

SEDAR

Southeast Data, Assessment, and Review

SEDAR 10
Stock Assessment Report

South Atlantic Gag Grouper

SEDAR 10
Stock Assessment Report 1

2006

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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 (*Myxteroperca 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 tilefish, blueline tilefish, and sand tilefish. | Snapper Grouper Amend 9 | 2/24/1999 |
| Approved definitions for overfished and overfishing. MSST = [(1-M) or 0.5 whichever is greater]*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-M)B _{MSY} | Not specified | (1-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 to decline 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 | $(1-M)B_{MSY}$ | 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 | $(1-M)SSB_{MSY}$ *(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 $\{(1-M)SSB_{MSY}\}$, 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 $(1-M)B_{MSY}$, 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 lbs¹) 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.

| Year | Commercial (gutted klb) | | Recreational (1000s) | | Discards (1000s) | | |
|------|-------------------------|--------|----------------------|--------|------------------|----------|--------|
| | 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/SSBm _{sy} | 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.

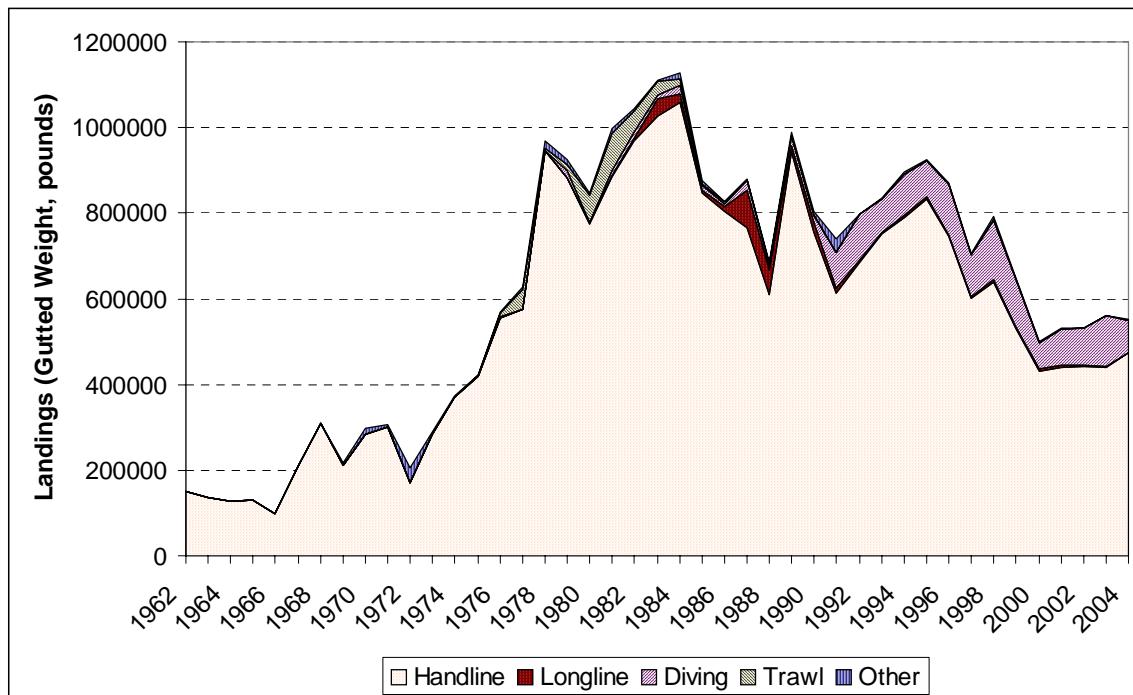


Figure 2. Total gag grouper catches (landings and discards) in numbers by sector from the U.S. South Atlantic, 1962-2004.

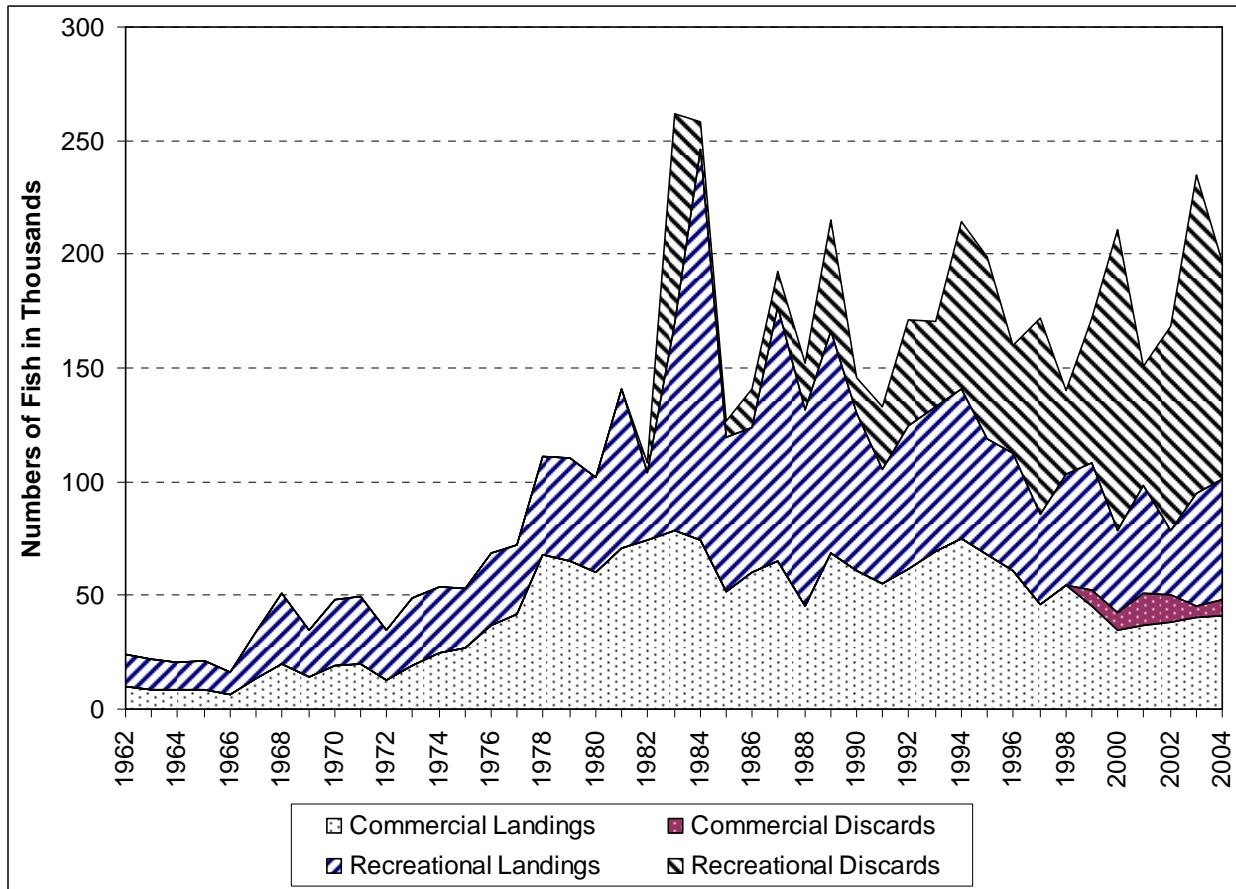


Figure 3. Estimated fully-selected fishing mortality rate. Solid horizontal line represents F_{MSY} .



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.

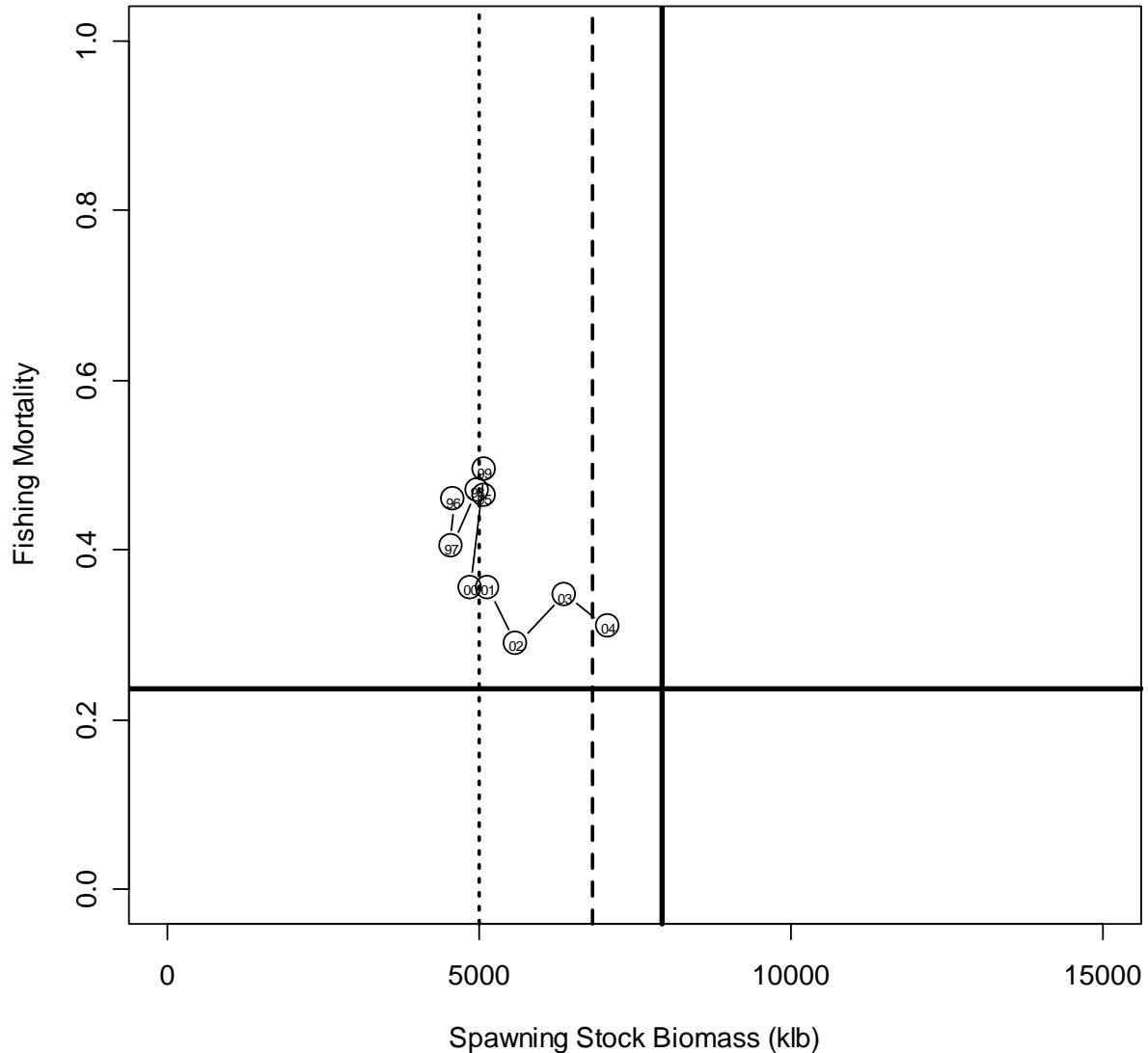


Figure 6. Projections under current fishing mortality rate for all years. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} and dashed line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

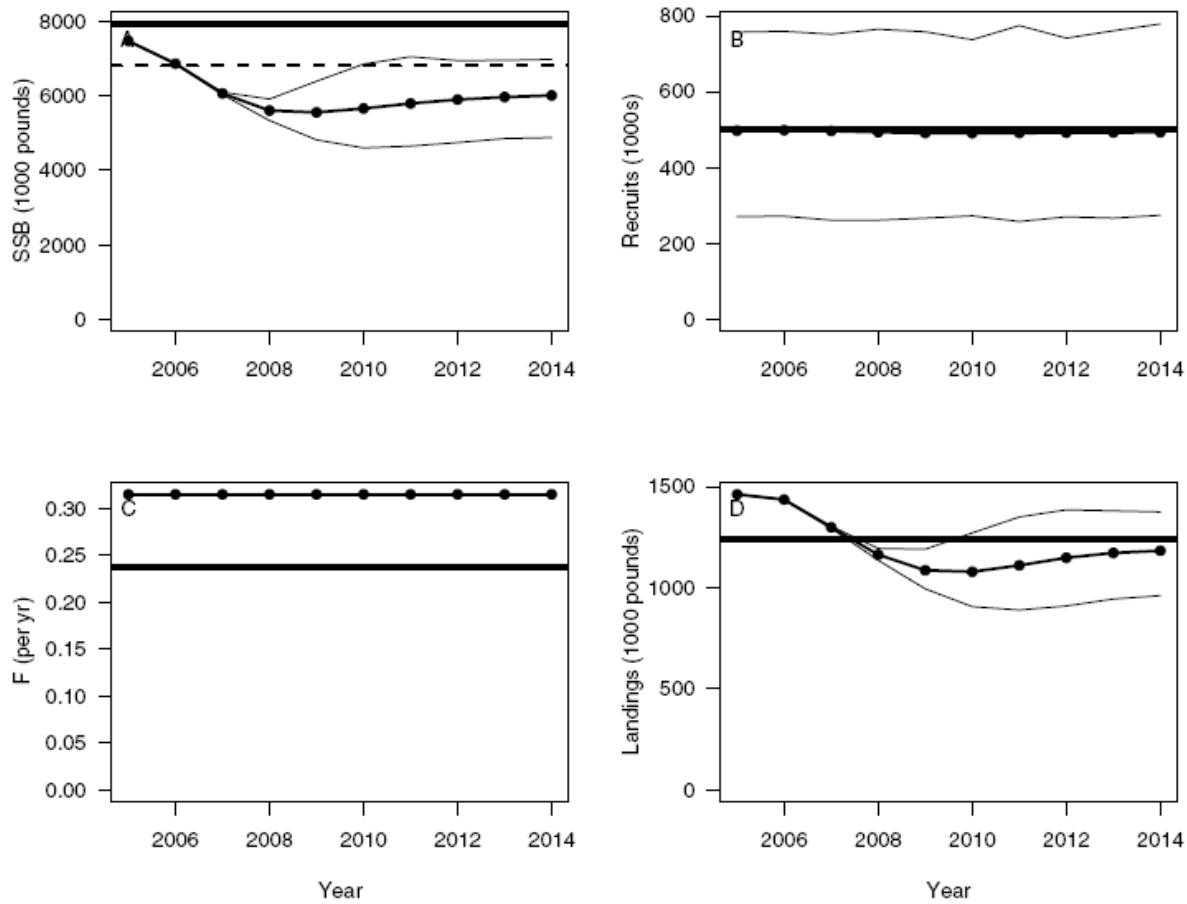


Figure 7. Projections under current fishing mortality rate in 2005-2007 and F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is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

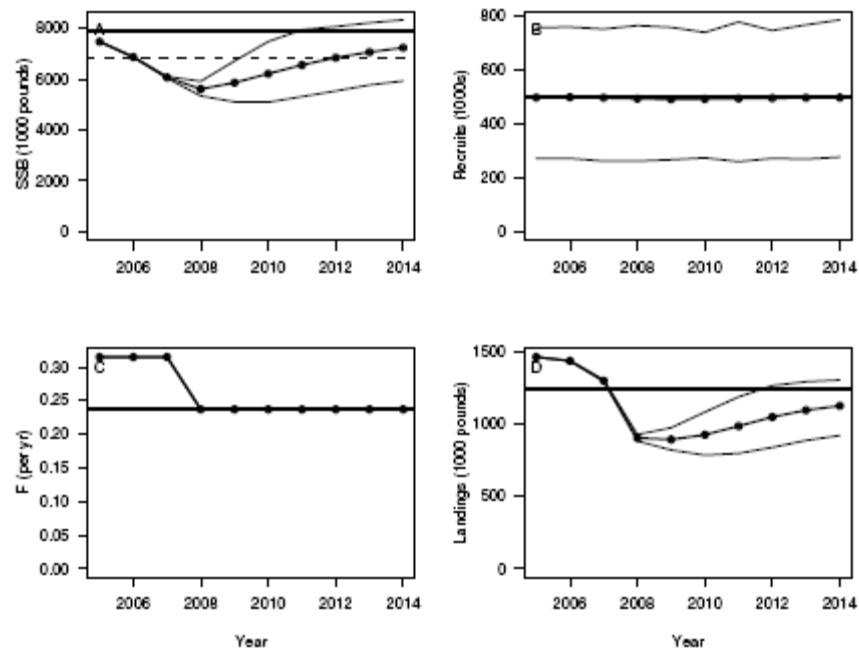


Figure 8. Projections under current fishing mortality rate in 2005-2007 and 85% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid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

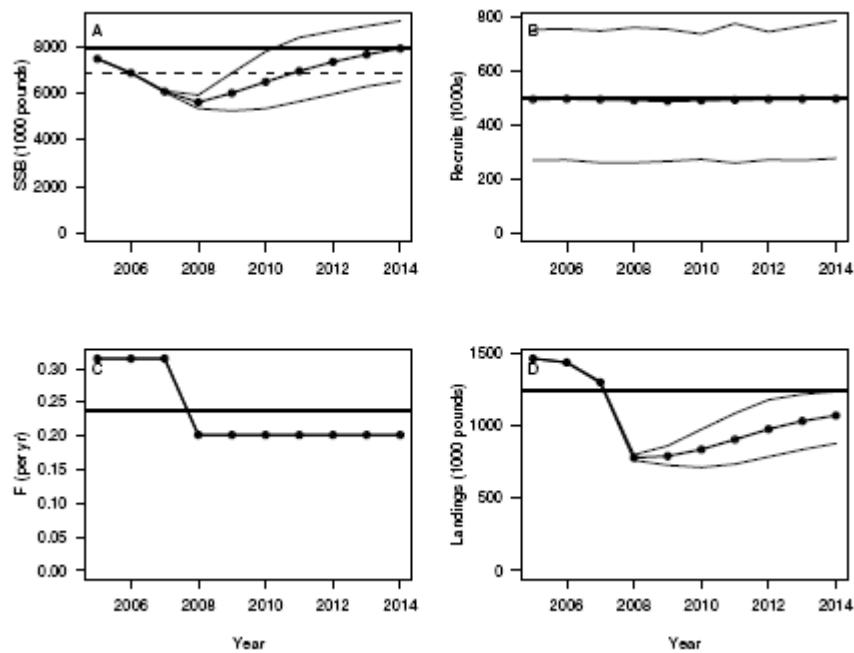


Figure 9. Projections under current fishing mortality rate in 2005-2007 and 75% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid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

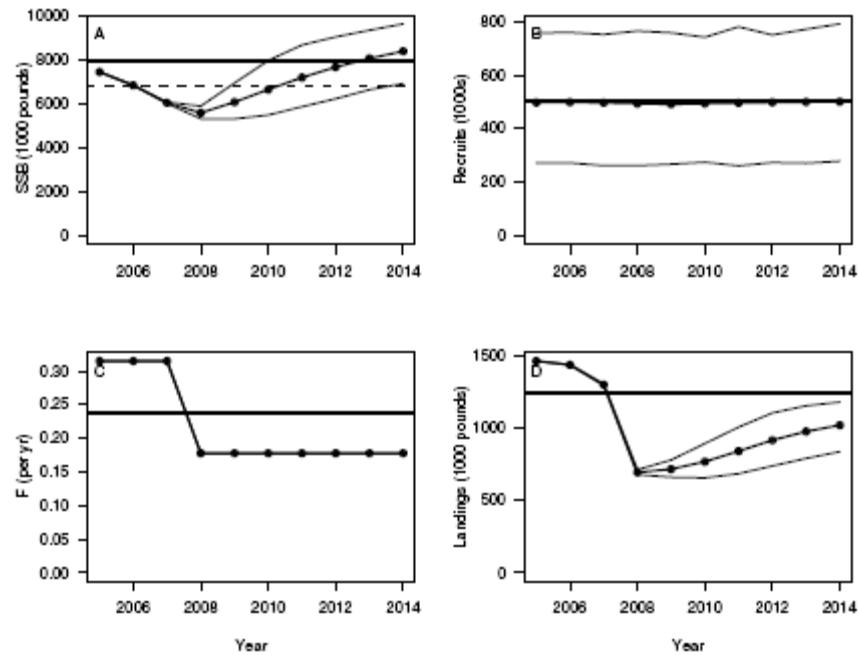


Figure 10. Projections under current fishing mortality rate in 2005-2007 and 65% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid 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.

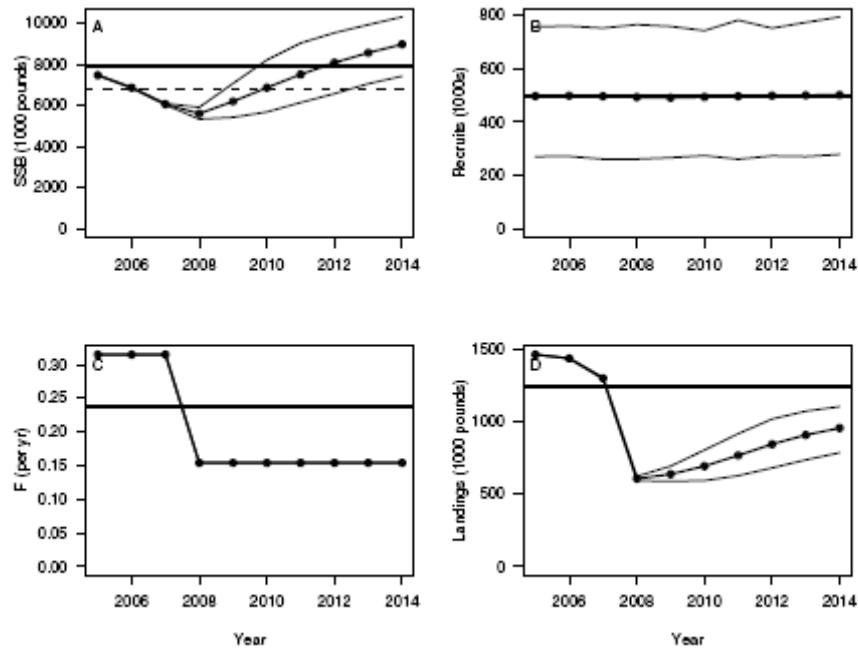


Figure 11. Estimated Beverton-Holt stock-recruitment relationship presented for South Atlantic gag grouper. Dashed curve is estimated relationship; Solid curve is estimated relationship with lognormal bias correction, from which benchmarks are derived.

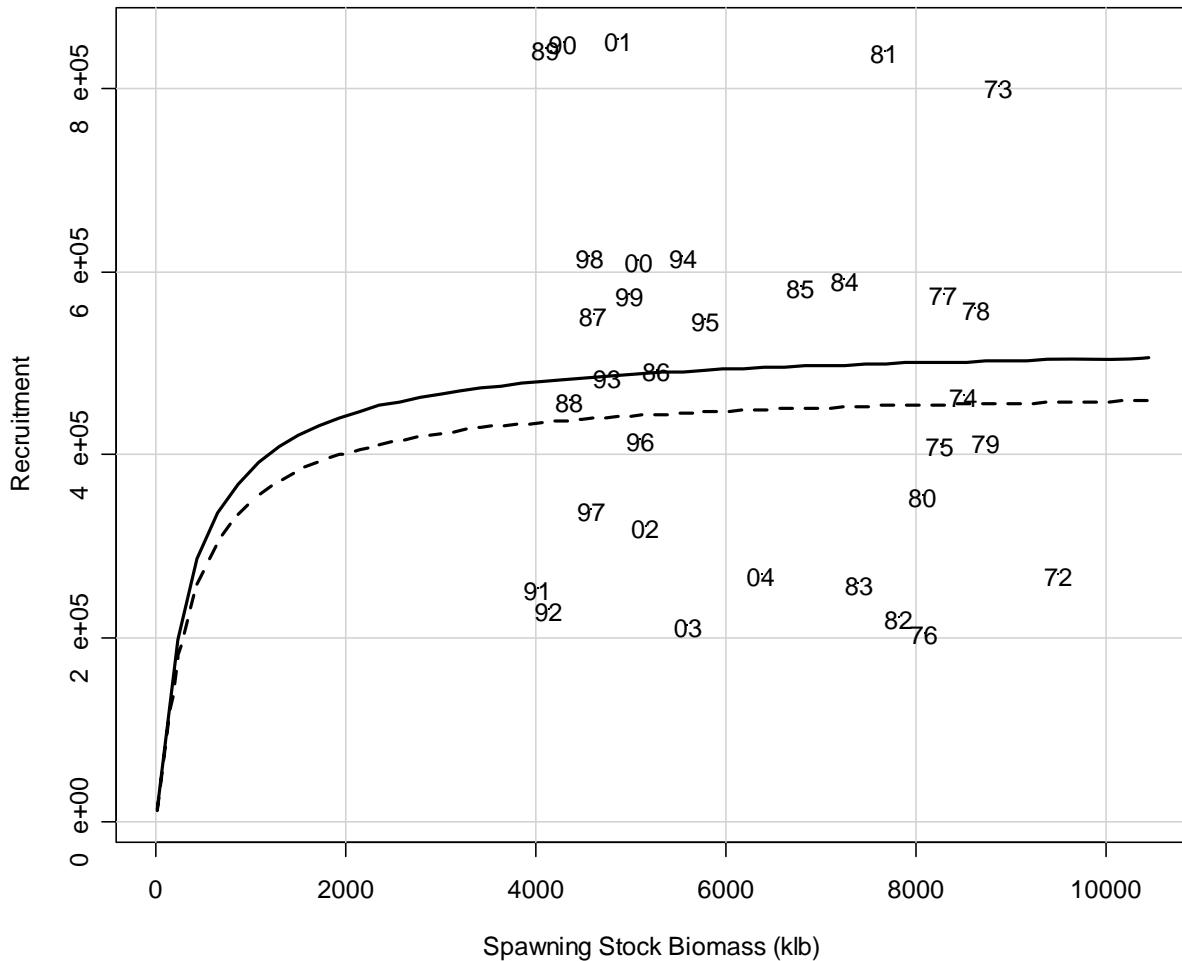


Figure 12. Estimated time series of spawning stock biomass (klb, gutted weight) from the base run model with constant catchability. The base run model with all data included is illustrated with a thick black line. Other runs with the labeled dataset left out of the model are shown in various colors and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

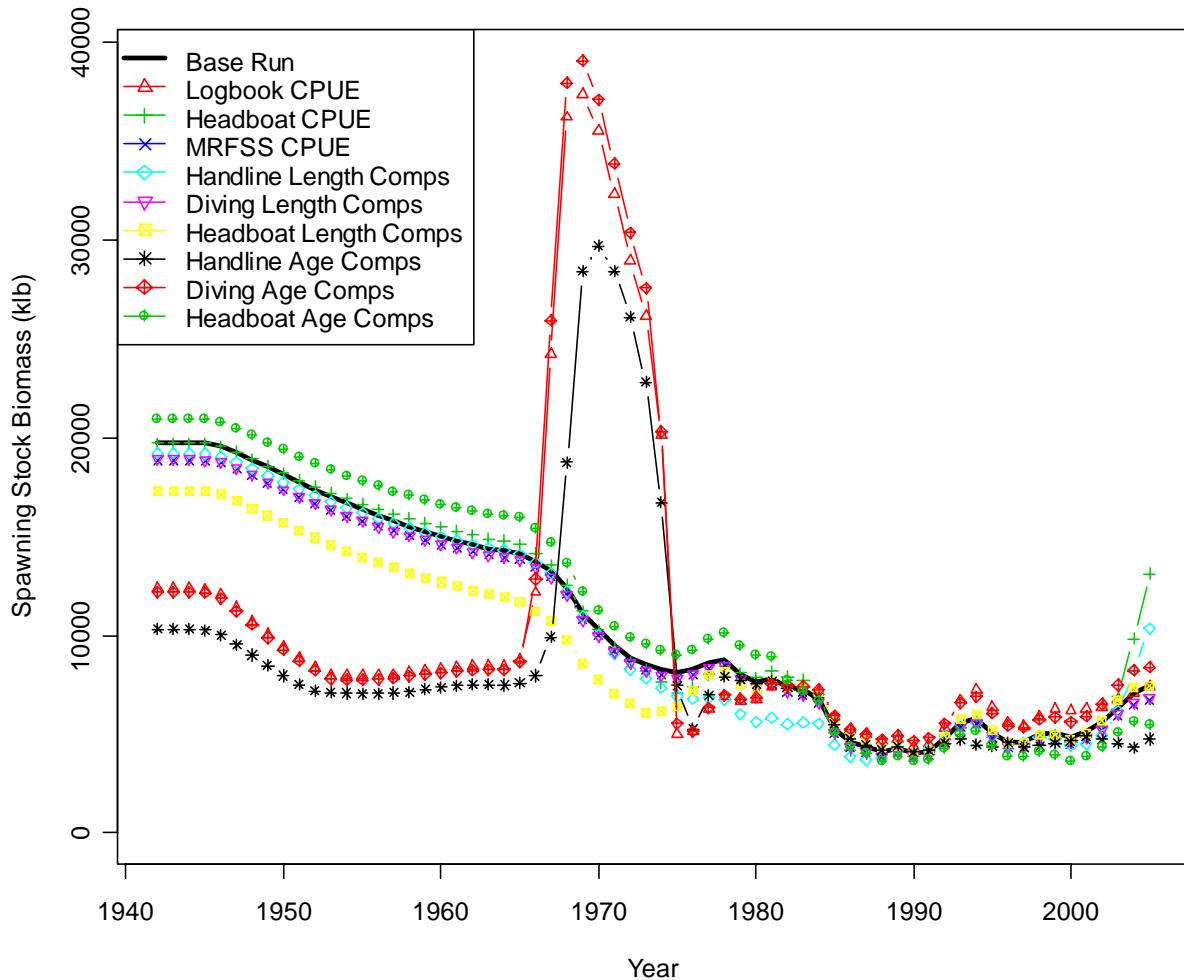


Figure 13. Estimated time series of fishing mortality rate from the base run model with constant catchability. The base run model with all data included is illustrated with a thick black line. Other runs with the labeled dataset left out of the model are shown in various colors and point markers.

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.

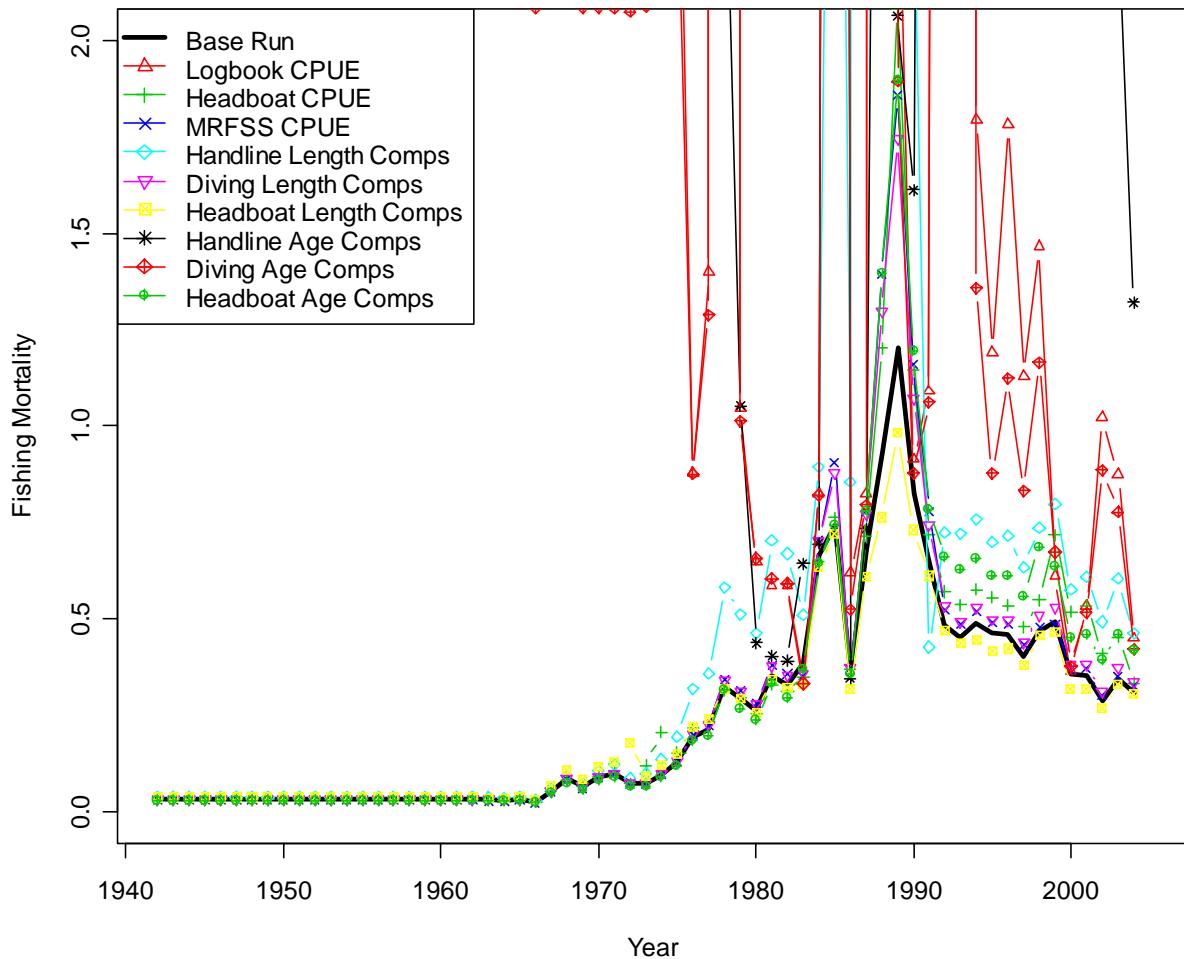
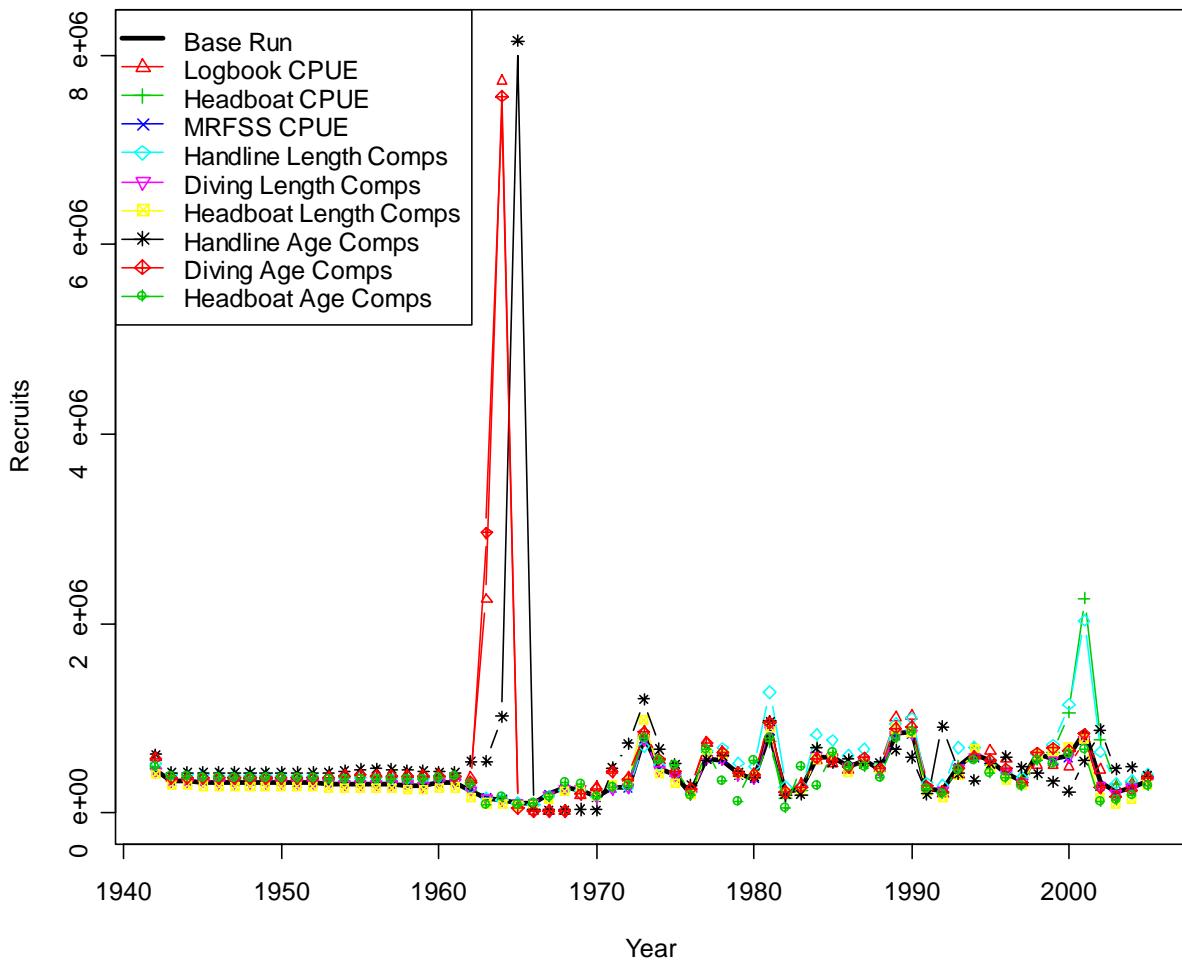


Figure 14. Estimated time series of recruitment from the base run model with constant catchability. The base run model with all data included is illustrated with a thick black line. Other runs with the labeled dataset left out of the model are shown in various colors and point markers.

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.

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 - 5.2.2 Issues Discussed at DW
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 - 5.4.1 Fishery-independent Indices of Adult Abundance
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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

| | |
|----------------------------|-----------------------------|
| Pam Baker..... | GMFMC Advisory Panel |
| Dr. Luiz Barbieri..... | GMFMC |
| Carolyn Belcher | SAFMC SSC, Univ. of Georgia |
| Alan Bianchi | NCDMF |
| Craig Brown..... | NMFS/SEFSC Miami, FL |
| Steve Brown..... | FL FWCC |
| Ken Brennan | NMFS/SEFSC Beaufort, NC |
| Mike Burton | NMFS/SEFSC Beaufort, NC |
| Shannon Calay | NMFS/SEFSC Miami, FL |
| Rob Cheshire..... | NMFS/SEFSC Beaufort, NC |
| Dr. Brian Cheuvront..... | SAFMC SSC, NCDMF |
| Ching Ping Chih..... | NMFS/SEFSC Miami, FL |
| William Collier | NCDMF |
| Nancie Cummings..... | NMFS/SEFSC Miami, FL |
| Guy Davenport..... | NMFS/SEFSC Miami, FL |
| Bob Dixon..... | NMFS/SEFSC Beaufort, NC |
| Karen Edwards..... | SAFMC Advisory Panel |
| Mark Fisher..... | GMFMC Advisory Panel |
| Gary Fitzhugh | NMFS/SEFSC Panama City, FL |
| David Gloeckner | SEFSC/NMFS Beaufort, NC |
| Dr. Patrick Harris..... | SAFMC SSC/SCDNR |
| Jack Holland..... | NCDMF |
| Walter Ingram | NMFS/SEFSC Pascagoula, MS |
| Nan Jenkins..... | SCDNR |
| Linda Lombardi-Carson..... | NMFS/SEFSC, Panama City, FL |
| Gus Loyal..... | GMFMC Advisory Panel |
| Vivian Matter | NMFS/SEFSC Miami, FL |
| Kevin McCarthy..... | NMFS/SEFSC Miami, FL |
| Josh Sladek Nowlis | NMFS/SEFSC Miami, FL |
| Mauricio Ortiz..... | NMFS/SEFSC Miami, FL |
| Patty Phares..... | NMFS/SEFSC Miami, FL |
| Jennifer Potts..... | NMFS/SEFSC Beaufort, NC |
| Marcel Reichert..... | SCDNR |
| Fritz Rohde..... | NCDMF |
| Dr. Jay Rooker | GMFMC Advisory Panel |
| Beverly Sauls | FLFWCC |
| Jerry Scott | NMFS/SEFSC Miami, FL |
| Kyle Shertzer | NMFS/SEFSC Beaufort, NC |

| | |
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| James Taylor | GMFMC Advisory Panel |
| Steve Turner..... | NMFS/SEFSC Miami, FL |
| Doug Vaughan | NMFS/SEFSC Beaufort, NC |
| Robert Wiggers | SCDNR |
| Erik Williams | NMFS/SEFSC Beaufort, NC |
| David Wyanski..... | SCDNR |

Observers

| | |
|--------------------|--------------|
| Roy Williams | GMFMC Member |
| David Cupka | SAFMC Member |

Staff

| | |
|----------------------|-------------|
| Steven Atran..... | GMFMC |
| John Carmichael..... | SAFMC/SEDAR |
| Rick DeVictor | SAFMC |
| Kerry O'Malley..... | SAFMC |
| Cynthia Morant..... | SAFMC/SEDAR |
| Gregg Waugh..... | SAFMC |

IT Staff

| | |
|------------------|----------------------|
| Tyree Davis..... | NMFS/SEFSC Miami, FL |
|------------------|----------------------|

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 Preliminary 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 | Exegeeses 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 (<i>Mycteroperca microlepis</i>) |
| 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 |
| <i>Oculina</i> 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 tilefish, blueline tilefish, and sand tilefish. | Snapper Grouper Amend 9 | 2/24/1999 |
| Approved definitions for overfished and overfishing. MSST = [(1-M) or 0.5 whichever is greater]*B _{MSY} . MFMT = F _{MSY} | Snapper Grouper Amend 11 | 12/2/1999 |
| Extended for an indefinite period the regulation prohibiting fishing for and possessing snapper grouper species within the <i>Oculina</i> 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 February 16, 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: $L_{\infty}=1310$ mm, TL range 245-1384 mm; SA $L_{\infty}=1051$ mm, TL range 215-1300 mm), growth coefficients (GOM: $k = 0.14 \text{ yr}^{-1}$; SA: $k=0.24 \text{ yr}^{-1}$) and predicted t_0 close to zero (GOM: $t_0 = -0.37 \text{ yr}$; SA: $t_0 = -0.48 \text{ yr}$).

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 transitinals 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 transitinals 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 transitinals 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.

South Atlantic: 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.

Gulf of Mexico: 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 SCNRD) 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 ($\beta > 0$). 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 mortality 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).

2.9. References

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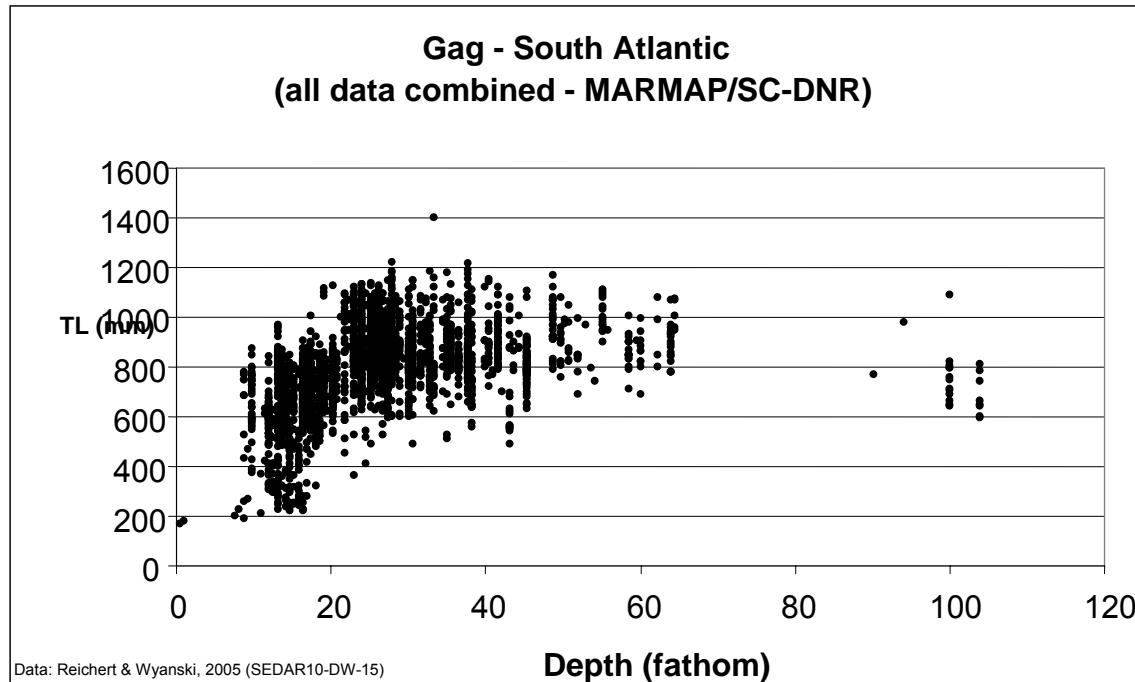


Figure 2.1. Gag total length (mm) plotted with depth (fm) for the South Atlantic. All gears were combined (fishery-independent and dependent) thus accounting for occurrences of undersized fish (below about 500 mm TL).

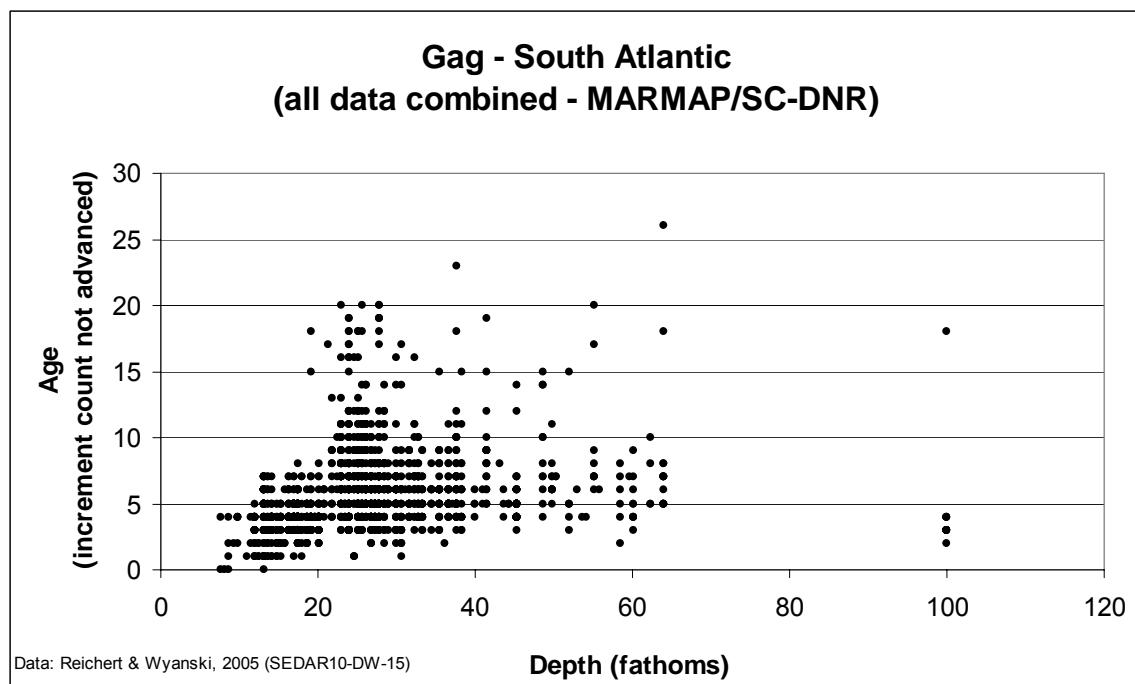


Figure 2.2. Gag age (increment count) plotted with depth (fm) for the South Atlantic. All gears combined (fishery-independent and dependent)

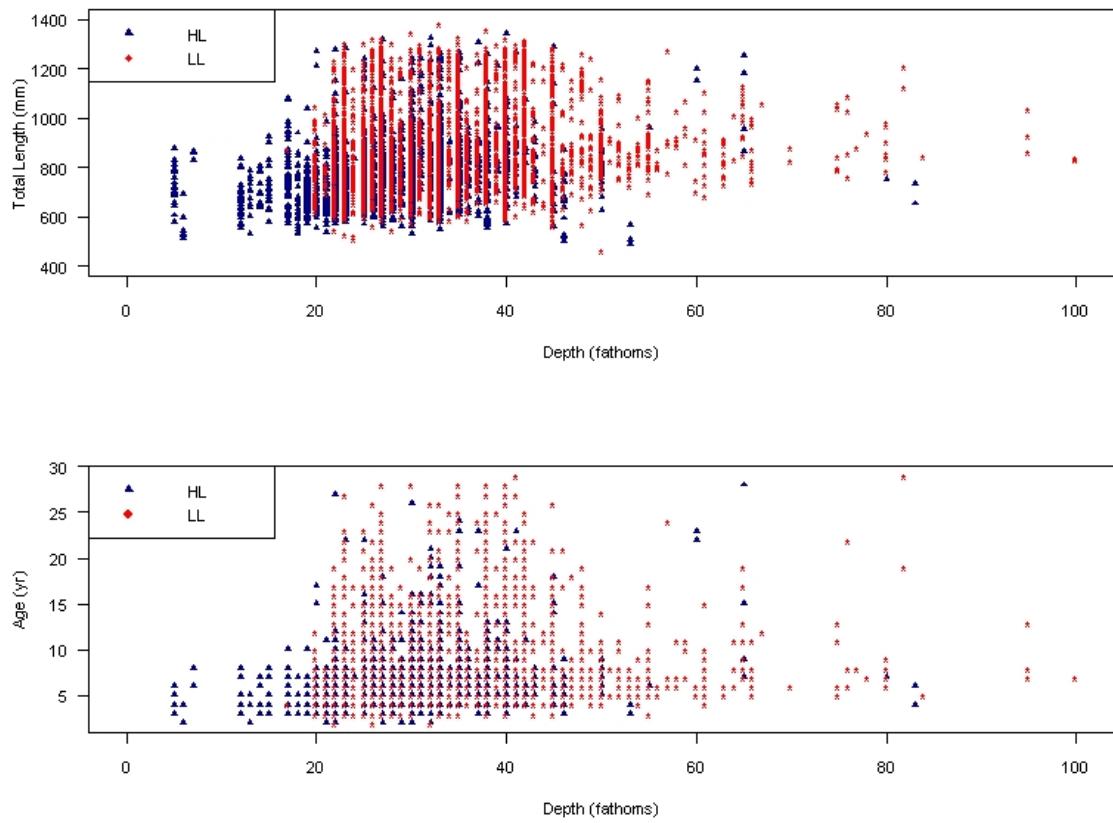


Figure 2.3. Age and length plotted with depth (fm) for the Gulf of Mexico for long-line (LL) and handline (HL) fisheries.

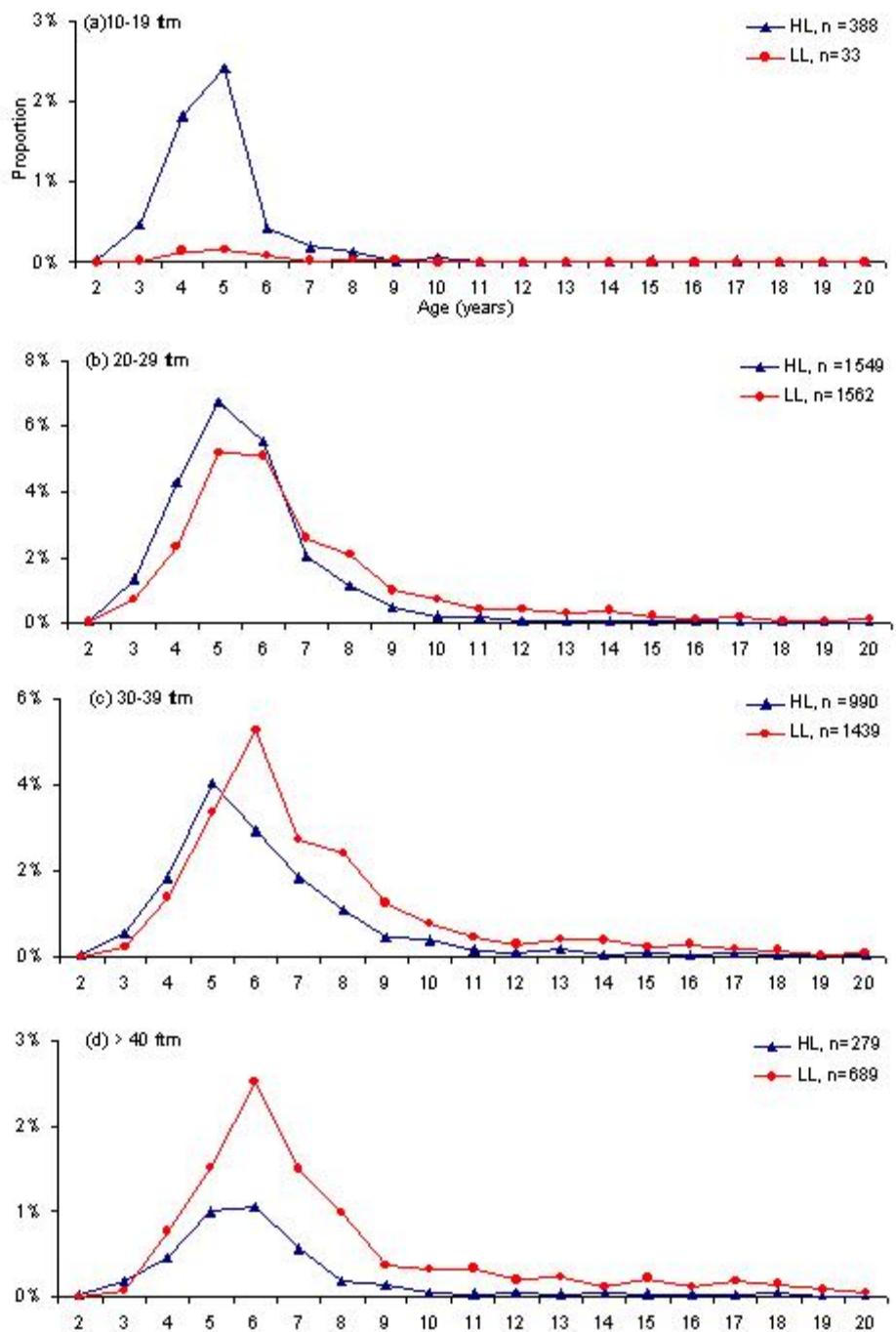


Figure 2.4. Age data proportioned to the depth (fm) fished and commercial gear type. Depth categories in 10-fm bins. Scales on y-axis vary.

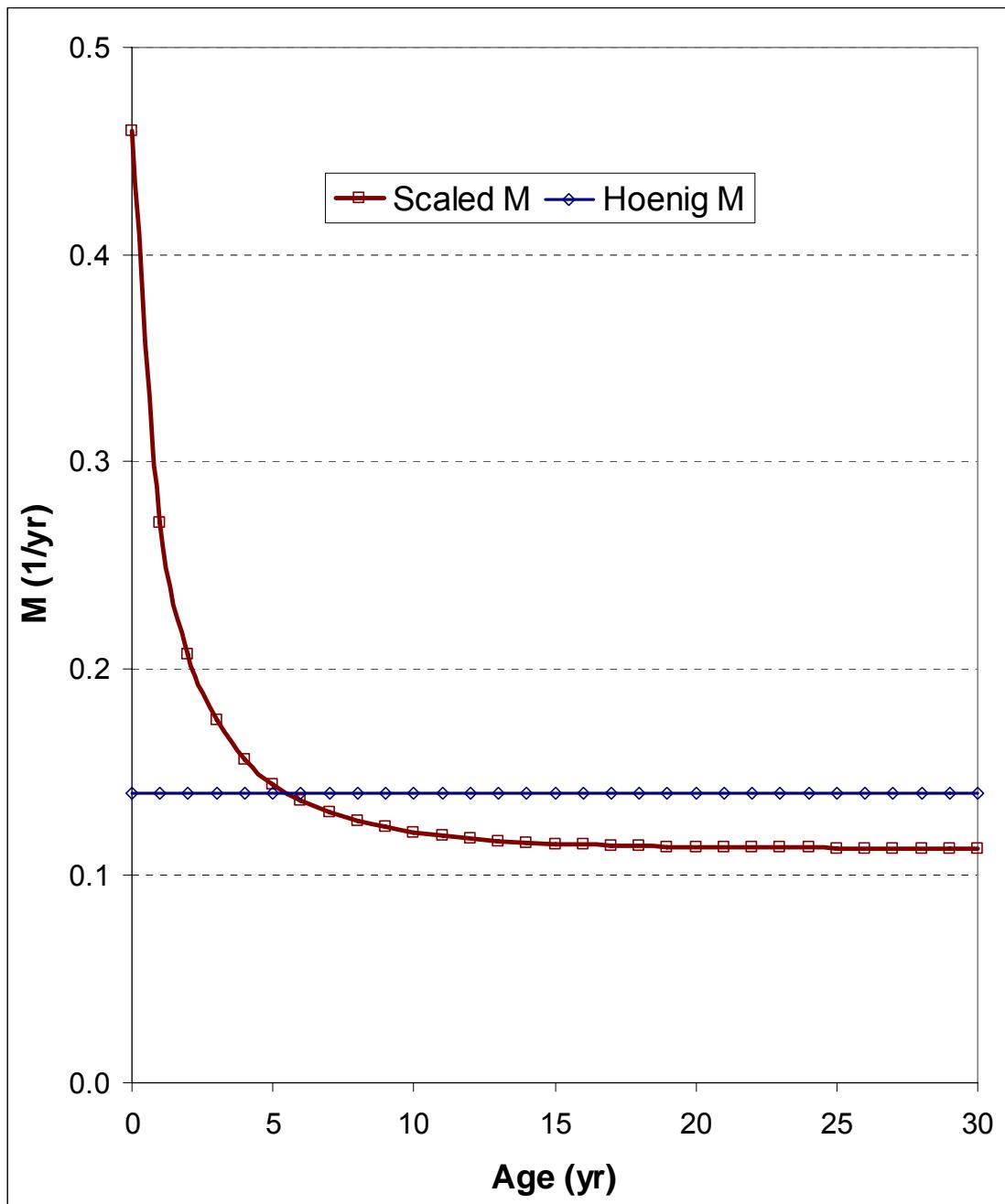


Figure 2.5. Age-varying estimates of South Atlantic gag grouper natural mortality based on Lorenzen's method (1996), re-scaled to 1.3% survival to oldest observed age (30), so as to be equivalent to the constant M (0.14 for maximum age of 30) from Hoenig (1983).

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 x 10 ⁻⁰⁸ * (TL ^{^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 x 10 ⁻⁰⁸ * (FL ^{^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 x 10 ⁻⁰⁸ * (TL ^{^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 x 10 ⁻⁹ * (FL ^{^3.05}) | 2407 | 0.98 | FL (mm): 432 – 1335 G. Wt (kg): 0.99 – 32.21 |
| SL (cm) to TL (cm) <i>for age-0 gag only</i> | 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 in 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).
-

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 late 1890s. 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

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

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

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

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

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

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

Florida

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

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

Georgia

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

South Carolina

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.

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

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

| Year | FL | | NC | |
|------|----------------------|----------------------|----------------------|----------------------|
| | 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.

| Year | Florida (Atlantic) | | | Georgia | | | | South Carolina | | | | North Carolina | |
|----------------|--------------------|-------------|-------------|-------------|-------------|------------|------------|----------------|-------------|-------------|-------------|----------------|-------------|
| | Handline | Longline | Diving | Handline | Longline | Diving | Trawl | Handline | Longline | Diving | Trawl | Handline | Longline |
| 1983 | | | | | | | | | | | | 12.6 | |
| 1984 | | | | | | | | | | | | 13.3 | 23.3 |
| 1985 | 21.0 | 21.8 | | 15.4 | 16.7 | | | 17.3 | 16.7 | 22.5 | | 15.2 | 25.3 |
| 1986 | 19.0 | | | 14.7 | 14.5 | | | 17.7 | 17.1 | 24.3 | 10.4 | 16.4 | 10.2 |
| 1987 | 10.7 | | | 16.5 | 14.4 | | 7.5 | 12.0 | 20.2 | 12.0 | 19.6 | 10.2 | 22.7 |
| 1988 | 13.2 | | | 14.4 | 16.5 | | | 16.5 | 15.3 | 19.9 | 15.6 | 13.7 | 21.7 |
| 1989 | 15.3 | | | 16.5 | | | | 11.9 | 11.4 | 17.0 | 21.0 | 12.5 | 17.7 |
| 1990 | 17.4 | | | 15.8 | 10.4 | 5.3 | | 10.7 | 12.3 | | | 11.2 | 18.9 |
| 1991 | 15.6 | | 12.6 | 15.4 | | | | 9.7 | | | | 11.5 | 19.6 |
| 1992 | 15.7 | 23.6 | 12.4 | 15.4 | | | | 9.8 | | | | 11.7 | 28.9 |
| 1993 | 17.6 | 20.1 | 15.6 | 15.4 | | | | 11.5 | | | | 11.4 | 16.5 |
| 1994 | 16.8 | 19.9 | 16.1 | 13.5 | 14.1 | 9.5 | | 13.7 | 14.9 | | | 11.4 | 12.6 |
| 1995 | 19.5 | 23.0 | 13.4 | 16.6 | | | | 14.8 | 22.8 | 12.2 | | 11.9 | 21.5 |
| 1996 | 13.0 | 20.9 | 7.7 | 15.3 | | | | 13.0 | | | | | 13.5 |
| 1997 | 19.2 | 15.0 | 6.2 | 16.3 | | | | 13.5 | | | | | 14.3 |
| 1998 | 14.8 | 17.9 | 12.2 | 16.5 | | | | 14.1 | | | | | 12.7 |
| 1999 | 12.7 | | 11.7 | | | | | 15.2 | | | | | 13.9 |
| 2000 | 13.6 | | 13.6 | 18.4 | | | | 12.6 | | | | | 13.5 |
| 2001 | 15.4 | | 12.7 | 18.7 | | | | 14.4 | | | | | 11.6 |
| 2002 | 16.0 | 15.9 | 12.7 | 17.7 | | | | 14.4 | 12.7 | | | | 11.6 |
| 2003 | 16.4 | | 13.4 | 17.8 | | | | | | | | | 12.4 |
| 2004 | 11.2 | | | 15.2 | | | | | | | | | 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.

| Year | DIVING | | | DIVING Total | Handline | | | | Handline Total | Longline | | | | Longline Total | TRAWL | | TRAWL Total | Grand Total |
|---------|--------|----|-----|--------------|----------|------|-------|-------|----------------|----------|----|-----|----|----------------|-------|----|-------------|-------------|
| | 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 | | | | 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.

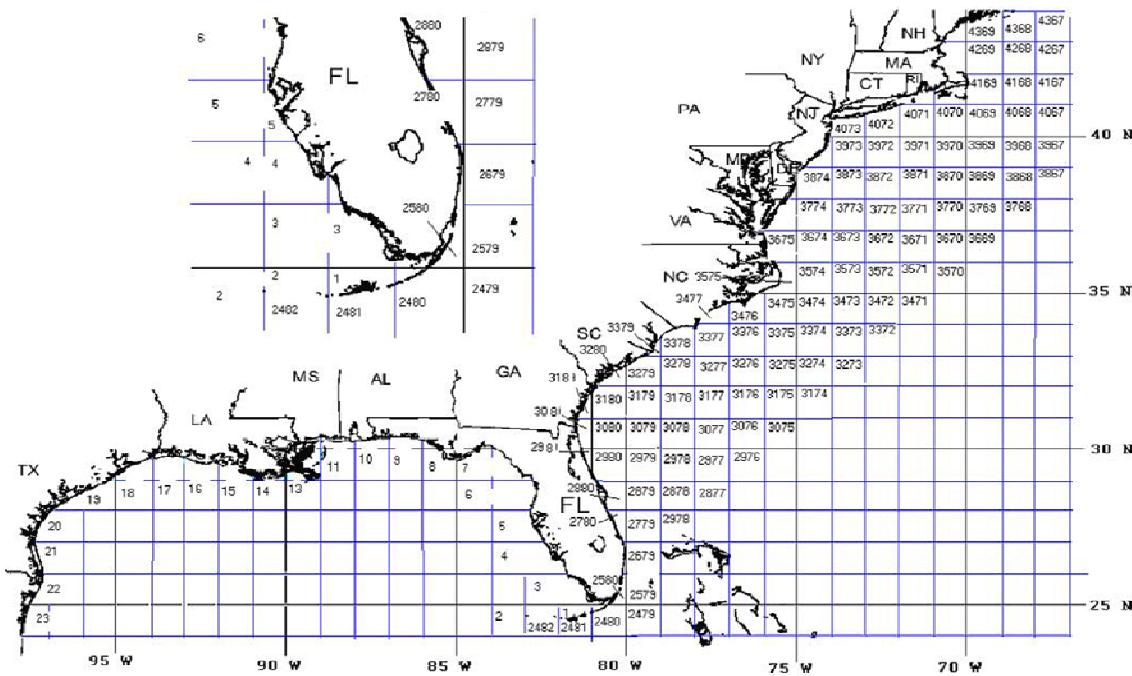


Figure 3.2. Map showing marine fisheries trip ticket fishing area code map for Florida.

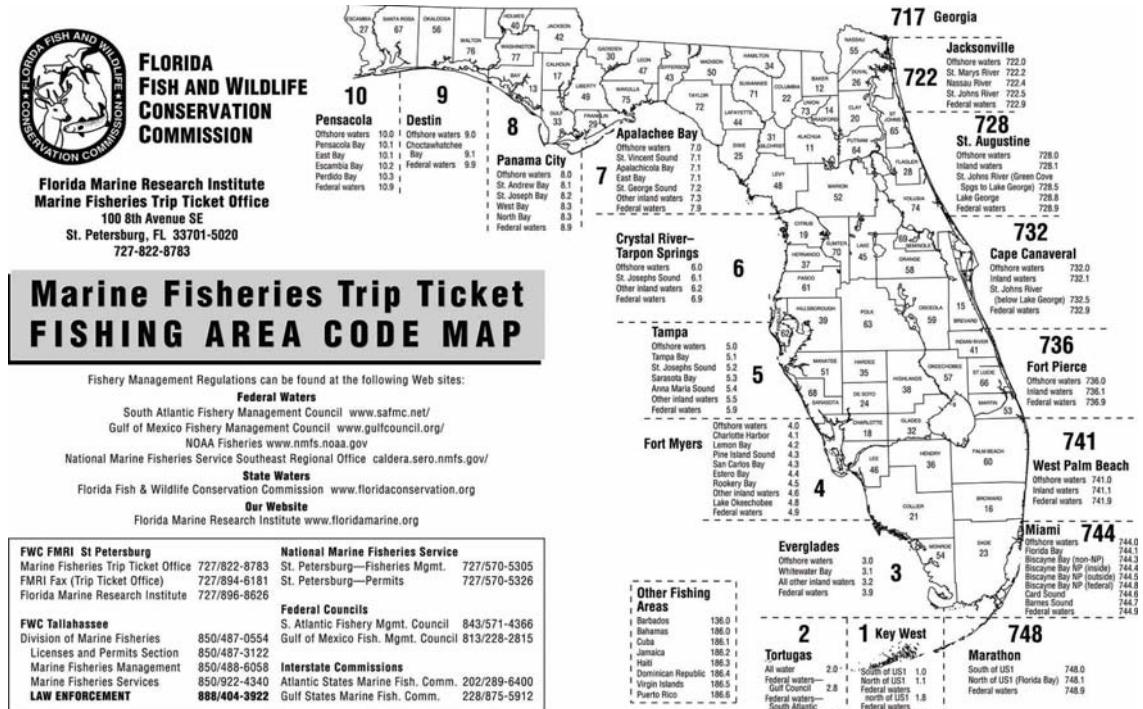


Figure 3.3. Proportion of gag misidentified as black grouper by seafood dealers in the South Atlantic by state and year, from TIP observation weight data.

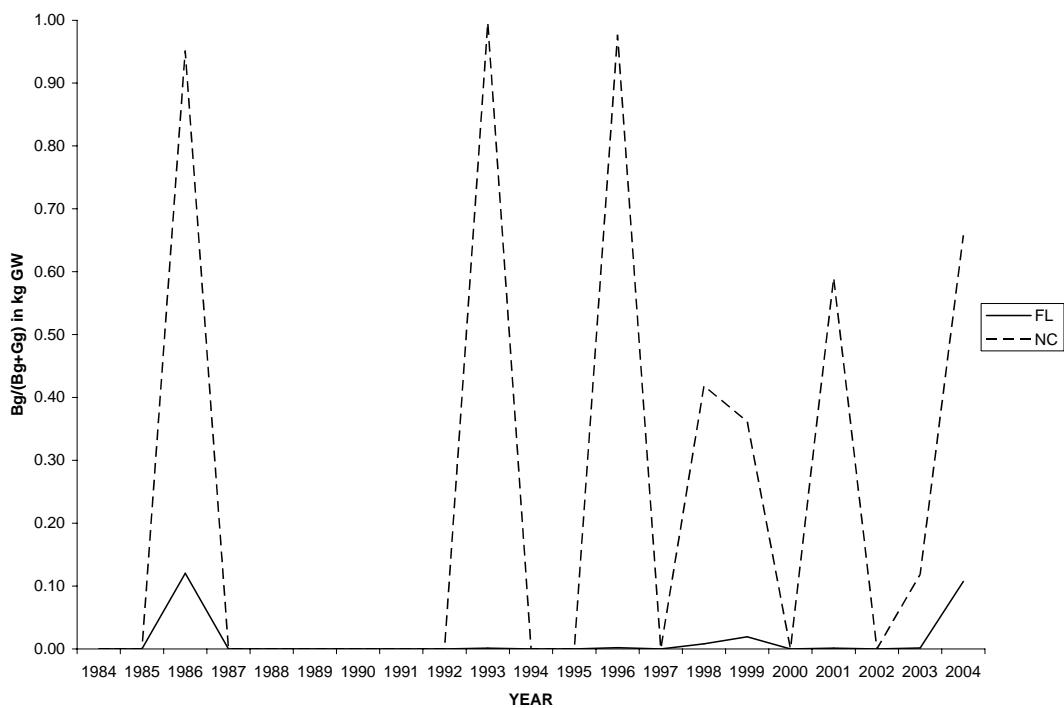


Figure 3.4. Unadjusted gag landings by gear for the U.S. South Atlantic, 1962-2004.

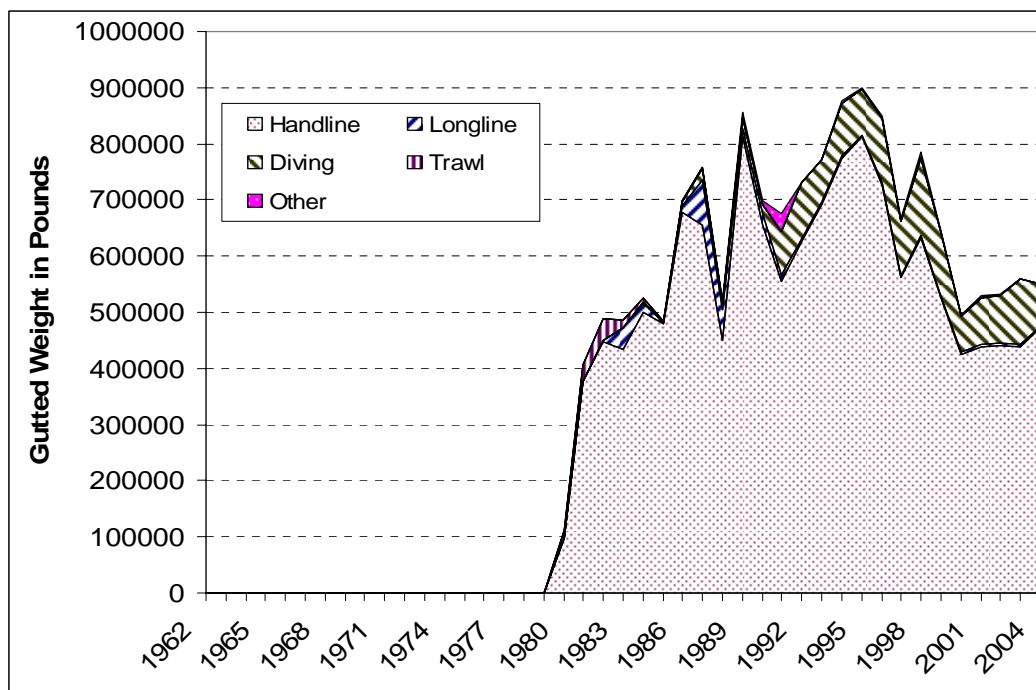


Figure 3.5. Unadjusted gag landings from the U.S. South Atlantic, 1962-2004.

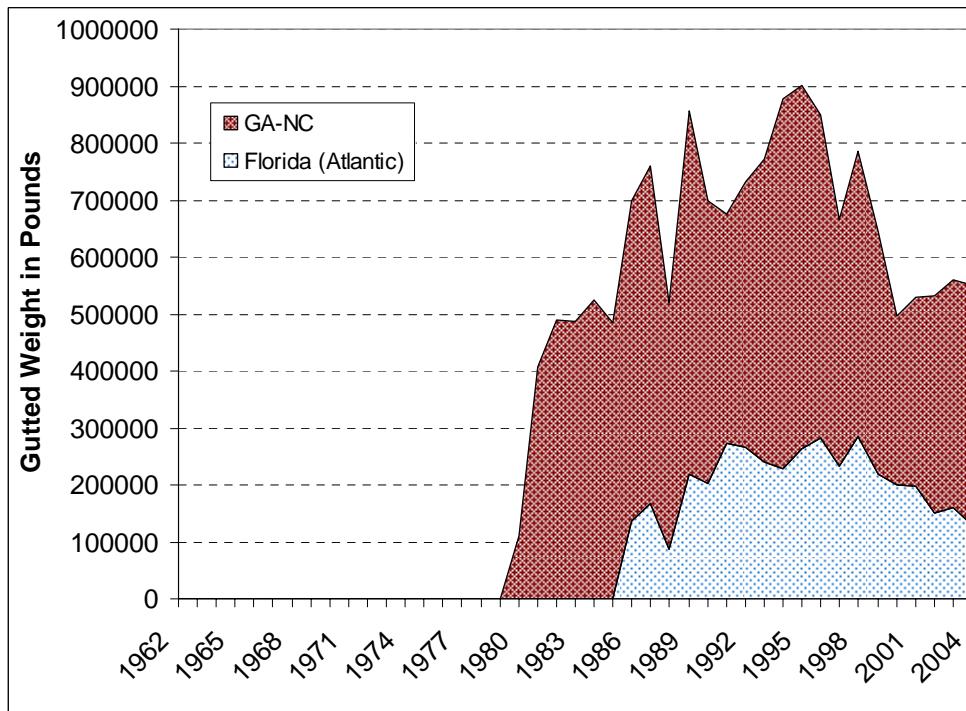


Figure 3.6. Unclassified grouper landings from the U.S. South Atlantic, 1962-2004.

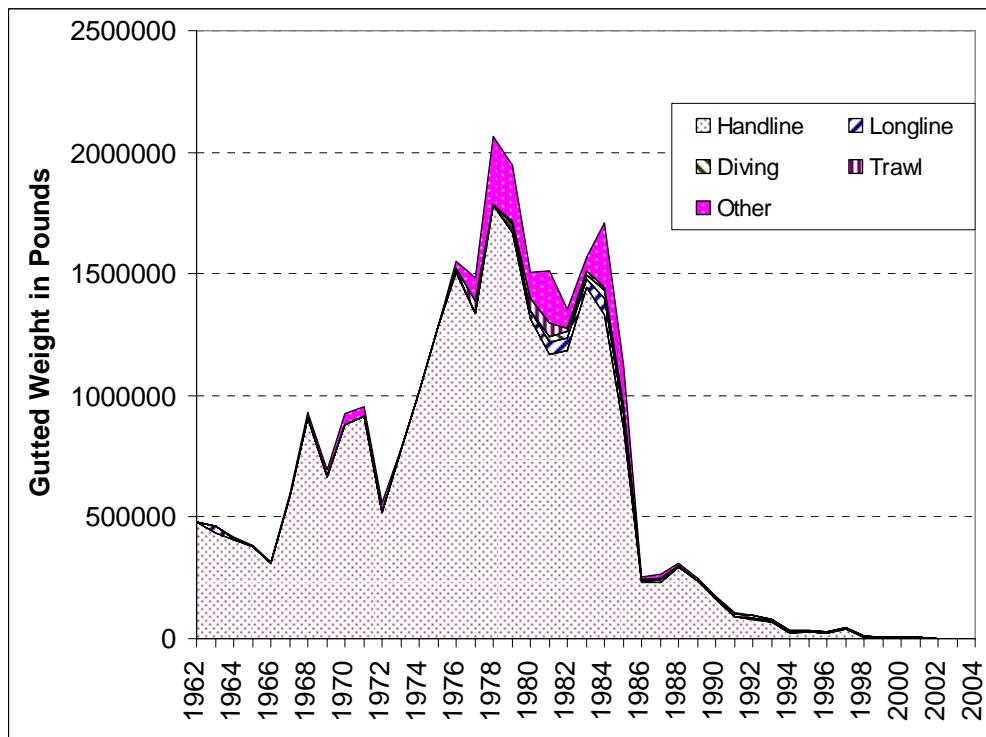


Figure 3.7. Classified grouper landings from the U.S. South Atlantic, 1962-2004.

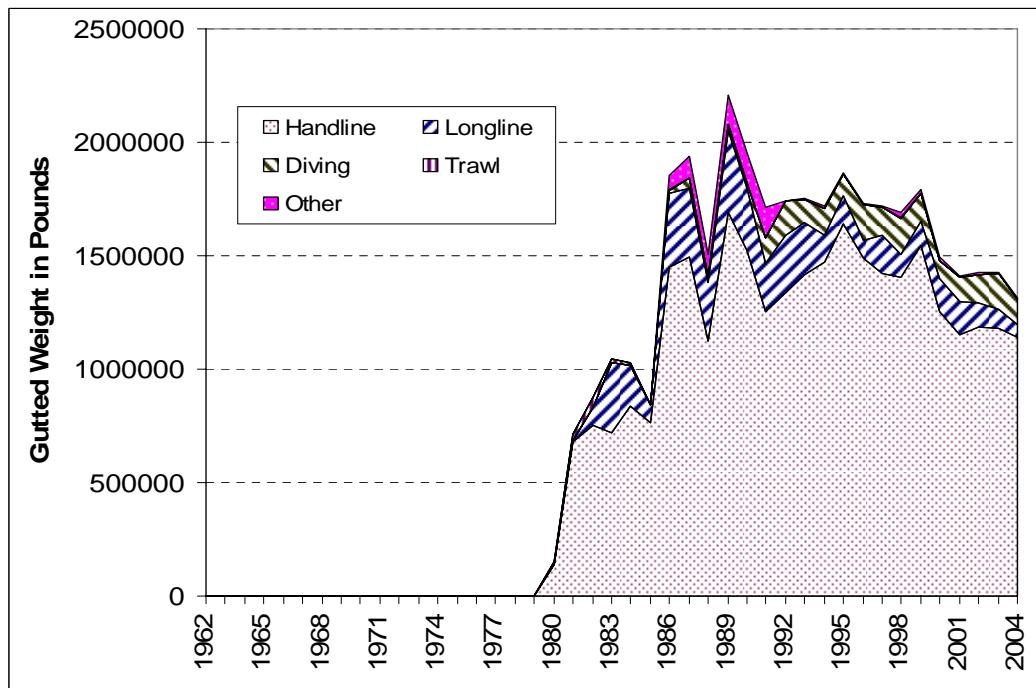


Figure 3.8. Classified versus unclassified grouper landings from the U.S. South Atlantic, 1962-2004.

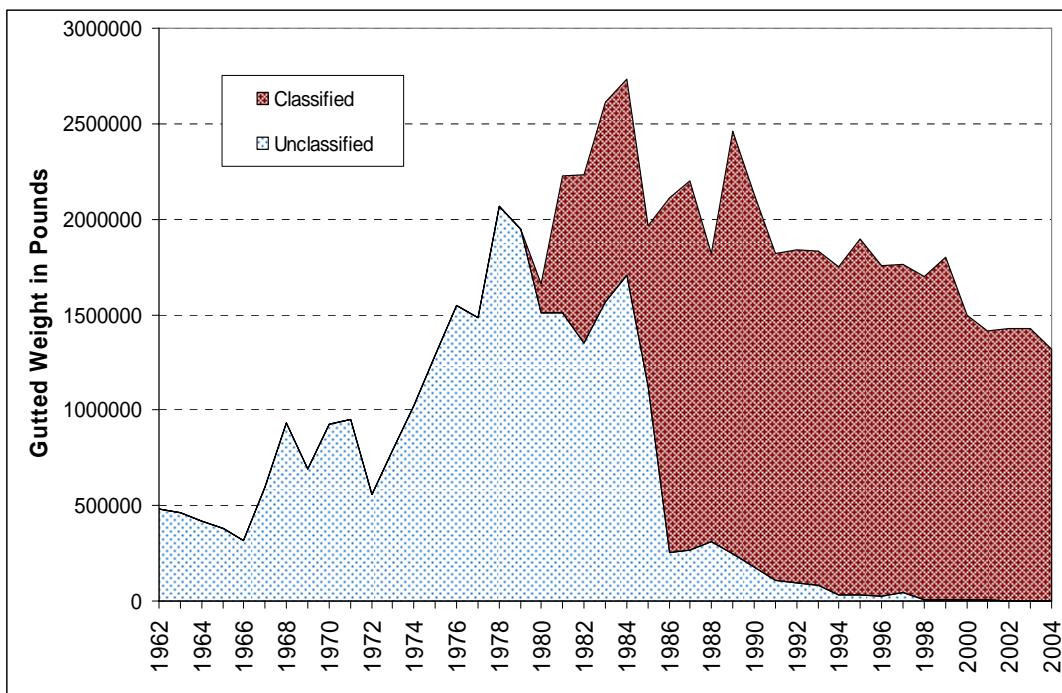


Figure 3.9. Adjusted gag grouper landings by gear from the U.S. South Atlantic, 1962-2004.

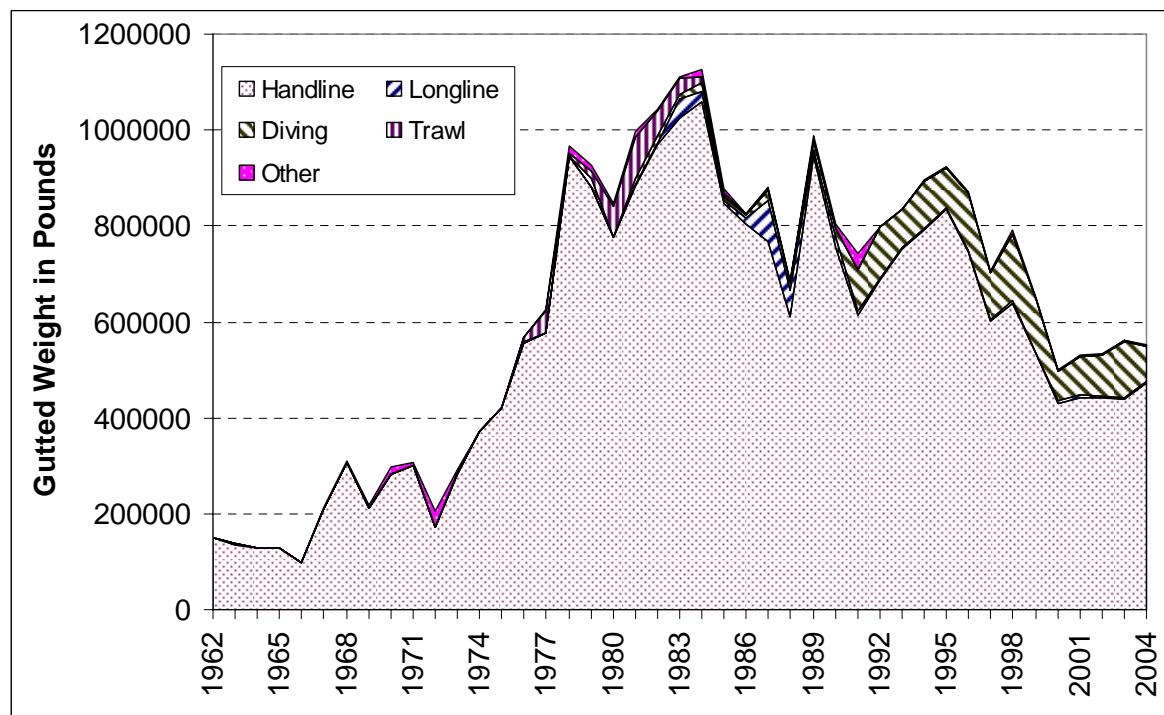


Figure 3.10. Adjusted gag grouper landings from the U.S. South Atlantic, 1962-2004.

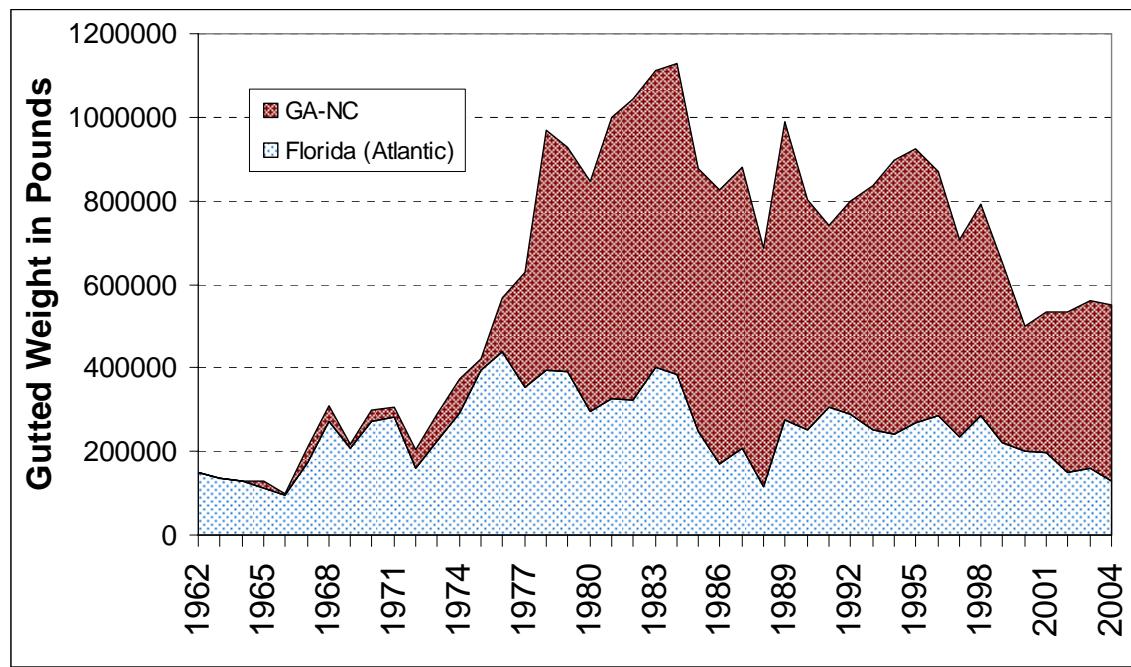


Figure 3.11. Comparison of unadjusted to adjusted gag grouper landings from the U.S. South Atlantic, 1962-2004.

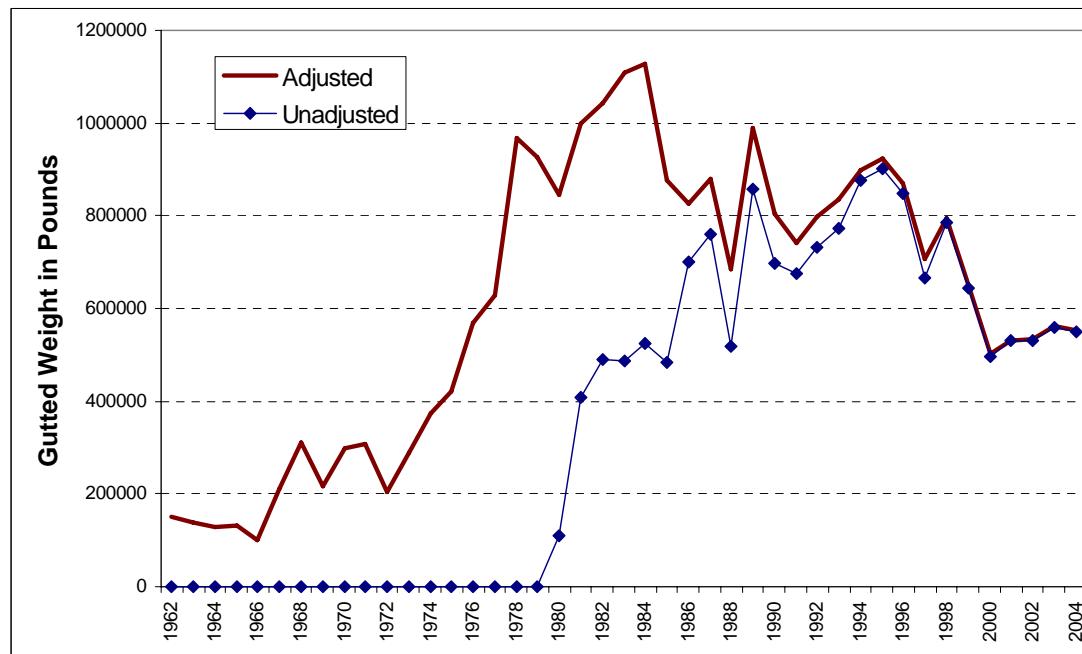


Figure 3.12. Lower bound on adjusted gag grouper landings by gear from the U.S. South Atlantic, 1962-2004

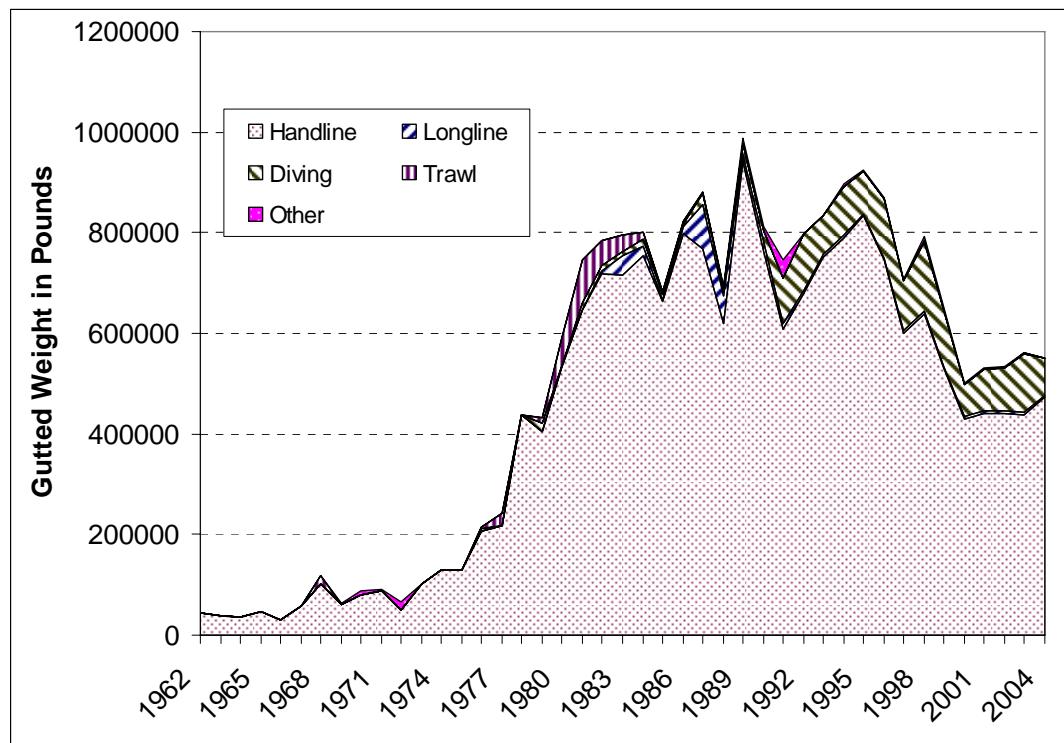


Figure 3.13. Lower bound on adjusted gag grouper landings from the U.S. South Atlantic, 1962-2004.

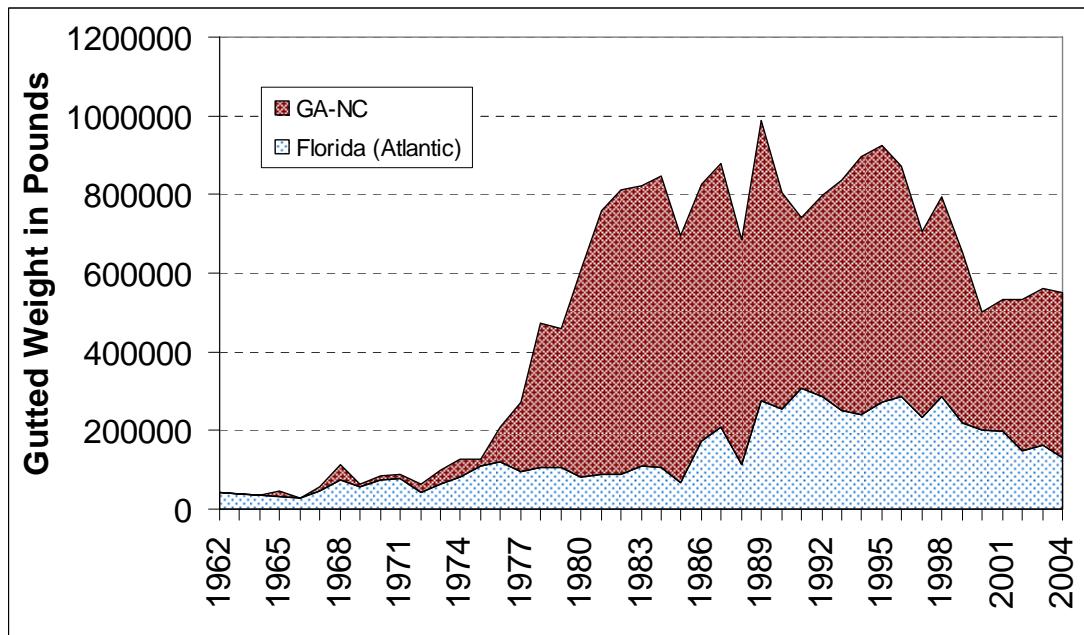


Figure 3.14. Upper bound on adjusted gag grouper landings by gear from the U.S. South Atlantic, 1962-2004.

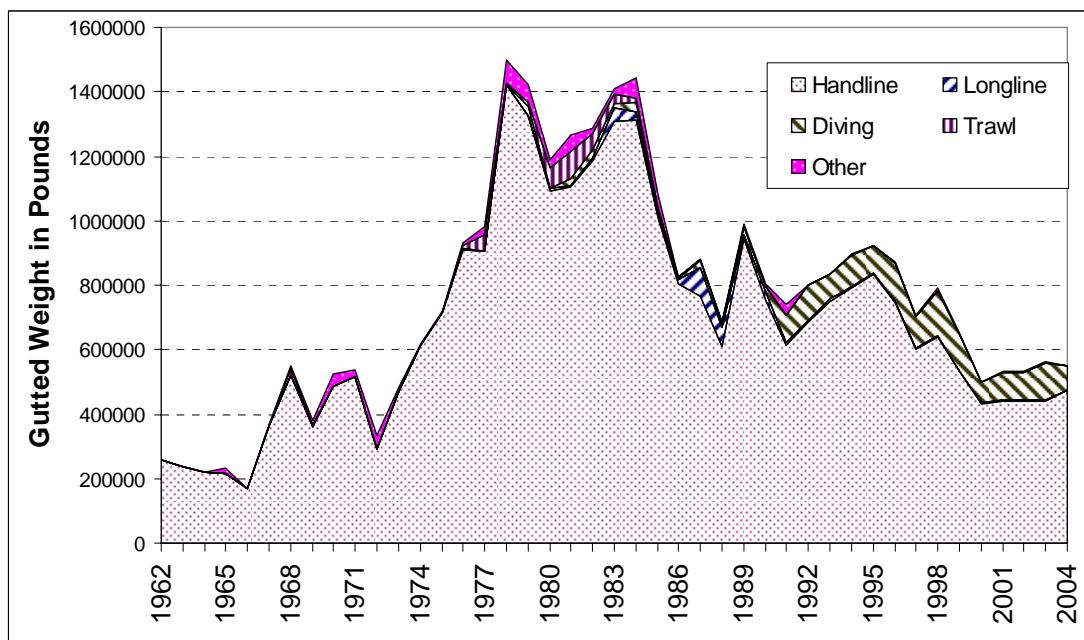


Figure 3.15. Upper bound on adjusted gag grouper landings from the U.S. South Atlantic, 1962-2004.

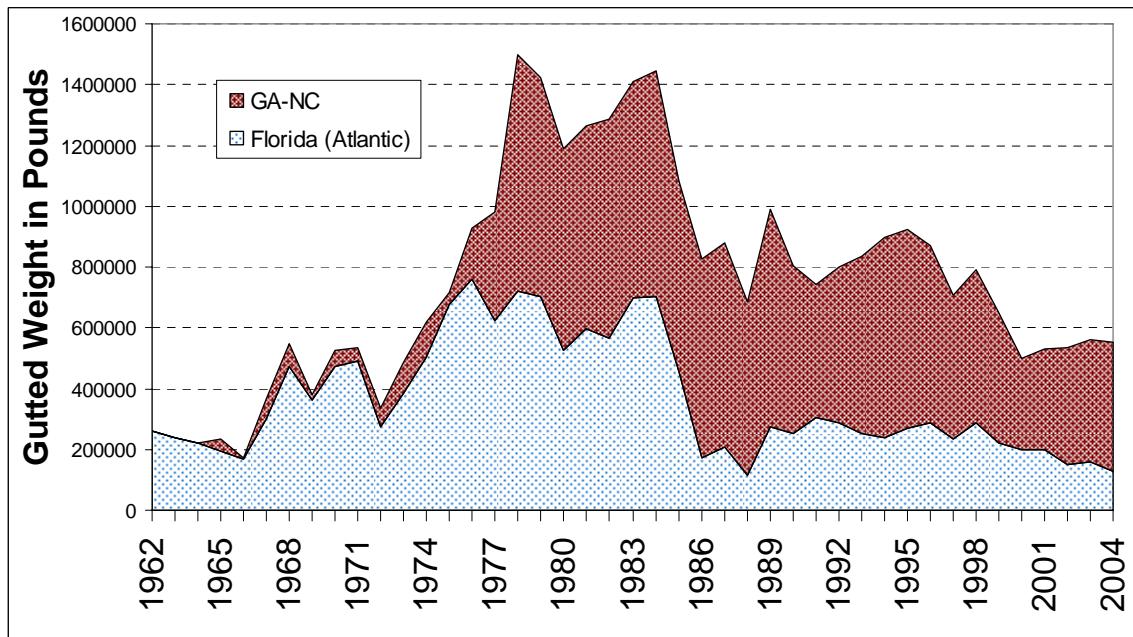


Figure 3.16. Range in adjusted gag grouper landings from the U.S. South Atlantic, 1962-2004.

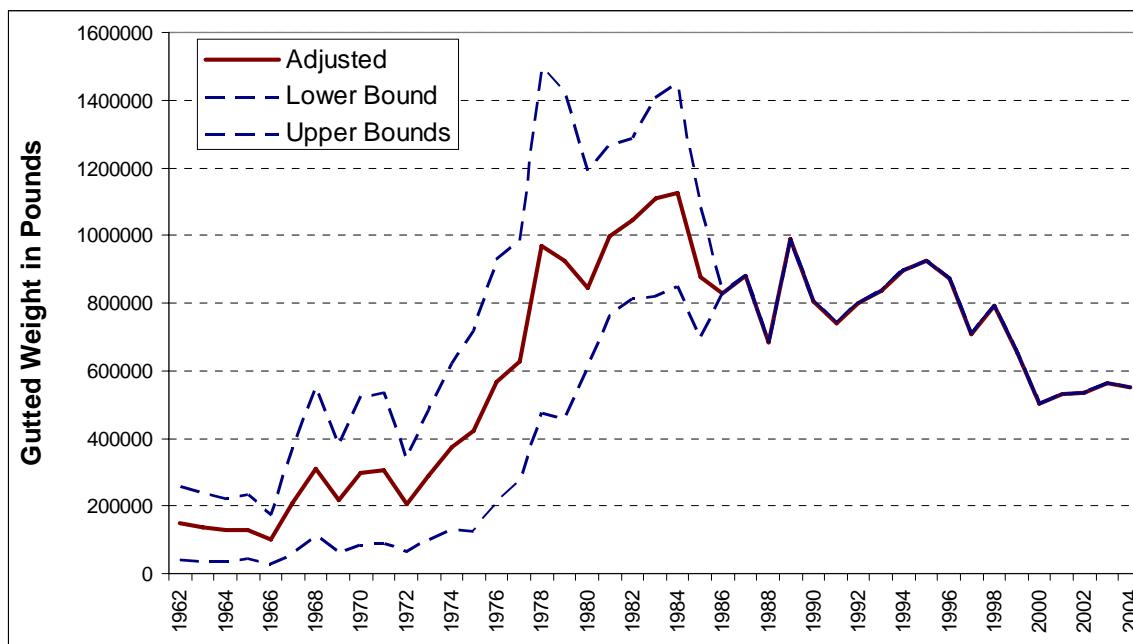


Figure 3.17. Adjusted gag grouper landings in numbers by gear from the U.S. South Atlantic, 1962-2004.

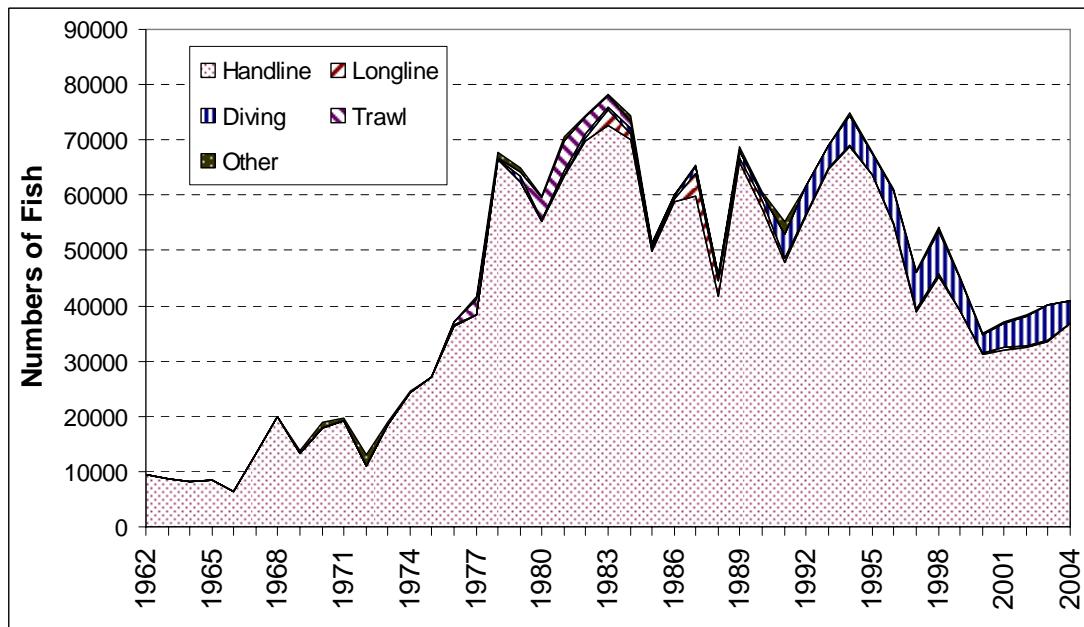


Figure 3.18. Adjusted gag grouper landings in numbers from the U.S. South Atlantic, 1962-2004.

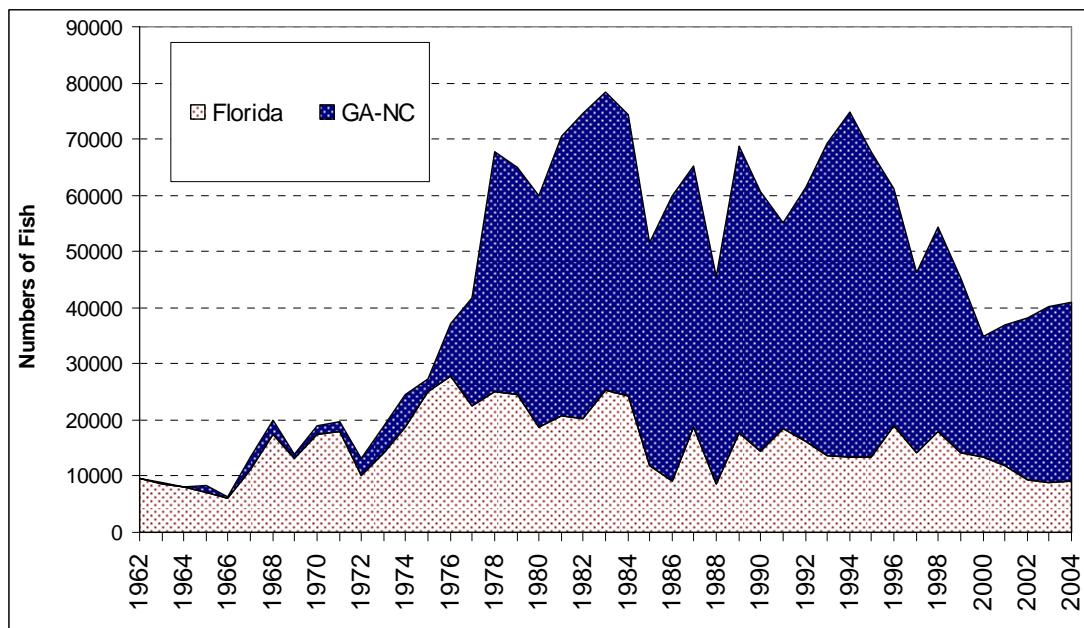


Figure 3.19. Length composition of gag grouper for commercial handline from TIP, 1983-2004. Weighting based on landings in numbers and trip catch in numbers.

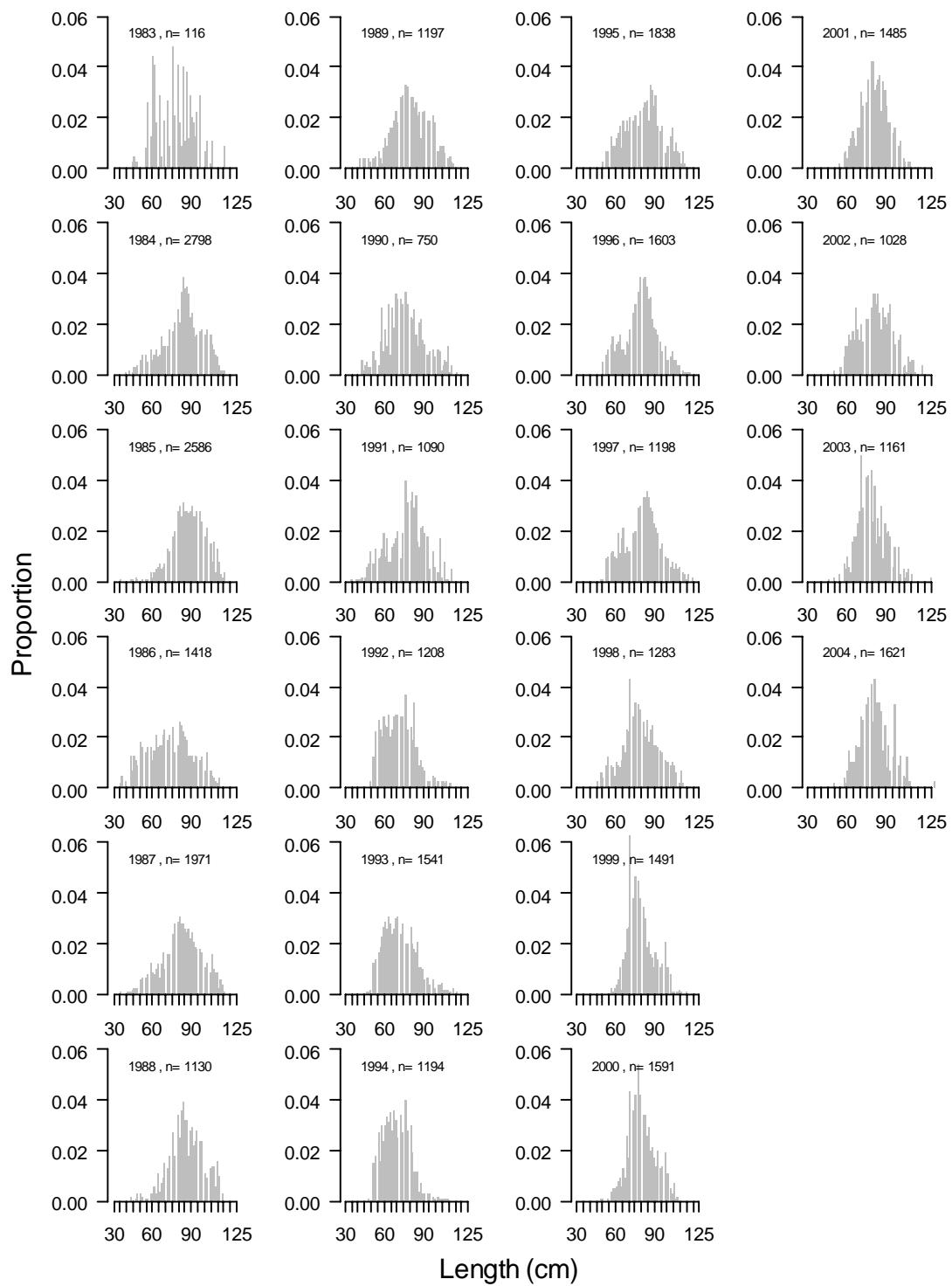


Figure 3.20. Length composition of gag grouper for commercial longline from TIP, 1984-1998, and 2002. Weighting based on landings in numbers and trip catch in numbers.

