SEDAR

SouthEast Data, Assessment, and Review

Stock Assessment
of the
Deepwater Snapper-Grouper Complex
in the South Atlantic

SEDAR 4 Stock Assessment Report 1

SEDAR4-SAR1
2004

SEDAR/SAFMC
1 Southpark Circle # 306
Charleston, SC 29414

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SEDAR 4

Stock Assessment Report 1

Atlantic Deepwater Snapper-Grouper Complex

SECTION I. Introduction

SEDAR4-SAR1

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1 Southpark Circle # 306
Charleston, SC 29414

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1. SEDAR Process

SEDAR (Southeast Data, Assessment and Review), is a process 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 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 and provide management advice. The Data and Assessment Workshops are organized and chaired by the SEDAR coordinator. Participants are drawn from Council SEDAR Committees, which include representatives of state and federal agencies, non-government organizations, Council Advisory Panels, and the fishing industry. The goal is to include a broad range of disciplines and perspectives when preparing stock assessments. The Review Workshop is led by a scientist selected by the Center for Independent Experts, an organization that provides independent, expert review of stock assessments and related work. Review panels typically include around 12 participants drawn from the Council SEDAR Panels, regional NOAA Fisheries Science Centers, and the CIE.

This assessment report of the fourth SEDAR addresses the Deepwater South Atlantic Snapper-Grouper complex. Caribbean Deepwater snapper-grouper species were also considered during SEDAR 4, however data were insufficient to produce any stock assessments for Caribbean species considered. Analysis of Caribbean species concluded with the data workshop. Results are summarized in a separate report (SEDAR4-AR2).

2. Management Overview

2.1 Management Unit Definition

The fishery management unit for the snapper-grouper fishery is the stocks within the FCZ in the area of authority of the South Atlantic Fishery Management Council and the waters within the seaward boundary of the states from North Carolina through the east coast of Florida. The FCZ extends from the North Carolina/Virginia border through the Atlantic side of the Florida Keys to 83° West longitude. The inner boundary of the FCZ is a line conterminous with the seaward boundary of each of the coastal states, and the outer boundary of such zone is a line drawn in such a manner that each point on it is 200 nautical miles from the baseline from which the territorial sea is measured. In the case of black sea bass the management regime applies only south of Cape Hatters, North Carolina.

2.2 Regulatory History

The SAFMC Snapper-Grouper Fishery Management Plan was approved in 1983. Twelve FMP Amendments approved through 2000 provide further management and monitoring requirements. Details of snapper-grouper management are provided in a working paper (SEDAR4-DW20), so only a summary is presented here with specific details that are relevant to tilefish and snowy grouper.

The original FMP limited the use of poison, traps, and trawls in harvesting snapper-grouper species, and established size and possession limits for some species. Amendment 2 established a moratorium on goliath grouper. Amendment 3 established a wreckfish management program. Amendment 4 was developed to reduce exploitation of overfished stocks and improve data collection. Management measures possibly affecting tilefish and snowy grouper include: allowing traps and pots only for harvesting black seabass; prohibiting the use of gill nets; prohibiting longlines within 50 fathoms; restricting bycatch of snapper-grouper in other fisheries to the snapper-grouper possession limit; an aggregate recreational possession limit of 10 snapper and 5 grouper; commercial permit requirement. Amendment 5 established an ITQ system for wreckfish. Amendment 6 was developed specifically to rebuild snowy grouper and tilefish, among other species. Regulations included quotas, trip limits, recreational bag limits and the Oculina closed area. Amendment 7 specified allowable gears and dealer, charter, and headboat fisheries. Amendment 8 established the limited entry program. Amendment 9 established a variety of species-specific measures. Amendment 10 addressed Essential Fish Habitat. Amendment 11 addressed non-EFH requirements of the SFA, establishing a proxy for Fmsy of F30%SPR (static), and a proxy for OY of F40% SPR (static). Amendment 12 established measures for rebuilding red porgy.

3. Assessment History

Five of the eight species of the deep water complex have been assessed by catch curve analysis and resulting spawning potential ratios (SPR). Blueline tilefish, *Caulolatilus microps*, misty grouper, *Epinephelus mystacinus*, and queen snapper, *Etelis oculatus*, have not been assessed in any way for the southeastern U.S. Misty grouper and queen snapper infrequently occur in the landings and do not have enough life history information to assess their stock status. Life history information for the blueline tilefish was also not available.

The warsaw grouper, *E. nigritus*, stock has been assessed by catch curve analysis of the 1988 and the 1990 fishing years (Staff 1991; Huntsman et al. 1992). Because Warsaw grouper is infrequently caught, a single length frequency was constructed from several years (e.g., 1983-1988) for the assessment of the 1988 fishing year and 1989-1990 length samples were used for the 1990 fishing year. A limited age-length key was applied to the length frequency to obtain catch-at-age data. No reproductive biology data were available; therefore, for SPR calculations the assumption for age-at-maturity was based on ½ L_∞. Static SPR values for warsaw grouper were 0.2% and 6% for 1988 and 1990 fishing years, respectively.

The speckled hind, *E. drummondhayi*, stock has been assessed for the 1988 and 1990 fishing years (Staff 1991; Huntsman et al. 1992) and then again for the 1996 fishing year (Potts et al. 1998) and for the 1999 fishing year (Potts and Brennan 2001). Length frequencies for each of the fishing years being assessed were constructed from that single years data. Length samples came primarily from the commercial fishery. Length samples from the 1996 and 1999 fishing years were greatly limited by the management regulation of allowing only one speckled hind per trip to be kept, but not sold. Again, dated age and growth data were available, and no reproductive biology data were available. The assumption of ½ L_∞ as the age of maturity was used for estimating the static SPR. SPR values were 25%, 12%, 8%, and 5% for 1988, 1990, 1996, and 1999 fishing years, respectively.

The yellowedge grouper, *E. flavolimbatus*, stock was assessed for the 1999 fishing year (Potts and Brennan 2001). Age and growth data came from unpublished data based on samples from the Gulf of Mexico. Reproductive biology data based on size were available from the U.S. South Atlantic and converted to age from the Gulf of Mexico age information. The resulting static SPR was 48%.

The tilefish, *Lopholatilus chamaeleonticeps*, stock has been assessed for the 1988, 1990 and 1999 fishing years (Staff 1991; Huntsman et al. 1992; Potts and Brennan 2001). The assessments of 1988 and 1990 fishing year data used limited age information from Georgia and reproductive biology data were not available. The assumption of ½ L_∞ as the age of maturity was used for estimating the static SPR. Static SPR values were 31% and 21% for 1988 and 1990, respectively. The assessment of the 1999 fishing year used age and reproductive biology data from North Carolina and South Carolina. The resulting static SPR was 27%.

The snowy grouper, *E. niveatus*, stock has been assessed for the 1988, 1990, 1996, and 1999 fishing years (Staff 1991; Huntsman et al. 1992; Potts et al. 1998; Potts and Brennan 2001). The 1988 and 1990 assessments used limited age and growth data and ½ L_∞ as the age of maturity to estimate static SPR. The 1996 and 1999 assessments used up-to-date age data and reproductive biology data. The resulting static SPRs were 15%, 15%, 5%, and 10% for the 1988, 1990, 1996, and 1999 fishing years, respectively.

4. Literature Cited

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Potts, J. C., M. L. Burton, and C. S. Manooch III. 1998. Trends in catch data and estimated static SPR values for fifteen species of reef fish landed along the southeastern United States. Report to the South Atlantic Fishery Management Council, One Southpark Circle, Suite 306, Charleston, SC 29407. 45p.

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Stock Assessment Report 1

Atlantic Deepwater Snapper-Grouper Complex

SECTION II. DATA WORKSHOP REPORT

Prepared by the SEDAR4 Data Workshop Panel, Atlantic Team
May, 2004

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1. Data Report Introduction

Fishery dependent and fishery independent data from eight snapper-grouper species, that make up the U.S. South Atlantic Deep Water Complex, were assembled and analyzed for their usefulness in subsequent stock assessments. These species included tilefish (golden), blueline tilefish, snowy grouper, speckled hind, warsaw grouper, yellowedge grouper, misty grouper, and queen snapper.

1.1 Workshop Time and Place

The Data Workshop convened in Charleston, SC, November 3-7, 2003. Data and analyses prepared for the workshop are documented in the SEDAR Working Papers Series (SEDAR4-DW-XX). Following the SEDAR approach, working groups were convened to address specific data issues: life history, commercial catch, recreational catch, commercial logbook, and independent indices. 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. Evaluate stock structure and develop a unit stock definition.
2. Evaluate the quality and reliability of life-history information (Age, growth, natural mortality, reproductive characteristics); develop models to describe growth, maturation, and fecundity by age, sex, or length as appropriate.
3. Evaluate the quality and reliability of fishery-independent measures of abundance; develop indices by appropriate strata (e.g., age, size, and fishery) for use in assessment modeling.
4. Evaluate the quality and reliability of fishery-dependent measures of abundance; develop indices for use in assessment modeling.
5. Evaluate the adequacy of the NMFS logbook data as a fishery-dependent measure of effort and catch rates; develop indices of abundance for use in assessment modeling.
6. Evaluate the quality and reliability of commercial and recreational fishery-dependent data for determining harvest and discard by species; develop estimates of total annual catch including both landings and discard removals by species.
7. Evaluate the quality and reliability of data available for characterizing the size and age distribution of the catch (landings and discard); characterize commercial, recreational, and headboat landings and discard by size and age.
8. Evaluate the quality and reliability of available data for estimating the impacts of management actions.
9. Recommend assessment methods and models that are appropriate given the quality and scope of the data sets reviewed and management requirements.

10. If data are not adequate for assessment modeling of each species listed in the complex, evaluate the feasibility of (1) using specific members of the stock complex as indicator species, or (2) using other metrics to evaluate stock status.
11. Provide recommendations for future research (research, sampling, monitoring, and assessment).
12. Prepare complete documentation of workshop actions and decisions, and generate introductory, descriptive, and research needs sections (1-4, 9) of the stock assessment report.

1.3 Data Workshop Participants

South Atlantic Panel Members
Alan Bianchi, NC Div. Mar. Fisheries
Jack Holland, NC DMF
Fritz Rohde, NC DMF
Pat Harris, SC DNR-MRD
Nan Jenkins, SC DNR-MRD
David Wyanski, SC DNR-MRD
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1.4 Data Workshop Working Papers

Document Number	Title	Author
SEDAR4-DW-01	Indices of Abundance from Commercial Logbook Data: South Atlantic stocks	Shertzer, K.; McCarthy, K.
SEDAR4-DW-02	MRFSS Landings and Length Data Summary for the South Atlantic	Vaughan, D. S.
SEDAR4-DW-03	General Canvass Landings Statistics for the South Atlantic Region	Poffenberger, J.
SEDAR4-DW-04	Summary information on commercial fishing operations in Puerto Rico from 1969-2001 and reporting rates needed to adjust commercial landings.	Cummings, N. Matos-Caraballo, D.
SEDAR4-DW-05	Summarized reported commercial landings in Puerto Rico from 1969-2001 with specific notes on the silk snapper landing category.	Cummings, N. Matos-Caraballo, D.
SEDAR4-DW-06	Not used	
SEDAR4-DW-07	Information on the general biology of silk and queen snapper in the Caribbean.	Cummings, N
SEDAR4-DW-08	Preliminary Estimation of Reported Landings, Expansion Factors and Expanded Landings for the Commercial Fisheries of the United States Virgin Islands.	Valle-Esquivel, M. Diaz, G. A.
SEDAR4-DW-09	Preliminary species composition estimates of TIP samples from commercial landings in the U.S. Virgin Islands.	Diaz, G. A. ; Valle-Esquivel, M.

Document Number	Title	Author
SEDAR4-DW-10	Standardized Catch Rates of Silk Snapper, Lutjanus vivanus, from the St. Croix U.S.Virgin Islands Handline Fishery during 1984 - 1997.	Cass-Calay, S.L.; Valle-Esquivel, M.
SEDAR4-DW-11	Standardized Catch Rates of Queen Snapper, Etelis oculatus, from the St. Croix U.S. Virgin Islands Handline Fishery during 1984 - 1997	Cass-Calay, S.L.; Valle-Esquivel, M.
SEDAR4-DW-12	Discard Estimates for the South Atlantic Region.	Poffenberger, J.
SEDAR4-DW-13	Size Frequency Data from the Trip Interview Program, South Atlantic Region	Poffenberger, J.
SEDAR4-DW-14	Size frequency distributions of silk snapper and queen snapper from dockside sampling of commercial landings in the U.S. VI	Diaz, G. A.; Valle-Esquivel, M.
SEDAR4-DW-15	Preliminary information on the recreational catch of silk, queen, and blackfin snapper, from 2000 through 2002 in Puerto Rico with additional notes on sand tilefish	Cummings, N.; Slater, B.; Turner, S.
SEDAR4-DW-16	Preliminary analysis of some deepwater species in the South Atlantic headboat survey data.	Williams, E.; Dixon, B.
SEDAR4-DW-17	Age, growth and reproductive biology of the blueline tilefish, *Caulolatilus microps*, along the southeastern coast of the United States, 1982-99.	Harris, P. J.; Wyanski, D.M.; Powers, P.T.
SEDAR4-DW-18	Age, growth and reproduction of tilefish, Lopholatilus chamaeleonticeps, along the southeast Atlantic coast of the United States, 1980-87 and 1996-98.	Palmer, S.M.; Harris, P.J.; Powers, P. T.
SEDAR4-DW-19	Deep-water species report. South Carolina and Georgia.	Low, B.
SEDAR4-DW-20	South Atlantic Snapper-Grouper Regulatory Overview	Carmichael, J.
SEDAR4-DW-21	Summary of MARMAP sampling	Anon.
SEDAR4-DW-22	Blueline tilefish life history; How to assess reef fish stocks: Excerpts from NMFS-SEFC-80	various
SEDAR4-DW-23	Preliminary size frequency information for silk, queen, and blackfin snapper from the Puerto Rico commercial fisheries from 1985 through 2002 with additional notes on sand tilefish	Cummings, N.J. Phares, P
SEDAR4-DW-24	Brief summary of SEAMAP data collected in the Caribbean Sea from 1975 to 2002	Ingram, W.
SEDAR4-DW-25	Yellowedge Grouper age-length key	Bullock & Godcharles
SEDAR4-DW-26	Estimating catches and fishing effort of the southeast united states headboat fleet, 1972-1982	Dixon, R. and G. Huntsman
SEDAR4-DW-27	Trends in Catch Data and Estimated Static SPR Values for Fifteen Species of Reef Fish Landed along the Southeastern United States, February 1998.	Potts, J., M. Burton, and C. Manooch
SEDAR4-DW-28	Trends in Catch Data and Estimated Static SPR Values for Fifteen Species of Reef Fish Landed along the Southeastern United States, February 2001.	Potts, J. and K. Brennan
SEDAR4-DW-29	Description of the Southeast Fisheries Science Center Logbook Program for Coastal Fisheries	Poffenberger, J.

2. Life History

2.1 Introduction

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Life history information for the eight deep water species of the Snapper Grouper complex of the Atlantic coast of the Southeastern U.S. is difficult to obtain or interpret. The species included are snowy grouper *Epinephelus niveatus*, warsaw grouper *Epinephelus nigritus,* yellowedge grouper *Epinephelus flavolimbatus*, misty grouper *Epinephelus mystacinus*, tilefish *Lopholatilus chamaeleonticeps,* blueline tilefish *Caulolatilus microps*, queen snapper *Etelis oculatus*, and speckled hind *Epinephelus drummondhayi*. Two of the species, misty grouper and queen snapper, rarely occur in recreational and commercial landings in the region. Warsaw grouper is not presently in high abundance in this region, and it along with speckled hind are regulated such that only one per fishing trip can be landed and cannot be sold. The other four species are primarily landed by the commercial fishery and thus have the most life history information available. Following are species by species accounts of available life history information and decisions made by the participants of the Data Workshop (hereafter called the "group").

During the Data Workshop, participants requested that the Life History Workgroup compute three estimates of M (Hoenig, Alverson and Carney, and Pauly) for blueline tilefish because none were available in the literature. John Carmichael did the computations and in the process did the same for other species if data were available (Table 1). The group had decided to leave discussion and decision on the range of M values with associated probabilities until the assessment workshop.

2.2 Life History Summary by Species

2.2.1 Misty Grouper

To date, no life history studies on misty grouper have been reported for the Atlantic coast of the Southeastern U.S. This species has been landed from North Carolina through the Florida Keys.

2.2.2 Queen Snapper

To date, no life history studies on queen snapper have been reported for the Atlantic coast of the Southeastern U.S. Very limited data are available from the Caribbean, but the group felt that it would be inappropriate to use life history information from the Caribbean for the Atlantic coast of the Southeastern U.S. stock. Studies on other species occurring in both regions have demonstrated geographical variation in life history characteristics (e.g., growth, age structure and reproductive biology). This species has been landed from North Carolina through the Florida Keys.

2.2.3 Warsaw Grouper

Age and growth information is available for warsaw grouper, but little is known about their reproductive biology. Warsaw grouper were aged from 124 sectioned otoliths collected from the Headboat Fishery from 1972-1985 (Manooch and Mason 1987). Ages ranged from 1 to 41, though Manooch and Mason (1987) believed the species could live 3 to 5 years longer based on the knowledge that larger individuals had been landed but not made available for their study. Ages were validated by marginal increment analysis. A von Bertalanffy growth equation was estimated (Table 2), and weight-length relation computed (Table 3). Raw age data from this study were not available, but an age-length key (years and areas combined) is available. Due to the shape of the caudal fin, no length-length conversion is needed. An estimate of natural mortality (M) of 0.10 was calculated from Hoenig's equation using a maximum age of 41 years as was used in the stock assessments from 1990 and 1991 (Plan Development Team 1990; National Marine Fisheries Service 1991) (Table 1).

Very limited maturity and sex ratio data, based on histology, are available from the Marine Resources Monitoring, Assessment, and Prediction (MARMAP) program of the South Carolina Department of Natural Resources (SCDNR) in Table 4.

2.2.4 *Speckled Hind*

For speckled hind, age and growth data from the 1970s and limited reproductive biology data from the MARMAP program are available. From 1,141 length and weight samples of this species taken by port agents for the Headboat fishery between 1972 and 1979, 463 otoliths samples were obtained (Matheson and Huntsman 1984). Ages ranged from 1 to 15 and were validated by marginal increment analysis. A von Bertalanffy growth equation was estimated (Table 2), and weight-length relation computed (Table 3). Raw age data from this study were not available, but an age-length key (years and areas combined) is available. Maximum age of 15 years intuitively seems low for a large, top level predator such as speckled hind, and Matheson and Huntsman (1984) felt that the species could live as long as 25 years, to which the group agreed. Preliminary data from the Gulf of Mexico show that 19 is the maximum age found thus far (pers. comm. Peter Hood, National Marine Fisheries Service, Southeast Regional Office, St. Petersburg, FL). Discussion from the group suggested that this species may occupy the mid-shelf depth range, thus the lower max age for this species may be real. The group decided to keep all life history information. MARMAP data were used to generate weight-length and length-length conversions (Table 3, Table 5).

Estimates of natural mortality have been computed from various equations. Matheson and Huntsman (1984) estimated natural mortality from the Pauly equation for M = 0.27. Reviewers of their manuscript suggested that M = 0.27 was too high, to which Matheson and Huntsman (1984) agreed and, thus, used M = 0.20 for their yield-per-recruit analysis. Potts et al. (1998) used eight different equations to estimate M, and used a range of 0.10 - 0.25, with the best estimate at 0.15 (Table 1). After group discussion about speckled hind being more of a mid-shelf species rather than a deep water species, the shorter longevity of the species compared to other groupers may not be out of reason, and the value of M might be a little higher than the other species being currently discussed.

Speckled hind is a protogynous hermaphrodite. MARMAP data (1978-01; n = 167, 68% fishery-independent and 32% fishery-dependent) based on histology provide female size at first maturity, 50% maturity, and 100% maturity, as well as size of smallest male and size at which 50% and 100% of specimens are males (Table 4).

2.2.5 *Yellowedge Grouper*

As for many deep water fish, yellowedge grouper are very long-lived and increments on otoliths are difficult to interpret. Age data for this species are available from the Atlantic and the Gulf of Mexico. The study from the Atlantic (Keener 1984) was based on 590 sectioned otoliths collected from the commercial fishery operating off South Carolina from 1977 to 1983. A few samples were obtained from the MARMAP program to provide fish smaller than those recruited to vertical hook-and-line gear. Only 27% of the otoliths were readable and ages ranged from 2 to 15, but validation of the increments as annuli was questionable. A von Bertalanffy growth equation was estimated and weight-length relation was computed (Table 2, Table 3). In contrast, age data from the Gulf of Mexico report yellowedge grouper living to 26 years (L. Bullock and M. Godcharles, unpublished data, Florida Marine Research Institute, 100 Eighth Avenue, SE, St. Petersburg, FL 33701) and to 85 years (Cass-Calay and Bahnick 2002). Bullock and Godcharles have provided an age-length key and a von Bertalanffy growth equation (Table 2). Bullock and Godcharles were not able to validate the increments on the otoliths as annuli and expressed concern over the interpretation of the increments. Weight-length relation and length-length conversion equations are available from Bullock et al. (1996) (Table 3, Table 5).

The most recent study on the age and growth of yellowedge grouper was done by Cass-Calay and Bahnick (2002). Ages were estimated from 95% of 535 sectioned otoliths from fish ranging in size from 107-1,170 mm TL collected from the commercial fishery and on NMFS research cruises in the Gulf of Mexico from 1979-2001. Ages ranged from 0-85 years and were validated by use of bomb radiocarbon dating. Raw age at length data and associated von Bertalanffy growth equation (Table 2) are available (pers. comm. M. Bahnick, NMFS Pascagoula Lab, Pascagoula, MS).

The group decided that age data and resulting estimates of the von Bertalanffy parameters from Cass-Calay and Bahnick (2002) were the best available. This decision was based on the validation technique used by Bahnick. MARMAP data were used to generate length-length conversions (Table 5).

Estimates of natural mortality were available from two sources. Potts and Brennan (2001) used a range of M based on data from Bullock et al. (1996): 0.10 - 0.25, with best estimate at 0.15 (Table 1). Cass-Calay and Bahnick (2002) used M = 0.0533 for their assessment based on the age data from Bahnick. A range of 0.05 to 0.20 for M was agreed upon by the group for use in the assessment of the Atlantic coast of the Southeastern U.S. stock. This range encompasses the values used most recently, and M=0.25 was considered to be to high given the expected maximum age. Further analysis of the range of M and the associated probabilities will be presented at the assessment workshop.

Reproductive biology information is available from the Atlantic and the Gulf of Mexico. This species is a protogynous hermaphrodite. Keener (1984) presents raw maturity data, based on histology, from which female size at first maturity, female size at 50% and 100% maturity, size of smallest males, and size at which 50% and 100% of specimens are males (Table 4) were determined. Limited maturity information is available from the Gulf of Mexico. Bullock et al. (1996) modeled female maturity, based on histology, as a function of total length:

$$\%\ \text{mature females} = (1/(1 + e^{(-0.26(TL + 568.6))}))*100.$$

The group decision was to use the reproductive biology data from Keener (1984). These data were from the Atlantic, based on size (not age), and more comprehensive than that available from Bullock et al. (1996).

2.2.6 *Blueline Tilefish*

Age and growth data for blueline tilefish caught along the Atlantic coast of the Southeastern U.S. coast are available from two sources. The first study (Ross and Huntsman (1982)) used 283 whole otoliths obtained from fish caught by the NMFS research vessel R/V *Onslow Bay* off North Carolina and South Carolina during 1972-1977. Ages ranged from 2 to 15 years and were validated by marginal increment analysis. A von Bertalanffy growth equation is available as well as a weight-length equation (Table 2, Table 3). In contrast, Harris et al. (In Review) estimated the maximum age of blueline tilefish from the southeastern U.S. as 42 years. Their samples were obtained primarily from the MARMAP fishery-independent sampling program during 1982-87 and from the commercial fishery operating off South Carolina during 1996-99. They estimated ages from 923 of 1,451 sectioned otoliths. Raw age and length data are available from this study; length data were used to generate weight-length and length-length conversions (Table 3, Table 5). Both aging studies did note that males attain a much larger size than females, and Harris et al. (In Review) have calculated sex specific von Bertalanffy growth parameters for the two time periods (Table 2). Also, available are von Bertalanffy growth parameters for sexes combined from each of the two time periods (Table 2).

Due to low confidence in age data derived from whole otoliths from a long-lived fish with dense opaque otoliths, the group decided not to use age data from Ross and Huntsman (1982). The group also asked that the growth parameters for periods and sexes combined as well as sex-specific and time-specific parameters from Harris et al. (In Review) be retained.

Given the lack of an estimate of M in the literature, the life history committee, at the request of the group, generated three estimates of M using the growth parameters available from the two sources.

Reproductive data are available from Ross and Merriner (1983) and Harris et al. (In Review). Ross and Merriner (1983) histologically examined gonads from 372 samples collected from the same sources as for the aging structures referenced in Ross and Huntsman (1982). Sex ratio and maturity (by age and length), and an estimate of total fecundity are available. Harris et al. (In Review) histologically examined 1,096 gonads that were collected from the same sources as referenced in the age data. Sex ratio (by age and length), a partial maturity schedule in text form, and an estimate of annual fecundity are available (Table 4).

The best available maturity schedule for females and males is found in Ross and Merriner (1983), though it is based on specimens collected in 1972-79. Though not available in Harris et al. (In Review), the partial maturity schedule (owing to a lack of specimens in smaller size and younger age intervals) in tabular format has been made available.

2.2.7 *Tilefish*

Tilefish are difficult to age and are long-lived. Harris and Grossman (1985) offer the earliest known age and growth data from the Atlantic coast of the Southeastern U.S.. They collected tilefish from a research vessel off the coast of Georgia from May 1982 to October 1983. They collected 1,351 males and 632 females, aged 1,145 males and 523 females using anal fin rays, and validated the ages by marginal increment analysis. Ages ranged from 5 to 33 years. They did look at dorsal spines and otoliths, but determined that anal fin rays showed the most consistent and readable pattern of rings on the structure. This species does exhibit differential growth between males and females with males attaining a much larger size than females. An age-standard length key and sex-specific and sexes combined von Bertalanffy growth parameters are available from Harris and Grossman (1985) (Table 2). They also provided weight-standard length and length-length conversions (Table 3, Table 5).

Age and growth data are available from Palmer et al. (In Review) for tilefish collected from research cruises and commercial fishery (primary source) operating off the coast of North Carolina and South Carolina during 1980-1987 and 1996-1998. Of 3,345 samples collected, 2,485 were aged with sectioned otoliths. Ages ranged from 2 to 40 years and they were validated by marginal increment analysis. Since this study was completed, a new sample was found to be 54 years old. Differential growth between males and females was evident (P. Harris, pers. comm., SCDNR, Charleston, SC). They also noted a shift in size-at-age between the two time periods. Therefore, they estimated the sex-specific von Bertalanffy growth parameters for the two time periods (Table 2). Raw age and length data are available from this study and were used to generate overall von Bertalanffy parameters for each period (Table 2) and weight-length and length-length conversions.

Currently, tilefish collected from the commercial fishery operating off East coast Florida from 1992 - 2003 are being aged at NMFS Beaufort Lab (pers. comm. J. Potts, NMFS Beaufort, NC). When finished, the data will be available for the SEDAR4 Assessment Workshop.

Since aging was completed by Palmer et al. (In Review), preliminary results from bomb radiocarbon dating of tilefish otoliths suggests that tilefish are being under-aged by five to ten years (P. Harris, unpublished data, S. Carolina Dept. of Natural Resources, P.O. Box 12559, Charleston, SC 29422). Before the SEDAR4 Assessment Workshop, Palmer and Harris (SCDNR) will attempt to correct age data to be consistent with the radiocarbon dating.

The group decided to retain the Harris and Grossman (1985) data for the growth parameters, but to use the data with caution because anal fin rays were used as the aging structure. Because of the differential growth between males and females and the shift in size-at-age between time periods from Palmer et al. (In Review), the group wants period- and sex-specific estimates as well as a sexes-combined and periods-combined estimate of von Bertalanffy parameters. The group agreed that the age data from the NMFS Beaufort Lab should be added.

Estimates of natural mortality (Table 1) are available from Hightower and Grossman (1988) and from Potts et al. (1998). Hightower and Grossman (1998) report M = 0.13 from the Hoenig equation, using the maximum age of 33 from Harris and Grossman (1985). They do suggest that M=0.13 is an upper bound for an estimate. Potts et al. (1998) estimated a range of M, 0.10 - 0.25, based on preliminary age data from an earlier report that preceded the manuscript by Palmer et al. (In Review), with M = 0.10 as the best estimate.

Reproductive biology data are available from Erickson and Grossman (1986). Samples were collected from research cruises off the coast of Georgia during 1982-1983. A total of 571 testes and 399 ovaries were prepared for histological analysis. They provide a maturity schedule, a total fecundity equation, and sex ratio by size and age interval (Table 4). Reproductive biology data are available from Palmer et al. (In Review). The samples were collected from from 1980-1987 and 1996-1998 from research cruises and the commercial fishery operating off North Carolina and South Carolina. A total of 2,469 fish were sexed from the two time periods, and 2,207 were examined histologically. They present evidence that males are being removed from the population, thus changing the sex ratio over time. Sex ratios from the two time periods are available as well as qualitative observations on maturity and an overall annual fecundity equation.

The group decided to retain the results from both studies, including period-specific data from Palmer et al. (In Review). Though not available in Palmer et al. (In Review), the partial maturity schedule (owing to a lack of specimens in smaller size and younger age intervals) in tabular format has been made available for each period. Although D. Wyanski raised a concern that the fecundity equations may not estimate annual fecundity, the group wanted them retained in the data summary because they are the only information available.

2.2.8 Snowy Grouper

Age and growth data are available from three different sources along the Atlantic coast of the Southeastern U.S.. Matheson and Huntsman (1984) aged snowy grouper from 536 sectioned otoliths collected from the Headboat fishery operating in North Carolina and South Carolina. They reported max age as 17, but thought that the species could live to at least 25. An age-length key, von Bertalanffy equation, and weight-length conversion equations are available (Table 2, Table 3). Moore and Labisky (1984) aged 178 sectioned snowy grouper otoliths collected from the commercial fishery in the lower Florida Keys from 1978 - 1981. They report the max age as 15 years. A von Bertalanffy growth curve along with weight-length equation are available . Wyanski et al. (2000) aged 2,263 snowy grouper by sectioned otoliths collected from research and commercial vessels operating off North Carolina and South Carolina during 1979-1985 and 1993-1995. Raw age and length data are available from this study as well as gear and time period specific von Bertalanffy growth parameters . Age-length keys for snowy grouper caught with bandit reels and longlines in 1993-94 are available (D. Wyanski, pers. comm., SCDNR, Charleston, SC) Max age reported from each gear type and time period ranged from 21 - 29 years. Recent bomb radiocarbon dating techniques on the otoliths of snowy grouper suggests that ages were under-estimated by 5 to 10 years. Weight-length and length-length conversions have been generated from MARMAP data (Table 3, Table 5).

A source of additional age data for snowy grouper will be from NMFS Beaufort Lab (pers. comm., J. Potts, NMFS, Beaufort, NC). Otoliths were collected from the catch of the commercial fishery operating along the east coast of Florida from 1992 - 2003.

The group decided to retain all age data from the three published studies and to include data from the NMFS study to be completed before the assessment workshop.

Estimates of natural mortality were derived in Matheson and Huntsman (1984) and Potts et al. (1998) (Table 1). Estimates of M ranged from 0.10 - 0.25, with 0.15 as the best estimate.

Reproductive biology data for snowy grouper from the Atlantic coast of the Southeastern U.S. are available from Moore and Labisky (1984) and Wyanski et al. (2000). Both studies agree that this species is a protogynous hermaphrodite. Moore and Labisky (1984) used 144 specimens, examined histologically, to produce a limited maturity schedule based on age (Table 4). Wyanski et al. (2000) histologically examined 870 gonad samples from commercial fisheries and research cruises from 1979-1995 and 90 samples from the Headboat fishery collected during 1973-1981. Sex ratios and maturity schedules by size and age intervals are available by period (1980-1985 and 1991-1995) and gear type. Their data does suggest that the number of males in the population has decreased over time. The group decided to retain all reproductive biology data available.

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2.4 Tables

Table 1. Estimates of natural mortality (M) for species of the deepwater complex of the snapper grouper fishery along the southeastern US.

Table 1. Estimates of natural mortality (M) for species of the deepwater complex of the Snapper Grouper Fishery along the Atlantic coast of the southeastern U.S. Estiamtes of M in ( ) are considered best estimates used in cited report.

		Observed		Rel. prob. Of M			M		
Species	Source	Max Age	Point est	Lower lim	Upper lim	M	Hoenig	Alv&Car	Pauly
Misty Grouper	none					unknown	NA		
							NA		
Queen Snapper	None					unknown	NA		
							NA		
Warsaw Grouper	Manooch and Mason 1987	41					0.11	0.12	0.05
	PDT 1990					0.1	NA		
							NA		
Speckled Hind	Matheson and Huntsman 1984	15				0.2	0.30	0.36	0.12
	Peter Hood (pers. Comm)	19					0.23	0.25	
	Potts et al. 1998					0.10 - 0.25 (0.15)	NA		
	PDT 1990					0.2	NA		
							NA		
Yellowedge Grouper	Keener 1984	15					0.30	0.32	0.14
							NA		
	Cass-Calay and Bahnick 2002	85				0.0533	0.05	0.03	0.07
	Bullock and Godcharles Unpub. Data	26					0.17	0.23	
	Potts and Brennan 2001					0.10 - 0.25 (0.15)	NA		
							NA		
Blueline Tilefish	Ross and Huntsman 1982	15					0.30	0.35	0.13
	Harris et al., In Review	42					0.11		
	1982-87, sexes combined	42					0.11	0.04	0.16
	1996-99, sexes combined	40					0.11	0.17	0.04
	1982-99, sexes combined	42					0.11	0.09	0.10
							NA		
Tilefish	Harris and Grossman 1985	33				0.10 -0.25	0.14	0.13	0.09
	Hightower and Grossman 1988					0.13	NA		
	Potts and Brennan 2001					0.10 -0.25 (0.10)	NA		
	Palmer et al., In Review	54					0.11		
	Potts and Carr, Unpubl. Data	38					0.12		
Snowy grouper	Wyanski et al. 2000						NA		
	Bandit reel, 1979-85	21					0.21	0.24	0.11
	Bandit reel, 1993-94	22					0.20	0.23	0.10
	Longline & kali pole, 1982-85	29					0.15	0.13	0.12
	Longline, 1993-94	21					0.21	0.23	0.11
	Moore and Labisky 1984						NA		0.08
	Matheson and Huntsman 1984	17				0.15	0.26	0.36	0.08
	Potts et al. 1998					0.10 - 0.25 (0.15)	NA		

Table 2. Von Bertlanffy growth parameters for Atlantic deepwater snapper-grouper.

		Observed				von Bertalanffy growth		
Species	Source	Max Age	Age range	Length range	n	Linf (SE)	K (SE)	t_o (SE)
Misty Grouper	none					Unknown	Unknown	Unknown
Queen Snapper	None					Unknown	Unknown	Unknown
Warsaw Grouper	Manooch and Mason 1987	41	1-41	300-2350 mm TL	124	2394	0.0544	-3.616
Speckled Hind	Matheson and Huntsman 1984	15	1-15	175-870 mm TL	449	967	0.13	-1.01
	Peter Hood (pers. Comm)	19						
Yellowedge Grouper	Keener 1984	15	2-15		159	891	0.163	-1.034
	Cass-Calay and Bahnick 2002	85	2-85	107-1150 mm TL	449	985.4	0.0577	6.869
	Bullock and Godcharles Unpub. Data	26	2-26	360-1083 mm TL	781	not estimated		
Blueline Tilefish	Ross and Huntsman 1982	15	2-15	270-780 mm TL	201	814	0.137	-1.03
	Harris et al., In Review							
	1982-99, sexes combined	43	2-43	333-784 mm TL	923	671	0.08	-8.69
	1982-99, female	43	3-43	333-711 mm TL	391	634	0.11	-4.54
	1982-99, male	43	3-43	385-784 mm TL	305	758	0.10	-5.4
	1982-87, sexes combined	43	3-43	336-784 mm TL	406	645	0.17	-2.36
	1982-87, female	43	3-43	336-702 mm TL	219	633	0.12	-5.21
	1982-87, male	43	3-43	396-784 mm TL	104	752	0.12	-4.83
	1996-99, sexes combined	40	3-40	333-734 mm TL	400	918	0.02	-37.6
	1996-99, female	40	4-40	333-711 mm TL	172	633	0.11	-4.94
	1996-99, male	40	3-40	385-734 mm TL	201	1088	0.01	-35.6
Tilefish	Harris and Grossman 1985	33	5-33	376-925 mm SL	1668	907	0.084	-0.92
	Palmer et al., In Review							
	1980-98, sexes combined	54	2-54	327-1155 mm TL	2485	925.7 (17.9)	0.136 (0.009)	-1.274 (0.297)
	1980-87, sexes combined	54	2-54	361-1110 mm TL	1204			
	1980-87, female	40	2-40	380-1092 mm TL		867.1	0.15	-2.09
	1980-87, male	27	2-27	361-1110 mm TL		1222.2	0.09	-1.84
	1996-98, sexes combined	32	2-32	327-1155 mm TL	1281			
	1996-98, female	32	3-32	327-1025 mm TL		777.4	0.10	-5.72
	1996-98, male	32	2-32	383-1155 mm TL		966.9	0.14	-0.44
	Potts and Carr, Unpubl. Data	38						
Snowy grouper	Wyanski et al. 2000							
	Bandit reel, 1979-85	21	1-21	252-1020 mm TL	326	970 (24)	0.109 (0.001)	-2.123 (0.336)
	Bandit reel, 1993-94	22	1-22	226-1110 mm TL	311	1201 (34)	0.103 (0.008)	-1.149 (0.231)
	Longline & kali pole, 1982-85	29	3-29	265-1020 mm TL	163	948 (28)	0.122 (0.017)	-0.668 (0.681)
	Longline, 1993-94	21	1-21	273-1137 mm TL	1218	1117 (13)	0.119 (0.004)	-1.409 (0.121)
	Moore and Labisky 1984	27	0-27			1320	0.087	-1.013
	Matheson and Huntsman 1984	17	1-17	150-900 mm TL	478	1255	0.074	-1.92

Table 3. Weight-length realtionsips for Atlantic deepwater snapper-grouper species

		Weight - Length (weight = aL^b unless noted)					
Species	Source	a (SE)	b (SE)	Units	n	R^2	Range of length
Misty Grouper	none	Unknown	Unknown				
Queen Snapper	None	Unknown	Unknown				
Warsaw Grouper	Manooch and Mason 1987	$2.097x10^{-5}$	2.9797	WW, g TL, mm	108	0.96	Unknown
Speckled Hind	Matheson and Huntsman 1984	$1.1x10^{-8}$	3.073	WW, kg TL, mm	462	0.99	175-870, all
	MARMAP data	$2.258x10^{-5}$ ($0.429x10^{-5}$)	2.980 (0.029)	WW, g TL, mm	266	0.98	164-930, all
		$4.024x10^{-5}$ ($1.672x10^{-5}$)	2.885 (0.063)	WW, g FL, mm	71	0.97	164-704, all
		0.00030 ($7.733x10^{-5}$)	2.643 (0.040)	WW, g SL, mm	251	0.94	139-850, all
Yellowedge Grouper	Keener 1984	$2.761x10^{-8}$	2.887	WW, kg TL, mm	150	0.97	330-1040, all
		log(WW) = -4.154 + 2.844 log(SL)		WW, kg SL, mm	108	0.96	
	Cass-Calay and Bahnick 2002	$1.313x10^{-8}$	2.98	WW, kg TL,mm	572	0.96	107-1170, all
		$1.572x10^{-8}$	2.975	GW, kg TL, mm	324	0.99	282-1086, all
	Bullock et al. 1996	$2.965x10^{-8}$	2.861	WW, kg TL, mm	465	0.99	370-1065, all
		$2.679x10^{-8}$	2.874	GW, kg TL, mm	713	0.98	368-1083, all
	MARMAP data	$3.110x10^{-5}$ ($1.427x10^{-5}$)	2.867 (0.067)	WW, g TL, mm	124	0.97	283-1060, all
		$2.969x10^{-5}$ ($1.271 x 10^{-5}$)	2.894 (0.063)	WW, g FL, mm	77	0.99	277-990, all
		0.00042 (0.00019)	2.568 (0.068)	WW, g SL, mm	113	0.96	225-880, all
Blueline Tilefish	Ross and Huntsman 1982	$log_e(WW) = -12.286 + 3.142 log_e(TL)$		WW, g TL, mm	601	0.96	N/A, all
		$log_e(WW) = -11.495 + 3.024 log_e(TL)$		WW, g TL, mm	120	0.96	N/A, female
		$log_e(WW) = -10.498 + 3.297 log_e(TL)$		WW, g TL, mm	113	0.97	N/A, male
	MARMAP data	$1.657 x 10^{-5}$ ($0.2478 x 10^{-5}$)	2.938 (0.023)	WW, g TL, mm	1306	0.93	333-784, all
		$2.434 x 10^{-5}$ ($0.656 x 10^{-5}$)	2.878 (0.042)	"	448	0.93	385-784, male
		$1.083 x 10^{-5}$ ($0.303 x 10^{-5}$)	3.005 (0.044)	"	662	0.90	333-711, female
		$1.239 x 10^{-5}$ ($0.214 x 10^{-5}$)	3.014 (0.027)	WW, g FL, mm	732	0.95	312-725, all
		$0.552 x 10^{-5}$ ($0.138 x 10^{-5}$)	3.140 (0.039)	"	345	0.95	364-725, male
		$0.475 x 10^{-5}$ ($0.133 x 10^{-5}$)	3.165 (0.044)	"	304	0.95	312-661, female
		$5.472 x 10^{-5}$ ($0.838 x 10^{-5}$)	2.841 (0.025)	WW, g SL, mm	1156	0.92	262-640, all
		$6.112 x 10^{-5}$ ($1.499 x 10^{-5}$)	2.824 (0.039)	"	449	0.93	308-640, male
		$0.287 x 10^{-5}$ ($0.091 x 10^{-5}$)	3.317 (0.052)	"	582	0.87	262-586, female

Table 3. Continued

		Weight - Length (weight = aL^b unless noted)					
Species	Source	a (SE)	b (SE)	Units	n	R^2	Range of length
Tilefish	Harris and Grossman 1985	$\log_e(WW) = -18.417 + 3.104 \log_e(SL)$		WW, kg SL, mm	1668	0.98	376-925, all
		$\log_e(WW) = -18.653 + 3.141 \log_e(SL)$		WW, kg SL, mm	1145	0.98	376-925, male
		$\log_e(WW) = -17.594 + 2.974 \log_e(SL)$		WW, kg SL, mm	523	0.96	385-778, female
	MARMAP data	0.334×10^{-5} (0.027×10^{-5})	3.214 (0.012)	WW, g FL, mm	1656	0.98	309-1027, all
		0.272×10^{-5} (0.033×10^{-5})	3.245 (0.018)	"	633	0.98	367-1027, male
		0.162×10^{-5} (0.020×10^{-5})	3.327 (0.019)	"	795	0.98	309-872, female
		0.407×10^{-5} (0.028×10^{-5})	3.154 (0.010)	WW, g TL, mm	2779	0.97	311-1110, all
		0.346×10^{-5} (0.039×10^{-5})	3.178 (0.016)	"	1087	0.98	311-1110, male
		0.470×10^{-5} (0.061×10^{-5})	3.133 (0.020)	"	1202	0.96	329-1069, female
		0.887×10^{-5} (0.066×10^{-5})	3.130 (0.011)	WW, g SL,mm	2764	0.97	254-925, all
		0.739×10^{-5} (0.087×10^{-5})	3.157 (0.018)	"	1079	0.97	254-925, male
		0.609×10^{-5} (0.090×10^{-5})	3.188 (0.023)	"	1187	0.95	271-760, female
Snowy grouper	MARMAP data	1.779×10^{-5} (0.314×10^{-5})	2.971 (0.026)	WW, g TL, mm	684	0.96	261-1090, all
		3.665×10^{-5} (0.654×10^{-5})	2.950 (0.027)	WW, g SL, mm	645	0.96	214-888, all
	Moore and Labisky 1984	2.45×10^{-8}	2.93	WW, kg TL, mm	269	r = 0.99	kg = 0.03-25.4
	Matheson and Huntsman 1984	7.0×10^{-8}	2.755	WW, kg TL, mm	428	0.98	150-900, all

Table 4. Reproductive biology data for Atlantic deepwater snapper-grouper species.

Species	Source	Maturity schedule	Fecundity	Sex ratios
Misty Grouper	none	immature female 550 mm TL	Unknown	Unknown
Queen Snapper	None	Unknown	Unknown	Unknown
Warsaw Grouper	MARMAP data	2 mature females: 725 and 750 mm TL		9 specimens; all female:624-969 mm TL
Speckled Hind	MARMAP data	female first maturity = 400-449 mm TL		smallest male: 350-399 mm TL
		L_{50} female = 497 mm TL (95% CI=473-530)		50% males at 710 mm TL (95% CI=667-768)
		100% female maturity = 500-549 mm TL		100% males at 800-849 mm TL
Yellowedge Grouper	Keener 1984	female first maturity 410-429 mm TL		smallest male: 590-609 mm TL
		100% female maturity: 610-629 mm TL		50% males at 810-829 mm TL
		Data from Table 10 presented in Deepgroupersizemat.xls		100% males at 1010-1029 mmTL
				Data from Table 8 presented in Deepgroupersexratio.xls
	Bullock et al. 1996	L_{50} female = 569 mm TL (SE = 3.55)		L_{50} males = 817 mm TL (SE = 2.923)
Blueline Tilefish	Ross and Merriner 1983	female first maturity = 376-400 mm TL	Not estimate of annual fecundity	See Tables 4 and 5 in source
		L_{50} female = 426-450 mm TL		
		100% female maturity - age 6, >500 mm TL		
		Mature females: 33% at age 3, 50% at age 4, 73% at age 5, and 100% at older ages.		
	males - macroscopic	male first maturity, 476-500 mm TL		
		L_{50} male = 501-525 mm TL		
		100% male maturity - >600 mm TL		
		Mature males: 0% at age 4, 12.5% at age 5, and 62.5% at age 6. All mature at older ages? - not stated		
	Harris et al., In review	female first maturity, <= 338 mm TL (age 4)	See Table 8 in source; Annual Fecundity = batch fec. X 136; # of spawning events = 136	See Tables 4 and 5 in source
		L_{50} female = 326-350 mm TL		
		100% female maturity = 401-425 mm TL		
		male first maturity, <= 393 mm TL (age 3)		

Table 4. Continued

Species	Source	Maturity schedule	Fecundity	Sex ratios
Tilefish	Erickson and Grossman 1986	female first maturity, <=475-499 mm TL, age <6	ln(F) = 12.590 + 1.497*ln(W, kg) n = 31; r^2 = 0.95; F = total fecundity	See Table 2 in source
		L_{50} female = 500 mm TL (age 6)	ln(F) = -16.508 +4.749*ln(TL, mm) n = 31; r^2 = 0.93	
		100% female maturity = 575-599 mm TL, age 7	ln(F) = 10.407 + 1.802*ln(Age, year) n = 25; r^2 = 0.77	
		male first maturity, <=450 mm TL, age <5	Not estimates of annual fecundity	
		L_{50} male = 450 mm TL (age 5)		
		100% male maturity, >= 725 mm TL, age 9		
	Palmer et al., In review	Female first maturity = 400-449 mm TL, age $\leq$2	AF = -9.539 X 10^5 + 3209.402(TL)	See Tables 5 and 6 in source
		L50 female = 429 mm TL (95% CI = 415-439)	AF = annual fecundity; likely an underestimate owing to low spawning frequency	
		100% female maturity = 500-549 mm TL, age 8		
Snowy grouper	Wyanski et al. 2000			
	Rod & reel, headboat, 1973-81			smallest male = 750-799 mm TL; 50% males at 850-899 mm; 100% males at 900-949 mm
	Bandit reel, commercial and MARMAP, 1980-84			smallest male = 750-799 mm TL; 50% males at 850-899 mm; 100% males at 1000-1049 mm; youngest male = age 8; 50% males at age 14; 100% males at age 19
	Longline & Kali pole, MARMAP, 1982-85			smallest male = 800-849 mm TL; 50% males at 850-899 mm; 100% males not reached at 1000-1049 mm; youngest male = age 10; 50% males at age 15; age at 100% males not reached
	Longline, commercial, 1993-94			only one male, 750-799 mm TL (age 9)
	Bandit reels/longlines, Comm. and MARMAP,1980-85	female first maturity = 483 mm TL, $\leq$ age 3		
		L_{50} = 486 mm TL (95% CI = 449-509), age 4		
		100% female maturity = 651-675 mm TL, age 10		
		Size and age at maturity schedules - see Tables 8 and 9 in source		
	Longlines/traps, Commercial and MARMAP,1991-95	female first maturity = 469 mm TL, age 3		
		L_{50} = 541 mm TL (95% CI = 529-553), age 5		
		100% female maturity = 576-600 mm TL, age 8		
		Size and age at maturity schedules - see Tables 8 and 9 in source		
	Moore and Labisky 1984	female first maturity = age 3		age of youngest male = 6
		100% female maturity = age 6		males = 40% of fish at ages >=8
				age at 100% male = 20

Table 5. Length-length relationships for Atlantic deepwater snapper-grouper

		Length - length					
Species	Source	Equation	Units	n	R^2	SE	Range of X
Misty Grouper	none	Unknown					
Queen Snapper	None	Unknown					
Warsaw Grouper	Manooch and Mason 1987	None needed: no FL					
Speckled Hind	MARMAP data	TL = 5.741 + 1.010(FL)	mm	75	0.99	3.998, 0.010	164-704, all
		TL = 13.923 + 1.169(SL)	mm	303	0.99	2.460, 0.007	139-850, all
		FL = -2.966 + 0.983(TL)	mm	75	0.99	3.985, 0.010	169-725, all
		FL = 11.495 + 1.142(SL)	mm	74	0.99	4.801, 0.014	140-601, all
		SL = -8.338 + 0.847(TL)	mm	303	0.99	2.149, 0.005	164-930, all
		SL = -6.493 + 0.867(FL)	mm	74	0.99	4.277, 0.010	164-704, all
Yellowedge Grouper	Keener 1984	TL = 28.514 + 1.22(SL)	mm	407	0.98		N/A, all
		SL = 10.896 + 0.801(TL)	mm	407	0.97		N/A, all
	Cass-Calay and Bahnick 2002	TL = 1.072(FL) - 18.565	mm	501	1.00		107-1170, all
		FL = 0.929(TL) +19.558	mm	501	1.00		107-1170, all
	Bullock et al. 1996	TL = -17.612 + 1.074(FL)	mm	1393	1.00		360-1083, all
	MARMAP data	TL = -12.980 + 1.070(FL)	mm	150	1.00	4.378, 0.006	277-1043, all
		TL = 23.515 + 1.232(SL)	mm	369	0.98	5.439, 0.009	225-880, all
		FL = 15.403 + 0.931(TL)	mm	150	1.00	4.008, 0.005	283-1100, all
		FL = 27.169 + 1.166(SL)	mm	150	0.99	5.651, 0.009	225-870, all
		SL = -7.215 + 0.796(TL)	mm	369	0.98	4.465, 0.006	283-1100, all
		SL = -17.479 + 0.850(FL)	mm	150	0.99	4.985, 0.007	277-1043, all
Blueline Tilefish	Ross and Huntsman 1982	SL = -19.21 + 0.864(TL)	mm		0.99		N/A, all
	MARMAP data	TL = -2.275 + 1.068(FL)	mm	820	1.00	1.097, 0.002	312-725, all
		TL = -2.611 + 1.067(FL)	"	375	1.00	1.668, 0.003	364-725, male
		TL = -2.822 + 1.069(FL)	"	334	1.00	1.786, 0.004	312-661, female
		TL = 22.192 + 1.178(SL)	mm	1239	0.98	2.098, 0.005	262-640, all
		TL = 23.965 + 1.177(SL)	"	480	0.98	3.294, 0.007	308-640, male
		TL = 24.383 + 1.168(SL)	"	580	0.97	3.582, 0.008	262-586, female
		FL = 4.091 + 0.933(TL)	mm	821	1.00	1.119, 0.002	333-775, all
		FL = 4.149 + 0.934(TL)	"	375	1.00	1.551, 0.003	385-775, male
		FL = 5.755 + 0.929(TL)	"	337	0.99	2.347, 0.005	333-711, female
		FL = 28.091 + 1.092(SL)	mm	810	0.98	2.115, 0.005	262-633, all
		FL = 30.023 + 1.090(SL)	"	375	0.98	3.304, 0.007	308-633, male
		FL = 30.137 + 1.083(SL)	"	305	0.98	3.824, 0.009	262-586, female
		SL = -11.148 + 0.836(TL)	mm	1258	0.98	1.757, 0.003	333-778, all
		SL = -12.363 + 0.836(TL)	"	481	0.98	2.862, 0.005	385-784, male
		SL = -10.935 + 0.837(TL)	"	611	0.98	2.754, 0.005	333-711, female
		SL = -17.583 + 0.900(FL)	mm	818	0.98	2.100, 0.004	312-725, all
		SL = -19.771 + 0.902(FL)	"	376	0.98	3.142, 0.006	364-725, male

Table 5 Continued.

		Length - length					
Species	Source	Equation	Units	n	R^2	SE	Range of X
Tilefish	Harris and Grossman 1985	TL = 5.533 + 1.211(SL)	mm	1668	0.99		376-925, all
		TL = -16.036 + 1.083(FL)	mm	"	0.99		
		FL = 22.541 + 1.112(SL)	mm	"	0.99		376-925, all
	MARMAP data	TL = -15.031 + 1.082(FL)	mm	1919	1.00	0.690, 0.001	309-1108, all
		TL = -16.864 + 1.084(FL)	"	645	1.00	1.229, 0.002	367-1108, male
		TL = -16.429 + 1.085(FL)	"	790	1.00	1.107, 0.002	309-872, female
		TL = 3.729 + 1.212(SL)	mm	3035	0.99	1.159, 0.002	254-925, all
		TL = 2.129 + 1.213(SL)	"	1093	0.99	1.292, 0.003	254-925, male
		TL = 9.381 + 1.201(SL)	"	1207	0.99	1.957, 0.004	271-790, female
		FL = 15.343 + 0.922(TL)	mm	1920	1.00	0.631, 0.001	327-1155, all
		FL = 16.723 + 0.921(TL)	"	645	1.00	1.106, 0.002	383-1155, male
		FL = 16.452 + 0.919(TL)	"	790	1.00	0.993, 0.002	329-925, female
		FL = 21.341 + 1.114(SL)	"	1906	0.99	1.429, 0.003	271-885, all
		FL = 20.202 + 1.115(SL)	"	639	0.99	2.122, 0.004	313-885, male
		FL = 24.817 + 1.107(SL)	mm	792	0.99	2.101, 0.004	271-760, female
		SL = 1.753 + 0.818(TL)	"	3035	0.99	0.953, 0.001	311-1110, all
		SL = 2.253 + 0.818(TL)	"	1087	0.99	1.356, 0.002	311-1110, male
		SL = -1.829 + 0.823(TL)	mm	1207	0.99	1.634, 0.003	329-975, female
		SL = -13.095 + 0.888(FL)	"	1898	0.99	1.255, 0.002	309-1027, all
		SL = -14.569 + 0.891(FL)	"	637	0.99	1.960, 0.003	367-1027, male
		SL = -17.869 + 0.896(FL)	mm	796	0.99	1.938, 0.003	309-872, female
Snowy grouper	MARMAP data	TL = 1.714 + 1.213(SL)	mm	1633	1.00	0.829, 0.002	182-888, all
		SL = 0.032 + 0.822(TL)	"	1633	1.00	0.683, 0.001	226-1090, all
	Moore and Labisky 1984	TL = 11.697 + 1.192(SL)	mm	306	r = 0.99		111-1180, all

3. Commercial Fishery

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3.1 Overview

This section contains five parts. Reported commercial landings are presented, including a discussion of adjustments made because of unclassified species groupings, and then a summary of adjusted commercial landings. Discards are discussed and estimates are presented for speckled hind and warsaw grouper. The final two sections present a summary of sampling intensity and then develop length frequency distributions by species and gear Commercial logbook indices are described in detail in a dedicated section.

3.2 Commercial Landings (Reported and Adjusted)

A description of the General Canvass was provided in SEDAR4-DW-03. In addition, landings are available from Trip Ticket programs in Florida (since 1985) and North Carolina (since 1994). Issues related to unclassified tilefish and groupers were addressed by the Commercial statistics working group during the SEDAR4 Data Workshop in the process of developing final (adjusted) commercial landings for use in future stock assessments. Modifications relative to these issues are described in this section.

3.2.1 Tilefishes

The landings statistics for tilefishes consist principally of (golden) tilefish and blueline tilefish. However, landings of blueline tilefish have only been reported since 1985 as a separate species. Because catches of blueline are documented in the TIP data prior to 1985, the Working Group concluded that a portion of the "tilefish" landings from 1962-1984 were probably blueline tilefish and should be identified as this species. The reported landings of tilefish (golden) and blueline tilefish are summarized by gear for 1985-2002 in Tables 4.1 and 4.2. Numerical gear codes for the tilefishes are divided into three categories: handline (600-660), longline (675-677), and other (all other codes). Additionally, there is an unclassified tilefish category from 1984 through 1995 as well as tilefish (golden) and blueline tilefish categories. Unclassified tilefish landings are summarized for 1962-2002 in Table 8. The commercial statistics working group decided that the unclassified categories should be proportioned between tilefish (golden) and blueline tilefish. The proportion of tilefish to tilefish (golden) plus blueline tilefish was calculated by state, gear and year for 1985-2002 and the proportion for each year was applied to the unclassified tilefish category for each of those years to augment the reported landings of tilefish (golden). The remaining unclassified tilefish (blueline tilefish/(blueline tilefish + tilefish)) are used to augment the reported landings of blueline tilefish. The mean proportions by gear for tilefish were also calculated for years 1985-1993 (prior to implementation of Amendment 6) and these proportions were applied to the "tilefish" category for 1962-1984. These adjusted landings of tilefish (golden) and blueline tilefish are summarized for 1962-2002 in Table 6 and Table 7. Reported and adjusted landings for tilefish (golden) and blueline tilefish are compared in Figures 4.1 and 4.2, respectively.

3.2.2 Groupers

Groupers considered in SEDAR 4 from the South Atlantic Deep Water complex include snowy grouper, speckled hind, warsaw grouper, yellowedge grouper, and misty grouper. These reported landings of groupers (and queen snapper) are summarized by gear for 1980-2002 in Table 11 and Table 16. Numerical gear codes for the groupers are divided into five categories: handline (600-660), longline (675-677), trawls (200s), pots (300s), and other (all other codes). Unclassified grouper landings are summarized for 1962-2002 in Table Table 17. Similar to the tilefishes, the landings for a particular species of grouper was compared to all identified groupers to estimate a proportion by state, gear and year to apply to the corresponding landings of unclassified grouper for the same year. For years prior to reported landings of that species back to 1962, a mean proportion was calculated by state and gear over the initial year through 1991 (prior to implementation Amendment 4). When no groupers (identified or not) were landed by a particular gear during the averaging period, then that proportion was treated as missing and not used in the calculating the mean proportion for that gear. Because the sale of speckled hind and warsaw grouper were prohibited in Amendment 6, only reported landings are given for 1994-2002. Because of the sparseness of landings for misty grouper (and queen snapper) only reported landings are presented. Available species-specific data for 1992-2002 were applied to separate out any unclassified groupers when no species-specific data in recent years (post 1992). These adjusted landings of groupers (with the exception of misty grouper) are summarized for 1962-2002 in Table 9 - Table 21. Although landing estimates are provided from 1962-2002 for all grouper except misty grouper, estimates for the early years (1962-late 1970s) should be viewed with more skepticism than the later years. Reported and adjusted landings for snowy grouper, speckled hind, warsaw grouper, and yellowedge grouper are compared in Figure 1- Figure 6.

3.3 Commercial Landings Tables

Table 6. Reported commercial landings of tilefish (golden) in kilograms from the U.S. south Atlantic, 1985-2002. Note that the commercial statistics working group judged that tilefish landings prior to 1985 were unclassified tilefishes.

Year	Handline	Longline	Other	Unknown	Total
1985	2043	98353	0	420635	521031
1986	9278	173754	50	368737	551819
1987	1018	45534	0	84573	131125
1988	366	70083	0	199183	269632
1989	2650	88560	0	328266	419476
1990	1550	117512	0	296956	416018
1991	24108	226449	0	202149	452706
1992	39729	405422	0	37098	482249
1993	81812	420846	0	17699	520357
1994	45567	324055	27524	565	397711
1995	41461	268399	24840	0	334700
1996	16585	142663	9570	0	168818
1997	15461	154897	8470	709	179537
1998	15557	162700	4202	477	182936
1999	16571	228711	126	2916	248324
2000	26112	326221	13	2398	354744
2001	6395	188010	0	648	195053
2002	15575	173569	64	0	189208

Table 7. Reported commercial landings of blueline tilefish in kilograms from the U.S. south Atlantic, 1985-2002.

Year	Handline	Longline	Other	Unknown	Total
1985	25031	17825	0	23536	66392
1986	18198	35156	2302	46538	102194
1987	31836	21337	46	10193	63412
1988	19565	15817	20	10145	45547
1989	20961	15537	5	12080	48583
1990	34205	20047	302	26508	81062
1991	48304	33440	870	10324	92938
1992	50795	74856	0	2330	127981
1993	32977	50224	0	4490	87691
1994	27809	41843	11951	261	81864
1995	27056	44755	4258	0	76069
1996	48973	14211	2001	27	65212
1997	43498	37494	7409	145	88546
1998	21037	21131	1932	9	44109
1999	31337	16730	3486	35	51588
2000	30539	18020	3514	127	52200
2001	37160	13960	1724	0	52844
2002	57034	50261	9664	0	116959

Note that the commercial statistics working group judged that tilefish landings prior to 1985 were unclassified tilefishes.

Table 8. Reported commercial landings of unclassified tilefishes in kilograms from the U.S. south Atlantic, 1962-2002.

Year	Handline	Longline	Other	Unknown	Total
1962	1542	0	0	0	1542
1963	1542	0	0	0	1542
1964	181	0	0	0	181
1965	11839	0	0	0	11839
1966	2223	0	0	0	2223
1967	5262	0	0	0	5262
1968	3221	0	0	0	3221
1969	2631	0	0	0	2631
1970	5216	0	0	0	5216
1971	9662	0	0	0	9662
1972	2994	0	0	0	2994
1973	20729	0	0	0	20729
1974	46176	0	0	0	46176
1975	79277	0	0	0	79277
1976	76317	726	0	0	77043
1977	7624	0	91	37037	44752
1978	33700	0	0	49093	82793
1979	18032	0	308	66548	84888
1980	59351	416	316	104959	165042
1981	105197	18231	2709	439328	565465
1982	94615	120485	199	1494809	1710108
1983	40703	249484	259	668295	958741
1984	75003	256571	482	362914	694970
1985	2060	1998	4	0	4062
1986	0	0	0	0	0
1987	460	6859	0	0	7319
1988	49	0	15	0	64
1989	20	0	0	0	20
1990	24	0	0	0	24
1991	7	0	0	0	7
1992	31	0	0	0	31
1993	7	0	0	0	7
1994	36	0	0	0	36
1995	6	0	0	0	6
1996	0	0	0	0	0
1997	0	0	0	0	0
1998	0	0	0	0	0
1999	0	0	0	0	0
2000	0	0	0	0	0
2001	0	0	0	0	0
2002	0	0	0	0	0

Table 9. Adjusted commercial landings of tilefish (golden) in kilograms from the U.S. south Atlantic, 1962-2002.

Year	Handline	Longline	Other	Total
1962	1430	0	0	1430
1963	1430	0	0	1430
1964	168	0	0	168
1965	10975	0	0	10975
1966	2060	0	0	2060
1967	4878	0	0	4878
1968	2986	0	0	2986
1969	2439	0	0	2439
1970	4836	0	0	4836
1971	8957	0	0	8957
1972	2775	0	0	2775
1973	19217	0	0	19217
1974	42807	0	0	42807
1975	73431	0	0	73431
1976	70307	673	0	70980
1977	6729	28747	1	35477
1978	11035	38105	0	49140
1979	11871	51653	0	63524
1980	23776	81779	0	105555
1981	79728	355931	0	435659
1982	237010	1258362	0	1495372
1983	103592	722194	0	825786
1984	72642	488629	0	561271
1985	70537	452511	0	523048
1986	69282	482488	50	551820
1987	14796	117504	0	132300
1988	32783	236853	0	269636
1989	56084	363409	0	419493
1990	49888	366145	0	416033
1991	57010	395703	0	452713
1992	45791	436484	0	482275
1993	84693	435665	0	520358
1994	45586	324055	28090	397731
1995	41463	268399	24840	334702
1996	16585	142663	9570	168818
1997	15461	154897	9179	179537
1998	15557	162700	4679	182936
1999	16571	228711	3041	248323
2000	26112	326221	2411	354744
2001	6395	188010	648	195053
2002	15575	173569	64	189208

Table 10. Adjusted commercial landings of blueline tilefish in kilograms from the U.S. south Atlantic, 1962-2002.

Year	Handline	Longline	Other	Total
1962	112	0	0	112
1963	112	0	0	112
1964	13	0	0	13
1965	863	0	0	863
1966	162	0	0	162
1967	384	0	0	384
1968	235	0	0	235
1969	192	0	0	192
1970	380	0	0	380
1971	704	0	0	704
1972	218	0	0	218
1973	1511	0	0	1511
1974	3366	0	0	3366
1975	5842	0	0	5842
1976	6005	53	0	6058
1977	7678	1489	105	9272
1978	31624	1974	20	33618
1979	18329	2676	334	21339
1980	54772	4325	358	59455
1981	105873	20964	2884	129721
1982	131314	82472	795	214581
1983	59433	72881	469	132783
1984	68749	64220	626	133595
1985	37471	30833	129	68433
1986	38813	60824	2557	102194
1987	36795	32659	102	69556
1988	24104	21413	75	45592
1989	26315	22200	71	48586
1990	45956	34667	447	81070
1991	52878	39134	926	92938
1992	51833	76141	13	127987
1993	34972	52700	25	87697
1994	27829	41843	12212	81884
1995	27058	44755	4258	76071
1996	48973	14211	2028	65212
1997	43498	37494	7554	88546
1998	21037	21131	1941	44109
1999	31337	16730	3520	51587
2000	30539	18020	3641	52200
2001	37160	13960	1724	52844
2002	57034	50261	9664	116959

Table 11. Reported commercial landings of snowy grouper in kilograms from the U.S. south Atlantic, 1980-2002.

Year	Handline	Longline	Trawls	Traps	Other	Unknown	Total
1980	3079	0	0	0	0	0	3079
1981	98640	2291	38	0	0	0	100969
1982	57895	33209	1403	0	0	0	92507
1983	62460	126368	304	0	0	0	189132
1984	62195	82569	108	0	0	0	144872
1985	34073	36516	0	0	0	80083	150672
1986	62818	57918	87	0	0	76164	196987
1987	49866	71922	0	19	0	32713	154520
1988	31097	59100	0	6	0	27066	117269
1989	95496	75729	0	0	0	35034	206259
1990	125510	92693	0	586	0	37032	255821
1991	104341	63872	0	1625	0	40407	210245
1992	145597	98582	0	0	4	7297	251480
1993	114718	73270	0	0	128	8493	196609
1994	78244	40825	0	5	9553	698	129325
1995	121832	34560	200	794	9164	131	166681
1996	106273	29584	0	37	3275	69	139238
1997	146854	79077	0	83	4135	117	230266
1998	96686	40793	97	249	1893	415	140133
1999	142188	43870	0	28	2574	672	189332
2000	116286	46940	0	385	343	448	164402
2001	83282	51828	0	55	837	259	136261
2002	79475	39803	12	117	931	0	120338

Table 12. Reported commercial landings of speckled hind in kilograms from the U.S. south Atlantic, 1980-2002.

Year	Handline	Longline	Trawls	Traps	Other	Unknown	Total
1980	473	0	265	0	0	0	738
1981	4917	0	128	0	0	0	5045
1982	4654	1288	161	0	0	0	6103
1983	12144	264	106	4	0	0	12518
1984	14554	233	10	0	0	0	14797
1985	14386	192	20	0	0	0	14598
1986	15840	370	49	21	0	0	16280
1987	9681	1918	0	3	43	0	11645
1988	6339	2878	0	0	10	0	9227
1989	8833	1402	0	0	34	0	10269
1990	8421	1210	0	262	0	0	9893
1991	7123	472	0	178	0	58	7831
1992	8312	885	0	0	12	13	9222
1993	9021	133	0	0	0	19	9173
1994	4430	1	0	0	0	18	4449
1995	914	0	0	0	0	0	914
1996	601	2	0	0	5	2	610
1997	215	1	0	0	12	0	228
1998	315	79	9	0	317	0	720
1999	170	0	0	0	6	0	176
2000	98	2	0	0	2	0	102
2001	117	2	0	0	0	0	119
2002	5	0	0	0	2	0	7

Table 13. Reported commercial landings of warsaw grouper in kilograms from the U.S. south Atlantic, 1962-2002.

Year	Handline	Longline	Trawls	Traps	Other	Unknown	Total
1962	5715	0	0	0	0	0	5715
1963	8618	0	0	0	0	0	8618
1964	8800	0	0	0	0	0	8800
1965	25719	0	0	0	0	0	25719
1966	10705	0	0	0	0	0	10705
1967	24812	0	0	0	0	0	24812
1968	36560	0	0	0	0	0	36560
1969	20003	0	0	0	0	0	20003
1970	26263	0	0	0	0	0	26263
1971	45405	0	0	0	0	0	45405
1972	22453	0	0	0	0	0	22453
1973	33974	0	0	0	0	0	33974
1974	32114	0	0	0	0	0	32114
1975	21455	0	0	0	0	0	21455
1976	15604	0	0	0	0	0	15604
1977	0	0	0	0	0	17602	17602
1978	0	0	0	0	0	9059	9059
1979	27	0	0	0	0	9968	9995
1980	84	0	0	0	0	03453	3537
1981	4432	0	0	0	0	6208	10640
1982	3616	22	25	0	0	6573	10236
1983	3382	112	26	0	0	5108	8628
1984	2159	17	60	0	0	5464	7700
1985	1685	0	0	0	0	6907	8592
1986	3283	21	131	0	0	8427	11862
1987	4473	237	0	0	0	11048	15758
1988	2326	187	0	0	15	8861	11389
1989	1110	58	28	0	0	6758	7954
1990	1438	27	0	13	0	5631	7109
1991	1771	606	0	0	0	3587	5964
1992	4883	2601	0	128	0	1689	9301
1993	6231	3373	0	0	17	948	10569
1994	3150	1040	0	0	126	162	4478
1995	1371	0	0	0	39	0	1410
1996	352	0	0	0	0	0	352
1997	222	0	0	0	13	0	235
1998	82	11	0	0	18	0	111
1999	436	54	0	0	0	0	490
2000	221	0	0	0	0	0	221
2001	99	0	0	0	0	0	99
2002	69	0	0	0	0	0	69

Table 14. Reported commercial landings of yellowedge grouper in kilograms from the U.S. south Atlantic, 1980-2002.

Year	Handline	Longline	Trawls	Traps	Other	Unknown	Total
1980	239	0	0	0	0	0	239
1981	156	0	0	0	0	0	156
1982	892	3759	0	0	0	0	4651
1983	357	8953	0	0	0	0	9310
1984	192	784	0	0	0	0	976
1985	33	229	0	0	0	5092	5354
1986	288	12883	0	0	0	10846	24017
1987	1742	3229	0	0	0	5081	10052
1988	175	4514	0	0	0	1092	5781
1989	81	2061	0	0	0	3315	5457
1990	131	1862	0	0	0	2802	4795
1991	233	6664	0	0	0	6093	12990
1992	1339	16986	0	0	0	670	18995
1993	5634	7685	0	0	31	1208	14558
1994	663	2941	0	20	1368	0	4992
1995	2257	6232	0	56	385	0	8930
1996	4593	6009	0	441	13	0	11056
1997	800	4596	0	0	709	6	6111
1998	766	2610	0	0	109	0	3485
1999	1001	4665	0	0	123	28	5817
2000	1149	17121	0	0	0	101	18371
2001	1080	9165	0	0	0	4	10249
2002	1396	4132	0	0	0	0	5528

Table 15. Reported commercial landings of misty grouper in kilograms from the U.S. south Atlantic, 1980-2002.

Year	Handline	Longline	Trawls	Traps	Other	Unknown	Total
1980	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0
1993	0	0	0	0	0	126	126
1994	21	0	0	0	0	0	21
1995	249	0	0	0	0	0	249
1996	422	0	0	0	0	0	422
1997	982	29	0	0	0	0	1011
1998	225	0	0	0	0	0	225
1999	909	0	0	0	0	0	909
2000	643	0	0	0	0	0	643
2001	1132	0	0	0	0	0	1132
2002	689	40	0	0	0	0	729

Table 16. Reported commercial landings of queen snapper in kilograms from the U.S. south Atlantic, 1980-2002.

Year	Handline	Longline	Trawls	Traps	Other	Unknown	Total
1980	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0
1992	7	0	0	0	0	0	7
1993	0	0	0	0	0	6	6
1994	0	0	0	0	0	16	16
1995	691	0	0	0	0	4	695
1996	1151	819	0	0	0	0	1970
1997	4408	0	0	0	0	6	4414
1998	779	628	0	0	0	21	1428
1999	2845	6	0	0	0	352	3203
2000	6455	0	0	0	0	0	6455
2001	2163	0	0	0	0	0	2163
2002	1840	0	0	0	0	0	1840

Table 17. Reported commercial landings of unclassified groupers in kilograms from the U.S. south Atlantic, 1962-2002.

Year	Handline	Longline	Trawls	Traps	Other	Unknown	Total
1962	218224	0	272	0	0	0	218496
1963	299054	12428	0	907	0	0	312389
1964	311482	1270	0	4536	0	0	317288
1965	265216	0	45	13653	0	0	278914
1966	209152	0	272	5715	0	0	215139
1967	368907	0	9344	8800	0	0	387051
1968	488202	0	12428	18325	0	0	518955
1969	376664	91	181	20321	0	0	397257
1970	519364	0	0	36786	0	0	556150
1971	530976	0	318	27442	0	0	558736
1972	354642	0	0	24728	0	0	379370
1973	482816	0	190	8162	0	0	491168
1974	648602	0	0	1994	0	0	650596
1975	764270	0	845	7262	0	0	772377
1976	1029653	0	4741	18526	3039	0	1055959
1977	195958	0	27104	60	0	735810	958932
1978	559704	398	3608	0	120	898632	1462462
1979	530369	0	7497	0	0	775731	1313597
1980	408875	4354	29683	0	273	593142	1036327
1981	271475	0	44905	44	0	807221	1123645
1982	292788	308	11195	0	29	763999	1068319
1983	291834	5948	11902	10	543	811529	1121766
1984	202328	14000	3622	136	0	820519	1040605
1985	133335	7427	1673	15	188	61815	204453
1986	93766	1046	562	327	0	68059	163760
1987	89756	5571	91	3332	61	75797	174608
1988	154446	4058	796	207	262	49616	209385
1989	78075	158	40	112	41	52832	131258
1990	70529	3369	0	239	478	50993	125608
1991	56822	2162	0	619	1728	24322	85653
1992	83983	1967	7	86	3050	2691	91784
1993	79409	244	137	190	3033	777	83790
1994	23678	2362	0	164	3190	265	29659
1995	23564	844	124	64	2865	60	27521
1996	18939	742	22	26	1886	0	21615
1997	14619	2722	0	106	669	0	18116
1998	8529	22	103	114	356	22	9146
1999	10659	86	3	190	512	59	11509
2000	9413	0	0	78	190	53	9734
2001	5281	273	0	136	14	0	5704
2002	4914	9	0	1	23	0	4947

Table 18. Adjusted commercial landings of snowy grouper in kilograms from the U.S. south Atlantic, 1962-2002.

Year	Handline	Longline	Trawls	Traps	Other	Total
1962	33085	0	34	0	0	33119
1963	45333	1883	0	137	0	47353
1964	47229	192	0	687	0	48108
1965	39320	0	1	886	0	40207
1966	31850	0	0	826	0	32676
1967	58921	0	1375	899	0	61195
1968	74152	0	240	2750	0	77142
1969	57116	39	0	2257	0	59412
1970	79631	0	0	3682	0	83313
1971	81905	0	6	3377	0	85288
1972	54209	0	0	853	0	55062
1973	72637	0	4	100	0	72741
1974	99622	0	0	20	0	99642
1975	116681	0	16	1005	0	117702
1976	152640	0	33	2768	460	155901
1977	100137	35812	332	25	76	136382
1978	182597	43980	25	31	93	226726
1979	168054	37755	143	26	80	206058
1980	134148	31523	1	20	61	165753
1981	276115	41579	113	27	83	317917
1982	203075	70645	1969	26	79	275794
1983	246389	171026	737	28	84	418264
1984	171548	133548	179	28	85	305388
1985	105778	70769	0	20	61	176628
1986	133064	86473	95	19	59	219710
1987	91191	88094	0	29	30	179344
1988	60673	71556	0	16	24	132269
1989	138528	89643	0	10	29	228210
1990	174170	109662	0	597	30	284459
1991	149594	79193	0	1688	93	230568
1992	176481	101533	0	10	244	278268
1993	134241	76073	0	13	481	210808
1994	81379	41473	0	9	10372	133233
1995	124194	34740	252	813	9780	169779
1996	108071	29720	0	38	3478	141307
1997	148617	81656	0	88	4188	234549
1998	97700	40946	200	265	1946	141057
1999	143448	44106	0	52	2598	190204
2000	117578	47087	0	433	365	165463
2001	84037	52081	0	60	838	137016
2002	80002	39805	12	118	938	120875

Table 19. Adjusted commercial landings of speckled hind in kilograms from the U.S. south Atlantic, 1962-2002.

Year	Handline	Longline	Trawls	Traps	Other	Total
1962	93	0	0	0	0	93
1963	123	5	0	0	0	128
1964	130	0	0	2	0	132
1965	445	0	0	424	0	869
1966	113	0	0	5	0	118
1967	2704	0	3	10	0	2717
1968	1188	0	82	7	0	1277
1969	315	0	0	145	0	460
1970	1042	0	0	284	0	1326
1971	1309	0	2	146	0	1457
1972	755	0	0	240	0	995
1973	2051	0	1	249	0	2301
1974	2465	0	0	6	0	2471
1975	862	0	6	4	0	872
1976	3458	0	45	7	0	3510
1977	6412	1	222	0	0	6635
1978	13077	8	28	0	0	13113
1979	10878	1	49	0	0	10928
1980	7618	67	1082	0	0	8767
1981	10628	1	203	0	0	10832
1982	6746	1299	238	0	0	8283
1983	14892	266	257	5	0	15420
1984	17871	285	13	0	0	18169
1985	17814	205	22	0	0	18041
1986	18259	374	49	24	0	18706
1987	11073	2019	0	3	43	13138
1988	8076	3020	0	0	10	11106
1989	9718	1408	0	0	34	11160
1990	9243	1236	0	262	0	10741
1991	7596	483	0	181	0	8260
1992	8878	889	0	0	13	9780
1993	9705	134	0	0	1	9840
1994	4451	2	0	0	0	4453
1995	916	0	0	0	0	916
1996	604	2	0	0	5	611
1997	216	1	0	0	12	229
1998	316	79	9	0	317	721
1999	171	0	0	0	6	177
2000	98	2	0	0	3	103
2001	117	2	0	0	0	119
2002	5	0	0	0	2	7

Table 20. Adjusted commercial landings of warsaw grouper in kilograms from the U.S. south Atlantic, 1962-2002.

Year	Handline	Longline	Trawls	Traps	Other	Total
1962	10519	0	11	0	0	10530
1963	15204	274	0	20	0	15498
1964	15650	28	0	100	0	15778
1965	31347	0	0	125	0	31472
1966	15259	0	39	120	0	15418
1967	32483	0	239	130	0	32852
1968	46771	0	12	400	0	47183
1969	28255	0	26	315	0	28596
1970	37556	0	0	503	0	38059
1971	56791	0	0	479	0	57270
1972	30130	0	0	62	0	30192
1973	43859	0	0	11	0	43870
1974	45185	0	0	0	0	45185
1975	37781	0	1	146	0	37928
1976	36786	0	61	402	67	37316
1977	28702	6458	214	109	12	35495
1978	28460	3324	109	56	6	31955
1979	25873	3657	18	62	7	29617
1980	16483	1270	444	21	2	18220
1981	20743	8805	1624	149	16	31337
1982	20287	8611	36	145	16	29095
1983	18192	8609	26	143	16	26986
1984	17211	8657	91	146	16	26121
1985	7190	3034	0	51	6	10281
1986	9879	3663	131	62	7	13742
1987	12726	4916	0	79	9	17730
1988	9400	3850	0	62	21	13333
1989	6203	2965	68	49	5	9290
1990	5822	2506	0	55	5	8388
1991	4581	2130	0	33	12	6756
1992	6406	3280	0	140	35	9861
1993	7169	3732	0	8	68	10977
1994	3451	1152	0	2	145	4750
1995	1514	19	0	0	55	1588
1996	425	16	0	0	22	463
1997	268	1	0	0	15	284
1998	114	11	0	2	18	145
1999	454	56	0	0	0	510
2000	242	0	0	0	2	244
2001	108	1	0	0	0	109
2002	78	0	0	0	0	78

Table 21. Adjusted commercial landings of yellowedge grouper in kilograms from the U.S. south Atlantic, 1962-2002.

Year	Handline	Longline	Trawls	Traps	Other	Total
1962	4193	0	4	0	0	4197
1963	5748	239	0	17	0	6004
1964	5979	24	0	87	0	6090
1965	4852	0	0	92	0	4944
1966	3970	0	0	105	0	4075
1967	6276	0	175	113	0	6564
1968	8744	0	20	349	0	9113
1969	7176	0	0	270	0	7446
1970	9722	0	0	428	0	10150
1971	9759	0	1	413	0	10173
1972	6600	0	0	45	0	6645
1973	8311	0	0	0	0	8311
1974	11035	0	0	0	0	11035
1975	14157	0	1	127	0	14285
1976	17961	0	3	351	58	18373
1977	3099	11272	28	0	15	14414
1978	3948	13777	2	0	18	17745
1979	3418	11883	12	0	15	15328
1980	2961	9203	0	0	12	12176
1981	3404	12366	0	0	16	15786
1982	3900	15492	0	0	15	19407
1983	3531	21405	0	0	16	24952
1984	3531	13574	0	0	16	17121
1985	1310	5245	0	0	6	6561
1986	2825	22738	0	0	13	25576
1987	3140	8544	0	0	7	11691
1988	596	6327	0	0	2	6925
1989	969	5516	0	0	4	6489
1990	921	4908	0	0	4	5833
1991	1719	11931	0	6	15	13671
1992	1912	17609	0	1	31	19553
1993	6129	8664	0	1	76	14870
1994	838	2998	0	22	1484	5342
1995	2383	6249	0	58	407	9097
1996	4659	6023	0	446	33	11161
1997	846	4759	0	0	718	6323
1998	798	2612	0	2	112	3524
1999	1035	4690	0	0	124	5849
2000	1215	17202	0	0	2	18419
2001	1089	9183	0	0	0	10272
2002	1406	4132	0	0	0	5538

3.4 Commercial Landings Figures

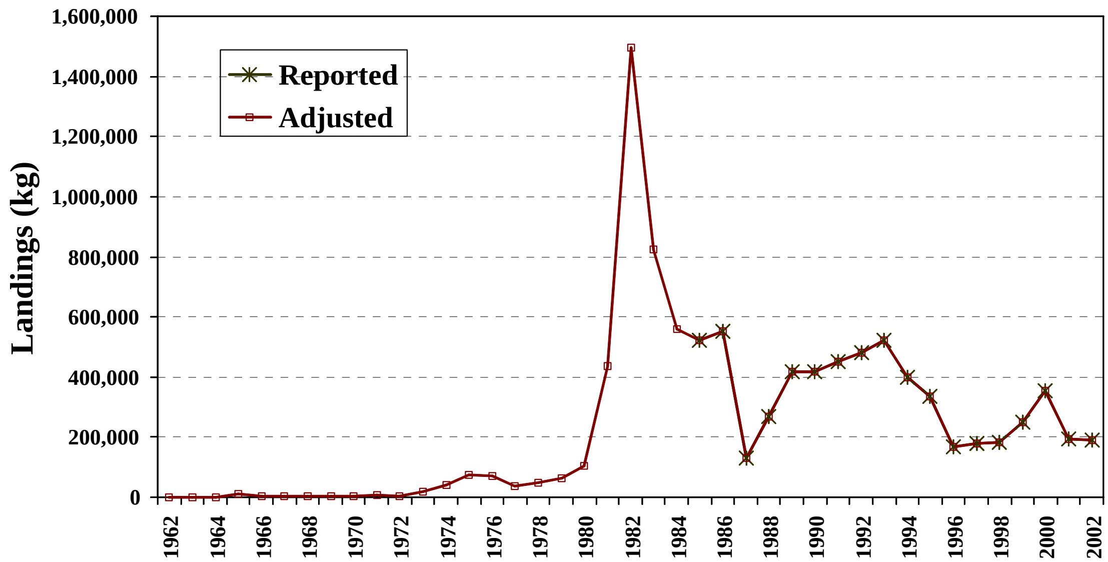


Figure 1. Reported and adjusted commercial landings of tilefish (golden) in the U.S. south Atlantic, 1962-2002.

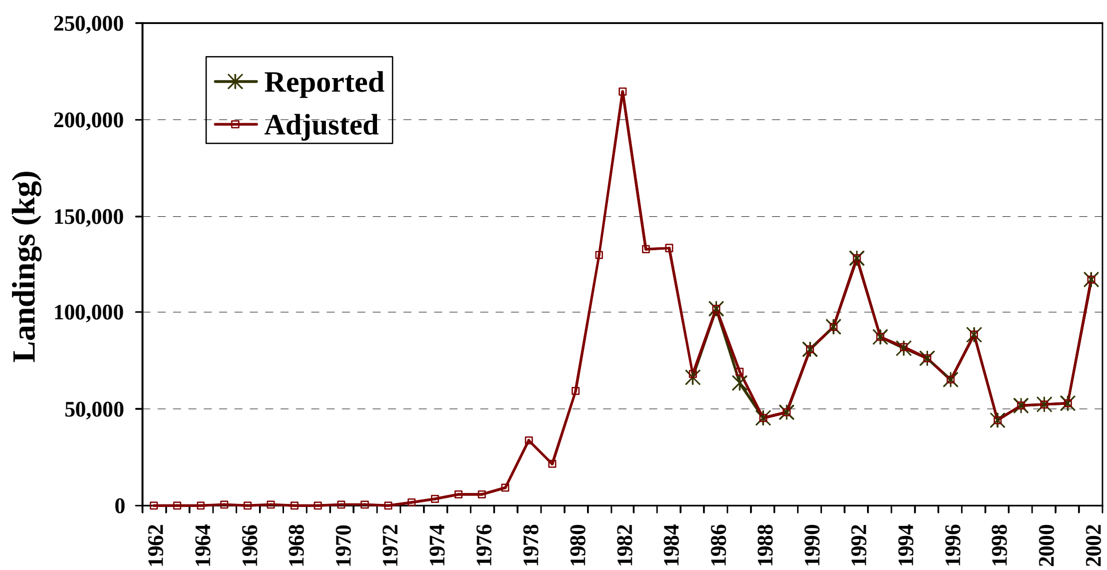


Figure 2. Reported and adjusted commercial landings of blueline tilefish

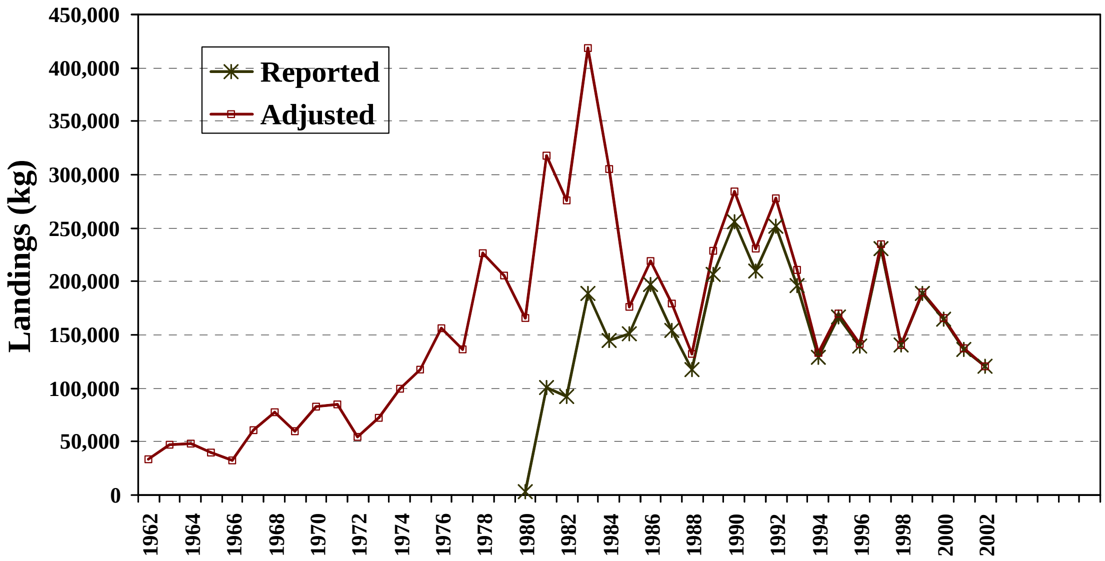


Figure 3. Reported and adjusted commercial landings of snowy grouper in the U.S. south Atlantic, 1962-2002.

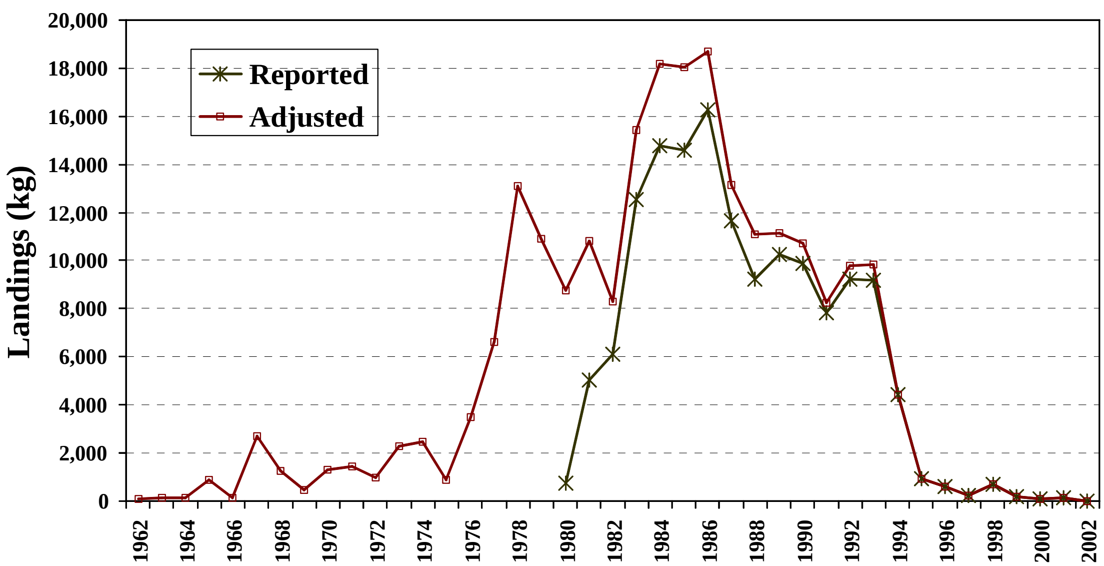


Figure 4. Reported and adjusted commercial landings of speckled hind in the U.S. south Atlantic, 1962-2002.

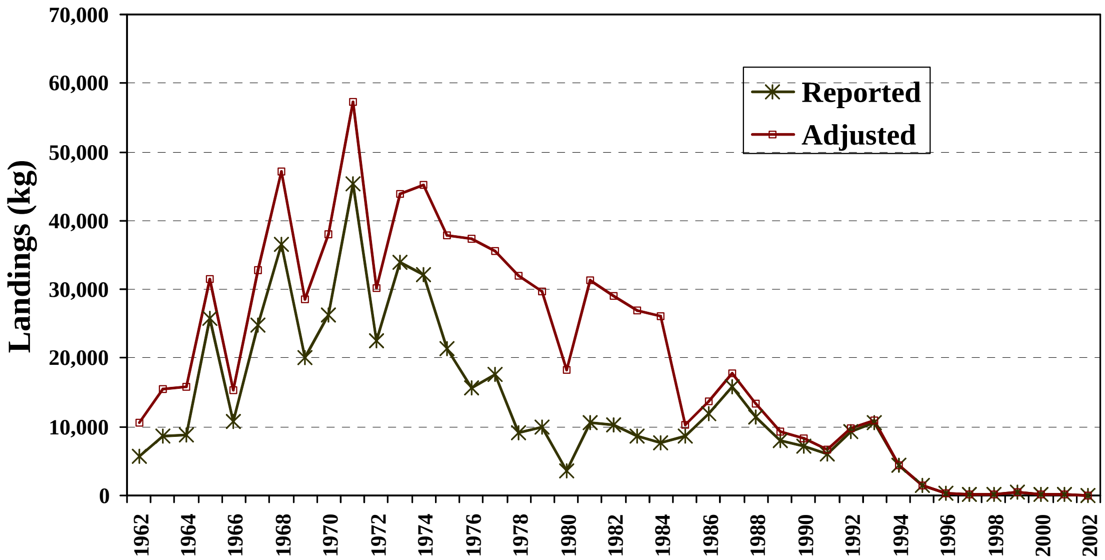


Figure 5. Reported and adjusted commercial landings of warsaw grouper in the U.S. south Atlantic, 1962-2002.

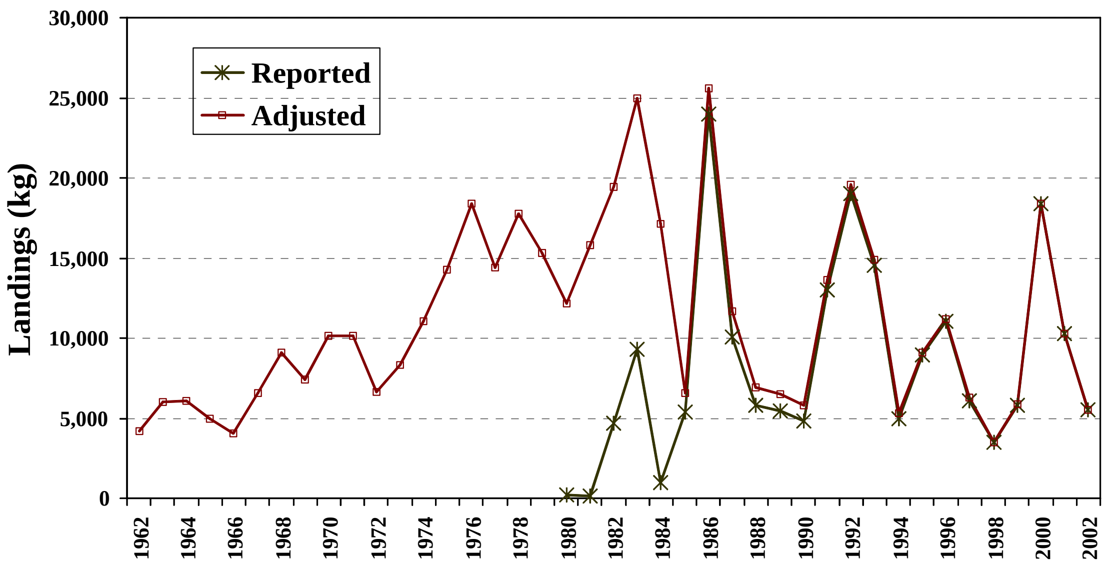


Figure 6. Reported and adjusted commercial landings of yellowedge grouper in the U.S. south Atlantic, 1962-2002.

3.5 Commercial Discards

The discard data from the SEFSC logbook program for the 8 deep water species were reviewed at the SEDAR Data Workshop (SEDAR4-DW-12). Discards were reported for 3 of the 8 species - snowy grouper, speckled hind and Warsaw grouper. Discards of snowy grouper were reported on 12 trips for the period, discards of speckled hind were reported on 115 trips and Warsaw grouper were reported on 32 trips for the period August 1, 2001 through July 31, 2003. After reviewing the discard data and discussions among the members of the commercial statistics working group, including participation of a bandit rig fisherman, the group decided not to estimate discards of snowy grouper. It is the opinion of the group that because of the economic value of snowy grouper, it is highly unlikely that these species would be discarded on a typical handline or bandit rig trip. Thus, discard estimates are only provided for speckled hind and Warsaw grouper.

The commercial statistics working group decided that the mean and standard deviation should be calculated for all trips in the discard database for the relevant types of gear. That is, trips where discards were reported and trips where no discards were reported should both be used for the calculations.

3.5.1 Speckled Hind:

For speckled hind, the total numbers of discards for both survey years is 2,014 fish from 115 trips. All of the discards for speckled hind were reported by vessels with handline or bandit rig gear, with the exception of one trip, which reportedly used trolling gear. Because of the unlikelihood that this species is caught by this type of gear, this trip is eliminated. Thus, there were 1,996 speckled hind discarded on 114 trips where handline/bandit rig were reported. The mean and standard deviation for the numbers of discards of speckled hind are calculated for all of the trips where handline or bandit rig gear were reported. There were 2,144 trips reported with handline/bandit rig gear during the two year survey. The mean number of speckled hind discards is 0.93 fish per trip with a standard deviation of 7.94 about that mean. The estimated numbers of discards per year by vessels with handline or bandit rig gear in the South Atlantic for the two survey years are presented (a table that is not provided)

3.5.2 Warsaw Grouper:

There were 210 discards of Warsaw grouper reported on 32 trips during the two survey years. All of these trips reported using handline or bandit rig gear. The mean and standard deviation of the numbers of discards for all of the trips where handline or bandit rig gear were used are 0.098 and 1.92 fish per trip, respectively. As with the speckled hind, there are 2,144 trips where handline or bandit rig gear were reported. The estimated numbers of discards per year by vessels with handline or bandit rig gear in the South Atlantic for the two survey years are presented in (Table not provided).

Table 22. Total trips and annual estimates from catch per trip for speckled hind and warsaw grouper from the South Atlantic handline fishery, 1994-2002.

Year	Total Trips	Speckled hind (Catch per trip = 0.93)	Warsaw grouper (Catch per trip = 0.10)
1994	15,366	14,290	1,537
1995	15,391	14,314	1,539
1996	16,636	15,471	1,664
1997	19,044	17,711	1,904
1998	18,693	17,384	1,869
1999	16,953	15,766	1,695
2000	15,603	14,511	1,560
2001	16,299	15,158	1,630
2002	16,679	15,511	1,668

3.6 Commercial Catch Rates

Inadequate time was available at the Data Workshop to discuss this topic relative to developing potential indices of abundance (CPUE) from NC and FL Trip Tickets. This topic would be redundant to some extent in the section describing CPUE from commercial logbooks.

3.7 Commercial Sampling Intensity

Procedures for TIP sampling for fish lengths are summarized in SEDAR4-DW-13. The commercial statistics working group (and Data Workshop) recommended converting fork length (FL) and standard length (SL) to total length (TL) with conversion equations from life history section for development of length frequency distributions. More recent relationship based on both sexes were used preferentially when more than one equation was available. Sample sizes by species for the different length types are summarized in Table 23. Conversion equations for FL to TL were available for blueline tilefish, tilefish, speckled hind and yellowedge grouper. No conversion was necessary for snowy and warsaw grouper (TL = FL). Conversion from SL to TL were available for blueline tilefish, tilefish, snowy grouper, and yellowedge grouper. Because there are no conversion equations from SL to TL for speckled hind and warsaw grouper, the limited numbers of specimens were not included, i.e., 11 and 2 respectively. With no conversion equations for misty grouper and queen snapper, these species were not considered because of the limited numbers of specimens, i.e., there were a total of 30 specimens for misty grouper and 25 specimens for queen snapper.

Sample size by species and gear type (for lengths > 0) are summarized in Table 24. Although the decision was made by the commercial statistics working group to include separate landings for trawl and trap gears, sample sizes associated with these gears are minimal. In particular, for snowy grouper only 5 trawl-caught fish and 175 trap-caught fish were sampled during the period 1984-2002; and for speckled hind only 1 trawl-caught fish and 39 trap-caught fish were sampled during the same period. No trawl- or trap-caught fish were sampled for the other South Atlantic grouper species considered in this data workshop. Also the commercial statistics working group decided that the trawl and trap gears should not be considered separately for the tilefishes. Hence, the small sample sizes associated with trawl and trap gears, would preclude their usefulness in any subsequent assessment.

Table 23. Numbers of specimens sampled in TIP by length type for 8 species in South Atlantic Deep Water Complex, generally 1984-2002.

Length Type	FL (cm; 1)	TL (cm; 2)	SL (cm; 5)	FL (mm; 9)	TL (mm; A)
Blueline tilefish	5940	8974	89	11	1
Tilefish (golden)	74750	31445	588	411	0
Misty grouper	1	29	0	0	0
Snowy grouper	6337	51383	397	676	115
Speckled hind	52	8854	11	19	14
Warsaw grouper	58	334	2	14	4
Yellowedge grouper	745	3707	35	2	1
Queen snapper	7	11	0	7	0

Table 24. Numbers of specimens sampled in TIP by gear type for 8 species in South Atlantic Deep Water Complex, generally 1984-2002.

Gear Type	Handline	Longline	Trawl	Traps	Other
Blueline tilefish	4476	10157	N/A	N/A	382
Tilefish (golden)	2478	101100	N/A	N/A	3616
Misty grouper	23	4	0	0	3
Snowy grouper	36766	19829	5	175	2133
Speckled hind	7910	720	1	39	270
Warsaw grouper	322	66	0	0	23
Yellowedge grouper	708	3642	0	0	140
Queen snapper	21	3	0	0	1

3.8 Commercial Catch-at-Length

Measurements that are either FL or SL and then converted to TL present a problem when these measurements are in cm, and subsequently a 10-mm (1 cm) bin is used for length frequency distributions. A mismatch occurs in the bins such that some bins will be overestimate and some underestimated. Two resolutions have been used in prior SEDAR assessments. For the red porgy assessment (SEDAR 1), FL measurements were replicated 10 times with each value representing the possible value in mm that would round to the value in cm (e.g., 52.5, 52.6, 52.7, ..., 53.4 would all round to 53). A weighting of 1/10 was then assigned to each of these values after conversion to TL in mm. This approach can be somewhat unwieldy with large samples sizes, so an alternative approach was developed for black seabass and vermilion snapper (SEDAR 2). This alternative approach randomly generates a more precise measurement from a U(-0.5, 0.5) for each FL or SL measurement, and then converts that value to TL in mm. The latter approach was used in this analysis as needed.

In developing length frequency distributions by species and gear as presented in this section, the individual lengths (all converted to TL in 1-cm bins) have been weighted by the corresponding landings from the general canvas by year, state and season (3-month). For some of these strata (year x state x season), there are length measurements with no corresponding general canvass landings. In these instances, adjusted landings (by species, gear, year, state) are used for weighting the length frequency distributions. Because of the minimal length information for misty grouper and queen snapper, no length frequency distributions were developed for these species.

Because assessments are currently planned only for snowy grouper and tilefish, annual length frequency distributions by gear were developed only for these species. Annual sample size and corresponding weighted mean weight in fishery are summarized for snowy grouper (Table 25) and tilefish (Table 26). Currently length frequency distributions have only been developed when at least a sample size of 50 is available. A higher cutoff value may be selected by the SEDAR 4 Assessment Workshop.

3.9 Commercial Length Distributions Tables and Figures

Table 25. Sample size and weighted mean weights by year and gear for snowy grouper. Weighting is based on commercial landings by state and season.

Year	Handline		Longline		Other Gear	
	n	Weight	n	Weight	n	Weight
1983	95	2.48	0	-	0	-
1984	1774	3.95	1070	7.35	1	3.66
1985	3467	3.47	988	4.03	0	-
1986	1435	2.15	1292	4.23	6	2.12
1987	1306	2.07	492	5.51	0	-
1988	740	1.81	461	2.63	8	2.01
1989	1335	1.96	154	5.60	116	4.09
1990	1543	2.25	539	2.84	296	3.27
1991	1643	3.26	897	5.14	174	1.78
1992	2983	3.70	1604	4.19	17	4.01
1993	2392	2.83	4427	3.18	280	2.35
1994	1911	2.30	521	3.16	317	1.28
1995	4095	2.58	1407	1.99	645	2.92
1996	2102	2.11	387	2.21	410	3.34
1997	1046	1.91	1367	2.55	0	-
1998	1656	2.13	443	2.27	32	4.19
1999	2205	3.54	1246	2.47	3	2.78
2000	2165	3.55	832	3.36	8	3.03
2001	1686	2.15	871	3.21	0	-
2002	1184	1.94	831	3.59	0	-

Table 26. Sample size and weighted mean weights by year and gear for tilefish. Weighting is based on commercial landings by state and season.

