s gutted pounds)
init_int styr_commHAL_L;
init_int endyr_commHAL_L;
init_vector obs_commHAL_L(styr_commHAL_L,endyr_commHAL_L); //vector of observed landings by year
init_vector commHAL_L_cv(styr_commHAL_L,endyr_commHAL_L);    //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 mortality for fitting
init_vector commHAL_D_cv(styr_commHAL_D,endyr_commHAL_D);    //vector of CV of discards by year

// Length Compositions (50mm 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 styr_commHAL_agec;
init_int endyr_commHAL_agec;
init_vector nsamp_commHAL_agec(styr_commHAL_agec,endyr_commHAL_agec);
init_matrix obs_commHAL_agec(styr_commHAL_agec,endyr_commHAL_agec,1,nages);

!!cout << "nsamp_commHAL_lenc = " << nsamp_commHAL_lenc << endl;

//#############################################################################
//#############################Commercial Diving fishery #######################
// Landings (1000s gutted pounds)
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 (50mm 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);

!!cout << "obs_commDV_agec = " << obs_commDV_agec << endl;

//#############################################################################
//###############################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 (numbers, 1000s)
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; //changed to 1992 at AW
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
!!cout << "HB_D_cv = " << HB_D_cv << endl;
// 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);

!!cout << "obs_HB_agec = " << obs_HB_agec << endl;


//##############################################################################
//############################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 (numbers, 1000s)
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 fitting
init_vector MRFSS_D_cv(styr_MRFSS_D,endyr_MRFSS_D);    //vector of CV of discards by year
// Length Compositions (50mm bins)
init_int styr_MRFSS_lenc;
init_int endyr_MRFSS_lenc;
init_vector nsamp_MRFSS_lenc(styr_MRFSS_lenc,endyr_MRFSS_lenc);
init_matrix obs_MRFSS_lenc(styr_MRFSS_lenc,endyr_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);

!!cout << "obs_MRFSS_agec = " << obs_MRFSS_agec << endl;
!!cout << "nsamp_MRFSS_agec = " << nsamp_MRFSS_agec << endl;

//##############################################################################
//#################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

!!cout << "set_w_cvlen_diff = " << set_w_cvlen_diff << endl;

//Initial guess for commercial landings bias parameter
init_number set_L_commHAL_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);

!!cout << "set_M = " << set_M << endl;

//--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;
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;

!!cout << "set_log_avg_F_MRFSS_D = " << set_log_avg_F_MRFSS_D << endl;

//Set some more initial guesses of estimated parameters
init_number set_log_R0;
init_number set_S1dS0;
init_number set_B1dB0;
init_number set_R1_mult;
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_L50_commHAL2;
init_number set_selpar_slope_commHAL2;

init_number set_selpar_L50_commDV1;
init_number set_selpar_slope_commDV1;
init_number set_selpar_L502_commDV1;
init_number set_selpar_slope2_commDV1;

init_number set_selpar_L50_HB1;
init_number set_selpar_slope_HB1;
init_number set_selpar_L50_HB2;
init_number set_selpar_slope_HB2;

init_number set_selpar_L50_MRFSS1;
init_number set_selpar_slope_MRFSS1;
init_number set_selpar_L50_MRFSS2;
init_number set_selpar_slope_MRFSS2;

// #######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<=2; iyear++)
     {
       cout << "*** WARNING: Data File NOT READ IN CORRECTLY ****" << endl;
       cout << "" <<endl;
     }
   }
   else
   {
    cout << "Data File read in correctly" << endl;
   }
 END_CALCS


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

  number Linf;
  number K;
  number t0;
  vector wgt_ww_mt(1,nages);      // whole wgt in mt
  vector wgt_ww_klb(1,nages);      //whole wgt in 1000 lb
  vector wgt_gut_klb(1,nages);  //gutted wgt in 1000 lb
  vector meanlen(1,nages);        //mean length at age
  number sqrt2pi;
  number g2mt;                    //conversion of grams to metric tons
  number mt2klb;

  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(styr_MRFSS_lenc,endyr_MRFSS_lenc,1,nlenbins);

  matrix pred_commHAL_agec(styr_commHAL_agec,endyr_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_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
  matrix N_spyr(styr,endyr,1,nages);     //Population numbers at time of spawning
  matrix N_mdyr(styr,endyr,1,nages);     //Population numbers by year and age at midpoint
  matrix B(styr,endyr+1,1,nages);          //Population biomass by year and age
  vector totB(styr,endyr+1);               //Total biomass by year
  number R1;

  //init_bounded_number log_R1(5,20,1);       //log(Recruits) in styrR
  vector SSB(styr,endyr+1);       //Spawning biomass by year
  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_mt(1,nages);         // SSB in metric units (mt)
```

```
  vector reprod_klb(1,nages);        // SSB in english units (1000 pounds)

//---Stock-Recruit Function (Beverton-Holt, steepness parameterization)----------
  init_bounded_number log_R0(10,30,1);       //log(virgin Recruitment)
  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(styrR,endyr,-5,5,2); //log recruitment deviations
  number var_rec_dev;                        //variance of log recruitment deviations.
  init_bounded_number R_autocorr(0,1.0,3);
                                             //Estimate from yrs with unconstrainted
                                             S-R(XXXX-XXXX)
  number BiasCor;                            //Bias correction in equilibrium recruits
  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 S1;                                 //initial SSB
  number S1dS0;                              //S(styrR)/S0
  number B1dB0;                              //B1dB0 computed and used in constraint
  number R1_mult;
  number S1S0;                    //SSB(styr) / virgin SSB
  number popstatus;               //SSB(endyr) / virgin SSB

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

  //Commercial hook and line
  matrix sel_commHAL(styr,endyr,1,nages);
  matrix sel_commHAL_D(styr,endyr,1,nages);
  init_bounded_number selpar_slope_commHAL1(0.5,10.0,2); //period 1
  init_bounded_number selpar_L50_commHAL1(1.0,8.0,2);
  //init_bounded_number selpar_slope_commHAL2(0.5,9.0,3); //period 2
  number selpar_slope_commHAL2;
  init_bounded_number selpar_L50_commHAL2(1.0,8,2);
  vector sel_commHAL_1(1,nages); //sel in period 1
  vector sel_commHAL_2(1,nages); //sel in period 2

  //Commercial diving
  matrix sel_commDV(styr,endyr,1,nages);            //time invariant
  init_bounded_number selpar_slope_commDV1(0.5,10.0,2);
  init_bounded_number selpar_L50_commDV1(1.0,8,2);
  //init_bounded_number selpar_slope2_commDV1(0.1,9.0,1);
  //init_bounded_number selpar_L502_commDV1(1.0,20.0,1);
  number selpar_slope2_commDV1;
  number selpar_L502_commDV1;
  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);
  matrix sel_HB_D(styr,endyr,1,nages);
  init_bounded_number selpar_slope_HB1(0.5,10.0,2); //period 1
  init_bounded_number selpar_L50_HB1(0.0,8.0,2);
  //init_bounded_number selpar_slope_HB2(0.5,9.0,3); //period 2
  number selpar_slope_HB2;
  init_bounded_number selpar_L50_HB2(0.0,8,2);
  vector sel_HB_1(1,nages); //sel in period 1
  vector sel_HB_2(1,nages); //sel in period 2

  //MRFSS:
  matrix sel_MRFSS(styr,endyr,1,nages);
  matrix sel_MRFSS_D(styr,endyr,1,nages);
  init_bounded_number selpar_slope_MRFSS1(0.5,10.0,2); //period 1
  init_bounded_number selpar_L50_MRFSS1(1.0,8.0,2);
  init_bounded_number selpar_slope_MRFSS2(0.5,10.0,2); //period 2
  init_bounded_number selpar_L50_MRFSS2(1.0,8,2);
  vector sel_MRFSS_1(1,nages); //sel in period 1
  vector sel_MRFSS_2(1,nages); //sel in period 2

  //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,-2,1);
  init_bounded_number log_q_HB(-30,-10,1);
  init_bounded_number log_q_MRFSS(-30,-10,-1);
  //init_bounded_number q_rate(-0.1,0.1,-3);
  number q_rate;

