SEDAR

Southeast Data, Assessment, and Review

SEDAR 10
Stock Assessment Report

South Atlantic Gag Grouper

SEDAR 10
Stock Assessment Report 1

2006

SEDAR
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Charleston, SC 29414
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Table of Contents

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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 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 10 was charged with assessing gag grouper (*Mycteroperca microlepis*) in the U.S. waters of the South Atlantic and Gulf of Mexico. A separate stock assessment will be prepared for each management unit. For assessment purposes, the two units will be divided at the Council boundaries.

2. Management Overview

2.1 Management Unit

The management unit for South Atlantic gag grouper is gag grouper found in all waters within South Atlantic Fishery Management Council Boundaries.

2.2 Current Stock Status

According to the NOAA Fisheries' report to Congress on the status of fisheries of the United States in 2003, the South Atlantic stock of gag is not overfished, based on an overfished criteria of 30%SPR. Gag are considered to be experiencing overfishing based on overfishing defined as a fishing mortality rate in excess of that corresponding to 30% static SPR.

Table 1. Regulations affecting gag grouper in the South Atlantic.

Action	FMP/Amendment	Effective Date
4" Trawl mesh size	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 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 20" TL minimum size and a 5 grouper bag limit.	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
24" TL size limit; no harvest or possession > bag limit, and no purchase or sale, during March and April. Vessels with longline gear aboard may only possess snowy grouper, warsaw grouper, yellowedge grouper, misty grouper, golden tilfefish, blueline tilefish, and sand tilefish.	Snapper Grouper Amend 9	2/24/1999
Approved definitions for overfished and overfishing. MSST = [(1-M) or 0.5 whichever is greater]*BMSY. MFMT = FMSY	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 2. Specific Management Criteria

Current and proposed management criteria for the gag stock in the south Atlantic as specified by the Council. Snapper Grouper FMP Amendment 11 specified the current definitions for all the criteria. The 1998 assessment (Potts and Manooch, 1998 provided the value of M).

Criteria	Current		Proposed	
	Definition	Value	Definition	Value
MSST	$(1\text{-}M)B_{MSY}$	Not specified	$(1\text{-}M)B_{MSY}$*	TBD
MFMT	$F_{30\%SPR} = F_{MSY}$	F=0.18	F_{MSY}	TBD
MSY	Yield at F_{MSY}	Not Specified	Yield at F_{MSY}	TBD
F_{MSY}	$F_{30\%SPR}$	F=0.18	F_{MSY}	TBD
OY	Yield at F_{OY}	Not Specified	Yield at F_{OY}	TBD
F_{OY}	$F_{45\%SPR}$	Not Specified	F_{OY} = 65%,75%, 85% F_{MSY}	TBD
M	n/a	0.15	SEDAR 10	TBD

Following SEDAR 10, the Council may want to consider alternative definitions of MSST. For example, if the assessment determines that M is very small, the Council may want to consider changing MSST to 0.75 B_{MSY}, 0.50* B_{MSY}, or some other definition.

Table 3. Stock Rebuilding Information

Rebuilding Parameter	Value
Rebuilding Plan Year 1	1991
Generation Time (Years)	UNK
Rebuilding Time (Years)	15*
Rebuilding Target Date	Dec. 31, 2006
$F_{rebuild}$	UNK
Time to rebuild @ F=0 (Years)	UNK

*The 15 year rebuilding schedule was established under Pre-SFA conditions.

Table 4. Stock projection information.

First Year of Management	2007
Projections for interim years should be based on	Exploitation rate
Projection criteria values for interim years should be determined from	Average of previous 3 years

3. Previous Assessment Efforts

Gag grouper in the South Atlantic were last assessed by Potts and Manooch (1998). This assessment evaluated trends in landings, size structure, and age structure by fishery for 1986 - 1997. Abundance and exploitation were estimated through a separable VPA. The assessment concluded that the stock was improving as a result of SAFMC management actions.

References

Potts, J. C. and C. S. Manooch, III. 1998. Population assessment of the gag (*Mycteroperca microlepis*) from the Southeastern United States.

4. Assessment Advisory Report

(Prepared by the SEDAR 10 Review Panel)

SEDAR 10 Review Workshop

Assessment Advisory Report

South Atlantic Gag Grouper

Reflecting recreational catch correction, February 2007

Stock Distribution and identification

- The management unit for South Atlantic gag grouper includes gag grouper found in all waters within South Atlantic Fishery Management Council Boundaries.
- The SEDAR 10 Review Workshop (RW), using several sources of information, examined and accepted the current stock definitions for the South Atlantic and Gulf of Mexico gag.

Assessment Methods

- The South Atlantic gag grouper stock was assessed with two models: a statistical catch-at-age model, as the primary assessment model, and an age-aggregated production model to investigate results under a different set of model assumptions. Within each type of model various configurations and sensitivity runs were explored. Details of all models are available in the Stock Assessment Report and Addendum to the Stock Assessment Report.

- The assessment workshop (AW) developed two base runs: one assuming a time-varying catchability and one assuming constant catchability for the fishery dependent indices. Each base run of the catch-at-age model was the basis for estimation of benchmarks and stock status.

- The SEDAR 10 RW recommended the run with constant catchability as the preferred 'base run'.

Assessment Data

- Data sources include fishery-dependent abundance indices, recorded landings, and samples of annual length and age compositions from fishery-dependent sources.

- Three fishery–dependent abundance indices were developed by the SEDAR 10 data workshop: one from the NMFS headboat survey, one from the commercial logbook program, and one from the Marine Recreational Fishing Statistical Survey (MRFSS). Currently, there are no usable fishery–independent abundance data for this stock of gag grouper.

- Landings data were available from all recreational (headboat, charter boat, private boat, and shore sectors) and commercial fisheries (handline and diving gears). This benchmark assessment included data through 2004.

- Complete details are available in the SEDAR 10 Data and Assessment Reports, and the SEDAR 10 workshop working papers. Additional information and discussion can be found in the companion SEDAR 10 Review Workshop Consensus Summary Report for South Atlantic Gag Grouper.

Catch Trends

- Landings are reported from the commercial and recreational sectors. The commercial landings are in gutted weight in pounds, while recreational landings are estimated in numbers. Commercial landings were converted to numbers for the assessment model (Table 1 and Figures 1-2).
- The commercial landings were dominated by handline gear peaking at over 1,000,000 pounds in 1984. Landings from the diving gear have been significant in recent years and are modeled separately. The contribution from other gears is small and included with the handline gear (Table 1 and Figure 1).
- The recreational sector catch peaked in 1984 at about 153,000 fish, and has two components: catch estimated from MRFSS which includes private and charter boats and a minor shore component, and catch estimated from a survey of headboats (larger for-hire vessels) (Table 1).
- When comparing across sectors, the largest landings in numbers are associated with the MRFSS (Table 1 and Figure 2).
- Coastwide landings of gag grouper in the South Atlantic had been increasing but have recently leveled off. The catch share among sectors has been changing over the last decade, with increased landings from the charter/private boat and shore mode recreational sectors relative to the commercial handline sector, which has been decreasing.

Fishing mortality trends

- Fishing mortality (fully selected F) increased from 0.03 in 1962 to 0.32 in 1983 (above F_{MSY} = 0.24; see discussion below). Fishing mortality has remained above F_{MSY} since then (Table 2 and Figure 3). Fishing mortality in 2004 was estimated as 0.31.

Stock abundance and biomass trends

- Total and spawning stock biomass (both sexes combined) declined from initial high values in the 1960s, went below levels corresponding to MSY in 1980s, continued in declined through the remainder of the 1980s and have apparently been on an increasing trend since the 1990s (Table 2 and Figure 4). In particular, spawning stock biomass declined from 14.6 million pounds (gutted weight) in 1962 to 4.0 million pounds in 1990 (below the current value of SSB_{MSY} = 7.9 million pounds). Spawning stock biomass rose to 7.0 million pounds in 2004 (above the MSST of 6.8 million pounds; Table 2). The 2005 SSB value is estimated to be 7.4 million pounds.

Status determination criteria and Stock Status

- Status Determination Criteria: The SFA and management criteria recommendations and values are estimated from the preferred base model by the RW as follows:

Stock Status	Current Definition	Value from Previous Assessment	Value from Current Assessment
MSST	$(1\text{-}M)B_{MSY}$	NA	6816 klb
MFMT	F_{MSY} Proxy = $F_{30\%SPR}$	0.18	0.21
MSY	Yield at F_{MSY}	NA	1238 klb
F_{OY}	$F_{45\%SPR}$	NA	0.12
OY	Yield at F_{OY} ($F_{45\%SPR}$)	NA	1570 klb
SSB_{MSY}	Biomass @ MSY	NA	7925 klb

Proposed Status Criteria	Definition	Value
MSST	$(1\text{-}M)SSB_{MSY}$ *(see special comment)	6816 klb
MFMT	F_{MSY}	0.24
MSY	Yield at F_{MSY}	1238 klb
OY	$65\%F_{MSY}$ (Alt. 1) $75\%F_{MSY}$ (Alt. 2) $85\%F_{MSY}$ (Alt. 3)	1188 klb 1217 klb 1230 klb
F_{OY}	$65\%F_{MSY}$ (Alt. 1) $75\%F_{MSY}$ (Alt. 2) $85\%F_{MSY}$ (Alt. 3)	0.16 0.18 0.20
M (Age-varying)	Constant Equivalent	0.14

Stock Status

- Current rates of exploitation indicate that overfishing is occurring for the South Atlantic gag grouper stock (Figure 5). Based on the current MFMT, which is an F_{MSY} proxy of $F_{30\%SPR}$, F_{2004}/MFMT = 1.5. Exploitation in 2004 relative to F_{MSY} = 1.3.
- Relative to the current MSST specified by the FMP {$(1\text{-}M)SSB_{MSY}$}, the South Atlantic stock of gag is approaching an overfishing condition (see projections, Figure 6). Relative to the MSST proposed by the RW, the stock is not overfished and is not projected to become overfished.
- The MSY-based benchmarks in this assessment are deemed useful for management.
- The current definition of MSST may be overly conservative. The RW recommends an operational definition of MSST of 5 million pounds (see Special Comments).

Projections

- Estimates of recruitment in 2002-2004 are below average and fishing mortality rates in 2002-2004 are above the MSY level. As a result, stock projections suggest that the stock will decline below the existing MSST in 2007. Projections for biomass, recruitment and fishing mortality at various levels of constant fishing mortality rates starting in 2008 are shown in Table 3 and Figures 6-10. The levels are based on current F (geometric mean of last three years of the base run, Figure 6), on F_{MSY} (Figure 7), and three levels of F_{OY} (65%, 75% and 85% of F_{MSY}, Figures 8-10).

Special Comments

- **Constant and time-varying catchability alternative**: The RW discussed the relationship of technology to catchability and the effects of catchability changes on fishery-dependent abundance indices. The RW recognized that technology improvements over time, particularly better electronics, have likely made fishermen more effective and efficient at catching fish. The RW, however, did not support an assessment that assumed a simple linear (2% annually) increase. Nevertheless, this is an important issue and the RW recommends further investigations of time-varying catchability.

- **Uncertainties**: The primary uncertainties in the assessment are from the model process errors and the data measurement errors. Because of the inherited high uncertainties from the assessment data and the estimated stock-recruitment relationship, the RW evaluated the uncertainties in this assessment with sensitivity runs to investigate the robustness of management benchmark parameter estimates to alternative choices about data usage.

- **Stock-recruitment relationship**: In both stock areas, the stock and recruitment scatter plot does not suggest that recruitment is strongly linked with SSB. In the South Atlantic, the Beverton-Holt stock-recruitment relationship indicates little change in recruitment for a wide range of SSB's and that B_{MSY} falls in the range of SSB's observed in the past. On the other hand, the Ricker stock-recruitment relationship indicates that maximum recruitment occurs at SSBs lower than those observed over the period of the assessment, which implies that B_{MSY} would also be lower than those observed in the period of the assessment. In the Gulf of Mexico, both the Beverton-Holt and Ricker relationships suggest that considerably higher recruitment would result from larger SSBs and SSB_{MSY} is estimated to be higher than SSB's observed in the past. The RW considers that the stock recruitment relationships in the two stock areas are equally uncertain. The derived benchmarks are considered useful for management in the South Atlantic, because they are within the range of past observed values. In the Gulf of Mexico, more stock and recruitment observations are necessary to confirm that the benchmarks estimated in the current assessment are indeed attainable.

- **Discussion of RW recommended MSST**: MSST, currently defined by the South Atlantic Council as $(1\text{-}M)B_{MSY}$, is very close to B_{MSY} because age-averaged natural mortality rate, M, is estimated as 0.14. Given the uncertainties in the assessment, the biomass would be expected to fall below MSST with a relatively high frequency even if the true biomass were close to B_{MSY}. In addition, MSST, as currently defined, may be overly conservative. There are no indications of impaired recruitment at the lowest observed SSB (around 5 million lbs[1]) and the RW suggests that MSST could be set at this level, operationally, to be re-examined at the next assessment.

[1]Update Note: Based on the revised assessment including corrected recreational harvest values, the lowest observed SSB changed to 4.0 million pounds, rather than the 5 million pounds estimated originally.

- **Sensitivity investigations**: The RW requested sensitivity model runs for the constant catchability model. The Panel wished to better understand the behavior of the model when certain data were left out of the model. The base model run contains three fishery-dependent CPUE indices and three sets of age and length composition datasets (one for the commercial handline, commercial diving, and recreational headboat fisheries). The stock analysts completed nine additional model runs removing each index, each fishery age composition dataset, and each fishery length composition dataset, one at a time. The results from this analysis suggest that the selected model provides a balanced fit to all data sources, illustrated by the base run falling within the middle of this set of sensitivity runs (Figures 12-14). When examining the spawning stock biomass time series, the run with the headboat CPUE data omitted shows the population increasing rapidly in the most recent years, reaching the highest terminal value of all the runs. In contrast, the run with the commercial handline CPUE omitted produces the lowest estimate of SSB value in the terminal year (Figure 12).

Sources of Information:

- The report from the Data Workshop along with the associated workshop documents.
- The report from the Assessment workshop along with associated documents.
- The SEDAR10 Review workshop discussions and presentations
- The SEDAR10 Review Workshop Consensus Summary Assessment of South Atlantic Gag Grouper

Report Revision History

Tables and figures included in this report were revised in February 2007 to reflect updated model results. The South Atlantic gag assessment model was revised to correct an error discovered in the recreational landings component of the model input.

Tables: Catch and Status

Table 1. Commercial landings by gear in weight (gutted), recreational landings in numbers, and discards in numbers for gag grouper from the U.S. South Atlantic, 1962-2004.

	Commercial (gutted klb)		Recreational (1000s)		Discards (1000s)		
Year	Handline	Diving	Headboat	MRFSS	Handline	Headboat	MRFSS
1962	150.3		8.41	6.17			
1963	137.0		7.66	5.62			
1964	128.4		7.18	5.27			
1965	130.4		7.41	5.44			
1966	99.1		5.58	4.09			
1967	210.9		11.77	8.62			
1968	309.9		17.72	12.98			
1969	217.2		12.13	8.89			
1970	299.0		16.66	12.20			
1971	306.7		17.18	12.59			
1972	204.5		13.44	8.37			
1973	290.5		17.99	12.15			
1974	372.8		13.92	15.68			
1975	421.8		8.57	17.48			
1976	565.0	3.75	7.56	23.77			
1977	627.6	8.81	8.48	21.94			
1978	967.4	13.87	6.01	37.54			
1979	907.5	18.92	9.55	35.70			
1980	846.2	16.40	6.96	35.39			
1981	984.0	13.88	13.86	56.69		0.03	0.00
1982	1027.4	15.85	11.84	17.85		0.02	4.32
1983	1101.1	9.08	16.46	74.82		0.04	91.88
1984	1108.2	18.75	18.69	153.25		0.03	11.95
1985	865.7	11.62	16.13	52.22		3.76	3.09
1986	819.8	6.34	17.35	46.78		4.05	12.48
1987	857.8	21.93	24.09	87.38		5.63	10.30
1988	672.4	12.96	24.21	62.07		5.65	15.01
1989	967.0	22.26	22.42	75.28		5.23	43.41
1990	784.3	19.07	17.59	52.20		4.11	11.46
1991	656.4	85.01	13.55	36.71		3.16	24.19
1992	691.7	106.76	13.94	49.32		7.74	38.66
1993	756.6	78.15	11.80	51.80		6.54	31.23
1994	800.0	97.50	9.81	56.22		5.45	68.29
1995	840.4	83.77	10.54	40.53		5.85	73.97
1996	751.9	118.56	7.50	43.92		4.16	43.00
1997	608.2	98.71	6.85	32.33		3.81	82.41
1998	654.5	138.79	8.67	40.32		4.82	32.22
1999	538.1	113.49	5.34	50.45	7.37	4.80	58.86
2000	438.2	63.02	5.98	29.87	7.77	5.38	126.63
2001	450.1	82.30	5.12	42.74	13.71	4.60	47.41
2002	448.3	84.52	4.58	24.03	11.91	4.12	85.73
2003	443.9	117.41	3.27	46.11	5.10	2.95	137.62
2004	476.4	74.97	6.66	46.25	7.20	6.00	89.54

Table 2. Estimated time series and status indicators. Exploitation rate (E) is of ages 2+, F is the fully selected fishing mortality rate, and SPR is static spawning potential ratio. SSB is in thousands of gutted pounds.

Year	E	E/Emsy	F	F/Fmsy	SSB	SSB/SSBmsy	SPR
1962	0.0217	0.335	0.0346	0.1460	14577	1.839	0.747
1963	0.0200	0.308	0.0324	0.1365	14375	1.814	0.761
1964	0.0197	0.304	0.0313	0.1321	14257	1.799	0.768
1965	0.0219	0.337	0.0331	0.1395	14094	1.778	0.755
1966	0.0181	0.279	0.0272	0.1149	13714	1.730	0.794
1967	0.0405	0.624	0.0552	0.2326	13242	1.671	0.629
1968	0.0651	1.002	0.0861	0.3632	12342	1.557	0.504
1969	0.0462	0.711	0.0646	0.2723	11101	1.401	0.586
1970	0.0615	0.947	0.0910	0.3838	10279	1.297	0.493
1971	0.0643	0.990	0.0992	0.4184	9498	1.198	0.471
1972	0.0485	0.747	0.0749	0.3158	8872	1.120	0.549
1973	0.0413	0.636	0.0733	0.3090	8503	1.073	0.559
1974	0.0519	0.799	0.0953	0.4017	8254	1.042	0.502
1975	0.0513	0.790	0.1267	0.5344	8085	1.020	0.447
1976	0.0647	0.997	0.1934	0.8157	8292	1.046	0.368
1977	0.0695	1.069	0.2155	0.9086	8635	1.090	0.358
1978	0.1188	1.829	0.3251	1.3708	8739	1.103	0.281
1979	0.1078	1.661	0.2956	1.2464	8075	1.019	0.279
1980	0.0953	1.467	0.2636	1.1114	7670	0.968	0.299
1981	0.1352	2.082	0.3539	1.4924	7818	0.986	0.221
1982	0.1063	1.637	0.3282	1.3840	7396	0.933	0.280
1983	0.1506	2.318	0.3867	1.6308	7243	0.914	0.171
1984	0.2855	4.396	0.6640	2.7999	6792	0.857	0.106
1985	0.1746	2.689	0.7424	3.1303	5269	0.665	0.187
1986	0.1756	2.704	0.3566	1.5039	4601	0.581	0.157
1987	0.2021	3.111	0.6809	2.8711	4354	0.549	0.132
1988	0.1498	2.306	0.9333	3.9356	4100	0.517	0.169
1989	0.1996	3.074	1.2012	5.0650	4287	0.541	0.121
1990	0.1684	2.593	0.8273	3.4884	4015	0.507	0.149
1991	0.1183	1.822	0.6567	2.7689	4133	0.522	0.179
1992	0.1285	1.978	0.4836	2.0393	4742	0.598	0.172
1993	0.1597	2.459	0.4518	1.9050	5549	0.700	0.174
1994	0.1979	3.047	0.4905	2.0685	5777	0.729	0.153
1995	0.1746	2.689	0.4634	1.9539	5091	0.642	0.163
1996	0.1518	2.337	0.4592	1.9363	4581	0.578	0.172
1997	0.1158	1.784	0.4038	1.7028	4562	0.576	0.197
1998	0.1450	2.232	0.4704	1.9833	4979	0.628	0.182
1999	0.1529	2.355	0.4947	2.0862	5076	0.641	0.176
2000	0.0946	1.457	0.3560	1.5011	4862	0.614	0.220
2001	0.1030	1.586	0.3554	1.4985	5153	0.650	0.221
2002	0.0749	1.153	0.2899	1.2224	5597	0.706	0.271
2003	0.0841	1.295	0.3471	1.4635	6368	0.804	0.232
2004	0.0992	1.527	0.3105	1.3091	7058	0.891	0.244
2005	.	.	.	.	7468	0.942	.

Table 3. Biomass, landings and discard projections under various fishing mortality (F) scenarios starting in 2008 (F fixed at the current value in 2005-2007). All results are in 1,000s of gutted pounds (klb). For reference, SSB_{MSY} = 9,374 klb, MSY = 1,774 klb, discards at MSY (D_{MSY}) = 88 klb

	Fcurrent	Fmsy	85% Fmsy	75% Fmsy	65% Fmsy
SSB (2005) (klb)	7468	7468	7468	7468	7468
SSB (2007) (klb)	6062	6062	6062	6062	6062
SSB (2010) (klb)	5660	6206	6478	6667	6863
SSB (2014) (klb)	6008	7227	7908	8413	8965
Landings (2005) (klb)	1462	1462	1462	1462	1462
Landings (2007) (klb)	1299	1299	1299	1299	1299
Landings (2010) (klb)	1079	925	836	768	693
Landings (2014) (klb)	1183	1125	1070	1020	956
Discards (2005) (klb)	108	108	108	108	108
Discards (2007) (klb)	99	99	99	99	99
Discards (2010) (klb)	135	105	91	81	71
Discards (2014) (klb)	134	105	91	82	72

Figure 1. Commercial gag grouper landings (gutted weight in pounds) by gear from the U.S. South Atlantic, 1962-2004.

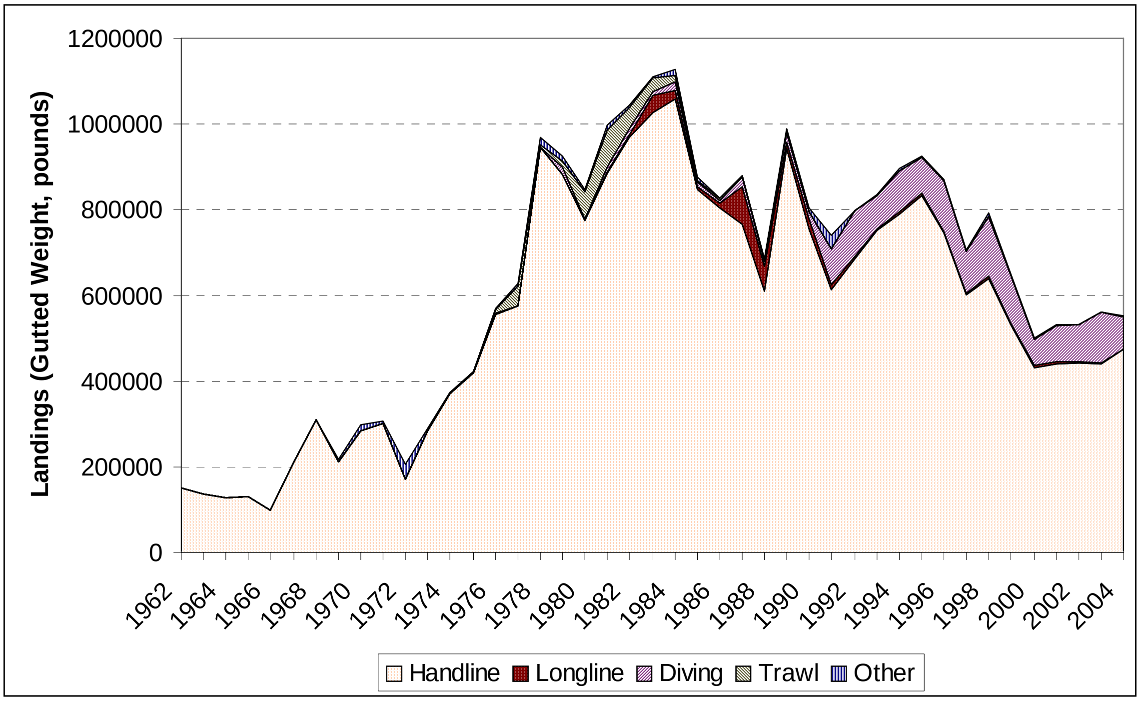


Figure 2. Total gag grouper catches (landings and discards) in numbers by sector from the U.S. South Atlantic, 1962-2004.

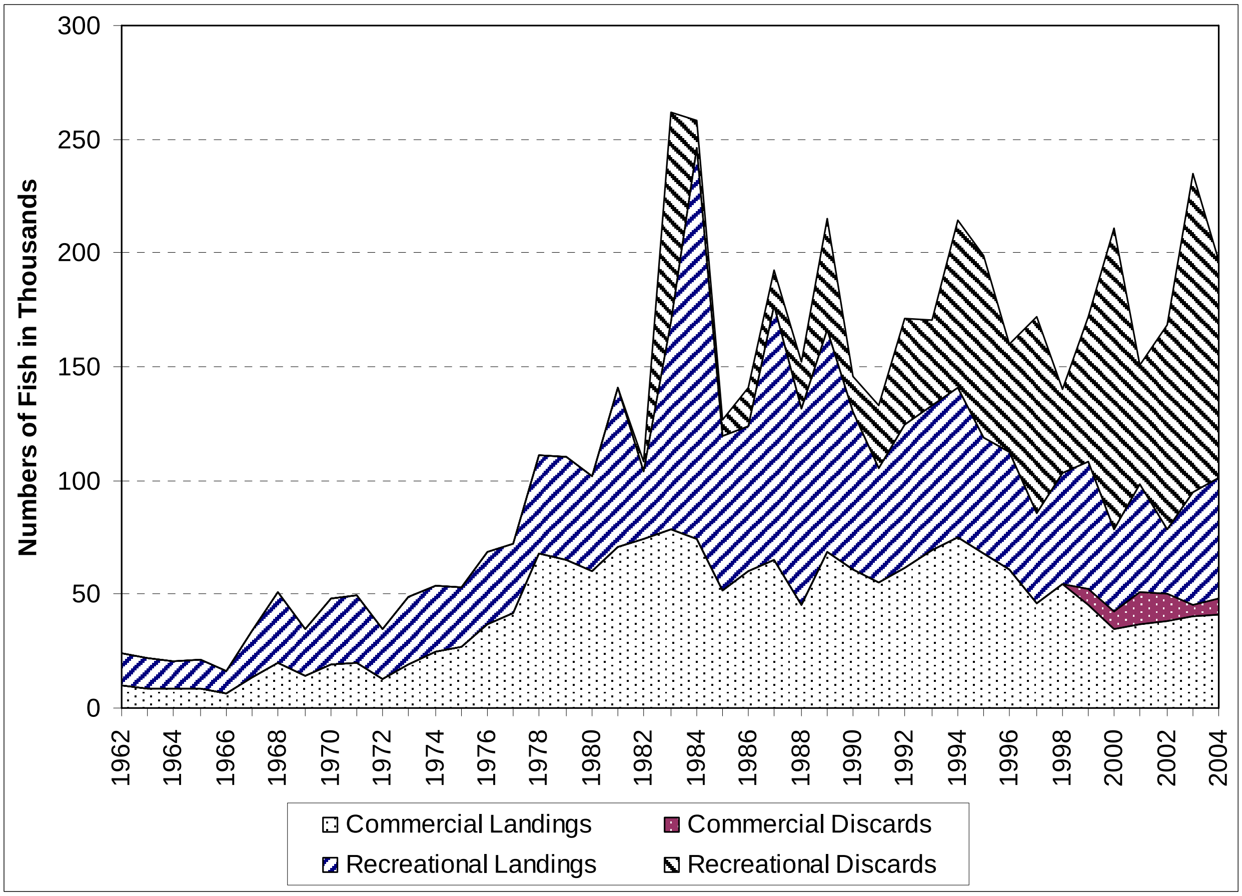


Figure 3. Estimated fully-selected fishing mortality rate. Solid horizontal line represents F_{MSY}.

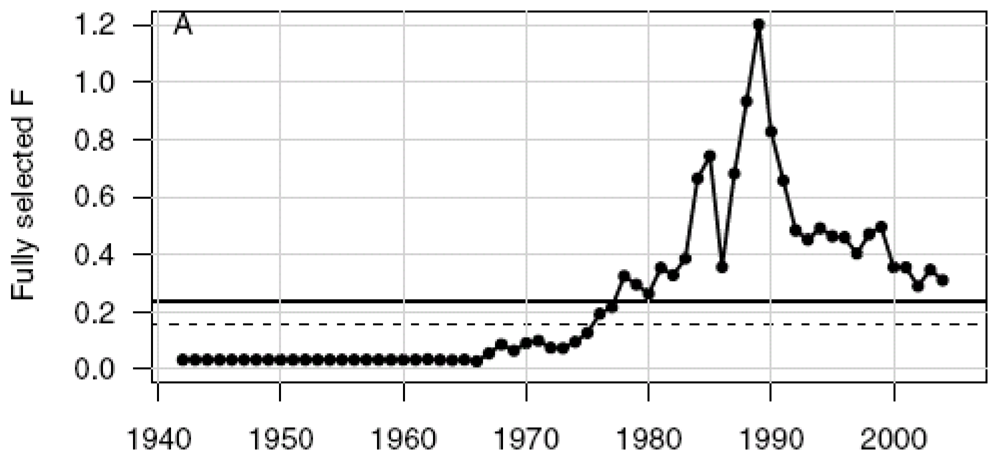


Figure 4. Estimated biomass time series (biomass in gutted weight). Total biomass (TOP) and spawning stock biomass (male mature biomass + female mature biomass, Bottom). The horizontal lines represents the level of biomass corresponding to MSY (B_{MSY} and SSB_{MSY}).

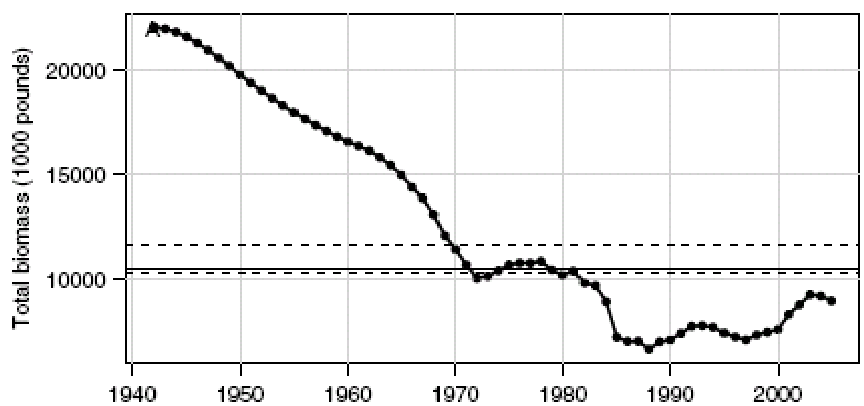


Figure 5. Phase plot of recent estimates of spawning stock biomass (klb, gutted weight) and fishing mortality rate. Solid lines correspond to MSY levels; vertical dashed line corresponds to MSST, defined as (1-M)SSB_{MSY}; and the vertical dotted line corresponds to the RW recommendation for an operational MSST.

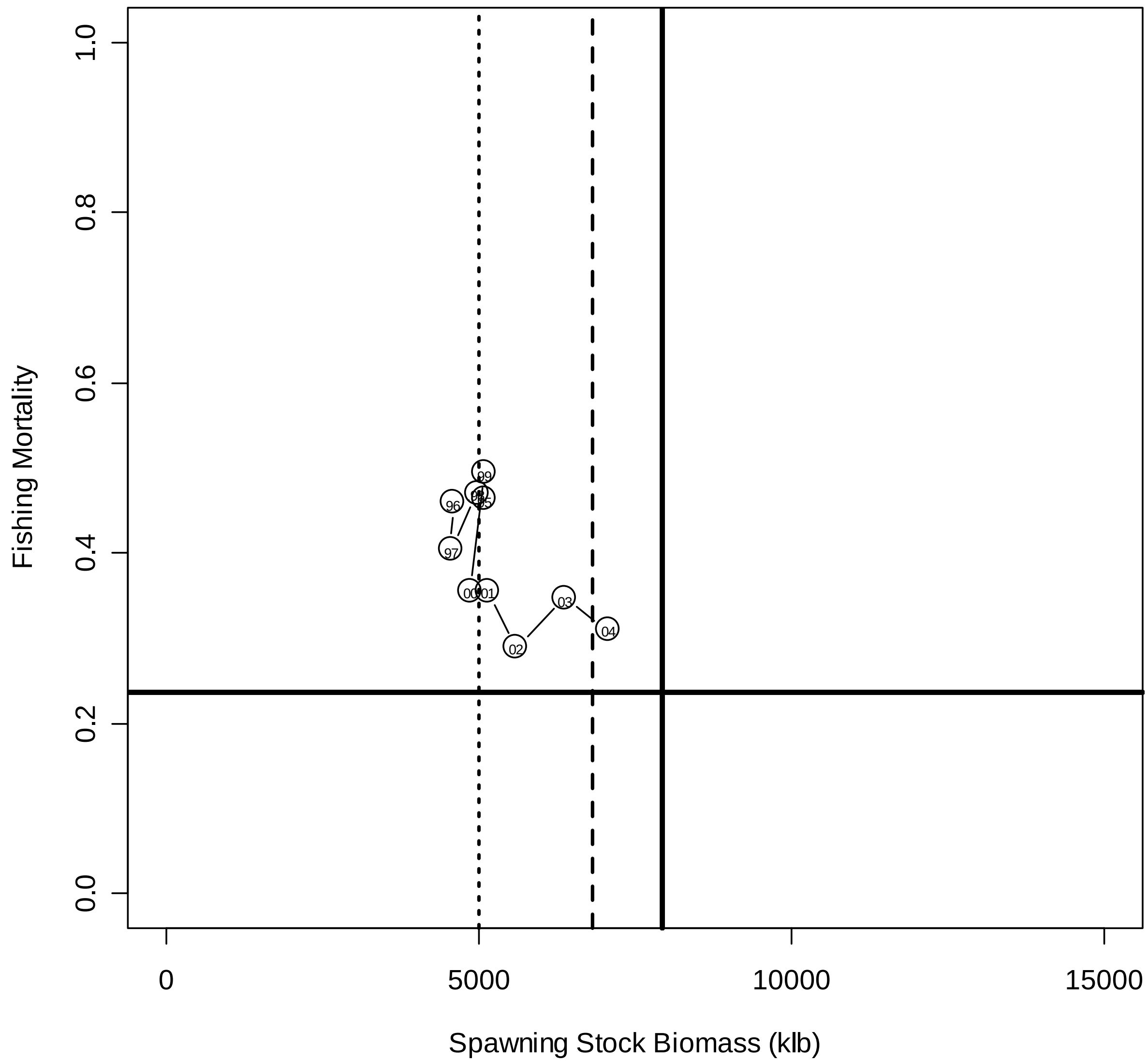


Figure 6. Projections under current fishing mortality rate for all years. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} and dashed line is MSST (defined as $(1\text{-}M)SSB_{MSY}$); B) Recruits, horizontal line is R_{MSY}; C) Fishing mortality rate, horizontal line is F_{MSY}; and D) Landings, horizontal line is MSY.

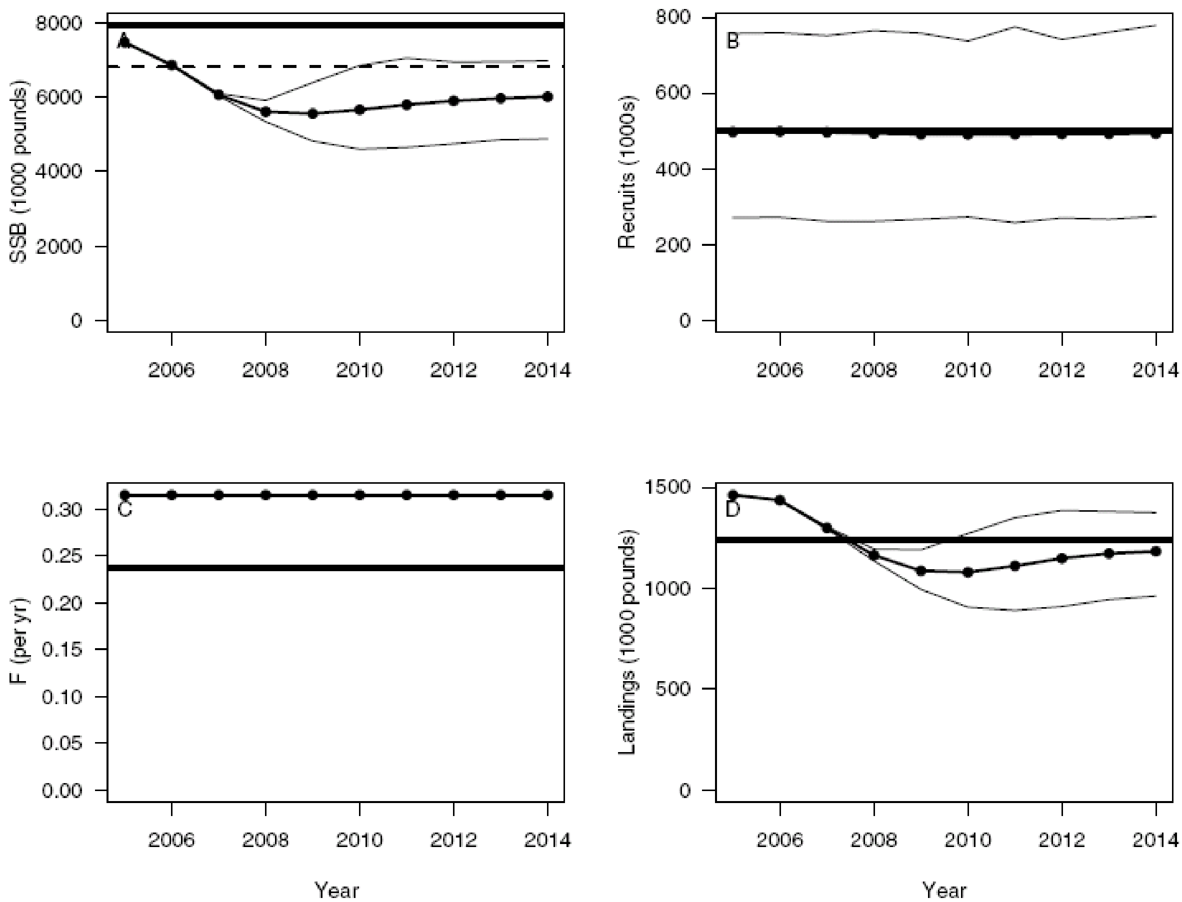


Figure 7. Projections under current fishing mortality rate in 2005-2007 and F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} and dashed line is MSST (defined as (1-M)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.

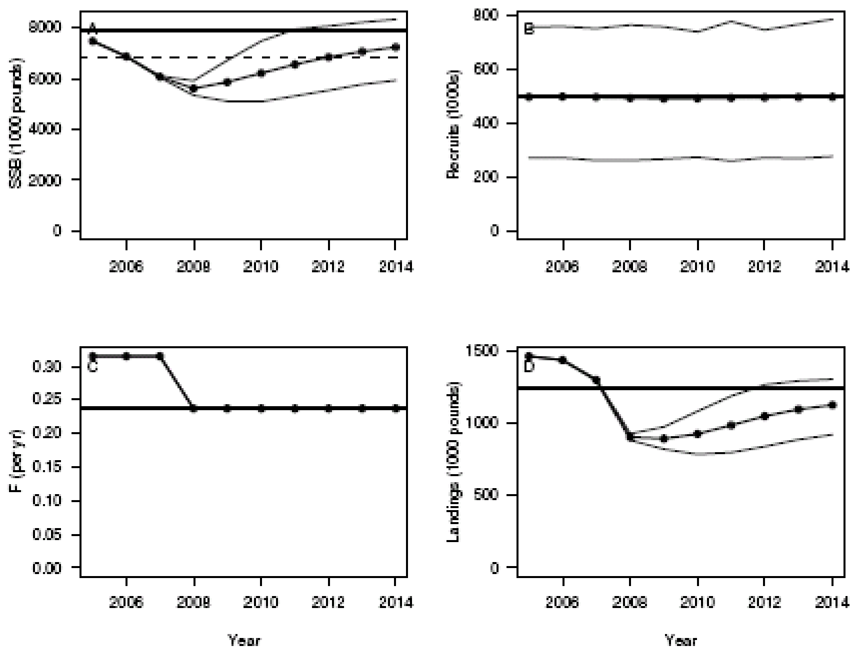


Figure 8. Projections under current fishing mortality rate in 2005-2007 and 85% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} and dashed line is MSST (defined as (1-M)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.

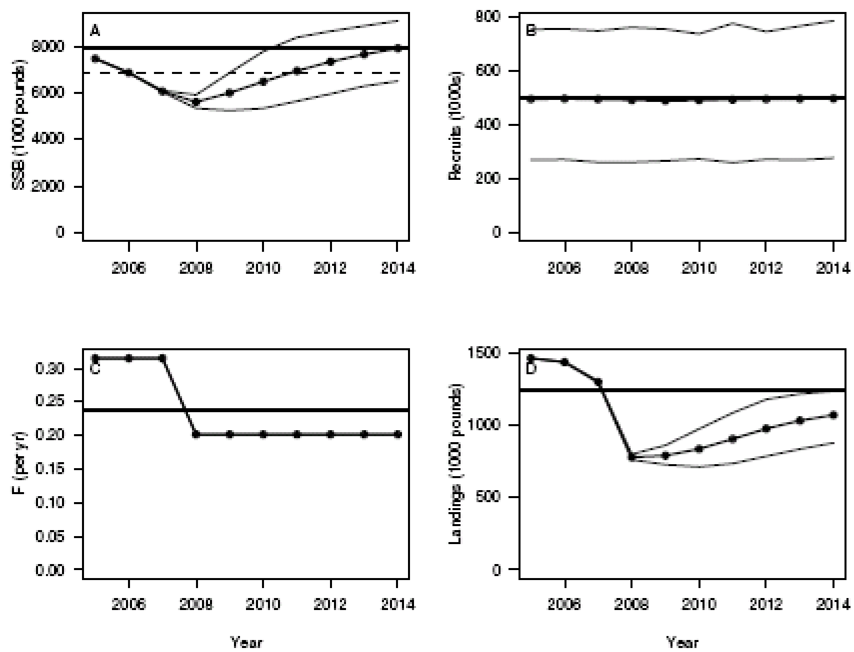


Figure 9. Projections under current fishing mortality rate in 2005-2007 and 75% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} and dashed line is MSST (defined as (1-M)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.

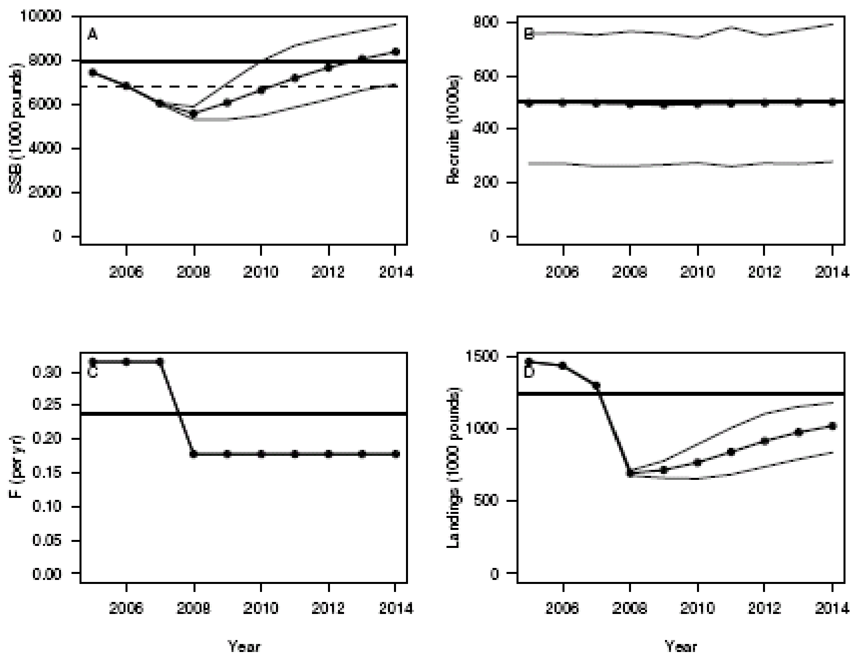


Figure 10. Projections under current fishing mortality rate in 2005-2007 and 65% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} and dashed line is MSST (defined as $(1-M)SSB_{MSY}$); B) Recruits, horizontal line is R_{MSY}; C) Fishing mortality rate, horizontal line is F_{MSY}; and D) Landings, horizontal line is MSY.

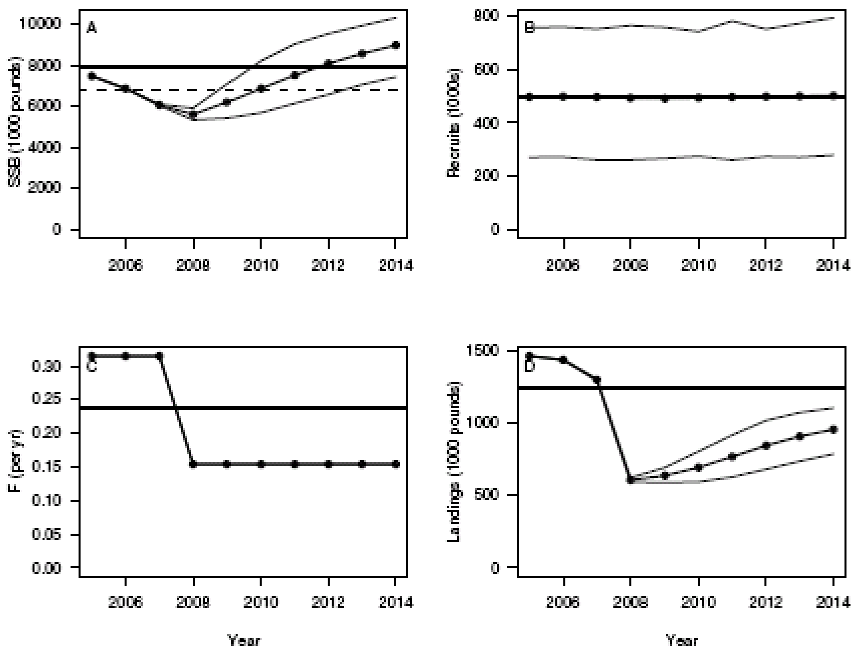


Figure 11. Estimated Beverton-Holt stock-recruitment relationship presented for South Atlantic gag grouper. Dashed curve is estimated relationship; Solid curve is estimated relationship with lognormal bias correction, from which benchmarks are derived.

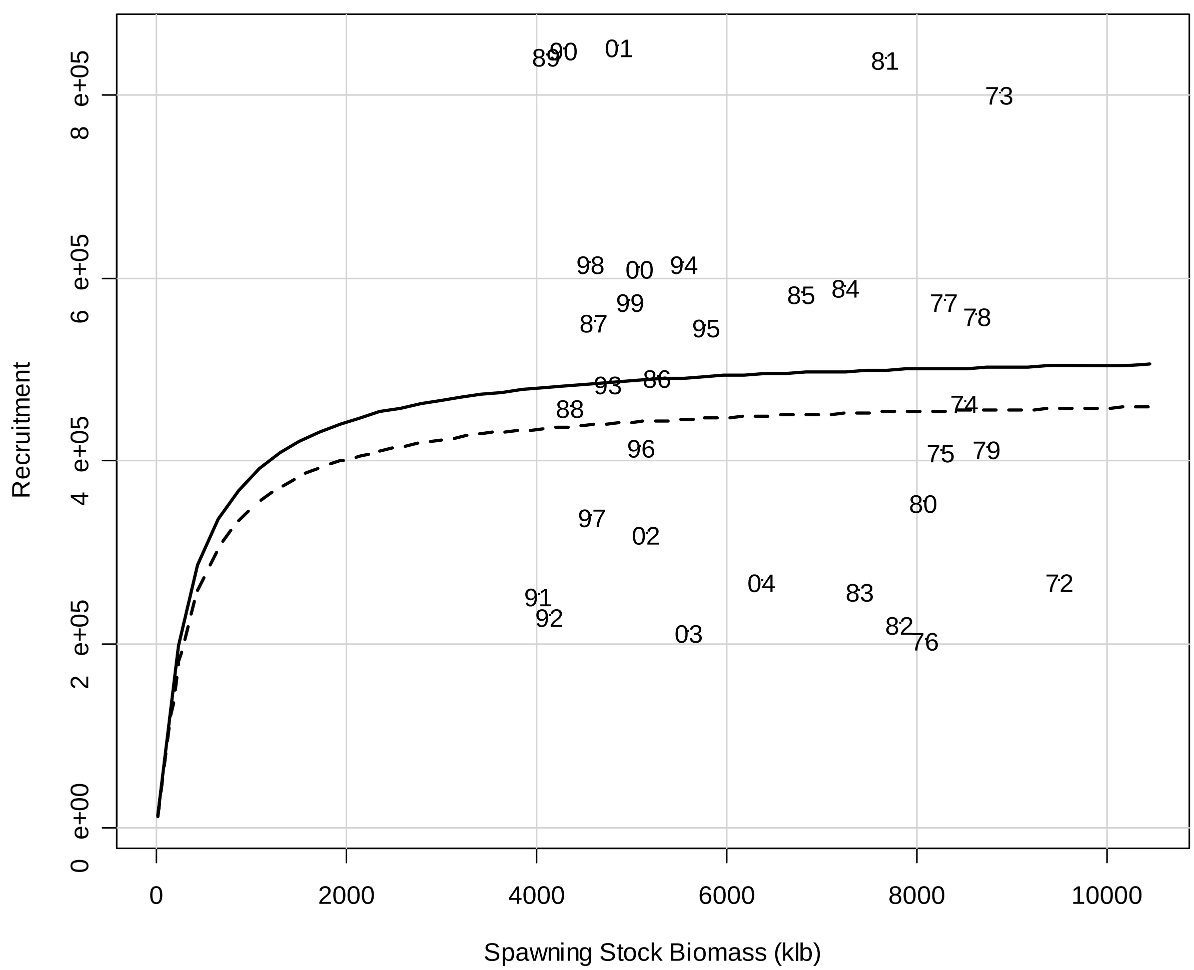


Figure 12. Estimated time series of spawning stock biomass (klb, gutted weight) from the base run model with constant catchability. The base run model with all data included is illustrated with a thick black line. Other runs with the labeled dataset left out of the model are shown in various colors and point markers.

Note: The time series of estimates for several of these sensitivities, notably logbook CPUE, handline age comp, and diving age comp changed considerably following the recreational data correction. The large spike in SSB predicted for these runs around 1970 did not appear in the original versions.

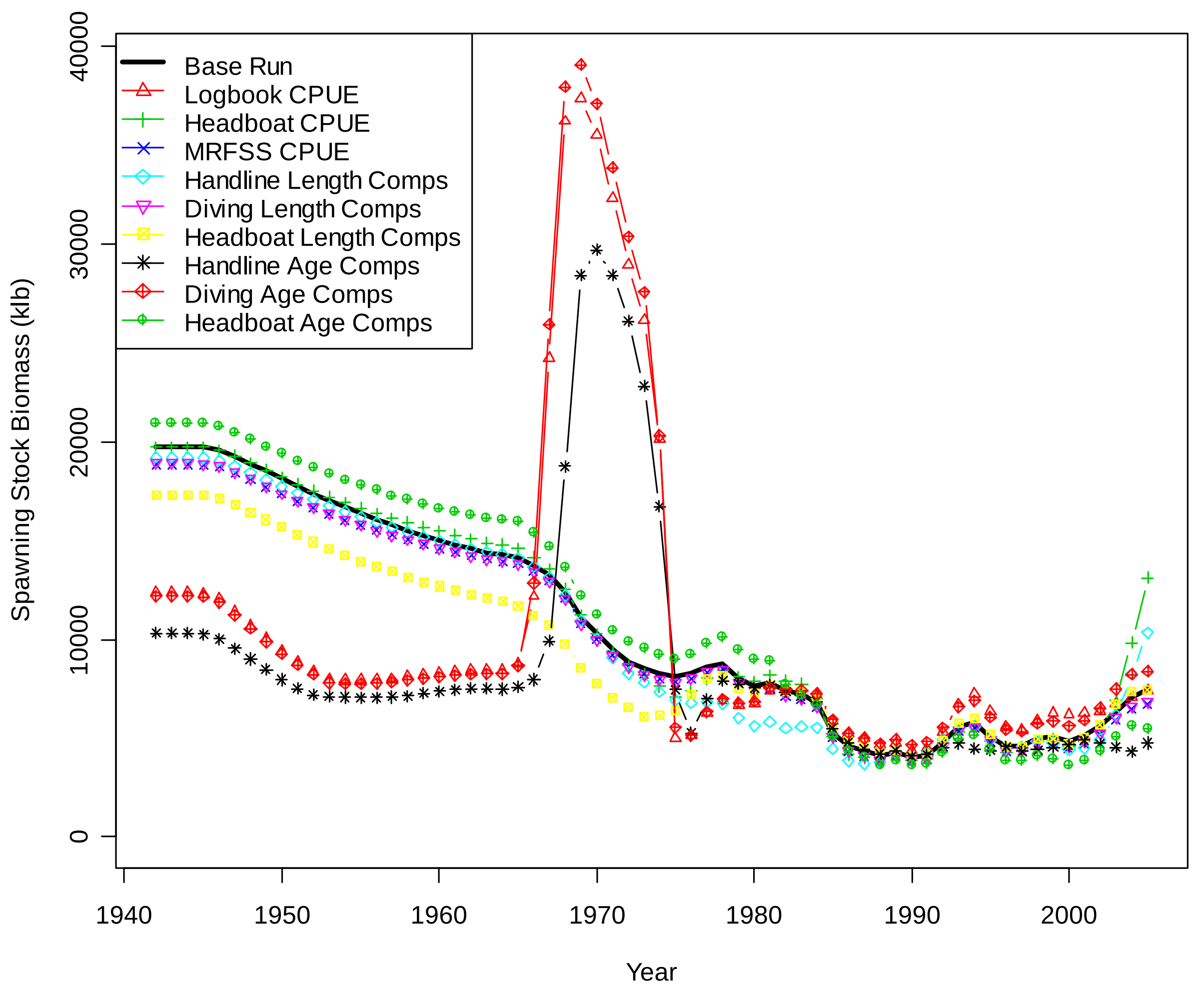


Figure 13. Estimated time series of fishing mortality rate from the base run model with constant catchability. The base run model with all data included is illustrated with a thick black line. Other runs with the labeled dataset left out of the model are shown in various colors and point markers.

Note: The time series of estimates for several of these sensitivities, notably logbook CPUE, handline age comp, and diving age comp changed considerably following the recreational data correction. In the original analyses these data series were less divergent from the others during the mid 1970's and mid 1990's.

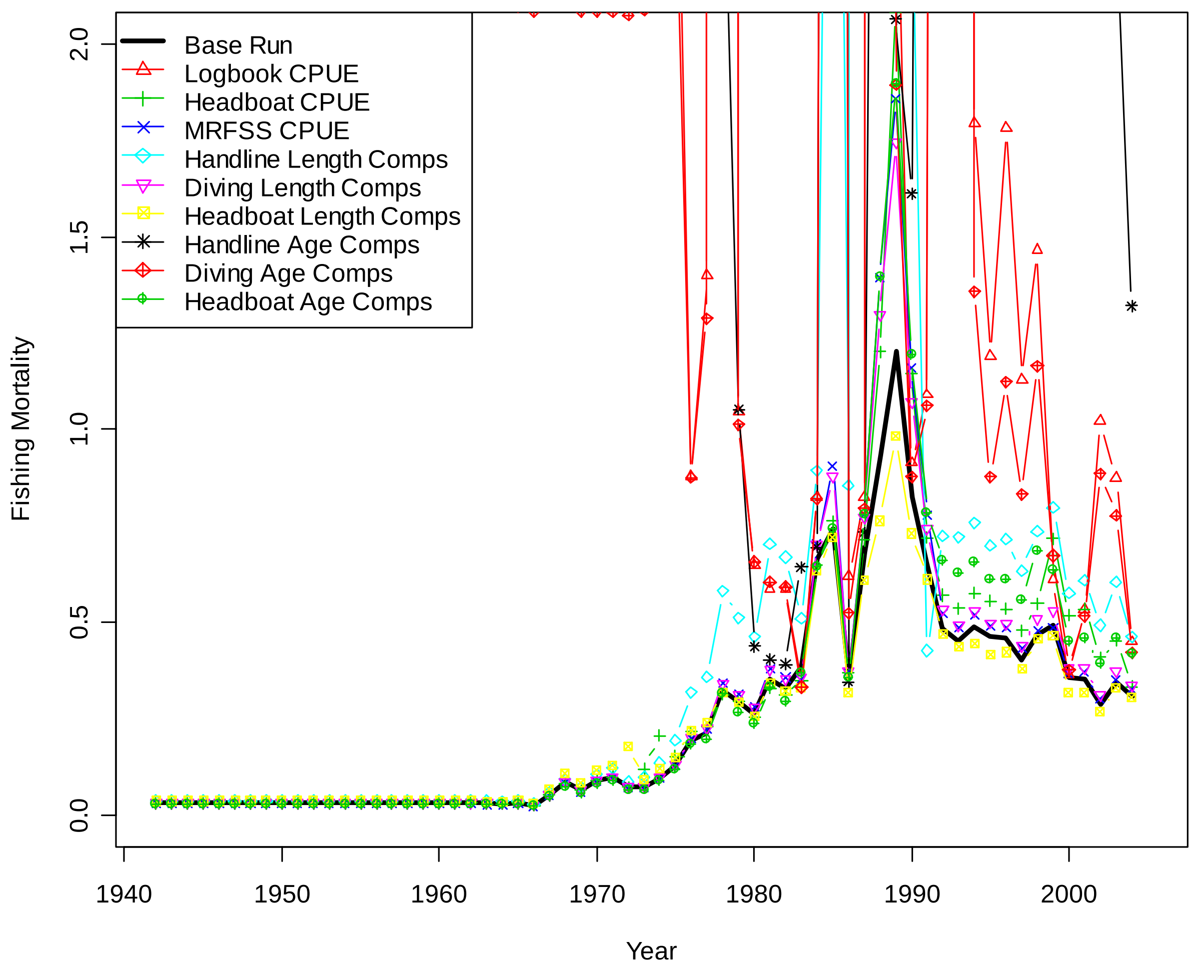
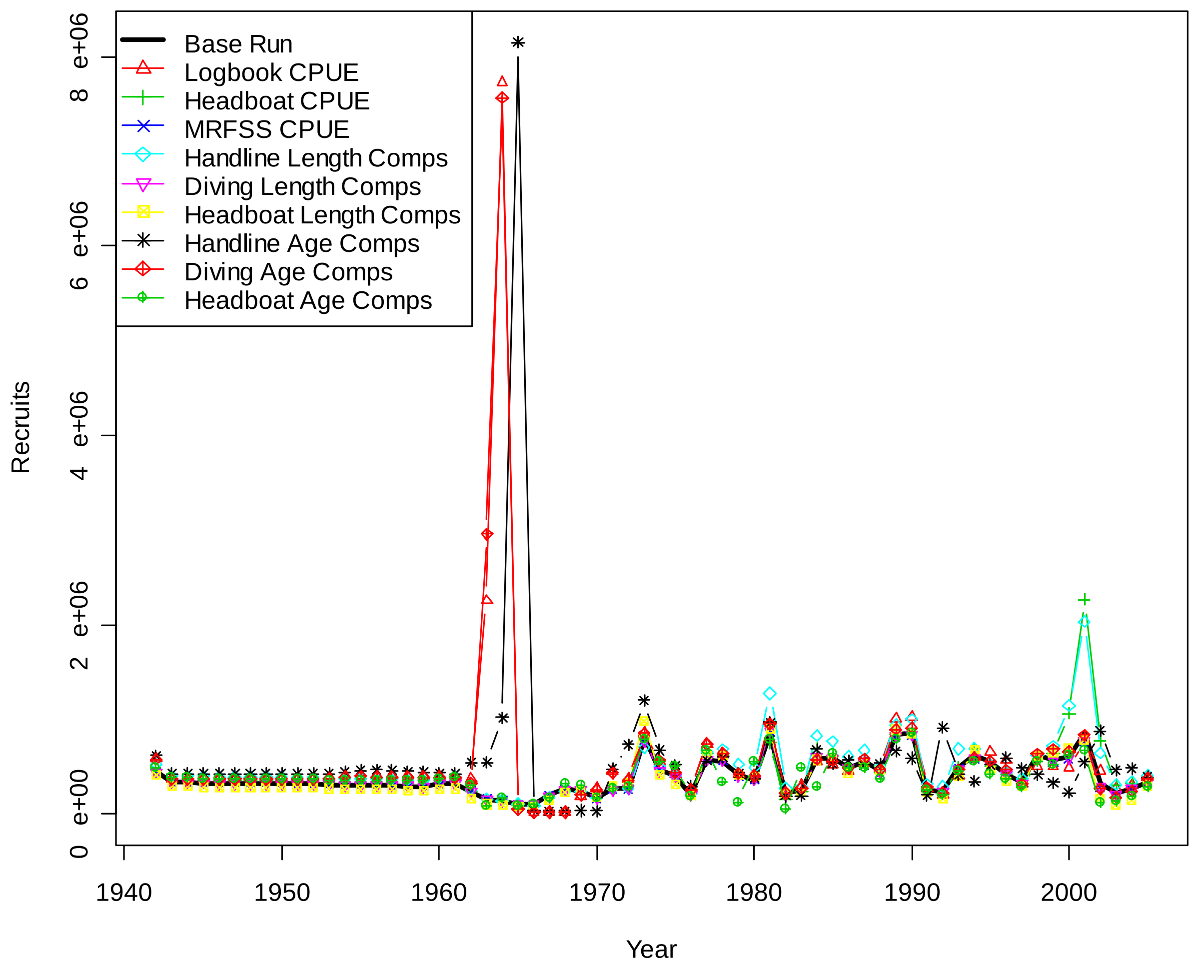


Figure 14. Estimated time series of recruitment from the base run model with constant catchability. The base run model with all data included is illustrated with a thick black line. Other runs with the labeled dataset left out of the model are shown in various colors and point markers.

Note: The time series of estimates for several of these sensitivities, notably logbook CPUE, handline age comp, and diving age comp changed considerably following the recreational data correction. The large recruitment spikes in the mid-1960's did not appear in the original analyses.



SEDAR

Southeast Data, Assessment, and Review

South Atlantic Gag Grouper
Stock Assessment Report

SECTION 2. DATA WORKSHOP

Prepared by the SEDAR10 Data Workshop Panel,
South Atlantic Panel

Final (Draft #5): June 5, 2006

REVISION HISTORY

Draft #1 – February 17, 2006

Initial draft prepared for review by Data Workshop participants.

Draft #2 – March 10, 2006

This revision includes major changes from the initial review.

Draft #3 – April 27, 2006

This revision includes correction to commercial landings (east coast of Florida); updating commercial and recreational length compositions; addition of commercial and recreational age compositions not previously included.

Draft #4 – May 12, 2006

This revision includes complete age compositions plots for both Recreational and Commercial fisheries (regardless of sample size); and the life history section was modified to reflect final values for release mortality used in the stock assessment.

Draft #5 – June 2, 2006

This revision incorporates results of two data decisions from the Assessment Workshop. The first concerns age-varying M based on Lorenzen (1996) (see Section 2.8). The second concerns interpolations of commercial diving landings for embedded years with no reported landings (1977-1978 and 1980) (see paragraph on p. II-40 in Section 3.2). Also, the commercial landings in numbers were miscopied from the excel spreadsheet when updating Table 3.8 for Draft #3 was corrected.

Table of Contents

4. Recreational Fisheries (SA Chair: Williams)
    4.1 Overview
    4.2 Headboat Survey
        4.2.1 Overview of Headboat Fishery
        4.2.2 Headboat Landings
        4.2.3 Headboat Discards
        4.2.4 Biological Sampling
    4.3 Adequacy of Data fro Assessment Model
    4.4 Recreational Survey (MRFSS)
        4.4.1 Overview of Recreational Survey
        4.4.2 Recreational Landings
        4.4.3 Recreational Discards
        4.4.4 Biological Sampling

5. Indices of Abundance (SA Chair: Shertzer)
    5.1 Index from Commercial Logbook (Handline)
        5.1.1 General Description
        5.1.2 Issues Discussed at DW
        5.1.3 Methods
        5.1.4 Results
        5.1.5 Discussion
    5.2 Index from Headboat Survey
        5.2.1 General Description
        5.2.2 Issues Discussed at DW
        5.2.3 Methods
        5.2.4 Results
        5.2.5 Discussion
    5.3 Index from MRFSS Data
        5.3.1 General Description
        5.3.2 Issues Discussed at DW
        5.3.3 Methods
        5.3.4 Results
        5.3.5 Discussion
    5.4 Fishery-Independent Indices
        5.4.1 Fishery-independent Indices of Adult Abundance
        5.4.2 Indices of Juvenile Abudance
    5.5 Research Recommendations

1. Date Report Introduction

Fishery dependent and fishery independent data for U.S. South Atlantic gag grouper were assembled and analyzed for there usefulness in subsequent stock assessment.

1.1 Workshop Time and Place

The Data Workshop was convened in Charleston, SC, January 23-27, 2006. Data and analyses prepared for the workshop are documented in the SEDAR Working Paper Series (SEDAR10-DW-XX). Following the SEDAR approach, working groups were convened to address specific data issues: life history, commercial catch, recreational catch, and indices of abundance (both fishery dependent and independent). Groups were charged with developing preferred and alternative solutions to each issue, and presenting these solutions to the group for resolution. Groups were also charged with documenting all decisions and preparing report sections according to the SEDAR assessment report outline.

1.2 Terms of Reference, Data Workshop

1. Characterize stock structure and develop a unit stock definition.
2. Tabulate available life history information (e.g., age, growth, natural mortality, discard mortality, reproductive characteristics); provide appropriate models to describe growth, maturation, and fecundity by age, sex, or length as applicable. Evaluate the adequacy of 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. Consider fishery dependent and independent data sources; provide measures of abundance by appropriate strata (e.g., age, size, area, and fishery); provide measures of precision. Provide analyses evaluating the degree to which available indices adequately represent fishery and population conditions.
4. Provide commercial and recreational catch, including both landings and discard removals, in pounds and numbers. Evaluate the adequacy of available data for accurately characterizing harvest and discard by species and fishery sector. Provide length and age distributions if feasible.
5. Evaluate the adequacy of available data for estimating the impacts of past and current management actions.
6. Recommend assessment methods and models that are appropriate given the quality and scope of the data sets reviewed and management requirements.
7. Provide recommendations for future research and monitoring. Include specific guidance on sampling intensity and coverage where possible.

8. Prepare complete documentation of workshop actions and decisions (Section II. of the SEDAR assessment report) and final datasets in a format accessible to all participants. Report and datasets are due no later than March 31, 2006.

1.3 Data Workshop Participants

Workshop Panel

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Gregg Waugh .... SAFMC

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1.4 Data Workshop Working Papers

Document #	Title	Authors
Documents Reviewed at the Data Workshop		
SEDAR10-DW1	Metadata for gag tagging data	McGovern, J., P. Harris
SEDAR10-DW2	Age, Length, and Growth of Gag from the NE Gulf of Mexico 1979-2005	Lombardi-Carlson, L. A., G. R. Fitzhugh, B. A. Fable, M. Ortiz, C. Gardner
SEDAR10-DW3	Update of gag reproductive parameters: Eastern Gulf of Mexico	Fitzhugh, G. R., H. M. Lyon, L. A. Collins, W. T. Walling, L. Lombardi Carlson
SEDAR10-DW4	Standardized Catch Rates of Gag from the United States headboat fishery in the Gulf of Mexico during 1986-2004	Brown, C. A.
SEDAR10-DW5	Description of MARMAP sampling program	Harris, P.
SEDAR10-DW6	Analysis of Prelminary Results for the Release of Satellite-Tracked Drifters over Gag Spawning Sites	Lesher, A. T., G. R. Sedberry

SEDAR10-DW7	Preliminary Notes on FL Gag Data and Trip Ticket Map	Brown, S.
SEDAR10-DW8	Review of Tagging Data for gag grouper from the Southeastern Gulf of Mexico region 1985-2005	Ortiz, M. K. Burns, J. Sprinkel
SEDAR10-DW9	Standardized catch rates for gag grouper from the MRFSS	Ortiz, M.
SEDAR10-DW10	Standardized catch rates for gag grouper from the United States Gulf of Mexico handline fishery during 1993-2004	McCarthy, K. J.
SEDAR10-DW11	Estimates of gag grouper discard by vessels with Federal Permits in the Gulf of Mexico	McCarthy, K. J.
SEDAR10-DW12	NOAA Fisheries Reef Fish Video Surveys: Yearly indices of abundance for Gag	Gledhill, C. T., G. W, Ingram, K. R. Rademacher, P. Felts, B. Trigg.
SEDAR10-DW-13	Report of a gag age workshop	Reichert, M., G. Fitzhugh, J. Potts
SEDAR10-DW-14	QA/QC procedures used for TIP online data	Gloeckner, D.
SEDAR10-DW-15	Analytical report on the age, growth, and reproductive biology of gag from the Southeastern United States	Reichert, M. , D. Wyanski
SEDAR10-DW-16	Gag history of management in the Gulf of Mexico	Rueter, J.
SEDAR10-DW-17	Overview of gag material in Draft SAFMC Snapper-Grouper Amendment 13B	Waugh, G.
SEDAR10-DW-18	Standardized catch rate indices for gag grouper landed by the US Gulf of Mexico longline fishery during 1993-2004	Cass-Calay, S. L.
SEDAR10-DW-19	Standardized catch rates of gag from the commercial handline fishery off the Southeastern United States	Shertzer, K.
SEDAR10-DW-20	Standardized catch rates of gag from the headboat fishery off the Southeastern United States	Cheshire, R., K. Shertzer
SEDAR10-DW-21	Recreational landings and length data summary for South Atlantic gag (DELETED FOLLOWING WORKSHOP DUE TO INCLUSION OF CONFIDENTIAL DATA)	Cheshire, R, and D. Vaughan
SEDAR10-DW-22	Commercial landings and length data summary for South Atlantic gag. (DELEDTED FOLLOWING WORKSHOP DUE TO INCLUSION OF CONFIDENTIAL DATA	Gloeckner, D., D. Vaughan
SEDAR10-DW-	Effect of some variations in sampling	Chih, C-P

23	practices on the length frequency distribution of gag groupers caught by commercial fisheries in the Gulf of Mexico	
SEDAR10-DW-24	Estimation of species misidentification in the commercial landing data of gag groupers and black groupers in the Gulf of Mexico	Chih, C-P., S. Turner
SEDAR10-DW-25	Habitat use by juvenile gag in subtropical Charlotte Harbor, FL.	Casey, J. P., G. R. Poulakis, P. W. Stevens
SEDAR10-DW-26	Recreational survey data for gag and black grouper in the Gulf of Mexico.	Phares, P., V. Matter, S. Turner
SEDAR10-DW-27	Spatial distribution of headboat trips from the Florida Keys	Matter, V. M.
SEDAR10-DW-28	Species ID south atlantic – ETA 1 week post workshop	Chih
SEDAR10-DW-29	Council Boundaries	anon
SEDAR10-DW-30	Annual indices of abundance for gag from Florida Estuaries	Igram, W., T. Macdonald, L. Barbieri
SEDAR10-DW-31	Age composition information South Atlantic	Potts, J.
Research Documents		
SEDAR10-RD01	Exegeses on Linear Models	Venables, W.N.
SEDAR10-RD02 1977	A reformulation of Linear Models J. Royal Stat. Soc. A 140(1):48-77	Nelder, J. A.
SEDAR10-RD03 1999	Stock identification of gag along the Southeast coast of the United States Mar. Biotechnol. 1, 137-146.	Chapman, R. W., Sedberry, G. R. , C. C. Koenig, B. M. Eleby
SEDAR10-RD04 2005	A tag and recapture study of gag off the Southeastern US Bull Mar Sci 76(1)47-59.	McGovern, J. C.,et al
SEDAR10-RD05 1983	Empirical use of longevity data to estimate mortality rates FishBull 82(1)898-903	Hoenig, J.M.
SEDAR10-RD06 2005	Bycatch, discard composition, and fate in the snapper grouper commercial fishery, North Carolina NCSU/CMAST Proj 04-FEG-08	Rudershaussen, P. J., A. Ng, A. Ng, J. A. Buckel

1.5 Management History

This section consists of a series of tables that summarize various aspects of south Atlantic gag grouper management, including general management information (Table 1.1), specific management criteria (Table 1.2), stock rebuilding information (Table 1.3), stock projection information (Table 1.4), and regulatory history (Table 1.5).

Table 1.1. General Management Information

Species	Gag (*Mycteroperca microlepis*)
Management Unit	Southeastern US
Management Unit Definition	All waters within South Atlantic Fishery Management Council Boundaries
Management Entity	South Atlantic Fishery Management Council
Management Contact	Gregg Waugh/Rick DeVictor
Current stock exploitation status	Overfishing (Post-SFA)
Current stock biomass status	Not overfished (Pre-SFA); Unknown (Post-SFA)

Table 1.2. Specific Management Criteria

Current and proposed management criteria for the gag stock in the south Atlantic as specified by the Council. Snapper Grouper FMP Amendment 11 specified the current definitions for all the criteria. The 1998 assessment (Potts and Manooch, 1998 provided the value of M).

Criteria	Current		Proposed	
	Definition	Value	Definition	Value
MSST	$(1-M)B_{MSY}$	Not specified	$(1-M)B_{MSY}$*	UNK (SEDAR 10)
MFMT	$F_{30\%SPR} = F_{MSY}$	F=0.18	F_{MSY}	UNK (SEDAR 10)
MSY	Yield at F_{MSY}	Not Specified	Yield at F_{MSY}	UNK (SEDAR 10)
F_{MSY}	$F_{30\%SPR}$	F=0.18	F_{MSY}	UNK (SEDAR 10)
OY	Yield at F_{OY}	Not Specified	Yield at F_{OY}	UNK (SEDAR 10)
F_{OY}	$F_{45\%SPR}$	Not Specified	F_{OY} = 65%,75%, 85% F_{MSY}	UNK (SEDAR 10)
M	n/a	0.15	SEDAR 10	UNK (SEDAR 10)

Following SEDAR 10, the Council may want to consider alternative definitions of MSST. For example, if the assessment determines that M is very small, the Council may want to consider changing MSST to 0.75 B_{MSY}, 0.50* B_{MSY}, or some other definition.

Table 1.3. Stock Rebuilding Information

Rebuilding Parameter	Value
Rebuilding Plan Year 1	1991
Generation Time (Years)	UNK
Rebuilding Time (Years)	15*
Rebuilding Target Date	Dec. 31, 2006
$F_{rebuild}$	UNK
Time to rebuild @ F=0 (Years)	UNK

*The 15 year rebuilding schedule was established under Pre-SFA conditions.

Table 1.4. Stock projection information.

First Year of Management	2007
Projections for interim years should be based on	Exploitation rate
Projection criteria values for interim years should be determined from	Average of previous 3 years

Table 1.5. Regulatory History

Description	FMP/Amendment	Effective Date
4" Trawl mesh size	Snapper-Grouper FMP	8/31/1983
Prohibit trawls	Snapper Grouper Amend 1	1/12/1989
Required permit to fish for, land or sell snapper grouper species	Snapper Grouper Amend 3	1/31/1991
Prohibited gear: fish traps except bsb traps north of Cape Canaveral, FL; entanglement nets; longline gear inside 50 fathoms; bottom longlines to harvest wreckfish; powerheads and bangsticks in designated SMZs off S. Carolina. Established 20" TL minimum size and a 5 grouper bag limit.	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
24" TL size limit; no harvest or possession > bag limit, and no purchase or sale, during March and April. Vessels with longline gear aboard may only possess snowy grouper, warsaw grouper, yellowedge grouper, misty grouper, golden tilfefish, blueline tilefish, and sand tilefish.	Snapper Grouper Amend 9	2/24/1999
Approved definitions for overfished and overfishing. MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}. MFMT = F_{MSY}	Snapper Grouper Amend 11	12/2/1999
Extended for an indefinite period the regulation prohibiting fishing for and possessing snapper grouper species within the *Oculina* Experimental Closed Area.	Snapper Grouper Amend 13A	4/26/2004

References

Potts, J. C. and C. S. Manooch, III. 1998. Population assessment of the gag, *Mycteroperca microlepis*, from the southeastern United States. South Atlantic Fishery Management Council, Charleston. 73 p.

2. Life History

2.1. Mortality Estimates – Total, Natural, and Release

2.1.1. Juvenile (YOY)

Mortality rates of juvenile gag were examined in shallow seagrass beds located on the northwest coast of Florida using catch curve analysis (regression of CPUE over sampling period). Daily instantaneous mortality (Z) ranged from 0.0027 to 0.0032, suggesting that daily mortality was less than 1% per day at all sampling stations (Koenig and Coleman 1998). Similar to other early life estimates of mortality, early life estimates of Z may be affected by emigration or immigration from juvenile habitats. These juvenile Z values will be taken into account when analyzing data for age-varying M, such as the Lorenzen (1996) model.

2.1.2. Sub-adult/Adult

Maximum age of gag in Gulf of Mexico is 31 years (SEDAR10-DW2) while estimates in the South Atlantic range from 26 (SEDAR10-DW15) to 30 years (SEDAR10-DW31). Using this information, natural mortality (M) of gag was estimated using the regression model reported by Hoenig (1983) for teleosts: $\ln(M) = 1.46-1.01*\ln(t_{max})$. It should be noted that the Data Workshop (DW) did not use the alternative "rule of thumb" approach for estimating M from longevity ($M=2.98/t_{max}$, Quinn and Deriso 1999, Cadima 2003). Recent work by Hewitt and Hoenig (2005) recommend the regression model over the rule-of-thumb approach. Using Hoenig's regression approach, natural mortality of gag was slightly lower in the Gulf (M = 0.13) than the South Atlantic (M = 0.14-0.16). Natural mortality was also estimated using a variety of models based on von Bertalanffy growth or reproductive parameters (e.g., Jensen 1996). Using these alternative models, M ranged from 0.15-0.22 and 0.17-0.33 in the Gulf of Mexico and South Atlantic, respectively. Estimates of natural mortality recommended by the DW are consistent with recently published mortality data (e.g., McGovern et al. 2005) as well as those applied in the previous gag assessment.

Recommendations:

1.) Use a baseline estimate of 0.15 for the initial evaluations for both the Gulf of Mexico and South Atlantic.
2.) For sensitivity analysis, the DW recommended the following ranges of M: Gulf of Mexico (0.10 and 0.20) and South Atlantic (0.10 and 0.25). The upper range of M in the South Atlantic is higher due to estimates of M from models using the von Bertalanffy parameters.
3.) Following the DW, investigate age-varying M models and their appropriateness.

Estimates of total instantaneous mortality (Z) have been reported from recapture data and catch curves. McGovern et al. (2005) reported Z values of 0.38 (recapture data) and 0.40 (catch curves) for gag from the southeastern U.S. Using data in the

SEDAR10-DW2 document, the DW estimated Z values for a range of strong year classes or cohorts (1985 = 0.60, 1989 = 0.53, 1993 = 0.30, and 1996 = 0.52) in the Gulf of Mexico (based on individuals ~ 4-12 years). Catch curve estimates of Z ranged from 0.30-0.62 among individual cohorts. Combining all cohorts for the 4-12 year age interval, an overall Z of 0.52 was observed. A catch curve was also developed for gag 13-25 years, and Z (0.21) was markedly lower than the estimate for individuals in the 4-12 year age interval.

2.1.3. Release Mortality

A previous gag population assessment for the South Atlantic used release mortality rates of 20% and 50%. The first value was from surface observations of released fish on Headboat fishing trips, and the latter value was used because it was expected that mortality would be higher than what was observed at the surface (Robert Dixon, NMFS, Beaufort, NC, *pers. comm*..; Potts and Manooch 1998). The 2001 Gulf of Mexico gag assessment used discard mortality rates of 20% for the recreational fishery and 30% for the commercial fishery based on different depths fished and an apparent increase in discard mortality rate with increasing depth (Turner et al. 2001). Recent work provides updated information on discard mortality in the South Atlantic and Gulf of Mexico. Discard mortality studies focusing on undersized gag utilized multiple techniques including observational indices (Rudershausen et al. 2005), tag release comparison (Burns et al. 2002; McGovern et al. 2005), and caging observations (Burns et al. 2002; Overton and Zabawski 2003).

A study by Rudershausen et al. (2005) reported pressure related effects, expressed as gastric distension and bleeding, on gag (n = 101) collected off North Carolina from depths ranging from 19-85 m (mean=29 m). Compared to five other species collected in the same study, gag exhibited the second highest rate of gastric distension (37.6%) and the highest occurrence of bleeding (16.8%). Of 29 gag released, all oriented and swam towards the bottom; only 5 were judged to swim in an erratic manner (condition 1 and 2; Patterson et al. 2000). However, gag with gastric distention or bleeding, if released, were expected to experience higher post-release mortality than predicted by the surface observations.

Improved estimates of post-release mortality were obtained through tag release and caging methods (Burns et al. 2002; Overton and Zabawski 2003; McGovern et al. 2005). Using these methods, mean mortality rates were estimated to be 21.2% for depths <35 m (Overton and Zabawski 2003), 23% over a variety of depths (McGovern et al. 2005), and 100% for depths >50 m (Wilson and Burns 1996).

Release mortality rates displayed a positive relationship (logistic regression) with depth, increasing from 14.2% at 15 m to 94.8% at 95 m with a 50% mortality rate at 45.5 m (McGovern et al. 2005). Burns et al. (2002) combined tag release comparison and caging observation methods to estimate discard mortality rate and found 50% mortality at a similar depth (47 m). The depth at 50% swimbladder rupture (47 m) was also similar to that for 50% mortality (Burns et al. 2002).

Vented gag showed increased survivorship compared to non-vented gag based on recapture data with all depths grouped. When recapture rates were stratified by depth, only the shallowest depth (0-12.2 m) had a significant difference between the vented and non-vented gag (Burns et al. 2002).

At depths less than 20 fm (37 m, inner shelf) where survival upon release is likely to be relatively high (about 50% or better survival with proper handling), ages and sizes of gag landed are consistently (in Gulf and SA) more truncated than at deeper depths (Figures 2.1-2.3). At depths greater than 40 fm, (73 m, outer shelf and upper slope) release mortality is likely to be quite high with little to no chance for survival. However, numbers of gag (in the compiled age-structure data) declines in this deepest zone compared to shallower depths; sizes and ages tend to increase compared to shallower depths (thus fewer potential discards, especially for the Gulf, Figure 3) and there appears to be a switch to landings dominated by long-line gear in the Gulf (Figure 2.4). Estimates of release mortality between the depths of 20-40 fm (37- 73 m, mid to outer shelf) are likely to be of *greatest concern* because this is the zone in which evident increases in release mortality (>50%) coincides with increasing depth. Also, compiled data from the Gulf and SA show that high numbers of gag from very broad age and size ranges can be harvested at 20-40 fm (Figures 2.1-2.3); thus undersized gag will be taken and will be at significant risk of mortality upon release. These suppositions are based upon example depth data accompanying biological samples. Conclusions may change when more complete landings data (by depth if available) are reviewed. The DW recognized that functional relationships of depth and release mortality potentially offers improved information over the use of simple point estimates of mortality representing broad depth intervals.

Recommendation:
The DW recommended further investigation into the practicality of applying depth-mortality functions as the assessment proceeds. Since discard mortality functions by depth were very similar between the Gulf of Mexico (Burns et al. 2002) and the South Atlantic (McGovern et al. 2005), a single function may apply to both unit stocks. Workgroup discussions then centered on the issue of whether it may be feasible to use age/length data and depths associated with discards or perhaps depth trends by fishery sector to estimate release mortality using these functions. Analysis is underway and will be made available to the assessment group prior to the Assessment Workshop. If a single function cannot be derived, then the group will further discuss options for release mortality values based on fishery sector.

If lack of adequate depth of fishing information from the various fisheries for gag in the South Atlantic makes the analysis difficult, the group recommended two values of release mortality. For the recreational fisheries (MRFSS and Headboat), release mortality should be set at 0.25. For the commercial fishery, release mortality should be set at 0.40. The group felt release mortality in the recreational fishery for gag would be lower than the commercial fishery because the recreational fishery tends to fish in shallower waters and inland than the commercial fishery. Also, handling and time spent by gag on deck in the commercial fishery may increase mortality of fish being released.

2.2 Age Data

2.2.1. Age Structure Samples

Three sets of age data were brought to the DW. Contributors included NMFS Panama City with data from the Gulf of Mexico commercial and recreational fisheries, NMFS Beaufort with data from the U.S. South Atlantic commercial and recreational fisheries, and SCDNR/MARMAP with data from the U.S. South Atlantic commercial and recreational fisheries and fishery-independent surveys, combining for a total of about 22,000 gag age estimates. Brief characterization of sampling and related issues follows:

Gulf of Mexico (SEDAR10-DW02)

Issues:
1.) Pre-1998 samples sizes of long-line collected otoliths were low compared to recent years.
2.) Throughout the time series the recreational industry, and in particular the private sector, was not well represented (n<200, 1991-2005). 3.) Fishery independent samples were also not well represented throughout the time series (n<500, 1991-2005).

Recommendations:
1.) Conduct further review of current sampling methodologies by sector, including detailed comparison of length data from otolith samples and from more expansive port-based length sampling (via TIP; see SEDAR10-DW24).
2.) Bring increased attention to the need for strategies to improve port sampling (representation of fishery sectors and random sampling)
3.) Increase the sampling of the recreational sector for biological samples throughout the docks and ports of Florida's west coast.
4.) Continue support of fishery-independent surveys including all gears (hand-line, long-line, and trap) throughout the west Florida shelf.
5.) Recognize that gag landings may be increasing elsewhere in the Gulf and bring increased attention to sampling the northern and western Gulf regions.

South Atlantic (SEDAR10-DW15, SEDAR10-DW31)

Issues:
Data collected by NMFS Beaufort was dominated by samples from the east coast of Florida from two major time periods (1976-1986; 1992-2004). The earlier time period collected mainly from the recreational sector whereas more recent years were from the commercial sector. Data were collected by SC-DNR throughout the region (NC through central FL), with most samples collected off the Carolinas. Most of these samples originated from the commercial sector during an intensive sampling period approximately every 10 years (1977-82, 1994-95, and 2004-05). In 2004-2005, SC-DNR employed commercial fishers under a special permit to collect all

sizes of fish (including undersized fish), and collections were made throughout the closed season.

The assignment of an otolith edge type, which allows estimates of annual (calendar) ages and biological (fractional) ages, has changed at SCDNR. Edge type are available for all aged fish collected after 1995, some edge types from samples collected in 1994-95 are available, and all samples collected after 1995 contain edge type information. This restricts the combination of data pre-1996.

Recommendations:
1.) The DW recommended combining the datasets from NMFS Beaufort and SCDNR to increase sample size, improve temporal coverage and growth pattern analysis.
2.) Continue with annual sampling for age structure with increased attention to representative sampling as above.
3.) SCDNR to include additional edge information based on available increment measurements to allow for age advancement, this will result in additional age data for 495 fish collected in 1976-1982, and for 763 fish collected in 1994-95 (this was completed post-DW and made available February16, 2006).
4.) SCDNR may be able to re-examine preparations to add edge information to allow for age advancement however, this will entail additional effort. (Data will be made available by February 17, 2006.)

2.2.2. Age Reader Precision

In September 2005, representatives of these three principal gag aging labs held a workshop to compare otolith interpretation, methods, and readings of gag otoliths for age estimates. Workshop results indicated that all labs use comparable procedures and methods for otolith examination. Furthermore, there was a high level of agreement and precision among readers from all labs and there was no appreciable reader bias evident from reader contrasts (SEDAR10-DW13).

Issue:
Differences in otolith interpretations and methodologies in the past have led, in some instances, to incompatible datasets.

Recommendation:
To continue exchanges of calibration otoliths sets and age workshops among state and federal agencies, and universities to continue improvements of data comparability and quality control.

2.2.3. Age Patterns

Gag year-class trends have been apparent for the Gulf of Mexico and the South Atlantic due to the ease of aging gag and the availability of a continuous series of age structure sampling from 1991 to 2005 from the Gulf, and 1981 to 1986 and 1999 to 2003 from the Atlantic. Strong year classes evident in the Gulf of Mexico were 1985, 1989, 1993, 1996, 1999, and possibly 2000. Strong year classes in the U.S. South Atlantic were 1974, 1978, 1981, 1990, 1994 and 1996. The available overlapping years for the Gulf and South Atlantic revealed similar age progression and a relatively strong 1996 year class in both regions. This further suggests that annual recruitment trends may be similar in both regions. The DW recommends that age structure sampling continue on an annual basis for both regions.

Contributors of the three age data sets found similar age ranges – 1-31 years, 0-30 years and 1-26 years, (NMFS Panama City, NMFS Beaufort, and SCDNR/MARMAP, respectively) – but did note differences in size-at-age and different maximum size between the Gulf of Mexico and the U.S. South Atlantic (SEDAR10-DW2, SEDAR10-DW15, SEDAR10-DW31).

2.3. Growth

There have been several growth studies on gag in the Gulf of Mexico and South Atlantic (see citations within SEDAR10-DW2, SEDAR10-DW15, and SEDAR10-DW31). The updated data sets provided increased sample sizes for improved temporal coverage and contrasts. Growth models can be influenced by the use of size-biased samples, for example, due to minimum size-limits affecting fishery-dependent sampling. Thus, a modified von Bertalanffy growth model accounting for size limited data was used for the Gulf of Mexico (1991-2005, n=16,147) and South Atlantic (1976-2005, n=5,734; Diaz et al. 2004). Model fits used area, sector and temporal specific size-limits (GOM: 1990-2000 all sectors 20 inches, 2000-2005 recreational 22 inches, 2000-2005 commercial 24 inches; SA 1992-1998 all sectors 20 inches, 1999-2005 all sectors 24 inches).

The model was fit to observed lengths and fractional ages. Gag data from the entire time series were fit to the modified von Bertalanffy growth model (TL mm), separately by area (GOM, SA), to obtain population growth parameters for each area. The modified growth model resulted in an asymptotic length within the range of observed lengths (GOM: L_∞=1310 mm, TL range 245-1384 mm; SA L_∞=1051 mm, TL range 215-1300 mm), growth coefficients (GOM: $k = 0.14\ yr^{-1}$; SA: $k=0.24\ yr^{-1}$) and predicted t_o close to zero (GOM: t_o =-0.37 yr; SA: t_o =-0.48 yr).

Issues:
SCDNR analysis of size-at-age data and von Bertalanffy growth among the three periods (1979-82, 1994-95, and 2004-05) using increment counts and non-weighted data indicated possible temporal patterns in growth (SEDAR10-DW15, SEDAR10-DW31). However, data from NMFS-Beaufort did not show similar patterns.

Recommendations:
Analysis of combined South Atlantic datasets (SCDNR, NMFS Beaufort) for size-at-age and growth with various versions of the von Bertalanffy growth model using unweighted and weighted data will be completed prior to assessment workshop. (Data analysis will be made available by the end of February 2006.)

2.4. Reproduction

There have been several investigations of the reproductive biology of the gag in the U.S. South Atlantic and eastern Gulf of Mexico. Studies have addressed reproductive seasonality, spawning depth, sex ratio, sexual maturity, sexual transition (from female to male), aspects of the mating system, principal spawning habitats and regions, behavior, coloration, reproductive endocrinology, fecundity and spawning frequency (see citations within SEDAR10-DW3 and SEDAR10-DW15). The review below presents a summary of gag reproductive parameters that are most relevant for stock assessment. Topics are discussed jointly for U.S. South Atlantic and eastern Gulf of Mexico.

2.4.1. Spawning Seasonality

Spawning season in the South Atlantic was estimated to extend from mid-January to early May (with a peak in March-April), corresponding to a 114 d spawning duration (SEDAR10-DW15). In the eastern Gulf of Mexico the spawning season was estimated to extend from late January to mid-April (with a peak in March), corresponding to a 91 d spawning duration (SEDAR10-DW3). For both areas, delineation of the spawning season was based on the presence of females in spawning condition (i.e., ovaries containing hydrated oocytes or postovulatory follicles).

2.4.2. Sexual Maturity

Gag are known to be protogynous hermaphrodites (female first, changing to male later in life). Consequently, sexual maturity is reported for females only. Male sexual maturity is being addressed under "Sexual Transition" below.

Although data for the South Atlantic (mostly fishery-dependent) suggested temporal changes in size- and age-at-maturity (Table 2.1.; SEDAR10-DW15), discussion by the Life History Working Group could not resolve the issue of whether these changes were real or a reflection of temporal changes in size limits. Data from the Gulf of Mexico (collected during 1991-2002; SEDAR10-DW3) indicated no temporal changes in size- and age-at-maturity for gag. Size at maturity for Gulf of Mexico gag was 585 mm TL corresponding to an age-at-maturity of 3.7 yrs. These estimates are similar to, or perhaps slightly smaller than, size at maturity reported previously in US waters of the Gulf of Mexico.

Recommendations for South Atlantic:

1.) Provide an estimate of length and age at 50% maturity (L_{50} and A_{50}) for the entire time period (i.e., mean and variance for the data pooled over years). The pooled length and age at 50% maturity estimates are 648 mm TL (3.0 yr). Also, further analysis of data using a modified logistic model that takes into account minimum size regulations will be done following this workshop.

2.) Provide estimates of L_{50} and A_{50} for each of the time periods sampled. Estimates for the 3 separate time periods can be found in SEDAR10-DW15, as well as parameter estimates for each period and periods combined.

2.4.3. Sexual Transition

Similar to what we observed for "Sexual Maturity" data for the South Atlantic showed evidence of temporal change in size and age at sexual transition for gag. Histological examination of 1,128 sexually mature gag collected during 2004-05 revealed that the percentage of males and transitionals increased from 5.5% in 1994-95 (see McGovern et al. 1998, cited in SEDAR10-DW15) to 8.2%. The current percentage of males and transitionals is still much lower than the revised estimate of 19.4% for samples collected during 1977-82; McGovern et al. (1998) reported 21.1% males and transitionals in the 1976-82 samples. However, similar to the approach we took for "Sexual Maturity", we are providing a single estimate for size and age at transition: 1,025 mm TL for length at 50% transition and 10.5 yr for age at 50% transition. Estimates for the 3 separate time periods can be found in SEDAR10-DW15.

Data for the Gulf of Mexico (collected during 1991-2002, see SEDAR10-DW3) showed no evidence of temporal changes in size and age at transition (compared to Hood & Schlieder's data from 1977-80, cited in SEDAR10-DW3). Additionally, the histological and visual analyses of female size at transition to male (i.e., visual identification of "copperbellies") yielded very similar results. Based on histological criteria, size at 50% transition was 1100 mm TL, and based upon visual pigmentation size at 50% transition was 1085 mm TL. In both analyses, transition appeared to begin after 800 mm TL and nearly all gag had undergone transition upon reaching 1300 mm TL. Age at 50% transition was 10.8 years. Transition to "copperbelly" pigmentation began at age 7 and nearly all fish were pigmented after about 15 years of age.

2.4.4. Batch Fecundity

Very consistent parameter estimates were found for Gulf and South Atlantic stocks.

<u>South Atlantic</u>: Batch fecundity as a function of total length did not differ between the three time intervals (Jan-Feb, Mar, and Apr-May), as indicated by the lack of differences in slopes (F=0.05; P=0.956; df=2) and intercepts (F=2.62; P=0.078; df=2). Given the similarity of the equations, data from all time intervals were combined. Linear regression parameters for the relationships between BF and fish size and age can be found in SEDAR10-DW15.

<u>Gulf of Mexico</u>: Batch fecundity (BF) increased with age and length of females, ranging from 60 thousand to 1.7 million ova per batch with a mean of 422 thousand ova (sd = 295 thousand). Variation in batch fecundity was generally high among age and size classes but the variation explained by linear fits of batch fecundity regressed on age and size were similar ($r^2 = 0.30$ and 0.34 respectively). As is common among fishes, the batch fecundity relationship was best predicted by regression with (ovary free) body weight ($r^2 = 0.53$). This is similar to results given in Collins et al. (1998) but expands the sample size of hydrated females. Linear regression parameters for the relationships between BF and fish size and age can be found in SEDAR10-DW3.

2.4.5. Spawning Frequency

South Atlantic: for a spawning season of 114 days the spawning frequency was estimated to be 1 spawn every 2.5 days (corresponding to 38 spawning events per season). See SEDAR10-DW15.
Gulf of Mexico: for a spawning season of 91 days the spawning frequency was estimated to be 1 spawn every 3.7-4.0 days (corresponding to 23-25 spawning events per season). See SEDAR10-DW3.

Recommendation:
Given that there is little evidence in both regions for an age effect on spawning frequency in both regions, annual fecundity at age would merely be the product of the expected number of spawns per female per season multiplied by batch fecundity at age.

2.5. Movements and migrations

The DW reviewed the results of two relatively large gag tagging studies. The objective was to gauge the degree of exchange between Atlantic and Gulf stock units. Approximately 6,500 gag were tagged primarily on the west Florida shelf, resulting in over 600 recaptures exhibiting limited movements (80% within a 9 km radius; SEDAR10-DW8). No movement was detected between the west Florida shelf and Atlantic stock units in this study. Most of these fish were recreational tag and recaptures and predominately showed ontogenetic movements from coastal to deeper waters of the shelf. In contrast, a South Atlantic tagging study (3,876 tags, 435 recaptures) reports a much higher proportion of fish moving a greater distance (23% over 185 km), primarily from the Carolinas towards the south to the Florida east coast (McGovern et al. 2005). There were several fish tagged in the South Atlantic that were recaptured from the Keys to the west Florida shelf.

Depth of tagging and size of fish appears to explain the different results from these two studies. In the Gulf tagging study, the modal size of tagged gag was approximately 400 mm. In the South Atlantic study, fish were tagged primarily from commercial boats across a broad depth range; fish were notably larger, ranging in mean size from 578-832 mm TL across 10-m depth categories. Mean distance moved was significantly greater for gag tagged in the 21-40 m depth range. It has also been reported that events such as hurricanes may cause large scale movements in shallow water groupers including gag. Gag were reported to be more abundant in Mississippi, Alabama and NW Florida after Hurricane Eloise in 1985 (Franks 2005).

In general, information suggests an ontogenetic movement to deeper waters; smaller gag (late juvenile to early adult) exhibit relatively high site fidelity with localized movements on the order of a few km. Gag then make larger along-shelf movements upon reaching depths of the mid to outer shelf (mature adults). There is some evidence that upon reaching older ages and outer shelf depths, associated with spawning habitats, gag again exhibit higher site fidelity (Coleman et al. 1996). Fish tagged and recaptured at the deepest depths (41-80 m) did not exhibit movements as large as those tagged at inner to mid-shelf depths less than 40 m (McGovern et al. 2005). Also, ongoing work suggests copperbelly gag tagged in spawning areas exhibit relatively high site fidelity (Koenig pers.comm.)

Recommendation:
Current data are inconclusive as to whether stock transfer or exchange is taking place between the US South Atlantic and the Gulf of Mexico. Therefore, no rate of migration, stock transfer or exchange should be implemented into the assessment models, and council boundaries should rule as the dividing line of the two stocks.

2.6. Stock definition and recommendations for research

Gag has been managed as separate Atlantic and Gulf stock units, and the SEDAR workshop panel was instructed by the SAFMC and GMFMC to continue with the two US management units in SEDAR 10. However, it was acknowledged that this may change in future assessments. The DW discussed stock identification issues, acknowledging work underway, and made recommendations for further research.

2.6.1 .Otolith Chemistry

Chemical signatures in otoliths have been used recently to discriminate gag from different nursery habitats. Hanson et al. (2004) demonstrated that chemical signatures in otoliths of gag could be used to classify juveniles from four nursery areas along the west coast of Florida (note: classification success ranged 66-100%). Results indicate the approach has promise for determining population structure and the relative contribution of gag from different nurseries. To date, the DW is not aware of reports characterizing chemical signatures in the otoliths of gag from the South Atlantic. If otolith signatures from the Gulf of Mexico and South Atlantic nurseries differ, these natural markers will provide a means of predicting the nursery origin of sub-adult and adult gag (retrospective determination based on quantifying material in the otolith core of sub-adults and adults, which corresponds to the nursery period). In addition, estimates of nursery origin could also be used to characterize population structure and connectivity of the two stocks. The DW recommends continued research on the use of otolith chemistry to evaluate the population structure of gag.

2.6.2. Population genetics

Genetic studies can provide both long-term and short-term estimates of connectivity among regional populations of Gag. Previous studies (Chapman et al 1999) exhibited evidence for population structure among different regions of the Gulf coast and Atlantic coast (a noteworthy result considering the high dispersal potential associated with this species), but significant departures from Hardy-Weinberg equilibrium within these sample groups. These departures from what is considered to be a neutral state assumption could be caused by many different processes such as high variance in reproductive success in individuals from year-to-year or regionally differential reproductive success in a structured population. Research underway addresses these questions and others associated with spatial and temporal population structure and their relationship to dispersal patterns, reproductive success, and effective population size (N. Jue, Florida State University). A recently funded Sea Grant proposal in South Carolina (Erik Sotka – PI, College of Charleston) will compare genetics of spawning gag captured in 2005 by commercial fishermen (sampled by MARMAP at SCDNR) to juveniles collected in North Carolina and South Carolina in subsequent months to determine the source of recruits, especially to North Carolina sounds. The DW recognizes the value of this research and that this type of genetics work can provide key insight into patterns in gag population structure. The DW further highly recommends every opportunity be taken to add Mexican (Campeche) samples to this analysis as these methods can be most informative in divining patterns of gene flow and population connectivity.

2.6.3. Demographic comparisons

Comparing estimates of growth, maturity, and sex-transition between Gulf and Atlantic management units provides inferences for stock connectivity. However, the DW recognized that subtle differences in methods of sampling, laboratory preparation and parameter estimation can obscure biological differences. The DW recognized that there have been recent workshops with productive outcomes on aging and reproductive assessments, targeting gag and similar species, and recommends that such workshops continue to be undertaken to eliminate potential methodological differences. The DW suggests that it may be particularly valuable to convene a workshop to address the potential non-random and non-representative sampling that hampers collection of small numbers of biological samples (relative to numbers of fish landed) which in turn are used for parameter estimates.

2.6.4. Age structure patterns

Gag year-class trends have been apparent for the Gulf of Mexico due to the ease of aging gag and the availability of a continuous series of age structure sampling from 1991 to 2005. The DW recommends that age structure sampling continue on an annual basis in the Gulf. Availability of age data in the South Atlantic is more episodic. The available overlapping years for the Gulf and South Atlantic revealed similar age progression and a relatively strong 1996 year class in both regions. This further suggests that annual recruitment trends are similar between regions. The DW recommends that long-term continuous monitoring of age structure be undertaken in the South Atlantic to test this hypothesis.

2.6.5. 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, Fitzhugh et al. 2005). Exploration using a wind-driven 2-d transport model further supported this hypothesis but was unable to account for cross-shelf transport. In addition, there may be larval connectivity between the southern Gulf of Mexico (Campeche) and the west Florida shelf (Fitzhugh et al. 2005). 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) is further supported.

2.6.6. Tagging

Tagging studies are needed to: 1) clarify the extent of movement between the Gulf and SA regions and within region, and 2) aid further development of age-specific estimates of depth-related mortality in the Gulf region. In the SA region, most of the tagging effort has been off South Carolina. Therefore, we recommend that additional tagging be completed off the east coast of Florida to examine the extent of northerly and southerly movements. In the Gulf region, the bulk of the tagging targeted juveniles and young adults in coastal areas, therefore we recommend that tagging effort be extended to the middle and outer shelf, perhaps with the assistance of cooperating commercial fishers, for the purpose of tagging adult gag. The DW recommends that future tagging studies should be done in a more coordinated manner between researchers in the Gulf and SA regions, particularly with respect to gear, fish size, and depth.

2.7. Meristic Conversions

Gulf of Mexico: Meristic relationships were calculated for gag caught in the Gulf of Mexico for length types (total and fork) and body weights (whole and gutted), (Table 2.2). Coefficients of determination were high for linear (length) and nonlinear (weight) regressions (r^2>0.96).

South Atlantic: Various fishery independent and dependent data sets were used to develop relationships among whole weight (WW), gutted weight (GW), total length (TL), fork length (FL), and standard length (SL). When relating among lengths or among weight no-intercept linear regressions were used (Table 2.3). A linearized regression (ln-ln) was used to relate whole weight to various length measurements (Table 4). Note that when retransforming back to arithmetic space from logarithmic space, a bias correction is necessary based on the mean squared error (MSE) from the regression (Beauchamp and Olson 1973, Sprugel 1983). Estimates for whole weight (WW) at length (L) are obtained from:

$$WW = \exp(\text{Intercept} + MSE/2 + \text{Slope}*\ln(L)).$$

If we let,

$$a = \exp(\text{Intercept} + MSE/2),$$

then

$$WW = a\ L^b.$$

These regressions were originally done by source for the South Atlantic, and ultimately summarized for the region as presented in the tables referenced. Fishery-independent data included whole weight, gutted weight, total length, fork length, and standard length from the SC DNR MARMAP program. These same data (less the gutted weight) were also available from FL FWCC. In recent years, the Headboat program has measured occasional fork lengths along with total lengths. Fishery dependent data for whole weight and lengths were available from headboat (TL), MRFSS (FL), and TIP (TL) for both coasts. All weights shown are in kilograms and all lengths are in millimeters.

2.8. Post Data Workshop: Natural Mortality Rate

An age-varying M (Lorenzen 1996) approach was developed subsequent to the SEDAR 10 DW. This approach inversely relates the natural mortality at age a (M_a) 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 shape parameter (β > 0). Lorenzen (1996) provided point estimates and 90% confidence intervals of α and β for oceanic fishes, which were used for the initial parameterization. As in the SEDAR 04 AW, it was concluded during the SEDAR 10 AW that the Lorenzen (1996) approach is more biologically plausible than a fixed M for all ages. Also as in the SEDAR 04 assessment, the Lorenzen estimates were re-scaled to the oldest observed age (30) so that the cumulative natural morality through this age was equivalent to that of constant M (0.14) for all ages from the Hoenig (1983) method (Table 2.5 and Figure 2.4).

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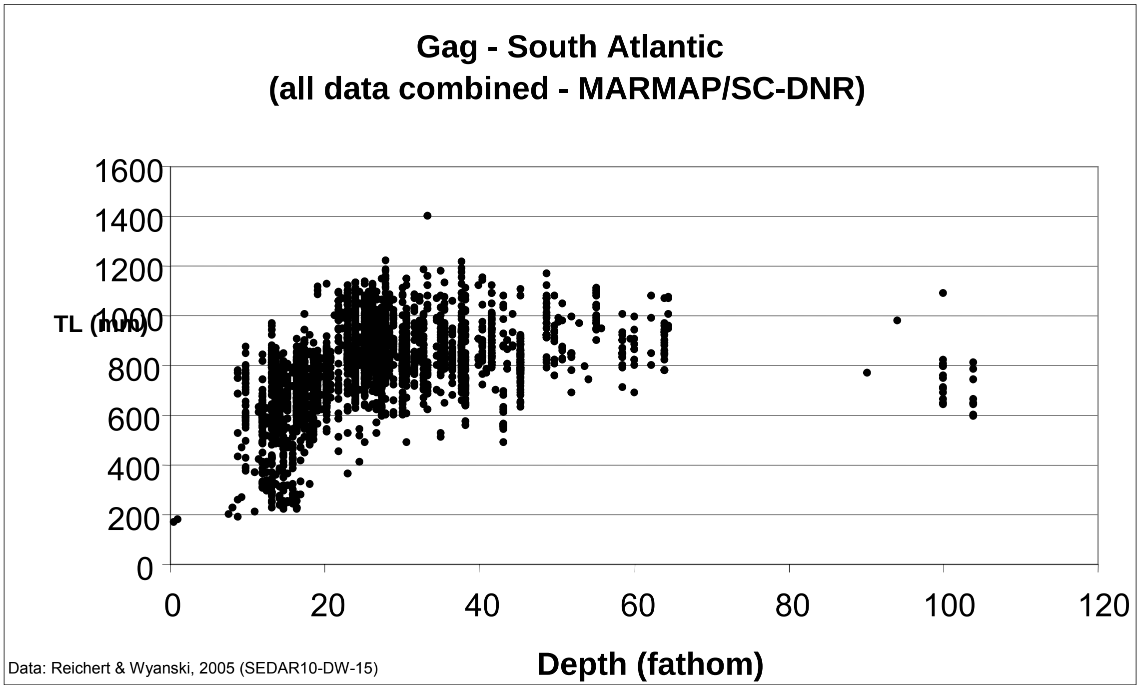

Figure 2.1. Gag total length (mm) plotted with depth (fm) for the South Atlantic. All gears were combined (fishery-independent and dependent) thus accounting for occurrences of undersized fish (below about 500 mm TL).

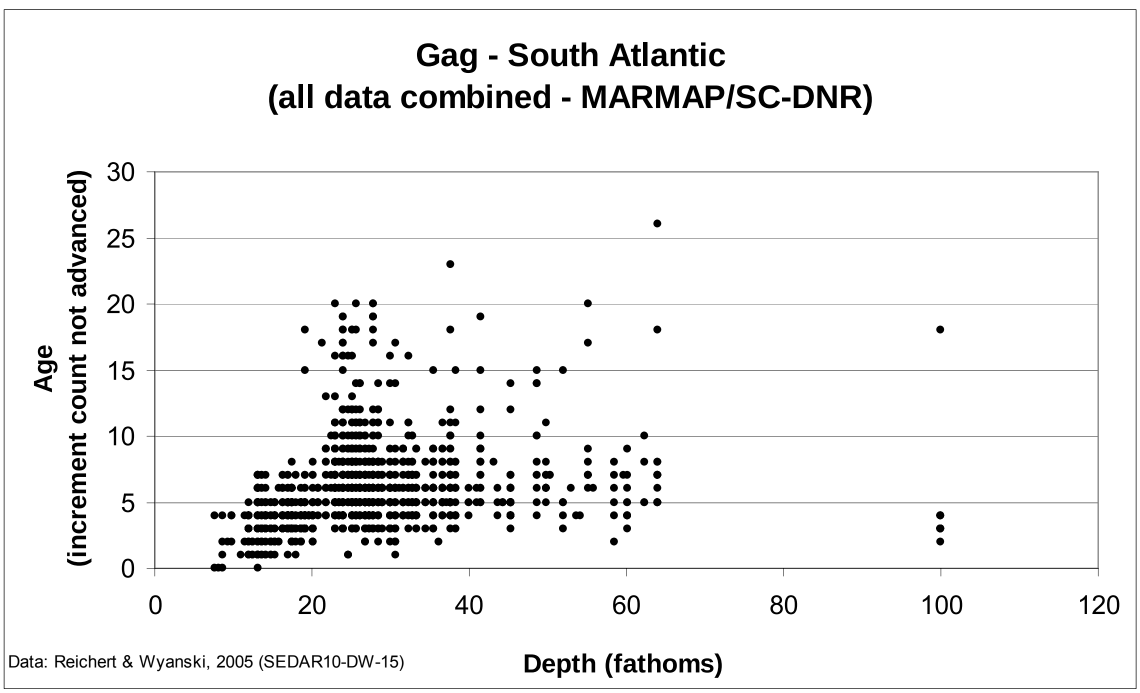

Figure 2.2. Gag age (increment count) plotted with depth (fm) for the South Atlantic. All gears combined (fishery-independent and dependent)

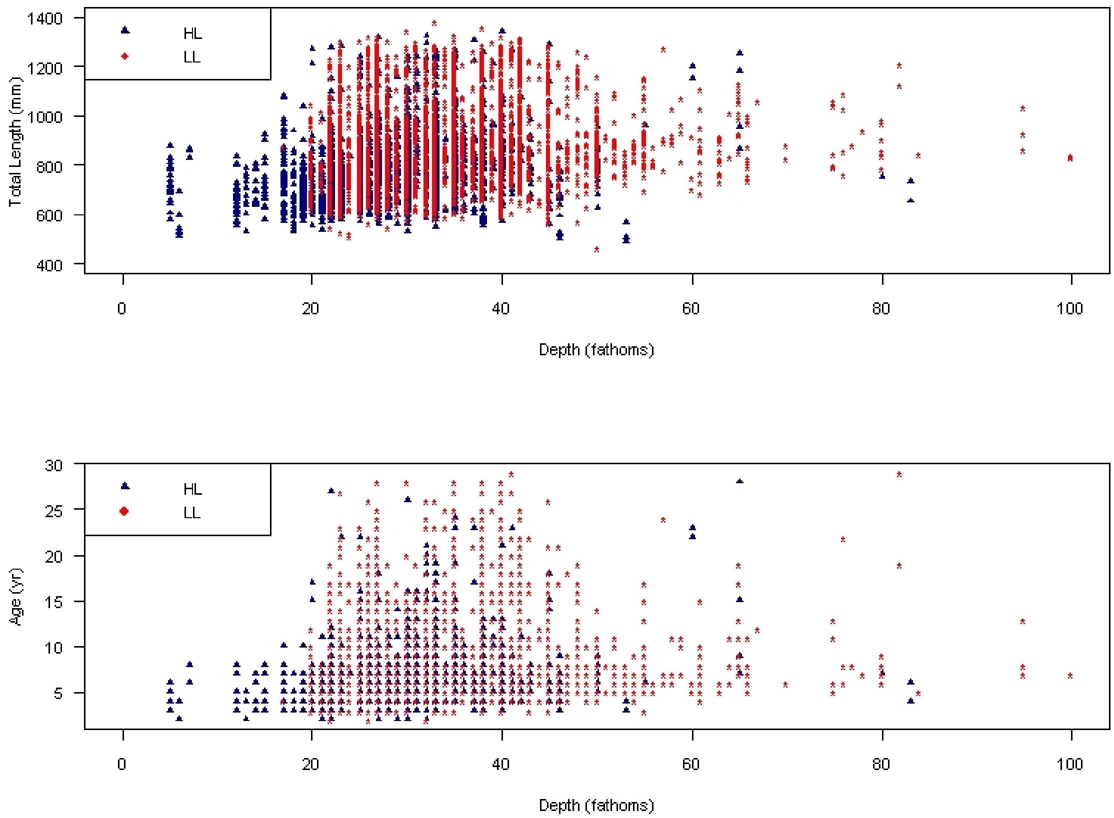

Figure 2.3. Age and length plotted with depth (fm) for the Gulf of Mexico for long-line (LL) and handline (HL) fisheries.

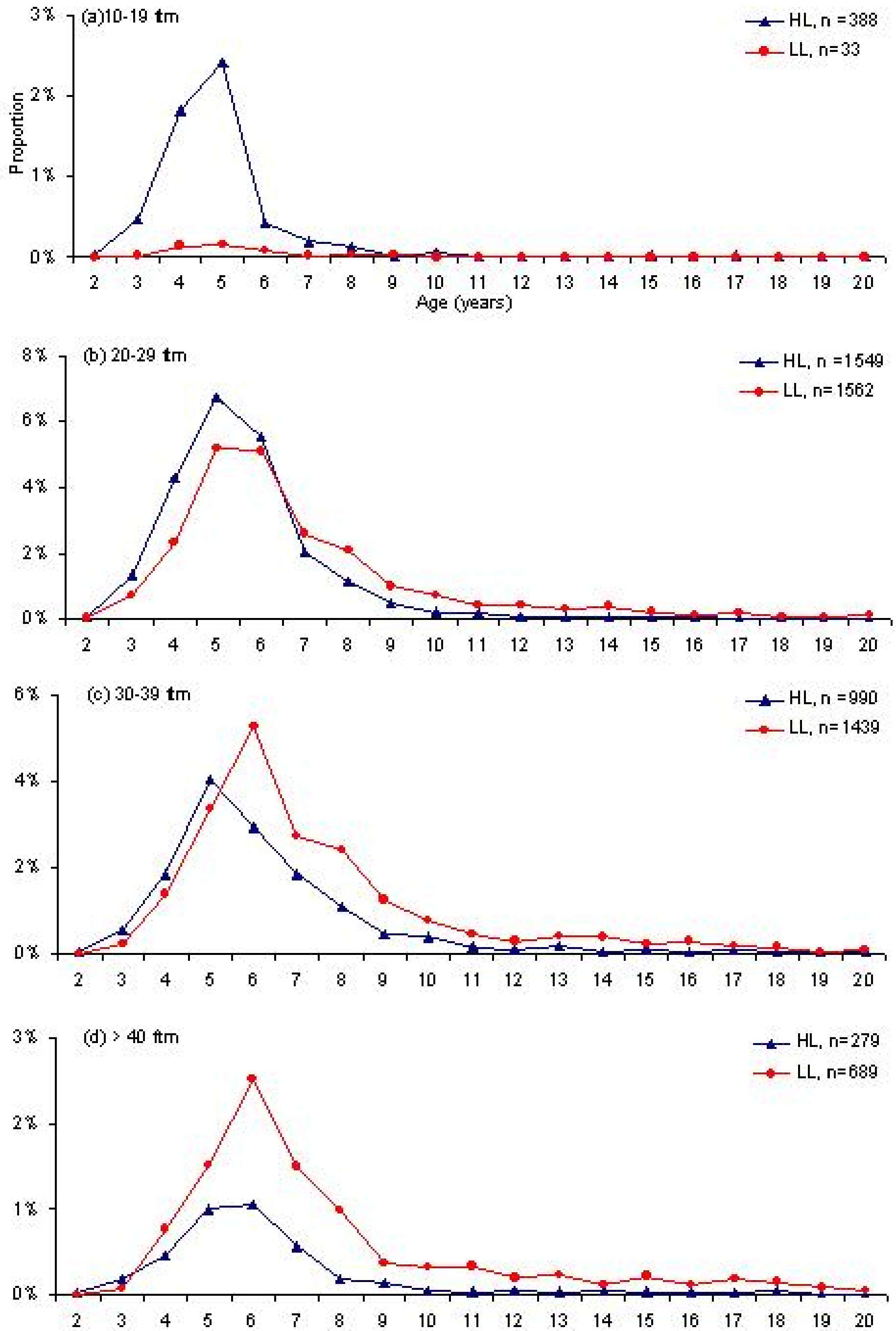

Figure 2.4. Age data proportioned to the depth (fm) fished and commercial gear type. Depth categories in 10-fm bins. Scales on y-axis vary.

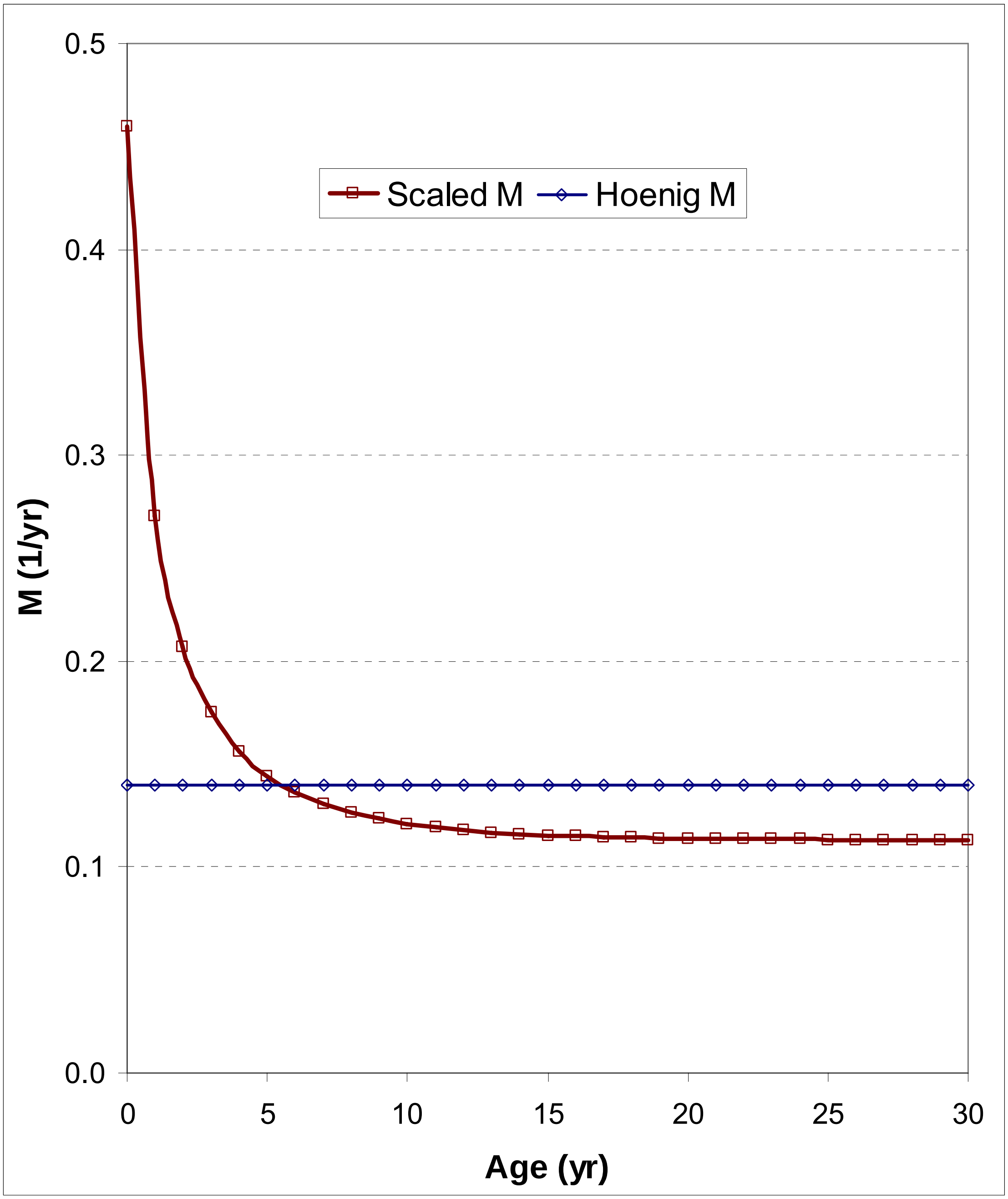

Figure 2.5. Age-varying estimates of South Atlantic gag grouper natural mortality based on Lorenzen's method (1996), re-scaled to 1.3% survival to oldest observed age (30), so as to be equivalent to the constant M (0.14 for maximum age of 30) from Hoenig (1983).

Table 2.1. Gag reproductive biology analysis – probit analysis – from the South Atlantic (SCDNR data – SEDAR10-DW15).

Analysis	Period	Cumul. Distrib.	N	Intercept	Standard Error	Independent variable	Standard Error
Age (count) at sex transition	1977-82	Normal	322	-3.37	0.41	0.287	0.047
	1994-95	Normal	1508	-4.26	1.03	0.406	0.129
	2004-05	Normal	1048	-4.60	0.28	0.474	0.036
	all	Normal	2878	-4.16	0.49	0.398	0.061
Total length at sex transition	1977-82	Logistic	501	-22.94	2.17	0.023	0.002
	1994-95	Normal	3836	-13.93	0.89	0.014	0.001
	2004-05	Logistic	1004	-29.45	3.82	0.028	0.004
	all	Logistic	5341	-19.29	0.60	0.018	0.001
Age (count) at maturity	1977-82	Logistic	329	-8.34	1.37	2.239	0.334
	1994-95	Logistic	1439	-6.42	0.77	2.442	0.227
	2004-05	Gompertz	1276	-5.41	0.48	1.594	0.136
	all	Logistic	3044	-7.68	0.81	2.529	0.240
Total length at maturity	1977-82	Gompertz	472	-9.60	1.37	0.015	0.002
	1994-95	Gompertz	3679	-12.68	1.01	0.020	0.002
	2004-05	Logistic	1239	-32.37	2.37	0.048	0.004
	all	Logistic	5390	-24.91	2.19	0.038	0.003

Table 2.2. Meristic regressions for gag from the Gulf of Mexico (1991-2005). Refer to SEDAR-10-DW-2, for details.

Gulf of Mexico

Conversion and Units	Equation	Sample Size	r^2 values	Data Ranges
FL (mm) to TL (mm)	TL = 1.03 * FL – 0.68	4999	0.99	TL (mm): 245 – 1360 FL (mm): 238 – 1321
TL (mm) to W. Wt (kg)	W. Wt = $1 \times 10^{-08} * (TL^{\wedge 3.03})$	4922	0.97	TL (mm): 245 – 1360 W. Wt (kg): 0.23 – 32.74
FL (mm) to W. Wt (kg)	W. Wt = $1 \times 10^{-08} * (FL^{\wedge 3.02})$	3809	0.97	FL (mm): 217 – 1321 W. Wt (kg): 0.13 – 32.74
TL (mm) to G. Wt (kg)	G. Wt = $1 \times 10^{-08} * (TL^{\wedge 2.99})$	527	0.96	TL (mm): 446 – 1295 G. Wt (kg): 0.99 – 27.02
FL (mm) to G. Wt (kg)	G. Wt = $9 \times 10^{-9} * (FL^{\wedge 3.05})$	2407	0.98	FL (mm): 432 – 1335 G. Wt (kg): 0.99 – 32.21
SL (cm) to TL (cm) *for age-0 gag only*	TL = 1.85 * SL – 0.23	165	0.99	SL (cm): 2.5-10.0 TL (cm): 3.1-12.1

Table 2.3. Length-length and weight-weight regressions (no-intercept) for gag from the South Atlantic.

Sources	Ind. Var.	Dep. Var.	N	Parameter	S.E.	Adj. R^2	Pr > F
Length-Length Regressions:							
FL FWCC (n=176), SC DNR (MARMAP; n=3301), Headboat (n=215)	TL (mm)	FL (mm)	3692	1.0341	0.00020	0.9999	<0.0001
FL FWCC (n=145) & SC DNR (MARMAP; n=3582)	TL (mm)	SL (mm)	3727	1.1908	0.00044	0.9999	<0.0001
Whole Weight (WW)-Gutted Weight (GW):							
SC DNR (MARMAP)	WW (kg)	GW (kg)	136	1.0585	0.0014	0.9998	<0.0001

Note: WW = whole weight; GW = gutted weight
TL = total length; FL = fork length; SL = standard length

Table 2.4. Linearized weight-length regressions for gag from the South Atlantic.

Source	Ind. Var.	Dep. Var.	N	Intercept	S.E. Int	Slope	S.E. Slope	MSE	Adj. R^2	Pr > F
SC DNR (MARMAP; n=4020), Headboat (n=11915), TIP (n=539)	ln(WW)	ln(TL)	16474	-17.843	0.040	2.943	0.006	0.047	0.933	<0.0001
SC DNR (MARMAP; n=2348), MRFSS (n=1334)	ln(WW)	ln(FL)	3682	-15.688	0.113	2.633	0.017	0.100	0.863	<0.0001
SC DNR (MARMAP)	ln(WW)	ln(SL)	2248	-17.332	0.066	2.949	0.010	0.020	0.9735	<0.0001

Note: WW = whole weight; TL = total length; FL = fork length; SL = standard length

Table 2.5. Summary of South Atlantic gag grouper life history values used in the statistical catch-at-age model. Lorenzen natural mortality (M) values are from Lorenzen (1996), while the scaled M are these values re-scaled to 1.3% surviving to age 30, and equivalent to the cumulative mortality from Hoenig (1983).

Age (years)	Total Length (mm)	Weight (kg)	Lorenzen M	Hoenig M		Scaled M
0	220.3	0.143	6.67	0.14		0.46
1	397.5	0.815	3.93	0.14		0.27
2	537.0	1.974	3.00	0.14		0.21
3	646.6	3.411	2.54	0.14		0.17
4	732.9	4.931	2.27	0.14		0.16
5	800.8	6.400	2.09	0.14		0.14
6	854.2	7.738	1.98	0.14		0.14
7	896.2	8.912	1.89	0.14		0.13
8	929.2	9.914	1.83	0.14		0.13
9	955.2	10.752	1.79	0.14		0.12
10	975.6	11.444	1.75	0.14		0.12
11	991.7	12.008	1.73	0.14		0.12
12	1004.4	12.464	1.71	0.14		0.12
13	1014.3	12.831	1.69	0.14		0.12
14	1022.1	13.125	1.68	0.14		0.12
15	1028.3	13.359	1.67	0.14		0.12
16	1033.1	13.545	1.67	0.14		0.11
17	1037.0	13.692	1.66	0.14		0.11
18	1040.0	13.809	1.66	0.14		0.11
19	1042.3	13.901	1.65	0.14		0.11
20	1044.2	13.974	1.65	0.14		0.11
21	1045.6	14.032	1.65	0.14		0.11
22	1046.8	14.077	1.65	0.14		0.11
23	1047.7	14.113	1.65	0.14		0.11
24	1048.4	14.141	1.64	0.14		0.11
25	1048.9	14.163	1.64	0.14		0.11
26	1049.4	14.181	1.64	0.14		0.11
27	1049.7	14.194	1.64	0.14		0.11
28	1050.0	14.205	1.64	0.14		0.11
29	1050.2	14.214	1.64	0.14		0.11
30	1050.4	14.220	1.64	0.14		0.11
			62.97	4.34	sum=	4.34
				0.013	exp(-sum)=	0.013

3 Commercial Fishery

3.1 Overview

A series of issues were discussed by the Commercial Working Group concerning stock boundaries between Gulf of Mexico and U.S. South Atlantic, the misidentification of gag as black grouper, and adjusting gag landings to include a portion of unclassified grouper species (primarily historical unclassified grouper landings prior to the mid-1980s). To adjust gag grouper for unclassified groupers, landings of all classified groupers are necessary (see grouper species codes in Table 3.1). Final adjusted commercial gag landings are then presented as a series of tables and figures for the U.S. South Atlantic gag grouper stock. Estimated discards are presented for recent years (2001-2004) subsequent to the last change in minimum size limit for the U.S. South Atlantic coast. The next section presents summaries of sampling intensity and annual length frequency distributions by gear. Several research recommendations are given.

3.2 Commercial Landings

The first discussion by the Commercial Working Group concerned the separation of stock boundary between U.S. South Atlantic and Gulf of Mexico waters. The Working Group decided to base it on the SAFMC-GMFMC boundary by using water body code designations found along the Florida Keys (Monroe County). Essentially, Florida Bay and waters north and west of the Florida Keys are designated in the Gulf of Mexico, while waters south and east of the Keys are designated in the South Atlantic. For historical landings data (1962-1992) from the Florida Atlantic (east) Coast, the water bodies are identified as 0010, 0019, 0029, 7200-7510, 7994, 7996, and also 0000, 9999 when the state was identified as code 10. Florida Gulf (west) Coast water bodies, specifically for the Florida Keys, are identified as 0011, 0018, 0020 and 0028 and a general Gulf of Mexico code of 5000. The data source for the water body allocations for Florida comes from the Florida General Canvass for the years 1977-1992. 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 the years 1993-2004 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 the state of Florida. 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.

The issue of misidentification of gag with black grouper was discussed by the Working Group at length. The discussions were based on the report SEDAR10-DW-24 for the Gulf of Mexico and following the Data Workshop a report was prepared for the U.S. South Atlantic: SEDAR10-DW-28). The following decisions were made by state. With minimal landings of black grouper reported for Georgia and South Carolina, no correction to gag grouper landings for black grouper misidentification was deemed necessary. In most years North Carolina generally had minimal landings of black grouper. However, as later noted in SEDAR10-DW-28, there major exceptions; i.e., large reported landings of black grouper were found for 1981-1985 and 1992-1993. These were deemed anomalous by the Commercial Working Group and all black grouper landings for these years in North Carolina were assigned to gag grouper landings.

The proportion of gag grouper misidentified as black grouper were calculated from TIP observation weights for fish identified as gag by samplers, but identified by the dealer as black grouper in the TIP landings data (Table 3.2; Figure 3.3). The observation weight of the fish identified by dealers as black grouper were divided by the combined observation weight of fish identified by dealers as gag grouper and those identified by dealers as black grouper (comparable to Method 2 in SEDAR10-DW-28). The proportions were calculated from observations in kilograms whole weight. The proportions showed no defined trend over time, so the decision was made not to make any additional adjustments to gag grouper landings for misidentification in the South Atlantic, especially as regards Florida Atlantic Coast. In particular, there were only two counties for FL for which TIP data could be linked to Florida trip ticket data resulting in small sample size: 62 blacks in TIP of which 21 should have been gag for 1984-2003 data. As judged during the DW, this was insufficient to apply a correction to black grouper landings to be treated as gag landings.

The decision was made to present all landings in gutted weight. The standard conversion of groupers for Georgia and Florida from whole weight to gutted weight is by dividing whole weight by 1.18. South Carolina uses a conversion of 1.11, while North Carolina uses a conversion of 1.25. 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. Their data suggest a conversion of 1.0585 (SE = 0.0014) using a no-intercept regression with sample size of 136 (see Section 2).

Numerical gear codes for grouper (gag, unclassified, and other classified groupers) were divided into five categories: handline (600-660), longline (675-677), diving (760, 943), trawls (200-299), and other (remaining gear codes). Small amounts of unknown (999) landings have been proportioned among known gears for that year. Historical annual gear data from Florida were used to distribute Florida ALS landings among the various gears for 1976-1996.

With the adjustments to North Carolina for black grouper in 1981-1985 and 1991-1992 and distribution of unknown gear (999) for Florida during 1976-1996, tables of "unadjusted" gag landings were developed (Tables 3.3; Figures 3.4-3.5).

A proportion of the unclassified grouper landings (1410) were then converted to gag grouper. Annual proportions or ratios were developed for each gear and state by comparing gag grouper landings to all classified groupers (1411-1430). Warsaw and goliath groupers were not included among classified groupers because they were identified historically back to 1962, while other groupers were classified beginning in the early 1980s. Summaries of unclassified and classified groupers are shown in Figures 3.6-3.8.

When gag grouper are classified in the same year as unclassified grouper, we used that year's ratio of gag/total classified grouper landings to separate out gag from unclassified grouper. For earlier years (generally 1962-1980), the Working Group recommended use of the average proportion across years for each state and gear starting with the earliest year of classified gag grouper (generally 1981) through 1991 (management changed in 1992). When no classified grouper (including gag grouper) are given for a state, gear, year combination, then that value is treated as a missing value in calculating the average ratio.

Adjusted landings are presented summarized for the U.S. South Atlantic by gear in Table 3.4 and by gear and area in Figures 3.9-3.10. A comparison of unadjusted to adjusted gag grouper landings in the U.S. South Atlantic is presented in Figure 3.11. Lower and upper bounds on the adjusted gag landings were developed from the unclassified groupers converted to gag. These bounds are based on the mean ratios plus or minus twice the standard deviation applied to the historical conversions. The lower bound on adjusted gag grouper landings are presented in Table 3.5 and Figures 3.12-3.13, while the upper bound on adjusted gag grouper landings are presented in Table 3.6 and Figures 3.14-3.15. The range in adjusted gag grouper landings for the U.S. South Atlantic are shown in Figure 3.16.

One final modification was made to commercial landings as used in the assessment models during the Assessment Workshop. No landings were recorded for 1977-1978 and 1980 for diving gear, while positive landings were determined before and after these years (1976, 1979, 1981-2004). Thus an adjustment was deemed necessary by the Assessment Workshop group, who replaced the zero landings for commercial diving with a linear interpolation of adjusted landings for this gear based on landings recorded before and after. For the base landings (see Table 3.4), 0 landings for 1977 became 8,810 pounds gutted weight, for 1978 – 13,867 pounds, and for 1980 – 16,404 pounds.

A final adjustment made to commercial landings were to estimate gag landings in numbers based on average weight (gutted) from the TIP data based for each state, gear, and year. These data was generally available from 1984 to 2004 for handlines (1983 for NC, and 1985 for FL). Data for the remaining gears were sparse, with data available from longlines (1984-1998, 2002), diving (1986-1987, 1991-2004), and trawl (1984, 1986-1988) were available. For earlier years and missing later years, annual averages for each state and gear were used. When a single year was missing bounded by estimates, the average of these neighboring years was used. Average weights are summarized in Table 3.7, and gag landings in numbers are summarize in Table 3.8 and Figures 3.17-3.18.

For detailed description of the Accumulated Landing System (ALS), see addendum to this section.

3.3 **Commercial Discards**

In the south Atlantic, gag grouper trips were defined as handline trips where four or fewer lines were fished, with three or fewer hooks per line, the reported days at sea was eight or less, and the number of crew members was four or less. Data from all trips that reported to the coastal logbook discard program and that met these criteria were considered gag grouper trips. The number of gag grouper discards reported from those trips, including trips with no gag discards, was used to calculate the mean number of discards per trip. Similarly, trips reporting to the coastal logbook program that met the above criteria for a gag grouper trip were used to determine the total number of gag grouper trips taken in the Gulf of Mexico and south Atlantic.

Minimum size limit regulations came into effect in the south Atlantic in February 1999. As no size information is reported to the coastal logbook discard program, discard calculations were restricted to the period March 1999-December 2004 for the south Atlantic.

As in the Gulf of Mexico, GLM analyses of the proportion of successful trips (trips that discarded gag grouper) and the catch rates on successful trips were conducted. Significant factors included year, area fished, days at sea, number of crew, and discard period (August-December or January-July of each year). Subdividing the data by so many factors again resulted in many of the strata containing no observations. Only year, area fished, and number of crew could be used to stratify these data and still retain sufficient sample size for calculation of mean discards per stratum. Discard calculations were made by multiplying the total number of trips in a stratum by the mean number of discards from trips in the same stratum. Strata in the south Atlantic were year/area/crew combinations where area was defined as:

Area 24 = south Atlantic statistical grids greater than 2300 and less than 2600
Area 26 = south Atlantic statistical grids greater than 2600 and less than 3200
Area 32 = south Atlantic statistical grids greater than 3200 and less than 3300
Area 33 = south Atlantic statistical grids greater than 3300 and less than 3400
Area 34 = south Atlantic statistical grids greater than 3400 and less than 3700

The number of crew was divided into classes defined as: 1 = 1 crew member, 2 = 2 crew members, and 3 = 3-4 crew members.

Calculations of discards during the period 2001-2004 (the period when discards were reported to the coastal logbook program) are provided in Table 3.10 for the south Atlantic. Discard reporting began August 1, 2001. As was done for the Gulf of Mexico data, the discard calculation for 2001 uses the mean gag discards determined for the period August 1, 2001-December 31, 2001 multiplied by the total number of gag grouper trips reported to the coastal logbook program during 2001.

For the south Atlantic, numbers of gag discarded were also calculated for the two years prior to the beginning of the discard program (1999-2000) because the size limit was the same in much of that period as it was in the period when discard reports were obtained. The mean number of discards for the entire period, 8/1/01-12/31/04, was determined for each area fished-crew size stratum. Those values were multiplied by the number of handline trips per year in the corresponding strata (Table 3.11). Yearly total numbers of discarded gag were calculated by summing all the calculated discards for each year (Tables 3.12).

South Atlantic discards were reported as “all alive” for approximately 53% of the gag released. Another 16% of gag were reported as “majority alive” at release. Only 0.25% of released gag were reported as “all dead”, while 26.7% were reported as “majority dead”. A further 3.7% of gag were reported as “kept, not sold”. The final 0.5% of gag grouper were reported as “unable to determine” or the condition of the released fish was not reported. Most gag grouper discards (94.5%) were reported as “due to regulations” and 4.5% were reportedly discarded “due to market conditions”.

3.4 Biological Sampling

A number of issues for developing length compositions were discussed by the Commercial Working Group. Lengths from Monroe County without identified water body were deleted. When gear code missing, the dominant gear for that cell was assigned. Fork lengths and standard lengths were converted to total lengths (see Section 2). We deleted any total lengths less than 30 cm TL (12” or 15 records) and any lengths greater than 150 cm TL (about 40 records). Length compositions are presented in 1 cm (10 mm) bin size.

3.4.1 Sampling Intensity Length

Sample sizes are summarized in Table 3.9 by gear, state and year for length data available for gag in the U.S. South Atlantic from the TIP data base.

3.4.2 Length/Age Distribution

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

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

Annual length compositions for commercial handlines are shown weighting by the product of the landings in numbers and trip catch in numbers (Figure 3.19). Annual length compositions for commercial longline (Figure 3.20) and diving (Figure 3.21) are also summarized using weighting by landings in numbers and by trip catch in numbers.

Annual age compositions and sample sizes for commercial handlines are shown Figure 3.22 weighting by length compositions shown in Figures 3.19. This corrects for a sampling bias of age samples relative to length samples (SEDAR10-DW-23). Annual age compositions and sample sizes for commercial diving are shown in Figure 3.23. The bias noted in commercial handline age samples was not apparent for commercial diving age samples, so weighting was by state landings in numbers.

3.4.3 Adequacy for characterizing lengths

Generally sample sizes for length composition may be adequate for the handline component of the commercial fishery (Table 3.9). More limited length compositions are available for longline and diving, with minimal information for trawl. Handline length compositions may need to be used to represent length compositions for these other specified gears. Any representation of length composition for the 'other' gear category will be based on handline gear.

3.5 Research Recommendations

- Increase sampling for otoliths for aging
- Improve at-sea observation for discards
- Continued education of samplers for species identification
- Conversions needed for different market categories (gutted, headed, filleted, whole weight).

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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 is not available.

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

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

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

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

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

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

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

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

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

Cooperative Statistics Program
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In the early 1980s, it became apparent that the collection of commercial fisheries statistics was an activity that was conducted by both the Federal government and individual state fishery agencies. Plans and negotiations were initiated to develop a program that would provide the fisheries statistics that are needed

for management by both Federal and state agencies. By the mid- 1980s, formal cooperative agreements had been signed between the NMFS/SEFSC and each of the eight coastal states in the southeast, Puerto Rico and the US Virgin Islands.

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

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

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

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

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. In order to make that determination you must consider the area of capture.

Florida Annual Canvass 1976-1996 considerations:

1. 1976-1985 Data is as landed weight which was normally landed in a gutted condition. To convert to whole weight, a factor of 1.18 is universally applied.
2. State 00 and Grid 0000 in the data set are marine product landed else where and trucked into the State of Florida and are considered duplicated else where because they are theoretically reported back to the State of landing and are not included in the Florida totals.
3. State 12 is in the data set which represents Florida interior counties which were landed on Florida East Coast and not included in the Gulf catches.

Table 3.1. Grouper codes for general canvass and TIP data bases. Code 1410 is referred to as unclassified groupers. Remaining codes refer to classified groupers. As noted in text, codes 1850 and 4740 were not included with classified groupers.

Numeric Code	Common Name	Scientific Name
1410	GROUPERS	Serranidae
1411	HIND,SPECKLED	Epinephelus drummondhayi
1412	HIND,ROCK	Epinephelus adscensionis
1413	HIND,RED	Epinephelus guttatus
1414	GROUPER,SNOWY	Epinephelus niveatus
1415	GROUPER,YELLOWEDGE	Epinephelus flavolimbatus
1416	GROUPER,RED	Epinephelus morio
1417	GROUPER,MARBLED	Epinephelus inermis
1418	GROUPER,BROOMTAIL	Mycteroperca xenarcha
1419	GROUPER, TIGER	Mycteroperca tigris
1420	GROUPER,MISTY	Epinephelus mystacinus
1422	GROUPER,BLACK	Mycteroperca bonaci
1423	GROUPER,GAG	Mycteroperca microlepis
1424	SCAMP	Mycteroperca phenax
1425	GROUPER,YELLOWMOUTH	Mycteroperca interstitialis
1426	GROUPER,YELLOWFIN	Mycteroperca venenosa
1427	CREOLE-FISH	Paranthias furcifer
1428	GRAYSBY	Epinephelus cruentatus
1429	CONEY	Epinephelus fulvus
1430	GROUPER,NASSAU	Epinephelus striatus
1850	JEWFISH	Epinephelus itajara
4740	GROUPER,WARSAW	Epinephelus nigritus

Table 3.2. Proportion of gag grouper misidentified as black grouper by year and state in the South Atlantic, derived from TIP observation weights.

	FL		NC	
Year	Proportion by weight	Proportion by number	Proportion by weight	Proportion by number
1984	-	-	-	-
1985	-	-	-	-
1986	0.12	0.24	0.95	0.96
1987	-	-	-	-
1988	-	-	-	-
1989	-	-	-	-
1990	-	-	-	-
1991	-	-	-	-
1992	-	-	-	-
1993	0.00	0.00	1.00	0.99
1994	-	-	-	-
1995	-	-	-	-
1996	0.00	0.00	0.98	0.96
1997	-	-	-	-
1998	0.01	0.01	0.42	0.31
1999	0.02	0.03	0.36	0.35
2000	-	-	-	-
2001	0.00	0.00	0.59	0.60
2002	-	-	-	-
2003	0.00	0.00	0.12	0.08
2004	0.11	0.20	0.66	0.65

Table 3.3. Unadjusted gag landings (gutted weight in pounds) by gear from the U.S. South Atlantic, 1962-2004.

Year	Handline	Longline	Diving	Trawl	Other	Total
1962	0	0	0	0	0	0
1963	0	0	0	0	0	0
1964	0	0	0	0	0	0
1965	0	0	0	0	0	0
1966	0	0	0	0	0	0
1967	0	0	0	0	0	0
1968	0	0	0	0	0	0
1969	0	0	0	0	0	0
1970	0	0	0	0	0	0
1971	0	0	0	0	0	0
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1974	0	0	0	0	0	0
1975	0	0	0	0	0	0
1976	0	0	0	0	0	0
1977	0	0	0	0	0	0
1978	0	0	0	0	0	0
1979	0	0	0	0	0	0
1980	97343	0	0	13438	0	110781
1981	376302	585	0	30557	0	407445
1982	446439	3821	0	39059	15	489335
1983	434380	38620	0	14285	40	487325
1984	499664	17391	168	8496	160	525878
1985	480070	2678	0	1851	0	484599
1986	677675	12450	5129	3796	221	699271
1987	654456	81787	18835	3145	701	758925
1988	450071	53576	12244	2299	1467	519656
1989	812541	13730	21217	0	8697	856185
1990	655525	20753	14651	0	7386	698314
1991	555877	9987	77745	0	31353	674962
1992	626150	5028	99684	0	261	731122
1993	690948	5317	74952	0	612	771829
1994	774301	3840	93297	0	5685	877124
1995	812289	3814	81806	0	2550	900459
1996	726243	3808	115318	0	3213	848582
1997	560531	4087	97981	0	3219	665817
1998	631418	5483	137973	1517	9175	785565
1999	525550	1758	113107	0	3803	644218
2000	424637	5065	62776	0	2973	495450
2001	438108	5843	82119	282	3245	529598
2002	439779	4570	84349	341	1897	530937
2003	437421	4488	117175	303	949	560337
2004	473521	1439	74794	0	801	550555

Table 3.4. Adjusted gag landings (gutted weight in pounds) by gear from the U.S. South Atlantic, 1962-2004.

Year	Handline	Longline	Diving	Trawl	Other	Total
1962	150340	0	0	0	0	150340
1963	136532	445	0	0	0	136977
1964	128068	45	0	0	277	128391
1965	130127	0	0	0	277	130404
1966	98769	0	0	0	344	99112
1967	209806	0	0	0	1125	210931
1968	308423	0	0	0	1500	309923
1969	210436	57	0	0	6675	217169
1970	282848	0	0	0	16186	299034
1971	299860	0	0	0	6864	306724
1972	170659	0	0	0	33820	204479
1973	283839	0	0	332	6322	290493
1974	371185	0	0	0	1581	372766
1975	420101	0	0	1478	187	421765
1976	555369	0	3753	7846	1829	568797
1977	576162	0	0	45946	5463	627571
1978	946541	117	0	5158	15581	967398
1979	881766	0	18924	12988	12795	926473
1980	775295	1857	0	63167	5833	846152
1981	885267	1346	13883	85746	11627	997870
1982	968907	4653	15849	49581	4289	1043280
1983	1026062	39800	9077	32235	3004	1110179
1984	1057420	21899	18746	13870	14999	1126933
1985	848082	3790	11620	4267	9583	877341
1986	802913	12593	6342	4080	252	826180
1987	767155	86745	21931	3145	736	879712
1988	610624	56387	12961	3768	1608	685349
1989	943975	13797	22258	0	9242	989272
1990	755466	21392	19066	0	7441	803365
1991	613752	10216	85011	0	32462	741441
1992	686335	5041	106759	13	276	798424
1993	750575	5428	78151	0	623	834777
1994	790311	3958	97503	0	5762	897533
1995	833996	3862	83766	0	2570	924195
1996	744817	3856	118564	0	3224	870462
1997	600875	4121	98706	0	3223	706924
1998	638227	5506	138788	1517	9210	793247
1999	532500	1764	113495	0	3815	651573
2000	430165	5082	63024	0	2978	501250
2001	440693	5858	82299	282	3250	532382
2002	441514	4579	84525	341	1900	532860
2003	438153	4498	117412	303	950	561317
2004	474142	1443	74967	0	802	551354

Table 3.5. Lower bound of adjusted gag landings (gutted weight in pounds) by gear from the U.S. South Atlantic, 1962-2004.

Year	Handline	Longline	Diving	Trawl	Other	Total
1962	41502	0	0	0	0	41502
1963	37694	0	0	0	0	37694
1964	35544	0	0	0	0	35544
1965	44476	0	0	59	0	44535
1966	28024	0	0	0	0	28024
1967	56533	0	0	0	0	56533
1968	97730	0	0	16057	43	113830
1969	59020	0	0	0	3190	62210
1970	77814	0	0	0	8320	86133
1971	84534	0	0	410	2931	87876
1972	48412	0	0	0	16518	64929
1973	98366	0	0	245	0	98611
1974	127097	0	0	0	684	127781
1975	125340	0	0	1091	0	126431
1976	202540	0	1617	2777	183	207117
1977	247436	0	0	23982	0	271418
1978	471228	0	0	2006	0	473234
1979	440701	0	8154	9588	0	458443
1980	550859	1278	0	55795	20	607953
1981	667469	585	5982	85746	0	759782
1982	750907	3849	6829	49581	15	811182
1983	745620	39246	3911	32235	56	821069
1984	803072	20833	8173	13870	400	846348
1985	684596	2856	5007	4267	0	696726
1986	802913	12593	6342	4080	252	826180
1987	767155	86745	21931	3145	736	879712
1988	610624	56387	12961	3768	1608	685349
1989	943975	13797	22258	0	9242	989272
1990	755466	21392	19066	0	7441	803365
1991	613752	10216	85011	0	32462	741441
1992	686335	5041	106759	13	276	798424
1993	750575	5428	78151	0	623	834777
1994	790311	3958	97503	0	5762	897533
1995	833996	3862	83766	0	2570	924195
1996	744817	3856	118564	0	3224	870462
1997	600875	4121	98706	0	3223	706924
1998	638227	5506	138788	1517	9210	793247
1999	532500	1764	113495	0	3815	651573
2000	430165	5082	63024	0	2978	501250
2001	440693	5858	82299	282	3250	532382
2002	441514	4579	84525	341	1900	532860
2003	438153	4498	117412	303	950	561317
2004	474142	1443	74967	0	802	551354

Table 3.6. Upper bound of adjusted gag landings (gutted weight in pounds) by gear from the U.S. South Atlantic, 1962-2004.

Year	Handline	Longline	Diving	Trawl	Other	Total
1962	259178	0	0	0	0	259178
1963	235370	1970	0	0	0	237340
1964	220592	201	0	0	1226	222020
1965	215777	0	0	90	18866	234733
1966	169514	0	0	0	1646	171160
1967	363079	0	0	0	5459	368537
1968	519117	0	0	24660	6412	550189
1969	361853	169	0	0	17466	379488
1970	487882	0	0	0	36407	524289
1971	515186	0	0	630	19662	535478
1972	292906	0	0	0	43098	336005
1973	469312	0	0	376	14575	484263
1974	615272	0	0	0	3228	618500
1975	714862	0	0	1676	932	717470
1976	908199	0	5888	9056	7075	930218
1977	904888	0	0	52620	24162	981670
1978	1421855	353	0	5944	68891	1497043
1979	1322831	0	29693	14726	56572	1423822
1980	1092721	6429	0	64560	25801	1189512
1981	1103065	3958	21785	85746	51407	1265961
1982	1186908	7410	24869	49581	18913	1287680
1983	1306503	41700	14243	32235	13090	1407771
1984	1311767	25556	29320	13870	64945	1445457
1985	1011567	6994	18232	4267	42369	1083430
1986	802913	12593	6342	4080	252	826180
1987	767155	86745	21931	3145	736	879712
1988	610624	56387	12961	3768	1608	685349
1989	943975	13797	22258	0	9242	989272
1990	755466	21392	19066	0	7441	803365
1991	613752	10216	85011	0	32462	741441
1992	686335	5041	106759	13	276	798424
1993	750575	5428	78151	0	623	834777
1994	790311	3958	97503	0	5762	897533
1995	833996	3862	83766	0	2570	924195
1996	744817	3856	118564	0	3224	870462
1997	600875	4121	98706	0	3223	706924
1998	638227	5506	138788	1517	9210	793247
1999	532500	1764	113495	0	3815	651573
2000	430165	5082	63024	0	2978	501250
2001	440693	5858	82299	282	3250	532382
2002	441514	4579	84525	341	1900	532860
2003	438153	4498	117412	303	950	561317
2004	474142	1443	74967	0	802	551354

Table 3.7. Mean gutted weight (pounds) of fish by state and gear for the U.S. South Atlantic from the TIP data, 1962-2004.

	Florida (Atlantic)			**Georgia**				**South Carolina**				**North Carolina**	
Year	**Handline**	**Longline**	**Diving**	**Handline**	**Longline**	**Diving**	**Trawl**	**Handline**	**Longline**	**Diving**	**Trawl**	**Handline**	**Longline**
1983												12.6	
1984				15.4				17.3			10.5	13.3	23.3
1985	21.0	21.8		16.7				16.7	22.5			15.2	25.3
1986	19.0			14.7				17.7	24.3	10.4	16.4	10.2	
1987	10.7			16.5			7.5	17.1	20.2	12.0	19.6	10.2	22.7
1988	13.2			14.4				16.5	19.9		15.6	13.7	21.7
1989	15.3			16.5				15.3				12.5	17.7
1990	17.4							11.9	17.0			11.2	18.9
1991	15.6		12.6	15.8	10.4	5.3		11.4	21.0			11.5	19.6
1992	15.7	23.6	12.4	15.4				10.7		12.3		11.7	28.9
1993	17.6	20.1	15.6	15.4				9.7				11.4	16.5
1994	16.8	19.9	16.1	13.5	14.1	9.5		9.8				11.4	12.6
1995	19.5	23.0	13.4	16.6				11.5				11.9	21.5
1996	13.0	20.9	7.7	15.3				13.7		12.2		13.5	
1997	19.2	15.0	6.2	16.3				14.9				14.3	
1998	14.8	17.9	12.2	16.5				14.8	22.8			12.7	
1999	12.7		11.7					13.0				13.9	
2000	13.6		13.6	18.4				13.5				13.5	
2001	15.4		12.7	18.7				14.1				11.6	
2002	16.0	15.9	12.7	17.7				15.2				11.6	
2003	16.4		13.4	17.8				12.6				12.4	
2004	11.2			15.2				14.4		12.7		11.7	
Average	15.7	19.8	12.3	16.1	12.2	7.4	7.5	13.9	21.1	11.9	15.5	12.4	20.8

Table 3.8. Adjusted gag landings (numbers) by gear from the U.S. South Atlantic, 1962-2004.

Year	Handline	Longline	Diving	Trawl	Other	Total
1962	9576	0	0	0	0	9576
1963	8696	36	0	0	0	8732
1964	8165	4	0	0	18	8186
1965	8437	0	0	0	18	8454
1966	6329	0	0	0	23	6352
1967	13309	0	0	0	86	13395
1968	19958	0	0	0	96	20054
1969	13416	4	0	0	416	13835
1970	17996	0	0	0	1006	19002
1971	19171	0	0	0	428	19599
1972	10883	0	0	0	2149	13032
1973	18452	0	0	21	463	18936
1974	24333	0	0	0	105	24438
1975	27096	0	0	95	15	27206
1976	36264	0	190	494	116	37063
1977	38329	0	0	2921	348	41598
1978	66382	6	0	325	992	67705
1979	62392	0	956	837	815	64999
1980	55323	109	0	4051	372	59854
1981	63507	102	701	5500	740	70551
1982	69883	341	800	3190	273	74487
1983	72729	2817	458	2074	192	78270
1984	70002	1088	949	1311	960	74311
1985	49937	246	532	304	457	51476
1986	58849	541	340	253	14	59996
1987	59956	3988	1175	161	52	65331
1988	41737	2671	735	242	121	45506
1989	66044	784	1244	0	605	68678
1990	57449	1691	963	0	610	60713
1991	47921	664	4294	0	2348	55226
1992	56319	235	4955	1	18	61528
1993	64655	405	4064	0	37	69161
1994	68855	260	5291	0	454	74860
1995	63540	240	3796	0	184	67760
1996	54663	433	5736	0	241	61074
1997	38824	652	6570	0	212	46257
1998	45366	406	7778	92	644	54286
1999	39096	150	5746	0	299	45291
2000	31132	375	3195	0	219	34921
2001	32064	459	4235	15	217	36990
2002	32411	350	5374	19	124	38278
2003	33490	335	6266	17	59	40167
2004	36732	117	4099	0	71	41019

Table 3.9. Sample sizes for gag commercial length compositions by gear, state, and year from TIP data base for the U.S. South Atlantic, 1983-2004.

	DIVING			DIVING Total	Handline				Handline Total	Longline				Longline Total	TRAWL		TRAWL Total	Grand Total
Year	FLEC	GA	SC		FLEC	GA	NC	SC		FLEC	GA	NC	SC		GA	SC		
1983							116		116									116
1984						20	1206	1572	2798			42		42		16	16	2856
1985					509	105	906	1066	2586	68		31	4	103				2689
1986			32	32	66	118	877	357	1418				6	6		25	25	1481
1987			10	10	12	199	814	946	1971			131	2	133	10	11	21	2135
1988					27	121	508	474	1130			194	6	200		38	38	1368
1989					56	90	601	450	1197			44		44				1241
1990					79		491	180	750			39	19	58				808
1991	14	12		26	47	215	461	367	1090		2	32	2	36				1152
1992	28		24	52	426	102	303	377	1208	3		6		9				1269
1993	35			35	468	176	308	589	1541	22		5		27				1603
1994	33	4		37	156	123	541	374	1194	10	1	8		19				1250
1995	34			34	945	146	465	282	1838	55		36		91				1963
1996	43		32	75	361	137	204	901	1603	17				17				1695
1997	22			22	184	133	70	811	1198	20				20				1240
1998	11			11	146	115	139	883	1283	1			10	11				1305
1999	224			224	258		274	959	1491									1715
2000	198			198	387	9	365	830	1591									1789
2001	109			109	247	22	426	790	1485									1594
2002	59			59	67	63	311	587	1028	6				6				1093
2003	324			324	54	11	323	773	1161									1485
2004			78	78	10	76	890	645	1621									1699
Grand T	1134	16	176	1326	4505	1981	10599	14213	31298	202	3	568	49	822	10	90	100	33546

Table 3.10. Calculated numbers of gag grouper discards for the south Atlantic handline fishery by year, area fished, and number of crew. Mean gag discards per trip were calculated as the average discards reported for each year/area/crew size strata.

Year	Area	Crew	Handline Trips	Mean Gag Discards	Calculated Discards
2001	24	1	3072	0.002722	8
2001	24	2	3490	0.114141	398
2001	24	3	618	0.368182	228
2001	26	1	2370	0.041614	99
2001	26	2	1183	0	0
2001	26	3	645	0.6875	443
2001	32	1	14	2.5	35
2001	32	2	198	0.666667	132
2001	32	3	195	0.6	117
2001	33	1	121	5	605
2001	33	2	586	3.891304	2,280
2001	33	3	173	0	0
2001	34	1	188	12.5	2,350
2001	34	2	582	9.894073	5,758
2001	34	3	339	3.709667	1,258
2002	24	1	3116	0.054153	169
2002	24	2	3497	0.029955	105
2002	24	3	611	0.00974	6
2002	26	1	2711	0	0
2002	26	2	1256	0.897436	1,127
2002	26	3	565	0	0
2002	32	1	31	1	31
2002	32	2	187	2.04	381
2002	32	3	195	5.387097	1,050
2002	33	1	123	1.777778	219
2002	33	2	545	2.828519	1,542
2002	33	3	204	0	0
2002	34	1	231	3.273453	756
2002	34	2	812	6.410358	5,205
2002	34	3	393	3.356226	1,319
2003	24	1	3346	0.05947	199
2003	24	2	3452	0.061721	213
2003	24	3	675	0.109848	74
2003	26	1	2947	0	0
2003	26	2	1587	0.051613	82
2003	26	3	475	1.084507	515
2003	32	1	26	0	0
2003	32	2	201	0.866056	174
2003	32	3	90	6.443427	580
2003	33	1	164	0	0
2003	33	2	488	0.944444	461
2003	33	3	164	1.380952	226
2003	34	1	181	2.727273	494
2003	34	2	621	2.743199	1,704
2003	34	3	287	1.317485	378

Table 3.10. continued

Year	Area	Crew	Handline Trips	Mean Gag Discards	Calculated Discards
2004	24	1	2,664	0.098365	262
2004	24	2	3,525	0.143882	507
2004	24	3	549	0.235294	129
2004	26	1	2,784	0	0
2004	26	2	1,510	0.069547	105
2004	26	3	462	0.065574	30
2004	32	1	20	0	0
2004	32	2	145	1.5	218
2004	32	3	124	3.933333	488
2004	33	1	139	0	0
2004	33	2	627	2.863636	1,796
2004	33	3	213	1.6875	359
2004	34	1	215	2.833333	609
2004	34	2	548	4.925051	2,699
2004	34	3	239	0	0
Total			56,719		37,924

Table 3.11. Calculated numbers of gag grouper discards for the US south Atlantic handline fishery by year, area, and number of crew. Calculations for 1999 are for March-December, the period following imposition of a 24 inch minimum size limit for gag grouper. Mean gag discards per trip were calculated as the average discards reported for each area/crew size combination for the period August 2001-December 2004.

Year	Area	Crew	Handline Trips	Mean Gag Discards	Calculated Discards
1999	24	1	2,544	0.061875624	157
1999	24	2	3,406	0.089253029	304
1999	24	3	467	0.154778555	72
1999	26	1	2,090	0.001414064	3
1999	26	2	970	0.129894717	126
1999	26	3	430	0.470319635	202
1999	32	1	10	0.735294118	7
1999	32	2	148	1.38309202	205
1999	32	3	148	4.783180769	708
1999	33	1	92	2.885714286	265
1999	33	2	386	2.91621368	1,126
1999	33	3	162	0.8	130
1999	34	1	187	3.367712062	630
1999	34	2	581	5.038029619	2,927
1999	34	3	289	1.752192235	506
2000	24	1	2,954	0.061875624	183
2000	24	2	3,366	0.089253029	300
2000	24	3	509	0.154778555	79
2000	26	1	2,401	0.001414064	3
2000	26	2	1,072	0.129894717	139
2000	26	3	519	0.470319635	244
2000	32	1	23	0.735294118	17
2000	32	2	186	1.38309202	257
2000	32	3	178	4.783180769	851
2000	33	1	89	2.885714286	257
2000	33	2	491	2.91621368	1,432
2000	33	3	211	0.8	169
2000	34	1	199	3.367712062	670
2000	34	2	510	5.038029619	2,569
2000	34	3	340	1.752192235	596
Total					15,136

Table 3.12. Calculated yearly south Atlantic handline fishery gag grouper discards.

Year	Handline Trips	Calculated Discards
1999	11,910	7,369
2000	13,048	7,767
2001	13,774	13,712
2002	14,477	11,910
2003	14,704	5,100
2004	13,764	7,202
Total	81,677	53,060

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

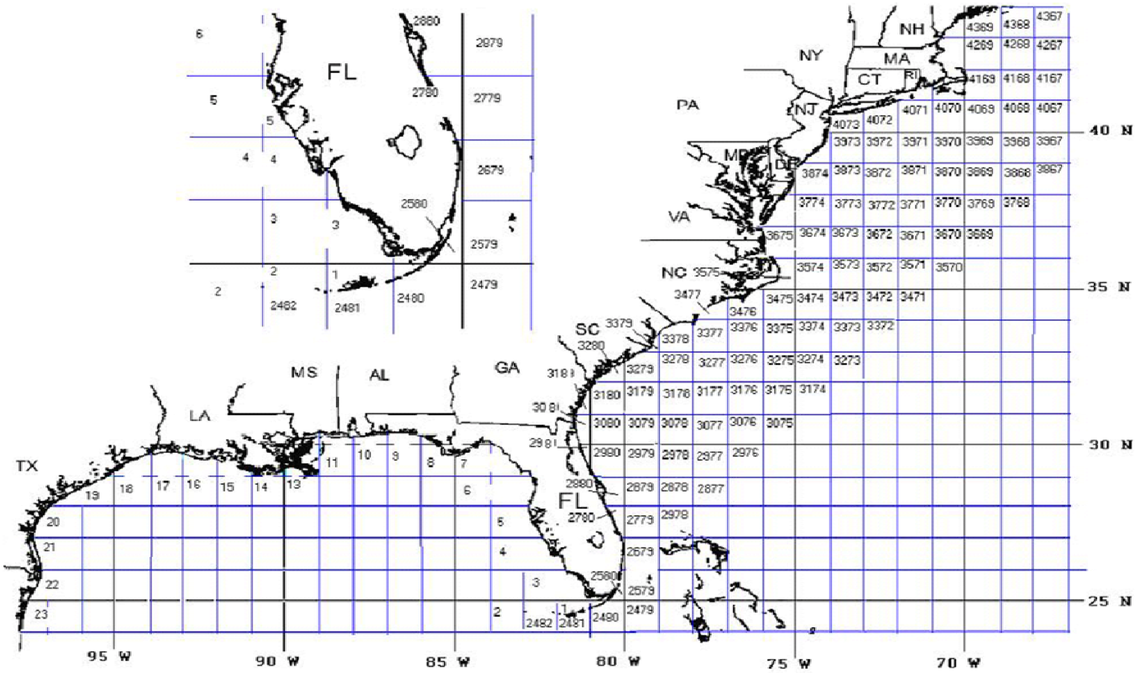


Figure 3.2. Map showing marine fisheries trip ticket fishing area code map for Florida.

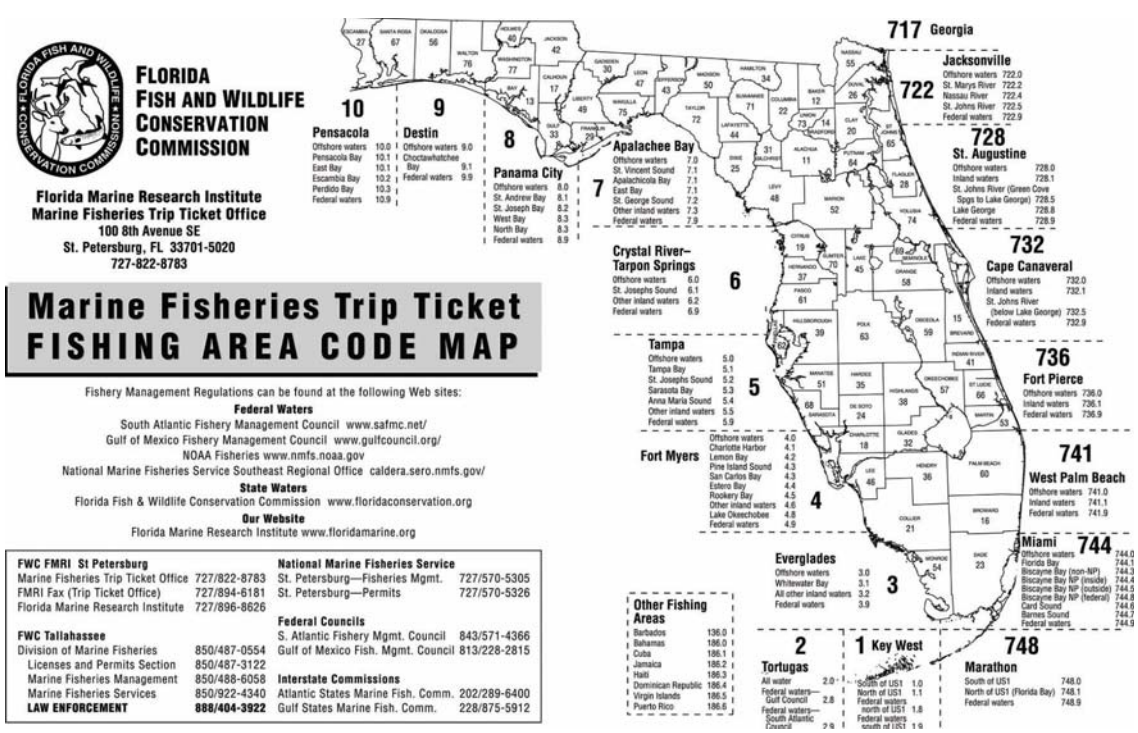


Figure 3.3. Proportion of gag misidentified as black grouper by seafood dealers in the South Atlantic by state and year, from TIP observation weight data.