Year	Handline		Longline		Other Gear	
	n	Weight (kg)	n	Weight (kg)	n	Weight (kg)
1983	0	-	0	-	0	-
1984	3	7.64	2352	3.95	0	-
1985	14	2.19	5037	3.55	0	-
1986	1	3.19	5414	2.62	0	-
1987	0	-	542	2.88	0	-
1988	3	1.49	1057	2.89	0	-
1989	68	4.06	766	2.44	0	-
1990	14	7.28	738	2.43	3	5.12
1991	70	3.65	6088	2.19	0	-
1992	166	1.81	11589	2.65	0	-
1993	54	7.20	28716	2.30	525	2.30
1994	170	2.07	11239	2.07	568	2.59
1995	0	-	8289	2.42	1713	2.71
1996	7	1.33	2135	2.82	688	2.26
1997	133	2.87	2632	2.77	17	2.21
1998	92	3.45	1713	2.24	0	-
1999	119	2.08	3722	2.46	0	-
2000	836	2.22	4952	2.48	102	2.62
2001	306	2.21	2188	2.63	0	-
2002	422	2.13	1930	3.02	0	-

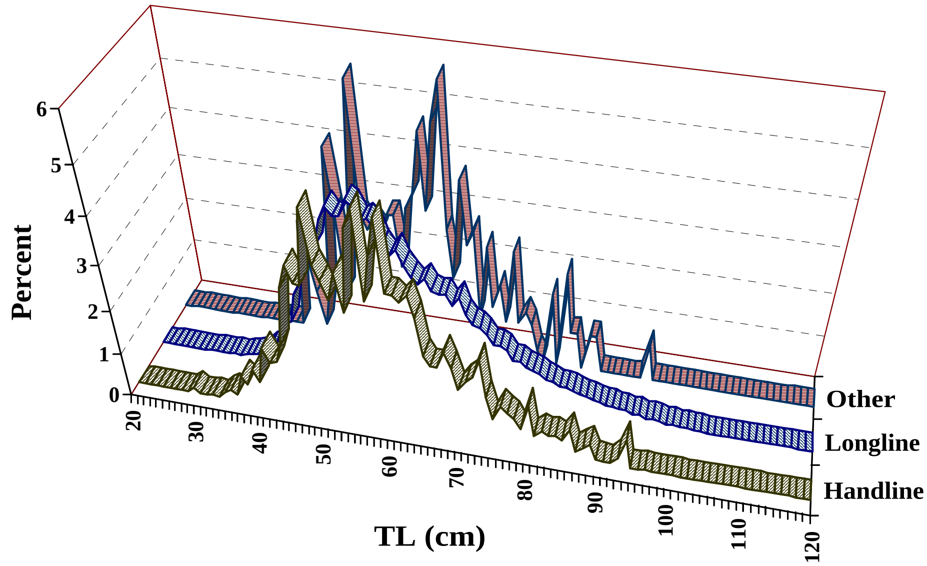


Figure 7. Length frequency distributions by gear for tilefish (golden) in the U.S. south Atlantic, pooled across 1984-2002

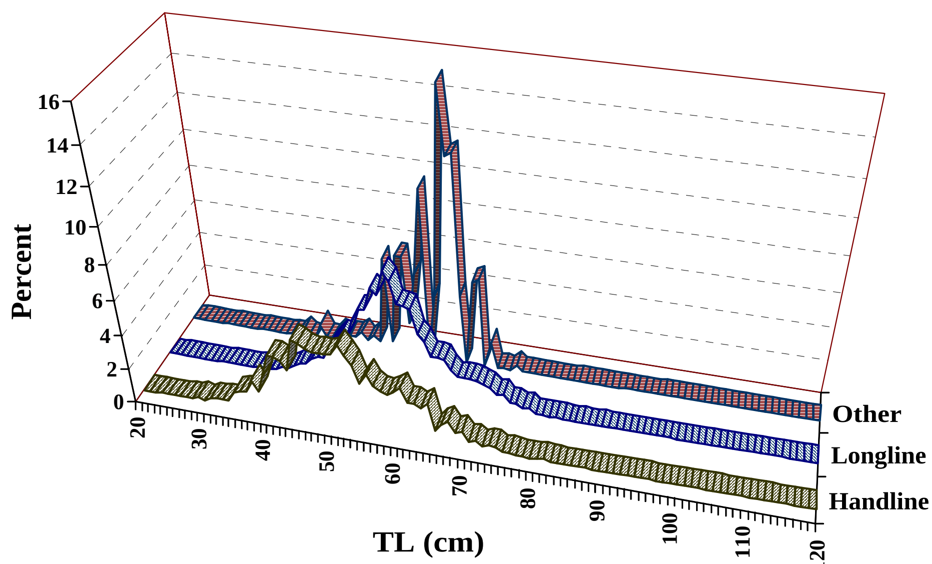


Figure 8. Length frequency distributions by gear for blueline tilefish in the U.S. south Atlantic, pooled across 1984-2002

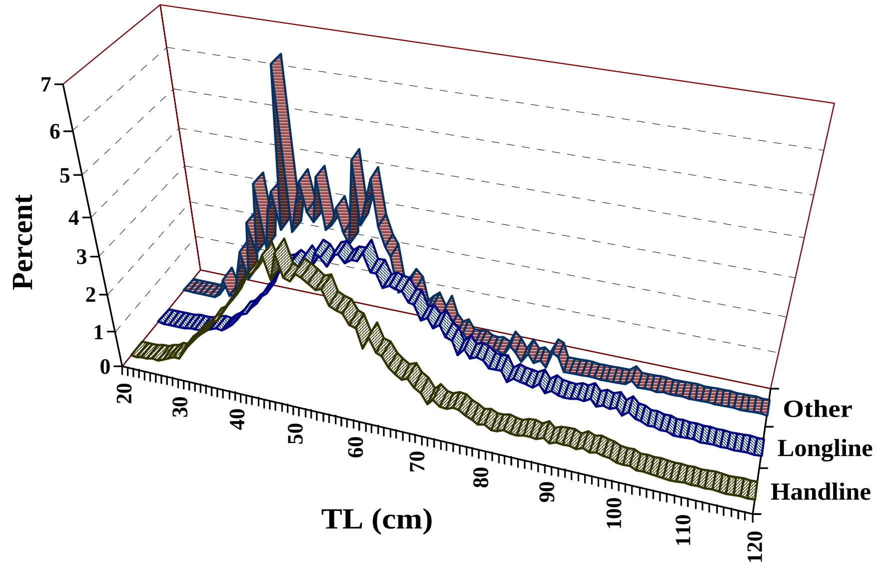


Figure 9. Length frequency distributions by gear for snowy grouper in the U.S. south Atlantic, pooled across 1984-2002

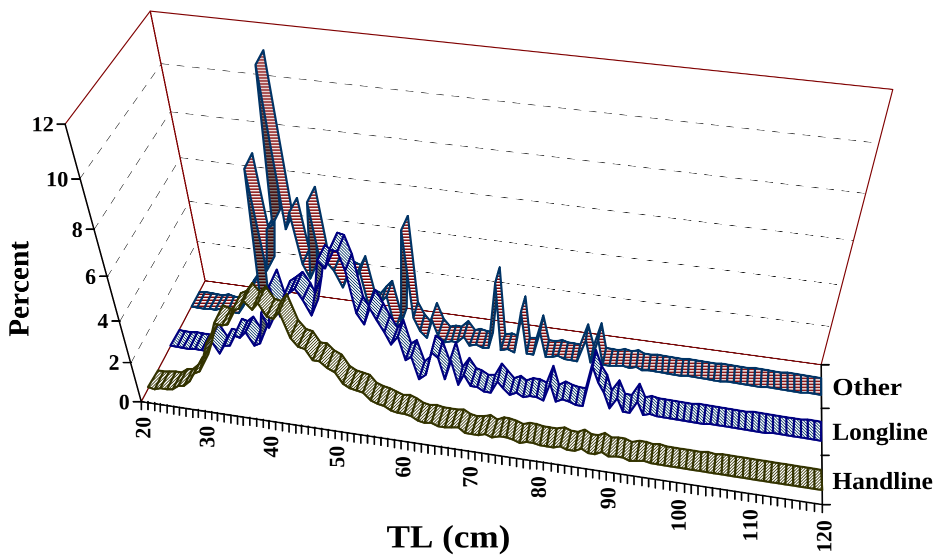


Figure 10. Length frequency distributions by gear for speckled hind in the U.S. south Atlantic, pooled across 1984-2002

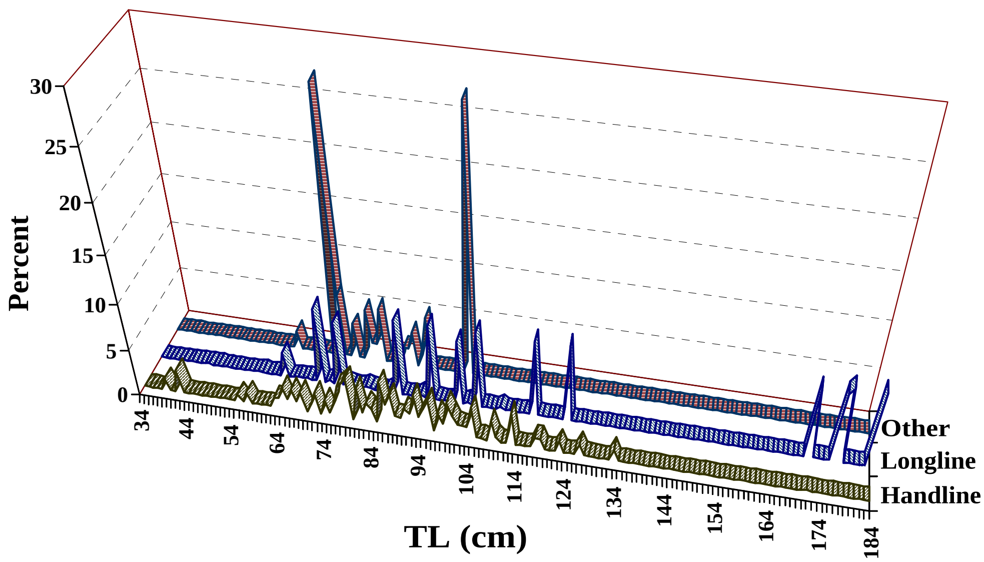


Figure 11. Length frequency distributions by gear for warsaw grouper in the U.S. south Atlantic, pooled across 1984-2002

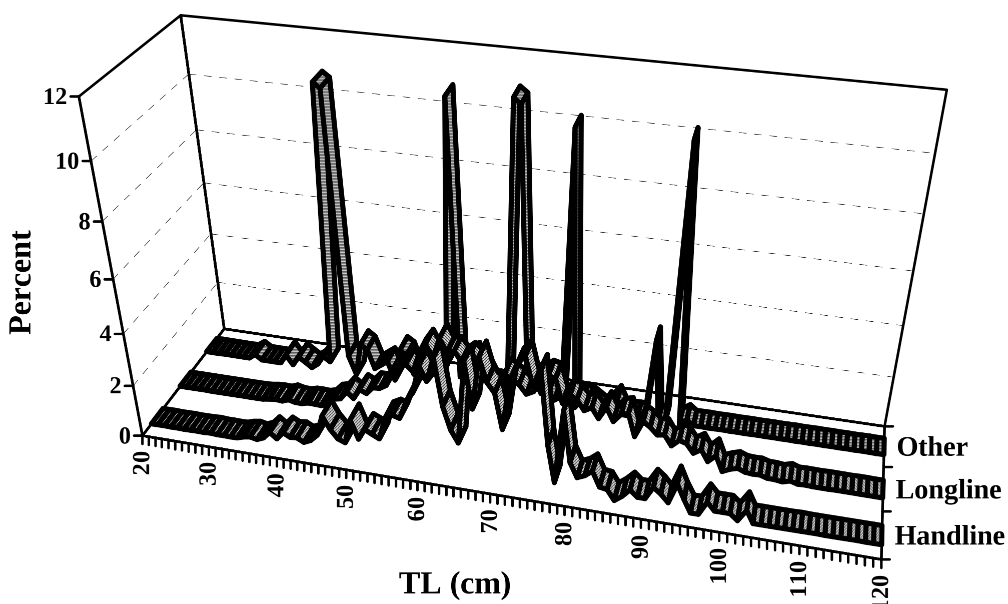


Figure 12. Length frequency distributions by gear for yellowedge grouper in the U.S. south Atlantic, pooled across 1984-2002

3.10 Commercial Logbook Data

3.10.1 Overview

Indices of abundance were developed from commercial logbook data. The indices were computed using the delta-lognormal distribution (Lo et al., 1992, Can. J. Fish. Aquat. Sci., 49:2515-2526), in which the binomial distribution describes positive versus zero catches and the normal distribution describes the log of positive catches-per-unit-effort. Factors used in the analysis were year, month, area, and gear. Depth was not included as a factor because it is not reported, and it could not be inferred due to the coarse geographic resolution (one degree latitude by one degree longitude) of the reported areas fished. To obtain estimates of variance, the analysis used an empirical bootstrap.

The commercial logbook data collection program is detailed in SEDAR4-DW-30. The data set contains unique records for each species caught on each reported fishing trip. The full data set was pared by excluding records that did not report necessary information: area fished, number of lines (or sets), number of hooks, time fished, length of longline (if appropriate), days-at-sea, or if hours fished exceeded 24 multiplied by days-at-sea. The data set was then constrained to areas in the South Atlantic (24-35 degrees latitude). The logbook data contain some entries that are clearly mis-reported or mis-recorded; such outliers were removed prior to analysis.

The duration of the usable data is 1992-2002, with only partial reporting in 1992. The number of records for each species by year is in Table 27

Table 27. The number of records in the south Atlantic (SA) by species and year.

Species	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
Snowy	667	1533	1595	1900	1905	2274	1613	1738	1698	1711	1534	18168
Blueline tilefish	326	826	847	830	948	1243	836	841	806	867	856	9226
Tilefish	327	828	751	688	503	548	453	543	705	472	560	6378
Speckled hind	460	498	291	166	177	153	129	102	100	135	123	2334
Yellowedge	86	171	149	140	192	231	183	196	243	216	230	2037
Warsaw	40	250	193	50	31	30	21	11	13	5	5	649
Queen snapper	6	19	23	24	34	89	34	50	81	85	58	503
Misty	1	25	30	12	39	59	54	29	30	28	21	328
Total	1913	4150	3879	3810	3829	4627	3323	3510	3676	3519	3387	39623

Records by gear are shown in Table 28. Almost all catches of the deepwater species were by three gear types: handline (H), longline (L), and electric reels (E). Therefore, the abundance indices are based on these three gears. For analyses, handlines and electric reels are considered a single gear type.

Table 28. Gear types used to catch deepwater species in the U.S. South Atlantic.

Gear	Frequency	Percent	Cumulative Percent
Handline (H)	28711	72.46	72.46
Longline (L)	8517	21.50	93.96
Electric reel (E)	1919	4.84	98.80
Troll (TR)	308	0.78	99.58
Trap (T)	141	0.36	99.93
Gillnet (GN)	27	0.07	100.0

The data set contains information on crew size and gear configuration, information that is crucial for determining effort. However, some of this information is clearly mis-reported or mis-recorded. Outliers by gear were removed according to the constraints in Table 29.

Table 29. Cutoffs for outlier exclusion

Crew size	>12	none
Hooks/line	>40	none
Number of lines or sets	>10	>42
Length/hook	not applicable	>100 feet

3.10.2 Catch

Catch is reported as total weight (lbs) per species per trip. No age or size data are reported. Consequently, total pounds of catch was not converted to numbers of fish. Instead, the indices of abundance were computed with units of catch in weight, as reported. The total catch by weight of each species is in Figure 13. Catch in pounds was converted to metric tons for analyses.

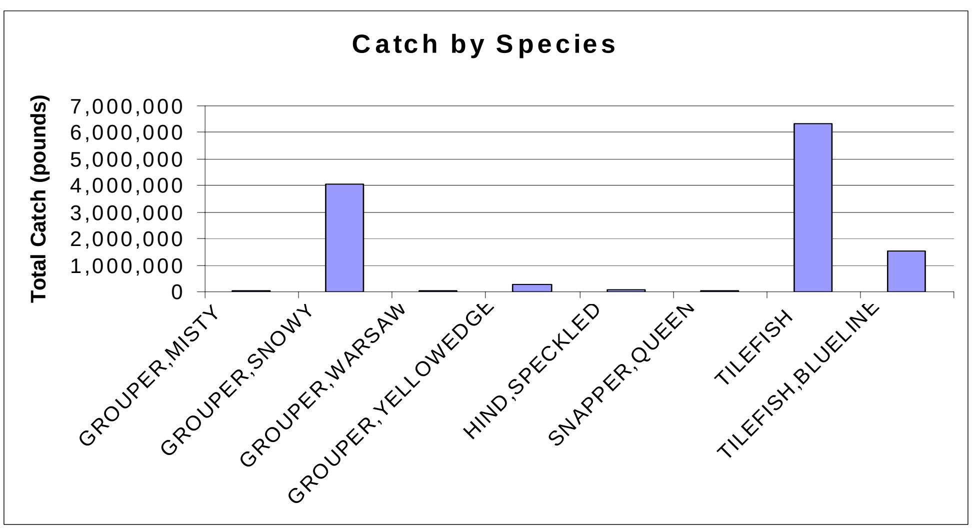


Figure 13. Total catch of the U.S. South Atlantic deepwater species reported in the commercial logbook program.

3.10.3 Effort

For a studied species, defining effort from the reef fish logbook data set is not straightforward. Without an adequate definition of 'trip', a reasonable estimation of 'effective effort' cannot be made. The data set contains information about species caught, but nothing about species targeted. This means that trips with effort but zero catch must be inferred. No depth information is available to define deepwater trips, and aspects of gear configuration did not appear informative for defining effective effort (SEDAR-DW-01).

To define effective effort in a changing fishery, we must choose trips that could have taken the studied species. We define trips as those that take a species commonly caught in connection with the studied species. An association statistic (A) was computed to determine species caught by gear alongside the studied species:

$$A = \frac{N(s,x)/N(s)}{N(x)/N}$$

N(s) is the number of trips that caught the studied species; N(x) is the number of trips that caught species x; N(s,x) is the number of trips that caught the studied species and species x; N is the total number of trips. The statistic gives less weight to species that are more abundant in the overall catches, and more weight to species that tend to be caught in connection with the studied species. A potential problem with the statistic is that unreasonably high scores are given to species caught very infrequently, but alongside the studied species. Consequently, the DW chose a minimum co-occurrence sample size of 100 (i.e., $N(s,x) \geq 100$). Species were then ranked by association statistic to create a list of possible inclusions. From that list, the group selected species to include in the analysis based on biological knowledge. Lists by gear for each species are presented in the species-specific sections below.

In addition to 'trips', units of effort must also be defined. The DW considered two different definitions, hook-hours and hook-days. However, for longline gear, hook-hours is problematic: the hours fished cannot be determined unambiguously. Before 1993, longline hours fished was reported per set. Beginning in 1993, hours fished was to be reported as total hours fished. But old forms continued to be used, and even with the new forms, some fishermen apparently continued to report hours fished per set. To avoid this problem altogether, the DW preferred to measure effort as hook-days.

The DW developed a primary index of abundance for each studied species considered to have adequate data. The DW also developed a secondary index based on a subset of vessels that were consistently in the fishery. Such vessels were determined as those that caught the studied species in at least 9 years of the 11-year period 1992-2002. These secondary indices were computed for comparison to the indices from all vessels, but were not recommend for use in the assessments.

Snowy grouper

Gears used to catch snowy grouper are shown in
Table 30. Based on the gear distribution, indices were developed using two gear types- longline (L) and a lumped category of handline (H) and electric reels (E).

Table 30. Gears used to catch snowy grouper in the SA, 1992-2002

gear	Frequency	Percent	Cumulative Frequency	Cumulative Percent
H	14761	81.25	14761	81.24
L	2212	12.18	16973	93.42
E	1011	5.56	17984	98.99
TR	125	0.69	18109	99.68
T	56	0.31	18165	99.98
GN	3	0.02	18168	100.00

To define effective effort, a gear-specific list of species was developed according to co-occurrence in the catches. The species were ranked by association index (A), and then those with the highest ranks were considered by the DW for inclusion (Table 31, Table 32). If a species were included, any trip that caught that species by the specified gear would be treated as a trip that could have caught the studied species, snowy grouper. Such trips constituted the analysis.

Table 31. Species assemblage for snowy grouper, gear=handline, electric reel

common	N(a,x)	N(x)	A	Include?
GROUPER,SNOWY	15772	15772	10.57	Y
BARRELFISH	453	521	9.19	Y
BLACK BELLIED ROSEFISH	1350	1588	8.98	Y
TILEFISH,BLUELINE	6447	7747	8.79	Y
EEL,CONGER	107	146	7.74	Y
GROUPER,YELLOWEDGE	774	1090	7.50	Y
HAKE,ATLANTIC,RED & WHITE	174	250	7.36	Y
SNAPPER,QUEEN	233	478	5.15	Y
BIGEYE	1103	2500	4.66	N
SNAPPER,SILK	937	2186	4.53	N
GROUPER,WARSAW	253	597	4.48	Y
TILEFISH	1003	2380	4.45	Y

Table 32. Species assemblage for snowy grouper, gear=longline

common	N(a,x)	N(x)	A	Include?
GROUPER,SNOWY	2212	2212	3.87	Y
SCORPIONFISH-THORNYHEADS	251	251	3.87	Y
EEL,AMERICAN	124	130	3.69	Y
PORGY,RED,UNC	237	254	3.61	N
SNAPPER,VERMILION	150	161	3.60	N
HAKE,ATLANTIC,RED & WHITE	345	372	3.58	Y
GROUPER,YELLOWEDGE	854	931	3.55	Y
BLACK BELLIED ROSEFISH	761	835	3.52	Y
LESSER AMBERJACK	169	189	3.46	N
EELS,UNC	209	237	3.41	Y
TILEFISH,BLUELINE	1183	1361	3.36	Y
ALMACO JACK	128	161	3.07	N
SCAMP	133	175	2.94	N
GREATER AMBERJACK	377	530	2.75	N
DOLPHINFISH	536	946	2.19	N
TILEFISH	1853	3923	1.83	Y

Based on all trips that caught the gear-specific associated species, an index of abundance was developed (Figure 14, Table Table 33). A second index of abundance was developed based on a subset of trips made by those vessels consistently in the fishery. For both indices, QQ-plots of the log positive-CPUE residuals can be used as a diagnostic for the assumption of lognormality (Figure 15).

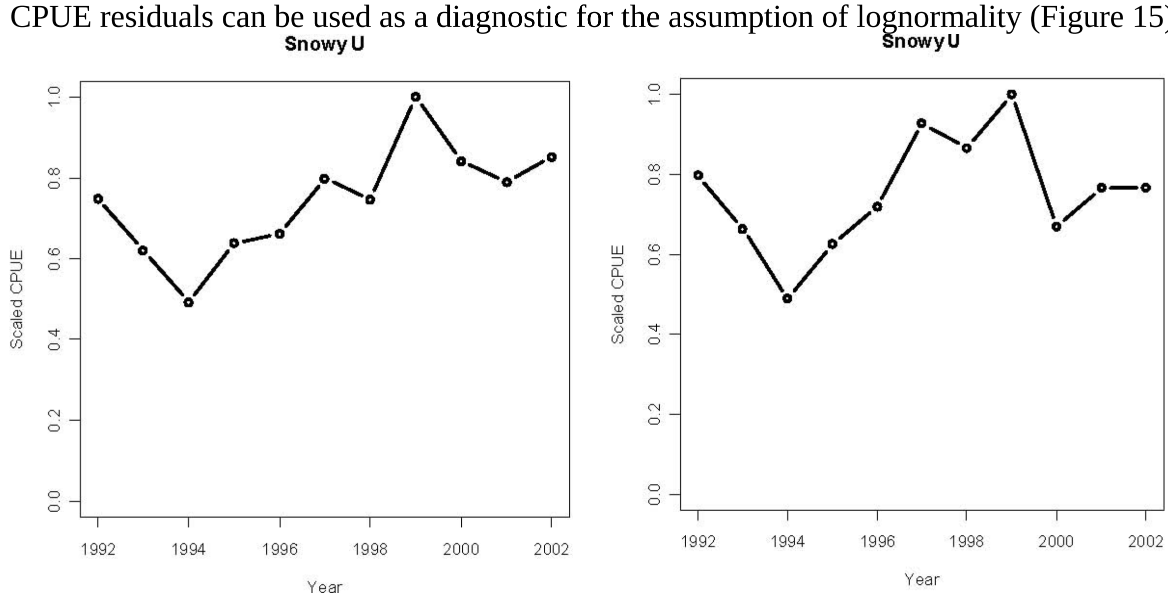


Figure 14. Snowy grouper indices of abundance (U), for all (left) and subset of trips (right).

Table 33. Fit and indices, snowy grouper.

	All vessels		Subset of vessels	
Year	fit	SE	fit	SE
1992	2.212E-04	2.048E-05	1.957E-04	2.233E-05
1993	1.832E-04	1.326E-05	1.630E-04	1.634E-05
1994	1.454E-04	1.121E-05	1.201E-04	1.131E-05
1995	1.885E-04	1.294E-05	1.535E-04	1.397E-05
1996	1.953E-04	1.482E-05	1.767E-04	1.748E-05
1997	2.358E-04	1.663E-05	2.278E-04	2.038E-05
1998	2.203E-04	1.668E-05	2.125E-04	1.867E-05
1999	2.953E-04	2.242E-05	2.455E-04	2.275E-05
2000	2.486E-04	1.821E-05	1.645E-04	1.495E-05
2001	2.331E-04	1.674E-05	1.881E-04	1.714E-05
2002	2.517E-04	1.881E-05	1.882E-04	1.875E-05

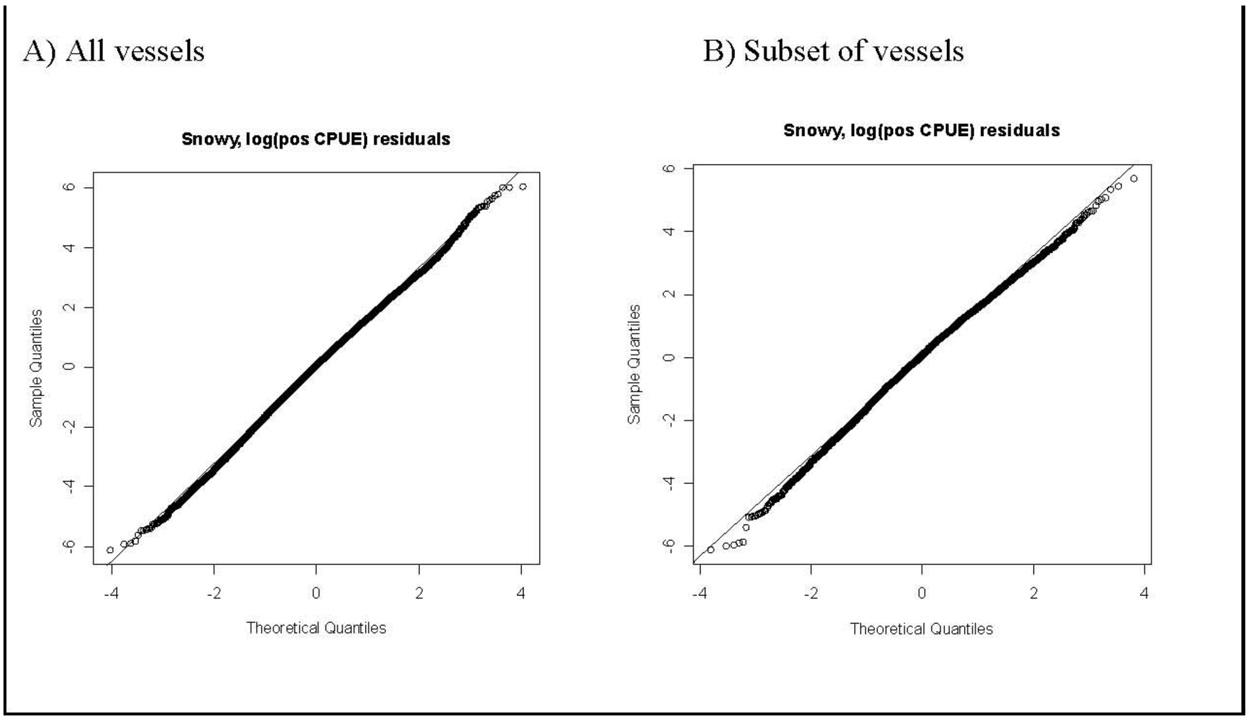


Figure 15. Snow grouper CPUE residual plots

Tilefish

Gears used to catch tilefish are shown in Table 34. Based on the gear distribution, indices were developed using two gear types- longline (L) and a lumped category of handline (H) and electric reels (E).

Table 34. Gears used to catch tilefish in the SA, 1992-2002

gear	Frequency	Percent	Cumulative Frequency	Cumulative Percent
L	3923	61.51	3923	61.51
H	2207	34.60	6130	96.11
E	173	2.71	6303	98.82
TR	65	1.02	6368	99.84
T	8	0.13	6376	99.97
GN	2	0.03	6378	100.00

To define effective effort, a gear-specific list of species was developed according to co-occurrence in the catches. The species were ranked by association index (A), and then those with the highest ranks were considered by the DW for inclusion (Table 35, Table 36). If a species were included, any trip that caught that species by the specified gear would be treated as a trip that could have caught the studied species, tilefish. Such trips constituted the analysis.

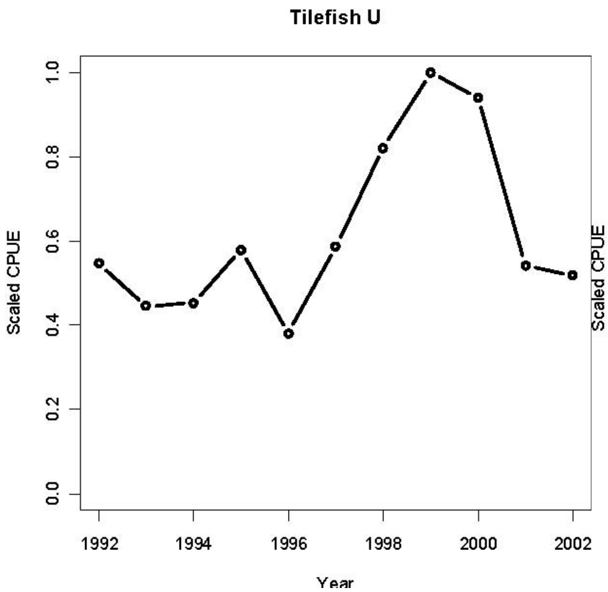
Table 35. Species assemblage for tilefish, gear=handline, electric reel

common	N(a,x)	N(x)	A	Include?
TILEFISH	2380	2380	70.03	Y
BLACK BELLIED ROSEFISH	211	1588	9.30	Y
GROUPER,YELLOWEDGE	100	1090	6.42	Y
GROUPER,SNOWY	1003	15772	4.45	Y
TILEFISH,BLUELINE	429	7747	3.88	Y

Table 36. Species assemblage for tilefish, gear=longline

common	N(a,x)	N(x)	A	Include?
TILEFISH	3923	3923	2.18	Y
HAKE,ATLANTIC,RED & WHITE	361	372	2.12	Y
EEL,AMERICAN	126	130	2.11	Y
BLACK BELLIED ROSEFISH	793	835	2.07	Y
SCORPIONFISH-THORNYHEADS	235	251	2.04	Y
LESSER AMBERJACK	173	189	2.00	N
GROUPER,YELLOWEDGE	840	931	1.97	Y
EELS,UNC	208	237	1.91	Y
TILEFISH,BLUELINE	1144	1361	1.83	Y
GROUPER,SNOWY	1853	2212	1.83	Y

Based on all trips that caught the gear-specific associated species, an index of abundance was developed (Figure 16, Table 37). A second index of abundance was developed based on a subset of trips made by those vessels consistently in the fishery. For both indices, QQ-plots of the log positive-CPUE residuals can be used as a diagnostic for the assumption of lognormality (Figure 17).



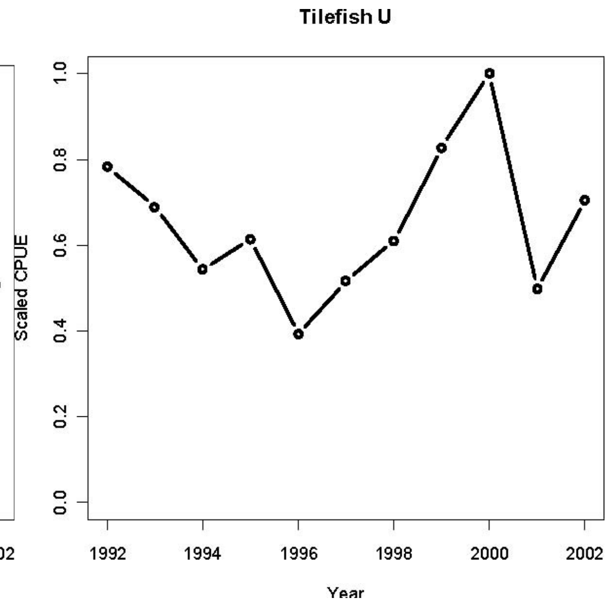


Figure 16. CPUE Indices for tilefish, all trips (left) and subset (right)

Table 37. Fit (metric tons per hook-day) and standard errors (SE) for the tilefish indices of abundance (based on all vessels or subset of vessels). SE's are computed from a bootstrap with 200 replicates.

	All vessels		Subset of vessels	
Year	**fit**	**SE**	**fit**	**SE**
1992	1.634E-04	1.970E-05	3.504E-04	5.452E-05
1993	1.438E-04	1.365E-05	2.852E-04	4.201E-05
1994	1.136E-04	1.145E-05	2.901E-04	4.223E-05
1995	1.282E-04	1.325E-05	3.707E-04	5.636E-05
1996	8.192E-05	9.246E-06	2.439E-04	3.836E-05
1997	1.078E-04	1.195E-05	3.758E-04	5.922E-05
1998	1.274E-04	1.379E-05	5.252E-04	8.800E-05
1999	1.727E-04	1.914E-05	6.400E-04	9.363E-05
2000	2.089E-04	2.068E-05	6.020E-04	8.723E-05
2001	1.042E-04	1.125E-05	3.471E-04	5.300E-05
2002	1.472E-04	1.467E-05	3.319E-04	6.157E-05

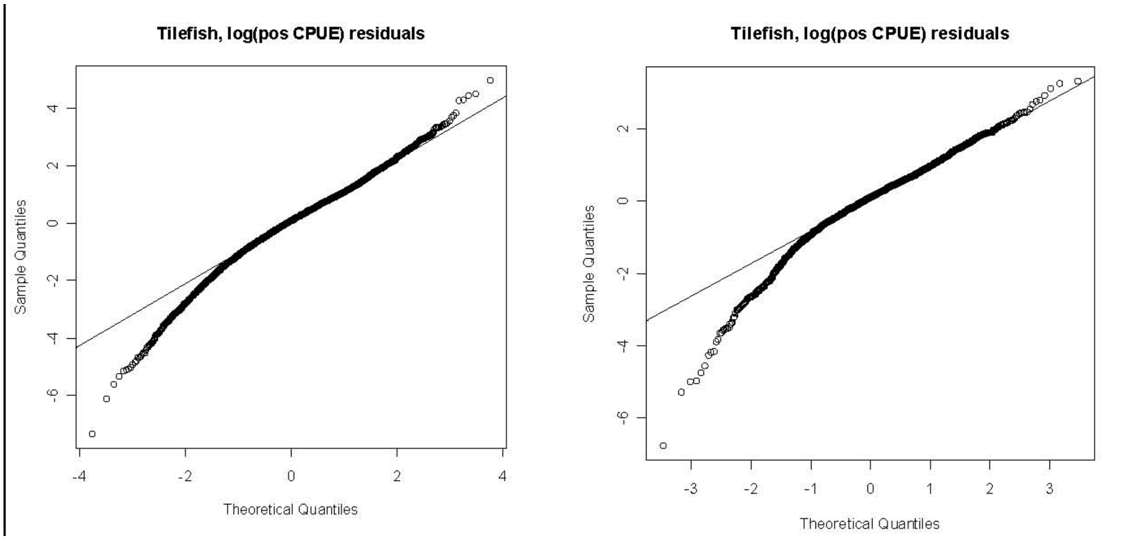


Figure 17. Tilfefish residual plots

Blueline tilefish

Gears used to catch blueline tilefish are shown in Table 38. Based on the gear distribution, indices were developed using two gear types- longline (L) and a lumped category of handline (H) and electric reels (E).

Table 38. Gears used to catch blueline tilefish in the SA, 1992-2002

gear	Frequency	Percent	Cumulative Frequency	Cumulative Percent
H	7198	78.02	7198	78.02
L	1361	14.75	8559	92.77
E	549	5.95	9108	98.72
T	61	0.66	9169	99.38
TR	41	0.44	9210	99.83
GN	16	0.17	9226	100.00

To define effective effort, a gear-specific list of species was developed according to co-occurrence in the catches. The species were ranked by association index (A), and then those with the highest ranks were considered by the DW for inclusion (Table 39 andTable 40). If a species were included, any trip that caught that species by the specified gear would be treated as a trip that could have caught the studied species, blueline tilefish. Such trips constituted the analysis.

Table 39. Species assemblage for blueline tilefish, gear=handline, electric reel

common	N(a,x)	N(x)	A	Include?
TILEFISH,BLUELINE	7747	7747	21.51	Y
BLACK BELLIED ROSEFISH	1177	1588	15.95	Y
HAKE,ATLANTIC,RED & WHITE	140	250	12.05	Y
GROUPER,YELLOWEDGE	602	1090	11.88	Y
GROUPER,SNOWY	6448	15772	8.80	Y
BARRELFISH	200	521	8.26	Y
SNAPPER,QUEEN	155	478	6.98	Y
SQUIRRELFISHES	146	550	5.71	N
BIGEYE	630	2500	5.42	N
TILEFISH,SAND	153	696	4.73	N
LESSER AMBERJACK	807	4174	4.16	N
SNAPPER,SILK	409	2186	4.03	N
TILEFISH	429	2380	3.88	Y

Table 40. Species assemblage for blueline tilefish, gear=longline

common	N(a,x)	N(x)	A	keep?
TILEFISH,BLUELINE	1361	1361	6.28	Y
SCORPIONFISH-THORNYHEADS	235	251	5.88	Y
EELS,UNC	209	237	5.54	Y
EEL,AMERICAN	110	130	5.32	Y
HAKE,ATLANTIC,RED & WHITE	314	372	5.30	Y
LESSER AMBERJACK	157	189	5.22	N
BLACK BELLIED ROSEFISH	662	835	4.98	Y
PORGY,RED,UNC	191	254	4.72	N
SNAPPER,VERMILION	120	161	4.68	N
GROUPER,YELLOWEDGE	659	931	4.45	Y
ALMACO JACK	107	161	4.18	N
GREATER AMBERJACK	288	530	3.41	N
GROUPER,SNOWY	1183	2212	3.36	Y
DOLPHINFISH	338	946	2.24	N
TILEFISH	1144	3923	1.83	Y

Based on all trips that caught the gear-specific associated species, an index of abundance was developed (Figure 18, Table 41). A second index of abundance was developed based on a subset of trips made by those vessels consistently in the fishery. For both indices, QQ-plots of the log positive-CPUE residuals can be used as a diagnostic for the assumption of lognormality (Figure 19).

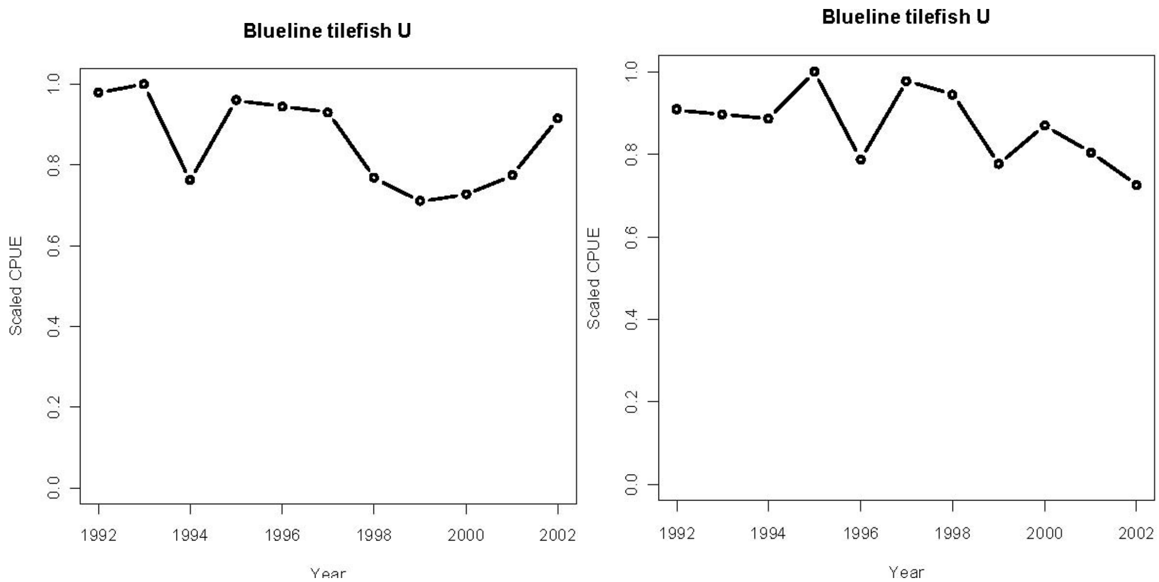


Figure 18. Blueline tilefish indices of abundance, all trips (left) and subset (right).

Table 41. Fit (metric tons per hook-day) and standard errors (SE) for the blueline tilefish indices of abundance (based on all vessels or subset of vessels). SE's are computed from a bootstrap with 200 replicates.

	All vessels		Subset of vessels	
Year	**fit**	**SE**	**fit**	**SE**
1992	3.502E-05	5.161E-06	3.525E-05	7.182E-06
1993	3.577E-05	4.466E-06	3.482E-05	5.289E-06
1994	2.726E-05	3.720E-06	3.443E-05	5.903E-06
1995	3.437E-05	4.803E-06	3.881E-05	7.385E-06
1996	3.381E-05	4.476E-06	3.059E-05	5.761E-06
1997	3.329E-05	4.425E-06	3.797E-05	6.149E-06
1998	2.746E-05	3.870E-06	3.668E-05	6.356E-06
1999	2.541E-05	3.714E-06	3.012E-05	5.444E-06
2000	2.602E-05	3.948E-06	3.376E-05	5.841E-06
2001	2.771E-05	4.113E-06	3.122E-05	5.514E-06
2002	3.275E-05	4.618E-06	2.814E-05	6.190E-06

A) All vessels B) Subset of vessels

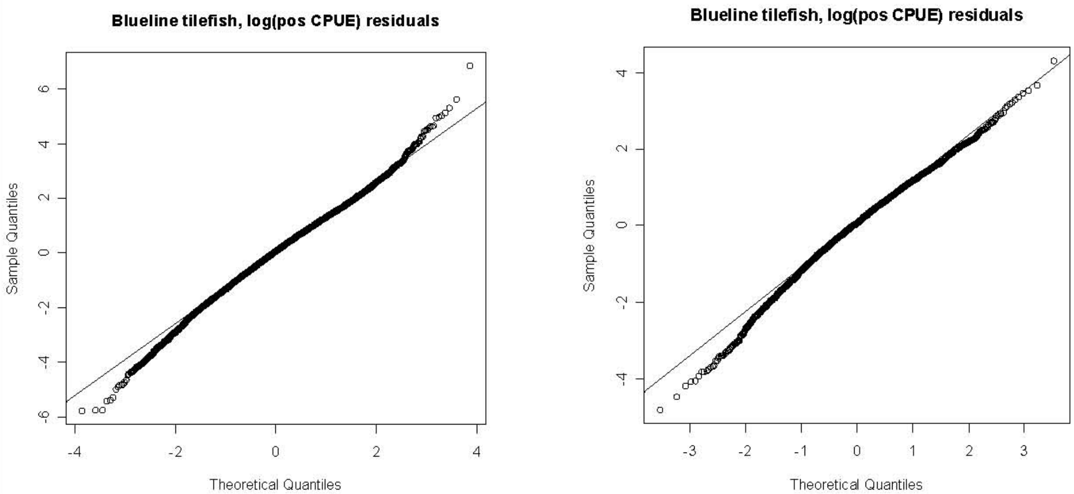


Figure 19. Blueline tilefish residual plots

Yellowedge grouper

Gears used to catch yellowedge grouper are shown in Table 42. Based on the gear distribution, indices were developed using two gear types- longline (L) and a lumped category of handline (H) and electric reels (E).

Table 42. Gears used to catch yellowedge grouper in the SA, 1992-2002

gear	Frequency	Percent	Cumulative Frequency	Cumulative Percent
H	1000	49.09	1000	49.09
L	931	45.70	1931	94.80
E	90	4.42	2021	99.21
TR	15	0.74	2036	99.95
T	1	0.05	2037	100.00

To define effective effort, a gear-specific list of species was developed according to co-occurrence in the catches. The species were ranked by association index (A), and then those with the highest ranks were considered by the DW for inclusion (Table 43, Table 44). If a species were included, any trip that caught that species by the specified gear would be treated as a trip that could have caught the studied species, yellowedge grouper. Such trips constituted the analysis.

Table 43. Species assemblage for yellowedge grouper, gear=handline, electric reel

common	N(a,x)	N(x)	A	Include?
GROUPER,YELLOWEDGE	1090	1090	152.91	Y
BLACK BELLIED ROSEFISH	147	1588	14.15	Y
TILEFISH,BLUELINE	602	7747	11.88	Y
SNAPPER,SILK	137	2186	9.58	N
GROUPER,SNOWY	774	15772	7.50	Y
TILEFISH	100	2380	6.42	Y

Table 44.. Species assemblage for yellowedge grouper, gear=longline

common	N(a,x)	N(x)	A	Inlcude?
GROUPER,YELLOWEDGE	931	931	9.18	Y
SCORPIONFISH-THORNYHEADS	221	251	8.09	Y
EEL,AMERICAN	101	130	7.14	Y
LESSER AMBERJACK	136	189	6.61	N
SNAPPER,VERMILION	108	161	6.16	N
HAKE,ATLANTIC,RED & WHITE	241	372	5.95	Y
PORGY,RED,UNC	155	254	5.60	N
EELS,UNC	136	237	5.27	Y
BLACK BELLIED ROSEFISH	419	835	4.61	Y
TILEFISH,BLUELINE	659	1361	4.45	Y
GROUPER,SNOWY	854	2212	3.55	Y
GREATER AMBERJACK	184	530	3.19	N
DOLPHINFISH	247	946	2.40	N
TILEFISH	840	3923	1.97	Y

Based on all trips that caught the gear-specific associated species, an index of abundance was developed (Figure 20, Table 45). A second index of abundance was developed (Figure 4.20B, Table 4.40) based on a subset of trips made by those vessels consistently in the fishery. For both indices, QQ-plots of the log positive-CPUE residuals can be used as a diagnostic for the assumption of lognormality (Figure 21).

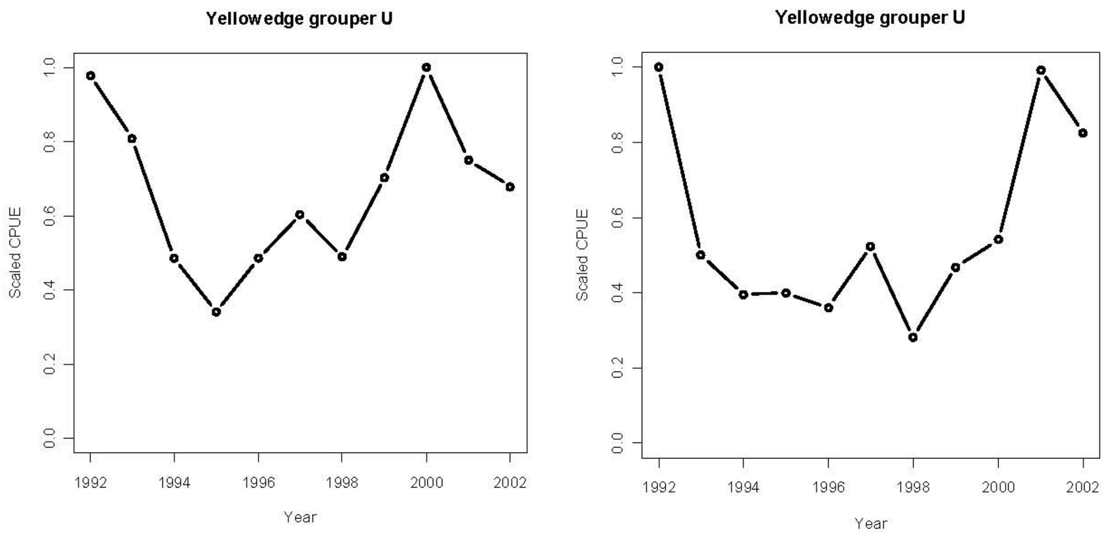


Figure 20. Yellowdge grouper CPUE, all (left) and subset (right)

Table 45. Fit (metric tons per hook-day) and standard errors (SE) for the yellowedge grouper indices of abundance (based on all vessels or subset of vessels). SE's are computed from a bootstrap with 200 replicates.

	All vessels		Subset of vessels	
Year	**fit**	**SE**	**fit**	**SE**
1992	1.119E-05	2.485E-06	7.624E-06	2.306E-06
1993	9.247E-06	1.825E-06	3.810E-06	8.318E-07
1994	5.551E-06	1.109E-06	3.009E-06	6.318E-07
1995	3.890E-06	8.398E-07	3.043E-06	5.615E-07
1996	5.546E-06	1.021E-06	2.741E-06	5.614E-07
1997	6.903E-06	1.304E-06	3.993E-06	7.929E-07
1998	5.606E-06	1.108E-06	2.141E-06	5.455E-07
1999	8.031E-06	1.541E-06	3.567E-06	7.658E-07
2000	1.143E-05	2.247E-06	4.122E-06	1.019E-06
2001	8.587E-06	1.709E-06	7.566E-06	1.899E-06
2002	7.760E-06	1.465E-06	6.287E-06	1.940E-06

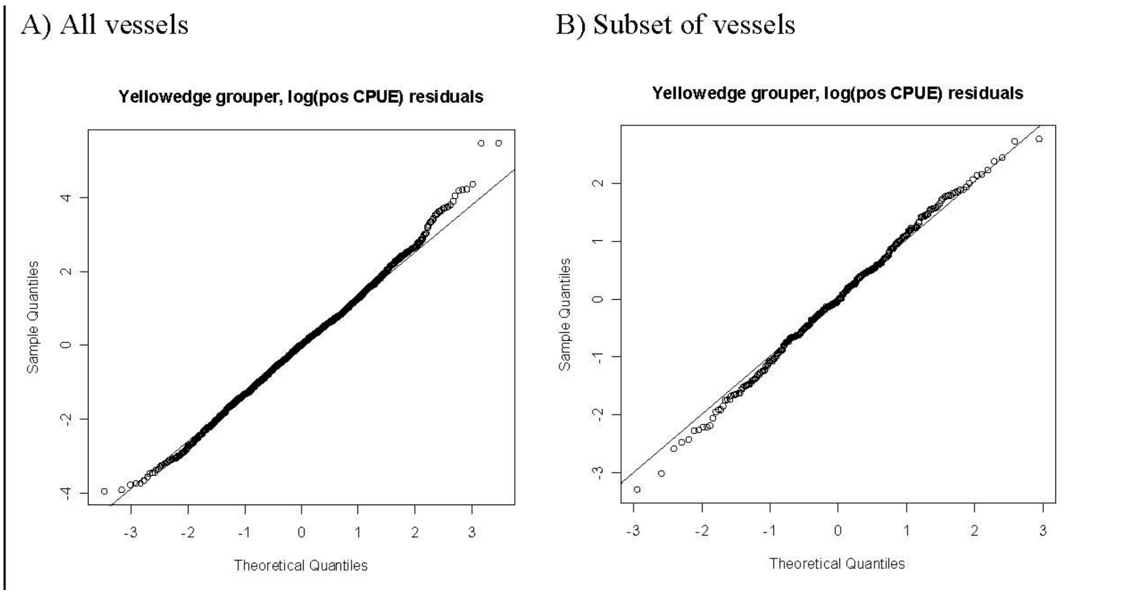


Figure 21. Yellowedge grouper residual plots

Speckled hind

Gears used to catch speckled hind are shown in Table 46. Based on the gear distribution, indices were developed using only one gear type- a lumped category of handline (H) and electric reels (E).

Table 46. Gears used to catch speckled hind in the SA, 1992-2002

gear	Frequency	Percent	Cumulative Frequency	Cumulative Percent
H	2194	94.00	2194	94.00
e	57	2.44	2251	96.44
TR	43	1.84	2294	98.29
L	27	1.16	2321	99.44
T	9	0.39	2330	99.83
GN	4	0.17	2334	100.00

To define effective effort, a gear-specific list of species was developed according to co-occurrence in the catches. The species were ranked by association index (A), and then those with the highest ranks were considered by the DW for inclusion (Table 47). If a species were included, any trip that caught that species by the specified gear would be treated as a trip that could have caught the studied species, speckled hind. Such trips constituted the analysis.

Table 47. Species assemblage for speckled hind, gear=handline, electric reel

common	N(a,x)	N(x)	A	Include?
HIND,SPECKLED	2251	2251	74.04	Y
TRIGGERFISHES	431	1301	24.53	N
SCUPS OR PORGIES,UNC	110	582	13.99	N
SHARK,UNC	179	1885	7.03	N
GRUNTS	527	5699	6.85	N
MARGATE	679	8082	6.22	N
HOGFISH	545	7165	5.63	N
LESSER AMBERJACK	313	4174	5.55	N
SCAMP	1582	22901	5.11	Y
SNAPPER,SILK	151	2186	5.11	Y
PORGY,RED,UNC	1559	25451	4.54	N
WAHOO	149	2462	4.48	N
SNAPPER,VERMILION	1731	30101	4.26	Y
BIGEYE	136	2500	4.03	N
PORGY,JOLTHEAD	366	6850	3.96	N
SNAPPER,RED	1078	20368	3.92	N
TRIGGERFISH,GRAY	1014	20815	3.61	Y
BANDED RUDDERFISH	178	3876	3.40	N
SEA BASSE,ATLANTIC,BLACK,UNC	1005	22178	3.36	N
GROUPER,RED	1240	27681	3.32	N
ALMACO JACK	349	8308	3.11	N
DOLPHINFISH	739	18608	2.94	N
GROUPER,SNOWY	609	15772	2.86	Y
GROUPER,GAG	948	27211	2.58	Y

Based on all trips that caught the gear-specific associated species, an index of abundance was developed (Figure 22, Table 48). A second index of abundance was developed based on a subset of trips made by those vessels consistently in the fishery. For both indices, QQ-plots of the log positive-CPUE residuals can be used as a diagnostic for the assumption of lognormality (Figure 23).

Amendment 7 to the Snapper-grouper Fishery Management Plan allowed only one speckled hind per vessel, starting in 1994. Therefore, the speckled hind indices exclude years 1992 and 1993. The second index uses vessels that were in the fishery for at least six years (rather than at least nine years as for the other species). This included five vessels.

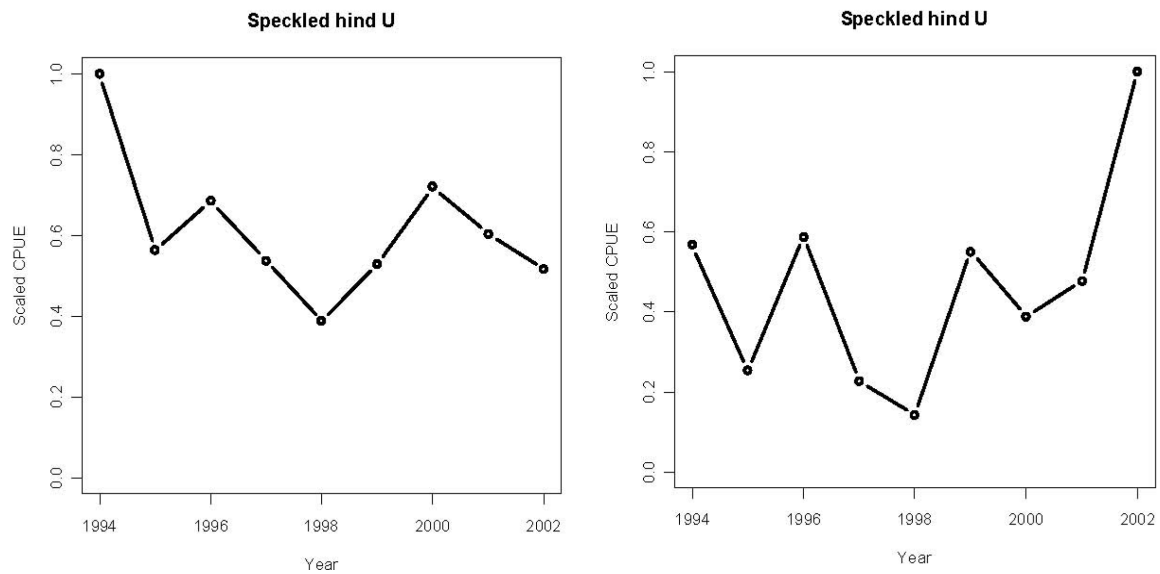


Figure 22. Speckled hind cpue, all trips (left) and subset (right).

Table 48. Fit (metric tons per hook-day) and standard errors (SE) for the speckled hind indices of abundance (based on all vessels or subset of vessels). SE's are computed from a bootstrap with 200 replicates.

	All vessels		Subset of vessels	
Year	**fit**	**SE**	**fit**	**SE**
1994	2.211E-05	4.176E-06	1.107E-04	2.505E-04
1995	1.246E-05	2.521E-06	4.951E-05	3.328E-05
1996	1.515E-05	3.121E-06	1.145E-04	6.466E-05
1997	1.188E-05	2.313E-06	4.441E-05	2.029E-05
1998	8.575E-06	1.807E-06	2.785E-05	1.564E-05
1999	1.167E-05	2.593E-06	1.073E-04	5.329E-05
2000	1.593E-05	3.361E-06	7.580E-05	5.180E-05
2001	1.336E-05	2.586E-06	9.299E-05	4.320E-05
2002	1.142E-05	2.394E-06	1.949E-04	1.444E-04

A) All vessels B) Subset of vessels

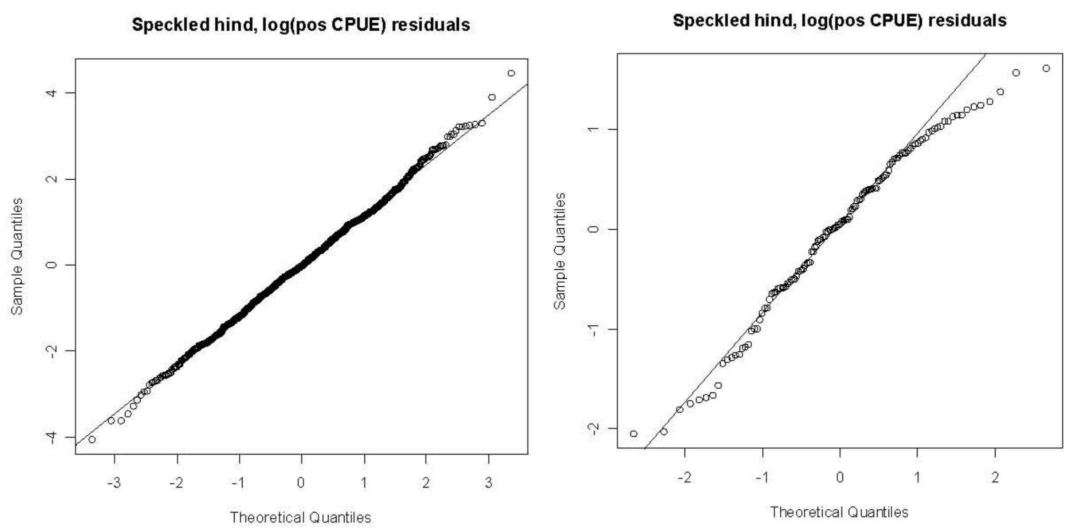


Figure 23 . Speckled hind residual plots

4. Recreational

4.1 Marine Recreational Fisheries Statistics Survey (MRFSS)

Contact person: Dr. Doug Vaughan, NMFS, Beaufort Laboratory, Beaufort, NC.

4.1.1 Overview

The Marine Fisheries Statistics Survey (MRFSS) collects information on size, number, and fishing effort for fish captured from the shore, charter boat, and private boat sectors of the recreational fishery along the Atlantic coast.

4.1.2 Landings

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 1 summarizes percent of total landings by these three categories for the eight deep water complex species considered in this report. 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 (A+B1+B2) by mode are summarized by species in Tables A1-A8. Plots of total landings with plus/minus 1 standard deviation for combined charter and private boats for 1981-2002 are shown for snowy grouper (Figure A1), tilefish (Figure A2), speckled hind (Figure A3), warsaw grouper (Figure A4), and blueline tilefish (Figure A5; charter boat only since 1993). Minimal landings information are available for queen snapper, misty grouper, and yellowedge grouper. Tilefish and speckled hind landings include a small number from the shore mode. There is one cell for this mode for tilefish (year=2000, wave=3, state=FL, area=<3 mi). There are three cells for this mode for speckled hind (1: year=1990, wave=4, state=NC, area=<3 mi; 2: year=1994, wave=5, state=NC, area=inland; and 3: year=1999, wave=1, state=FL, area=<10 mi).

Working Group Issue: Is it appropriate to drop shore based catches from the analysis? It was pointed out during the presentation to the Panel that there were only four data cells with landings data from the shore mode. The working group felt that it was appropriate to discard these data and limit the landings to charter and private mode only. The species of interest are deepwater species by nature and any shore-based catches are highly likely to be misreported.

Panel Response: There was no opposition to deleting shore data.

Table 49. Years with positive landings, percent of total landings by catch type, and percent of estimated type A fish with available mean weight for eight species in Deep Water Complex.

Deep Water Complex Species	**Years with Landings (out of 22)**	**Total Landings Ratios: *A:B1:B2* (%)**	**%*Type A* Landings with Mean Weight**
Snowy grouper	19	78/11/11	81.9
Tilefish	18	57/38/5	71.1
Speckled hind	17	31/0/69	54.9
Warsaw grouper	22	78/3/19	97.8
Blueline tilefish	7	100/0/0	87.6
Queen snapper	6	97/0/3	99.9
Misty grouper	2	62/0/38	100.0
Yellowedge grouper	5	100/0/0	64.0

Table 50. Estimated total landings (A+B1+B2) of Snowy grouper by year with proportional standard error by mode and total from the MRFSS, 1981-2002.

Year	Charter Boats A+B1+B2	Charter Boats PSE	Private Boats A+B1+B2	Private Boats PSE	Total A+B1+B2	Total PSE
1981	0	0%	17647	54%	17647	54%
1982	4652	65%	365	0%	5017	61%
1983	4723	46%	2879	100%	7602	47%
1984	0	0%	1648	77%	1648	77%
1985	0	0%	0	0%	0	0%
1986	0	0%	0	0%	0	0%
1987	513	53%	4841	63%	5354	57%
1988	112	43%	2318	100%	2430	95%
1989	0	0%	0	0%	0	0%
1990	0	0%	1601	84%	1601	84%
1991	97	65%	0	0%	97	65%
1992	670	48%	1719	71%	2388	53%
1993	123	66%	8444	100%	8567	99%
1994	867	96%	0	0%	867	96%
1995	2718	77%	5836	85%	8554	63%
1996	0	0%	1567	64%	1567	64%
1997	146	100%	17872	44%	18018	44%
1998	570	71%	0	0%	570	71%
1999	3761	45%	4333	69%	8095	43%
2000	1286	55%	1133	100%	2419	55%
2001	7034	56%	3220	70%	10254	45%
2002	1643	55%	505	100%	2148	48%

Table 51. Estimated total landings (A+B1+B2) of tilefish (golden) by year with proportional standard error by mode and total from the MRFSS, 1981-2002.

	Charter Boats		Private Boats		Total	
Year	A+B1+B2	PSE	A+B1+B2	PSE	A+B1+B2	PSE
1981	0	0%	0	0%	0	0%
1982	0	0%	0	0%	0	0%
1983	367	100%	0	0%	367	100%
1984	0	0%	1648	77%	1648	77%
1985	577	100%	20384	60%	20960	59%
1986	46	100%	0	0%	46	100%
1987	33	100%	0	0%	33	100%
1988	0	0%	900	56%	900	56%
1989	0	0%	0	0%	0	0%
1990	48	49%	0	0%	48	49%
1991	65	65%	0	0%	65	65%
1992	1062	62%	706	100%	1768	55%
1993	0	0%	700	0%	700	100%
1994	2607	41%	0	0%	2607	41%
1995	0	0%	0	0%	0	0%
1996	45	100%	1069	100%	1114	96%
1997	750	72%	6165	72%	6915	65%
1998	472	101%	0	0%	472	101%
1999	1952	62%	0	0%	1952	62%
2000	732	50%	3164	78%	3896	64%
2001	2464	54%	687	73%	3150	45%
2002	2036	45%	0	0%	2036	45%

Table 52. Estimated total landings (A+B1+B2) of speckled hind by year with proportional standard error by mode and total from the MRFSS, 1981-2002.

	Charter Boats		Private Boats		Total	
Year	A+B1+B2	PSE	A+B1+B2	PSE	A+B1+B2	PSE
1981	0	0%	0	0%	0	0%
1982	0	0%	0	0%	0	0%
1983	0	0%	0	0%	0	0%
1984	0	0%	0	0%	0	0%
1985	0	0%	0	0%	0	0%
1986	189	100%	0	0%	189	100%
1987	114	47%	1260	71%	1374	65%
1988	98	80%	0	0%	98	80%
1989	56	44%	0	0%	56	44%
1990	0	0%	893	71%	893	71%
1991	0	0%	2896	59%	2896	59%
1992	19	44%	6768	0%	6787	39%
1993	106	27%	0	0%	106	27%
1994	543	40%	549	40%	1092	28%
1995	50	100%	2048	89%	2098	87%
1996	618	93%	2083	85%	2701	69%
1997	1012	59%	0	0%	1012	59%
1998	425	71%	592	71%	1017	51%
1999	292	100%	3446	38%	3738	36%
2000	180	74%	7938	81%	8118	79%
2001	289	58%	442	100%	731	65%
2002	0	0%	3633	38%	3633	38%

Table 53. Estimated total landings (A+B1+B2) of warsaw grouper by year with proportional standard error by mode and total from the MRFSS, 1981-2002.

	Charter Boats		Private Boats		Total	
Year	A+B1+B2	PSE	A+B1+B2	PSE	A+B1+B2	PSE
1981	178	100%	0	0%	178	100%
1982	804	100%	3608	50%	4412	45%
1983	18986	74%	17789	68%	36775	50%
1984	530	52%	5231	72%	5761	66%
1985	756	55%	131653	50%	132409	50%
1986	0	0%	140	61%	140	61%
1987	3074	100%	1577	40%	4651	67%
1988	1609	63%	4049	71%	5658	54%
1989	0	0%	26398	31%	26398	31%
1990	48	49%	259	100%	307	85%
1991	533	100%	6803	41%	7336	39%
1992	150	53%	554	21%	704	20%
1993	610	100%	0	0%	610	100%
1994	960	48%	1671	71%	2631	48%
1995	3084	54%	942	100%	4027	47%
1996	661	88%	2470	51%	3131	44%
1997	513	101%	785	100%	1298	72%
1998	1020	75%	1461	66%	2481	50%
1999	762	50%	1378	58%	2139	41%
2000	654	45%	692	73%	1346	44%
2001	204	69%	0	0%	204	69%
2002	1083	45%	0	0%	1083	45%

Table 54. Estimated total landings (A+B1+B2) of blueline tilefish by year with proportional standard error from charter boats from the MRFSS, 1993-2002.

	Charter Boats		Private Boats		Total	
Year	A+B1+B2	PSE	A+B1+B2	PSE	A+B1+B2	PSE
1993	2792	74%	0	0%	2792	74%
1994	0	0%	0	0%	0	0%
1995	2185	99%	0	0%	2185	99%
1996	312	100%	0	0%	312	100%
1997	6560	100%	0	0%	6560	100%
1998	0	0%	0	0%	0	0%
1999	0	0%	0	0%	0	0%
2000	26	98%	0	0%	26	98%
2001	1971	99%	0	0%	1971	99%
2002	79	100%	349	100%	428	84%

Table 55. Estimated total landings (A+B1+B2) of queen snapper by year with proportional standard error by mode and total from the MRFSS, 1982, 1989, 1996, 1999, 2001-2002.

	Charter Boat		Private Boat		Total	
Year	A+B1+B2	PSE	A+B1+B2	PSE	A+B1+B2	PSE
1982			341	100%	341	100%
1989	24357	86%			24357	86%
1996			1080	100%	1080	100%
1999	883	72%			883	72%
2001	18	94%			18	94%
2002			319	100%	319	100%

Table 56. Estimated total landings (A+B1+B2) of misty grouper by year with proportional standard error by mode (private boats only) from the MRFSS, 1987 and 1995.

Year	A+B1+B2	PSE
1987	2450	59%
1995	1516	100%

Table 57. Estimated total landings (A+B1+B2) of yellowedge grouper by year with proportional standard error by mode and total from the MRFSS, 1988, 1997, 2000-2001.

	Charter Boat		Private Boat		Total	
Year	A+B1+B2	PSE	A+B1+B2	PSE	A+B1+B2	PSE
1988			1101	59%	1101	59%
1997	81	100%			81	100%
2000	23	103%			23	103%
2001	85	99%	690	100%	775	90%

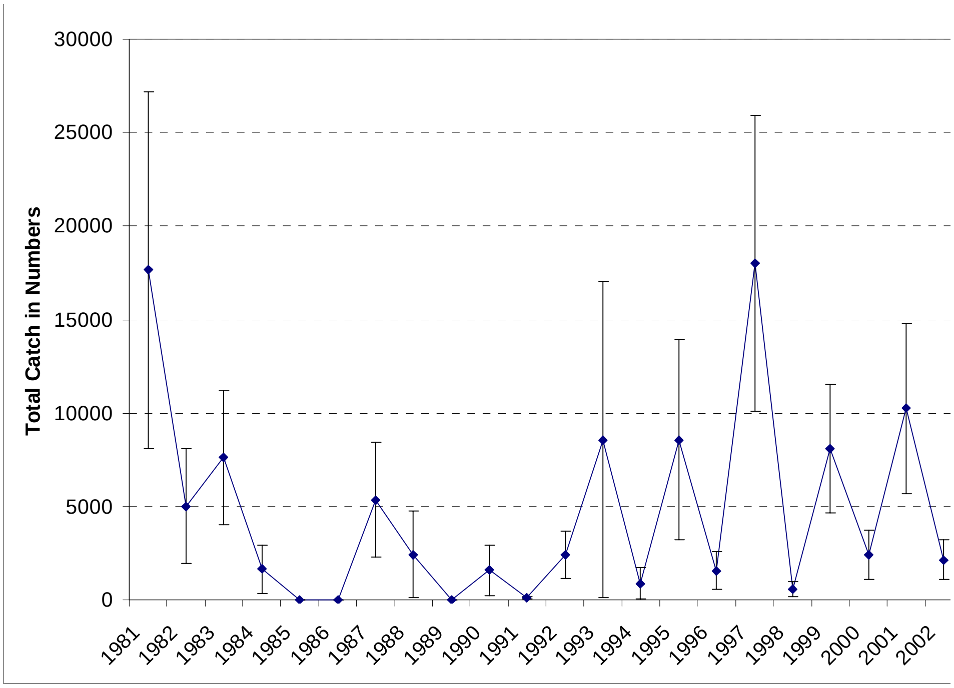


Figure 24. Snowy grouper private - charter catch

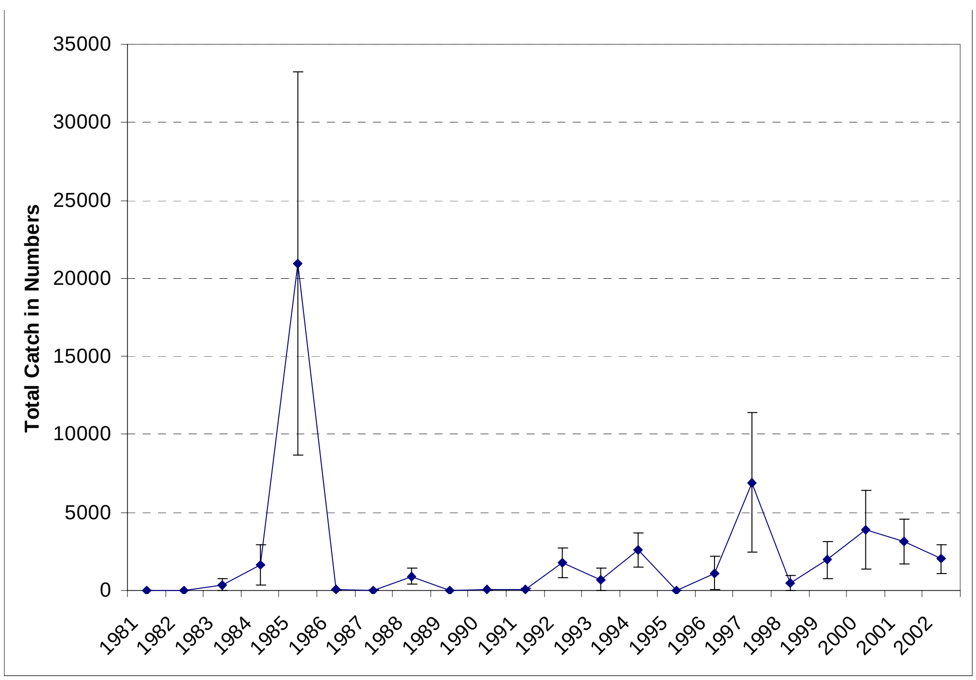


Figure 25. Tilefish private-charter catch

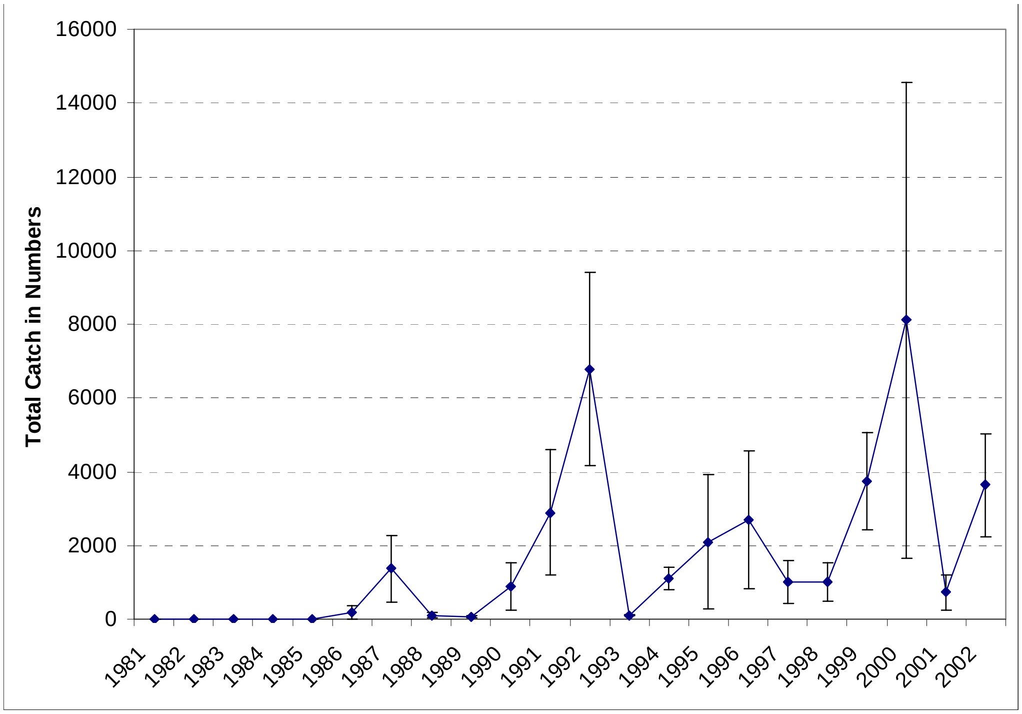


Figure 26. Speckled hind Private-Charter catch

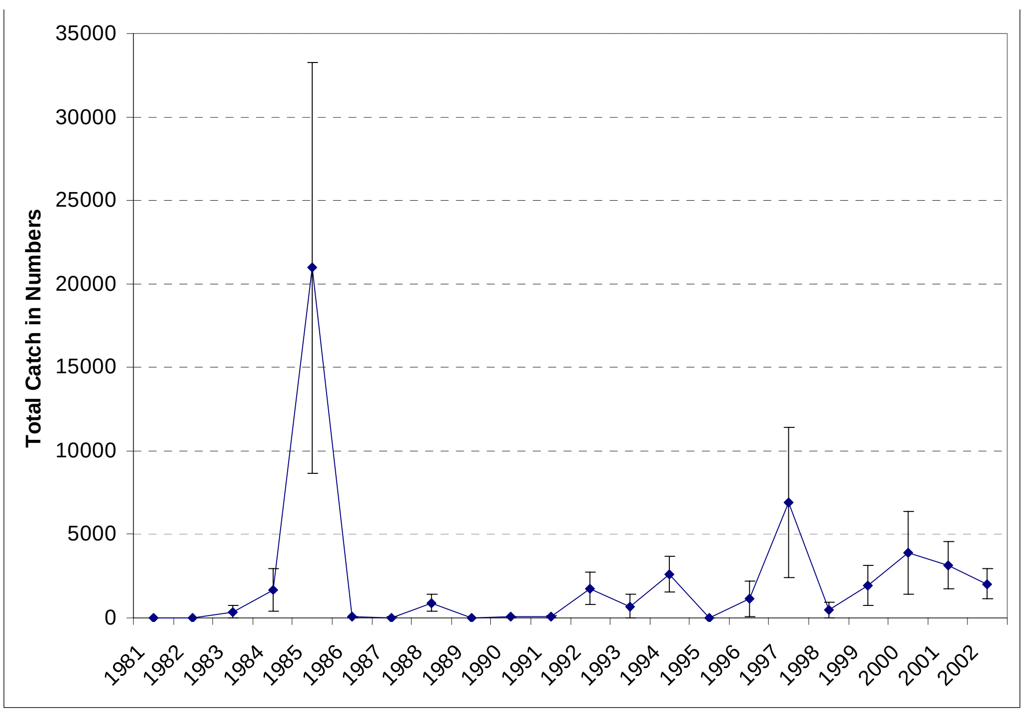


Figure 27. Warsaw Grouper private- charter catch

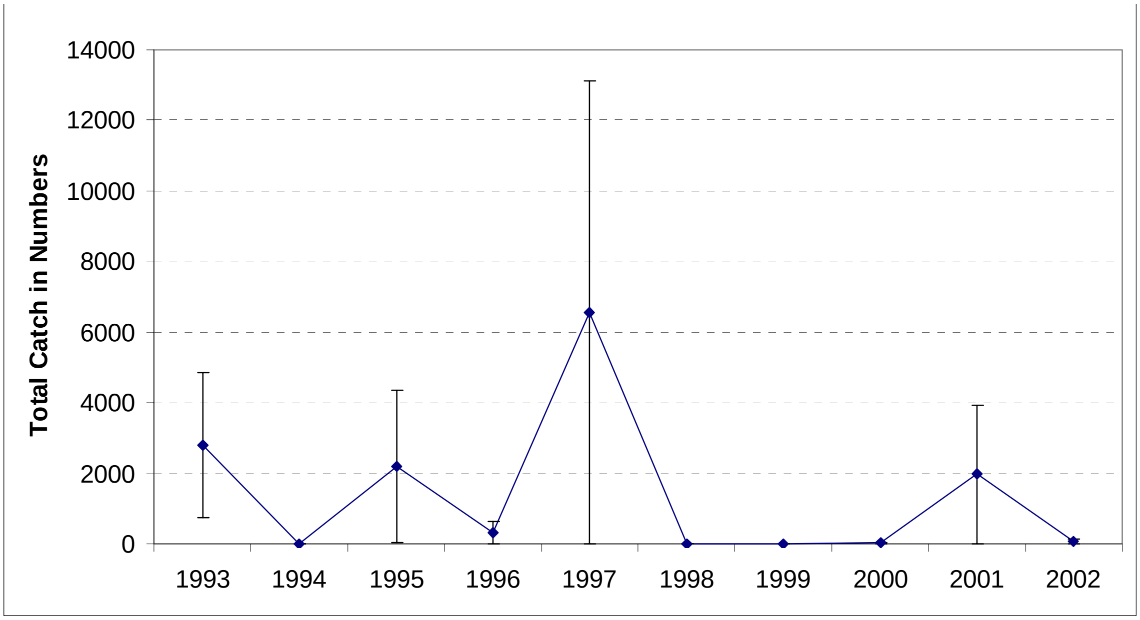


Figure 28. Blueline tilefish charter catch

Working Group Issue: It appears that the rarity of these species in the MRFSS data results in landings estimates (based on expansion factors) which indicate an unrealistic year to year variation. There was a proposal to consider smoothing the landings estimates.

Panel Response: The DW panel recommended the landings be left as is (unsmoothed) because they ultimately only constitute a small fraction of the total landings for these species. Furthermore, the use of any smoothing process will not allow for a proper treatment of the annual estimated error range of the estimates.

Landings in Biomass

Obtaining estimates of landings in biomass can be difficult to estimate when mean weight of fish by cell [year, wave (2-month period), mode of fishing, and area fished (distance from shore)] are unavailable. If mean weight is unavailable for the cell, then a missing value (or zero) is given as the mean weight, and when the landings in weight are accumulated across cells, then the weight of landings for that cell are zero. The percent of landings in numbers representing type A fish for which a mean weight is available for expanding is given in Table 49. By definition, no mean weight is available for *type B1* and *B2* fish. It is reasonable to use the mean weight of *type A* fish for *type B1* fish. It is more problematic as to what to use to represent the mean weight for *type B2* fish, especially when bag and/or size limits are in effect.

Working Group Issue: A proposal was put forth to consider using the headboat mean weights for converting the MRFSS landings in numbers into weight estimates.

Panel Response: There was no opposition to using headboat weights.

4.1.3 Discards

Discards are represented by the type B2 fish (see above).

4.1.4 Length and Weight Samples

Length Frequency Data:

The sample size of fish from the Deep Water Complex that were intercepted for measurement (*type A*) by the MRFSS for the period 1981-2002 are summarized in Table 58. Length frequency distributions were developed from the available lengths from charter and/or private boats as weighted by the landings in numbers (*A+B1*). Figures developed from these data are summarized for snowy grouper (Figure 24), tilefish (Figure 25), speckled hind (Figure 26), warsaw grouper (Figure 27), and blueline tilefish (Figure 28; charter boat only). Minimal data were available for queen snapper, misty grouper and yellowedge grouper (less than 5 fish total for 1981-2002).

Working Group Issue: The sample sizes are too small to determine selectivity for each species from the MRFSS data alone. The workgroup proposed merging these data with the headboat data to assess selectivity. The combined selectivity estimate would then be applied to both the MRFSS and headboat data for each species.

Panel Response: There was no opposition to merging data sets. Both fisheries use hook and line gear for catching the deepwater species and are also likely to be fishing in similar areas.

Table 58. Sample sizes of intercepted fish from the Deep Water Complex available for measurement (type A fish).

Year	Snowy grouper	Tilefish	Speckled hind	Warsaw grouper	Blueline tilefish	Queen snapper	Misty grouper	Yellow-edge grouper	Total
1981	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0
1983	7	2	0	14	0	0	0	0	23
1984	1	1	0	3	0	0	0	0	5
1985	0	1	0	13	0	0	0	0	14
1986	0	0	1	1	0	0	0	0	2
1987	1	1	1	7	0	0	2	0	12
1988	2	1	0	3	0	0	0	1	7
1989	0	0	1	13	0	0	0	0	14
1990	1	1	1	2	0	0	0	0	5
1991	3	2	0	5	0	0	0	0	10
1992	0	0	0	4	0	0	0	0	4
1993	1	0	0	0	2	0	0	0	3
1994	1	2	3	3	0	0	0	0	9
1995	10	0	0	6	2	0	0	0	18
1996	2	1	2	2	7	1	0	0	15
1997	8	14	2	1	15	0	0	1	41
1998	3	3	1	5	0	0	0	0	12
1999	13	2	1	5	0	2	0	0	23
2000	1	5	3	4	1	0	0	0	14
2001	32	18	3	2	15	0	0	1	71
2002	18	28	0	17	2	0	0	0	65
Total	104	82	19	110	44	3	2	3	367

4.1.5 *Catch Rates (CPUE/Abundance Indices)*

Working Group Issue: There does not appear to be sufficient data to calculate CPUE indices from the MRFSS data.

Panel Response: Panel agreed that any computed CPUE index is likely to be noisy, incomplete in some years, and not reflect any trends in the fishery.

4.1.6 *Catch-at-Age/Length*

There is insufficient data to obtain catch-at-age/length information from the MRFSS data.

4.2 South Atlantic Headboat Survey

Contact person: Dr. Erik H. Williams, NMFS, Beaufort Laboratory, Beaufort, NC.

4.2.1 Overview

For a complete description of the methods used in estimating catches and fishing effort of the Southeast United States headboat fleet see the draft report by Dixon and Huntsman, "Estimating Catches and Fishing Effort of the Southeast United States Headboat Fleet, 1972-1982", National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Beaufort Laboratory, Beaufort, North Carolina.

Deepwater Species Review

The species selected for this analysis include the following:

Table 59. Deepwater species selected for this analysis with their corresponding code used in the headboat survey database

code	common name	scientific name
20	Speckled Hind	*Epinephelus drummondhayi*
21	Snowy Grouper	*Epinephelus niveatus*
23	Warsaw Grouper	*Epinephelus nigritus*
25	Yellowedge Grouper	*Epinephelus flavolimbatus*
40	Blueline Tilefish	*Caulolatilus microps*
43	Tilefish	*Lopholatilus chamaeleonticeps*
59	Misty Grouper	*Epinephelus mystacinus*
260	Queen Snapper	*Etelis oculatus*

Geographic Coverage

1972 - 1975 = Cape Hatteras, NC - Charleston, SC 1/
1976 - 1977 = Cape Hatteras, NC - Cape Canaveral, FL 2/
1978 - 2002 = Cape Hatteras, NC - Key West, FL (includes Dry Tortugas) 3/

1/ This period did not include vessels south of Charleston, SC, as did 1976 - 2002.
2/ The 1976 - 1977 definition of Area 8 was only as far south as Cape Canaveral, FL, while the 1978 - 2002 definition of Area 8 was from Daytona Beach, FL - Sebastian, FL.
3/ Coverage of South Florida and Florida Keys, by port agents, was very sparse and only part- time in the Florida Keys, 1978 - 1980, so landings and effort estimates were imprecise.

Working Group Issue: From 1972 through 1977, the headboat survey was not conducted in the entire South Atlantic. For those years, we know that the landings reported from the headboat fishery are underestimated and provide data primarily for North and South Carolina only. The question arose whether we should estimate a rough percentage for the underestimation. If you review the data for species with substantial landings from later years, you may be able to break it down by region (NC and

SC compared to GA and FL) and estimate a correction factor for the years in which you do not have data in the southern region.

Panel Response: There was no opposition to reporting that the landings are an underestimate due to incomplete coverage. If there was a difference in the species composition between the areas, especially one that changed over time, a correction for the underestimate is likely inappropriate. The number of unaccounted headboats operating during the early years is completely unknown. Furthermore, since the portion of landings contributed by the headboats is small, this underestimation is likely not significant for the deepwater species.

4.2.2 Landings

All landings estimates were calculated by hand prior to 1980. A computer was used in 1980 and 1981, to sum species by vessel/month and calculate mean weights of common species, but all expansions for missing trips and means weights of species with small sample size, were still calculated by hand. From 1981 - 2002, a computer program was used for all estimates except mean weights of rare species.

Landings data by species are not in computer files prior to 1981 and therefore, are unavailable for many species. Some previous reports included data by species, so landings data were available for snowy grouper, speckled hind, and blueline tilefish, 1973 - 1980.

For 1973 - 1980, landings data were unavailable for warsaw grouper and yellowedge grouper. The 1973 - 1980 estimates of grouper landings were grouped into *Mycteroperca* species and *Epinephelus* species. The following formula was used to estimate the 1973 - 1980 landings of these two species:

(Rep Wgr / Rep *E).* x (Est of *E.)* 1/
and
(Rep Yegr / Rep *E.)* x (Est of *E.)* 1/

1/ Rep Wgr = Number of warsaw grouper reported on trip reports
Rep *E.* = Number of *Epinephelus* groupers reported on trip reports
Est of *E.* = Number of *Epinephelus* groupers estimated (correcting for missing trips)
Rep Yegr = Number of yellowedge grouper reported on trip reports

For 1973 - 1975, the data were combined to produce one estimate of the North Carolina and South Carolina landings. For 1976 - 1980, the data were combined to produce an estimate of NC and SC landings, and a separate estimate of the Georgia and north Florida landings. No estimates were calculated for south Florida and the Florida Keys.

The calculated estimates, using the above equation, were somewhat imprecise. For three of the estimates, the estimated number landed were smaller (in parentheses) than the reported number landed. They were: (1) 1978 NC/SC Warsaw grouper (54) 58
(2) 1978 NC/SC Yellowedge grouper (322) 354
(3) 1979 NC/SC Warsaw grouper (83) 136

For these three estimates, the reported numbers were used in the data series.

To get an associated weight of landed fish for the Warsaw and yellowedge species before 1980 and 1981, respectively, the average weight of landed fish from 1980-1984 and 1981-1985 for Warsaw and yellowedge, respectively, were multiplied by the number estimated above. This extended the time series of landings back to 1972 and 1973 for Warsaw and yellowedge, respectively.

Note that reported landings before 1978 do not include all headboats which may have been in operation in the South Atlantic (see Geographic Coverage above). No correction factor has been determined at this time to account for any possible headboats operating in non-coverage areas from 1972-1977.

Working Group Issue: Prior to 1980, a portion of the grouper species landings were not available as species specific data, but rather were grouped together with other grouper species. Because of this, a ratio method was used to estimate species specific landings. The working group wanted to bring attention to this estimation method and determine whether the Panel thought this was appropriate.

Panel Response: As an alternate option it was suggested to truncate the data to only 1980-present to eliminate the grouped data. However, the issue becomes more complicated when you take into account that pre-1980, some of the grouper data were species specific while some of it was grouped. Is there a bias towards which species are grouped and if there is a bias, is consistent through the years? The reporting tended to be across a vessel (all grouped or none), not necessarily across varying species within one vessel. For these reasons, the group accepted the ratio method for ungrouping the grouped groupers.

Table 60. Estimated total number of deepwater species landed from the South Atlantic headboat fishery.

Year	Speckled Hind	Snowy Grouper	Warsaw Grouper	Yellowedge Grouper	Blueline Tilefish	Tilefish	Misty Grouper	Queen Snapper
1972	4387	1035	243	-	-	-	-	-
1973	8189	636	44	1001	-	-	-	-
1974	4829	1793	84	522	3389	-	-	-
1975	3049	1039	368	380	1576	-	-	-
1976	2544	2486	104	373	3141	-	-	-
1977	2486	1157	110	92	1267	-	-	-
1978	1776	797	207	354	1450	-	-	-
1979	1691	1142	151	683	360	-	-	-
1980	1069	2664	491	520	3606	-	-	-
1981	844	3046	326	241	1621	94	-	-
1982	2319	2243	334	344	2566	12	-	-
1983	2189	3895	675	421	3015	-	-	-
1984	1476	570	283	87	389	-	-	-
1985	2735	1108	455	8	649	-	-	-
1986	2590	1338	519	17	679	-	1	-
1987	2022	1134	249	105	475	10	-	-
1988	2138	953	288	12	436	-	-	-
1989	793	1118	70	26	432	10	-	-
1990	649	677	66	32	209	14	-	-
1991	406	529	74	31	319	-	-	-
1992	349	238	74	8	1393	20	-	1
1993	314	325	353	27	151	-	1	1
1994	228	438	287	22	98	8	-	-
1995	175	395	229	22	254	-	-	-
1996	188	722	119	52	2534	-	1	-
1997	148	411	190	5	140	190	-	-
1998	613	172	109	34	94	-	2	-
1999	668	142	74	-	31	5	-	-
2000	455	178	95	49	23	-	-	-
2001	687	411	111	5	166	-	-	-
2002	268	200	200	7	157	-	-	-

Table 61. Estimated total weight (mt) of deepwater species landed from the South Atlantic headboat fishery.

Year	Speckled Hind	Snowy Grouper	Warsaw Grouper	Yellowedge Grouper	Blueline Tilefish	Tilefish	Misty Grouper	Queen Snapper
1972	18.33	5.12	1.94	-	-	-	-	-
1973	27.62	4.98	0.35	2.75	-	-	-	-
1974	17.98	9.58	0.67	1.43	7.52	-	-	-
1975	12.02	6.16	2.93	1.04	4.66	-	-	-
1976	11.20	11.16	0.83	1.02	8.11	-	-	-
1977	6.72	3.47	0.88	0.25	2.97	-	-	-
1978	4.10	4.58	1.65	0.97	3.98	-	-	-
1979	5.84	4.48	1.20	1.88	0.82	-	-	-
1980	3.10	9.00	7.73	1.43	7.77	-	-	-
1981	1.27	7.65	1.76	0.96	3.29	0.187	-	-
1982	4.96	7.52	1.94	0.60	4.21	0.008	-	-
1983	3.82	10.65	4.44	1.38	6.08	-	-	-
1984	1.66	1.10	1.79	0.28	0.59	-	-	-
1985	4.34	1.96	2.16	0.01	1.18	-	-	-
1986	3.31	1.92	4.77	0.04	0.99	-	0.004	-
1987	3.09	2.00	1.59	0.44	0.98	0.036	-	-
1988	3.76	1.49	1.69	0.02	0.54	-	-	-
1989	1.47	1.83	0.39	0.04	0.20	0.006	-	-
1990	0.52	1.29	0.34	0.04	0.34	0.003	-	-
1991	0.74	0.99	0.49	0.04	0.36	-	-	-
1992	0.57	0.40	0.62	0.02	1.26	0.012	-	0.0005
1993	0.25	0.49	2.12	0.05	0.11	-	0.003	0.0007
1994	0.23	0.33	2.05	0.12	0.07	0.005	-	-
1995	0.41	0.33	1.68	0.11	0.26	-	-	-
1996	0.18	1.55	0.82	0.23	5.30	-	0.002	-
1997	0.14	1.00	1.80	0.01	0.12	0.439	-	-
1998	1.02	0.59	1.12	0.12	0.12	-	0.004	-
1999	0.38	0.23	0.59	-	0.03	0.004	-	-
2000	0.37	0.23	0.97	0.08	0.01	-	-	-
2001	0.38	0.43	0.93	0.02	0.10	-	-	-
2002	0.58	0.26	0.26	0.02	0.65	-	-	-

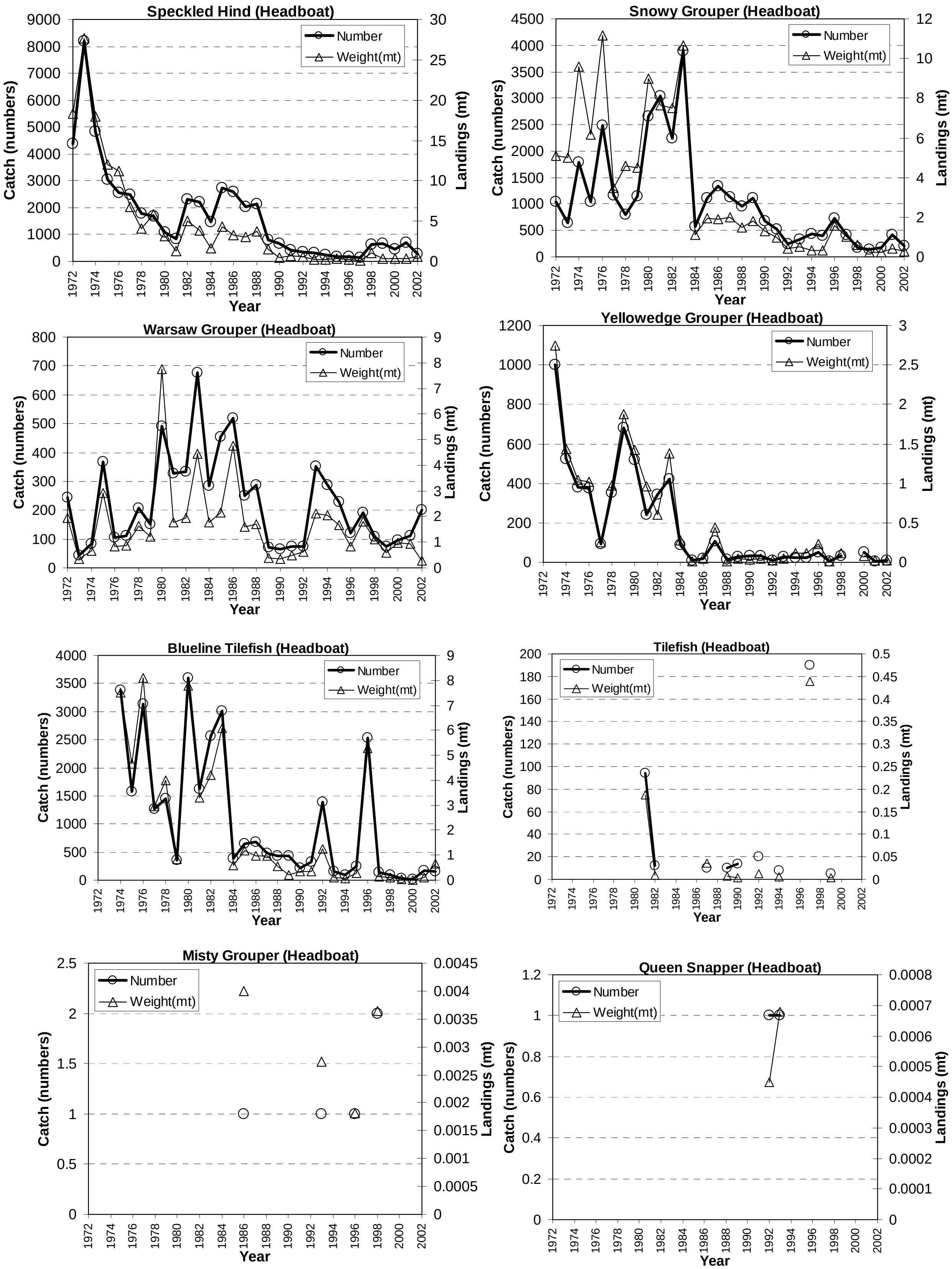


Figure 29. Number and weight (mt) of landed deepwater species from the South Atlantic headboat fishery.

4.2.3 Discards

There are no estimates of discards available from the headboat fishery survey.

4.2.4 Length and Weight Samples

Measurements of length and weight are collected by port samplers either at the return of a headboat trip (i.e. dockside) or by riding on the headboat during a fishing trip. Fish are measured for total length (TL) to the nearest millimeter and for weight to the nearest gram. For some records there are fish weight measurements with no associated length. For those cases a length-weight relationship was fit and then used to predict the missing length. Some records have a length measurement with no associated weight measurement. In those cases the length measurement is likely a duplicate record for cases when additional otolith or gonad samples were collected. Therefore these data records were removed for later analyses.

Table 62. Sample sizes of length and weight measurements sampled deepwater species from the South Atlantic headboat fishery.

Year	Speckled Hind	Snowy Grouper	Warsaw Grouper	Yellowedge Grouper	Blueline Tilefish	Tilefish	Misty Grouper	Queen Snapper
1972	140	67	10	14	125			
1973	241	23	1	4	80			
1974	175	180	13	14	76			
1975	177	145	8	31	38			
1976	101	104	18	15	62			
1977	149	39	5	3	40		1	
1978	124	29	17	4	29			
1979	28	32	4	11	59			
1980	30	51	14	4	45			
1981	14	52	22	3	36	1		
1982	41	24	20	1	18			
1983	84	67	17	11	43			
1984	108	42	43	3	29			
1985	82	68	12	1	20			
1986	75	77	19		30			
1987	48	35	9	2	9			
1988	48	45	1	1	8			
1989	30	50	15	2	10	17		
1990	12	6	3		6	13		
1991	7	3	1		2			
1992	7	1				1		
1993	11	7	6					
1994	12	15	7					
1995	14	11	10	1				
1996	12	18	2	4	2			
1997	21	33	9	1	32		5	2
1998	22	10	8		6			
1999	15	1	4	1		2		
2000	10	4		7	36			
2001	4	12	2	3	15	2	1	
2002	7	5	5					

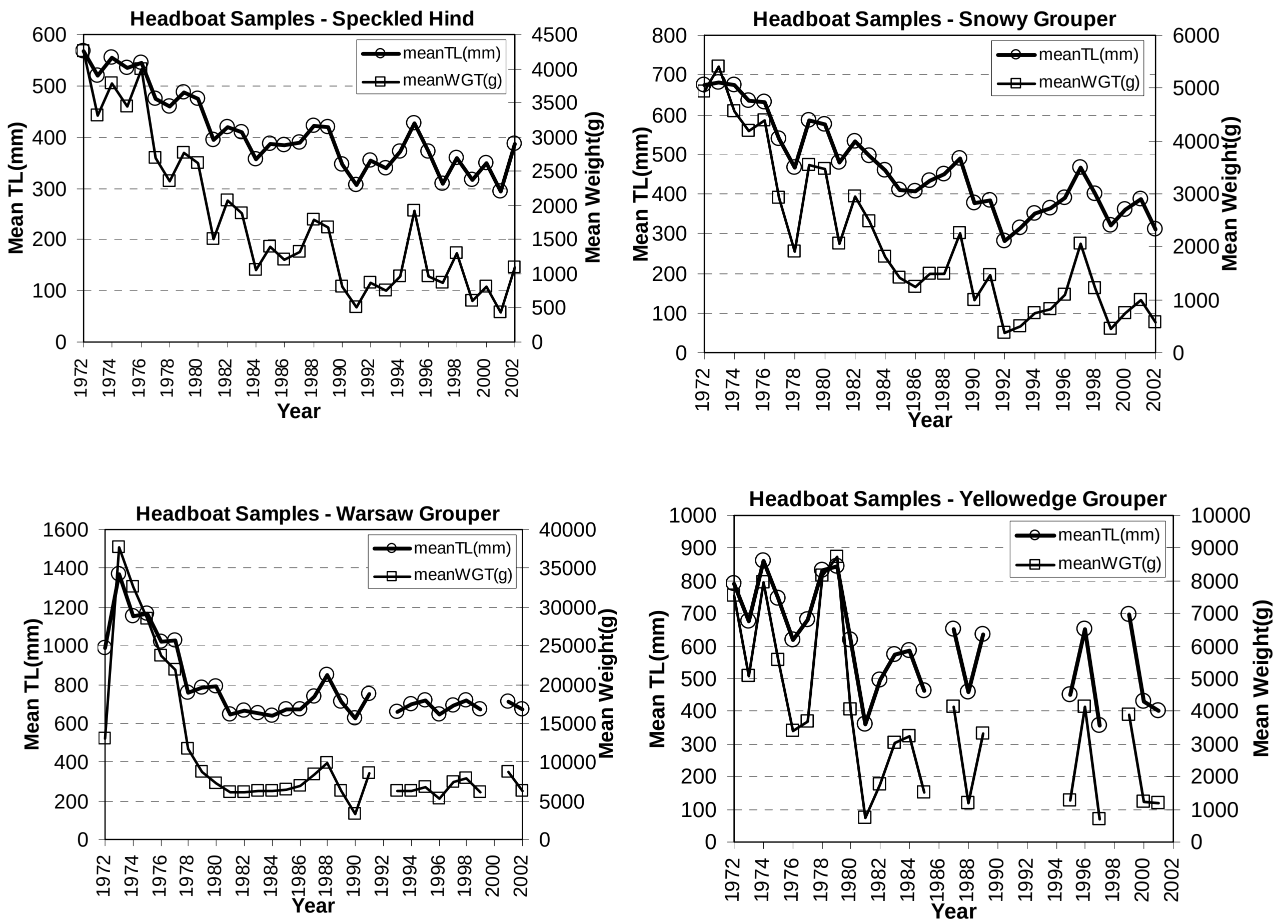


Figure 30. Average length (mm) and weight (kg) of sampled deepwater species from the South Atlantic headboat fishery.

Working Group Issue: The length and weight data for the deepwater species over time shows a general decrease for each species. Can the change in length and weight over time for some of the better sampled species be used as an index in the assessment.

Panel Response: (see Panel Response below for a general discussion of the applicability of headboat indices)

4.2.5 Catch Rates (CPUE/Abundance Indices)

Catch and Effort

Recorded catch records from the headboat survey include trip specific information including the date, trip duration, number of anglers, number of fish by species, area, and location. Table 63 indicates the total number of trips recorded for 1972-2002 from the South Atlantic headboat fishery. It is clear that the percentage of trips catching deepwater species declined rapidly in the 1970's and has remained fairly low, with a longterm average of approximately 5%.

Table 63. Recorded trips in the South Atlantic headboat survey. Species trips include trips which reported catching at least one member of the deepwater complex listed in Table 1. Location trips include trips with a valid location record.

Year	Total Trips	Location Trips	Location Trips
1973	725	8	1.1%
1974	1236	522	42.2%
1975	1913	1207	63.1%
1976	3010	2619	87.0%
1977	3563	3051	85.6%
1978	4903	4180	85.3%
1979	8033	6293	78.3%
1980	11182	10611	94.9%
1981	11129	10943	98.3%
1982	12097	11831	97.8%
1983	11935	11855	99.3%
1984	11039	10789	97.7%
1985	11678	10645	91.2%
1986	13609	13340	98.0%
1987	13824	13534	97.9%
1988	11753	11326	96.4%
1989	10596	10212	96.4%
1990	11046	10938	99.0%
1991	10480	10243	97.7%
1992	14782	13556	91.7%
1993	13709	12136	88.5%
1994	12441	10841	87.1%
1995	12168	10500	86.3%
1996	9084	6343	69.8%
1997	6359	3408	53.6%
1998	9260	4429	47.8%
1999	7676	3783	49.3%
2000	7766	3893	50.1%
2001	6950	3345	48.1%
2002	5733	2851	49.7%

Location Information

The location information from the catch records of the headboat survey is reported by the captain of the headboat as a 10’ x 10’ grid location (Figure 31). From Table 63 it can be seen that the percentage of trips which have “valid” location information was initially low (1973-1975), then remained above 80% through 1995, then dropped to around 50% until the present. The term “valid” is used rather loosely here. The location was converted to a latitude and longitude position representing the center of the 10’ x 10’ grid reported. Obvious records in the Arctic circle and near the equator were removed, more precisely latitudes were restricted to latitudes between 20 and 40 degrees N and longitudes between -85 and -73 degrees W. A plot of the remaining “valid” locations with a superimposed coastline clearly indicates that there remains some errant location records (Figure 32).

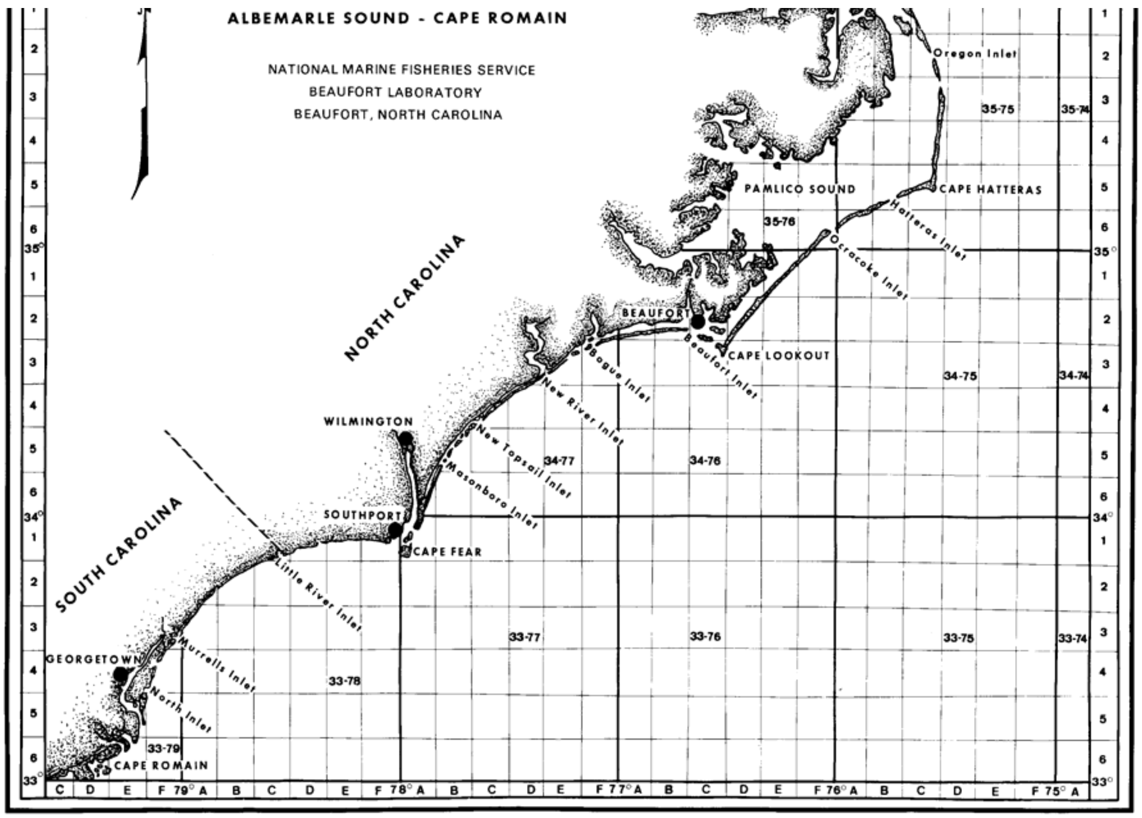


Figure 31 . Example of 10’ x 10’ latitude and longitude grid system used for reporting headboat fishing locations.