//---Catch (numbers), Landings (mt)--------------------------------------------------
  matrix C_commHAL(styr,endyr,1,nages);                 //catch (numbers) at age
  matrix L_commHAL(styr,endyr,1,nages);                 //landings (1000 lb) at age
  vector pred_commHAL_L(styr_commHAL_L,endyr_commHAL_L); //yearly landings summed over ages

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

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

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

  matrix C_total(styr,endyr,1,nages);
  matrix L_total(styr,endyr,1,nages);
  vector L_total_yr(styr,endyr);                        //total landings 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 mortalit
  y

  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 C_MRFSS_D(styr_MRFSS_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

//---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 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
  vector N_age_msy_mdyr(1,nages);
  vector N_age_msy_spyr(1,nages);
  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 bpr_msy(1,n_iter_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 D_eq(1,n_iter_msy);     //equilibrium discards (1000s) corresponding to F values in F_msy

  vector FdF_msy(styr,endyr);
  vector SdSSB_msy(styr,endyr+1);
  number SdSSB_msy_end;
  number FdF_msy_end;

//--------Mortality------------------------------------------------------------------
  vector M(1,nages);
  matrix F(styr,endyr,1,nages);
  vector fullF(styr,endyr);                  //Fishing mortality rate by year
  matrix Z(styr,endyr,1,nages);

  init_bounded_number log_avg_F_commHAL(-10,0,1);
  init_bounded_dev_vector log_F_dev_commHAL(styr_commHAL_L,endyr_commHAL_L,-10,5,2);
  matrix F_commHAL(styr,endyr,1,nages);
  vector F_commHAL_out(styr,endyr); //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); //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);       //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); //used for intermediate calculations in fcn get_mortality
  number log_F_init_MRFSS;

//--Discard mortality stuff------------------------------------------------------------------------------
  init_bounded_number log_avg_F_commHAL_D(-20,0,1);
  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_commHAL_D,endyr_commHAL_D); //used for intermediate calculations in fcn
  get_mortality

  //init_bounded_number log_avg_F_HB_D(-20,0,1);
  //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_HB_D,endyr_HB_D); //used for intermediate calculations in fcn get_mortality
```

```
  init_bounded_number log_avg_F_MRFSS_D(-20,0,1);
  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_MRFSS_D,endyr_MRFSS_D); //used for intermediate calculations in fcn get_mortality

  number Dmort_commHAL;
  number Dmort_HB;
  number Dmort_MRFSS;

////---Per-recruit stuff----------------------------------------------------------------------------------
  vector N_age_spr(1,nages);         //numbers at age for SPR calculations
  vector N_age_spr_spyr(1,nages);
  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
  vector N_bpr_F0(1,nages);          //Used to compute bpr at F=0
  number spr_F0;                     //Spawning biomass per recruit at F=0
  number bpr_F0;                     //Biomass per recruit

//-------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;
  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_last3;         //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(styrR)/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;

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
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;

  Linf=set_Linf;
  K=set_K;
  t0=set_t0;
  log_len_cv=log(set_len_cv);
  log_R0=set_log_R0;
  S1dS0=set_S1dS0;
  B1dB0=set_B1dB0;
  R1_mult=set_R1_mult;

  M=set_M;
  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;

  selpar_L50_commHAL1=set_selpar_L50_commHAL1;
  selpar_slope_commHAL1=set_selpar_slope_commHAL1;
  selpar_L50_commHAL2=set_selpar_L50_commHAL2;
  selpar_slope_commHAL2=set_selpar_slope_commHAL2;
```

```
  selpar_L50_commDV1=set_selpar_L50_commDV1;
  selpar_slope_commDV1=set_selpar_slope_commDV1;
  selpar_L502_commDV1=set_selpar_L502_commDV1;
  selpar_slope2_commDV1=set_selpar_slope2_commDV1;

  selpar_L50_HB1=set_selpar_L50_HB1;
  selpar_slope_HB1=set_selpar_slope_HB1;
  selpar_L50_HB2=set_selpar_L50_HB2;
  selpar_slope_HB2=set_selpar_slope_HB2;

  selpar_L50_MRFSS1=set_selpar_L50_MRFSS1;
  selpar_slope_MRFSS1=set_selpar_slope_MRFSS1;
  selpar_L50_MRFSS2=set_selpar_L50_MRFSS2;
  selpar_slope_MRFSS2=set_selpar_slope_MRFSS2;

  log_avg_F_commHAL=set_log_avg_F_commHAL;
  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;

  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;

  sqrt2pi=sqrt(2.*3.14159265);
  g2mt=0.000001;         //conversion of grams to metric tons
  mt2klb=2.20462;        //converstion of metric tons to 1000 lb
  zero_dum=0.0;
  //additive constant to prevent division by zero
  dzero_dum=0.001;

  SSB_msy_out=0.0;

  maturity_f=maturity_f_obs;
  prop_f=prop_f_obs;

//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_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_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 and Catch matrices 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();

//##-->><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##-->><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
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_biascorr();
 //cout << "got bias correction" << endl;
 get_numbers_at_age();
 //cout << "got numbers at age" << endl;
 get_catch();
 //cout << "got catch at age" << endl;
 get_landings();
 //cout << "got landings" << endl;
 get_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_ww_mt=g2mt*wgtpar_a*pow(meanlen,wgtpar_b);    //mt of whole wgt: g2mt converts g to mt
    wgt_ww_klb=mt2klb*wgt_ww_mt;                      //1000 lb of whole wgt
    wgt_gut_klb=wgtpar_w2g*wgt_ww_klb;                //1000 lb of gutted wgt
```

```
FUNCTION get_reprod
   //product of stuff going into reproductive capacity calcs
   reprod_mt=elem_prod(elem_prod(prop_f,maturity_f),wgt_ww_mt);
   reprod_klb=elem_prod(elem_prod(prop_f,maturity_f),wgt_ww_klb);

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);
    //len_cv(iage)=mfexp(log_len_cv+log_len_cv_dev(iage));
    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)/4.0);//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_bpr_F0(iage)=N_bpr_F0(iage-1)*mfexp(-1.0*(M(iage-1)));
    N_spr_F0(iage)=N_bpr_F0(iage)*mfexp(-1.0*M(iage)/4.0);
  }
  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_mt));
  bpr_F0=sum(elem_prod(N_bpr_F0,wgt_ww_mt));

FUNCTION get_selectivity
// ------- compute selectivities by period
  selpar_slope_commHAL2=selpar_slope_commHAL1;
  selpar_slope_HB2=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_2(iage)=1./(1.+mfexp(-1.*selpar_slope_commHAL2*(double(agebins(iage))-selpar_L50_commHAL2)));
      //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_2(iage)=1./(1.+mfexp(-1.*selpar_slope_HB2*(double(agebins(iage))-selpar_L50_HB2))); //logistic
     sel_MRFSS_1(iage)=1./(1.+mfexp(-1.*selpar_slope_MRFSS1*(double(agebins(iage))-selpar_L50_MRFSS1)));
     //logistic
     sel_MRFSS_2(iage)=1./(1.+mfexp(-1.*selpar_slope_MRFSS2*(double(agebins(iage))-selpar_L50_MRFSS2)));
     //logistic
  }
  sel_commDV_vec=sel_commDV_vec/max(sel_commDV_vec); //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_MRFSS_1;
  }
```

```
for (iyear=endyr_period1+1; iyear<=endyr; 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;
}

//Discard selectivities

if((selpar_L50_commHAL2-selpar_L50_commHAL1)<0.5)
{
  for (iyear=styr_commHAL_D;iyear<=endyr_commHAL_D;iyear++)
  {
    for (iage=1; iage<=nages; iage++)
    {
      sel_commHAL_D(iyear,iage)=sel_commHAL_1(iage)-1./(1.+mfexp(-1.*selpar_slope_commHAL1*(double
      (agebins(iage))-selpar_L50_commHAL1-0.5)));
    }
    sel_commHAL_D(iyear)=sel_commHAL_D(iyear)/(max(sel_commHAL_D(iyear))+dzero_dum); //prevent
    division by zero
  }
}
else
{
  for (iyear=styr_commHAL_D;iyear<=endyr_commHAL_D;iyear++)
  {
     sel_commHAL_D(iyear)=sel_commHAL_1-sel_commHAL_2;
     sel_commHAL_D(iyear)=sel_commHAL_D(iyear)/(max(sel_commHAL_D(iyear))+dzero_dum); //prevent
     division by zero
  }
}