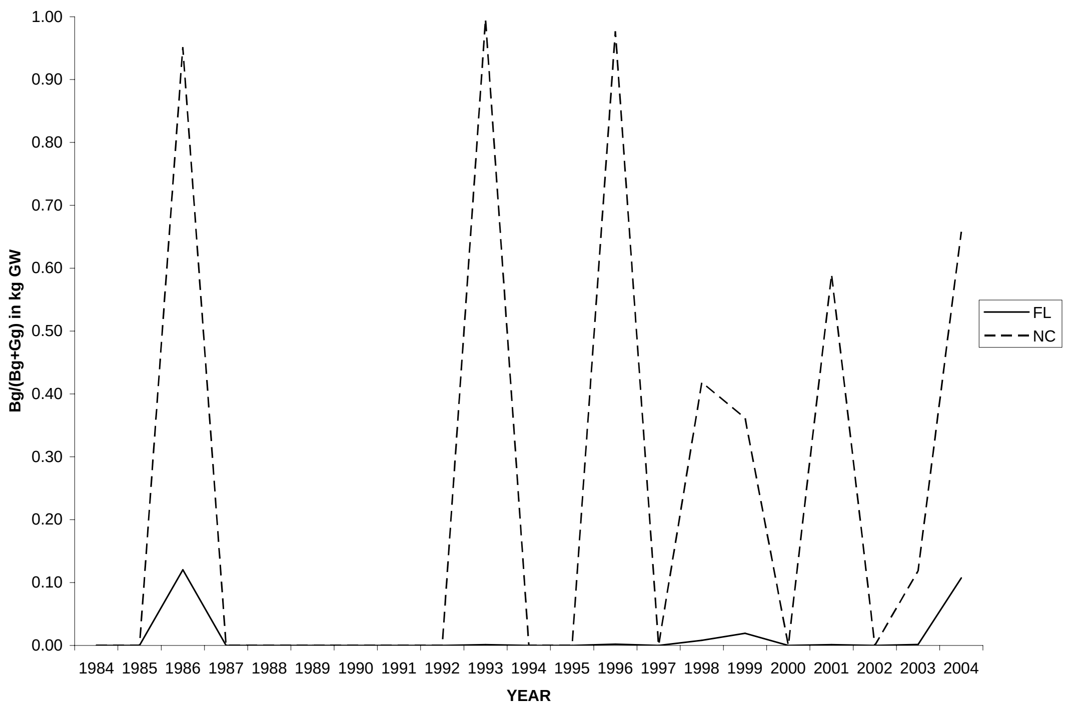


Figure 3.4. Unadjusted gag landings by gear for the U.S. South Atlantic, 1962-2004.

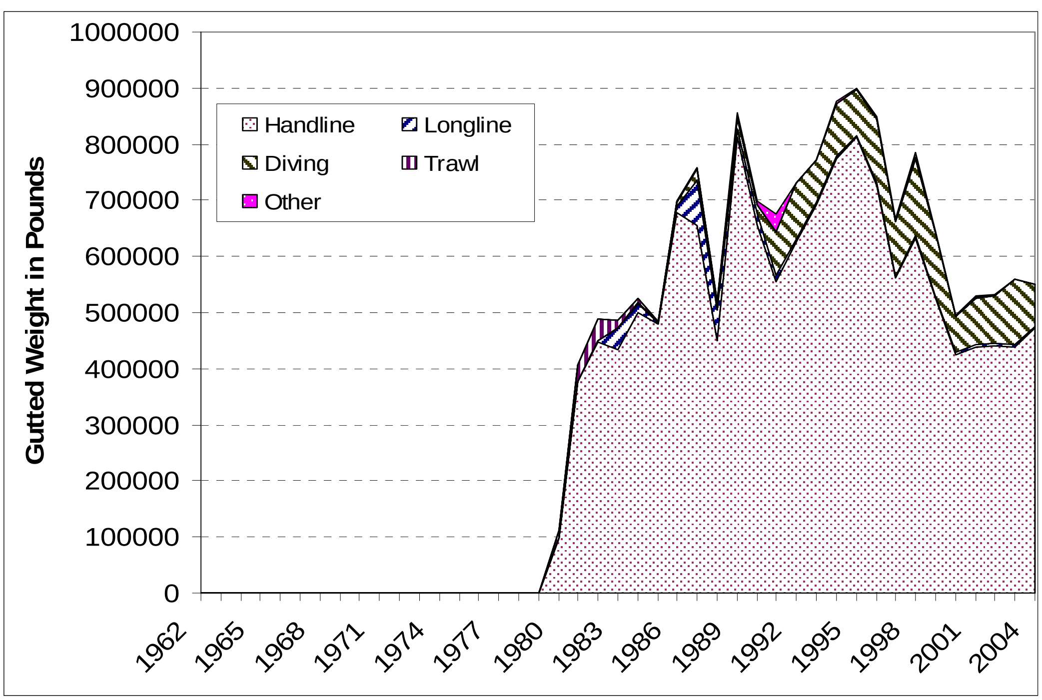


Figure 3.5. Unadjusted gag landings from the U.S. South Atlantic, 1962-2004.

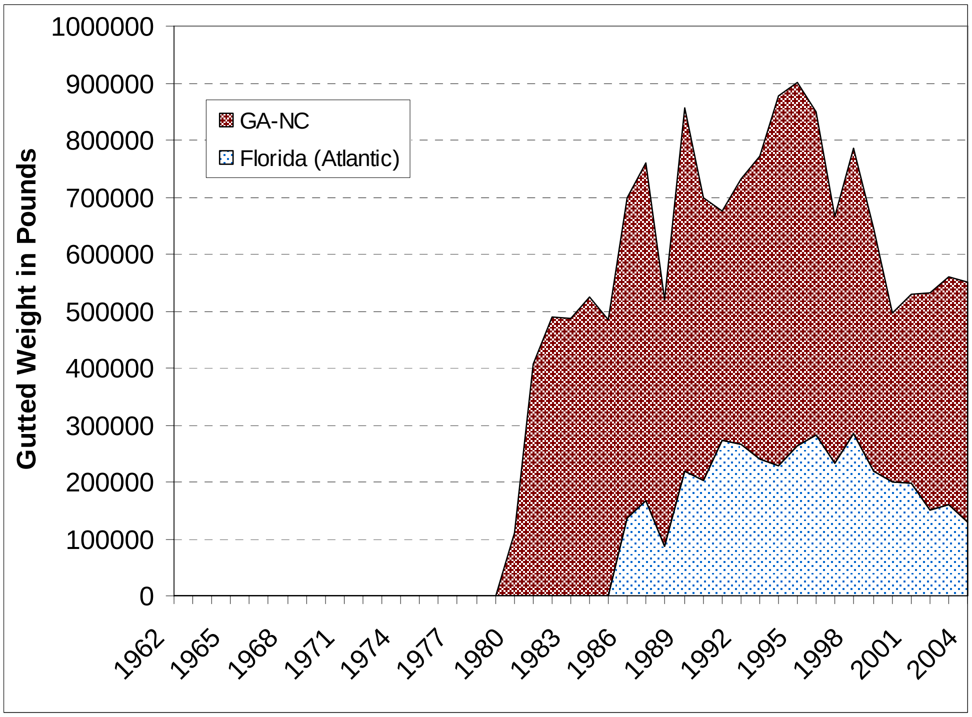


Figure 3.6. Unclassified grouper landings from the U.S. South Atlantic, 1962-2004.

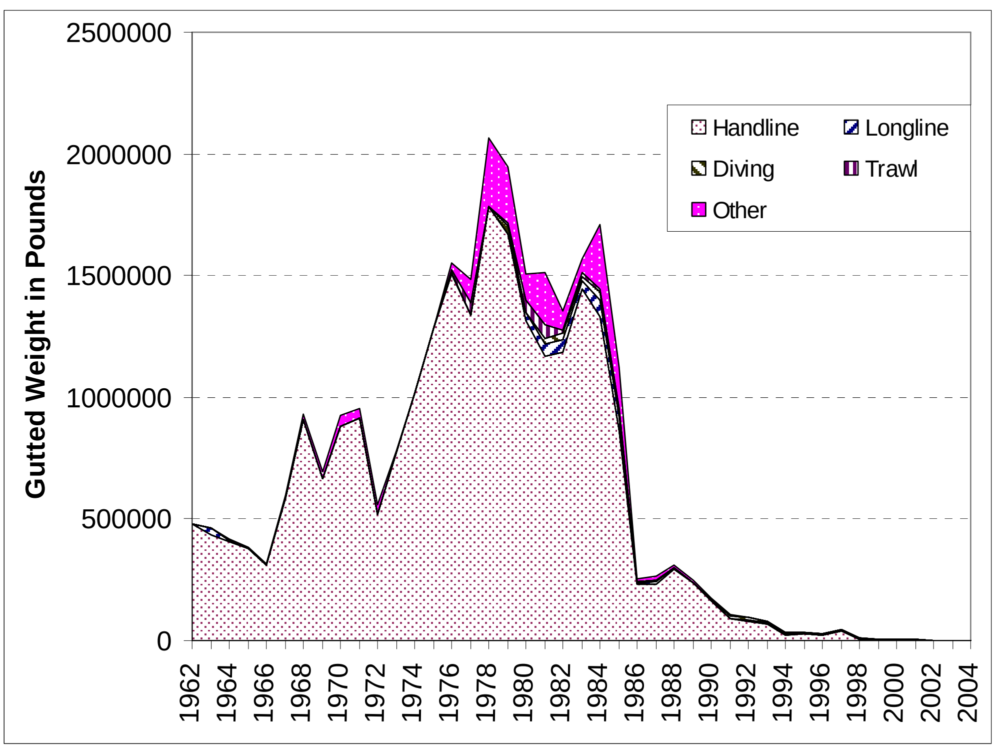


Figure 3.7. Classified grouper landings from the U.S. South Atlantic, 1962-2004.

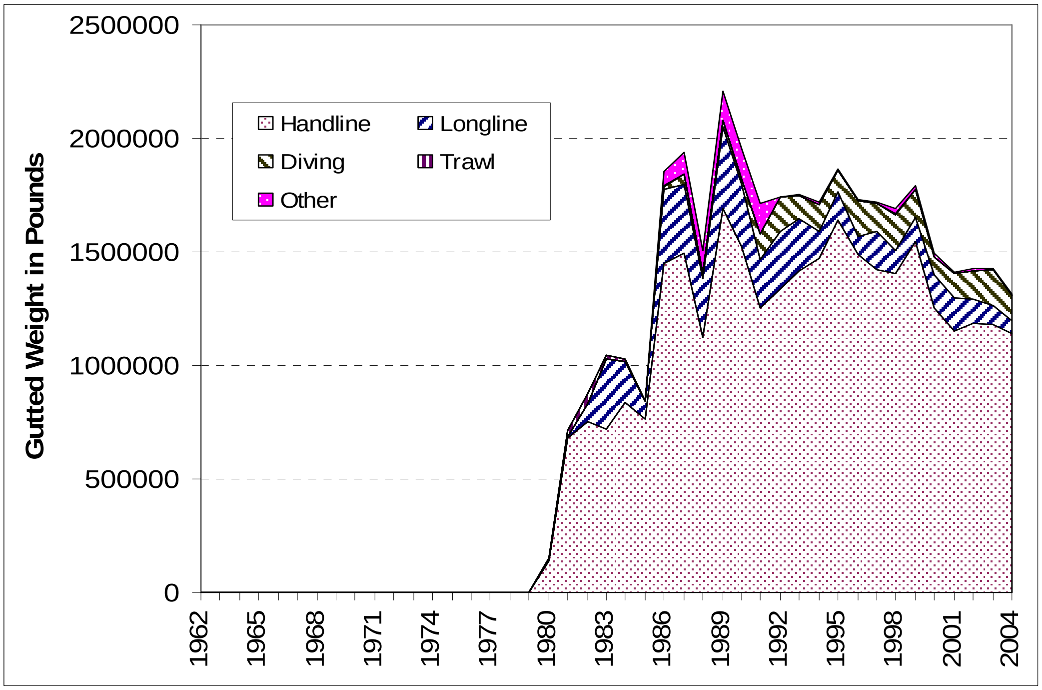


Figure 3.8. Classified versus unclassified grouper landings from the U.S. South Atlantic, 1962-2004.

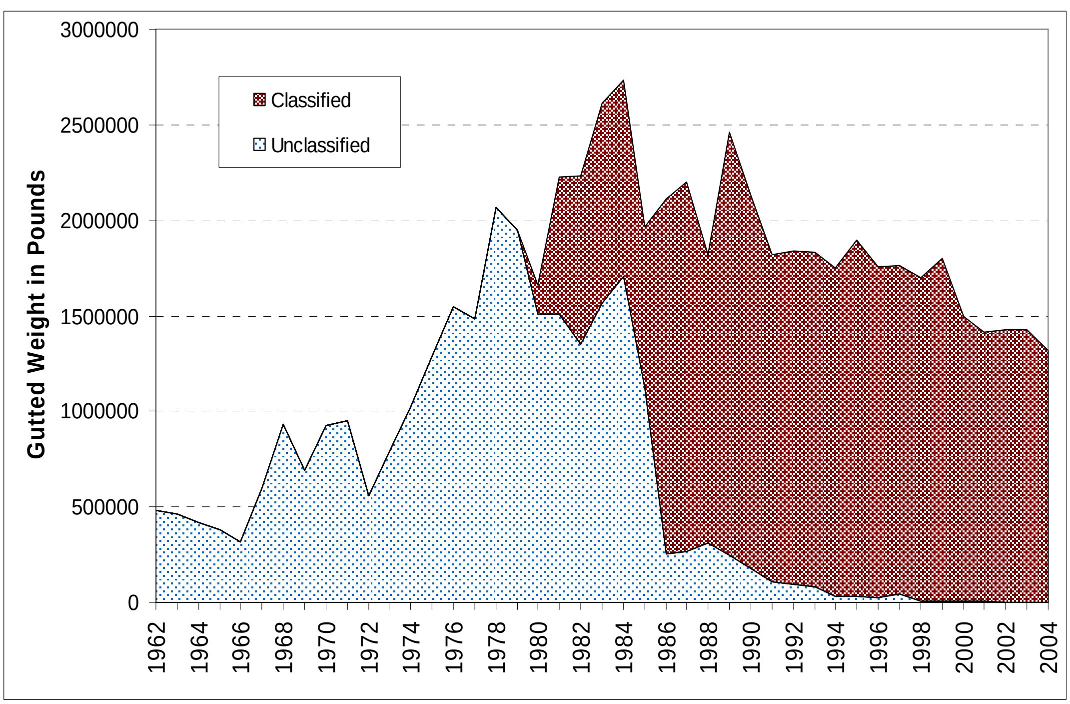


Figure 3.9. Adjusted gag grouper landings by gear from the U.S. South Atlantic, 1962-2004.

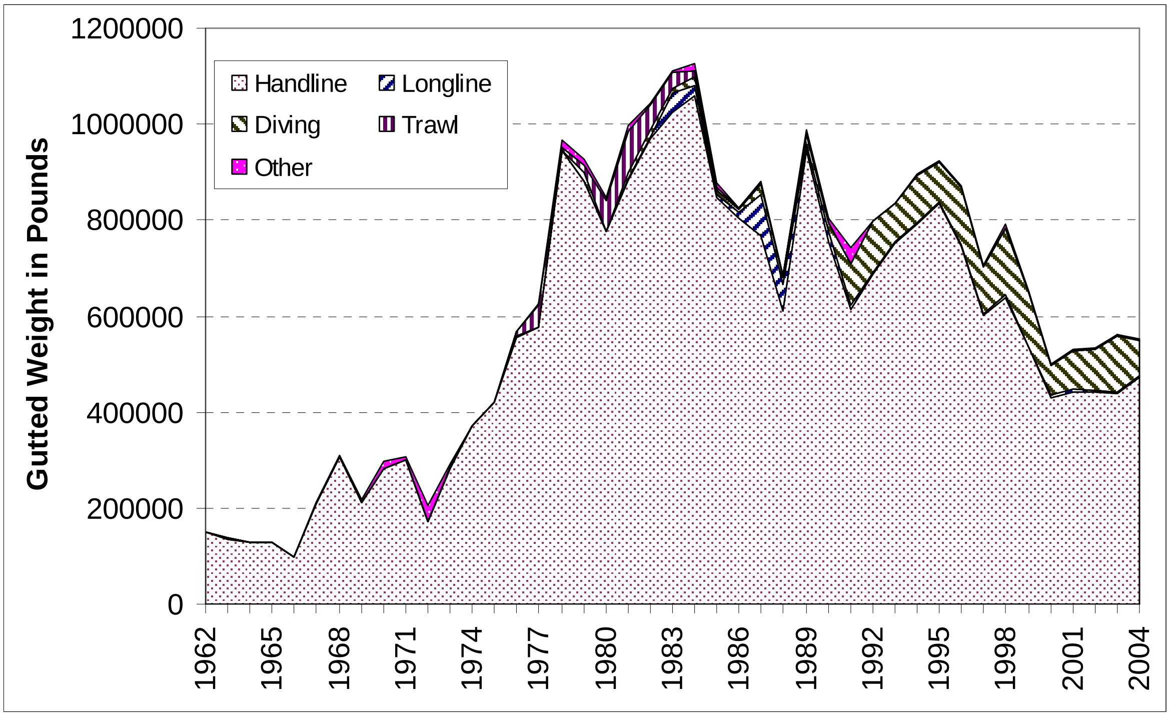


Figure 3.10. Adjusted gag grouper landings from the U.S. South Atlantic, 1962-2004.

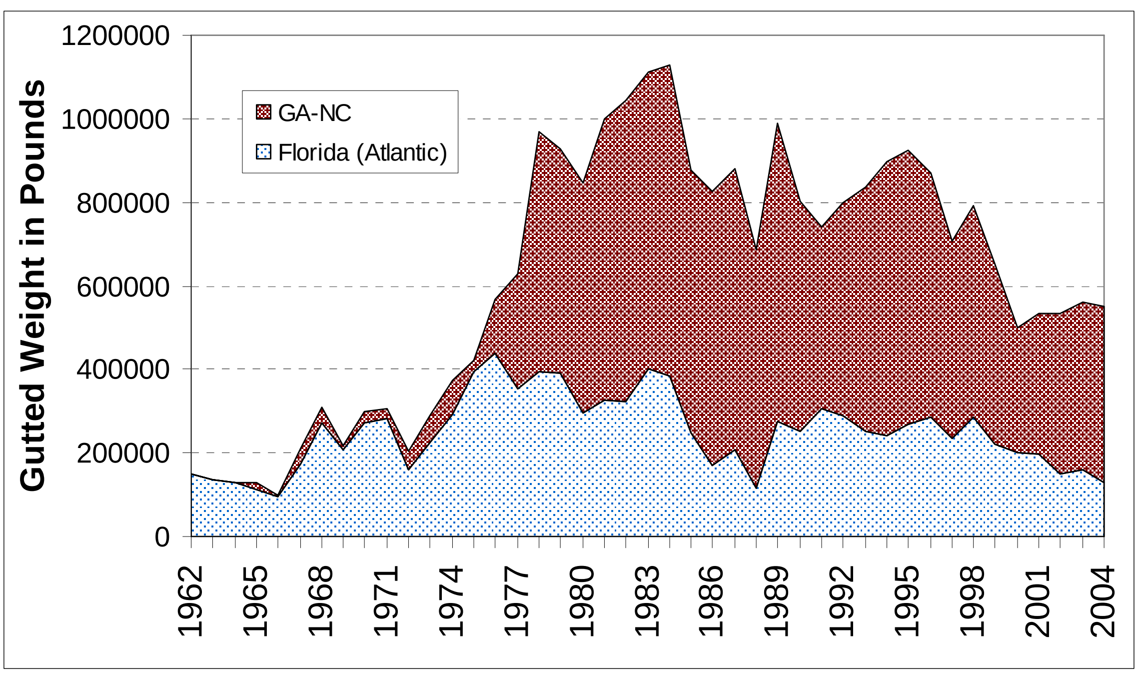


Figure 3.11. Comparison of unadjusted to adjusted gag grouper landings from the U.S. South Atlantic, 1962-2004.

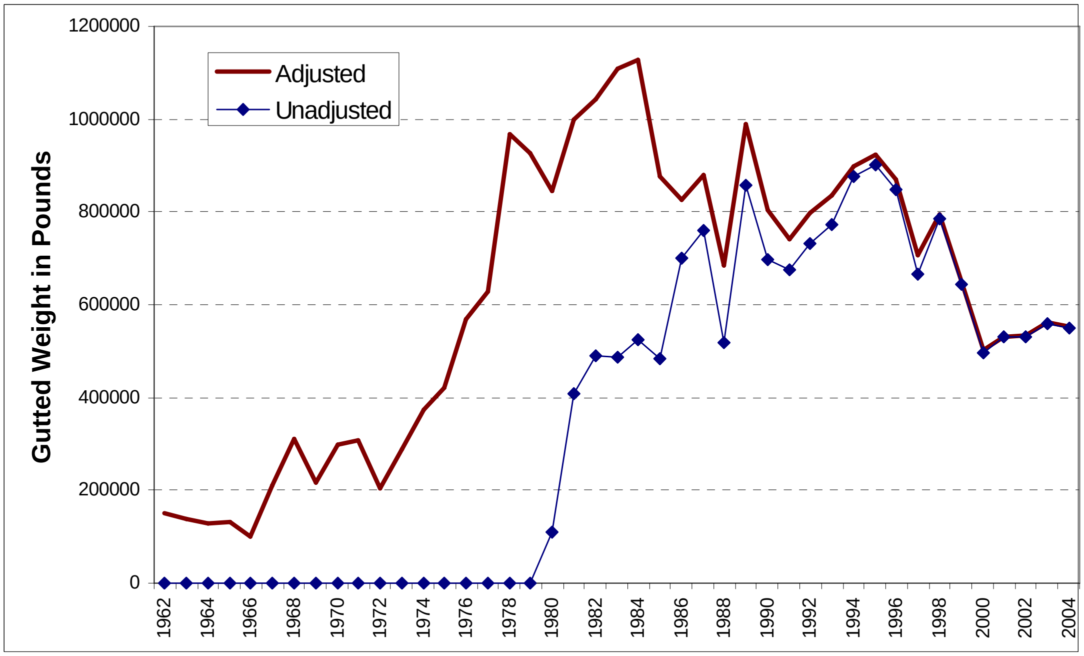


Figure 3.12. Lower bound on adjusted gag grouper landings by gear from the U.S. South Atlantic, 1962-2004

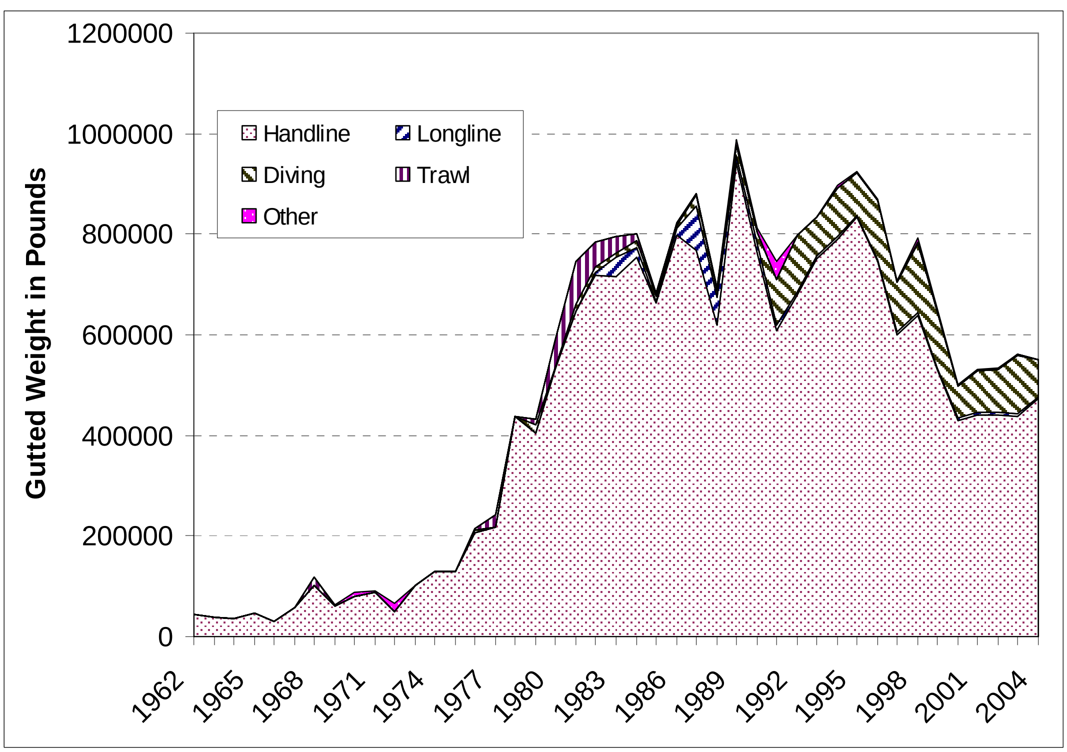


Figure 3.13. Lower bound on adjusted gag grouper landings from the U.S. South Atlantic, 1962-2004.

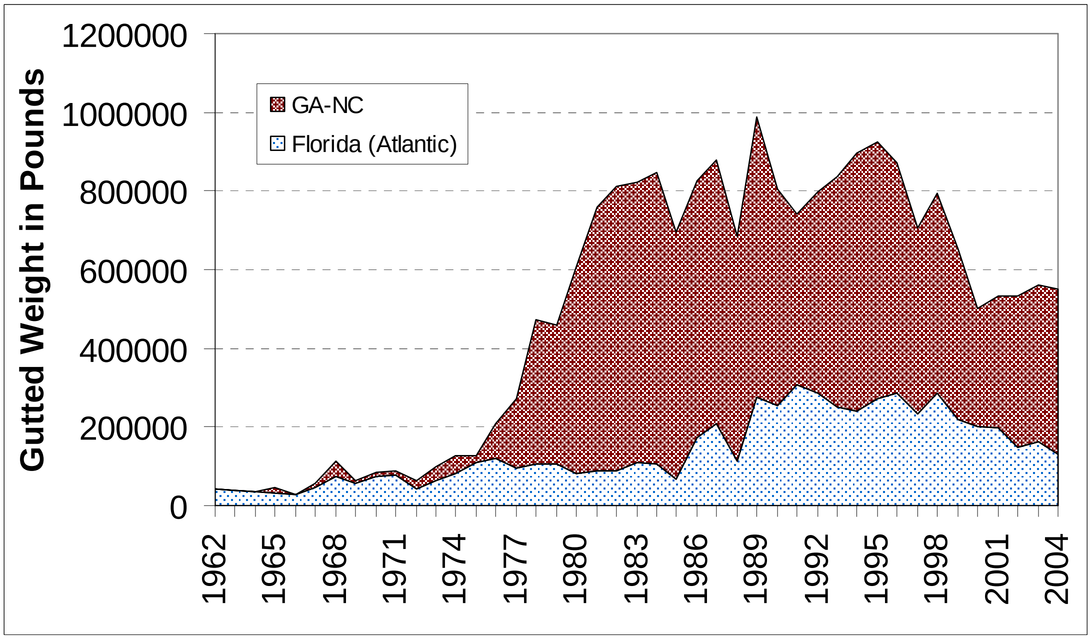


Figure 3.14.Upper bound on adjusted gag grouper landings by gear from the U.S. South Atlantic, 1962-2004.

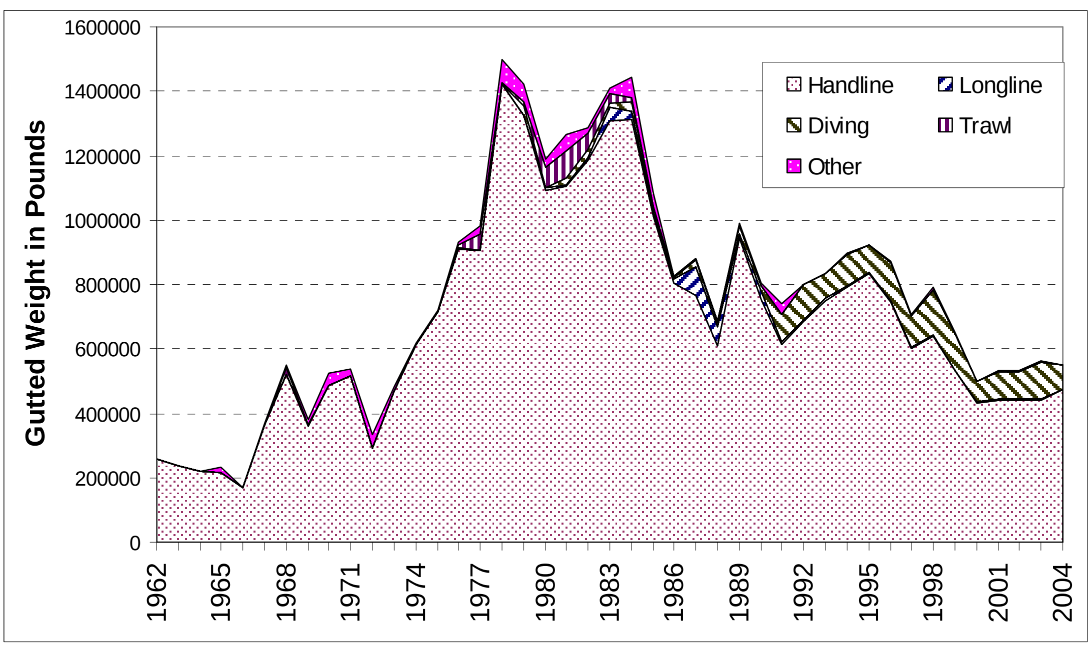


Figure 3.15. Upper bound on adjusted gag grouper landings from the U.S. South Atlantic, 1962-2004.

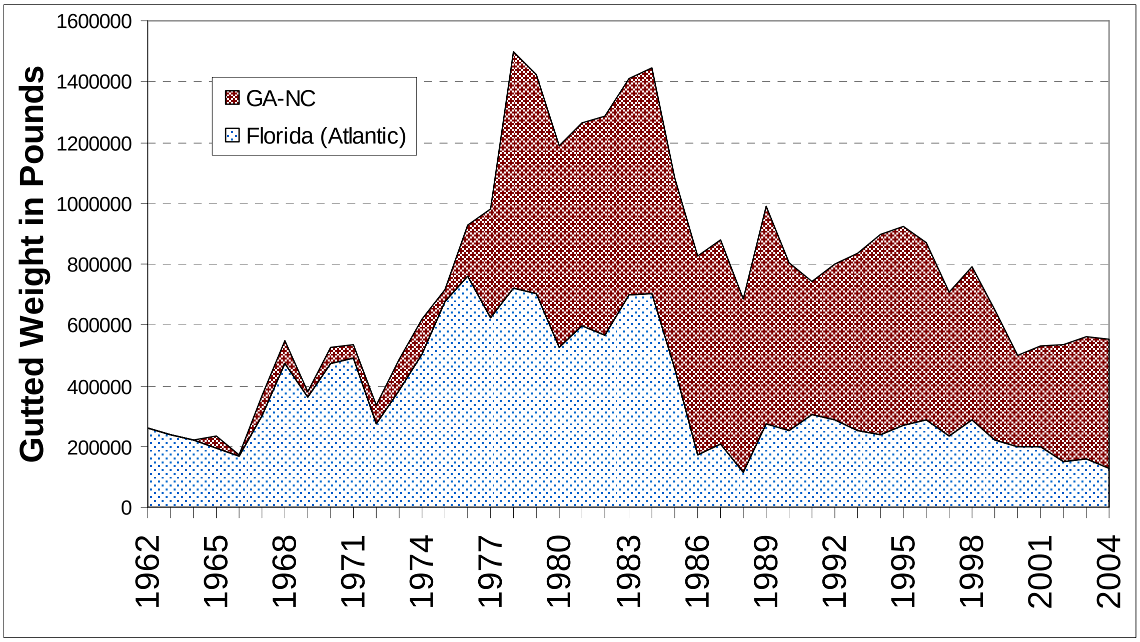


Figure 3.16. Range in adjusted gag grouper landings from the U.S. South Atlantic, 1962-2004.

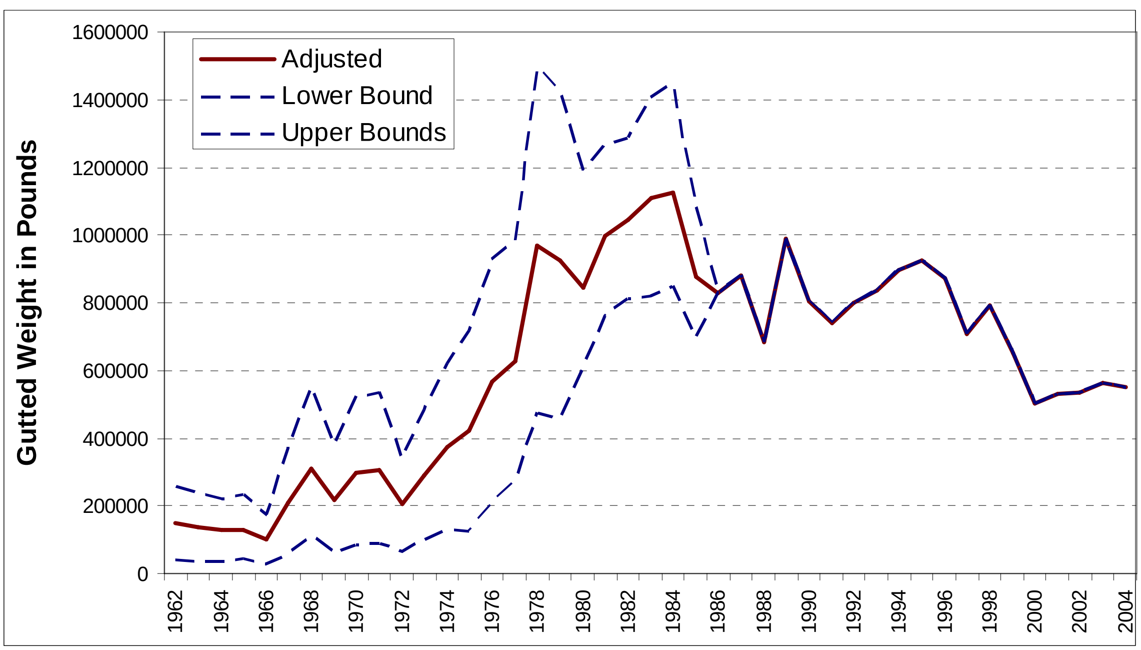


Figure 3.17. Adjusted gag grouper landings in numbers by gear from the U.S. South Atlantic, 1962-2004.

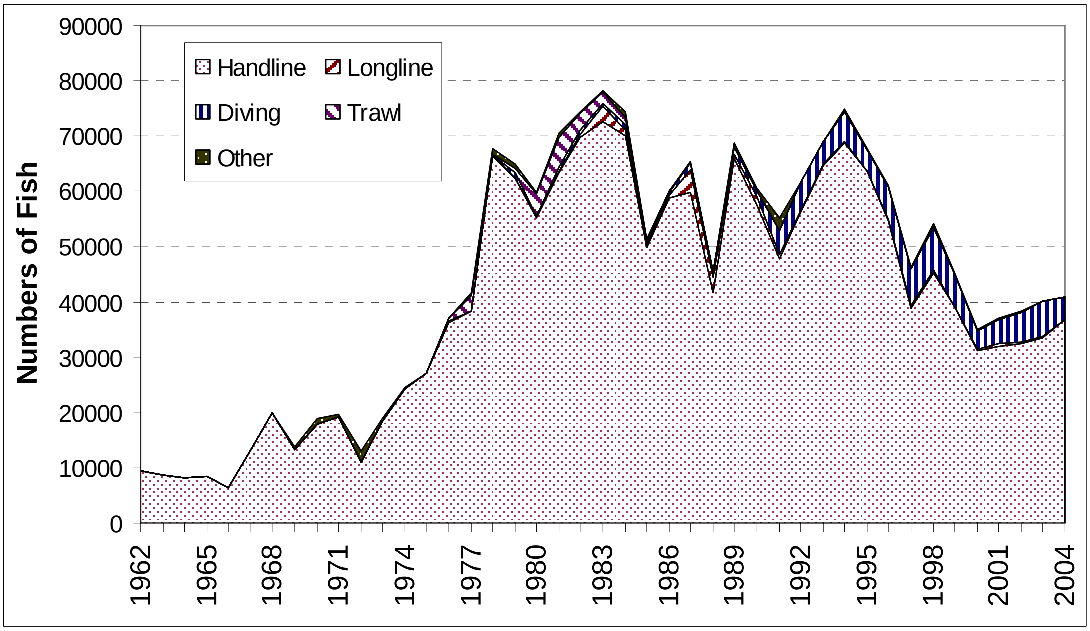


Figure 3.18. Adjusted gag grouper landings in numbers from the U.S. South Atlantic, 1962-2004.

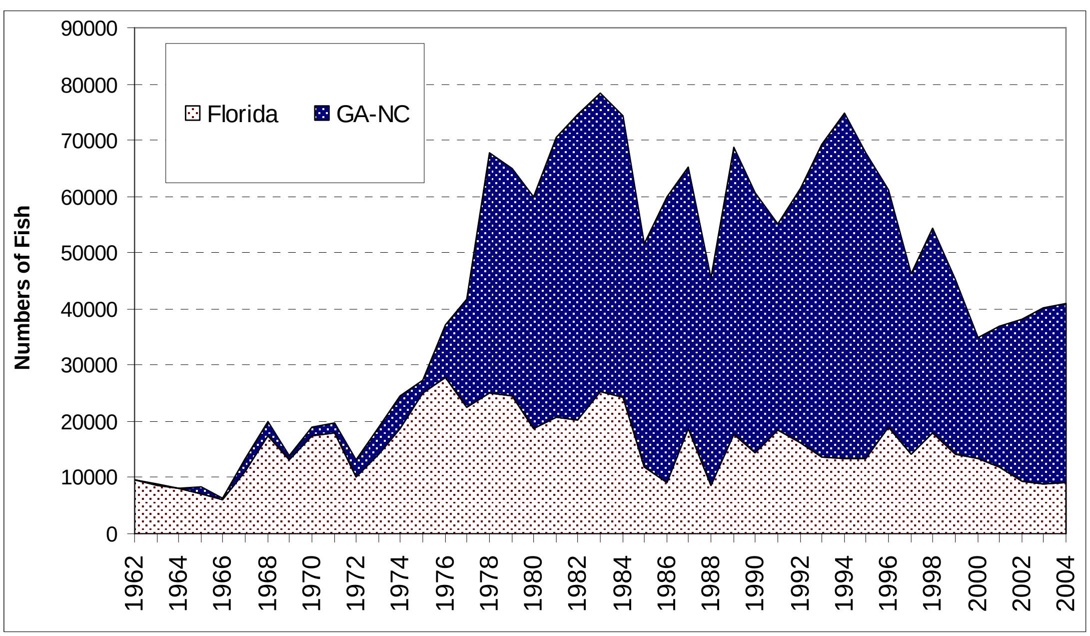


Figure 3.19. Length composition of gag grouper for commercial handline from TIP, 1983-2004. Weighting based on landings in numbers and trip catch in numbers.

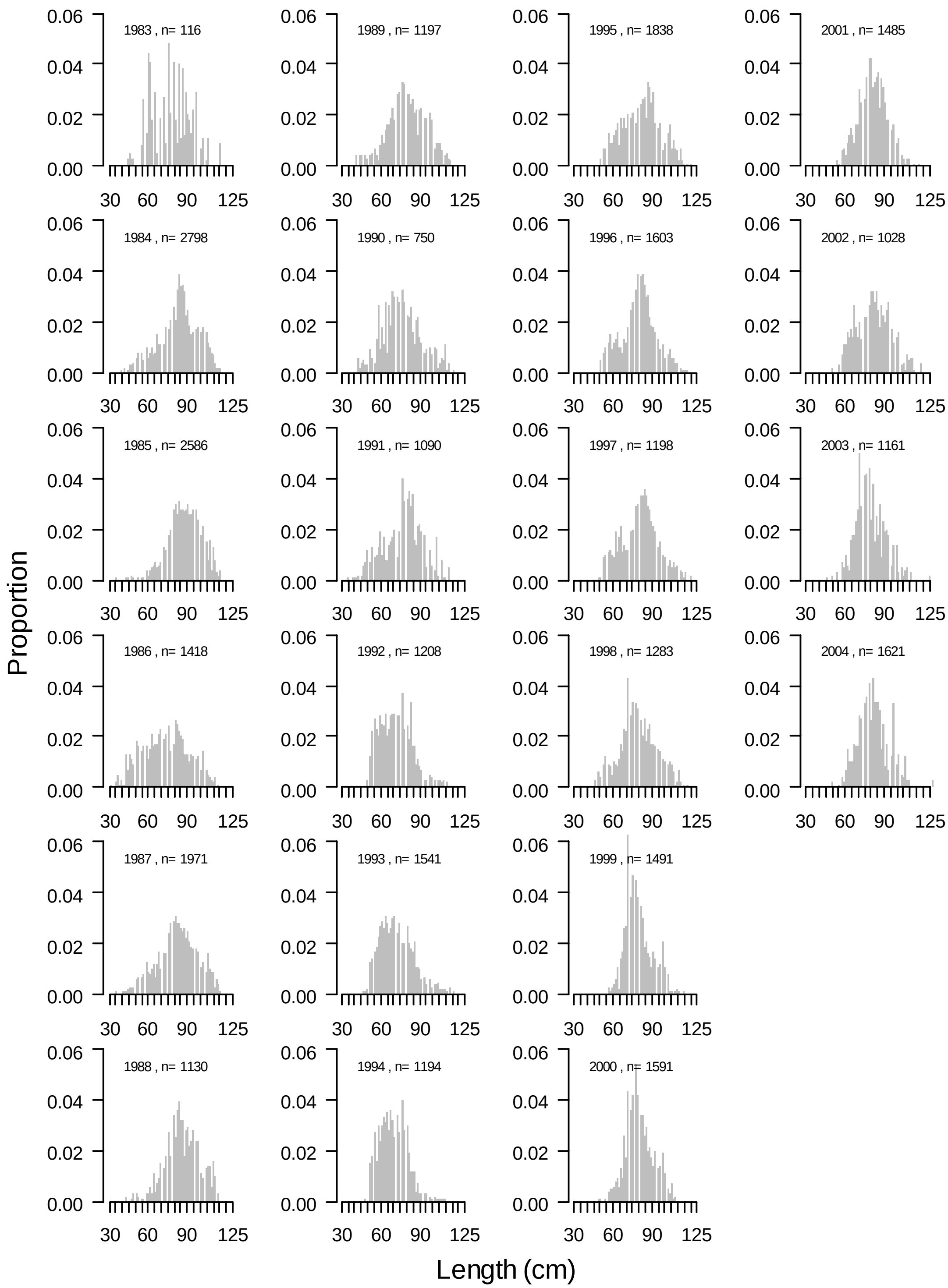


Figure 3.20. Length composition of gag grouper for commercial longline from TIP, 1984-1998, and 2002. Weighting based on landings in numbers and trip catch in numbers.

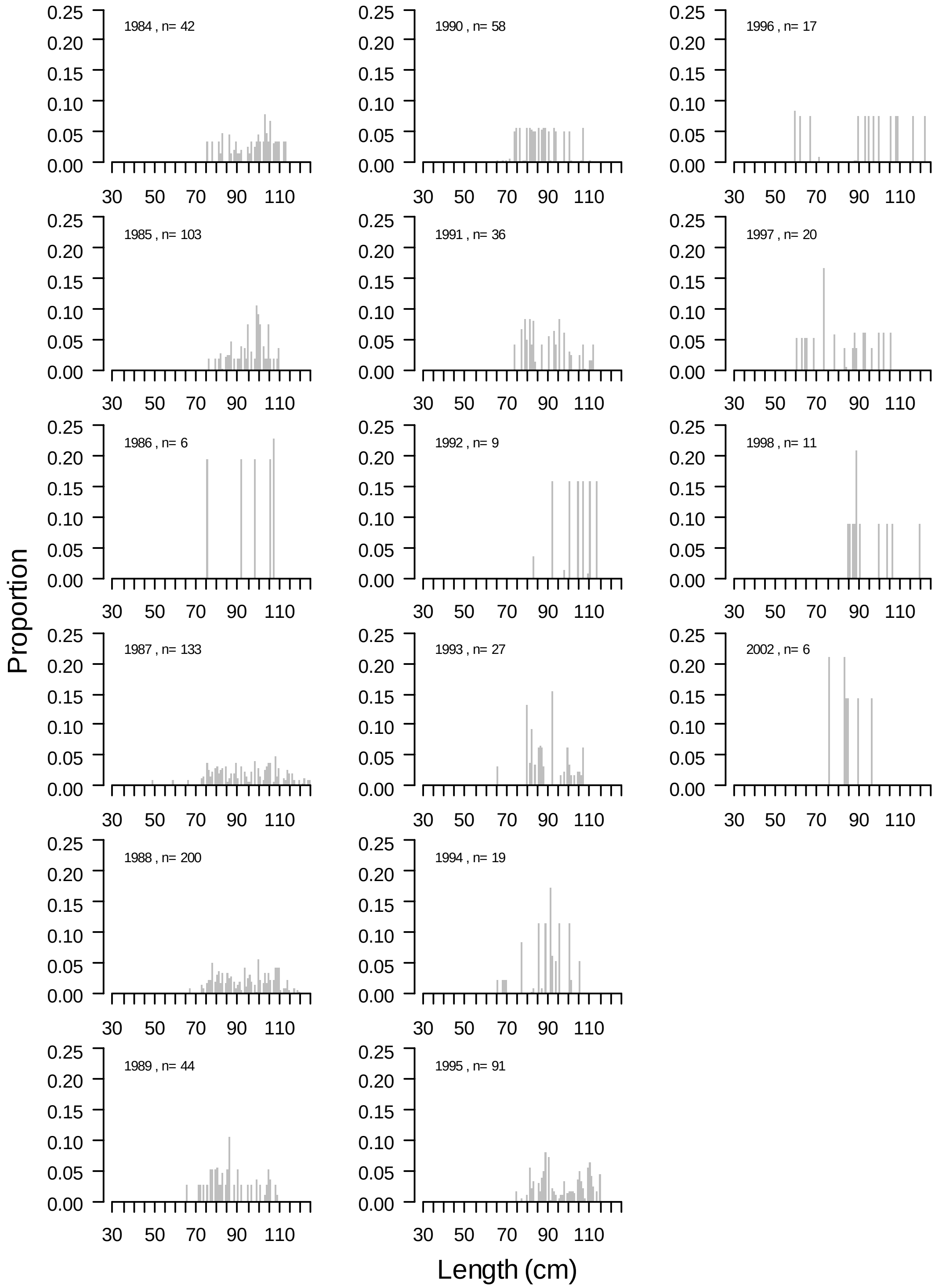


Figure 3.21. Length composition of gag grouper for commercial diving from TIP, 1986-1987, 1991-2004. Weighting based on landings in numbers and trip catch in numbers.

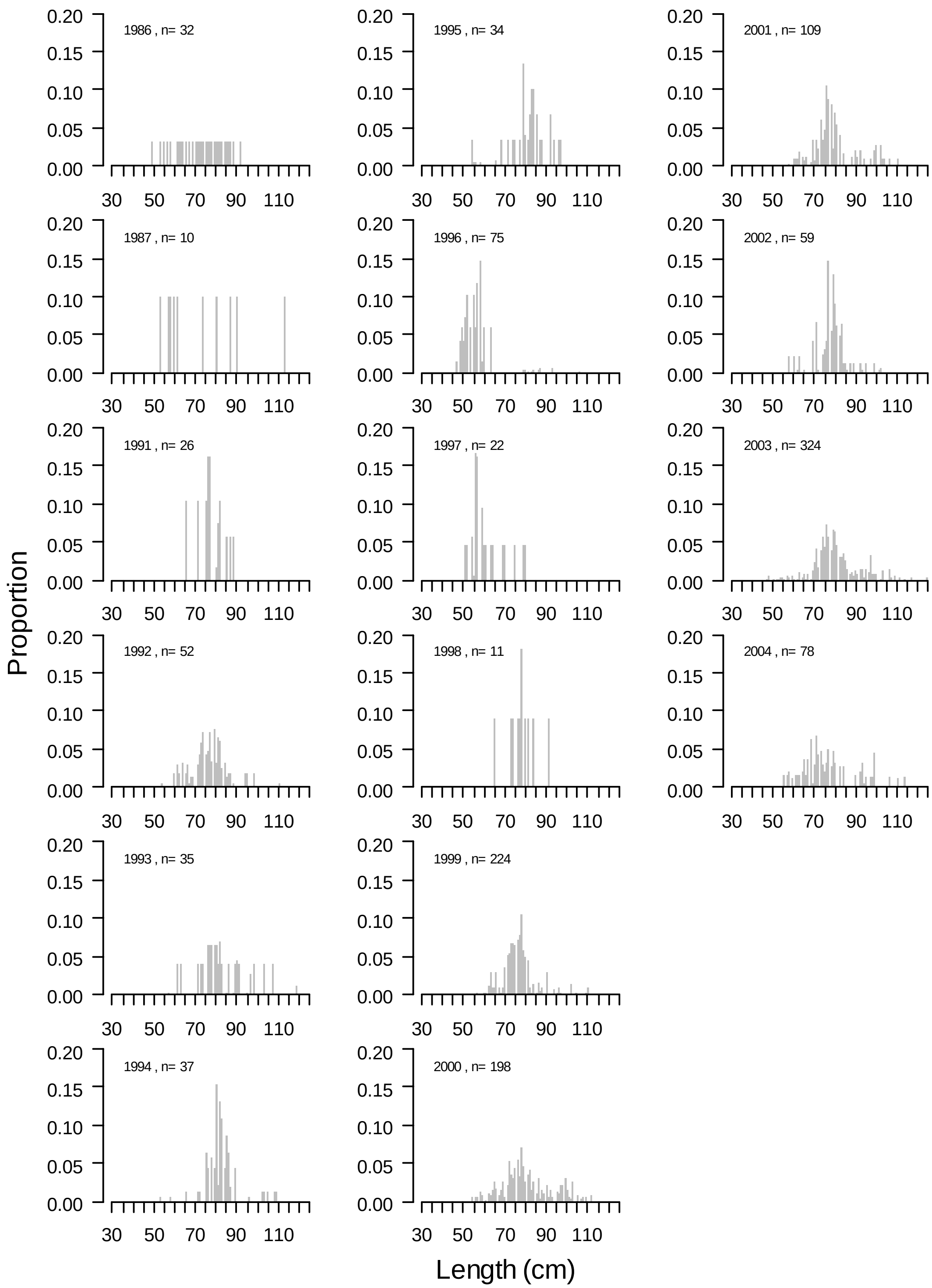


Figure 3.22. Age composition of gag grouper for commercial handline from TIP, 1979-1981, 1992-1997, 1999-2004. Weighting based on corresponding length composition available for 1992-2004.

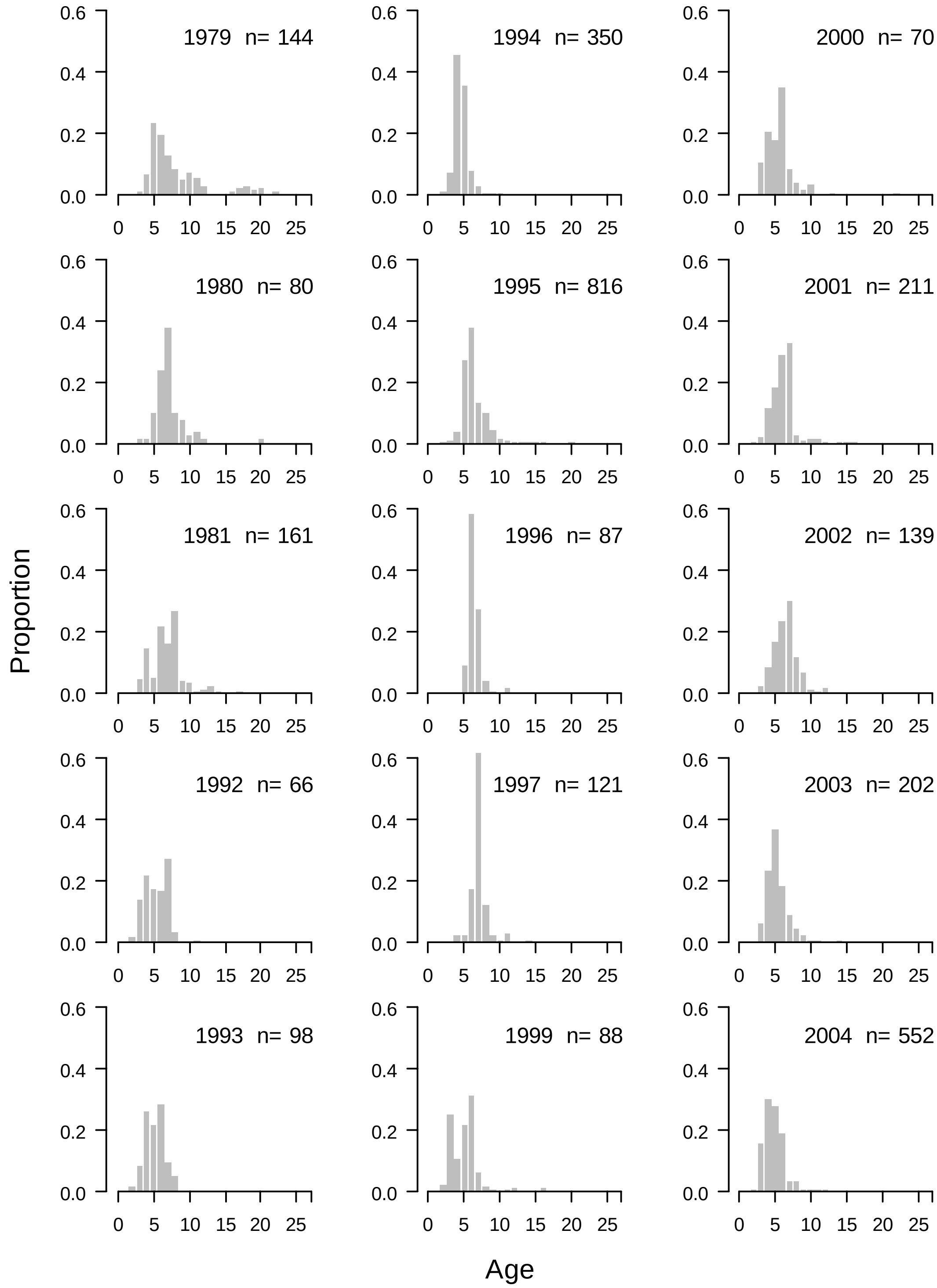
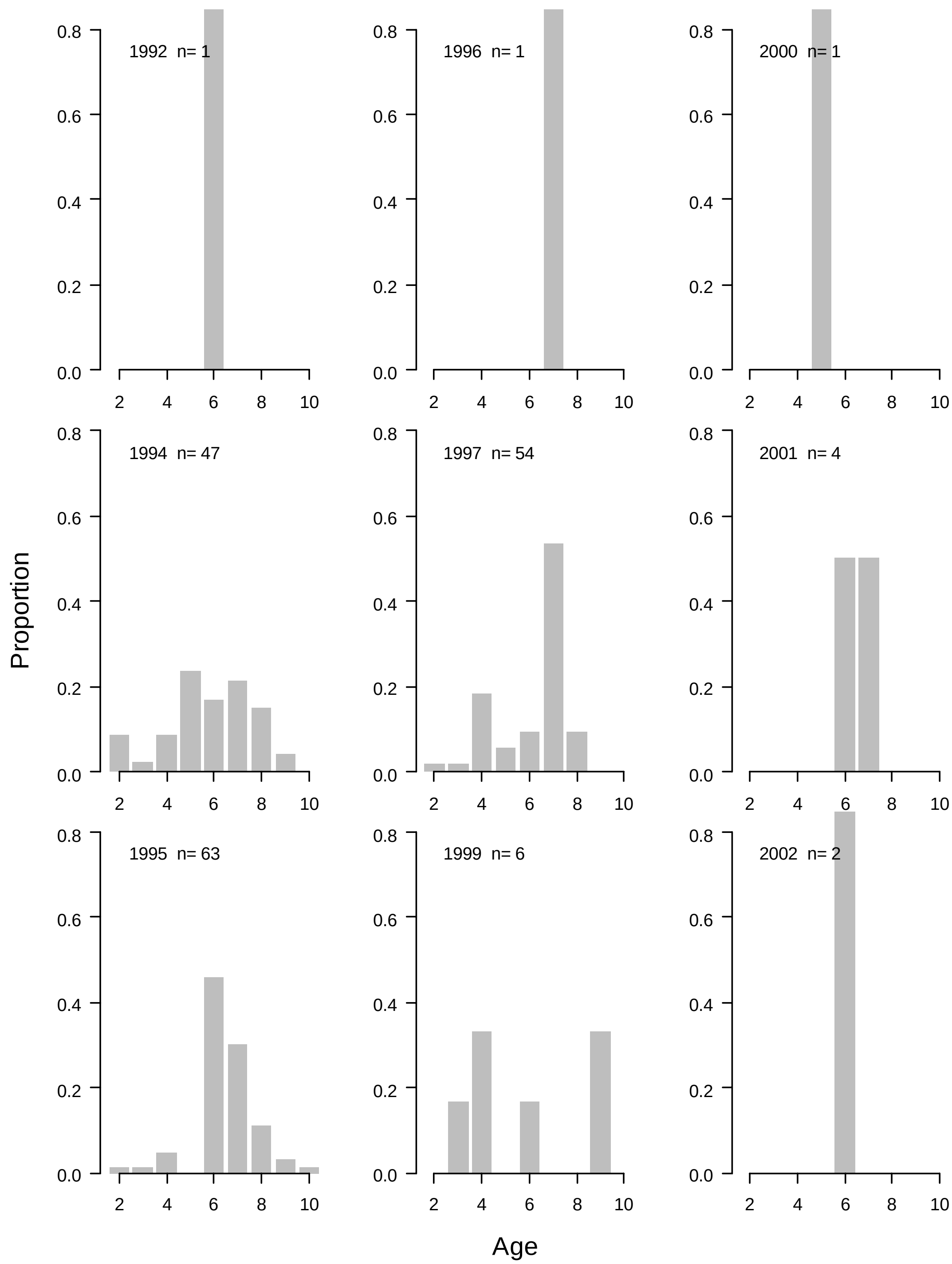


Figure 3.23. Age composition of gag grouper for commercial diving from TIP, 1992, 1994-1997, 1999-2002. Weighting based on landings in numbers by state.



4 Recreational Fisheries

4.1 Overview

Catch of gag, by recreational anglers in the southeastern U.S., can be estimated from at least two sources. The Southeast Region Headboat Survey, conducted by NOAA Fisheries Service at the NOAA Center for Coastal Fisheries and Habitat Research (CCFHR), collects catch and effort data from headboats that operate primarily in the offshore waters of the U. S. South Atlantic Ocean and Gulf of Mexico. Due to Coast Guard license differences, vessels operating in the Gulf of Mexico are defined, as headboats if licensed to carry 15 or more passengers, regardless of the method of payment, and primarily target reef fish. Vessels that operate in the U.S. South Atlantic Ocean are defined as headboats if they are licensed to carry over 6 anglers, regardless of method of payment. Catch and effort data are recorded by trip by the vessel crew. These trip reports are edited by port agents based on their recent sampling observations and after consultation with the crew member who completed the trip report. These trip reports are keyed into a database by a contracted company. The database is stored and summary reports generated at CCFHR. Total landings are estimated by expanding the reported data based on fishing effort information listed on vessel activity reports. In addition to catch and effort data, port agents collect length, weight, and biological materials from fish when the vessel returns to the dock.

The Marine Recreational Fishery Statistics Survey (MRFSS) conducts telephone and creel interviews from saltwater recreational fishermen throughout the US. Estimates of catch are then generated using census information to expand the reported trips and associated catch. Creel samplers also collect length and weight information.

4.2 Headboat Survey

4.2.1 Overview of Headboat Survey

The Southeast Region Headboat Survey included vessels only in North Carolina and South Carolina during the early part of the survey (1972-1975). The Survey expanded to northeast Florida in 1976, to southeast Florida in 1978, and finally to the Gulf of Mexico in 1986. Easily accessible, computer generated estimates are not available prior to 1981. From 1981-present the Survey included all headboats operating in the southeastern U.S. EEZ, encompassing the areas shown in Figure 1 .

4.2.2 Headboat Landings

Prior to 1981, landings estimates for Mycteroperca species were grouped into one landings estimate in the standard headboat data summaries. However, species specific landing estimates of gag were created for North Carolina and South Carolina from 1972-1980 for previous reports, and were digitized for this assessment. Trip reports for other areas began in 1976 and gradually increased so that all the currently sampled areas (NC to the Tortugas) were included by 1978. Landings for the non-coverage areas is discussed below presented with the estimates of landings in number and metric tons (see Table 1 and Table

2, and Figure 2). Landings estimates in gutted whole pounds were calculated using the conversion created for this assessment in the life history report (See Table 3).

1. ***Issue: Placement of landings from areas 12 and 17 corresponding to Southern Florida and the Tortugas. Should areas of South Florida, from Key Largo to Key West, and the Tortugas be placed in GMFMC or SAFMC jurisdiction***

   The data workshop recreational group decided that although some vessels were fishing in the Gulf of Mexico, the majority of the landings in these areas were in the Atlantic. The areas Northwest of the Florida Keys, primarily the waters of Florida Bay, are not deep enough, except in very small areas near channels and in the Intercoastal Waterway, to allow headboats to navigate. Headboat personnel at the workshop were not aware of any vessels in mid and upper Keys that operated in Florida Bay. The group discussed portioning the landings based on the location data in the trip reports. However, based on accuracy of the headboat location data and comments from the headboat personnel at the meeting, the group concluded the location information was insufficient to split the landings from these areas. Also, this decision was based on the time needed to re-estimate the landings if such a decision were made. This decision is consistent with previous SEDAR data workshop decisions regarding headboat landings in these areas.

2 ***Issue: Approach for extending landings for non–coverage areas.***

   To address these missing landings, we regressed landings of North Carolina and South Carolina catches combined against Georgia and Florida catches combined to predict landings for non-coverage areas from 1972–1980. The catch in numbers r-square value was 0.54 with $p<0.0001$. The catch in weight regression r-square value was 0.36 with $p<.0014$ (see Figure 3). Based on error estimates from this regression analysis, a lower and upper bound for the Georgia and Florida headboat landings were computed based on + and – 2 standard deviations and are given in Table 1 and Table 2 and in Figure 2

3 ***Issue: Approach for extending landings from 1971 through 1962.***

   Extending landings back to 1962. "From a stock assessment modeling perspective it is often desirable to extend landings estimates for primary fisheries as far back in time as is reasonable. Based on interviews with some headboat captains and a detailed report on the history of fishing in a town in South Carolina, it is clear that headboat fishing for offshore snapper-grouper species dates back to the years immediately following World War II. In fact many of the vessels employed as headboats were obtained as WWII surplus vessels. It is also well documented that commercial and recreational fishing efforts from large vessels was severely restricted during WWII. These facts confirm that headboat fishing was occurring as far back as the late 1940's and that headboat fishing was likely non-existent during the years of WWII. In an attempt to match commercial landings estimates which extend back to 1962, we examined two linear predictors for estimating historic headboat landings.

One approach involved regressing the headboat landings in 1972-2004 against the commercial landings for the same years. The regression of headboat landings without estimated released fish was significant at the 0.10 level using the robust linear model analysis (See Figure 4).

The other option considered for estimating historic headboat landings used the coastal human population estimates as a linear predictor. The results of this are shown in Figure 5.

There was no preferred recommendation from the data workshop panel on this issue. The SEDAR 10 Atlantic working group decided to use the regression equation of headboat landings against commercial landings to predict headboat landings from 1962–1971. (See Table 4).

4.2.3 Headboat Discards

Collection of discard data began in 2004 in the headboat survey, but were unavailable for this assessment. However, estimates of released(B2) fish from the MRFSS charter boat mode were used to estimate the proportion of released fish from the headboat fishery. (See Table 5) The charter boat mode is thought to most closely approximate fishing practices followed by headboats. The ratio of released:retained(A+B1) fish in the charter boat mode from MRFSS was averaged over regulation time periods (See Table 6 and Figure 6). These ratios were then applied to the headboat catch in numbers, providing estimates of the number of released fish in the headboat fishery. Prior to 1985, discards were assumed to be zero.

The 2004 headboat discard information was made available after the data workshop and was not reviewed by all workshop participants and therefore not available for the assessment workshop. However, releases of gag from the headboat survey in 2004 was estimated to be 83% which is very similar to the estimate of 90% from the most recent time period discussed above.

4.2.4 Biological Sampling

Length and weight measurements from fishes taken by anglers on headboats are collected by port agents throughout the coverage area. Also, biological samples (scales, otoliths, spines, stomachs and gonads) are collected routinely. Length-weight data are used to compute average weights for each species and to compute age frequencies and mortality rates. This information combined with catch record data are used to calculate an estimate of total weight (kg) of reef fish landed in the headboat fishery. Port agents are instructed to look for stringers with the less common species including groupers, red snapper, and unusual porgies. Common species are adequately represented because stringers with unusual fish usually include many of the common species.

If possible, ten or more fish of each species present in the total catch are weighed and measured for lengths. To avoid size- or species selectivity bias complete stringers of fish are measured.

After sampling is completed, data are electronically downloaded and edited for errors. It is also the responsibility of each sampler to review trip reports (catch records) for missing information and any other apparent errors, such as, coding errors, misidentification, or questionable weights and lengths.

Mean Weight

The plot of mean weight for North Carolina and South Carolina (Carolinas) and Georgia–Florida show similar trends with mean weight decreasing from the early 1970's to the mid 1980's and then increasing slightly. Implementation of size limits are likely responsible for the increases (see Figure 7).

Sampling Intensity

The number of length samples taken for gag has varied temporally and spatially. Changes in sampling intensity over time seem to follow the trend in landings as would be expected (see Table 7).

Length Compositions

Length compositions were created by assigning an estimated landings value to each fish length by year, state, and 4-month time interval. The estimated landings were summed by year and length (1cm bins). The proportion estimated landings for each length by year was calculated and reported as the annual weighted length composition (See Figure 8 and Figure 9).

Trends in the length composition data are difficult to examine in Figures 8 and 9, therefore we examined the data by year and length intervals (See Figures 10 and 11). Trends in these figures suggest that in the early years of the headboat fishery, there was a significant proportion of 95+ cm fish which disappeared by the early 1980s. This resulted in an increased proportion of smaller fish, which then began to drop out of the length composition data as size regulations came into place. The effects of the 20 and 24 inch minimum size limits can clearly be seen in the temporal changes occurring in the 30–50 and 51–60 cm length groups (See Figure 10 and 11).

Age Compositions

Recreational age data were available from charter boat and headboat collections. Most of the aged fish were from the headboat survey (91%). Headboat ages were weighted by the sum of the catch in each year, month (3 intervals), and area (North Carolina, South Carolina, and Georgia/Florida) in the headboat fishery associated with the sample. The charter boat ages were weighted using the same method with estimates of catch from the MRFSS. The combined headboat and charter boat age compositions are shown in Figures 12 and 13.

4.3 Adequacy of Data for Assessment Model

The data workshop concluded that the headboat landings data reported herein, represent the best available data and are adequate for use in the stock assessment model.

The data workshop concluded that the headboat discard data reported herein, represent the best available data and are adequate for use in the stock assessment model.

4.4 Recreational Survey(MRFSS)

4.4.1 Overview of Recreational Survey

(excerpt from MRFSS user's guide) The National Marine Fisheries Service (NMFS) initiated a series of surveys in 1979 to obtain standardized and comparable estimates of participation, effort, and catch by recreational anglers in the marine waters of the United States. Continued efforts to develop and maintain a comprehensive marine recreational fisheries data acquisition and analysis system implemented the first priority of the NMFS Marine Recreational Fisheries Policy established in 1981.

The primary MRFSS data files for this assessment are the landings estimated by year, wave (2–month intervals) and mode of fishing(charter boat, private vessel and shore-based) and creel interview data (MRFSS designated intercept–type 3). The intercept data includes biological information. Data from the MRFSS useful for the estimation of catch and effort for gag grouper begins in Wave 2 (March), 1981. In 2003 the MRFSS began new landings estimation methods (For Hire Survey method) to better estimate landings from charter vessels. Landings estimates for 2003–4 consistent with estimates prior to 2003 are available from the MRFSS by request.

4.4.2 Recreational Landings

A snapshot of the catch and intercept data was obtained from the MRFSS ftp: site on October 6, 2005. Catch estimates for 2003 and 2004 were requested using the estimation procedures as in 1981–2002 instead of the new For Hire Survey methods to maintain consistency. The types of catch are defined as:

Catch Type A
Fish brought to land and identified to species by the interviewer

Catch Type B1
Fish that were unavailable for verification by creel interviewer and were either used for bait, filleted, or consumed for some other use.

Catch Type B2
Fish that were unavailable for verification by the creel interviewer and were released alive.

4 ***Issue: Monroe County gag catches applied to GMFMC or SAFMC***

The MRFSS data are reported by regions, which includes regions for East Florida and West Florida. When creating these regions, MRFSS includes Monroe County, Florida in their estimates for the West Florida region. Monroe County, Florida includes the Florida Keys which form the boundary line for the South Atlantic (SAFMC) and Gulf of Mexico (GMFMC) fishery management councils. The GMFMC territory to the Northwest of the Florida Keys is largely composed of the shallow waters of Florida Bay, unsuitable habitat for adult gag, but possibly suitable habitat for juvenile gag. It is likely that most of the catches of gag in Monroe County are from areas south of the Florida Keys in SAFMC jurisdiction. However, there still remains uncertainty about the catches of gag from Key West, Florida which may include angler trips in areas surrounding the Dry Tortugas, which may include both GMFMC and SAFMC jurisdictions. Ultimately it was decided at the data workshop that Monroe County should be included in the East Florida region, contributing to the U.S. South Atlantic totals. Staff at MRFSS provided a data query with separate catch estimates for Monroe County. This data was added into the total U.S. South Atlantic estimates.

5 ***Issue: Removal of headboat estimates from MRFSS for–hire vessel, charter and headboats,estimates in 1981-1985.***

From 1981-1985 the MRFSS included some headboats in their survey for the for–hire vessel estimates. The NMFS Headboat Survey was sampling these same vessels for those years. To avoid double counting landings estimates from headboats, the MRFSS headboat catches need to be removed. There is no distinction for these two types of vessels made for the catch estimates from MRFSS. However the intercept data does include an accounting of the number of each of these types of vessels. The data workshop decided to use the ratio of charter boats to headboats from the intercept data to create a correction factor for discounting the catch estimates, thereby removing the headboat catches from MRFSS.

The intercept data for headboats and charter boats in 1981-1985 are quite small. Annual correction factors could not be computed, but state specific correction factors were discussed as a possibility (see Table below). The preferred option decided upon by the data workshop was to use a single overall correction factor of 0.4138 to discount headboat catches.

State	Proportion Charter	Sample Size
NC	0.393	28
SC	0.333	9
GA	1	4
FL	0.353	17

6 ***Issue: Misreported gag grouper as black grouper***

In the Gulf of Mexico there were some known cases of gag samples being misreported as black grouper, owing to a common misnomer among the angling community. It was unclear if this same problem existed in the U.S. South Atlantic. We examined the ratios of gag to (gag + black grouper) by region. There was some slight indication that the ratio was lower in early years(See Figure 14), which would have been consistent with the pattern found in the Gulf of Mexico, however, the pattern in the Gulf of Mexico was much more extreme . Furthermore, the Gulf of Mexico had a case of a known change in interviewer training, interviewer supervision, and contractor quality assurance and control implemented in 1990. This coincided with a rapid change in the reported ratio of gag:(gag + black grouper). Therefore it was decided by the data workshop to not make any adjustments to the East Florida MRFSS estimates.

The examination of the ratio of gag:(g ag + black grouper) for Georgia, South Carolina, and North Carolina did show some rapid changes in the ratio for some years (See Figure 14 and Table 8). Black grouper are known to occur in South Florida and there appearance north of Florida becomes increasingly rare. For this reason, it was decided that the reported black grouper in some years north of Florida were likely gag. The data workshop decided to include all reported black grouper catches north of Florida with gag for the U.S. South Atlantic.

7 ***Issue: Fill in estimates for Wave 1 in 1981.***

The MRFSS survey did not begin full operations in 1981 until March (Wave 2). The data workshop decided to estimate the missing Wave 1 estimates using a ratio of Wave 1 to Waves 2-6 for years 1982-1985. This ratio was then applied to the 1981 Wave 2-6 estimates to estimate Wave 1 in 1981. As it turns out, the only state with any Wave 1 estimates in 1982-1985 is Florida. Therefore the estimates of Wave 1 in 1981 are very minor; an addition of only 4,146 fish to the A+B1 category.

8 ***Issue: Estimate historic landings back to 1962***

From a stock assessment modeling perspective it is often desirable to extend landings estimates for primary fisheries as far back in time as is reasonable. In an attempt to match commercial landings estimates, which extend back to 1962, we examined two linear predictors for estimating historic MRFSS landings.

The first approach involved regressing the MRFSS landings in 1981-2004 against the commercial landings for the same years. The regression of MRFSS landings without estimated released fish was not significant using the linear model. However, the regression of MRFSS landings without released fish was significant using the robust linear model (See Figure 4).

The other option considered for estimating historic MRFSS landings used the coastal human population estimates as a linear predictor. The results of this are shown in Figure 5.

There was no preferred recommendation from the data workshop panel on this issue. The SEDAR 10 Atlantic working group decided to use the regression of headboat landings to commercial landings to predict headboat landings from 1962–1980. (See Table 4).

Landings in Numbers Landings in numbers are estimated in the MRFSS for three (3) landings categories: retained fish available for measurement (type A), retained fish unavailable for measurement (type B1), and released fish (type B2). Table 9 and Figure 15 summarize landings with percent standard error for private boats, charter boats, and shore-based fishing. Most landings represent two modes of fishing: private boats and charter boats. The latter are smaller for-hire vessels, not including headboats. Estimated total landings in numbers by state are also reported (see Table 10 and Figure 16).

Landings in Biomass

9 ***Issue: Use weight estimates or not.***

The MRFSS intercept samples with weight information is limited. Approximately 10% of the expansion cells have no information on weight. The data workshop discussed methods for borrowing weight estimates from neighboring cells to fill in missing weight samples. In addition, the records that do include weight may have been calculated using substitutions from other cells possibly based on only one fish. Ultimately, the data workshop decided not to use the weight estimates, since the assessment model was equipped to handle catch in numbers just as easily as catch in weight. Furthermore, the estimates of released fish do not have any weight estimates associated with them, suggesting MRFSS catches are best handled as numbers in the assessment model.

4.4.3 Recreational Discards

Discard data is collected during every MRFSS interview and has been collected consistently since the inception of the MRFSS. Anglers are asked to recall discards the day of their completed fishing trip by creel samplers during interviews. Early years of discard estimates are variable, probably due to low incidence of gag discards in the intercept sample, but variability has been reduced in more recent years with the an increase in the frequency of intercepts and a higher incidence of gag discards. (See Table 11)

4.4.4 Biological Sampling

Sampling Intensity There are limited length and weight samples from the MRFSS, especially in the first few years of the survey (see Table 12).

Length Compositions Length compositions were created by assigning an estimated landings value to each fish length by year, wave and fishing mode. The fork lengths were converted to total length using the conversion factor provided by the life history section for this assessment.

$$TotalLength = ForkLength * 1.034 \tag{1}$$

. The estimated landings associated with each fish were summed by year and fish length (1cm bins). The proportion estimated landings for each length by year was calculated and reported as the annual weighted length composition (see Figure 17 and Figure 18).

Table 1. Estimated numbers of gag landed from Headboat vessels in the Southeast US Atlantic. Fish in thousands of fish. The upper and lower 95% confidence intervals for predicted values of Georgia and Florida are reported.

Year	NC	SC	GA-FL	Lower	Upper	Total
1972	6.20	1.17	6.08	1.91	10.24	13.44
1973	8.25	2.00	7.74	3.50	11.98	17.99
1974	6.72	0.95	6.25	2.08	10.42	13.92
1975	2.92	1.36	4.29	0.10	8.49	8.57
1976	2.11	1.52	3.92	0.00	8.14	7.56
1977	3.31	0.91	4.26	0.07	8.45	8.48
1978	2.16	0.49	3.36	0.00	7.61	6.01
1979	4.07	0.82	4.65	0.47	8.83	9.55
1980	1.57	1.68	3.70	0.00	7.93	6.96
1981	3.42	1.39	9.05			13.86
1982	2.98	0.95	7.91			11.84
1983	3.44	3.90	9.12			16.46
1984	7.71	1.29	9.69			18.69
1985	6.90	1.61	7.62			16.13
1986	8.51	1.60	7.24			17.35
1987	10.60	2.50	11.00			24.09
1988	10.97	2.49	10.76			24.21
1989	12.58	1.88	7.95			22.42
1990	7.93	3.58	6.08			17.59
1991	5.46	3.50	4.59			13.55
1992	6.15	2.36	5.44			13.94
1993	4.84	1.79	5.16			11.80
1994	4.38	1.11	4.32			9.81
1995	4.26	0.88	5.40			10.54
1996	3.30	0.59	3.61			7.50
1997	2.67	0.39	3.80			6.85
1998	3.72	0.60	4.36			8.67
1999	1.28	0.91	3.14			5.34
2000	1.92	0.76	3.30			5.98
2001	1.74	1.21	2.17			5.12
2002	1.65	1.23	1.70			4.58
2003	1.66	0.25	1.36			3.27
2004	1.80	1.24	3.62			6.66

Table 2. Weights in metric tons of gag landed from Headboat vessels in the Southeast US Atlantic.

Year	NC	SC	GA-FL	Lower	Upper	Total
1972	44.71	9.43	52.99	24.19	81.78	107.12
1973	68.41	17.41	80.00	41.59	118.41	165.82
1974	55.57	10.26	62.96	31.08	94.84	128.79
1975	20.58	12.89	35.37	9.95	60.78	68.84
1976	15.21	10.92	29.10	4.08	54.12	55.22
1977	20.38	6.43	29.69	4.65	54.72	56.50
1978	16.16	2.74	22.95	0.00	48.03	41.85
1979	25.01	5.55	32.88	7.69	58.08	63.45
1980	8.62	10.93	23.49	0.00	48.55	43.03
1981	14.37	5.73	46.80			66.89
1982	12.94	3.75	41.32			58.01
1983	11.32	14.05	34.60			59.97
1984	27.10	6.54	59.88			93.52
1985	21.55	10.51	39.53			71.59
1986	23.19	8.18	29.46			60.84
1987	28.15	10.14	46.65			84.94
1988	30.30	8.41	52.56			91.27
1989	34.49	9.96	34.27			78.71
1990	23.44	17.09	22.38			62.91
1991	16.74	18.34	16.59			51.67
1992	18.56	9.92	27.99			56.47
1993	15.86	6.79	32.41			55.05
1994	14.77	5.89	22.39			43.05
1995	17.51	6.18	26.75			50.44
1996	9.92	3.53	16.65			30.09
1997	10.01	2.22	15.70			27.93
1998	13.34	3.89	14.92			32.15
1999	6.31	5.66	14.49			26.46
2000	9.58	4.37	13.67			27.63
2001	7.79	5.26	10.90			23.94
2002	5.94	6.44	10.55			22.93
2003	5.95	1.28	7.50			14.74
2004	8.43	5.59	23.30			37.31

Table 3. Weights in gutted whole pounds of gag landed from Headboat vessels in the Southeast US Atlantic.

Year	NC	SC	GA-FL	Lower	Upper	Total
1972	93113	19641	110360	50386	170334	223113
1973	142473	36265	166627	86628	246627	345365
1974	115742	21367	131129	64733	197525	268239
1975	42862	26851	73658	20732	126584	143370
1976	31673	22738	60609	8506	112712	115020
1977	42453	13392	61833	9694	113972	117678
1978	33666	5711	47789	0	100041	87166
1979	52097	11557	68491	16007	120976	132145
1980	17945	22759	48921	0	101121	89624
1981	29928	11932	97466			139327
1982	26947	7808	86062			120817
1983	23578	29258	72071			124908
1984	56436	13628	124724			194787
1985	44876	21884	82338			149098
1986	48302	17046	61367			126715
1987	58624	21122	97159			176905
1988	63106	17515	109474			190094
1989	71825	20734	71379			163938
1990	48819	35604	46608			131030
1991	34867	38205	34554			107627
1992	38649	20653	58305			117607
1993	33031	14140	67493			114665
1994	30761	12260	46641			89661
1995	36474	12870	55709			105053
1996	20655	7347	34674			62676
1997	20852	4632	32696			58180
1998	27782	8102	31075			66960
1999	13153	11793	30175			55121
2000	19960	9108	28474			57543
2001	16215	10948	22692			49856
2002	12375	13420	21969			47764
2003	12392	2675	15630			30697
2004	17548	11643	48527			77718

Table 4. Estimated numbers of gag landed from Headboat vessels and recreational anglers in the South Atlantic. Headboat and MRFSS (A+B1) landings are predicted from commercial landings for 1962–1971 and 1962–1980 respectively.

Year	HB	HB +releases	MRFSS (A+B1)	MRFSS (A+B1+B2)
1962	8.41	8.41	6.17	6.17
1963	7.66	7.66	5.62	5.62
1964	7.18	7.18	5.27	5.27
1965	7.41	7.41	5.44	5.44
1966	5.58	5.58	4.09	4.09
1967	11.77	11.77	8.62	8.62
1968	17.72	17.72	12.98	12.98
1969	12.13	12.13	8.89	8.89
1970	16.66	16.66	12.20	12.20
1971	17.18	17.18	12.59	12.59
1972	13.44	13.44	8.37	8.37
1973	17.99	17.99	12.15	12.15
1974	13.92	13.92	15.68	15.68
1975	8.57	8.57	17.48	17.48
1976	7.56	7.56	23.77	23.77
1977	8.48	8.48	21.94	21.94
1978	6.01	6.01	37.54	37.54
1979	9.55	9.55	35.70	35.70
1980	6.96	6.96	35.39	35.39
1981	13.86	13.89	56.69	56.69
1982	11.84	11.86	17.85	22.17
1983	16.46	16.50	74.82	166.70
1984	18.69	18.72	153.25	165.20
1985	16.13	19.89	52.22	55.31
1986	17.35	21.40	46.78	59.26
1987	24.09	29.72	87.38	97.68
1988	24.21	29.86	62.07	77.08
1989	22.42	27.65	75.28	118.69
1990	17.59	21.70	52.20	63.66
1991	13.55	16.71	36.71	60.90
1992	13.94	21.68	49.32	87.98
1993	11.80	18.34	51.80	83.03
1994	9.81	15.26	56.22	124.51
1995	10.54	16.39	40.53	114.50
1996	7.50	11.66	43.92	86.92
1997	6.85	10.66	32.33	114.74
1998	8.67	13.49	40.32	72.54
1999	5.34	10.14	50.45	109.31
2000	5.98	11.36	29.87	156.50
2001	5.12	9.72	42.74	90.15
2002	4.58	8.70	24.03	109.76
2003	3.27	6.22	46.11	183.73
2004	6.66	12.66	46.25	135.79

Table 5. Percent gag released in the recreation angler fishery of the Southeast US Atlantic.

Charter Mode			
Year	B2	A+B1	B2/(A+B1)
1981	0	458	0%
1982	0	706	0%
1983	0	596	0%
1984	106	13382	1%
1985	1392	6449	22%
1986	749	718	104%
1987	0	4218	0%
1988	1793	22112	8%
1989	0	15564	0%
1990	1407	13445	10%
1991	1636	8730	19%
1992	9447	15899	59%
1993	12287	18666	66%
1994	11987	22303	54%
1995	13960	18213	77%
1996	2825	11822	24%
1997	6329	10521	60%
1998	3981	8168	49%
1999	5033	16913	30%
2000	7759	10666	73%
2001	2707	7968	34%
2002	4839	5857	83%
2003	19577	9152	214%
2004	8892	8270	108%

Table 6. Percent gag released in the recreation angler fishery of the Southeast US Atlantic averaged over each regulation period.

Charter Mode	
Regulation Period	B2/(A+B1)
1981–1984	0%
1985–1991	23%
1992–1998	55%
1999–2004	90%

Table 7. Frequency of headboat biological sampling of gag in the Southeast US Atlantic.

year	NC	SC	GA/FL	Total
1972	118	33		151
1973	124	116		240
1974	93	53		146
1975	180	53		233
1976	198	31	23	252
1977	271	36	73	380
1978	158	24	142	324
1979	91	16	180	287
1980	177	9	147	333
1981	94	1	361	456
1982	230	15	353	598
1983	283	67	551	901
1984	505	82	672	1259
1985	362	44	558	964
1986	325	27	319	671
1987	359	86	254	699
1988	323	60	161	544
1989	262	37	173	472
1990	166	27	173	366
1991	90	38	56	184
1992	123	71	82	276
1993	97	79	106	282
1994	71	123	94	288
1995	134	184	166	484
1996	76	42	105	223
1997	55	16	128	199
1998	77	20	270	367
1999	49	36	188	273
2000	40	3	154	197
2001	54	0	136	190
2002	37	8	61	106
2003	46	29	67	142
2004	55	7	47	109

Table 8. Percentage of MRFSS landings that were gag of the gag plus black grouper landings.

Year	North Carolina	South Carolina	Georgia	Florida
1981	100	0	20	57
1982	100	20	20	25
1983	0	0	100	33
1984	100	100	20	52
1985	100	100	100	75
1986	20	100	100	27
1987	100	100	100	76
1988	100	100	100	100
1989	100	95	100	82
1990	100	100	100	100
1991	100	100	100	100
1992	100	100	100	56
1993	100	100	100	100
1994	100	100	100	96
1995	100	100	100	70
1996	97	100	100	53
1997	100	20	100	64
1998	100	20	100	74
1999	50	100	100	90
2000	100	100	100	85
2001	100	100	100	83
2002	100	100	100	87
2003	100	100	100	84
2004	100	100	100	87

Table 9. MRFSS Estimates of numbers of gag landed by recreational anglers in the Southeast US Atlantic with percent standard error estimates (PSE). Landings are in thousands of fish.

	Private Boats		Charter Boats		Shore-based		Total	
Year	A + B1	PSE	A + B1	PSE	A + B1	PSE	A + B1	PSE
1981	0.46	100.00	50.53	50.98	5.71	71.50	56.69	46.51
1982	0.71	61.11	15.47	63.47	1.67	100.00	17.85	47.9
1983	0.60	77.38	74.23	52.77	0.00		74.82	52.32
1984	13.38	30.70	137.45	29.13	2.41	49.74	153.25	20.66
1985	6.45	37.31	37.90	44.18	7.87	56.38	52.22	29.78
1986	0.72	52.98	19.91	27.72	26.15		46.78	26.93
1987	4.22	29.18	80.78	38.82	2.38	73.39	87.38	35.81
1988	22.11	25.44	39.96	24.49	0.00		62.07	20.36
1989	15.56	24.51	55.29	22.39	4.43	100.00	75.28	17.49
1990	13.45	18.90	37.37	36.36	1.38	71.58	52.20	26.71
1991	8.73	17.20	23.85	24.36	4.13		36.71	19.05
1992	15.90	24.51	33.42	16.21	0.00		49.32	13.53
1993	18.67	26.66	32.75	28.68	0.38	70.94	51.80	20.43
1994	22.30	20.97	32.27	26.10	1.64	66.67	56.22	17.2
1995	18.21	33.16	19.04	26.97	3.28	100.00	40.53	20.82
1996	11.82	30.67	31.33	26.93	0.77	99.04	43.92	20.48
1997	10.52	35.79	21.81	25.79	0.00		32.33	21.86
1998	8.17	38.77	32.15	33.49	0.00		40.32	29.44
1999	16.91	20.51	33.08	31.70	0.46	100.00	50.45	22.25
2000	10.67	25.69	19.21	20.80	0.00		29.87	16.24
2001	7.97	18.98	31.93	22.55	2.84	71.13	42.74	18.1
2002	5.86	18.59	18.18	24.99	0.00		24.03	19.36
2003	9.15	35.14	36.96	17.58	0.00		46.11	15.73
2004	8.27	18.15	37.99	20.00	0.00		46.25	17.14

Table 10. MRFSS Estimates gag landings by recreational anglers in the Southeast US Atlantic by state with associated percent standard error(PSE). Landings are in thousands of fish.

	North Carolina		South Carolina		Georgia		Florida		Total	
YEAR	A+B1	PSE	A+B1	PSE	A+B1	PSE	A+B1	PSE	A+B1	PSE
1981	4.07	71.50	0.16				52.47	50.33	56.69	55.64
1982	3.35	59.14	0.00				14.50	61.11	17.85	
1983	47.37		0.18		0.41	49.87	26.85	53.69	74.82	60.65
1984	9.29	37.94	3.35	38.90	0.00		140.61	27.01	153.25	43.47
1985	9.23	46.34	5.56	46.49	1.42	34.91	36.00	44.89	52.22	41.39
1986	0.00		8.20	40.56	1.42	41.74	37.16	40.03	46.78	63.16
1987	32.01	78.74	4.34	46.08	0.42	50.93	50.60	30.35	87.38	34.34
1988	17.43	22.52	3.16	40.23	0.57	100.00	40.91	32.38	62.07	35.25
1989	23.84	26.66	8.10	33.58	0.47	69.11	42.87	29.24	75.28	34.05
1990	38.23	33.96	2.59	45.15	0.00		11.38	38.00	52.20	55.51
1991	13.57	31.61	8.56	42.46	1.57	63.10	13.01	30.97	36.71	30.44
1992	12.13	18.91	8.42	41.54	3.58	34.94	25.19	20.13	49.32	24.2
1993	13.47	59.61	7.85	49.11	9.97	31.43	20.50	21.98	51.80	25.02
1994	7.05	20.53	1.41	44.68	13.89	30.27	33.87	25.53	56.22	31.2
1995	7.34	49.90	4.96	79.63	5.33	28.95	22.91	27.14	40.53	30.15
1996	1.99	32.53	3.66	71.99	5.50	28.82	32.78	27.04	43.92	33.57
1997	3.77	48.48	0.76	100.00	2.73	42.91	25.06	27.68	32.33	37.34
1998	1.93	44.03	0.00		0.70	45.40	37.69	31.80	40.32	30.37
1999	5.00	46.90	5.51	39.54	0.25	68.52	39.69	26.17	50.45	25.69
2000	2.31	45.65	1.97	24.89	0.08	58.35	25.52	18.48	29.87	18.76
2001	4.05	38.88	1.03	67.86	0.10	55.22	37.55	20.11	42.74	21.96
2002	3.61	61.14	1.07	74.10	0.01	95.27	19.34	20.60	24.03	23.56
2003	7.65	49.20	3.88	56.81	0.02	99.04	34.57	16.42	46.11	21.29
2004	14.82	41.22	2.78	35.72	1.49	42.29	27.17	17.22	46.25	19.08

Table 11. MRFSS Estimates of released gag by recreational anglers in the Southeast US Atlantic with associated percent standard error(PSE). Releases are estimates of individual fish.

	Private Boats		Charter Boats		Shore-based	
YEAR	B2	PSE	B2	PSE	B2	PSE
1981	0	-	0	-	12444	100
1982	1461	100	0	-	1671	100
1983	1812	100	0	-	-	-
1984	4122	71	256	100	0	-
1985	1697	53	3526	61	11809	76
1986	24158	36	1220	53	-	-
1987	14727	39	0	-	8253	100
1988	13217	83	0	-	-	-
1989	67337	24	0	-	0	-
1990	22012	37	0	-	0	-
1991	27682	26	1636	74	0	-
1992	27675	27	5074	40	-	-
1993	20081	34	11800	90	3405	48
1994	68070	25	1416	45	12504	69
1995	61110	20	11120	30	17452	44
1996	55905	18	4179	36	4080	58
1997	63123	18	791	52	2395	100
1998	31587	25	1036	100	1310	100
1999	47226	15	2276	34	4596	47
2000	114400	30	6713	26	9568	67
2001	74727	15	1924	51	3308	65
2002	121940	14	4673	22	3348	52
2003	124300	13	6389	33	23406	29
2004	94128	14	3715	26	1372	72

Table 12. Sample sizes of gag weights and lengths collected by MRFSS.

	Number of Gag Weighed			Number of Gag Measured		
Year	Charter Boats	Private Boats	Shore-based	Charter Boats	Private Boats	Shore-based
1981	1	7	2	1	7	2
1982	1	1	1	1	1	1
1983	1	7	–	1	7	–
1984	25	11	1	26	14	1
1985	11	15	6	11	15	6
1986	1	14	–	1	14	–
1987	22	24	1	24	35	1
1988	24	13	–	55	13	–
1989	26	14	1	66	24	1
1990	55	12	2	94	21	2
1991	15	24	3	27	25	3
1992	54	26	–	63	28	–
1993	37	29	1	38	31	1
1994	62	16	1	79	17	1
1995	37	19	1	54	20	1
1996	21	5	1	29	11	1
1997	18	8	–	19	8	–
1998	21	18	–	23	20	–
1999	47	32	–	54	35	–
2000	73	23	–	75	26	–
2001	67	29	–	71	30	–
2002	74	15	–	76	18	–
2003	51	17	–	53	23	–
2004	52	22	–	65	25	–

Figures

Figure 1. Areas sampled by the headboat survey in the Southeast US Atlantic.

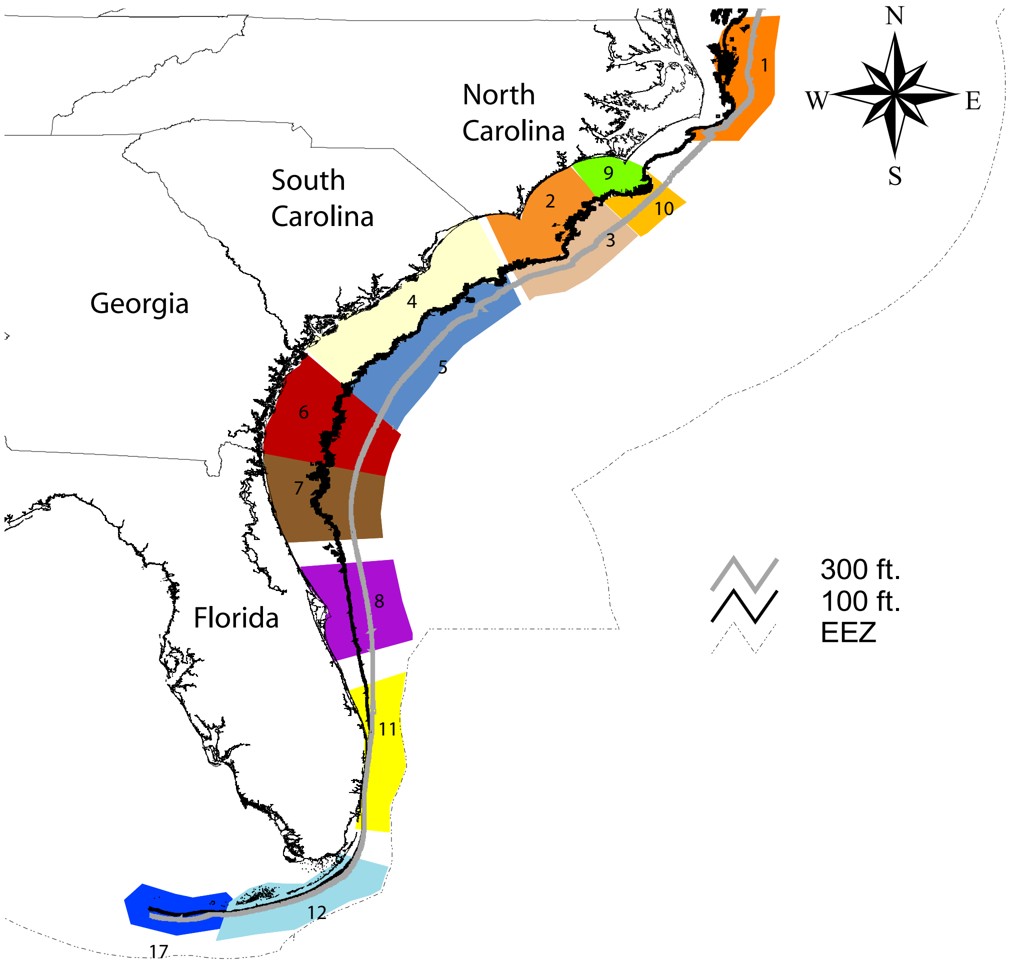


Figure 2. Landings of gag from the headboat survey by area in thousands of fish and in metric tons. The 95% confidence intervals are displayed for predicted landings from Georgia and Florida from 1972–1980

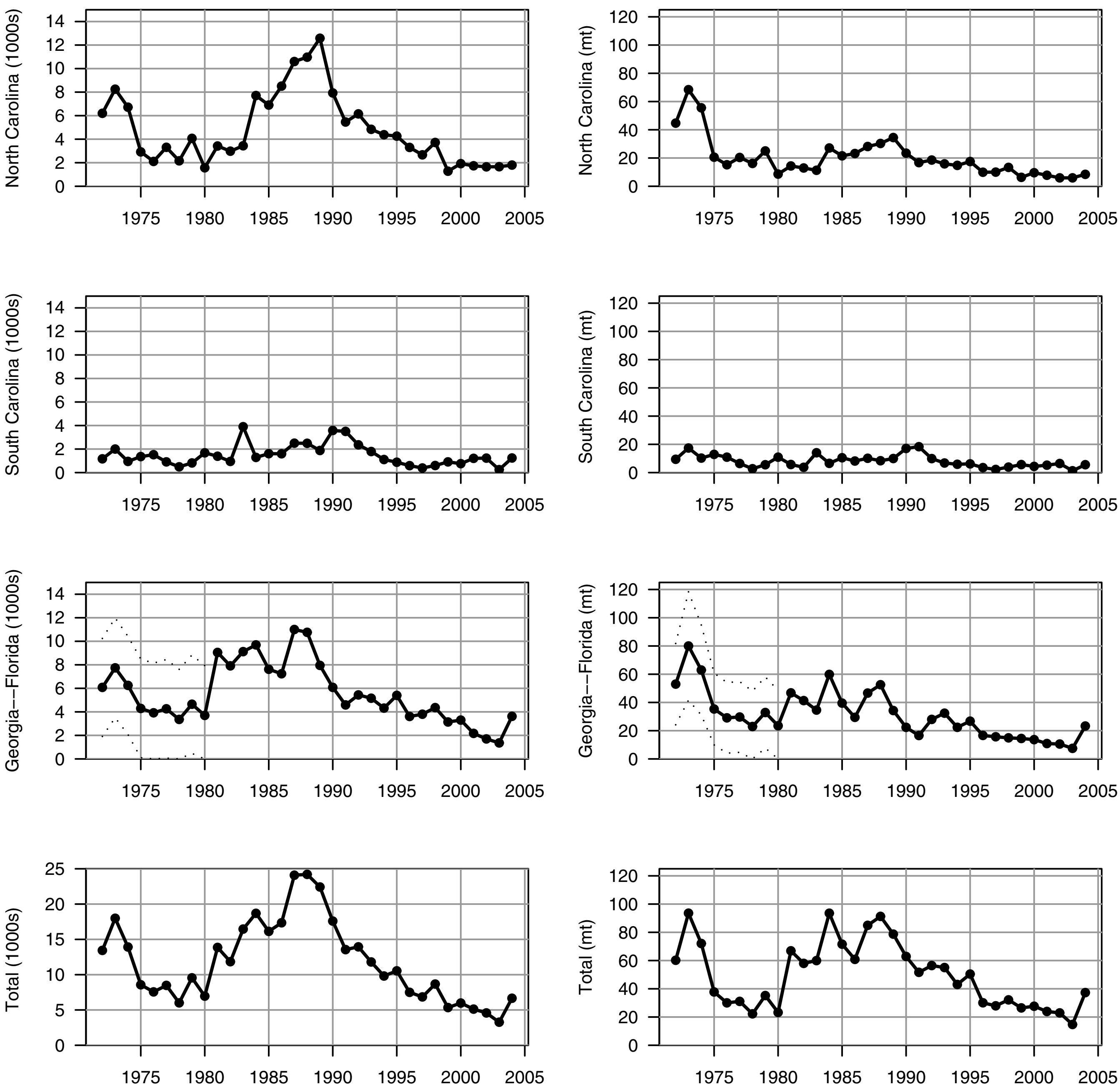
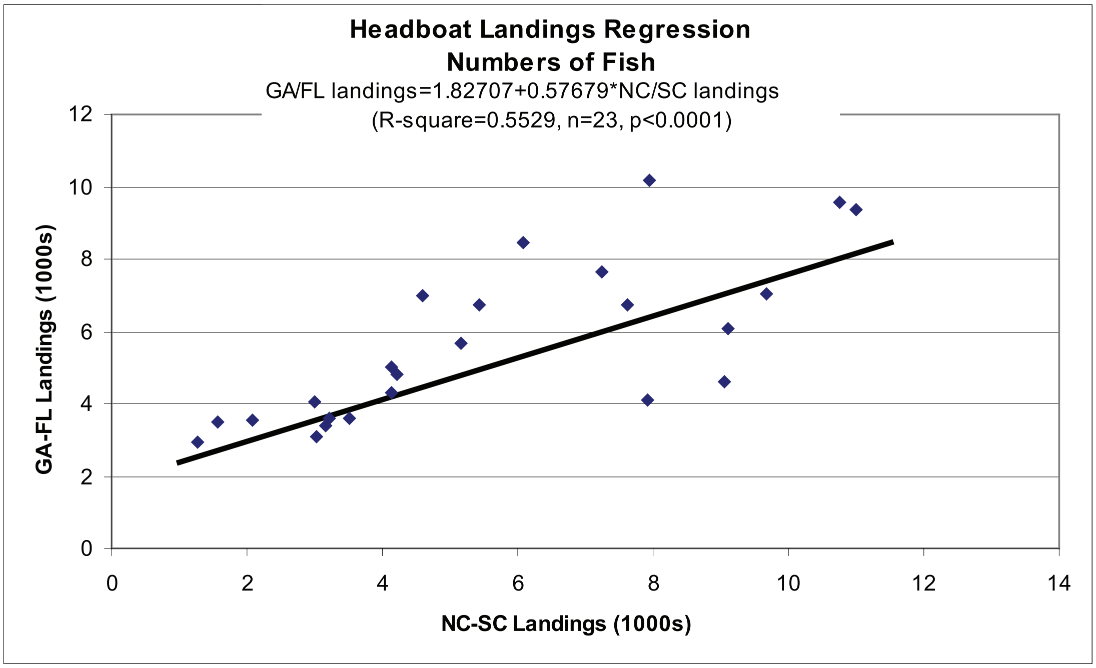


Figure 3. Landings and predicted landings of gag from the Headboat Survey in thousands of fish (A) and metric tons (B).



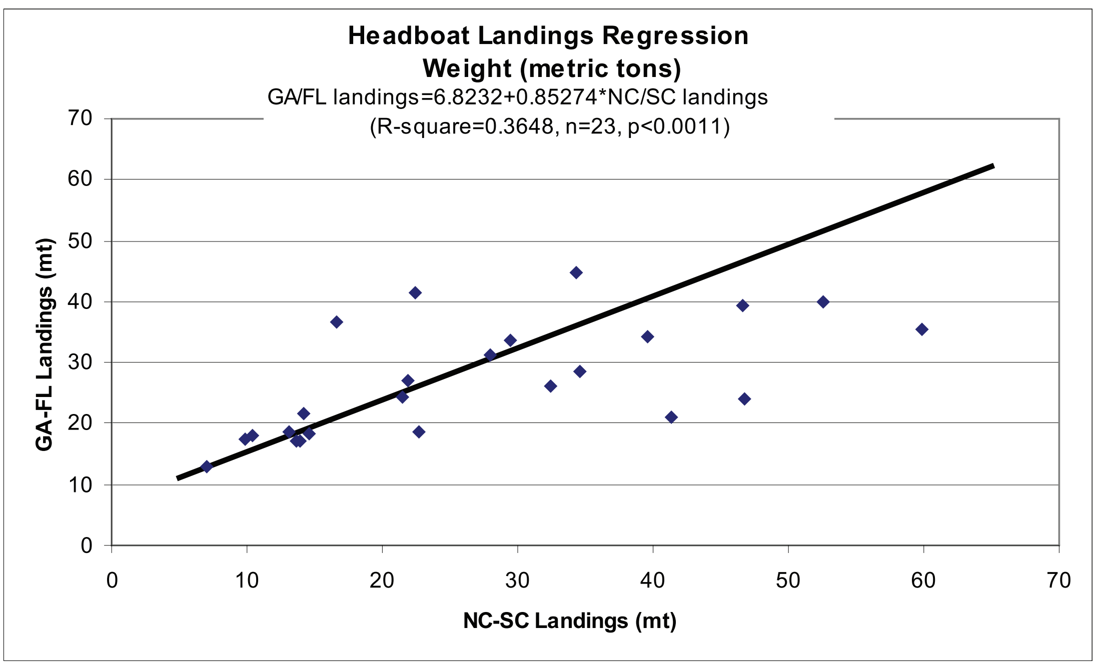


Figure 4. Linear model and Robust Linear Model regressions of gag landings from the recreational data sources against commercial landings for all years where both occurred.

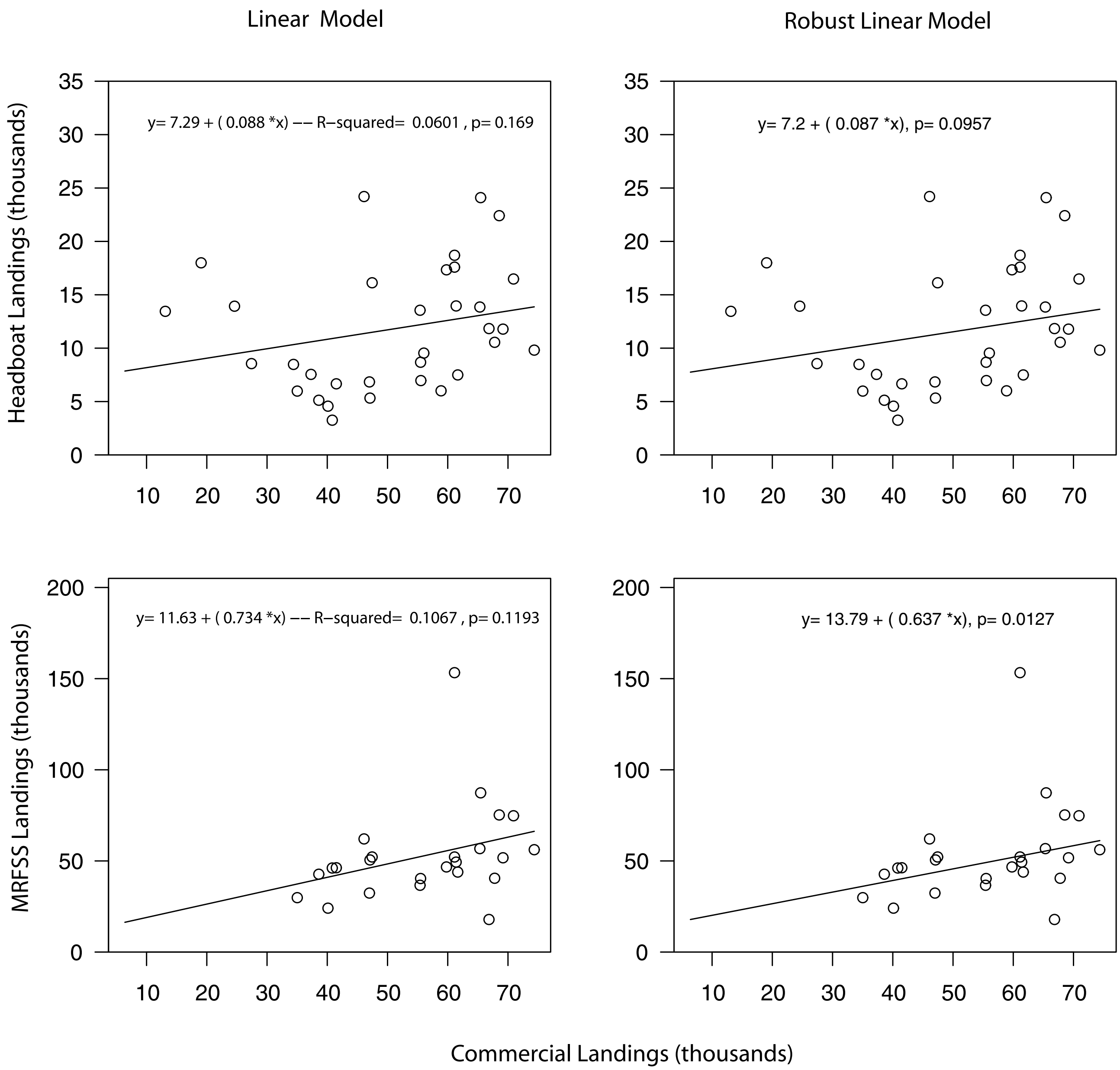


Figure 5. Regressions of headboat(A) and MRFSS (B) landings in number against coastal human population. Population trends by state displayed (C).

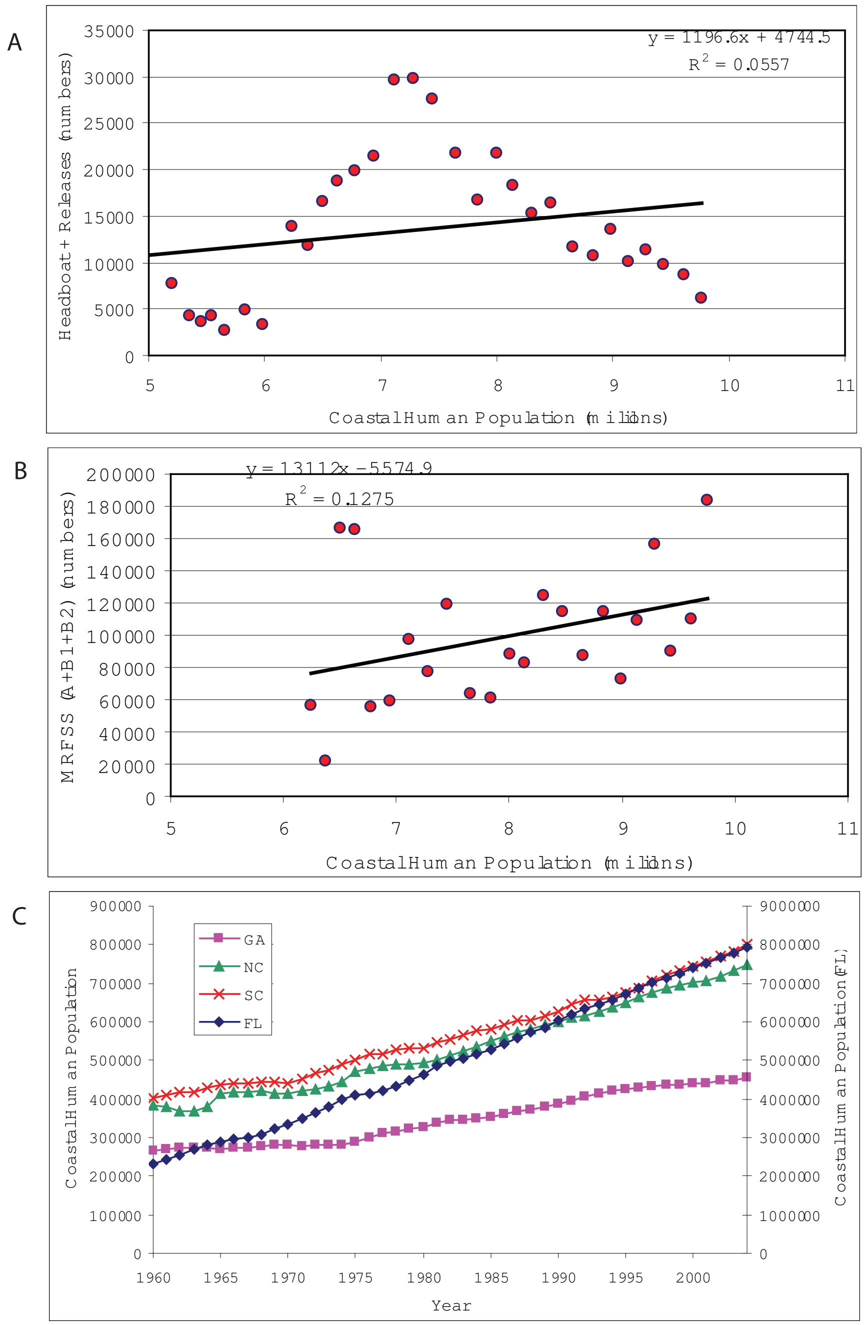


Figure 6. Release rates of gag used to predict headboat releases.

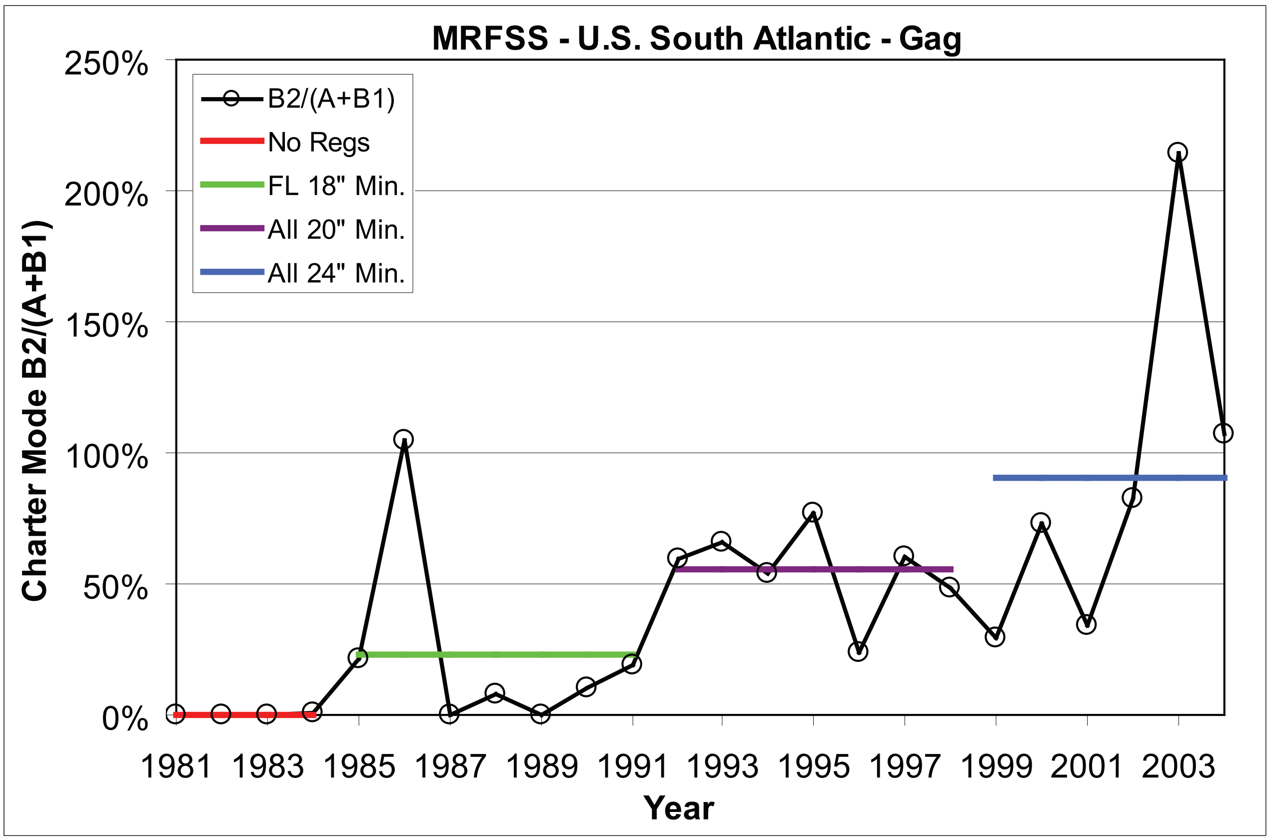


Figure 7. Mean weight in kg for North and South Carolina (Carolinas) and Georgia and Florida (GA/FL).

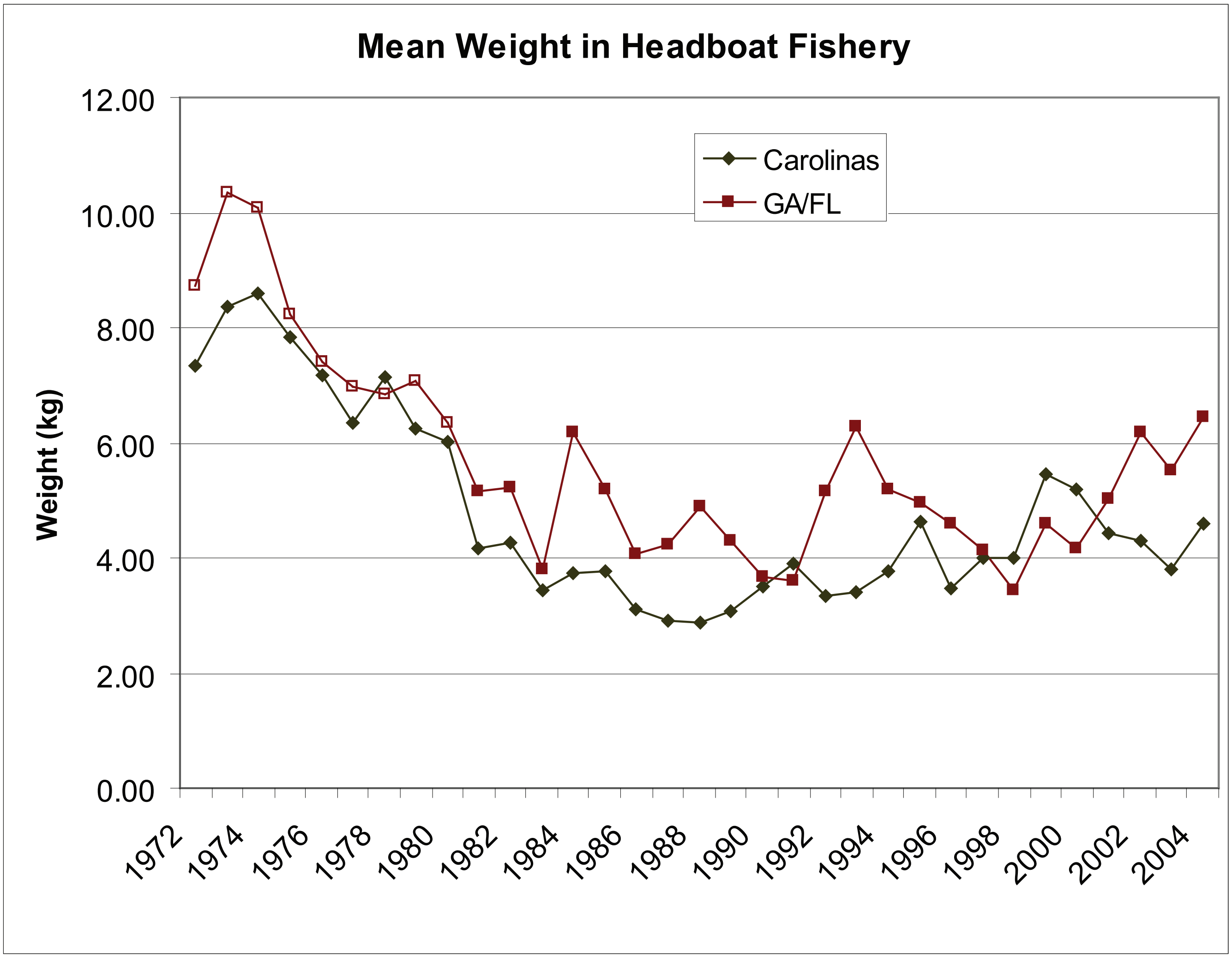


Figure 8. Length composition of gag from the headboat survey for 1972 to 1989. Lengths are in 1 cm bins from 20 cm to 125 cm.

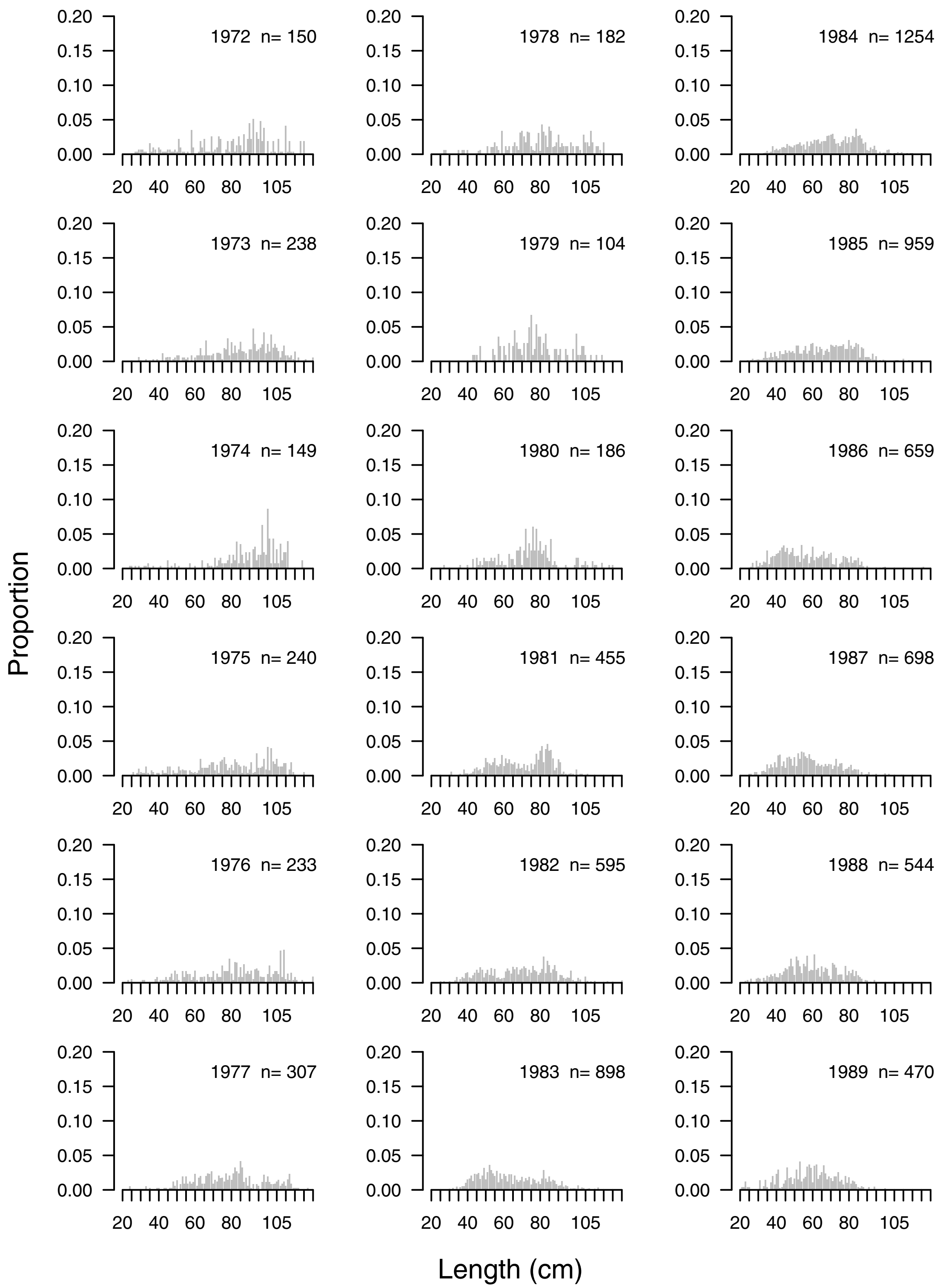


Figure 9. Length composition of gag from the headboat survey for 1990 to 2004. Lengths are in 1 cm bins from 20 cm to 125 cm.

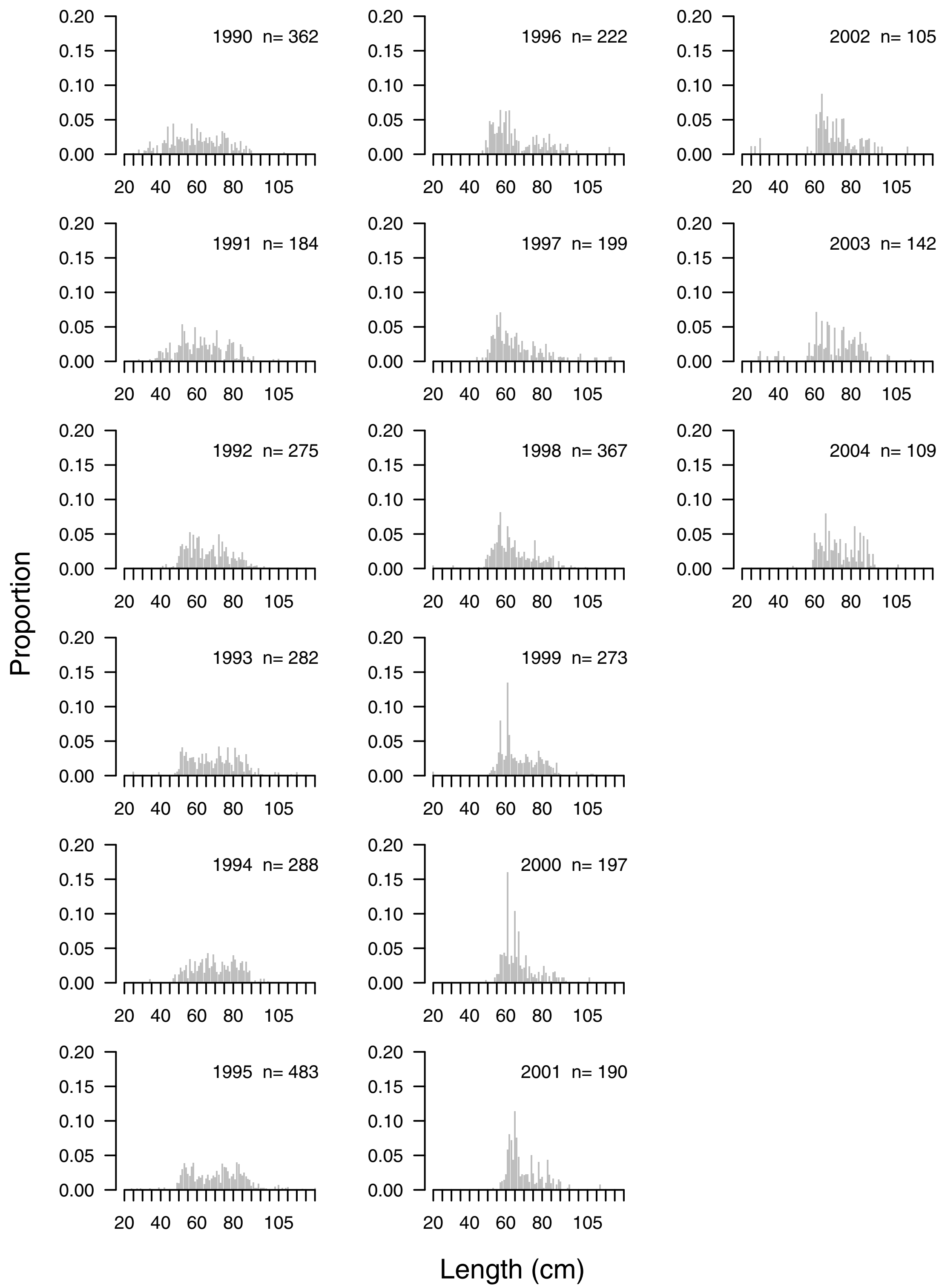
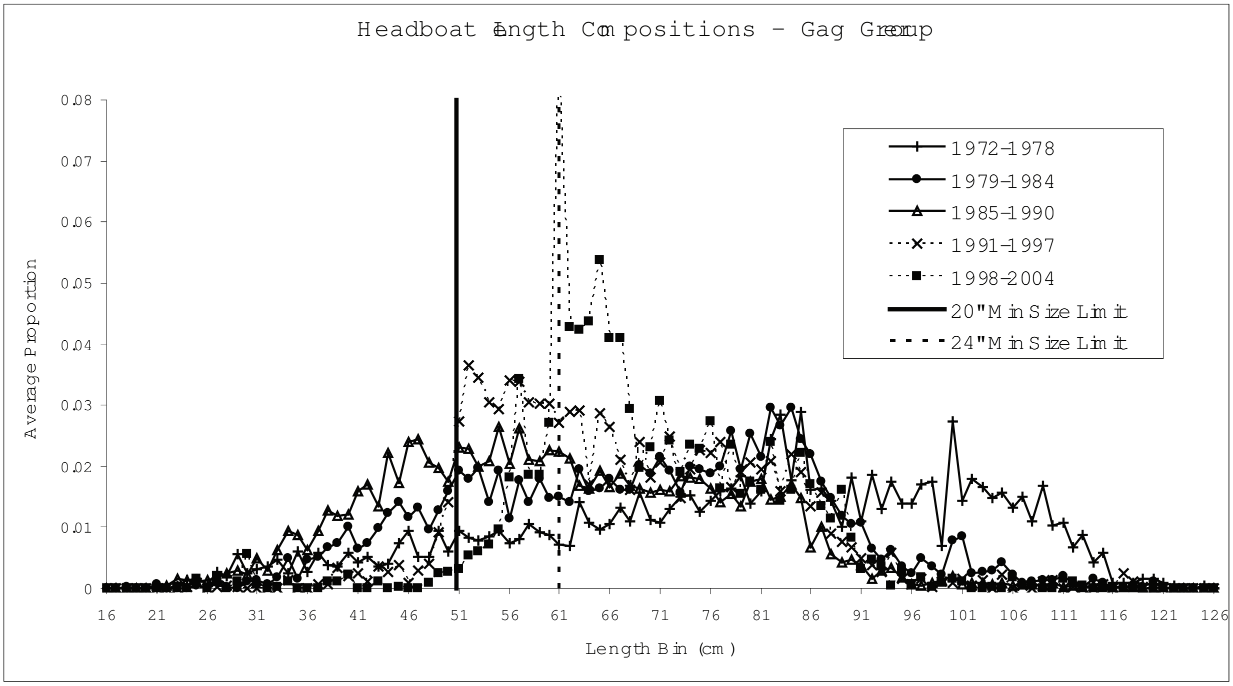


Figure 10. Analysis of changes in lengths of gag over time in the headboat survey.

A



B

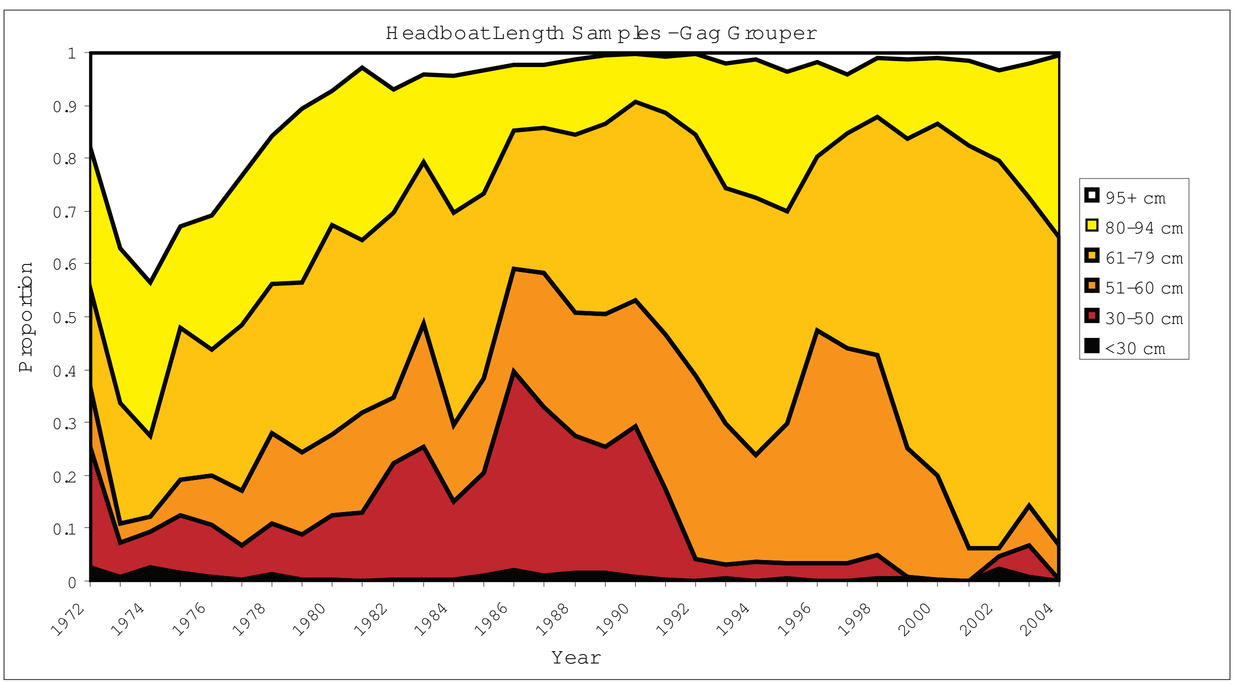


Figure 11. Analysis of changes in lengths of gag over time in the headboat survey.

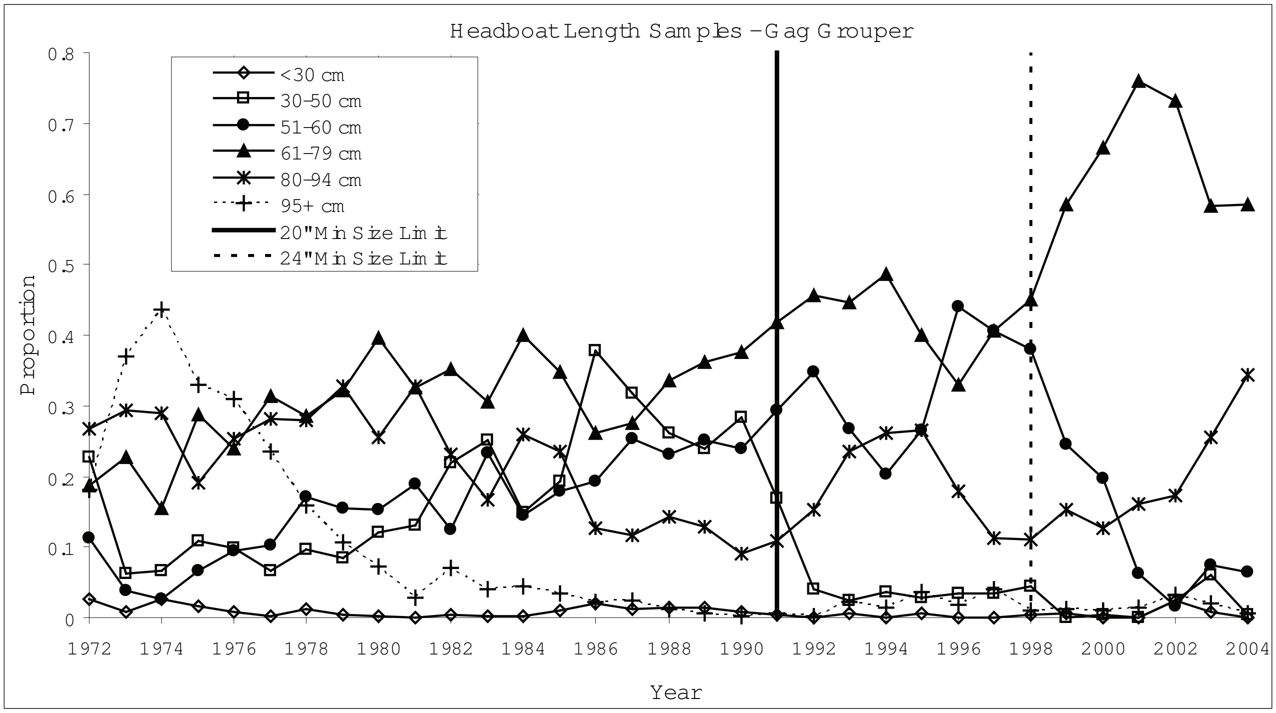


Figure 12. Age compositions of gag from the recreational data (headboat and charter vessel) for 1975-1990.

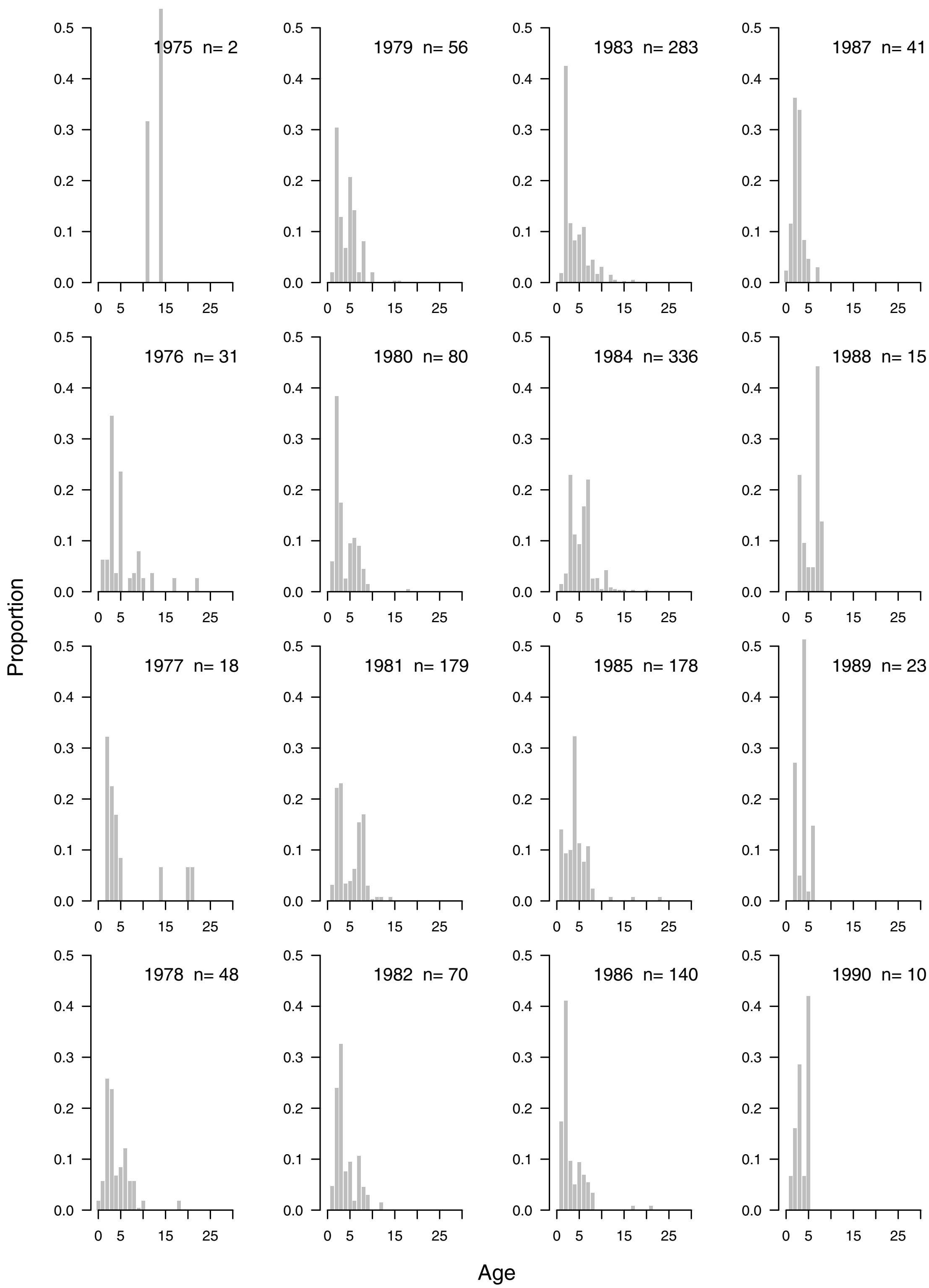


Figure 13. Age composition of gag from the recreational data (headboat and charter vessel) for 1991-2004, no ages were available from 1999 or 2000.

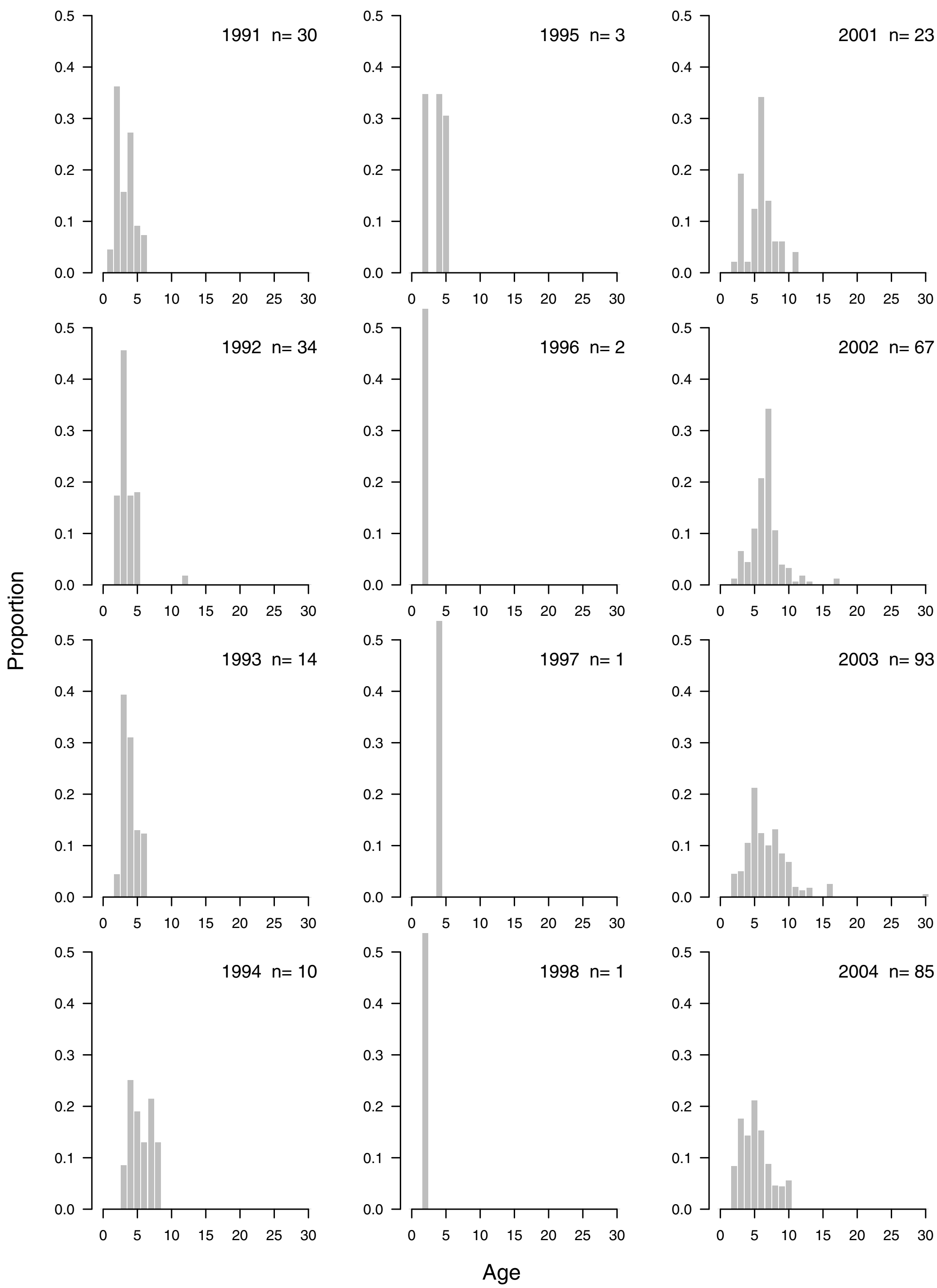


Figure 14. Percent of MRFSS landings in Number that were gag of total gag and black grouper.

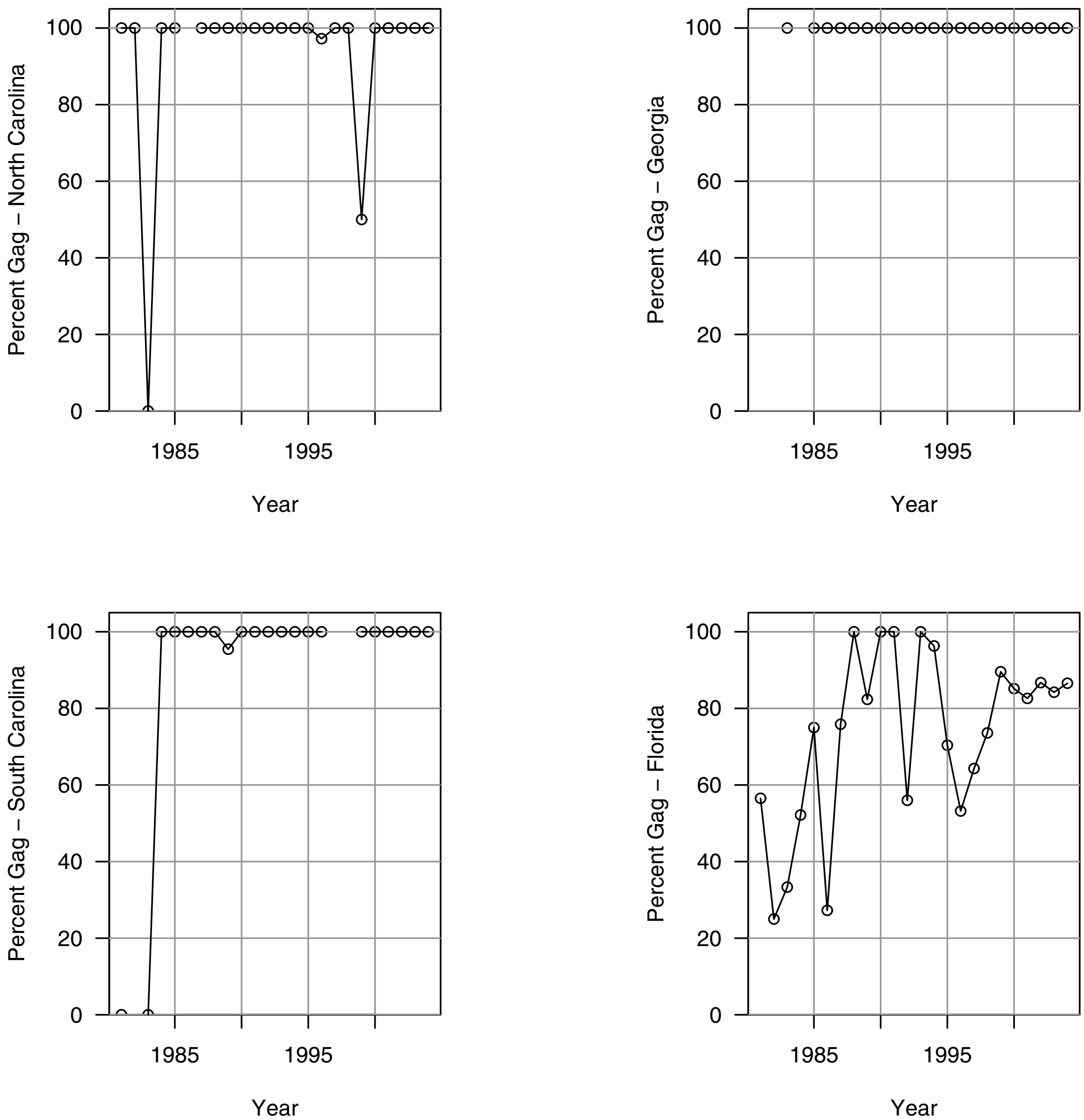


Figure 15. Landings in thousands of fish of gag from the MRFSS by fishing mode.

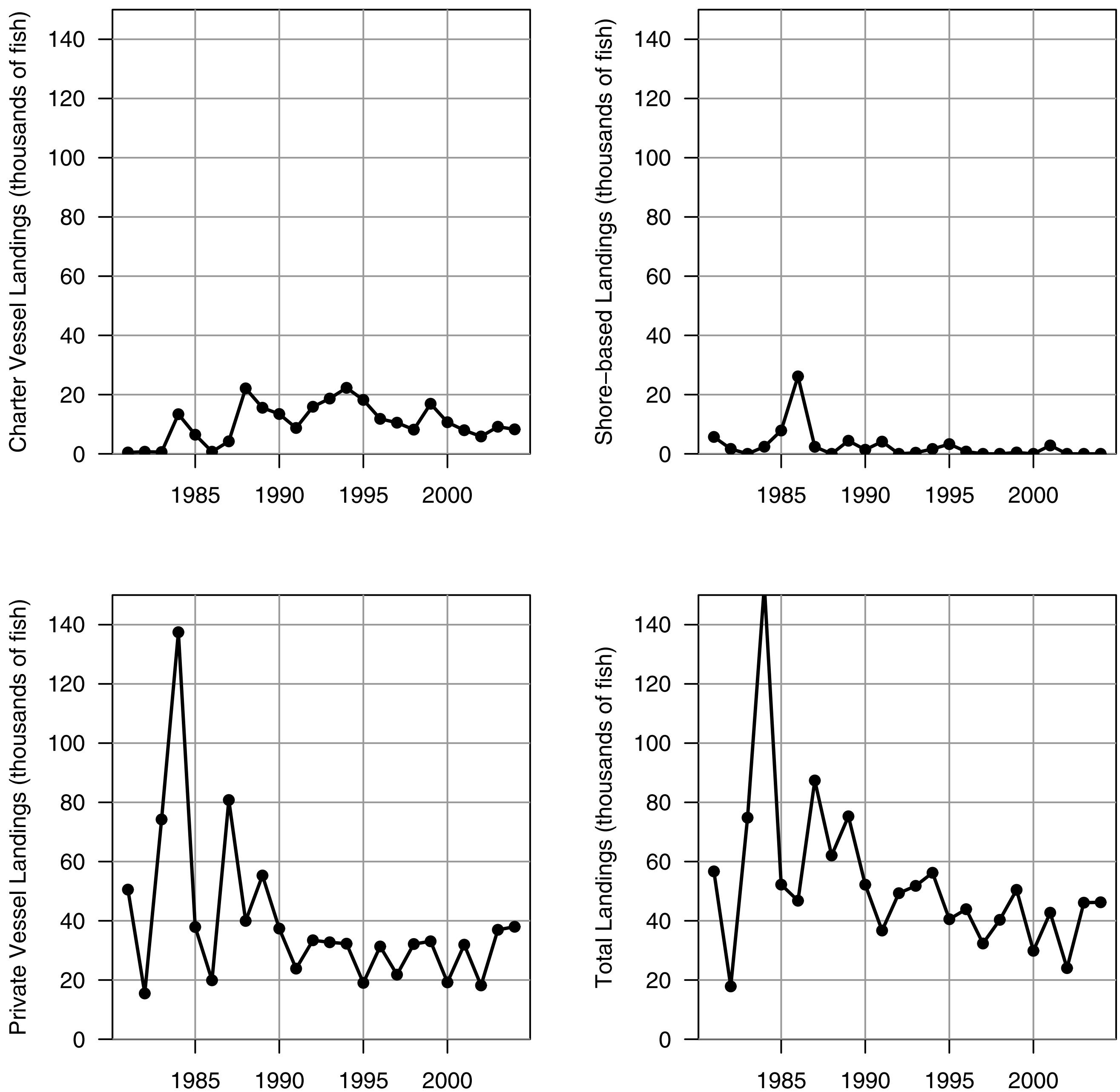


Figure 16. Landings of gag from MRFSS by state in thousands of fish.

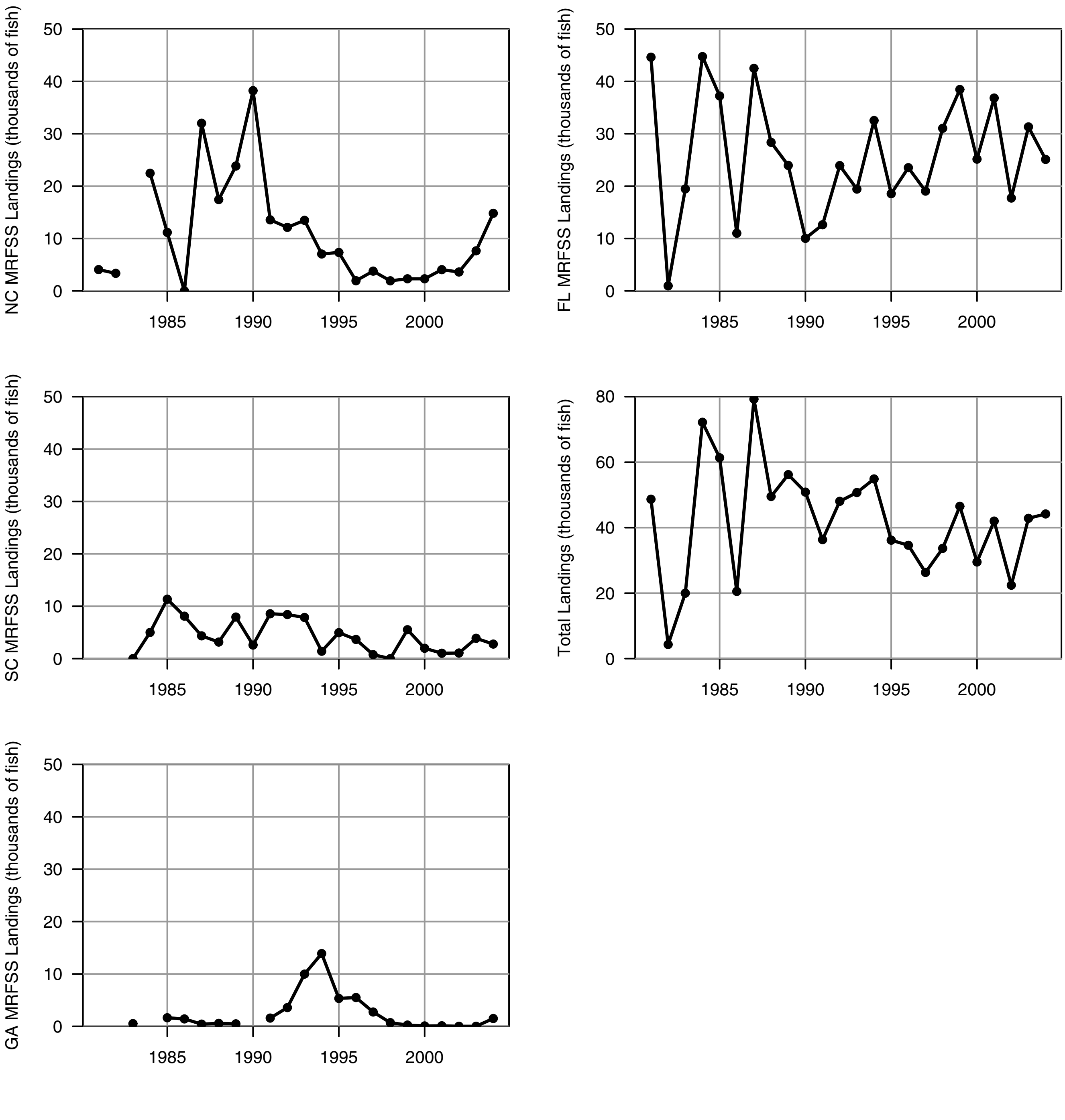


Figure 17. Length composition of gag from the MRFSS for 1981 to 1992. Lengths are in 1 cm bins from 20 cm to 125 cm.

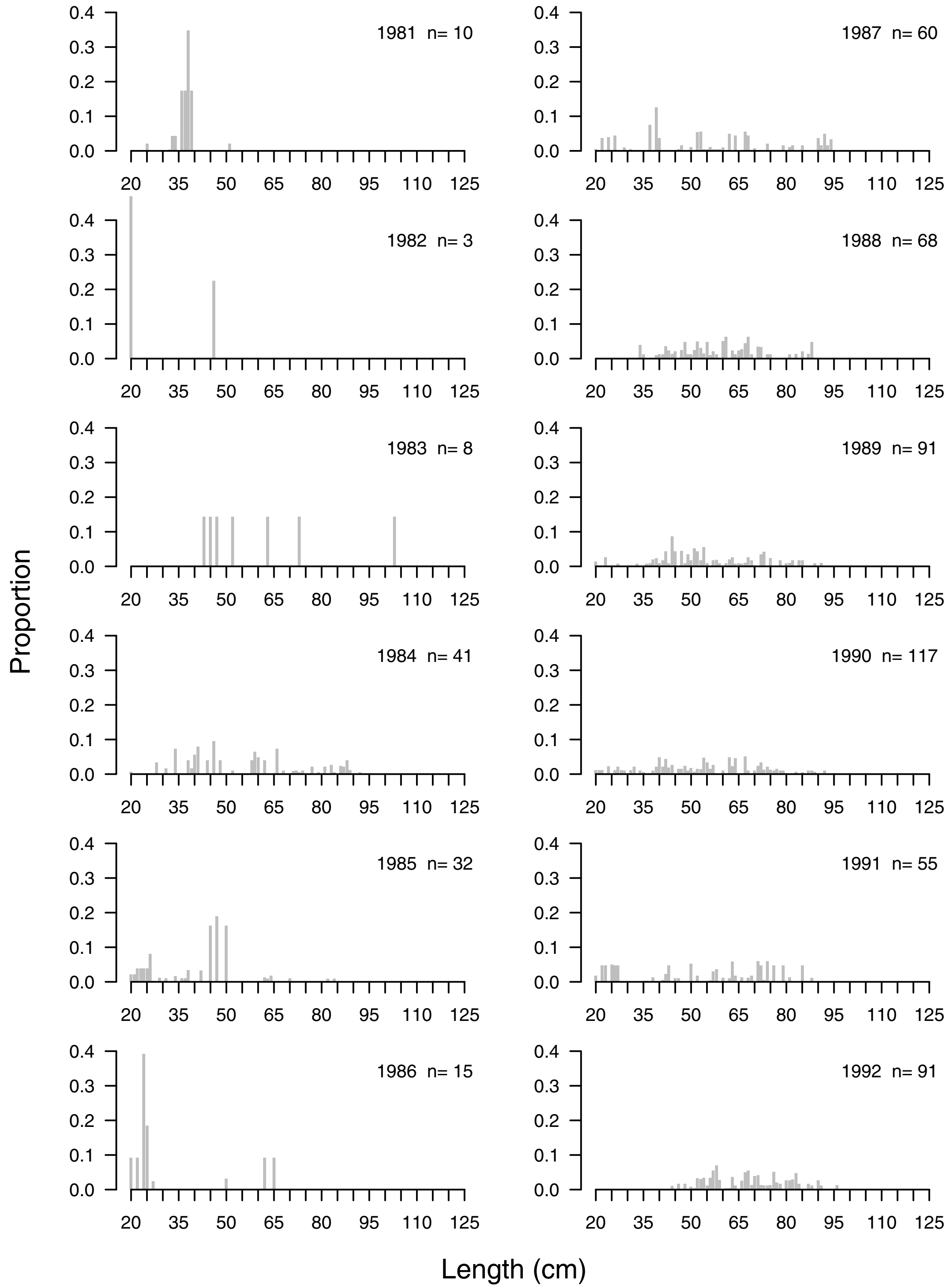
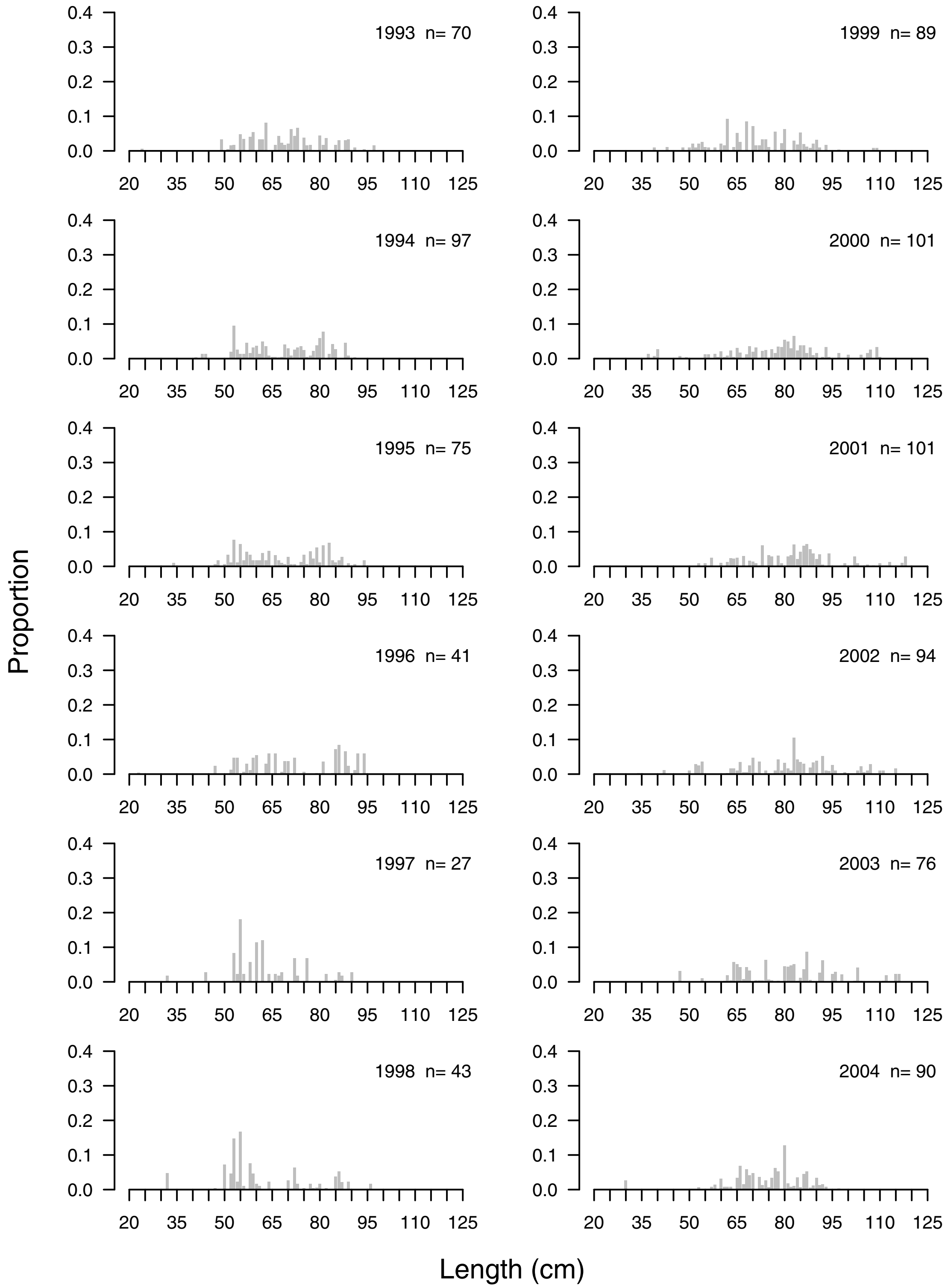


Figure 18. Length composition of gag from the MRFSS for 1993 to 2004. Lengths are in 1 cm bins from 20 cm to 125 cm.



5. INDICES OF ABUNDANCE

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 – one from commercial logbook data, one from headboat data, and one from general recreational data (Figure 5.1, Table 5.6). The DW did not recommend using any of the fishery-independent indices, due to inadequacies in the data.

5.1 INDEX FROM COMMERCIAL LOGBOOK (HANDLINE)

5.1.1 General description

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 catch. 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 1992–2004 (SEDAR10-DW-19).

5.1.2 Issues discussed at DW

Issue 1: Trip selection using method of Stephens and MacCall (2004)

Option 1: Include all positive trips and use Stephens and MacCall method to identify zero trips only.

Option 2: Include only those trips with associated probability of catching gag above the threshold probability, as in Stephens and MacCall (2004).

Decision: Option 2, to be consistent with the published method and to exclude trips with incidental catches of gag.

Issue 2: Misidentification of gag as black grouper

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 problematic areas. For other areas where black grouper are known to be rare, convert all landings reported as black grouper to gag.

Decision: Option 3. Much effort was devoted to achieving option 2, however, an acceptable method for correcting the landings could not be developed during the DW given available data. Option 3 was chosen because it corrects many records believed to be in error (SEDAR10-DW-19 SEDAR10-DW-28), with little chance of introducing new errors (i.e., converting black grouper to gag incorrectly). Option 3 was implemented by excluding areas south of 29 degrees latitude (near Cape Canaveral) and converting all reported black grouper to gag in areas equal to and north of 29 degrees.

Issue 3: Interaction terms in the delta-GLM

Option 1: Include only main effects

Option 2: Investigate interaction terms
Decision: Option 2. Investigate interaction terms. The group decided not to include interactions with year effects, because such effects may be inseparable from annual changes in abundance.

Miscellaneous decisions

- Exclude months of March and April from all years in the analysis, because of bag limits that started midway through the time series, in 1999.
- Include areas 2482 and 2382 in the Atlantic, because of council boundaries. Due to the decision on issue 2 (above), however, these areas were not used in the analysis, because they are south of 29 degrees latitude.

5.1.3 Methods

Standardized catch rates were estimated using a generalized linear model assuming delta-lognormal error structure (Lo et al., 1992, Can. J. Fish. Aquat. Sci., 49:2515-2526), 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 month*area interaction. A forward stepwise approach was used to construct each GLM (SEDAR DW-19). The approach identified area as the only factor other than year to be used in the binomial GLM, and it identified area, month, and area*month interaction as factors to be used in the lognormal GLM. The CPUE was in units total pounds caught per hook-hour.

Effective effort was based on those trips that caught gag (positive CPUE) and those that *could* have caught gag (zero catch, but positive effort). Positive catches are readily available from the data, but without information on targeting by fishermen, zero catches must be inferred. To do so, we applied the method of Stephens and MacCall (Stephens and MacCall, 2004, Fish. Res. 70:299-3210). In essence, the method uses multiple logistic regression to estimate a probability for each trip that gag was caught, given other species caught in that trip. Species used as factors in the regression were selected as those caught in at least 5% of trips. This cutoff simplifies the regression, by excluding rarely caught species; however, preliminary analyses indicated results were insensitive to the value of the cutoff (examined over a range of 0% to 10%). Trips were included if their associated probability was higher than a threshold probability. The threshold's value was defined as that which results in the same number of predicted and observed positive trips, as in Stephens and MacCall (2004).

5.1.4 Results

Estimates of CPUE (pounds/hook-hr) and CV are presented in Table 5.3 and in Figure 5.1.

5.1.5 Discussion

The logbook index was recommended by the DW for use in the assessment (Table 5.2). The DW, however, did express several concerns about this data set. 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.

Two concerns merit further description. First, 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 gag as black grouper.

Second 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.

5.2 INDEX FROM HEADBOAT SURVEY

5.2.1 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. Using the headboat data, an index of abundance was computed for 1973–2004 (SEDAR10-DW-20).

5.2.2 Issues discussed at DW

Issue 1: Trip selection using method of Stephens and MacCall (2004)

Option 1: Include all positive trips and use Stephens and MacCall method to identify zero trips only.

Option 2: Include only those trips with associated probability of catching gag above the threshold probability, as in Stephens and MacCall (2004).

Decision: Option 2, to be consistent with the published method and to exclude trips with incidental catches of gag.

Issue 2: Interaction terms in the delta-GLM

Option 1: Include only main effects

Option 2: Investigate interaction terms

Decision: Option 2. Investigate interaction terms. The group decided not to include interactions with year effects, because such effects may be inseparable from annual changes in abundance.