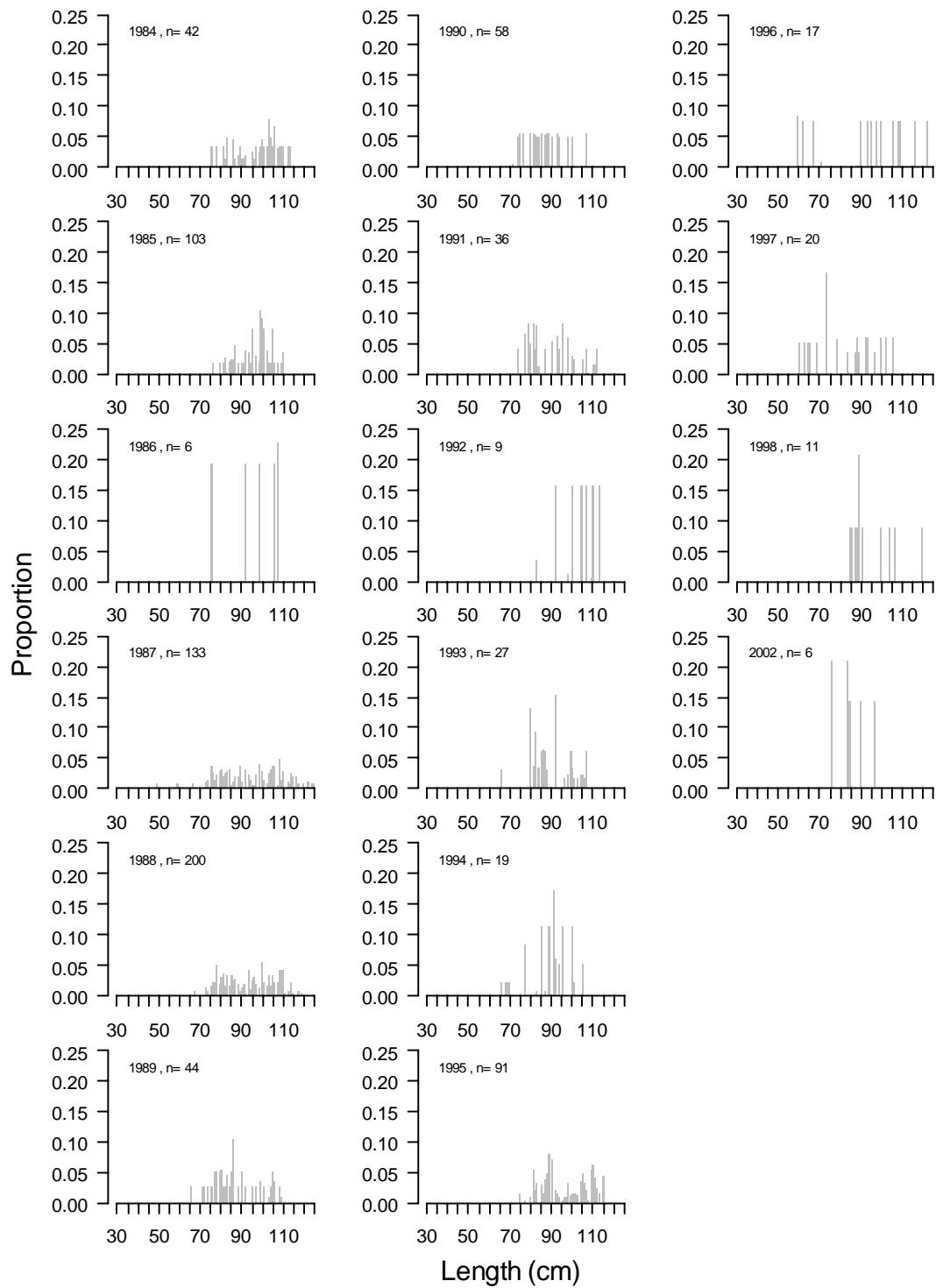


Figure 3.21. Length composition of gag grouper for commercial diving from TIP, 1986-1987, 1991-2004. Weighting based on landings in numbers and trip catch in numbers.

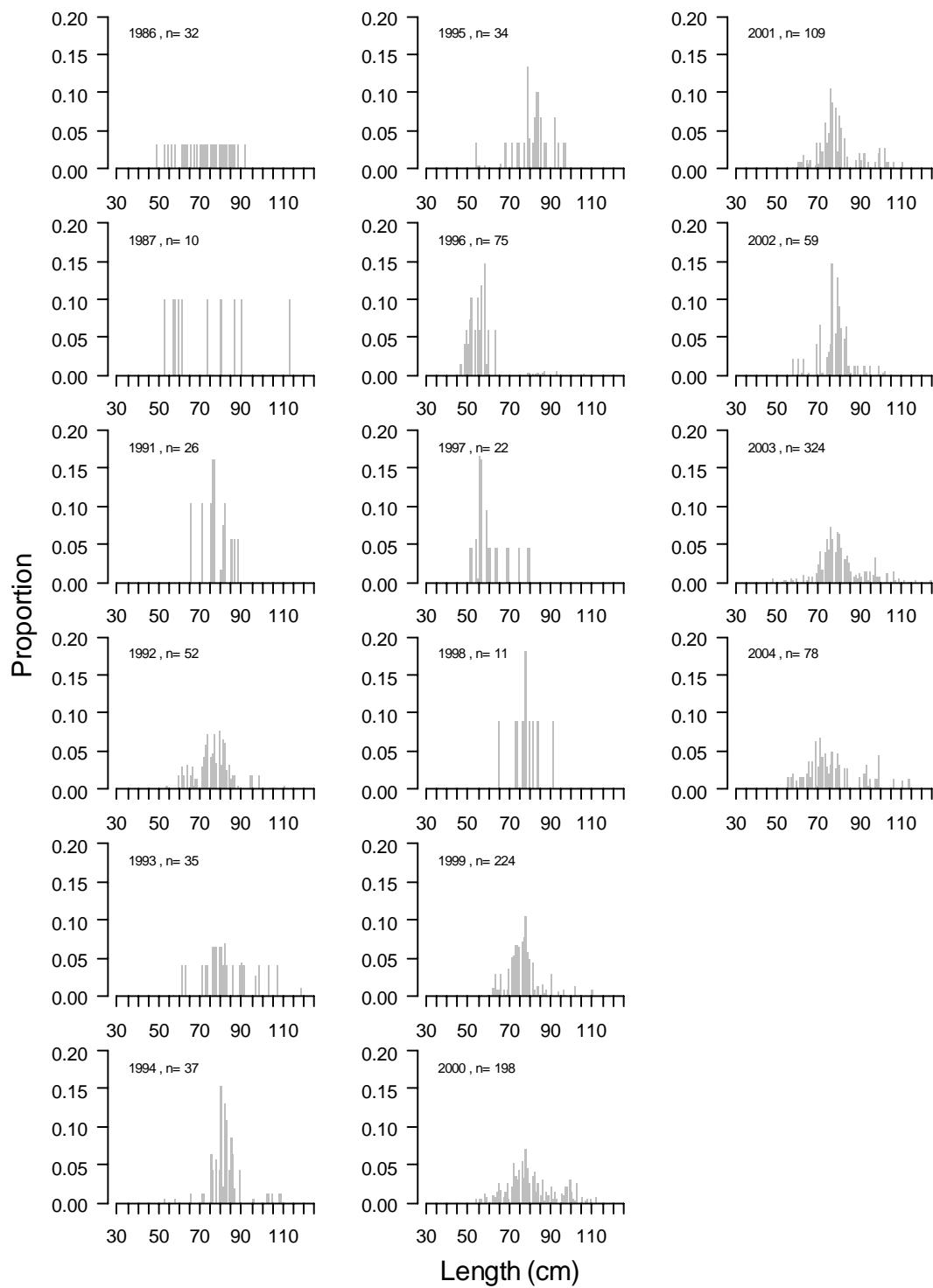


Figure 3.22. Age composition of gag grouper for commercial handline from TIP, 1979-1981, 1992-1997, 1999-2004. Weighting based on corresponding length composition available for 1992-2004.

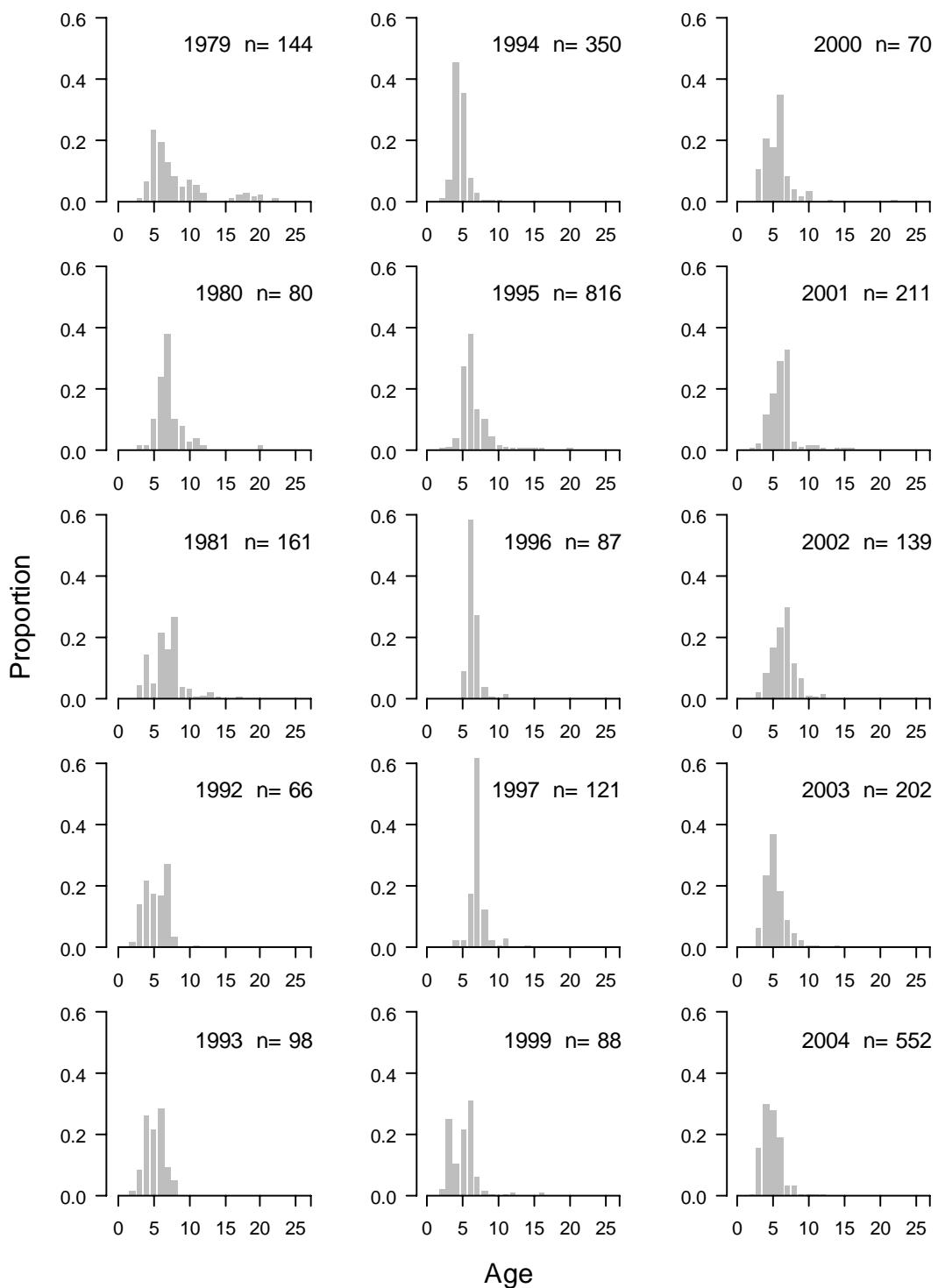
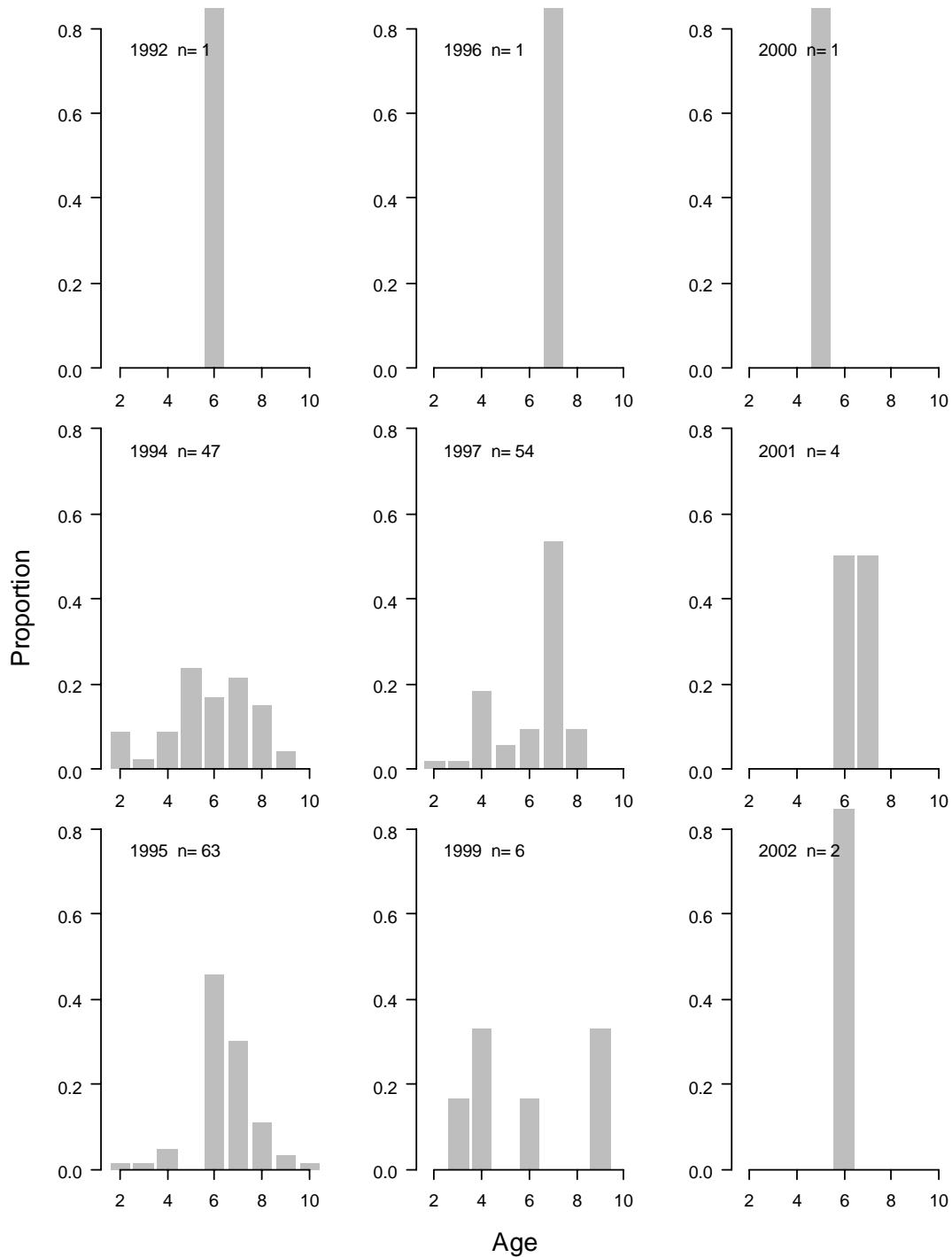


Figure 3.23. Age composition of gag grouper for commercial diving from TIP, 1992, 1994-1997, 1999-2002. Weighting based on landings in numbers by state.



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:(gag + 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 their 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.

$$\text{TotalLength} = \text{ForkLength} * 1.034 \quad (1)$$

- . 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).

Tables

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.

| Year | Private Boats | | Charter Boats | | Shore-based | | Total | |
|------|---------------|--------|---------------|-------|-------------|--------|--------|-------|
| | 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.

| YEAR | Private Boats | | Charter Boats | | Shore-based | |
|------|---------------|-----|---------------|-----|-------------|-----|
| | 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.

| Year | Number of Gag Weighed | | | Number of Gag Measured | | |
|------|-----------------------|---------------|-------------|------------------------|---------------|-------------|
| | 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.

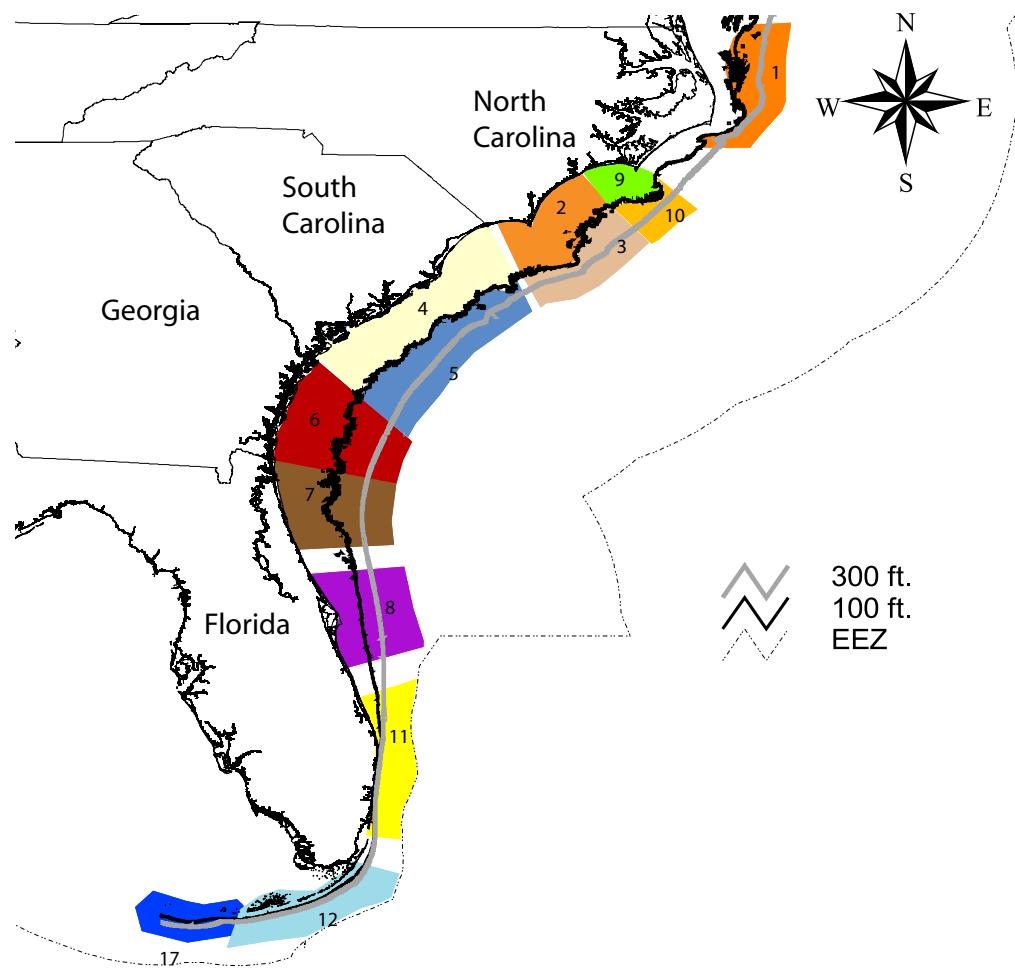


Figure 2. Landings of gag from the headboat survey by area in thousands of fish and in metric tons. The 95% confidence intervals are displayed for predicted landings from Georgia and Florida from 1972–1980

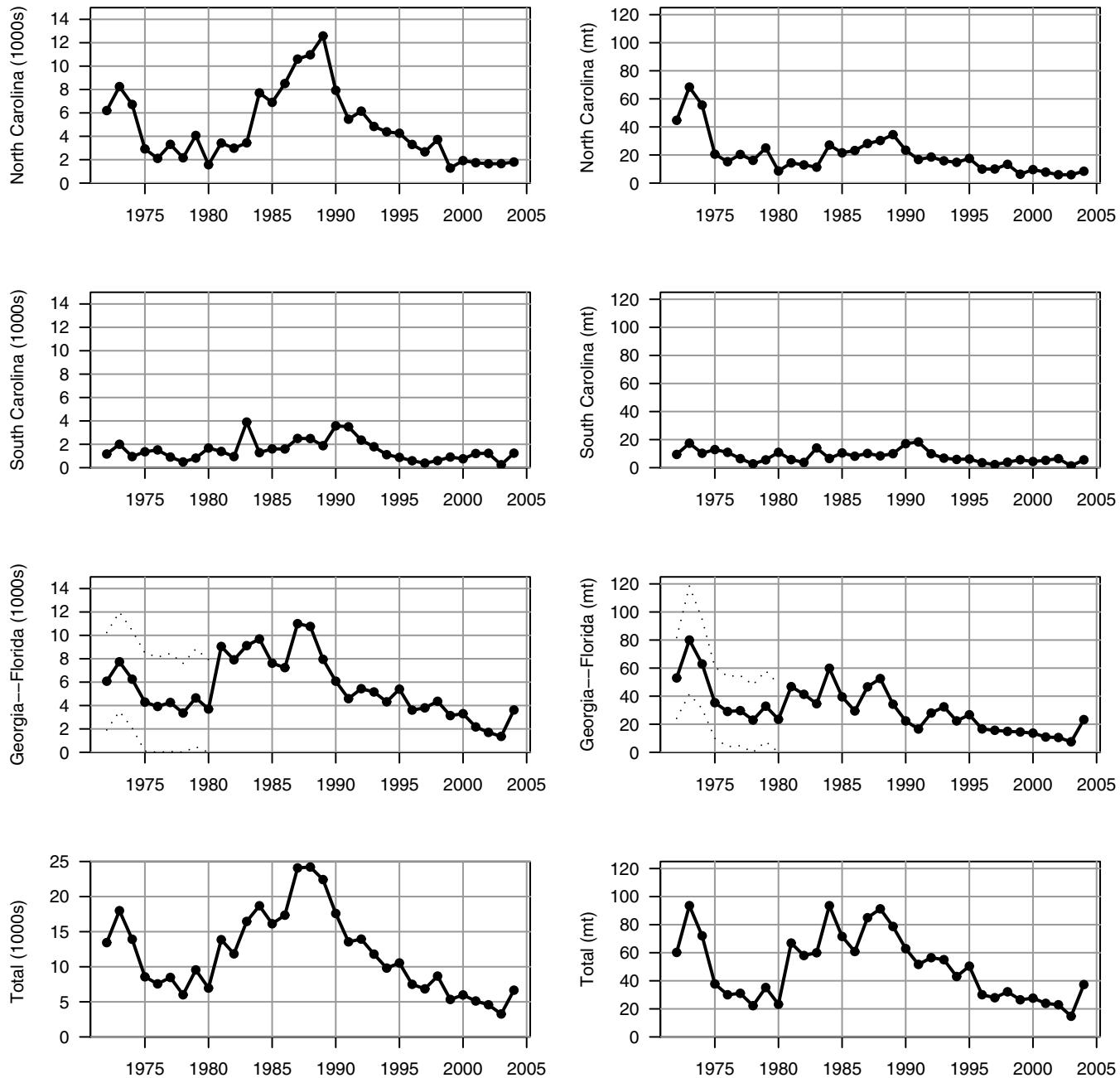


Figure 3. Landings and predicted landings of gag from the Headboat Survey in thousands of fish (A) and metric tons (B).

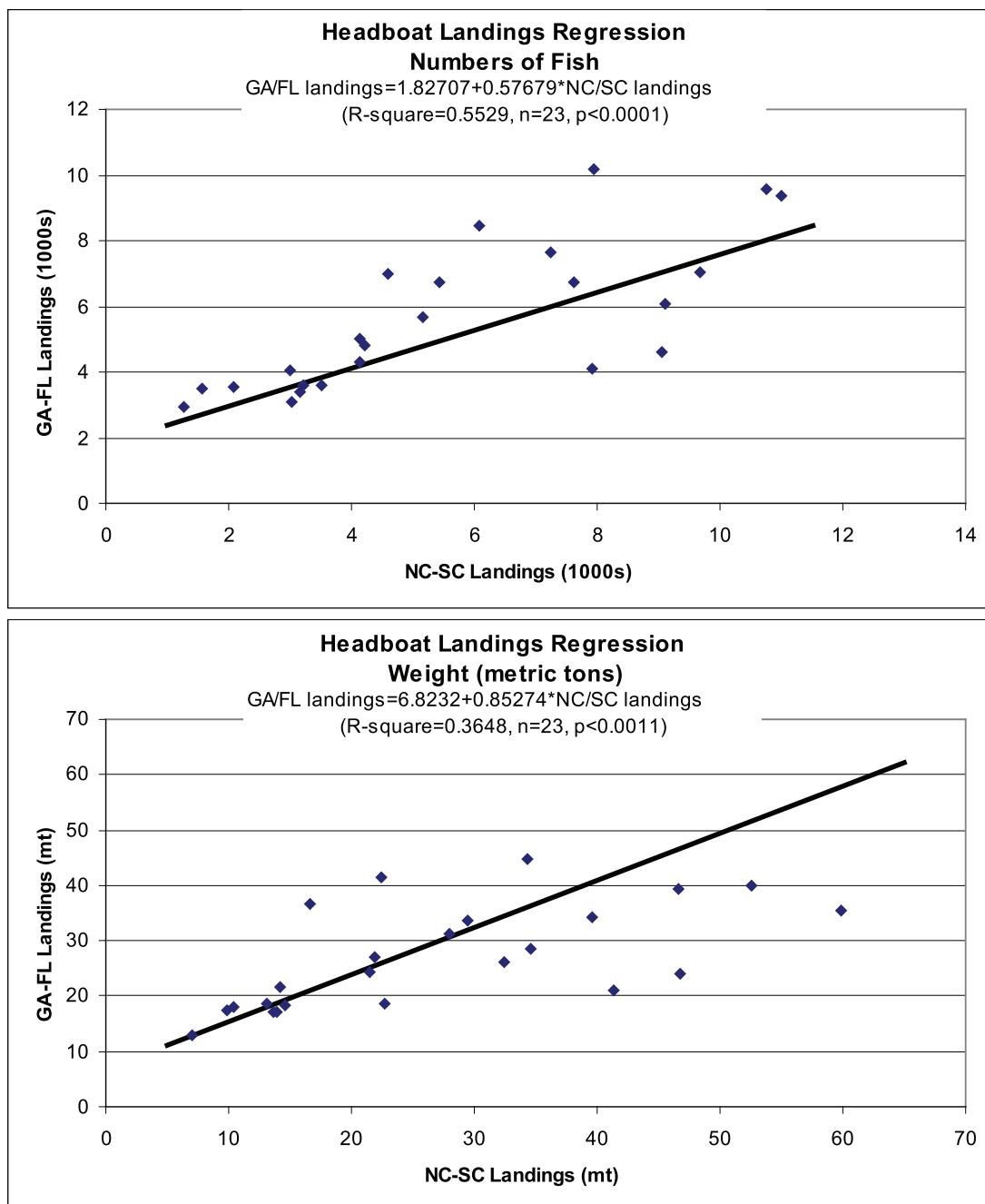


Figure 4. Linear model and Robust Linear Model regressions of gag landings from the recreational data sources against commercial landings for all years where both occurred.

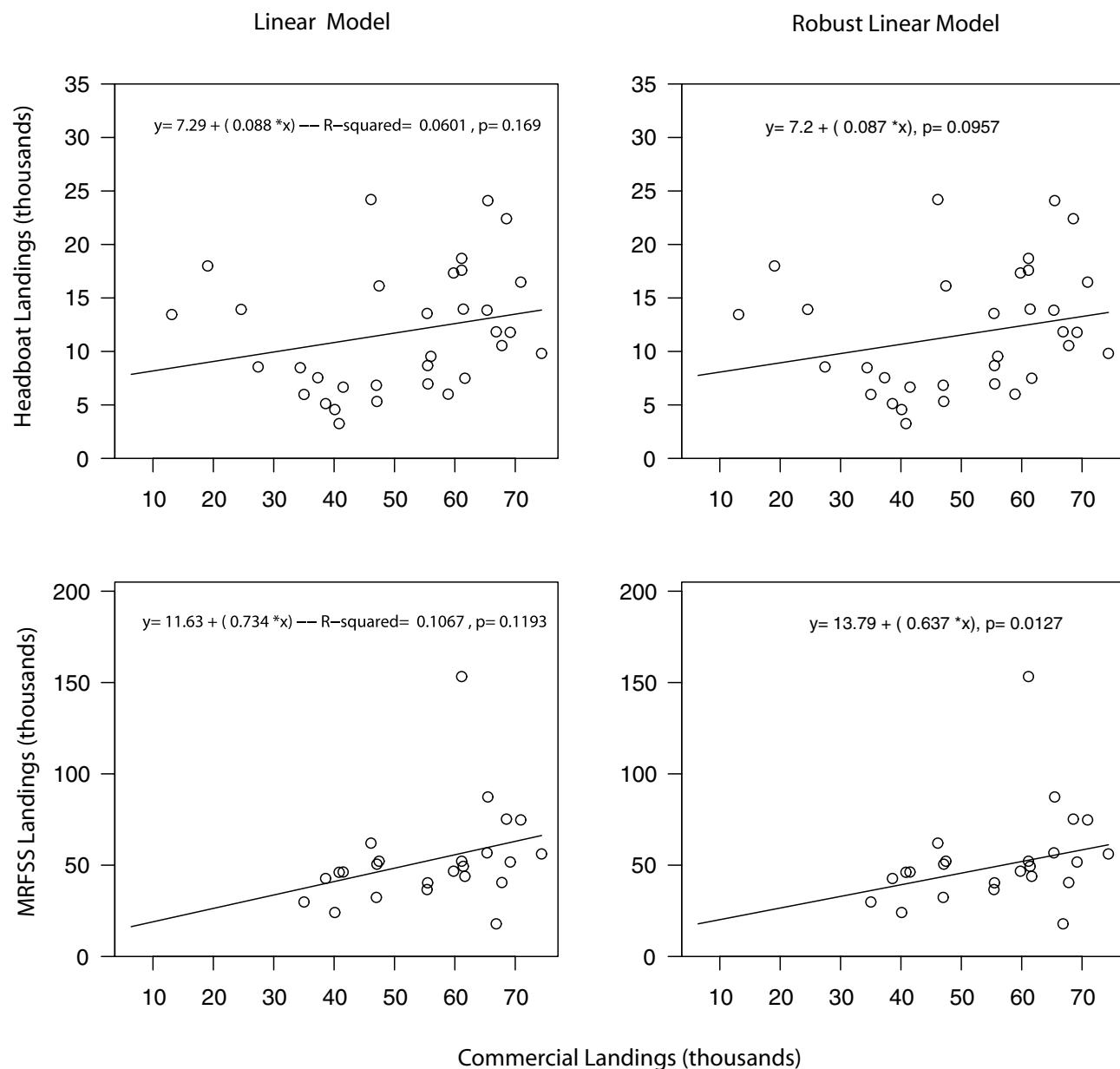


Figure 5. Regressions of headboat(A) and MRFSS (B) landings in number against coastal human population. Population trends by state displayed (C).

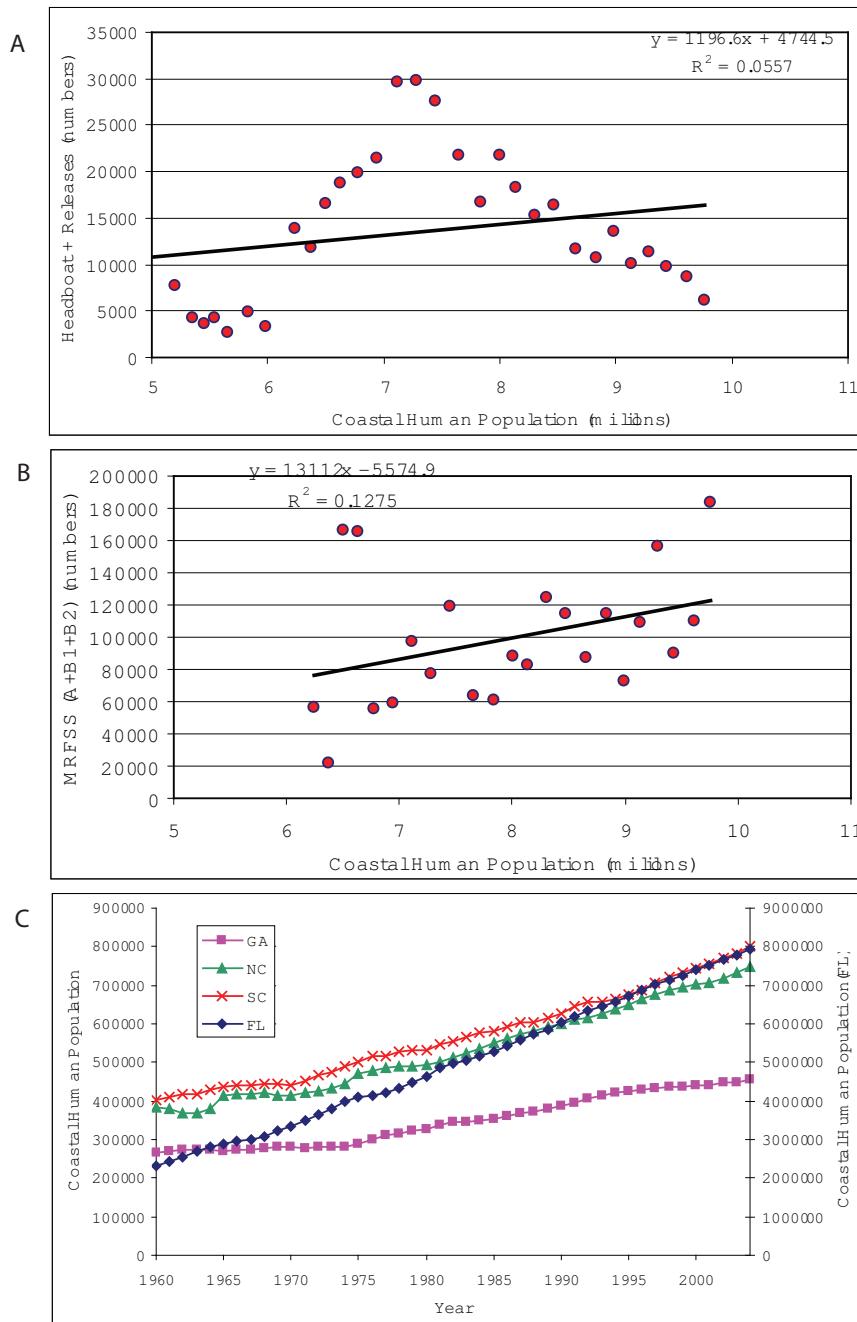


Figure 6. Release rates of gag used to predict headboat releases.

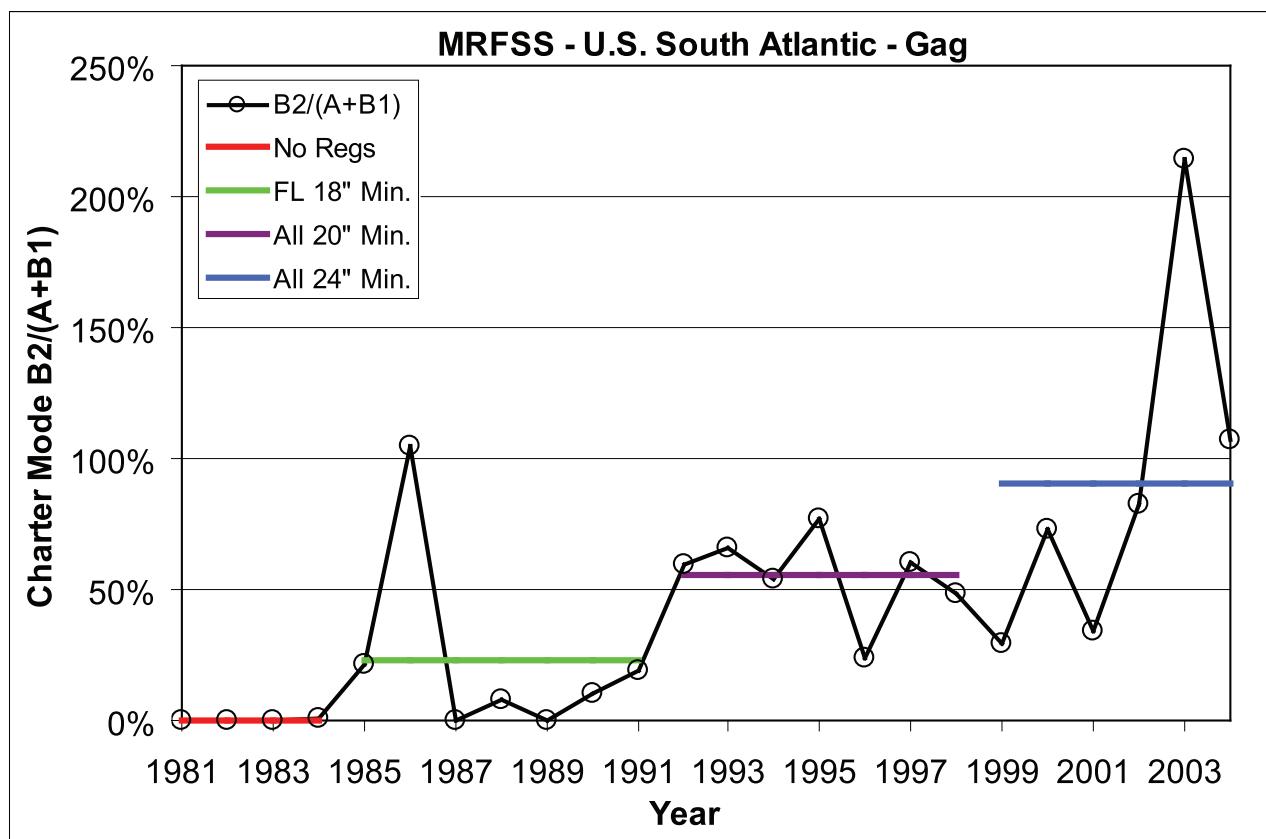


Figure 7. Mean weight in kg for North and South Carolina (Carolinas) and Georgia and Florida (GA/FL).

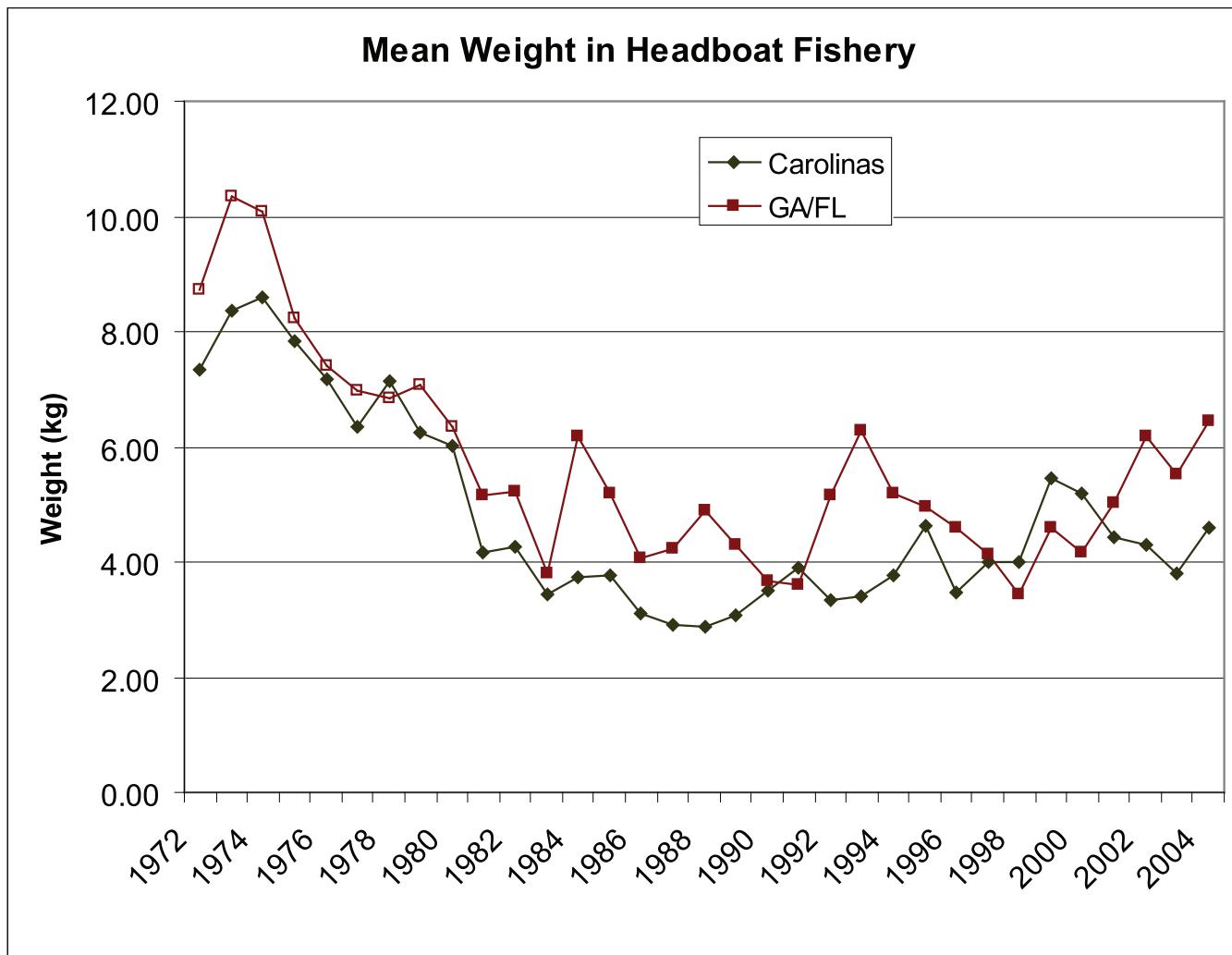


Figure 8. Length composition of gag from the headboat survey for 1972 to 1989. Lengths are in 1 cm bins from 20 cm to 125 cm.

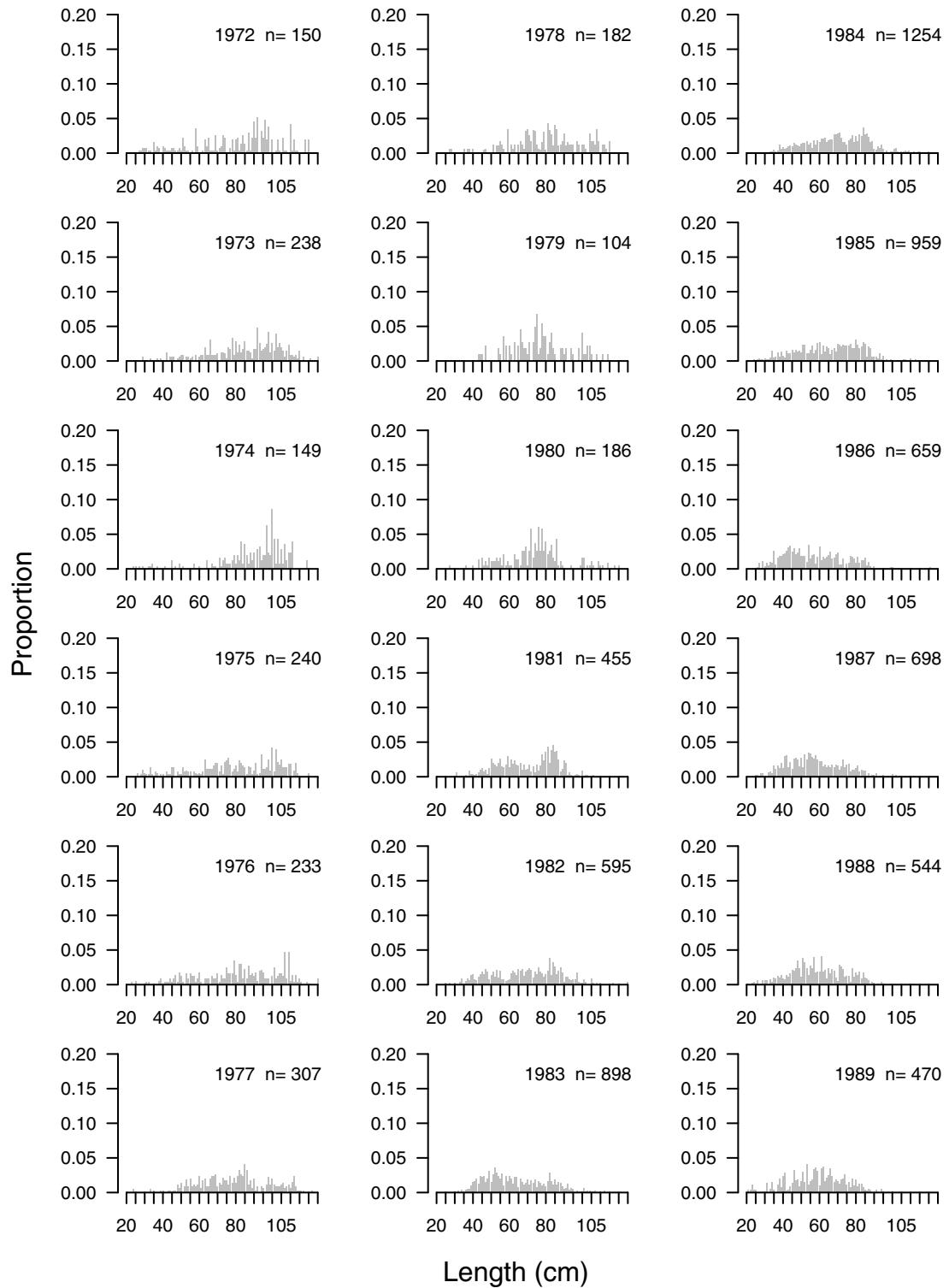


Figure 9. Length composition of gag from the headboat survey for 1990 to 2004. Lengths are in 1 cm bins from 20 cm to 125 cm.

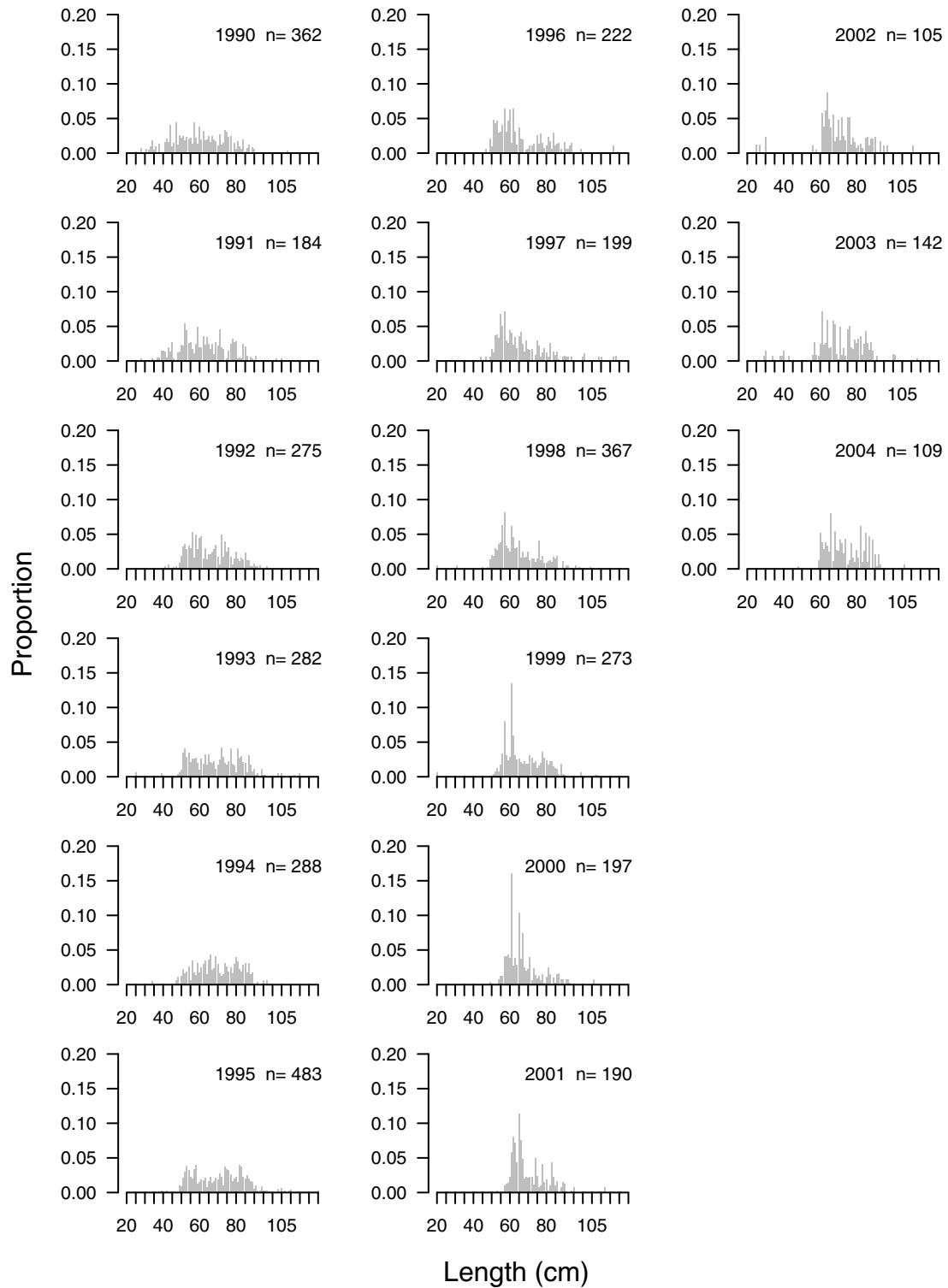


Figure 10. Analysis of changes in lengths of gag over time in the headboat survey.

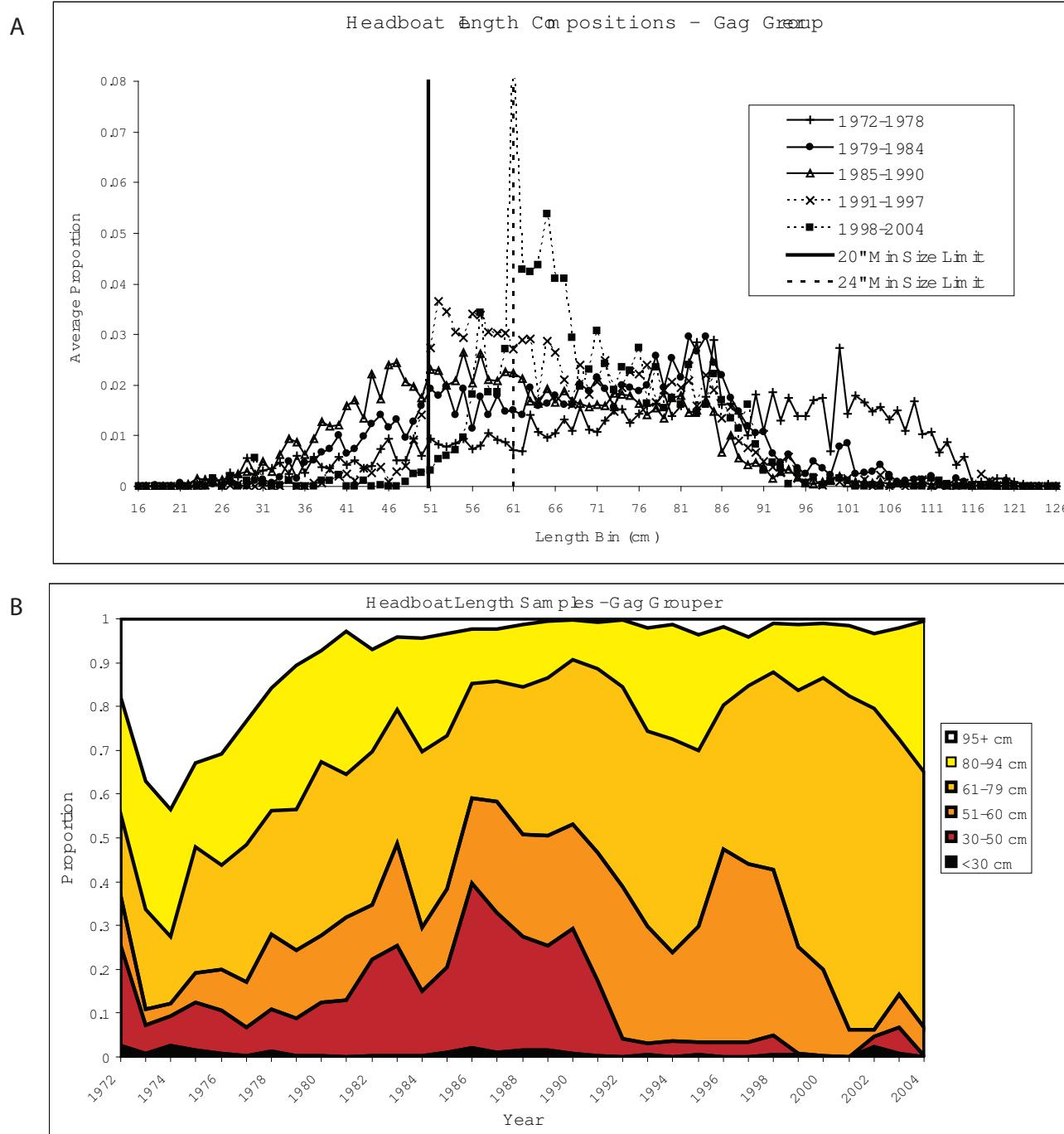


Figure 11. Analysis of changes in lengths of gag over time in the headboat survey.

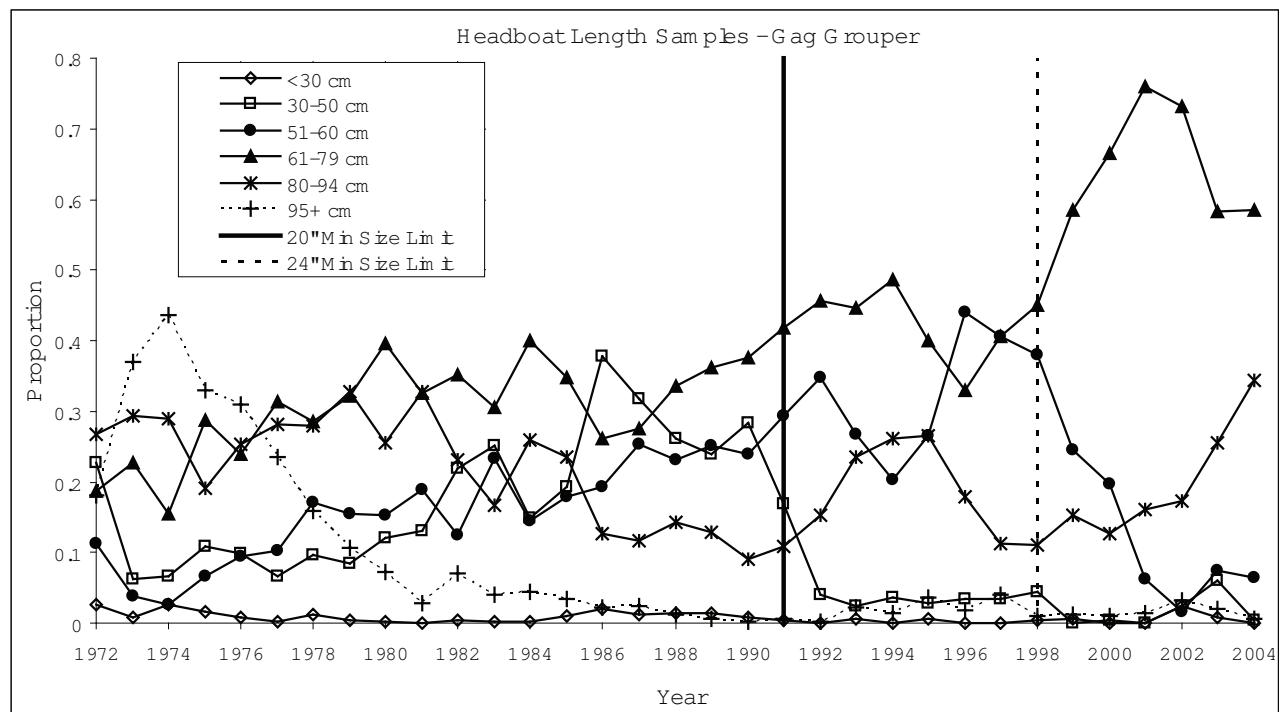


Figure 12. Age compositions of gag from the recreational data (headboat and charter vessel) for 1975-1990.

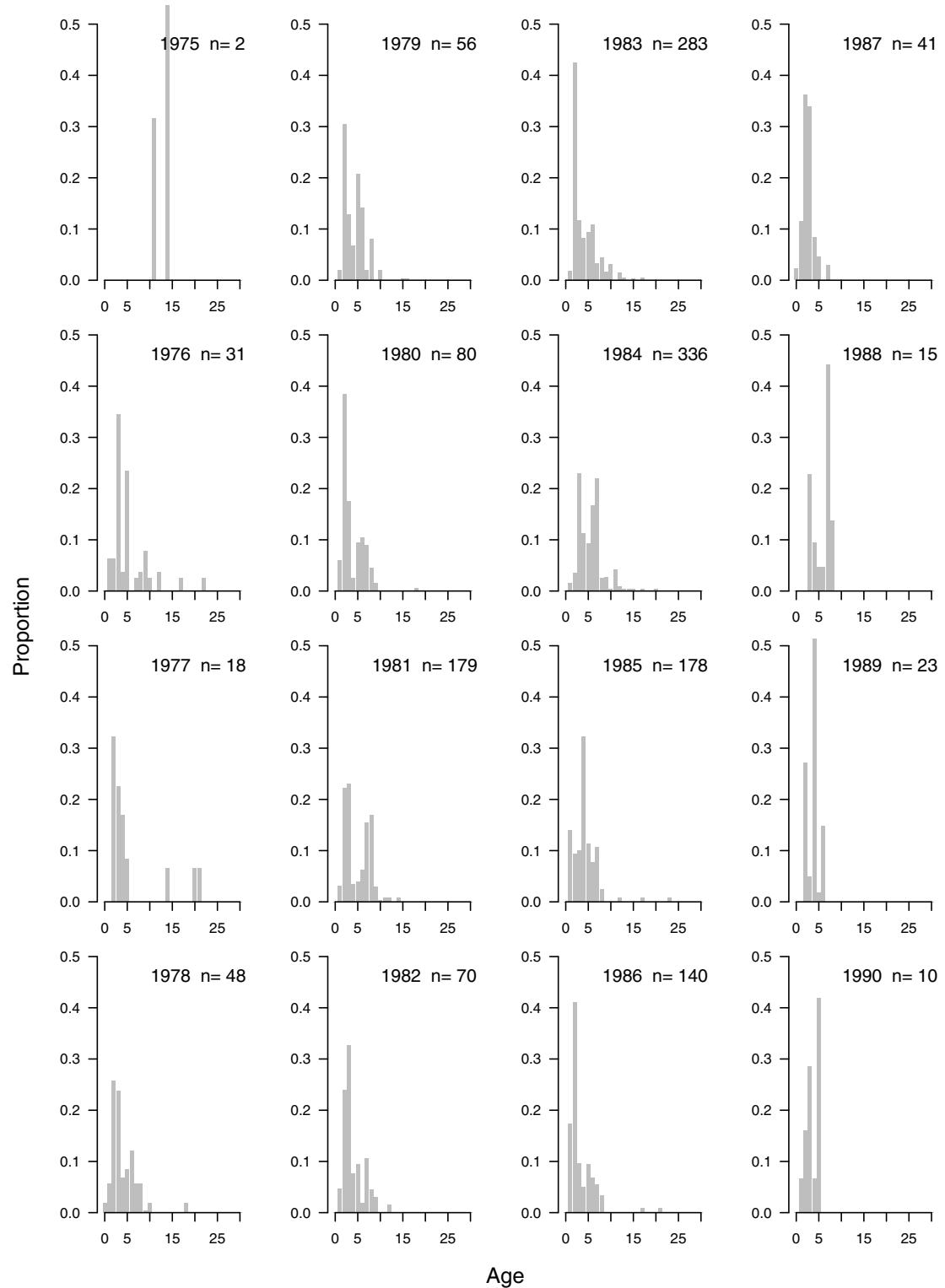


Figure 13. Age composition of gag from the recreational data (headboat and charter vessel) for 1991-2004, no ages were available from 1999 or 2000.

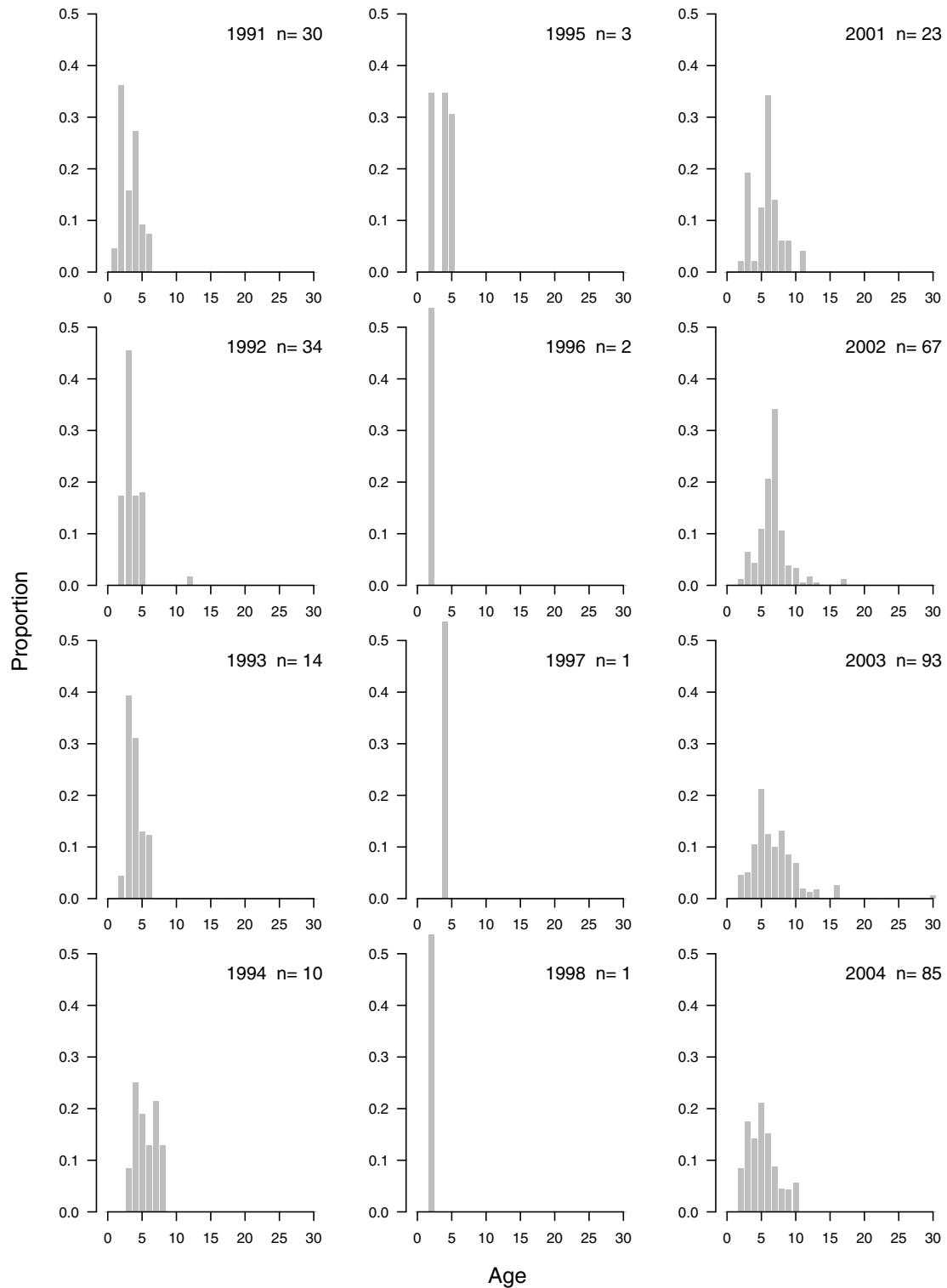


Figure 14. Percent of MRFSS landings in Number that were gag or total gag and black grouper.

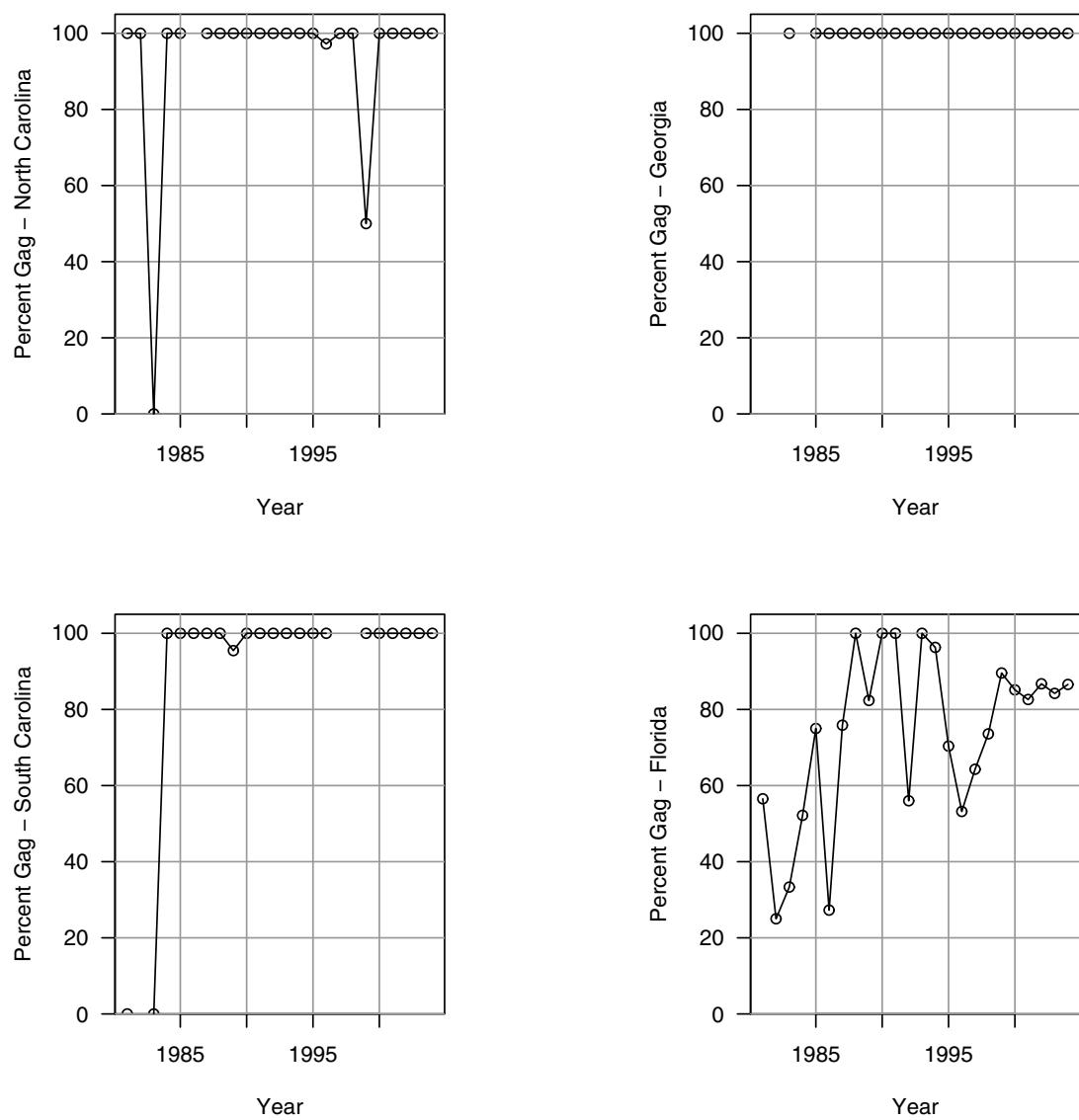


Figure 15. Landings in thousands of fish of gag from the MRFSS by fishing mode.

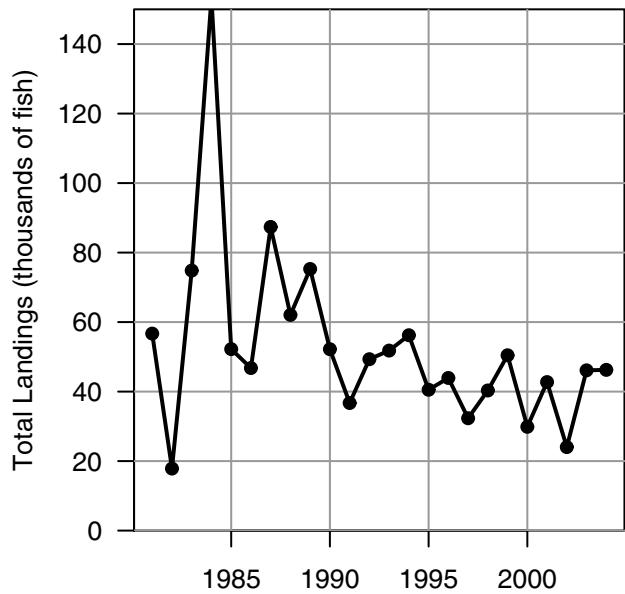
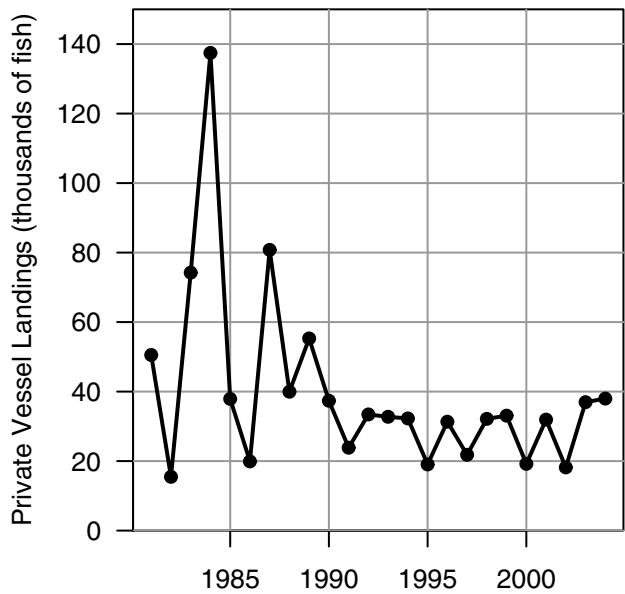
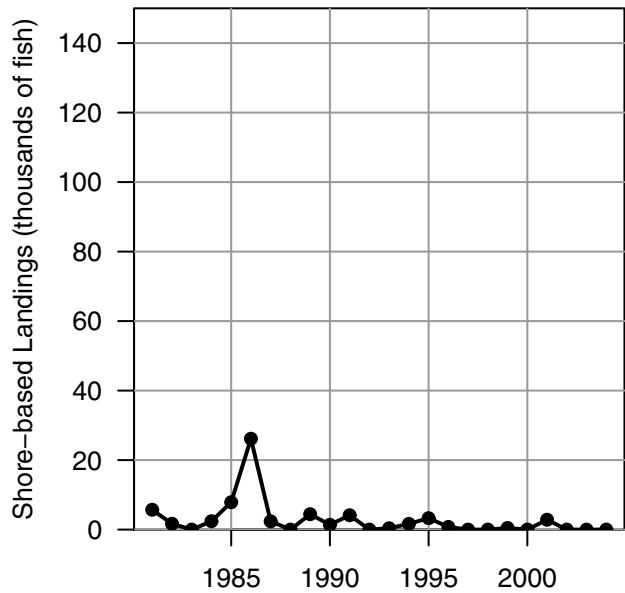
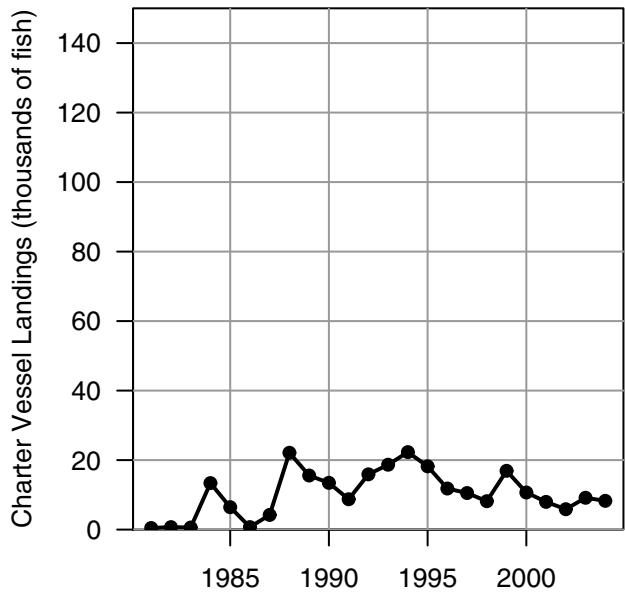


Figure 16. Landings of gag from MRFSS by state in thousands of fish.

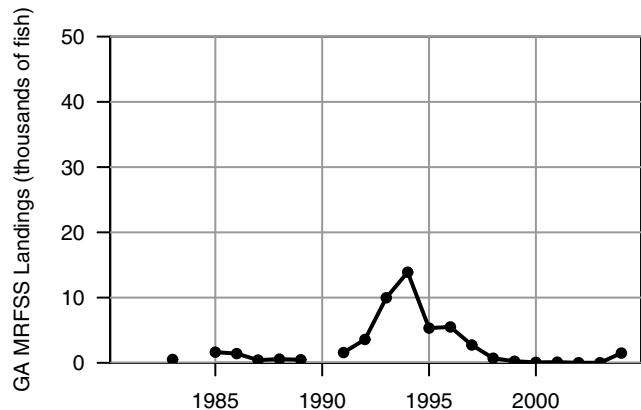
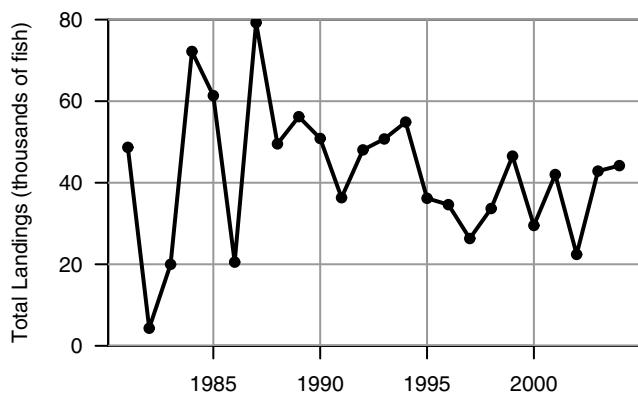
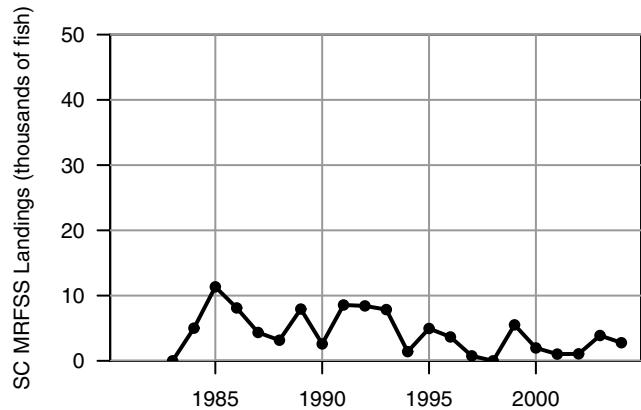
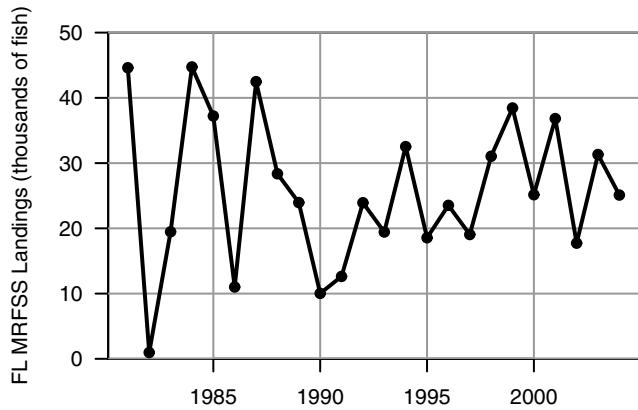
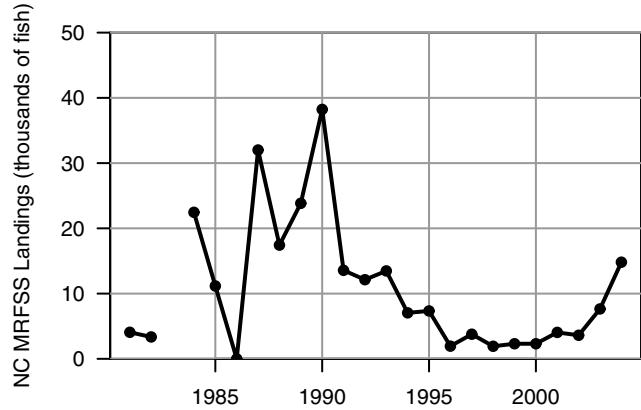


Figure 17. Length composition of gag from the MRFSS for 1981 to 1992. Lengths are in 1 cm bins from 20 cm to 125 cm.

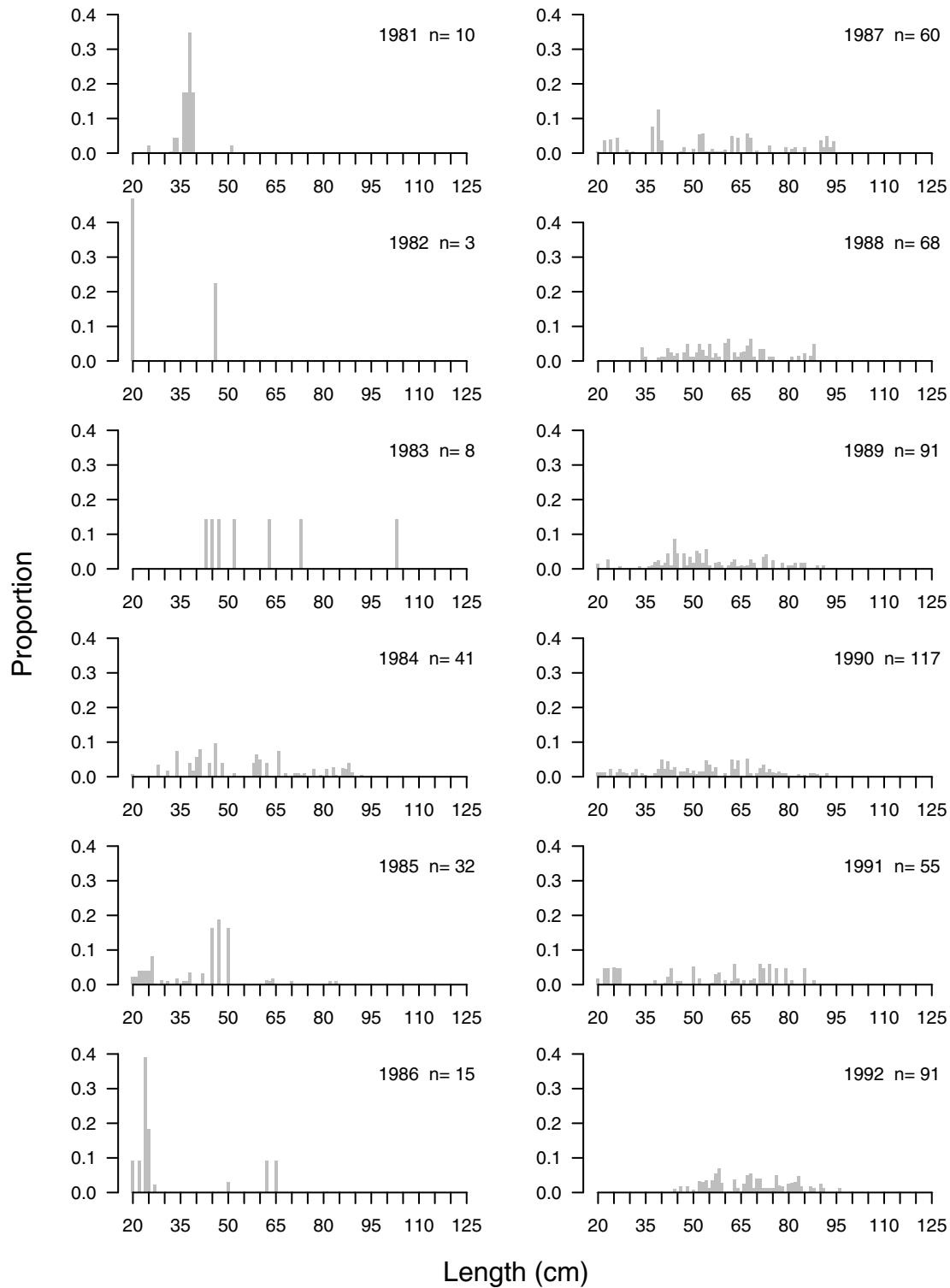
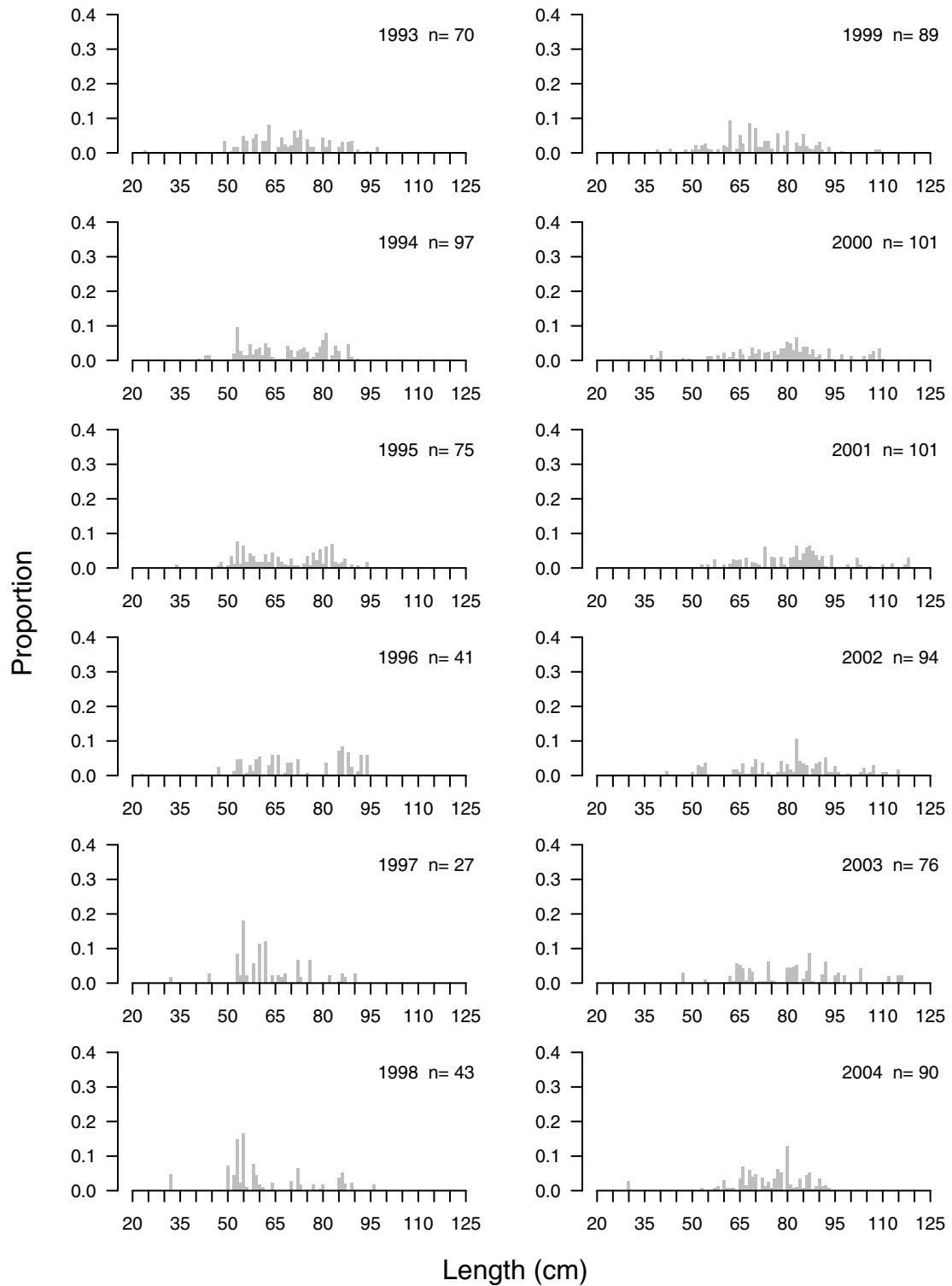


Figure 18. Length composition of gag from the MRFSS for 1993 to 2004. Lengths are in 1 cm bins from 20 cm to 125 cm.



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 Florida trap | Atlantic | 1983-1987 | Number per trap-hr | Nominal | 31 to 73 cm n=10 | Trap avoidance suspected | N |
| | 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 hectare | 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.

Fishery-dependent Indices

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.

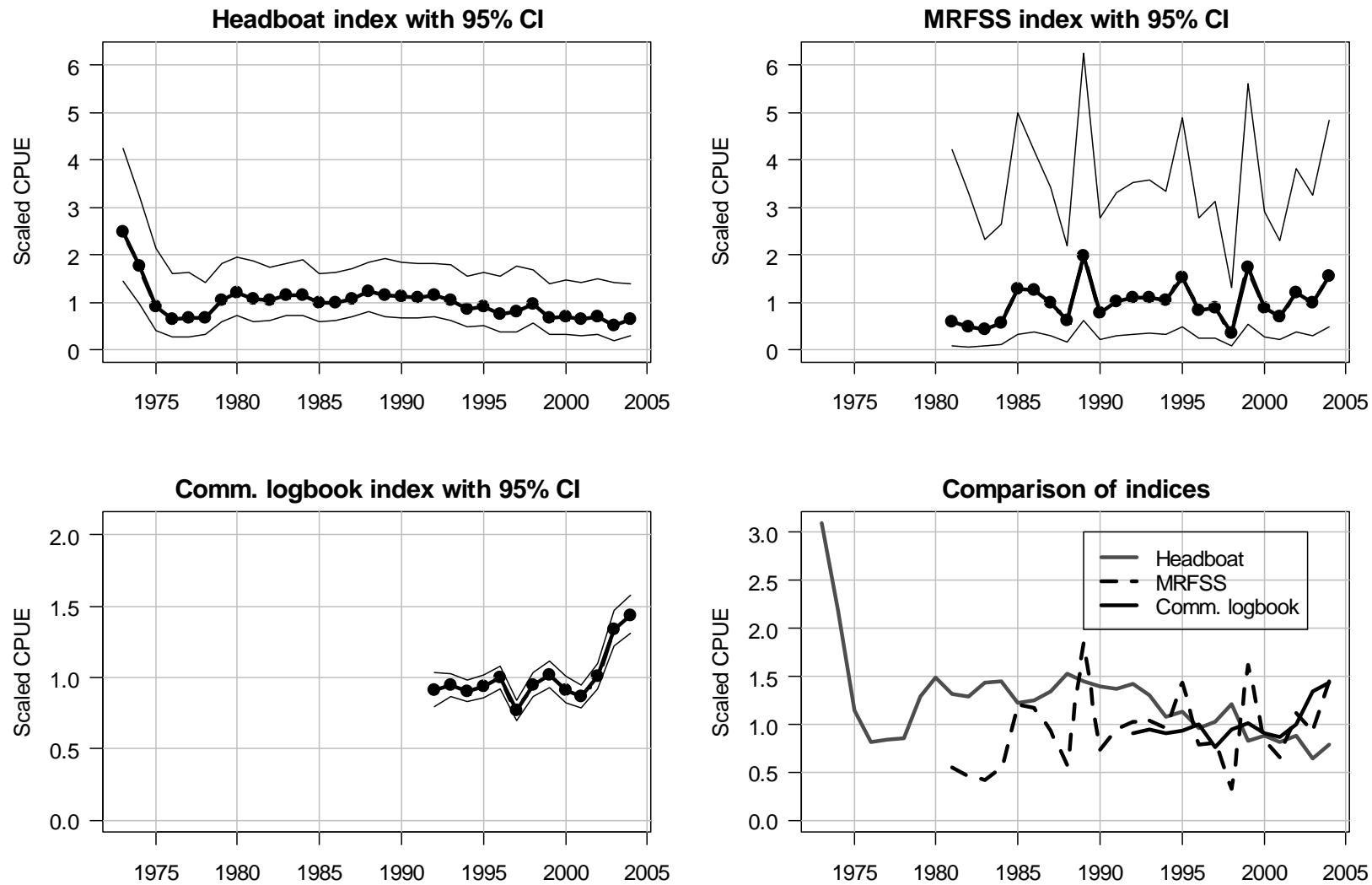
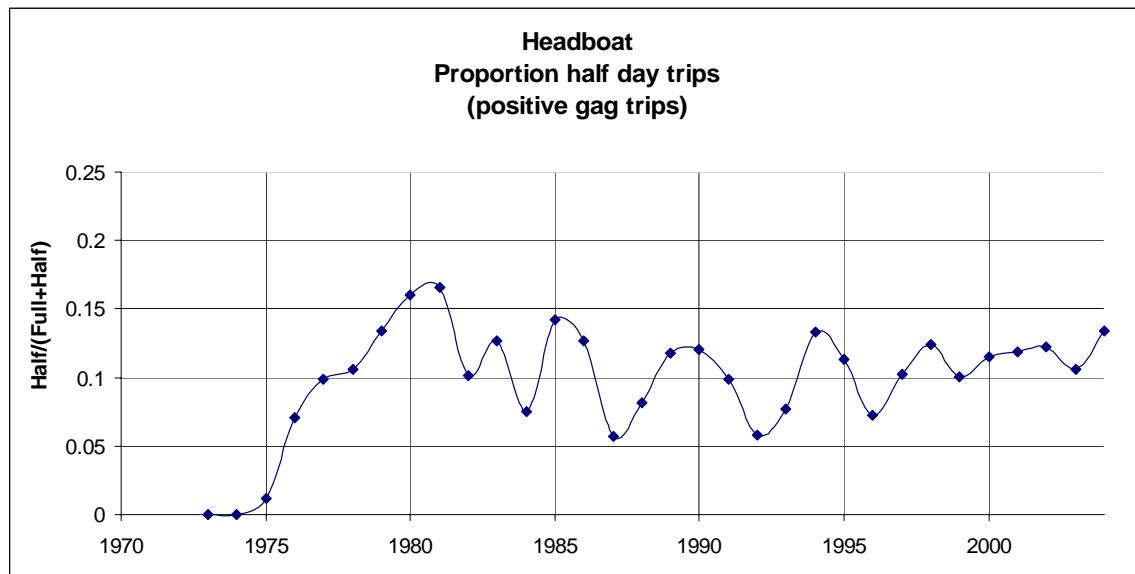


Figure 5.2. Proportion of positive gag headboat trips that are half day trips.



Executive Summary

The stock of gag (*Mycteroperca microlepis*) off the United States South Atlantic was assessed during a SEDAR¹ 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 $(1 - M)SSB_{MSY}$ 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.

¹Abbreviations 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
 $F=F_{current}$, $F=F_{MSY}$, $F=F_{target}(OY)$
 - 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/Univ. 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. Schaaef. |
| 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 84 th 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, <i>Mycteroperca microlepis</i> , 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 |
|---|---|
| Carolinians = 19% | Carolinians = 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.

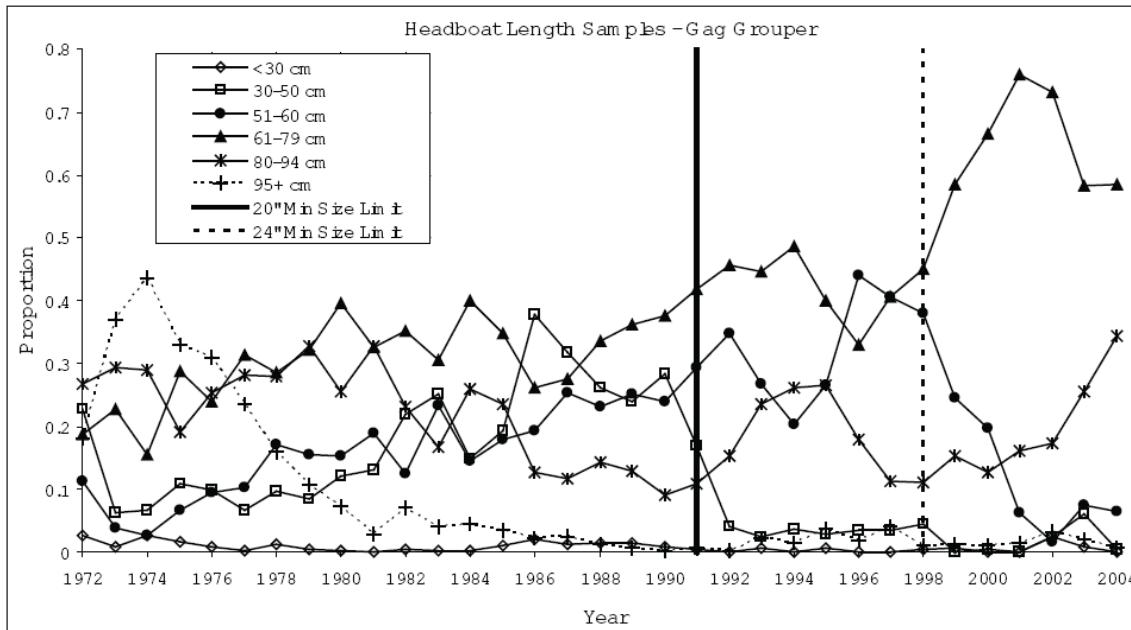


Figure 1.1. Analysis of changes in lengths of gag over time in the headboat survey. From SEDAR 10, 2006, Figure 4-11.

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 ($M = 0.10, 0.15, 0.20, \text{ and } 0.25$). 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.

AW Research Recommendations

- 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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May 2006

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 hermaphrodisim 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 Koenig 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 Heppell 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 compensatory 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 OF COMMERCE
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National Marine Fisheries Service
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November 15, 2006

Robert Mahood
 Executive Director
 South Atlantic Fishery Management Council
 Southpark Building, Suite 306
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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.

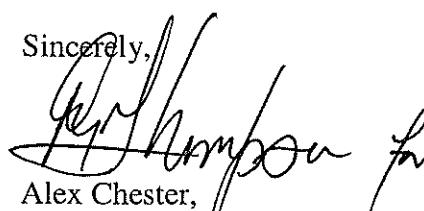
The error occurred with Marine Recreational Fisheries Statistics Survey (MRFSS) landings data (1982-2004), when the assessment scientists were compiling Data Workshop data into a single spreadsheet for model input. The Stock Assessment scientists retrieved “landings + discard” data instead of “landings” 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 SEDAR¹ 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 SSB_{MSY}, 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 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.

¹Abbreviations 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): $W = 3.7996 \times 10^{-8} \cdot TL^{2.943}$.

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 | 0.003 | 0.006 | 0.013 | 0.026 | 0.050 | 0.086 | 0.140 | 0.216 | 0.309 | 0.416 | 0.529 | 0.641 | 0.742 | 0.825 | 0.889 | 0.934 | 0.964 | 0.981 | 0.991 |
| 1984 | 0 | 0.001 | 0.003 | 0.006 | 0.013 | 0.026 | 0.050 | 0.086 | 0.140 | 0.216 | 0.309 | 0.416 | 0.529 | 0.641 | 0.742 | 0.825 | 0.889 | 0.934 | 0.964 | 0.981 | 0.991 |
| 1985 | 0 | 0.001 | 0.003 | 0.006 | 0.013 | 0.026 | 0.050 | 0.086 | 0.140 | 0.216 | 0.309 | 0.416 | 0.529 | 0.641 | 0.742 | 0.825 | 0.889 | 0.934 | 0.964 | 0.981 | 0.991 |
| 1986 | 0 | 0.001 | 0.003 | 0.006 | 0.013 | 0.026 | 0.050 | 0.086 | 0.140 | 0.216 | 0.309 | 0.416 | 0.529 | 0.641 | 0.742 | 0.825 | 0.889 | 0.934 | 0.964 | 0.981 | 0.991 |
| 1987 | 0 | 0.001 | 0.003 | 0.006 | 0.013 | 0.026 | 0.050 | 0.086 | 0.140 | 0.216 | 0.309 | 0.416 | 0.529 | 0.641 | 0.742 | 0.825 | 0.889 | 0.934 | 0.964 | 0.981 | 0.991 |
| 1988 | 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 |
| 1989 | 0 | 0.000 | 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 |
| 1990 | 0 | 0.000 | 0.001 | 0.003 | 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 |
| 1991 | 0 | 0.000 | 0.001 | 0.002 | 0.006 | 0.012 | 0.024 | 0.047 | 0.085 | 0.144 | 0.225 | 0.322 | 0.443 | 0.563 | 0.675 | 0.772 | 0.849 | 0.906 | 0.945 | 0.970 | 0.984 |
| 1992 | 0 | 0.000 | 0.001 | 0.002 | 0.006 | 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 |
| 1993 | 0 | 0.000 | 0.001 | 0.002 | 0.006 | 0.012 | 0.022 | 0.044 | 0.084 | 0.146 | 0.235 | 0.346 | 0.471 | 0.598 | 0.709 | 0.802 | 0.872 | 0.922 | 0.955 | 0.978 | 0.994 |
| 1994 | 0 | 0.000 | 0.001 | 0.002 | 0.006 | 0.013 | 0.023 | 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 |
| 1995 | 0 | 0.000 | 0.001 | 0.002 | 0.006 | 0.013 | 0.024 | 0.042 | 0.082 | 0.149 | 0.244 | 0.365 | 0.499 | 0.730 | 0.832 | 0.896 | 0.938 | 0.965 | 0.991 | 0.996 | 1.000 |
| 1996 | 0 | 0.000 | 0.000 | 0.001 | 0.004 | 0.013 | 0.035 | 0.081 | 0.150 | 0.249 | 0.374 | 0.512 | 0.646 | 0.760 | 0.847 | 0.908 | 0.946 | 0.970 | 0.984 | 0.992 | 1.000 |
| 1997 | 0 | 0.000 | 0.000 | 0.001 | 0.004 | 0.013 | 0.035 | 0.081 | 0.151 | 0.253 | 0.383 | 0.526 | 0.663 | 0.777 | 0.862 | 0.919 | 0.953 | 0.975 | 0.987 | 0.994 | 1.000 |
| 1998 | 0 | 0.000 | 0.000 | 0.001 | 0.004 | 0.013 | 0.036 | 0.085 | 0.174 | 0.265 | 0.393 | 0.540 | 0.680 | 0.794 | 0.877 | 0.931 | 0.963 | 0.980 | 0.995 | 0.998 | 1.000 |
| 1999 | 0 | 0.000 | 0.000 | 0.001 | 0.004 | 0.013 | 0.037 | 0.086 | 0.180 | 0.271 | 0.402 | 0.554 | 0.696 | 0.812 | 0.893 | 0.943 | 0.971 | 0.986 | 0.993 | 0.997 | 1.000 |
| 2000 | 0 | 0.000 | 0.000 | 0.001 | 0.004 | 0.013 | 0.037 | 0.090 | 0.186 | 0.268 | 0.411 | 0.568 | 0.713 | 0.829 | 0.908 | 0.955 | 0.979 | 0.991 | 0.996 | 0.998 | 1.000 |
| 2001 | 0 | 0.000 | 0.000 | 0.001 | 0.004 | 0.013 | 0.038 | 0.093 | 0.192 | 0.337 | 0.511 | 0.582 | 0.730 | 0.846 | 0.923 | 0.966 | 0.987 | 0.996 | 0.999 | 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.

| Year | Commercial (gutted klb) | | Recreational (1000s) | | Coefficient of Variation | | | |
|------|-------------------------|--------|----------------------|--------|--------------------------|--------|----------|-------|
| | 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.

| Year | Indices | | | Coefficient of variation | | |
|------|------------|----------|--------------|--------------------------|----------|--------------|
| | Commercial | | Recreational | Commercial | | Recreational |
| | 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.

| Year | Discards (1000s) | | | Coefficient of variation | | |
|------|------------------|----------|--------------|--------------------------|----------|--------------|
| | Commercial | | Recreational | Commercial | | Recreational |
| | 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 handline¹.

| 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 | 0.002 | 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 | 0.017 | 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 | 0.004 | 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 | 0.001 | 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 | 0.007 | 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 | 0.001 | 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 | 0.005 | 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 | 0.002 | 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 | 0.003 | 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 | 0.004 | 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 | 0.001 | 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 | 0.001 | 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 | 0.033 | 0.022 | 0.016 | 0.016 | 0.016 | 0.013 | 0.007 | 0.005 | 0.003 | 0.001 | 0.000 | 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 | |

¹Includes 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 | 0.000 | 0.000 | 0.005 | 0.003 | 0.043 | 0.048 | 0.021 | 0.140 | | |
| 2000 | 198 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.000 | 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 | 0.000 | 0.000 | 0.000 | 0.012 | 0.038 | 0.031 | 0.038 | 0.063 | | |
| 2003 | 324 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.006 | 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 | 0.000 | 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 | 0.006 | 0.003 | 0.000 | 0.006 | 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 | 0.062 | 0.066 | 0.078 | 0.058 | 0.070 | 0.056 | 0.060 | 0.054 | 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 | 0.001 | 0.006 | 0.014 | 0.026 | 0.081 | 0.062 | 0.068 | 0.090 | 0.074 | 0.059 |
| 1994 | 385 | 0.000 | 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 | 0.059 |
| 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 | 0.005 | 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 | 0.002 | 0.000 | 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 | 0.085 | 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 | 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 | 0.003 | 0.000 | |
| 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 | 0.000 | 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. | | | | | | | | | | | | | | | | |

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 | 0.007 | 0.021 | 0.028 | 0.014 | 0.028 | |
| 1980 | 80 | 0 | 0 | 0.000 | 0.013 | 0.043 | 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 | 0.013 | |
| 1981 | 161 | 0 | 0 | 0.000 | 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 | 0.000 | 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 | |
| 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 | 0.000 | 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 | 0.004 | 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 | 0.001 | |
| 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 | |
| 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 | 0.004 | 0.007 | 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 | 0.000 | 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 | 0.012 | 0.005 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | |
| 2001 | 211 | 0 | 0 | 0.003 | 0.018 | 0.112 | 0.182 | 0.286 | 0.328 | 0.025 | 0.010 | 0.014 | 0.005 | 0.000 | 0.001 | 0.002 | 0.000 | 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 | 0.015 | 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 | 0.001 | |
| 2004 | 552 | 0 | 0 | 0.006 | 0.154 | 0.239 | 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 | 0.001 | |

Table 10. Gag: Age compositions from commercial diving.

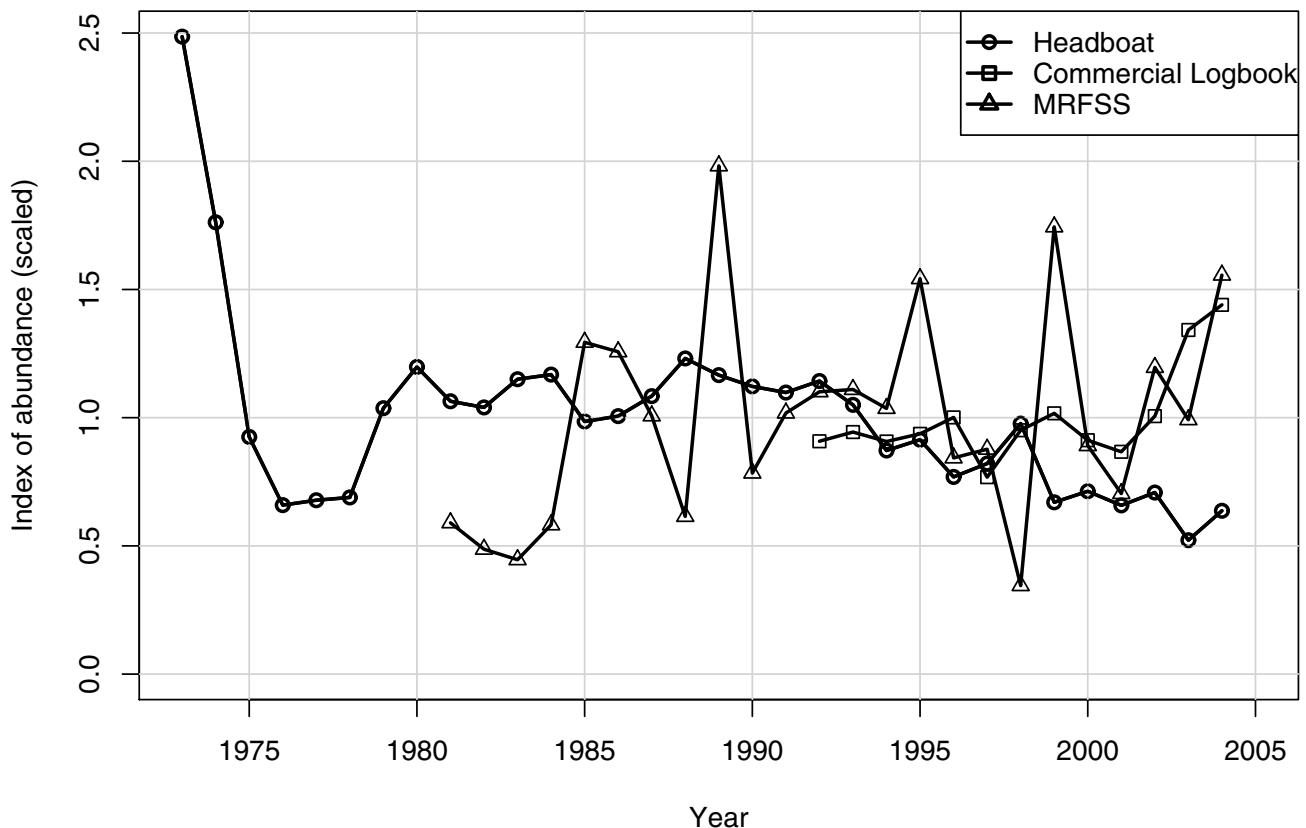
| Year | N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|------|----|---|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|----|----|----|----|----|----|----|----|----|----|
| 1994 | 47 | 0 | 0 | 0.085 | 0.021 | 0.085 | 0.234 | 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 | 0.048 | 0.000 | 0.460 | 0.302 | 0.111 | 0.032 | 0.016 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1997 | 54 | 0 | 0 | 0.019 | 0.019 | 0.056 | 0.093 | 0.537 | 0.093 | 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 | 0.004 | 0.018 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.018 | 0 | 0.000 | 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 | 0.004 | 0.004 | 0.000 | 0 | 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 | 0.005 | 0 | 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 | 0.004 | 0.008 | 0.008 | 0.000 | 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 | 0.005 | 0.005 | 0.000 | 0.003 | 0.001 | 0.005 | 0.000 | 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 | 0.007 | 0.000 | 0 | 0.007 | 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 | 0.033 | 0.006 | 0.006 | 0.008 | 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 | 0.100 | 0.132 | 0.085 | 0.068 | 0.018 | 0.012 | 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 | 0.088 | 0.046 | 0.044 | 0.056 | 0.000 | 0.000 | 0.025 | 0.000 | 0.000 | 0 | 0.000 | 0 | 0.000 |
| 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 | 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 of 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} , SSB_{MSY} , B_{MSY} , and MSY were estimated by the method of Shepherd (1982). In that method, the point of maximum yield is identified from the 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 SSB_{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 (ζ) is computed from the estimated variance (σ^2) of recruitment deviation: $\zeta = \exp(\sigma^2/2)$. Then, equilibrium recruitment (R_{eq}) associated with any F is,

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

where R_0 is virgin recruitment, h is steepness, and Φ_F is spawning potential ratio given growth, maturity, and total mortality at age (including natural, fishing, and discard mortality rates). The R_{eq} and mortality schedule imply an equilibrium age structure and an average sustainable yield (ASY). The estimate of F_{MSY} is the F giving the highest ASY (excluding discards), and the estimate of MSY is that ASY. The estimate of SSB_{MSY} follows from the corresponding equilibrium age structure, as does the estimate of discard mortalities (D_{MSY}), here separated from ASY (and consequently, MSY).