//for (iyear=styr_HB_D;iyear<=endyr_HB_D;iyear++)
//{
   //if(iyear<=endyr_period1)
   //{
   //  sel_HB_D(iyear)=sel_HB_1;
   //}
   //else
   //{
     if((selpar_L50_HB2-selpar_L50_HB1)<0.5)
     {
       for (iyear=styr_HB_D;iyear<=endyr_HB_D;iyear++)
       {
         for (iage=1; iage<=nages; iage++)
         {
           sel_HB_D(iyear,iage)=sel_HB_1(iage)-(1./(1.+mfexp(-1.*selpar_slope_HB1*
           (double(agebins(iage))-selpar_L50_HB1-0.5))));
         }
         sel_HB_D(iyear)=sel_HB_D(iyear)/(max(sel_HB_D(iyear))+dzero_dum); //prevent division by zero
       }
     }
     else
     {
       for (iyear=styr_HB_D;iyear<=endyr_HB_D;iyear++)
       {
          sel_HB_D(iyear)=sel_HB_1-sel_HB_2;
          sel_HB_D(iyear)=sel_HB_D(iyear)/(max(sel_HB_D(iyear))+dzero_dum); //prevent division by zero
       }
     }
   //}
//}

for (iyear=styr_MRFSS_D;iyear<=endyr_MRFSS_D;iyear++)
{
  if(iyear<=endyr_period1)
  {
    sel_MRFSS_D(iyear)=sel_MRFSS_1;
  }
  else
```

```
    {
      sel_MRFSS_D(iyear)=sel_MRFSS_2;
    }
  }


FUNCTION get_mortality
  fullF=0.0;

  for (iyear=styr; iyear<=endyr; iyear++)
  {
    if(iyear>=styr_commHAL_L)
    {
      F_commHAL_out(iyear)=mfexp(log_avg_F_commHAL+log_F_dev_commHAL(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)=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)=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)=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);
    }
    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_out(iyear)=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);
    }

    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_biascorr
//Compute the bias correction from recruitment deviations
  var_rec_dev=norm2(log_dev_N_rec(styrR,(endyr-3))-sum(log_dev_N_rec(styrR,(endyr-3)))
            /(nyrsR-3))/(nyrsR-4.); //sample variance from yrs styr_rec_dev-2003
  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;
  S1=S0*S1dS0;
  R1=R1_mult*mfexp(log(((0.8*R0*steep*S1)/
     (0.2*R0*spr_F0*(1.0-steep)+(steep-0.2)*S1))+dzero_dum))*BiasCor;  //need bias correction
  //Assume equilibrium age structure for first year
  N(styr,1)=R1;
  N_spyr(styr,1)=N(styr,1)*mfexp(-1.*Z(styr,1)/4.0);
  N_mdyr(styr,1)=N(styr,1)*mfexp(-1.*Z(styr,1)/2.0);
  for (iage=2; iage<=nages; iage++)
  {
    N(styr,iage)=N(styr,iage-1)*mfexp(-1.*Z(styr,iage-1));
    N_spyr(styr,iage)=N(styr,iage)*mfexp(-1.0*Z(styr,iage)/4.0);
    N_mdyr(styr,iage)=N(styr,iage)*mfexp(-1.*Z(styr,iage)/2.0);
  }
  //plus group calculation
  N(styr,nages)=N(styr,nages)/(1.-mfexp(-1.*Z(styr,nages)));
  N_spyr(styr,nages)=N_spyr(styr,nages)/(1.-mfexp(-1.*Z(styr,nages)));
  N_mdyr(styr,nages)=N_mdyr(styr,nages)/(1.-mfexp(-1.*Z(styr,nages)));
  SSB(styr)=sum(elem_prod(N_spyr(styr),reprod_mt));
  B(styr)=elem_prod(N(styr),wgt_ww_mt);
  totB(styr)=sum(B(styr));

//Rest of years
  for (iyear=styr; iyear<endyr; iyear++)
  {
    if(iyear<(styrR-1)) //recruitment follows S-R curve exactly
    {
        //add 0.00001 to avoid log(zero)
        //use bias correction in years when no rec dev is estimated
        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))*BiasCor;
        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_spyr(iyear+1)(1,nages)=elem_prod(N(iyear+1)(1,nages),(mfexp(-1.*(Z(iyear+1)(1,nages))/4.0))); //spyr
        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_spyr(iyear+1),reprod_mt));
        B(iyear+1)=elem_prod(N(iyear+1),wgt_ww_mt);
        totB(iyear+1)=sum(B(iyear+1));
    }
    else   //recruitment follows S-R curve with lognormal deviation
    {
        //add 0.00001 to avoid log(zero)
        // no bias correction used here
        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_spyr(iyear+1)(1,nages)=elem_prod(N(iyear+1)(1,nages),(mfexp(-1.*(Z(iyear+1)(1,nages))/4.0))); //spyr
        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_spyr(iyear+1),reprod_mt));
        B(iyear+1)=elem_prod(N(iyear+1),wgt_ww_mt);
        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
    B(endyr+1)=elem_prod(N(endyr+1),wgt_ww_mt);
    totB(endyr+1)=sum(B(endyr+1));
//Recruitment time series
  rec=column(N,1);

FUNCTION get_catch //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

//---Predicted landings------------------------
  for (iyear=styr; iyear<=endyr; iyear++)
  {
    L_commHAL(iyear)=elem_prod(C_commHAL(iyear),wgt_ww_klb);
    L_commDV(iyear)=elem_prod(C_commDV(iyear),wgt_ww_klb);
    L_HB(iyear)=elem_prod(C_HB(iyear),wgt_ww_klb);
    L_MRFSS(iyear)=elem_prod(C_MRFSS(iyear),wgt_ww_klb);
  }

  for (iyear=styr_commHAL_L; iyear<=endyr_commHAL_L; iyear++)
    {
     pred_commHAL_L(iyear)=sum(L_commHAL(iyear));
    }
  for (iyear=styr_commDV_L; iyear<=endyr_commDV_L; iyear++)
    {
     pred_commDV_L(iyear)=sum(L_commDV(iyear));
    }
  for (iyear=styr_HB_L; iyear<=endyr_HB_L; iyear++)
    {
     pred_HB_L(iyear)=sum(L_HB(iyear));
    }
  for (iyear=styr_MRFSS_L; iyear<=endyr_MRFSS_L; iyear++)
    {
     pred_MRFSS_L(iyear)=sum(L_MRFSS(iyear));
    }


FUNCTION get_discards //Baranov catch eqn
  //dead discards at age (number fish)
  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_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_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_ww_klb);
      pred_HAL_cpue(iyear)=mfexp(log_q_HAL)*(1+(iyear-styr_HAL_cpue)*q_rate)*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));
  }
  //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));
  }

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=styr_MRFSS_lenc;iyear<=endyr_MRFSS_lenc;iyear++)
  {
    pred_MRFSS_lenc(iyear)=(C_MRFSS(iyear)*lenprob)/sum(C_MRFSS(iyear));
  }


FUNCTION get_age_comps
 //Commercial
  for (iyear=styr_commHAL_agec;iyear<=endyr_commHAL_agec;iyear++)
  {
    pred_commHAL_agec(iyear)=C_commHAL(iyear)/sum(C_commHAL(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((5.0*log_avg_F_commHAL+sum(log_F_dev_commHAL(endyr-4,endyr)))/5.0);
  F_temp_sum+=mfexp((5.0*log_avg_F_commDV+sum(log_F_dev_commDV(endyr-4,endyr)))/5.0);
  F_temp_sum+=mfexp((5.0*log_avg_F_HB+sum(log_F_dev_HB(endyr-4,endyr)))/5.0);
  F_temp_sum+=mfexp((5.0*log_avg_F_MRFSS+sum(log_F_dev_MRFSS(endyr-4,endyr)))/5.0);
  F_temp_sum+=mfexp((5.0*log_avg_F_commHAL_D+sum(log_F_dev_commHAL_D(endyr-4,endyr)))/5.0);
  //F_temp_sum+=mfexp((5.0*log_avg_F_HB_D+sum(log_F_dev_HB_D(endyr-4,endyr)))/5.0);
  F_temp_sum+=mfexp((5.0*log_avg_F_HB+sum(log_F_dev_HB(endyr-4,endyr)))/5.0);
  F_temp_sum+=mfexp((5.0*log_avg_F_MRFSS_D+sum(log_F_dev_MRFSS_D(endyr-4,endyr)))/5.0);