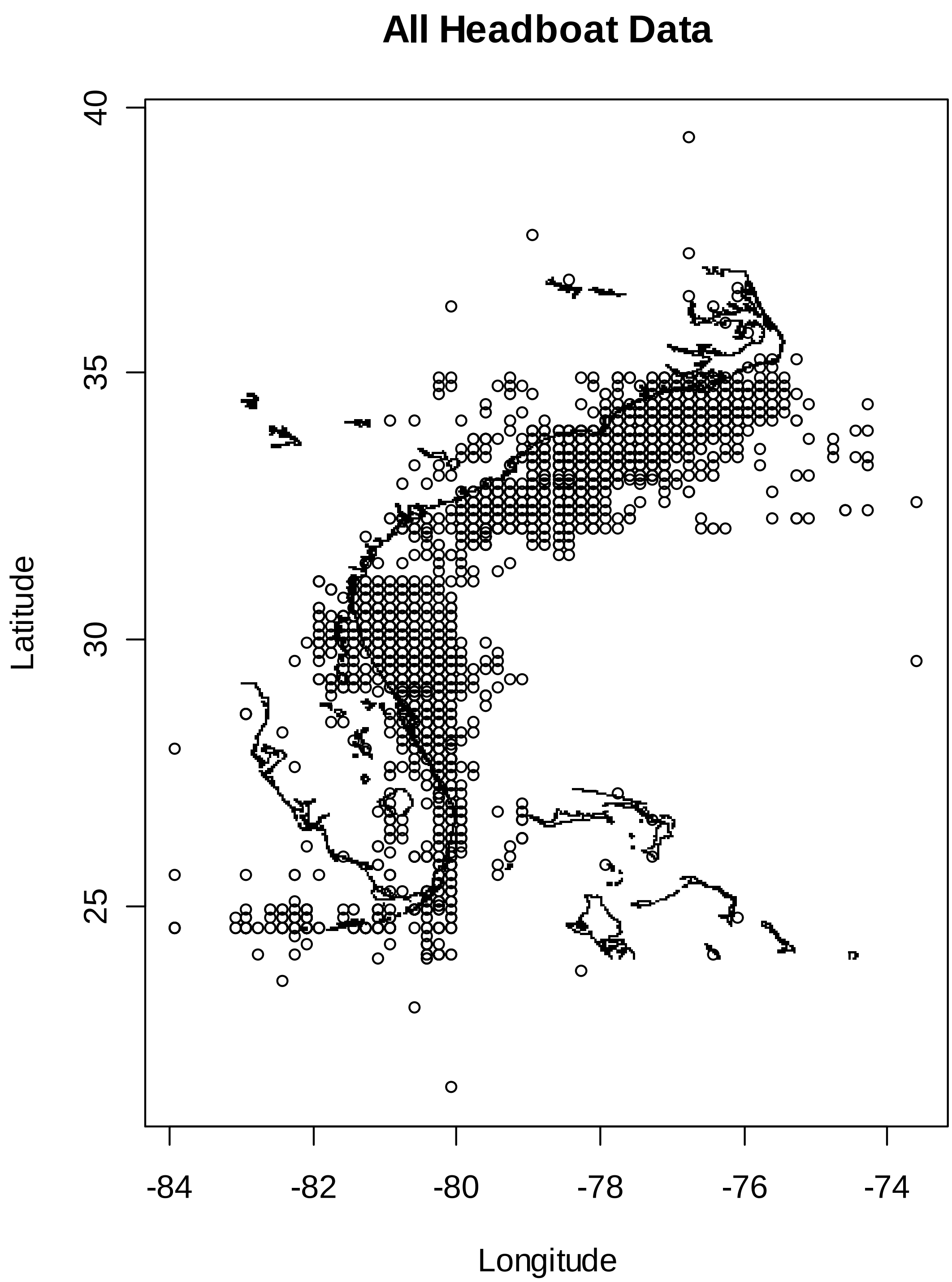


Figure 32. South Atlantic coastline showing set of unique location records from the South Atlantic headboat survey catch records.

The converted latitude and longitude grid centers were then used to get an associated depth measurement. A dataset of 10’ x 10’ grid depth measurements for the South Atlantic was provided by Jon Hare, National Ocean Service, Beaufort Laboratory, Beaufort, North Carolina. The depth measurements corresponded to the corners of the grids shown in Figure 31. The depth associated with the grid center was computed by trimming the minimum and maximum values and then taking the average of the remaining two measurements.

Working Group Issue: Is the depth information estimated from 10’ x 10’ latitude and longitude grids useful information for drawing inference about fishing for deepwater species or to subset trips for further GLM analyses of CPUE?

Panel Response: The panel expressed concern about the ability to accurately represent depth for an area as broad as 10’ x 10’ latitude and longitude. The shelf break and slope are so narrow, particularly off the Carolina coast, that some grids may contain ranges of 20-400m. For this reason, the panel felt this data is not at a sufficient spatial scale for drawing any meaningful inference about fishing and targeting of deepwater species.

Subsetting Catch Records into Targeted Trips

The headboat fishery is diverse and generally does not target particular species, rather species assemblages and high fish density areas. The deepwater species in this analysis constitute a small portion of the total headboat landings and trips (Table 64). Because of the rarity of the deepwater species, it was necessary to subset the headboat trips in the catch records to those trips which were fishing in areas where deepwater species are likely to be encountered. The first attempt to subset the trips involved using only trips in which at least one of the 8 deepwater species listed in Table 1 were captured.

Working Group Issue: How to subset the headboat data to “targeted” deepwater species trips?

Panel Response:

The use of trips which caught at least 1 deepwater species raised concerns for some panel members who thought that speckled hind did not belong in the complex. Futhermore, analysis of the frequency of deepwater species caught per trip (Figure 39) indicated that more than 50% of all trips only caught 1-2 deepwater species. This limited the ability to further subset the “targeted” trips based on a raised minimum number of deepwater species caught per trip. Furthermore, the uncertainty in the location derived depth measures (see above) prevented further subsetting with this data.

Table 64. Number of total trips and trips with at least one of the indicated species by year from the South Atlantic headboat survey.

Year	Total Trips	Speckled Hind	Snowy Grouper	Warsaw Grouper	Yellowedge Grouper	Blueline Tilefish	Tilefish	Misty Grouper	Queen Snapper
1973	725	387	49	48	45	195	-	-	-
1974	1236	483	71	20	26	190	-	-	-
1975	1913	410	71	41	37	179	-	-	-
1976	3010	374	99	69	23	138	-	1	-
1977	3563	342	36	51	9	60	-	-	-
1978	4903	358	71	85	29	121	4	1	-
1979	8033	285	83	105	67	34	1	1	-
1980	11182	301	151	100	40	196	-	-	-
1981	11129	158	132	266	38	78	-	-	-
1982	12097	349	165	217	45	119	1	-	-
1983	11935	367	211	184	62	143	-	-	-
1984	11039	267	85	194	22	53	-	-	-
1985	11678	735	194	202	49	268	-	-	-
1986	13609	356	167	188	11	95	-	1	-
1987	13824	275	135	206	13	78	3	-	-
1988	11753	315	120	126	2	91	-	-	-
1989	10596	123	98	128	7	71	3	-	-
1990	11046	115	68	30	5	49	1	-	-
1991	10480	113	59	41	4	42	-	-	-
1992	14782	99	67	54	5	63	3	-	1
1993	13709	102	105	60	5	12	-	1	1
1994	12441	102	90	254	4	10	1	-	-
1995	12168	105	77	248	6	11	-	-	-
1996	9084	101	75	161	4	49	-	1	-
1997	6359	76	42	64	2	12	-	-	-
1998	9260	92	50	167	7	34	-	2	-
1999	7676	132	26	94	-	11	2	-	-
2000	7766	105	29	41	8	7	-	-	-
2001	6950	152	60	83	2	12	-	-	-
2002	5733	146	24	74	3	12	-	-	-

An analysis was performed using an association statistic to determine other potential indicator species which could be used to define "targeted" deepwater species trips. The association statistic was computed as the ratio of the probability of capturing the target species and each other species divided by the probability of capturing each species. An arbitrary number of species with the highest association statistics is then chosen to define a "targeted" deepwater trip. Initially this statistic resulted in a list of species including many rare species which did not appear to match the biology of the deepwater species. The list of potential species was then limited with a minimum positive trip size threshold. This resulted in a species list very similar to the 8 species in the deepwater complex. This analysis also suggested that speckled hind were associated with the deepwater species and hence should be included in the "targeted" trip definition. Two additional species were included in the list; short bigeye (*Pristigenys alta*) and silk snapper (*Lutjanus vivanus*). This list of 8 species plus the 2 suggested by the association statistic analysis were then used to subset the headboat survey trips for use in a GLM analysis for computing CPUE.

CPUE Indices

Catch per unit effort was computed for the “targeted” subset of headboat trips as the number of fish caught divided by the product of anglers and trip days. A delta-lognormal GLM procedure was used to obtain an annual index for use as an indicator of population abundance. Factors used in the GLM analysis included month and area (Figure 33). Given the amount of data available, indices could only be computed for 5 of the 8 species. An overall index was also computed for all species of the deepwater complex. The resulting indices are shown in Figure 34 - Figure 39.

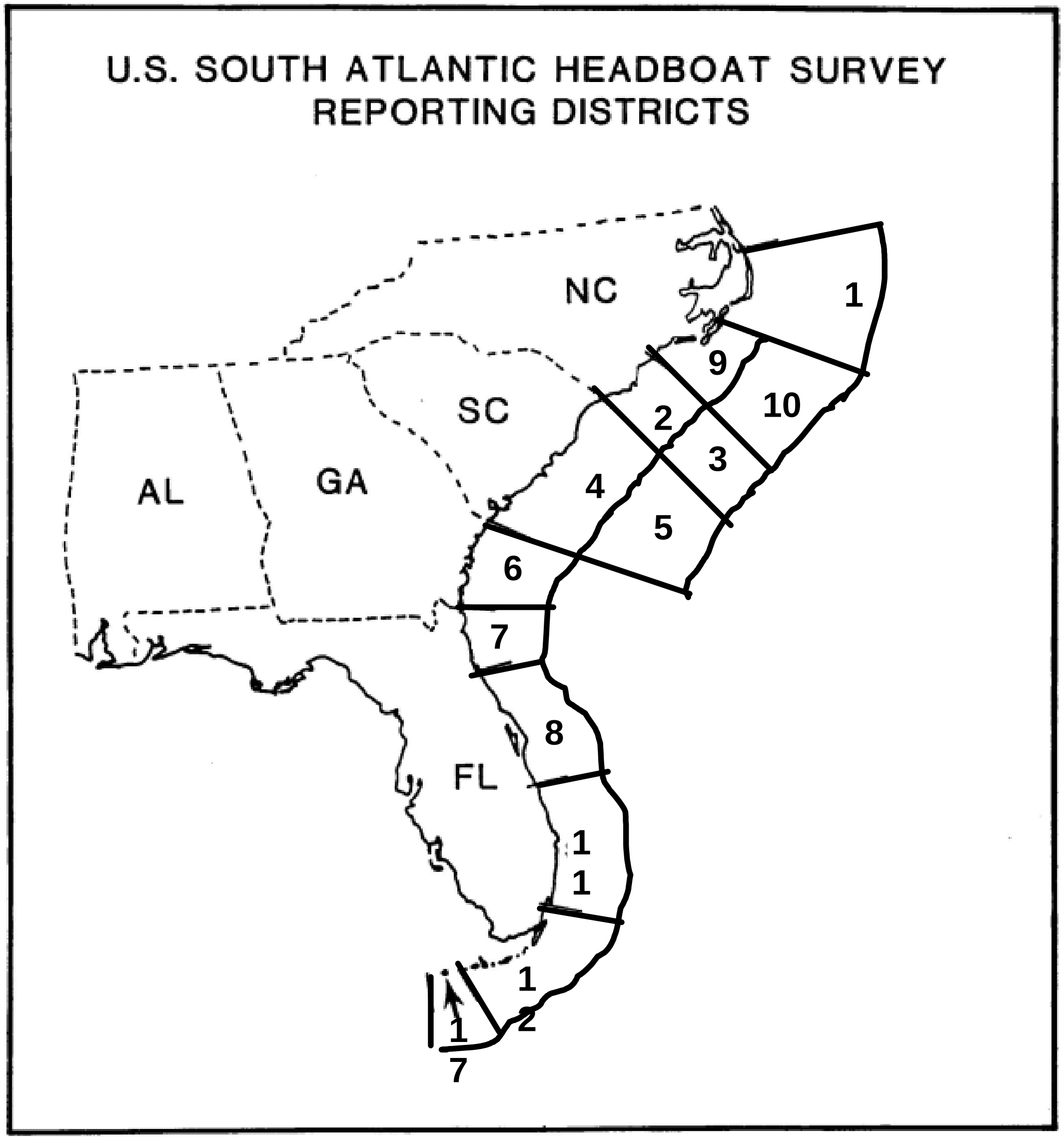


Figure 33 . Reporting areas used in the South Atlantic headboat survey.

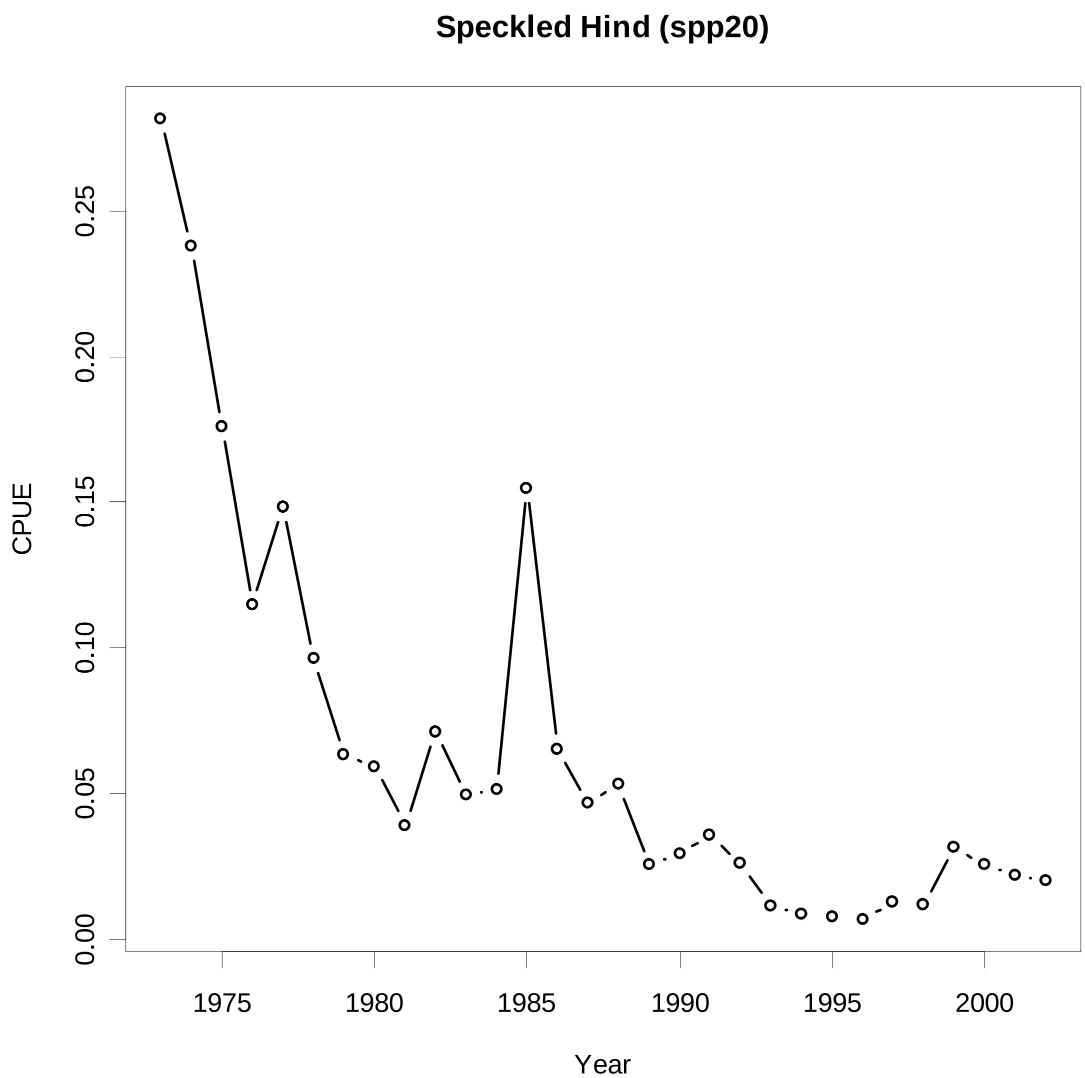


Figure 34. Catch per unit effort index from the South Atlantic headboat survey for speckled hind.

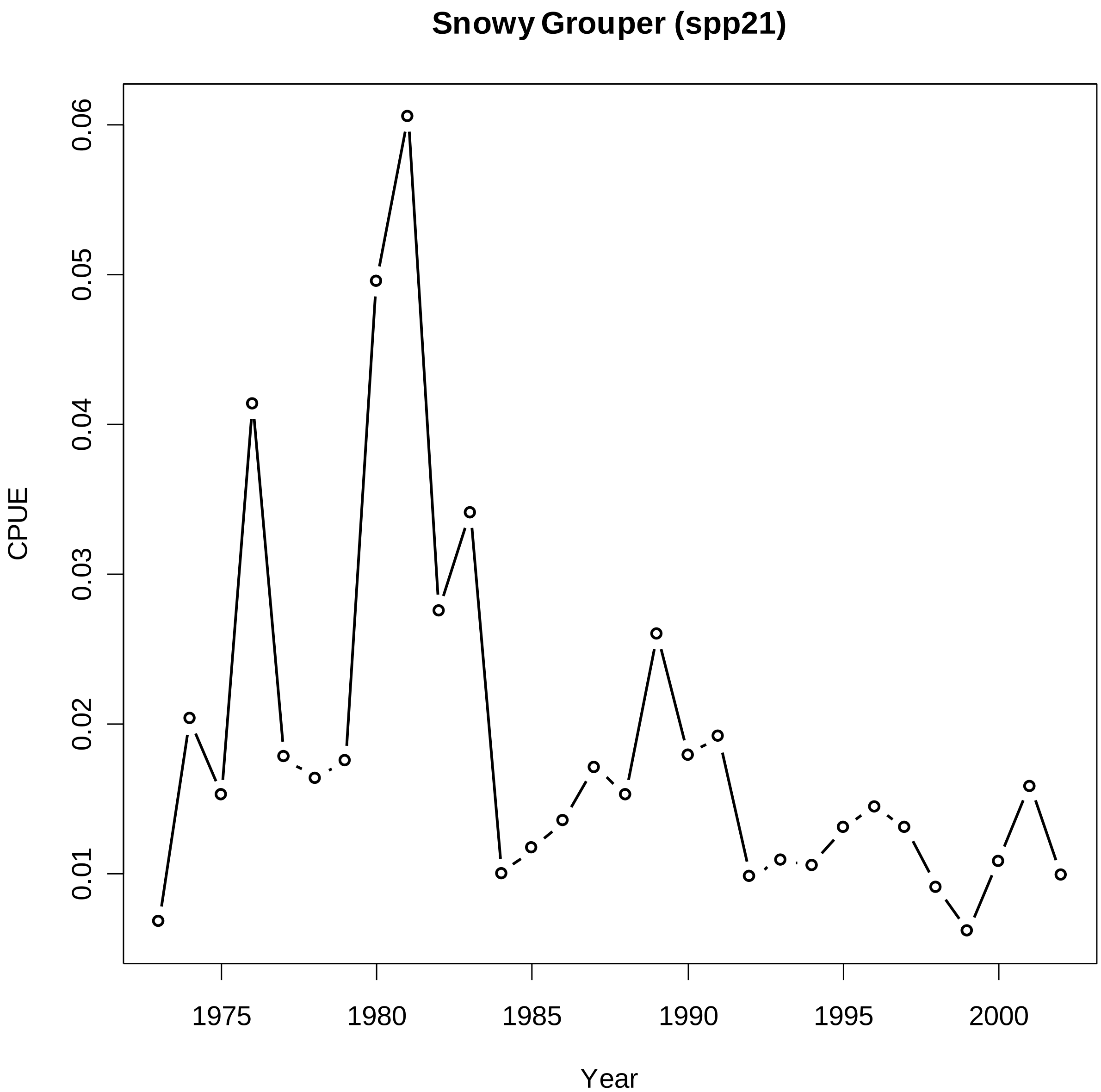


Figure 35. Catch per unit effort index from the South Atlantic headboat survey for snowy grouper.

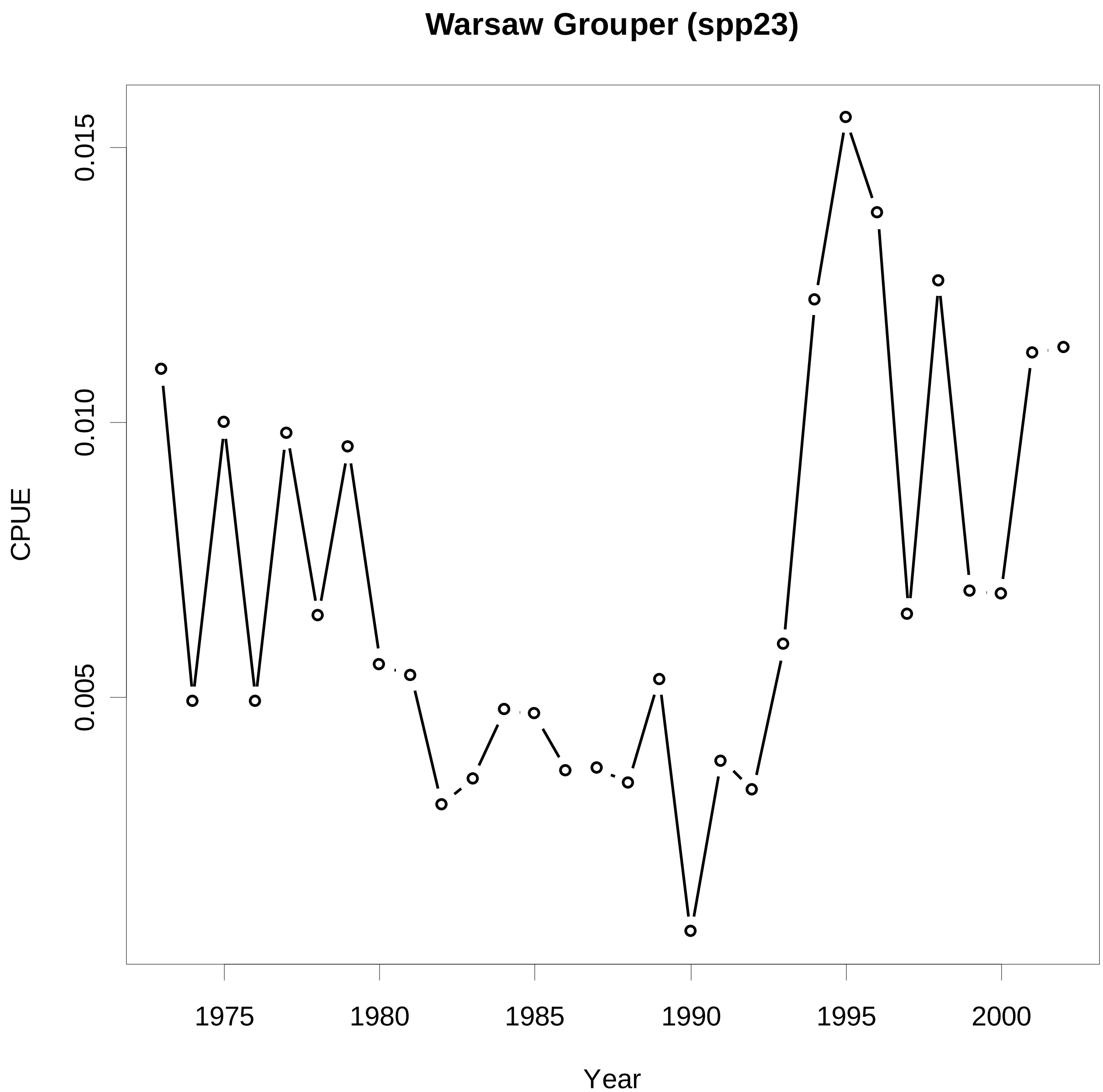


Figure 36. Catch per unit effort index from the South Atlantic headboat survey for Warsaw grouper.

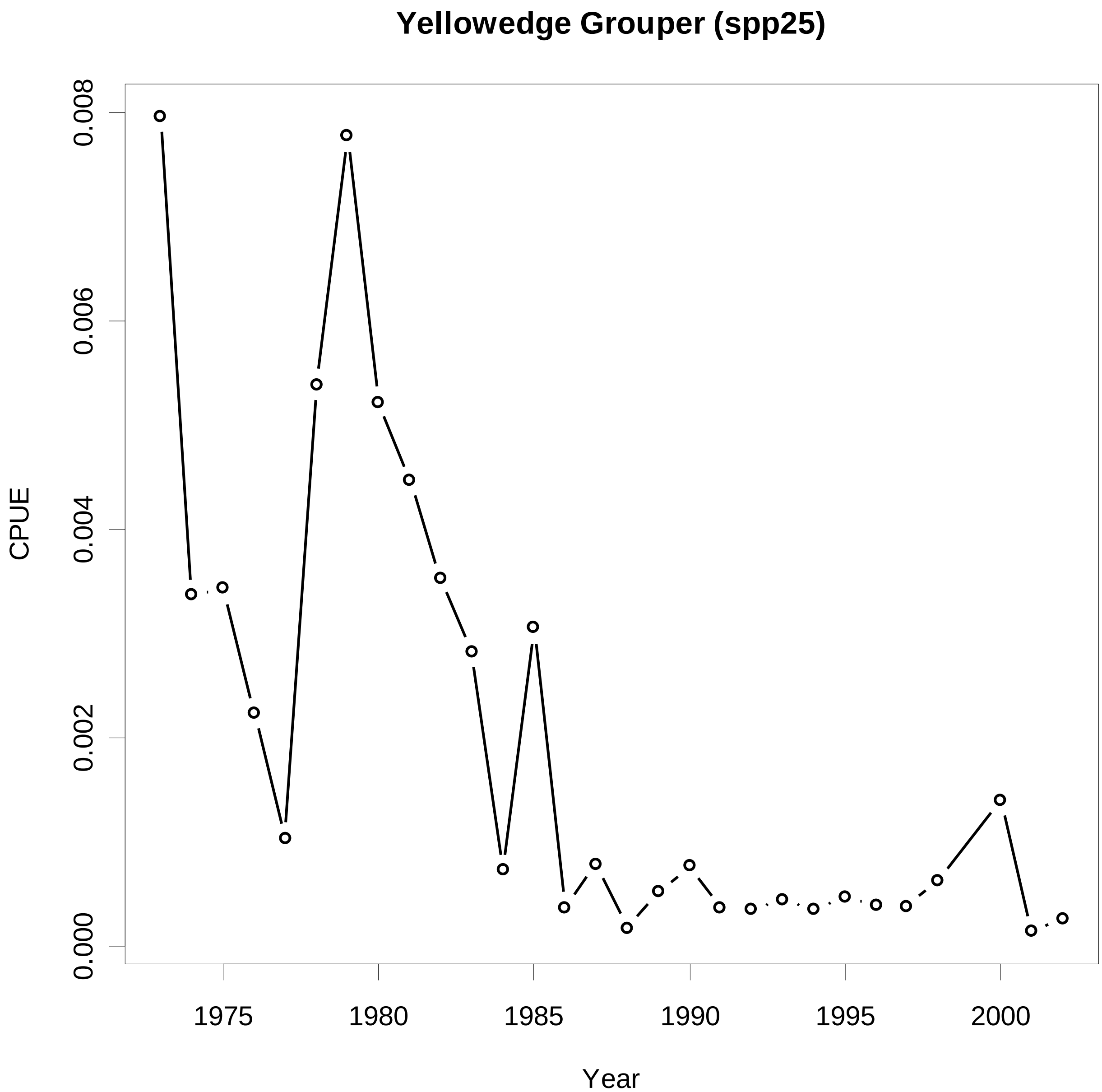


Figure 37. Catch per unit effort index from the South Atlantic headboat survey for yellowedge grouper.

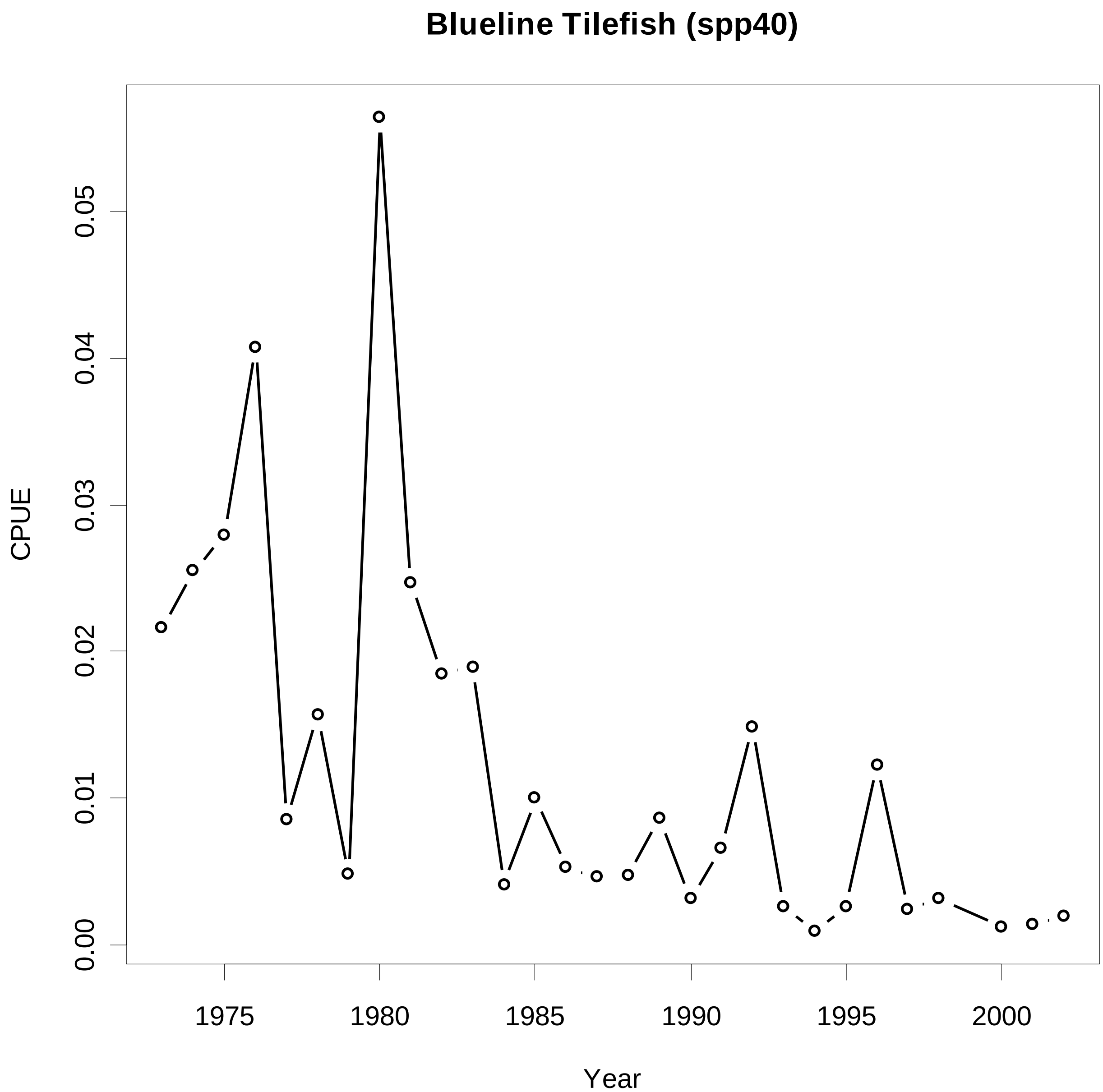


Figure 38. Catch per unit effort index from the South Atlantic headboat survey for blueline tilefish

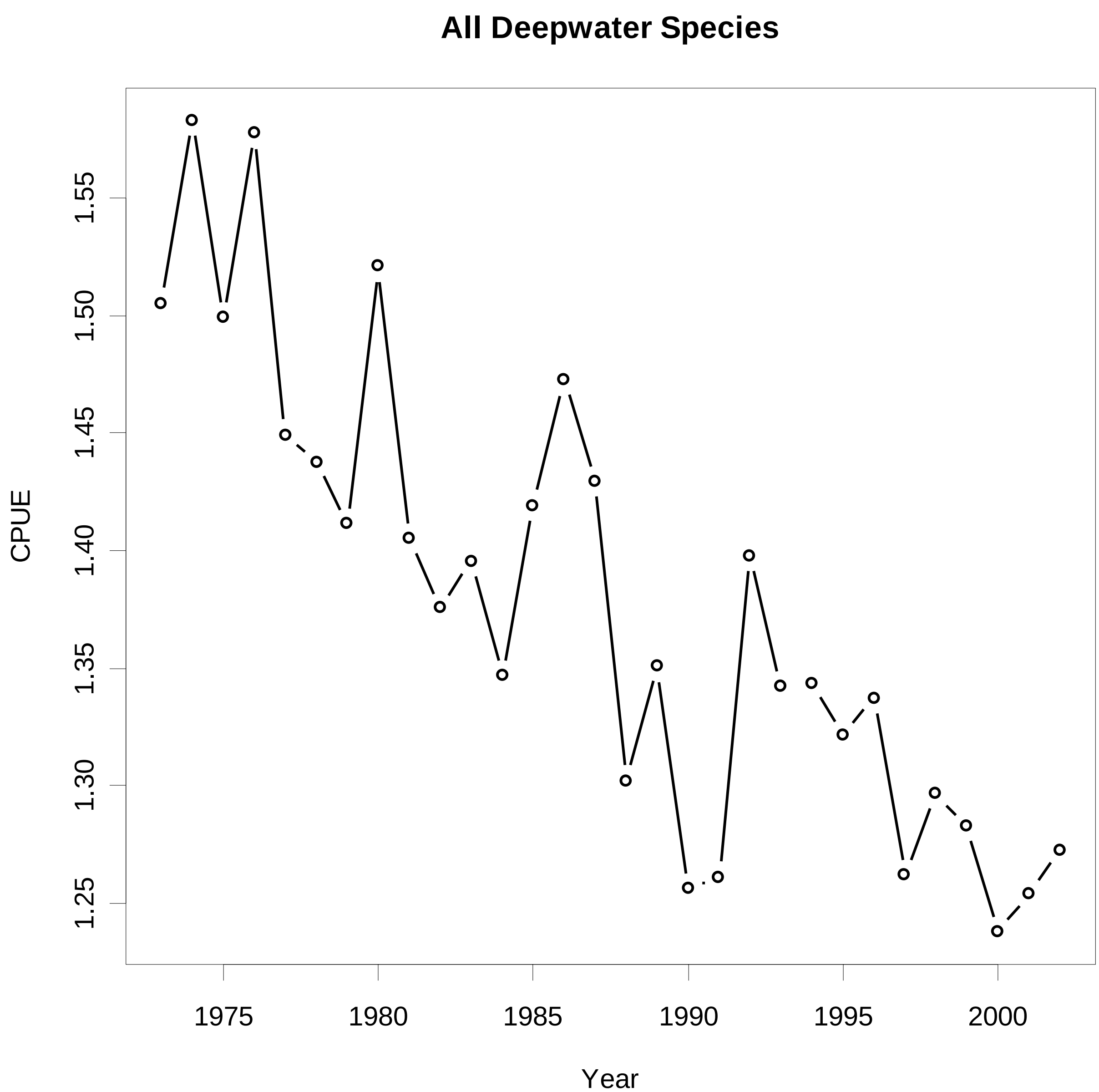


Figure 39. Catch per unit effort index from the South Atlantic headboat survey for the deepwater complex.

Working Group Issue: Is a CPUE or mean length/weight index derived from the headboat survey applicable for use in a stock assessment?

Panel Response: The panel expressed several concerns regarding the representativeness and use of an index derived from the headboat fishery. There was lots of discussion on this issue and the major concerns are as follows:

(1) The headboat fishery appears to be operating in the shallow areas of these species depth range. Any information from the headboat fishery may only represent the "fringe" of the population and may not reflect any trends in the overall population. However, if there exists ontogenetic shifts in the species depth distribution with size, then the "fringe" may represent a juvenile area and an index derived from the headboat may represent an index of recruitment.

(2) The headboat fishery appears to have gone through some changes over time, most notably, there appears to have been a shift from more frequent "deep" water trips in the earliest years with the use of electric reels to more shallow water trips with discontinued use of electric reels. Electric reels are primarily used for fishing the deepest areas. Unfortunately, there does not appear to be any reliable data on use of electric reels (other than we know they were used, but not to what extent) or fishing depth information (the 10' x 10' grid depths were not deemed adequate, see discussion above). Therefore we have no means of verifying any fishing depth changes over time and certainly no information on the magnitude of this change. If there was a significant change in fishing depth over time, then this may bias any population index derived from the headboat fishery, particularly if there exists ontogenetic shifts in size with depth.

(3) Regulations went into place in 1993 which limited the vessels to one speckled hind and one Warsaw grouper per vessel per trip. This certainly can affect any measure of CPUE and possibly mean length and weight. Therefore, any index should be treated as two indices with a break in between 1992 and 1993. It appears the regulations from 1993-2002 were constant and therefore represent a time period of constant regulation, as does the 1973-1992 period.

Given the concerns above and the lack of definitive information to confirm or reject these concerns, the panel decided that in the stock assessment the models should consider runs with and without the headboat indices. There is simply not enough information to draw any conclusions as to whether inclusion or exclusion of the headboat data is less biased.

4.2.6 Catch-at-Age/Length

There is insufficient information for computing annual catch-at-age/length information from the headboat survey data (Table 64).

5. Fishery-Independent Survey Data

5.1 MARMAP survey outline

For thirty years, the Marine Resources Research Institute (MRRI) at the South Carolina Department of Natural Resources (SCDNR), through the Marine Resources Monitoring, Assessment and Prediction (MARMAP) program, has conducted fisheries-independent research on groundfish, reef fish, ichthyoplankton, and coastal pelagic fishes within the region between Cape Lookout, North Carolina, and Cape Canaveral, Florida. The overall mission of the program has been to determine distribution, relative abundance, and critical habitat of economically and ecologically important fishes of the South Atlantic Bight (SAB), and to relate these features to environmental factors and exploitation activities. Research toward fulfilling these goals has included trawl surveys (from 6-350 m depth); ichthyoplankton surveys; location and mapping of reef habitat; sampling of reefs throughout the SAB; life history and population studies of priority species; tagging studies of commercially important species and special studies directed at specific management problems in the region. Survey work has also provided a monitoring program that has allowed the standardized sampling of fish populations over time, and development of an historical base for future comparisons of long-term trends.

5.1.1 *Methods, gears, coverage and time series.*

For a complete description of gear types used by MARMAP see document 'SEDAR4-DW-21: Description of MARMAP sampling'.

Since 1978, MARMAP has monitored reef fish abundance and collected specimens for life history studies. The primary gear types that have been used to sample reef fishes are Florida traps, blackfish traps, chevron traps, bottom longline, kali pole, vertical longline, and hook and line gear. From 1978 to 1987, Florida traps and blackfish traps baited with cut clupeids were soaked for approximately two hours during daylight at 12 study areas with known live-bottom and/or rocky ridges. In 1988 and 1989, Florida snapper and chevron traps were fished synoptically for approximately 90 minutes from a 33.5 m research vessel that was anchored over a randomly selected reef locations. After 1989, blackfish traps and Florida traps were discontinued. Only chevron traps were deployed at stations randomly selected by computer from a database of approximately 2,500 live bottom and shelf edge locations and buoyed for approximately 90 minutes. This database was compiled from MARMAP visual UWTV studies with additional locations added from catch records from the MARMAP and other MRRI projects. During the 1990s, additional sites were obtained for the North Carolina and south Florida area from scientific and commercial fisheries sources to facilitate expanding the overall sampling coverage.

Sample sites are all located in the central SAB from 27^0 N to 34^0 N. Trapping has occurred to depths as great as 218 m but the majority of trap sampling has occurred at 16 to 91 m. During all years, sampling was conducted during daylight to eliminate light phase as a variable. Night hours were reserved for workup of fishes, steaming time between sites and for tagging and recapture of priority species. Temperature and salinity profiles of the water column were taken with a conductivity, temperature, and depth profiler (CTD) after each trap set and before each longline set.

Hook and line stations were fished during dawn and dusk periods, one hour preceding and after actual sunrise and sunset. Fishing rods utilizing Electromate motors powered 6/0 Penn Senator reels and 36 kg test monofilament line were used for 30 minutes by three anglers. The terminal tackle consisted of three 4/0 hooks on 23 kg monofilament leaders 0.25 m long and 0.3 m apart, weighted with sinkers 0.5 to 1 kg. The top and bottom hooks were baited with cut squid and the middle hook baited with cut cigar minnow (*Decapterus sp.*). This same method of sampling was used between 1978-2001. However, less emphasis has been placed on hook and line sampling during the 1990s to put more effort on tagging of fishes at night and running between stations.

In 1996 we began using two types of longline gear to sample the snapper-grouper complex in depths greater than 90 m. Each type of long line was intended to sample one of two unique bottom types (smooth tilefish grounds or rough bottom). In the tilefish grounds (areas of smooth mud), a horizontal long line was deployed and in areas of rough bottom contours, a short vertical long line was used to follow the bottom profile. The horizontal long line consists of 1676 m of 3.2 mm galvanized cable deployed from a longline reel. A total of 1219 m of the cable is used as groundline and the remaining 457 m is buoyed to the surface. One hundred gangions, comprising of an AK snap, approximately 0.5 m of 90 kg monofilament and a #6 or #7 tuna circle hook, are baited with a whole squid and clipped to the ground cable at intervals of 12 m. The gear is set while running with the current at a speed of 4 - 5 knots. An 11 kg weight is attached to the terminal end and 100 gangions are then attached to the ground line, followed by another weight at the terminal end of the ground line. The remaining cable is pulled off of the reel and buoyed with a Hi-Flyer and a polyball trailer buoy. The gear is soaked for 90 minutes and retrieved by fairleading the cable from a side davit of the vessel back on to the longline reel. A similar bottom longline was deployed by MARMAP during the 1980s.

Where bottom type is rough at depths of 90 to 200 m, short vertical relief longlines consisted of 25.6 m of 6.4 mm solid braid dacron groundline dipped in green copper naphenate. The line is deployed by stretching the groundline along the vessel's gunwale with 11 kg weights attached at the ends of the line. Twenty gangions baited with a whole squid were placed 1.2 m apart on the groundline which was then brommelled to an appropriate length of poly warp and buoyed to the surface with a Hi-Flyer. Sets are made for 90 minutes and the gear is retrieved utilizing a pot hauler. This gear type has been used since 1997.

Where bottom topography was rough during 1984,1985 and 1986, three replicates of three off bottom units of 20 Kali poles (5 hooks/pole) was deployed at the same sites where short long line was deployed during 1996 and 1997. The main line (183 m) of 0.79 cm polyethylene was brommeled to the buoy warp and lowered from the stern with a 11 kg weight attached to the outboard end. At 15 m from the weight, the first 2.4 m pole (each with five 45 cm leaders of 56-90 kg monofilament and #6 or #7 tuna circle hooks) was clipped to the main line. After 20 poles were clipped at intervals of 7.6 m, 15 m of line was again released prior to attaching another 11 kg weight and the second 275 buoy warp.

UWTV recordings were made using a Simrad-Osprey Subsea low light camera attached to a vane stabilized frame during day light hours. The camera is maintained off the bottom 1 - 2 m as the vessel either drifted with the wind and/or current or was towed at low speeds. Recordings for fish identification on bottom habitat and to document new live bottom sites for the MARMAP data base were made on VHS tape and archived for future analysis.

5.1.2 *Collection of size and age data*

Length-frequency data from the catches (to the nearest 1 cm) were recorded by a shipboard data acquisition system. This comprised of a Limnoterra FMB IV digital measuring board and a Toledo model 8142 digital scale, interfaced by an XT personal computer with customized software. During length frequency, subsample tables for priority species were also kept so specimens could be retained for additional life history studies. After length frequency workup, fishes are stored on ice for life history workup during night.

From the 1990s through the present, specimens for life history workup were collected from eight geographical areas designated by each whole degree of latitude from 27^0 N to 34^0 N. South of 32^0 N and north of 33^0 N, fifteen specimens of each 1 cm size class were retained from each trip for *Centropristis striata*, and *Rhomboplites aurorubens*. Fifty specimens for *Pagrus pagrus* and *Balistes capriscus were retained.* In mid latitudes, 32^0 N to 33^0 N, five specimens of each 1 cm size class were retained for *Centropristis striata, Rhomboplites aurorubens, Balistes capriscus, Haemulon aurolineatum* and *Diplectrum formosum*. Ten specimens were retained for *Pagrus pagrus*. All other priority specimens, including all species of the deep-water complex as defined for SEDAR 4, were kept for the entire sampling area. During the 1980s, all priority species (species of commercial and recreational important) caught were retained for life history workup.

During life history workup, a Limnoterra fish measuring board with 1-mm resolution was used to measure priority species (SL, FL, and TL) with their weights determined by a triple beam balance to the nearest gram. This system was connected to an AT 486-type computer for life history data storage with a paper output as backup.

5.1.3 *Issues identified and resolved .*

1. The group decided that due to extremely low sample sizes for Warsaw grouper (9) and yellowedge grouper (6), no indices or length frequencies be develop for these two species from MARMAP data.
2. No data were available for misty grouper or queen snapper.
3. Based on recommendations by all workshop participants, CPUE for all longline gears is reported as catch per 100 hooks per hour, instead of simply catch per 100 hooks. It was thought that incorporating the duration of sampling would render the CPUE more precise, and account for a potential source of variation if soak time varied from the standard 90 minutes.
4. Based on recommendations by all workshop participants, no depth stratification was performed for any species. The group suggested depth stratification might be important for snowy grouper in particular, where smaller fish were sampled in shallower depths. However, the workshop felt the stratification would dilute an already small sample size and complicate any modeling effort, without adding significantly to the assessment. It was felt that the smaller fish would be accounted for in the overall length frequency index without incorporating a depth stratification.
5. The group chose to use only the Florida trap shelf edge survey, and not incorporate the Florida trap inshore survey for CPUE and length frequency indices for speckled hind.

5.1.4 *Catch per Unit Effort.*

Annual catch per unit effort was calculated for traps as:

$$\text{Mean CPUE (no. fish per trap-hr.)} = \frac{\sum \frac{\text{no. fish caught}}{\text{soak time (hr.)}}}{\text{no. samples}} .$$

Catch per unit effort for horizontal longlines and kali poles was calculated as:

Mean CPUE (no. fish per100 hooks per hour) = (Σ no. fish caught/100)/(Σ soak time/60).

Catch per unit effort for vertical longline was calculated as:

Mean CPUE (no. fish per100 hooks per hour) = ((Σ no. fish caught/20)/ (Σsoak time/60)).

5.1.5 Gear types chosen for CPUE and length frequency indices

Tilefish

The group chose to use the horizontal longline index for to estimate CPUE of tilefish as catches of tilefish using other gear types were too small to be of any value. This gear was used during 1984-1985 and 1996-2002.

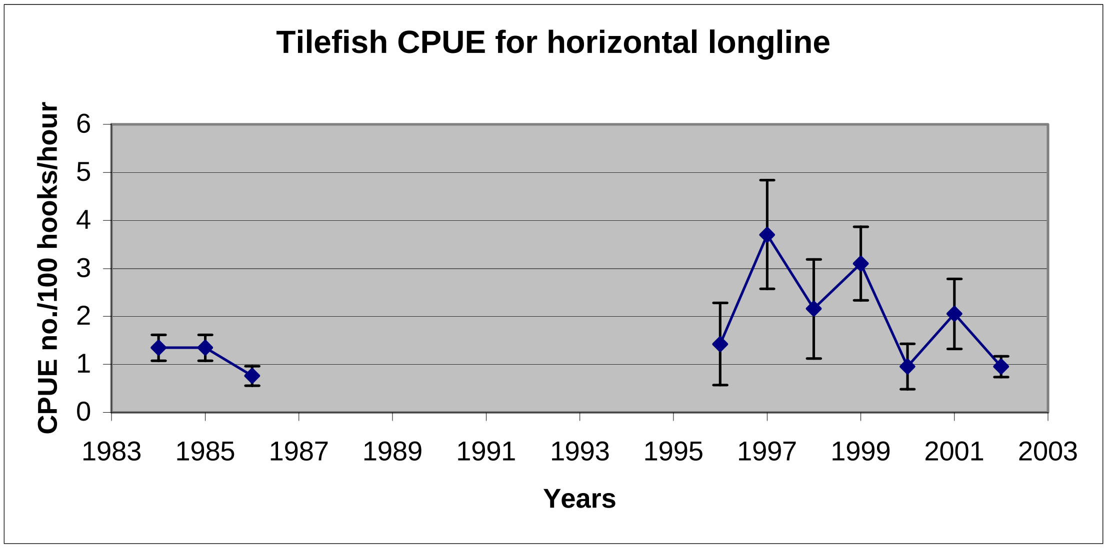


Figure 40. MARMAP longline CPUE, Tilefish.

Speckled hind

The Florida trap shelf edge survey (1983-1987) and the chevron survey for 1990-2001 were used to provide two CPUE indices for speckled hind. Samples collected during 1988-1989 were not included because the trapping gear was tethered from the boat. Four shelf edge areas off SC were sampled with Florida trap during 1983-1987. Locations for the shelf edge study areas were: 32°15' N, 79°09' W; 32°16' N, 79°09' W; 32°22' N, 79°01' W and 32°26' N, 79°56' W. The sites are ~ 50 m deep with a bottom type that consists of rock outcroppings and 1-2 m of relief.

Due to small sample sizes, no indices were developed or other gear types (vertical longline; n=14 and hook and line; n=37) that sampled speckled hind.

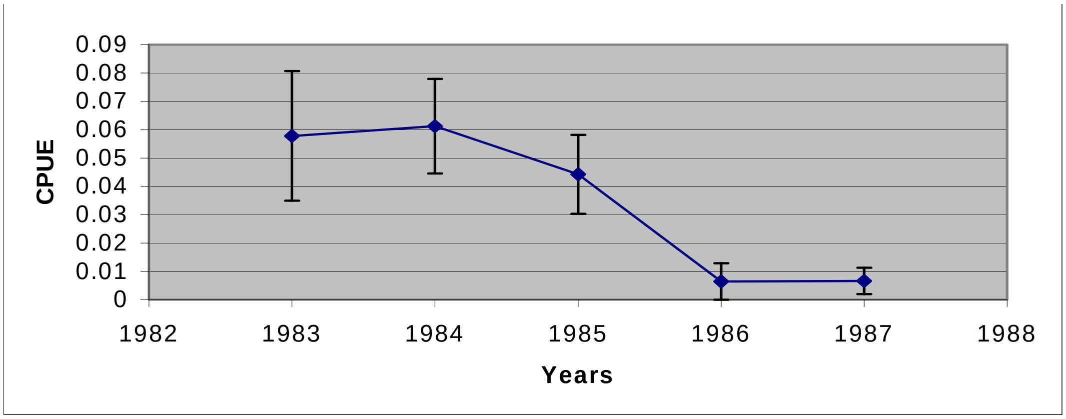


Figure 41. MARMAP speckled hind CPUE, Florida Tap.

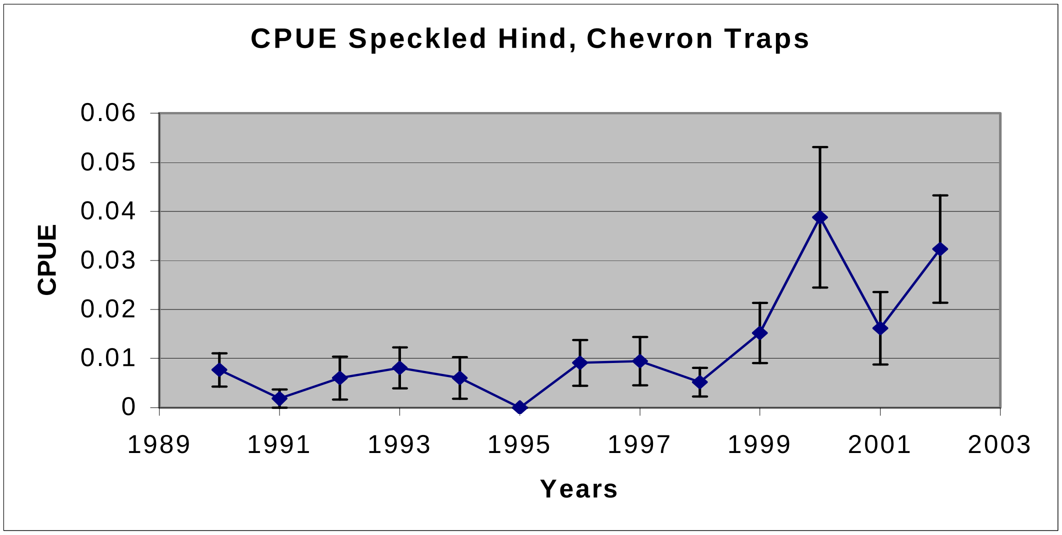


Figure 42. MARMAP speckled hind CPUE, Chevron Trap

Snowy grouper

The Kali pole (1983-86), short longline (1996-2002), and chevron trap surveys (1990-2002) were used to develop CPUE and length frequency indices for snowy grouper.

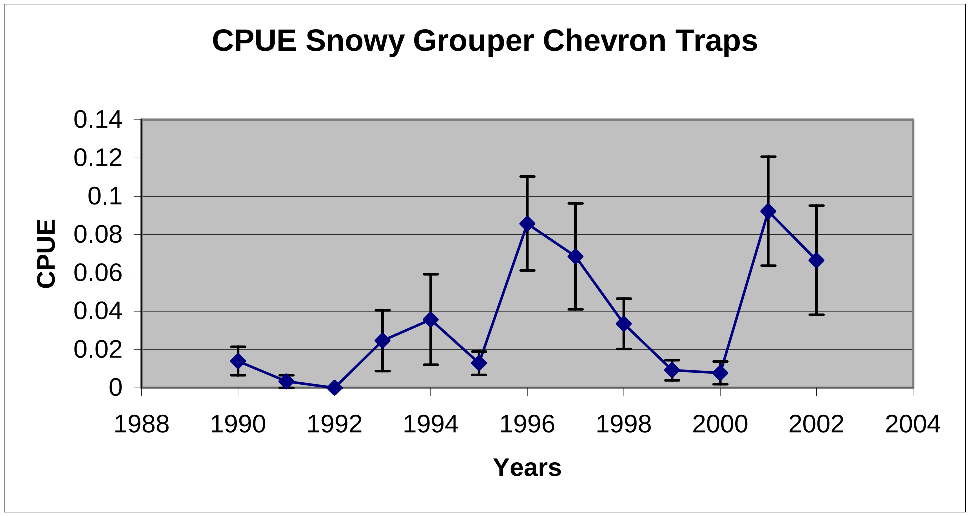


Figure 43. MARMAP Snowy Grouper CPUE, chevron trap

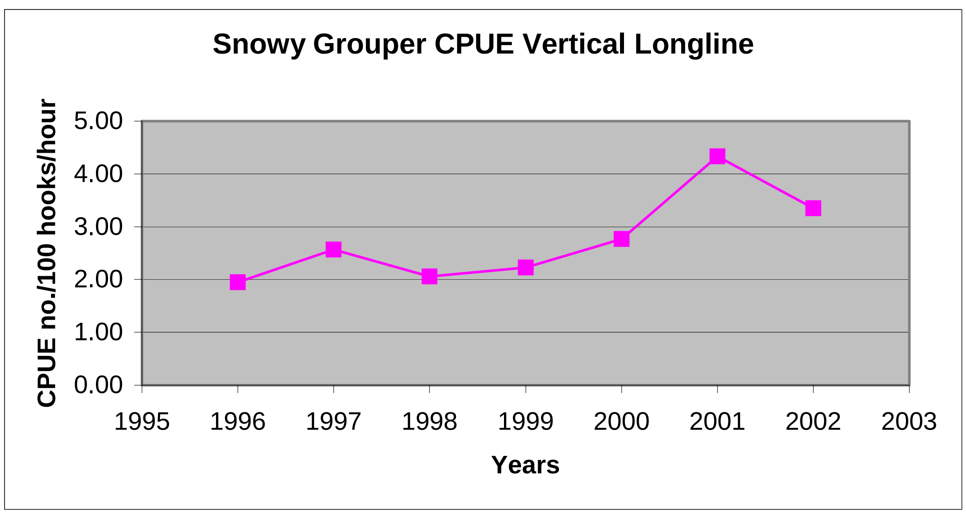


Figure 44. MARMAP snowy grouper CPUE, vertical longline.

Blueline tilefish
The kali pole and short longline survey was used to determine CPUE for blueline tilefish.

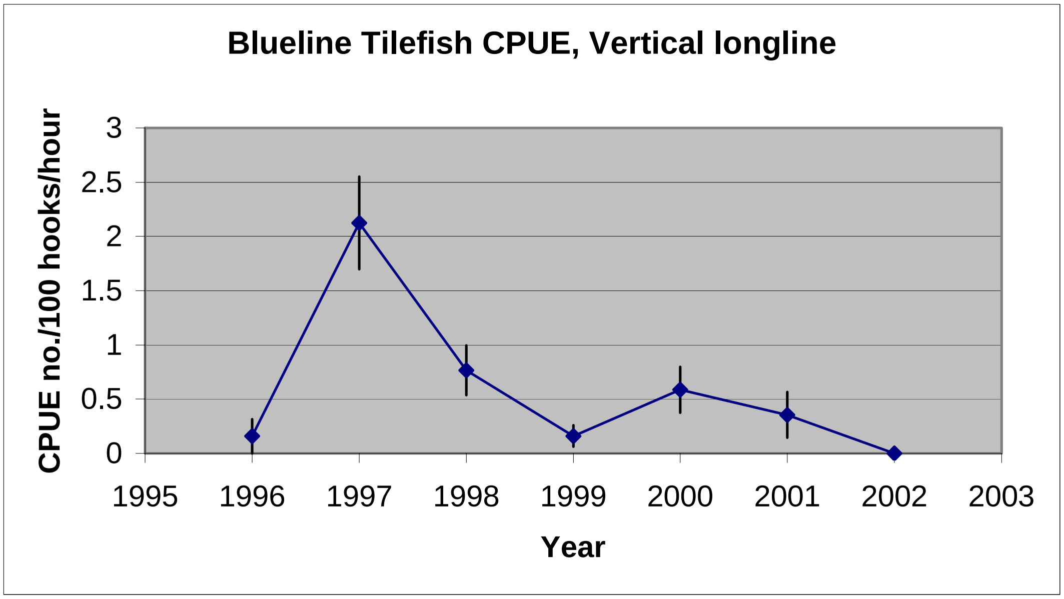


Figure 45. MARMAP CPUE, Blueline Tilefish vertical longline

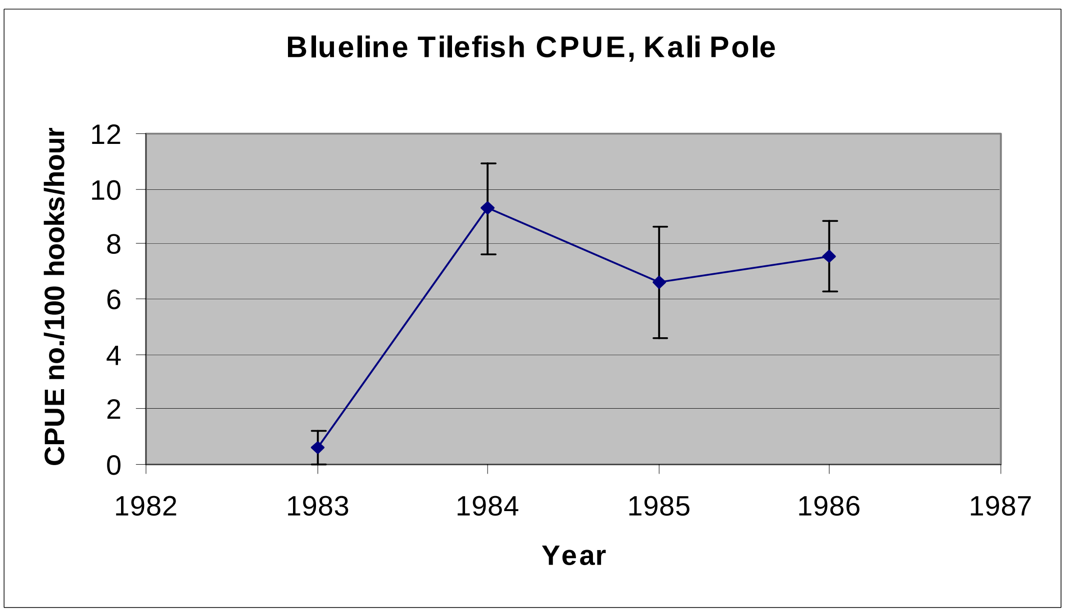


Figure 46. MARMAP CPUE, Blueline tilefish, Kali pole

5.1.6 Output

An Excel spreadsheet containing CPUE and length frequency output was saved in s:\data\survey\species name data workshop.xls. Each file contains CPUE and length frequency for each gear. The excel output for the different species looks like the table below.

	Variable	Mean	Sum	N	Std Dev	Std Error
1999	TOTWGT	12.58593	364.992	29	14.16796	2.630925
1999	MNFWT	3.152078	59.88948	19	1.617455	0.37107
1999	WT100HOOKS	12.58593	364.992	29	14.16796	2.630925
1999	NUM100HOOKS	5.37931	156	29	6.997009	1.299312
1999	WT100HOOKSHR	7.203549	208.9029	29	8.317128	1.544452
1999	NUM100HOOKSHR	3.102298	89.96663	29	4.142367	0.769218

The variables are TOTWGT = total weight (kg), NUM = number, MNFWT = mean fish weight (TOTWGT/NUM), WT100HOOKS = the cpue of weight per 100 hooks, NUM100HOOKS = average number per 100 hooks, N = the number of sets. NUM100HOOKSHR is the average number of tilefish caught per 100 hooks per hour. Notice that N is lower for MNFWT since that N represents the number of set that tilefish occurred in.

Length frequency and mean length are provided in other sheets in the excel file.

Included in the Data\survey folder are the SAS programs used to generate length frequency data (SEDARLF.SAS) and catch per unit effort for each gear type (SEDAR4CPUESLL.SAS, SEDAR4CPUEHLL.SAS, SEDARspeckledhindshelf.sas), the data file (ASCII) containing all MARMAP catch data since 1978 for all species and areas (GRND).

SEDAR

SouthEast Data, Assessment, and Review

Stock Assessment
of the
Deepwater Snapper-Grouper Complex
in the South Atlantic

SEDAR 4 Stock Assessment Report 1

SECTION III
Stock Assessment Workshop Reports

III.A : Snowy Grouper
III. B : Tilefish

SEDAR 4 Assessment Workshop
South Atlantic Deepwater Snapper – Grouper: Tilefish & Snowy Grouper

TERMS OF REFERENCE

1. Select several appropriate modeling approaches, based on available data sources, parameters and values required to manage the stock, and recommendations of the Data Workshop.
2. Develop and solve the chosen population models, incorporating data that are the best available, the most recent and up-to-date, and scientifically sound.
3. Provide measures of model performance, reliability, and goodness of fit.
4. Estimate values and provide tables of relevant stock parameters (abundance, biomass, fishery selectivity, stock-recruitment relationship, etc; by age and year).
5. Consider sources of uncertainty related to input data, modeling approach, and model configuration. Provide appropriate and representative measures of precision for stock parameter estimates.
6. Provide Yield-per-Recruit and Stock-Recruitment analyses.
7. Provide complete SFA criteria: evaluate existing SFA benchmarks; estimate alternative SFA benchmarks if appropriate; estimate SFA benchmarks (MSY, Fmsy, Bmsy, MSST, and MFMT) if not previously estimated; develop stock control rules.
8. Provide declarations of stock status relative to SFA benchmarks: MSY, Fmsy, Bmsy, MSST, MFMT.
9. Estimate the Allowable Biological Catch (ABC) for each stock.
10. Estimate probable future stock conditions and develop rebuilding schedules if warranted; include estimates of generation time.
11. Evaluate the impacts of current management actions, with emphasis on determining progress toward stated management goals.
12. Provide recommendations for future research and data collection (field and assessment); be as specific as possible in describing sampling design and sampling intensity.
13. Provide thorough justification for any deviations from recommendations of the Data Workshop or subsequent modification of data sources provided by the Data Workshop.
14. Fully document all activities: Draft Section III of the SEDAR Stock Assessment Report; Provide tables of estimated values; Prepare a first draft of the Advisory Report based on the Assessment Workshop’s recommended base assessment run for consideration by the Review Panel. Reports are to be finalized within 3 weeks of the conclusion of the Assessment Workshop.

SEDAR 4 Stock Assessment Workshop Participants

Workshop Panel:
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SEDAR 4 Stock Assessment Workshop Time and Place

The SEDAR 4 Stock Assessment Workshop convened at the NOAA/NOS Center for Coastal Fisheries and Habitat Research, Beaufort NC, from Monday, June 7 through Friday, June 11.

SEDAR

SouthEast Data, Assessment, and Review

SEDAR 4 Stock Assessment Report

Section III. A
Assesssment of Snowy Grouper (*Epinephelus niveatus*)
in the
South Atlantic Fisheries Management Council
Management Area

by the SEDAR 4 Stock Assessment Panel

August 08, 2004

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III. A. Snowy Grouper Stock Assessment

(Developed by SEDAR Stock Assessment Workshop)

1. Introduction and Overview

The SEDAR-4 Assessment Workshop met in Beaufort, North Carolina, June 7-11, 2004, to conduct assessments of snowy grouper (*Epinephelus niveatus*) and tilefish (*Lopholatilus chamaeleonticeps*). This material describes the Assessment Workshop's work on snowy grouper.

To assess the status of snowy grouper, two models were considered: (1) a statistical catch-at-age model and (2) an age-aggregated production model. Previous stock assessments of snowy grouper were limited to simple per-recruit analyses (Potts and Brennan, 2001). The present Assessment Workshop (AW) followed the recommendation of the SEDAR-4 Data Workshop (DW) to use a forward-projecting statistical catch-at-age model as the primary assessment tool for snowy grouper. Such a model was preferred over simple VPA methods primarily because of its increased flexibility in formulation and statistical treatment of the data sources. Per-recruit analyses and stock-recruitment modeling were done within the statistical catch-at-age model.

Throughout this report, the SEDAR-4 Assessment Workshop is referred to as the AW; the preceding SEDAR-4 Data Workshop is referred to as the DW. Reports prepared for and available to the DW are listed in Appendix I.

1.1 Data Issues and Deviations from DW Recommendations

1.1.1 Conversions

Length–weight data are available from several sources. At the DW, only data from the Marine Resources Monitoring, Assessment, and Prediction Program (MARMAP) were used to develop a length–weight conversion model. The AW agreed that all length-weight data, combined from the headboat fishery and the MARMAP program, should be used to develop a length-weight conversion model (DW report: Table 3, Section 3). This relationship is given by:

$W = 4.630\text{E-}5 * L^{2.824}$, $R^2 = 0.95$, n = 2,299,

where *W* is weight in grams, and *L* is total length in mm.

1.1.2 Growth

Data on size at age of snowy grouper are available from MARMAP and the National Marine Fisheries Service (NMFS) Beaufort Laboratory. Only the MARMAP age data were available at the DW (DW report: Table 2, Section 3); NMFS data were provided later because otolith analysis was still in progress at the time of the DW. An inspection of the plotted data demonstrates that the MARMAP lengths are typically greater for a given age than the NMFS data (Figure 1). MARMAP data indicate a larger, younger population compared to NMFS data, which assign older ages to the larger fish. An ongoing study at the South Carolina Department of Natural Resources (SCDNR) to validate the age of deep water species using bomb-radiocarbon analysis (Patrick Harris, SCDNR, Pers. Comm.), suggests that ages assigned by MARMAP are too low. Because of this concern that the MARMAP ages may be biased low, the AW chose to use only the NMFS age data in the assessment. This decision affects the analyses for life history-based estimates of natural mortality (*M*), logistic fits for sex ratios and female maturity, and data availability for age compositions.

Von Bertalanffy growth parameters were estimated from the two data sets, pooled and separated (Figure 1). Initially, the growth curves were fit with nonlinear least squares. The growth curves used in the assessment model were fit by a maximum likelihood procedure, under the assumption of variance (in length at age) proportional to mean length at age. Fitting the growth models resulted in a high negative t_0 (e.g., –3.182) value, likely due to selectivity of faster growing young fish with small sample size at the youngest ages (Goodyear 1996). Because of these large, negative estimates of t_0, additional growth model fits were made fixing t_0 at –0.5. In addition, samples were re-weighted based on the inverse of sample size at age. This resulted in a more reasonable pattern of residuals at the oldest ages. The AW used the von Bertalanffy growth curve estimated by this maximum likelihood procedure in all aspects of the stock assessment model (Figure 2).

At the AW, it was suggested that the difference in ageing between MARMAP and NMFS could partly be due to temporal or geographic differences in sampling. The NMFS age data were collected during 1980–2002, primarily off northern Florida, while the MARMAP age data were collected during 1993–94 off North Carolina and South Carolina. The AW compared estimates of von Bertalanffy parameters obtained from the pooled data for 1990–2002 with estimates from the NMFS data set for 1990-2002. The results below show that the parameters estimated for the combined data set are similar to those from the NMFS 1980–2002 and NMFS 1990–2002 data sets. The value of L_∞ is realistic, as it is slightly smaller than the maximum observed length of 1137 mm total length (TL), suggesting no differences among the fitted growth models.

Data set	L_∞ (SE)	K (SE)	t_0 (SE)
NMFS & MARMAP 1979-2002	1009 (16.2)	0.106 (0.004)	-1.486 (0.137)
NMFS, 1980-2002	1103 (33.7)	0.067 (0.004)	-3.182 (0.244)
MARMAP, 1979-1985 & 1993-1994	978 (14.3)	0.137 (0.006)	-0.658 (0.128)
NMFS & MARMAP, 1990-2002	1092 (26.0)	0.093 (0.005)	-1.676 (0.161)
NMFS, 1990-2002	1113 (33.5)	0.066 (0.004)	-3.211 (0.248)
MARMAP, 1993-94	1332 (52.6)	0.082 (0.006)	-1.160 (0.166)

Maximum Likelihood Estimates (Fix t_0 = -0.5)

	n	L_∞	K	CV
NMFS & MARMAP, 1979-2002	3,389	933.6	0.171	0.157
NMFS & MARMAP, 1990-2002	2,761	962.7	0.165	0.163
NMFS, 1980-2002	1,292	959.2	0.131	0.139

Total length and weight at age (mid-year) based on the NMFS, 1980-2002, data and used in the assessment model are summarized in Table 1.

1.1.3 Natural Mortality Rate

Several life history approaches were investigated for estimating age-invariant *M* (Alverson and Carney 1975; Hoenig 1983, Pauly 1980, Beverton 1992) and age-varying *M* (Lorenzen 1996). The Lorenzen 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 a shape parameter (β<0). Lorenzen (1996) provided point estimates and 90% confidence intervals of α and β for oceanic fishes, which were used in this assessment. The AW discussed the possibility of a fixed *M* sensitivity but concluded that the Lorenzen (1996) approach is more biologically plausible. However, 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 1.4%, a value from a recent analysis by Dave Hewitt of equations developed by Hoenig (1983) (VIMS, Pers. Comm., manuscript in review with

Fish. Bull.). Values of M at age are summarized in Table 1 and Figure 3. The maximum observed age from NMFS samples is 35 for snowy grouper.

1.1.4 Sex Ratio at Age

Data on sex ratio at age are available from the MARMAP program. Because of concerns that the MARMAP ageing may be biased, MARMAP ages associated with sex ratios were corrected to the ages that would have been estimated from NMFS size at age data. This was accomplished by first converting the ages to lengths using the inverse of the MARMAP growth curve, and then converting the lengths to ages using the Beaufort growth curve described above. A logistic function was then fit to the MARMAP sex data using the NMFS-converted ages (Table 1). The observed and model fitted proportions of female at NMFS-converted ages are shown (Figure 4). Age at 50% proportion male is at 20.5 years, with 25-75% proportion male occurring at 17.0-23.9 years, respectively.

1.1.5 Female Maturity and Generation Time

A maturity ogive was developed from MARMAP age data with female reproduction (preliminary information in DW report: Section 3). Given the concerns with the MARMAP ages, the available lengths were used to estimate age based on the von Bertalanffy growth parameters estimated from the NMFS age data. A logistic function was then fit to the MARMAP maturity data using the NMFS ages. Observed and predicted female maturity are compared in Figure 5, and predicted female maturity is given in Table 1. Age at 50% female maturity is at 5.6 years, with 25-75% female maturity occurring at 5.0-6.1 years. Length at 50% female maturity is at 524 mm total length (TL), with 25-75% female maturity occurring at 493-555 mm TL.

Generation time (T) was defined as mean age of reproduction (Case 2000). It was computed by following a cohort of individuals from birth until the maximum age, counting all the offspring they produce during their lifetimes at each age x, and averaging across ages:

$$T = \frac{\sum_{x=0}^{\max} l_x b_x x}{\sum_{x=0}^{\max} l_x b_x}$$

where l_x is survivorship to age x, b_x is the per–capita birth rate of adults, and *max* is the asymptotic maximum age. For this analysis, survivorship was determined by the scaled Lorenzen estimates of M (Table 1), the birth rate was assumed proportional to weight, and *max* assumed a value of *100*. The generation time of snowy grouper was estimated to be $T = 20.8$ years.

1.1.6 Landings

Commercial landings by gear (mt) were developed during the DW (DW report: Table 4.4 and Table 4.6, Section 4.1). Commercial landings are summarized by state and gear (Table 2) and by gear (Table 3). For purposes of the assessment the small amount of landings other than handlines and longlines was proportionally distributed between these two gears (Table 4 and Figure 6). Commercial landings are compared by state in Figure 7.

Previous SEDARs have indicated that uncertainty in the quality of landings should be addressed. The confidence in commercial landings has greatly increased since the 1960's. The progressive recognition of the importance of these data resulted in greater effort through the 1970's and mid-1980's to collect these data. In 1984 the state of Florida implemented a trip-ticket program. From the period 1984 to 1994, the South Atlantic states all made strides to improve commercial landings data collection. In 1994, the North Carolina trip ticket program was implemented, resulting in much greater confidence in the landings data from the primary Snapper-Grouper producing states of Florida and North Carolina. As of 2003 the remaining South Atlantic states of Georgia and South Carolina implemented trip ticket programs. The variable coefficient of variation (CV) imposed on the time series of landings by the AW reflect these progressive changes in our confidence in the landings data from a survey to a near census. CVs were assumed to be about 50% in the early years (1962-1984) relative to about 30% in the later years (1994-2002); intervening CVs were linearly interpolated (Figure 8 and Table 6).

Recreational landings were developed during the DW (DW report: Section 4.2). Landings in numbers and weight for the two major recreational components are summarized in Table 5 and Figure 9. Coefficients of variation (CV) are available from the MRFSS (Table 6 and Figure 10). The AW noted an unrealistic variability in year-to-year estimates of landings in the MRFSS. Because such landings are a small portion of the total, no remedial action was taken. Landings from the headboat fishery were kept separate from MRFSS landings (Table 5), and CVs for the headboat landings were 10% in 1972-1995 and 25% in 1996-2002. This decision was based on a significant drop in the level of catch record reporting in southeast Florida since 1996 (Table 6 and Figure 11). Total landings for recreational and commercial fisheries combined are shown in Figure 12.

1.1.7 Indices of Abundance

Two fishery-independent indices were developed from MARMAP vertical longlines and chevron traps during the DW (DW report: Section 5.1.4). A fishery-dependent headboat index was also developed (DW report: Section 4.2.2.5) (Figure 13). Corresponding CVs are available for these indices. These indices and their corresponding CVs are summarized in Table 7. The AW discussed the strengths and weaknesses of these indices and concluded they should be included in the assessment. The greatest problems with the MARMAP longline data identified by the AW included a short time series and small sample size.

In the early 1970's the headboat fishery included some vessels which operated in deeper water using electric reels. Throughout the 1980's there was an apparent change. The vessels with electric reels began to abandon deep-water trips, opting for more shallow water trips. Smaller, juvenile snowy grouper are found in more shallow waters, while the bigger fish are found in deeper waters. This change in the fishery was accommodated in the assessment model by allowing a change in selectivity of the fishery over time. The AW concluded that this would account for the fishery change and allow the use of the index as a measure of abundance.

A fishery-dependent index was also developed from commercial logbook data after discussion at the DW (DW report: Section 4.1.7). However, the AW noted that the commercial logbook program was not designed to be an index of abundance for any species. It could underestimate a population decline, since fishermen might shift effort to areas of greatest abundance. Additional concerns were discussed about what is and is not a directed trip (or a trip capable of taking snowy grouper), regulation changes (quota, 2-for-1 permits), technology creep, effective effort, and the ability of commercial fisherman to easily exploit populations of aggregative fish. This was of particular concern for this species, which is highly aggregative. The consensus opinion of the AW was to drop the commercial logbook index from consideration in the snowy grouper assessment model.

1.1.8 Length Compositions

Commercial length composition data were developed from the TIP database for commercial handline and longline gears in 30 mm TL bins for use in the model. These bins ranged from 225 to 1095 (midpoint values)(mm) for snowy grouper. Individual length measurements were weighted by landings in numbers by state and season in developing the annual length compositions for commercial gears. Individual length measurements were weighted by landings in number by area and season in developing annual length compositions for headboat. MARMAP length compositions were developed by MARMAP.

Snowy grouper have been sampled for length composition since 1983 for commercial handline, 1984 for commercial longlines, 1972 for headboat, 1996 for MARMAP vertical longline and 1990 for MARMAP chevron trap. Sample sizes range from 1 per sector and year to thousands. Although the assessment model effectively downweights small sample sizes, it was decided that some year-sector combinations provided no useful information and should be excluded. The MARMAP and headboat data are more complicated as a clear natural break does not occur. A visual examination of the data helped to distinguish MARMAP and headboat years that likely provided useful information from those that did not. All MARMAP length data were examined for signs of strong recruitment signals corresponding to peaks in adjacent years. This analysis suggested that sample sizes of 25 or less contained little useful information and should be discarded. Sample sizes above 25 provided apparently useful data and were included. Table 8, Figure 14, and Figure 18 summarize the snowy grouper length compositions used in the statistical catch-at-age model.

Figure 19 shows the change in the length distribution of landed snowy grouper from the headboat fishery. The dramatic change in mean size and distribution of lengths is partly explained by changes in the fishery over time (see section 1.1.7).

An examination of the fishery length composition data relative to the maturity information suggests the commercial fisheries are harvesting primarily young, immature fish (Figure 20 through Figure 22). The commercial handline fishery, which is the dominant fishery by landings (Figure 6), appears to have been landing mostly immature fish since 1983, the beginning of the length data collection program and, continues to do so through 2002 (Figure 20 through Figure 22).

1.1.9 Age Compositions

Annual age compositions (ages 0 to 35) were available only for the commercial handline and longline fisheries and for the headboat fishery. Snowy grouper have been sampled for age composition since 1992 from commercial handlines and longlines, and from 1980 to 1997 for headboat. Sample sizes range from 1 per sector and year to greater than one hundred. Although the assessment model effectively downweights small sample sizes, the AW decided that some year-sector combinations with very small samples provided no useful information and should be excluded.

The commercial and headboat sampling had a natural break in sample sizes, with efforts falling below 21 fish in a few year-sector combinations and at or above 29 for the rest. All age data were examined for signs of strong recruitment signals corresponding to peaks in adjacent years. This analysis suggested that sample sizes of 25 or less contained little useful information and should be discarded. Sample sizes above 25 were retained. Table 9 and Figure 23 through Figure 25 summarize the snowy grouper age compositions used in the statistical catch-at-age model.

1.1.10 Discovery of "Virgin" Reefs

There are reports from North Carolina and South Carolina fishermen of newly found "virgin" reefs with snowy grouper populations. The reports suggested that such reefs were discovered in the late 1980's and then again in the late 1990's. The reef discovered in the late 1980's was named Adrian's Mark and is reported by Epperly and Dodrill (1995). The effect of catches from this location on the average weight and length data can be seen in Figure 26 and Figure 29 in 1991-1993. The effect is more pronounced in the handline fishery, which is the major fishery for snowy grouper. The most recent virgin reef discovery is a site referred to as the "snowy wreck". The effects of this site on size of landed fish can be seen in Figure 26 and Figure 29 in the years 1999-2000. The increased size of fish landed due to the snowy wreck appears to be limited to the handline fishery. It is important to realize that the brief increase in size of landed fish in the years 1991-1993 and 1999-2000 is apparently a direct result of fishermen finding virgin reef sites and rapidly exploiting them in 2-3 years. This exemplifies the fisheries' ability to rapidly exploit this species and the limited ability of the species to replenish larger fish to the fishable population.

2. Model 1 – Statistical Catch-at-age Model

2.1 General Modeling Approach

The essence of statistical catch-at-age models is to simulate a population that is projected forward in time like the population being assessed. Aspects of the fishing process (i.e., gear selectivity) are also simulated. Quantities to be estimated are systematically varied from starting values until the simulated populations characteristics match available data on the real population as closely as possible. Such data include total catch by fishery and year; observed age and length composition by gear and year; and observed indices of abundance.

The method of forward projection has a long history in fishery models. It was introduced by Pella and Tomlinson (1969) for fitting production models and then used by Fournier and Archibald (1982), Deriso et al. (1985) in their CAGEAN model, and Methot (1989) in his stock-synthesis model. The model developed for this assessment is an elaboration of the CAGEAN and stock-synthesis models and very similar in structure to models used for assessment of Gulf of Mexico cobia (Williams 2001), South Atlantic red porgy (Anonymous 2002), and South Atlantic black sea bass (Anonymous 2003). Statistical catch-at-age models share many attributes with ADAPT-style tuned and untuned VPAs.

2.2 Methods

A statistical catch-at-age model was used to assess the snowy grouper population. An initial model run was determined through iterative re-weighting of the likelihood components, with central values of important parameters, until a reasonably balanced fit was obtained to the data. In a second stage of modeling, uncertainty was represented by using a mixed Monte Carlo and bootstrap sampling procedure (MCB). A general description of the assessment model follows, followed by more detailed descriptions of the initial run and the MCB procedure.

2.2.1 Properties of age-structured model

The statistical catch-at-age model for this assessment was implemented in the AD Model Builder (ADMB) software (Otter Research 2001) on a microcomputer. The ADMB model code is attached as Appendix II. A summary of the model equations are shown in Table 10. The formulation's major characteristics are summarized as follows:

Natural mortality rate - The natural mortality rate was assumed constant over time. A vector of age-specific *M* estimates based on Lorenzen (1996) was used as a starting estimate. The age-specific *M* vector was then re-scaled based on a fraction of survivors at the oldest age consistent with the findings of Hoenig (1983).

Stock dynamics - The standard Baranov catch equation was applied. This assumes exponential decay in population size due to fishing and natural mortality processes.

Growth/Maturity - Size and proportion female mature at age was assumed constant across years. Snowy grouper is a protogynous species and it was assumed that all males are fully mature.

Recruitment - A Beverton–Holt recruitment model was estimated internally. Estimated recruitments were loosely conditioned on that model.

Biological benchmarks - Biological benchmarks were calculated based on maximum sustainable yield (MSY) estimates from the Beverton–Holt recruitment model. These include the exploitation rate, fishing mortality rate, and total mature biomass at MSY (Emsy, Fmsy, and SSBmsy, respectively).

Fishing - Four fisheries were modeled individually: handline, longline, headboat, and private/charter boat. Separate fishing mortality rates and selectivity at age patterns were estimated for each fishery. For the headboat and MRFSS (private/charter) fisheries, the missing landings data in years 1961-1971 and 1961-1980, respectively, was treated by fixing a value of *F* for those years. A geometric mean *F* for the earliest 3 years was applied to 1971 and 1980, for the headboat and MRFSS fisheries, respectively. The remaining years were then fixed by linear interpolation back in time, such that F=0 in 1961.

Selectivity functions - Selectivity was fit parametrically, using a logistic model for the longline fishery and double–logistic models for the remaining fisheries, rather than estimating independent selectivity values for each age. That approach reduces the number of estimated parameters and imposes theoretical structure on the estimates. The age of inflection points for the ascending and descending portions of the double-logistic curve for the headboat selectivity were allowed to vary over time to mimic known changes in the fishery operation (see Table 10 for details).

Discards – Discards are believed to be negligible and are therefore ignored in the assessment model (from DW).

Abundance indices -The model used three separately modeled indices of abundance. They include fishery independent trap (years 1990-2002) and longline (years 1996-2002) indices and a fishery dependent headboat CPUE index (years 1973-2002).

Fitting criterion -The fitting criterion was a total likelihood approach in which fishery catch, observed age and length compositions, and the abundance index patterns were fit to the degree that they are compatible. Landings data and abundance index data were fit using a lognormal likelihood. Age and length composition data were fit using a multinomial likelihood. Relative statistical weightings of likelihood components for an initial model run were chosen at the assessment workshop after examining many candidate model runs. The criteria for choice were a balance of reasonable fit to all available data and a good degree of biological realism in estimated population trajectory.

Characterization of Uncertainty – After selection of an initial run model, uncertainty was characterized by use of a mixed Monte Carlo and bootstrap sampling procedure (MCB). The procedure involved random sampling of parameter values, index data, and likelihood component weights from the initial model run. The assessment model was then fit to each set of sampled parameter, index, and weight values. The median result from these runs was taken as the best point estimate of any estimated quantity. The 10^{th} and 90^{th} percentiles were used to characterize uncertainty.

Estimated Parameters -- The model estimates 204 parameters. These parameters were estimated in two phases. In the first phase parameters were estimated for virgin recruitment (1), index catchability coefficients (3), and average fully selected fishing mortality for each fishery (4). Then in the second phase the parameters for selectivity (20), annual fully selected fishing mortality (135), and annual recruitment deviations (41) were added to the optimization procedure.

2.2.2 Likelihood Component Weights

The selection of likelihood component weights for the initial run model involved an iterative process of model fitting, examination of the fit, and adjustment of the weights. The performance of an individual model run was evaluated based on its fit to the observed datasets. These datasets include four time series of landings, three abundance indices, and age and length compositions from both fishery and survey sources. The influence of each dataset on the overall model fit is determined by the specification of the error terms in each likelihood component. In the case of lognormal likelihoods, it is the annual coefficient of variation, and for the multinomial components, it is the annual sample sizes. These terms determine the influence of each year of data relative to other years of the same data source. However, the relative influence of different components can only be treated by re-weighting each likelihood. An objective determination of these weights is an unsolved problem in statistical modeling. In this case, the weights were determined by examination of overdispersion, model mis-specification (e.g. runs of residuals), and the general reliability (i.e. our understanding of information content) of the data source.

We reduced the number of weights to be examined by grouping likelihood components based on their type, scale, and method of collection. For example, the four fisheries landings data were grouped, so that a single weight was applied to all four components. Similarly the index components were grouped, the age composition components were grouped, and the length composition components were grouped. The model also contains a likelihood component for the annual recruitment deviation parameters, which are constrained to follow a Beverton–Holt stock-recruit curve. The end result was five statistical weights (for landings, indices, age compositions, length compositions, and recruitment deviations) which were iteratively adjusted in the model to find a balanced fit to all the data sets in accordance with our understanding of their information content.

After many exploratory runs of the model, the recruitment deviation weight was fixed at a value of 50. This value allowed the annual recruitment deviations (from the estimated curve) to vary substantially, while preventing extreme single parameter estimates (e.g., on the order of 50 times the average). This reduced the number of weights which needed to be examined for the overall model fit to four.

2.3 Initial Model Run

This section describes the initial model run upon which the MCB procedure was based.

2.3.1 Fixed Parameters

Natural mortality in the initial model run was fixed at the Lorenzen (1996) age-specific estimates of *M*, scaled so that the cumulative survival to the oldest observed age was 1.4% (see Section 1.2.3). Steepness was fixed at 0.7, based on meta-analyses (see Section 2.3.2).

It is believed this stock was lightly exploited in the years prior to 1961, the first year in the assessment model. Therefore the first year's estimated numbers-at-age in the model were forced to be near a virgin, unfished level. This was accomplished by heavily penalizing the model for deviating from a starting year condition of SSB(1961)/SSB(virgin) = 0.9. The parameters determining this ratio include the virgin recruitment, recruitment deviation in 1961, and fishing mortality parameters in 1961.

2.3.2 Likelihood Component Weights

Various weighting schemes of the grouped likelihood components were explored extensively with values from 1-100 (Table 11). A starting scheme with all weights set to 1 revealed a poor fit to the landings and indices, with landings estimates on the order of 5-10 times the observed value in 1 or 2 of the early years. The poor fits to the indices often resulted in predicted trends opposite to the observed data.

Many model runs were explored by incrementally increasing the weight of each likelihood component. The fit to each of these runs was examined, with the best overall fits occurring when the landings and indices components were weighted higher than the composition data. After careful consideration of many combinations of weighting schemes, a final scheme was chosen by the AW. The weighting scheme for the initial run was as follows:

Likelihood Component	Weight
Landings	20
Indices	20
Age Compositions	1
Length Compositions	1
Recruitment Deviations	50

This weighting scheme resulted in a balanced fit to the observed data in accordance with the expert knowledge about the data information content.

2.4 Modeling Uncertainty

To characterize uncertainty in the assessment, the AW adopted a mixed Monte Carlo and bootstrap (MCB) approach. Monte Carlo and bootstrap methods (Efron and Tibshirani 1993; Manly 1997) are commonly used to characterize uncertainty in ecological modeling, and the mixed approach has been used successfully in previous stock assessments (Restrepo et al. 1992; Legault et al. 2001). The MCB approach translates uncertainty in model input into uncertainty in model output by fitting the model many times with different values of key input parameters. Each time the model is fit, a new value for each key input parameter is chosen from a statistical distribution representing the state of knowledge about its possible values. In this approach, the results describe a range of possible outcomes, so that uncertainty is characterized more thoroughly than it could be by any single fit or handful of sensitivity fits. A minor disadvantage of the approach is that computational demands are relatively high.

In this assessment, the MCB approach used the R software (R Foundation for Statistical Computing 2004) to generate a new data input file for each MCB trial and then execute the assessment model (an external program). Each input quantity either remained fixed at the value used in the initial run or was selected at random from a statistical distribution, as described below. Inputs that varied by MCB trial were steepness, the shape parameter of the natural mortality curve, the scale of the natural mortality curve, initial stock biomass, yearly values of abundance indices, and likelihood weights.

2.4.1 Natural Mortality Rate

As noted above, an age-varying natural mortality function was estimated by the method of Lorenzen (1996), and then scaled to match estimates of survival. This method provided point estimates and nonparametric 90% confidence intervals on parameters of the natural mortality function ($M_a = \alpha W_a^{\beta}$). The point estimate of the shape parameter β was −0.305, and the 90% confidence interval was estimated to be [–0.351,–0.257]. In each MCB trial, the shape parameter was drawn from a uniform distribution on the 90% confidence interval.

In addition to uncertainty in the shape parameter, the MCB procedure incorporated uncertainty in the scale of natural mortality. Given a value of the shape parameter β, the natural mortality function M_a was scaled to achieve a certain probability of reaching the observed maximum age. In MCB trials, the probability of reaching the maximum age was chosen from a uniform distribution on the range 0.1% to 5.0% (Quinn and Deriso 1999).

2.4.2 Steepness

Steepness is a parameter in the stock–recruit curve that controls how quickly recruitment approaches the virgin level as spawning stock biomass increases (Table 10). Steepness values are constrained biologically between 0.2 and 1.0, where 0.2 describes a linearly increasing stock–recruit curve and 1.0 describes a flat stock–recruit curve at the virgin level. Attempts were made to estimate steepness in exploratory fits of the assessment model, however those estimates almost always converged to an upper or lower bound on the parameter. Therefore the AW decided that steepness should be described from a probability distribution.

In choosing a distribution of steepness values for the MCB procedure, the AW relied on several published studies. Myers et al. (1999) examined stock–recruitment parameters for a wide range of species. Rose et al. (2001) identified several general life history characteristics for fish within the data from Myers and co-workers, and snowy grouper and tilefish both fall in Rose's periodic spawner category. This category encompassed species that reproduce several times over their lifetime and may vary in their success substantially from one reproductive event to another. Even this category encompassed a broad range of species, from sardines to bluefin tuna. We further limited the species under consideration by eliminating freshwater species and pelagic species, leaving only marine or anadromous demersal periodic spawners. Finally, we removed rockfish species (*Sebastes* spp.), a slow-growing, long-lived group that has uncharacteristically low steepness for marine demersal species. This left 19 species.

The steepness values for the 19 species ranged from 0.34 to 0.95 (steepness in general may range between 0.2 and 1). The median of the distribution of steepness values was 0.81, and the mean was 0.74. When transformed, these data fit a lognormal distribution with a mean of –0.33289 and a standard deviation of 0.280926. To sample a steepness parameter value, the MCB procedure drew from this distribution and exponentiated the result. In other words, a steepness value (y) could be drawn from a lognormal distribution as follows:

$$y = e^{x} \quad where \quad x \sim N(-0.33289, 0.280926)$$

To avoid biologically unrealistic limits of steepness (0.2 and 1), the resulting distribution was truncated to range from 0.25 to 0.95.

2.4.3 Initial Stock Biomass relative to Virgin Biomass

By using a strong constraint, the initial spawning stock biomass was effectively fixed in the initial model run at 90% of carrying capacity, to reflect the light level of exploitation before the assessment period (i.e., before 1962). (Here, the steady-state carrying capacity was considered the virgin biomass.) Because many factors other than exploitation (e.g., environmental and ecological conditions) also affect abundance, the AW included a wide range of initial stock conditions in the MCB procedure. The initial stock biomass was drawn from a uniform distribution that ranged from 0.5 to 1.3 of SSB(virgin) [expected value = 0.9 SSB(virgin)].

2.4.4 Abundance Indices

To account for uncertainty in the indices of abundance, the AW recommended a parametric bootstrap with multiplicative lognormal error (Quinn and Deriso 1999). To implement this approach in the assessment model runs, random variables ($x_{u,y}$) were drawn for each year *y* of index *u* from a normal distribution with mean 0 and variance $\sigma^2_{u,y}$ [that is, $x_{u,y} \sim N(0, \sigma^2_{u,y})$]. Yearly index observations were then perturbed with the following equation:

$$U_{u,y} = \hat{U}_{u,y}[\exp(x_{u,y}) - \sigma^2_{u,y}/2].$$

The term $\sigma^2_{u,y}/2$ represents a bias correction, which centers the multiplicative error on a value of one. The year-specific standard deviations ($\sigma_{u,y}$) were set equal to the corresponding estimated coefficients of variation (CV) from computation of the indices, scaled to a maximum of 0.3. The values were scaled because, at values less than 0.3, the CV in arithmetic space approximately equals the standard deviation in log space, but that relationship breaks down at higher values.

2.4.5 Likelihood Component Weights

Relative likelihood weights assigned to the various data components influence model fidelity to each component. Many combinations of likelihood weights are conceivable, and in many assessments, a definitive choice among them is impossible. To capture this uncertainty, the MCB trials used weights selected at random from uniform distributions. These were centered on the values used in the initial run and ranged ± 25% around them.

2.5 Acceptance Criteria

To apply the mixed MCB procedure, the model was fit a total of 2317 times (including the initial run), where each fit used a different set of parameter values, input data, and weighting scheme, generated as described above. After the fits were obtained, inspection of the results revealed that many of the fits converged on parameter estimates that were deemed biologically unreasonable. The unreasonable runs appeared to be a distinct cluster, possibly representing a local minimum of the likelihood surface. The primary unreasonable features of these runs were very high population estimates and extremely low fishery exploitation, to the point that the fishery had absolutely no effect on the population, a biologically unreasonable situation.

The 2316 MCB runs were examined to determine if a single or combination of input parameters were associated with the biologically unreasonable runs. Figure 30 shows the distribution of estimates of the exploitation rate (E) and total mature biomass (SSB) in 2002 from the model MCB runs. The highest density of points occurs in the upper left hand corner indicating $E_{2002} \approx 0.1$ and $SSB_{2002} \approx 400$ (mt). There is another high density of points estimating $E_{2002} \approx 0.0005$ and $SSB_{2002} \approx 500{,}000$ (mt), and some of the extreme points suggesting $E_{2002} \approx 0.00000001$ and $SSB_{2002} \approx 100{,}000{,}000$ (mt). An SSB of 500,000 mt for snowy grouper is biologically unreasonable. For comparison, the most recent stock assessment of Atlantic menhaden (*Brevoortia tyrannus*) estimated the SSB to be less than 100,000 mt in 2002 and Eastern Bering Sea walleye pollock (the largest fishery in the world) SSB was estimated to be 3,680,600 mt in 2002.

The MCB runs estimating unreasonably high SSB also resulted in high SSB(2002)/SSBmsy estimates. The AW agreed on a criteria for culling these unreasonable runs, cases where SSB(2002)/SSBmsy > 2.0. Figure 31 shows the density distribution of SSB(2002)/SSBmsy for all 2316 MCB runs with the culling value of 2.0 indicated as a vertical line. After culling the unreasonable MCB runs, there were 1470 reasonable runs remaining. These runs were used in subsequent reported results of the assessment model. Median values are used to demonstrate central tendencies of the results, and 10^{th} and 90^{th} percentiles are used as an empirical 80% interval to demonstrate variability.

2.6 Results

Section 2.4.1 describes the assessment model fit for the initial run only. Sections following this represent results from the reasonable MCB runs (n=1470).

2.6.1 Model Fit – Initial Run

As mentioned earlier, the likelihood component weights were adjusted to fit the various data sources in accordance with expert knowledge about their information content. In fitting the landings data (Figure 32), the model overestimated handline and longline landings in the early 1980's. This fit is not inconsistent with present understanding of the uncertainty in these data, in particular the belief that the CV's were higher during those years, because of reporting problems. There appears to be a strong signal in the non-landings data sources indicating the population should be at a low level in the more recent time period. One way the model can fit this is by overestimating landings in some early years, resulting in an estimated population decline.

The fit to the abundance indices (Figure 33) fails to mimic the rapid annual changes, but rather fits a smooth line through the data. This is typical of such models when fit to relatively noisy abundance indices, and is considered more biologically realistic than a tight fit. In all cases, the model appears to be picking up the general trend indicated by the indices.

The fits of the age and length composition data are generally good (Figure 34 through Figure 41). An interesting pattern is that in some years the proportion of very large fish in the handline catch is underestimated. This appears to reflect the discovery of "virgin" reefs discussed in the data section above (section 1.1.10, Figure 37). The longline length-composition data show rapid annual changes in the proportion of very large fish harvested in the first four years. The model did not fit this feature, which may be due to noise caused by patchy distribution of fish and fishing (Figure 38). The annual headboat and MARMAP surveys sample sizes are fairly small, resulting in noisy length composition data and poorer fits (Figure 39 through Figure 41).

The estimated numbers at age (1961–2002) from the initial run model are listed in Table 12.

2.6.2 Selectivity (MCB results)

The estimates of selectivity from the MCB trials are shown in Figure 42 and Figure 44. As expected, the headboat and MARMAP selectivity estimates are more variable, due to the small sample sizes of their length and age composition estimates. In the handline and longline fisheries, full selection occurs around age 5. Snowy grouper are not fully mature until age 8 (Figure 5).

2.6.3 Population Time Series (MCB results)

Estimates were made of several time series of management interest. These include annual exploitation rate, fishing mortality rate, total landings, number of recruits, mature biomass, and total biomass. Results (Figure 45 through Figure 47; Table 13) include estimates from the initial run, plus median and 80% interval from the MCB procedure. These figures show a population beginning a decline as early as 1966, reaching its lowest levels in the most recent years (Figure 46). Increasing exploitation of snowy grouper begins at about the same time as the population decline, which coincides with an increase in the reported landings of snowy grouper (Figure 44 and Figure 45).

2.6.4 Stock and Recruitment (MCB results)

The estimated Beverton–Holt stock-recruit relationship (Figure 48) is perhaps even more uncertain than illustrated, as the range of curves is largely governed by the assumptions made about the distribution of the steepness parameter (see section 2.4.2).

As is often the case, there is little information for estimating the earliest and latest recruitment points; therefore, these estimates rely more heavily on the stock–recruit relationship. The below average recruitment estimated in the early part of the time series is likely a result of counterbalancing a high initial condition [SSB(1961)/SSB(virgin) = 0.9] with the fishery information, which suggests that the population was at a low level in the early 1980s. The estimated low recruitment results in an estimated population decline in the early years. As mentioned in the discussion of the fit to the initial model (section 2.5.1), another way the model appears to reduce the population is by overestimating the landings in the some of the early years.

2.6.5 Per-recruit Analyses

The static spawning potential ratio (SPR) for each year was calculated based on an equilibrium age-structure and the age-specific total exploitation from the combined fisheries (Figure 49). According to the model, the static SPR has remained below 0.15 since 1981.

After each MCB trial, a per-recruit analysis was completed using the average exploitation ratios among the four fisheries from the last three years (1999–2002) and their respective selectivity patterns. Estimates of SSB-per-recruit and yield-per-recruit are shown in Figure 50 and Figure 51, along with estimates of some common benchmarks (medians from the MCB procedure).

2.6.6 Equilibrium Analyses

As in the per-recruit analyses above, equilibrium analyses were computed using the average exploitation ratios among the four fisheries from the last three years (1999–2002) and their respective selectivity patterns. In addition, equilibrium analyses take into account the estimated stock-recruit relationship. The equilibrium total mature biomass and yield as functions of exploitation are shown in Figure 52 and Figure 53, along with estimates of corresponding benchmarks (medians from the MCB procedure).

2.6.7 Management Benchmarks

We computed management benchmarks in terms of exploitation rates, computed for ages 1+. Benchmarks computed include the exploitation rates at maximum yield-per-recruit (Emax), spawning potential ratio of 0.3 and 0.4 (E30% and E40%, respectively), and maximum sustainable yield (Emsy) (Table 14). The same set of benchmarks were also computed for the corresponding fishing mortality levels, computed as population weighted for ages 2+. Ranges of these values from the MCB runs are listed in Table 13. This table also lists the benchmarks for maximum sustainable yield (MSY), total mature biomass at MSY (SSBmsy), and total biomass at MSY (Bmsy), with their ranges from the MCB runs.

2.6.8 Stock Status in 2002

Stock status at the beginning of 2002 (the end of the assessment period) was analyzed relative to the benchmarks listed above. The maximum fishing mortality threshold (MFMT; limit reference point in F) is assumed equal to Emsy or Fmsy, depending on the preferred measure of exploitation. Fishing status was determined relative to these. A value of maximum spawning size threshold (MSST; limit reference point in biomass) was not computed here. We present the measures of spawning stock size relative to SSBmsy.

Figure 54 suggests overfishing of snowy grouper began in the mid 1970's and has continued since. Figure 55 shows the population response to the fishing with a steady population decline to levels below SSBmsy starting in the early 1980's.

The range of relative measures of exploitation and SSB in the last year (2002) of the model is shown in Figure 56 and Figure 57. The AW concluded that snowy grouper was overfished and overfishing was occurring in 2002.

The estimated stock status for snowy grouper in 2002 is quite low, median of 18% for SSB(2002)/SSBmsy. This corresponds to a stock status in 2002 relative to the virgin stock size [SSB(2002)/SSBvirgin] of about 5%. The input data for the assessment model do not include a consistent abundance index that covers the whole time period of the model. The headboat CPUE and length composition data extends back to 1972, but as discussed earlier (see section 1.1.8) changes in the fishery make interpretation of the observed trends in this index difficult. The other abundance indices do not start until 1990 or later. Therefore the model must rely on data sources other than abundance indices for determining stock status.

Other data that provide information on stock status are the average weight and length from the fisheries landings as well as the observed age and length composition data. Assuming an equilibrium age-structure, Figure 58 shows the change in average weight and length of landed fish for the commercial handline and longline fisheries relative to stock status. Included on these figures is the observed average weight and length from the most recent year of data (2002). The rest of the time series of average weights and lengths from the commercial fisheries can be seen in Figure 26 and Figure 27. The 2002 average weights and lengths from the commercial fisheries suggest the population is at very low levels. The average weight and length in 2002 from the handline fishery suggests the population is near 11% and 3% of SSBmsy, respectively (Figure 58). The average weight and length in 2002 from the longline fishery suggests the population is near 44% and 28% of SSBmsy, respectively (Figure 58). The length composition data from the most recent years (2000-2002) also suggests a depleted population of snowy grouper. Figure 59 shows observed length distributions which are skewed toward smaller fish compared to an equilibrium, virgin state length composition.

2.7 Model Projections

2.7.1 Projection Methods

The stock was projected for 35 years beyond the assessment period (2003–2037). Projections were implemented as part of the Monte Carlo/bootstrap routine, so that the fixed and estimated parameters from each run were carried forward in n = 1470 projections. In each projection, recruitment was modeled using a nonparametric bootstrap procedure. This procedure computed mean yearly recruitment from the estimated stock–recruit curve, to which recruitment deviations were added. These recruitment deviations were selected at random from recruitment residuals estimated in the assessment period (1962–2002). Therefore, an underlying assumption is that past recruitment typifies future recruitment. Since snowy grouper appear to be overfished, the stock was projected under one scenario of fishing mortality (F=0).

2.7.2 Projection Results

Under the scenario of F=0, the snowy grouper population does not recover to SSBmsy for 13 years (Figure 60, Figure 61; Table 15). Since the last year of the model is 2002 and we are well into 2004 with little change in management that is likely to affect snowy grouper, it is highly probable that the stock status is lower and recovery will take longer than that reported here.

3. Model 2 – PRODUCTION MODEL

3.1 Overview

An age-aggregated production model was also fit to available data. Production models are particularly useful when data are inadequate to classify individuals based on age or size. They are also a useful tool for exploration of management consequences because their relative simplicity makes it easier to understand the details of how manipulations are affecting results and performance. Their simplicity may also allow them to more powerfully fit observations that lack age or size structure, for example landings and abundance indices. However, the age or size structure of the population can give useful insight into its history and status. Consequently, when reliable data are available on the age, size, or both of individuals in a population, an age- or size-structured model can often be more informative. That is particularly true when data on relative abundance are uncertain or fragmented, as in this assessment.

Given the above, the workshop was hesitant to apply such a model this stock. Ultimately, the group decided that application of such a model should be examined in the course of the workshop, and that its results would have to pass critical examination before being accepted.

3.2 Methods (Production Model)

In this task, the Prager (1994) form of the Graham–Schaefer production model was used. This is a continuous time formulation, conditioned on catch, that does not assume equilibrium conditions. By conditioning on catch, the landings data are assumed more precise than the abundance indices. The model fits more than one abundance index by assuming they are correlated measures of stock abundance and that differences between indices can be considered sampling error. The Schaefer (1954; 1957) form of the production model, used here, assumes $B_{MSY} = 0.5K$, where K is the carrying capacity of the stock (virgin stock size). The Schaefer form is often used as a default because of its theoretical simplicity and because it is considered a central case among possible shapes of production model. The ASPIC software of Prager (1995) was used.

3.3 Data Sources (Production Model)

Data used for production modeling were total landings and the three abundance indices described above.