Estimates of MSY and related benchmarks are conditional on selectivity pattern. The selectivity pattern used here was 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 F s 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: $F_{OY} = 65\%F_{MSY}$, $F_{OY} = 75\%F_{MSY}$, and $F_{OY} = 85\%F_{MSY}$. 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 SSB/SSB_{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 $SSB/SSB_{MSY} = 0.91$ and $SSB/SSB_{MSY} = 0.94$ 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 $(1 - M)SSB_{MSY}$ (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,

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

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 ($\check{}$) indicates estimated quantities whose fit to data forms the objective function.

| Quantity | Symbol | Description or definition |
|-----------------------------------|-------------------------|--|
| General Definitions | | |
| Index of years | y | $y = \{1942 \dots 2004\}$ |
| Index of ages | a | $a = \{0 \dots A\}$, where $A = 20^+$ |
| Index of size-limit periods | r | $r = \{1 \dots 3\}$ 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 | $l = \{1 \dots 35\}$ |
| Length bins | l' | $l' = \{200, 230, \dots, 1220\}$, with values as midpoints and bin size of 30 mm |
| Index of fisheries | f | $f = \{1 \dots 4\}$ where 1=commercial handline, 2=commercial diving, 3=recreational headboat, 4=recreational MRFSS |
| Index of CPUE | u | $u = \{1 \dots 3\}$ 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 | $p_{(f,u),l,y}^\lambda$ | Proportional contribution of length bin l in year y to fishery f or index u |
| Observed age compositions | $p_{(f,u),a,y}^\alpha$ | Proportional contribution of age class a in year y to fishery f or index u |
| Length comp. sample sizes | $n_{(f,u),y}^\lambda$ | Number of length samples collected in year y from fishery f or index u |
| Age comp. sample sizes | $n_{(f,u),y}^\alpha$ | 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 | $c_{f,y}^L$ | 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 | $c_{f,y}^D$ | Annual values estimated for MRFSS; for other sectors, assumed to be twice $c_{f,y}^L$ |

Table 12. (continued)

| Quantity | Symbol | Description or definition |
|------------------------------------|-------------------------|---|
| Observed abundance indices | $U_{u,y}$ | $u = 1$, commercial logbook, $y = \{1992 \dots 2004\}$ $u = 2$, MRFSS, $y = \{1981 \dots 2004\}$ $u = 3$, headboat, $y = \{1973 \dots 2004\}$ |
| CVs of abundance indices | $c_{u,y}^U$ | $u = \{1 \dots 3\}$ 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 | $l_a = \widehat{L}_\infty(1 - \exp[-\widehat{K}(a + 0.5 - \widehat{t}_0)])$ where \widehat{K} , \widehat{L}_∞ , and \widehat{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 | \widehat{c}_a^λ | Estimated |
| Age-length conversion | $\psi_{a,l}$ | $\psi_{a,l} = \frac{1}{\sqrt{2\pi}(\widehat{c}_a^\lambda l_a)} \frac{\exp[-(l'_l - l_a)^2]}{(2(\widehat{c}_a^\lambda l_a)^2)}$, 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 | $s_{f,a,r}$ | $s_{f,a,r} = \begin{cases} \frac{1}{1+\exp[-\widehat{\eta}_{1,f,r}(a-\widehat{\alpha}_{1,f,r})]} & : \text{for } f = 1, 3 \\ \left(\frac{1}{\max s_{f,a,r}}\right) \left(\frac{1}{1+\exp[-\widehat{\eta}_{1,f,r}(a-\widehat{\alpha}_{1,f,r})]}\right) & : \text{for } f = 2 \\ s_{3,a,r} & : \text{for } f = 4 \end{cases}$ where $\widehat{\eta}_{1,f,r}$, $\widehat{\eta}_{2,f,r}$, $\widehat{\alpha}_{1,f,r}$, and $\widehat{\alpha}_{2,f,r}$ are fishery-specific parameters estimated for each regulation period, with the exception of the no-size-limit period ($r = 1$) in which $\widehat{\alpha}$ 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 | $F_{f,a,y}$ | $F_{f,a,y} = s_{f,a,y} \widehat{F}_{f,y}$ where $\widehat{F}_{f,y}$ 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 | $F_{f,a,y}^D$ | $F_{f,a,y}^D = s'_{f,a} \widehat{F}_{f,y}^D$ where $\widehat{F}_{f,y}^D$ 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 | $F_y = \sum_f (\hat{F}_{f,y} + \hat{F}_{f,y}^D)$ |
| Total mortality rate | $Z_{a,y}$ | $Z_{a,y} = M_a + \sum_{f=1}^4 F_{f,a,y} + \sum_{f=1,3,4} F_{f,a,y}^D$ |
| Abundance at age | $N_{a,y}$ | $N_{0,1942} = \hat{\gamma} \hat{R}_0$ $N_{a+1,1942} = N_{a,1942} \exp(-Z_{a,1942})$ $N_{A,1942} = N_{A-1,1942} \frac{\exp(-Z_{A-1,1942})}{1 - \exp(-Z_{A,1942})}$ $N_{0,y+1} = \frac{0.8 \hat{R}_0 \hat{h} S_y}{0.2 \phi_0 \hat{R}_0 (1 - \hat{h}) + (\hat{h} - 0.2) S_y} + \hat{R}_{y+1}$ $N_{a+1,y+1} = N_{a,y} \exp(-Z_{a,y})$ $N_{A,y} = N_{A-1,y-1} \frac{\exp(-Z_{A-1,y-1})}{1 - \exp(-Z_{A,y-1})}$ <p>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.</p> |
| Virgin mature biomass per recruit | ϕ_0 | $\phi_0 = \sum_a N'_a w_a [\rho_{a,y} m'_a + (1 - \rho_{a,y}) m_a]$ <p>where $N'_0 = 1$; $N'_{a+1} = N'_a \exp(-M_a)$; $N'_A = N'_{A-1} \frac{\exp(-M_A)}{1 - \exp(-M_A)}$</p> |
| Mature biomass | S_y | $S_y = \sum_a N_{a,y} w_a [\rho_{a,y} m'_a + (1 - \rho_{a,y}) m_a]$ <p>Also referred to as SSB</p> |
| 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 | $C_{f,a,y}^D$ | $C_{f,a,y}^D = \frac{F_{f,a,y}^D}{Z_{a,y}} N_{a,y} [1 - \exp(-Z_{a,y})]$ |
| Predicted landings | $\check{L}_{f,y}$ | $\check{L}_{f,y} = \sum_a C_{f,a,y} w_a$ |
| Predicted dead discards | $\check{D}_{f,y}$ | $\check{D}_{f,y} = \sum_a \delta_f C_{f,a,y}^D w_a$ |
| Predicted length compositions | $\check{p}_{(f,u),l,y}^\lambda$ | $\check{p}_{(f,u),l,y}^\lambda = \frac{C_{(f,u),l,y}}{\sum_l C_{(f,u),l,y}}$ |
| Predicted age compositions | $\check{p}_{(f,u),a,y}^\alpha$ | $\check{p}_{(f,u),a,y}^\alpha = \frac{C_{(f,u),a,y}}{\sum_a C_{(f,u),a,y}}$ |
| Predicted CPUE | $\check{U}_{u,y}$ | $\check{U}_{u,y} = \hat{q}_u \sum_a N_{a,y} s''_{u,a}$ <p>where \hat{q}_u is the estimated catchability coefficient of index u</p> |
| Negative Log-Likelihood | | |
| Multinomial length compositions | Λ_1 | $\Lambda_1 = -\omega_1 \sum_{f,u} \sum_y \left(n_{(f,u),y}^\lambda \sum_l (p_{(f,u),l,y}^\lambda + x) \log(\check{p}_{(f,u),l,y}^\lambda + x) \right)$ <p>where ω_1 is a preset weight and $x = 0.0001$ is an arbitrary value to avoid log zero. Bins are 30mm wide.</p> |
| Multinomial age compositions | Λ_2 | $\Lambda_2 = -\omega_2 \sum_{f,u} \sum_y \left(n_{(f,u),y}^\alpha \sum_a (p_{(f,u),a,y}^\alpha + x) \log(\check{p}_{(f,u),a,y}^\alpha + x) \right)$ <p>where ω_2 is a preset weight and $x = 0.0001$ is an arbitrary value to avoid log zero</p> |

Table 12. (continued)

| Quantity | Symbol | Description or definition |
|--------------------------------------|----------------|--|
| Lognormal landings | Λ_3 | $\Lambda_3 = \omega_3 \sum_f \sum_y \frac{[\log((L_{f,y}+x)/(\check{L}_{f,y}+x))]^2}{2(c_{f,y}^L)^2}$ 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 | $\Lambda_4 = \omega_4 \sum_f \sum_y \frac{[\log((\delta_f D_{f,y}+x)/(\check{D}_{f,y}+x))]^2}{2(c_{f,y}^D)^2}$ 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 | $\Lambda_5 = \sum_u \omega_{5,u} \sum_y \frac{[\log((U_{u,y}+x)/(\check{U}_{u,y}+x))]^2}{2(c_{u,y}^U)^2}$ 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_7 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} | $\Lambda_{10} = \omega_{10} \sum_a (c_a^\lambda)^2$ 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 | 0.027 | 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 | 0.018 | 0.022 | 0.025 | 0.025 | 0.025 | 0.023 | 0.023 | 0.023 | 0.023 | 0.023 | 0.023 | 0.023 | 0.023 | 0.023 | 0.024 | |
| 1964 | 0.000 | 0.002 | 0.013 | 0.013 | 0.014 | 0.014 | 0.016 | 0.020 | 0.024 | 0.027 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | |
| 1965 | 0.000 | 0.002 | 0.014 | 0.014 | 0.014 | 0.013 | 0.016 | 0.021 | 0.021 | 0.021 | 0.021 | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 | |
| 1966 | 0.000 | 0.001 | 0.011 | 0.012 | 0.012 | 0.013 | 0.016 | 0.021 | 0.021 | 0.021 | 0.021 | 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 | 0.026 | 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 | |
| 1968 | 0.000 | 0.005 | 0.042 | 0.043 | 0.043 | 0.047 | 0.057 | 0.066 | 0.071 | 0.072 | 0.071 | 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 | 0.028 | 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 | |
| 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 | |
| 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 | |
| 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 | |
| 1973 | 0.000 | 0.004 | 0.026 | 0.026 | 0.028 | 0.033 | 0.046 | 0.064 | 0.066 | 0.065 | 0.065 | 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 | |
| 1975 | 0.000 | 0.001 | 0.028 | 0.031 | 0.039 | 0.056 | 0.074 | 0.084 | 0.084 | 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 | |
| 1977 | 0.000 | 0.000 | 0.008 | 0.047 | 0.058 | 0.084 | 0.109 | 0.121 | 0.123 | 0.123 | 0.123 | 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 | |
| 1979 | 0.000 | 0.005 | 0.058 | 0.063 | 0.082 | 0.126 | 0.169 | 0.190 | 0.195 | 0.195 | 0.192 | 0.191 | 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 | 0.193 | 0.190 | 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 | |
| 1982 | 0.000 | 0.007 | 0.044 | 0.052 | 0.081 | 0.151 | 0.221 | 0.254 | 0.262 | 0.262 | 0.257 | 0.254 | 0.254 | 0.254 | 0.254 | 0.254 | 0.254 | 0.254 | 0.254 | 0.254 | |
| 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 | |
| 1984 | 0.001 | 0.038 | 0.278 | 0.298 | 0.358 | 0.455 | 0.519 | 0.544 | 0.549 | 0.543 | 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 | |
| 1986 | 0.006 | 0.050 | 0.058 | 0.063 | 0.082 | 0.126 | 0.169 | 0.190 | 0.195 | 0.195 | 0.192 | 0.191 | 0.190 | 0.190 | 0.190 | 0.190 | 0.190 | 0.190 | 0.190 | 0.190 | |
| 1987 | 0.001 | 0.058 | 0.177 | 0.193 | 0.248 | 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 | |
| 1988 | 0.001 | 0.074 | 0.123 | 0.133 | 0.180 | 0.234 | 0.343 | 0.386 | 0.428 | 0.428 | 0.428 | 0.428 | 0.428 | 0.428 | 0.428 | 0.428 | 0.428 | 0.428 | 0.428 | 0.428 | |
| 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 | |
| 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 | |
| 1991 | 0.002 | 0.011 | 0.095 | 0.117 | 0.188 | 0.316 | 0.426 | 0.489 | 0.505 | 0.505 | 0.453 | 0.424 | 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 | 0.515 | 0.458 | 0.426 | 0.419 | 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 | 0.488 | 0.426 | 0.426 | 0.426 | 0.426 | 0.426 | 0.426 | 0.426 | 0.426 | 0.426 | 0.426 | |
| 1994 | 0.006 | 0.025 | 0.123 | 0.202 | 0.251 | 0.360 | 0.447 | 0.505 | 0.509 | 0.509 | 0.426 | 0.436 | 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 | 0.483 | 0.486 | 0.486 | 0.421 | 0.426 | 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 | 0.510 | 0.431 | 0.434 | 0.427 | 0.426 | 0.425 | 0.425 | 0.425 | 0.425 | 0.425 | 0.425 | |
| 1997 | 0.006 | 0.023 | 0.088 | 0.140 | 0.188 | 0.235 | 0.377 | 0.432 | 0.436 | 0.436 | 0.392 | 0.367 | 0.360 | 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 | 0.545 | 0.462 | 0.415 | 0.404 | 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 | 0.552 | 0.473 | 0.429 | 0.417 | 0.416 | 0.416 | 0.416 | 0.416 | 0.416 | 0.416 | 0.416 | |
| 2000 | 0.009 | 0.036 | 0.080 | 0.122 | 0.213 | 0.317 | 0.368 | 0.407 | 0.407 | 0.407 | 0.329 | 0.309 | 0.304 | 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 | 0.407 | 0.349 | 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 | 0.323 | 0.284 | 0.262 | 0.257 | 0.256 | 0.256 | 0.256 | 0.256 | 0.256 | 0.256 | 0.256 | |
| 2003 | 0.009 | 0.033 | 0.078 | 0.119 | 0.275 | 0.328 | 0.377 | 0.378 | 0.378 | 0.378 | 0.324 | 0.294 | 0.287 | 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 | 0.341 | 0.309 | 0.291 | 0.286 | 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 | |
| 1963 | 0.001 | 0.003 | 0.010 | 0.014 | 0.017 | 0.020 | 0.024 | 0.029 | 0.030 | 0.031 | 0.029 | 0.028 | 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 | |
| 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 | |
| 1966 | 0.001 | 0.003 | 0.008 | 0.012 | 0.014 | 0.017 | 0.021 | 0.026 | 0.026 | 0.023 | 0.023 | 0.023 | 0.022 | 0.022 | 0.022 | 0.022 | 0.022 | 0.022 | 0.022 | 0.022 | |
| 1967 | 0.001 | 0.007 | 0.010 | 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 | |
| 1968 | 0.002 | 0.008 | 0.011 | 0.014 | 0.017 | 0.021 | 0.026 | 0.031 | 0.032 | 0.033 | 0.032 | 0.032 | 0.032 | 0.032 | 0.032 | 0.032 | 0.032 | 0.032 | 0.032 | 0.032 | |
| 1969 | 0.002 | 0.008 | 0.012 | 0.016 | 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 | |
| 1970 | 0.002 | 0.011 | 0.016 | 0.022 | 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 | |
| 1971 | 0.003 | 0.012 | 0.023 | 0.033 | 0.040 | 0.050 | 0.058 | 0.067 | 0.080 | 0.092 | 0.095 | 0.094 | 0.094 | 0.094 | 0.094 | 0.094 | 0.094 | 0.094 | 0.094 | 0.094 | |
| 1972 | 0.002 | 0.009 | 0.023 | 0.033 | 0.043 | 0.050 | 0.057 | 0.065 | 0.070 | 0.072 | 0.072 | 0.070 | 0.070 | 0.070 | 0.070 | 0.070 | 0.070 | 0.070 | 0.070 | 0.070 | |
| 1973 | 0.003 | 0.023 | 0.033 | 0.043 | 0.052 | 0.060 | 0.068 | 0.075 | 0.083 | 0.091 | 0.091 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 | |
| 1974 | 0.012 | 0.023 | 0.031 | 0.036 | 0.049 | 0.068 | 0.084 | 0.094 | 0.107 | 0.114 | 0.121 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | |
| 1975 | 0.001 | 0.004 | 0.014 | 0.017 | 0.038 | 0.054 | 0.071 | 0.094 | 0.114 | 0.134 | 0.154 | 0.174 | 0.186 | 0.189 | 0.190 | 0.191 | 0.191 | 0.191 | 0.191 | 0.191 | |
| 1976 | 0.000 | 0.001 | 0.006 | 0.024 | 0.066 | 0.109 | 0.146 | 0.174 | 0.208 | 0.230 | 0.256 | 0.280 | 0.299 | 0.309 | 0.316 | 0.321 | 0.326 | 0.331 | 0.336 | 0.341 | |
| 1977 | 0.000 | 0.001 | 0.005 | 0.020 | 0.060 | 0.110 | 0.156 | 0.191 | 0.206 | 0.218 | 0.230 | 0.249 | 0.260 | 0.270 | 0.279 | 0.288 | 0.297 | 0.306 | 0.315 | 0.324 | |
| 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 | |
| 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 | |
| 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 | |
| 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 | |
| 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 | |
| 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 | |
| 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 | |
| 1985 | 0.011 | 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 | |
| 1986 | 0.012 | 0.048 | 0.118 | 0.190 | 0.259 | 0.309 | 0.344 | 0.421 | 0.500 | 0.584 | 0.639 | 0.650 | 0.655 | 0.655 | 0.655 | 0.655 | 0.655 | 0.655 | 0.655 | 0.655 | |
| 1987 | 0.015 | 0.061 | 0.140 | 0.190 | 0.234 | 0.323 | 0.463 | 0.584 | 0.639 | 0.650 | 0.655 | 0.655 | 0.655 | 0.655 | 0.655 | 0.655 | 0.655 | 0.655 | 0.655 | 0.655 | |
| 1988 | 0.017 | 0.060 | 0.109 | 0.142 | 0.181 | 0.287 | 0.487 | 0.701 | 0.829 | 0.883 | 0.903 | 0.909 | 0.912 | 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 | |
| 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 | |
| 1991 | 0.005 | 0.022 | 0.061 | 0.100 | 0.150 | 0.257 | 0.421 | 0.568 | 0.606 | 0.578 | 0.636 | 0.644 | 0.654 | 0.654 | 0.654 | 0.654 | 0.654 | 0.654 | 0.654 | 0.654 | |
| 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 | |
| 1993 | 0.003 | 0.011 | 0.074 | 0.143 | 0.211 | 0.318 | 0.389 | 0.431 | 0.424 | 0.389 | 0.375 | 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 | |
| 1995 | 0.006 | 0.022 | 0.098 | 0.169 | 0.222 | 0.318 | 0.384 | 0.422 | 0.416 | 0.384 | 0.372 | 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 | 0.367 | 0.367 | 0.367 | 0.367 | 0.367 | 0.367 | 0.367 | 0.367 | |
| 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 | |
| 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 | 0.329 | 0.329 | 0.329 | 0.329 | 0.329 | 0.329 | 0.329 | |
| 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 | 0.346 | 0.346 | 0.346 | 0.346 | 0.346 | 0.346 | 0.346 | 0.346 | |
| 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 | |
| 2001 | 0.003 | 0.014 | 0.039 | 0.089 | 0.179 | 0.260 | 0.324 | 0.316 | 0.285 | 0.274 | 0.242 | 0.212 | 0.201 | 0.199 | 0.198 | 0.198 | 0.198 | 0.198 | 0.198 | 0.198 | |
| 2002 | 0.005 | 0.018 | 0.043 | 0.073 | 0.130 | 0.192 | 0.224 | 0.250 | 0.242 | 0.212 | 0.192 | 0.171 | 0.151 | 0.131 | 0.111 | 0.091 | 0.071 | 0.051 | 0.031 | 0.011 | |
| 2003 | 0.007 | 0.029 | 0.064 | 0.098 | 0.156 | 0.220 | 0.258 | 0.293 | 0.282 | 0.241 | 0.225 | 0.201 | 0.179 | 0.151 | 0.121 | 0.091 | 0.061 | 0.031 | 0.011 | 0.001 | |
| 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 | |

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 | 136.3 | 104.7 | 89.4 | 76.5 | 65.8 | 57.1 | 49.6 | 43.1 | 37.5 | 32.8 | 28.7 | 23.8 | 20.9 | 19.2 | 17.9 | 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 | 54.4 | 42.3 | 37.0 | 32.4 | 28.2 | 24.7 | 21.7 | 19.0 | 16.6 | 14.5 | 12.7 | 103.5 | |
| 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 | 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 | 456.1 | 268.4 | 146.5 | 155.7 | 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 | 209.0 | 160.0 | 93.6 | 37.2 | 27.9 | 29.7 | 28.1 | 47.2 | 40.0 | 32.1 | 28.2 | 21.5 | 19.0 | 16.7 | 12.9 | 11.3 | 10.7 | 86.5 | |
| 1971 | 853.8 | 216.2 | 171.7 | 123.9 | 115.8 | 45.4 | 36.3 | 34.3 | 34.4 | 39.0 | 33.1 | 26.6 | 23.4 | 20.4 | 17.9 | 13.9 | 12.2 | 10.7 | 81.5 | 76.5 | |
| 1972 | 317.1 | 539.0 | 164.1 | 129.4 | 76.8 | 30.5 | 22.8 | 24.3 | 23.0 | 28.3 | 22.0 | 19.3 | 16.7 | 14.9 | 13.1 | 11.6 | 10.2 | 9.8 | 9.8 | 73.6 | |
| 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 | 69.8 |
| 1974 | 245.4 | 174.0 | 149.0 | 117.8 | 111.2 | 89.0 | 52.8 | 15.7 | 16.8 | 16.1 | 19.9 | 22.6 | 19.3 | 15.5 | 13.7 | 12.8 | 11.3 | 9.9 | 8.7 | 65.5 | |
| 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 | 18.6 | 15.9 | 13.1 | 10.5 | 9.3 |
| 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 | 113.7 | 116.0 | 77.6 | 173.8 | 56.7 | 58.1 | 46.1 | 27.4 | 11.0 | 8.3 | 8.6 | 10.7 | 12.2 | 10.4 | 8.4 | 7.4 | 6.6 | 49.3 | |
| 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 | 41.2 |
| 1979 | 361.9 | 370.5 | 277.3 | 78.3 | 71.4 | 71.3 | 54.6 | 52.5 | 33.0 | 33.0 | 26.4 | 6.3 | 4.8 | 5.2 | 6.2 | 7.1 | 6.0 | 5.2 | 4.6 | 3.8 | 34.9 |
| 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 | 52.4 | 17.8 | 14.3 | 9.7 | 8.5 | 3.4 | 2.6 | 2.7 | 2.7 | 29.5 |
| 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 | 173.3 | 92.7 | 61.5 | 10.4 | 13.9 | 13.9 | 11.6 | 11.1 | 7.1 | 15.6 | 5.1 | 5.3 | 4.3 | 2.6 | 1.0 | 0.8 | 0.5 | 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 | 532.2 | 370.8 | 264.3 | 41.8 | 122.8 | 41.4 | 27.7 | 26.6 | 15.7 | 2.5 | 3.4 | 2.8 | 2.7 | 1.7 | 3.8 | 1.3 | 0.6 | 0.7 | 0.6 | 3.3 | 3.4 |
| 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 | 184.8 | 125.9 | 40.1 | 18.5 | 41.9 | 13.4 | 8.9 | 8.7 | 5.2 | 8.8 | 2.2 | 1.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| 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 | 0.3 | 0.4 | 0.4 | 0.3 | 0.2 | 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 | 111.4 | 86.6 | 54.1 | 27.5 | 5.9 | 2.0 | 3.5 | 1.0 | 0.7 | 0.4 | 0.4 | 0.2 | 0.0 | 0.1 | 0.1 | 0.1 | 0.3 |
| 1992 | 228.1 | 148.0 | 387.9 | 264.1 | 111.6 | 79.6 | 54.7 | 30.8 | 14.5 | 3.2 | 1.1 | 2.0 | 0.6 | 0.4 | 0.4 | 0.2 | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 |
| 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 | 0.1 | 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 | 0.0 | 0.0 | 0.0 | 0.1 |
| 1995 | 500.5 | 355.6 | 219.7 | 57.3 | 140.2 | 79.6 | 45.5 | 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 | 0.1 |
| 1996 | 389.2 | 314.1 | 265.0 | 160.7 | 54.5 | 38.8 | 23.7 | 37.2 | 48.1 | 23.7 | 7.6 | 4.4 | 2.9 | 1.6 | 0.8 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 |
| 1997 | 315.2 | 244.9 | 236.5 | 197.4 | 114.5 | 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 |
| 1998 | 559.4 | 197.8 | 182.6 | 144.1 | 81.2 | 99.4 | 50.0 | 13.3 | 7.2 | 14.0 | 6.8 | 4.4 | 2.3 | 1.6 | 0.6 | 0.3 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 |
| 1999 | 498.8 | 352.1 | 149.1 | 137.0 | 127.4 | 84.0 | 57.9 | 10.1 | 2.2 | 2.7 | 1.5 | 0.6 | 0.4 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2000 | 526.4 | 313.3 | 262.7 | 191.7 | 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 |
| 2001 | 702.3 | 320.6 | 197.1 | 141.8 | 247.4 | 179.1 | 148.8 | 44.9 | 33.1 | 21.2 | 9.7 | 2.5 | 1.5 | 3.2 | 1.8 | 0.6 | 0.4 | 0.3 | 0.1 | 0.0 | 0.0 |
| 2002 | 280.9 | 441.8 | 247.4 | 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 | 0.0 |
| 2003 | 203.3 | 265.4 | 127.3 | 129.9 | 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 |
| 2004 | 265.4 | 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 |
| 2005 | 343.2 | | | | | | | | | | | | | | | | | | | | |

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 | 155.6 | 113.6 | 126.1 | 100.5 | 78.1 | 66.8 | 57.5 | 49.5 | 43.2 | 37.5 | 32.7 | 28.2 | 24.8 | 21.6 | 18.9 | 16.4 | 14.3 | 12.5 | 10.9 |
| 1964 | 138.6 | 95.8 | 151.3 | 113.6 | 126.1 | 100.5 | 78.1 | 66.4 | 56.6 | 49.0 | 42.8 | 37.2 | 32.4 | 28.2 | 24.6 | 21.5 | 18.7 | 16.3 | 14.3 | 12.4 | 10.8 |
| 1965 | 99.8 | 87.4 | 72.8 | 91.5 | 104.4 | 58.6 | 75.6 | 87.7 | 71.7 | 56.4 | 48.4 | 41.8 | 36.8 | 31.7 | 27.7 | 24.2 | 21.1 | 18.5 | 16.3 | 14.3 | 12.4 |
| 1966 | 99.9 | 62.9 | 66.4 | 58.6 | 75.6 | 87.7 | 71.7 | 56.4 | 48.2 | 41.6 | 36.1 | 31.5 | 27.5 | 24.1 | 21.0 | 18.4 | 16.1 | 14.1 | 12.3 | 10.8 | 88.5 |
| 1967 | 203.0 | 63.0 | 47.9 | 53.6 | 48.6 | 63.8 | 74.7 | 61.3 | 48.2 | 40.3 | 34.9 | 30.4 | 26.6 | 23.3 | 20.3 | 17.8 | 15.6 | 13.6 | 11.6 | 10.4 | 80.9 |
| 1968 | 263.6 | 128.0 | 47.7 | 38.2 | 43.7 | 40.2 | 53.2 | 62.3 | 51.0 | 41.4 | 32.8 | 28.5 | 24.9 | 21.8 | 19.1 | 16.7 | 14.6 | 12.8 | 11.2 | 9.8 | 75.1 |
| 1969 | 245.7 | 166.0 | 96.5 | 37.6 | 30.6 | 35.4 | 32.8 | 43.2 | 50.4 | 41.4 | 34.5 | 27.4 | 23.9 | 20.9 | 19.5 | 17.0 | 14.9 | 13.1 | 11.5 | 10.1 | 8.8 |
| 1970 | 173.1 | 154.9 | 125.6 | 76.7 | 50.5 | 25.2 | 27.1 | 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 |
| 1971 | 265.7 | 109.0 | 116.8 | 99.0 | 61.4 | 24.7 | 20.5 | 23.8 | 21.9 | 23.2 | 23.2 | 22.6 | 18.1 | 15.8 | 12.1 | 10.6 | 9.3 | 8.2 | 60.9 | | |
| 1972 | 270.9 | 167.3 | 82.2 | 79.0 | 49.6 | 20.0 | 16.5 | 17.5 | 19.0 | 17.5 | 17.5 | 17.5 | 15.0 | 13.4 | 11.5 | 10.1 | 8.8 | 8.2 | 7.8 | 57.4 | |
| 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 | 13.4 | 11.5 | 10.1 | 8.8 | 7.8 | 54.3 |
| 1974 | 464.6 | 494.7 | 122.3 | 53.3 | 61.7 | 53.9 | 44.0 | 27.3 | 10.9 | 9.0 | 10.4 | 9.7 | 12.9 | 15.3 | 12.7 | 10.1 | 9.5 | 8.4 | 7.4 | 7.8 | 50.3 |
| 1975 | 411.3 | 289.9 | 368.7 | 100.6 | 81.8 | 44.0 | 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 |
| 1976 | 206.2 | 239.5 | 230.2 | 294.8 | 81.3 | 66.3 | 51.5 | 26.8 | 29.8 | 25.2 | 6.2 | 5.2 | 6.0 | 5.6 | 7.5 | 8.9 | 7.5 | 5.9 | 5.2 | 37.8 | |
| 1977 | 575.9 | 130.1 | 197.7 | 177.9 | 241.7 | 65.1 | 194.6 | 50.5 | 38.4 | 19.4 | 21.4 | 18.1 | 11.2 | 4.5 | 3.7 | 4.0 | 5.4 | 6.4 | 5.3 | 4.3 | 31.1 |
| 1978 | 560.5 | 363.4 | 99.1 | 153.9 | 146.4 | 146.4 | 143.8 | 12.5 | 25.3 | 13.8 | 11.7 | 7.2 | 2.4 | 2.6 | 3.4 | 4.2 | 3.5 | 3.5 | 3.0 | | |
| 1979 | 415.5 | 276.6 | 261.9 | 129.8 | 114.9 | 100.9 | 86.0 | 102.3 | 23.8 | 16.9 | 8.3 | 9.2 | 7.8 | 4.9 | 1.9 | 1.6 | 1.8 | 2.3 | 2.8 | | |
| 1980 | 356.5 | 261.9 | 267.6 | 281.8 | 62.8 | 100.9 | 86.0 | 102.3 | 23.8 | 16.9 | 8.3 | 9.2 | 7.8 | 4.9 | 1.9 | 1.6 | 1.8 | 2.3 | 2.8 | | |
| 1981 | 840.1 | 224.5 | 197.4 | 210.1 | 172.6 | 100.5 | 128.6 | 77.4 | 62.7 | 16.3 | 12.9 | 11.9 | 15.9 | 18.8 | 15.6 | 12.7 | 10.1 | 9.5 | 8.4 | 7.4 | |
| 1982 | 223.4 | 52.5 | 167.2 | 150.0 | 157.5 | 128.6 | 35.7 | 52.4 | 44.9 | 10.2 | 7.2 | 10.2 | 7.2 | 3.6 | 4.0 | 3.4 | 2.1 | 0.8 | 0.7 | 0.8 | 9.9 |
| 1983 | 260.7 | 140.8 | 369.2 | 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 | 162.7 | 110.7 | 93.9 | 83.2 | 82.7 | 62.2 | 15.8 | 21.7 | 16.4 | 18.2 | 1.5 | 1.5 | 1.6 | 1.4 | 0.7 | 0.8 | 0.6 | 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 | 136.3 | 41.2 | 31.3 | 24.3 | 14.6 | 3.3 | 4.4 | 4.4 | 3.3 | 3.6 | 3.3 | 3.0 | 0.3 | 0.3 | 0.3 | 0.2 | 1.1 |
| 1987 | 553.0 | 307.9 | 265.8 | 166.9 | 60.9 | 34.6 | 87.7 | 52.5 | 19.5 | 15.1 | 9.1 | 2.1 | 2.8 | 2.1 | 2.3 | 1.3 | 1.1 | 1.2 | 1.2 | 1.6 | |
| 1988 | 460.3 | 344.0 | 220.3 | 187.9 | 136.7 | 41.3 | 47.6 | 42.6 | 9.1 | 7.0 | 4.2 | 5.7 | 6.3 | 5.4 | 3.3 | 1.3 | 1.1 | 1.3 | 1.2 | 1.6 | |
| 1989 | 842.7 | 285.7 | 247.1 | 160.5 | 138.6 | 101.5 | 29.8 | 14.2 | 5.1 | 5.1 | 7.8 | 1.6 | 1.0 | 0.7 | 0.4 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | |
| 1990 | 850.5 | 52.3 | 204.6 | 175.1 | 112.5 | 94.5 | 61.7 | 32.1 | 6.2 | 2.1 | 3.1 | 0.6 | 0.4 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | |
| 1991 | 254.7 | 52.5 | 385.7 | 152.5 | 128.9 | 79.5 | 53.3 | 34.1 | 16.0 | 3.0 | 1.0 | 0.6 | 0.2 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | |
| 1992 | 232.6 | 160.0 | 397.5 | 255.2 | 115.8 | 94.9 | 59.3 | 30.9 | 18.8 | 8.9 | 1.6 | 0.6 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| 1993 | 486.9 | 146.5 | 120.7 | 301.4 | 216.0 | 120.7 | 149.7 | 50.6 | 35.1 | 17.6 | 10.8 | 5.4 | 1.1 | 0.4 | 0.6 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | |
| 1994 | 617.7 | 306.5 | 110.4 | 91.1 | 219.2 | 63.3 | 47.6 | 29.6 | 19.7 | 10.0 | 6.4 | 3.2 | 0.7 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | |
| 1995 | 548.6 | 387.6 | 228.3 | 80.4 | 187.9 | 136.7 | 101.5 | 29.8 | 14.2 | 5.1 | 5.1 | 3.5 | 3.6 | 0.7 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | |
| 1996 | 417.9 | 344.4 | 289.2 | 168.2 | 57.0 | 43.4 | 93.0 | 55.3 | 37.5 | 24.8 | 21.6 | 18.9 | 16.4 | 14.3 | 12.5 | 10.9 | 9.0 | 8.0 | 7.0 | 6.0 | |
| 1997 | 341.4 | 262.9 | 259.4 | 217.6 | 121.8 | 39.5 | 27.4 | 21.3 | 17.3 | 13.5 | 9.8 | 6.9 | 3.7 | 2.4 | 1.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | |
| 1998 | 617.5 | 214.4 | 196.4 | 105.2 | 160.8 | 87.6 | 26.4 | 17.3 | 13.5 | 9.3 | 6.3 | 4.5 | 2.4 | 1.6 | 0.8 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | |
| 1999 | 575.5 | 368.8 | 161.7 | 149.1 | 143.7 | 113.5 | 56.5 | 15.7 | 9.7 | 19.1 | 11.9 | 4.0 | 2.9 | 1.6 | 0.5 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | |
| 2000 | 612.1 | 361.5 | 290.8 | 124.0 | 112.0 | 70.1 | 33.0 | 8.7 | 5.5 | 11.6 | 7.4 | 2.5 | 1.8 | 1.0 | 0.6 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | |
| 2001 | 853.1 | 383.3 | 267.4 | 202.5 | 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 | 0.1 | 0.1 | |
| 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 | 0.5 | 0.3 | 0.2 | 0.1 | 0.1 | |
| 2003 | 214.7 | 344.4 | 289.2 | 168.2 | 121.8 | 48.2 | 37.7 | 20.5 | 9.9 | 2.8 | 4.0 | 2.6 | 1.8 | 0.9 | 0.5 | 0.3 | 0.2 | 0.1 | 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 | 0.8 | 0.6 | 0.4 | 0.2 | 0.1 | 0.1 | |
| 2005 | 344.0 | 169.3 | 99.9 | 115.1 | 234.1 | 125.6 | 83.8 | 60.9 | 22.0 | 13.9 | 10.2 | 5.0 | 1.4 | 0.9 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | |

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 | 235 | 643 | 881 | 974 | 1072 | 1089 | 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 | 1077 | 1141 | 1062 | 1009 | 940 | 869 | 793 | 716 | 640 | 571 | 507 | 449 | 396 | 349 | 307 | 2517 | 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 | 853 | 775 | 704 | 633 | 565 | 501 | 444 | 393 | 345 | 308 | 2419 | 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 | 359 | 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 | 619 | 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 | 447 | 373 | 348 | 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 | 439 | 512 | 445 | 393 | 324 | 287 | 253 | 225 | 1691 | |
| 1975 | 56 | 272 | 680 | 2456 | 1052 | 1312 | 1189 | 705 | 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 | 864 | 235 | 183 | 203 | 198 | 249 | 288 | 248 | 201 | 173 | 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 | 110 | 146 | 999 |
| 1980 | 76 | 338 | 1044 | 1375 | 381 | 740 | 784 | 861 | 597 | 1394 | 480 | 428 | 323 | 263 | 108 | 83 | 91 | 88 | 110 | 126 | 845 |
| 1981 | 169 | 324 | 641 | 1573 | 389 | 1521 | 1526 | 1362 | 1545 | 396 | 487 | 496 | 331 | 757 | 256 | 323 | 197 | 81 | 62 | 67 | 718 |
| 1982 | 49 | 718 | 609 | 815 | 1521 | 1526 | 1336 | 532 | 1545 | 268 | 399 | 356 | 358 | 237 | 538 | 181 | 192 | 156 | 95 | 42 | 544 |
| 1983 | 61 | 210 | 1367 | 824 | 936 | 1079 | 878 | 1275 | 1088 | 187 | 271 | 239 | 187 | 238 | 156 | 353 | 118 | 125 | 101 | 61 | 25 |
| 1984 | 125 | 259 | 389 | 1682 | 863 | 1079 | 1038 | 950 | 758 | 756 | 566 | 103 | 147 | 129 | 83 | 187 | 62 | 66 | 53 | 32 | 13 |
| 1985 | 128 | 532 | 467 | 417 | 1510 | 664 | 1510 | 448 | 1473 | 545 | 305 | 52 | 72 | 63 | 40 | 89 | 30 | 31 | 25 | 15 | 157 |
| 1986 | 121 | 548 | 982 | 587 | 1785 | 1785 | 1785 | 1007 | 831 | 454 | 300 | 294 | 148 | 36 | 14 | 26 | 8 | 16 | 5 | 3 | 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 | 1172 | 481 | 205 | 686 | 243 | 174 | 179 | 111 | 19 | 26 | 22 | 21 | 14 | 21 | 14 | 11 | 11 | 41 |
| 1989 | 168 | 433 | 828 | 1160 | 1264 | 1130 | 414 | 187 | 378 | 116 | 50 | 8 | 11 | 10 | 9 | 3 | 3 | 2 | 5 | 10 | 23 |
| 1990 | 178 | 715 | 768 | 889 | 1168 | 1097 | 763 | 203 | 75 | 142 | 43 | 29 | 15 | 9 | 1 | 2 | 2 | 1 | 1 | 1 | 7 |
| 1991 | 51 | 760 | 1327 | 966 | 1040 | 1038 | 777 | 445 | 107 | 38 | 72 | 22 | 15 | 9 | 5 | 1 | 1 | 1 | 1 | 1 | 5 |
| 1992 | 50 | 219 | 1441 | 1707 | 1038 | 950 | 785 | 506 | 262 | 61 | 23 | 44 | 13 | 9 | 5 | 1 | 1 | 1 | 1 | 0 | 1 |
| 1993 | 103 | 212 | 415 | 1888 | 1785 | 922 | 700 | 503 | 294 | 148 | 36 | 14 | 26 | 8 | 16 | 5 | 3 | 3 | 2 | 0 | 2 |
| 1994 | 124 | 437 | 402 | 541 | 1961 | 1580 | 681 | 454 | 300 | 171 | 89 | 22 | 8 | 16 | 5 | 3 | 2 | 2 | 1 | 1 | 3 |
| 1995 | 109 | 526 | 816 | 503 | 534 | 1035 | 507 | 466 | 1235 | 742 | 260 | 155 | 102 | 61 | 32 | 8 | 3 | 6 | 2 | 1 | 0 |
| 1996 | 85 | 464 | 984 | 1035 | 507 | 466 | 1235 | 742 | 260 | 155 | 148 | 433 | 91 | 61 | 36 | 19 | 5 | 2 | 3 | 1 | 1 |
| 1997 | 69 | 362 | 879 | 1276 | 1066 | 445 | 341 | 789 | 233 | 495 | 265 | 93 | 58 | 39 | 23 | 12 | 3 | 2 | 1 | 1 | 1 |
| 1998 | 122 | 292 | 678 | 1138 | 1341 | 973 | 345 | 134 | 719 | 219 | 131 | 272 | 156 | 57 | 36 | 24 | 14 | 7 | 2 | 1 | 1 |
| 1999 | 109 | 521 | 554 | 886 | 1186 | 1192 | 942 | 1007 | 831 | 444 | 122 | 72 | 159 | 94 | 34 | 21 | 14 | 8 | 10 | 6 | 1 |
| 2000 | 115 | 463 | 976 | 739 | 854 | 1157 | 1385 | 704 | 645 | 542 | 383 | 188 | 80 | 48 | 108 | 64 | 23 | 14 | 9 | 6 | 1 |
| 2001 | 154 | 487 | 857 | 1274 | 791 | 854 | 1385 | 1307 | 574 | 483 | 380 | 263 | 132 | 37 | 22 | 49 | 29 | 10 | 6 | 4 | 2 |
| 2002 | 61 | 653 | 919 | 1157 | 1283 | 1307 | 1385 | 1307 | 574 | 483 | 380 | 247 | 178 | 91 | 25 | 34 | 20 | 7 | 4 | 3 | 2 |
| 2003 | 44 | 261 | 1224 | 1234 | 1324 | 1169 | 1031 | 412 | 320 | 247 | 172 | 1207 | 927 | 753 | 284 | 216 | 169 | 123 | 63 | 5 | 2 |
| 2004 | 58 | 188 | 483 | 1602 | 1324 | 1169 | 1031 | 412 | 320 | 247 | 172 | 1207 | 927 | 753 | 284 | 216 | 169 | 123 | 63 | 5 | 2 |
| 2005 | 75 | 246 | 349 | 1721 | 1721 | 1721 | 1721 | 1721 | 1721 | 1721 | 1721 | 1721 | 1721 | 1721 | 1721 | 1721 | 1721 | 1721 | 1721 | 1721 | 1721 |

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 | 936 | 913 | 874 | 825 | 776 | 715 | 653 | 591 | 532 | 476 | 424 | 377 | 333 |
| 1964 | 98 | 195 | 450 | 792 | 885 | 929 | 936 | 922 | 904 | 865 | 817 | 762 | 703 | 643 | 587 | 529 | 474 | 422 | 375 | 332 | 2916 |
| 1965 | 71 | 178 | 289 | 919 | 963 | 999 | 997 | 918 | 894 | 855 | 807 | 753 | 696 | 636 | 577 | 521 | 468 | 417 | 374 | 331 | 2824 |
| 1966 | 71 | 128 | 263 | 368 | 666 | 999 | 997 | 918 | 894 | 855 | 807 | 753 | 696 | 636 | 577 | 521 | 468 | 417 | 371 | 329 | 2746 |
| 1967 | 144 | 128 | 190 | 336 | 428 | 726 | 1038 | 997 | 980 | 850 | 803 | 749 | 692 | 633 | 576 | 519 | 466 | 417 | 371 | 329 | 2623 |
| 1968 | 187 | 361 | 189 | 240 | 385 | 748 | 1039 | 1014 | 942 | 824 | 776 | 724 | 668 | 612 | 556 | 503 | 452 | 404 | 360 | 320 | 2508 |
| 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 | 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 | 597 | 522 | 466 | 421 | 379 | 340 | 303 | 270 | 2053 | | |
| 1972 | 192 | 341 | 325 | 577 | 696 | 565 | 696 | 565 | 565 | 565 | 558 | 515 | 569 | 475 | 431 | 389 | 351 | 314 | 281 | 1889 | |
| 1973 | 569 | 348 | 501 | 409 | 654 | 737 | 568 | 268 | 249 | 319 | 321 | 455 | 568 | 493 | 409 | 369 | 332 | 298 | 266 | 237 | |
| 1974 | 330 | 1009 | 504 | 631 | 720 | 501 | 707 | 716 | 503 | 222 | 199 | 284 | 284 | 250 | 227 | 199 | 244 | 339 | 417 | 283 | 1685 |
| 1975 | 292 | 591 | 1461 | 632 | 1852 | 716 | 755 | 493 | 638 | 435 | 189 | 167 | 206 | 201 | 278 | 339 | 290 | 235 | 209 | 1560 | |
| 1976 | 146 | 529 | 872 | 1055 | 1055 | 1118 | 2127 | 741 | 716 | 530 | 516 | 346 | 148 | 130 | 158 | 153 | 211 | 237 | 211 | 188 | |
| 1977 | 409 | 265 | 783 | 1005 | 1290 | 2216 | 702 | 626 | 358 | 437 | 402 | 266 | 113 | 98 | 119 | 114 | 156 | 190 | 161 | 131 | |
| 1978 | 398 | 741 | 393 | 1096 | 502 | 1143 | 1302 | 1999 | 1999 | 1999 | 1999 | 1999 | 1999 | 1999 | 1999 | 1999 | 1999 | 1999 | 1999 | 1999 | |
| 1979 | 295 | 721 | 1096 | 1370 | 554 | 1149 | 1196 | 1665 | 439 | 345 | 185 | 219 | 196 | 127 | 53 | 45 | 55 | 52 | 71 | 85 | 550 |
| 1980 | 253 | 534 | 1060 | 1370 | 554 | 1149 | 1196 | 1665 | 1665 | 1665 | 1665 | 1665 | 1665 | 1665 | 1665 | 1665 | 1665 | 1665 | 1665 | 1665 | 1665 |
| 1981 | 596 | 458 | 782 | 1319 | 1521 | 1521 | 1021 | 1319 | 1319 | 1319 | 1319 | 1319 | 1319 | 1319 | 1319 | 1319 | 1319 | 1319 | 1319 | 1319 | 1319 |
| 1982 | 159 | 1076 | 663 | 942 | 1387 | 1464 | 1464 | 853 | 744 | 919 | 227 | 172 | 90 | 104 | 141 | 91 | 32 | 38 | 37 | 50 | 439 |
| 1983 | 185 | 387 | 1581 | 832 | 1055 | 1418 | 1354 | 1012 | 643 | 643 | 644 | 157 | 118 | 61 | 70 | 92 | 24 | 21 | 25 | 23 | 308 |
| 1984 | 420 | 332 | 406 | 1813 | 827 | 1143 | 1149 | 1012 | 291 | 444 | 363 | 433 | 104 | 78 | 40 | 46 | 40 | 25 | 16 | 16 | 215 |
| 1985 | 414 | 476 | 444 | 1614 | 646 | 650 | 688 | 547 | 150 | 224 | 181 | 213 | 51 | 38 | 19 | 22 | 19 | 12 | 5 | 146 | |
| 1986 | 350 | 744 | 1079 | 1522 | 1552 | 1552 | 1552 | 510 | 448 | 298 | 73 | 104 | 82 | 96 | 23 | 17 | 8 | 10 | 8 | 5 | 73 |
| 1987 | 393 | 626 | 1053 | 1237 | 536 | 395 | 1205 | 420 | 360 | 309 | 203 | 49 | 70 | 54 | 63 | 15 | 11 | 5 | 6 | 5 | 24 |
| 1988 | 327 | 707 | 873 | 1180 | 1205 | 470 | 775 | 775 | 233 | 185 | 155 | 100 | 24 | 34 | 26 | 30 | 7 | 5 | 3 | 3 | 14 |
| 1989 | 508 | 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 | 10 | 8 | 5 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| 1992 | 165 | 326 | 1575 | 1854 | 1020 | 1081 | 741 | 525 | 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 | 1 | 1 |
| 1994 | 439 | 625 | 438 | 572 | 1931 | 1704 | 704 | 572 | 326 | 222 | 119 | 26 | 10 | 15 | 3 | 2 | 2 | 1 | 1 | 1 | 1 |
| 1995 | 389 | 791 | 904 | 505 | 558 | 1682 | 1292 | 482 | 482 | 205 | 143 | 77 | 17 | 6 | 10 | 2 | 1 | 1 | 0 | 1 | 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 | 1 | 1 |
| 1998 | 438 | 437 | 778 | 1226 | 1416 | 998 | 366 | 282 | 618 | 395 | 140 | 107 | 61 | 42 | 22 | 5 | 2 | 3 | 1 | 1 | 1 |
| 1999 | 409 | 793 | 641 | 937 | 1266 | 1292 | 786 | 256 | 179 | 391 | 264 | 95 | 72 | 41 | 28 | 15 | 3 | 2 | 0 | 1 | 1 |
| 2000 | 435 | 737 | 1152 | 784 | 987 | 1116 | 922 | 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 | 5 | 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 | 38 | 38 | 13 | 10 | 6 | 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 | 426 | 518 | 527 | 482 | 426 | 394 | 360 | 325 | 290 | 259 | 230 | 204 | 180 | 158 | 139 | 142 | 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 | 515 | 515 | 450 | 421 | 387 | 352 | 319 | 287 | 256 | 227 | 202 | 178 | 157 | 138 | 1097 | |
| 1968 | 42 | 120 | 149 | 226 | 274 | 401 | 514 | 476 | 408 | 376 | 342 | 308 | 276 | 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 | 395 | 202 | 182 | 221 | 230 | 255 | 343 | 417 | 373 | 311 | 282 | 253 | 226 | 202 | 180 | 159 | 140 | 124 |
| 1971 | 85 | 145 | 352 | 469 | 418 | 199 | 169 | 199 | 203 | 180 | 304 | 363 | 321 | 266 | 240 | 214 | 190 | 170 | 151 | 133 | 117 | 895 |
| 1972 | 31 | 361 | 277 | 481 | 546 | 189 | 199 | 169 | 199 | 159 | 274 | 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 | 372 | 138 | 157 | 156 | 199 | 232 | 202 | 165 | 147 | 130 | 115 | 102 | 767 | |
| 1975 | 26 | 124 | 308 | 345 | 1114 | 595 | 540 | 352 | 151 | 120 | 134 | 133 | 168 | 195 | 169 | 138 | 122 | 108 | 95 | 719 | | |
| 1976 | 14 | 169 | 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 | 115 | 293 | 385 | 509 | 403 | 1012 | 361 | 399 | 336 | 209 | 87 | 67 | 74 | 72 | 90 | 104 | 89 | 73 | 542 | | |
| 1979 | 36 | 248 | 467 | 152 | 388 | 336 | 391 | 810 | 282 | 308 | 256 | 158 | 65 | 50 | 55 | 53 | 67 | 66 | 57 | 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 | 313 | 212 | 178 | 488 | 166 | 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 | 160 | 54 | 57 | 46 | 28 | 11 | 9 | 128 | | |
| 1985 | 58 | 241 | 212 | 189 | 685 | 301 | 262 | 343 | 257 | 47 | 67 | 58 | 38 | 38 | 85 | 28 | 30 | 24 | 15 | 6 | 71 | |
| 1986 | 55 | 249 | 445 | 266 | 203 | 668 | 270 | 218 | 138 | 23 | 33 | 28 | 18 | 41 | 13 | 14 | 11 | 7 | 37 | 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 | 6 | 14 | 5 | 5 | 19 | | |
| 1989 | 76 | 197 | 376 | 526 | 573 | 512 | 188 | 85 | 171 | 53 | 34 | 36 | 37 | 23 | 4 | 4 | 3 | 1 | 0 | 0 | 10 | |
| 1990 | 81 | 324 | 449 | 530 | 498 | 346 | 92 | 202 | 49 | 33 | 17 | 30 | 13 | 13 | 8 | 1 | 2 | 2 | 1 | 2 | 4 | |
| 1991 | 23 | 345 | 602 | 438 | 472 | 471 | 353 | 202 | 49 | 30 | 10 | 20 | 6 | 4 | 4 | 2 | 0 | 1 | 0 | 0 | 3 | |
| 1992 | 23 | 99 | 654 | 774 | 471 | 431 | 356 | 229 | 119 | 28 | 10 | 12 | 4 | 2 | 0 | 1 | 0 | 0 | 0 | 2 | | |
| 1993 | 47 | 96 | 188 | 856 | 810 | 418 | 318 | 228 | 133 | 67 | 16 | 6 | 12 | 4 | 2 | 2 | 0 | 1 | 0 | 0 | | |
| 1994 | 56 | 198 | 182 | 245 | 889 | 716 | 309 | 206 | 136 | 78 | 40 | 10 | 4 | 7 | 2 | 1 | 1 | 0 | 0 | 1 | | |
| 1995 | 50 | 238 | 370 | 228 | 242 | 762 | 519 | 197 | 120 | 78 | 46 | 24 | 6 | 2 | 4 | 1 | 1 | 0 | 0 | 1 | | |
| 1996 | 39 | 211 | 447 | 469 | 230 | 211 | 560 | 337 | 118 | 70 | 46 | 28 | 14 | 4 | 1 | 3 | 1 | 0 | 0 | 0 | | |
| 1997 | 31 | 164 | 399 | 579 | 484 | 202 | 154 | 358 | 196 | 67 | 41 | 28 | 16 | 9 | 2 | 1 | 1 | 0 | 0 | 0 | | |
| 1998 | 55 | 133 | 308 | 516 | 608 | 441 | 156 | 106 | 225 | 120 | 42 | 27 | 18 | 10 | 5 | 1 | 1 | 0 | 0 | 0 | | |
| 1999 | 49 | 236 | 251 | 402 | 538 | 541 | 326 | 99 | 59 | 124 | 71 | 26 | 16 | 11 | 6 | 3 | 1 | 0 | 0 | 0 | | |
| 2000 | 52 | 210 | 443 | 335 | 427 | 535 | 387 | 377 | 201 | 55 | 32 | 135 | 36 | 22 | 49 | 29 | 10 | 6 | 4 | 3 | | |
| 2001 | 70 | 221 | 389 | 578 | 359 | 359 | 357 | 270 | 135 | 85 | 246 | 24 | 14 | 32 | 19 | 7 | 4 | 3 | 2 | 1 | | |
| 2002 | 28 | 296 | 417 | 525 | 628 | 319 | 293 | 261 | 219 | 172 | 119 | 60 | 17 | 10 | 22 | 13 | 5 | 3 | 2 | 1 | | |
| 2003 | 20 | 118 | 556 | 560 | 582 | 593 | 468 | 187 | 145 | 112 | 81 | 41 | 12 | 7 | 15 | 9 | 3 | 2 | 1 | 1 | | |
| 2004 | 26 | 85 | 219 | 727 | 601 | 530 | 420 | 342 | 129 | 98 | 77 | 56 | 28 | 8 | 5 | 10 | 6 | 2 | 1 | 1 | | |
| 2005 | 34 | 111 | 158 | 287 | 781 | 548 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | | |

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 | 425 | 406 | 383 | 356 | 328 | 299 | 271 | 243 | 218 | 194 | 172 | 152 | 1373 | |
| 1963 | 49 | 138 | 281 | 346 | 401 | 426 | 426 | 424 | 414 | 397 | 374 | 349 | 322 | 294 | 268 | 241 | 216 | 192 | 171 | 151 | |
| 1964 | 45 | 89 | 204 | 359 | 401 | 403 | 421 | 418 | 417 | 393 | 371 | 346 | 325 | 291 | 264 | 238 | 214 | 192 | 170 | 151 | |
| 1965 | 32 | 81 | 131 | 261 | 317 | 437 | 437 | 418 | 410 | 405 | 388 | 366 | 342 | 316 | 289 | 262 | 236 | 212 | 189 | 168 | |
| 1966 | 32 | 58 | 119 | 167 | 302 | 453 | 452 | 416 | 405 | 388 | 366 | 342 | 316 | 289 | 262 | 236 | 212 | 189 | 168 | 149 | |
| 1967 | 63 | 58 | 86 | 153 | 194 | 329 | 471 | 452 | 404 | 386 | 364 | 340 | 314 | 287 | 261 | 235 | 211 | 189 | 168 | 149 | |
| 1968 | 85 | 118 | 86 | 109 | 175 | 208 | 335 | 460 | 427 | 374 | 352 | 328 | 303 | 278 | 252 | 228 | 205 | 183 | 163 | 145 | |
| 1969 | 79 | 154 | 173 | 107 | 122 | 183 | 207 | 319 | 422 | 384 | 331 | 308 | 284 | 260 | 237 | 214 | 192 | 172 | 154 | 136 | |
| 1970 | 56 | 143 | 226 | 219 | 282 | 245 | 128 | 129 | 176 | 183 | 267 | 341 | 302 | 254 | 232 | 211 | 191 | 172 | 154 | 136 | |
| 1971 | 86 | 101 | 210 | 210 | 256 | 262 | 316 | 126 | 126 | 159 | 162 | 234 | 294 | 258 | 216 | 195 | 177 | 159 | 143 | 122 | |
| 1972 | 87 | 155 | 148 | 155 | 148 | 227 | 186 | 297 | 334 | 258 | 121 | 113 | 145 | 145 | 206 | 258 | 224 | 186 | 167 | 143 | |
| 1973 | 258 | 158 | 227 | 186 | 297 | 319 | 340 | 250 | 113 | 103 | 130 | 129 | 181 | 224 | 193 | 159 | 128 | 115 | 102 | 808 | |
| 1974 | 150 | 458 | 229 | 286 | 213 | 327 | 321 | 325 | 227 | 328 | 101 | 90 | 112 | 110 | 154 | 189 | 162 | 133 | 119 | 106 | |
| 1975 | 132 | 268 | 663 | 287 | 327 | 342 | 224 | 298 | 289 | 197 | 86 | 76 | 76 | 93 | 91 | 126 | 154 | 131 | 108 | 95 | |
| 1976 | 66 | 240 | 396 | 840 | 325 | 342 | 250 | 198 | 250 | 234 | 157 | 67 | 59 | 72 | 69 | 96 | 116 | 99 | 81 | 635 | |
| 1977 | 185 | 120 | 355 | 507 | 965 | 336 | 325 | 250 | 100.5 | 319 | 284 | 162 | 198 | 182 | 121 | 51 | 44 | 34 | 32 | 532 | |
| 1978 | 180 | 336 | 178 | 456 | 585 | 100.5 | 319 | 284 | 162 | 198 | 182 | 121 | 51 | 44 | 34 | 30 | 36 | 35 | 30 | 437 | |
| 1979 | 134 | 327 | 497 | 228 | 518 | 591 | 907 | 259 | 212 | 116 | 139 | 126 | 83 | 83 | 35 | 30 | 36 | 35 | 47 | 48 | |
| 1980 | 115 | 242 | 481 | 622 | 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 | 508 | 508 | 151 | 117 | 62 | 72 | 64 | 41 | 17 | 15 | 17 | 199 | |
| 1982 | 72 | 488 | 301 | 427 | 629 | 664 | 225 | 387 | 338 | 417 | 103 | 78 | 41 | 47 | 42 | 27 | 11 | 9 | 11 | 140 | |
| 1983 | 84 | 130 | 717 | 378 | 478 | 643 | 614 | 186 | 202 | 242 | 292 | 71 | 53 | 28 | 32 | 28 | 18 | 7 | 6 | 98 | |
| 1984 | 191 | 151 | 184 | 823 | 375 | 430 | 521 | 459 | 132 | 132 | 196 | 457 | 35 | 18 | 21 | 18 | 11 | 5 | 4 | 66 | |
| 1985 | 188 | 342 | 212 | 201 | 732 | 293 | 255 | 312 | 248 | 68 | 102 | 82 | 97 | 23 | 17 | 9 | 10 | 9 | 5 | 33 | |
| 1986 | 159 | 338 | 490 | 250 | 210 | 704 | 260 | 231 | 203 | 135 | 33 | 47 | 37 | 43 | 10 | 8 | 4 | 4 | 2 | 15 | |
| 1987 | 178 | 284 | 478 | 561 | 243 | 179 | 546 | 190 | 163 | 140 | 92 | 22 | 32 | 25 | 28 | 7 | 5 | 2 | 3 | 11 | |
| 1988 | 148 | 318 | 396 | 535 | 535 | 213 | 137 | 352 | 106 | 84 | 70 | 45 | 11 | 15 | 12 | 14 | 3 | 2 | 1 | 6 | |
| 1989 | 271 | 444 | 457 | 554 | 524 | 188 | 105 | 224 | 188 | 215 | 51 | 35 | 28 | 17 | 4 | 6 | 4 | 5 | 1 | 3 | |
| 1990 | 274 | 484 | 368 | 499 | 449 | 488 | 389 | 105 | 43 | 72 | 16 | 11 | 8 | 5 | 1 | 2 | 1 | 1 | 0 | 1 | |
| 1991 | 82 | 493 | 693 | 434 | 515 | 411 | 375 | 237 | 52 | 19 | 32 | 7 | 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 | |
| 1993 | 157 | 136 | 217 | 859 | 863 | 415 | 374 | 228 | 157 | 83 | 18 | 7 | 11 | 2 | 1 | 0 | 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 | |
| 1995 | 177 | 359 | 410 | 229 | 253 | 763 | 586 | 218 | 165 | 93 | 65 | 35 | 7 | 3 | 4 | 2 | 3 | 1 | 0 | 0 | |
| 1996 | 134 | 319 | 520 | 479 | 228 | 224 | 587 | 408 | 143 | 106 | 61 | 42 | 23 | 5 | 2 | 3 | 1 | 1 | 0 | 0 | |
| 1997 | 110 | 243 | 466 | 620 | 487 | 204 | 173 | 406 | 262 | 91 | 69 | 40 | 28 | 15 | 3 | 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 | |
| 1999 | 185 | 360 | 291 | 425 | 574 | 586 | 356 | 116 | 81 | 178 | 120 | 43 | 33 | 19 | 13 | 7 | 1 | 1 | 0 | 0 | |
| 2000 | 197 | 334 | 522 | 356 | 448 | 506 | 442 | 244 | 73 | 51 | 117 | 80 | 29 | 22 | 12 | 8 | 4 | 1 | 0 | 0 | |
| 2001 | 275 | 355 | 480 | 628 | 377 | 418 | 422 | 345 | 181 | 54 | 38 | 87 | 59 | 21 | 16 | 9 | 6 | 3 | 1 | 0 | |
| 2002 | 104 | 497 | 518 | 595 | 677 | 348 | 321 | 248 | 129 | 39 | 27 | 62 | 42 | 15 | 11 | 6 | 4 | 2 | 1 | 0 | |
| 2003 | 69 | 188 | 723 | 640 | 652 | 658 | 304 | 279 | 249 | 190 | 100 | 30 | 21 | 47 | 32 | 11 | 8 | 5 | 3 | 2 | |
| 2004 | 87 | 124 | 270 | 874 | 683 | 616 | 558 | 240 | 207 | 183 | 144 | 76 | 23 | 16 | 35 | 23 | 8 | 6 | 3 | 2 | |
| 2005 | 111 | 157 | 180 | 328 | 935 | 649 | 528 | 450 | 184* | 157 | 140 | 110 | 57 | 17 | 12 | 26 | 17 | 6 | 4 | 2 | |

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) | F_{MSY} | F_{2004}/F_{MSY} | E_{MSY} | E_{2004}/E_{MSY} | $\text{SSB}_{\text{MSY}} (\text{klb})$ | $\text{SSB}_{2005}/\text{SSB}_{\text{MSY}}$ |
|--|---------------|-------------|-------------|------------------|---------------------------|------------------|---------------------------|--|---|
| 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) | F _{MSY} | 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 1000s, 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 1000s, 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 F_{MSY} (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 1000s, $F_{MSY} = 0.28/\text{yr}$, 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 F_{MSY} (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 1000s, 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 F_{MSY} (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 1000s, $F_{MSY} = 0.28/\text{yr}$, 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 F_{MSY} (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 1000s, 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 F_{MSY} (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 1000s, $F_{MSY} = 0.28/\text{yr}$, 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 F_{MSY} (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 1000s, 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 F_{MSY} (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 1000s, $F_{MSY} = 0.28/\text{yr}$, 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 F_{MSY} (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 1000s, 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.

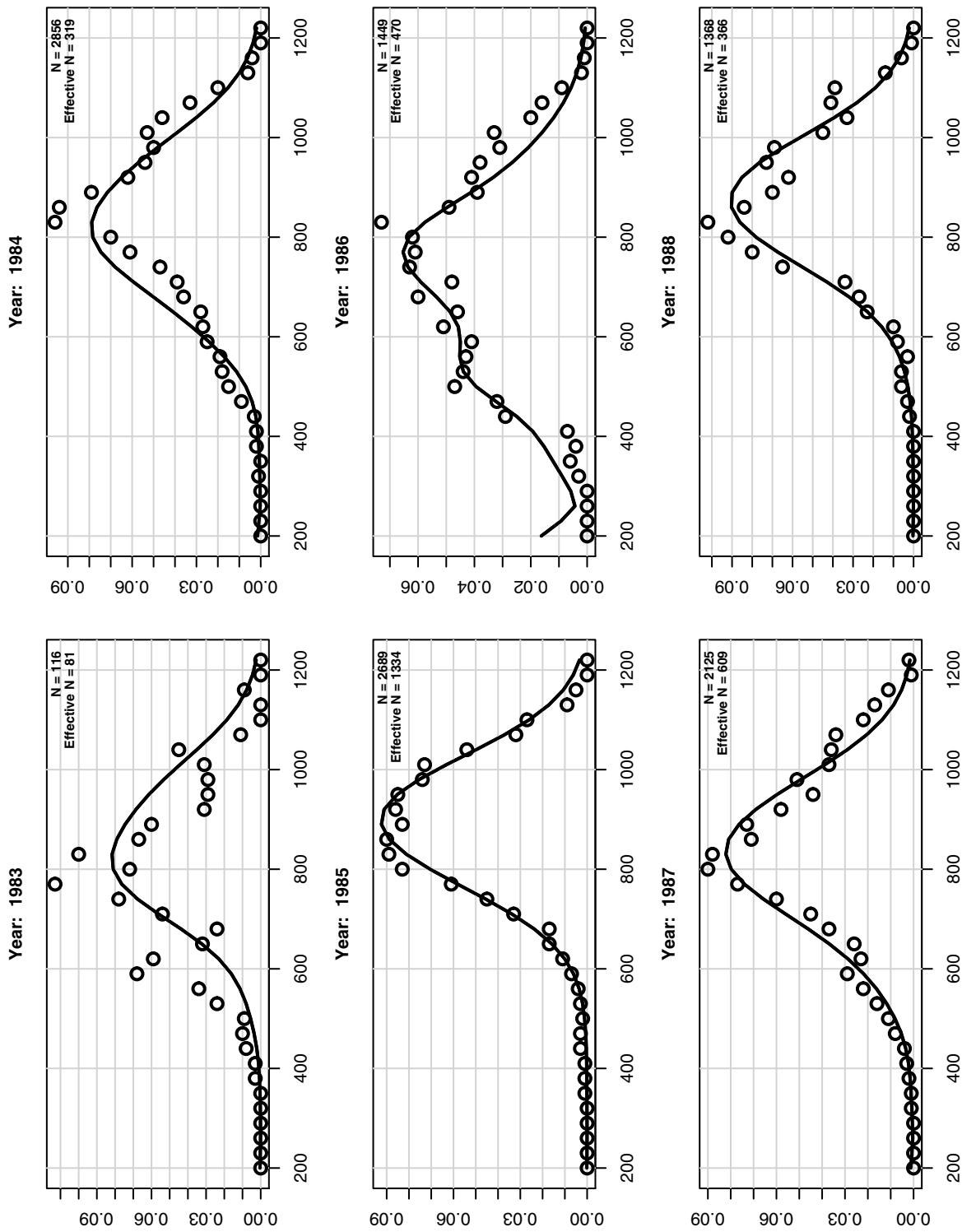


Figure 2. (cont.) Gag- Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from commercial handline. Observed sample sizes (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

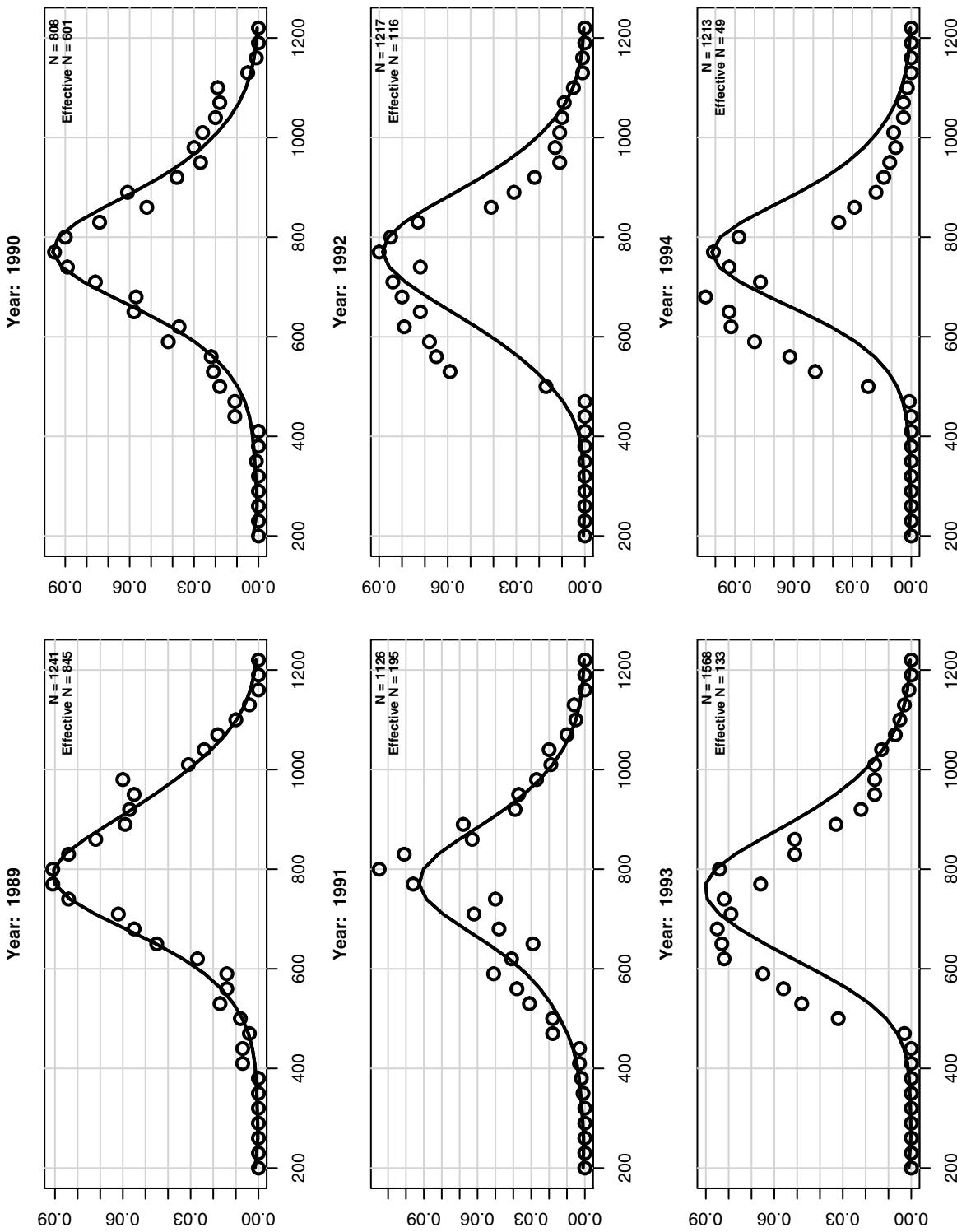


Figure 2. (cont.) Gag- Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from commercial handline. Observed sample sizes (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

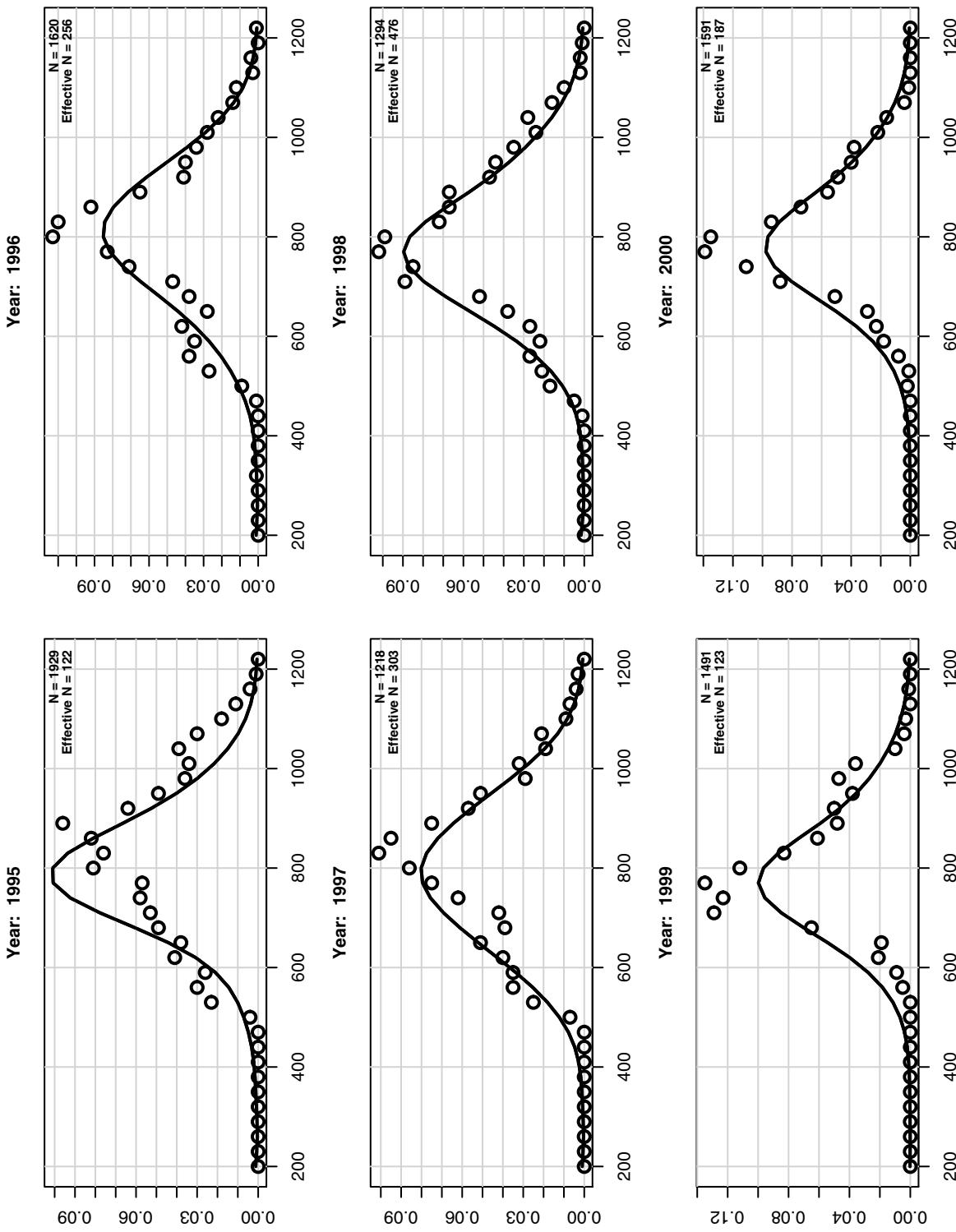


Figure 2. (cont.) Gag- Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from commercial handline. Observed sample sizes (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

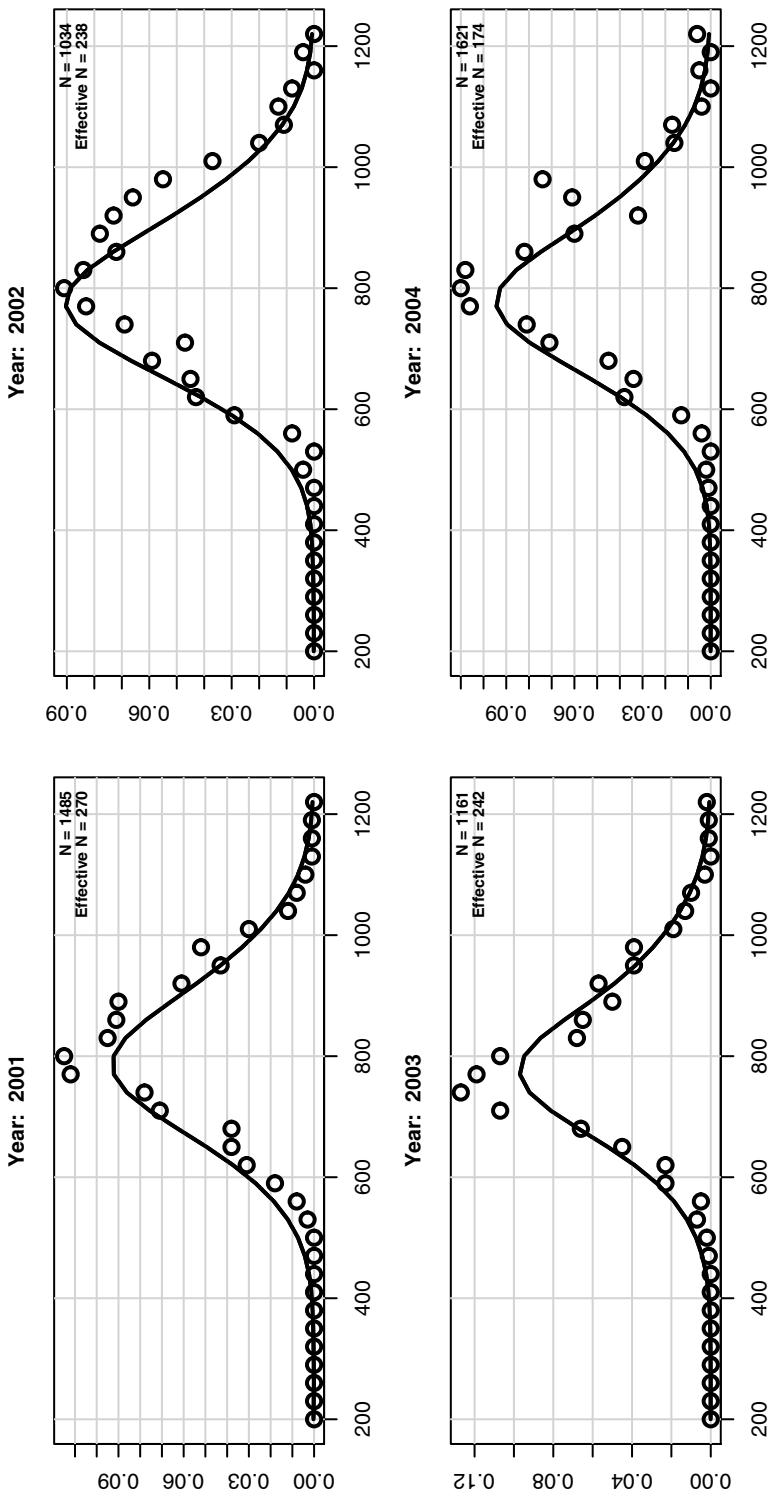


Figure 3. Gag- Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

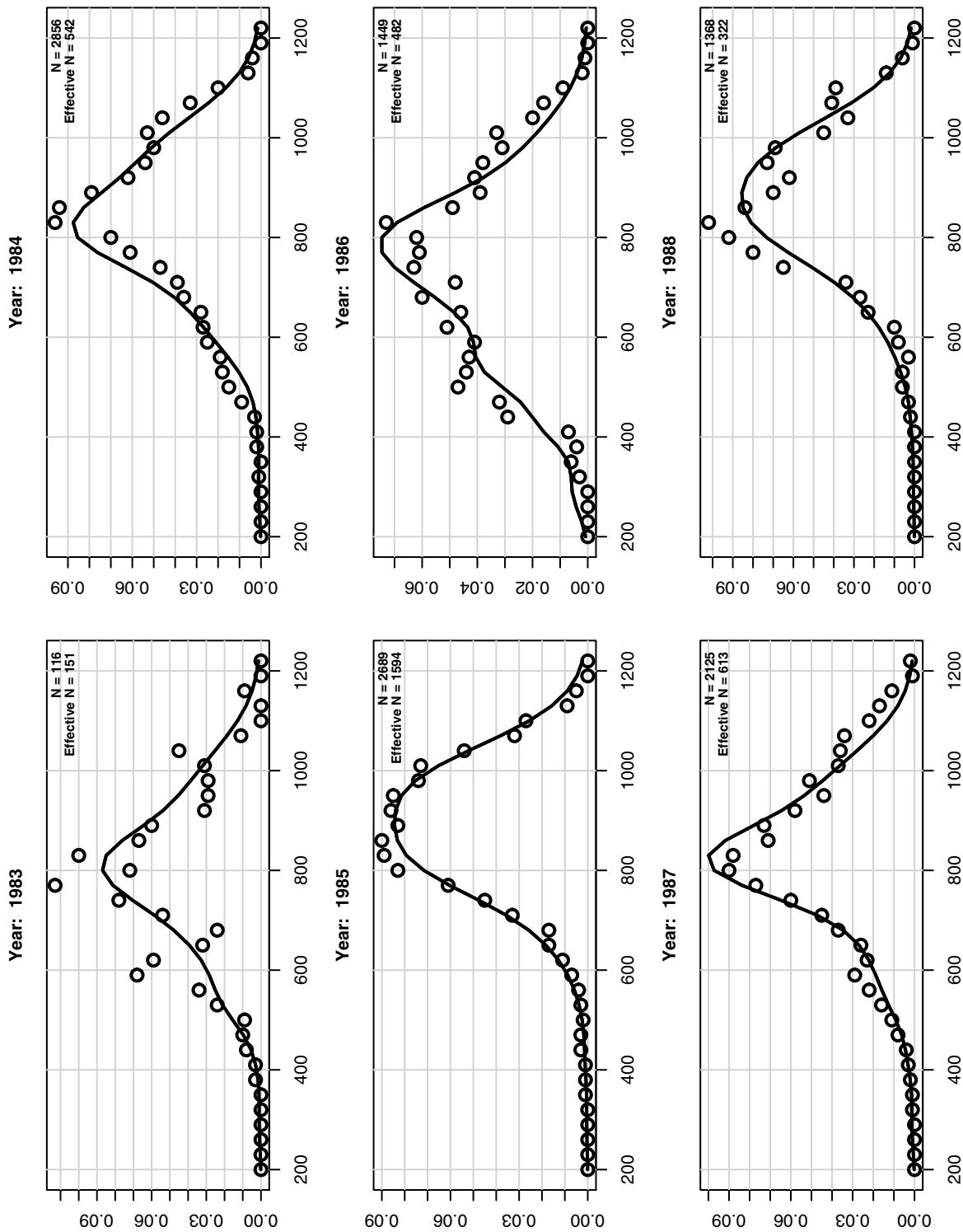


Figure 3. (cont.) Gag-Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

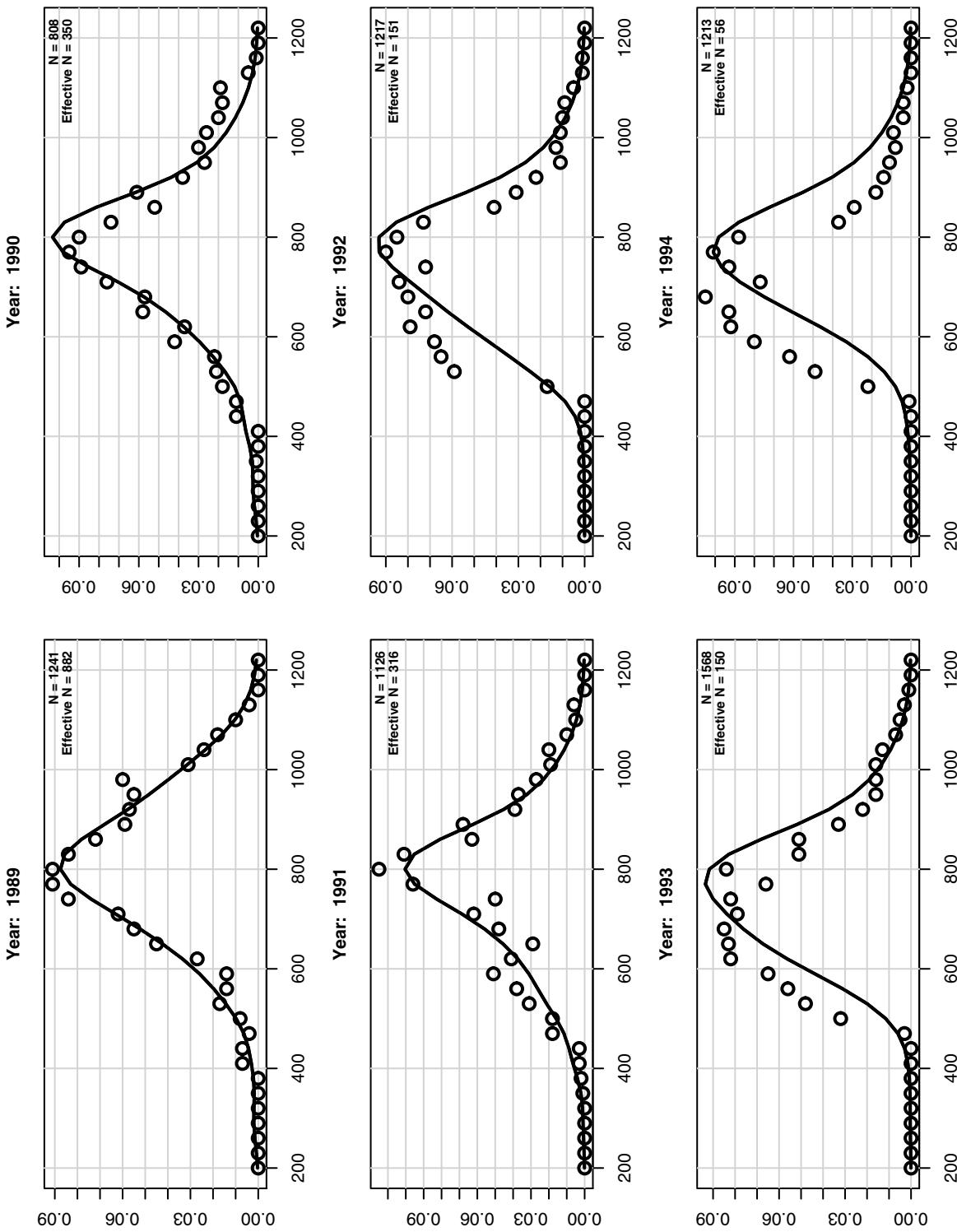


Figure 3. (cont.) Gag-Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

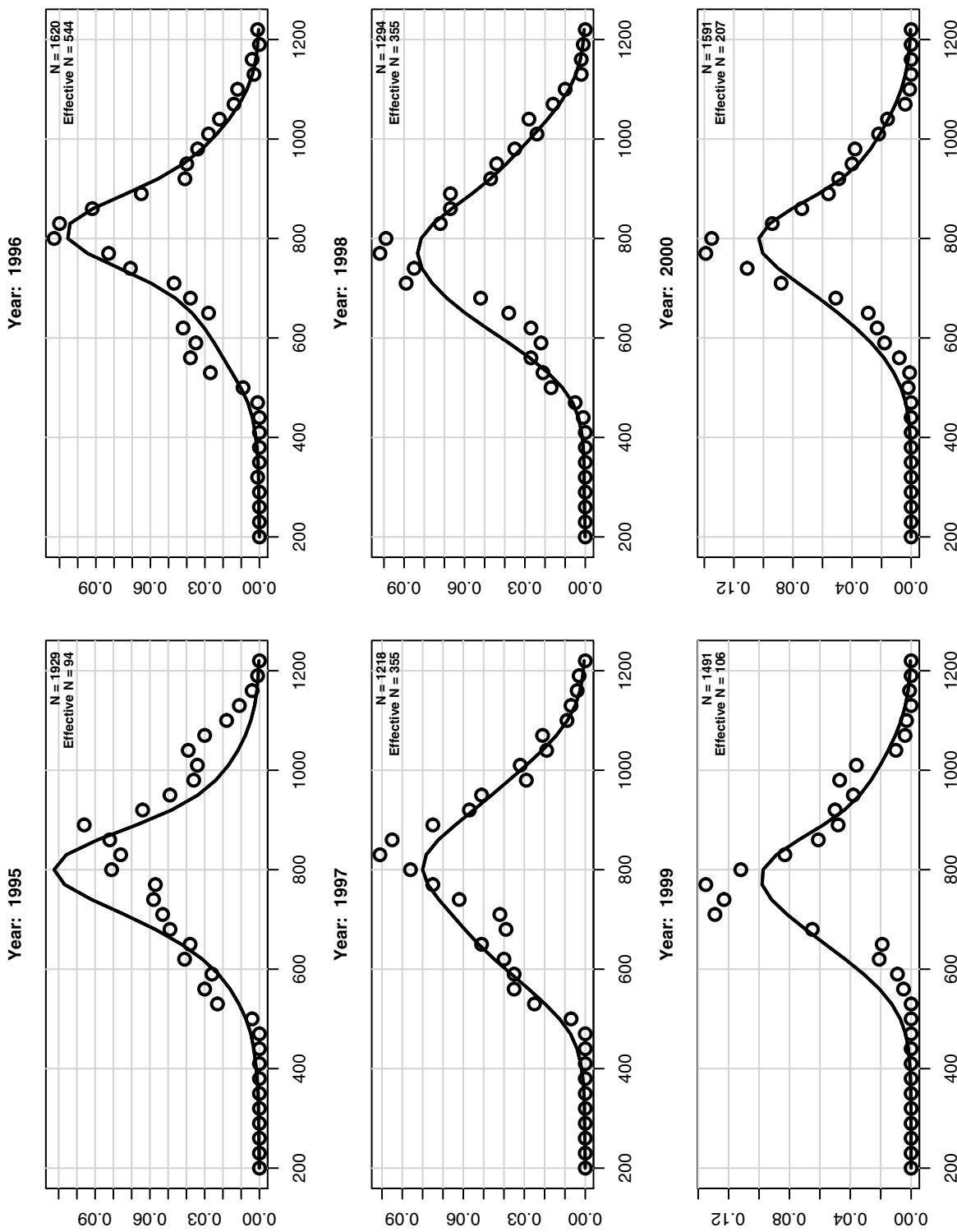


Figure 3. (cont.) Gag-Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

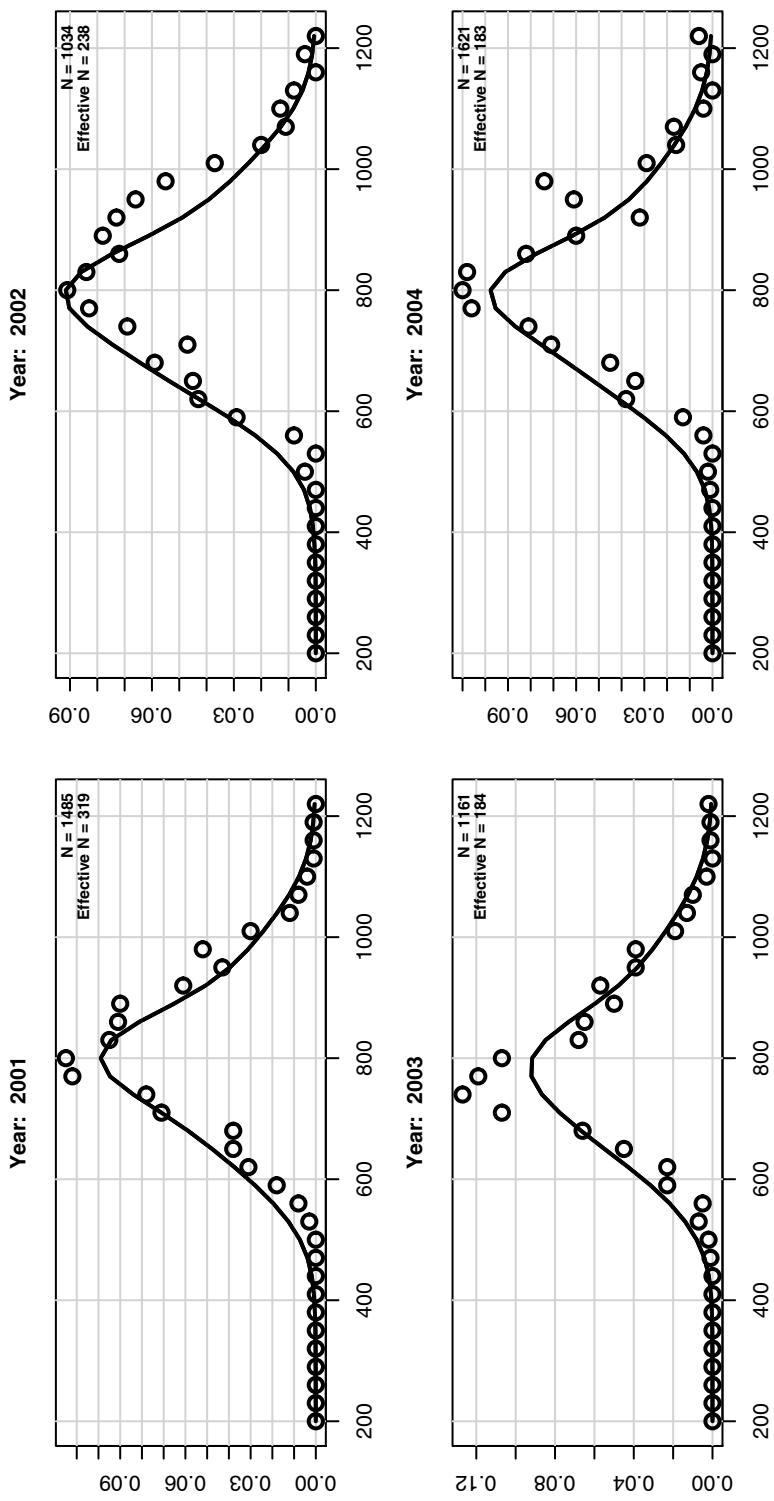


Figure 4. Gag-Base run with time-varying catchability: Bubble plot of length composition residuals from the commercial handline fishery; Dark bubbles are overestimates and light bubbles are underestimates.

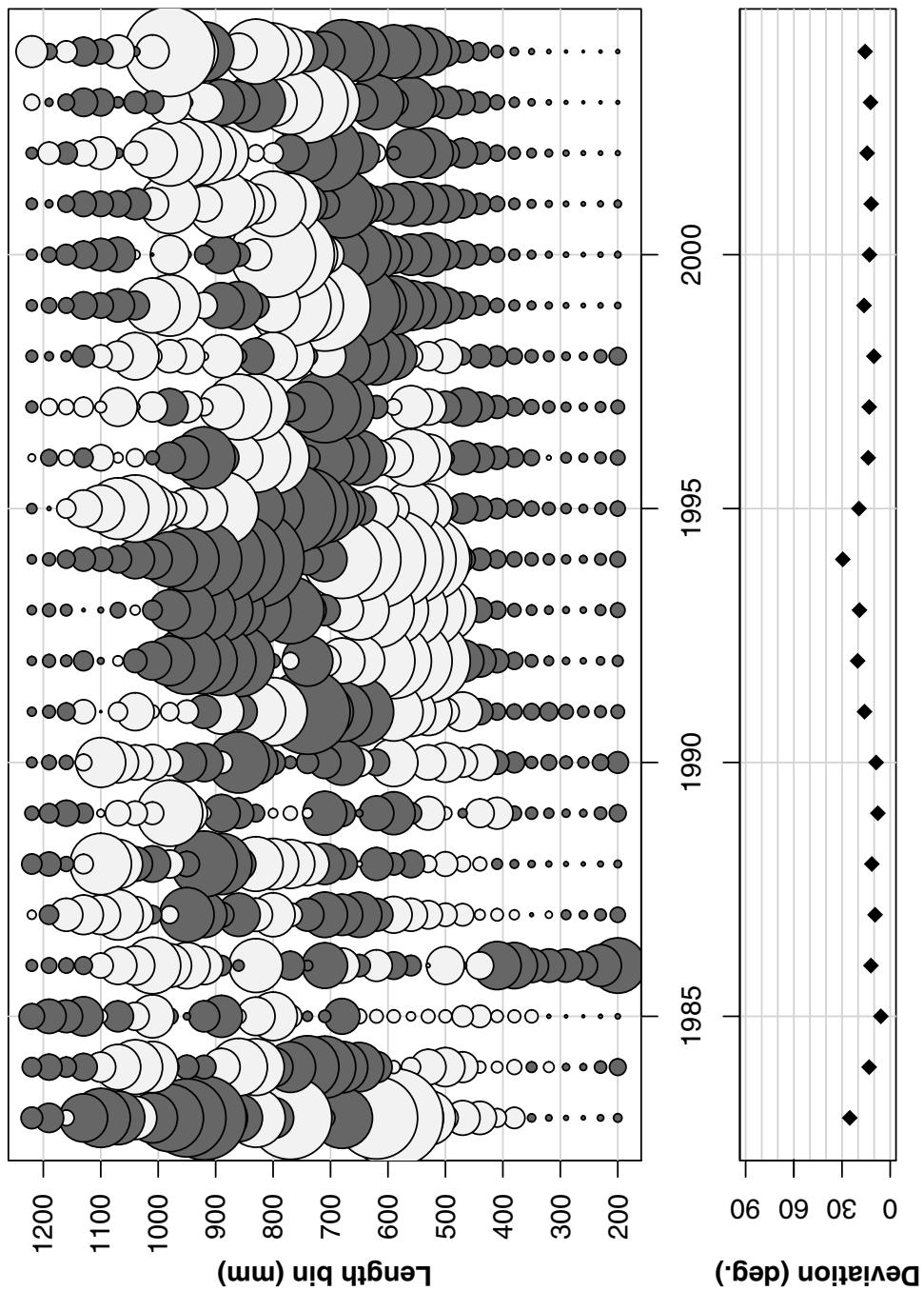


Figure 5. Gag-Base run with constant catchability: Bubble plot of length composition residuals from the commercial handline fishery; Dark bubbles are overestimates and light bubbles are underestimates.

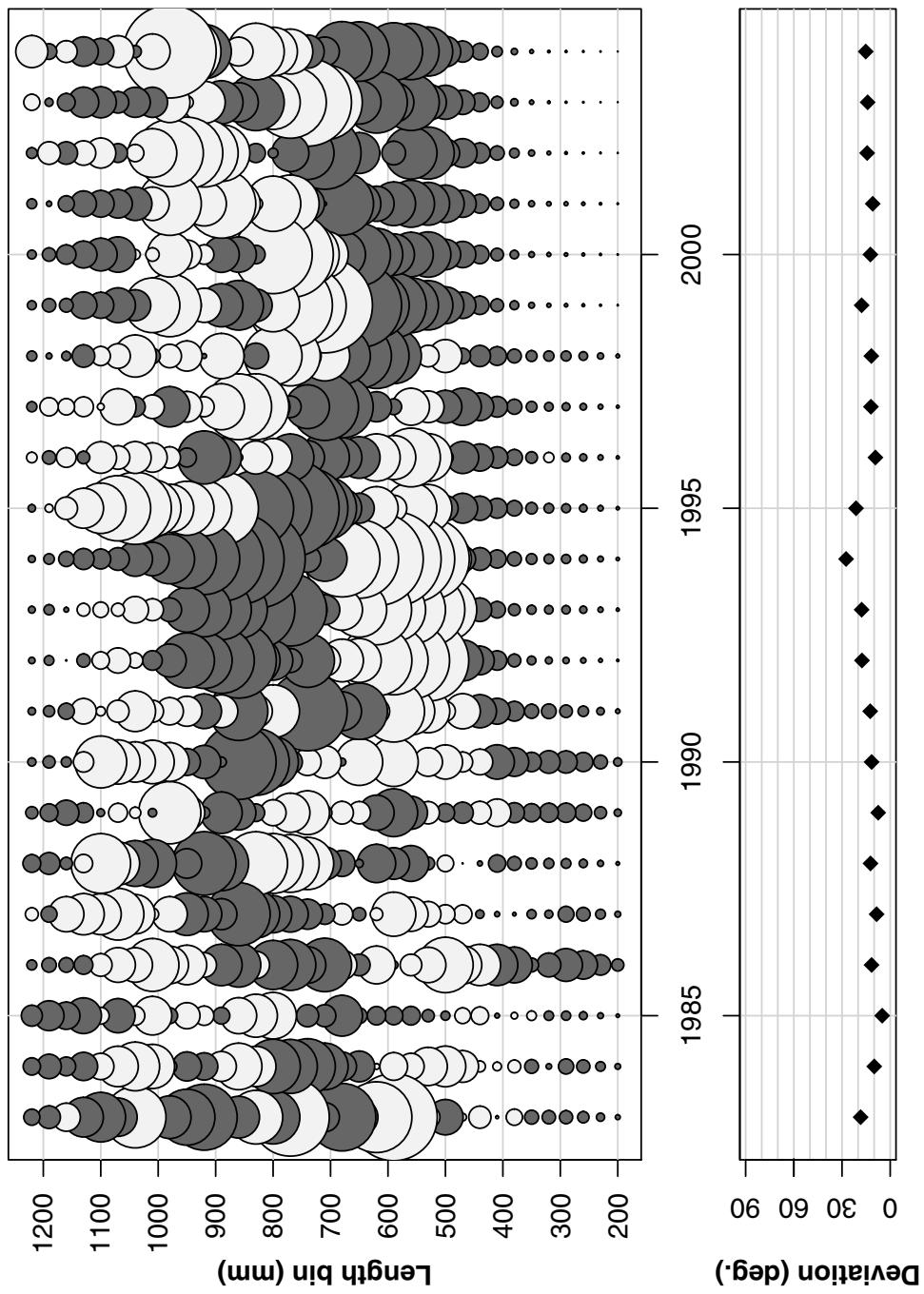


Figure 6. Gag-B run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from commercial diving. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

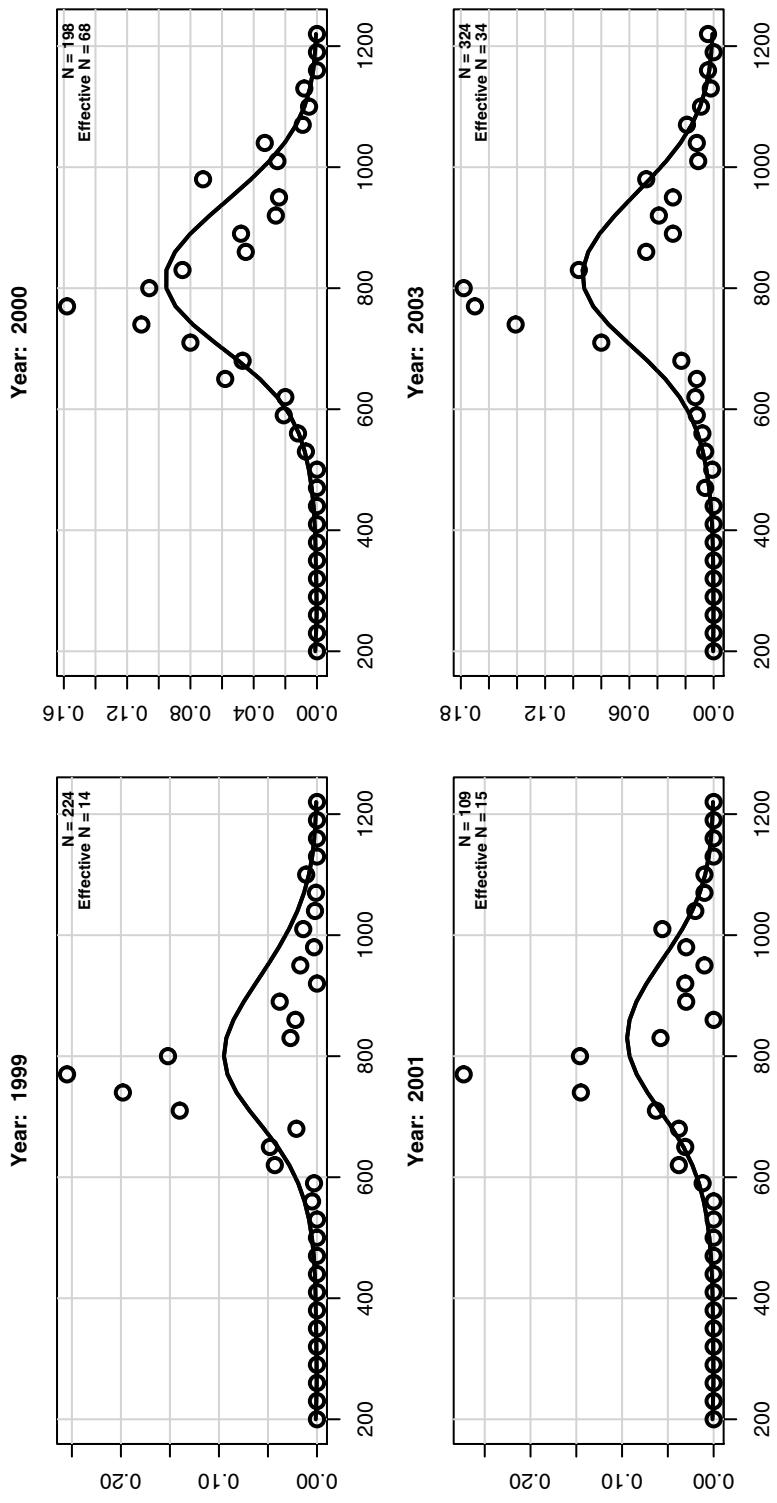


Figure 7. Gag- Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from commercial diving. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

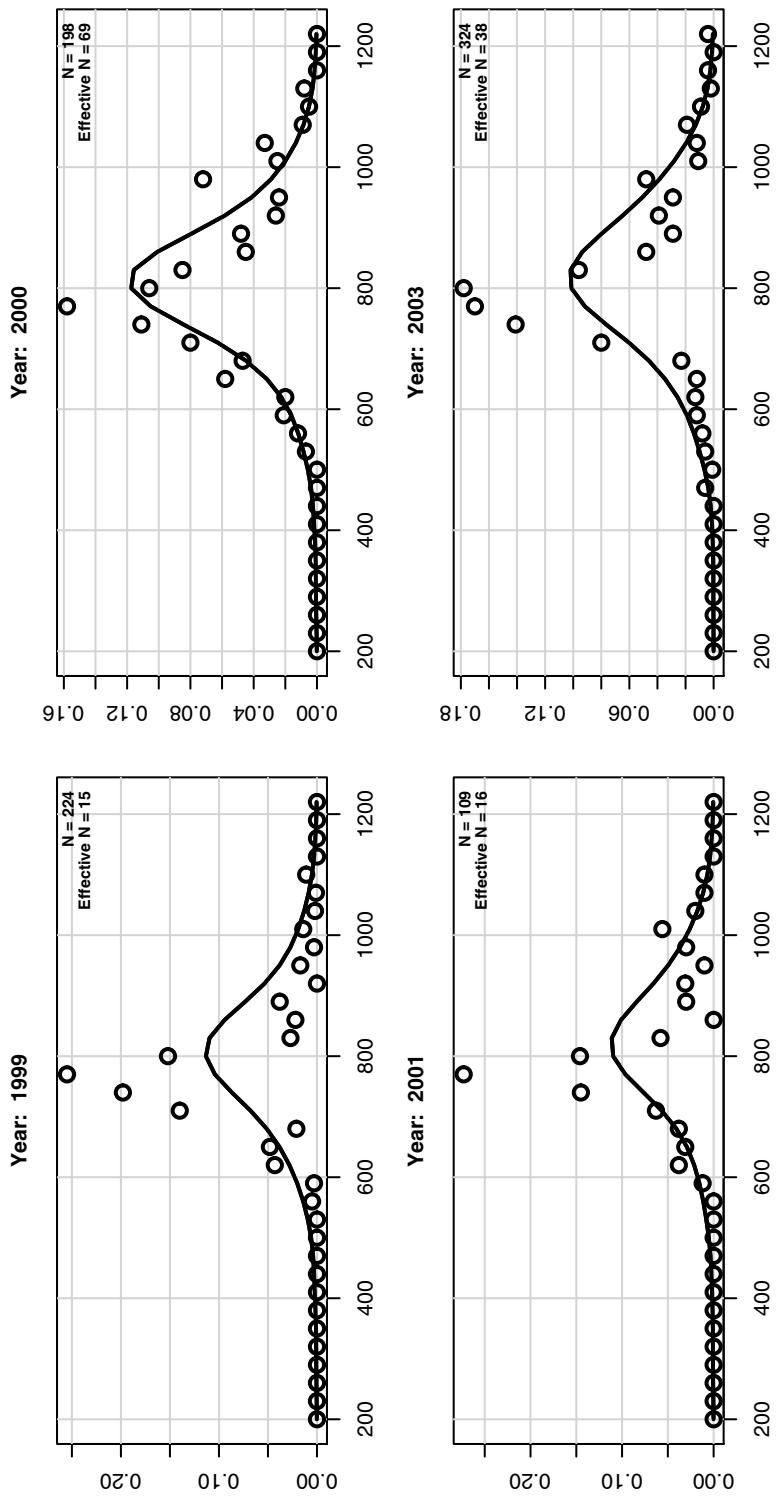


Figure 8. Gag-Base run with time-varying catchability: Bubble plot of length composition residuals from the commercial diving fishery. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

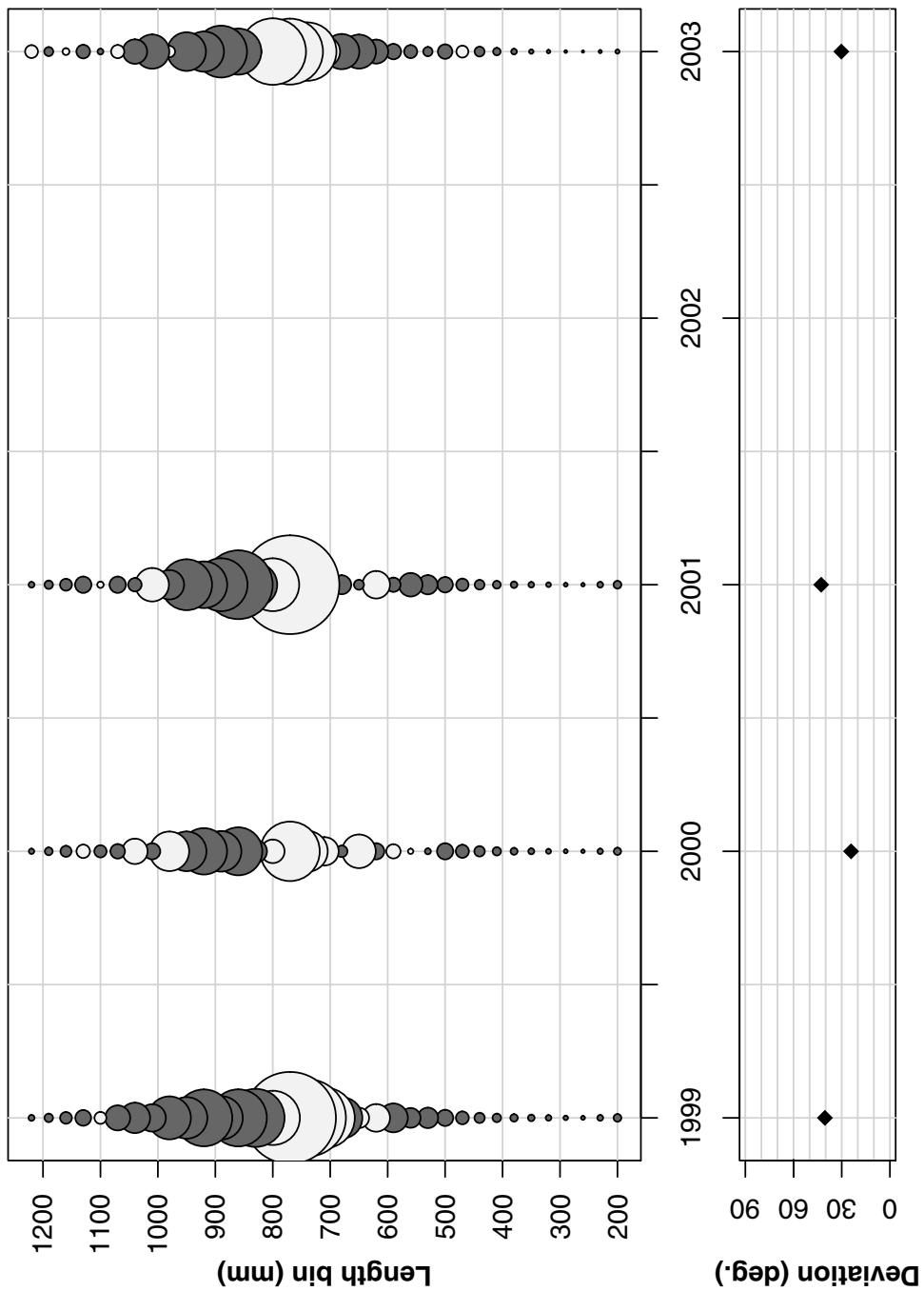


Figure 9. Gag-Base run with constant catchability: Bubble plot of length composition residuals from the commercial diving fishery. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