Issue 3: 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, but without a complete census. All headboats across all states were sampled starting in 1978.

Option 1: Exclude early years, starting the time series in either 1976 (full area coverage) or 1978 (full vessel coverage).
Option 2: Include early years, unless there is compelling empirical reason not to.
Decision: Option 2. The DW decided to include the early years, starting in 1973, because the sampling covered a substantial proportion of the geographic area, and because the GLM accounts for area as a factor. Exploratory data analysis revealed nothing to suggest data in those early years were flawed.

Miscellaneous decisions
• Landings in 2004 from vessel #308 were apparently reported incorrectly. These landings were corrected for computing CPUE, as they were for computing headboat landings.

5.2.3 Methods

Standardized catch rates were estimated using a generalized linear model assuming delta-lognormal error structure (Lo et al., 1992, Can. J. Fish. Aquat. Sci., 49:2515-2526), 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, trip type, and interaction terms. A forward stepwise approach was used to construct each GLM (SEDAR DW-20). For the binomial GLM, the stepwise approach identified all main effects—area, month, and trip type—for inclusion in the analysis. For the lognormal GLM, it identified all main effects plus the area*trip type interaction for inclusion. The CPUE was in units number caught per angler-hour.

Effective effort was based on those trips that caught gag (positive CPUE) and those that *could* have caught gag (zero catch, but positive effort). Positive catches are readily available from the data, but without information on targeting by fishermen, zero catches must be inferred. To do so, we applied the method of Stephens and MacCall (Stephens and MacCall, 2004, Fish. Res. 70:299-3210). In essence, the method uses multiple logistic regression to estimate a probability for each trip that gag was caught, given other species caught in that trip. Species used as factors in the regression were selected as those caught in at least 5% of trips. This cutoff simplifies the regression, by excluding rarely caught species; however, preliminary analyses indicated results were insensitive to the value of the cutoff (examined over a range of 0% to 10%). Trips were included if their associated probability was higher than a threshold probability. The threshold's value was defined as that which results in the same number of predicted and observed positive trips, as in Stephens and MacCall (2004).

5.2.4 Results

Estimates of CPUE (number/angler-hr) and CV are presented in Table 5.4 and in Figure 5.1.

5.2.5 Discussion

The headboat index was recommended by the DW for use in the assessment (Table 5.2). One concern was that this index may contain problems associated with fishery-dependent indices, as described in section 5.1.5. The DW, however, did note that the headboat fishery is not a directed fishery for gag. 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 gag 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 gag trips reveals that no such shift occurred during the 1980s (Figure 5.2). Half-day trips were initiated during the mid- to late-1970s, but since have shown no striking trends. Similar analyses of all headboat trips, by state and overall, revealed similar patterns. 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, full plus) is 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.

5.3 INDEX FROM MRFSS DATA

5.3.1 General description

The general recreational fishery is sampled by MRFSS. This general fishery includes all recreational fishing from shore, private boats, and charter boats (for-hire vessels that usually accommodate six or fewer anglers). Using the MRFSS data, an index of abundance was computed for 1981–2004 (SEDAR10-DW-09).

5.3.2 Issues discussed at DW

Issue 1: Trip selection

Option 1: Method of Stephens and MacCall (2004)

Option 2: Use guild – reef, non-reef, or pelagic – as reported in the MRFSS.

Decision: Option 2. Option 2 selected trip/interview records for which the angler reported targeted species from guilds. Given direct information on targeting, sub-setting trips via the method of Stephens and MacCall is unnecessary. That method, however, was still investigated, but the regression failed to converge.

Miscellaneous decisions

The group acknowledged the possibility that some gag were misreported as black grouper. In states north of Florida, the ratio of gag:gag+grouper was near one in most years. In Florida, the ratio was lower; however, the data were insufficient to make any corrections. Therefore the MRFSS data were used as reported. This approach assumes that if gag were misreported, the misreporting was not systematic, such that the gag reported could be considered a random sample of all gag caught.

5.3.3 Methods

The MRFSS data include only the areas between North Carolina and Florida east coast, including the Monroe County in the Florida Keys. No recreational catches of gag have ever been reported in the New England region. Gag nominal catch rates (number of fish caught AB1B2 per number of angler-hours) were standardized following a delta modeling approach as the proportion of trip/interviews that reported gag catches were low (~ 1%). The model assumed a binomial distribution for the proportion of positive trips and a lognormal distribution for the catch rates of positive gag trips. Factors evaluated in the model were mode (shore, charter, private/rental), area (inshore, ocean < 3 miles, 3 < ocean < 10 miles, ocean > 10 miles), region (Florida east coast, Georgia-North Carolina), season (Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec), and guild (inshore species, reef species, non-reef species, and pelagic species, unclassified). The last factor guild, classified trips according to the intended target species of the trip declared by the angler, if no target was defined then the trip was assigned as unclassified. The standardization model also evaluated interactions between factors.

5.3.4 Results

The results show no discernible trend for the Atlantic gag standardized catch rates between 1981 and 2004 (Fig 16 SEDAR DW-09). Estimated 95% confidence bounds were wide and overlapped any estimate-point trend; average estimated coefficient of variance was 63%. Estimates of CPUE (number/1000 angler-hr) and CV are presented in Table 5.5 and in Figure 5.1.

5.3.5 Discussion

The MRFSS index was recommended by the DW for use in the assessment (Table 5.2). One concern was that this index may contain problems associated with fishery-dependent indices, as described in section 5.1.5. Another concern was the large uncertainty in MRFSS estimates.

5.4 FISHERY-INDEPENDENT INDICES

5.4.1 Fishery-independent indices of adult abundance

Gag have been sampled in low numbers with a variety of gear types since the inception of MARMAP (described in working paper SEDAR10-DW-05), including chevron traps (n=103), Florida traps (n=10), blackfish traps (n=14), hook and line (n=53), vertical longline (n=6) and several other experimental gear types (n=39). The DW considered indices from two gear types: the chevron trap (1990-2004) and hook and line (1979-2004).

5.4.1.1 MARMAP Chevron trap:

The DW did not recommend using an index developed from MARMAP chevron trap samples. The percentage of traps each year that captured gag was extremely low, in spite of relatively extensive regional coverage. As gag is one of the most commonly captured species in the region, the group was concerned that the low frequency of occurrence of gag in chevron traps demonstrated some level of trap avoidance by gag. Trap avoidance may have occurred if soak time was insufficient for gag to enter the trap, if the presence of other species in the trap deterred the entrance of gag, or for unknown reasons. The group concluded there was a strong possibility that the chevron trap samples did not provide an index of abundance for gag off the Southeastern U.S.

5.4.1.2 MARMAP hook and line:

The DW did not recommend using an index from MARMAP hook and line samples as an index of abundance for the following reasons:

i) Approximately 50% of years sampled had zero catches.

ii) Changes in personnel and level of effort have changed over time, compromising the utility of the hook and line survey as an index.

iii) 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 gag.

5.4.2 Indices of juvenile abundance

5.4.2.1 Charleston, SC survey:

A survey of juvenile gag was conducted by SCDNR scientists near Charleston, SC SEDAR 10 DW05). The limited nature of the data generated by the study meant its utility as an index of juvenile abundance or recruitment was extremely low. The study lasted only three years, and only one site provided data for all three years. The limited geographic range of sampling and the low number of years sampled led the DW to reject the juvenile gag survey for inclusion as either a recruitment index or abundance index in the gag stock assessment.

5.4.2.2 SEAMAP trawl survey:

SEAMAP-SA is a random stratified shallow water sand bottom trawl survey from Onslow Bay, NC to Cape Canaveral FL from 1990 to the present. However, only three gag have been reported from the survey – two in 1990, and one in 1993. The potential of the SEAMAP survey as an index of abundance for gag was rejected by the DW due to the almost non-existent samples of gag collected in the survey.

5.4.2.3 FMRI estuarine survey:

Gag abundance and habitat data were collected throughout Florida estuaries [Southern Indian River Lagoon, Northern Indian River Lagoon, and Northeast Florida (St. Johns, Nassau, and St. Marks Rivers)] by the Florida Fish and Wildlife Conservation Commission (FWC), Fish and Wildlife Research Institute's Fisheries-Independent Monitoring program from 1996 to 2004 (SEDAR10-DW30). Monthly stratified-random sampling was conducted during the day by using three different seines. Estuaries used in the study were adequately sampled; however, few gag were caught in the Northeast Florida estuary. The DW questioned whether recruitment in two Florida estuaries could be used to infer recruitment across the entire assessment region (FL, GA, SC, and NC). Because of the strong possibility that observed recruitment was localized, the DW did not recommend use of the index from the FMRI survey.

5.5 RESEARCH RECOMMENDATIONS

1) Investigate further the issue of misidentification between black grouper and gag. Develop a suitable method to correct misidentifications on a trip by trip basis. This issue will also be of concern when assessing black grouper. The catches of gag grouper misidentified as black is likely a substantial proportion of reported black grouper landings.

2) We recognize that many valuable and well designed fishery-independent sampling programs have been underfunded or discontinuously funded, resulting in low sample sizes, variable sampling effort (in time and space), discontinuous time series, and poorly stratified designs. The group strongly recommends increased funding toward developing and maintaining fishery-independent sampling programs, and stresses that quality indices require continuous funding over meaningful time periods (ideally decades).

3) It was proposed that the index working group examine the possibility of including environmental variables in computation of indices. Variables discussed included wave height, sea surface temperature, surface currents and hurricane impact. The group considered that other model parameters, particularly the spawner-recruit relationship, might be a meaningful way to include environment variables in assessment models.

4) Examine methods to account for changes in catchability over time of abundance. This is of particular importance when considering fisheries-dependent indices.

5) Develop coast-wide sampling of larval and juvenile abundance.

Table 5.1

Table . A summary of catch series from the Atlantic available for the SEDAR10 data workshop.

Fishery Type	Data Source	Area	Years	Units	Standardization Method	Size Range	Issues	Use?
Recreational	Headboat	Atlantic	1973-2004	Number per angler-hr	Stephens and MacCall; delta-lognormal GLM	Same as fishery	Fishery-dependent	Y
Commercial	Handline	Atlantic	1992-2004	Pounds per hook-hr)	Stephens and MacCall; delta-lognormal GLM	Same as fishery	Fishery-dependent	Y
Recreational	MRFSS	Atlantic	1981-2004	Number per 1000 hours	Trips included by guild composition, delta-lognormal GLM	Same as fishery	Fishery-dependent	Y
Independent	Juvenile Gag Survey	Charleston/ close by locales	1981, 1995-1997	Number per Witham Collector	Nominal	Larvae/Juvenile	Low sample size; localized	N
Independent	MARMAP:trap	Atlantic					Trap avoidance suspected	N
	Florida trap		1983-1987	Number per trap-hr	Nominal	31 to 73 cm n=10		
	Chevron		1990-2004			22 to 93 cm n=103		
Independent	MARMAP; hook and line	Atlantic	1979-present	Number per hook-hr	Nominal		Low sample sizes; freq. annual zeros	N
Independent	SEAMAP	Atlantic	1990	Number per hectacre	Nominal		Low samples sizes	N
Independent	FMRI Estuarine Survey	Both coasts (FL)	1996-2004		Delta-lognormal GLM	Juvenile		N

Table 5.2 Issues of each data set considered for CPUE, as discussed by the DW.

<u>Fishery-dependent Indices</u>

Commercial Logbook – Handline (*Recommended for use*)

Pros:
- Complete census
- Covers broad geographical area
- Continuous, 13-year time series

Cons:
- Unknown if catch rates are proportional to abundance; however could be accounted for in the assessment
- Data are self-reported and largely unverified
- Lacks information on discard rates
- Variability in fishing practices at vessel level
- Catchability may vary over time

Issues Addressed:
- In some cases, self-reported landings have been compared to TIP data, and they appear reliable

Recreational Headboat (*Recommended for use*)

Pros:
- Complete census
- Cover complete area
- Long time series
- Data are verified by port samplers
- Consistent sampling
- Large sample size
- Non-targeted for gag

Cons:
- Unknown if catch rates are proportional to abundance; however could be accounted for in the assessment
- Lacks information on discard rates until 2004
- Variability in fishing practices at vessel level
- Catchability may vary over time

Issues Addressed:
- Possible shift in fisherman preference (Stephens and McCall approach)
- Perception that trip duration has shifted toward half-day trips (Exploratory data analysis reveals no such shift, on positive gag trips or on headboat trips overall; Trip duration is a factor in GLM)

MRFSS (*Recommended for use*)

Pros:
- Methods are statistically valid
- Long time series
- Complete area coverage
- Only FD index that includes discard information (AB1B2)

Cons:
- High PSE's for grouper species
- Unknown if catch rates are proportional to abundance; however could be accounted for in the assessment

Table 5.2 (cont.)

Fishery-independent

MARMAP

Chevron Trap Index (Not recommended for use)

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

Cons: Trap avoidance is suspected due to low percent occurrence relative to total sample set
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: In ~50% of years there are zero catches. In other years the highest observed number of fish is 10. Generally less than 5 were observed
Primarily midshelf sampled
High standard errors
Ability of samplers may have decreased over time
Level of effort has decreased over time

Charleston, SC Juvenile Gag Survey (not recommended for use)

Pros: Fishery-independent attempt to monitor abundance of gag

Cons: Limited geographic range (4 sites – 3 in SC, one in NC)
Limited time frame (3 years for 1 SC site, 2 years 2 SC sites, 1 year for NC site)
Observed only 103 specimens over all sites, gears, for all years

SEAMAP Trawl Survey (Not Recommended for use)

Pros: stratified random sample design
Adequate regional coverage
Standardized sampling techniques

Cons: Sand bottom survey
Only captured 3 gag since program inception (1990)

FMRI Estuarine Survey (Not recommended for use)

Pros: Stratified random sample design
Adequate coverage of estuaries sampled (3 sites in FL)
Standardized sampling techniques

Cons: Could not conclude that estuaries sampled represented entire assessment region (FL, GA, SC, and NC)
Low frequency of occurrence of gag

Table 5.3. Estimated CPUE (lb/hook-hr) of gag off the Southeastern U.S., including lower (LCI) and upper (UCI) 95% confidence intervals and CV. Estimates based on handline gear reported in commercial logbooks.

YEAR	CPUE (lb/hook-hr)	Relative CPUE	LCI	UCI	CV
1992	1.505	0.908	0.797	1.034	6.53%
1993	1.566	0.944	0.868	1.027	4.22%
1994	1.505	0.907	0.835	0.986	4.13%
1995	1.553	0.937	0.862	1.017	4.13%
1996	1.660	1.001	0.924	1.085	4.02%
1997	1.274	0.768	0.703	0.839	4.41%
1998	1.577	0.951	0.872	1.037	4.32%
1999	1.686	1.017	0.926	1.116	4.66%
2000	1.512	0.912	0.823	1.009	5.09%
2001	1.438	0.867	0.791	0.951	4.60%
2002	1.668	1.006	0.917	1.103	4.62%
2003	2.226	1.342	1.223	1.473	4.65%
2004	2.388	1.440	1.313	1.579	4.62%

Table 5.4 Estimated CPUE (number/angler-hr) of gag off the Southeastern U.S., including lower (LCI) and upper (UCI) 95% confidence intervals and CV. Estimates based on data from the headboat fishery.

YEAR	CPUE (number/angler-hr)	Relative CPUE	LCI	UCI	CV
1973	0.027	2.486	1.452	4.256	27.37%
1974	0.019	1.762	0.956	3.247	31.29%
1975	0.010	0.925	0.397	2.154	44.20%
1976	0.007	0.659	0.270	1.609	46.97%
1977	0.007	0.678	0.280	1.642	46.47%
1978	0.007	0.689	0.335	1.418	37.30%
1979	0.011	1.037	0.589	1.826	28.87%
1980	0.013	1.198	0.732	1.958	24.97%
1981	0.011	1.064	0.607	1.866	28.66%
1982	0.011	1.040	0.625	1.733	25.92%
1983	0.012	1.150	0.723	1.829	23.52%
1984	0.012	1.168	0.718	1.901	24.71%
1985	0.011	0.985	0.601	1.613	25.06%
1986	0.011	1.006	0.614	1.649	25.09%
1987	0.012	1.084	0.690	1.705	22.92%
1988	0.013	1.231	0.819	1.850	20.59%
1989	0.012	1.166	0.705	1.928	25.55%
1990	0.012	1.122	0.682	1.846	25.30%
1991	0.012	1.098	0.664	1.818	25.60%
1992	0.012	1.143	0.712	1.835	24.02%
1993	0.011	1.050	0.615	1.793	27.26%
1994	0.009	0.872	0.488	1.560	29.68%
1995	0.010	0.914	0.515	1.624	29.34%
1996	0.008	0.769	0.380	1.555	36.35%
1997	0.009	0.821	0.379	1.780	40.18%
1998	0.010	0.977	0.564	1.690	27.96%
1999	0.007	0.670	0.320	1.402	38.26%
2000	0.008	0.713	0.341	1.487	38.07%
2001	0.007	0.658	0.306	1.414	39.69%
2002	0.008	0.708	0.333	1.503	39.03%
2003	0.006	0.522	0.190	1.429	53.76%
2004	0.007	0.637	0.290	1.400	40.95%

Table 5.5 Estimated CPUE (number/1000 angler-hr) of gag off the Southeastern U.S., including lower (LCI) and upper (UCI) 95% confidence intervals and CV. Estimates based on data from the MRFSS.

YEAR	CPUE (number/1000 angler-hr)	Relative CPUE	LCI	UCI	CV
1981	0.784	0.590	0.083	4.219	127.69%
1982	0.646	0.487	0.071	3.323	123.14%
1983	0.593	0.446	0.086	2.322	98.66%
1984	0.773	0.582	0.128	2.648	87.98%
1985	1.719	1.294	0.336	4.992	75.97%
1986	1.669	1.257	0.376	4.199	66.24%
1987	1.337	1.007	0.297	3.414	67.22%
1988	0.817	0.615	0.173	2.193	70.52%
1989	2.631	1.982	0.628	6.249	62.51%
1990	1.042	0.784	0.221	2.786	70.28%
1991	1.352	1.018	0.313	3.313	64.54%
1992	1.462	1.101	0.342	3.538	63.72%
1993	1.473	1.110	0.343	3.585	64.06%
1994	1.376	1.036	0.322	3.335	63.82%
1995	2.047	1.542	0.486	4.885	62.82%
1996	1.120	0.843	0.256	2.780	65.37%
1997	1.165	0.877	0.246	3.126	70.54%
1998	0.458	0.345	0.091	1.303	74.52%
1999	2.316	1.744	0.543	5.606	63.73%
2000	1.183	0.891	0.271	2.927	65.16%
2001	0.935	0.704	0.215	2.306	64.92%
2002	1.589	1.196	0.374	3.828	63.42%
2003	1.318	0.992	0.303	3.250	64.94%
2004	2.067	1.556	0.500	4.842	61.63%

Table 5.6 Correlation among indices (Pearson correlation coefficient).

	Headboat	MRFSS	Comm. logbook
Headboat	1.00	-0.24	-0.54
MRFSS	-0.24	1.00	0.37
Comm. logbook	-0.54	0.37	1.00

Figure 5.1 Fishery-dependent indices of abundance for gag off the southeastern U.S.

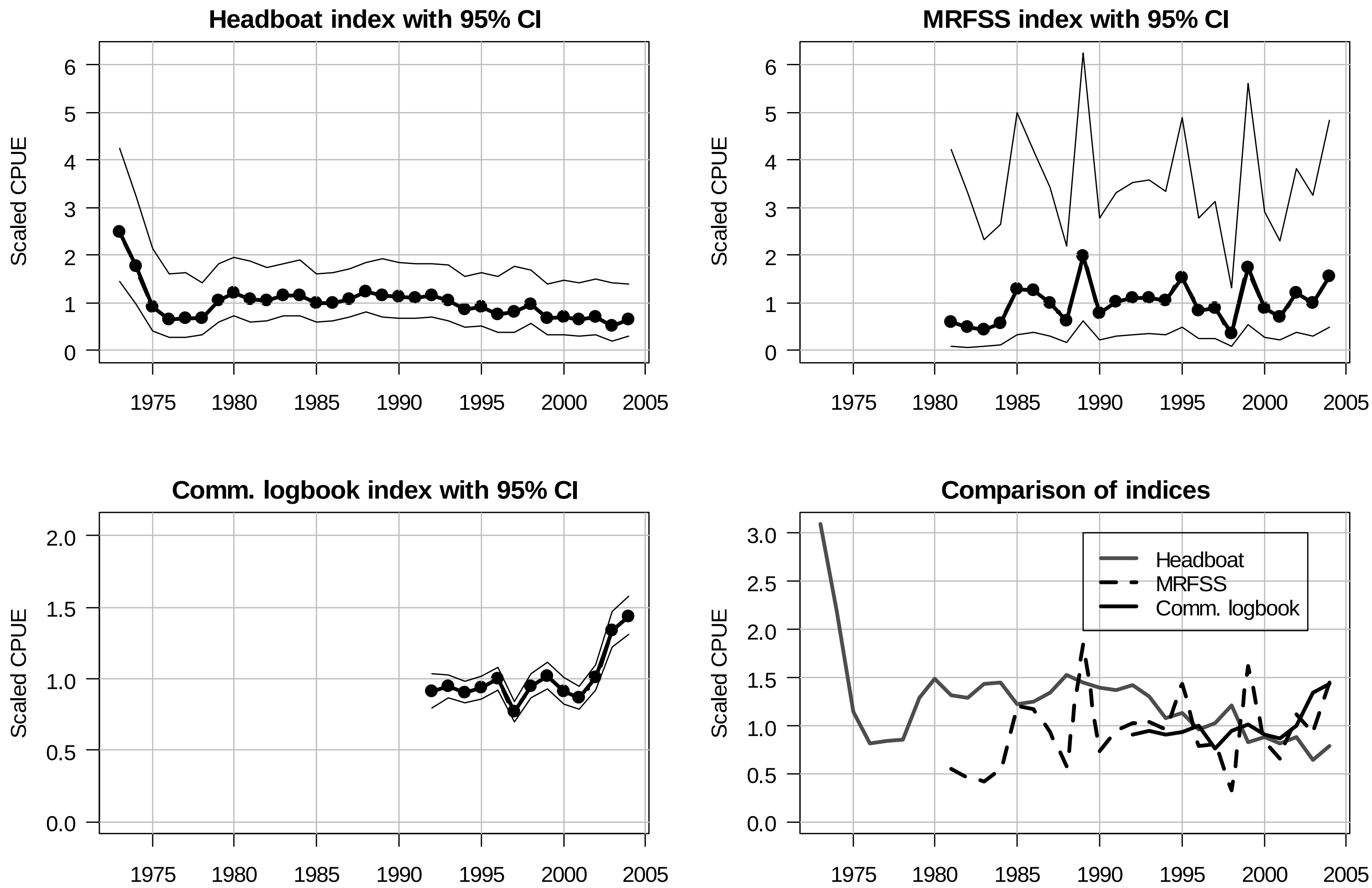
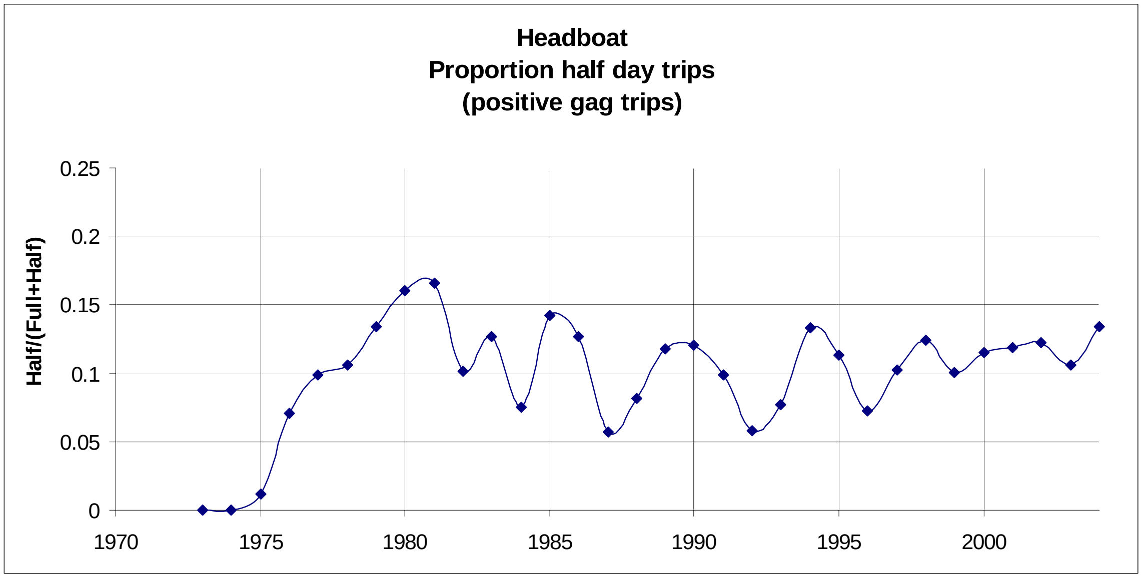


Figure 5.2. Proportion of positive gag headboat trips that are half day trips.



Executive Summary

The stock of gag (*Mycteroperca microlepis*) off the United States South Atlantic was assessed during a SEDAR[1] assessment workshop, held at the Wyndham Grand Bay Hotel, Miami, Florida, on May 1–5, 2006. The workshop's objectives were to complete the SEDAR-10 benchmark assessment of gag and to conduct stock projections (See the terms of reference). Participants in the benchmark assessment (See the list of participants, Table 1.1.3) included state, federal, and university scientists, as well as SAFMC members and staff, and various observers. All decisions regarding stock assessment methods and acceptable data were made by consensus.

Available data on the species included abundance indices, recorded landings, and samples of annual size compositions and age compositions from fishery-dependent sources. Three fishery–dependent abundance indices were developed by the SEDAR-10 data workshop: one from the NMFS headboat survey, one from the commercial logbook program, and one from the MRFSS survey. There are no usable fishery–independent abundance data for this stock of gag at this time. Landings data were available from all recreational and commercial fisheries. This benchmark assessment included data through 2004.

A statistical model of catch at age was used as the primary assessment model. In addition, an age-aggregated production model was used to investigate results under a different set of model assumptions. The AW developed two base runs; one assuming a time-varying catchability and one assuming constant catchability for the fishery dependent indices. Each base run of the catch-at-age model was the basis for estimation of benchmarks and stock status.

Results suggest that spawning stock biomass fell below values corresponding to MSY in the early 1980's and remained there until the most recent years. The 2005 estimate of SSB is 9,335 and 11,005 thousand pounds (klb) from the time-varying and constant catchability base model runs, respectively. These estimates correspond to about 120% and 137% of MSST, by the Council's definition of MSST as $(1 - M)\text{SSB}_{\text{MSY}}$ and assuming a natural mortality rate of $M = 0.14$ and 103% and 117% of MSY. The 2004 estimates of fishing mortality were 160% and 136% of F_{MSY}, where F_{MSY} is the MFMT. These results indicate that the stock is not overfished, but is undergoing overfishing.

Stock projections were evaluated under five scenarios starting in 2008. Each scenario applied the current F in years 2005–2007. Starting in 2008 the five projection scenarios included: (1) current F, (2) F_{MSY}, (3) 85% of F_{MSY}, (4) 75% of F_{MSY}, and (5) 65% of F_{MSY}. All projections agree that under current F through 2006, the stock biomass will dip below the MSY and MSST levels by the beginning of 2007.

[1]Abbreviations and acronyms used in this report are defined in Appendix A

SEDAR

SouthEast Data, Assessment, and Review

SEDAR 10
Stock Assessment Report 1

South Atlantic Gag Grouper

SECTION 3. Assessment Workshop

1. Workshop Proceedings

1.1. Introduction

1.1.1. Workshop Time and Place

The SEDAR 10 Assessment Workshop was held May 1 - 5 at the Wyndham Grand Bay, Miami FL.

1.1.2. Assessment Workshop Terms of Reference

1. Select several modeling approaches based on available data sources, parameters and values required to manage the stock, and recommendations of the data workshop. SEE NOTE 1.
2. Provide justification for the chosen data sources and for any deviations from data workshop recommendations.
3. Provide estimates of stock parameters (fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, etc); include appropriate and representative measures of precision for parameter estimates and measures of model ‘goodness of fit’.
4. Characterize uncertainty in the assessment, considering components such as input data, modeling approach, and model configuration.
5. Provide yield-per-recruit, spawners per recruit, and stock-recruitment analyses.
6. Provide complete SFA criteria. This may include evaluating existing SFA benchmarks or estimating alternative SFA benchmarks (SFA benchmarks include MSY, F_{MSY}, B_{MSY}, MSST, and MFMT); recommend proxy values where necessary; provide stock control rules.
7. Provide declarations of stock status relative to SFA benchmarks: MSY, F_{MSY}, B_{MSY}, MSST, MFMT.
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, $F=F_{MSY}$, F_{target} (OY),
      F=Frebuild (max that rebuild in allowed time)
   B) If stock is overfishing
      $F=F_{curren}$t, $F=F_{MSY}$, $F= F_{target}$ (OY)
   C) If stock is neither overfished nor overfishing
      $F=F_{current}$, $F=F_{MSY}$, $F=F_{target}$ (OY)
10. Evaluate the results of past management actions and probable impacts of current management actions with emphasis on determining progress toward stated management goals.
11. Provide recommendations for future research and data collection (field and assessment); be as specific as practicable in describing sampling design and sampling intensity.

12. Provide the Assessment Workshop Report (Section III of the SEDAR Stock Assessment Report) including tables of estimated values within 4 weeks of workshop conclusion. SEE NOTE 2.

MODEL ACCEPTANCE NOTE 1: The SEDAR Steering Committee requires that models be standard configurations, such as those provided in the NMFS toolbox or other validated sources. Custom programming during the workshops is strongly discouraged. If custom or modified programs are considered, the following must be addressed: 1) complete documentation and code must be provided; 2) an executable version of the program and all necessary input and control files must be provided to workshop participants; 3) the custom code/application used must be validated through application of known parameter datasets and such results must be provided as part of the assessment documentation; 4) justification for use of custom programming in lieu of readily available models must be provided in writing in the assessment documentation.

REPORT COMPLETION NOTE 2: The Assessment Workshop report is due no later than Monday, June 5, 2006. If final assessment results are not available for review by workshop panelists during the workshop, the panel shall determine deadlines and methods for distribution and review of the final results and completion of the workshop report.

1.1.3. List of Participants

Assessment Workshop Panel

Tom Burgess .... SAFMC AP/Commercial
Shannon Calay .... NMFS/SEFSC Miami, FL
Marianne Cufone .... GMFMC/Environment Matters
Doug Gregory .... GMFMC SSC/Unvi. Florida Sea Grant
Sherry Larkin .... SAFMC SSC/Univ. of Florida
Behzad Mahmoudi .... GMFMC FAP/FL FWRI
Josh Sladek Nowlis .... NMFS/SEFSC Miami, FL
Mauricio Ortiz .... NMFS/SEFSC Miami, FL
Clay Porch .... NMFS/SEFSC Miami, FL
Mike Prager .... NMFS/SEFSC Beaufort, NC
Robert Spaeth .... GMFMC AP/Commercial
Frank Stephenson .... GMFMC AP/Recreational
Helen Takade .... SAFMC/NCDMF
Steve Turner .... NMFS/SEFSC Miami, FL
Carl Walters .... GMFMC FAP/Mote Marine Lab
Erik Williams .... NMFS/SEFSC Beaufort, NC
Bob Zales, II .... GMFMC AP/Charter.

Observers

Roy Williams .... GMFMC Member
Alex Chester .... NMFS/SEFSC Miami, FL
David Cupka .... SAFMC Member
Dennis Heinemann .... Ocean Conservancy
Albert Jones .... GMFMC SSC
Russell Nelson .... CCA
John Walter .... NMFS/SEFSC Miami FL
Rob Cheshire .... NMFS/SEFSC Beaufort, NC

Staff

Steven Atran..GMFMC
John Carmichael.. SEDAR
Tyree Davis.. NMFS/SEFSC Miami, FL
Meg Kosick..GMFMC
Gregg Waugh..SAFMC

1.1.4. List of Assessment Workshop Working Papers

SEDAR10-AW1	SEDAR 10 stock assessment model, US South Atlantic gag	Williams, Erik H.
SEDAR10-AW2	Preliminary status of gag grouper in the Gulf of Mexico: continuity run VPA, SEDAR 10	Ortiz, M.
SEDAR10-AW3	Preliminary status of gag grouper in the Gulf of Mexico, SEDAR 10	Ortiz, M.

1.1.5. Research Documents Provided at the Assessment Workshop

SEDAR10-RD07 2007	CASAL users manual version 2.07-2005/08/21 NIWA Tech Rpt.127. ISSN 1174-2631	Bull, B. et al
SEDAR10-RD08 1994	Simulation of the impact of fishing on reproduction of a protogynous grouper, the graysby. NAJFM 14:41-52	Huntsman, G. R. and W. E. Schaaf.
SEDAR10-RD09	Review of effects from fishing mortality on protogynous species and implications for management	SEFSC/MIA SFD Presentation
SEDAR10-RD10 2006	Models to compare management options for a protogynous fish. Ecolog. Apps. 16(1):238-249	Heppell, S. S. et al
SEDAR10-RD11 2004	The effects of size-selective fisheries on the stock dynamics of and sperm limitation in sex changing stocks. Fish Bull 102(1):1-13.	Alonzo, S. H., M. Mangel.
SEDAR10-RD12 2001	Effects of fishing on a protogynous hermaphrodite CJFAS. 58:568-578.	Armsworth, P. R.
SEDAR10-RD13 1996	Production Functions of the Norwegian bottom trawl fisheries of cod in the Barents Sea 84th ICES Statutory Meeting	Skjold, F., A. Eide, O. Flaaten
SEDAR10-RD14 1998	The impact of global positioning systems and plotters on fishing power in the northern prawn fishery, Australia Can. J. Fish. Aquat. Sci. **55**: 1645.1651	Robins, C. M., Y.-G. Wang, D. Die
SEDAR10-RD15 1998	Changes in the sex ratio and size at maturity of gag, *Mycteroperca microlepis*, from the Atlantic Coast of the Southeastern United States, 1976-1995 Fish Bull 96:797-807	McGovern et al.
SEDAR10-RD16	Release mortality of undersized fish from the snapper-grouper complex off the North Carolina Coast. NC SEAGRANT 03-FEG-21	Overton, A. S., J. Zabawski

1.2. Panel Recommendations and Comment

1.2.1. Critique and Review of Models

The initial model run included a landings bias parameter that was intended to correct for early landings (prior to 1980). The early landings were estimated to be much higher than the observed values by a factor of approximately 2.9, but recent fit is very good for the commercial landings. Removing the bias parameter results in a comparable fit to the run that includes the landings bias parameter except a pattern in the recruitment residuals appears. Both initial runs (with and without the bias parameter) indicated that the stock was experiencing overfishing but was not currently overfished. Since 1980, all but two of the recruitment residuals were above the mean for the time period. The consensus was to remove the landings bias parameter and attempt other sensitivity runs to remove the pattern in the recruitment residuals.

The headboat index had unusually high values in 1973 and 1974, which occurred at the same time that the survey covered only North and South Carolina. The first year the survey covered the entire south Atlantic range was 1976. A sensitivity run was conducted removing three years of data from the headboat index and length composition (1973-1975) data. The removal of these years had little effect on the overall model fit and the pattern in the recruitment residuals remained and stock status was unchanged. Consensus was to leave those years in the model.

The initial runs assumed that only commercial diving exhibited double logistic (‘dome-shaped’) selectivity. The commercial hook and line and the headboat data were each separately allowed to fit double logistic selectivities, as these fisheries tend to focus on catching gag in near shore waters, which contain fewer large fish than may occupy deeper water habitat, a resulting in double logistic selectivity. The hook and line selectivity was slightly double logistic in the very earliest years (from 1992 on it stayed completely flat topped), indicating that the data support logistic selectivity for commercial hook and line. There was evidence that the headboats do experience double logistic selectivity in recent years. For both runs the stock status was the same as initial runs and both runs showed little difference in terms of the overall model fit.

The panel was concerned about the selectivity patterns and hypothesized that the length compositions may be influencing the selectivities. Length compositions were down-weighted to 20% of their original weight. There was an improvement in the recruitment residuals pattern, with a less dramatic post-1980 increase in recruitment. The overall B/B_{MSY} pattern did not exhibit much change but the magnitude of F went down a small amount and the model fits resembled previous runs. The panel agreed that down weighting the length compositions should be retained, as it appears that the length compositions had been overly influential.

A report written for the DW found that there were sampling biases in collecting age samples in the Gulf of Mexico. Analysis on the south Atlantic data did not indicate bias in sampling except for the commercial handline, which was missing some of the largest and smallest lengths, exhibiting a slight bias towards larger animals. The age data had a correction applied where it was re-weighted by the length samples. However, the adjustments did not compensate for missing data. Examination of the age composition fits indicated that the model was not closely fitting years with considerable missing data and no further actions were taken.

The initial commercial discard mortality was 0.4, which some panel members indicated was higher than what actually occurs. Therefore, a lower commercial discard mortality was used in a sensitivity run (i.e., 0.1) to determine the importance of commercial discard on the overall removals. The new discard mortality rate had little impact, as the commercial discards were a relatively small amount of the total removals. Discards accounted for approximately 5,000 to 20,000 fish when approximately a million to two million were harvested. The group decided to leave the commercial release mortality at the original value of 0.4 since it had a relatively small effect and would have been a slight underestimation of total removals.

Given the uncertainty in the MRFSS estimates, there was considerable interest by the panel in attempting to determine the affects of consistent biases in sampling. Sensitivity runs were conducted both increasing the MRFSS catch by 50% and decreasing the MRFSS catch by 50%. For the increased case, the overall model fit and other outputs remained largely unchanged from earlier runs. There was a slight downturn in biomass estimates in the most recent years and the magnitude of F increased. For the decreased case, the model fits were also largely unchanged from earlier runs. The decreased MRFSS catch run did change the stock status to overfished and increased the magnitude of the F estimates. The stock status probably changed because the benchmarks probably also changed. In addition, removing the proportion of the MRFSS catch can make the stock appear to be less productive. The panel concluded that any potential MRFSS inaccuracy has the potential to change the stock status if the problem is consistent. If the inaccuracy is not consistent over time, then it is impossible to know the impacts. Given the lack of evidence of a consistent and persistent bias in the MRFSS data, the decision was made to use the original data.

In order to further examine uncertainty, a series of retrospective runs were conducted. Retrospective analyses compare estimates for each year from data available as of each year to the data available in fullness of time. This kind of analysis often reveals structural errors in assessment models. The continued concern about the trend in the recruitment residuals, and that trend appeared to be confounded with selectivity and fishing mortality. The analysis could only go back to 1999 because earlier time periods resulted in losing large amounts of data, including the entire commercial diving time series. The retrospective analysis did appear to show that the uncertainty was being underestimated. Also, it appeared that the pattern in the recruitment was holding the stock at approximately MSY.

For data from 1962 to 1980, gag landings had to be determined as a proportion of the unclassified grouper category. The panel expressed interest in doubling the proportion of gag from the unclassified groupers to determine if that could impact the recruitment residual pattern. The residual pattern remained the same, as did the current stock status. This sensitivity run did reduce the F estimates, which was probably re-scaling the total population.

The pre-1980 recruitment residuals were restrained to a greater degree than previous runs, again as an attempt to remove the pattern from the recruitment residuals. The post-1980 residual pattern remained, and the overall model fit remained similar to previous runs.

There was considerable discussion by the panel about the stock-recruitment relationship that was estimated including years prior to 1972, which was the first year that an index was available. The alternative was to estimate the stock-recruitment relationship using the period since 1972. The result was that steepness was quite high, the SSB_{msy} was much higher than previous runs, but the current stock status remained unchanged from previous runs.

The AW discussed the relationship of technology to catchability and the effects of catchability changes on fishery-dependent abundance indices. The group recognized that technology improvements over time, in particular better electronics, have made fishermen more effective and efficient at catching fish, although there was no firm conclusion about details. This issue is important for the present stock assessment because the assessments rely heavily on fishery-dependent catch rate abundance indices. Such indices divide catch by effort. When a unit of effort becomes more efficient at catching fish, the resulting abundance index becomes biased, making fish appear relatively more abundant. In contrast, fishery-independent indices are on standardized methods to control fishing efficiency over time and are not subject to this problem. No fishery-independent indices were available for the Atlantic gag assessment, and only short time series were available for the Gulf.

In response, a proposal was discussed to assume an increased catchability of 2% per year (non-compounding), beginning in 1980 and continuing to the present. The value of 2% reflects findings of a recent published paper (Robins et al., 1996) and an ICES paper (Skjold et al., 1996), which examined other fisheries. The starting data reflects increased availability of better electronics. The AW supported that proposal, and the current stock status does not change with increasing catchability. However, the AW was unable to agree whether to label a run with constant or increasing catchability as the base run. Participants believe that some increase in catchability has occurred, but that estimating its magnitude is too difficult to be done at this assessment workshop. Workshop participants agreed to send to the Review Workshop runs made under both assumptions (constant or increasing catchability), without labeling either one the “base run” to the exclusion of the other.

A biomass production model was also applied, including total removals, total landings, and indices. Like the age-structured model, the biomass production model assumed catchability changes since 1980. The model exhibited relative insensitivity to the assumed initial conditions. The relative estimates of biomass all come out to be fairly close to those estimated by the age-structured model, though the current stock status is overfished. The high points in the early years of the headboat index about which the panel expressed concern about appeared to exert little influence. In general, this kind of model does not fit the increases and decreases as closely as an age-structured model. The biomass was lower and the F estimates were higher than the age-structured model. In comparison between the two models, the age-structured model predicts a higher F rate than the production model, but the qualitative result was the same. The biomass production agrees with the general pattern of the age-structured model but was slightly more optimistic overall. It should be noted that the status of the stock might look better in a production model because the reference points are different between the two.

1.2.2. Preferred Model and Configuration Recommendation

The age-structured model recommended configuration did not include the landings bias parameter, contains a Beverton-Holt stock-recruitment relationship based on the years 1972-2004, and down-weights the length compositions. These decisions came as the result of the sensitivity runs. The consensus was that the landings bias parameter, while removing the recruitment residuals pattern, it resulted in landings estimates that extremely and possibly unreasonably high. The stock-recruitment relationship based on the 1972-2004 data was agreed to because it would be based in a time period with at least one index on which to base the relationship. The length compositions were down-weighted as the result of that sensitivity run improved the recruitment residual pattern, leading to the conclusion that the length compositions were initially overly influential. The mature biomass includes both sexes. Parallel runs were conducted with an increasing catchability of 2% each year since 1980 and with catchability remaining constant throughout. The parallel runs were recommended because the AW agreed that there had been some improvement in catchability because of technology, but that the magnitude could not be accurately determined within the workshop.

1.2.3. Recommended SFA/Management Criteria/ABC Range

Stock Status Criteria

Current and proposed stock status criteria for the gag stock in the south Atlantic as specified by the Council are shown in Table 1.1. Snapper Grouper FMP Amendment 11 specified the current definitions for all the criteria. The 1998 assessment (Potts and Manooch, 1998) provided the value of M.

Updated values for the Council's stock status criteria are provided in Table 1.1. Proposed values for parameters not specified by the Council in Amendment 11 are also provided in Table 1.1.

Table 1.1. Stock status criteria for gag grouper. MSST, MSY, and OY are expressed in kilograms of gutted weight.

Criteria	Current (Amendment 11)		Proposed (Amendment 13B or Framework)		
	Definition	Value	Definition	Value (time-varying catchability)	Value (constant catchability)
MSST	(1-M) B_{MSY}	Not specified	(1-M) B_{MSY}	7,790,000	8,062,000
MFMT	$F_{30\%SPR} = F_{MSY}$	F = 0.18	F_{MSY}	0.323	0.295
MSY	Yield at F_{MSY}	Not Specified	Yield at F_{MSY}	1,750,000	1,774,000
OY	Yield at F_{OY}	Not Specified	Yield at F_{OY}	1,697,000, 1,725,000, 1,742,000	1,714,000, 1,747,000, 1,765,000
F_{OY}	$F_{45\%SPR}$	Not Specified	F_{OY} = 65%,75%, 85% F_{MSY}	0.210, 0.242, 0.275	0.192, 0.221, 0.251
M	Potts and Manooch (1998)	0.15	SEDAR 10	0.10-0.25	0.10-0.25

Acceptable Biological Catch (ABC)

Projections will be provided to allow the Council's SSCs to develop ABC recommendations.

1.2.4. Status of Stock Declarations

Pre-SEDAR Declarations

According to the NOAA Fisheries' report to Congress on the status of fisheries of the United States in 2005, the South Atlantic stock of gag is not overfished. Stocks in the unit are overfished when the SPR falls below 30% based on a pre-SFA definition. Gag grouper are considered to be experiencing overfishing. Overfishing is defined as a fishing mortality rate in excess of that corresponding to 30% static SPR based on a post-SFA definition.

Post-SEDAR Declarations

Current assessment results estimate the 2005 SSB to be 9,335,000 and 11,005,000 pounds from the time-varying and constant catchability base model runs, respectively. These estimates correspond to about 120% and 137% of MSST, by the Council's definition of MSST as *(*1 −

M)SSB_{MSY} and assuming a natural mortality rate of $M = 0.14$. The 2004 estimates of fishing mortality were 160% and 136% of F_{MSY}, where F_{MSY} is the MFMT, and 103% and 117% of MSY. These results indicate that the stock is not overfished, but is undergoing overfishing.

1.2.5. Management Evaluation

Review of Previous Stock Assessments and Past Management Actions

Trawl (roller-rig trawl) landings of gag grouper began in 1973 and ended in 1988 (Table 1.2) with catches ranging from a low of 332 pounds gutted weight in 1973 to a high of 85,746 pounds gutted weight in 1981. Sporadic landings by trawls show up in 1992, 1998, 2001, 2002, and 2003.

Table 1.2. Adjusted gag landings (gutted weight in pounds) for commercial longline and trawl from U.S. South Atlantic. From SEDAR 10, 2006, Table 3.4.

Year	Longline	Trawl	Year	Longline	Trawl
1962	0	0	1984	21,899	13,870
1963	445	0	1985	3,790	4,267
1964	45	0	1986	12,593	4,080
1965	0	0	1987	86,745	3,145
1966	0	0	1988	56,387	3,768
1967	0	0	1989	13,797	0
1968	0	0	1990	21,392	0
1969	57	0	1991	10,216	0
1970	0	0	1992	5,041	13
1971	0	0	1993	5,428	0
1972	0	0	1994	3,958	0
1973	0	332	1995	3,862	0
1974	0	0	1996	3,856	0
1975	0	1,478	1997	4,121	0
1976	0	7,846	1998	5,506	1,517
1977	0	45,946	1999	1,764	0
1978	117	5,158	2000	5,082	0
1979	0	12,988	2001	5,858	282
1980	1,875	63,167	2002	4,579	341
1981	1,346	85,746	2003	4,498	303
1982	4,653	49,581	2004	1,443	0
1983	39,800	32,235			

In the original Snapper Grouper Fishery Management Plan, the Council specified a 4 inch trawl mesh size mainly directed at reducing the catch of small vermilion snapper. Regulations became effective on August 31, 1983 and resulted in a decrease in trawl landings. This may be more attributed to a decrease in overall trawl effort rather than a direct effect of fish being released through the mesh.

In Amendment 1 to the Snapper Grouper Fishery Management Plan, the Council prohibited trawls in the snapper grouper fishery to protect habitat that was being damaged by the bottom-tending roller-rig trawl gear. Regulations became effective on January 12, 1989 and trawl landings have been zero ever since except for sporadic low landings.

The first stock assessment for gag grouper was conducted in 1990 (PDT, 1990) using data from 1972 to 1988/89. SSR (=SPR) was calculated separately for recreational and commercial gag fisheries (Table 1.3). The assessment indicated that a minimum size limit of 20 inches would result in the recreational fishery being at the overfishing/overfished level of 30% SPR while the commercial fishery would be well above the overfishing/overfished level.

Table 1.3. Stock assessment results for gag grouper from 1990.

RECREATIONAL	COMMERCIAL
Carolinas = 19%	Carolinas = 47%
FL = 32 - 30%	Florida = 47%
SSR with 20 inch Minimum Size Limit:	SSR with 20 inch Minimum Size Limit:
30%	67%

In Amendment 4 to the Snapper Grouper Fishery Management Plan, the Council prohibited fish traps, entanglement nets, and longlines within 50 fathoms for the entire snapper grouper fishery; specified a 20 inch size limit in both the recreational and commercial gag fisheries; and specified a 5 grouper recreational bag limit. Regulations became effective on January 1, 1992.

Two stock assessments provided combined recreational and commercial estimates of SSR based on catch curves (Table 1.4; NMFS, 1991; NMFS, 1992). Both assessments indicated there was no overfishing and the stock was not overfished. Further, more a minimum size limit of 20 inches would result in the SSR increasing to a level above the overfishing/overfished level of 30%.

Table 1.4. Catch curve assessments for gag grouper.

Assessment Year	Catch Data From	Overall SSR	SSR with Minimum Sizes
1991	1988	32%	34%
1992	1990	35%	39%

The size limit and bag limit implemented on January 1, 1992 does not appear to have affected landings by the commercial handline and diving fisheries or the recreational fisheries (Table 2.3). Commercial longline landings did decrease from 10,216 pounds to 5,041 pounds gutted weight (Table 1.2). Impacts of the size limit on the lengths of gag in the headboat fishery are shown in Figure 1.1. The time-period from 1972 to 1991 operated without any size limit. A 20-inch size limit was implemented on January 1, 1992 and remained in place through 1998. Landings of fish below 20 inches declined but did continue due to low compliance.

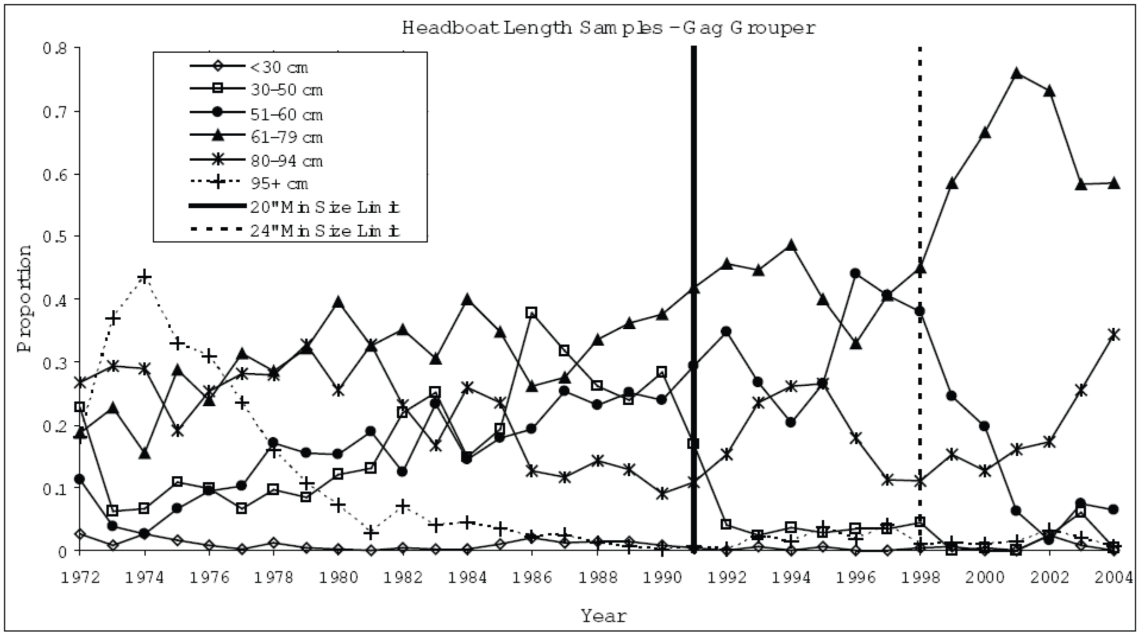


Figure 1.1. Analysis of changes in lengths of gag over time in the headboat survey. From SEDAR 10, 2006, Figure 4-11.

Compliance through 2001 is summarized by sector in Table 1.5. See Burton (2002) for the breakout by region and for numbers of fish measured. Burton (2002) established a criterion of number of fish measured must be greater than or equal to 15 and percent of fish below the size limit must be greater than or equal to 15 as the minimum combination that had to be met in order to return a finding of significant non-compliance. Gag are most abundant in the commercial and headboat intercept data, and in most years the gradient of abundance runs from the Carolinas (most) to south Florida (least). In January 1992, a new 20-inch size limit was enacted. Compliance from the commercial and headboat sectors was excellent. However, non-compliance was evident for the private and charter recreational sectors.

Table 1.5. Compliance with gag grouper size limits; note changes to minimum size limits as shown in Table 24A. Source: Burton (2002).

	Percent	Landed Below	Legal Size Limit	Regulation Change
Year	Commercial	Headboat	Private & Charter	
1992	2.5	3.6	13.0	20" size limit and 5 grouper bag limit effective 1/1/92
1993	1.2	2.8	7.1	
1994	2.2	1.1	24.0	
1995	0.3	0.4	9.1	
1996	0.3	2.1	6.7	
1997	0.3	4.0	7.9	
1998	0.2	5.2	9.6	
1999	1.4	21.0	5.6	24" size limit, 1 gag or black w/in 5 grouper bag limit, March/April spawning closure - effective 2/24/99
2000	2.8	17.8	22.9	
2001	3.5	9.0	14.0	

A VPA assessment was conducted by Potts and Manooch (1998) using data from 1986 to 1997:

"Changes in the age structure and population size of gag, Mycteroperca microlepis, from North Carolina through the Florida Keys were examined using records of landings and size frequencies of fish from commercial, recreational, and headboat fisheries from 1986-1997. Population size in numbers at age was estimated for each year by applying separable virtual population analysis (SVPA) to the landings in numbers at age. SVPA was used to estimate annual, age-specific fishing mortality (F) for four levels of natural mortality (M = 0.10, 0.15, 0.20, and 0.25). We believe that the best estimate of M is 0.15. Landings of gag for the three fisheries have generally decreased in recent years, but minimum fish size regulations have resulted in an increase in the mean size of fish landed. Age at entry and age at full recruitment were age-0 and age-4 for 1986-1991 and age-0 and age-5 for 1992-1997. With M = 0.15, levels of fishing mortality (F) on the fully-recruited ages were 0.32 for 1986-1991 and 0.20 for 1992-1997. Spawning potential ratio (SPR) was 30% with M = 0.15 for the most recent time period, 1992-1997. However, a more conservative estimate of 27% resulted from incorporating a 50% release mortality on the undersized fish. The proposed size limit regulation of 24 inches could produce a SPR of 30% even with a 50% released fish mortality."

In February 1999, a new 24-inch size limit was enacted. Compliance from the commercial sector was excellent. Non-compliance was evident for the Carolinas headboat fishery, as well as for the private recreational sector from the Carolinas and south Florida. Given that the assessment incorporated a 50% release mortality, it appears that the lack of adequate enforcement of the minimum size limit did not allow the SPR to increase above 30% SPR. The current assessment estimated a static SPR of approximately 0.19 after a drop from the mid-1960's to the mid 1980's.

A catch curve analysis conducted in 2001 using data through 2000 indicated that the overall SPR was 30% and that the overall SPR was expected to be above 30% with the 24-inch size limit.

Current SEDAR Biomass-Based Stock Assessment and Past Management Actions

A statistical catch-at-age model was used to assess gag grouper stock status based on data from 1962 to 2004 (landings were estimated back to 1942). Natural mortality was variable by age ranging from 0.10 to 0.25 and the release mortality was assumed to be 40% for the commercial sector and 25% for the recreational sector.

The static SPR from the current assessment for 2004 is 0.193 and 0.216. There are two possible explanations for the lack of improvements in SPR, compliance with the regulations was low or that release mortality was greater than the levels incorporated into the assessments (40% for the commercial sector and 25% for the recreational sector).

1.2.6. Possible impacts of proposed management actions

No impacts are currently proposed in Amendment 15. The Council could implement the stock status criteria and regulations via the framework or, given the need for rapid management action as shown by the results of this assessment they could choose to include gag measures in Amendment 15. Amendment 13C indicates that the Council would likely use a quota on the commercial fishery and a change in the bag limit and possibly a seasonal closure on the recreational fishery.

1.2.7. Research Recommendations

DW Research Recommendations

The AW agrees with the research recommendations from the DW.

1. Stock Definition:
   a. The DW recommends continued research on the use of otolith chemistry to evaluate the population structure of gag.
   b. The DW recognizes the value of the genetic study currently underway in South Carolina and that this type of genetics work can provide key insight into patterns in gag population structure. The DW further highly recommends every opportunity be taken to add Mexican (Campeche) samples to this analysis as these methods can be most informative in divining patterns of gene flow and population connectivity.
   c. The DW recognized that there have been recent workshops with productive outcomes on aging and reproductive assessments, targeting gag and similar species, and recommends that such workshops continue to be undertaken to eliminate potential methodological differences. The DW suggests that it may be particularly valuable to convene a workshop to address the potential non-random and non-representative sampling that hampers collection of small numbers of

biological samples (relative to numbers of fish landed), which in turn are used for parameter estimates.

d. The DW recommends that age structure sampling continue on an annual basis in the Gulf. The DW recommends that long-term continuous monitoring of age structure be undertaken in the South Atlantic to test the hypothesis that annual recruitment trends are similar between regions.
e. 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) is further supported.
f. The DW recommends that additional tagging be completed off the east coast of Florida to examine the extent of northerly and southerly movements. In the Gulf region, the bulk of the tagging targeted juveniles and young adults in coastal areas, therefore the DW recommends that tagging effort be extended to the middle and outer shelf, perhaps with the assistance of cooperating commercial fishers, for the purpose of tagging adult gag. The DW recommends that future tagging studies should be done in a more coordinated manner between researchers in the Gulf and South Atlantic regions, particularly with respect to gear, fish size, and depth.

2. The DW recommends an increase in sampling for otoliths for aging.
3. The DW recommends an improvement in at-sea observation for discards.
4. The DW recommends continued education of samplers for species identification.
5. The DW notes that conversions are needed for different market categories (gutted, headed, filleted, whole weight).
6. The DW recommends continued improvement in data comparability and quality control in otolith aging.

<u>AW Research Recommendations</u>

1. The AW recommends that spatial information, including the depth related mortality functions suggested by the DW, continue to receive research attention. Improved spatial information on gag grouper to be used for depth related mortality functions (DW suggestion that could not be implemented for the south Atlantic assessment), and to monitor for potential changes in range that may affect assessment results. The AW also recommends that data be collected in the South Atlantic on effort and discards by depth.
2. The AW recommends a fishery independent index of abundance be developed. A major missing component is the availability of a fishery independent index, as all three available indices were fishery dependent and therefore subject to shifts in efficiency and regulations.
3. The AW recommends that the gag grouper mature sex ratio needs to be observed, from which it may also be possible to infer information about male fertility and the number of sperm required for successful fertilization. The potential results of shifts in sex ratio in a protogynous species like gag are not entirely known.
4. The AW recommends further examination and reconstruction of the catch and total removals history (prior to 1962) from data sources not currently contributing the assessment history.

5. The AW suggests that methods like DNA tagging may prove useful as a means for gaining an independent snapshot of total mortality. Estimates of mortality may be difficult to attain or determine if current estimates are on the correct scale.
6. The AW recommends that effectiveness of effort from technological changes (e.g., electronics, GPS) be examined. The assessment ran alternate base runs that both assumed increasing catchability from improvements in technology and no increases in catchability. The AW agreed that this increase in technology had occurred, though any level had to be heavily inferred from studies in other fisheries. Research should be conducted in the major grouper fisheries to determine a more appropriate level and degree of increasing catchability.

1.2.8. References

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Appendix 1. RECOMMENDATIONS FOR SEDAR ASSESSMENTS

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Here are a few recommendations for SEDAR stock assessment scientists; the aims of these recommendations are to uncover possible weaknesses in assessments, and to provide more information for the Council.

1. **Never rely on any one assessment procedure**.
   It is a good idea to run both VPA (backward reconstruction) and SCA (stock synthesis, forward reconstruction) models, especially when vulnerability schedules may have changed in complex ways due to changes in factors like depth targeting of fishing effort. VPA is robust to such changes; SCA is not, and may give spurious indications of having found information about mortality rates in age-size composition data that are in fact uninformative. Further, assessments should present a range of estimates of key reference points (MSY, etc.) for not only age-structured models, but also simple equilibrium and non-equilibrium surplus production models.
2. **Include retrospective analyses showing how estimates change with time**.
   Retrospective analyses (compare estimates for each year from data available as of that year to data available in fullness of time) often reveal serious structural errors in assessment models. They are easy to implement in ADMB, and should be included as a matter of routine in software packages like CASAL. Remember the Canadian cod debacle: retrospective analyses revealed that ADAPT was failing long before the final stock collapse (due to changing vulnerability schedules and increasing commercial catchability as the stock declined), but the warnings were ignored.
3. **Beware of complex size-age and temporally changing vulnerability schedules**.
   Dome-shaped and temporally variable vulnerability schedules "use up" information about mortality and recruitment that would otherwise be present in size-age composition data. When a large number of nuisance parameters need be included in the model to describe such changes, the data then essentially contribute nothing to assessments of overall abundance and rates, except for modest information about relative sizes of adjacent year-classes. The overall assessments then end up being dominated in their basic results by patterns in relative abundance data, which can also be misleading for a variety of obvious reasons.
4. **Beware of confounding between stock-recruitment and recruitment anomaly (environmental) effects**.
   It is not unusual for SCAs to indicate very strong recruitment compensation (steep recruitment curve) while at the same time giving recruitment anomaly trends that are strongly, positively correlated with spawning stock size (which is indicative of a positive effect of spawn abundance on recruitment). This can happen for both recovering stocks (gag) and declining ones (eg boccacio rockfish in California). Alternative hypotheses about stock-recruitment versus environmental forcing effects cannot be resolved by stock

assessment procedures, and demand careful management policy analysis to deal with the deep uncertainty that they represent.

5. **Examine implications of relative abundance time series that give contradictory indications of time trends.**
   When all relative abundance time series indicate the same stock trend, they simply reinforce one another in driving the assessed stock size while perhaps helping a bit to average out measurement errors. But when they give contradictory signals (one index showing decline, another showing increase), at least one must be wrong, and the overall assessment results are suspect no matter how the different data sources are "weighted" for statistical analysis. Results should be presented showing the full range of uncertainty about stock trend resulting from different weightings of the data, not just a single "best" reconstruction, and assessment scientists should refuse to speculate on which of the alternatives is "correct"; that cannot be decided scientifically except by further experience and possibly analysis of possible causes for one or another index to not be representative of stock trends.
6. **Provide time series estimates of fishing mortality rates.**
   Time series estimates of fishing mortality provide a valuable indication of whether protective management measures have been successful, and are much more useful in this regard than catch data. During stock collapses it is quite common for catches to decline more slowly than stock size, due to ineffective regulations and range collapse effects on catchability, so that fishing mortality rate and impact are actually increasing while the catch data indicate the opposite.
7. **Run assessments on the longest possible catch data series, to give the best possible long term perspective on stock status.**
   Assessments based on short time series, no matter how much detailed composition data are available in recent times, can give very misleading estimates of current stock status relative to unfished stock levels. The only way to guard against this problem is to use "stock reduction analysis", where the assessment model is solved forward in time from the beginning of the fishery, so as to estimate cumulative fishery impacts prior to the advent of detailed sampling programs. Absent such assessments, our methods are very likely to contribute to the "shifting baseline syndrome".
8. **Carefully examine any available spatial data for evidence of range collapse or expansion**
   Relative abundance time series, including those from spatially consistent surveys that do not fully cover stock ranges, can give grossly misleading patterns for stocks that exhibit range contractions/expansions with changes in overall abundance. In most fisheries there is enough spatial logbook information, along with anecdotal information from experienced fishers, to provide a basic narrative evaluation of historical range changes and how these have likely affected catch and relative abundance time series.

Appendix 2. Notes on fishing mortality considerations for a protogynous hermaphrodite species. The case of gag grouper Gulf of Mexico stock.

Gag grouper are protogynous hermaphrodites, where individuals start life as females and later transform to males. Females mature as early as 3 years of age, by age 4 approximately 70% are mature, and all are mature by 6 years of age (Ortiz 2006). Sex transformation starts in individuals that are 7-8 years old, with 50% transformation occurring by age 13 (Ortiz 2006). Virtually all individuals older than 16 years of age are males (Hood & Schlieder 1992). Transformation in gag appears to be driven primarily by endogenous processes, where most individuals transform within a fairly narrow size/age range, and all individuals eventually transform (McGovern et al. 1998). Transformation is also driven in part exogenously, some evidence of more rapid transformation when the sex ratio is female biased (Huntsman and Schaaf 1994). Several authors have suggested that selective fishing that results in higher fishing pressure on larger individuals coupled with protogynous hermaphrodism would make protogynous species especially vulnerable to recruitment overfishing (Bannerot et al. 1987, Huntsman and Schaaf 1994, Coleman et al. 1996, Coleman et al. 2000, Armsworth 2001, Fu et al. 2001, Alonzo and Mangel 2004, Heppell et al. 2006). If transformation is driven primarily by endogenous processes then typical size-selective fishing would remove more males than females, and if in the extreme could lead to sperm limitation in the population. If transformation is driven exogenously then facultative transformations could keep the proportion of males sufficiently high, but would result in a decrease in average size of mature females with possible reduction in egg production. Modelling studies have suggested that age/size truncation resulting in changes in sex ratio or female size could result in increased variation in recruitment and increased probability of catastrophic collapse (Armsworth 2001). Estimates of the sex ratio in this population from various time periods have indicated a large decreases in the proportion of males in the Gulf of Mexico and Atlantic (Coleman et al. 1996, McGovern et al 1998).

There are various management implications that derive from this information and the modeling studies that have been conducted (Huntsman and Schaaf 1994, Armsworth 2001, Fu et al. 2001, Alonzo and Mangel 2004, Heppell et al. 2006). First, the selectivity imposed by a fishery is critical. Management options that reduce F on males (larger individuals) will tend to reduce the chance of producing a dangerously low sex ratio. Because large fish are typically targeted in many fisheries and the inherent tendency of many gear types to be size selective this may be difficult to achieve in many fisheries. This has led some authors to argue that the most effective way to protect males would be to establish appropriate MPAs (Coleman et al. 2000). This may work because data indicate that old males are at least partially resident on deep-water reefs (Coleman et al. 1996). Data collected recently from two gag spawning aggregation closures on the west Florida shelf are providing some collaboration for this hypothesis (Coleman and Koening reference in Heppell et al 2006). However, because these large individuals may move considerable distances, the size of such closures is critical to their success, and Heppel et al. (2006) have suggested that such closures would have to be coupled with reductions in F outside the closures. Alternatively, controls could be imposed differentially on fisheries based on their selectivity, or F controls could be depth dependent. A modeling study of gag grouper by Heppell et al. (2006) has suggested that simply reducing F substantially (50% in the model) for all age classes could be equally effective. Second, the transition to depensatory dynamics caused by sperm limitation is likely to be abrupt and patchy in space because males may show site fidelity. However, biological knowledge is currently insufficient to estimate a sperm-limitation threshold. Given the uncertainty in the form of the depensatory function and the long lags in population assessment imposed by the management system, it is important from this perspective to set conservative benchmarks for gag.

Figure 7 of the SEDAR-10, Gulf of Mexico Stock Assessment Workshop Report shows the estimated trends of spawning biomass for males and females gag grouper GOM stock. By 2004, male proportion was about 7% of mature individuals by weight, and 3% of mature individuals by number. Although, overall spawning biomass for gag GOM has increased in recent years, male biomass component has a much lower rate of increase compared to the female component (Figure 6, SEDAR-10, 2006).

SEDAR 10
Assessment Report 1

Revised Estimates for South Atlantic Gag

February 2007

This document corrects a transcription error in the recreational fisheries landings discovered in the Fall of 2006. Results in this document supersede those reported in the original assessment report, Section III.

UNITED STATE DEPARTMENT OFCOMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
75 Virginia Beach Drive
Miami, Florida 33149 U.S.A.

November 15, 2006

Robert Mahood
Executive Director
South Atlantic Fishery Management Council
Southpark Building, Suite 306
1 Southpark Circle
Charleston, SC 29407

Dear Bob,

This letter is to inform you that a data error has been discovered in the 2006 U.S. South Atlantic gag stock assessment. SERO and SAFMC staff noted a discrepancy in landings data between the Data Workshop report and the Assessment Workshop report. Investigations into this discrepancy led to the discovery of an error in the data input for the gag stock assessment model.

The error occurred with Marine Recreational Fisheries Statistics Survey (MRFSS) landings data (1982-2004), when the assessment scientists were compiling Data Workshop data into a single spreadsheet for model input. The Stock Assessment scientists retrieved "landings + discard" data instead of "landings" data for their analyses – as a result, *discard estimates* (commonly referred to as B2 fish) were included in both the "landed" data and in the discard data.

The following recommendations will serve to avoid this and other errors in data compilation:

A. Have the Data Workshop participants and other stock assessment scientists review the model input file created by the Assessment Workshop scientists.

B. Have the Data Workshop compile a single model input data file (*rather than a series of files to be compiled by Assessment Workshop participants, as is currently the case*) by the close of the Workshop. Stock Assessment scientists would be responsible for providing a template of the structure and format for the single input data file. The input data file would then be:1) reviewed and certified by all Data Workshop participants (*currently not the practice*); and 2) reviewed by Assessment Workshop participants prior to the assessment. All subsequent changes to the input data file by the assessment scientists would be reviewed and approved by Data Workshop participants.

We are currently doing preliminary model runs with the corrected discard estimates, however, because of the amount of work involved, and to ensure no further errors, it will not be possible to complete the updated analysis and documentation in time for the December, 2006 SAFMC meeting. We anticipate that the revised assessment will be completed by February 2007.

Sincerely,

Alex Chester,
Acting Center Director

Cc: Gregg Waugh
Roy Crabtree
Peter Thompson
John Carmichael
Nancy Thompson
Aleta Hohn

Executive Summary

The stock of gag (*Mycteroperca microlepis*) off the United States South Atlantic was assessed during a SEDAR[1] assessment workshop, held at the Wyndham Grand Bay Hotel, Miami, Florida, on May 1–5, 2006. The workshop's objectives were to complete the SEDAR-10 benchmark assessment of gag and to conduct stock projections (See the terms of reference). Participants in the benchmark assessment (See the list of participants, Table 1.1.3) included state, federal, and university scientists, as well as SAFMC members and staff, and various observers. All decisions regarding stock assessment methods and acceptable data were made by consensus.

Available data on the stock included abundance indices, recorded landings, and samples of annual size compositions and age compositions from fishery-dependent sources. Three fishery–dependent abundance indices were developed by the SEDAR-10 data workshop: one from the NMFS headboat survey, one from the commercial logbook program, and one from the MRFSS survey. There are no usable fishery–independent abundance data for this stock of gag at this time. Landings data were available from all recreational and commercial fisheries. This benchmark assessment included data through 2004.

A forward projecting statistical model of catch at age was used as the primary assessment model. In addition, an age-aggregated production model was used to investigate results under a different set of model assumptions. The AW developed two base runs; one assuming a time-varying catchability and one assuming constant catchability for the fishery dependent indices. Each base run of the catch-at-age model was the basis for estimation of benchmarks and stock status.

Results suggest that spawning stock biomass fell below values corresponding to MSY in the early 1980's and remained there until the most recent years. The 2005 estimate of SSB is 5720 and 7468 thousand pounds (klb) from the time-varying and constant catchability base model runs, respectively. These estimates correspond to about 106% and 110% of MSST and 91% and 94% of $\mathrm{SSB}_{\mathrm{MSY}}$, by the Council's definition of MSST as $(1-M)\mathrm{SSB}_{\mathrm{MSY}}$ and assuming a natural mortality rate of $M = 0.14$. The 2004 estimates of fishing mortality were 146% and 131% of F_{MSY}, where F_{MSY} is the MFMT. These results indicate that the stock is not overfished, but is undergoing overfishing.

Stock projections were evaluated under five scenarios starting in 2008. Each scenario applied the current F in years 2005–2007. Starting in 2008, the five projection scenarios included: (1) current F, (2) F_{MSY}, (3) 85% of F_{MSY}, (4) 75% of F_{MSY}, and (5) 65% of F_{MSY}. All projections agree that under current F through 2006, the stock biomass will dip below the MSY and MSST levels by the beginning of 2007.

[1] Abbreviations and acronyms used in this report are defined in Appendix A

2 Data Review and Update

Processing of data for the assessment is described in the SEDAR 10 Data Workshop Report. This section provides tabulation of data with the groupings and truncation as used in the assessment. In general, all age-based data were categorized as ages 0 to 20^+. Length compositions were defined in 30 mm bins from 200mm to 1220mm.

Discard mortality fraction was assumed constant at the following rates:

Commercial	Recreational	
Hook and Line	Headboat	MRFSS
0.40	0.25	0.25

Von Bertalanffy growth parameters were estimated within the assessment model, along with coefficients of variation of length at each age.

The length–weight relationship used in the model converts total length in millimeters (TL) to weight in gutted pounds (W): $W = 3.7996 \times 10^{-8} \cdot \text{TL}^{2.943}$.

The proportions of males by year and age as used in the assessment model is given in Table 1. The proportion of mature gag at age is presented in Table 2 by sex. The sex ratio and maturity data were used over ages 0 to 20^+.

Landings by fishery and year, as used in the assessment, are given in Table 3 along with associated coefficients of variation. Commercial landings are in thousands of gutted pounds, while headboat and MRFSS landings are in thousands of individual fish. The indices of abundance are provided in Table 4. The units are fish caught per angler hour for headboat, number of fish caught per 1000 hook hours for MRFSS, and pounds per hook for commercial. Scaled indices of abundance by fishery are given in Figure 1. The numbers of discards by fishery and year are given in Table 5. All discard values are reported in thousands of individual fish.

Length composition data are provided for commercial handline which also includes some longline and trawl length samples (Table 6), commercial diving (Table 7), and the recreational fishery comprised of headboat and the private and charter modes from the MRFSS (Table 8). These are presented in 30 mm bins from 200mm to 1220mm as used in the assessment model.

Age composition data are provided for commercial handline (Table 9), commercial diving (Table 10), and the headboat fishery (Table 11). These are defined in annual bins from age 0 to 20+.

2.1 Tables—Data Review and Update

Table 1. Gag: Proportion males by year and age.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1962	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1963	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1964	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1965	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1966	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1967	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1968	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1969	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1970	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1971	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1972	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1973	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1974	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1975	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1976	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1977	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1978	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1979	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1980	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1981	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1982	0	0.001	0.003	0.006	0.013	0.026	0.050	0.087	0.141	0.216	0.309	0.416	0.529	0.641	0.742	0.825	0.889	0.934	0.964	0.981	0.991
1983	0	0.001	0.002	0.006	0.012	0.025	0.048	0.086	0.143	0.220	0.318	0.429	0.546	0.658	0.757	0.837	0.897	0.939	0.967	0.983	0.992
1984	0	0.001	0.002	0.005	0.012	0.024	0.047	0.085	0.144	0.225	0.327	0.443	0.563	0.675	0.772	0.849	0.906	0.945	0.970	0.984	0.993
1985	0	0.001	0.002	0.005	0.011	0.023	0.046	0.085	0.145	0.230	0.337	0.457	0.580	0.692	0.787	0.860	0.914	0.950	0.973	0.986	0.993
1986	0	0.001	0.002	0.004	0.010	0.022	0.044	0.084	0.146	0.235	0.346	0.471	0.596	0.709	0.802	0.872	0.922	0.955	0.975	0.987	0.994
1987	0	0.001	0.002	0.004	0.009	0.021	0.043	0.083	0.147	0.239	0.355	0.485	0.613	0.726	0.817	0.884	0.930	0.960	0.978	0.989	0.995
1988	0	0.001	0.001	0.004	0.009	0.020	0.042	0.082	0.149	0.244	0.365	0.499	0.630	0.743	0.832	0.896	0.938	0.965	0.981	0.991	0.996
1989	0	0.000	0.001	0.003	0.008	0.019	0.041	0.082	0.150	0.249	0.374	0.512	0.646	0.760	0.847	0.908	0.946	0.970	0.984	0.992	0.996
1990	0	0.000	0.001	0.003	0.007	0.017	0.039	0.081	0.151	0.253	0.383	0.526	0.663	0.777	0.862	0.919	0.955	0.975	0.987	0.994	0.997
1991	0	0.000	0.001	0.002	0.006	0.016	0.038	0.080	0.152	0.258	0.393	0.540	0.680	0.794	0.877	0.931	0.963	0.980	0.990	0.995	0.998
1992	0	0.000	0.001	0.002	0.006	0.015	0.037	0.080	0.153	0.263	0.402	0.554	0.696	0.812	0.893	0.943	0.971	0.986	0.993	0.997	0.998
1993	0	0.000	0.000	0.002	0.005	0.014	0.035	0.079	0.155	0.268	0.411	0.568	0.713	0.829	0.908	0.955	0.979	0.991	0.996	0.998	0.999
1994	0	0.000	0.000	0.001	0.004	0.013	0.034	0.078	0.156	0.272	0.421	0.582	0.730	0.846	0.923	0.966	0.987	0.996	0.999	1.000	1.000
1995	0	0.000	0.000	0.001	0.004	0.013	0.034	0.078	0.156	0.272	0.421	0.582	0.730	0.846	0.923	0.966	0.987	0.996	0.999	1.000	1.000
1996	0	0.000	0.000	0.001	0.004	0.013	0.035	0.081	0.162	0.283	0.436	0.598	0.744	0.856	0.929	0.969	0.989	0.996	0.999	1.000	1.000
1997	0	0.000	0.000	0.001	0.004	0.013	0.035	0.083	0.168	0.294	0.451	0.615	0.759	0.867	0.935	0.973	0.990	0.997	0.999	1.000	1.000
1998	0	0.000	0.000	0.001	0.004	0.013	0.036	0.085	0.174	0.305	0.466	0.631	0.774	0.877	0.942	0.976	0.991	0.997	0.999	1.000	1.000
1999	0	0.000	0.000	0.001	0.004	0.013	0.037	0.088	0.180	0.315	0.481	0.648	0.788	0.888	0.948	0.979	0.992	0.998	0.999	1.000	1.000
2000	0	0.000	0.000	0.001	0.004	0.013	0.037	0.090	0.186	0.326	0.496	0.664	0.803	0.899	0.954	0.982	0.994	0.998	0.999	1.000	1.000
2001	0	0.000	0.000	0.001	0.004	0.013	0.038	0.093	0.192	0.337	0.511	0.681	0.818	0.909	0.960	0.985	0.995	0.998	1.000	1.000	1.000
2002	0	0.000	0.000	0.001	0.004	0.013	0.038	0.095	0.198	0.348	0.526	0.697	0.832	0.920	0.967	0.988	0.996	0.999	1.000	1.000	1.000
2003	0	0.000	0.000	0.001	0.004	0.013	0.039	0.097	0.204	0.358	0.541	0.714	0.847	0.930	0.973	0.991	0.997	0.999	1.000	1.000	1.000
2004	0	0.000	0.000	0.001	0.003	0.013	0.040	0.100	0.210	0.369	0.556	0.730	0.862	0.941	0.979	0.994	0.999	1.000	1.000	1.000	1.000

Table 2. Gag: Proportion mature by age and sex.

Age	Male	Female
0	0	0.000462
1	1	0.005760
2	1	0.067736
3	1	0.476767
4	1	0.919532
5	1	0.993070
6	1	0.999444
7	1	0.999956
8	1	0.999996
9	1	1.000000
10	1	1.000000
11	1	1.000000
12	1	1.000000
13	1	1.000000
14	1	1.000000
15	1	1.000000
16	1	1.000000
17	1	1.000000
18	1	1.000000
19	1	1.000000
20	1	1.000000

Table 3. Gag: Landings and associated coefficient of variation as used in the assessment.

	Commercial (gutted klb)		Recreational (1000s)		Coefficient of Variation			
Year	Handline	Diving	Headboat	MRFSS	Handline	Diving	Headboat	MRFSS
1962	150.3		8.41	6.17	0.300		0.10	0.49
1963	137.0		7.66	5.62	0.300		0.10	0.49
1964	128.4		7.18	5.27	0.300		0.10	0.49
1965	130.4		7.41	5.44	0.300		0.10	0.49
1966	99.1		5.58	4.09	0.300		0.10	0.49
1967	210.9		11.77	8.62	0.300		0.10	0.49
1968	309.9		17.72	12.98	0.300		0.10	0.49
1969	217.2		12.13	8.89	0.300		0.10	0.49
1970	299.0		16.66	12.20	0.300		0.10	0.49
1971	306.7		17.18	12.59	0.300		0.10	0.49
1972	204.5		13.44	8.37	0.300		0.10	0.49
1973	290.5		17.99	12.15	0.300		0.10	0.49
1974	372.8		13.92	15.68	0.300		0.10	0.49
1975	421.8		8.57	17.48	0.300		0.10	0.49
1976	565.0	3.75	7.56	23.77	0.300	0.300	0.10	0.49
1977	627.6	8.81	8.48	21.94	0.300	0.300	0.10	0.49
1978	967.4	13.87	6.01	37.54	0.300	0.300	0.10	0.49
1979	907.5	18.92	9.55	35.70	0.300	0.300	0.10	0.49
1980	846.2	16.40	6.96	35.39	0.300	0.300	0.10	0.49
1981	984.0	13.88	13.86	56.69	0.300	0.300	0.05	0.47
1982	1027.4	15.85	11.84	17.85	0.300	0.300	0.05	0.48
1983	1101.1	9.08	16.46	74.82	0.300	0.300	0.05	0.52
1984	1108.2	18.75	18.69	153.25	0.277	0.277	0.05	0.21
1985	865.7	11.62	16.13	52.22	0.255	0.255	0.05	0.30
1986	819.8	6.34	17.35	46.78	0.232	0.232	0.05	0.27
1987	857.8	21.93	24.09	87.38	0.209	0.209	0.05	0.36
1988	672.4	12.96	24.21	62.07	0.186	0.186	0.05	0.20
1989	967.0	22.26	22.42	75.28	0.164	0.164	0.05	0.17
1990	784.3	19.07	17.59	52.20	0.141	0.141	0.05	0.27
1991	656.4	85.01	13.55	36.71	0.118	0.118	0.05	0.19
1992	691.7	106.76	13.94	49.32	0.095	0.095	0.05	0.14
1993	756.6	78.15	11.80	51.80	0.073	0.073	0.05	0.20
1994	800.0	97.50	9.81	56.22	0.050	0.050	0.05	0.17
1995	840.4	83.77	10.54	40.53	0.050	0.050	0.05	0.21
1996	751.9	118.56	7.50	43.92	0.050	0.050	0.05	0.20
1997	608.2	98.71	6.85	32.33	0.050	0.050	0.05	0.22
1998	654.5	138.79	8.67	40.32	0.050	0.050	0.05	0.29
1999	538.1	113.49	5.34	50.45	0.050	0.050	0.05	0.22
2000	438.2	63.02	5.98	29.87	0.050	0.050	0.05	0.16
2001	450.1	82.30	5.12	42.74	0.050	0.050	0.05	0.18
2002	448.3	84.52	4.58	24.03	0.050	0.050	0.05	0.19
2003	443.9	117.41	3.27	46.11	0.050	0.050	0.05	0.16
2004	476.4	74.97	6.66	46.25	0.050	0.050	0.05	0.17

Table 4. Gag: Indices of abundance by fishery, as used in assessment.

	Indices			Coefficient of variation		
	Commercial	Recreational		Commercial	Recreational	
Year	Handline	Headboat	MRFSS	Handline	Headboat	MRFSS
1972						
1973		2.486			0.274	
1974		1.762			0.313	
1975		0.925			0.442	
1976		0.659			0.470	
1977		0.678			0.465	
1978		0.689			0.373	
1979		1.037			0.289	
1980		1.198			0.250	
1981		1.064	0.590		0.287	1.277
1982		1.040	0.487		0.259	1.231
1983		1.150	0.446		0.235	0.987
1984		1.168	0.582		0.247	0.880
1985		0.985	1.294		0.251	0.760
1986		1.006	1.257		0.251	0.662
1987		1.084	1.007		0.229	0.672
1988		1.231	0.615		0.206	0.705
1989		1.166	1.982		0.256	0.625
1990		1.122	0.784		0.253	0.703
1991		1.098	1.018		0.256	0.645
1992	0.908	1.143	1.101	0.065	0.240	0.637
1993	0.944	1.050	1.110	0.042	0.273	0.641
1994	0.907	0.872	1.036	0.041	0.297	0.638
1995	0.937	0.914	1.542	0.041	0.293	0.628
1996	1.001	0.769	0.843	0.040	0.364	0.654
1997	0.768	0.821	0.877	0.044	0.402	0.705
1998	0.951	0.977	0.345	0.043	0.280	0.745
1999	1.017	0.670	1.744	0.047	0.383	0.637
2000	0.912	0.713	0.891	0.051	0.381	0.652
2001	0.867	0.658	0.704	0.046	0.397	0.649
2002	1.006	0.708	1.196	0.046	0.390	0.634
2003	1.342	0.522	0.992	0.047	0.538	0.649
2004	1.440	0.637	1.556	0.046	0.410	0.616

Table 5. Gag: Discards and associated coefficients of variation, as used in assessment.

	Discards (1000s)			Coefficient of variation		
	Commercial	Recreational		Commercial	Recreational	
Year	Handline	Headboat	MRFSS	Handline	Headboat	MRFSS
1981		0.03	0.00	0.600	0.200	
1982		0.02	4.32	0.600	0.200	0.71
1983		0.04	91.88	0.600	0.200	1.00
1984		0.03	11.95	0.555	0.191	0.67
1985		3.76	3.09	0.509	0.182	0.55
1986		4.05	12.48	0.464	0.173	0.34
1987		5.63	10.30	0.418	0.164	0.44
1988		5.65	15.01	0.373	0.155	0.83
1989		5.23	43.41	0.327	0.145	0.24
1990		4.11	11.46	0.282	0.136	0.37
1991		3.16	24.19	0.236	0.127	0.25
1992		7.74	38.66	0.191	0.118	0.23
1993		6.54	31.23	0.145	0.109	0.36
1994		5.45	68.29	0.100	0.100	0.23
1995		5.85	73.97	0.100	0.100	0.17
1996		4.16	43.00	0.100	0.100	0.16
1997		3.81	82.41	0.100	0.100	0.17
1998		4.82	32.22	0.100	0.100	0.23
1999	7.37	4.80	58.86	0.100	0.100	0.14
2000	7.77	5.38	126.63	0.100	0.100	0.27
2001	13.71	4.60	47.41	0.100	0.100	0.14
2002	11.91	4.12	85.73	0.100	0.100	0.13
2003	5.10	2.95	137.62	0.100	0.100	0.11
2004	7.20	6.00	89.54	0.100	0.100	0.14

Table 6. Gag: Length compositions from commercial handline[1]*.*

Year	N	200	230	260	290	320	350	380	410	440	470	500	530	560	590	620	650	680	710
1983	116	0	0	0	0	0.000	0.000	0.003	0.003	0.008	0.010	0.009	0.024	0.034	0.068	0.059	0.032	0.024	0.054
1984	2856	0	0	0	0	0.001	0.000	0.002	0.002	0.003	0.009	0.015	0.018	0.019	0.025	0.027	0.028	0.036	0.039
1985	2689	0	0	0	0	0.000	0.001	0.001	0.001	0.003	0.003	0.002	0.003	0.004	0.007	0.011	0.017	0.017	0.033
1986	1449	0	0	0	0	0.003	0.006	0.004	0.007	0.029	0.032	0.047	0.044	0.043	0.041	0.051	0.046	0.060	0.048
1987	2125	0	0	0	0	0.001	0.001	0.002	0.003	0.004	0.008	0.011	0.016	0.022	0.029	0.023	0.026	0.037	0.045
1988	1368	0	0	0	0	0.000	0.000	0.000	0.000	0.002	0.003	0.006	0.006	0.003	0.008	0.010	0.023	0.027	0.034
1989	1241	0	0	0	0	0.000	0.000	0.000	0.007	0.007	0.004	0.008	0.017	0.014	0.014	0.027	0.045	0.055	0.062
1990	808	0	0	0	0	0.000	0.001	0.000	0.000	0.011	0.011	0.018	0.021	0.022	0.042	0.037	0.058	0.057	0.076
1991	1126	0	0	0	0	0.000	0.001	0.002	0.003	0.003	0.018	0.018	0.031	0.038	0.051	0.041	0.029	0.048	0.062
1992	1217	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.059	0.065	0.068	0.079	0.072	0.080	0.084
1993	1568	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.003	0.032	0.048	0.056	0.065	0.082	0.083	0.085	0.079
1994	1213	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.001	0.022	0.049	0.062	0.080	0.092	0.093	0.105	0.077
1995	1929	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.023	0.030	0.026	0.041	0.038	0.049	0.053
1996	1620	0	0	0	0	0.001	0.000	0.000	0.000	0.000	0.001	0.009	0.027	0.038	0.035	0.042	0.028	0.038	0.047
1997	1218	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.025	0.035	0.035	0.040	0.051	0.039	0.042
1998	1294	0	0	0	0	0.000	0.000	0.000	0.000	0.001	0.005	0.017	0.021	0.027	0.022	0.027	0.038	0.052	0.089
1999	1491	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.009	0.021	0.019	0.065	0.129
2000	1591	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.008	0.018	0.023	0.029	0.051	0.088
2001	1485	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.008	0.018	0.031	0.038	0.038	0.071
2002	1034	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.008	0.029	0.043	0.045	0.059	0.047
2003	1161	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.007	0.005	0.023	0.023	0.045	0.066	0.107
2004	1621	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.004	0.013	0.038	0.034	0.045	0.071

Year	N	740	770	800	830	860	890	920	950	980	1010	1040	1070	1100	1130	1160	1190	1220
1983	116	0.078	0.113	0.072	0.100	0.067	0.060	0.031	0.029	0.029	0.031	0.045	0.011	0.000	0.000	0.009	0.000	0.000
1984	2856	0.047	0.061	0.070	0.096	0.094	0.079	0.062	0.054	0.050	0.053	0.046	0.033	0.020	0.006	0.004	0.000	0.000
1985	2689	0.045	0.061	0.083	0.089	0.090	0.083	0.086	0.085	0.074	0.073	0.054	0.032	0.027	0.009	0.005	0.000	0.000
1986	1449	0.063	0.061	0.062	0.073	0.049	0.039	0.041	0.038	0.031	0.033	0.020	0.016	0.009	0.002	0.001	0.000	0.000
1987	2125	0.060	0.077	0.090	0.088	0.071	0.073	0.058	0.044	0.051	0.037	0.036	0.034	0.022	0.017	0.011	0.001	0.002
1988	1368	0.065	0.080	0.092	0.102	0.084	0.070	0.062	0.073	0.069	0.045	0.033	0.041	0.039	0.014	0.006	0.001	0.000
1989	1241	0.084	0.091	0.091	0.084	0.072	0.059	0.057	0.055	0.060	0.031	0.024	0.018	0.010	0.004	0.000	0.000	0.000
1990	808	0.089	0.095	0.090	0.074	0.052	0.061	0.038	0.027	0.030	0.026	0.020	0.018	0.019	0.005	0.001	0.000	0.000
1991	1126	0.050	0.096	0.115	0.101	0.063	0.068	0.039	0.037	0.027	0.019	0.020	0.010	0.005	0.006	0.000	0.000	0.000
1992	1217	0.072	0.090	0.085	0.073	0.041	0.031	0.022	0.011	0.013	0.011	0.010	0.009	0.005	0.001	0.001	0.000	0.000
1993	1568	0.082	0.066	0.084	0.051	0.051	0.033	0.022	0.016	0.016	0.016	0.013	0.007	0.005	0.003	0.001	0.000	0.000
1994	1213	0.093	0.101	0.088	0.037	0.029	0.018	0.014	0.011	0.008	0.009	0.004	0.004	0.002	0.000	0.000	0.000	0.000
1995	1929	0.058	0.057	0.081	0.076	0.082	0.096	0.064	0.049	0.036	0.034	0.039	0.030	0.018	0.011	0.004	0.001	0.000
1996	1620	0.071	0.083	0.113	0.110	0.092	0.065	0.041	0.040	0.034	0.028	0.022	0.014	0.012	0.003	0.004	0.000	0.001
1997	1218	0.062	0.075	0.086	0.101	0.095	0.075	0.057	0.051	0.029	0.032	0.019	0.021	0.009	0.007	0.004	0.003	0.000
1998	1294	0.085	0.102	0.099	0.072	0.067	0.067	0.047	0.044	0.035	0.024	0.028	0.016	0.010	0.002	0.002	0.001	0.000
1999	1491	0.123	0.135	0.112	0.083	0.061	0.048	0.050	0.038	0.047	0.036	0.010	0.004	0.003	0.000	0.001	0.000	0.000
2000	1591	0.111	0.139	0.135	0.094	0.074	0.056	0.049	0.040	0.038	0.022	0.016	0.004	0.001	0.000	0.000	0.000	0.000
2001	1485	0.078	0.112	0.115	0.095	0.091	0.090	0.061	0.043	0.052	0.030	0.012	0.008	0.004	0.001	0.001	0.001	0.000
2002	1034	0.069	0.083	0.091	0.084	0.072	0.078	0.073	0.066	0.055	0.037	0.020	0.011	0.013	0.008	0.000	0.004	0.000
2003	1161	0.127	0.119	0.107	0.068	0.065	0.050	0.057	0.039	0.039	0.019	0.013	0.010	0.003	0.000	0.001	0.001	0.002
2004	1621	0.081	0.106	0.110	0.108	0.082	0.060	0.032	0.061	0.074	0.029	0.016	0.017	0.004	0.000	0.005	0.000	0.006

[1] Includes some longline and a small number of trawl length samples.

Table 7. Gag: Length compositions from commercial diving.

Year	N	200	230	260	290	320	350	380	410	440	470	500	530	560	590	620	650	680	710
1999	224	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.005	0.003	0.043	0.048	0.021	0.140
2000	198	0	0	0	0	0	0	0	0	0	0.000	0.000	0.007	0.012	0.021	0.020	0.058	0.047	0.080
2001	109	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0.012	0.038	0.031	0.038	0.063
2003	324	0	0	0	0	0	0	0	0	0	0.006	0.001	0.006	0.008	0.012	0.013	0.012	0.023	0.080

Year	N	740	770	800	830	860	890	920	950	980	1010	1040	1070	1100	1130	1160	1190	1220
1999	224	0.198	0.255	0.152	0.027	0.022	0.038	0.000	0.017	0.003	0.014	0.002	0.001	0.011	0.000	0.000	0	0.000
2000	198	0.111	0.158	0.106	0.085	0.045	0.048	0.026	0.024	0.072	0.025	0.033	0.009	0.005	0.008	0.000	0	0.000
2001	109	0.145	0.273	0.146	0.058	0.000	0.030	0.031	0.010	0.030	0.056	0.020	0.010	0.010	0.000	0.000	0	0.000
2003	324	0.141	0.170	0.178	0.096	0.048	0.029	0.039	0.029	0.048	0.011	0.012	0.019	0.009	0.002	0.004	0	0.004

Table 8. Gag: Length compositions from the recreational fishery (headboat and MRFSS private and MRFSS charter modes).

Year	N	200	230	260	290	320	350	380	410	440	470	500	530	560	590	620	650	680	710
1972	150	0.000	0.000	0.003	0.016	0.013	0.019	0.016	0.019	0.013	0.013	0.032	0.016	0.003	0.044	0.022	0.035	0.032	0.019
1973	238	0.000	0.000	0.000	0.006	0.003	0.000	0.006	0.011	0.011	0.009	0.022	0.011	0.008	0.014	0.036	0.047	0.025	0.023
1974	149	0.000	0.004	0.008	0.004	0.008	0.008	0.004	0.004	0.012	0.004	0.012	0.000	0.008	0.004	0.000	0.012	0.015	0.020
1975	240	0.000	0.000	0.005	0.020	0.021	0.012	0.009	0.012	0.021	0.021	0.021	0.025	0.015	0.014	0.036	0.035	0.046	0.043
1976	233	0.000	0.004	0.005	0.000	0.008	0.000	0.013	0.008	0.017	0.026	0.034	0.025	0.042	0.030	0.013	0.018	0.029	0.034
1977	307	0.000	0.005	0.000	0.000	0.005	0.003	0.003	0.003	0.006	0.018	0.020	0.036	0.041	0.043	0.044	0.038	0.074	0.035
1978	182	0.000	0.000	0.006	0.006	0.000	0.006	0.011	0.006	0.000	0.010	0.011	0.020	0.034	0.034	0.028	0.028	0.048	0.077
1979	104	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.027	0.022	0.000	0.018	0.045	0.045	0.036	0.067	0.063	0.036
1980	186	0.000	0.000	0.005	0.000	0.000	0.005	0.000	0.005	0.029	0.021	0.037	0.037	0.042	0.021	0.026	0.032	0.084	0.089
1981	465	0.000	0.000	0.000	0.000	0.007	0.008	0.028	0.009	0.028	0.021	0.056	0.051	0.052	0.059	0.065	0.052	0.037	0.035
1982	598	0.004	0.000	0.004	0.002	0.004	0.014	0.029	0.029	0.044	0.057	0.040	0.043	0.035	0.019	0.054	0.055	0.053	0.066
1983	906	0.000	0.000	0.001	0.002	0.003	0.009	0.021	0.051	0.060	0.061	0.072	0.090	0.058	0.062	0.056	0.051	0.039	0.048
1984	1295	0.001	0.000	0.001	0.002	0.004	0.011	0.022	0.024	0.030	0.041	0.035	0.043	0.038	0.048	0.061	0.053	0.071	0.078
1985	991	0.001	0.006	0.010	0.008	0.009	0.024	0.033	0.027	0.041	0.045	0.053	0.043	0.047	0.065	0.043	0.047	0.045	0.066
1986	674	0.002	0.011	0.016	0.014	0.023	0.040	0.051	0.067	0.086	0.072	0.065	0.061	0.053	0.055	0.045	0.063	0.050	0.034
1987	758	0.000	0.007	0.009	0.010	0.013	0.029	0.060	0.069	0.042	0.073	0.052	0.093	0.082	0.073	0.054	0.043	0.051	0.037
1988	612	0.000	0.006	0.005	0.012	0.012	0.025	0.033	0.033	0.050	0.077	0.070	0.073	0.089	0.055	0.081	0.049	0.060	0.062
1989	561	0.006	0.021	0.005	0.000	0.017	0.017	0.041	0.058	0.045	0.066	0.063	0.076	0.062	0.071	0.082	0.073	0.058	0.047
1990	479	0.006	0.009	0.009	0.011	0.023	0.028	0.019	0.055	0.060	0.066	0.062	0.066	0.078	0.058	0.070	0.056	0.060	0.054
1991	239	0.004	0.022	0.033	0.002	0.000	0.003	0.021	0.031	0.059	0.015	0.057	0.099	0.050	0.083	0.076	0.066	0.053	0.092
1992	366	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.007	0.012	0.047	0.096	0.098	0.116	0.080	0.051	0.095	0.078
1993	352	0.000	0.001	0.005	0.000	0.000	0.000	0.004	0.000	0.000	0.003	0.048	0.089	0.074	0.063	0.090	0.060	0.058	0.092
1994	385	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.001	0.006	0.014	0.026	0.081	0.062	0.068	0.090	0.074	0.077	0.059
1995	558	0.000	0.002	0.002	0.002	0.000	0.003	0.003	0.003	0.000	0.003	0.041	0.100	0.083	0.067	0.060	0.051	0.048	0.064
1996	263	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.065	0.117	0.119	0.135	0.096	0.077	0.027	0.036
1997	226	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.009	0.005	0.031	0.107	0.190	0.108	0.100	0.090	0.064	0.052
1998	410	0.004	0.000	0.000	0.001	0.010	0.000	0.000	0.000	0.002	0.003	0.054	0.106	0.182	0.092	0.123	0.081	0.051	0.056
1999	362	0.004	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.003	0.003	0.011	0.035	0.104	0.070	0.196	0.076	0.065	0.083
2000	298	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.009	0.000	0.002	0.003	0.005	0.052	0.095	0.162	0.130	0.095	0.062
2001	291	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.019	0.036	0.150	0.169	0.075	0.053
2002	199	0.000	0.000	0.012	0.012	0.000	0.003	0.000	0.006	0.000	0.000	0.005	0.043	0.006	0.003	0.092	0.119	0.066	0.103
2003	218	0.000	0.000	0.000	0.015	0.000	0.005	0.010	0.010	0.005	0.011	0.000	0.003	0.023	0.026	0.087	0.116	0.107	0.041
2004	199	0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.003	0.003	0.055	0.067	0.122	0.103	0.096

Year	N	740	770	800	830	860	890	920	950	980	1010	1040	1070	1100	1130	1160	1190	1220
1972	150	0.048	0.025	0.045	0.041	0.044	0.070	0.073	0.102	0.057	0.022	0.022	0.029	0.045	0.025	0.000	0.038	0.000
1973	238	0.026	0.070	0.048	0.053	0.057	0.031	0.090	0.051	0.078	0.078	0.065	0.034	0.040	0.017	0.019	0.000	0.008
1974	149	0.035	0.027	0.047	0.058	0.063	0.059	0.059	0.051	0.106	0.138	0.078	0.055	0.087	0.000	0.000	0.012	0.000
1975	240	0.048	0.052	0.035	0.058	0.031	0.026	0.029	0.056	0.047	0.089	0.062	0.039	0.036	0.034	0.000	0.005	0.000
1976	233	0.042	0.050	0.053	0.068	0.058	0.043	0.042	0.048	0.017	0.046	0.046	0.068	0.066	0.023	0.013	0.004	0.009
1977	307	0.056	0.050	0.059	0.083	0.085	0.044	0.011	0.014	0.045	0.039	0.029	0.029	0.033	0.035	0.009	0.000	0.003
1978	182	0.076	0.026	0.078	0.070	0.084	0.057	0.037	0.023	0.028	0.028	0.045	0.062	0.028	0.017	0.017	0.000	0.000
1979	104	0.143	0.080	0.080	0.085	0.009	0.045	0.018	0.027	0.018	0.058	0.054	0.009	0.009	0.009	0.000	0.000	0.000
1980	186	0.079	0.144	0.087	0.076	0.058	0.016	0.000	0.005	0.005	0.031	0.021	0.005	0.021	0.008	0.000	0.010	0.000
1981	465	0.038	0.055	0.100	0.102	0.096	0.042	0.027	0.007	0.005	0.013	0.002	0.003	0.000	0.001	0.000	0.000	0.000
1982	598	0.043	0.059	0.046	0.083	0.059	0.046	0.029	0.021	0.024	0.014	0.009	0.005	0.003	0.000	0.002	0.002	0.003
1983	906	0.041	0.040	0.037	0.056	0.045	0.028	0.024	0.012	0.006	0.010	0.007	0.004	0.002	0.003	0.000	0.000	0.000
1984	1295	0.041	0.062	0.056	0.086	0.075	0.039	0.021	0.018	0.006	0.014	0.004	0.006	0.003	0.003	0.001	0.001	0.000
1985	991	0.065	0.062	0.069	0.064	0.049	0.030	0.020	0.010	0.005	0.001	0.001	0.004	0.003	0.003	0.001	0.000	0.000
1986	674	0.023	0.042	0.041	0.032	0.030	0.008	0.002	0.001	0.004	0.004	0.001	0.000	0.002	0.000	0.000	0.000	0.002
1987	758	0.052	0.033	0.038	0.026	0.016	0.008	0.013	0.007	0.002	0.006	0.001	0.001	0.002	0.001	0.000	0.000	0.000
1988	612	0.043	0.036	0.039	0.041	0.026	0.012	0.002	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000
1989	561	0.059	0.038	0.034	0.034	0.013	0.005	0.006	0.004	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000
1990	479	0.071	0.045	0.031	0.027	0.020	0.014	0.003	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000
1991	239	0.031	0.065	0.058	0.025	0.032	0.010	0.006	0.000	0.000	0.002	0.003	0.000	0.000	0.000	0.000	0.000	0.000
1992	366	0.071	0.063	0.053	0.054	0.040	0.020	0.011	0.003	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	352	0.073	0.073	0.062	0.070	0.054	0.041	0.008	0.013	0.003	0.000	0.008	0.000	0.000	0.002	0.004	0.000	0.000
1994	385	0.077	0.053	0.122	0.066	0.066	0.039	0.003	0.006	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	558	0.076	0.075	0.067	0.098	0.064	0.033	0.015	0.015	0.004	0.000	0.010	0.002	0.006	0.000	0.000	0.001	0.002
1996	263	0.034	0.047	0.041	0.044	0.056	0.032	0.029	0.022	0.004	0.000	0.000	0.000	0.000	0.000	0.009	0.001	0.000
1997	226	0.036	0.043	0.032	0.037	0.027	0.015	0.011	0.005	0.000	0.015	0.000	0.000	0.010	0.000	0.005	0.006	0.000
1998	410	0.037	0.066	0.027	0.035	0.042	0.012	0.007	0.006	0.003	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000
1999	362	0.060	0.067	0.072	0.056	0.041	0.033	0.007	0.000	0.005	0.000	0.000	0.006	0.002	0.000	0.000	0.000	0.000
2000	298	0.046	0.049	0.071	0.056	0.054	0.030	0.024	0.002	0.005	0.005	0.004	0.019	0.013	0.000	0.000	0.000	0.000
2001	291	0.089	0.060	0.038	0.090	0.075	0.060	0.014	0.020	0.004	0.011	0.003	0.003	0.004	0.010	0.004	0.010	0.000
2002	199	0.053	0.069	0.046	0.085	0.062	0.077	0.039	0.028	0.008	0.001	0.018	0.019	0.016	0.000	0.008	0.000	0.000
2003	218	0.072	0.059	0.088	0.079	0.101	0.029	0.035	0.018	0.008	0.013	0.015	0.000	0.001	0.009	0.016	0.000	0.000
2004	199	0.059	0.103	0.095	0.077	0.107	0.057	0.033	0.000	0.001	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000

Table 9. Gag: Age compositions from commercial handline.

Year	N	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1979	144	0	0	0.000	0.007	0.063	0.229	0.194	0.125	0.083	0.049	0.069	0.056	0.028	0.000	0.000	0.000	0.007	0.021	0.028	0.014	0.028
1980	80	0	0	0.000	0.013	0.013	0.100	0.238	0.375	0.100	0.075	0.025	0.038	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.013
1981	161	0	0	0.000	0.043	0.143	0.050	0.217	0.161	0.267	0.037	0.031	0.006	0.012	0.019	0.006	0.000	0.000	0.006	0.000	0.000	0.000
1992	66	0	0	0.014	0.135	0.213	0.168	0.165	0.271	0.032	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	98	0	0	0.017	0.083	0.259	0.217	0.282	0.094	0.047	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
1994	350	0	0	0.011	0.070	0.452	0.354	0.075	0.025	0.005	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	816	0	0	0.001	0.011	0.037	0.268	0.377	0.132	0.097	0.041	0.016	0.009	0.003	0.002	0.001	0.003	0.001	0.000	0.000	0.000	0.001
1996	87	0	0	0.000	0.000	0.000	0.087	0.582	0.271	0.039	0.003	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	121	0	0	0.000	0.000	0.019	0.021	0.168	0.617	0.122	0.023	0.003	0.024	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000
1999	88	0	0	0.022	0.246	0.106	0.217	0.309	0.062	0.014	0.005	0.000	0.004	0.007	0.000	0.000	0.000	0.009	0.000	0.000	0.000	0.000
2000	70	0	0	0.000	0.103	0.204	0.177	0.347	0.083	0.036	0.013	0.031	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.001
2001	211	0	0	0.003	0.018	0.112	0.182	0.286	0.328	0.025	0.010	0.012	0.014	0.005	0.000	0.001	0.001	0.002	0.000	0.000	0.000	0.000
2002	139	0	0	0.000	0.019	0.082	0.166	0.231	0.299	0.116	0.063	0.007	0.002	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	202	0	0	0.001	0.057	0.231	0.364	0.183	0.085	0.044	0.022	0.003	0.004	0.001	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.001
2004	552	0	0	0.006	0.154	0.299	0.279	0.187	0.032	0.030	0.004	0.003	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001

Table 10. Gag: Age compositions from commercial diving.

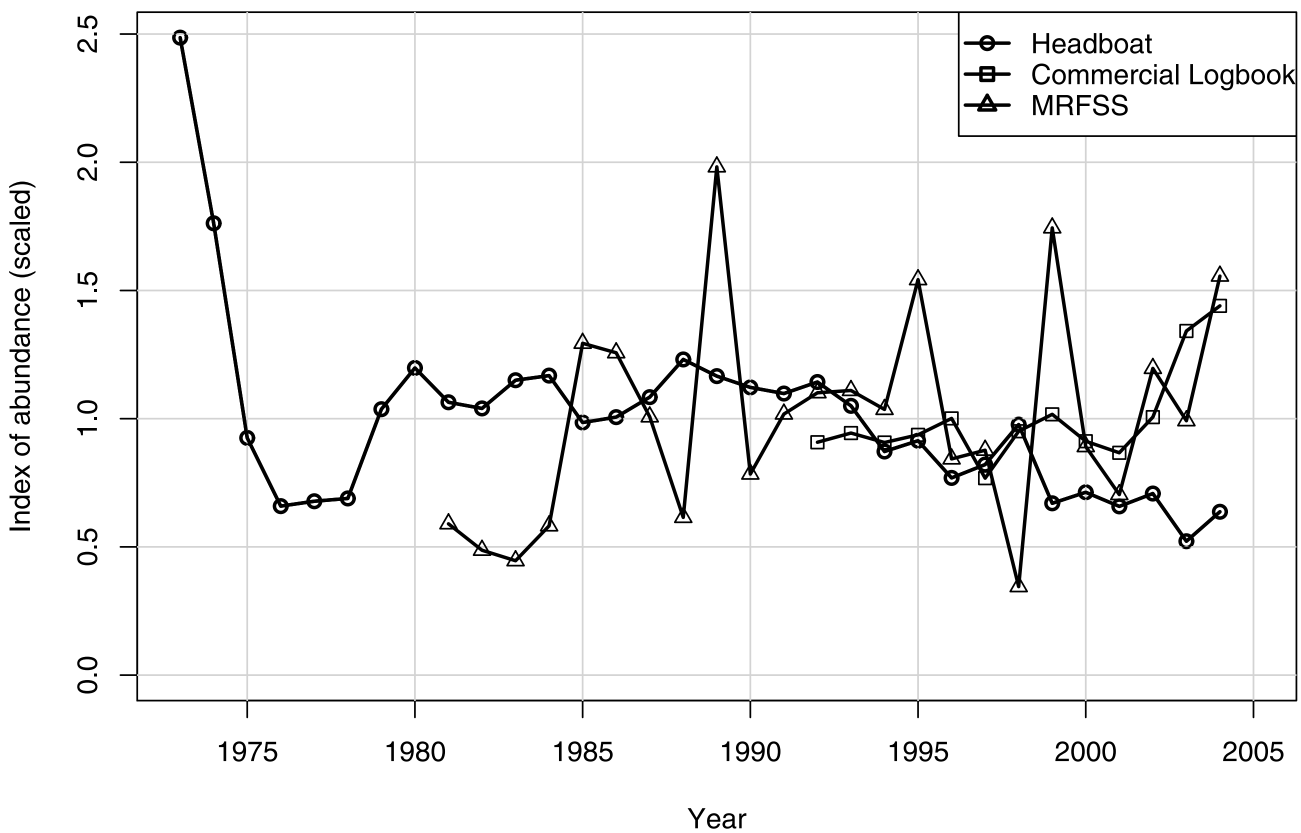
Year	N	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1994	47	0	0	0.085	0.021	0.085	0.234	0.170	0.213	0.149	0.043	0.000	0	0	0	0	0	0	0	0	0	0
1995	63	0	0	0.016	0.016	0.048	0.000	0.460	0.302	0.111	0.032	0.016	0	0	0	0	0	0	0	0	0	0
1997	54	0	0	0.019	0.019	0.185	0.056	0.093	0.537	0.093	0.000	0.000	0	0	0	0	0	0	0	0	0	0

Table 11. Gag: Age compositions from the headboat survey.

Year	N	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1978	48	0.018	0.057	0.258	0.238	0.068	0.084	0.121	0.057	0.057	0.004	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0	0.000
1979	56	0.000	0.020	0.305	0.129	0.068	0.207	0.142	0.020	0.081	0.000	0.020	0.000	0.000	0.000	0.000	0.004	0.004	0.000	0.000	0	0.000
1980	80	0.000	0.060	0.384	0.175	0.025	0.095	0.105	0.090	0.045	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0	0.000
1981	179	0.000	0.032	0.222	0.231	0.034	0.039	0.063	0.154	0.170	0.030	0.004	0.008	0.008	0.000	0.008	0.000	0.000	0.000	0.000	0	0.000
1982	70	0.000	0.047	0.240	0.327	0.076	0.095	0.019	0.107	0.046	0.030	0.000	0.000	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0	0.000
1983	283	0.000	0.018	0.425	0.117	0.083	0.094	0.109	0.033	0.045	0.017	0.031	0.000	0.015	0.005	0.000	0.003	0.001	0.005	0.000	0	0.000
1984	336	0.000	0.015	0.035	0.229	0.113	0.093	0.167	0.220	0.026	0.027	0.005	0.043	0.008	0.005	0.004	0.004	0.000	0.004	0.000	0	0.004
1985	178	0.000	0.141	0.093	0.100	0.323	0.113	0.076	0.107	0.024	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.007	0.000	0	0.007
1986	140	0.000	0.174	0.411	0.096	0.050	0.094	0.069	0.055	0.033	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.000	0	0.008
2002	67	0.000	0.000	0.012	0.066	0.044	0.109	0.207	0.342	0.106	0.039	0.033	0.006	0.018	0.006	0.000	0.000	0.000	0.012	0.000	0	0.000
2003	93	0.000	0.000	0.045	0.050	0.105	0.212	0.124	0.100	0.132	0.085	0.068	0.019	0.012	0.018	0.000	0.000	0.025	0.000	0.000	0	0.006
2004	85	0.000	0.000	0.084	0.176	0.143	0.211	0.153	0.088	0.046	0.044	0.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0	0.000

2.2 Figures

Figure 1. Gag: Indices of abundance used in catch-at-age model, with each scaled to its own mean. CPUE from commercial handline computed in units of pounds per hook, CPUE from headboat computed in units of number fish per angler-hour, and CPUE from MRFSS computed as number of fish per 1000 hook-hours.



3 Stock assessment methods

3.1 Model 1: Catch-at-age model

The primary model in this assessment was a statistical catch-at-age model (Quinn and Deriso 1999), implemented in the AD Model Builder software (Otter Research 2000) (code in Appendix B). The model is detailed in Table 12. Its major characteristics can be summarized as follows:

3.1.0.1 **Natural mortality rate** The AW discussed the possibility of a fixed M for the assessment model, but concluded that the Lorenzen (1996) approach is more biologically plausible. The Lorenzen (1996) approach inversely relates the natural mortality at age a 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. Based on the Lorenzen estimates, the cumulative survival to the oldest observed age was extremely small. The AW therefore recalibrated the Lorenzen age-specific estimates of M, so that the cumulative survival to the oldest observed age was equivalent to the value obtained from a constant value of M at age derived from Hoenig (1983), $M = 0.14$.

3.1.0.2 **Stock dynamics** In the assessment model, new biomass was acquired through growth and recruitment processes, and population size experienced exponential decay due to fishing and natural mortality processes. The population was assumed closed (no net migration to or from the study area). The oldest age class, 20, allowed for the accumulation of fish (i.e., a plus group).

3.1.0.3 **Growth** A von Bertalanffy growth model, constant over time, was used, with parameters estimated within the assessment model along with coefficients of variation of length at each age.

3.1.0.4 **Recruitment** A Beverton–Holt recruitment model was estimated internally. Estimated annual recruitment was loosely conditioned on that model. The AW raised concerns about the pattern of recruitment residuals being estimated by the model. The AW decided that the stock-recruit curve should be estimated externally from the model and only use data from 1972–2004, when recruitment estimates are believed to be more reliable.

3.1.0.5 **Biological reference points (benchmarks)** In the SEDAR-10 assessment of gag, the quantities E_{MSY}, 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 recruitment curve (estimated externally) and parameters describing growth, natural mortality, maturity, and selectivity. While the method applied in SEDAR-10 is widely used, it has the disadvantage that the estimated F_{MSY} may not always lead to $\mathrm{SSB}_{\mathrm{MSY}}$ in recovery simulations. This inconsistency occurs because recruitment in recovery simulations is, on average, higher than that of the recruitment curve, due to lognormal deviation of recruitment.

In this assessment, the method of benchmark estimation accounted for lognormal deviation by including a bias correction in equilibrium recruitment. The bias correction (ς) is 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,

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

where R_0 is virgin recruitment, h is steepness, and Φ_F is spawning potential ratio given growth, maturity, and total mortality at age (including natural, fishing, and discard mortality rates). The R_{eq} and mortality schedule imply an equilibrium age structure and an average sustainable yield (ASY). The estimate of F_{MSY} is the F giving the highest ASY (excluding discards), and the estimate of MSY is that ASY. The estimate of $\mathrm{SSB}_{\mathrm{MSY}}$ 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 (2002–2004), a period of unchanged regulations.

3.1.0.6 **Fishing** Four fisheries were modeled individually: commercial handline, commercial diving, recreational headboat, and general recreational (sampled by MRFSS). Separate fishing mortality rates were estimated for each fishery.

3.1.0.7 **Selectivity functions** Rather than estimating independent selectivity values for each age, selectivity curves were fit parametrically. This approach reduces the number of estimated parameters and imposes structure on the estimates. Selectivity was modeled using a logistic function for commercial handline and recreational headboat gears. Because of limited samples, the recreational headboat selectivity was applied to the general MRFSS recreational gear. The commercial diving gear selectivity was modeled with a double logistic function.

The selectivity parameters were estimated internally by the assessment model. Selectivity parameters of the two major fisheries (commercial handline and recreational) were estimated separately for three different periods of size-limit regulations (See Table 1.4 in Section 1): 1972–1991, no size limit; 1992–1998, 20-inch limit; and 1999–2004, 24-inch limit (See regulation Table). A single set of selectivity parameters for commercial diving was estimated for all periods. The location parameter (age at 50% selection) was estimated annually for commercial handline and recreational fisheries in the earliest period of no size-limit regulation.

3.1.0.8 **Landings** Landings were estimated via the standard Baranov catch equation (Quinn and Deriso 1999).

3.1.0.9 **Discards** Discard estimates from commercial handline, headboat, and MRFSS are available for 1999–2004, 1981–2004, and 1981–2004, respectively.

Dead discards in these years were modeled with the same approach applied toward landings—by using the Baranov catch equation to estimate an instantaneous mortality rate (Quinn and Deriso 1999). To do so requires a discard selectivity curve and a release mortality rate. For each fishery, the discard selectivity at age was estimated as the difference between the estimated curve and a curve computed by shifting the ages to 2 years younger. Release mortality rates were those specified by the SEDAR-10 DW: 40% for commercial handline, and 25% for headboat and MRFSS.

3.1.0.10 **Indices of abundance** The model was fit to the three fishery-dependent indices of abundance described in the SEDAR-10 Data Workshop Report: commercial logbook, 1999–2004; headboat, 1973–2004; MRFSS, 1981–2004. Considerable discussion occurred at the AW concerning the use of time-varying or constant catchability coefficients for the abundance indices. Panelists agreed that catchability has likely increased over the last few decades, but disagreed on how much. For this reason, the AW decided that two base model runs would be brought forward for review, one with constant catchability and another with linear time-varying catchability modeled with a 2% per annum increase starting in 1980.

3.1.0.11 **Initialization** The assessment period starts in 1962 when landings data are available on all fisheries. The assessment model, however, starts in 1942. This initialization period (1942–1961) was used to define the age structure at the start of the assessment period, and thus its duration was set to the maximum age modeled (20 years). To initialize the assessment model, total biomass in 1942 relative to unexploited biomass (B_{1942}/B_0) was treated as a fixed quantity. By use of a constraint, the AW fixed initial relative biomass at $B_{1942}/B_0 \approx 1.0$, which reflects a belief that the 1942 stock had been unexploited. The initial age structure in 1942 was set to the stable age structure, given the estimated total mortality rate of that year. Recruitment during the initialization period was constrained to the stock–recruit curve more heavily than during the assessment period, because the earliest data provided little information to estimate annual recruitment in the initialization.

3.1.0.12 **Fitting criterion** The fitting criterion was a 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 are compatible. Landings, discards, and index data were fit using a lognormal likelihood, the value of which is inversely related to the CV (Table 3 – 5). Composition data were fit using a multinomial likelihood.

The total likelihood also included penalty terms to discourage fully selected F greater than 5.0 in any year, large variability in CVs of length at age, and large variability in recruitment during the initialization period and last three assessment years. Relative statistical weighting of each likelihood component was chosen by the AW after examining many candidate model runs. The criterion for choice was a balance between reasonable fit to all available data and the degree of biological realism in estimated population trajectory. The chosen weighting scheme helped define the two base runs of the assessment model.

3.1.1 Quality control

The assessment model was tested on simulated data prior to the AW. It accurately estimated model parameters, indicating that the model has been implemented correctly and can provide an accurate assessment. In addition, computer programs used for projections were reviewed and tested by several stock assessment biologists. Computer files of data input were reviewed for accuracy by participants of the AW.

3.1.2 Measures of precision

Precision of estimated benchmarks was computed by a bootstrap of the stock–recruit data. The bootstrap procedure re–samples the recruitment residuals and then estimates a stock–recruit curve and its associated MSY benchmarks. After 1,000 bootstrap samples have been fit, the 10th and 90th percentiles of each benchmark are computed.

Uncertainty is addressed in the projections by a parametric bootstrap procedure, with sampled time series of future recruitments determined by a random lognormal deviate. The variance of this distribution is calculated from the assessment model estimated recruitments. After 1,000 samples, the 10th and 90th percentiles are computed and reported in the projection output.

3.1.3 Sensitivity analyses

In addition to the base run, the AW identified six sensitivity runs for each of the base runs of the assessment model. A sensitivity run was made with allowing a double logistic selectivity function for the recreational fisheries. Another sensitivity run doubled the fraction of gag assumed to be part of the unclassified grouper category in the commercial landings. Two sensitivity runs explore the use of mature male or female biomass as the measure of reproductive output (SSB). Owing to recent concerns about the sampling design for the MRFSS survey, two sensitivity runs increased and decreased the MRFSS landings by 50%.

3.2 Model 2: Production model

A surplus production model was used as a supplement to the primary age-structured model. Two runs of the production model are presented, corresponding to the two base runs of the age-structured model. Run G102 assumes constant catchability over time; run G117 assumes catchability increasing linearly at 2%/yr starting in 1980. Both runs are constrained by the initial condition $B_1/K = 0.9$. Several additional runs were made to examine model sensitivity to that condition.

3.2.1 Methods

Production modeling used the ASPIC formulation and software of Prager (1994; 1995). This is an observation-error estimator of the continuous-time form of the Schaefer (logistic) production model (Schaefer 1954; 1957).

Data included total landings in weight and three abundance indices, also computed on a weight basis. The three indices were from the commercial logbook, headboat survey, and MRFSS programs. Indices were weighted equally. Modeling was conditioned on catch.

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

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

4 Assessment results

4.1 Results of catch-at-age model

4.1.1 Model fit

In general, the model fits the available data well. Fits to length compositions from the fisheries are close in most years (Figure 2 through Figure 13). Fits to age compositions from the fisheries are adequate (Figure 14 through Figure 25). Bubble plots of composition data show a measure of fit using angular deviation in degrees based on observed and model predicted estimates. Effective sample size calculations are based on the multinomial distribution using observed and model predicted estimates.

The model was configured to fit observed commercial and recreational landings closely (Figures 26–27, Figures 28–29). In addition, it fits observed discards almost exactly (Figures 30–31). The model predicted landings in numbers (Tables 13–14 and Figures 32–33) and weight (Tables 15–16 and Figures 34–35) show that the MRFSS and commercial hook and line sectors land about the same amount in the most recent years. However, MRFSS is responsible for the largest amount of discards (Tables 17–18 and Figures 36–37).

Fits to indices of abundance were reasonable (Figures 38–39). The headboat and commercial logbook indices were fit well, with a compromising fit to both in the most recent years. The MRFSS index was fit less well due to high annual variability in the data.

4.1.2 Growth

Estimated length at age and variance of length at age from the assessment model are shown in Tables 19–20 and Figures 40 and 41.

4.1.3 Selectivity

Estimated selectivities of commercial gears are presented in Tables 21 and 22 and Figures 42 through 45, and those of recreational fishing (headboat and MRFSS) in Tables 21 and 22 and Figures 46 and 47. In the recent period of size regulations, fish were nearly fully selected by both commercial handline and recreational fishing at age six or seven. Discarded fish were fully selected at younger ages (Figures 48 and 49). The commercial diving was estimated to have dome-shaped selectivity (Figures 44 and 45).

4.1.4 Fishing mortality and exploitation rates

The estimated time series of fishing mortality rate (F) shows a steady increase between the early 1970's until the late 1980's and consistently high values through the 1990's to the present (Tables 23 and 24, and Figures 50 through 53). Trends in the estimated time series of exploitation rate (E) of fish age 2^+ shows a steady increase between the early 1970's until the mid 1980's. Then beginning in the mid 1980's, the exploitation rate shows a steady decrease to the present (See Tables 23 – 24 and Figures 50 through 53).

4.1.5 Fishing mortality rate at age

Estimated *F* at age is shown in Tables 25 and 26. In any given year, the maximum *F* at age may be less than that year's fully selected *F*. This inequality is slight and exists due to the combination of two features of estimated selectivities: full selection occurs at different ages among gears and at least one gear (commercial diving) has dome-shaped selectivity.

4.1.6 Abundance and biomass at age

The catch-at-age model provides estimates of abundance in numbers at age (Tables 27–28) and in biomass at age (Tables 29 through 32). Numbers and biomass at age display a general decrease from the beginning of the assessment period until the present, particularly for the older ages.

4.1.7 Total biomass and spawning stock

Total biomass (*B*) and spawning stock biomass (SSB) show similar patterns: steady decline from 1942 to the lowest levels in the late 1980's, followed by a slight increase to the present (Figures 54–55). By 1990, estimated *B* and SSB had declined to their lowest levels, with *B* at about 30% of its early assessment value (1942-46 average), and SSB at about 20% of its early value. The base run with time-varying catchability suggests the increase in the 1990's is less pronounced as compared to the base run with constant catchability (Figures 54–55).

4.1.8 Stock and recruitment

The estimated stock-recruitment relationship shows the usual scatter about a fitted Beverton–Holt recruitment curve (Figures 56–57). Parameter estimates of the stock-recruit curve are listed in Tables 33 – 34.

The estimated time series of recruitment shows nearly invariant recruitment in the initialization period (1942–1962) followed by a decrease in the mid 1960's, then followed by a steady increase until 2001 (Figures 58 – 59). The low values estimated in 1960's prompted the AW to recommend using the 1972–2004 recruitment estimates for fitting a stock-recruit curve. In 2002–2004 the models estimated below average recruitment. These recruitment patterns have implications for future projections discussed below.

4.1.9 Per recruit analyses

Static spawning potential ratio (SPR) shows a trend of decrease from the mid 1960's to the mid 1980's, and then the static SPR has remained fairly constant at about 19% until the present (Tables 23 –24, Figures 60 – 61). Static SPR of each year is computed as spawners per recruit given that year's fishery-specific *F*s and selectivities, divided by spawners per recruit that would be obtained in an unexploited stock. In this form, 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*).

As shown in Figures 62 – 69, yield per recruit, SSB per recruit relative to virgin level (%SPR), equilibrium yield, and equilibrium SSB were computed as functions of *F* and *E* (Goodyear 1993). These computations applied the average ratios of F and E among existing fisheries from the last three years (2002–2004), along with the most recent selectivity patterns.

Overlaid on these curves are values of F_{max}, $F_{30\%}$, $F_{45\%}$, and F_{MSY} and E_{max}, $E_{30\%}$, $E_{45\%}$,and E_{MSY}. The value of F_{max} was computed as the F that maximizes yield per recruit; the values of $F_{30\%}$ and $F_{45\%}$ were computed as those Fs corresponding to 30 and 45 %SPR, respectively; and the value of F_{MSY} was computed from the stock-recruitment relationship (§3.1.0.5, Figures 56 – 57). Mace (1994) recommended $F_{40\%}$ as a proxy benchmark when F_{MSY} cannot be estimated; however, later studies have found that $F_{40\%}$ can be too high across some life-history strategies (Williams and Shertzer 2003) and can lead to undesirably low levels of biomass and recruitment (Clark 2002). For this stock of gag, values near $F_{25\%}$ and $E_{40\%}$ correspond to F_{MSY} and E_{MSY}, respectively (Figures 62 – 69), but of course, a proxy is unnecessary here because F_{MSY} is estimated directly.

4.1.10 Miscellaneous

The model specification in ADMB language is given in Appendix B. Raw model output, including all parameter estimates for the base run, is given in Appendix C.

4.2 Results of production model

4.2.0.1 **Model Fit** Fits to indices are shown in figures 70–72. There is little of consequence to distinguish fits between the two runs (constant vs. increasing catchability). Because the index derived from the commercial logbook data shows a different time pattern from the other indices, fit to that index is particularly poor in all runs

4.2.0.2 **Parameter Estimates and Uncertainty** Parameter estimates with confidence intervals are printed in the ASPIC output, this is included as Appendix D.

4.2.0.3 **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 figures that examine sensitivity to assumptions on starting biomass. Estimates of current status are quite insensitive to that starting assumption under increasing catchability (Figures 73(b) and 74(b)). There is slightly more sensitivity of B/B_{MSY} under constant catchability (Figures 73(a) and 74(a)). However, the difference is slight.

A direct comparison of the two assumptions on catchability is given in Figure 75. Making an assumption of constant catchability results in a more optimistic picture of the stock and fishery. Regardless of the assumption, the production model estimates that stock size is below B_{MSY} and that the level of fishing exceeds the limit reference point F_{MSY}.

A comparison of the age-structured and surplus-production model results indicates similar conclusions about the stock status; the stock is overfished and overfishing is occurring in 2005 (Figures 76 and 77).

4.2.0.4 **Benchmarks, uncertainty** Estimates of MSY and related quantities from the production model, together with confidence intervals derived through the bootstrap, are given in Appendix D.

5 Biological reference points

5.1 Estimation methods

As described in §3.1.0.5, biological reference points were derived analytically assuming equilibrium dynamics, corresponding to the estimated stock-recruit curve with bias correction (Figures 56 – 57). This approach is consistent with methods used in rebuilding projections. The reference points estimated were F_{MSY}, E_{MSY}, MSY, B_{MSY} and SSB_{MSY}. Based on F_{MSY}, three values of F at optimum yield (OY) were considered: $F_{\text{OY}} = 65\%F_{\text{MSY}}$, $F_{\text{OY}} = 75\%F_{\text{MSY}}$, and $F_{\text{OY}} = 85\%F_{\text{MSY}}$. For each, the corresponding yield was computed. Uncertainty of these benchmarks was computed from 1,000 bootstrap replicates described in section 3.1.2, Tables 35 – 36, and Figures 78 – 81.

In addition to the MSY-related benchmarks, proxies based on per recruit analyses were computed, as described in section §4.1.9. These proxies include $F_{30\%}$, $F_{45\%}$, and related yields from the equilibrium landings curve (Tables 35 – 36).

5.2 Results

Estimates of biological reference points are summarized in Tables 35 – 36. Time series of estimated B, SSB, F, and $E(2+)$ relative to corresponding MSY benchmarks are shown in Figures 82–85. The trajectory of $\text{SSB}/\text{SSB}_{\text{MSY}}$ starts well above one in the early assessment period, declines into the mid 1980s, and reaches its lowest value in 1990. Starting in 1990, the estimated trajectories increase steadily until reaching values of $\text{SSB}/\text{SSB}_{\text{MSY}} = 0.91$ and $\text{SSB}/\text{SSB}_{\text{MSY}} = 0.94$ in 2005 for the time-varying and constant catchability models, respectively (Tables 23–24, 35–36, and Figures 82–83). The trajectories of F/F_{MSY} and E/E_{MSY} for both base run models are above one starting in the early 1980's, indicating that overfishing has occurred throughout much of the recent assessment period. The values of F/F_{MSY} and E/E_{MSY} in 2004 are all above 1.0 (Tables 23–24, 35–36, and Figures 84–85).

5.3 Status indicators

5.3.1 Definitions

The maximum fishing mortality threshold (MFMT) is defined by the council as F_{MSY}, and the minimum stock size threshold (MSST) is defined by the Council as $(1-M)\text{SSB}_{\text{MSY}}$ (Restrepo et al. 1998), with constant M defined here as 0.14. Overfishing is defined as $F >$ MFMT and overfished as SSB $<$ MSST. Current status of the fishery is estimated to be that of the latest assessment year, and current status of the stock is estimated to be that at the beginning of 2005.

5.3.2 Status of stock and fishery

At the beginning of 2005, the status of the stock is estimated to be SSB_{2005}/SSB_{MSY} = 0.91 and 0.94 and $SSB_{2005}/MSST$ = 1.06 and 1.10 for the time-varying and constant catchability base models, respectively. The uncertainty for these estimates includes values below 1.0 and are listed in Tables 35–36, and Figures 82–85. The status of the fishery is estimated to be F_{2004}/F_{MSY} = 1.46 and 1.31 and E_{2004}/E_{MSY} = 1.86 and 1.53 (Tables 35 – 36, and Figures 82–85). The range of uncertainty for these estimates includes values all above 1.0. Thus the stock is estimated to be undergoing overfishing. The point estimates of $SSB_{2005}/MSST$ suggest the stock is not overfished, but the uncertainty includes values below 1.0.

5.3.3 Sensitivity analyses

Sensitivity analyses (described in §3.1.3) included six model runs and a five year retrospective analysis in addition to the base run. All six sensitivity model runs estimate that the exploitation rates are above their limit, suggesting the stock is undergoing overfishing (Tables 33 and 34). The sensitivity analyses are mixed with respect to the biomass stock status, with some results above the limit and a few below. The five year retrospective analysis suggests a tendency for the model to overestimate the fishing mortality and exploitation rates (Figures 86 through 89) and underestimate the biomass (Figures 90 through 93).

6 Projections (rebuilding analyses)

6.1 Projection methods

Projections were run to provide estimates of future status out to the year 2014. The structure of the projection model was the same as that of the assessment model, and parameter estimates were those from the assessment base runs. Time-varying parameters, such as the proportion female schedule and fishery selectivity curves, were fixed to the most recent values of the assessment period. Fully selected F was apportioned between landings and dead discards according to the selectivity curves averaged across fisheries (Tables 21 – 22).

6.1.1 Initialization

In these projections, any change in fishing effort was assumed to start in 2008 because that is expected to be the earliest management regulations would be implemented. Since the assessment period ended in 2004, the projections required a three-year initialization period (2005–2007). The initial abundance at age in 2005, other than age 0s, was taken to be the 2004 estimate of abundance at age, discounted by natural and fishing mortalities. The initial abundance of age 0s was computed using the estimated stock-recruit model and based on the 2004 estimate of SSB. The fully selected fishing mortality rate in the initialization period was taken to be the geometric mean of fully selected F of 2002–2004.

Annual estimates of SSB, F, recruitment, landings, and discards were represented by deterministic recovery projections. These projections were built on the estimated stock-recruit relationship with bias correction, and were thus consistent with estimated benchmarks.

6.1.2 Stochasticity

Projections used a bootstrap procedure to generate stochasticity in the stock–recruit relationship. The bias-corrected Beverton–Holt model 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,

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

Here γ_y was drawn from a normal distribution with mean 0 and standard deviation estimated by the assessment model (Table 12). The distribution was truncated at two standard deviations, which includes 95% of all possible values, but excludes extreme recruitment events from the tails of the distribution.

The bootstrap 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 is represented by the 10th and 90th percentiles of 1000 recovery projections.

6.2 Projection results

Projections were calculated under five scenarios: current F, F_{MSY}, 85% of F_{MSY}, 75% of F_{MSY}, and 65% of F_{MSY} (Tables 37 – 46 and Figures 94 – 103). All projections agree that in the near future the stock biomass will remain below the MSY levels, reaching the lowest value in 2008.

6.3 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:

- Initial abundance at age of the projections are based on estimates from the assessment. If those estimates are inaccurate, rebuilding will likely be affected.
- Fisheries are assumed to continue fishing at their estimated current proportions of total effort, using their estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect rebuilding.
- In constant-landings scenarios, it is necessary to reduce the fishing mortality rate F continually as the population increases. This implies decreasing the annual fishing effort throughout the recovery period.
- The projections assume 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 assume that the estimated stock-recruit relationship applies in the future and that past residuals represent future uncertainty in recruitment. The assessment results suggest that the stock may be characterized by periods of unusually high or low recruitment, possibly due in part to environmental conditions. If so, rebuilding may be affected.

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6.3.1 Tables—Data

Table 12. General descriptions and definitions of the 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	$y = \{1942 \ldots 2004\}$
Index of ages	a	$a = \{0 \ldots A\}$, where $A = 20^+$
Index of size-limit periods	r	$r = \{1 \ldots 3\}$ where 1 = 1942 − 1991 (no size limit), 2 = 1992 − 1998 (20 inch limit), and 3 = 1999 − 2004 (24 inch limit)
Index of length bins	l	$l = \{1 \ldots 35\}$
Length bins	l'	$l' = \{200, 230, \ldots, 1220\}$, with values as midpoints and bin size of 30 mm
Index of fisheries	f	$f = \{1 \ldots 4\}$ where 1=commercial handline, 2=commercial diving, 3=recreational headboat, 4=recreational MRFSS
Index of CPUE	u	$u = \{1 \ldots 3\}$ where 1 = commercial logbook, 2 = MRFSS, 3 = headboat
Input Data		
Proportion male at age	$\rho_{a,y}$	Determined by logistic regression estimated from SCDNR samples, varies across years
Proportion female at age	$1 - \rho_{a,y}$	Complement of above
Proportion mature at age: males	m'_a	All males age 1^+ considered mature, constant across years
Proportion mature at age: females	m_a	Determined by logistic regression estimated from MARMAP samples
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 in year y from fishery f. Commercial landings in weight, recreational in numbers
CVs of landings	$c^L_{f,y}$	Annual values estimated for MRFSS; for other sectors, based on understanding of historical accuracy of data
Observed discards	$D_{f,y}$	Discards (1000s) in year y from fishery $f = 1, 3, 4$
CVs of discards	$c^D_{f,y}$	Annual values estimated for MRFSS; for other sectors, assumed to be twice $c^L_{f,y}$

Table 12. (continued)

Quantity	Symbol	Description or definition
Observed abundance indices	$U_{u,y}$	$u = 1$, commercial logbook, $y = \{1992 \ldots 2004\}$ $u = 2$, MRFSS, $y = \{1981 \ldots 2004\}$ $u = 3$, headboat, $y = \{1973 \ldots 2004\}$
CVs of abundance indices	$c^U_{u,y}$	$u = \{1 \ldots 3\}$ as above; Annual values estimated from delta-lognormal GLM
Natural mortality rate	M_a	Lorenzen function, rescaled based on Hoenig estimate
Discard mortality rate	δ_f	Proportion discards by fishery f that die. Fixed by Data Workshop at 0.25 for MRFSS and Headboat and 0.40 for commercial handline
Population Model		
Mean length at age	l_a	$l_a = \widehat{L_\infty}(1 - \exp[-\hat{K}(a + 0.5 - \hat{t_0})])$ where $\hat{K}$, $\widehat{L_\infty}$, and $\hat{t_0}$ are estimated parameters; Mean length is that at the midpoint of the year (accounted for by the term 0.5)
CVs of l_a	$\hat{c}^\lambda_a$	Estimated
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 unity across ages
Individual weight at age	w_a	Computed from length at age at the midpoint of the year by $w_a = \theta_1 \cdot l_a^{\theta_2}$ where θ_1 and θ_2 are fixed parameters
Fishery selectivity	$s_{f,a,r}$	$s_{f,a,r} = \begin{cases} \frac{1}{1+\exp[-\hat{\eta}_{1,f,r}(a-\hat{\alpha}_{1,f,r})]} & \text{: for } f = 1,3 \\ \left(\frac{1}{\max s_{f,a,r}}\right)\left(\frac{1}{1+\exp[-\hat{\eta}_{1,f,r}(a-\hat{\alpha}_{1,f,r})]}\right) \left(1 - \frac{1}{1+\exp[-\hat{\eta}_{2,f,r}(a-[\hat{\alpha}_{1,f,r}+\hat{\alpha}_{2,f,r}])]}\right) & \text{: for } f = 2 \\ s_{3,a,r} & \text{: for } f = 4 \end{cases}$ where $\hat{\eta}_{1,f,r}$, $\hat{\eta}_{2,f,r}$, $\hat{\alpha}_{1,f,r}$, and $\hat{\alpha}_{2,f,r}$ are fishery-specific parameters estimated for each regulation period, with the exception of the no-size-limit period ($r = 1$) in which $\hat{\alpha}$ of the commercial handline and recreational fisheries are annual estimates; Selectivity of commercial diving is assumed constant across all regulation periods. Selectivity of MRFSS and headboat assumed equal
Discard selectivity	$s'_{f,a}$	Equal to fishery selectivity, but with age at 50% selection shifted two years younger; Defined for $f = 1,3,4$
Index selectivity	$s''_{u,a}$	$s''_{u,a} = \begin{cases} s_{1,a} & \text{: for } u = 1 \\ s_{3,a} & \text{: for } u = 2,3 \end{cases}$
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	$F^D_{f,a,y}$	$F^D_{f,a,y} = s'_{f,a}\hat{F}^D_{f,y}$ where $\hat{F}^D_{f,y}$ is an estimated fully selected fishing mortality rate of discards by fishery

Table 12. (continued)

Quantity	Symbol	Description or definition
Total fishing mortality rate	F_y	$F_y = \sum_f \left(\hat{F}_{f,y} + \hat{F}^D_{f,y}\right)$
Total mortality rate	$Z_{a,y}$	$Z_{a,y} = M_a + \sum_{f=1}^{4} F_{f,a,y} + \sum_{f=1,3,4} F^D_{f,a,y}$
Abundance at age	$N_{a,y}$	$N_{0,1942} = \hat{\gamma}\hat{R}_0$ $N_{a+1,1942} = N_{a,1942}\exp(-Z_{a,1942})$ $N_{A,1942} = N_{A-1,1942}\frac{\exp(-Z_{A-1,1942})}{1-\exp(-Z_{A,1942})}$ $N_{0,y+1} = \frac{0.8\hat{R}_0\hat{h}S_y}{0.2\phi_0\hat{R}_0(1-\hat{h})+(\hat{h}-0.2)S_y} + \hat{R}_{y+1}$ $N_{a+1,y+1} = N_{a,y}\exp(-Z_{a,y})$ $N_{A,y} = N_{A-1,y-1}\frac{\exp(-Z_{A-1,y-1})}{1-\exp(-Z_{A,y-1})}$ where 1942 is the initialization year, $\hat{\gamma}$ is an estimated parameter that scales the initial conditions, $\hat{R}_0$ (virgin recruitment) and $\hat{h}$ (steepness) are estimated parameters of the stock-recruit curve, and $\hat{R}_y$ is estimated annual recruitment deviation. Quantities ϕ_0 and S_y are described immediately below.
Virgin mature biomass per recruit	ϕ_0	$\phi_0 = \sum_a N'_a w_a[\rho_{a,y}m'_a + (1-\rho_{a,y})m_a]$ where $N'_0 = 1$; $N'_{a+1} = N'_a\exp(-M_a)$; $N'_A = N'_{A-1}\frac{\exp(-M_a)}{1-\exp(-M_a)}$
Mature biomass	S_y	$S_y = \sum_a N_{a,y}w_a[\rho_{a,y}m'_a + (1-\rho_{a,y})m_a]$ Also referred to as SSB
Population biomass	B_y	$B_y = \sum_a N_{a,y}w_a$
Landed catch at age	$C_{f,a,y}$	$C_{f,a,y} = \frac{F_{f,a,y}}{Z_{a,y}}N_{a,y}[1-\exp(-Z_{a,y})]$
Discarded catch 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	$\breve{L}_{f,y}$	$\breve{L}_{f,y} = \sum_a C_{f,a,y}w_a$
Predicted dead discards	$\breve{D}_{f,y}$	$\breve{D}_{f,y} = \sum_a \delta_f C^D_{f,a,y}w_a$
Predicted length compositions	$\breve{p}^\lambda_{(f,u),l,y}$	$\breve{p}^\lambda_{(f,u),l,y} = \frac{C_{(f,u),l,y}}{\sum_l C_{(f,u),l,y}}$
Predicted age compositions	$\breve{p}^\alpha_{(f,u),a,y}$	$\breve{p}^\alpha_{(f,u),a,y} = \frac{C_{(f,u),a,y}}{\sum_a C_{(f,u),a,y}}$
Predicted CPUE	$\breve{U}_{u,y}$	$\breve{U}_{u,y} = \hat{q}_u\sum_a N_{a,y}s''_{u,a}$ where $\hat{q}_u$ is the estimated catchability coefficient of index u
Negative Log-Likelihood		
Multinomial length compositions	Λ_1	$\Lambda_1 = -\omega_1\sum_{f,u}\sum_y\left(n^\lambda_{(f,u),y}\sum_l(p^\lambda_{(f,u),l,y}+x)\log(\breve{p}^\lambda_{(f,u),l,y}+x)\right)$ where ω_1 is a preset weight and $x = 0.0001$ is an arbitrary value to avoid log zero. Bins are 30mm wide.
Multinomial age compositions	Λ_2	$\Lambda_2 = -\omega_2\sum_{f,u}\sum_y\left(n^\alpha_{(f,u),y}\sum_a(p^\alpha_{(f,u),a,y}+x)\log(\breve{p}^\alpha_{(f,u),a,y}+x)\right)$ where ω_2 is a preset weight and $x = 0.0001$ is an arbitrary value to avoid log zero

Table 12. (continued)

Quantity	Symbol	Description or definition
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 ω_3 is a preset weight and $x = 0.0001$ is an arbitrary value to avoid log zero or division by zero
Lognormal discard mortalities	Λ_4	$\Lambda_4 = \omega_4 \sum_f \sum_y \frac{\left[\log\left((\delta_f D_{f,y}+x)/(\check{D}_{f,y}+x)\right)\right]^2}{2(c^D_{f,y})^2}$ where ω_4 is a preset weight and $x = 0.0001$ 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 $\omega_{5,u}$ is a preset weight for $u = 1,2,3$ and $x = 0.0001$ is an arbitrary value to avoid log zero or division by zero
Constraint on recruitment	Λ_6	$\Lambda_6 = \omega_6 \sum_y R_y^2$ where ω_6 is a preset weight
Additional constraint on recruitment	Λ_7	$\Lambda_7 = \omega_7 \left(\sum_{y=1942}^{1962} R_y^2 + \sum_{y=2002}^{2004} R_y^2\right)$ where ω_5 is a preset weight
Constraint on $\frac{B_{1942}}{B_0}$	Λ_8	$\Lambda_8 = \omega_8 (\frac{B_{1942}}{B_0} - \chi)^2$ where ω_8 is a preset weight and $\chi = 1.0$ is fixed initial B relative to B_0
Constraint on F_y	Λ_9	$\Lambda_9 = \omega_9 \sum_y I_y (F_y - \psi)^2$ where ω_9 is a preset weight, $\psi = 5.0$ is the max unconstrained F_y, and $I_y = \begin{cases} 1 & : \text{if } F_y > \psi \\ 0 & : \text{otherwise} \end{cases}$
Constraint on CV of length at age	Λ_{10}	$\Lambda_{10} = \omega_{10} \sum_a (c^\lambda_a)^2$ where ω_{10} is a preset weight
Total likelihood	Λ	$\Lambda = \sum_{i=1}^{10} \Lambda_i$ Objective function minimized by the assessment model

Table 13. Gag– Time –varying catchability run: Model estimated time series of landings in number (1000s) for each fishery.

Year	C.HAL	C.Diving	Headboat	MRFSS	Total
1962	7759	447	8472	6171	22849
1963	7077	442	7715	5614	20848
1964	6643	438	7227	5258	19566
1965	6768	436	7457	5419	20080
1966	5132	436	5619	4072	15259
1967	10823	432	11845	8592	31692
1968	15690	401	17689	13001	46781
1969	10862	339	12212	8924	32337
1970	14871	267	16710	12256	44104
1971	15403	216	17244	12622	45485
1972	10571	204	13335	8375	32485
1973	15859	239	18408	12945	47451
1974	21379	321	14084	17573	53357
1975	24982	411	8653	18671	52717
1976	34379	239	7671	25518	67807
1977	37780	558	8547	23135	70020
1978	56877	858	6328	38788	102851
1979	51473	1145	9802	35201	97621
1980	47193	1001	6996	35110	90300
1981	55182	871	14002	53986	124041
1982	59759	1037	11901	17864	90561
1983	65013	614	16443	65031	147101
1984	72123	1246	18751	148602	240722
1985	46658	759	16264	48853	112534
1986	81794	424	17330	43591	143139
1987	56865	1473	24101	86133	168572
1988	39632	885	24383	60317	125217
1989	69635	1602	21902	75373	168512
1990	63115	1465	17356	51227	133163
1991	55007	6044	13568	40652	115271
1992	57984	7423	13946	49364	128717
1993	63328	5431	11741	51401	131901
1994	64079	6672	9761	54647	135159
1995	62664	5638	10573	39097	117972
1996	54455	7777	7508	43291	113031
1997	45191	6282	6915	31420	89808
1998	50969	9249	8687	40693	109598
1999	41166	8025	5373	51348	105912
2000	32987	4373	5995	29806	73161
2001	33310	5574	5147	41797	85828
2002	33857	5594	4577	23605	67633
2003	33638	7895	3310	45733	90576
2004	35850	5131	6714	45810	93505

Table 14. Gag– Constant catchability run: Model estimated time series of landings in number (1000s) for each fishery.

Year	C.HAL	C.Diving	Headboat	MRFSS	Total
1962	6621	801	8412	6193	22027
1963	6042	792	7662	5640	20136
1964	5671	786	7181	5289	18927
1965	5758	781	7410	5445	19394
1966	4368	783	5580	4093	14824
1967	9237	773	11771	8635	30416
1968	13403	703	17723	13017	44846
1969	9236	568	12131	8908	30843
1970	12541	422	16662	12232	41857
1971	12795	327	17182	12622	42926
1972	8603	295	13441	8383	30722
1973	12577	332	17997	12232	43138
1974	16732	427	13926	15861	46946
1975	19661	505	8574	17853	46593
1976	27701	248	7564	24651	60164
1977	32917	606	8484	22618	64625
1978	54298	986	6010	37956	99250
1979	52930	1322	9550	35714	99516
1980	49476	1087	6960	35260	92783
1981	57220	894	13859	55322	127295
1982	60072	1046	11839	17627	90584
1983	72934	621	16456	67630	157641
1984	68583	1278	18689	152215	240765
1985	47093	790	16131	52576	116590
1986	72841	435	17350	46761	137387
1987	55800	1514	24088	86370	167772
1988	38661	900	24209	61986	125756
1989	68283	1654	22420	75223	167580
1990	62618	1478	17590	52155	133841
1991	52750	6334	13550	36702	109336
1992	59307	7761	13942	49492	130502
1993	64618	5660	11802	52493	134573
1994	65289	7037	9808	55610	137744
1995	63792	5916	10537	39868	120113
1996	54657	8017	7500	43970	114144
1997	45114	6495	6849	31948	90406
1998	50547	9581	8671	40801	109600
1999	41613	8384	5341	51944	107282
2000	33017	4540	5981	30113	73651
2001	33113	5686	5120	42412	86331
2002	33510	5771	4580	23904	67765
2003	33444	8151	3270	46145	91010
2004	35698	5278	6660	46304	93940

Table 15. Gag– Time –varying catchability run: Model estimated time series of landings in gutted weight (klb) for each fishery.

Year	C.HAL	C.Diving	Headboat	MRFSS	Total
1962	151	7	122	89	369
1963	138	7	110	80	335
1964	129	7	106	77	319
1965	132	7	114	83	336
1966	100	7	89	65	261
1967	213	7	194	141	555
1968	313	7	290	213	823
1969	219	6	185	135	545
1970	302	4	228	167	701
1971	310	4	221	162	697
1972	206	3	156	98	463
1973	298	4	180	126	608
1974	390	5	146	182	723
1975	444	6	106	229	785
1976	601	4	109	363	1077
1977	665	9	124	336	1134
1978	1017	14	87	532	1650
1979	931	19	114	409	1473
1980	855	16	72	364	1307
1981	978	14	150	577	1719
1982	1008	16	123	184	1331
1983	1045	9	153	604	1811
1984	1093	19	186	1475	2773
1985	868	12	143	429	1452
1986	832	6	135	339	1312
1987	857	22	172	616	1667
1988	678	13	155	384	1230
1989	970	23	148	508	1649
1990	794	20	118	349	1281
1991	673	85	95	284	1137
1992	709	107	110	388	1314
1993	770	79	104	455	1408
1994	803	96	99	552	1550
1995	834	82	105	387	1408
1996	748	118	67	387	1320
1997	601	97	60	271	1029
1998	652	138	78	364	1232
1999	532	113	59	565	1269
2000	436	63	67	332	898
2001	447	83	56	458	1044
2002	447	84	50	256	837
2003	442	117	36	501	1096
2004	475	75	75	515	1140

Table 16. Gag– Constant catchability run: Model estimated time series of landings in gutted weight (klb) for each fishery.

Year	C.HAL	C.Diving	Headboat	MRFSS	Total
1962	151	13	136	100	400
1963	137	13	124	91	365
1964	129	12	119	87	347
1965	130	12	127	93	362
1966	99	12	100	73	284
1967	211	12	218	160	601
1968	310	11	331	243	895
1969	217	9	219	161	606
1970	299	7	286	210	802
1971	307	5	281	206	799
1972	205	4	211	132	552
1973	292	5	123	84	504
1974	376	6	118	134	634
1975	427	8	117	244	796
1976	577	4	123	401	1105
1977	642	9	130	346	1127
1978	984	14	85	539	1622
1979	914	19	110	411	1454
1980	845	16	71	360	1292
1981	974	14	149	595	1732
1982	1004	16	124	185	1329
1983	1040	9	158	649	1856
1984	1082	19	186	1515	2802
1985	865	12	141	458	1476
1986	820	6	135	363	1324
1987	852	22	174	625	1673
1988	669	13	157	402	1241
1989	963	22	149	500	1634
1990	783	19	116	343	1261
1991	656	85	95	256	1092
1992	695	107	108	385	1295
1993	761	78	103	457	1399
1994	799	97	97	552	1545
1995	838	84	105	397	1424
1996	752	119	68	402	1341
1997	607	99	60	281	1047
1998	655	139	79	371	1244
1999	539	114	60	580	1293
2000	439	63	68	342	912
2001	450	82	58	477	1067
2002	448	85	51	265	849
2003	444	117	37	517	1115
2004	476	75	76	532	1159

Table 17. Gag– Time –varying catchability run: Model estimated time series of dead discards in number for each fishery.

Year	C.HAL	Headboat	MRFSS	Total
1981	2937	8	0	2945
1982	3097	5	1061	4163
1983	5468	10	20308	25786
1984	4759	8	3006	7773
1985	2043	955	783	3781
1986	2888	1023	3118	7029
1987	2937	1429	2592	6958
1988	3097	1434	3828	8359
1989	5468	1320	10913	17701
1990	4759	1033	2887	8679
1991	2043	792	6071	8906
1992	2888	1937	9641	14466
1993	2937	1632	7786	12355
1994	3097	1368	17071	21536
1995	5468	1479	18516	25463
1996	4759	1049	10735	16543
1997	2043	958	20576	23577
1998	2888	1210	8071	12169
1999	2937	1210	14811	18958
2000	3097	1358	32013	36468
2001	5468	1163	11932	18563
2002	4759	1043	21541	27343
2003	2043	745	34445	37233
2004	2888	1498	22390	26776

Table 18. Gag– Constant catchability run: Model estimated time series of dead discards in number for each fishery.

Year	C.HAL	Headboat	MRFSS	Total
1981	2948	7	0	2955
1982	3108	5	1079	4192
1983	5484	10	21197	26691
1984	4763	8	3003	7774
1985	2040	940	773	3753
1986	2881	1012	3119	7012
1987	2948	1407	2573	6928
1988	3108	1412	3749	8269
1989	5484	1307	10849	17640
1990	4763	1027	2865	8655
1991	2040	790	6047	8877
1992	2881	1935	9668	14484
1993	2948	1635	7798	12381
1994	3108	1362	17029	21499
1995	5484	1463	18514	25461
1996	4763	1040	10745	16548
1997	2040	952	20507	23499
1998	2881	1205	8060	12146
1999	2948	1200	14730	18878
2000	3108	1345	31898	36351
2001	5484	1150	11851	18485
2002	4763	1030	21422	27215
2003	2040	737	34359	37136
2004	2881	1500	22362	26743

Table 19. Gag—Base run with time-varying catchability: Length at age (mid-year)

Age	Length (mm)	Length (in)	CV of length (mm)
0	198.1	7.8	0.14
1	379.3	14.9	0.20
2	518.8	20.4	0.13
3	626.2	24.7	0.12
4	708.8	27.9	0.14
5	772.4	30.4	0.11
6	821.4	32.3	0.15
7	859.1	33.8	0.13
8	888.1	35.0	0.13
9	910.5	35.8	0.13
10	927.6	36.5	0.12
11	940.9	37.0	0.12
12	951.1	37.4	0.12
13	958.9	37.8	0.12
14	964.9	38.0	0.12
15	969.6	38.2	0.12
16	973.2	38.3	0.12
17	975.9	38.4	0.12
18	978.0	38.5	0.12
19	979.7	38.6	0.12
20	980.9	38.6	0.11

Table 20. Gag– Base run with constant catchability: Length at age (mid-year)

Age	Length (mm)	Length (in)	CV of length (mm)
0	295.6	11.6	0.16
1	423.2	16.7	0.11
2	530.2	20.9	0.10
3	620.2	24.4	0.12
4	695.7	27.4	0.13
5	759.1	29.9	0.13
6	812.3	32.0	0.08
7	857.0	33.7	0.13
8	894.5	35.2	0.12
9	926.1	36.5	0.11
10	952.5	37.5	0.09
11	974.7	38.4	0.08
12	993.4	39.1	0.08
13	1009.1	39.7	0.08
14	1022.2	40.2	0.09
15	1033.3	40.7	0.09
16	1042.6	41.0	0.09
17	1050.4	41.4	0.09
18	1056.9	41.6	0.09
19	1062.4	41.8	0.09
20	1067.0	42.0	0.08

Table 21. Gag—Base run with time-varying catchability: Selectivity at age

Age	Length (mm)	Length (in)	C.Hl	C.Trp	Rec	L.avg	D.C.Hl	D.Rec	D.avg
0	198.1	7.8	0.0001	0.0003	0.0029	0.0011	0.0117	0.1302	0.0193
1	379.3	14.9	0.0011	0.0010	0.0170	0.0065	0.0897	0.5211	0.0783
2	518.8	20.4	0.0091	0.0036	0.0924	0.0363	0.4857	1.0000	0.1570
3	626.2	24.7	0.0697	0.0134	0.3752	0.1619	1.0000	0.8425	0.1450
4	708.8	27.9	0.3802	0.0487	0.7798	0.4476	0.7798	0.3086	0.0620
5	772.4	30.4	0.8340	0.1689	0.9543	0.7377	0.2133	0.0645	0.0140
6	821.4	32.3	0.9763	0.5004	0.9919	0.8835	0.0306	0.0114	0.0023
7	859.1	33.8	0.9970	1.0000	0.9986	0.9984	0.0038	0.0019	0.0004
8	888.1	35.0	0.9996	1.0000	0.9998	0.9999	0.0005	0.0003	0.0001
9	910.5	35.8	1.0000	0.4190	1.0000	0.8801	0.0001	0.0001	0.0000
10	927.6	36.5	1.0000	0.0983	1.0000	0.8139	0.0000	0.0000	0.0000
11	940.9	37.0	1.0000	0.0191	1.0000	0.7976	0.0000	0.0000	0.0000
12	951.1	37.4	1.0000	0.0036	1.0000	0.7943	0.0000	0.0000	0.0000
13	958.9	37.8	1.0000	0.0007	1.0000	0.7937	0.0000	0.0000	0.0000
14	964.9	38.0	1.0000	0.0001	1.0000	0.7936	0.0000	0.0000	0.0000
15	969.6	38.2	1.0000	0.0000	1.0000	0.7936	0.0000	0.0000	0.0000
16	973.2	38.3	1.0000	0.0000	1.0000	0.7936	0.0000	0.0000	0.0000
17	975.9	38.4	1.0000	0.0000	1.0000	0.7936	0.0000	0.0000	0.0000
18	978.0	38.5	1.0000	0.0000	1.0000	0.7936	0.0000	0.0000	0.0000
19	979.7	38.6	1.0000	0.0000	1.0000	0.7936	0.0000	0.0000	0.0000
20	980.9	38.6	1.0000	0.0000	1.0000	0.7936	0.0000	0.0000	0.0000

Table 22. Gag– Base run with constant catchability: Selectivity at age

Age	Length (mm)	Length (in)	C.Hl	C.Trp	Rec	L.avg	D.C.Hl	D.Rec	D.avg
0	295.6	11.6	0.0001	0.0005	0.0037	0.0015	0.0113	0.1404	0.0218
1	423.2	16.7	0.0010	0.0016	0.0195	0.0078	0.0962	0.5196	0.0821
2	530.2	20.9	0.0091	0.0053	0.0953	0.0395	0.5349	1.0000	0.1662
3	620.2	24.4	0.0778	0.0180	0.3584	0.1668	1.0000	0.8919	0.1606
4	695.7	27.4	0.4363	0.0604	0.7476	0.4712	0.6868	0.3687	0.0729
5	759.1	29.9	0.8765	0.1931	0.9401	0.7585	0.1525	0.0883	0.0172
6	812.3	32.0	0.9849	0.5333	0.9881	0.8933	0.0187	0.0175	0.0031
7	857.0	33.7	0.9983	1.0000	0.9977	0.9994	0.0021	0.0033	0.0006
8	894.5	35.2	0.9998	0.8455	0.9996	0.9687	0.0002	0.0006	0.0001
9	926.1	36.5	1.0000	0.2722	0.9999	0.8499	0.0000	0.0001	0.0000
10	952.5	37.5	1.0000	0.0535	1.0000	0.8046	0.0000	0.0000	0.0000
11	974.7	38.4	1.0000	0.0092	1.0000	0.7954	0.0000	0.0000	0.0000
12	993.4	39.1	1.0000	0.0015	1.0000	0.7938	0.0000	0.0000	0.0000
13	1009.1	39.7	1.0000	0.0003	1.0000	0.7935	0.0000	0.0000	0.0000
14	1022.2	40.2	1.0000	0.0000	1.0000	0.7935	0.0000	0.0000	0.0000
15	1033.3	40.7	1.0000	0.0000	1.0000	0.7935	0.0000	0.0000	0.0000
16	1042.6	41.0	1.0000	0.0000	1.0000	0.7935	0.0000	0.0000	0.0000
17	1050.4	41.4	1.0000	0.0000	1.0000	0.7935	0.0000	0.0000	0.0000
18	1056.9	41.6	1.0000	0.0000	1.0000	0.7935	0.0000	0.0000	0.0000
19	1062.4	41.8	1.0000	0.0000	1.0000	0.7935	0.0000	0.0000	0.0000
20	1067.0	42.0	1.0000	0.0000	1.0000	0.7935	0.0000	0.0000	0.0000

Table 23. Gag—Base run with time-varying catchability: Estimated time series and status indicators. Exploitation rate (E) is of ages 2+, F is the fully selected fishing mortality rate, and SPR is static spawning potential ratio. SSB is in thousand pounds.

Year	E	E/E_{MSY}	F	F/F_{MSY}	SSB	SSB/SSB_{MSY}	SPR
1962	0.0202	0.308	0.0286	0.1027	15107	2.399	0.782
1963	0.0185	0.282	0.0264	0.0950	14926	2.370	0.796
1964	0.0180	0.275	0.0255	0.0917	14826	2.354	0.802
1965	0.0198	0.302	0.0271	0.0974	14673	2.330	0.790
1966	0.0162	0.247	0.0218	0.0786	14292	2.269	0.826
1967	0.0364	0.554	0.0463	0.1664	13796	2.190	0.676
1968	0.0577	0.878	0.0726	0.2613	12890	2.047	0.559
1969	0.0395	0.601	0.0523	0.1879	11700	1.858	0.648
1970	0.0497	0.756	0.0710	0.2554	11021	1.750	0.574
1971	0.0488	0.743	0.0746	0.2683	10611	1.685	0.565
1972	0.0331	0.503	0.0516	0.1857	10529	1.672	0.659
1973	0.0372	0.567	0.0660	0.2374	10792	1.713	0.595
1974	0.0443	0.675	0.0783	0.2816	11338	1.800	0.559
1975	0.0488	0.744	0.0848	0.3048	11963	1.899	0.554
1976	0.0668	1.017	0.1148	0.4129	12005	1.906	0.488
1977	0.0749	1.141	0.1244	0.4474	11557	1.835	0.470
1978	0.1250	1.904	0.1952	0.7021	10862	1.725	0.346
1979	0.1085	1.651	0.1962	0.7056	9484	1.506	0.352
1980	0.0931	1.418	0.1949	0.7010	8593	1.364	0.360
1981	0.1360	2.071	0.2797	1.0059	8485	1.347	0.257
1982	0.1088	1.657	0.2660	0.9568	7913	1.256	0.318
1983	0.1488	2.266	0.3736	1.3435	7538	1.197	0.211
1984	0.2964	4.513	0.5572	2.0038	6959	1.105	0.108
1985	0.1757	2.676	0.6460	2.3231	5343	0.848	0.219
1986	0.1911	2.910	0.3150	1.1328	4621	0.734	0.167
1987	0.2150	3.274	0.5785	2.0806	4332	0.688	0.144
1988	0.1516	2.308	0.7434	2.6734	4042	0.642	0.189
1989	0.2132	3.246	0.9643	3.4680	4289	0.681	0.130
1990	0.1827	2.781	0.6301	2.2659	4028	0.640	0.164
1991	0.1405	2.139	0.5170	1.8591	4061	0.645	0.194
1992	0.1351	2.057	0.5336	1.9188	4540	0.721	0.186
1993	0.1686	2.567	0.5083	1.8279	5238	0.832	0.185
1994	0.2098	3.194	0.5558	1.9990	5416	0.860	0.161
1995	0.1853	2.822	0.5258	1.8908	4661	0.740	0.172
1996	0.1649	2.511	0.5332	1.9176	4101	0.651	0.179
1997	0.1279	1.947	0.4783	1.7202	4024	0.639	0.199
1998	0.1620	2.467	0.5660	2.0354	4363	0.693	0.183
1999	0.1709	2.602	0.5945	2.1381	4377	0.695	0.177
2000	0.1074	1.635	0.4370	1.5717	4095	0.650	0.211
2001	0.1196	1.821	0.4441	1.5972	4280	0.680	0.213
2002	0.0888	1.352	0.3708	1.3334	4582	0.727	0.252
2003	0.1018	1.550	0.4444	1.5981	5148	0.817	0.214
2004	0.1221	1.859	0.4053	1.4575	5568	0.884	0.221
2005	.	.	.	.	5720	0.908	.

Table 24. Gag– Base run with constant catchability: Estimated time series and status indicators. Exploitation rate (E) is of ages 2+, F is the fully selected fishing mortality rate, and SPR is static spawning potential ratio. SSB is in thousand pounds.