The headboat fishery moved inshore during the data period and consequently selectivity in the fishery changed. In the age-structured modeling, this was accommodated by dividing the headboat index into three time periods: with constant selectivity in 1972–1976 a possibly different constant selectivity in 1992–2002, and selectivity varying between them in 1977–1991. The production model has no age structure and consequently cannot accommodate changes in selectivity. This was handled here by fitting the 1972–1976 and 1992–2002 as separate indices and not using the middle years.

In stocks that display a sharp initial decline, production model results can include unrealistically high values of B1/K, where B1 is the biomass at the start of the time series, and K is the carrying capacity. In such cases, a value of B1/K is assumed, rather than estimated. Here, that expedient was not found necessary.

3.4 Results (Production Model)

Fits to the index data series are quite approximate, as the indices have sharp year-to-year changes not expected in a grouper population (Figure 62 through Figure 65). Also, the indices are not well correlated with one another, so that fitting one necessarily results in lack of fit to another (see correlation matrix in ASPIC output file, Appendix III).

Estimates of MSY, stock status, and related parameters from the production model are given in Table 16.

In general the production model is much more optimistic about the stock's potential for recovery than the age-structured model. This is apparent both in Figure 66 (which estimates rapid population increases) and in the estimates, which estimate Fmsy = 1.0. Even though estimates of absolute F from production model are generally less reliable than of relative F, the estimate in this case seems particularly unlikely. Biologically, it seems impossible that a slow-growing long-lived species could sustain $F = 1.0$ at MSY. The figure is more typical of small schooling species, such as sardines or menhaden.

The production-model estimates come about because the available indices show periods of rapid increase and decline. The group believes that the indices probably exaggerate population trends and also, being short, are subject to sampling error. The age- and length-composition data used in the age-structured model, serve to moderate the apparent vigor of the population represented in the abundance indices. The production model does not have the advantage of using those data.

The group concluded that the production model fit, while an interesting exercise, should not be used in assessment of this stock.

4. Research Recommendations

1. Ageing discrepancies between laboratories should be resolved. State and Federal investigators should continue efforts to standardize techniques and resolve the systematic discrepancies in age determinations. Additional research should be undertaken to verify and validate age determinations.

2. Sampling programs are required to quantify discard rates. Research should also be initiated to identify management strategies that could reduce discard mortality. Discarding may become an increasingly important concern as the stock recovers and compliance with measures such as trip limits become more difficult.

3. Fishery-independent data collected by the MARMAP program are important to understanding the dynamics of this population, and the National Research Council has recommended that fishery-independent data play a more important role in stock assessment. However, it has been noted that the MARMAP sampling programs do not having ideal extent, both in area coverage and in sampling intensity, for many important species in the South Atlantic snapper–grouper complex. It would be highly desirable for the MARMAP program to receive sufficient funding to expand its coverage and thus provide improved measures of stock abundance.

4. Recent West Coast stock assessments were criticized by the U.S. General Accounting Office (GAO 2004) for not including at least one NMFS (i.e., fishery-independent) data source of sufficient scope and accuracy collected from an unbiased, statistical, and scientifically designed program. Effort should be devoted toward developing an independent data source for the South Atlantic snapper-grouper complex that meets the requirements outlined in the Stock Assessment Improvement Plan and the 1998 National Research Council report on improving stock assessment. This could be done through the MARMAP program or otherwise.

5. Representative age, length, and sex composition data are needed for all fisheries, seasons, and areas. Sampling should be distributed according to the pattern of landings. Initial sampling targets are suggested as 20 age structure samples per age and 5 length samples per age sample. This provides approximate snowy grouper sampling targets of 700 age structures and 3500 lengths.

6. Additional life history and biological research is needed, especially that which covers the full geographic range of the species. Among other items, fecundity and reproductive research is needed (batch fecundity and frequency at age and/or size).

7. Further research is needed into the implications of sex change for fishery management.

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6. Tables

Table **1**: Summary of snowy grouper life history values used in the statistical catch-at-age model. Lorenzen natural mortality (M) values are from Lorenzen (1996) and scaled M are these values re-scaled to 1.4% surviving to age 35.

Age (years)	Total Length (mm)	Weight (kg)	Proportion Females	Proportion Female Maturity	Lorenzen M	Scaled M
0	117.8	0.03	1.00	0.00	1.27	0.50
1	221.1	0.19	1.00	0.00	0.74	0.29
2	311.7	0.51	1.00	0.00	0.55	0.22
3	391.2	0.97	1.00	0.01	0.45	0.18
4	461.0	1.54	0.99	0.04	0.39	0.16
5	522.1	2.19	0.99	0.24	0.35	0.14
6	575.8	2.88	0.99	0.69	0.32	0.13
7	622.9	3.60	0.99	0.94	0.30	0.12
8	664.2	4.31	0.98	0.99	0.29	0.11
9	700.4	5.01	0.98	1.00	0.27	0.11
10	732.2	5.68	0.97	1.00	0.26	0.10
11	760.0	6.31	0.95	1.00	0.26	0.10
12	784.5	6.90	0.94	1.00	0.25	0.10
13	805.9	7.45	0.92	1.00	0.24	0.10
14	824.8	7.95	0.89	1.00	0.24	0.09
15	841.3	8.41	0.85	1.00	0.23	0.09
16	855.7	8.82	0.81	1.00	0.23	0.09
17	868.5	9.20	0.75	1.00	0.23	0.09
18	879.6	9.54	0.69	1.00	0.23	0.09
19	889.4	9.84	0.62	1.00	0.22	0.09
20	897.9	10.11	0.54	1.00	0.22	0.09
21	905.5	10.35	0.46	1.00	0.22	0.09
22	912.1	10.56	0.38	1.00	0.22	0.09
23	917.8	10.75	0.31	1.00	0.22	0.09
24	922.9	10.92	0.24	1.00	0.22	0.09
25	927.4	11.07	0.19	1.00	0.22	0.09
26	931.3	11.20	0.14	1.00	0.21	0.08
27	934.7	11.32	0.11	1.00	0.21	0.08
28	937.7	11.42	0.08	1.00	0.21	0.08
29	940.4	11.52	0.06	1.00	0.21	0.08
30	942.7	11.60	0.04	1.00	0.21	0.08
31	944.7	11.67	0.03	1.00	0.21	0.08
32	946.5	11.73	0.02	1.00	0.21	0.08
33	948.0	11.78	0.02	1.00	0.21	0.08
34	949.4	11.83	0.01	1.00	0.21	0.08
35	950.6	11.87	0.01	1.00	0.21	0.08

Table 2: Commercial snowy grouper landings (mt) by state and by fishing gear for years, 1962-2002.

Year	Florida & Georgia (mt)	South Carolina (mt)	North Carolina (mt)	Total (mt)
1962	33.08	0.00	0.04	33.12
1963	47.32	0.00	0.04	47.35
1964	47.97	0.01	0.13	48.11
1965	38.76	1.45	0.00	40.21
1966	32.08	0.00	0.59	32.68
1967	61.00	0.00	0.19	61.19
1968	73.10	1.72	2.32	77.14
1969	59.20	0.21	0.00	59.41
1970	83.16	0.16	0.00	83.31
1971	83.81	0.17	1.32	85.29
1972	54.72	0.35	0.00	55.06
1973	68.81	3.02	0.92	72.74
1974	90.76	2.55	6.33	99.64
1975	112.98	0.64	4.09	117.70
1976	147.51	7.30	1.09	155.90
1977	120.38	13.25	2.75	136.38
1978	149.87	20.67	56.18	226.73
1979	125.31	17.25	63.50	206.06
1980	94.97	7.15	63.64	165.75
1981	122.85	50.35	144.72	317.92
1982	119.96	63.59	92.24	275.79
1983	127.28	132.83	158.16	418.26
1984	161.02	64.14	80.23	305.39
1985	102.70	37.27	36.66	176.63
1986	114.91	51.70	53.10	219.71
1987	54.75	55.84	68.75	179.34
1988	41.09	55.83	35.35	132.27
1989	51.56	98.80	77.86	228.21
1990	52.01	109.02	123.43	284.46
1991	72.66	49.25	108.65	230.57
1992	77.25	40.88	160.14	278.27
1993	82.66	45.00	83.14	210.81
1994	42.76	34.06	56.41	133.23
1995	77.66	27.54	64.58	169.78
1996	54.71	30.44	56.15	141.31
1997	103.89	56.25	74.41	234.55
1998	54.84	29.98	56.23	141.06
1999	57.29	33.90	99.02	190.20
2000	47.52	32.87	85.07	165.46
2001	43.80	44.34	48.88	137.02
2002	27.94	42.39	50.55	120.87

Table 2 (cont'd): Commercial snowy grouper landings (mt) by state and by fishing gear for years 1962-2002.

Year	Handline (mt)	Longline (mt)	Trawl (mt)	Traps (mt)	Other (mt)	Total (mt)
1962	33.09	0.00	0.03	0.00	0.00	33.12
1963	45.33	1.88	0.00	0.14	0.00	47.35
1964	47.23	0.19	0.00	0.69	0.00	48.11
1965	39.32	0.00	0.00	0.89	0.00	40.21
1966	31.85	0.00	0.00	0.83	0.00	32.68
1967	58.92	0.00	1.37	0.90	0.00	61.19
1968	74.15	0.00	0.24	2.75	0.00	77.14
1969	57.12	0.04	0.00	2.26	0.00	59.41
1970	79.63	0.00	0.00	3.68	0.00	83.31
1971	81.91	0.00	0.01	3.38	0.00	85.29
1972	54.21	0.00	0.00	0.85	0.00	55.06
1973	72.64	0.00	0.00	0.10	0.00	72.74
1974	99.62	0.00	0.00	0.02	0.00	99.64
1975	116.68	0.00	0.02	1.00	0.00	117.70
1976	152.64	0.00	0.03	2.77	0.46	155.90
1977	100.14	35.81	0.33	0.03	0.08	136.38
1978	182.60	43.98	0.03	0.03	0.09	226.73
1979	168.05	37.76	0.14	0.03	0.08	206.06
1980	134.15	31.52	0.00	0.02	0.06	165.75
1981	276.11	41.58	0.11	0.03	0.08	317.92
1982	203.08	70.64	1.97	0.03	0.08	275.79
1983	246.39	171.03	0.74	0.03	0.08	418.26
1984	171.55	133.55	0.18	0.03	0.08	305.39
1985	105.78	70.77	0.00	0.02	0.06	176.63
1986	133.06	86.47	0.09	0.02	0.06	219.71
1987	91.19	88.09	0.00	0.03	0.03	179.34
1988	60.67	71.56	0.00	0.02	0.02	132.27
1989	138.53	89.64	0.00	0.01	0.03	228.21
1990	174.17	109.66	0.00	0.60	0.03	284.46
1991	149.59	79.19	0.00	1.69	0.09	230.57
1992	176.48	101.53	0.00	0.01	0.24	278.27
1993	134.24	76.07	0.00	0.01	0.48	210.81
1994	81.38	41.47	0.00	0.01	10.37	133.23
1995	124.19	34.74	0.25	0.81	9.78	169.78
1996	108.07	29.72	0.00	0.04	3.48	141.31
1997	148.62	81.66	0.00	0.09	4.19	234.55
1998	97.70	40.95	0.20	0.26	1.95	141.06
1999	143.45	44.11	0.00	0.05	2.60	190.20
2000	117.58	47.09	0.00	0.43	0.37	165.46
2001	84.04	52.08	0.00	0.06	0.84	137.02
2002	80.00	39.80	0.01	0.12	0.94	120.87

Table 3: Commercial snowy grouper landings (mt) by fishing gear, 1962-2002, from the South Atlantic Fisheries Management Council management area.

Year	Handline	Longline	Trawl	Traps	Other	Total
1962	33.09	0.00	0.03	0.00	0.00	33.12
1963	45.33	1.88	0.00	0.14	0.00	47.35
1964	47.23	0.19	0.00	0.69	0.00	48.11
1965	39.32	0.00	0.00	0.89	0.00	40.21
1966	31.85	0.00	0.00	0.83	0.00	32.68
1967	58.92	0.00	1.37	0.90	0.00	61.19
1968	74.15	0.00	0.24	2.75	0.00	77.14
1969	57.12	0.04	0.00	2.26	0.00	59.41
1970	79.63	0.00	0.00	3.68	0.00	83.31
1971	81.91	0.00	0.01	3.38	0.00	85.29
1972	54.21	0.00	0.00	0.85	0.00	55.06
1973	72.64	0.00	0.00	0.10	0.00	72.74
1974	99.62	0.00	0.00	0.02	0.00	99.64
1975	116.68	0.00	0.02	1.00	0.00	117.70
1976	152.64	0.00	0.03	2.77	0.46	155.90
1977	100.14	35.81	0.33	0.03	0.08	136.38
1978	182.60	43.98	0.03	0.03	0.09	226.73
1979	168.05	37.76	0.14	0.03	0.08	206.06
1980	134.15	31.52	0.00	0.02	0.06	165.75
1981	276.11	41.58	0.11	0.03	0.08	317.92
1982	203.08	70.64	1.97	0.03	0.08	275.79
1983	246.39	171.03	0.74	0.03	0.08	418.26
1984	171.55	133.55	0.18	0.03	0.08	305.39
1985	105.78	70.77	0.00	0.02	0.06	176.63
1986	133.06	86.47	0.09	0.02	0.06	219.71
1987	91.19	88.09	0.00	0.03	0.03	179.34
1988	60.67	71.56	0.00	0.02	0.02	132.27
1989	138.53	89.64	0.00	0.01	0.03	228.21
1990	174.17	109.66	0.00	0.60	0.03	284.46
1991	149.59	79.19	0.00	1.69	0.09	230.57
1992	176.48	101.53	0.00	0.01	0.24	278.27
1993	134.24	76.07	0.00	0.01	0.48	210.81
1994	81.38	41.47	0.00	0.01	10.37	133.23
1995	124.19	34.74	0.25	0.81	9.78	169.78
1996	108.07	29.72	0.00	0.04	3.48	141.31
1997	148.62	81.66	0.00	0.09	4.19	234.55
1998	97.70	40.95	0.20	0.26	1.95	141.06
1999	143.45	44.11	0.00	0.05	2.60	190.20
2000	117.58	47.09	0.00	0.43	0.37	165.46
2001	84.04	52.08	0.00	0.06	0.84	137.02
2002	80.00	39.80	0.01	0.12	0.94	120.87

Table **4**: Commercial snowy grouper landings (mt) distributed among two major fishing gears, 1962-2002, from the South Atlantic Fisheries Management Council management area.

Year	Handline	Longline	Total
1962	33.12	0.00	33.12
1963	45.46	1.89	47.35
1964	47.91	0.20	48.11
1965	40.21	0.00	40.21
1966	32.68	0.00	32.68
1967	61.19	0.00	61.19
1968	77.14	0.00	77.14
1969	59.37	0.04	59.41
1970	83.31	0.00	83.31
1971	85.29	0.00	85.29
1972	55.06	0.00	55.06
1973	72.74	0.00	72.74
1974	99.64	0.00	99.64
1975	117.70	0.00	117.70
1976	155.90	0.00	155.90
1977	100.46	35.93	136.38
1978	182.72	44.01	226.73
1979	168.26	37.80	206.06
1980	134.22	31.54	165.75
1981	276.31	41.61	317.92
1982	204.61	71.18	275.79
1983	246.89	171.37	418.26
1984	171.71	133.68	305.39
1985	105.83	70.80	176.63
1986	133.17	86.54	219.71
1987	91.22	88.12	179.34
1988	60.69	71.58	132.27
1989	138.55	89.66	228.21
1990	174.55	109.90	284.46
1991	150.76	79.81	230.57
1992	176.64	101.63	278.27
1993	134.56	76.25	210.81
1994	88.26	44.98	133.23
1995	132.67	37.11	169.78
1996	110.83	30.48	141.31
1997	151.38	83.17	234.55
1998	99.40	41.66	141.06
1999	145.48	44.73	190.20
2000	118.15	47.31	165.46
2001	84.59	52.42	137.02
2002	80.71	40.16	120.87

Table **5**: Recreational snowy grouper landings in numbers and weight (mt), 1972-2002, from the South Atlantic Fisheries Management Council management area.

	Headboat		MRFSS (A+B1+B2)	
Year	**Numbers**	**Weight (mt)**	**Numbers**	**Weight (mt)**
1972	1035	5.12		
1973	636	4.98		
1974	1793	9.58		
1975	1039	6.16		
1976	2486	11.16		
1977	1157	3.47		
1978	797	4.58		
1979	1142	4.48		
1980	2664	9.00		
1981	3046	7.65	17647	62.12
1982	2243	7.52	5017	2.51
1983	3895	10.65	7602	22.73
1984	570	1.10	1648	0.82
1985	1108	1.96	0	0.00
1986	1338	1.92	0	0.00
1987	1134	2.00	5354	11.31
1988	953	1.49	2430	1.67
1989	1118	1.83	0	0.00
1990	677	1.29	1601	0.80
1991	529	0.99	97	0.13
1992	238	0.40	2388	9.02
1993	325	0.49	8567	40.34
1994	438	0.33	867	0.75
1995	395	0.33	8554	9.00
1996	722	1.55	1567	1.02
1997	411	1.00	18018	103.66
1998	172	0.59	570	2.64
1999	142	0.23	8095	12.70
2000	178	0.23	2419	7.45
2001	411	0.43	10254	19.05
2002	200	0.26	2148	4.78

Table **6**: Commercial and recreational snowy grouper landings and associated coefficient of variation (CV), from the South Atlantic Fisheries Management Council management area.

	Commercial (mt)		Recreational (1000s)			CV's			
Year	**Handline**	**Longline**	**Headboat**	**MRFSS**	**Total**	**Handline**	**Longline**	**Headboat**	**MRFSS**
1962	33.12	0.00				0.500	0.5		
1963	45.46	1.89				0.500	0.5		
1964	47.91	0.20				0.500	0.5		
1965	40.21	0.00				0.500	0.5		
1966	32.68	0.00				0.500	0.5		
1967	61.19	0.00				0.500	0.5		
1968	77.14	0.00				0.500	0.5		
1969	59.37	0.04				0.500	0.5		
1970	83.31	0.00				0.500	0.5		
1971	85.29	0.00				0.500	0.5		
1972	55.06	0.00	1.04		1.04	0.500	0.5	0.1	
1973	72.74	0.00	0.64		0.64	0.500	0.5	0.1	
1974	99.64	0.00	1.79		1.79	0.500	0.5	0.1	
1975	117.70	0.00	1.04		1.04	0.500	0.5	0.1	
1976	155.90	0.00	2.49		2.49	0.500	0.5	0.1	
1977	100.46	35.93	1.16		1.16	0.500	0.5	0.1	
1978	182.72	44.01	0.80		0.80	0.500	0.5	0.1	
1979	168.26	37.80	1.14		1.14	0.500	0.5	0.1	
1980	134.22	31.54	2.66		2.66	0.500	0.5	0.1	
1981	276.31	41.61	3.05	17.65	20.69	0.500	0.5	0.1	0.541
1982	204.61	71.18	2.24	5.02	7.26	0.500	0.5	0.1	0.611
1983	246.89	171.37	3.90	7.60	11.50	0.500	0.5	0.1	0.474
1984	171.71	133.68	0.57	1.65	2.22	0.500	0.5	0.1	0.774
1985	105.83	70.80	1.11	0.00	1.11	0.460	0.46	0.1	0.642
1986	133.17	86.54	1.34	0.00	1.34	0.420	0.42	0.1	0.642
1987	91.22	88.12	1.13	5.35	6.49	0.380	0.38	0.1	0.571
1988	60.69	71.58	0.95	2.43	3.38	0.340	0.34	0.1	0.954
1989	138.55	89.66	1.12	0.00	1.12	0.300	0.30	0.1	0.642
1990	174.55	109.90	0.68	1.60	2.28	0.260	0.26	0.1	0.842
1991	150.76	79.81	0.53	0.10	0.63	0.220	0.22	0.1	0.651
1992	176.64	101.63	0.24	2.39	2.63	0.180	0.18	0.1	0.526
1993	134.56	76.25	0.33	8.57	8.89	0.140	0.14	0.1	0.986
1994	88.26	44.98	0.44	0.87	1.31	0.100	0.1	0.1	0.959
1995	132.67	37.11	0.40	8.55	8.95	0.100	0.1	0.1	0.627
1996	110.83	30.48	0.72	1.57	2.29	0.100	0.1	0.3	0.635
1997	151.38	83.17	0.41	18.02	18.43	0.100	0.1	0.3	0.439
1998	99.40	41.66	0.17	0.57	0.74	0.100	0.1	0.3	0.710
1999	145.48	44.73	0.14	8.09	8.24	0.100	0.1	0.3	0.425
2000	118.15	47.31	0.18	2.42	2.60	0.100	0.1	0.3	0.552
2001	84.59	52.42	0.41	10.25	10.66	0.100	0.1	0.3	0.446
2002	80.71	40.16	0.20	2.15	2.35	0.100	0.1	0.3	0.483

Note: Commercial landings by other gear are distributed proportionately between handline and longline.

Table **7**: Indices of abundance (re-scaled to their respective means) and associated coefficient of variation (CV) for snowy grouper. The commercial logbook index was not used in the assessment model.

Years	Headboat (fish/angler-day)	MARMAP Chevron Trap (fish/trap-hour)	MARMAP Vertical Longline (fish/20 hook-hours)	Commercial logbook	Headboat (CV)	MM Chevron Trap (CV)	MM Vert. Longline (CV)	Logbook (CV)
1973	0.355				0.267			
1974	1.066				0.237			
1975	0.805				0.204			
1976	2.201				0.199			
1977	0.932				0.279			
1978	0.864				0.210			
1979	0.928				0.192			
1980	2.666				0.176			
1981	3.283				0.166			
1982	1.488				0.148			
1983	1.839				0.142			
1984	0.529				0.199			
1985	0.619				0.163			
1986	0.720				0.178			
1987	0.915				0.171			
1988	0.813				0.189			
1989	1.398				0.187			
1990	0.950	0.400			0.219	0.304		
1991	1.025	0.094			0.237	0.237		
1992	0.524	0.000		1.006	0.203	0.237		0.093
1993	0.591	0.705		0.833	0.180	0.223		0.072
1994	0.565	1.022		0.661	0.190	0.238		0.077
1995	0.699	0.367		0.857	0.223	0.151		0.069
1996	0.771	2.456	0.708	0.888	0.220	0.237	0.235	0.076
1997	0.700	1.965	0.933	1.072	0.288	0.220	0.188	0.071
1998	0.484	0.958	0.749	1.002	0.247	0.284	0.191	0.076
1999	0.325	0.262	0.810	1.343	0.386	0.234	0.230	0.076
2000	0.574	0.221	1.006	1.131	0.332	0.329	0.285	0.073
2001	0.847	2.642	1.576	1.060	0.208	0.241	0.223	0.072
2002	0.522	1.908	1.218	1.145	0.352	0.148	0.163	0.075

Footnotes defining units:

Headboat		Catch in numbers per angler-day	
MARMAP	Vertical Longline	Catch in numbers per 20 hooks per hour *(Harris email dated 4/22/04)*	*(gear 61)*
	Chevron Trap	Catch in numbers per trap-hr	*(gear 324)*
Commercial Logbook		metric tons per hook-day	

Table **8**: Snowy grouper length compositions from commercial longline and handline gears, and from MARMAP horizontal longline gear.

Commercial Handline Proportion at Length

Year	N	225	255	285	315	345	375	405	435	465	495	525	555	585	615	645	675	705	735	765	795	825	855	885	915	945	975	1005	1035	1065	1095
1983	95	0.00	0.00	0.00	0.02	0.05	0.05	0.09	0.11	0.14	0.15	0.05	0.02	0.06	0.07	0.05	0.03	0.04	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
1984	1774	0.00	0.00	0.01	0.02	0.02	0.04	0.06	0.09	0.10	0.11	0.09	0.08	0.07	0.05	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00
1985	3468	0.00	0.00	0.01	0.02	0.04	0.04	0.06	0.06	0.09	0.09	0.09	0.09	0.08	0.07	0.04	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.01	0.00	0.00	0.00
1986	1435	0.00	0.00	0.01	0.03	0.07	0.10	0.11	0.14	0.11	0.10	0.09	0.06	0.05	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	1306	0.00	0.00	0.02	0.04	0.08	0.10	0.12	0.11	0.11	0.10	0.09	0.07	0.04	0.03	0.03	0.02	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	740	0.01	0.01	0.02	0.05	0.10	0.11	0.13	0.13	0.12	0.07	0.08	0.06	0.04	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	1335	0.00	0.01	0.02	0.06	0.08	0.11	0.12	0.12	0.10	0.10	0.07	0.04	0.05	0.03	0.03	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	1543	0.00	0.01	0.01	0.02	0.03	0.07	0.10	0.14	0.12	0.12	0.09	0.07	0.06	0.05	0.03	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	1644	0.00	0.01	0.02	0.06	0.06	0.08	0.09	0.08	0.10	0.09	0.09	0.07	0.05	0.04	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00
1992	2983	0.00	0.00	0.01	0.02	0.04	0.04	0.06	0.07	0.08	0.08	0.09	0.09	0.08	0.06	0.05	0.04	0.03	0.03	0.03	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.00
1993	2392	0.00	0.00	0.01	0.02	0.03	0.04	0.06	0.08	0.10	0.10	0.09	0.10	0.09	0.07	0.06	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
1994	1911	0.00	0.00	0.01	0.05	0.08	0.10	0.09	0.09	0.11	0.10	0.09	0.07	0.05	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	4095	0.00	0.00	0.01	0.02	0.04	0.06	0.08	0.10	0.12	0.11	0.09	0.08	0.08	0.05	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	2102	0.00	0.00	0.01	0.04	0.06	0.08	0.11	0.13	0.13	0.12	0.09	0.07	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	1046	0.00	0.01	0.03	0.05	0.05	0.06	0.10	0.11	0.13	0.14	0.10	0.08	0.06	0.03	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	1656	0.00	0.00	0.01	0.03	0.05	0.09	0.10	0.12	0.11	0.12	0.10	0.07	0.06	0.04	0.03	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	2205	0.00	0.00	0.01	0.02	0.04	0.05	0.08	0.10	0.09	0.09	0.08	0.06	0.06	0.04	0.05	0.03	0.03	0.02	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.00	0.00
2000	2165	0.00	0.00	0.01	0.02	0.05	0.08	0.08	0.10	0.10	0.10	0.10	0.07	0.04	0.04	0.03	0.02	0.02	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.00	0.00
2001	1686	0.00	0.00	0.02	0.05	0.07	0.09	0.09	0.10	0.09	0.09	0.10	0.07	0.05	0.04	0.04	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	1184	0.00	0.00	0.02	0.04	0.07	0.11	0.11	0.13	0.12	0.10	0.09	0.06	0.03	0.03	0.03	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Commercial Longline Proportion at Length

Year	N	225	255	285	315	345	375	405	435	465	495	525	555	585	615	645	675	705	735	765	795	825	855	885	915	945	975	1005	1035	1065	1095
1984	1070	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.05	0.04	0.07	0.06	0.08	0.07	0.05	0.06	0.05	0.07	0.06	0.05	0.03	0.02	0.00	0.00
1985	988	0.00	0.00	0.00	0.01	0.01	0.03	0.04	0.05	0.06	0.06	0.08	0.08	0.08	0.08	0.07	0.06	0.06	0.05	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00
1986	1292	0.00	0.00	0.00	0.01	0.02	0.03	0.06	0.07	0.05	0.05	0.05	0.06	0.06	0.05	0.06	0.07	0.05	0.04	0.05	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.01	0.00	0.00	0.00
1987	492	0.00	0.00	0.00	0.00	0.02	0.04	0.08	0.05	0.05	0.05	0.04	0.04	0.05	0.04	0.03	0.04	0.04	0.03	0.04	0.03	0.04	0.05	0.04	0.04	0.03	0.04	0.03	0.02	0.01	0.02
1988	461	0.00	0.00	0.00	0.04	0.07	0.09	0.10	0.12	0.11	0.09	0.11	0.08	0.04	0.02	0.02	0.03	0.02	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
1989	154	0.00	0.00	0.00	0.00	0.03	0.02	0.06	0.08	0.06	0.10	0.07	0.04	0.04	0.03	0.06	0.01	0.04	0.01	0.03	0.04	0.01	0.10	0.01	0.03	0.05	0.06	0.04	0.01	0.00	0.00
1990	539	0.00	0.00	0.00	0.02	0.02	0.03	0.07	0.08	0.09	0.09	0.12	0.08	0.10	0.09	0.08	0.05	0.03	0.00	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	897	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.06	0.08	0.09	0.10	0.08	0.06	0.06	0.06	0.04	0.04	0.03	0.02	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.01	0.01	0.01
1992	1604	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.06	0.08	0.07	0.08	0.11	0.11	0.09	0.07	0.05	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
1993	4427	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.06	0.07	0.08	0.09	0.11	0.11	0.10	0.08	0.07	0.05	0.03	0.02	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00
1994	521	0.00	0.00	0.00	0.03	0.03	0.05	0.06	0.07	0.08	0.07	0.08	0.08	0.06	0.08	0.07	0.07	0.05	0.03	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00
1995	1407	0.00	0.00	0.00	0.01	0.02	0.06	0.09	0.13	0.15	0.15	0.12	0.08	0.07	0.04	0.04	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	387	0.00	0.00	0.00	0.01	0.01	0.04	0.10	0.13	0.13	0.14	0.13	0.11	0.06	0.05	0.03	0.02	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	1367	0.00	0.00	0.00	0.01	0.02	0.02	0.04	0.09	0.13	0.14	0.14	0.11	0.08	0.05	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	443	0.00	0.00	0.01	0.03	0.03	0.06	0.07	0.12	0.12	0.09	0.12	0.08	0.06	0.05	0.02	0.04	0.02	0.02	0.02	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	1246	0.00	0.00	0.00	0.01	0.04	0.03	0.05	0.08	0.10	0.11	0.10	0.12	0.08	0.06	0.07	0.04	0.03	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	832	0.00	0.00	0.00	0.01	0.02	0.04	0.05	0.07	0.06	0.09	0.12	0.09	0.09	0.07	0.07	0.04	0.04	0.03	0.02	0.02	0.02	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00
2001	871	0.00	0.00	0.02	0.01	0.01	0.02	0.03	0.06	0.06	0.10	0.10	0.09	0.09	0.07	0.07	0.06	0.05	0.06	0.03	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	831	0.00	0.00	0.00	0.01	0.02	0.05	0.04	0.07	0.10	0.11	0.09	0.09	0.06	0.05	0.07	0.04	0.04	0.04	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00

Table 8 (con't): Snowy grouper length compositions from commercial longline and handline gears, and from MARMAP horizontal longline gear.

Recreational Headboat Proportion at Length

Year	N	225	255	285	315	345	375	405	435	465	495	525	555	585	615	645	675	705	735	765	795	825	855	885	915	945	975	1005	1035	1065	1095
1972	67	0.00	0.00	0.00	0.01	0.03	0.03	0.01	0.03	0.03	0.04	0.03	0.01	0.06	0.06	0.13	0.09	0.04	0.03	0.03	0.03	0.04	0.10	0.01	0.06	0.03	0.03	0.00	0.00	0.00	0.00
1973	23	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.13	0.00	0.00	0.09	0.13	0.00	0.04	0.04	0.09	0.04	0.00	0.04	0.09	0.09	0.04	0.00	0.00	0.00	0.00	0.00	0.04
1974	180	0.00	0.00	0.00	0.02	0.01	0.01	0.03	0.03	0.03	0.03	0.04	0.06	0.07	0.05	0.04	0.05	0.06	0.08	0.07	0.11	0.06	0.04	0.04	0.02	0.02	0.01	0.01	0.00	0.00	0.01
1975	145	0.00	0.01	0.02	0.05	0.02	0.03	0.01	0.03	0.04	0.03	0.10	0.07	0.03	0.06	0.06	0.04	0.05	0.06	0.07	0.04	0.03	0.03	0.05	0.02	0.01	0.01	0.03	0.00	0.00	0.01
1976	104	0.01	0.00	0.00	0.00	0.03	0.00	0.09	0.06	0.03	0.07	0.07	0.04	0.03	0.06	0.08	0.12	0.06	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.02	0.01	0.00	0.00	0.01	0.00
1977	39	0.00	0.03	0.00	0.05	0.00	0.08	0.13	0.03	0.15	0.03	0.03	0.15	0.03	0.08	0.00	0.03	0.05	0.00	0.08	0.00	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	29	0.07	0.00	0.10	0.03	0.07	0.00	0.14	0.03	0.03	0.07	0.14	0.03	0.07	0.07	0.03	0.07	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	32	0.00	0.00	0.00	0.00	0.03	0.06	0.03	0.00	0.13	0.06	0.00	0.13	0.13	0.13	0.09	0.00	0.03	0.06	0.03	0.00	0.03	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	51	0.00	0.02	0.00	0.00	0.00	0.02	0.08	0.10	0.06	0.08	0.10	0.08	0.12	0.04	0.04	0.04	0.08	0.04	0.02	0.04	0.00	0.00	0.02	0.00	0.02	0.02	0.00	0.00	0.00	0.00
1981	65	0.00	0.00	0.00	0.05	0.01	0.09	0.04	0.22	0.01	0.01	0.30	0.13	0.09	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	36	0.00	0.00	0.05	0.02	0.05	0.10	0.05	0.00	0.16	0.00	0.05	0.00	0.20	0.05	0.00	0.05	0.05	0.08	0.05	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	78	0.00	0.00	0.00	0.04	0.06	0.00	0.02	0.08	0.27	0.10	0.02	0.06	0.06	0.10	0.02	0.02	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00
1984	45	0.00	0.00	0.02	0.11	0.05	0.31	0.03	0.01	0.12	0.16	0.10	0.03	0.04	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	72	0.00	0.01	0.02	0.05	0.05	0.21	0.08	0.05	0.17	0.04	0.00	0.10	0.12	0.01	0.00	0.04	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	82	0.02	0.03	0.01	0.05	0.14	0.09	0.09	0.15	0.11	0.08	0.10	0.06	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	37	0.00	0.00	0.00	0.01	0.09	0.04	0.00	0.01	0.54	0.07	0.08	0.10	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	50	0.02	0.05	0.00	0.14	0.05	0.01	0.07	0.07	0.13	0.07	0.19	0.14	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	50	0.00	0.00	0.00	0.04	0.11	0.29	0.12	0.01	0.17	0.00	0.03	0.11	0.02	0.02	0.01	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	15	0.00	0.00	0.06	0.25	0.27	0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	7	0.00	0.00	0.00	0.00	0.09	0.01	0.00	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	5	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	21	0.00	0.36	0.20	0.00	0.25	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	24	0.00	0.14	0.58	0.11	0.06	0.06	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	21	0.03	0.00	0.00	0.47	0.05	0.00	0.00	0.19	0.00	0.10	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	18	0.02	0.02	0.01	0.01	0.00	0.21	0.10	0.11	0.18	0.12	0.11	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	33	0.00	0.06	0.00	0.02	0.03	0.13	0.41	0.11	0.06	0.03	0.01	0.03	0.01	0.02	0.00	0.04	0.00	0.02	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	23	0.00	0.00	0.00	0.07	0.39	0.39	0.00	0.00	0.03	0.04	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	12	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	10	0.00	0.00	0.24	0.00	0.56	0.12	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	18	0.00	0.05	0.10	0.00	0.53	0.02	0.00	0.00	0.10	0.00	0.04	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	10	0.00	0.74	0.23	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Marmap Vertical Longline Proportion at length

Year	N	225	255	285	315	345	375	405	435	465	495	525	555	585	615	645	675	705	735	765	795	825	855	885	915	945	975	1005	1035	1065	1095
1996	13	0	0	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.15	0.23	0.00	0.00	0.00	0.00	0.08	0.08	0.15	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0
1997	43	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.12	0.14	0.19	0.09	0.05	0.02	0.00	0.05	0.09	0.05	0.05	0.05	0.00	0.02	0.00	0.00	0	0	0	0
1998	45	0	0	0.00	0.00	0.00	0.00	0.02	0.00	0.09	0.02	0.04	0.11	0.11	0.11	0.09	0.09	0.09	0.09	0.04	0.00	0.02	0.00	0.00	0.04	0.02	0.00	0	0	0	0
1999	63	0	0	0.03	0.02	0.00	0.00	0.02	0.06	0.08	0.08	0.11	0.14	0.16	0.10	0.02	0.05	0.02	0.02	0.05	0.00	0.03	0.02	0.00	0.00	0.02	0.00	0	0	0	0
2000	36	0	0	0.00	0.03	0.03	0.06	0.06	0.08	0.06	0.08	0.06	0.03	0.08	0.06	0.14	0.03	0.06	0.00	0.03	0.06	0.03	0.00	0.00	0.00	0.00	0.06	0	0	0	0
2001	43	0	0	0.00	0.00	0.00	0.00	0.05	0.05	0.09	0.16	0.07	0.07	0.05	0.02	0.02	0.12	0.09	0.09	0.05	0.00	0.02	0.00	0.00	0.05	0.00	0.00	0	0	0	0
2002	27	0	0	0.00	0.00	0.00	0.07	0.30	0.19	0.04	0.07	0.11	0.07	0.11	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0

Marmap Chevron Trap Proportion at Length

Year	N	225	255	285	315	345	375	405	435	465	495	525	555	585	615	645	675	705	735	765	795	825	855	885	915	945	975	1005	1035	1065	1095
1990	9	0.11	0.11	0.11	0.00	0.00	0.00	0.00	0.33	0.00	0.22	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0	0.00	0	0	0	0	0	0	0	0	0	0	0
1991	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00	0	0	0	0	0	0	0	0	0	0	0
1992	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00	0	0	0	0	0	0	0	0	0	0	0
1993	19	0.00	0.00	0.05	0.16	0.11	0.00	0.05	0.05	0.21	0.05	0.16	0.05	0.00	0.11	0.00	0.00	0.00	0	0.00	0	0	0	0	0	0	0	0	0	0	0
1994	59	0.00	0.02	0.07	0.10	0.08	0.10	0.08	0.05	0.12	0.08	0.08	0.02	0.10	0.07	0.02	0.00	0.00	0	0.00	0	0	0	0	0	0	0	0	0	0	0
1995	22	0.00	0.00	0.00	0.00	0.09	0.05	0.27	0.09	0.14	0.14	0.09	0.05	0.05	0.05	0.00	0.00	0.00	0	0.00	0	0	0	0	0	0	0	0	0	0	0
1996	60	0.03	0.00	0.02	0.07	0.07	0.10	0.12	0.13	0.13	0.10	0.07	0.05	0.05	0.02	0.02	0.02	0.02	0	0.00	0	0	0	0	0	0	0	0	0	0	0
1997	59	0.00	0.03	0.03	0.07	0.12	0.05	0.05	0.14	0.20	0.10	0.08	0.05	0.03	0.00	0.02	0.00	0.00	0	0.02	0	0	0	0	0	0	0	0	0	0	0
1998	22	0.09	0.09	0.00	0.09	0.05	0.05	0.05	0.14	0.05	0.18	0.05	0.14	0.00	0.05	0.00	0.00	0.00	0	0.00	0	0	0	0	0	0	0	0	0	0	0
1999	7	0.00	0.00	0.14	0.29	0.00	0.14	0.14	0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00	0	0	0	0	0	0	0	0	0	0	0
2000	5	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.20	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00	0	0	0	0	0	0	0	0	0	0	0
2001	39	0.00	0.03	0.05	0.13	0.10	0.10	0.00	0.10	0.08	0.13	0.10	0.08	0.05	0.03	0.00	0.00	0.03	0	0.00	0	0	0	0	0	0	0	0	0	0	0
2002	29	0.00	0.00	0.14	0.03	0.17	0.14	0.14	0.24	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00	0	0	0	0	0	0	0	0	0	0	0

Table **9**: Snowy grouper age compositions from commercial longline and handline gears.

Commercial Handline Proportion at age

Year	**N**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**
1992	38	0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.0	0.0	0	0	0	0	0	0.0	0	0	0
1993	2	0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.0	0.0	0	0	0	0	0	0.0	0	0	0
1994	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.0	0.0	0	0	0	0	0	0.0	0	0	0
1995	1	0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.0	0.0	0	0	0	0	0	0.0	0	0	0
1996	5	0	0.0	0.0	0.0	0.0	0.4	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.2	0.0	0	0	0	0	0	0.0	0	0	0
1997	47	0	0.0	0.0	0.1	0.3	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.0	0.0	0	0	0	0	0	0.0	0	0	0
1998	61	0	0.0	0.1	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.0	0.0	0	0	0	0	0	0.0	0	0	0
1999	67	0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.0	0.0	0	0	0	0	0	0.0	0	0	0
2000	100	0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.0	0.0	0	0	0	0	0	0.0	0	0	0
2001	70	0	0.0	0.0	0.0	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.0	0.0	0	0	0	0	0	0.0	0	0	0
2002	53	0	0.0	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.0	0.0	0	0	0	0	0	0.0	0	0	0

Commercial Longline Proportion at age

Year	N	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1992	1	0	0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0	0.0
1993	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0	0.0
1994	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0	0.0
1995	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0	0.0
1996	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0	0.0
1997	99	0	0	0.0	0.2	0.1	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0	0.0
1998	84	0	0	0.1	0.2	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0	0.0
1999	95	0	0	0.0	0.1	0.1	0.2	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0	0.0
2000	95	0	0	0.0	0.0	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0	0.0
2001	109	0	0	0.0	0.0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0	0.0
2002	127	0	0	0.1	0.1	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0	0.0

Recreational Headboat Proportion at age

Year	N	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1980	21	0	0.0	0.0	0.1	0.1	0.1	0.2	0.4	0.0	0.0	0.0	0.0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	49	0	0.0	0.0	0.0	0.1	0.1	0.3	0.2	0.1	0.0	0.1	0.0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	1	0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	17	0	0.0	0.0	0.1	0.1	0.3	0.1	0.3	0.0	0.0	0.0	0.0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	12	0	0.0	0.0	0.3	0.2	0.2	0.0	0.2	0.1	0.1	0.0	0.0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	6	0	0.2	0.3	0.0	0.3	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	29	0	0.0	0.2	0.2	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	4	0	0.0	0.0	0.5	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	2	0	0.0	0.0	0.0	0.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	2	0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	5	0	0.0	0.2	0.4	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	3	0	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	2	0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	1	0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	7	0	0.1	0.3	0.3	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	1	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table **10**: General definitions, input data, population model, and negative log-likelihood components of the forward-projecting statistical age-structured model used for snowy grouper.

General Definitions	Symbol	**Description/Definition**
Year index	y	y = {1961,..,2002}
Age index	a	a = {0,...,A}, where A = 35+
Length bin (mm)	l'	l' = {225,255,…,1095}, bin size = 30 mm
Fishery index	f	f = {1 handline, 2 longline, 3 headboat, 4 private/charter}
CPUE index	u	u = {1 MARMAP handline, 2 MARMAP longline, 3 headboat}
Input Data	Symbol	**Description/Definition**
Mean length-at-age	l_a	$l_a = L_\infty\left(1-\exp\left[-K\left(a-t_0\right)\right]\right)$ where parameters L_∞, K, and t_0 are fixed
Age-length conversion matrix	$\psi_{a,l'}$	$\psi_{a,l'} = \frac{\exp\left[-\left(\frac{l'-l_a}{2c^l l_a}\right)\right]}{\sqrt{2\pi}\left(c^l l_a\right)^2}$ where c^l is a fixed value for the coefficient of variation in length at age and the matrix is re-scaled to sum to 1 across ages
Population weight-at-age	w_a	Computed from size at age at the midpoint of the year $w_a = \gamma l_a^\beta$, where γ and β are fixed
Maturity-at-age	m_a	Logistic function of age, estimated from MARMAP sampled data
Observed CPUE indices	$U_{u,y}$	u=1, MARMAP handline (y = 1990,…,2002), based on numbers of fish captured per trap-hour. u=2, MARMAP longline (y = 1996,…,2002), based on numbers of fish captured per 20 hooks per hour. u=3, headboat (y = 1973,…,2002), based on numbers of fish per angler day from a subset of “deepwater fish” trips.
Coefficient of variation for U ‘s	$c_{u,y}$	u = {1, 2, 3} (see above), annual values from GLM model or sampling error, then re-scaled to maximum 0.3
Observed age compositions	$p_{f,a,y}$	Computed as percent age composition at age (a) for each year (y) and fishery (f)
Age composition sample sizes	$n_{f,y}$	Number of age samples collected in each year (y) from each fishery (f)
Observed length compositions	$p'_{f,l,y}$	Computed as percent length composition at length (l) for each year (y) and fishery (f)
Length composition sample sizes	$n'_{f,y}$	Number of length samples collected in each year (y) from each fishery (f)

Observed fishery landings	$L_{f,y}$	Reported landings in weight for each year (y) from each fishery (f)
Coefficient of variation for L_f	$c_{L_{f,y}}$	Annual values fixed based on understanding of historical accuracy of estimates
Age-specific natural mortality	M_a	Fixed across years from Lorenzen (1996), re-scaled based on Hoenig (1983)

Population Model	**Symbol**	**Description/Definition**
Fishery selectivity	$s_{f,a}$	Constant for all years (y), except for headboat (f = 3) $s_{f,a} = \begin{cases} \left[\frac{1}{1+\exp(-\eta_{1,f}[a-\alpha_{1,f}])}\right] & \text{for } f = 1 \\ \left[\frac{1}{1+\exp(-\eta_{1,f}[a-\alpha_{1,f}])}\right]\left[1-\frac{1}{1+\exp(-\eta_{2,f}[a-(\alpha_{1,f}+\alpha_{2,f})])}\right]\left[\frac{1}{\max(s_{f,a})}\right] & \text{for f=\{2,3,4\}} \end{cases}$ where $\eta_{1,f}$, $\eta_{2,f}$, $\alpha_{1,f}$ and $\alpha_{2,f}$ are estimated parameters, for headboat (f = 3), parameters $\alpha_{1,f}$ and $\alpha_{2,f}$ were multiplied by terms $\alpha_{3,f}$ and $\alpha_{4,f}$, respectively, for y = {1977,…,1991} to allow for a linear change over time and for MRFSS (f = 4), selectivity is fixed at the estimates from headboat in y = 2002.
Index selectivity	$s'_{u,a}$	Assumed constant for all years (y) $s'_{u,a} = \left[\frac{1}{1+\exp(-\eta'_{1,u}[a-\alpha'_{1,u}])}\right]\left[1-\frac{1}{1+\exp(-\eta'_{2,u}[a-\alpha'_{2,u}])}\right]\left[\frac{1}{\max(s'_{u,a})}\right]$ for u = {1,2} where $\eta'_{1,U}$, $\eta'_{2,U}$, $\alpha'_{1,U}$ and $\alpha'_{2,U}$ are estimated parameters, for u = 3, $s'_{u,a} = s_{3,a}$
Fishing mortality	$F_{f,a,y}$	$F_{f,a,y} = s_{f,a} F_{f,y}$ where $F_{f,y}$'s are fully selected estimated parameters
Total mortality	$Z_{a,y}$	$Z_{a,y} = M_a + \sum_{f=1}^{4} F_{f,a,y}$
Mature biomass per recruit at F = 0	ϕ_y	$\phi_y = \sum_{a=0}^{A} N_{a,y} m_a w_a \Big/ N_{0,y}$ where $N_{a+1,y} = N_{a,y} \exp(-Z_{a,y})$ and $N_{A,y} = N_{A-1,y} \exp(-Z_{A-1,y}) / [1-\exp(-Z_{A,y})]$

Population numbers Population mature biomass	$N_{a,y}$ S_y	$N_{0,1961} = R_0 + R_{1961}$ $N_{a+1,1961} = N_{a,1961} \exp(-Z_{a,1961})$ $N_{A,1961} = N_{A-1,1961} \exp(-Z_{A-1,1961}) / [1-\exp(-Z_{A,1961})]$ $N_{0,y} = \dfrac{0.8 R_0 h \varepsilon_y}{0.2\phi_y R_0 (1-h) + (h-0.2)\varepsilon_y} + R_y$ $N_{a+1,y+1} = N_{a,y} \exp(-Z_{a,y})$ $N_{A,y} = N_{A-1,y-1} \exp(-Z_{A-1,y-1}) + N_{A,y-1} \exp(-Z_{A,y-1})$ $S_y = \sum_{a=0}^{A} N_{a,y} m_a w_a$ where R_0 (virgin recruitment) and h (steepness) are parameters of the stock-recruit curve and R_y are annual recruitment deviation parameters.
Population biomass	B_y	$B_y = \sum_{a=0}^{A} N_{a,y} w_a$
Predicted catch-at-age	$\hat{C}_{f,a,y}$	$\hat{C}_{f,a,y} = \dfrac{F_{f,a,y}}{Z_{a,y}} N_{a,y} [1-\exp(-Z_{a,y})]$
Predicted landings	$\hat{L}_{f,y}$	$\hat{L}_{f,y} = \sum_{a=0}^{A} \hat{C}_{f,a,y} w_a$
Predicted age composition	$\hat{p}_{\{f,u\},a,y}$	$\hat{p}_{\{f,u\},a,y} = \hat{C}_{\{f,u\},a,y} \Big/ \sum_{a=0}^{A} \hat{C}_{\{f,u\},a,y}$

Predicted CPUE indices	$\hat{U}_{u,y}$	$\hat{U}_{u,y} = \begin{cases} \sum_{a=0}^{A} N_{a,y} s'_{1,a} q_1 & \text{for } u = 1 \\ \sum_{a=0}^{A} N_{a,y} s'_{2,a} q_2 & \text{for } u = 2 \\ \sum_{a=0}^{A} N_{a,y} s_{3,a} q_3 & \text{for } u = 3 \end{cases}$ where q_1, q_2, and q_3 are catchability parameters
Negative Log-Likelihood	**Symbol**	**Description/Definition**
Multinomial age composition	Λ_1	$\Lambda_1 = -\lambda_1 n_{\{f,u\},y} \sum_{a=0}^{A} (p_{\{f,u\},a,y} + x) \log(\hat{p}_{\{f,u\},a,y} + x) - (p_{\{f,u\},a,y} + x) \log(p_{\{f,u\},a,y} + x)$ where λ_1 is a preset weighting factor and x is fixed at an arbitrary value of 0.001

Multinomial length composition	Λ_2	$\Lambda_2 = -\lambda_2 n'_{\{f,u\},y} \sum_{l'=225}^{1095} \left(p'_{\{f,u\},l',y} + x\right) \log\left(\hat{p}'_{\{f,u\},l',y} + x\right) - \left(p'_{\{f,u\},l',y} + x\right) \log\left(p'_{\{f,u\},l',y} + x\right)$ where λ_2 is a preset weighting factor and *x* is fixed at an arbitrary value of 0.001
Lognormal indices	Λ_3	$\Lambda_3 = \lambda_3 \sum_y \frac{\left[\log\left(U_{u,y} + x\right) - \log\left(\hat{U}_{u,y} + x\right)\right]^2}{2c_{u,y}^2}$ where λ_3 is a preset weighting factor and *x* is fixed at an arbitrary value of 0.001
Lognormal landings	Λ_4	$\Lambda_4 = \lambda_4 \sum_y \frac{\left[\log\left(L_{f,y} + x\right) - \log\left(\hat{L}_{f,y} + x\right)\right]^2}{2c_{L_f,y}^2}$ where λ_4 is a preset weighting factor and *x* is fixed at an arbitrary value of 0.001
Recruitment constraint	Λ_5	$\Lambda_5 = \lambda_5 \sum_y R_y^2$

Table **11**: Preliminary runs exploring various weighting values for the likelihood components of the statistical catch-at-age model. Recruitment deviation component weight was fixed at 50 for all runs.

Run Number	**Landings Weight**	**Index Weight**	**Length Composition Weight**	**Age Composition Weight**	**Description of fit**
1	1	1	1	1	Poor fit to landings in early years; index fits virtually ignored
2	10	1	1	1	Landings fit good; index fits good; biologically unreasonable stock size
3	100	1	10	10	Landings fit poor in early years; index fits acceptable; biologically reasonable stock size
4	100	1	100	100	Landings fit very poor; index fits ignored; biologically reasonable stock size
5	50	1	10	10	Landings fits poor in early years; index fits acceptable; biologically reasonable stock size
6	50	10	10	10	Landings fit well; index fits acceptable; biologically unreasonable stock size
7	50	10	1	1	Landings fits well; index fits good; biologically unreasonable stock size
8	1	10	1	1	Landings fit bad in early years; index fits acceptable; reasonable stock size
9	10	10	1	1	Landings fit poor; index fit acceptable; reasonable stock size
10	20	20	1	1	Landings fit acceptable; index fit acceptable; reasonable stock size

Table **12**: Numbers at age (1000's) estimated in the initial run of the statistical catch-at-age model for snowy grouper.

	Age																																		
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35+**
1961	412	187	135	109	91	79	69	61	55	49	45	41	37	34	31	28	26	24	22	20	19	17	16	15	14	13	12	11	10	9	9	8	8	7	7	84
1962	246	187	135	109	91	79	69	61	55	49	45	41	37	34	31	28	26	24	22	20	19	17	16	15	14	13	12	11	10	9	9	8	8	7	7	84
1963	242	112	135	109	91	78	69	61	55	49	45	41	37	34	31	28	26	24	22	20	19	17	16	15	14	13	12	11	10	9	9	8	8	7	7	84
1964	233	110	81	109	91	78	68	61	55	49	45	40	37	34	31	28	26	24	22	20	19	17	16	15	14	13	12	11	10	9	9	8	8	7	7	84
1965	226	106	79	65	91	78	68	60	54	49	44	40	37	34	31	28	26	24	22	20	19	17	16	15	14	13	12	11	10	9	9	8	8	7	7	84
1966	217	103	76	64	54	77	67	59	53	48	44	40	36	33	31	28	26	24	22	20	19	17	16	15	14	13	12	11	10	9	9	8	8	7	6	84
1967	214	98	74	61	53	46	66	58	53	48	43	40	36	33	30	28	26	24	22	20	19	17	16	15	14	13	12	11	10	9	9	8	8	7	6	84
1968	208	97	71	60	51	44	39	57	51	46	42	39	35	32	30	27	25	23	22	20	18	17	16	15	14	13	12	11	10	9	9	8	7	7	6	84
1969	211	95	70	57	50	42	37	33	49	45	41	37	34	32	29	27	25	23	21	20	18	17	16	14	13	12	12	11	10	9	9	8	7	7	6	83
1970	228	96	68	56	47	41	35	32	29	43	40	36	33	31	28	26	24	22	21	19	18	16	15	14	13	12	11	11	10	9	9	8	7	7	6	83
1971	265	104	69	55	47	39	34	30	27	25	38	35	32	29	27	25	23	22	20	19	17	16	15	14	13	12	11	10	10	9	8	8	7	7	6	82
1972	340	120	75	56	45	38	32	28	26	24	22	33	30	28	26	24	22	21	19	18	17	16	15	14	13	12	11	10	9	9	8	8	7	7	6	82
1973	338	154	87	60	46	37	31	27	25	22	21	19	29	27	25	23	22	20	19	18	16	15	14	13	12	12	11	10	9	9	8	8	7	7	6	81
1974	330	153	112	70	50	37	30	26	23	21	20	18	17	26	24	22	21	20	18	17	16	15	14	13	12	11	11	10	9	9	8	7	7	7	6	80
1975	439	150	111	89	57	39	30	25	22	20	18	17	16	15	23	21	20	19	17	16	15	14	13	12	12	11	10	10	9	8	8	7	7	6	6	79
1976	705	200	108	89	73	45	31	24	21	19	17	15	14	14	13	20	18	17	16	15	14	13	13	12	11	10	10	9	9	8	8	7	7	6	6	78
1977	501	320	144	87	71	50	31	22	18	15	14	13	12	11	11	10	16	15	14	13	13	12	11	11	10	9	9	8	8	7	7	7	6	6	6	75
1978	380	228	232	116	71	55	38	24	18	15	13	12	11	10	9	9	9	13	13	12	12	11	10	10	9	9	8	8	8	7	7	6	6	6	5	73
1979	486	173	165	185	93	48	37	27	18	13	11	10	9	8	8	7	7	7	11	10	10	9	9	9	8	8	7	7	7	6	6	6	5	5	5	69
1980	318	221	125	132	150	67	34	27	21	14	10	9	8	7	6	6	6	6	6	9	9	8	8	8	7	7	7	6	6	6	6	5	5	5	5	66
1981	210	145	160	100	107	109	48	26	21	16	11	8	7	6	6	5	5	5	5	5	8	7	7	7	7	6	6	6	6	5	5	5	5	5	4	63
1982	431	96	105	127	78	65	65	31	18	15	11	8	6	5	5	4	4	4	4	4	4	6	6	6	5	5	5	5	5	5	5	4	4	4	4	58
1983	488	196	69	84	101	49	40	41	20	12	10	8	5	4	3	3	3	3	3	3	3	3	5	4	4	4	4	4	4	4	4	4	4	4	3	53
1984	538	221	141	55	66	61	28	24	26	13	7	6	5	4	3	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	45
1985	696	244	160	113	44	41	36	16	14	16	8	5	4	3	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	37
1986	502	316	177	128	91	29	26	22	11	9	10	5	3	3	2	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	31
1987	554	228	228	142	101	53	16	14	12	6	5	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	25
1988	230	252	165	183	114	66	32	10	9	8	4	4	4	2	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	21
1989	12	104	182	132	150	85	48	24	7	7	6	3	3	3	2	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	18
1990	683	5	75	146	107	103	56	32	16	5	5	4	2	2	2	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	15
1991	518	310	4	60	117	69	63	34	20	10	3	3	3	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	12
1992	347	235	224	3	49	80	45	41	23	13	7	2	2	2	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
1993	679	157	170	180	2	31	46	27	25	14	8	4	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
1994	555	308	114	136	140	1	16	26	16	15	8	5	3	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
1995	384	252	223	91	110	97	1	11	18	11	10	6	4	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
1996	283	174	182	178	72	69	59	1	7	12	7	7	4	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
1997	256	129	126	146	144	49	46	40	0	5	8	5	5	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
1998	843	116	93	101	114	82	25	25	23	0	3	5	3	3	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
1999	1059	383	84	75	82	79	55	17	17	16	0	2	4	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2000	146	481	277	67	59	50	46	33	11	11	10	0	1	2	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2001	140	66	348	222	54	38	31	29	21	7	7	7	0	1	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2002	136	64	48	278	177	35	23	20	19	14	5	5	5	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table **13**: Predicted time series from the statistical catch-at-age model for snowy grouper (median values).

Year	Exploitation Rate (Age 1+)	Fishing Mortality (Age 2+)	Total Landings (mt)	Recruits (Age 0) (1000's)	Total Mature Biomass (SSB) (mt)	Total Biomass (mt)
1961	0.001	0.001	5.0	330.0	5924.4	6325.2
1962	0.001	0.001	5.6	207.2	5924.4	6324.7
1963	0.002	0.003	10.6	206.3	5924.4	6318.1
1964	0.003	0.003	10.8	202.1	5918.4	6292.0
1965	0.010	0.012	50.6	192.7	5908.9	6247.7
1966	0.009	0.010	42.3	179.7	5855.8	6152.8
1967	0.016	0.018	80.3	169.1	5792.3	6040.8
1968	0.021	0.025	106.7	159.8	5654.4	5894.4
1969	0.017	0.020	80.4	165.9	5455.8	5697.4
1970	0.026	0.031	125.3	188.3	5297.4	5520.0
1971	0.029	0.035	136.3	249.7	5077.5	5271.1
1972	0.017	0.022	78.9	288.1	4788.6	4998.0
1973	0.022	0.028	102.6	234.3	4606.9	4820.9
1974	0.035	0.044	161.2	255.3	4392.7	4636.3
1975	0.040	0.051	168.1	531.5	4111.6	4382.3
1976	0.072	0.121	401.0	903.7	3851.1	4166.6
1977	0.035	0.062	210.5	328.7	3418.7	3812.7
1978	0.063	0.087	380.9	253.1	3135.3	3639.9
1979	0.062	0.081	228.9	401.7	2781.4	3379.5
1980	0.080	0.113	238.1	282.3	2595.6	3224.9
1981	0.139	0.201	429.1	187.9	2514.0	3051.2
1982	0.141	0.195	422.9	390.0	2294.4	2682.5
1983	0.142	0.236	433.7	421.3	1982.8	2311.8
1984	0.124	0.213	421.8	442.7	1628.0	1938.3
1985	0.082	0.136	254.6	700.6	1279.3	1602.8
1986	0.095	0.193	304.0	416.7	1077.5	1463.3
1987	0.078	0.124	213.0	310.1	858.4	1296.8
1988	0.058	0.083	138.1	232.9	760.7	1250.2
1989	0.118	0.168	226.5	232.2	772.0	1283.2
1990	0.149	0.222	263.7	511.7	762.9	1214.4
1991	0.102	0.190	208.4	245.5	734.9	1091.0
1992	0.130	0.204	254.8	558.5	711.0	1024.3
1993	0.104	0.211	217.5	519.0	597.4	911.0
1994	0.066	0.116	133.0	388.5	491.4	849.8
1995	0.095	0.157	178.0	252.9	478.6	892.5
1996	0.090	0.130	142.6	249.6	466.0	887.0
1997	0.179	0.290	260.5	406.1	487.0	917.3
1998	0.091	0.158	140.2	693.6	442.3	798.9
1999	0.096	0.214	196.1	183.3	478.0	823.9
2000	0.090	0.131	163.5	132.6	447.5	792.8
2001	0.113	0.156	150.9	123.7	407.5	790.0
2002	0.115	0.154	124.4	117.5	394.4	785.8

Table **14**: Snowy grouper benchmarks for age 1+ exploitation rate (*E*), age 2+ fishing mortality (*F*), maximum sustainable yield (*MSY*), total mature biomass (*SSB*), and total biomass (*B*) estimated by the statistical catch-at-age model.

Percentile	Emax	E30%	E40%	Emsy
10th	0.059	0.043	0.032	0.026
50th	0.065	0.046	0.035	0.037
90th	0.071	0.048	0.037	0.049

Percentile	Fmax	F30%	F40%	Fmsy
10th	0.078	0.054	0.039	0.034
50th	0.096	0.064	0.047	0.050
90th	0.127	0.073	0.055	0.071

Percentile	MSY (mt)	SSBmsy (mt)	Bmsy (mt)
10th	111	1383	1792
50th	142	2116	2481
90th	169	3267	3644

Table **15**: Projected recruits and total mature biomass (SSB) from the statistical catch-at-age model for snowy grouper with fishing mortality (F) equal to zero (median values).

Year	Recruits (Age 0) (1000's)	Total Mature Biomass (SSB) (mt)
2003	159.23	454.93
2004	170.42	663.61
2005	198.33	853.72
2006	236.85	990.63
2007	257.63	1108.43
2008	255.95	1208.58
2009	274.99	1324.18
2010	292.30	1444.99
2011	295.46	1573.86
2012	306.08	1711.10
2013	324.68	1862.27
2014	329.90	2045.45
2015	330.69	2234.86
2016	335.69	2407.77
2017	333.86	2584.89
2018	356.50	2771.97
2019	347.61	2972.81
2020	348.66	3178.62
2021	369.49	3366.75
2022	380.98	3525.13
2023	375.01	3710.26
2024	385.62	3895.69
2025	372.80	4045.05
2026	372.93	4204.01
2027	396.69	4354.85
2028	400.86	4510.67
2029	399.43	4670.66
2030	401.92	4845.22
2031	384.40	5017.03
2032	413.41	5167.39
2033	396.96	5319.69
2034	403.86	5478.89
2035	400.05	5610.65
2036	401.33	5751.07
2037	430.68	5871.81

Table **16**: Estimates from production model of snowy grouper. Model was rejected by the assessment workshop and is included here for completeness only.

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)		
Parameter		**Estimate**
B1/K	Starting relative biomass (in 1962)	0.718
MSY	Maximum sustainable yield	304.6
K	Maximum population size	577.6
phi	Shape of production curve (Bmsy/K)	0.50
	Catchability Coefficients by Data Series -	
q(1)	SNG HBT Index (early) and Total Landing	0.00169
q(2)	SNG HBT Index (late)	0.00162
q(3)	MARMAP Chevron Trap	0.00160
q(4)	MARMAP Vertical LL	0.00209

MANAGEMENT and DERIVED PARAMETER ESTIMATES (NON-BOOTSTRAPPED)		
Parameter		**Estimate**
MSY	Maximum sustainable yield	304.6
Bmsy	Stock biomass giving MSY	288.8
Fmsy	Fishing mortality rate at MSY	1.06
B./Bmsy	Ratio: B(2003)/Bmsy	2
F./Fmsy	Ratio: F(2002)/Fmsy	0.24
Fmsy/F.	Ratio: Fmsy/F(2002)	4.17
Y.(Fmsy)	Approx. yield available at Fmsy in 2003	532.4
	...as proportion of MSY	1.75
Ye.	Equilibrium yield available in 2003	134.3
	...as proportion of MSY	0.4
fmsy(1)	SNG HBT Index (early) and Total Landing	623.0

7. Figures

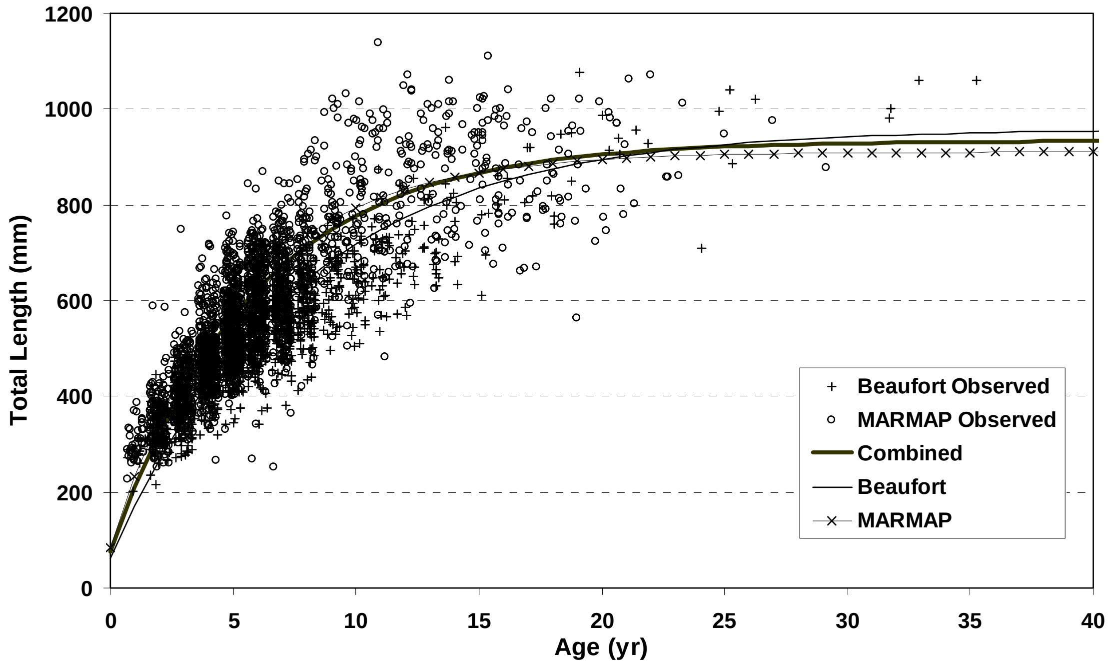


Figure **1**: Observed and predicted snowy grouper growth by data source. Fits are based on non-linear least squares (NLLS) of the von Bertalanffy equation (N = 4,983)

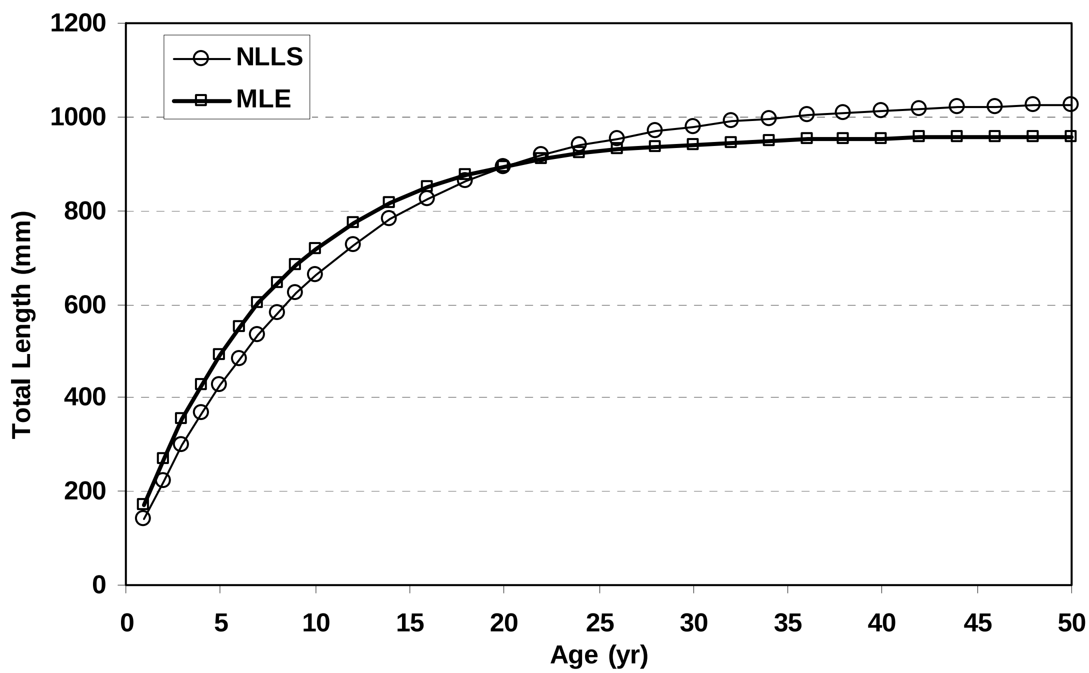


Figure **2**: Comparison of snowy grouper growth between two statistical methods, non-linear least squares (NLLS) and maximum likelihood estimation (MLE) with NMFS Data (N = 2,683).

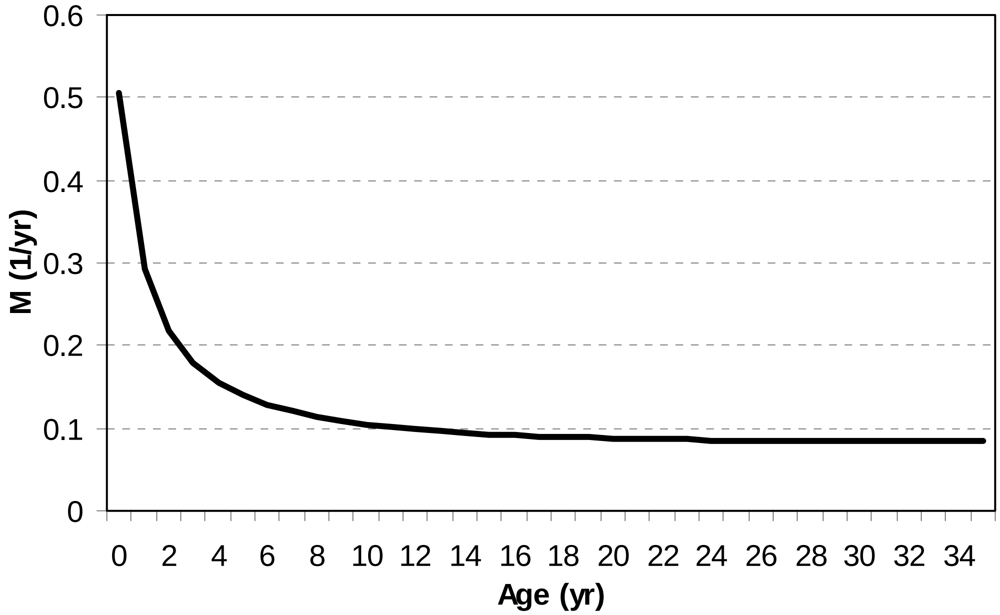


Figure **3**: Age-varying estimates of snowy grouper natural mortality based on Lorenzen's method (1996), re-scaled to 1.4% survival to oldest observed age (35).

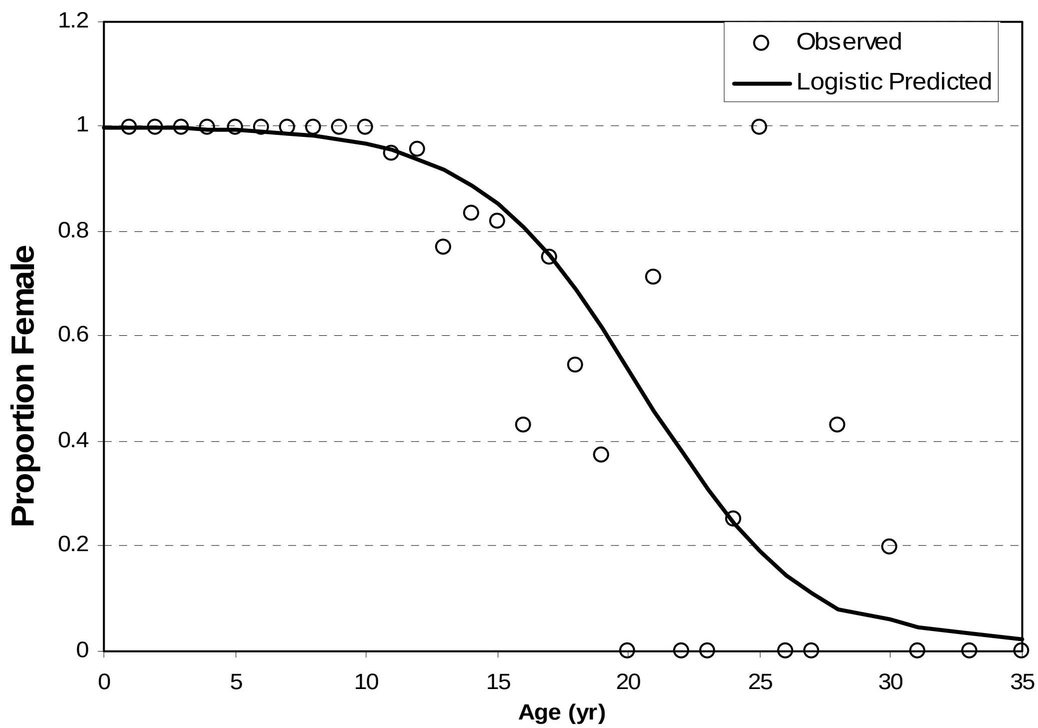


Figure **4**: Observed and logistic model predicted snowy grouper sex ratio at age.

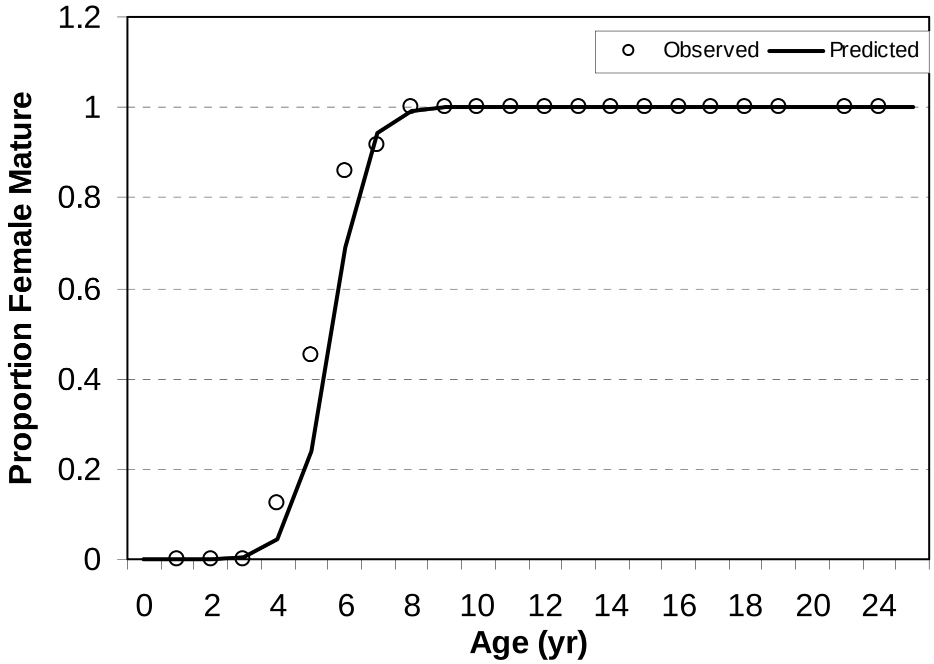


Figure **5**: Observed and logistic model predicted snowy grouper female maturity at age.

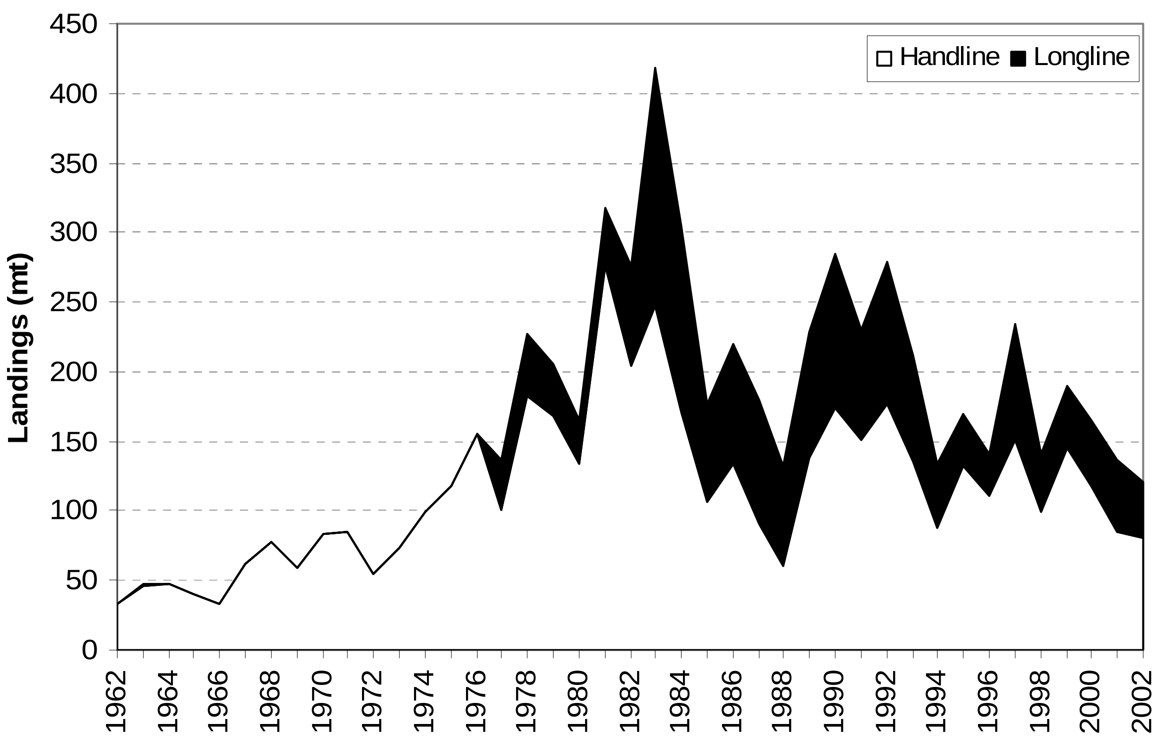


Figure **6**: Annual snowy grouper landings (mt) from the commercial fishery by gear (handline and longline).

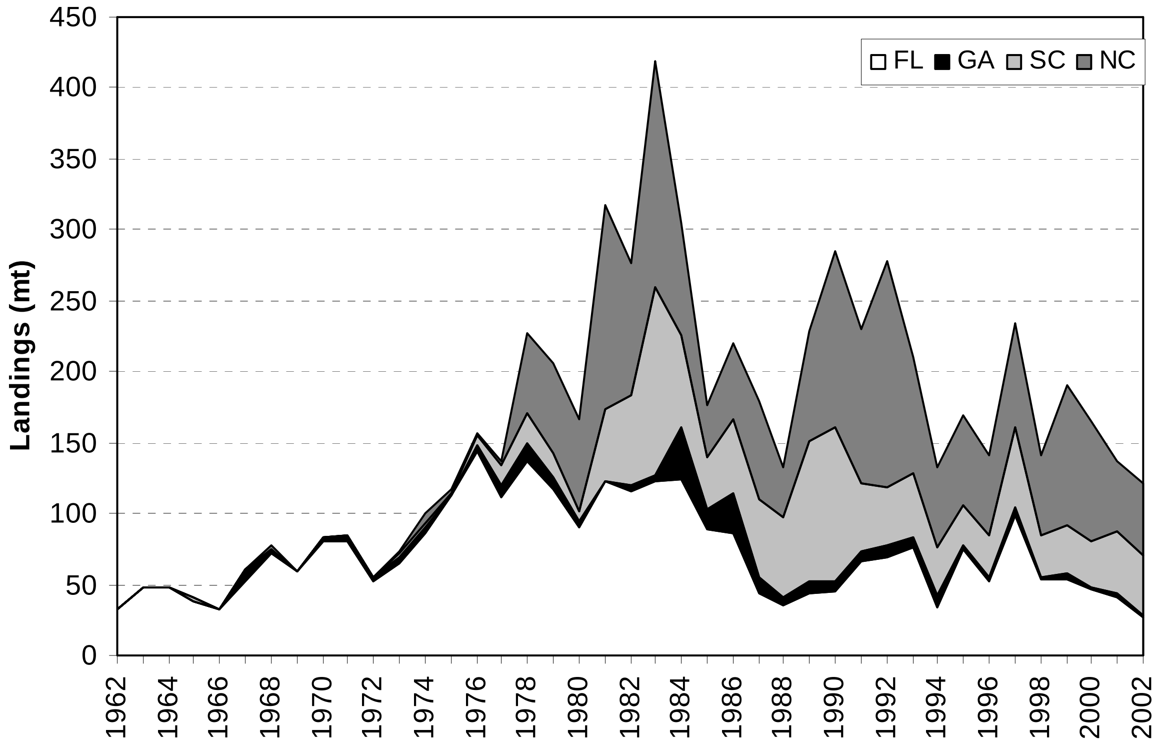


Figure **7**: Annual snowy grouper commercial landings (mt) by state.

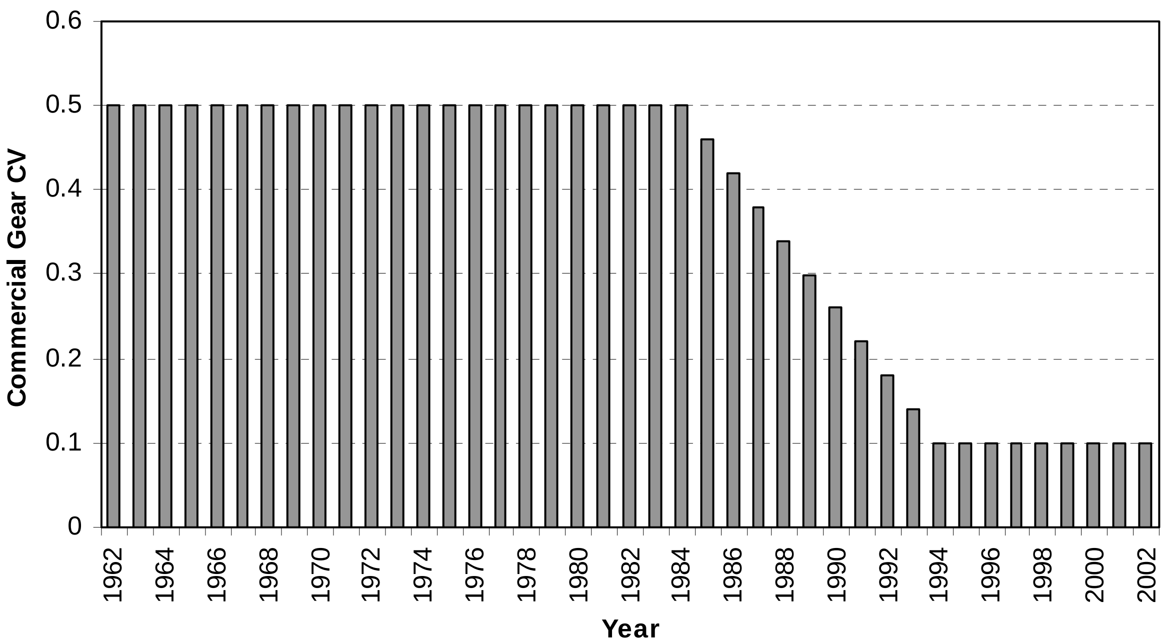


Figure **8**: Coefficients of variation (CV) for snowy grouper commercial handline and longline landings used in the statistical catch-at-age model.

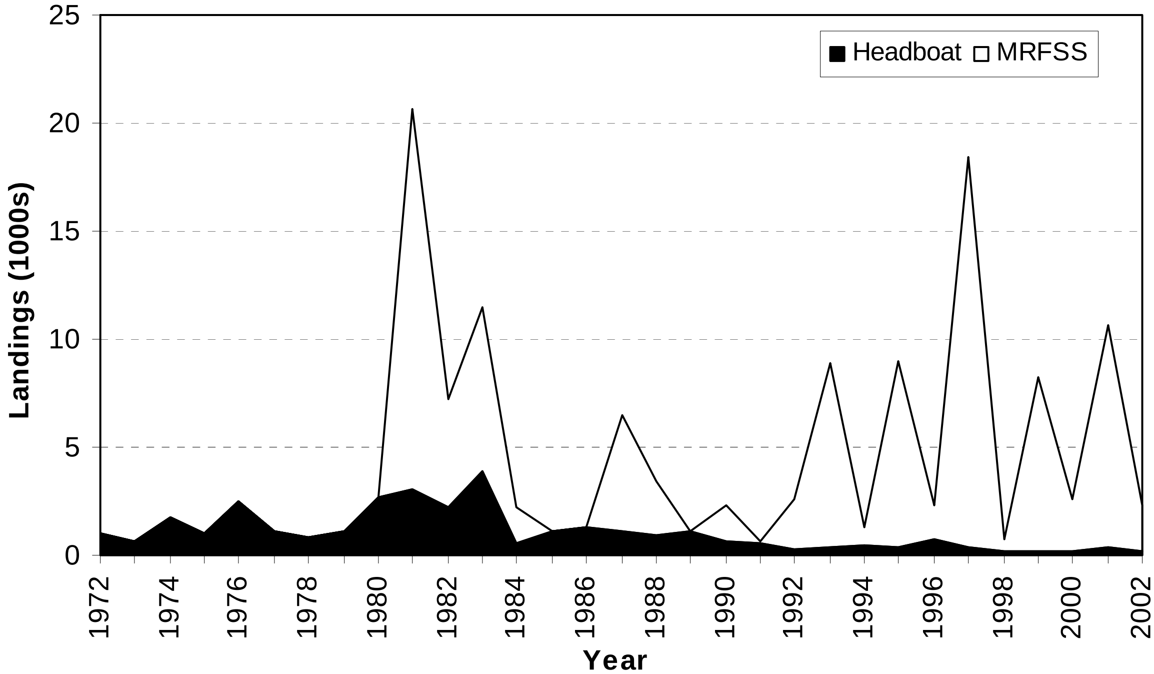


Figure **9**: Annual snowy grouper landings (1000's) from the recreational sector (MRFSS and Headboat).

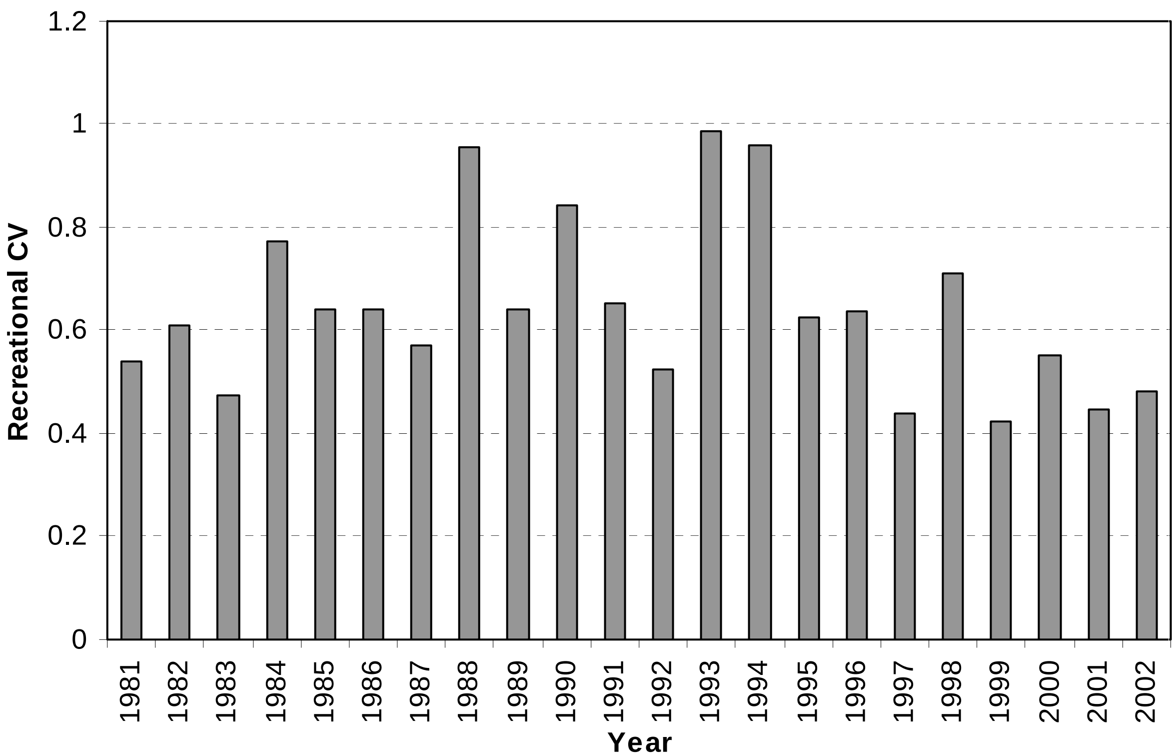


Figure **10**: Coefficients of variation (CV) for estimated snowy grouper MRFSS recreational landings used in the statistical catch-at-age model.

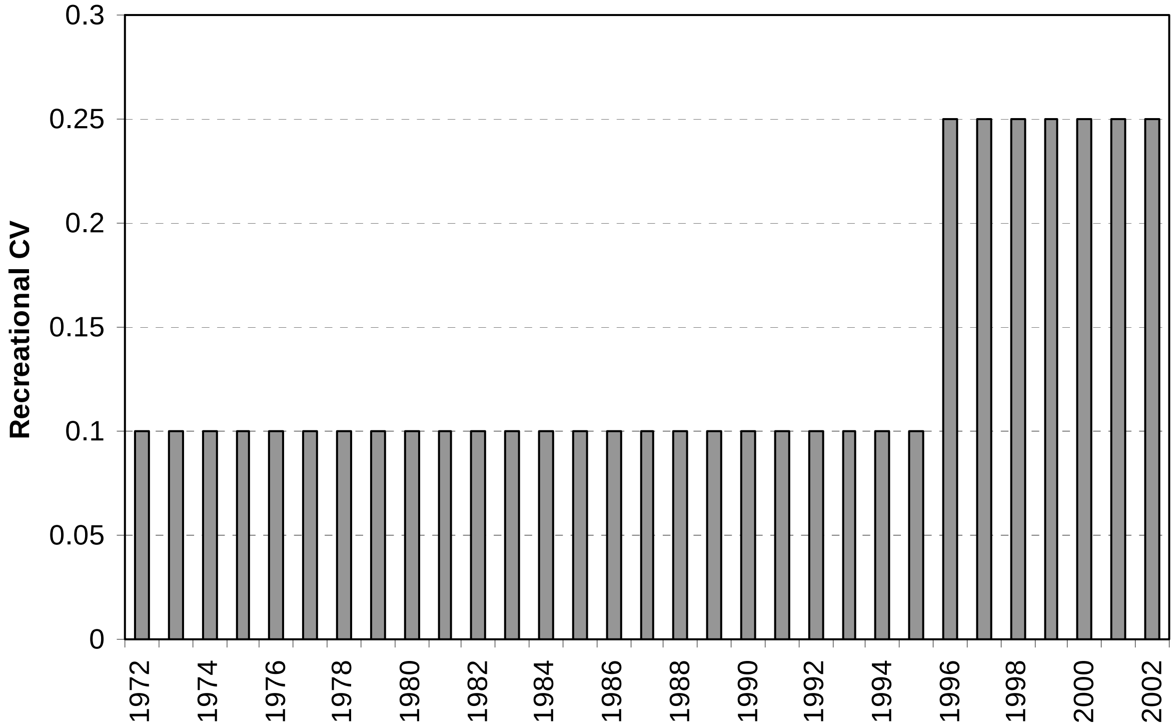


Figure **11**: Coefficients of variation (CV) for snowy grouper recreational headboat landings used in the statistical catch-at-age model.

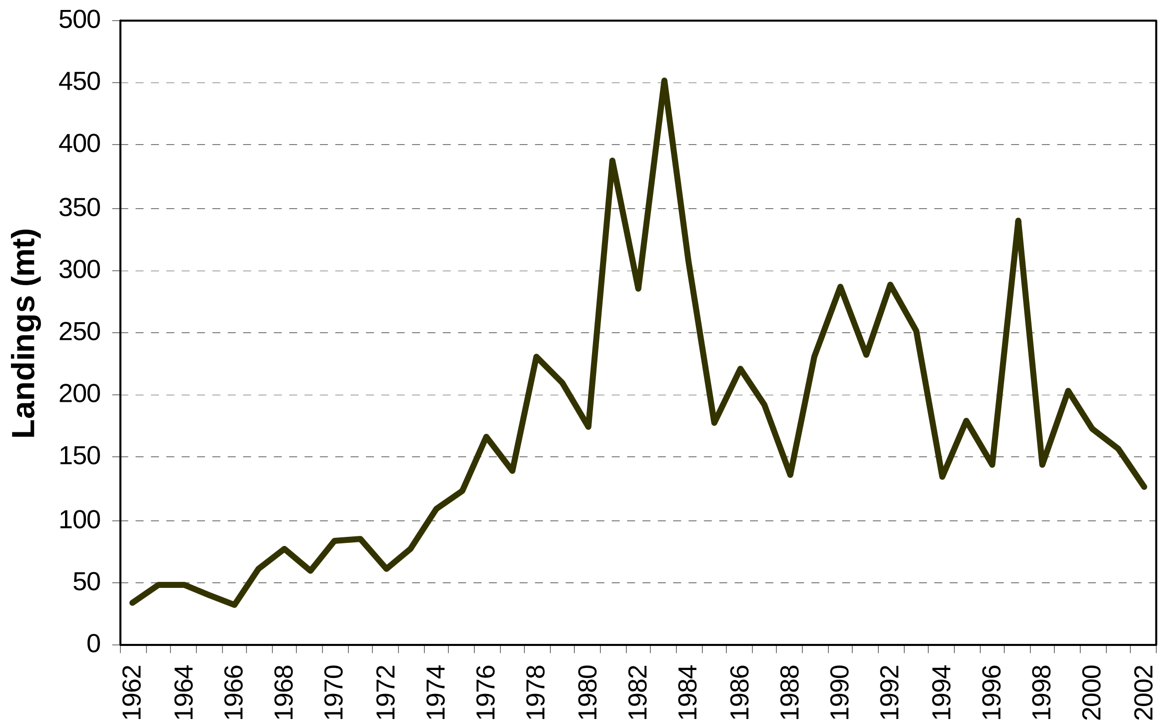


Figure **12**: Total snowy grouper landings (mt) from commercial and recreational sectors.

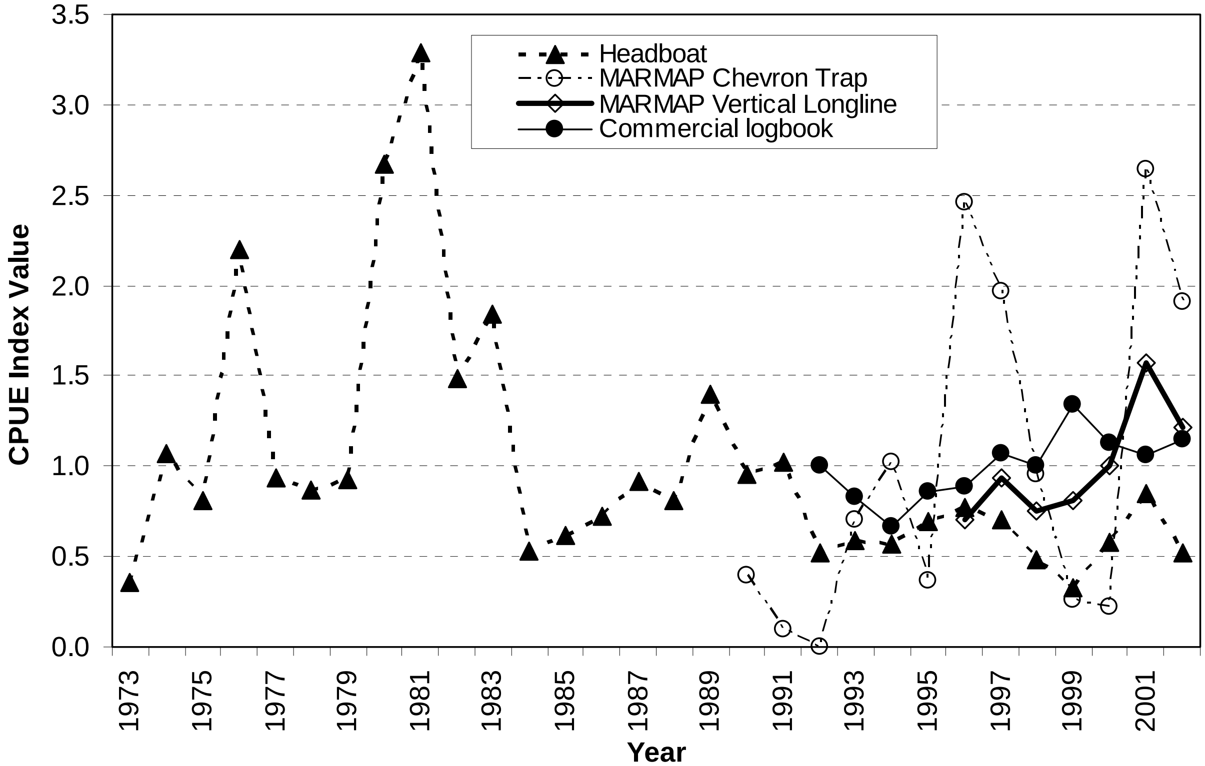


Figure **13**: Snowy grouper indices of abundance derived from MARMAP vertical longline and chevron traps, headboat and commercial logbook data. Values have been re-scaled to their respective means.

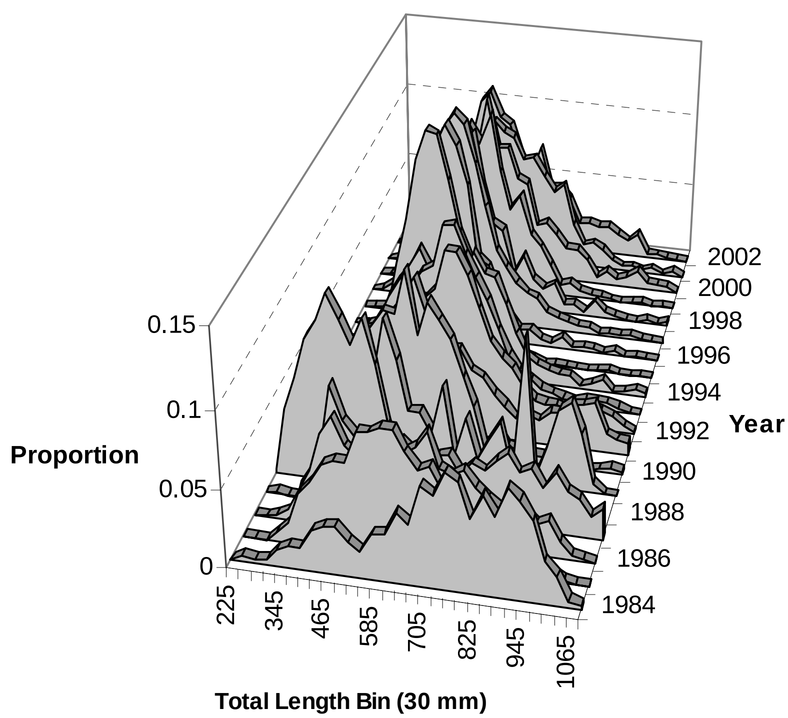


Figure **14**: Snowy grouper commercial longline length composition from samples collected in 1984-2002.

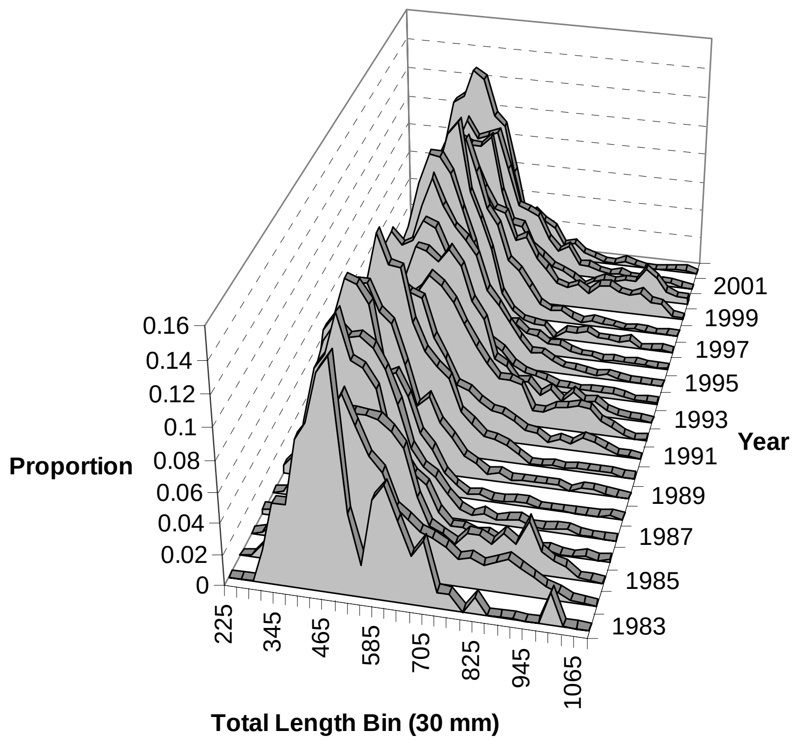


Figure **15**: Snowy grouper commercial handline length composition from samples collected in 1983-2002.

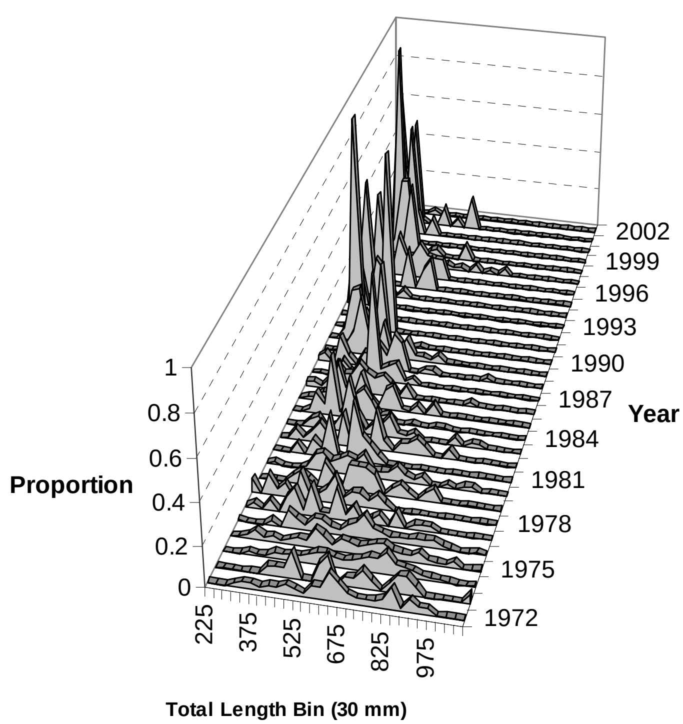


Figure **16**: Snowy grouper headboat length composition from samples collected in 1972-2002. Not all years were fit in the assessment model.

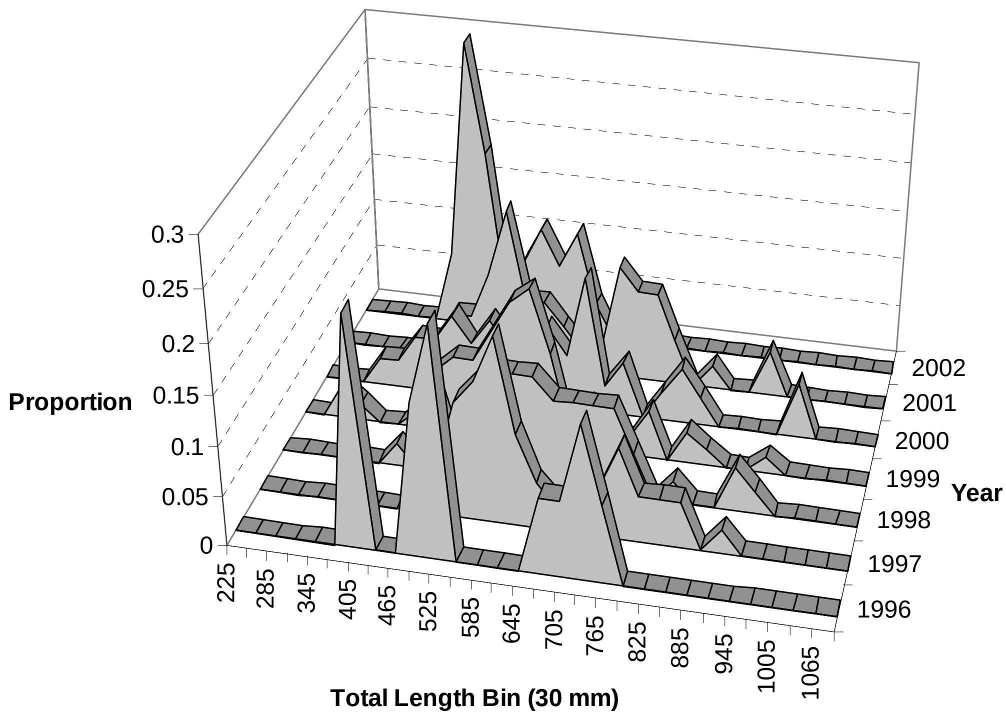


Figure **17**: Snowy grouper MARMAP vertical longline length composition from samples collected in 1996-2002. Not all years were fit in the assessment model.

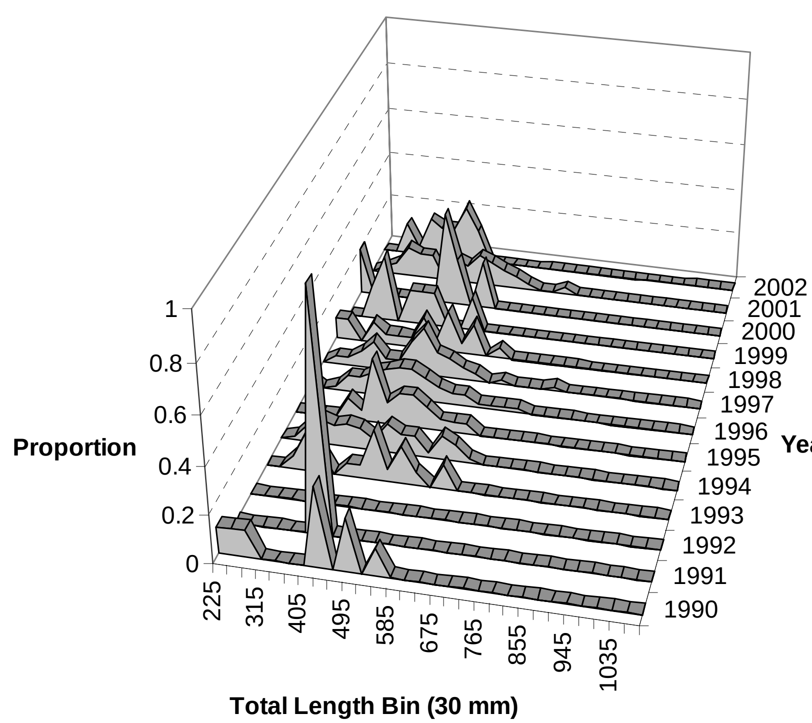


Figure **18**: Snowy grouper MARMAP chevron trap length compositions from samples collected in 1990-2002. Not all years were fit in the assessment model.