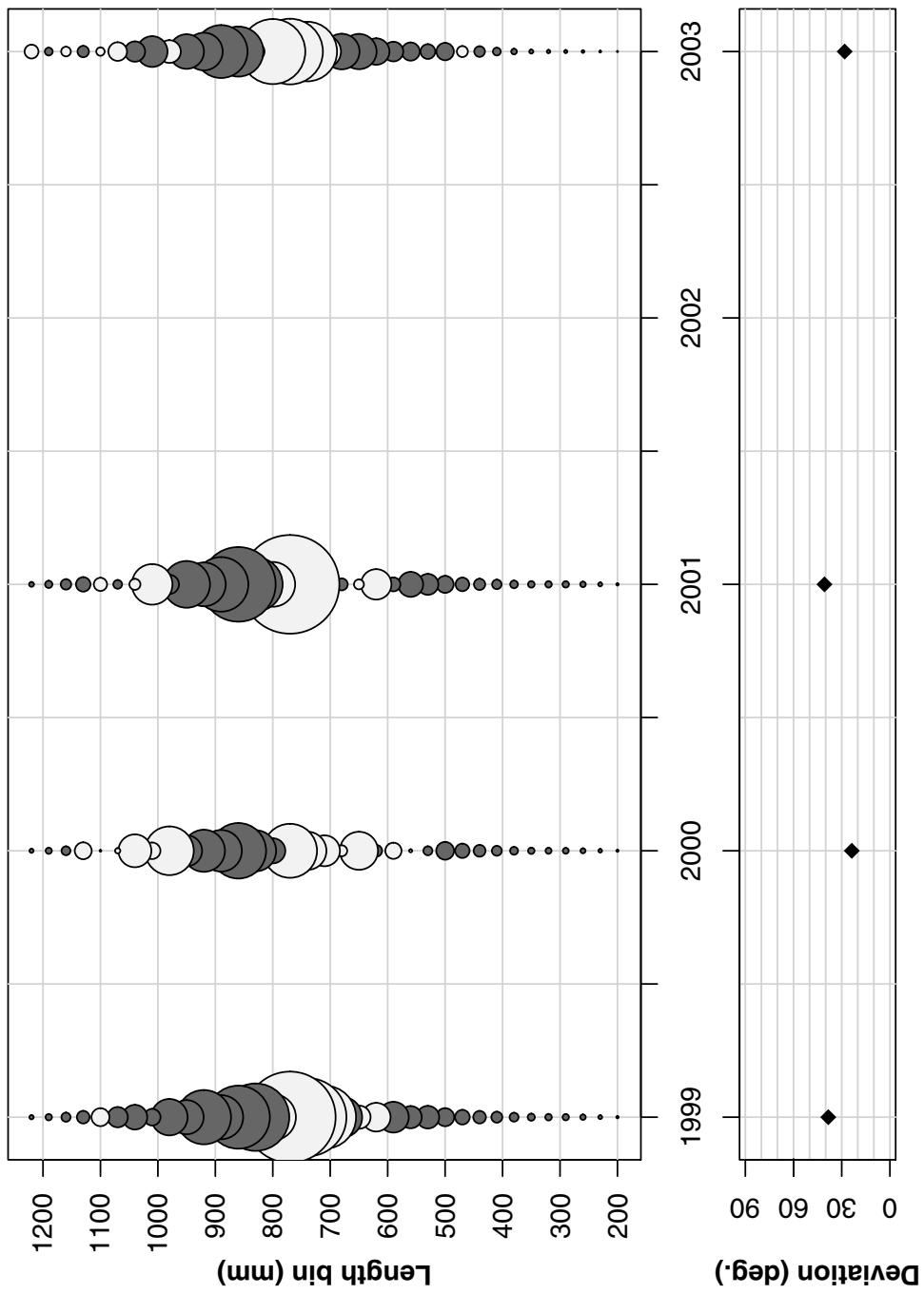


Figure 10. Gag-Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions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

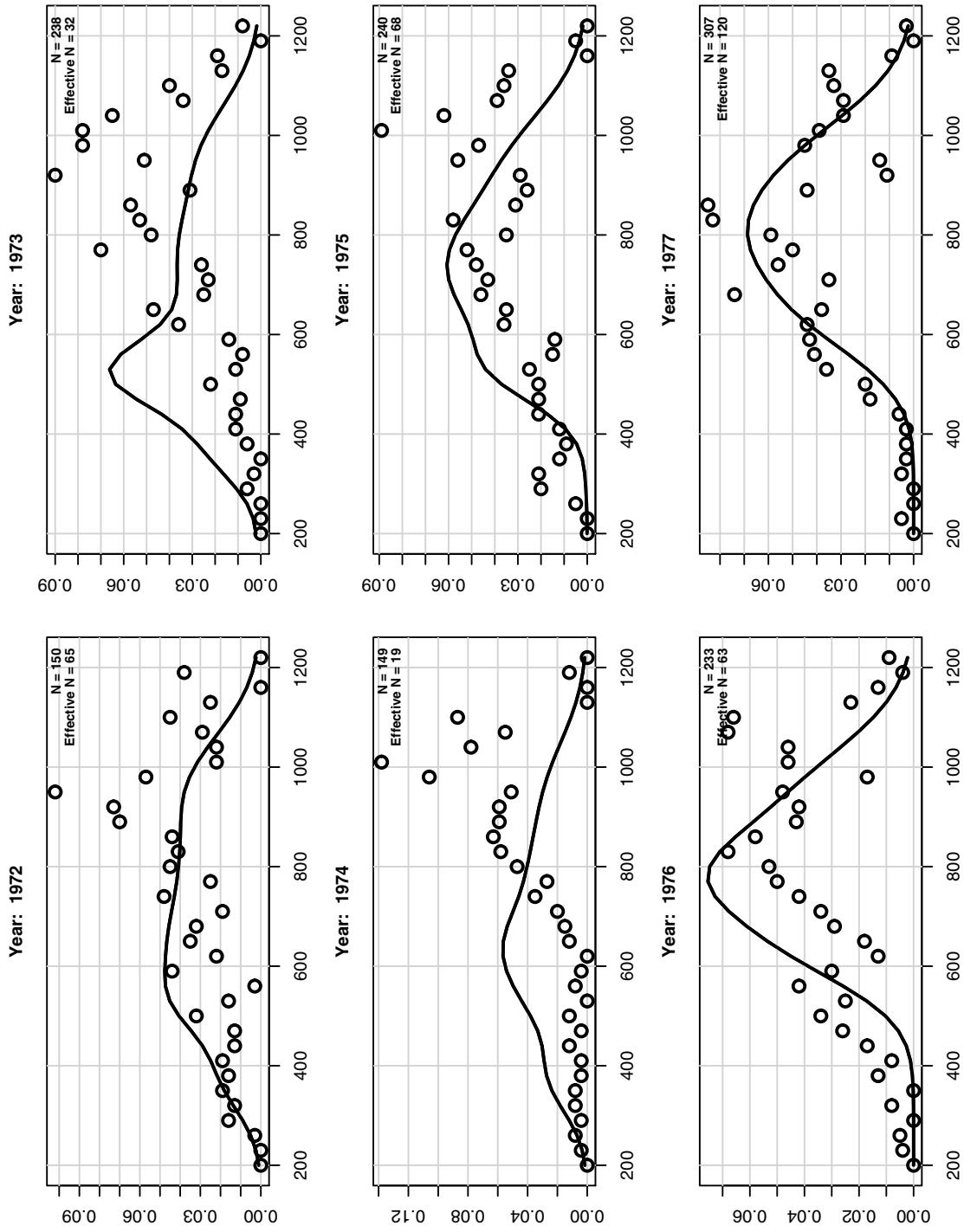


Figure 10. (cont.) Gag- Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions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

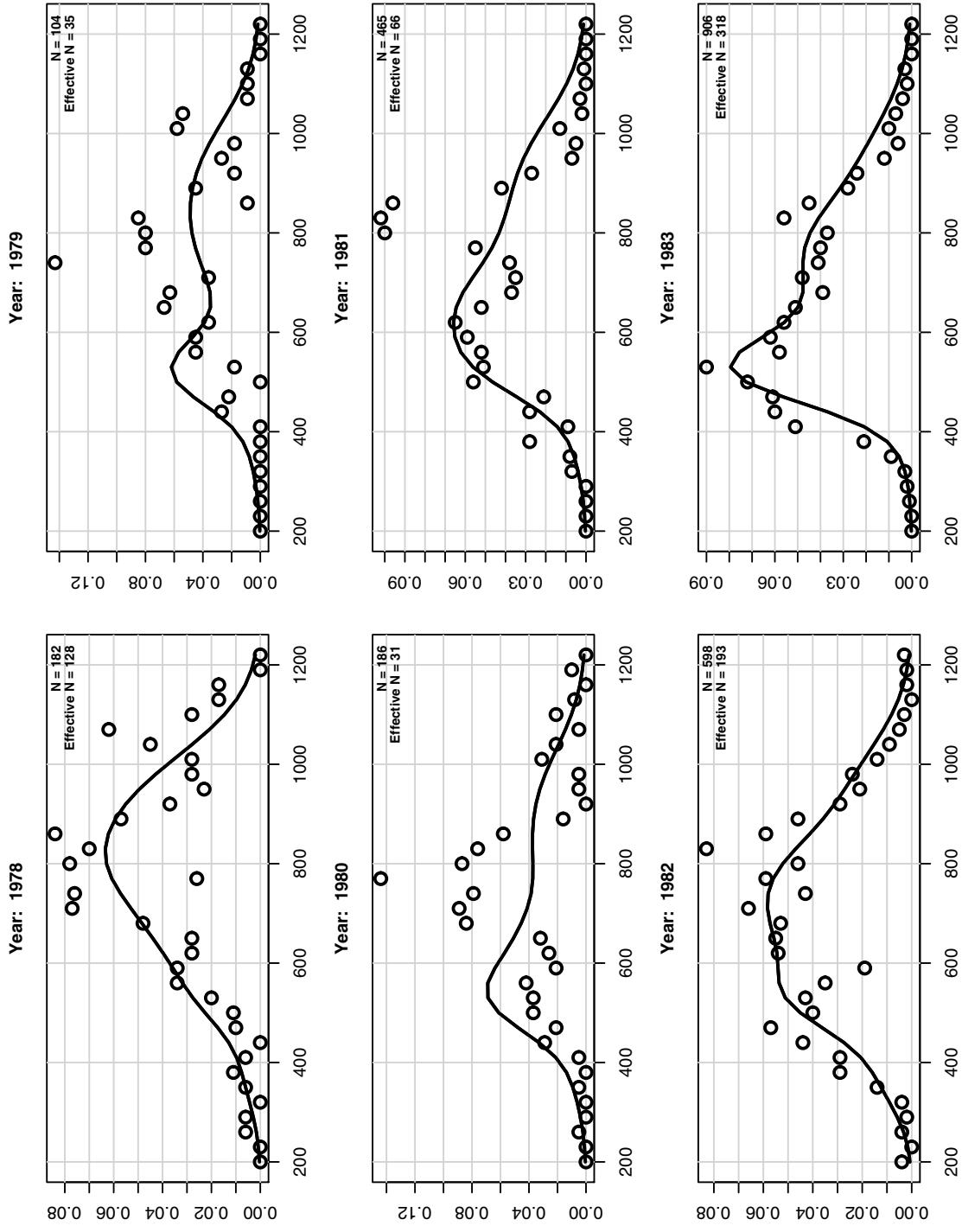


Figure 10. (cont.) Gag- Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions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

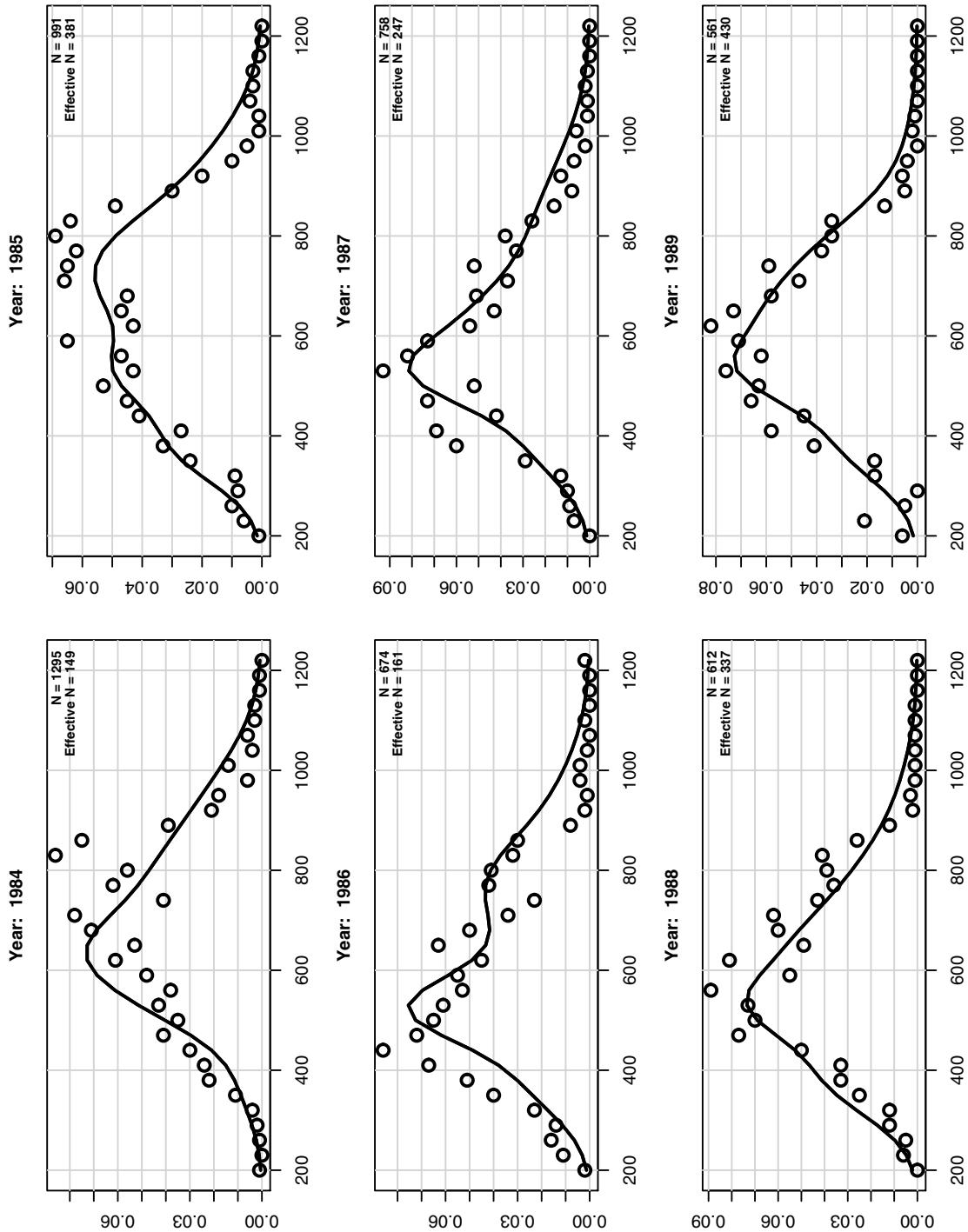


Figure 10. (cont.) Gag- Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions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

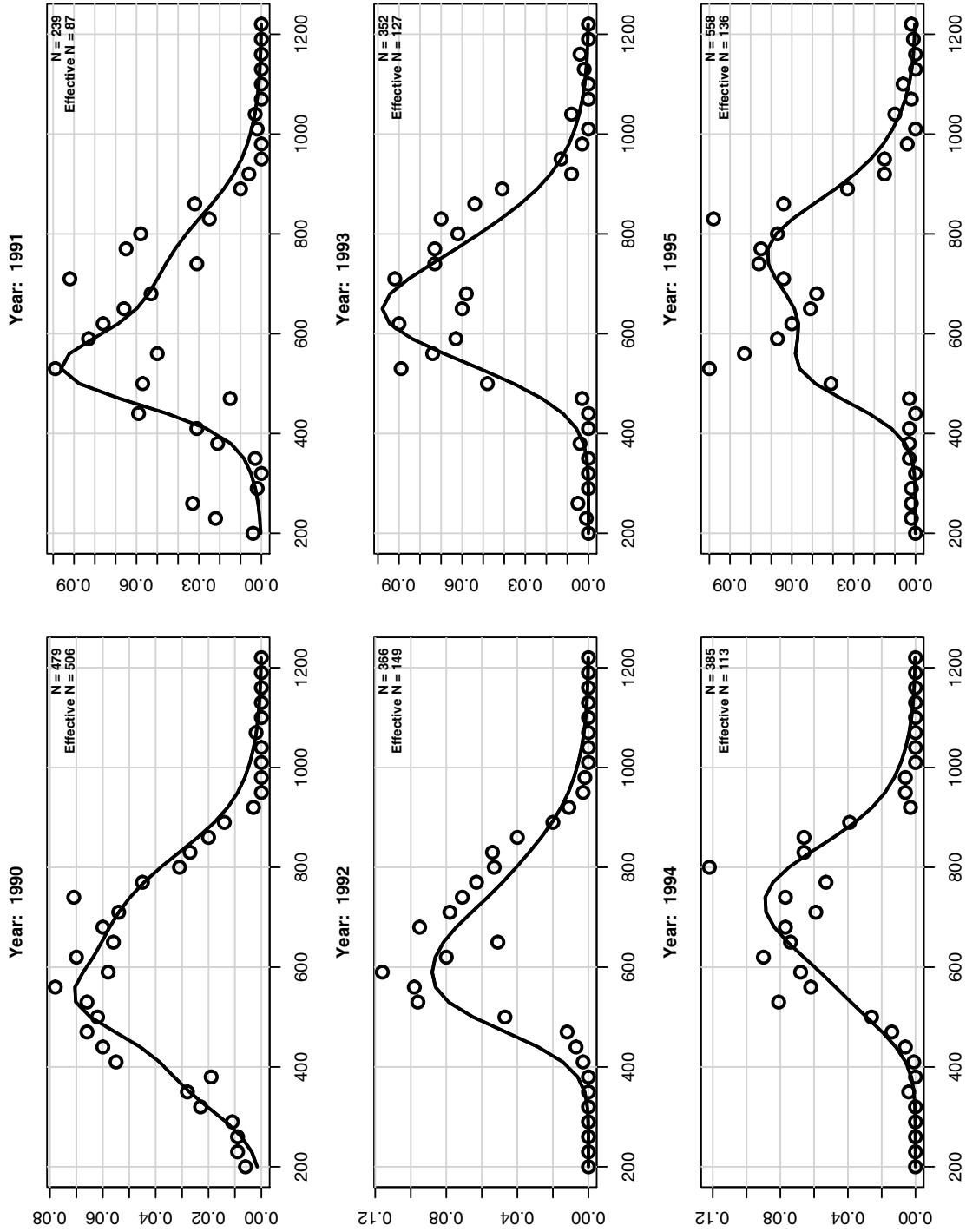


Figure 10. (cont.) Gag- Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions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

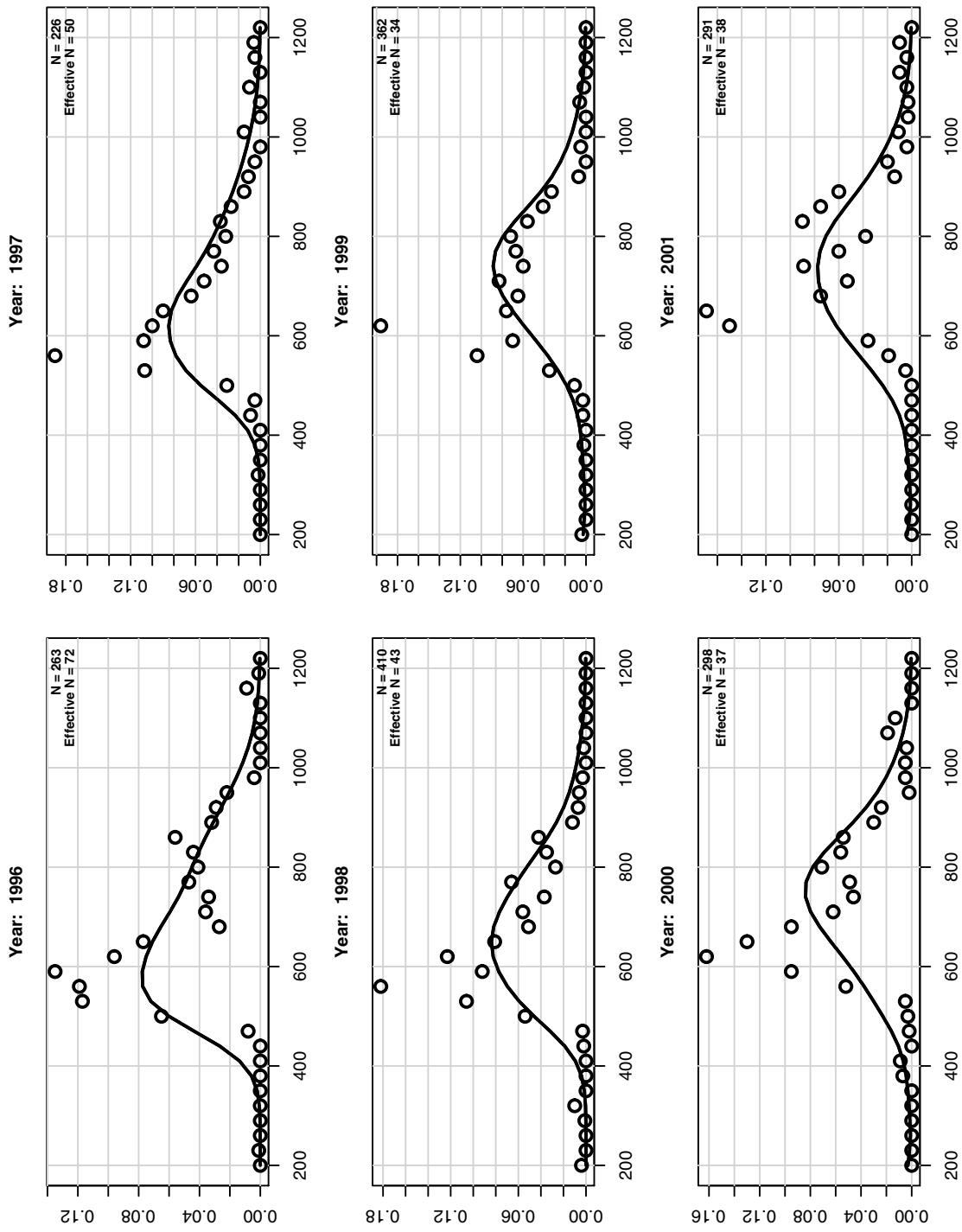


Figure 10. (cont.) Gag- Base run with time-varying catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions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

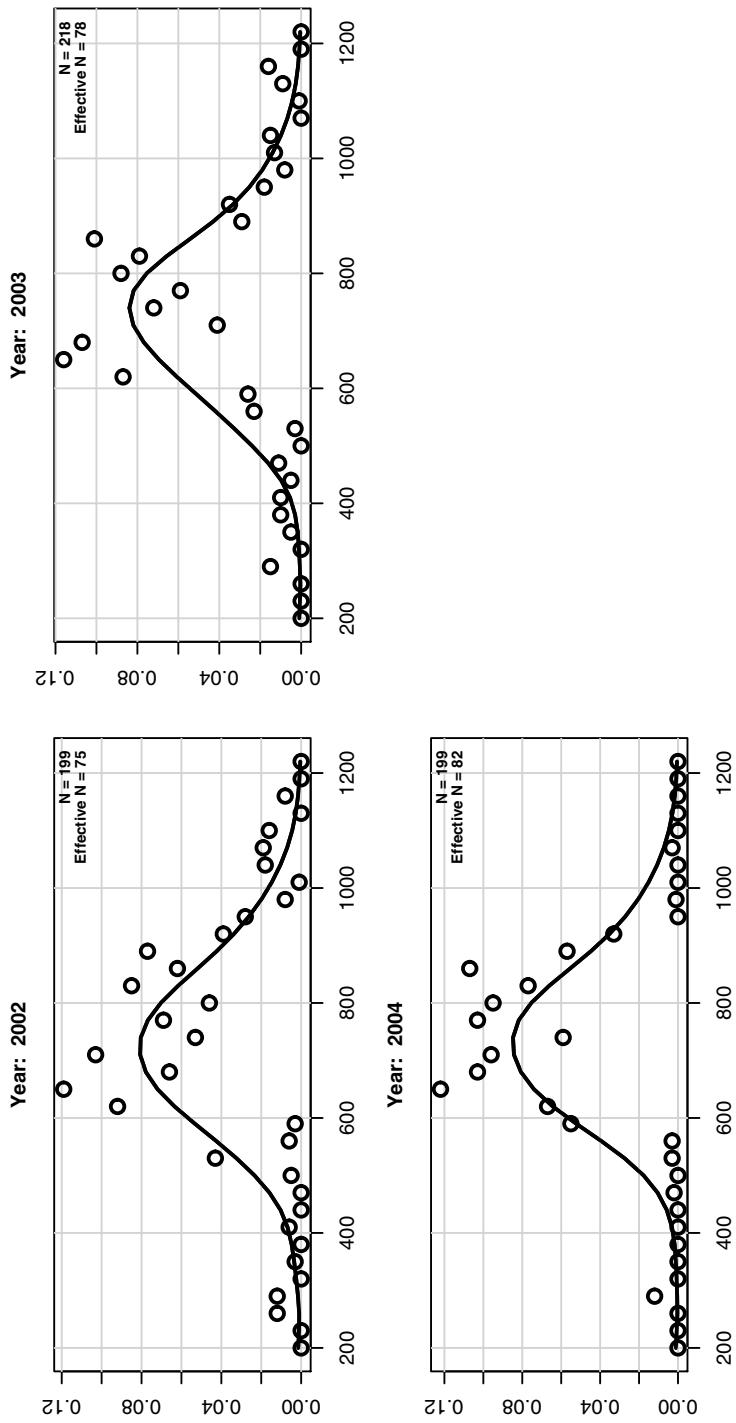


Figure 11. Gag-Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are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

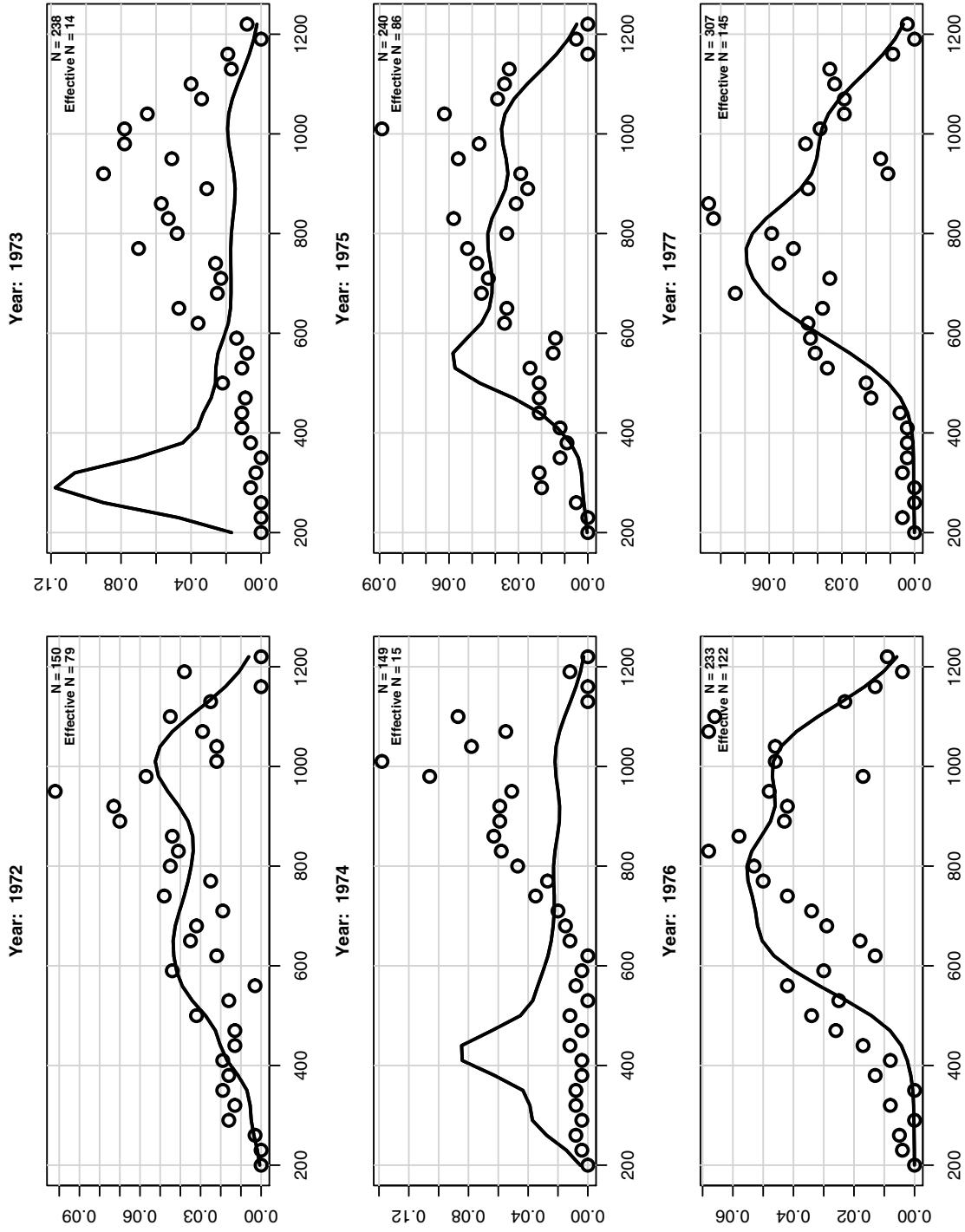


Figure 11. (cont.) Gag-Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions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

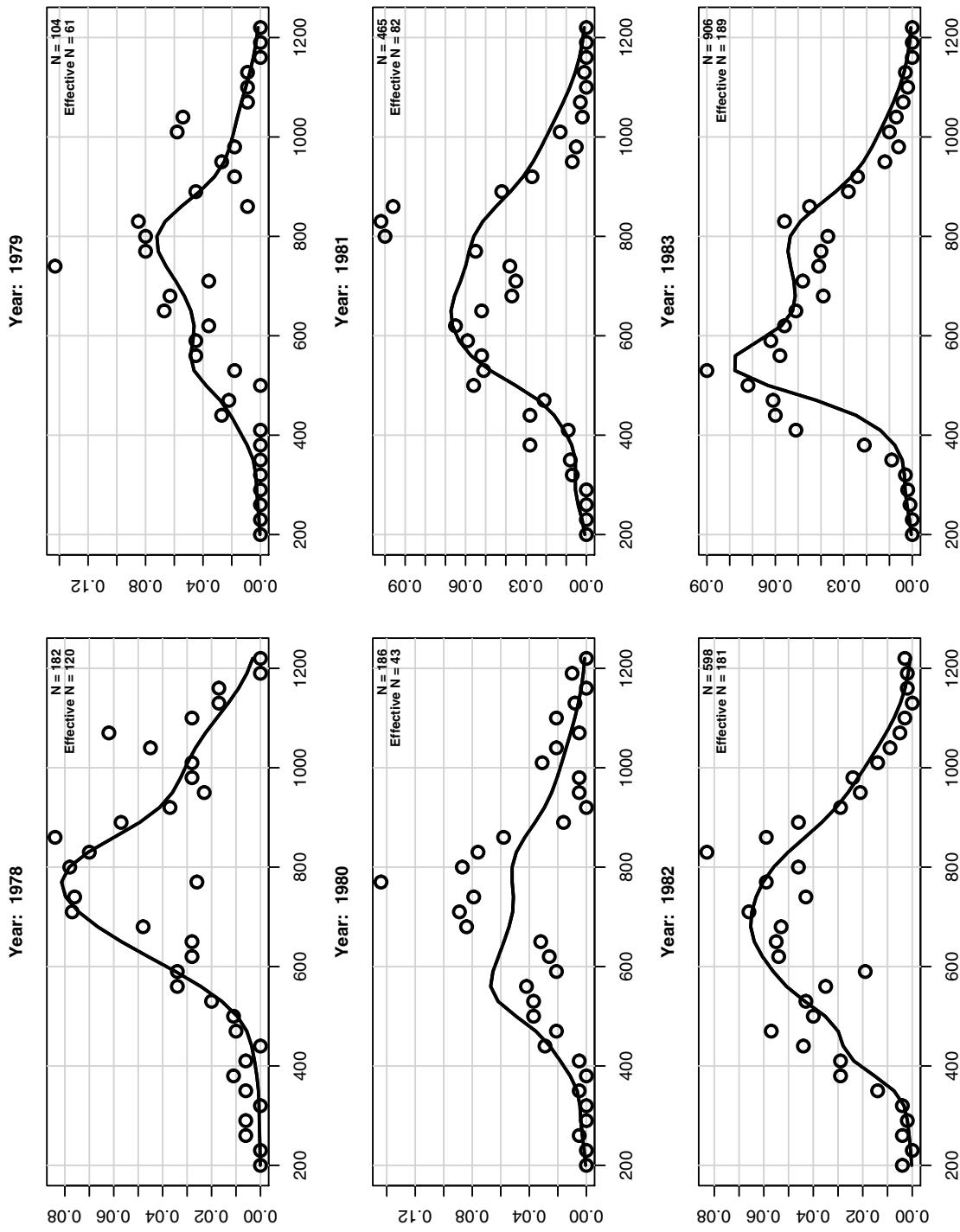


Figure 11. (cont.) Gag-Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions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

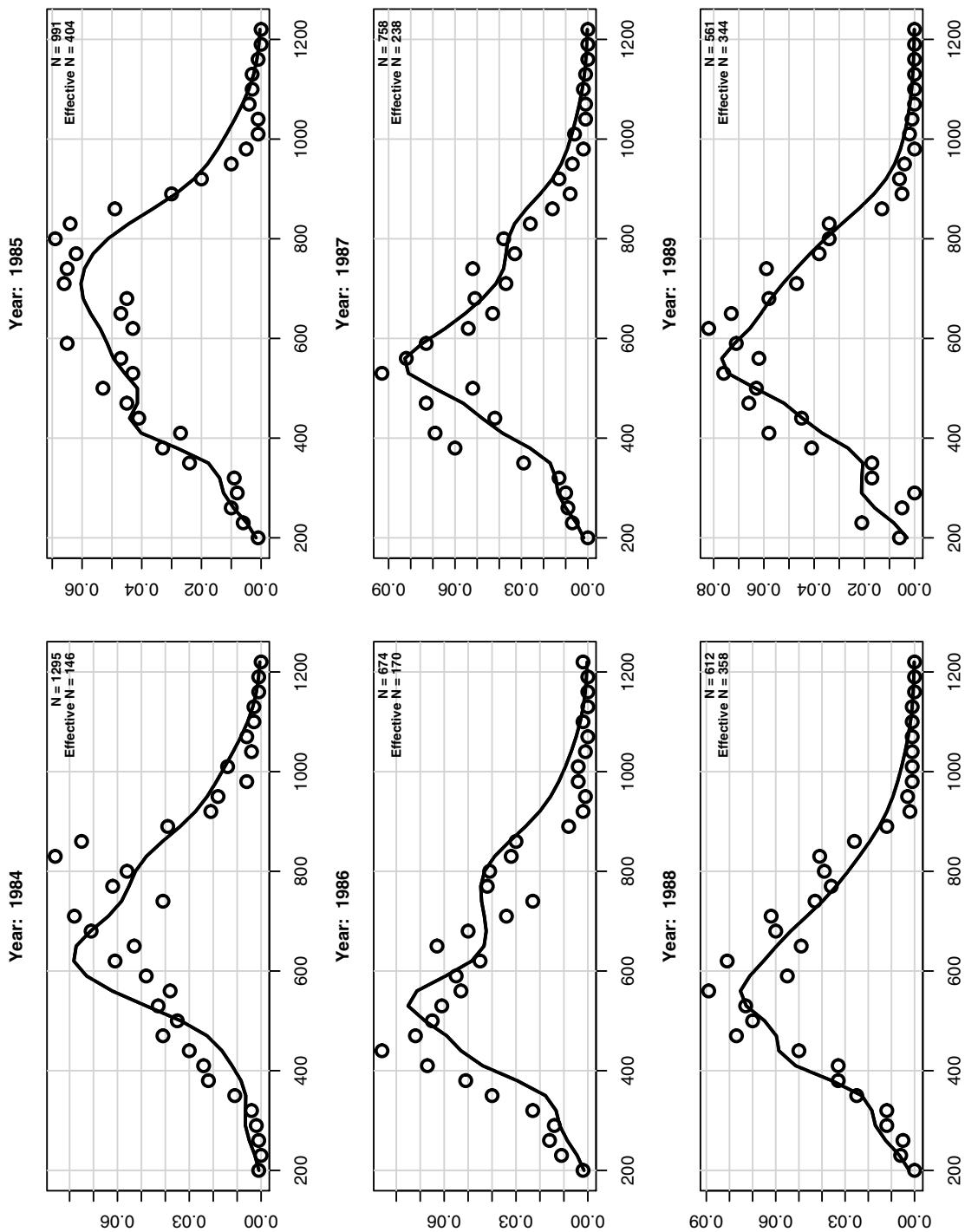


Figure 11. (cont.) Gag-Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions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

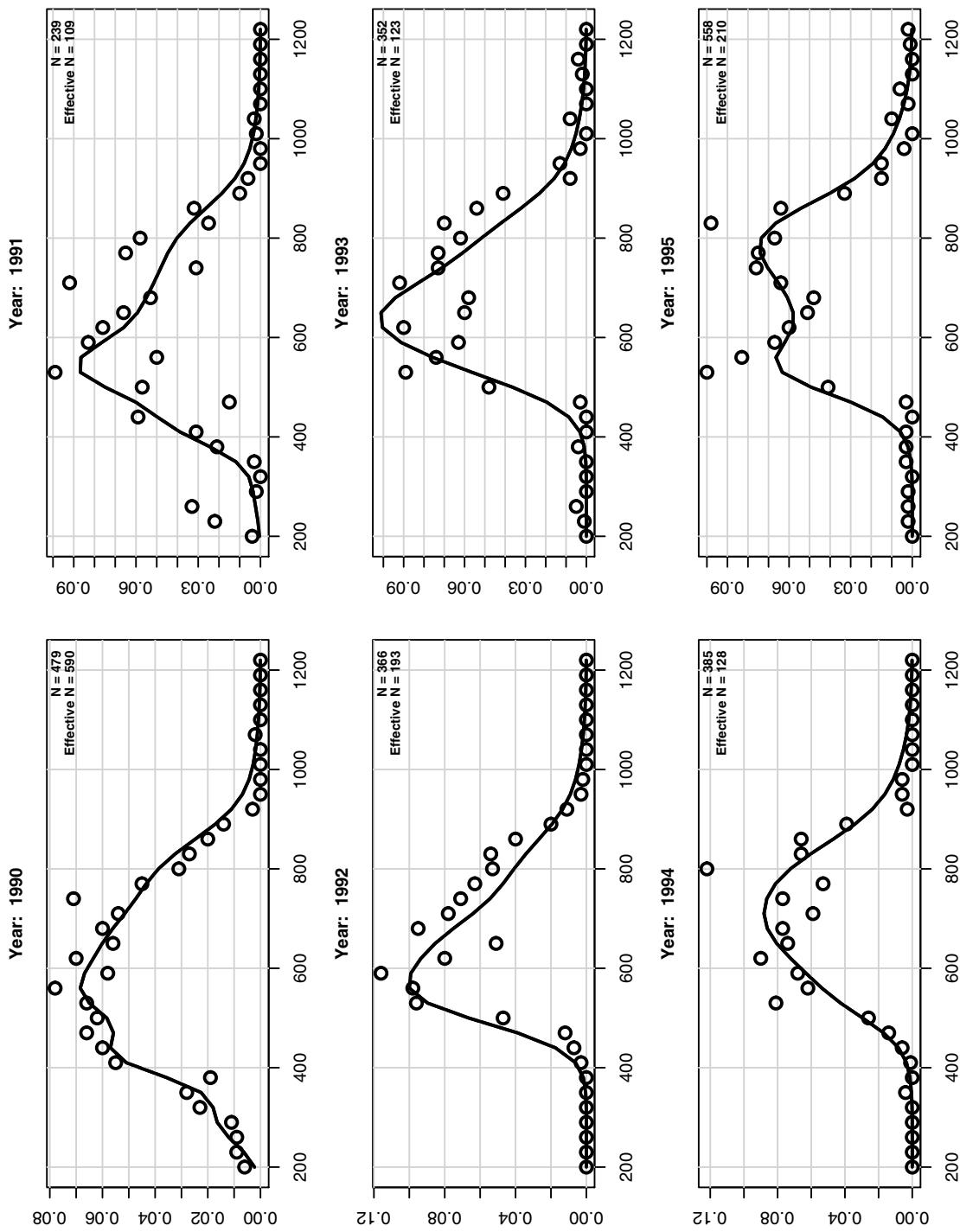


Figure 11. (cont.) Gag-Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions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

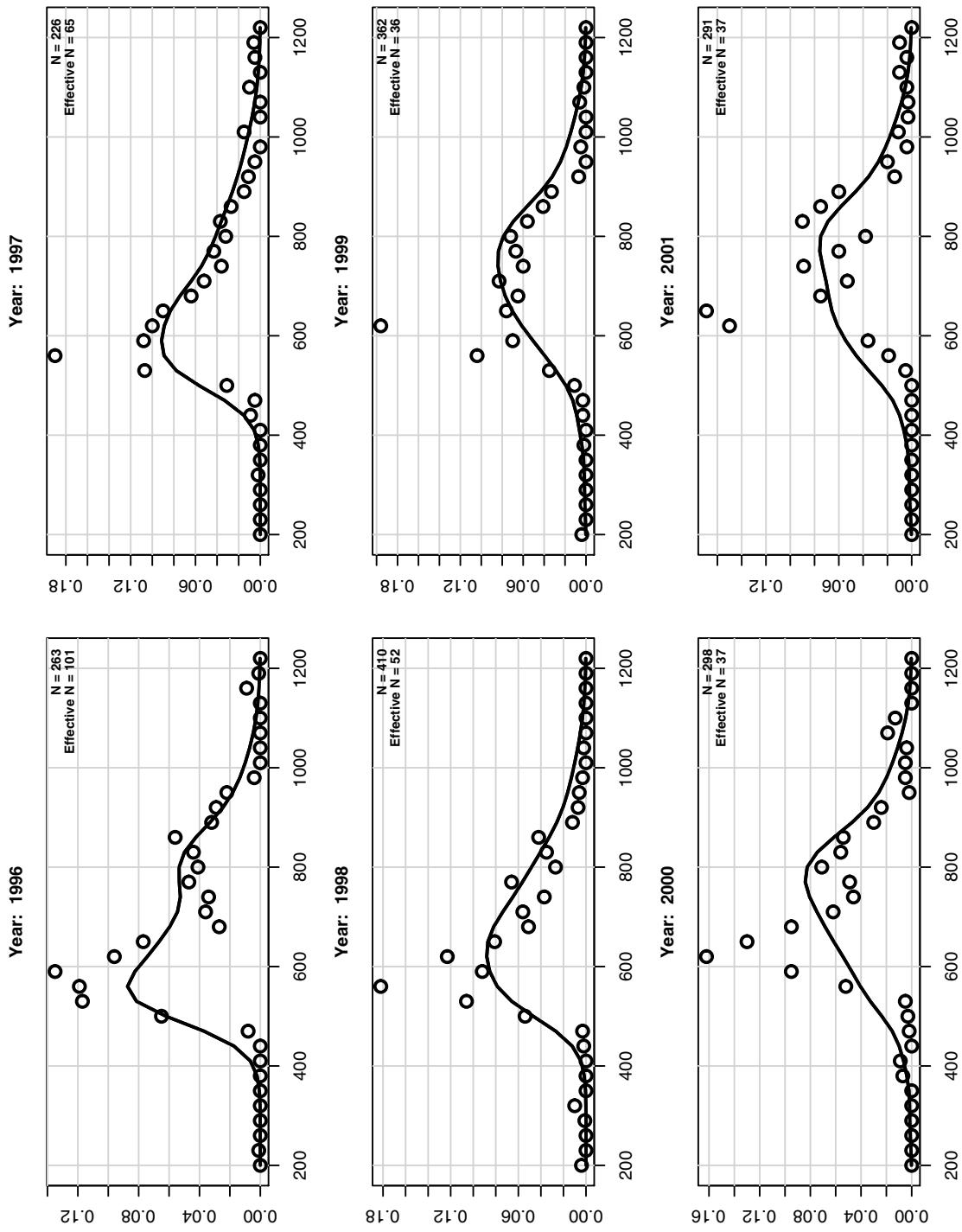


Figure 11. (cont.) Gag-Base run with constant catchability: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions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

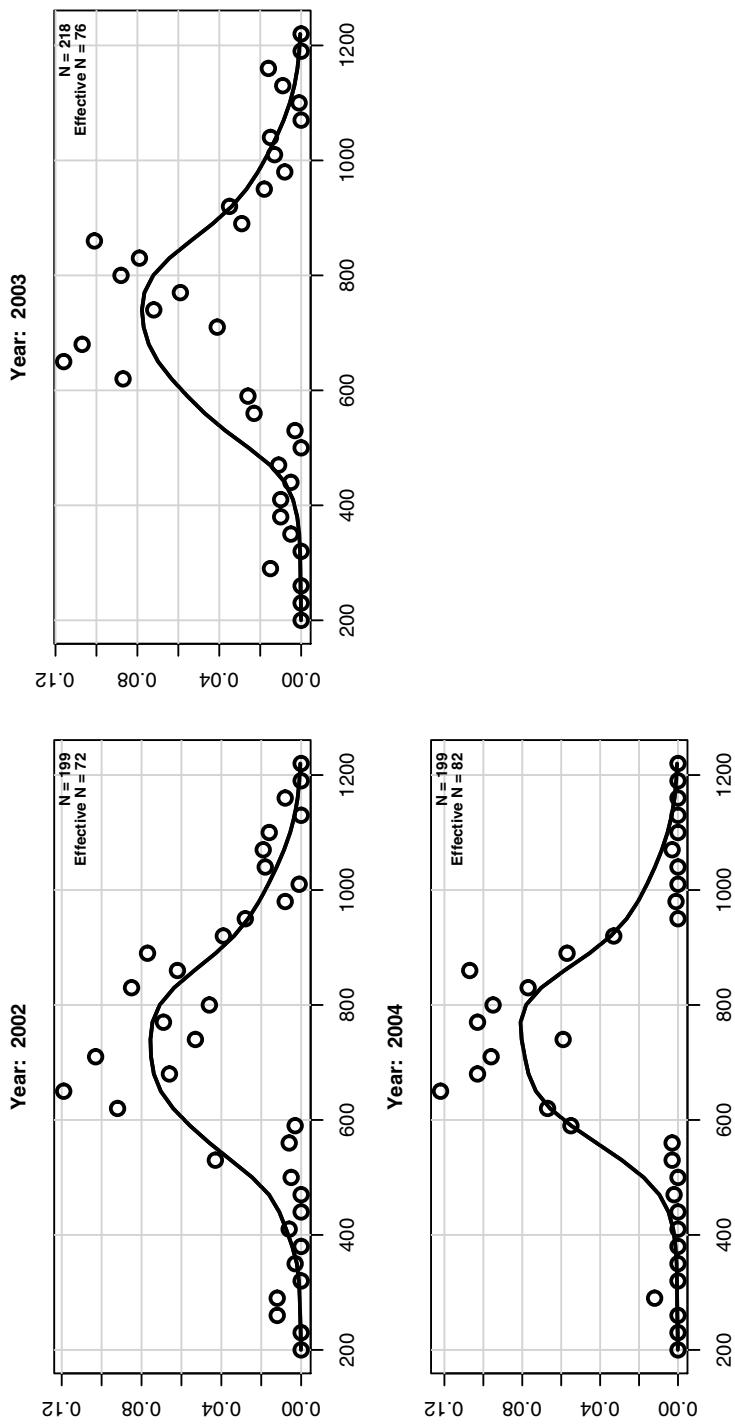


Figure 12. Gag- Base run with time-varying catchability: Bubble plot of length composition residuals from the headboat fishery; Dark bubbles are overestimates and light bubbles are underestimates.

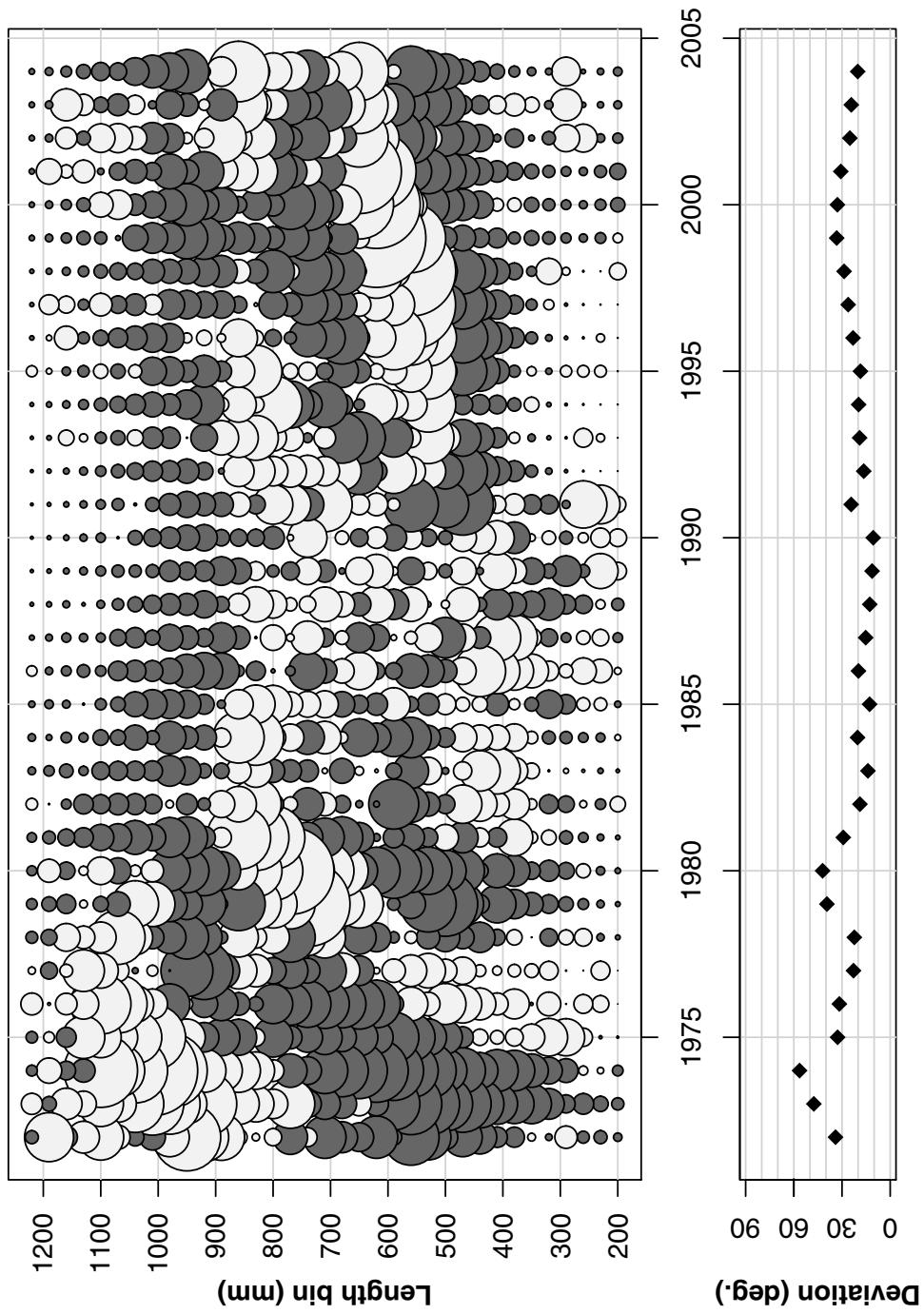


Figure 13. Gag-Base run with constant catchability: Bubble plot of length composition residuals from the headboat fishery; Dark bubbles are overestimates and light bubbles are underestimates.

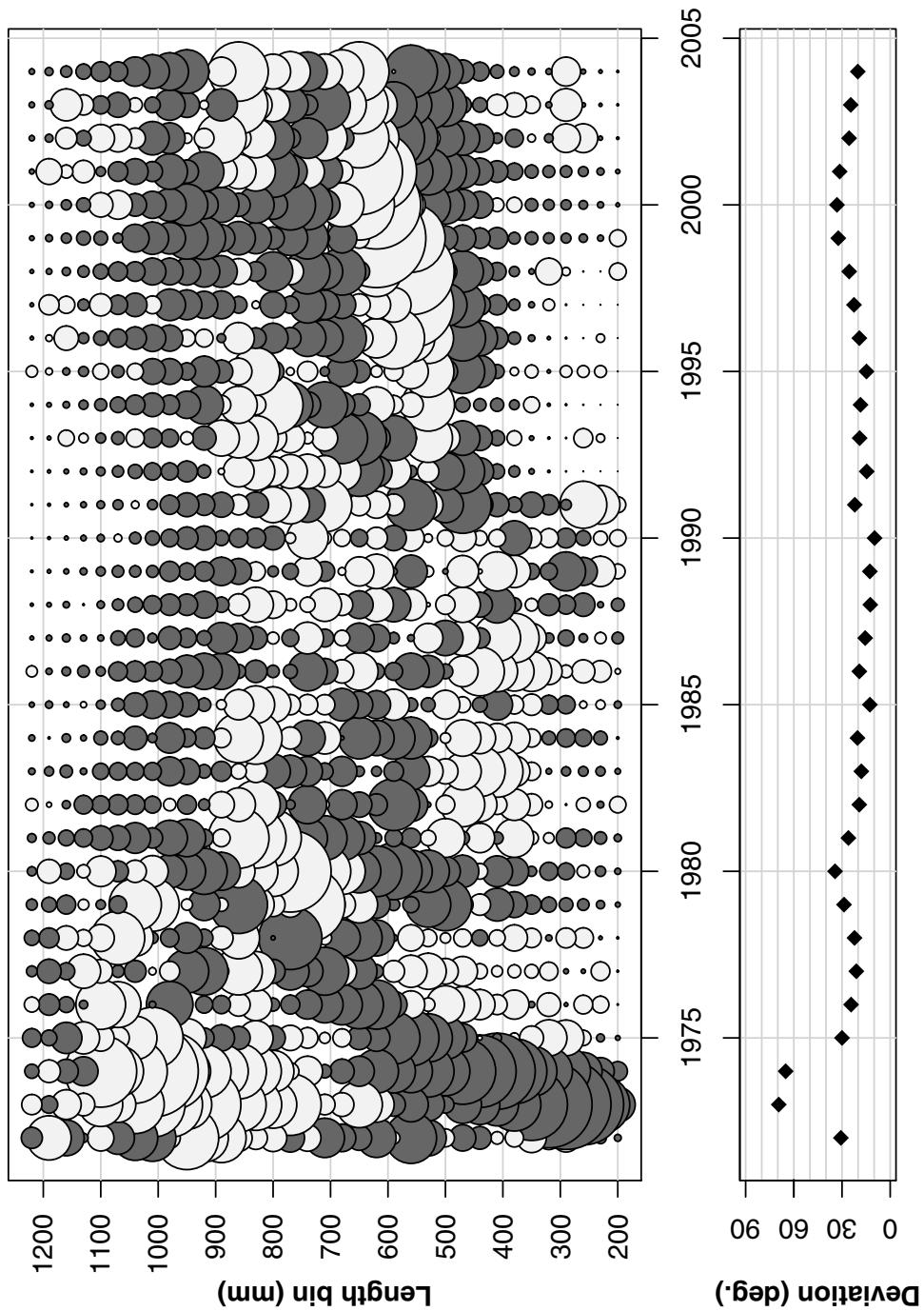


Figure 14. Gag-Base run with time-varying catchability: Estimated (line) and observed (circles) annual age compositions from commercial haulline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

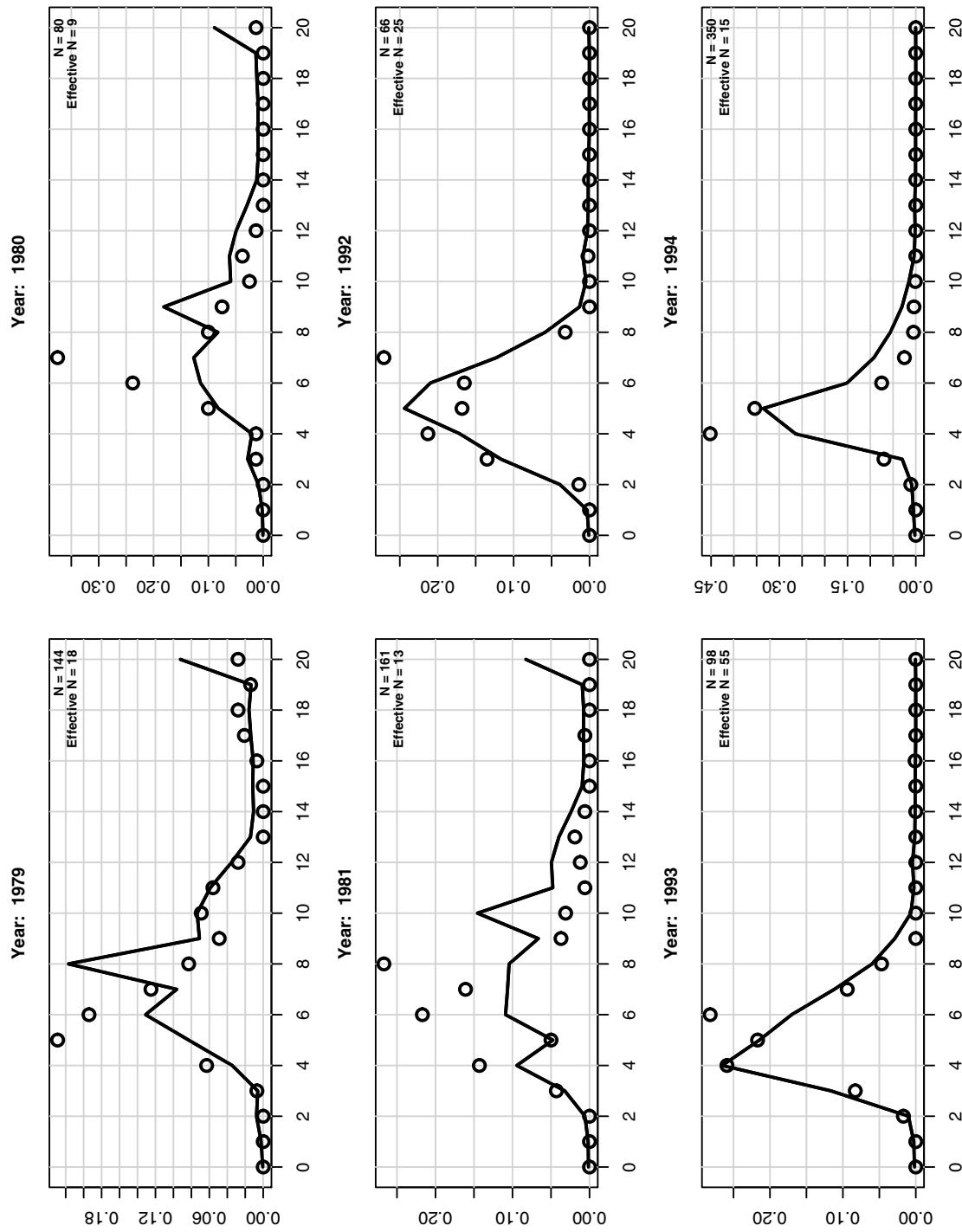


Figure 14. (cont.) Gag-Base run with time-varying catchability: Estimated (line) and observed (circles) annual age compositions from commercial handshake. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

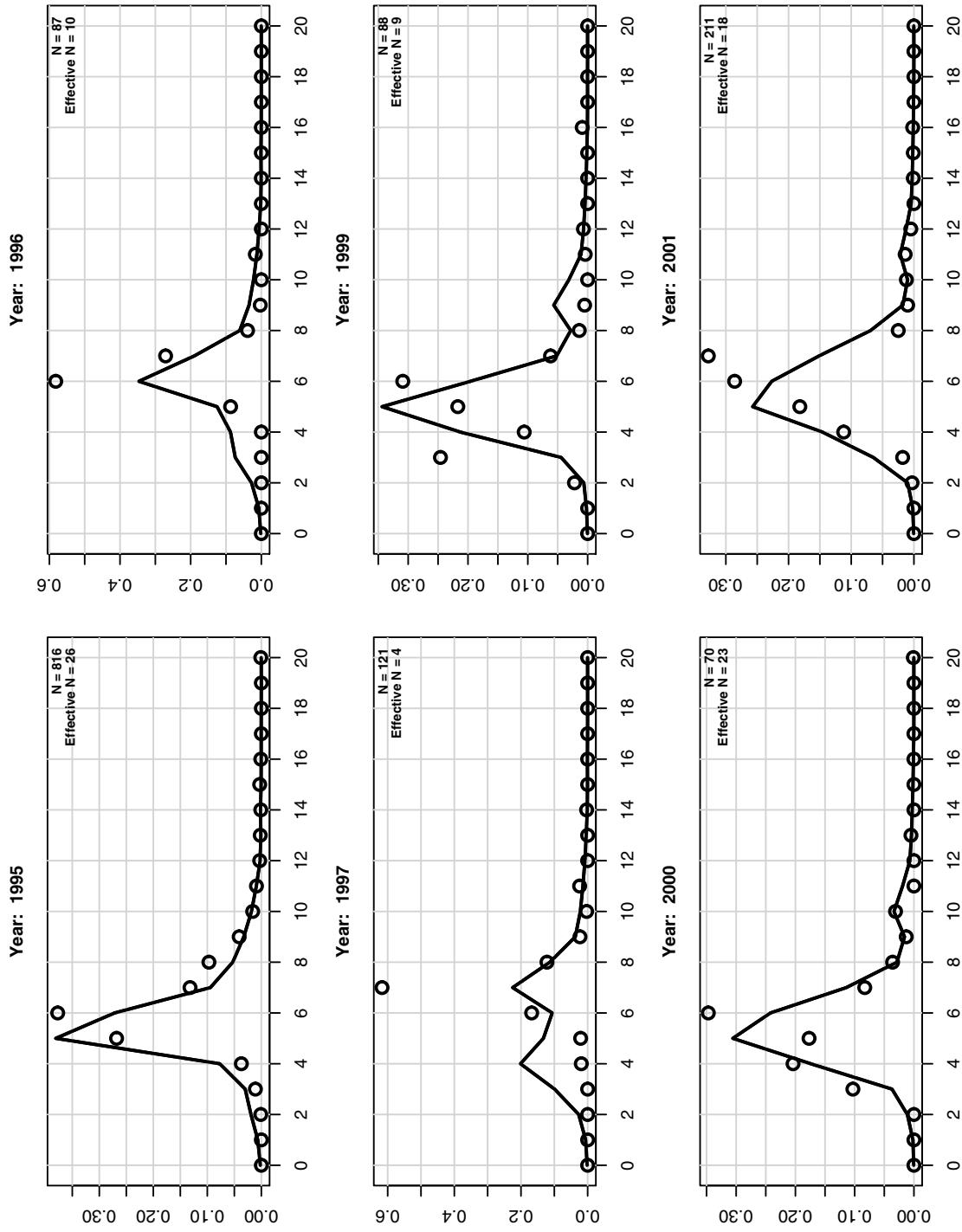


Figure 14. (cont.) Gag- Base run with time-varying catchability: Estimated (line) and observed (circles) annual age compositions from commercial harpoon. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

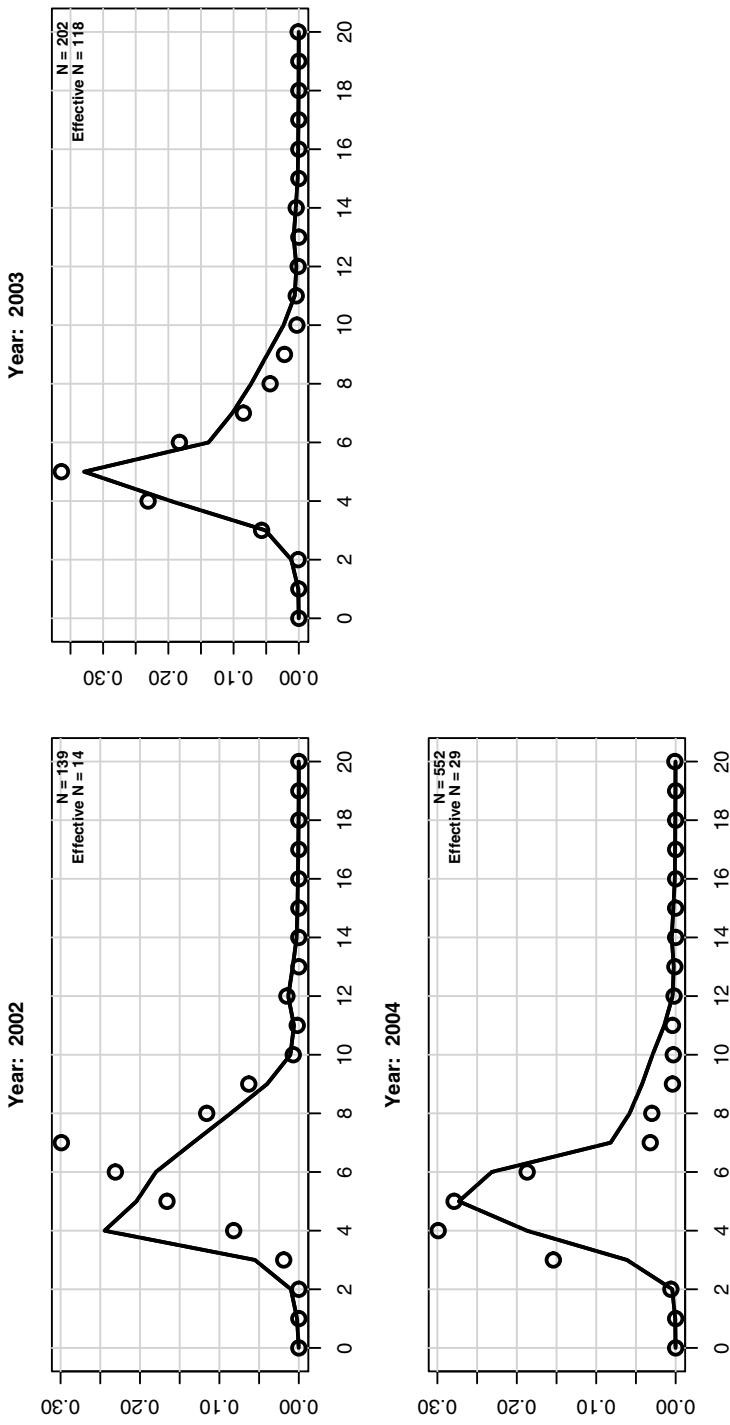


Figure 15. Gag- Base run with constant catchability: Estimated (line) and observed (circles) annual age compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

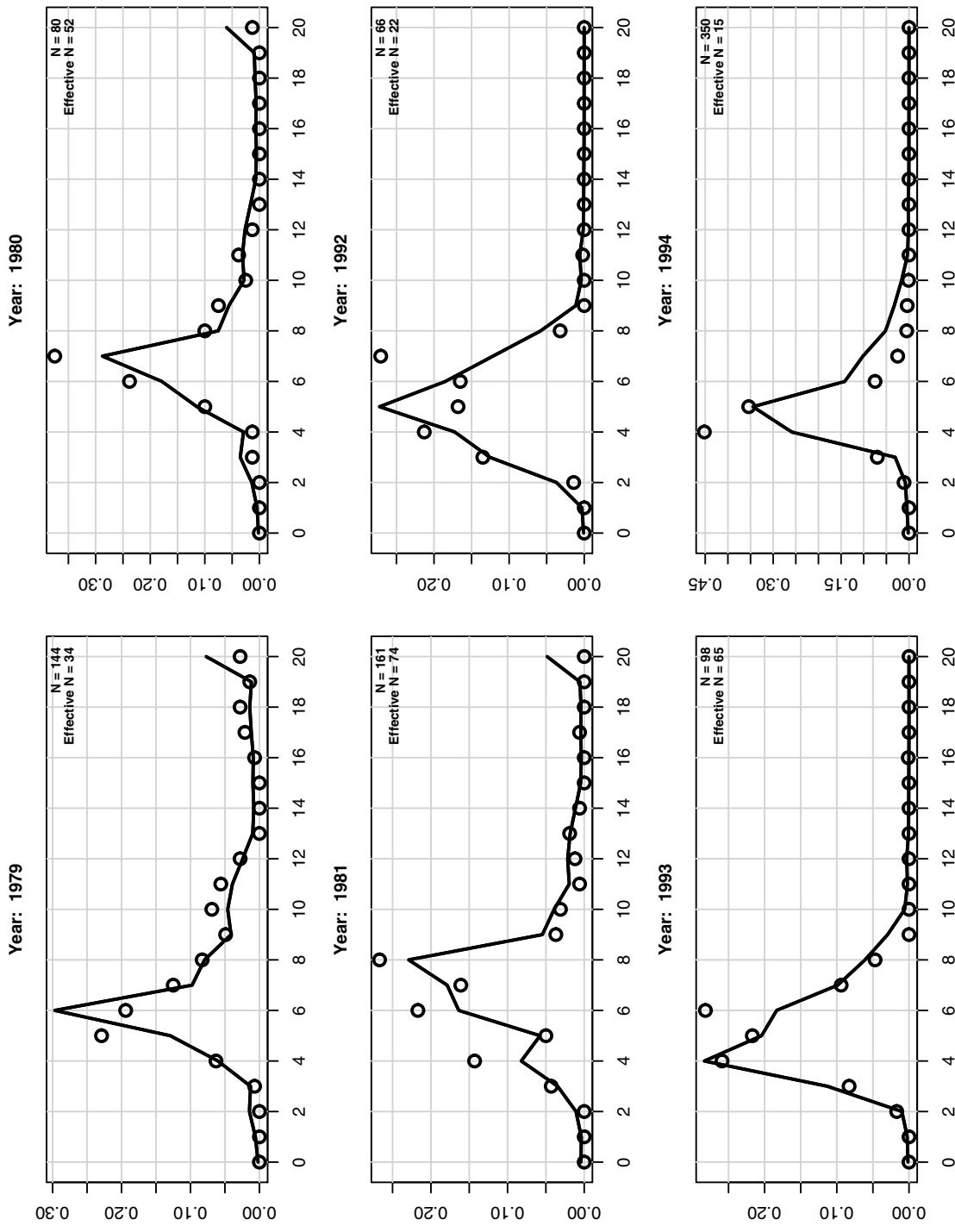


Figure 15. (cont.) Gag-Base run with constant catchability: Estimated (line) and observed (circles) annual age compositions from commercial handline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

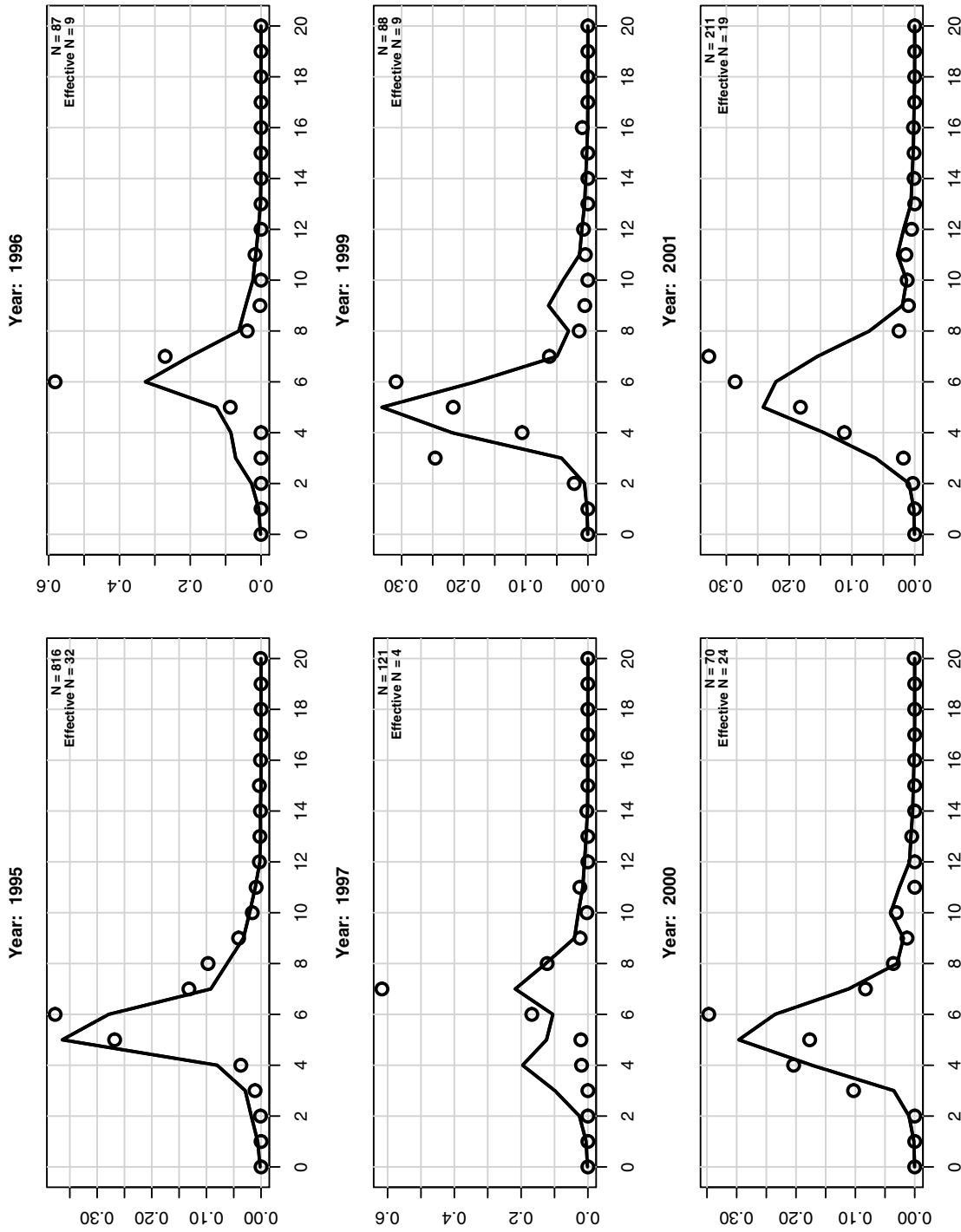


Figure 15. (cont.) Gag-Base run with constant catchability: Estimated (line) and observed (circles) annual age compositions from commercial haulline. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

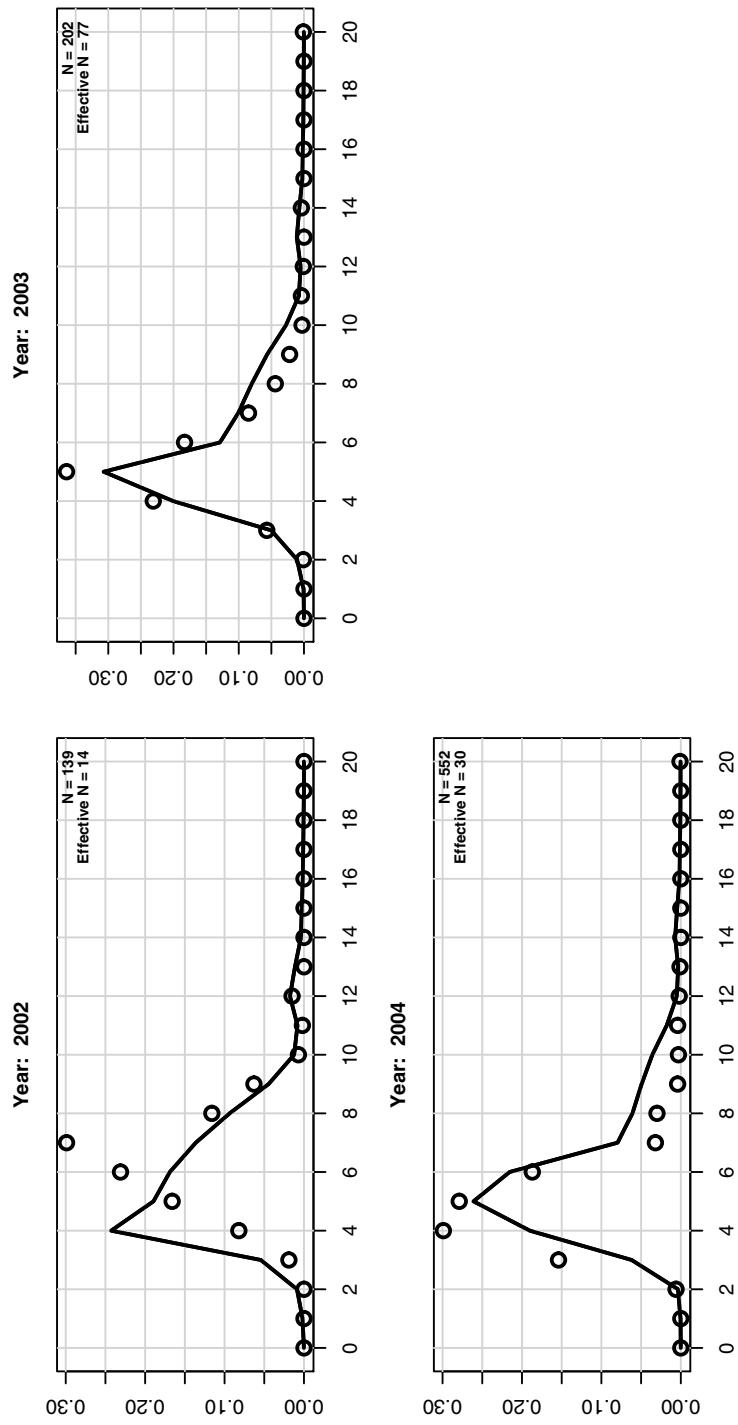


Figure 16. Gag- Base run with time-varying catchability: Bubble plot of age composition residuals from the commercial handline fishery; Dark bubbles are overestimates and light bubbles are underestimates.

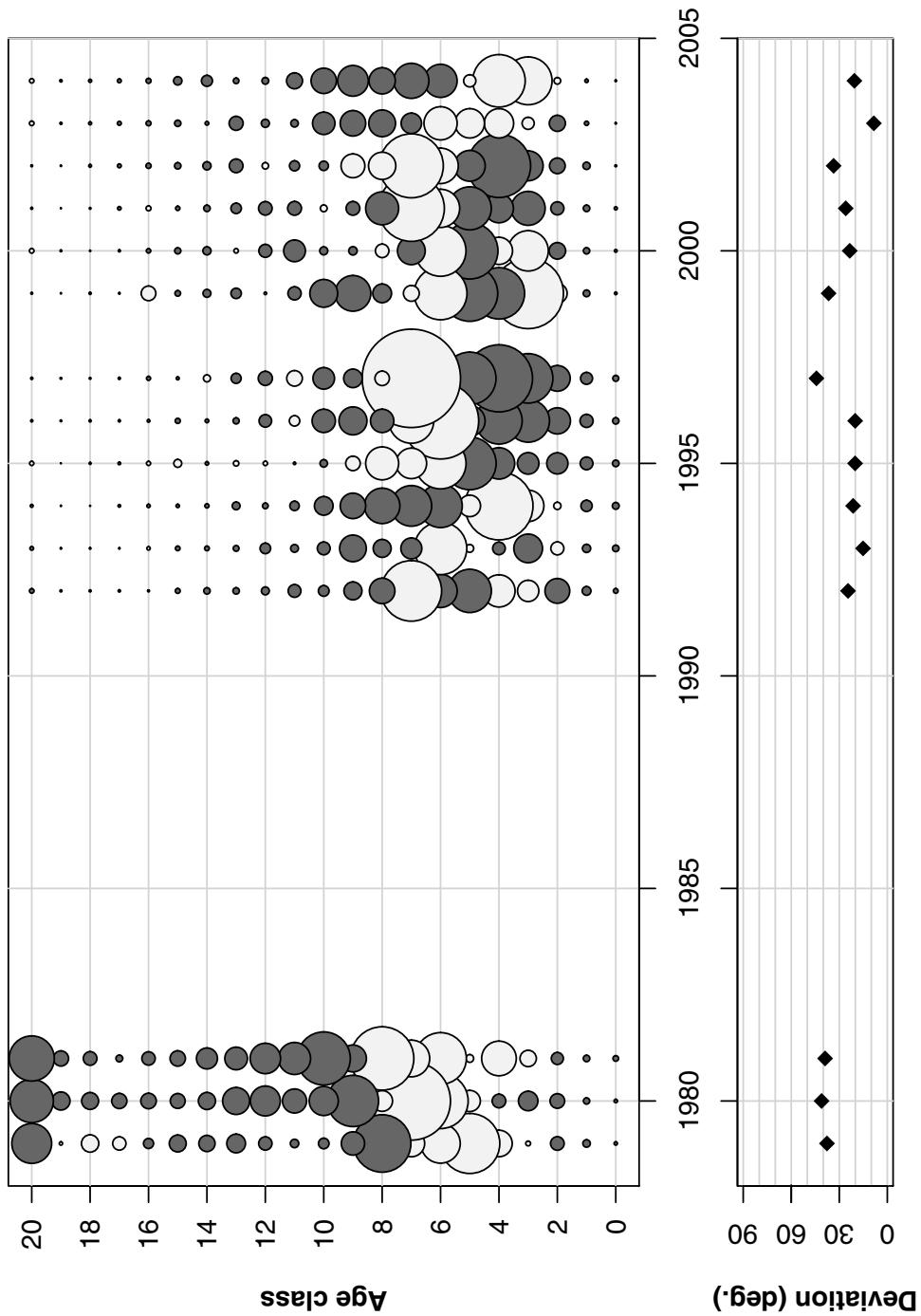


Figure 17. Gag-Base run with constant catchability: Bubble plot of age composition residuals from the commercial handline fishery; Dark bubbles are overestimates and light bubbles are underestimates.

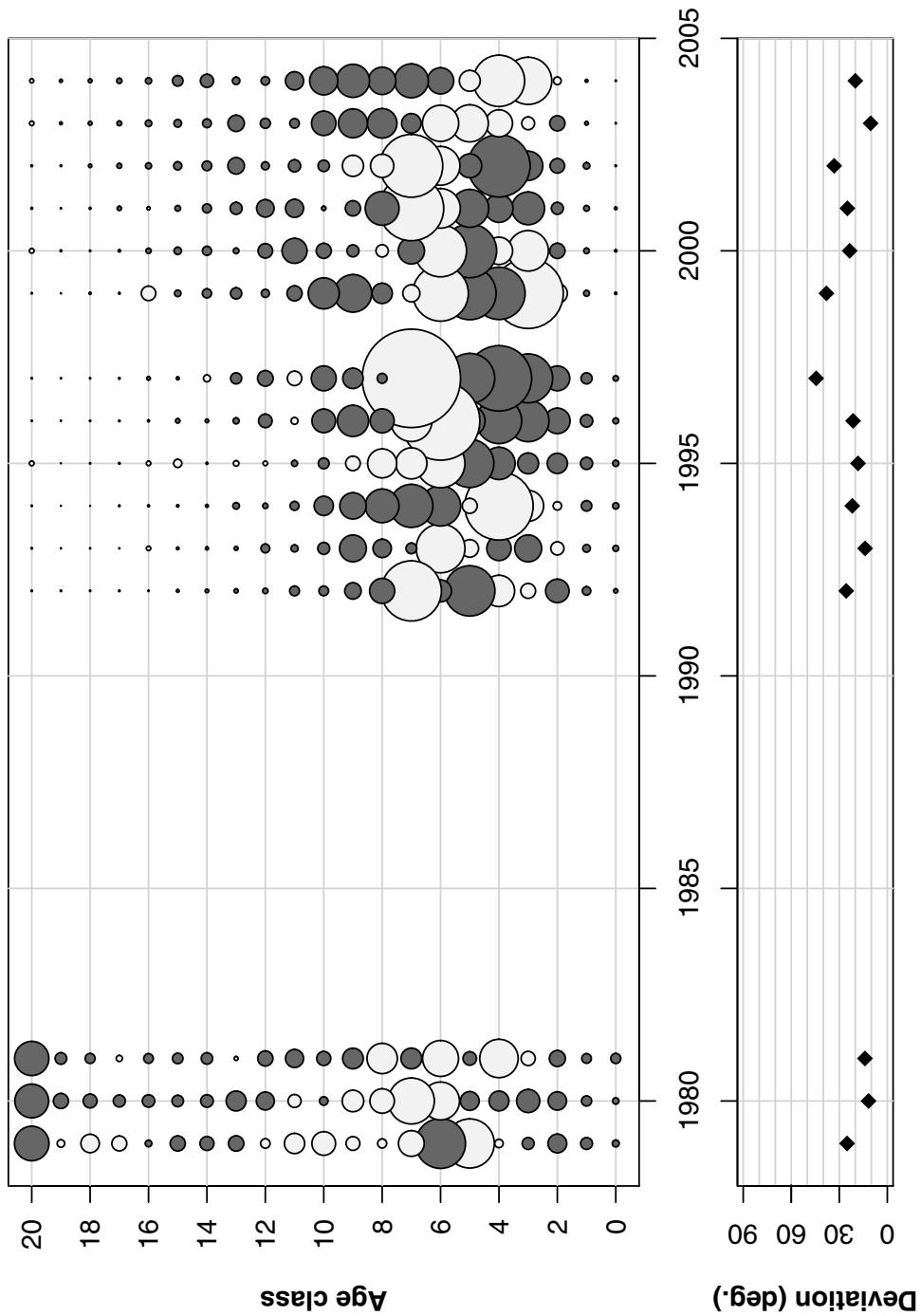


Figure 18. Gag-Base run with time-varying catchability: Estimated (line) and observed (circles) annual age compositions from commercial diving. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown.

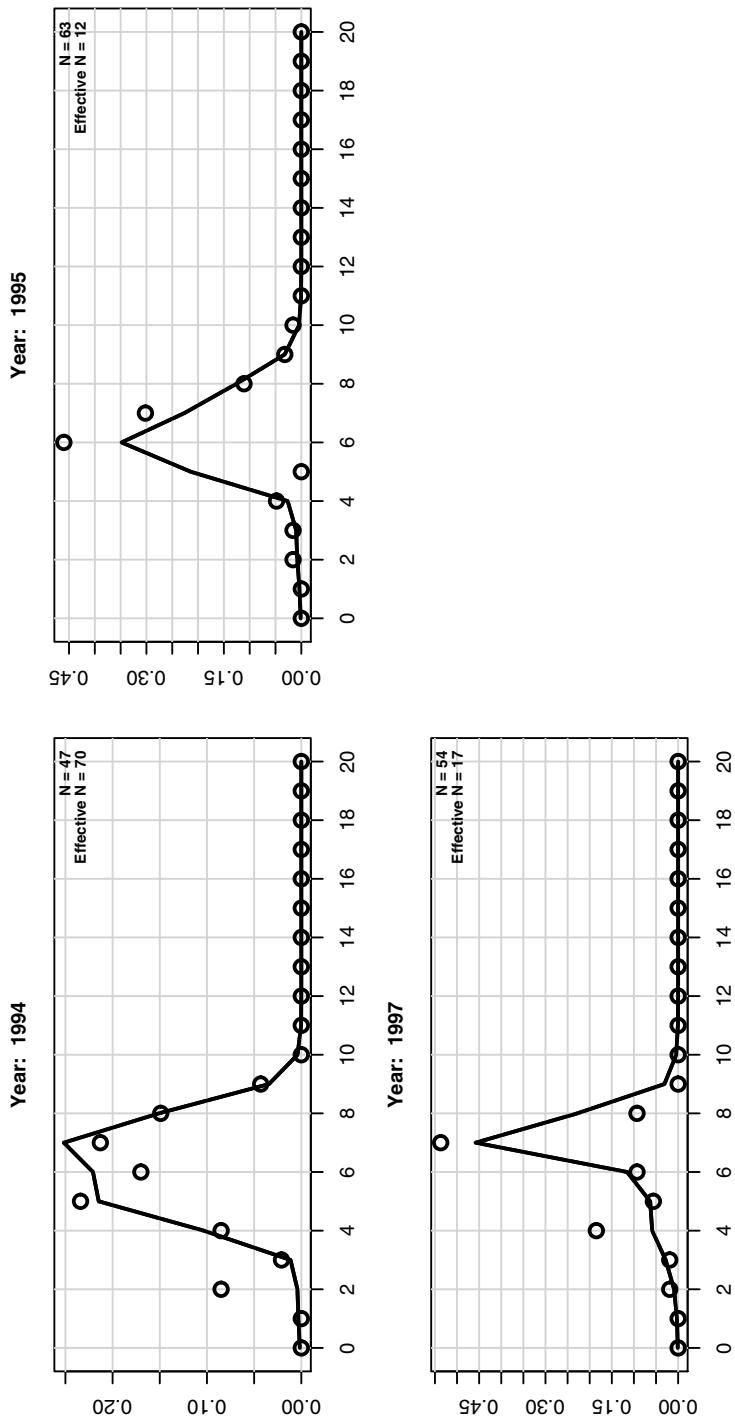


Figure 19. Gag- Base run with constant catchability: Estimated (line) and observed (circles) annual age compositions from commercial diving. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are shown. Observed sample size (N) and effective sample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

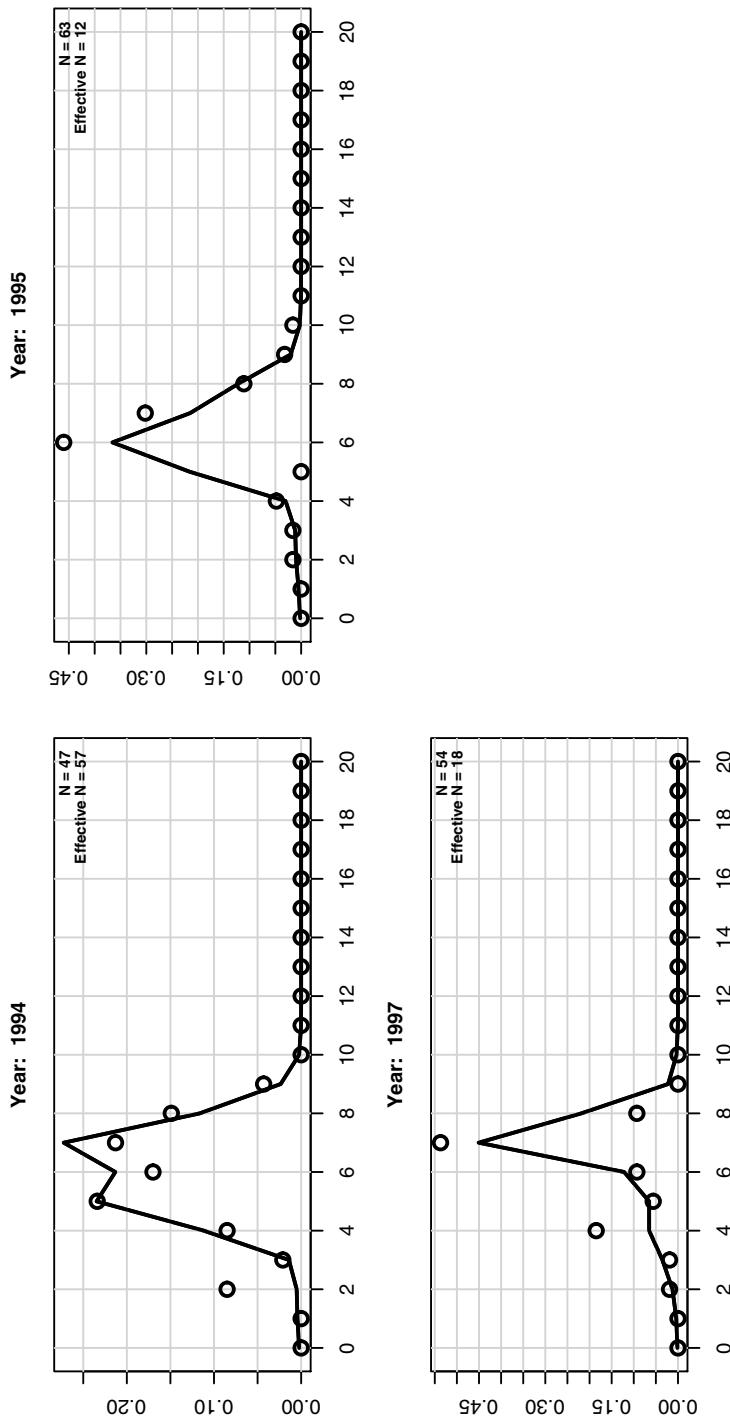


Figure 20. Gag-Base run with time-varying catchability: Bubble plot of age composition residuals from the commercial diving fishery; Dark bubbles are overestimates and light bubbles are underestimates.

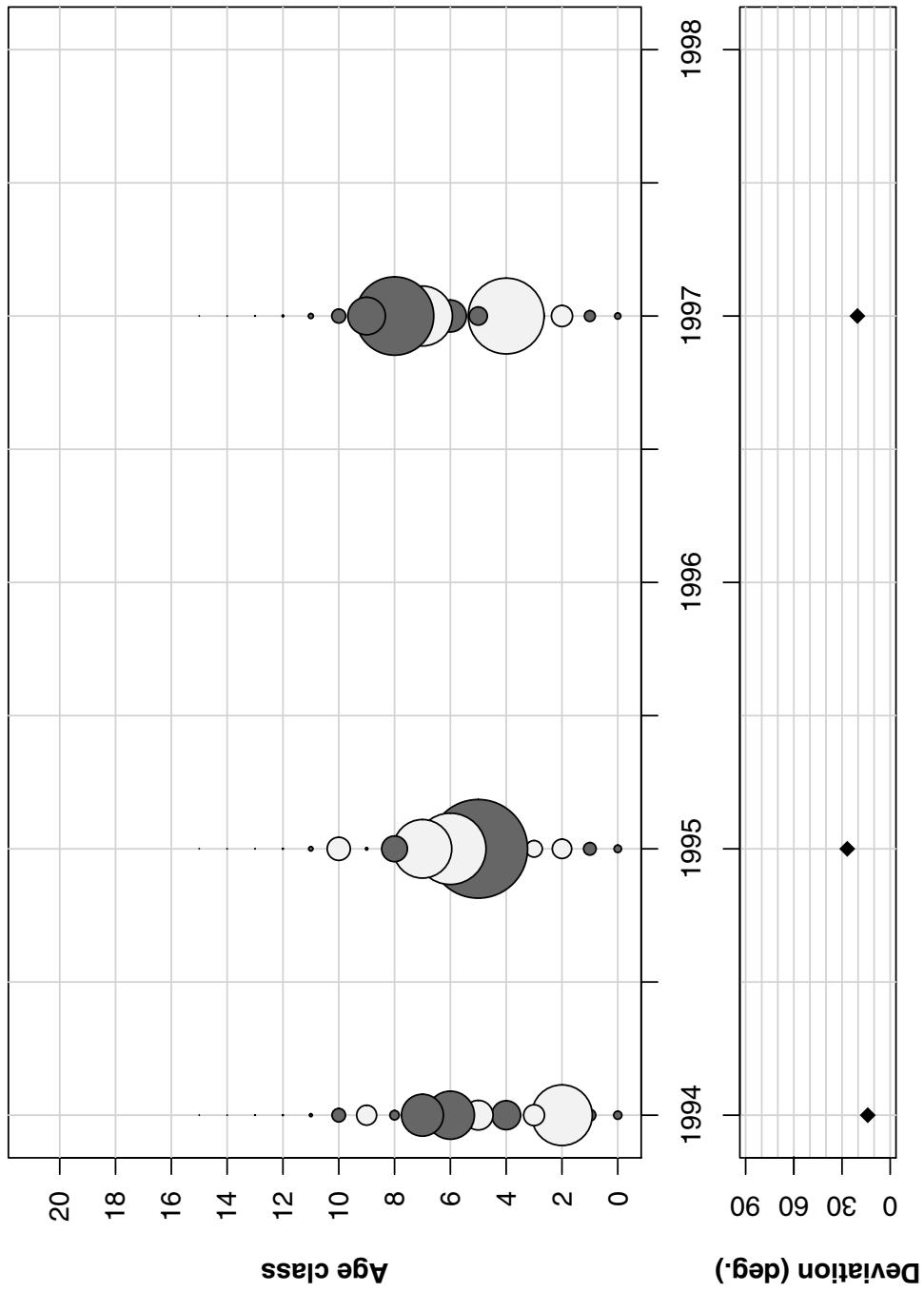


Figure 21. Gag - Base run with constant catchability: Bubble plot of age composition residuals from the commercial diving fishery; Dark bubbles are overestimates and light bubbles are underestimates.

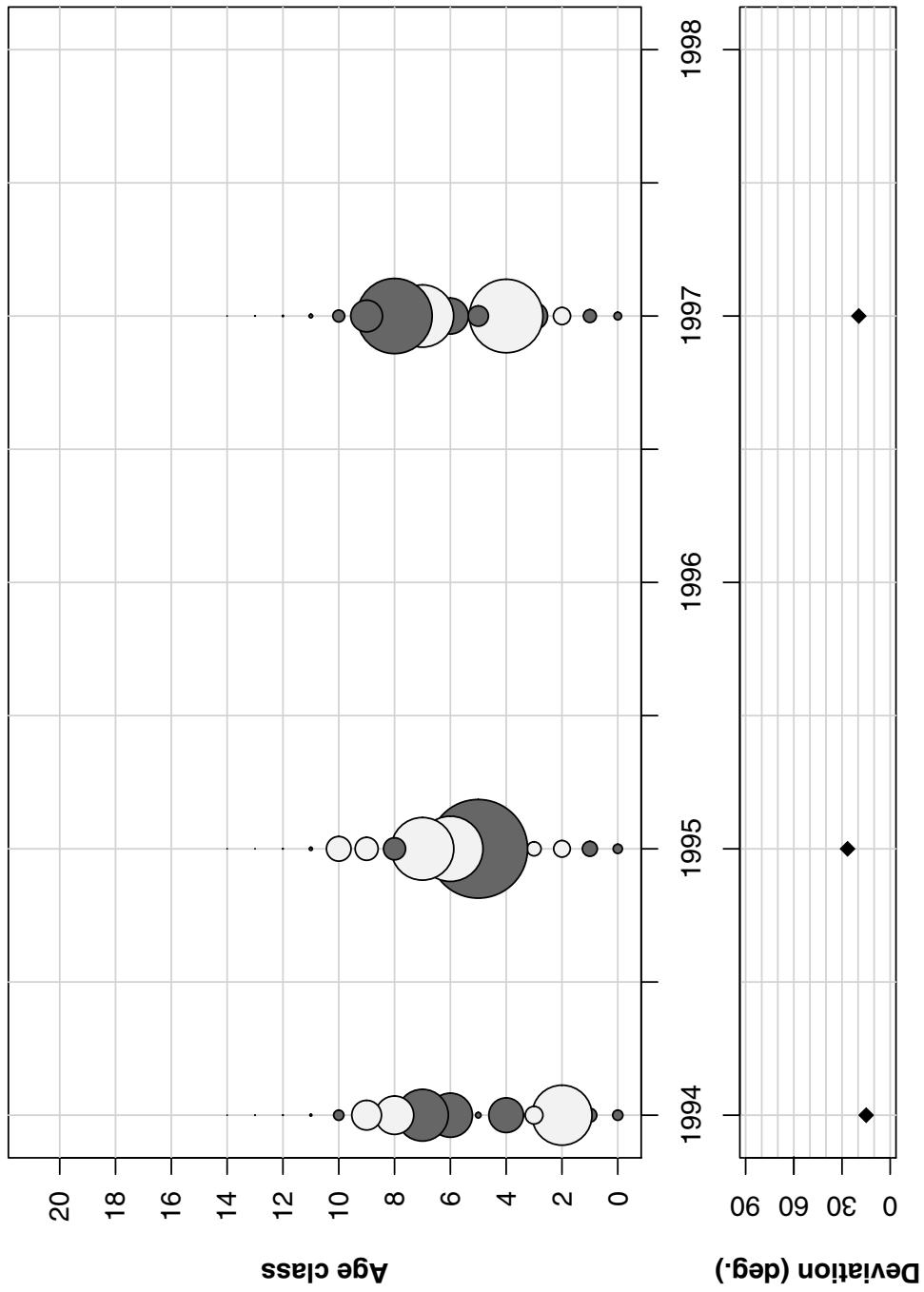


Figure 22. Gag- Base run with time-varying catchability: Estimated (line) and observed (circles) annual age compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions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

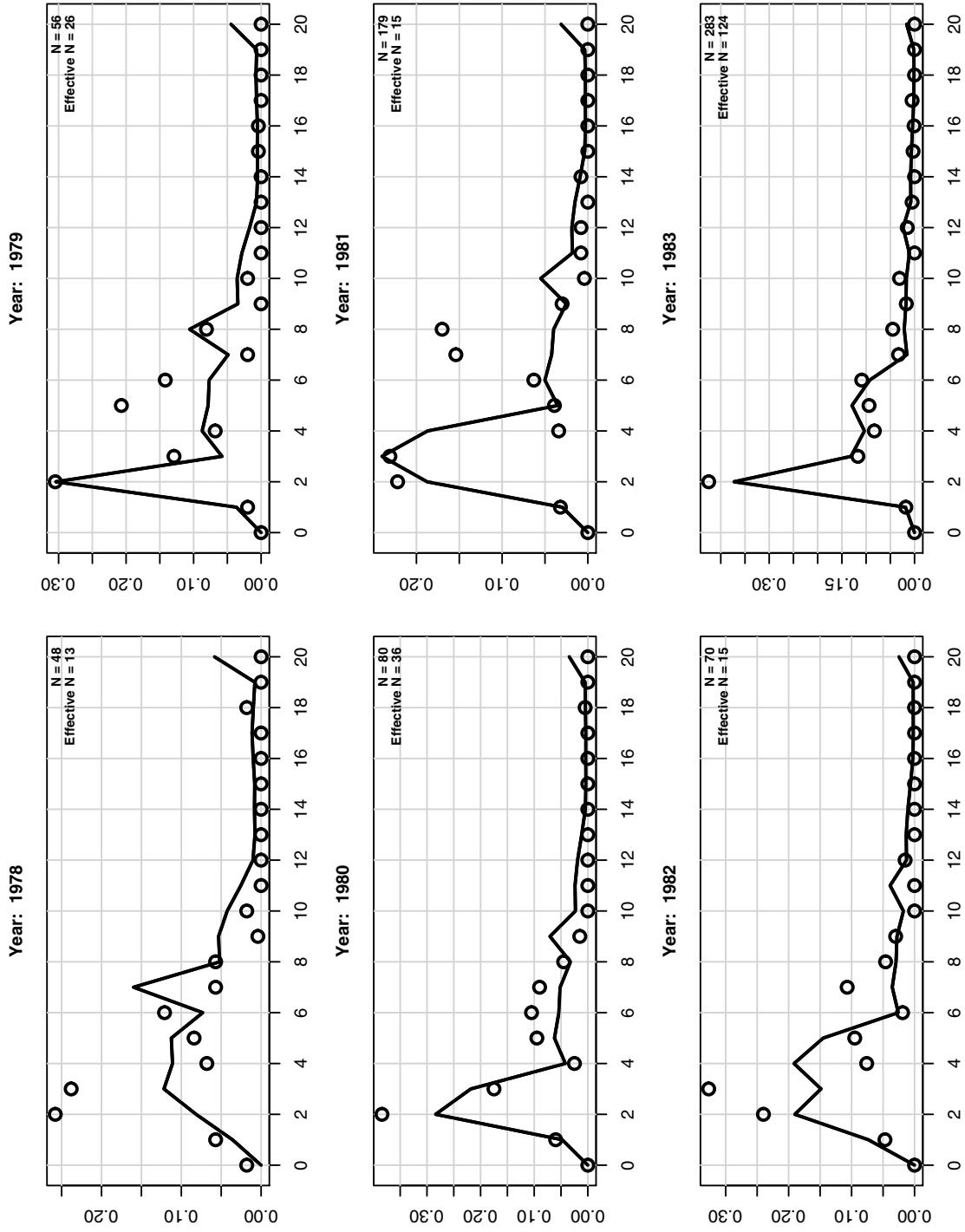


Figure 22. (cont.) Gag-Base run with time-varying catchability: Estimated (line) and observed (circles) annual age compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions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

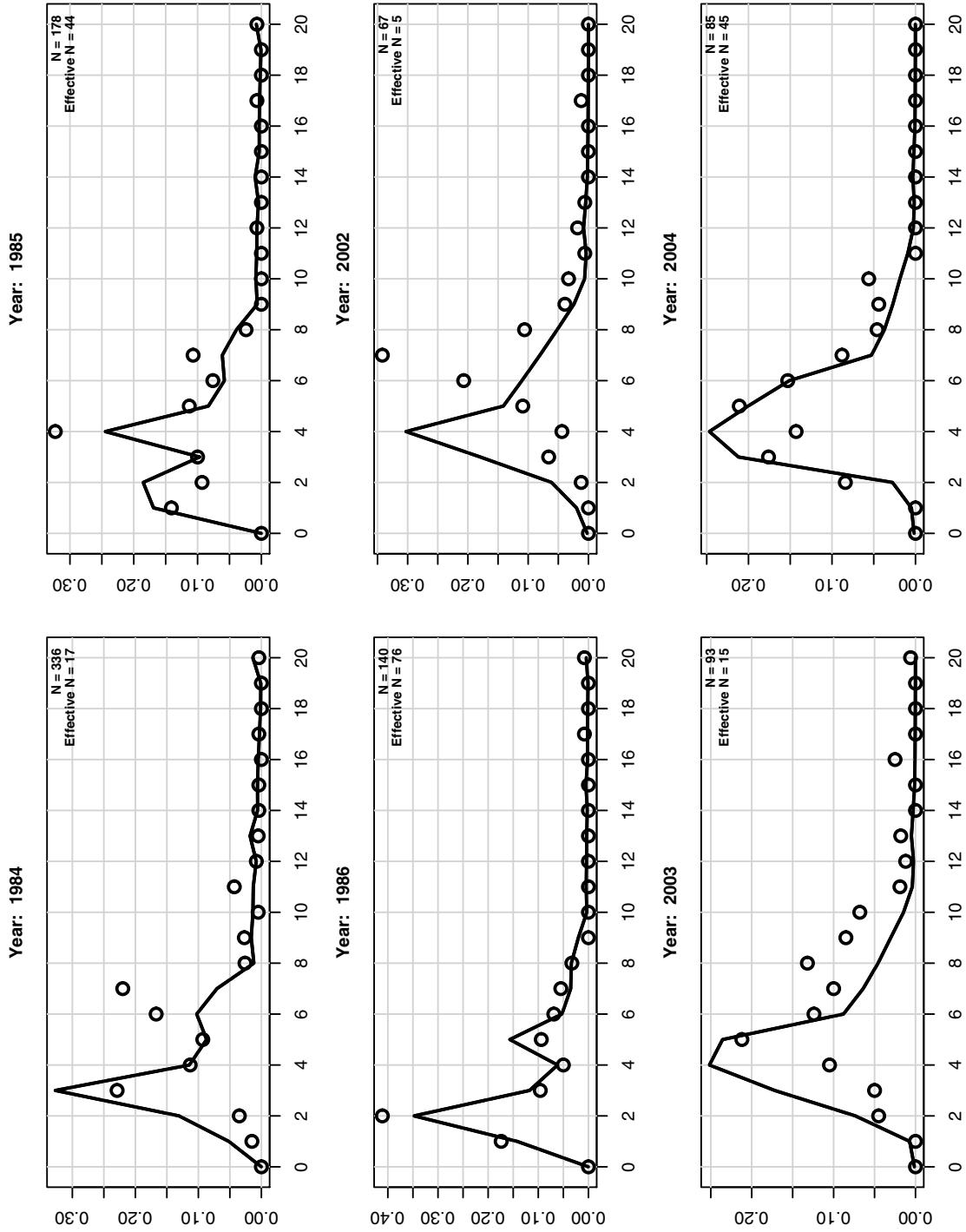


Figure 23. Gag- Base run with constant catchability: Estimated (line) and observed (circles) annual age compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions are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

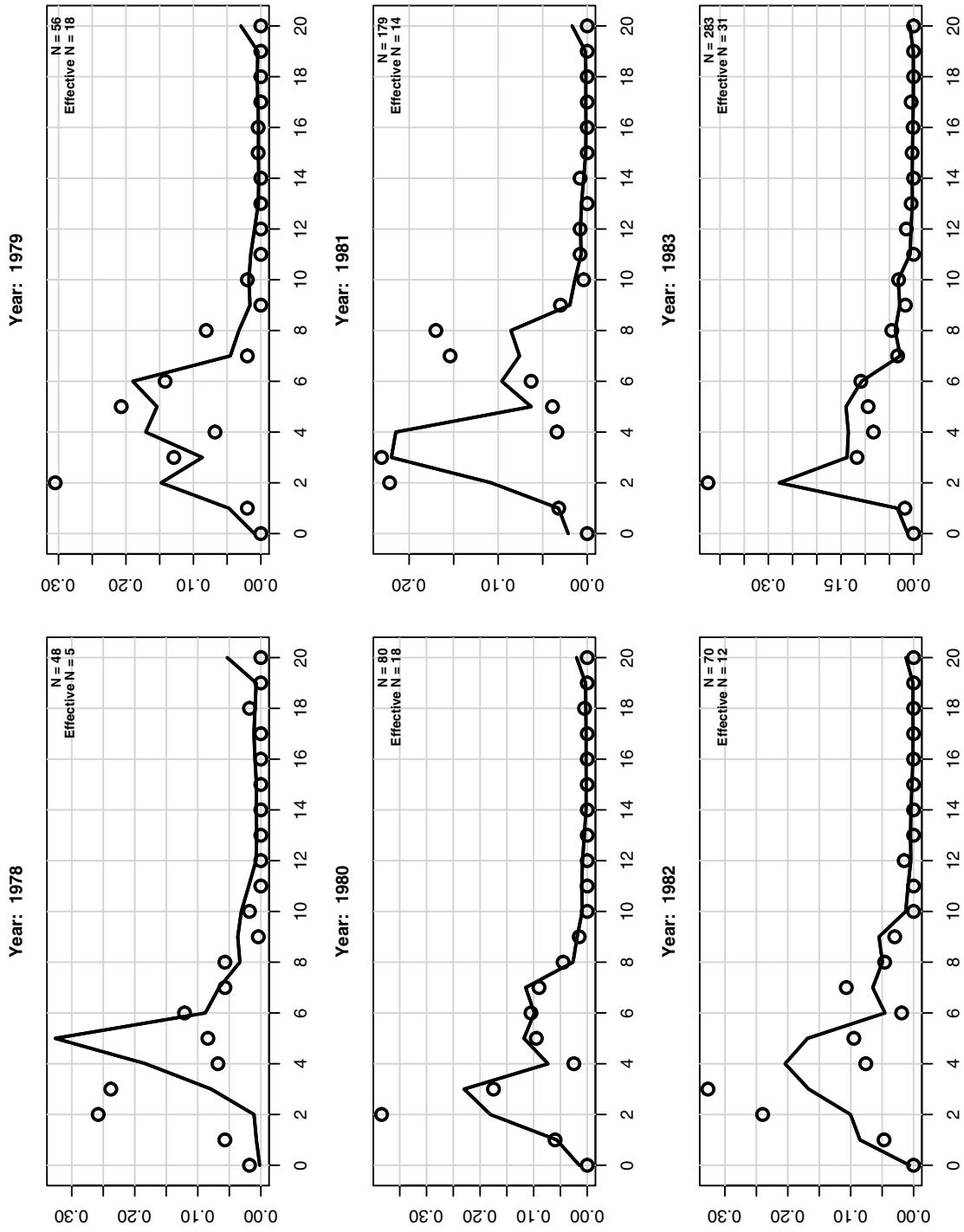


Figure 23. (cont.) Gag-Base run with constant catchability: Estimated (line) and observed (circles) annual age compositions from the recreational fishery component sampled by the headboat program. Observed sample size (N) and effective sample sizes, based on the observed and model estimated compositions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

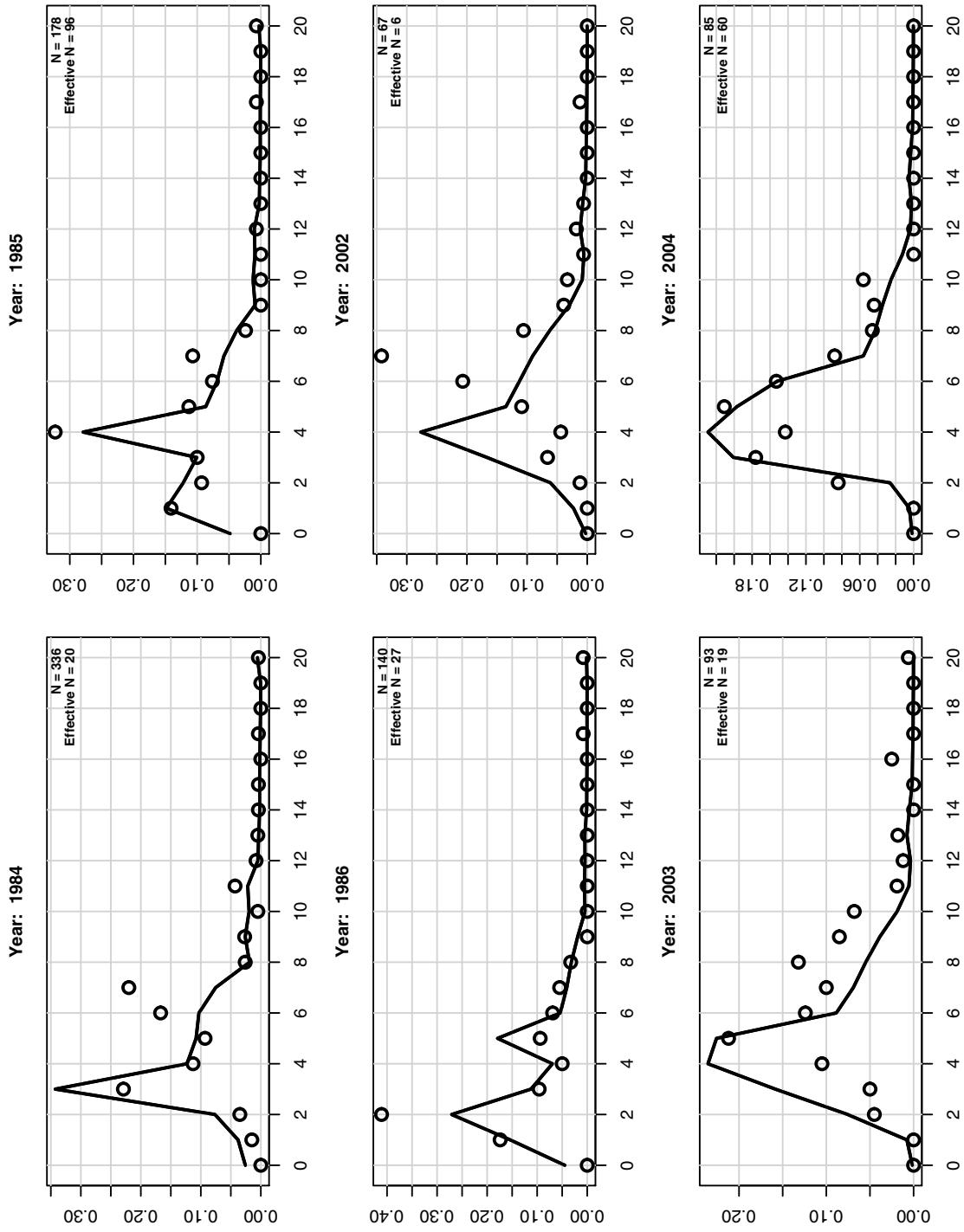


Figure 24. Gag-Base run with time-varying catchability: Bubble plot of age composition residuals from the recreational headboat fishery; Dark bubbles are overestimates and light bubbles are underestimates.