  F_commHAL_prop=mfexp((5.0*log_avg_F_commHAL+sum(log_F_dev_commHAL(endyr-4,endyr)))/5.0)/F_temp_sum;
  F_commDV_prop=mfexp((5.0*log_avg_F_commDV+sum(log_F_dev_commDV(endyr-4,endyr)))/5.0)/F_temp_sum;
  F_HB_prop=mfexp((5.0*log_avg_F_HB+sum(log_F_dev_HB(endyr-4,endyr)))/5.0)/F_temp_sum;
  F_MRFSS_prop=mfexp((5.0*log_avg_F_MRFSS+sum(log_F_dev_MRFSS(endyr-4,endyr)))/5.0)/F_temp_sum;
  F_commHAL_D_prop=mfexp((5.0*log_avg_F_commHAL_D+sum(log_F_dev_commHAL_D(endyr-4,endyr)))/5.0)/F_temp_sum;
  //F_HB_D_prop=mfexp((5.0*log_avg_F_HB_D+sum(log_F_dev_HB_D(endyr-4,endyr)))/5.0)/F_temp_sum;
  F_HB_D_prop=mfexp((5.0*log_avg_F_HB+sum(log_F_dev_HB(endyr-4,endyr)))/5.0)/F_temp_sum;
  F_MRFSS_D_prop=mfexp((5.0*log_avg_F_MRFSS_D+sum(log_F_dev_MRFSS_D(endyr-4,endyr)))/5.0)/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;
    N_age_msy_spyr=1.0*mfexp(-1.0*Z_age_msy(1)/4.0);
    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_spyr(iage)=N_age_msy(iage)*mfexp(-1.*Z_age_msy(iage)/4.0);
```

```
    }
    N_age_msy(nages)=N_age_msy(nages)/(1.0-mfexp(-1.*Z_age_msy(nages)));
    N_age_msy_spyr(nages)=N_age_msy_spyr(nages)/(1.0-mfexp(-1.*Z_age_msy(nages)));

    spr_msy(ff)=sum(elem_prod(N_age_msy_spyr,reprod_mt));
    bpr_msy(ff)=sum(elem_prod(N_age_msy,wgt_ww_mt));


    //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_spyr*=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_spyr,reprod_mt));
    B_eq(ff)=sum(elem_prod(N_age_msy,wgt_ww_mt));
    L_eq(ff)=sum(elem_prod(C_age_msy,wgt_ww_klb));
    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);
        F_msy_out=F_msy(ff);
        spr_msy_out=spr_msy(ff);
      }
  }

////-----------------------------------------------------------------------------------------------
----------------------------------------------------------------------------------------
FUNCTION get_miscellaneous_stuff
//compute total catch-at-age and landings
  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);
    }

//----------------------------------------------------------------------------------------------------
------------------------------------------------------------------------------------
FUNCTION get_per_recruit_stuff

  //static per-recruit stuff

  for(iyear=styr; iyear<=endyr; iyear++)
  {
    N_age_spr(1)=1.0;
    N_age_spr_spyr(1)=1.0*mfexp(-1.0*Z(iyear,1)/4.0);
    for(iage=2; iage<=nages; iage++)
    {
```

```
      N_age_spr(iage)=N_age_spr(iage-1)*mfexp(-1.*Z(iyear,iage-1));
      N_age_spr_spyr(iage)=N_age_spr(iage)*mfexp(-1.*Z(iyear,iage)/4.0);
    }
    N_age_spr(nages)=N_age_spr(nages)/(1.0-mfexp(-1.*Z(iyear,nages)));
    N_age_spr_spyr(nages)=N_age_spr_spyr(nages)/(1.0-mfexp(-1.*Z(iyear,nages)));
    spr_static(iyear)=sum(elem_prod(N_age_spr_spyr,reprod_mt))/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;
    N_age_spr_spyr(1)=1.0*mfexp(-1.0*Z_age_spr(1)/4.0);
    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_spyr(iage)=N_age_spr(iage)*mfexp(-1.*Z_age_spr(iage)/4.0);
    }
    N_age_spr(nages)=N_age_spr(nages)/(1-mfexp(-1.*Z_age_spr(nages)));
    N_age_spr_spyr(nages)=N_age_spr_spyr(nages)/(1-mfexp(-1.*Z_age_spr(nages)));

    spr_spr(ff)=sum(elem_prod(N_age_spr_spyr,reprod_mt));
    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_ww_klb(iage);
    }

  }

FUNCTION evaluate_objective_function
  fval=0.0;
  fval_unwgt=0.0;

//---likelihoods---------------------------
  //--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;

//cout << "made it through cpue" << endl;

//-Landings------------
f_commHAL_L=0.0; //in 1000s whole pounds
for (iyear=styr_commHAL_L; iyear<=endyr_commHAL_L; iyear++)
{
  f_commHAL_L+=square(log((pred_commHAL_L(iyear)+dzero_dum)/
      (obs_commHAL_L(iyear)+dzero_dum)))/(2.0*square(commHAL_L_cv(iyear)));
}
fval+=w_L*f_commHAL_L;
fval_unwgt+=f_commHAL_L;

f_commDV_L=0.0; //in 1000s whole 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 whole pounds
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 whole pounds
for (iyear=styr_MRFSS_L; 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;

//cout << "made it through landings" << endl;

//--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;

//cout << "made it through discards" << endl;

//--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(pred_commHAL_lenc(iyear)+dzero_dum))
       -elem_prod((obs_commHAL_lenc(iyear)+dzero_dum),log(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(pred_commDV_lenc(iyear)+dzero_dum))
       -elem_prod((obs_commDV_lenc(iyear)+dzero_dum),log(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(pred_HB_lenc(iyear)+dzero_dum))
      -elem_prod((obs_HB_lenc(iyear)+dzero_dum),log(obs_HB_lenc(iyear)+dzero_dum)));
}
fval+=w_lc*f_HB_lenc;
fval_unwgt+=f_HB_lenc;

f_MRFSS_lenc=0.0;
for (iyear=styr_MRFSS_lenc; iyear<=endyr_MRFSS_lenc; iyear++)
{
  f_MRFSS_lenc-=nsamp_MRFSS_lenc(iyear)*
      sum(elem_prod((obs_MRFSS_lenc(iyear)+dzero_dum),log(pred_MRFSS_lenc(iyear)+dzero_dum))
      -elem_prod((obs_MRFSS_lenc(iyear)+dzero_dum),log(obs_MRFSS_lenc(iyear)+dzero_dum)));
}
fval+=w_lc*f_MRFSS_lenc;
fval_unwgt+=f_MRFSS_lenc;

//cout << "made it through length comps" << endl;

//--Age Comps---------------------
f_commHAL_agec=0.0;
for (iyear=styr_commHAL_agec; iyear<=endyr_commHAL_agec; iyear++)
{
  f_commHAL_agec-=nsamp_commHAL_agec(iyear)*
      sum(elem_prod((obs_commHAL_agec(iyear)+dzero_dum),log(pred_commHAL_agec(iyear)+dzero_dum))
      -elem_prod((obs_commHAL_agec(iyear)+dzero_dum),log(obs_commHAL_agec(iyear)+dzero_dum)));
}
fval+=w_lc*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(pred_commDV_agec(iyear)+dzero_dum))
          -elem_prod((obs_commDV_agec(iyear)+dzero_dum),log(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(pred_HB_agec(iyear)+dzero_dum))
            -elem_prod((obs_HB_agec(iyear)+dzero_dum),log(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(pred_MRFSS_agec(iyear)+dzero_dum))
        -elem_prod((obs_MRFSS_agec(iyear)+dzero_dum),log(obs_MRFSS_agec(iyear)+dzero_dum)));
  }
  fval+=w_lc*f_MRFSS_agec;
  fval_unwgt+=f_MRFSS_agec;

  //cout << "made it through age comps" << endl;