Year	E	E/E_{MSY}	F	F/F_{MSY}	SSB	SSB/SSB_{MSY}	SPR
1962	0.0217	0.335	0.0346	0.146	14577	1.839	0.747
1963	0.0200	0.308	0.0324	0.137	14375	1.814	0.761
1964	0.0197	0.304	0.0313	0.132	14257	1.799	0.768
1965	0.0219	0.337	0.0331	0.140	14094	1.778	0.755
1966	0.0181	0.279	0.0272	0.115	13714	1.730	0.794
1967	0.0405	0.624	0.0552	0.233	13242	1.671	0.629
1968	0.0651	1.002	0.0861	0.363	12342	1.557	0.504
1969	0.0462	0.711	0.0646	0.272	11101	1.401	0.586
1970	0.0615	0.947	0.0910	0.384	10279	1.297	0.493
1971	0.0643	0.990	0.0992	0.418	9498	1.198	0.471
1972	0.0485	0.747	0.0749	0.316	8872	1.120	0.549
1973	0.0413	0.636	0.0733	0.309	8503	1.073	0.559
1974	0.0519	0.799	0.0953	0.402	8254	1.042	0.502
1975	0.0513	0.790	0.1267	0.534	8085	1.020	0.447
1976	0.0647	0.997	0.1934	0.816	8292	1.046	0.368
1977	0.0695	1.070	0.2155	0.909	8635	1.090	0.358
1978	0.1188	1.829	0.3251	1.371	8739	1.103	0.281
1979	0.1078	1.661	0.2956	1.246	8075	1.019	0.279
1980	0.0953	1.467	0.2636	1.111	7670	0.968	0.299
1981	0.1352	2.082	0.3539	1.492	7818	0.986	0.221
1982	0.1063	1.637	0.3282	1.384	7396	0.933	0.280
1983	0.1506	2.318	0.3867	1.631	7243	0.914	0.171
1984	0.2855	4.396	0.6640	2.800	6792	0.857	0.106
1985	0.1746	2.689	0.7424	3.130	5269	0.665	0.187
1986	0.1756	2.704	0.3566	1.504	4601	0.581	0.157
1987	0.2021	3.111	0.6809	2.871	4354	0.549	0.132
1988	0.1498	2.306	0.9333	3.936	4100	0.517	0.169
1989	0.1996	3.074	1.2012	5.065	4287	0.541	0.121
1990	0.1684	2.593	0.8273	3.488	4015	0.507	0.149
1991	0.1183	1.822	0.6567	2.769	4133	0.522	0.179
1992	0.1285	1.978	0.4836	2.039	4742	0.598	0.172
1993	0.1597	2.459	0.4518	1.905	5549	0.700	0.174
1994	0.1979	3.047	0.4905	2.069	5777	0.729	0.153
1995	0.1746	2.689	0.4634	1.954	5091	0.642	0.163
1996	0.1518	2.337	0.4592	1.936	4581	0.578	0.172
1997	0.1158	1.784	0.4038	1.703	4562	0.576	0.197
1998	0.1450	2.232	0.4704	1.983	4979	0.628	0.182
1999	0.1529	2.355	0.4947	2.086	5076	0.641	0.176
2000	0.0946	1.457	0.3560	1.501	4862	0.614	0.220
2001	0.1030	1.586	0.3554	1.499	5153	0.650	0.221
2002	0.0749	1.153	0.2899	1.222	5597	0.706	0.271
2003	0.0841	1.295	0.3471	1.464	6368	0.804	0.232
2004	0.0992	1.527	0.3105	1.309	7058	0.891	0.244
2005	.	.	.	.	7468	0.942	.

Table 25. Gag—Base run with time-varying catchability: Estimated instantaneous fishing mortality rate (per yr) at age, including discard mortality

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1962	0.000	0.002	0.014	0.015	0.016	0.021	0.025	0.028	0.028	0.027	0.027	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026
1963	0.000	0.002	0.013	0.013	0.015	0.019	0.023	0.026	0.026	0.025	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
1964	0.000	0.002	0.013	0.013	0.015	0.018	0.022	0.025	0.025	0.024	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023
1965	0.000	0.002	0.014	0.014	0.016	0.020	0.024	0.027	0.027	0.026	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
1966	0.000	0.001	0.011	0.012	0.013	0.016	0.019	0.021	0.022	0.021	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
1967	0.000	0.003	0.026	0.026	0.029	0.035	0.042	0.045	0.046	0.045	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044
1968	0.000	0.005	0.042	0.043	0.047	0.057	0.066	0.071	0.072	0.071	0.071	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
1969	0.000	0.003	0.028	0.029	0.032	0.040	0.047	0.051	0.052	0.051	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
1970	0.000	0.004	0.036	0.037	0.042	0.053	0.064	0.069	0.071	0.070	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069
1971	0.000	0.004	0.036	0.037	0.042	0.055	0.067	0.073	0.074	0.073	0.073	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072
1972	0.000	0.005	0.024	0.025	0.028	0.037	0.046	0.050	0.051	0.050	0.050	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049
1973	0.000	0.024	0.026	0.028	0.033	0.046	0.058	0.064	0.066	0.065	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064
1974	0.000	0.023	0.028	0.030	0.037	0.052	0.068	0.076	0.078	0.077	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076
1975	0.000	0.001	0.028	0.031	0.039	0.056	0.074	0.082	0.084	0.083	0.083	0.083	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082
1976	0.000	0.000	0.003	0.045	0.056	0.079	0.102	0.111	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114
1977	0.000	0.000	0.008	0.047	0.058	0.084	0.109	0.121	0.124	0.123	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122
1978	0.000	0.005	0.063	0.069	0.087	0.129	0.170	0.189	0.194	0.193	0.192	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191
1979	0.000	0.005	0.058	0.063	0.082	0.126	0.169	0.190	0.195	0.192	0.191	0.190	0.190	0.190	0.190	0.190	0.190	0.190	0.190	0.190	0.190
1980	0.000	0.010	0.050	0.055	0.075	0.121	0.167	0.188	0.193	0.190	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188
1981	0.002	0.020	0.106	0.110	0.127	0.184	0.243	0.271	0.278	0.275	0.273	0.272	0.272	0.272	0.272	0.272	0.272	0.272	0.272	0.272	0.272
1982	0.000	0.007	0.044	0.052	0.081	0.151	0.221	0.254	0.262	0.257	0.254	0.254	0.254	0.253	0.253	0.253	0.253	0.253	0.253	0.253	0.253
1983	0.005	0.033	0.139	0.144	0.161	0.229	0.297	0.326	0.333	0.331	0.330	0.329	0.329	0.329	0.329	0.329	0.329	0.329	0.329	0.329	0.329
1984	0.001	0.063	0.278	0.298	0.358	0.455	0.519	0.544	0.549	0.543	0.539	0.539	0.538	0.538	0.538	0.538	0.538	0.538	0.538	0.538	0.538
1985	0.001	0.038	0.117	0.118	0.122	0.148	0.238	0.420	0.567	0.618	0.630	0.633	0.634	0.634	0.634	0.634	0.634	0.634	0.634	0.634	0.634
1986	0.006	0.050	0.167	0.239	0.284	0.298	0.304	0.307	0.307	0.304	0.303	0.302	0.302	0.302	0.302	0.302	0.302	0.302	0.302	0.302	0.302
1987	0.001	0.058	0.177	0.193	0.248	0.375	0.498	0.555	0.568	0.560	0.554	0.553	0.553	0.552	0.552	0.552	0.552	0.552	0.552	0.552	0.552
1988	0.001	0.074	0.123	0.124	0.133	0.186	0.343	0.565	0.685	0.714	0.719	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720
1989	0.003	0.077	0.169	0.183	0.238	0.429	0.710	0.880	0.927	0.921	0.914	0.912	0.912	0.912	0.912	0.912	0.912	0.912	0.912	0.912	0.912
1990	0.001	0.033	0.118	0.140	0.215	0.381	0.534	0.604	0.619	0.607	0.599	0.597	0.597	0.596	0.596	0.596	0.596	0.596	0.596	0.596	0.596
1991	0.002	0.011	0.095	0.117	0.188	0.316	0.426	0.499	0.505	0.453	0.424	0.417	0.416	0.416	0.415	0.415	0.415	0.415	0.415	0.415	0.415
1992	0.003	0.011	0.077	0.145	0.215	0.342	0.442	0.510	0.515	0.458	0.426	0.419	0.417	0.417	0.417	0.417	0.417	0.417	0.417	0.417	0.417
1993	0.003	0.012	0.082	0.152	0.219	0.340	0.429	0.483	0.487	0.448	0.426	0.420	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.419
1994	0.006	0.025	0.123	0.202	0.251	0.360	0.447	0.505	0.509	0.462	0.436	0.430	0.428	0.428	0.428	0.428	0.428	0.428	0.428	0.428	0.428
1995	0.006	0.023	0.109	0.180	0.234	0.345	0.428	0.479	0.483	0.446	0.426	0.421	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420
1996	0.003	0.013	0.087	0.160	0.227	0.350	0.444	0.506	0.510	0.461	0.434	0.427	0.426	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425
1997	0.006	0.023	0.088	0.140	0.188	0.293	0.377	0.432	0.436	0.392	0.367	0.360	0.359	0.359	0.359	0.359	0.359	0.359	0.359	0.359	0.359
1998	0.003	0.012	0.080	0.148	0.215	0.340	0.451	0.541	0.545	0.462	0.415	0.404	0.402	0.401	0.401	0.401	0.401	0.401	0.401	0.401	0.401
1999	0.005	0.022	0.059	0.128	0.260	0.398	0.478	0.551	0.552	0.473	0.429	0.419	0.417	0.416	0.416	0.416	0.416	0.416	0.416	0.416	0.416
2000	0.009	0.036	0.080	0.122	0.195	0.284	0.330	0.365	0.365	0.329	0.309	0.304	0.303	0.303	0.303	0.303	0.303	0.303	0.303	0.303	0.303
2001	0.004	0.016	0.046	0.106	0.213	0.317	0.368	0.407	0.407	0.367	0.345	0.340	0.339	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338
2002	0.005	0.022	0.052	0.087	0.155	0.240	0.285	0.322	0.323	0.284	0.262	0.257	0.256	0.256	0.256	0.256	0.256	0.256	0.256	0.256	0.256
2003	0.009	0.035	0.078	0.119	0.190	0.275	0.328	0.377	0.378	0.324	0.294	0.287	0.285	0.285	0.285	0.285	0.285	0.285	0.285	0.285	0.285
2004	0.008	0.033	0.074	0.118	0.190	0.269	0.309	0.341	0.341	0.309	0.291	0.286	0.285	0.285	0.285	0.285	0.285	0.285	0.285	0.285	0.285

Table 26. Gag– Base run with constant catchability: Estimated instantaneous fishing mortality rate (per yr) at age, including discard mortality

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1962	0.001	0.004	0.010	0.016	0.018	0.022	0.027	0.032	0.033	0.031	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
1963	0.001	0.003	0.010	0.014	0.017	0.020	0.025	0.030	0.031	0.029	0.028	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027
1964	0.001	0.003	0.009	0.014	0.016	0.019	0.024	0.029	0.030	0.028	0.027	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026
1965	0.001	0.004	0.010	0.015	0.018	0.021	0.026	0.031	0.032	0.029	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
1966	0.001	0.003	0.008	0.012	0.014	0.017	0.021	0.026	0.026	0.023	0.023	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022
1967	0.001	0.007	0.019	0.028	0.033	0.038	0.045	0.052	0.053	0.051	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
1968	0.002	0.011	0.031	0.047	0.054	0.061	0.071	0.081	0.083	0.082	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081
1969	0.002	0.008	0.023	0.034	0.039	0.044	0.053	0.060	0.062	0.061	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060
1970	0.002	0.011	0.032	0.047	0.055	0.063	0.074	0.085	0.088	0.087	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086
1971	0.003	0.012	0.033	0.050	0.058	0.067	0.080	0.092	0.096	0.095	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094
1972	0.002	0.009	0.025	0.037	0.043	0.050	0.060	0.070	0.072	0.071	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
1973	0.023	0.023	0.023	0.025	0.029	0.038	0.053	0.065	0.070	0.069	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
1974	0.012	0.023	0.028	0.031	0.036	0.049	0.068	0.084	0.091	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090
1975	0.001	0.004	0.017	0.038	0.054	0.071	0.094	0.114	0.121	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122
1976	0.000	0.001	0.006	0.024	0.066	0.109	0.146	0.174	0.186	0.189	0.190	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191
1977	0.000	0.001	0.005	0.020	0.060	0.110	0.156	0.191	0.206	0.208	0.209	0.209	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210
1978	0.001	0.002	0.009	0.034	0.091	0.158	0.230	0.286	0.310	0.314	0.316	0.316	0.317	0.317	0.317	0.317	0.317	0.317	0.317	0.317	0.317
1979	0.002	0.008	0.030	0.065	0.096	0.141	0.204	0.258	0.281	0.284	0.286	0.286	0.286	0.286	0.286	0.286	0.286	0.286	0.286	0.286	0.286
1980	0.002	0.011	0.035	0.059	0.081	0.121	0.180	0.228	0.250	0.255	0.256	0.257	0.257	0.257	0.257	0.257	0.257	0.257	0.257	0.257	0.257
1981	0.005	0.023	0.068	0.113	0.139	0.184	0.253	0.311	0.338	0.345	0.347	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348
1982	0.002	0.008	0.026	0.051	0.079	0.133	0.212	0.278	0.308	0.315	0.317	0.318	0.318	0.318	0.318	0.318	0.318	0.318	0.318	0.318	0.318
1983	0.011	0.046	0.117	0.170	0.208	0.265	0.313	0.338	0.345	0.345	0.345	0.345	0.345	0.345	0.345	0.345	0.345	0.345	0.345	0.345	0.345
1984	0.011	0.052	0.166	0.279	0.347	0.432	0.535	0.610	0.639	0.644	0.645	0.646	0.646	0.646	0.646	0.646	0.646	0.646	0.646	0.646	0.646
1985	0.008	0.035	0.088	0.122	0.140	0.175	0.264	0.423	0.583	0.674	0.711	0.724	0.728	0.730	0.730	0.730	0.730	0.730	0.730	0.730	0.730
1986	0.012	0.048	0.118	0.190	0.259	0.309	0.334	0.345	0.347	0.345	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344
1987	0.015	0.061	0.140	0.190	0.234	0.323	0.463	0.584	0.639	0.650	0.653	0.655	0.655	0.655	0.655	0.655	0.655	0.656	0.656	0.656	0.656
1988	0.017	0.060	0.109	0.129	0.142	0.181	0.287	0.487	0.701	0.829	0.883	0.903	0.909	0.911	0.912	0.912	0.912	0.912	0.912	0.912	0.912
1989	0.016	0.063	0.137	0.181	0.227	0.354	0.606	0.894	1.064	1.123	1.143	1.150	1.152	1.153	1.153	1.154	1.154	1.154	1.154	1.154	1.154
1990	0.008	0.035	0.087	0.132	0.190	0.319	0.518	0.692	0.771	0.789	0.794	0.797	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798
1991	0.005	0.022	0.061	0.100	0.150	0.257	0.421	0.568	0.606	0.578	0.566	0.564	0.564	0.564	0.565	0.565	0.565	0.565	0.565	0.565	0.565
1992	0.003	0.011	0.070	0.138	0.210	0.325	0.408	0.464	0.453	0.401	0.382	0.378	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377
1993	0.003	0.011	0.074	0.143	0.211	0.318	0.389	0.431	0.424	0.389	0.375	0.373	0.372	0.372	0.372	0.372	0.372	0.372	0.372	0.372	0.372
1994	0.006	0.024	0.110	0.189	0.239	0.332	0.401	0.446	0.438	0.397	0.382	0.378	0.378	0.378	0.378	0.378	0.378	0.378	0.378	0.378	0.378
1995	0.006	0.022	0.098	0.169	0.222	0.318	0.384	0.422	0.416	0.384	0.372	0.370	0.369	0.369	0.369	0.369	0.369	0.369	0.369	0.369	0.369
1996	0.003	0.012	0.077	0.148	0.212	0.316	0.390	0.436	0.428	0.386	0.370	0.367	0.366	0.366	0.366	0.366	0.366	0.366	0.366	0.366	0.366
1997	0.005	0.021	0.077	0.128	0.173	0.259	0.323	0.365	0.357	0.318	0.304	0.301	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300
1998	0.003	0.011	0.068	0.132	0.192	0.295	0.381	0.450	0.433	0.362	0.335	0.329	0.329	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328
1999	0.005	0.020	0.052	0.111	0.227	0.339	0.401	0.457	0.440	0.375	0.351	0.346	0.345	0.345	0.345	0.345	0.345	0.345	0.345	0.345	0.345
2000	0.008	0.031	0.070	0.106	0.169	0.237	0.269	0.294	0.286	0.258	0.247	0.245	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244
2001	0.003	0.014	0.039	0.089	0.179	0.260	0.296	0.324	0.316	0.285	0.274	0.271	0.271	0.271	0.271	0.271	0.271	0.271	0.271	0.271	0.271
2002	0.005	0.018	0.043	0.073	0.130	0.192	0.224	0.250	0.242	0.212	0.201	0.199	0.198	0.198	0.198	0.198	0.198	0.198	0.198	0.198	0.198
2003	0.007	0.029	0.064	0.098	0.156	0.220	0.258	0.293	0.282	0.241	0.225	0.222	0.221	0.221	0.221	0.221	0.221	0.221	0.221	0.221	0.221
2004	0.007	0.026	0.060	0.095	0.152	0.210	0.237	0.259	0.252	0.228	0.218	0.217	0.216	0.216	0.216	0.216	0.216	0.216	0.216	0.216	0.216

Table 27. Gag—Base run with time-varying catchability: Estimated abundance at age (1000s)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1962	272.9	227.2	170.0	126.5	106.2	90.2	77.3	66.9	57.9	50.1	43.5	38.0	33.1	29.0	25.3	22.1	19.3	16.9	14.7	12.9	113.0
1963	189.5	172.3	172.9	136.3	104.7	89.4	76.5	65.8	57.1	49.6	43.1	37.5	32.8	28.7	25.1	21.9	19.2	16.7	14.7	12.8	109.4
1964	169.3	119.6	131.2	138.8	112.9	88.2	75.9	65.3	56.2	49.0	42.8	37.3	32.5	28.5	24.9	21.8	19.1	16.7	14.6	12.8	106.5
1965	133.8	106.9	91.1	105.3	115.0	95.2	75.0	64.8	55.8	48.3	42.3	37.0	32.4	28.2	24.7	21.7	19.0	16.6	14.5	12.7	103.9
1966	148.7	84.4	81.4	73.0	87.2	96.8	80.8	63.9	55.4	47.9	41.7	36.6	32.1	28.1	24.5	21.5	18.9	16.5	14.4	12.7	101.5
1967	305.9	93.9	64.3	65.4	60.6	73.6	82.5	69.2	54.9	47.8	41.5	36.2	31.8	27.9	24.5	21.4	18.8	16.5	14.5	12.6	99.9
1968	425.2	193.1	71.4	51.0	53.5	50.4	61.5	69.1	58.0	46.2	40.4	35.2	30.7	27.1	23.8	20.9	18.3	16.0	14.1	12.3	96.1
1969	436.1	268.4	146.5	55.7	41.0	43.6	41.2	50.3	56.4	47.6	38.0	33.3	29.1	25.5	22.4	19.7	17.3	15.2	13.3	11.7	90.2
1970	342.4	275.3	204.0	115.8	45.4	34.0	36.3	34.3	41.9	47.2	40.0	32.1	28.2	24.6	21.5	19.0	16.7	14.7	12.9	11.3	86.5
1971	853.8	216.2	209.0	160.0	93.6	37.2	27.9	29.7	28.1	34.4	39.0	33.1	26.6	23.4	20.4	17.9	15.8	13.9	12.2	10.7	81.5
1972	317.1	539.0	164.1	164.0	129.4	76.8	30.5	22.8	24.3	23.0	28.3	32.1	27.3	22.0	19.3	16.9	14.9	13.1	11.6	10.2	76.5
1973	388.8	200.2	408.9	130.3	134.3	107.6	64.1	25.5	19.0	20.3	19.3	23.8	27.1	23.1	18.6	16.4	14.4	12.6	11.1	9.8	73.6
1974	291.8	245.4	149.0	323.8	106.4	111.2	89.0	52.8	20.9	15.7	16.8	16.1	19.9	22.6	19.3	15.5	13.7	12.0	10.6	9.3	69.8
1975	257.4	184.2	182.9	117.8	263.9	87.8	91.3	72.6	42.9	17.1	12.8	13.8	13.2	16.4	18.6	15.9	12.8	11.3	9.9	8.7	65.5
1976	141.3	162.5	140.3	144.6	95.9	217.2	71.8	74.0	58.6	34.8	13.9	10.5	11.3	10.8	13.4	15.3	13.1	10.5	9.3	8.2	61.0
1977	579.2	89.2	123.9	113.7	116.0	77.6	173.8	56.7	58.1	46.1	27.4	11.0	8.3	9.0	8.6	10.7	12.2	10.4	8.4	7.4	55.0
1978	586.9	365.6	68.0	99.9	91.1	93.6	61.8	136.1	44.0	45.3	36.1	21.5	8.6	6.5	7.1	6.8	8.4	9.6	8.2	6.6	49.3
1979	361.9	370.5	277.3	51.9	78.3	71.4	71.3	45.5	98.8	32.0	33.0	26.4	15.8	6.3	4.8	5.2	5.0	6.2	7.1	6.0	41.2
1980	347.2	228.4	281.0	212.8	40.9	61.7	54.6	52.5	33.0	71.7	23.3	24.2	19.4	11.6	4.7	3.5	3.8	3.7	4.6	5.2	34.9
1981	771.4	219.2	172.4	217.3	169.0	32.5	47.4	40.3	38.2	24.0	52.4	17.1	17.8	14.3	8.5	3.4	2.6	2.8	2.7	3.4	29.7
1982	224.9	485.8	163.8	126.1	163.4	127.3	23.4	32.4	27.0	25.5	16.1	35.3	11.6	12.0	9.7	5.8	2.3	1.8	1.9	1.8	22.5
1983	279.5	141.9	368.0	127.5	100.5	128.9	94.8	16.4	22.1	18.3	17.4	11.1	24.3	8.0	8.3	6.7	4.0	1.6	1.2	1.3	16.8
1984	570.9	175.5	104.7	260.3	92.7	73.3	88.7	61.5	10.4	13.9	11.6	11.1	7.1	15.6	5.1	5.3	4.3	2.6	1.0	0.8	11.7
1985	587.8	359.9	125.6	64.5	162.2	55.4	40.2	46.1	31.3	5.3	7.2	6.0	5.8	3.7	8.1	2.7	2.8	2.2	1.3	0.5	6.5
1986	552.2	370.8	264.3	90.9	48.1	122.8	41.4	27.7	26.6	15.7	2.5	3.4	2.8	2.7	1.7	3.8	1.3	1.3	1.1	0.6	3.3
1987	499.3	346.7	269.0	181.8	60.1	31.0	78.9	26.7	17.9	17.2	10.2	1.6	2.2	1.9	1.8	1.1	2.5	0.8	0.9	0.7	2.6
1988	464.8	314.8	249.5	183.1	125.9	40.1	18.5	41.9	13.4	8.9	8.7	5.2	0.8	1.1	1.0	0.9	0.6	1.3	0.4	0.4	1.7
1989	768.6	293.0	222.8	179.5	135.8	94.2	28.8	11.4	20.9	6.0	3.9	3.8	2.2	0.4	0.5	0.4	0.4	0.3	0.6	0.2	0.9
1990	815.7	483.7	206.8	153.0	125.5	91.5	53.1	12.4	4.2	7.3	2.1	1.4	1.3	0.8	0.1	0.2	0.1	0.1	0.1	0.2	0.4
1991	234.8	514.3	357.1	149.4	111.7	86.6	54.1	27.2	5.9	2.0	3.5	1.0	0.7	0.7	0.4	0.1	0.1	0.1	0.1	0.0	0.3
1992	228.1	148.0	387.9	264.1	111.6	79.2	54.7	30.8	14.5	3.2	1.1	2.0	0.6	0.4	0.4	0.2	0.0	0.1	0.0	0.0	0.2
1993	469.4	143.6	111.6	292.1	191.8	76.9	48.7	30.7	16.2	7.6	1.8	0.6	1.2	0.4	0.2	0.2	0.1	0.0	0.0	0.0	0.1
1994	566.8	295.5	108.2	83.6	210.7	131.8	47.4	27.7	16.6	8.8	4.3	1.0	0.4	0.7	0.2	0.1	0.1	0.1	0.0	0.0	0.1
1995	500.5	355.6	219.7	77.8	57.3	140.2	79.6	26.5	14.7	8.8	4.9	2.5	0.6	0.2	0.4	0.1	0.1	0.1	0.0	0.0	0.1
1996	389.2	314.1	265.0	160.1	54.5	38.8	86.0	45.3	14.4	8.0	5.0	2.8	1.4	0.3	0.1	0.2	0.1	0.0	0.0	0.0	0.0
1997	315.2	244.9	236.5	197.4	114.5	37.2	23.7	48.1	23.9	7.6	4.4	2.9	1.6	0.8	0.2	0.1	0.1	0.0	0.0	0.0	0.0
1998	559.4	197.8	182.6	176.0	144.1	81.2	24.0	14.2	27.4	13.6	4.5	2.7	1.8	1.0	0.5	0.1	0.0	0.1	0.0	0.0	0.0
1999	498.8	352.1	149.1	137.0	127.4	99.4	50.0	13.3	7.2	14.0	7.6	2.7	1.6	1.1	0.6	0.3	0.1	0.0	0.1	0.0	0.0
2000	526.4	313.3	262.7	114.3	101.2	84.0	57.9	27.1	6.8	3.7	7.7	4.4	1.6	0.9	0.6	0.4	0.2	0.0	0.0	0.0	0.0
2001	702.3	329.5	230.6	197.1	84.9	71.2	54.7	36.3	16.5	4.1	2.3	5.0	2.9	1.0	0.6	0.4	0.2	0.1	0.0	0.0	0.0
2002	280.9	441.8	247.4	179.1	148.8	58.7	44.9	33.1	21.2	9.7	2.5	1.5	3.2	1.8	0.6	0.4	0.3	0.1	0.1	0.0	0.0
2003	203.4	176.4	329.7	191.0	137.8	109.1	40.0	29.5	21.0	13.5	6.4	1.7	1.0	2.2	1.3	0.4	0.3	0.2	0.1	0.1	0.0
2004	265.4	127.3	129.9	247.9	142.3	97.5	71.8	25.2	17.7	12.7	8.7	4.3	1.1	0.7	1.5	0.8	0.3	0.2	0.1	0.1	0.1
2005	343.2	166.2	94.0	98.0	184.9	100.7	64.5	46.0	15.7	11.1	8.2	5.7	2.8	0.8	0.5	1.0	0.6	0.2	0.1	0.1	0.1

Table 28. Gag– Base run with constant catchability: Estimated abundance at age (1000s)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1962	236.9	206.1	150.9	112.3	93.7	79.7	68.4	58.9	50.7	43.8	38.0	33.0	28.8	25.0	21.8	19.0	16.6	14.4	12.6	10.9	97.6
1963	151.9	149.4	156.6	121.4	92.8	78.7	67.5	58.1	50.0	43.2	37.5	32.7	28.5	24.8	21.6	18.9	16.4	14.3	12.5	10.9	94.0
1964	138.6	95.8	113.6	126.1	100.5	78.1	66.8	57.5	49.5	42.8	37.2	32.4	28.2	24.6	21.5	18.7	16.3	14.3	12.4	10.8	91.0
1965	99.8	87.4	72.8	91.5	104.4	84.6	66.3	56.9	49.0	42.3	36.8	32.1	28.0	24.4	21.3	18.6	16.3	14.2	12.4	10.8	88.5
1966	99.9	62.9	66.4	58.6	75.6	87.7	71.7	56.4	48.4	41.8	36.4	31.7	27.7	24.2	21.1	18.5	16.1	14.1	12.3	10.7	86.2
1967	203.0	63.0	47.9	53.6	48.6	63.8	74.7	61.3	48.2	41.6	36.1	31.5	27.5	24.1	21.0	18.4	16.1	14.1	12.3	10.7	84.6
1968	263.6	128.0	47.7	38.2	43.7	40.2	53.2	62.3	51.0	40.3	34.9	30.4	26.6	23.3	20.3	17.8	15.6	13.6	11.9	10.4	80.9
1969	245.7	166.0	96.5	37.6	30.6	35.4	32.8	43.2	50.4	41.4	32.8	28.5	24.9	21.8	19.1	16.7	14.6	12.8	11.2	9.8	75.1
1970	173.1	154.9	125.6	76.7	30.5	25.2	29.4	27.1	35.7	41.8	34.5	27.4	23.9	20.9	18.3	16.0	14.0	12.3	10.8	9.4	71.4
1971	265.7	109.0	116.8	99.0	61.4	24.7	20.5	23.8	21.9	28.8	33.9	28.0	22.3	19.5	17.0	14.9	13.1	11.5	10.1	8.8	66.2
1972	270.9	167.3	82.2	91.8	79.0	49.6	20.0	16.5	19.0	17.5	23.2	27.3	22.6	18.1	15.8	13.8	12.1	10.6	9.3	8.2	60.9
1973	801.5	170.7	126.5	65.1	74.2	64.7	40.8	16.4	13.5	15.6	14.4	19.1	22.6	18.7	15.0	13.1	11.5	10.1	8.8	7.8	57.4
1974	464.6	494.7	127.3	100.5	53.3	61.7	53.9	33.8	13.5	11.1	12.9	11.9	15.9	18.8	15.6	12.5	10.9	9.5	8.4	7.4	54.3
1975	411.5	289.9	368.7	100.6	81.8	44.0	50.9	44.0	27.3	10.9	9.0	10.4	9.7	12.9	15.3	12.7	10.1	8.9	7.8	6.8	50.3
1976	206.2	259.5	220.2	294.8	81.3	66.3	35.5	40.4	34.5	21.3	8.5	7.0	8.2	7.6	10.2	12.0	10.0	8.0	7.0	6.1	45.1
1977	575.9	130.1	197.7	177.9	241.5	65.1	51.5	26.8	29.8	25.2	15.6	6.2	5.2	6.0	5.6	7.5	8.9	7.4	5.9	5.2	37.8
1978	560.5	363.4	99.1	159.9	146.4	194.6	50.5	38.4	19.4	21.4	18.1	11.2	4.5	3.7	4.3	4.0	5.4	6.4	5.3	4.3	31.1
1979	415.5	353.7	276.6	79.9	129.8	114.4	143.8	35.1	25.3	12.5	13.8	11.7	7.2	2.9	2.4	2.8	2.6	3.5	4.2	3.5	23.0
1980	356.5	261.9	267.6	218.1	62.8	100.9	86.0	102.3	23.8	16.9	8.3	9.2	7.8	4.8	1.9	1.6	1.9	1.8	2.3	2.8	17.7
1981	840.1	224.5	197.4	210.1	172.6	49.6	77.4	62.7	71.4	16.3	11.6	5.7	6.3	5.4	3.3	1.3	1.1	1.3	1.2	1.6	14.1
1982	223.4	527.5	167.2	150.0	157.5	128.6	35.7	52.4	40.3	44.9	10.2	7.2	3.6	4.0	3.4	2.1	0.8	0.7	0.8	0.8	9.9
1983	260.7	140.8	399.2	132.5	119.7	124.5	97.4	25.2	34.8	26.1	29.0	6.6	4.7	2.3	2.6	2.2	1.4	0.5	0.5	0.5	6.9
1984	592.2	162.7	102.5	288.7	93.9	83.2	82.7	62.2	15.8	21.7	16.4	18.2	4.1	2.9	1.5	1.6	1.4	0.9	0.3	0.3	4.7
1985	583.8	369.8	117.8	70.6	183.3	56.8	46.8	42.3	29.6	7.3	10.1	7.6	8.5	1.9	1.4	0.7	0.8	0.6	0.4	0.2	2.3
1986	492.4	365.7	272.4	87.7	52.5	136.3	41.2	31.3	24.3	14.6	3.3	4.4	3.3	3.6	0.8	0.6	0.3	0.3	0.3	0.2	1.1
1987	553.0	307.0	265.8	196.9	60.9	34.6	86.7	25.8	19.5	15.1	9.1	2.1	2.8	2.1	2.3	0.5	0.4	0.2	0.2	0.2	0.8
1988	460.3	344.0	220.3	187.9	136.7	41.3	21.7	47.6	12.6	9.1	7.0	4.2	1.0	1.3	1.0	1.1	0.2	0.2	0.1	0.1	0.4
1989	842.7	285.7	247.1	160.5	138.6	101.5	29.8	14.2	25.7	5.5	3.5	2.6	1.5	0.3	0.5	0.3	0.4	0.1	0.1	0.0	0.2
1990	850.5	523.7	204.6	175.1	112.5	94.5	61.7	14.2	5.1	7.8	1.6	1.0	0.7	0.4	0.1	0.1	0.1	0.1	0.0	0.0	0.1
1991	254.7	532.5	385.7	152.5	128.9	79.5	59.5	32.1	6.2	2.1	3.1	0.6	0.4	0.3	0.2	0.0	0.1	0.0	0.0	0.0	0.0
1992	232.6	160.0	397.5	295.2	115.8	94.9	53.3	34.1	16.0	3.0	1.0	1.6	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
1993	486.9	146.5	120.7	301.4	216.0	80.3	59.4	30.9	18.8	8.9	1.8	0.6	1.0	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0
1994	617.7	306.5	110.4	91.1	219.2	149.7	50.6	35.1	17.6	10.8	5.4	1.1	0.4	0.6	0.1	0.1	0.1	0.0	0.0	0.0	0.0
1995	548.6	387.6	228.3	80.4	63.3	147.7	93.0	29.6	19.7	10.0	6.4	3.2	0.7	0.2	0.4	0.1	0.0	0.0	0.0	0.0	0.0
1996	417.7	344.4	289.2	168.2	57.0	43.4	93.0	55.3	17.0	11.5	6.0	3.9	2.0	0.4	0.1	0.2	0.0	0.0	0.0	0.0	0.0
1997	341.4	262.9	259.4	217.6	121.8	39.5	27.4	55.0	31.3	9.8	6.9	3.7	2.4	1.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0
1998	617.5	214.4	196.4	195.2	160.8	87.6	26.4	17.3	33.5	19.3	6.3	4.5	2.4	1.6	0.8	0.2	0.1	0.1	0.0	0.0	0.0
1999	575.5	388.8	161.7	149.1	143.7	113.5	56.5	15.7	9.7	19.1	11.9	4.0	2.9	1.6	1.0	0.5	0.1	0.0	0.1	0.0	0.0
2000	612.1	361.5	290.8	124.8	112.0	98.0	70.1	33.0	8.7	5.5	11.6	7.4	2.5	1.8	1.0	0.6	0.3	0.1	0.0	0.0	0.0
2001	853.1	383.3	267.4	220.5	94.3	81.0	67.0	46.7	21.6	5.8	3.8	8.1	5.2	1.7	1.3	0.7	0.4	0.2	0.0	0.0	0.0
2002	322.9	536.8	288.4	209.0	169.4	67.4	54.1	43.5	29.7	13.9	3.8	2.5	5.4	3.5	1.2	0.9	0.5	0.3	0.2	0.0	0.0
2003	214.7	202.9	402.1	224.6	163.1	127.3	48.2	37.7	29.7	20.5	9.9	2.8	1.8	4.0	2.6	0.9	0.6	0.3	0.2	0.1	0.1
2004	270.0	134.5	150.4	306.7	170.9	119.3	88.5	32.5	24.7	19.7	14.3	7.0	2.0	1.3	2.8	1.8	0.6	0.4	0.2	0.2	0.1
2005	344.0	169.3	99.9	115.1	234.1	125.6	83.8	60.9	22.0	16.9	13.9	10.2	5.0	1.4	0.9	2.0	1.3	0.4	0.3	0.2	0.2

Table 29. Gag—Base run with time-varying catchability: Estimated biomass at age (klb)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1962	60	336	632	818	989	1082	1110	1097	1046	975	894	813	733	656	583	517	456	402	354	310	2737
1963	41	255	643	881	974	1072	1099	1079	1032	965	886	804	726	650	579	513	454	399	352	309	2650
1964	37	177	487	897	1051	1058	1091	1070	1017	953	879	799	719	645	575	510	451	398	350	308	2578
1965	29	158	338	681	1071	1141	1077	1062	1009	940	869	793	716	640	571	507	449	396	349	307	2517
1966	33	125	302	472	811	1161	1161	1048	1001	932	856	783	709	635	565	503	446	394	347	305	2459
1967	67	139	239	423	564	883	1186	1134	992	929	853	775	704	633	565	501	444	393	347	305	2419
1968	93	285	265	329	498	604	884	1133	1049	898	830	754	680	613	549	488	432	382	338	298	2327
1969	95	397	544	360	382	523	592	824	1020	925	782	714	644	577	518	462	410	362	320	282	2184
1970	75	407	758	748	423	407	522	563	757	919	821	687	623	558	497	445	396	350	309	273	2094
1971	187	320	777	1034	872	446	401	488	508	669	800	708	587	529	472	419	374	332	294	259	1972
1972	69	797	610	1060	1204	921	439	373	438	447	581	688	604	498	446	396	351	313	278	245	1853
1973	85	296	1519	842	1250	1290	920	417	343	395	397	511	600	523	429	383	340	301	267	237	1782
1974	64	363	554	2093	990	1333	1279	865	378	305	346	344	439	512	445	364	324	287	253	225	1691
1975	56	272	680	762	2456	1052	1312	1189	775	332	264	296	292	371	430	372	304	270	239	210	1585
1976	31	240	521	934	893	2604	1032	1214	1060	676	285	224	250	245	309	358	309	251	223	197	1476
1977	127	132	460	735	1079	930	2497	929	1050	897	564	235	183	203	198	249	288	248	201	179	1333
1978	128	541	253	646	848	1122	888	2230	796	880	741	461	191	148	163	158	199	229	197	160	1195
1979	79	548	1030	335	729	856	1024	746	1785	622	678	565	349	144	111	122	118	148	170	146	999
1980	76	338	1044	1375	381	740	784	861	597	1394	480	518	428	263	108	83	91	88	110	126	845
1981	169	324	641	1405	1573	389	680	661	690	466	1076	367	393	323	197	81	62	67	65	81	718
1982	49	718	609	815	1521	1526	336	532	487	496	331	757	256	273	223	136	55	42	46	45	544
1983	61	210	1367	824	936	1545	1362	268	399	356	358	237	538	181	192	156	95	39	29	32	408
1984	125	259	389	1682	863	878	1275	1008	187	271	239	238	156	353	118	125	101	61	25	19	282
1985	128	532	467	417	1510	664	578	756	566	103	147	129	127	83	187	62	66	53	32	13	157
1986	121	548	982	587	448	1473	595	454	480	305	52	72	63	61	40	89	30	31	25	15	81
1987	109	512	999	1175	559	372	1134	437	323	335	210	35	49	42	41	27	60	20	21	17	63
1988	102	465	927	1184	1172	481	265	686	243	174	179	111	19	26	22	21	14	31	10	11	41
1989	168	433	828	1160	1264	1130	414	187	378	116	79	81	50	8	11	10	9	6	13	4	23
1990	178	715	768	989	1168	1097	763	203	75	142	43	29	30	18	3	4	3	3	2	5	10
1991	51	760	1327	966	1040	1038	777	445	107	38	72	22	15	15	9	1	2	2	2	1	7
1992	50	219	1441	1707	1038	950	785	506	262	61	23	44	13	9	9	5	1	1	1	1	5
1993	103	212	415	1888	1785	922	700	503	294	148	36	14	26	8	5	5	3	1	1	1	3
1994	124	437	402	541	1961	1580	681	454	300	171	89	22	8	16	5	3	3	2	0	0	2
1995	109	526	816	503	534	1680	1144	434	265	171	101	53	13	5	9	3	2	2	1	0	2
1996	85	464	984	1035	507	466	1235	742	260	155	102	61	32	8	3	6	2	1	1	1	1
1997	69	362	879	1276	1066	445	341	789	433	148	91	61	36	19	5	2	3	1	1	1	1
1998	122	292	678	1138	1341	973	345	233	495	265	93	58	39	23	12	3	1	2	1	0	1
1999	109	521	554	886	1186	1192	719	219	131	272	156	57	36	24	14	7	2	1	1	0	1
2000	115	463	976	739	942	1007	831	444	122	72	159	94	34	21	14	8	4	1	0	1	1
2001	154	487	857	1274	791	854	786	595	298	80	48	108	64	23	14	10	6	3	1	0	1
2002	61	653	919	1157	1385	704	645	542	383	188	52	31	70	41	15	9	6	4	2	0	1
2003	44	261	1225	1234	1283	1307	574	483	380	263	132	37	22	49	29	10	6	4	2	1	1
2004	58	188	483	1602	1324	1169	1031	412	320	247	178	91	25	15	34	20	7	4	3	2	1
2005	75	246	349	633	1721	1207	927	753	284	216	169	123	63	17	10	23	13	5	3	2	2

Table 30. Gag– Base run with constant catchability: Estimated biomass at age (klb)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1962	168	420	598	705	826	908	951	959	936	895	844	785	723	659	596	536	480	427	379	335	3027
1963	108	305	620	763	817	897	939	946	924	884	834	776	715	653	591	532	476	424	377	333	2916
1964	98	195	450	792	885	889	929	936	913	874	825	769	709	648	587	529	474	422	375	332	2824
1965	71	178	289	575	919	963	922	926	904	865	817	762	703	643	583	526	471	420	374	331	2746
1966	71	128	263	368	666	999	997	918	894	855	807	753	696	636	577	521	468	417	371	329	2673
1967	144	128	190	336	428	726	1038	997	890	850	803	749	692	633	575	519	466	417	371	329	2623
1968	187	261	189	240	385	458	739	1014	942	824	776	724	668	612	556	503	452	404	360	320	2509
1969	174	339	382	236	269	404	456	704	931	846	729	678	626	573	521	471	424	379	338	301	2330
1970	123	316	498	482	269	287	408	442	659	854	765	651	600	549	499	452	406	364	325	289	2215
1971	189	222	463	622	541	282	285	387	404	589	752	666	561	512	466	421	379	340	303	270	2053
1972	192	341	325	577	696	565	278	268	351	358	515	649	569	475	431	389	351	314	281	250	1889
1973	569	348	501	409	654	737	568	268	249	319	321	455	568	493	409	369	332	298	266	237	1782
1974	330	1009	504	631	470	703	750	550	250	227	286	284	399	494	426	351	316	283	253	225	1685
1975	292	591	1461	632	720	501	707	716	503	222	199	248	244	339	417	358	294	263	235	209	1560
1976	146	529	872	1852	716	755	493	658	636	435	189	167	206	201	278	339	290	237	211	188	1400
1977	409	265	783	1118	2127	741	716	436	550	516	346	148	130	158	153	211	257	218	178	158	1172
1978	398	741	393	1005	1290	2216	702	626	358	437	402	266	113	98	119	114	156	190	161	131	964
1979	295	721	1096	502	1143	1302	1999	570	468	256	307	278	182	77	66	80	76	104	125	106	713
1980	253	534	1060	1370	554	1149	1196	1665	439	345	185	219	196	127	53	45	55	52	71	85	550
1981	596	458	782	1319	1521	564	1075	1021	1319	334	257	136	159	141	91	38	32	38	37	50	439
1982	159	1076	663	942	1387	1464	496	853	744	919	227	172	90	104	92	59	24	21	25	23	308
1983	185	287	1581	832	1055	1418	1354	410	643	534	644	157	118	61	70	62	39	16	14	16	215
1984	420	332	406	1813	827	947	1149	1012	291	444	363	433	104	78	40	46	40	25	10	9	146
1985	414	754	467	444	1614	646	650	688	547	150	224	181	213	51	38	19	22	19	12	5	73
1986	350	746	1079	551	462	1552	573	510	448	298	73	104	82	96	23	17	8	10	8	5	33
1987	393	626	1053	1237	536	395	1205	420	360	309	203	49	70	54	63	15	11	5	6	5	24
1988	327	702	873	1180	1205	470	302	775	233	185	155	100	24	34	26	30	7	5	3	3	14
1989	598	583	979	1008	1221	1156	414	231	474	113	78	61	38	9	12	10	11	3	2	1	6
1990	604	1068	811	1100	991	1076	858	231	94	160	35	24	18	11	3	4	3	3	1	1	2
1991	181	1086	1528	958	1135	906	827	522	115	43	70	15	10	8	5	1	1	1	1	0	1
1992	165	326	1575	1854	1020	1081	741	555	295	61	23	38	8	5	4	2	1	1	1	1	1
1993	346	299	478	1893	1902	915	825	503	347	183	39	15	24	5	3	3	2	0	0	0	1
1994	439	625	438	572	1931	1704	704	572	326	222	119	26	10	15	3	2	2	1	0	0	1
1995	389	791	904	505	558	1682	1292	482	364	205	143	77	17	6	10	2	1	1	1	0	1
1996	296	702	1146	1057	502	494	1293	899	314	235	134	94	50	11	4	6	1	1	1	0	0
1997	242	536	1028	1367	1073	449	381	895	579	200	153	88	61	32	7	2	4	1	1	0	1
1998	438	437	778	1226	1416	998	366	282	618	395	140	107	61	42	22	5	2	3	1	0	1
1999	409	793	641	937	1266	1292	786	256	179	391	264	95	72	41	28	15	3	1	2	0	1
2000	435	737	1152	784	987	1116	974	538	161	112	258	177	63	48	27	18	9	2	1	1	1
2001	606	782	1059	1385	830	922	931	761	399	118	83	191	130	46	35	19	13	7	1	1	1
2002	229	1095	1143	1313	1492	768	752	707	548	284	85	60	137	92	32	24	13	9	5	1	1
2003	152	414	1593	1411	1437	1450	670	614	548	420	221	66	46	105	70	24	18	10	7	3	2
2004	192	274	596	1927	1506	1359	1230	529	456	404	317	167	50	35	77	51	18	13	7	5	4
2005	244	345	396	723	2062	1430	1165	992	406	346	309	241	126	37	26	57	38	13	10	5	6

Table 31. Gag—Base run with time-varying catchability: Estimated biomass at age (mt)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1962	27	152	287	371	448	491	504	498	475	442	405	369	332	298	264	234	207	183	160	141	1242
1963	19	116	291	400	442	486	499	489	468	438	402	365	329	295	263	233	206	181	160	140	1202
1964	17	80	221	407	477	480	495	485	461	432	399	362	326	292	261	232	205	180	159	140	1169
1965	13	72	154	309	486	518	489	482	458	426	394	360	325	290	259	230	204	180	158	139	1142
1966	15	57	137	214	368	527	527	475	454	423	388	355	322	288	256	228	202	179	157	139	1115
1967	30	63	108	192	256	400	538	515	450	421	387	352	319	287	256	227	202	178	157	138	1097
1968	42	129	120	149	226	274	401	514	476	408	376	342	308	278	249	221	196	173	153	135	1056
1969	43	180	247	163	173	237	269	374	463	420	355	324	292	262	235	210	186	164	145	128	991
1970	34	185	344	339	192	185	237	255	343	417	373	311	282	253	226	202	180	159	140	124	950
1971	85	145	352	469	395	202	182	221	230	304	363	321	266	240	214	190	170	151	133	117	895
1972	31	361	277	481	546	418	199	169	199	203	264	312	274	226	202	180	159	142	126	111	840
1973	39	134	689	382	567	585	417	189	156	179	180	232	272	237	195	174	154	136	121	107	808
1974	29	165	251	949	449	604	580	392	172	138	157	156	199	232	202	165	147	130	115	102	767
1975	26	124	308	345	1114	477	595	540	352	151	120	134	133	168	195	169	138	122	108	95	719
1976	14	109	236	424	405	1181	468	551	481	307	129	102	113	111	140	162	140	114	101	89	670
1977	57	60	209	333	490	422	1133	421	476	407	256	107	83	92	90	113	131	112	91	81	605
1978	58	245	115	293	385	509	403	1012	361	399	336	209	87	67	74	72	90	104	89	73	542
1979	36	248	467	152	331	388	464	338	810	282	308	256	158	65	50	55	53	67	77	66	453
1980	34	153	474	624	173	336	355	391	271	632	218	235	194	119	49	37	41	40	50	57	383
1981	76	147	291	637	714	176	309	300	313	212	488	166	178	147	89	37	28	31	30	37	326
1982	22	326	276	370	690	692	152	241	221	225	150	343	116	124	101	62	25	19	21	20	247
1983	28	95	620	374	424	701	618	122	181	161	162	108	244	82	87	71	43	17	13	15	185
1984	57	118	176	763	391	398	578	457	85	123	108	108	71	160	54	57	46	28	11	9	128
1985	58	241	212	189	685	301	262	343	257	47	67	58	58	38	85	28	30	24	15	6	71
1986	55	249	445	266	203	668	270	206	218	138	23	33	28	28	18	41	13	14	11	7	37
1987	49	232	453	533	254	169	514	198	146	152	95	16	22	19	19	12	27	9	9	8	29
1988	46	211	420	537	531	218	120	311	110	79	81	51	8	12	10	10	6	14	5	5	19
1989	76	197	376	526	573	512	188	85	171	53	36	37	23	4	5	4	4	3	6	2	10
1990	81	324	349	449	530	498	346	92	34	64	20	13	13	8	1	2	2	2	1	2	4
1991	23	345	602	438	472	471	353	202	49	17	33	10	7	7	4	1	1	1	1	0	3
1992	23	99	654	774	471	431	356	229	119	28	10	20	6	4	4	2	0	1	0	0	2
1993	47	96	188	856	810	418	318	228	133	67	16	6	12	4	2	2	1	0	0	0	2
1994	56	198	182	245	889	716	309	206	136	78	40	10	4	7	2	1	1	1	0	0	1
1995	50	238	370	228	242	762	519	197	120	78	46	24	6	2	4	1	1	1	1	0	1
1996	39	211	447	469	230	211	560	337	118	70	46	28	14	4	1	3	1	0	0	0	0
1997	31	164	399	579	484	202	154	358	196	67	41	28	16	9	2	1	1	0	0	0	0
1998	55	133	308	516	608	441	156	106	225	120	42	27	18	10	5	1	0	1	0	0	0
1999	49	236	251	402	538	541	326	99	59	124	71	26	16	11	6	3	1	0	1	0	0
2000	52	210	443	335	427	457	377	201	55	32	72	43	16	10	6	4	2	0	0	0	0
2001	70	221	389	578	359	387	357	270	135	36	22	49	29	10	7	4	3	1	0	0	0
2002	28	296	417	525	628	319	293	246	174	85	24	14	32	19	7	4	3	2	1	0	0
2003	20	118	556	560	582	593	261	219	172	119	60	17	10	22	13	5	3	2	1	1	0
2004	26	85	219	727	601	530	468	187	145	112	81	41	12	7	15	9	3	2	1	1	1
2005	34	111	158	287	781	548	420	342	129	98	77	56	28	8	5	10	6	2	1	1	1

Table 32. Gag– Base run with constant catchability: Estimated biomass at age (mt)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1962	76	191	271	320	374	412	431	435	425	406	383	356	328	299	271	243	218	194	172	152	1373
1963	49	138	281	346	371	407	426	429	419	401	378	352	325	296	268	241	216	192	171	151	1323
1964	45	89	204	359	401	403	421	424	414	397	374	349	322	294	266	240	215	192	170	151	1281
1965	32	81	131	261	417	437	418	420	410	393	371	346	319	291	264	238	214	191	170	150	1246
1966	32	58	119	167	302	453	452	416	405	388	366	342	316	289	262	236	212	189	168	149	1213
1967	65	58	86	153	194	329	471	452	404	386	364	340	314	287	261	235	211	189	168	149	1190
1968	85	118	86	109	175	208	335	460	427	374	352	328	303	278	252	228	205	183	163	145	1138
1969	79	154	173	107	122	183	207	319	422	384	331	308	284	260	237	214	192	172	154	136	1057
1970	56	143	226	219	122	130	185	200	299	387	347	295	272	249	226	205	184	165	147	131	1005
1971	86	101	210	282	245	128	129	176	183	267	341	302	254	232	211	191	172	154	138	122	931
1972	87	155	148	262	316	256	126	122	159	162	234	294	258	216	195	177	159	143	127	113	857
1973	258	158	227	186	297	334	258	121	113	145	145	206	258	224	186	167	151	135	121	108	808
1974	150	458	229	286	213	319	340	250	113	103	130	129	181	224	193	159	143	128	115	102	764
1975	132	268	663	287	327	227	321	325	228	101	90	112	110	154	189	162	133	119	106	95	708
1976	66	240	396	840	325	342	224	298	289	197	86	76	93	91	126	154	131	108	96	85	635
1977	185	120	355	507	965	336	325	198	250	234	157	67	59	72	69	96	116	99	81	72	532
1978	180	336	178	456	585	1005	319	284	162	198	182	121	51	44	54	52	71	86	73	59	437
1979	134	327	497	228	518	591	907	259	212	116	139	126	83	35	30	36	35	47	57	48	323
1980	115	242	481	622	251	521	542	755	199	156	84	99	89	58	24	21	25	24	32	39	249
1981	271	208	355	598	690	256	488	463	598	151	117	62	72	64	41	17	15	17	17	23	199
1982	72	488	301	427	629	664	225	387	338	417	103	78	41	47	42	27	11	9	11	11	140
1983	84	130	717	378	478	643	614	186	292	242	292	71	53	28	32	28	18	7	6	7	98
1984	191	151	184	823	375	430	521	459	132	202	165	196	47	35	18	21	18	11	5	4	66
1985	188	342	212	201	732	293	295	312	248	68	102	82	97	23	17	9	10	9	5	2	33
1986	159	338	490	250	210	704	260	231	203	135	33	47	37	43	10	8	4	4	4	2	15
1987	178	284	478	561	243	179	546	190	163	140	92	22	32	25	28	7	5	2	3	2	11
1988	148	318	396	535	546	213	137	352	106	84	70	45	11	15	12	14	3	2	1	1	6
1989	271	264	444	457	554	524	188	105	215	51	35	28	17	4	6	4	5	1	1	0	3
1990	274	484	368	499	449	488	389	105	43	72	16	11	8	5	1	2	1	1	0	0	1
1991	82	493	693	434	515	411	375	237	52	19	32	7	5	3	2	0	1	1	1	0	0
1992	75	148	714	841	463	490	336	252	134	28	10	17	4	2	2	1	0	0	0	0	0
1993	157	136	217	859	863	415	374	228	157	83	18	7	11	2	2	1	1	0	0	0	0
1994	199	284	198	260	876	773	319	259	148	101	54	12	4	7	1	1	1	0	0	0	0
1995	177	359	410	229	253	763	586	218	165	93	65	35	7	3	4	1	1	0	0	0	0
1996	134	319	520	479	228	224	587	408	143	106	61	42	23	5	2	3	1	0	0	0	0
1997	110	243	466	620	487	204	173	406	262	91	69	40	28	15	3	1	2	0	0	0	0
1998	199	198	353	556	643	453	166	128	281	179	63	49	28	19	10	2	1	1	0	0	0
1999	185	360	291	425	574	586	356	116	81	178	120	43	33	19	13	7	1	1	1	0	0
2000	197	334	522	356	448	506	442	244	73	51	117	80	29	22	12	8	4	1	0	1	0
2001	275	355	480	628	377	418	422	345	181	54	38	87	59	21	16	9	6	3	1	0	1
2002	104	497	518	595	677	348	341	321	248	129	39	27	62	42	15	11	6	4	2	0	1
2003	69	188	723	640	652	658	304	279	249	190	100	30	21	47	32	11	8	5	3	2	1
2004	87	124	270	874	683	616	558	240	207	183	144	76	23	16	35	23	8	6	3	2	2
2005	111	157	180	328	935	649	528	450	184	157	140	110	57	17	12	26	17	6	4	2	3

Table 33. Gag—Base run with time-varying catchability: 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). Exploitation rate (E) is of ages 2^+. Sensitivity runs are described with more detail in section §3.1.3. Symbols, abbreviations, and acronyms are listed in Appendix A.

Description	R_0	Steepness	MSY (klb)	Fmsy	F_{2004}/F_{MSY}	E_{MSY}	E_{2004}/E_{MSY}	SSB_{MSY} (klb)	SSB_{2005}/SSB_{MSY}
Base Run	**417411**	**0.95**	**1111**	**0.28**	**1.46**	**0.07**	**1.86**	**6298**	**0.91**
Double-logistic selectivity for HB	452697	0.95	1218	0.27	1.44	0.06	1.81	7103	0.85
Double fraction of gag in unclassified	573745	0.83	1407	0.20	1.90	0.06	2.14	10460	0.57
Reproductive output as female biomass	444736	0.95	1230	0.28	1.38	0.07	1.55	5563	1.00
Reproductive output as male biomass	549068	0.95	1427	0.20	1.87	0.05	2.15	2831	0.24
Increase MRFSS landings by 50%	532079	0.95	1407	0.24	1.71	0.07	1.92	8219	0.74
Decrease MRFSS landings by 50%	468656	0.81	1094	0.71	1.28	0.05	2.21	7284	0.61

Table 34. Gag– Base run with constant catchability: 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). Exploitation rate (E) is of ages 2^+. Sensitivity runs are described with more detail in section §3.1.3. Symbols, abbreviations, and acronyms are listed in Appendix A.

Description	R_0	Steepness	MSY (klb)	Fmsy	F_{2004}/F_{MSY}	E_{MSY}	E_{2004}/E_{MSY}	SSB_{MSY} (klb)	SSB_{2005}/SSB_{MSY}
Base Run	**468463**	**0.95**	**1238**	**0.24**	**1.31**	**0.06**	**1.53**	**7925**	**0.94**
Double-logistic selectivity for HB	457044	0.95	1210	0.26	1.29	0.06	1.74	7360	0.95
Double fraction of gag in unclassified	556175	0.86	1397	0.20	1.58	0.06	1.85	10266	0.70
Reproductive output as female biomass	445974	0.95	1208	0.26	1.26	0.07	1.56	5568	1.09
Reproductive output as male biomass	618031	0.95	1485	0.47	0.67	0.05	1.72	2101	0.71
Increase MRFSS landings by 50%	543855	0.95	1416	0.23	1.45	0.07	1.73	8517	0.88
Decrease MRFSS landings by 50%	387026	0.95	960	0.21	1.48	0.06	1.53	6430	0.91

Table 35. Gag—Base run with time-varying catchability: Estimated status indicators, benchmarks, and related quantities from the catch-at-age model, conditional on estimated current selectivities. Precision is represented by 10th and 90th percentiles of stochastic simulations. Exploitation rates E are of ages 2^+. Estimates of yield are in thousand pounds; estimates of yield $Y_{30\%SPR}$ and $Y_{45\%SPR}$ correspond to sustainable yield given $F_{30\%}$ and $F_{45\%}$, respectively. Estimates of yield do not include discards; D_{MSY} represents discard mortalities expected when fishing at F_{MSY}. Rate estimates (F, E) are in units of per year; status indicators are dimensionless; and biomass estimates are in units of mt or pounds, as indicated. Symbols, abbreviations, and acronyms are listed in Appendix A.

Quantity	Estimate	10th Percentile	90th Percentile
F_{MSY}	0.278	0.189	0.278
$F_{30\%}$	0.250	–	–
$F_{45\%}$	0.130	–	–
F_{max}	0.300	–	–
E_{MSY}	0.066	0.046	0.066
$E_{30\%}$	0.095	–	–
$E_{45\%}$	0.060	–	–
E_{max}	0.106	–	–
SSB_{MSY}	6298	6165	7342
MSST	5416	5302	6314
MSY	1111	1013	1284
D_{MSY}	96	60	98
R_{MSY}	446267	–	–
Y at 85%F_{MSY}	1104	–	–
Y at 75%F_{MSY}	1092	–	–
Y at 65%F_{MSY}	1066	–	–
Y at $F_{30\%}$	1108	–	–
Y at $F_{45\%}$	979	–	–
Y at F_{max}	1110	–	–
F_{2004}/F_{MSY}	1.457	2.150	1.456
E_{2004}/E_{MSY}	1.859	2.649	1.857
SSB_{2005}/SSB_{MSY}	0.908	0.928	0.779
SSB_{2005}/MSST	1.056	1.079	0.906

Table 36. Gag– Base run with constant catchability: Estimated status indicators, benchmarks, and related quantities from the catch-at-age model, conditional on estimated current selectivities. Precision is represented by 10th and 90th percentiles of stochastic simulations. Exploitation rates E are of ages 2^+. *Estimates of yield are in thousand pounds; estimates of yield* $Y_{30\%SPR}$ *and* $Y_{45\%SPR}$ *correspond to sustainable yield given* $F_{30\%}$ *and* $F_{45\%}$, *respectively. Estimates of yield do not include discards;* D_{MSY} *represents discard mortalities expected when fishing at* F_{MSY}. *Rate estimates (F, E) are in units of per year; status indicators are dimensionless; and biomass estimates are in units of mt or pounds, as indicated. Symbols, abbreviations, and acronyms are listed in Appendix A.*

Quantity	Estimate	10th Percentile	90th Percentile
F_{MSY}	0.237	0.157	0.237
$F_{30\%}$	0.210	–	–
$F_{45\%}$	0.120	–	–
F_{max}	0.260	–	–
E_{MSY}	0.065	0.044	0.065
$E_{30\%}$	0.085	–	–
$E_{45\%}$	0.056	–	–
E_{max}	0.098	–	–
SSB_{MSY}	7925	7782	9419
MSST	6816	6693	8100
MSY	1238	1142	1566
D_{MSY}	107	64	108
R_{MSY}	500131	–	–
Y at 85%F_{MSY}	1230	–	–
Y at 75%F_{MSY}	1217	–	–
Y at 65%F_{MSY}	1188	–	–
Y at $F_{30\%}$	1234	–	–
Y at $F_{45\%}$	1115	–	–
Y at F_{max}	1236	–	–
F_{2004}/F_{MSY}	1.309	1.979	1.308
E_{2004}/E_{MSY}	1.527	2.238	1.526
SSB_{2005}/SSB_{MSY}	0.942	0.960	0.793
$SSB_{2005}/MSST$	1.096	1.116	0.922

Table 37. Gag—Base run with time-varying catchability: Projection results under current F (starting in 2008) (fishing mortality rate fixed at the current value in 2005-2007). 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 SSB_{MSY} = 6298 mt, R_{MSY} = 446 *recruits in* 1000*s*, F_{MSY} = 0.28/yr, *and* MSY = 1111 klb.

Year	SSB(klb)	R(1000s)	F(/yr)	L(mt)	L(klb)	Sum L(klb)	D(1000s)	D (klb)
2005	5720	444	0.406	615	1356	1356	21.9	102
2006	5064	444	0.406	583	1286	2643	22.9	82
2007	4331	442	0.406	509	1122	3765	27.8	98
2008	3971	438	0.406	446	984	4749	31.1	120
2009	3996	435	0.406	421	928	5677	32	130
2010	4145	435	0.406	427	942	6619	32	131
2011	4290	436	0.406	446	984	7603	31.8	130
2012	4388	437	0.406	464	1022	8625	31.8	130
2013	4442	438	0.406	474	1044	9670	31.8	130
2014	4472	438	–	–	–	–	–	–

Table 38. Gag– Base run with constant catchability: Projection results under current F (starting in 2008) (fishing mortality rate fixed at the current value in 2005-2007). 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 SSB_{MSY} = 7925 mt, R_{MSY} = 500 *recruits in* 1000*s*, F_{MSY} = 0.24/yr, *and* MSY = 1238 klb.

Year	SSB(klb)	R(1000s)	F(/yr)	L(mt)	L(klb)	Sum L(klb)	D(1000s)	D (klb)
2005	7468	497	0.315	663	1462	1462	21.4	108
2006	6860	499	0.315	651	1436	2898	21.4	85
2007	6062	497	0.315	589	1299	4197	26	99
2008	5604	494	0.315	528	1163	5360	29.7	122
2009	5555	491	0.315	493	1086	6447	30.9	133
2010	5660	491	0.315	489	1079	7526	30.9	135
2011	5793	492	0.315	504	1111	8636	30.8	135
2012	5898	492	0.315	521	1148	9785	30.8	134
2013	5965	493	0.315	532	1172	10,957	30.8	134
2014	6008	493	–	–	–	–	–	–

Table 39. Gag—Base run with time-varying catchability: Projection results under Fmsy (starting in 2008) (fishing mortality rate fixed at the current value in 2005-2007). 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 $\mathrm{SSB_{MSY}} = 6298$ mt, $R_{\mathrm{MSY}} = 446$ *recruits in* 1000*s*, $F_{\mathrm{MSY}} = 0.28$/yr, *and* MSY = 1111 klb.

Year	SSB(klb)	R(1000s)	F(/yr)	L(mt)	L(klb)	Sum L(klb)	D(1000s)	D (klb)
2005	5720	444	0.406	615	1356	1356	21.9	102
2006	5064	444	0.406	583	1286	2643	22.9	82
2007	4331	442	0.406	509	1122	3765	27.8	98
2008	3971	438	0.278	321	709	4473	21.6	84
2009	4319	435	0.278	330	728	5201	22.5	92
2010	4734	438	0.278	356	786	5987	22.7	94
2011	5109	440	0.278	390	860	6847	22.6	94
2012	5400	442	0.278	422	930	7777	22.7	94
2013	5610	443	0.278	444	980	8757	22.8	95
2014	5764	444	–	–	–	–	–	–

Table 40. Gag– Base run with constant catchability: Projection results under Fmsy (starting in 2008) (fishing mortality rate fixed at the current value in 2005-2007). 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 $\mathrm{SSB}_{\mathrm{MSY}}$ = 7925 mt, R_{MSY} = 500 *recruits in* 1000*s*, F_{MSY} = 0.24/yr, *and* MSY = 1238 klb.

Year	SSB(klb)	R(1000s)	F(/yr)	L(mt)	L(klb)	Sum L(klb)	D(1000s)	D (klb)
2005	7468	497	0.315	663	1462	1462	21.4	108
2006	6860	499	0.315	651	1436	2898	21.4	85
2007	6062	497	0.315	589	1299	4197	26	99
2008	5604	494	0.237	410	903	5100	22.6	93
2009	5855	491	0.237	405	893	5993	23.7	103
2010	6206	493	0.237	420	925	6919	23.8	105
2011	6550	494	0.237	447	985	7904	23.8	105
2012	6837	496	0.237	476	1048	8952	23.8	105
2013	7057	497	0.237	497	1095	10,047	23.9	105
2014	7227	497	–	–	–	–	–	–

Table 41. Gag—Base run with time-varying catchability: Projection results under 85% of Fmsy (starting in 2008) (fishing mortality rate fixed at the current value in 2005-2007). 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 SSB_{MSY} = 6298 mt, R_{MSY} = 446 *recruits in* 1000*s*, F_{MSY} = 0.28/yr, *and* MSY = 1111 klb.

Year	SSB(klb)	R(1000s)	F(/yr)	L(mt)	L(klb)	Sum L(klb)	D(1000s)	D (klb)
2005	5720	444	0.406	615	1356	1356	21.9	102
2006	5064	444	0.406	583	1286	2643	22.9	82
2007	4331	442	0.406	509	1122	3765	27.8	98
2008	3971	438	0.236	278	612	4377	18.4	72
2009	4431	435	0.236	294	647	5024	19.3	80
2010	4951	438	0.236	323	713	5737	19.5	82
2011	5423	441	0.236	360	794	6531	19.5	82
2012	5804	443	0.236	395	871	7402	19.5	82
2013	6093	445	0.236	421	929	8331	19.6	82
2014	6315	446	–	–	–	–	–	–

Table 42. Gag– Base run with constant catchability: Projection results under 85% of Fmsy (starting in 2008) (fishing mortality rate fixed at the current value in 2005-2007). 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 SSB_{MSY} = 7925 mt, R_{MSY} = 500 *recruits in* 1000*s*, F_{MSY} = 0.24/yr, *and* MSY = 1238 klb.

Year	SSB(klb)	R(1000s)	F(/yr)	L(mt)	L(klb)	Sum L(klb)	D(1000s)	D (klb)
2005	7468	497	0.315	663	1462	1462	21.4	108
2006	6860	499	0.315	651	1436	2898	21.4	85
2007	6062	497	0.315	589	1299	4197	26	99
2008	5604	494	0.202	353	779	4976	19.2	80
2009	5998	491	0.202	358	790	5766	20.3	88
2010	6478	493	0.202	379	836	6601	20.5	91
2011	6940	495	0.202	410	904	7506	20.5	91
2012	7335	497	0.202	443	976	8482	20.5	91
2013	7651	498	0.202	468	1031	9513	20.6	91
2014	7908	499	–	–	–	–	–	–

Table 43. Gag—Base run with time-varying catchability: Projection results under 75% of Fmsy (starting in 2008) (fishing mortality rate fixed at the current value in 2005-2007). 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 SSB_{MSY} = 6298 mt, R_{MSY} = 446 *recruits in* 1000*s*, F_{MSY} = 0.28/yr, *and* MSY = 1111 klb.

Year	SSB(klb)	R(1000s)	F(/yr)	L(mt)	L(klb)	Sum L(klb)	D(1000s)	D (klb)
2005	5720	444	0.406	615	1356	1356	21.9	102
2006	5064	444	0.406	583	1286	2643	22.9	82
2007	4331	442	0.406	509	1122	3765	27.8	98
2008	3971	438	0.209	248	546	4311	16.3	64
2009	4508	435	0.209	267	588	4899	17.1	71
2010	5102	439	0.209	298	658	5557	17.3	73
2011	5647	442	0.209	336	741	6298	17.3	73
2012	6097	444	0.209	372	821	7119	17.4	73
2013	6449	446	0.209	401	883	8002	17.5	73
2014	6727	447	–	–	–	–	–	–

Table 44. Gag– Base run with constant catchability: Projection results under 75% of Fmsy (starting in 2008) (fishing mortality rate fixed at the current value in 2005-2007). 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 SSB_{MSY} = 7925 mt, R_{MSY} = 500 *recruits in* 1000*s*, F_{MSY} = 0.24/yr, *and* MSY = 1238 klb.

Year	SSB(klb)	R(1000s)	F(/yr)	L(mt)	L(klb)	Sum L(klb)	D(1000s)	D (klb)
2005	7468	497	0.315	663	1462	1462	21.4	108
2006	6860	499	0.315	651	1436	2898	21.4	85
2007	6062	497	0.315	589	1299	4197	26	99
2008	5604	494	0.178	315	694	4891	17	70
2009	6096	491	0.178	325	716	5607	18	79
2010	6667	494	0.178	348	768	6375	18.2	81
2011	7216	496	0.178	381	840	7215	18.2	81
2012	7693	498	0.178	415	916	8131	18.2	81
2013	8087	499	0.178	443	976	9107	18.3	81
2014	8413	501	–	–	–	–	–	–

Table 45. Gag—Base run with time-varying catchability: Projection results under 65% of Fmsy (starting in 2008) (fishing mortality rate fixed at the current value in 2005-2007). 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 SSB_{MSY} = 6298 mt, R_{MSY} = 446 *recruits in* 1000*s*, F_{MSY} = 0.28/yr, *and* MSY = 1111 klb.

Year	SSB(klb)	R(1000s)	F(/yr)	L(mt)	L(klb)	Sum L(klb)	D(1000s)	D (klb)
2005	5720	444	0.406	615	1356	1356	21.9	102
2006	5064	444	0.406	583	1286	2643	22.9	82
2007	4331	442	0.406	509	1122	3765	27.8	98
2008	3971	438	0.181	217	478	4243	14.2	55
2009	4587	435	0.181	238	526	4769	14.9	62
2010	5260	439	0.181	270	596	5365	15.1	64
2011	5884	442	0.181	308	680	6044	15.2	64
2012	6411	445	0.181	345	761	6805	15.2	64
2013	6836	447	0.181	375	826	7631	15.3	65
2014	7181	448	–	–	–	–	–	–

Table 46. Gag– Base run with constant catchability: Projection results under 65% of Fmsy (starting in 2008) (fishing mortality rate fixed at the current value in 2005-2007). 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 $\mathrm{SSB_{MSY}}$ = 7925 mt, R_{MSY} = 500 *recruits in* 1000*s*, F_{MSY} = 0.24/yr, *and* MSY = 1238 klb.

Year	SSB(klb)	R(1000s)	F(/yr)	L(mt)	L(klb)	Sum L(klb)	D(1000s)	D (klb)
2005	7468	497	0.315	663	1462	1462	21.4	108
2006	6860	499	0.315	651	1436	2898	21.4	85
2007	6062	497	0.315	589	1299	4197	26	99
2008	5604	494	0.154	275	607	4804	14.8	61
2009	6195	491	0.154	289	638	5442	15.7	69
2010	6863	494	0.154	314	693	6135	15.9	71
2011	7507	497	0.154	348	767	6902	15.9	71
2012	8076	499	0.154	383	844	7747	15.9	71
2013	8557	501	0.154	412	908	8655	16	71
2014	8965	502	–	–	–	–	–	–

6.3.2 Figures

Figure 2. Gag– Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

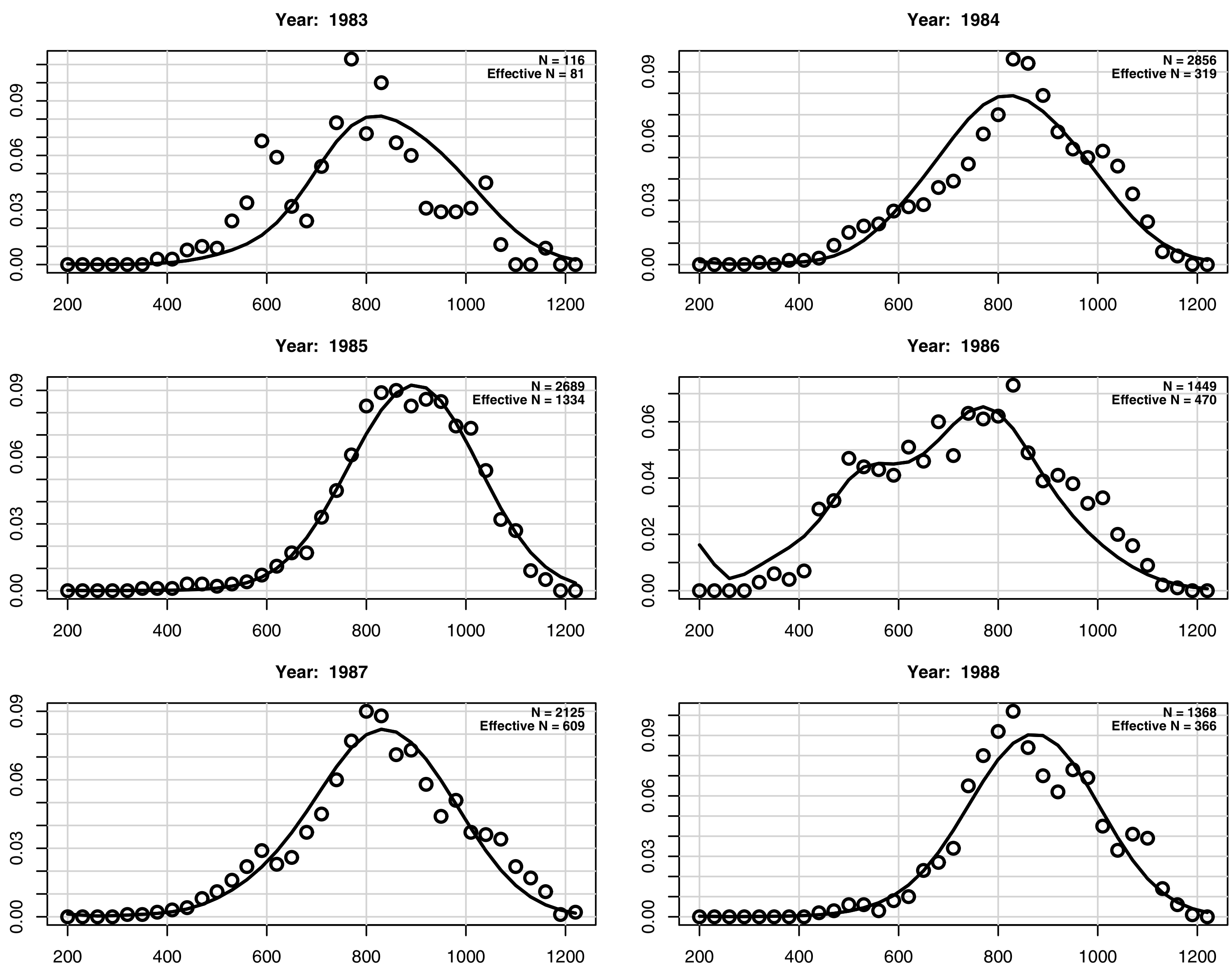


Figure 2. (cont.) Gag– Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

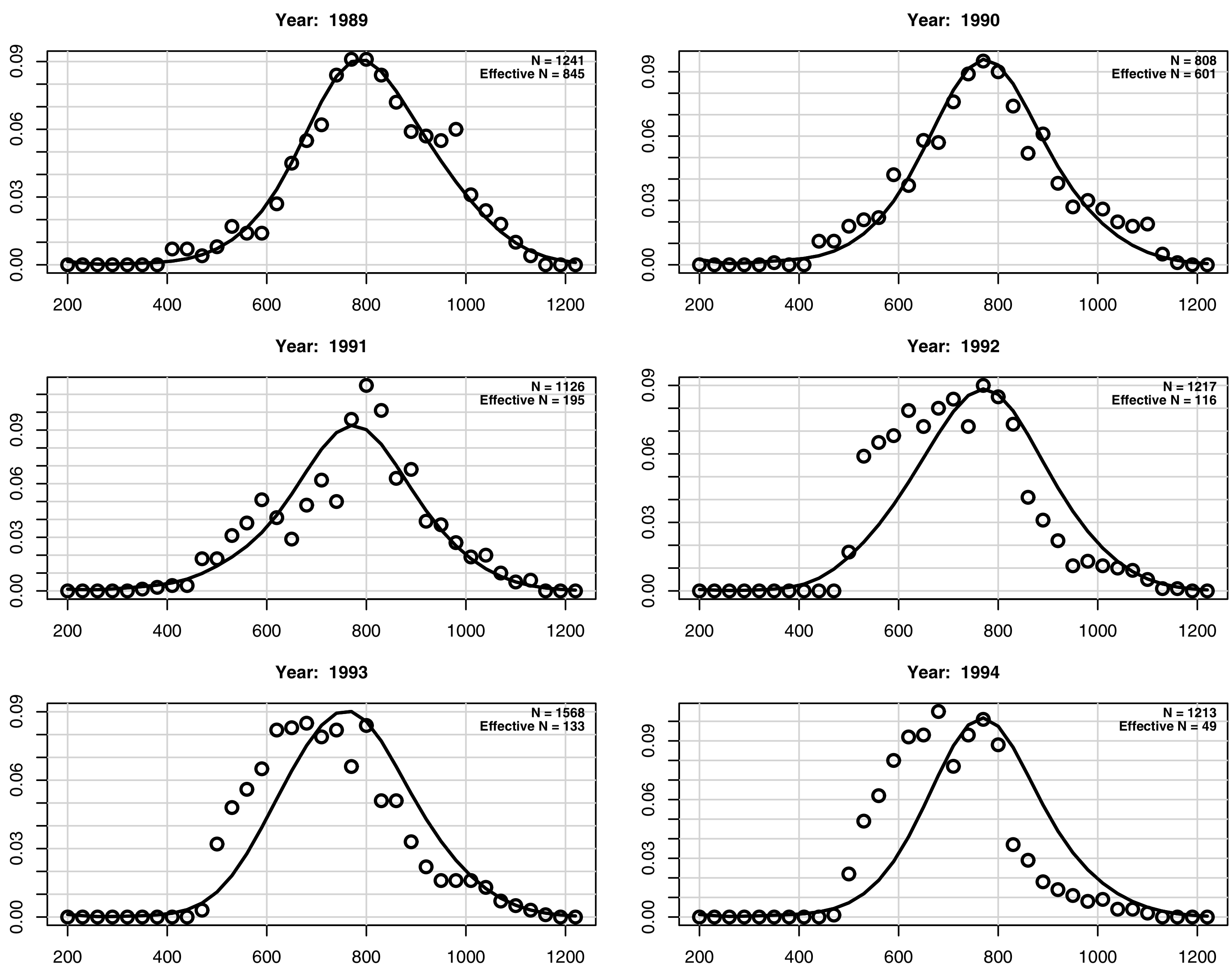


Figure 2. (cont.) Gag– Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

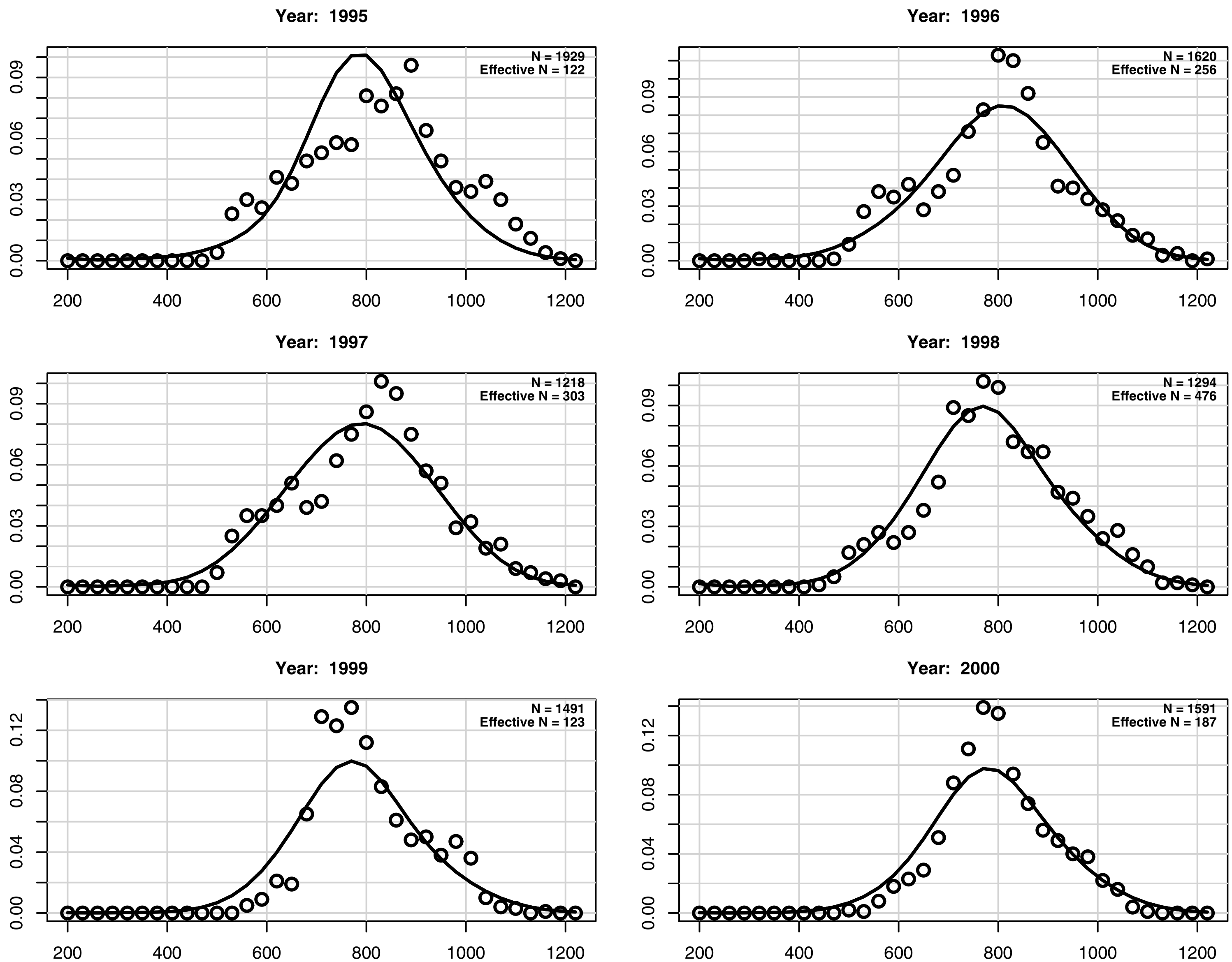


Figure 2. (cont.) Gag– Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

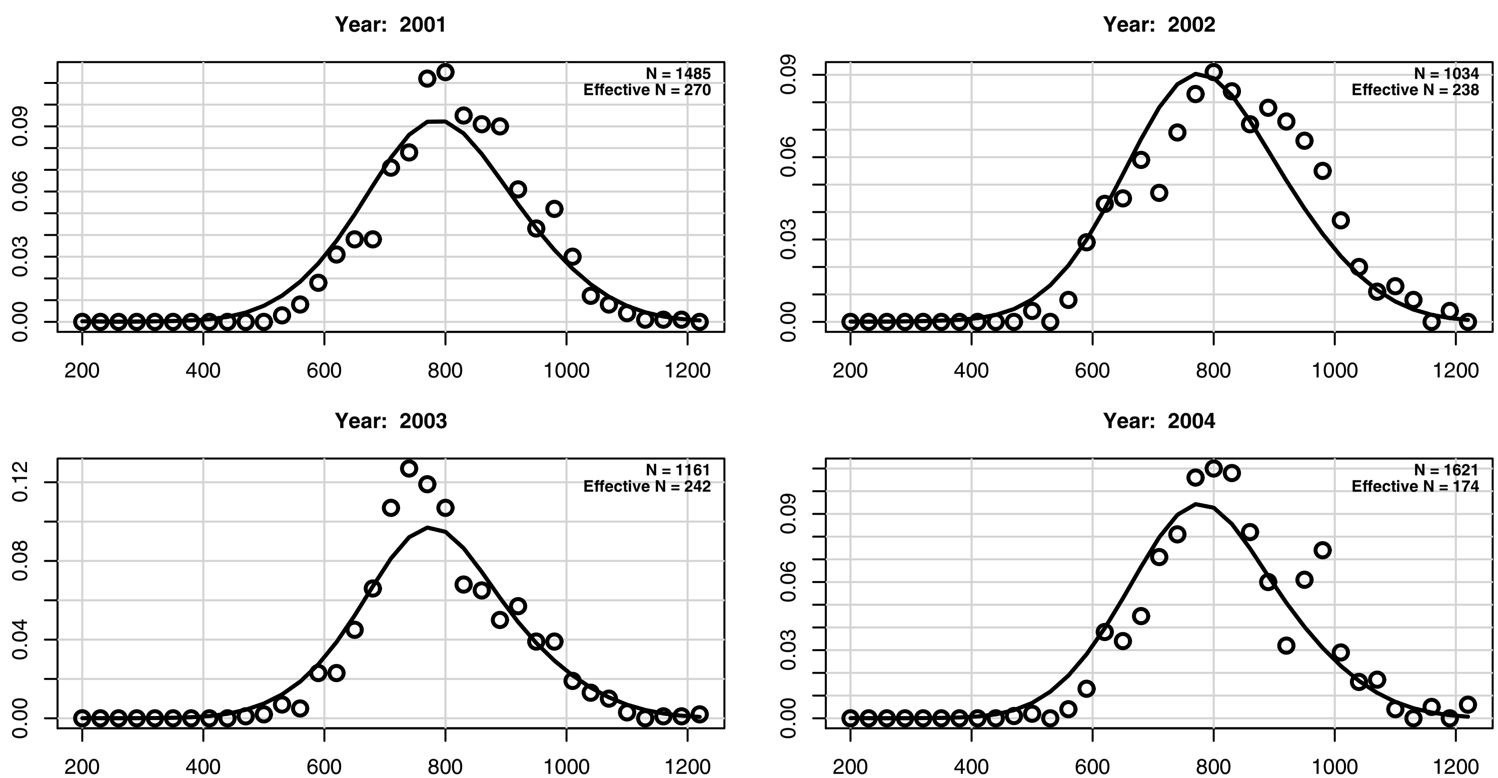


Figure 3. Gag– Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

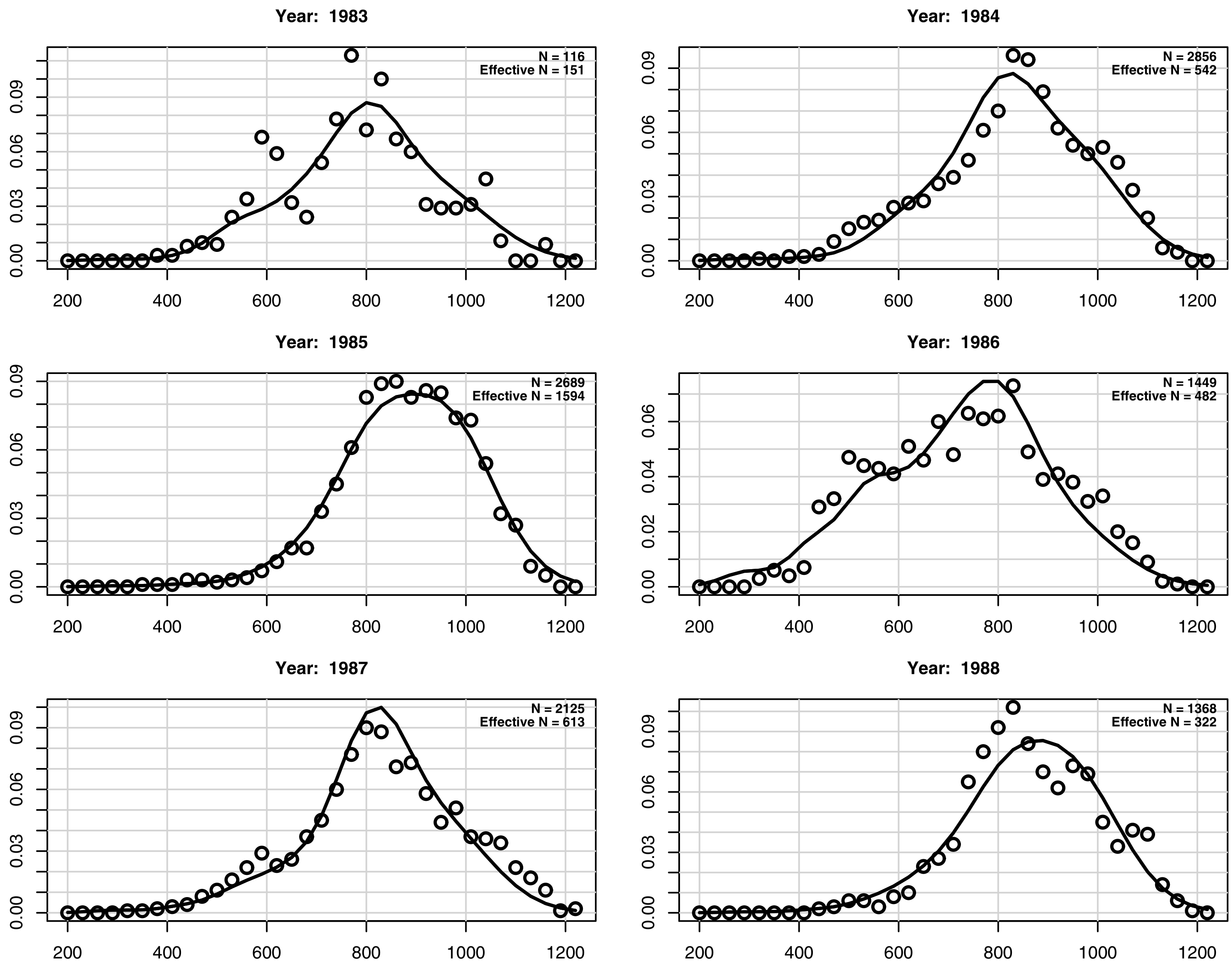


Figure 3. (cont.) Gag– Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

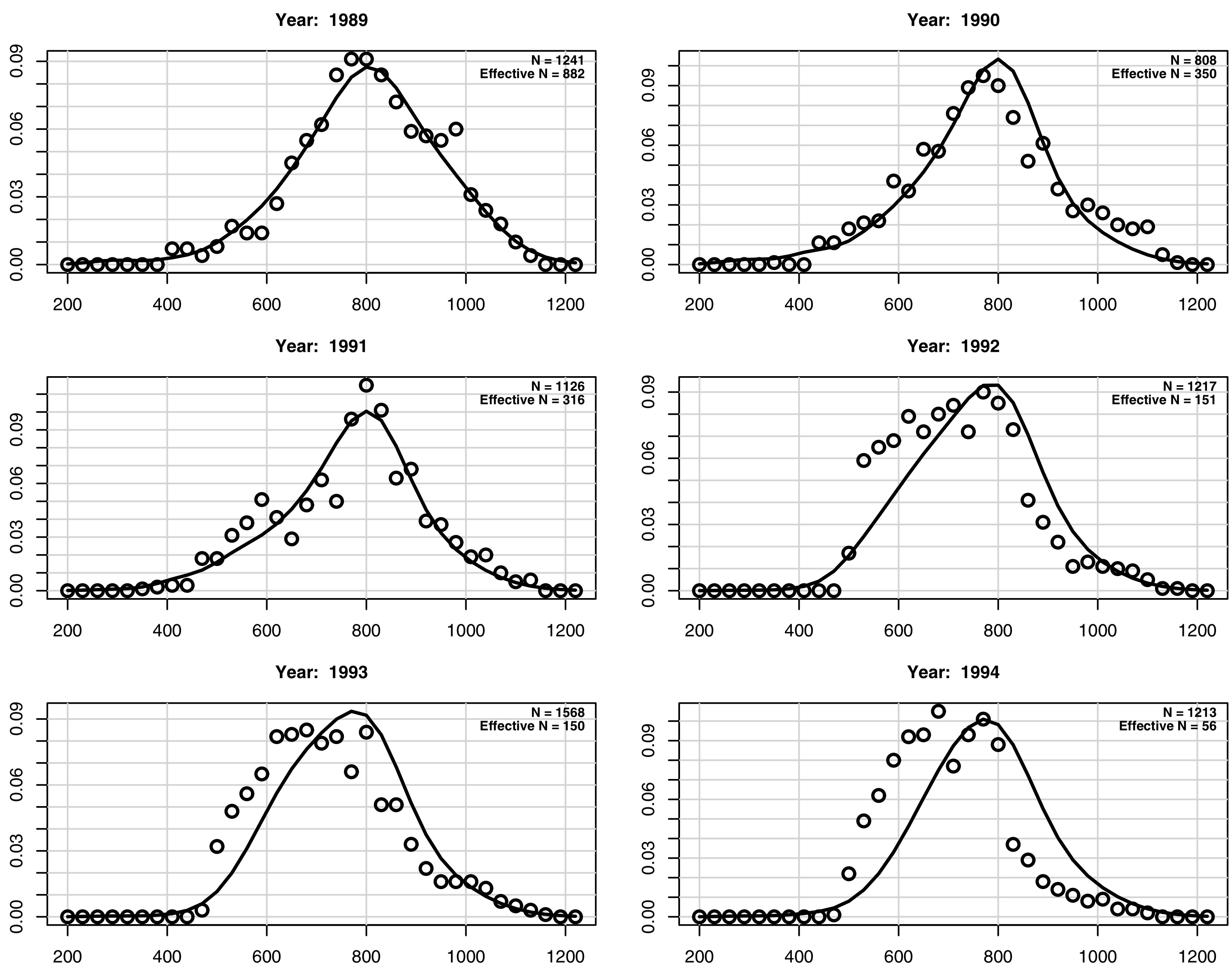


Figure 3. (cont.) Gag– Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

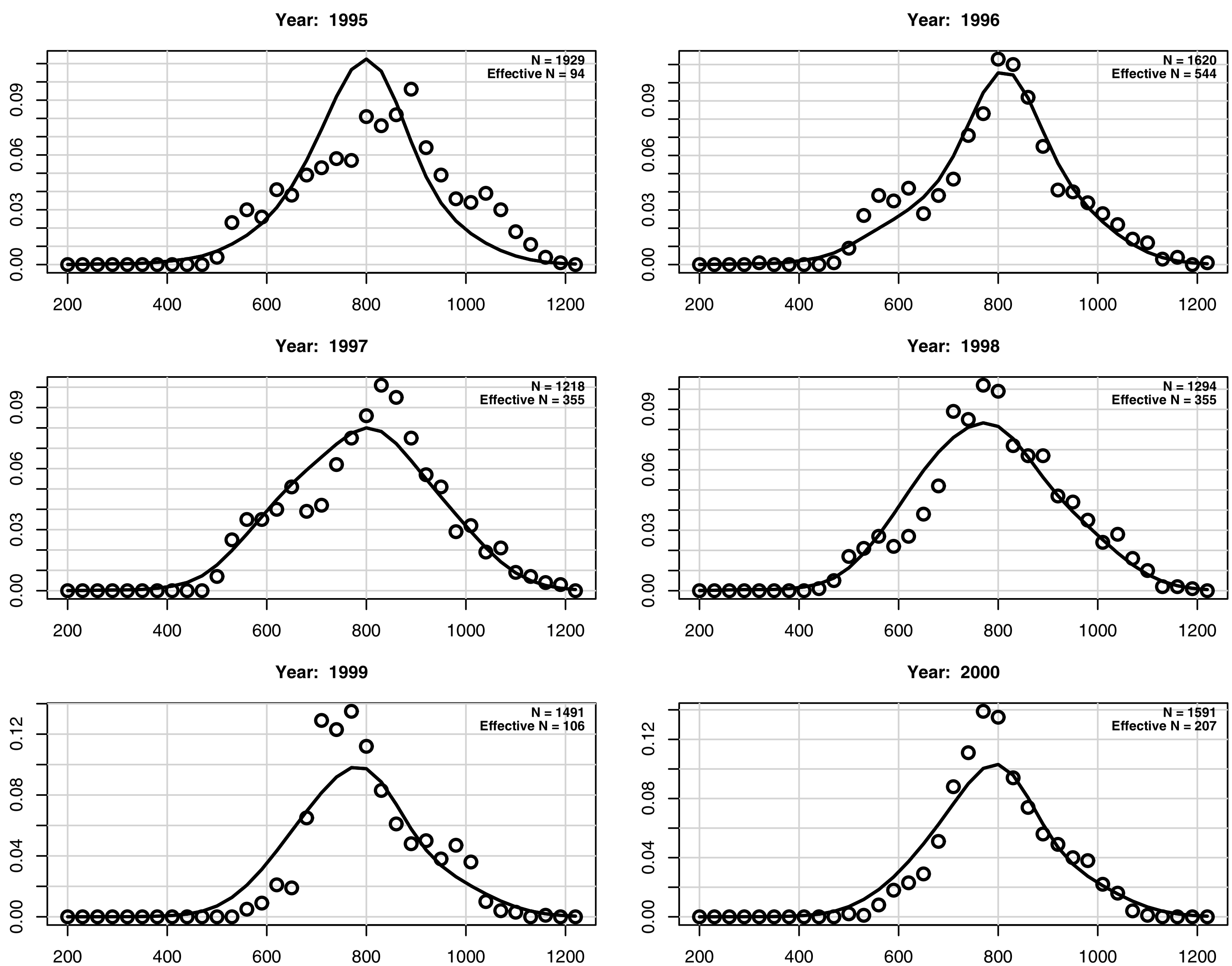


Figure 3. (cont.) Gag– Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

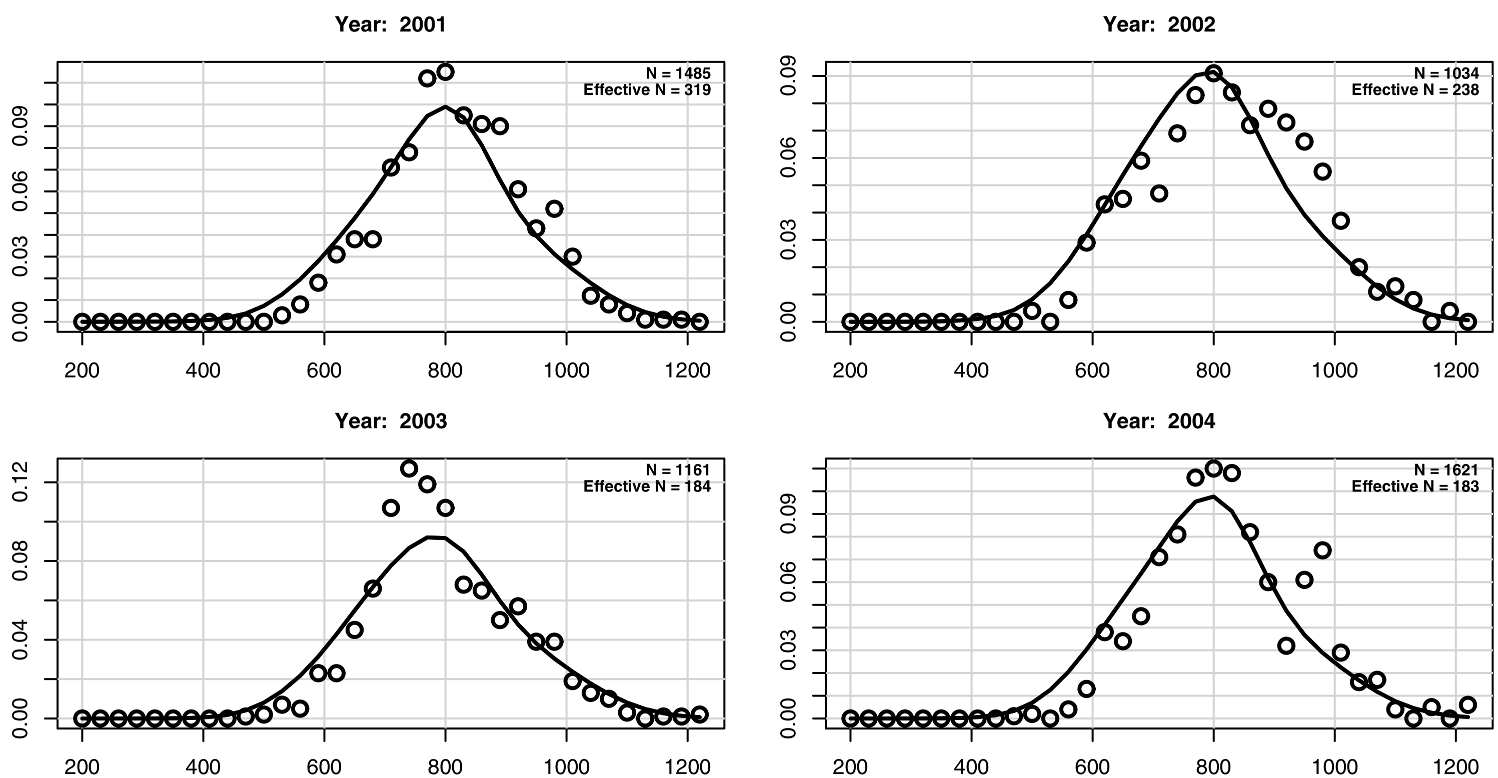


Figure 4. Gag– Base run with time-varying catchability: Bubble plot of length composition residuals from the commercial handline fishery; Dark bubbles are overestimates and light bubbles are underestimates.

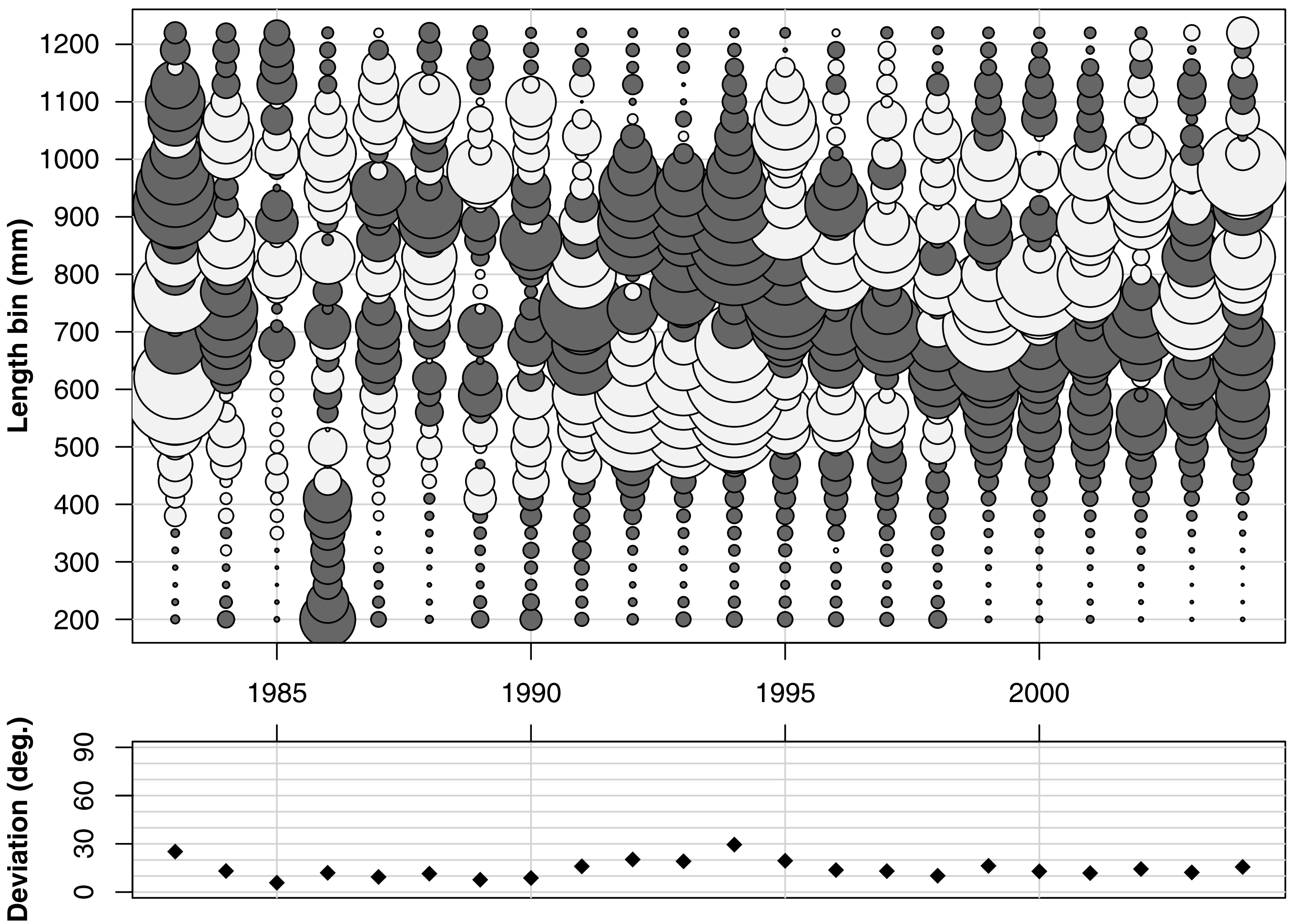


Figure 5. Gag– Base run with constant catchability: Bubble plot of length composition residuals from the commercial handline fishery; Dark bubbles are overestimates and light bubbles are underestimates.

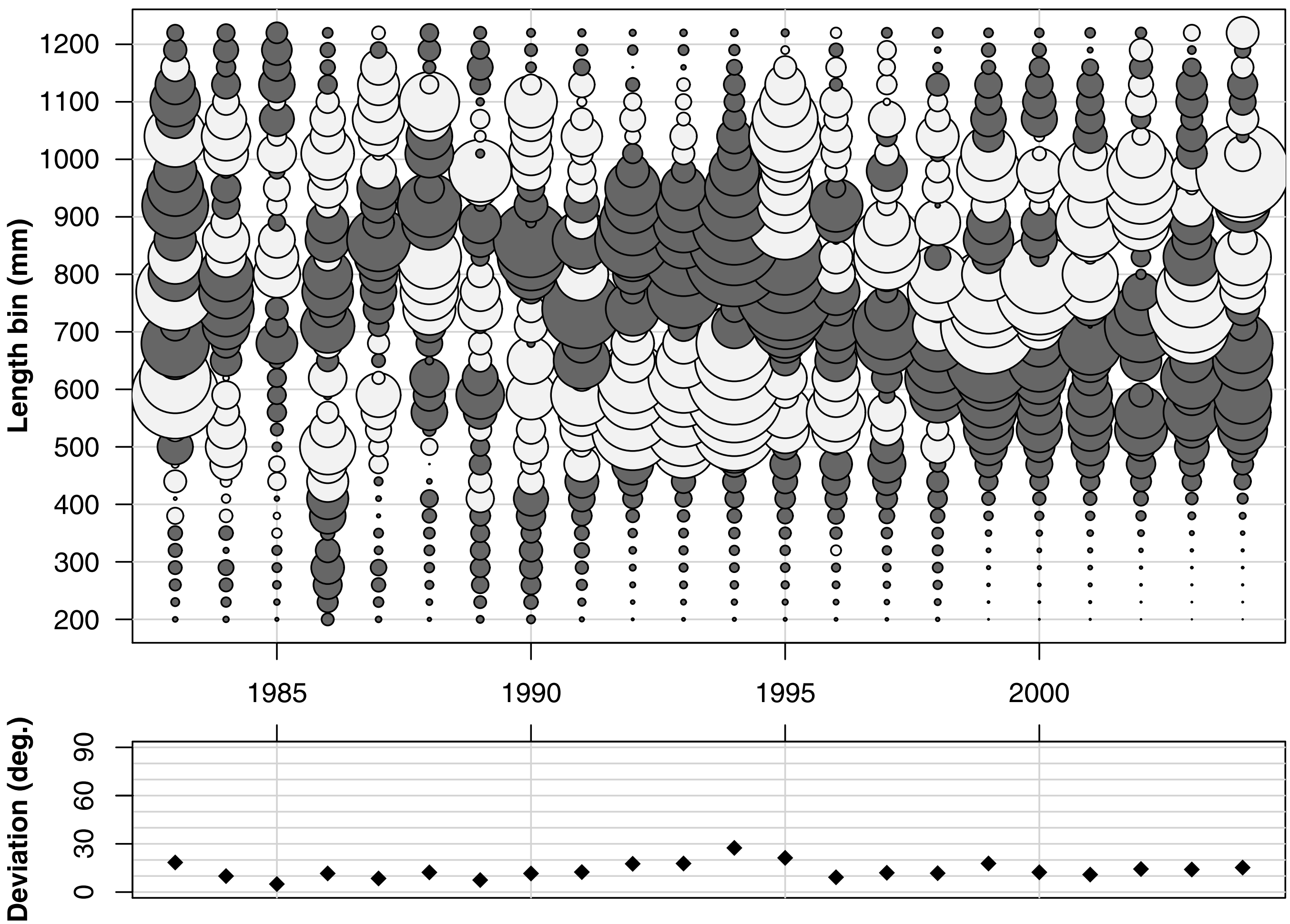


Figure 6. Gag– Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from commercial diving. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

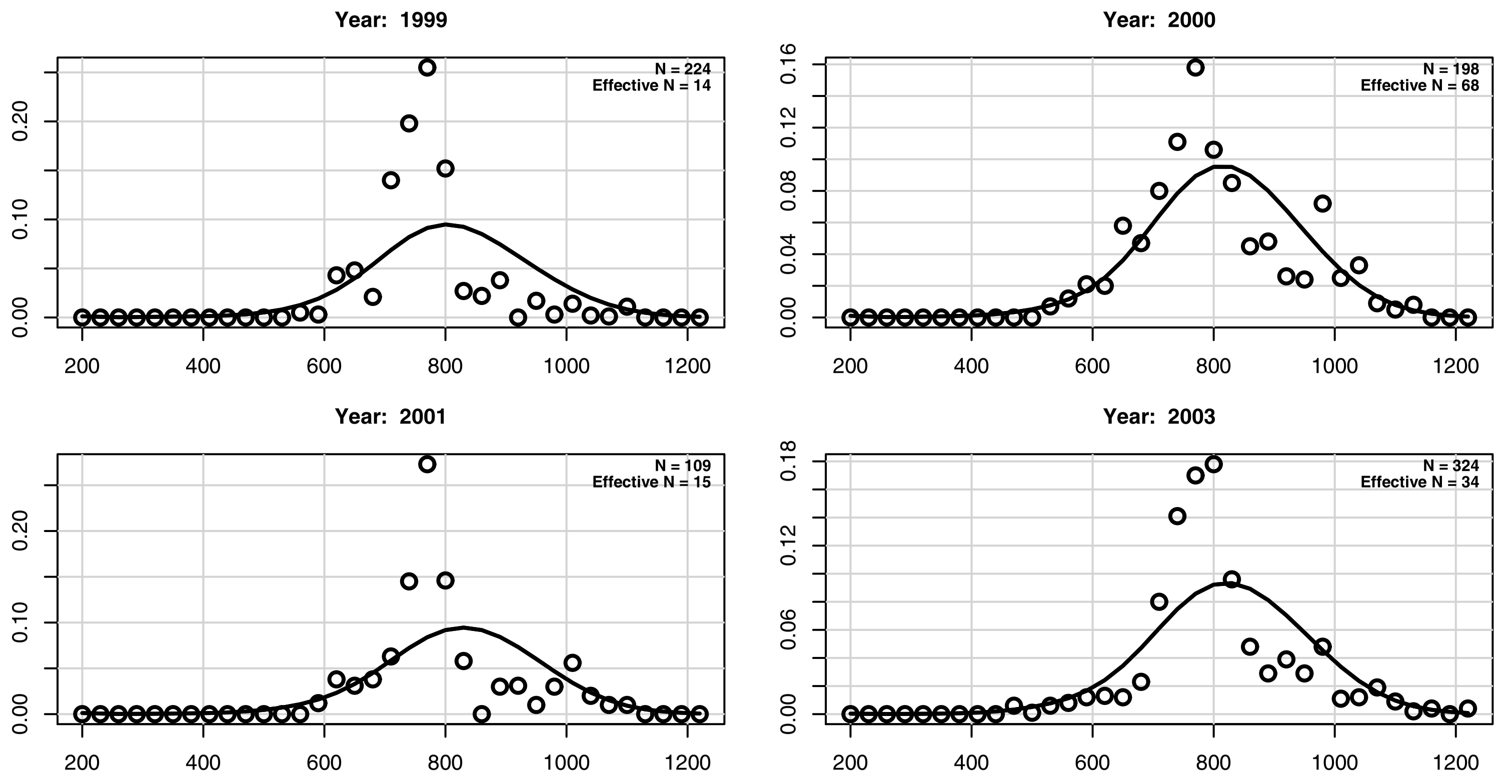


Figure 7. Gag– Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from commercial diving. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

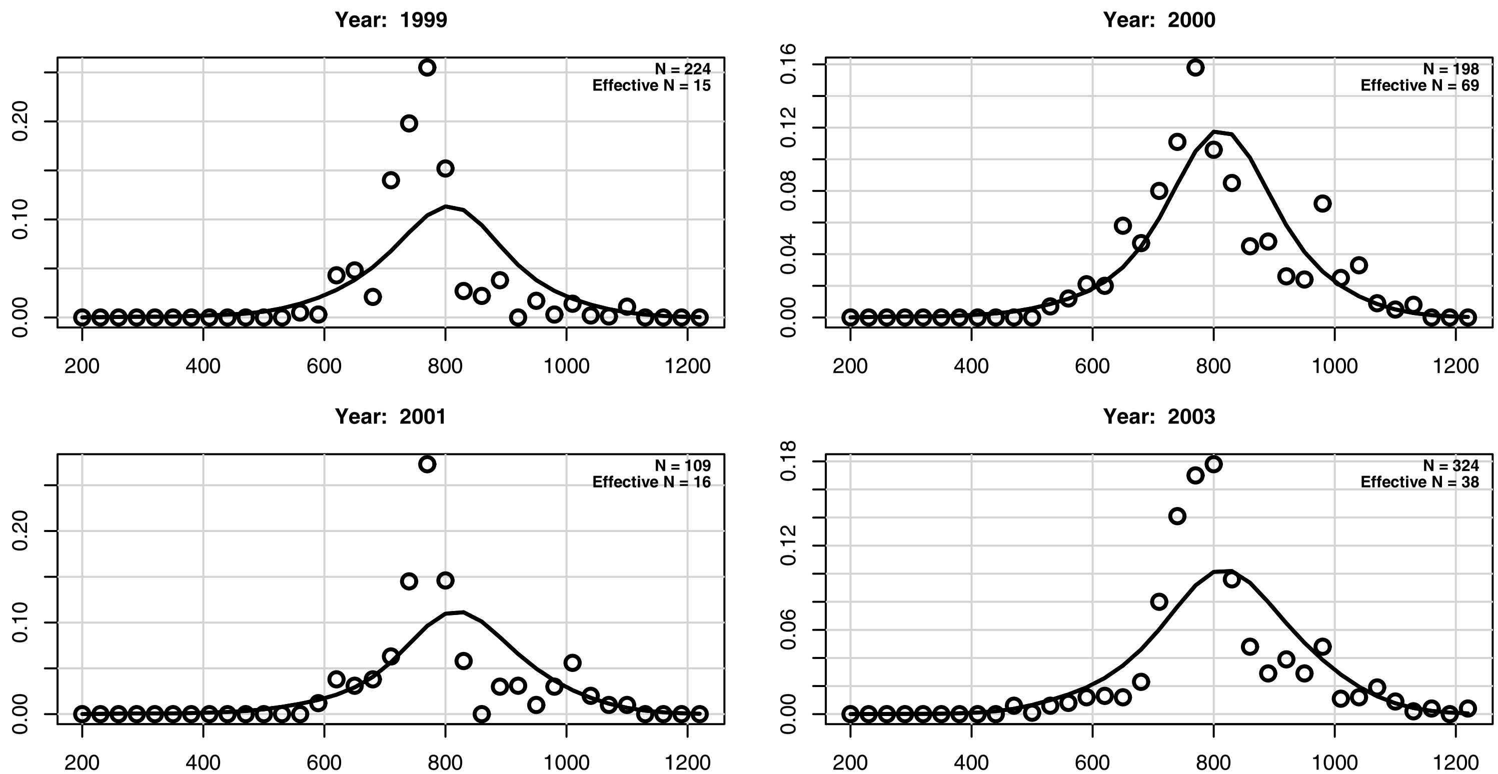


Figure 8. Gag– Base run with time-varying catchability: Bubble plot of length composition residuals from the commercial diving fishery. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

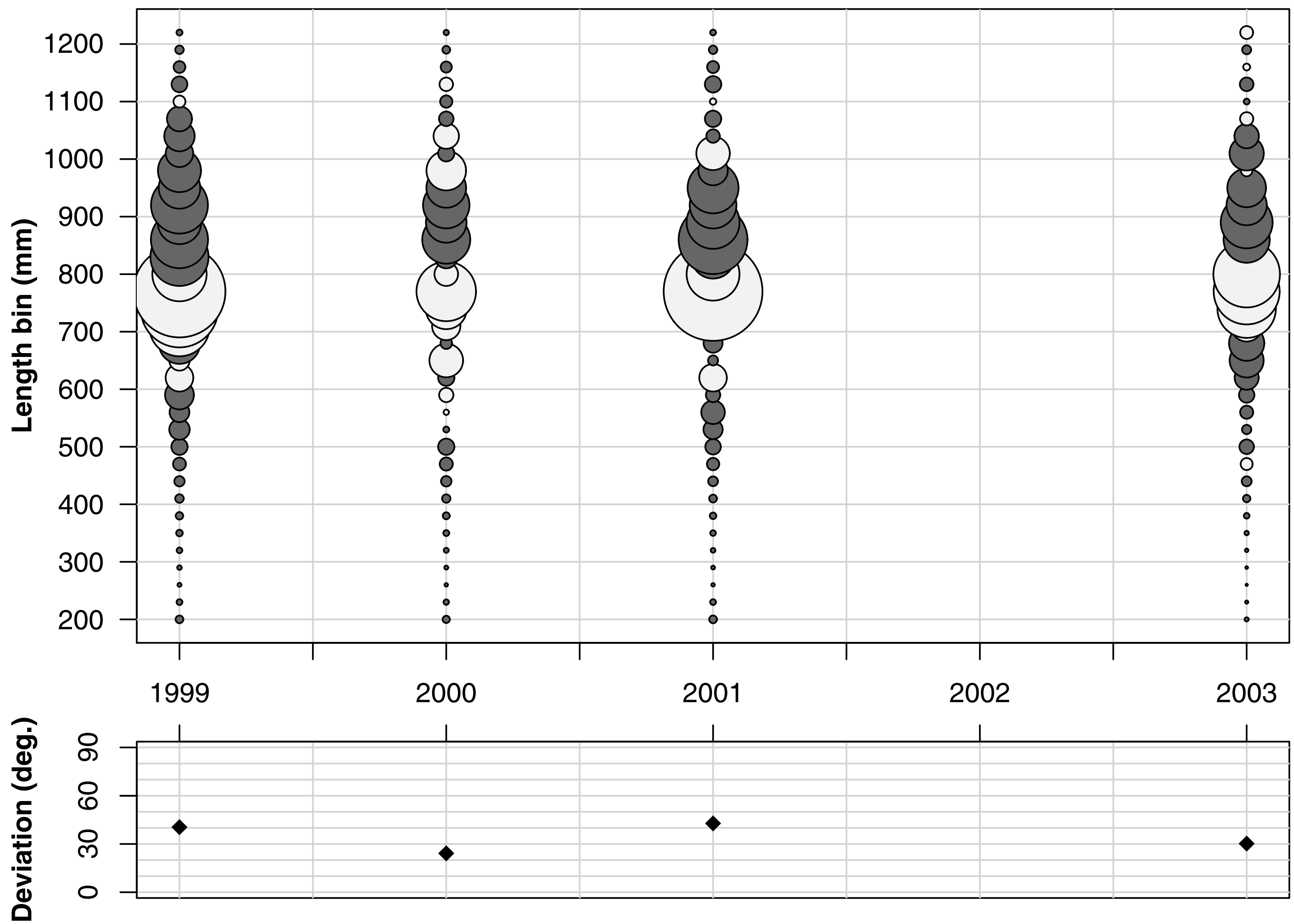


Figure 9. Gag– Base run with constant catchability: Bubble plot of length composition residuals from the commercial diving fishery. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

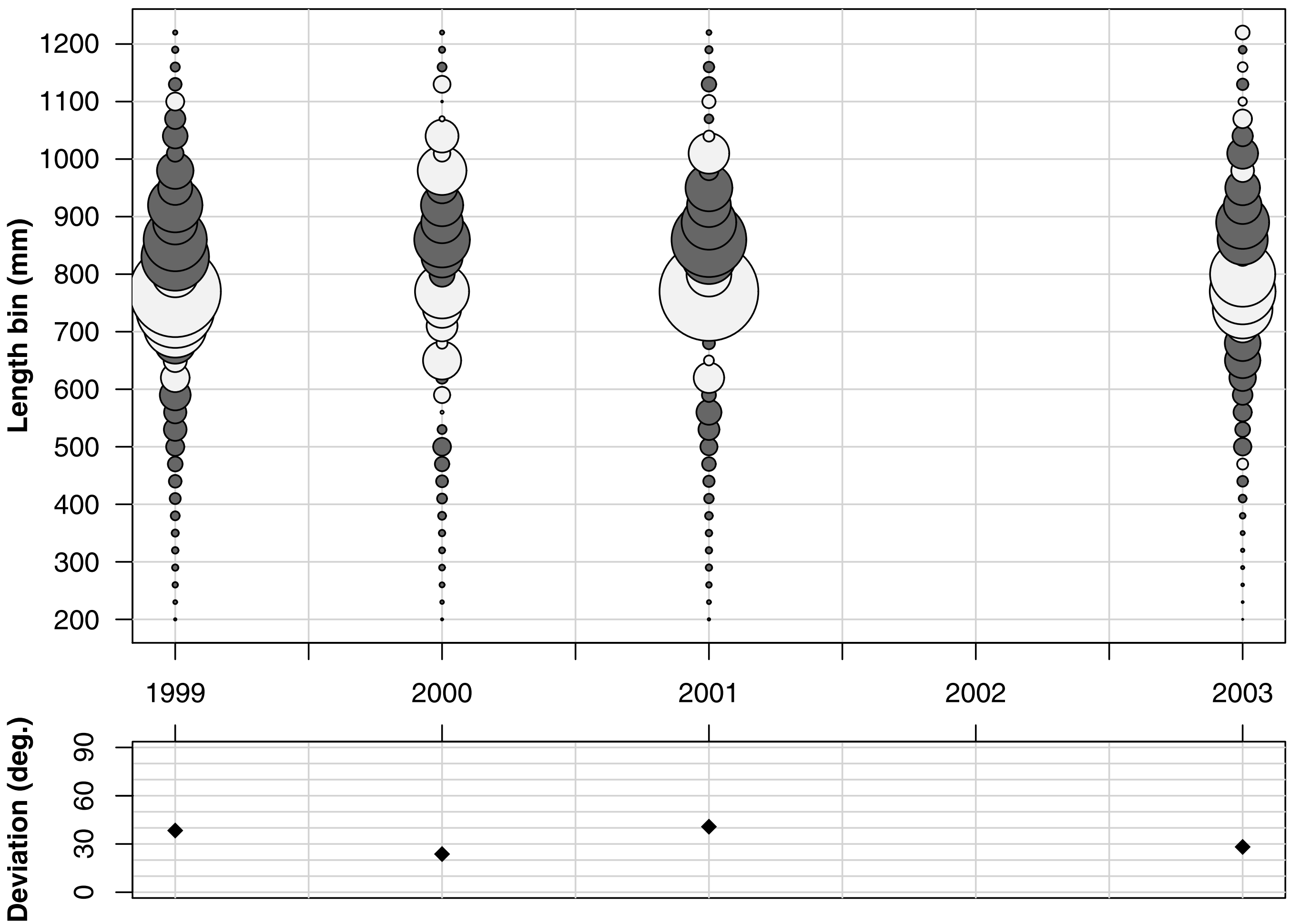


Figure 10. Gag– Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

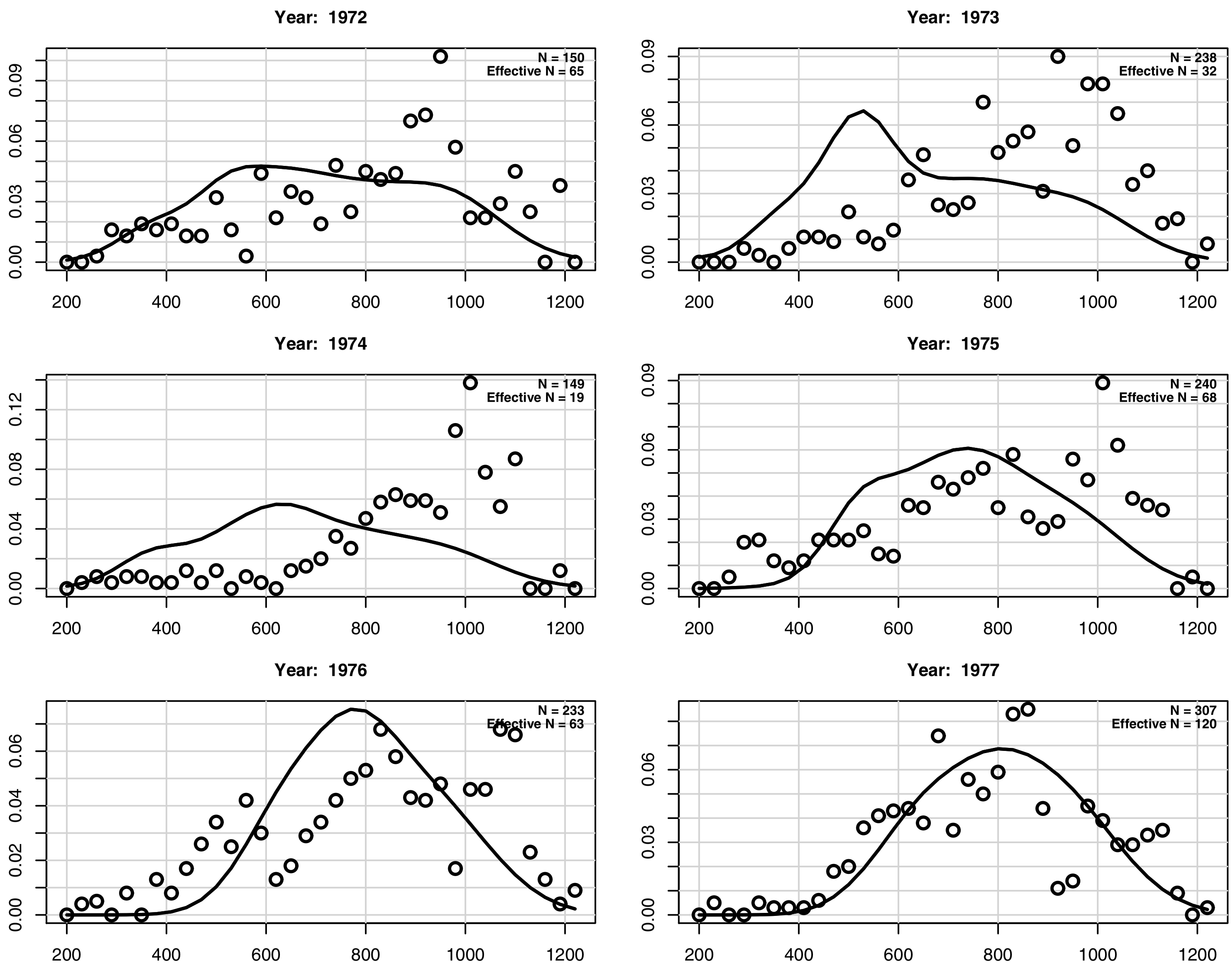


Figure 10. (cont.) Gag– Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

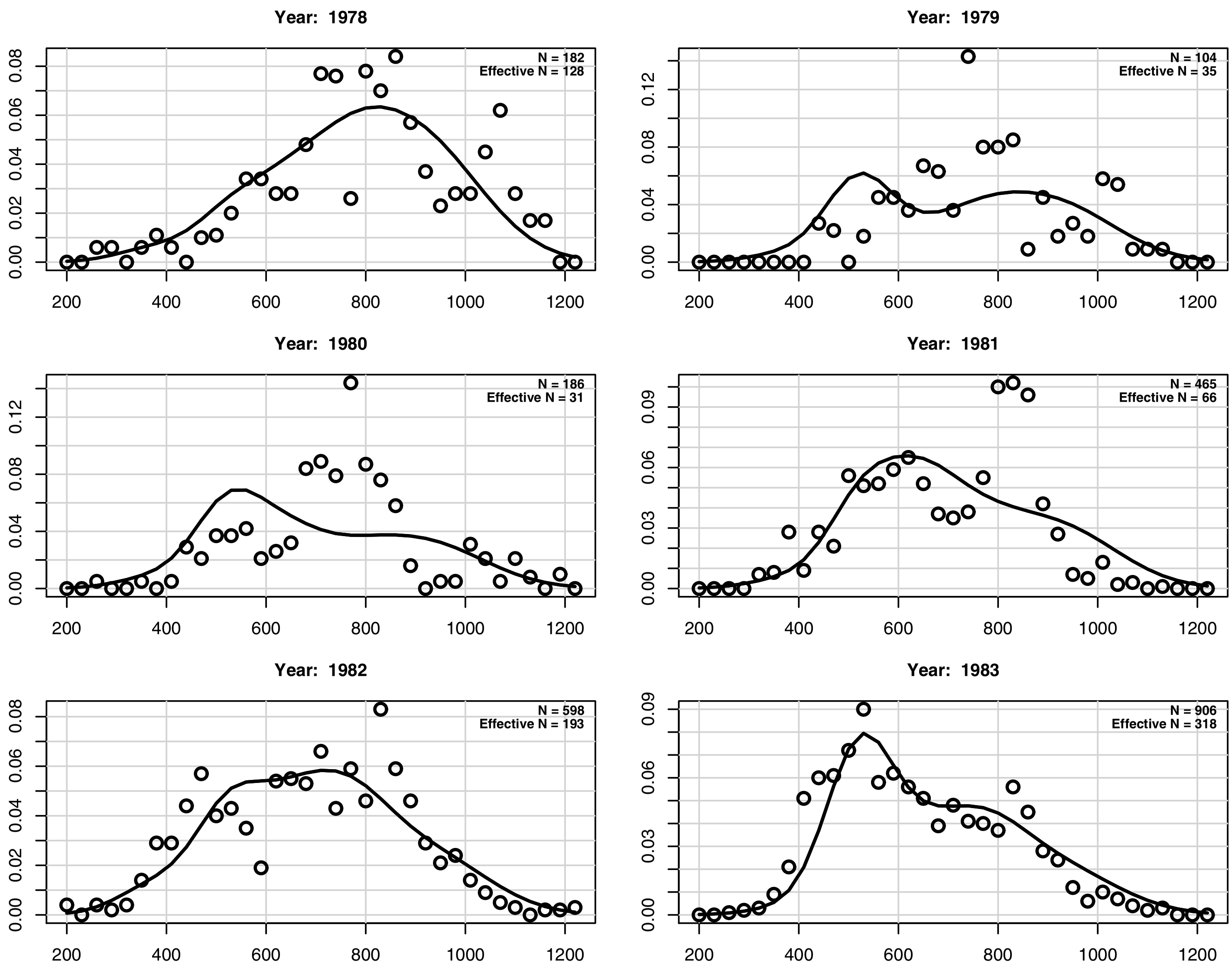


Figure 10. (cont.) Gag– Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

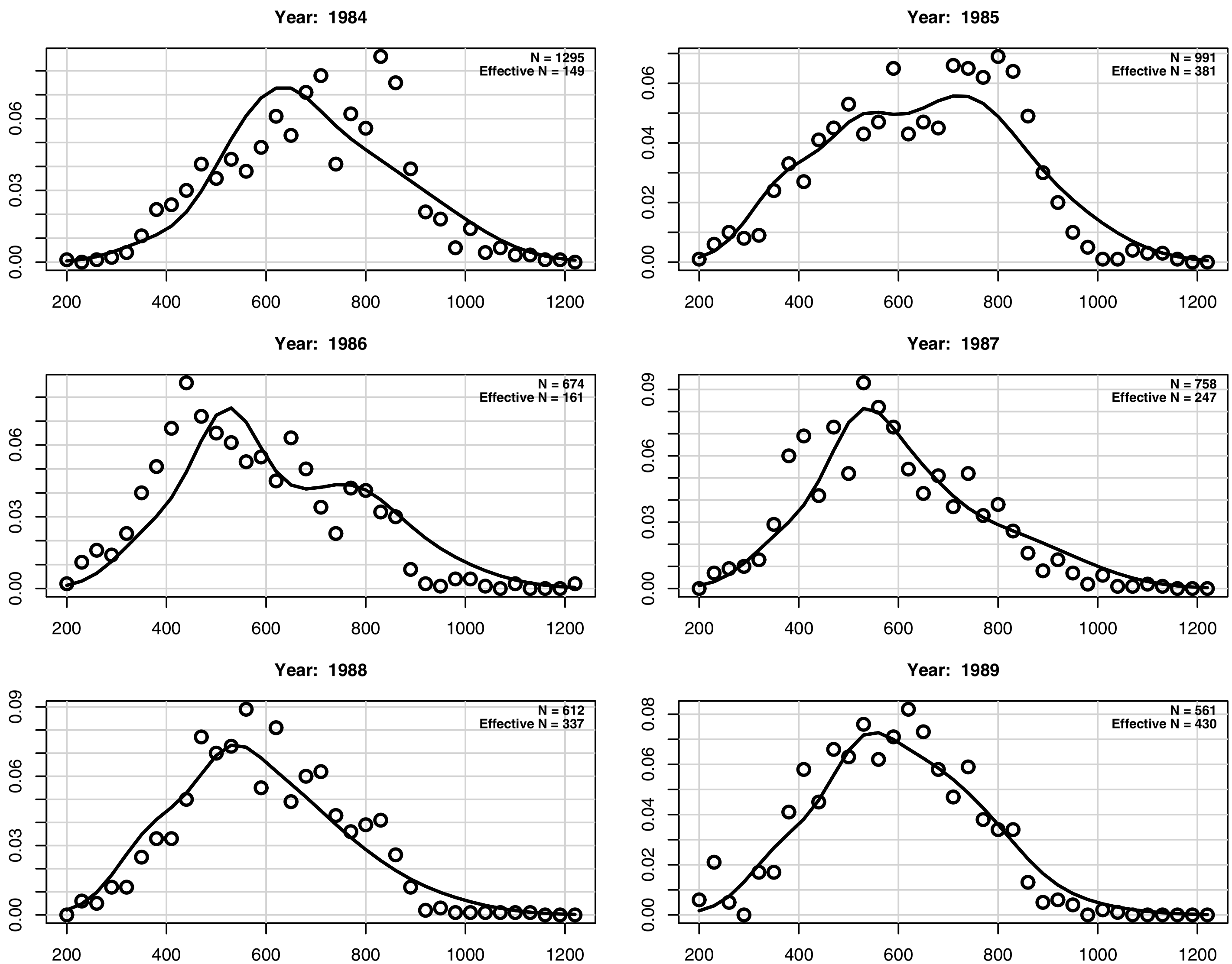


Figure 10. (cont.) Gag– Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

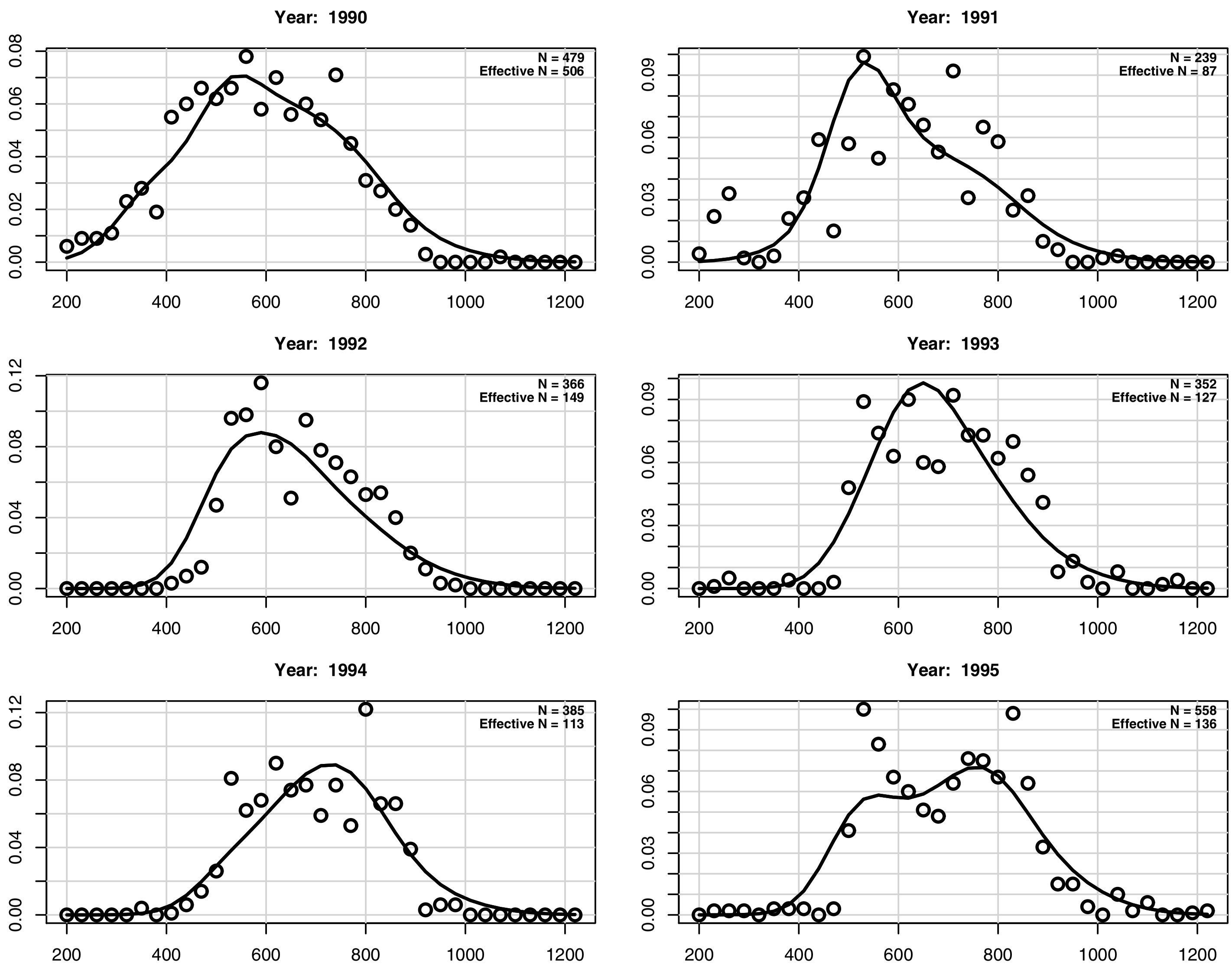


Figure 10. (cont.) Gag– Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

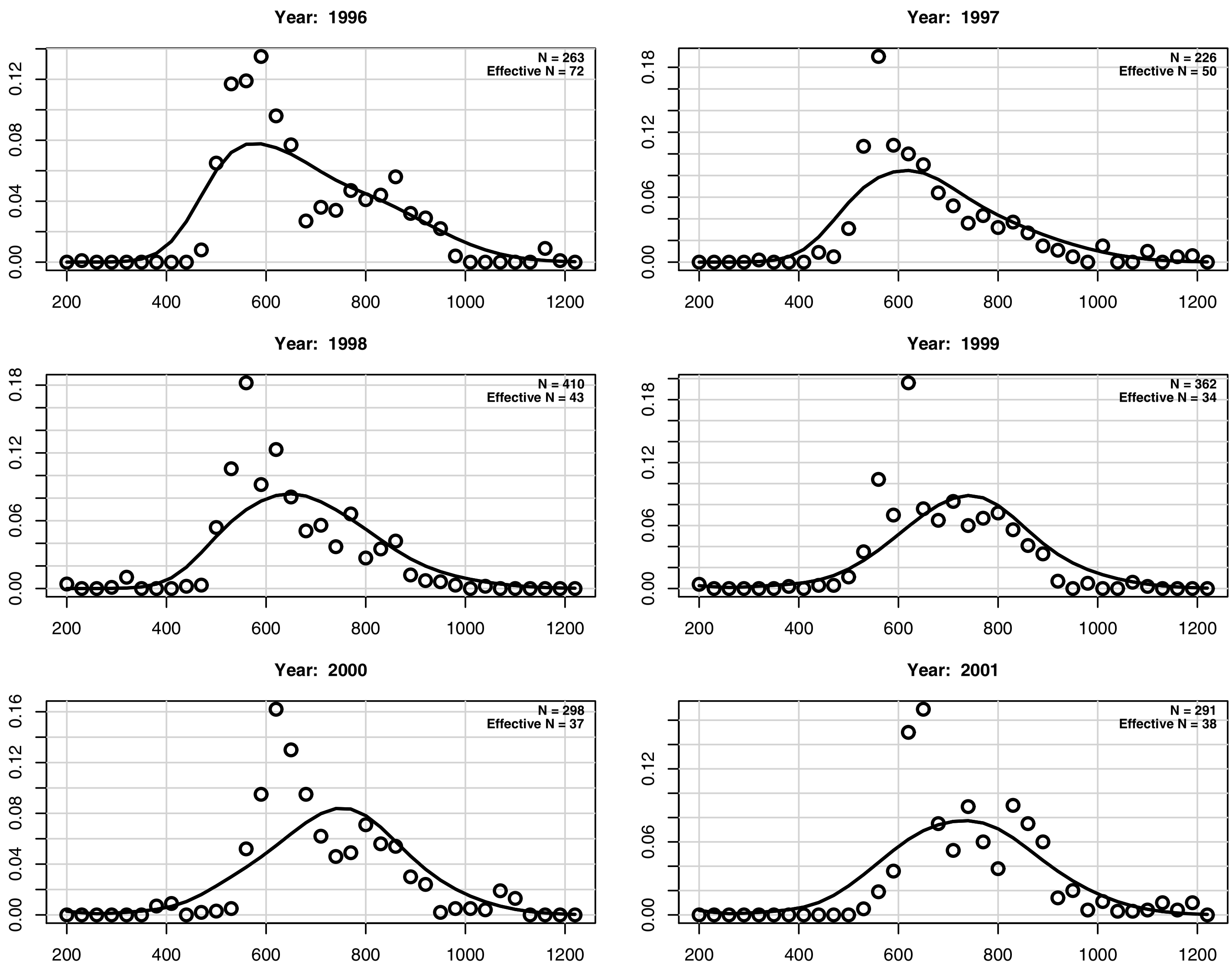


Figure 10. (cont.) Gag– Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

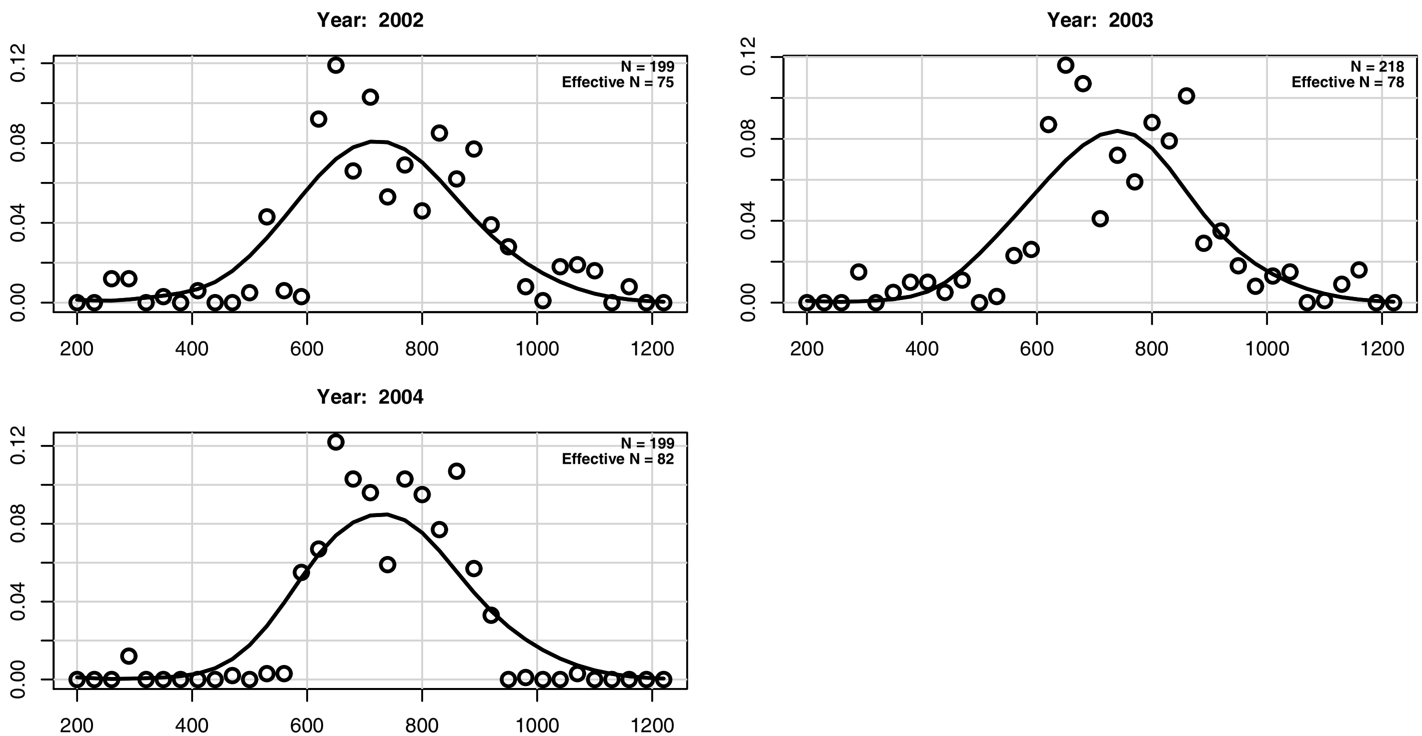


Figure 11. Gag– Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

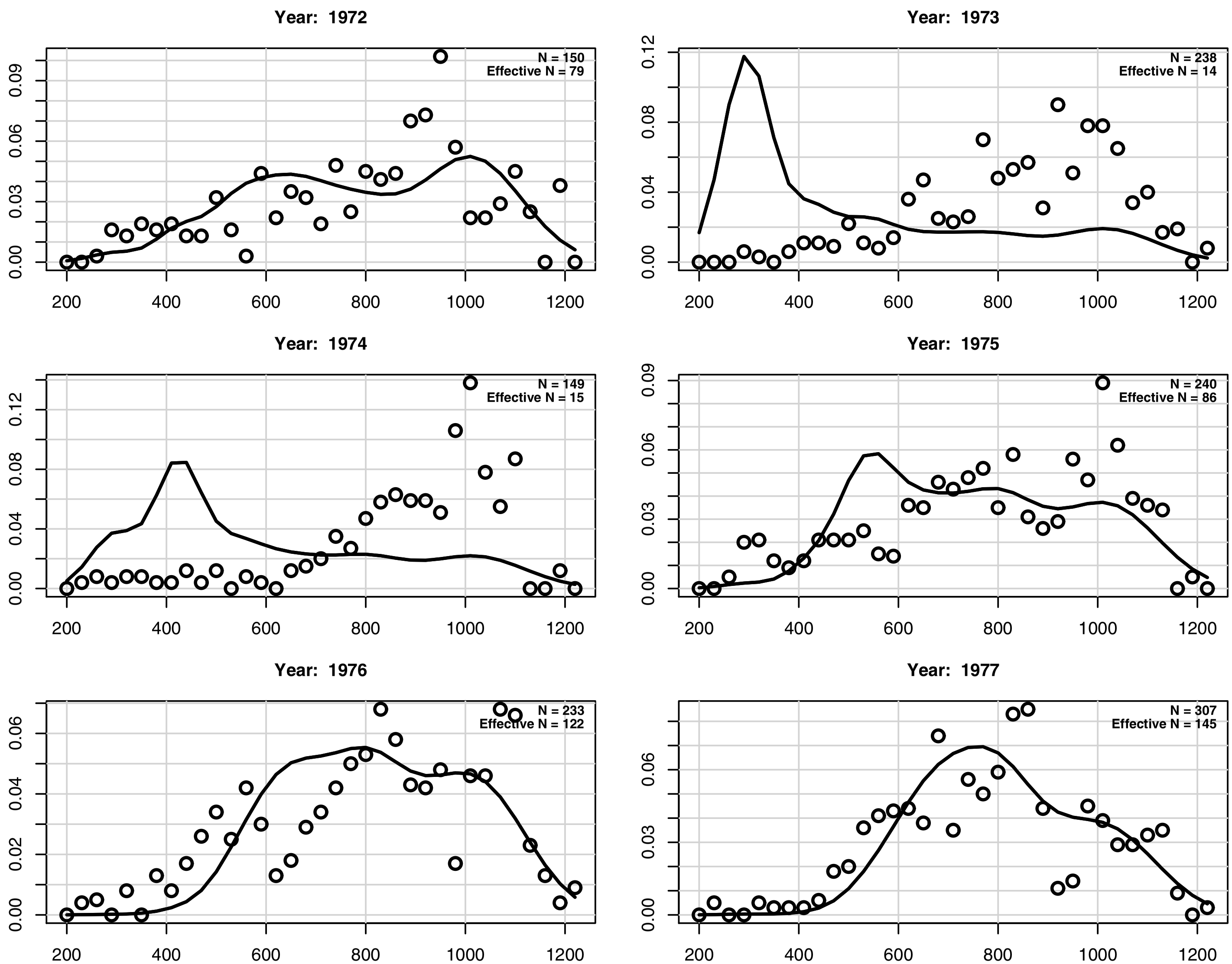


Figure 11. (cont.) Gag– Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

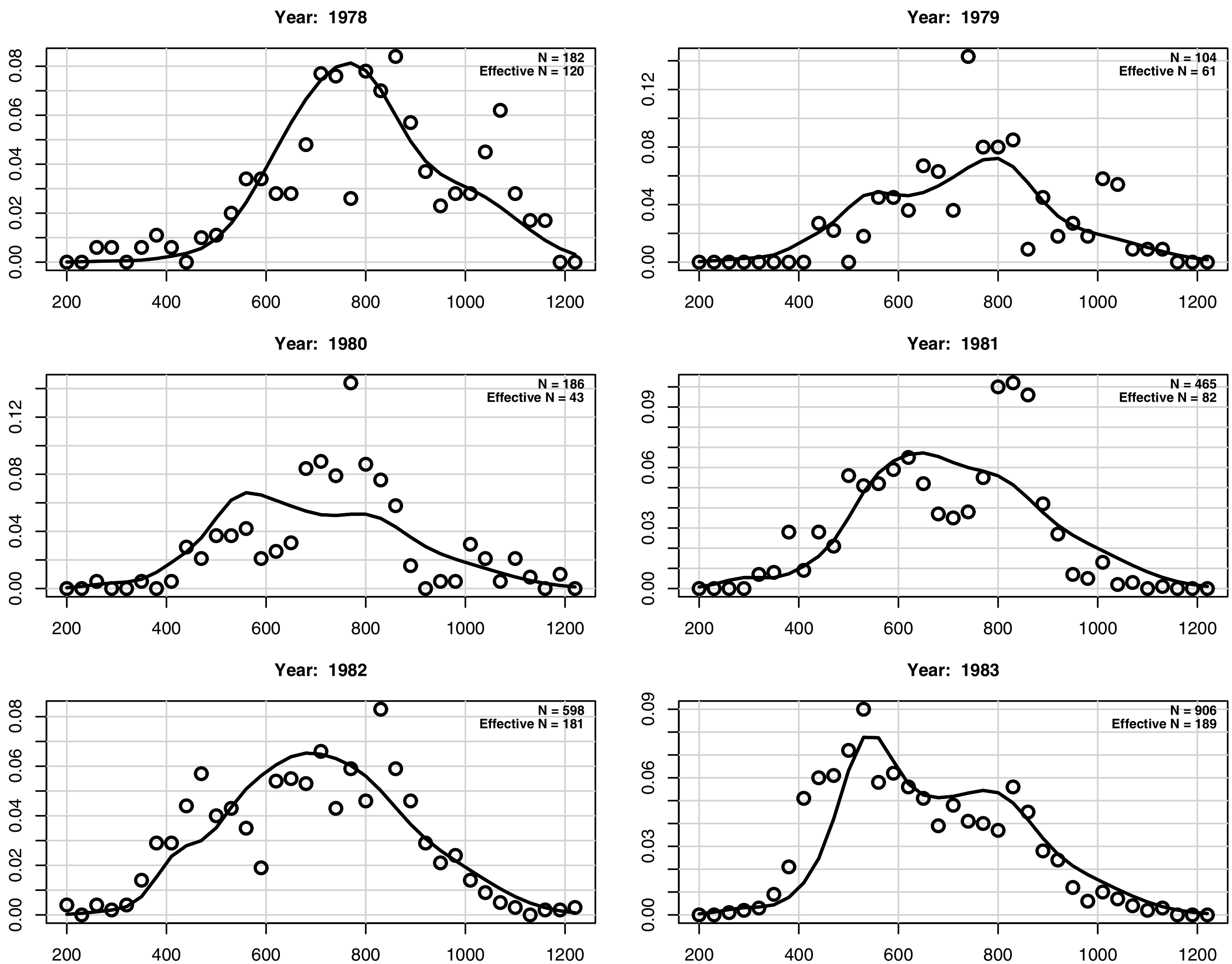


Figure 11. (cont.) Gag– Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

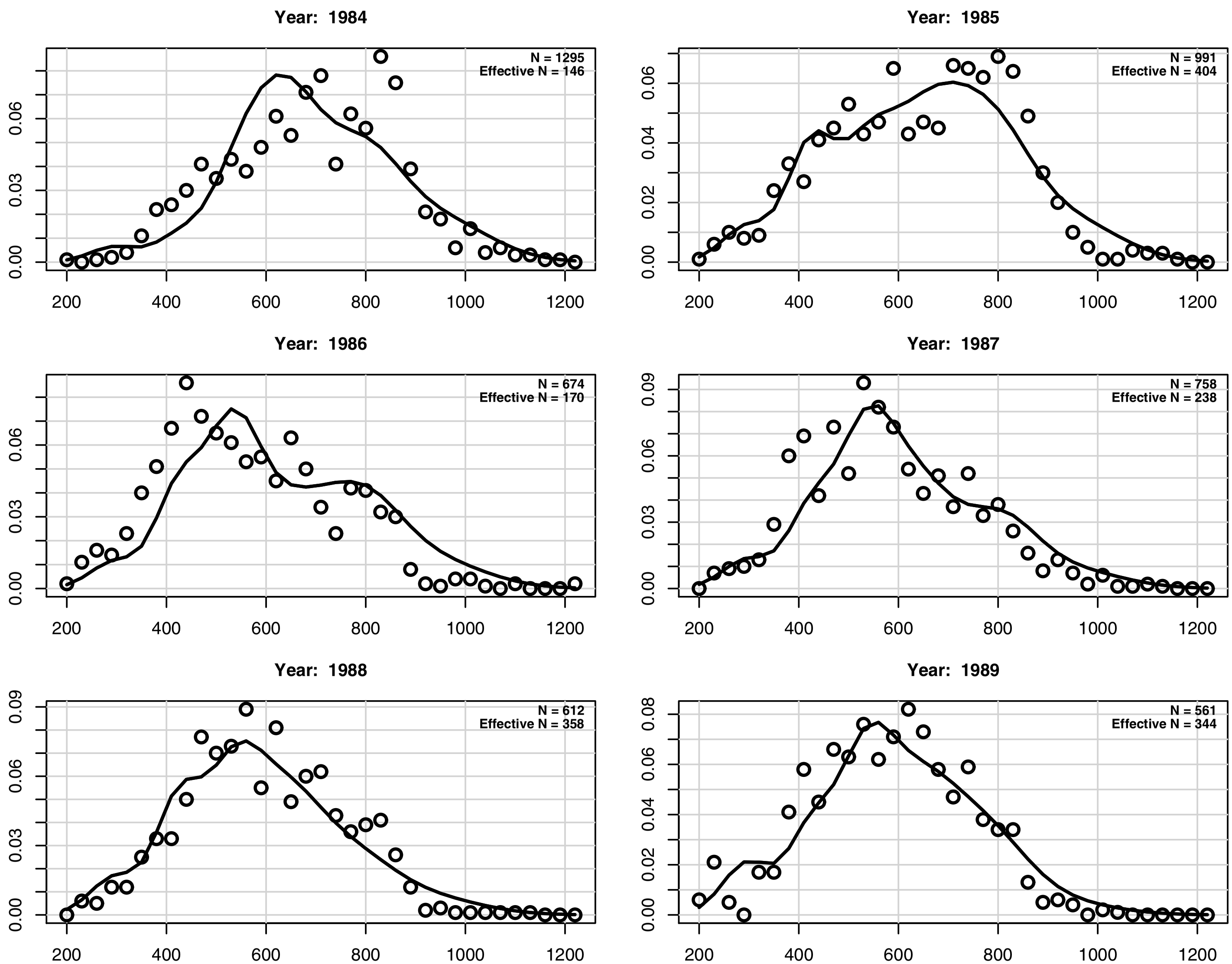


Figure 11. (cont.) Gag– Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

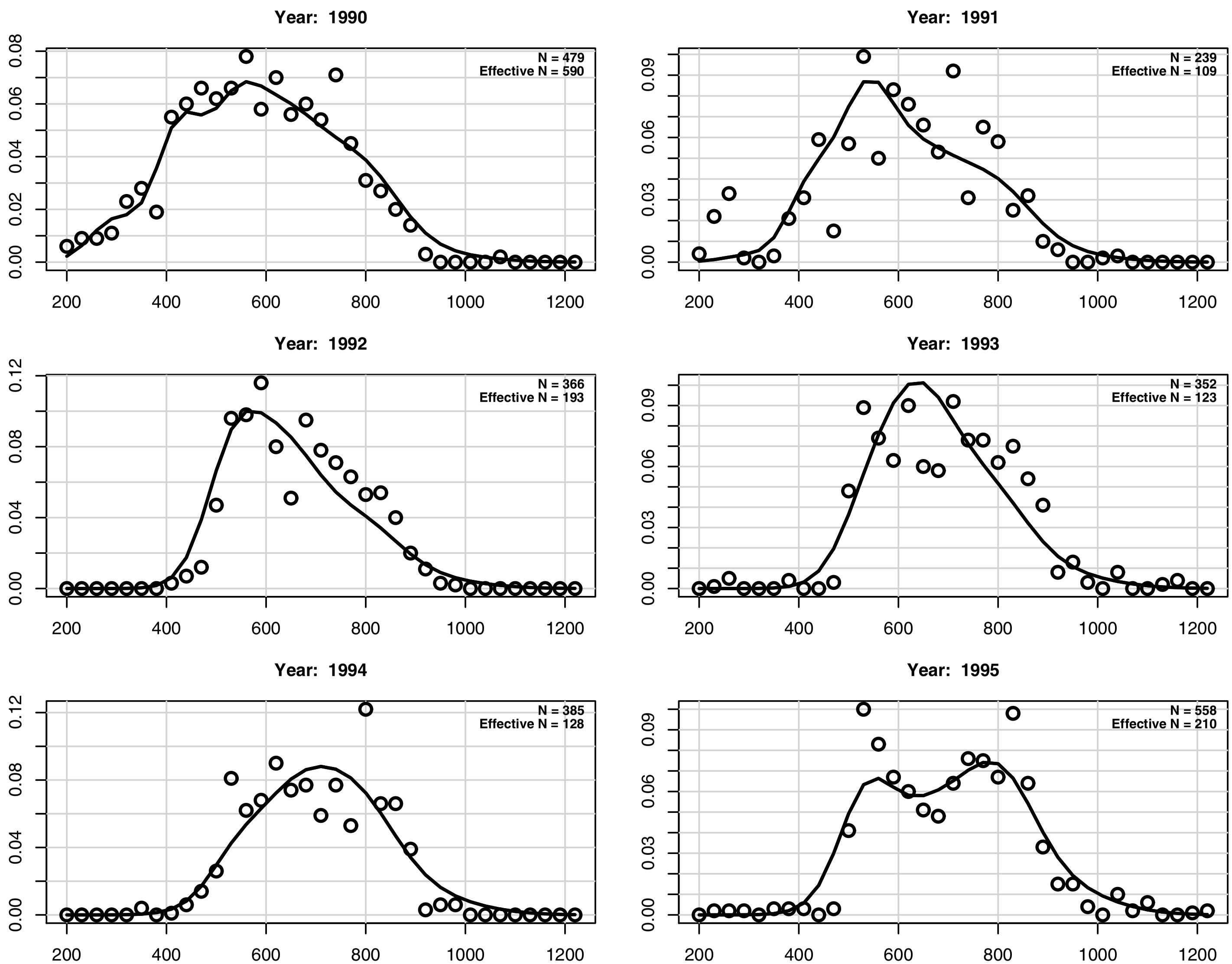


Figure 11. (cont.) Gag– Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

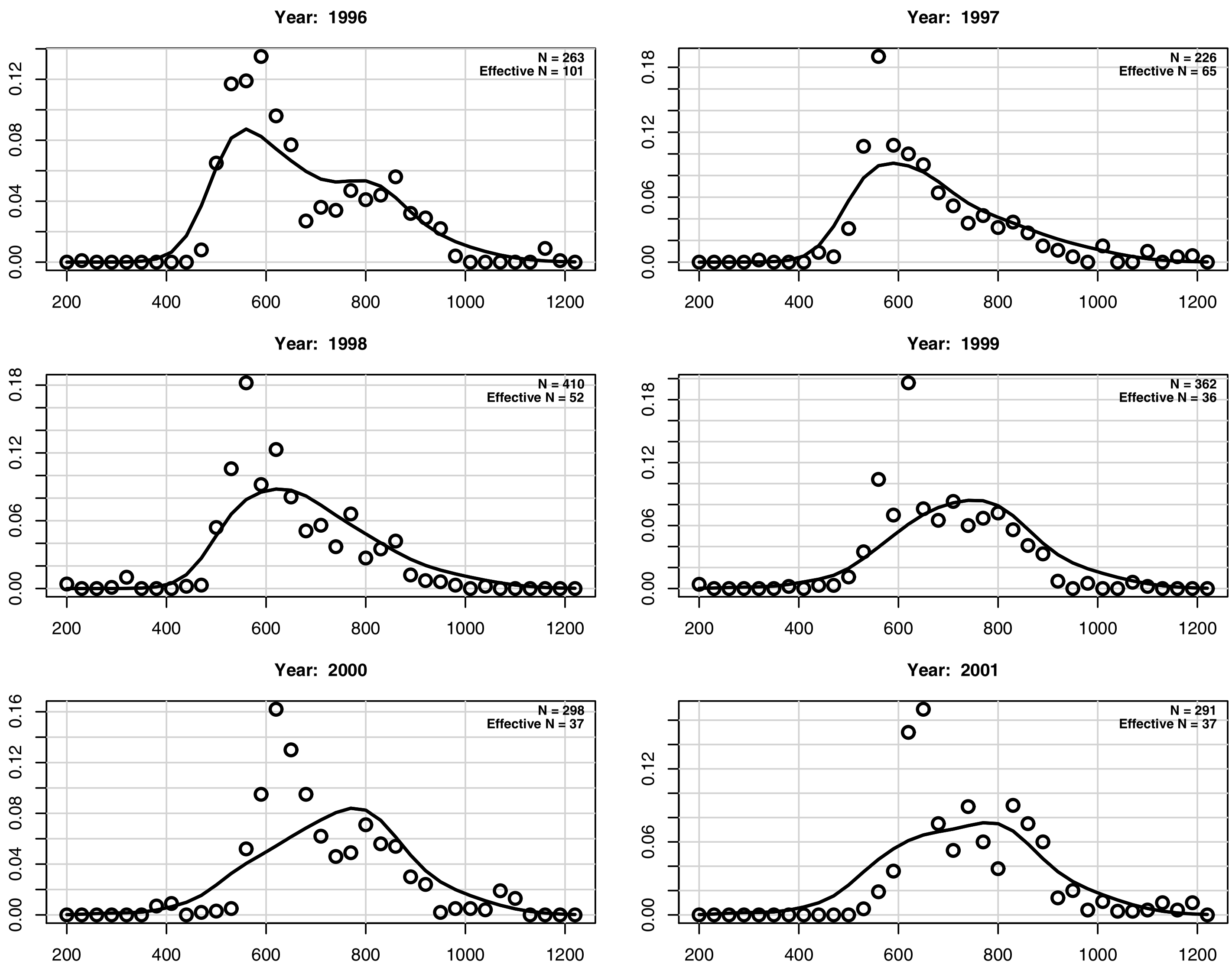


Figure 11. (cont.) Gag– Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

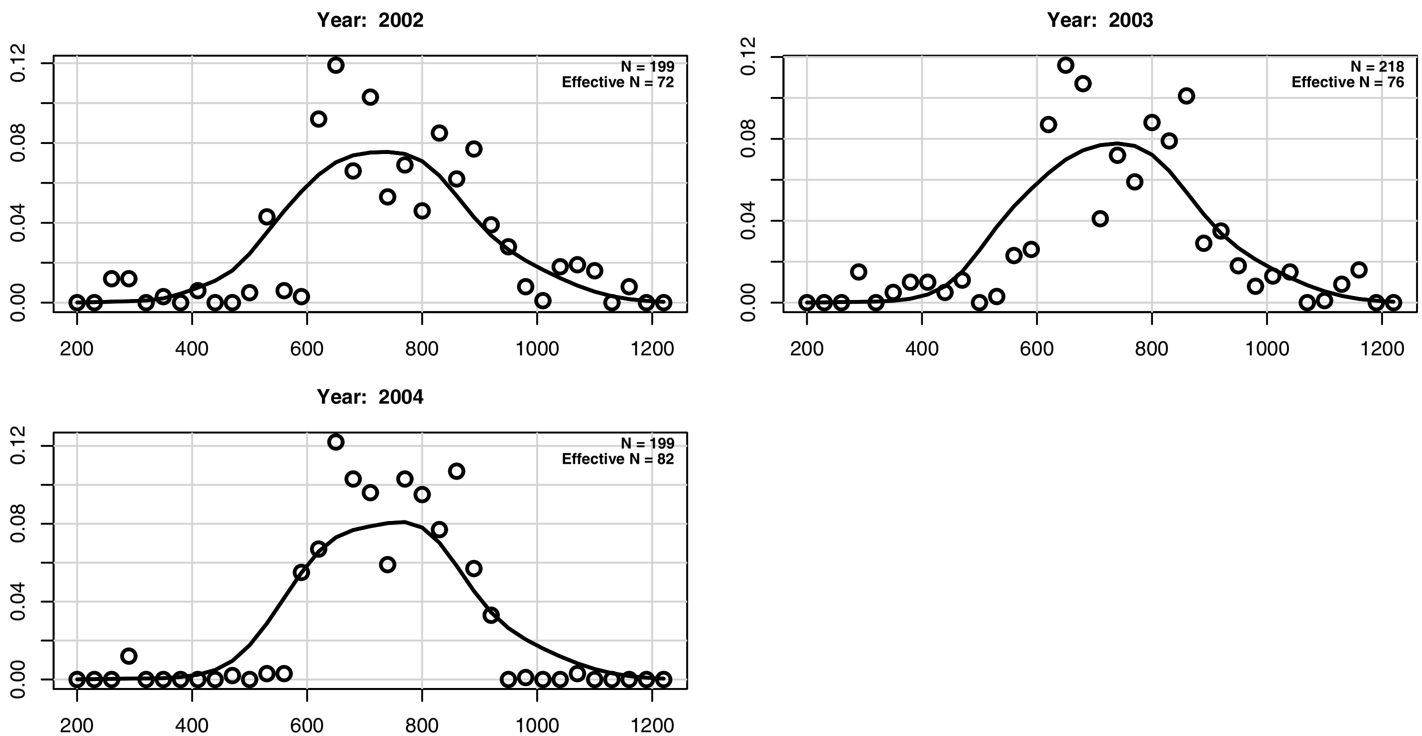


Figure 12. Gag– Base run with time-varying catchability: Bubble plot of length composition residuals from the headboat fishery; Dark bubbles are overestimates and light bubbles are underestimates.