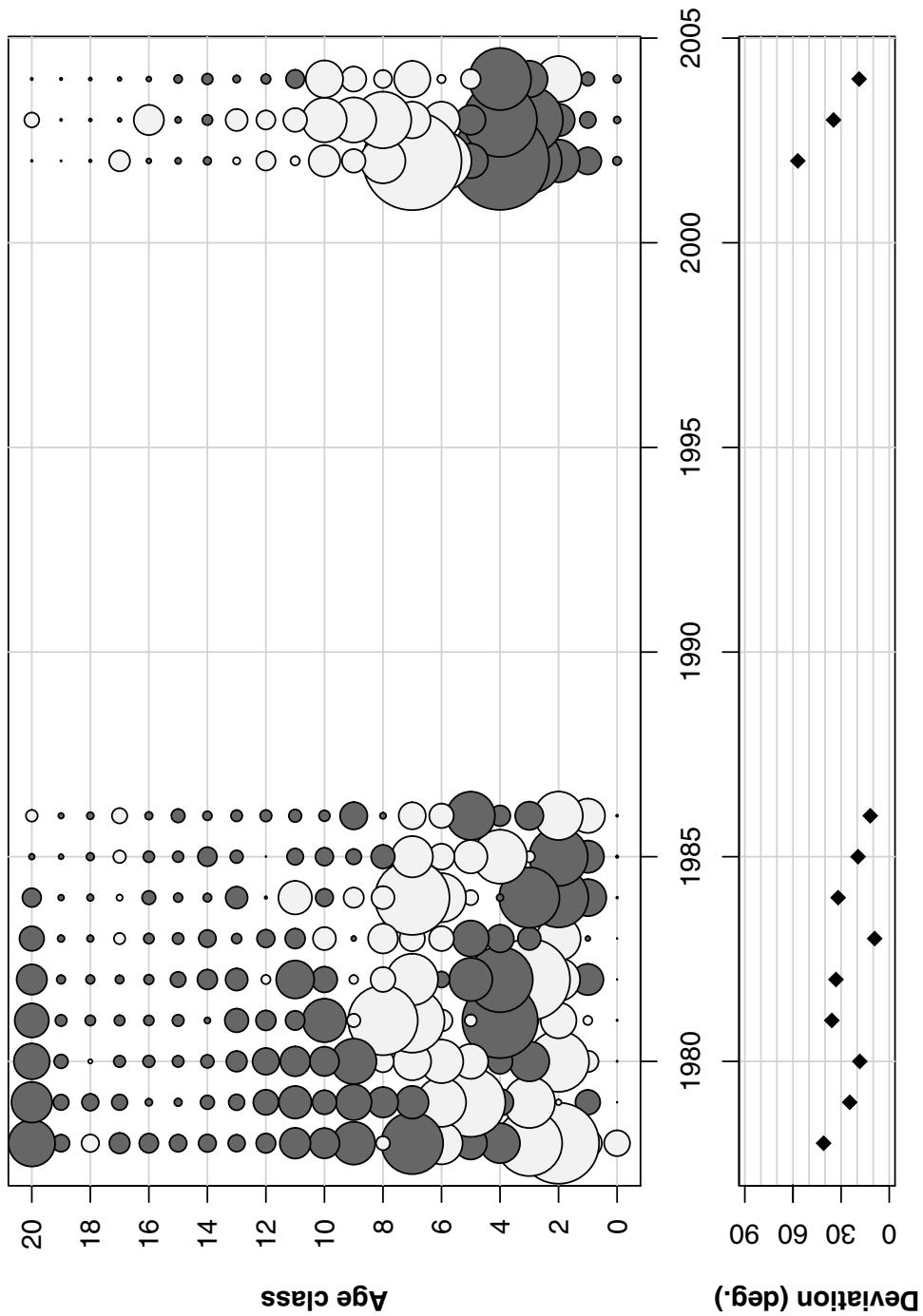


Figure 25. Gag-Base run with constant catchability: Bubble plot of age composition residuals from the recreational headboat fishery; Dark bubbles are overestimates and light bubbles are underestimates.

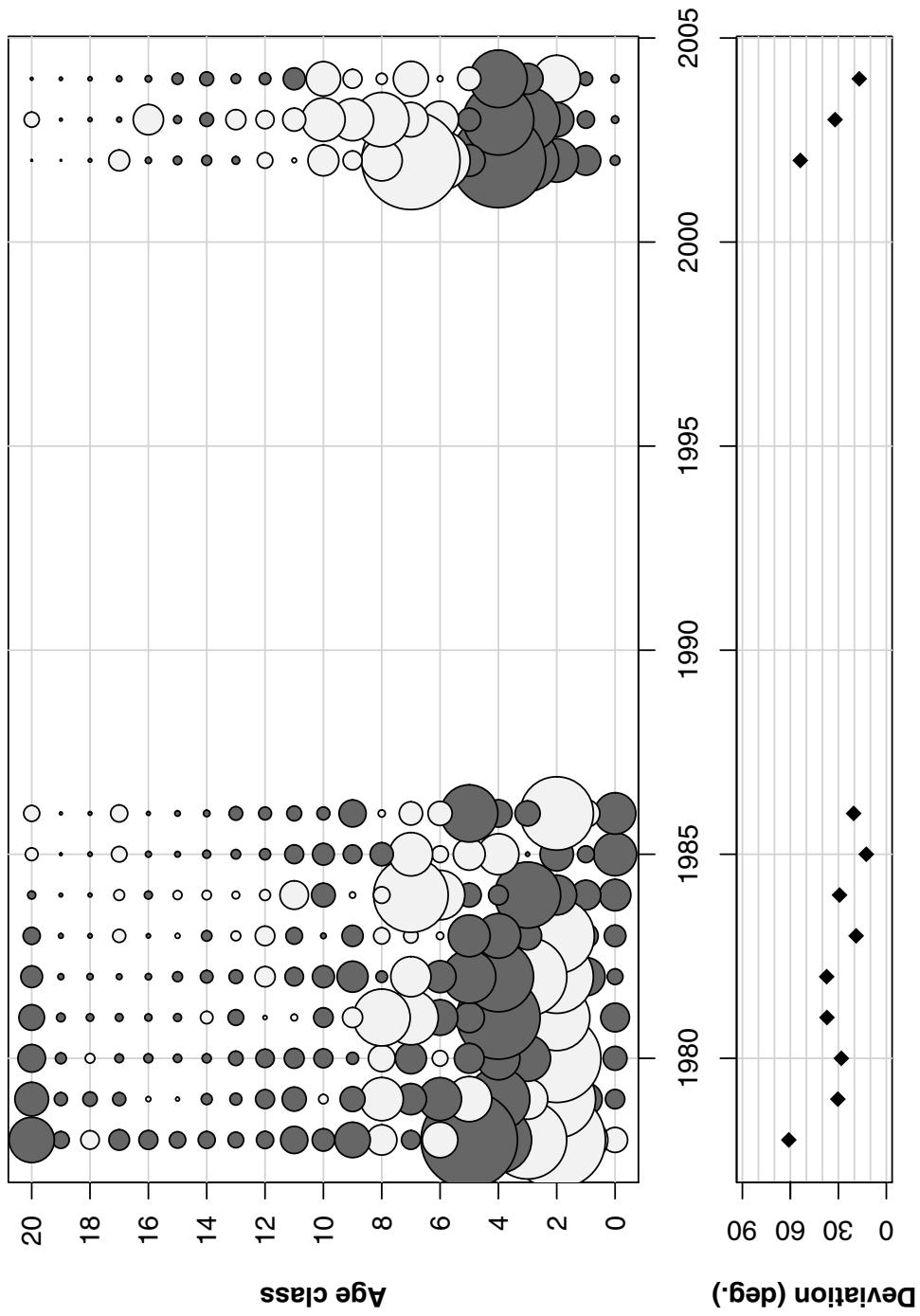


Figure 26. Gag- Time-varying catchability run: Commercial landings (klb) of gag from the assessment model, estimated (line, filled circles) and observed (open circles). A) Handline; and B) Diving. Note difference of scales.

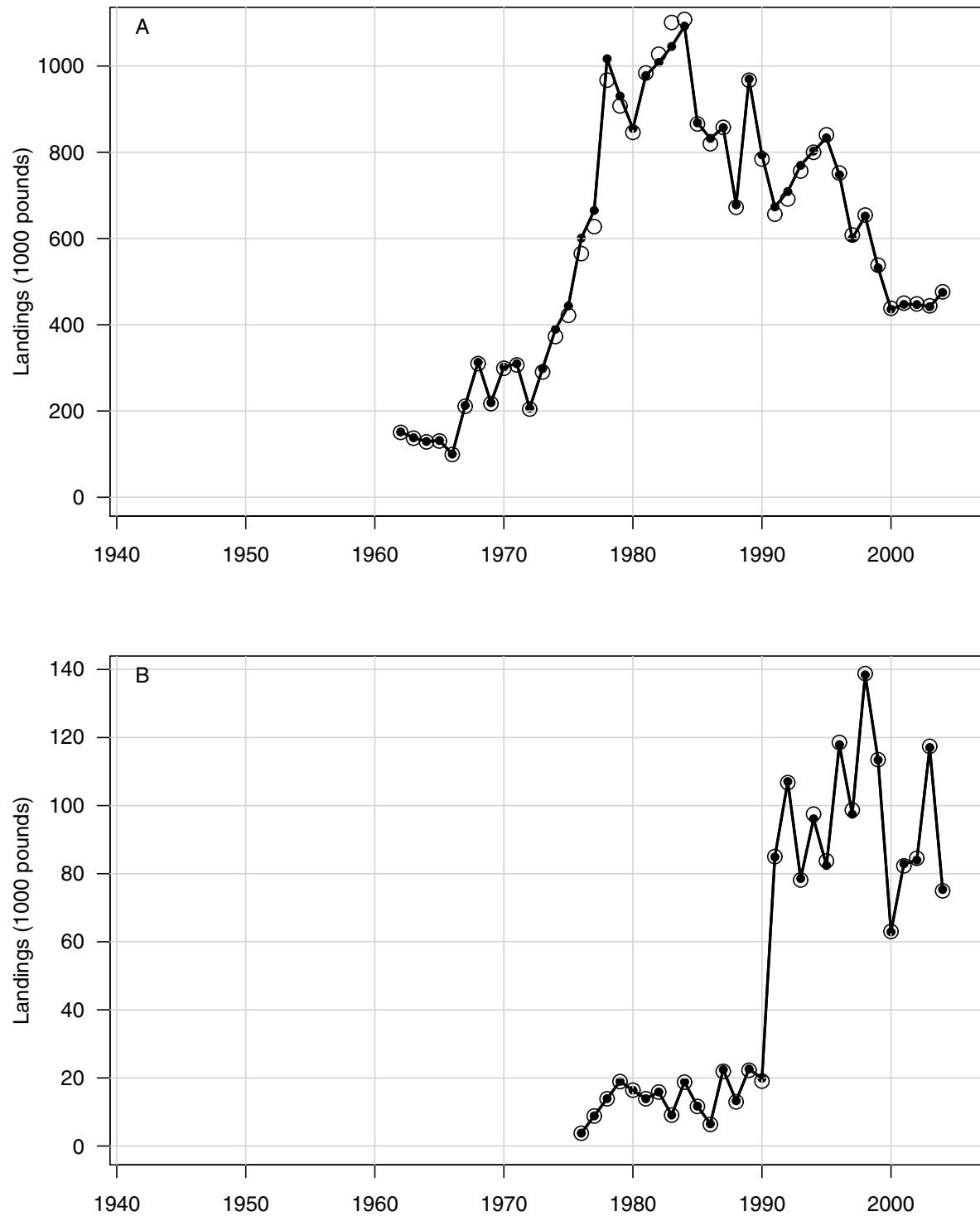


Figure 27. Constant catchability run: Commercial landings (klb) of gag from the assessment model, estimated (line, filled circles) and observed (open circles). A) Handline; and B) Diving. Note difference of scales.

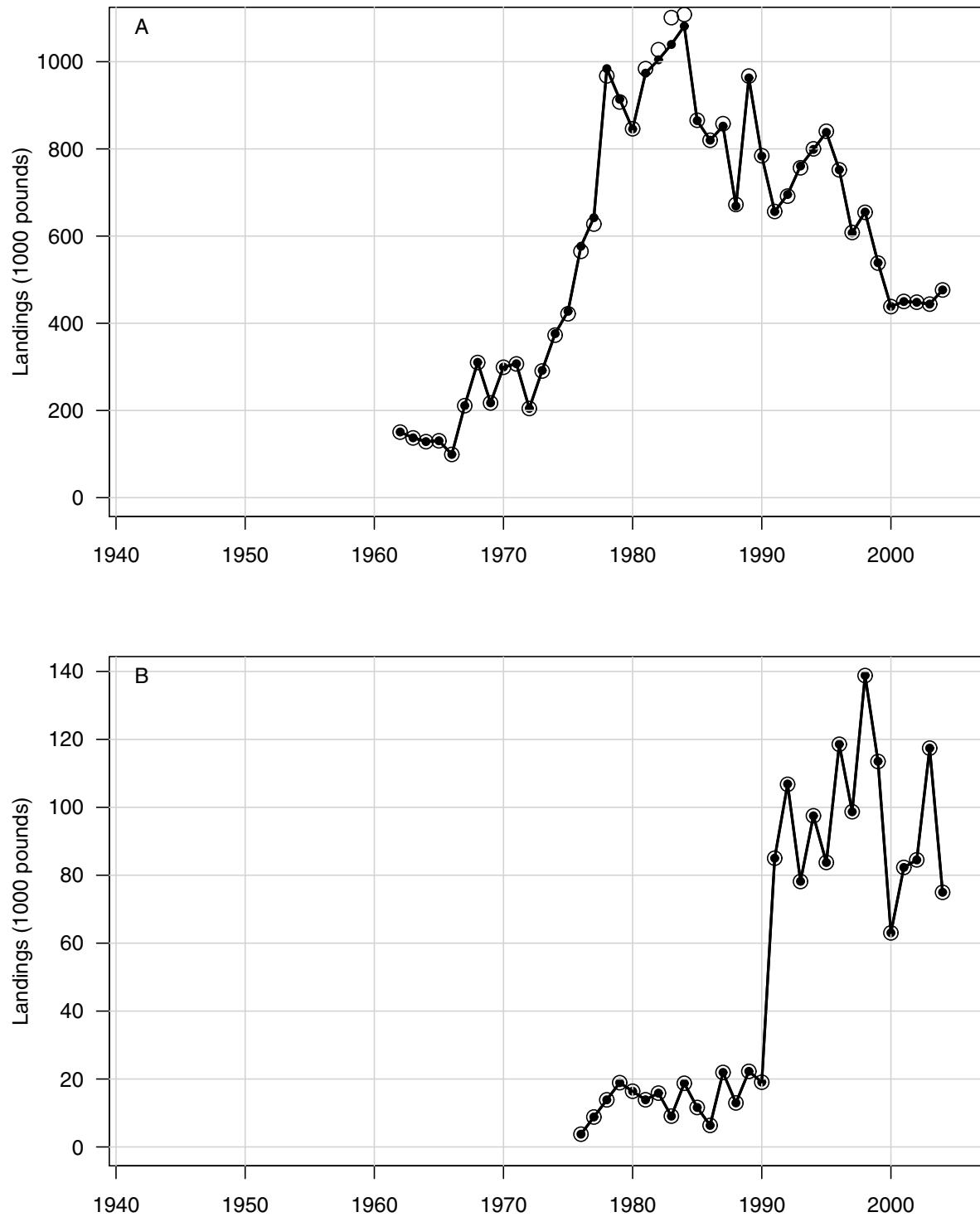


Figure 28. Gag- Time-varying catchability run: Recreational landings (1000s fish) of gag from the assessment model, estimated (line, filled circles) and observed (open circles). A) Headboat and B) MRFSS. Note difference of scales.

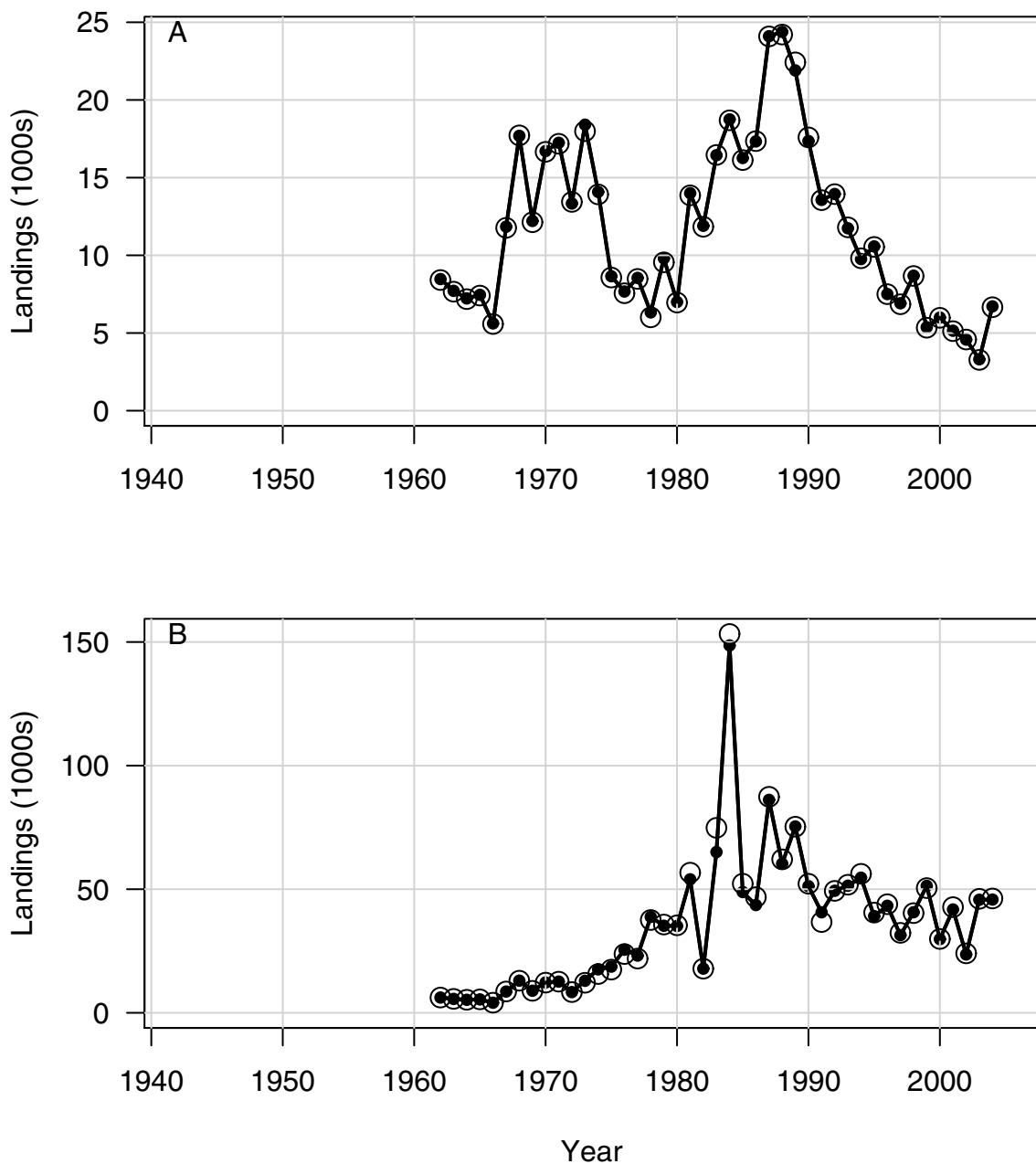


Figure 29. Gag- Constant catchability run: Recreational landings (1000s fish) of gag from the assessment model, estimated (line, filled circles) and observed (open circles). A) Headboat and B) MRFSS. Note difference of scales.

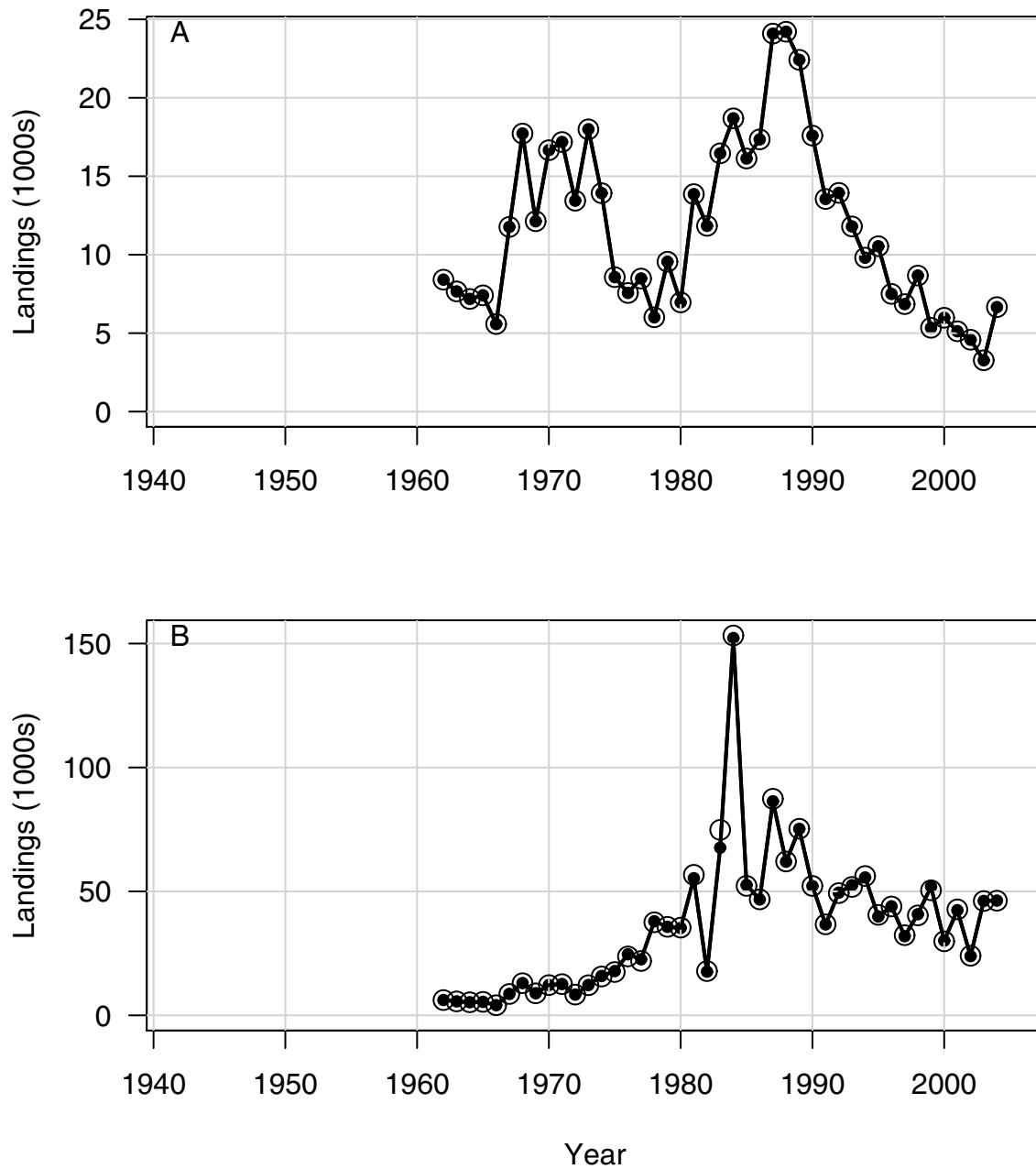


Figure 30. Gag- Discard mortalities (1000s fish) of gag from the time-varying assessment model, estimated (line, filled circles) and observed (open circles). A) Commercial handline; B) Headboat; and C) MRFSS. Note difference of scales.

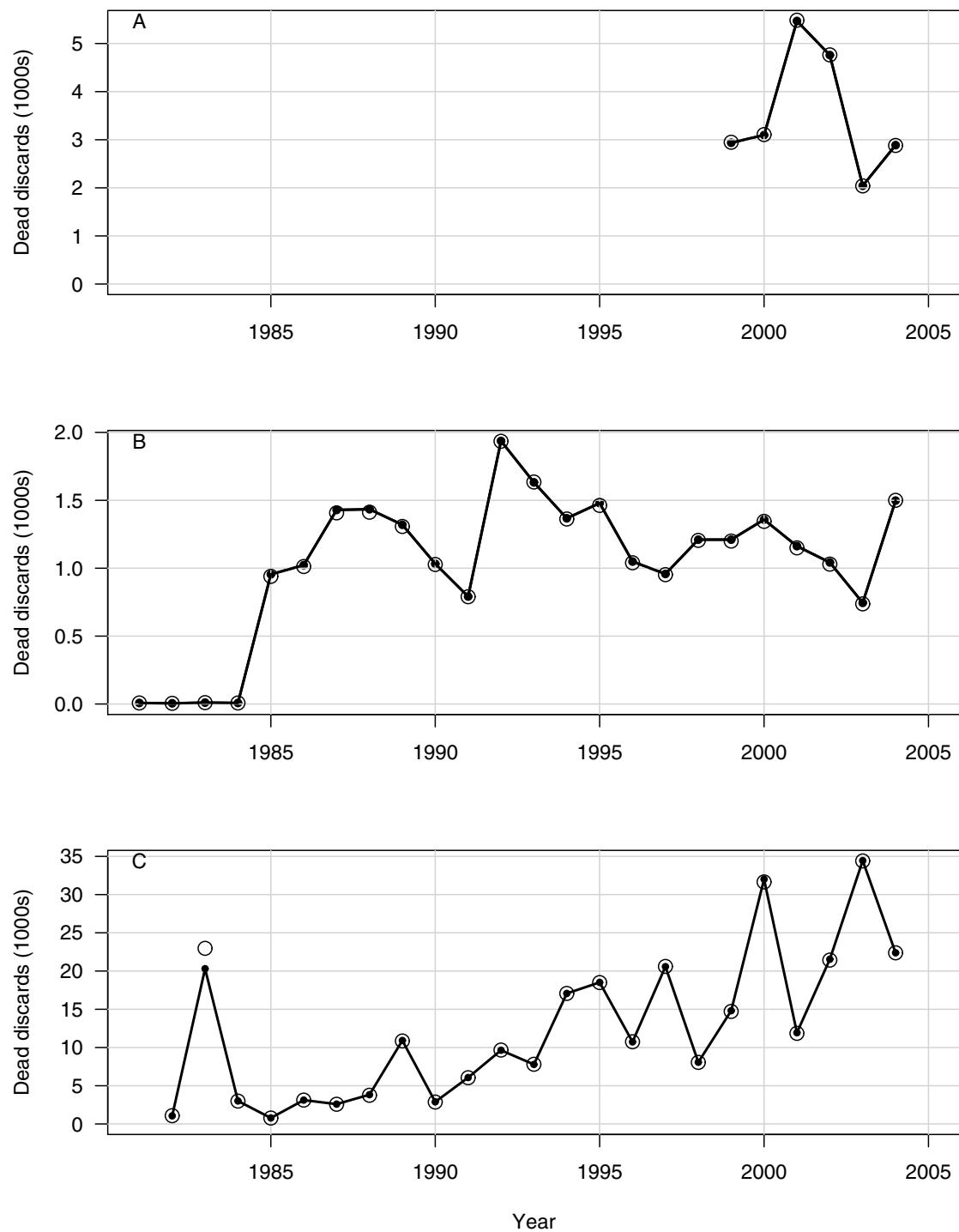


Figure 31. Gag- Discard mortalities (1000s fish) of gag from the constant assessment model, estimated (line, filled circles) and observed (open circles). A) Commercial handline; B) Headboat; and C) MRFSS. Note difference of scales.

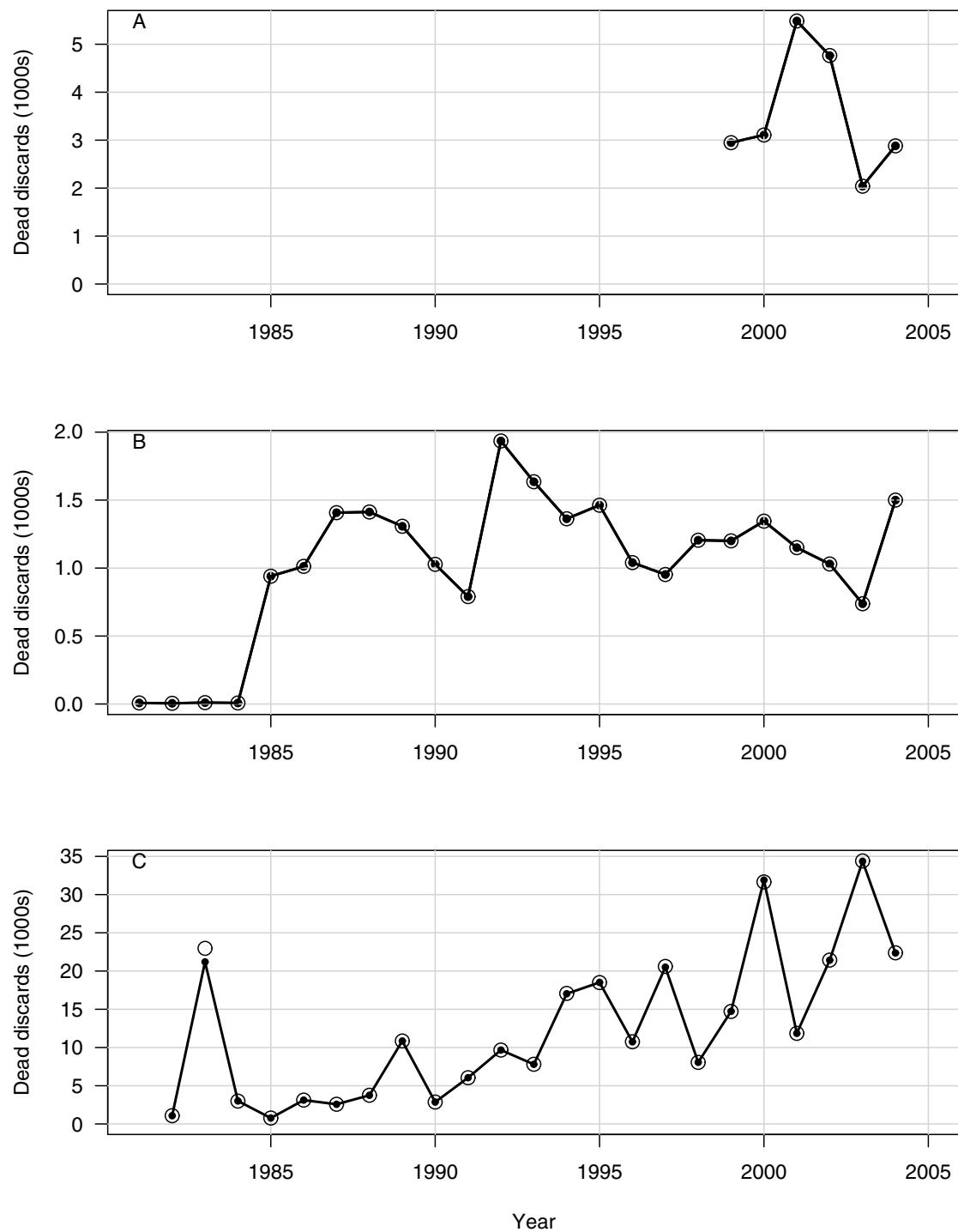


Figure 32. Gag- Base run with time-varying catchability: Estimated catch in numbers by fishery from the stock assessment model.

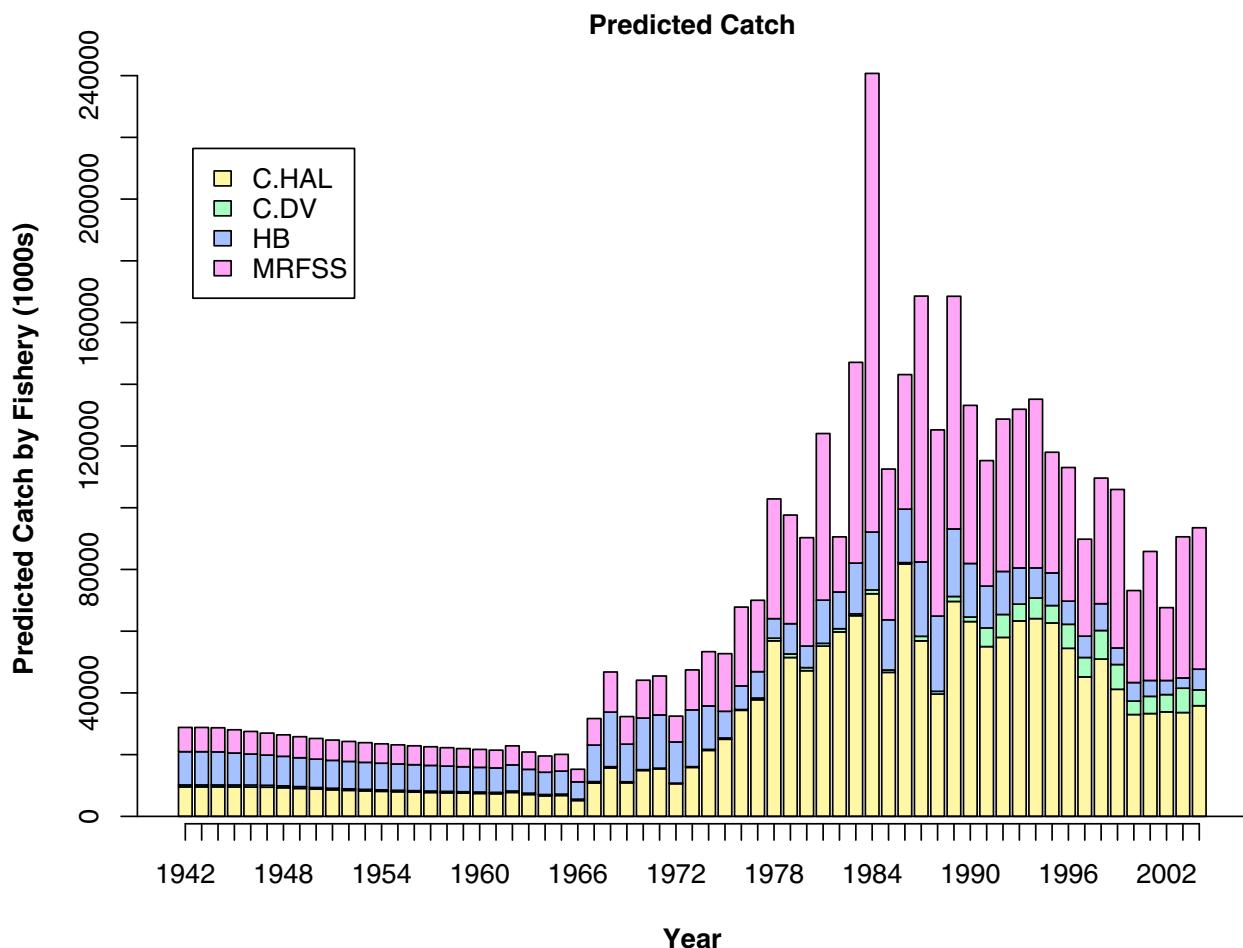


Figure 33. Gag- Base run with constant catchability: Estimated catch in numbers by fishery from the stock assessment model.

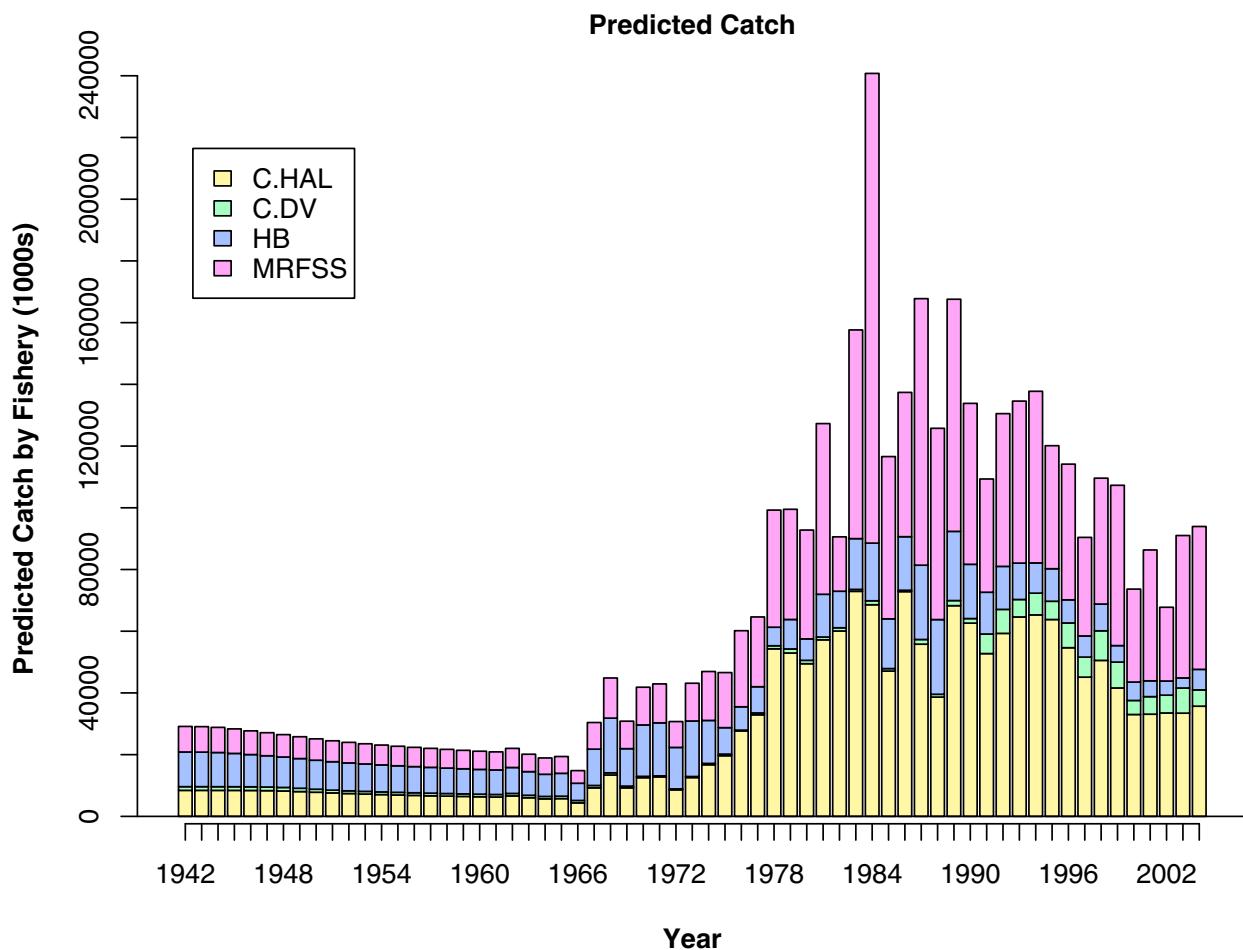


Figure 34. Gag- Base run with time-varying catchability: Estimated landings in weight (klb) by fishery from the stock assessment model.

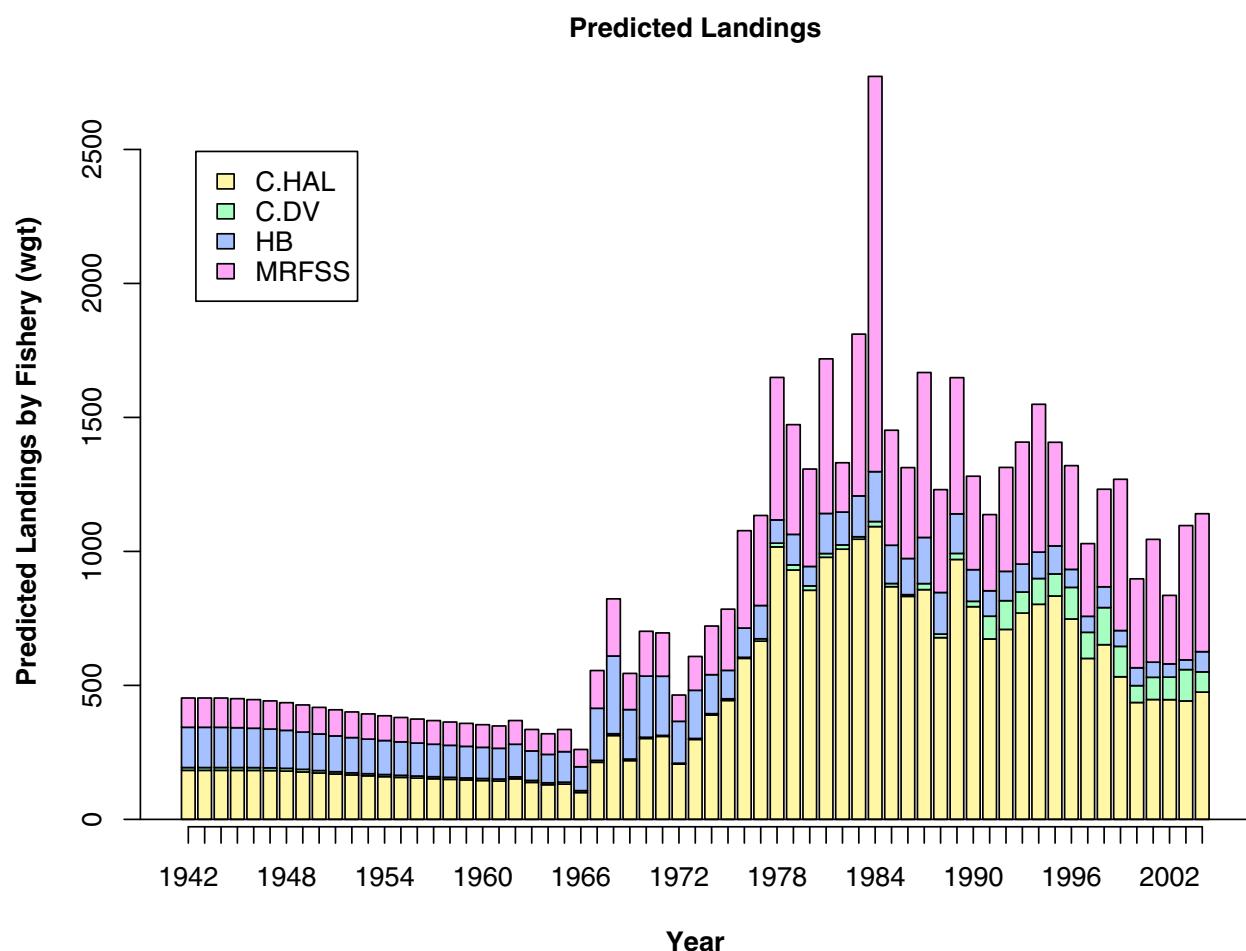


Figure 35. Gag- Base run with constant catchability: Estimated landings in weight (klb) by fishery from the stock assessment model.

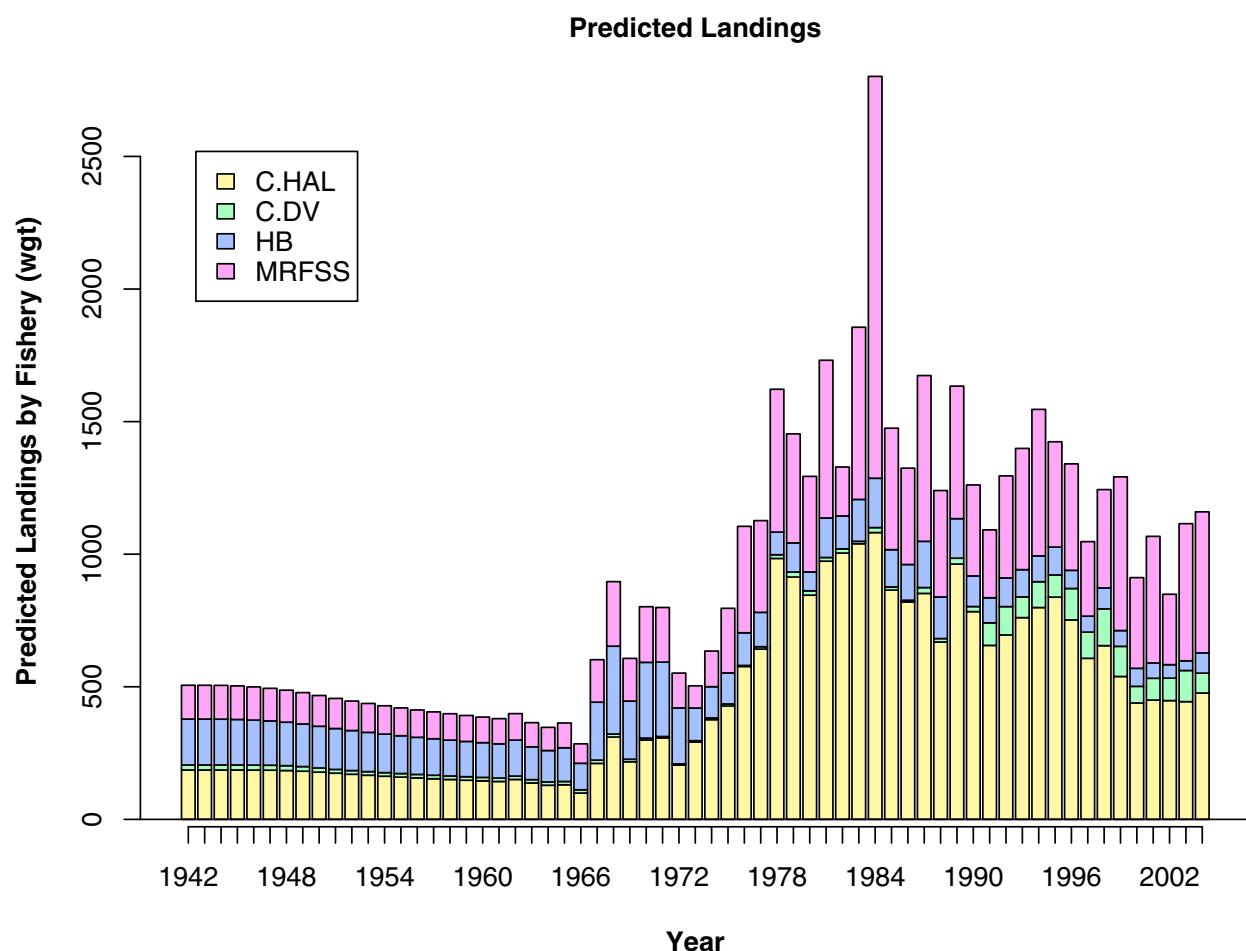


Figure 36. Gag- Base run with time-varying catchability: Estimated dead discards in numbers by fishery from the stock assessment model.

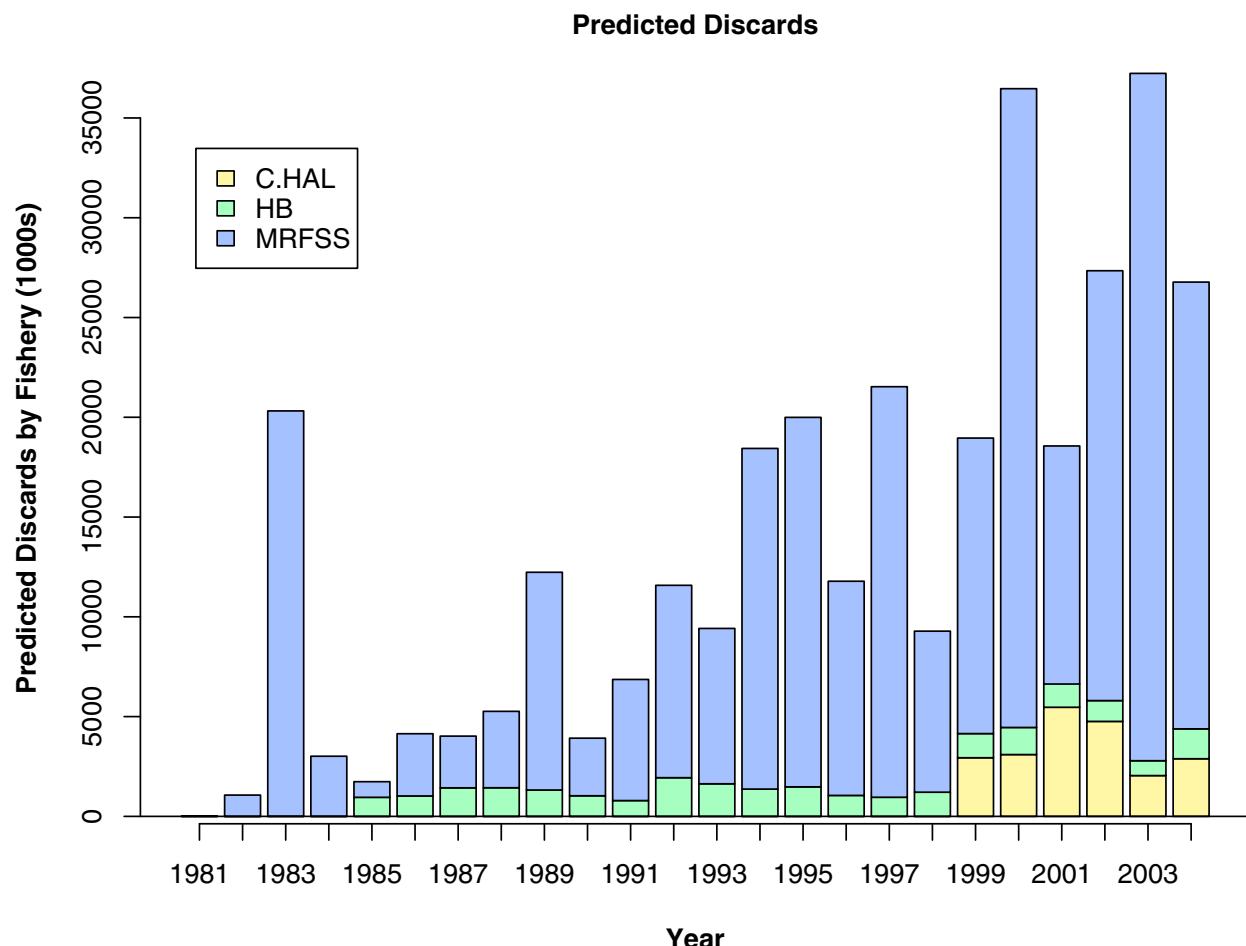


Figure 37. Gag- Base run with constant catchability: Estimated dead discards in numbers by fishery from the stock assessment model.

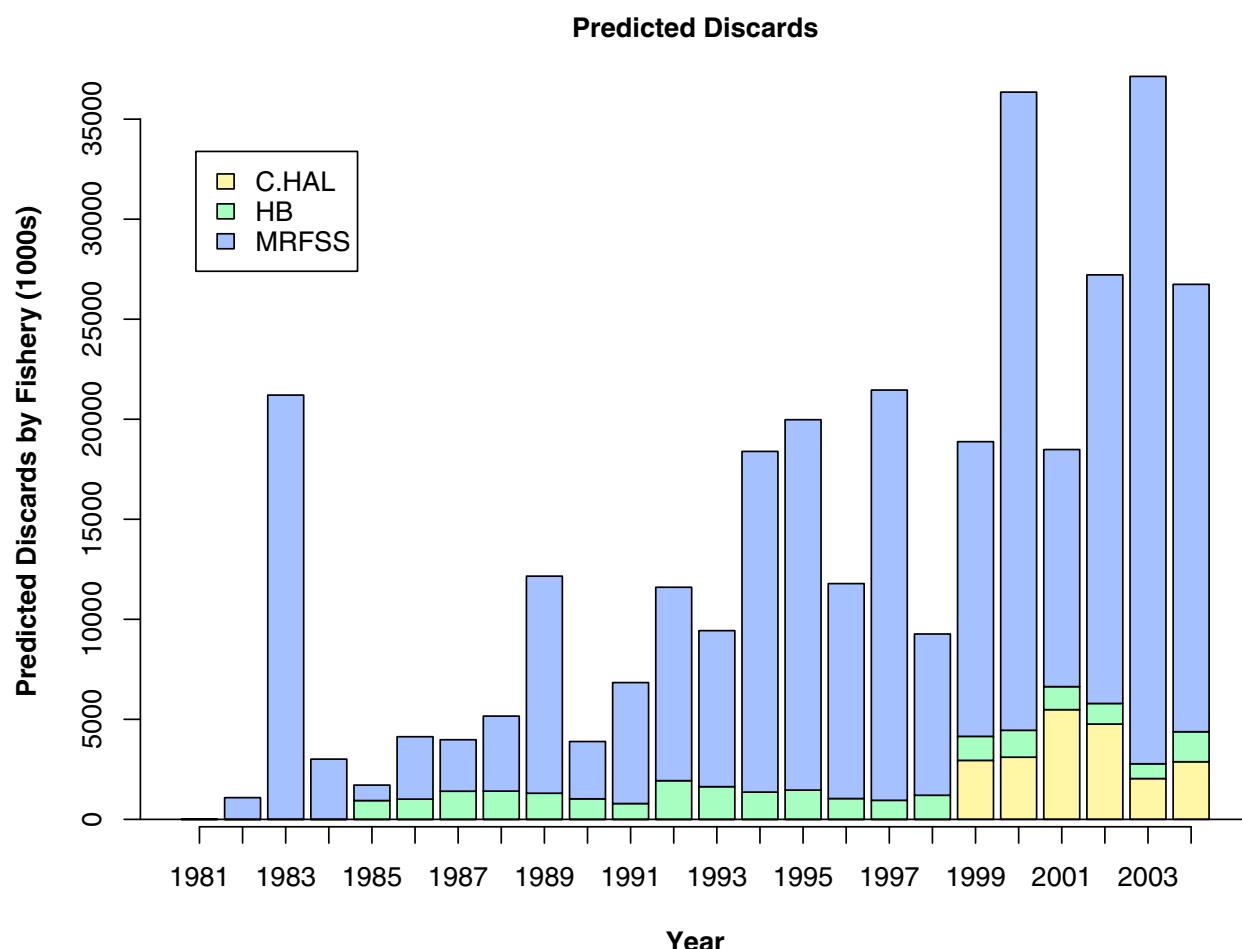


Figure 38. Gag- Time-varying catchability run: Fits to indices of gag abundance, estimated (line, solid circle) and observed (open circles). A) Commercial logbook (handline gear); B) Recreational MRFSS; and C) Recreational Headboat.

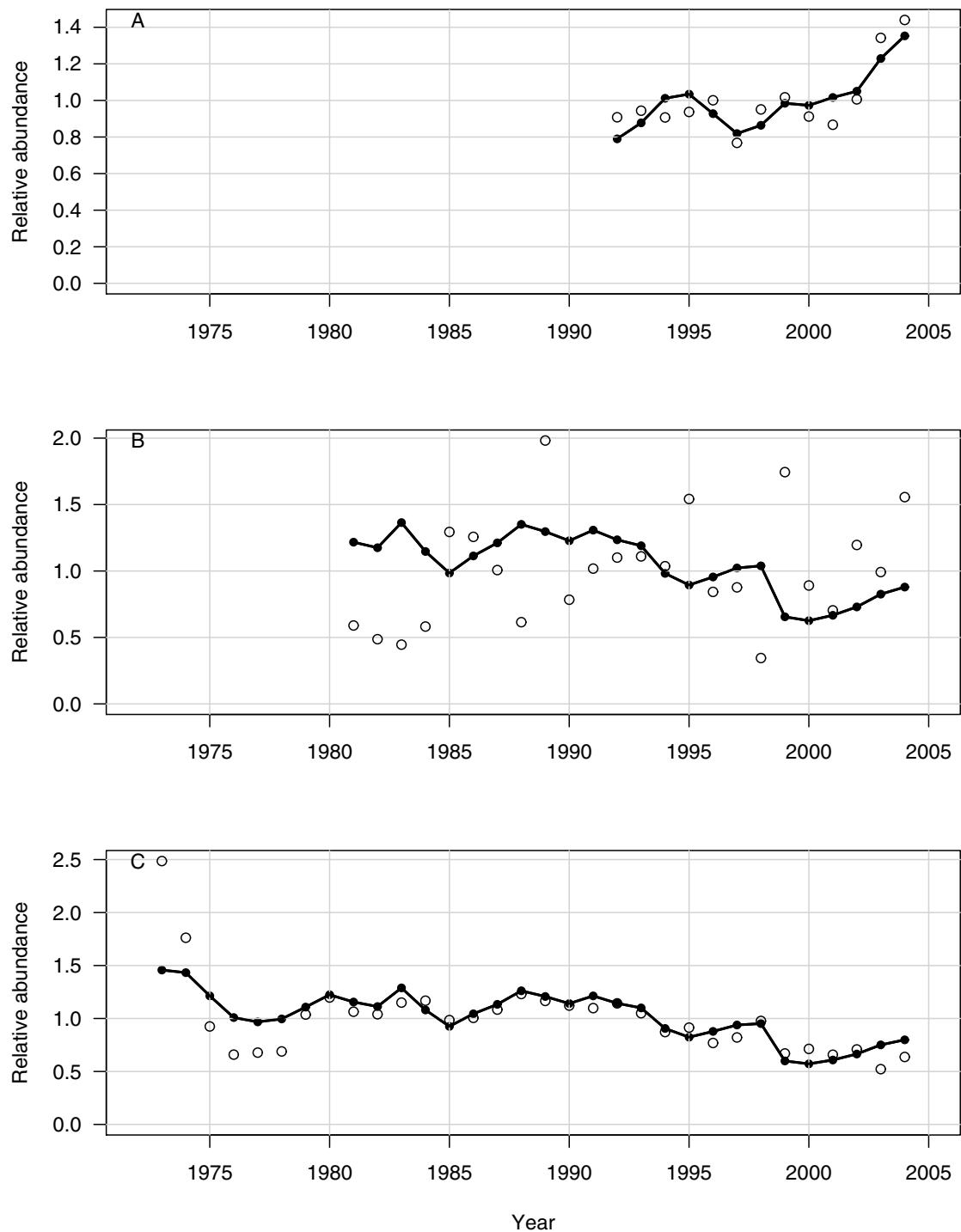


Figure 39. Gag- Constant catchability run: Fits to indices of gag abundance, estimated (line, solid circle) and observed (open circles). A) Commercial logbook (handline gear); B) Recreational MRFSS; and C) Recreational Headboat.

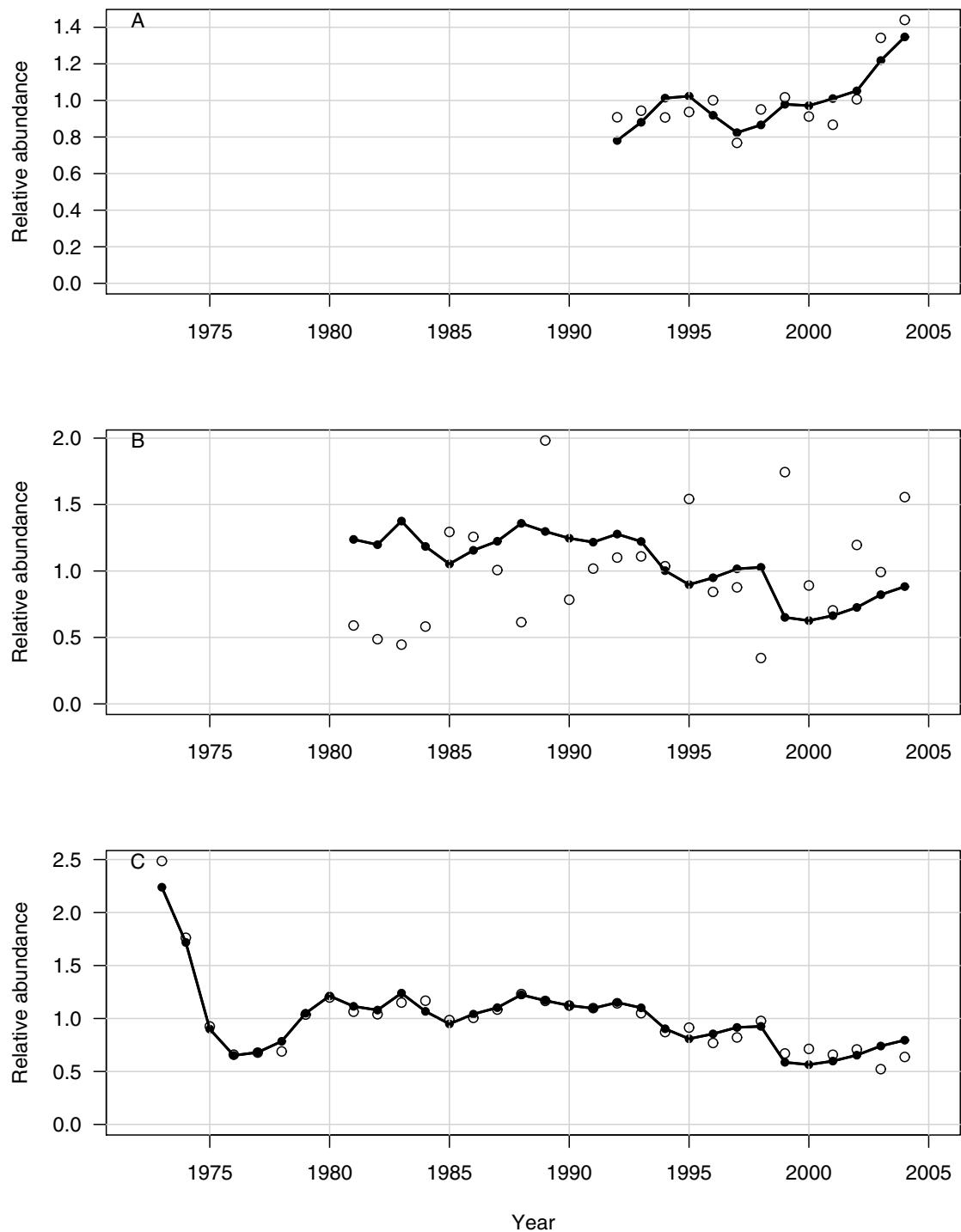


Figure 40. Gag- Time-varying catchability run: Mean length (mm) at age (midyear) of gag, estimated internally by the assessment model assuming von Bertalanffy growth. Dotted line at L_∞ and thin lines represent 95% confidence intervals from estimated CV parameters at each age.

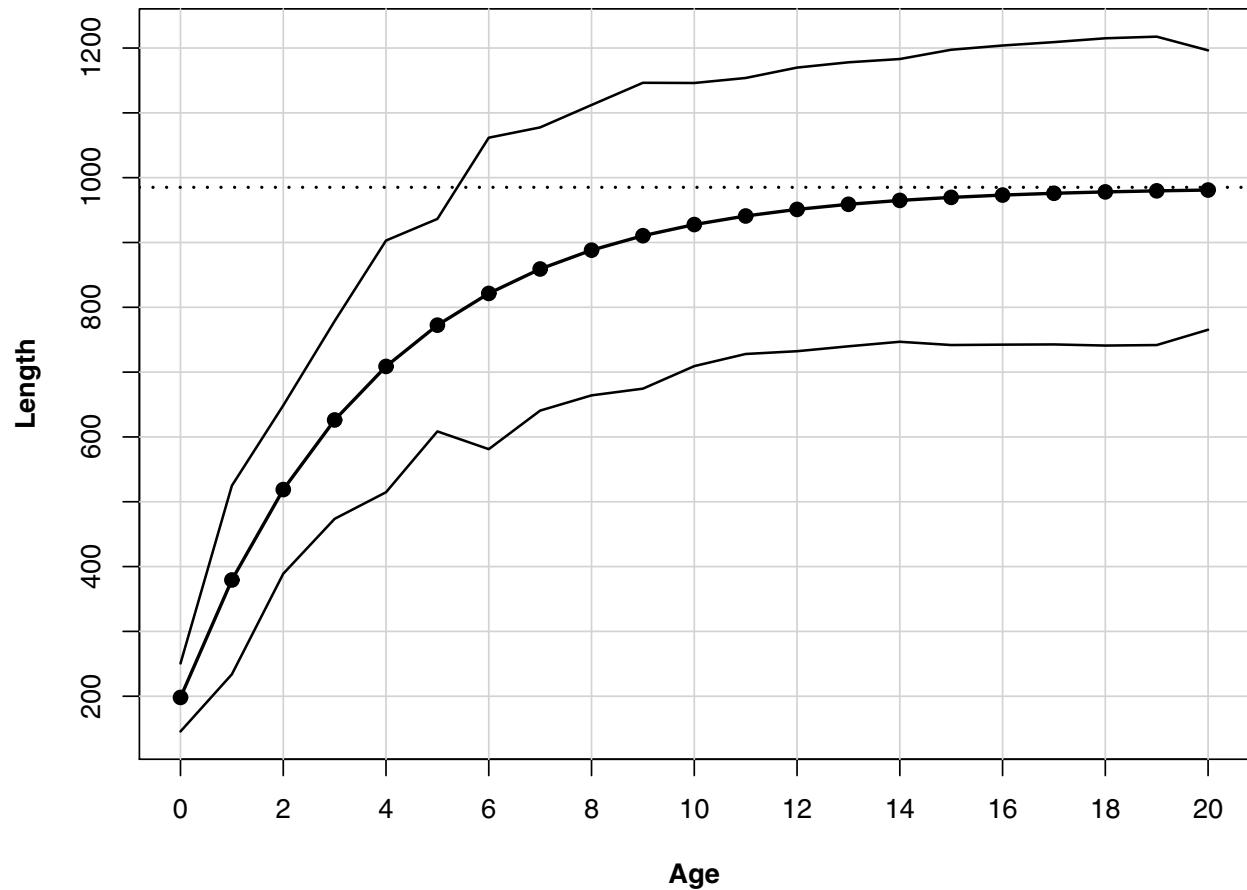


Figure 41. Gag- Constant catchability run: Mean length (mm) at age (midyear) of gag, estimated internally by the assessment model assuming von Bertalanffy growth. Dotted line at L_∞ and thin lines represent 95% confidence intervals from estimated CV parameters at each age.

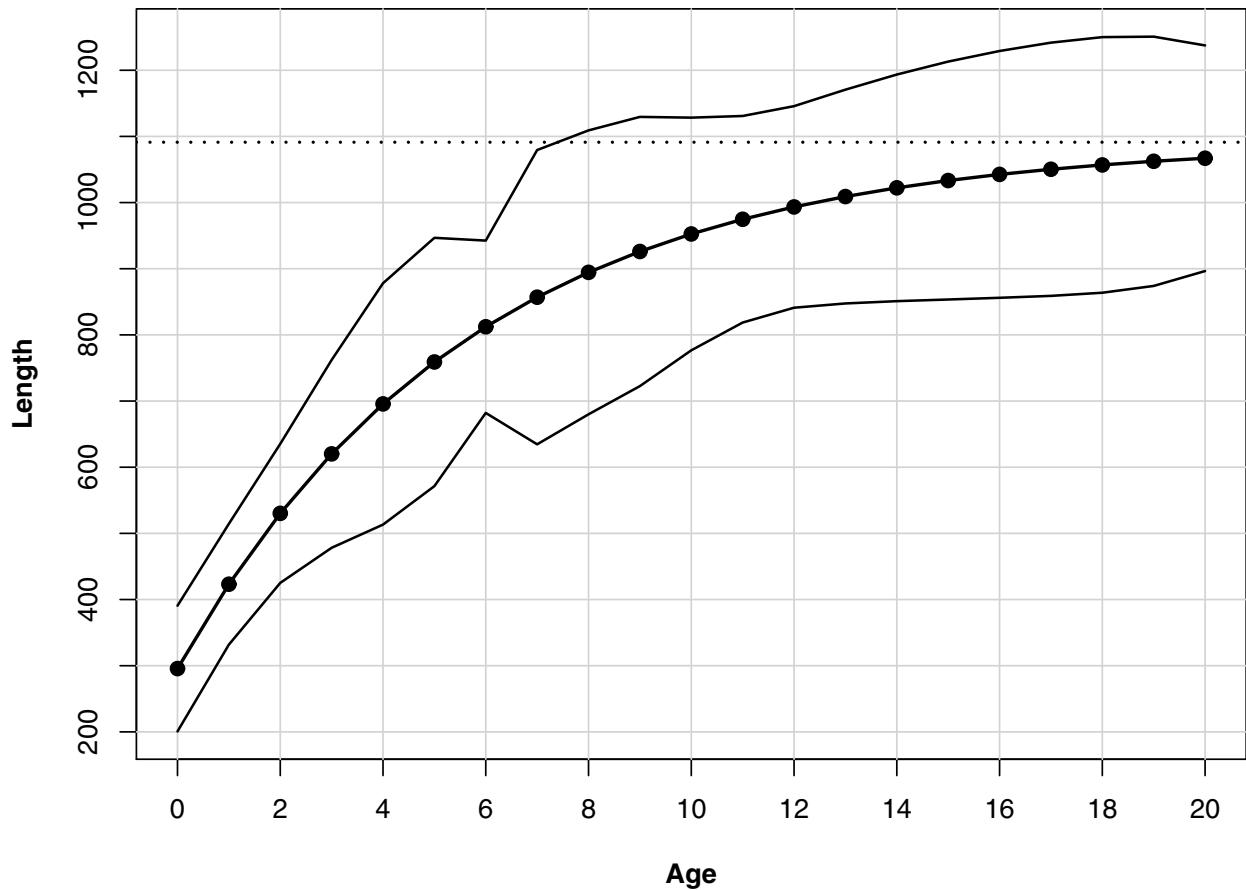


Figure 42. Gag- Base run with time-varying catchability: Estimated selectivities of commercial handline. A) Period one (1962-1991); B) Period two (1992-1998); and C) Period three (1999-2004). In period one, age at 50% selection estimated annually—average curve presented.

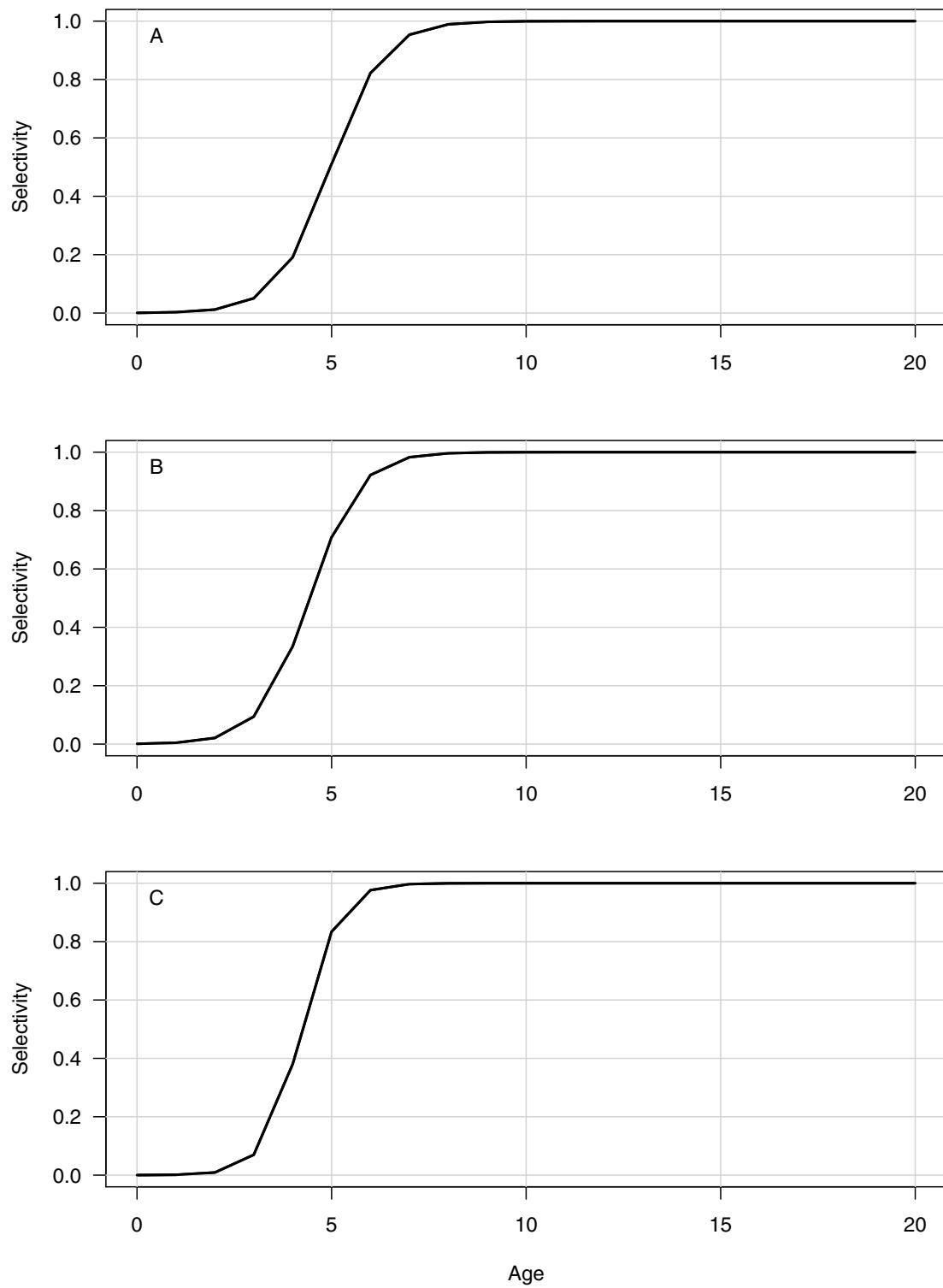


Figure 43. Gag- Base run with constant catchability: Estimated selectivities of commercial handline. A) Period one (1962-1991); B) Period two (1992-1998); and C) Period three (1999-2004). In period one, age at 50% selection estimated annually—average curve presented.

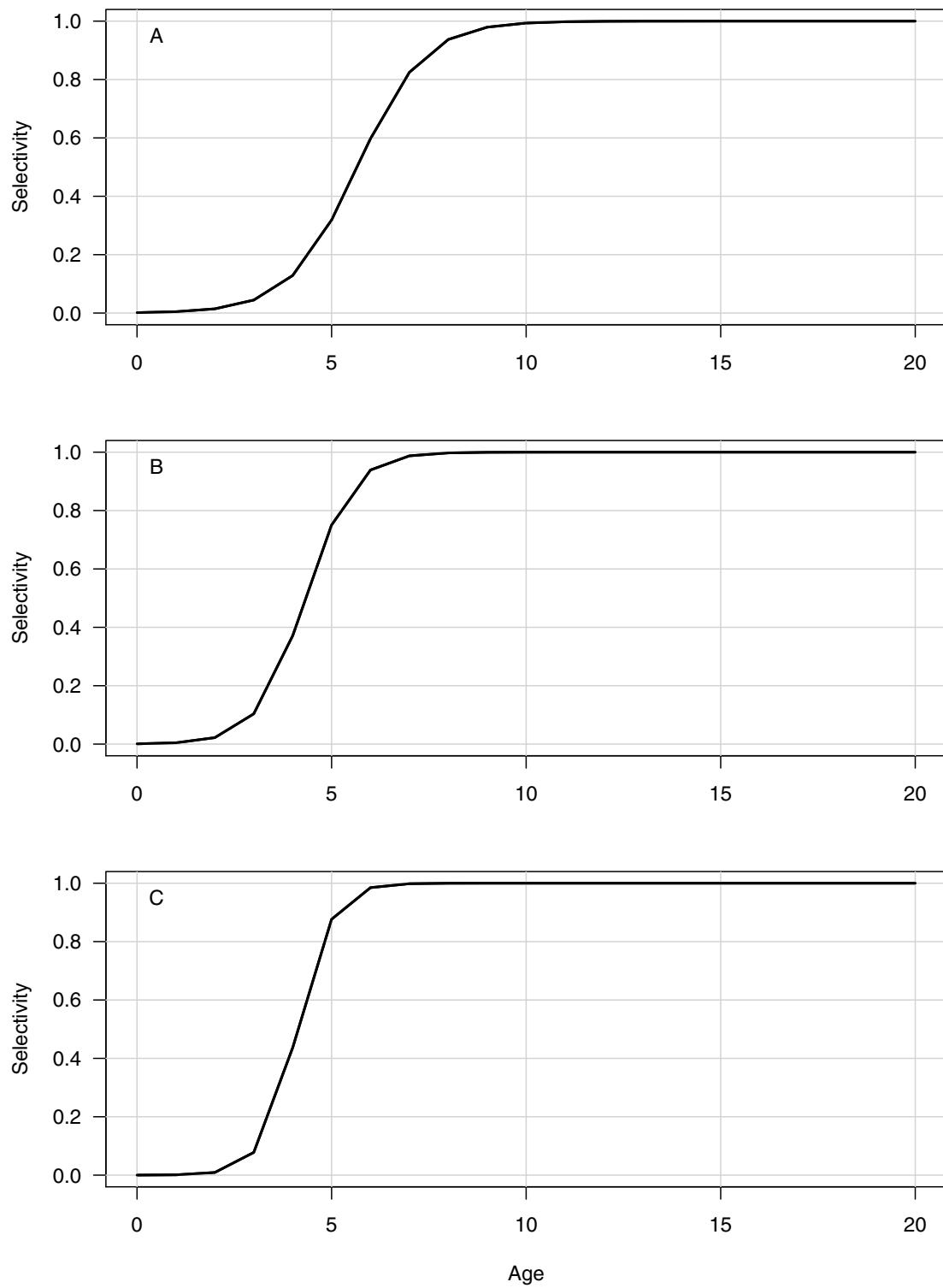


Figure 44. Gag- Base run with time-varying catchability: Estimated selectivity of commercial diving applied to all years in the assessment model.

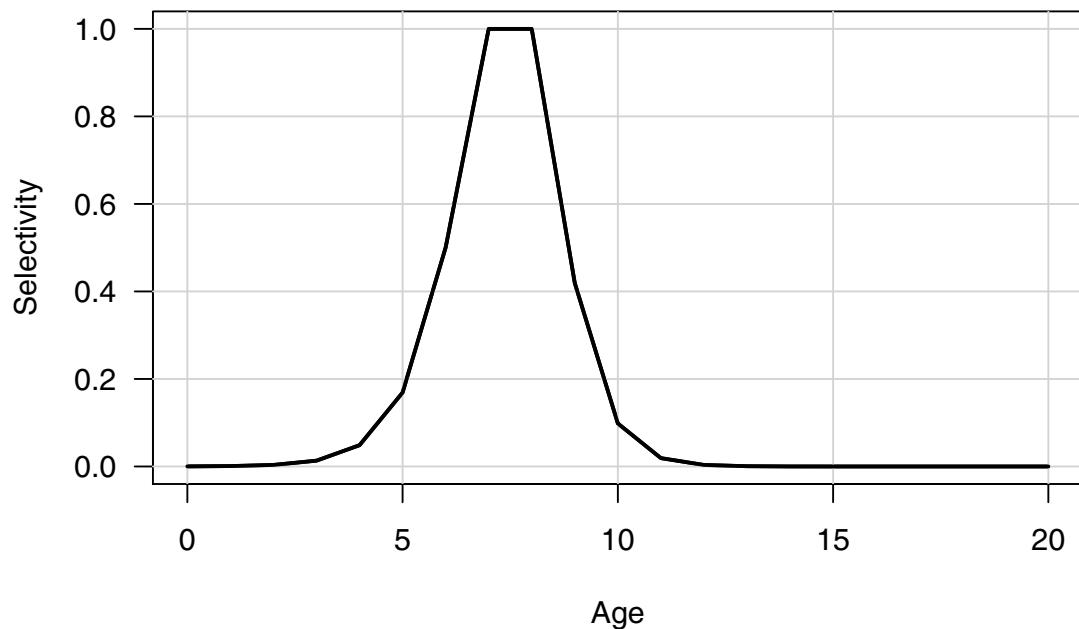


Figure 45. Gag- Base run with constant catchability: Estimated selectivity of commercial diving applied to all years in the assessment model.

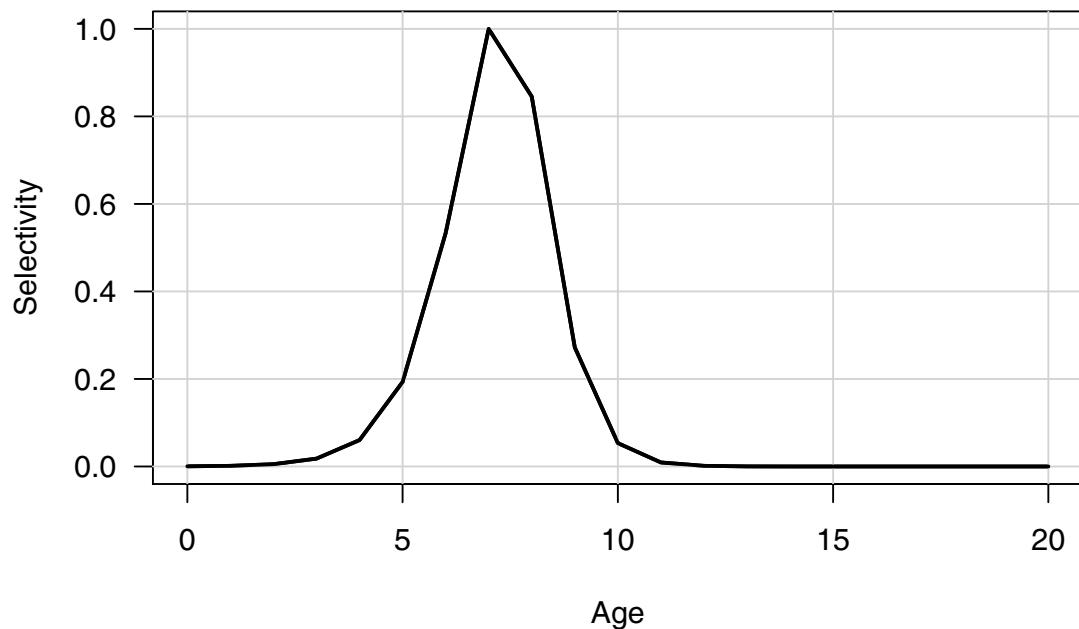


Figure 46. Gag- Base run with time-varying catchability: Estimated selectivities of recreational (headboat and MRFSS) fisheries. A) Period one (1962–1991); B) Period two (1992–1998); and C) Period three (1999–2004). In period one, age at 50% selection estimated annually—average curve presented.

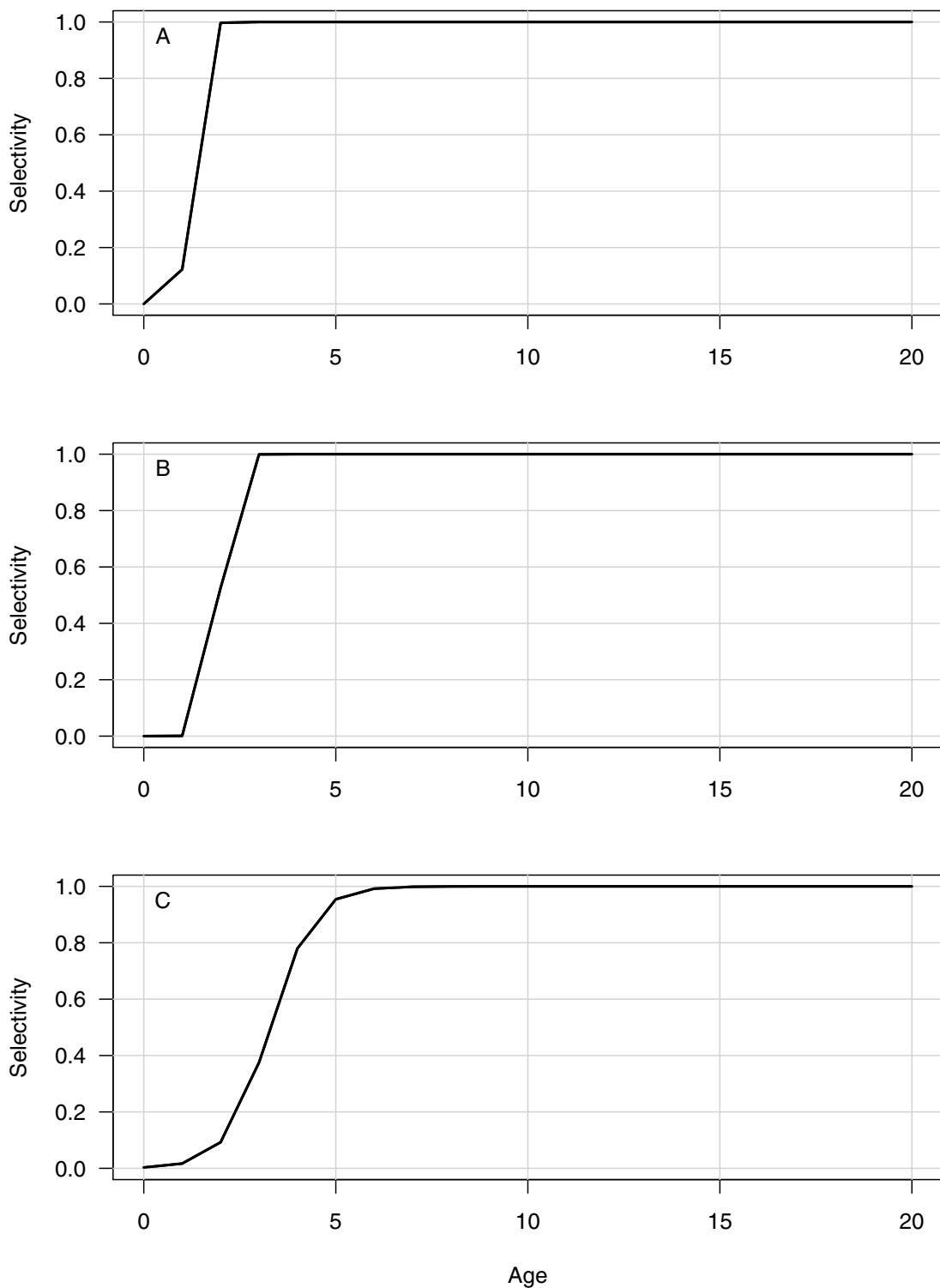


Figure 47. Gag- Base run with constant catchability: Estimated selectivities of recreational (headboat and MRFSS) fisheries. A) Period one (1962-1991); B) Period two (1992-1998); and C) Period three (1999-2004). In period one, age at 50% selection estimated annually—average curve presented.

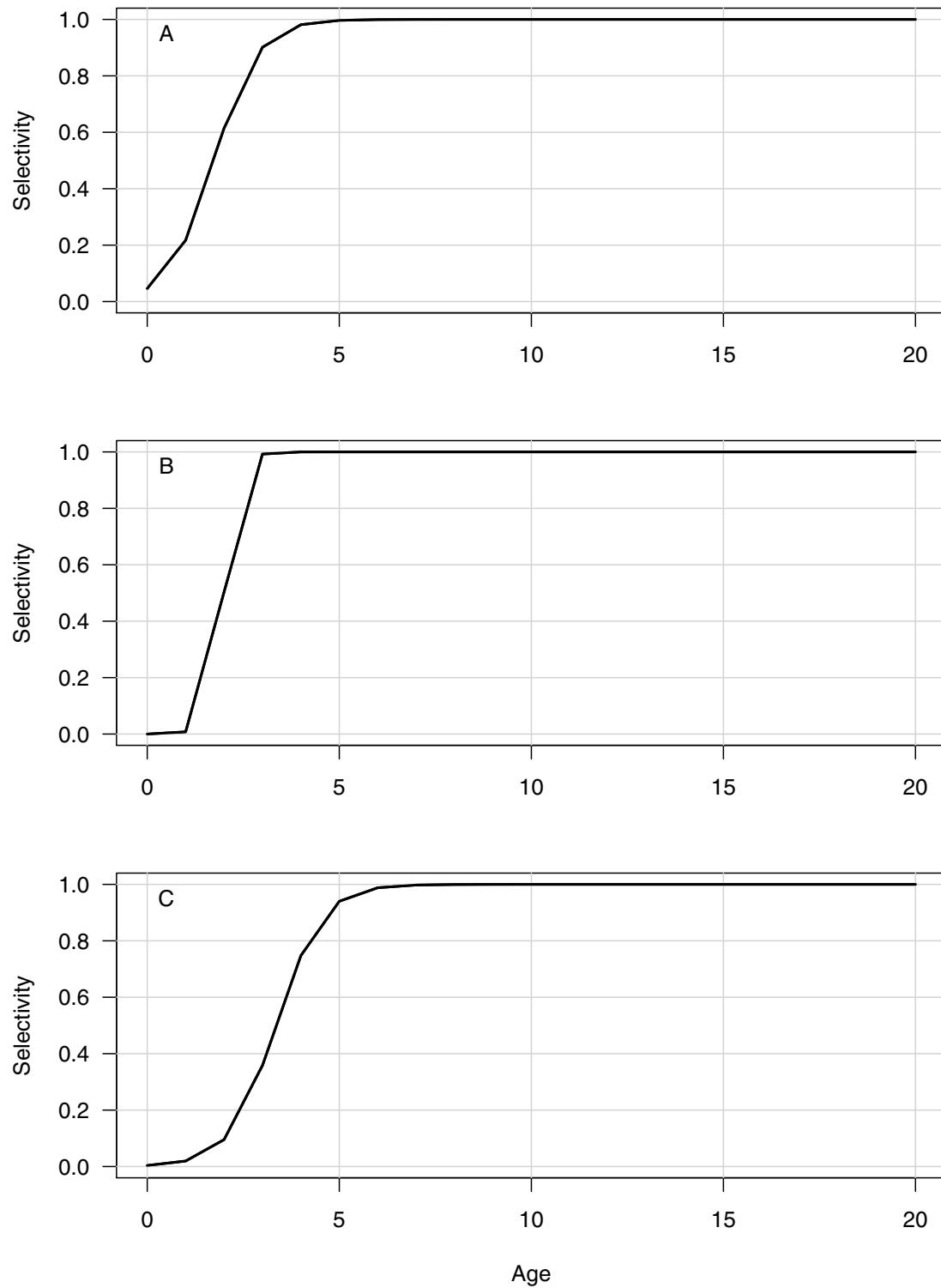


Figure 48. Gag- Base run with time-varying catchability: Estimated selectivities applied to discard rates in 1981–2004. A) Commercial handline; B) Recreational (headboat and MRFSS).

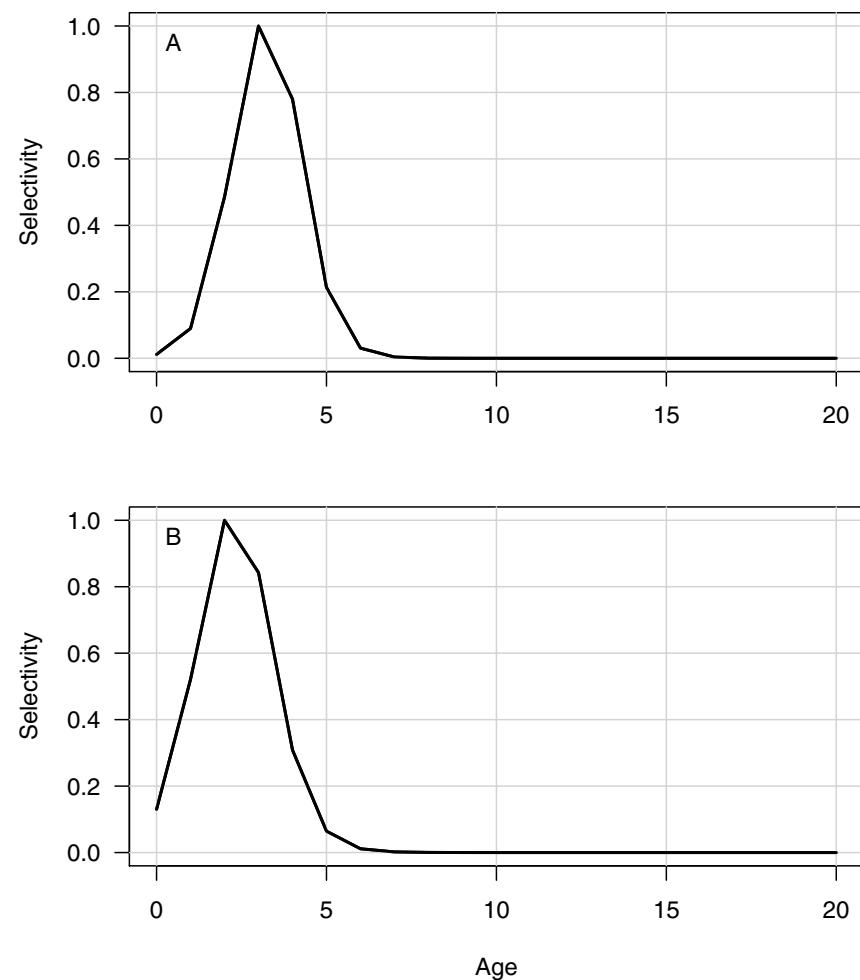


Figure 49. Gag- Base run with constant catchability: Estimated selectivities applied to discard rates in 1981-2004. A) Commercial handline; B) Recreational (headboat and MRFSS).

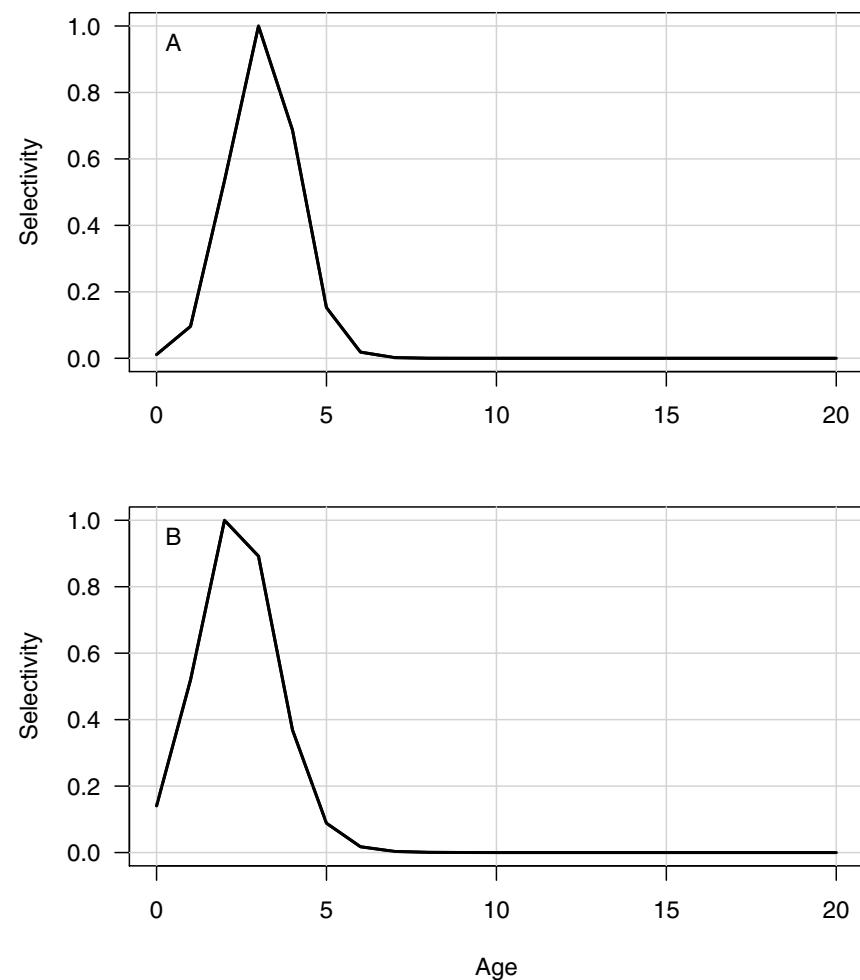


Figure 50. Gag- Base run with time-varying catchability: Estimated fishing mortality and exploitation rates. A) Fully selected fishing mortality rate and B) Exploitation rate of fish age 2^+ . Solid horizontal line represents the level corresponding to MSY and the horizontal dashed lines represent the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

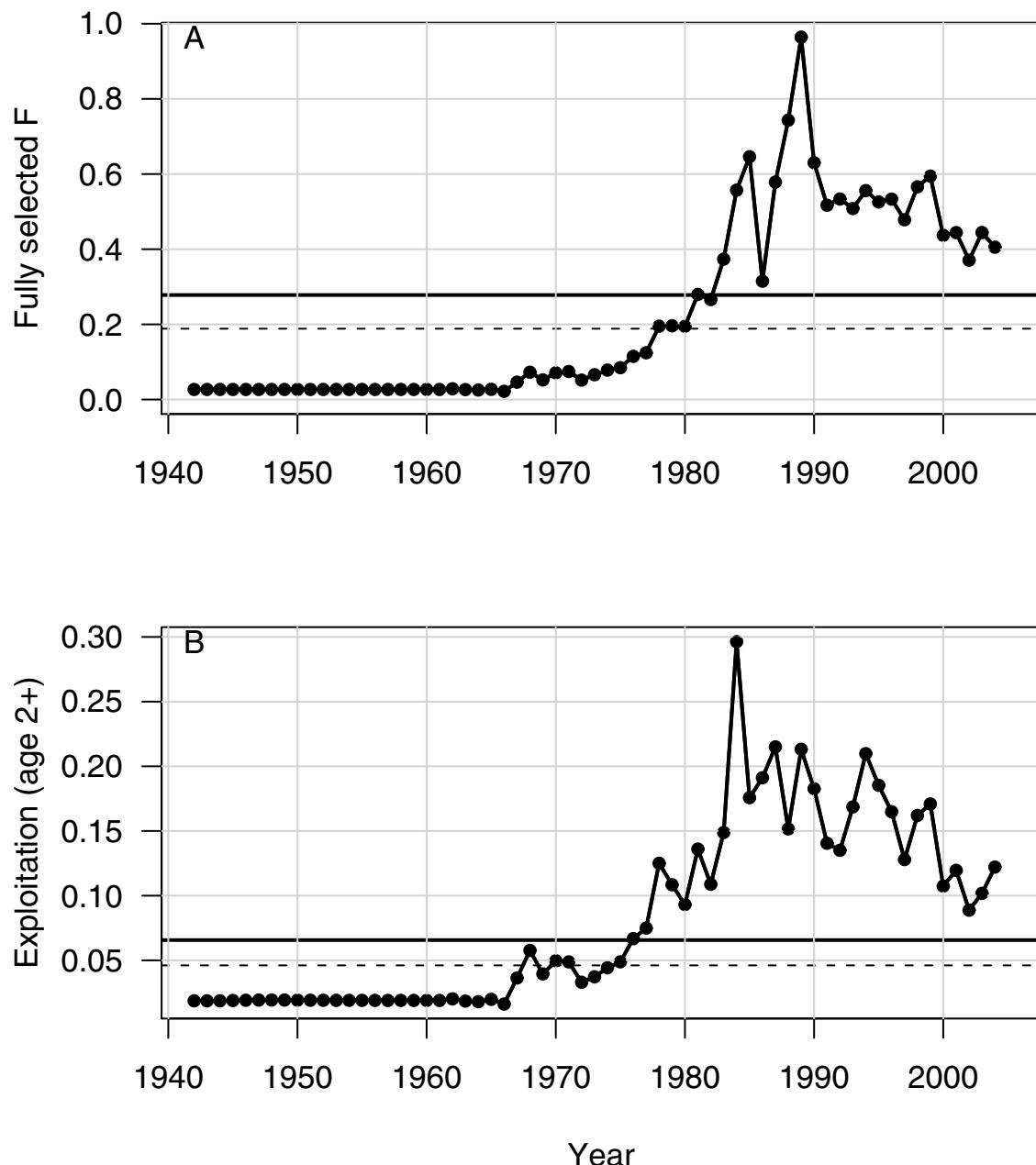


Figure 51. Gag- Base run with constant catchability: Estimated fishing mortality and exploitation rates. A) Fully selected fishing mortality rate and B) Exploitation rate of fish age 2^+ . Solid horizontal line represents the level corresponding to MSY and the horizontal dashed lines represent the 10th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

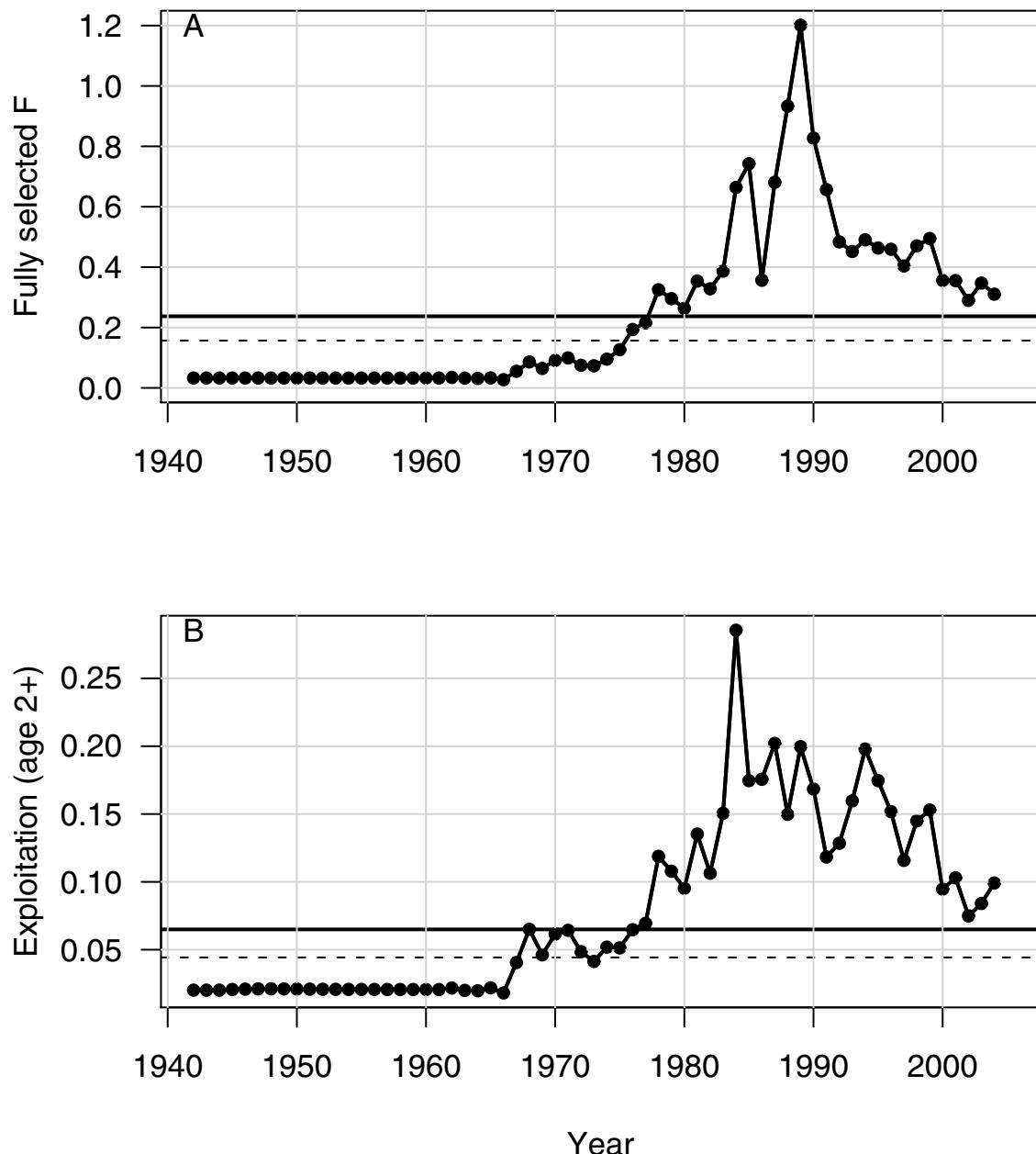


Figure 52. Gag- Base run with time-varying catchability: Stacked bar plot of fully selected fishing mortality rates by fishery.

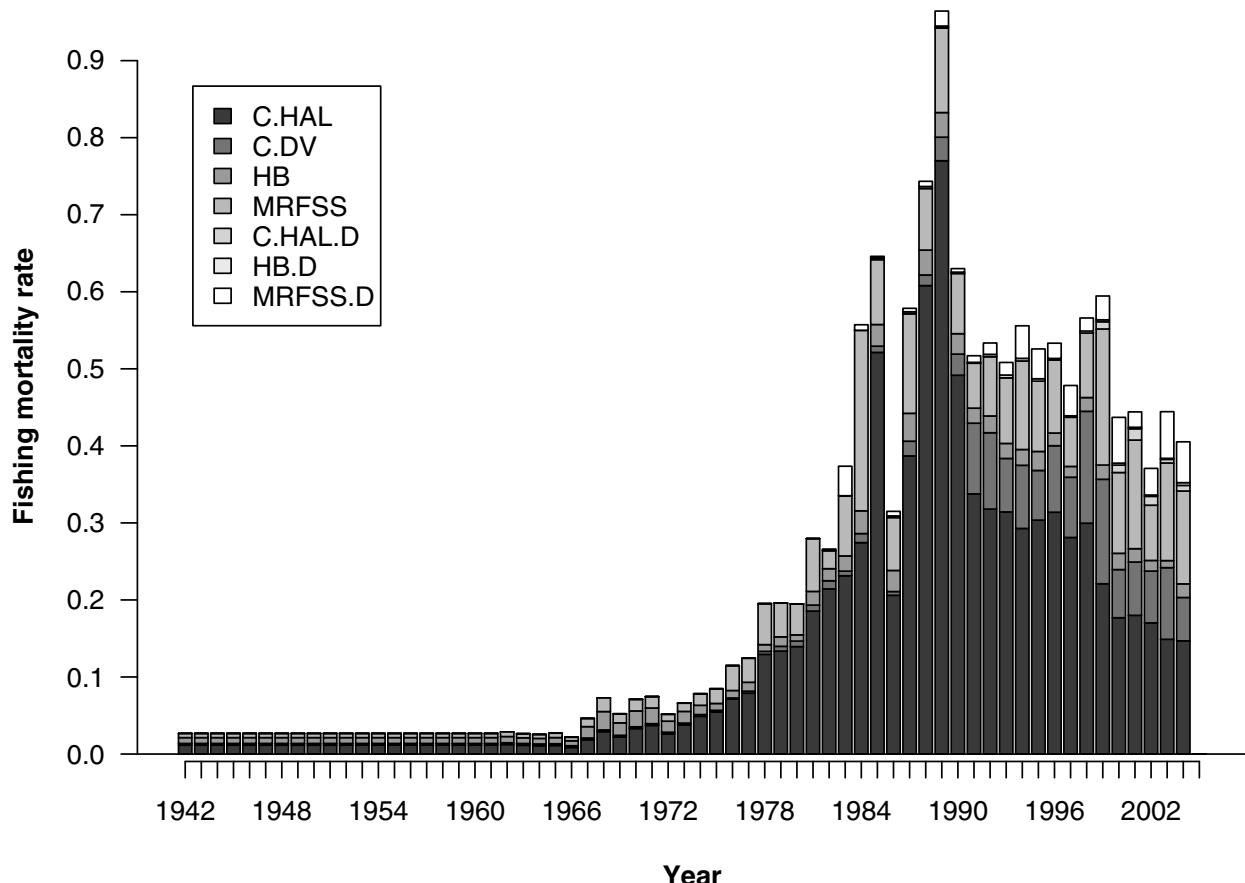


Figure 53. Gag- Base run with constant catchability: Stacked bar plot of fully selected fishing mortality rates by fishery.