//-----------Constraints and penalties--------------------------------
  f_N_dev=0.0;
  f_N_dev=pow(log_dev_N_rec(styrR),2);
  for(iyear=(styrR+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(styrR,styrR+2));
  fval+=w_R_init*f_N_dev_early;

  f_N_dev_last3=0.0;
  f_N_dev_last3=norm2(log_dev_N_rec(endyr-2,endyr));
  fval+=w_R_end*f_N_dev_last3;

  f_B1dB0_constraint=0.0;
  f_B1dB0_constraint=square(totB(styrR)/B0-B1dB0);
  //fval+=w_B1dB0*f_B1dB0_constraint;

  f_Fend_constraint=0.0;
  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 << "made it through sel_weighted_current" << endl;
  get_msy();
  cout << "made it through msy" << endl;
```

```
get_miscellaneous_stuff();
cout << "made it through miscellaneous_stuff" << endl;
get_per_recruit_stuff();
cout << "made it through per_recruit_stuff" << endl;
cout << "BC Fmsy=" << F_msy_out<< "   BC SSBmsy=" << SSB_msy_out <<endl;
cout << "var_rec_resid (81-06)="<<var_rec_dev<<endl;

report << "TotalLikelihood " << fval << endl;
report << "Unwgtd Likelihood" << fval_unwgt << endl;
report<<" "<<endl;

report << "Bias-corrected (BC) MSY stuff" << endl;
report << "BC Fmsy " << F_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 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 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_ww_mt " << wgt_ww_mt << 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(1946)/VirginSSB " << S1S0 << endl;
report << "SSB(2006)/VirginSSB " << popstatus << endl;
report << "SSB " << SSB << endl;
report << "Biomass " << totB << endl;
report << "log recruit deviations (1981-2006)   " << log_dev_N_rec(styrR,endyr) <<endl;
report << "variance of log rec dev (1981-2006)  "<<var_rec_dev<<endl;
report<<" "<<endl;

report << "Fully-selected F (1958-2004)" << 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 (ww klb)"<<obs_HB_L << endl;
report << "pred HB landings (ww klb)"<<pred_HB_L << endl;
report << "Obs  MRFSS landings (ww klb)"<<obs_MRFSS_L << endl;
report << "pred MRFSS landings (ww klb)"<<pred_MRFSS_L << endl;
report << "Obs  commHAL landings (ww klb)"<<obs_commHAL_L << endl;
report << "pred commHAL landings (ww klb)"<<pred_commHAL_L << endl;
report << "Obs  commDV landings (ww klb)"<<obs_commDV_L << endl;
report << "pred commDV landings (ww klb)"<<pred_commDV_L << endl;

#include "gaj_make_Robject01.cxx"   // write the S-compatible report
```

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

```
# Number of parameters = 328  Objective function value = 8514.47  Maximum gradient component = 5.52249e-05
# log_len_cv:
-2.17194
# log_R0:
12.9475
# steep:
0.744462
# log_dev_N_rec:
 -0.129293 0.371133 -1.19998 0.403827 0.275422 -0.598074 0.132008 0.950514 -0.0665252 -0.748339 -0.567653 0.592
 847 0.492761 0.222812 0.287393 -0.422888 0.485466 -0.740820 0.179969 0.540353 -0.0301922 0.400060 1.03733 0.02
 28607 -1.05022 -0.730299 -0.379339 0.268860
# R_autocorr:
0.0179027
# selpar_slope_commHAL1:
3.11837
# selpar_L50_commHAL1:
2.71047
# selpar_L50_commHAL2:
3.75633
# selpar_slope_commDV1:
9.99999
# selpar_L50_commDV1:
3.11293
# selpar_slope_HB1:
10.0000
# selpar_L50_HB1:
0.886726
# selpar_L50_HB2:
1.31301
# selpar_slope_MRFSS1:
0.982925
# selpar_L50_MRFSS1:
3.71542
# selpar_slope_MRFSS2:
2.54147
# selpar_L50_MRFSS2:
2.34660
# log_q_HAL:
-8.71063
# log_q_HB:
-13.8248
# log_q_MRFSS:
-14.0000
# log_avg_F_commHAL:
-5.02261
# log_F_dev_commHAL:
 -3.05259 -2.35706 -1.94901 -1.80004 -1.89914 -1.35087 -1.57023 -1.99157 -2.82744 -2.39089 -4.00414 -2.05200 -1
 .20362 -1.54730 -3.40320 -3.04459 -3.02558 -2.99584 -2.87321 -1.96622 -1.91721 -1.73433 -2.11644 -1.23686 -1.7
 4409 -2.56873 -1.18485 -1.10911 -0.855321 -0.716738 -0.734999 -1.17800 -0.800000 -0.658599 -0.272107 0.356059
  0.0617484 0.613912 0.500238 1.45699 2.52859 2.44567 2.55689 2.91683 3.32844 3.87716 3.58793 3.49612 3.47426 3
  .40719 3.52731 3.30755 3.29131 3.25666 3.25351 3.23342 2.96951 3.05966 3.01354 2.61141
# log_avg_F_commDV:
-4.46508
# log_F_dev_commDV:
 -1.49917 -0.170428 -0.188877 -0.172069 0.191452 0.714342 0.969088 0.306864 0.506187 0.337248 0.169150 0.426056
  0.204161 0.203880 0.631769 -0.375653 0.0930797 -0.318227 -0.607035 -0.717531 -0.704287
# log_avg_F_HB:
-5.32015
# log_F_dev_HB:
 -2.25981 -1.97098 -1.74593 -1.56099 -1.40364 -1.26611 -1.14370 -1.03363 -0.933603 -0.841582 -0.756249 -0.67638
 2 -0.600566 -0.528814 -0.461571 -0.398036 -0.337317 -0.279149 -0.223261 -0.169215 -0.116856 -0.0661842 -0.0172
 352 0.0305225 0.0769928 0.121575 0.165367 0.208721 0.251299 0.293235 0.334265 0.374229 0.424789 0.474212 0.381
 889 1.00645 0.215193 1.07747 0.494645 0.632935 1.21399 0.909515 0.618108 0.731380 1.02532 1.12462 1.11169 0.84
 4173 0.525018 0.647127 0.155898 0.213948 0.398197 1.05253 0.688719 0.319153 0.733447 0.372109 -0.367952 -0.089
 9970
```

```
# log_avg_F_MRFSS:
-3.21600
# log_F_dev_MRFSS:
 -3.55362 -2.85809 -2.44929 -2.15771 -1.93032 -1.74299 -1.58310 -1.44368 -1.31997 -1.20835 -1.10640 -1.01220 -0
 .923669 -0.840487 -0.763033 -0.690348 -0.621273 -0.555381 -0.492277 -0.431405 -0.372509 -0.315570 -0.260604 -0
 .207022 -0.154829 -0.104761 -0.0555919 -0.00676212 0.0413486 0.0888886 0.135398 0.188364 0.261345 0.369795 0.9
 46402 0.285088 -0.488223 1.42133 1.21870 1.73078 1.67174 1.64616 1.48230 1.48078 1.41997 1.30621 0.780502 1.35
 554 0.869791 1.25021 0.988067 0.691930 1.77366 1.04251 0.901371 0.926807 1.07801 0.977400 0.576460 0.742603
# log_avg_F_commHAL_D:
-4.98864
# log_F_dev_commHAL_D:
 -0.578715 -0.566769 -0.0405059 -0.00281191 0.493204 0.237140 0.545839 0.109747 -0.0812871 0.150334 -0.229745 -
 0.770230 -0.344128 0.472649 0.605282
# log_avg_F_MRFSS_D:
-5.19858
# log_F_dev_MRFSS_D:
 -3.55421 -2.85954 -2.45187 -2.16151 -1.93525 -1.74902 -1.59025 -1.45199 -1.32946 -1.21905 -1.11841 -1.02558 -0
 .938628 -0.857189 -0.781497 -0.710543 -0.643227 -0.579136 -0.517893 -0.458974 -0.402153 -0.347390 -0.294680 -0
 .243445 -0.193728 -0.146140 -0.0995313 -0.0534749 -0.00831127 0.0361015 0.0794645 0.123537 0.184042 0.238477 0
 .668998 0.129755 0.396366 0.914472 1.39951 1.51808 1.38122 1.19553 1.06773 1.34268 1.54271 1.21000 1.02578 0.6
 61474 0.802741 0.902653 0.981676 1.03487 1.24524 1.31729 1.39135 1.23486 1.23871 1.51223 1.47971 1.46483
```

Appendix C ASPIC Input: Computer input file to run base production model.