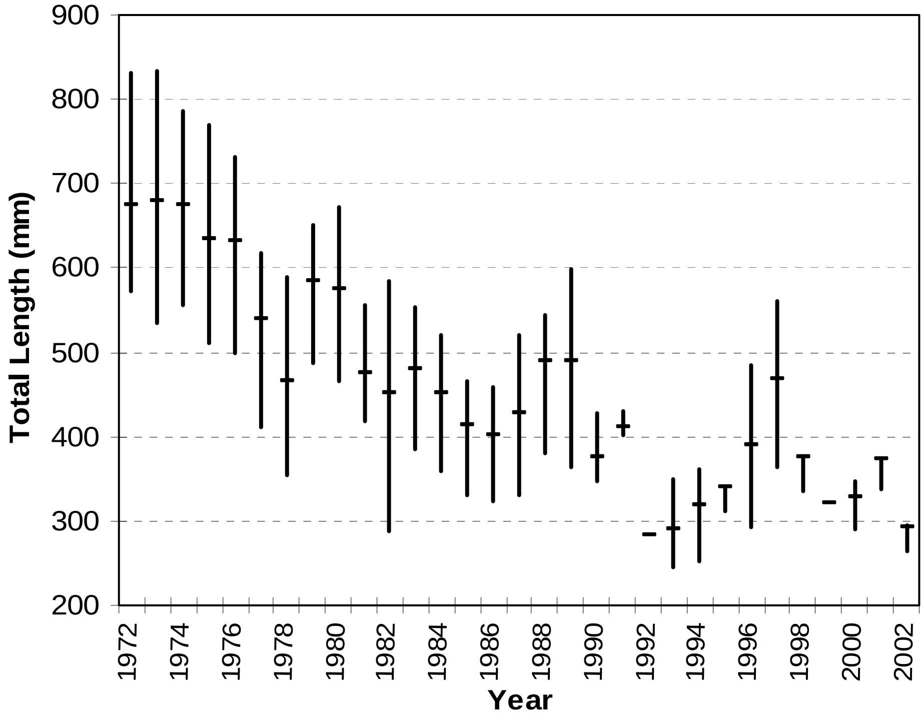


Figure **19**: Mean (horizontal dash) and interquartile range (vertical lines) of length samples collected from the headboat fishery in years 1972-2002.

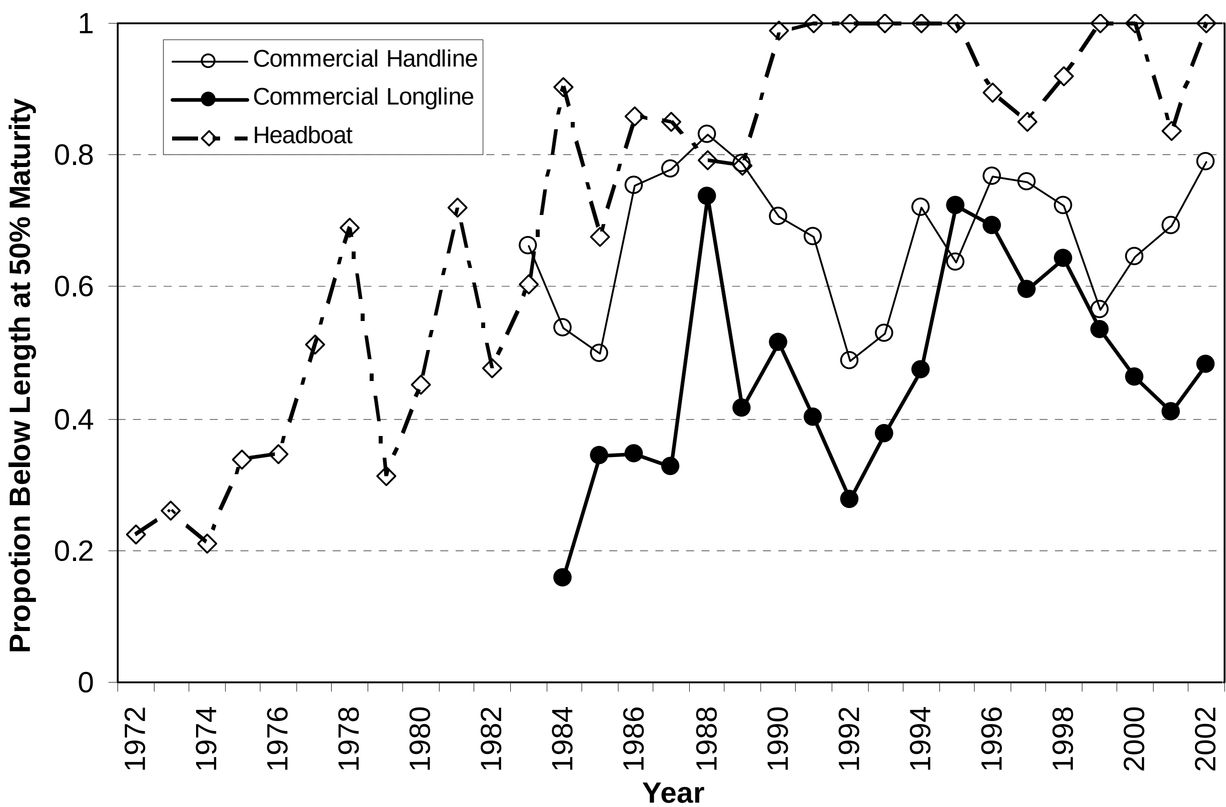


Figure **20**: The proportion of fish below the size at 50% maturity captured in the primary fisheries for snowy grouper.

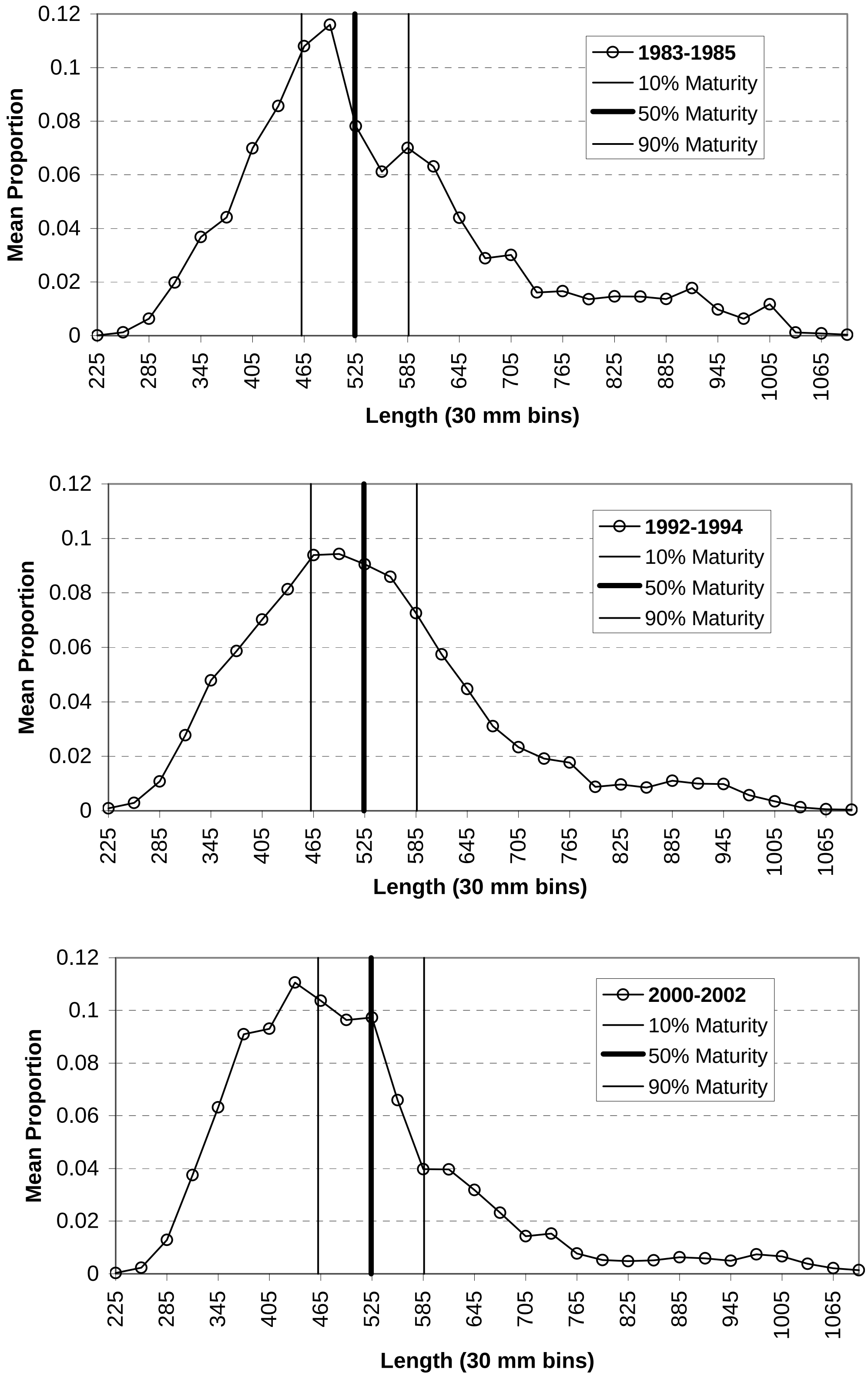


Figure **21**: Averaged length compositions for selected years from the commercial handline fishery for snowy grouper with sizes at various levels of maturity indicated.

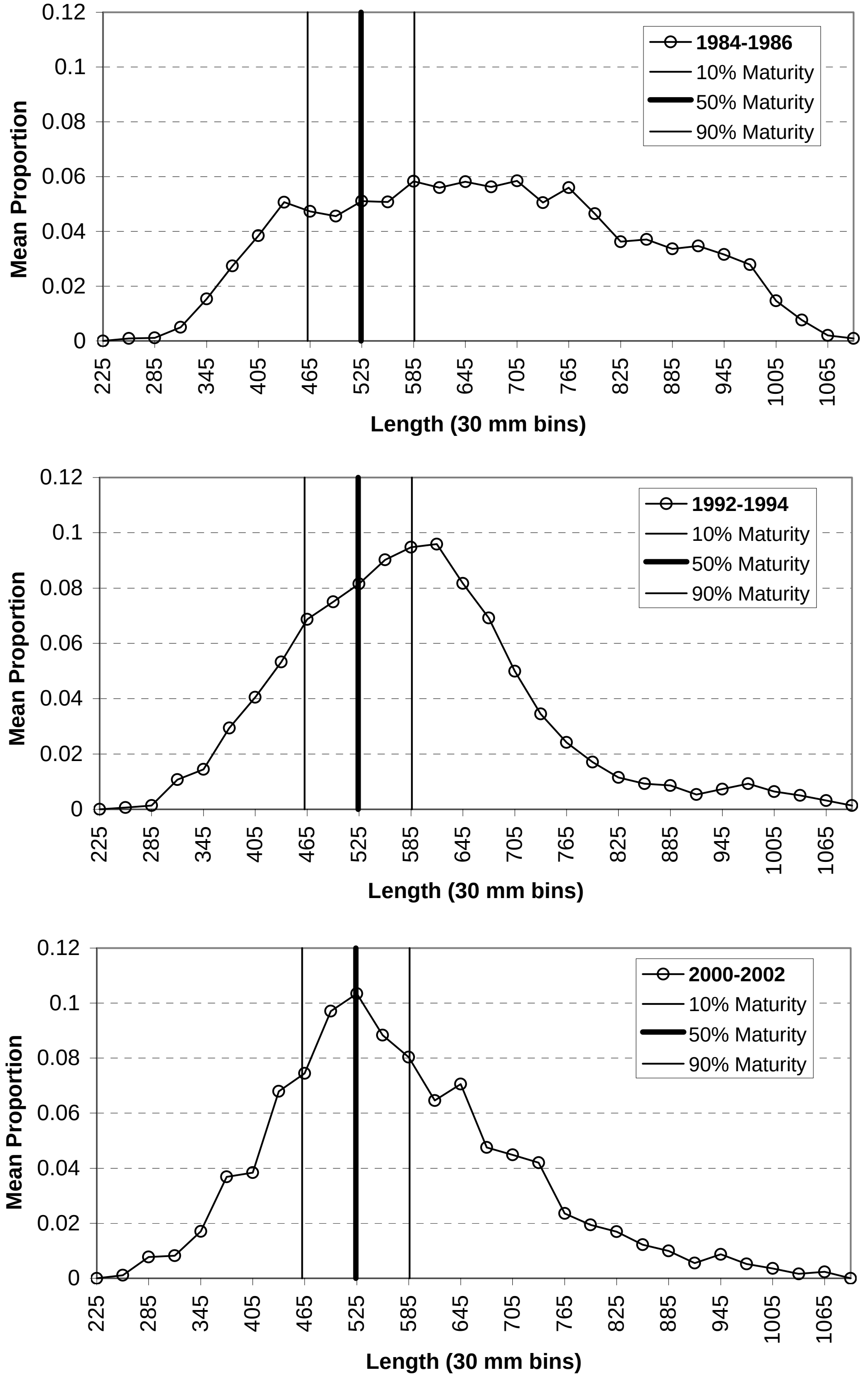


Figure **22**: Averaged length compositions for selected years from the commercial longline fishery for snowy grouper with sizes at various levels of maturity indicated.

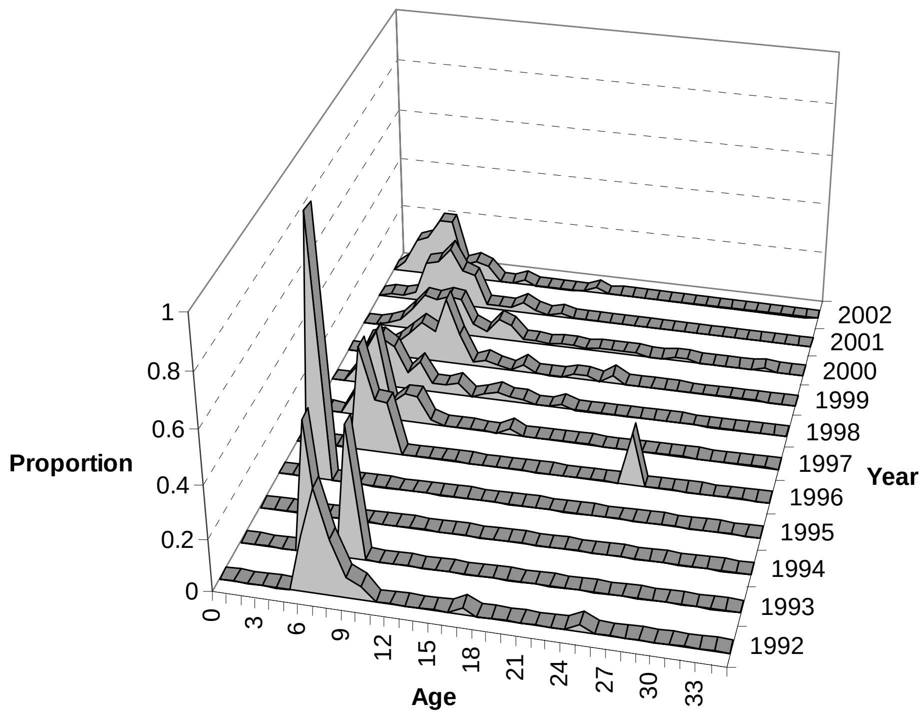


Figure **23**: Snowy grouper commercial handline age compositions from samples collected in 1992-2002. Not all years were fit in the assessment model.

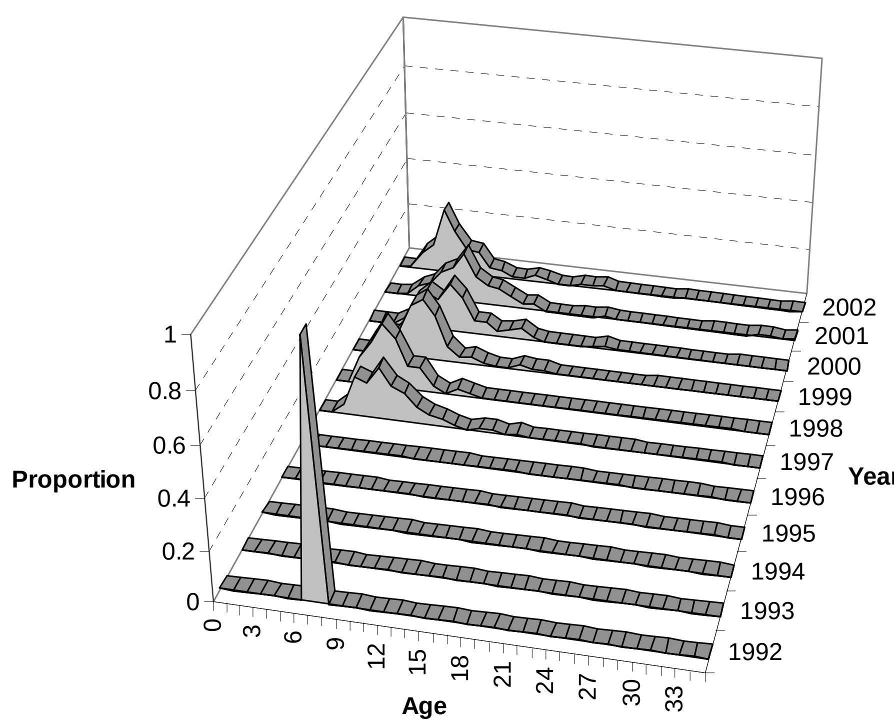


Figure **24**: Snowy grouper commercial longline age compositions from samples collected in 1992-2002. Not all years were fit in the assessment model.

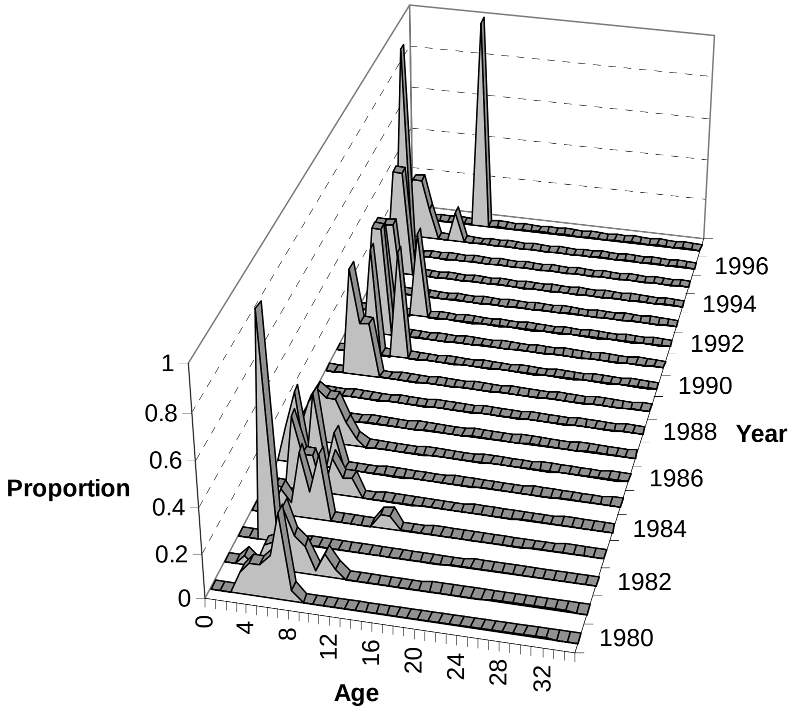


Figure **25**: Snowy grouper recreational headboat age compositions from samples collected in 1980-1997. Not all years were fit in the assessment model.

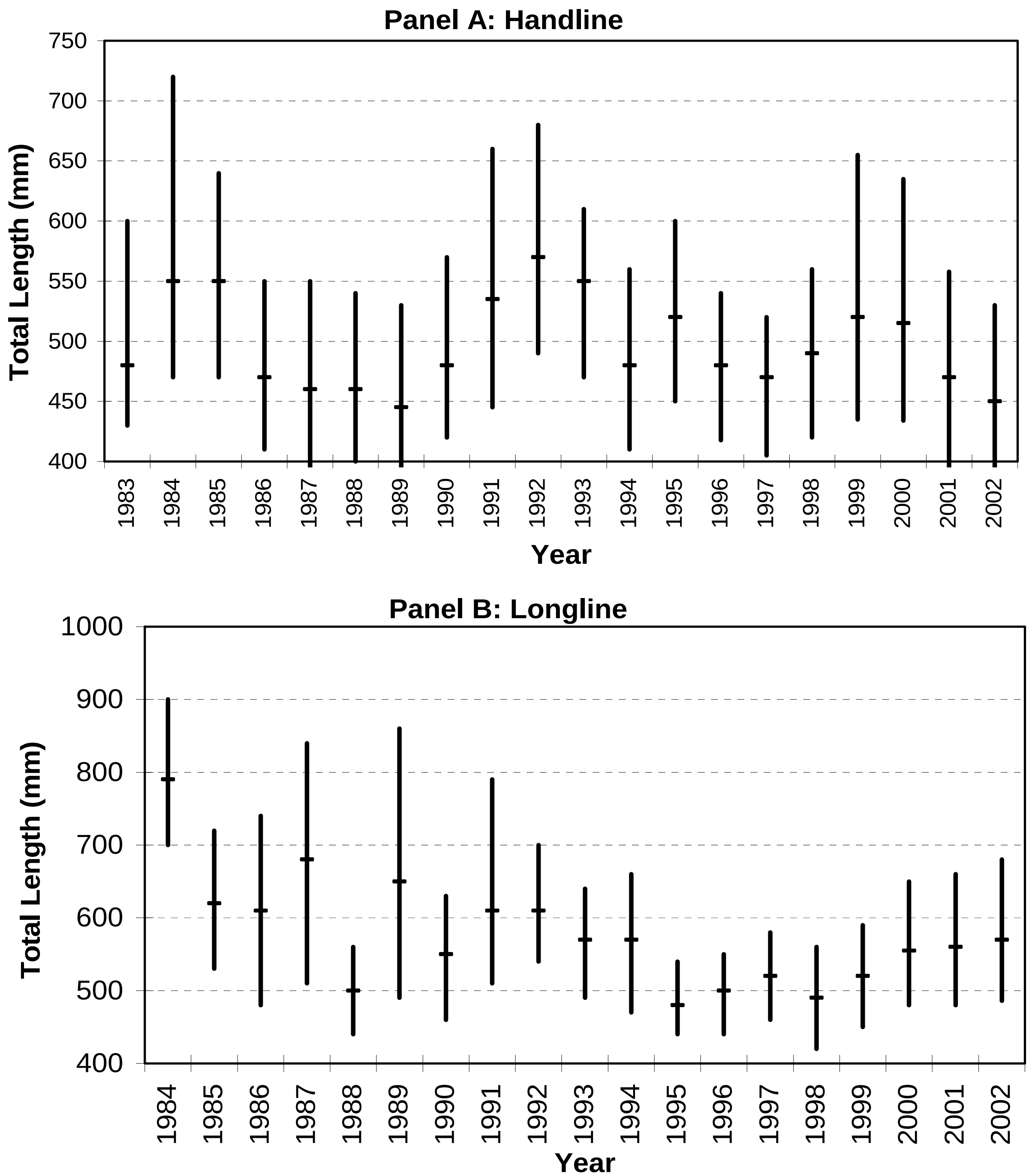


Figure **26**: Mean (horizontal dash) and interquartile range (vertical lines) of length samples collected from the handline (a) and longline (b) fisheries in years 1983-2002.

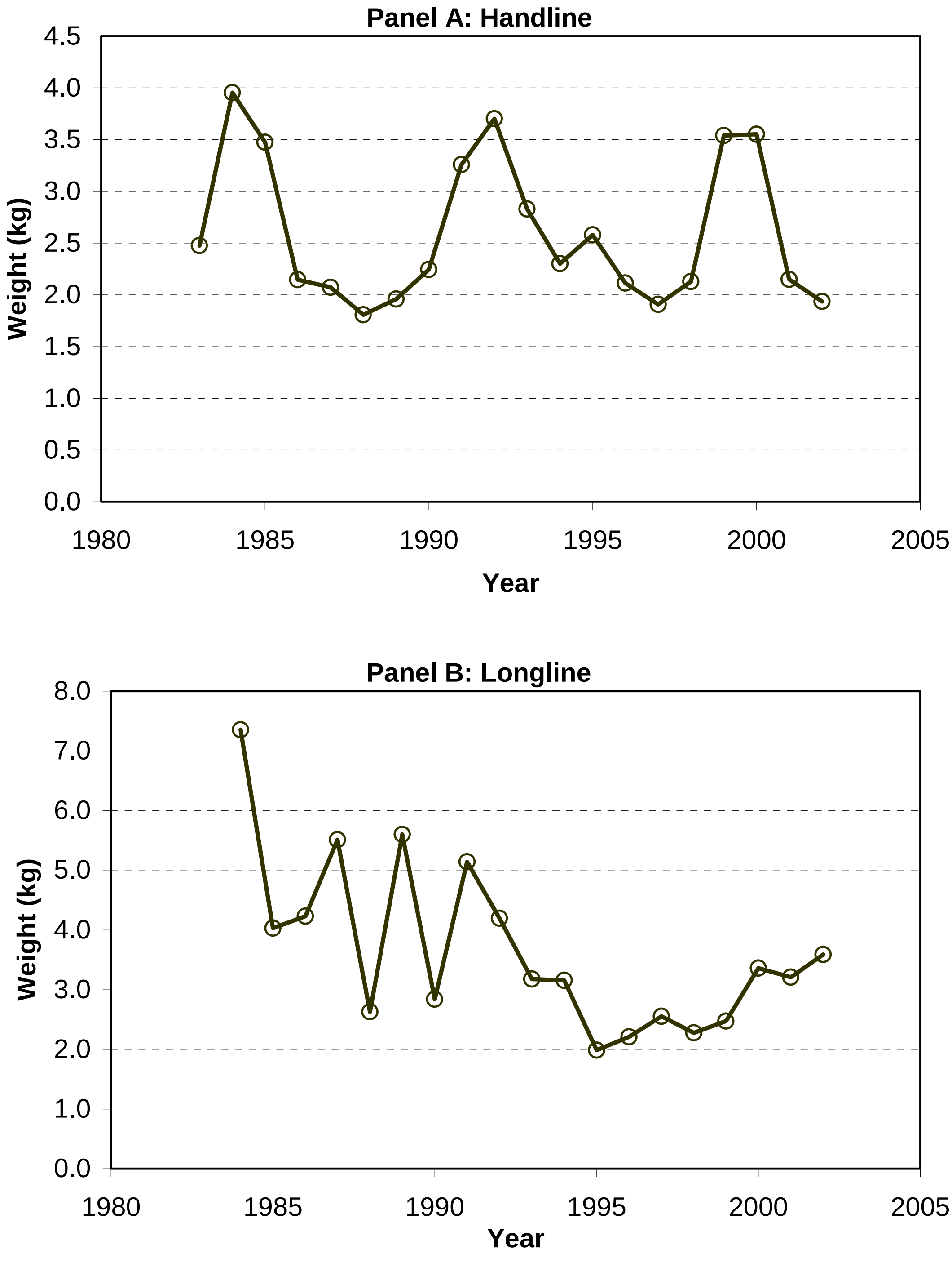


Figure **27**: Landings-weighted mean weight (kg) samples collected from the handline (a) and longline (b) fisheries in years 1983-2002.

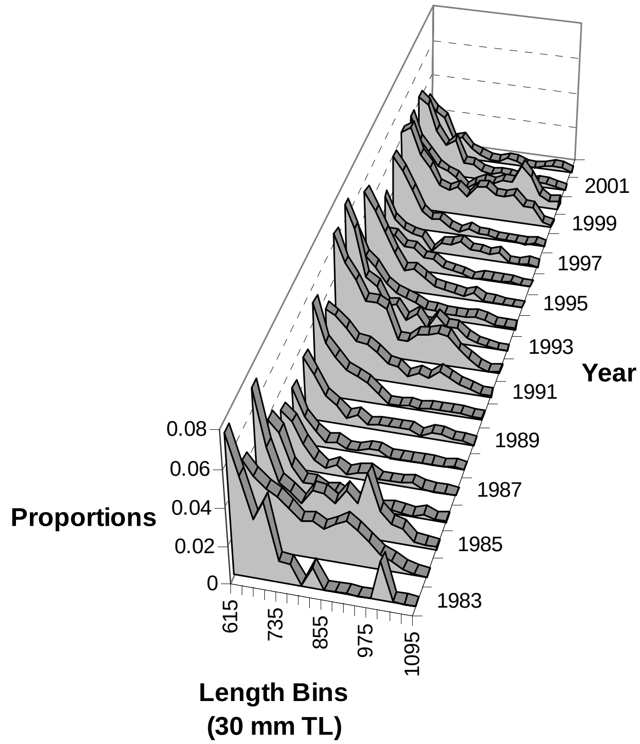


Figure **28**: Snowy grouper commercial handline length compositions of lengths greater than 600 mm total length (TL), from samples collected in 1983-2002.

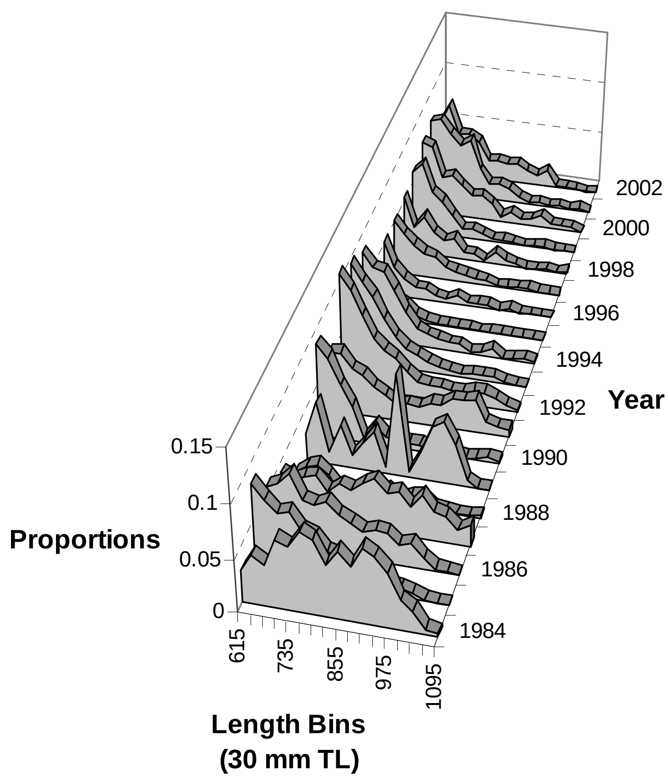


Figure **29**: Snowy grouper commercial longline length compositions of lengths greater than 600 mm total length (TL), from samples collected in 1984-2002.

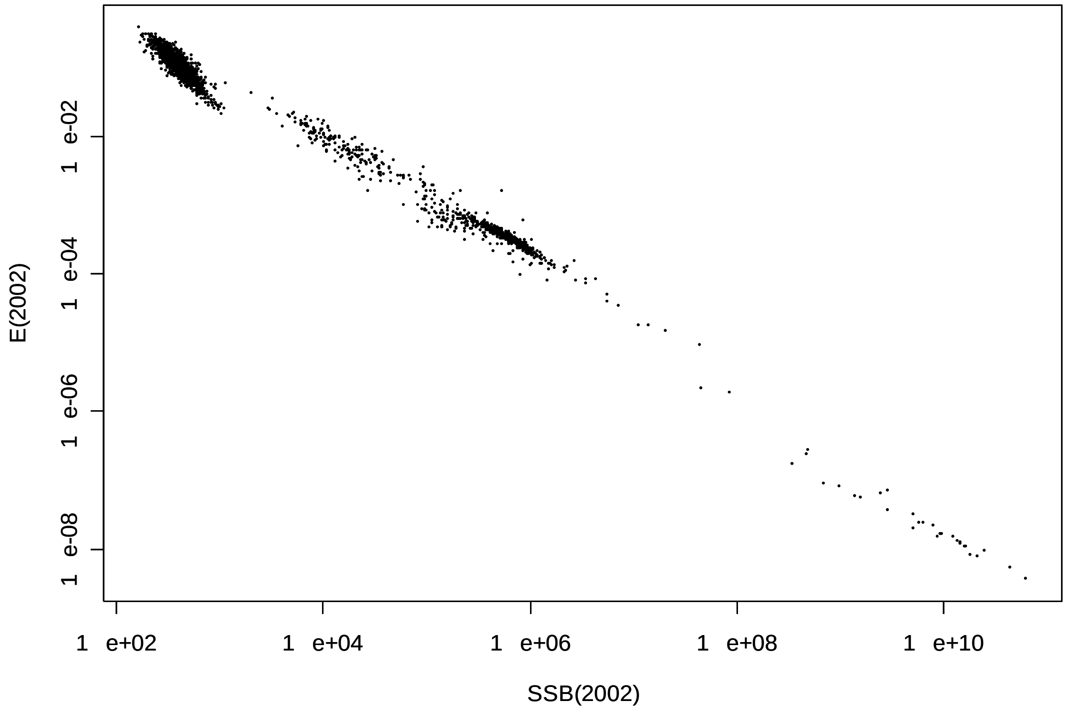


Figure **30**: Estimates of exploitation rate (E) and total mature biomass (SSB) in 2002 from all 2316 Monte Carlo/bootstrap runs.

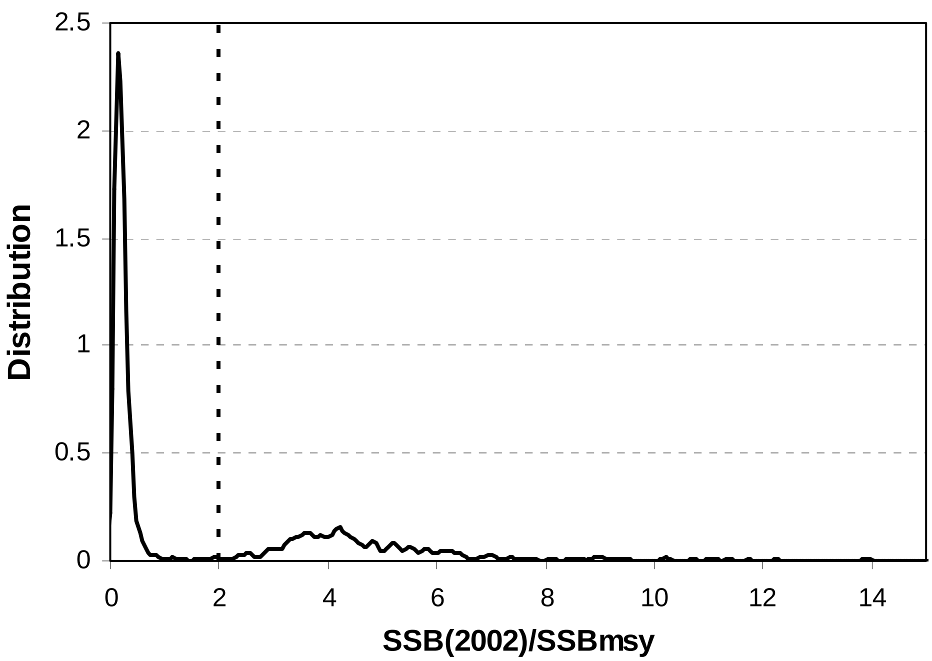


Figure **31**: Distribution of the ratio SSB(2002)/SSBmsy for all 2316 Monte Carlo/bootstrap runs with the value of 2.0 used for culling runs indicated as a vertical line.

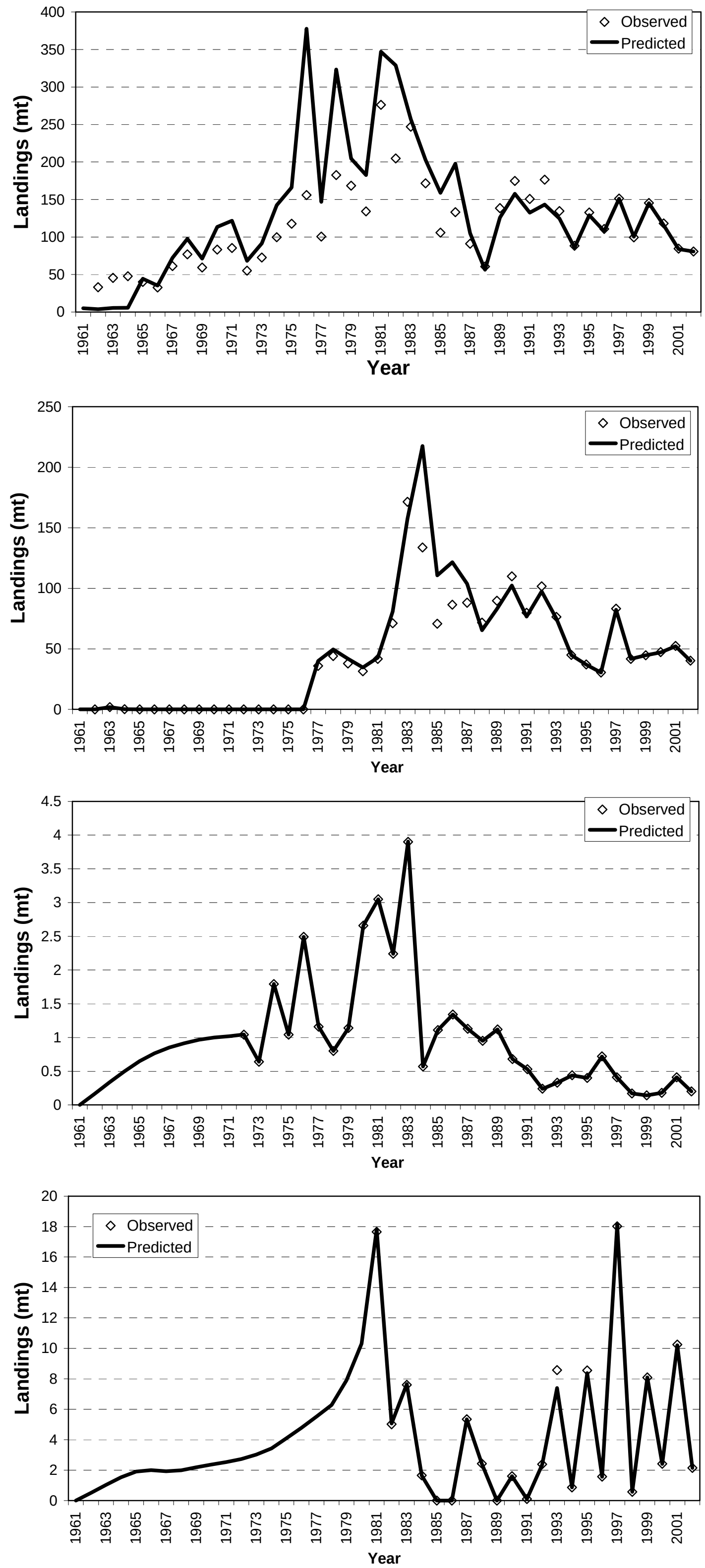


Figure **32**: Observed and model predicted landings (mt) estimates from the initial run of the snowy grouper stock assessment model.

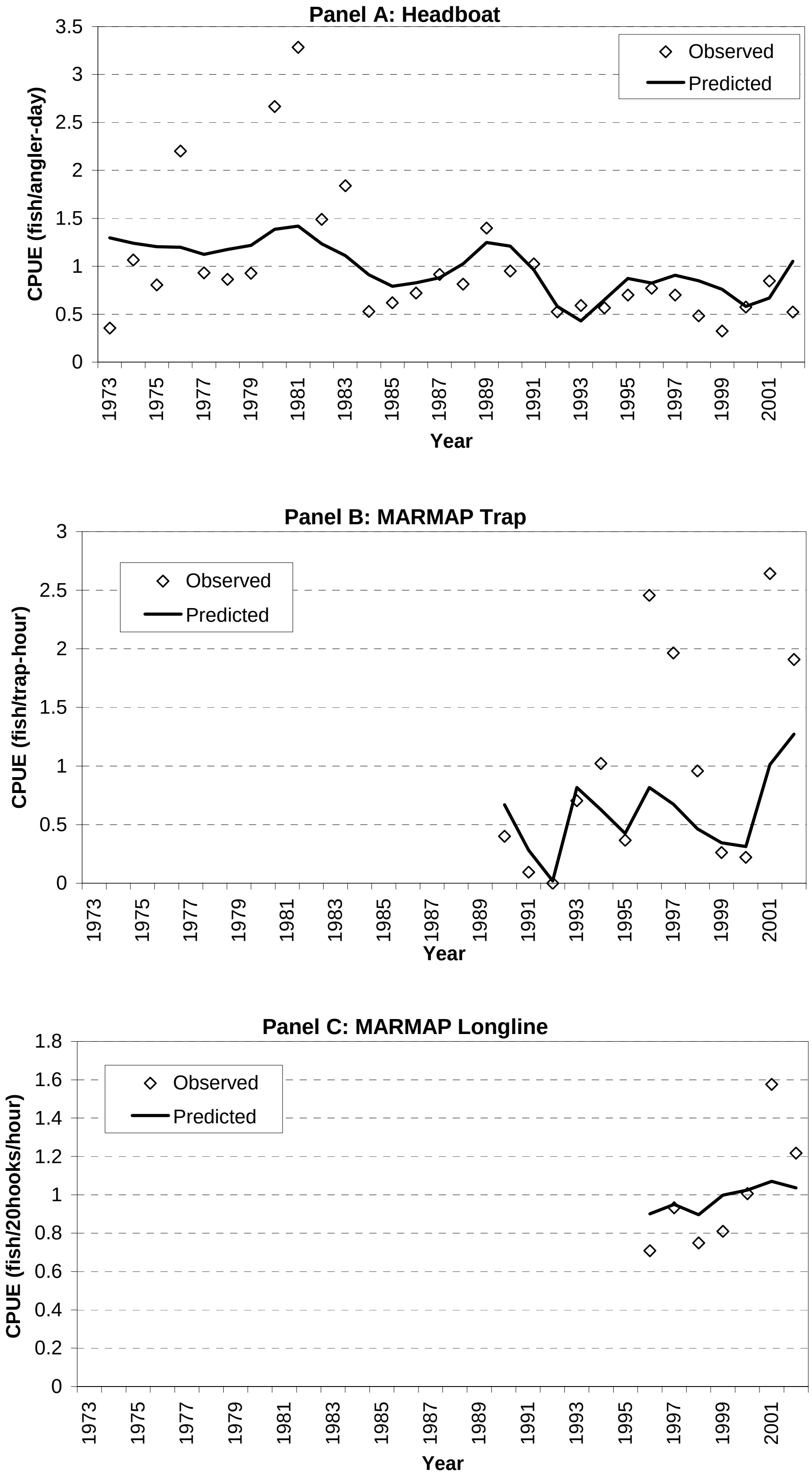


Figure **33**: Observed and model predicted index estimates from the initial run of the snowy grouper stock assessment model.

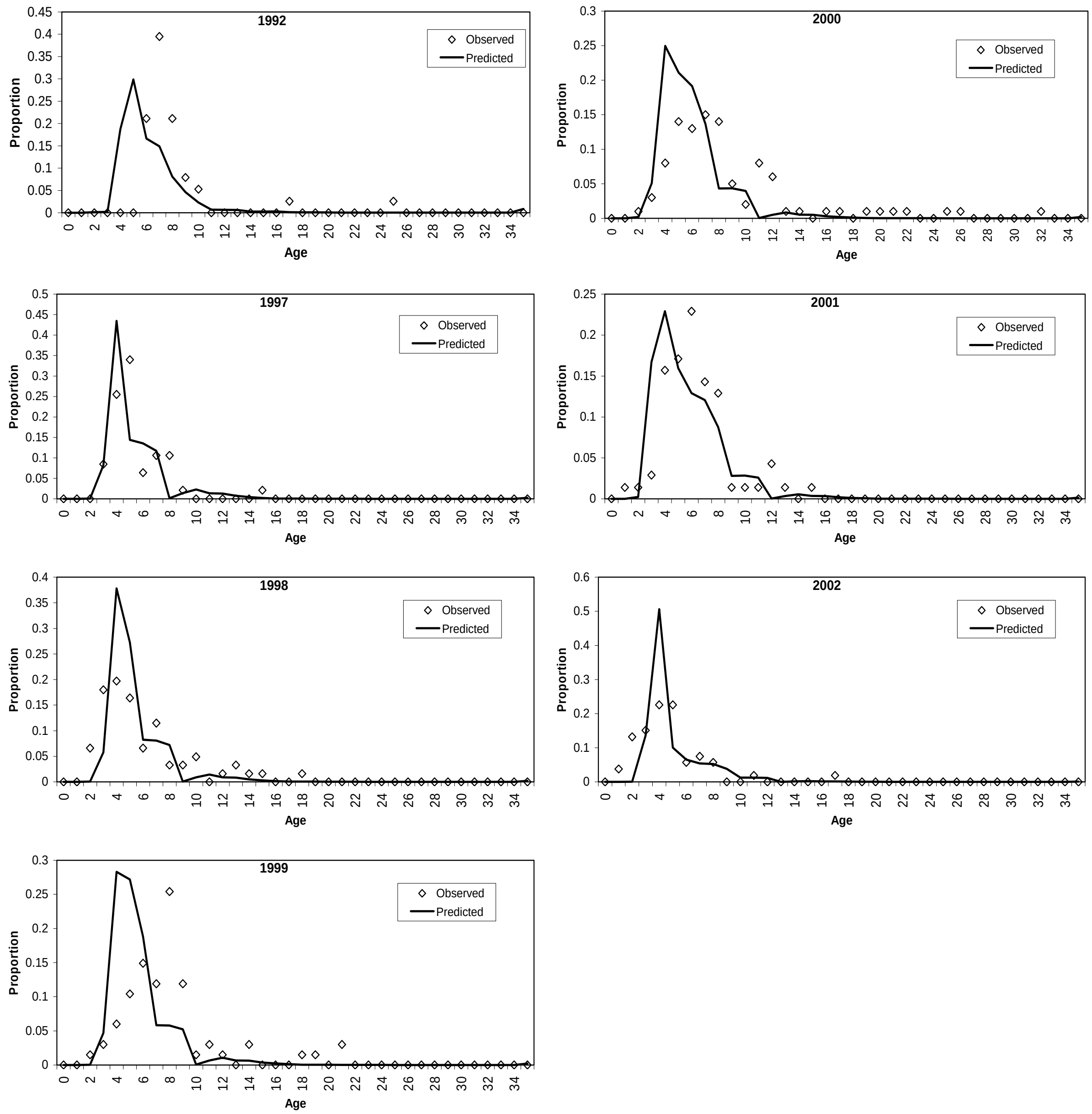


Figure **34**: Observed and model predicted age composition estimates by year from the commercial handline fishery from the initial run of the snowy grouper stock assessment model.

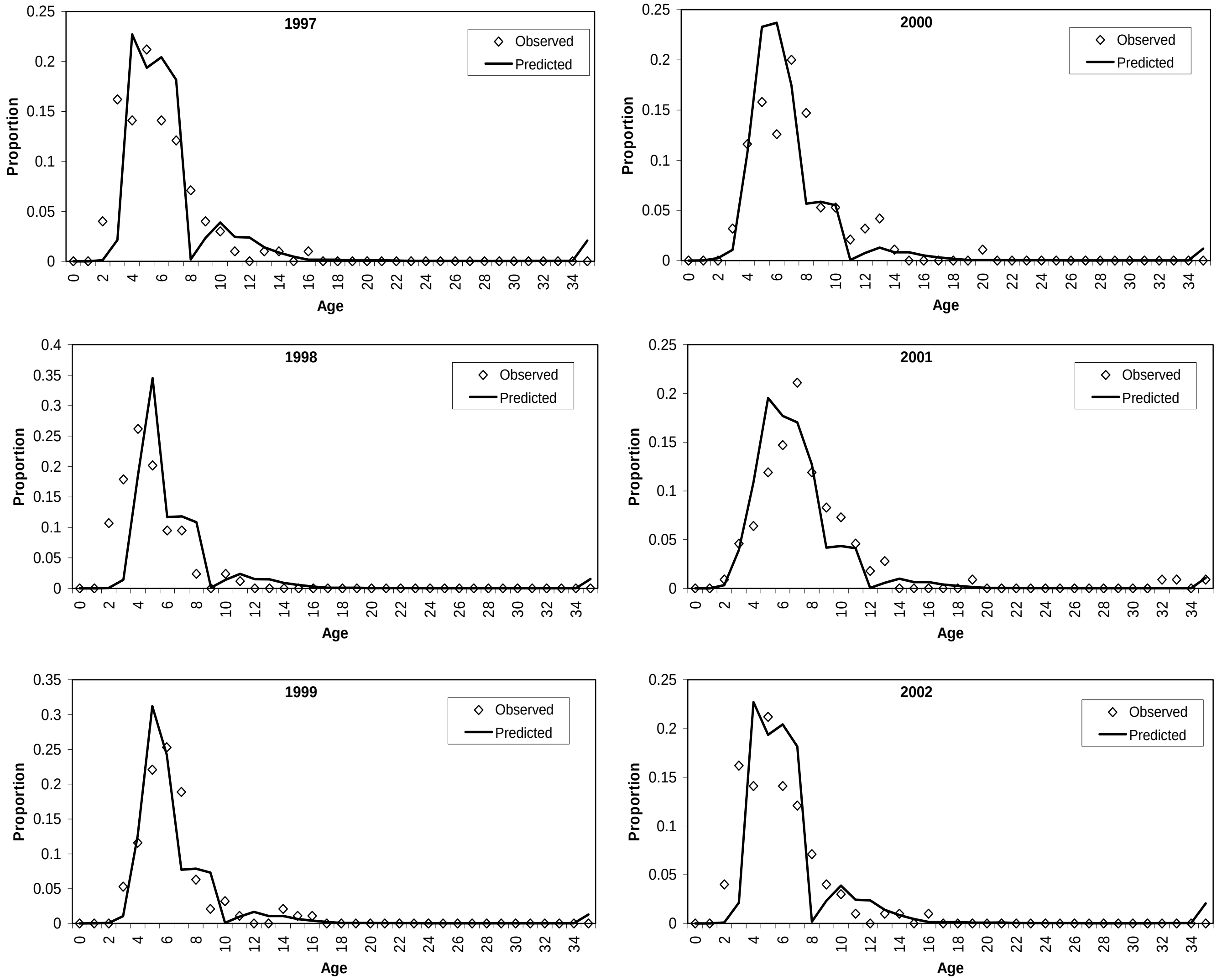
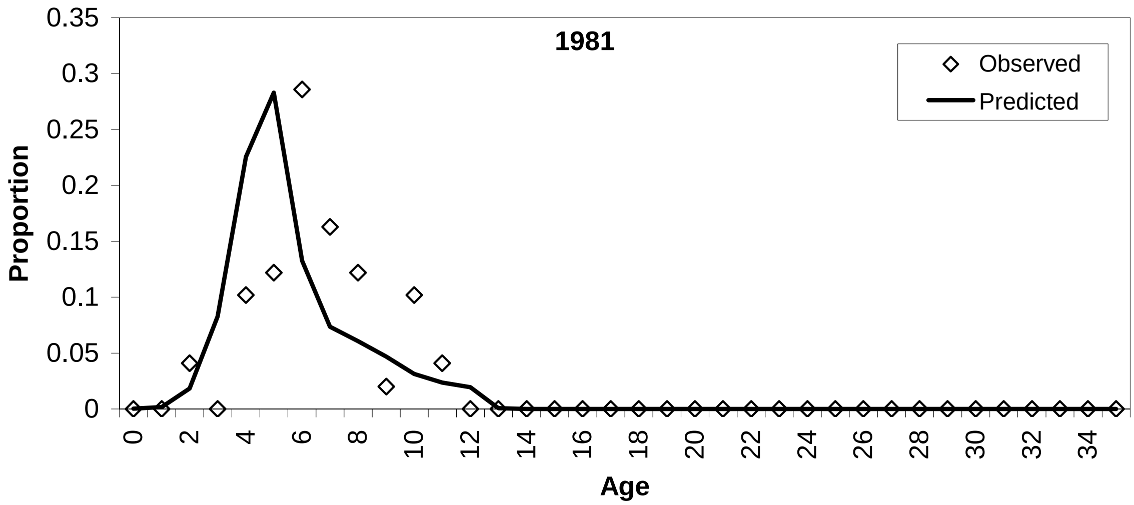


Figure **35:** Observed and model predicted age composition estimates by year from the commercial longline fishery from the initial run of the snowy grouper stock assessment model.



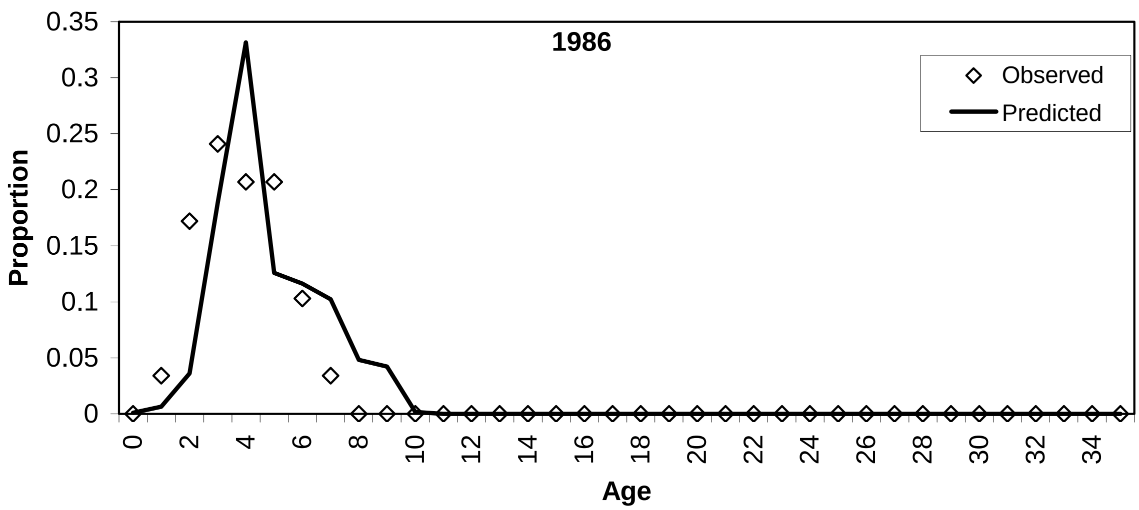


Figure **36**: Observed and model predicted age composition estimates by year from the recreational headboat fishery from the initial run of the snowy grouper stock assessment model.

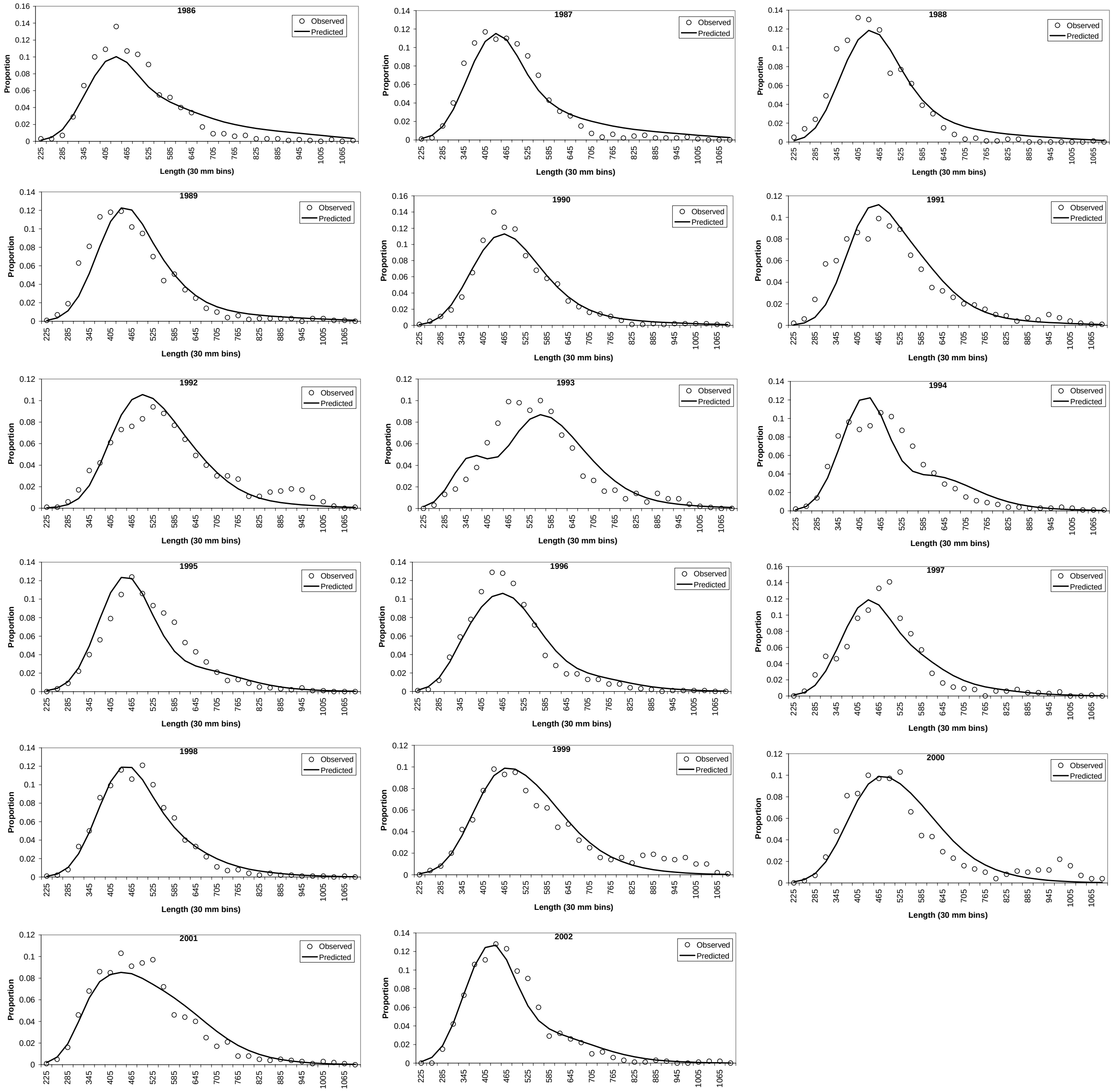


Figure **37**: Observed and model predicted length composition estimates by year from the commercial handline fishery from the initial run of the snowy grouper stock assessment model.

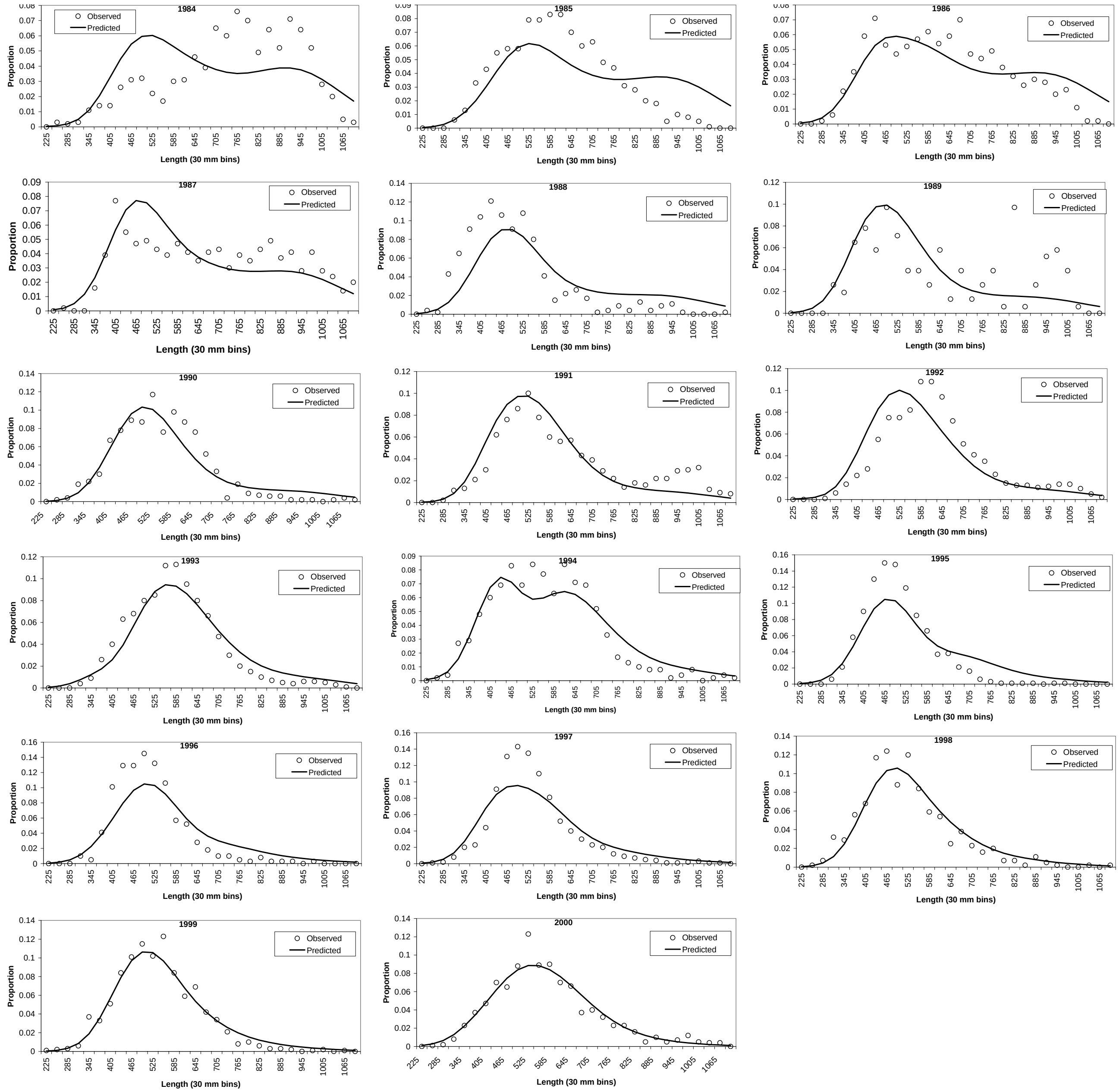


Figure **38**: Observed and model predicted length composition estimates from the commercial longline fishery from the initial run of the snowy grouper stock assessment model.

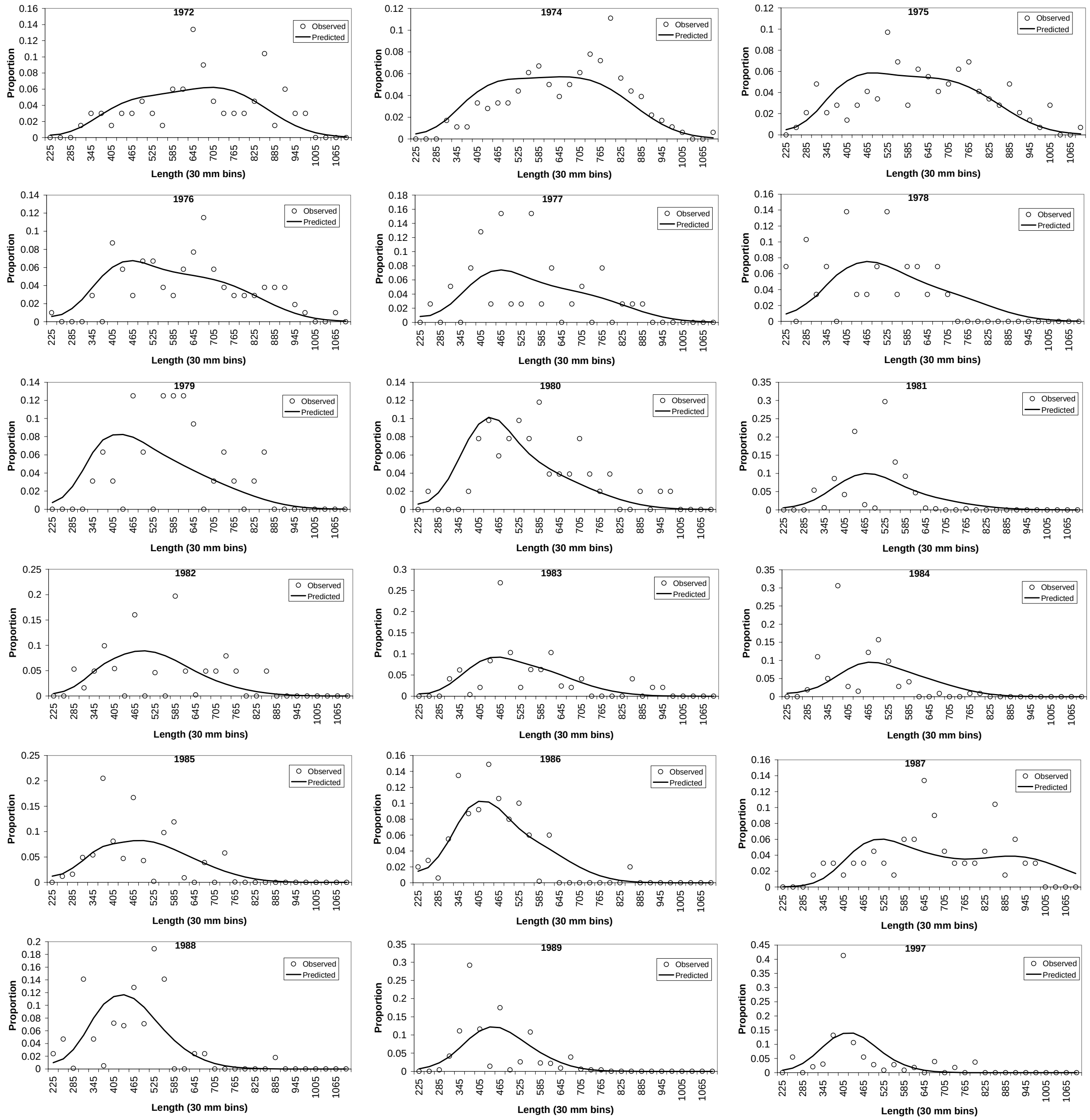


Figure **39**: Observed and model predicted length composition estimates from the recreational headboat fishery from the initial run of the snowy grouper stock assessment model.

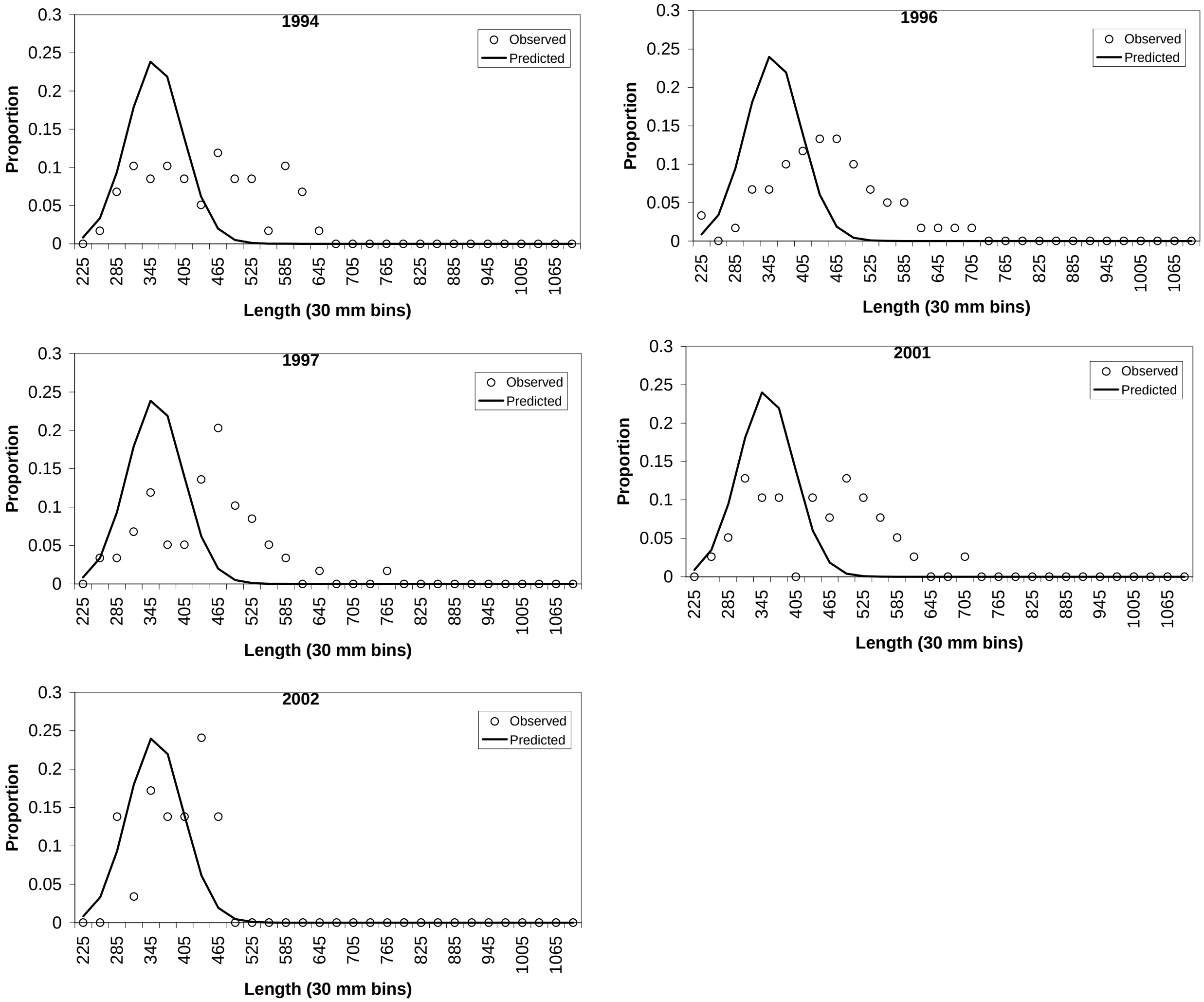


Figure **40**: Observed and model predicted length composition estimates from the MARMAP Chevron trap survey from the initial run of the snowy grouper stock assessment model.

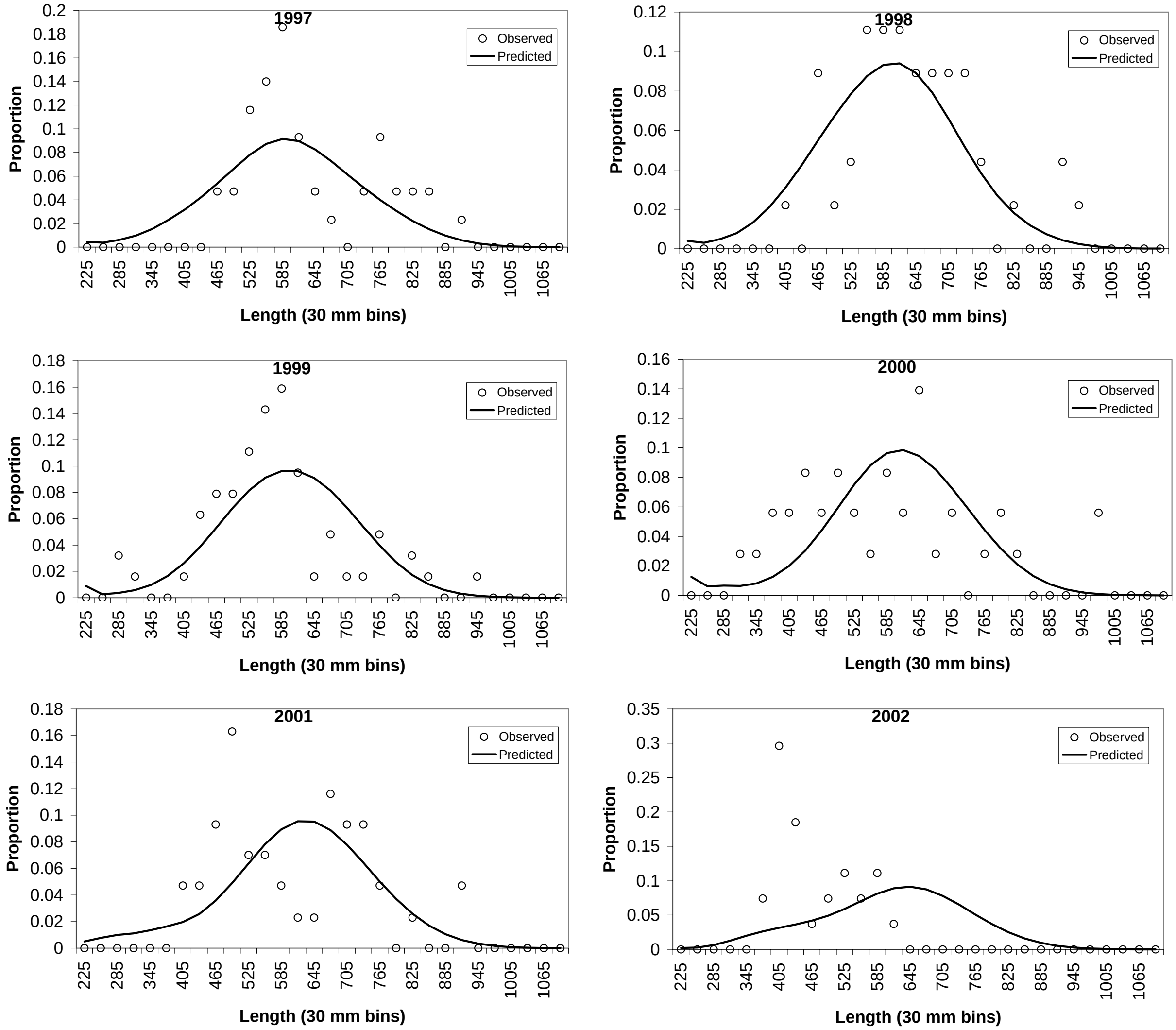
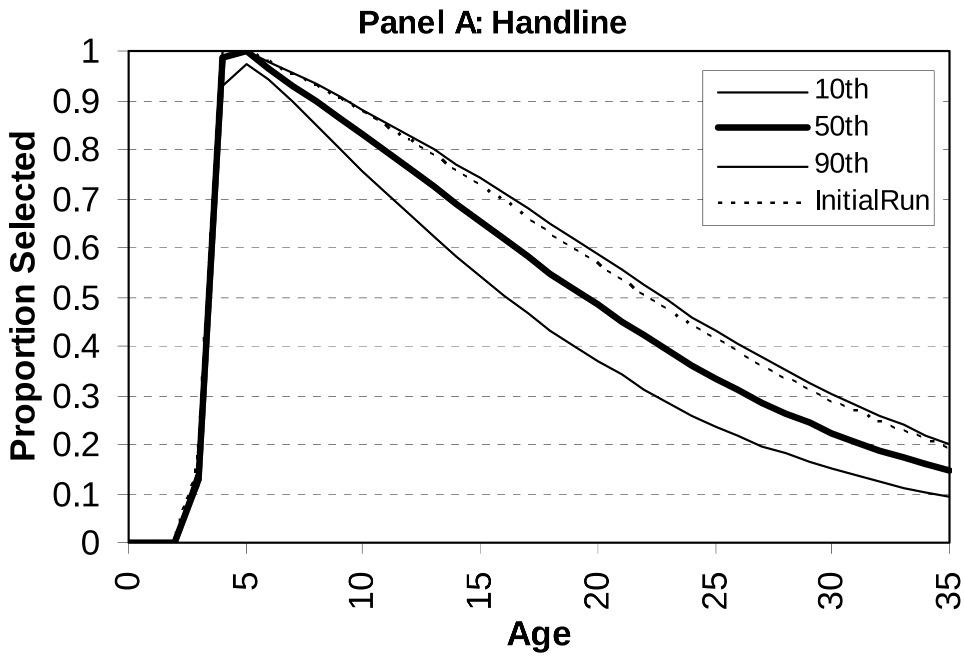


Figure **41**: Observed and model predicted length composition estimates from the MARMAP longline survey from the initial run of the snowy grouper stock assessment model.



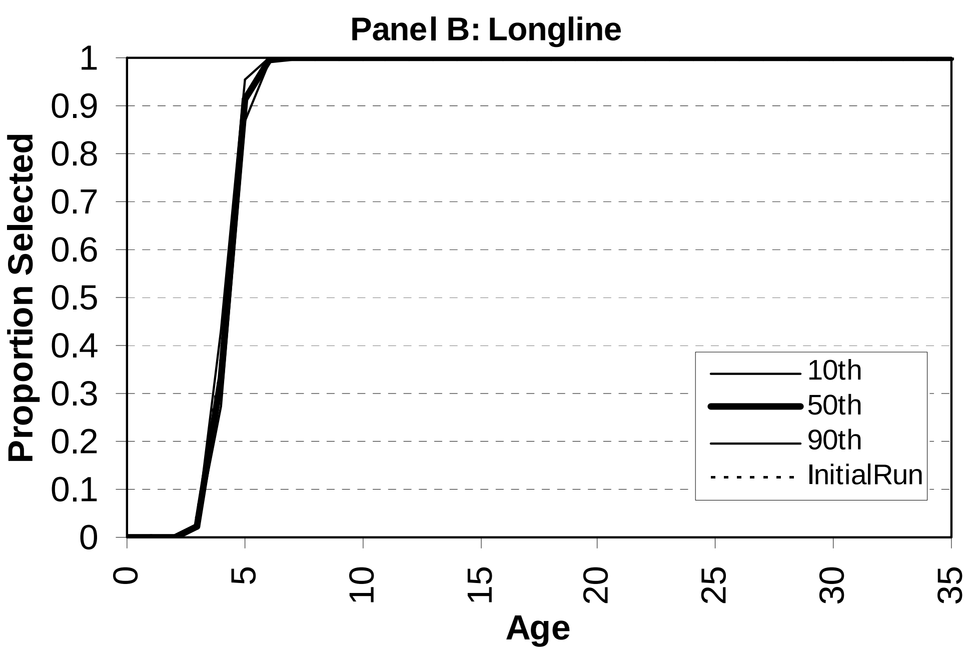


Figure **42**: The median, 10th, and 90th percentiles of the Monte Carlo/bootstrap runs (n=1470) and initial run estimates of selectivity at age for the commercial handline (a) and longline (b) fisheries.

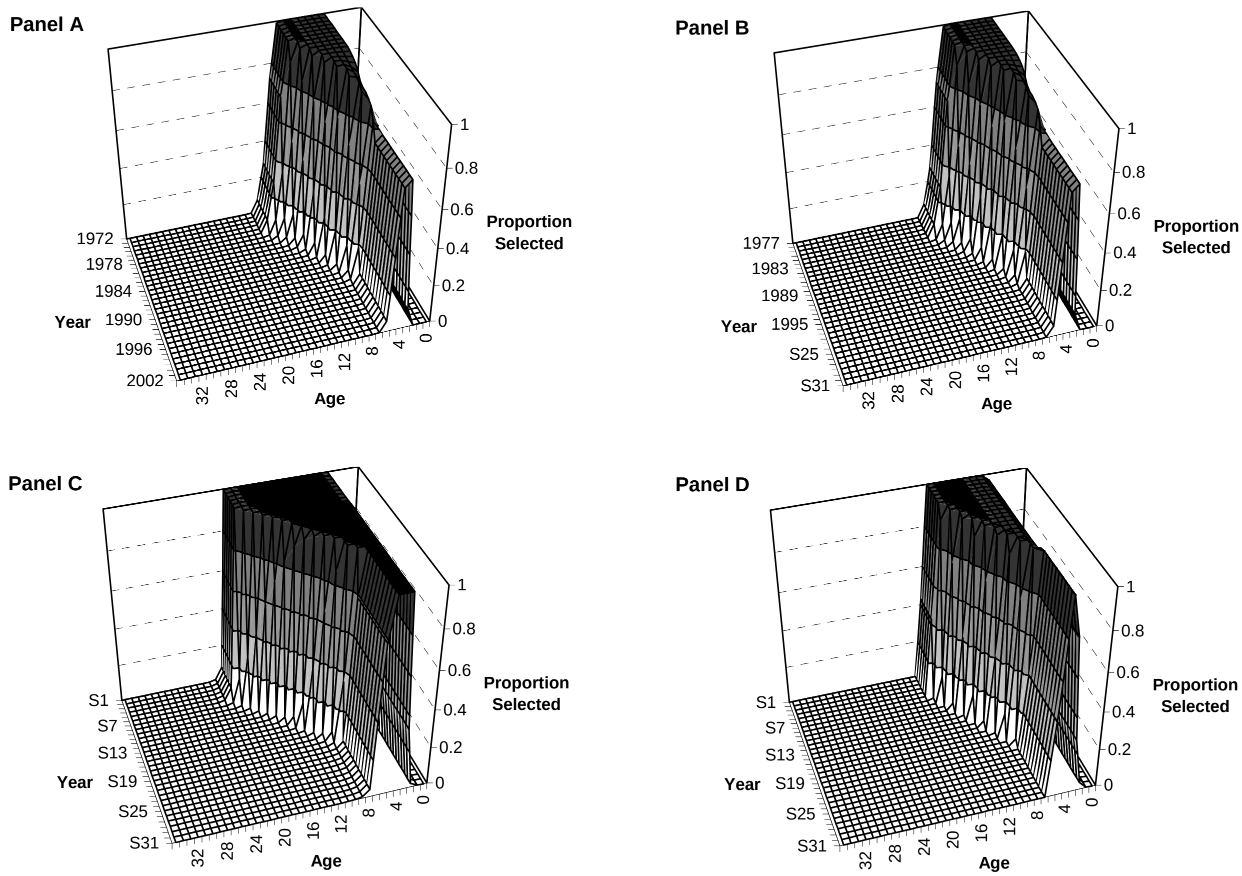


Figure **43**: The 10th (a), median (b), and 90th (c) percentiles of the Monte Carlo/bootstrap runs (n=1470) and initial run (d) estimates of selectivity at age by year for the recreational headboat fishery.

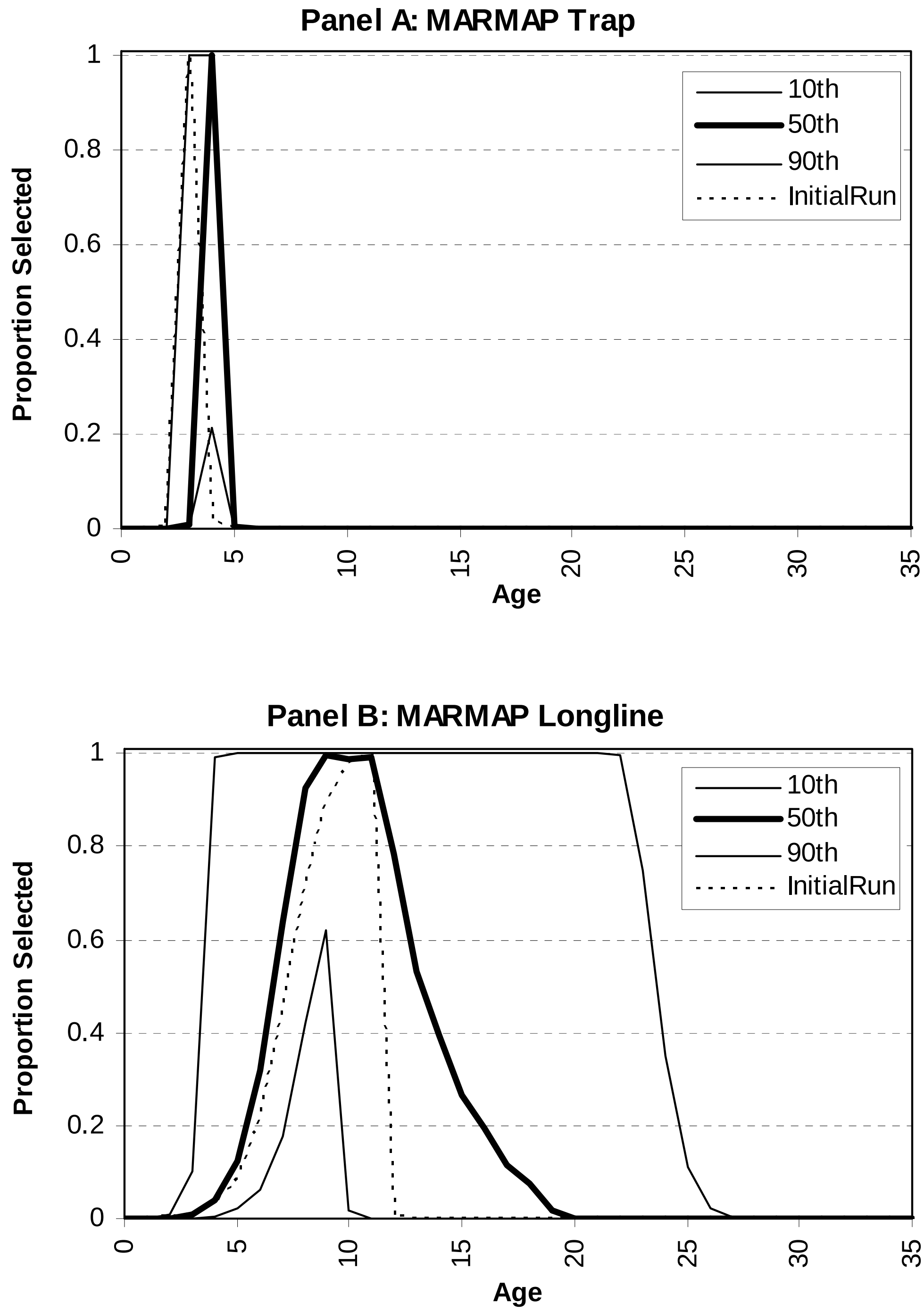


Figure **44**: The median, 10th, and 90th percentiles of the Monte Carlo/bootstrap runs (n=1470) and initial run estimates of selectivity at age for the MARMAP Chevron trap (a) and longline (b) surveys.

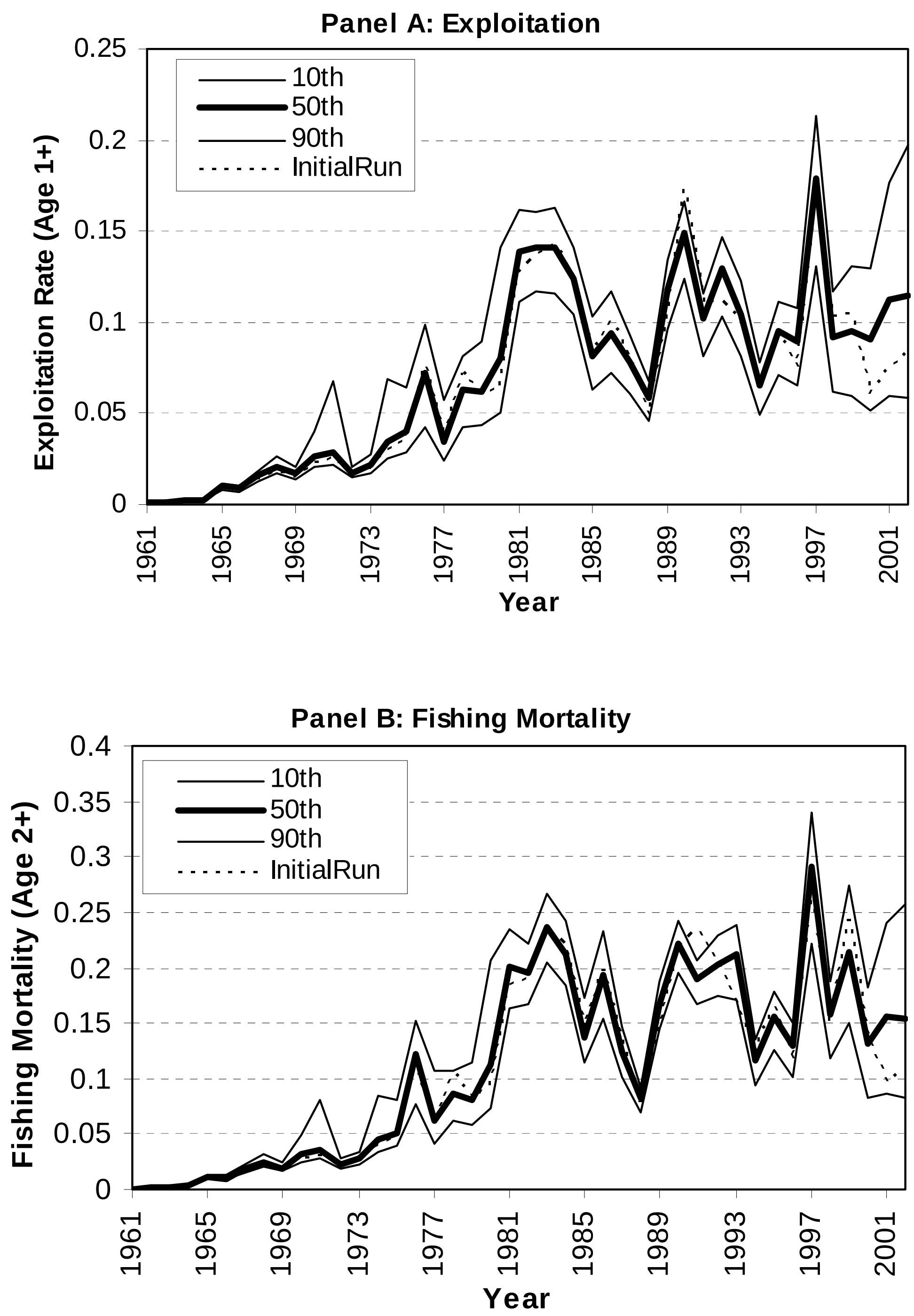


Figure **45**: The median, 10th, and 90th percentiles of the Monte Carlo/bootstrap runs (n=1470) and initial run estimates of age 1+ exploitation rate (a) and age 2+ fishing mortality (b).

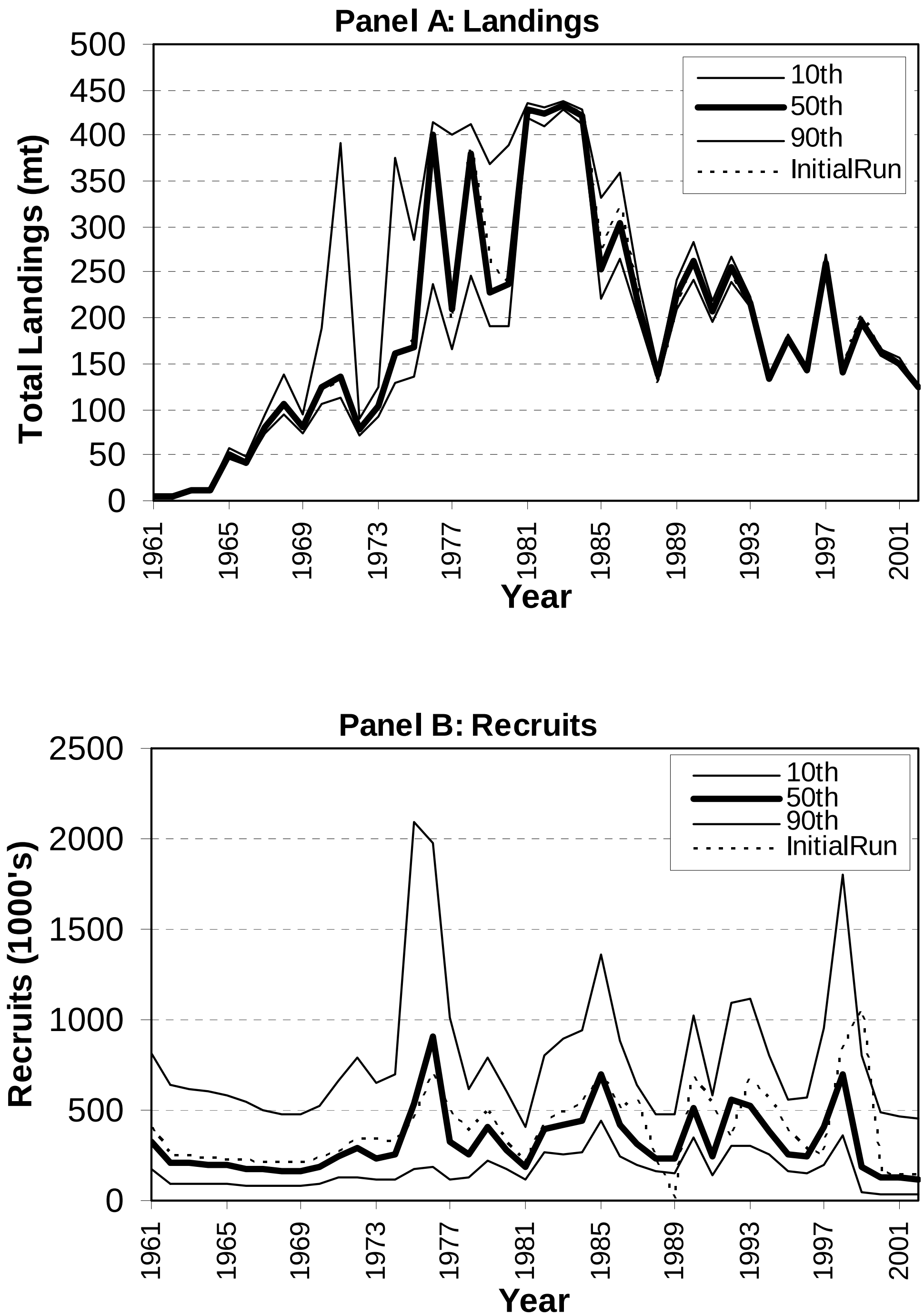


Figure **46**: The median, 10th, and 90th percentiles of the Monte Carlo/bootstrap runs (n=1470) and initial run estimates of total landings (mt) (a) and age 0 recruits (1000's) (b).

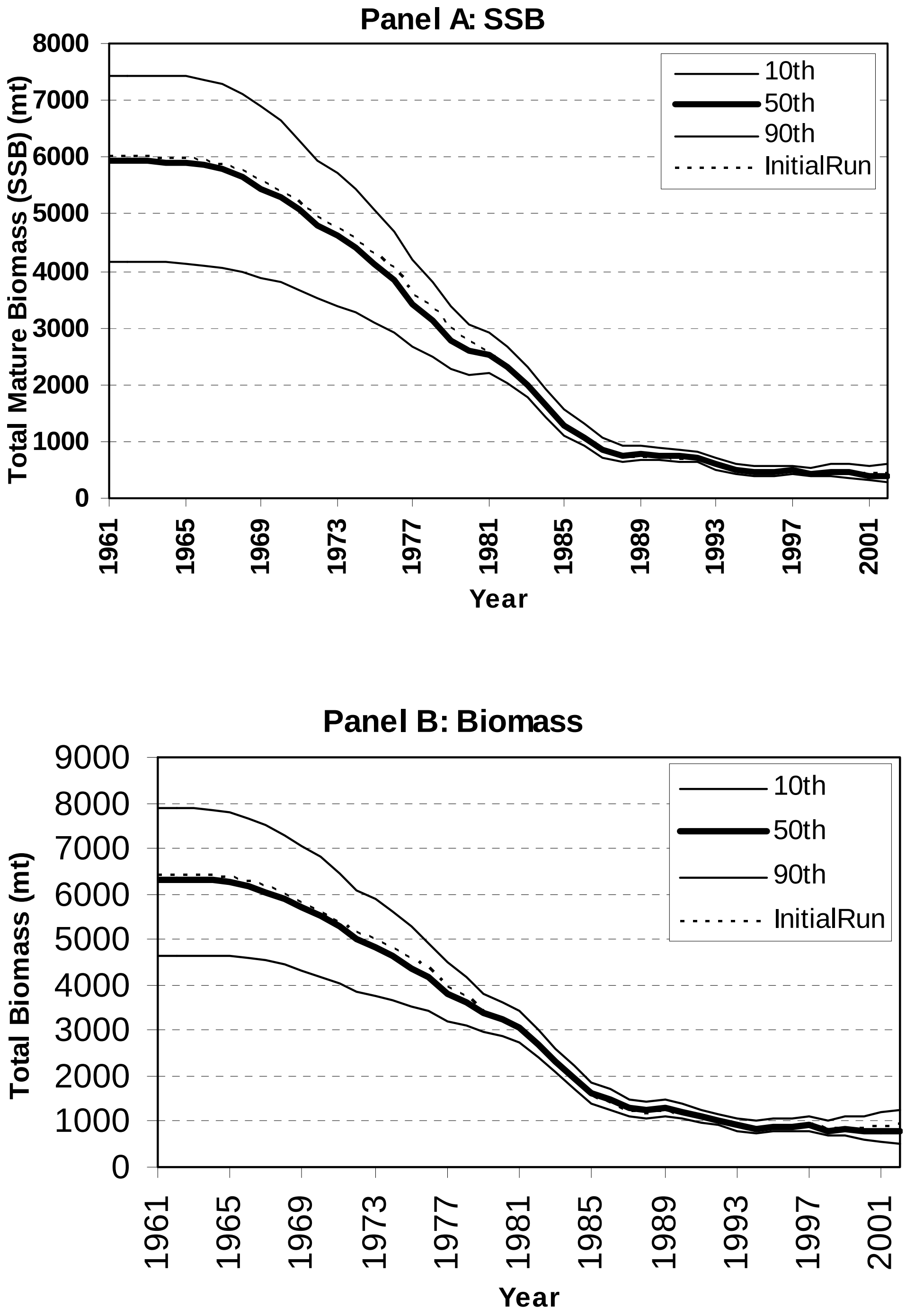


Figure **47**: The median, 10^{th}, and 90^{th} percentiles of the Monte Carlo/bootstrap runs (n=1470) and initial run estimates of total mature biomass (mt) (a) and total biomass (mt) (b).

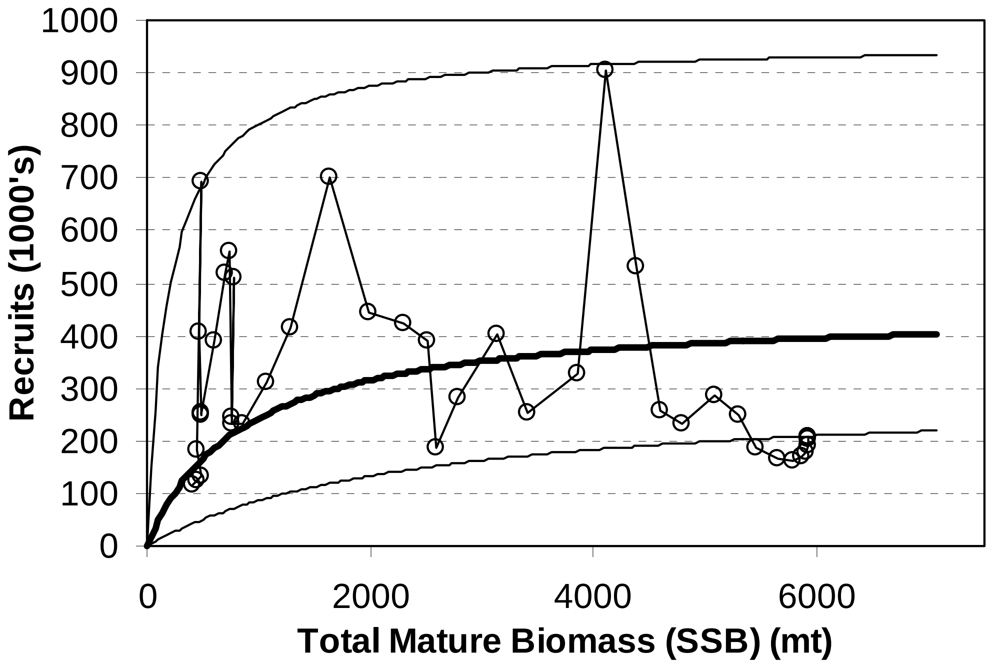


Figure 48: The median (heavy line), 10th (lower thin line) and 90th (upper thin line) percentiles of the Monte Carlo/bootstrap runs (n=1470) stock and recruitment relationship with median point estimates (circles).

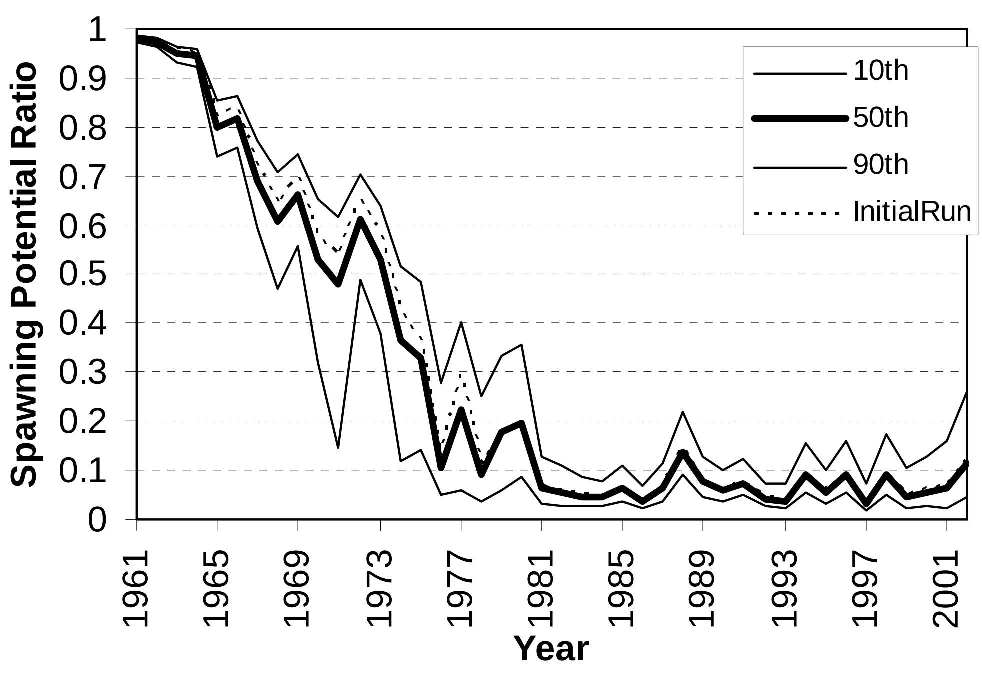


Figure **49**: The median, 10th, and 90th percentiles of the Monte Carlo/bootstrap runs (n=1470) and initial run estimates of the annual static spawning potential ratio.

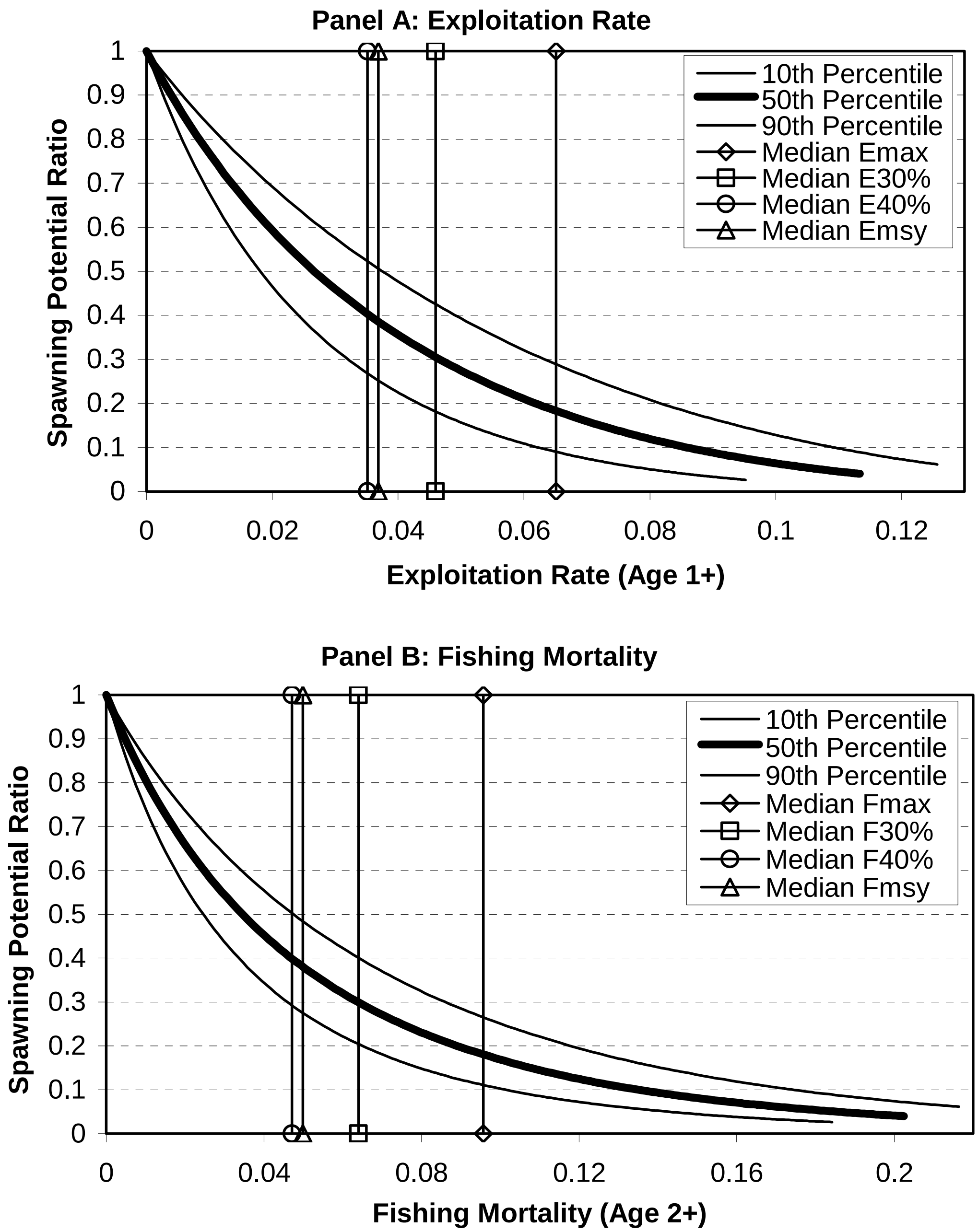


Figure **50**: The median, 10th, and 90th percentiles of the Monte Carlo/bootstrap runs (n=1470) and initial run estimates of the spawning potential ratio for age 1+ exploitation rate (a) and age 2+ fishing mortality (b).