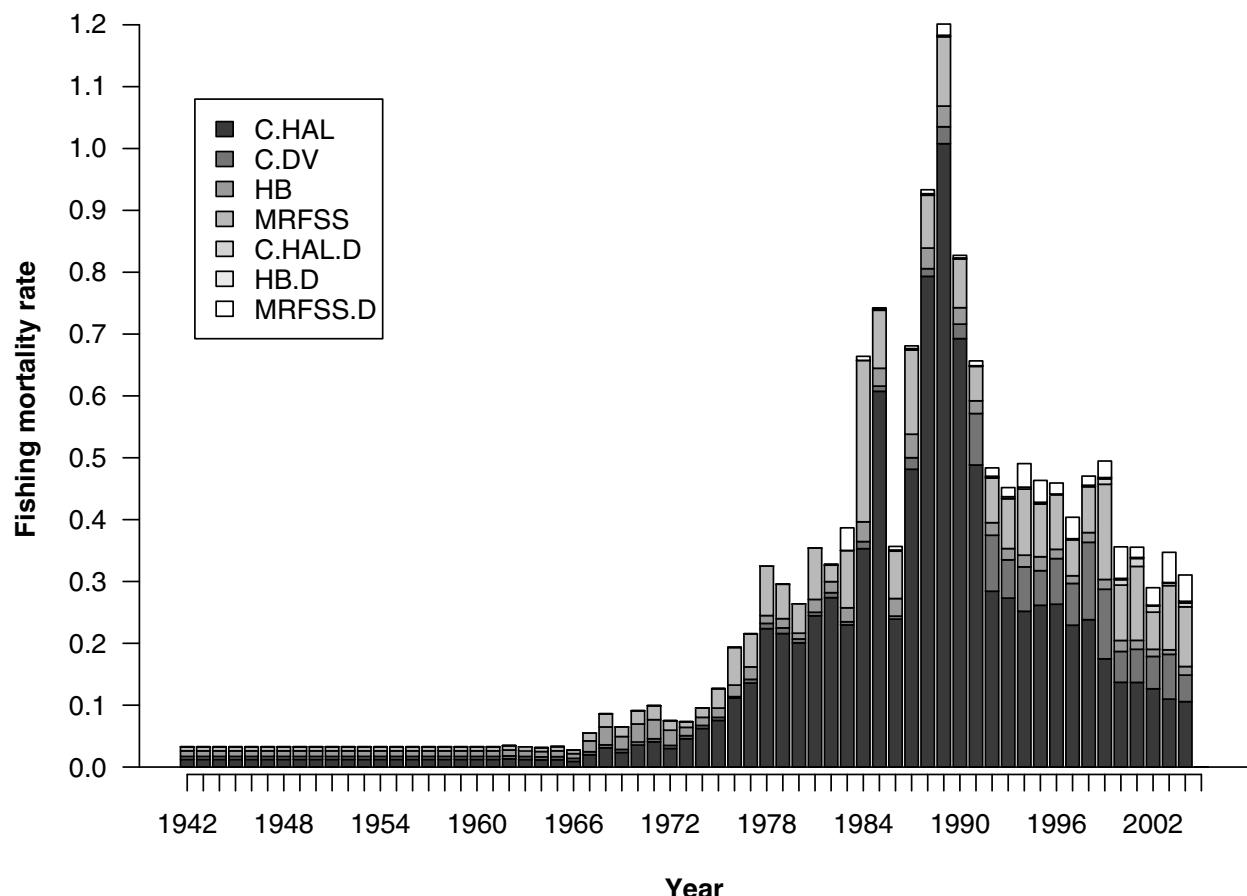


Figure 54. Gag- Base run with time-varying catchability: Estimated biomass time series. A) Total biomass and B) Spawning stock biomass (male mature biomass + female mature biomass). The solid horizontal line represents the level corresponding to MSY and the horizontal dashed lines represent the 10th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

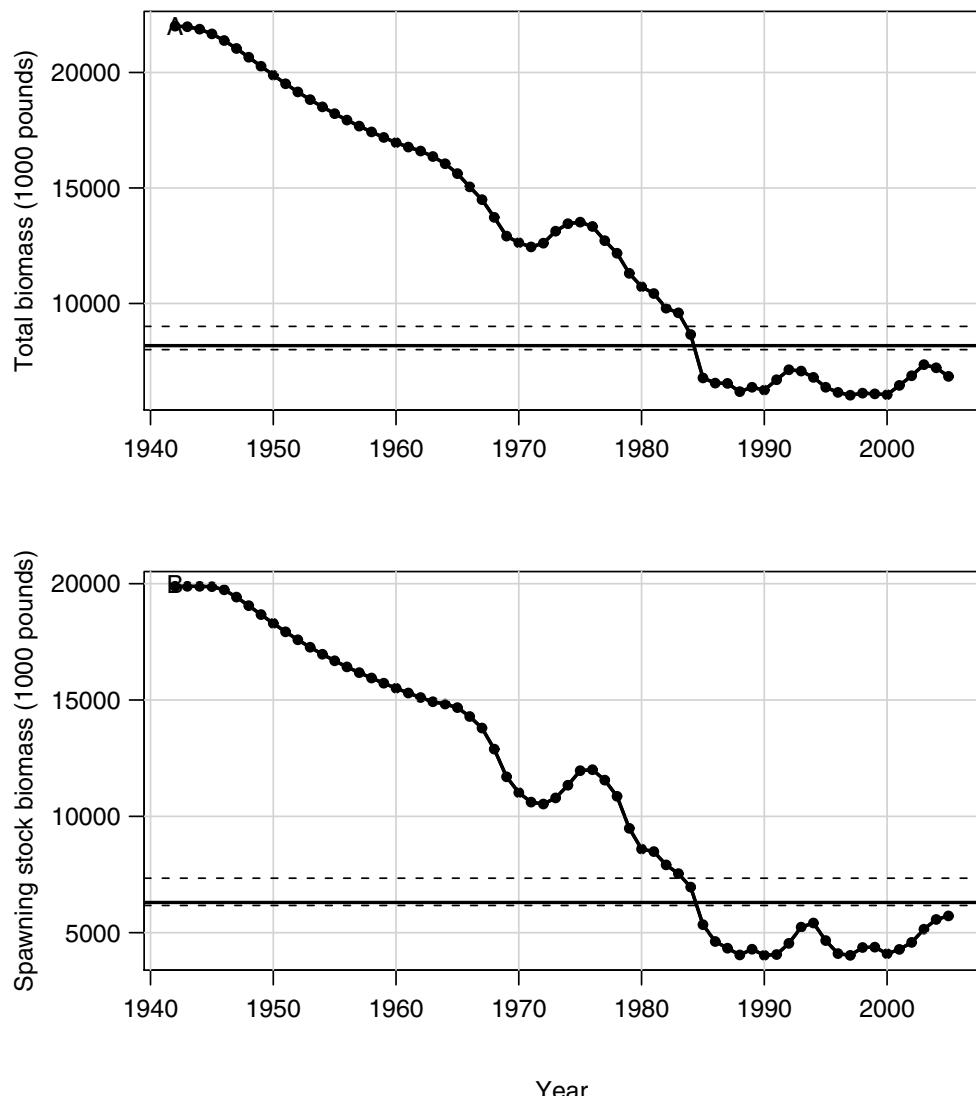


Figure 55. Gag- Base run with constant catchability: Estimated biomass time series. A) Total biomass and B) Spawning stock biomass (male mature biomass + female mature biomass). The solid horizontal line represents the level corresponding to MSY and the horizontal dashed lines represent the 10th and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

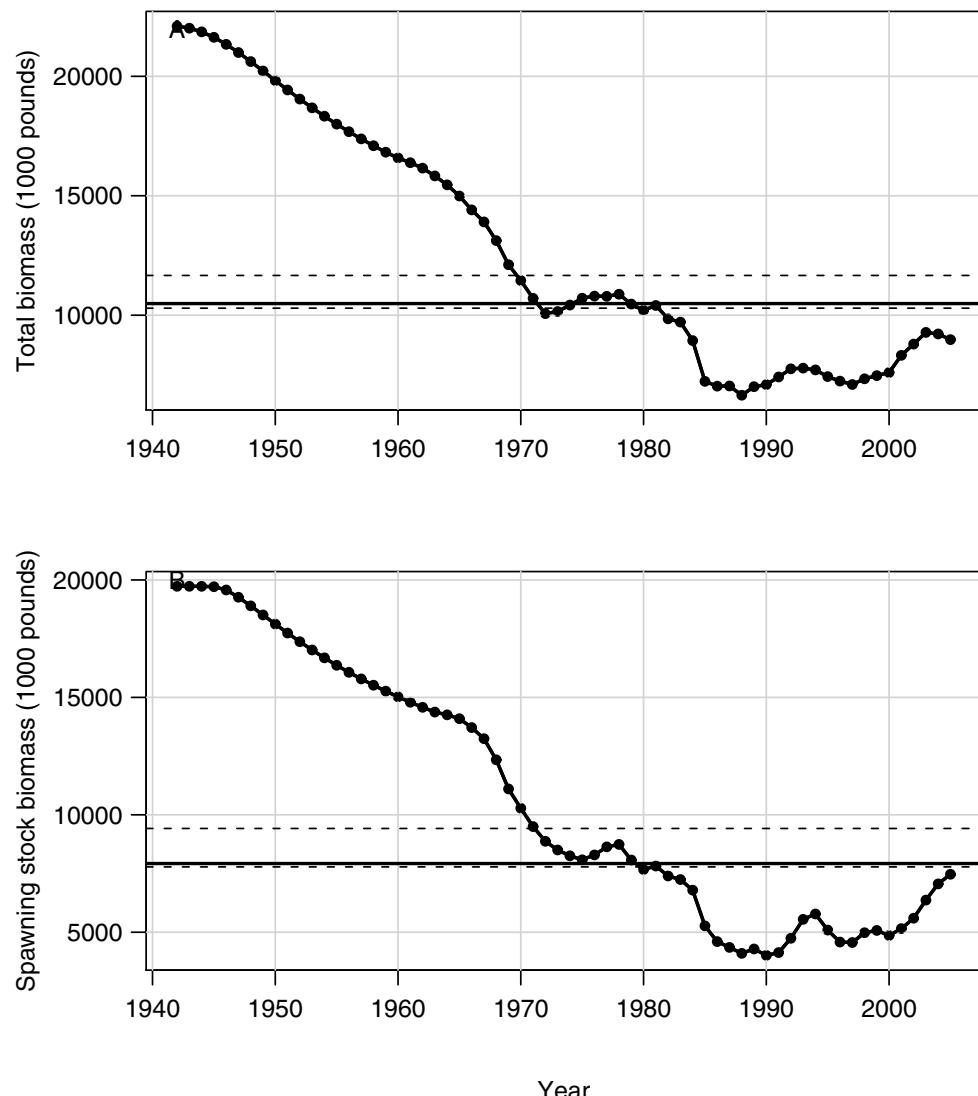


Figure 56. Gag- Base run with time-varying catchability: Estimated stock-recruitment relationship of gag grouper. Circles represent estimated recruitment values from 1972-2004; Dashed curve is estimated relationship; Solid curve is estimated relationship with lognormal bias correction, from which benchmarks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

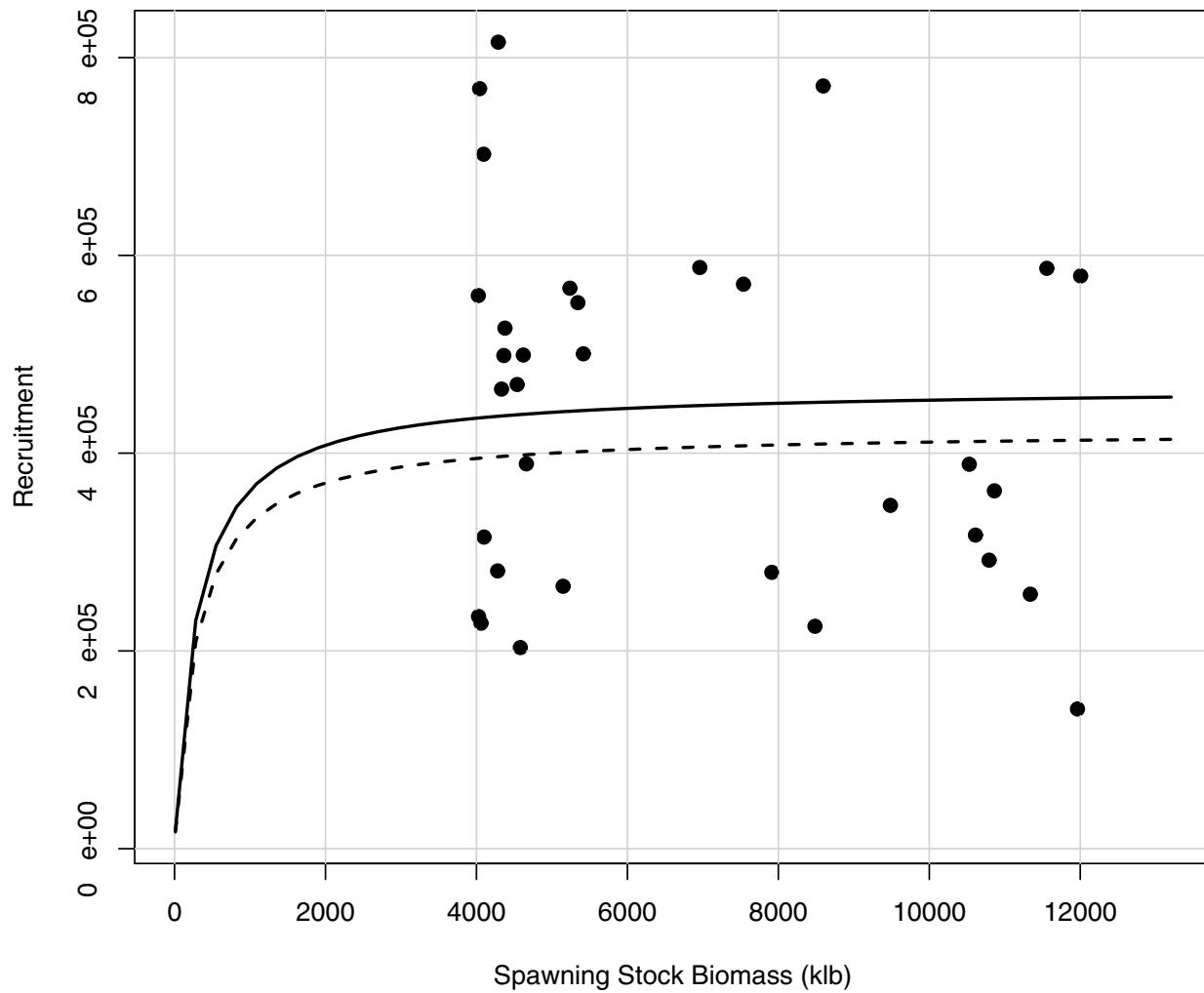


Figure 57. Gag- Base run with constant catchability: Estimated stock-recruitment relationship of gag grouper. Circles represent estimated recruitment values from 1972-2004; Dashed curve is estimated relationship; Solid curve is estimated relationship with lognormal bias correction, from which benchmarks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

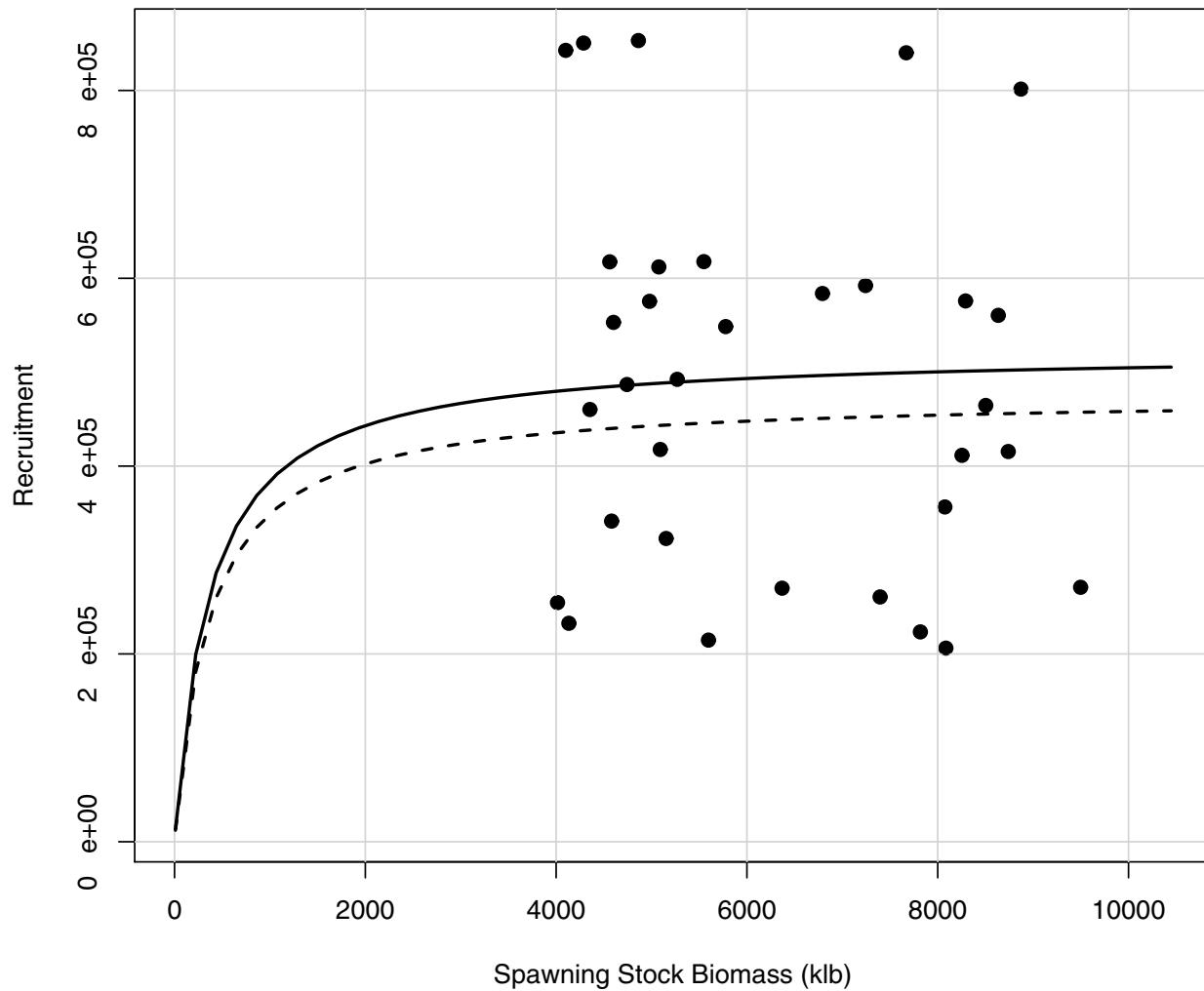


Figure 58. Time-varying catchability run: Estimated time series of gag recruitment. A) Number of recruits; dashed line at \hat{R}_{msy} . B) Log of recruitment residuals; dashed line at zero, the value indicating no deviation from the estimated stock-recruit curve.

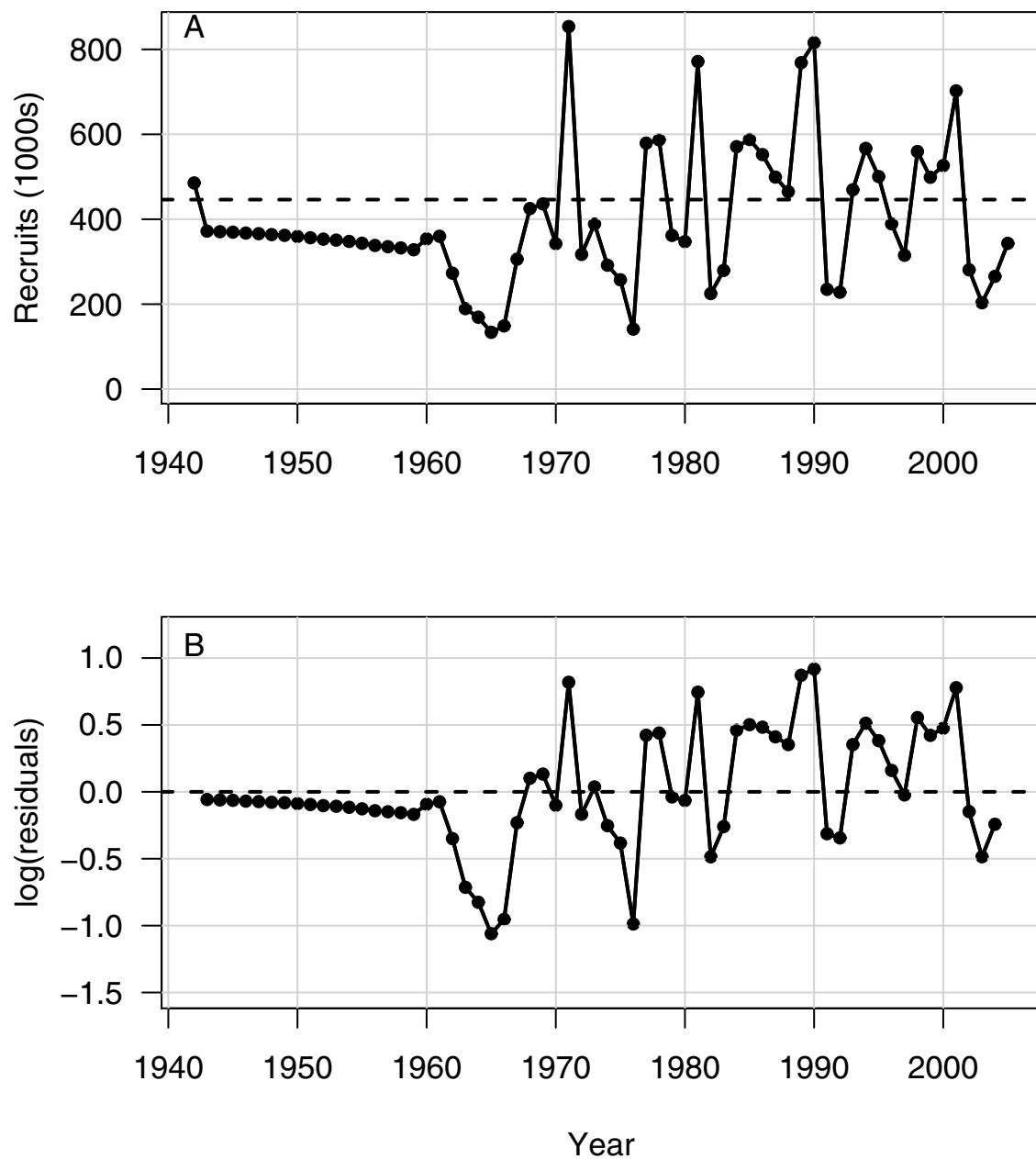


Figure 59. Constant catchability run: Estimated time series of gag recruitment. A) Number of recruits; dashed line at \hat{R}_{msy} . B) Log of recruitment residuals; dashed line at zero, the value indicating no deviation from the estimated stock-recruit curve.

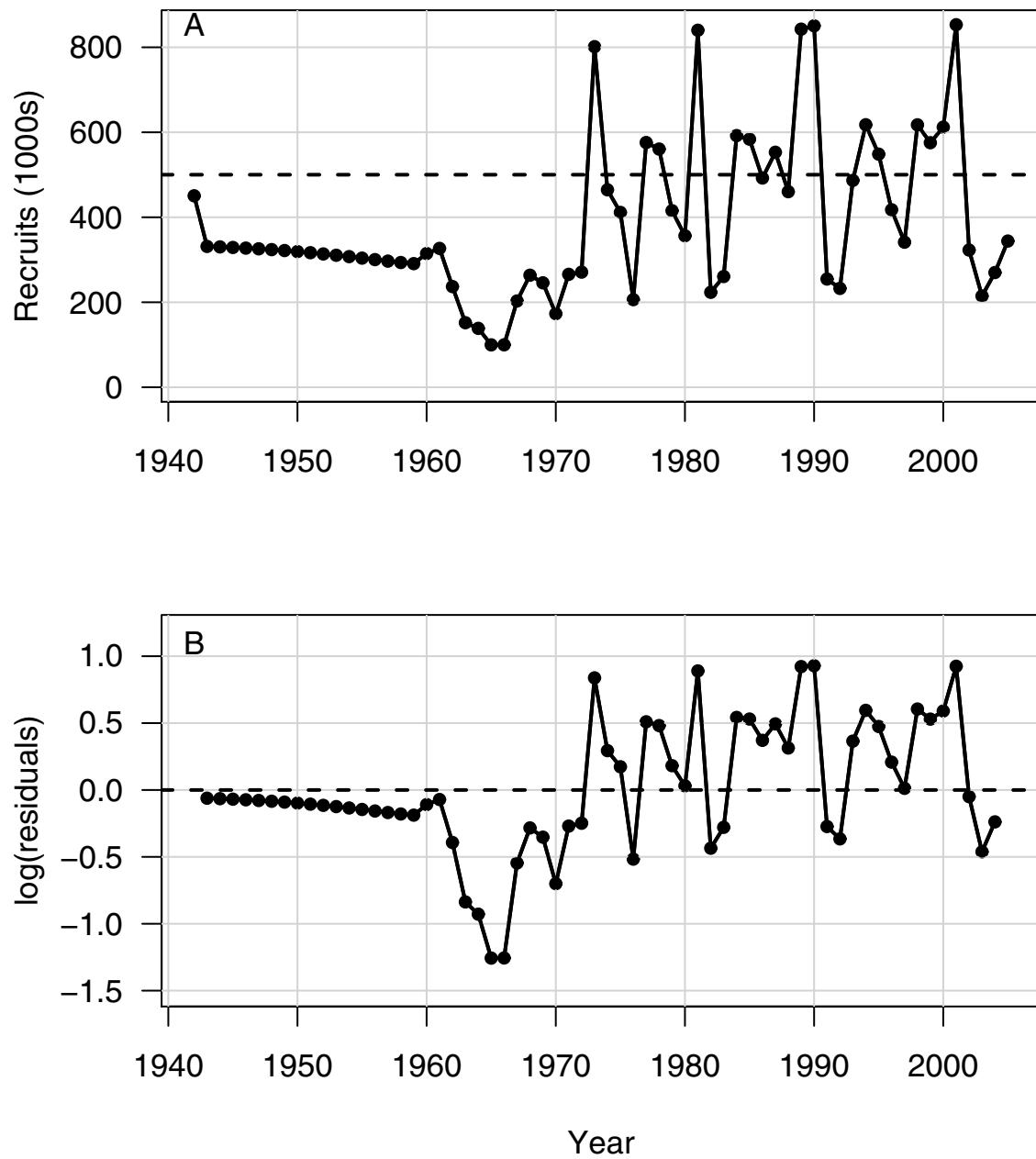


Figure 60. Gag- Base run with time-varying catchability: Estimated time series of static spawning potential ratio (SPR) using fully selected fishing mortality rates.

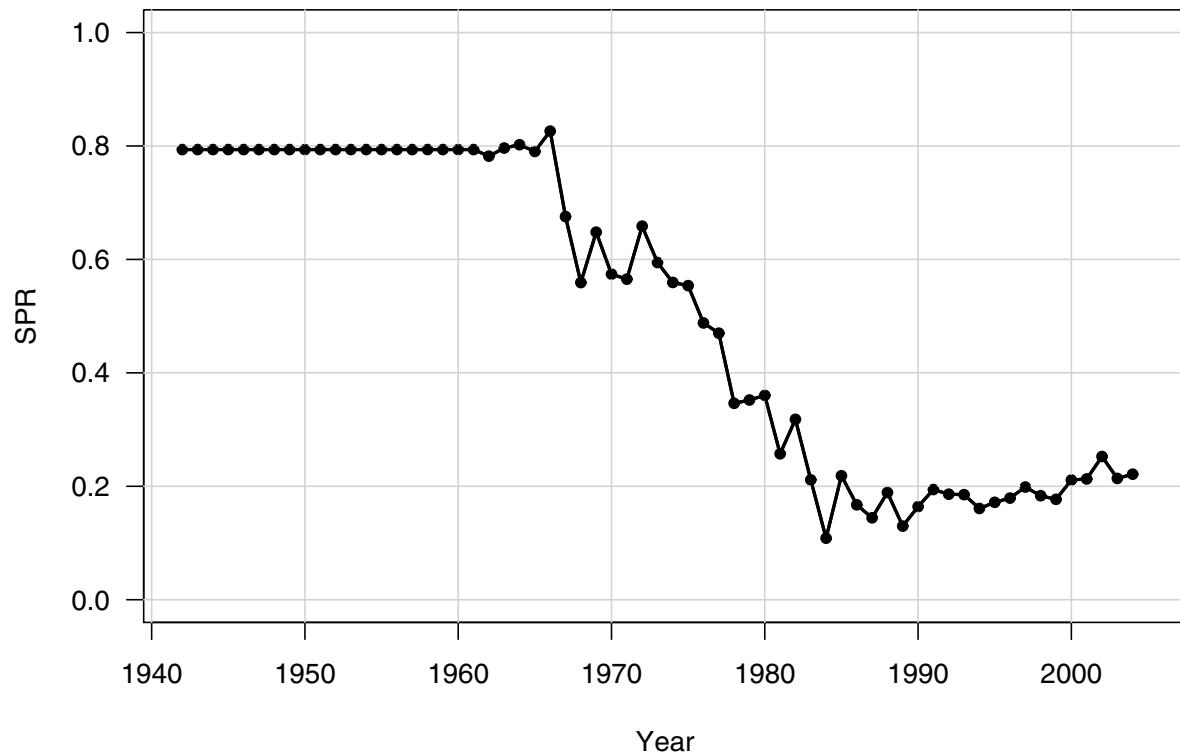


Figure 61. Gag- Base run with constant catchability: Estimated time series of static spawning potential ratio (SPR) using fully selected fishing mortality rates.

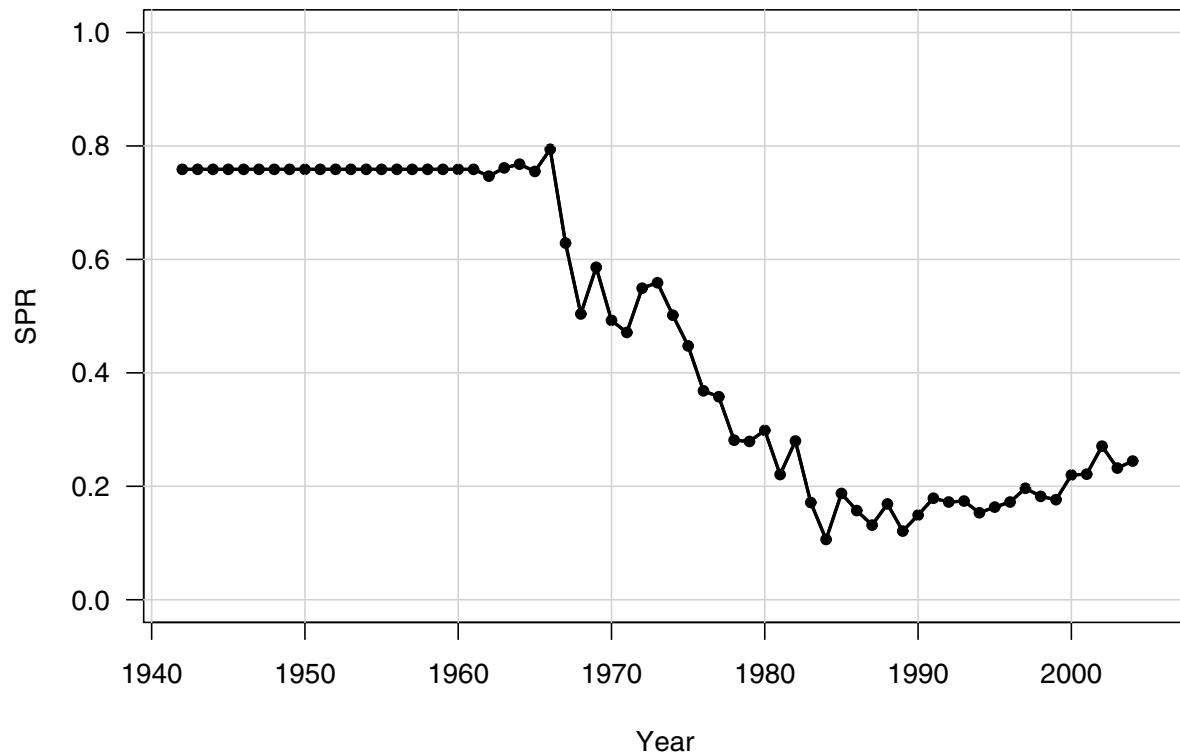


Figure 62. Gag- Base run with time-varying catchability: Estimated A) yield and B) spawning stock biomass (SSB) per recruit (Vertical lines represent F_{max} , $F_{30\%}$, $F_{45\%}$, and F_{MSY} .

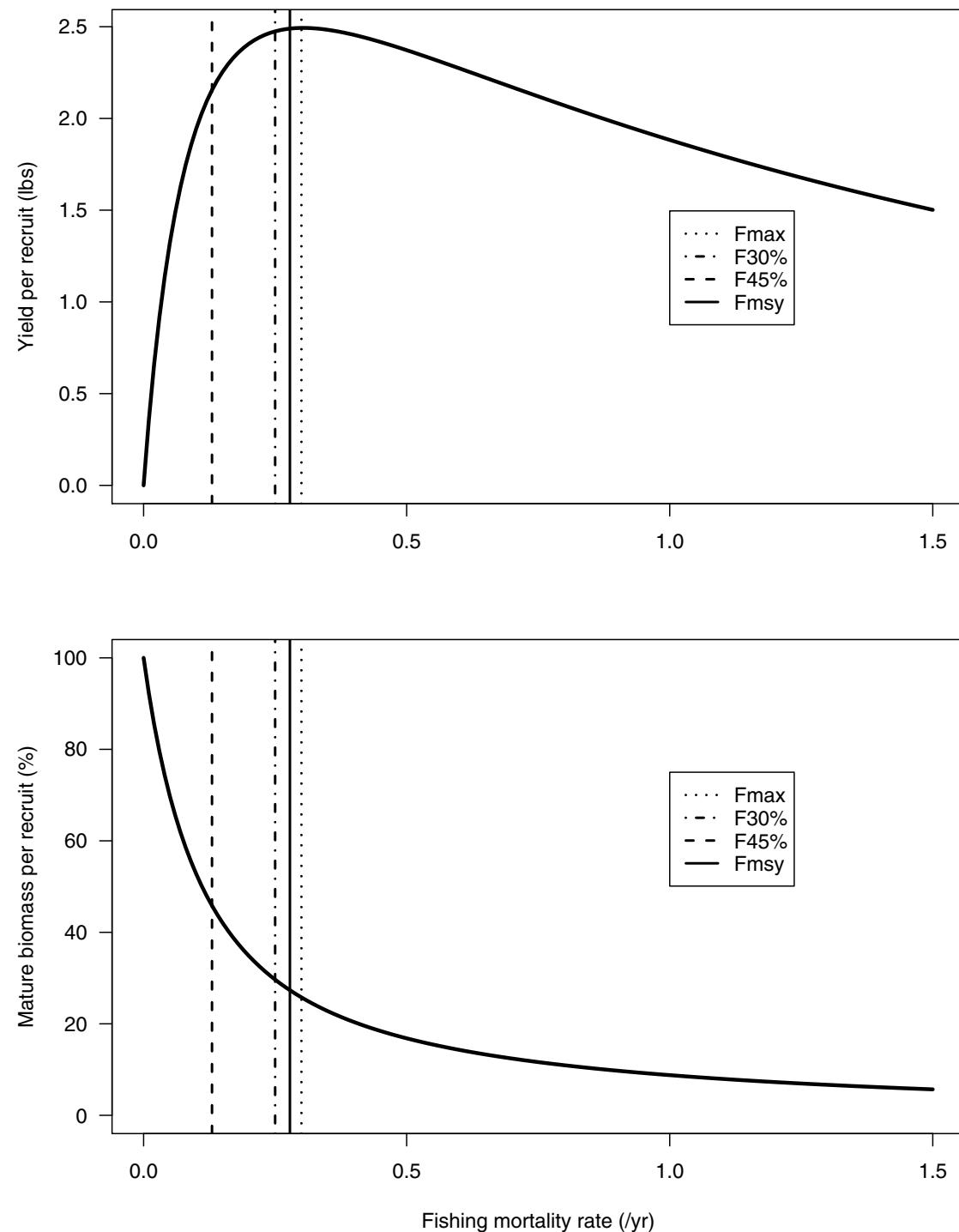


Figure 63. Gag- Base run with constant catchability: Estimated A) yield and B) spawning stock biomass (SSB) per recruit (%SPR) as functions of fully selected fishing mortality rate. Vertical lines represent F_{max} , $F_{30\%}$, $F_{45\%}$, and F_{MSY} .

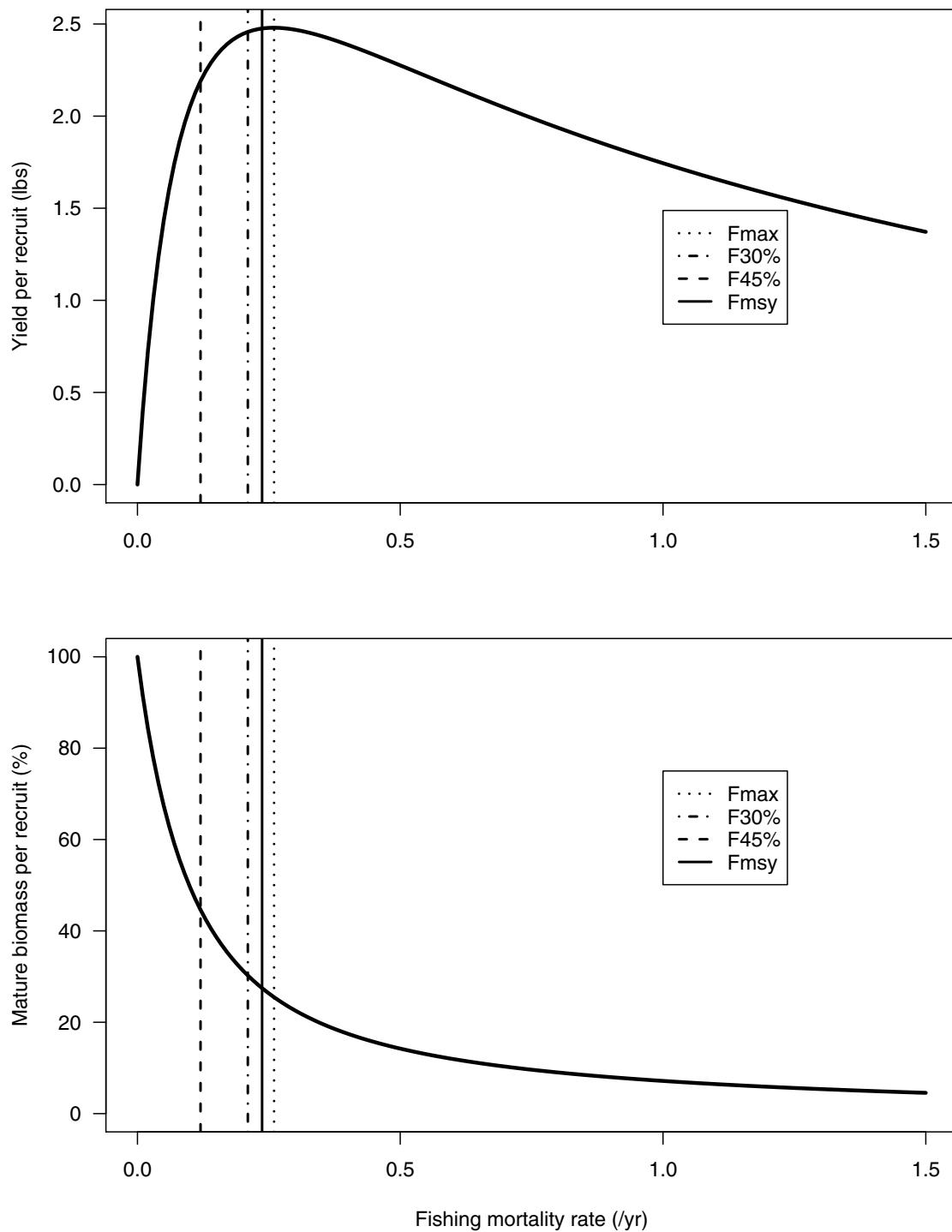


Figure 64. Gag- Base run with time-varying catchability: Estimated A) yield and B) spawning stock biomass (SSB) per recruit (%SPR) as functions of exploitation rate of age 2+. Vertical lines represent E_{MAX} , $E_{30\%}$, $E_{45\%}$, and E_{MSY} .

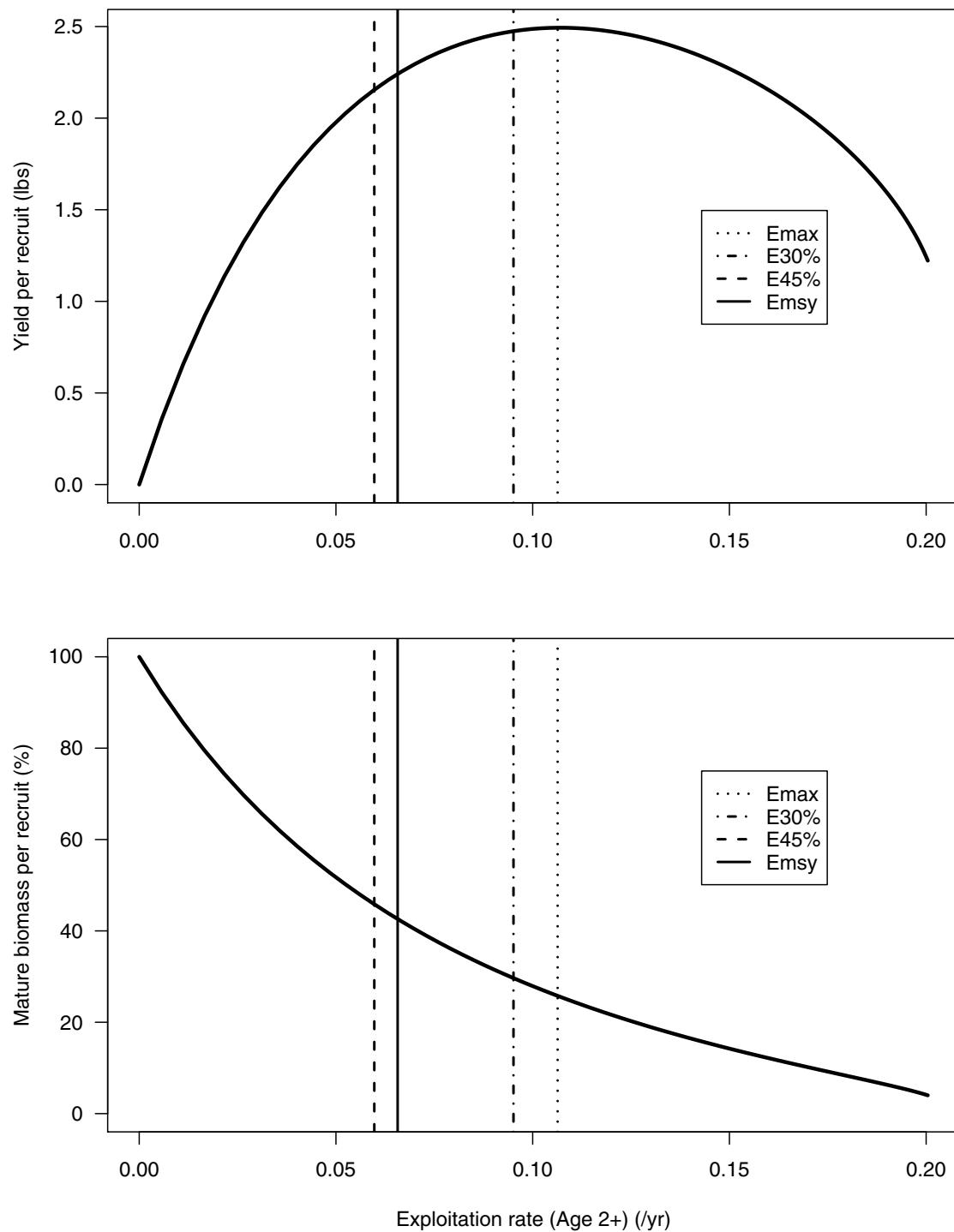


Figure 65. Gag- Base run with constant catchability: Estimated A) yield and B) spawning stock biomass (SSB) per recruit (%SPR) as functions of exploitation rate of age 2⁺. Vertical lines represent E_{MAX} , $E_{30\%}$, $E_{45\%}$, and E_{MSY} .

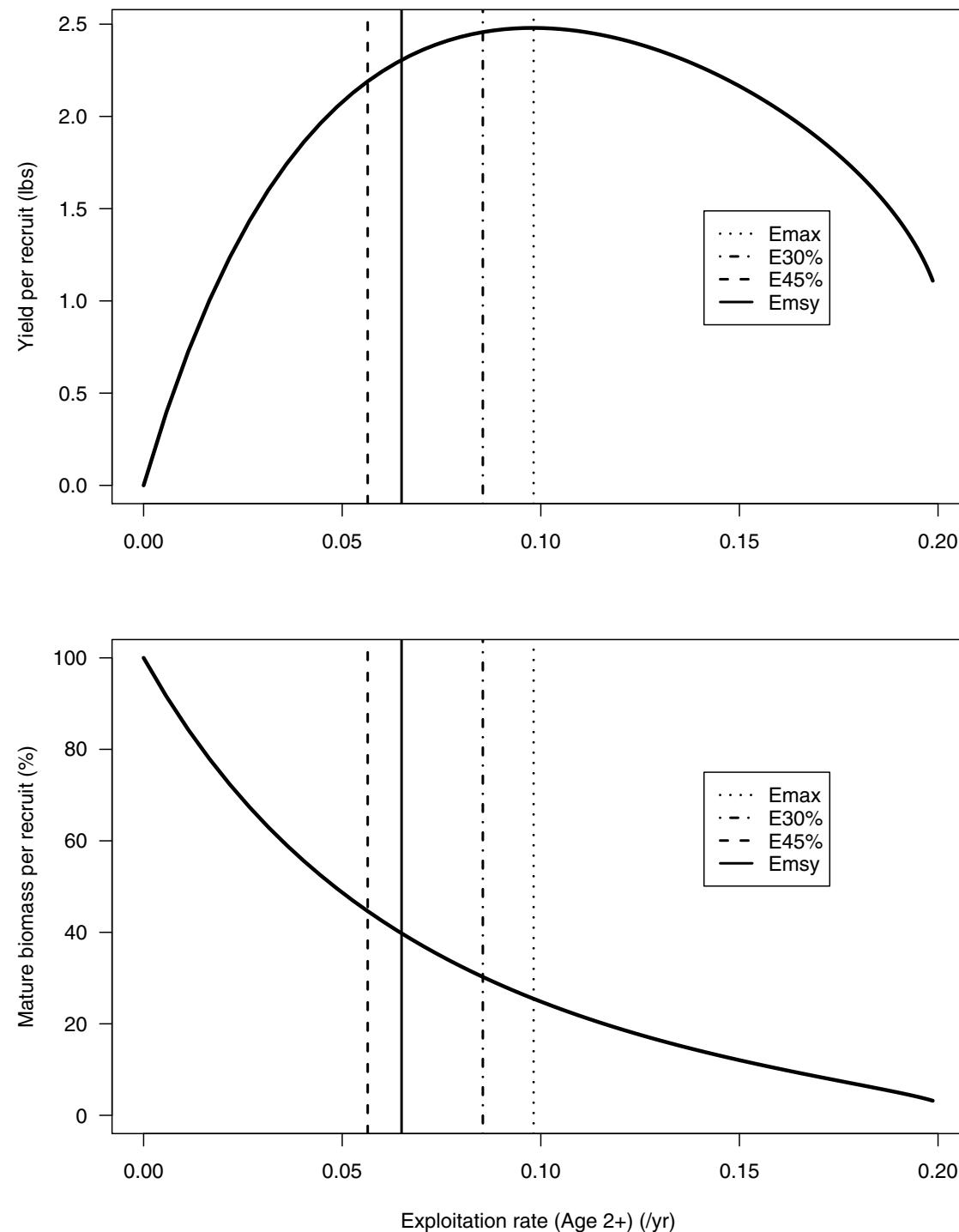


Figure 66. Gag- Base run with time-varying catchability: Equilibrium A) landings and B) SSB, as expected from the estimated stock-recruit curve with bias correction. Vertical lines represent F_{MSY} , the F that maximizes equilibrium landings, and $F_{30\%}$, $F_{45\%}$, and F_{max} , as computed from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

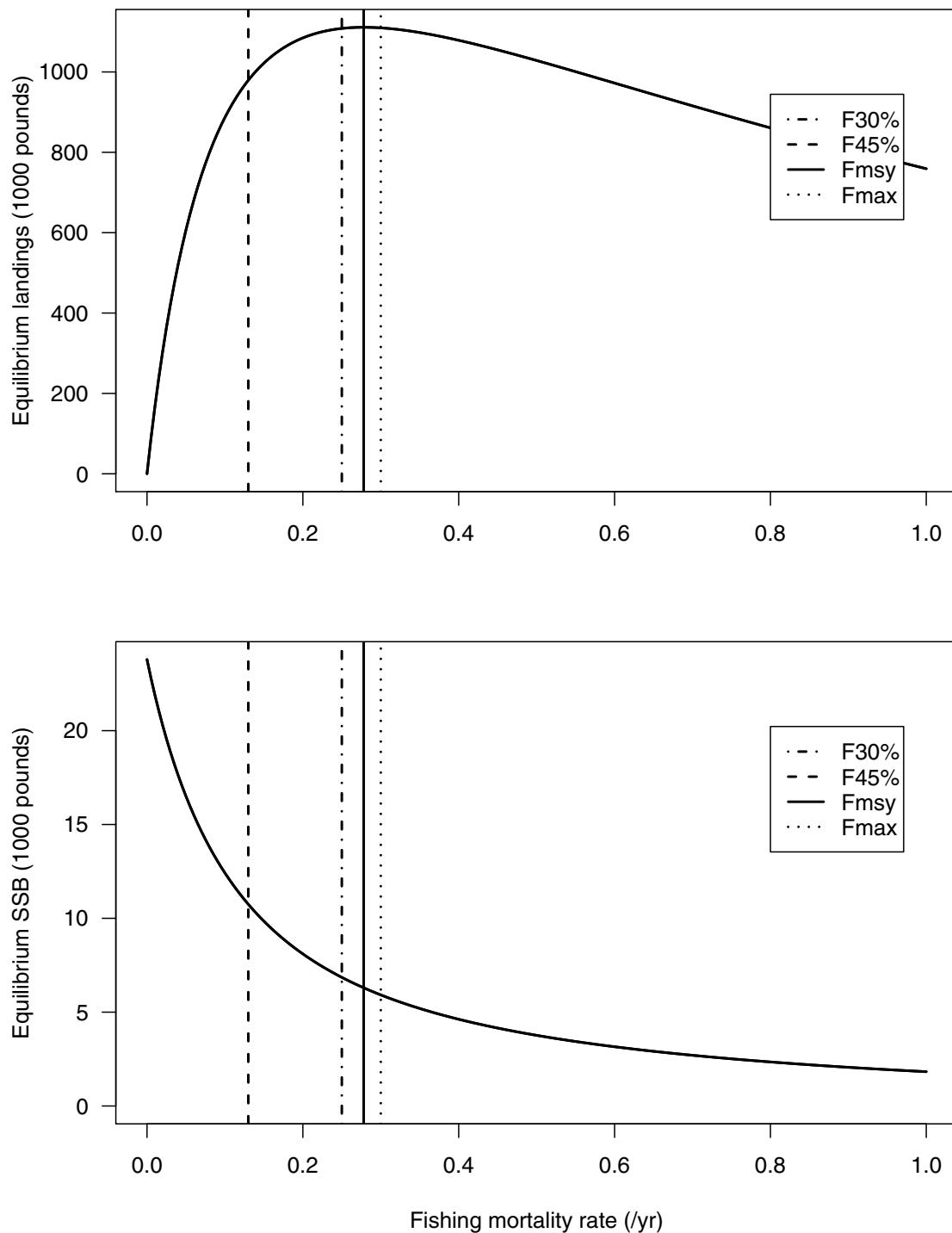


Figure 67. Gag- Base run with constant catchability: Equilibrium A) landings and B) SSB, as expected from the estimated stock-recruit curve with bias correction. Vertical lines represent F_{MSY} , the F that maximizes equilibrium landings, and $F_{30\%}$, $F_{45\%}$, and F_{max} , as computed from per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

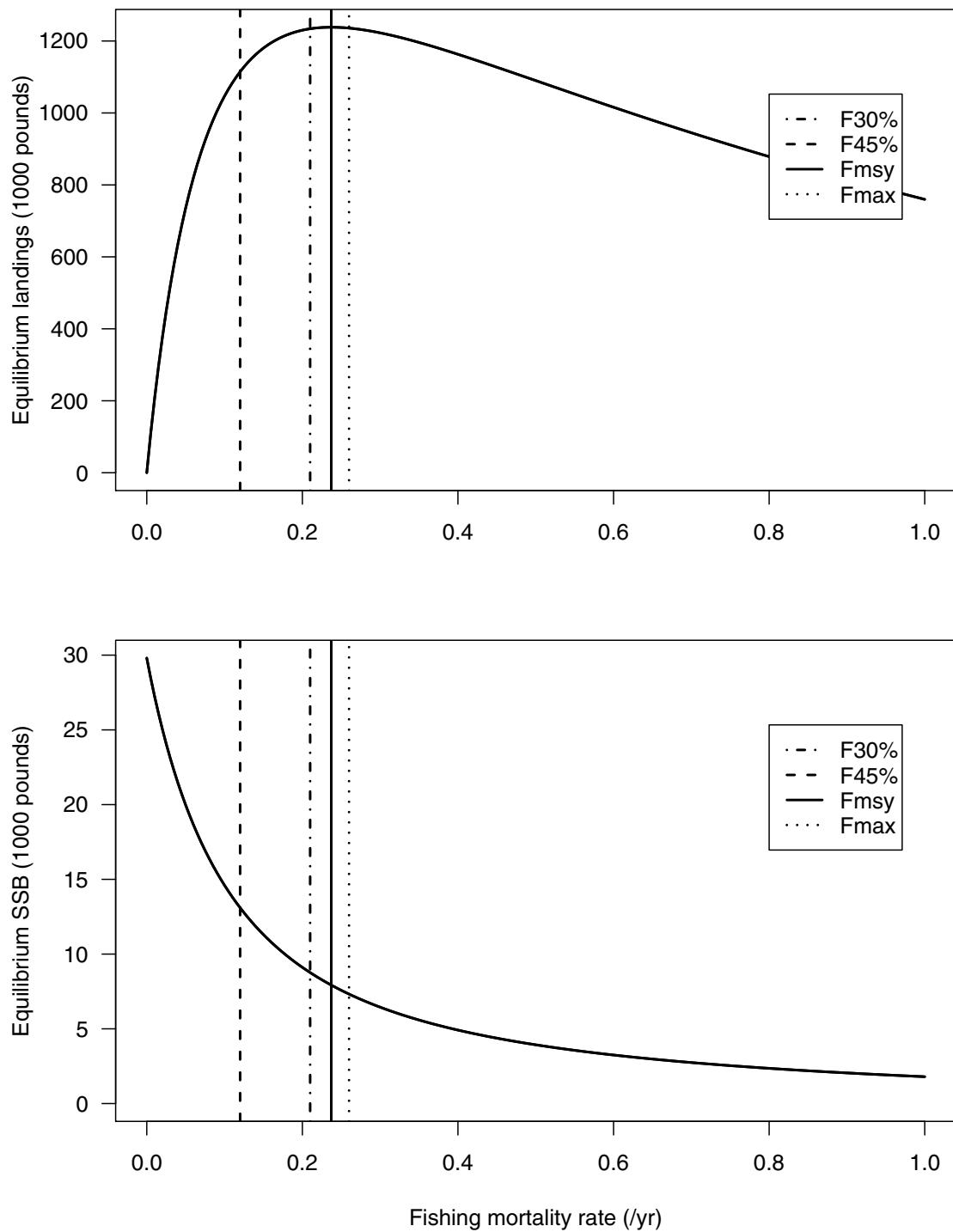


Figure 68. Gag- Base run with time-varying catchability: Equilibrium A) landings and B) SSB, as expected from the estimated stock-recruit curve with bias correction. Vertical lines represent E_{MSY} , the E that maximizes equilibrium landings, and $E_{30\%}$, $E_{45\%}$, and E_{MAX} , as computed from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

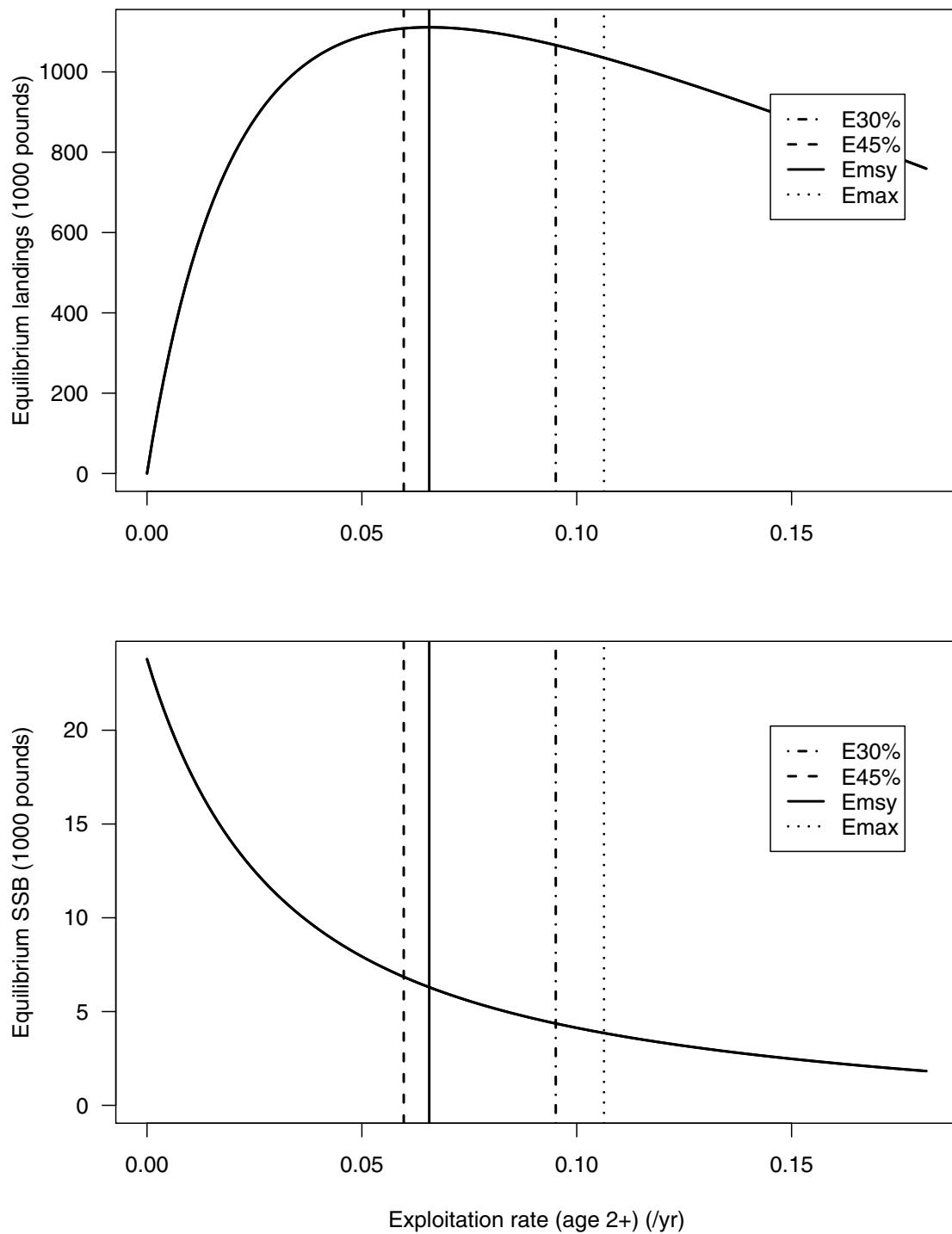


Figure 69. Gag- Base run with constant catchability: Equilibrium A) landings and B) SSB, as expected from the estimated stock-recruit curve with bias correction. Vertical lines represent E_{MSY} , the E that maximizes equilibrium landings, and $E_{30\%}$, $E_{45\%}$, and E_{MAX} , as computed from per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

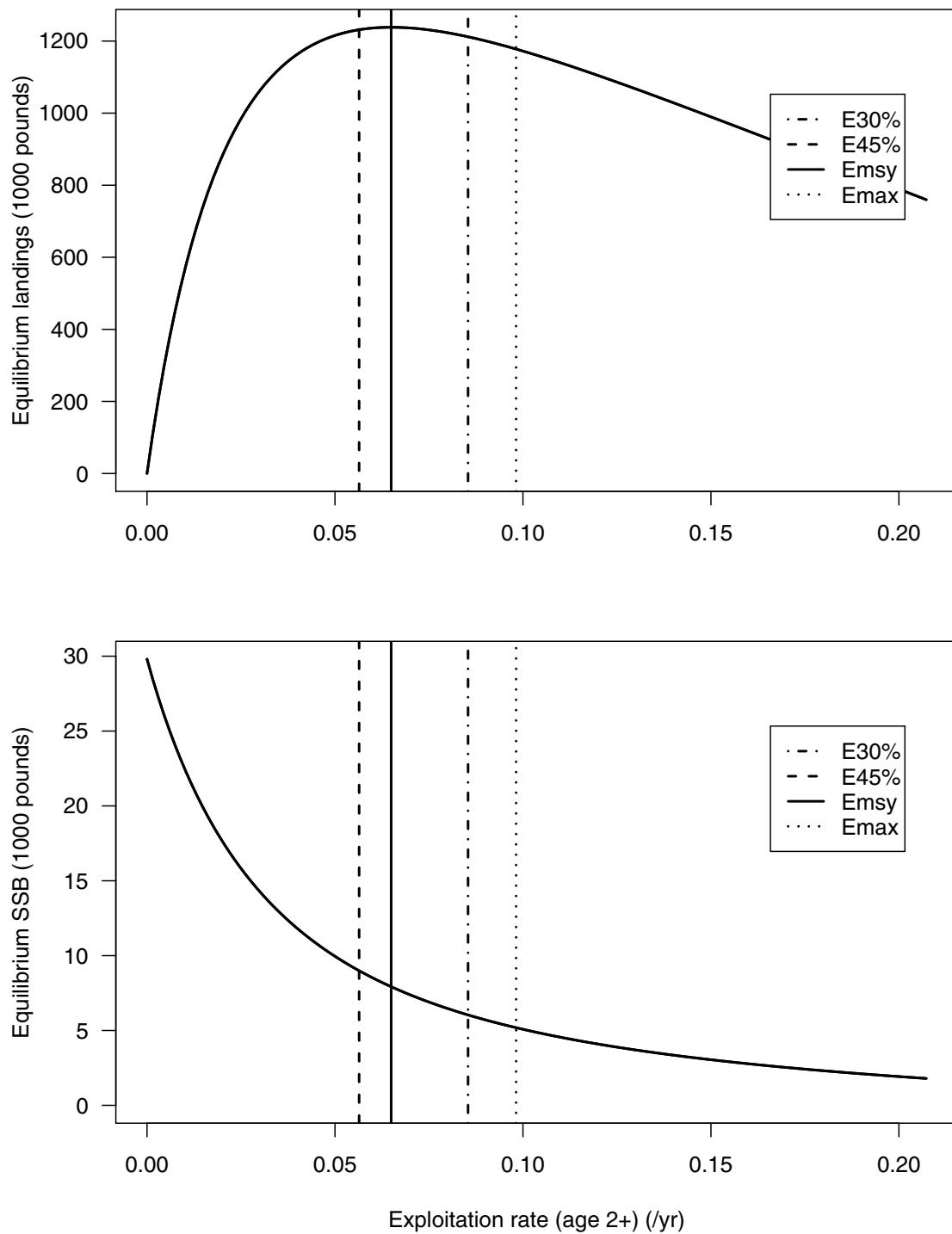


Figure 70. Gag in Atlantic: Fit of production models to headboat index. Panel (a), run G102, constant catchability assumed; (b), run G117, catchability increasing since 1980 assumed.

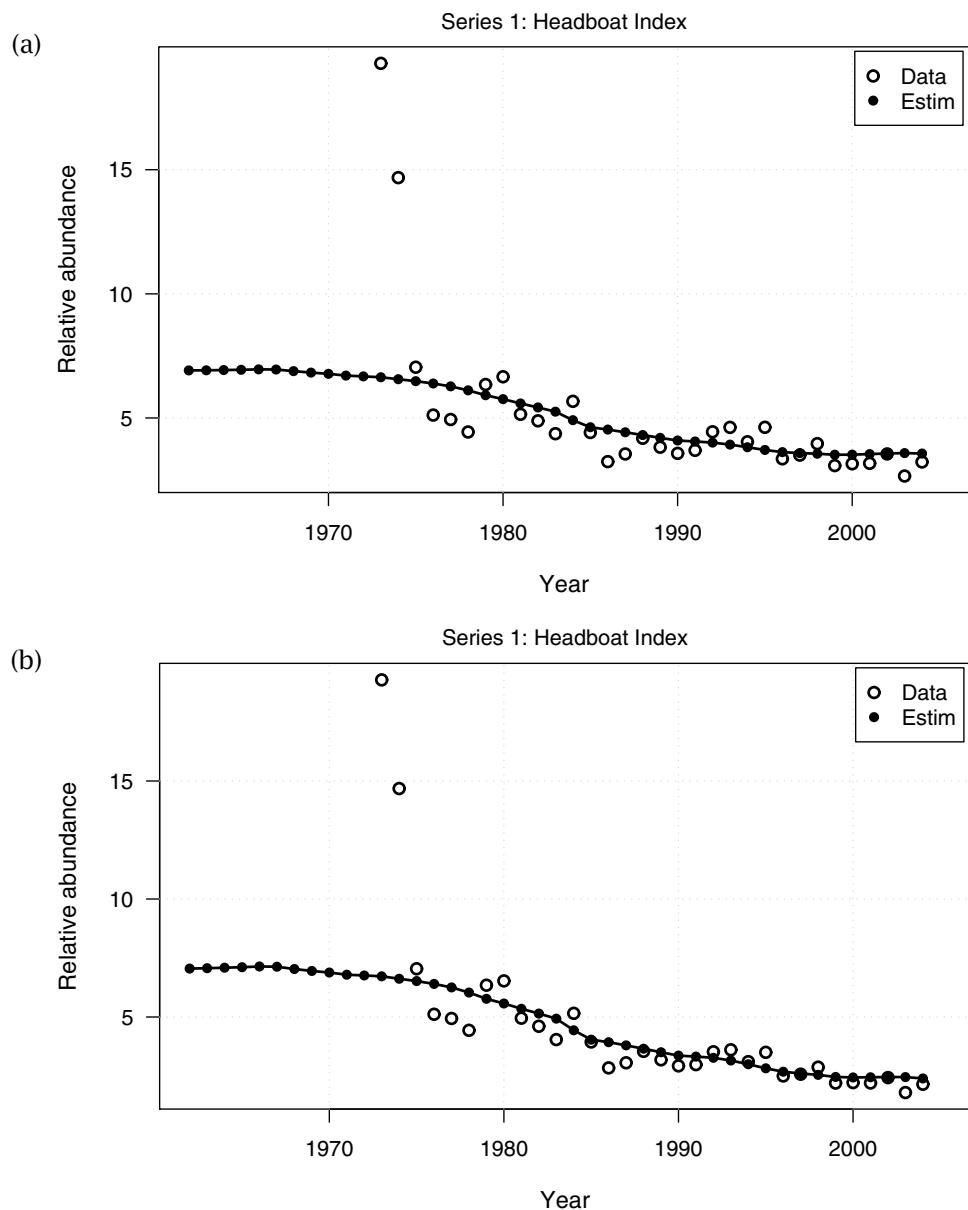


Figure 71. Gag in Atlantic: Fit of production models to commercial logbook index. Panel (a), run G102, constant catchability assumed; (b), run G117, catchability increasing since 1980 assumed.

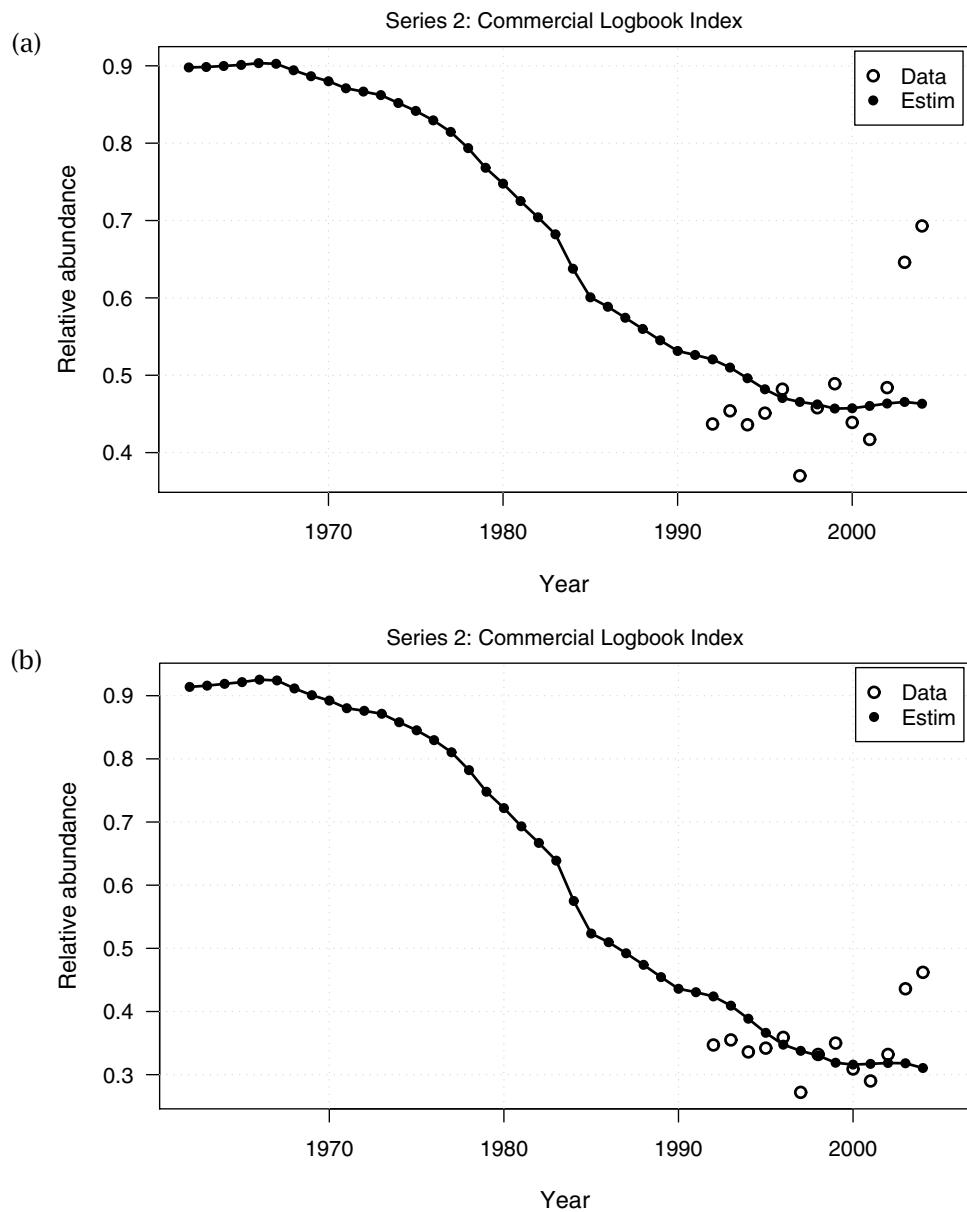


Figure 72. Gag in Atlantic: Fit of production models to MRFSS index. Panel (a), run G102, constant catchability assumed; (b), run G117, catchability increasing since 1980 assumed.

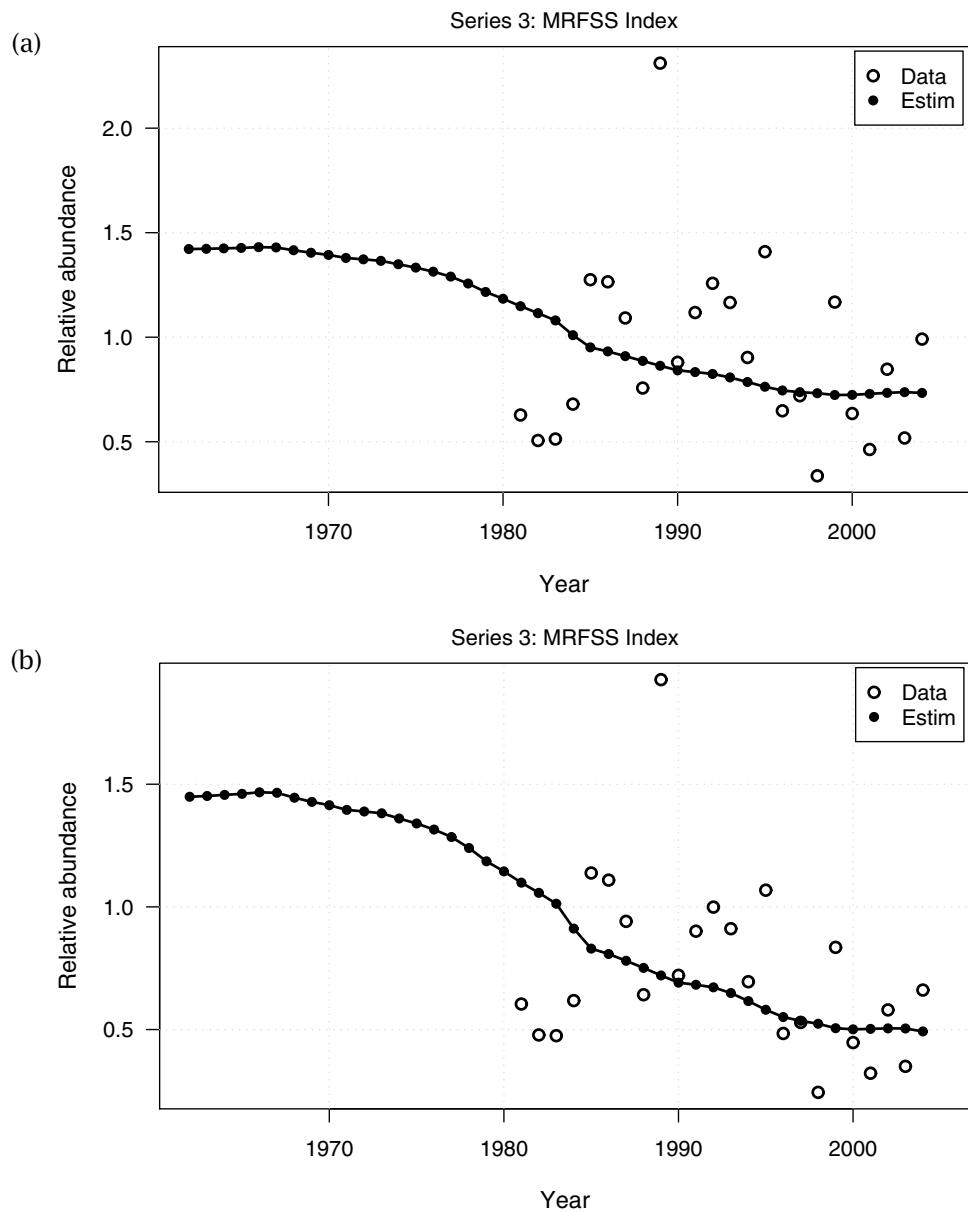


Figure 73. Gag in Atlantic: Time trajectory of biomass from production model under different assumptions about starting biomass. In each panel runs reflect $B_1/K = \{0.9, 0.7, 0.5\}$. Panel (a), constant catchability assumed; (b), catchability assumed to increase linearly at 2%/yr starting in 1980.

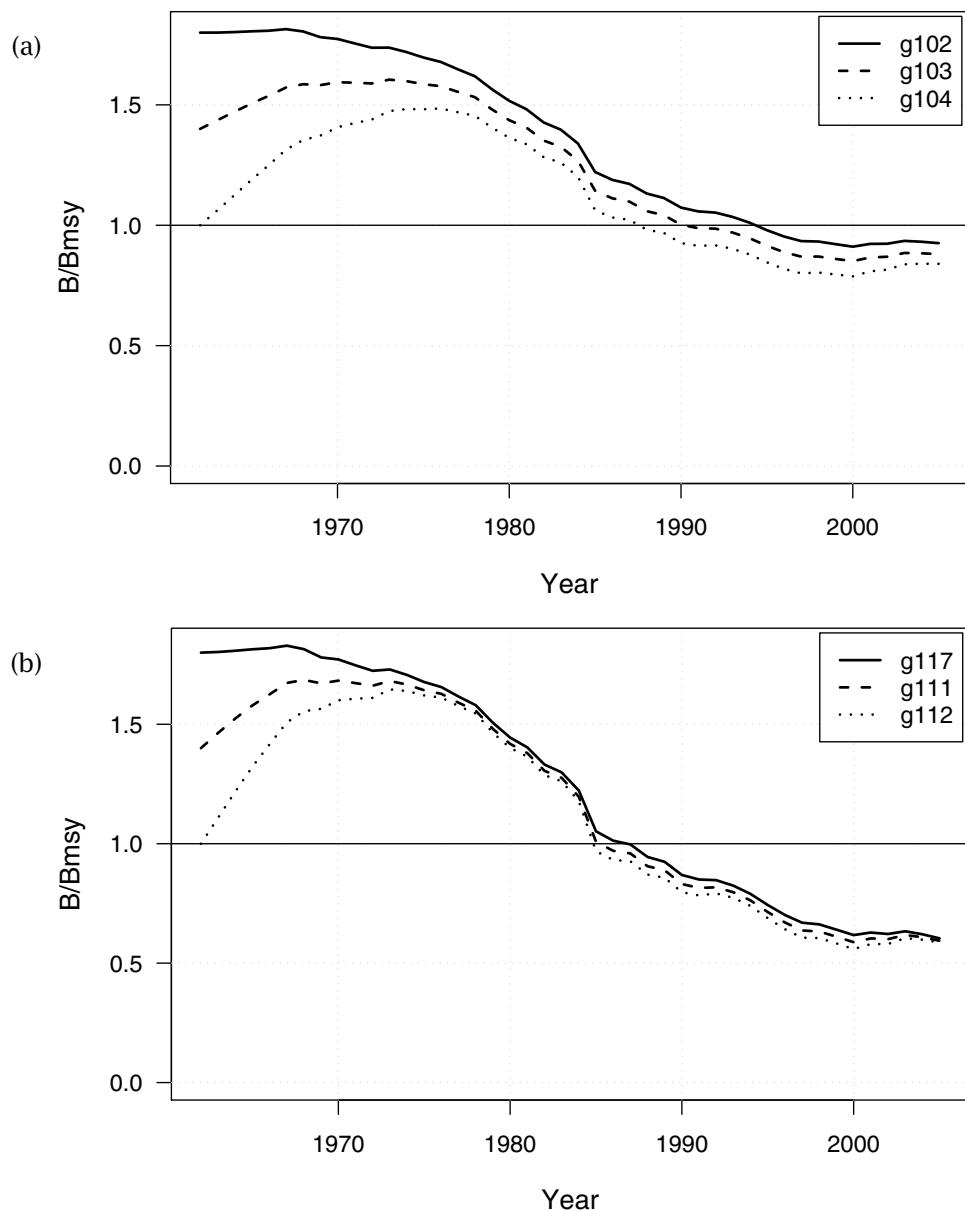


Figure 74. Gag in Atlantic: Time trajectory of fishing mortality rate from production model under different assumptions about starting biomass. In each panel runs reflect $B_1/K = \{0.9, 0.7, 0.5\}$. Panel (a), constant catchability assumed; (b), catchability assumed to increase linearly at 2%/yr starting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

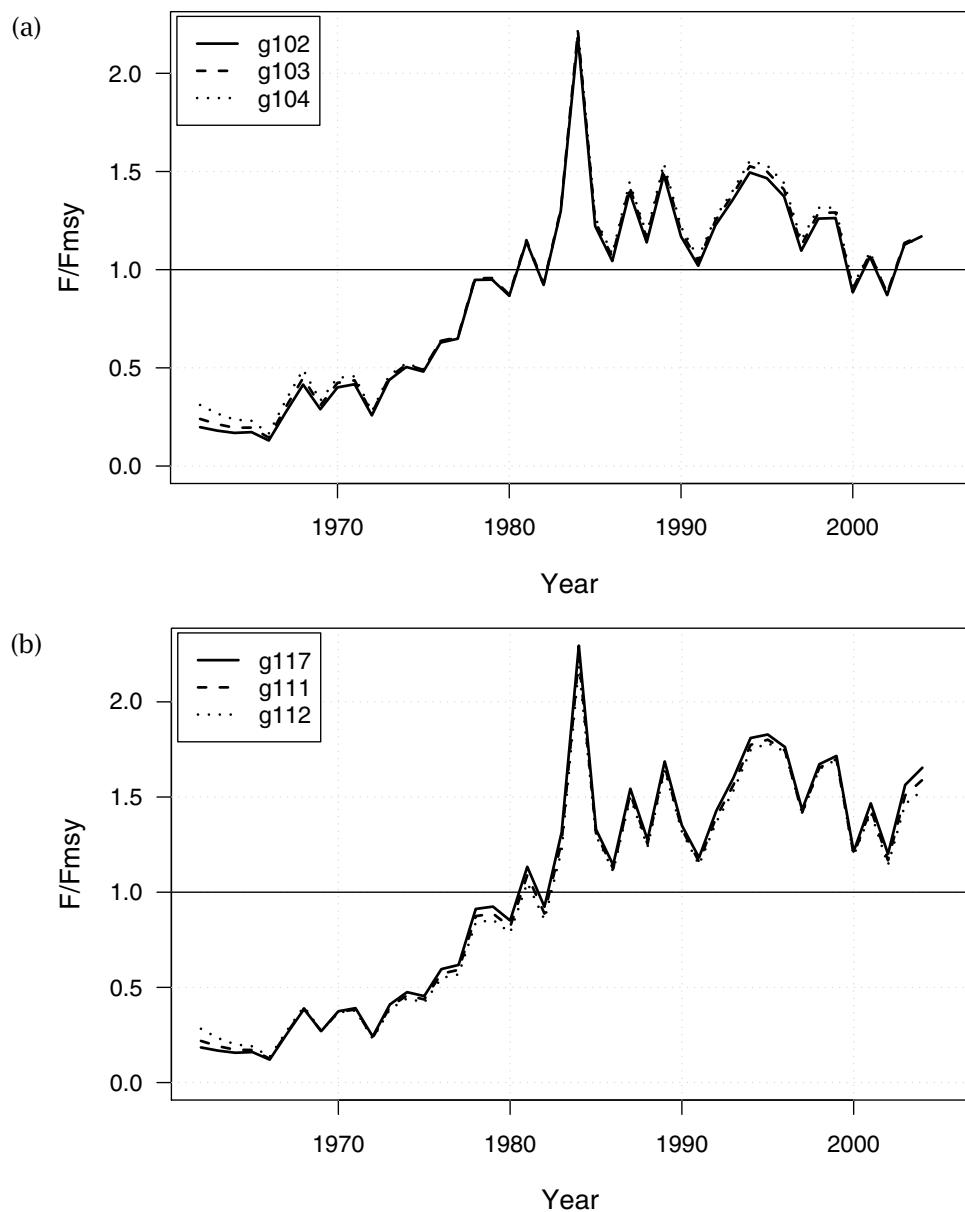


Figure 75. Gag in Atlantic: Time trajectories from production model under constant catchability (run G102) or increasing catchability over time (run G117). Panel (a), relative biomass; (b), relative fishing mortality rate.

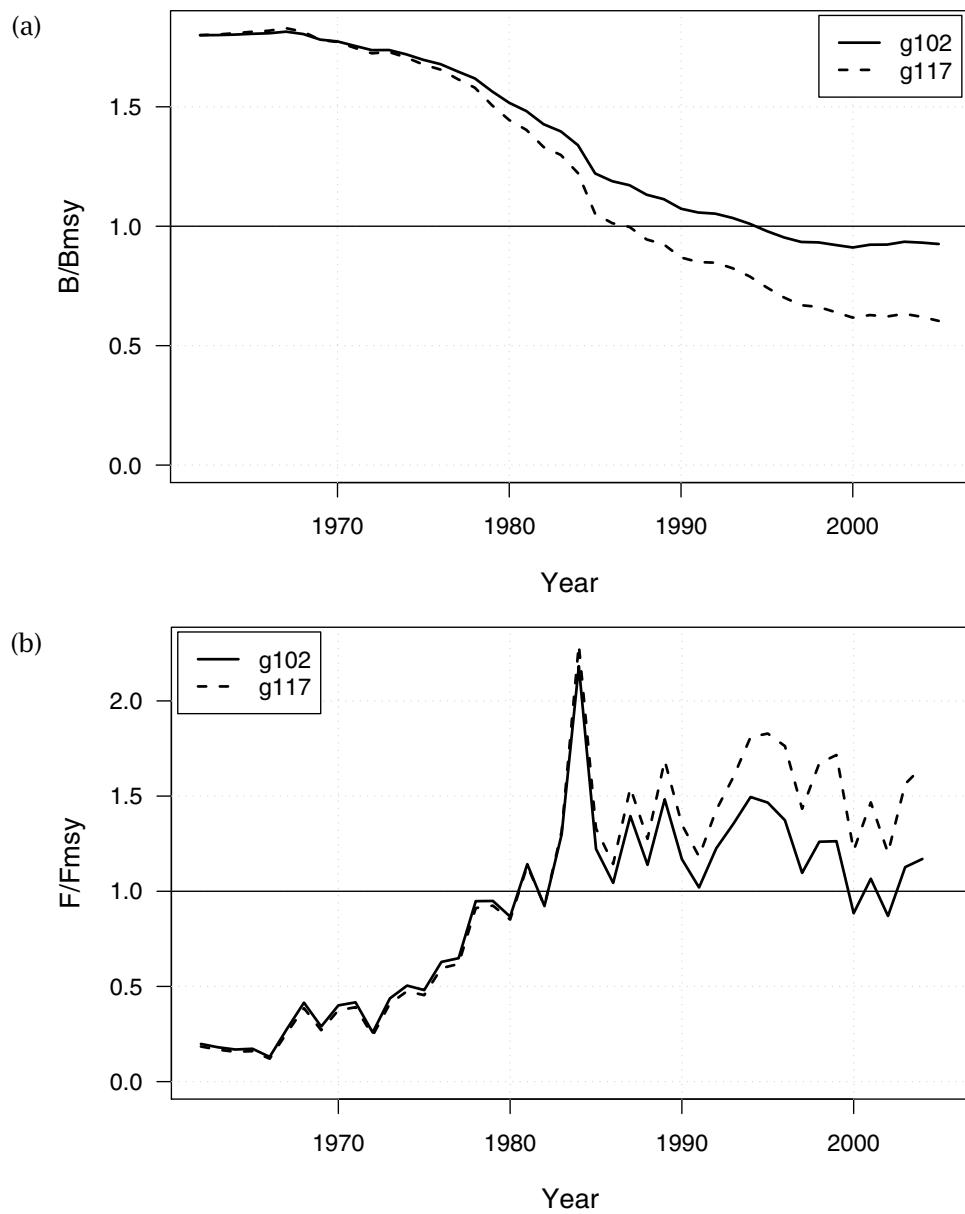
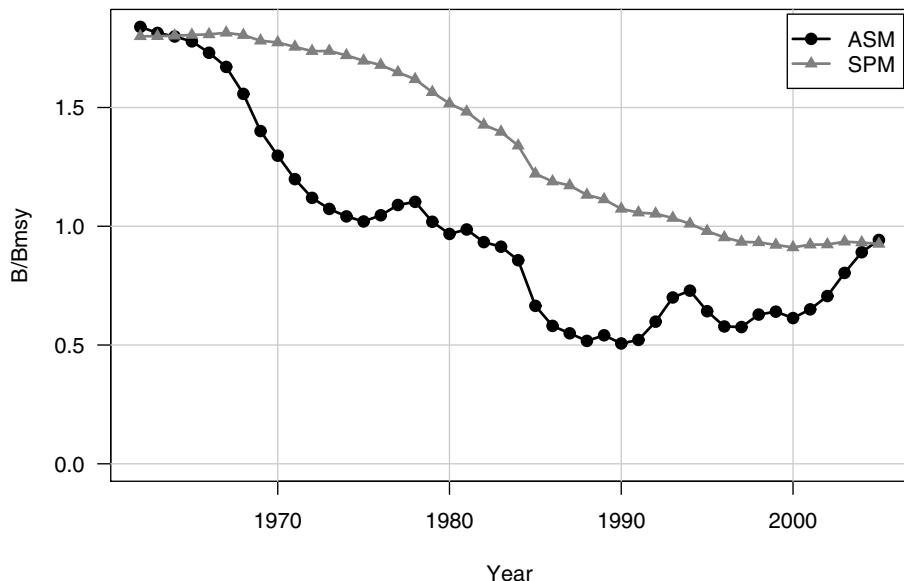


Figure 76. Gag in Atlantic: Comparison of stock-status trajectories estimated from age-structured model (ASM) and surplus-production model (SPM). Panel (a), constant catchability assumed; (b), catchability assumed to increase linearly at 2%/yr starting in 1980.

(a)



(b)

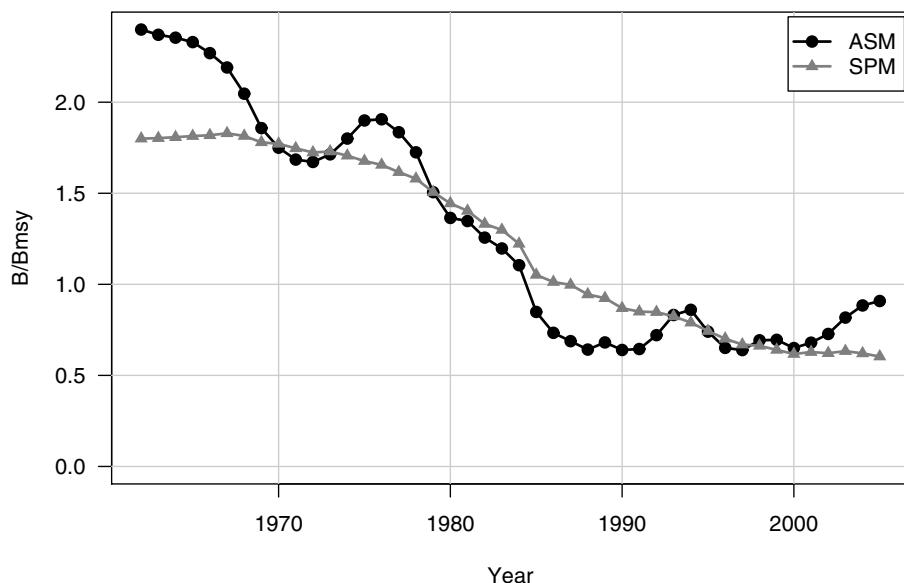
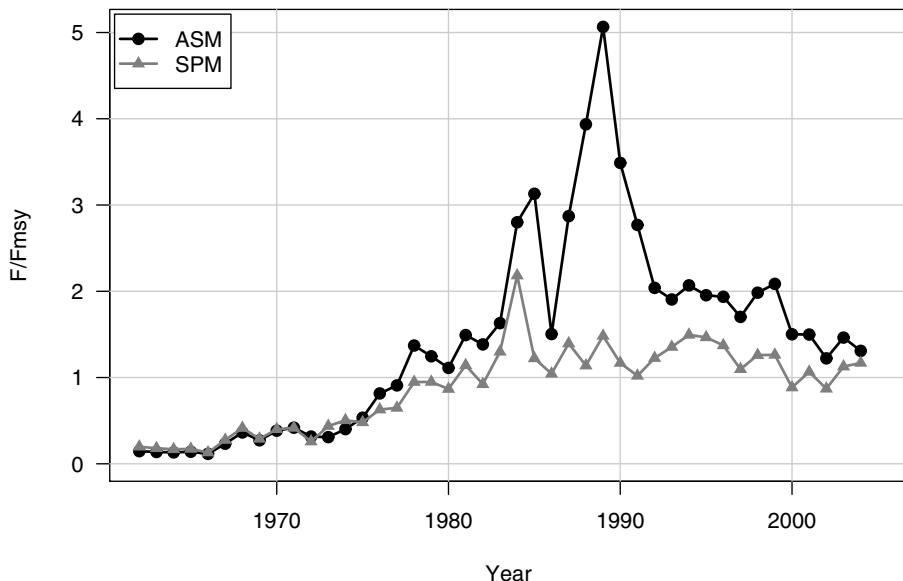


Figure 77. Gag in Atlantic: Comparison of fishery-status trajectories estimated from age-structured model (ASM) and surplus-production model (SPM). Panel (a), constant catchability assumed; (b), catchability assumed to increase linearly at 2%/yr starting in 1980.

(a)



(b)

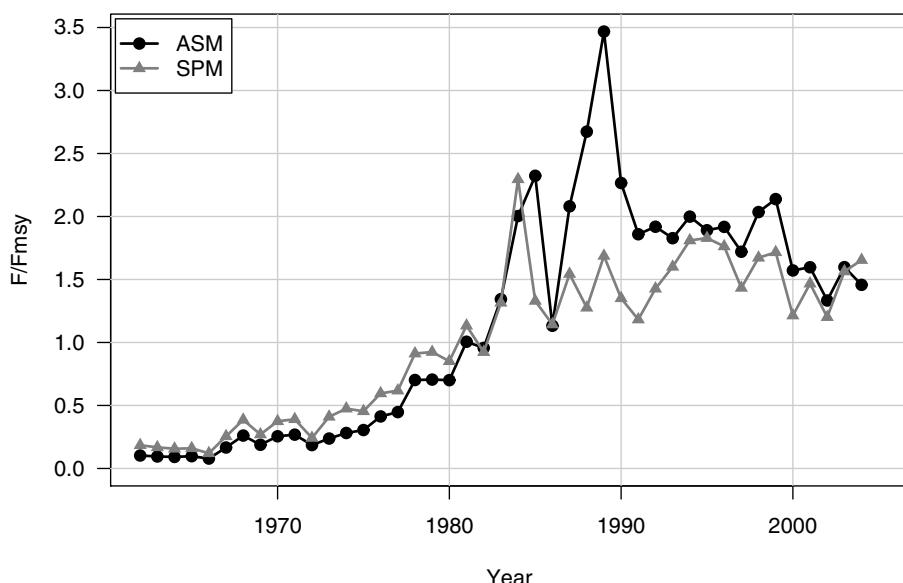


Figure 78. Gag- Base run with time-varying catchability: Probability density of stock-recruit parameters R_0 (virgin recruitment) and steepness, and maximum sustainable yield (MSY) and recruitment at MSY (R_{MSY}). Vertical line represents base run estimate.

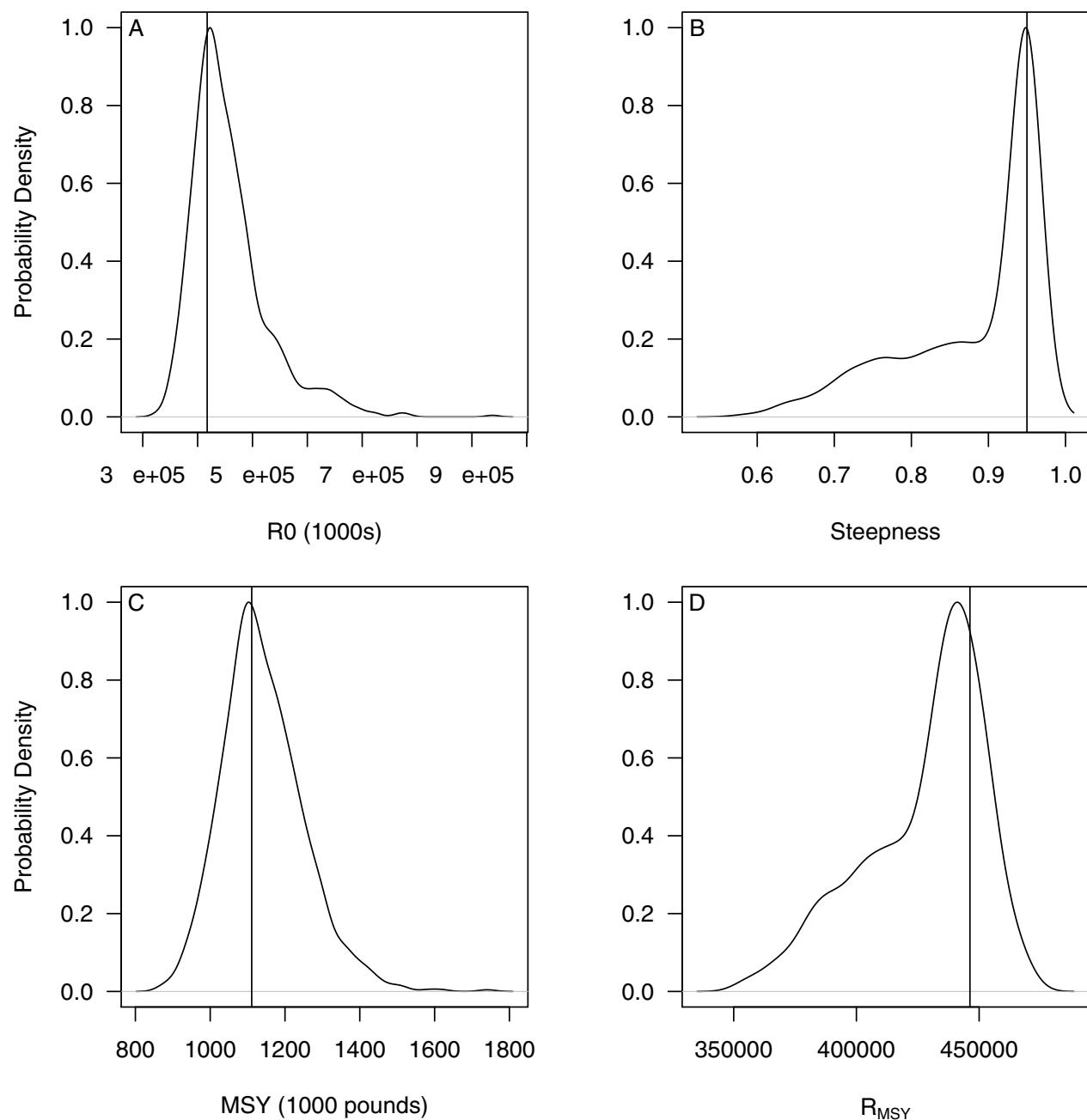


Figure 79. Gag- Base run with constant catchability: Probability density of stock-recruit parameters R_0 (virgin recruitment) and steepness, and maximum sustainable yield (MSY) and recruitment at MSY (R_{MSY}). Vertical line represents base run estimate.

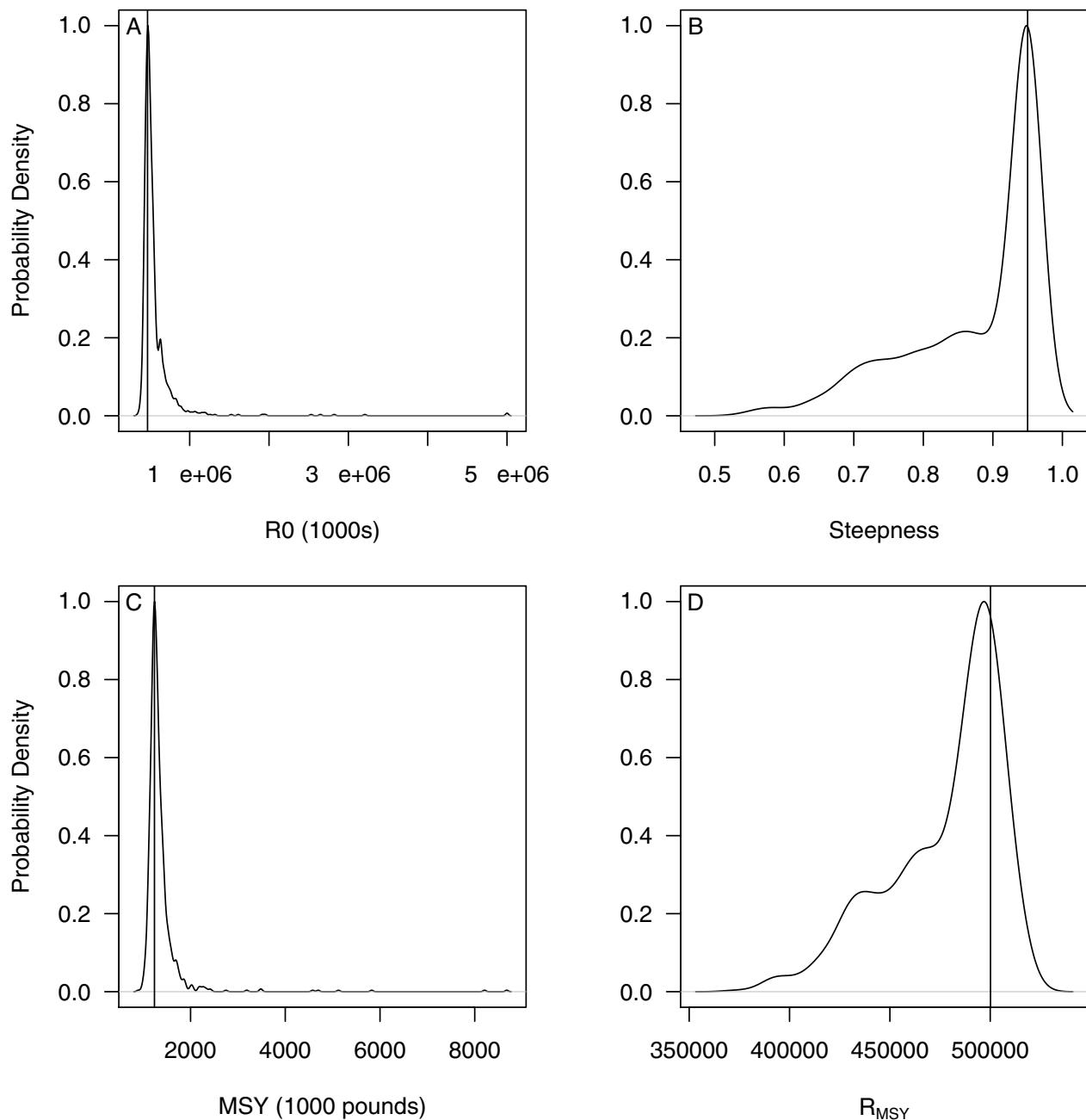


Figure 80. Gag- Base run with time-varying catchability: Probability density of maximum sustainable yield (MSY) benchmarks, fishing mortality rate at MSY (F_{MSY}), exploitation rate of age-2+ at MSY (E_{MSY}), spawning stock biomass (klb) at MSY (SSB_{MSY}), total biomass (klb) at MSY (B_{MSY}). Vertical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

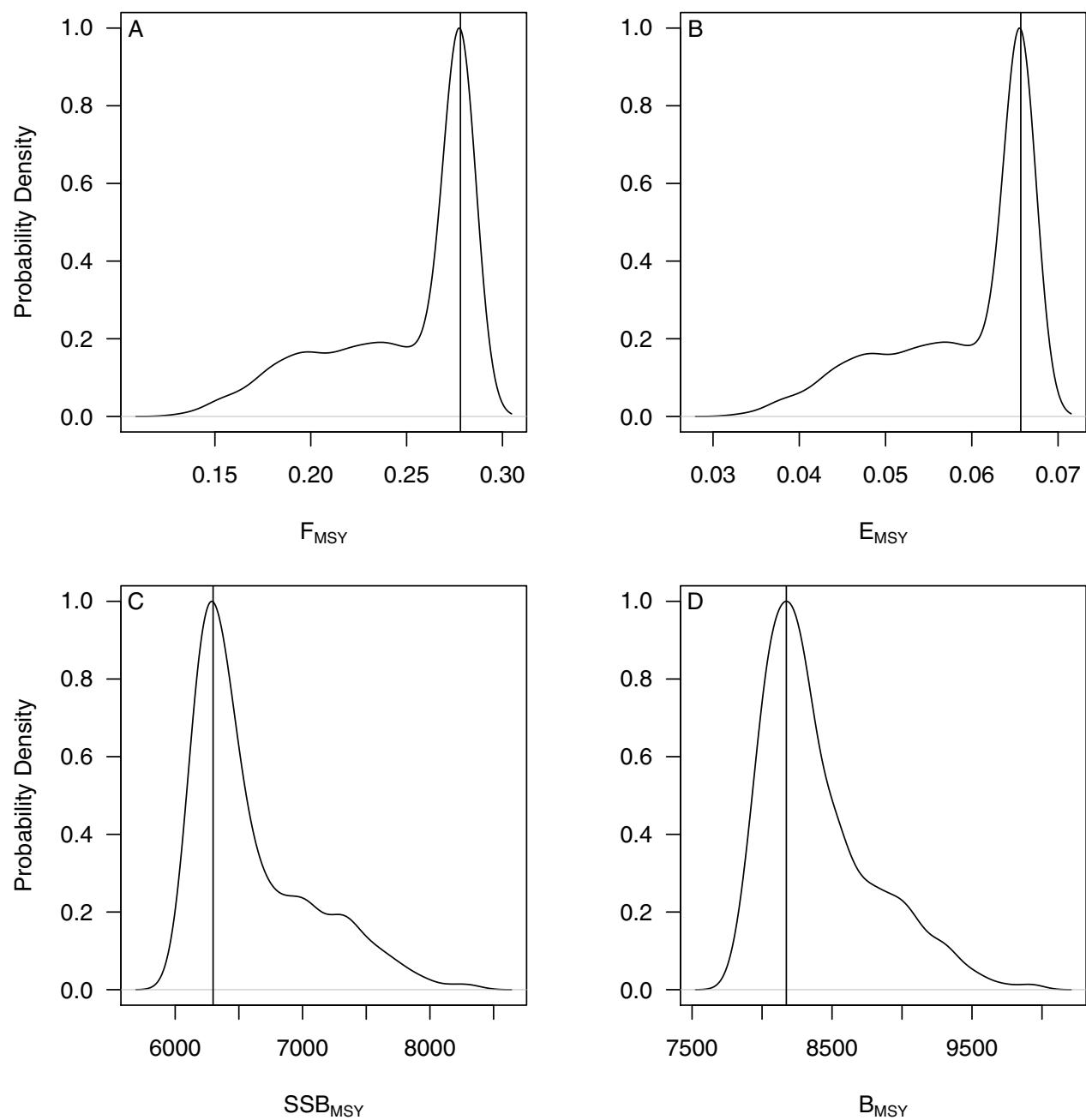


Figure 81. Gag- Base run with constant catchability: Probability density of maximum sustainable yield (MSY) benchmarks, fishing mortality rate at MSY (F_{MSY}), exploitation rate of age-2+ at MSY (E_{MSY}) , spawning stock biomass (klb) at MSY (SSB_{MSY}), total biomass (klb) at MSY (B_{MSY}). Vertical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

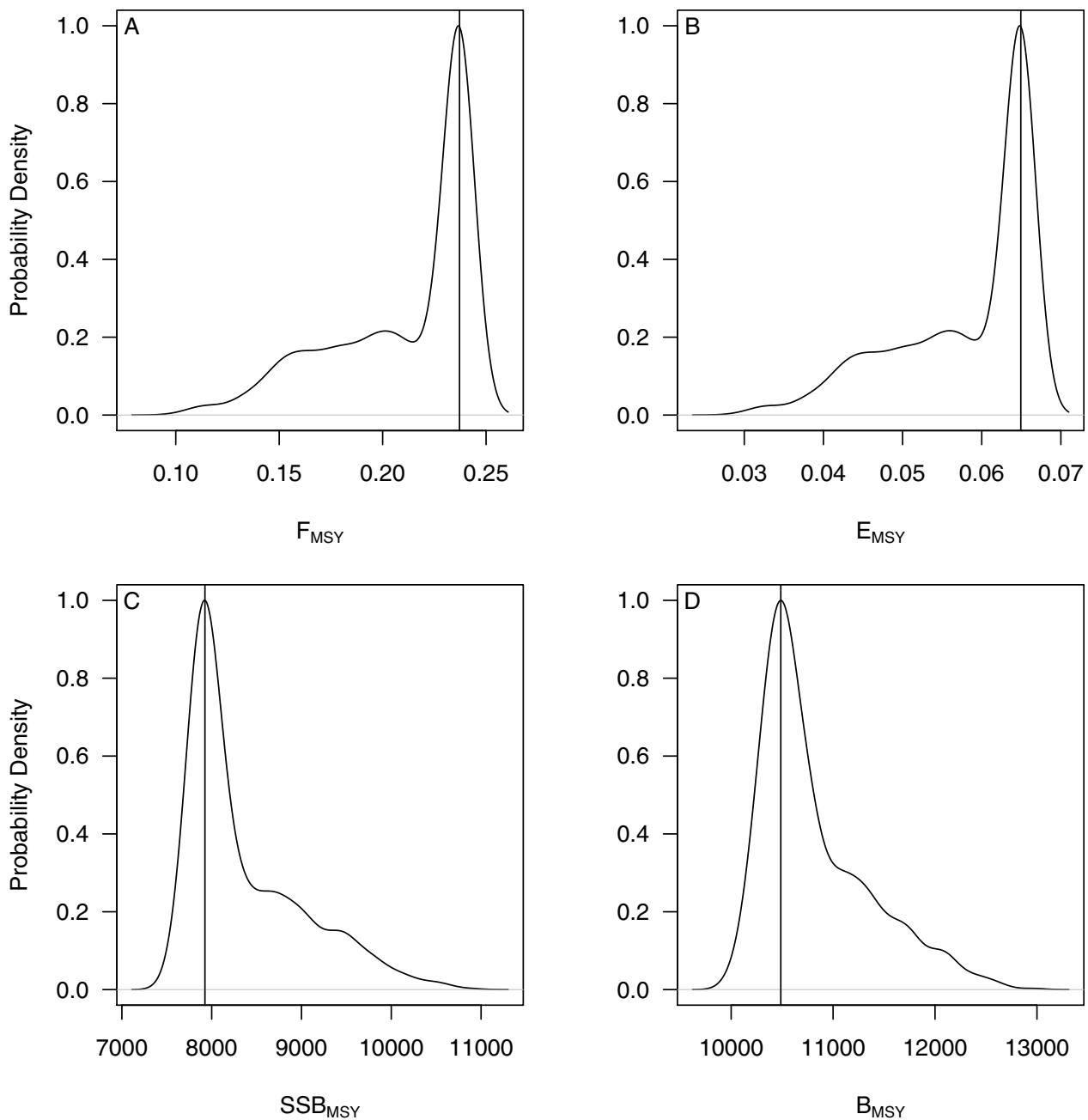


Figure 82. Gag- Base run with time-varying catchability: Estimated biomass time series, relative to MSY benchmarks, of A) B relative to B_{MSY} and B) SSB relative to SSB_{MSY} . In each panel, a dashed horizontal line at one indicates where an estimated time series would equal its related benchmark; 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.