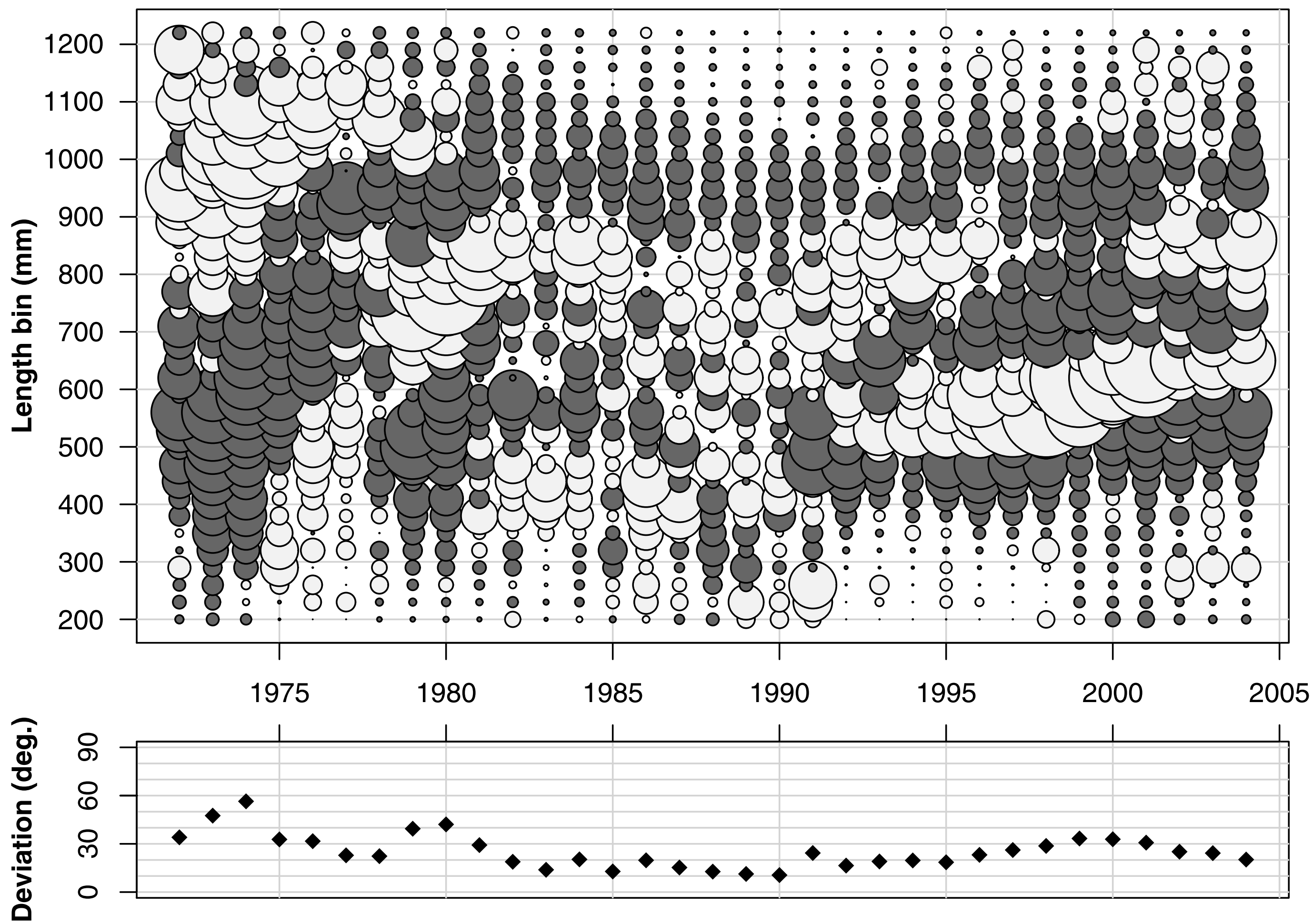


Figure 13. Gag– Base run with constant catchability: Bubble plot of length composition residuals from the headboat fishery; Dark bubbles are overestimates and light bubbles are underestimates.

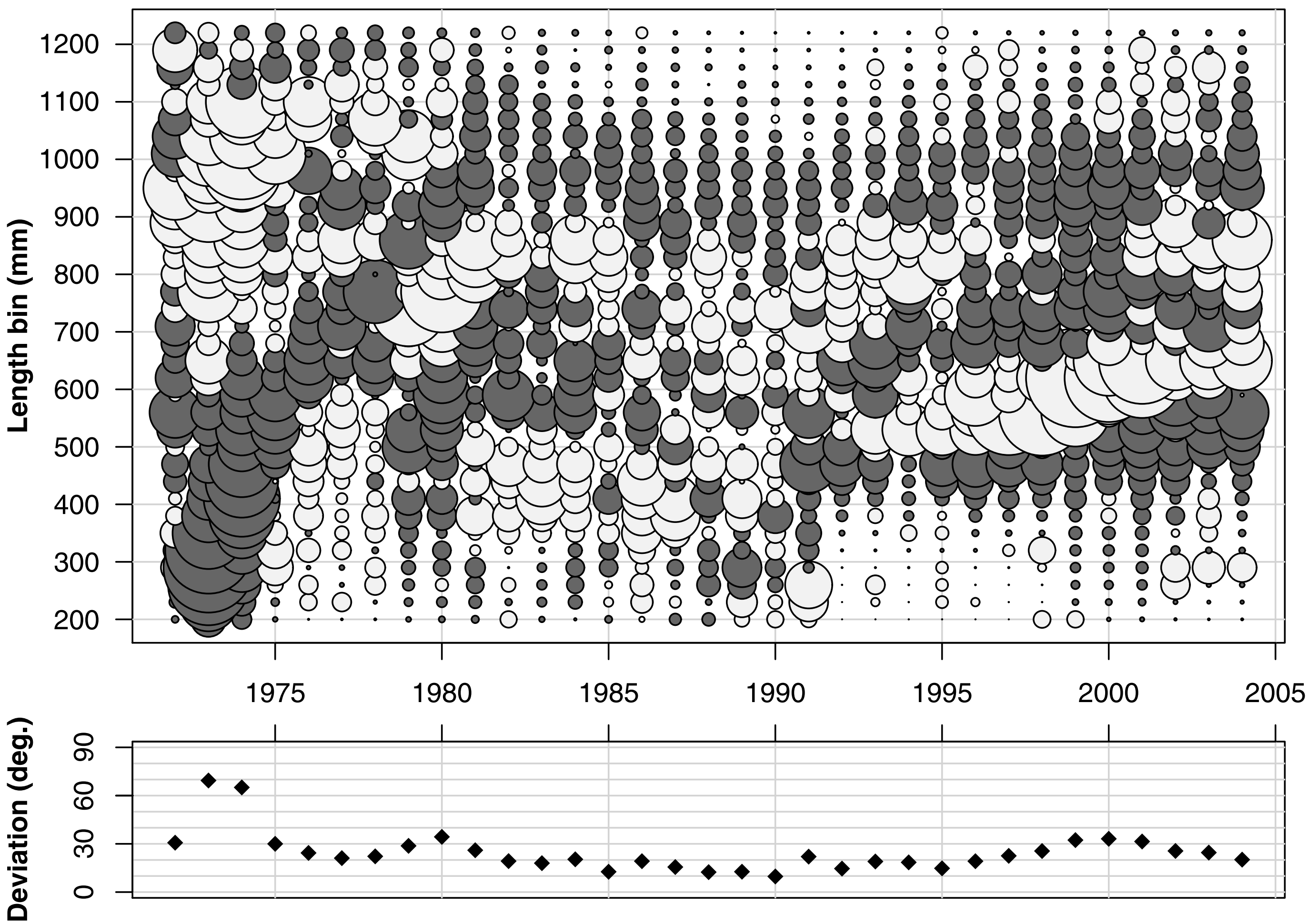


Figure 14. Gag– Base run with time-varying catchability: Estimated (line) and observed (circles) annual age compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

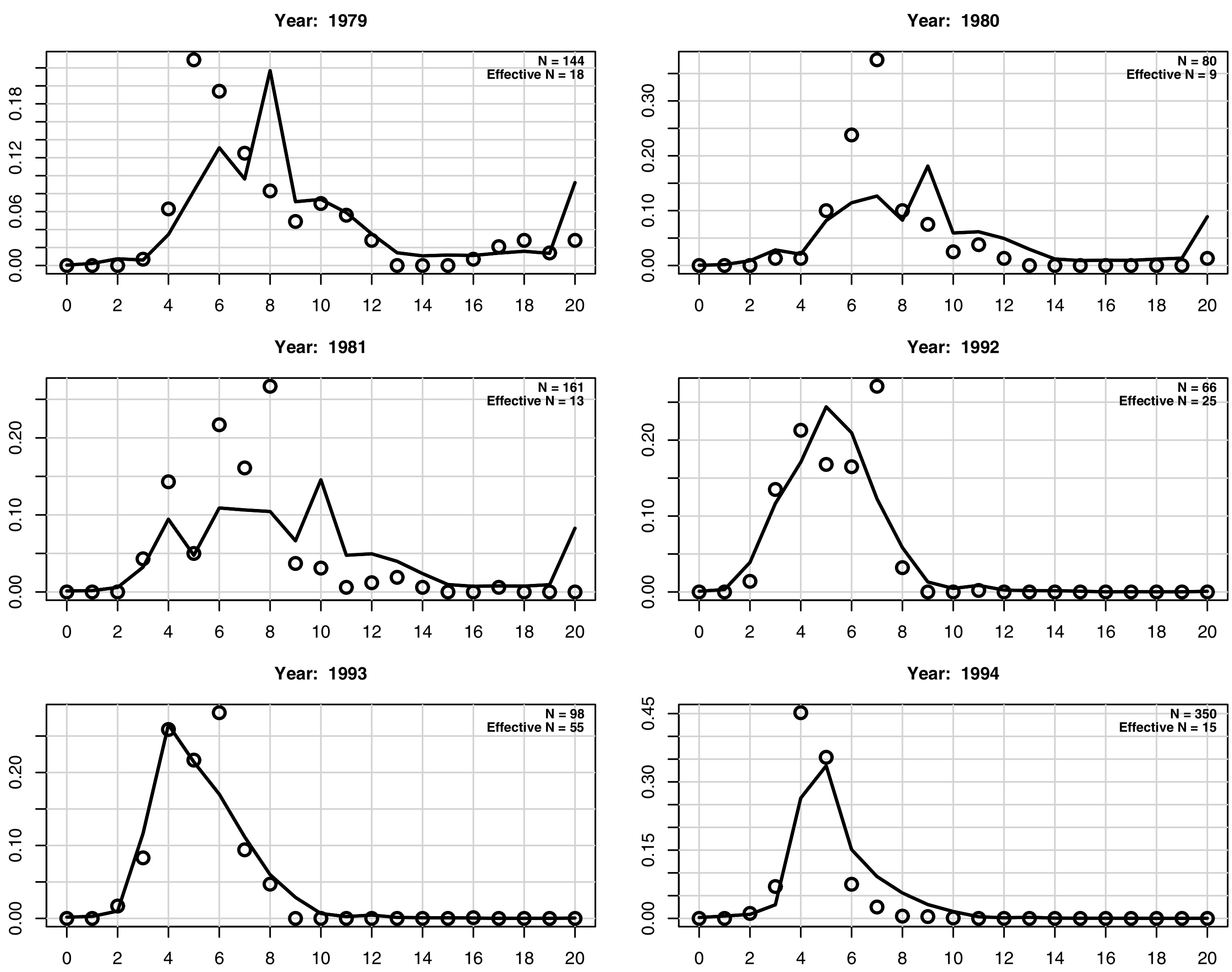


Figure 14. (cont.) Gag– Base run with time-varying catchability: Estimated (line) and observed (circles) annual age compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

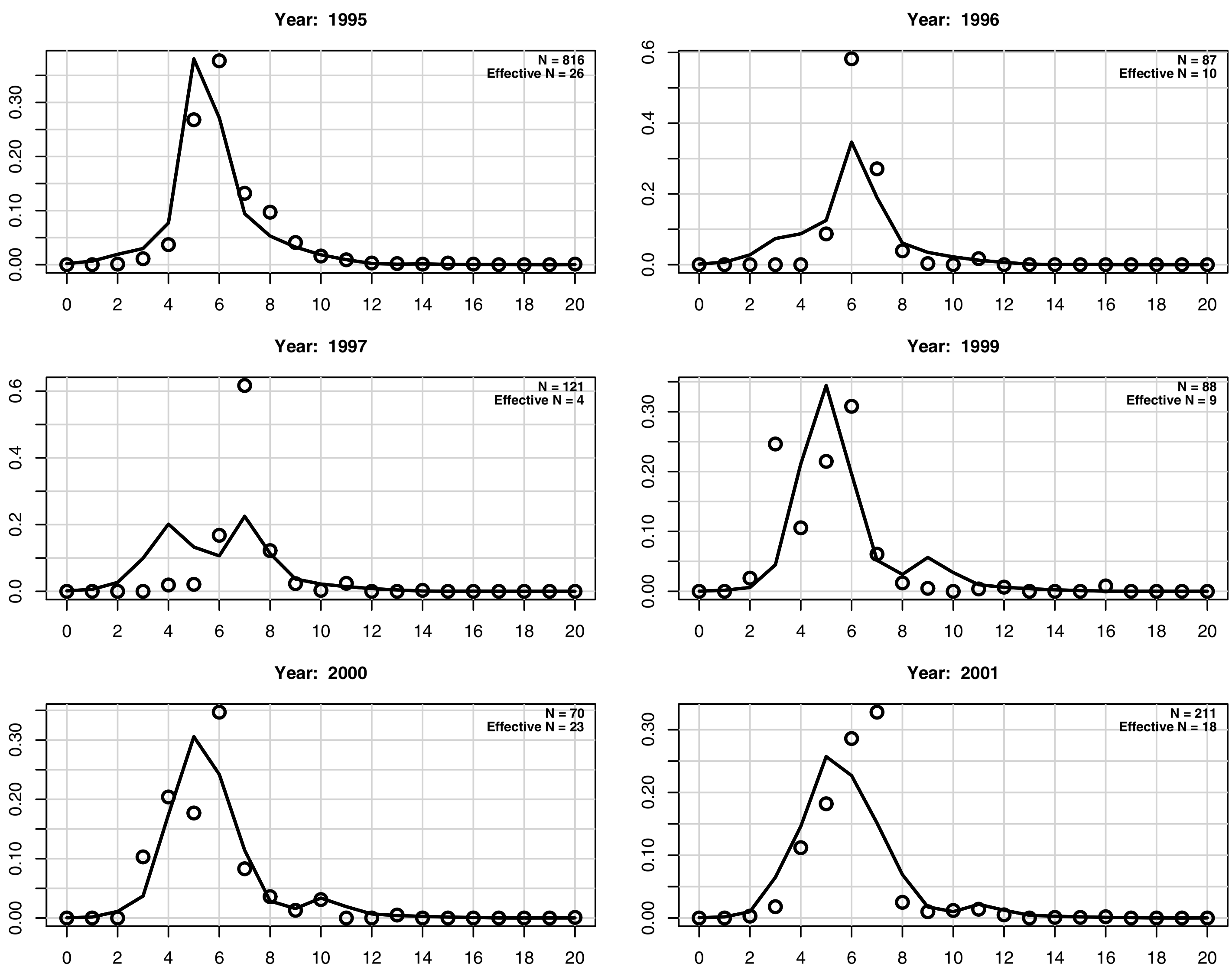


Figure 14. (cont.) Gag– Base run with time-varying catchability: Estimated (line) and observed (circles) annual age compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

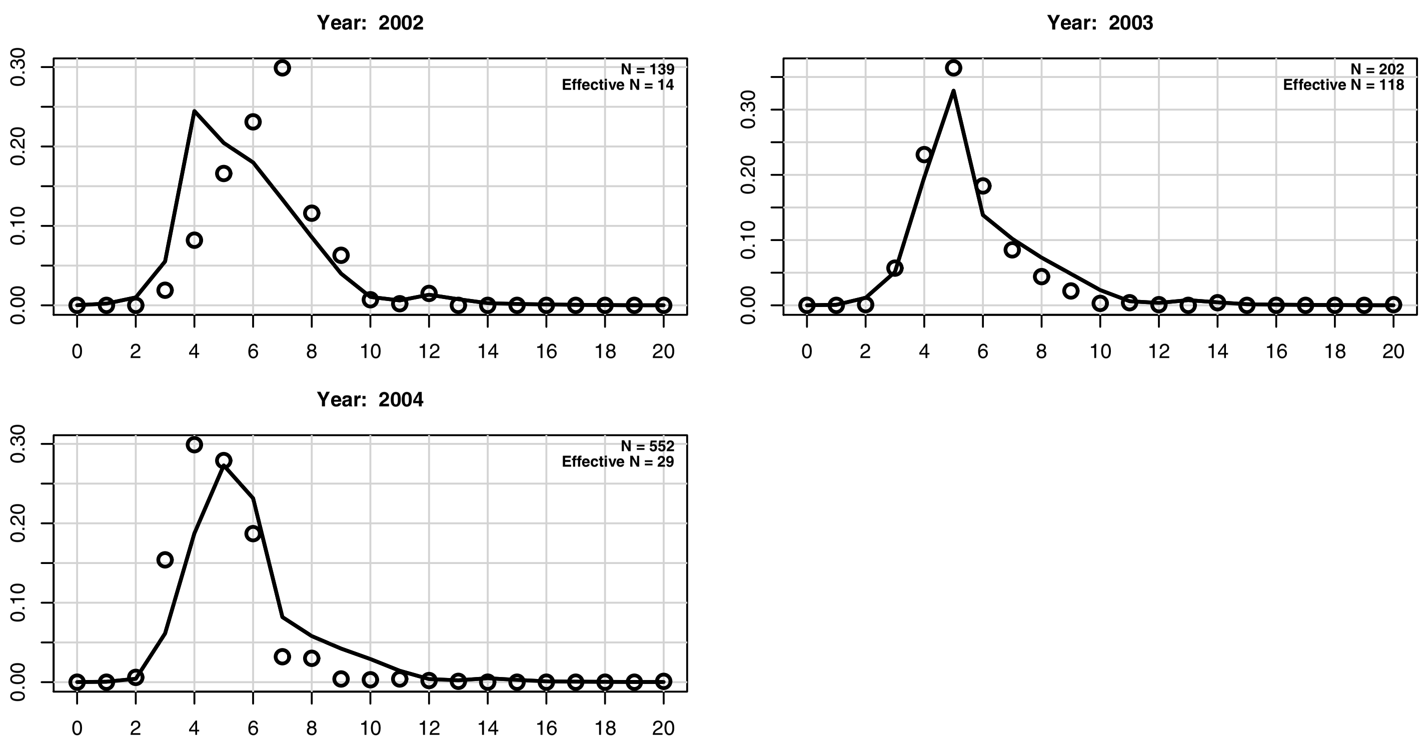


Figure 15. Gag– Base run with constant catchability: Estimated (line) and observed (circles) annual age compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

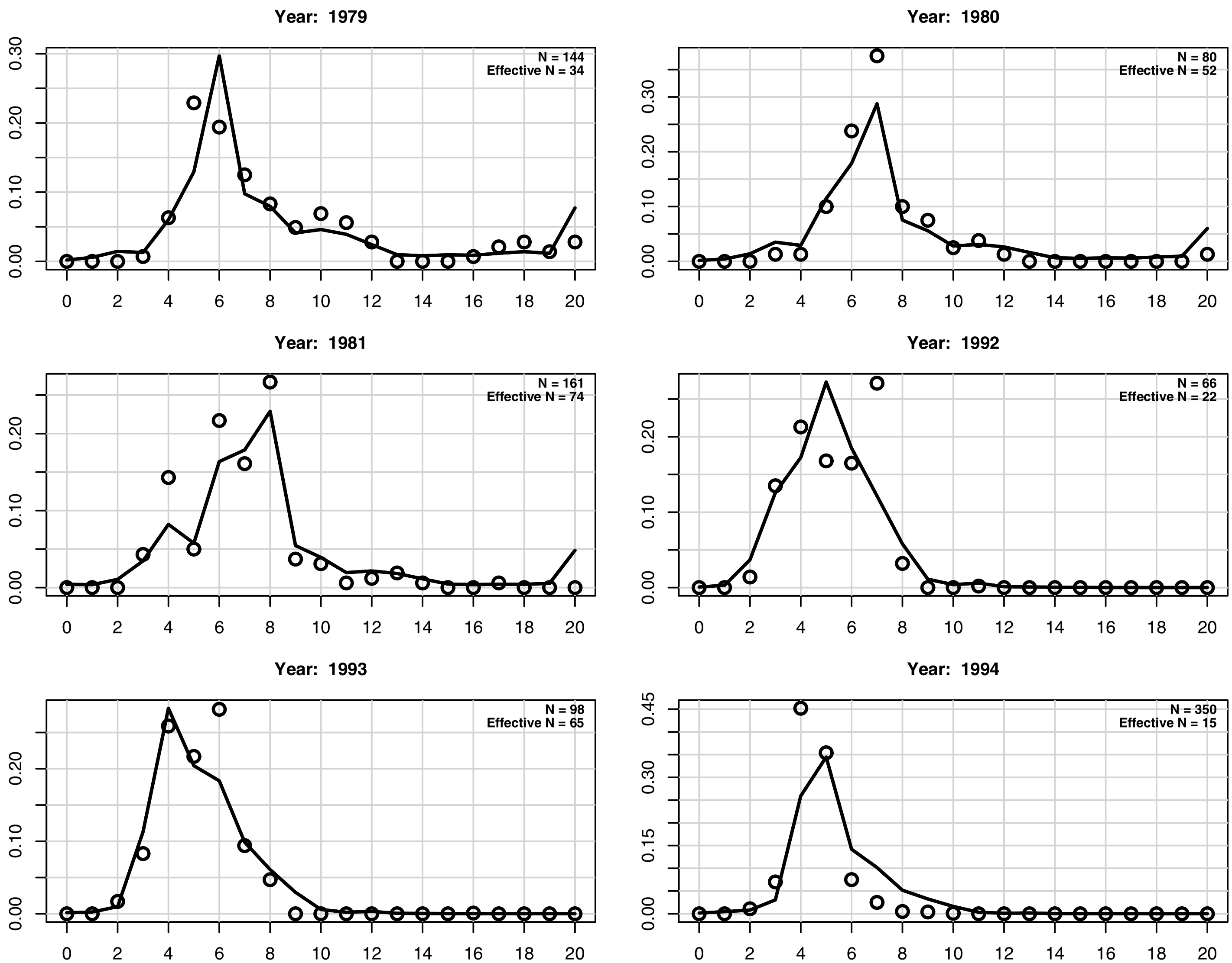


Figure 15. (cont.) Gag– Base run with constant catchability: Estimated (line) and observed (circles) annual age compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

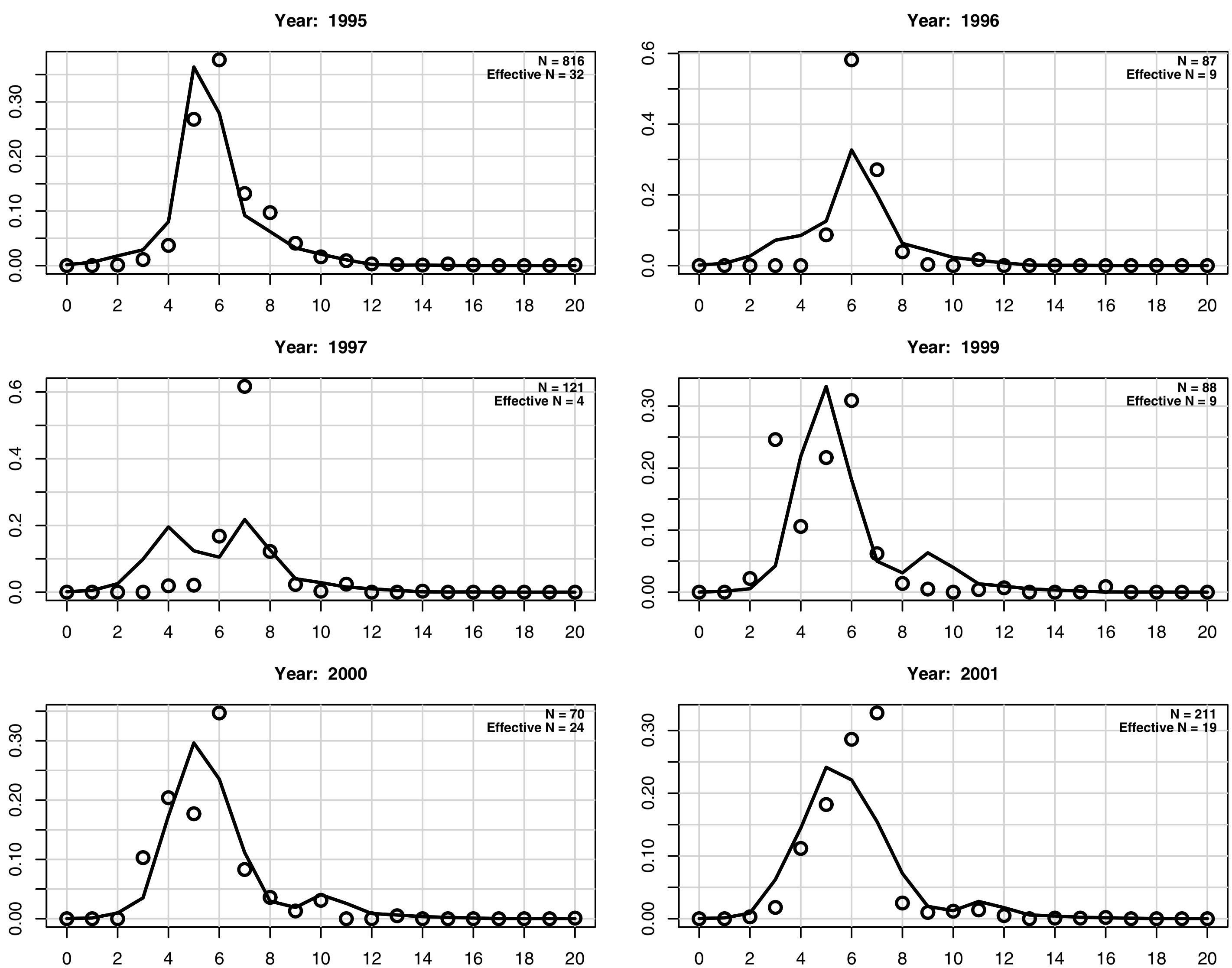


Figure 15. (cont.) Gag– Base run with constant catchability: Estimated (line) and observed (circles) annual age compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

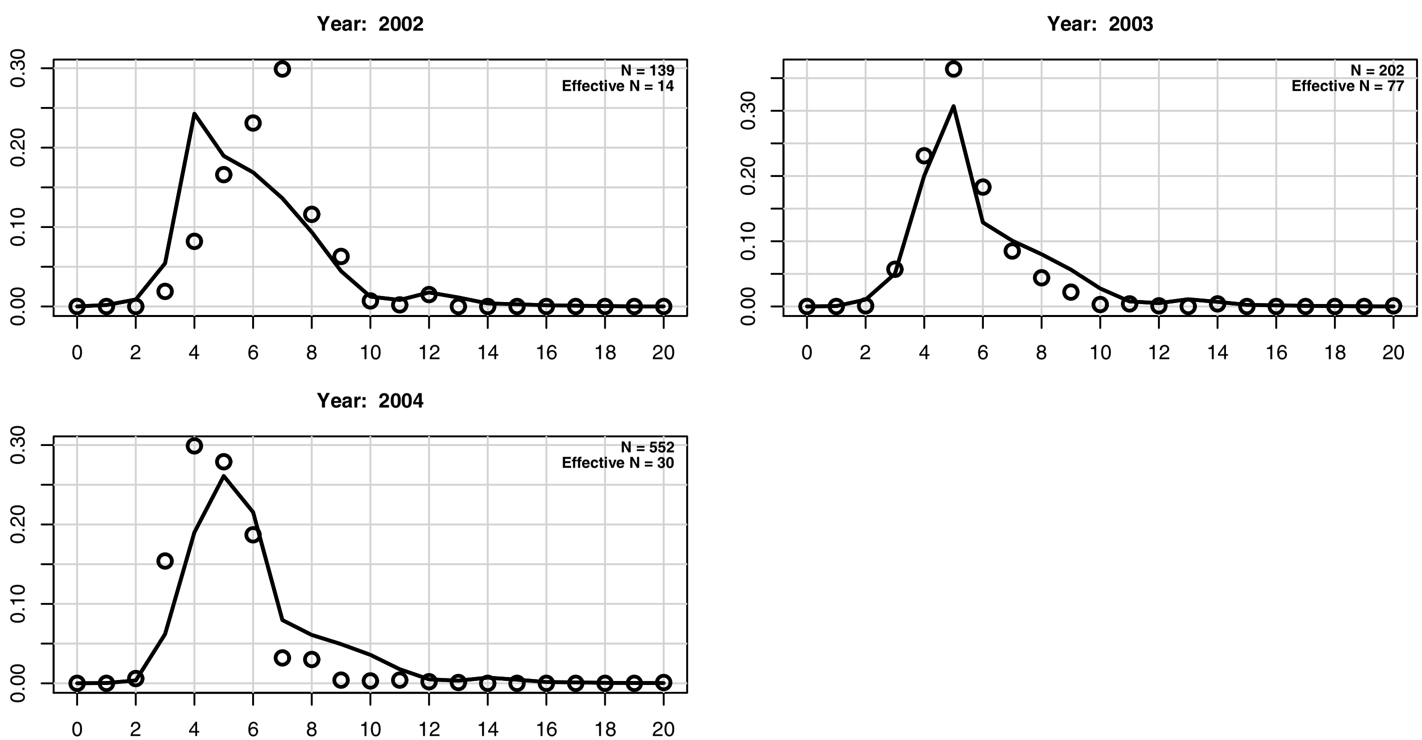


Figure 16. Gag– Base run with time-varying catchability: Bubble plot of age composition residuals from the commercial handline fishery; Dark bubbles are overestimates and light bubbles are underestimates.

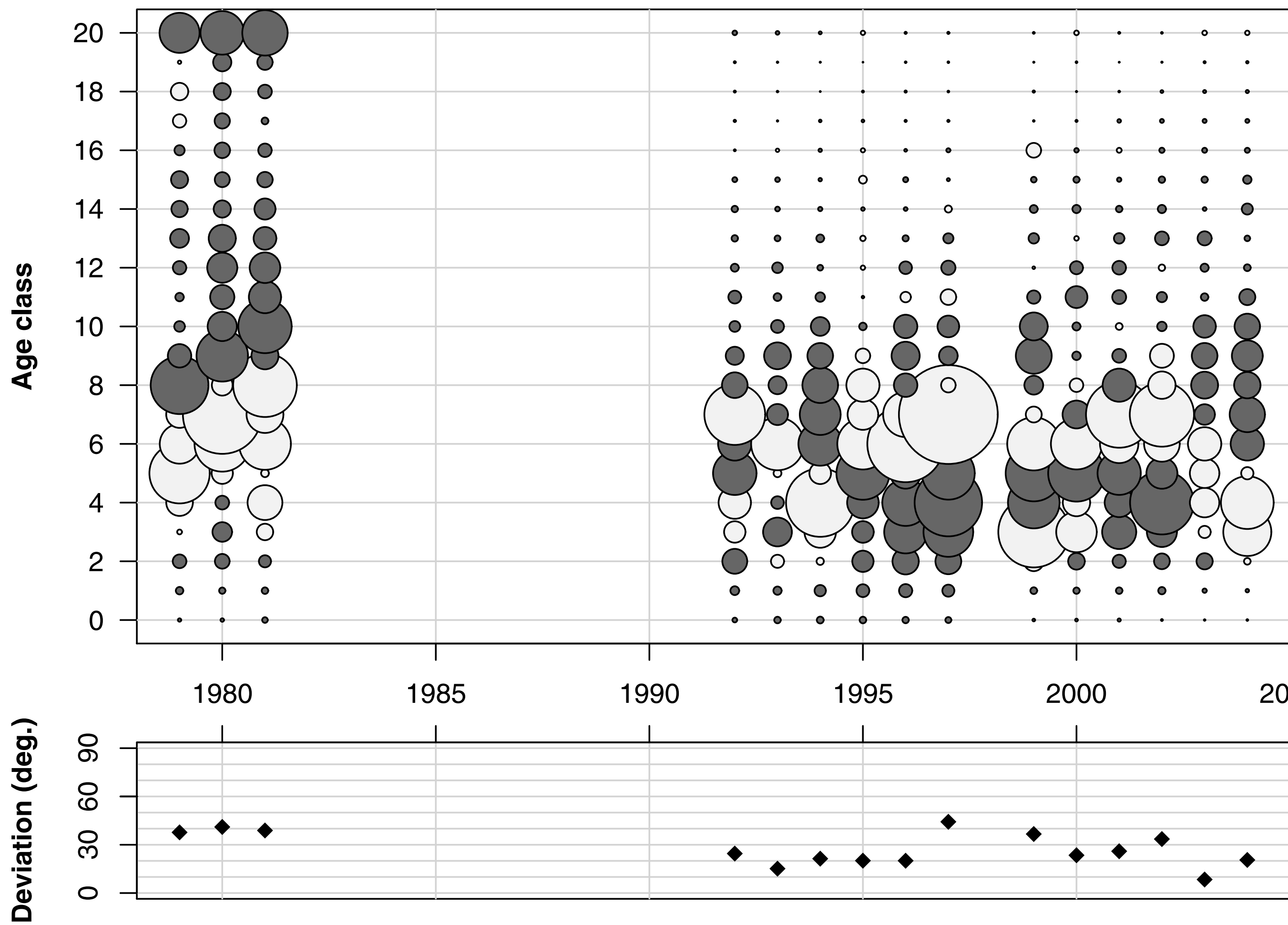


Figure 17. Gag– Base run with constant catchability: Bubble plot of age composition residuals from the commercial handline fishery; Dark bubbles are overestimates and light bubbles are underestimates.

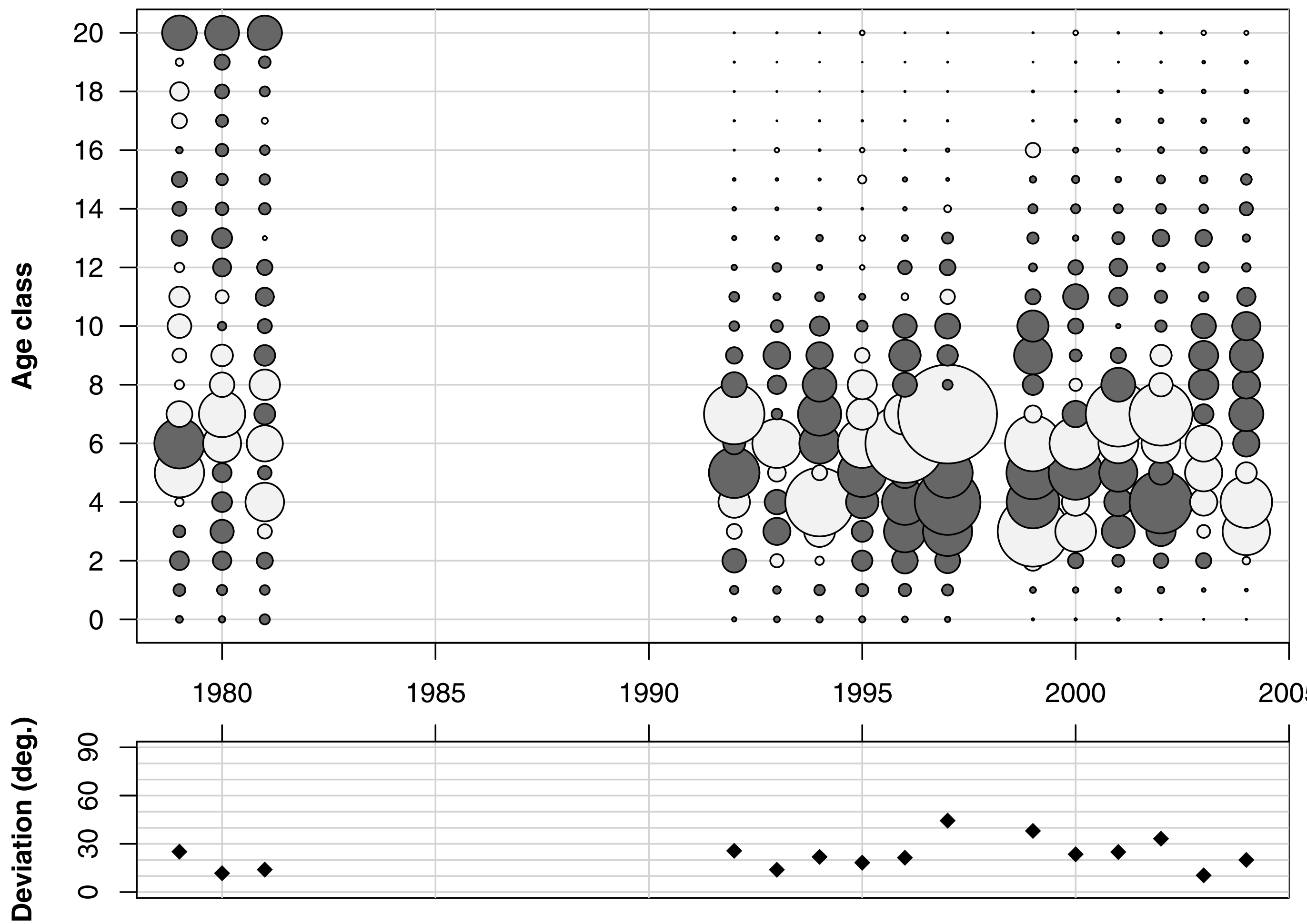


Figure 18. Gag– Base run with time-varying catchability: Estimated (line) and observed (circles) annual age compositions from commercial diving. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

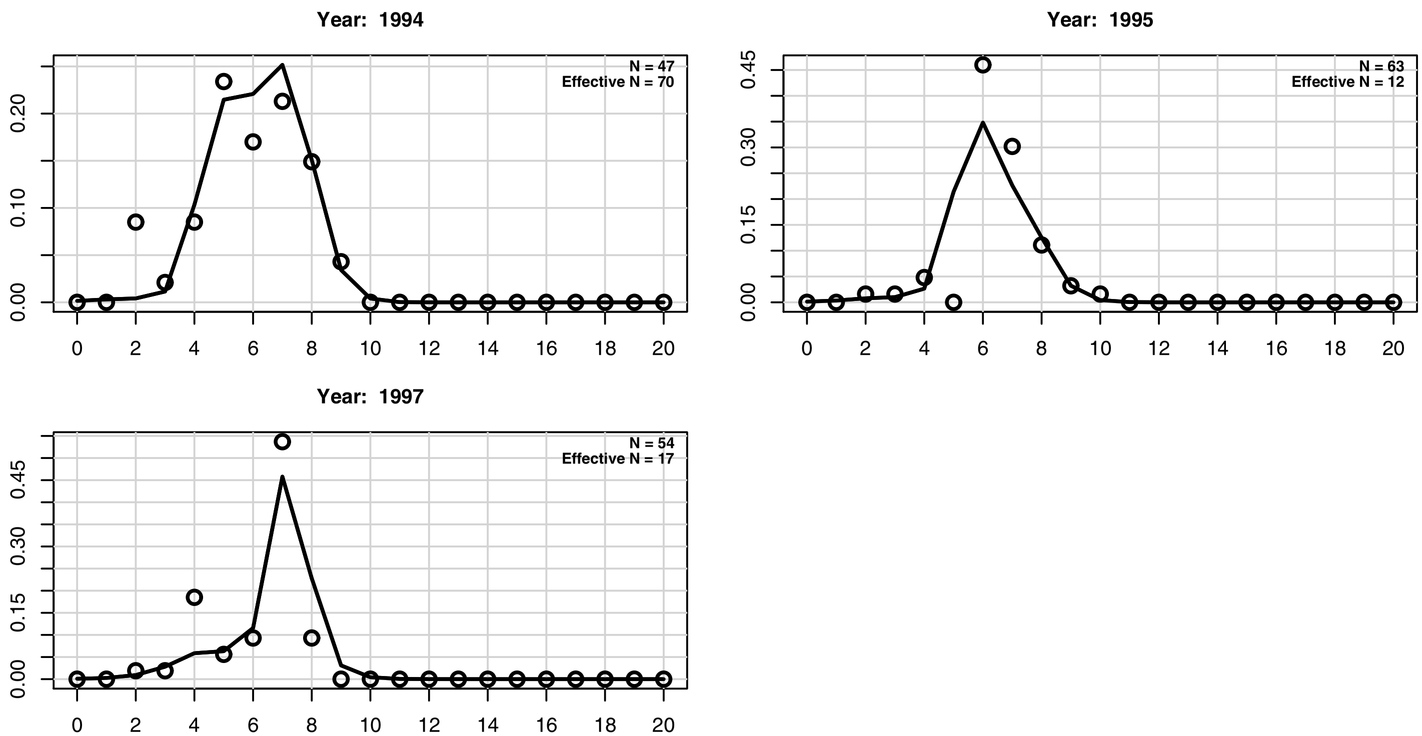


Figure 19. Gag– Base run with constant catchability: Estimated (line) and observed (circles) annual age compositions from commercial diving. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

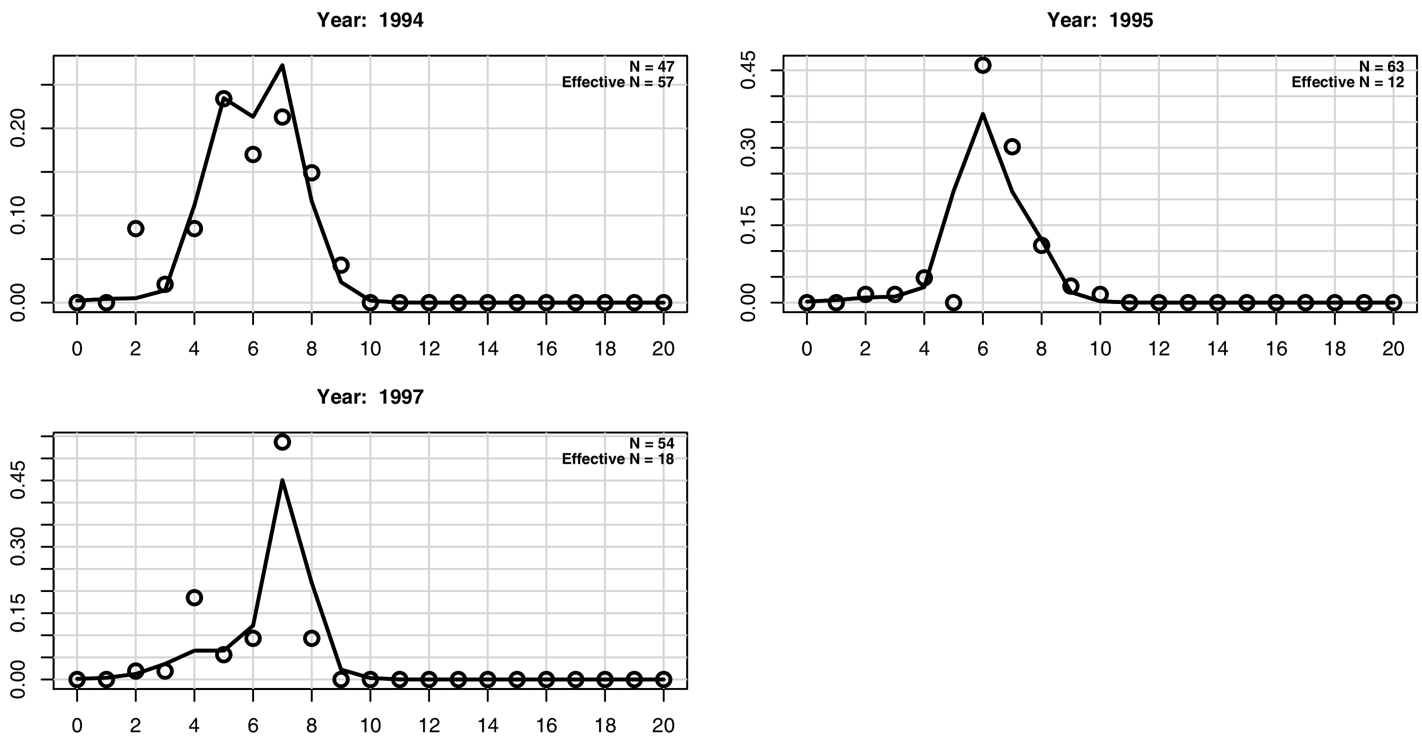


Figure 20. Gag– Base run with time-varying catchability: Bubble plot of age composition residuals from the commercial diving fishery; Dark bubbles are overestimates and light bubbles are underestimates.

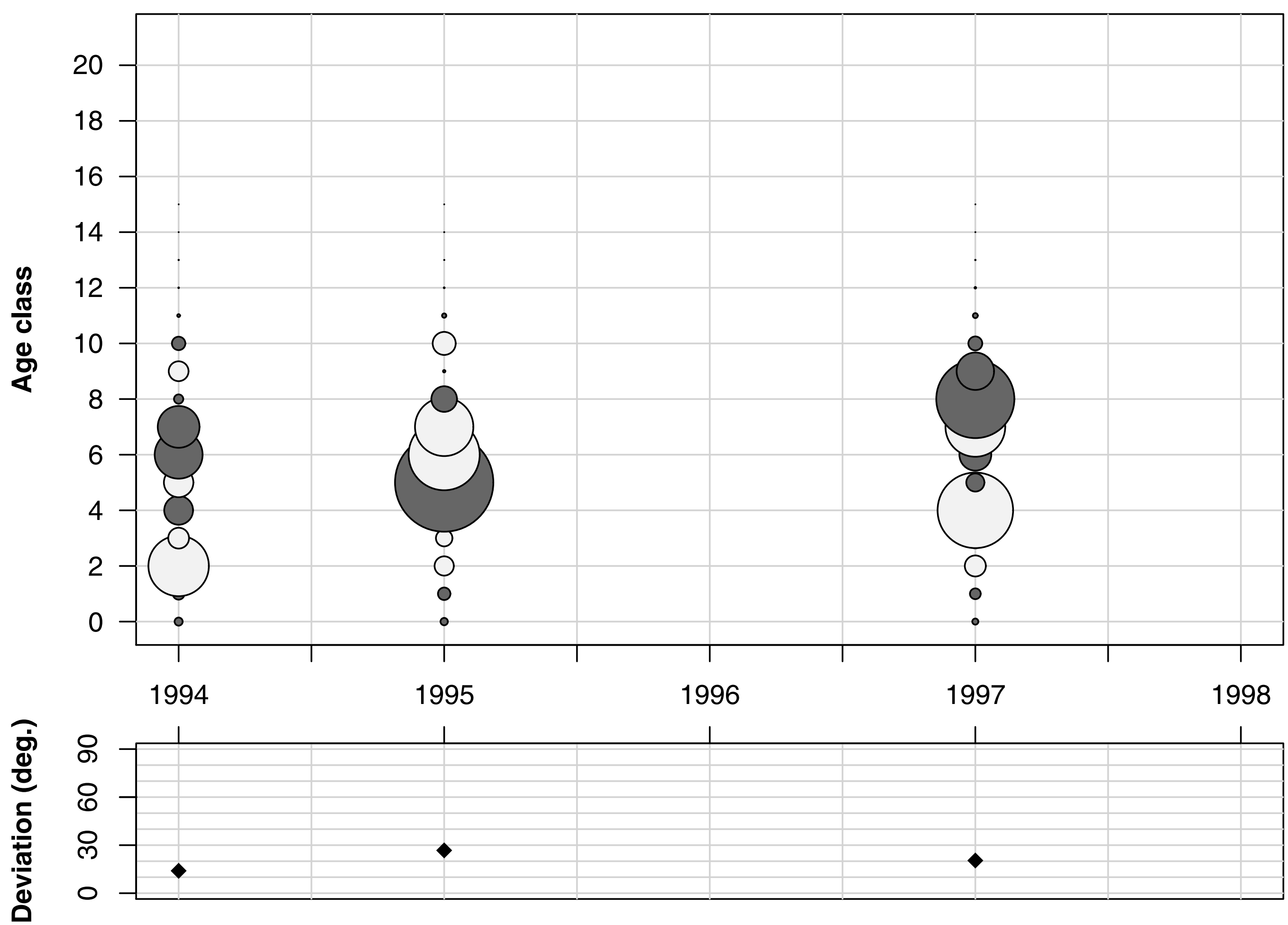


Figure 21. Gag– Base run with constant catchability: Bubble plot of age composition residuals from the commercial diving fishery; Dark bubbles are overestimates and light bubbles are underestimates.

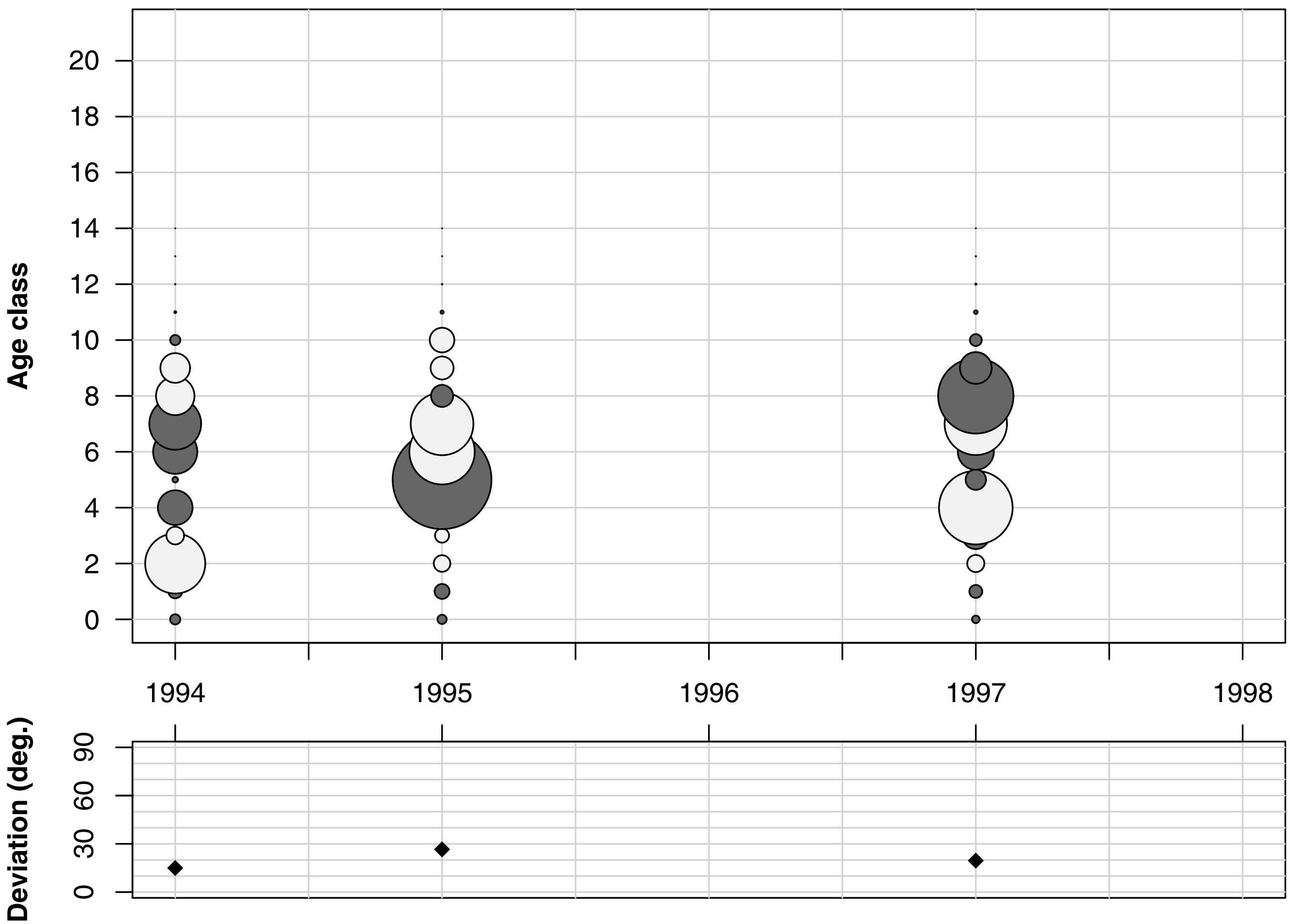


Figure 22. Gag– Base run with time-varying catchability: Estimated (line) and observed (circles) annual age compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

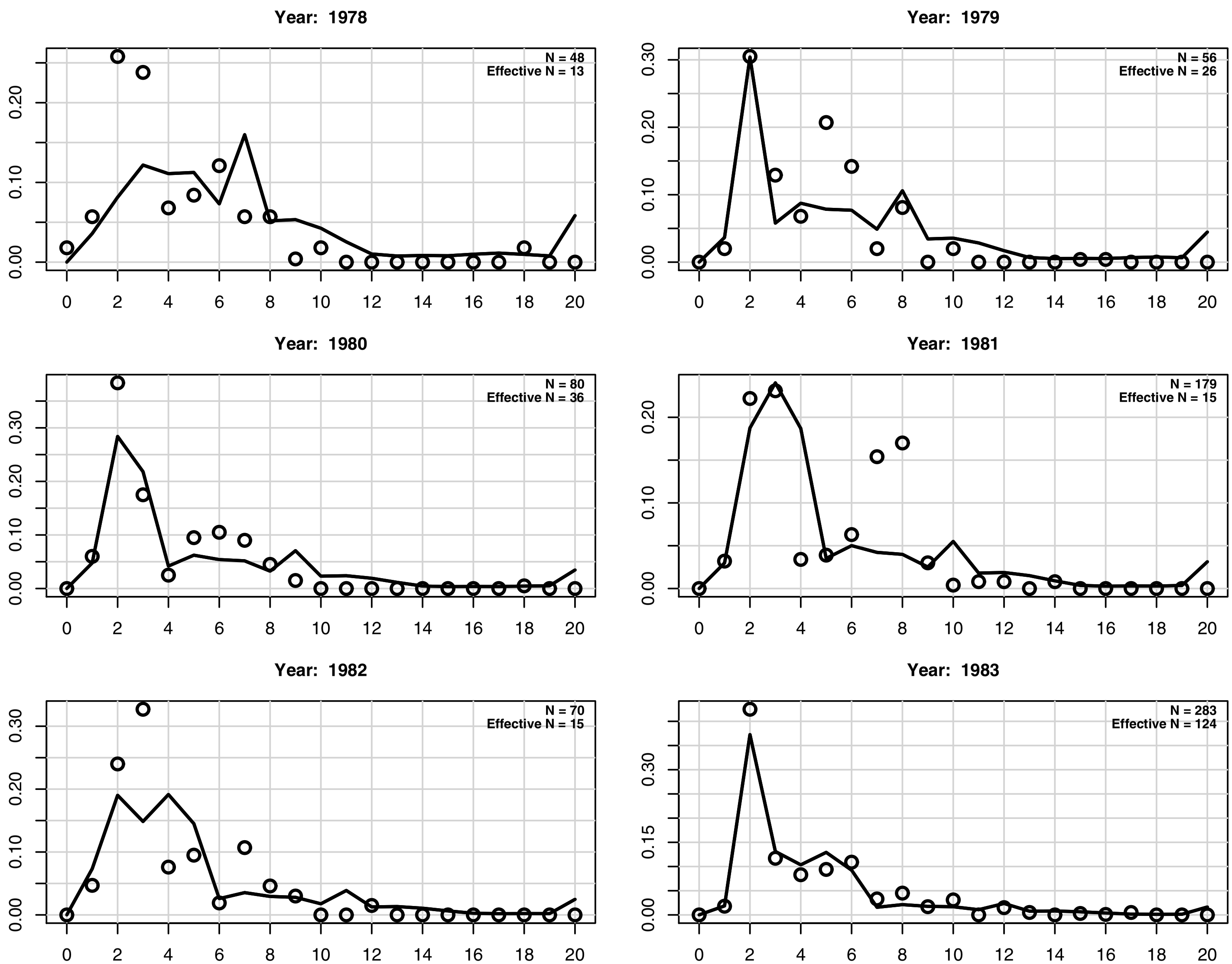


Figure 22. (cont.) Gag– Base run with time-varying catchability: Estimated (line) and observed (circles) annual age compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

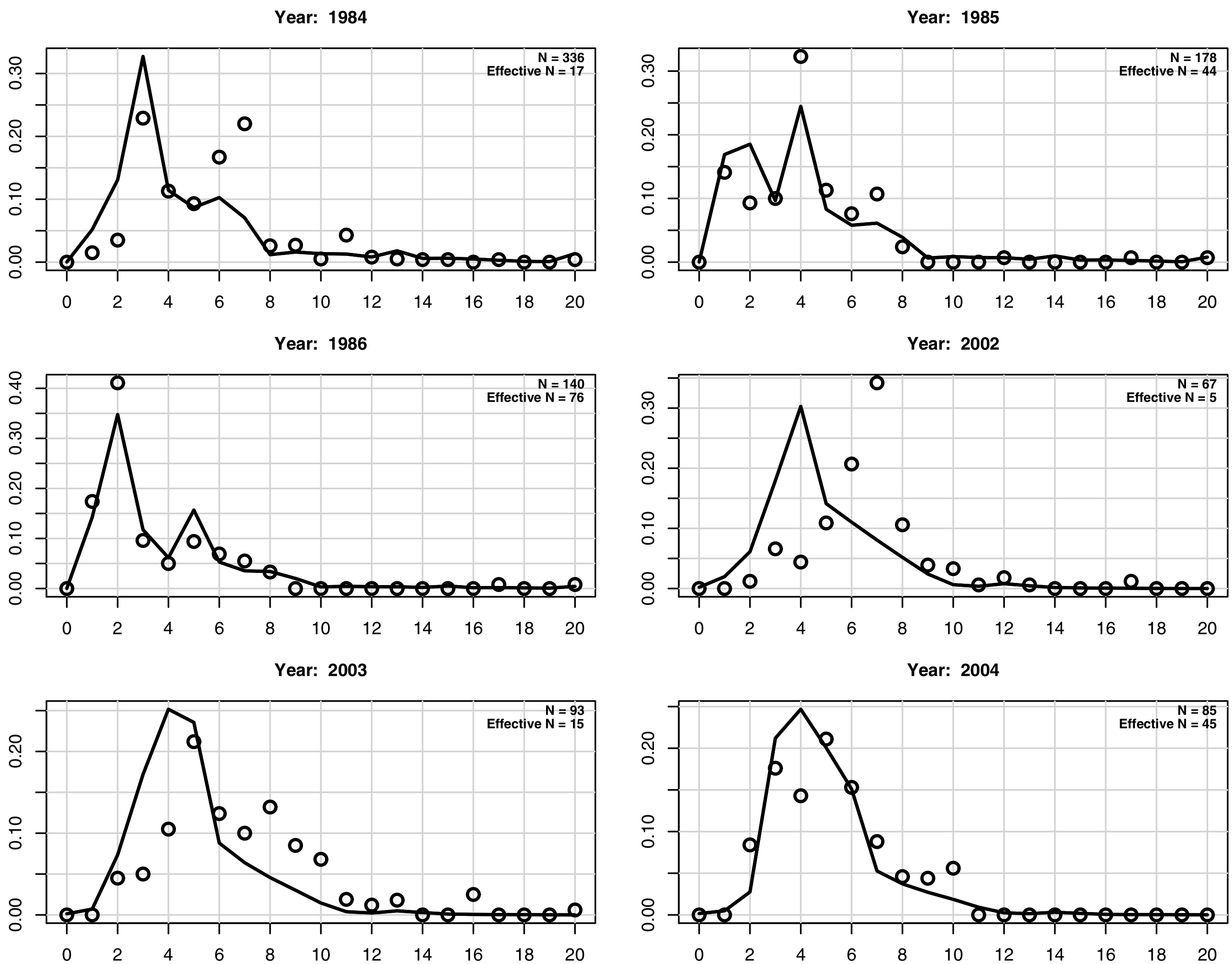


Figure 23. Gag– Base run with constant catchability: Estimated (line) and observed (circles) annual age compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

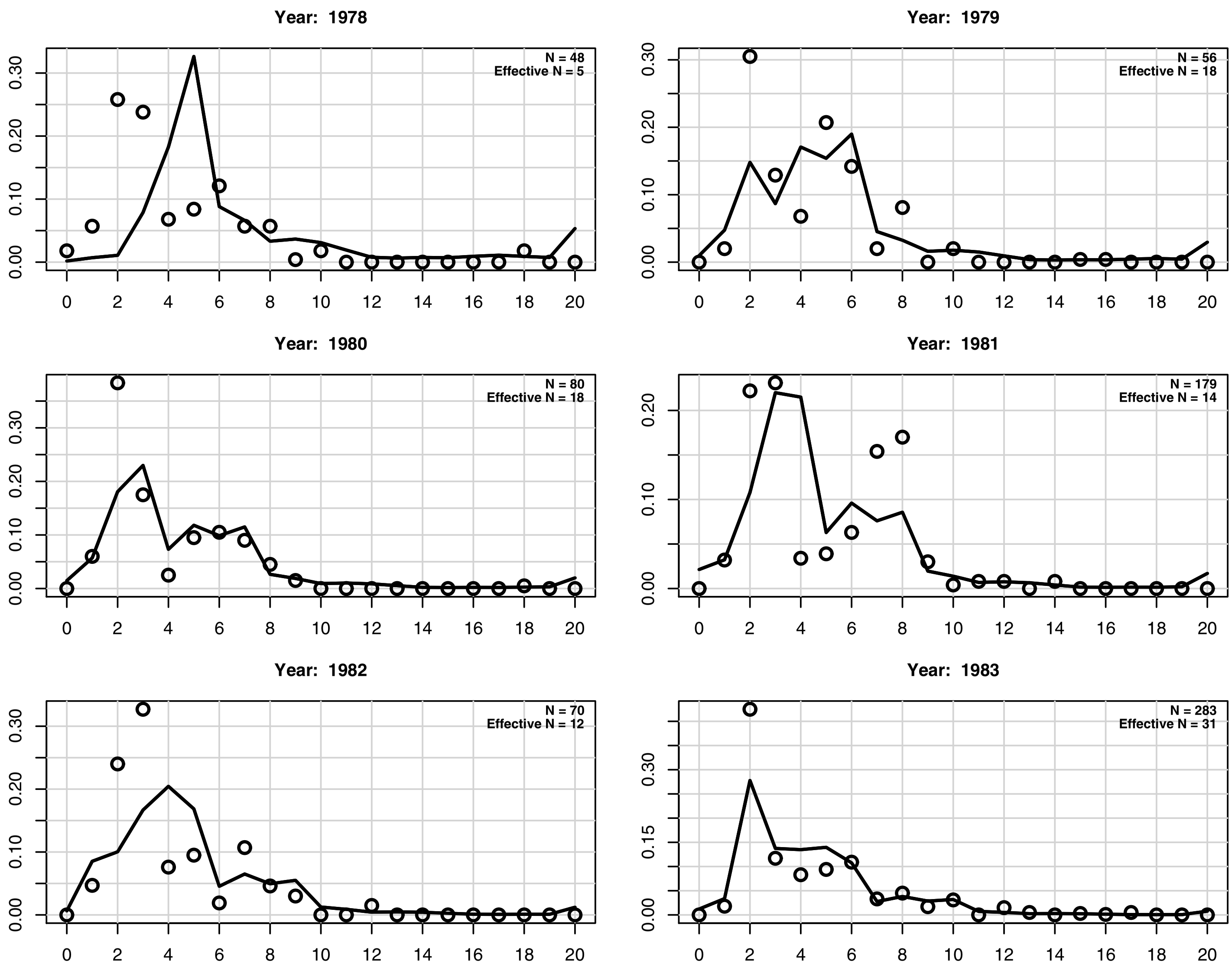


Figure 23. (cont.) Gag– Base run with constant catchability: Estimated (line) and observed (circles) annual age compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

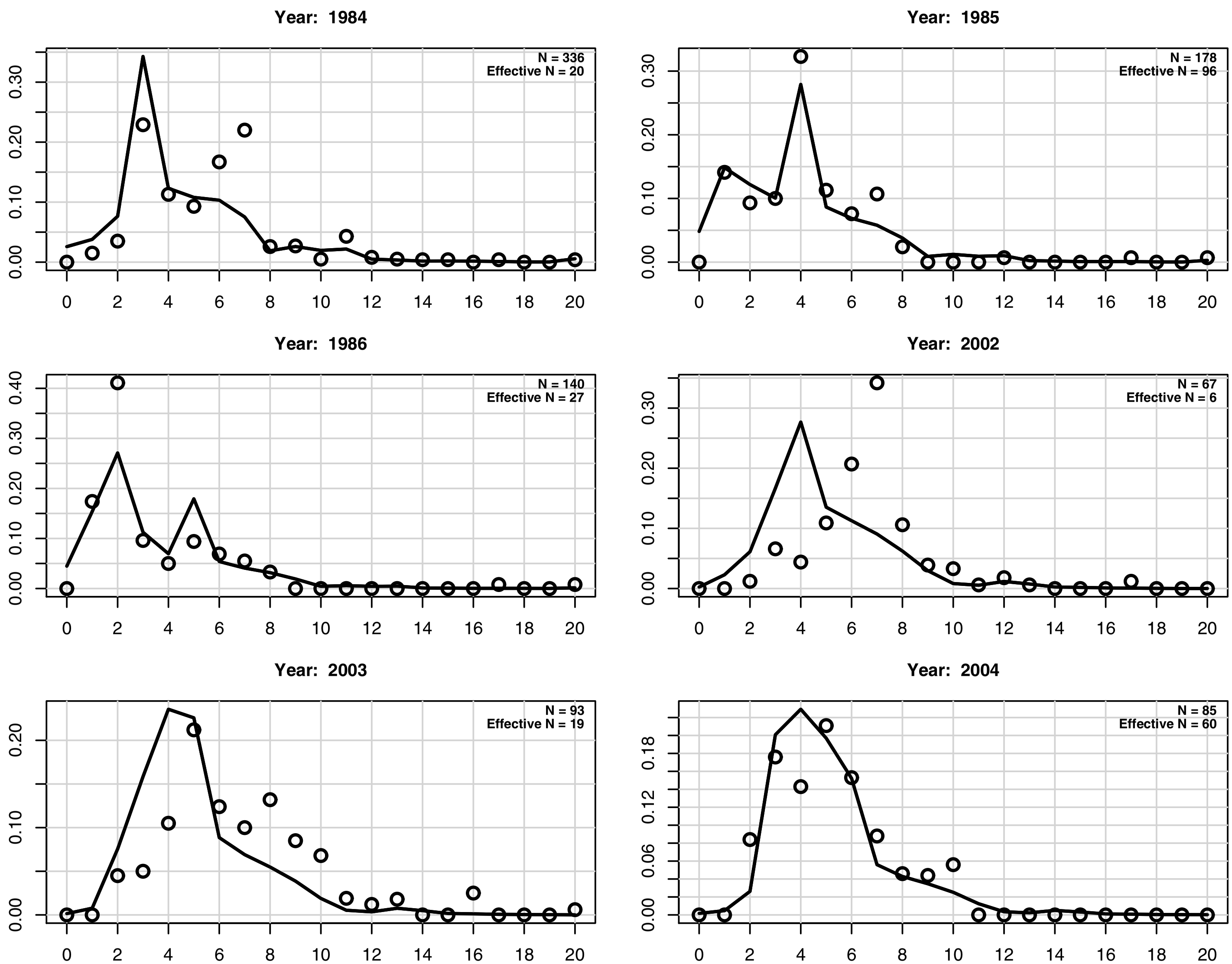


Figure 24. Gag– Base run with time-varying catchability: Bubble plot of age composition residuals from the recreational headboat fishery; Dark bubbles are overestimates and light bubbles are underestimates.

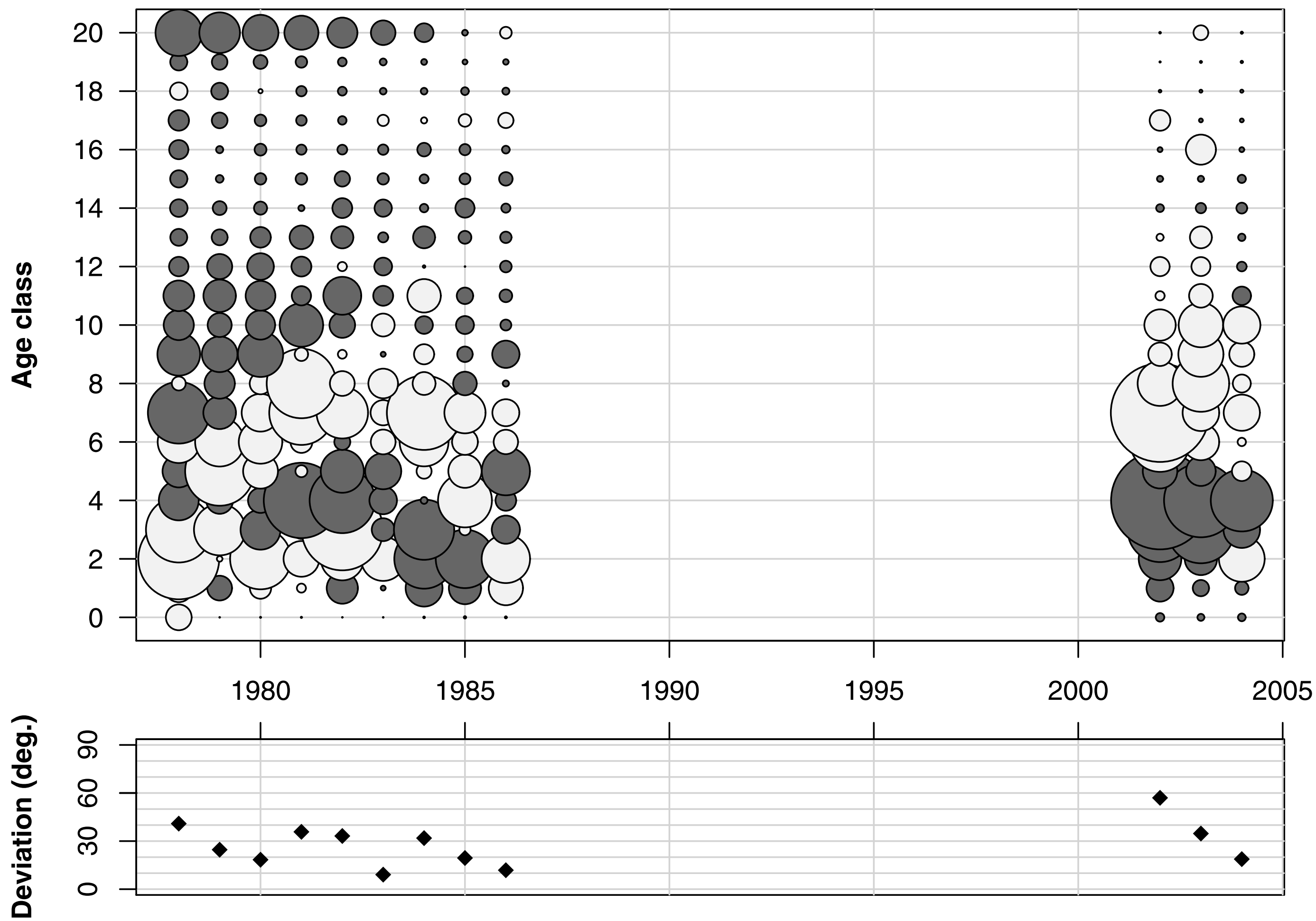


Figure 25. Gag– Base run with constant catchability: Bubble plot of age composition residuals from the recreational headboat fishery; Dark bubbles are overestimates and light bubbles are underestimates.

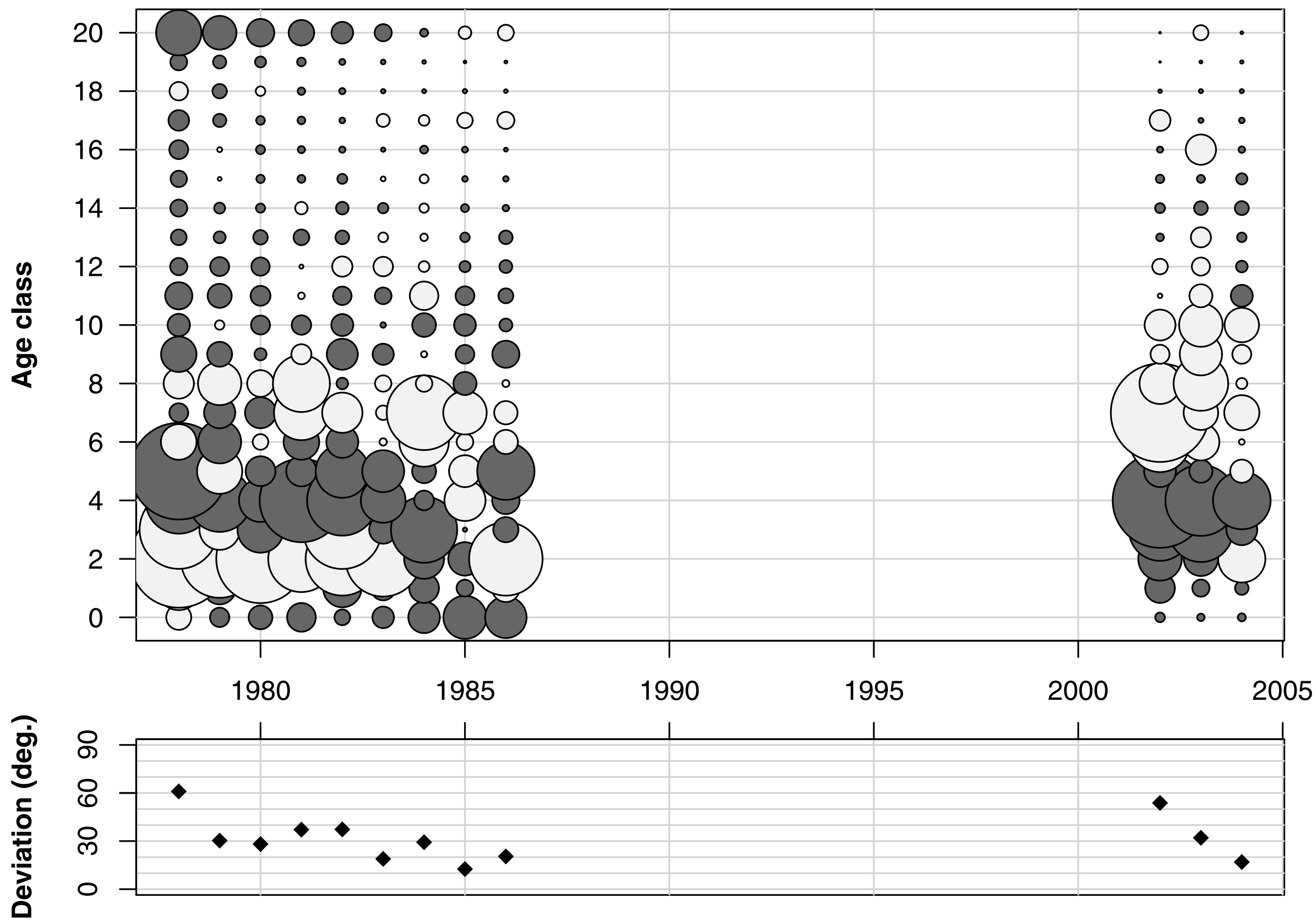


Figure 26. Gag– Time-varying catchability run: Commercial landings (klb) of gag from the assessment model, estimated (line, filled circles) and observed (open circles). A) Handline; and B) Diving. Note difference of scales.

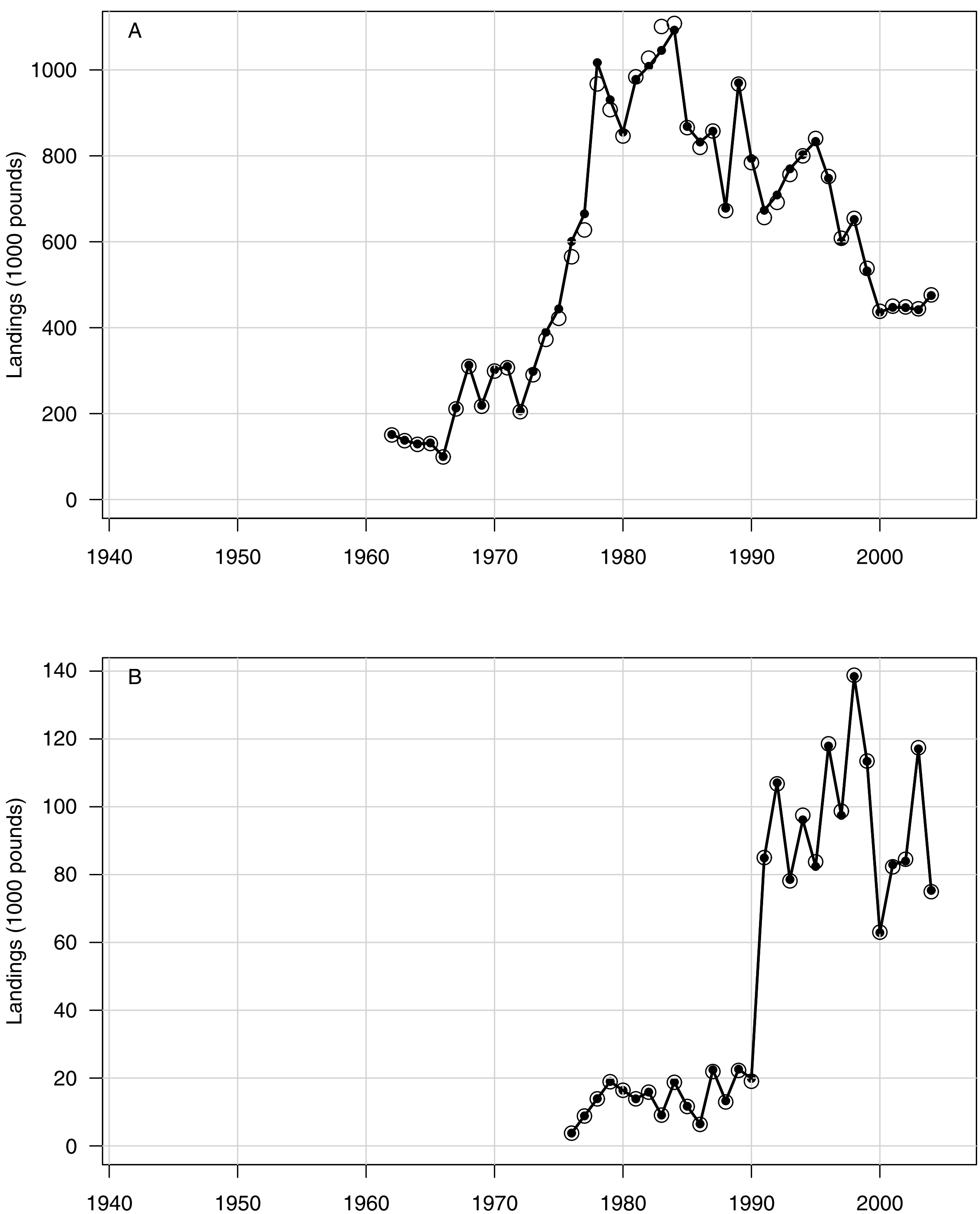


Figure 27. Constant catchability run: Commercial landings (klb) of gag from the assessment model, estimated (line, filled circles) and observed (open circles). A) Handline; and B) Diving. Note difference of scales.

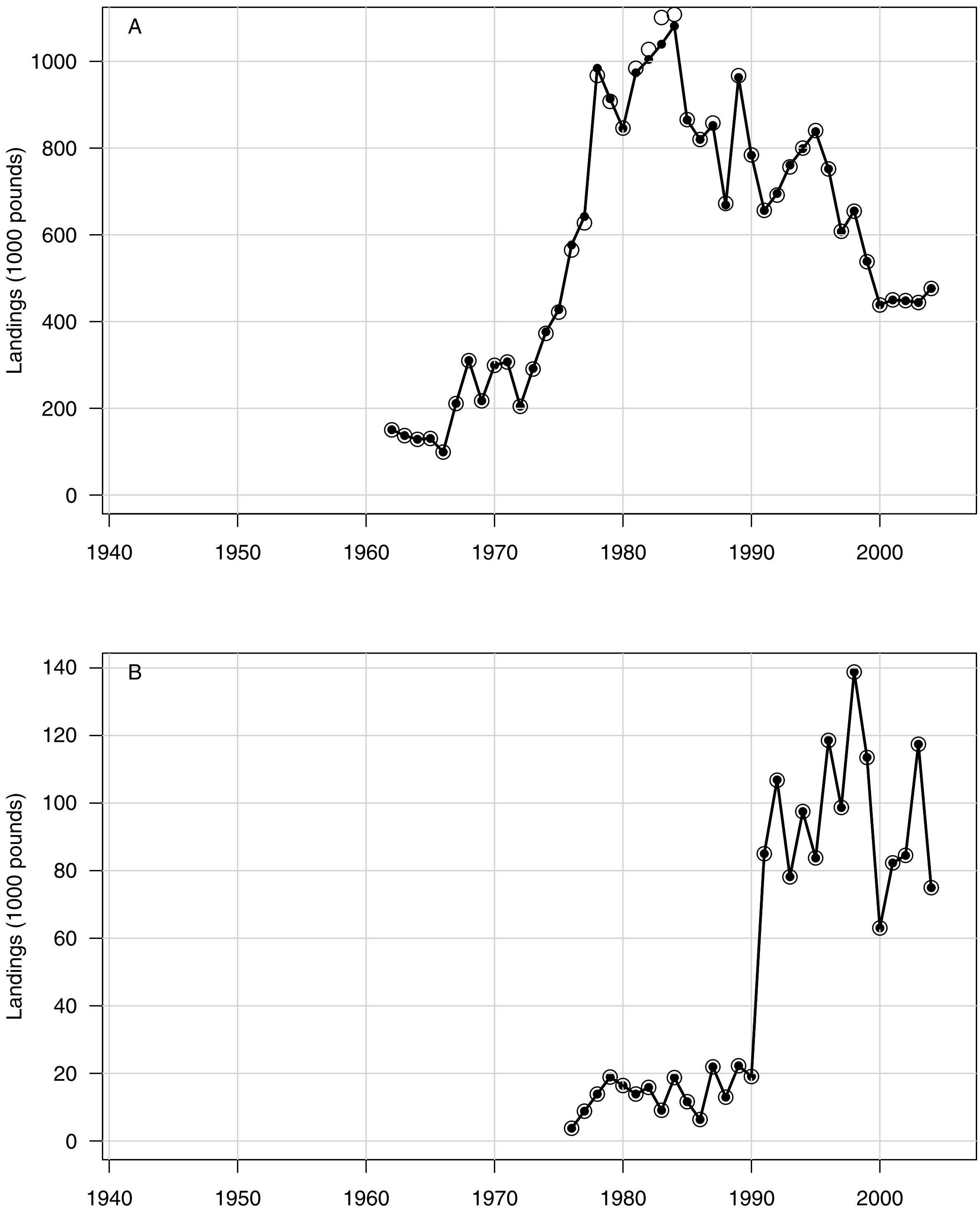


Figure 28. Gag– Time-varying catchability run: Recreational landings (1000s fish) of gag from the assessment model, estimated (line, filled circles) and observed (open circles). A) Headboat and B) MRFSS. Note difference of scales.

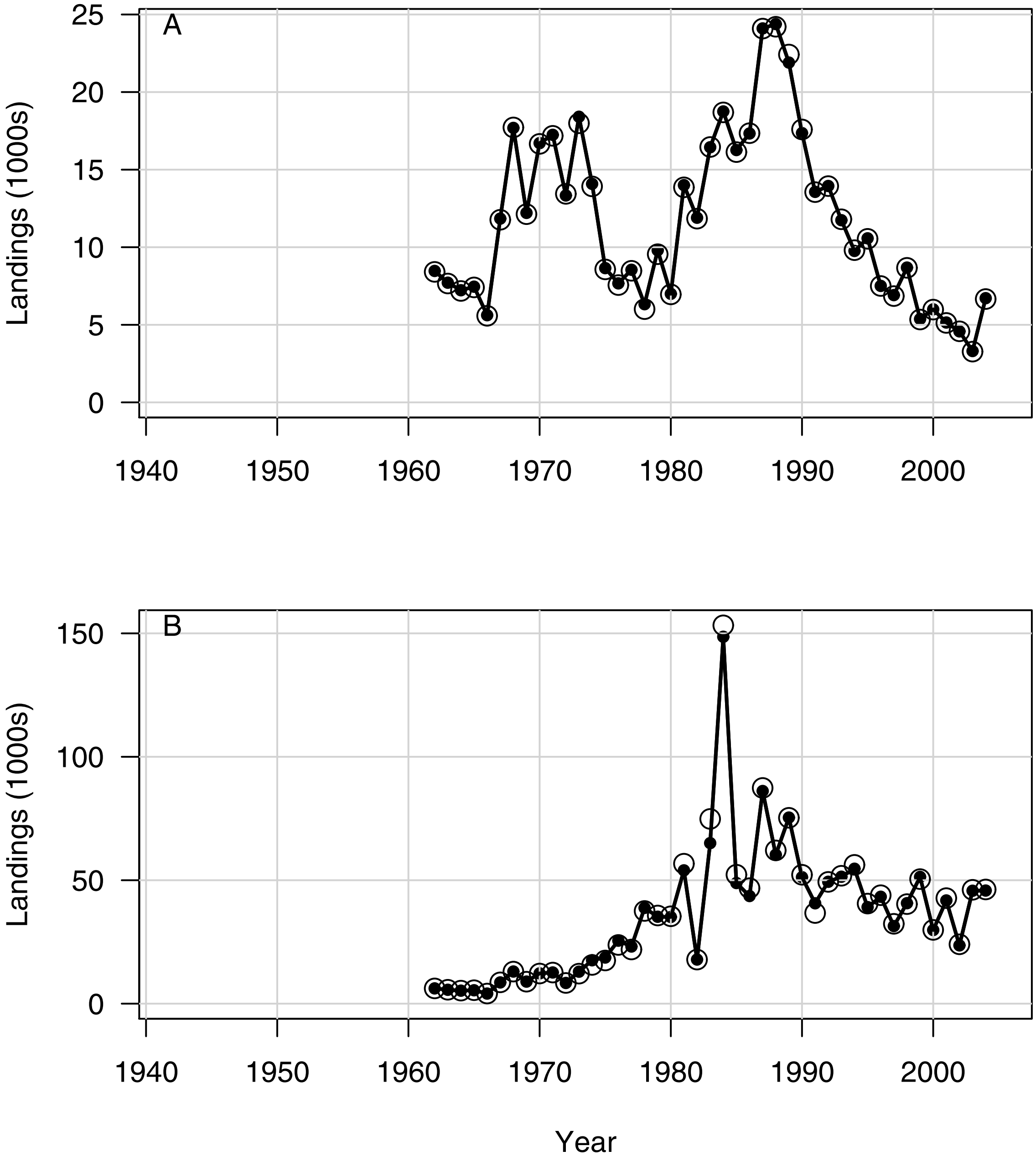


Figure 29. Gag– Constant catchability run: Recreational landings (1000s fish) of gag from the assessment model, estimated (line, filled circles) and observed (open circles). A) Headboat and B) MRFSS. Note difference of scales.

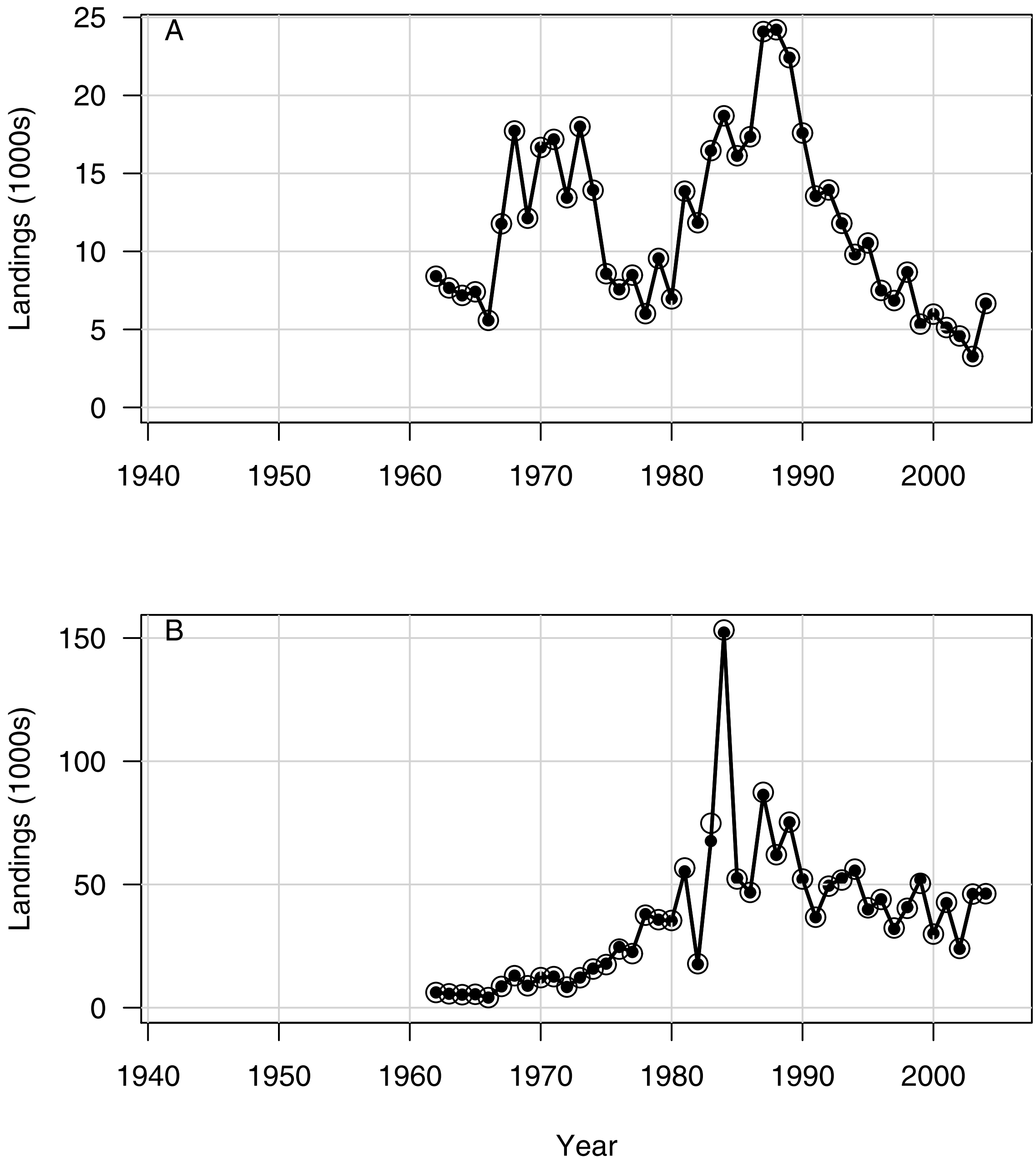


Figure 30. Gag– Discard mortalities (1000s fish) of gag from the time-varying assessment model, estimated (line, filled circles) and observed (open circles). A) Commercial handline; B) Headboat; and C) MRFSS. Note difference of scales.

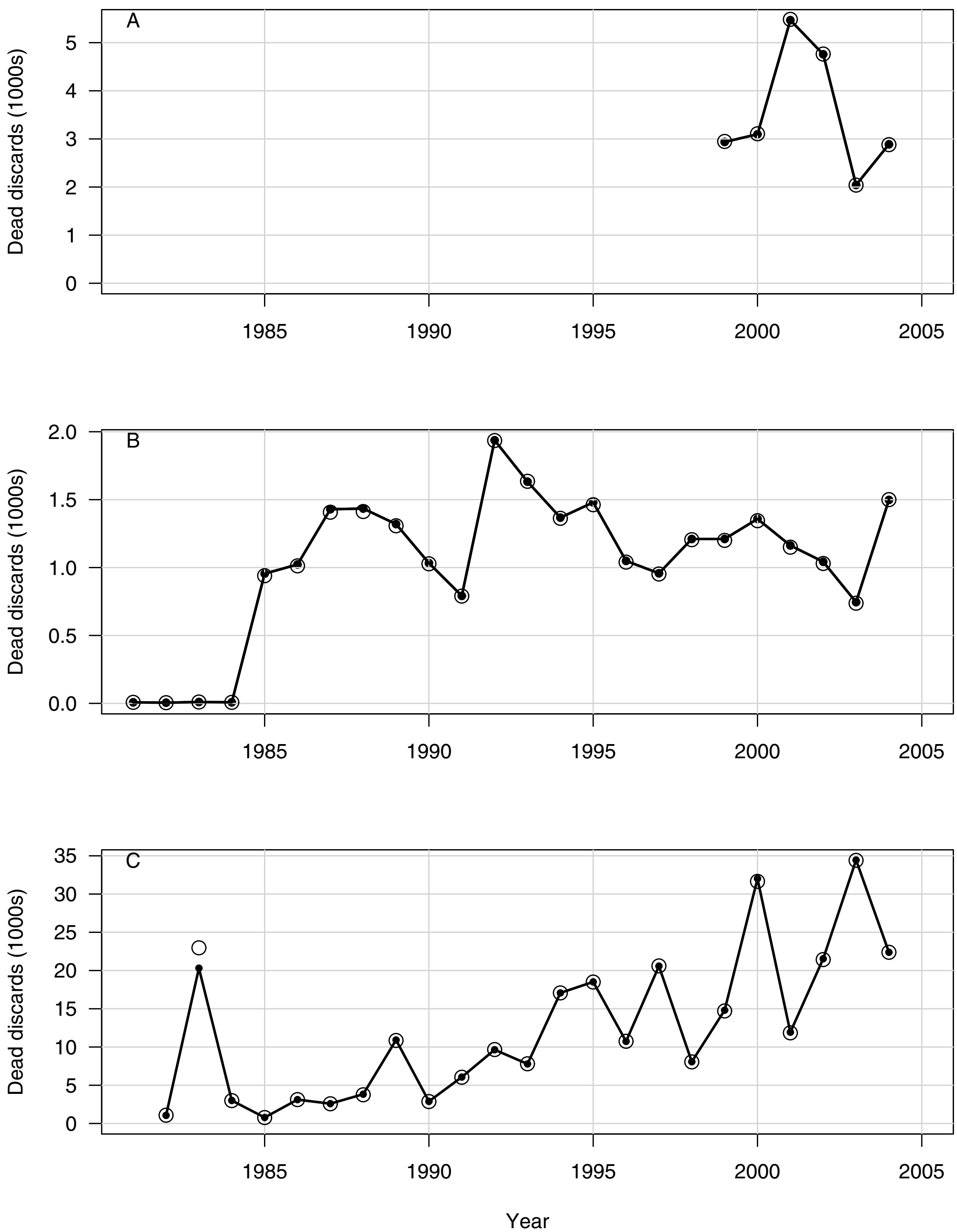


Figure 31. Gag– Discard mortalities (1000s fish) of gag from the constant assessment model, estimated (line, filled circles) and observed (open circles). A) Commercial handline; B) Headboat; and C) MRFSS. Note difference of scales.

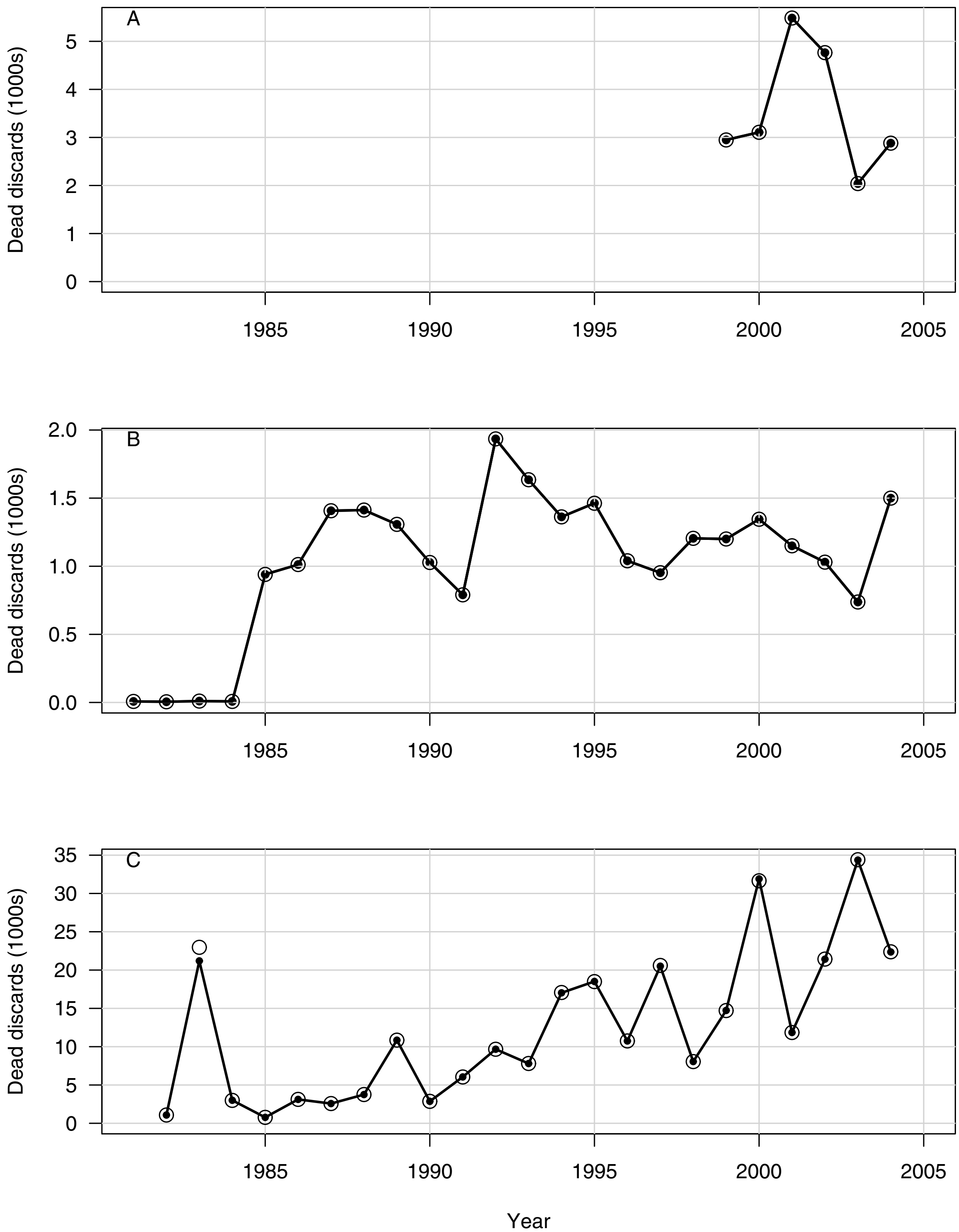


Figure 32. Gag- Base run with time-varying catchability: Estimated catch in numbers by fishery from the stock assessment model.

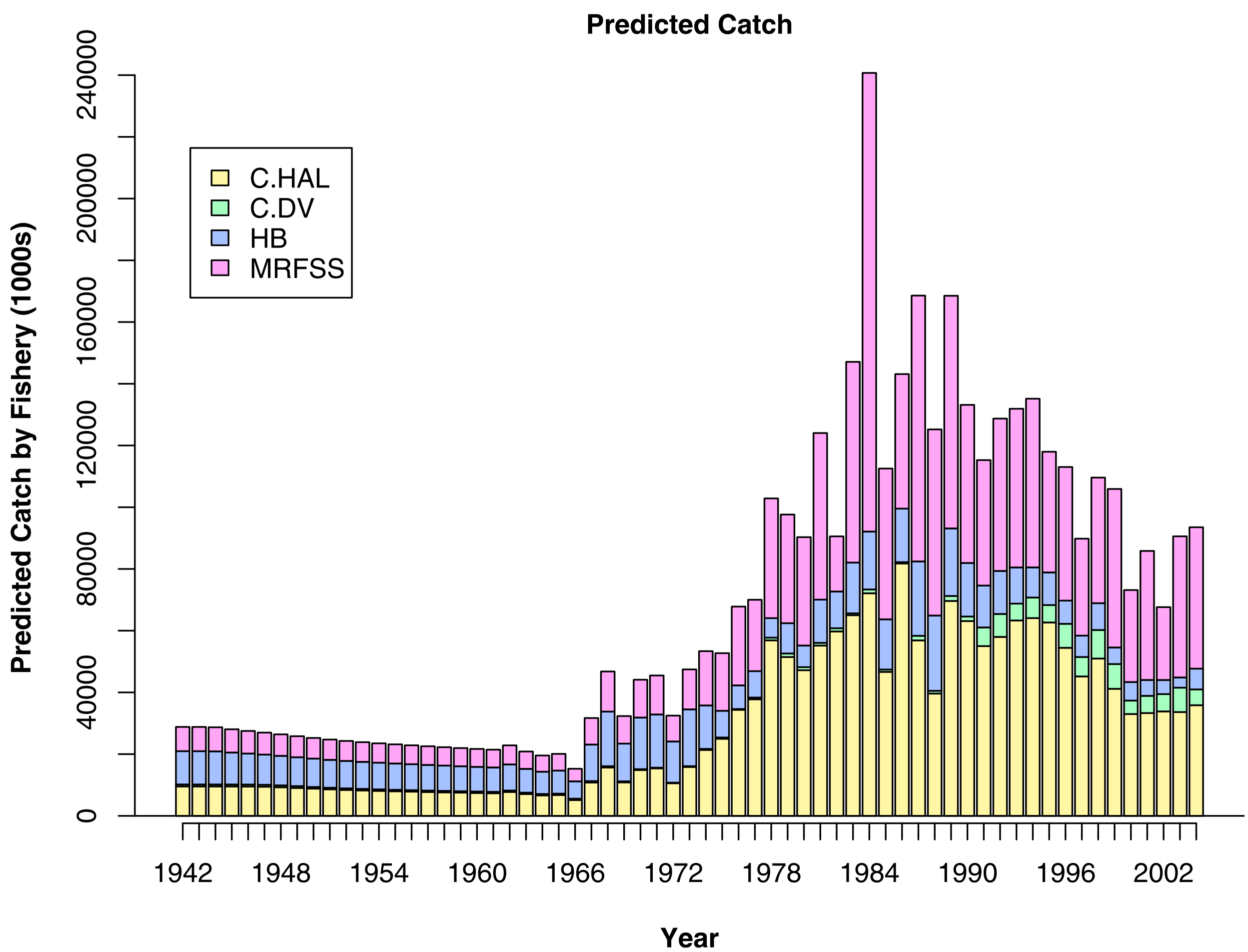


Figure 33. Gag– Base run with constant catchability: Estimated catch in numbers by fishery from the stock assessment model.

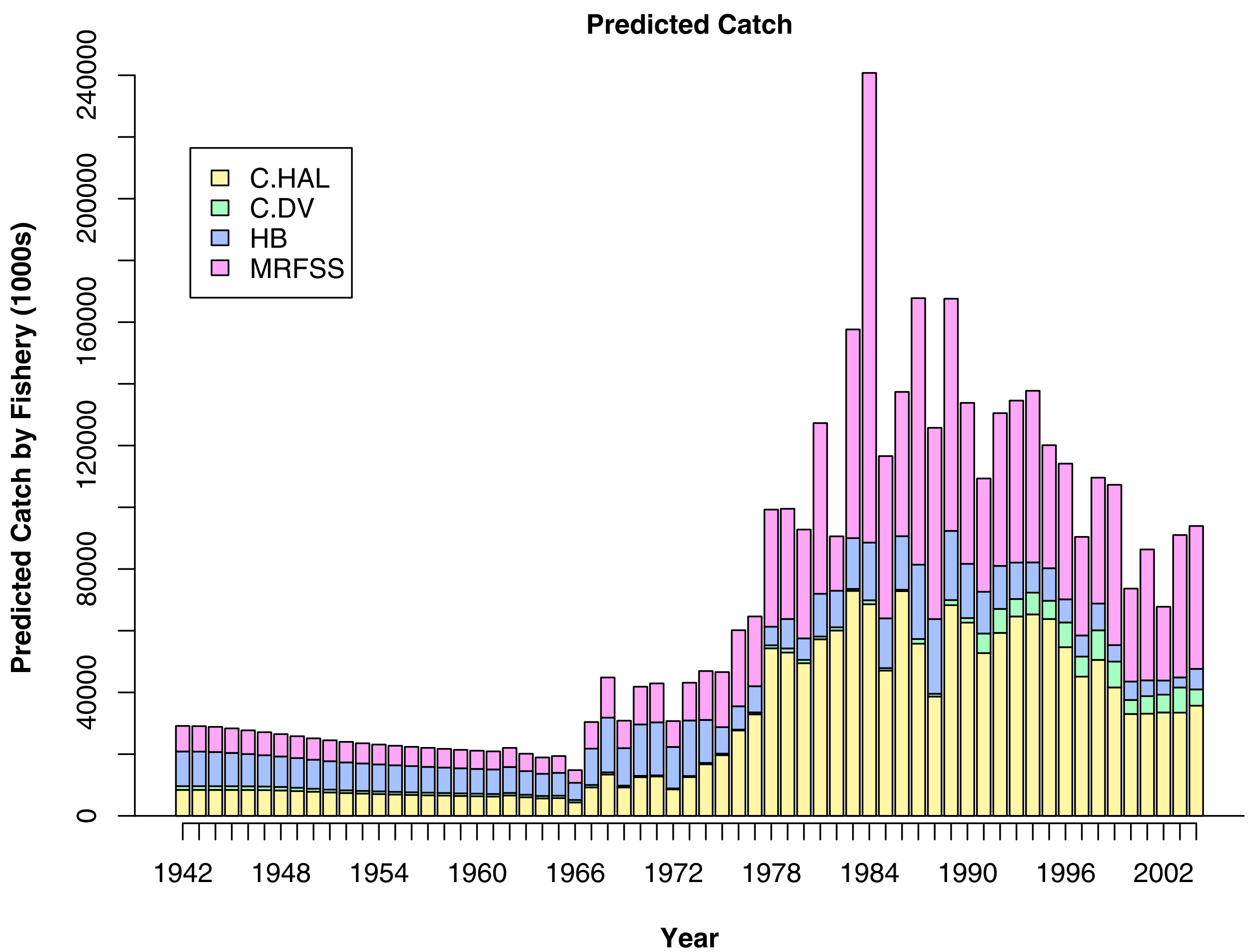


Figure 34. Gag– Base run with time-varying catchability: Estimated landings in weight (klb) by fishery from the stock assessment model.

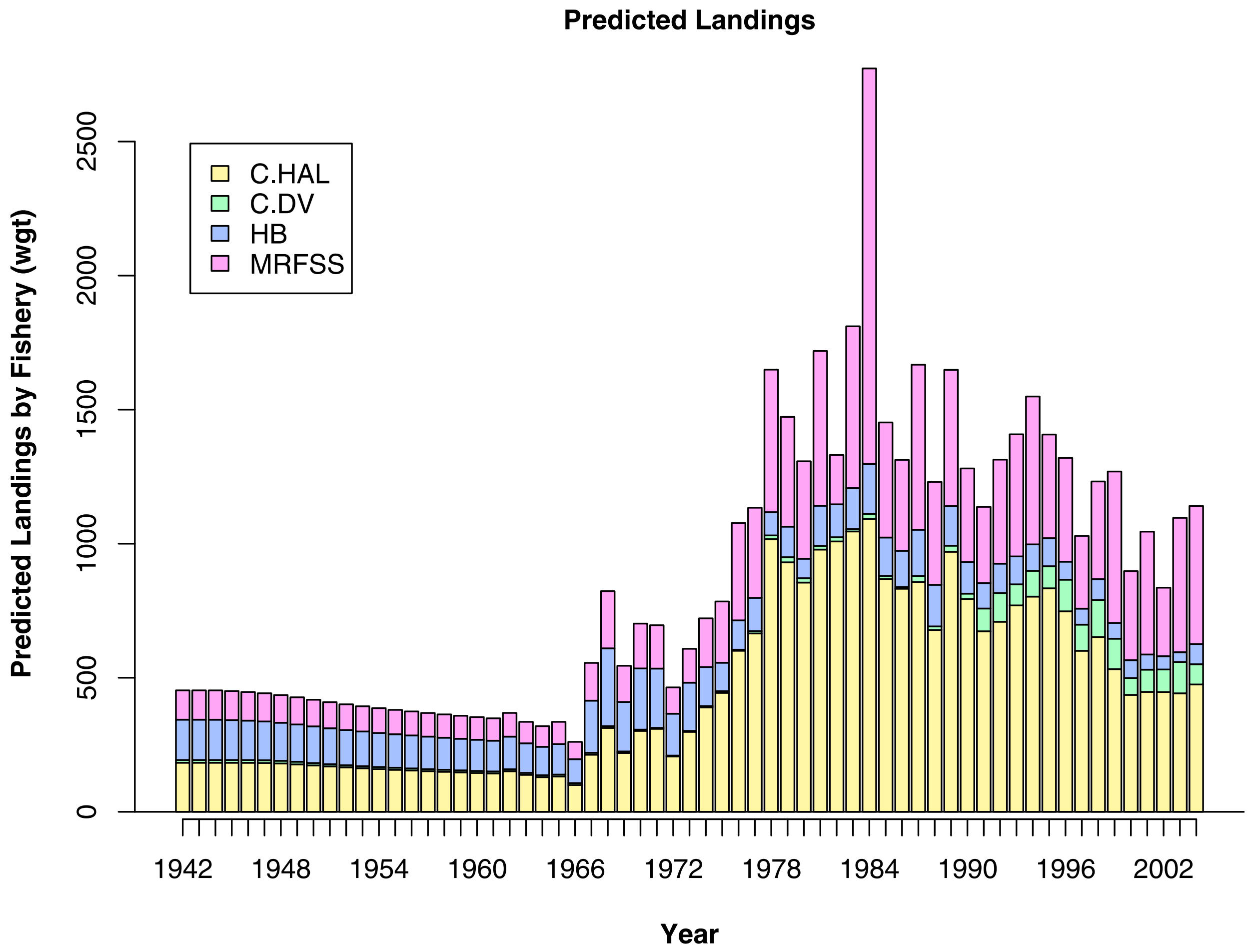


Figure 35. Gag- Base run with constant catchability: Estimated landings in weight (klb) by fishery from the stock assessment model.

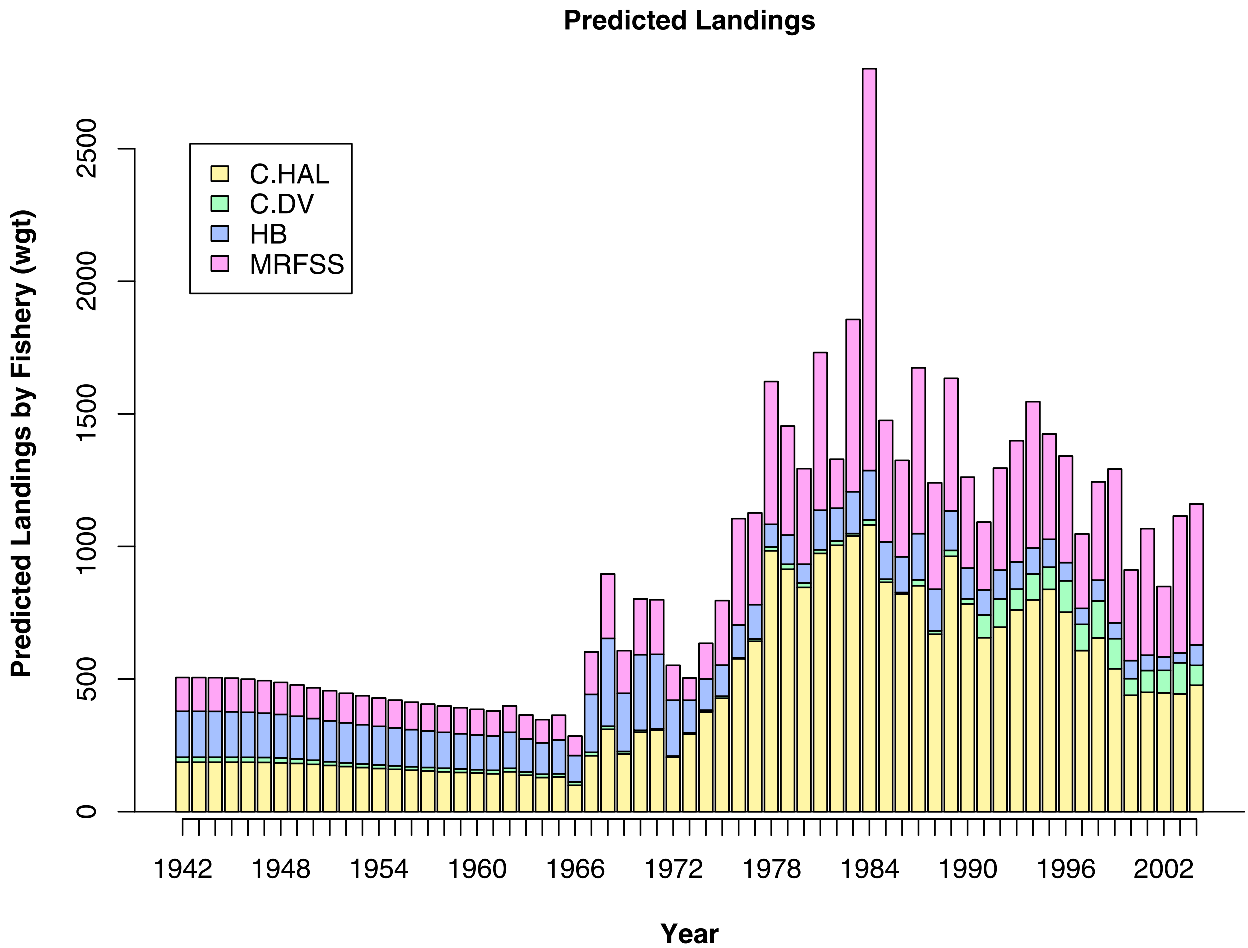


Figure 36. Gag– Base run with time-varying catchability: Estimated dead discards in numbers by fishery from the stock assessment model.

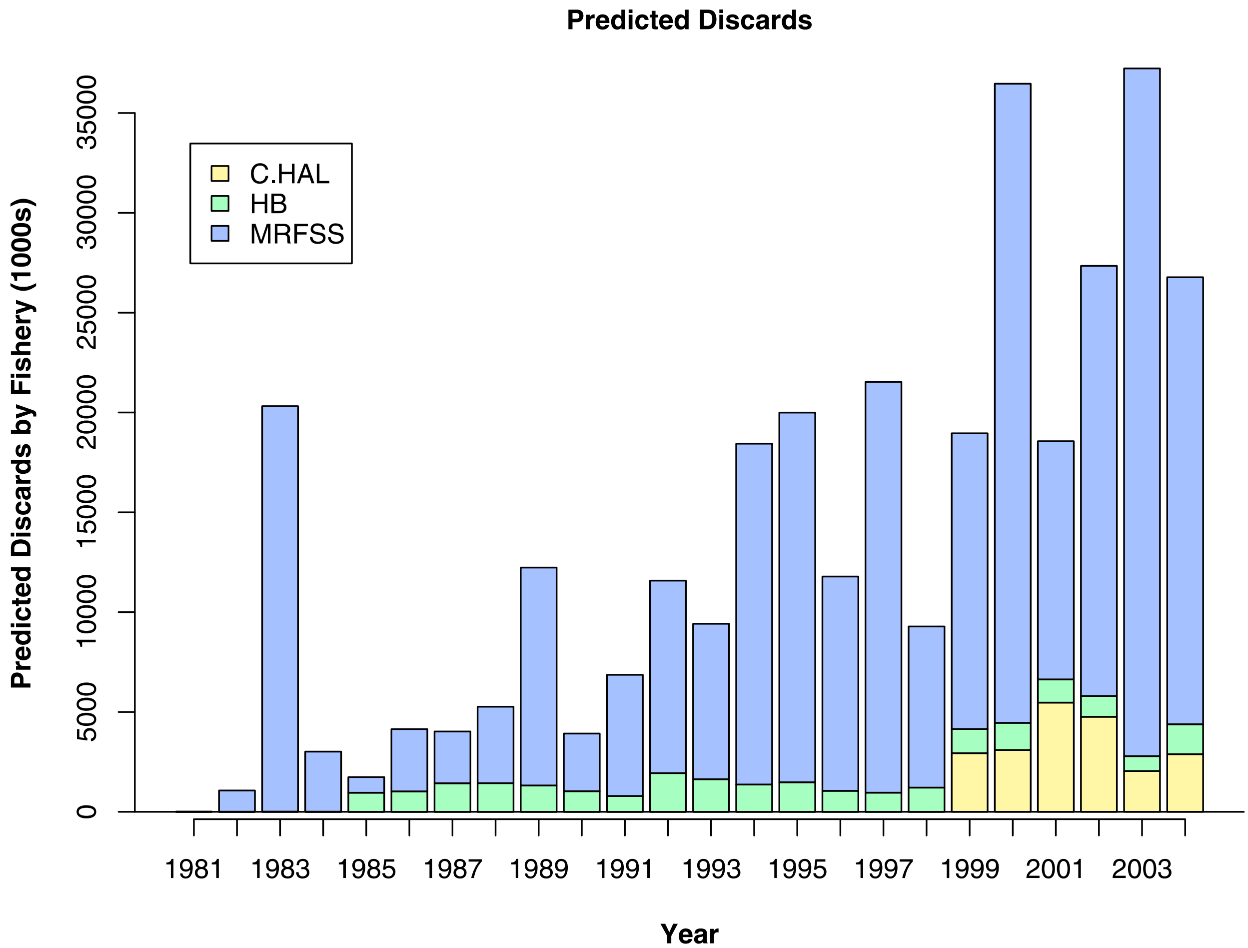


Figure 37. Gag- Base run with constant catchability: Estimated dead discards in numbers by fishery from the stock assessment model.

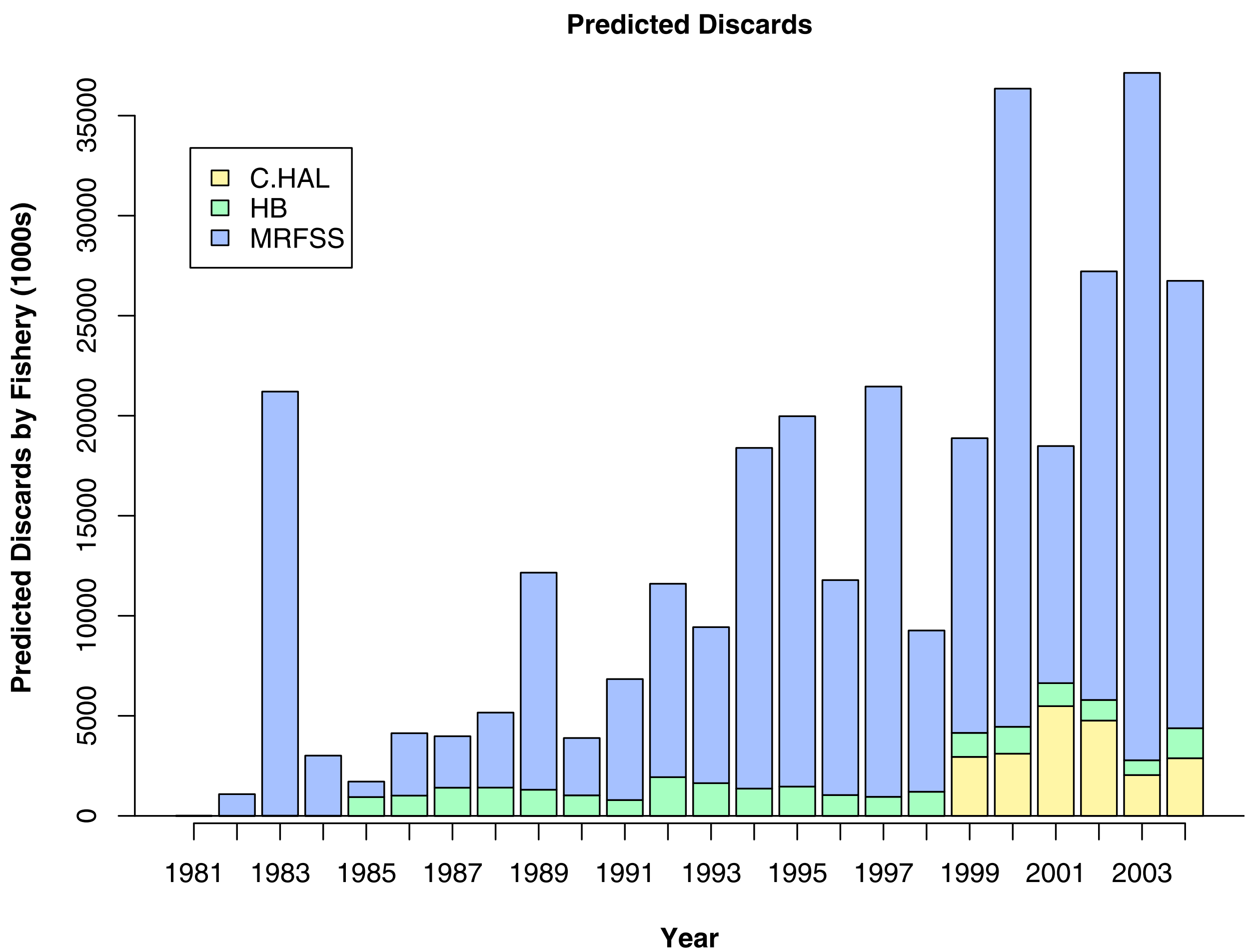


Figure 38. Gag– Time-varying catchability run: Fits to indices of gag abundance, estimated (line, solid circle) and observed (open circles). A) Commercial logbook (handline gear); B) Recreational MRFSS; and C) Recreational Headboat.

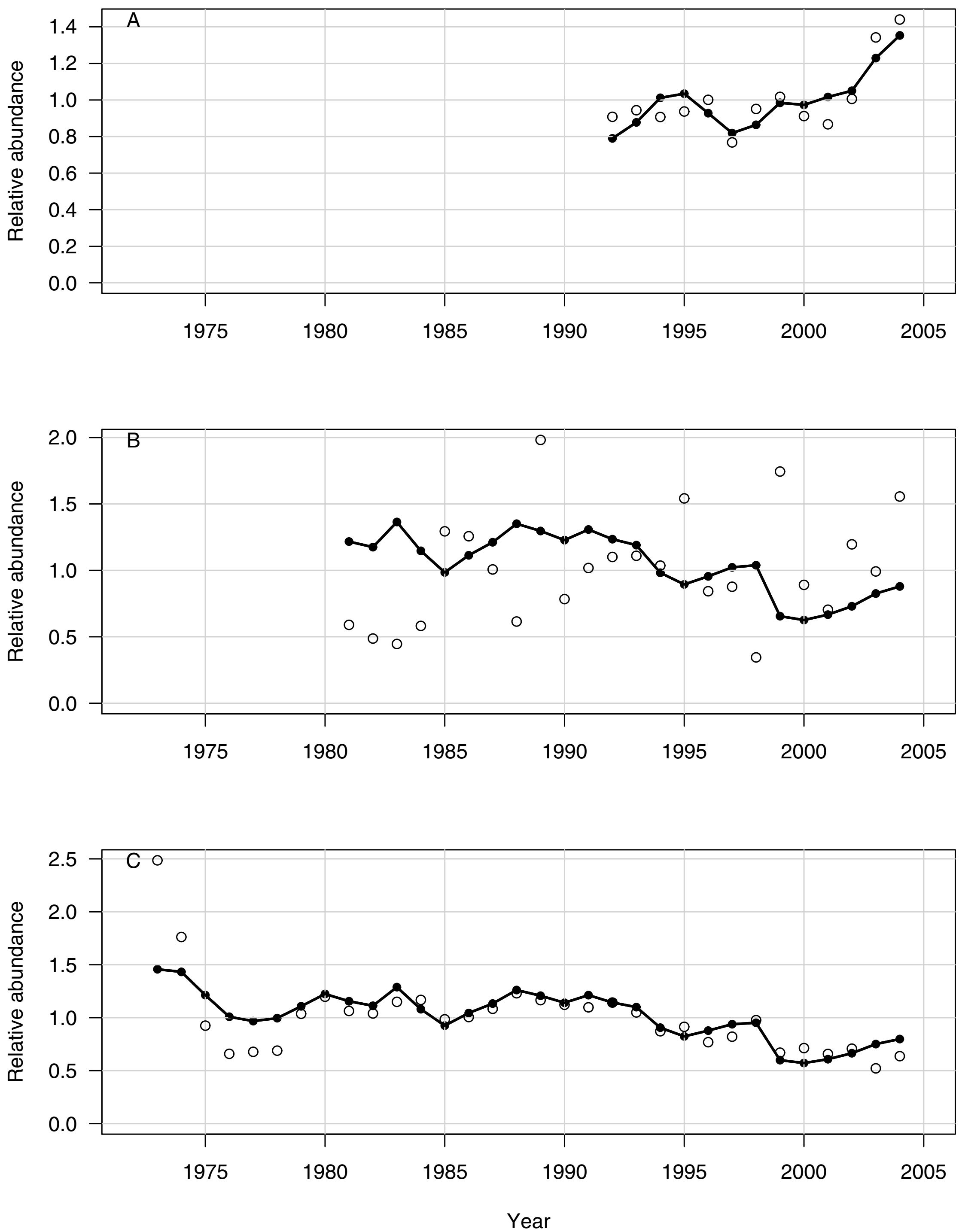


Figure 39. Gag– Constant catchability run: Fits to indices of gag abundance, estimated (line, solid circle) and observed (open circles). A) Commercial logbook (handline gear); B) Recreational MRFSS; and C) Recreational Headboat.

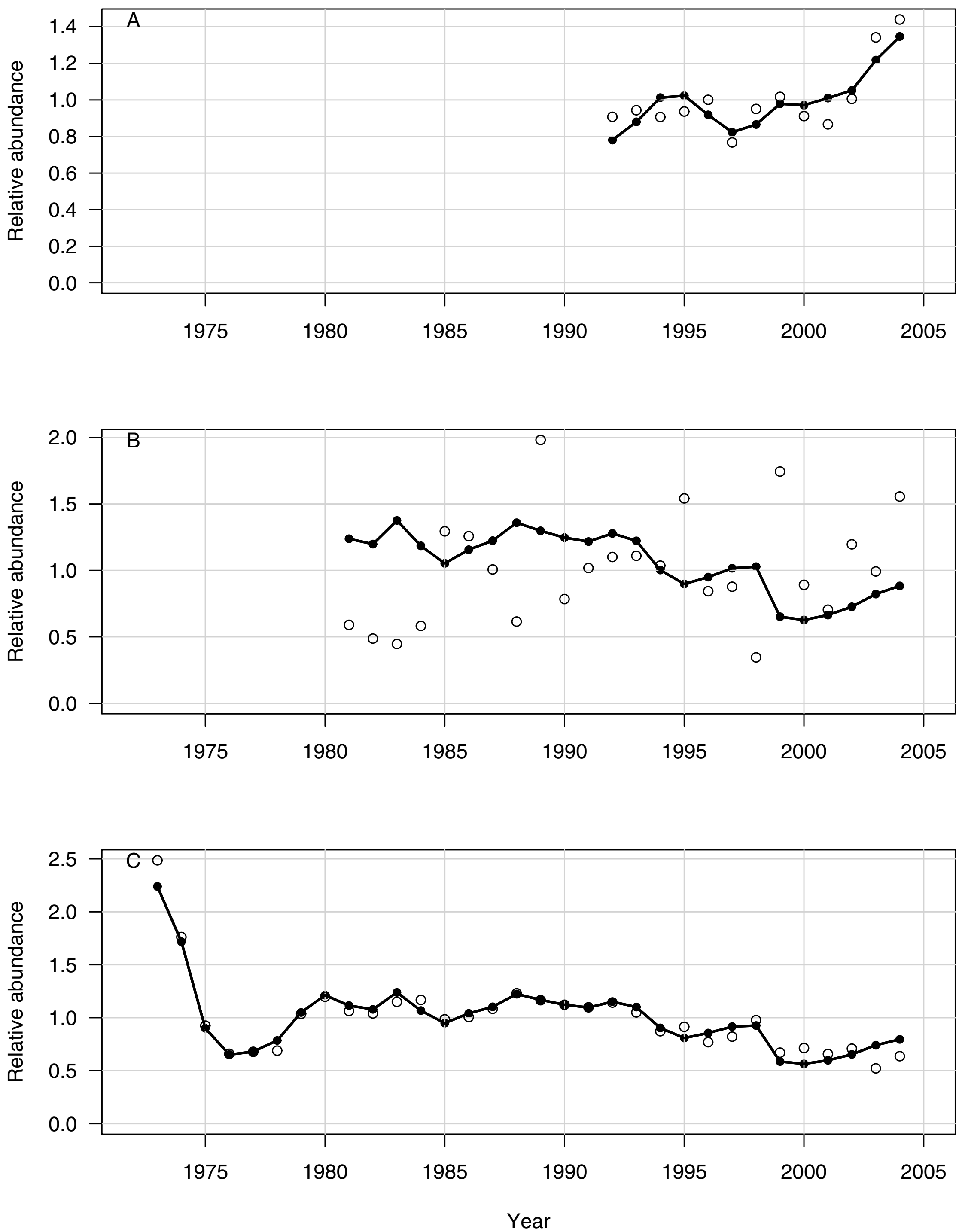


Figure 40. Gag– Time-varying catchability run: Mean length (mm) at age (midyear) of gag, estimated internally by the assessment model assuming von Bertalanffy growth. Dotted line at L_∞ and thin lines represent 95% confidence intervals from estimated CV parameters at each age.

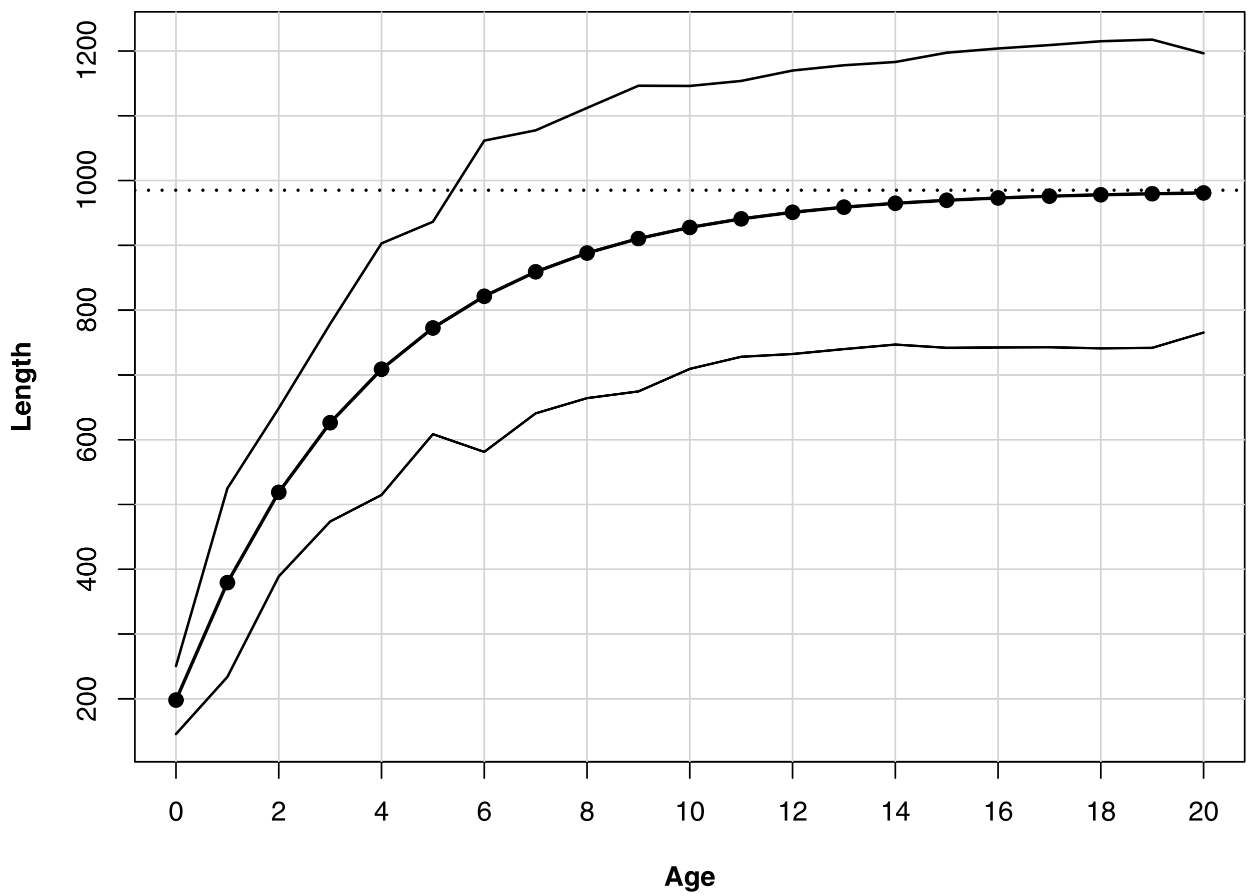


Figure 41. Gag– Constant catchability run: Mean length (mm) at age (midyear) of gag, estimated internally by the assessment model assuming von Bertalanffy growth. Dotted line at L_∞ and thin lines represent 95% confidence intervals from estimated CV parameters at each age.

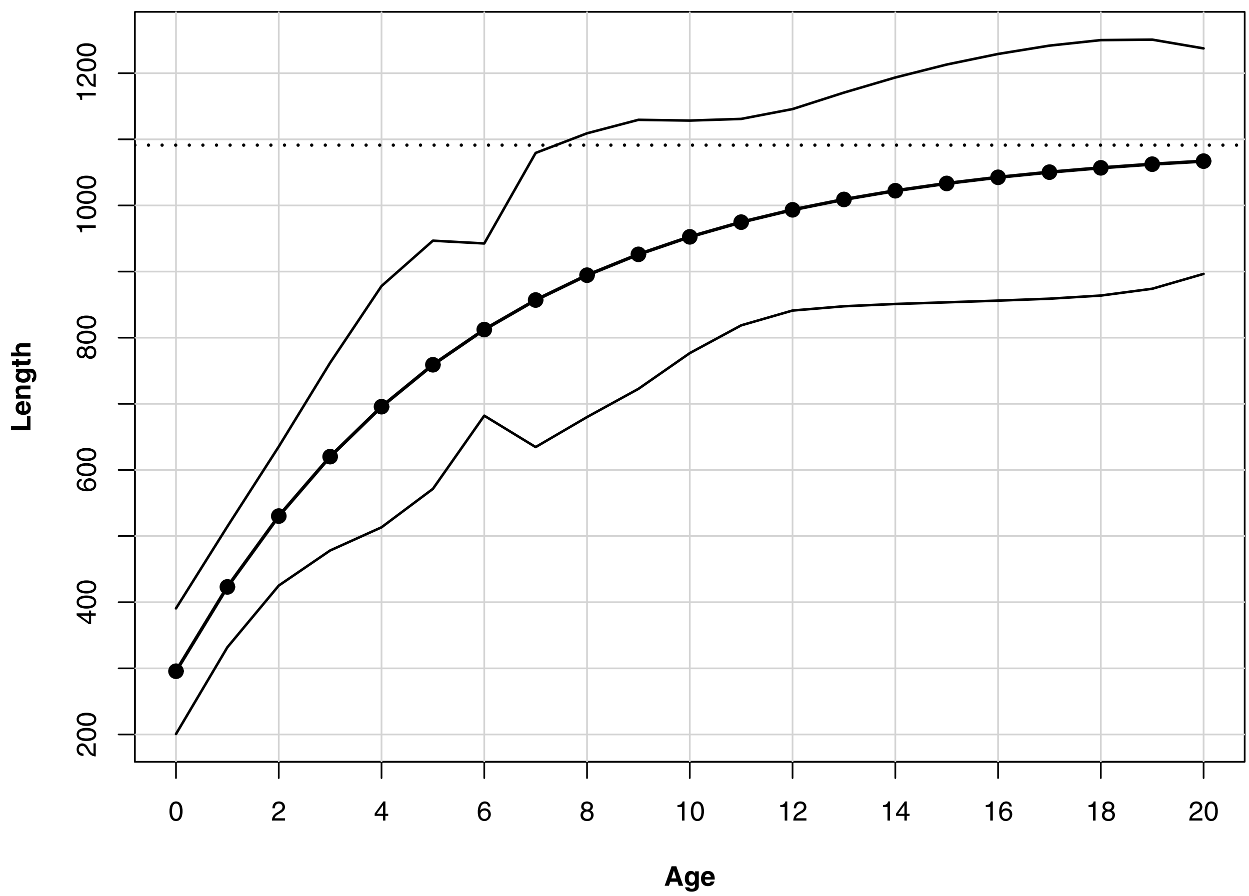


Figure 42. Gag– Base run with time-varying catchability: Estimated selectivities of commercial handline. A) Period one (1962–1991); B) Period two (1992–1998); and C) Period three (1999–2004). In period one, age at 50% selection estimated annually—average curve presented.

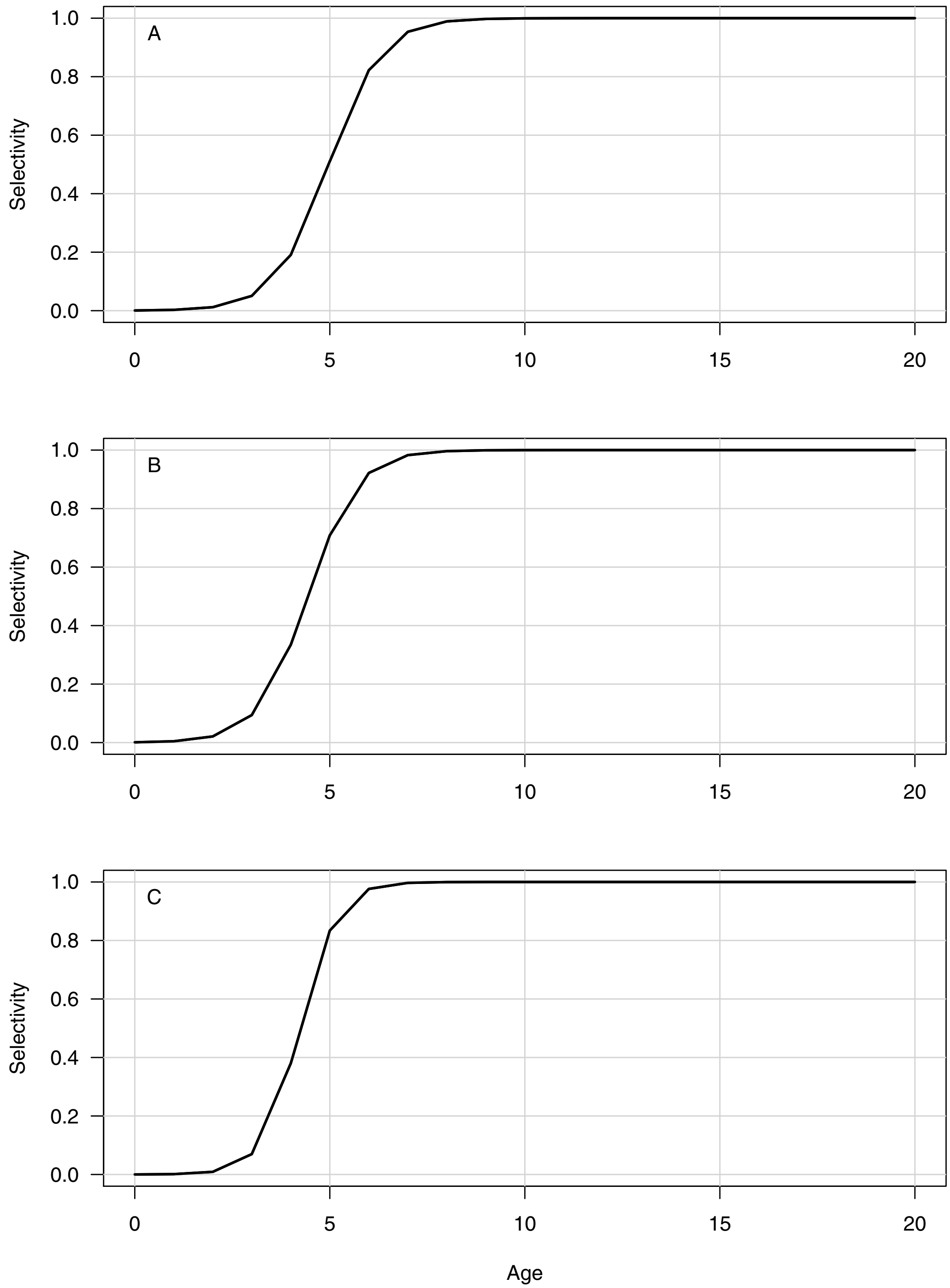


Figure 43. Gag– Base run with constant catchability: Estimated selectivities of commercial handline. A) Period one (1962–1991); B) Period two (1992–1998); and C) Period three (1999–2004). In period one, age at 50% selection estimated annually—average curve presented.

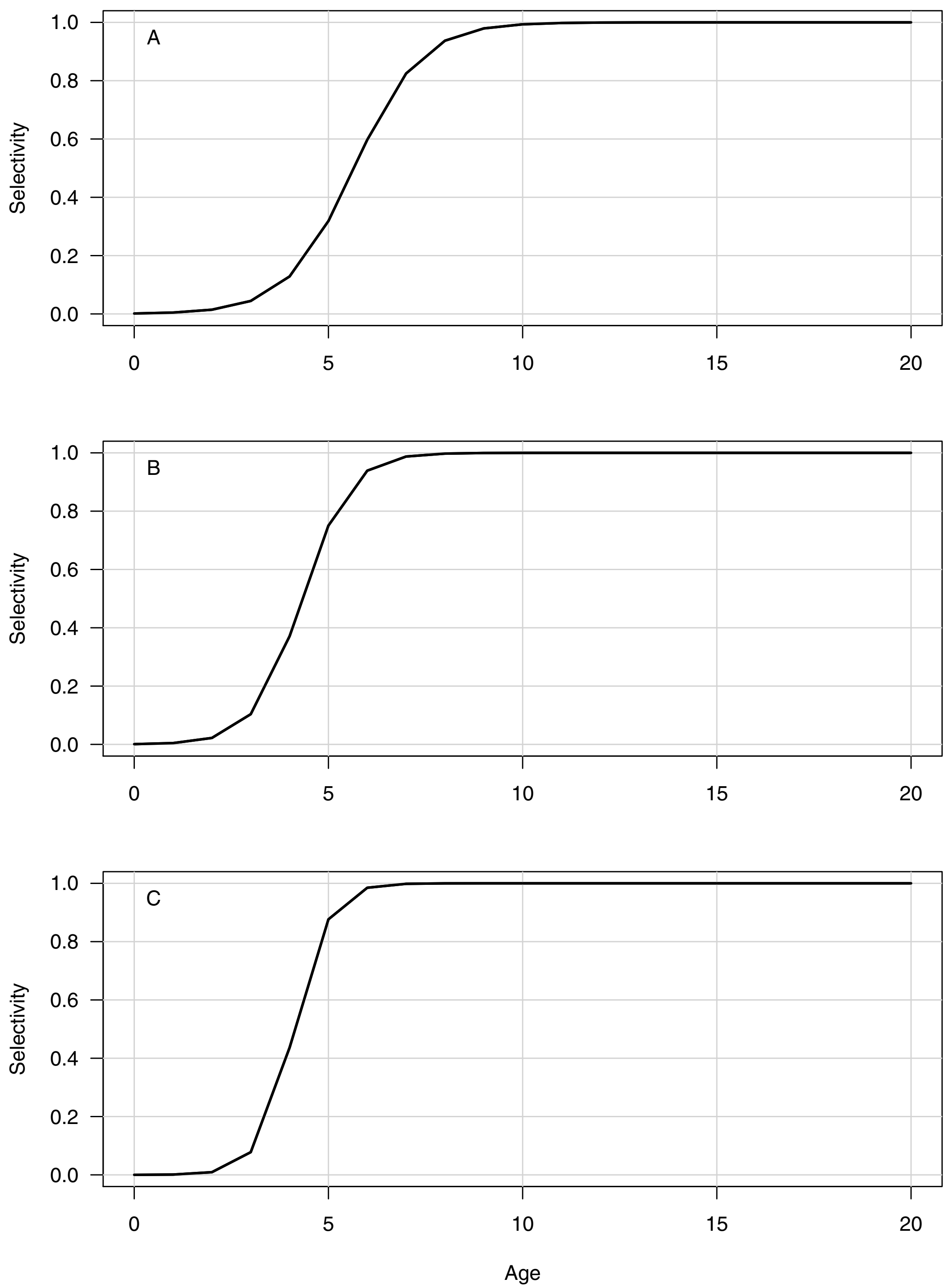


Figure 44. Gag– Base run with time-varying catchability: Estimated selectivity of commercial diving applied to all years in the assessment model.

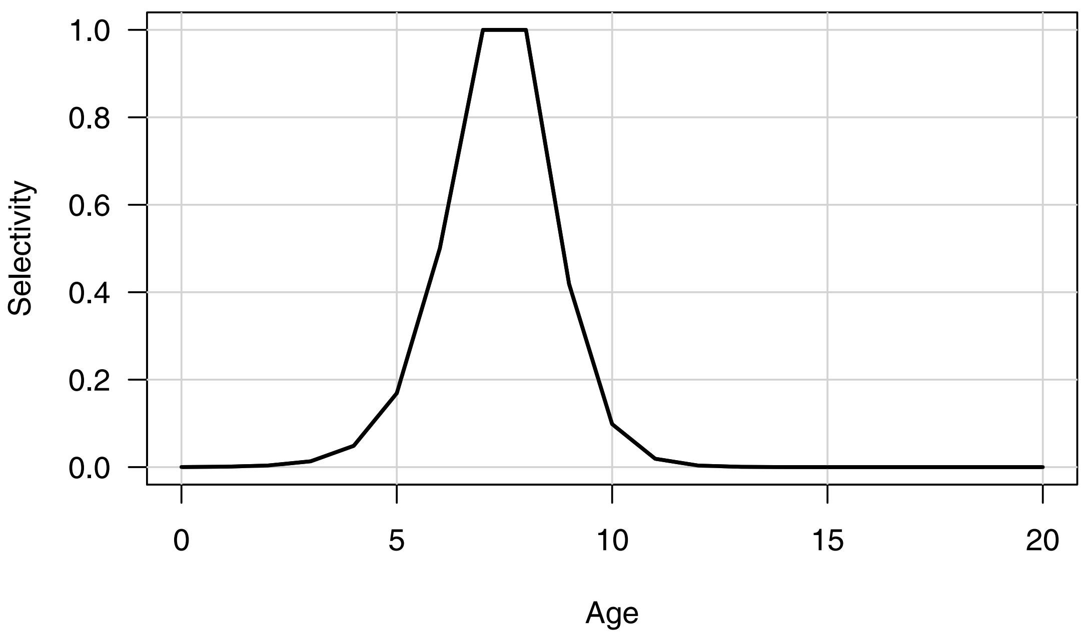


Figure 45. Gag– Base run with constant catchability: Estimated selectivity of commercial diving applied to all years in the assessment model.

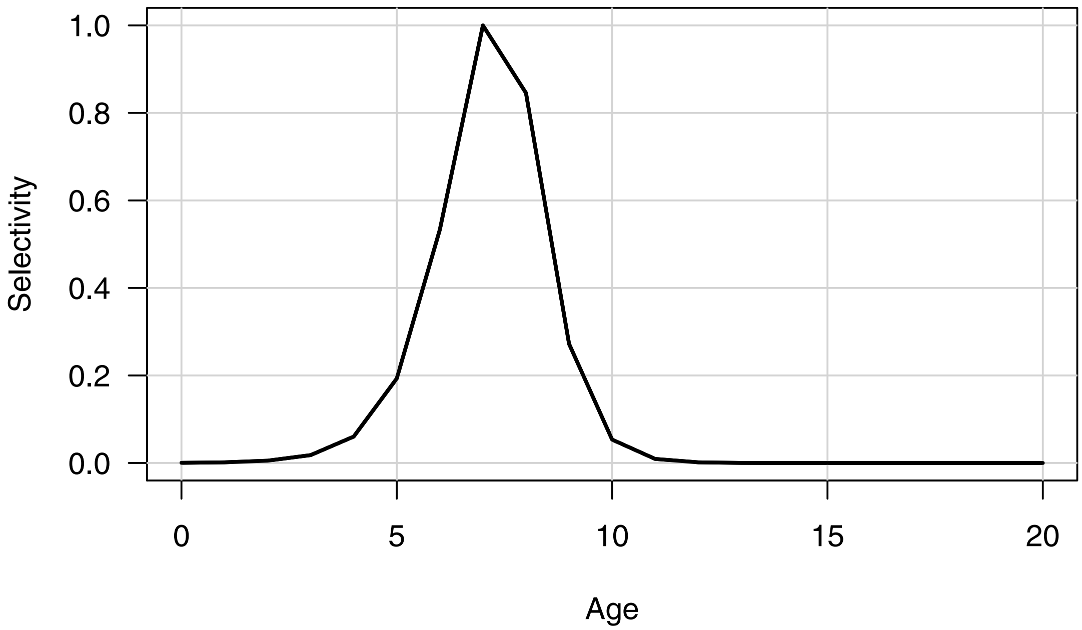


Figure 46. Gag– Base run with time-varying catchability: Estimated selectivities of recreational (headboat and MRFSS) fisheries. A) Period one (1962–1991); B) Period two (1992–1998); and C) Period three (1999–2004). In period one, age at 50% selection estimated annually—average curve presented.

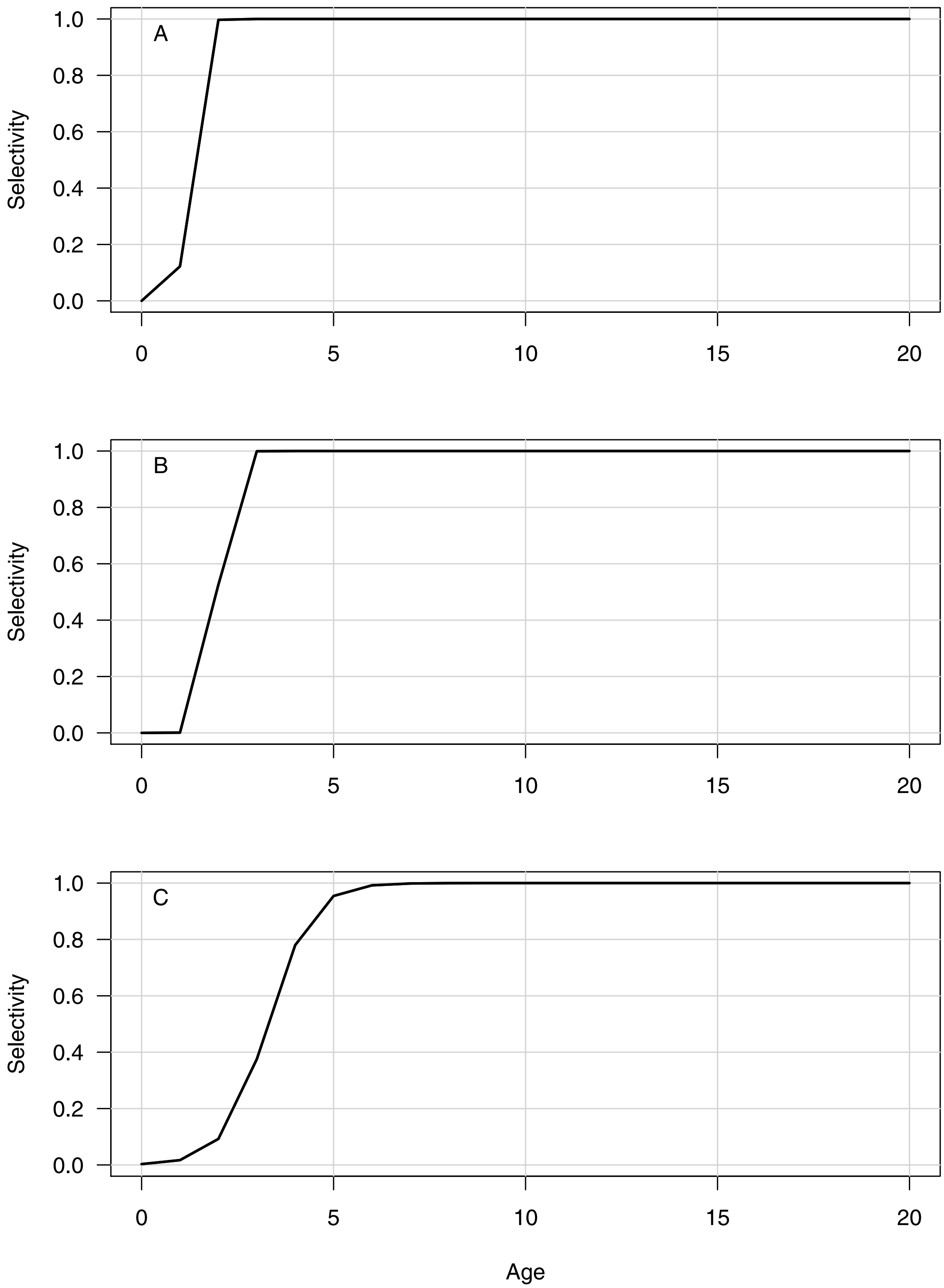


Figure 47. Gag- Base run with constant catchability: Estimated selectivities of recreational (headboat and MRFSS) fisheries. A) Period one (1962–1991); B) Period two (1992–1998); and C) Period three (1999–2004). In period one, age at 50% selection estimated annually—average curve presented.

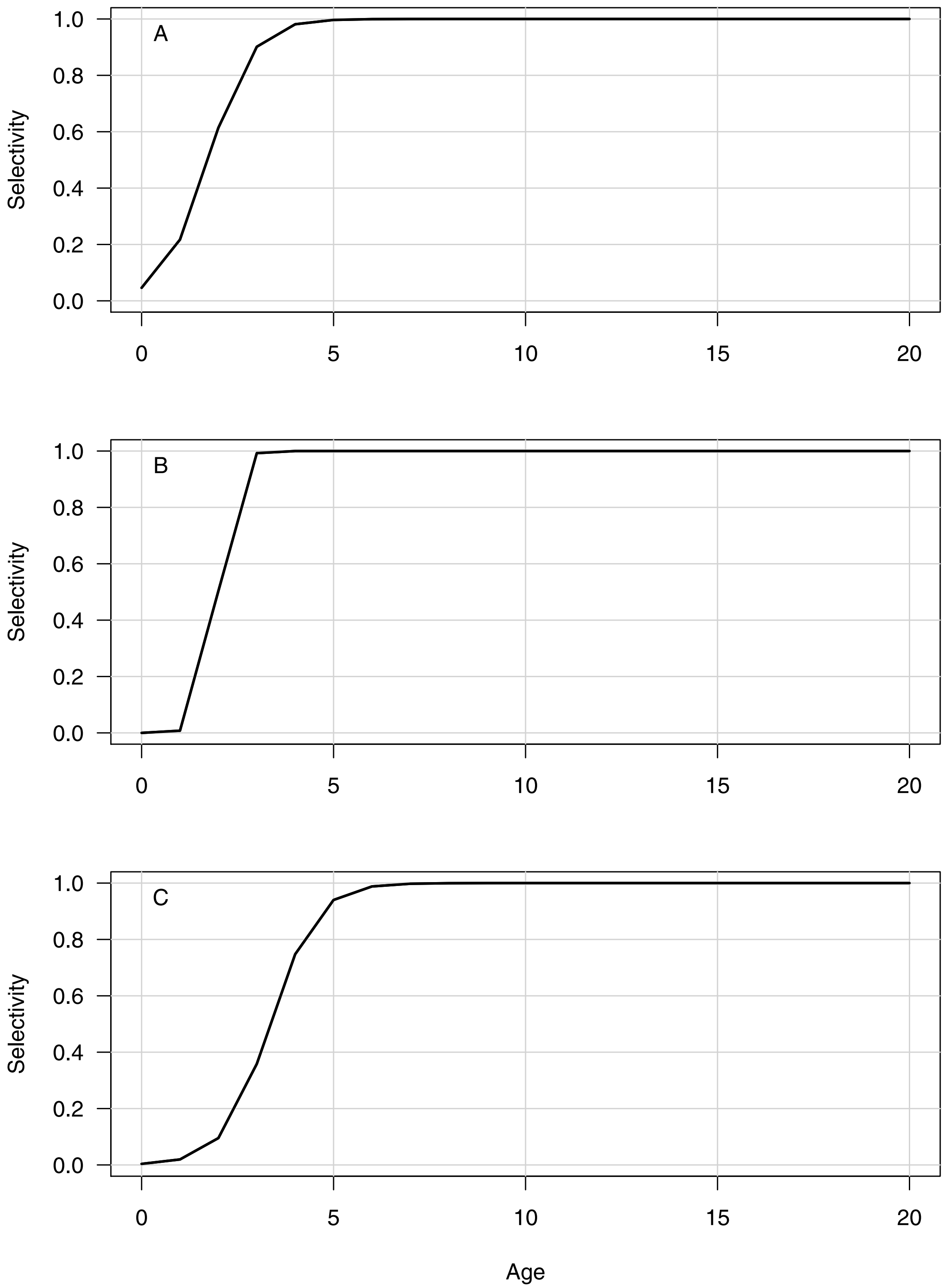


Figure 48. Gag– Base run with time-varying catchability: Estimated selectivities applied to discard rates in 1981–2004. A) Commercial handline; B) Recreational (headboat and MRFSS).

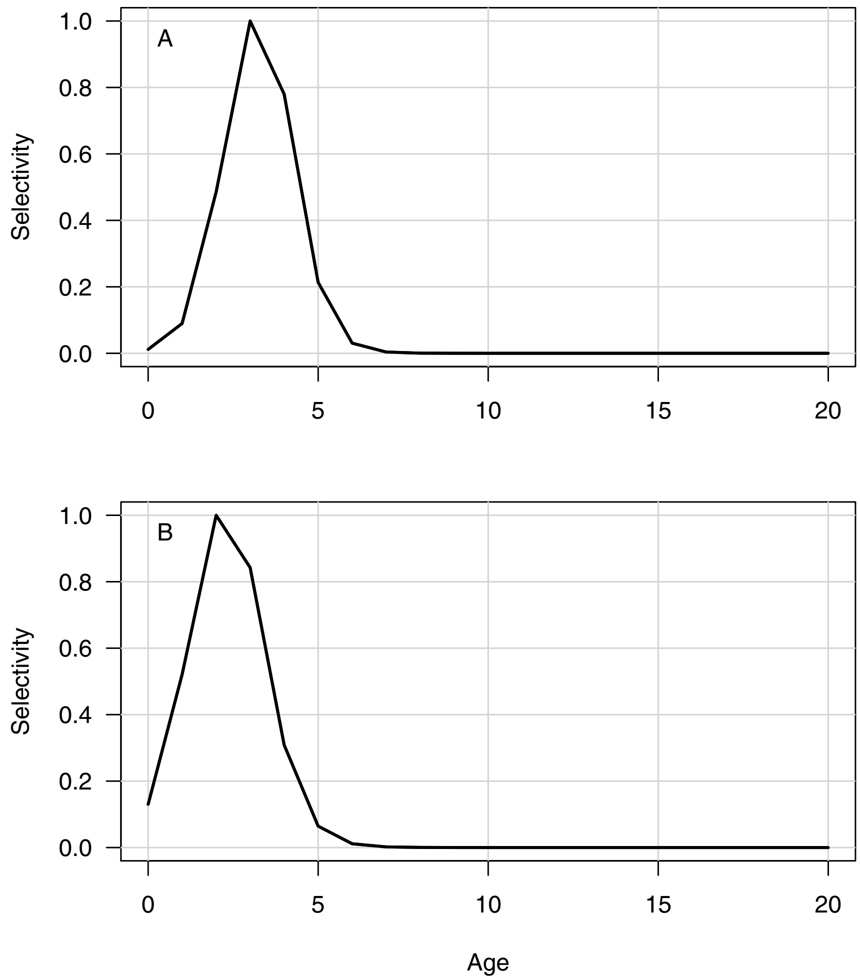


Figure 49. Gag– Base run with constant catchability: Estimated selectivities applied to discard rates in 1981–2004. A) Commercial handline; B) Recreational (headboat and MRFSS).

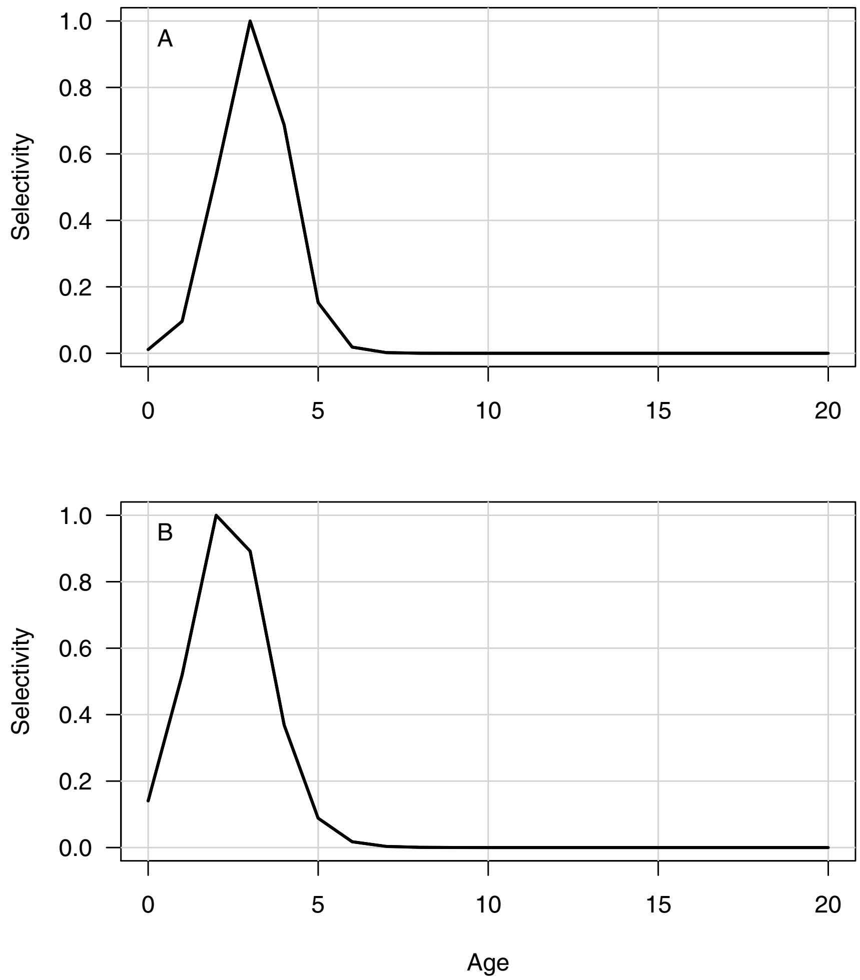


Figure 50. Gag– Base run with time-varying catchability: Estimated fishing mortality and exploitation rates. A) Fully selected fishing mortality rate and B) Exploitation rate of fish age 2^+. *Solid horizontal line represents the level corresponding to* MSY *and the horizontal dashed lines represent the 10th and 90th percentiles of the* MSY *level. The 90th percentile line is hidden by the solid* MSY *line.*

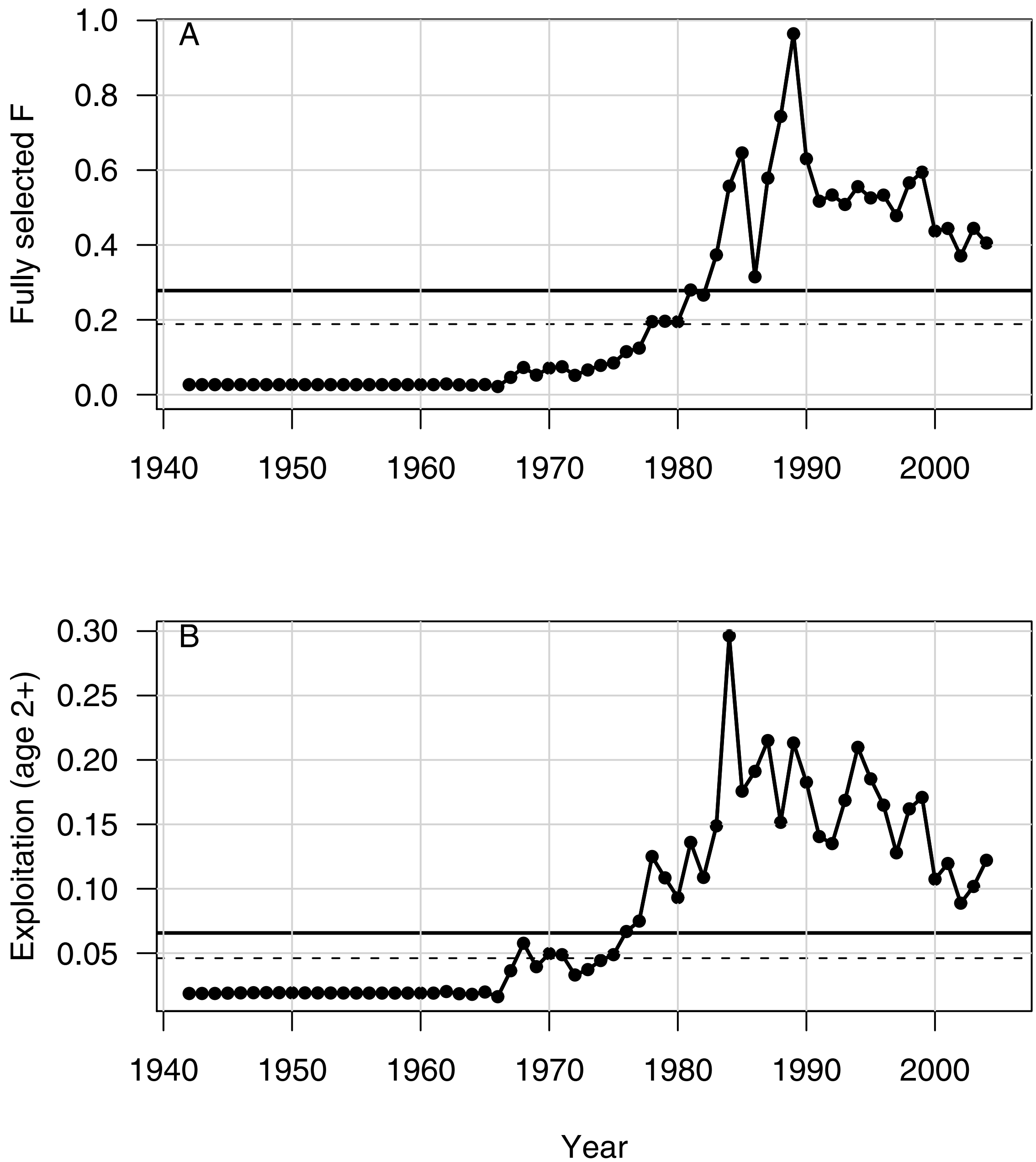


Figure 51. Gag– Base run with constant catchability: Estimated fishing mortality and exploitation rates. A) Fully selected fishing mortality rate and B) Exploitation rate of fish age 2^+*. Solid horizontal line represents the level corresponding to* MSY *and the horizontal dashed lines represent the 10th and 90th percentiles of the* MSY *level. The 90th percentile line is hidden by the solid* MSY *line.*

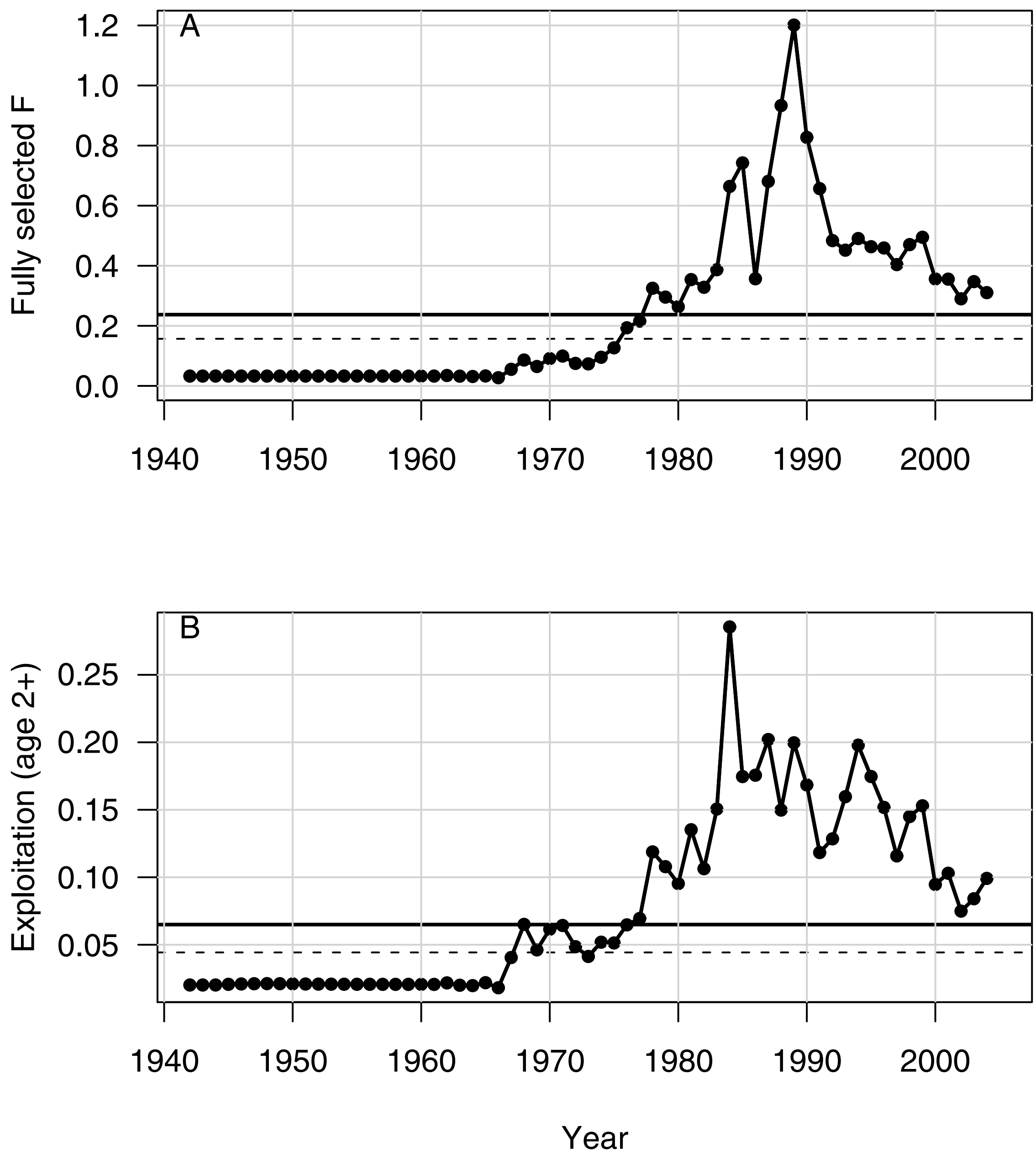


Figure 52. Gag– Base run with time-varying catchability: Stacked bar plot of fully selected fishing mortality rates by fishery.