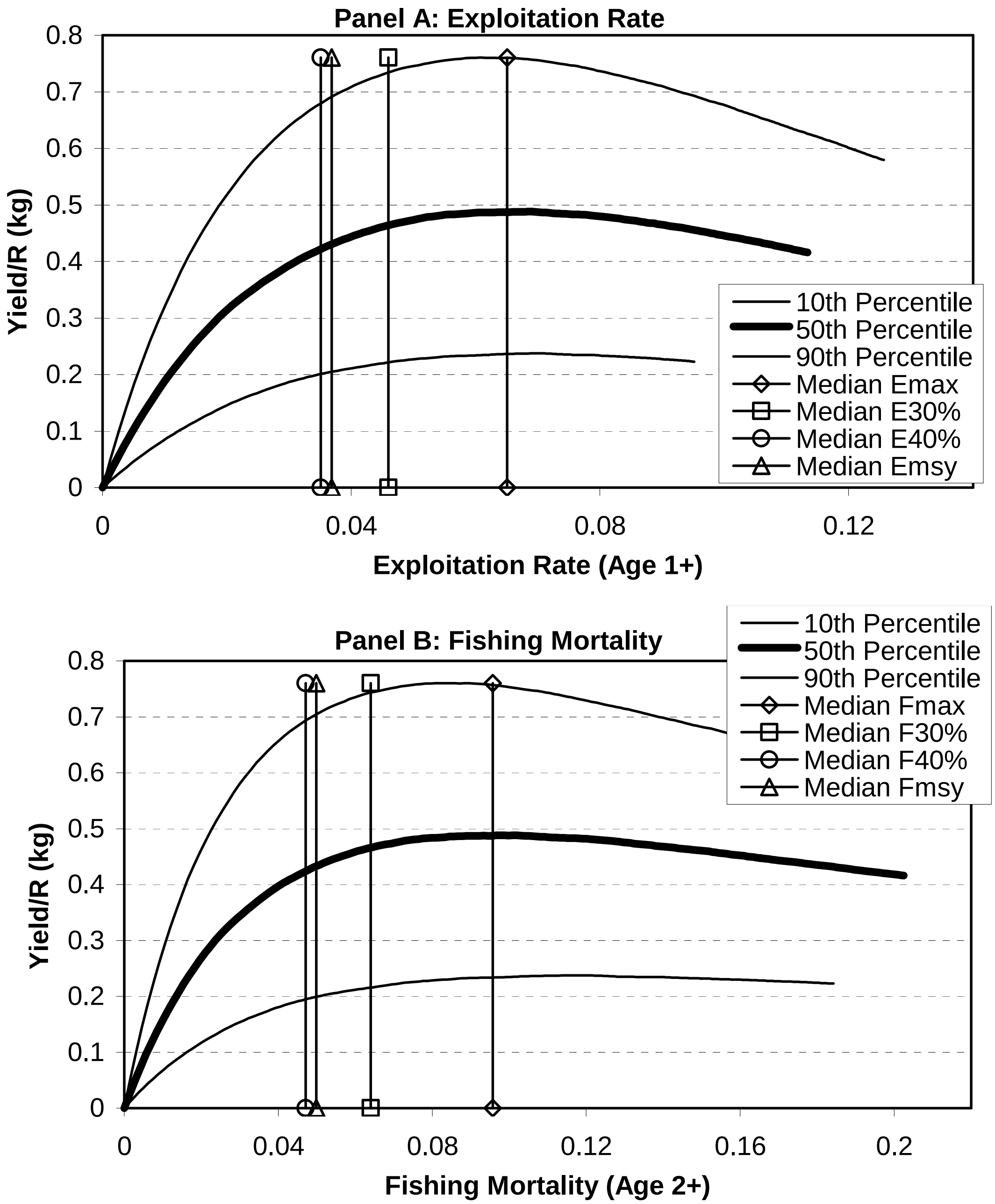


Figure **51**: The median, 10th, and 90th percentiles of the Monte Carlo/bootstrap runs (n=1470) and initial run estimates of the yield-per-recruit (kg) for age 1+ exploitation rate (a) and age 2+ fishing mortality (b).

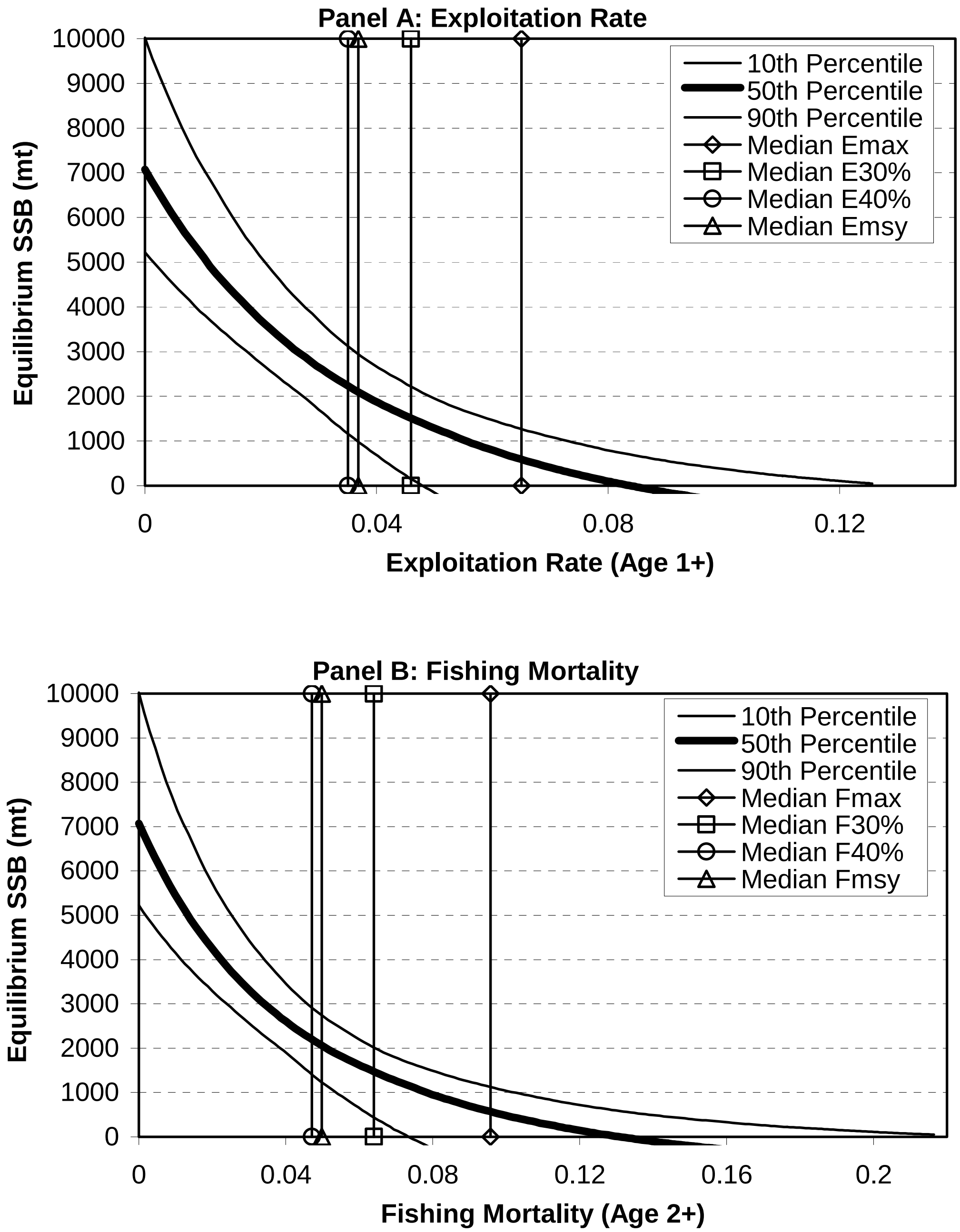


Figure **52**: The median, 10th, and 90th percentiles of the Monte Carlo/bootstrap runs (n=1470) and initial run estimates of the equilibrium total mature biomass (*SSB*) (mt) for age 1+ exploitation rate (a) and age 2+ fishing mortality (b).

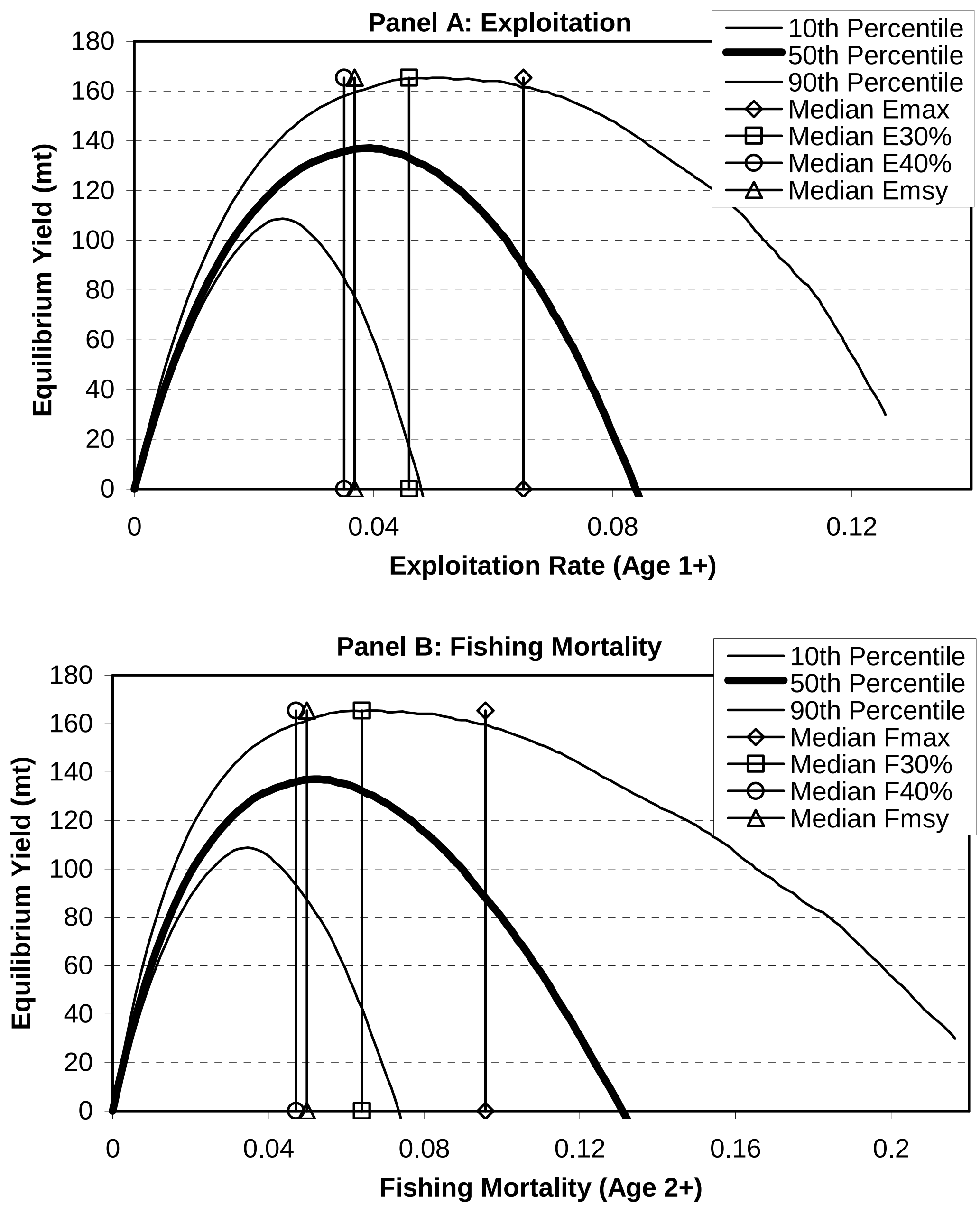


Figure **53**: The median, 10^{th}, and 90^{th} percentiles of the Monte Carlo/bootstrap runs (n=1470) and initial run estimates of the equilibrium yield (mt) for age 1+ exploitation rate (a) and age 2+ fishing mortality (b).

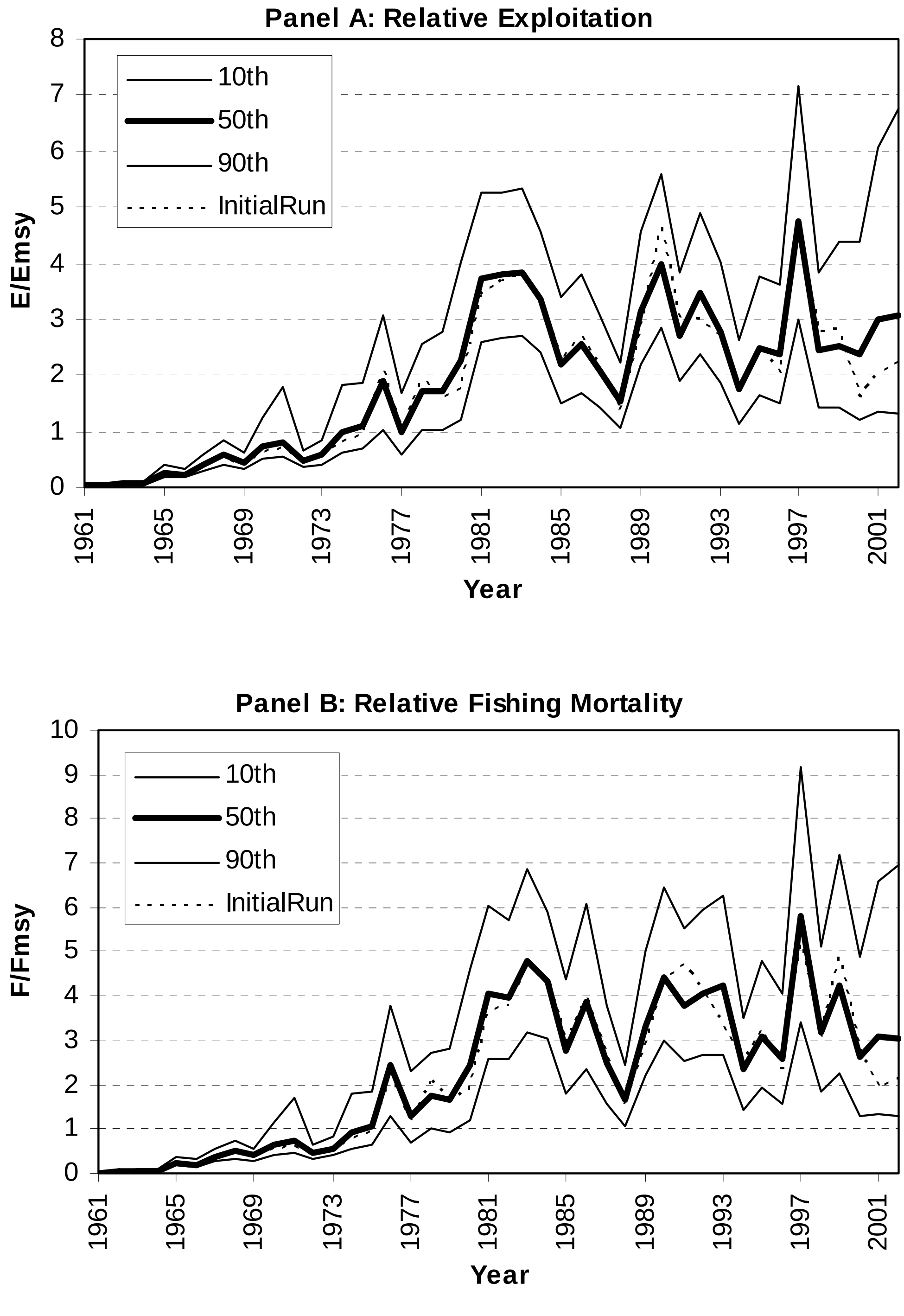


Figure **54**: The median, 10^{th}, and 90^{th} percentiles of the Monte Carlo/bootstrap runs (n=1470) and initial run annual estimates of the age 1+ exploitation rate (*E*) (a) and age 2+ fishing mortality (*F*) (b) relative to the values at maximum sustainable yield (MSY).

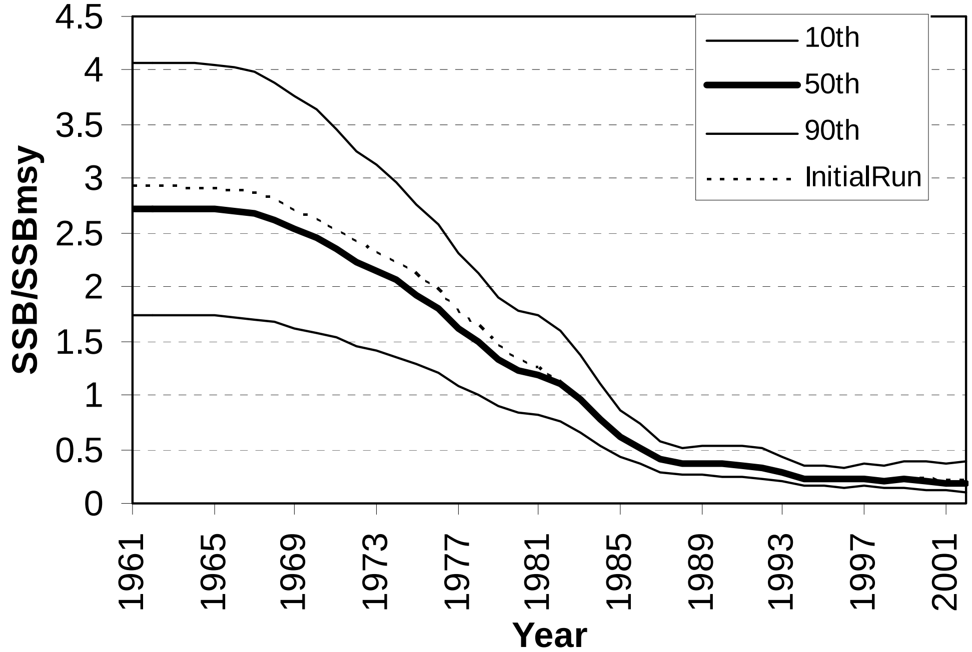


Figure **55**: The median, 10th, and 90th percentiles of the Monte Carlo/bootstrap runs (n=1470) and initial run annual estimates of total mature biomass (*SSB*) (mt) relative to the value at maximum sustainable yield (*SSB*msy).

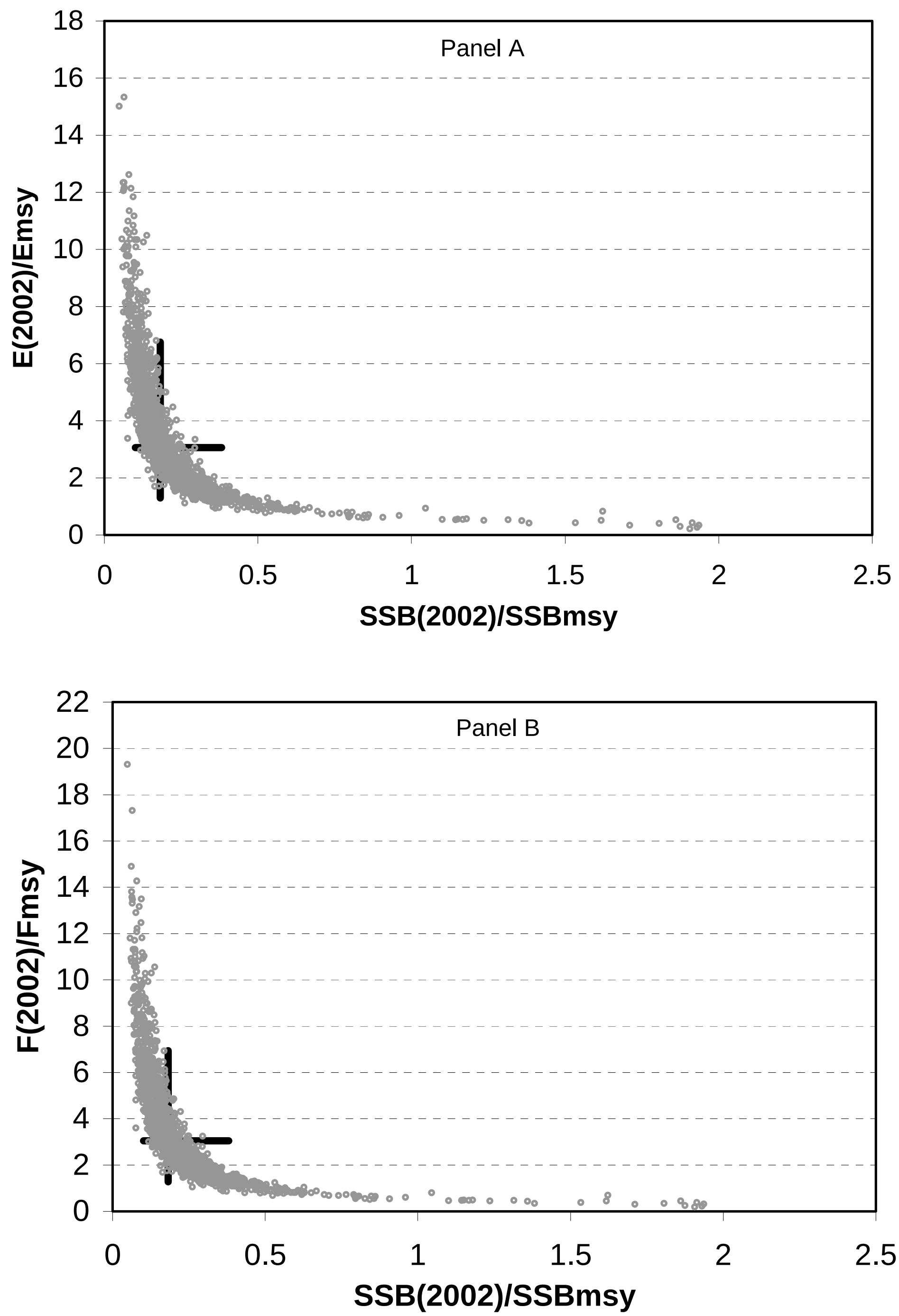


Figure 56: The Monte Carlo/bootstrap runs (n=1470) of the age 1+ exploitation rate (*E*) (a) and age 2+ fishing mortality (*F*) (b) in 2002 relative to the values at maximum sustainable yield (MSY).

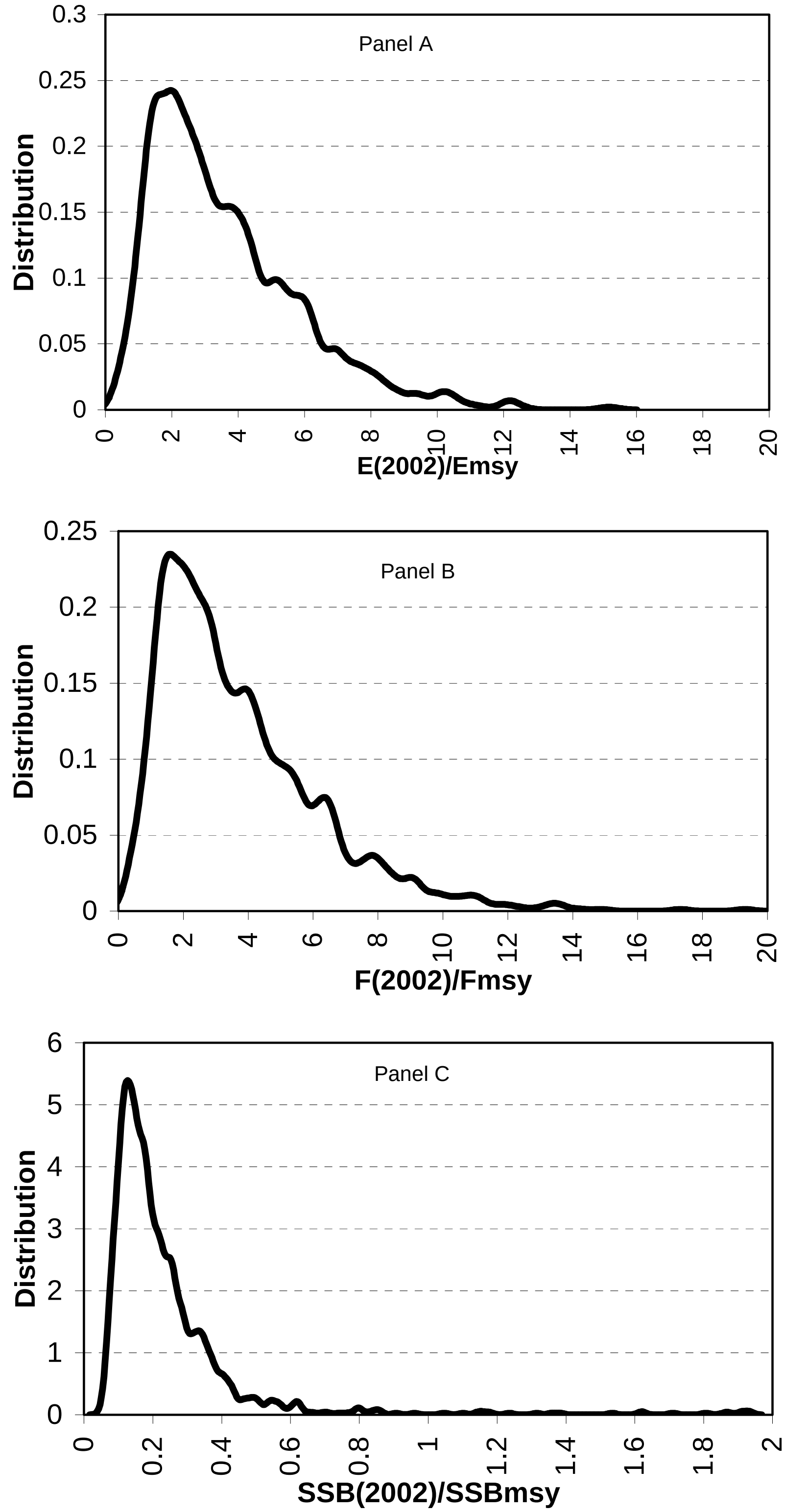


Figure **57**: Distributions of the Monte Carlo/bootstrap runs (n=1470) for age 1+ exploitation rate (*E*) (a), age 2+ fishing mortality (*F*) (b), and total mature biomass (*SSB*) (mt) in 2002 relative to the values at maximum sustainable yield (MSY).

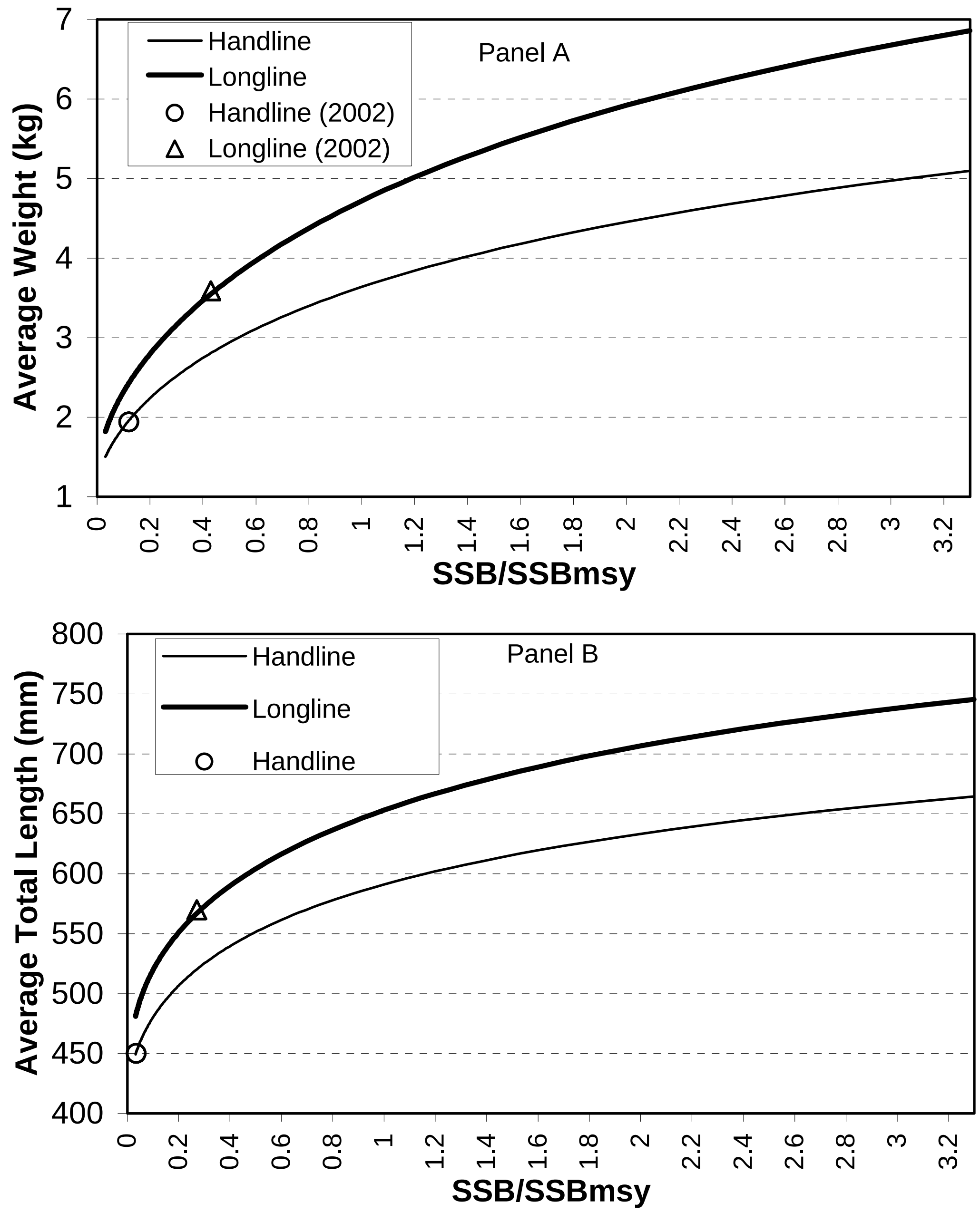


Figure **58**: The average weight (kg) (a) and total length (mm) (b) of landed fish from the commercial handline and longline fisheries relative to stock status (SSB/SSBmsy, where SSB is total mature biomass) for snowy grouper using the selectivity estimates from the initial run model and assuming an equilibrium age-structure.

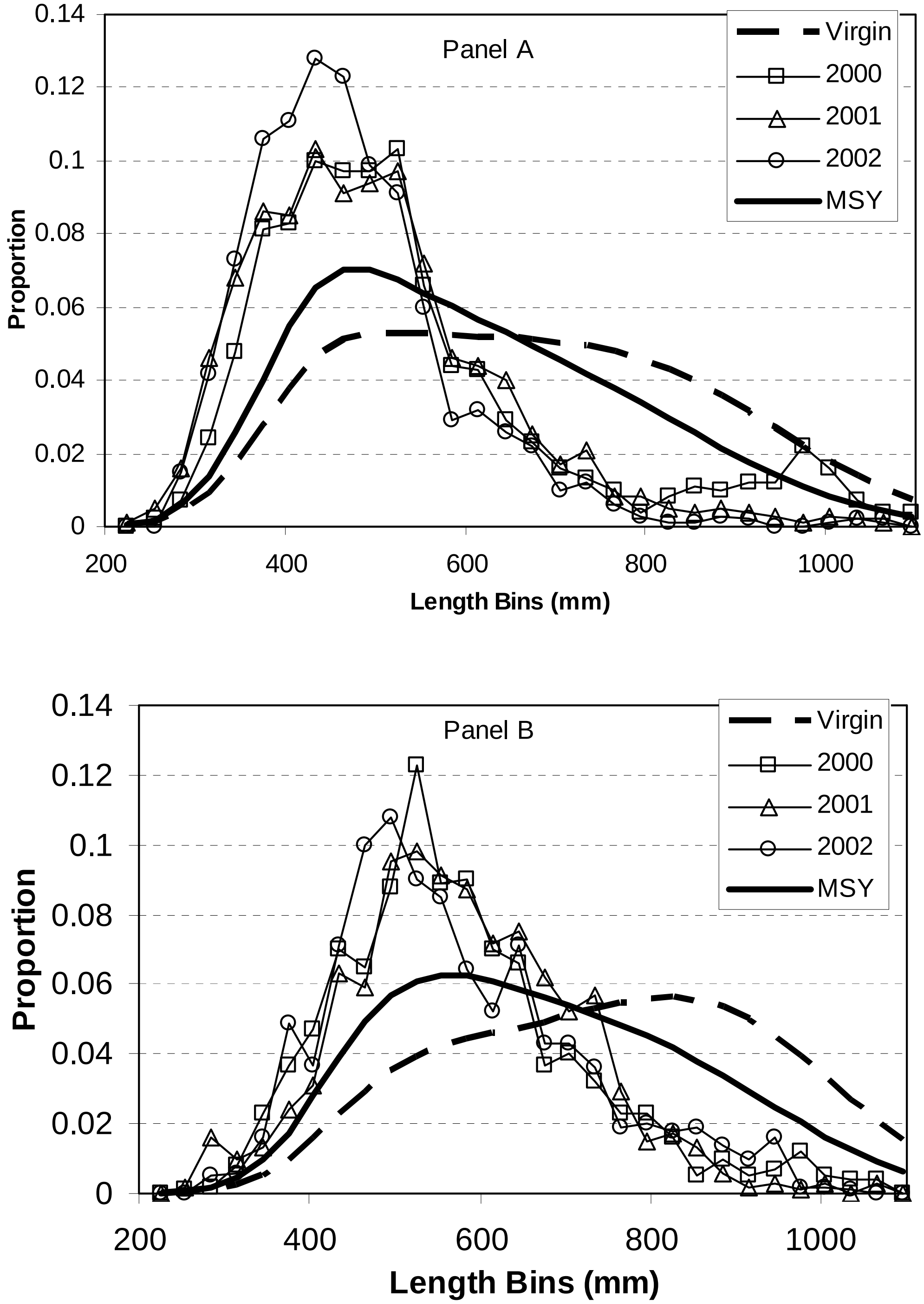
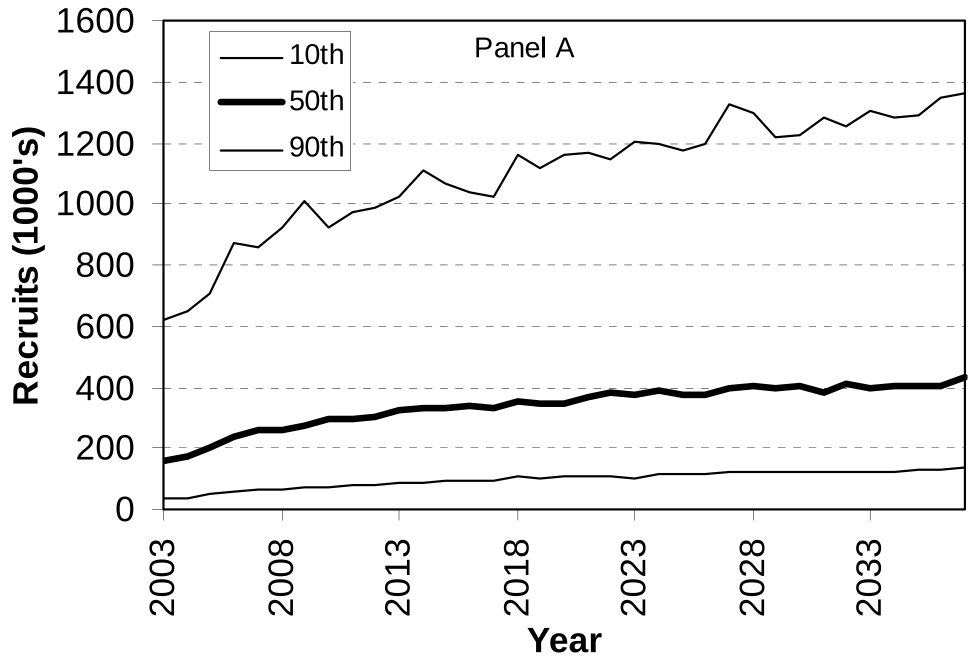


Figure **59**: The hypothetical virgin, MSY, and observed (years 2000-2002) length compositions of landed fish from the commercial handline (a) and longline (b) fisheries for snowy grouper using the selectivity estimates from the initial run model and assuming an equilibrium age-structure.



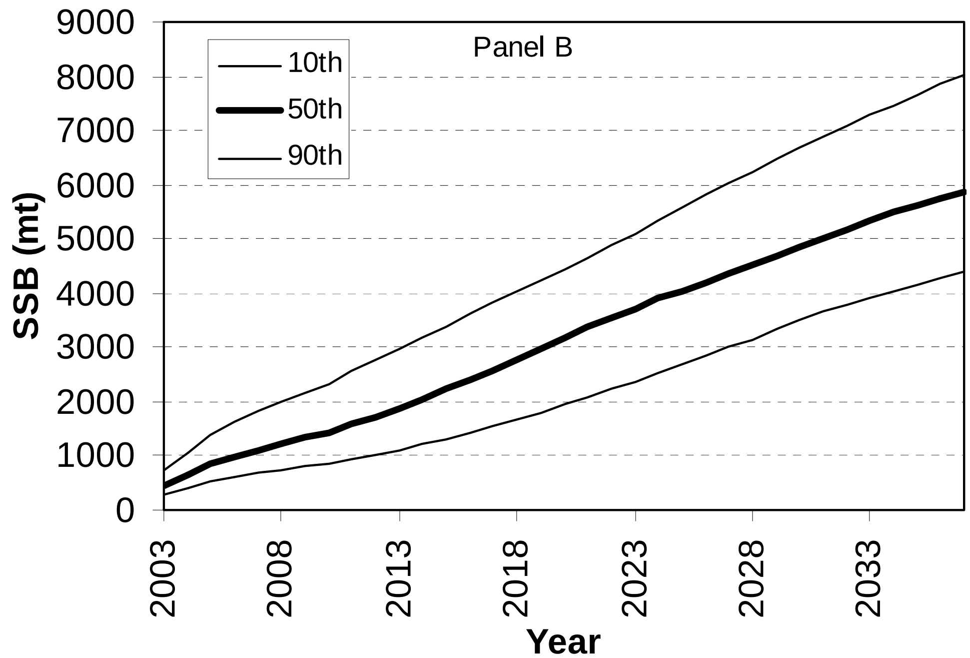


Figure **60**: The median, 10th, and 90th percentiles of the Monte Carlo/bootstrap runs (n=1470) future projections for age 0 recruitment (1000's) (a) and total mature biomass (*SSB*) (mt) (b).

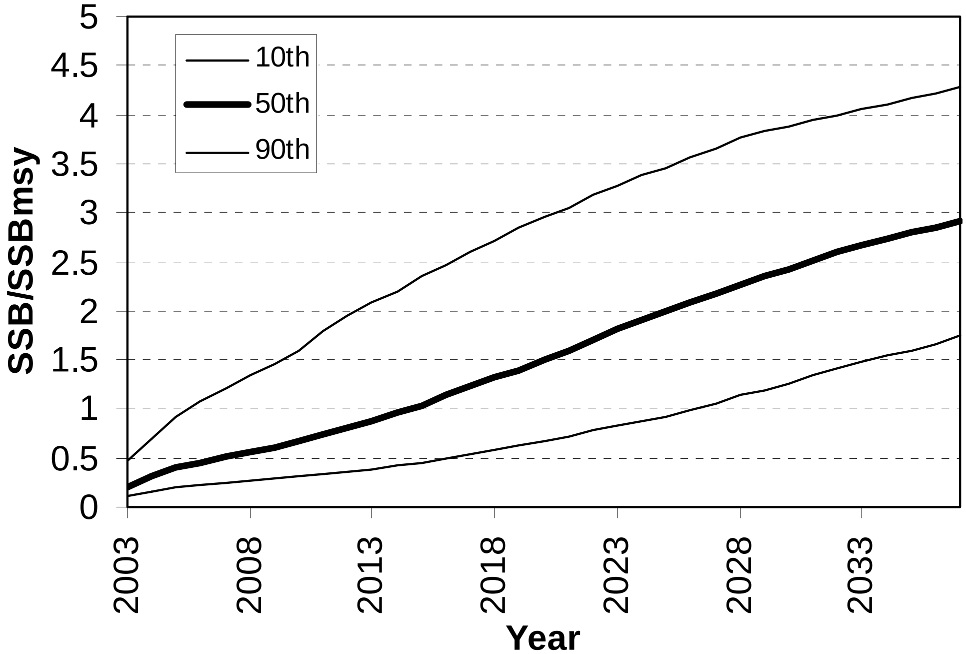


Figure **61**: The median, 10th, and 90th percentiles of the Monte Carlo/bootstrap runs (n=1470) future projections for total mature biomass (*SSB*) (mt) relative to the estimate at maximum sustainable yield (*SSB*msy).

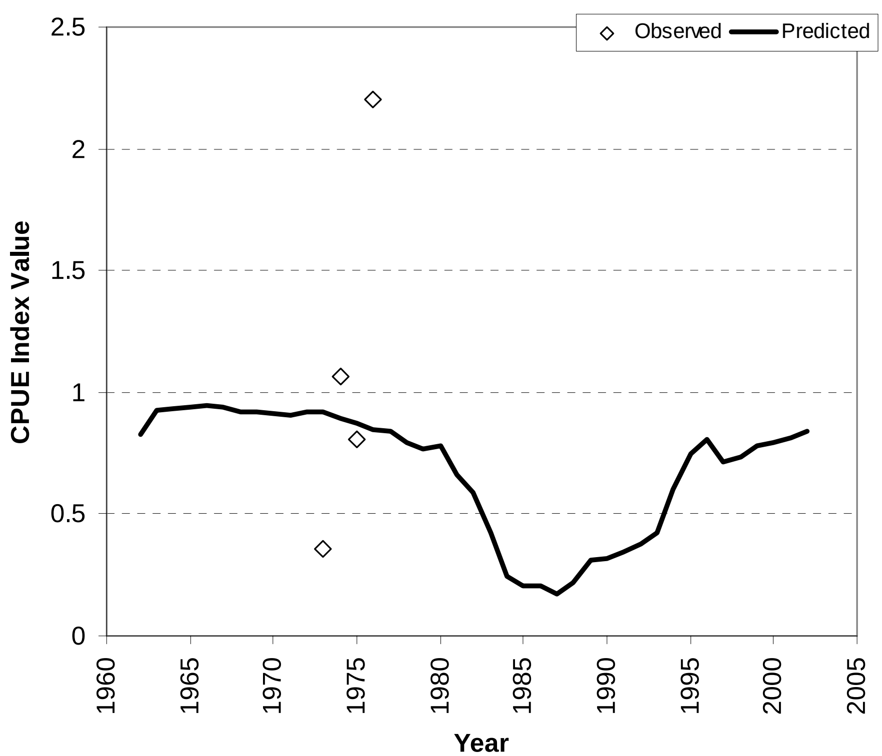


Figure **62**: Fit of production model to headboat index (early years).

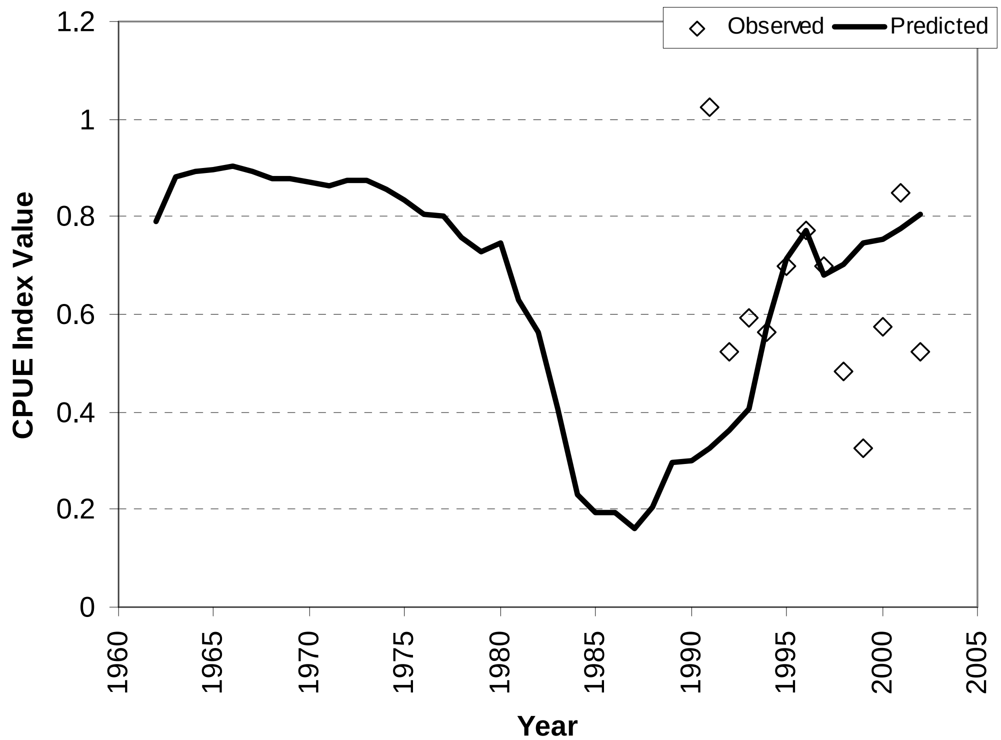


Figure **63**: Fit of production model to headboat index (late years).

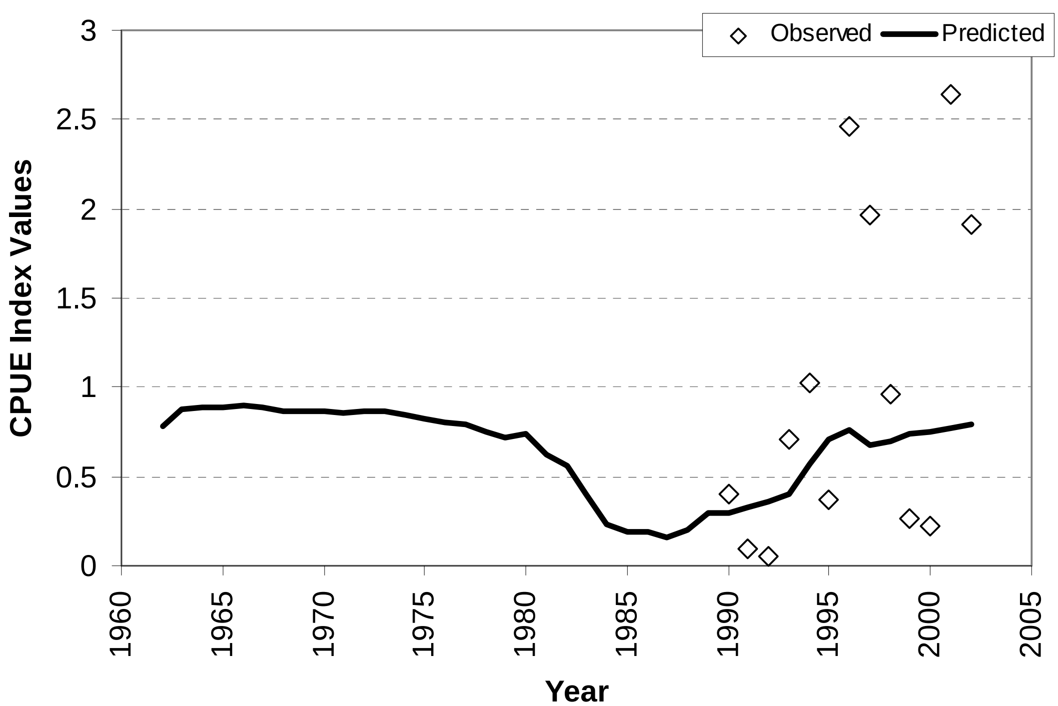


Figure **64**: Fit of production model to MARMAP chevron-trap abundance index.

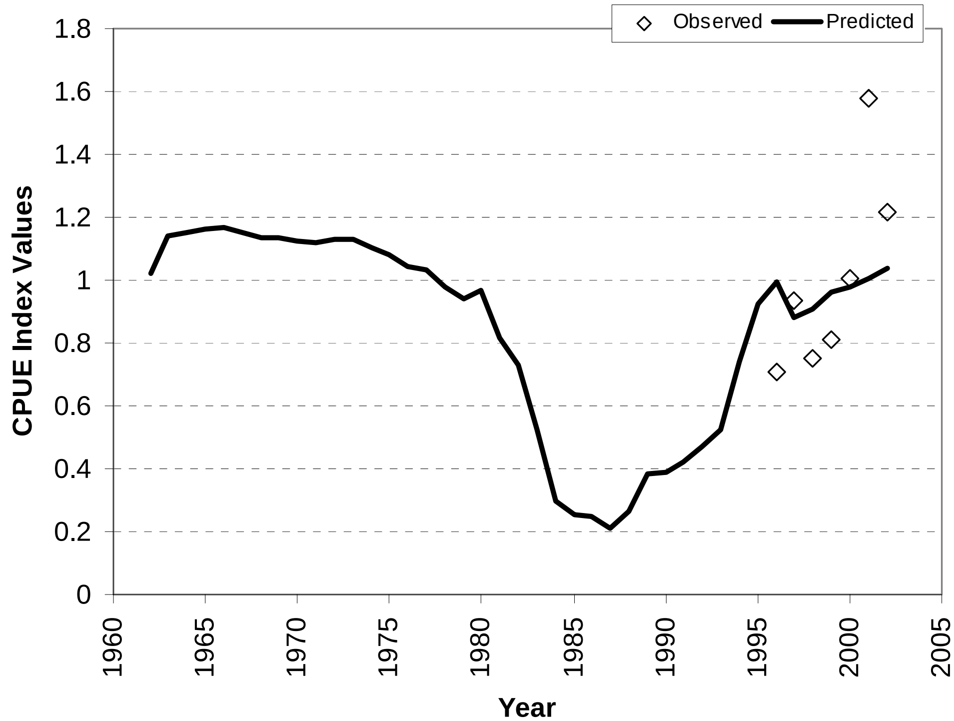


Figure **65**: Fit of production model to MARMAP vertical longline abundance index.

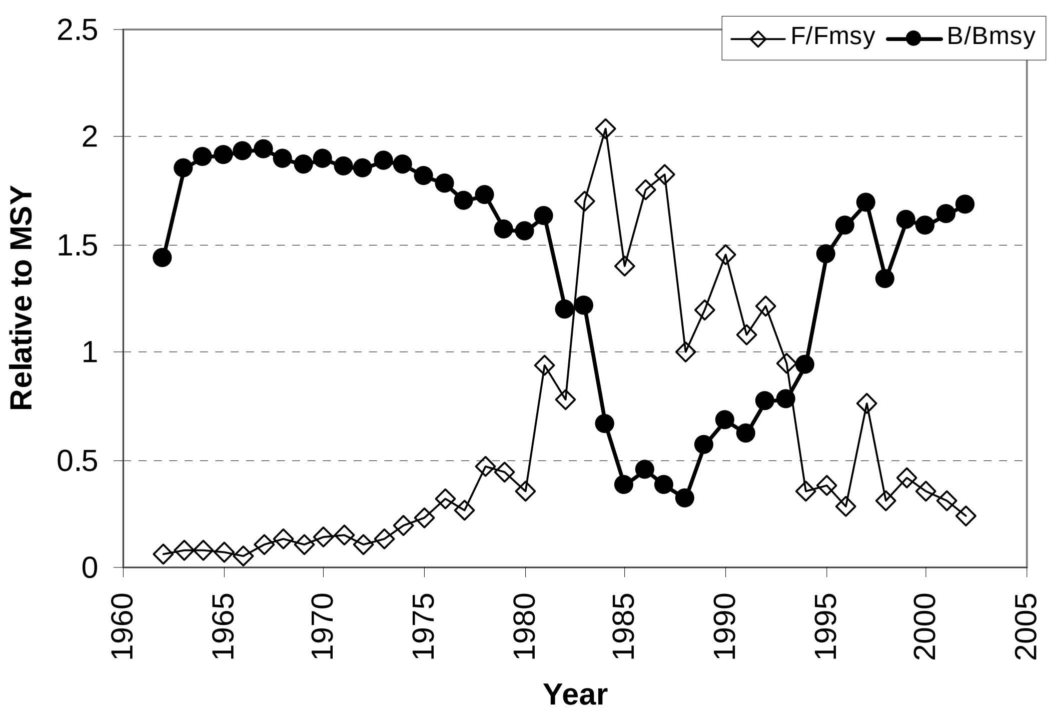


Figure **66**: Estimates of relative biomass (filled circles) and relative fishing mortality rate (open diamonds) from production model.

8. Appendices

8.1 Appendix I. SEDAR4 South Atlantic Deepwater Snapper Grouper Document List

#	Title	Author(s)
SEDAR4-DW-01	Indices of Abundance from Commercial Logbook Data: South Atlantic stocks	Shertzer, K.; McCarthy, K.
SEDAR4-DW-02	MRFSS Landings and Length Data Summary for the South Atlantic	Vaughan, D. S.
SEDAR4-DW-03	General Canvass Landings Statistics for the South Atlantic Region	Poffenberger, J.
SEDAR4-DW-12	Discard Estimates for the South Atlantic Region.	Poffenberger, J.
SEDAR4-DW-13	Size Frequency Data from the Trip Interview Program, South Atlantic Region	Poffenberger, J.
SEDAR4-DW-16	Preliminary analysis of some deepwater species in the South Atlantic headboat survey data.	Williams, E.; Dixon, B.
SEDAR4-DW-17	Age, growth and reproductive biology of the blueline tilefish, *Caulolatilus microps*, along the southeastern coast of the United States, 1982-99.	Harris, P. J.; Wyanski, D.M.; Powers, P.T.
SEDAR4-DW-18	Age, growth and reproduction of tilefish, Lopholatilus chamaeleonticeps, along the southeast Atlantic coast of the United States, 1980-87 and 1996-98.	Palmer, S.M.; Harris, P.J.; Powers, P. T.
SEDAR4-DW-19	Deep-water species report. South Carolina and Georgia.	Low, B.
SEDAR4-DW-20	South Atlantic Snapper-Grouper Regulatory Overview	Carmichael, J.
SEDAR4-DW-21	Summary of MARMAP sampling	Anon.
SEDAR4-DW-22	Blueline tilefish life history; How to assess reef fish stocks: Excerpts from NMFS-SEFC-80	various
SEDAR4-DW-25	Yellowedge Grouper age-length key	Bullock & Godcharles
SEDAR4-DW-26	Estimating catches and fishing effort of the southeast united states headboat fleet, 1972-1982	Dixon & Huntsman
SEDAR4-DW-27	Trends in Catch Data and Estimated Static SPR Values for Fifteen Species of Reef Fish Landed along the Southeastern United States, February 1998.	Potts, Burton & Manooch
SEDAR4-DW-28	Trends in Catch Data and Estimated Static SPR Values for Fifteen Species of Reef Fish Landed along the Southeastern United States, February 2001.	Potts & Brennan
SEDAR4-DW-29	Description of the Southeast Fisheries Science Center's Logbook Program for Coastal Fisheries	Poffenberger, J.

8.2 Appendix II. AD Model Builder code for snowy grouper statistical catch-at-age model.

```
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--
//
//  Snowy Grouper Assessment Model
//
//  Erik H. Williams, NMFS, Beaufort Lab
//  (erik.williams@noaa.gov)
//  Last Modified: May 28, 2004 (EHW)
//
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--

DATA_SECTION
//--Monte Carlo stuff-------------------------------------------------------------------------------------------------------
init_int MCcount;                                            //counter for Monte Carlo runs, if 0 then R output file created instead
!!CLASS ofstream MCreport1("montecarlofile1.dat",ios::app);  //create file for Monte Carlo output
!!CLASS ofstream MCreport2("montecarlofile2.dat",ios::app);  //create file for Monte Carlo output
!!CLASS ofstream MCreport3("montecarlofile3.dat",ios::app);  //create file for Monte Carlo output
!!CLASS ofstream MCreport4("montecarlofile4.dat",ios::app);  //create file for Monte Carlo output

//--model set up stuff------------------------------------------------------------------------------------------------------
init_int styr;                     // Starting year of the data
init_int endyr;                    // Ending year of the data
init_int nages;                    // Number of ages
init_ivector agebins(1,nages);     // Vector of ages for age bins
init_int nlenbins;                 // Number of length bins
init_ivector lenbins(1,nlenbins);  // Vector of length bin midpoints
int nyrs;                          // Number of years of data
int styr_eq;                       // Starting year for recruitment estimates
//this section MUST BE INDENTED!!!
 LOCAL_CALCS
   nyrs=endyr-styr+1;
   styr_eq=styr-1;
 END_CALCS

!!cout << "lenbins=" << lenbins << endl;

//--observed landings data (mt)----------------------------------------------------------------------------------------------
init_int L_handline_styr;                                      //starting year of data
init_int L_handline_endyr;                                     //ending year of data
init_vector L_handline_obs(L_handline_styr,L_handline_endyr);  //vector of observed landings by year
init_vector L_handline_cv(L_handline_styr,L_handline_endyr);   //vector of CV of landings by year

init_int L_longline_styr;                                      //starting year of data
init_int L_longline_endyr;                                     //ending year of data
init_vector L_longline_obs(L_longline_styr,L_longline_endyr);  //vector of observed landings by year
init_vector L_longline_cv(L_longline_styr,L_longline_endyr);   //vector of CV of landings by year
```

```
!!cout << "L_longline_cv=" << L_longline_cv << endl;

//--observed catch data (1000s)------------------------------------------------------------------------------------------
init_int C_headboat_styr;                                  //starting year of data
init_int C_headboat_endyr;                                 //ending year of data
init_vector C_headboat_obs(C_headboat_styr,C_headboat_endyr);  //vector of observed landings by year
init_vector C_headboat_cv(C_headboat_styr,C_headboat_endyr);   //vector of CV of landings by year

init_int C_MRFSS_styr;                                     //starting year of data
init_int C_MRFSS_endyr;                                    //ending year of data
init_vector C_MRFSS_obs(C_MRFSS_styr,C_MRFSS_endyr);           //vector of observed landings by year
init_vector C_MRFSS_cv(C_MRFSS_styr,C_MRFSS_endyr);            //vector of CV of landings by year

!!cout << "C_MRFSS_cv=" << C_MRFSS_cv << endl;

//--observed length composition data------------------------------------------------------------------------------------------
init_int lc_handline_styr;                                              //starting year of data
init_int lc_handline_endyr;                                             //ending year of data
init_vector lc_handline_ss(lc_handline_styr,lc_handline_endyr);              //vector of samples sizes by year
init_matrix lc_handline_obs(lc_handline_styr,lc_handline_endyr,1,nlenbins);  //matrix of observed data, year by length

!!cout << "lc_handline_ss=" << lc_handline_ss << endl;

init_int lc_longline_styr;                                              //starting year of data
init_int lc_longline_endyr;                                             //ending year of data
init_vector lc_longline_ss(lc_longline_styr,lc_longline_endyr);              //vector of samples sizes by year
init_matrix lc_longline_obs(lc_longline_styr,lc_longline_endyr,1,nlenbins);  //matrix of observed data, year by length

!!cout << "lc_longline_ss=" << lc_longline_ss << endl;

init_int lc_headboat_styr;                                              //starting year of data
init_int lc_headboat_endyr;                                             //ending year of data
init_vector lc_headboat_ss(lc_headboat_styr,lc_headboat_endyr);              //vector of samples sizes by year
init_matrix lc_headboat_obs(lc_headboat_styr,lc_headboat_endyr,1,nlenbins);  //matrix of observed data, year by length

!!cout << "lc_headboat_ss=" << lc_headboat_ss << endl;

init_int lc_MMtrap_nyrs;                              //starting year of data
init_ivector lc_MMtrap_yrs(1,lc_MMtrap_nyrs);            //ending year of data
init_vector lc_MMtrap_ss(1,lc_MMtrap_nyrs);              //vector of samples sizes by year
init_matrix lc_MMtrap_obs(1,lc_MMtrap_nyrs,1,nlenbins);  //matrix of observed data, year by length

!!cout << "lc_MMtrap_ss=" << lc_MMtrap_ss << endl;

init_int lc_MMlongline_styr;                                                  //starting year of data
init_int lc_MMlongline_endyr;                                                 //ending year of data
init_vector lc_MMlongline_ss(lc_MMlongline_styr,lc_MMlongline_endyr);              //vector of samples sizes by year
init_matrix lc_MMlongline_obs(lc_MMlongline_styr,lc_MMlongline_endyr,1,nlenbins);  //matrix of observed data, year by length

!!cout << "lc_MMlongline_ss=" << lc_MMlongline_ss << endl;
```

```
//--observed age composition data------------------------------------------------------------------------------------------------
init_int ac_handline_nyrs;                               //number of years of data
init_ivector ac_handline_yrs(1,ac_handline_nyrs);        //vector of years of data
init_vector ac_handline_ss(1,ac_handline_nyrs);          //vector of sample sizes by year
init_matrix ac_handline_obs(1,ac_handline_nyrs,1,nages); //matrix of observed data, year by age
!!cout << "ac_handline_ss=" << ac_handline_ss << endl;
!!cout << "ac_handline_obs=" << ac_handline_obs << endl;
init_int ac_longline_nyrs;                               //number of years of data
init_ivector ac_longline_yrs(1,ac_longline_nyrs);        //vector of years of data
init_vector ac_longline_ss(1,ac_longline_nyrs);          //vector of sample sizes by year
init_matrix ac_longline_obs(1,ac_longline_nyrs,1,nages); //matrix of observed data, year by age
!!cout << "ac_longline_ss=" << ac_longline_ss << endl;
init_int ac_headboat_nyrs;                               //number of years of data
init_ivector ac_headboat_yrs(1,ac_headboat_nyrs);        //vector of years of data
init_vector ac_headboat_ss(1,ac_headboat_nyrs);          //vector of sample sizes by year
init_matrix ac_headboat_obs(1,ac_headboat_nyrs,1,nages); //matrix of observed data, year by age

!!cout << "ac_headboat_ss=" << ac_headboat_ss << endl;

//--observed abundance indices------------------------------------------------------------------------------------------------
init_int I_headboat_styr;                                           //starting year of data
init_int I_headboat_endyr;                                          //ending year of data
init_vector I_headboat_obs(I_headboat_styr,I_headboat_endyr);       //vector of observed index by year
init_vector I_headboat_cv(I_headboat_styr,I_headboat_endyr);        //vector of CV of index by year

init_int I_MMtrap_styr;                                             //starting year of data
init_int I_MMtrap_endyr;                                            //ending year of data
init_vector I_MMtrap_obs(I_MMtrap_styr,I_MMtrap_endyr);             //vector of observed index by year
init_vector I_MMtrap_cv(I_MMtrap_styr,I_MMtrap_endyr);              //vector of CV of index by year

!!cout << "I_MMtrap_cv=" << I_MMtrap_cv << endl;

init_int I_MMlongline_styr;                                         //starting year of data
init_int I_MMlongline_endyr;                                        //ending year of data
init_vector I_MMlongline_obs(I_MMlongline_styr,I_MMlongline_endyr); //vector of observed index by year
init_vector I_MMlongline_cv(I_MMlongline_styr,I_MMlongline_endyr);  //vector of CV of index by year

init_int I_logbook_styr;                                            //starting year of data
init_int I_logbook_endyr;                                           //ending year of data
init_vector I_logbook_obs(I_logbook_styr,I_logbook_endyr);          //vector of observed index by year
init_vector I_logbook_cv(I_logbook_styr,I_logbook_endyr);           //vector of CV of index by year

!!cout << "I_logbook_cv=" << I_logbook_cv << endl;

//--selectivity parameter values----------------------------------------------------------------------------------------------
//-element 1 = slope for logistic
//-element 2 = 50% for logistic
//-element 3 = slope for descending part of double logistic
//-element 4 = 50% for descending part of double logistic
init_vector set_sel_handline(1,4);    //parameter values for selectivity function
init_vector set_sel_longline(1,4);    //parameter values for selectivity function
```

```
init_vector set_sel_headboat(1,6);    //parameter values for selectivity function
init_vector set_sel_MRFSS(1,4);       //parameter values for selectivity function
init_vector set_sel_MMtrap(1,4);      //parameter values for selectivity function
init_vector set_sel_MMlongline(1,4);  //parameter values for selectivity function

//--biologicals----------------------------------------------------------------------------------------------------------
init_number set_Linf;              // vonBertalanffy asymptotic length (mm)
init_number set_K;                 // Browdy growth coefficient
init_number set_t0;                // vonBertalanffy parameter, age at length=0
init_number set_len_CV;            // Coefficient of variation of length at age
init_vector set_wgt_age(1,nages);  // Weight-at-age (kg)
init_vector set_mat_age(1,nages);  // Proportion females mature at age
init_vector set_sex_age(1,nages);  // Proportion female at age
init_vector set_M_age(1,nages);    // Natural mortality at age

//--stock-recruit stuff--------------------------------------------------------------------------------------------------
init_number SRswitch;                   //Stock-recruit function (1=Bev-Holt,2=Ricker)
init_number set_logR0;                  //Virgin log-recruitment
init_number set_steep;                  //Stock-Recruit steepness (0.2-1.0)
init_number set_S1dS0;                  //Reproductive capacity relative to virgin in first year
init_number set_SenddS0;                //Reproductive capacity relative to virgin in last year
init_vector set_logR_dev(styr,endyr);   //Annual log-recruitment deviations (nyrs+1)

!!cout << "S1dS0=" << set_S1dS0 << endl;

//--fishing mortality----------------------------------------------------------------------------------------------------
init_number set_mulogF_handline;                                  //Mean F (log)
init_vector set_logF_handline(L_handline_styr,L_handline_endyr);  //F deviations (log) by year
init_number set_mulogF_longline;                                  //Mean F (log)
init_vector set_logF_longline(L_longline_styr,L_longline_endyr);  //F deviations (log) by year
init_number set_mulogF_headboat;                                  //Mean F (log)
init_vector set_logF_headboat(C_headboat_styr,C_headboat_endyr);  //F deviations (log) by year
init_number set_mulogF_MRFSS;                                     //Mean F (log)
init_vector set_logF_MRFSS(C_MRFSS_styr,C_MRFSS_endyr);           //F deviations (log) by year

!!cout << "muF_handline=" << set_mulogF_handline;
!!cout << " muF_longline=" << set_mulogF_longline;
!!cout << " muF_headboat=" << set_mulogF_headboat;
!!cout << " muF_MRFSS=" << set_mulogF_MRFSS << endl;

//--index catchability---------------------------------------------------------------------------------------------------
init_number set_logq_headboat;    //catchability coefficient (log) for the headboat index
init_number set_logq_MMtrap;      //catchability coefficient (log) for the MARMAP trap gear index
init_number set_logq_MMlongline;  //catchability coefficient (log) for the MARMAP longline gear index
init_number set_logq_logbook;     //catchability coefficient (log) for the logbook index

!!cout << "q_headboat=" << set_logq_headboat << " q_MMtrap=" << set_logq_MMtrap;
!!cout << " q_MMlongline=" << set_logq_MMlongline << " q_logbook=" << set_logq_logbook << endl;

//--weights for likelihood components-------------------------------------------------------------------------------
init_number set_w_L;
```

```
init_number set_w_lc;
init_number set_w_ac;
init_number set_w_I;
init_number set_w_R;
init_number set_w_S1;
init_number set_w_Send;

//--future projection set-up----------------------------------------------------------------------------------------------------
init_int nyrs_fut;      //number of years for future projections
init_int project_type;  //switch for stochastic (1) versus deterministic (2) recruitment projections
init_int seed;          //random number seed for stochastic projections
int styr_fut;           //starting year of future projections
int endyr_fut;          //ending year of future projections
 LOCAL_CALCS
   styr_fut=endyr+1;
   endyr_fut=endyr+nyrs_fut;
 END_CALCS

!!cout << "seed=" << seed << endl;

//--indices for year(y), age(a), and length(l)-----------------------------------------------------------------------------------
int y;
int a;
int l;

PARAMETER_SECTION
//--parameters/fixed variables which have values read in to data section---------------------------------------------------------
//--[init_] prefix declares a parameter to be estimated--------------------------------------------------------------------------
init_bounded_number par_sel1_handline(0.1,10,2);
init_bounded_number par_sel2_handline(1,10,2);
init_bounded_number par_sel3_handline(0.1,10,2);
init_bounded_number par_sel4_handline(0,20,2);
init_bounded_number par_sel1_longline(0.1,10,2);
init_bounded_number par_sel2_longline(1,10,2);
number par_sel3_longline;
number par_sel4_longline;
init_bounded_number par_sel1_headboat(0.1,10,2);
init_bounded_number par_sel2_headboat(1,5,2);
init_bounded_number par_sel3_headboat(0.1,10,2);
init_bounded_number par_sel4_headboat(1,20,2);
init_bounded_number par_sel5_headboat(-1,0,2);  //slope of changing sel2 parameter
init_bounded_number par_sel6_headboat(-1,-0.3,2);  //slope of changing sel4 parameter
number par_sel1_MRFSS;
number par_sel2_MRFSS;
number par_sel3_MRFSS;
number par_sel4_MRFSS;
init_bounded_number par_sel1_MMtrap(0.1,10,2);
init_bounded_number par_sel2_MMtrap(1,10,2);
init_bounded_number par_sel3_MMtrap(0.1,10,2);
init_bounded_number par_sel4_MMtrap(1,20,2);
init_bounded_number par_sel1_MMlongline(0.1,10,2);
```

```
init_bounded_number par_sel2_MMlongline(1,10,2);
init_bounded_number par_sel3_MMlongline(0.1,10,2);
init_bounded_number par_sel4_MMlongline(1,20,2);
number par_Linf;
number par_K;
number par_t0;
number par_len_CV;
vector wgt_age(1,nages);
vector mat_age(1,nages);
vector sex_age(1,nages);
vector M_age(1,nages);
init_bounded_number par_logR0(5,20,1);
//init_bounded_number par_steep(0.25,0.95,2);
number par_steep;
//init_bounded_number par_S1dS0(0.01,2.0,1);
number par_S1dS0;
number par_SenddS0;
init_bounded_dev_vector par_logR_dev(styr,endyr,-3,3,2);
init_bounded_number par_mulogF_handline(-25,0,1);
init_bounded_dev_vector par_logF_handline(L_handline_styr,L_handline_endyr,-15,10,2);
init_bounded_number par_mulogF_longline(-25,0,1);
init_bounded_dev_vector par_logF_longline(L_longline_styr,L_longline_endyr,-15,10,2);
init_bounded_number par_mulogF_headboat(-25,0,1);
init_bounded_dev_vector par_logF_headboat(C_headboat_styr,C_headboat_endyr,-15,10,2);
init_bounded_number par_mulogF_MRFSS(-25,0,1);
init_bounded_dev_vector par_logF_MRFSS(C_MRFSS_styr,C_MRFSS_endyr,-15,10,2);
init_number par_logq_headboat;
init_number par_logq_MMtrap;
init_number par_logq_MMlongline;
init_number par_logq_logbook;
//----------------------------------------------------------------------------------------------------------------------------

//--length stuff--------------------------------------------------------------------------------------------------------------
vector meanlen_age(1,nages);         //Mean length at age
vector stdlen_age(1,nages);          //Standard deviation of length at age (computed from par_len_CV)
matrix age2len(1,nages,1,nlenbins);  //Age to length conversion matrix

//--selectivity at age--------------------------------------------------------------------------------------------------------
vector sel_handline(1,nages);                                     //Handline fisheries selectivity at age
vector sel_longline(1,nages);                                     //Longline fisheries selectivity at age
matrix sel_headboat(lc_headboat_styr,lc_headboat_endyr,1,nages);  //Recreational headboat fisheries selectivity at age
number temp_sel2;
number temp_sel4;
vector sel_MRFSS(1,nages);                                        //Recreational MRFSS fisheries selectivity at age
vector sel_MMtrap(1,nages);                                       //MARMAP Chevron trap selectivity at age
vector sel_MMlongline(1,nages);                                   //MARMAP longline selectivity at age
matrix sel_logbook(I_logbook_styr,I_logbook_endyr,1,nages);       //Logbook selectivity at age (catch-weighted by year)

//--fishing stuff-------------------------------------------------------------------------------------------------------------
vector F_full(styr_eq,endyr);                 //Total fully selected fishing mortality by year
vector F_age2plus(styr_eq,endyr);             //Population weighted fishing mortality (age 2+)
```

```
vector E(styr_eq,endyr);                       //Exploitation rate by year (age 1+)
vector E_mat(styr_eq,endyr);                   //Exploitation rate of mature fish by year
matrix F_age_total(styr_eq,endyr,1,nages);     //Total fishing mortality at age
matrix C_age_total(styr_eq,endyr,1,nages);     //Total catch (numbers) at age
matrix L_age_total(styr_eq,endyr,1,nages);     //Total landings (mt) at age
vector L_total(styr_eq,endyr);                 //Total landings by year
matrix Z_age(styr_eq,endyr,1,nages);           //Total mortality at age
matrix F_age_handline(styr_eq,endyr,1,nages);  //Fishing mortality at age, handline fishery
matrix F_age_longline(styr_eq,endyr,1,nages);  //Fishing mortality at age, longline fishery
matrix F_age_headboat(styr_eq,endyr,1,nages);  //Fishing mortality at age, recreational headboat fishery
matrix F_age_MRFSS(styr_eq,endyr,1,nages);     //Fishing mortality at age, recreational MRFSS fishery
matrix C_age_handline(styr_eq,endyr,1,nages);  //Catch (numbers) at age, handline fishery
matrix C_age_longline(styr_eq,endyr,1,nages);  //Catch (numbers) at age, longline fishery
matrix C_age_headboat(styr_eq,endyr,1,nages);  //Catch (numbers) at age, recreational headboat fishery
matrix C_age_MRFSS(styr_eq,endyr,1,nages);     //Catch (numbers) at age, recreational MRFSS fishery
matrix L_age_handline(styr_eq,endyr,1,nages);  //Landings (mt) at age, handline fishery
matrix L_age_longline(styr_eq,endyr,1,nages);  //Landings (mt) at age, longline fishery
matrix L_age_headboat(styr_eq,endyr,1,nages);  //Landings (mt) at age, recreational headboat fishery
matrix L_age_MRFSS(styr_eq,endyr,1,nages);     //Landings (mt) at age, recreational MRFSS fishery
number F_avg;                                  //temporary storage for average F used in calculations

//--miscellaneous stuff-------------------------------------------------------------------------------------------------
vector reprod(1,nages);               //Product of weight, sex ratio, and maturity by age
vector N_spr_F0(1,nages);             //Numbers storage vector for computing spr_F0
number spr_F0;                        //Reproduction-per-recruit at F=0
number R0;                            //Virgin recruitment
number R1_eq;                         //Equilibrium recruitment estimate for first year in model
number S0;                            //Virgin reproductive potential
matrix N_age(styr_eq,endyr,1,nages);  //Population numbers by year at age (beginning of year)
matrix B_age(styr_eq,endyr,1,nages);  //Total biomass by year at age (beginning of year)
vector SSB(styr_eq,endyr);            //Reproductive potential by year
number SenddS0                        //Reproductive potential ratio in last year

//--predicted data objects----------------------------------------------------------------------------------------------
vector L_handline_pred(L_handline_styr,L_handline_endyr);
vector L_longline_pred(L_longline_styr,L_longline_endyr);
vector C_headboat_pred(C_headboat_styr,C_headboat_endyr);
vector C_MRFSS_pred(C_MRFSS_styr,C_MRFSS_endyr);
matrix lc_handline_pred(lc_handline_styr,lc_handline_endyr,1,nlenbins);
matrix lc_longline_pred(lc_longline_styr,lc_longline_endyr,1,nlenbins);
matrix lc_headboat_pred(lc_headboat_styr,lc_headboat_endyr,1,nlenbins);
matrix lc_MMtrap_pred(1,lc_MMtrap_nyrs,1,nlenbins);
matrix lc_MMlongline_pred(lc_MMlongline_styr,lc_MMlongline_endyr,1,nlenbins);
matrix ac_handline_pred(1,ac_handline_nyrs,1,nages);
matrix ac_longline_pred(1,ac_longline_nyrs,1,nages);
matrix ac_headboat_pred(1,ac_headboat_nyrs,1,nages);
vector I_headboat_pred(I_headboat_styr,I_headboat_endyr);
vector I_MMtrap_pred(I_MMtrap_styr,I_MMtrap_endyr);
vector I_MMlongline_pred(I_MMlongline_styr,I_MMlongline_endyr);
vector I_logbook_pred(I_logbook_styr,I_logbook_endyr);
```

```
//--MSY objects-------------------------------------------------------------------------------------------------------------------
vector F_ratio(1,4);         //number of rows is based on number of fisheries with differing selectivities
vector F_msy(1,3);           //average F last 3 years
vector L_msy(1,3);           //landings (mt)
vector C_msy(1,nages);       //catch (numbers)
matrix Z_msy(1,3,1,nages);   //total mortality
matrix N_msy(1,3,1,nages);   //numbers at age (beginning of year)
vector spr_msy(1,3);         //reproductive potential per recruit
vector R_eq(1,3);            //equilibrium recruitment
number msy_pred;             //MSY
number F_msy_pred;           //fully selected fishing mortality at MSY
number F_msy_age2plus;       //population weighted fishing mortality (age 2+) at MSY
number R_msy_pred;           //recruitment at MSY
number SSB_msy_pred;         //reproductive potential at MSY
number B_msy_pred;           //biomass at MSY
number E_msy_pred;           //exploitation rate (age 1+) at MSY
number E_mat_msy_pred;       //exploitation rate of mature pop at MSY
number diff;                 //difference value to use in Newton's method
number dy;                   //first derivative approximation
number ddy;                  //second derivative approximation

//--per-recruit objects-------------------------------------------------------------------------------------------------------
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(styr_eq,endyr);  //vector of static SPR values by year
vector F_spr(1,201);               //values of full F to be used in per-recruit and equilibrium calculations
vector spr_spr(1,201);             //reporductive capacity-per-recruit values corresponding to F values in F_spr
vector L_spr(1,201);               //landings(mt)-per-recruit values corresponding to F values in F_spr
vector R_spr_eq(1,201);            //equilibrium recruitment values corresponding to F values in F_spr
vector L_spr_eq(1,201);            //equilibrium landings(mt) values corresponding to F values in F_spr
vector SSB_spr_eq(1,201);          //equilibrium reproductive capacity values corresponding to F values in F_spr
vector B_spr_eq(1,201);            //equilibrium biomass values corresponding to F values in F_spr
vector E_spr(1,201);               //exploitation rate (age 1+) values corresponding to F values in F_spr
vector E_mat_spr(1,201);           //exploitation rate (mature pop) values corresponding to F values in F_spr
vector F_spr_age2plus(1,201);      //fishing mortality (age2+) values corresponding to F values in F_spr

//--future projection objects-------------------------------------------------------------------------------------------------
vector logR_dev_fut(styr_fut,endyr_fut);       //recruitment(log) deviations in future
matrix N_age_fut(styr_fut,endyr_fut,1,nages);  //numbers at age by year in future
vector SSB_fut(styr_fut,endyr_fut);            //reproductive capacity by year in future
vector Z_age_fut(1,nages);                     //total mortality at age in future
number F_fut;                                  //fully selected fishing mortality in future
vector L_fut(styr_fut,endyr_fut);              //landings(mt) by year in future
!!CLASS random_number_generator rng(seed);     //random number declaration
number nyrs_num;                               //double precision number of years
number rand_draw;                              //storage for random number draw
number nyr_bins;                               //temporary bin for parsing random draw

//--negative log-likelihood components----------------------------------------------------------------------------------------
number f_L_handline;
```

```
number f_L_longline;
number f_C_headboat;
number f_C_MRFSS;
number f_lc_handline;
number f_lc_longline;
number f_lc_headboat;
number f_lc_MMtrap;
number f_lc_MMlongline;
number f_ac_handline;
number f_ac_longline;
number f_ac_headboat;
number f_I_headboat;
number f_I_MMtrap;
number f_I_MMlongline;
number f_I_logbook;
number f_R_constraint;
number f_S1_constraint;
number f_Send_constraint;
number f_sumL_constraint;
number f_EdEmsy_constraint;

//--negative log-likelihood weights-------------------------------------------------------------------------------------------------
number w_L;
number w_lc;
number w_ac;
number w_I;
number w_R;
number w_S1;
number w_Send;

//--values to constrain-------------------------------------------------------------------------------------------------
number sumL_constraint;  //2 times the maximum observed landings
number EdEmsy_constraint;  //for constraining E/Emsy

number sqrt2pi;

objective_function_value f;

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

RUNTIME_SECTION

maximum_function_evaluations 10000;
convergence_criteria 1e-8;

PRELIMINARY_CALCS_SECTION
 sqrt2pi=sqrt(2*3.14159265);  //square root of 2 pi
 diff=1e-5;                   //differencing value to use in Newton's method
 //--set likelihood weightings-------------------------------------------------------------------------------------------------
```

```
w_L=set_w_L;
w_lc=set_w_lc;
w_ac=set_w_ac;
w_I=set_w_I;
w_R=set_w_R;
w_S1=set_w_S1;
w_Send=set_w_Send;
//------------------------------------------------------------------------------------------------------------------------------

//--fix value of parameters-----------------------------------------------------------------------------------------
par_sel1_handline=set_sel_handline(1);
par_sel2_handline=set_sel_handline(2);
par_sel3_handline=set_sel_handline(3);
par_sel4_handline=set_sel_handline(4);
par_sel1_longline=set_sel_longline(1);
par_sel2_longline=set_sel_longline(2);
par_sel3_longline=set_sel_longline(3);
par_sel4_longline=set_sel_longline(4);
par_sel1_headboat=set_sel_headboat(1);
par_sel2_headboat=set_sel_headboat(2);
par_sel3_headboat=set_sel_headboat(3);
par_sel4_headboat=set_sel_headboat(4);
par_sel5_headboat=set_sel_headboat(5);
par_sel6_headboat=set_sel_headboat(6);
par_sel1_MRFSS=set_sel_MRFSS(1);
par_sel2_MRFSS=set_sel_MRFSS(2);
par_sel3_MRFSS=set_sel_MRFSS(3);
par_sel4_MRFSS=set_sel_MRFSS(4);
par_sel1_MMtrap=set_sel_MMtrap(1);
par_sel2_MMtrap=set_sel_MMtrap(2);
par_sel3_MMtrap=set_sel_MMtrap(3);
par_sel4_MMtrap=set_sel_MMtrap(4);
par_sel1_MMlongline=set_sel_MMlongline(1);
par_sel2_MMlongline=set_sel_MMlongline(2);
par_sel3_MMlongline=set_sel_MMlongline(3);
par_sel4_MMlongline=set_sel_MMlongline(4);
par_Linf=set_Linf;
par_K=set_K;
par_t0=set_t0;
par_len_CV=set_len_CV;
wgt_age=set_wgt_age;
mat_age=set_mat_age;
sex_age=set_sex_age;
M_age=set_M_age;
par_logR0=set_logR0;
par_steep=set_steep;
par_S1dS0=set_S1dS0;
par_SenddS0=set_SenddS0;
par_logR_dev=set_logR_dev;
par_mulogF_handline=set_mulogF_handline;
par_logF_handline=set_logF_handline;
```

```
 par_mulogF_longline=set_mulogF_longline;
 par_logF_longline=set_logF_longline;
 par_mulogF_headboat=set_mulogF_headboat;
 par_logF_headboat=set_logF_headboat;
 par_mulogF_MRFSS=set_mulogF_MRFSS;
 par_logF_MRFSS=set_logF_MRFSS;
 par_logq_headboat=set_logq_headboat;
 par_logq_MMtrap=set_logq_MMtrap;
 par_logq_MMlongline=set_logq_MMlongline;
 par_logq_logbook=set_logq_logbook;

 //--set constraint values------------------------------------------------------------------------------------------
 sumL_constraint=450;
 EdEmsy_constraint=0.01;

TOP_OF_MAIN_SECTION

 arrmblsize=2000000;
 gradient_structure::set_MAX_NVAR_OFFSET(1600);
 gradient_structure::set_GRADSTACK_BUFFER_SIZE(15000000);
 gradient_structure::set_CMPDIF_BUFFER_SIZE(100000000);
 gradient_structure::set_NUM_DEPENDENT_VARIABLES(1000);

PROCEDURE_SECTION

 //reprod=elem_prod(elem_prod(sex_age,mat_age),wgt_age);  //product of stuff going into reproductive capacity calcs
 reprod=elem_prod(mat_age,wgt_age);

 get_length_stuff();
 //cout << "made it through get_length_stuff" << endl;
 get_selectivity();
 //cout << "made it through get_selectivity" << endl;
 get_mortality();
 //cout << "made it through get_mortality" << endl;
 get_spr_F0();
 //cout << "made it through get_spr_F0" << endl;
 get_numbers_at_age();
 //cout << "made it through get_numbers_at_age" << endl;
 get_catch_and_landings();
 //cout << "made it through get_catch_and_landings" << endl;
 get_predicted_stuff();
 //cout << "made it through get_predicted_stuff" << endl;
 get_miscellaneous_stuff();
 get_msy();
 evaluate_the_objective_function();
 //cout << "made it through evaluate_the_objective_function" << endl;

//------------------------------------------------------------------------------------------------------------------------
FUNCTION get_length_stuff
  //compute mean length at age from vonBertalanffy equation
  meanlen_age=par_Linf*(1-mfexp(-par_K*(agebins-par_t0)));
```

```
  //compute standard deviation of length at age based on constant CV
  stdlen_age=meanlen_age*par_len_CV;
  //compute age to length probability conversion matrix
  for (a=1;a<=nages;a++)
  {
    for (l=1;l<=nlenbins;l++)
    {
      age2len(a,l)=(mfexp(-(square(lenbins(l)-meanlen_age(a))/(2.*square(stdlen_age(a)))))/(sqrt2pi*stdlen_age(a)));
    }
    age2len(a)/=(sum(age2len(a))+0.000001);
  }

//----------------------------------------------------------------------------------------------------------------------------
FUNCTION get_selectivity
  //compute selectivity at age using double logistic equation (reduces to logistic with last 2 parameters = 0)
  for (a=1; a<=nages; a++)
  {
    sel_handline(a)=(1./(1.+mfexp(-1.*par_sel1_handline*(double(agebins(a))-par_sel2_handline))))
                    *(1-(1./(1.+mfexp(-1.*par_sel3_handline*(double(agebins(a))-(par_sel2_handline+par_sel4_handline))))));
    sel_longline(a)=(1./(1.+mfexp(-1.*par_sel1_longline*(double(agebins(a))-par_sel2_longline))))
                    *(1-(1./(1.+mfexp(-1.*par_sel3_longline*(double(agebins(a))-(par_sel2_longline+par_sel4_longline))))));
    //sel_headboat(a)=(1./(1.+mfexp(-1.*par_sel1_headboat*(double(agebins(a))-par_sel2_headboat))))
    //                *(1-(1./(1.+mfexp(-1.*par_sel3_headboat*(double(agebins(a))-(par_sel2_headboat+par_sel4_headboat))))));
    sel_MMtrap(a)=(1./(1.+mfexp(-1.*par_sel1_MMtrap*(double(agebins(a))-par_sel2_MMtrap))))
                  *(1-(1./(1.+mfexp(-1.*par_sel3_MMtrap*(double(agebins(a))-(par_sel2_MMtrap+par_sel4_MMtrap))))));
    sel_MMlongline(a)=(1./(1.+mfexp(-1.*par_sel1_MMlongline*(double(agebins(a))-par_sel2_MMlongline))))
                      *(1-(1./(1.+mfexp(-1.*par_sel3_MMlongline*(double(agebins(a))-(par_sel2_MMlongline+par_sel4_MMlongline))))));
  }

  for(y=lc_headboat_styr; y<=lc_headboat_endyr; y++)
  {
    if(y<=1976)
    {
      temp_sel2=par_sel2_headboat+par_sel5_headboat;
      temp_sel4=par_sel4_headboat+par_sel6_headboat;
    }
    if(y>1976)
    {
      temp_sel2=par_sel2_headboat+par_sel5_headboat*(y-1976);
      temp_sel4=par_sel4_headboat+par_sel6_headboat*(y-1976);
    }
    if(y>1991)
    {
      temp_sel2=par_sel2_headboat+par_sel5_headboat*(1992-1976);
      temp_sel4=par_sel4_headboat+par_sel6_headboat*(1992-1976);
    }
    for (a=1; a<=nages; a++)
    {
      sel_headboat(y,a)=(1./(1.+mfexp(-1.*par_sel1_headboat*(double(agebins(a))-temp_sel2))))
                        *(1-(1./(1.+mfexp(-1.*par_sel3_headboat*(double(agebins(a))-(par_sel2_headboat+temp_sel4))))));
    }
```

```
    sel_headboat(y)=sel_headboat(y)/max(sel_headboat(y));
  }
  sel_handline=sel_handline/max(sel_handline);
  sel_longline=sel_longline/max(sel_longline);
  sel_MMtrap=sel_MMtrap/max(sel_MMtrap);
  sel_MMlongline=sel_MMlongline/max(sel_MMlongline);
  sel_MRFSS=sel_headboat(lc_headboat_endyr);

//-----------------------------------------------------------------------------------------------------------------------------
FUNCTION get_mortality
  //compute fishing mortality-at-age for all years
  //use median of first 3 years to fill in earlier years
  F_full=0.0;

  for (y=styr_eq; y<=endyr; y++)
  {
    if(y>=L_handline_styr)
    {
      F_age_handline(y)=sel_handline*mfexp(par_mulogF_handline+par_logF_handline(y));
      F_full(y)+=mfexp(par_mulogF_handline+par_logF_handline(y));
    }
    else
    {
      F_age_handline(y)=sel_handline*mfexp((3.0*par_mulogF_handline+sum(par_logF_handline(L_handline_styr,L_handline_styr+2)))/3);
      F_full(y)+=mfexp((3.0*par_mulogF_handline+sum(par_logF_handline(L_handline_styr,L_handline_styr+2)))/3);
    }

    if(y>=L_longline_styr)
    {
      F_age_longline(y)=sel_longline*mfexp(par_mulogF_longline+par_logF_longline(y));
      F_full(y)+=mfexp(par_mulogF_longline+par_logF_longline(y));
    }
    else
    {
      F_age_longline(y)=sel_longline*mfexp((3.0*par_mulogF_longline+sum(par_logF_longline(L_longline_styr,L_longline_styr+2)))/3);
      F_full(y)+=mfexp((3.0*par_mulogF_longline+sum(par_logF_longline(L_longline_styr,L_longline_styr+2)))/3);
    }

    if(y>=C_headboat_styr)
    {
      F_age_headboat(y)=sel_headboat(y)*mfexp(par_mulogF_headboat+par_logF_headboat(y));
      F_full(y)+=mfexp(par_mulogF_headboat+par_logF_headboat(y));
    }
    else
    {
      F_avg=mfexp((3.0*par_mulogF_headboat+sum(par_logF_headboat(C_headboat_styr,C_headboat_styr+2)))/3);
      F_age_headboat(y)=sel_headboat(lc_headboat_styr)*F_avg*(y-styr_eq)/(C_headboat_styr+1-styr_eq);
      F_full(y)+=F_avg*(y-styr_eq)/(C_headboat_styr+1-styr_eq);
    }

    if(y>=C_MRFSS_styr)
```

```
    {
      F_age_MRFSS(y)=sel_MRFSS*mfexp(par_mulogF_MRFSS+par_logF_MRFSS(y));
      F_full(y)+=mfexp(par_mulogF_MRFSS+par_logF_MRFSS(y));
    }
    else
    {
      F_avg=mfexp((3.0*par_mulogF_MRFSS+sum(par_logF_MRFSS(C_MRFSS_styr,C_MRFSS_styr+2)))/3);
      F_age_MRFSS(y)=sel_MRFSS*F_avg*(y-styr_eq)/(C_MRFSS_styr+1-styr_eq);
      F_full(y)+=F_avg*(y-styr_eq)/(C_MRFSS_styr+1-styr_eq);
    }

    F_age_total(y)=F_age_handline(y)+F_age_longline(y)+F_age_headboat(y)+F_age_MRFSS(y);
    Z_age(y)=F_age_total(y)+M_age;
  }

//--------------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_spr_F0
  //compute reproductive capacity-per-recruit at F=0
  N_spr_F0(1)=1.0;
  for(a=2; a<=nages; a++)
  {
    N_spr_F0(a)=N_spr_F0(a-1)*mfexp(-1.*M_age(a-1));
  }
  N_spr_F0(nages)=N_spr_F0(nages-1)*mfexp(-1.*M_age(nages-1))/(1-mfexp(-1.*M_age(nages)));
  spr_F0=sum(elem_prod(N_spr_F0,reprod));

//-------------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_numbers_at_age
  //compute the numbers-at-age, reproductive capacity, biomass, and recruitment
  R0=mfexp(par_logR0);
  S0=spr_F0*R0;
  //recruitment for first year in model (1 year prior to start of data)
  R1_eq=mfexp(par_logR0+log(par_S1dS0));
  //age-structure for first year in model (assumes equilibrium age-structure)
  N_age(styr_eq,1)=R1_eq;
  for (a=2; a<=nages; a++)
  {
    N_age(styr_eq,a)=N_age(styr_eq,a-1)*mfexp(-1.*Z_age(styr_eq,a-1));
  }
  N_age(styr_eq,nages)=N_age(styr_eq,nages-1)*mfexp(-1.*Z_age(styr_eq,nages-1))/(1.-mfexp(-1.*Z_age(styr_eq,nages)));
  SSB(styr_eq)=sum(elem_prod(N_age(styr_eq),reprod));
  B_age(styr_eq)=elem_prod(N_age(styr_eq),wgt_age);
  //subsequent years in model
  for (y=styr_eq; y<endyr; y++)
  {
    if(SRswitch<2)//Beverton-Holt stock-recruit function
    {
      N_age(y+1,1)=mfexp(log(((0.8*R0*par_steep*SSB(y))/(0.2*R0*spr_F0*(1-par_steep)+(par_steep-0.2)*SSB(y)))+0.00001)+par_logR_dev(y+1));
    }
    if(SRswitch>1)//Ricker stock-recruit function
    {
```

```
      N_age(y+1,1)=mfexp(log((SSB(y)/spr_F0)*mfexp(log((par_steep*4)/(1-par_steep))*(1-SSB(y)/(R0*spr_F0)))+0.00001)+par_logR_dev(y+1));
    }
    N_age(y+1)(2,nages)=++elem_prod(N_age(y)(1,nages-1),(mfexp(-1.*Z_age(y)(1,nages-1))));
    N_age(y+1,nages)+=N_age(y,nages)*mfexp(-1.*Z_age(y,nages));
    SSB(y+1)=sum(elem_prod(N_age(y+1),reprod));
    B_age(y+1)=elem_prod(N_age(y+1),wgt_age);
  }
  SenddS0=SSB(endyr)/S0;

//-------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_catch_and_landings
  //compute catch-at-age and landings by year for each fishery
  for (y=styr_eq; y<=endyr; y++)
  {
    for(a=1; a<=nages; a++)
    {
      C_age_handline(y,a)=N_age(y,a)*F_age_handline(y,a)*(1.-mfexp(-1.*Z_age(y,a)))/Z_age(y,a);
      C_age_longline(y,a)=N_age(y,a)*F_age_longline(y,a)*(1.-mfexp(-1.*Z_age(y,a)))/Z_age(y,a);
      C_age_headboat(y,a)=N_age(y,a)*F_age_headboat(y,a)*(1.-mfexp(-1.*Z_age(y,a)))/Z_age(y,a);
      C_age_MRFSS(y,a)=N_age(y,a)*F_age_MRFSS(y,a)*(1.-mfexp(-1.*Z_age(y,a)))/Z_age(y,a);
    }
    L_age_handline(y)=elem_prod(C_age_handline(y),wgt_age);
    L_age_longline(y)=elem_prod(C_age_longline(y),wgt_age);
    L_age_headboat(y)=elem_prod(C_age_headboat(y),wgt_age);
    L_age_MRFSS(y)=elem_prod(C_age_MRFSS(y),wgt_age);
  }

//-----------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_predicted_stuff
  //predicted landings
  for (y=L_handline_styr; y<=L_handline_endyr; y++)
  {
    L_handline_pred(y)=sum(L_age_handline(y));
  }
  for (y=L_longline_styr; y<=L_longline_endyr; y++)
  {
    L_longline_pred(y)=sum(L_age_longline(y));
  }
  for (y=C_headboat_styr; y<=C_headboat_endyr; y++)
  {
    C_headboat_pred(y)=sum(C_age_headboat(y));
  }
  for (y=C_MRFSS_styr; y<=C_MRFSS_endyr; y++)
  {
    C_MRFSS_pred(y)=sum(C_age_MRFSS(y));
  }
  //predicted length compositions
  for (y=lc_handline_styr; y<=lc_handline_endyr; y++)
  {
    lc_handline_pred(y)=C_age_handline(y)*age2len;
    lc_handline_pred(y)=lc_handline_pred(y)/sum(lc_handline_pred(y));
```

```
}
for (y=lc_longline_styr; y<=lc_longline_endyr; y++)
{
  lc_longline_pred(y)=C_age_longline(y)*age2len;
  lc_longline_pred(y)=lc_longline_pred(y)/sum(lc_longline_pred(y));
}
for (y=lc_headboat_styr; y<=lc_headboat_endyr; y++)
{
  lc_headboat_pred(y)=C_age_headboat(y)*age2len;
  lc_headboat_pred(y)=lc_headboat_pred(y)/sum(lc_headboat_pred(y));
}
for (y=1; y<=lc_MMtrap_nyrs; y++)
{
  lc_MMtrap_pred(y)=elem_prod(N_age(lc_MMtrap_yrs(y)),sel_MMtrap)*age2len;
  lc_MMtrap_pred(y)=lc_MMtrap_pred(y)/sum(lc_MMtrap_pred(y));
}
for (y=lc_MMlongline_styr; y<=lc_MMlongline_endyr; y++)
{
  lc_MMlongline_pred(y)=elem_prod(N_age(y),sel_MMlongline)*age2len;
  lc_MMlongline_pred(y)=lc_MMlongline_pred(y)/sum(lc_MMlongline_pred(y));
}
//predicted age compositions
for (y=1; y<=ac_handline_nyrs; y++)
{
  ac_handline_pred(y)=C_age_handline(ac_handline_yrs(y))/sum(C_age_handline(ac_handline_yrs(y)));
}
for (y=1; y<=ac_longline_nyrs; y++)
{
  ac_longline_pred(y)=C_age_longline(ac_longline_yrs(y))/sum(C_age_longline(ac_longline_yrs(y)));
}
for (y=1; y<=ac_headboat_nyrs; y++)
{
  ac_headboat_pred(y)=C_age_headboat(ac_headboat_yrs(y))/sum(C_age_headboat(ac_headboat_yrs(y)));
}
//predicted indices
for (y=I_headboat_styr; y<=I_headboat_endyr; y++)
{
  I_headboat_pred(y)=mfexp(par_logq_headboat)*N_age(y)*sel_headboat(y);
}
for (y=I_MMtrap_styr; y<=I_MMtrap_endyr; y++)
{
  I_MMtrap_pred(y)=mfexp(par_logq_MMtrap)*N_age(y)*sel_MMtrap;
}
for (y=I_MMlongline_styr; y<=I_MMlongline_endyr; y++)
{
  I_MMlongline_pred(y)=mfexp(par_logq_MMlongline)*N_age(y)*sel_MMlongline;
}
for (y=I_logbook_styr; y<=I_logbook_endyr; y++)
{
```

```
//sel_logbook(y)=elem_div((elem_prod(C_age_handline(y),sel_handline)+elem_prod(C_age_longline(y),sel_longline)),(C_age_handline(y)+C_age_lon
gline(y)));
    sel_logbook(y)=sum(C_age_handline(y))*sel_handline+sum(C_age_longline(y))*sel_longline;
    sel_logbook(y)/=(sum(C_age_handline(y))+sum(C_age_longline(y)));
    sel_logbook(y)/=max(sel_logbook(y));
    I_logbook_pred(y)=mfexp(par_logq_logbook)*B_age(y)*sel_logbook(y);
  }

//-------------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_msy
  //compute MSY statistics

  //compute geometric mean F from last 3 years of fishery
  F_ratio(1)=mfexp((3.0*par_mulogF_handline+sum(par_logF_handline(L_handline_endyr-2,L_handline_endyr)))/3);
  F_ratio(2)=mfexp((3.0*par_mulogF_longline+sum(par_logF_longline(L_longline_endyr-2,L_longline_endyr)))/3);
  F_ratio(3)=mfexp((3.0*par_mulogF_headboat+sum(par_logF_headboat(C_headboat_endyr-2,C_headboat_endyr)))/3);
  F_ratio(4)=mfexp((3.0*par_mulogF_MRFSS+sum(par_logF_MRFSS(C_MRFSS_endyr-2,C_MRFSS_endyr)))/3);
  F_ratio=F_ratio/sum(F_ratio);
  //do Newton's method for 10 iterations
  F_msy(1)=M_age(nages)*0.5;
  for (int i=1; i<=10; i++){
    L_msy=0.0;
    C_msy=0.0;
    F_msy(2)=F_msy(1)-diff;
    F_msy(3)=F_msy(1)+diff;

    Z_msy(1)=sel_handline*F_msy(1)*F_ratio(1);
    Z_msy(1)+=sel_longline*F_msy(1)*F_ratio(2);
    Z_msy(1)+=sel_headboat(lc_headboat_endyr)*F_msy(1)*F_ratio(3);
    Z_msy(1)+=sel_MRFSS*F_msy(1)*F_ratio(4);

    Z_msy(1)+=M_age;
    Z_msy(2)=sel_handline*F_msy(2)*F_ratio(1);
    Z_msy(2)+=sel_longline*F_msy(2)*F_ratio(2);
    Z_msy(2)+=sel_headboat(lc_headboat_endyr)*F_msy(2)*F_ratio(3);
    Z_msy(2)+=sel_MRFSS*F_msy(2)*F_ratio(4);
    Z_msy(2)+=M_age;
    Z_msy(3)=sel_handline*F_msy(3)*F_ratio(1);
    Z_msy(3)+=sel_longline*F_msy(3)*F_ratio(2);
    Z_msy(3)+=sel_headboat(lc_headboat_endyr)*F_msy(3)*F_ratio(3);
    Z_msy(3)+=sel_MRFSS*F_msy(3)*F_ratio(4);
    Z_msy(3)+=M_age;

    N_msy(1,1)=1.0;
    N_msy(2,1)=1.0;
    N_msy(3,1)=1.0;
    for (a=2; a<=nages; a++)
    {
      N_msy(1,a)=N_msy(1,a-1)*mfexp(-1.*Z_msy(1,a-1));
      N_msy(2,a)=N_msy(2,a-1)*mfexp(-1.*Z_msy(2,a-1));
```

```
      N_msy(3,a)=N_msy(3,a-1)*mfexp(-1.*Z_msy(3,a-1));
    }
    N_msy(1,nages)=N_msy(1,nages-1)*mfexp(-1.*Z_msy(1,nages-1))/(1.-mfexp(-1.*Z_msy(1,nages)));
    N_msy(2,nages)=N_msy(2,nages-1)*mfexp(-1.*Z_msy(2,nages-1))/(1.-mfexp(-1.*Z_msy(2,nages)));
    N_msy(3,nages)=N_msy(3,nages-1)*mfexp(-1.*Z_msy(3,nages-1))/(1.-mfexp(-1.*Z_msy(3,nages)));
    spr_msy(1)=sum(elem_prod(N_msy(1),reprod));
    spr_msy(2)=sum(elem_prod(N_msy(2),reprod));
    spr_msy(3)=sum(elem_prod(N_msy(3),reprod));
    if(SRswitch<2) //Beverton-Holt
    {
      R_eq(1)=(R0/((5*par_steep-1)*spr_msy(1)))*(4*par_steep*spr_msy(1)-spr_F0*(1-par_steep));
      R_eq(2)=(R0/((5*par_steep-1)*spr_msy(2)))*(4*par_steep*spr_msy(2)-spr_F0*(1-par_steep));
      R_eq(3)=(R0/((5*par_steep-1)*spr_msy(3)))*(4*par_steep*spr_msy(3)-spr_F0*(1-par_steep));
    }
    if(SRswitch>1) //Ricker
    {
      R_eq(1)=(R0/(spr_msy(1)/spr_F0))*(1+log(spr_msy(1)/spr_F0)/log((par_steep*4)/(1-par_steep)));
      R_eq(2)=(R0/(spr_msy(2)/spr_F0))*(1+log(spr_msy(2)/spr_F0)/log((par_steep*4)/(1-par_steep)));
      R_eq(3)=(R0/(spr_msy(3)/spr_F0))*(1+log(spr_msy(3)/spr_F0)/log((par_steep*4)/(1-par_steep)));
    }

    N_msy(1)*=R_eq(1);
    N_msy(2)*=R_eq(2);
    N_msy(3)*=R_eq(3);
    for(a=1; a<=nages; a++){
      C_msy(a)=N_msy(1,a)*((Z_msy(1,a)-M_age(a))/Z_msy(1,a))*(1.-mfexp(-1.*Z_msy(1,a)));
      L_msy(1)+=N_msy(1,a)*((Z_msy(1,a)-M_age(a))/Z_msy(1,a))*(1.-mfexp(-1.*Z_msy(1,a)))*wgt_age(a);
      L_msy(2)+=N_msy(2,a)*((Z_msy(2,a)-M_age(a))/Z_msy(2,a))*(1.-mfexp(-1.*Z_msy(2,a)))*wgt_age(a);
      L_msy(3)+=N_msy(3,a)*((Z_msy(3,a)-M_age(a))/Z_msy(3,a))*(1.-mfexp(-1.*Z_msy(3,a)))*wgt_age(a);
    }
    dy=(L_msy(3)-L_msy(2))/(2.*diff);
    ddy=(L_msy(3)-2.*L_msy(1)+L_msy(2))/square(diff);
    if(square(ddy)>1e-12){
      F_msy(1)-=(dy/ddy);
    }
    if(F_msy(1)<=diff){
      F_msy(1)=diff;
    }
  }
  msy_pred=L_msy(1);
  F_msy_pred=F_msy(1);
  E_mat_msy_pred=sum(C_msy)/sum(elem_prod(N_msy(1),mat_age));
  E_msy_pred=sum(C_msy(2,nages))/sum(N_msy(1)(2,nages));
  F_msy_age2plus=((Z_msy(1)-M_age)(3,nages)*N_msy(1)(3,nages))/sum(N_msy(1)(3,nages));
  R_msy_pred=R_eq(1);
  SSB_msy_pred=sum(elem_prod(N_msy(1),reprod));
  B_msy_pred=sum(elem_prod(N_msy(1),wgt_age));

//-------------------------------------------------------------------------------------------------------------------
FUNCTION get_miscellaneous_stuff
  //compute total catch-at-age and landings
```

```
  C_age_total=C_age_handline;
  C_age_total+=C_age_longline;
  C_age_total+=C_age_headboat;
  C_age_total+=C_age_MRFSS;
  //compute exploitation rate and population-weighted F(age2+)
  for(y=styr_eq; y<=endyr; y++)
  {
    L_age_total(y)=elem_prod(C_age_total(y),wgt_age);
    L_total(y)=sum(L_age_total(y));
    E_mat(y)=sum(C_age_total(y))/sum(elem_prod(N_age(y),mat_age));
    E(y)=sum(C_age_total(y)(2,nages))/sum(N_age(y)(2,nages));

F_age2plus(y)=((F_age_handline(y)(3,nages)+F_age_longline(y)(3,nages)+F_age_headboat(y)(3,nages)+F_age_MRFSS(y)(3,nages))*N_age(y)(3,nages))
/sum(N_age(y)(3,nages));
  }
//-----------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_per_recruit_stuff
  //static per-recruit stuff
  for(y=styr_eq; y<=endyr; y++)
  {
    N_age_spr(1)=1.0;
    for(a=2; a<=nages; a++)
    {
      N_age_spr(a)=N_age_spr(a-1)*mfexp(-1.*Z_age(y,a-1));
    }
    N_age_spr(nages)=N_age_spr(nages-1)*mfexp(-1.*Z_age(y,nages-1))/(1-mfexp(-1.*Z_age(y,nages)));
    spr_static(y)=sum(elem_prod(N_age_spr,reprod))/spr_F0;
  }

  //fill in F's for per-recruit stuff
  F_spr.fill_seqadd(0,0.0025);
  //compute SSB/R and YPR as functions of F
  for(int ff=1; ff<=201; ff++)
  {
    //uses F-weighted selectivity estimated in the MSY section
    Z_age_spr=sel_handline*F_spr(ff)*F_ratio(1);
    Z_age_spr+=sel_longline*F_spr(ff)*F_ratio(2);
    Z_age_spr+=sel_headboat(lc_headboat_endyr)*F_spr(ff)*F_ratio(3);
    Z_age_spr+=sel_MRFSS*F_spr(ff)*F_ratio(4);
    Z_age_spr+=M_age;

    N_age_spr(1)=1.0;
    for (a=2; a<=nages; a++)
    {
      N_age_spr(a)=N_age_spr(a-1)*mfexp(-1.*Z_age_spr(a-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));
    L_spr(ff)=0.0;
    for (a=1; a<=nages; a++)
    {
```

```
      C_age_spr(a)=N_age_spr(a)*((Z_age_spr(a)-M_age(a))/Z_age_spr(a))*(1.-mfexp(-1.*Z_age_spr(a)));
      L_spr(ff)+=C_age_spr(a)*wgt_age(a);
    }
    E_spr(ff)=sum(C_age_spr(2,nages))/sum(N_age_spr(2,nages));
    E_mat_spr(ff)=sum(C_age_spr)/sum(elem_prod(N_age_spr,mat_age));
    F_spr_age2plus(ff)=((Z_age_spr-M_age)(3,nages)*N_age_spr(3,nages))/sum(N_age_spr(3,nages));

    //Compute equilibrium values of R, SSB and Yield at each F
    if(SRswitch<2) //Beverton-Holt
    {
      R_spr_eq(ff)=(R0/((5*par_steep-1)*spr_spr(ff)))*(4*par_steep*spr_spr(ff)-spr_F0*(1-par_steep));
    }
    if(SRswitch>1) //Ricker
    {
      R_spr_eq(ff)=(R0/(spr_spr(ff)/spr_F0))*(1+log(spr_spr(ff)/spr_F0)/log((par_steep*4)/(1-par_steep)));
    }
    N_age_spr*=R_spr_eq(ff);
    SSB_spr_eq(ff)=sum(elem_prod(N_age_spr,reprod));
    B_spr_eq(ff)=sum(elem_prod(N_age_spr,wgt_age));
    L_spr_eq(ff)=sum(elem_prod(C_age_spr*R_spr_eq(ff),wgt_age));
  }

//----------------------------------------------------------------------------------------------------------------------------------------
FUNCTION evaluate_the_objective_function
  f=0;
  f_sumL_constraint=0.0;
  //landings data (lognormal)
  f_L_handline=0.0;
  for (y=L_handline_styr; y<=L_handline_endyr; y++)
  {
    f_L_handline+=square(log(L_handline_obs(y)+.001)-log(L_handline_pred(y)+.001))/(2.0*square(L_handline_cv(y)));
    //f_sumL_constraint+=pow(2,(L_handline_pred(y)-L_handline_obs(y)*sumL_constraint)*0.01);
  }
  f+=w_L*f_L_handline;
  f_L_longline=0.0;
  for (y=L_longline_styr; y<=L_longline_endyr; y++)
  {
    f_L_longline+=square(log(L_longline_obs(y)+.001)-log(L_longline_pred(y)+.001))/(2.0*square(L_longline_cv(y)));
    //f_sumL_constraint+=pow(2,(L_longline_pred(y)-L_longline_obs(y)*sumL_constraint)*0.01);
  }
  f+=w_L*f_L_longline;
  f_C_headboat=0.0;
  for (y=C_headboat_styr; y<=C_headboat_endyr; y++)
  {
    f_C_headboat+=square(log(C_headboat_obs(y)+.001)-log(C_headboat_pred(y)+.001))/(2.0*square(C_headboat_cv(y)));
    //f_sumL_constraint+=pow(2,(C_headboat_pred(y)-C_headboat_obs(y)*sumL_constraint)*0.01);
  }
  f+=w_L*f_C_headboat;
  f_C_MRFSS=0.0;
  for (y=C_MRFSS_styr; y<=C_MRFSS_endyr; y++)
  {
```

```
    f_C_MRFSS+=square(log(C_MRFSS_obs(y)+.001)-log(C_MRFSS_pred(y)+.001))/(2.0*square(C_MRFSS_cv(y)));
    //f_sumL_constraint+=pow(2,(C_MRFSS_pred(y)-C_MRFSS_obs(y)*sumL_constraint)*0.01);
  }
  f+=w_L*f_C_MRFSS*10;
  //length composition data (multinomial)
  f_lc_handline=0.0;
  for (y=lc_handline_styr; y<=lc_handline_endyr; y++)
  {
    f_lc_handline+=-lc_handline_ss(y)*sum(elem_prod((lc_handline_obs(y)+.001),log(lc_handline_pred(y)+.001))-
elem_prod((lc_handline_obs(y)+.001),log(lc_handline_obs(y)+.001)));
  }
  f+=w_lc*f_lc_handline;
  f_lc_longline=0.0;
  for (y=lc_longline_styr; y<=lc_longline_endyr; y++)
  {
    f_lc_longline+=-lc_longline_ss(y)*sum(elem_prod((lc_longline_obs(y)+.001),log(lc_longline_pred(y)+.001))-
elem_prod((lc_longline_obs(y)+.001),log(lc_longline_obs(y)+.001)));
  }
  f+=w_lc*f_lc_longline;
  f_lc_headboat=0.0;
  for (y=lc_headboat_styr; y<=lc_headboat_endyr; y++)
  {
    f_lc_headboat+=-lc_headboat_ss(y)*sum(elem_prod((lc_headboat_obs(y)+.001),log(lc_headboat_pred(y)+.001))-
elem_prod((lc_headboat_obs(y)+.001),log(lc_headboat_obs(y)+.001)));
  }
  f+=w_lc*f_lc_headboat;
  f_lc_MMtrap=0.0;
  for (y=1; y<=lc_MMtrap_nyrs; y++)
  {
    f_lc_MMtrap+=-lc_MMtrap_ss(y)*sum(elem_prod((lc_MMtrap_obs(y)+.001),log(lc_MMtrap_pred(y)+.001))-
elem_prod((lc_MMtrap_obs(y)+.001),log(lc_MMtrap_obs(y)+.001)));
  }
  f+=w_lc*f_lc_MMtrap;
  f_lc_MMlongline=0.0;
  for (y=lc_MMlongline_styr; y<=lc_MMlongline_endyr; y++)
  {
    f_lc_MMlongline+=-lc_MMlongline_ss(y)*sum(elem_prod((lc_MMlongline_obs(y)+.001),log(lc_MMlongline_pred(y)+.001))-
elem_prod((lc_MMlongline_obs(y)+.001),log(lc_MMlongline_obs(y)+.001)));
  }
  f+=w_lc*f_lc_MMlongline;
  //age composition data (multinomial)
  f_ac_handline=0.0;
  for (y=1; y<=ac_handline_nyrs; y++)
  {
    f_ac_handline+=-ac_handline_ss(y)*sum(elem_prod((ac_handline_obs(y)+.001),log(ac_handline_pred(y)+.001))-
elem_prod((ac_handline_obs(y)+.001),log(ac_handline_obs(y)+.001)));
  }
  f+=w_ac*f_ac_handline;
  f_ac_longline=0.0;
  for (y=1; y<=ac_longline_nyrs; y++)
  {
```

```
    f_ac_longline+=-ac_longline_ss(y)*sum(elem_prod((ac_longline_obs(y)+.001),log(ac_longline_pred(y)+.001))-
elem_prod((ac_longline_obs(y)+.001),log(ac_longline_obs(y)+.001)));
  }
  f+=w_ac*f_ac_longline;
  f_ac_headboat=0.0;
  for (y=1; y<=ac_headboat_nyrs; y++)
  {
    f_ac_headboat+=-ac_headboat_ss(y)*sum(elem_prod((ac_headboat_obs(y)+.001),log(ac_headboat_pred(y)+.001))-
elem_prod((ac_headboat_obs(y)+.001),log(ac_headboat_obs(y)+.001)));
  }
  f+=w_ac*f_ac_headboat;
  //indices data (lognormal)
  f_I_headboat=0.0;
  for (y=I_headboat_styr; y<=I_headboat_endyr; y++)
  {
    f_I_headboat+=square(log(I_headboat_obs(y)+.001)-log(I_headboat_pred(y)+.001))/(2.0*square(I_headboat_cv(y)));
  }
  f+=w_I*f_I_headboat;
  f_I_MMtrap=0.0;
  for (y=I_MMtrap_styr; y<=I_MMtrap_endyr; y++)
  {
    f_I_MMtrap+=square(log(I_MMtrap_obs(y)+.001)-log(I_MMtrap_pred(y)+.001))/(2.0*square(I_MMtrap_cv(y)));
  }
  f+=w_I*f_I_MMtrap;
  f_I_MMlongline=0.0;
  for (y=I_MMlongline_styr; y<=I_MMlongline_endyr; y++)
  {
    f_I_MMlongline+=square(log(I_MMlongline_obs(y)+.001)-log(I_MMlongline_pred(y)+.001))/(2.0*square(I_MMlongline_cv(y)));
  }
  f+=w_I*f_I_MMlongline;
  f_I_logbook=0.0;
  for (y=I_logbook_styr; y<=I_logbook_endyr; y++)
  {
    f_I_logbook+=square(log(I_logbook_obs(y)+.001)-log(I_logbook_pred(y)+.001))/(2.0*square(I_logbook_cv(y)));
  }
  f+=w_I*f_I_logbook*0.0;
  //recruitment deviations (lognormal)
  f_R_constraint=norm2(par_logR_dev);
  f+=w_R*f_R_constraint;
  f_Send_constraint=square(SenddS0-par_SenddS0);
  f+=w_Send*f_Send_constraint;
  f_S1_constraint=square(SSB(styr_eq)/S0-par_S1dS0);
  f+=w_S1*f_S1_constraint;


//---------------------------------------------------------------------------------------------------------------------------
FUNCTION project_into_the_future
  //do future projections (1=stochastic,2=deterministic)
  //compute future random recruitment (if stochastic option chosen)
  if(project_type<2)
  {
```

```
    int counter;
    nyrs_num=nyrs;
    for(y=styr_fut; y<=endyr_fut; y++)
    {
      rand_draw=randu(rng);
      counter=0;
      for(int y2=0; y2<=nyrs; y2++)
      {
        nyr_bins=y2/nyrs_num;
        if(rand_draw>nyr_bins)
        {
          counter+=1;
        }
      }
      logR_dev_fut(y)=par_logR_dev(styr+counter-1);
    }
  }
  //set future F equal to median of last 3 years
  //F_fut=mfexp(sum(log(F_full(endyr-2,endyr)))/3);
  F_fut=0.0;

  //use selectivity from MSY calcs
  Z_age_fut=sel_handline*F_fut*F_ratio(1);
  Z_age_fut+=sel_longline*F_fut*F_ratio(2);
  Z_age_fut+=sel_headboat(lc_headboat_endyr)*F_fut*F_ratio(3);
  Z_age_fut+=sel_MRFSS*F_fut*F_ratio(4);
  Z_age_fut+=M_age;
  //project age-structure into future
  for (y=styr_fut-1; y<endyr_fut; y++)
  {
    if(y<=endyr)
    {
      if(SRswitch<2)//Beverton-Holt stock-recruit function
      {
        N_age_fut(y+1,1)=mfexp(log(((0.8*R0*par_steep*SSB(y))/(0.2*R0*spr_F0*(1-par_steep)+(par_steep-
0.2)*SSB(y)))+0.00001)+logR_dev_fut(y+1));
      }
      if(SRswitch>1)//Ricker stock-recruit function
      {
        N_age_fut(y+1,1)=mfexp(log((SSB(y)/spr_F0)*mfexp(log((par_steep*4)/(1-par_steep))*(1-
SSB(y)/(R0*spr_F0)))+0.00001)+logR_dev_fut(y+1));
      }
      N_age_fut(y+1)(2,nages)=++elem_prod(N_age(y)(1,nages-1),(mfexp(-1.*Z_age(y)(1,nages-1))));
      N_age_fut(y+1,nages)+=N_age(y,nages)*mfexp(-1.*Z_age(y)(nages));
    }
    else
    {
      if(SRswitch<2)//Beverton-Holt stock-recruit function
      {
        N_age_fut(y+1,1)=mfexp(log(((0.8*R0*par_steep*SSB_fut(y))/(0.2*R0*spr_F0*(1-par_steep)+(par_steep-
0.2)*SSB_fut(y)))+0.00001)+logR_dev_fut(y+1));
```

```
      }
      if(SRswitch>1)//Ricker stock-recruit function
      {
        N_age_fut(y+1,1)=mfexp(log((SSB_fut(y)/spr_F0)*mfexp(log((par_steep*4)/(1-par_steep))*(1-
SSB_fut(y)/(R0*spr_F0)))+0.00001)+logR_dev_fut(y+1));
      }
      N_age_fut(y+1)(2,nages)=++elem_prod(N_age_fut(y)(1,nages-1),(mfexp(-1.*Z_age_fut(1,nages-1))));
      N_age_fut(y+1,nages)+=N_age_fut(y,nages)*mfexp(-1.*Z_age_fut(nages));
    }
    SSB_fut(y+1)=sum(elem_prod(N_age_fut(y+1),reprod));
    L_fut(y+1)=0;
    for (a=1; a<=nages; a++)
    {
      L_fut(y+1)+=N_age_fut(y+1,a)*((Z_age_fut(a)-M_age(a))/Z_age_fut(a))*(1.-mfexp(-1.*Z_age_fut(a)));
    }
  }

//---------------------------------------------------------------------------------------------------------------------------------------
FUNCTION append_MC_output_file1
  if(MCcount==1)
  {
    MCreport1 << "MCcount";
    MCreport1 << " par_sel1_handline";
    MCreport1 << " par_sel2_handline";
    MCreport1 << " par_sel3_handline";
    MCreport1 << " par_sel4_handline";
    MCreport1 << " par_sel1_longline";
    MCreport1 << " par_sel2_longline";
    MCreport1 << " par_sel3_longline";
    MCreport1 << " par_sel4_longline";
    MCreport1 << " par_sel1_headboat";
    MCreport1 << " par_sel2_headboat";
    MCreport1 << " par_sel3_headboat";
    MCreport1 << " par_sel4_headboat";
    MCreport1 << " par_sel5_headboat";
    MCreport1 << " par_sel6_headboat";
    MCreport1 << " par_sel1_MRFSS";
    MCreport1 << " par_sel2_MRFSS";
    MCreport1 << " par_sel3_MRFSS";
    MCreport1 << " par_sel4_MRFSS";
    MCreport1 << " par_sel1_MMtrap";
    MCreport1 << " par_sel2_MMtrap";
    MCreport1 << " par_sel3_MMtrap";
    MCreport1 << " par_sel4_MMtrap";
    MCreport1 << " par_sel1_MMlongline";
    MCreport1 << " par_sel2_MMlongline";
    MCreport1 << " par_sel3_MMlongline";
    MCreport1 << " par_sel4_MMlongline";
    MCreport1 << " par_Linf";
    MCreport1 << " par_K";
    MCreport1 << " par_t0";
```

```
    MCreport1 << " par_len_CV";
    for(a=1; a<=nages; a++)
    {
       MCreport1 << " M_age_" << agebins(a);
    }
    MCreport1 << " par_logR0";
    MCreport1 << " par_steep";
    MCreport1 << " par_S1dS0";
    MCreport1 << " par_SenddS0";
    for(y=styr; y<=endyr; y++)
    {
      MCreport1 << " par_logR_dev_" << y;
    }
    MCreport1 << " par_mulogF_handline";
    for(y=L_handline_styr; y<=L_handline_endyr; y++)
    {
      MCreport1 << " par_logF_handline_" << y;
    }
    MCreport1 << " par_mulogF_longline";
    for(y=L_longline_styr; y<=L_longline_endyr; y++)
    {
      MCreport1 << " par_logF_longline_" << y;
    }
    MCreport1 << " par_mulogF_headboat";
    for(y=C_headboat_styr; y<=C_headboat_endyr; y++)
    {
      MCreport1 << " par_logF_headboat_" << y;
    }
    MCreport1 << " par_mulogF_MRFSS";
    for(y=C_MRFSS_styr; y<=C_MRFSS_endyr; y++)
    {
      MCreport1 << " par_logF_MRFSS_" << y;
    }
    MCreport1 << " par_logq_headboat";
    MCreport1 << " par_logq_MMtrap";
    MCreport1 << " par_logq_MMlongline";
    MCreport1 << " par_logq_logbook";
    MCreport1 << endl;
  }
  MCreport1 << MCcount << " ";
  MCreport1 << par_sel1_handline << " ";
  MCreport1 << par_sel2_handline << " ";
  MCreport1 << par_sel3_handline << " ";
  MCreport1 << par_sel4_handline << " ";
  MCreport1 << par_sel1_longline << " ";
  MCreport1 << par_sel2_longline << " ";
  MCreport1 << par_sel3_longline << " ";
  MCreport1 << par_sel4_longline << " ";
  MCreport1 << par_sel1_headboat << " ";
  MCreport1 << par_sel2_headboat << " ";
  MCreport1 << par_sel3_headboat << " ";
```

```
  MCreport1 << par_sel4_headboat << " ";
  MCreport1 << par_sel5_headboat << " ";
  MCreport1 << par_sel6_headboat << " ";
  MCreport1 << par_sel1_MRFSS << " ";
  MCreport1 << par_sel2_MRFSS << " ";
  MCreport1 << par_sel3_MRFSS << " ";
  MCreport1 << par_sel4_MRFSS << " ";
  MCreport1 << par_sel1_MMtrap << " ";
  MCreport1 << par_sel2_MMtrap << " ";
  MCreport1 << par_sel3_MMtrap << " ";
  MCreport1 << par_sel4_MMtrap << " ";
  MCreport1 << par_sel1_MMlongline << " ";
  MCreport1 << par_sel2_MMlongline << " ";
  MCreport1 << par_sel3_MMlongline << " ";
  MCreport1 << par_sel4_MMlongline << " ";
  MCreport1 << par_Linf << " ";
  MCreport1 << par_K << " ";
  MCreport1 << par_t0 << " ";
  MCreport1 << par_len_CV << " ";
  MCreport1 << M_age(1,nages) << " ";
  MCreport1 << par_logR0 << " ";
  MCreport1 << par_steep << " ";
  MCreport1 << par_S1dS0 << " ";
  MCreport1 << par_SenddS0 << " ";
  MCreport1 << par_logR_dev(styr,endyr) << " ";
  MCreport1 << par_mulogF_handline << " ";
  MCreport1 << par_logF_handline(L_handline_styr,L_handline_endyr) << " ";
  MCreport1 << par_mulogF_longline << " ";
  MCreport1 << par_logF_longline(L_longline_styr,L_longline_endyr) << " ";
  MCreport1 << par_mulogF_headboat << " ";
  MCreport1 << par_logF_headboat(C_headboat_styr,C_headboat_endyr) << " ";
  MCreport1 << par_mulogF_MRFSS << " ";
  MCreport1 << par_logF_MRFSS(C_MRFSS_styr,C_MRFSS_endyr) << " ";
  MCreport1 << par_logq_headboat << " ";
  MCreport1 << par_logq_MMtrap << " ";
  MCreport1 << par_logq_MMlongline << " ";
  MCreport1 << par_logq_logbook << " ";
  MCreport1 << endl;

FUNCTION append_MC_output_file2
  if(MCcount==1)
  {
    MCreport2 << "MCcount";
    for(y=styr_eq; y<=endyr; y++)
    {
      MCreport2 << " spr_static_" << y;
    }
    for(y=1; y<=201; y++)
    {
      MCreport2 << " F_spr";
    }
```

```
    for(y=1; y<=201; y++)
    {
      MCreport2 << " E_spr";
    }
    for(y=1; y<=201; y++)
    {
      MCreport2 << " F_spr_age2plus";
    }
    for(y=1; y<=201; y++)
    {
      MCreport2 << " spr_spr";
    }
    for(y=1; y<=201; y++)
    {
      MCreport2 << " L_spr";
    }
    for(y=1; y<=201; y++)
    {
      MCreport2 << " SSB_spr_eq";
    }
    for(y=1; y<=201; y++)
    {
      MCreport2 << " B_spr_eq";
    }
    for(y=1; y<=201; y++)
    {
      MCreport2 << " L_spr_eq";
    }
    MCreport2 << endl;
  }
  MCreport2 << MCcount << " ";
  for(y=styr_eq; y<=endyr; y++)
  {
    MCreport2 << spr_static(y) << " ";
  }
  MCreport2 << F_spr << " ";
  MCreport2 << E_spr << " ";
  MCreport2 << F_spr_age2plus << " ";
  MCreport2 << spr_spr << " ";
  MCreport2 << L_spr << " ";
  MCreport2 << SSB_spr_eq << " ";
  MCreport2 << B_spr_eq << " ";
  MCreport2 << L_spr_eq << " ";
  MCreport2 << endl;

//----------------------------------------------------------------------------------------------------------------------------------------
FUNCTION append_MC_output_file3
  //this file contains recruitment, SSB, biomass, F, F(age2+), and E time series
  if(MCcount==1)
  {
    MCreport3 << "MCcount";
```

```
    for(y=styr_eq; y<=endyr; y++)
    {
      MCreport3 << " R_" << y;
    }
    for(y=styr_eq; y<=endyr; y++)
    {
      MCreport3 << " SSB_" << y;
    }
    for(y=styr_eq; y<=endyr; y++)
    {
      MCreport3 << " B_" << y;
    }
    for(y=styr_eq; y<=endyr; y++)
    {
      MCreport3 << " Ffull_" << y;
    }
    for(y=styr_eq; y<=endyr; y++)
    {
      MCreport3 << " Fage2+_" << y;
    }
    for(y=styr_eq; y<=endyr; y++)
    {
      MCreport3 << " Eage1+_" << y;
    }
    MCreport3 << endl;
  }
  MCreport3 << MCcount << " ";
  for(y=styr_eq; y<=endyr; y++)
  {
    MCreport3 << N_age(y)(1) << " ";
  }
  MCreport3 << SSB << " ";
  for(y=styr_eq; y<=endyr; y++)
  {
    MCreport3 << sum(B_age(y)) << " ";
  }
  MCreport3 << F_full << " ";
  MCreport3 << F_age2plus << " ";
  MCreport3 << E << " ";
  MCreport3 << endl;

//----------------------------------------------------------------------------------------------------------------------------------------
FUNCTION append_MC_output_file4
  //this file contains total landings, spr.F0, MSY stuff, projection stuff, and likelihood components
  if(MCcount==1)
  {
    MCreport4 << "MCcount";
    for(y=styr_eq; y<=endyr; y++)
    {
      MCreport4 << " L_total_" << y;
    }
```

```
MCreport4 << " spr_F0";
MCreport4 << " Fratio_handline";
MCreport4 << " Fratio_longline";
MCreport4 << " Fratio_headboat";
MCreport4 << " Fratio_MRFSS";
MCreport4 << " Fmsy";
MCreport4 << " Fmsy_age2+";
MCreport4 << " Emsy";
MCreport4 << " Ematmsy";
MCreport4 << " MSY";
MCreport4 << " Rmsy";
MCreport4 << " SSBmsy";
MCreport4 << " Bmsy";
MCreport4 << " rnd_seed";
MCreport4 << " project_type";
MCreport4 << " F_fut" << " ";
for(y=styr_fut; y<=endyr_fut; y++)
{
  MCreport4 << " R_fut_" << y;
}
for(y=styr_fut; y<=endyr_fut; y++)
{
  MCreport4 << " L_fut_" << y;
}
for(y=styr_fut; y<=endyr_fut; y++)
{
  MCreport4 << " SSB_fut_" << y;
}
MCreport4 << " f_L_handline";
MCreport4 << " f_L_longline";
MCreport4 << " f_C_headboat";
MCreport4 << " f_C_MRFSS";
MCreport4 << " f_lc_handline";
MCreport4 << " f_lc_longline";
MCreport4 << " f_lc_headboat";
MCreport4 << " f_lc_MMtrap";
MCreport4 << " f_lc_MMlongline";
MCreport4 << " f_ac_handline";
MCreport4 << " f_ac_longline";
MCreport4 << " f_ac_headboat";
MCreport4 << " f_I_headboat";
MCreport4 << " f_I_MMtrap";
MCreport4 << " f_I_MMlongline";
MCreport4 << " f_I_logbook";
MCreport4 << " f_R_constraint";
MCreport4 << " f_S1_constraint";
MCreport4 << " f_Send_constraint";
MCreport4 << " f_sumL_constraint";
MCreport4 << " f_EdEmsy_constraint";
MCreport4 << " w_L";
MCreport4 << " w_lc";
```

```
    MCreport4 << " w_ac";
    MCreport4 << " w_I";
    MCreport4 << " w_R";
    MCreport4 << " w_S1";
    MCreport4 << " w_Send";
    MCreport4 << " f_total";
    MCreport4 << endl;
  }
  MCreport4 << MCcount << " ";
  for(y=styr_eq; y<=endyr; y++)
  {
    MCreport4 << sum(L_age_total(y)) << " ";
  }
  MCreport4 << spr_F0         << " ";
  MCreport4 << F_ratio        << " ";
  MCreport4 << F_msy_pred     << " ";
  MCreport4 << F_msy_age2plus << " ";
  MCreport4 << E_msy_pred     << " ";
  MCreport4 << E_mat_msy_pred << " ";
  MCreport4 << msy_pred       << " ";
  MCreport4 << R_msy_pred     << " ";
  MCreport4 << SSB_msy_pred   << " ";
  MCreport4 << B_msy_pred     << " ";
  MCreport4 << seed           << " ";
  MCreport4 << project_type   << " ";
  MCreport4 << F_fut          << " ";
  for(y=styr_fut; y<=endyr_fut; y++)
  {
    MCreport4 << N_age_fut(y)(1) << " ";
  }
  for(y=styr_fut; y<=endyr_fut; y++)
  {
    MCreport4 << L_fut(y) << " ";
  }
  for(y=styr_fut; y<=endyr_fut; y++)
  {
    MCreport4 << SSB_fut(y) << " ";
  }
  MCreport4 << f_L_handline << " ";
  MCreport4 << f_L_longline << " ";
  MCreport4 << f_C_headboat << " ";
  MCreport4 << f_C_MRFSS << " ";
  MCreport4 << f_lc_handline << " ";
  MCreport4 << f_lc_longline << " ";
  MCreport4 << f_lc_headboat << " ";
  MCreport4 << f_lc_MMtrap << " ";

  MCreport4 << f_lc_MMlongline << " ";
  MCreport4 << f_ac_handline << " ";
  MCreport4 << f_ac_longline << " ";
  MCreport4 << f_ac_headboat << " ";
```

```
  MCreport4 << f_I_headboat << " ";
  MCreport4 << f_I_MMtrap << " ";
  MCreport4 << f_I_MMlongline << " ";
  MCreport4 << f_I_logbook << " ";
  MCreport4 << f_R_constraint << " ";
  MCreport4 << f_S1_constraint << " ";
  MCreport4 << f_Send_constraint << " ";
  MCreport4 << f_sumL_constraint << " ";
  MCreport4 << f_EdEmsy_constraint << " ";
  MCreport4 << w_L << " ";
  MCreport4 << w_lc << " ";
  MCreport4 << w_ac << " ";
  MCreport4 << w_I << " ";
  MCreport4 << w_R << " ";
  MCreport4 << w_S1 << " ";
  MCreport4 << w_Send << " ";
  MCreport4 << f << " ";
  MCreport4 << endl;

//---------------------------------------------------------------------------------------------------------------------------------------------
FINAL_SECTION
 cout << "dy = " << dy << endl;
 cout << "Fmsy = " << F_msy_pred << endl;
 get_per_recruit_stuff();
 project_into_the_future();
 if(MCcount>0)
 {
   append_MC_output_file1();  //appends the Monte Carlo file
   append_MC_output_file2();  //appends the Monte Carlo file
   append_MC_output_file3();  //appends the Monte Carlo file
   append_MC_output_file4();  //appends the Monte Carlo file
 }
 if(MCcount<1)
 {
   #include "s-report-snowy-6.cxx"   // ADMB code to write the S-compatible report
 }
```