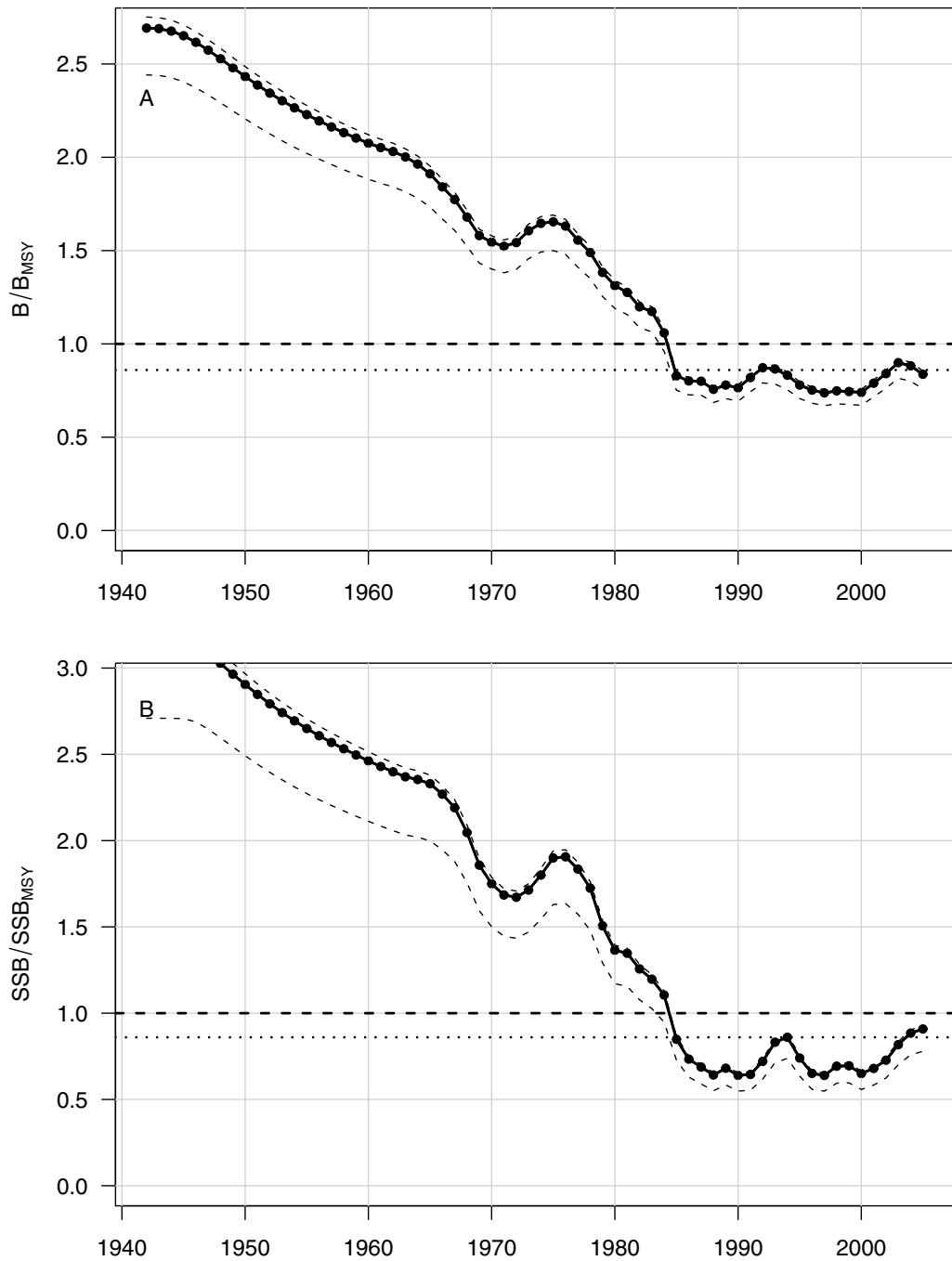


Figure 83. Gag- Base run with constant catchability: Estimated biomass time series, relative to MSY benchmarks, of A) B relative to B_{MSY} and B) SSB relative to SSB_{MSY} . In each panel, a dashed horizontal line at one indicates where an estimated time series would equal its related benchmark; a dotted 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.

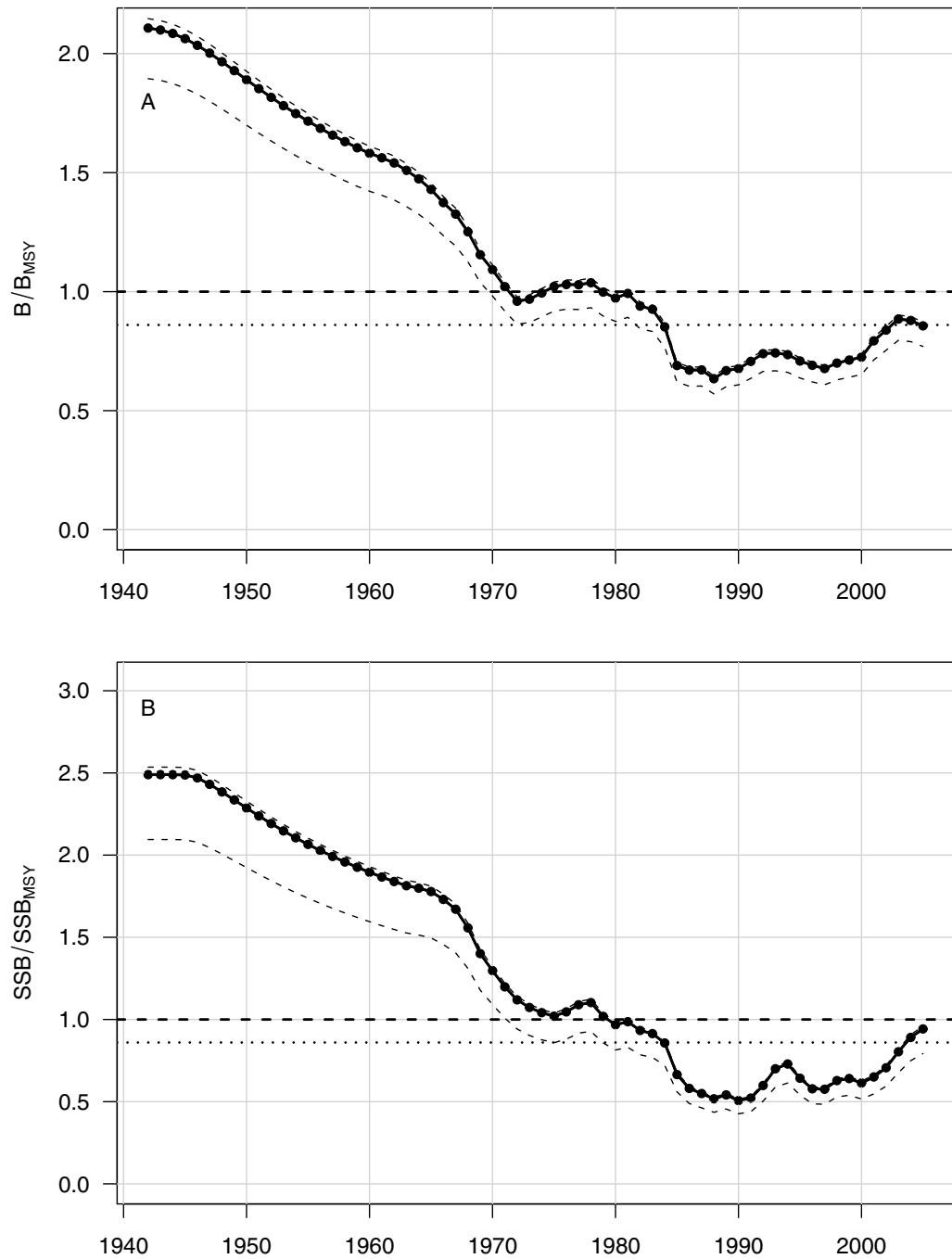


Figure 84. Gag- Base run with time-varying catchability: Estimated exploitation time series, relative to MSY benchmarks, of A) Fishing mortality rate (F) relative to F_{MSY} and B) Exploitation rate (E) relative to E_{MSY} . In each panel, a dashed horizontal line at one indicates where an estimated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

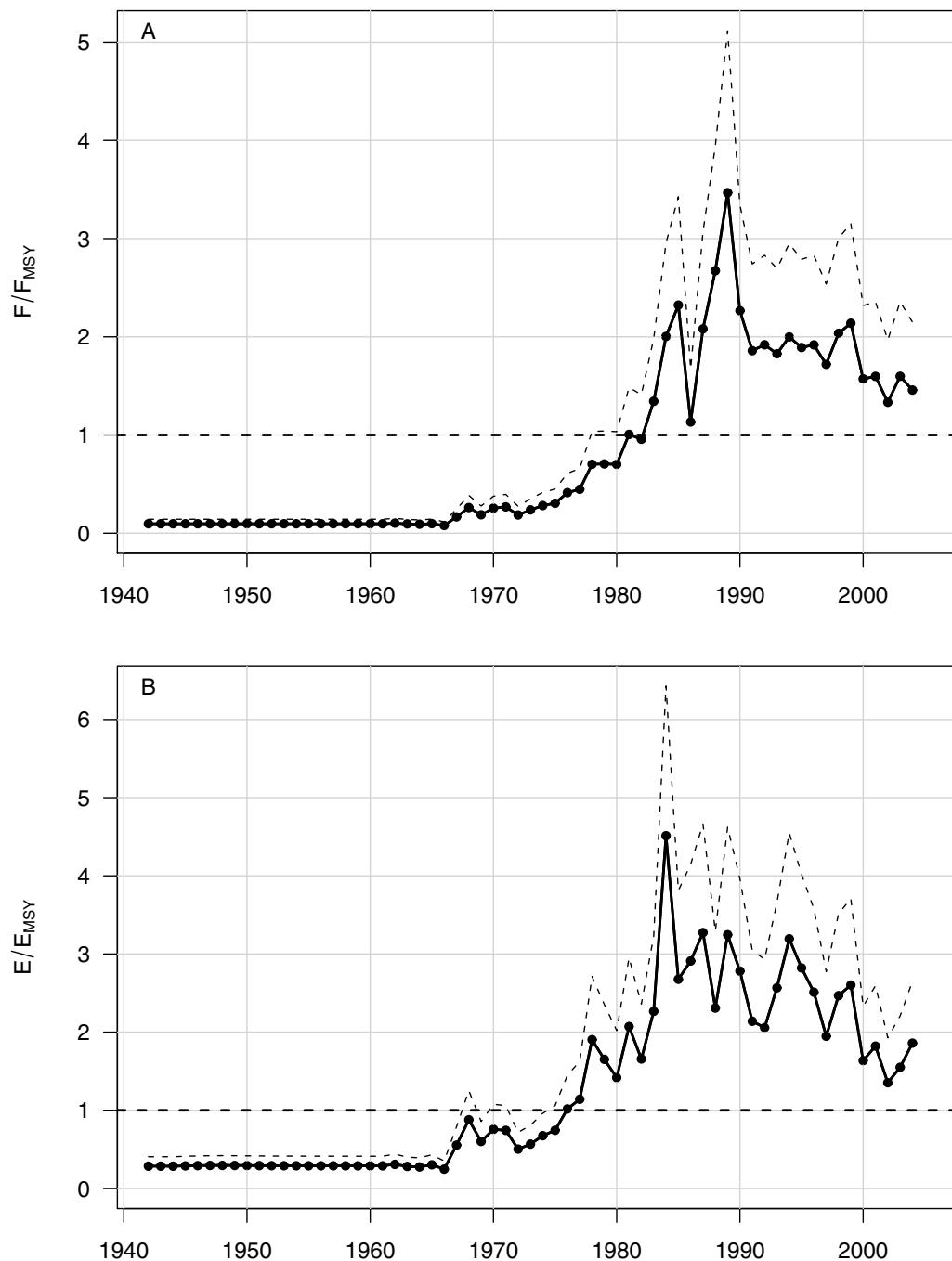


Figure 85. Gag- Base run with constant catchability: Estimated exploitation time series, relative to MSY benchmarks, of A) Fishing mortality rate (F) relative to F_{MSY} and B) Exploitation rate (E) relative to E_{MSY} . In each panel, a dashed horizontal line at one indicates where an estimated time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

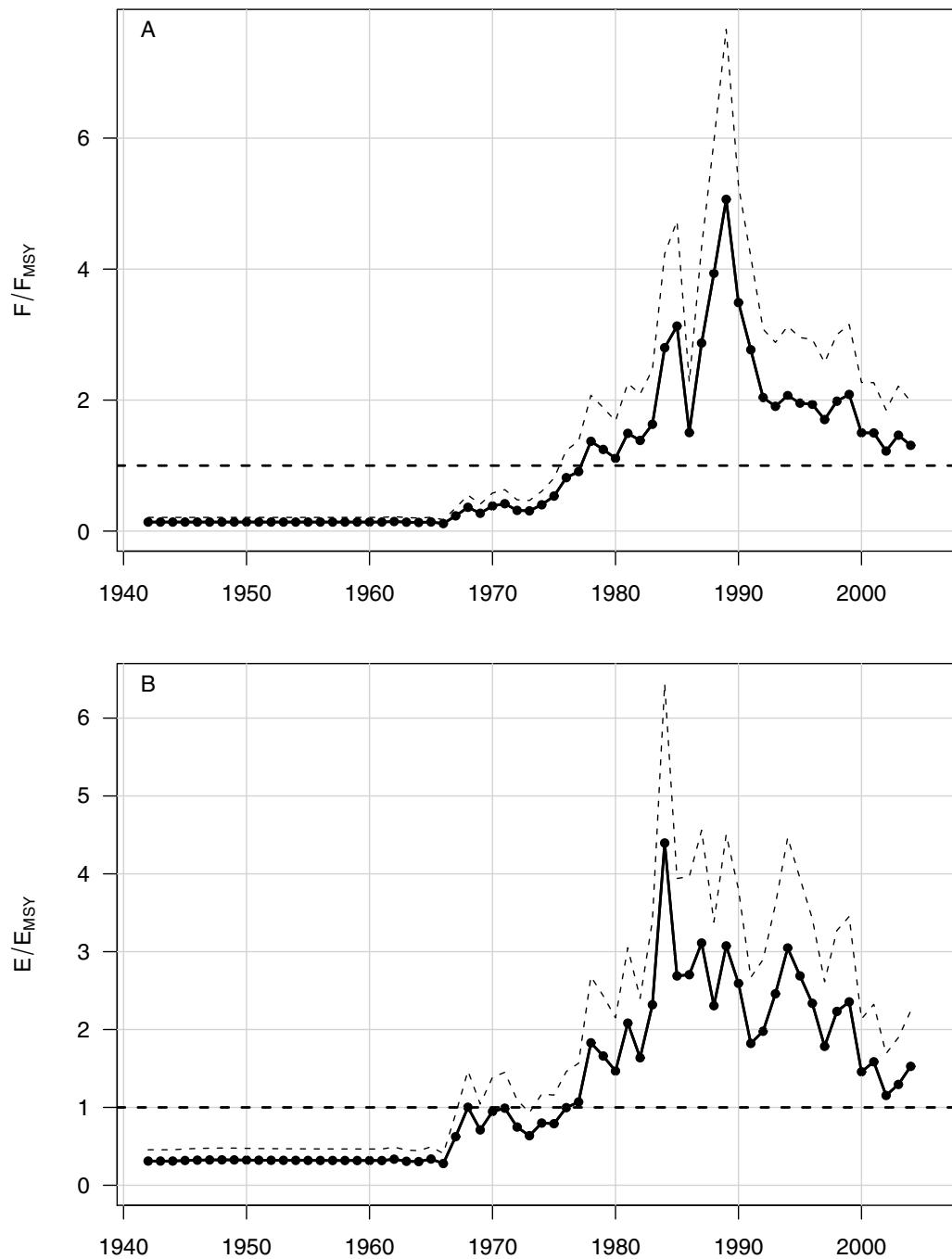


Figure 86. Gag- Base run with time-varying catchability: Estimates of exploitation rate from a retrospective analysis back to 1999. Ending year of model run is indicated by open circle in last year.

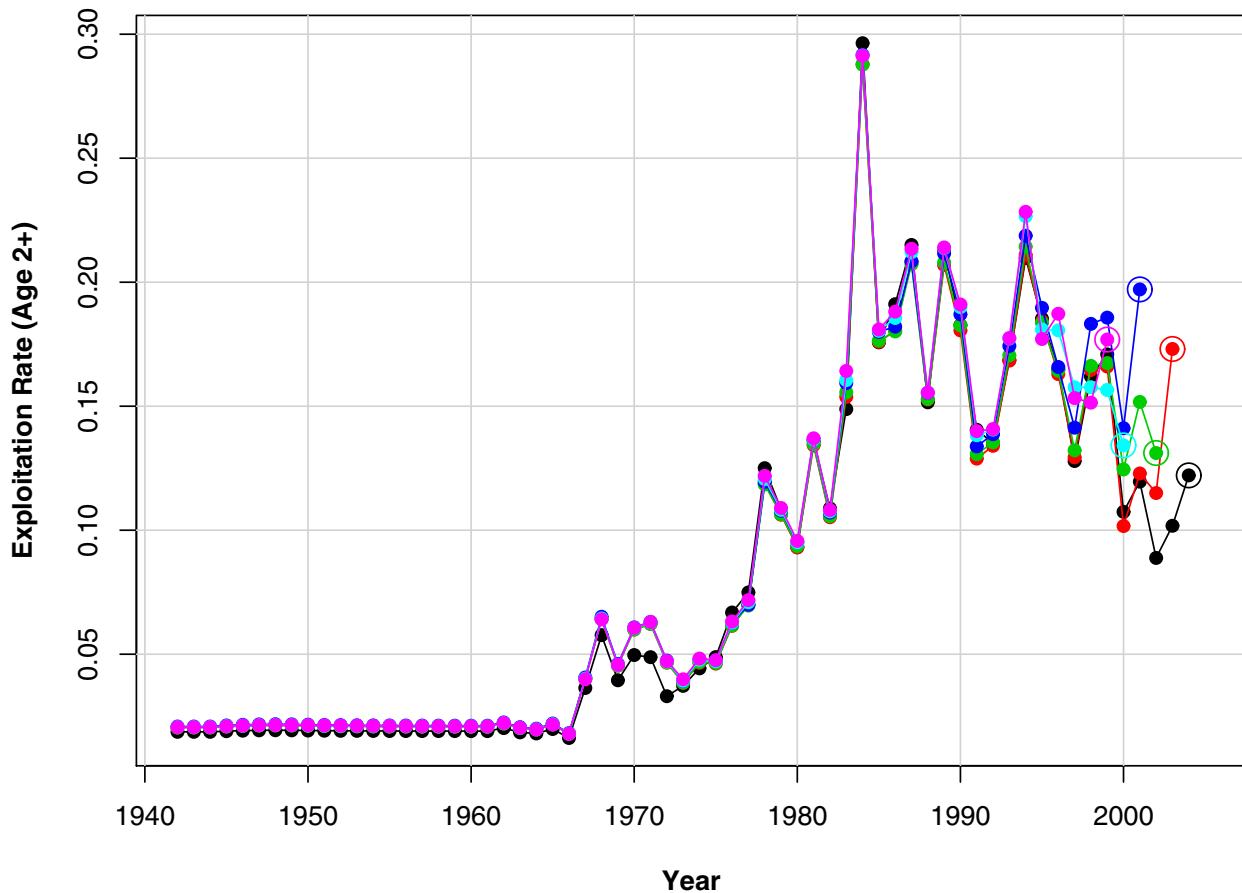


Figure 87. Gag- Base run with constant catchability: Estimates of exploitation rate from a retrospective analysis back to 1999. Ending year of model run is indicated by open circle in last year.

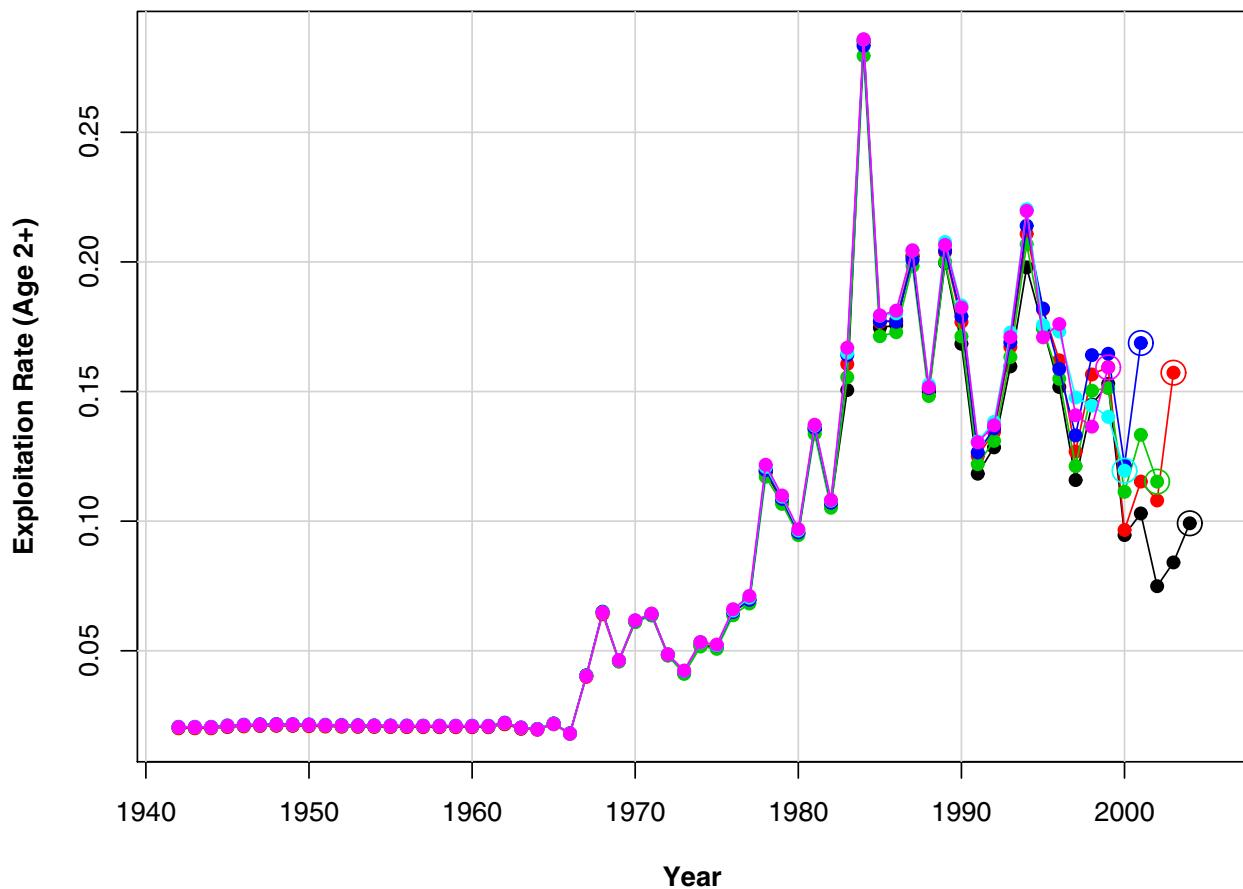


Figure 88. Gag- Base run with time-varying catchability: Estimates of fishing mortality rate from a retrospective analysis back to 1999. Ending year of model run is indicated by open circle in last year.

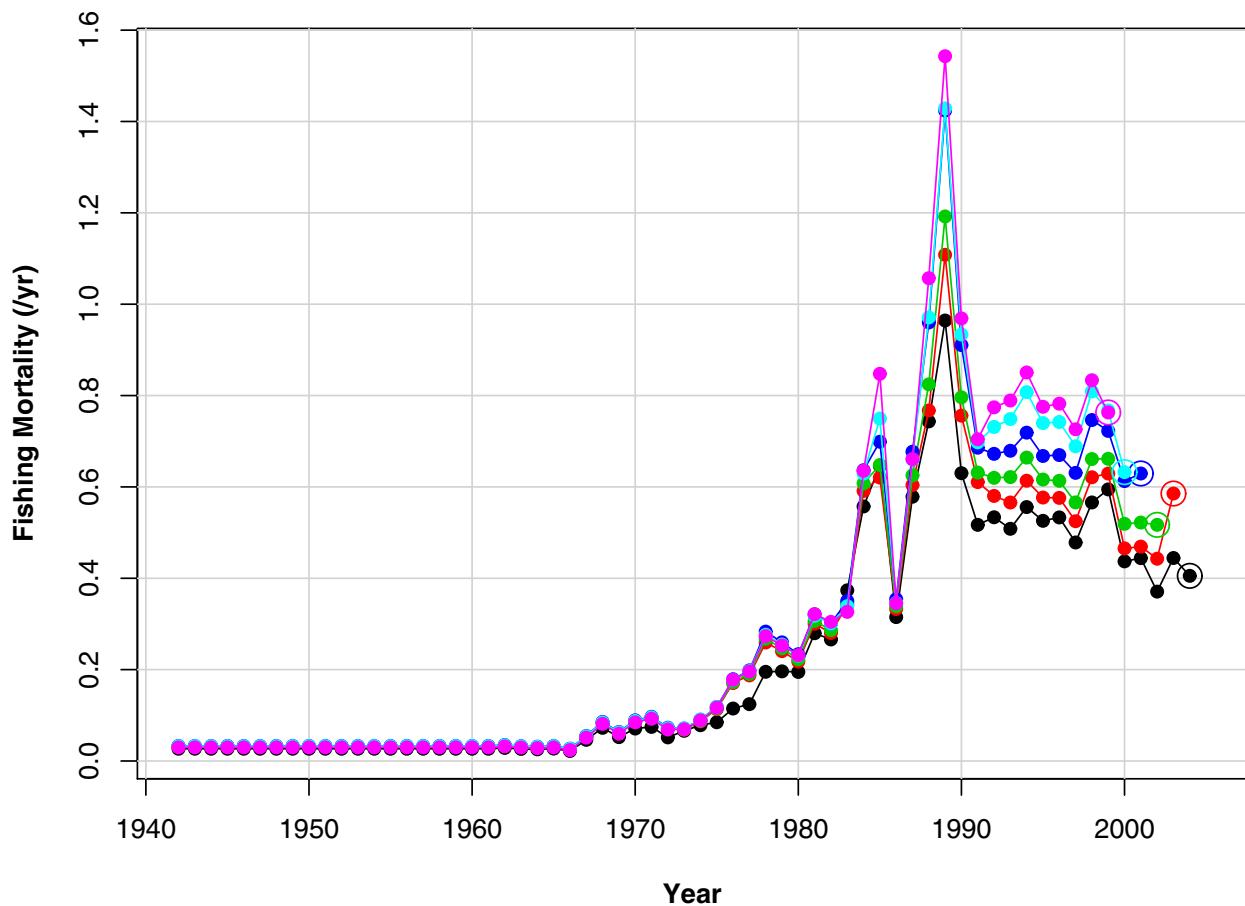


Figure 89. Gag- Base run with constant catchability: Estimates of fishing mortality rate from a retrospective analysis back to 1999. Ending year of model run is indicated by open circle in last year.

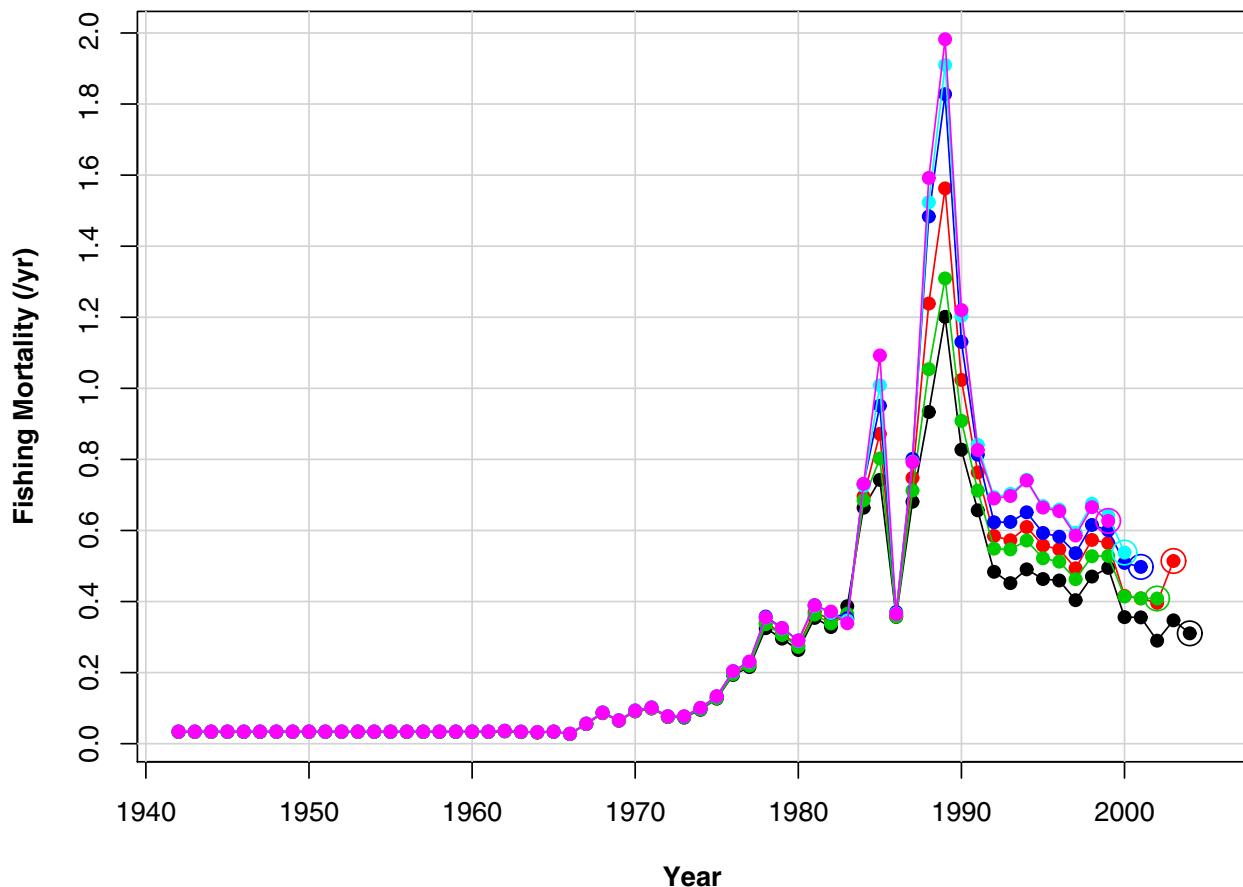


Figure 90. Gag- Base run with time-varying catchability: Estimates of total biomass (klb) from a retrospective analysis back to 1999. Ending year of model run is indicated by open circle in last year.

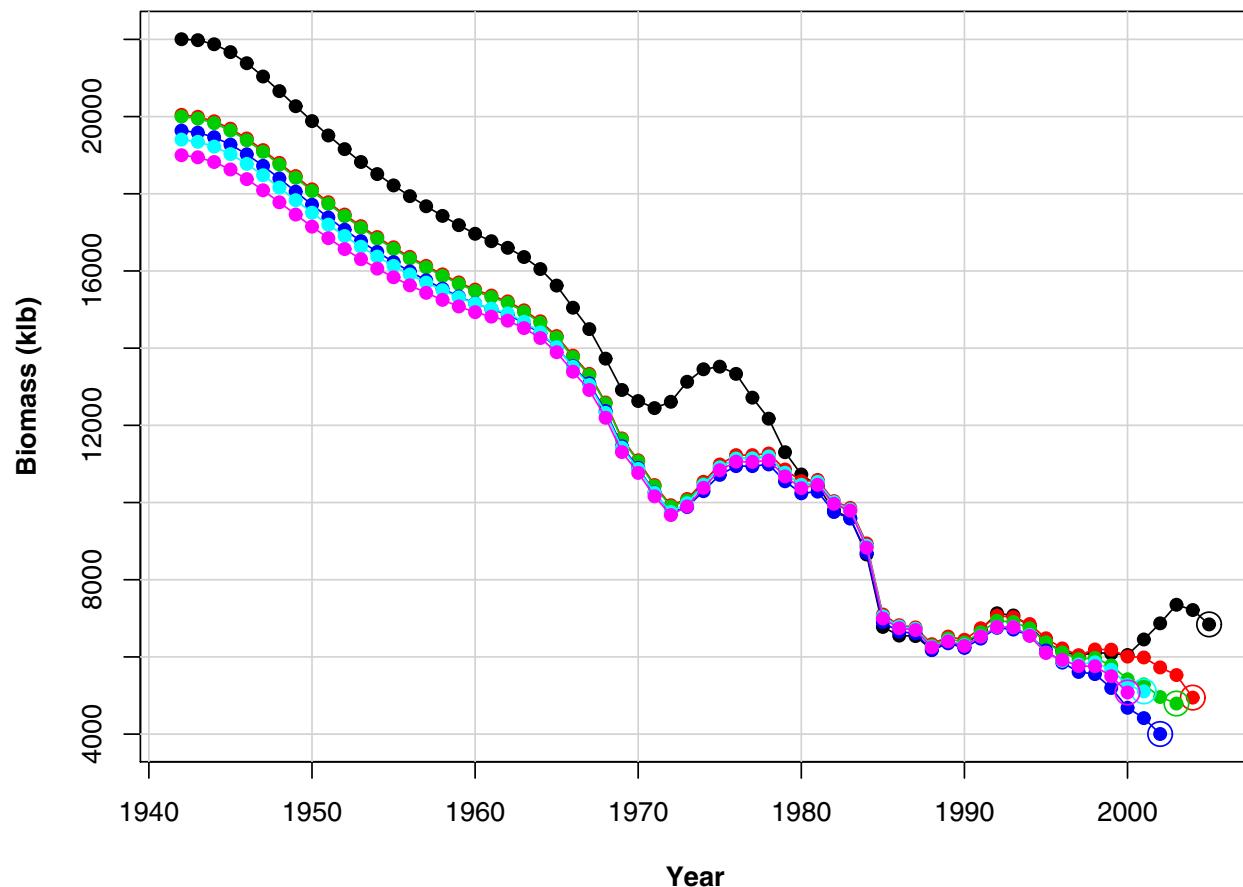


Figure 91. Gag- Base run with constant catchability: Estimates of total biomass (klb) from a retrospective analysis back to 1999. Ending year of model run is indicated by open circle in last year.

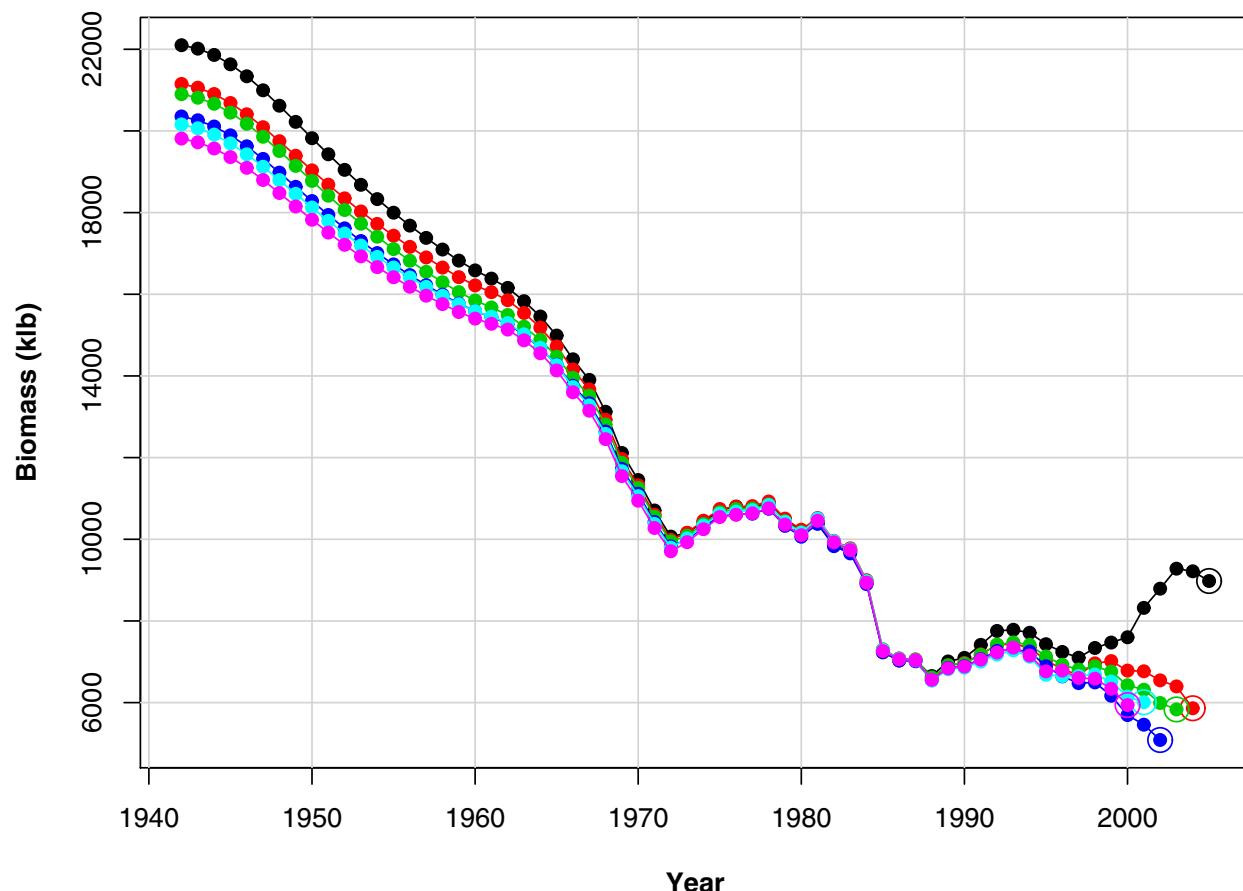


Figure 92. Gag- Base run with time-varying catchability: Estimates of spawning stock biomass (klb) from a retrospective analysis back to 1999. Ending year of model run is indicated by open circle in last year.

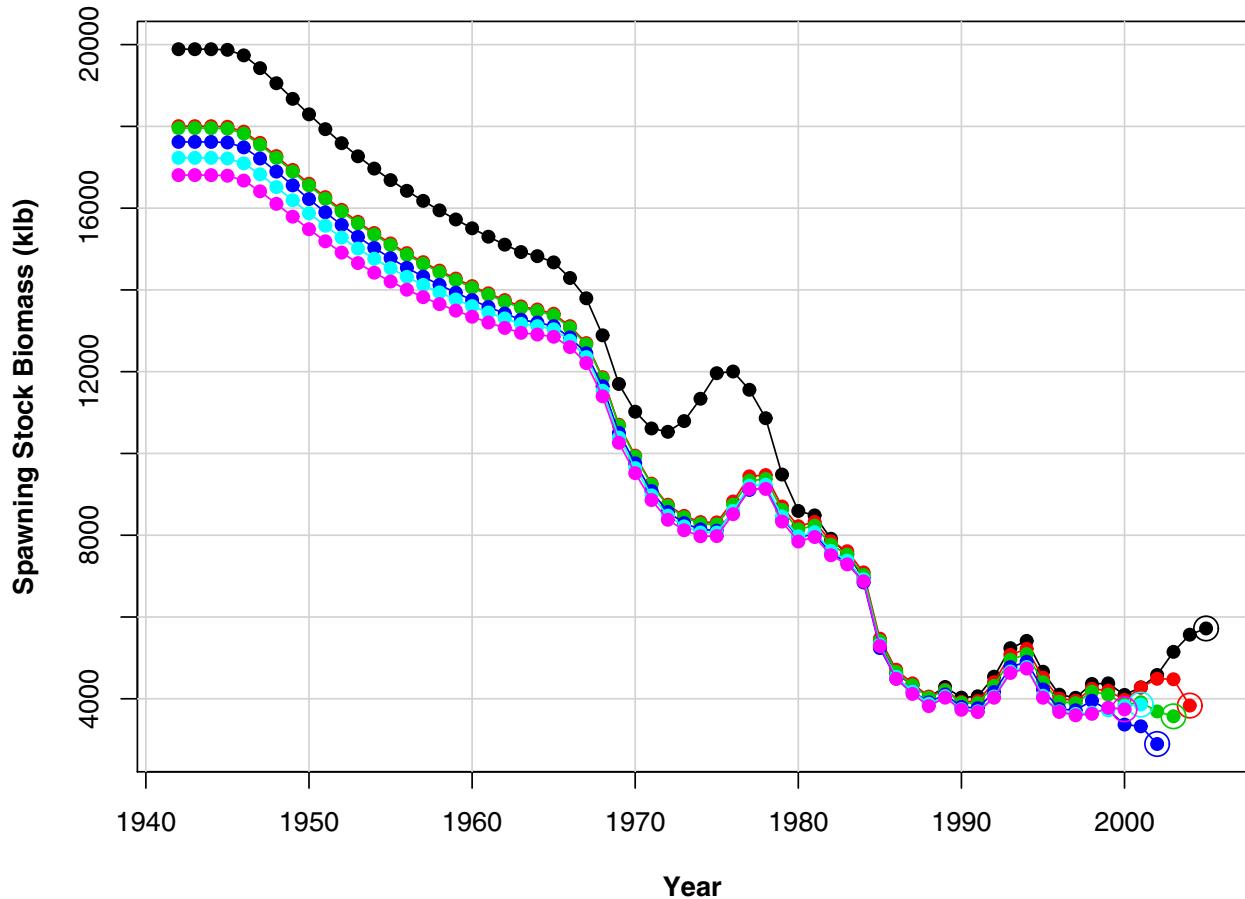


Figure 93. Gag- Base run with constant catchability: Estimates of spawning stock biomass (klb) from a retrospective analysis back to 1999. Ending year of model run is indicated by open circle in last year.

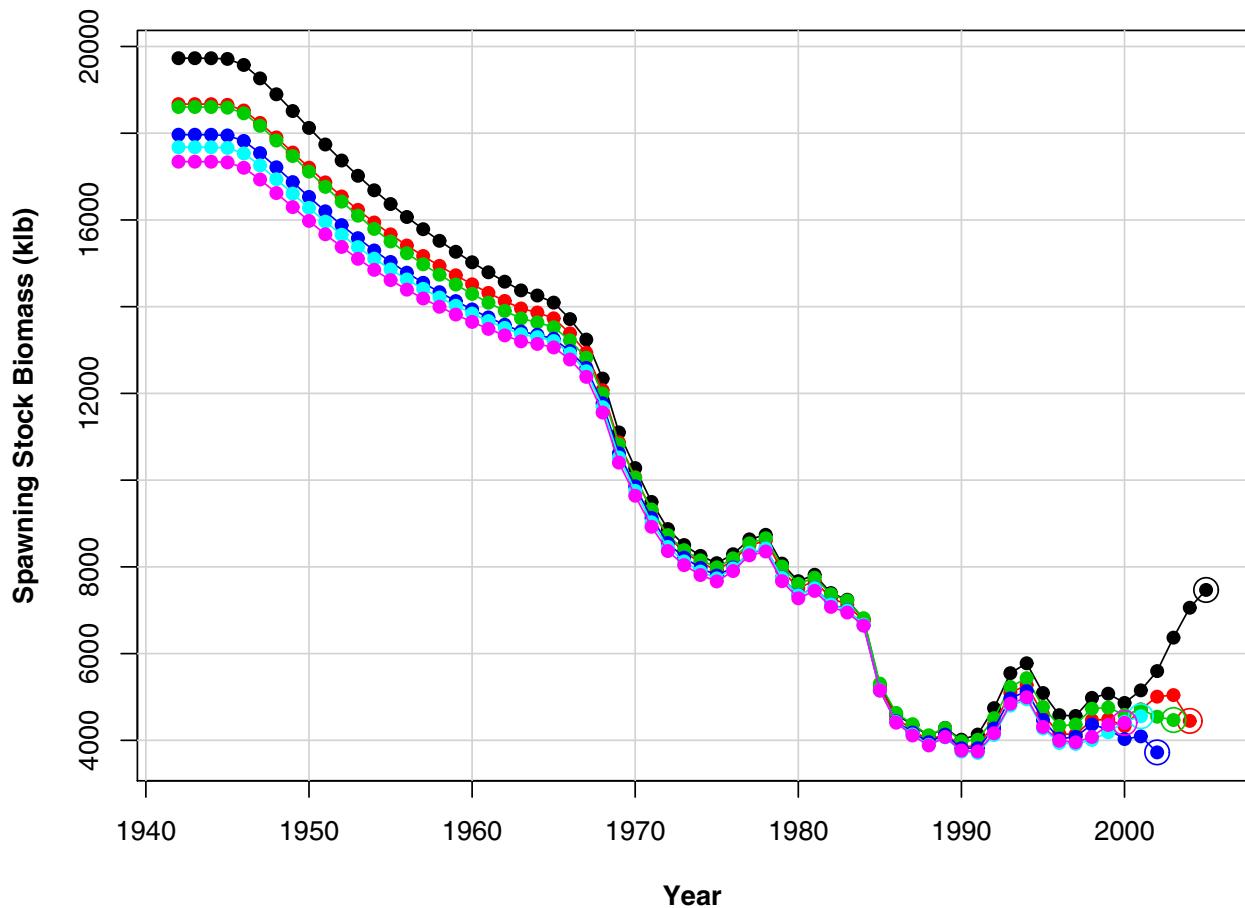


Figure 94. Gag- Base run with time-varying catchability: Projections under current fishing mortality rate for all years. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is 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.

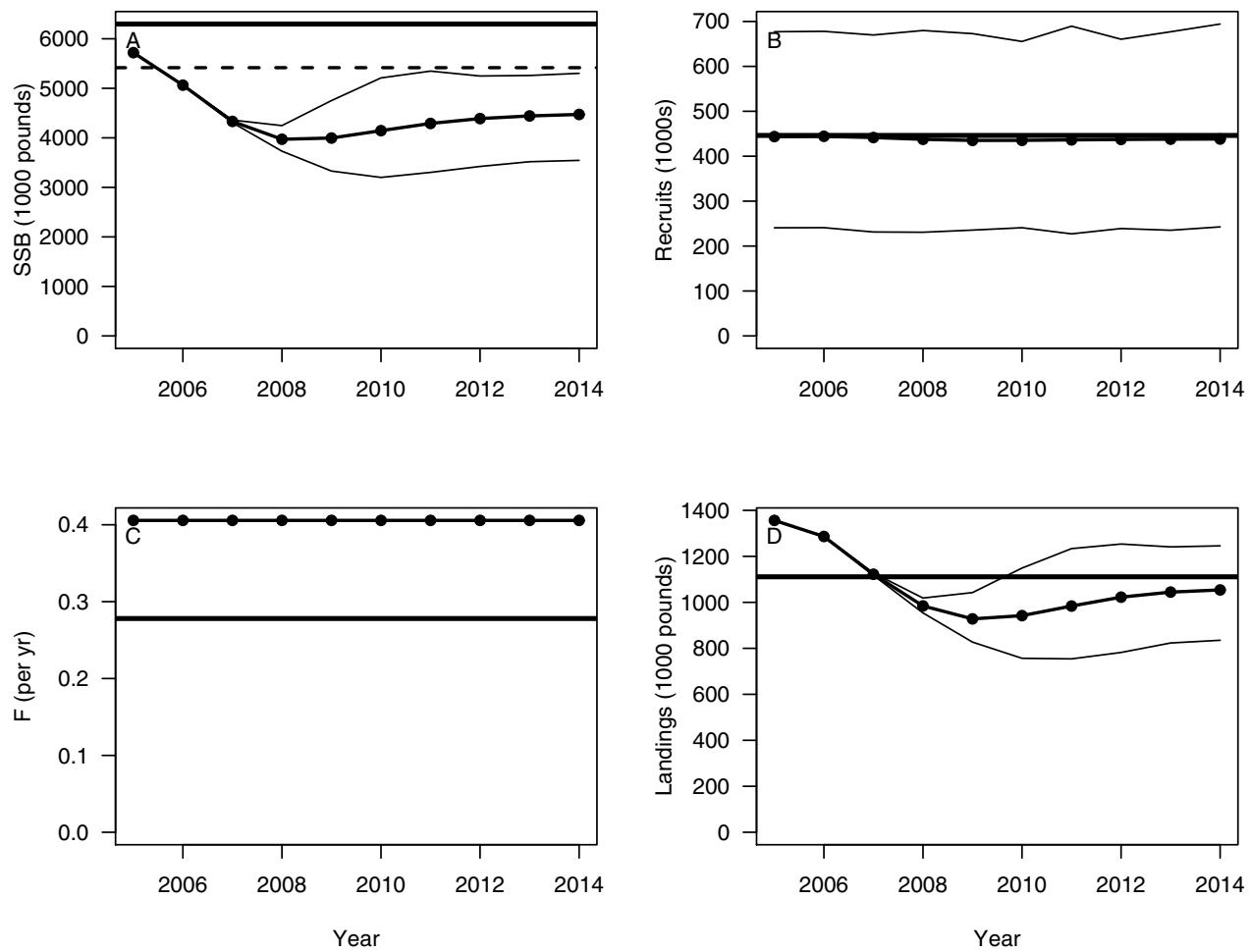


Figure 95. Gag- Base run with constant catchability: Projections under current fishing mortality rate for all years. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is 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.

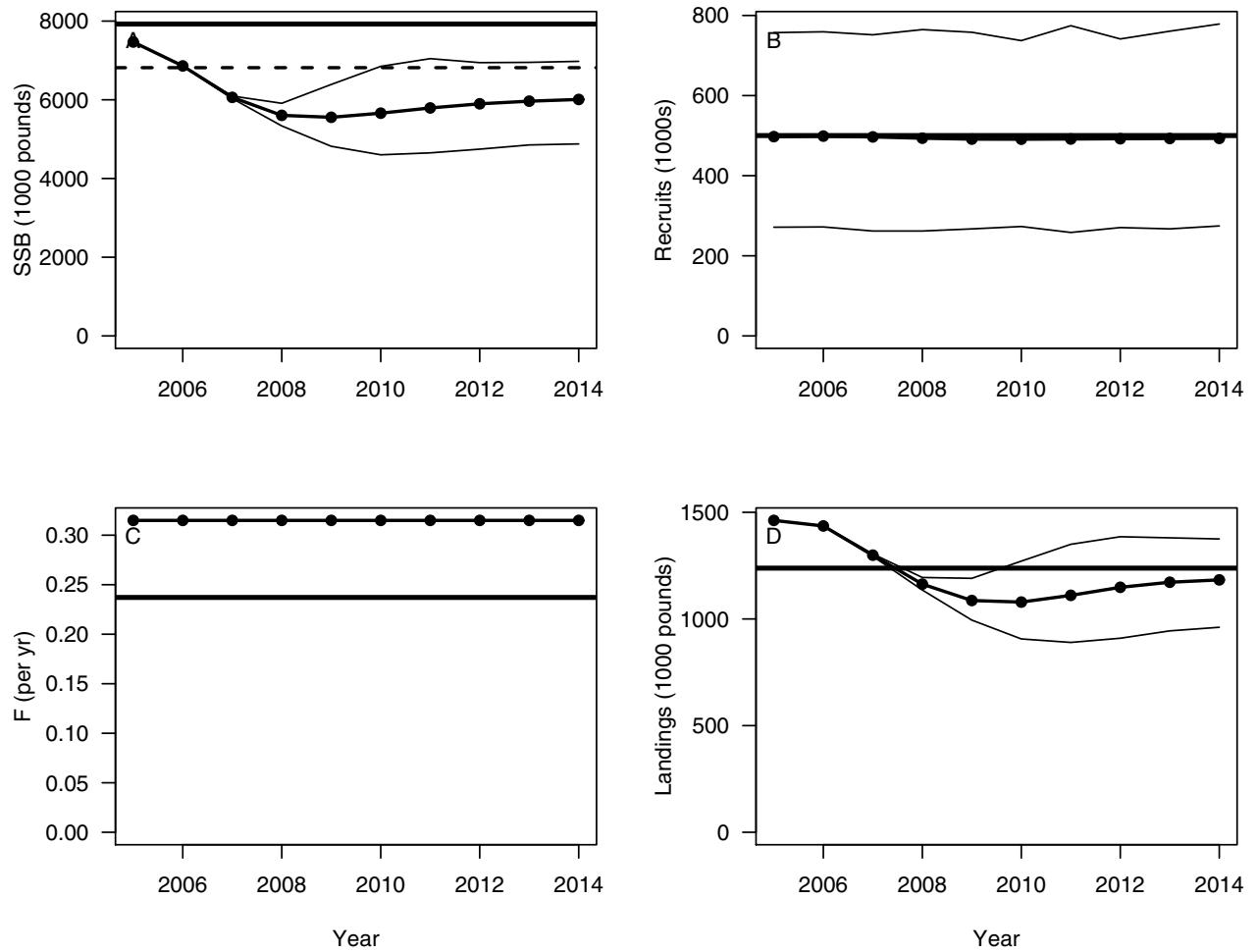


Figure 96. Gag- Base run with time-varying catchability: Projections under current fishing mortality rate in 2005-2007 and F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap 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.

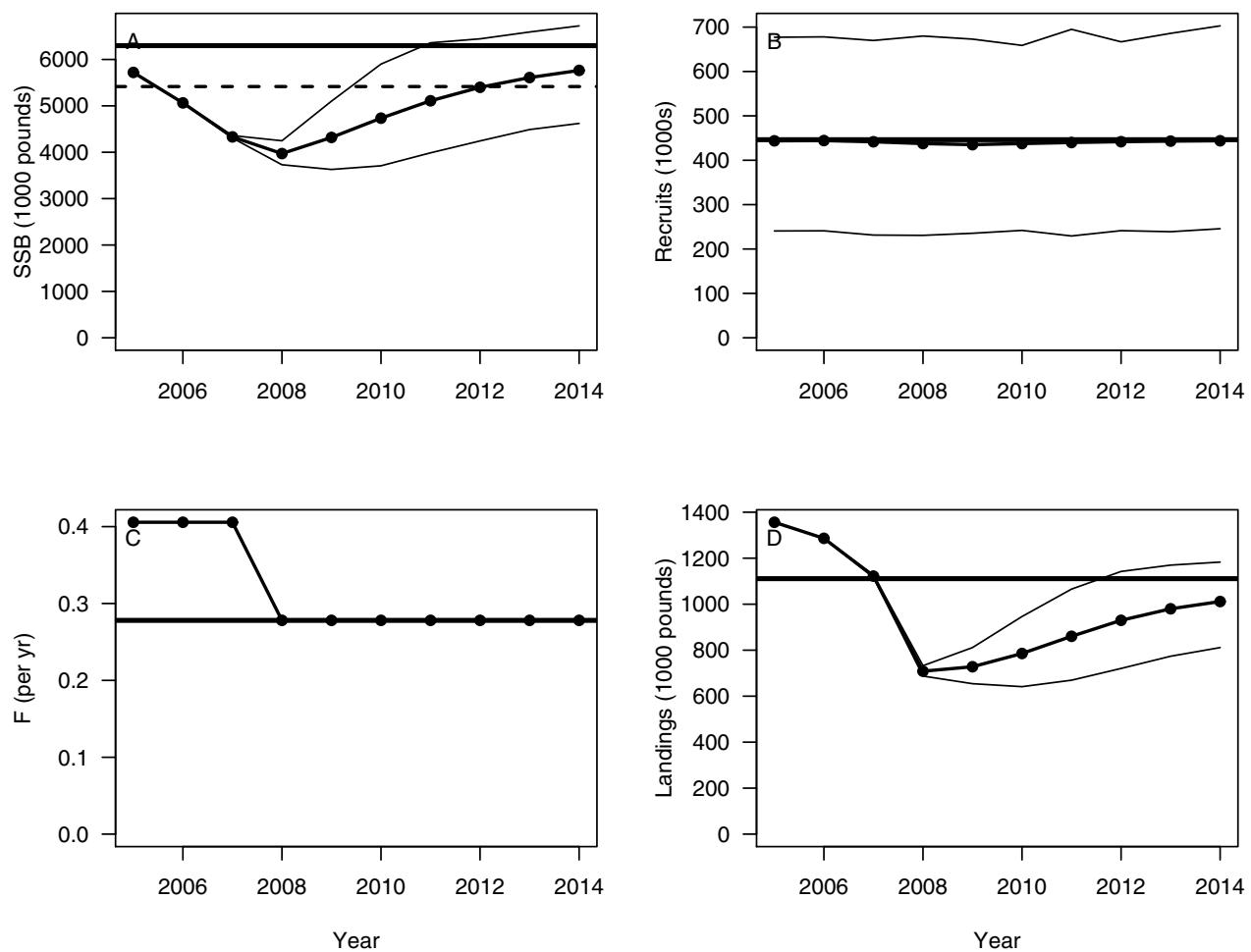


Figure 97. Gag- Base run with constant catchability: Projections under current fishing mortality rate in 2005-2007 and F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap 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.

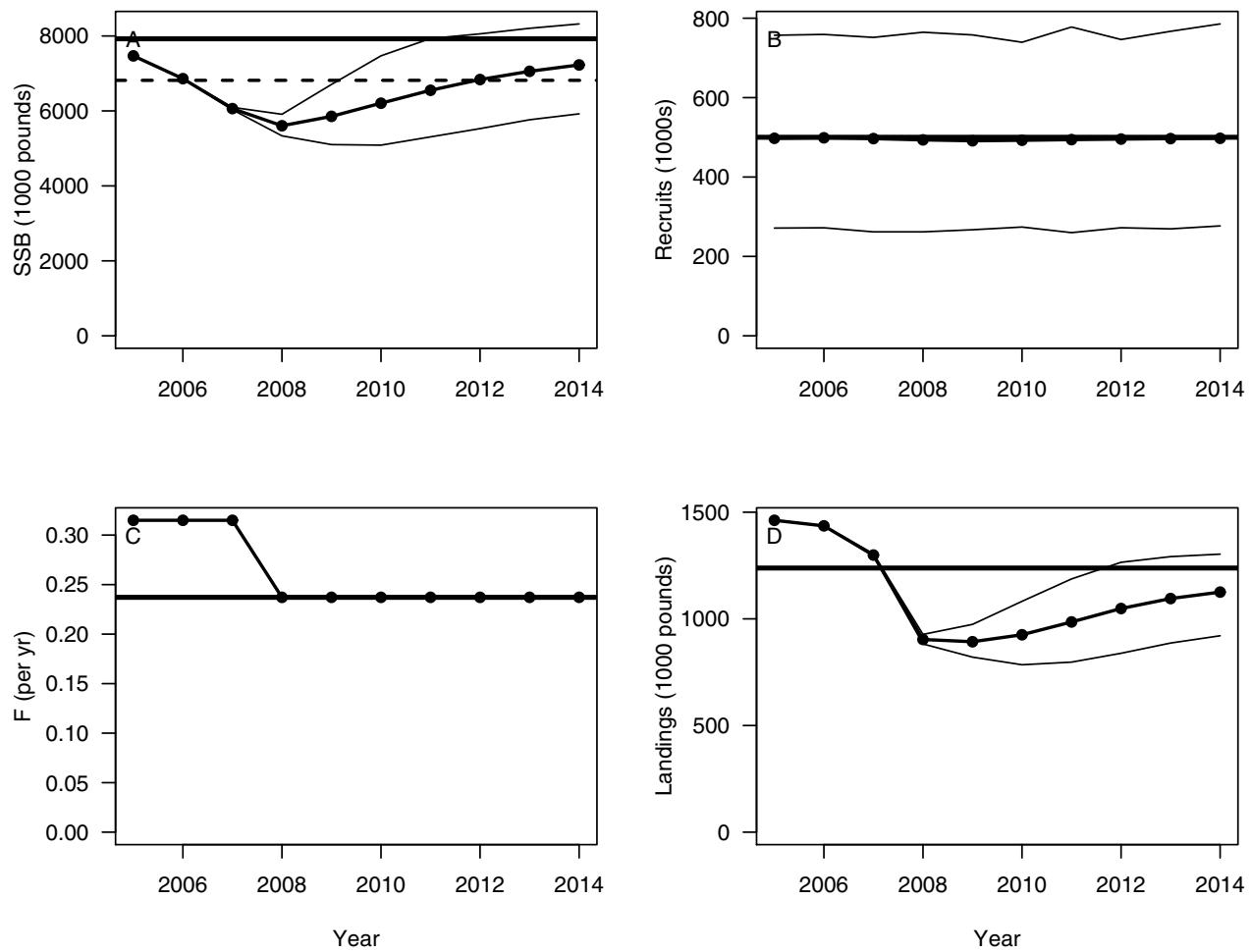


Figure 98. Gag- Base run with time-varying catchability: Projections under current fishing mortality rate in 2005-2007 and 85% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is 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.

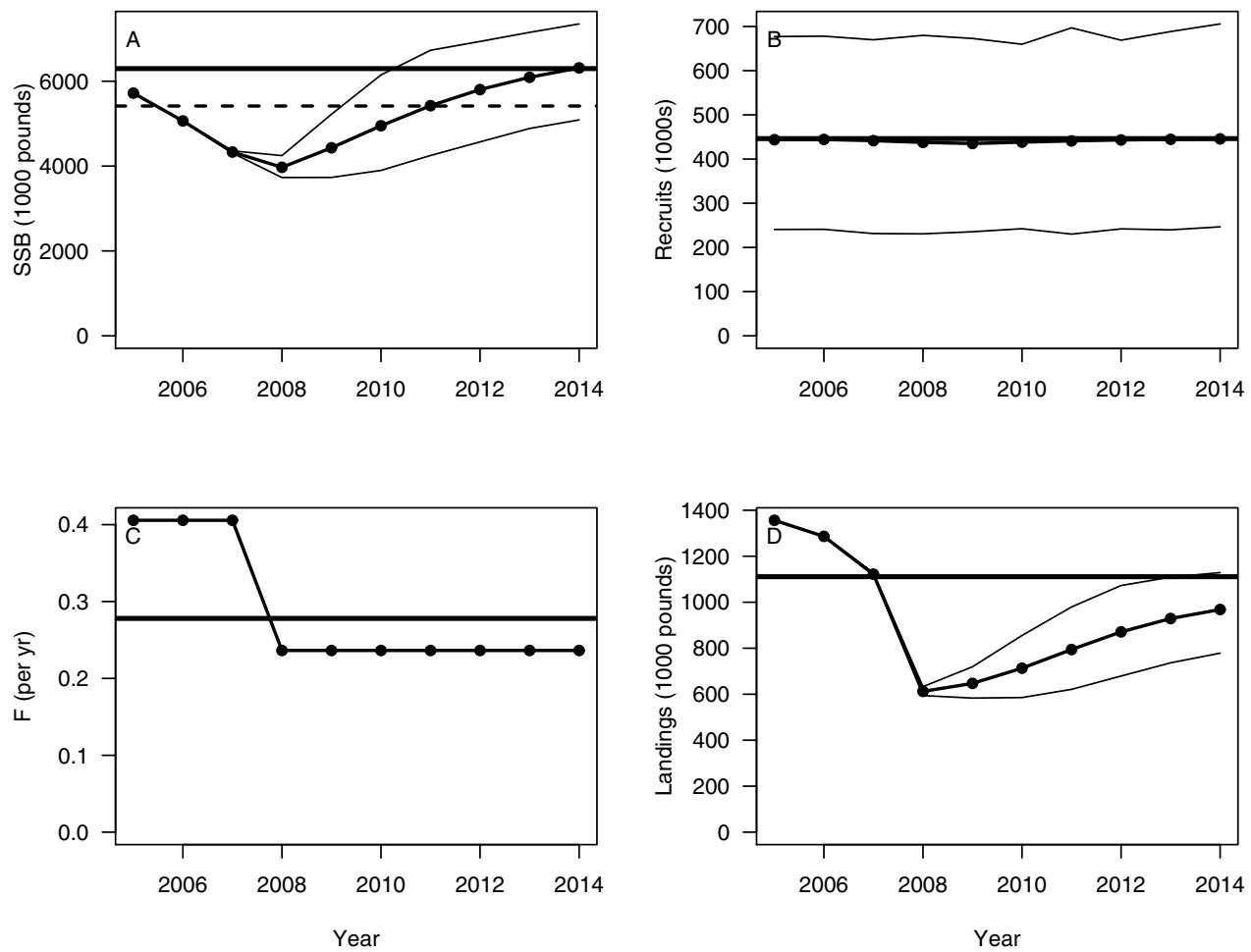


Figure 99. Gag- Base run with constant catchability: Projections under current fishing mortality rate in 2005-2007 and 85% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap 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.

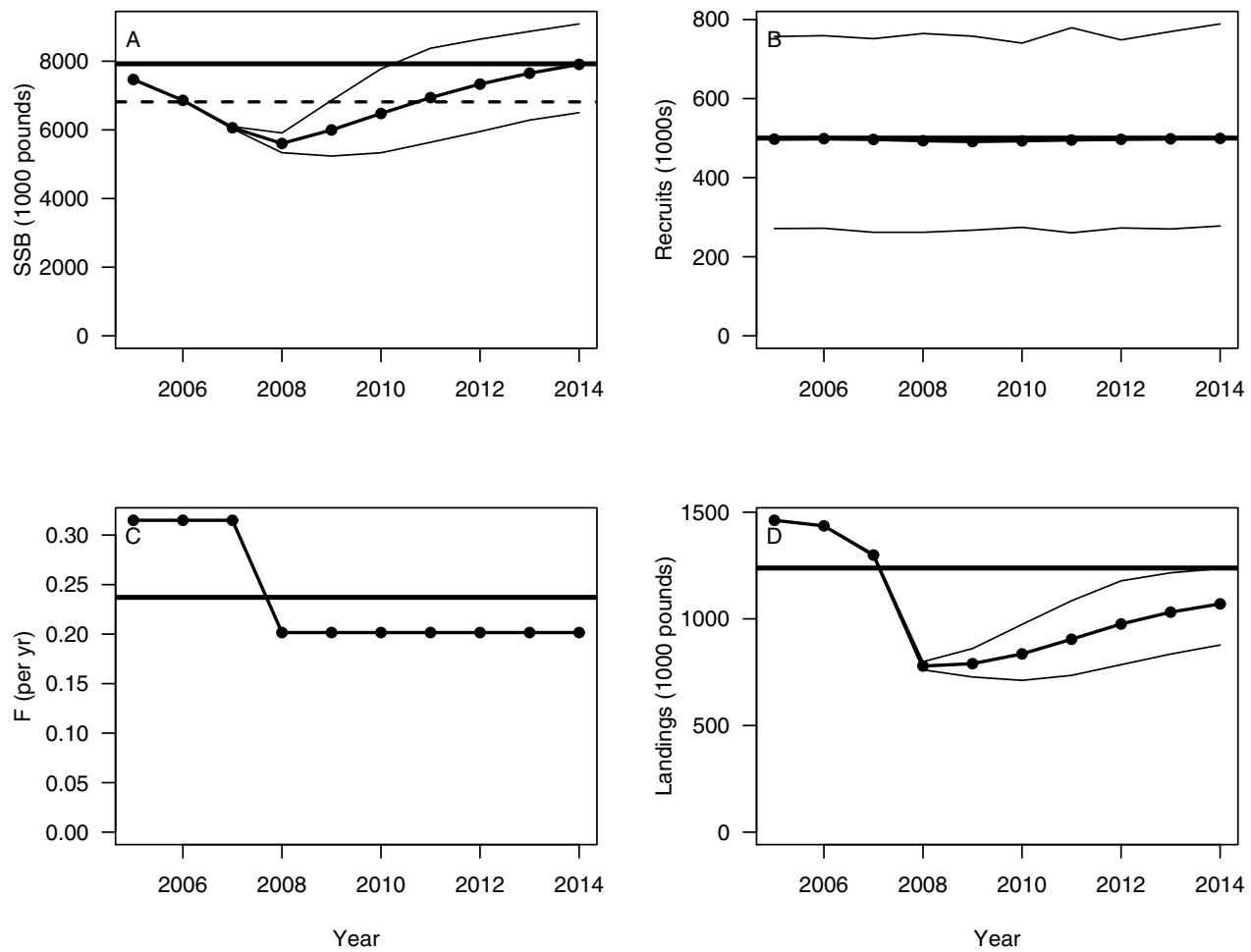


Figure 100. Gag- Base run with time-varying catchability: Projections under current fishing mortality rate in 2005-2007 and 75% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 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.

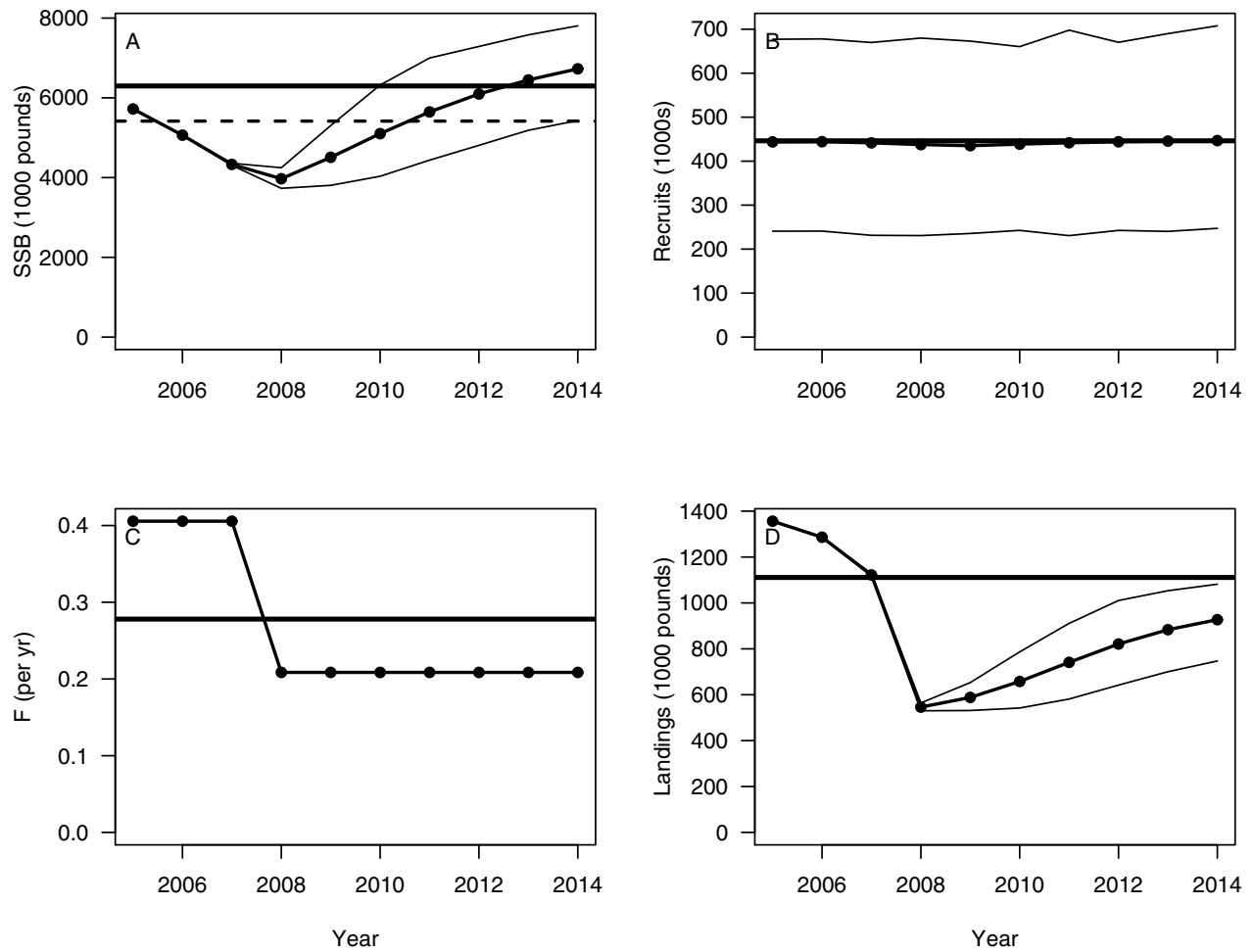


Figure 101. Gag- Base run with constant catchability: Projections under current fishing mortality rate in 2005-2007 and 75% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap 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.

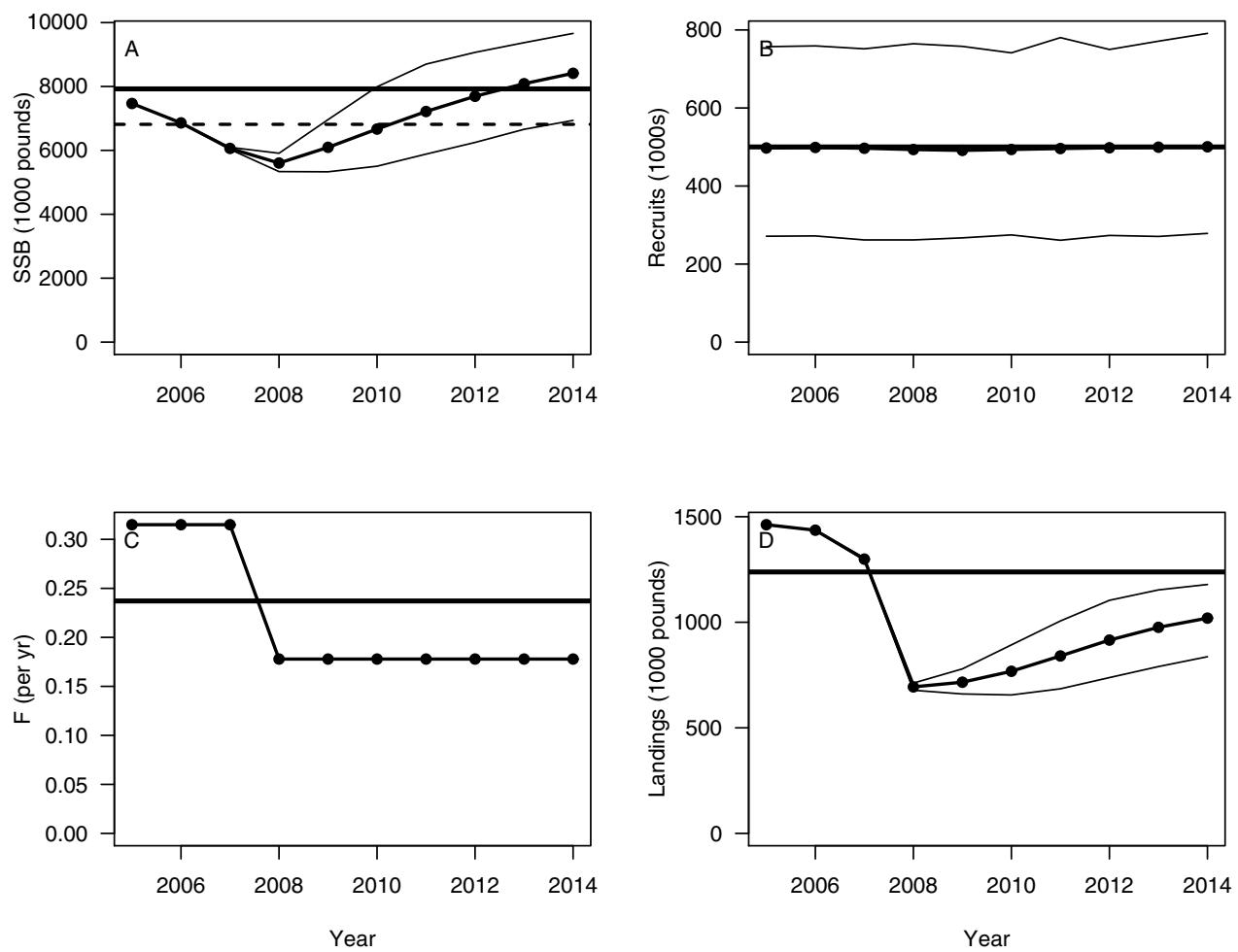


Figure 102. Gag- Base run with time-varying catchability: Projections under current fishing mortality rate in 2005-2007 and 65% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is 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.

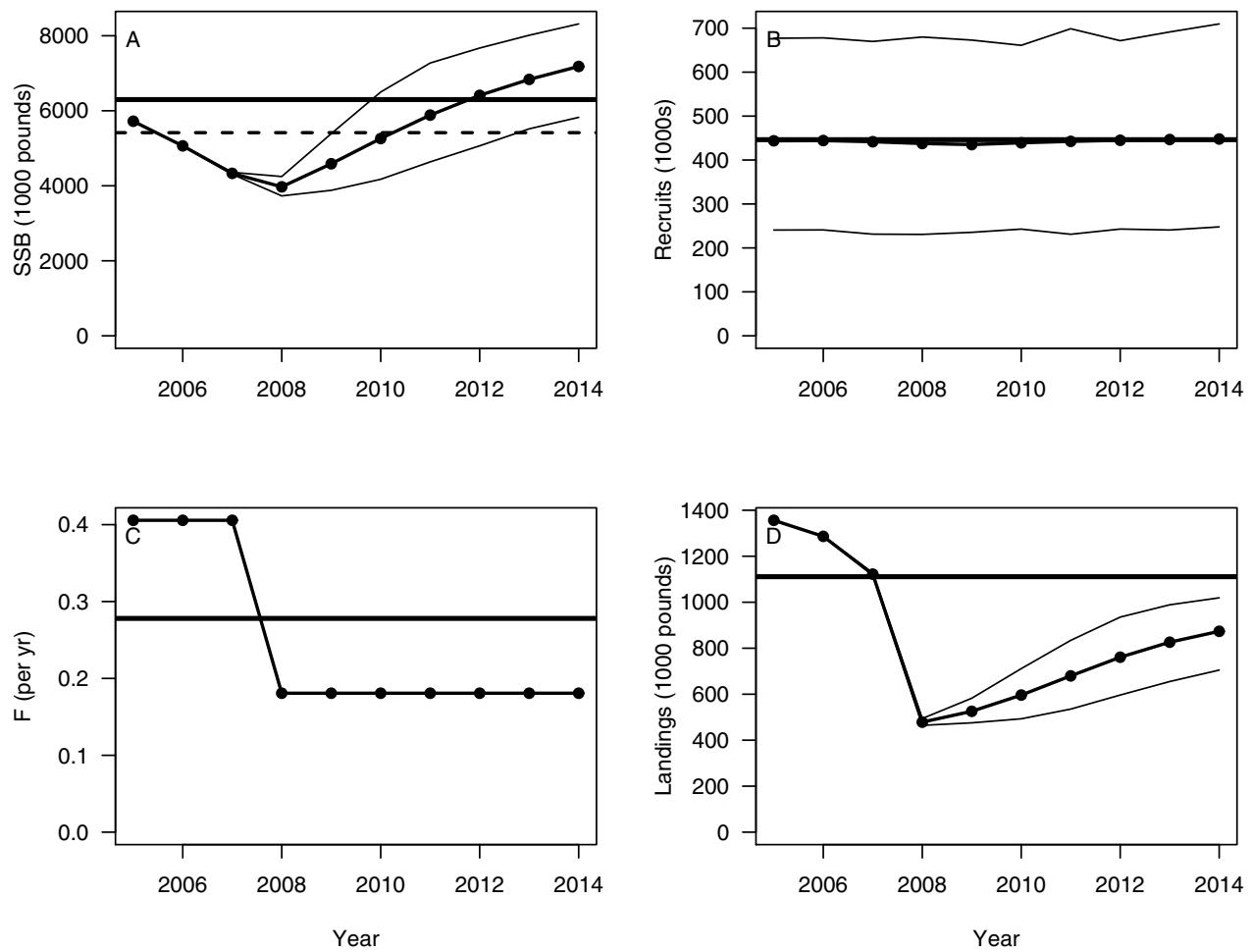
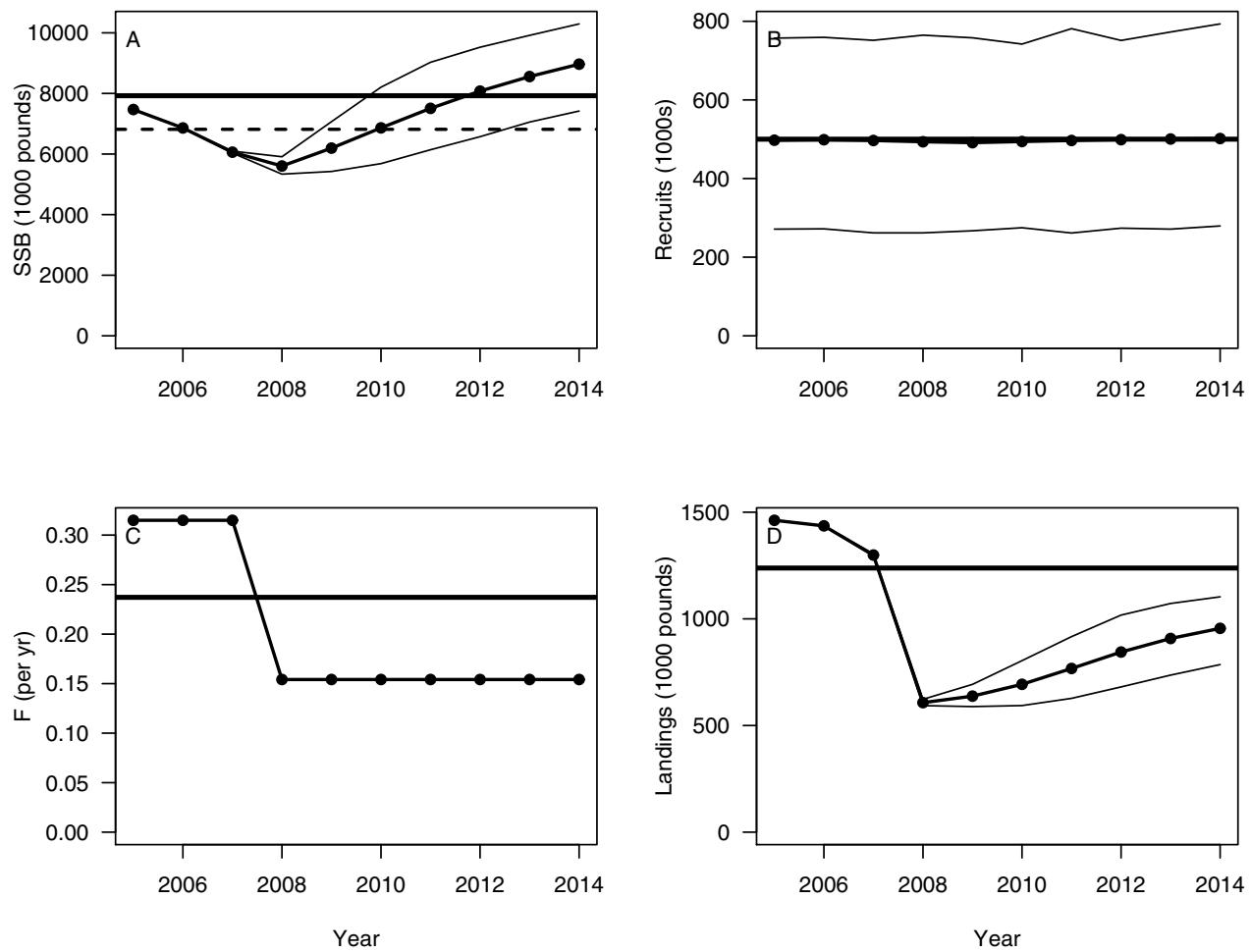


Figure 103. Gag- Base run with constant catchability: Projections under current fishing mortality rate in 2005-2007 and 65% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap 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 $(1 - M)SSB_{MSY}$. |
| MSY | Maximum sustainable yield (per year) |
| mt | Metric ton(s). One mt is 1000 kg, or about 2205 lb. |
| N | Number of fish in a stock, conventionally on January 1 |
| NC | State of North Carolina |
| NMFS | National Marine Fisheries Service, same as "NOAA Fisheries Service" |
| NOAA | National Oceanic and Atmospheric Administration; parent agency of NMFS |
| OY | Optimum yield; SFA specifies that OY \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

```

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_commmHAL_L;
init_int endyr_commmHAL_L;
init_vector obs_commmHAL_L(styr_commmHAL_L,endyr_commmHAL_L); //vector of observed landings by year
init_vector commHAL_L_cv(styr_commmHAL_L,endyr_commmHAL_L); //vector of CV of landings by year

// Discards (1000s)
init_int styr_commmHAL_D;
init_int endyr_commmHAL_D;
init_vector obs_commmHAL_released(styr_commmHAL_D,endyr_commmHAL_D); //vector of observed releases by year,
multiplied by discard mortality for fitting
init_vector commHAL_D_cv(styr_commmHAL_D,endyr_commmHAL_D); //vector of CV of discards by year
// Length Compositions (30mm bins)
init_int styr_commmHAL_lenc;
init_int endyr_commmHAL_lenc;
init_vector nsamp_commmHAL_lenc(styr_commmHAL_lenc,endyr_commmHAL_lenc);
init_matrix obs_commmHAL_lenc(styr_commmHAL_lenc,endyr_commmHAL_lenc,1,nlenbins10);
// Age Compositions
init_int nyr_commmHAL_agec;
init_ivector yrs_commmHAL_agec(1,nyr_commmHAL_agec);
init_vector nsamp_commmHAL_agec(1,nyr_commmHAL_agec);
init_matrix obs_commmHAL_agec(1,nyr_commmHAL_agec,1,nages);

//#####Commercial Diving fishery#####
// Landings (1000s gutted pounds)
init_int styr_commdV_L;
init_int endyr_commdV_L;
init_vector obs_commdV_L(styr_commdV_L,endyr_commdV_L);
init_vector commD_V_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;

```



```

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_commmHAL_lenc(styr_commmHAL_lenc, endyr_commmHAL_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_commmHAL_agec(1, nyr_commmHAL_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_commmHAL_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 unconstrained 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_commmHAL(styrR, endyr, 1, nages);
init_bounded_number selpar_slope_commmHAL1(0.5, 9.0, 1); //period 1
init_bounded_number selpar_L50_commmHAL1(1.0, 10.0, 1);
//init_bounded_number selpar_slope2_commmHAL1(0.1, 9.0, 3); //period 1
//init_bounded_number selpar_L502_commmHAL1(1.0, 25.0, 3);
number selpar_slope2_commmHAL1; //period 1
number selpar_L502_commmHAL1;
init_bounded_number selpar_slope_commmHAL2(0.5, 9.0, 1); //period 2
init_bounded_number selpar_L50_commmHAL2(1.0, 10.0, 1);
//init_bounded_number selpar_slope2_commmHAL2(0.1, 9.0, 3); //period 2
//init_bounded_number selpar_L502_commmHAL2(1.0, 25.0, 3);

```

```

number selpar_slope2_commmHAL2; //period 1
number selpar_L502_commmHAL2;
init_bounded_number selpar_slope_commmHAL3(0.5,9.0,1); //period 3
init_bounded_number selpar_L50_commmHAL3(1.0,10,1);
//init_bounded_number selpar_slope2_commmHAL3(0.1,9.0,3); //period 3
//init_bounded_number selpar_L502_commmHAL3(1.0,25.0,3);
number selpar_slope2_commmHAL3; //period 1
number selpar_L502_commmHAL3;
init_bounded_dev_vector selpar_L50_commmHAL_dev(styr_commmHAL_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_commmHAL_bias(0.1,5.0,-3);

//---Catch (numbers), Landings (mt)-----
matrix C_commmHAL(styrR,endyr,1,nages); //catch (numbers) at age
matrix L_commmHAL(styrR,endyr,1,nages); //landings (mt) at age
vector pred_commmHAL_L(styr_commmHAL_L,endyr_commmHAL_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); //values of full F to be used in per-recruit and equilibrium calculations
vector F_msy(1,n_iter_msy); //reproductive capacity-per-recruit values corresponding to F values in F_msy
vector spr_msy(1,n_iter_msy); //equilibrium recruitment values corresponding to F values in F_msy
vector R_eq(1,n_iter_msy); //equilibrium landings(mt) values corresponding to F values in F_msy
vector L_eq(1,n_iter_msy); //equilibrium reproductive capacity values corresponding to F values in F_msy
vector SSB_eq(1,n_iter_msy); //equilibrium biomass values corresponding to F values in F_msy
vector B_eq(1,n_iter_msy); //equilibrium exploitation rates corresponding to F values in F_msy
vector E_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); //reproductive 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;

```



```

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_commmHAL3=set_selpar_L50_commmHAL3;
selpar_slope_commmHAL3=set_selpar_slope_commmHAL3;
selpar_L502_commmHAL3=set_selpar_L502_commmHAL3;
selpar_slope2_commmHAL3=set_selpar_slope2_commmHAL3;

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_commmHAL_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_commmHAL_agec; iyear++)
{
    nsamp_commmHAL_agec_allyr(yrs_commmHAL_agec(iyear))=nsamp_commmHAL_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
arrbmlsize=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); //0.001 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_commmHAL(iyear,iage)=1./(1.+mfexp(-1.*selpar_slope_commmHAL1*(double(agebins(iage))-selpar_L50_commmHAL1))); →
    //logistic
    sel_commmHAL(iyear,iage)=(1./(1.+mfexp(-1.*selpar_slope_commmHAL1*(double(agebins(iage))-selpar_L50_commmHAL1)))*(1-(1./(1.+mfexp(-1.*selpar_slope2_commmHAL1*(
      double(agebins(iage))-(selpar_L50_commmHAL1+selpar_L502_commmHAL1)))))); //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_commmHAL_lenc)
{
  for (iage=1; iage<=nages; iage++)
  {
    //sel_commmHAL(iyear, iage)=1./(1.+mfexp(-1.*selpar_slope_commmHAL1*(double(agebins(iage))
    //      -(selpar_L50_commmHAL1+selpar_L50_commmHAL_dev(iyear))))); //logistic
    sel_commmHAL(iyear, iage)=(1./(1.+mfexp(-1.*selpar_slope_commmHAL1*(double(agebins(iage))-
      (selpar_L50_commmHAL1+selpar_L50_commmHAL_dev(iyear)))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_commmHAL1*
      (double(agebins(iage))-(selpar_L50_commmHAL1+selpar_L502_commmHAL1)))))); //double logistic
  }
}
sel_commdV(iyear)=sel_commdV(iyear)/max(sel_commdV(iyear)); //re-normalize double logistic
sel_commmHAL(iyear)=sel_commmHAL(iyear)/max(sel_commmHAL(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_commmHAL(iyear, iage)=1./
    // (1.+mfexp(-1.*selpar_slope_commmHAL2*(double(agebins(iage))-selpar_L50_commmHAL2))); //logistic
    sel_commmHAL(iyear, iage)=(1./(1.+mfexp(-1.*selpar_slope_commmHAL2*(double(agebins(iage))-
      selpar_L50_commmHAL2)))*(1-(1./(1.+mfexp(-1.*selpar_slope2_commmHAL2*
      (double(agebins(iage))-(selpar_L50_commmHAL2+selpar_L502_commmHAL2)))))); //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_commmHAL(iyear)=sel_commmHAL(iyear)/max(sel_commmHAL(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_commmHAL(iyear, iage)=1./
    // (1.+mfexp(-1.*selpar_slope_commmHAL3*(double(agebins(iage))-selpar_L50_commmHAL3))); //logistic
    sel_commmHAL(iyear, iage)=(1./(1.+mfexp(-1.*selpar_slope_commmHAL3*(double(agebins(iage))-
      selpar_L50_commmHAL3)))*(1-(1./(1.+mfexp(-1.*selpar_slope2_commmHAL3*
      (double(agebins(iage))-(selpar_L50_commmHAL3+selpar_L502_commmHAL3)))))); //double logistic
  }
  sel_commdV(iyear)=sel_commdV(endyr_period2); //period3 sel same as period2 sel
  sel_commmHAL(iyear)=sel_commmHAL(iyear)/max(sel_commmHAL(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_commmHAL_D;iyear<=endyr_commmHAL_D;iyear++)
//{
//  for (iage=1; iage<=nages; iage++)
//  {
//    sel_commmHAL_D(iyear,iage)=(max(column(sel_commmHAL, iage))-sel_commmHAL(endyr,iage));
//  }
//  sel_commmHAL_D(iyear)=sel_commmHAL_D(iyear)/(max(sel_commmHAL_D(iyear))+dzero_dum); //prevent division by zero
//}

//Alternate way of expressing commercial discard selectivity
//Uses a 2 age shift
for (iyear=styr_commmHAL_D;iyear<=endyr_commmHAL_D;iyear++)
{
  for (iage=1; iage<=(nages-2); iage++)
  {
    sel_commmHAL_D(iyear,iage)=(sel_commmHAL(endyr,iage+2)-sel_commmHAL(endyr,iage));
    if(sel_commmHAL_D(iyear,iage)<0.0)
    {
      sel_commmHAL_D(iyear,iage)=0.0;
    }
  }
}