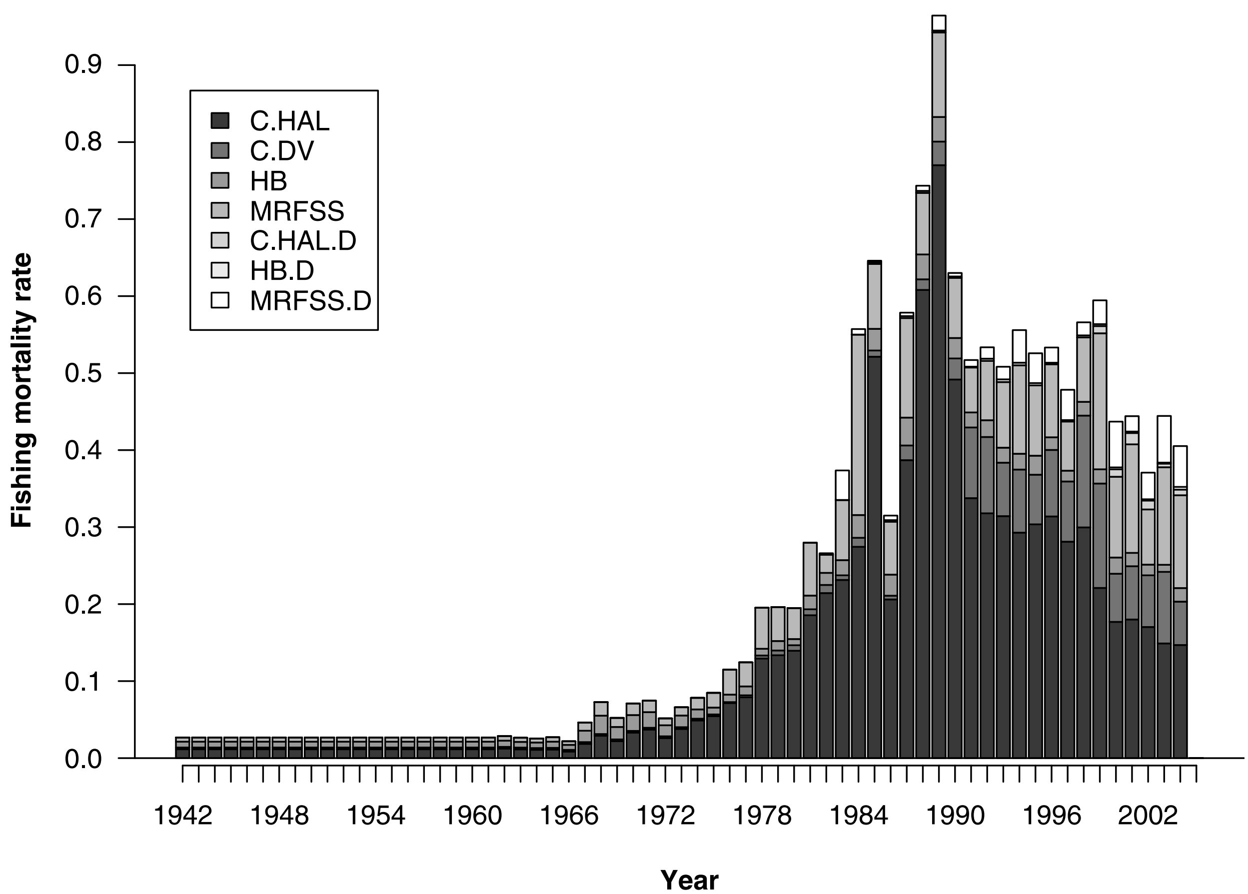


Figure 53. Gag- Base run with constant catchability: Stacked bar plot of fully selected fishing mortality rates by fishery.

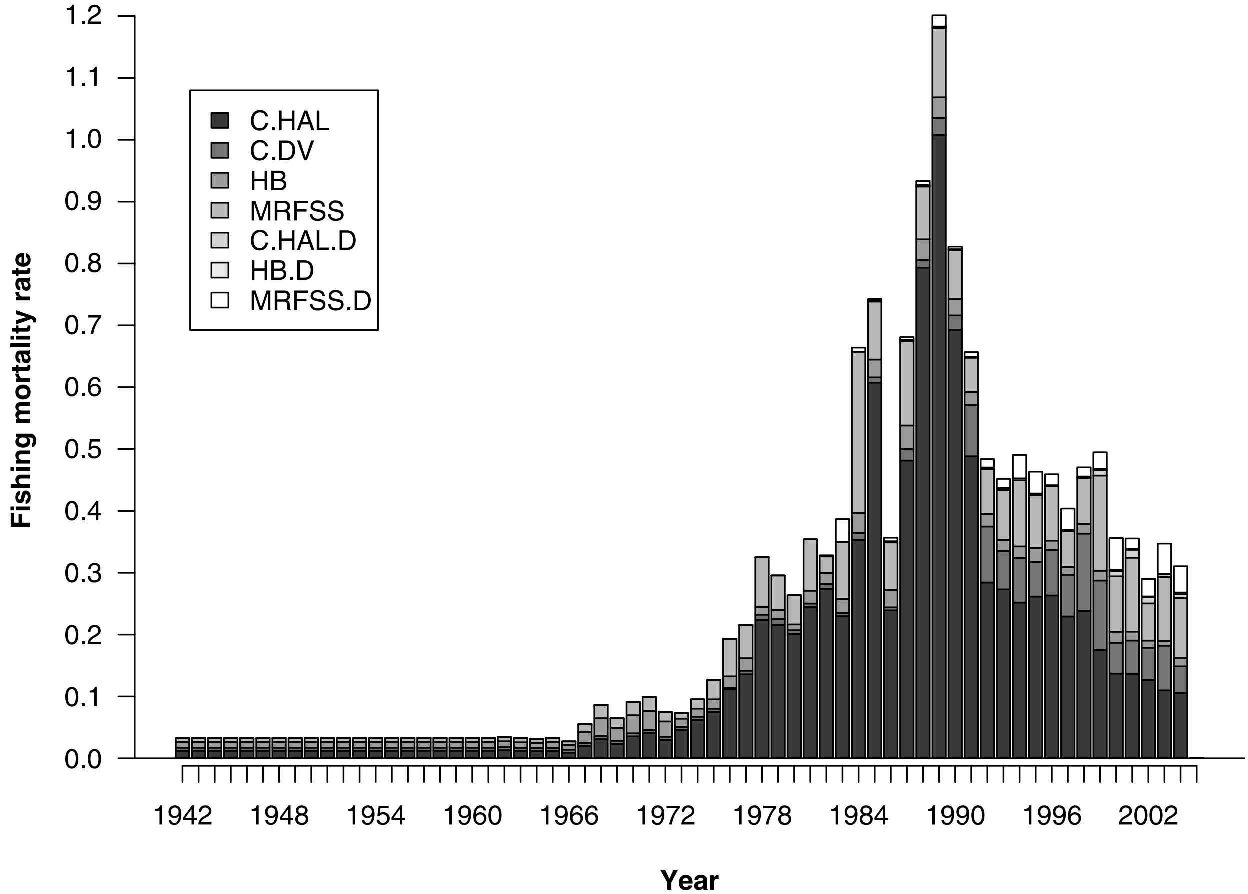


Figure 54. Gag– Base run with time-varying catchability: Estimated biomass time series. A) Total biomass and B) Spawning stock biomass (male mature biomass + female mature biomass). The solid horizontal line represents the level corresponding to MSY *and the horizontal dashed lines represent the 10th and 90th percentiles of the* MSY *level.*

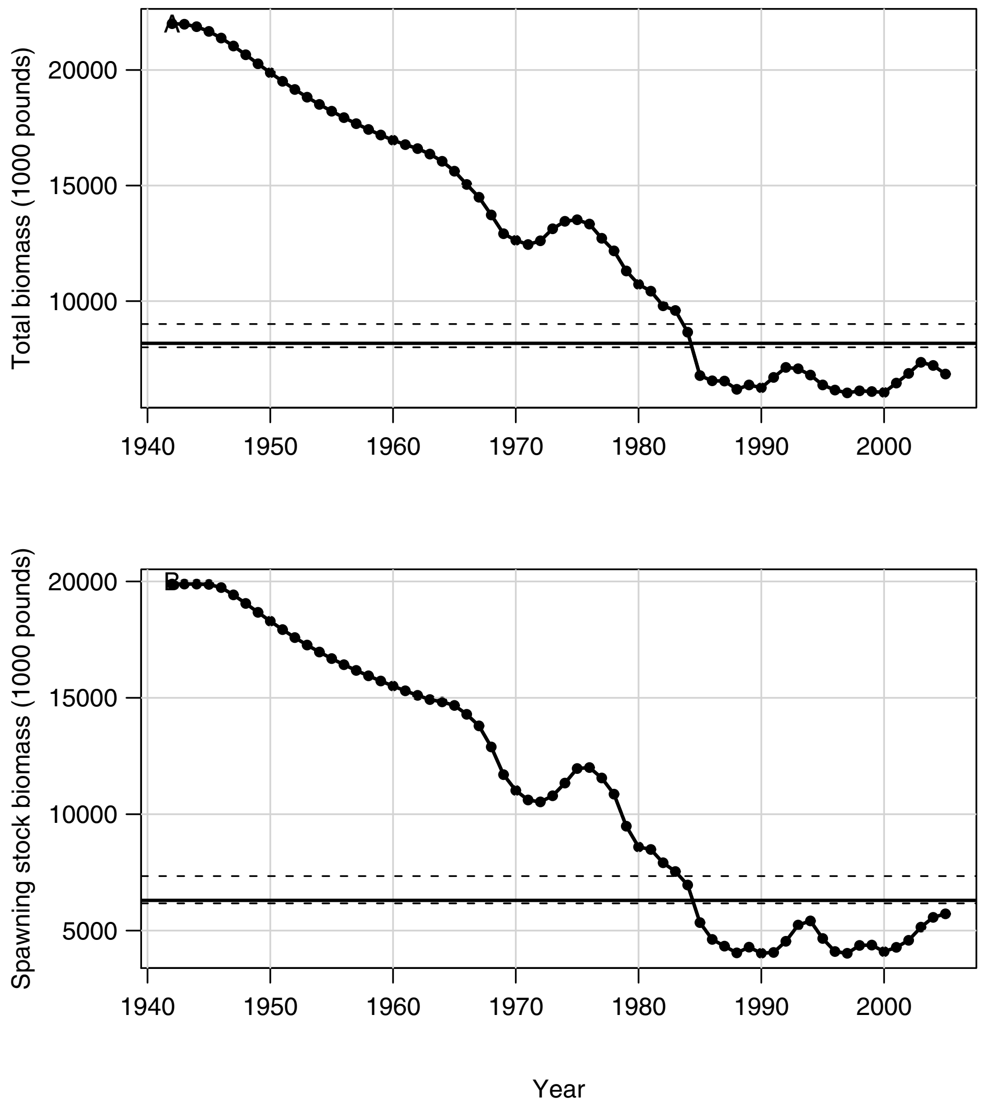


Figure 55. Gag– Base run with constant catchability: Estimated biomass time series. A) Total biomass and B) Spawning stock biomass (male mature biomass + female mature biomass). The solid horizontal line represents the level corresponding to MSY *and the horizontal dashed lines represent the 10th and 90th percentiles of the* MSY *level.*

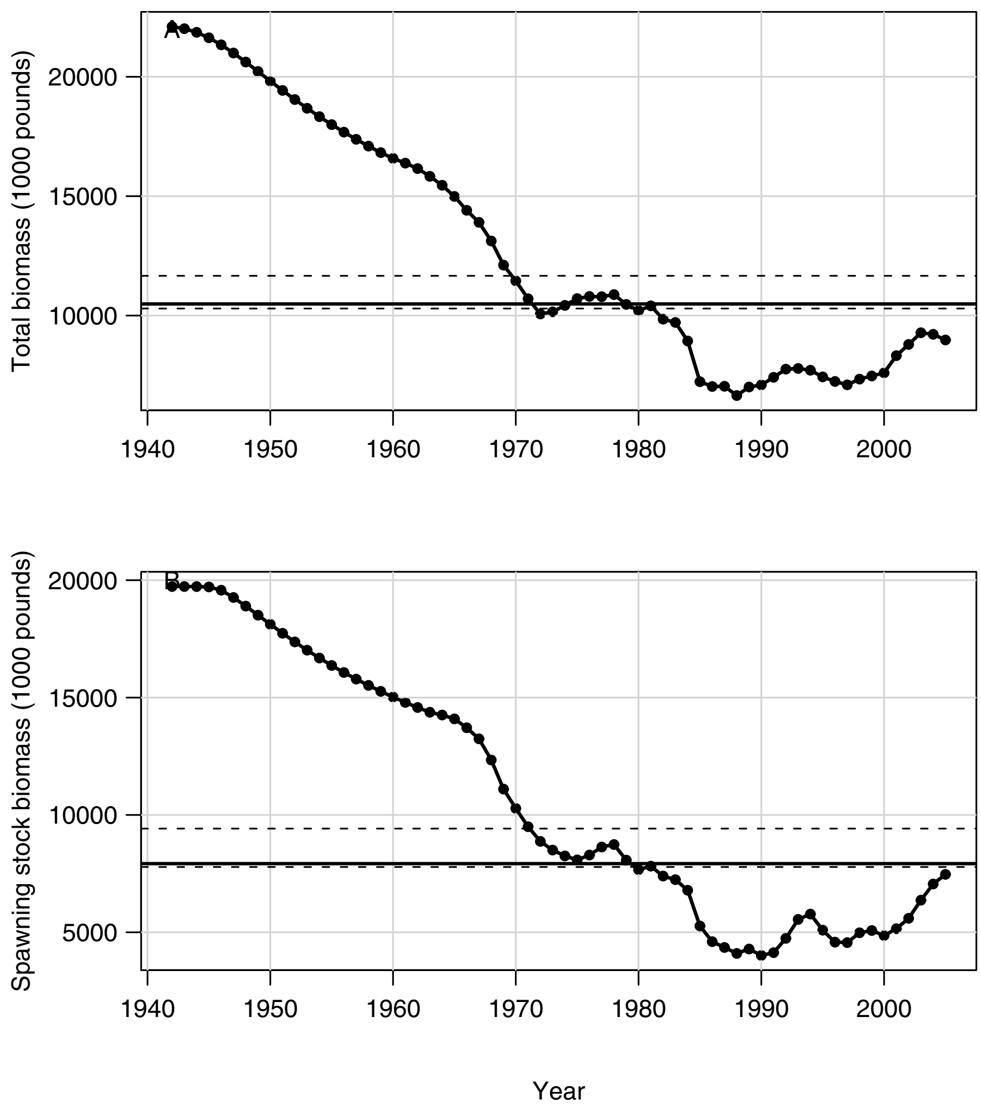


Figure 56. Gag– Base run with time-varying catchability: Estimated stock-recruitment relationship of gag grouper. Circles represent estimated recruitment values from 1972-2004; Dashed curve is estimated relationship; Solid curve is estimated relationship with lognormal bias correction, from which benchmarks are derived.

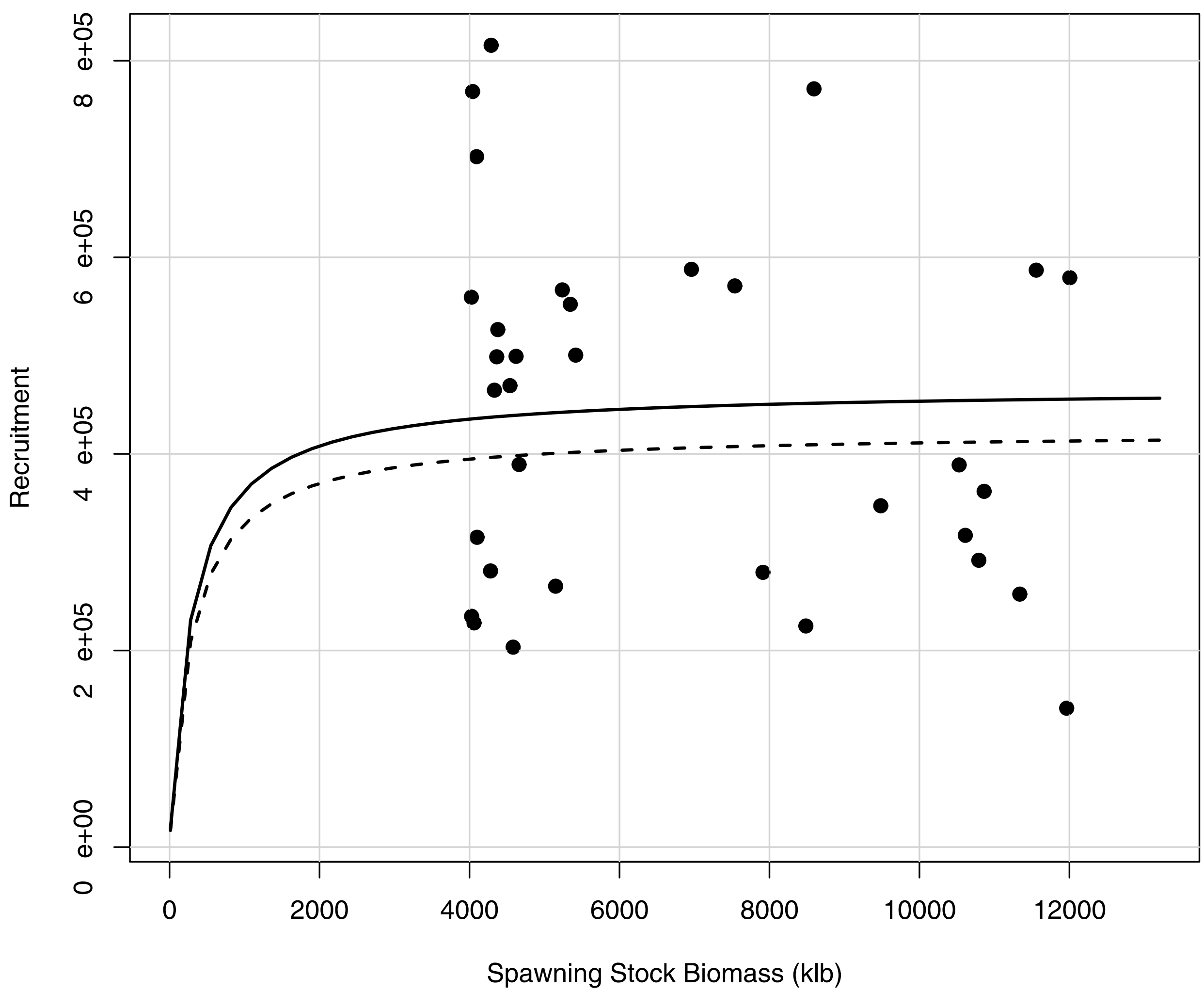


Figure 57. Gag– Base run with constant catchability: Estimated stock-recruitment relationship of gag grouper. Circles represent estimated recruitment values from 1972-2004; Dashed curve is estimated relationship; Solid curve is estimated relationship with lognormal bias correction, from which benchmarks are derived.

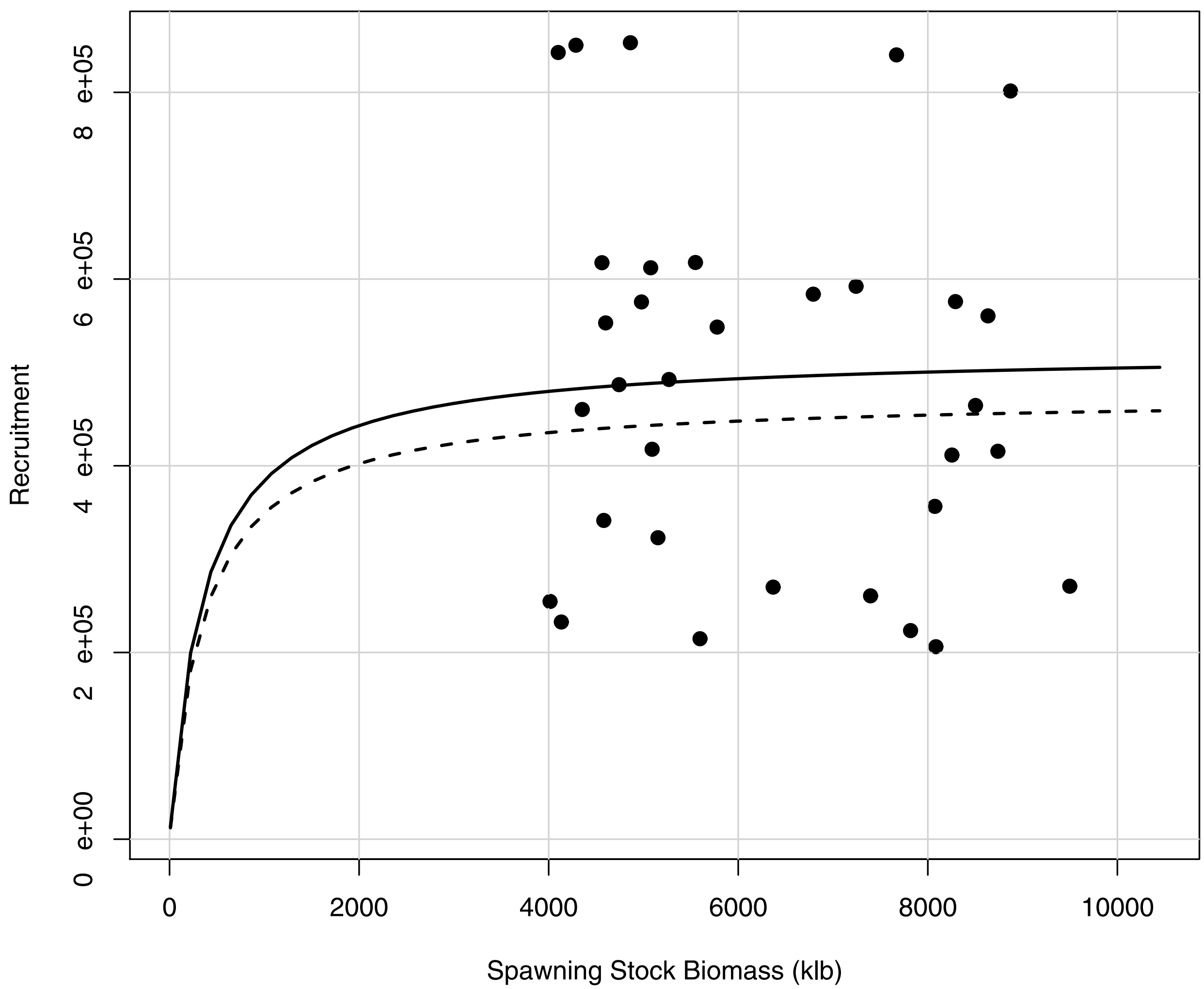


Figure 58. Time-varying catchability run: Estimated time series of gag recruitment. A) Number of recruits; dashed line at $\hat{R}_{\mathrm{msy}}$. B) Log of recruitment residuals; dashed line at zero, the value indicating no deviation from the estimated stock-recruit curve.

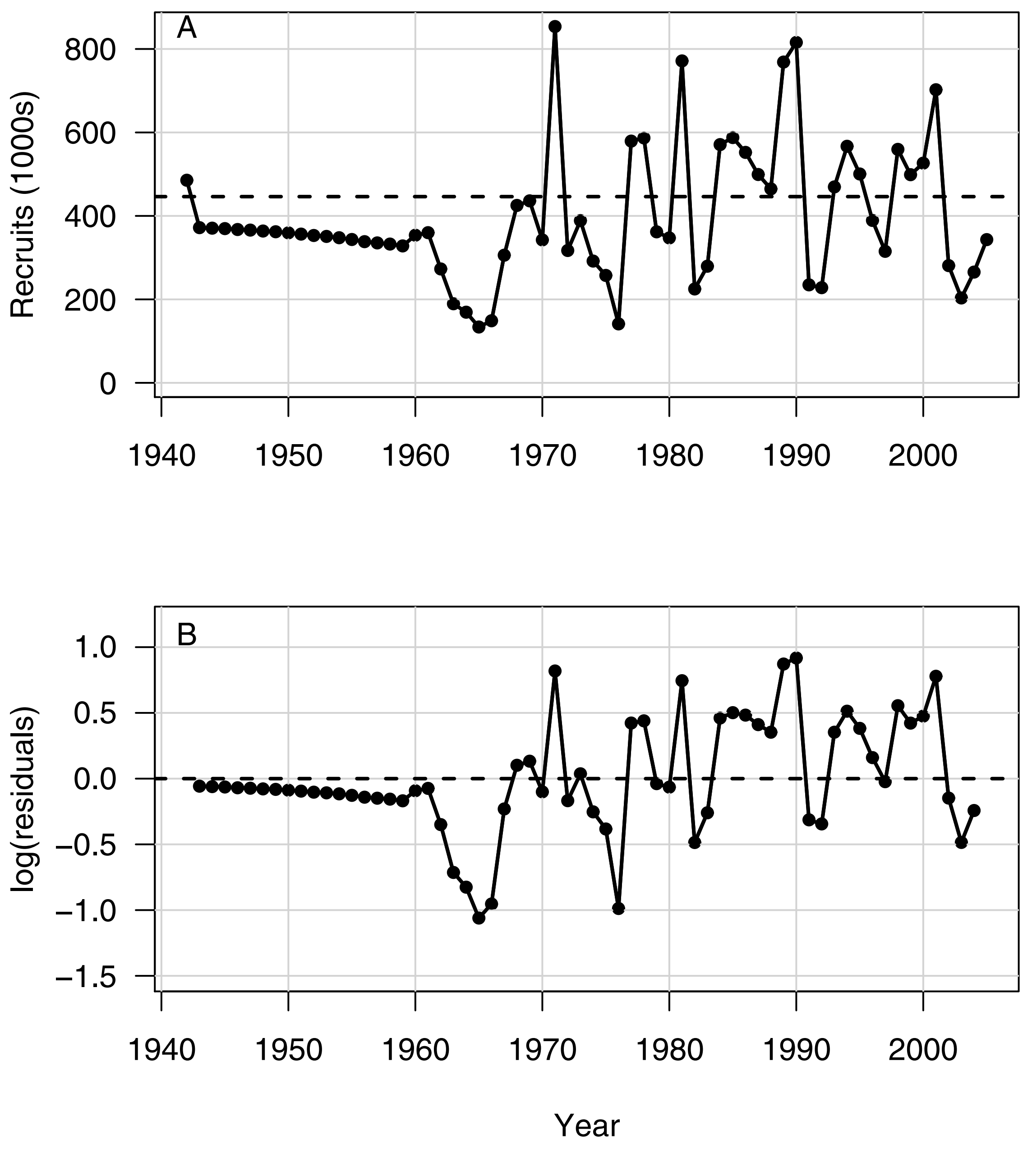


Figure 59. Constant catchability run: Estimated time series of gag recruitment. A) Number of recruits; dashed line at $\hat{R}_{msy}$. B) Log of recruitment residuals; dashed line at zero, the value indicating no deviation from the estimated stock-recruit curve.

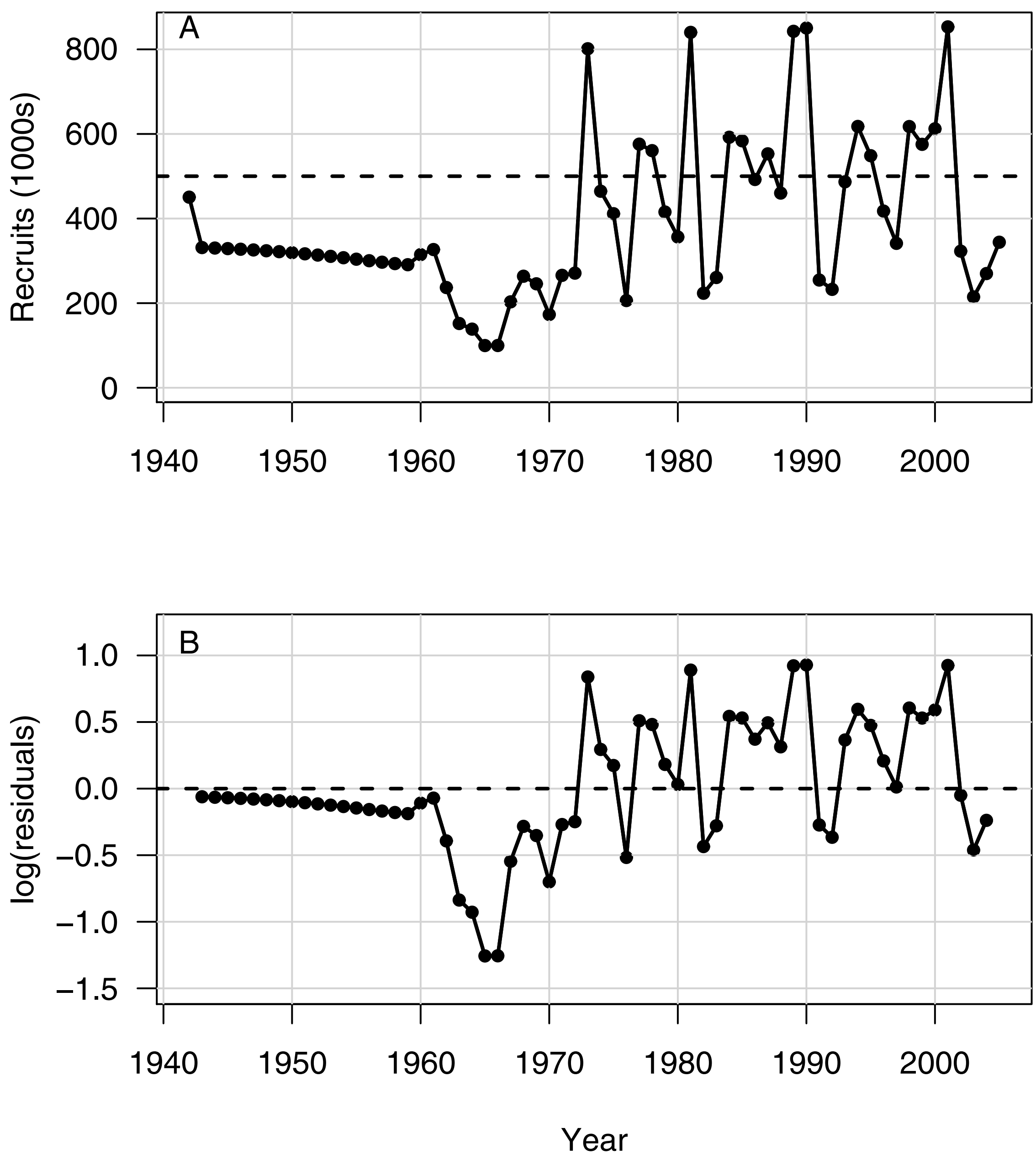


Figure 60. Gag– Base run with time-varying catchability: Estimated time series of static spawning potential ratio (SPR) using fully selected fishing mortality rates.

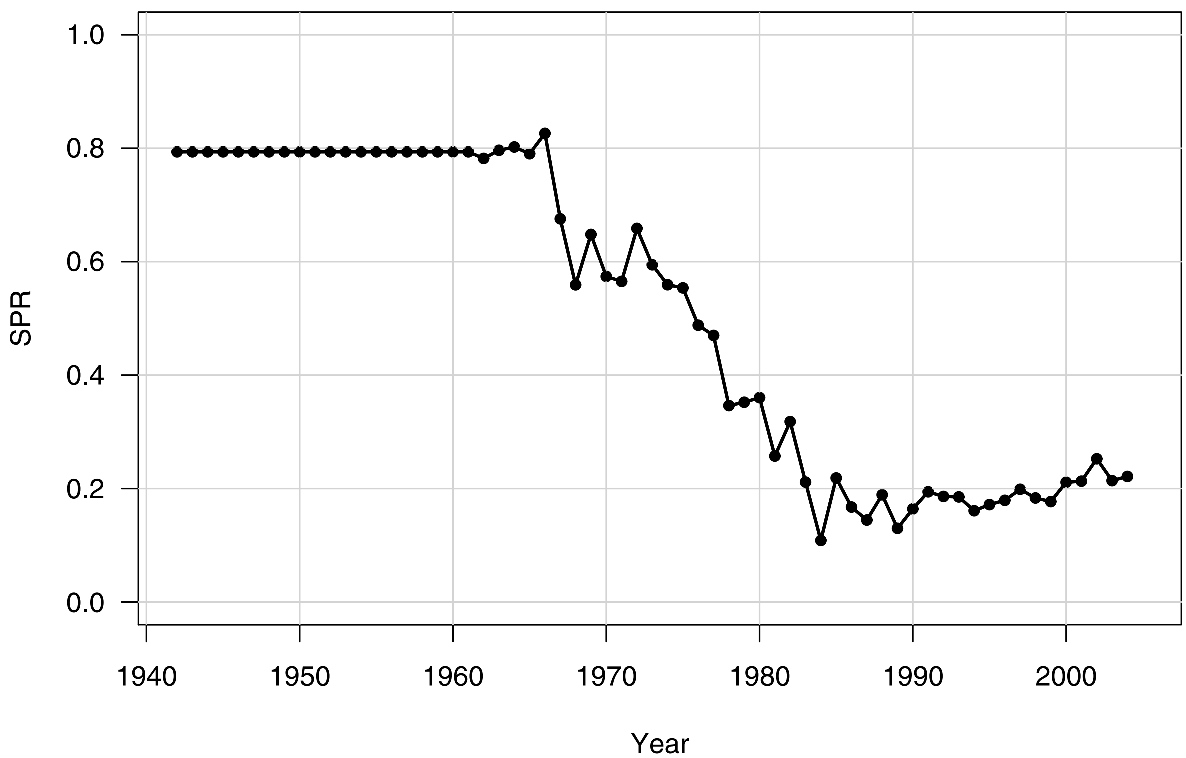


Figure 61. Gag– Base run with constant catchability: Estimated time series of static spawning potential ratio (SPR) using fully selected fishing mortality rates.

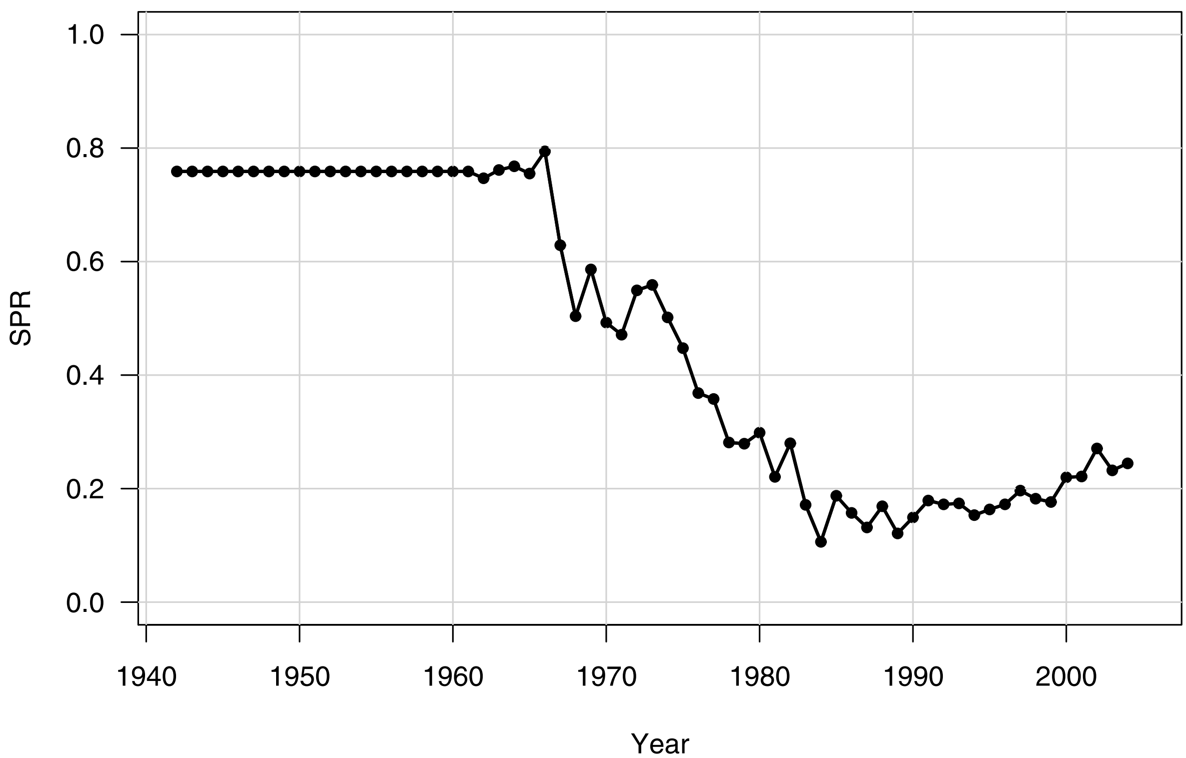


Figure 62. Gag– Base run with time-varying catchability: Estimated A) yield and B) spawning stock biomass (SSB) per recruit (Vertical lines represent F_{max}, $F_{30\%}$, $F_{45\%}$, and F_{MSY}.

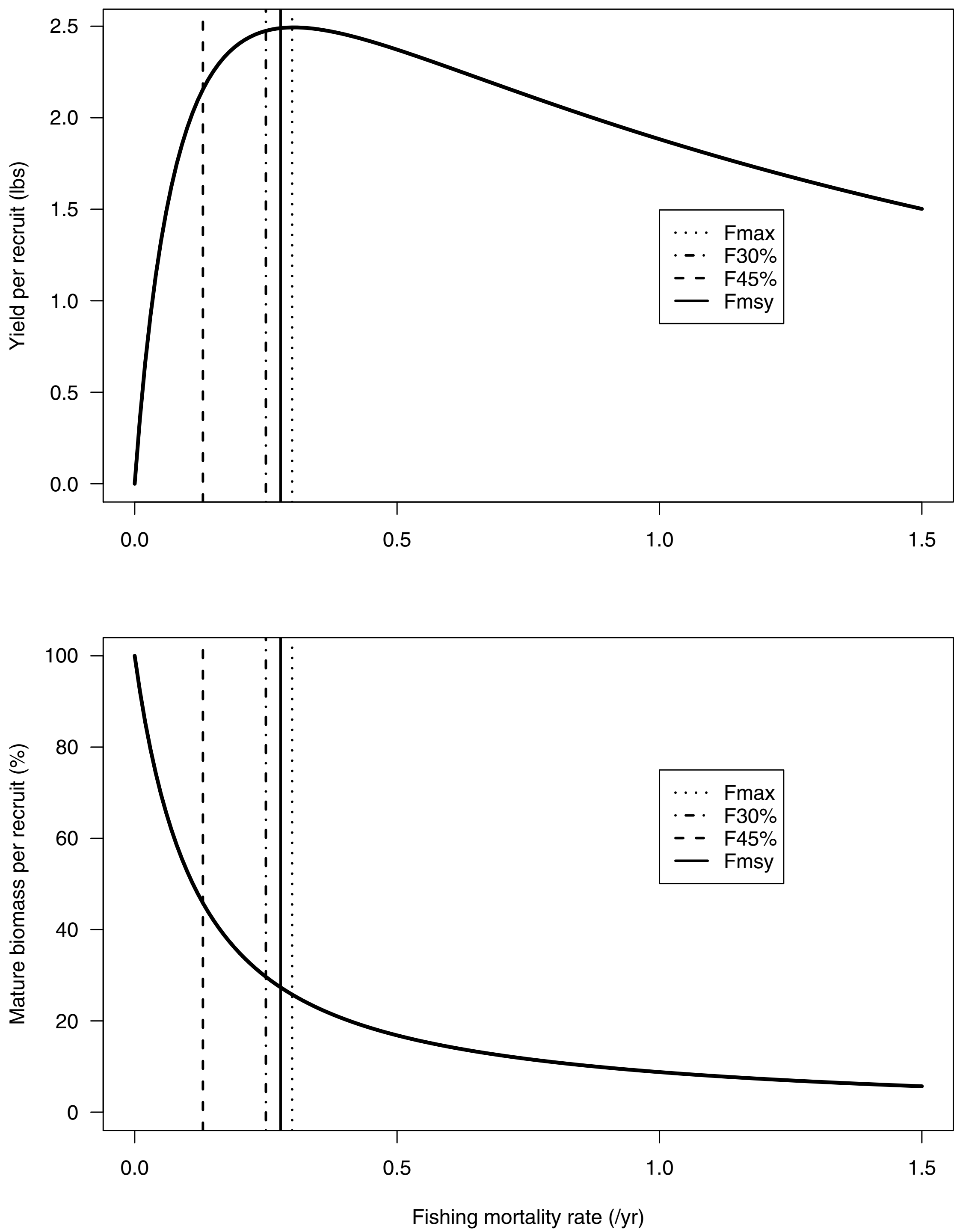


Figure 63. Gag– Base run with constant catchability: Estimated A) yield and B) spawning stock biomass (SSB) per recruit (%SPR) as functions of fully selected fishing mortality rate. Vertical lines represent F_{max}, $F_{30\%}$, $F_{45\%}$, and F_{MSY}.

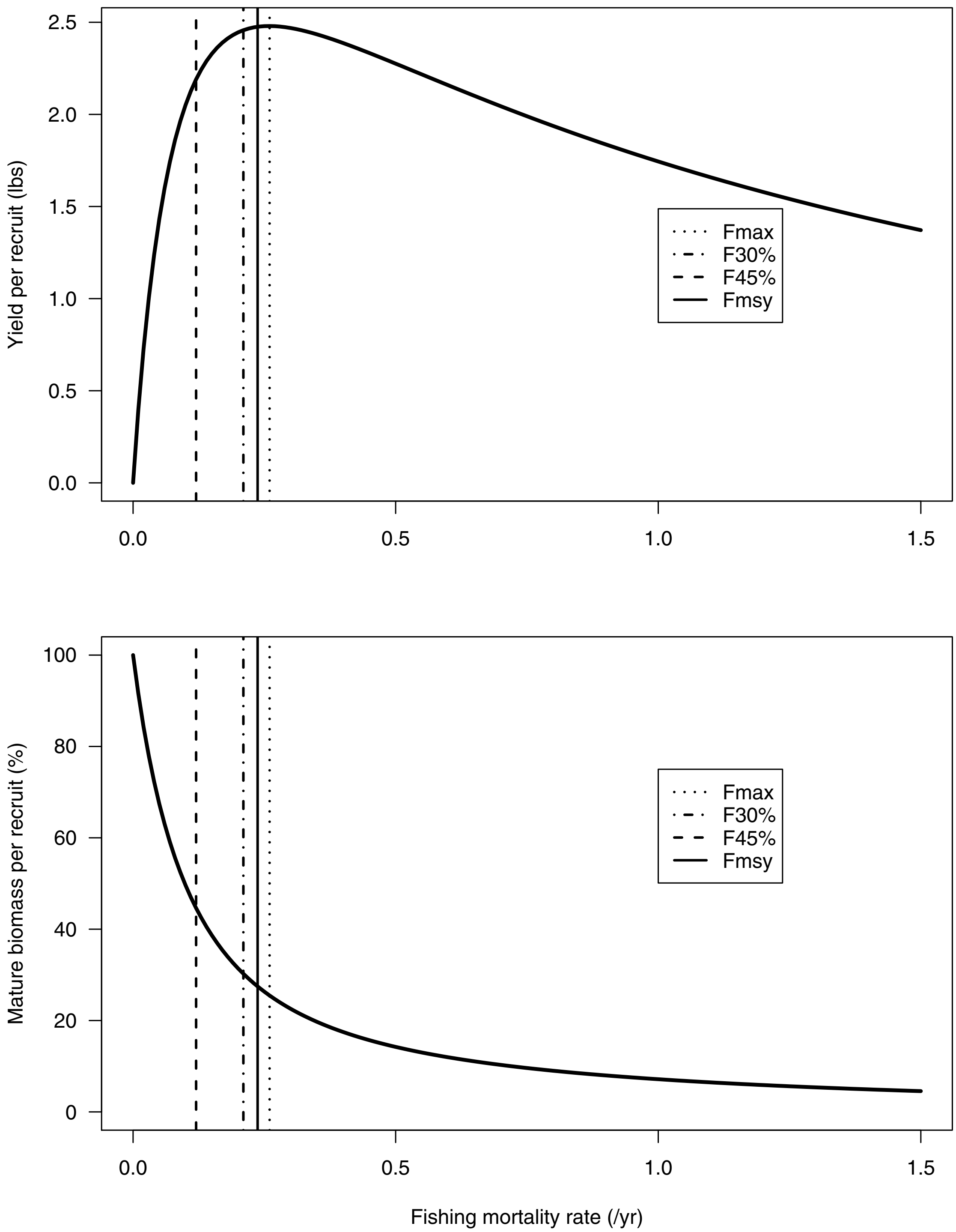


Figure 64. Gag– Base run with time-varying catchability: Estimated A) yield and B) spawning stock biomass (SSB) per recruit (%SPR) as functions of exploitation rate of age 2^+. *Vertical lines represent* E_{MAX} , $E_{30\%}$, $E_{45\%}$, *and* E_{MSY}.

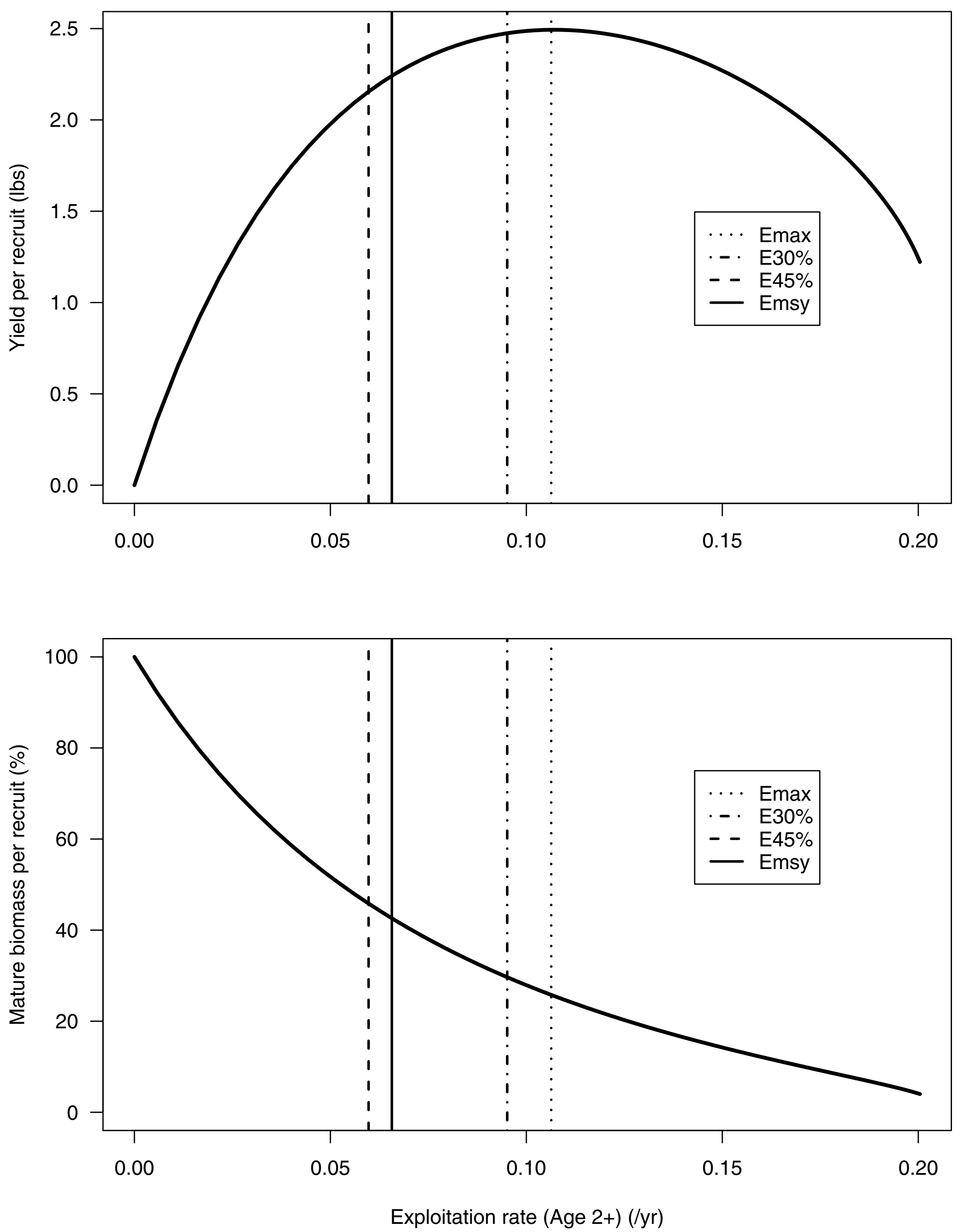


Figure 65. Gag- Base run with constant catchability: Estimated A) yield and B) spawning stock biomass (SSB) per recruit (%SPR) as functions of exploitation rate of age 2^+. Vertical lines represent E_{MAX} , $E_{30\%}$, $E_{45\%}$, *and* E_{MSY}.

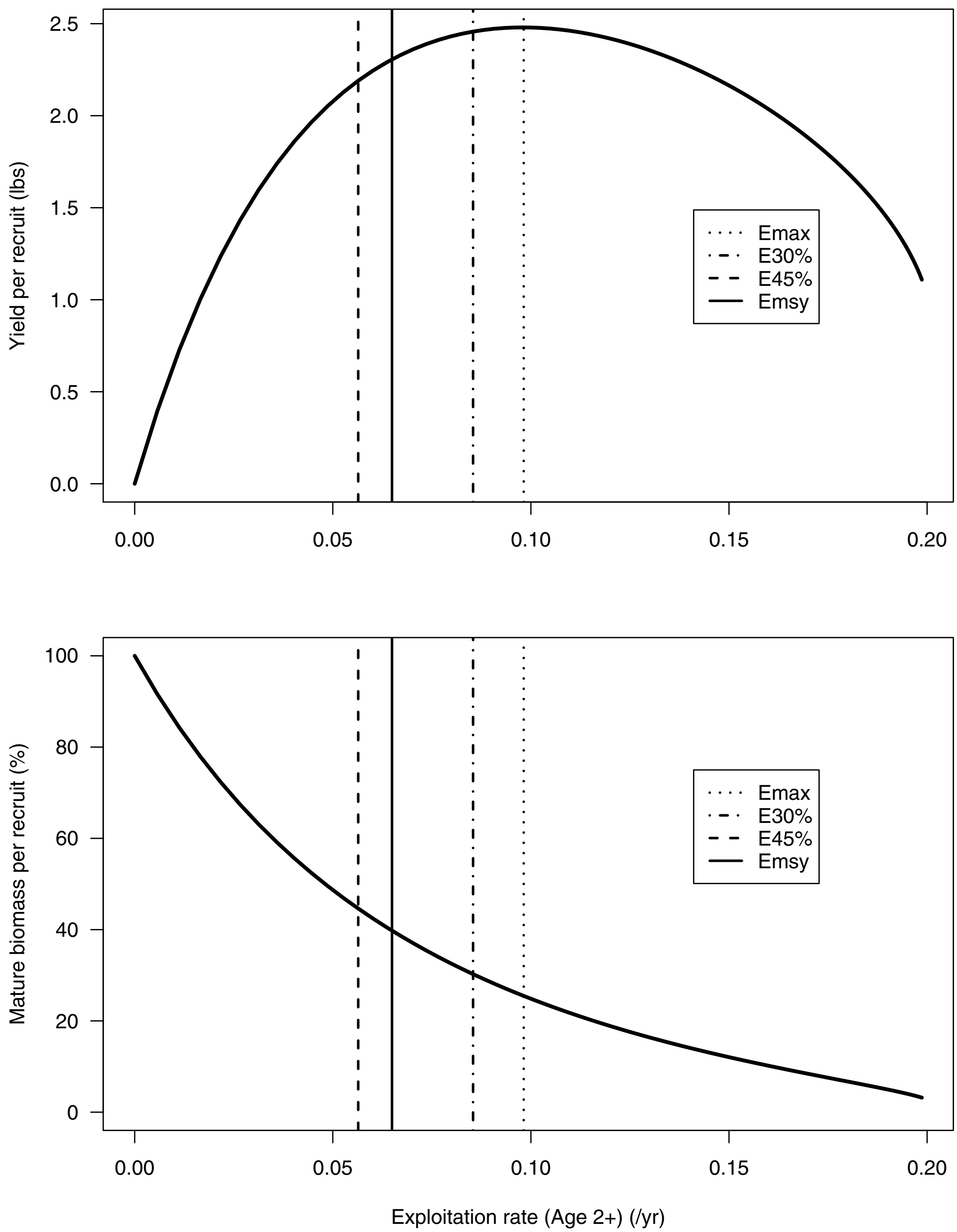


Figure 66. Gag– Base run with time-varying catchability: Equilibrium A) landings and B) SSB, as expected from the estimated stock-recruit curve with bias correction. Vertical lines represent F_{MSY}, the F that maximizes equilibrium landings, and $F_{30\%}$, $F_{45\%}$, and $F_{\max}$, as computed from per recruit analysis.

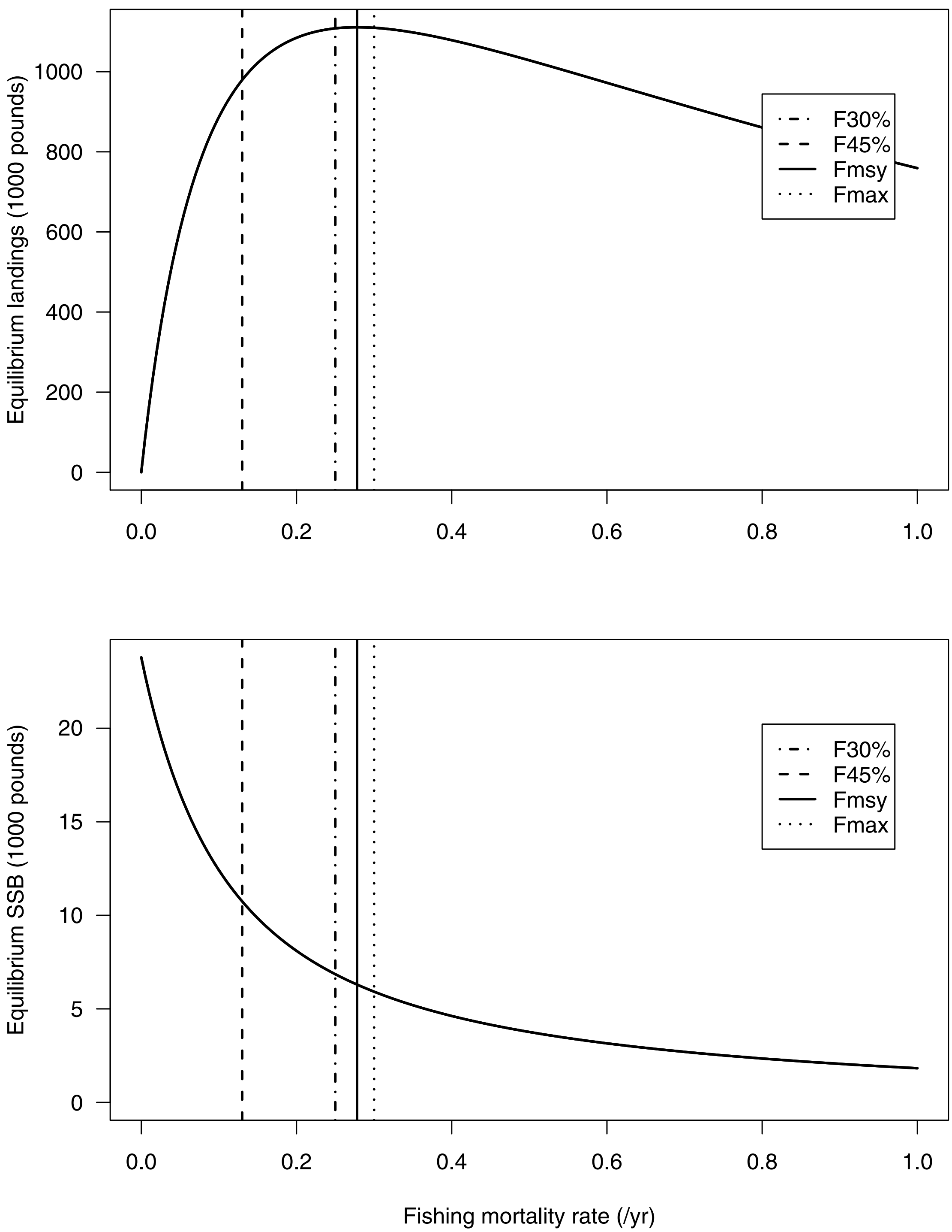


Figure 67. Gag– Base run with constant catchability: Equilibrium A) landings and B) SSB*, as expected from the estimated stock-recruit curve with bias correction. Vertical lines represent F_{MSY}, the F that maximizes equilibrium landings, and $F_{30\%}$, $F_{45\%}$, and F_{max}, as computed from per recruit analysis.*

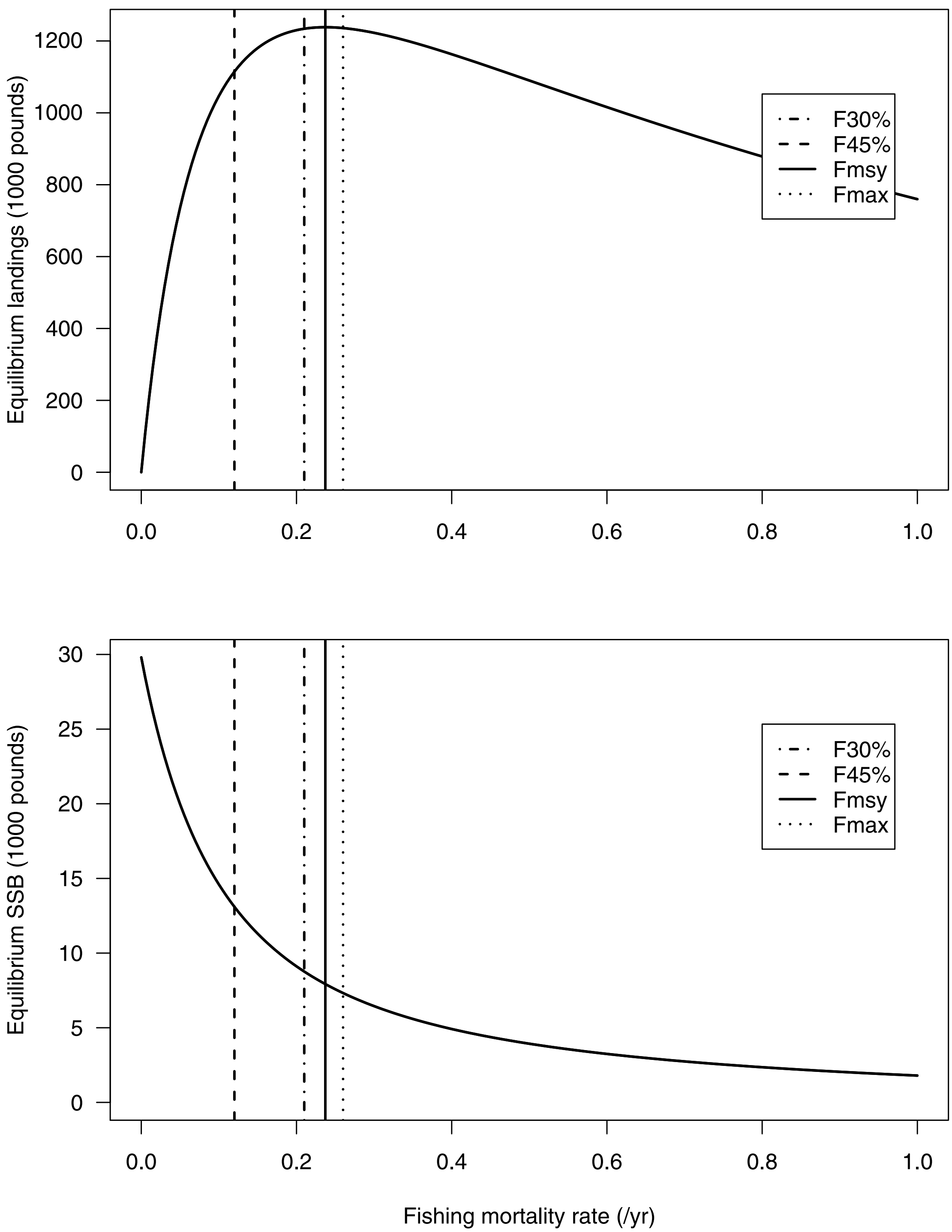


Figure 68. Gag– Base run with time-varying catchability: Equilibrium A) landings and B) SSB, *as expected from the estimated stock-recruit curve with bias correction. Vertical lines represent* E_{MSY}*, the E that maximizes equilibrium landings, and* $E_{30\%}$, $E_{45\%}$*, and* E_{MAX}*, as computed from per recruit analysis.*

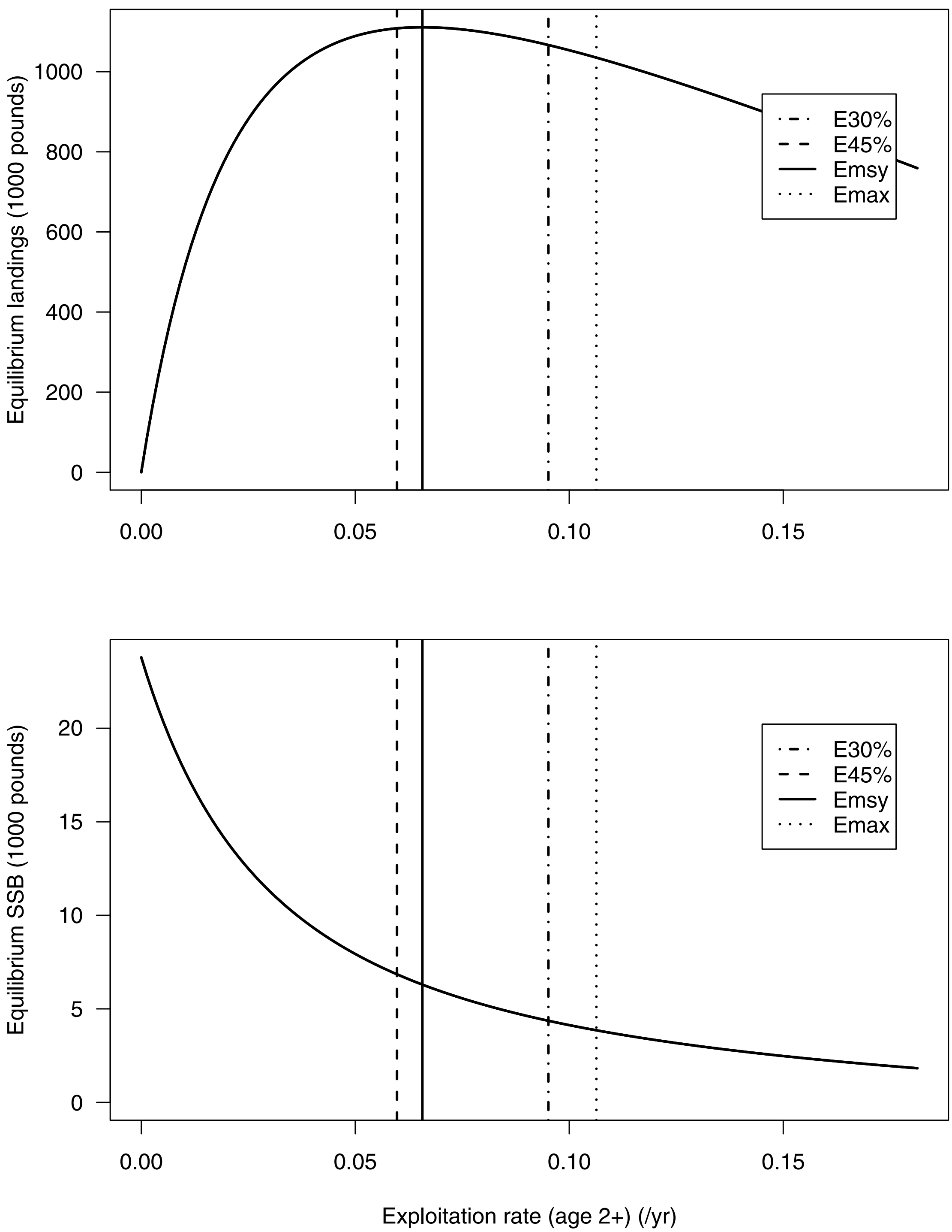


Figure 69. Gag– Base run with constant catchability: Equilibrium A) landings and B) SSB, *as expected from the estimated stock-recruit curve with bias correction. Vertical lines represent* E_{MSY}*, the E that maximizes equilibrium landings, and* $E_{30\%}$, $E_{45\%}$, *and* E_{MAX}, *as computed from per recruit analysis.*

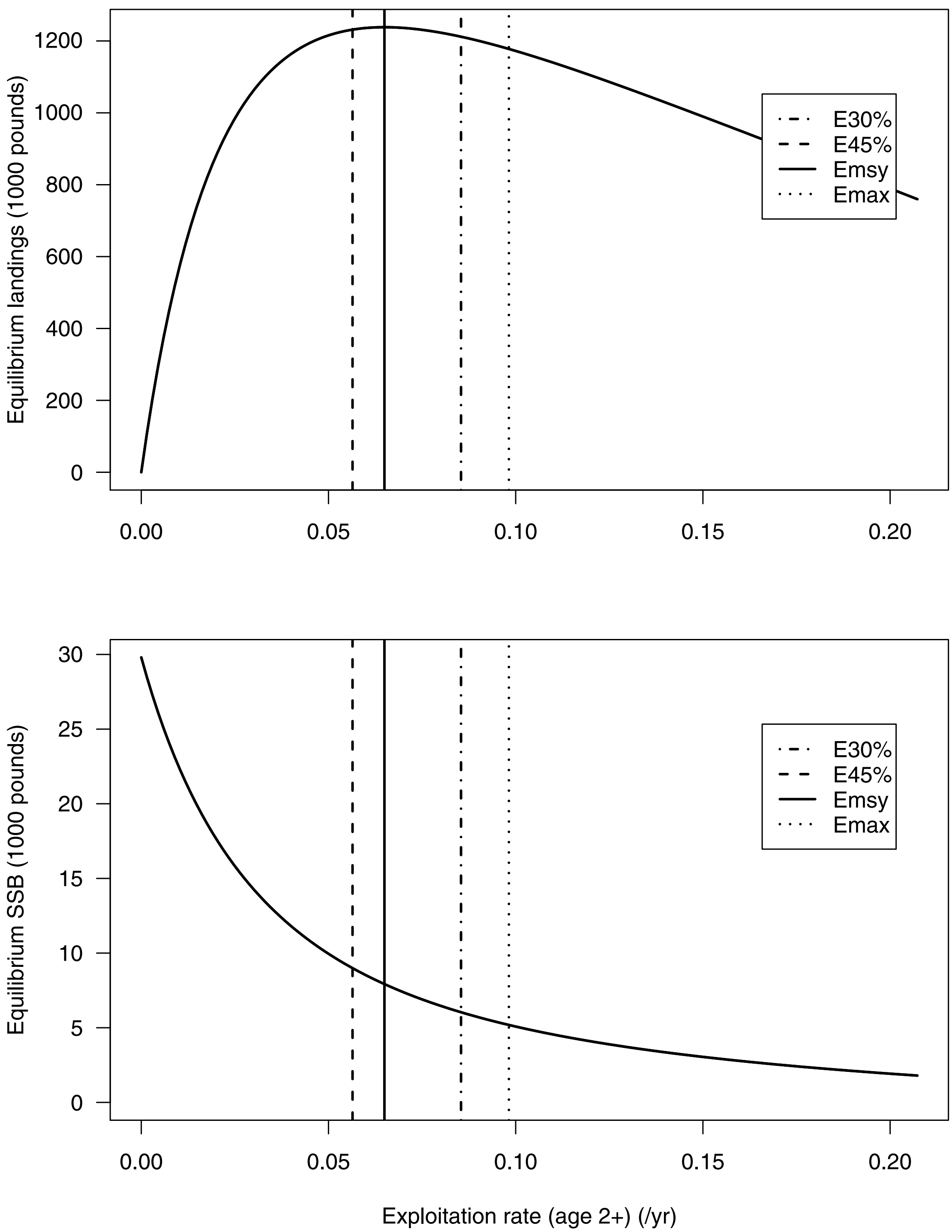
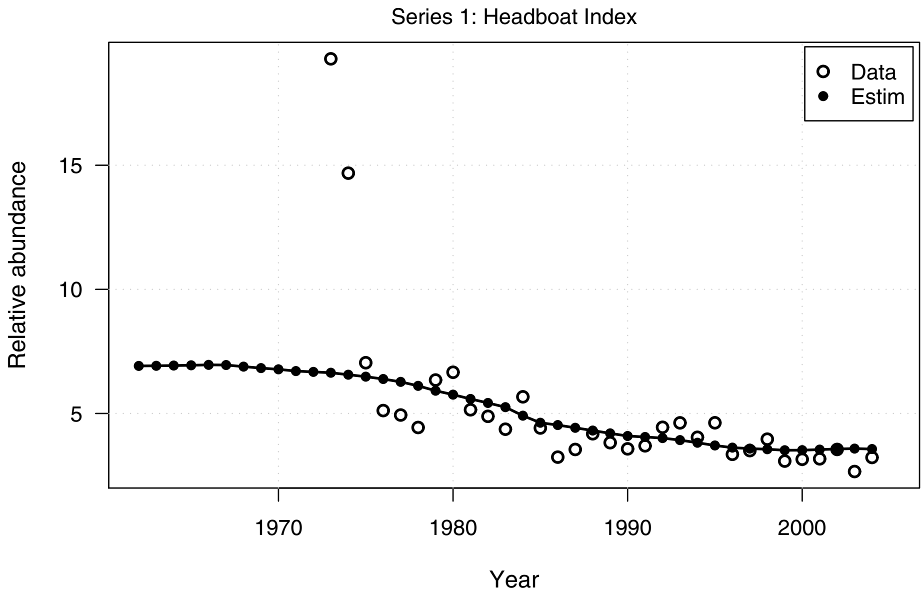


Figure 70. Gag in Atlantic: Fit of production models to headboat index. Panel (a), run G102, constant catchability assumed; (b), run G117, catchability increasing since 1980 assumed.

(a)



(b)

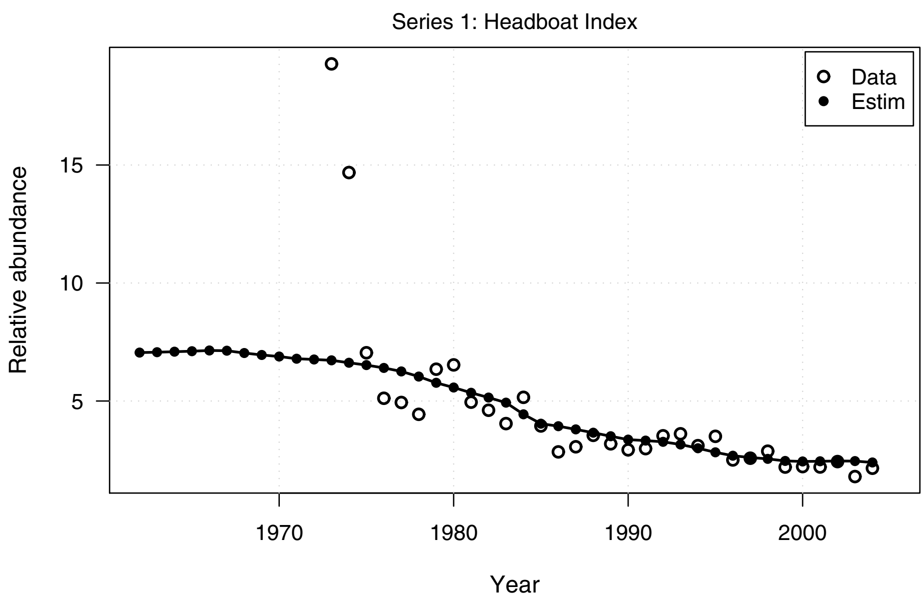


Figure 71. Gag in Atlantic: Fit of production models to commercial logbook index. Panel (a), run G102, constant catchability assumed; (b), run G117, catchability increasing since 1980 assumed.

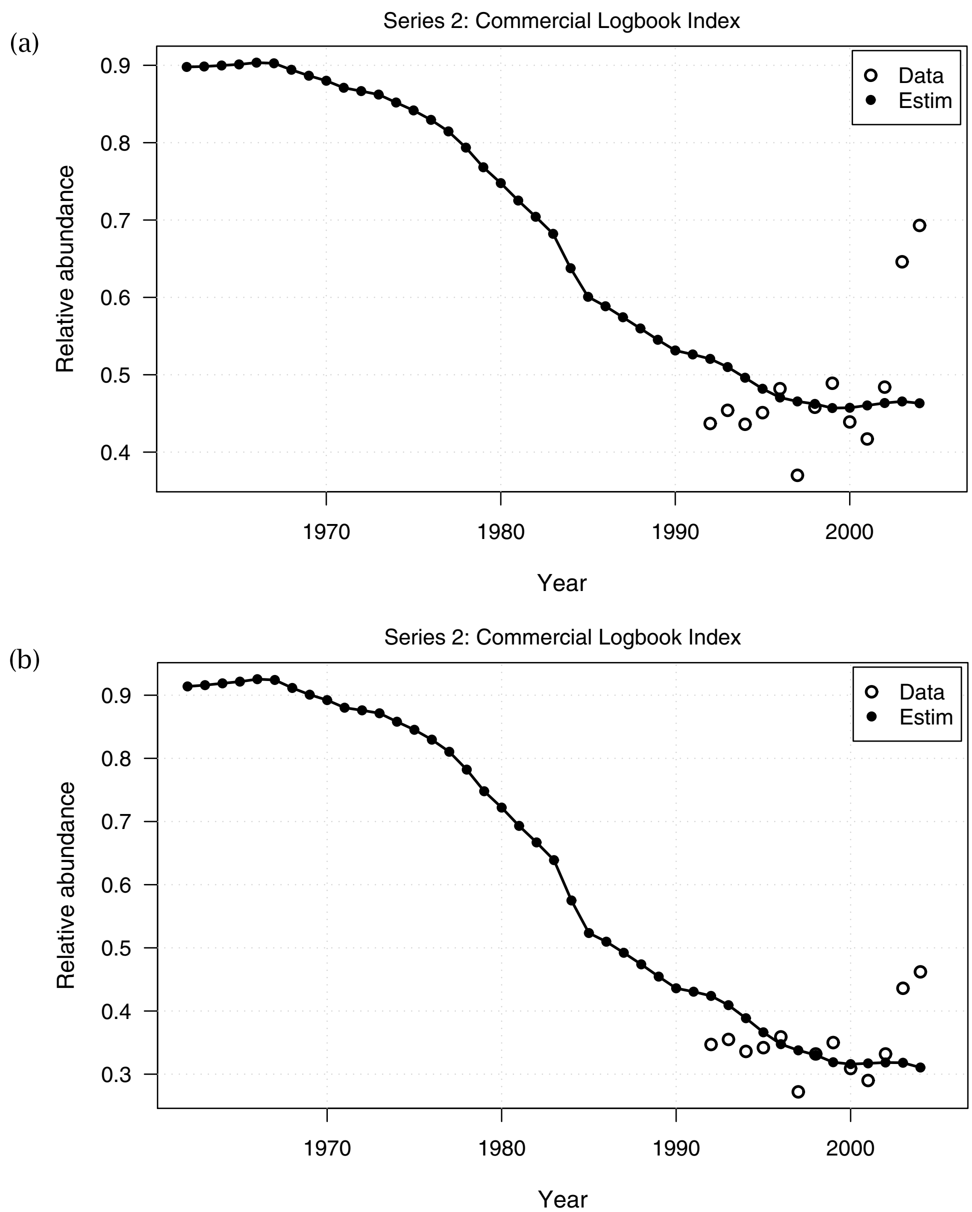


Figure 72. Gag in Atlantic: Fit of production models to MRFSS index. Panel (a), run G102, constant catchability assumed; (b), run G117, catchability increasing since 1980 assumed.

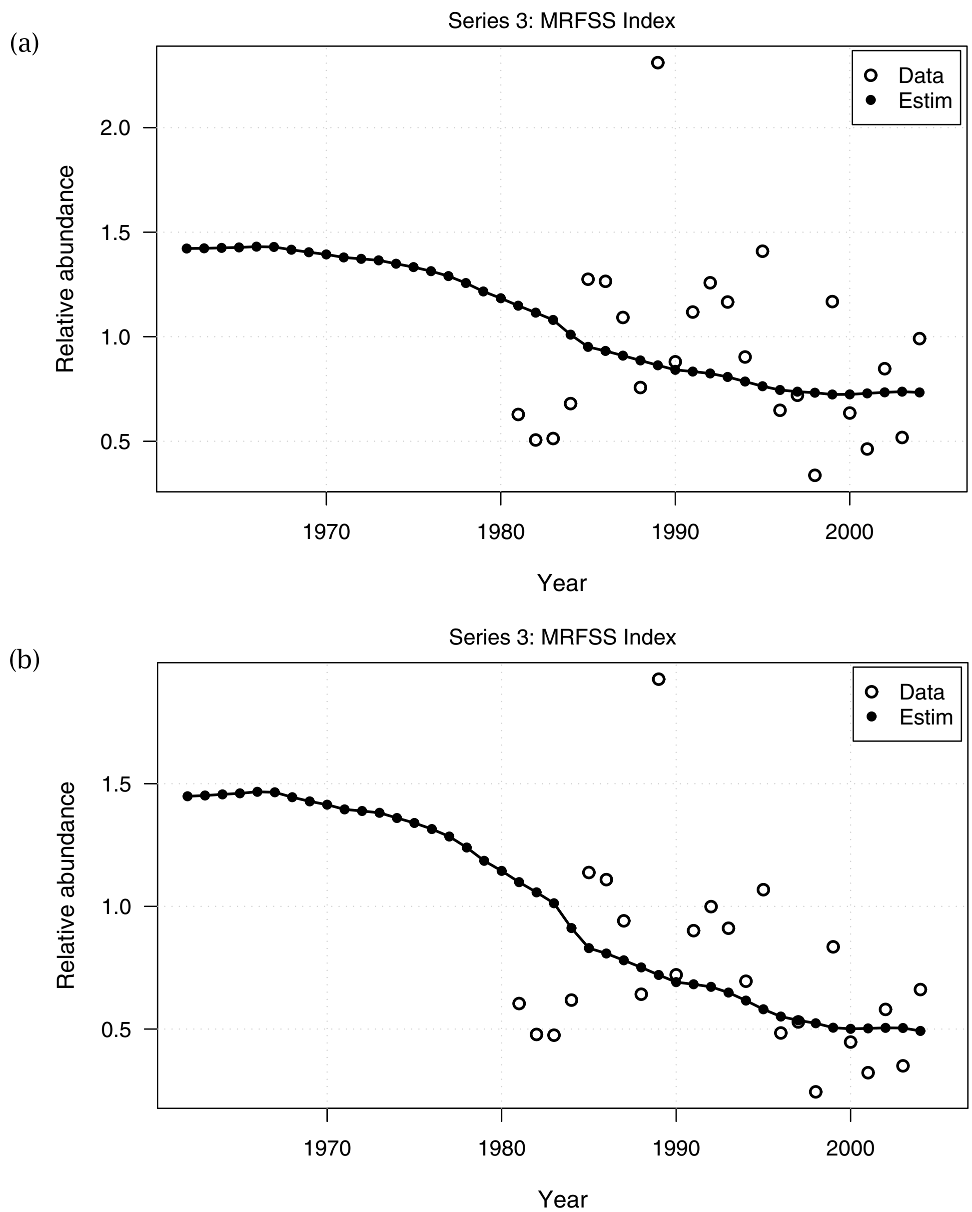


Figure 73. Gag in Atlantic: Time trajectory of biomass from production model under different assumptions about starting biomass. In each panel runs reflect $B_1/K = \{0.9, 0.7, 0.5\}$. Panel (a), constant catchability assumed; (b), catchability assumed to increase linearly at 2%/yr starting in 1980.

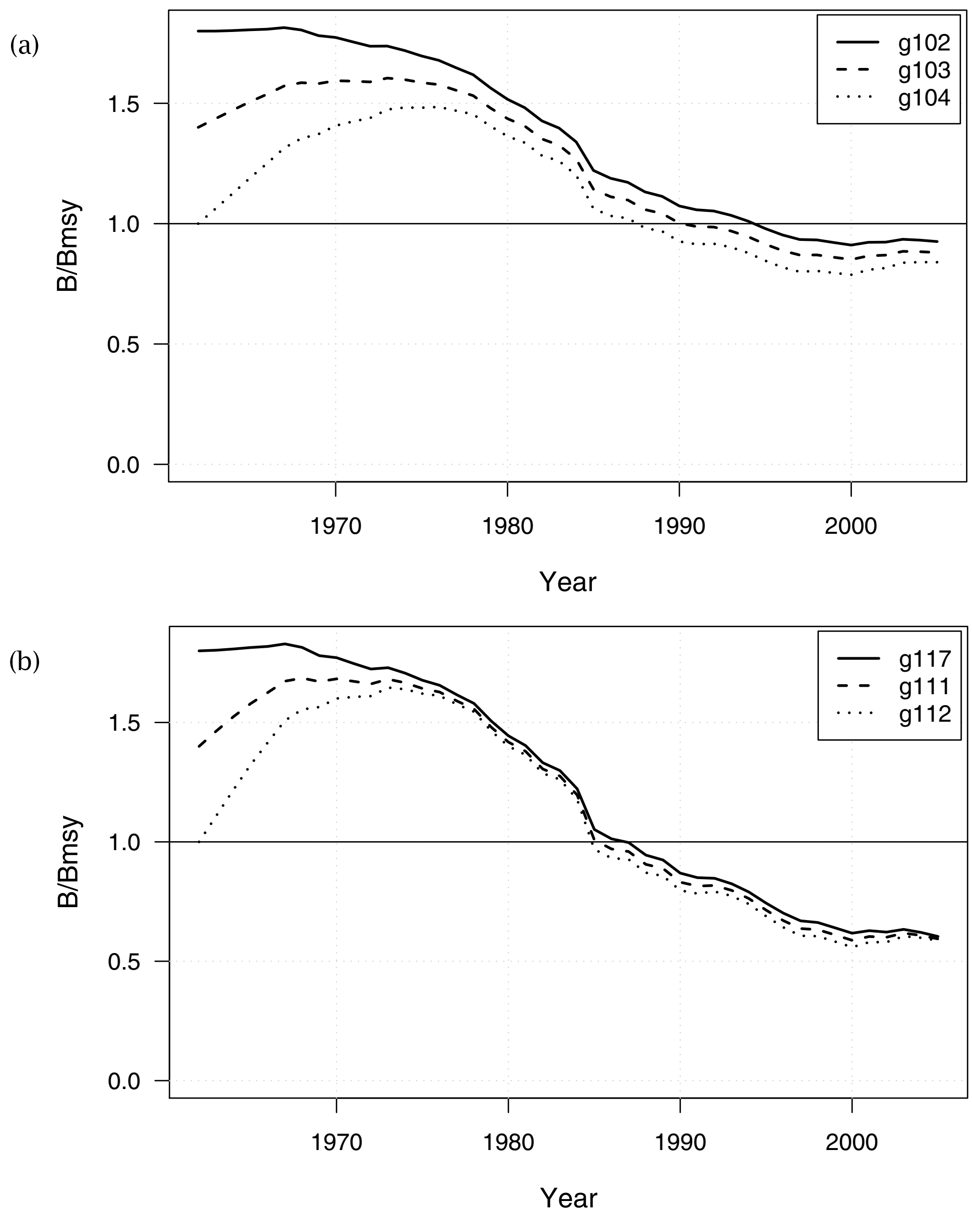


Figure 74. Gag in Atlantic: Time trajectory of fishing mortality rate from production model under different assumptions about starting biomass. In each panel runs reflect $B_1/K = \{0.9, 0.7, 0.5\}$. Panel (a), constant catchability assumed; (b), catchability assumed to increase linearly at 2%/yr starting in 1980.

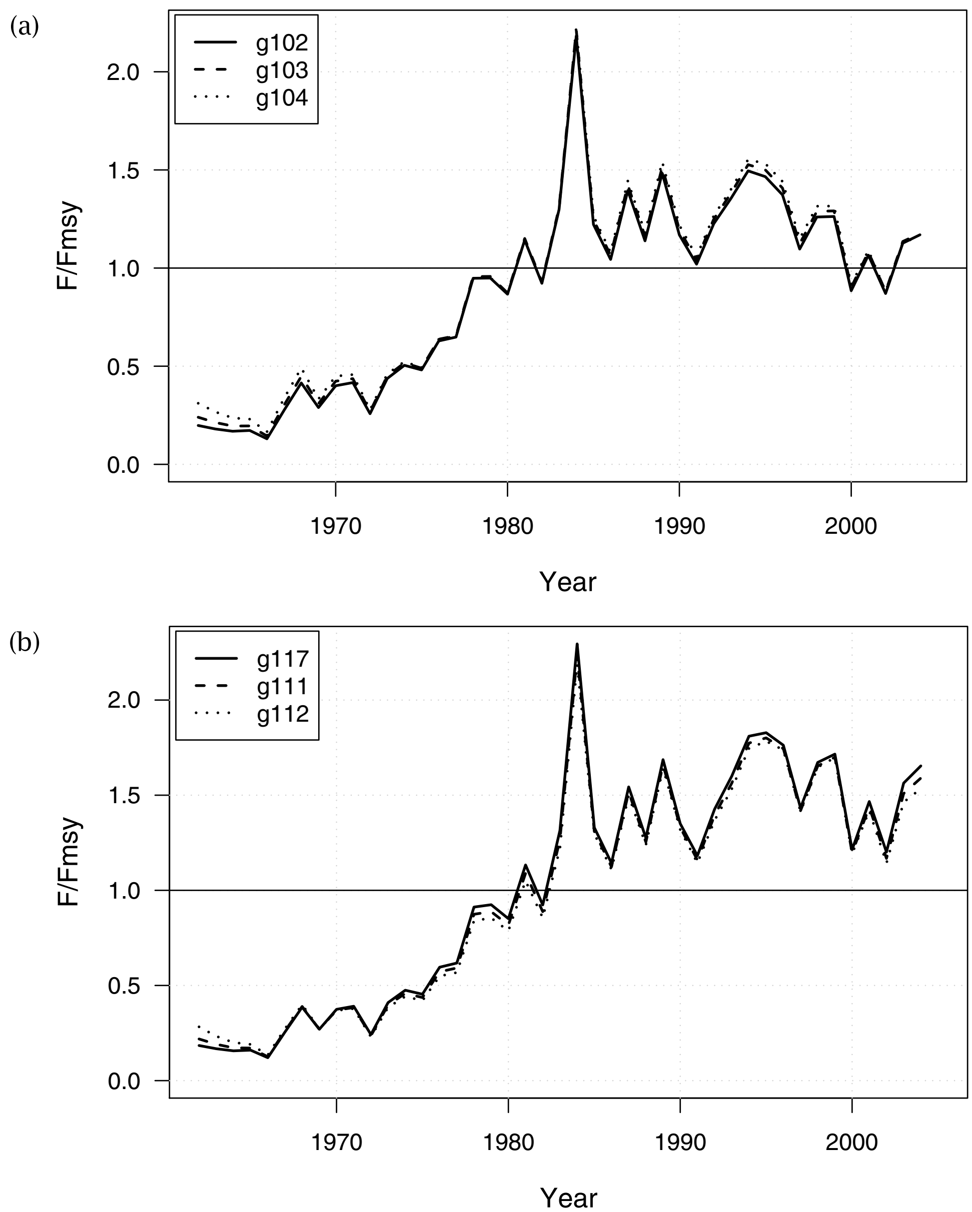


Figure 75. Gag in Atlantic: Time trajectories from production model under constant catcahability (run G102) or increasing catchability over time (run G117). Panel (a), relative biomass; (b), relative fishing mortality rate.

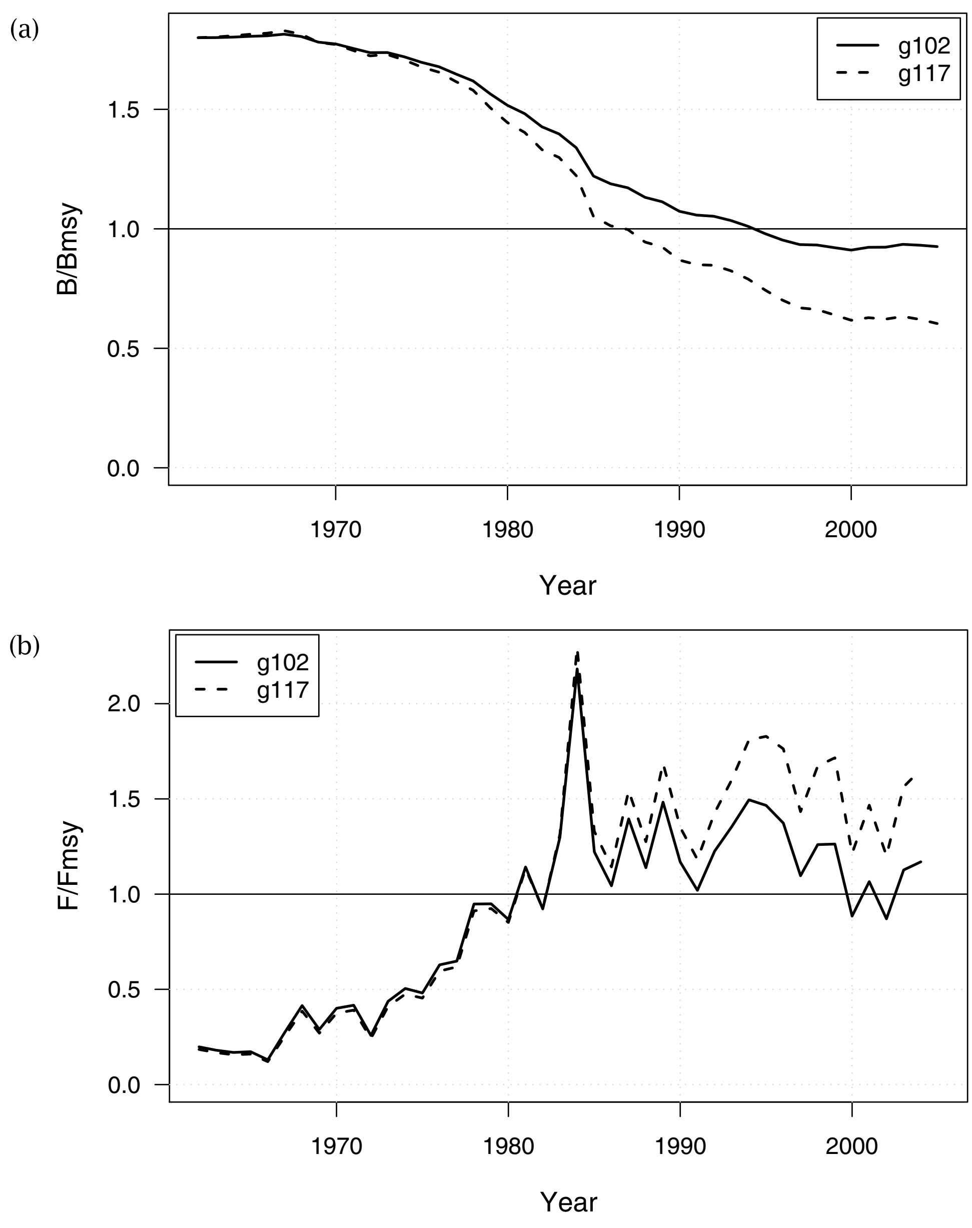
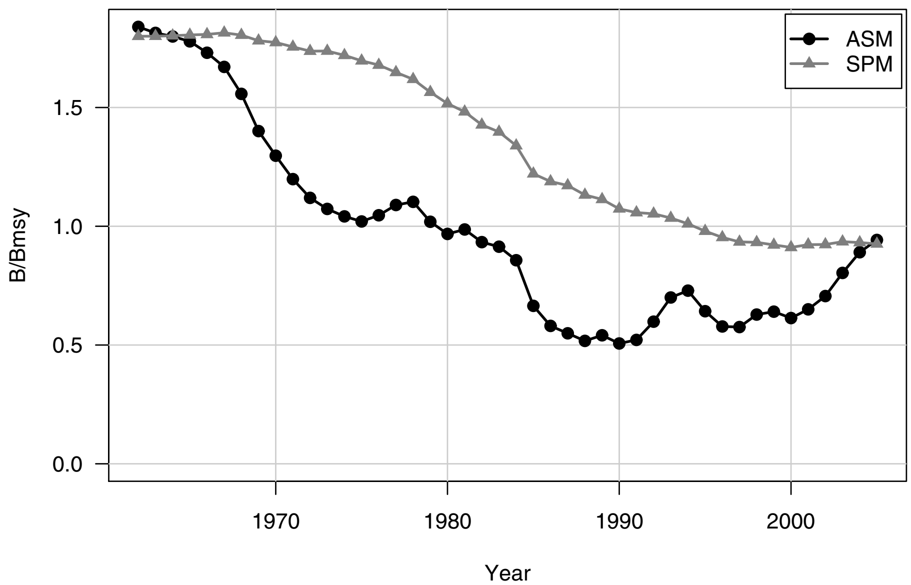


Figure 76. Gag in Atlantic: Comparison of stock-status trajectories estimated from age-structured model (ASM) and surplus-production model (SPM). Panel (a), constant catchability assumed; (b), catchability assumed to increase linearly at 2%/yr starting in 1980.

(a)



(b)

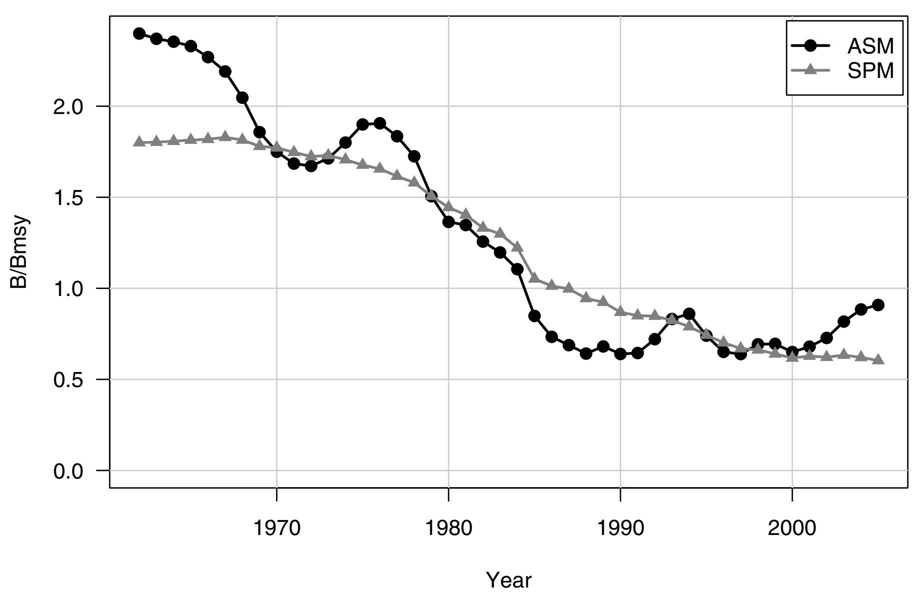
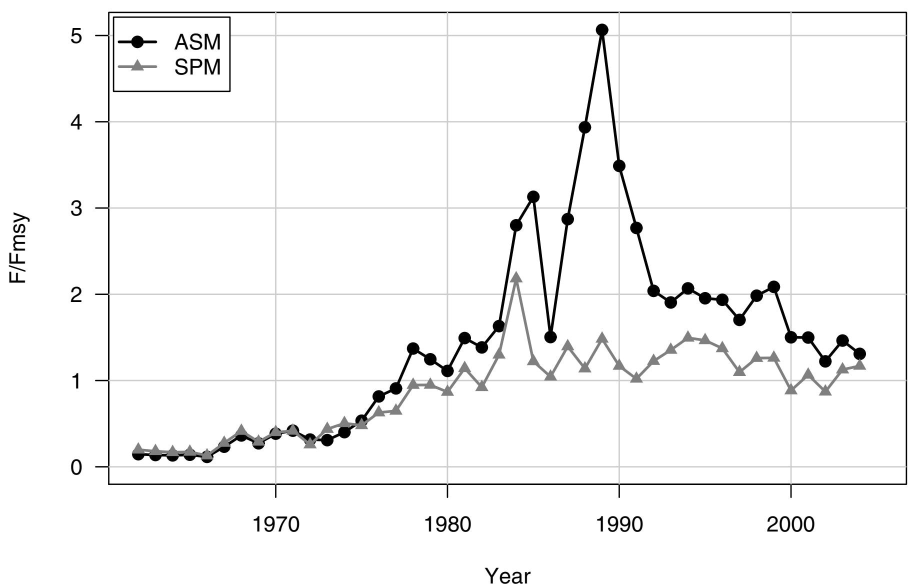


Figure 77. Gag in Atlantic: Comparison of fishery-status trajectories estimated from age-structured model (ASM) and surplus-production model (SPM). Panel (a), constant catchability assumed; (b), catchability assumed to increase linearly at 2%/yr starting in 1980.

(a)



(b)

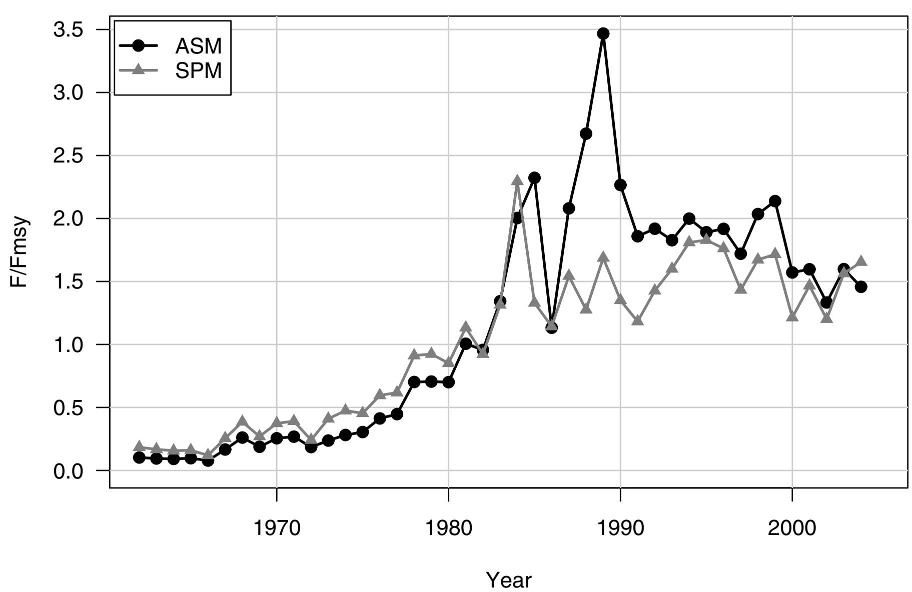


Figure 78. Gag– Base run with time-varying catchability: Probability density of stock-recruit parameters R0 (virgin recruitment) and steepness, and maximum sustainable yield (MSY) and recruitment at MSY (Rmsy). Vertical line represents base run estimate.

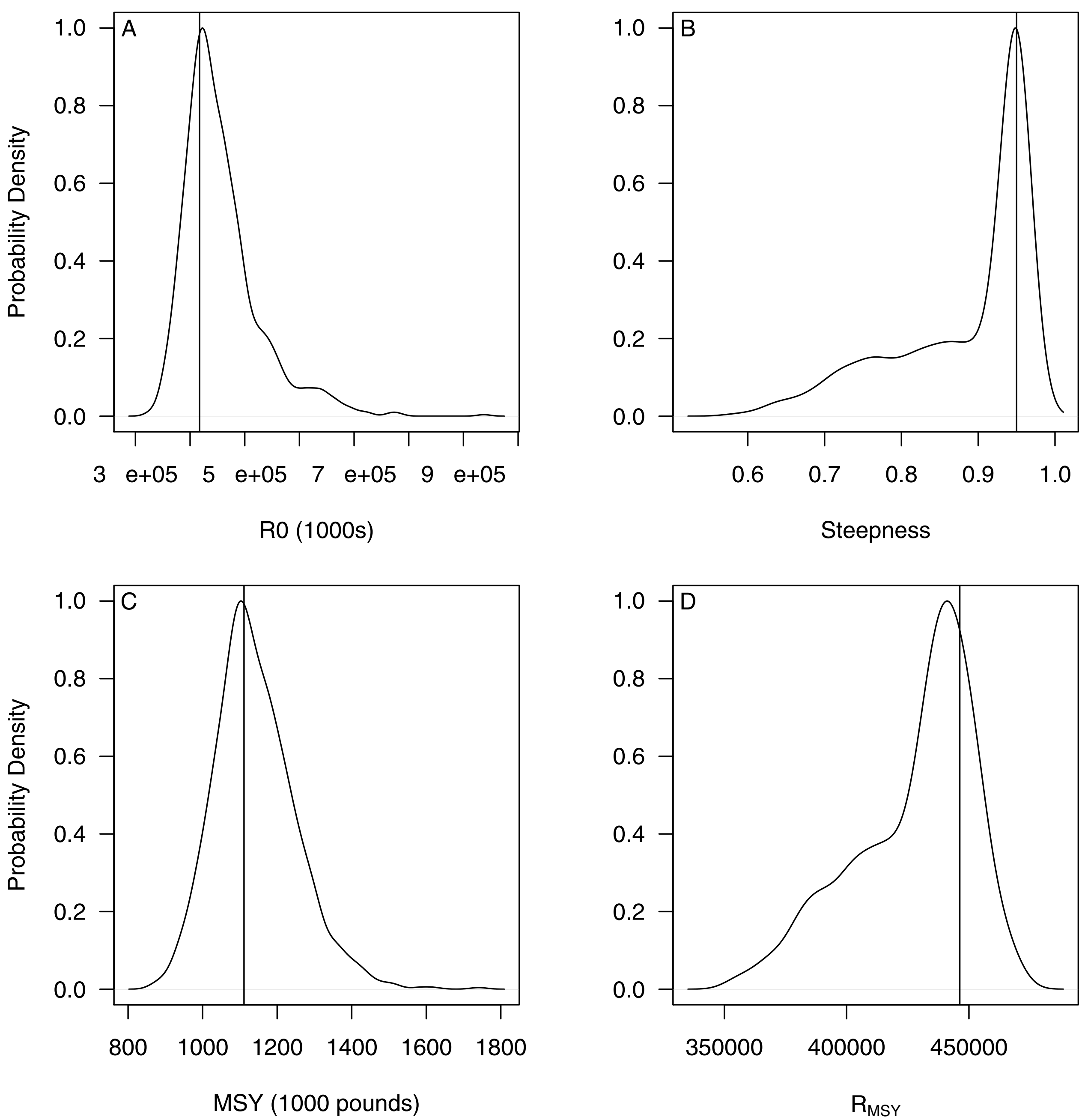


Figure 79. Gag– Base run with constant catchability: Probability density of stock-recruit parameters R0 (virgin recruitment) and steepness, and maximum sustainable yield (MSY) and recruitment at MSY (Rmsy). Vertical line represents base run estimate.

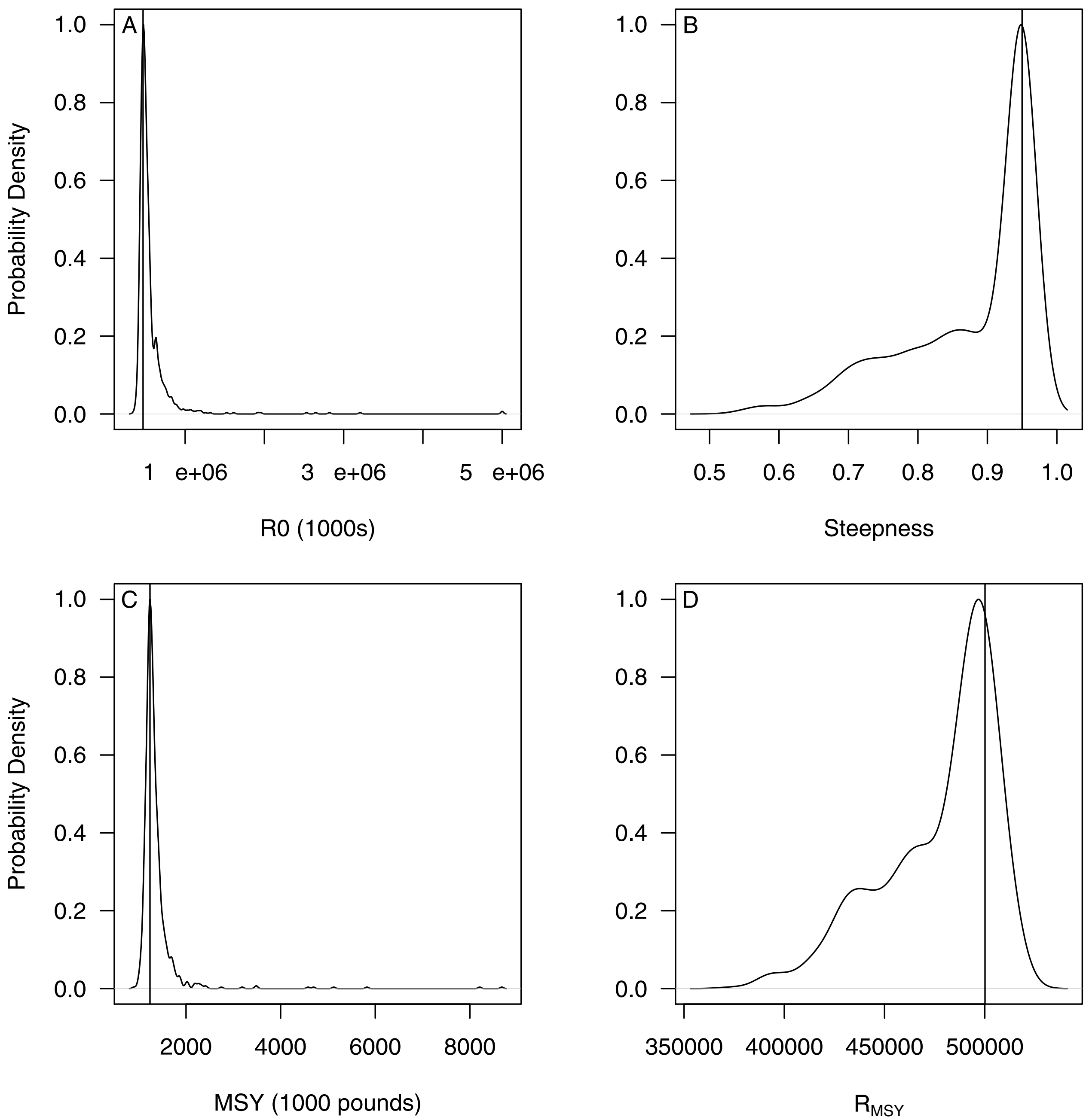


Figure 80. Gag– Base run with time-varying catchability: Probability density of maximum sustainable yield (MSY) benchmarks, fishing mortality rate at MSY (F_{MSY}), exploitation rate of age-2+ at MSY (E_{MSY}), spawning stock biomass (klb) at MSY (SSB_{MSY}), total biomass (klb) at MSY (B_{MSY}). Vertical line represents base run estimate.

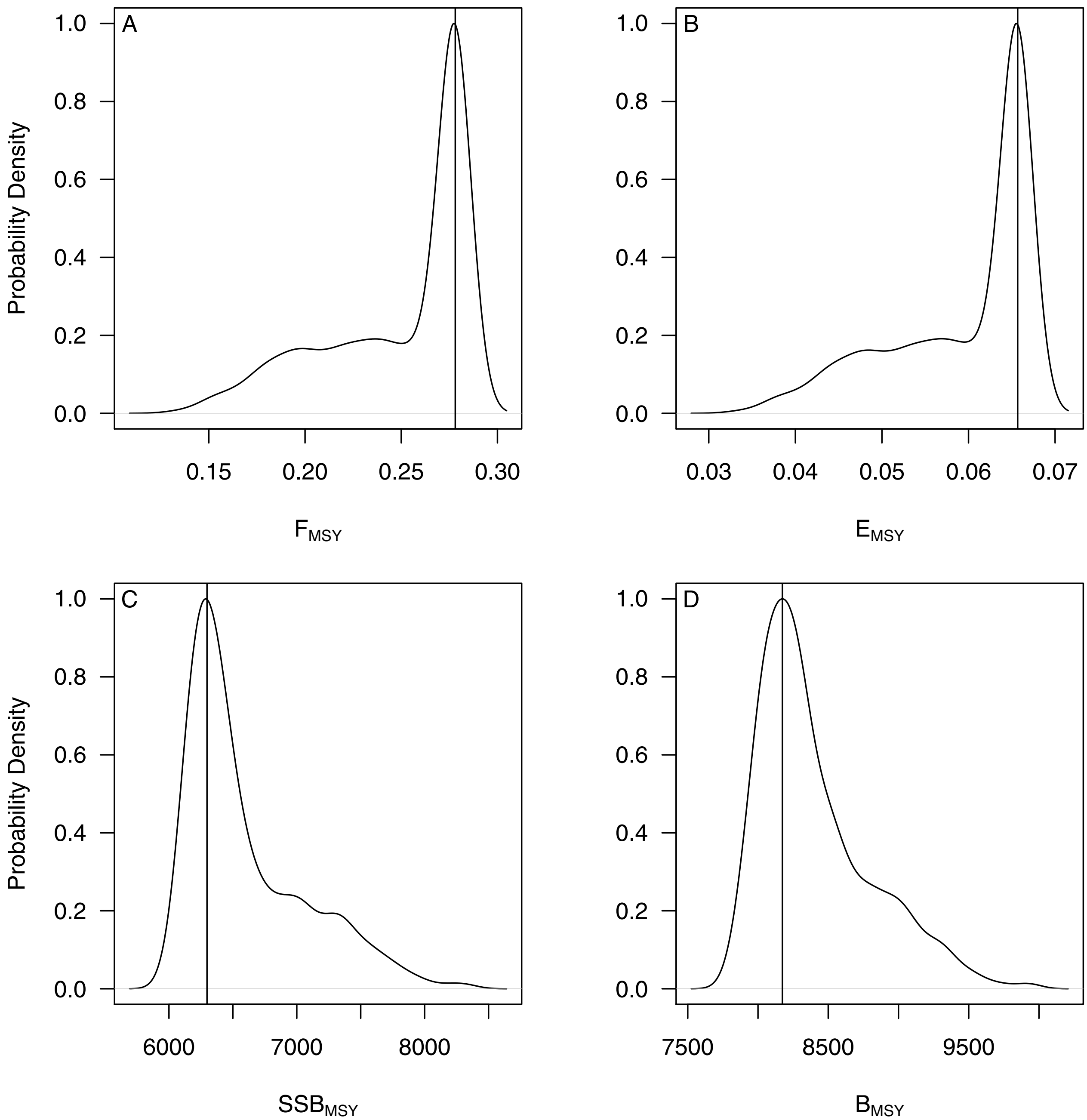


Figure 81. Gag– Base run with constant catchability: Probability density of maximum sustainable yield (MSY) benchmarks, fishing mortality rate at MSY (F_{MSY}), exploitation rate of age-2+ at MSY (E_{MSY}) , spawning stock biomass (klb) at MSY (SSB_{MSY}), total biomass (klb) at MSY (B_{MSY}). Vertical line represents base run estimate.

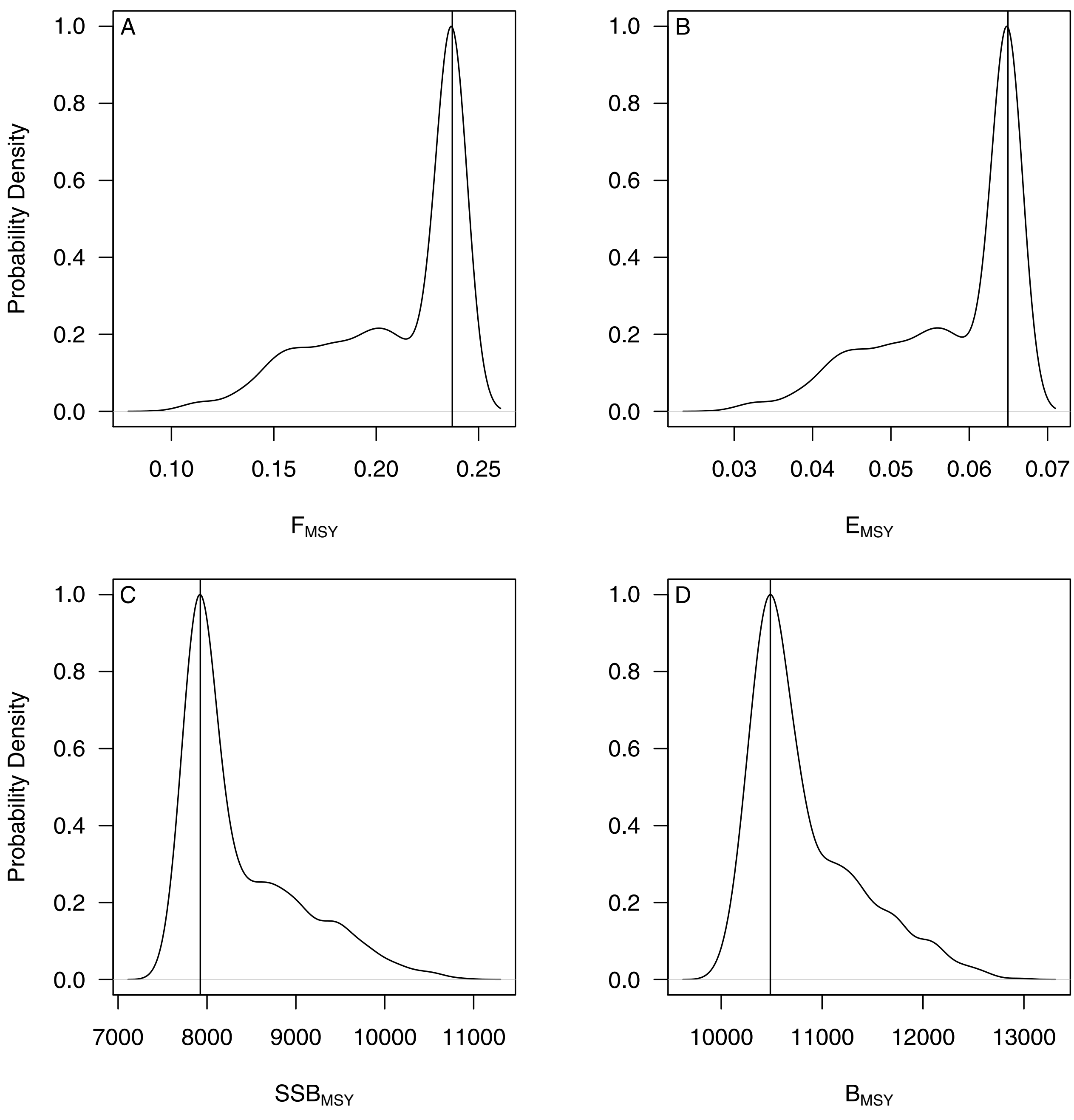


Figure 82. Gag– Base run with time-varying catchability: Estimated biomass time series, relative to MSY *bench-marks, of A) B relative to* B_{MSY} *and B) SSB relative to* SSB_{MSY}*. In each panel, a dashed horizontal line at one indicates where an estimated time series would equal its related benchmark; a dotted horizontal line at* $1 - M$ *indicates where estimated* SSB *would equal* MSST*; thin dashed lines indicate 90% range of uncertainty from 1000 bootstrap estimates of stock-recruit curve.*

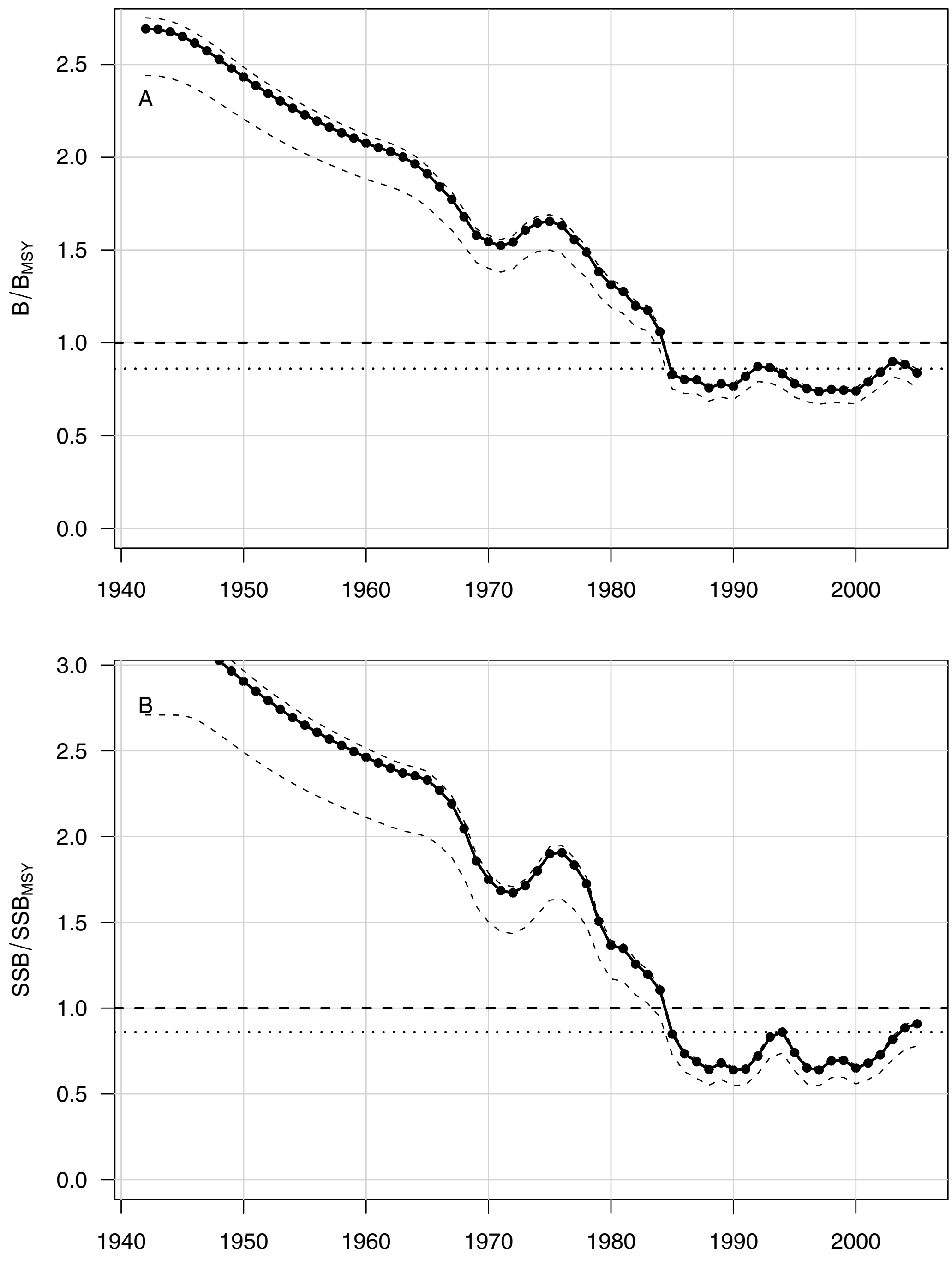


Figure 83. Gag– Base run with constant catchability: Estimated biomass time series, relative to MSY *benchmarks, of A) B relative to B_{MSY} and B) SSB relative to* $\mathrm{SSB}_{\mathrm{MSY}}$*. In each panel, a dashed horizontal line at one indicates where an estimated time series would equal its related benchmark; a dotted horizontal line at* $1 - M$ *indicates where estimated* SSB *would equal* MSST*; thin dashed lines indicate 90% range of uncertainty from 1000 bootstrap estimates of stock-recruit curve.*

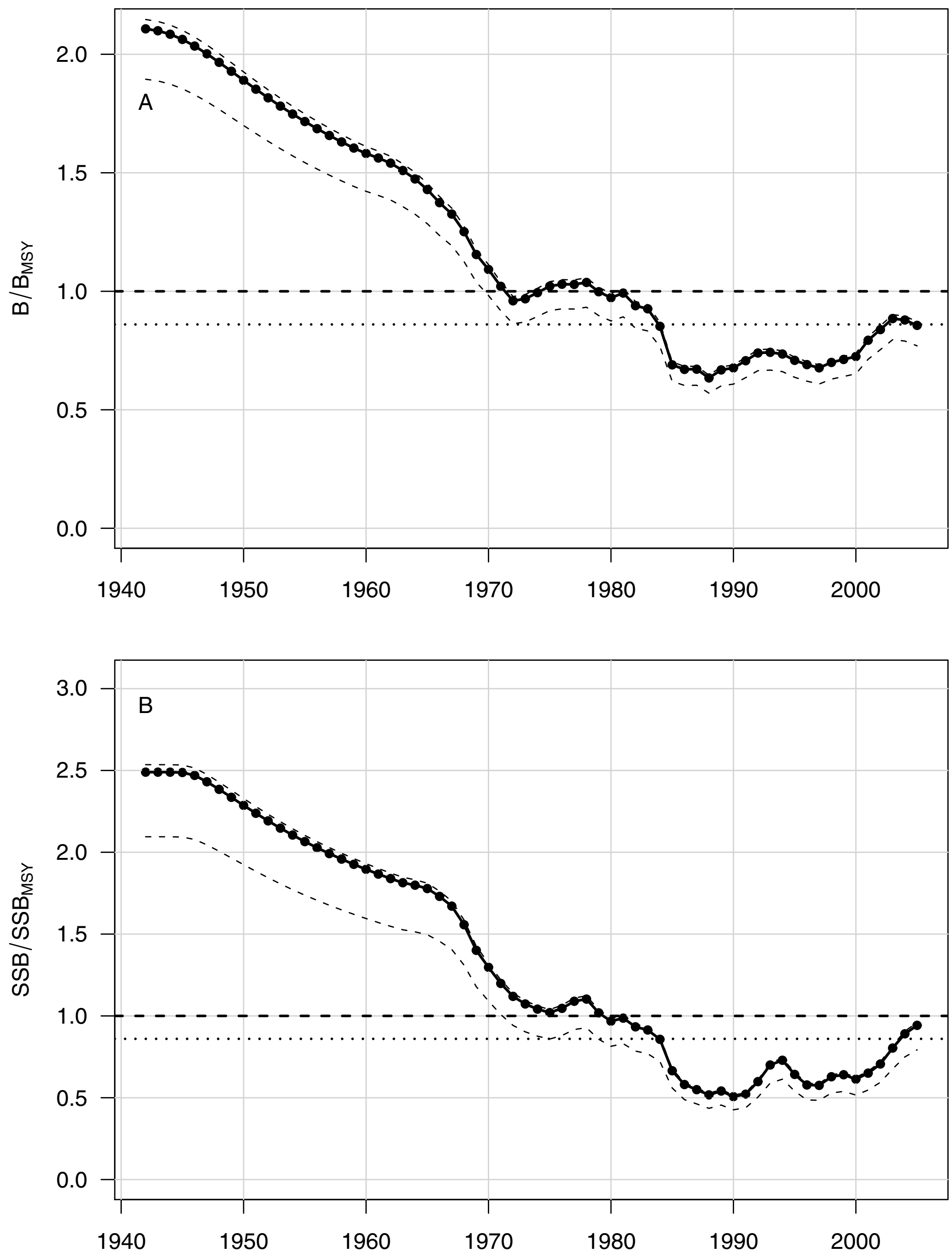


Figure 84. Gag– Base run with time-varying catchability: Estimated exploitation time series, relative to MSY *benchmarks, of A) Fishing mortality rate (F) relative to* F_{MSY} *and B) Exploitation rate (E) relative to* E_{MSY} *. In each panel, a dashed horizontal line at one indicates where an estimated time series would equal its related benchmark; thin dashed lines indicate 90% range of uncertainty from 1000 bootstrap estimates of stock-recruit curve.*

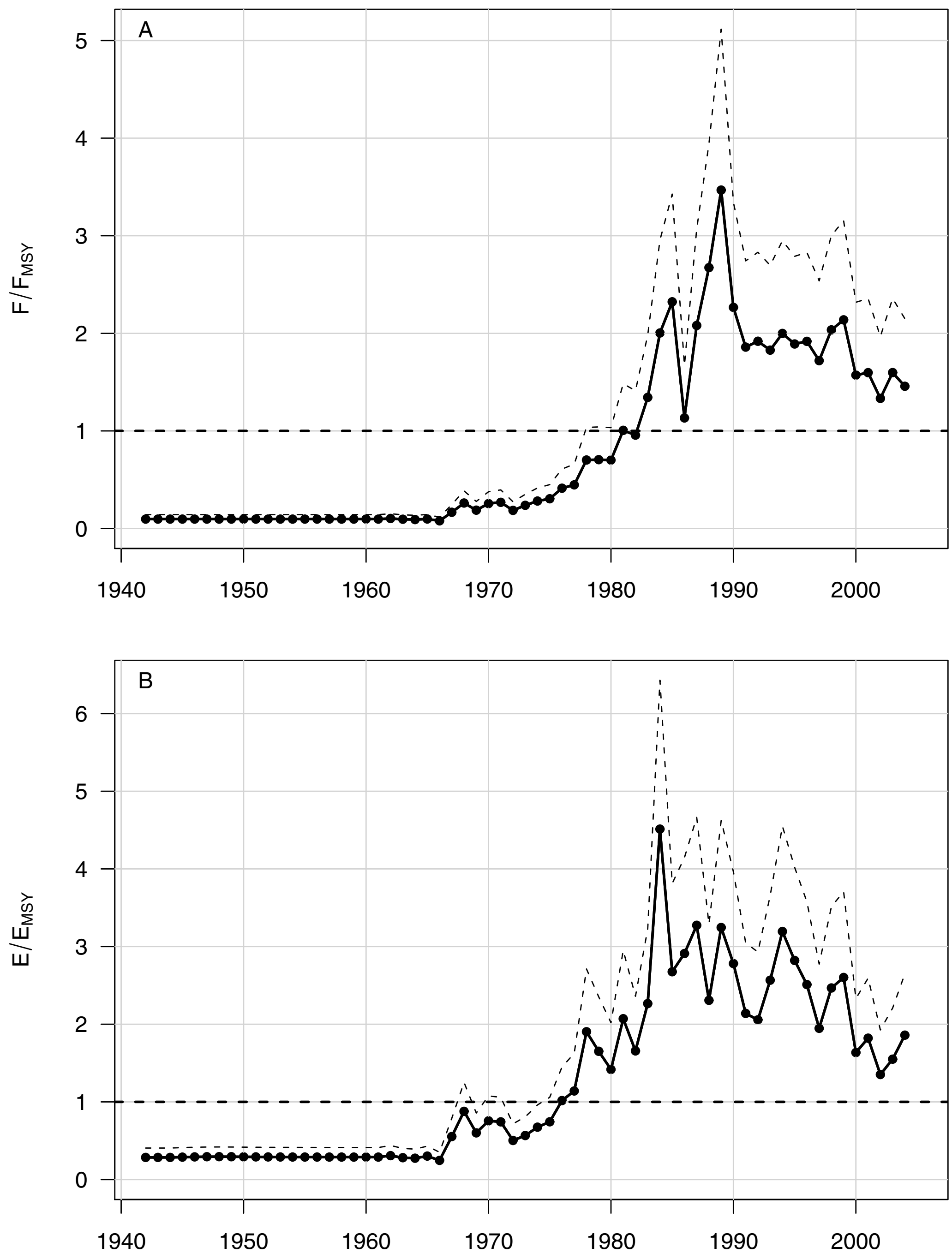


Figure 85. Gag– Base run with constant catchability: Estimated exploitation time series, relative to MSY benchmarks, of A) Fishing mortality rate (F) relative to F_{MSY} and B) Exploitation rate (E) relative to E_{MSY}. In each panel, a dashed horizontal line at one indicates where an estimated time series would equal its related benchmark; thin dashed lines indicate 90% range of uncertainty from 1000 bootstrap estimates of stock-recruit curve.

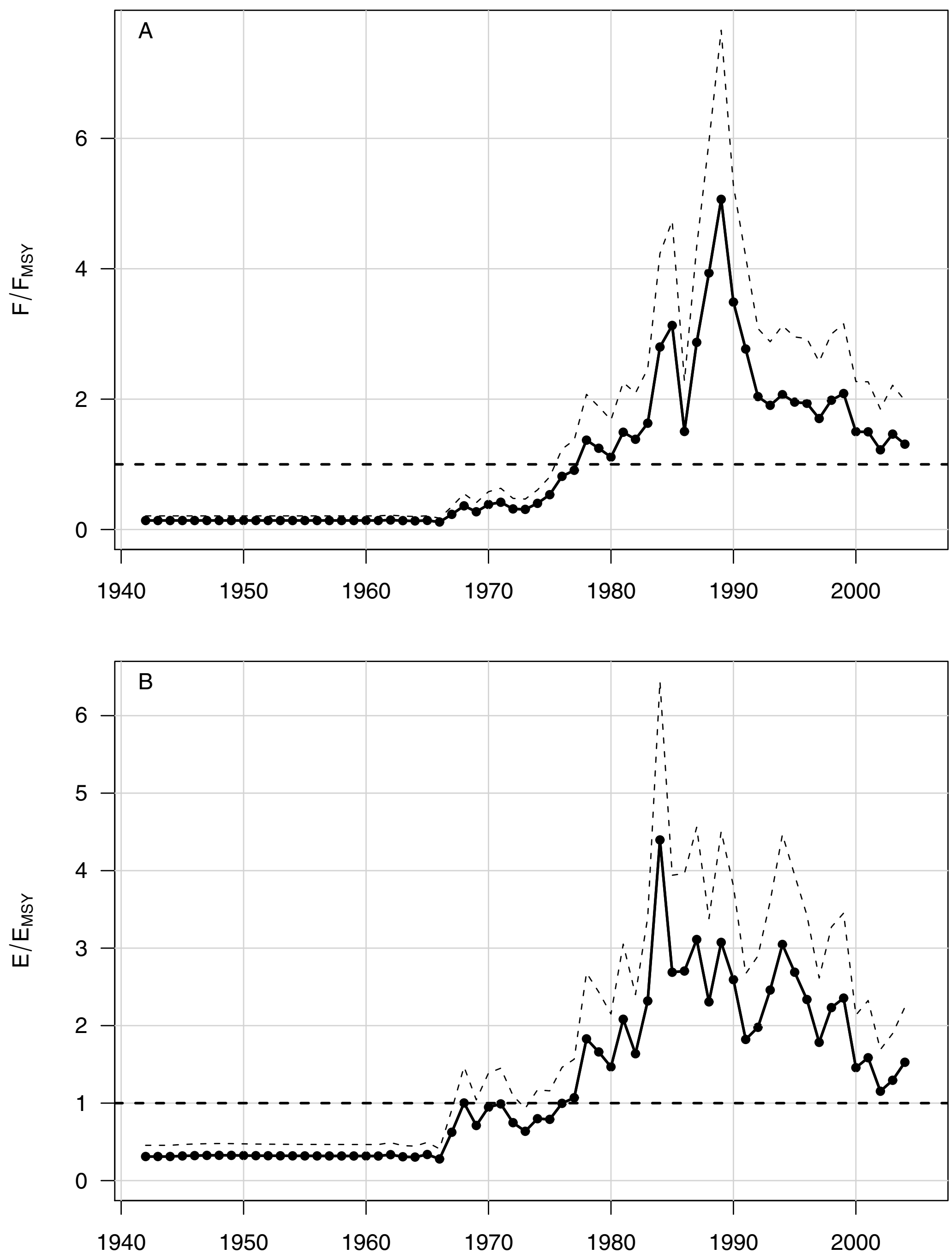


Figure 86. Gag– Base run with time-varying catchability: Estimates of exploitation rate from a retrospective analysis back to 1999. Ending year of model run is indicated by open circle in last year.

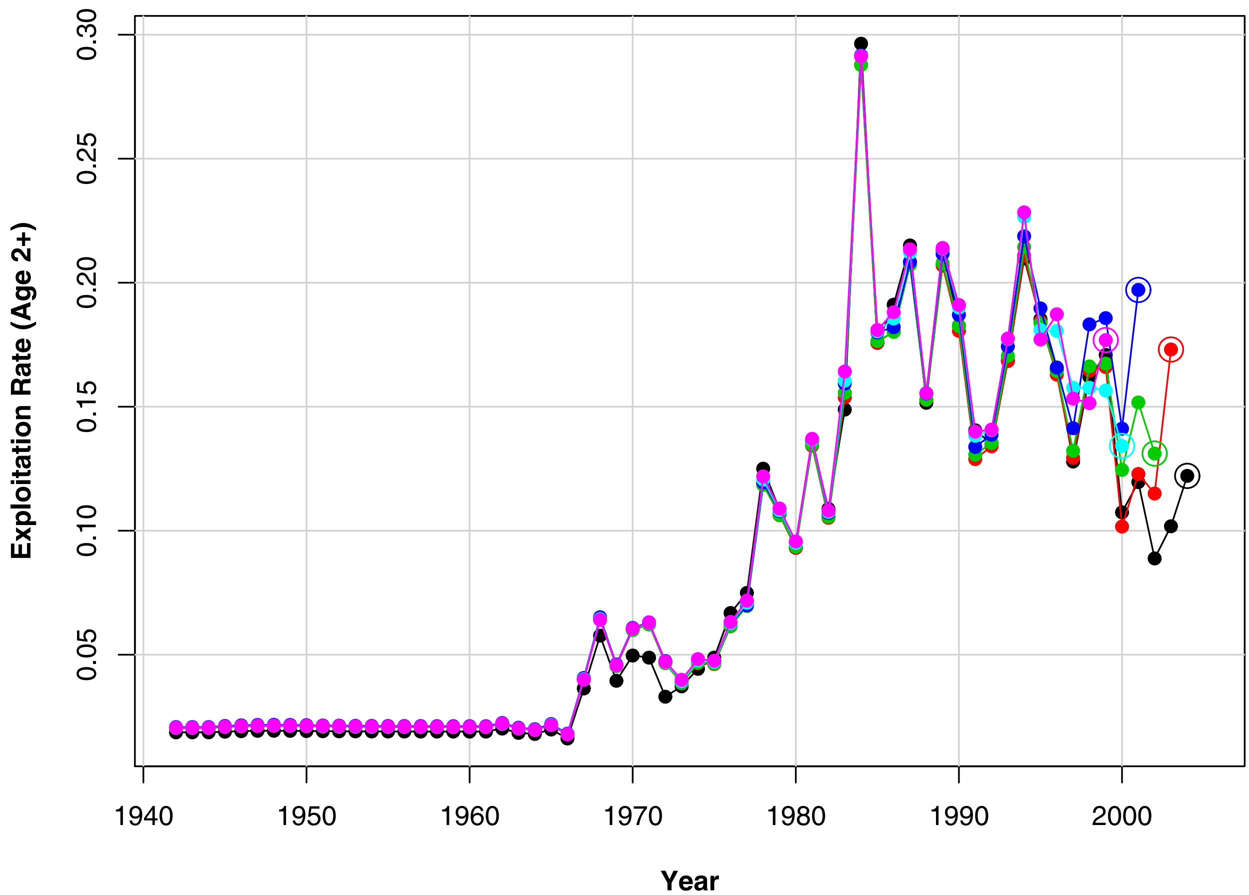


Figure 87. Gag- Base run with constant catchability: Estimates of exploitation rate from a retrospective analysis back to 1999. Ending year of model run is indicated by open circle in last year.

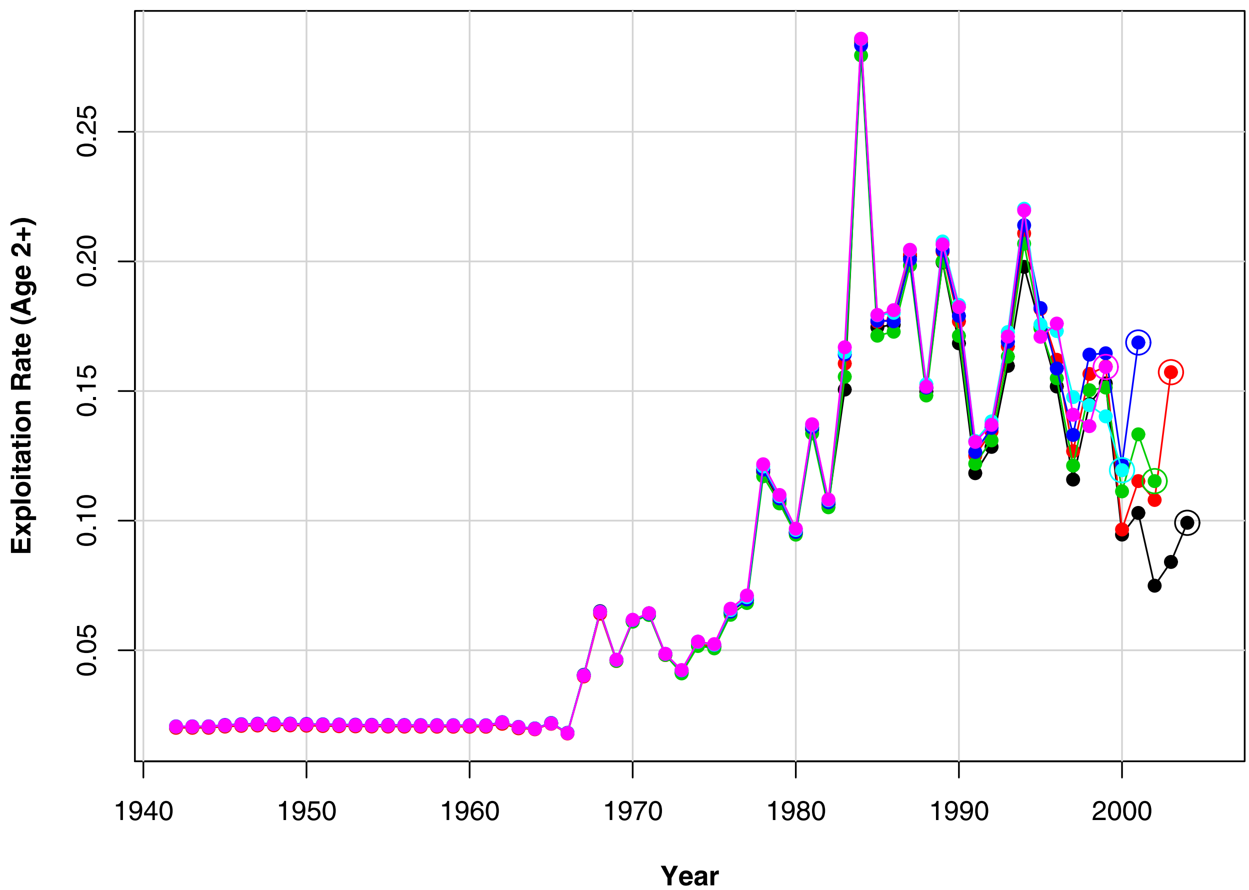


Figure 88. Gag– Base run with time-varying catchability: Estimates of fishing mortality rate from a retrospective analysis back to 1999. Ending year of model run is indicated by open circle in last year.

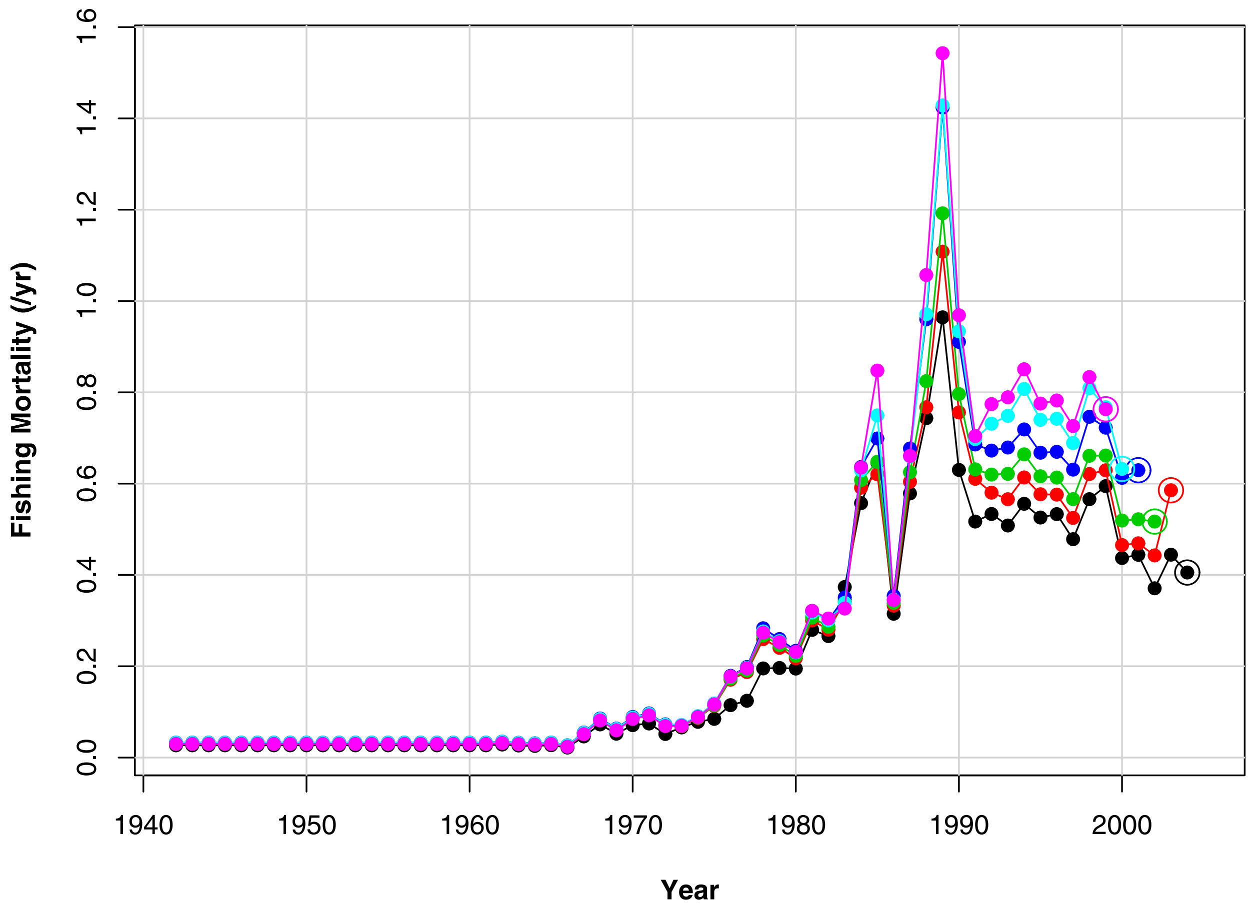


Figure 89. Gag– Base run with constant catchability: Estimates of fishing mortality rate from a retrospective analysis back to 1999. Ending year of model run is indicated by open circle in last year.

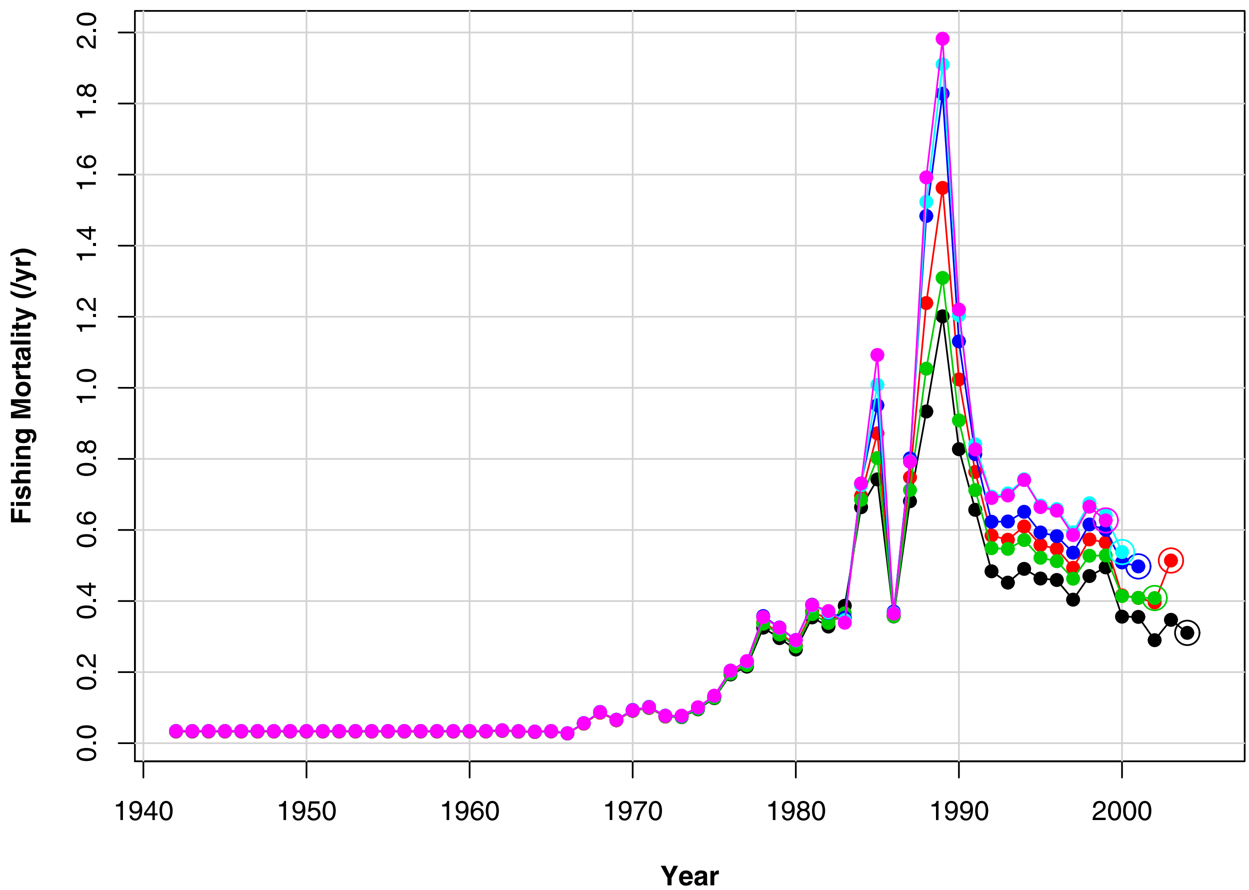


Figure 90. Gag– Base run with time-varying catchability: Estimates of total biomass (klb) from a retrospective analysis back to 1999. Ending year of model run is indicated by open circle in last year.

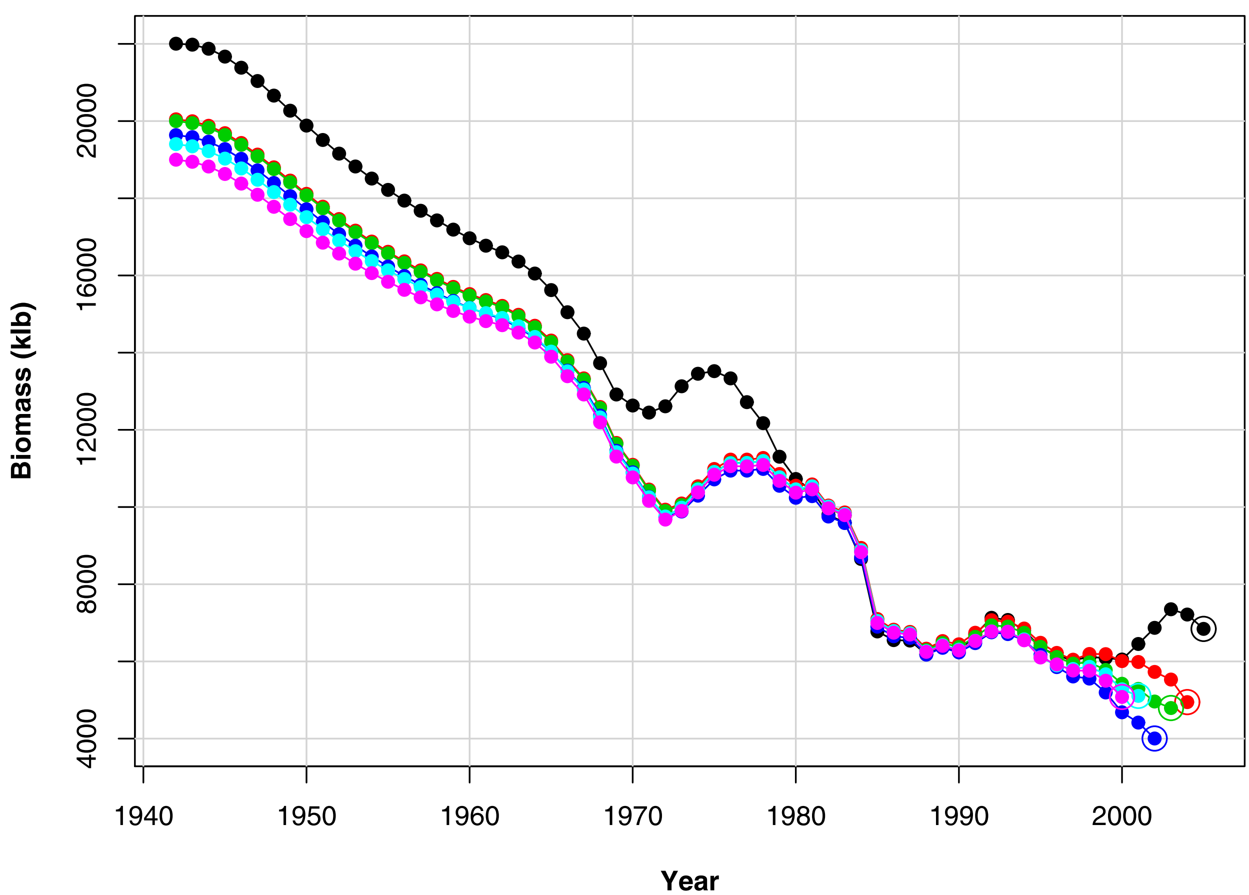


Figure 91. Gag– Base run with constant catchability: Estimates of total biomass (klb) from a retrospective analysis back to 1999. Ending year of model run is indicated by open circle in last year.

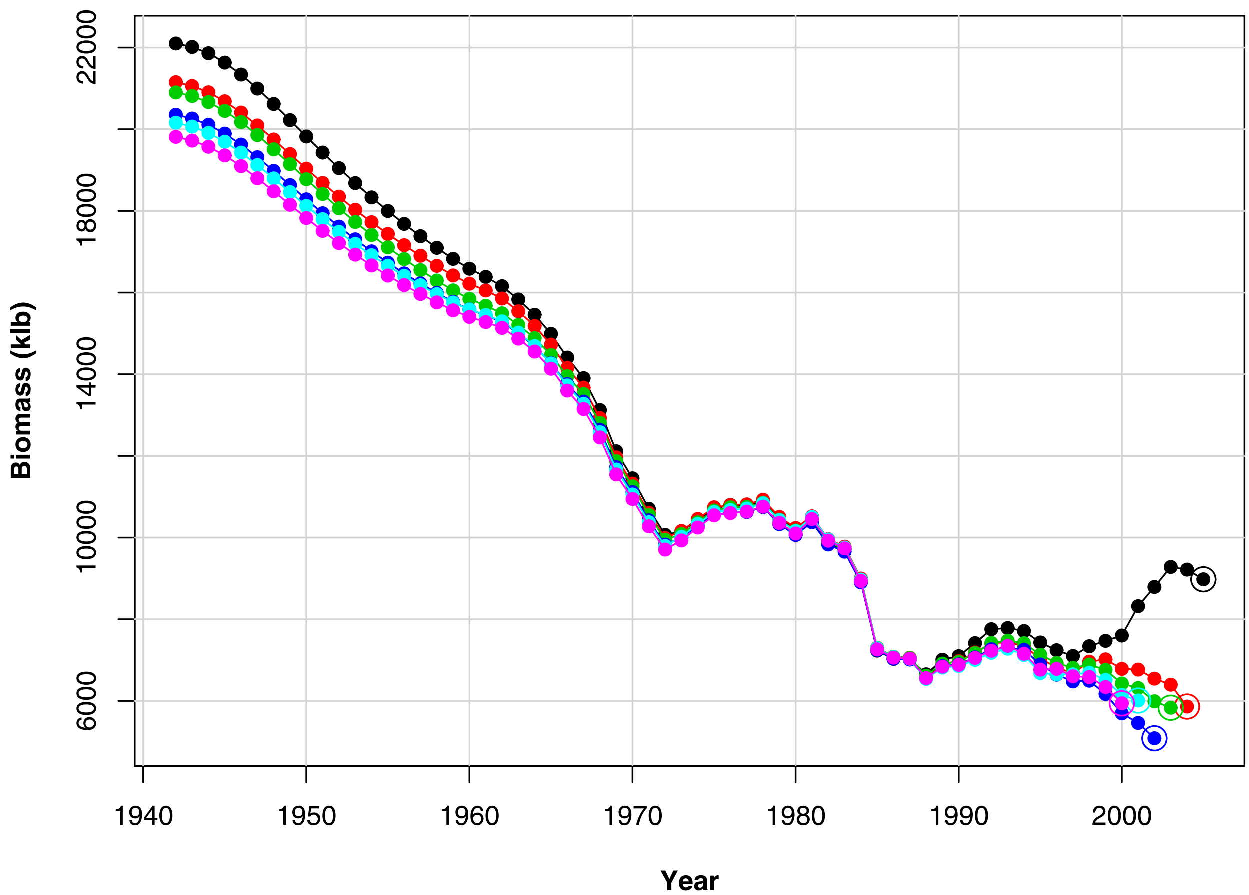


Figure 92. Gag– Base run with time-varying catchability: Estimates of spawning stock biomass (klb) from a retrospective analysis back to 1999. Ending year of model run is indicated by open circle in last year.

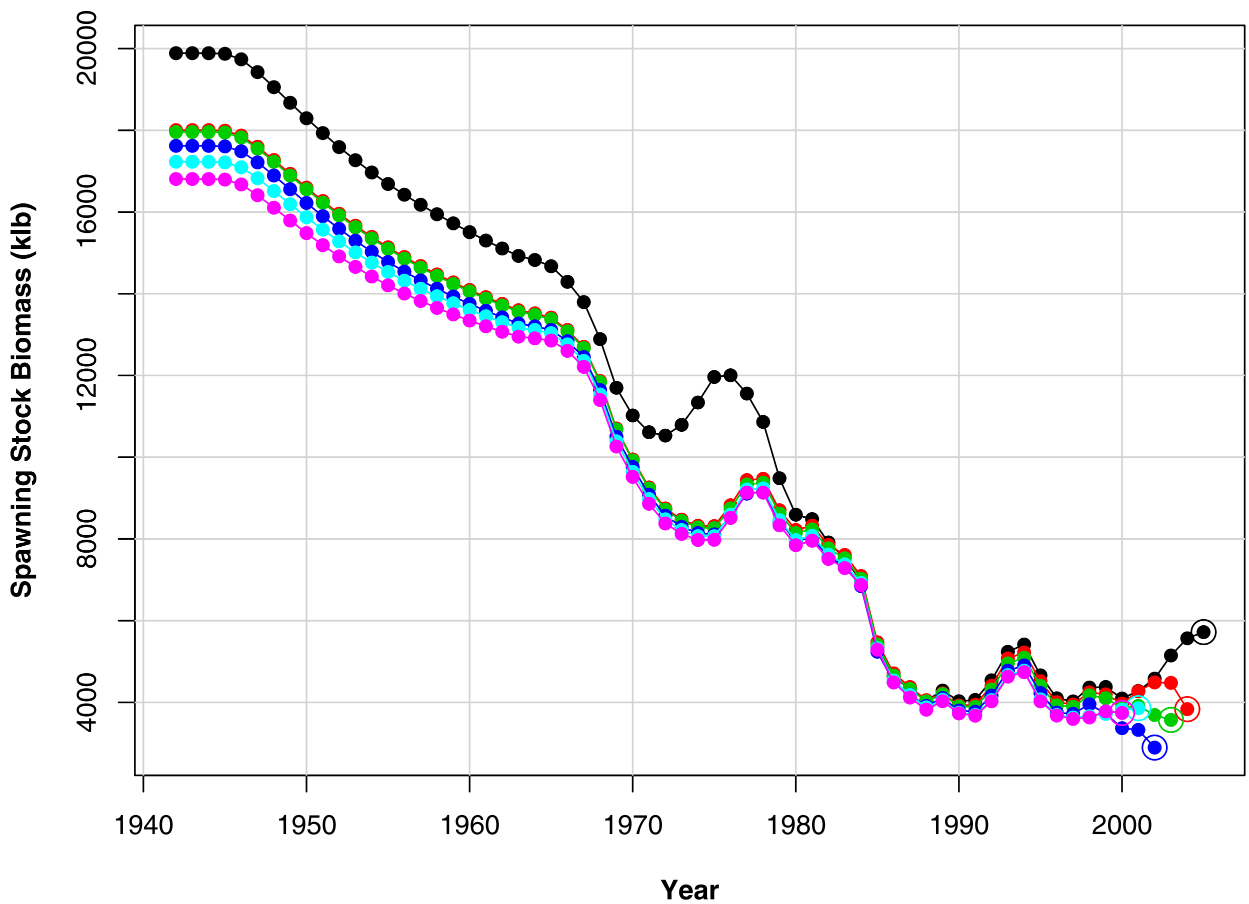


Figure 93. Gag– Base run with constant catchability: Estimates of spawning stock biomass (klb) from a retrospective analysis back to 1999. Ending year of model run is indicated by open circle in last year.