8.3 Appendix III. ASPIC model output from surplus-production model application to snowy grouper.

```
Snowy Grouper - June, 2004 - SEDAR AW
Page 1

Thursday, 10 Jun 2004 at 16:53:36
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 5.05)

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

Reference:  Prager, M. H. 1994. A suite of extensions to a nonequilibrium
ASPIC User's Manual is available
            surplus-production model.  Fishery Bulletin 92: 374-389.
gratis from the author.

CONTROL PARAMETERS USED (FROM INPUT FILE)
Input file: sng007.inp
--------------------------------------------------------------------------------
-------------------------------------------
Operation of ASPIC:  Fit logistic (Schaefer) model by direct optimization.
Number of years analyzed:                        41             Number of
bootstrap trials:                           0
Number of data series:                            4             Lower bound
on MSY:                           2.000E+01
Objective function:                   Least squares             Upper bound
on MSY:                           1.000E+03
Relative conv. criterion (simplex):       1.000E-08             Lower bound
on K:                             3.000E+01
Relative conv. criterion (restart):       3.000E-08             Upper bound
on K:                             5.000E+04
Relative conv. criterion (effort):        1.000E-04             Random number
seed:                             4120359
Maximum F allowed in fitting:                 4.000             Monte Carlo
search mode, trials:       0             0
Identical convergences required in fitting:       8


PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS)
error code   0
--------------------------------------------------------------------------------
-------------------------------------------
Normal convergence
Number of restarts required for convergence:    161


CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE
OBSERVATIONS BELOW)
--------------------------------------------------------------------------------
-------------------------------------------
                                                   |
```

```
 1  SNG HBT Index (early) and Total... |   1.000
                                       |       4
                                       |
 2  SNG HBT Index (late)               |   0.000   1.000
                                       |       0      12
                                       |
 3  MARMAP Chevron Trap                |   0.000   0.264   1.000
                                       |       0      12      13
                                       |
 4  MARMAP Vertical LL                 |   0.000   0.449   0.431   1.000
                                       |       0       7       7       7
                                       --------------------------------------
------------
                                               1       2       3       4


GOODNESS-OF-FIT AND WEIGHTING (NON-BOOTSTRAPPED ANALYSIS)
-----------------------------------------------------------------------------
-------------------------------------------
                                                         Weighted
Weighted      Current    Inv. var.    R-squared
Loss component number and title                              SSE     N
MSE       weight       weight      in CPUE

Loss(-1)  SSE in yield                                 0.000E+00
Loss(0)   Penalty for B1 > K                           0.000E+00     1
N/A    1.000E+00          N/A
Loss(1)   SNG HBT Index (early) and Total Landing   1.855E+00     4
9.277E-01    1.000E+00    2.704E-01       -0.181
Loss(2)   SNG HBT Index (late)                         2.681E+00    12
2.681E-01    1.000E+00    9.355E-01       -1.351
Loss(3)   MARMAP Chevron Trap                          1.404E+01    13
1.276E+00    1.000E+00    1.965E-01       -0.011
Loss(4)   MARMAP Vertical LL                           4.153E-01     7
8.307E-02    1.000E+00    3.020E+00        0.131
.............................................................................
................
TOTAL OBJECTIVE FUNCTION, MSE, RMSE:           1.89926376E+01
6.549E-01    8.093E-01
Estimated contrast index (ideal = 1.0):              0.8120         C* =
(Bmax-Bmin)/K
Estimated nearness index (ideal = 1.0):              1.0000         N* = 1
- |min(B-Bmsy)|/K
```

```
MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
-----------------------------------------------------------------------------
-------------------------------------------
Parameter                                            Estimate     User/pgm
guess    2nd guess    Estimated   User guess

B1/K      Starting relative biomass (in 1962)       7.179E-01
8.000E-01    3.129E-01            1            1
MSY       Maximum sustainable yield                 3.046E+02
4.100E+02    1.433E+02            1            1
K         Maximum population size                   5.776E+02
2.050E+03    8.596E+02            1            1
phi       Shape of production curve (Bmsy/K)        0.5000              0.5000
----           0           1

--------- Catchability Coefficients by Data Series ---------------
q(1)      SNG HBT Index (early) and Total Landing   1.693E-03
1.000E-04    9.500E-03            1            1
q(2)      SNG HBT Index (late)                      1.615E-03
1.000E-03    9.500E-02            1            1
q(3)      MARMAP Chevron Trap                       1.600E-03
5.000E-04    4.750E-02            1            1
q(4)      MARMAP Vertical LL                        2.087E-03
5.000E-04    4.750E-02            1            1


MANAGEMENT and DERIVED PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
-----------------------------------------------------------------------------
-------------------------------------------
Parameter                                            Estimate
Logistic formula           General formula

MSY       Maximum sustainable yield                 3.046E+02
----                      ----
Bmsy      Stock biomass giving MSY                  2.888E+02
K/2            K*n**(1/(1-n))
Fmsy      Fishing mortality rate at MSY             1.055E+00
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(2003)/Bmsy                       1.748E+00
----                      ----
F./Fmsy   Ratio: F(2002)/Fmsy                       2.397E-01
----                      ----
Fmsy/F.   Ratio: Fmsy/F(2002)                       4.171E+00
----                      ----

Y.(Fmsy)  Approx. yield available at Fmsy in 2003   5.324E+02
MSY*B./Bmsy               MSY*B./Bmsy
          ...as proportion of MSY                   1.748E+00
----                      ----
```

```
Ye.       Equilibrium yield available in 2003       1.343E+02
4*MSY*(B/K-(B/K)**2)      g*MSY*(B/K-(B/K)**n)
          ...as proportion of MSY                   4.410E-01
----                      ----

--------- Fishing effort rate at MSY in units of each CE or CC series -------
--
fmsy(1)   SNG HBT Index (early) and Total Landing   6.230E+02
Fmsy/q( 1)                Fmsy/q( 1)
```

SEDAR

Southeast Data, Assessment, and Review

SEDAR 4

Stock Assessment Report 1

SECTION III.B

Assessment of Tilefish, *Lopholatilus chamaeleonticeps,*

in the

South Atlantic Fishery Management Council

Management Area

Prepared by:

SEDAR 4 Stock Assessment Panel

July 12, 2004

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1. Introduction

The SEDAR-4 Assessment Workshop met in Beaufort, North Carolina, June 7-11, 2004, to conduct assessments of snowy grouper (*Epinephelus niveatus*) and tilefish (*Lopholatilus chamaeleonticeps*). This material describes the Assessment Workshop's work on snowy grouper.

To assess tilefish, two models were considered: (1) a statistical catch-at-age model and (2) an age-aggregated production model. The forward-projecting statistical catch-at-age model was preferred over VPA methods primarily because of the increased flexibility in formulation and statistical treatment of the data sources. Per-recruit analyses and stock-recruitment modeling were done within the statistical catch-at-age model.

Throughout this report, the SEDAR-4 Assessment Workshop is referred to as the AW, and the preceding SEDAR-4 Data Workshop is referred to as the DW. Abbreviations and symbols used throughout the report are listed in Appendix A. Reports prepared for and available to the DW are listed in Appendix B.

1.1 <u>Data Issues and Deviations from Data Workshop (DW) Recommendations</u>

1.1.1 Length-Weight Relationship

Length-weight data are available from several sources. At the DW, only data from the Marine Resources Monitoring Assessment and Protection (MARMAP) program were used to develop a length-weight conversion model. The AW conlcuded that all length-weight data, combined from the headboat fishery and the MARMAP program, should be used to develop a length-weight conversion model (DW report: Table 3, Section 3). This relationship is given by:

$$W = 4.040E{-}9 * L^{3.155},\ R^2 = 0.94,\ n = 3{,}047,$$

where W is weight in kg and L is total length in mm.

1.1.2 Growth

Size-at-age data for tilefish are available from MARMAP and the National Marine Fisheries Service (NMFS) Beaufort Laboratory. The fish aged by MARMAP were collected off Georgia to North Carolina during 1980–1987 and 1996–1998, mostly from fishery-dependent sources. The fish aged by the NMFS Beaufort Laboratory were collected off North Florida during 1992–2002, all from fishery-dependent sources. The AW recognized that tilefish otoliths are extremely difficult to interpret and might not accurately reflect ages. For a given size, the estimated age from MARMAP was typically greater than from the Beaufort Laboratory (Figure 1). Although not definitive, early results of a bomb radio-carbon age validation conducted by MARMAP scientists suggested that MARMAP specimens may have been underaged by 5-10 years (P. Harris, MARMAP, Pers. Comm.). Otoliths read by the NMFS Beaufort Laboratory were interpreted in light of the radiocarbon analysis of MARMAP ages.

The AW was concerned that tilefish lengths off North Florida provided by the NMFS Beaufort Laboratory might not represent those of the rest of the stock. Hence, the AW compared the length distribution of aged fish to the length distribution of fish landed off the Southeastern

United States, and determined that the distributions were similar. The AW also considered combining MARMAP- and NMFS-estimated ages to broaden the spatial coverage of samples. However, this option was discarded because of the known bias in MARMAP ages and because MARMAP collected few large fish during the 1990s. Therefore, the AW concluded that the NMFS-estimated ages were the best data to use in the assessment. This decision affects the analyses for life history-based estimates of *M*, logistic models of sex ratios and female maturity, and data for age compositions.

Von Bertalanffy growth parameters were estimated from the two data sets, pooled and separated. Initially, the growth curves were fit with nonlinear least squares (Figure 1). The growth curves used in the assessment model were fit by a maximum likelihood procedure, under the assumption of variance (in length at age) proportional to mean length at age. The two fitting methods provided similar fits (Figure 2). Fitting the growth models resulted in a high negative t_0 (e.g., –4.844) value, likely due to selectivity of faster growing young fish with small sample size at the youngest ages (Goodyear 1996). Because of these biologically unreasonable estimates of t_0, additional growth model fits were made fixing t_0 at –0.5. In addition, samples were re-weighted based on the inverse of sample size at age. This resulted in a more reasonable pattern of residuals at the oldest ages. The AW used the von Bertalanffy growth parameters estimated by this maximum likelihood procedure in all aspects of the stock assessment model.

The AW noted that there was a substantial difference in growth between males and females (Figure 3). However, because landings and length composition data are not sex-specific, it was not possible to address dimorphic growth explicitly in the assessment model. Instead, estimated growth for sexes combined was used to fit landings and length composition data, and estimated growth of females was used to compute spawning stock biomass (SSB). Based on the von Bertalanffy growth equation, mean total length (mm) for sexes combined was estimated to be:

$$L_a = 790.2(1 - \exp(-0.159(a + 0.5))),\ CV = 0.141,\ n = 2{,}683,$$

where L is total length in mm, a is age in years, and CV is coefficient of variation. Mean total length (mm) for females only was estimated to be:

$$L_a = 694.5(1 - \exp(-0.183(a + 0.5))),\ CV = 0.124,\ n = 187.$$

The growth curves for sexes combined and females only are compared in Figure 4. The length-weight relationship is shown in Figure 5. Total length and weight at age (mid-year) are summarized in Table 1.

1.1.3 Natural Mortality Rate

Several life history approaches were investigated for estimating age-invariant *M* (Alverson and Carney 1975; Hoenig 1983, Pauly 1980, Beverton 1992) and age-dependent M (Lorenzen 1996). The Lorenzen 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 a shape parameter ($\beta<0$). The function effects higher *M* at younger ages. Lorenzen (1996) provided point estimates and 90% confidence intervals of α and β for oceanic fishes, which were used in this assessment. The AW discussed the possibility of applying a fixed M, but concluded that the Lorenzen (1996) approach is more biologically plausible. However, based on the Lorenzen estimates, the cumulative survival to the oldest observed age was extremely small. The AW therefore recalibrated the Lorenzen age-dependent estimates of *M* so that the cumulative survival to the oldest observed age was 1.4%, a value from a recent analysis of equations developed by Hoenig (1983) (D. Hewitt, Virginia Institute of Marine Science, Pers. Comm., manuscript in review with Fish. Bull.). Values of predicted and recalibrated M at age are summarized in Table 1 and Figure 6. The AW used a maximum age of 54 from the MARMAP data rather than 44 from the NMFS Beaufort data, because the 54-year old individual was aged after after early results of the radiocarbon aging study indicated a possible under-aging bias. The AW acknowledged that since the maximum age was estimated from a period of heavy fishing that tilefish might live longer than 54 years.

1.1.4 Sex ratio at age

Data on sex ratio at age are available from the MARMAP program. Because of concerns that the MARMAP aging is biased, MARMAP ages associated with sex ratios were corrected to the ages that would have been estimated from the NMFS-Beaufort size-at-age data. This was accomplished by converting the observed MARMAP lengths to ages using the inverse of the NMFS male-specific and female-specific growth curves (Figure 3). The sex ratio at age was indistinguishable from 1:1 (Figure 7, Table 1), and therefore a 1:1 sex ratio was used in the assessment model.

Tilefish are territorial and the largest individuals are probably more aggressive and out-compete smaller fish for bait. Grimes et al. (1988) and Harris et al. (2001) suggested that two categories of males exist. Larger males are able to maintain burrows and engage in spawning, whereas smaller males, although mature, do not occupy burrows and might not participate in spawning. Similarly, a female unable to hold a territory within that of a male’s probably will not reproduce in spite of being sexually mature (Harris et al. 2001). The AW acknowledged that sexual dimorphic growth existed and that size-based behavior could affect the functional sex ratio. Indeed, there was a significant difference from 1:1 in the sex ratio with respect to size during the 1990s, but not during the 1980s, which could be due to the removal of the larger males in recent years. The AW would have preferred to incorporate growth by sex with an explicit two-sex assessment model, but concluded that the data were inadequate to fit a two–sex model.

1.1.5 Female Maturity and Generation Time

During the DW, female maturity was estimated from MARMAP data using logistic regression. Afterward, new analyses of reproductive tissues indicated that some fish previously thought to be resting were immature, and the logistic maturity model was corrected. Observed and predicted female maturity are compared in Figure 8, and predicted female maturity is given in Table 1. Age at 50% female maturity is 4.8 years, with 25–75% female maturity occurring at 4.2–5.3 years.

Generation time (T) was defined as mean age of reproduction (Case 2000). It was computed by following a cohort of females from birth until the maximum age, counting all the daughters they produce during their lifetimes at each age *x*, and averaging across ages:

$$T = \frac{\sum_{x=0}^{max} l_x b_x x}{\sum_{x=0}^{max} l_x b_x}$$

where l_x is survivorship to age x, b_x is the per-capita birth rate of females, and *max* is the asymptotic maximum age. For this analysis, survivorship was determined by the scaled Lorenzen estimates of *M* (Table 1), the birth rate was assumed proportional to female weight, and *max* assumed a value of *100*. The generation time of tilefish was estimated to be $T = 23.6$ years.

1.1.6 Landings

Commercial landings by gear (mt) were developed during the DW (DW report, Table 4.4). The geographic extent of landings was the North Carolina/Virginia border to Monroe County, Florida. Landings are summarized by state and gear (Table 2). For purposes of this assessment the small amount of landings other than handlines and longlines was proportionally distributed between these two gears (Table 4 and Figure 9). Commercial landings by state are compared in Figure 10, which shows that the majority of landings have come from Florida. Total landings were small until 1981, and they peaked at 1495 mt in 1982. Total landings then decreased to 132 mt in 1987. Between 1983 and 1987, many fishermen may have shifted effort from bottom longline to pelagic longline (Low 2003). After 1987 landings increased to a maximum of 520 mt in 1993 and then decreased to 169 mt in 1996. Another smaller peak in landings occurred at 355 mt in 2000.

Previous SEDARs have indicated that uncertainty in the quality of landings should be addressed. The AW noted that confidence in commercial landings has greatly increased since the 1960’s. The progressive recognition of the importance of fishery information resulted in greater effort through the 1970’s and mid-1980’s to collect landings data. In 1984, the state of Florida implemented a trip-ticket program. From 1984 to 1994, the South Atlantic states all made strides to improve commercial landings data collection. In 1994, the North Carolina trip ticket program was implemented, resulting in much greater confidence in the landings data from the primary Snapper-Grouper producing states of Florida and North Carolina. As of 2003 the remaining South Atlantic states of Georgia and South Carolina implemented trip ticket programs. The variable coefficients of variation (CV) imposed on the time series of landings by the AW reflects these progressive changes. CVs were assumed to be 50% in the early years (1962–1984) relative to 10% in the later years (1994–2002); intervening CVs were linearly interpolated (Figure 11).

Recreational landings (headboat and MRFSS) were developed during the DW (DW report, Section 4.2). Tilefish landings by headboat were extremely small relative to MRFSS (private and charter boat), and thus all recreational landings were combined for analysis (Figure 12 and Table 5). CVs available from the MRFSS (Figure 13) were applied to the combined MRFSS and headboat fisheries. The AW noted an unrealistic variability in year-to-year estimates of landings in the MRFSS. Because such landings are a small portion of the total, no remedial action was taken.

Landings by fishery and corresponding CVs are shown in Table 6. Total landings from all fisheries combined are shown in Figure 14.

1.1.7 Indices of Abundance

There are two indices of abundance available for tilefish (Figure 15 and Table 7). A fishery-independent index was developed from MARMAP horizontal-longline data (DW report, section 5.1.4), augmented with a 1983 value after the DW. A fishery-dependent index was developed from commercial logbook data (DW report, section 4.1.7), following recommendations from previous SEDARs that those data be evaluated for use in stock assessments. Corresponding CVs are available for both indices of abundance.

Each index has its own strengths and weaknesses as a measure of relative abundance. The MARMAP index has a small sample size, the time series is short and begins after the 1982 peak in landings, the geographic area does not cover the entire range of the stock, and there are minor differences in gear between the two time periods (1980s and 1990s). (During the 1980s gangions were attached to polywarp; during the 1990s gangions were attached to galvanized cable and a different research vessel was used.) However, the MARMAP index is a well-designed survey, it covers a fairly broad area (waters off Georgia and South Carolina), and there are many important similarities in gear and procedure between the two periods. During both periods, the survey used the same size hooks, same number of hooks, same bait (squid), same soak time, and same sampling areas. Furthermore, tilefish spawn in or near the Gulf Stream and produce pelagic larvae that colonize a broad area along the east coast of the United States, so the areas sampled may indeed reflect abundance of the stock from outside the study area. Ultimately, the AW considered the MARMAP index a reasonable measure of relative abundance for the assessment.

The logbook index is derived from fishery-dependent data. As with any fishery-dependent index, CPUE may not reflect relative abundance. As abundance decreases, CPUE will not decrease if fishermen shift effort to areas of greatest abundance, and as abundance increases, CPUE may not increase due to limits in handling time and hauling capacity. These issues are of particular concern for species that aggregate, like snowy grouper. The AW discussed additional issues with the logbook index, including the difficulty in defining a directed trip, regulation changes (quota, 2-for-1 permits), technology creep, and effective effort. However, it was noted that the tilefish logbook index had a large sample size and broad spatial coverage. Additionally, tilefish do not aggregate, so fluctuations in CPUE are less inclined to reflect localized exploitations. Thus the AW accepted the recommendation of the DW to include the logbook index.

1.1.8 Length Compositions

The composition of commercial length data was developed from the Trip Interview Program (TIP) database for handline and longline gear (DW report, section 4.1.6). Subsequently the data were allocated to 30 mm (total length) bins for use in the model. These bins ranged from 345 to 1005 (midpoint values) and included data from 1984–2002. Individual length measurements were weighted by landings in numbers by state and season to develop the annual length compositions for commercial gear. Fishery-dependent and independent length data were also available from the MARMAP program during 1983–1986 and 1996–2002. Sample sizes of lengths from TIP and MARMAP ranged from one fish per year to tens of thousands (Table 8).

Some year-sector combinations with small sample sizes apparently provided no useful information, only noise. The AW decided that such data should be excluded from the analysis. There was a natural break in the sample sizes of commercial length data, with sample sizes falling below 15 fish in a few of the year-sector combinations and above 50 for the rest. This natural break appears to distinguish the sample sizes worth keeping (50 and above) from those that should be discarded (below 15). The MARMAP data are more complicated as the same natural break does not occur. A visual examination of MARMAP data helped to distinguish years that provided useful information from those that did not. All MARMAP length data were examined for signs of strong recruitment signals corresponding to peaks in adjacent years. This examination suggested that sample sizes of 25 or less contained little useful information and should be discarded. Sample sizes above 25 appeared to provide useful information and were included. Table 8 and Figure 16 – Figure 18 summarize the tilefish length compositions used by the catch-at-age model.

1.1.9 Age Compositions

For tilefish, annual age compositions of the commercial handline and longline fisheries were available from the NMFS age data (ages 0 to 44). MARMAP age composition data (1983–1986; 1996–2002) were also available, but the AW rejected them due to a likely bias as described above.

The AW concluded that year-sector combinations with sample sizes of 25 or less contained little useful information and should be discarded. Sample sizes above 25 appeared to provide useful information and were included. Table 9 and Figure 19 – Figure 20 summarize the tilefish age compositions used by the catch–at–age model.

The length compositions corresponding to aged samples from the commercial longline (Figure 21) were inspected for any major deviations from the overall length composition data (Figure 16). The length compositions from aged fish appeared to consistently depict larger yearly modes than did the overall length compositions. This indicates that fish selected for aging were not chosen at random, but rather with a bias toward older, larger fish. These age composition data were not given much weight when fitting the statistical catch-at-age model.

2. Statistical Catch–at–Age Model

2.1 General Modeling Approach (Catch–At–Age Model)

The essence of statistical catch-at-age models is to simulate a population forward in time like the population being assessed. Aspects of the fishing process (i.e., gear selectivity) are also simulated. Quantities to be estimated are systematically varied from starting values until the simulated characteristics of the population match available data on the real population as closely as possible. Such data include total catch by fishery and year; observed age composition by gear and year; and observed indices of abundance.

The method of forward projection has a long history in fishery models. It was introduced by Pella and Tomlinson (1969) for fitting production models and then used by Fournier and Archibald (1982), Deriso et al. (1985) in their CAGEAN model, and Methot (1989) in his stock-synthesis model. The model developed for this assessment is an elaboration of the CAGEAN and stock–synthesis models and very similar in structure to models used for assessment of Gulf of Mexico cobia (Williams 2001), South Atlantic red porgy (Anonymous 2002), and South Atlantic black sea bass (Anonymous 2003). Statistical catch-at-age models share many attributes with ADAPT-style tuned and untuned VPAs.

2.2 Methods (Catch–At–Age Model)

A statistical catch-at-age model was used to assess the tilefish population. An initial model run was determined through iterative re-weighting of the likelihood components, with central values of important parameters, until a reasonably balanced fit was obtained to the data. In a second stage of modeling, uncertainty was represented by using a mixed Monte Carlo and bootstrap sampling procedure (MCB). A general description of the assessment model follows, followed by more detailed descriptions of the initial run and the MCB procedure.

2.2.1 Properties of age–structured model

The statistical catch-at-age model for this assessment was implemented in the AD Model Builder (ADMB) software (Otter Research Ltd. 2001) on a microcomputer (ADMB code in Appendix C). A summary of the model equations are in Table 10.

Natural mortality rate

The natural mortality rate was assumed constant over time. A vector of age-dependent M estimates based on Lorenzen (1996) was used as a starting estimate. The age-dependent M vector was then re–scaled based on a fraction of survivors at the oldest age consistent with the findings of Hoenig (1983).

Stock dynamics

The standard Baranov catch equation was applied. This assumes exponential decay in population size due to fishing and natural mortality processes.

Growth/Maturity

Size-at-age and percent-mature-females-at-age were assumed constant across years.

Stock and Recruitment

A Beverton–Holt stock–recruitment model was estimated internally. Estimated recruitments were loosely conditioned on that model. The spawning stock biomass (SSB) was computed as the mature biomass of females, under the assumption of a 50:50 sex ratio.

Biological benchmarks

Biological benchmarks were calculated based on maximum sustainable yield (MSY) estimates from the Beverton-Holt recruitment model. These include biomass at MSY (Bmsy), spawning stock biomass at MSY (SSBmsy), fishing rate at MSY (Fmsy), and exploitation rate at MSY (Emsy).

Fishing

Three fisheries were modeled: commercial handline, commercial longline, and recreational (MRFSS and headboat). Yearly fishing mortality rates and selectivity-at-age patterns were estimated for each fishery. For the recreational fishery, the missing landings data (1961–1980) were treated by fixing values of *F* for those years. A geometric mean *F* for the earliest 3 years (1981–1983) was applied to 1980. The remaining years were then fixed by linear interpolation back in time, such that *F*=0 in 1961.

Selectivity functions

Selectivity was fit parametrically, rather than by estimating independent selectivity values for each age (see Table 10 for details). The parametric approach reduces the number of estimated parameters and imposes theoretical structure on the estimates. The assessment used the logistic model for the commercial longline fishery and the double-logistic model for the remaining fisheries and MARMAP index. There was no information to estimate a unique selectivity for the recreational fishery, so the recreational selectivity was assumed to equal that of the commercial handline. Selectivity of the commercial logbook index was assumed to vary by year as a catch-weighted combination of the estimated commercial longline and handline selectivities.

Discards

The DW believed discards to be negligible. Discards are therefore ignored in the assessment model.

Abundance indices

The model used two separately modeled indices of abundance: a fishery-independent (MARMAP longline) index spanning years 1983–1986 and 1996–2002, and a fishery-dependent (commercial logbook) index spanning years 1992–2002.

Fitting criterion

The fitting criterion was a total likelihood approach in which fishery landings, observed age and length compositions, and the abundance indices were fit to the degree that they are compatible. Landings data and abundance index data were fit using a lognormal likelihood, the value of which is inversely related to the CV. Age and length composition data were fit using a multinomial likelihood. Relative statistical weighting of each likelihood component for the initial run was chosen at the AW after examining many candidate model runs. The criteria for choice were a balance of reasonable fit to all available data and a good degree of biological realism in estimated population trajectory.

Characterization of Uncertainty

Uncertainty was characterized by use of a mixed Monte Carlo and bootstrap sampling procedure in which fixed parameter values, index data, and likelihood component weights were randomly sampled, and the assessment model was fit for each sample. Median values of Monte Carlo/bootstrap results are taken as point estimates of quantities of interest (e.g., benchmark estimates), and the 10^{th} and 90^{th} percentiles are used to characterize uncertainty.

2.2.2 Estimated Parameters

The initial model run estimated 147 parameters. These parameters were estimated in three phases using the ADMB software package. In the first phase, parameters were estimated for virgin recruitment (1), index catchability coefficients (2), and average fully selected fishing mortality for each fishery (3). In the second phase, parameters for selectivity (6), annual fully selected fishing mortality (90), and annual recruitment deviations (41) were added to the optimization procedure. In the third phase, parameters were added that control the descending limb of double logistic selectivities (4).

2.3 Likelihood Component Weights

The performance of each individual model run was evaluated based on its fit to the observed data. These data sets include three time series of landings, two abundance indices, two age compositions from commercial fisheries, and three length compositions from commercial fisheries and the MARMAP survey. Landings and indices were fit using a lognormal likelihood, and age and length compositions were fit using a multinomial likelihood. The influence of each data set on the overall model fit is determined by the specification of the error terms in each likelihood component. In the case of lognormal likelihoods, the annual coefficient of variation influences the fit, and in the case of multinomial likelihoods, the annual sample size influences the fit. These terms determine the influence of each year of data relative to other years of the same data source. However, the relative influence of different components can only be treated by re-weighting each likelihood. An objective determination of these weights is an unsolved problem in statistical modeling. In this case, the weights were determined by examination of overdispersion, model mis-specification (e.g. runs of residuals), and the general reliability of each data source (i.e. the AW’s understanding of information content).

The AW reduced the number of weights to be examined by grouping likelihood components based on their type, scale, and method of collection. For example, the three fisheries landings data were grouped, so that a single weight was applied to all three components. Similarly the age composition components were grouped and the length composition components were grouped. The two indices were assigned the same weight in the initial model run, but index weights were allowed to vary independently in subsequent Monte Carlo/bootstrap runs, because each index had a unique set of merits and possible shortcomings as a measure of relative abundance. The model also contains a likelihood component for the annual recruitment deviation parameters, which were constrained to follow a Beverton-Holt stock–recruit curve. The six resulting weights (landings, two indices, age compositions, length compositions, and recruitment deviations) were adjusted in exploratory runs of the model to find a balanced fit to all the data, based on the expertise of the AW.

After many exploratory runs, the recruitment deviation weight was fixed at a value of 400. This value allowed the annual recruitment deviations to vary substantially, while preventing any extreme single parameter estimates (i.e. on the order of 100 times the average). This reduced the number of weights that needed to be examined for overall model fit to five.

2.4 Initial Run (Catch–At–Age Model)

This section describes the initial model run, upon which the MCB runs were based.

2.4.1 Fixed parameters

Natural mortality in the initial model run was fixed at the Lorenzen (1996) age-dependent estimates of *M*, scaled so that the cumulative survival to the oldest observed age is 1.4% (see Section 1.1.3). The value of steepness (*h*), a parameter in the stock–recruit curve, was fixed at $h = \exp(-0.33) \approx 0.72$ based on meta-analyses (see Section 2.5.1). It is believed this stock was lightly exploited in the years prior to 1961, the first year in the model. Therefore in the first model year, spawning stock biomass (SSB) was effectively fixed near the virgin level by heavily penalizing the model for deviating from a starting year condition of SSB(1961)/SSB(virgin) = 0.9. The parameters that control this ratio include the virgin recruitment, recruitment deviation in 1961, and fishing mortality parameters in 1961. All other non–estimated parameters were fixed at values described in Section 1 of this report.

2.4.2 Likelihood Component Weights

Many exploratory runs of the assessment model were made. Various weighting schemes were explored extensively with values from 1–1000. The performance of each individual model run was evaluated based on fits to the different data sets: three sets of landings, two sets of abundance indices, two sets of age compositions, and three sets of length compositions. In different runs, each data set was given a higher or lower overall weight, chosen to span the range of extremes.

In many runs, there appeared to be a trade-off between fitting closely to landings and indices. The AW agreed that the year-to-year variations in landings data were more reliable than in index data, and so landings should receive priority (i.e., a higher weight). The AW also agreed that age composition data were the least reliable of the various data sources. In several runs, unrealistic spikes in recruitment estimates indicated that the weight on recruitment deviations needed to be relatively high; that weight was eventually fixed at 400 as described above. Some exploratory runs removed the MARMAP index, because of concerns that the index may not have adequately represented relative abundance (Section 1.1.7). Due to minor differences in gear used by MARMAP during the two periods, runs were made with different catchability coefficients (q) during the two periods covered by the longline gear. But after further consideration, the AW concluded that the MARMAP index should be included and that the two periods used similar enough procedures to justify a single q. Appendix D shows samples of exploratory weighting schemes. After carefully scrutinizing many combinations of weighting schemes, a final weighting scheme was accepted by the AW:

Likelihood Components	Weight
Landings	1000
Commercial logbook index	100
MARMAP Index	100
Age Compositions	10
Length Compositions	10
Recruitment Deviations	400

2.5 Modeling Uncertainty (Catch–At–Age Model)

To represent uncertainty in the assessment, the AW adopted a mixed Monte Carlo and bootstrap approach (MCB). Monte Carlo and bootstrap methods (Efron and Tibshirani 1993; Manly 1997) are often used to characterize uncertainty in ecological modeling, and the mixed approach has been applied successfully in stock assessment (Restrepo et al. 1992; Legault et al. 2001). The approach translates uncertainty in model input into uncertainty in model output, by fitting the model many times with different values of key input parameters. Each time the model is fit, a new value for each key input parameter is chosen from a statistical distribution that represented the state-of-knowledge about that parameter. A chief advantage of the approach is that the results describe a range of possible outcomes, so that uncertainty is characterized more thoroughly than it could be by any single fit or handful of sensitivity fits. A minor disadvantage of the approach is that computational demands are relatively high.

In this assessment, the approach was implemented with the software R (R Foundation for Statistical Computing 2004), which successively created new data input files and called the assessment model for fitting. In each MCB trial, inputs either remained fixed at those values used in the initial run or were selected at random from statistical distributions, as described below. The inputs that varied by MCB trial were the steepness parameter of the stock–recruit curve, the shape parameter of the natural mortality curve, the scale of the natural mortality curve, initial stock biomass, yearly values of indices of abundance, and likelihood weights.

2.5.1 Steepness

Steepness is a parameter in the stock-recruit curve that controls how quickly recruitment approaches the virgin level as spawning stock biomass increases (Table 10). Steepness values are constrained biologically between 0.2 and 1.0, where 0.2 describes a linearly increasing stock–recruit curve and 1.0 describes a flat stock-recruit curve at the virgin level. Attempts were made to estimate steepness in exploratory fits of the assessment model; however, those estimates generally converged to an upper or lower bound on the parameter. Therefore the AW decided that steepness should be fixed as described below.

Myers et al. (1999) examined stock-recruitment parameters for a wide range of species. Rose et al. (2001) pointed out several general life history characteristics for fishes from data provided by Myers et al. (1999). Snowy grouper and tilefish would fall in the periodic spawner category identified by Myers et al. (1999). This category encompassed species that reproduce several times during their lifetime and may vary in their success substantially from one reproductive event to another. The category comprised a broad range of species, from sardines to bluefin tuna. For this assessment, freshwater species and pelagic species were eliminated from the analysis, leaving only marine or anadromous demersal periodic spawners. Rockfish species (*Sebastes* spp.) were also removed since they seem to have uncharacteristically low steepness for marine demersal species. This left 19 species in the periodic spawning category.

The steepness value of their stock-recruitment relationships varied from 0.34 to 0.95. The median of the steepness values was 0.81 and the mean was 0.74. When transformed, these data fit a lognormal distribution with a mean of –0.33289 and a standard deviation of 0.280926.

In the assessment model runs, steepness values were drawn from the estimated lognormal distribution. That is, steepness values (h) were sampled as follows:

$$h = e^x \quad where \quad x \sim N(-0.33289, 0.280926)\,.$$

To avoid the biologically unrealistic limits of steepness (0.2 and 1), this distribution was truncated to range from 0.25 to 0.95.

2.5.2 Natural Mortality Rate

Lorenzen (1996) provided point estimates and 90% confidence intervals for parameters of the natural mortality function ($M_a = \alpha W_a^{\beta}$). Based on a nonparameteric analysis, the shape parameter β was estimated to be –0.305 and the 90% confidence interval was estimated to be [–0.351,–0.257]. In the assessment model runs, the shape parameter was drawn from a uniform distribution that covered the 90% confidence interval.

In addition to uncertainty in the shape parameter, the assessment model included uncertainty in the scale (α) of natural mortality. For any value of the shape parameter β, the natural mortality function M_a was scaled to achieve a given probability of reaching the maximum age. In the MCB trials, the probability of reaching the maximum observed age was chosen from a uniform distribution that ranged from 0.1% to 5.0% (Quinn and Deriso 1999).

2.5.3 Initial Stock Status

By using a strong constraint, the initial spawning stock biomass relative to virgin biomass was effectively fixed in the initial model run at 90% of that at carrying capacity [SSB(1961) = 0.9SSB(virgin)], to reflect the light level of exploitation prior to the assessment period (i.e., before 1962). Because many factors other than exploitation affect abundance (such as environmental and ecological conditions), a wide range of initial stock biomass levels was examined in the MCB trials. The initial spawning stock biomass was drawn from a uniform distribution that ranged from 0.5 to 1.3 of SSB(virgin) [expected value = 0.9SSB(virgin)].

2.5.4 Indices of Abundance

To account for uncertainty in the indices of abundance, the AW used a parametric bootstrap with multiplicative lognormal error (Quinn and Deriso 1999). To implement this approach in the MCB trials, random variables ($x_{u,y}$) were drawn for each year y of index u from a normal distribution with mean 0 and variance $\sigma^2_{u,y}$ [that is, $x_{u,y} \sim N(0, \sigma^2_{u,y})$]. Yearly index observations were then perturbed with the following equation:

$$U_{u,y} = \hat{U}_{u,y}[\exp(x_{u,y}) - \sigma^2_{u,y}/2]\,.$$

The term $\sigma^2_{u,y}/2$ represents a bias correction, which centers the multiplicative error on a value of one. The year-specific standard deviations ($\sigma_{u,y}$) were set equal to the corresponding estimated coefficients of variation (Table 7), scaled to a maximum of 0.3. The values were scaled because, at values less than 0.3, the CV in arithmetic space approximately equals the standard deviation in log space, but that relationship breaks down at higher values.

2.5.5 Likelihood Component Weights

Relative likelihood weights assigned to the various data components influence model fidelity to each component. Many combinations of likelihood weights are conceivable, and a definitive choice among them may be impossible. To capture this uncertainty, MCB trials used weights selected at random from a uniform distribution centered on the values used in the initial run and ranging ± 25%.

2.5.6 Number of Replicates and Acceptance Criteria

To apply the mixed Monte Carlo/bootstrap (MCB) procedure, the model was fit a total of 1100 times (including the initial run), where each trial used a different set of parameter values, input data, and weighting scheme, generated as described above. Inspection of the results revealed that two trials did not converge properly. Those were subsequently discarded, and results are presented for the remaining n=1098 trials. Median values are used to demonstrate central tendencies of the results, and 10^{th} and 90^{th} percentiles are used as an empirical 80% interval to demonstrate variability.

2.6 Results (Catch–At–Age Model)

Section (2.6.1) shows fits of the initial run only. The remaining results sections (2.6.3–2.6.8) show summary results from the MCB runs.

2.6.1 Model Fit (Initial Run)

Predicted numbers at age from the initial model run are illustrated in Table 11. Figure 22 shows the predicted stock–recruitment curve, with the time series overlaid. SSB was estimated to be highest in the early part of the time series and lowest in more recent years. In general, the time series follows the estimated recruitment curve, but with some large, positive residuals near the middle of the time series.

As mentioned earlier, parameter estimates (initial run estimates in Appendix E) are influenced by the likelihood component weights, and the initial likelihood component weights were chosen to fit the various data sources in accordance with the AW's knowledge about information content of each data set. The AW decided to heavily weight the landings, and consequently the model fits the observed landings data closely (Figure 23 – Figure 25).

The fit to the abundance indices (Figure 26 - Figure 27) fails to mimic the rapid annual changes, but rather fits a smooth curve through the data. This is typical of such models when fit to relatively noisy abundance indices, and is considered more biologically realistic than a tight fit. In all cases, the model appears to be picking up the general trend indicated by the indices.

The fits to the age and length composition data are shown in Figure 28 – Figure 32. In general, the fits to the age composition data are poor. Predicted age compositions are skewed more toward younger ages as compared to observed age compositions, which is consistent with the perceived bias toward older fish in the observed ages (Figure 21). The model gives relatively little weight to age compositions, because the age compositions were believed to be the least reliable. The fits to the length composition data appear to be adequate. Of the three length composition data sources, the best fits are to those describing commercial longline. This is not surprising given that the length composition sample sizes for commercial longline are much greater (by orders of magnitude) than those for commercial handline and MARMAP longline.

2.6.2 Selectivity (MCB Trials)

The estimates of selectivity from the MCB runs are shown in Figure 33 – Figure 35. The handline and longline selectivities were estimated as knife-edge, with full selection near age six. Almost all females are mature by age six (Figure 8). The handline selectivity, though modeled as double logistic, was estimated to be logistic (a special case of the double logistic model). Variability in the handline and longline selectivity estimates was very low. MARMAP gear selectivities were estimated to be dome-shaped. The ascending portion of estimated MARMAP selectivities had low variability, but the descending portion was quite variable, probably due to a lack of MARMAP age composition data and small sample sizes in MARMAP length composition data.

2.6.3 Estimated Time Series (MCB Trials)

The range of the estimated time series of exploitation rate, fishing mortality rate, total landings, recruits, spawning stock biomass, and total biomass are shown in Figure 36 – Figure 41. The medians of those time series are listed in Table 12. Prior to 1980, the tilefish fishery was relatively small. It increased dramatically in the early 1980s, with a peak in 1982 in exploitation rate, fishing mortality rate, and landings. As exploitation increased in the early 1980s, the estimated spawning stock biomass and total biomass declined until about 1987, and has been relatively level since.

2.6.4 Stock and Recruitment (MCB Trials)

The estimated Beverton-Holt stock-recruit relationship (Figure 42) is perhaps even more uncertain than illustrated, as the range of curves is largely governed by the assumptions made about the distribution of the steepness parameter (Section 2.5.1).

As is often the case, there is little observed information for estimating the earliest and latest recruitment points, and therefore these points tend to rely more heavily on the stock-recruit relationship. The model predicts large, positive residuals in the middle of the time series, which are probably necessary for the model to match subsequent length composition data and peaks in landings data.

2.6.5 Per–recruit Analyses (MCB Trials)

Static spawning potential ratio for each year was based on an equilibrium age-structure and the age-specific total exploitation from the combined fisheries (Figure 43). Estimates of the static SPR have generally ranged between 0.1 and 0.3 since the early 1980s.

After each MCB trial, per-recruit analyses were computed using the average exploitation ratios among the three fisheries from the last three years (1999–2002) and their respective selectivity patterns. Estimates of SSB-per-recruit and yield-per-recruit are shown in Figure 44 and Figure 45. These figures also indicate the medians of selected benchmarks described in Section 2.6.7 (Emax or Fmax; E40% or F40%; E30% or F30%; and Emsy or Fmsy) and the median of the 2002 harvest rate.

2.6.6 Equilibrium Analyses (MCB Trials)

As in the per-recruit analysis above, equilibrium analyses were computed using the average exploitation ratios among the three fisheries from the last three years (1999–2002) and their respective selectivity patterns. In addition, equilibrium analyses take into account the estimated stock-recruit relationship. The equilibrium SSB and yield as functions of exploitation are shown in Figure 46 and Figure 47. These figures also indicate the medians of selected benchmarks (Emax or Fmax; E40% or F40%; E30% or F30%; and Emsy or Fmsy).

2.6.7 Management Benchmarks (MCB Trials)

Management benchmarks (Table 13) were computed in terms of exploitation rates, based on ages 1+. This approach is considered to be more representative of overall fishing pressure than computation in terms of fully-selected fishing mortality rates. Benchmarks examined include maximum yield-per-recruit (Emax), spawning potential ratio of 0.3 and 0.4 (E30% and E40%, respectively), and maximum sustainable yield (Emsy). Also examined were the analogous fishing-mortality-rate benchmarks (Fmax, F30%, F40%, and Fmsy), based on population-weighted Fs of ages 2+. Table 13 includes the estimates of maximum sustainable yield (MSY), spawning stock biomass at MSY (SSBmsy), and total biomass at MSY (Bmsy).

2.6.8 Exploitation and Stock Status in 2002 (MCB Trials)

Exploitation status in 2002 was analyzed relative to the maximum fishing mortality threshold (MFMT; limit reference point in *F*). The MFMT was assumed equal to Emsy or Fmsy, depending on the measure of exploitation. Stock status in 2002 was estimated relative to SSBmsy and to two *ad hoc* measures of maximum spawning size threshold (MSST). The first (MSST1) was computed as a fraction *c* of SSBmsy. Restrepo et al. (1998) recommend a default definition for that fraction: $c=\max(1-M,1/2)$, where *M* is the natural mortality rate. However, this definition does not account for age-dependent *M*, as was used in this assessment. Hence to accommodate the default definition, a constant *M* was computed that would correspond to an age-dependent *M*, by providing the same proportion of survivors at the maximum observed age [$M = -\log(P)/A$, where *P* is the proportion survivors at maximum observed age *A*]. This value of constant *M* was computed uniquely for each of the MCB runs. The value of *c* ranged from 0.87 to 0.94, with a median of 0.93. Because these values were near one (i.e., MSST1 was near SSBmsy), a second MSST was considered, defined as MSST2 = 0.75SSBmsy.

Figure 48 suggests overfishing of tilefish (F>MFMT) began in the early 1980's and has since continued in most years. Figure 49 shows the population response to fishing with a steady population decline to levels near SSBmsy starting in the mid-1980's.

Relative measures of exploitation and SSB estimated for the last year (2002) are shown in Figure 50 and Figure 51. The median value of E(2002)/Emsy is 1.55, with a 10^{th} to 90^{th} percentile range of [0.77,3.25]. The median value of F(2002)/Fmsy is 1.53, with a range of [0.72,3.31]. The median value of SSB(2002)/SSBmsy is 0.95, with a range of [0.61,1.53]. The median value of SSB(2002)/MSST1 is 1.02, with a range of [0.65,1.67]. The median value of SSB(2002)/MSST2 is 1.27, with a range of [0.81,2.04]. From Figure 50 and Figure 51, it appears likely that overfishing was occurring in 2002; however it is less clear whether the stock was overfished in 2002. The assessment suggests that, despite overfishing, the stock has remained near SSBmsy since the mid-1980s due to a few strong recruitment events.

The data do not include an abundance index that covers the entire assessment period. To determine stock status, therefore, the assessment must rely in part on other data sources, such as average weight and length from landings as well as the observed age and length composition data. This was explored in the following way: Assuming an equilibrium age-structure, Figure 52 shows the predicted average weight of landed fish from commercial fisheries as a function of stock status. The average observed weights from commercial fisheries in the most recent years (2000–2002) are consistent with a stock between 50% and 100% of SSBmsy (Figure 52), if the age structure were in equilibrium. The length composition data from the most recent years suggest that tilefish SSB is near SSBmsy. Figure 53 shows observed length distributions, which are skewed toward smaller fish as compared to the equilibrium virgin length composition, but correspond more closely to the predicted length composition at SSBmsy.

2.7 Projections (Catch–At–Age Model)

2.7.1 Projection Methods

The stock was projected for 25 years beyond the assessment period (2003–2027). Projections were implemented as part of the MCB routine, so that the fixed and estimated parameters from each run were carried forward in n=1098 projections. In each projection, recruitment was modeled using a nonparametric bootstrap procedure. This procedure computed mean yearly recruitment from the estimated stock–recruit curve, to which recruitment deviations were added. These recruitment deviations were selected at random from recruitment residuals estimated in the assessment period (1962–2002). Therefore, an underlying assumption is that past recruitment typifies future recruitment.

The stock was projected under two different scenarios of fishing mortality. In the first, the fishing mortality rate was set to zero ($F=0$). In the second, the fishing mortality rate was set to the current fishing mortality rate ($F=Fnow$), defined as the geometric mean of the fully-selected Fs in the last three years of the assessment period (2000–2002). The fully-selected F was then divided among the three fisheries according to their current proportions.

2.7.2 Projection Results

Under F=0, the median projection depicts a tilefish stock that recovers to SSBmsy within one year (Figure 54, Table 14). Under $F=Fnow$, the median projection depicts a spawning stock biomass that initially declines and then stabilizes near 72% of SSBmsy, with a yield that decreases toward MSY (Figure 55, Table 15). If projections were extended, yield would continue to decline to a level somewhere below MSY.

3. Surplus–Production Model

3.1 Overview (Production Model)

An age-aggregated production model was also fit to available data. Production models are particularly useful when data are inadequate to classify individuals based on age or size. They are also a useful tool for exploration of management consequences because their relative simplicity makes it easier to understand the details of how manipulations are affecting results and performance. Their simplicity may also allow them to more powerfully fit observations that lack age or size structure, for example landings and abundance indices. However, the age or size structure of the population can give useful insight into its history and status. Consequently, when reliable data are available on the age, size, or both of individuals in a population, an age- or size-structured model can often be more informative. That is particularly true when data on relative abundance are uncertain or fragmented, as in this assessment.

Given the above, the workshop was hesitant to apply such a model to this stock. Ultimately, the group decided that application of such a model should be examined in the course of the workshop, and that its results would have to pass critical examination before being accepted.

3.2 Methods (Production Model)

In this task, the Prager (1994) implementation of the Graham-Schaefer production model was used. This is a continuous time formulation, conditioned on catch, that does not assume equilibrium conditions. By conditioning on catch, the landings data are assumed more precise than the abundance indices. The model uses more than one abundance index by assuming that indices are correlated measures of stock abundance and that differences between indices can be considered sampling error. The Schaefer (1954; 1957) form of the production model, used here, assumes B_{MSY} = 0.5K, where K is the carrying capacity of the stock (virgin stock size). The Schaefer form is often used as a default because of its theoretical simplicity and because it is considered a central case among possible shapes of production model. The ASPIC software of Prager (1995) was used.

Data used for production modeling were total landings and two abundance indices, the MARMAP horizontal longline index and the commercial logbook index.

3.3 Results (Production Model)

Fits to the index data series are quite approximate, as the indices have sharp year-to-year changes not expected in a slow–growing species with an extended age structure (Figure 56). The indices are not well correlated with one another, so that fitting one necessarily results in lack of fit to another (see correlation matrix in ASPIC output file, Appendix F).

Estimates of MSY, stock status, and related parameters from the production model are given in Table 16.

In general the production model is much more optimistic about the stock's status than the age-structured model. This is apparent both in Figure 57 (which estimates rapid population increases) and in the estimates themselves, which portray a stock at high levels (B_{2003} = 1.8 B_{MSY}) being fished at a relatively low rate (F_{2002} = 0.4 F_{MSY}). This picture of the stock is derived from the MARMAP index (Figure 56A), which suggest a doubling of the stock between the mid-1980s and late 1990s. However, the AW did not believe (on biological grounds) that this stock could grow that rapidly, and noted that the most recent (2000–2002) index values suggest a much more moderate increase, to an average stock level about 30% higher than that in the mid–1980s.

The production–model estimates come about in part because the available indices show periods of rapid increase and decline. The AW noted that the indices are subject to sampling error and are relatively short. The age- and length-composition data used in the age-structured model serve to moderate the apparent vigor of the population represented in the MARMAP abundance indices. The production model does not have the advantage of using those data.

The group concluded that the production model fit, while a worthwhile exercise, should not be used in this assessment.

4. Research Recommendations

1. Ageing discrepancies between laboratories should be resolved. State and Federal investigators should continue efforts to standardize techniques and resolve the systematic discrepancies in age determinations. Additional research should be undertaken to verify and validate age determinations.

2. Sampling programs are required to quantify discard rates. Research should also be initiated to identify management strategies that could reduce discard mortality. Discarding may become an increasingly important concern as the stock recovers and compliance with measures such as trip limits become more difficult.

3. Fishery-independent data collected by the MARMAP program are important to understanding the dynamics of this population, and the National Research Council has recommended that fishery-independent data play a more important role in stock assessment. However, it has been noted that the MARMAP sampling programs do not having ideal extent, both in area coverage and in sampling intensity, for many important species in the South Atlantic snapper–grouper complex. It would be highly desirable for the MARMAP program to receive sufficient funding to expand its coverage and thus provide improved measures of stock abundance.

4. Recent West Coast stock assessments were criticized by the U.S. General Accounting Office (GAO 2004) for not including at least one NMFS (i.e., fishery-independent) data source of sufficient scope and accuracy collected from an unbiased, statistical, and scientifically designed program. Effort should be devoted toward developing an independent data source for the South Atlantic snapper-grouper complex that meets the requirements outlined in the Stock Assessment Improvement Plan and the 1998 National Research Council report on improving stock assessment. This could be done through the MARMAP program or otherwise.

5. Representative age, length, and sex composition data are needed for all fisheries, seasons, and areas. Sampling should be distributed according to the pattern of landings. Initial sampling targets are suggested as 20 age structure samples per age and 5 length samples per age sample. This provides approximate tilefish sampling targets of 1000 age structures and 5,000 lengths.

6. Additional life history and biological research is needed, especially that which covers the full geographic range of the species. Among other items, fecundity and reproductive research is needed (batch fecundity and frequency at age and/or size).

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5. Tables

Table 1:Summary of tilefish life history as used in the statistical catch-at-age model.

Age (years)	Female Total Length (mm)	Sexes Combined Total Length (mm)	Female Weight (kg)	Sexes Combined Weight (kg)	Proportion Females	Female Maturity	Lorenzen M (Based on sexes combined weight)	Scaled M to 1.4% Survival to Maximum Observed Age
0	116.1	116.2	0.01	0.01	0.5	0.000	1.68	0.39
1	212.9	215.2	0.09	0.09	0.5	0.000	0.93	0.21
2	293.4	299.8	0.25	0.26	0.5	0.003	0.67	0.16
3	360.5	371.9	0.47	0.52	0.5	0.025	0.55	0.13
4	416.3	433.4	0.74	0.84	0.5	0.172	0.47	0.11
5	462.9	485.8	1.04	1.21	0.5	0.623	0.42	0.10
6	501.6	530.6	1.34	1.60	0.5	0.929	0.39	0.09
7	533.9	568.7	1.63	1.99	0.5	0.990	0.36	0.08
8	560.7	601.3	1.90	2.37	0.5	0.999	0.35	0.08
9	583.1	629.1	2.15	2.73	0.5	1.000	0.33	0.08
10	601.7	652.7	2.37	3.07	0.5	1.000	0.32	0.07
11	617.2	673.0	2.57	3.38	0.5	1.000	0.31	0.07
12	630.2	690.2	2.75	3.66	0.5	1.000	0.30	0.07
13	640.9	704.9	2.90	3.91	0.5	1.000	0.30	0.07
14	649.9	717.4	3.03	4.13	0.5	1.000	0.29	0.07
15	657.3	728.1	3.14	4.33	0.5	1.000	0.29	0.07
16	663.6	737.3	3.23	4.51	0.5	1.000	0.28	0.07
17	668.7	745.0	3.31	4.66	0.5	1.000	0.28	0.07
18	673.0	751.7	3.38	4.79	0.5	1.000	0.28	0.06
19	676.6	757.3	3.44	4.90	0.5	1.000	0.28	0.06
20	679.6	762.2	3.48	5.00	0.5	1.000	0.27	0.06
21	682.1	766.3	3.53	5.09	0.5	1.000	0.27	0.06
22	684.2	769.8	3.56	5.16	0.5	1.000	0.27	0.06
23	685.9	772.8	3.59	5.23	0.5	1.000	0.27	0.06
24	687.3	775.4	3.61	5.28	0.5	1.000	0.27	0.06
25+	688.5	777.5	3.63	5.33	0.5	1.000	0.27	0.06

Table 2: Commercial tilefish landings (mt) by state and by fishing gear for years, 1962-2002.

Year	Florida & Georgia (mt)	South Carolina (mt)	North Carolina (mt)	Total (mt)
1962	1.43	0.00	0.00	1.43
1963	1.43	0.00	0.00	1.43
1964	0.17	0.00	0.00	0.17
1965	10.97	0.00	0.00	10.97
1966	2.06	0.00	0.00	2.06
1967	4.88	0.00	0.00	4.88
1968	2.99	0.00	0.00	2.99
1969	2.44	0.00	0.00	2.44
1970	4.84	0.00	0.00	4.84
1971	8.96	0.00	0.00	8.96
1972	2.78	0.00	0.00	2.78
1973	19.22	0.00	0.00	19.22
1974	42.81	0.00	0.00	42.81
1975	73.42	0.01	0.08	73.51
1976	70.90	0.08	0.59	71.57
1977	34.35	1.13	7.92	43.40
1978	45.56	3.01	0.57	49.14
1979	61.70	1.48	0.35	63.52
1980	97.67	7.12	0.77	105.56
1981	407.81	26.81	1.04	435.66
1982	1391.86	102.40	1.11	1495.37
1983	624.51	195.77	5.51	825.79
1984	361.97	174.15	25.15	561.27
1985	433.78	74.79	14.47	523.05
1986	382.77	142.33	26.71	551.82
1987	86.01	39.22	7.07	132.30
1988	199.30	35.01	35.33	269.64
1989	331.42	59.98	28.09	419.49
1990	301.09	80.22	34.73	416.03
1991	339.57	53.06	60.09	452.71
1992	279.26	109.76	93.25	482.27
1993	361.65	88.56	70.15	520.36
1994	252.36	78.72	66.65	397.73
1995	221.48	69.59	43.62	334.70
1996	110.88	32.04	25.90	168.82
1997	99.22	62.15	18.17	179.54
1998	129.25	42.88	10.80	182.94
1999	190.34	55.71	2.28	248.32
2000	279.36	67.62	7.76	354.74
2001	126.30	59.49	9.27	195.05
2002	114.12	73.40	1.68	189.21

Table 2 (cont'd): Commercial tilefish landings (mt) by state and by fishing gear for years 1962-2002.

Year	Handline (mt)	Longline (mt)	Other (mt)	Total (mt)
1962	1.43	0.00	0.00	1.43
1963	1.43	0.00	0.00	1.43
1964	0.17	0.00	0.00	0.17
1965	10.97	0.00	0.00	10.97
1966	2.06	0.00	0.00	2.06
1967	4.88	0.00	0.00	4.88
1968	2.99	0.00	0.00	2.99
1969	2.44	0.00	0.00	2.44
1970	4.84	0.00	0.00	4.84
1971	8.96	0.00	0.00	8.96
1972	2.78	0.00	0.00	2.78
1973	19.22	0.00	0.00	19.22
1974	42.81	0.00	0.00	42.81
1975	73.44	0.02	0.05	73.51
1976	70.39	0.84	0.34	71.57
1977	7.86	31.01	4.53	43.40
1978	11.03	38.10	0.00	49.14
1979	11.87	51.65	0.00	63.52
1980	23.78	81.78	0.00	105.56
1981	79.73	355.93	0.00	435.66
1982	237.01	1258.36	0.00	1495.37
1983	103.59	722.19	0.00	825.79
1984	72.64	488.63	0.00	561.27
1985	70.54	452.51	0.00	523.05
1986	69.28	482.49	0.05	551.82
1987	14.80	117.50	0.00	132.30
1988	32.78	236.85	0.00	269.64
1989	56.08	363.41	0.00	419.49
1990	49.89	366.15	0.00	416.03
1991	57.01	395.70	0.00	452.71
1992	45.79	436.48	0.00	482.27
1993	84.69	435.66	0.00	520.36
1994	45.59	324.06	28.09	397.73
1995	41.46	268.40	24.84	334.70
1996	16.58	142.66	9.57	168.82
1997	15.46	154.90	9.18	179.54
1998	15.56	162.70	4.68	182.94
1999	16.57	228.71	3.04	248.32
2000	26.11	326.22	2.41	354.74
2001	6.39	188.01	0.65	195.05
2002	15.57	173.57	0.06	189.21

Table 3: Commercial tilefish landings in metric tons by fishing gear, 1962-2002.

Year	Handline	Longline	Other	Total
1962	1.43	0.00	0.00	1.43
1963	1.43	0.00	0.00	1.43
1964	0.17	0.00	0.00	0.17
1965	10.97	0.00	0.00	10.97
1966	2.06	0.00	0.00	2.06
1967	4.88	0.00	0.00	4.88
1968	2.99	0.00	0.00	2.99
1969	2.44	0.00	0.00	2.44
1970	4.84	0.00	0.00	4.84
1971	8.96	0.00	0.00	8.96
1972	2.78	0.00	0.00	2.78
1973	19.22	0.00	0.00	19.22
1974	42.81	0.00	0.00	42.81
1975	73.44	0.02	0.05	73.51
1976	70.39	0.84	0.34	71.57
1977	7.86	31.01	4.53	43.40
1978	11.03	38.10	0.00	49.14
1979	11.87	51.65	0.00	63.52
1980	23.78	81.78	0.00	105.56
1981	79.73	355.93	0.00	435.66
1982	237.01	1258.36	0.00	1495.37
1983	103.59	722.19	0.00	825.79
1984	72.64	488.63	0.00	561.27
1985	70.54	452.51	0.00	523.05
1986	69.28	482.49	0.05	551.82
1987	14.80	117.50	0.00	132.30
1988	32.78	236.85	0.00	269.64
1989	56.08	363.41	0.00	419.49
1990	49.89	366.15	0.00	416.03
1991	57.01	395.70	0.00	452.71
1992	45.79	436.48	0.00	482.27
1993	84.69	435.66	0.00	520.36
1994	45.59	324.06	28.09	397.73
1995	41.46	268.40	24.84	334.70
1996	16.58	142.66	9.57	168.82
1997	15.46	154.90	9.18	179.54
1998	15.56	162.70	4.68	182.94
1999	16.57	228.71	3.04	248.32
2000	26.11	326.22	2.41	354.74
2001	6.39	188.01	0.65	195.05
2002	15.57	173.57	0.06	189.21

Table 4: Commercial tilefish landings in metric tons as distributed among two major fishing gears, 1962-2002.

Year	Handline	Longline	Total
1962	1.43	0.00	1.43
1963	1.43	0.00	1.43
1964	0.17	0.00	0.17
1965	10.97	0.00	10.97
1966	2.06	0.00	2.06
1967	4.88	0.00	4.88
1968	2.99	0.00	2.99
1969	2.44	0.00	2.44
1970	4.84	0.00	4.84
1971	8.96	0.00	8.96
1972	2.78	0.00	2.78
1973	19.22	0.00	19.22
1974	42.81	0.00	42.81
1975	73.49	0.02	73.51
1976	70.73	0.85	71.57
1977	8.78	34.62	43.40
1978	11.03	38.10	49.14
1979	11.87	51.65	63.52
1980	23.78	81.78	105.56
1981	79.73	355.93	435.66
1982	237.01	1258.36	1495.37
1983	103.59	722.19	825.79
1984	72.64	488.63	561.27
1985	70.54	452.51	523.05
1986	69.29	482.53	551.82
1987	14.80	117.50	132.30
1988	32.78	236.85	269.64
1989	56.08	363.41	419.49
1990	49.89	366.15	416.03
1991	57.01	395.70	452.71
1992	45.79	436.48	482.27
1993	84.69	435.66	520.36
1994	49.05	348.68	397.73
1995	44.79	289.91	334.70
1996	17.58	151.24	168.82
1997	16.29	163.24	179.54
1998	15.97	166.97	182.94
1999	16.78	231.55	248.32
2000	26.29	328.45	354.74
2001	6.42	188.64	195.05
2002	15.58	173.63	189.21

Table 5: Recreational tilefish landings in numbers and weight, 1981-2002.

	Headboat		MRFSS (A+B1+B2)	
Year	Number.	metric ton	Number	Metric Ton
1981	94	0.2	0	0.0
1982	12	0.0	0	0.0
1983	0	0.0	367	1.5
1984	0	0.0	1648	0.3
1985	0	0.0	20960	21.0
1986	0	0.0	46	0.1
1987	10	0.0	33	0.0
1988	0	0.0	900	1.8
1989	10	0.0	0	0.0
1990	14	0.0	48	0.1
1991	0	0.0	65	0.1
1992	20	0.0	1768	3.6
1993	0	0.0	700	1.4
1994	8	0.0	2607	7.2
1995	0	0.0	0	0.0
1996	0	0.0	1114	1.8
1997	190	0.4	6915	12.7
1998	0	0.0	472	1.0
1999	5	0.0	1952	3.6
2000	0	0.0	3896	6.8
2001	0	0.0	3150	12.2
2002	0	0.0	2036	4.9

Table 6: Commercial and recreational tilefish landings and associated coefficient of variation (CV).

	Commercial (mt)		Recreational (number *1000)			CV's		
Year	Handline	Longline	Headboat	MRFSS	Total	Handline	Longline	MRFSS
1962	1.430	0.000				0.5	0.5	
1963	1.430	0.000				0.5	0.5	
1964	0.168	0.000				0.5	0.5	
1965	10.975	0.000				0.5	0.5	
1966	2.060	0.000				0.5	0.5	
1967	4.878	0.000				0.5	0.5	
1968	2.986	0.000				0.5	0.5	
1969	2.439	0.000				0.5	0.5	
1970	4.836	0.000				0.5	0.5	
1971	8.957	0.000				0.5	0.5	
1972	2.775	0.000				0.5	0.5	
1973	19.217	0.000				0.5	0.5	
1974	42.807	0.000				0.5	0.5	
1975	73.431	0.000				0.5	0.5	
1976	70.307	0.673				0.5	0.5	
1977	6.729	28.748				0.5	0.5	
1978	11.035	38.105				0.5	0.5	
1979	11.871	51.653				0.5	0.5	
1980	23.777	81.779				0.5	0.5	
1981	79.728	355.931	0.094	0.000	0.094	0.5	0.5	0.711
1982	237.010	1258.362	0.012	0.000	0.012	0.5	0.5	0.711
1983	103.592	722.194	0.000	0.367	0.367	0.5	0.5	1.000
1984	72.642	488.629	0.000	1.648	1.648	0.5	0.5	0.774
1985	70.537	452.511	0.000	20.960	20.960	0.460	0.460	0.586
1986	69.288	482.532	0.000	0.046	0.046	0.420	0.420	1.000
1987	14.796	117.504	0.010	0.033	0.043	0.380	0.380	1.000
1988	32.783	236.853	0.000	0.900	0.900	0.340	0.340	0.556
1989	56.084	363.409	0.010	0.000	0.010	0.300	0.300	0.711
1990	49.888	366.145	0.014	0.048	0.062	0.260	0.260	0.493
1991	57.010	395.703	0.000	0.065	0.065	0.220	0.220	0.651
1992	45.791	436.484	0.020	1.768	1.788	0.180	0.180	0.548
1993	84.693	435.665	0.000	0.700	0.700	0.140	0.140	1.000
1994	49.051	348.681	0.008	2.607	2.615	0.1	0.1	0.411
1995	44.787	289.915	0.000	0.000	0.000	0.1	0.1	0.711
1996	17.582	151.237	0.000	1.114	1.114	0.1	0.1	0.961
1997	16.294	163.242	0.190	6.915	7.105	0.1	0.1	0.647
1998	15.966	166.971	0.000	0.472	0.472	0.1	0.1	1.010
1999	16.777	231.547	0.005	1.952	1.957	0.1	0.1	0.620
2000	26.290	328.453	0.000	3.896	3.896	0.1	0.1	0.643
2001	6.416	188.636	0.000	3.150	3.150	0.1	0.1	0.449
2002	15.580	173.628	0.000	2.036	2.036	0.1	0.1	0.454

Note: Commercial landings by other gear are distributed proportionately between handline and longline.

Table 7: Indices of abundance and associated coefficient of variation (CV) for tilefish.

Years	MARMAP Horizontal Longline	Commercial Logbook	MM Horiz. Longline (CV)	Logbook (CV)
1983	0.691	NA	1.507	NA
1984	0.813	NA	1.506	NA
1985	0.459	NA	1.760	NA
1986	0.354	NA	1.697	NA
1987	NA	NA	NA	NA
1988	NA	NA	NA	NA
1989	NA	NA	NA	NA
1990	NA	NA	NA	NA
1991	NA	NA	NA	NA
1992	NA	1.199	NA	0.121
1993	NA	1.055	NA	0.095
1994	NA	0.833	NA	0.101
1995	NA	0.940	NA	0.103
1996	0.860	0.601	2.332	0.113
1997	2.245	0.791	1.369	0.111
1998	1.306	0.935	1.357	0.118
1999	1.879	1.267	1.335	0.111
2000	0.576	1.533	1.643	0.099
2001	1.241	0.764	1.330	0.108
2002	0.576	1.080	1.212	0.100

Footnote:

Gear	Units
MARMAP Horizontal Longline (gear 87)	Catch per 100 hooks per hour, scaled to mean
Commercial Logbook	Metric tons per hook-day, scaled to mean

Table 8: Tilefish length compositions from commercial longline and handline gears, and from MARMAP horizontal longline gear.

Tilefish Commercial Longline Annual Length Compositions

Year	N	345	375	405	435	465	495	525	555	585	615	645	675	705	735	765	795	825	855	885	915	945	975	1005
1984	2352	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.03	0.03	0.06	0.08	0.11	0.12	0.10	0.09	0.08	0.07	0.05	0.03	0.03	0.02	0.01	0.02
1985	5037	0.00	0.00	0.00	0.01	0.01	0.03	0.04	0.05	0.07	0.10	0.09	0.11	0.10	0.10	0.09	0.07	0.05	0.04	0.02	0.01	0.00	0.00	0.00
1986	5414	0.00	0.00	0.01	0.03	0.04	0.06	0.05	0.06	0.07	0.09	0.10	0.10	0.08	0.07	0.06	0.04	0.04	0.03	0.02	0.01	0.01	0.01	0.01
1987	542	0.00	0.00	0.01	0.02	0.02	0.04	0.05	0.09	0.08	0.06	0.05	0.04	0.08	0.08	0.07	0.06	0.06	0.02	0.04	0.04	0.03	0.02	0.02
1988	1057	0.00	0.00	0.01	0.04	0.05	0.07	0.14	0.13	0.10	0.07	0.05	0.07	0.05	0.05	0.04	0.03	0.02	0.02	0.02	0.03	0.00	0.01	0.01
1989	766	0.01	0.02	0.03	0.08	0.10	0.11	0.13	0.11	0.08	0.08	0.05	0.03	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
1990	738	0.00	0.00	0.01	0.01	0.03	0.06	0.06	0.10	0.11	0.11	0.09	0.07	0.08	0.06	0.05	0.03	0.03	0.02	0.02	0.01	0.02	0.01	0.01
1991	6088	0.01	0.01	0.04	0.08	0.09	0.07	0.07	0.07	0.09	0.09	0.07	0.06	0.05	0.04	0.04	0.03	0.02	0.01	0.01	0.01	0.00	0.01	0.01
1992	11589	0.00	0.01	0.02	0.04	0.06	0.09	0.11	0.10	0.09	0.08	0.08	0.07	0.06	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.00	0.01
1993	28717	0.00	0.01	0.02	0.06	0.10	0.13	0.13	0.11	0.09	0.07	0.06	0.05	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00
1994	11239	0.00	0.00	0.01	0.04	0.11	0.15	0.15	0.13	0.10	0.07	0.06	0.05	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
1995	8289	0.00	0.00	0.01	0.02	0.04	0.09	0.14	0.15	0.14	0.09	0.08	0.07	0.05	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00
1996	2135	0.00	0.01	0.01	0.02	0.03	0.07	0.10	0.13	0.11	0.10	0.08	0.09	0.08	0.05	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00
1997	2632	0.00	0.00	0.02	0.06	0.06	0.07	0.09	0.10	0.10	0.09	0.08	0.07	0.05	0.05	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01
1998	1713	0.00	0.01	0.01	0.03	0.10	0.15	0.13	0.09	0.10	0.08	0.06	0.05	0.03	0.03	0.03	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00
1999	3722	0.00	0.00	0.01	0.02	0.05	0.10	0.14	0.14	0.11	0.09	0.07	0.06	0.04	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2000	4952	0.00	0.00	0.01	0.03	0.06	0.09	0.11	0.14	0.13	0.11	0.08	0.05	0.04	0.04	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00
2001	2188	0.00	0.01	0.02	0.04	0.07	0.08	0.09	0.09	0.10	0.09	0.08	0.07	0.06	0.05	0.04	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.02
2002	1930	0.00	0.01	0.01	0.03	0.05	0.06	0.08	0.10	0.08	0.09	0.10	0.09	0.08	0.06	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01

Table 8 (cont'd): Tilefish length compositions from commercial longline and handline gears, and from MARMAP horizontal longline gear.

Tilefish Commercial Handline Annual Length Compositions

Year	N	345	375	405	435	465	495	525	555	585	615	645	675	705	735	765	795	825	855	885	915	945	975	1005
1984	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.33
1985	14	0.00	0.00	0.00	0.14	0.00	0.14	0.00	0.07	0.07	0.00	0.00	0.21	0.07	0.07	0.14	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00
1986	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	3	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	68	0.00	0.00	0.00	0.01	0.01	0.01	0.04	0.12	0.12	0.07	0.06	0.09	0.06	0.06	0.06	0.04	0.04	0.06	0.07	0.03	0.01	0.01	0.00
1990	14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.14	0.07	0.21	0.00	0.07	0.00	0.00	0.07	0.00	0.07	0.07	0.00	0.00	0.21
1991	70	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.11	0.13	0.09	0.03	0.13	0.14	0.10	0.06	0.03	0.03	0.01	0.04	0.01	0.01	0.03	0.00
1992	166	0.01	0.01	0.05	0.09	0.12	0.10	0.17	0.14	0.10	0.05	0.02	0.02	0.03	0.03	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.00
1993	54	0.02	0.00	0.02	0.02	0.02	0.02	0.09	0.04	0.09	0.11	0.09	0.06	0.04	0.02	0.06	0.04	0.00	0.04	0.06	0.00	0.06	0.04	0.09
1994	170	0.00	0.00	0.01	0.01	0.04	0.15	0.13	0.15	0.12	0.07	0.12	0.08	0.04	0.05	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
1996	7	0.00	0.29	0.00	0.14	0.29	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	133	0.00	0.00	0.02	0.03	0.06	0.05	0.09	0.09	0.10	0.15	0.07	0.07	0.02	0.07	0.08	0.03	0.05	0.02	0.02	0.00	0.00	0.00	0.00
1998	92	0.00	0.00	0.00	0.01	0.01	0.04	0.02	0.12	0.07	0.14	0.15	0.04	0.05	0.07	0.09	0.04	0.03	0.08	0.01	0.01	0.01	0.00	0.00
1999	119	0.00	0.00	0.03	0.03	0.08	0.08	0.10	0.17	0.13	0.09	0.08	0.04	0.03	0.03	0.03	0.02	0.02	0.03	0.00	0.01	0.00	0.00	0.00
2000	836	0.00	0.00	0.01	0.04	0.08	0.09	0.13	0.15	0.15	0.11	0.06	0.05	0.03	0.02	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00
2001	306	0.01	0.04	0.06	0.07	0.09	0.09	0.09	0.06	0.05	0.06	0.06	0.05	0.09	0.05	0.04	0.01	0.02	0.02	0.02	0.01	0.01	0.00	0.00
2002	422	0.01	0.02	0.05	0.10	0.11	0.10	0.08	0.07	0.08	0.10	0.10	0.04	0.04	0.04	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00

Continued: Table 8: Tilefish length compositions from commercial longline and handline gears, and from MARMAP horizontal longline gear.

Tilefish MARMAP Horizontal Longline Annual Length Compositions

Year	N	345	375	405	435	465	495	525	555	585	615	645	675	705	735	765	795	825	855	885	915	945	975	1005
1983	76	0.00	0.00	0.00	0.00	0.01	0.00	0.04	0.07	0.16	0.03	0.12	0.11	0.08	0.03	0.12	0.09	0.04	0.03	0.01	0.01	0.03	0.00	0.04
1984	161	0.00	0.02	0.01	0.01	0.01	0.02	0.01	0.03	0.03	0.08	0.07	0.06	0.09	0.09	0.08	0.12	0.11	0.04	0.04	0.00	0.02	0.00	0.06
1985	53	0.00	0.00	0.04	0.15	0.25	0.08	0.04	0.06	0.08	0.06	0.06	0.06	0.02	0.02	0.02	0.04	0.02	0.00	0.04	0.00	0.00	0.00	0.00
1986	24	0.00	0.00	0.08	0.04	0.25	0.29	0.04	0.13	0.00	0.04	0.04	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	48	0.00	0.02	0.17	0.08	0.19	0.13	0.15	0.04	0.04	0.04	0.06	0.00	0.02	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	120	0.00	0.01	0.02	0.07	0.10	0.16	0.13	0.13	0.08	0.03	0.06	0.08	0.04	0.03	0.04	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
1998	25	0.00	0.00	0.00	0.00	0.08	0.28	0.24	0.08	0.08	0.12	0.00	0.08	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	157	0.00	0.00	0.01	0.03	0.10	0.12	0.22	0.13	0.11	0.05	0.06	0.03	0.05	0.01	0.03	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00
2000	19	0.00	0.00	0.00	0.16	0.26	0.05	0.05	0.21	0.05	0.05	0.00	0.00	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	49	0.00	0.02	0.02	0.00	0.02	0.10	0.10	0.10	0.08	0.08	0.16	0.10	0.10	0.00	0.00	0.04	0.00	0.04	0.00	0.02	0.00	0.00	0.00
2002	25	0.00	0.00	0.00	0.00	0.08	0.04	0.12	0.04	0.00	0.04	0.08	0.00	0.08	0.08	0.04	0.08	0.16	0.08	0.04	0.00	0.00	0.04	0.00

Table 9: Tilefish age compositions from commercial longline and handline gears.

Tilefish Commerical Longline Annual Age Compositions (NMFS ages only):

Year	N	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25+
1992	97	0	0	0	0.00	0.01	0.08	0.10	0.07	0.13	0.11	0.16	0.11	0.04	0.02	0.02	0.01	0.02	0.02	0.03	0.02	0.01	0.00	0.00	0.01	0.00	0.00
1993	188	0	0	0	0.00	0.00	0.01	0.02	0.11	0.11	0.15	0.18	0.12	0.09	0.05	0.03	0.01	0.03	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.03
1994	8	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.25	0.13	0.00	0.13	0.13	0.00	0.00	0.13	0.00	0.13	0.00	0.00	0.00	0.00	0.00
1995	343	0	0	0	0.00	0.01	0.03	0.08	0.15	0.11	0.14	0.13	0.11	0.06	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.02
1996	181	0	0	0	0.00	0.01	0.02	0.04	0.03	0.02	0.04	0.10	0.14	0.10	0.09	0.10	0.05	0.04	0.02	0.03	0.02	0.02	0.01	0.03	0.02	0.02	0.06
1997	134	0	0	0	0.00	0.00	0.00	0.00	0.03	0.01	0.07	0.09	0.16	0.07	0.07	0.07	0.05	0.07	0.04	0.06	0.04	0.06	0.01	0.01	0.01	0.01	0.03
1998	138	0	0	0	0.00	0.00	0.00	0.01	0.07	0.10	0.08	0.12	0.12	0.07	0.14	0.11	0.05	0.03	0.04	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.01
1999	187	0	0	0	0.00	0.00	0.02	0.02	0.02	0.05	0.07	0.04	0.08	0.11	0.12	0.11	0.06	0.05	0.05	0.04	0.02	0.03	0.01	0.01	0.01	0.01	0.06
2000	281	0	0	0	0.00	0.00	0.00	0.02	0.05	0.04	0.05	0.07	0.07	0.12	0.07	0.09	0.08	0.07	0.03	0.05	0.05	0.02	0.03	0.02	0.01	0.01	0.05
2001	189	0	0	0	0.00	0.01	0.05	0.04	0.06	0.13	0.11	0.14	0.08	0.10	0.07	0.05	0.05	0.03	0.03	0.02	0.01	0.01	0.01	0.00	0.01	0.00	0.01
2002	30	0	0	0	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.10	0.03	0.03	0.07	0.07	0.17	0.10	0.13	0.07	0.00	0.00	0.03	0.00	0.00	0.13

Tilefish Commerical Handline Annual Age Compositions (NMFS ages only):

Year	N	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25+
1992	6	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.17	0.00	0.17	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	1	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
1995	12	0	0	0	0.00	0.00	0.00	0.00	0.08	0.25	0.00	0.08	0.17	0.08	0.00	0.00	0.08	0.00	0.08	0.08	0.00	0.00	0.00	0.08	0.00	0.00	0.00
1997	40	0	0	0	0.00	0.08	0.18	0.20	0.10	0.08	0.05	0.05	0.03	0.05	0.08	0.03	0.00	0.00	0.05	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
1998	58	0	0	0	0.00	0.02	0.02	0.03	0.07	0.07	0.02	0.02	0.03	0.07	0.10	0.09	0.10	0.09	0.03	0.09	0.02	0.05	0.03	0.00	0.00	0.00	0.05
1999	32	0	0	0	0.00	0.00	0.00	0.06	0.09	0.13	0.13	0.13	0.03	0.13	0.09	0.03	0.03	0.03	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
2000	240	0	0	0	0.00	0.00	0.01	0.05	0.12	0.18	0.16	0.09	0.09	0.07	0.06	0.03	0.03	0.03	0.01	0.02	0.01	0.02	0.00	0.01	0.00	0.00	0.01
2001	43	0	0	0	0.00	0.07	0.12	0.02	0.09	0.07	0.26	0.16	0.07	0.02	0.05	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	198	0	0	0	0.03	0.10	0.16	0.12	0.10	0.10	0.08	0.09	0.05	0.04	0.01	0.01	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01

Table 10: General definitions and structure of the statistical catch-at-age model used for tilefish.