```
FIT                        Run Mode
'SAFMC Greater Amberjack SEDAR 15 (2007) Landings and Indices, B1/K=0.85'
LOGISTIC YLD SSE           Modeltype, conditioning, loss fn
112                        Verbosity
600                        N Bootstraps
1  100000                   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
4                          Number of series
1.0d0 1d0 1d0 1d0                 Series weights
0.85d0                      B1/K guess
2.0e6                      MSY guess
2.0e7                      K guess
5d-8 5d-8 5d-8 5d-8              q guess
0 1 1 1 1 1 1                 Estimate flags
2e4  2e7                   MSY bounds
1e6  1e9                   K bounds
82184571                   Random seed
60                         Number of years
"Headboat Index period 1 (1947-2006), Total Ldgs whole pounds"
"CC"
1947 -1         48427.49426
1948 -1         87311.91201
1949 -1         126196.3298
1950 -1         161096.0332
1951 -1         189885.038
1952 -1         238293.7951
1953 -1         261452.8519
1954 -1         281508.4273
1955 -1         300787.08
1956 -1         337057.1158
1957 -1         357116.2246
1958 -1         405175.2081
1959 -1         462217.2588
1960 -1         480151.8473
1961 -1         484637.843
1962 -1         518058.0885
1963 -1         549482.6856
1964 -1         580983.6187
1965 -1         613206.6519
1966 -1         656375.2473
1967 -1         688531.8177
1968 -1         723810.5732
1969 -1         747155.2511
1970 -1         801643.502
1971 -1         816898.0685
1972 -1         834806.2071
1973 -1         896578.7507
1974 -1         930649.6968
1975 -1         973916.4717
1976 -1         1012742.233
1977 -1         1042214.176
1978 0.832677853 1051267.46
1979 0.78517638 1099589.622
1980 0.853964777 1137990.277
1981 0.525409733 1846614.671
1982 0.86712804 1147477.186
1983 0.597848805 611744.1406
1984 0.917781701 2629467.537
1985 0.62340571 2129911.503
1986 0.816102913 3448607.288
1987 0.898269567 4654220.63
1988 0.866904455 3496574.086
```

```
1989 0.346010066 3447773.811
1990 0.629109254 3548541.388
1991 1.065378476 3495527.826
1992 -0.853323291 3645976.643
1993 -0.771114856 2673144.293
1994 -0.764596814 3583269.7
1995 -0.57092707 2543432.557
1996 -0.903603912 2512067.789
1997 -0.514634113 2108347.941
1998 -0.408827614 1732517.446
1999 -0.648895299 2955586.536
2000 -1.207950163 2040405.715
2001 -0.905906625 1863647.871
2002 -1.284551718 1978851.956
2003 -1.541113679 2202093.311
2004 -0.849340819 2003275.089
2005 -0.320235193 1796943.347
2006 -0.407813037 1468222.776

"Headboat Index, period 2"
"I1"
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    -0.832677853
1979    -0.78517638
1980    -0.853964777
1981    -0.525409733
1982    -0.86712804
1983    -0.597848805
1984    -0.917781701
1985    -0.62340571
1986    -0.816102913
1987    -0.898269567
1988    -0.866904455
1989    -0.346010066
1990    -0.629109254
1991    -1.065378476
1992    0.853323291
1993    0.771114856
1994    0.764596814
1995    0.57092707
1996    0.903603912
```

```
1997    0.514634113
1998    0.408827614
1999    0.648895299
2000    1.207950163
2001    0.905906625
2002    1.284551718
2003    1.541113679
2004    0.849340819
2005    0.320235193
2006    0.407813037


"Commercial Logbook Index"
"I1"
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
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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 0.652796662
1994 0.684741659
1995 0.782402709
1996 0.696201704
1997 0.657100687
1998 0.667775408
1999 0.521422891
2000 0.627858655
2001 0.670605606
2002 0.691819576
2003 0.672451147
```

```
2004 0.939002524
2005 0.845114409
2006 0.65744616



"MRFSS Index"
"I1"
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
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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 1.032783839
1987 1.516751335
1988 0.903926359
1989 1.009749866
1990 0.765735621
1991 0.833589484
1992 0.817950675
1993 0.805376002
1994 0.901453604
1995 0.722416486
1996 0.770948873
1997 0.699659546
1998 0.634858031
1999 0.610542165
2000 0.612863103
2001 0.398588745
2002 0.569299846
2003 0.63710947
2004 0.484785648
2005 0.55704512
2006 0.523483606


Note: Source of data is file "GAJInput.xls" dated 20 SEP 2007, prepared by DSV/RTC
```