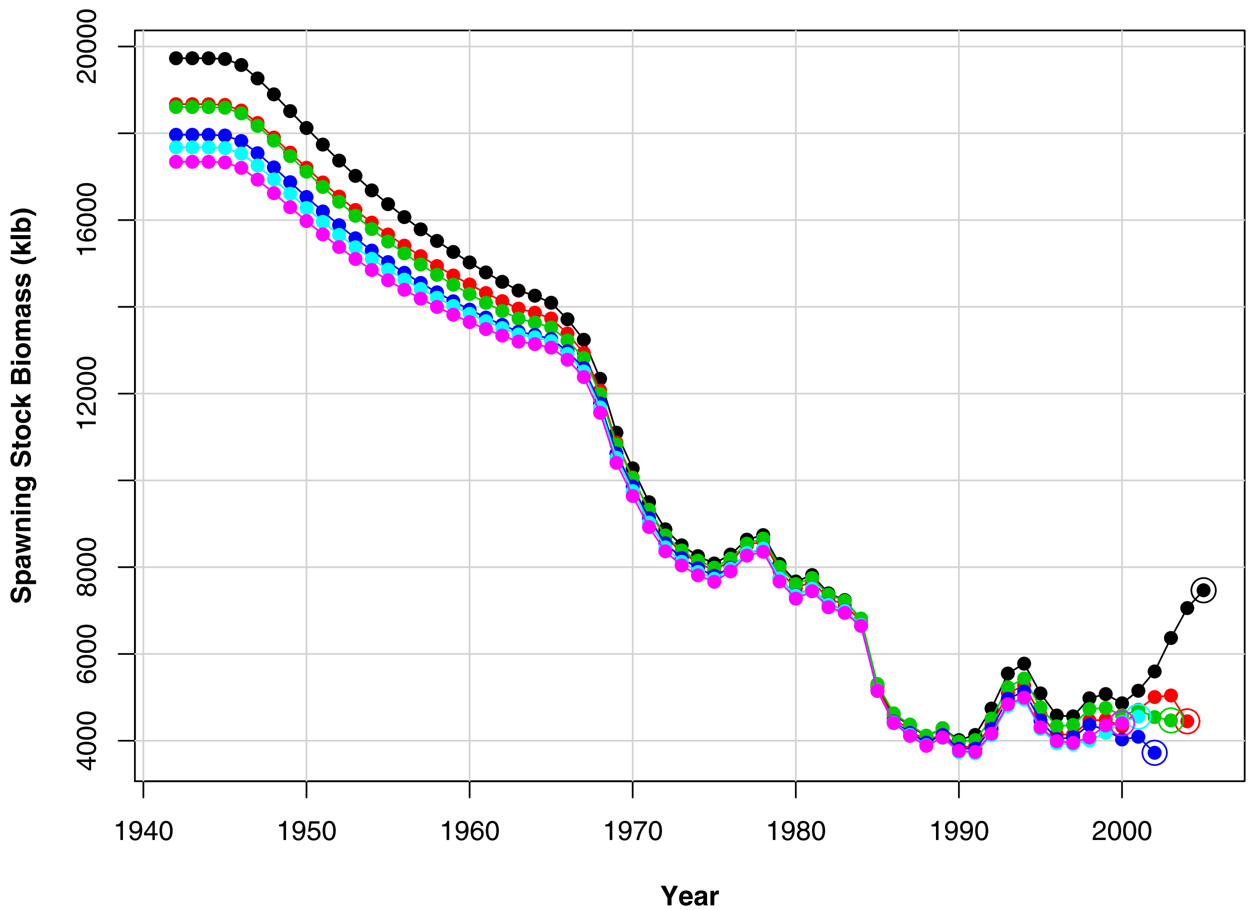


Figure 94. Gag– Base run with time-varying catchability: Projections under current fishing mortality rate for all years. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is $\mathrm{SSB}_{\mathrm{MSY}}$ *and dashed line is* MSST*; B) Recruits, horizontal line is* R_{MSY}*; C) Fishing mortality rate, horizontal line is* F_{MSY}*; and D) Landings, horizontal line is MSY.*

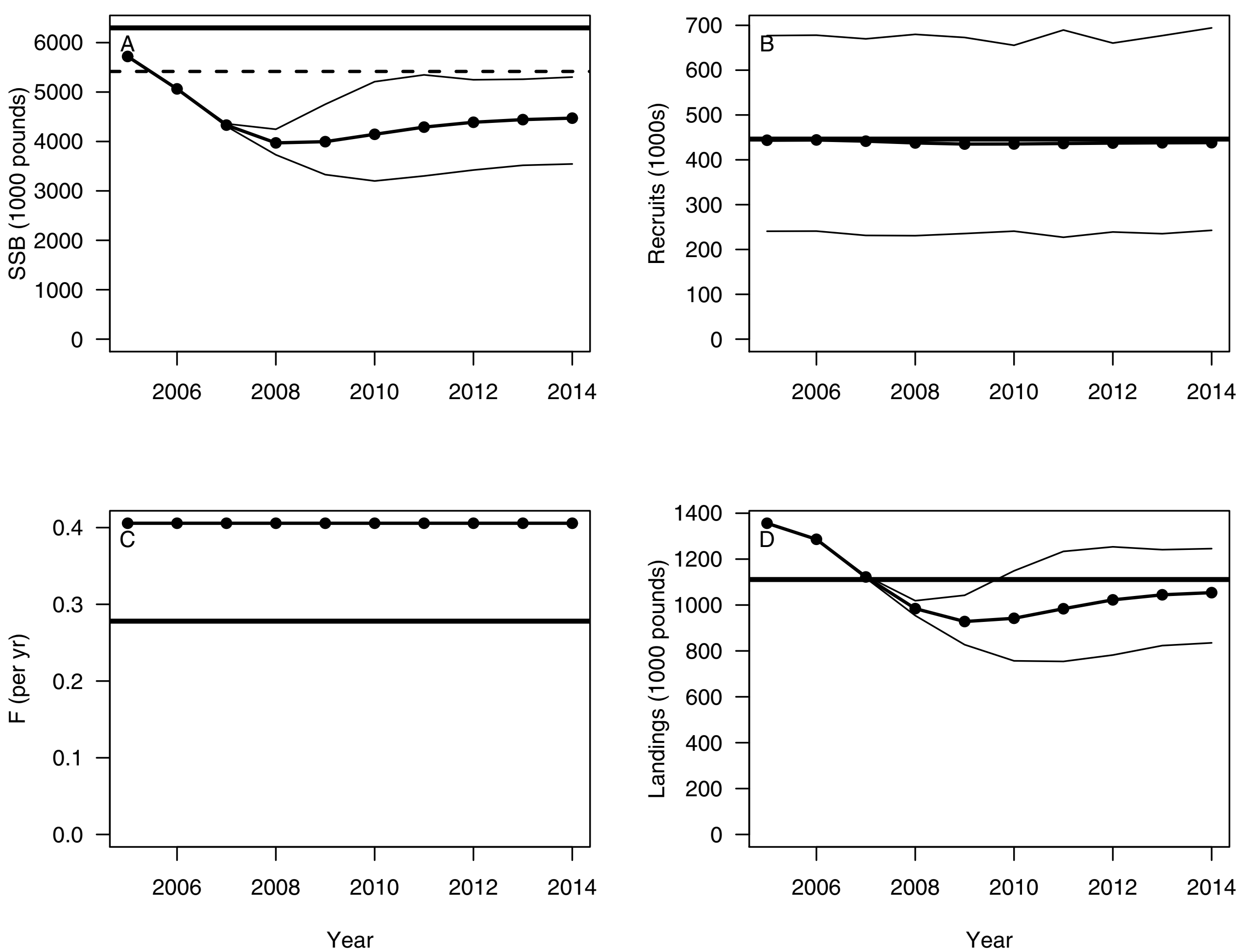


Figure 95. Gag– Base run with constant catchability: Projections under current fishing mortality rate for all years. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is $\mathrm{SSB_{MSY}}$ *and dashed line is* MSST*; B) Recruits, horizontal line is* R_{MSY}*; C) Fishing mortality rate, horizontal line is* F_{MSY}*; and D) Landings, horizontal line is MSY.*

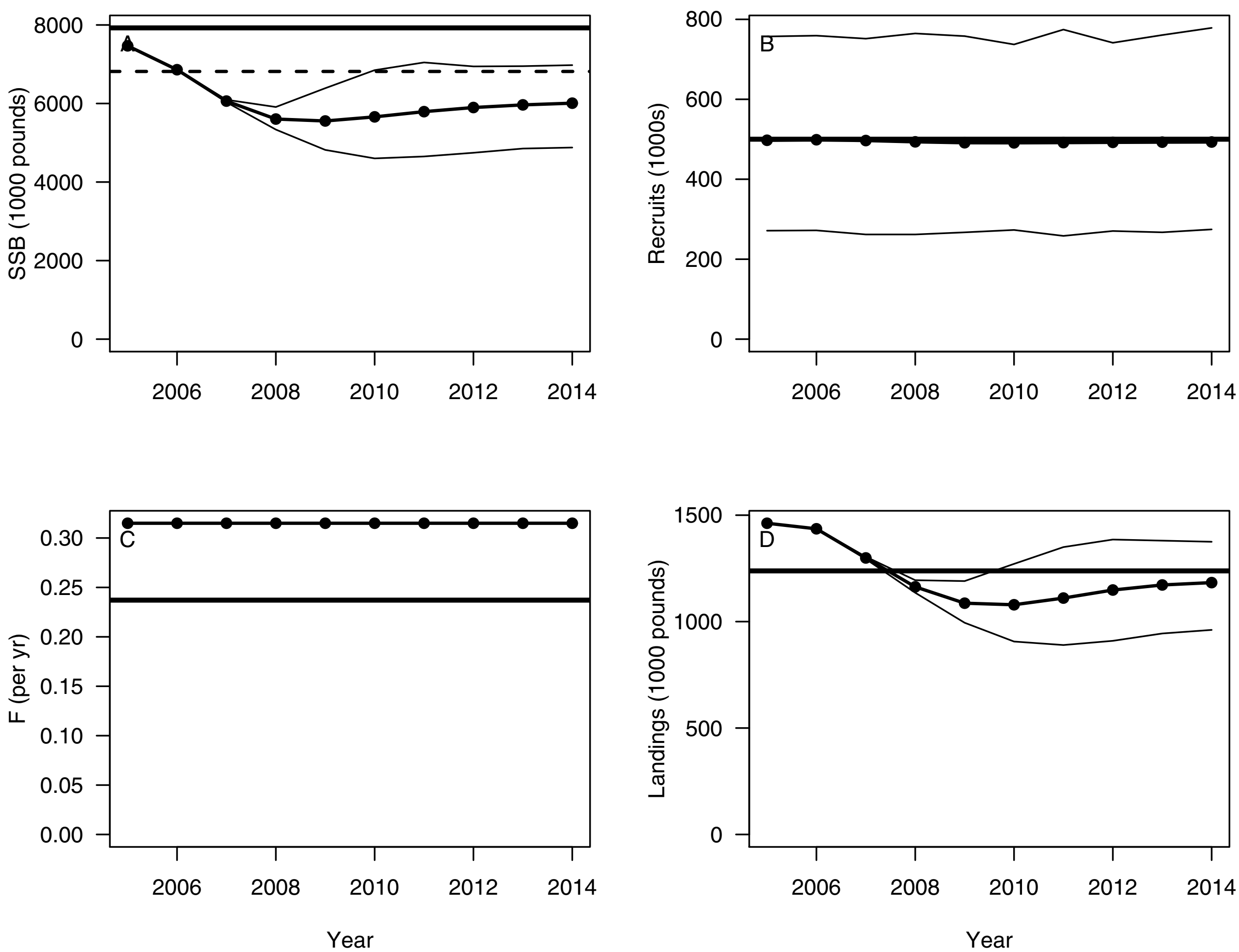


Figure 96. Gag– Base run with time-varying catchability: Projections under current fishing mortality rate in 2005-2007 and F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} *and dashed line is* MSST*; B) Recruits, horizontal line is R_{MSY}; C) Fishing mortality rate, horizontal line is F_{MSY}; and D) Landings, horizontal line is MSY.*

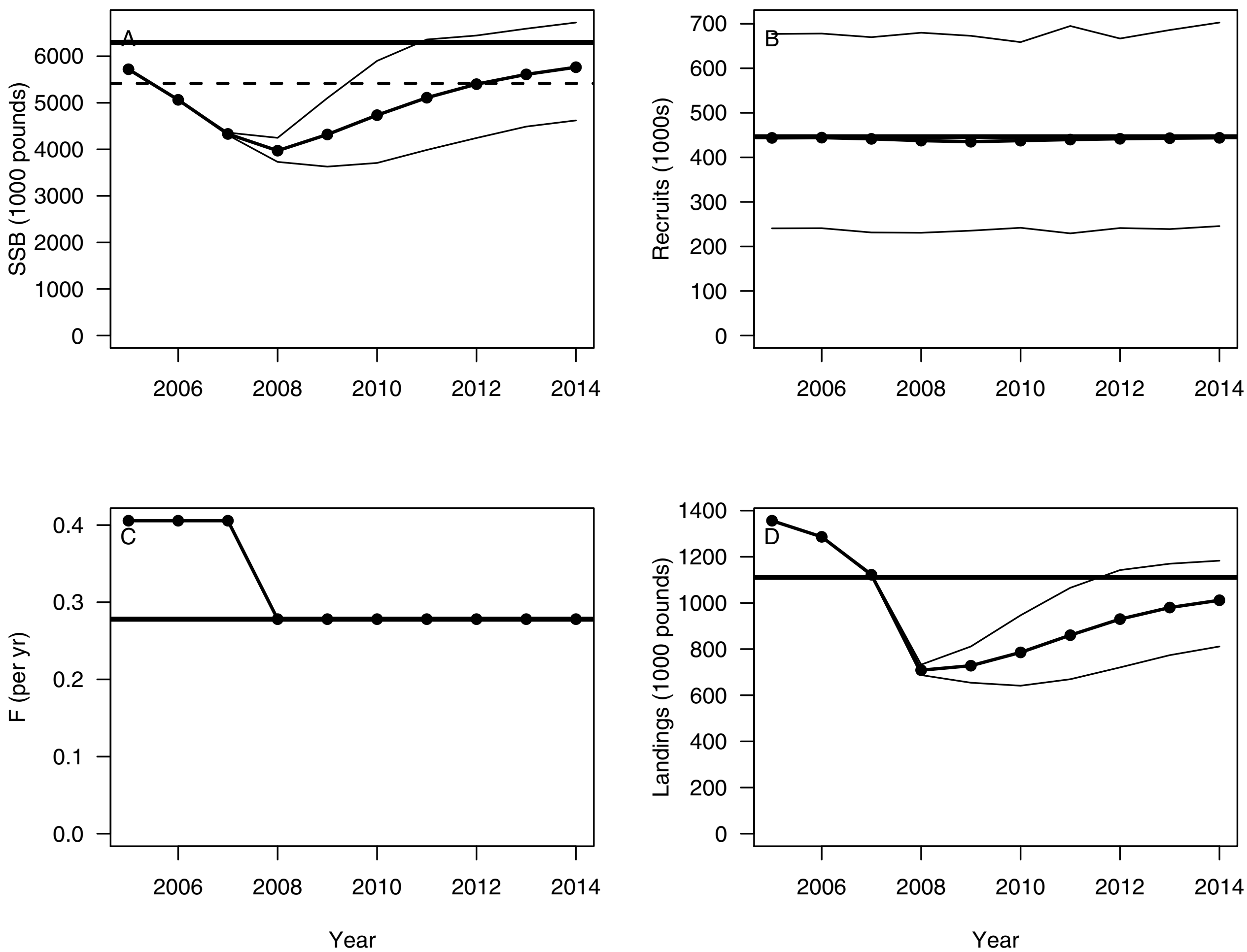


Figure 97. Gag– Base run with constant catchability: Projections under current fishing mortality rate in 2005-2007 and F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} *and dashed line is* MSST*; B) Recruits, horizontal line is R_{MSY}; C) Fishing mortality rate, horizontal line is F_{MSY}; and D) Landings, horizontal line is MSY.*

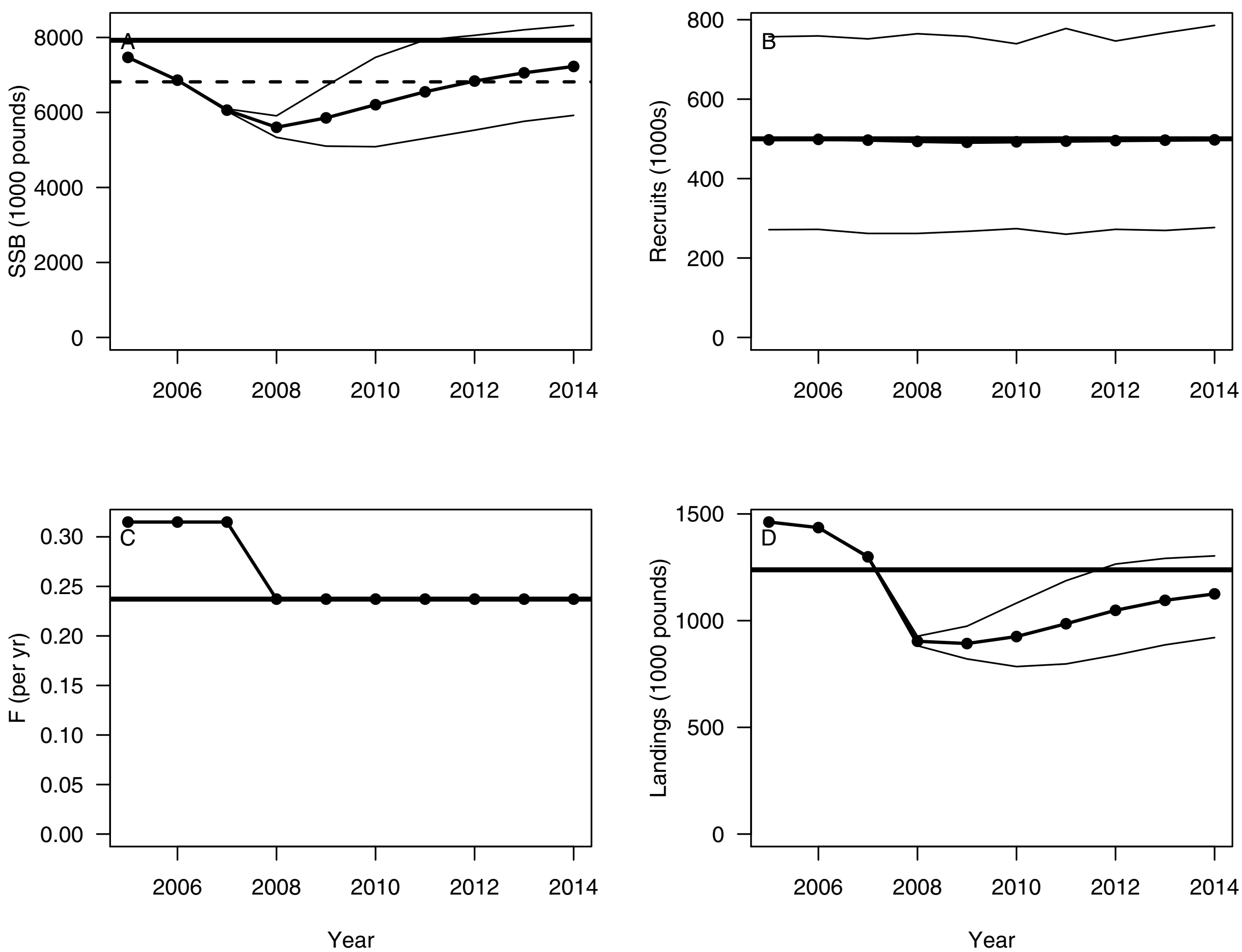


Figure 98. Gag– Base run with time-varying catchability: Projections under current fishing mortality rate in 2005-2007 and 85% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is $\mathrm{SSB}_{\mathrm{MSY}}$ *and dashed line is* MSST*; B) Recruits, horizontal line is R_{MSY}; C) Fishing mortality rate, horizontal line is F_{MSY}; and D) Landings, horizontal line is MSY.*

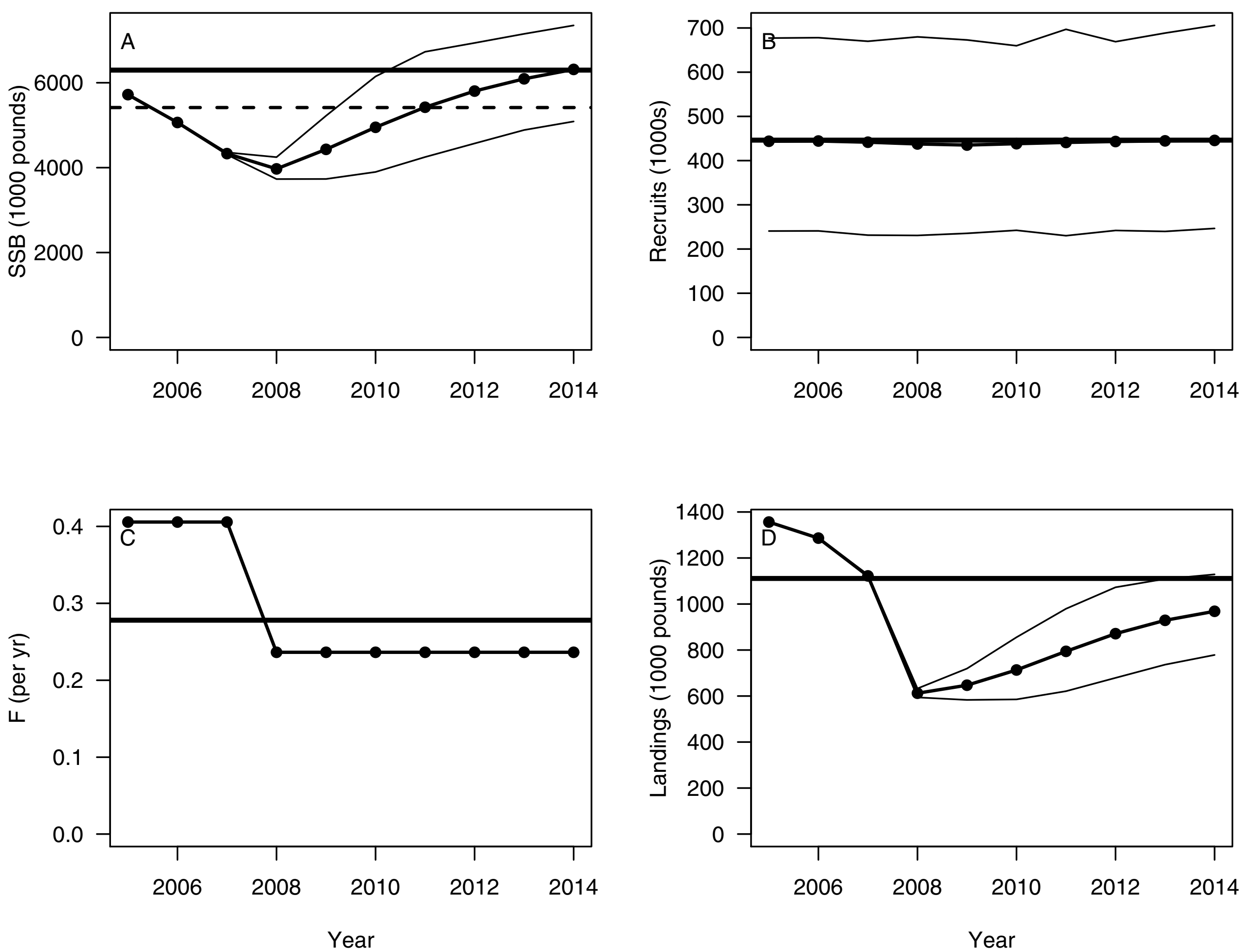


Figure 99. Gag– Base run with constant catchability: Projections under current fishing mortality rate in 2005-2007 and 85% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} *and dashed line is* MSST*; B) Recruits, horizontal line is R_{MSY}; C) Fishing mortality rate, horizontal line is F_{MSY}; and D) Landings, horizontal line is MSY.*

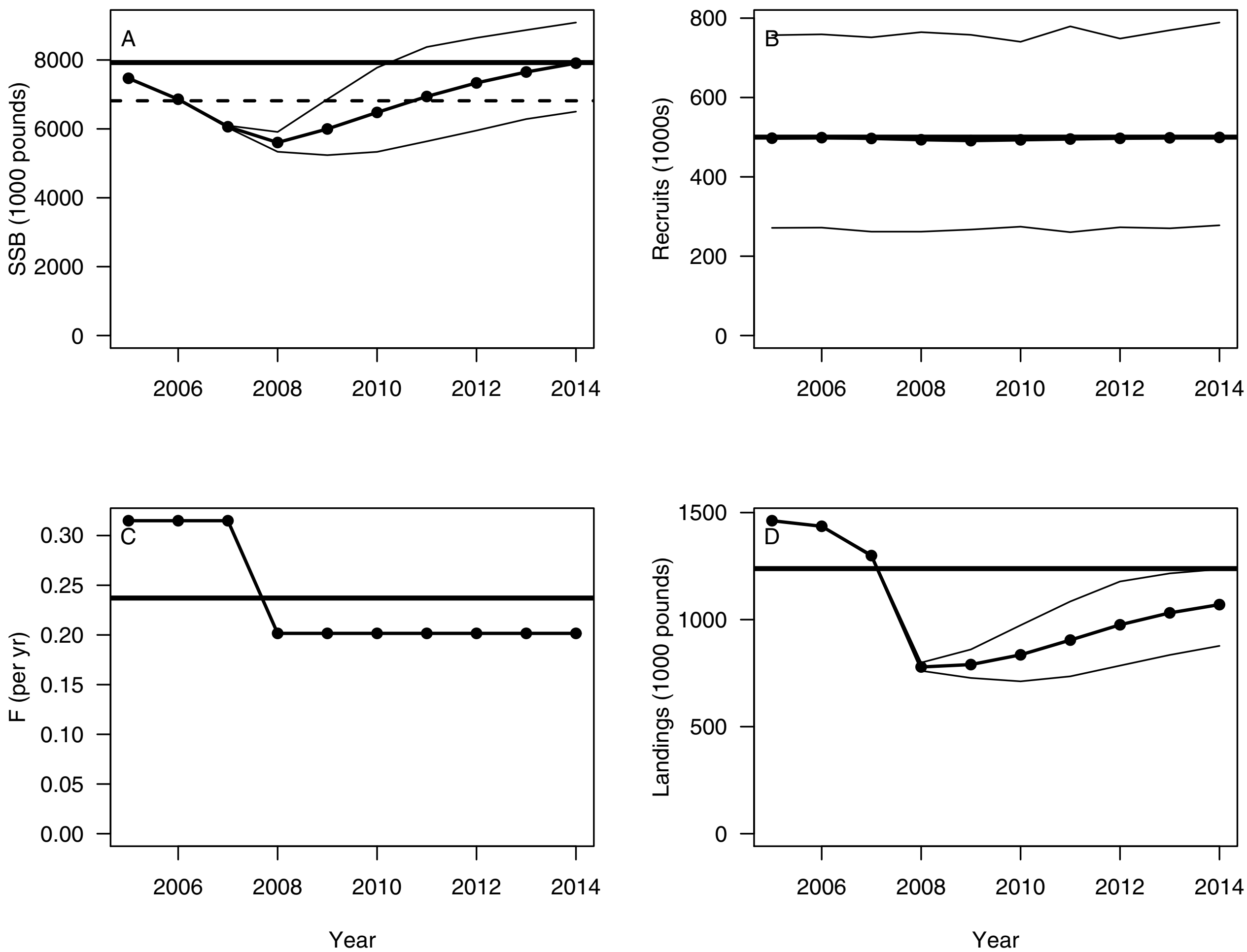


Figure 100. Gag– Base run with time-varying catchability: Projections under current fishing mortality rate in 2005-2007 and 75% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} and dashed line is MSST; B) Recruits, horizontal line is R_{MSY}; C) Fishing mortality rate, horizontal line is F_{MSY}; and D) Landings, horizontal line is MSY.

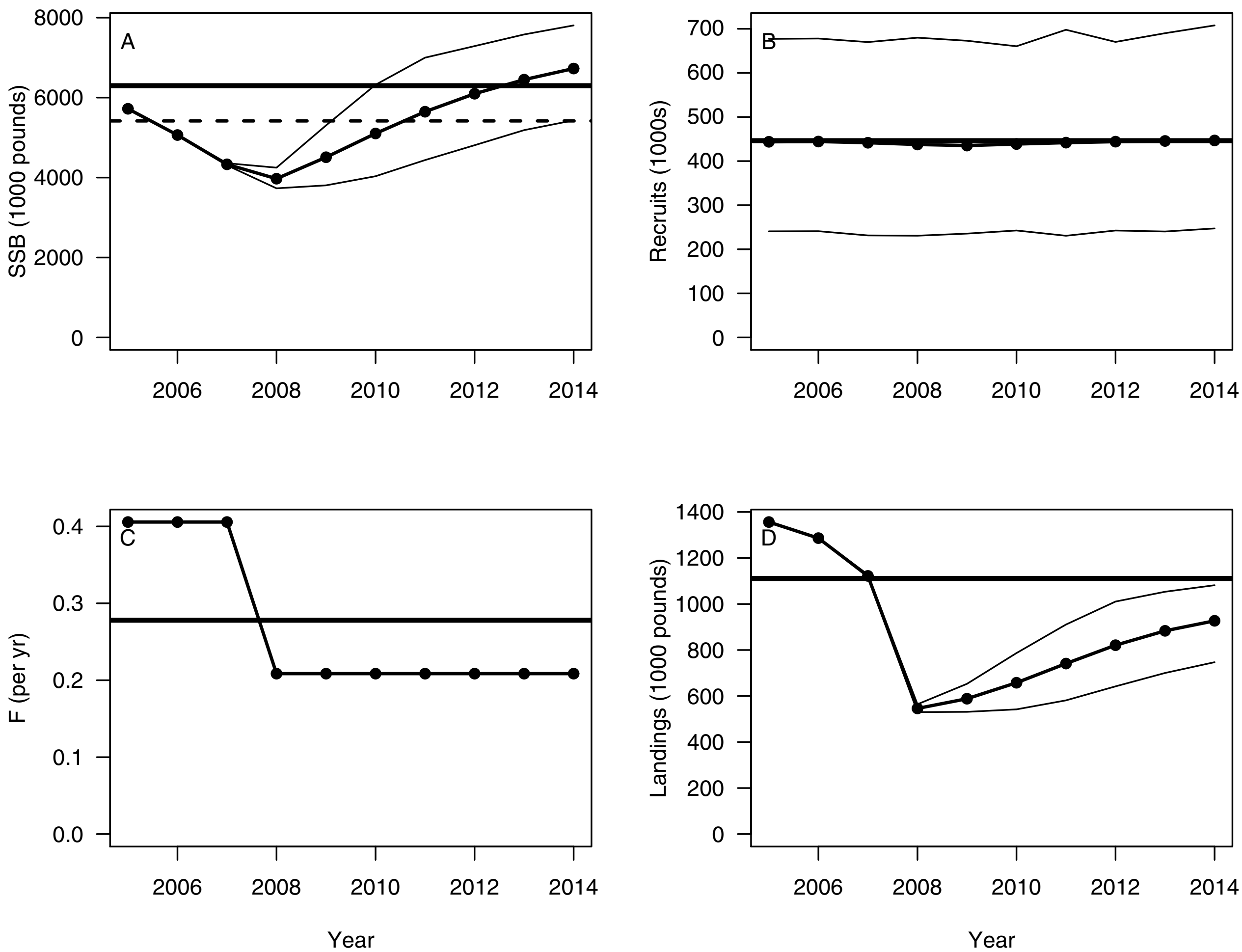


Figure 101. Gag– Base run with constant catchability: Projections under current fishing mortality rate in 2005-2007 and 75% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} *and dashed line is* MSST*; B) Recruits, horizontal line is R_{MSY}; C) Fishing mortality rate, horizontal line is F_{MSY}; and D) Landings, horizontal line is MSY.*

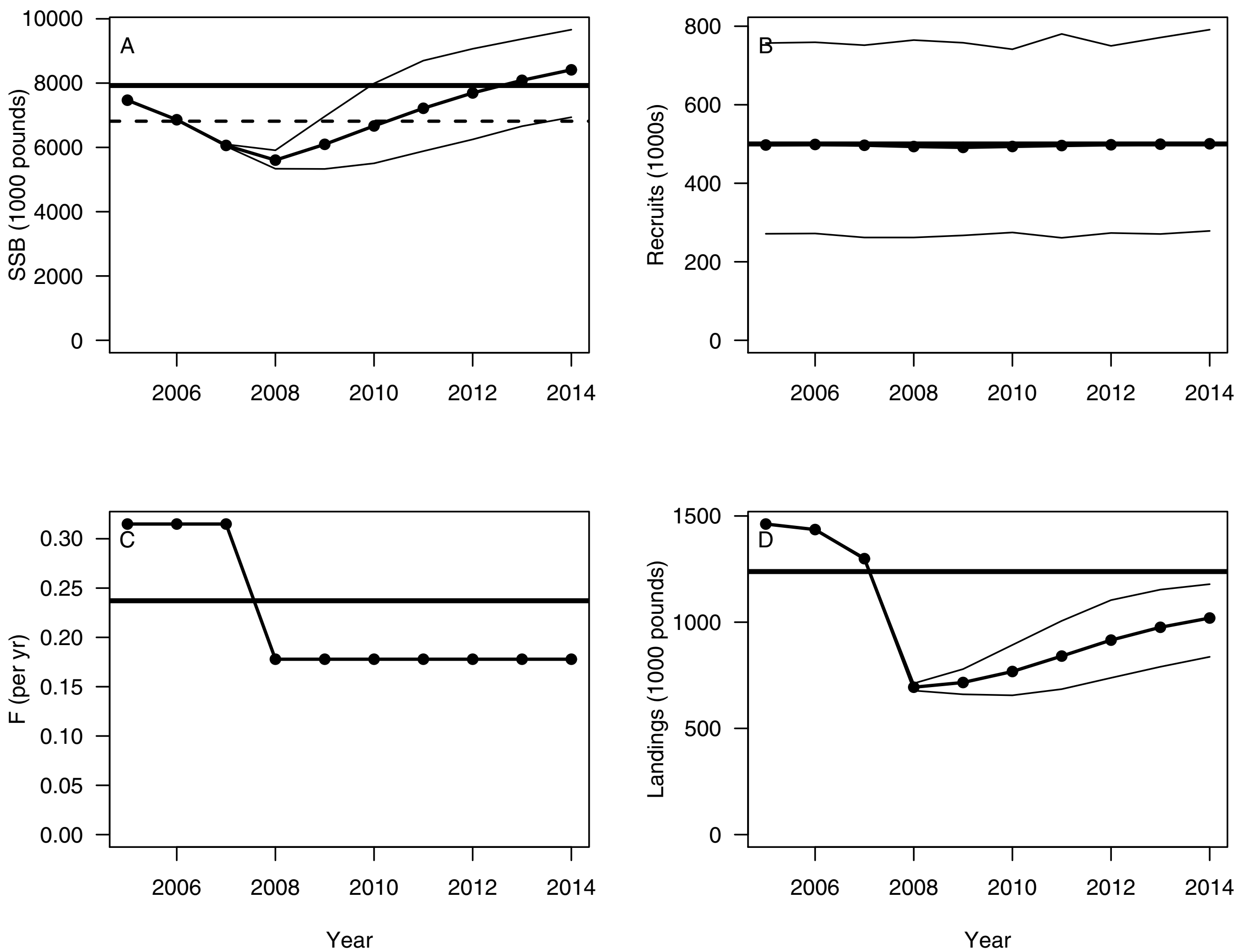


Figure 102. Gag– Base run with time-varying catchability: Projections under current fishing mortality rate in 2005-2007 and 65% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is $\mathrm{SSB_{MSY}}$ *and dashed line is* MSST*; B) Recruits, horizontal line is* R_{MSY}*; C) Fishing mortality rate, horizontal line is* F_{MSY}*; and D) Landings, horizontal line is* MSY*.*

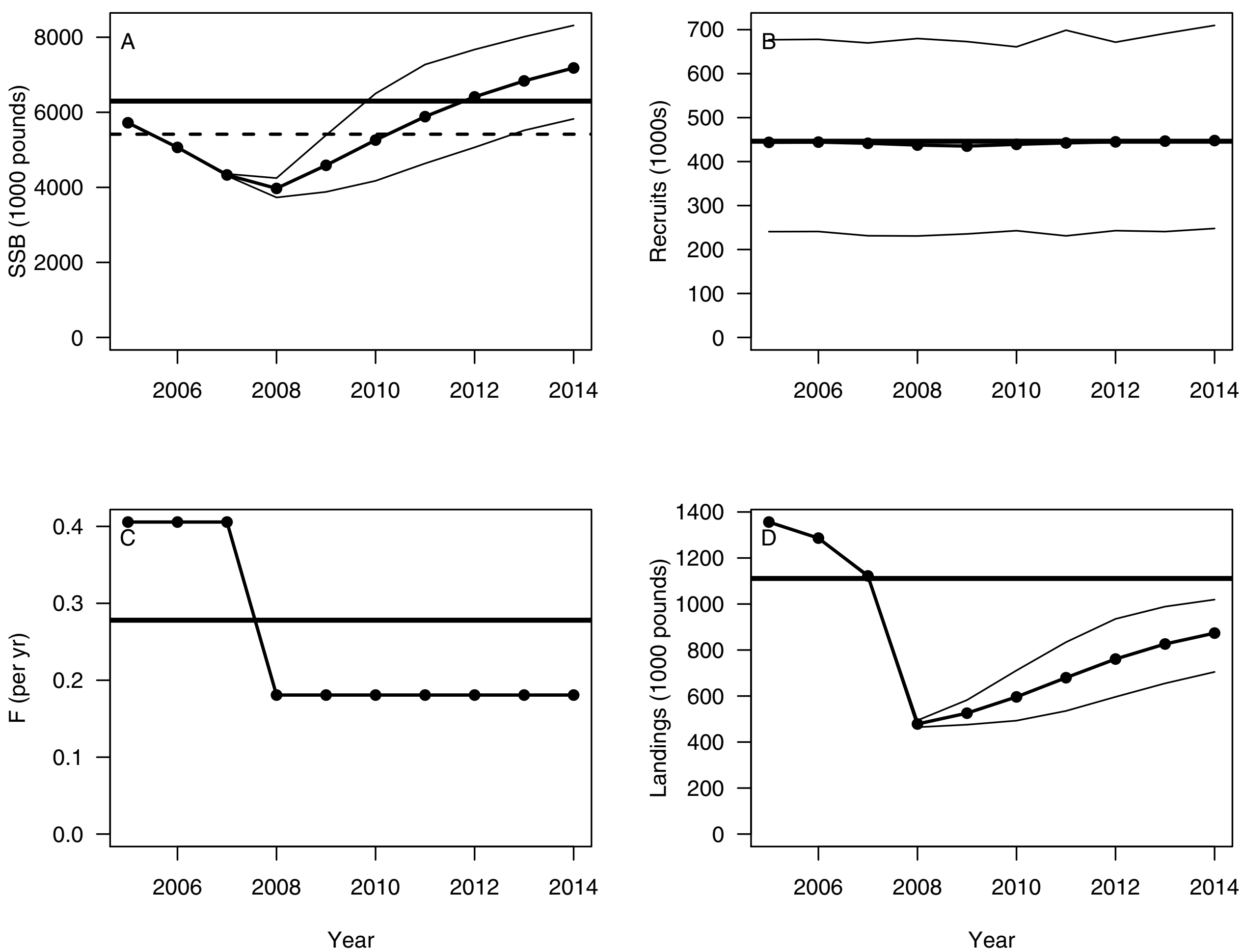
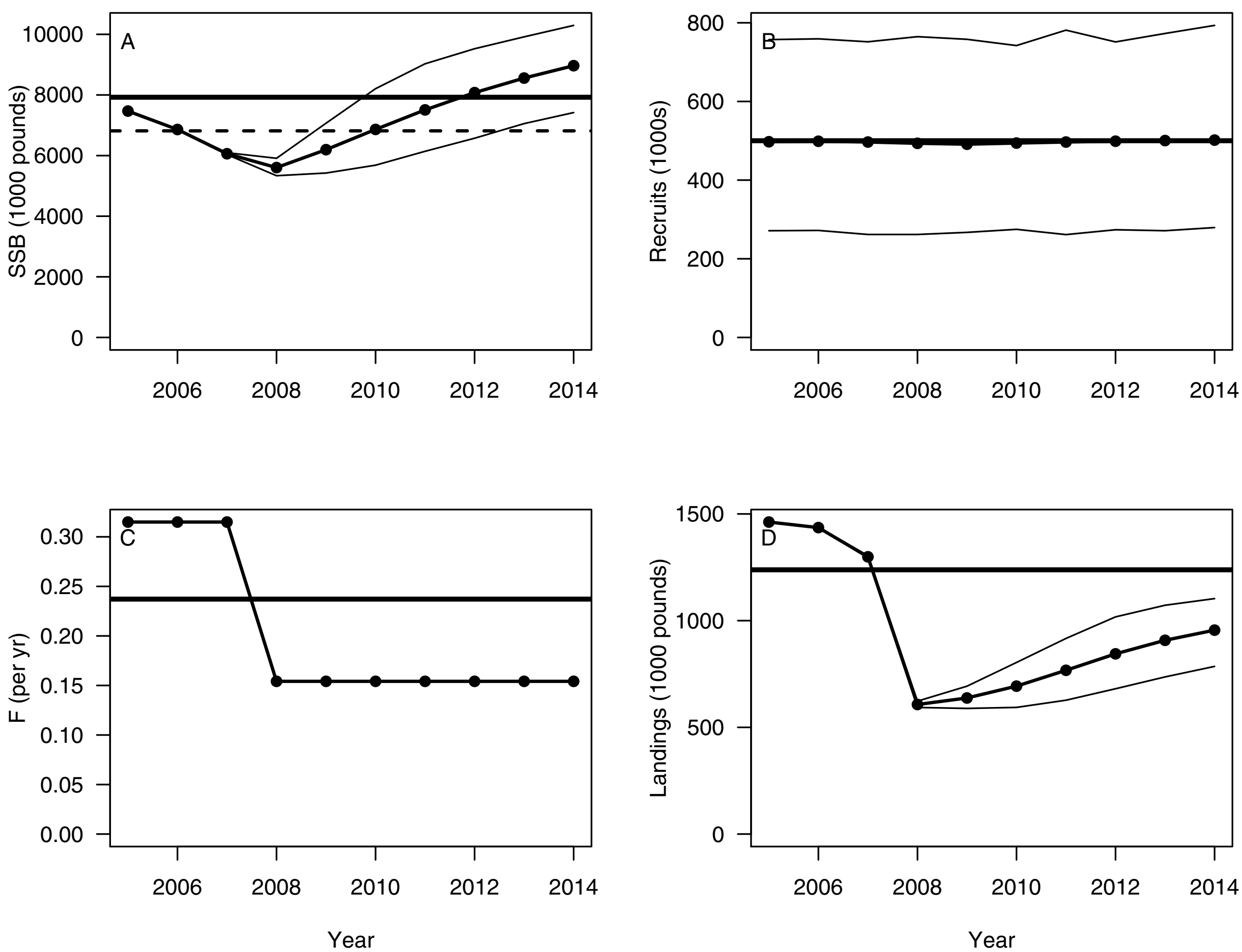


Figure 103. Gag– Base run with constant catchability: Projections under current fishing mortality rate in 2005-2007 and 65% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} *and dashed line is* MSST*; B) Recruits, horizontal line is R_{MSY}; C) Fishing mortality rate, horizontal line is F_{MSY}; and D) Landings, horizontal line is MSY.*



Appendix A Abbreviations and symbols

Table 47. Acronyms, abbreviations, and mathematical symbols used in this report

Symbol	Meaning
AW	Assessment Workshop (here, for gag)
ASY	Average Sustainable Yield
B	Total biomass of stock, conventionally on January 1st
CPUE	Catch per unit effort; used after adjustment as an index of abundance
CV	Coefficient of variation
DW	Data Workshop (here, for gag)
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	Von Bertalanffy growth coefficient
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 gag as $(1 - M)\text{SSB}_{\text{MSY}}$.
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 $\leq$ 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)

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

```
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##
//##  SEDAR Update Assessment: Gag, May 2006
//##
//##  Erik Williams, NMFS, Beaufort Lab
//##  Erik.Williams@noaa.gov
//##
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>

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

!!cout << "Starting Gag Assessment Model" << endl;

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

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

//Total number of ages
init_int nages;

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

//starting year for recruitment estimation (not being read in) and number assessment years
int styrR;
number nyrs;
//this section MUST BE INDENTED!!!
 LOCAL_CALCS
   styrR=styr-(nages-1);
   nyrs=endyr-styr+1.;
 END_CALCS

//Total number of length bins for each matrix
init_int nlenbins10;
//init_int nlenbins20;

// Vector of lengths for length bins (mm)(midpoint)
init_ivector lenbins10(1,nlenbins10);
//init_ivector lenbins20(1,nlenbins20);

//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 age for exploitation rate: ages 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 (from McGovern et al.)
init_number set_Linf;
init_number set_K;
init_number set_t0;
//CV of length at age
init_number set_len_cv;

//length(mm)-weight(gutted lbs) relationship: W=aL^b
init_number wgtpar_a;
```

```
init_number wgtpar_b;

//Sex ratio and maturity
init_matrix prop_m_obs(styr,endyr,1,nages);         //Proportion male by age
init_vector maturity_m_obs(1,nages);            //total maturity of males
init_vector maturity_f_obs(1,nages);            //total maturity of females

//##################Commercial Hook and Line fishery landings########################
//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 (30mm bins)
init_int styr_commHAL_lenc;
init_int endyr_commHAL_lenc;
init_vector nsamp_commHAL_lenc(styr_commHAL_lenc,endyr_commHAL_lenc);
init_matrix obs_commHAL_lenc(styr_commHAL_lenc,endyr_commHAL_lenc,1,nlenbins10);
// Age Compositions
init_int nyr_commHAL_agec;
init_ivector yrs_commHAL_agec(1,nyr_commHAL_agec);
init_vector nsamp_commHAL_agec(1,nyr_commHAL_agec);
init_matrix obs_commHAL_agec(1,nyr_commHAL_agec,1,nages);

//##############################Commercial Diving fishery 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 (30mm bins)
init_int nyr_commDV_lenc;
init_ivector yrs_commDV_lenc(1,nyr_commDV_lenc);
init_vector nsamp_commDV_lenc(1,nyr_commDV_lenc);
init_matrix obs_commDV_lenc(1,nyr_commDV_lenc,1,nlenbins10);
// Age Compositions
init_int nyr_commDV_agec;
init_ivector yrs_commDV_agec(1,nyr_commDV_agec);
init_vector nsamp_commDV_agec(1,nyr_commDV_agec);
init_matrix obs_commDV_agec(1,nyr_commDV_agec,1,nages);

//################################Headboat landings#####################################
//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;
init_int endyr_HB_D;
init_vector obs_HB_released(styr_HB_D,endyr_HB_D); //vector of observed releases by year, multiplied
by discard mortality for fitting
init_vector HB_D_cv(styr_HB_D,endyr_HB_D);    //vector of CV of discards by year
```

```
// Length Compositions (10mm bins)
init_int styr_HB_lenc;
init_int endyr_HB_lenc;
init_vector nsamp_HB_lenc(styr_HB_lenc,endyr_HB_lenc);
init_matrix obs_HB_lenc(styr_HB_lenc,endyr_HB_lenc,1,nlenbins10);
// Age compositions
init_int nyr_HB_agec;
init_ivector yrs_HB_agec(1,nyr_HB_agec);
init_vector nsamp_HB_agec(1,nyr_HB_agec);
init_matrix obs_HB_agec(1,nyr_HB_agec,1,nages);

//#############################MRFSS landings #################################
//CPUE
init_int styr_MRFSS_cpue;
init_int endyr_MRFSS_cpue;
init_vector obs_MRFSS_cpue(styr_MRFSS_cpue,endyr_MRFSS_cpue);//Observed CPUE
init_vector MRFSS_cpue_cv(styr_MRFSS_cpue,endyr_MRFSS_cpue); //CV of cpue
// Landings (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

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

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

//--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;

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

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

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

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

// #######Indices for year(iyear), age(iage),length(ilen) ###############
int iyear;
int iage;
int ilen10;
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<=1000; iyear++)
     {
       cout << "*** WARNING: Data File NOT READ IN CORRECTLY ****" << endl;
       cout << "" <<endl;
     }
   }
 END_CALCS

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

  init_bounded_number Linf(600,1400,2);
  init_bounded_number K(0.05,0.6,2);
  init_bounded_number t0(-2.0,0.0,2);
```

```
  vector wgt(1,nages);
  vector meanlen(1,nages);                          //mean length at age
  number sqrt2pi;
  matrix lenprob10(1,nages,1,nlenbins10);           //distn of size at age (age-length key, 10 mm bins)
  //init_bounded_vector len_cv(1,nages,0.01,0.5,3); //cv of length at age
  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);

//----Age and length compositions
  matrix pred_commHAL_lenc(styr_commHAL_lenc,endyr_commHAL_lenc,1,nlenbins10);
  matrix pred_commDV_lenc(1,nyr_commDV_lenc,1,nlenbins10);
  matrix pred_HB_lenc(styr_HB_lenc,endyr_HB_lenc,1,nlenbins10);
  matrix pred_commHAL_agec(1,nyr_commHAL_agec,1,nages);
  matrix pred_commDV_agec(1,nyr_commDV_agec,1,nages);
  matrix pred_HB_agec(1,nyr_HB_agec,1,nages);

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

//-----Population-----------------------------------------------------------------------------------
  matrix N(styrR,endyr+1,1,nages);          //Population numbers by year and age
  matrix B(styrR,endyr+1,1,nages);          //Population biomass by year and age
  vector totB(styrR,endyr+1);               //Total biomass by year
  number R1;                                //Recruits in styrR

  //init_bounded_number log_R1(5,20,1);       //log(Recruits) in styrR
  sdreport_vector SSB(styrR,endyr+1);       //Spawning biomass by year
  sdreport_vector rec(styrR,endyr+1);       //Recruits by year
  matrix prop_m(styrR,endyr,1,nages);       //Proportion male by age
  matrix prop_f(styrR,endyr,1,nages);        //Proportion female by age
  matrix maturity_f(styrR,endyr,1,nages);
  matrix maturity_m(styrR,endyr,1,nages);  //time-invariant, but left with flexibility to change that
  matrix reprod(styrR,endyr,1,nages);

//---Stock-Recruit Function (Beverton-Holt, steepness parameterization)----------
  init_bounded_number log_R0(5,20,1);       //log(virgin Recruitment)
  sdreport_number R0;
  init_bounded_number steep(0.25,0.95,1);     //steepness
  //number steep;  //uncomment to fix steepness, comment line directly above
  init_bounded_dev_vector log_dev_N_rec(styrR+1,endyr,-3,3,2); //log recruitment deviations
  number var_rec_dev;                       //variance of log recruitment deviations.
                                            //Estimated from yrs with unconstrainted S-R(1972-2001)
  number BiasCor;                           //Bias correction in equilibrium recruits
  sdreport_number steep_sd;                 //steepness for stdev report
  number S0;                                //equal to spr_F0*R0 = virgin SSB
  number B0;                                //equal to bpr_F0*R0 = virgin B
  number S1;                                //initial SSB
  number S1dS0;                             //S1967/S0
  number B1dB0;                             //B1dB0 computed and used in constraint
  init_bounded_number R1_mult(0.5,1.5,1);     //R1967=R1_mult*R0
  sdreport_number S1S0;                     //SSB(styr) / virgin SSB
  sdreport_number popstatus;                //SSB(endyr) / virgin SSB

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

  //Commercial hook and line
  matrix sel_commHAL(styrR,endyr,1,nages);
  init_bounded_number selpar_slope_commHAL1(0.5,9.0,1); //period 1
  init_bounded_number selpar_L50_commHAL1(1.0,10.0,1);
  //init_bounded_number selpar_slope2_commHAL1(0.1,9.0,3); //period 1
  //init_bounded_number selpar_L502_commHAL1(1.0,25.0,3);
  number selpar_slope2_commHAL1; //period 1
  number selpar_L502_commHAL1;
  init_bounded_number selpar_slope_commHAL2(0.5,9.0,1); //period 2
  init_bounded_number selpar_L50_commHAL2(1.0,10,1);
  //init_bounded_number selpar_slope2_commHAL2(0.1,9.0,3); //period 2
  //init_bounded_number selpar_L502_commHAL2(1.0,25.0,3);
```

```
  number selpar_slope2_commHAL2; //period 1
  number selpar_L502_commHAL2;
  init_bounded_number selpar_slope_commHAL3(0.5,9.0,1); //period 3
  init_bounded_number selpar_L50_commHAL3(1.0,10,1);
  //init_bounded_number selpar_slope2_commHAL3(0.1,9.0,3); //period 3
  //init_bounded_number selpar_L502_commHAL3(1.0,25.0,3);
  number selpar_slope2_commHAL3; //period 1
  number selpar_L502_commHAL3;
  init_bounded_dev_vector selpar_L50_commHAL_dev(styr_commHAL_lenc,endyr_period1,-5,5,3);
  //Commercial diving
  matrix sel_commDV(styrR,endyr,1,nages);            //period 1
  init_bounded_number selpar_slope_commDV1(0.5,9.0,1);
  init_bounded_number selpar_L50_commDV1(1.0,10,1);
  init_bounded_number selpar_slope2_commDV1(0.1,9.0,1);
  init_bounded_number selpar_L502_commDV1(1.0,20.0,1);//period 2
  //Headboat: logistic, parameters allowed to vary with period defined by size restrictions
  matrix sel_HB(styrR,endyr,1,nages);
  init_bounded_number selpar_slope_HB1(0.5,9.0,1); //period 1
  init_bounded_number selpar_L50_HB1(1.0,10.0,1);
  //init_bounded_number selpar_slope2_HB1(0.1,9.0,3); //period 1
  //init_bounded_number selpar_L502_HB1(1.0,25.0,3);
  number selpar_slope2_HB1;
  number selpar_L502_HB1;
  init_bounded_number selpar_slope_HB2(0.5,9.0,1); //period 2
  init_bounded_number selpar_L50_HB2(1.0,10,1);
  //init_bounded_number selpar_slope2_HB2(0.1,9.0,3); //period 2
  //init_bounded_number selpar_L502_HB2(1.0,25.0,3);
  number selpar_slope2_HB2;
  number selpar_L502_HB2;
  init_bounded_number selpar_slope_HB3(0.5,9.0,1); //period 3
  init_bounded_number selpar_L50_HB3(1.0,10,1);
  //init_bounded_number selpar_slope2_HB3(0.1,9.0,3); //period 3
  //init_bounded_number selpar_L502_HB3(1.0,25.0,3);
  number selpar_slope2_HB3;
  number selpar_L502_HB3;
  init_bounded_dev_vector selpar_L50_HB_dev(styr_HB_lenc,endyr_period1,-5,5,3);
  //MRFSS: same as HB selectivity (AW)
  matrix sel_MRFSS(styrR,endyr,1,nages);

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

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

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

//---Landings Bias--------------------------------------------------------------------
  init_bounded_number L_commHAL_bias(0.1,5.0,-3);

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

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

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

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

  matrix C_total(styrR,endyr,1,nages);
  matrix L_total(styrR,endyr,1,nages);
  vector L_total_yr(styrR,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 mortality

  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_HB_D,endyr_MRFSS_D,1,nages);      //discards (numbers) at age
  vector pred_MRFSS_D(styr_MRFSS_D,endyr_MRFSS_D);           //yearly discards summed over ages
  vector obs_MRFSS_D(styr_MRFSS_D,endyr_MRFSS_D);         //observed releases multiplied by discard mortality

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

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

  number SSB_msy_out;           //SSB at msy
  number F_msy_out;             //F at msy
  number msy_out;               //max sustainable yield
  number B_msy_out;             //total biomass at MSY
  number E_msy_out;             //exploitation rate (age 1+) 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 C_age_msy(1,nages);         //catch at age for MSY calculations
  vector Z_age_msy(1,nages);         //total mortality at age for MSY calculations
  vector D_age_msy(1,nages);         //discard mortality (dead discards) at age for MSY calculations
  vector F_L_age_msy(1,nages);       //fishing mortality (landings, not discards) at age for MSY calculations
  vector F_D_age_msy(1,nages);
  vector F_msy(1,n_iter_msy);        //values of full F to be used in per-recruit and equilibrium calculations
  vector spr_msy(1,n_iter_msy);      //reproductive capacity-per-recruit values corresponding to F values in F_msy
  vector R_eq(1,n_iter_msy);     //equilibrium recruitment values corresponding to F values in F_msy
  vector L_eq(1,n_iter_msy);     //equilibrium landings(mt) values corresponding to F values in F_msy
  vector SSB_eq(1,n_iter_msy);   //equilibrium reproductive capacity values corresponding to F values in F_msy
  vector B_eq(1,n_iter_msy);     //equilibrium biomass values corresponding to F values in F_msy
  vector E_eq(1,n_iter_msy);     //equilibrium exploitation rates corresponding to F values in F_msy
  vector D_eq(1,n_iter_msy);     //equilibrium discards (1000s) corresponding to F values in F_msy

  vector FdF_msy(styrR,endyr);
  vector EdE_msy(styrR,endyr);
  vector SdSSB_msy(styrR,endyr+1);
  number SdSSB_msy_end;
  number FdF_msy_end;
  number EdE_msy_end;

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

```
  vector E(styrR,endyr);                         //Exploitation rate by year
  sdreport_vector fullF_sd(styrR,endyr);
  sdreport_vector E_sd(styrR,endyr);
  matrix Z(styrR,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,-10,5,1);
  matrix F_commHAL(styrR,endyr,1,nages);
  vector F_commHAL_out(styrR,endyr_commHAL_L); //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(styrR,endyr,1,nages);
  vector F_commDV_out(styrR,endyr_commDV_L); //used for intermediate calculations in fcn get_mortality
  number log_F_init_commDV;

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

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

//--Discard mortality stuff------------------------------------------------------------------------------
  init_bounded_number log_avg_F_commHAL_D(-10,0,1);
  init_bounded_dev_vector log_F_dev_commHAL_D(styr_commHAL_D,endyr_commHAL_D,-10,5,2);
  matrix F_commHAL_D(styrR,endyr,1,nages);
  vector F_commHAL_D_out(styr_commHAL_D,endyr_commHAL_D); //used for intermediate calculations in fcn get_mortality
  matrix sel_commHAL_D(styrR,endyr,1,nages);

  init_bounded_number log_avg_F_HB_D(-10,0,1);
  init_bounded_dev_vector log_F_dev_HB_D(styr_HB_D,endyr_HB_D,-10,5,2);
  matrix F_HB_D(styrR,endyr,1,nages);
  vector F_HB_D_out(styr_HB_D,endyr_HB_D); //used for intermediate calculations in fcn get_mortality
  matrix sel_HB_D(styrR,endyr,1,nages);

  init_bounded_number log_avg_F_MRFSS_D(-10,0,1);
  init_bounded_dev_vector log_F_dev_MRFSS_D(styr_MRFSS_D,endyr_MRFSS_D,-10,5,2);
  matrix F_MRFSS_D(styrR,endyr,1,nages);
  vector F_MRFSS_D_out(styr_MRFSS_D,endyr_MRFSS_D); //used for intermediate calculations in fcn get_mortality
  matrix sel_MRFSS_D(styrR,endyr,1,nages);

  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 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(styrR,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 spr_F0(styrR,endyr);        //Spawning biomass per recruit at F=0
  vector bpr_F0(styrR,endyr);        //Biomass per recruit at F=0

//-------Objective function components------------------------------------------------------------------------------
  number w_L;
  number w_D;
  number w_lc;
```

```
  number w_ac;
  number w_I_HAL;
  number w_I_HB;
  number w_I_MRFSS;
  number w_R;
  number w_R_init;
  number w_R_end;
  number w_F;
  number w_B1dB0;
  number w_fullF;
  number w_cvlen_dev;
  number w_cvlen_diff;

  number f_HAL_cpue;
  number f_HB_cpue;
  number f_MRFSS_cpue;

  number f_commHAL_L;
  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_commHAL_agec;
  number f_commDV_agec;
  number f_HB_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(1967)/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(styrR,endyr);
  vector xdum2(styrR,endyr+1);
//--Other dummy variables ----
  number sel_diff_dum;
  number zero_dum;
  number dzero_dum;

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

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


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

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
RUNTIME_SECTION
 maximum_function_evaluations 500, 2000, 10000;
```

```
 convergence_criteria 1e-1, 1e-2, 1e-4;

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
PRELIMINARY_CALCS_SECTION

// Set values of fixed parameters or set initial guess of estimated parameters
  Dmort_commHAL=set_Dmort_commHAL;
  Dmort_HB=set_Dmort_HB;
  Dmort_MRFSS=set_Dmort_MRFSS;

  obs_commHAL_D=Dmort_commHAL*obs_commHAL_released;
  obs_HB_D=Dmort_HB*obs_HB_released;
  obs_MRFSS_D=Dmort_MRFSS*obs_MRFSS_released;

  E_age_st=set_E_age_st;   //E computed over (E_age_st-1)+   [minus 1 bc model starts with age 0]

  Linf=set_Linf;
  K=set_K;
  t0=set_t0;

  M=set_M;
  steep=set_steep;
  log_dev_N_rec=0.0;

  log_q_HAL=set_logq_HAL;
  log_q_HB=set_logq_HB;
  log_q_MRFSS=set_logq_MRFSS;
  q_rate=set_q_rate;

  L_commHAL_bias=set_L_commHAL_bias;

  w_L=set_w_L;
  w_D=set_w_D;
  w_lc=set_w_lc;
  w_ac=set_w_ac;
  w_I_HAL=set_w_I_HAL;
  w_I_HB=set_w_I_HB;
  w_I_MRFSS=set_w_I_MRFSS;
  w_R=set_w_R;
  w_R_init=set_w_R_init;
  w_R_end=set_w_R_end;
  w_F=set_w_F;
  w_B1dB0=set_w_B1dB0;
  w_fullF=set_w_fullF;
  w_cvlen_dev=set_w_cvlen_dev;
  w_cvlen_diff=set_w_cvlen_diff;

  log_avg_F_commHAL=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;

  log_len_cv=log(set_len_cv);
  log_R0=set_log_R0;
  S1dS0=set_S1dS0;
  R1_mult=set_R1_mult;
  B1dB0=set_B1dB0;

  selpar_L50_commHAL1=set_selpar_L50_commHAL1;
  selpar_slope_commHAL1=set_selpar_slope_commHAL1;
  selpar_L502_commHAL1=set_selpar_L502_commHAL1;
  selpar_slope2_commHAL1=set_selpar_slope2_commHAL1;
  selpar_L50_commHAL2=set_selpar_L50_commHAL2;
  selpar_slope_commHAL2=set_selpar_slope_commHAL2;
  selpar_L502_commHAL2=set_selpar_L502_commHAL2;
  selpar_slope2_commHAL2=set_selpar_slope2_commHAL2;
```

```
  selpar_L50_commHAL3=set_selpar_L50_commHAL3;
  selpar_slope_commHAL3=set_selpar_slope_commHAL3;
  selpar_L502_commHAL3=set_selpar_L502_commHAL3;
  selpar_slope2_commHAL3=set_selpar_slope2_commHAL3;

  selpar_L50_commDV1=set_selpar_L50_commDV1;
  selpar_L502_commDV1=set_selpar_L502_commDV1;
  selpar_slope_commDV1=set_selpar_slope_commDV1;
  selpar_slope2_commDV1=set_selpar_slope2_commDV1;
  //selpar_L50_commDV2=set_selpar_L50_commDV2;
  //selpar_L502_commDV2=set_selpar_L502_commDV2;
  //selpar_slope_commDV2=set_selpar_slope_commDV2;
  //selpar_slope2_commDV2=set_selpar_slope2_commDV2;

  selpar_L50_HB1=set_selpar_L50_HB1;
  selpar_slope_HB1=set_selpar_slope_HB1;
  selpar_L502_HB1=set_selpar_L502_HB1;
  selpar_slope2_HB1=set_selpar_slope2_HB1;
  selpar_L50_HB2=set_selpar_L50_HB2;
  selpar_slope_HB2=set_selpar_slope_HB2;
  selpar_L502_HB2=set_selpar_L502_HB2;
  selpar_slope2_HB2=set_selpar_slope2_HB2;
  selpar_L50_HB3=set_selpar_L50_HB3;
  selpar_slope_HB3=set_selpar_slope_HB3;
  selpar_L502_HB3=set_selpar_L502_HB3;
  selpar_slope2_HB3=set_selpar_slope2_HB3;

 sqrt2pi=sqrt(2.*3.14159265);
 //df=0.001; //difference for msy derivative approximations
 zero_dum=0.0;

 //additive constant to prevent division by zero
 dzero_dum=0.001;

 SSB_msy_out=0.0;

//Fill in maturity matrix for calculations for styrR to styr
    for(iyear=styrR; iyear<=styr-1; iyear++)
      {
         maturity_f(iyear)=maturity_f_obs;
         maturity_m(iyear)=maturity_m_obs;
         prop_m(iyear)=prop_m_obs(styr);
         prop_f(iyear)=1.0-prop_m_obs(styr);
      }
    for (iyear=styr;iyear<=endyr;iyear++)
      {
         maturity_f(iyear)=maturity_f_obs;
         maturity_m(iyear)=maturity_m_obs;
         prop_m(iyear)=prop_m_obs(iyear);
         prop_f(iyear)=1.0-prop_m_obs(iyear);
      }

//Fill in sample sizes of comps sampled in nonconsec yrs.
//Used only for output in R object
      nsamp_commDV_lenc_allyr=missing; //"missing" defined in admb2r.cpp
      nsamp_commHAL_agec_allyr=missing;
      nsamp_commDV_agec_allyr=missing;
      nsamp_HB_agec_allyr=missing;
      for (iyear=1; iyear<=nyr_commDV_lenc; iyear++)
         {
           nsamp_commDV_lenc_allyr(yrs_commDV_lenc(iyear))=nsamp_commDV_lenc(iyear);
         }
      for (iyear=1; iyear<=nyr_commHAL_agec; iyear++)
         {
           nsamp_commHAL_agec_allyr(yrs_commHAL_agec(iyear))=nsamp_commHAL_agec(iyear);
         }
      for (iyear=1; iyear<=nyr_commDV_agec; iyear++)
         {
           nsamp_commDV_agec_allyr(yrs_commDV_agec(iyear))=nsamp_commDV_agec(iyear);
         }
      for (iyear=1; iyear<=nyr_HB_agec; iyear++)
```

```
         {
           nsamp_HB_agec_allyr(yrs_HB_agec(iyear))=nsamp_HB_agec(iyear);
         }



//fill in F's 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();
 get_reprod();
 //cout << "got length and weight transitions" <<endl;
 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_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 (gutted pounds) at age
```

```
  for (iage=1;iage<=nages;iage++)
  {
    meanlen(iage)=Linf*(1.0-mfexp(-K*((agebins(iage)+0.5)-t0)));
    wgt(iage)=0.001*wgtpar_a*pow(meanlen(iage),wgtpar_b); //.001 converts from gutted pounds to 1000 gutted pounds
  }

FUNCTION get_reprod
  for (iyear=styrR;iyear<=endyr;iyear++)
  {
   //product of stuff going into reproductive capacity calcs
   reprod(iyear)=elem_prod((elem_prod(prop_f(iyear),maturity_f(iyear))+elem_prod(prop_m(iyear),maturity_m(iyear))),wgt);
  }

FUNCTION get_length_at_age_dist
  //compute matrix of length at age, based on the normal distribution
  for (iage=1;iage<=nages;iage++)
  {
    len_cv(iage)=mfexp(log_len_cv+log_len_cv_dev(iage));
    for (ilen10=1;ilen10<=nlenbins10;ilen10++)
    {
      lenprob10(iage,ilen10)=(mfexp(-(square(lenbins10(ilen10)-meanlen(iage))/
      (2.*square(len_cv(iage)*meanlen(iage)))))/(sqrt2pi*len_cv(iage)*meanlen(iage)));
    }
    lenprob10(iage)/=sum(lenprob10(iage)); //standardize to account for truncated normal (i.e., no sizes<0)

  }

FUNCTION get_spr_F0
  N_spr_F0(1)=1.0;
  for (iage=2; iage<=nages; iage++)
  {
    N_spr_F0(iage)=N_spr_F0(iage-1)*mfexp(-1.0*M(iage-1));
  }
  N_spr_F0(nages)=N_spr_F0(nages-1)*mfexp(-1.0*M(nages-1))/(1.0-mfexp(-1.0*M(nages))); //plus group

  for(iyear=styrR; iyear<=endyr; iyear++)
  {
    //spr_F0(iyear)=sum(elem_prod( elem_prod(elem_prod(N_spr_F0,prop_f),maturity_f(iyear))+
    //elem_prod(elem_prod(N_spr_F0,prop_m),maturity_m(iyear)) ,wgt));
    spr_F0(iyear)=sum(elem_prod(N_spr_F0,reprod(iyear)));
    bpr_F0(iyear)=sum(elem_prod(N_spr_F0,wgt));
  }


FUNCTION get_selectivity

//---time-varying selectivities

  for (iyear=styrR; iyear<=endyr_period1; iyear++)
  {
     for (iage=1; iage<=nages; iage++)
     {
       //sel_HB(iyear,iage)=1./(1.+mfexp(-1.*selpar_slope_HB1*(double(agebins(iage))-selpar_L50_HB1))); //logistic
       sel_HB(iyear,iage)=(1./(1.+mfexp(-1.*selpar_slope_HB1*(double(agebins(iage))-
                       selpar_L50_HB1))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_HB1*
                       (double(agebins(iage))-(selpar_L50_HB1+selpar_L502_HB1)))))); //double logistic

       //sel_commHAL(iyear,iage)=1./(1.+mfexp(-1.*selpar_slope_commHAL1*(double(agebins(iage))-selpar_L50_commHAL1))); ➔
            //logistic
       sel_commHAL(iyear,iage)=(1./(1.+mfexp(-1.*selpar_slope_commHAL1*(double(agebins(iage))-
                       selpar_L50_commHAL1))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_commHAL1*
                       (double(agebins(iage))-(selpar_L50_commHAL1+selpar_L502_commHAL1)))))); //double logistic

       sel_commDV(iyear,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
     }
     if (iyear>=styr_HB_lenc)
     {
       for (iage=1; iage<=nages; iage++)
       {
```

```
      //sel_HB(iyear,iage)=1./(1.+mfexp(-1.*selpar_slope_HB1*(double(agebins(iage))
      //     -(selpar_L50_HB1+selpar_L50_HB_dev(iyear))))); //logistic
      sel_HB(iyear,iage)=(1./(1.+mfexp(-1.*selpar_slope_HB1*(double(agebins(iage))-
                    (selpar_L50_HB1+selpar_L50_HB_dev(iyear))))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_HB1*
                    (double(agebins(iage))-(selpar_L50_HB1+selpar_L502_HB1)))))); //double logistic
    }
  }
  if (iyear>=styr_commHAL_lenc)
  {
    for (iage=1; iage<=nages; iage++)
    {
      //sel_commHAL(iyear,iage)=1./(1.+mfexp(-1.*selpar_slope_commHAL1*(double(agebins(iage))
      //     -(selpar_L50_commHAL1+selpar_L50_commHAL_dev(iyear))))); //logistic
      sel_commHAL(iyear,iage)=(1./(1.+mfexp(-1.*selpar_slope_commHAL1*(double(agebins(iage))-
                    (selpar_L50_commHAL1+selpar_L50_commHAL_dev(iyear))))))*(1-(1./(1.+mfexp(-1.*➔
                         selpar_slope2_commHAL1*
                    (double(agebins(iage))-(selpar_L50_commHAL1+selpar_L502_commHAL1)))))); //double logistic
    }
  }
  sel_commDV(iyear)=sel_commDV(iyear)/max(sel_commDV(iyear)); //re-normalize double logistic
  sel_commHAL(iyear)=sel_commHAL(iyear)/max(sel_commHAL(iyear)); //re-normalize double logistic
  sel_HB(iyear)=sel_HB(iyear)/max(sel_HB(iyear)); //re-normalize double logistic
}


for (iyear=endyr_period1+1; iyear<=endyr_period2; iyear++)
{
  for (iage=1; iage<=nages; iage++)
  {
    //sel_HB(iyear,iage)=1./
    // (1.+mfexp(-1.*selpar_slope_HB2*(double(agebins(iage))-selpar_L50_HB2))); //logistic
    sel_HB(iyear,iage)=(1./(1.+mfexp(-1.*selpar_slope_HB2*(double(agebins(iage))-
                    selpar_L50_HB2))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_HB2*
                    (double(agebins(iage))-(selpar_L50_HB2+selpar_L502_HB2)))))); //double logistic

    //sel_commHAL(iyear,iage)=1./
    // (1.+mfexp(-1.*selpar_slope_commHAL2*(double(agebins(iage))-selpar_L50_commHAL2))); //logistic
    sel_commHAL(iyear,iage)=(1./(1.+mfexp(-1.*selpar_slope_commHAL2*(double(agebins(iage))-
                    selpar_L50_commHAL2))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_commHAL2*
                    (double(agebins(iage))-(selpar_L50_commHAL2+selpar_L502_commHAL2)))))); //double logistic

    sel_commDV(iyear,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))))));
  }
  sel_commDV(iyear)=sel_commDV(iyear)/max(sel_commDV(iyear));
  sel_commHAL(iyear)=sel_commHAL(iyear)/max(sel_commHAL(iyear)); //re-normalize double logistic
  sel_HB(iyear)=sel_HB(iyear)/max(sel_HB(iyear)); //re-normalize double logistic
}

for (iyear=endyr_period2+1; iyear<=endyr; iyear++)
{
  for (iage=1; iage<=nages; iage++)
  {
    //sel_HB(iyear,iage)=1./
    // (1.+mfexp(-1.*selpar_slope_HB3*(double(agebins(iage))-selpar_L50_HB3))); //logistic
    sel_HB(iyear,iage)=(1./(1.+mfexp(-1.*selpar_slope_HB3*(double(agebins(iage))-
                    selpar_L50_HB3))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_HB3*
                    (double(agebins(iage))-(selpar_L50_HB3+selpar_L502_HB3)))))); //double logistic

    //sel_commHAL(iyear,iage)=1./
    // (1.+mfexp(-1.*selpar_slope_commHAL3*(double(agebins(iage))-selpar_L50_commHAL3))); //logistic
    sel_commHAL(iyear,iage)=(1./(1.+mfexp(-1.*selpar_slope_commHAL3*(double(agebins(iage))-
                    selpar_L50_commHAL3))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_commHAL3*
                    (double(agebins(iage))-(selpar_L50_commHAL3+selpar_L502_commHAL3)))))); //double logistic
  }
  sel_commDV(iyear)=sel_commDV(endyr_period2); //period3 sel same as period2 sel
  sel_commHAL(iyear)=sel_commHAL(iyear)/max(sel_commHAL(iyear)); //re-normalize double logistic
  sel_HB(iyear)=sel_HB(iyear)/max(sel_HB(iyear)); //re-normalize double logistic
 }
```

```
//Discard selectivities

//for (iyear=styr_HB_D;iyear<=endyr_HB_D;iyear++)
//{
//   if(iyear<=endyr_period2)
//   {
//     for (iage=1; iage<=nages; iage++)
//     {
//       sel_HB_D(iyear,iage)=(max(column(sel_HB, iage))-sel_HB(endyr_period2,iage));
//       if(iage>5)
//       {
//         sel_HB_D(iyear,iage)=0.0;
//       }
//     }
//     sel_HB_D(iyear)=sel_HB_D(iyear)/(max(sel_HB_D(iyear))+dzero_dum); //prevent division by zero
//   }
//   else
//   {
//     for (iage=1; iage<=nages; iage++)
//     {
//       sel_HB_D(iyear,iage)=(max(column(sel_HB, iage))-sel_HB(endyr,iage));
//       if(iage>5)
//       {
//         sel_HB_D(iyear,iage)=0.0;
//       }
//     }
//     sel_HB_D(iyear)=sel_HB_D(iyear)/(max(sel_HB_D(iyear))+dzero_dum); //prevent division by zero
//   }
//}
//sel_MRFSS=sel_HB;
//sel_MRFSS_D=sel_HB_D;

//Uses a 2 age shift
for (iyear=styr_HB_D;iyear<=endyr_HB_D;iyear++)
{
   for (iage=1; iage<=(nages-2); iage++)
   {
     sel_HB_D(iyear,iage)=(sel_HB(endyr,iage+2)-sel_HB(endyr,iage));
     if(sel_HB_D(iyear,iage)<0.0)
     {
       sel_HB_D(iyear,iage)=0.0;
     }
   }
   sel_HB_D(iyear,(nages-1))=0.0;
   sel_HB_D(iyear,nages)=0.0;
   sel_HB_D(iyear)=sel_HB_D(iyear)/max(sel_HB_D(iyear));
}
sel_MRFSS=sel_HB;
sel_MRFSS_D=sel_HB_D;

//for (iyear=styr_commHAL_D;iyear<=endyr_commHAL_D;iyear++)
//{
//   for (iage=1; iage<=nages; iage++)
//   {
//     sel_commHAL_D(iyear,iage)=(max(column(sel_commHAL, iage))-sel_commHAL(endyr,iage));
//   }
//   sel_commHAL_D(iyear)=sel_commHAL_D(iyear)/(max(sel_commHAL_D(iyear))+dzero_dum); //prevent division by zero
//}

//Alternate way of expressing commercial discard selectivity
//Uses a 2 age shift
for (iyear=styr_commHAL_D;iyear<=endyr_commHAL_D;iyear++)
{
   for (iage=1; iage<=(nages-2); iage++)
   {
     sel_commHAL_D(iyear,iage)=(sel_commHAL(endyr,iage+2)-sel_commHAL(endyr,iage));
     if(sel_commHAL_D(iyear,iage)<0.0)
     {
       sel_commHAL_D(iyear,iage)=0.0;
     }
   }
```

```
      sel_commHAL_D(iyear,(nages-1))=0.0;
      sel_commHAL_D(iyear,nages)=0.0;
      sel_commHAL_D(iyear)=sel_commHAL_D(iyear)/max(sel_commHAL_D(iyear));
   }


FUNCTION get_mortality
  fullF=0.0;
  //initialization F is avg of first 3 yrs (1962-1964)
  log_F_init_commHAL=sum(log_F_dev_commHAL(styr_commHAL_L,(styr_commHAL_L+2)))/3.0;
  log_F_init_commDV=sum(log_F_dev_commDV(styr_commDV_L,(styr_commDV_L+2)))/3.0;
  log_F_init_HB=sum(log_F_dev_HB(styr_HB_L,(styr_HB_L+2)))/3.0;
  log_F_init_MRFSS=sum(log_F_dev_MRFSS(styr_MRFSS_L,(styr_MRFSS_L+2)))/3.0;

  for (iyear=styrR; iyear<=endyr; iyear++)
  {
    if(iyear<styr_commHAL_L)
    {
      F_commHAL_out(iyear)=mfexp(log_avg_F_commHAL+log_F_init_commHAL);
    }
    else
    {
      F_commHAL_out(iyear)=mfexp(log_avg_F_commHAL+log_F_dev_commHAL(iyear));
    }
    F_commHAL(iyear)=sel_commHAL(iyear)*F_commHAL_out(iyear);
    F_commHAL_D(iyear)=sel_commHAL_D(iyear)*Dmort_commHAL*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_init_commDV);
    }
    else
    {
      F_commDV_out(iyear)=mfexp(log_avg_F_commDV+log_F_dev_commDV(iyear));
    }
    F_commDV(iyear)=sel_commDV(iyear)*F_commDV_out(iyear);
    fullF(iyear)+=F_commDV_out(iyear);

    if(iyear<styr_HB_L)
    {
      F_HB_out(iyear)=mfexp(log_avg_F_HB+log_F_init_HB);
    }
    else
    {
      F_HB_out(iyear)=mfexp(log_avg_F_HB+log_F_dev_HB(iyear));
    }
    F_HB(iyear)=sel_HB(iyear)*F_HB_out(iyear);
    F_HB_D(iyear)=sel_HB_D(iyear)*Dmort_HB*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_init_MRFSS);
    }
    else
    {
      F_MRFSS_out(iyear)=mfexp(log_avg_F_MRFSS+log_F_dev_MRFSS(iyear));
    }
    F_MRFSS(iyear)=sel_MRFSS(iyear)*F_MRFSS_out(iyear);
    F_MRFSS_D(iyear)=sel_HB_D(iyear)*Dmort_MRFSS*F_MRFSS_out(iyear); //use HB selectivity
    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(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_numbers_at_age
//Initial age
  S0=spr_F0(styrR)*R0;
  B0=bpr_F0(styrR)*R0;
  S1=S0*S1dS0;
  R1=R1_mult*mfexp(log(((0.8*R0*steep*S1)/
     (0.2*R0*spr_F0(styrR)*(1.0-steep)+(steep-0.2)*S1))+dzero_dum));
  N(styrR,1)=R1;
  for (iage=2; iage<=nages; iage++)
  {
    N(styrR,iage)=N(styrR,iage-1)*mfexp(-1.*Z(styrR,iage-1));
  }
  //plus group calculation
  N(styrR,nages)=N(styrR,nages-1)*mfexp(-1.*Z(styrR,nages-1))/
                 (1.-mfexp(-1.*Z(styrR,nages)));
  SSB(styrR)=sum(elem_prod(N(styrR),reprod(styrR)));
  B(styrR)=elem_prod(N(styrR),wgt);
  totB(styrR)=sum(B(styrR));

//Rest of years ages
  for (iyear=styrR; iyear<endyr; iyear++)
  {
    //add 0.00001 to avoid log(zero)
    N(iyear+1,1)=mfexp(log(((0.8*R0*steep*SSB(iyear))/(0.2*R0*spr_F0(iyear)*
        (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
    SSB(iyear+1)=sum(elem_prod(N(iyear+1),reprod(iyear+1)));
    B(iyear+1)=elem_prod(N(iyear+1),wgt);
    totB(iyear+1)=sum(B(iyear+1));
  }

    //last year (projection) has no recruitment variability
    N(endyr+1,1)=mfexp(log(((0.8*R0*steep*SSB(endyr))/(0.2*R0*spr_F0(endyr)*
                 (1.0-steep)+(steep-0.2)*SSB(endyr)))+dzero_dum));
    N(endyr+1)(2,nages)=++elem_prod(N(endyr)(1,nages-1),(mfexp(-1.*Z(endyr)(1,nages-1))));
    N(endyr+1,nages)+=N(endyr,nages)*mfexp(-1.*Z(endyr,nages));//plus group
    SSB(endyr+1)=sum(elem_prod(N(endyr+1),reprod(endyr)));
    B(endyr+1)=elem_prod(N(endyr+1),wgt);
    totB(endyr+1)=sum(B(endyr+1));

//Recruitment time series
  rec=column(N,1);

//Benchmark parameters
```

```
  S1S0=SSB(styr)/S0;
  popstatus=SSB(endyr+1)/S0;


FUNCTION get_catch //Baranov catch eqn
  for (iyear=styrR; 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);
    }
  }

  //pred recreational catches in 1000s
  for (iyear=styr_HB_L; iyear<=endyr_HB_L; iyear++)
    {
     pred_HB_L(iyear)=sum(C_HB(iyear))/1000.0;
    }
  for (iyear=styr_MRFSS_L; iyear<=endyr_MRFSS_L; iyear++)
    {
     pred_MRFSS_L(iyear)=sum(C_MRFSS(iyear))/1000.0;
    }

FUNCTION get_landings

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

  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));
    }


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++)
  {
      N_HAL(iyear)=elem_prod(elem_prod(N(iyear),sel_commHAL(iyear)),wgt); //index in weight units
      pred_HAL_cpue(iyear)=mfexp(log_q_HAL)*(1+(iyear-styr_HAL_cpue)*q_rate)*sum(N_HAL(iyear));
      //pred_HAL_cpue(iyear)=mfexp(log_q_HAL)*sum(N_HAL(iyear));
  }
 //Headboat cpue
  for (iyear=styr_HB_cpue; iyear<=endyr_HB_cpue; iyear++)
  {
      N_HB(iyear)=elem_prod(N(iyear),sel_HB(iyear)); //index in number units
      pred_HB_cpue(iyear)=mfexp(log_q_HB)*(1+(iyear-styr_HB_cpue)*q_rate)*sum(N_HB(iyear));
      //pred_HB_cpue(iyear)=mfexp(log_q_HB)*sum(N_HB(iyear));
  }
  //MRFSS cpue
  for (iyear=styr_MRFSS_cpue; iyear<=endyr_MRFSS_cpue; iyear++)
  {
      N_MRFSS(iyear)=elem_prod(N(iyear),sel_MRFSS(iyear)); //index in number units
      pred_MRFSS_cpue(iyear)=mfexp(log_q_MRFSS)*(1+(iyear-styr_MRFSS_cpue)*q_rate)*sum(N_MRFSS(iyear));
      //pred_MRFSS_cpue(iyear)=mfexp(log_q_MRFSS)*sum(N_MRFSS(iyear));
  }


FUNCTION get_length_comps
 //Commercial
  for (iyear=styr_commHAL_lenc;iyear<=endyr_commHAL_lenc;iyear++)
  {
    pred_commHAL_lenc(iyear)=(C_commHAL(iyear)*lenprob10)/sum(C_commHAL(iyear));
  }
  for (iyear=1;iyear<=nyr_commDV_lenc;iyear++)
  {
    pred_commDV_lenc(iyear)=(C_commDV(yrs_commDV_lenc(iyear))*lenprob10)
                             /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)*lenprob10)/sum(C_HB(iyear));
  }


FUNCTION get_age_comps
 //Commercial
  for (iyear=1;iyear<=nyr_commHAL_agec;iyear++)
  {
    pred_commHAL_agec(iyear)=C_commHAL(yrs_commHAL_agec(iyear))/
                            sum(C_commHAL(yrs_commHAL_agec(iyear)));
  }
  for (iyear=1;iyear<=nyr_commDV_agec;iyear++)
  {
    pred_commDV_agec(iyear)=C_commDV(yrs_commDV_agec(iyear))/
                            sum(C_commDV(yrs_commDV_agec(iyear)));
  }
 //Headboat
  for (iyear=1;iyear<=nyr_HB_agec;iyear++)
```

```
  {
    pred_HB_agec(iyear)=C_HB(yrs_HB_agec(iyear))/sum(C_HB(yrs_HB_agec(iyear)));
  }


//------------------------------------------------------------------------------------------------------------------------------------

FUNCTION get_sel_weighted_current
  F_temp_sum=0.0;
  F_temp_sum+=mfexp((3.0*log_avg_F_commHAL+sum(log_F_dev_commHAL(endyr-2,endyr)))/3);
  F_temp_sum+=mfexp((3.0*log_avg_F_commDV+sum(log_F_dev_commDV(endyr-2,endyr)))/3);
  F_temp_sum+=mfexp((3.0*log_avg_F_HB+sum(log_F_dev_HB(endyr-2,endyr)))/3);
  F_temp_sum+=mfexp((3.0*log_avg_F_MRFSS+sum(log_F_dev_MRFSS(endyr-2,endyr)))/3);
  F_temp_sum+=mfexp((3.0*log_avg_F_commHAL_D+sum(log_F_dev_commHAL_D(endyr-2,endyr)))/3);
  F_temp_sum+=mfexp((3.0*log_avg_F_HB_D+sum(log_F_dev_HB_D(endyr-2,endyr)))/3);
  F_temp_sum+=mfexp((3.0*log_avg_F_MRFSS_D+sum(log_F_dev_MRFSS_D(endyr-2,endyr)))/3);

  F_commHAL_prop=mfexp((3.0*log_avg_F_commHAL+sum(log_F_dev_commHAL(endyr-2,endyr)))/3)/F_temp_sum;
  F_commDV_prop=mfexp((3.0*log_avg_F_commDV+sum(log_F_dev_commDV(endyr-2,endyr)))/3)/F_temp_sum;
  F_HB_prop=mfexp((3.0*log_avg_F_HB+sum(log_F_dev_HB(endyr-2,endyr)))/3)/F_temp_sum;
  F_MRFSS_prop=mfexp((3.0*log_avg_F_MRFSS+sum(log_F_dev_MRFSS(endyr-2,endyr)))/3)/F_temp_sum;
  F_commHAL_D_prop=mfexp((3.0*log_avg_F_commHAL_D+sum(log_F_dev_commHAL_D(endyr-2,endyr)))/3)/F_temp_sum;
  F_HB_D_prop=mfexp((3.0*log_avg_F_HB_D+sum(log_F_dev_HB_D(endyr-2,endyr)))/3)/F_temp_sum;
  F_MRFSS_D_prop=mfexp((3.0*log_avg_F_MRFSS_D+sum(log_F_dev_MRFSS_D(endyr-2,endyr)))/3)/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
  var_rec_dev=norm2(log_dev_N_rec(styr,(endyr-3))-sum(log_dev_N_rec(styr,(endyr-3)))
              /(nyrs-3))/(nyrs-4.); //sample variance yrs 1962-2004
  if (set_BiasCor <= 0.0) {BiasCor=mfexp(var_rec_dev/2.0);}   //bias correction
  else {BiasCor=set_BiasCor;}

  //fill in Fs for per-recruit stuff
  F_msy.fill_seqadd(0,.001);


  //compute values as functions of F
  for(int ff=1; ff<=n_iter_msy; ff++)
  {
    //uses fishery-weighted F's
    Z_age_msy=0.0;
    F_L_age_msy=0.0;
    F_D_age_msy=0.0;

    F_L_age_msy=F_msy(ff)*sel_wgted_L;

    F_D_age_msy=F_msy(ff)*sel_wgted_D;

    Z_age_msy=M+F_L_age_msy+F_D_age_msy;


    N_age_msy(1)=1.0;
    for (iage=2; iage<=nages; iage++)
    {
```

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


    spr_msy(ff)=sum(elem_prod(N_age_msy,reprod(endyr)));



    //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(endyr)*(1.0-steep));
    if (R_eq(ff)<dzero_dum) {R_eq(ff)=dzero_dum;}
    N_age_msy*=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,reprod(endyr)));
    B_eq(ff)=sum(elem_prod(N_age_msy,wgt));
    L_eq(ff)=sum(elem_prod(C_age_msy,wgt));
    E_eq(ff)=sum(C_age_msy(E_age_st,nages))/sum(N_age_msy(E_age_st,nages));
    D_eq(ff)=sum(D_age_msy)/1000.0;
  }

  msy_out=max(L_eq);

  for(ff=1; ff<=n_iter_msy; ff++)
  {
   if(L_eq(ff) == msy_out)
      {
        SSB_msy_out=SSB_eq(ff);
        B_msy_out=B_eq(ff);
        R_msy_out=R_eq(ff);
        D_msy_out=D_eq(ff);
        E_msy_out=E_eq(ff);
        F_msy_out=F_msy(ff);
        spr_msy_out=spr_msy(ff);
      }
  }

//-----------------------------------------------------------------------------------------------------------------------

FUNCTION get_miscellaneous_stuff

  //compute total catch-at-age and landings
  C_total=(C_HB+C_MRFSS+C_commHAL+C_commDV)/1000.0; //catch in 1000s
  L_total=L_HB+L_MRFSS+L_commHAL+L_commDV;

  //compute exploitation rate of age 2+
  for(iyear=styrR; iyear<=endyr; iyear++)
  {
    E(iyear)=(1000.0*sum(C_total(iyear)(E_age_st,nages)))/sum(N(iyear)(E_age_st,nages)); //catch in 1000s
    L_total_yr(iyear)=sum(L_total(iyear));
  }

  steep_sd=steep;
  fullF_sd=fullF;
  E_sd=E;

  if(E_msy_out>0)
    {
      EdE_msy=E/E_msy_out;
      EdE_msy_end=EdE_msy(endyr);
```

```
    }
  if(F_msy_out>0)
    {
      FdF_msy=fullF/F_msy_out;
      FdF_msy_end=FdF_msy(endyr);
    }
  if(SSB_msy_out>0)
    {
      SdSSB_msy=SSB/SSB_msy_out;
      SdSSB_msy_end=SdSSB_msy(endyr+1);
    }


//-----------------------------------------------------------------------------------------------------------------------------------

FUNCTION get_per_recruit_stuff
  //static per-recruit stuff

  for(iyear=styrR; iyear<=endyr; iyear++)
  {
    N_age_spr(1)=1.0;
    for(iage=2; iage<=nages; iage++)
    {
      N_age_spr(iage)=N_age_spr(iage-1)*mfexp(-1.*Z(iyear,iage-1));
    }
    N_age_spr(nages)=N_age_spr(nages-1)*mfexp(-1.*Z(iyear,nages-1))/
                    (1.0-mfexp(-1.*Z(iyear,nages)));
    spr_static(iyear)=sum(elem_prod(N_age_spr,reprod(iyear)))/spr_F0(iyear);
  }

  //fill in Fs for per-recruit stuff
  F_spr.fill_seqadd(0,.01);
  //compute SSB/R and YPR as functions of F
  for(int ff=1; ff<=n_iter_spr; ff++)
  {
    //uses fishery-weighted F's, same as in MSY calculations
    Z_age_spr=0.0;
    F_L_age_spr=0.0;

    F_L_age_spr=F_spr(ff)*sel_wgted_L;

    Z_age_spr=M+F_L_age_spr+F_spr(ff)*sel_wgted_D;

    N_age_spr(1)=1.0;
    for (iage=2; iage<=nages; iage++)
    {
      N_age_spr(iage)=N_age_spr(iage-1)*mfexp(-1.*Z_age_spr(iage-1));
    }
    N_age_spr(nages)=N_age_spr(nages-1)*mfexp(-1.*Z_age_spr(nages-1))/
                     (1-mfexp(-1.*Z_age_spr(nages)));
    spr_spr(ff)=sum(elem_prod(N_age_spr,reprod(endyr)));
    L_spr(ff)=0.0;
    for (iage=1; iage<=nages; iage++)
    {
      C_age_spr(iage)=N_age_spr(iage)*(F_L_age_spr(iage)/Z_age_spr(iage))*
                      (1.-mfexp(-1.*Z_age_spr(iage)));
      L_spr(ff)+=C_age_spr(iage)*wgt(iage);
    }
    E_spr(ff)=sum(C_age_spr(E_age_st,nages))/sum(N_age_spr(E_age_st,nages));

  }

//-----------------------------------------------------------------------------------------------------------------------------------


FUNCTION evaluate_objective_function
  fval=0.0;
  fval_unwgt=0.0;

//---likelihoods---------------------------
```

```
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;


f_commHAL_L=0.0; //in 1000s gutted pounds
for (iyear=styr_commHAL_L; iyear<=endyr_commHAL_L; iyear++)
{
  if(iyear<=1983)
  {
    f_commHAL_L+=square(log((pred_commHAL_L(iyear)+dzero_dum)/
      (obs_commHAL_L(iyear)*L_commHAL_bias+dzero_dum)))/(2.0*square(commHAL_L_cv(iyear)));
  }
  else
  {
    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 gutted pounds
for (iyear=styr_commDV_L; iyear<=endyr_commDV_L; iyear++)
{
  f_commDV_L+=square(log((pred_commDV_L(iyear)+dzero_dum)/
      (obs_commDV_L(iyear)+dzero_dum)))/(2.0*square(commDV_L_cv(iyear)));
}
fval+=w_L*f_commDV_L;
fval_unwgt+=f_commDV_L;

f_HB_L=0.0; //in 1000s
for (iyear=styr_HB_L; iyear<=endyr_HB_L; iyear++)
{
  f_HB_L+=square(log((pred_HB_L(iyear)+dzero_dum)/
      (obs_HB_L(iyear)+dzero_dum)))/(2.0*square(HB_L_cv(iyear)));
}
fval+=w_L*f_HB_L;
fval_unwgt+=f_HB_L;

f_MRFSS_L=0.0; //in 1000s
for (iyear=styr_MRFSS_L; iyear<=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;
```

```
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;


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)));
}
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)));
}
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)));
}
fval+=w_lc*f_HB_lenc;
fval_unwgt+=f_HB_lenc;

f_commHAL_agec=0.0;
for (iyear=1; iyear<=nyr_commHAL_agec; iyear++)
{
  f_commHAL_agec-=nsamp_commHAL_agec(iyear)*
          sum(elem_prod((obs_commHAL_agec(iyear)+dzero_dum),log(pred_commHAL_agec(iyear)+dzero_dum)));
}
fval+=w_ac*f_commHAL_agec;
fval_unwgt+=f_commHAL_agec;

f_commDV_agec=0.0;
for (iyear=1; iyear<=nyr_commDV_agec; iyear++)
{
  f_commDV_agec-=nsamp_commDV_agec(iyear)*
          sum(elem_prod((obs_commDV_agec(iyear)+dzero_dum),log(pred_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)));
  }
  fval+=w_ac*f_HB_agec;
  fval_unwgt+=f_HB_agec;

//-----------Constraints and penalties--------------------------------
  f_N_dev=0.0;
  f_N_dev=norm2(log_dev_N_rec);
  fval+=w_R*f_N_dev;

  f_N_dev_early=0.0;
  f_N_dev_early=norm2(log_dev_N_rec(styrR+1,styr-1));
  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-3,endyr)));
  fval+=w_F*f_Fend_constraint;

  f_fullF_constraint=0.0;
  for (iyear=styrR; iyear<=endyr; iyear++)
    {
     if (fullF(iyear)>5.0)
     {
     f_fullF_constraint+=square(fullF(iyear)-5.0);
     }
    }
  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();
  get_msy();
  get_miscellaneous_stuff();
  get_per_recruit_stuff();
  cout << "BC Fmsy=" << F_msy_out<< "   BC SSBmsy=" << SSB_msy_out <<endl;
  cout << "var_rec_resid (72-01)="<<var_rec_dev<<endl;

    report << "TotalLikelihood " << fval << endl;
    report<<" "<<endl;

  report << "Bias-corrected (BC) MSY stuff" << endl;
  report << "BC Fmsy " << F_msy_out << endl;
  report << "BC Emsy(2+) " << E_msy_out << endl;
  report << "BC SSBmsy " << SSB_msy_out << endl;
```

```
 report << "BC Rmsy " << R_msy_out << endl;
 report << "BC Bmsy " << B_msy_out << endl;
 report << "BC MSY " << msy_out << endl;
 report << "BC F/Fmsy " << fullF/F_msy_out << endl;
 report << "BC E/Emsy " << E/E_msy_out << endl;
 report << "BC SSB/SSBmsy " << SSB/SSB_msy_out << endl;
 report << "BC B/Bmsy " << totB/B_msy_out << endl;
 report << "BC Yield/MSY " << L_total_yr/msy_out <<endl;
 report << "BC F(2004)/Fmsy " << fullF(endyr)/F_msy_out << endl;
 report << "BC E(2004)/Emsy " << E(endyr)/E_msy_out << endl;
 report << "BC SSB(2005)/SSBmsy " << SSB(endyr+1)/SSB_msy_out << endl;
 report << "BC Predicted Landings(2004)/MSY " << L_total_yr(endyr)/msy_out <<endl;
 report  << " "<<endl;

 report << "Mortality and growth" << endl;
 report << "M "<<M<<endl;
 report << "Linf="<<Linf << "   K=" <<K<<"   t0="<< t0<<endl;
 report << "mean length " << meanlen << endl;
   report << "cv length " << len_cv << endl;
 report << "wgt " << wgt << endl;
 report<<" "<<endl;

 report << "Stock-Recruit " << endl;
 report << "R0= " << R0 << endl;
 report << "Steepness= " << steep << endl;
 report << "spr_F0= " << spr_F0 << endl;
 report << "Recruits(R) " << rec << endl;
 report << "VirginSSB " << S0 << endl;
 report << "SSB(1978)/VirginSSB " << S1S0 << endl;
 report << "SSB(2004)/VirginSSB " << popstatus << endl;
 report << "SSB " << SSB << endl;
 report << "Biomass " << totB << endl;
 report << "log recruit deviations (1978-2003)   " << log_dev_N_rec(1978,2003) <<endl;
 report << "variance of log rec dev (1978-2000)  "<<var_rec_dev<<endl;
 report<<" "<<endl;

 report << "Exploitation rate (1958-2004)" << endl;
report << E << 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 (1000s)"<<obs_HB_L << endl;
report << "pred HB landings (1000s)"<<pred_HB_L << endl;
report << "Obs  MRFSS landings (1000s)"<<obs_MRFSS_L << endl;
report << "pred MRFSS landings (1000s)"<<pred_MRFSS_L << endl;
report << "Obs  commHAL landings (mt)"<<obs_commHAL_L << endl;
report << "pred commHAL landings (mt)"<<pred_commHAL_L << endl;
report << "Obs  commDV landings (mt)"<<obs_commDV_L << endl;
report << "pred commDV landings (mt)"<<pred_commDV_L << endl;

#include "gag_make_Robject3.cxx"   // write the S-compatible report
```

Appendix C Catch-age model, parameter files

C.1 Run with increasing catchability starting in 1980

```
# Number of parameters = 356  Objective function value = 39508.6  Maximum gradient component = 1643.45
# Linf:
1020.25
# K:
0.220383
# t0:
-0.757991
# log_len_cv:
-2.15805
# log_len_cv_dev:
 0.150973 0.233512 0.0753419 0.0586285 0.238618 -0.100583 0.264493 -0.0272085 0.0760984 0.0894969 0.0154018
 -0.0926083 -0.141418 -0.111369 -0.0815970 -0.0786237 -0.0823358 -0.0785021 -0.0792625 -0.110196 -0.218859
# log_R0:
12.9903
# steep:
0.845781
# log_dev_N_rec:
 -0.0723133 -0.0786899 -0.0817173 -0.0886780 -0.0922689 -0.101008 -0.105230 -0.115343 -0.121382 -0.129408
 -0.143304 -0.148267 -0.165601 -0.182040 -0.197004 -0.212379 -0.222761 -0.156800 -0.135836 -0.674363
 -1.12617 -1.14511 -1.40499 -1.41636 -0.722505 -0.405717 -0.411509 -0.732456 -0.240770 -0.161211 1.06832
 0.0703965 -0.180045 -0.696243 0.493066 0.409032 0.0183475 0.0136438 0.840556 -0.590284 -0.401515 0.396372
 0.471331 0.470642 0.609493 0.444005 1.10088 1.06321 -0.0869263 -0.229871 0.563367 0.919015
0.638671 0.507777 0.385279 0.939126 0.877144 1.03445 1.19219 -0.170457 -0.738553 -0.441220
# R1_mult:
1.21630
# selpar_slope_commHAL1:
1.46704
# selpar_L50_commHAL1:
5.02906
# selpar_slope_commHAL2:
1.56573
# selpar_L50_commHAL2:
4.55019
# selpar_slope_commHAL3:
1.86462
# selpar_L50_commHAL3:
4.60695
# selpar_L50_commHAL_dev:
 1.00716 -0.350915 1.33927 -2.18076 -0.291094 0.945312 0.160782 -0.269566 -0.360195
# selpar_slope_commDV1:
1.32089
# selpar_L50_commDV1:
6.47958
# selpar_slope2_commDV1:
2.29397
# selpar_L502_commDV1:
1.94778
# selpar_slope_HB1:
3.30722
# selpar_L50_HB1:
1.39204
# selpar_slope_HB2:
2.01377
# selpar_L50_HB2:
2.58932
# selpar_slope_HB3:
1.05629
# selpar_L50_HB3:
4.35197
# selpar_L50_HB_dev:
 -0.120005 -3.78559 -1.76540 0.556443 1.78588 2.27835 0.769811 0.316890 -0.0570839 0.218992 0.248094
 0.166749 -0.0299391 -0.259074 -0.236681 -0.221972 -0.360161 -0.122369 0.0611612 0.555901
# log_q_HAL:
-8.49668
# log_q_HB:
```

```
-13.9151
# log_q_MRFSS:
-13.7040
# q_rate:
0.0200000
# L_commHAL_bias:
1.00000
# log_avg_F_commHAL:
-2.38134
# log_F_dev_commHAL:
 -2.15622 -2.23367 -2.28466 -2.25711 -2.51828 -1.72883 -1.26771 -1.52966 -1.10739 -0.966383 -1.27916
 -0.866888 -0.572389 -0.399204 -0.0450494 0.0824972 0.468948 0.369219 0.315174 0.537574 0.637355
 1.00246 0.952368 1.32840 0.612278 1.09513 1.32276 1.65976 1.32250 1.01941 0.948938 0.918366 0.832021
 0.893277 0.930082 0.828659 0.854663 0.595648 0.402474 0.446193 0.356206 0.250525 0.229726
# log_avg_F_commDV:
-3.97134
# log_F_dev_commDV:
 -2.28574 -1.45322 -1.15371 -1.12832 -1.48286 -1.56691 -1.05965 -1.44417 -0.695430 -1.08598 -1.60790
 -0.274557 -0.680397 0.107597 0.0552140 1.30832 1.36540 0.967166 1.09720 0.866881 1.18191 1.11592
 1.70467 1.55577 0.811105 0.947619 0.893781 1.23115 0.709137
# log_avg_F_HB:
-4.23963
# log_F_dev_HB:
 -0.666475 -0.741432 -0.741486 -0.622744 -0.820060 0.0239700 0.530788 0.189317 0.506544 0.557377
 0.308631 -0.375211 -0.513603 -0.357838 -0.130481 -0.0406875 -0.650712 -0.291858 -0.747549 0.0560797
 -0.0662726 0.196551 0.557005 0.466481 0.466516 0.761291 0.653393 0.661011 0.436305 0.213515 0.366167
 0.133349 0.0865041 0.338294 -0.0194926 -0.225080 -0.0462619 0.0883263 0.210412 0.00979064 -0.215097
 -0.615815 0.0705342
# log_avg_F_MRFSS:
-2.95532
# log_F_dev_MRFSS:
 -2.25687 -2.33218 -2.33162 -2.21514 -2.41417 -1.56999 -1.06159 -1.40356 -1.08653 -1.03490 -1.44791
 -2.04160 -1.66260 -0.900166 -0.218934 -0.324255 -0.0816575 -0.242509 -0.394433 0.180318 -0.727556
 1.09435 1.45807 0.428624 0.416291 0.880379 0.528323 1.04203 0.434429 0.430018 0.937942 0.842921
 1.32790 1.38114 1.13938 1.26024 0.784369 1.84671 2.18271 1.57272 1.65090 2.12250 1.80589
# log_avg_F_commHAL_D:
-5.31069
# log_F_dev_commHAL_D:
 0.0680077 0.127168 0.528042 0.224482 -0.681243 -0.266458
# log_avg_F_HB_D:
-7.37954
# log_F_dev_HB_D:
 -4.11461 -4.49268 -3.73064 -3.87806 1.02474 1.05490 1.27846 1.18692 1.00552 0.647936 0.299274 1.17746
 1.08673 1.03397 1.14434 0.699091 0.547348 0.750031 0.725430 0.770381 0.472684 0.310171 0.0446841
 0.955908
# log_avg_F_MRFSS_D:
-4.60148
# log_F_dev_MRFSS_D:
 -1.89744 1.09773 -0.664551 -1.94804 -0.597554 -0.895470 -0.613109 0.343172 -1.10521 -0.444554 0.0129861
 -0.117048 0.778102 0.899840 0.255986 0.837634 -0.129702 0.454245 1.15119 0.0269639 0.566607 1.10815
 0.880085
```

C.2 Run with constant catchability

```
# Number of parameters = 356  Objective function value = 39437.7  Maximum gradient component = 0.000883552
# Linf:
1036.35
# K:
0.209986
# t0:
-0.862327
# log_len_cv:
-2.19434
# log_len_cv_dev:
 0.191609 0.197216 0.0538455 0.0777073 0.256341 -0.0906604 0.269311 0.00291303 0.0972784 0.107148 0.0209044
 -0.0922260 -0.145794 -0.123268 -0.100487 -0.0923820 -0.0875292 -0.0823903 -0.0857933 -0.123595 -0.250149
# log_R0:
12.9398
# steep:
0.950000
# log_dev_N_rec:
 -0.0709469 -0.0747529 -0.0790515 -0.0839041 -0.0893714 -0.0955157 -0.102408 -0.110123 -0.118732 -0.128307
 -0.138239 -0.149977 -0.163647 -0.178299 -0.192475 -0.207060 -0.222013 -0.154900 -0.131372 -0.641872 -1.07565
 -1.15372 -1.44045 -1.42390 -0.732840 -0.413120 -0.443358 -0.793314 -0.327843 -0.281555 0.857451 0.0682629
 -0.150956 -0.616439 0.498881 0.408927 0.0415216 0.0306765 0.856099 -0.560395 -0.346634 0.426054 0.467513
 0.418445 0.556314 0.384264 1.06428 1.04432 -0.108350 -0.191338 0.523483 0.909178 0.692016 0.527269 0.372229
 0.966528 0.921032 1.06193 1.25511 -0.0895413 -0.674863 -0.394548
# R1_mult:
1.22946
# selpar_slope_commHAL1:
1.34471
# selpar_L50_commHAL1:
5.29564
# selpar_slope_commHAL2:
1.59389
# selpar_L50_commHAL2:
4.45283
# selpar_slope_commHAL3:
1.97236
# selpar_L50_commHAL3:
4.43963
# selpar_L50_commHAL_dev:
 0.792274 -0.297113 1.40327 -2.23819 -0.228330 1.04898 0.174222 -0.276530 -0.378580
# selpar_slope_commDV1:
1.27520
# selpar_L50_commDV1:
6.87348
# selpar_slope2_commDV1:
1.68238
# selpar_L502_commDV1:
1.00000
# selpar_slope_HB1:
2.95979
# selpar_L50_HB1:
1.42232
# selpar_slope_HB2:
2.50730
# selpar_L50_HB2:
2.31378
# selpar_slope_HB3:
1.12913
# selpar_L50_HB3:
4.05857
# selpar_L50_HB_dev:
 -0.129459 -4.31325 -1.42404 0.656029 1.86597 2.23031 1.00102 0.402482 0.0509311 0.295700 0.303131 0.178875
 0.0107836 -0.244187 -0.254971 -0.279300 -0.475231 -0.240977 -0.0443890 0.410572
# log_q_HAL:
-8.52421
# log_q_HB:
-13.6797
# log_q_MRFSS:
-13.5820
# q_rate:
```

```
0.00000
# L_commHAL_bias:
1.00000
# log_avg_F_commHAL:
-2.35473
# log_F_dev_commHAL:
 -2.13444 -2.21209 -2.26321 -2.23566 -2.49774 -1.71190 -1.25511 -1.52000 -1.09809 -0.954423 -1.26041 -0.839800
 -0.535866 -0.351575 0.0239022 0.190449 0.625573 0.549412 0.486118 0.695199 0.794175 1.12565 1.09746 1.55431
 0.679956 1.22197 1.49724 1.78038 1.41563 1.09076 0.877443 0.823610 0.724067 0.774104 0.786731 0.655059 0.670860
 0.378421 0.172078 0.199083 0.0932891 -0.0363517 -0.0762435
# log_avg_F_commDV:
-3.94518
# log_F_dev_commDV:
 -2.17003 -1.30522 -0.985819 -0.932737 -1.28749 -1.34432 -0.945088 -1.40654 -0.668218 -1.00547 -1.53993
 -0.235938 -0.652383 0.157982 0.0242061 1.26692 1.33750 0.932604 1.05424 0.808582 1.08647 1.01346 1.61181
 1.43792 0.671680 0.791670 0.733637 1.04947 0.501044
# log_avg_F_HB:
-4.24752
# log_F_dev_HB:
 -0.608585 -0.683724 -0.687880 -0.571986 -0.768117 0.0774575 0.585333 0.247185 0.568455 0.624219 0.379919
 -0.213021 -0.296296 -0.156313 0.0537122 0.122858 -0.488730 -0.163468 -0.641213 0.147134 0.0131070 0.260185
 0.605086 0.501209 0.483227 0.763212 0.637932 0.638490 0.396314 0.148168 0.236081 0.0271482 0.0127849 0.238694
 -0.161911 -0.376749 -0.189761 -0.0930459 0.0170656 -0.198569 -0.438379 -0.858014 -0.189219
# log_avg_F_MRFSS:
-2.96565
# log_F_dev_MRFSS:
 -2.19681 -2.27200 -2.27579 -2.16197 -2.35985 -1.51403 -1.00476 -1.34335 -1.02228 -0.965833 -1.37388 -1.87898
 -1.44513 -0.700365 -0.0397261 -0.168792 0.0627484 -0.127767 -0.300088 0.249873 -0.654355 1.11735 1.50237
 0.464093 0.434957 0.885466 0.515996 1.02434 0.400823 0.368927 0.807569 0.729570 1.25609 1.29518 1.00603
 1.12065 0.651935 1.67164 1.99875 1.37237 1.43611 1.88538 1.54753
# log_avg_F_commHAL_D:
-5.42502
# log_F_dev_commHAL_D:
 0.107151 0.135879 0.512112 0.209676 -0.697934 -0.266884
# log_avg_F_HB_D:
-7.40926
# log_F_dev_HB_D:
 -4.07087 -4.44824 -3.69352 -3.83683 1.05758 1.06092 1.27593 1.20304 1.02700 0.653444 0.293187 1.18289 1.12667
 1.07627 1.13993 0.673235 0.531220 0.738284 0.699197 0.718955 0.406635 0.248576 -0.00351411 0.940020
# log_avg_F_MRFSS_D:
-4.63283
# log_F_dev_MRFSS_D:
 -1.85135 1.13965 -0.622018 -1.91410 -0.589663 -0.896499 -0.594360 0.366833 -1.09774 -0.448089 0.0185107
 -0.0797541 0.822602 0.898831 0.232184 0.824063 -0.139278 0.429735 1.10316 -0.0371613 0.506871 1.06169
 0.865882
```

Appendix D ASPIC (Production Model) Output

D.1 ASPIC results based on constant catchability

```
CORRECTED SAFMC Gag SEDAR 10 (2006) Landings and Indices, B1/K=0.9                                      Page 1
                                                                               Thursday, 14 Dec 2006 at 13:17:39
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 5.16)
                                                                                              BOT program mode
Author:     Michael H. Prager; NOAA Center for Coastal Fisheries and Habitat Research          LOGISTIC model mode
            101 Pivers Island Road; Beaufort, North Carolina  28516  USA                      YLD conditioning
            Mike.Prager@noaa.gov                                                              SSE optimization

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

CONTROL PARAMETERS (FROM INPUT FILE)                                               Input file: gag2006_102_boot.inp
-------------------------------------------------------------------------------------------------------------------
Operation of ASPIC:  Fit logistic (Schaefer) model by direct optimization with bootstrap.
Number of years analyzed:                        43          Number of bootstrap trials:                     600
Number of data series:                            3          Bounds on MSY (min, max):       1.000E+02     2.000E+03
Objective function:                   Least squares          Bounds on K (min, max):         1.200E+03     4.000E+04
Relative conv. criterion (simplex):       1.000E-08          Monte Carlo search mode, trials:        1         20000
Relative conv. criterion (restart):       3.000E-08          Random number seed:                            82184571
Relative conv. criterion (effort):        1.000E-04          Identical convergences required in fitting:           8
Maximum F allowed in fitting:                 4.000


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

WARNING: Negative correlations detected between some indices.  A fundamental assumption of ASPIC is that all indices
         represent the abundance of the stock.  That assumption appears to be violated.


CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
-------------------------------------------------------------------------------------------------------------------
                                       |
 1  Headboat Index (1962-2004), Tota...|   1.000
                                       |      32
                                       |
 2  Commercial Logbook Index           |  -0.447   1.000
                                       |      13      13
                                       |
 3  MRFSS Index                        |   0.007  -0.023   1.000
                                       |      24      13      24
                                       --------------------------------------------------
                                               1       2       3


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

Loss(-1)  SSE in yield                              0.000E+00
Loss(0)   Penalty for B1 > K                        0.000E+00     1         N/A    1.000E+00           N/A
Loss(1)   Headboat Index (1962-2004), Total Ldgs    2.547E+00    32   8.489E-02    1.000E+00     9.742E-01        0.305
Loss(2)   Commercial Logbook Index                  4.062E-01    13   3.692E-02    1.000E+00     2.240E+00       -0.170
Loss(3)   MRFSS Index                               5.014E+00    24   2.279E-01    1.000E+00     3.629E-01       -0.165
.....................................................................................................
TOTAL OBJECTIVE FUNCTION, MSE, RMSE:           7.96732657E+00         1.245E-01    3.528E-01
Estimated contrast index (ideal = 1.0):                0.4517         C* = (Bmax-Bmin)/K
Estimated nearness index (ideal = 1.0):                1.0000         N* = 1 - |min(B-Bmsy)|/K
```

CORRECTED SAFMC Gag SEDAR 10 (2006) Landings and Indices, B1/K=0.9 Page 2

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	User/pgm guess	2nd guess	Estimated	User guess
B1/K	Starting relative biomass (in 1962)	9.000E-01	9.000E-01	4.000E-01	0	1
MSY	Maximum sustainable yield	4.945E+02	5.000E+02	4.495E+02	1	1
K	Maximum population size	1.561E+04	6.000E+03	2.697E+03	1	1
phi	Shape of production curve (Bmsy/K)	0.5000	0.5000	----	0	1
---------	Catchability Coefficients by Data Series ---------------					
q(1)	Headboat Index (1962-2004), Total Ldgs	4.922E-04	5.000E-04	4.750E-02	1	1
q(2)	Commercial Logbook Index	6.391E-05	5.000E-05	4.750E-03	1	1
q(3)	MRFSS Index	1.012E-04	5.000E-05	4.750E-03	1	1

MANAGEMENT and DERIVED PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	Logistic formula	General formula
MSY	Maximum sustainable yield	4.945E+02	----	----
Bmsy	Stock biomass giving MSY	7.805E+03	K/2	K*n**(1/(1-n))
Fmsy	Fishing mortality rate at MSY	6.336E-02	MSY/Bmsy	MSY/Bmsy
n	Exponent in production function	2.0000	----	----
g	Fletcher's gamma	4.000E+00	----	[n**(n/(n-1))]/[n-1]
B./Bmsy	Ratio: B(2005)/Bmsy	9.257E-01	----	----
F./Fmsy	Ratio: F(2004)/Fmsy	1.170E+00	----	----
Fmsy/F.	Ratio: Fmsy/F(2004)	8.551E-01	----	----
Y.(Fmsy)	Approx. yield available at Fmsy in 2005	4.578E+02	MSY*B./Bmsy	MSY*B./Bmsy
	...as proportion of MSY	9.257E-01	----	----
Ye.	Equilibrium yield available in 2005	4.918E+02	4*MSY*(B/K-(B/K)**2)	g*MSY*(B/K-(B/K)**n)
	...as proportion of MSY	9.945E-01	----	----
---------	Fishing effort rate at MSY in units of each CE or CC series ---------			
fmsy(1)	Headboat Index (1962-2004), Total Ldgs	1.287E+02	Fmsy/q(1)	Fmsy/q(1)

CORRECTED SAFMC Gag SEDAR 10 (2006) Landings and Indices, B1/K=0.9 Page 3

ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

Obs	Year or ID	Estimated total F mort	Estimated starting biomass	Estimated average biomass	Observed total yield	Model total yield	Estimated surplus production	Ratio of F mort to Fmsy	Ratio of biomass to Bmsy
1	1962	0.013	1.405E+04	1.405E+04	1.762E+02	1.762E+02	1.779E+02	1.980E-01	1.800E+00
2	1963	0.011	1.405E+04	1.406E+04	1.605E+02	1.605E+02	1.770E+02	1.802E-01	1.800E+00
3	1964	0.011	1.407E+04	1.408E+04	1.504E+02	1.504E+02	1.749E+02	1.686E-01	1.802E+00
4	1965	0.011	1.409E+04	1.410E+04	1.542E+02	1.542E+02	1.727E+02	1.726E-01	1.805E+00
5	1966	0.008	1.411E+04	1.414E+04	1.165E+02	1.165E+02	1.690E+02	1.301E-01	1.808E+00
6	1967	0.017	1.416E+04	1.412E+04	2.467E+02	2.467E+02	1.704E+02	2.757E-01	1.814E+00
7	1968	0.026	1.409E+04	1.399E+04	3.677E+02	3.677E+02	1.837E+02	4.148E-01	1.805E+00
8	1969	0.018	1.390E+04	1.387E+04	2.542E+02	2.542E+02	1.957E+02	2.892E-01	1.781E+00
9	1970	0.025	1.384E+04	1.377E+04	3.494E+02	3.494E+02	2.056E+02	4.005E-01	1.774E+00
10	1971	0.026	1.370E+04	1.363E+04	3.596E+02	3.596E+02	2.192E+02	4.165E-01	1.755E+00
11	1972	0.016	1.356E+04	1.356E+04	2.217E+02	2.217E+02	2.255E+02	2.580E-01	1.737E+00
12	1973	0.028	1.356E+04	1.349E+04	3.736E+02	3.736E+02	2.320E+02	4.371E-01	1.738E+00
13	1974	0.032	1.342E+04	1.333E+04	4.260E+02	4.260E+02	2.467E+02	5.044E-01	1.720E+00
14	1975	0.030	1.324E+04	1.317E+04	4.013E+02	4.013E+02	2.608E+02	4.809E-01	1.697E+00
15	1976	0.040	1.310E+04	1.298E+04	5.170E+02	5.170E+02	2.771E+02	6.287E-01	1.679E+00
16	1977	0.041	1.286E+04	1.275E+04	5.235E+02	5.235E+02	2.963E+02	6.483E-01	1.648E+00
17	1978	0.060	1.263E+04	1.242E+04	7.458E+02	7.458E+02	3.217E+02	9.480E-01	1.619E+00
18	1979	0.060	1.221E+04	1.202E+04	7.228E+02	7.228E+02	3.502E+02	9.492E-01	1.564E+00
19	1980	0.055	1.184E+04	1.170E+04	6.426E+02	6.426E+02	3.713E+02	8.670E-01	1.517E+00
20	1981	0.072	1.157E+04	1.135E+04	8.213E+02	8.213E+02	3.925E+02	1.142E+00	1.482E+00
21	1982	0.058	1.114E+04	1.102E+04	6.438E+02	6.438E+02	4.106E+02	9.222E-01	1.427E+00
22	1983	0.082	1.090E+04	1.067E+04	8.782E+02	8.782E+02	4.275E+02	1.299E+00	1.397E+00
23	1984	0.138	1.045E+04	9.978E+03	1.380E+03	1.380E+03	4.556E+02	2.183E+00	1.339E+00
24	1985	0.077	9.529E+03	9.400E+03	7.279E+02	7.279E+02	4.738E+02	1.222E+00	1.221E+00
25	1986	0.066	9.275E+03	9.209E+03	6.091E+02	6.091E+02	4.785E+02	1.044E+00	1.188E+00
26	1987	0.088	9.144E+03	8.986E+03	7.943E+02	7.943E+02	4.831E+02	1.395E+00	1.172E+00
27	1988	0.072	8.833E+03	8.760E+03	6.320E+02	6.320E+02	4.871E+02	1.139E+00	1.132E+00
28	1989	0.094	8.688E+03	8.530E+03	8.016E+02	8.016E+02	4.902E+02	1.483E+00	1.113E+00
29	1990	0.074	8.377E+03	8.314E+03	6.157E+02	6.157E+02	4.924E+02	1.169E+00	1.073E+00
30	1991	0.065	8.254E+03	8.234E+03	5.321E+02	5.321E+02	4.930E+02	1.020E+00	1.057E+00
31	1992	0.078	8.215E+03	8.144E+03	6.324E+02	6.324E+02	4.936E+02	1.226E+00	1.052E+00
32	1993	0.086	8.076E+03	7.979E+03	6.847E+02	6.847E+02	4.943E+02	1.354E+00	1.035E+00
33	1994	0.095	7.885E+03	7.763E+03	7.354E+02	7.354E+02	4.945E+02	1.495E+00	1.010E+00
34	1995	0.093	7.644E+03	7.540E+03	7.002E+02	7.002E+02	4.939E+02	1.466E+00	9.794E-01
35	1996	0.087	7.438E+03	7.363E+03	6.405E+02	6.405E+02	4.929E+02	1.373E+00	9.530E-01
36	1997	0.069	7.291E+03	7.284E+03	5.061E+02	5.061E+02	4.923E+02	1.097E+00	9.341E-01
37	1998	0.080	7.277E+03	7.233E+03	5.775E+02	5.775E+02	4.919E+02	1.260E+00	9.323E-01
38	1999	0.080	7.191E+03	7.150E+03	5.721E+02	5.721E+02	4.911E+02	1.263E+00	9.213E-01
39	2000	0.056	7.110E+03	7.155E+03	4.010E+02	4.010E+02	4.911E+02	8.845E-01	9.110E-01
40	2001	0.068	7.200E+03	7.203E+03	4.863E+02	4.863E+02	4.916E+02	1.066E+00	9.225E-01
41	2002	0.055	7.206E+03	7.252E+03	3.999E+02	3.999E+02	4.921E+02	8.704E-01	9.232E-01
42	2003	0.071	7.298E+03	7.284E+03	5.200E+02	5.200E+02	4.923E+02	1.127E+00	9.350E-01
43	2004	0.074	7.270E+03	7.247E+03	5.370E+02	5.370E+02	4.920E+02	1.170E+00	9.315E-01
44	2005		7.225E+03						9.257E-01

CORRECTED SAFMC Gag SEDAR 10 (2006) Landings and Indices, B1/K=0.9 Page 4

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED) Headboat Index (1962-2004), Total Ldgs m

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

Obs	Year	Observed CPUE	Estimated CPUE	Estim F	Observed yield	Model yield	Resid in log scale	Statist weight
1	1962	*	6.916E+00	0.0125	1.762E+02	1.762E+02	0.00000	1.000E+00
2	1963	*	6.920E+00	0.0114	1.605E+02	1.605E+02	0.00000	1.000E+00
3	1964	*	6.930E+00	0.0107	1.504E+02	1.504E+02	0.00000	1.000E+00
4	1965	*	6.941E+00	0.0109	1.542E+02	1.542E+02	0.00000	1.000E+00
5	1966	*	6.959E+00	0.0082	1.165E+02	1.165E+02	0.00000	1.000E+00
6	1967	*	6.952E+00	0.0175	2.467E+02	2.467E+02	0.00000	1.000E+00
7	1968	*	6.887E+00	0.0263	3.677E+02	3.677E+02	0.00000	1.000E+00
8	1969	*	6.828E+00	0.0183	2.542E+02	2.542E+02	0.00000	1.000E+00
9	1970	*	6.778E+00	0.0254	3.494E+02	3.494E+02	0.00000	1.000E+00
10	1971	*	6.708E+00	0.0264	3.596E+02	3.596E+02	0.00000	1.000E+00
11	1972	*	6.675E+00	0.0163	2.217E+02	2.217E+02	0.00000	1.000E+00
12	1973	1.929E+01	6.641E+00	0.0277	3.736E+02	3.736E+02	-1.06610	1.000E+00
13	1974	1.468E+01	6.562E+00	0.0320	4.260E+02	4.260E+02	-0.80532	1.000E+00
14	1975	7.044E+00	6.483E+00	0.0305	4.013E+02	4.013E+02	-0.08298	1.000E+00
15	1976	5.117E+00	6.389E+00	0.0398	5.170E+02	5.170E+02	0.22199	1.000E+00
16	1977	4.938E+00	6.274E+00	0.0411	5.235E+02	5.235E+02	0.23946	1.000E+00
17	1978	4.436E+00	6.112E+00	0.0601	7.458E+02	7.458E+02	0.32058	1.000E+00
18	1979	6.348E+00	5.917E+00	0.0601	7.228E+02	7.228E+02	-0.07035	1.000E+00
19	1980	6.661E+00	5.759E+00	0.0549	6.426E+02	6.426E+02	-0.14552	1.000E+00
20	1981	5.149E+00	5.586E+00	0.0724	8.213E+02	8.213E+02	0.08139	1.000E+00
21	1982	4.885E+00	5.424E+00	0.0584	6.438E+02	6.438E+02	0.10465	1.000E+00
22	1983	4.367E+00	5.254E+00	0.0823	8.782E+02	8.782E+02	0.18497	1.000E+00
23	1984	5.671E+00	4.912E+00	0.1383	1.380E+03	1.380E+03	-0.14374	1.000E+00
24	1985	4.416E+00	4.627E+00	0.0774	7.279E+02	7.279E+02	0.04672	1.000E+00
25	1986	3.242E+00	4.533E+00	0.0661	6.091E+02	6.091E+02	0.33522	1.000E+00
26	1987	3.550E+00	4.423E+00	0.0884	7.943E+02	7.943E+02	0.21998	1.000E+00
27	1988	4.183E+00	4.312E+00	0.0721	6.320E+02	6.320E+02	0.03040	1.000E+00
28	1989	3.824E+00	4.199E+00	0.0940	8.016E+02	8.016E+02	0.09354	1.000E+00
29	1990	3.575E+00	4.093E+00	0.0741	6.157E+02	6.157E+02	0.13529	1.000E+00
30	1991	3.698E+00	4.053E+00	0.0646	5.321E+02	5.321E+02	0.09172	1.000E+00
31	1992	4.444E+00	4.009E+00	0.0777	6.324E+02	6.324E+02	-0.10299	1.000E+00
32	1993	4.622E+00	3.928E+00	0.0858	6.847E+02	6.847E+02	-0.16274	1.000E+00
33	1994	4.041E+00	3.821E+00	0.0947	7.354E+02	7.354E+02	-0.05587	1.000E+00
34	1995	4.625E+00	3.712E+00	0.0929	7.002E+02	7.002E+02	-0.22003	1.000E+00
35	1996	3.355E+00	3.625E+00	0.0870	6.405E+02	6.405E+02	0.07733	1.000E+00
36	1997	3.505E+00	3.585E+00	0.0695	5.061E+02	5.061E+02	0.02270	1.000E+00
37	1998	3.966E+00	3.561E+00	0.0798	5.775E+02	5.775E+02	-0.10777	1.000E+00
38	1999	3.082E+00	3.520E+00	0.0800	5.721E+02	5.721E+02	0.13282	1.000E+00
39	2000	3.155E+00	3.522E+00	0.0560	4.010E+02	4.010E+02	0.11016	1.000E+00
40	2001	3.174E+00	3.546E+00	0.0675	4.863E+02	4.863E+02	0.11076	1.000E+00
41	2002	3.552E+00	3.570E+00	0.0551	3.999E+02	3.999E+02	0.00503	1.000E+00
42	2003	2.662E+00	3.586E+00	0.0714	5.200E+02	5.200E+02	0.29783	1.000E+00
43	2004	3.228E+00	3.568E+00	0.0741	5.370E+02	5.370E+02	0.10003	1.000E+00

* Asterisk indicates missing value(s).

CORRECTED SAFMC Gag SEDAR 10 (2006) Landings and Indices, B1/K=0.9 Page 5

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

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

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Statist weight
1	1962	0.000E+00	0.000E+00	--	*	8.979E-01	0.00000	1.000E+00
2	1963	0.000E+00	0.000E+00	--	*	8.985E-01	0.00000	1.000E+00
3	1964	0.000E+00	0.000E+00	--	*	8.998E-01	0.00000	1.000E+00
4	1965	0.000E+00	0.000E+00	--	*	9.012E-01	0.00000	1.000E+00
5	1966	0.000E+00	0.000E+00	--	*	9.035E-01	0.00000	1.000E+00
6	1967	0.000E+00	0.000E+00	--	*	9.026E-01	0.00000	1.000E+00
7	1968	0.000E+00	0.000E+00	--	*	8.942E-01	0.00000	1.000E+00
8	1969	0.000E+00	0.000E+00	--	*	8.866E-01	0.00000	1.000E+00
9	1970	0.000E+00	0.000E+00	--	*	8.800E-01	0.00000	1.000E+00
10	1971	0.000E+00	0.000E+00	--	*	8.710E-01	0.00000	1.000E+00
11	1972	0.000E+00	0.000E+00	--	*	8.667E-01	0.00000	1.000E+00
12	1973	0.000E+00	0.000E+00	--	*	8.622E-01	0.00000	1.000E+00
13	1974	0.000E+00	0.000E+00	--	*	8.519E-01	0.00000	1.000E+00
14	1975	0.000E+00	0.000E+00	--	*	8.417E-01	0.00000	1.000E+00
15	1976	0.000E+00	0.000E+00	--	*	8.295E-01	0.00000	1.000E+00
16	1977	0.000E+00	0.000E+00	--	*	8.146E-01	0.00000	1.000E+00
17	1978	0.000E+00	0.000E+00	--	*	7.936E-01	0.00000	1.000E+00
18	1979	0.000E+00	0.000E+00	--	*	7.682E-01	0.00000	1.000E+00
19	1980	0.000E+00	0.000E+00	--	*	7.477E-01	0.00000	1.000E+00
20	1981	0.000E+00	0.000E+00	--	*	7.252E-01	0.00000	1.000E+00
21	1982	0.000E+00	0.000E+00	--	*	7.042E-01	0.00000	1.000E+00
22	1983	0.000E+00	0.000E+00	--	*	6.822E-01	0.00000	1.000E+00
23	1984	0.000E+00	0.000E+00	--	*	6.377E-01	0.00000	1.000E+00
24	1985	0.000E+00	0.000E+00	--	*	6.008E-01	0.00000	1.000E+00
25	1986	0.000E+00	0.000E+00	--	*	5.886E-01	0.00000	1.000E+00
26	1987	0.000E+00	0.000E+00	--	*	5.743E-01	0.00000	1.000E+00
27	1988	0.000E+00	0.000E+00	--	*	5.599E-01	0.00000	1.000E+00
28	1989	0.000E+00	0.000E+00	--	*	5.452E-01	0.00000	1.000E+00
29	1990	0.000E+00	0.000E+00	--	*	5.314E-01	0.00000	1.000E+00
30	1991	0.000E+00	0.000E+00	--	*	5.263E-01	0.00000	1.000E+00
31	1992	1.000E+00	1.000E+00	--	4.370E-01	5.205E-01	-0.17490	1.000E+00
32	1993	1.000E+00	1.000E+00	--	4.540E-01	5.100E-01	-0.11626	1.000E+00
33	1994	1.000E+00	1.000E+00	--	4.360E-01	4.962E-01	-0.12925	1.000E+00
34	1995	1.000E+00	1.000E+00	--	4.510E-01	4.819E-01	-0.06625	1.000E+00
35	1996	1.000E+00	1.000E+00	--	4.820E-01	4.706E-01	0.02390	1.000E+00
36	1997	1.000E+00	1.000E+00	--	3.700E-01	4.655E-01	-0.22965	1.000E+00
37	1998	1.000E+00	1.000E+00	--	4.580E-01	4.623E-01	-0.00938	1.000E+00
38	1999	1.000E+00	1.000E+00	--	4.890E-01	4.570E-01	0.06769	1.000E+00
39	2000	1.000E+00	1.000E+00	--	4.390E-01	4.573E-01	-0.04091	1.000E+00
40	2001	1.000E+00	1.000E+00	--	4.170E-01	4.604E-01	-0.09893	1.000E+00
41	2002	1.000E+00	1.000E+00	--	4.840E-01	4.635E-01	0.04328	1.000E+00
42	2003	1.000E+00	1.000E+00	--	6.460E-01	4.655E-01	0.32763	1.000E+00
43	2004	1.000E+00	1.000E+00	--	6.930E-01	4.632E-01	0.40287	1.000E+00

* Asterisk indicates missing value(s).

RESULTS FOR DATA SERIES # 3 (NON-BOOTSTRAPPED) MRFSS Index

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

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Statist weight
1	1962	0.000E+00	0.000E+00	--	*	1.422E+00	0.00000	1.000E+00
2	1963	0.000E+00	0.000E+00	--	*	1.423E+00	0.00000	1.000E+00
3	1964	0.000E+00	0.000E+00	--	*	1.425E+00	0.00000	1.000E+00
4	1965	0.000E+00	0.000E+00	--	*	1.427E+00	0.00000	1.000E+00
5	1966	0.000E+00	0.000E+00	--	*	1.431E+00	0.00000	1.000E+00
6	1967	0.000E+00	0.000E+00	--	*	1.429E+00	0.00000	1.000E+00
7	1968	0.000E+00	0.000E+00	--	*	1.416E+00	0.00000	1.000E+00
8	1969	0.000E+00	0.000E+00	--	*	1.404E+00	0.00000	1.000E+00
9	1970	0.000E+00	0.000E+00	--	*	1.394E+00	0.00000	1.000E+00
10	1971	0.000E+00	0.000E+00	--	*	1.379E+00	0.00000	1.000E+00
11	1972	0.000E+00	0.000E+00	--	*	1.372E+00	0.00000	1.000E+00
12	1973	0.000E+00	0.000E+00	--	*	1.365E+00	0.00000	1.000E+00
13	1974	0.000E+00	0.000E+00	--	*	1.349E+00	0.00000	1.000E+00
14	1975	0.000E+00	0.000E+00	--	*	1.333E+00	0.00000	1.000E+00
15	1976	0.000E+00	0.000E+00	--	*	1.314E+00	0.00000	1.000E+00
16	1977	0.000E+00	0.000E+00	--	*	1.290E+00	0.00000	1.000E+00
17	1978	0.000E+00	0.000E+00	--	*	1.257E+00	0.00000	1.000E+00
18	1979	0.000E+00	0.000E+00	--	*	1.217E+00	0.00000	1.000E+00
19	1980	0.000E+00	0.000E+00	--	*	1.184E+00	0.00000	1.000E+00
20	1981	1.000E+00	1.000E+00	--	6.280E-01	1.148E+00	-0.60361	1.000E+00
21	1982	1.000E+00	1.000E+00	--	5.060E-01	1.115E+00	-0.79024	1.000E+00
22	1983	1.000E+00	1.000E+00	--	5.130E-01	1.080E+00	-0.74473	1.000E+00
23	1984	1.000E+00	1.000E+00	--	6.800E-01	1.010E+00	-0.39549	1.000E+00
24	1985	1.000E+00	1.000E+00	--	1.275E+00	9.514E-01	0.29279	1.000E+00
25	1986	1.000E+00	1.000E+00	--	1.265E+00	9.320E-01	0.30546	1.000E+00
26	1987	1.000E+00	1.000E+00	--	1.092E+00	9.095E-01	0.18288	1.000E+00
27	1988	1.000E+00	1.000E+00	--	7.570E-01	8.866E-01	-0.15802	1.000E+00
28	1989	1.000E+00	1.000E+00	--	2.311E+00	8.633E-01	0.98464	1.000E+00
29	1990	1.000E+00	1.000E+00	--	8.800E-01	8.415E-01	0.04471	1.000E+00
30	1991	1.000E+00	1.000E+00	--	1.118E+00	8.334E-01	0.29382	1.000E+00
31	1992	1.000E+00	1.000E+00	--	1.258E+00	8.243E-01	0.42275	1.000E+00
32	1993	1.000E+00	1.000E+00	--	1.166E+00	8.076E-01	0.36728	1.000E+00
33	1994	1.000E+00	1.000E+00	--	9.030E-01	7.857E-01	0.13914	1.000E+00
34	1995	1.000E+00	1.000E+00	--	1.409E+00	7.631E-01	0.61323	1.000E+00
35	1996	1.000E+00	1.000E+00	--	6.480E-01	7.453E-01	-0.13985	1.000E+00
36	1997	1.000E+00	1.000E+00	--	7.200E-01	7.372E-01	-0.02360	1.000E+00
37	1998	1.000E+00	1.000E+00	--	3.370E-01	7.321E-01	-0.77586	1.000E+00
38	1999	1.000E+00	1.000E+00	--	1.168E+00	7.237E-01	0.47869	1.000E+00
39	2000	1.000E+00	1.000E+00	--	6.350E-01	7.242E-01	-0.13148	1.000E+00
40	2001	1.000E+00	1.000E+00	--	4.630E-01	7.290E-01	-0.45398	1.000E+00
41	2002	1.000E+00	1.000E+00	--	8.470E-01	7.340E-01	0.14320	1.000E+00
42	2003	1.000E+00	1.000E+00	--	5.180E-01	7.372E-01	-0.35289	1.000E+00
43	2004	1.000E+00	1.000E+00	--	9.910E-01	7.335E-01	0.30086	1.000E+00

* Asterisk indicates missing value(s).

CORRECTED SAFMC Gag SEDAR 10 (2006) Landings and Indices, B1/K=0.9 Page 7

ESTIMATES FROM BOOTSTRAPPED ANALYSIS

Param name	Point estimate	Estimated bias in pt estimate	Estimated relative bias	Bias-corrected approximate confidence limits 80% lower	80% upper	50% lower	50% upper	Inter-quartile range	Relative IQ range
B1/K	9.000E-01	0.000E+00	0.00%	9.000E-01	9.000E-01	9.000E-01	9.000E-01	0.000E+00	0.000
K	1.561E+04	1.023E+02	0.66%	1.045E+04	3.522E+04	1.328E+04	2.785E+04	1.457E+04	0.933
q(1)	4.922E-04	1.415E-04	28.74%	2.073E-04	8.096E-04	2.677E-04	6.131E-04	3.454E-04	0.702
q(2)	6.391E-05	1.907E-05	29.84%	2.491E-05	1.049E-04	3.471E-05	7.845E-05	4.373E-05	0.684
q(3)	1.012E-04	2.910E-05	28.75%	4.055E-05	1.627E-04	5.358E-05	1.229E-04	6.934E-05	0.685
MSY	4.945E+02	7.153E+00	1.45%	1.995E+02	5.627E+02	3.088E+02	5.204E+02	2.116E+02	0.428
Ye(2005)	4.918E+02	-5.383E+00	-1.09%	2.433E+02	5.692E+02	3.651E+02	5.294E+02	1.643E+02	0.334
Y.@Fmsy	4.578E+02	1.709E+01	3.73%	2.669E+02	6.141E+02	3.569E+02	5.323E+02	1.754E+02	0.383
Bmsy	7.805E+03	5.115E+01	0.66%	5.225E+03	1.761E+04	6.641E+03	1.393E+04	7.285E+03	0.933
Fmsy	6.336E-02	2.135E-02	33.70%	1.460E-02	1.092E-01	2.579E-02	8.073E-02	5.493E-02	0.867
fmsy(1)	1.287E+02	-1.172E+00	-0.91%	8.845E+01	1.571E+02	1.117E+02	1.428E+02	3.114E+01	0.242
fmsy(2)	9.914E+02	4.914E+00	0.50%	6.831E+02	1.311E+03	8.415E+02	1.135E+03	2.936E+02	0.296
fmsy(3)	6.260E+02	-1.086E+00	-0.17%	4.513E+02	8.026E+02	5.599E+02	7.235E+02	1.636E+02	0.261
B./Bmsy	9.257E-01	7.836E-03	0.85%	7.667E-01	1.161E+00	8.524E-01	1.060E+00	2.079E-01	0.225
F./Fmsy	1.170E+00	1.121E-01	9.58%	8.750E-01	1.970E+00	1.007E+00	1.487E+00	4.801E-01	0.410
Ye./MSY	9.945E-01	-2.369E-02	-2.38%	9.807E-01	1.000E+00	9.931E-01	9.999E-01	6.795E-03	0.007
q2/q1	1.298E-01	7.974E-04	0.61%	1.095E-01	1.513E-01	1.173E-01	1.419E-01	2.459E-02	0.189
q3/q1	2.056E-01	5.346E-05	0.03%	1.814E-01	2.339E-01	1.936E-01	2.204E-01	2.674E-02	0.130

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

Unitless limit reference point in F (Fmsy/F.): 0.8551
CV of above (from bootstrap distribution): 0.3423

NOTES ON BOOTSTRAPPED ESTIMATES:

- Bootstrap results were computed from 600 trials.
- Results are conditional on bounds set on MSY and K in the input file.
- All bootstrapped intervals are approximate. The statistical literature recommends using at least 1000 trials for accurate 95% intervals. The default 80% intervals used by ASPIC should require fewer trials for equivalent accuracy. Using at least 500 trials is recommended.
- Bias estimates are typically of high variance and therefore may be misleading.

Trials replaced for lack of convergence:	0	Trials replaced for MSY out of bounds:	18
Trials replaced for q out-of-bounds:	0		
Trials replaced for K out-of-bounds:	68	Residual-adjustment factor:	1.0383

Elapsed time: 0 hours, 5 minutes, 45 seconds.

D.2 ASPIC results based on increasing catchability

```
CORRECTED SAFMC Gag SEDAR 10 (2006), increasing q 2%/yr from 1980                                         Page 1
                                                                              Thursday, 14 Dec 2006 at 13:18:06
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 5.16)
                                                                                               BOT program mode
Author:    Michael H. Prager; NOAA Center for Coastal Fisheries and Habitat Research         LOGISTIC model mode
           101 Pivers Island Road; Beaufort, North Carolina  28516  USA                        YLD conditioning
           Mike.Prager@noaa.gov                                                                SSE optimization

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

CONTROL PARAMETERS (FROM INPUT FILE)                                            Input file: gag2006_117_boot.inp
------------------------------------------------------------------------------------------------------------------------
Operation of ASPIC:  Fit logistic (Schaefer) model by direct optimization with bootstrap.
Number of years analyzed:                        43          Number of bootstrap trials:                         600
Number of data series:                            3          Bounds on MSY (min, max):       1.000E+02     2.000E+03
Objective function:                   Least squares          Bounds on K (min, max):         1.200E+03     4.000E+04
Relative conv. criterion (simplex):       1.000E-08          Monte Carlo search mode, trials:        1         20000
Relative conv. criterion (restart):       3.000E-08          Random number seed:                            82184571
Relative conv. criterion (effort):        1.000E-04          Identical convergences required in fitting:           8
Maximum F allowed in fitting:                 4.000


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

WARNING: Negative correlations detected between some indices.  A fundamental assumption of ASPIC is that all indices
         represent the abundance of the stock.  That assumption appears to be violated.


CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
------------------------------------------------------------------------------------------------------------------------
                                       |
 1  Headboat Index (1962-2004), Tota...|   1.000
                                       |      32
                                       |
 2  Commercial Logbook Index           |  -0.244   1.000
                                       |      13      13
                                       |
 3  MRFSS Index                        |   0.145   0.094   1.000
                                       |      24      13      24
                                       --------------------------------------------------
                                               1       2       3


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

Loss(-1)  SSE in yield                              0.000E+00
Loss(0)   Penalty for B1 > K                        0.000E+00     1           N/A     1.000E+00          N/A
Loss(1)   Headboat Index (1962-2004), Total Ldgs    2.489E+00    32     8.298E-02     1.000E+00     9.896E-01        0.408
Loss(2)   Commercial Logbook Index                  4.102E-01    13     3.729E-02     1.000E+00     2.202E+00       -0.718
Loss(3)   MRFSS Index                               4.979E+00    24     2.263E-01     1.000E+00     3.628E-01       -0.142
..............................................................................................
TOTAL OBJECTIVE FUNCTION, MSE, RMSE:           7.87852204E+00           1.231E-01     3.509E-01
Estimated contrast index (ideal = 1.0):                0.6128           C* = (Bmax-Bmin)/K
Estimated nearness index (ideal = 1.0):                1.0000           N* = 1 - |min(B-Bmsy)|/K
```

CORRECTED SAFMC Gag SEDAR 10 (2006), increasing q 2%/yr from 1980 Page 2

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	User/pgm guess	2nd guess	Estimated	User guess
B1/K	Starting relative biomass (in 1962)	9.000E-01	9.000E-01	4.000E-01	0	1
MSY	Maximum sustainable yield	5.304E+02	5.000E+02	4.495E+02	1	1
K	Maximum population size	1.009E+04	6.000E+03	2.697E+03	1	1
phi	Shape of production curve (Bmsy/K)	0.5000	0.5000	----	0	1
---------	Catchability Coefficients by Data Series ---------------					
q(1)	Headboat Index (1962-2004), Total Ldgs	7.764E-04	5.000E-04	4.750E-02	1	1
q(2)	Commercial Logbook Index	1.006E-04	5.000E-05	4.750E-03	1	1
q(3)	MRFSS Index	1.595E-04	5.000E-05	4.750E-03	1	1

MANAGEMENT and DERIVED PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	Logistic formula	General formula
MSY	Maximum sustainable yield	5.304E+02	----	----
Bmsy	Stock biomass giving MSY	5.043E+03	K/2	K*n**(1/(1-n))
Fmsy	Fishing mortality rate at MSY	1.052E-01	MSY/Bmsy	MSY/Bmsy
n	Exponent in production function	2.0000	----	----
g	Fletcher's gamma	4.000E+00	----	[n**(n/(n-1))]/[n-1]
B./Bmsy	Ratio: B(2005)/Bmsy	6.037E-01	----	----
F./Fmsy	Ratio: F(2004)/Fmsy	1.654E+00	----	----
Fmsy/F.	Ratio: Fmsy/F(2004)	6.046E-01	----	----
Y.(Fmsy)	Approx. yield available at Fmsy in 2005	3.202E+02	MSY*B./Bmsy	MSY*B./Bmsy
	...as proportion of MSY	6.037E-01	----	----
Ye.	Equilibrium yield available in 2005	4.471E+02	4*MSY*(B/K-(B/K)**2)	g*MSY*(B/K-(B/K)**n)
	...as proportion of MSY	8.429E-01	----	----
---------	Fishing effort rate at MSY in units of each CE or CC series ---------			
fmsy(1)	Headboat Index (1962-2004), Total Ldgs	1.355E+02	Fmsy/q(1)	Fmsy/q(1)

CORRECTED SAFMC Gag SEDAR 10 (2006), increasing q 2%/yr from 1980 Page 3

ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

Obs	Year or ID	Estimated total F mort	Estimated starting biomass	Estimated average biomass	Observed total yield	Model total yield	Estimated surplus production	Ratio of F mort to Fmsy	Ratio of biomass to Bmsy
1	1962	0.019	9.077E+03	9.084E+03	1.762E+02	1.762E+02	1.898E+02	1.844E-01	1.800E+00
2	1963	0.018	9.091E+03	9.104E+03	1.605E+02	1.605E+02	1.864E+02	1.676E-01	1.803E+00
3	1964	0.016	9.117E+03	9.133E+03	1.504E+02	1.504E+02	1.815E+02	1.566E-01	1.808E+00
4	1965	0.017	9.148E+03	9.160E+03	1.542E+02	1.542E+02	1.770E+02	1.601E-01	1.814E+00
5	1966	0.013	9.171E+03	9.198E+03	1.165E+02	1.165E+02	1.703E+02	1.204E-01	1.819E+00
6	1967	0.027	9.224E+03	9.186E+03	2.467E+02	2.467E+02	1.724E+02	2.553E-01	1.829E+00
7	1968	0.041	9.150E+03	9.060E+03	3.677E+02	3.677E+02	1.938E+02	3.858E-01	1.814E+00
8	1969	0.028	8.976E+03	8.954E+03	2.542E+02	2.542E+02	2.114E+02	2.699E-01	1.780E+00
9	1970	0.039	8.933E+03	8.869E+03	3.494E+02	3.494E+02	2.251E+02	3.745E-01	1.771E+00
10	1971	0.041	8.809E+03	8.749E+03	3.596E+02	3.596E+02	2.439E+02	3.908E-01	1.747E+00
11	1972	0.025	8.693E+03	8.708E+03	2.217E+02	2.217E+02	2.503E+02	2.420E-01	1.724E+00
12	1973	0.043	8.722E+03	8.662E+03	3.736E+02	3.736E+02	2.573E+02	4.101E-01	1.730E+00
13	1974	0.050	8.606E+03	8.529E+03	4.260E+02	4.260E+02	2.770E+02	4.749E-01	1.706E+00
14	1975	0.048	8.457E+03	8.402E+03	4.013E+02	4.013E+02	2.951E+02	4.541E-01	1.677E+00
15	1976	0.063	8.350E+03	8.247E+03	5.170E+02	5.170E+02	3.163E+02	5.960E-01	1.656E+00
16	1977	0.065	8.150E+03	8.056E+03	5.235E+02	5.235E+02	3.411E+02	6.178E-01	1.616E+00
17	1978	0.096	7.967E+03	7.775E+03	7.458E+02	7.458E+02	3.745E+02	9.120E-01	1.580E+00
18	1979	0.097	7.596E+03	7.435E+03	7.228E+02	7.228E+02	4.109E+02	9.243E-01	1.506E+00
19	1980	0.090	7.284E+03	7.177E+03	6.426E+02	6.426E+02	4.353E+02	8.512E-01	1.444E+00
20	1981	0.119	7.077E+03	6.890E+03	8.213E+02	8.213E+02	4.591E+02	1.133E+00	1.403E+00
21	1982	0.097	6.715E+03	6.629E+03	6.438E+02	6.438E+02	4.779E+02	9.233E-01	1.331E+00
22	1983	0.138	6.549E+03	6.351E+03	8.782E+02	8.782E+02	4.945E+02	1.315E+00	1.299E+00
23	1984	0.241	6.165E+03	5.716E+03	1.380E+03	1.380E+03	5.197E+02	2.295E+00	1.222E+00
24	1985	0.140	5.305E+03	5.203E+03	7.279E+02	7.279E+02	5.298E+02	1.330E+00	1.052E+00
25	1986	0.120	5.107E+03	5.067E+03	6.091E+02	6.091E+02	5.304E+02	1.143E+00	1.013E+00
26	1987	0.162	5.028E+03	4.892E+03	7.943E+02	7.943E+02	5.298E+02	1.544E+00	9.971E-01
27	1988	0.134	4.764E+03	4.711E+03	6.320E+02	6.320E+02	5.281E+02	1.276E+00	9.446E-01
28	1989	0.177	4.660E+03	4.518E+03	8.016E+02	8.016E+02	5.245E+02	1.687E+00	9.240E-01
29	1990	0.142	4.383E+03	4.334E+03	6.157E+02	6.157E+02	5.199E+02	1.351E+00	8.691E-01
30	1991	0.124	4.287E+03	4.280E+03	5.321E+02	5.321E+02	5.183E+02	1.182E+00	8.501E-01
31	1992	0.150	4.273E+03	4.214E+03	6.324E+02	6.324E+02	5.161E+02	1.427E+00	8.473E-01
32	1993	0.168	4.157E+03	4.068E+03	6.847E+02	6.847E+02	5.106E+02	1.600E+00	8.243E-01
33	1994	0.190	3.983E+03	3.863E+03	7.354E+02	7.354E+02	5.013E+02	1.810E+00	7.897E-01
34	1995	0.192	3.749E+03	3.641E+03	7.002E+02	7.002E+02	4.893E+02	1.828E+00	7.433E-01
35	1996	0.185	3.538E+03	3.455E+03	6.405E+02	6.405E+02	4.778E+02	1.763E+00	7.015E-01
36	1997	0.151	3.375E+03	3.357E+03	5.061E+02	5.061E+02	4.712E+02	1.433E+00	6.692E-01
37	1998	0.176	3.340E+03	3.283E+03	5.775E+02	5.775E+02	4.658E+02	1.672E+00	6.623E-01
38	1999	0.180	3.228E+03	3.170E+03	5.721E+02	5.721E+02	4.572E+02	1.716E+00	6.402E-01
39	2000	0.128	3.113E+03	3.141E+03	4.010E+02	4.010E+02	4.550E+02	1.214E+00	6.174E-01
40	2001	0.154	3.167E+03	3.152E+03	4.863E+02	4.863E+02	4.559E+02	1.467E+00	6.281E-01
41	2002	0.126	3.137E+03	3.166E+03	3.999E+02	3.999E+02	4.569E+02	1.201E+00	6.221E-01
42	2003	0.164	3.194E+03	3.162E+03	5.200E+02	5.200E+02	4.566E+02	1.564E+00	6.334E-01
43	2004	0.174	3.131E+03	3.087E+03	5.370E+02	5.370E+02	4.506E+02	1.654E+00	6.208E-01
44	2005		3.044E+03						6.037E-01

CORRECTED SAFMC Gag SEDAR 10 (2006), increasing q 2%/yr from 1980 Page 4

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED) Headboat Index (1962-2004), Total Ldgs m

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

Obs	Year	Observed CPUE	Estimated CPUE	Estim F	Observed yield	Model yield	Resid in log scale	Statist weight
1	1962	*	7.053E+00	0.0194	1.762E+02	1.762E+02	0.00000	1.000E+00
2	1963	*	7.068E+00	0.0176	1.605E+02	1.605E+02	0.00000	1.000E+00
3	1964	*	7.090E+00	0.0165	1.504E+02	1.504E+02	0.00000	1.000E+00
4	1965	*	7.111E+00	0.0168	1.542E+02	1.542E+02	0.00000	1.000E+00
5	1966	*	7.141E+00	0.0127	1.165E+02	1.165E+02	0.00000	1.000E+00
6	1967	*	7.132E+00	0.0269	2.467E+02	2.467E+02	0.00000	1.000E+00
7	1968	*	7.034E+00	0.0406	3.677E+02	3.677E+02	0.00000	1.000E+00
8	1969	*	6.952E+00	0.0284	2.542E+02	2.542E+02	0.00000	1.000E+00
9	1970	*	6.886E+00	0.0394	3.494E+02	3.494E+02	0.00000	1.000E+00
10	1971	*	6.793E+00	0.0411	3.596E+02	3.596E+02	0.00000	1.000E+00
11	1972	*	6.761E+00	0.0255	2.217E+02	2.217E+02	0.00000	1.000E+00
12	1973	1.929E+01	6.725E+00	0.0431	3.736E+02	3.736E+02	-1.05355	1.000E+00
13	1974	1.468E+01	6.621E+00	0.0499	4.260E+02	4.260E+02	-0.79627	1.000E+00
14	1975	7.044E+00	6.523E+00	0.0478	4.013E+02	4.013E+02	-0.07688	1.000E+00
15	1976	5.117E+00	6.402E+00	0.0627	5.170E+02	5.170E+02	0.22410	1.000E+00
16	1977	4.938E+00	6.254E+00	0.0650	5.235E+02	5.235E+02	0.23625	1.000E+00
17	1978	4.436E+00	6.036E+00	0.0959	7.458E+02	7.458E+02	0.30802	1.000E+00
18	1979	6.348E+00	5.772E+00	0.0972	7.228E+02	7.228E+02	-0.09511	1.000E+00
19	1980	6.530E+00	5.572E+00	0.0895	6.426E+02	6.426E+02	-0.15863	1.000E+00
20	1981	4.951E+00	5.349E+00	0.1192	8.213E+02	8.213E+02	0.07730	1.000E+00
21	1982	4.609E+00	5.147E+00	0.0971	6.438E+02	6.438E+02	0.11035	1.000E+00
22	1983	4.043E+00	4.930E+00	0.1383	8.782E+02	8.782E+02	0.19842	1.000E+00
23	1984	5.156E+00	4.437E+00	0.2414	1.380E+03	1.380E+03	-0.15010	1.000E+00
24	1985	3.943E+00	4.040E+00	0.1399	7.279E+02	7.279E+02	0.02423	1.000E+00
25	1986	2.844E+00	3.934E+00	0.1202	6.091E+02	6.091E+02	0.32432	1.000E+00
26	1987	3.060E+00	3.798E+00	0.1624	7.943E+02	7.943E+02	0.21613	1.000E+00
27	1988	3.545E+00	3.657E+00	0.1342	6.320E+02	6.320E+02	0.03114	1.000E+00
28	1989	3.186E+00	3.507E+00	0.1774	8.016E+02	8.016E+02	0.09607	1.000E+00
29	1990	2.930E+00	3.365E+00	0.1421	6.157E+02	6.157E+02	0.13832	1.000E+00
30	1991	2.983E+00	3.323E+00	0.1243	5.321E+02	5.321E+02	0.10786	1.000E+00
31	1992	3.527E+00	3.271E+00	0.1501	6.324E+02	6.324E+02	-0.07522	1.000E+00
32	1993	3.611E+00	3.158E+00	0.1683	6.847E+02	6.847E+02	-0.13401	1.000E+00
33	1994	3.109E+00	2.999E+00	0.1904	7.354E+02	7.354E+02	-0.03604	1.000E+00
34	1995	3.504E+00	2.827E+00	0.1923	7.002E+02	7.002E+02	-0.21486	1.000E+00
35	1996	2.503E+00	2.682E+00	0.1854	6.405E+02	6.405E+02	0.06909	1.000E+00
36	1997	2.577E+00	2.606E+00	0.1507	5.061E+02	5.061E+02	0.01134	1.000E+00
37	1998	2.874E+00	2.549E+00	0.1759	5.775E+02	5.775E+02	-0.12002	1.000E+00
38	1999	2.201E+00	2.461E+00	0.1805	5.721E+02	5.721E+02	0.11164	1.000E+00
39	2000	2.221E+00	2.438E+00	0.1277	4.010E+02	4.010E+02	0.09333	1.000E+00
40	2001	2.204E+00	2.447E+00	0.1543	4.863E+02	4.863E+02	0.10462	1.000E+00
41	2002	2.433E+00	2.458E+00	0.1263	3.999E+02	3.999E+02	0.01010	1.000E+00
42	2003	1.799E+00	2.455E+00	0.1645	5.200E+02	5.200E+02	0.31078	1.000E+00
43	2004	2.152E+00	2.396E+00	0.1740	5.370E+02	5.370E+02	0.10757	1.000E+00

* Asterisk indicates missing value(s).

CORRECTED SAFMC Gag SEDAR 10 (2006), increasing q 2%/yr from 1980 Page 5

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

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

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Statist weight
1	1962	0.000E+00	0.000E+00	--	*	9.140E-01	0.00000	1.000E+00
2	1963	0.000E+00	0.000E+00	--	*	9.160E-01	0.00000	1.000E+00
3	1964	0.000E+00	0.000E+00	--	*	9.188E-01	0.00000	1.000E+00
4	1965	0.000E+00	0.000E+00	--	*	9.215E-01	0.00000	1.000E+00
5	1966	0.000E+00	0.000E+00	--	*	9.254E-01	0.00000	1.000E+00
6	1967	0.000E+00	0.000E+00	--	*	9.242E-01	0.00000	1.000E+00
7	1968	0.000E+00	0.000E+00	--	*	9.115E-01	0.00000	1.000E+00
8	1969	0.000E+00	0.000E+00	--	*	9.009E-01	0.00000	1.000E+00
9	1970	0.000E+00	0.000E+00	--	*	8.923E-01	0.00000	1.000E+00
10	1971	0.000E+00	0.000E+00	--	*	8.803E-01	0.00000	1.000E+00
11	1972	0.000E+00	0.000E+00	--	*	8.761E-01	0.00000	1.000E+00
12	1973	0.000E+00	0.000E+00	--	*	8.715E-01	0.00000	1.000E+00
13	1974	0.000E+00	0.000E+00	--	*	8.581E-01	0.00000	1.000E+00
14	1975	0.000E+00	0.000E+00	--	*	8.453E-01	0.00000	1.000E+00
15	1976	0.000E+00	0.000E+00	--	*	8.297E-01	0.00000	1.000E+00
16	1977	0.000E+00	0.000E+00	--	*	8.105E-01	0.00000	1.000E+00
17	1978	0.000E+00	0.000E+00	--	*	7.822E-01	0.00000	1.000E+00
18	1979	0.000E+00	0.000E+00	--	*	7.480E-01	0.00000	1.000E+00
19	1980	0.000E+00	0.000E+00	--	*	7.221E-01	0.00000	1.000E+00
20	1981	0.000E+00	0.000E+00	--	*	6.932E-01	0.00000	1.000E+00
21	1982	0.000E+00	0.000E+00	--	*	6.670E-01	0.00000	1.000E+00
22	1983	0.000E+00	0.000E+00	--	*	6.389E-01	0.00000	1.000E+00
23	1984	0.000E+00	0.000E+00	--	*	5.750E-01	0.00000	1.000E+00
24	1985	0.000E+00	0.000E+00	--	*	5.235E-01	0.00000	1.000E+00
25	1986	0.000E+00	0.000E+00	--	*	5.098E-01	0.00000	1.000E+00
26	1987	0.000E+00	0.000E+00	--	*	4.922E-01	0.00000	1.000E+00
27	1988	0.000E+00	0.000E+00	--	*	4.739E-01	0.00000	1.000E+00
28	1989	0.000E+00	0.000E+00	--	*	4.545E-01	0.00000	1.000E+00
29	1990	0.000E+00	0.000E+00	--	*	4.360E-01	0.00000	1.000E+00
30	1991	0.000E+00	0.000E+00	--	*	4.306E-01	0.00000	1.000E+00
31	1992	1.000E+00	1.000E+00	--	3.470E-01	4.240E-01	-0.20029	1.000E+00
32	1993	1.000E+00	1.000E+00	--	3.550E-01	4.093E-01	-0.14225	1.000E+00
33	1994	1.000E+00	1.000E+00	--	3.360E-01	3.886E-01	-0.14554	1.000E+00
34	1995	1.000E+00	1.000E+00	--	3.420E-01	3.663E-01	-0.06863	1.000E+00
35	1996	1.000E+00	1.000E+00	--	3.590E-01	3.476E-01	0.03235	1.000E+00
36	1997	1.000E+00	1.000E+00	--	2.720E-01	3.378E-01	-0.21656	1.000E+00
37	1998	1.000E+00	1.000E+00	--	3.320E-01	3.303E-01	0.00506	1.000E+00
38	1999	1.000E+00	1.000E+00	--	3.500E-01	3.189E-01	0.09299	1.000E+00
39	2000	1.000E+00	1.000E+00	--	3.090E-01	3.160E-01	-0.02234	1.000E+00
40	2001	1.000E+00	1.000E+00	--	2.900E-01	3.171E-01	-0.08940	1.000E+00
41	2002	1.000E+00	1.000E+00	--	3.320E-01	3.185E-01	0.04152	1.000E+00
42	2003	1.000E+00	1.000E+00	--	4.360E-01	3.181E-01	0.31524	1.000E+00
43	2004	1.000E+00	1.000E+00	--	4.620E-01	3.106E-01	0.39721	1.000E+00

* Asterisk indicates missing value(s).

CORRECTED SAFMC Gag SEDAR 10 (2006), increasing q 2%/yr from 1980 Page 6

RESULTS FOR DATA SERIES # 3 (NON-BOOTSTRAPPED) MRFSS Index

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

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Statist weight
1	1962	0.000E+00	0.000E+00	--	*	1.449E+00	0.00000	1.000E+00
2	1963	0.000E+00	0.000E+00	--	*	1.452E+00	0.00000	1.000E+00
3	1964	0.000E+00	0.000E+00	--	*	1.456E+00	0.00000	1.000E+00
4	1965	0.000E+00	0.000E+00	--	*	1.461E+00	0.00000	1.000E+00
5	1966	0.000E+00	0.000E+00	--	*	1.467E+00	0.00000	1.000E+00
6	1967	0.000E+00	0.000E+00	--	*	1.465E+00	0.00000	1.000E+00
7	1968	0.000E+00	0.000E+00	--	*	1.445E+00	0.00000	1.000E+00
8	1969	0.000E+00	0.000E+00	--	*	1.428E+00	0.00000	1.000E+00
9	1970	0.000E+00	0.000E+00	--	*	1.414E+00	0.00000	1.000E+00
10	1971	0.000E+00	0.000E+00	--	*	1.395E+00	0.00000	1.000E+00
11	1972	0.000E+00	0.000E+00	--	*	1.389E+00	0.00000	1.000E+00
12	1973	0.000E+00	0.000E+00	--	*	1.381E+00	0.00000	1.000E+00
13	1974	0.000E+00	0.000E+00	--	*	1.360E+00	0.00000	1.000E+00
14	1975	0.000E+00	0.000E+00	--	*	1.340E+00	0.00000	1.000E+00
15	1976	0.000E+00	0.000E+00	--	*	1.315E+00	0.00000	1.000E+00
16	1977	0.000E+00	0.000E+00	--	*	1.285E+00	0.00000	1.000E+00
17	1978	0.000E+00	0.000E+00	--	*	1.240E+00	0.00000	1.000E+00
18	1979	0.000E+00	0.000E+00	--	*	1.186E+00	0.00000	1.000E+00
19	1980	0.000E+00	0.000E+00	--	*	1.145E+00	0.00000	1.000E+00
20	1981	1.000E+00	1.000E+00	--	6.040E-01	1.099E+00	-0.59834	1.000E+00
21	1982	1.000E+00	1.000E+00	--	4.780E-01	1.057E+00	-0.79378	1.000E+00
22	1983	1.000E+00	1.000E+00	--	4.750E-01	1.013E+00	-0.75712	1.000E+00
23	1984	1.000E+00	1.000E+00	--	6.180E-01	9.115E-01	-0.38860	1.000E+00
24	1985	1.000E+00	1.000E+00	--	1.138E+00	8.298E-01	0.31583	1.000E+00
25	1986	1.000E+00	1.000E+00	--	1.109E+00	8.080E-01	0.31665	1.000E+00
26	1987	1.000E+00	1.000E+00	--	9.410E-01	7.802E-01	0.18737	1.000E+00
27	1988	1.000E+00	1.000E+00	--	6.420E-01	7.512E-01	-0.15712	1.000E+00
28	1989	1.000E+00	1.000E+00	--	1.926E+00	7.204E-01	0.98333	1.000E+00
29	1990	1.000E+00	1.000E+00	--	7.210E-01	6.911E-01	0.04229	1.000E+00
30	1991	1.000E+00	1.000E+00	--	9.010E-01	6.825E-01	0.27769	1.000E+00
31	1992	1.000E+00	1.000E+00	--	9.990E-01	6.720E-01	0.39650	1.000E+00
32	1993	1.000E+00	1.000E+00	--	9.110E-01	6.487E-01	0.33954	1.000E+00
33	1994	1.000E+00	1.000E+00	--	6.950E-01	6.160E-01	0.12062	1.000E+00
34	1995	1.000E+00	1.000E+00	--	1.068E+00	5.806E-01	0.60947	1.000E+00
35	1996	1.000E+00	1.000E+00	--	4.840E-01	5.509E-01	-0.12953	1.000E+00
36	1997	1.000E+00	1.000E+00	--	5.290E-01	5.354E-01	-0.01201	1.000E+00
37	1998	1.000E+00	1.000E+00	--	2.440E-01	5.236E-01	-0.76355	1.000E+00
38	1999	1.000E+00	1.000E+00	--	8.350E-01	5.055E-01	0.50184	1.000E+00
39	2000	1.000E+00	1.000E+00	--	4.470E-01	5.009E-01	-0.11376	1.000E+00
40	2001	1.000E+00	1.000E+00	--	3.220E-01	5.027E-01	-0.44537	1.000E+00
41	2002	1.000E+00	1.000E+00	--	5.800E-01	5.049E-01	0.13877	1.000E+00
42	2003	1.000E+00	1.000E+00	--	3.500E-01	5.042E-01	-0.36511	1.000E+00
43	2004	1.000E+00	1.000E+00	--	6.610E-01	4.923E-01	0.29475	1.000E+00

* Asterisk indicates missing value(s).

CORRECTED SAFMC Gag SEDAR 10 (2006), increasing q 2%/yr from 1980 Page 7

ESTIMATES FROM BOOTSTRAPPED ANALYSIS

Param name	Point estimate	Estimated bias in pt estimate	Estimated relative bias	Bias-corrected approximate confidence limits 80% lower	80% upper	50% lower	50% upper	Inter-quartile range	Relative IQ range
B1/K	9.000E-01	-1.371E-10	-0.00%	9.000E-01	9.000E-01	9.000E-01	9.000E-01	4.148E-11	0.000
K	1.009E+04	9.167E+02	9.09%	6.113E+03	2.104E+04	8.028E+03	1.578E+04	7.755E+03	0.769
q(1)	7.764E-04	1.329E-04	17.12%	3.318E-04	1.378E-03	4.701E-04	1.020E-03	5.497E-04	0.708
q(2)	1.006E-04	1.889E-05	18.78%	4.192E-05	1.869E-04	6.013E-05	1.344E-04	7.430E-05	0.739
q(3)	1.595E-04	2.940E-05	18.43%	6.349E-05	2.916E-04	9.285E-05	2.089E-04	1.161E-04	0.728
MSY	5.304E+02	-9.986E+00	-1.88%	2.938E+02	6.234E+02	4.044E+02	5.753E+02	1.709E+02	0.322
Ye(2005)	4.471E+02	-8.858E+00	-1.98%	2.679E+02	5.432E+02	3.599E+02	4.945E+02	1.346E+02	0.301
Y.@Fmsy	3.202E+02	-6.108E-01	-0.19%	1.865E+02	4.077E+02	2.509E+02	3.621E+02	1.113E+02	0.348
Bmsy	5.043E+03	4.584E+02	9.09%	3.057E+03	1.052E+04	4.014E+03	7.891E+03	3.877E+03	0.769
Fmsy	1.052E-01	2.087E-02	19.84%	3.005E-02	2.044E-01	5.177E-02	1.439E-01	9.209E-02	0.876
fmsy(1)	1.355E+02	-4.484E+00	-3.31%	9.031E+01	1.533E+02	1.143E+02	1.443E+02	2.998E+01	0.221
fmsy(2)	1.045E+03	-3.133E+01	-3.00%	8.125E+02	1.305E+03	9.556E+02	1.184E+03	2.285E+02	0.219
fmsy(3)	6.596E+02	-2.372E+01	-3.60%	4.896E+02	7.654E+02	5.994E+02	7.106E+02	1.111E+02	0.168
B./Bmsy	6.037E-01	9.642E-03	1.60%	4.936E-01	7.361E-01	5.477E-01	6.634E-01	1.157E-01	0.192
F./Fmsy	1.654E+00	2.092E-01	12.65%	1.319E+00	2.817E+00	1.479E+00	2.094E+00	6.152E-01	0.372
Ye./MSY	8.429E-01	-1.331E-03	-0.16%	7.436E-01	9.304E-01	7.954E-01	8.867E-01	9.131E-02	0.108
q2/q1	1.296E-01	1.079E-03	0.83%	1.116E-01	1.522E-01	1.194E-01	1.406E-01	2.122E-02	0.164
q3/q1	2.054E-01	1.228E-03	0.60%	1.838E-01	2.316E-01	1.949E-01	2.203E-01	2.542E-02	0.124

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

Unitless limit reference point in F (Fmsy/F.): 0.6046
CV of above (from bootstrap distribution): 0.2606

NOTES ON BOOTSTRAPPED ESTIMATES:

- Bootstrap results were computed from 600 trials.
- Results are conditional on bounds set on MSY and K in the input file.
- All bootstrapped intervals are approximate. The statistical literature recommends using at least 1000 trials for accurate 95% intervals. The default 80% intervals used by ASPIC should require fewer trials for equivalent accuracy. Using at least 500 trials is recommended.
- Bias estimates are typically of high variance and therefore may be misleading.

Trials replaced for lack of convergence: 0
Trials replaced for q out-of-bounds: 0
Trials replaced for K out-of-bounds: 0
Trials replaced for MSY out of bounds: 41
Residual-adjustment factor: 1.0383

Elapsed time: 0 hours, 5 minutes, 41 seconds.

SEDAR 10

Stock Assessment Report 1

South Atlantic Gag Grouper

SECTION IV. Review Workshop

SEDAR
1 Southpark Circle # 306
Charleston, SC 29414

SEDAR 10 Review Workshop Report

South Atlantic Gag Grouper

Prepared by the SEDAR 10 Review Panel
June 26 - 30, 2006
Atlanta GA

Executive Summary

The SEDAR 10 Review Workshop took place in Atlanta, Georgia, June 26-30, 2006 and reviewed two stock assessments; South Atlantic gag grouper and Gulf of Mexico gag grouper. On Monday, June 26, the Review Workshop Panel received a presentation from the South Atlantic gag grouper assessment team, and on Tuesday, June 27, a similar presentation from the Gulf of Mexico gag grouper assessment team. The balance of the week, through Thursday afternoon, was devoted to additional discussion with the assessment teams to refine and better understand the assessments. Draft versions of the two advisory reports were discussed on Thursday. All parts of the meeting, with the exception of Friday morning, were open to the public. On Friday, the Panel discussed initial drafts of the Consensus Summary documents.

The Review Panel commends the two assessment teams and was especially impressed by the responsiveness of both teams to requests for additional analyses and clarifying information. The Review Panel was also very appreciative of the helpful feedback and suggestions from all SEDAR 10 attendees as we discussed initial drafts of Review Workshop documents.