```

```

sel_commmHAL_D(iyear,(nages-1))=0.0;
sel_commmHAL_D(iyear,nages)=0.0;
sel_commmHAL_D(iyear)=sel_commmHAL_D(iyear)/max(sel_commmHAL_D(iyear));
}

FUNCTION get_mortality
fullF=0.0;
//initialization F is avg of first 3 yrs (1962-1964)
log_F_init_commmHAL=sum(log_F_dev_commmHAL(styr_commmHAL_L,(styr_commmHAL_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_commmHAL_L)
  {
    F_commmHAL_out(iyear)=mfexp(log_avg_F_commmHAL+log_F_init_commmHAL);
  }
  else
  {
    F_commmHAL_out(iyear)=mfexp(log_avg_F_commmHAL+log_F_dev_commmHAL(iyear));
  }
  F_commmHAL(iyear)=sel_commmHAL(iyear)*F_commmHAL_out(iyear);
  F_commmHAL_D(iyear)=sel_commmHAL_D(iyear)*Dmort_commmHAL*F_commmHAL_out(iyear);
  fullF(iyear)+=F_commmHAL_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_commmHAL_D)
{
  F_commmHAL_D_out(iyear)=mfexp(log_avg_F_commmHAL_D+log_F_dev_commmHAL_D(iyear));
  F_commmHAL_D(iyear)=sel_commmHAL_D(iyear)*F_commmHAL_D_out(iyear);
  fullF(iyear)+=F_commmHAL_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_commmHAL(iyear,iage)=N(iyear,iage)*F_commmHAL(iyear,iage)*
      (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
    C_commdDV(iyear,iage)=N(iyear,iage)*F_commdDV(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=styr; iyear<=endyr; iyear++)
{
  L_commmHAL(iyear)=elem_prod(C_commmHAL(iyear),wgt);
  L_commdDV(iyear)=elem_prod(C_commdDV(iyear),wgt);
  L_HB(iyear)=elem_prod(C_HB(iyear),wgt);
  L_MRFSS(iyear)=elem_prod(C_MRFSS(iyear),wgt);
}

for (iyear=styr_commmHAL_L; iyear<=endyr_commmHAL_L; iyear++)
{
  pred_commmHAL_L(iyear)=sum(L_commmHAL(iyear));
}
for (iyear=styr_commdDV_L; iyear<=endyr_commdDV_L; iyear++)
{
  pred_commdDV_L(iyear)=sum(L_commdDV(iyear));
}

FUNCTION get_discards //Baranov catch eqn
//dead discards at age (number fish)
for (iyear=styr_commmHAL_D; iyear<=endyr_commmHAL_D; iyear++)
{
  for (iage=1; iage<=nages; iage++)
  {
    C_commmHAL_D(iyear,iage)=N(iyear,iage)*F_commmHAL_D(iyear,iage)*
      (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
  }
  pred_commmHAL_D(iyear)=sum(C_commmHAL_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_wgtd_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_wgtd_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_wgtd_tot=sel_wgtd_L+sel_wgtd_D;

max_sel_wgtd_tot=max(sel_wgtd_tot);
sel_wgtd_tot/=max_sel_wgtd_tot;
sel_wgtd_L/=max_sel_wgtd_tot; //landings sel bumped up by same amount as total sel
sel_wgtd_D/=max_sel_wgtd_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_wgtd_L;
  F_D_age_msy=F_msy(ff)*sel_wgtd_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_wgtd_L;

    Z_age_spr=M+F_L_age_spr+F_spr(ff)*sel_wgtd_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_commmHAL_L=0.0; //in 1000s gutted pounds
for (iyear=styr_commmHAL_L; iyear<=endyr_commmHAL_L; iyear++)
{
  if(iyear<=1983)
  {
    f_commmHAL_L+=square(log((pred_commmHAL_L(iyear)+dzero_dum)/
      (obs_commmHAL_L(iyear)*L_commmHAL_bias+dzero_dum)))/(2.0*square(commHAL_L_cv(iyear)));
  }
  else
  {
    f_commmHAL_L+=square(log((pred_commmHAL_L(iyear)+dzero_dum)/
      (obs_commmHAL_L(iyear)+dzero_dum)))/(2.0*square(commHAL_L_cv(iyear)));
  }
}
fval+=w_L*f_commmHAL_L;
fval_unwgt+=f_commmHAL_L;

f_commdDV_L=0.0; //in 1000s gutted pounds
for (iyear=styr_commdDV_L; iyear<=endyr_commdDV_L; iyear++)
{
  f_commdDV_L+=square(log((pred_commdDV_L(iyear)+dzero_dum)/
    (obs_commdDV_L(iyear)+dzero_dum)))/(2.0*square(commDV_L_cv(iyear)));
}
fval+=w_L*f_commdDV_L;
fval_unwgt+=f_commdDV_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_commmHAL_D=0.0; //in 1000s
for (iyear=styr_commmHAL_D; iyear<=endyr_commmHAL_D; iyear++)
{
  f_commmHAL_D+=square(log((pred_commmHAL_D(iyear)+dzero_dum)/
    (obs_commmHAL_D(iyear)+dzero_dum)))/(2.0*square(commHAL_D_cv(iyear)));
}
fval+=w_D*f_commmHAL_D;
fval_unwgt+=f_commmHAL_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_commmHAL_lenc=0.0;
for (iyear=styr_commmHAL_lenc; iyear<=endyr_commmHAL_lenc; iyear++)
{
  f_commmHAL_lenc-=nsamp_commmHAL_lenc(iyear)*
    sum(elem_prod((obs_commmHAL_lenc(iyear)+dzero_dum), log(pred_commmHAL_lenc(iyear)+dzero_dum)));
}
fval+=w_lc*f_commmHAL_lenc;
fval_unwgt+=f_commmHAL_lenc;

f_commdV_lenc=0.0;
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_commmHAL_agec=0.0;
for (iyear=1; iyear<=nyr_commmHAL_agec; iyear++)
{
  f_commmHAL_agec-=nsamp_commmHAL_agec(iyear)*
    sum(elem_prod((obs_commmHAL_agec(iyear)+dzero_dum), log(pred_commmHAL_agec(iyear)+dzero_dum)));
}
fval+=w_ac*f_commmHAL_agec;
fval_unwgt+=f_commmHAL_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_commmHAL1:
1.34471
# selpar_L50_commmHAL1:
5.29564
# selpar_slope_commmHAL2:
1.59389
# selpar_L50_commmHAL2:
4.45283
# selpar_slope_commmHAL3:
1.97236
# selpar_L50_commmHAL3:
4.43963
# selpar_L50_commmHAL_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
 LOGISTIC model mode
 YLD conditioning
 SSE optimization

Author: Michael H. Prager; NOAA Center for Coastal Fisheries and Habitat Research
 101 Pivers Island Road; Beaufort, North Carolina 28516 USA
 Mike.Prager@noaa.gov

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

ASPIC User's Manual is available 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 | 2 | 3 |
|---|--------------------------------------|--------------|--------------|-------------|
| 1 | Headboat Index (1962-2004), Total... | 1.000 32 | | |
| 2 | Commercial Logbook Index | -0.447 13 | 1.000 13 | |
| 3 | MRFSS Index | 0.007 24 | -0.023 13 | 1.000 24 |

GOODNESS-OF-FIT AND WEIGHTING (NON-BOOTSTRAPPED ANALYSIS)

| Loss component number and title | Weighted SSE | N | Weighted MSE | Current weight | Inv. var. weight | R-squared 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

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MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

| Parameter | | Estimate | User/pgm guess | 2nd guess | Estimated | User guess |
|--|--|-----------|----------------|-----------|-----------|------------|
| B1/K | Starting relative biomass (in 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 |
| <hr/> | | | | | | |
| 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 ...as proportion of MSY | 4.578E+02 9.257E-01 | MSY*B./Bmsy ---- | MSY*B./Bmsy ---- |
| Ye. | Equilibrium yield available in 2005 ...as proportion of MSY | 4.918E+02 9.945E-01 | 4*MSY*(B/K-(B/K)**2) ---- | g*MSY*(B/K-(B/K)**n) ---- |
| <hr/> | | | | |
| 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

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ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

| Obs | Year or ID | Estimated total F mort | Estimated starting biomass | Estimated average biomass | Observed total yield | Model total yield | Estimated surplus production | Ratio of F mort to Fmsy | Ratio of biomass to Bmsy |
|-----|------------|------------------------|----------------------------|---------------------------|----------------------|-------------------|------------------------------|-------------------------|--------------------------|
| 1 | 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 | | | | | | | | 9.257E-01 |

CORRECTED SAFMC Gag SEDAR 10 (2006) Landings and Indices, B1/K=0.9

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| 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).

| 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

ESTIMATES FROM BOOTSTRAPPED ANALYSIS

| Param name | Point estimate | Estimated bias in pt estimate | Estimated relative bias | Bias-corrected approximate confidence limits | | | | Inter-quartile range | Relative IQ range |
|-----------------|------------------------|-------------------------------|-------------------------|--|------------------------|------------------------|------------------------|------------------------|-------------------|
| | | | | 80% lower | 80% upper | 50% lower | 50% upper | | |
| B1/K | 9.000E-01 1.561E+04 | 0.000E+00 1.023E+02 | 0.00% 0.66% | 9.000E-01 1.045E+04 | 9.000E-01 3.522E+04 | 9.000E-01 1.328E+04 | 9.000E-01 2.785E+04 | 0.000E+00 1.457E+04 | 0.000 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. \cdot 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. \cdot 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. \cdot 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. \cdot 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 | Residual-adjustment factor: | 1.0383 |
| Trials replaced for K out-of-bounds: | 68 | | |

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

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Thursday, 14 Dec 2006 at 13:18:06

ASPIIC -- A Surplus-Production Model Including Covariates (Ver. 5.16)

Author: Michael H. Prager; NOAA Center for Coastal Fisheries and Habitat Research
101 Pivers Island Road; Beaufort, North Carolina 28516 USA
Mike.Prager@noaa.govBOT program mode
LOGISTIC model mode
YLD conditioning
SSE optimization

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

ASPIIC User's Manual is available gratis from the author.

CONTROL PARAMETERS (FROM INPUT FILE)

Input file: gag2006_117_boot.inp

Operation of ASPIIC: 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 ASPIIC 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 | 2 | 3 |
|---|-----------------------------------|--------------|-------------|-------------|
| 1 | Headboat Index (1962-2004), Total | 1.000 32 | | |
| 2 | Commercial Logbook Index | -0.244 13 | 1.000 13 | |
| 3 | MRFSS Index | 0.145 24 | 0.094 13 | 1.000 24 |

GOODNESS-OF-FIT AND WEIGHTING (NON-BOOTSTRAPPED ANALYSIS)

| Loss component number and title | Weighted SSE | N | Weighted MSE | Current weight | Inv. var. weight | R-squared 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

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MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

| Parameter | | Estimate | User/pgm guess | 2nd guess | Estimated | User guess |
|--|--|-----------|----------------|-----------|-----------|------------|
| B1/K | Starting relative biomass (in 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 |
| <hr/> | | | | | | |
| 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 ...as proportion of MSY | 3.202E+02 6.037E-01 | MSY*B./Bmsy | MSY*B./Bmsy |
| Ye. | Equilibrium yield available in 2005 ...as proportion of MSY | 4.471E+02 8.429E-01 | 4*MSY*(B/K-(B/K)**2) ---- | g*MSY*(B/K-(B/K)**n) ---- |
| <hr/> | | | | |
| 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

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ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

| Obs | Year or ID | Estimated total F mort | Estimated starting biomass | Estimated average biomass | Observed total yield | Model total yield | Estimated surplus production | Ratio of F mort to Fmsy | Ratio of biomass to Bmsy |
|-----|------------|------------------------|----------------------------|---------------------------|----------------------|-------------------|------------------------------|-------------------------|--------------------------|
| 1 | 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

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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

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| 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

ESTIMATES FROM BOOTSTRAPPED ANALYSIS

| Param name | Point estimate | Estimated bias in pt estimate | Estimated relative bias | Bias-corrected approximate confidence limits | | | | Inter-quartile range | Relative IQ range |
|------------|------------------------|-------------------------------|-------------------------|--|------------------------|------------------------|------------------------|------------------------|-------------------|
| | | | | 80% lower | 80% upper | 50% lower | 50% upper | | |
| B1/K | 9.000E-01 1.009E+04 | -1.371E-10 9.167E+02 | -0.00% 9.09% | 9.000E-01 6.113E+03 | 9.000E-01 2.104E+04 | 9.000E-01 8.028E+03 | 9.000E-01 1.578E+04 | 4.148E-11 7.755E+03 | 0.000 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 MSY out of bounds: | 41 |
| Trials replaced for q out-of-bounds: | 0 | Residual-adjustment factor: | 1.0383 |
| Trials replaced for K out-of-bounds: | 0 | | |

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, F_{msy}, B_{msy}, 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 <i>Review Draft</i> | South Atlantic Gag Grouper SEDAR Assessment Report | |
| SEDASR10-SAR2 <i>Review Draft</i> | 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 (*S10SARI-SAgag Sect12.pdf* and *S10SARI Sect3AtlGagAW.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 *S10SARI-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 *S10SARI Sect3AtlGagAW.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 *S10SARI-SAag 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, F_{msy} , B_{msy} , 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 1 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:

$$y = \ln(wt) = \ln(a) + b \ln(L) + \varepsilon = \alpha + \beta \ln(L) + \varepsilon \quad (1)$$

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:

$$\hat{w}_0 = e^{\hat{\alpha} + \hat{\beta} \ln(L_0)} \quad (2)$$

Or with a bias corrected equations as in both assessments as

$$\hat{w}_0 = e^{\hat{\alpha} + MSE/2 + \hat{\beta} \ln(L_0)} \quad (3)$$

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

$$E(\hat{w}) = E\left(e^{\hat{\alpha} + \hat{\beta} \ln(L) + \varepsilon}\right) = e^{E(\hat{\alpha} + \hat{\beta} \ln(L) + \varepsilon) + \frac{V(\hat{\alpha} + \hat{\beta} \ln(L) + \varepsilon)}{2}} = e^{\alpha + \beta \ln(L)} e^{\frac{V(\hat{\alpha} + \hat{\beta} \ln(L) + \varepsilon)}{2}} = w \times e^{\frac{V(\hat{\alpha} + \hat{\beta} \ln(L) + \varepsilon)}{2}}$$

The predicted weight from the estimated log-log length-weight model is biased-high with the bias: $e^{\frac{V(\hat{\alpha} + \hat{\beta} \ln(L) + \varepsilon)}{2}} = e^{\frac{\sigma^2 + V(\hat{\alpha} + \hat{\beta} \ln(L))}{2}}$.

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 $len_0 = (\text{mean observed length})$. 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 $(1-M)*B_{MSY}$, 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

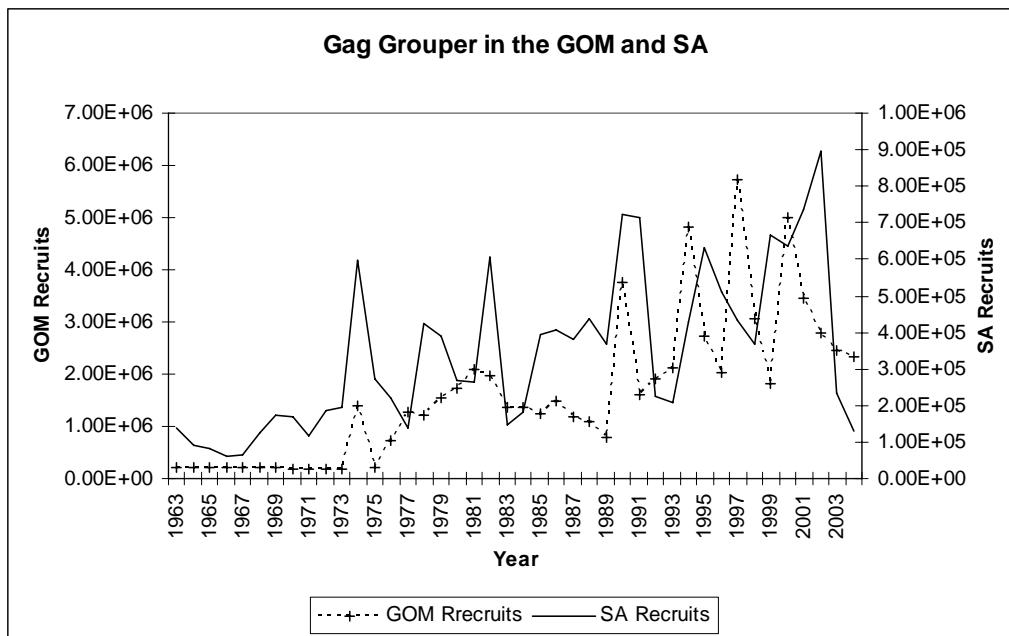
(Note that comparisons presented here are based on Atlantic gag assessment results available to the review panel. Final results after correction of an input data error are different. See the Assessment Workshop report for details.)

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>.

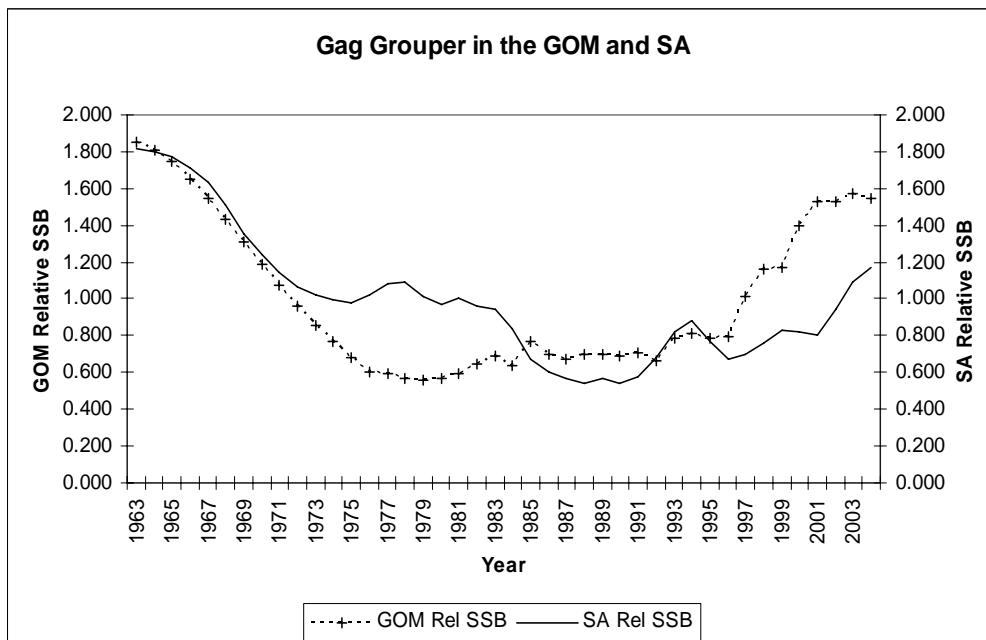
For the South Atlantic, a production model (ASPIC) was also run and for the Gulf of Mexico two VPA's were run: one was a strict continuity run and the other one was parameterized to mimic the CASAL run. VPA was not used in the South Atlantic because of insufficient complete catch at age information. 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.

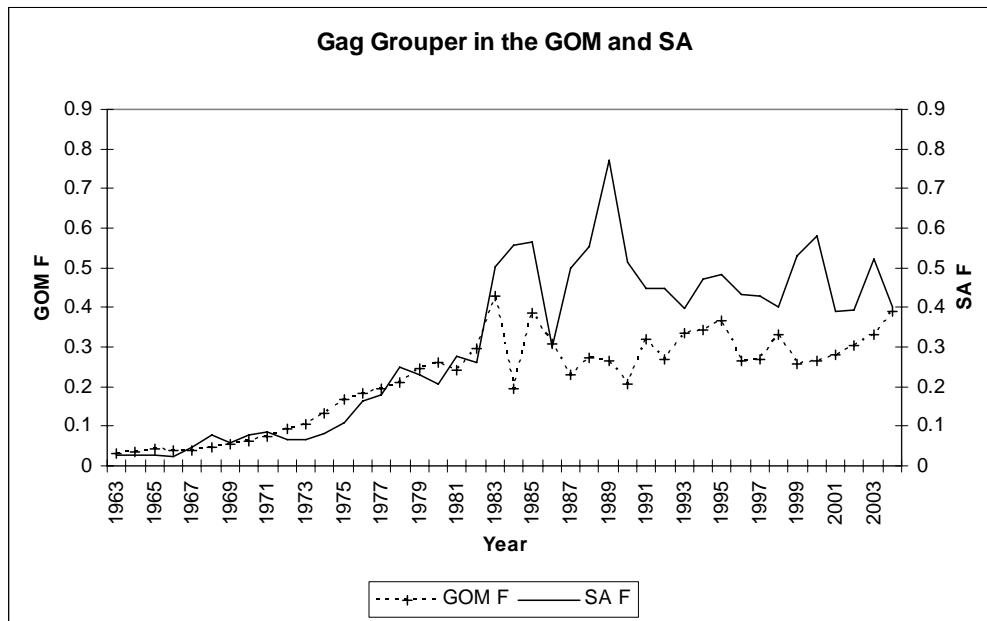
In both stock areas, recruitment has increased in recent years, although the increase is more pronounced in the Gulf of Mexico than in the South Atlantic. Recruitment is estimated to have been about 5 times higher, on average, in the Gulf of Mexico than in the Atlantic.



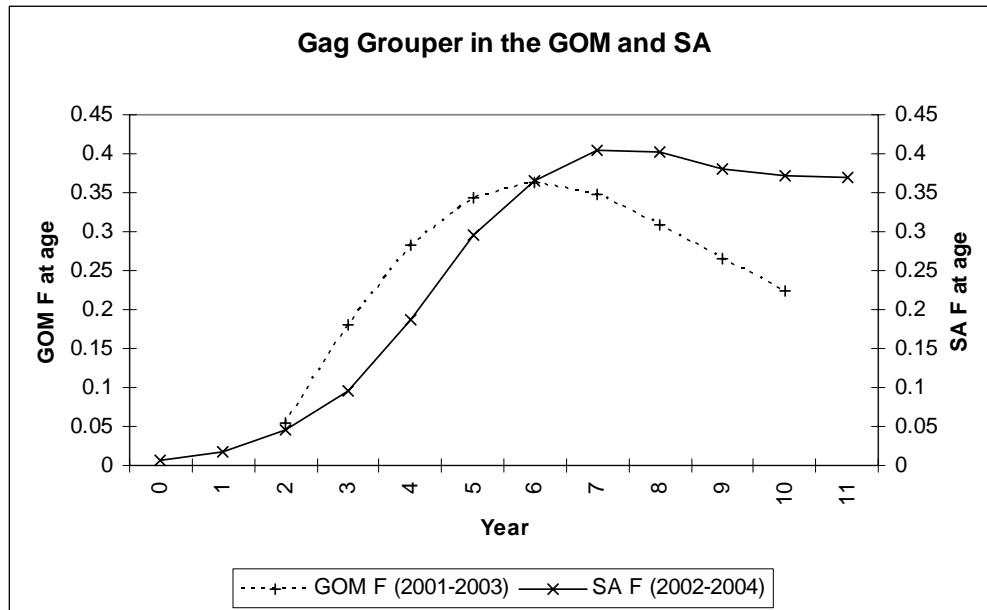
For both stocks, relative SSB's were high in the early 1960s, declined more or less regularly until the early 1990s when both started to increase. The 2004 SSB in the Gulf of Mexico is almost 60% above average, close to the maximum observed in the early 1960s, while for the South Atlantic, the 2004 SSB 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
1 Southpark Circle # 306
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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

| Year | Headboat Catch-at-age (1000's) | | | | | | | | | | | | | | | | | | | | |
|------|--------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | Age | | | | | | | | | | | | | | | | | | | | |
| 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 | 0.03 | 0.03 | 0.00 | 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 | 0.00 | 0.04 | 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

| Year | Commercial Diving Catch-at-age (kib) | | | | | | | | | | | | | | | | | | | | |
|------|--------------------------------------|------|------|------|-------|-------|-------|-------|-------|------|------|------|------|------|------|------|------|------|------|------|------|
| | Age | | | | | | | | | | | | | | | | | | | | |
| 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

| Year | Commercial Handline (kib) | | | | | | | | | | | | | | | | | | | | |
|------|---------------------------|------|-------|--------|--------|--------|--------|--------|--------|-------|-------|-------|-------|-------|------|------|------|-------|-------|-------|-------|
| | Age | | | | | | | | | | | | | | | | | | | | |
| 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 | 0.10 | 0.89 | 0.00 | 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 | 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 | 0.00 |
| 1997 | 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 | 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 | 4.83 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2000 | 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 | 0.00 | 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.

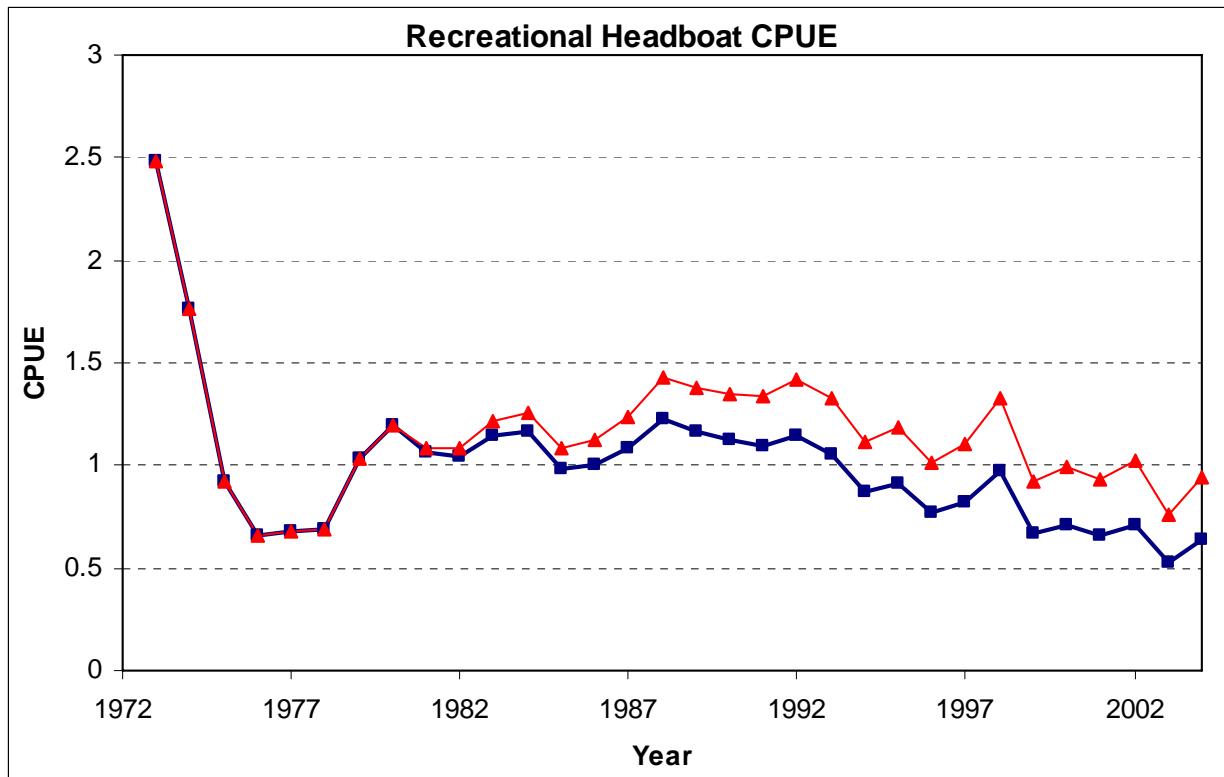


Figure 2. Recreational MRFSS catch-per-unit-effort (CPUE) observed index (red triangles) and catchability adjusted index (blue squares). Adjustment is based on an additive 2% per year change starting in 1980.

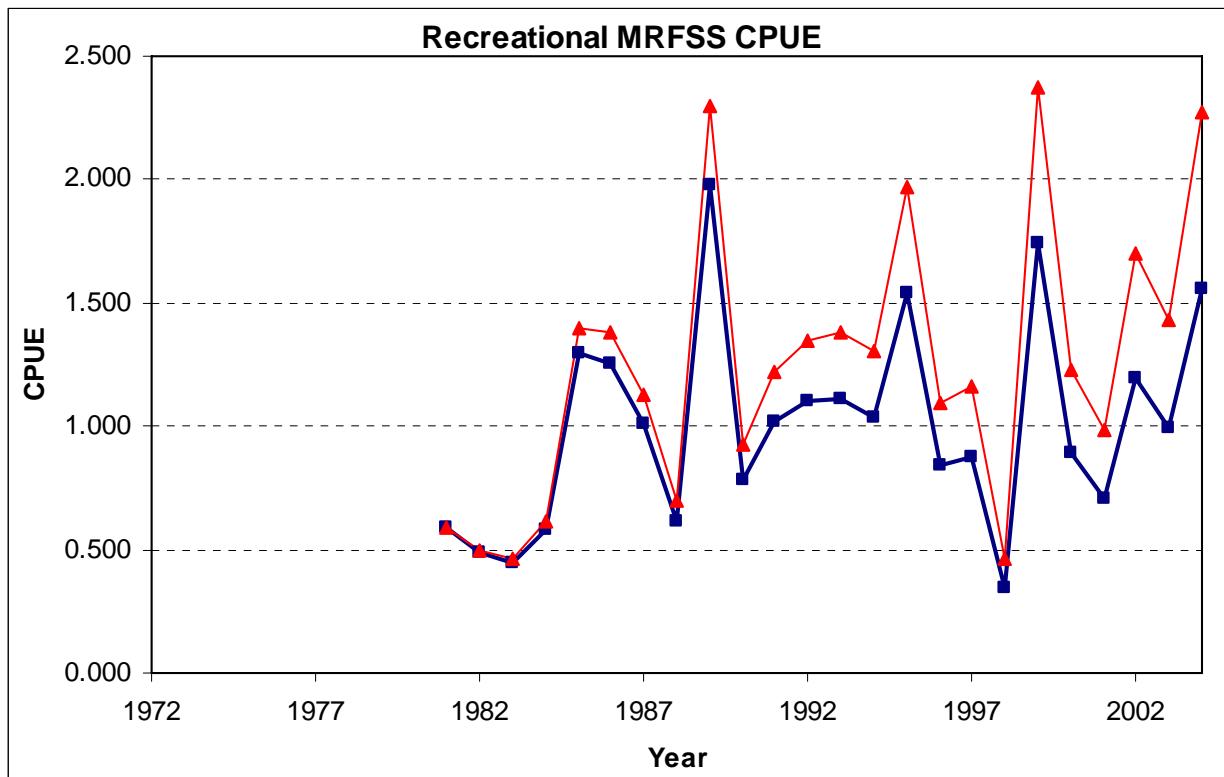
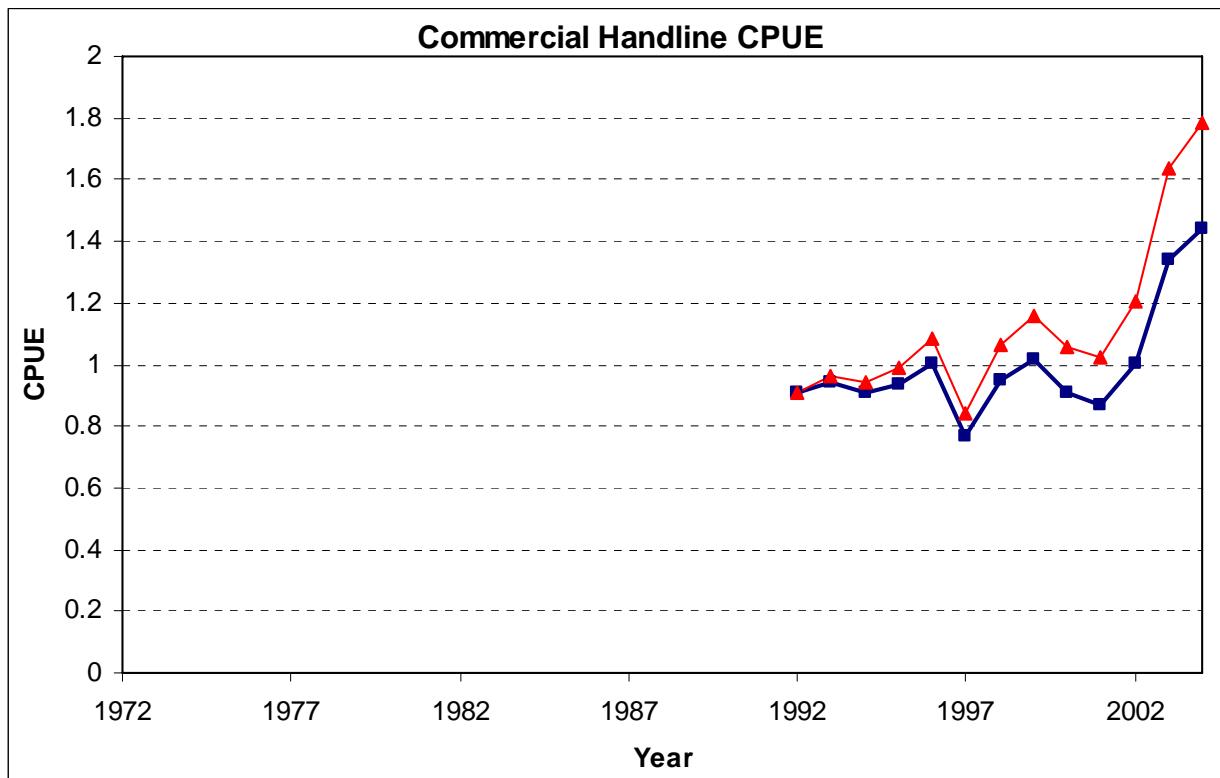


Figure 3. Commercial handline catch-per-unit-effort (CPUE) observed index (red triangles) and catchability adjusted index (blue squares). Adjustment is based on an additive 2% per year change starting in 1980.



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.

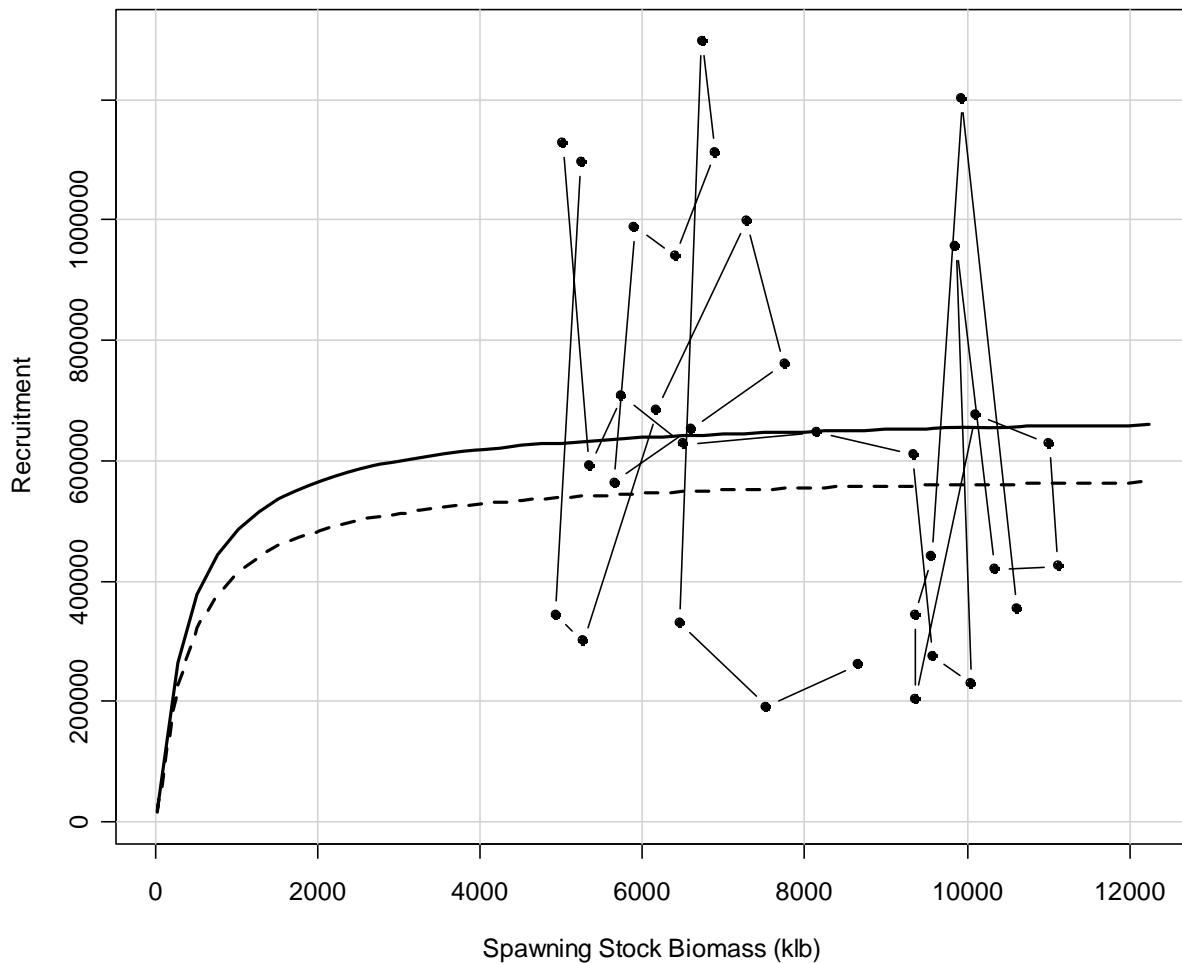


Figure 5. Base run with constant catchability: Estimated stock-recruitment relationship. Circles represent estimated spawning biomass and recruitment values from 1972-2004, connected temporally by lines; Dashed curve is estimated relationship; Solid curve is estimated relationship with lognormal bias correction.

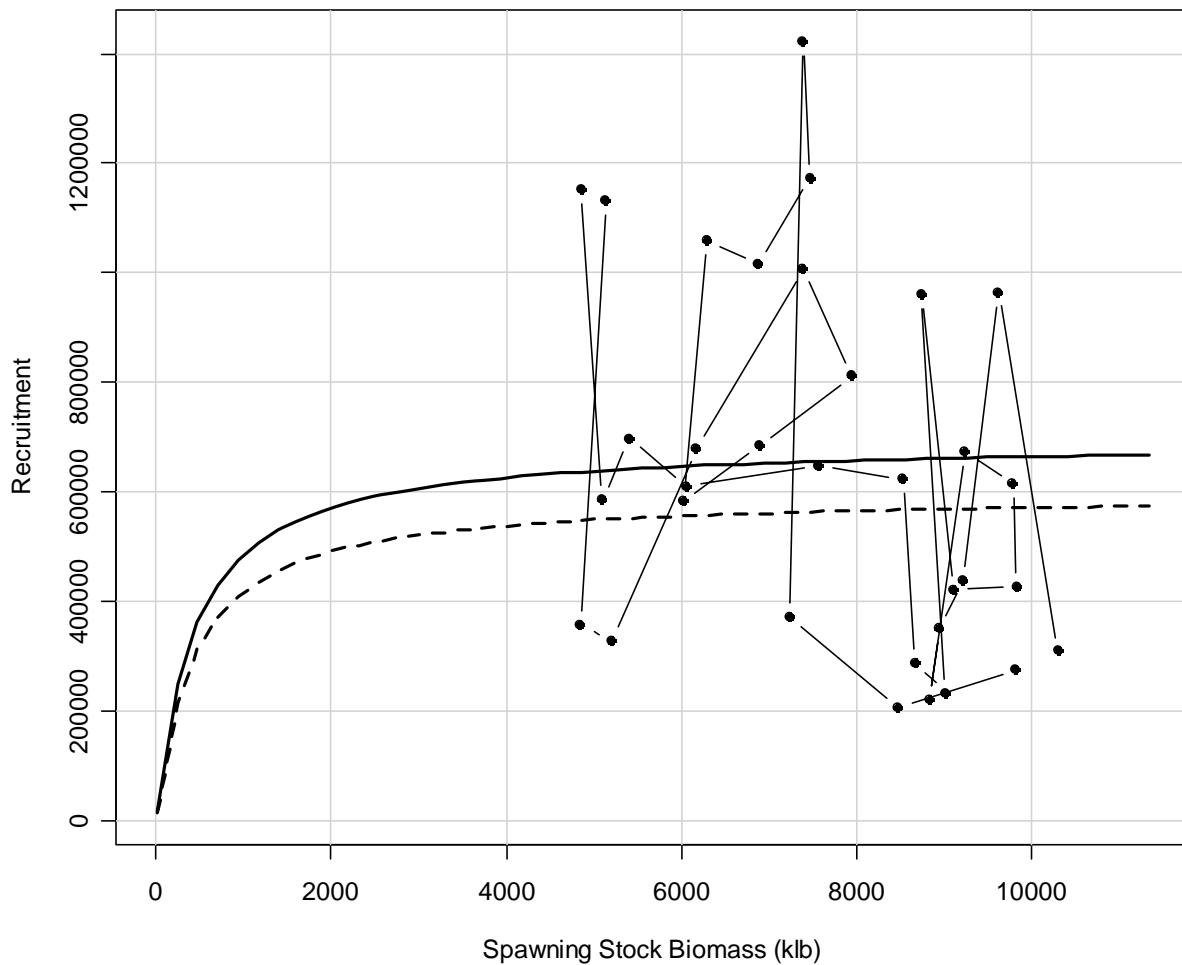


Figure 6. Base run with time-varying catchability: Estimated stock-recruitment relationship. Two digit year labels represent estimated spawning biomass and recruitment values from 1972-2004; Dashed curve is estimated relationship; Solid curve is estimated relationship with lognormal bias correction.

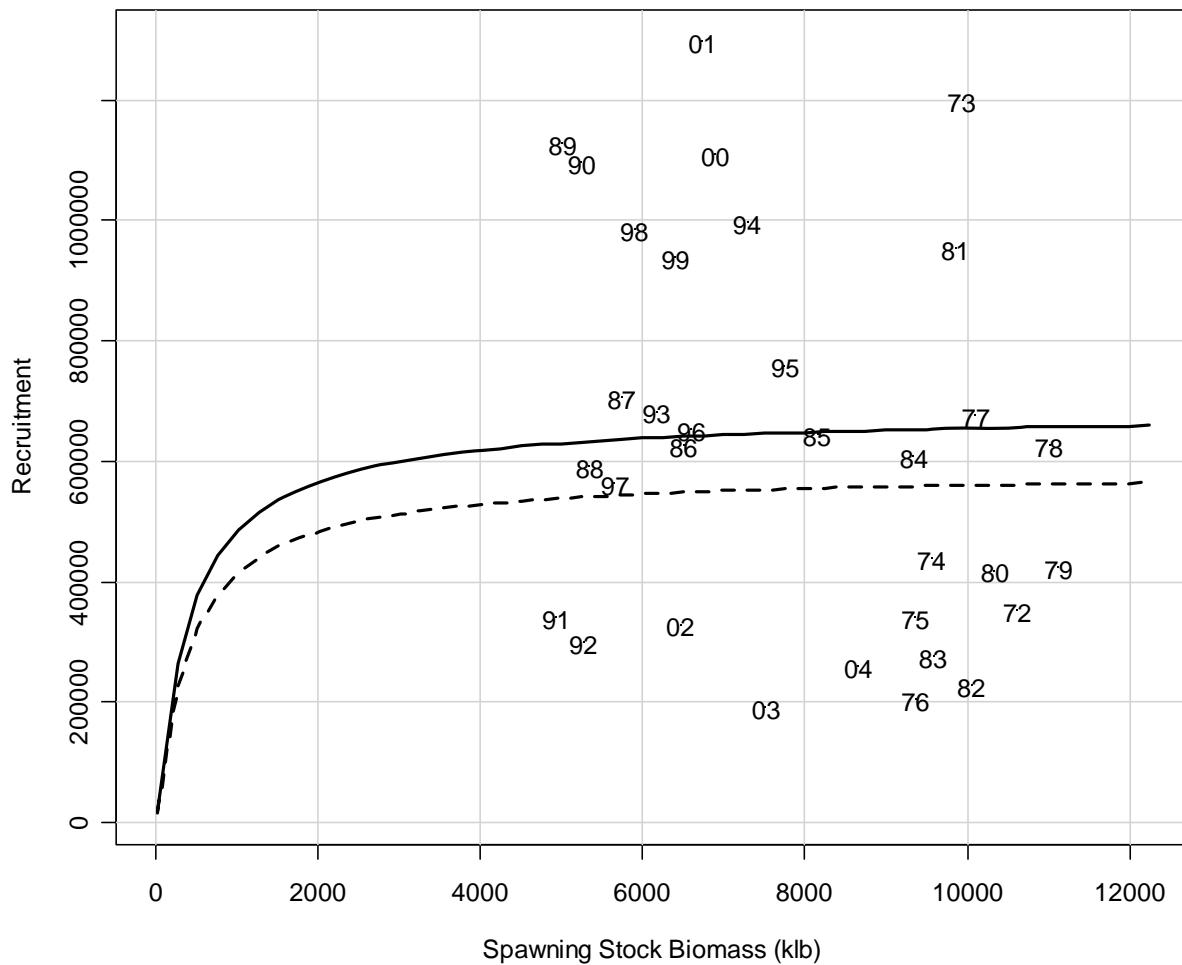
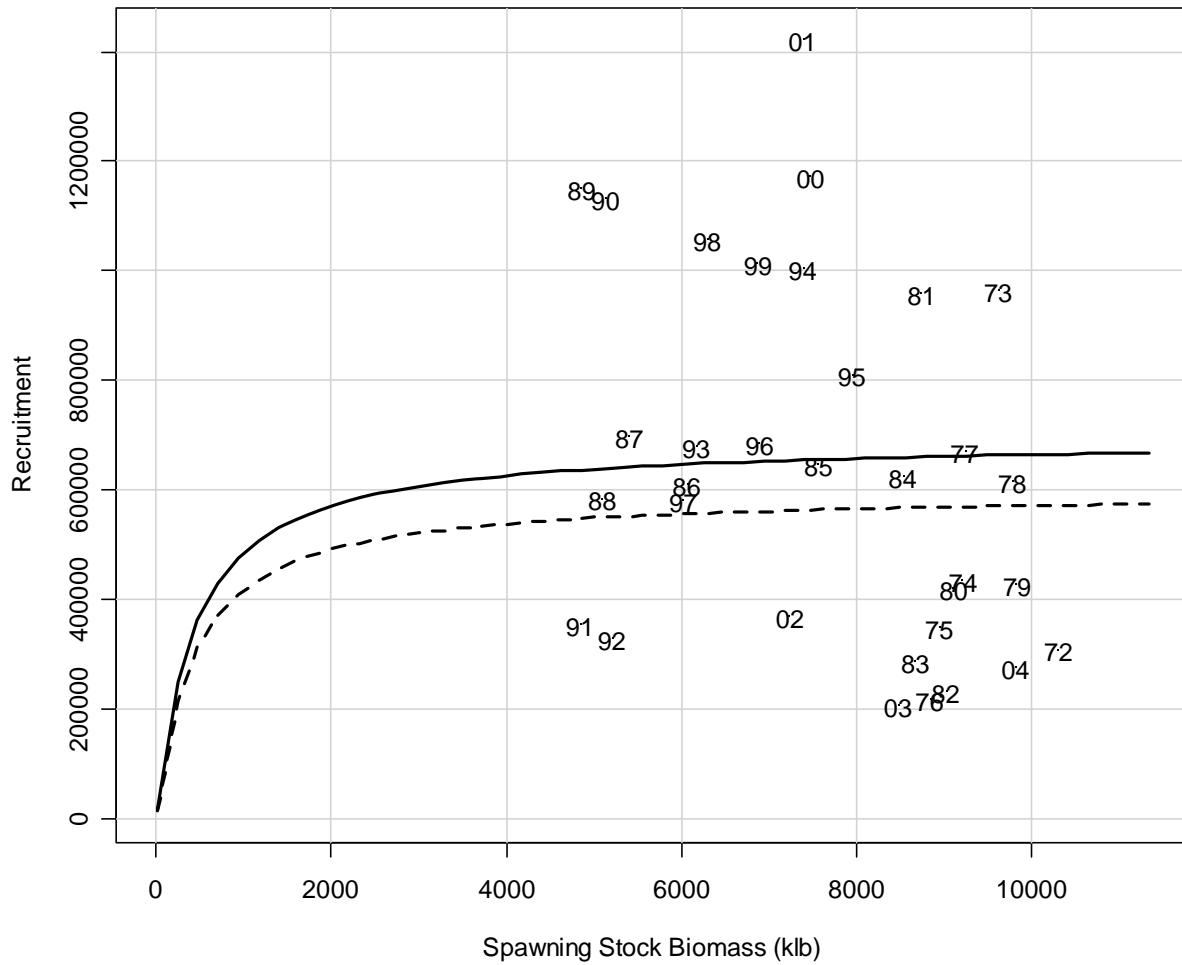


Figure 7. Base run with constant catchability: Estimated stock-recruitment relationship. Two digit year labels represent estimated spawning biomass and recruitment values from 1972-2004; Dashed curve is estimated relationship; Solid curve is estimated relationship with lognormal bias correction.



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.

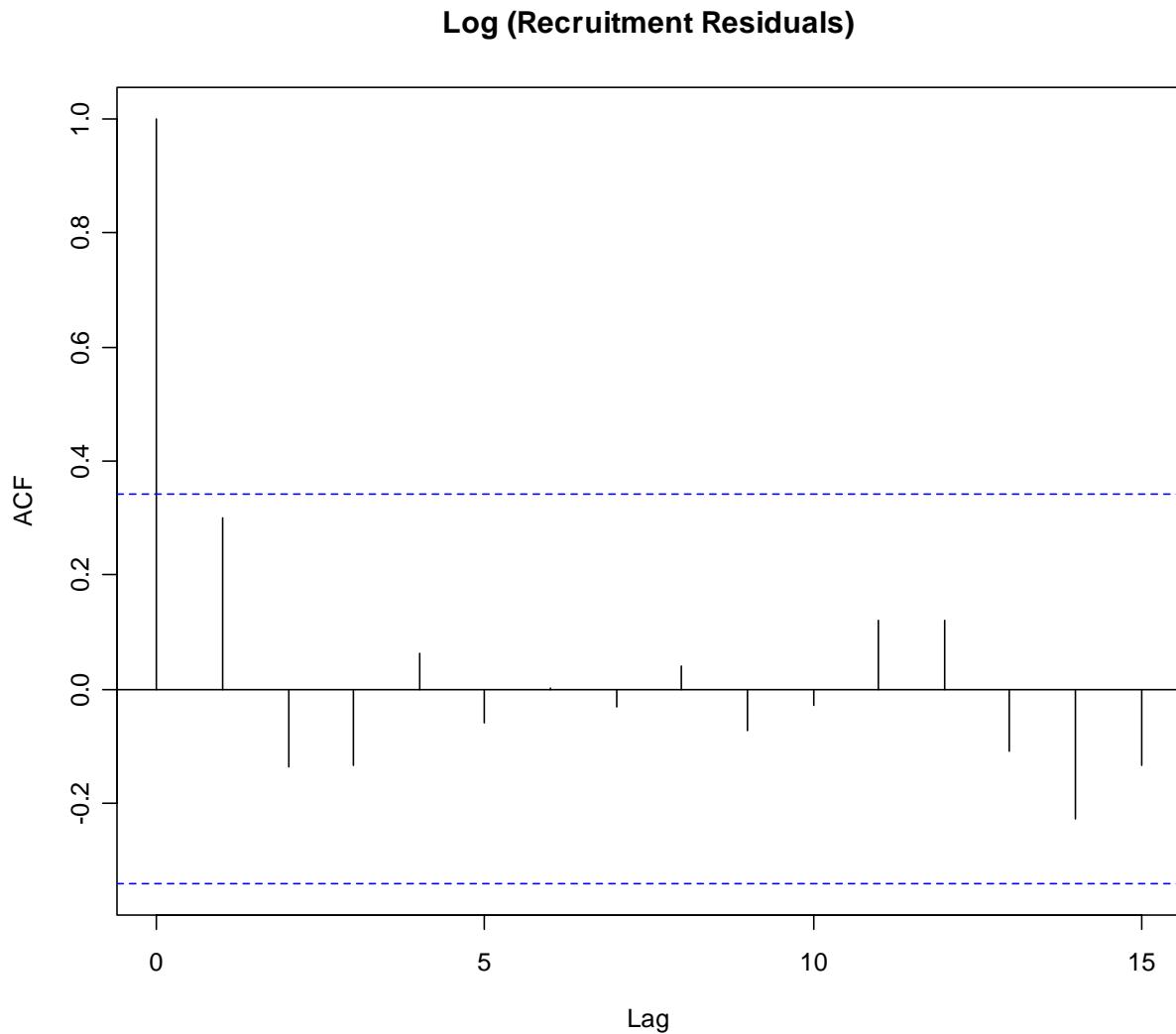


Figure 9. Autocorrelation function applied to the log-recruitment residuals from the constant catchability model run. Significance levels are indicated by horizontal dashed lines.

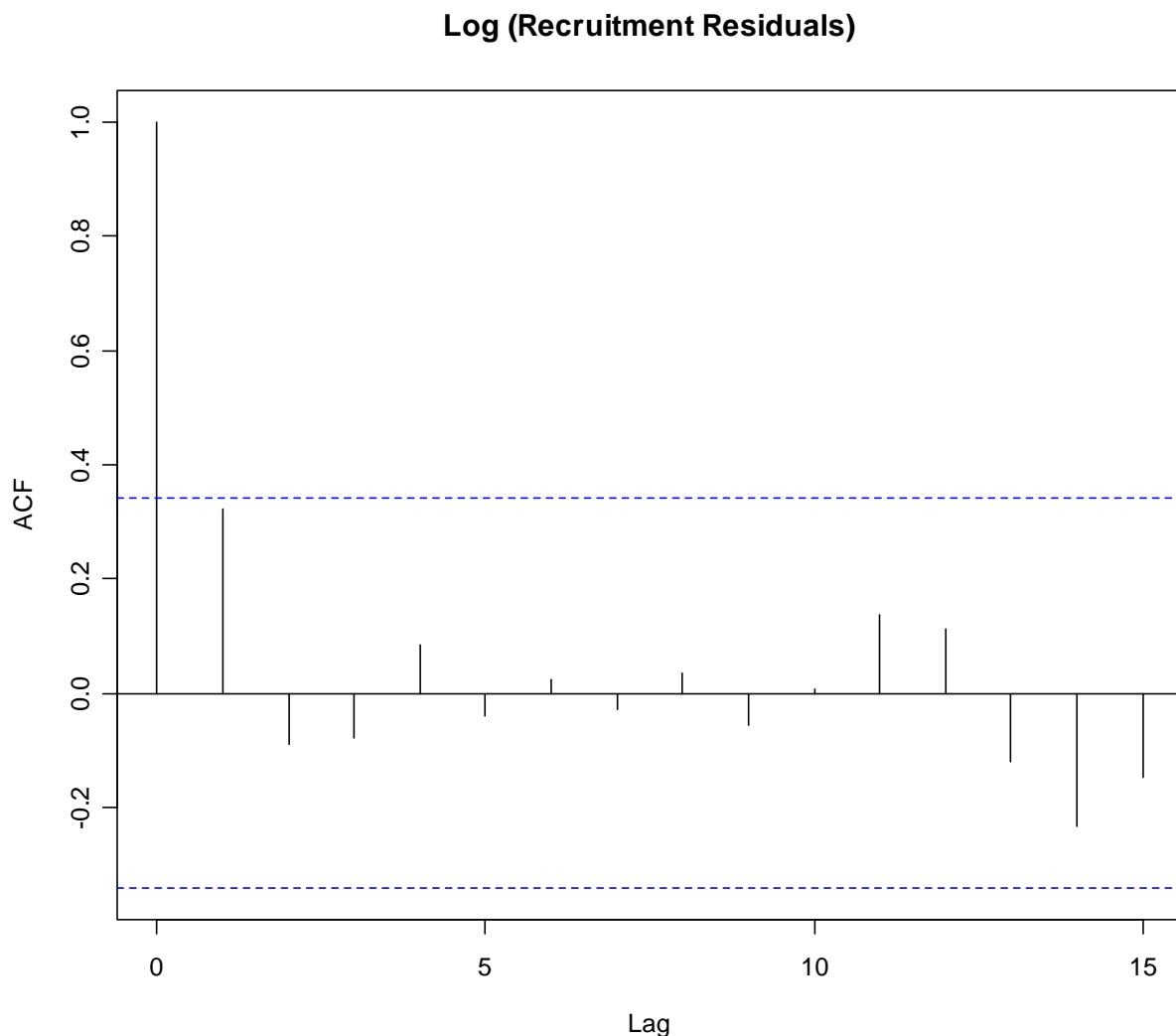


Figure 10. Plot of 1 year lagged log recruitment residuals from the time-varying catchability stock assessment model.

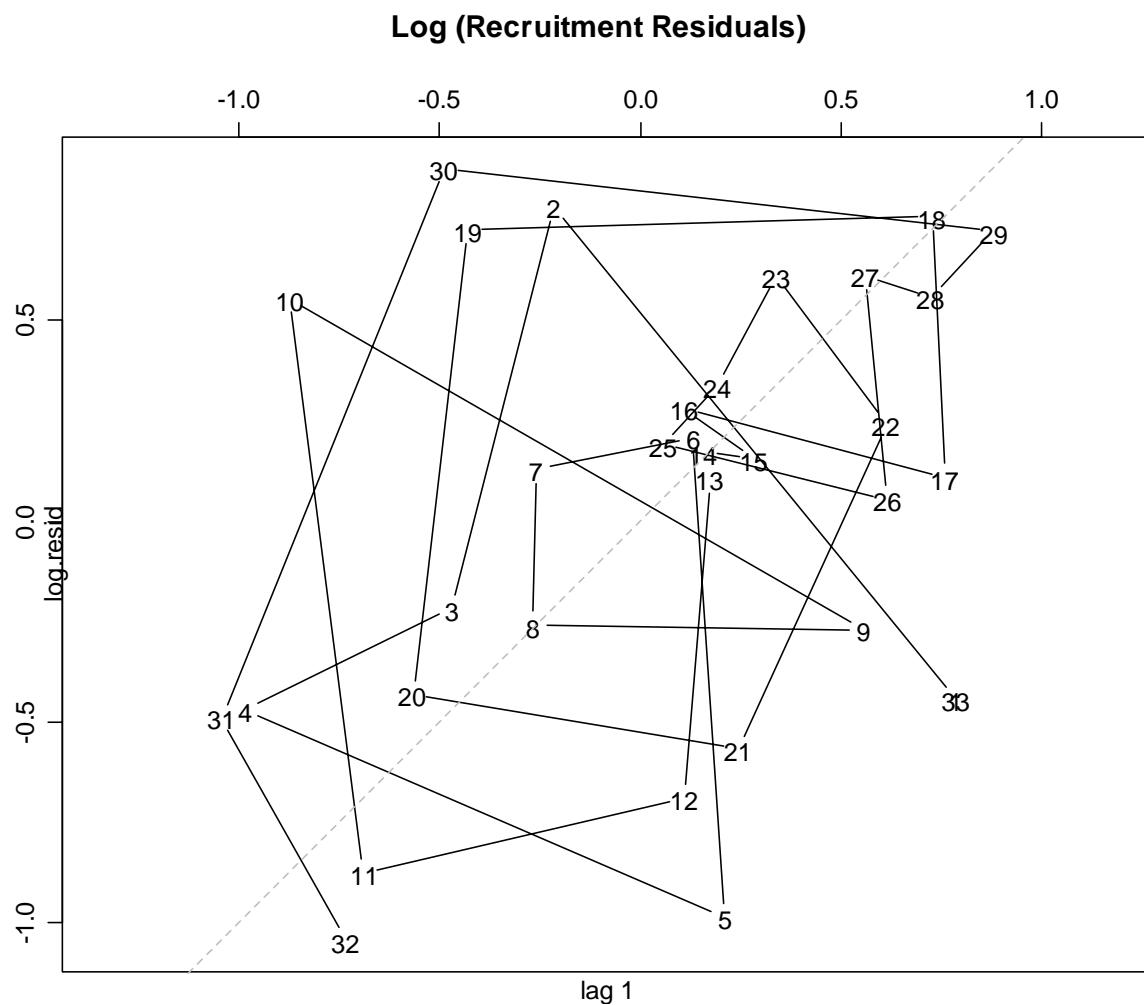


Figure 11. Plot of 1 year lagged log recruitment residuals from the constant catchability stock assessment model.

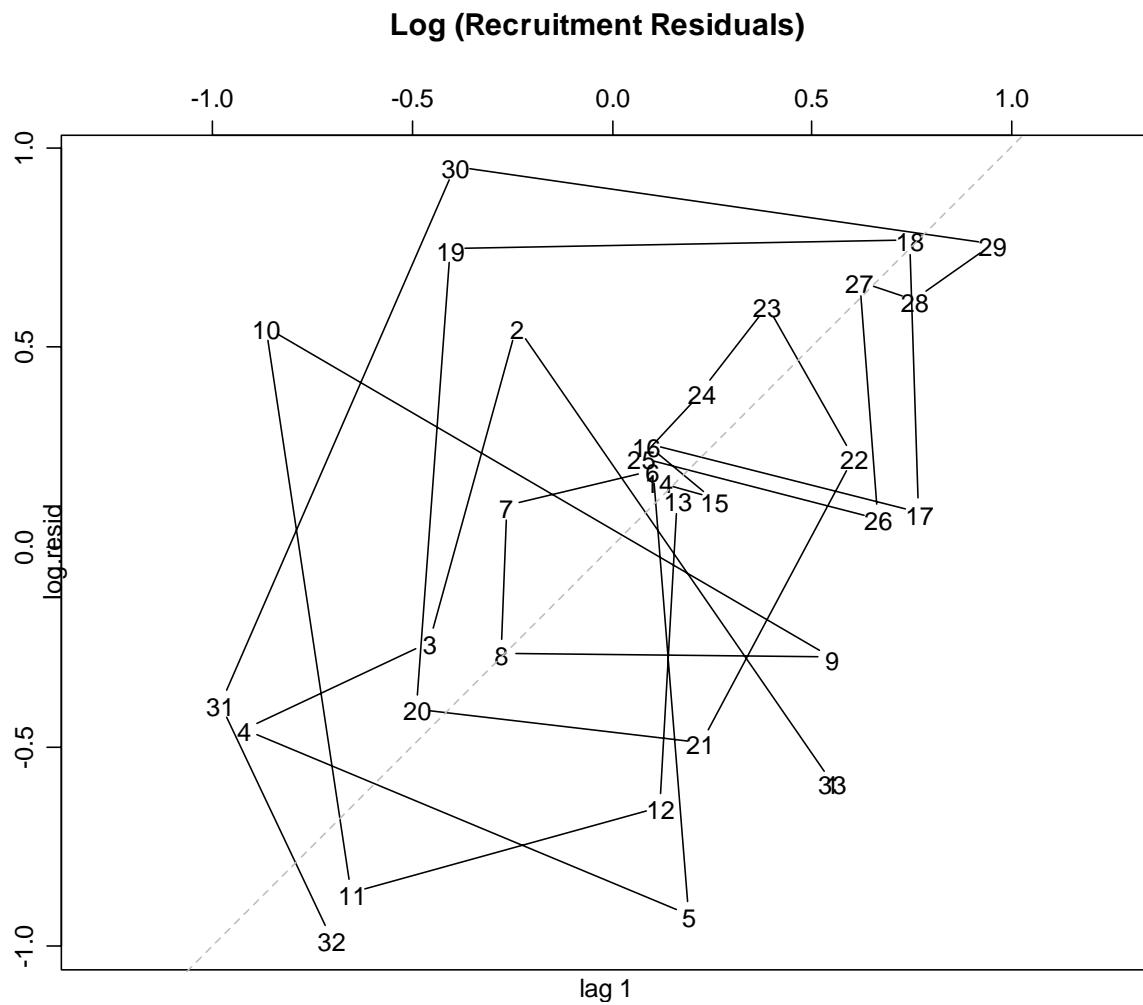


Figure 12. Base run with time-varying catchability: Estimated stock-recruitment relationship. Circles represent estimated spawning biomass and recruitment values from 1972-2004; Dashed curve is estimated relationship (black with no autocorrelation, red with lag 1 autocorrelation parameter); Solid curve is estimated relationship with lognormal bias correction (black with no autocorrelation, red with lag 1 autocorrelation parameter).

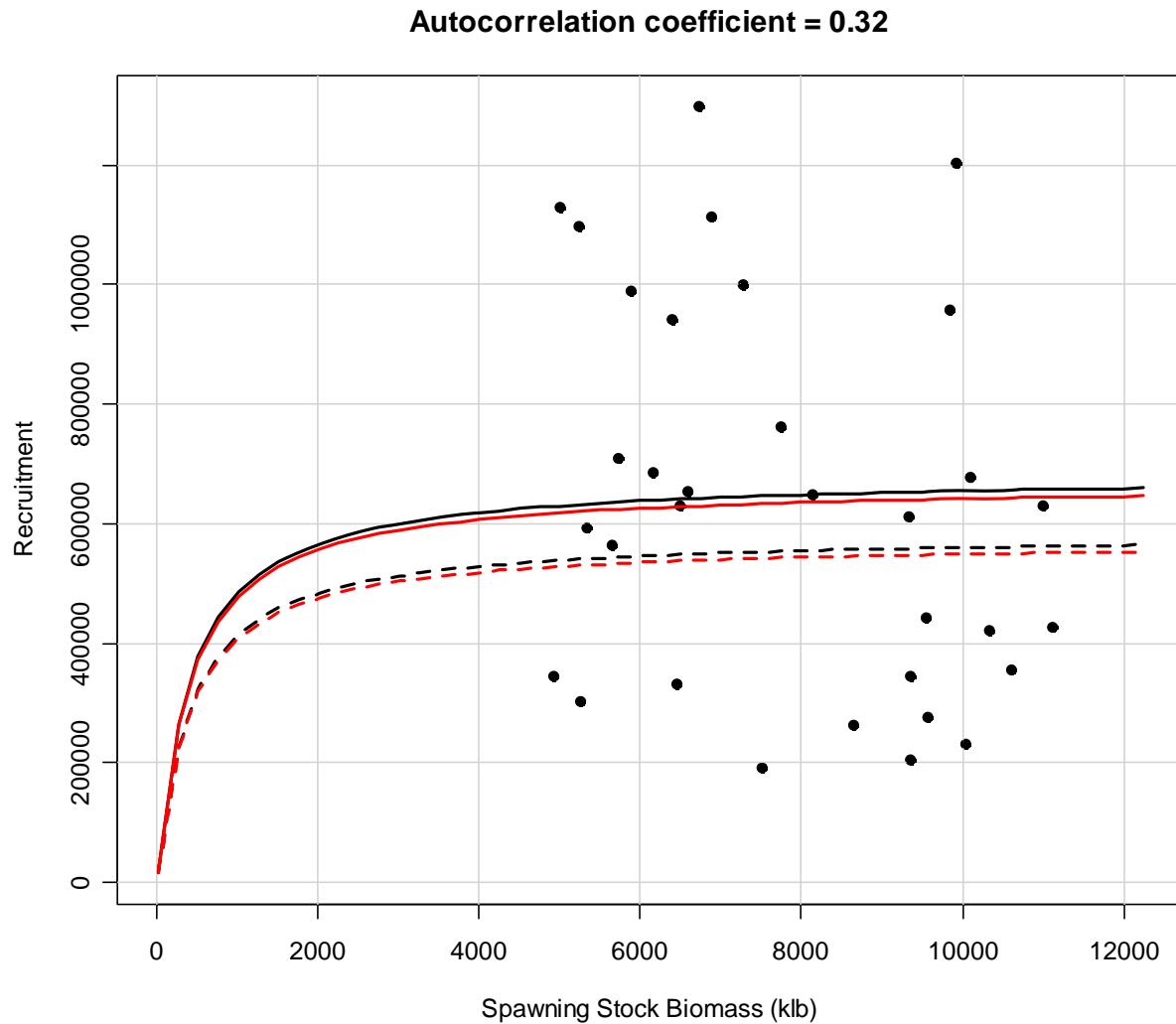
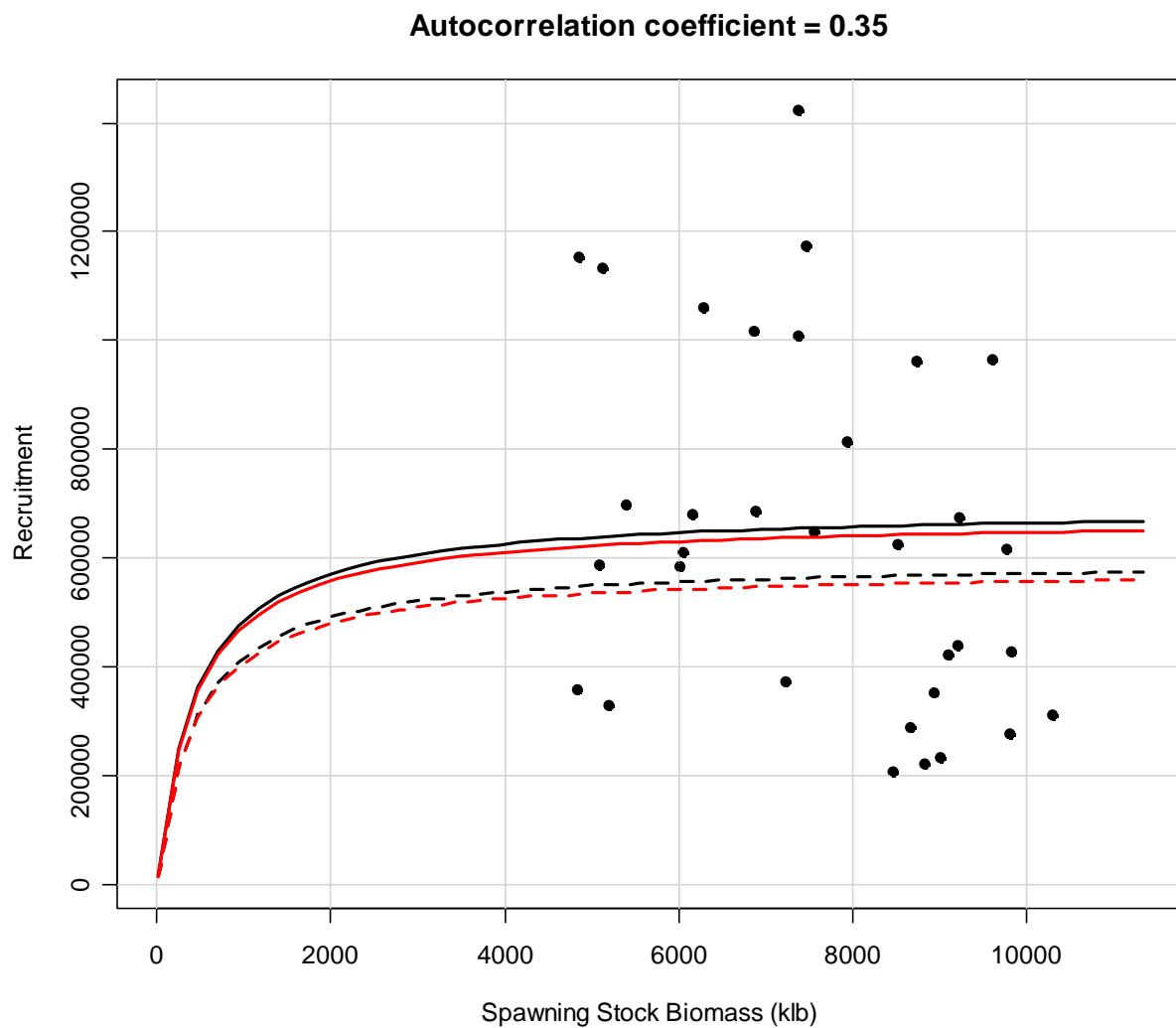


Figure 13. Base run with constant catchability: Estimated stock-recruitment relationship. Circles represent estimated spawning biomass and recruitment values from 1972-2004; Dashed curve is estimated relationship (black with no autocorrelation, red with lag 1 autocorrelation parameter); Solid curve is 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.

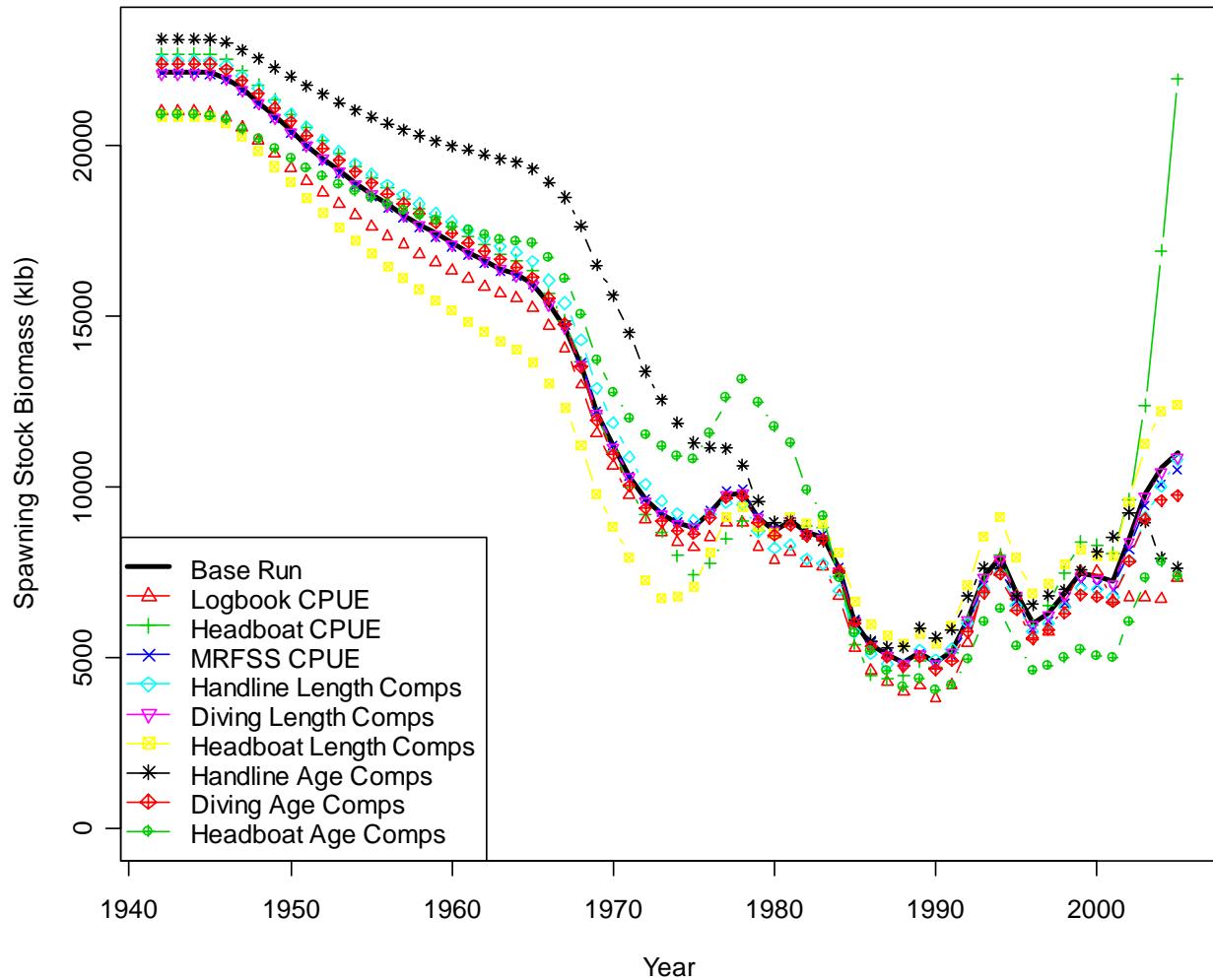


Figure 15. Estimated time series of fishing mortality rate from the base run model with constant catchability. The base run model with all data included is illustrated with a thick black line. Other runs with the labeled dataset left out of the model are shown in various colors and point markers.

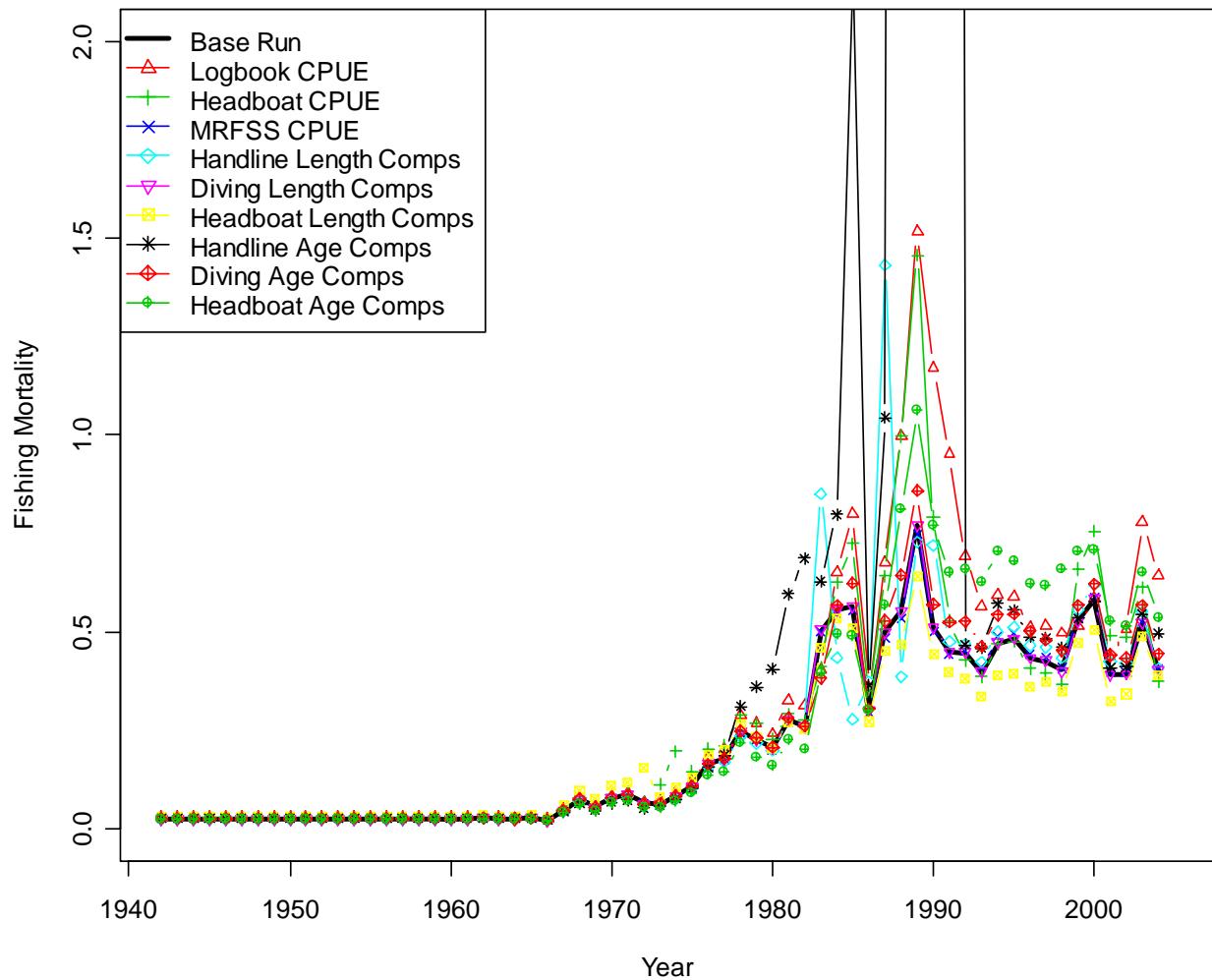
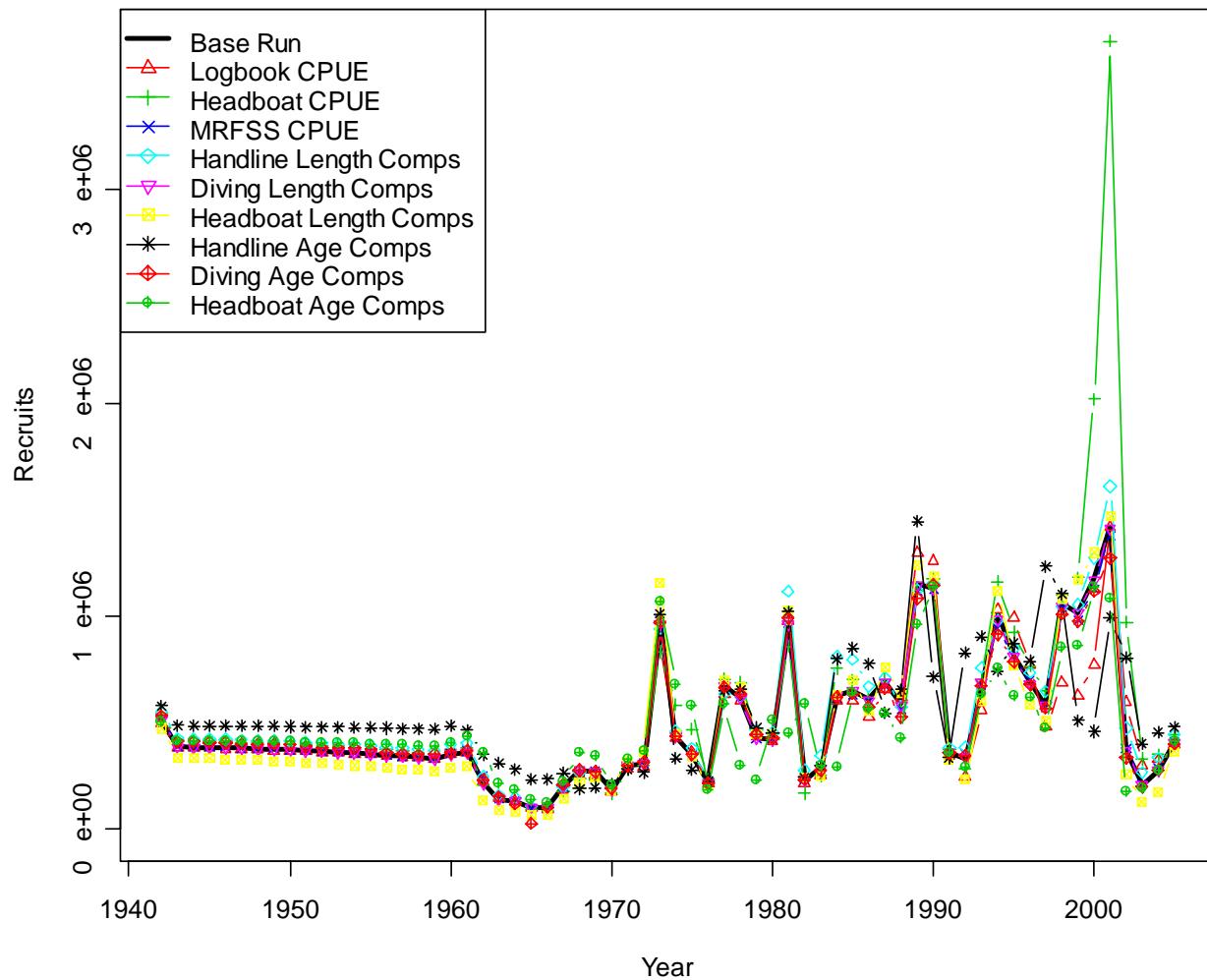


Figure 16. Estimated time series of recruitment from the base run model with constant catchability. The base run model with all data included is illustrated with a thick black line. Other runs with the labeled dataset left out of the model are shown in various colors and point markers.



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-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-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 $(1-M)B_{MSY}$, 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.

| Year | Commercial (gutted klb) | | Recreational (1000s) | | Discards (1000s) | | |
|------|-------------------------|--------|----------------------|--------|------------------|----------|--------|
| | 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.

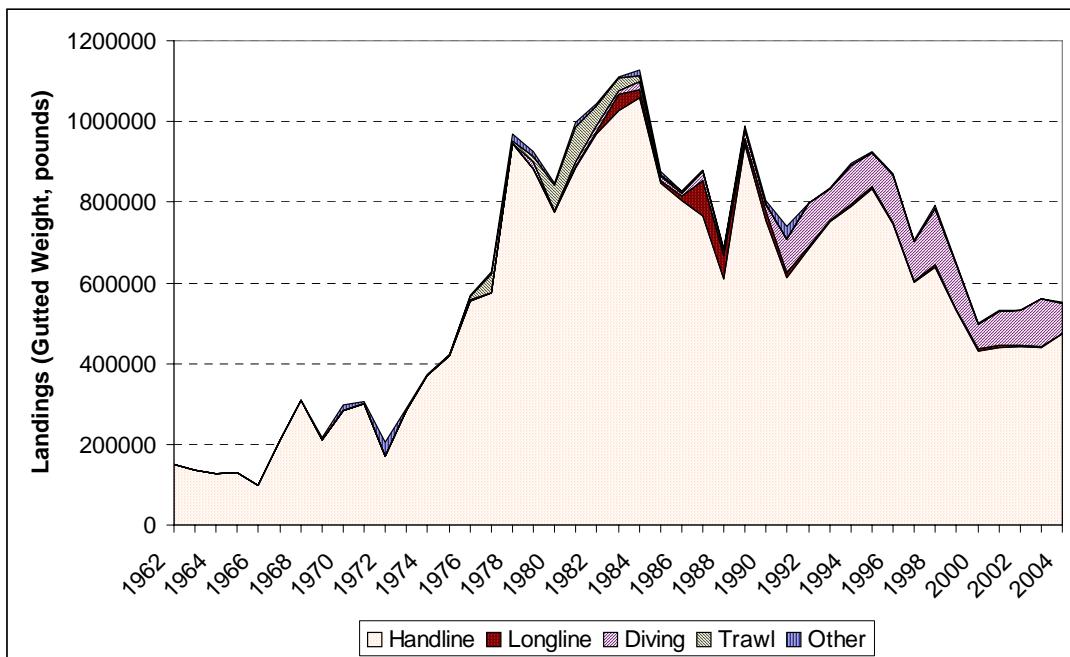


Figure 2. Total gag grouper catches (landings and discards) in numbers by sector from the U.S. South Atlantic, 1962-2004.

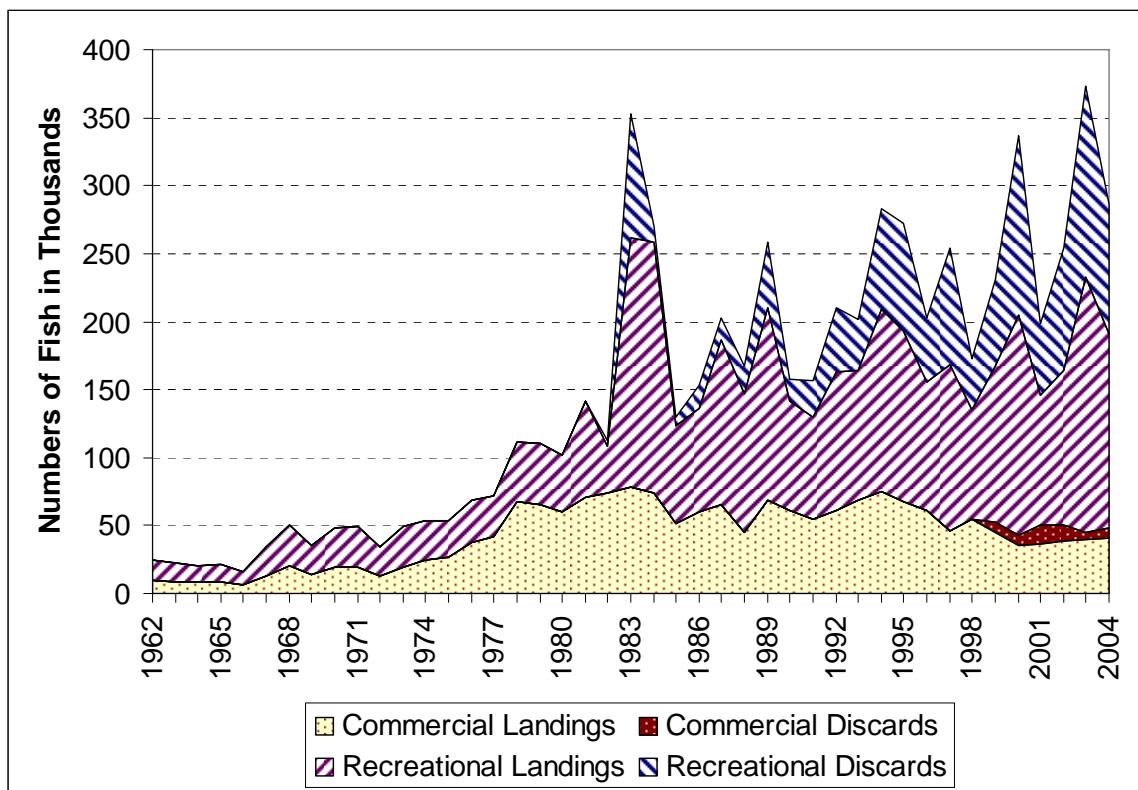


Figure 3. Estimated fully-selected fishing mortality rate. Solid horizontal line represents F_{MSY} .

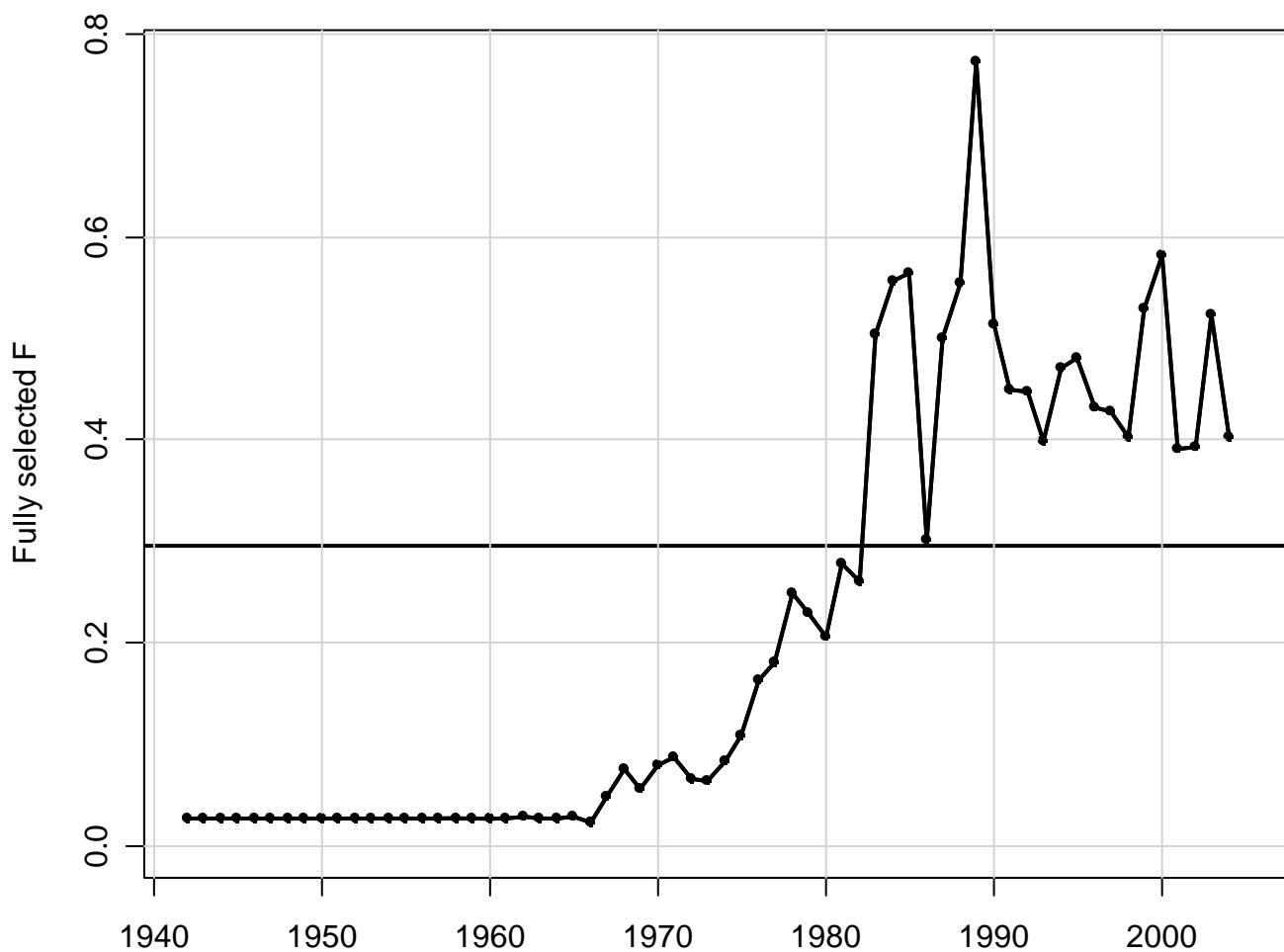


Figure 4. Estimated biomass time series (biomass in gutted weight). Total biomass (solid trend line) and spawning stock biomass (male mature biomass + female mature biomass, dashed trend line). The horizontal lines represents the level of biomass corresponding to MSY (B_{MSY}) and SSB MSY .

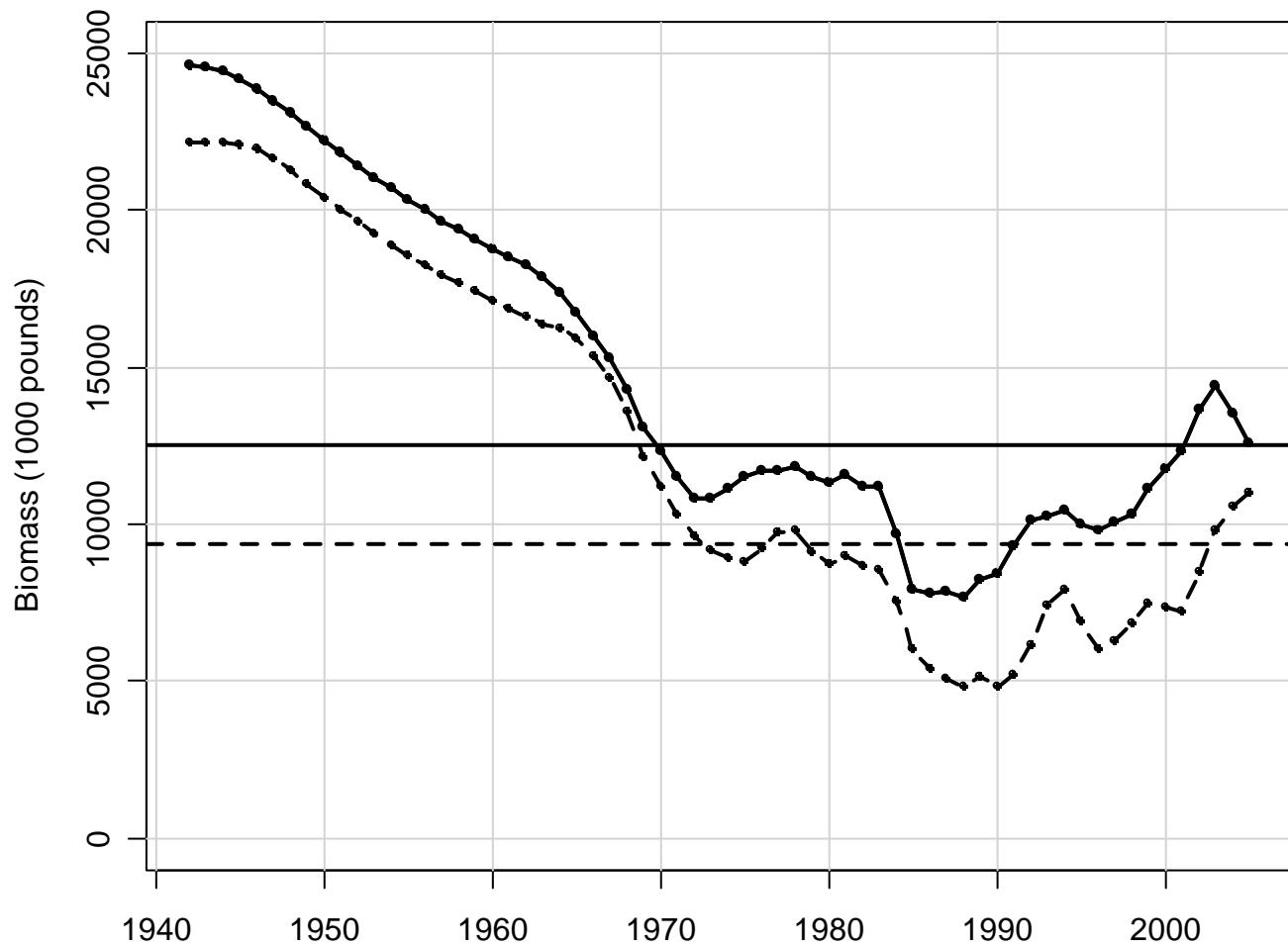


Figure 5. Phase plot of recent estimates of spawning stock biomass (klb, gutted weight) and fishing mortality rate. Solid lines correspond to MSY levels; vertical dashed line corresponds to MSST, defined as $(1-M)SSB_{MSY}$; and the vertical dotted line corresponds to the RW recommendation for an operational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

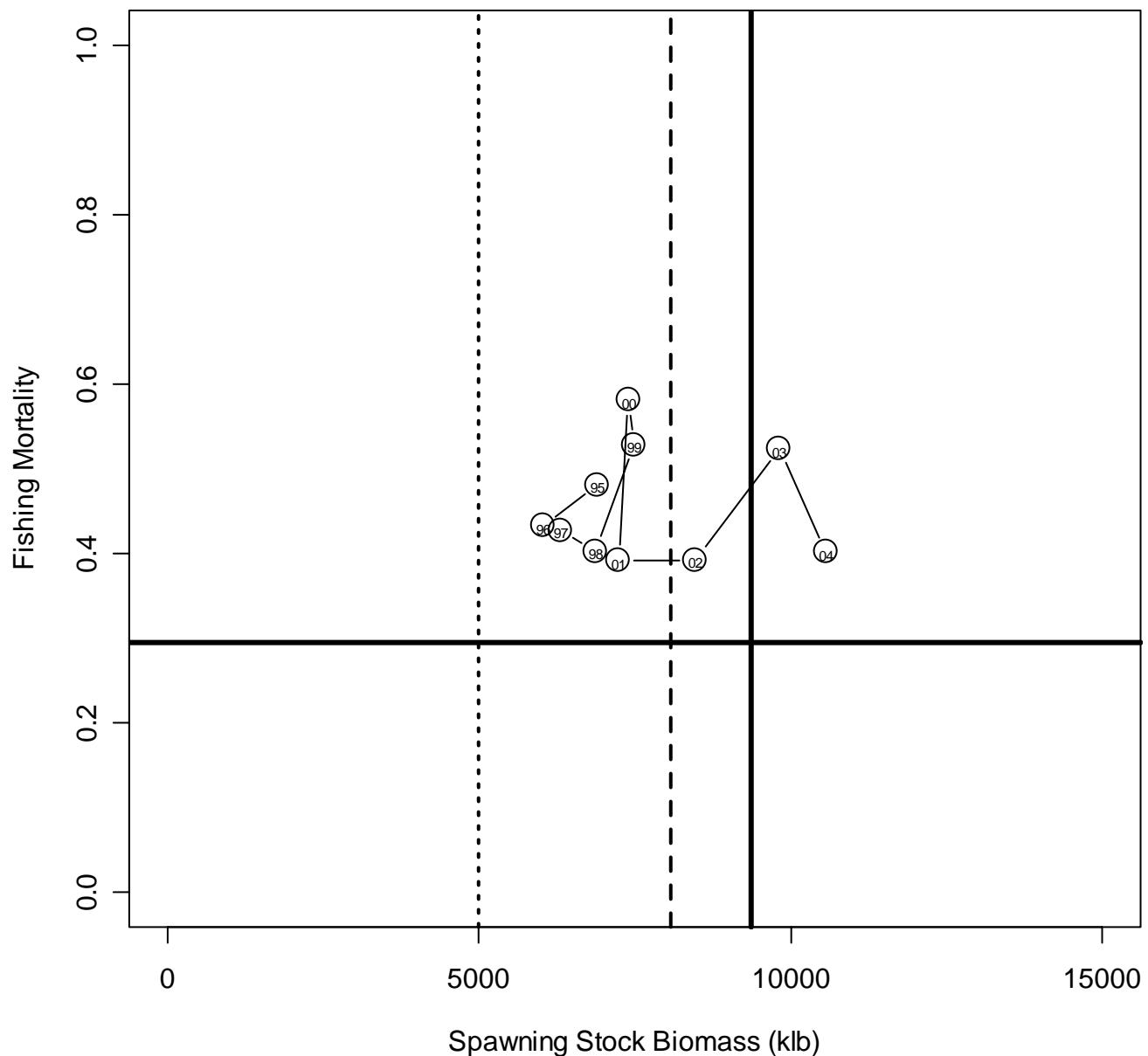


Figure 6. Projections under current fishing mortality rate for all years. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid line is SSB_{MSY} and dashed line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

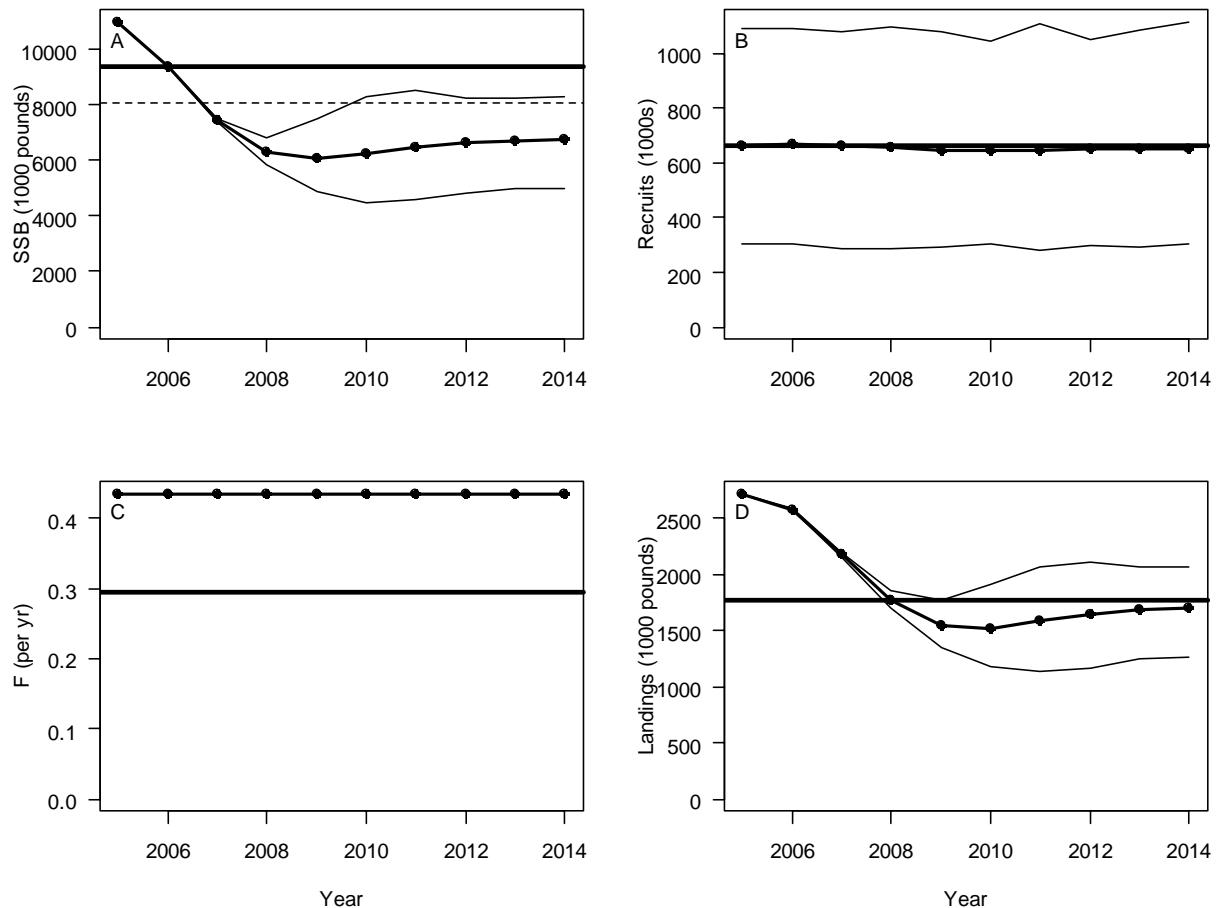


Figure 7. Projections under current fishing mortality rate in 2005-2007 and F_{MSY} in 2008-2014.

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.

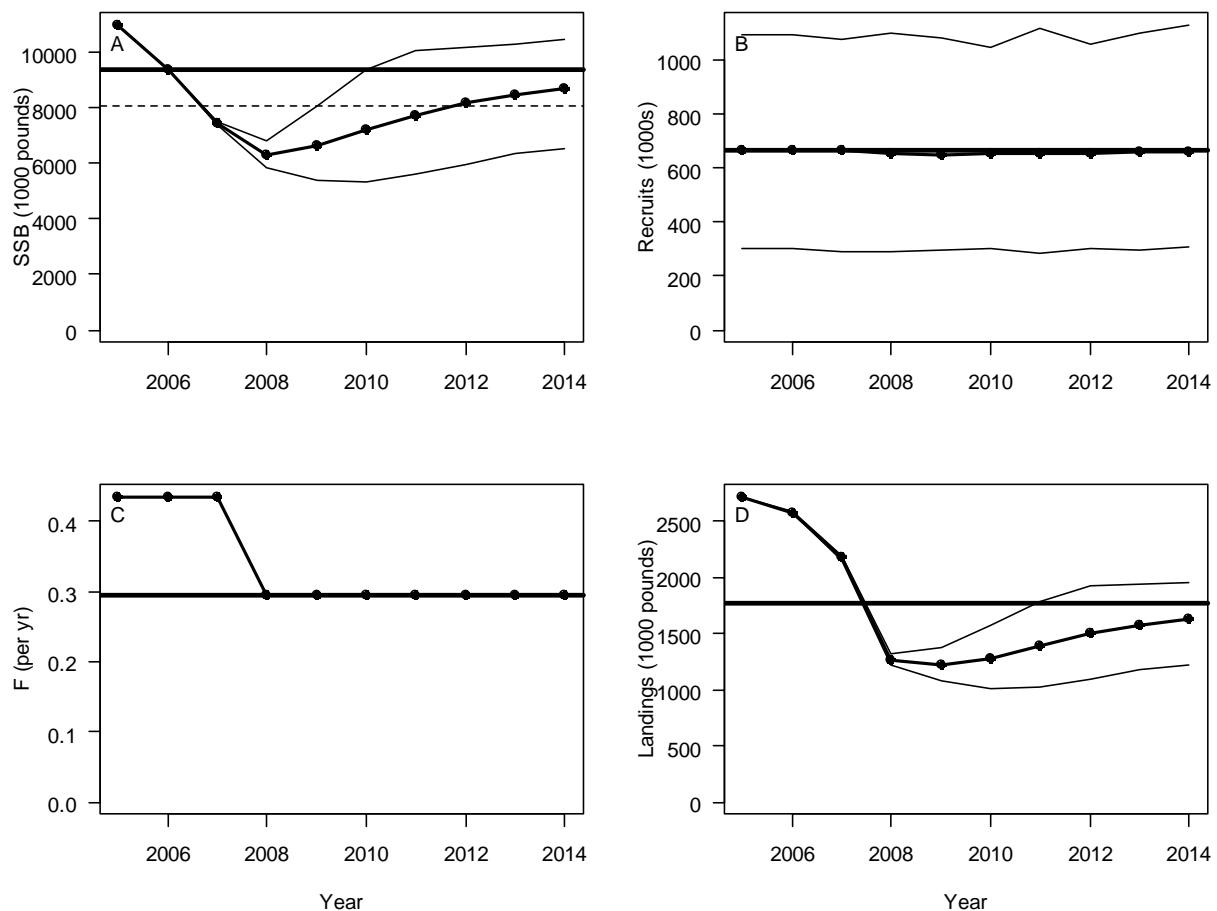


Figure 8. Projections under current fishing mortality rate in 2005-2007 and 85% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid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

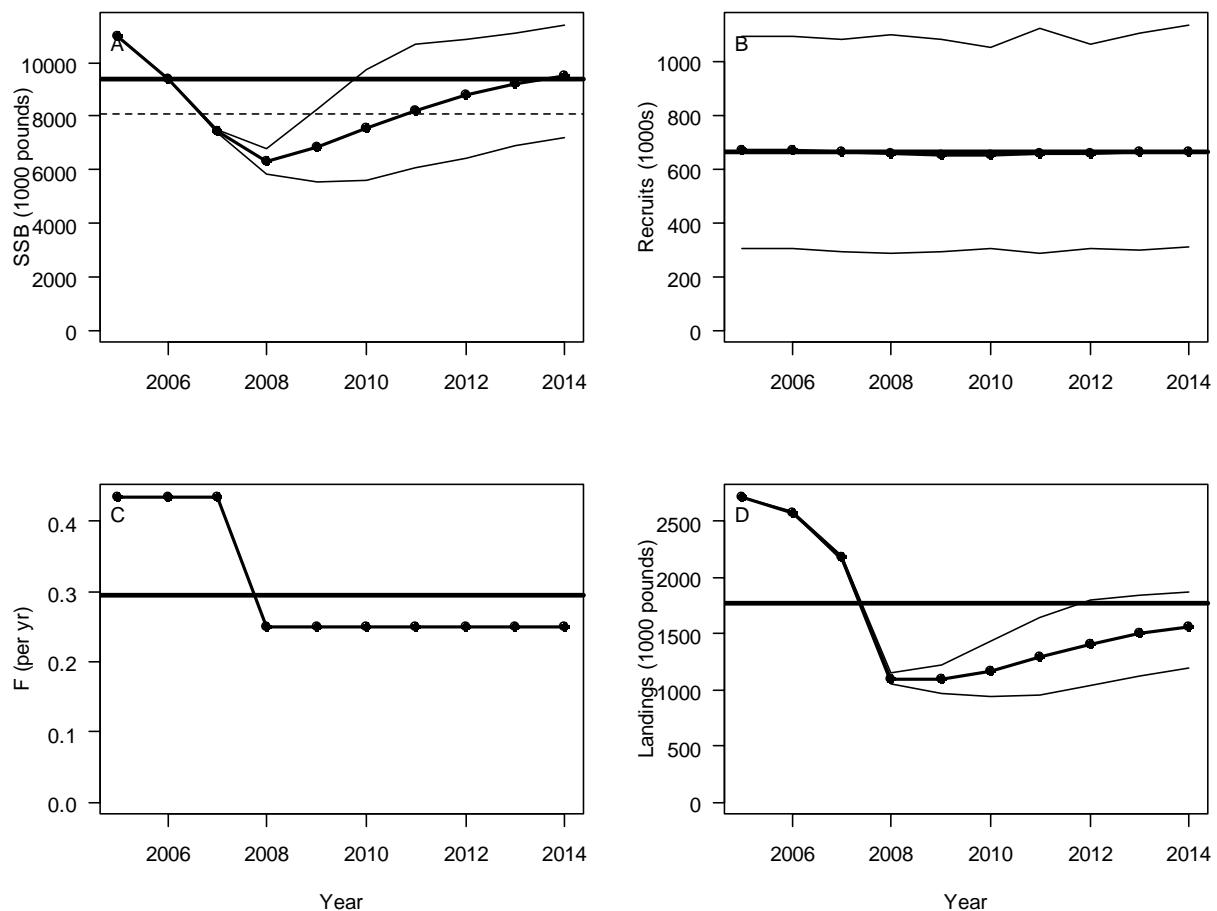


Figure 9. Projections under current fishing mortality rate in 2005-2007 and 75% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid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

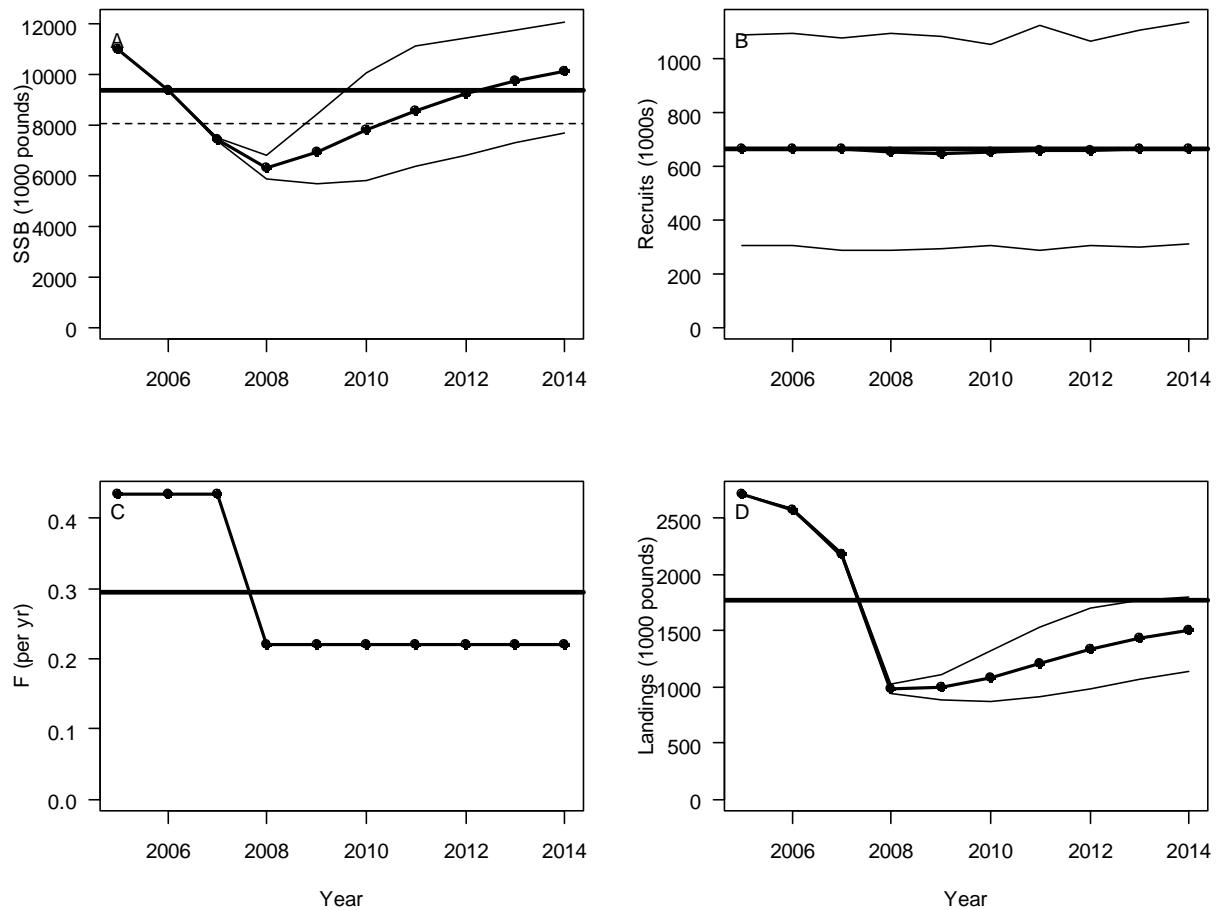


Figure 10. Projections under current fishing mortality rate in 2005-2007 and 65% of F_{MSY} in 2008-2014. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, horizontal solid 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.

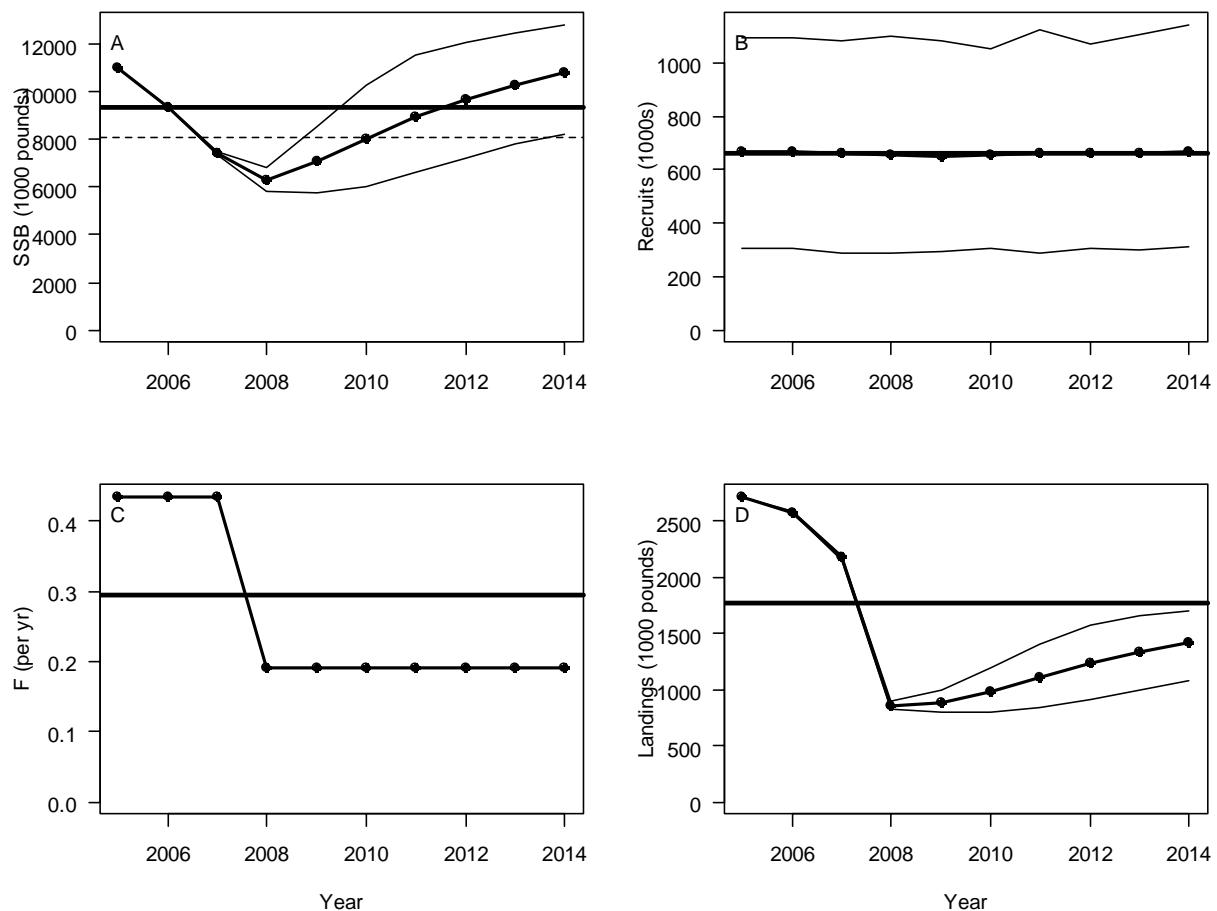


Figure 11. Estimated Beverton-Holt stock-recruitment relationship presented for South Atlantic gag grouper. Two digit year labels represent estimated recruitment values from 1972-2004; Dashed curve is estimated relationship; Solid curve is estimated relationship with lognormal bias correction, from which benchmarks are derived.

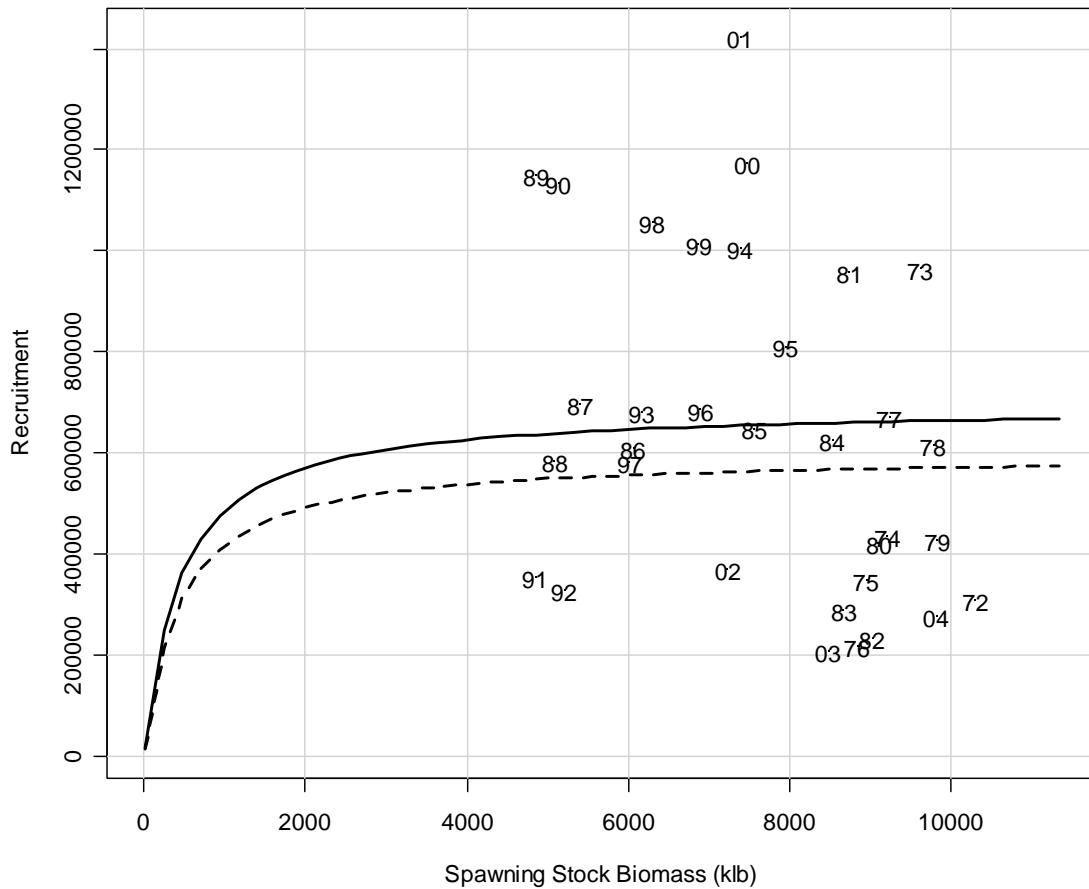


Figure 12. Estimated time series of spawning stock biomass (klb, gutted weight) from the base run model with constant catchability. The base run model with all data included is illustrated with a thick black line. Other runs with the labeled dataset left out of the model are shown in various colors and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

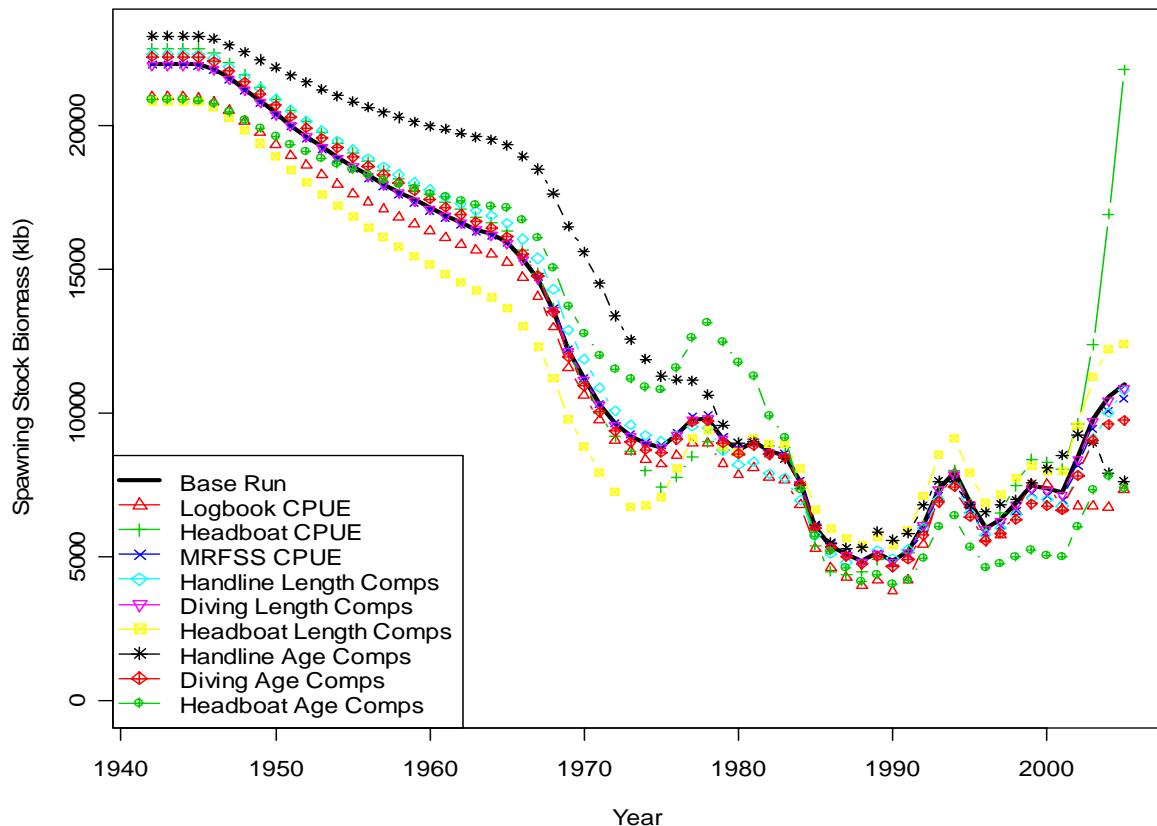


Figure 13. Estimated time series of fishing mortality rate from the base run model with constant catchability. The base run model with all data included is illustrated with a thick black line. Other runs with the labeled dataset left out of the model are shown in various colors and point markers.

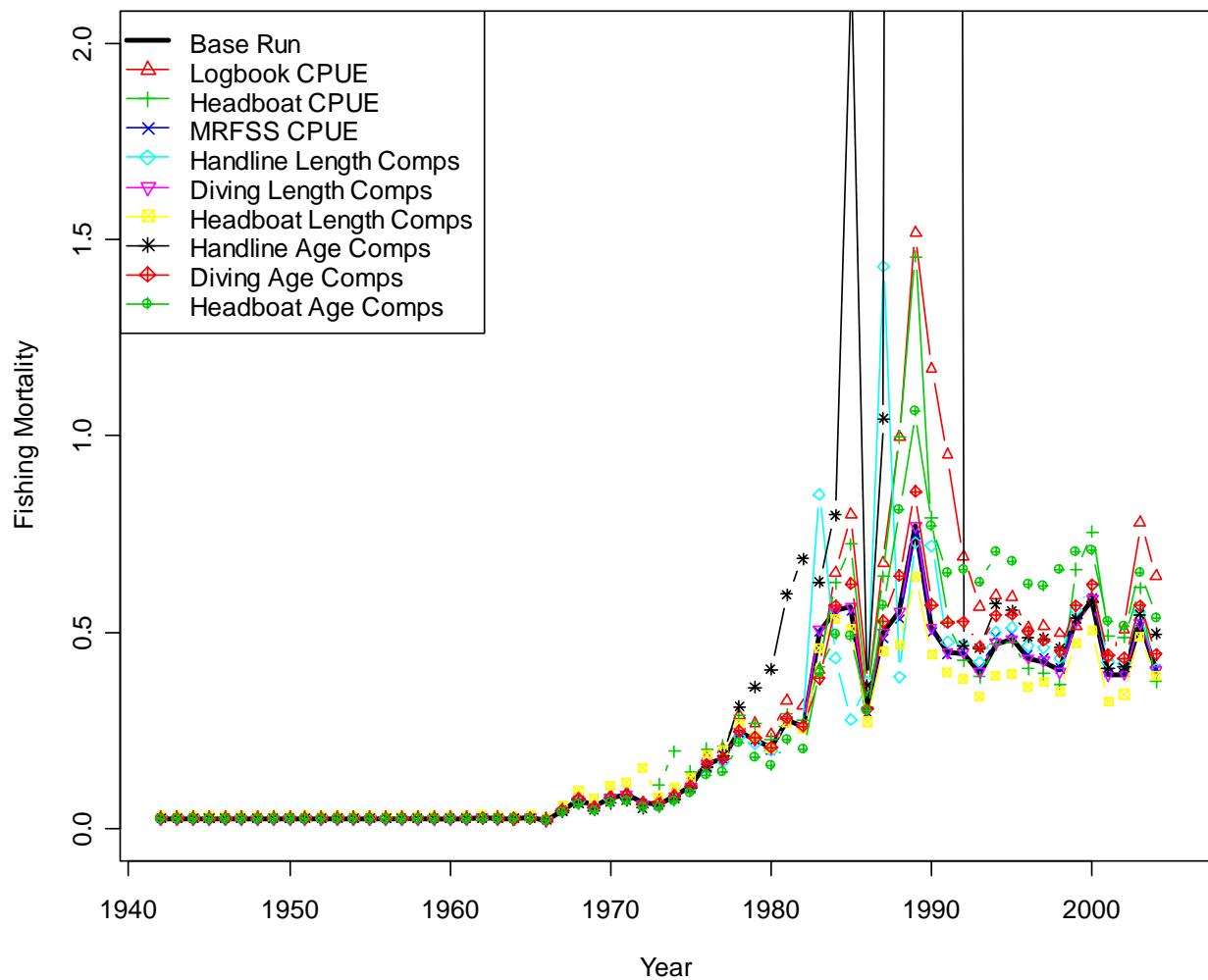


Figure 14. Estimated time series of recruitment from the base run model with constant catchability. The base run model with all data included is illustrated with a thick black line. Other runs with the labeled dataset left out of the model are shown in various colors and point markers