```
This input file prepared by RTC, 20 SEP 2007
```

Appendix D Abbreviations and symbols

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

Symbol	Meaning
AW	Assessment Workshop (here, for greater amberjack)
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 greater amberjack)
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 greater amberjack as $(1 - M)\text{SSB}_{\text{MSY}} = 0.7\text{SSB}_{\text{MSY}}$.
MSY	Maximum sustainable yield (per year)
mt	Metric ton(s). One mt is 1000 kg, or about 2205 lb.
N	Number of fish in a stock, conventionally on January 1
NC	State of North Carolina
NMFS	National Marine Fisheries Service, same as “NOAA Fisheries Service”
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
OY	Optimum yield; SFA specifies that OY ≤ MSY.
PSE	Proportional standard error
R	Recruitment
SAFMC	South Atlantic Fishery Management Council (also, Council)
SC	State of South Carolina
SCDNR	Department of Natural Resources of SC
SEDAR	SouthEast Data Assessment and Review process
SFA	Sustainable Fisheries Act; the Magnuson–Stevens Act, as amended
SL	Standard length (of a fish)
SPR	Spawning potential ratio
SSB	Spawning stock biomass; mature biomass of males and females
SSB_{MSY}	Level of SSB at which MSY can be attained
SW	Scoping workshop; first of 3 workshops in SEDAR updates
TIP	Trip Interview Program, a fishery-dependent biodata collection program of NMFS
TL	Total length (of a fish), as opposed to FL (fork length) or SL (standard length)
VPA	Virtual population analysis, an age-structured assessment model characterized by computations backward in time; may use abundance indices to influence the estimates
yr	Year(s)

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.

The review panel generally felt that the data used within the assessment were adequate and appropriate for the assessment methods used, and their application was suitable. The uncertainties in the available data limit the robustness of conclusions that can be derived from the assessment. Discussion on the data focused upon the length and age compositions used within the model and the abundance indices.

MRFSS length composition shift before and after management
It was noted that the MRFSS length compositions shift to smaller sizes following the imposition of size limit regulations, when the opposite trend would have been expected. The pattern was noted to be that expected for trophy fishermen; historically, only the larger fish may have been kept as trophy fish. Following imposition of the size limit all fish larger than that limit may have been kept as a result.

The increasing popularity of oily fish for consumption following the redfish craze and increasing smoked-fish markets, may have led to amberjack becoming a food fishery rather than a catch-and-release fishery. For species caught for consumption, high-grading may result from possession limits. However, parasitic worm infestations in amberjack are known to be worse in larger fish, which would argue against high-grading when fish were kept for consumption.

Age composition – commercial diving and handline
A concern was raised that the upper end of the distribution of age compositions for commercial diving and handline were quite different; as the logistic selectivity function was used in both cases the distributions would be expected to be similar. In contrast, the length compositions of the commercial diving and handline catches are similar. It was noted that the commercial diving age composition was from one year only, compared to the handline data, and differences could result from year class strengths that are averaged out in handline data.

Abundance Indices
The abundance indices are a crucial element of the available data; the indices used were all fisheries based and therefore may be subject to bias. The bias may be 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, and sensitivity analyses performed on this value. 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.

The panel briefly discussed the poor correlation between the headboat and commercial indices, noting that correlation improved to 0.8 with a 2-year lag. This correlation was mainly driven by peaks in abundance in later years. The biological basis for implementing the lag was that it takes about 2 years for greater amberjack to grow from the 28 inch minimum size limit for recreational anglers to the 36 inch minimum size limit for commercial fishermen. The correlation between the series suggested that they were 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).

Historical catch time series
Uncertainty over the historical landings series was noted. Available historical data were examined in an attempt to understand whether the linear interpolation approach taken was appropriate (see section 2.3). The panel noted that running sensitivity analyses where uncertainty in the historical time series was bracketed by alternative plausible hypotheses would be worthwhile.

2. Evaluate the adequacy, appropriateness, and application of methods used to assess the stock.

The review panel found the methods, and in particular the base case catch-at-age model used to assess stock status, were generally adequate and appropriate, and their application were sensible. The review panel was pleased to note that two different assessment models had been applied, which provided some view on model uncertainty. The principal method was an age structure model 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 catch-at-age model is complex, and 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.

Following, the review panel provides a number of detailed comments on the two models and their application.

Discard selectivity assumptions for MRFSS recreational data
The review panel raised the concern that, prior to size limits being imposed there may have been discarding because there was no market for greater amberjack. The general feeling of the assessment analysts was that there was little targeting for greater amberjack prior to size limits. This suggests that some discards will have occurred in early years, contrary to the no discards assumption currently made. However, there was no

information on which to determine the level of early commercial discards. The review panel acknowledged the lack of information, and suggested documenting this issue as a source of uncertainty.

Landings data
The review panel was concerned that landings did not fit as well as would be expected given the settings within the model. The Assessment Workshop accepted the imperfect fit to the landings and attributed it to problems with species identification that still persist. The review panel requested that a further run be performed with the likelihood weights increased on landings so that the model fitted the landings data exactly (see section 2.3).

The review panel noted that the assumption of a linear decline in historical catch data was a strong assumption, and requested that alternative historical data sources be examined (see section 2.3). The panel suggested that examining the impact of alternative plausible hypotheses on historical catch levels, with that data given a high likelihood weighting, would increase understanding of the influence these had on model results.

Improvements to selectivity parameterization
The review panel suggested that future assessments should examine alternative (two or three parameter) selectivity functions to resolve the persistent patterns in age and length compositions residuals (see bubble plots within the assessment report, Figures 3.2-3.9), which were suspected to result from the overly restrictive logistic selectivity functions used.

Splitting headboat index in surplus-production model
The review panel questioned why the headboat index was split into two time periods, representing periods before and after size limit regulations. It was noted that the length compositions showed a shift in the size of fish captured, with larger fish caught after the size regulation implementation. The model could not converge on an adequate fit without accounting for changes in the index and catch associated with the size regulations.

Likelihood weightings
The review panel discussed the different likelihood weighting schemes used in the red snapper and greater amberjack assessments, given that the time series of data used within the assessment were similar (although it was noted that the composition data were quite different). It was acknowledged that considerable effort was applied to obtain the best set of weightings; for example, 180 runs were examined for greater amberjack before the base run was selected. The review panel requested an additional run to examine the impact of a comparable weighting scheme to that used in the red snapper assessment (see section 2.3).

The review panel raised some concern that the approach of setting likelihood weights with the aim of achieving a subjective ‘best’ model fit was not necessary appropriate. This might prevent assessments being replicated by another analyst, since the process through which the analyst selected the base case from the 180 runs examined was not transparent. The panel suggested that *a priori* weighting of indices based upon the perceived reliability (e.g. time series length, geographical coverage of the stock, etc.) would be more appropriate. An alternative suggestion, adjusting the weights based upon the likelihood components, was not practical due to the differences in the normal and multinomial likelihoods. Options discussed included the examination of standardized residuals in order to determine weightings (and potentially exclude problematic indices), the use of sum-squared residuals to generate a hierarchy of components, and iterative re-weighting schemes, although all these approaches could also lead to problems, with erroneous weighting schemes resulting if precision were favored over accuracy of the data. The example was given where a precise index that was trending upwards would be weighted higher than a less precise index with a reliable history that was trending down and was consistent with *a priori* knowledge that the fishery was in decline.

While the need to find a more systematic method to select the weights was stressed, the panel accepted the values used in the assessment.

von Bertalanffy
The review panel discussed the development of a bias-corrected von Bertalanffy growth curve for the population. While its use was appropriate in many components of the model, its use when dealing with fishery specific metrics could lead to bias in the analysis. The panel therefore recommended that growth curves developed from the uncorrected data from the fishery be used in these areas of the model.

3. Recommend appropriate estimates of stock abundance, biomass, and exploitation.

The catch-at-age model was accepted as the most appropriate.

There are substantial uncertainties in model results and the Assessment Workshop provided numerous sensitivity runs to illustrate the possible range of uncertainty. Clearly, the vast majority of runs show the same qualitative results, indicating that the stock is neither overfished nor 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 review panel accepted the results of the base run using the catch-at-age model as the most appropriate estimates of stock abundance, biomass and exploitation. However, the review panel noted that the estimates are conditioned on the assumptions made within that base run. 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 review panel accepted the values of MSY and F_{MSY}, noting that the values were conditioned on the data and assumptions used within the base run. The acceptance of MSY was justified because there was adequate contrast in the spawning stock size and recruitment data to allow reasonable knowledge of the asymptote of the stock-recruitment relationship, upon which MSY is based. In turn, the stock-recruitment data estimated by the model was located around the plateau of the relationship, in the approximate area where MSY is located. The review panel therefore had sufficient information to endorse the use of MSY benchmarks.

The review panel noted that the estimates of MSY were more sensitive to the changes in the model and the data than the $F_{40\%}$ benchmarks, in particular to assumptions made on the value of catchability (q) and natural mortality.

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} and SSB_{MSY} are less important than the ratios $F_{current}/F_{MSY}$ and $SSB_{current}/SSB_{MSY}$. The overwhelming majority of sensitivity runs suggested that the stock was neither overfished nor that overfishing was occurring. 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.

Examining the relative position of the population to the benchmark values, the panel noted that the stock was very close to the threshold in most sensitivity analyses. Where a lower natural mortality or higher catchability were selected, ovefishing could be occurring. The population trajectory is trending down toward the MSY level, following a peak as the strong 2001 year class matured. The evolution of the population in future years should be studied carefully.