The Review Panel also appreciates the organization of SEDAR 10 in that two gag grouper stocks were assessed via a common Data Workshop and concurrent and complementary Assessment Workshops. This allowed the Review Panel to not only better understand the individual stock assessments but to offer more consistent advice to the two managing Councils.

From that point of view the Review Panel notes that the development of the stocks has been similar, presumably because the fisheries have followed similar paths.

In both stock areas, recruitment has increased in recent years, although the increase is more pronounced in the Gulf of Mexico than in the South Atlantic. Recruitment is estimated to have been about 5 times higher, on average, in the Gulf of Mexico than in the Atlantic.

For both stocks, relative SSB's were high in the early 1960s, declined more or less regularly until the early 1990s when both started to increase. The 2004 SSB in the Gulf of Mexico is almost 60% above average, close to the maximum observed in the early 1960s, while for the South Atlantic, the 2004 SSB is 20% above average.

Estimated fishing mortality increased at a very similar rate from the early 1960s to the early 1980s. Since then, both have fluctuated without a clear trend around an average of 0.48 in the South Atlantic and about 0.30 in the Gulf of Mexico.

An important result of the Review Workshop is determination of current stock status relative to biological reference points established in the respective FMPs.

In both stock areas, the stock and recruitment scatter plot do not suggest that recruitment is strongly linked with SSB. In the South Atlantic, the Beverton-Holt stock-recruitment relationship indicates little change in recruitment for a wide range of SSB's and that B_{MSY} falls in the range of SSB's observed in the past. On the other hand, the Ricker stock-recruitment relationship indicates that maximum recruitment occurs at SSB's lower than those observed over the period of the assessment, which implies that B_{MSY} would also be lower than those observed in the period of the assessment. In the Gulf of Mexico, both the Beverton-Holt and Ricker relationships suggest that considerably higher recruitment would result from larger SSB's and B_{MSY} is estimated to be higher than SSB's observed in the past. The Review Panel considers that the stock recruitment relationships in the two stock areas are equally uncertain. The derived benchmarks are considered useful for management in the South Atlantic, because they are within the range of past observed values. In the Gulf of Mexico, more stock and recruitment observations are necessary to confirm that the benchmarks estimated in the current assessment are indeed attainable.

The Minimum Stock Size Threshold (MSST), currently defined by the South Atlantic Council as $(1-M)*B_{MSY}$, is very close to B_{MSY} because age-averaged natural mortality rate, M, is estimated as 0.14. Given the uncertainties in the assessment, the biomass would be expected to fall below MSST with a relatively high frequency even if, in fact, the true biomass was close to B_{MSY}. In addition, MSST, as currently defined, may be overly conservative. There are no indications of impaired recruitment at the lowest observed SSB (around 5 million lbs) and the Review Panel suggests that MSST could be set at this level as an operational definition to be re-examined at the next assessment.

Current rates of exploitation indicate that overfishing is occurring for the South Atlantic gag grouper stock. Relative to the current value of the MSST specified by the FMP, South Atlantic gag is approaching an overfished condition and is projected to become overfished in 2007 (see Advisory Report projections). Relative to the MSST proposed by the Review Panel, the stock is not overfished and is not projected to become overfished under any of suggested constant fishing mortality mid-term projection scenarios (also discussed and displayed in the Advisory Report).

Post-Review Workshop Note:
An error was identified in the Atlantic gag input values for the recreational (MRFSS) harvest. The error was corrected and updated model results provided in February 2007. However, comments in this report are based on those results available to the review panel and may differ slightly in some instances from the results of the updated model. Values in the advisory report were updated to reflect the corrected model, and notes are added to this consensus report to indicate any values which differ as a result of the error correction.

1. Introduction

1.1. Workshop Time and Place

The SEDAR 10 Review Workshop met at the Doubletree Atlanta Buckhead in Atlanta, Georgia from June 26 - 30, 2006.

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 values for management benchmarks, 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.
6. Ensure that stock assessment results are clearly and accurately presented in the Stock Assessment Report and that reported results are consistent with Review Panel recommendations.
7. Evaluate the performance of the Data and Assessment Workshops with regard to their respective Terms of Reference; state whether or not the Terms of Reference for those previous workshops were met and are adequately addressed in the Stock Assessment Report.
8. Review research recommendations provided by the Data and Assessment workshops and make any additional recommendations warranted.
9. 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.)

1.3. List of Participants

Review Panel

Terry Smith, Chair ....NOAA Fisheries/Sea Grant
Din Chen .... CIE
Jean-Jacques Maguire .... CIE
John Wheeler .... CIE

Presenters

Mauricio Ortiz...SEFSC
Clay Porch..SEFSC

Steve Turner....................SEFSC
Doug Vaughan....................SEFSC
Erik Williams....................SEFSC

Appointed Observers

Brian Cheuvront....................SAFMC SSC
Phil Conklin....................SAFMC AP
Marianne Cufone....................GMFMC NGO Representative
George Geiger....................SAFMC
Will Patterson....................GMFMC SSC
Roy Williams....................GMFMC
Bob Zales II....................GMFMC AP

Observers

Roy Crabtree....................SERO
Elizabeth Fetherstone....................Ocean Conservancy
Dennis O'Hern....................GMFMC AP
Andy Strelchek....................SERO

Staff

Steven Atran....................GMFMC
John Carmichael....................SEDAR
Tyree Davis....................SEFSC
Rick DeVictor....................SAFMC

1.4. List of Review Workshop Working Papers & Documents

The Review Panel was provided all SEDAR Working Papers and associated research documents considered at the SEDAR 10 Data and Assessment Workshops. Additional resources provided for the Review Workshop are listed below.

SEDAR Working Papers		
SEDAR10-RW01	Virtual population analysis of the Gulf of Mexico gag grouper stock: the continuity case.	Sladek-Nowlis, J.
SEDAR10-RW02	Status review of gag grouper in the US Gulf of Mexico, SEDAR 10.	Ortiz, M
SEDAR DRAFT ASSESSMENT REPORTS		
SEDAR10-SAR1 *Review Draft*	South Atlantic Gag Grouper SEDAR Assessment Report	
SEDASR10-SAR2 *Review Draft*	Gulf of Mexico Gag Grouper SEDAR Assessment Report	

2. Consensus Summary

2.1. Background and summary

- **Documents provided and reviewed**: The Review Workshop (RW) is the third meeting in the SEDAR 10 process. The Panel was provided reports (*S10SAR1-SAgag Sect12.pdf* and *S10SAR1Sect3AtlGagAW.pdf*) from both Data Workshop (DW) and Assessment Workshop (AW) before the Review Workshop. The panel reviewed these documents and the series of working documents cited in those reports.

- **Assessment Scientists:** The Atlantic gag grouper assessment was presented by Drs. Erik Williams and Doug Vaughan on Monday, June 26th.

- **Assessment Data**: The Assessment was based on the data from the Data Workshop, which are summarized in *S10SAR1-SAgag Sect12.pdf*. Data sources include abundance indices, recorded landings (commercial handline and diving, recreational headboat and recreational landings derived from the Marine Recreational Fishing Statistics Survey, MRFSS), and samples of annual size compositions and age compositions. Three fishery–dependent abundance indices were developed by the SEDAR-10 DW: one from the NMFS headboat survey, one from the commercial logbook program, and one from the MRFSS survey. There are no usable fishery–independent abundance data for this stock at this time. Landings data were available from all recreational and commercial fisheries.

- **AW Assessment Model and base runs:** The South Atlantic gag grouper stock was assessed with two models: a statistical catch-at-age model as the primary assessment model and an age-aggregated production model to investigate results under a different set of model assumptions. Within each type of model various configurations and sensitivity runs were explored. The AW developed two base runs: one assuming a time-varying catchability and one assuming constant catchability for the fishery dependent indices. Each base run of the catch-at-age model was the basis for estimation of benchmarks and stock status. Assumptions and results are summarized in *S10SAR1Sect3AtlGagAW.pdf.*

- **RW Preferred based model**: The Review Panel evaluated the assessment and identified a number of concerns, which led to requests for clarifications and several sensitivity runs. As a result, the Panel recommended the base run with constant catchability as the preferred “base model”.

2.2. Review Workshop Terms of Reference

1. Evaluate the adequacy, appropriateness, and application of data used in the assessment.

- **Assessment Data Adequacy, Appropriateness**: The data for this species were finalized from the SEDAR Data Workshop and reported in *S10SAR1-SAgag Sect12.pdf*. Overall, the data were deemed appropriate and used in an appropriate manner subject to the concerns of lacking systematic age and length sampling, no fishery independent indices, and highly variable annual MFRSS estimates.

- **MFRSS**: The RW was concerned about the MFRSS series because of highly variable annual estimates and the lack of age/length composition. Lack of length samples from MRFSS resulted in use of headboat length compositions to reflect MRFSS landings. Because charter boat landings dominated MRFSS, the RW agreed that this was a reasonable assumption although headboat length compositions may differ from those observed in the private boat mode.

  MRFSS PSE (proportion standard error) was highly variable with generally higher values in the earlier years (1980s). More importantly, the sensitivity runs by the AW which examined model output by increasing and decreasing MRFSS catch by 50% (especially the decreasing run), substantively changed the view of the status of the stock. In addition, removing a portion of the MRFSS catch can make the stock appear to be less productive. However, given the lack of evidence of a consistent and persistent bias in the MRFSS data, the RW panel concluded that the MFRSS was variable, but not biased, and the decision was made to use the original data.

  MRFSS landings are the largest contributor to total landings but are poorly sampled. The MRFSS landings are dominated by charter boat landings, presumably from fishing similar to that on headboats. It was noted that the MRFSS index is based on catch (A+B1+B2) while headboat and commercial handline indices are based only on landings.

- **Model fits to sex ratio data:** A detailed description of the life history data and initial probit analysis on sex ratio and maturity of South Atlantic gag was presented in a report prior to the Data Workshop (SEDAR10-DW-15). Following the Data Workshop, final parameter fits were developed and summarized in Table 2.1 (p. II-33) of the Data Workshop Report (Section II). Discussion by the panel was concerned with the data available for the probit analysis on sex transition (proportion females) at age. Initially a request was made to compare the observed proportions female at age with model predicted female at age for each time period. Because these data was not readily available, the sample sizes available for each time period were provided:

Early period (1977-82): 322 fish
- Middle period (1994-95): 1508 fish
- Late period (2004-05): 1048 fish

These sample sizes were deemed adequate for representing sex ratio. Linear interpolation of the model predicted proportion female-at-age was applied to years between these periods.

- **Catchability**: The RW discussed the relationship of technology to catchability and the effects of catchability changes on fishery-dependent abundance indices. The RW recognized that technology improvements over time, particularly better electronics, have made fishermen more effective and efficient at catching fish, but disagreed with the assumption of a simple linear (2% annually) constant increase. This issue is important for the present stock assessment because the assessments rely heavily on fishery-dependent catch rate abundance (CPUE) indices.

  When a unit of effort becomes more efficient at catching fish, the resulting abundance index becomes biased, making fish appear relatively more abundant. In contrast, fishery-independent indices based on standardized methods to control fishing efficiency over time are not subject to this problem. No fishery-independent indices were available for the South Atlantic gag assessment.

- **Indices:** Correlation among the three fishery dependent indices was discussed. It was noted that there was a marginally significant negative correlation between the headboat and commercial handline indices. In the most recent few years, commercial handline CPUE has been increasing while the headboat index has been declining.

- **Stock structure**: South Atlantic gag grouper and Gulf of Mexico gag grouper were assessed as two separate stocks. The RW discussed stock movement and mixing. It was reported that there were several mark-recapture experiments carried out on fish movement between these two regions. However, there was no consensus and quantitative analysis for these mark-recapture experiments. The RW believes that input data and assessment approaches are similar and there is common ground for these two assessments.

  Differences between life history (e.g., sex ratio, maturity, etc.) for the Gulf and South Atlantic stocks were noted and habitat differences were suggested as possibly contributing to the differences.

Nevertheless, the biological parameters (growth, maturity, natural mortality, gender changes) for the two stock areas appear sufficiently similar to imply that it could be worthwhile to re-estimate the parameters using pooled data.

In the South Atlantic, the age range tabulated in the analyses extend to age 20 while in the Gulf of Mexico (GOM) it extends to age 12.

- **Natural mortality rate**: The DW and AW recommended age-based natural mortality (averaged M=0.14) using the Lorenzen (1996) approach. The RW discussed this rate and recommended that the DW and AW analyze the existing mark-recapture data with some appropriate mark-recapture models, such as a Brownie model, to estimate the natural mortality.

- **Length-weight bias**: The RW discussed the bias correction used for weight-length regressions and confirmed that there was no transformation of the data prior to running the regression. It was noted that the correction assumes that the regression parameters are known (based on lognormal distributional properties). However, these parameters are estimated and not known. The proper statistical correction can be found in Chen (2004). Here, given the small value of MSE (~0.047), the difference is generally small (but would be larger for extreme values of lengths away from mean length). A more detailed discussion of this topic can be found in the research recommendations.

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

- **Methods:** The assessment methods are considered to be appropriate for the available data. The methods used for standardization of the catch and effort data are appropriate. The RW Panel was impressed with the presentation and the number of sensitivity analyses.

- **Models**: For the available data, two models were used as the assessment methods for this stock. A statistical catch-at-age model was used as the primary assessment model and an age-aggregated production model was used to investigate results under a different set of model assumptions. Within each type of model various configurations and sensitivity runs were explored for the catchability coefficient.

- **Residuals**: The RW was concerned about patterns in the recruitment residuals which might indicate that the stock-recruitment model did not fit the data properly. The RW requested further investigation, including graphs, showing the year of the stock-recruit data observation. Results indicated that temporal autocorrelation was not statistically significant.

- **Spawner-recruit models**: The management benchmarks are based on the estimated stock-recruitment model. The RW had extensive discussion on this topic and requested analysis of autocorrelation in the recruitment time series (as reported above). The RW also requested that the stock-recruit relationship be re-estimated with an additional autocorrelation parameter. The autocorrelation function fit suggests there is no significant autocorrelation at lag 1 or higher (Figs 8 and 9 in the Addendum to Stock Assessment Report).

The S/R plot with year information suggested a negative slope to the S/R relationship (Fig 6 in the Addendum). The RW suggested incorporating environmental information into the SR analysis and recommended further investigation of the relationship in future assessments.

In the assessment, the parameters of the Beverton-Holt (BH) spawner-recruit model were estimated within the assessment model (based on years 1972-2004) with lognormal deviations (a loose constraint was put on these deviations). Concern was raised that no model fits were made for an alternate model such as a Ricker spawner-recruitment relationship. During the meeting the RW was provided results from a Ricker SR model and found that the Ricker model provided a statistically better fit to the SR data than the BH model. The RW discussed the fact that the fitted Ricker relationship, if correct, implies the existence of some mechanism which leads to lower recruitment at higher SSB. Mechanisms were proposed and discussed but the issue could not be resolved given available data and life history information. The RW noted that the stock–recruitment relationship is crucial in determining the validity and value of status determination reference points and suggested that the stock-recruitment relationship for the two stocks reviewed in SEDAR 10 be comprehensively re-examined prior to the next formal assessment of gag grouper.

- **CPUE Index Weighting**: The RW discussed the weightings on indices, suggesting that increased weighting on MRFSS would lead to poorer fits.

- **Sensitivity investigations**: To better understand the behavior of the assessment model for the input data series, the RW panel requested sensitivity model runs for the preferred base model (i.e., constant catchability). The base model run contains three fishery dependent CPUE indices and three sets of age and length composition datasets (commercial handline, commercial diving, and recreational headboat fisheries). Nine additional model runs removing each index, each fishery age composition dataset, and each fishery length composition dataset, one at a time, were provided. Results suggest that the base model provides a balanced fit to all the data sources, illustrated by the base run falling within the middle of this set of sensitivity runs (Figures 12-14 in the Advisory Report). Relative to SSB, the run with the headboat CPUE data omitted shows the population increasing rapidly in the most recent years, reaching the highest terminal value of all the runs. In contrast, the run with the commercial handline CPUE omitted results in the lowest SSB value in the terminal year (Figure 12 in the Advisory report). This highlights the balanced fit between these two indices, which show opposite trends in the last few years.. The RW Panel recommends that a way of displaying the influence of each data source on the final assessment results be found and shown in the next assessment.

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

- The details and rationale for the appropriate estimate of stock abundance, biomass and exploitation are listed in the Advisory report and the Addendum to the Assessment Report.

4. *Evaluate the methods used to estimate population benchmarks and management parameters (e.g., MSY, Fmsy, Bmsy, MSST, MFMT, or their proxies); provide values for management benchmarks, range of ABC, and declarations of stock status.*

- The methods to estimate population benchmarks and management parameters are based on the B-H stock-recruitment model estimated externally from the catch at age model with the RW preferred “base model”. The estimates of these benchmarks are listed in the Advisory report and summarized as follows:

  MFMT, the Maximum Fishing Mortality Threshold, is set to F_{MSY} Proxy = $F_{30\%SPR}$.
  MSST, the Minimum Stock Size Threshold, is set to (1-M)B_{msy}.

- Status Determination Criteria: The SFA and management criteria recommendations and values are estimated from the preferred base model by the RW and summarized in the advisory report.

Declarations of Stock Status:

- Stock Status: Current rates of exploitation indicate that overfishing is occurring for the South Atlantic gag grouper stock. Relative to the current value of the MSST specified by the FMP, South Atlantic gag is approaching an overfished condition and is projected to become overfished in 2007. Relative to the MSST proposed by the RW, the stock is not overfished and is not projected to become overfished under any of the projection scenarios (see Figure 6, South Atlantic Gag Grouper Advisory Report).

- The current definition of MSST may be overly conservative. The RW recommended an operational definition of MSST of 5 million pounds (see Advisory Report). (*Post-Workshop NOTE: The 5 million pounds cited here is based on the original results provided the panel. After correction of an error in the recreational (MRFSS) landings tabulation of the assessment input file, the comparable MSST based on the arguments made by the review panel is 4 million pounds.)*

- SEDAR and management agencies should be aware that all reference points are considered to be imprecisely estimated.

5. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status; recommend appropriate estimates of future stock condition.

- Projection of this stock is based on the RW-recommended “base model

- Estimates of recruitment in 2002-2004 are below average and fishing mortality rates in 2002-2004 are above the MSY level. Nevertheless, the stock projections suggest that the stock will remain above the proposed MSST in the medium-term. Projections with various constant fishing mortality rates starting in 2008 are shown in Table 3 and Figures 6-10 in the Advisory report.

- These projection methods are not adequate for forecasting the effects of management measures that involve changing selection patterns, such as changes to minimum landing sizes and bag limits. The methods are, however, adequate for exploring the information content and management implications of small and incomplete data sets such as that available for gag grouper.

6. Ensure that stock assessment results are clearly and accurately presented in the Stock Assessment Report and that reported results are consistent with Review Panel recommendations.

- The panel recommended a preferred “base model” for this stock based on an assumption of constant catchability. Alternative configurations l are listed in the Stock Assessment Report and the Addendum to the Assessment Report.

7. *Evaluate the performance of the Data and Assessment Workshops with regard to their respective Terms of Reference; state whether or not the Terms of Reference for those previous workshops* were met and are adequately addressed in the Stock Assessment Report.

- The RW evaluated the terms of reference from both DW and AW with consensus that the TOR were met.

8. Review research recommendations provided by the Data and Assessment workshops and make any additional recommendations warranted.

Additional Recommendations

- **Time-varying catchability**: The RW is of the opinion that catchability has changed over time, however, it does not believe that a constant 2% increase per year adequately describes the changes in catchability that are likely to have occurred. Step changes with the introduction of new equipment or management measures are more likely than monotonic changes. Learning and technological changes in navigation, fish detection and catching equipment have no doubt increased the efficiency of nominal fishing effort. However, management measures (increases in minimum size, time and area closures, bag limits) and changes in fishing behavior (moving on when "enough" fish have been caught) would be expected to result in decreased catchability. The Panel believes that, overall, catchability is likely to have increased. The Panel recommends that a special workshop be convened to estimate and quantify changes in catchability over the last 25 to 30 years.

- Strengthen the **MRFSS** program to provide more precise estimations of the age/length composition.

- Provide more detailed model diagnostics, such as complete lists of estimated parameters together with their estimated standard errors, in model sensitivity runs.

- Enforce the model residuals diagnostics to test for time series autocorrelation contributions to the lack of goodness of fit in the assessment.

- **Mark-recapture experiments**: Analyze the existing mark-recapture data and initiate new mark-recapture studies, which will help identify movements and migrations between two stocks, estimate fishing mortality, enhance population estimates; and better identify the stock structure and habitat preferences.

  The RW recommends analysis of the existing tagging data for movement within/between the two stocks., Quinn and Deriso (1999) comprehensively reviewed different forms of movement models, including: the diffusion model (Hilborn 1987; Deriso et al. 1991; Fournier et al. 1998), the generalized movement estimation (Ishii 1979, Sibert 1984, Anganuzzi et al. 1994; Xiao 1996, Xiao et al. 1999,; Xiao and McShane 2000), and the movement-estimation mark–recapture methods (Seber 1982, Brownie et al. 1985, Schwarz et al. 1993). The Brownie model may be an excellent approach to alternate estimates of natural mortality rate.

  The RW recommends new tagging experiments, in order to estimate mixing rates and the associated fishing mortality independent of the commercial fishing. It is essential to analyze the existing tagging database to ascertain what can be done with the existing data in order to develop a new design for the future tagging experiment. This would include an effective design for tagging mortality, tagging shedding, reporting rates to get a higher confidence level in stock assessment, migration patterns, and growth.

- **Bias on estimating weight from the log-log length-weight relationship**

The two stocks reviewed in SEDAR 10 used a log-log length-weight relationship to estimate weights from a back-transformation. The RW discussed a potential bias associated with this back-transformation illustrated as follows:

Usually, the length-weight relationship is assumed to be $wt = aL^b$ with a log-normal error. A log-transformation is commonly used to linearize the equation and cast the estimation problem into the simple linear regression as:

$$y = \ln(wt) = \ln(a) + b\ln(L) + \varepsilon = \alpha + \beta\ln(L) + \varepsilon \qquad (1)$$

The parameters from this simple linear regression can be estimated by least squares. With estimated parameters: $\hat{\alpha}, \hat{\beta}$, the predicted weight ($w_0$) from a specific length (L_0) is then back-calculated:

$$\hat{w}_0 = e^{\hat{\alpha} + \hat{\beta}\ln(L_0)} \qquad (2)$$

Or with a bias corrected equations as in both assessments as

$$\hat{w}_0 = e^{\hat{\alpha} + MSE/2 + \hat{\beta}\ln(L_0)} \qquad (3)$$

We would want an unbiased predicted weight of w. It can be shown that both back-calculations in (2) and (3) are biased high as an estimate to the weight of $wt = e^{\alpha + \beta\ln(L)} = aL^b$ with (3) used in the Assessment bias-higher than (2) since

$$E(\hat{w}) = E\left(e^{\hat{\alpha} + \hat{\beta}\ln(L) + \varepsilon}\right) = e^{E\left(\hat{\alpha} + \hat{\beta}\ln(L) + \varepsilon\right) + \frac{V\left(\hat{\alpha} + \hat{\beta}\ln(L) + \varepsilon\right)}{2}} = e^{\alpha + \beta\ln(L)} e^{\frac{V\left(\hat{\alpha} + \hat{\beta}\ln(L) + \varepsilon\right)}{2}} = w \times e^{\frac{V\left(\hat{\alpha} + \hat{\beta}\ln(L) + \varepsilon\right)}{2}}$$

The predicted weight from the estimated log-log length-weight model is biased-high with the bias: $e^{\frac{V\left(\hat{\alpha} + \hat{\beta}\ln(L) + \varepsilon\right)}{2}} = e^{\frac{\sigma^2 + V\left(\hat{\alpha} + \hat{\beta}\ln(L)\right)}{2}}$.

Therefore this bias is not only dependent on the estimated model variance $\hat{\sigma}^2$=MSE, but is also dependent on the estimated correlation between the parameters. In addition, the bias is dependent on the specified length (len_0) to be predicted with the smallest bias at len_0 = (mean observed length). This means that the prediction bias is not constant over the data range (contrary to the common bias correction $wt_0 = e^{\hat{\alpha} + \hat{\beta} \times len_0 - \hat{\sigma}^2/2}$). In the case of extrapolation to large lengths, this bias could be remarkably significant. Details can be found in Chen (2004).

9. 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.)

First drafts of the Consensus Summary and Advisory Report were completed during the Review Workshop. All Review Panel members contributed to the Consensus Report. The assessment team completed the first draft of the Advisory Report which was then reviewed by the Review Panel. The Consensus Report and Advisory Report were completed by email subsequent to the Review Workshop.

2.3. General recommendations to SEDAR

- There was large volume of documentation associated with this RW. The Review Panel recommends a clear executive summary for all substantive Data and Assessment Documents.

- It could be more informative to distribute a succinct table of model equations and parameters (estimated and observed) to be provided for each assessment along with, if appropriate, a table of management options (e.g. a decision table) and the risks associated with them.

2.4 Special Comments

In both stock areas, the stock and recruitment scatter plot do not suggest that recruitment is strongly linked with SSB. In the South Atlantic, the Beverton-Holt stock-recruitment relationship indicates little change in recruitment for a wide range of SSB's and that B_{MSY} falls in the range of SSB's observed in the past. The Ricker stock-recruitment relationship indicates that maximum recruitment occurs at SSB's lower than those observed over the period of the assessment, which implies that B_{MSY} would also be lower than those observed in the period of the assessment. In the Gulf of Mexico, both the Beverton and Holt and Ricker relationships suggest that considerably higher recruitment would result from larger SSB's and B_{MSY} is estimated to be higher than SSB's observed in the past. The RW considers that the stock recruitment relationships in the two stock areas are equally uncertain. The derived benchmarks are considered useful for management in the South Atlantic, because they are within the range of past observed values. In the Gulf of Mexico, more stock and recruitment observations are necessary to confirm that the benchmarks estimated in the current assessment are indeed attainable.

MSST, currently defined in the FMP as (1-M)*BMSY, will be very close to B_{MSY} because M = 0.14 is used. Given the uncertainties in the assessment, the biomass would be expected to be estimated to fall below MSST with a relatively high frequency even if the true biomass were close to B_{MSY}. In addition, MSST, as currently defined, may be overly conservative for the South Atlantic. There are no indications of impaired recruitment at the lowest observed SSB (around 5 million lbs) and the MSST could be set at 5 million lbs as an operational definition to be re-examined at the next assessment.

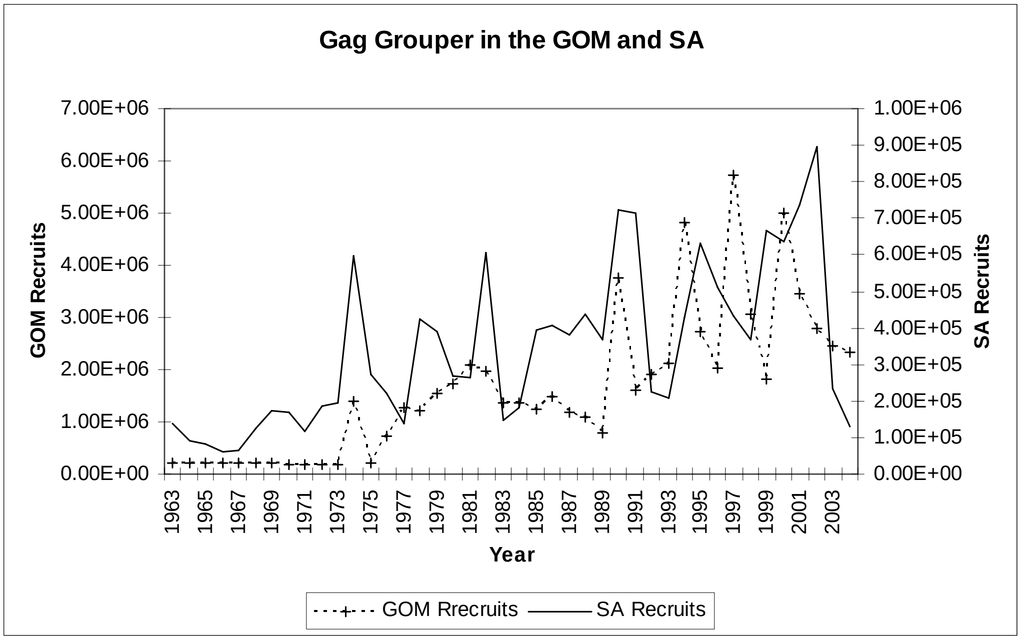
Comparing and Contrasting the Two Gag Grouper Assessments

(Note that comparisons presented here are based on Atlantic gag assessment results available to the review panel. Final results after correction of an input data error are different. See the Assessment Workshop report for details.)

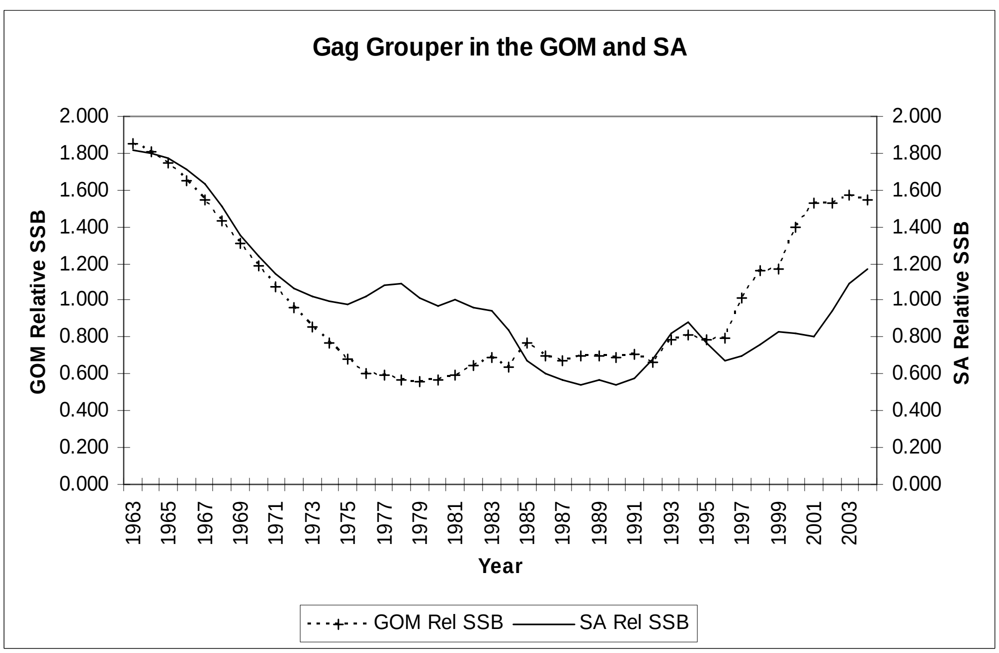
The main assessment model for both stock areas is a statistical catch at age model, but the implementations differ. For the South Atlantic a customized model has been developed using ADMB while for the Gulf of Mexico, an existing piece of software (CASAL (C++ algorithmic stock assessment laboratory which can be downloaded from ftp://ftp.niwa.co.nz/software/casal) was used. CASAL was one of several integrated assessment software programs recently evaluated by the IATTC; the report can be downloaded at http://www.iattc.org/PDFFiles2/Assessment-methods-WS-Nov05-ReportENG.pdf. For the South Atlantic, a production model (ASPIC) was also run and for the Gulf of Mexico two VPA's were run: one was a strict continuity run and the other one was parameterized to mimic the CASAL run. VPA was not used in the South Atlantic because of insufficient complete catch at age information. The RW Panel considers that the statistical catch at age approach has better statistical foundations and more flexibility in the type of information that can be used than VPA or general production models. The RW Panel recommends that alternate assessment approaches (ASPIC for the South Atlantic and VPA for the Gulf of Mexico) continue to be used in parallel and that the results be presented in the report of the Assessment Workshops. Standard inputs (catch at age, length at age, weights at age, indices of stock size, by age and length if appropriate) and outputs (population numbers at age, population biomass at age, spawning biomass, fishing mortality at age) should be provided in a format easily readable by spreadsheet programs. Neither of the assessments considers gender explicitly.

Although the approach has been used in the assessment of other species, it is not clear that the ADMB statistical catch at age implementation conforms to the Model Acceptance Note 1 in the ToRs of the AW. The assessment team is encouraged to provide the required documentation and work towards including the assessment in the NFT packages. Presumably, the evaluation performed by the IATTC implies that the CASAL does conform to the Model Acceptance Note 1 in the provided Terms of Reference.

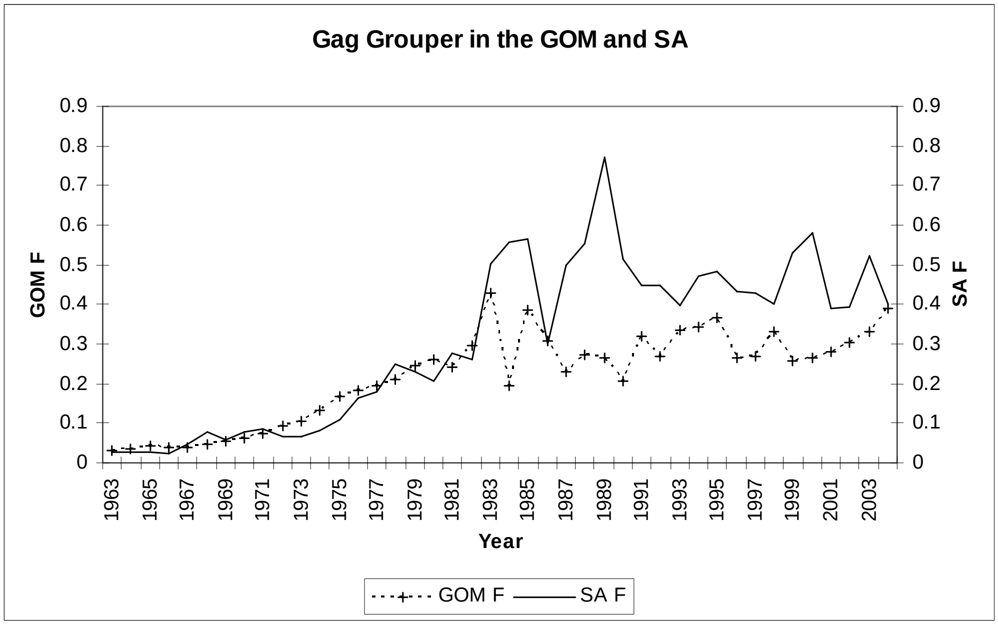
In both stock areas, recruitment has increased in recent years, although the increase is more pronounced in the Gulf of Mexico than in the South Atlantic. Recruitment is estimated to have been about 5 times higher, on average, in the Gulf of Mexico than in the Atlantic.



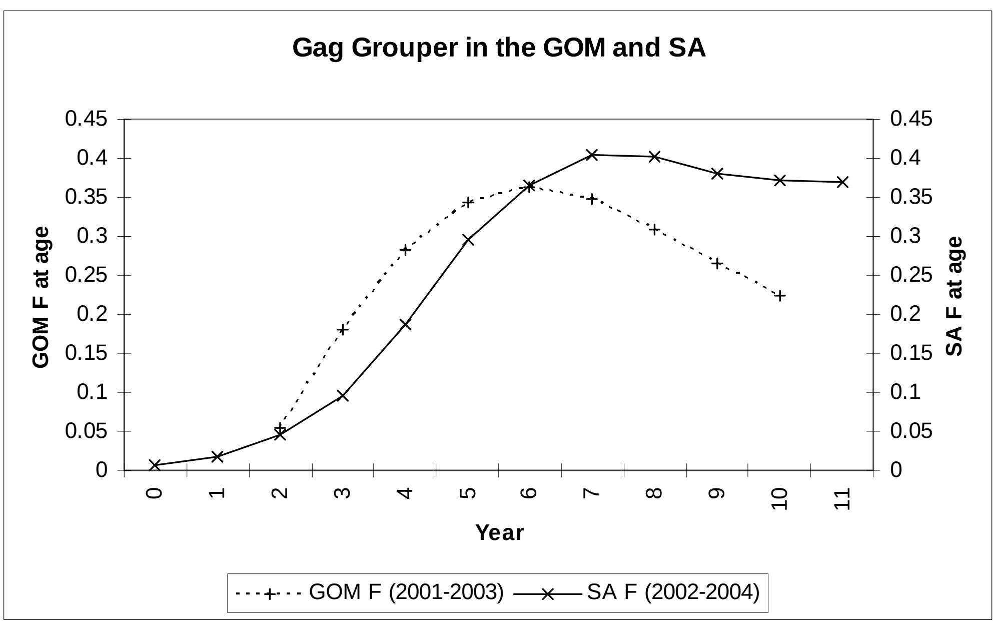
For both stocks, relative SSB's were high in the early 1960s, declined more or less regularly until the early 1990s when both started to increase. The 2004 SSB in the Gulf of Mexico is almost 60% above average, close to the maximum observed in the early 1960s, while for the South Atlantic, the 2004 SSB is 20% above average.



Estimated fishing mortality increased at a very similar rate from the early 1960s to the early 1980s. Since then, both have fluctuated without a clear trend around an average of 0.48 in the South Atlantic and about 0.30 in the Gulf of Mexico.



Average fishing mortality at age (2001-2003 for the GOM, 2002-2004 for the SA) show different patterns. F's are higher at age 3-5 in the Gulf of Mexico than in the South Atlantic but at older ages it is the opposite. The F at age pattern is clearly dome shaped in the Gulf of Mexico and nearly flat topped in the South Atlantic.



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SEDAR 10

Stock Assessment Report 1

South Atlantic Gag Grouper

SECTION V. Addenda

SEDAR
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South Atlantic Gag - Addendum Report

Note that this addendum was NOT updated following identification of the recreational data error.

During the SEDAR10 review workshop requests were made to the stock assessment analysts for various information regarding the input data, stock assessment model, and model estimates. Results of these requests are presented here.

Tables of catch-at-age were requested for each of the fisheries for which age data existed. These are presented below.

Table of catch-at-age for headboat fishery

Headboat Catch-at-age (1000's)					Age																
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20+**
1978	0.11	0.34	1.55	1.43	0.41	0.51	0.73	0.34	0.34	0.03	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00
1979	0.00	0.19	2.91	1.23	0.65	1.97	1.36	0.19	0.78	0.00	0.19	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00
1980	0.00	0.42	2.67	1.22	0.18	0.66	0.73	0.63	0.31	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00
1981	0.00	0.44	3.07	3.20	0.47	0.54	0.87	2.13	2.35	0.41	0.05	0.11	0.11	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00
1982	0.00	0.56	2.84	3.87	0.90	1.12	0.22	1.26	0.54	0.36	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	0.00	0.30	7.00	1.92	1.36	1.55	1.79	0.54	0.73	0.28	0.51	0.00	0.25	0.08	0.00	0.05	0.01	0.08	0.00	0.00	0.00
1984	0.00	0.28	0.66	4.29	2.10	1.74	3.13	4.11	0.48	0.50	0.09	0.80	0.16	0.09	0.07	0.07	0.00	0.07	0.00	0.00	0.07
1985	0.00	2.27	1.50	1.62	5.20	1.83	1.23	1.73	0.38	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.12
1986	0.00	3.02	7.13	1.67	0.87	1.63	1.20	0.95	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.15
2002	0.00	0.00	0.05	0.30	0.20	0.50	0.95	1.57	0.49	0.18	0.15	0.03	0.08	0.03	0.00	0.00	0.00	0.05	0.00	0.00	0.00
2003	0.00	0.00	0.15	0.16	0.34	0.69	0.40	0.33	0.43	0.28	0.22	0.06	0.04	0.06	0.00	0.00	0.08	0.00	0.00	0.00	0.02
2004	0.00	0.00	0.56	1.17	0.95	1.41	1.02	0.58	0.31	0.29	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table of catch-at-age for commercial diving fishery

Commercial Diving Catch-at-age (klb)					Age																
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20+**
1994	0.00	0.00	8.30	2.07	8.30	22.82	16.60	20.75	14.52	4.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	0.00	0.00	1.33	1.33	3.99	0.00	38.56	25.26	9.31	2.66	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	0.00	0.00	1.83	1.83	18.28	5.48	9.14	53.01	9.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table of catch-at-age for commercial handline fishery

Commercial Handline (klb)					Age																
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20+**
1979	0.00	0.00	0.00	6.30	56.72	207.98	176.47	113.44	75.63	44.12	63.02	50.42	25.21	0.00	0.00	0.00	6.30	18.91	25.21	12.60	25.21
1980	0.00	0.00	0.00	10.58	10.58	84.62	200.96	317.31	84.62	63.46	21.15	31.73	10.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.58
1981	0.00	0.00	0.00	42.78	140.57	48.89	213.91	158.90	262.80	36.67	30.56	6.11	12.22	18.34	6.11	0.00	0.00	6.11	0.00	0.00	0.00
1992	0.00	0.00	9.68	93.31	147.65	116.25	113.94	187.33	22.46	0.00	0.00	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	0.00	0.00	12.56	62.93	195.82	163.96	213.48	71.02	35.86	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.89	0.00	0.00	0.00	0.00
1994	0.00	0.11	8.97	56.28	361.63	283.28	60.19	20.20	4.39	3.25	1.01	0.12	0.00	0.15	0.00	0.15	0.02	0.29	0.00	0.00	0.00
1995	0.00	0.00	0.54	9.33	30.92	225.48	316.76	110.80	81.93	34.31	13.29	7.89	2.34	1.38	0.99	2.19	0.74	0.31	0.00	0.00	1.33
1996	0.00	0.00	0.00	0.00	0.00	65.68	437.78	204.10	29.42	1.92	0.00	13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	0.00	0.00	0.00	0.00	11.43	12.66	102.16	375.33	74.49	14.21	1.54	14.44	0.00	0.00	1.95	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.00	0.00	11.98	132.11	56.91	116.86	166.13	33.59	7.52	2.66	0.00	1.96	3.53	0.00	0.00	0.00	4.83	0.00	0.00	0.00	0.00
2000	0.00	0.00	0.00	45.25	89.43	77.46	152.20	36.41	15.84	5.80	13.40	0.00	0.01	2.05	0.00	0.00	0.00	0.00	0.00	0.00	0.37
2001	0.00	0.00	1.47	8.25	50.38	81.84	128.76	147.85	11.24	4.60	5.59	6.28	2.17	0.03	0.34	0.34	0.91	0.00	0.00	0.00	0.02
2002	0.00	0.00	0.00	8.51	36.61	74.32	103.78	134.21	51.95	28.30	3.31	0.77	6.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.00	0.00	0.55	25.50	102.56	161.40	81.15	37.68	19.61	9.91	1.36	1.64	0.43	0.00	1.88	0.00	0.00	0.00	0.00	0.00	0.24
2004	0.00	0.00	2.73	73.28	142.30	132.83	89.25	15.18	14.24	1.80	1.37	1.86	0.79	0.34	0.11	0.00	0.00	0.00	0.00	0.00	0.31

The review workshop panel requested figures showing the change in the abundance indices resulting from the inclusion of a 2% change in catchability per year starting in 1980. These figures are shown below.

Figure 1. Recreational headboat catch-per-unit-effort (CPUE) observed index (red triangles) and catchability adjusted index (blue squares). Adjustment is based on an additive 2% per year change starting in 1980.

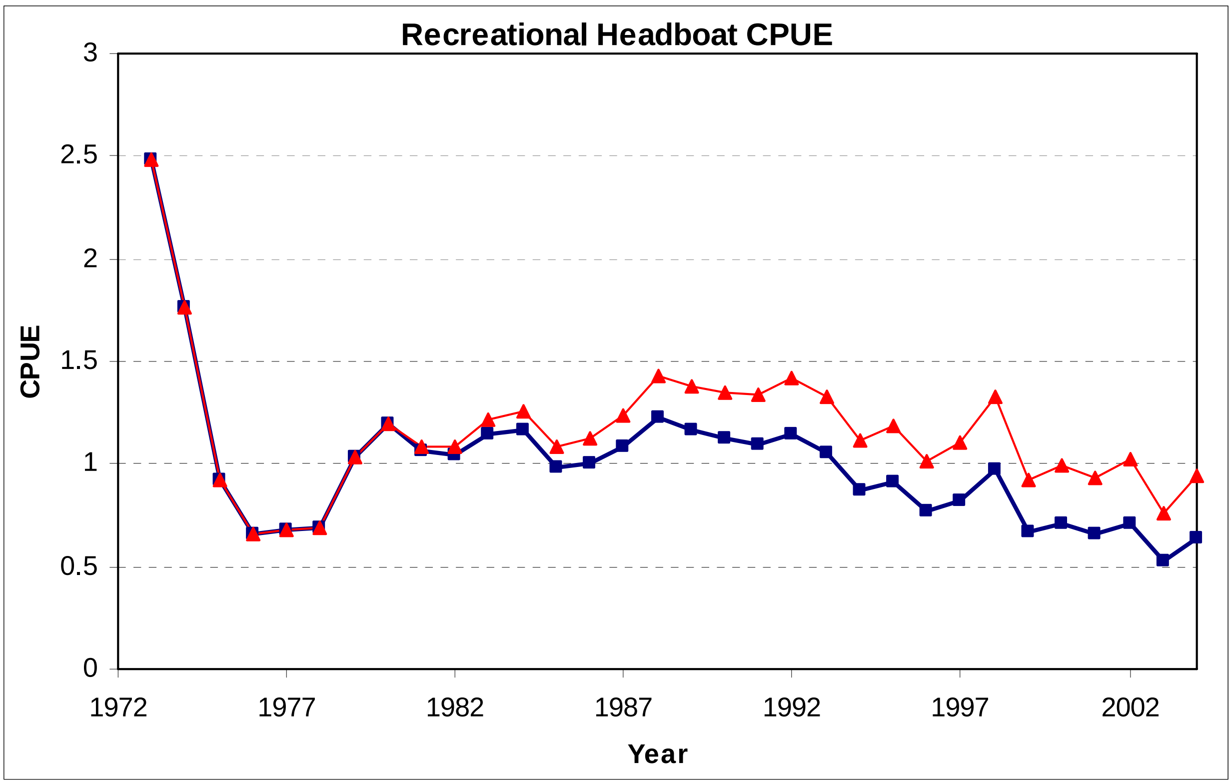


Figure 2. Recreational MRFSS catch-per-unit-effort (CPUE) observed index (red triangles) and catchability adjusted index (blue squares). Adjustment is based on an additive 2% per year change starting in 1980.

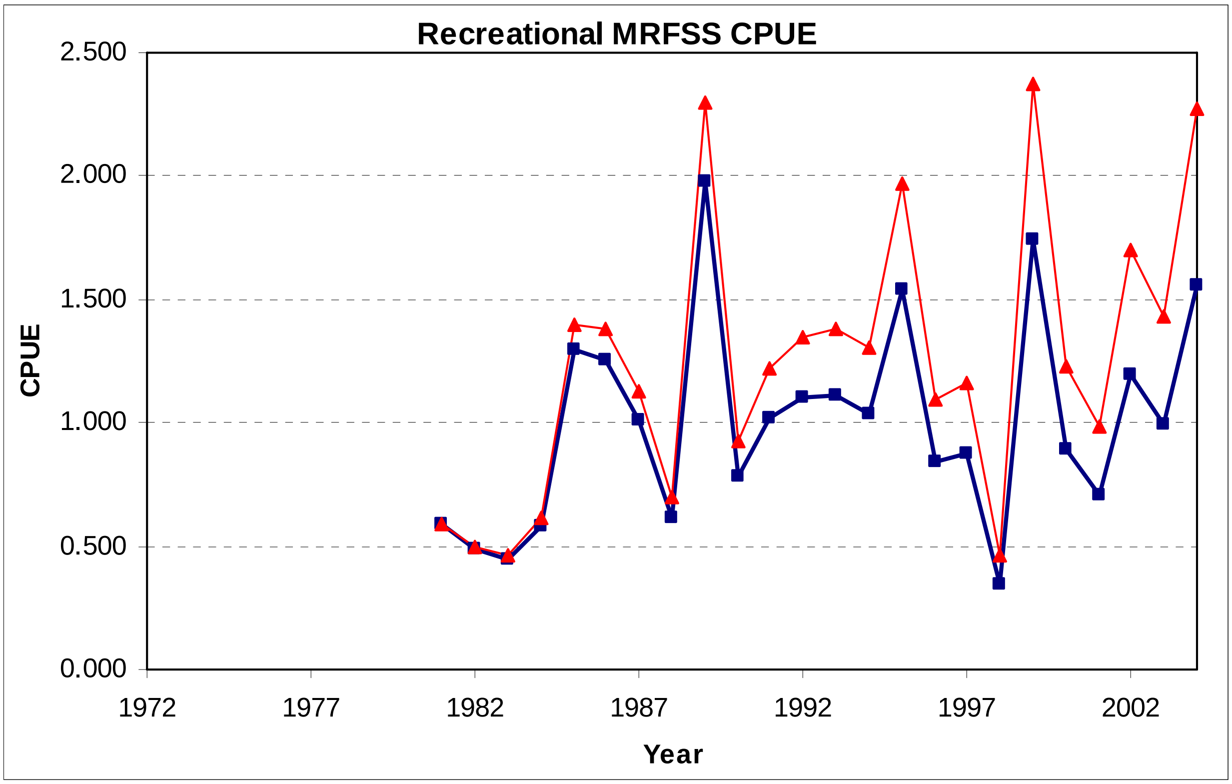
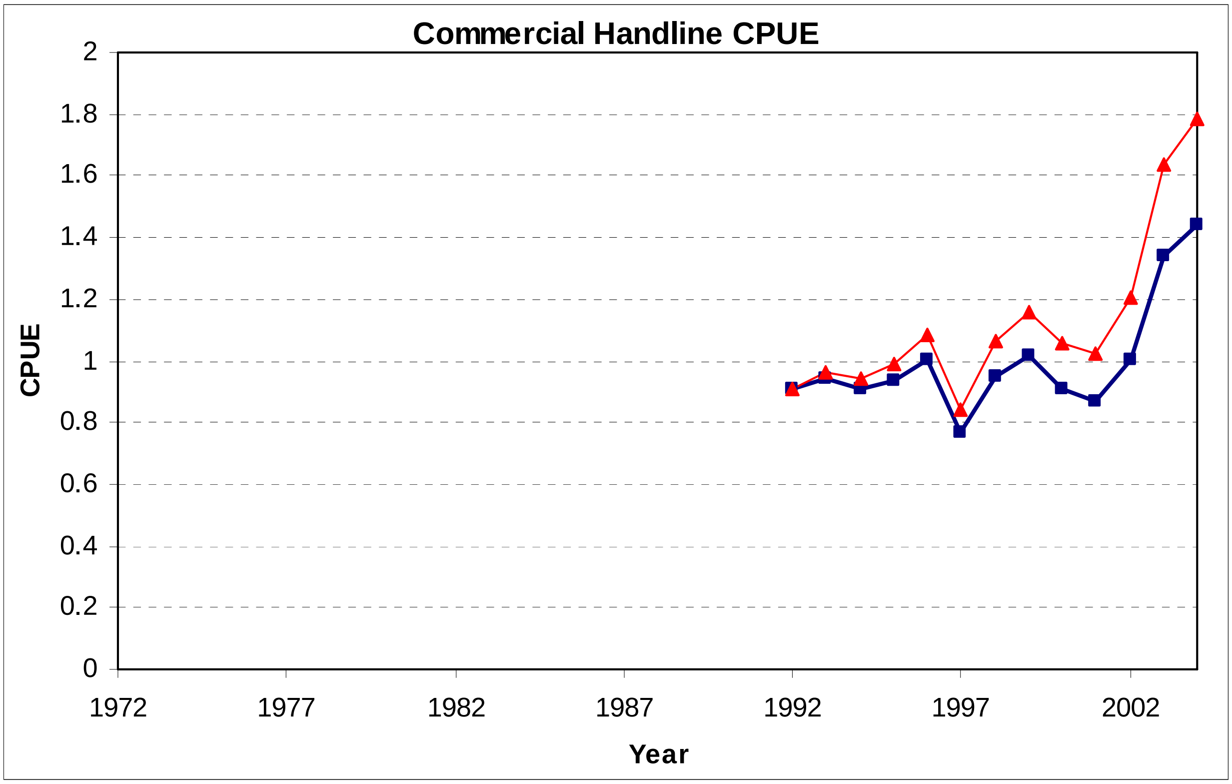


Figure 3. Commercial handline catch-per-unit-effort (CPUE) observed index (red triangles) and catchability adjusted index (blue squares). Adjustment is based on an additive 2% per year change starting in 1980.



The review workshop panel requested figures showing the stock-recruit data with time trend information. This request was accommodated by the stock analysts with plots of the stock-recruit scatter with connected lines by year and plots of the stock-recruit scatter with year labels (see below).

Figure 4. Base run with time-varying catchability: Estimated stock-recruitment relationship. Circles represent estimated spawning biomass and recruitment values from 1972-2004, connected temporally by lines; Dashed curve is estimated relationship; Solid curve is estimated relationship with lognormal bias correction.

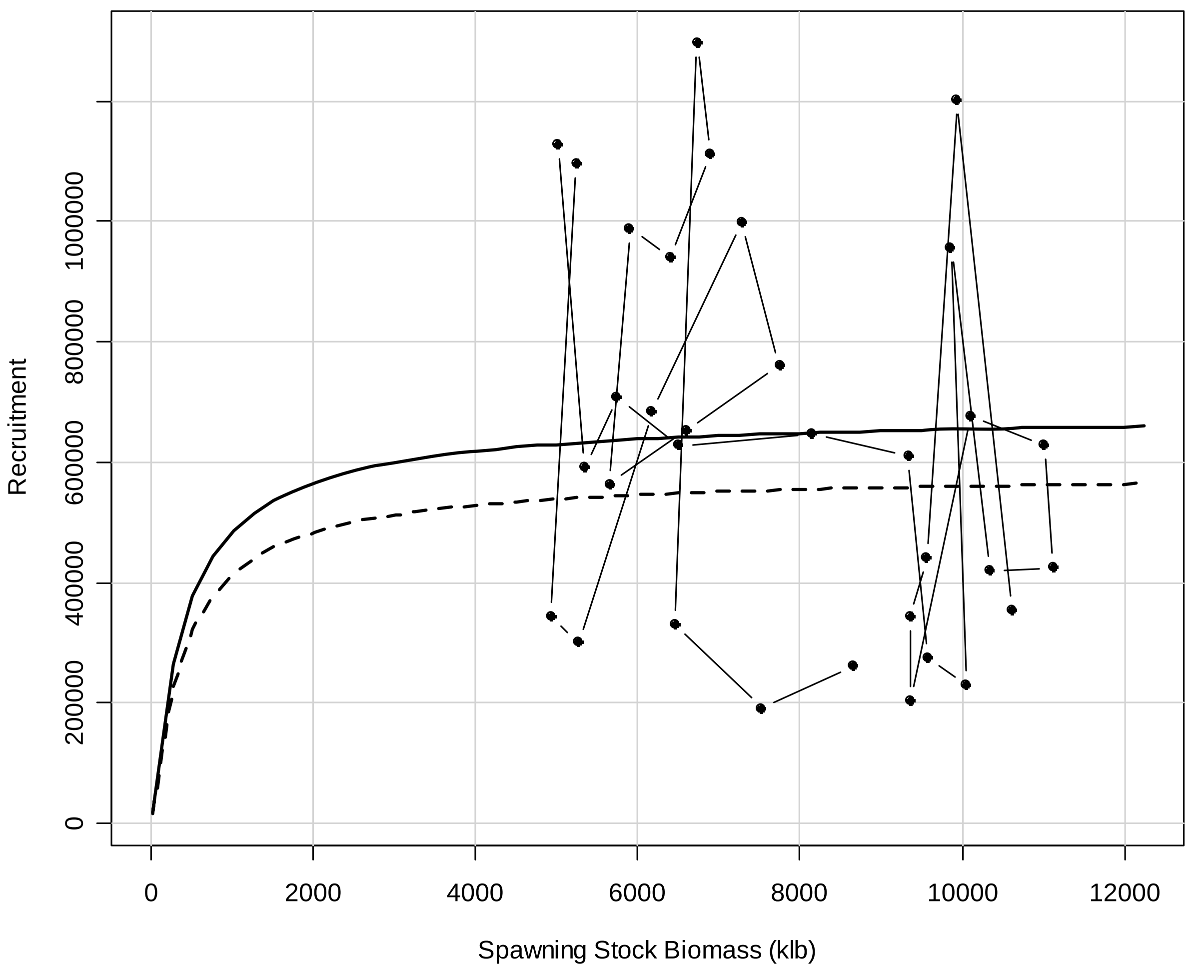


Figure 5. Base run with constant catchability: Estimated stock-recruitment relationship. Circles represent estimated spawning biomass and recruitment values from 1972-2004, connected temporally by lines; Dashed curve is estimated relationship; Solid curve is estimated relationship with lognormal bias correction.

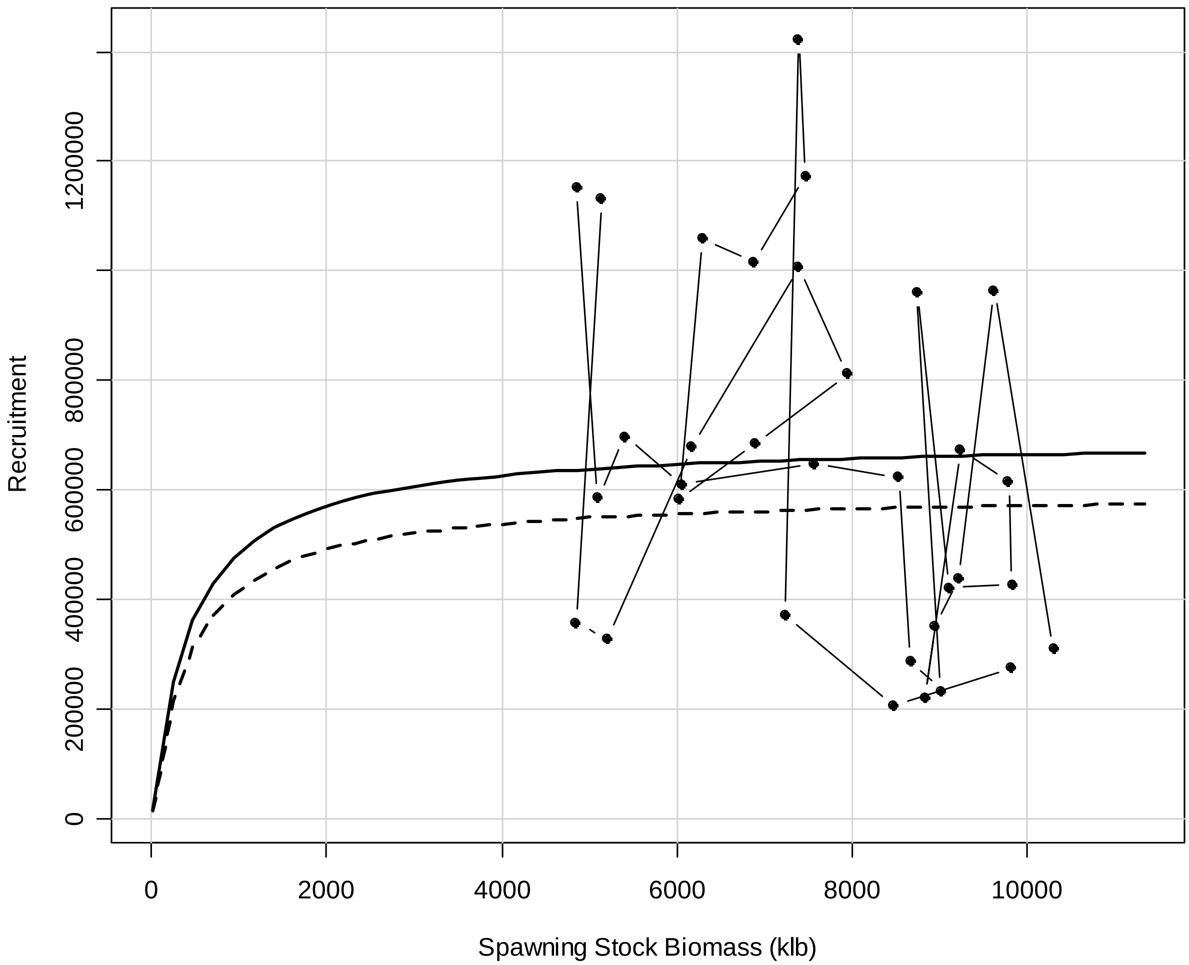


Figure 6. Base run with time-varying catchability: Estimated stock-recruitment relationship. Two digit year labels represent estimated spawning biomass and recruitment values from 1972-2004; Dashed curve is estimated relationship; Solid curve is estimated relationship with lognormal bias correction.

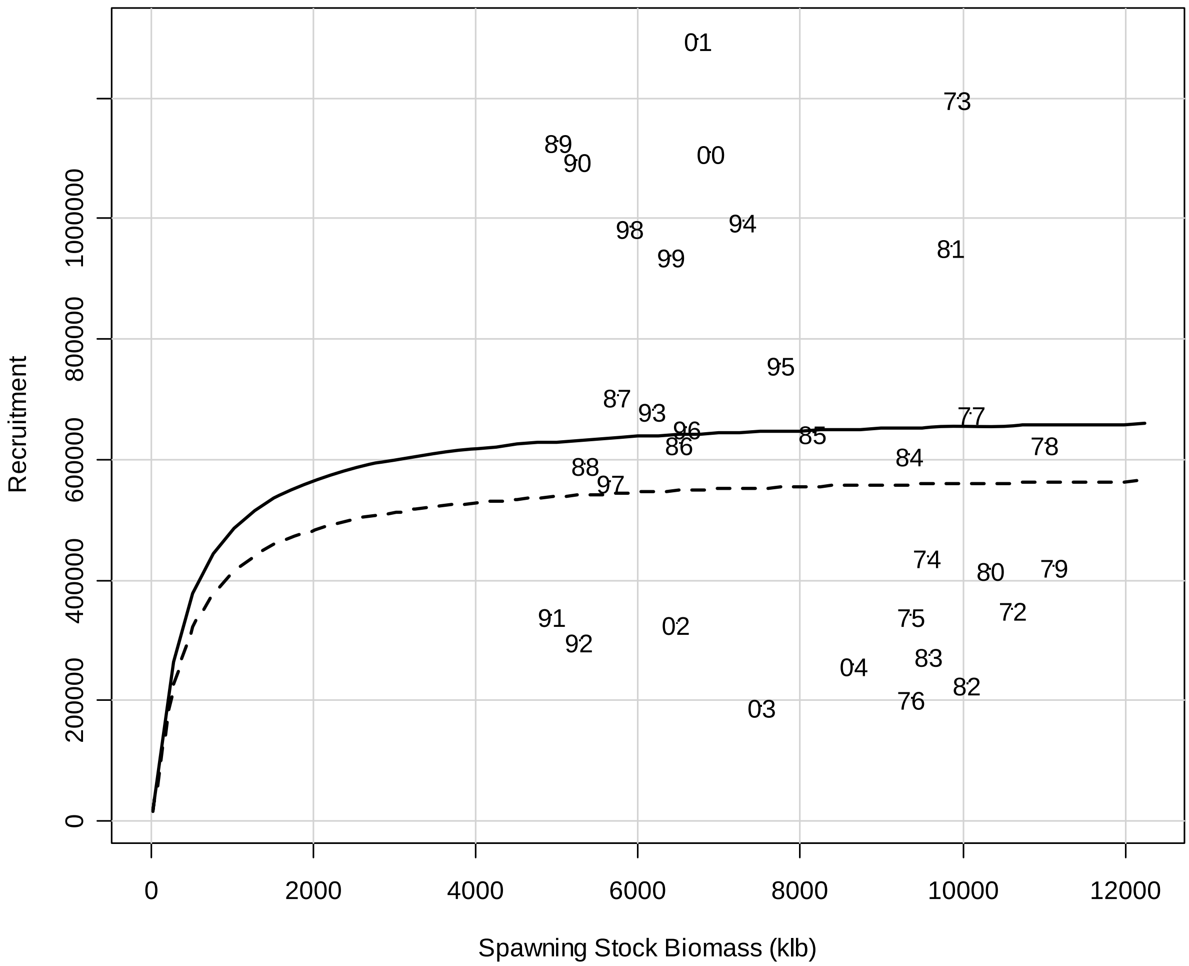
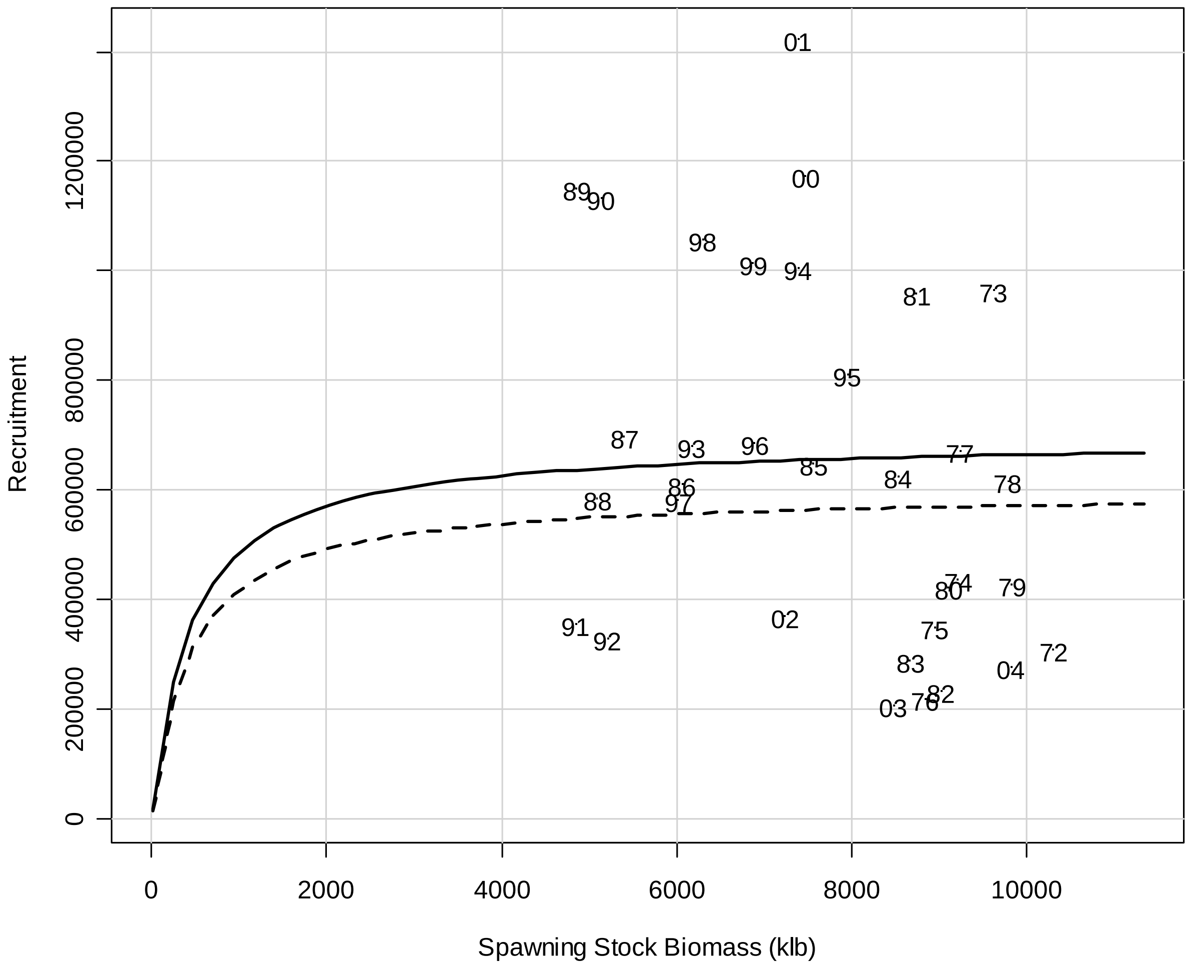


Figure 7. Base run with constant catchability: Estimated stock-recruitment relationship. Two digit year labels represent estimated spawning biomass and recruitment values from 1972-2004; Dashed curve is estimated relationship; Solid curve is estimated relationship with lognormal bias correction.



The review workshop panel requested analysis of autocorrelation in the recruitment time series and requested that the stock-recruit relationship be re-estimated with an additional autocorrelation parameter. The autocorrelation function fit suggests there is no significant autocorrelation at lag 1 or higher (Figures 8 and 9). The lag 1 correlation was examined visually in Figures 10 and 11.

Figure 8. Autocorrelation function applied to the log-recruitment residuals from the time-varying catchability model run. Significance levels are indicated by horizontal dashed lines.

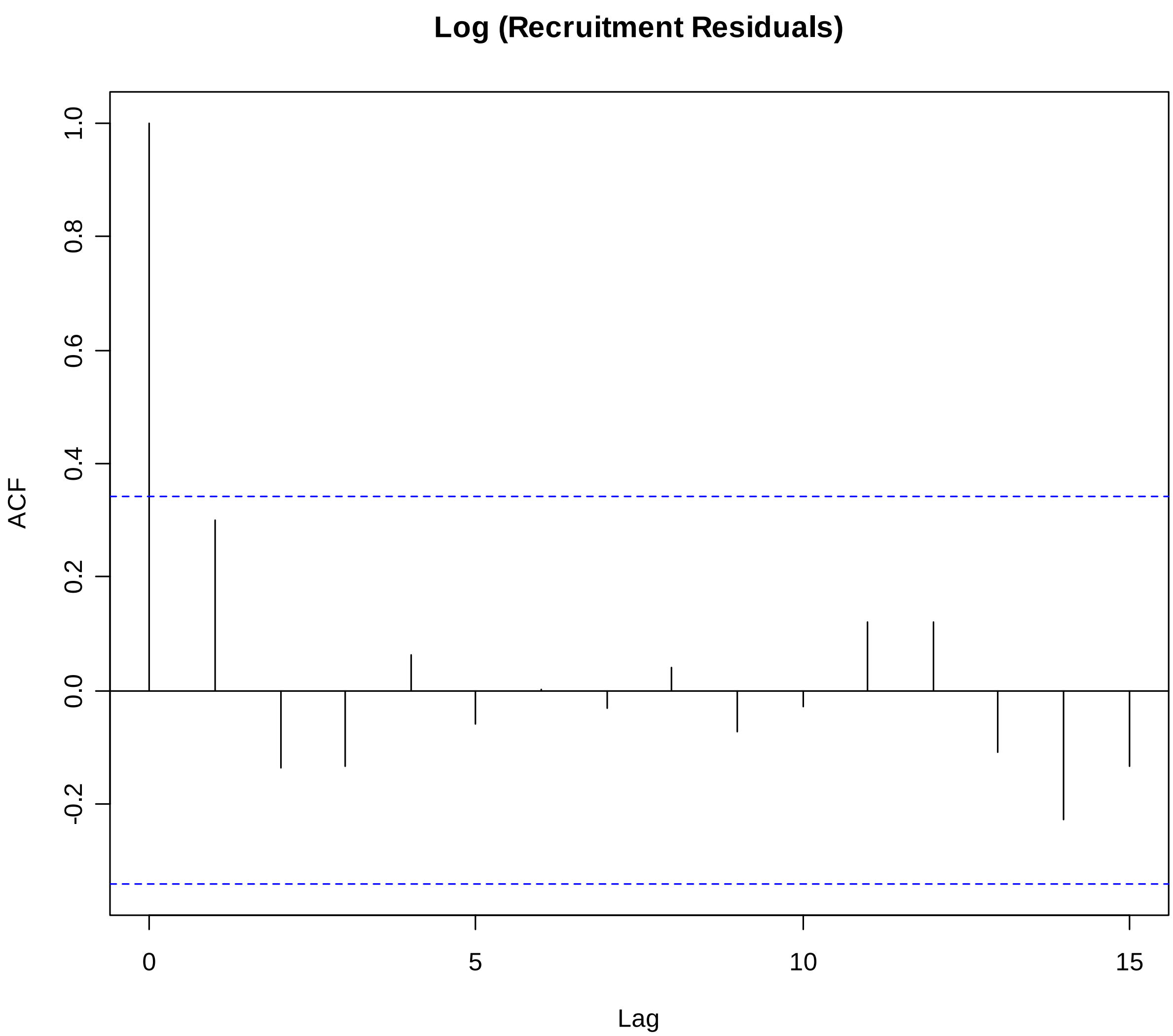


Figure 9. Autocorrelation function applied to the log-recruitment residuals from the constant catchability model run. Significance levels are indicated by horizontal dashed lines.

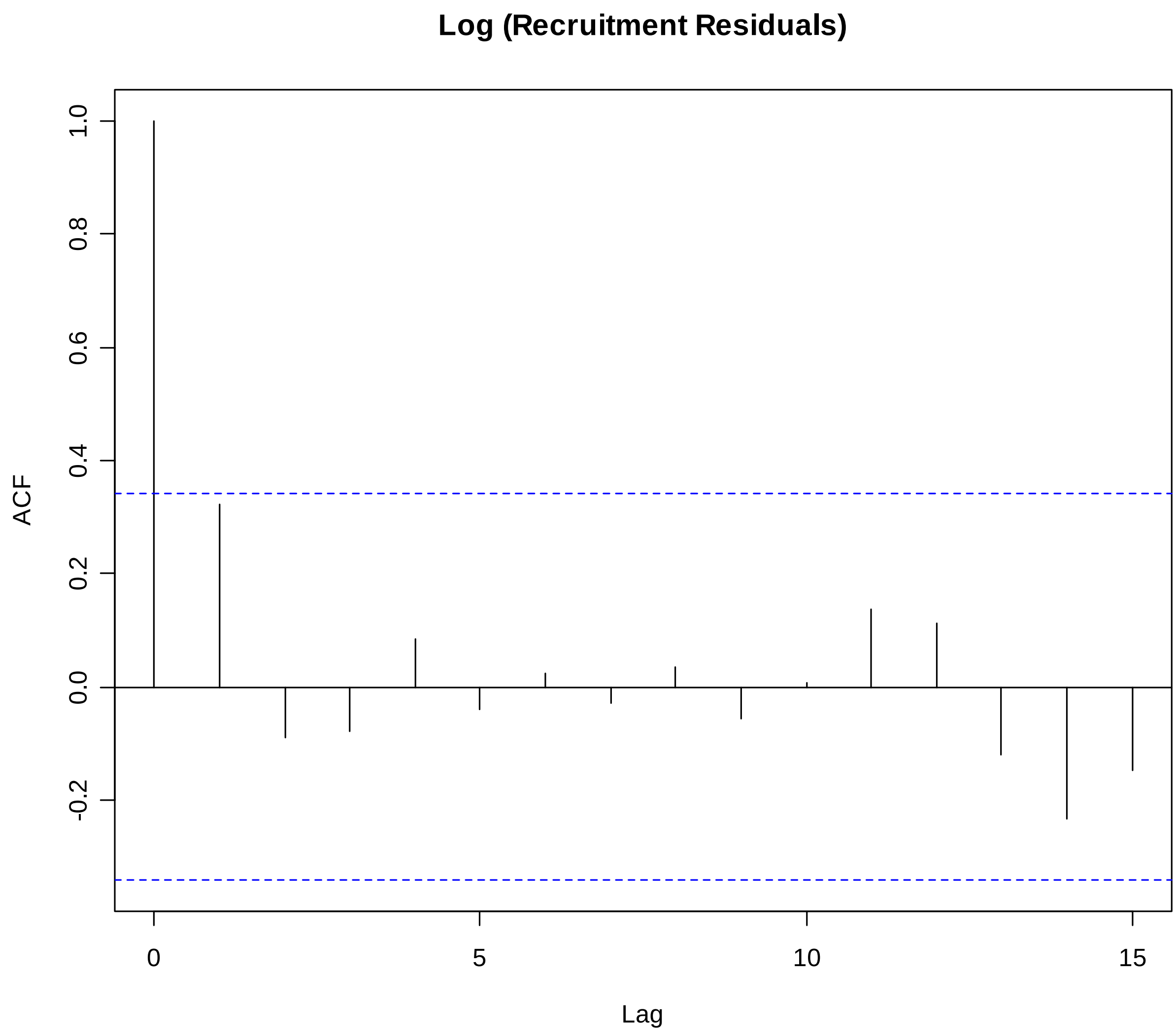


Figure 10. Plot of 1 year lagged log recruitment residuals from the time-varying catchability stock assessment model.

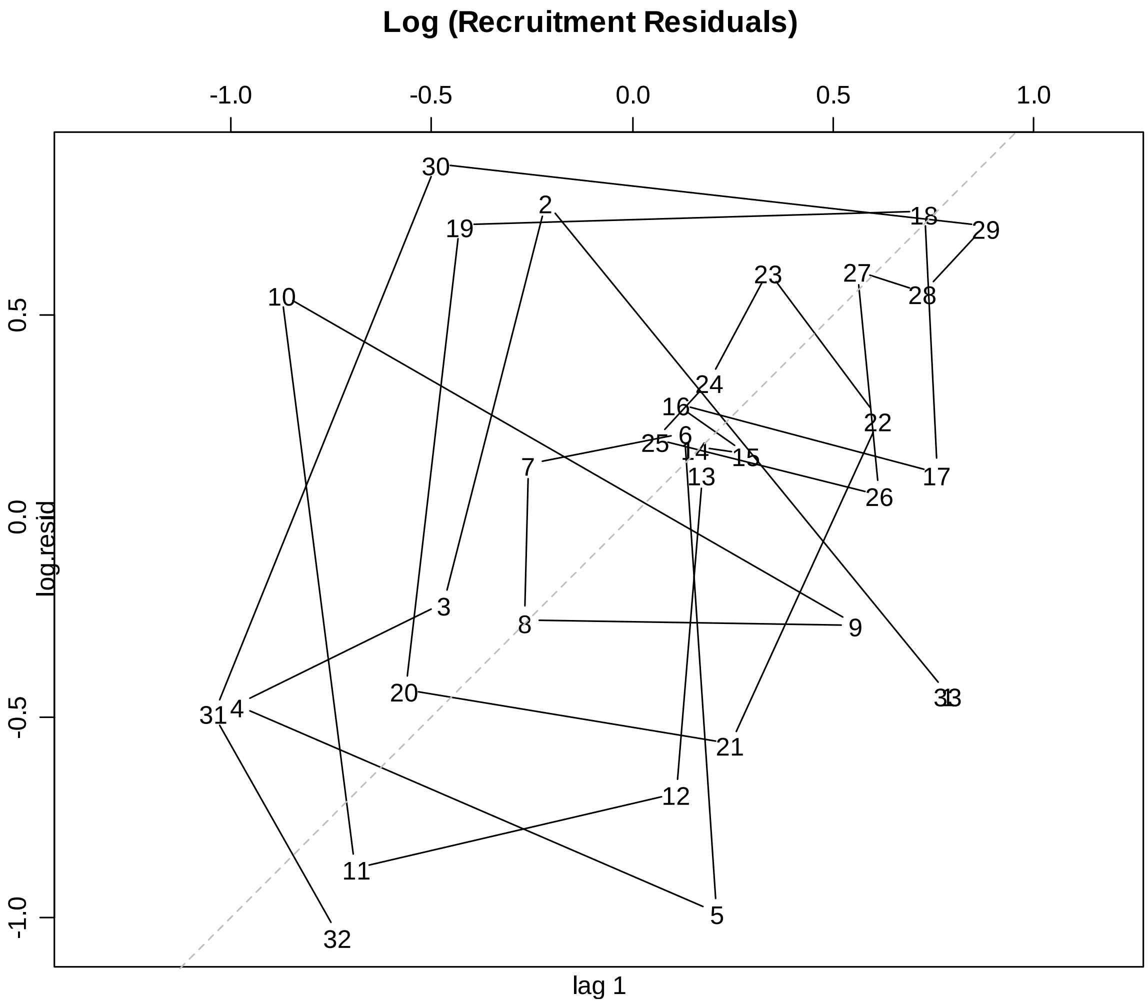


Figure 11. Plot of 1 year lagged log recruitment residuals from the constant catchability stock assessment model.

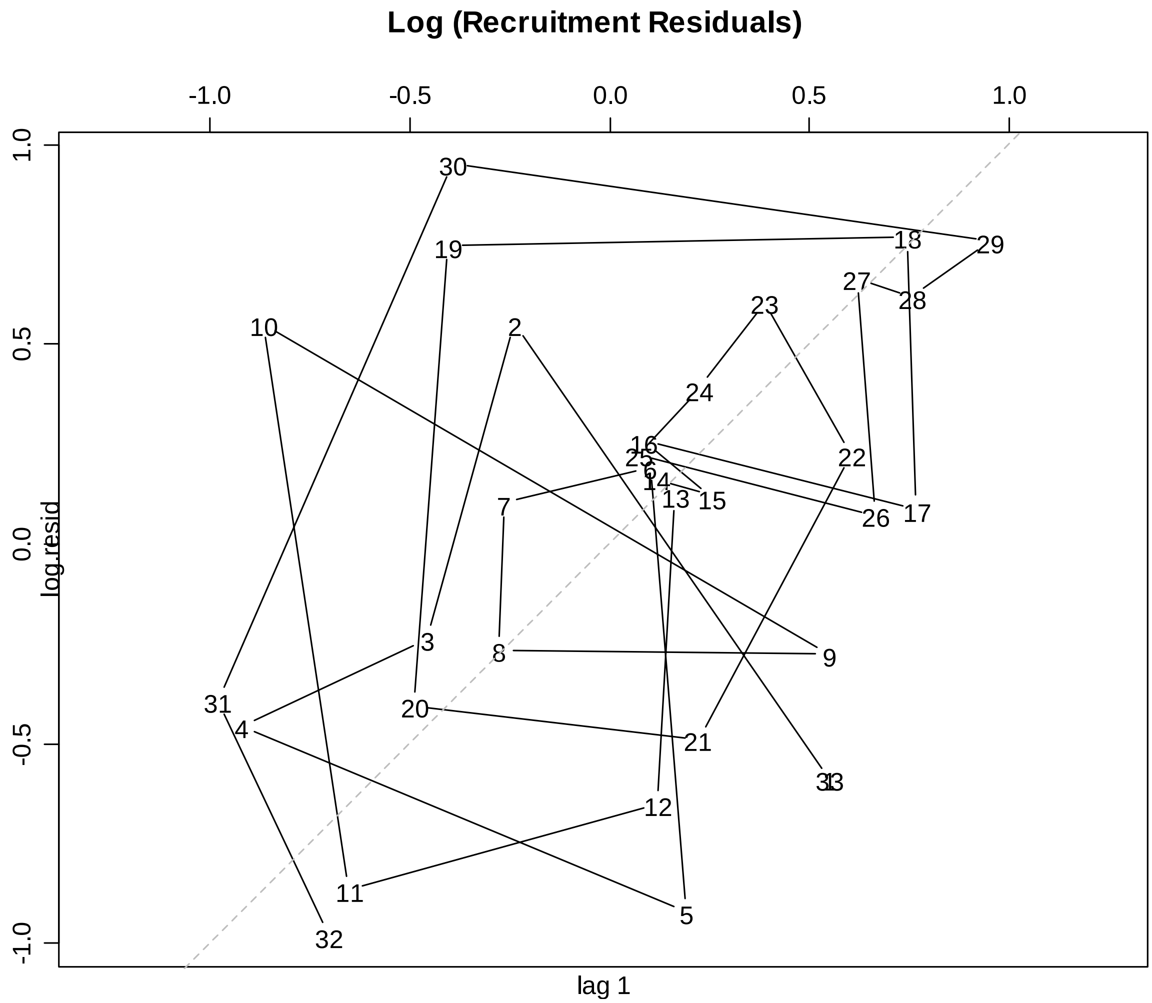


Figure 12. Base run with time-varying catchability: Estimated stock-recruitment relationship. Circles represent estimated spawning biomass and recruitment values from 1972-2004; Dashed curve is estimated relationship (black with no autocorrelation, red with lag 1 autocorrelation parameter); Solid curve is estimated relationship with lognormal bias correction (black with no autocorrelation, red with lag 1 autocorrelation parameter).

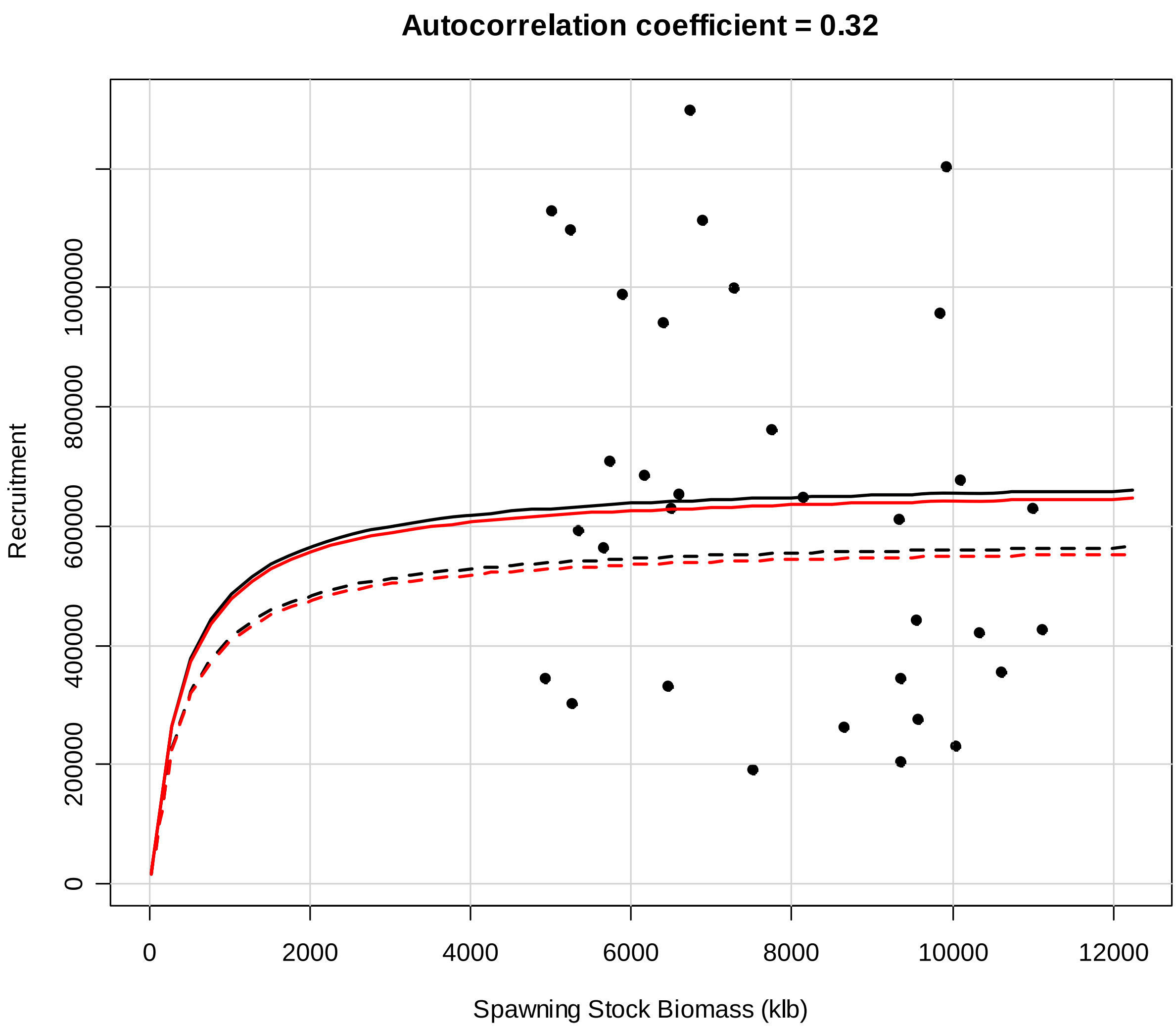
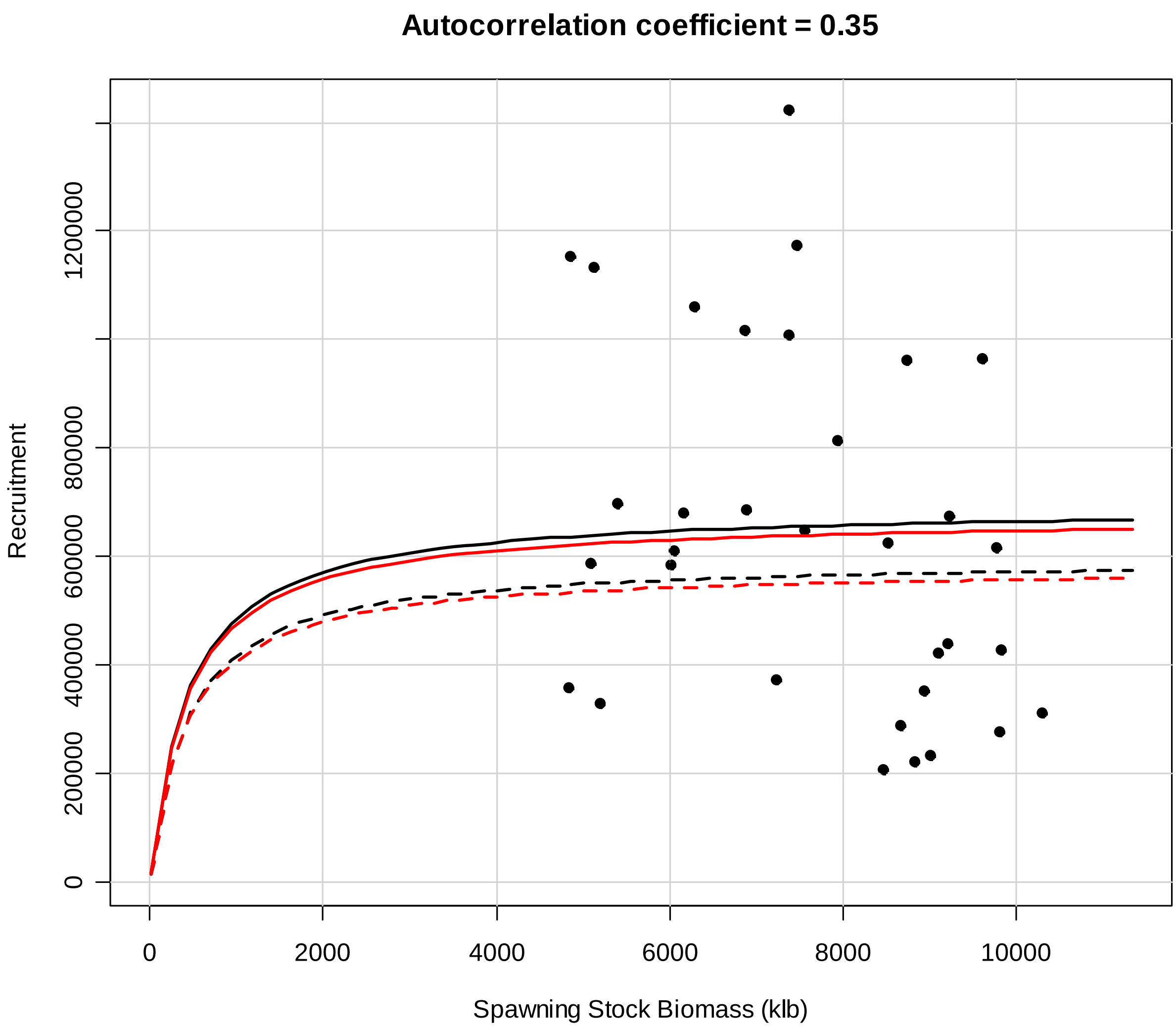


Figure 13. Base run with constant catchability: Estimated stock-recruitment relationship. Circles represent estimated spawning biomass and recruitment values from 1972-2004; Dashed curve is estimated relationship (black with no autocorrelation, red with lag 1 autocorrelation parameter); Solid curve is estimated relationship with lognormal bias correction (black with no autocorrelation, red with lag 1 autocorrelation parameter).



The review workshop panel requested sensitivity model runs for the constant catchability model. The panel wished to better understand the behavior of the model when certain data were left out of the model. The base model run contains three fishery dependent CPUE indices and three sets of age and length composition datasets (one for the commercial handline, commercial diving, and recreational headboat fisheries). The stock analysts completed nine additional model runs removing each index, each fishery age composition dataset, and each fishery length composition dataset one at a time, similar to a jackknife procedure.

The results from this analysis suggest that the model is a balanced fit to all the data sources, illustrated by the base run falling within the middle of this set of sensitivity runs (Figures 14-16). When examining the spawning stock biomass time series, the run with the headboat CPUE data left out shows the population increasing rapidly in the most recent years, reaching the highest terminal value of all the runs. In contrast, the run with the commercial handline CPUE left out results in the lowest value in the terminal year (Figure 14). This highlights the balanced fit between these two indices, which show opposite trends in the last few years.

Figure 14. Estimated time series of spawning stock biomass (klb) from the base run model with constant catchability. The base run model with all data included is illustrated with a thick black line. Other runs with the labeled dataset left out of the model are shown in various colors and point markers.

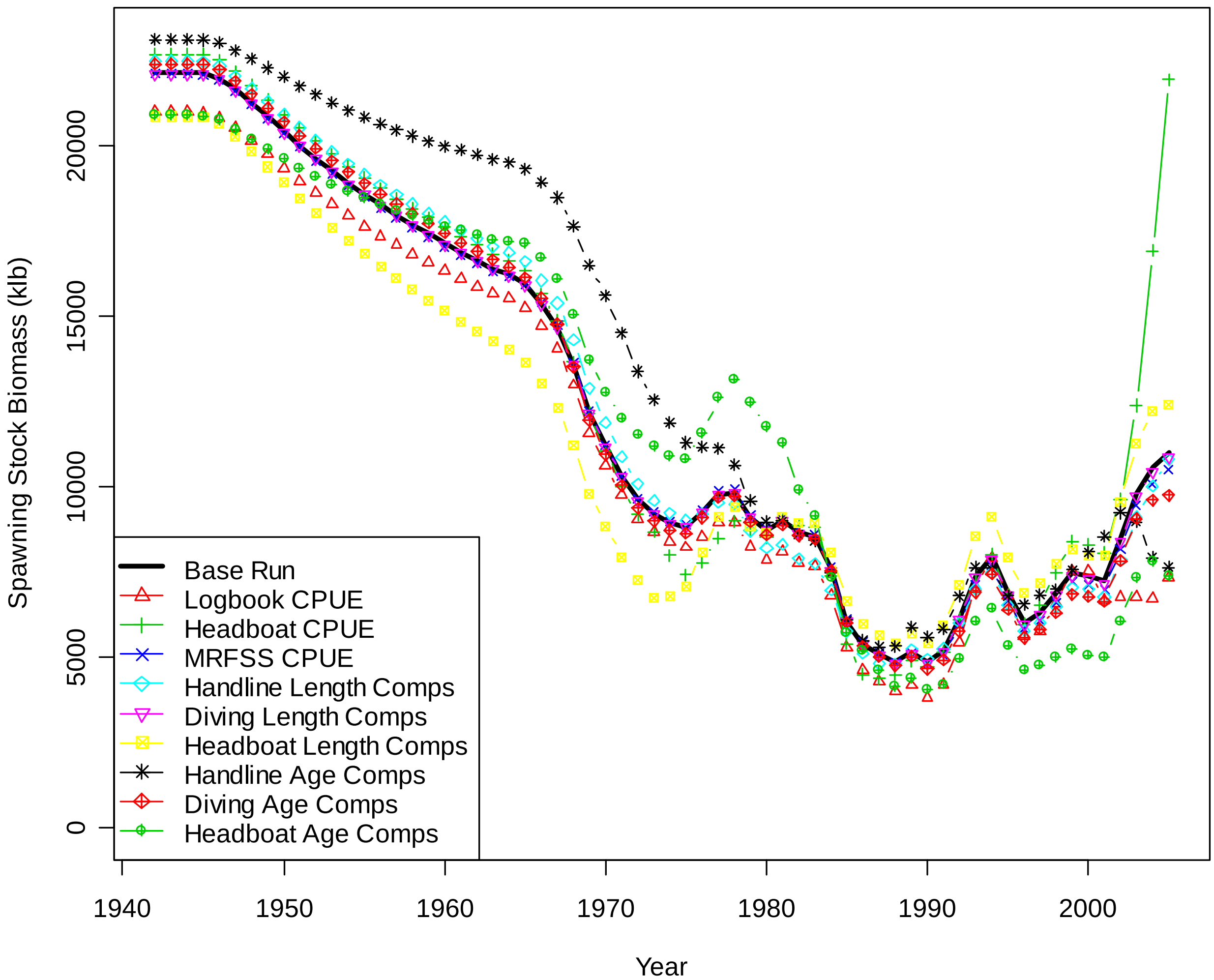


Figure 15. Estimated time series of fishing mortality rate from the base run model with constant catchability. The base run model with all data included is illustrated with a thick black line. Other runs with the labeled dataset left out of the model are shown in various colors and point markers.

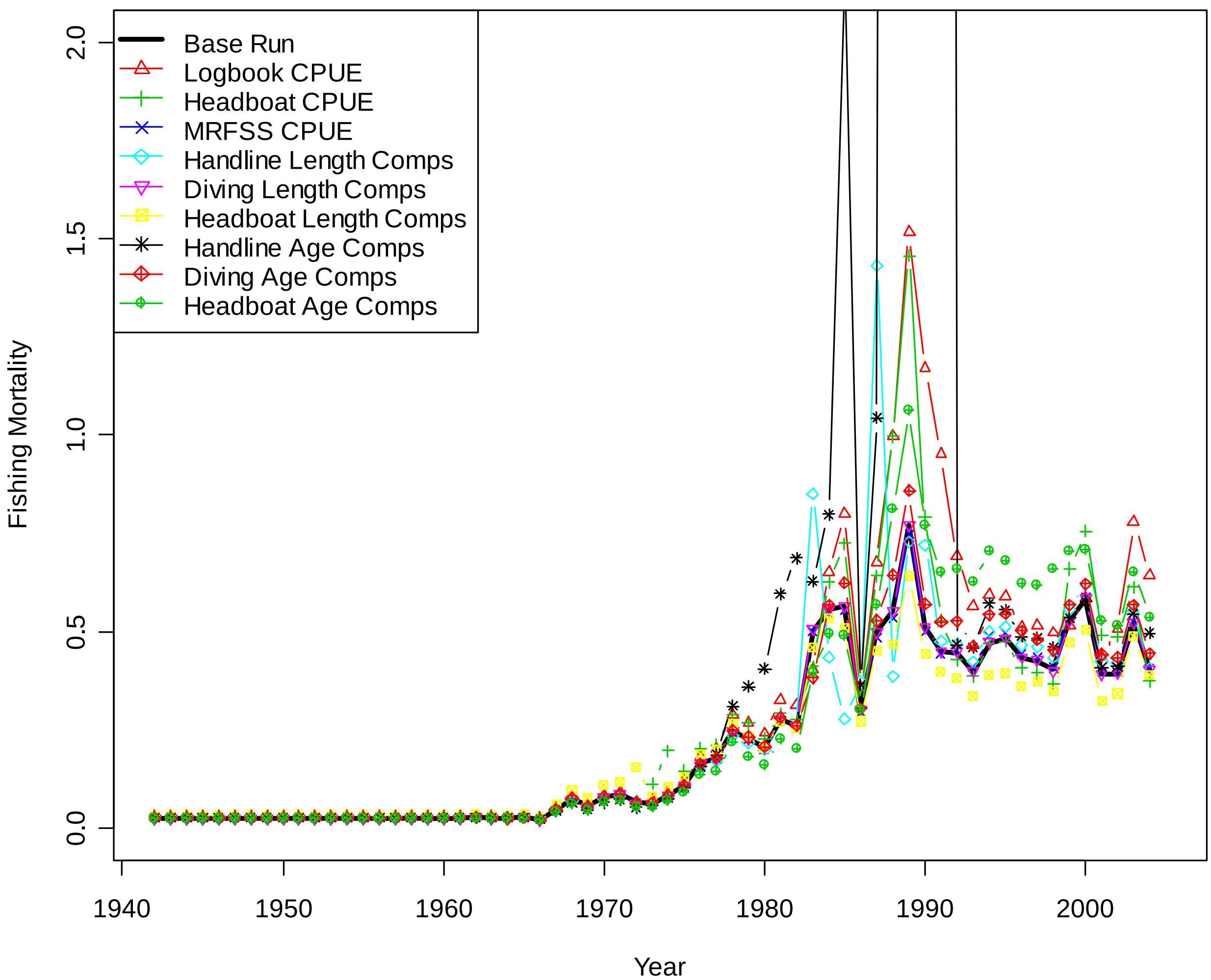
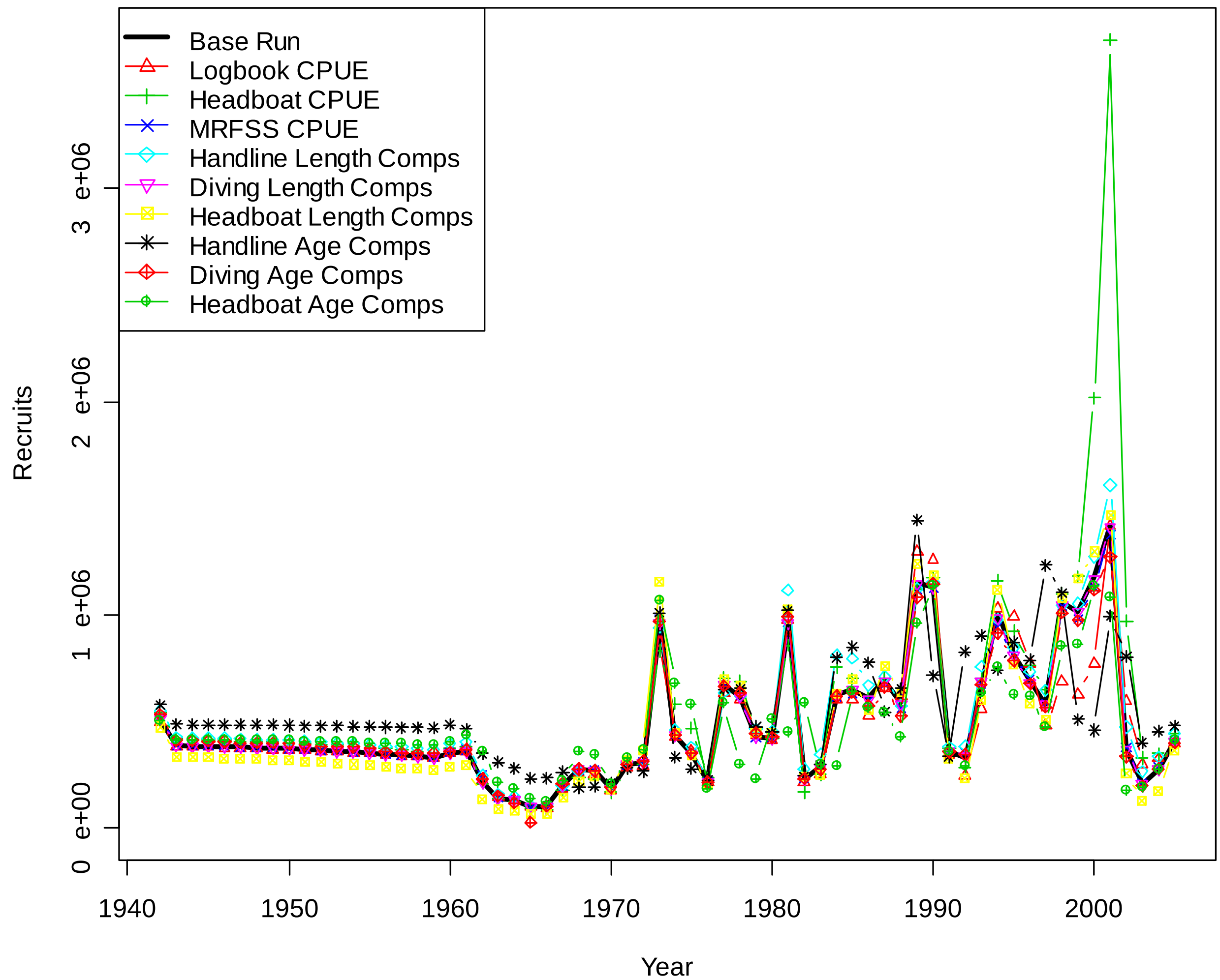


Figure 16. Estimated time series of recruitment from the base run model with constant catchability. The base run model with all data included is illustrated with a thick black line. Other runs with the labeled dataset left out of the model are shown in various colors and point markers.



SEDAR 10 Review Workshop

Assessment Advisory Report

South Atlantic Gag Grouper

Stock Distribution and identification

- The management unit for South Atlantic gag grouper includes gag grouper found in all waters within South Atlantic Fishery Management Council Boundaries.
- The SEDAR 10 Review Workshop (RW), using several sources of information, examined and accepted the current stock definitions for the South Atlantic and Gulf of Mexico gag.

Assessment Methods

- The South Atlantic gag grouper stock was assessed with two models: a statistical catch-at-age model, as the primary assessment model, and an age-aggregated production model to investigate results under a different set of model assumptions. Within each type of model various configurations and sensitivity runs were explored. Details of all models are available in the Stock Assessment Report and Addendum to the Stock Assessment Report.
- The assessment workshop (AW) developed two base runs: one assuming a time-varying catchability and one assuming constant catchability for the fishery dependent indices. Each base run of the catch-at-age model was the basis for estimation of benchmarks and stock status.
- The SEDAR 10 RW recommended the run with constant catchability as the preferred ‘base run’.

Assessment Data

- Data sources include fishery-dependent abundance indices, recorded landings, and samples of annual length and age compositions from fishery-dependent sources.
- Three fishery–dependent abundance indices were developed by the SEDAR 10 data workshop: one from the NMFS headboat survey, one from the commercial logbook program, and one from the Marine Recreational Fishing Statistical Survey (MRFSS). Currently, there are no usable fishery–independent abundance data for this stock of gag grouper.
- Landings data were available from all recreational (headboat, charter boat, private boat, and shore sectors) and commercial fisheries (handline and diving gears). This benchmark assessment included data through 2004.
- Complete details are available in the SEDAR 10 Data and Assessment Reports, and the SEDAR 10 workshop working papers. Additional information and discussion can be found in the companion SEDAR 10 Review Workshop Consensus Summary Report for South Atlantic Gag Grouper.

Catch Trends

- Landings are reported from the commercial and recreational sectors. The commercial landings are in gutted weight in pounds, while recreational landings are estimated in numbers. Commercial landings were converted to numbers for the assessment model (Table 1 and Figures 1-2).
- The commercial landings were dominated by handline gear peaking at over 1,000,000 pounds in 1984. Landings from the diving gear have been significant in recent years and are modeled separately. The contribution from other gears is small and included with the handline gear (Table 1 and Figure 1).
- The recreational sector catch peaked in 1984 at about 180,000 fish, and has two components: catch estimated from MRFSS which includes private and charter boats and a minor shore component, and catch estimated from a survey of headboats (larger for-hire vessels) (Table 1).
- When comparing across sectors, the largest landings in numbers are associated with the MRFSS (Table 1 and Figure 2).
- Coastwide landings of gag grouper in the South Atlantic had been increasing but have recently leveled off. The catch share among sectors has been changing over the last decade, with increased landings from the charter/private boat and shore mode recreational sectors relative to the commercial handline sector, which has been decreasing.

Fishing mortality trends

- Fishing mortality (fully selected F) increased from 0.03 in 1962 to 0.50 in 1983 (above F_{MSY} = 0.295; see discussion below). Fishing mortality has remained above F_{MSY} since then (Table 2 and Figure 3). Fishing mortality in 2004 was estimated as 0.40.

Stock abundance and biomass trends

- Total and spawning stock biomass (both sexes combined) declined from initial high values in the 1960s, went below levels corresponding to MSY in 1970s, remained relatively constant through the early 1980s, declined through the remainder of the 1980s and have apparently been on an increasing trend since (Table 2 and Figure 4). In particular, spawning stock biomass declined from 16.6 million pounds (gutted weight) in 1962 to 9.1 million pounds in 1979 (below the current value of SSB_{MSY} = 9.4 million pounds). Spawning stock biomass rose to 9.8 million pounds in 2003 (Table 2). The 2005 SSB value is estimated to be 11.0 million pounds.

Status determination criteria and Stock Status

- Status Determination Criteria: The SFA and management criteria recommendations and values are estimated from the preferred base model by the RW as follows:

Stock Status	Current Definition	Value from Previous Assessment	Value from Current Assessment
MSST	$(1\text{-}M)B_{MSY}$	NA	8062 klb
MFMT	F_{MSY} Proxy = $F_{30\%SPR}$	0.18	0.24
MSY	Yield at F_{MSY}	NA	1774 klb
F_{OY}	$F_{45\%SPR}$	NA	0.13
OY	Yield at F_{OY} ($F_{45\%SPR}$)	NA	1570 klb

Proposed Status Criteria	Definition	Value
MSST	$(1\text{-}M)SSB_{MSY}$ *(see special comment)	5000 klb
MFMT	F_{MSY}	0.295
MSY	Yield at F_{MSY}	1774 klb
OY	65%F_{MSY} (Alt. 1) 75%F_{MSY} (Alt. 2) 85%F_{MSY} (Alt. 3)	1714 klb 1747 klb 1765 klb
F_{OY}	65%F_{MSY} (Alt. 1) 75%F_{MSY} (Alt. 2) 85%F_{MSY} (Alt. 3)	0.192 0.221 0.251
M (Age-varying)	Constant Equivalent	0.14

Additional Benchmarks	Exploitation Rate	SSB	Yield
F_{MAX}	0.330	8592 klb	1770 klb
$F_{20\%SPR}$	0.420	7087 klb	1737 klb
$F_{30\%SPR}$	0.240	10929 klb	1760 klb
$F_{45\%SPR}$	0.130	16370 klb	1570 klb

Stock Status

- Current rates of exploitation indicate that overfishing is occurring for the South Atlantic gag grouper stock (Figure 5). Relative to the current value of the MSST specified by the FMP, South Atlantic gag is approaching an overfished condition and is projected to become overfished in 2007 (see projections, Figure 6). Relative to the MSST proposed by the RW, the stock is not overfished and is not projected to become overfished under any of the projection scenarios (Figure 6).
- The MSY-based benchmarks in this assessment are deemed useful for management.
- The current definition of MSST may be overly conservative. The RW recommends an operational definition of MSST of 5 million pounds (see Special Comments).

Projections

- Estimates of recruitment in 2002-2004 are below average and fishing mortality rates in 2002-2004 are above the MSY level. As a result, stock projections suggest that the stock will decline below the existing MSST in 2007. Projections for biomass, recruitment and fishing mortality at various levels of constant fishing mortality rates starting in 2008 are shown in Table 3 and Figures 6-10. The levels are based on current F (geometric mean of last three years of the base run, Figure 6), on F_{MSY} (Figure 7), and three levels of F_{OY} (65%, 75% and 85% of F_{MSY}, Figures 8-10).

Special Comments

- **Constant and time-varying catchability alternative**: The RW discussed the relationship of technology to catchability and the effects of catchability changes on fishery-dependent abundance indices. The RW recognized that technology improvements over time, particularly better electronics, have likely made fishermen more effective and efficient at catching fish. The RW, however, did not support an assessment that assumed a simple linear (2% annually) increase. Nevertheless, this is an important issue and the RW recommends further investigations of time-varying catchability.

- **Uncertainties**: The primary uncertainties in the assessment are from the model process errors and the data measurement errors. Because of the inherited high uncertainties from the assessment data and the estimated stock-recruitment relationship, the RW evaluated the uncertainties in this assessment with sensitivity runs to investigate the robustness of management benchmark parameter estimates to alternative choices about data usage.

- **Stock-recruitment relationship**: In both stock areas, the stock and recruitment scatter plot does not suggest that recruitment is strongly linked with SSB. In the South Atlantic, the Beverton-Holt stock-recruitment relationship indicates little change in recruitment for a wide range of SSB's and that B_{MSY} falls in the range of SSB's observed in the past. On the other hand, the Ricker stock-recruitment relationship indicates that maximum recruitment occurs at SSBs lower than those observed over the period of the assessment, which implies that B_{MSY} would also be lower than those observed in the period of the assessment. In the Gulf of

Mexico, both the Beverton-Holt and Ricker relationships suggest that considerably higher recruitment would result from larger SSBs and SSB_{MSY} is estimated to be higher than SSB's observed in the past. The RW considers that the stock recruitment relationships in the two stock areas are equally uncertain. The derived benchmarks are considered useful for management in the South Atlantic, because they are within the range of past observed values. In the Gulf of Mexico, more stock and recruitment observations are necessary to confirm that the benchmarks estimated in the current assessment are indeed attainable.

- **Discussion of RW recommended MSST**: MSST, currently defined by the South Atlantic Council as $(1\text{-}M)B_{MSY}$, is very close to B_{MSY} because age-averaged natural mortality rate, M, is estimated as 0.14. Given the uncertainties in the assessment, the biomass would be expected to fall below MSST with a relatively high frequency even if the true biomass were close to B_{MSY}. In addition, MSST, as currently defined, may be overly conservative. There are no indications of impaired recruitment at the lowest observed SSB (around 5 million lbs) and the RW suggests that MSST could be set at this level, operationally, to be re-examined at the next assessment.

- **Sensitivity investigations**: The RW requested sensitivity model runs for the constant catchability model. The Panel wished to better understand the behavior of the model when certain data were left out of the model. The base model run contains three fishery-dependent CPUE indices and three sets of age and length composition datasets (one for the commercial handline, commercial diving, and recreational headboat fisheries). The stock analysts completed nine additional model runs removing each index, each fishery age composition dataset, and each fishery length composition dataset, one at a time. The results from this analysis suggest that the selected model provides a balanced fit to all data sources, illustrated by the base run falling within the middle of this set of sensitivity runs (Figures 12-14). When examining the spawning stock biomass time series, the run with the headboat CPUE data omitted shows the population increasing rapidly in the most recent years, reaching the highest terminal value of all the runs. In contrast, the run with the commercial handline CPUE omitted produces the lowest estimate of SSB value in the terminal year (Figure 12).

Sources of Information:

- The report from the Data Workshop along with the associated workshop documents.
- The report from the Assessment workshop along with associated documents.
- The SEDAR10 Review workshop discussions and presentations
- The SEDAR10 Review Workshop Consensus Summary Assessment of South Atlantic Gag Grouper

Tables: Catch and Status

Table 1. Commercial landings by gear in weight (gutted), recreational landings in numbers, and discards in numbers for gag grouper from the U.S. South Atlantic, 1962-2004.

	Commercial (gutted klb)		Recreational (1000s)		Discards (1000s)		
Year	Handline	Diving	Headboat	MRFSS	Handline	Headboat	MRFSS
1962	150.3		8.41	6.17			
1963	137.0		7.66	5.62			
1964	128.4		7.18	5.27			
1965	130.4		7.41	5.44			
1966	99.1		5.58	4.09			
1967	210.9		11.77	8.62			
1968	309.9		17.72	12.98			
1969	217.2		12.13	8.89			
1970	299.0		16.66	12.20			
1971	306.7		17.18	12.59			
1972	204.5		13.44	8.37			
1973	290.5		17.99	12.15			
1974	372.8		13.92	15.68			
1975	421.8		8.57	17.48			
1976	565.0	3.75	7.56	23.77			
1977	627.6	8.81	8.48	21.94			
1978	967.4	13.87	6.01	37.54			
1979	907.5	18.92	9.55	35.70			
1980	846.2	16.40	6.96	35.39			
1981	984.0	13.88	13.86	56.69		0.03	0.00
1982	1027.4	15.85	11.84	22.17		0.02	4.32
1983	1101.1	9.08	16.46	166.70		0.04	91.88
1984	1108.2	18.75	18.69	165.20		0.03	11.95
1985	865.7	11.62	16.13	55.31		3.76	3.09
1986	819.8	6.34	17.35	59.26		4.05	12.48
1987	857.8	21.93	24.09	97.68		5.63	10.30
1988	672.4	12.96	24.21	77.08		5.65	15.01
1989	967.0	22.26	22.42	118.69		5.23	43.41
1990	784.3	19.07	17.59	63.66		4.11	11.46
1991	656.4	85.01	13.55	60.90		3.16	24.19
1992	691.7	106.76	13.94	87.98		7.74	38.66
1993	756.6	78.15	11.80	83.03		6.54	31.23
1994	800.0	97.50	9.81	124.51		5.45	68.29
1995	840.4	83.77	10.54	114.50		5.85	73.97
1996	751.9	118.56	7.50	86.92		4.16	43.00
1997	608.2	98.71	6.85	114.74		3.81	82.41
1998	654.5	138.79	8.67	72.54		4.82	32.22
1999	538.1	113.49	5.34	109.31	7.37	4.80	58.86
2000	438.2	63.02	5.98	156.50	7.77	5.38	126.63
2001	450.1	82.30	5.12	90.15	13.71	4.60	47.41
2002	448.3	84.52	4.58	109.76	11.91	4.12	85.73
2003	443.9	117.41	3.27	183.73	5.10	2.95	137.62
2004	476.4	74.97	6.66	135.79	7.20	6.00	89.54

Table 2. Estimated time series and status indicators. Exploitation rate (E) is of ages 2+, F is the fully selected fishing mortality rate, and SPR is static spawning potential ratio. SSB is in thousands of gutted pounds.

Year	E	E/E_{MSY}	F	F/F_{MSY}	SSB	SSB/SSB_{MSY}	SPR
1962	0.0191	0.233	0.0291	0.0987	16639	1.775	0.783
1963	0.0176	0.216	0.0273	0.0926	16402	1.750	0.795
1964	0.0177	0.217	0.0267	0.0907	16236	1.732	0.799
1965	0.0199	0.243	0.0285	0.0967	15958	1.702	0.785
1966	0.0166	0.203	0.0237	0.0803	15383	1.641	0.819
1967	0.0372	0.456	0.0483	0.1638	14698	1.568	0.662
1968	0.0601	0.735	0.0760	0.2577	13598	1.451	0.539
1969	0.0430	0.527	0.0569	0.1930	12180	1.299	0.620
1970	0.0575	0.704	0.0798	0.2707	11201	1.195	0.531
1971	0.0601	0.735	0.0872	0.2959	10310	1.100	0.509
1972	0.0446	0.546	0.0652	0.2213	9623	1.027	0.587
1973	0.0376	0.461	0.0648	0.2197	9220	0.984	0.598
1974	0.0460	0.563	0.0827	0.2805	8953	0.955	0.545
1975	0.0462	0.566	0.1090	0.3696	8839	0.943	0.490
1976	0.0601	0.736	0.1640	0.5564	9243	0.986	0.408
1977	0.0675	0.826	0.1798	0.6097	9788	1.044	0.402
1978	0.1131	1.384	0.2483	0.8421	9832	1.049	0.318
1979	0.0991	1.213	0.2295	0.7785	9112	0.972	0.325
1980	0.0861	1.054	0.2054	0.6966	8741	0.933	0.348
1981	0.1233	1.509	0.2780	0.9429	9022	0.962	0.258
1982	0.0987	1.208	0.2603	0.8830	8673	0.925	0.317
1983	0.1816	2.223	0.5038	1.7087	8535	0.910	0.161
1984	0.2768	3.388	0.5572	1.8901	7566	0.807	0.113
1985	0.1614	1.975	0.5650	1.9162	6068	0.647	0.213
1986	0.1746	2.137	0.3014	1.0224	5402	0.576	0.174
1987	0.1953	2.390	0.4991	1.6930	5097	0.544	0.149
1988	0.1439	1.761	0.5551	1.8827	4854	0.518	0.191
1989	0.2106	2.578	0.7721	2.6186	5138	0.548	0.124
1990	0.1530	1.873	0.5134	1.7413	4853	0.518	0.178
1991	0.1148	1.405	0.4493	1.5241	5214	0.556	0.204
1992	0.1239	1.516	0.4475	1.5178	6175	0.659	0.187
1993	0.1458	1.785	0.3979	1.3495	7395	0.789	0.202
1994	0.2091	2.559	0.4707	1.5964	7951	0.848	0.159
1995	0.1953	2.391	0.4814	1.6328	6894	0.735	0.153
1996	0.1412	1.728	0.4323	1.4664	6019	0.642	0.183
1997	0.1447	1.771	0.4271	1.4486	6298	0.672	0.177
1998	0.1249	1.528	0.4031	1.3671	6877	0.734	0.214
1999	0.1468	1.797	0.5283	1.7920	7475	0.797	0.188
2000	0.1503	1.839	0.5810	1.9707	7394	0.789	0.161
2001	0.0948	1.161	0.3911	1.3267	7235	0.772	0.230
2002	0.0946	1.158	0.3927	1.3320	8479	0.904	0.226
2003	0.1247	1.526	0.5233	1.7749	9823	1.048	0.178
2004	0.1260	1.542	0.4019	1.3633	10563	1.127	0.216
2005	.	.	.	.	11005	1.174	.

Table 3. Biomass, landings and discard projections under various fishing mortality (F) scenarios starting in 2008 (F fixed at the current value in 2005-2007). All results are in 1,000s of gutted pounds (klb). For reference, SSB_{MSY} = 9,374 klb, MSY = 1,774 klb, discards at MSY (D_{MSY}) = 88 klb

	Fcurrent	Fmsy	85% Fmsy	75% Fmsy	65% Fmsy
SSB (2005) (klb)	11005	11005	11005	11005	11005
SSB (2007) (klb)	7435	7435	7435	7435	7435
SSB (2010) (klb)	6265	7206	7545	7784	8034
SSB (2014) (klb)	6769	8689	9499	10112	10793
Landings (2005) (klb)	2720	2720	2720	2720	2720
Landings (2007) (klb)	2175	2175	2175	2175	2175
Landings (2010) (klb)	1523	1278	1166	1079	981
Landings (2014) (klb)	1698	1626	1560	1497	1415
Discards (2005) (klb)	138	138	138	138	138
Discards (2007) (klb)	75	75	75	75	75
Discards (2010) (klb)	117	84	73	65	58
Discards (2014) (klb)	118	87	76	68	60

Figure 1. Commercial gag grouper landings (gutted weight in pounds) by gear from the U.S. South Atlantic, 1962-2004.

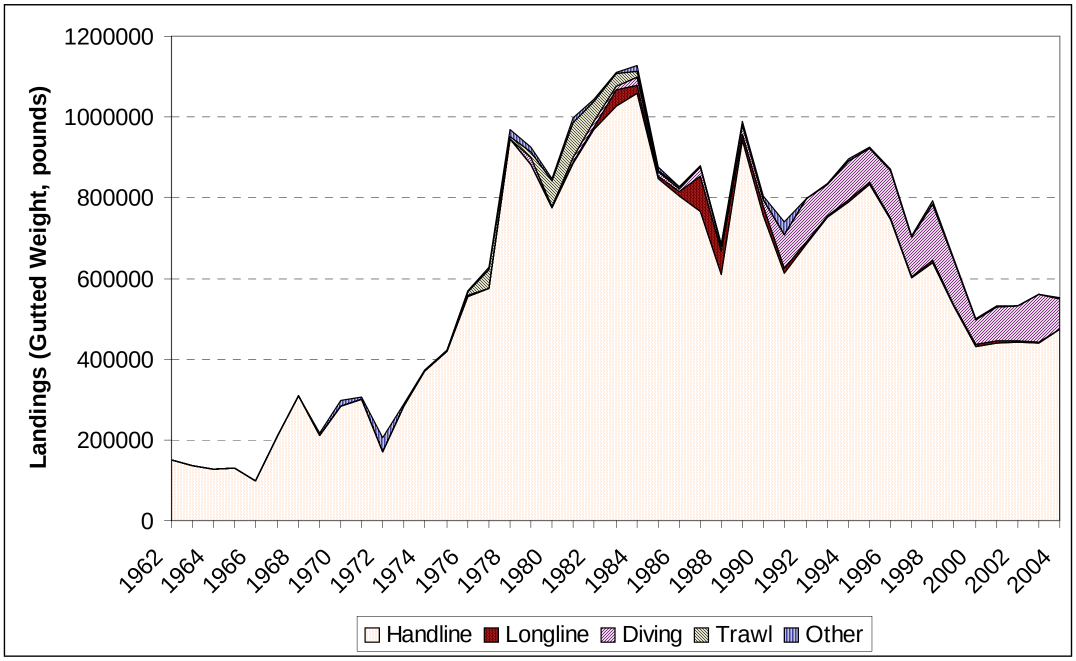


Figure 2. Total gag grouper catches (landings and discards) in numbers by sector from the U.S. South Atlantic, 1962-2004.

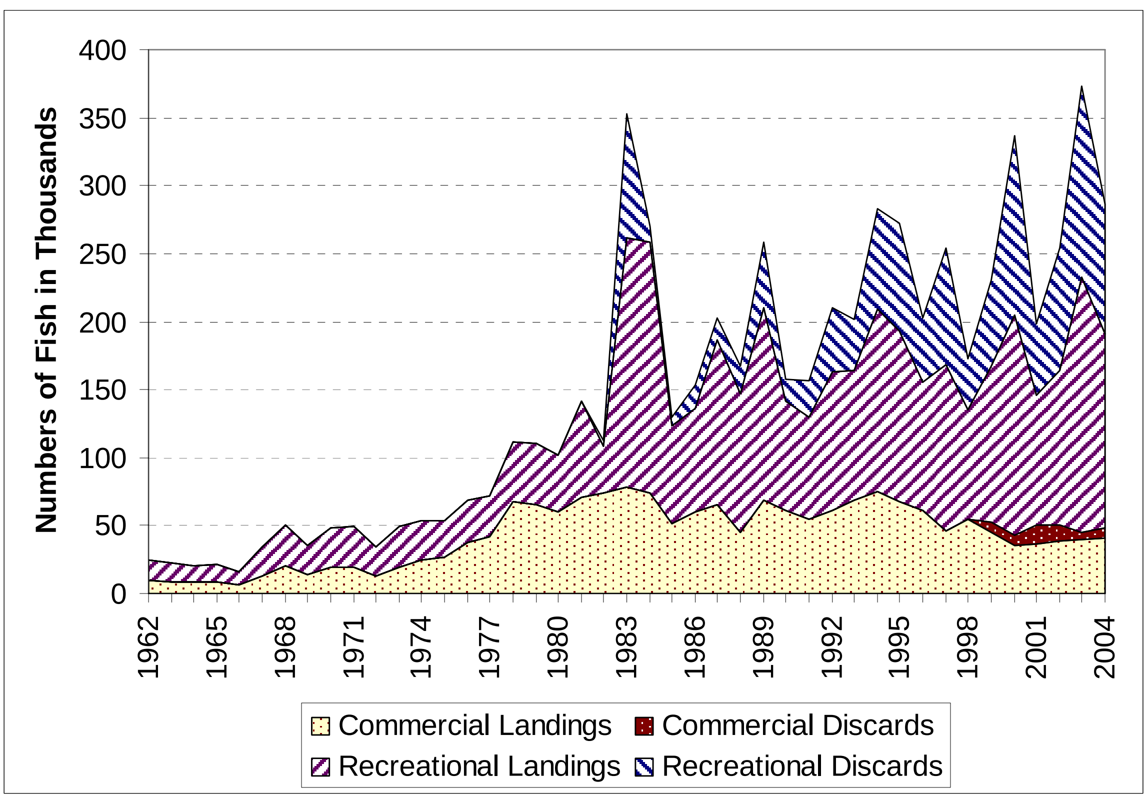


Figure 3. Estimated fully-selected fishing mortality rate. Solid horizontal line represents F_{MSY}.

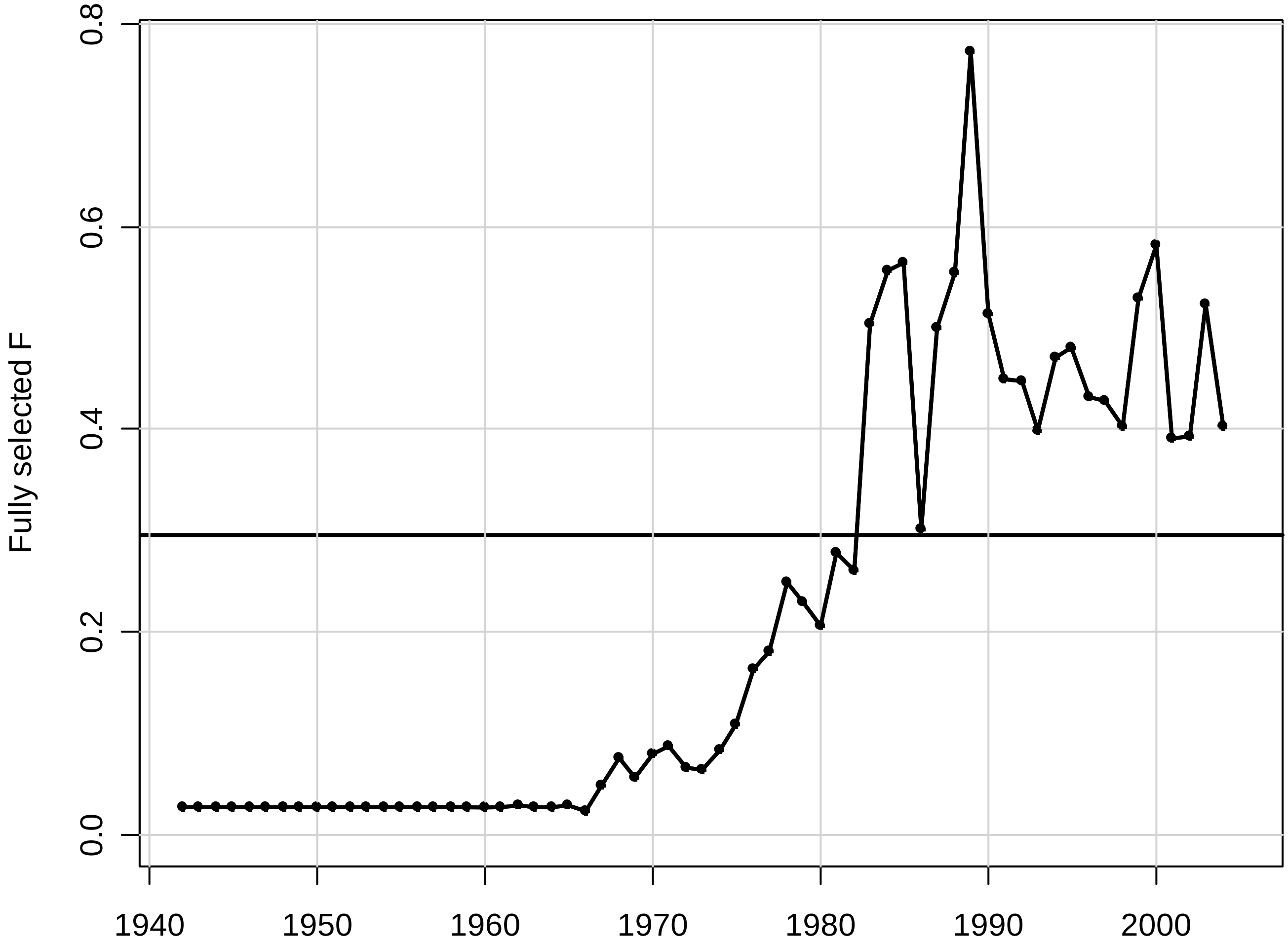


Figure 4. Estimated biomass time series (biomass in gutted weight). Total biomass (solid trend line) and spawning stock biomass (male mature biomass + female mature biomass, dashed trend line). The horizontal lines represents the level of biomass corresponding to MSY (B_{MSY} and SSB_{MSY}).

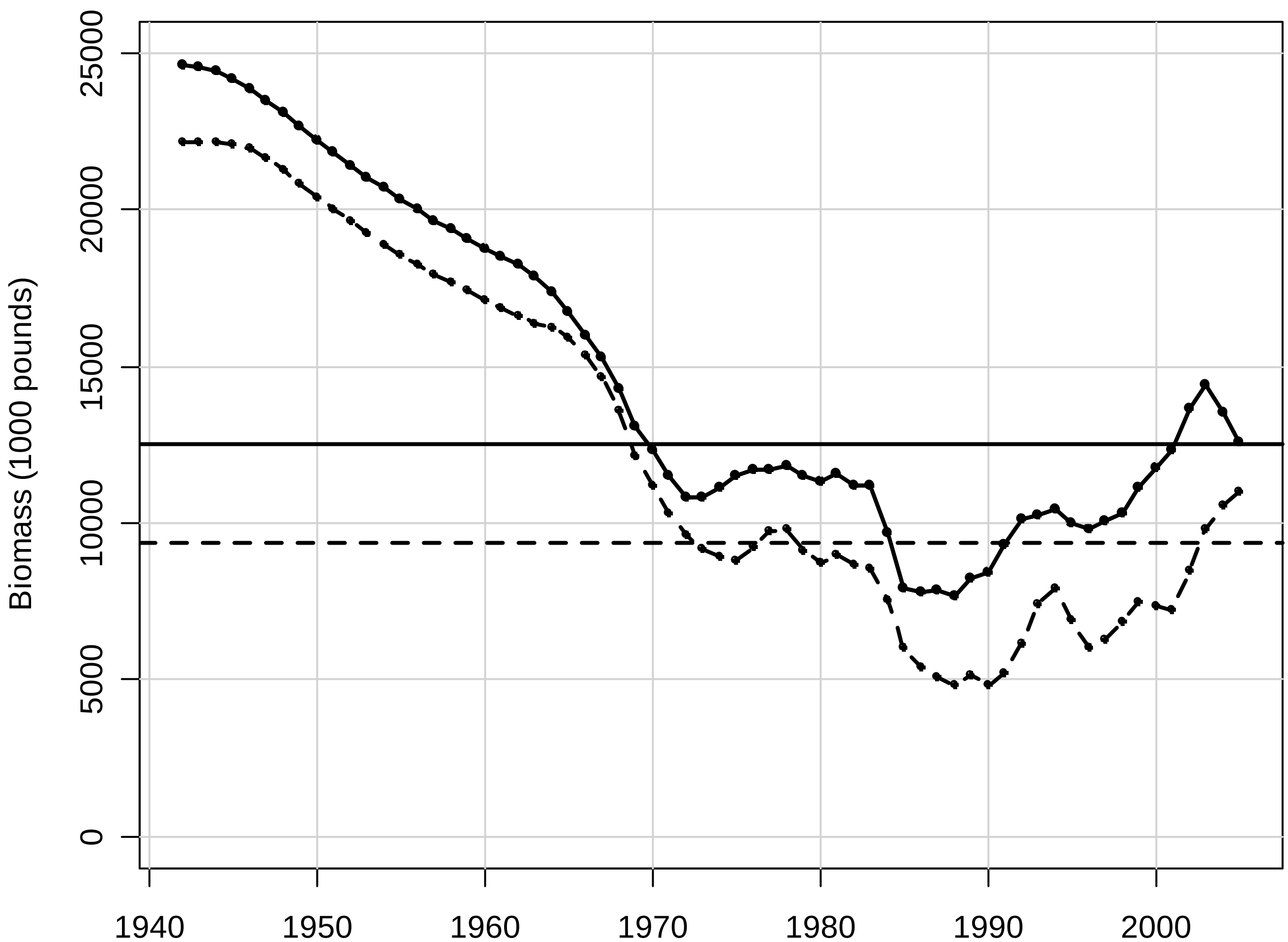


Figure 5. Phase plot of recent estimates of spawning stock biomass (klb, gutted weight) and fishing mortality rate. Solid lines correspond to MSY levels; vertical dashed line corresponds to MSST, defined as (1-M)SSB_{MSY}; and the vertical dotted line corresponds to the RW recommendation for an operational MSST.

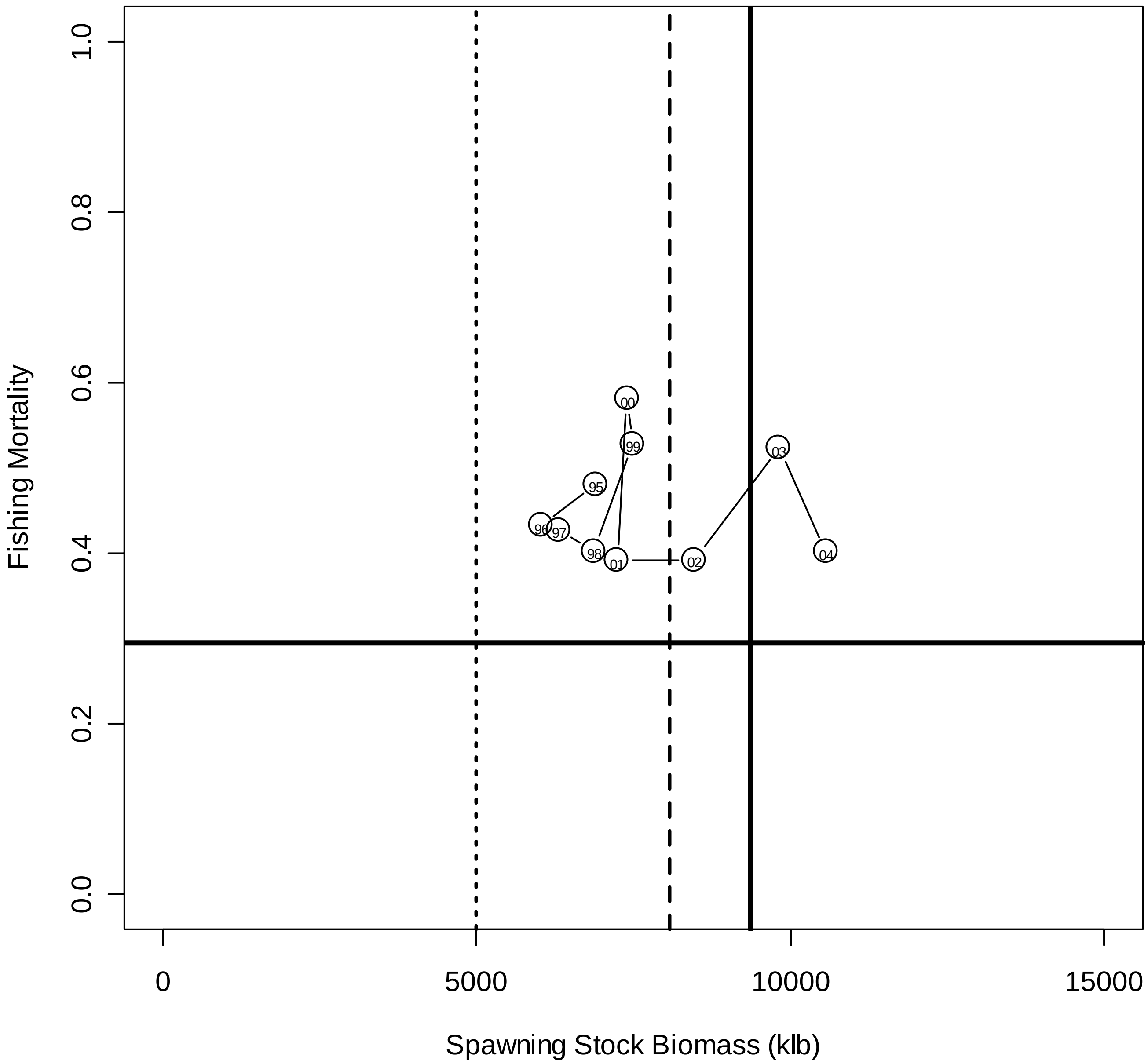


Figure 6. Projections under current fishing mortality rate for all years. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} and dashed line is MSST (defined as $(1\text{-}M)SSB_{MSY}$); B) Recruits, horizontal line is R_{MSY}; C) Fishing mortality rate, horizontal line is F_{MSY}; and D) Landings, horizontal line is MSY.

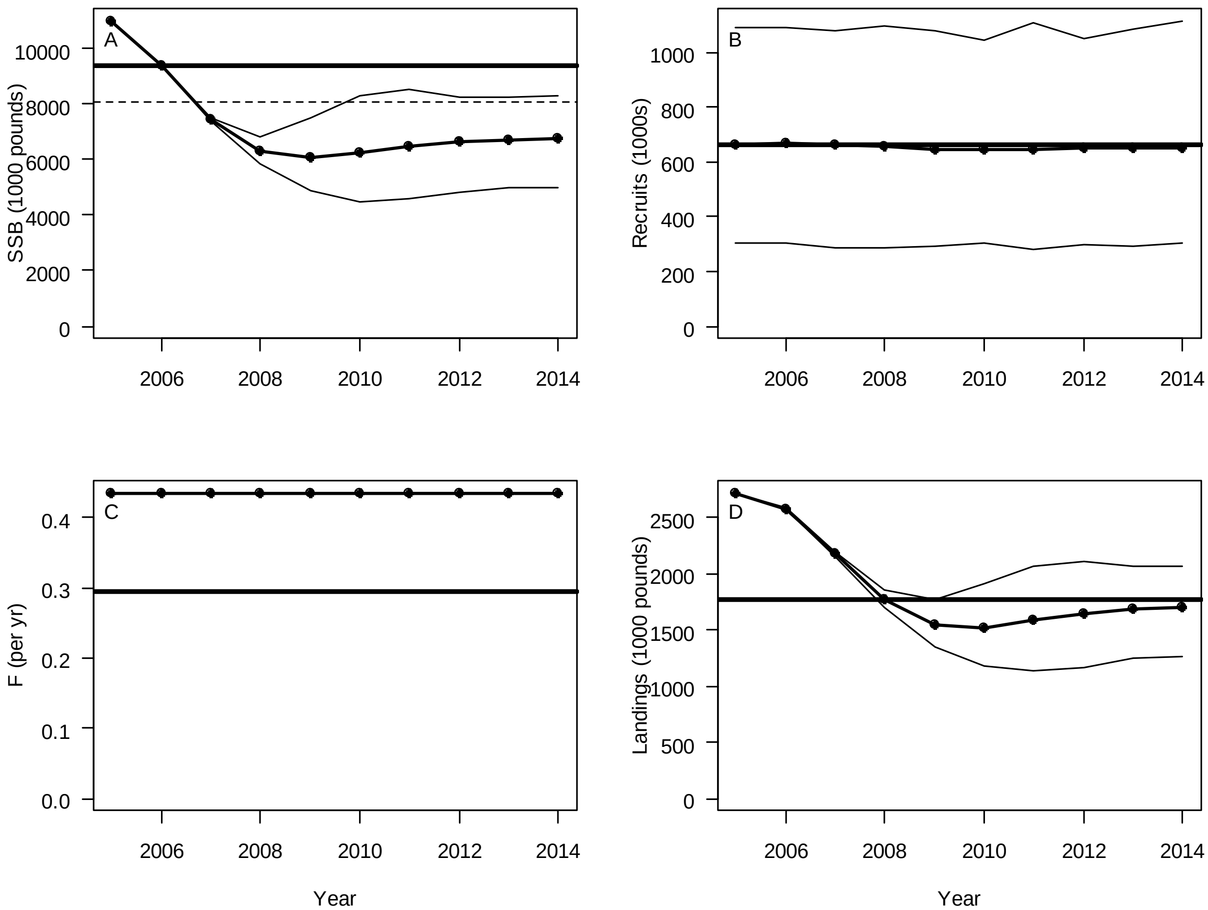


Figure 7. Projections under current fishing mortality rate in 2005-2007 and F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} and dashed line is MSST (defined as (1-M)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.

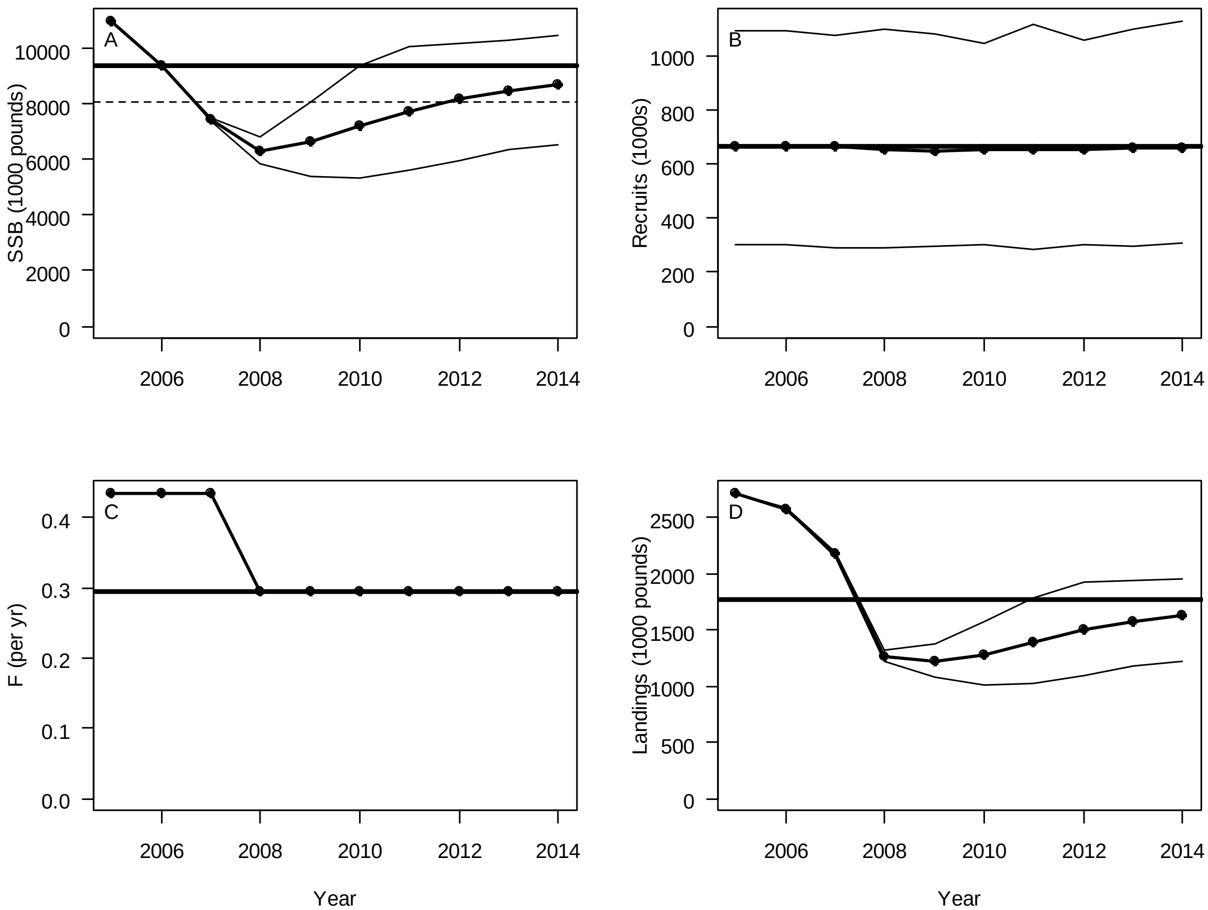


Figure 8. Projections under current fishing mortality rate in 2005-2007 and 85% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} and dashed line is MSST (defined as (1-M)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.

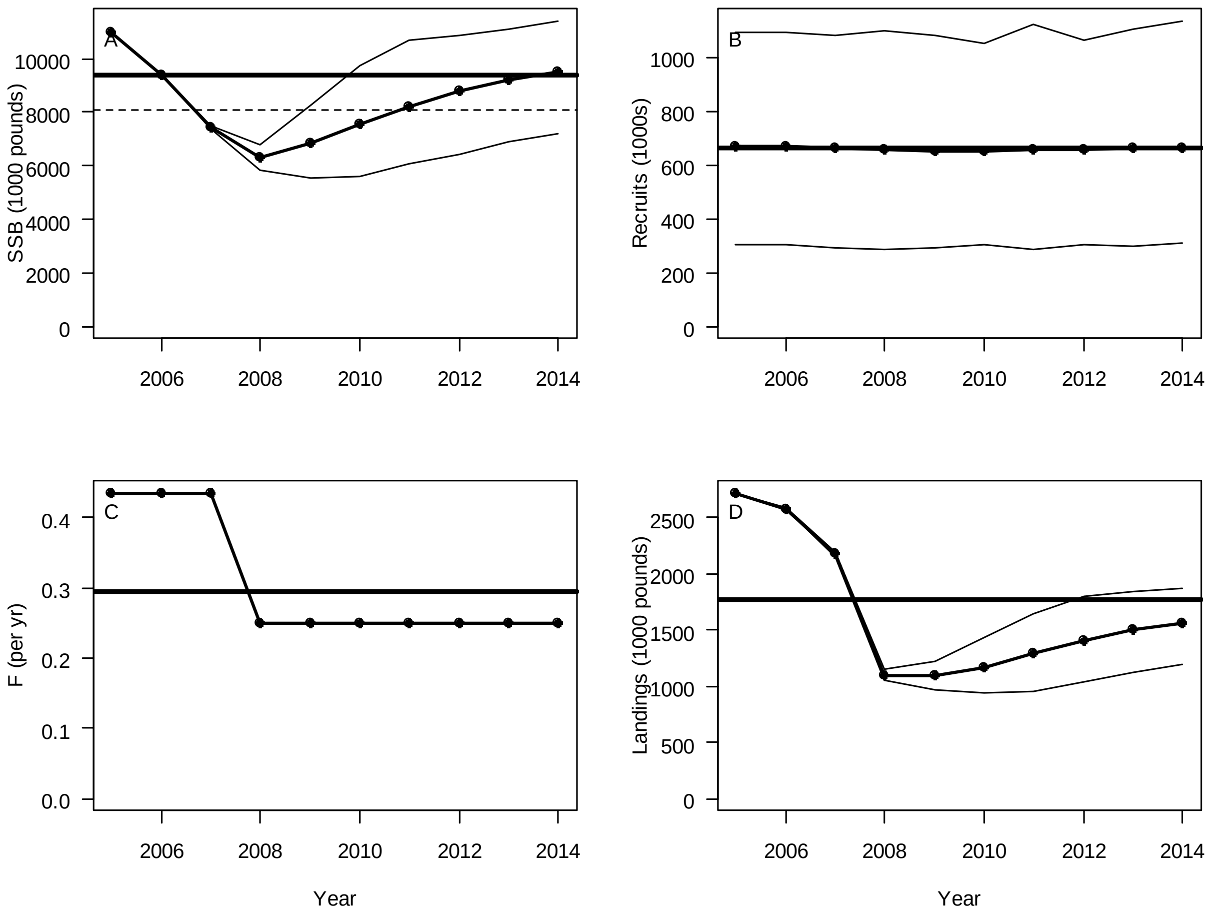


Figure 9. Projections under current fishing mortality rate in 2005-2007 and 75% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} and dashed line is MSST (defined as $(1\text{-}M)SSB_{MSY}$); B) Recruits, horizontal line is R_{MSY}; C) Fishing mortality rate, horizontal line is F_{MSY}; and D) Landings, horizontal line is MSY.

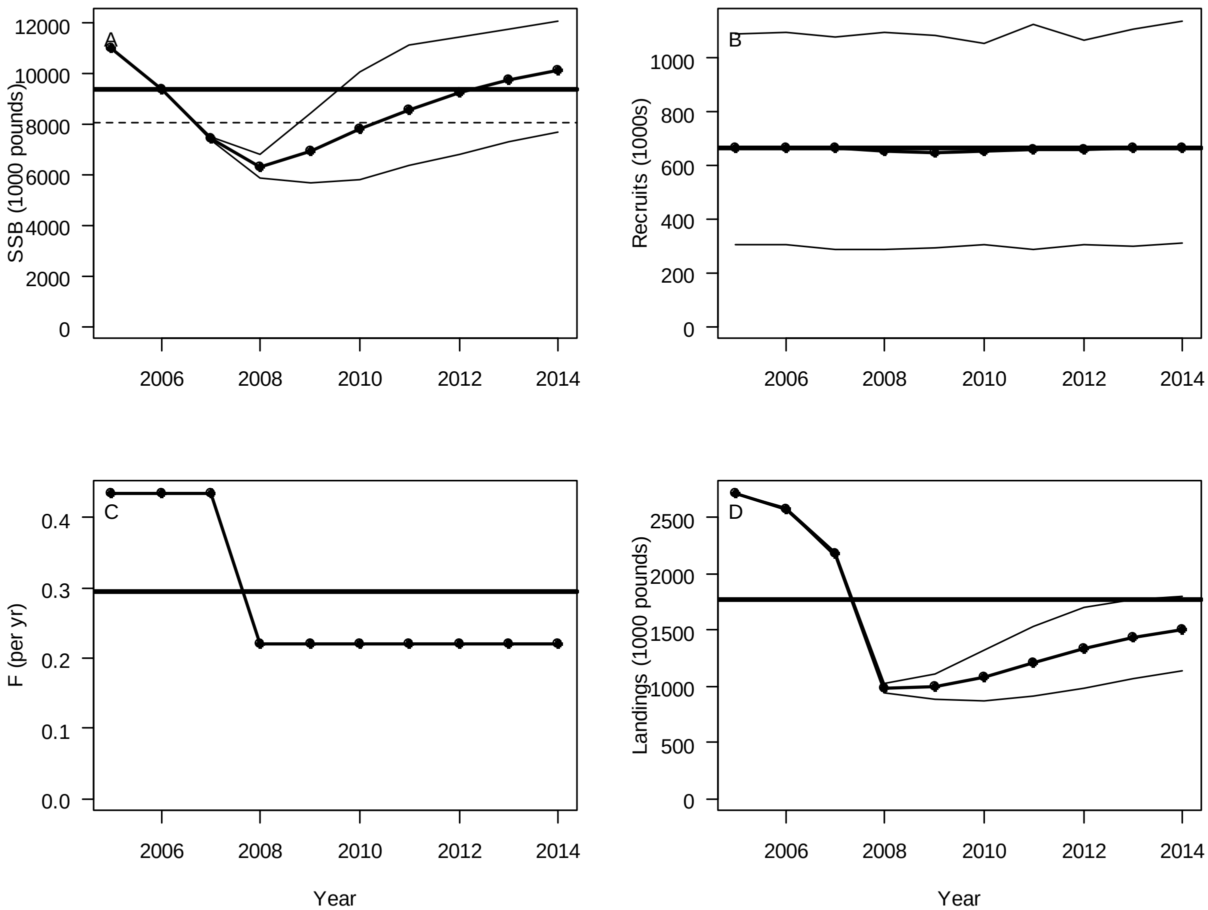


Figure 10. Projections under current fishing mortality rate in 2005-2007 and 65% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} and dashed line is MSST (defined as $(1-M)SSB_{MSY}$); B) Recruits, horizontal line is R_{MSY}; C) Fishing mortality rate, horizontal line is F_{MSY}; and D) Landings, horizontal line is MSY.

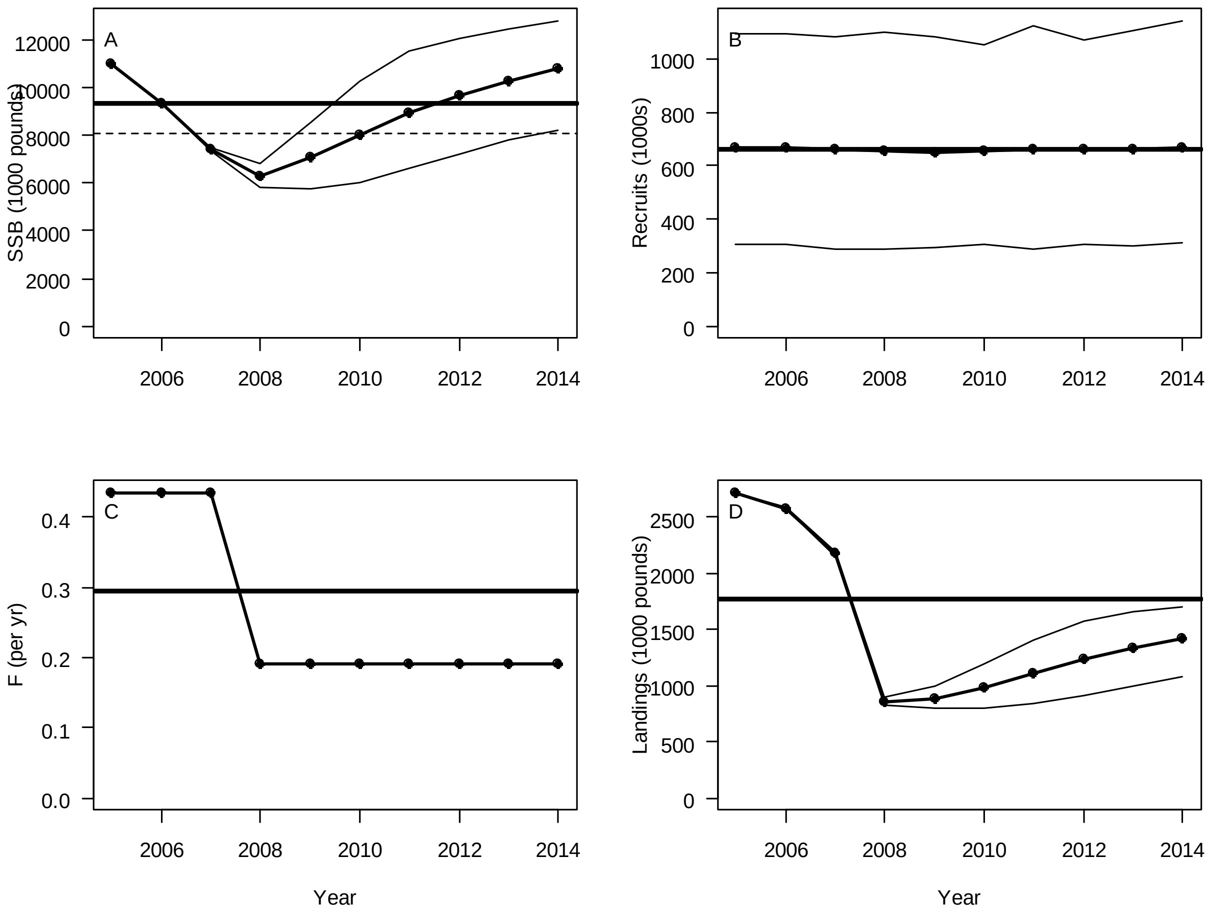


Figure 11. Estimated Beverton-Holt stock-recruitment relationship presented for South Atlantic gag grouper. Two digit year labels represent estimated recruitment values from 1972-2004; Dashed curve is estimated relationship; Solid curve is estimated relationship with lognormal bias correction, from which benchmarks are derived.

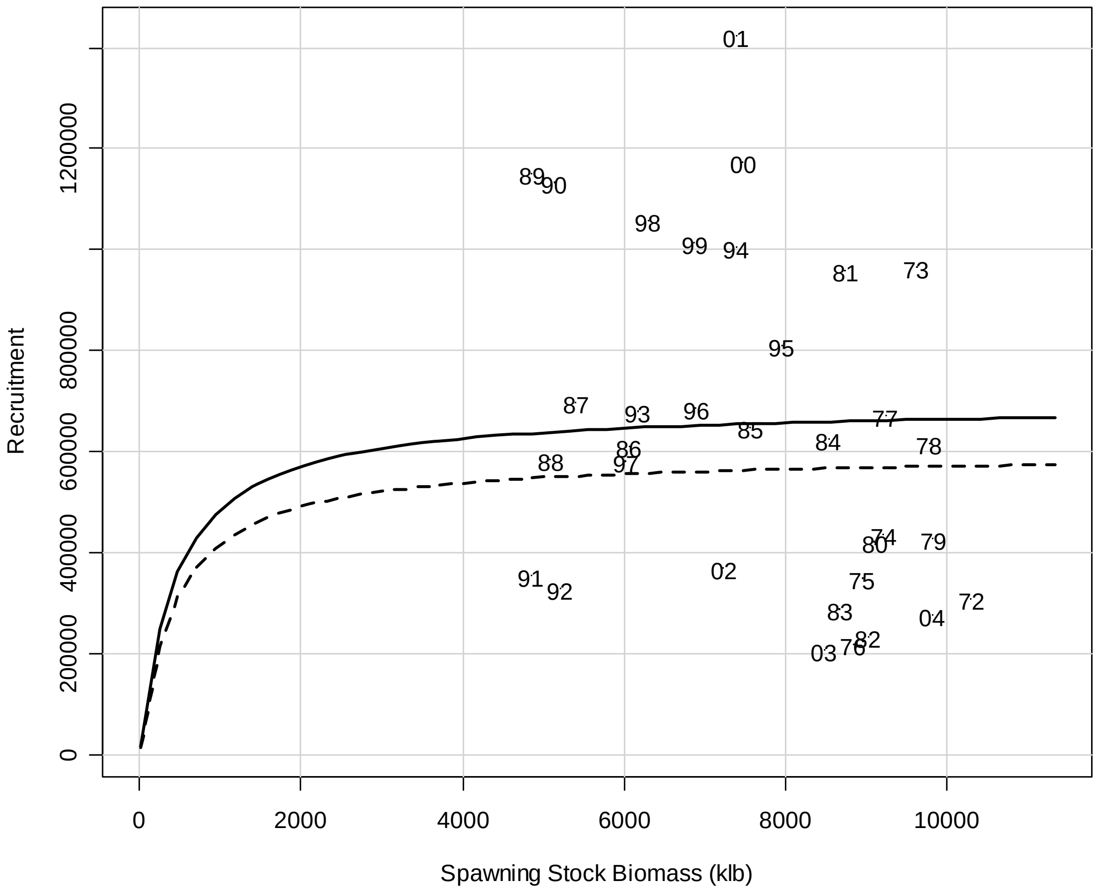


Figure 12. Estimated time series of spawning stock biomass (klb, gutted weight) from the base run model with constant catchability. The base run model with all data included is illustrated with a thick black line. Other runs with the labeled dataset left out of the model are shown in various colors and point markers.

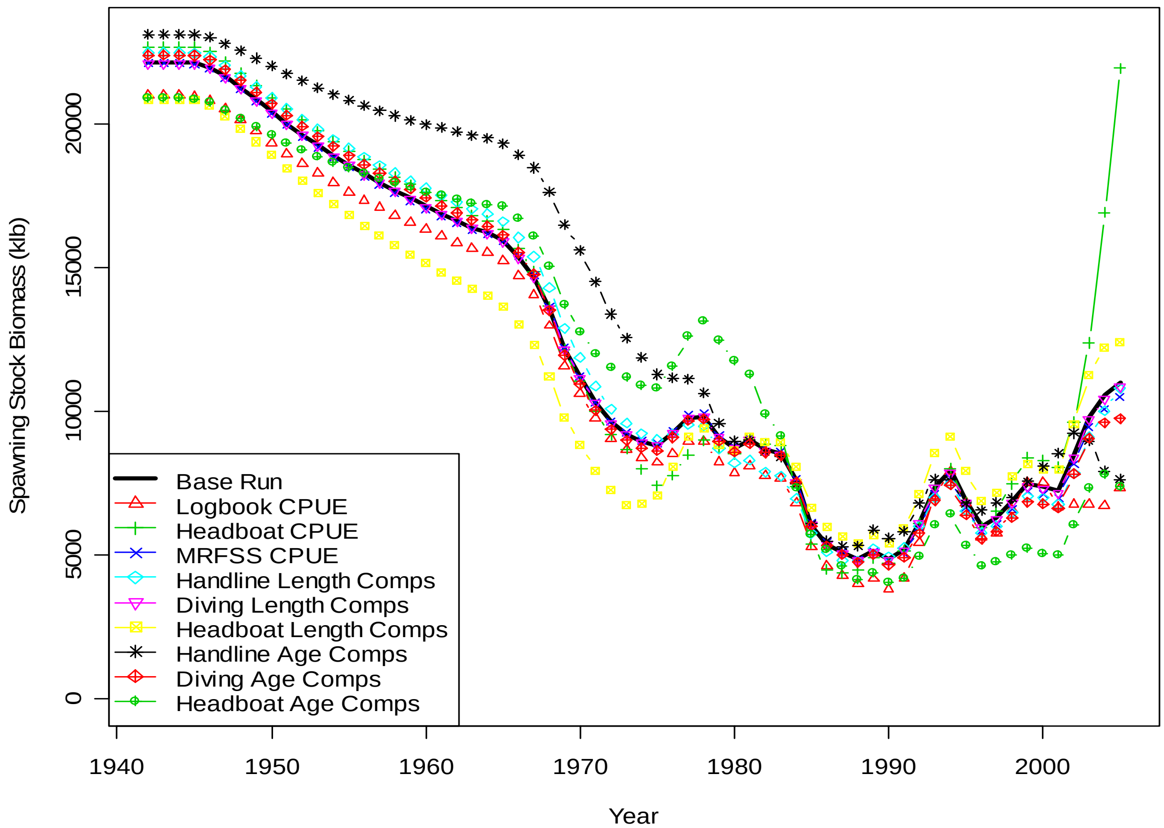


Figure 13. Estimated time series of fishing mortality rate from the base run model with constant catchability. The base run model with all data included is illustrated with a thick black line. Other runs with the labeled dataset left out of the model are shown in various colors and point markers.

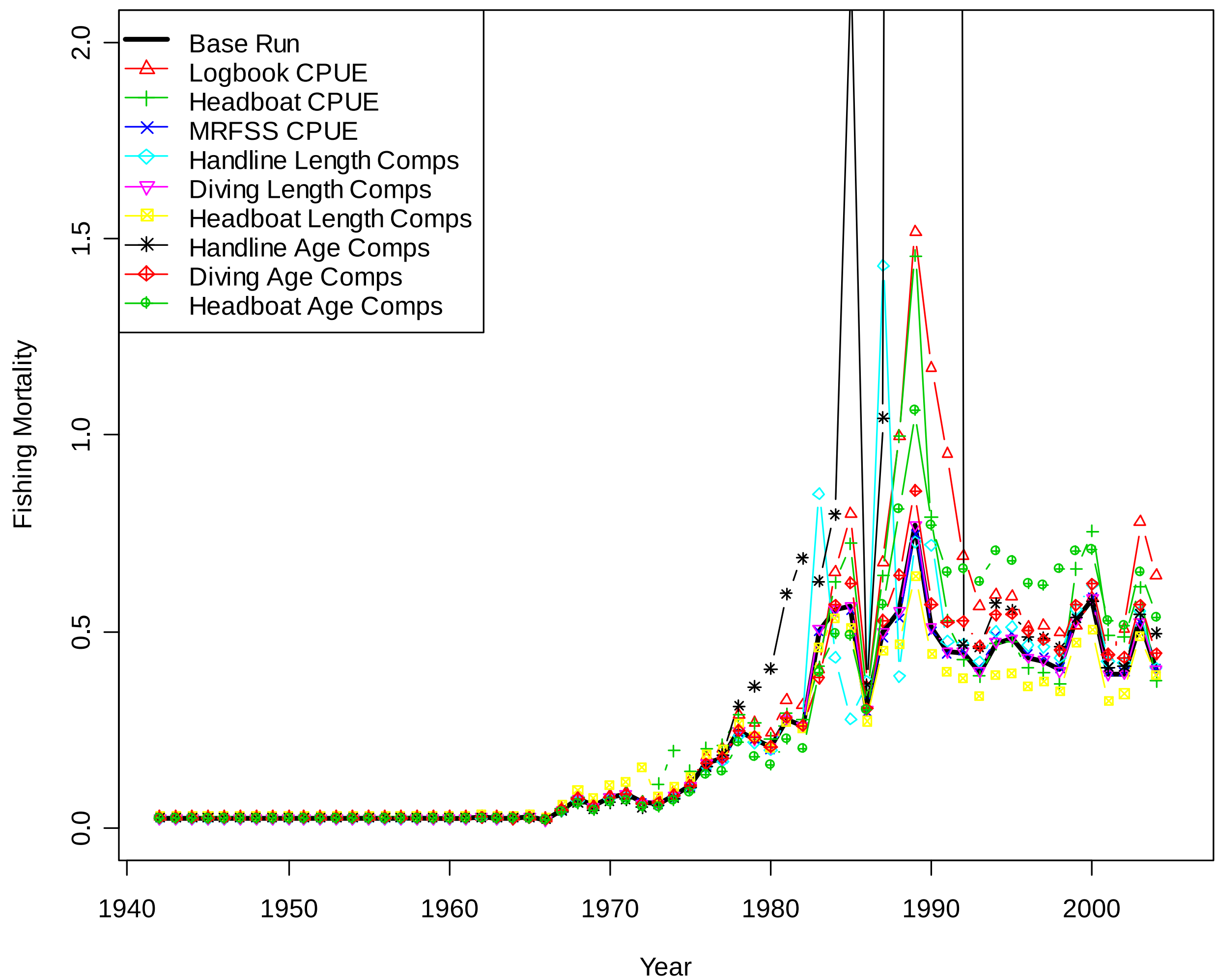


Figure 14. Estimated time series of recruitment from the base run model with constant catchability. The base run model with all data included is illustrated with a thick black line. Other runs with the labeled dataset left out of the model are shown in various colors and point markers