Given the choice of the base 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 in a future assessment given their sensitivity to equally plausible model configurations.

Table 1. Management quantities based on MSY for greater amberjack, from the base run.

Quantity	Units	Estimate
F_{MSY}	y^{-1}	0.424
B_{MSY}	mt	5491
SSB_{MSY}	mt	1940
MSST	mt	1455
MSY	1000 lb	2005
D_{MSY}	1000 fish	18
R_{MSY}	1000 fish	435
F_{2006}/F_{MSY}	–	0.531
SSB_{2006}/SSB_{MSY}	–	1.096
SSB_{2006}/MSST	–	1.461

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 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).**

The review panel felt the methods applied to project the stock were adequate and appropriate. They noted that the projections are strongly conditional on the assumptions of the base run on which they are based.

The panel noted that the projections include stochasticity only in the stock recruitment model and the assumption of fixed values for all other quantities, which generally will underestimate the overall uncertainty in future projections. In particular, the assumption of a fixed initial population size limits the range of likely uncertainty on future stock development; the sensitivity runs presented provide an indication of the uncertainty of the current stock condition. 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.

The panel discussed the value of projections made beyond 5-10 years. Clearly, uncertainty increases rapidly with time as the currently estimated 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.

6. **Evaluate the adequacy, appropriateness, and application of methods used to characterize uncertainty in estimated parameters. Provide measures of uncertainty for estimated parameters. Ensure that the implications of uncertainty in technical conclusions are clearly stated.**

The review panel noted that uncertainty in the assessment had 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 considered by the panel. It was felt that these offered a useful insight into the robustness of the SCA assessment model.

The review panel noted that it was particularly important to characterize uncertainty since the fishery was estimated to be near target levels. The panel was concerned that sensitivity runs available were not sufficient to fully characterize uncertainty in assessment results. While the majority of runs suggested that the stock was close to management benchmarks, the panel noted that particular runs did suggest overexploitation. As a result, it was noted that uncertainty was not characterized well enough to say with complete certainty that the stock was not overfished, or subject to overfishing.

The panel suggested a subset of the sensitivity runs as a summary of the uncertainty in the assessment. The results are given in Table 2.

The uncertainty described above is conditioned on the structural assumptions in the model and will only give a partial impression of overall uncertainty. The Assessment Workshop also ran a production model, which gave further insight into uncertainty. The review panel welcomed this. The absolute values of SSB and F were quite different, but the values relative to estimated benchmarks were similar to those from the catch-at-age model (Table 2). Estimated relative biomass had dropped slightly below 1 since 2000.

Table 2. Results of sensitivity runs characterizing the uncertainty in the assessment.

Description	R_0	steep	autocorr	SSB_0 (mt)	MSY ('000 lbs)	B_{MSY}	F_{MSY}	$F_{(2006)}/F_{MSY}$	SSB_{MSY} (mt)	$SSB_{(2006)}/SSB_{MSY}$	$F_{40\%}$	$F_{30\%}$	F_{max}
Base run	419797	0.74	0.02	5294	2005	18.3	0.42	0.53	1940	1.1	0.34	0.56	0.75
M rescaled (0.05)	219505	0.95	0.02	5462	1836	12.2	0.47	0.88	1607	0.77	0.24	0.38	0.53
M rescaled (0.01)	516356	0.62	0.04	5562	1998	18.1	0.35	0.54	2266	1.12	0.37	0.62	0.81
Q rate = 0.0	457462	0.95	0.14	5770	2474	30.8	0.85	0.14	1641	2.45	0.39	0.64	0.96
Q rate = 0.04	451555	0.55	0.03	5695	1749	11.9	0.34	1.17	2406	0.61	0.45	0.76	1.16
Start Yr Rdevs = 1977	416162	0.95	0	5249	2331	27.1	0.93	0.22	1503	1.72	0.42	0.68	1.06
Start Yr Rdevs = 1981	416747	0.79	0.09	5256	2062	19.3	0.6	0.38	1779	1.27	0.41	0.68	1.03
MRFSS CPUE added	550717	0.55	0.08	6946	2058	19.8	0.22	0.56	3062	1.13	0.28	0.42	0.55
Landings fit	524028	0.58	0.07	6609	2100	19.8	0.26	0.48	2829	1.25	0.31	0.5	0.65
Surplus production					1505		0.04	1.07	39540	0.91			

The estimate of F_{2006}/F_{MSY} did not indicate severe overfishing in the terminal year; however, estimated F had exceeded F_{MSY} since the mid–1980s.

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 Greater Amberjack 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 greater amberjack. 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 review panel agreed that the recommendations for future work presented in the data and assessment workshop reports were appropriate. The following additional comments were developed:

Data Workshop - Life history:

- The panel particularly endorsed approaches to develop better estimates of natural mortality and discard release mortality.

- Given that age information is relatively low-cost and of high value, and that the fishery may shift more to the commercial sector in the future, the panel particularly endorsed efforts to improve and collect additional ageing information.

- The review panel noted that satellite pop-up tags might not be the most appropriate method to estimate stock mixing rates. Approaches using other tagging methods should be considered as they may prove more appropriate and cost effective.

Data Workshop – Commercial:

- The review panel noted that the additional study of historical discard levels would be worthwhile to resolve historical commercial landings for the suite of snapper/ grouper species.

- Initiatives to improve understanding of discard mortality levels within the fishery were welcomed, particularly given the size-limit management approaches employed.

Data Workshop – Indices:

- The review panel stressed the benefits of developing time series for a fishery-independent survey. The current approaches needed to ensure that coverage better corresponded to the stock areas in the Southeast. If MRFSS coverage were expanded, there was a need to consider the spatial and temporal increase in effort, as well as covering other gears.

Assessment Workshop:

- The review panel was slightly concerned over the methods used to determine how the likelihood weights for different data sets were developed. The panel suggested that an objective approach to developing this weighting, for example iterative reweighting approaches, the incorporation of process error into indices, and other approaches.

- The review panel suggested that Bayesian posterior predictive inference be considered to better encompass uncertainty within the assessment. The approach would allow priors to be developed on steepness, natural mortality, and other parameters, which would allow uncertainty in stock status and benchmarks to be derived. In order for this to be investigated, more time dedicated to research activities between assessments would be required so that stock assessment personnel could develop needed tools.

- The review panel suggested that the next assessment be held in 3 years time. The relatively short time interval was to ensure that the current stock status close to benchmark values had not moved to an overfishing state. The additional few years of age composition data (with a good sample size) over this period might reduce assessment uncertainty, since age compositions are relatively limited in the current assessment. In addition, the panel noted the opinion that there was potential for a more directed fishery to develop for amberjack, which might increase exploitation levels in the near future.

- The review panel suggested the development of indicators (triggers) based upon key data sources to prompt assessment as a precaution to avoid overfishing. For example, these might be based on catch rates in key fishery components, with declines prompting re-assessment of the stock.

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 Greater Amberjack.

Reviewer Statements

The panel attests that the Review Panel Consensus Summary for greater amberjack provides an 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

Early recreational landings
The review panel discussed the inclusion of the three estimates for "Jacks" from the salt-water angler survey (SEDAR 15-RD08, RD09, RD10) in the historical data (Table 3). These points had not been included in the assessment as the fishery did not really focus on amberjack until the 1980's.

Table 3. Salt Water Fishery Survey catches for Jacks, and comparison to Linear Interpolated catch weights used within the model for Greater Amberjack

Year	N ('000s)	Weight ('000 lbs)	Linear interpolation ('000 lbs)
1960	8241	41200	414
1965	672	1504	559
1970	7254	33149	703

Discussion: Presentation of the table of "Jacks" catches from saltwater fishing survey in numbers and weight, compared to the linear interpolation used for the model. The review panel noted that the values from the survey did not follow the linear trend assumed within the data for the model. However, the difficulties in segregating greater amberjack from the total jack data meant that the panel felt the linear interpolation of historical numbers was reasonable.

Catch curve analysis
The review panel requested the examination of total mortality for greater amberjack using the available age frequency data and catch curves. The peak of the Z estimates from the model was 0.75. Catch curve analysis estimates Z to be somewhat higher than expected, but this was felt a result of the influence of strong year classes on the analysis. Further investigation of the data suggested Z to be lower than initially estimated. The panel felt that the results were thus consistent with those from the assessment model.

Sensitivity Runs
The review panel noted that the approach to weighting amberjack catch and catch rate time series within the model was different to that used for red snapper. In the latter, landings had been given a high weight to ensure they were fitted exactly. The panel therefore requested an additional run for amberjack with the landings fitted with similar high weighting on the likelihood. This had not been performed at the Assessment Workshop as slight increases in the weighting of the amberjack landings likelihood had resulted in poorer fits.

Additional Runs: Run with landings data fitted exactly – likelihood weighting 1000.
The model run with high weighting on the landings was considered to fit the data better but do not significantly impact the estimates of benchmarks. Although the review panel did not feel that this run should replace the base run, it was felt useful to present as a further sensitivity run (Table 2).

Examination of fishermen opinion of a loss of larger fish
The review panel investigated the frequent comment by fishermen that larger amberjack were no longer found in the fishery. Plots of mean weight by fishery over time did not show any clear trends to suggest this is true. However, the data series only went back to the early 1980s, which was likely after any declines had occurred. It was noted that a decline in the size of individuals was entirely consistent with the fishing of an unexploited stock down to a level near MSY.

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.

<u>Capt. Chuck Schimmelan Dee Cee Holiday Isle Marina</u>

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.

<u>Capt. Greg Pope Tag 'Em Holiday Isle Marina</u>

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 In addition to changes to the Stock Assessment Models and Review component of the review workshop report discussed in (2) below, the following revision was made to Indicators of Population Abundance portion of the data workshop report. Text has been clarified in the descriptions of how effective effort was computed (first two sentences of second paragraph of sections 5.3.1.3 and 5.3.2.3).

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:

Summary of changes to the SEDAR 15
Greater Amberjack SAR 2 Section III
Peer Review Document
After the Review Workshop
Last edited: February 19, 2008

1. Stated units in several locations of the text (landings in 1000 lb whole weight, discards in 1000 dead fish, spawning biomass in mt)

2. Corrected 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 was inaccurate, as discussed during the review.

3. Table 3.4 – The units mistakenly reported as gutted weight in the figure caption were changed to whole weight.

4. Table 3.11 – The units for B and SSB were clarified in the figure caption to identify them as whole weight in metric tons.

5. Figure 3.80 was revised to use correct surplus production model estimates of B/Bmsy and F/Fmsy. This was a result of an error in the .rdat output file from ASPIC 5.0 bootstrap analysis. The problem has been reported and corrected in ASPIC 5.0.