General Definitions	Symbol	**Description/Definition**
Year index	y	y = {1961,..,2002}
Age index	a	a = {0,...,A}, where A = 25+
Length bin (mm)	l'	l' = {345,…,1005}, bin size = 30 mm
Fishery index	f	f = {1 handline, 2 longline, 3 recreational}
CPUE index	u	u = {1 MARMAP longline, 2 commercial logbook}
Input Data	Symbol	**Description/Definition**
Mean length-at-age, both sexes	l_a	$l_a = L_\infty\left(1-\exp\left[-K\left(a-t_0\right)\right]\right)$ where parameters L_∞, K, and t_0 are fixed
Mean length-at-age, females only	l''_a	$l''_a = L''_\infty\left(1-\exp\left[-K''\left(a-t''_0\right)\right]\right)$ where parameters L''_∞, K'', and t''_0 are fixed
Age-length conversion matrix	$\psi_{a,l'}$	$\psi_{a,l'} = \dfrac{\exp\left[-\left(\dfrac{l'-l_a}{2c^l l_a}\right)\right]}{\sqrt{2\pi}\left(c^l l_a\right)^2}$ where c^l is a fixed value for the coefficient of variation in length at age and the matrix is re-scaled to sum to 1 across ages
Mean weight-at-age, both sexes	w_a	Computed from size at age at the midpoint of the year $w_a = \gamma(l_a)^\beta$, where γ and β are fixed
Mean weight-at-age, females only	w''_a	Computed from size at age at the midpoint of the year $w''_a = \gamma(l''_a)^\beta$, where γ and β are fixed
Maturity-at-age	m_a	Logistic function of age, estimated from MARMAP sampled data
Observed CPUE indices	$U_{u,y}$	u=1, MARMAP longline (y = 1983,…,1986, 1996,…,2002), based on numbers of fish captured per 100 hooks per hour. u=2, commercial logbook (y = 1992,…,2002), based on metric tons of fish captured per hook-day.
Coefficient of variation for U ‘s	$c_{u,y}$	u = {1, 2} (see above), annual values from GLM model or sampling error, then re-scaled to maximum of 0.3
Observed age compositions	$p_{f,a,y}$	Computed as percent age composition at age (a) for each year (y) and fishery (f)
Age composition sample sizes	$n_{f,y}$	Number of age samples collected in each year (y) from each fishery (f)
Observed length compositions	$p'_{f,l,y}$	Computed as percent length composition at length (l) for each year (y) and fishery (f)
Length composition sample sizes	$n'_{f,y}$	Number of length samples collected in each year (y) from each fishery (f)

Observed fishery landings	$L_{f,y}$	Reported landings in weight for each year (*y*) from each fishery (*f*)
Coefficient of variation for L_f	$c_{L_f,y}$	Annual values fixed based on understanding of historical accuracy of estimates
Age-dependent natural mortality	M_a	Fixed across years from Lorenzen (1996), re-scaled based on Hoenig (1983)
Population Model	**Symbol**	Description/Definition
Fishery selectivity	$s_{f,a}$	$s_{f,a} = \begin{cases} \left[\frac{1}{1+\exp\left(-\eta_{1,f}\left[a-\alpha_{1,f}\right]\right)}\right]\left[1-\frac{1}{1+\exp\left(-\eta_{2,f}\left[a-\left(\alpha_{1,f}+\alpha_{2,f}\right)\right]\right)}\right]\left[\frac{1}{\max\left(s_{f,a}\right)}\right] & \text{for } f=\{1,2\} \\ s_{1,a} & \text{for } f=3 \end{cases}$ where $\eta_{1,f}$, $\eta_{2,f}$, $\alpha_{1,f}$ and $\alpha_{2,f}$ are estimated parameters. Constant for all years (y).
Index selectivity	$s'_{u,a}$	$s'_{u,a} = \begin{cases} \left[\frac{1}{1+\exp\left(-\eta'_{1,u}\left[a-\alpha'_{1,u}\right]\right)}\right]\left[1-\frac{1}{1+\exp\left(-\eta'_{2,u}\left[a-\alpha'_{2,u}\right]\right)}\right]\left[\frac{1}{\max\left(s'_{u,a}\right)}\right] & \text{for } u=1 \\ (\hat{C}_{1,y}s_{1,a}+\hat{C}_{2,y}s_{2,a})/(\hat{C}_{1,y}+\hat{C}_{2,y}) & \text{for } u=2 \end{cases}$ where $\eta'_{1,U}$, $\eta'_{2,U}$, $\alpha'_{1,U}$ and $\alpha'_{2,U}$ are estimated parameters, and $\hat{C}_{f,y}$ is estimated total catch of fishery *f* in year *y*, summed across ages.
Fishing mortality	$F_{f,a,y}$	$F_{f,a,y} = s_{f,a}F_{f,y}$ where $F_{f,y}$'s are fully selected estimated parameters
Total mortality	$Z_{a,y}$	$Z_{a,y} = M_a + \sum_{f=1}^{3} F_{f,a,y}$
Mature female biomass per recruit at $F = 0$	ϕ_y	$\phi_y = \sum_{a=0}^{A} 0.5 N_{a,y} m_a w''_a \Big/ N_{0,y}$ where $N_{a+1,y} = N_{a,y}\exp\left(-Z_{a,y}\right)$ and $N_{A,y} = N_{A-1,y}\exp\left(-Z_{A-1,y}\right)/\left[1-\exp\left(-Z_{A,y}\right)\right]$

Population numbers Spawning stock biomass (mature female)	$N_{a,y}$ S_y	$N_{0,1961} = R_0 + R_{1961}$ $N_{a+1,1961} = N_{a,1961}\exp(-Z_{a,1961})$ $N_{A,1961} = N_{A-1,1961}\exp(-Z_{A-1,1961})/[1-\exp(-Z_{A,1961})]$ $N_{0,y} = \dfrac{0.8R_0 h\varepsilon_y}{0.2\phi_y R_0(1-h)+(h-0.2)\varepsilon_y} + R_y$ $N_{a+1,y+1} = N_{a,y}\exp(-Z_{a,y})$ $N_{A,y} = N_{A-1,y-1}\exp(-Z_{A-1,y-1}) + N_{A,y-1}\exp(-Z_{A,y-1})$ $S_y = \sum_{a=0}^{A} 0.5 N_{a,y} m_a w''_a$ where R_0 (virgin recruitment) and h (steepness) are parameters of the stock-recruit curve and R_y are annual recruitment deviation parameters.
Population biomass	B_y	$B_y = \sum_{a=0}^{A} N_{a,y} w_a$
Predicted catch-at-age	$\hat{C}_{f,a,y}$	$\hat{C}_{f,a,y} = \dfrac{F_{f,a,y}}{Z_{a,y}} N_{a,y}[1-\exp(-Z_{a,y})]$
Predicted landings	$\hat{L}_{f,y}$	$\hat{L}_{f,y} = \sum_{a=0}^{A} \hat{C}_{f,a,y} w_a$
Predicted age composition	$\hat{p}_{\{f,u\},a,y}$	$\hat{p}_{\{f,u\},a,y} = \hat{C}_{\{f,u\},a,y} \Big/ \sum_{a=0}^{A} \hat{C}_{\{f,u\},a,y}$

Predicted CPUE indices	$\hat{U}_{u,y}$	$\hat{U}_{u,y} = \begin{cases} \sum_{a=0}^{A} N_{a,y} s'_{1,a} q_1 & \text{for } u = 1 \\ \sum_{a=0}^{A} N_{a,y} s'_{2,a} q_2 & \text{for } u = 2 \end{cases}$ where q_1 and q_2 are catchability parameters
Negative Log-Likelihood	**Symbol**	**Description/Definition**
Multinomial age composition	Λ_1	$\Lambda_1 = -\lambda_1 n_{\{f,u\},y} \sum_{a=0}^{A} (p_{\{f,u\},a,y} + x)\log(\hat{p}_{\{f,u\},a,y} + x) - (p_{\{f,u\},a,y} + x)\log(p_{\{f,u\},a,y} + x)$ where λ_1 is a preset weighting factor and x is fixed at an arbitrary value of 0.001
Multinomial length composition	Λ_2	$\Lambda_2 = -\lambda_2 n'_{\{f,u\},y} \sum_{l'} (p'_{\{f,u\},l',y} + x)\log(\hat{p}'_{\{f,u\},l',y} + x) - (p'_{\{f,u\},l',y} + x)\log(p'_{\{f,u\},l',y} + x)$ where λ_2 is a preset weighting factor and x is fixed at an arbitrary value of 0.001

Lognormal indices	Λ_3	$\Lambda_3 = \lambda_3 \sum_y \frac{\left[\log\left(U_{u,y} + x\right) - \log\left(\hat{U}_{u,y} + x\right)\right]^2}{2c_{u,y}^2}$ where λ_3 is a preset weighting factor and *x* is fixed at an arbitrary value of 0.001
Lognormal landings	Λ_4	$\Lambda_4 = \lambda_4 \sum_y \frac{\left[\log\left(L_{f,y} + x\right) - \log\left(\hat{L}_{f,y} + x\right)\right]^2}{2c_{L_f,y}^2}$ where λ_4 is a preset weighting factor and *x* is fixed at an arbitrary value of 0.001
Recruitment constraint	Λ_5	$\Lambda_5 = \lambda_5 \sum_y R_y^2$

Table 11: Numbers at age (1000s) estimated in the initial run of the statistical catch-at-age model for tilefish.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1961	344	232	187	159	140	125	113	103	95	88	81	75	70	65	61	57	53	50	46	43	41	38	36	34	31	480
1962	255	232	187	159	140	125	113	103	95	88	81	75	70	65	61	57	53	50	46	43	41	38	36	34	31	480
1963	256	172	187	159	140	125	113	103	95	88	81	75	70	65	61	57	53	50	46	43	41	38	36	34	31	480
1964	258	173	138	159	140	125	113	103	95	88	81	75	70	65	61	57	53	50	46	43	41	38	36	34	31	480
1965	261	174	139	118	140	125	113	103	95	88	81	75	70	65	61	57	53	50	46	43	41	38	36	34	31	480
1966	265	176	140	118	104	125	113	103	95	87	81	75	70	65	61	57	53	49	46	43	41	38	36	33	31	479
1967	271	179	141	119	104	93	113	103	95	87	81	75	70	65	61	57	53	49	46	43	41	38	36	33	31	479
1968	280	183	144	121	105	93	84	103	95	87	81	75	70	65	61	57	53	49	46	43	41	38	36	33	31	479
1969	294	189	147	123	106	94	84	77	95	87	81	75	70	65	60	56	53	49	46	43	41	38	36	33	31	479
1970	309	198	152	125	108	95	85	77	70	87	81	75	70	65	60	56	53	49	46	43	41	38	36	33	31	478
1971	476	208	159	130	110	96	86	77	71	65	81	75	70	65	60	56	53	49	46	43	41	38	36	33	31	478
1972	520	321	168	136	114	99	87	78	71	65	60	75	70	65	60	56	53	49	46	43	40	38	36	33	31	478
1973	546	351	258	143	119	102	89	80	72	65	60	56	70	65	60	56	53	49	46	43	40	38	36	33	31	477
1974	478	368	282	220	126	107	92	81	73	66	60	56	52	65	60	56	53	49	46	43	40	38	35	33	31	476
1975	370	322	296	241	193	112	96	84	74	67	61	56	51	48	60	56	52	49	46	43	40	38	35	33	31	473
1976	297	250	259	252	212	173	101	87	76	68	61	56	51	47	44	55	52	48	45	42	40	37	35	33	31	467
1977	219	200	201	221	222	189	155	91	79	69	62	56	51	47	44	41	51	48	45	42	39	37	34	32	30	462
1978	155	148	161	171	194	199	171	141	83	72	64	57	52	47	44	40	38	47	44	42	39	36	34	32	30	459
1979	194	104	119	137	151	174	179	155	128	76	66	58	53	48	44	40	38	35	44	41	39	36	34	32	30	456
1980	372	130	84	101	121	135	157	162	141	117	70	61	54	48	44	40	37	35	32	41	38	36	34	32	30	451
1981	304	251	105	71	89	108	122	141	147	128	107	64	56	49	44	41	37	34	32	30	38	35	33	31	29	444
1982	513	205	202	90	63	80	97	104	121	126	111	93	55	49	43	39	35	33	30	28	26	33	31	29	27	416
1983	457	346	165	172	79	56	70	69	74	87	91	80	67	40	35	31	28	26	24	22	21	19	24	23	21	324
1984	362	308	278	141	151	70	50	53	53	57	67	71	62	52	31	28	25	22	20	19	17	16	15	19	18	271
1985	736	244	248	237	124	135	62	39	42	42	46	54	57	50	42	25	22	20	18	16	15	14	13	12	15	233
1986	478	496	196	212	209	110	118	47	30	32	32	35	41	44	38	32	19	17	15	14	13	12	11	10	9	193
1987	1265	322	399	168	186	186	97	88	35	22	24	24	26	31	33	29	25	15	13	12	11	10	9	8	8	154
1988	865	852	259	340	147	166	168	84	76	31	19	21	21	23	28	29	26	22	13	12	10	9	9	8	7	144
1989	204	583	685	221	299	132	149	137	69	63	25	16	18	18	19	23	24	22	18	11	10	9	8	7	7	127
1990	244	137	469	585	194	267	117	113	104	53	48	20	12	14	14	15	18	19	17	14	9	8	7	6	6	104
1991	515	164	110	400	514	173	237	87	85	79	40	37	15	9	10	10	12	14	15	13	11	7	6	5	5	84
1992	877	347	132	94	351	459	153	172	64	62	58	30	27	11	7	8	8	9	10	11	10	8	5	4	4	66
1993	543	591	279	113	83	314	406	107	121	45	44	41	21	19	8	5	6	6	6	7	8	7	6	4	3	50
1994	438	366	475	238	99	74	275	285	75	86	32	31	29	15	14	6	4	4	4	4	5	6	5	4	3	39
1995	279	296	294	406	209	88	65	205	213	57	65	24	24	22	11	11	4	3	3	3	3	4	4	4	3	31
1996	332	188	238	251	356	187	78	50	156	164	44	50	19	18	17	9	8	3	2	2	2	3	3	3	3	27
1997	288	224	151	203	221	319	168	65	41	131	137	37	42	16	16	15	8	7	3	2	2	2	2	3	3	26
1998	321	194	180	129	178	197	285	138	54	34	109	115	31	35	13	13	12	6	6	2	2	2	2	2	2	24
1999	261	216	156	153	113	159	177	239	117	46	29	93	98	26	30	11	11	11	5	5	2	1	1	1	2	23
2000	256	176	174	133	135	101	143	145	197	96	38	24	78	82	22	25	10	9	9	5	4	2	1	1	1	20
2001	256	172	142	148	117	120	90	111	114	155	76	30	19	62	65	18	20	8	8	7	4	3	1	1	1	17
2002	252	172	139	121	130	105	108	75	93	95	131	64	25	16	53	56	15	17	7	6	6	3	3	1	1	16

Table 12: Predicted time series from the statistical catch-at-age model for tilefish (median values)

Year	E (1+) (1/yr)	F (2+) (1/yr)	Landings (mt)	Recruits (1000s)	SSB (mt)	Total Biomass (mt)
1961	0.00010	0.00011	0.96	252.8	2533.8	7400.4
1962	0.00015	0.00016	1.41	168.4	2533.8	7399.2
1963	0.00015	0.00017	1.43	169.1	2533.6	7392.8
1964	0.00006	0.00006	0.51	170.7	2533.5	7378.5
1965	0.00119	0.00131	10.79	172.8	2533.4	7354.4
1966	0.00024	0.00026	2.10	176.1	2527.4	7308.6
1967	0.00055	0.00060	4.87	180.9	2516.2	7260.8
1968	0.00034	0.00038	3.03	186.2	2496.6	7201.6
1969	0.00029	0.00031	2.52	195.3	2471.5	7137.5
1970	0.00055	0.00061	4.87	207.0	2447.5	7073.3
1971	0.00101	0.00112	8.92	290.6	2418.8	7017.3
1972	0.00032	0.00036	2.89	324.2	2389.8	6959.6
1973	0.00204	0.00232	19.02	361.3	2364.5	6925.9
1974	0.00442	0.00508	42.38	341.2	2337.1	6909.4
1975	0.00753	0.00865	73.08	277.4	2309.3	6887.1
1976	0.00784	0.00887	74.27	228.7	2291.7	6849.8
1977	0.00351	0.00391	33.33	176.1	2299.6	6802.9
1978	0.00509	0.00558	46.14	123.5	2312.3	6794.7
1979	0.00693	0.00748	59.40	157.0	2318.8	6754.9
1980	0.01191	0.01309	98.54	301.5	2313.0	6692.9
1981	0.04745	0.05623	397.42	232.7	2287.0	6581.1
1982	0.16462	0.21004	1307.22	411.8	2138.7	6175.5
1983	0.10245	0.13741	748.13	362.3	1638.7	4800.2
1984	0.07629	0.09982	539.53	283.3	1368.6	4098.7
1985	0.08672	0.11165	568.54	602.0	1199.2	3660.3
1986	0.07762	0.11680	529.54	377.1	1038.4	3236.7
1987	0.02021	0.02534	127.65	1005.5	912.0	2900.1
1988	0.03512	0.05637	265.31	675.4	948.3	3033.5
1989	0.05332	0.07569	412.50	150.3	938.3	3084.2
1990	0.06179	0.07425	412.48	177.8	895.9	3011.6
1991	0.08196	0.10163	449.46	387.1	878.0	2943.6
1992	0.09345	0.12944	485.08	679.4	889.6	2829.2
1993	0.10661	0.16608	519.32	404.8	897.7	2669.6
1994	0.08736	0.11916	402.31	323.6	823.3	2465.0
1995	0.07068	0.09304	333.25	199.4	750.7	2361.8
1996	0.03766	0.04508	170.49	236.0	720.9	2326.4
1997	0.04565	0.05590	195.01	196.7	795.1	2447.9
1998	0.04678	0.05600	183.35	200.6	863.2	2527.9
1999	0.06483	0.07932	252.55	163.5	909.7	2599.2
2000	0.09646	0.11911	363.92	160.7	904.4	2562.1
2001	0.05633	0.06784	203.20	160.1	836.2	2391.0
2002	0.05497	0.06644	194.36	156.7	825.0	2348.3

Table 13: Tilefish benchmarks for age 1+ exploitation rate (E), age 2+ fishing mortality (F), maximum sustainable yield (MSY), total mature biomass (SSB), and total biomass (B) estimated by the statistical catch-at-age model.

Benchmarks	10th percentile	median	90th percentile
SSBmsy(mt)	677.8	879.4	1128.4
Bmsy(mt)	2050.5	2611.4	3326.9
MSY(mt)	104.9	152.6	209.0
Fmax(1/yr)	0.075	0.081	0.095
F30%(1/yr)	0.054	0.059	0.068
F40%(1/yr)	0.039	0.043	0.050
Fmsy(1/yr)	0.027	0.043	0.063
Emax(1/yr)	0.059	0.061	0.064
E30%(1/yr)	0.044	0.047	0.049
E40%(1/yr)	0.033	0.035	0.038
Emsy(1/yr)	0.023	0.035	0.049

Table 14: Projected SSB, recruits and yield (median values) from the statistical catch-at-age model for tilefish with fully selected F = 0.

Year	F (1/yr)	SSB (mt)	Recruits (1000s)	Yield (mt)
2003	0	810.8	221.8	0
2004	0	867.9	221.8	0
2005	0	918.8	218.7	0
2006	0	967.9	231.1	0
2007	0	1012.4	238.2	0
2008	0	1062.3	236.3	0
2009	0	1116.7	233.1	0
2010	0	1180.0	244.0	0
2011	0	1242.3	230.6	0
2012	0	1303.2	258.3	0
2013	0	1364.7	243.2	0
2014	0	1421.6	246.8	0
2015	0	1480.4	248.7	0
2016	0	1547.9	263.2	0
2017	0	1602.5	253.3	0
2018	0	1660.5	265.2	0
2019	0	1714.4	267.3	0
2020	0	1775.0	250.0	0
2021	0	1830.3	252.4	0
2022	0	1875.9	265.6	0
2023	0	1927.5	261.9	0
2024	0	1973.5	264.6	0
2025	0	2019.2	270.7	0
2026	0	2066.7	264.4	0
2027	0	2118.6	272.6	0

Table 15: Projected SSB, recruits and yield (median values) from the statistical catch-at-age model for tilefish with fully selected F = Fnow.

Year	F(/y)	SSB(mt)	Recruits(1000s)	Yield(mt)
2003	0.124	810.8	221.8	234.0
2004	0.124	775.0	221.8	225.4
2005	0.124	737.6	209.8	214.5
2006	0.124	703.0	216.3	203.8
2007	0.124	669.9	215.6	193.8
2008	0.124	650.3	206.8	185.0
2009	0.124	646.6	202.0	182.6
2010	0.124	635.9	206.9	180.9
2011	0.124	639.4	194.6	180.0
2012	0.124	635.9	207.5	180.0
2013	0.124	633.4	195.9	178.0
2014	0.124	630.2	194.5	177.6
2015	0.124	631.2	193.8	176.6
2016	0.124	631.1	202.5	176.3
2017	0.124	630.7	195.3	175.7
2018	0.124	627.4	199.7	176.1
2019	0.124	625.9	201.5	175.9
2020	0.124	623.0	188.2	174.4
2021	0.124	621.7	193.8	174.1
2022	0.124	615.7	193.2	173.9
2023	0.124	621.5	185.9	172.6
2024	0.124	620.2	193.4	173.3
2025	0.124	617.8	193.7	173.7
2026	0.124	613.0	187.0	172.6
2027	0.124	607.1	191.0	173.5

Table 16: Estimates from production model of tilefish. Model was rejected by the assessment workshop and is included here for completeness only.

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)		
Parameter		Estimate
B1/K	Starting relative biomass (in 1962)	0.99
MSY	Maximum sustainable yield (mt)	550.0
K	Maximum population size (mt)	2797.0
	Catchability Coefficients by Data Series -	
q(1)	TIL MARMAP Horiz LL Idx, Total Landings	0.00047
q(2)	TIL Commercial Logbook Idx	0.00044
MANAGEMENT and DERIVED PARAMETER ESTIMATES (NON-BOOTSTRAPPED)		
Parameter		Estimate
MSY	Maximum sustainable yield (mt)	550.0
Bmsy	Stock biomass giving MSY (mt)	1398.0
Fmsy	Fishing mortality rate at MSY (1/yr)	0.39
n	Exponent in production function	2
g	Fletcher's gamma	4.00
B./Bmsy	Ratio: B(2003)/Bmsy	1.76
F./Fmsy	Ratio: F(2002)/Fmsy	0.20
Fmsy/F.	Ratio: Fmsy/F(2002)	4.96
Y.(Fmsy)	Approx. yield available at Fmsy in 2003 (mt)	970.1
	...as proportion of MSY	1.76
Ye.	Equilibrium yield available in 2003 (mt)	229.2
	...as proportion of MSY	0.42

6. Figures

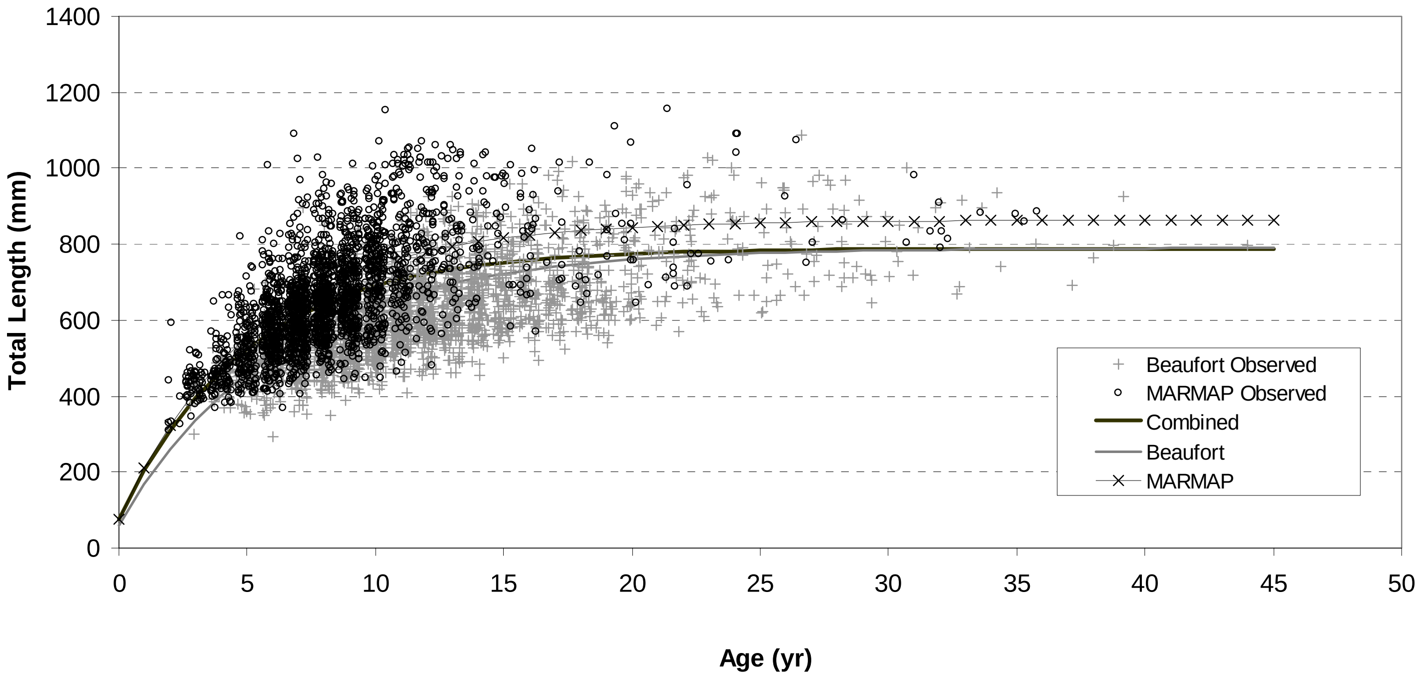


Figure 1: Observed and predicted tilefish growth by data source. Fits are based on non-linear least squares (NLLS) of the von Bertalanffy equation (N = 4,983)

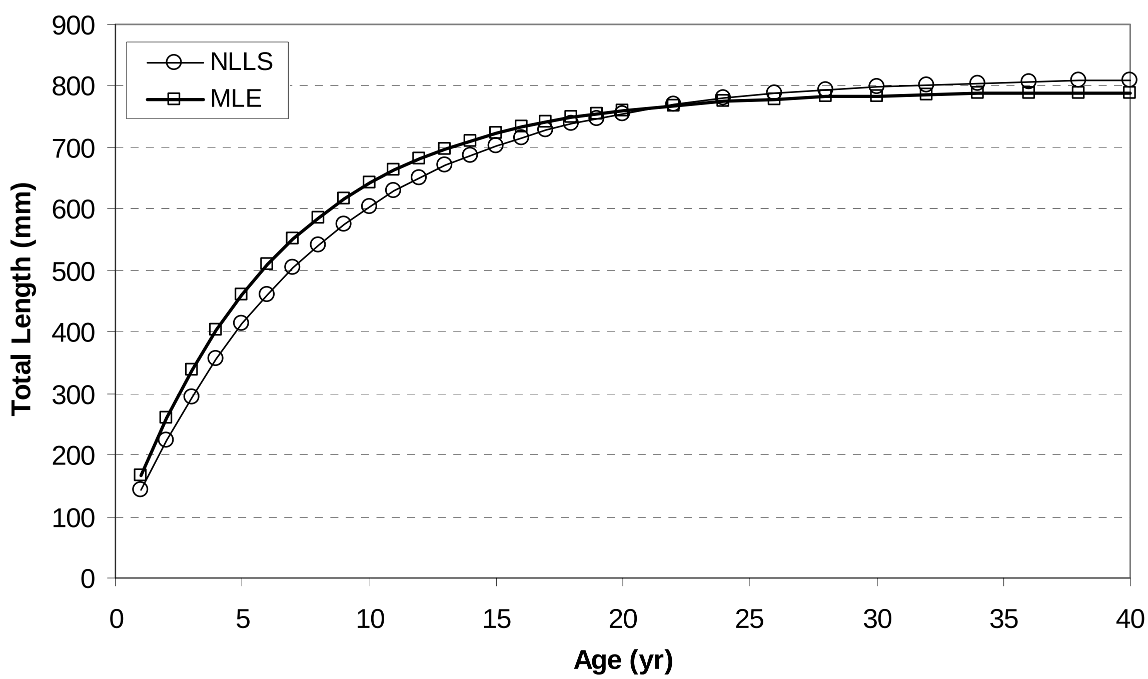


Figure 2: Comparison of tilefish Growth between two statistical methods, non-linear least squares (NLLS) and maximum likelihood estimation (MLE) with NMFS Data (N = 2,683).

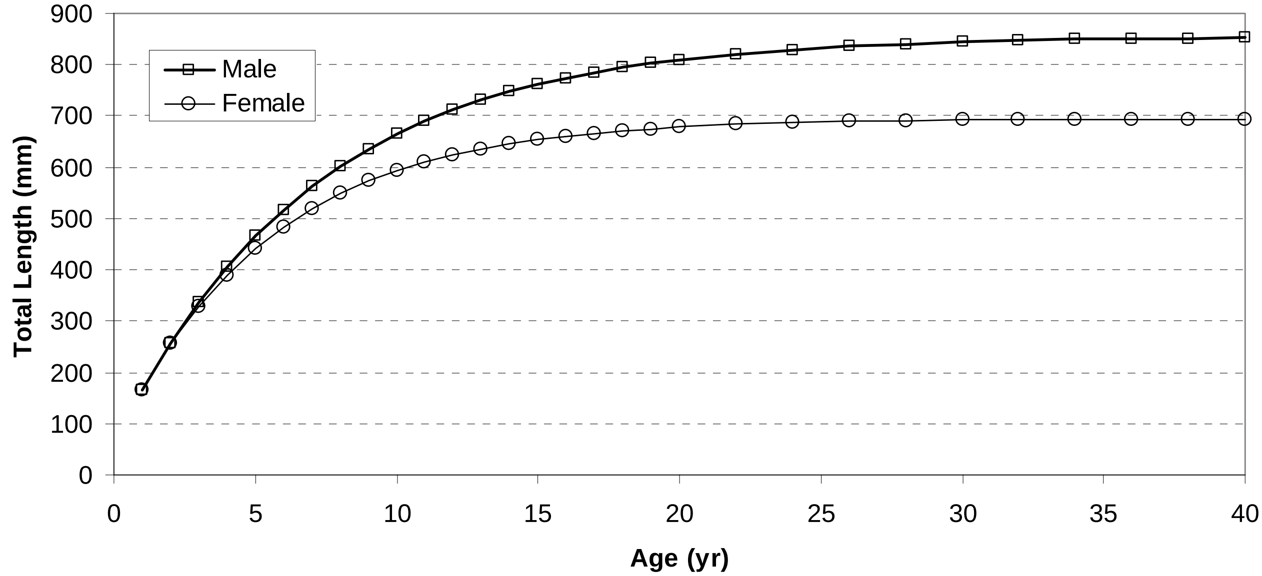


Figure 3: Comparison of male (N=228) and female (N=187) tilefish growth based on MLE on NMFS Data.

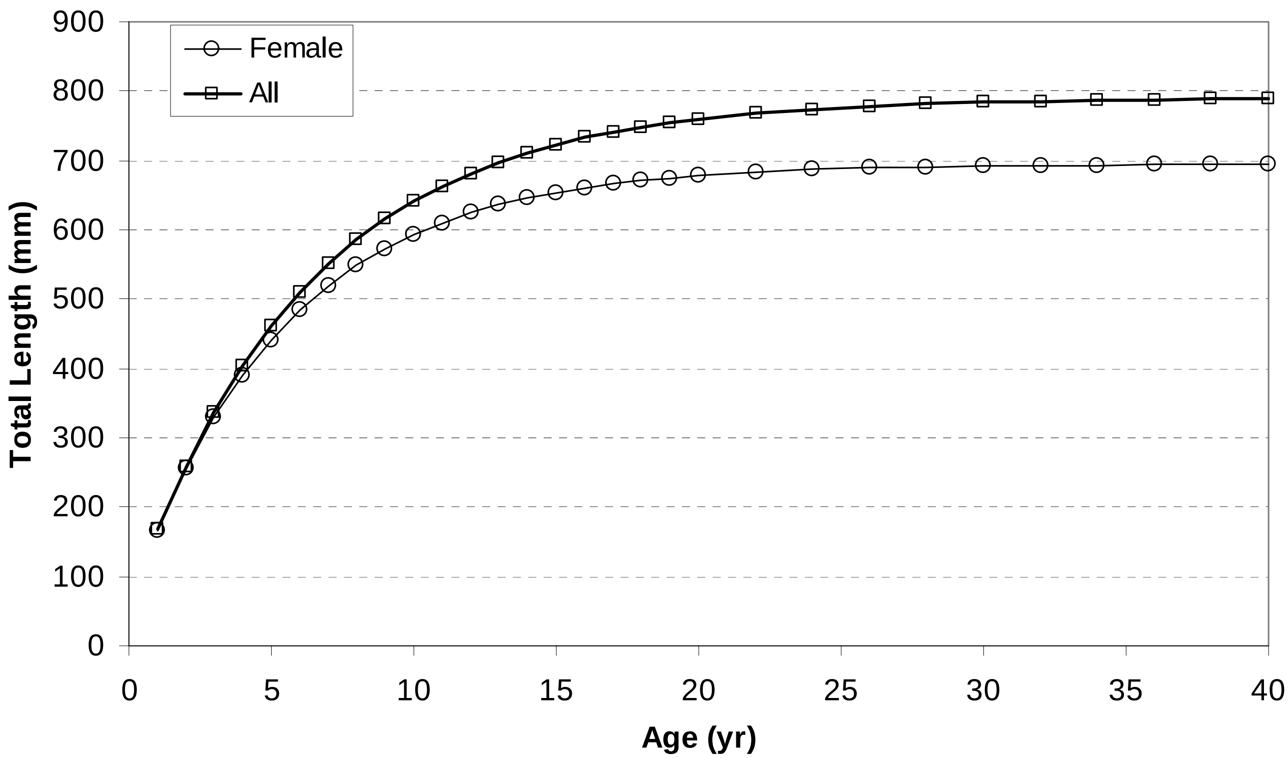


Figure 4: Comparison of tilefish growth between females only (N=187) and all (2,683) curves estimated using Maximum Likelihood Estimation (MLE) on NMFS data.

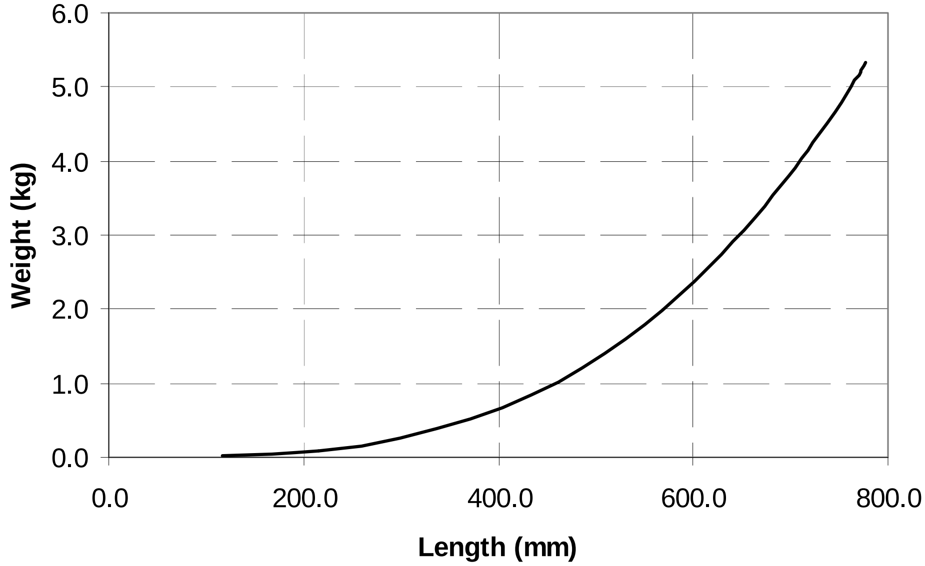


Figure 5: Length-weight relationship of tilefish (mid-year values)

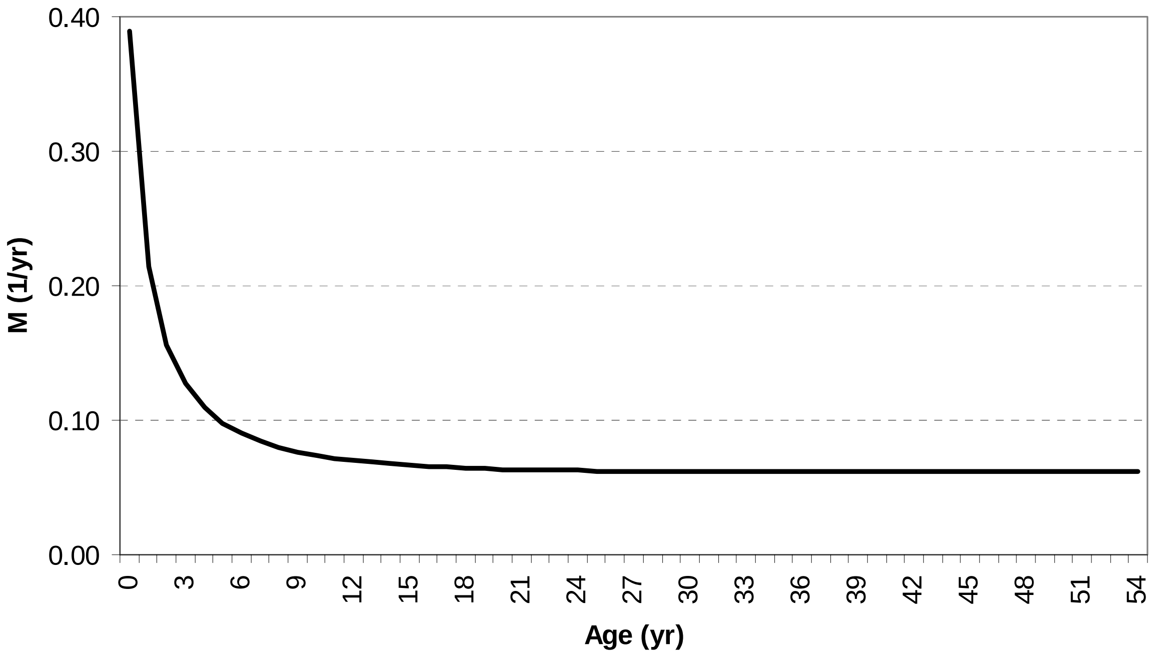


Figure 6: Age-dependent estimates of tilefish natural mortality based on method of Lorenzen (1996), re-scaled to 1.4% survival to oldest observed age.

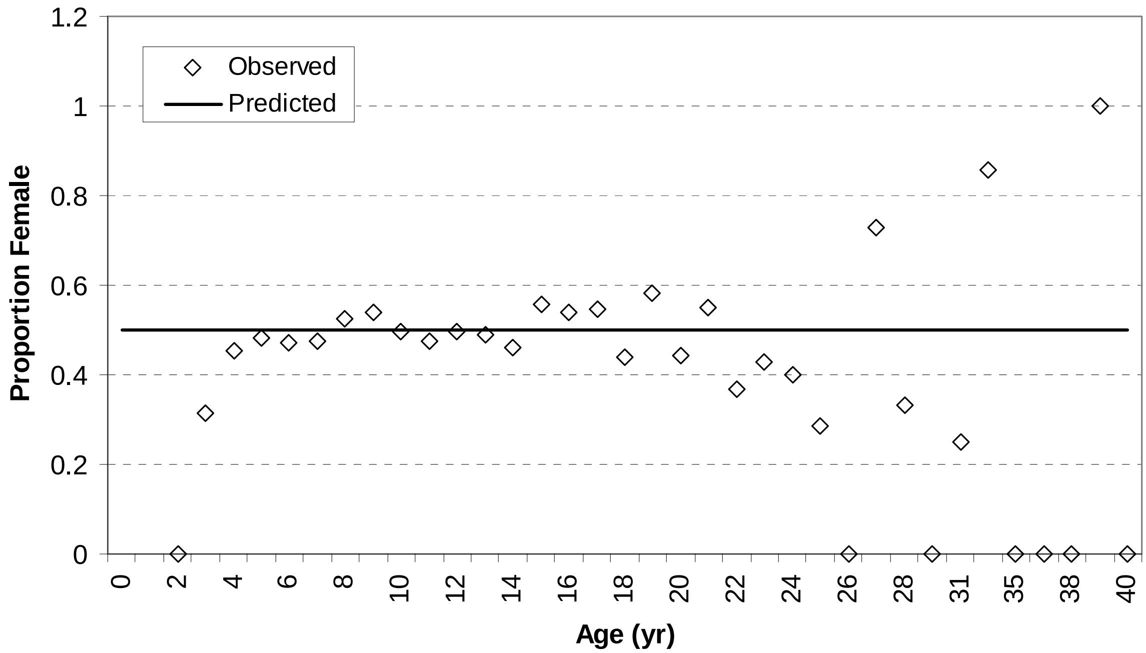


Figure 7: Observed and predicted tilefish sex ratio at age. Because logistic fit was non-significant with age, constant value of 0.5 used.

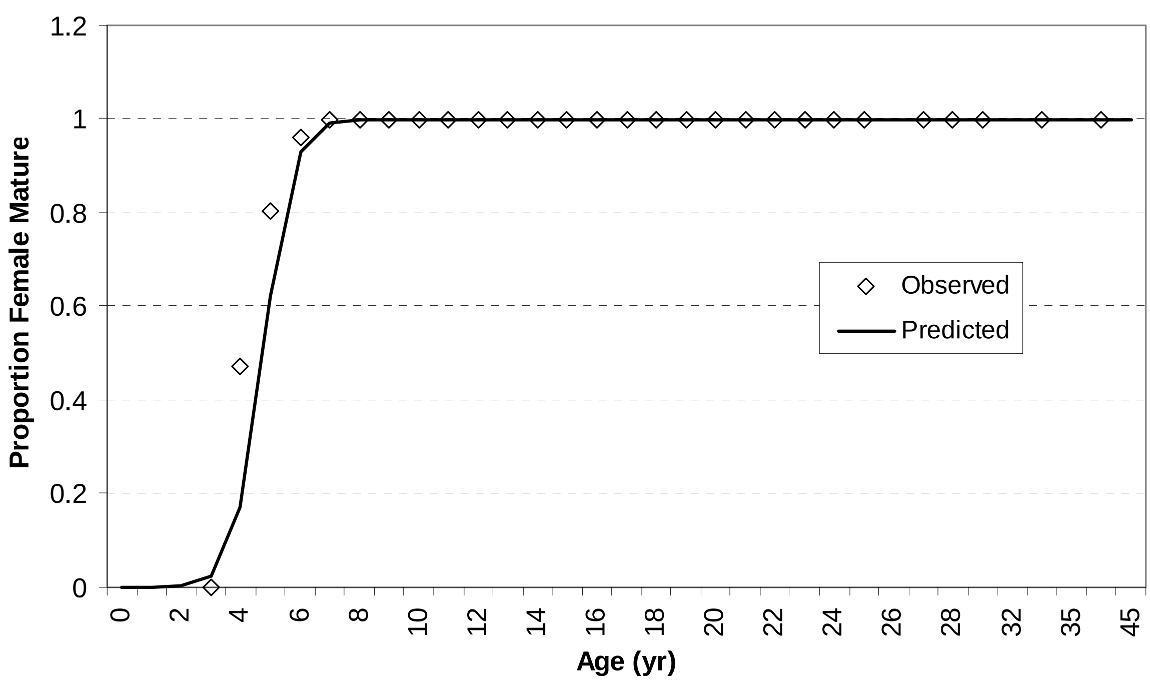


Figure 8: Observed and predicted tilefish female maturity.

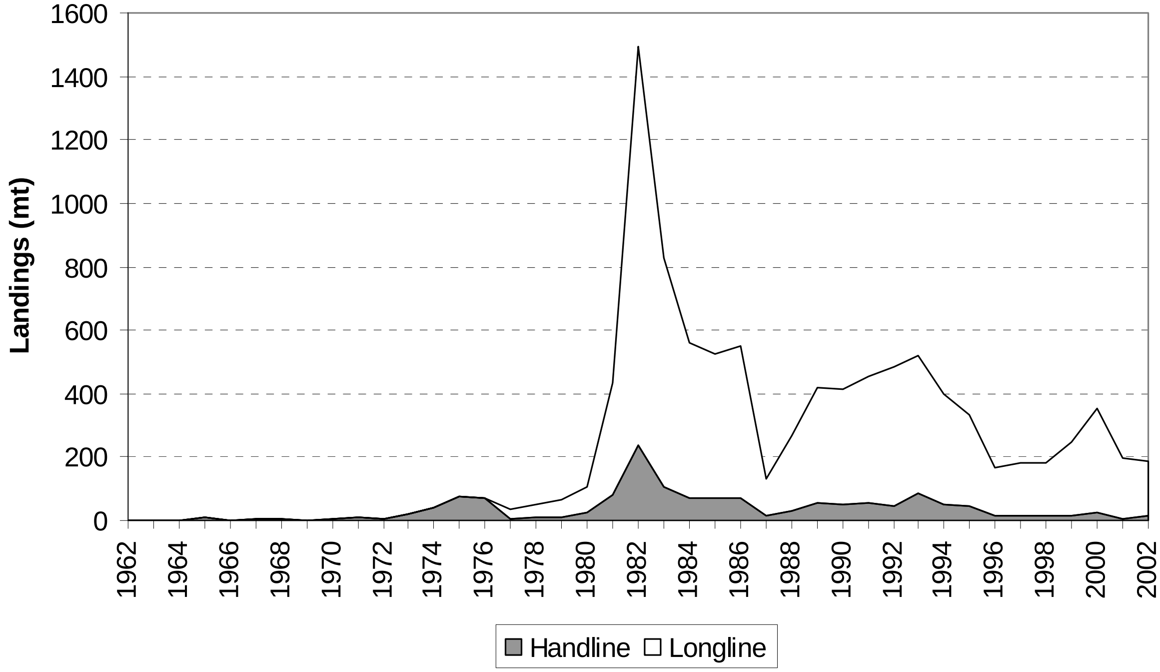


Figure 9: Tilefish landings from the commercial fishery by gear (handline and longline).

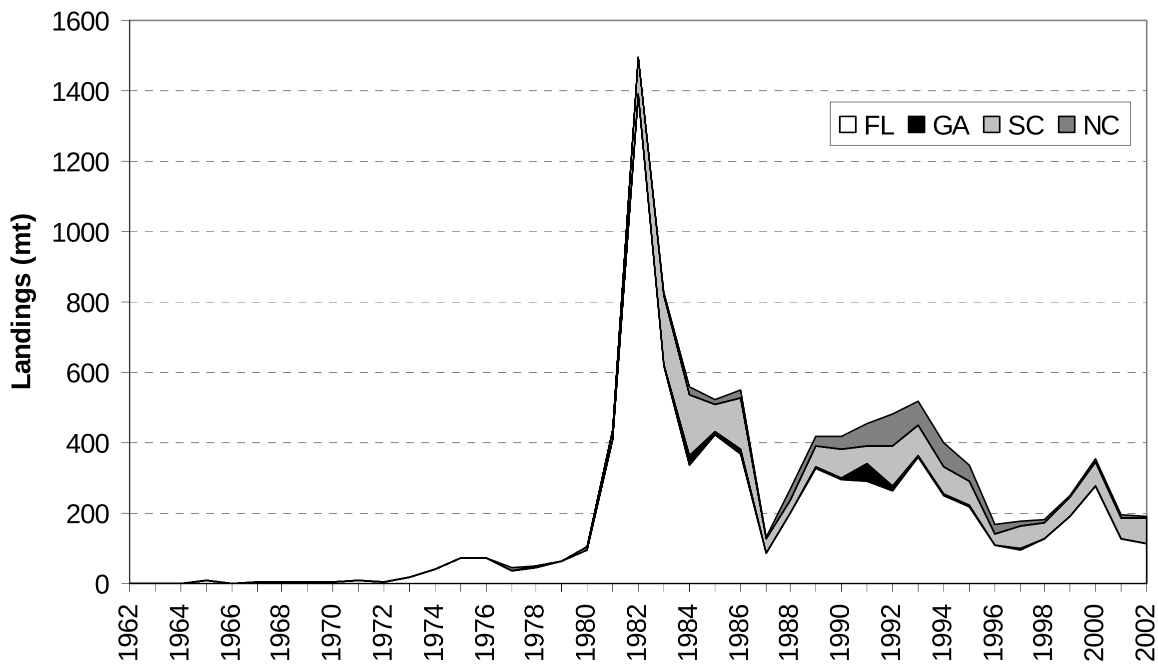


Figure 10: Tilefish commercial landings by state.

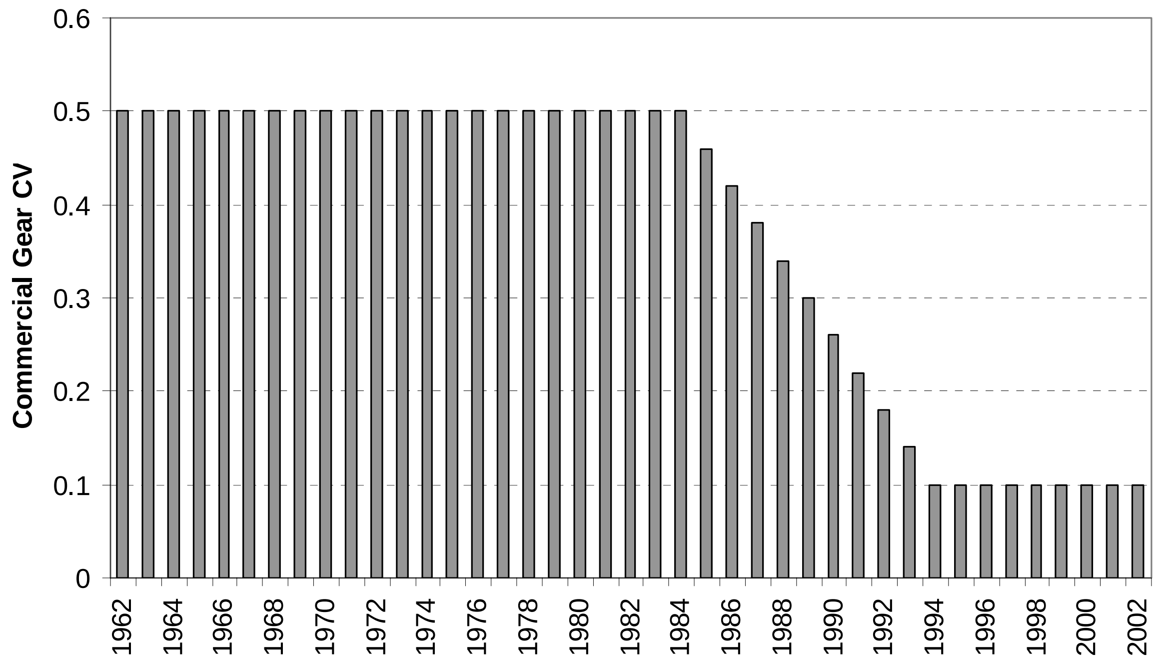


Figure 11: Coefficients of variation (CV) for tilefish commercial handline and longline landings used in the statistical catch-at-age model.

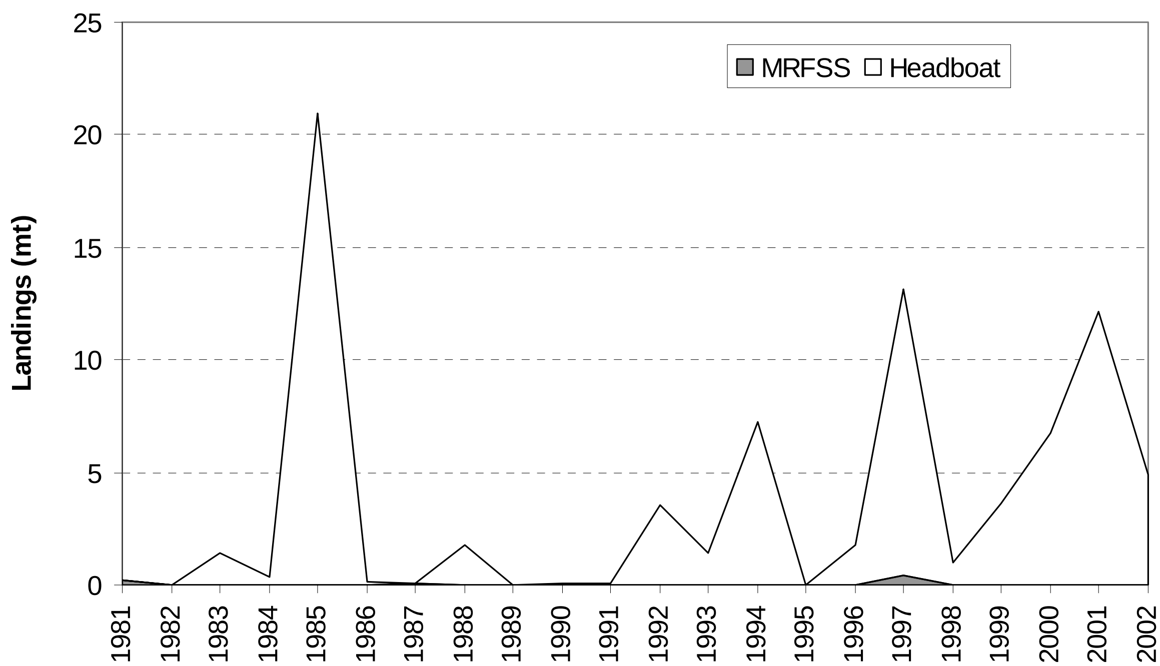


Figure 12: Tilefish landings from the recreational sector (MRFSS and Headboat).

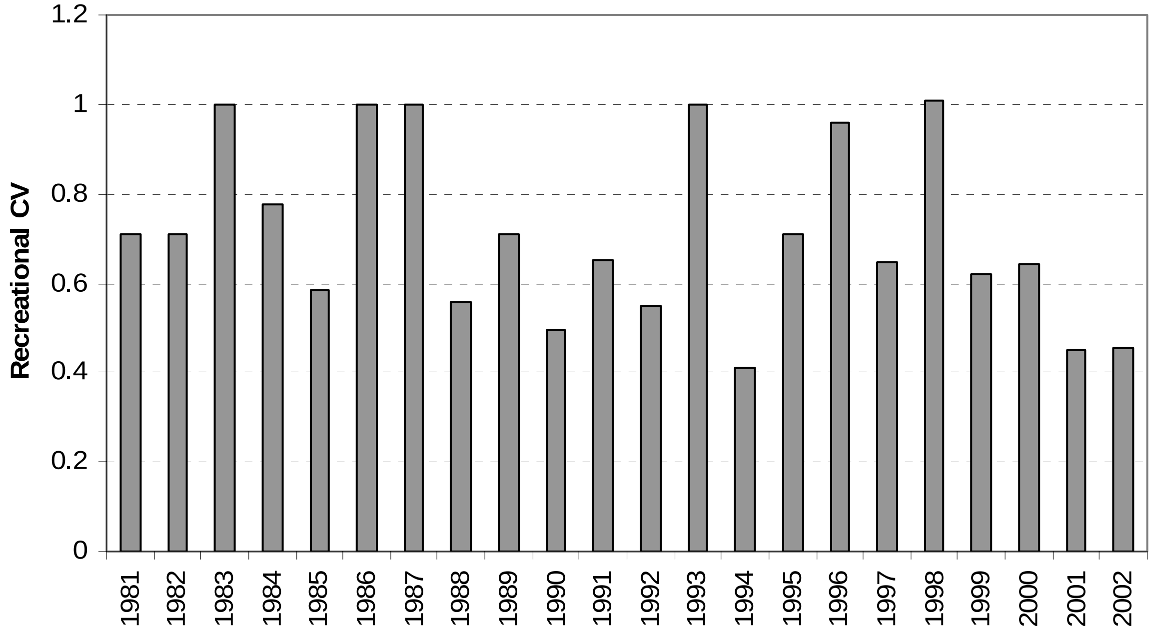


Figure 13: Coefficients of variation (CV) for tilefish recreational landings estimated by MRFSS used in the statistical catch-at-age model.

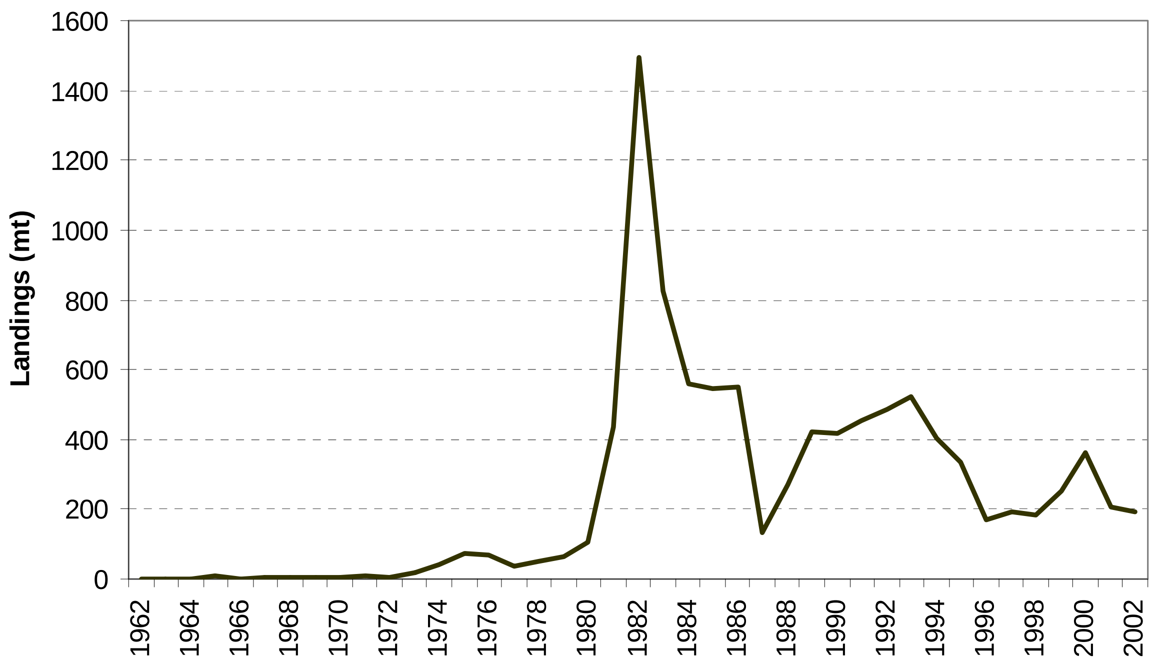


Figure 14: Total tilefish landings from commercial and recreational sectors.

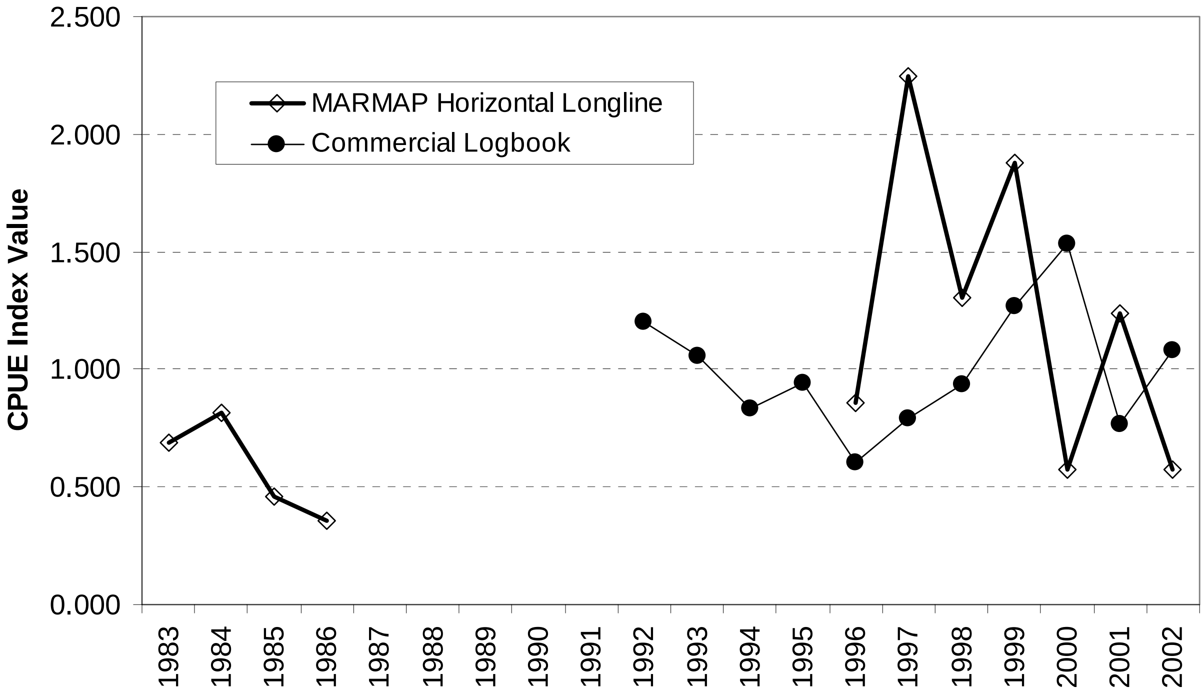


Figure 15: Indices of abundance derived from MARMAP horizontal longline and commercial logbook data, each scaled to its mean.

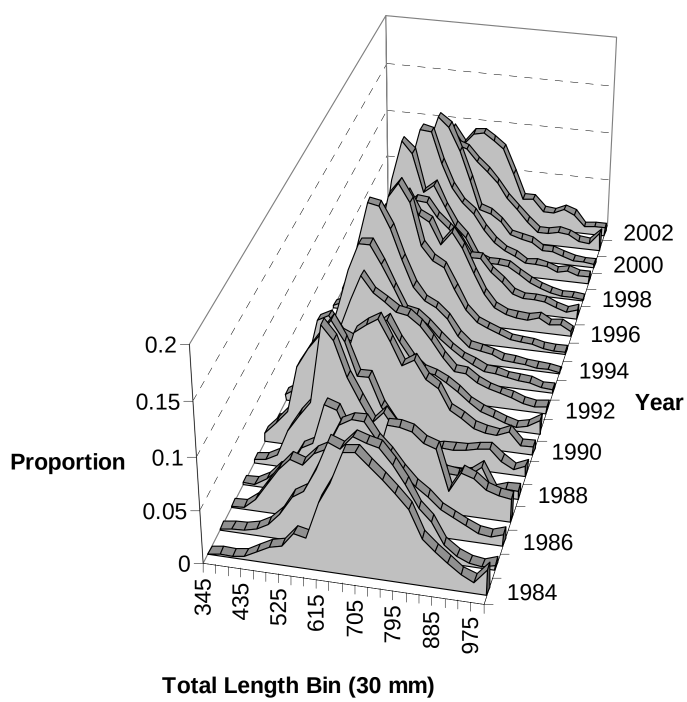


Figure 16: Tilefish commercial longline length composition, 1984-2002.

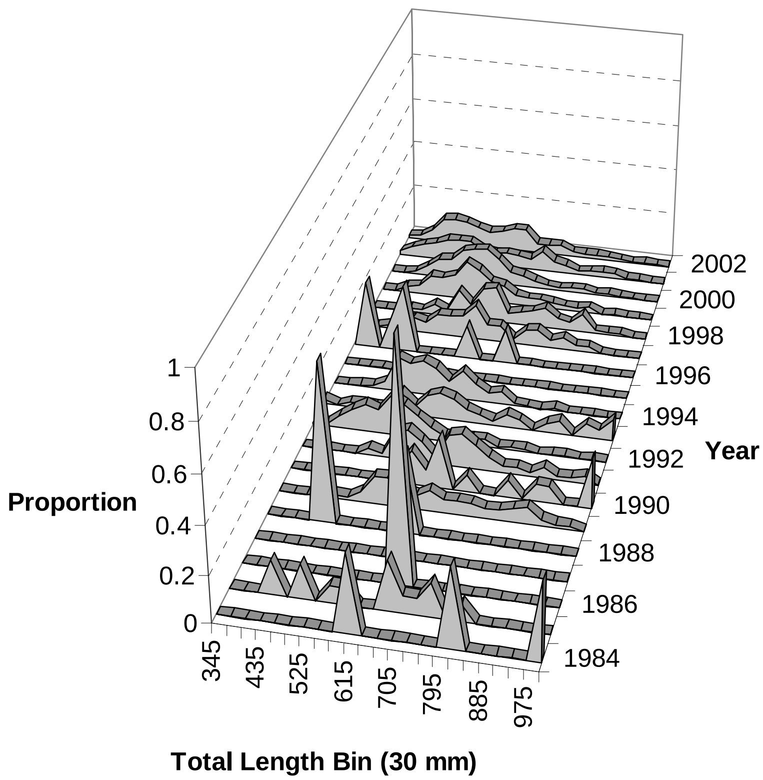


Figure 17: Tilefish commercial handline length composition, 1984-2002.

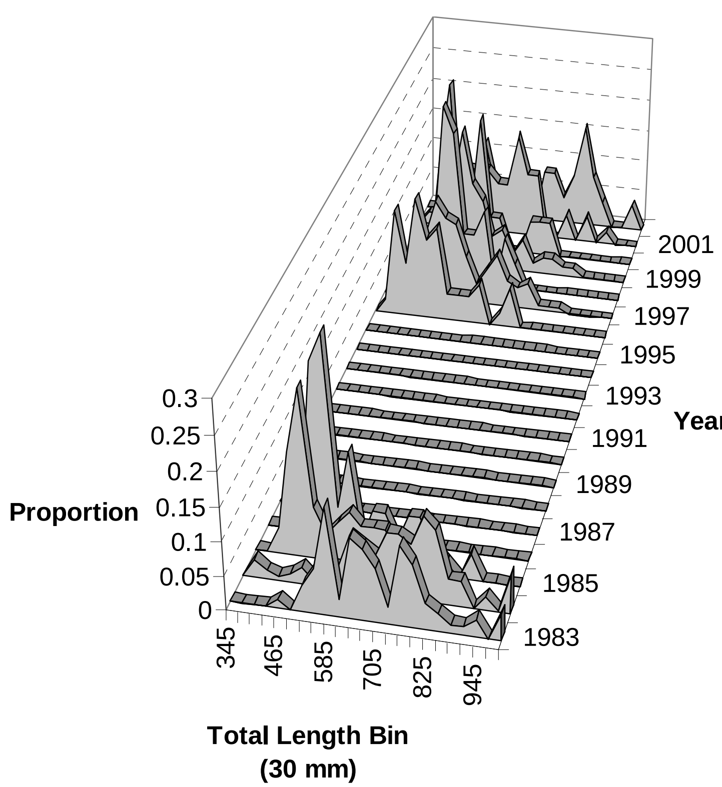


Figure 18: Tilefish MARMAP horizontal longline length composition, 1983-1986 and 1996-2002.

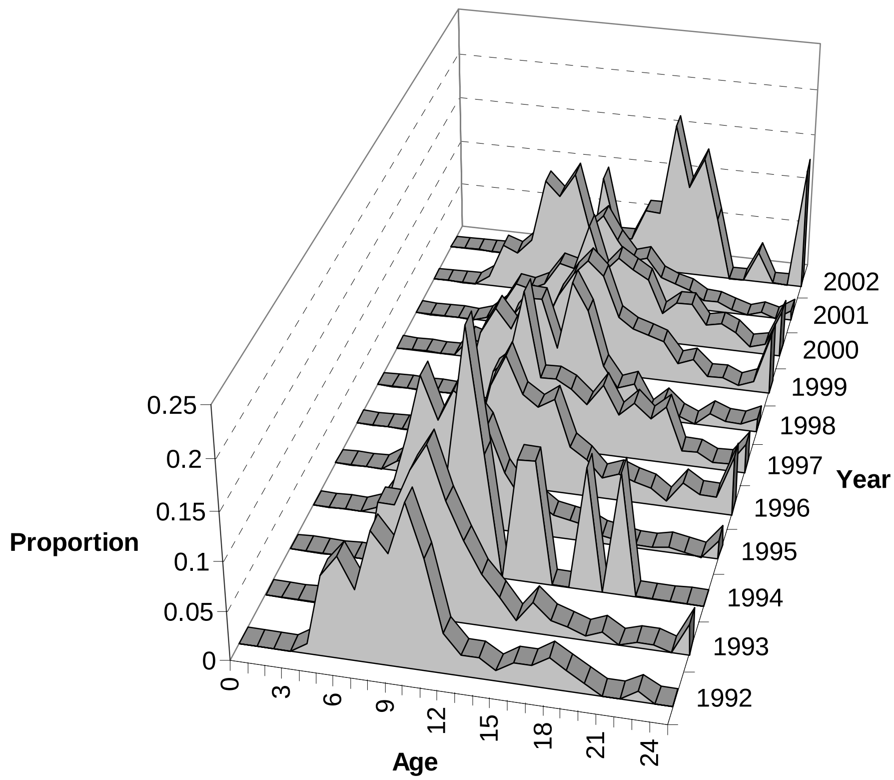


Figure 19: Tilefish commercial longline age composition, 1992-2002.

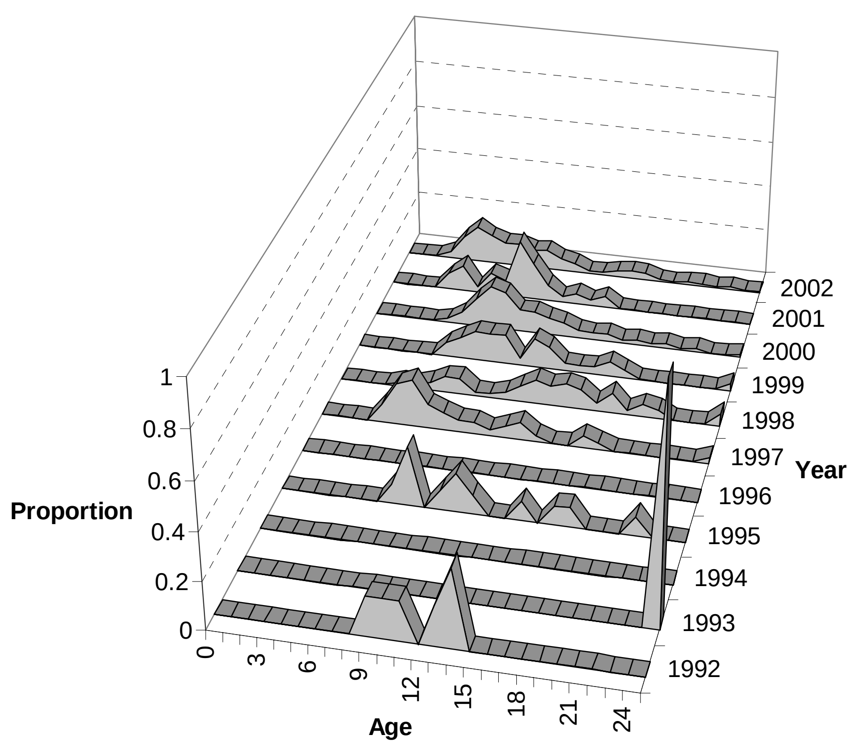


Figure 20: Tilefish commercial handline age composition, 1992-1993, 1995, 1997-2002.

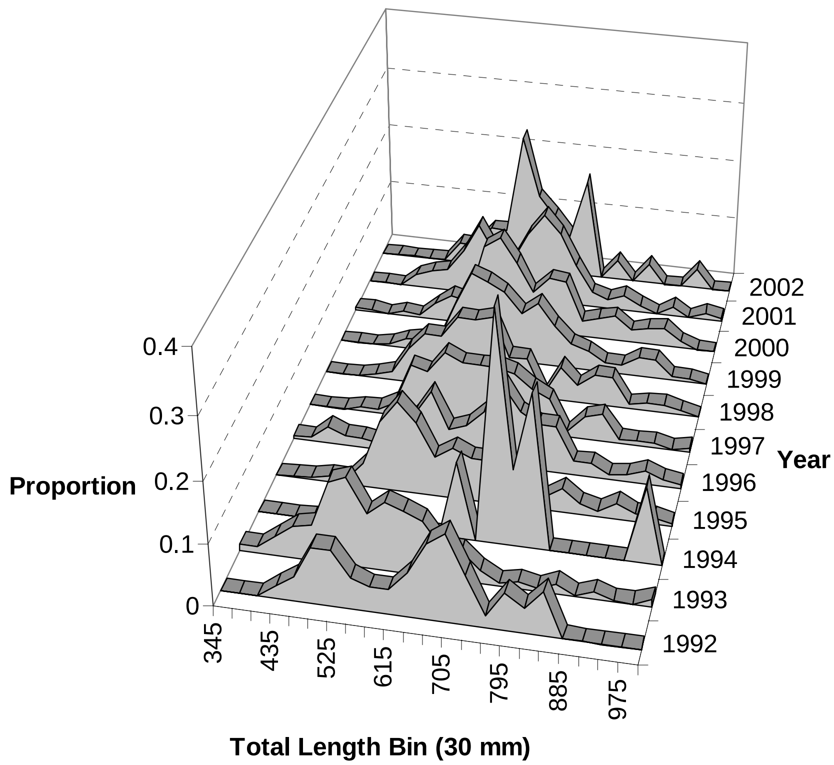


Figure 21: Tilefish commercial longline length composition from aged sample, 1992-2002.

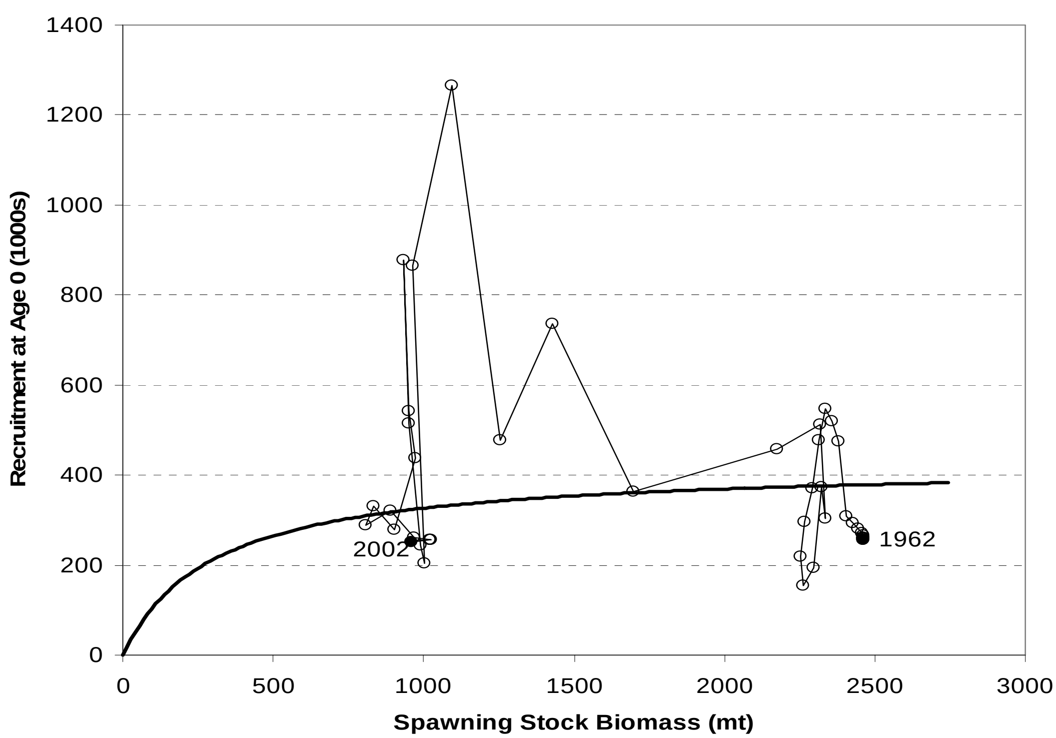


Figure 22: Stock-recruit curve estimated in the initial run of the tilefish model, with stock-recruit time series overlaid (circles). Beginning (1962) and end (2002) of time series indicated by solid circles.

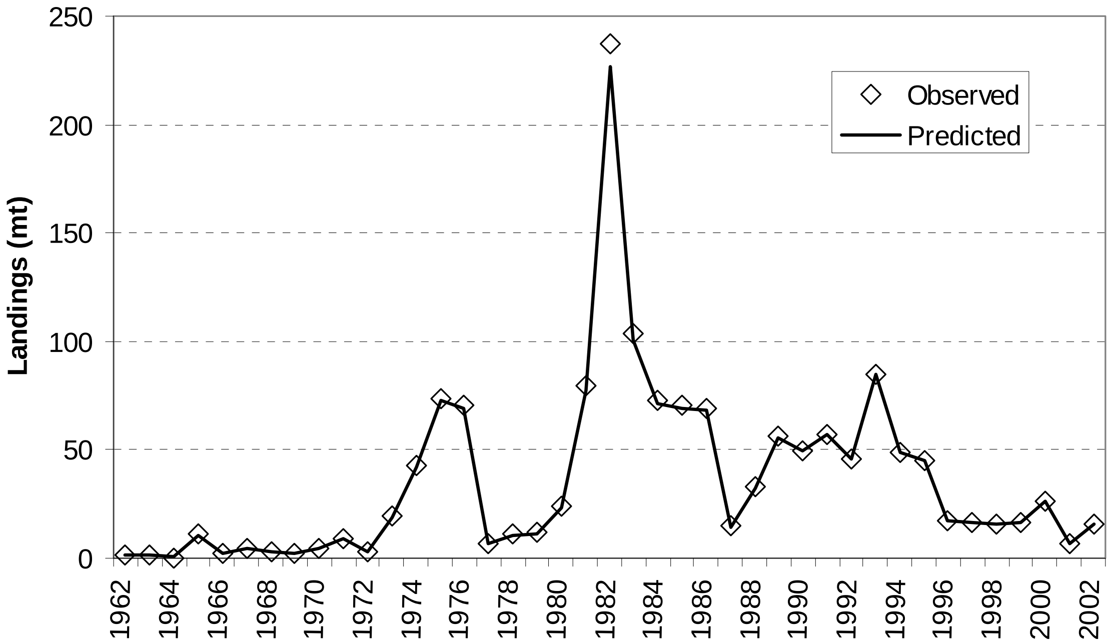


Figure 23: Commercial handline landings (mt) estimated in the initial runof the tilefish model.

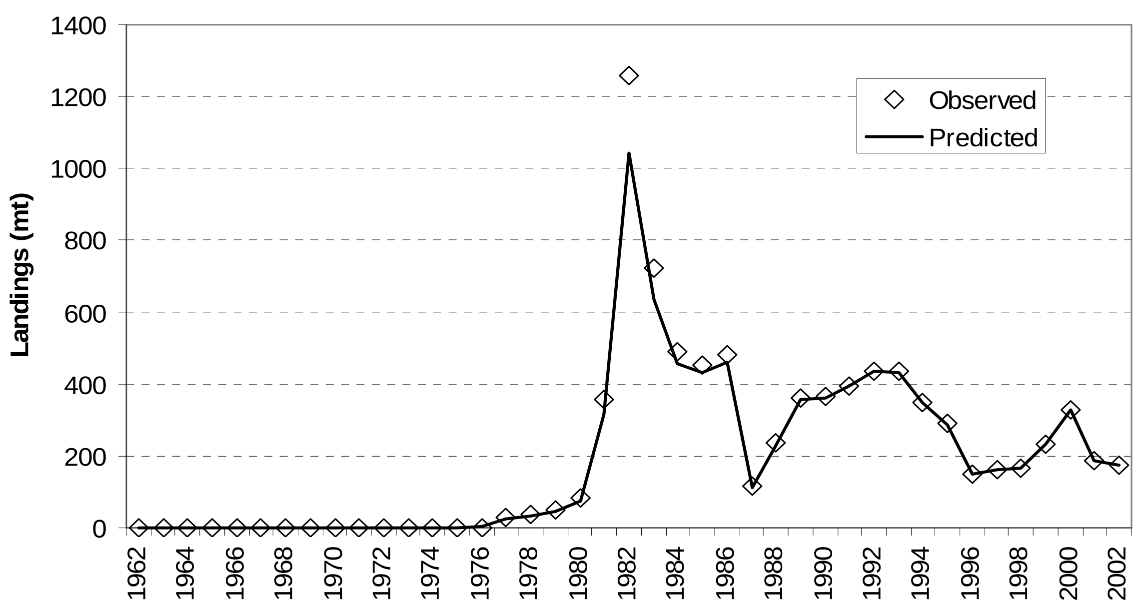


Figure 24: Commercial longline landings (mt) estimated in the initial run of the tilefish model.

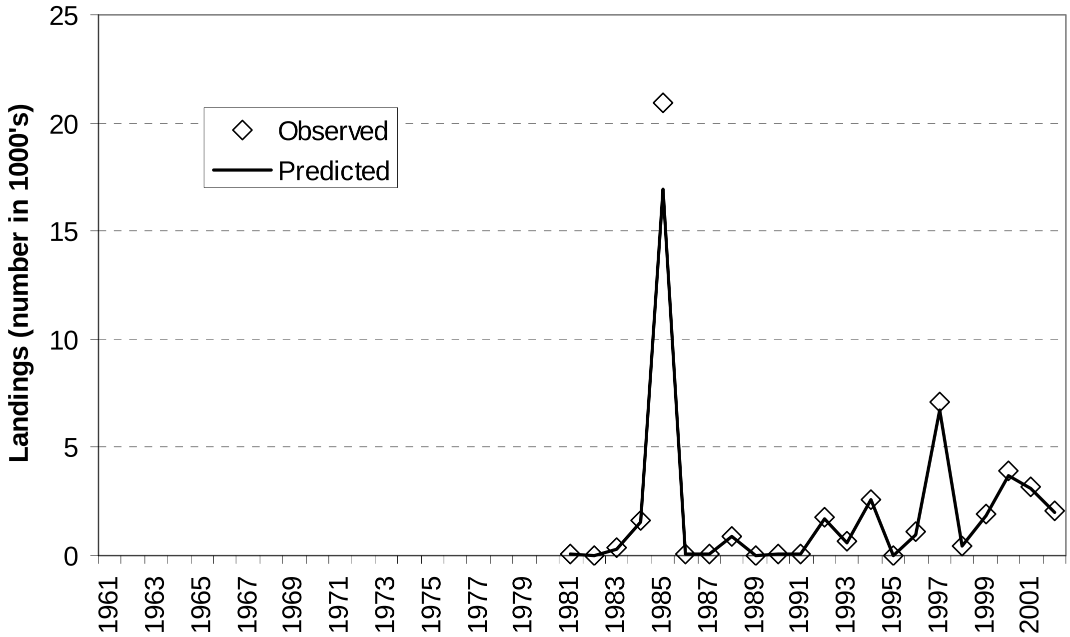


Figure 25: Recreational landings (1000s) estimated in the initial run of the tilefish model.

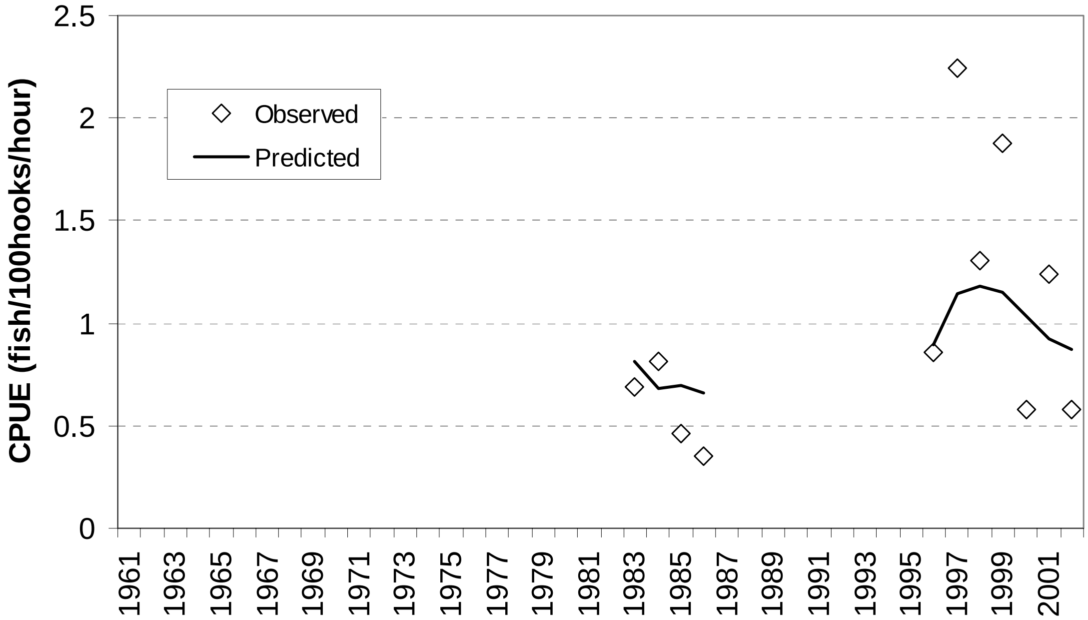


Figure 26: MARMAP index of abundance estimated in the initial run of the tilefish model.

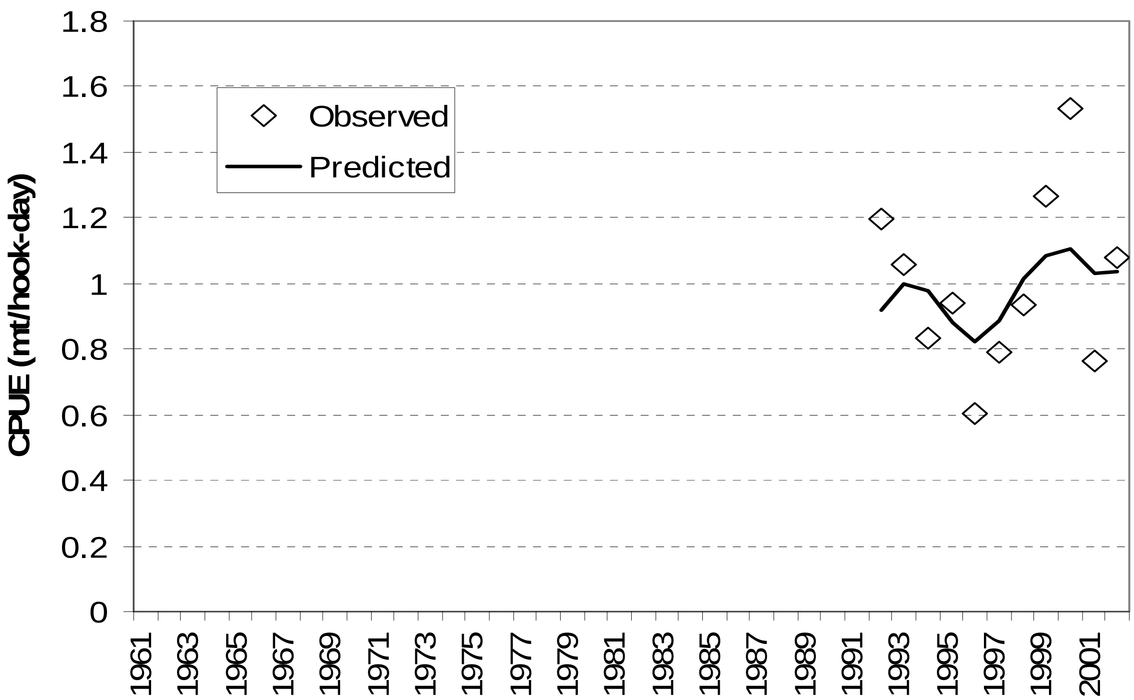


Figure 27: Commercial logbook index of abundance estimated in the initial run of the tilefish model.

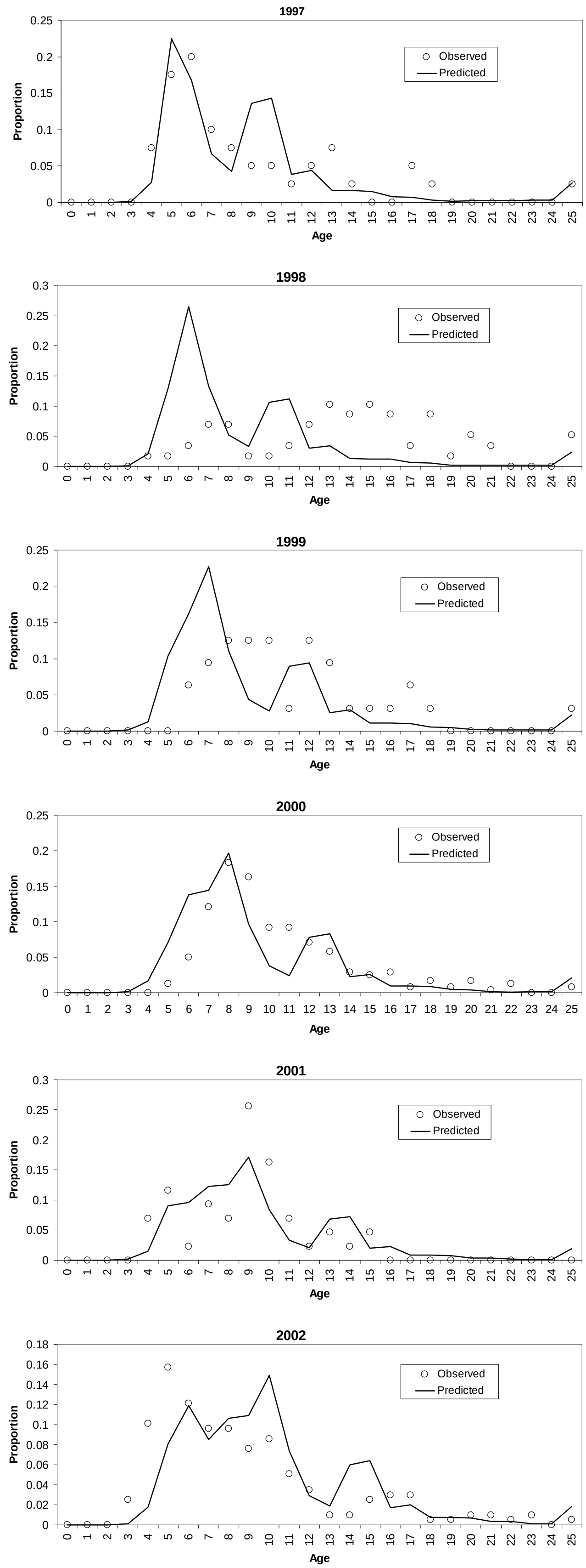


Figure 28: Commercial handline age compositions estimated in the initial run of the tilefish model.

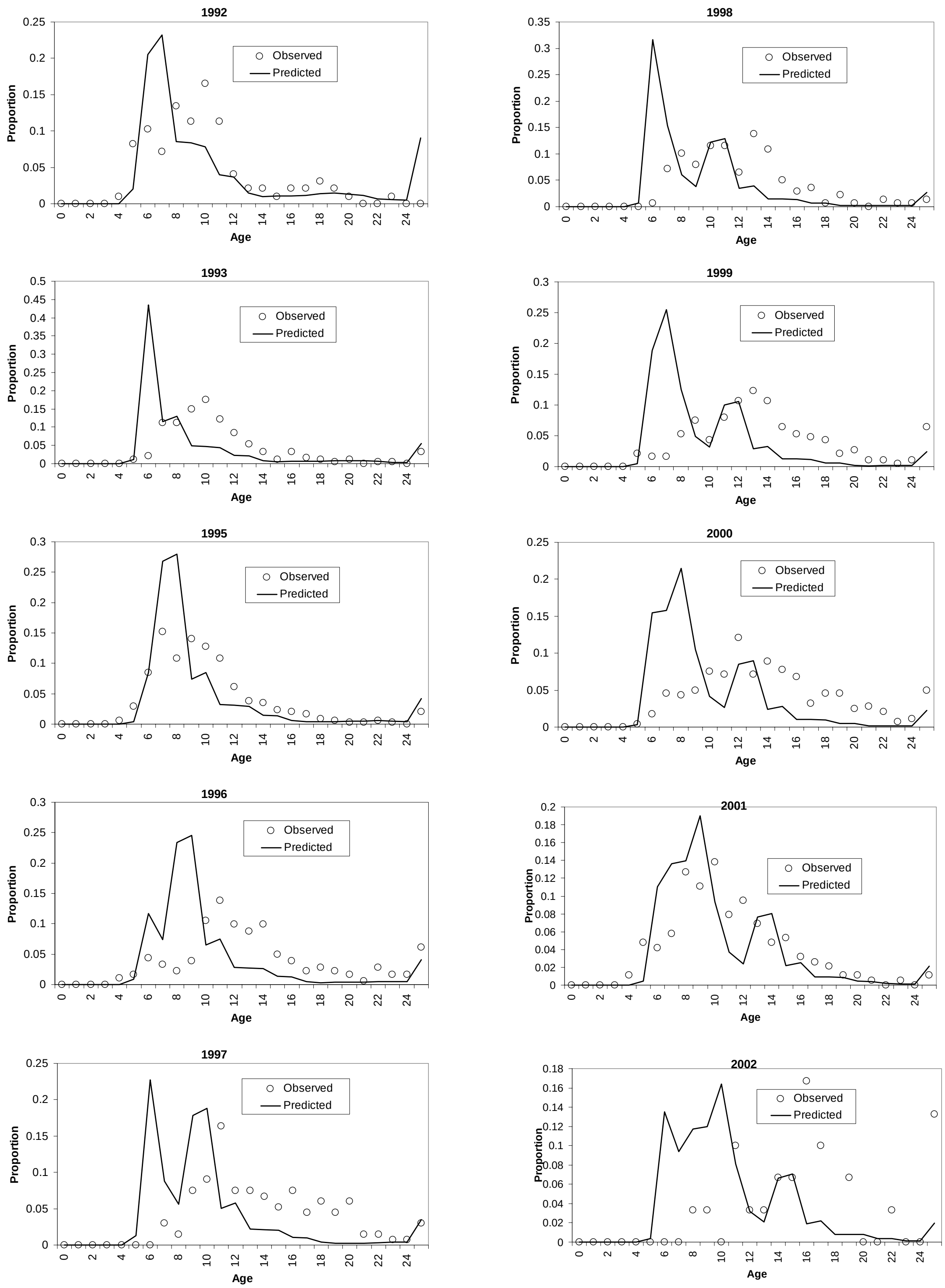


Figure 29: Commercial longline age compositions estimated in the initial run of the tilefish model.

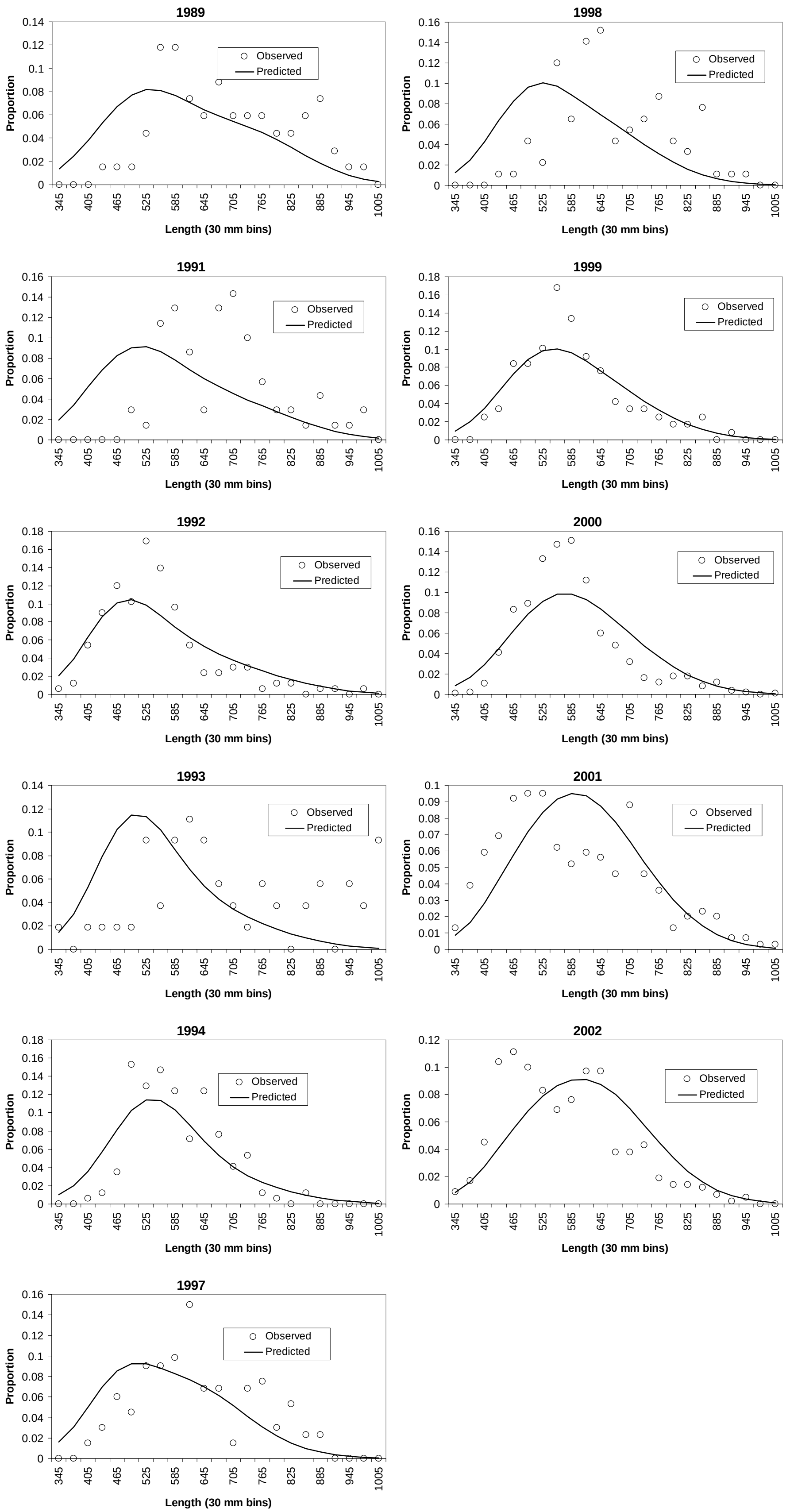


Figure 30: Commercial handline length compositions estimated in the initial run of the tilefish model.

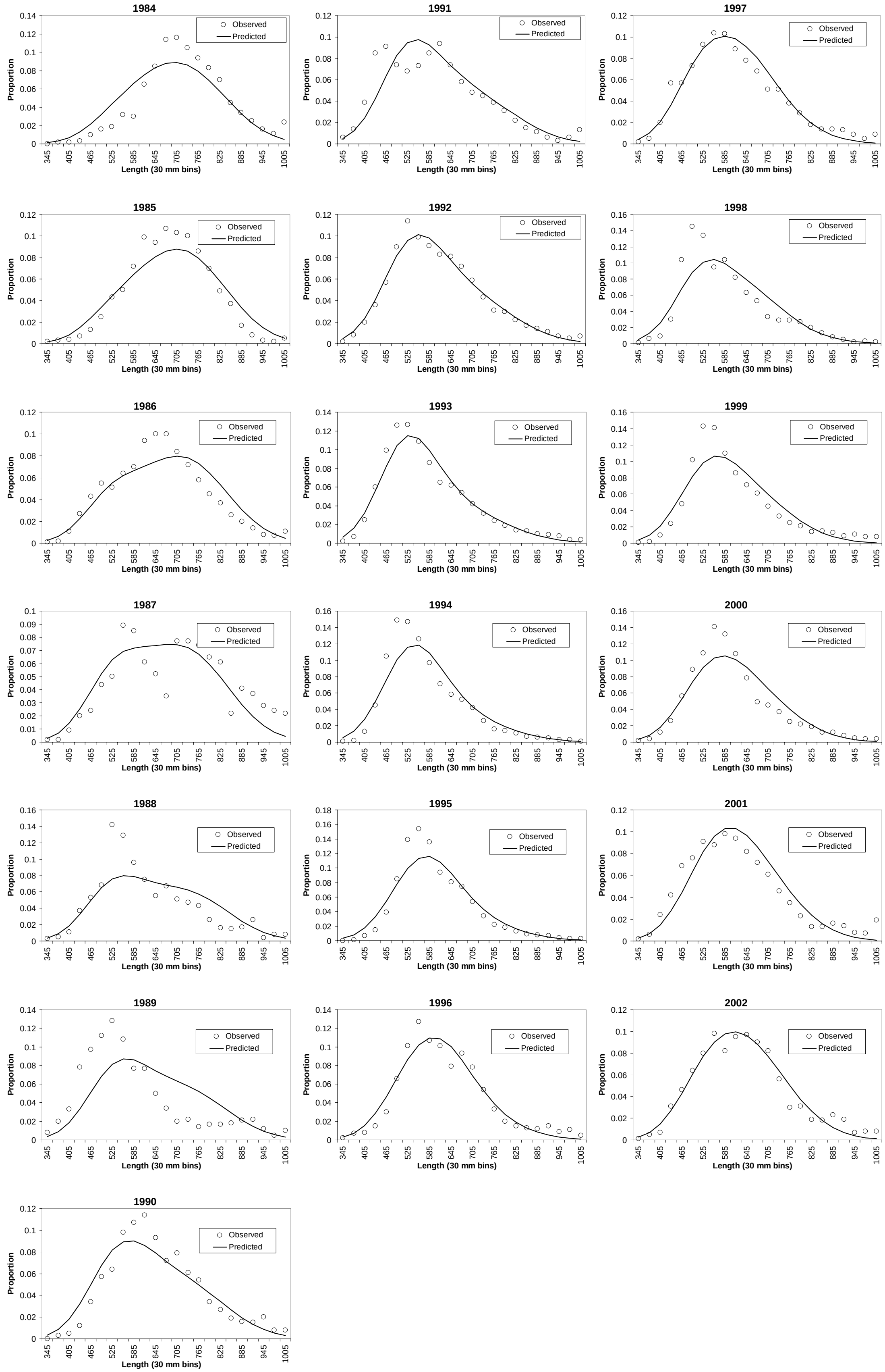


Figure 31: Commercial longline length compositions estimated in the initial run of the tilefish model.

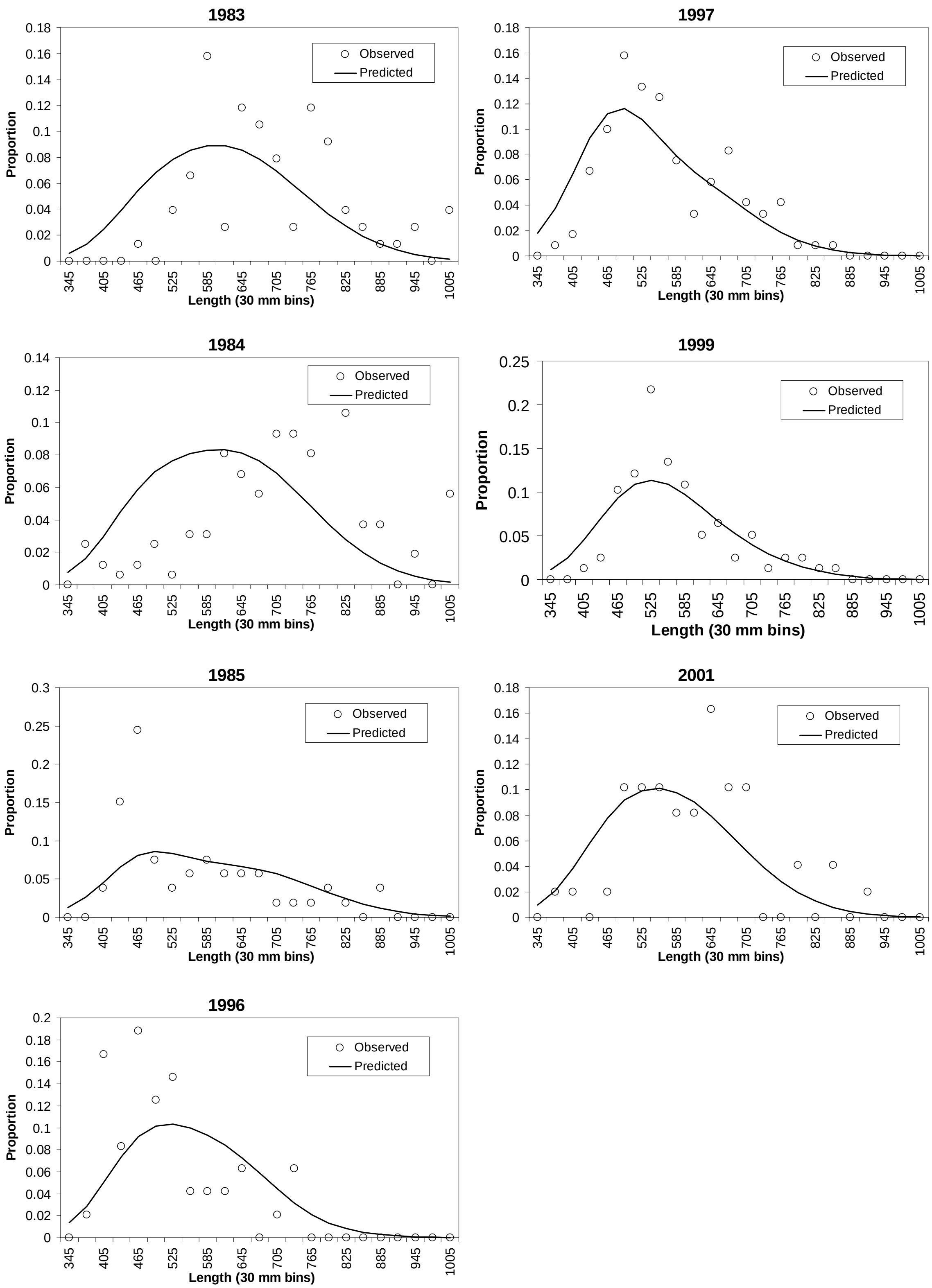


Figure 32: MARMAP horizontal longline length compositions estimated in the initial run of the tilefish model.

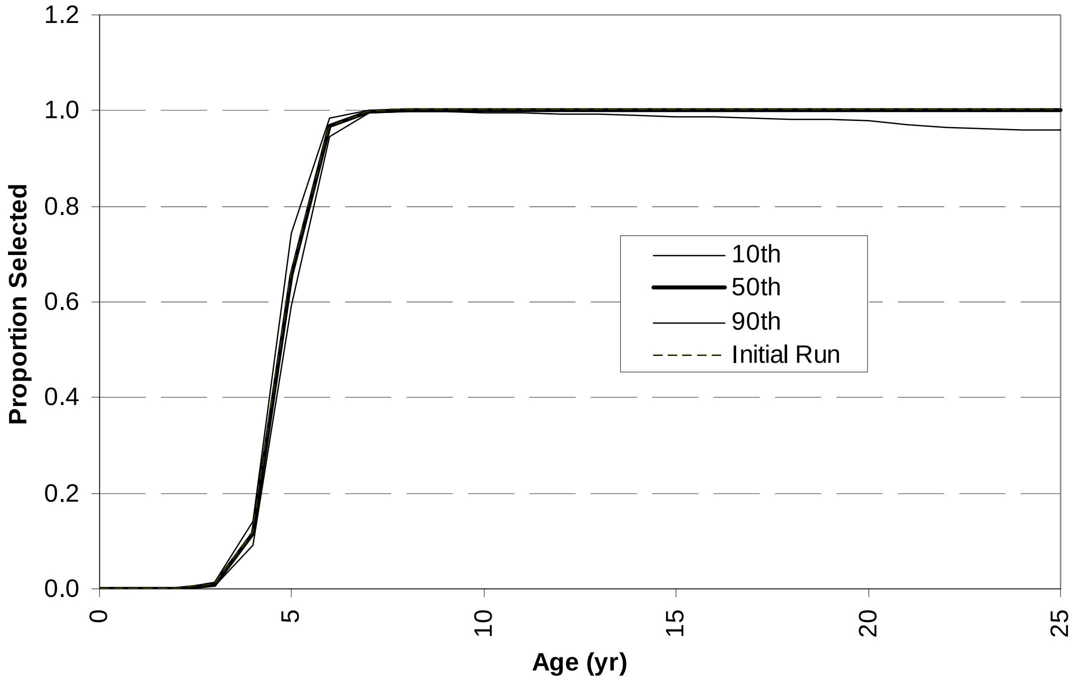


Figure 33: Commercial handline selectivity estimated in the tilefish model. Results shown are those of the initial run and the 10th, 50th (median), and 90th percentiles of the MCB runs.

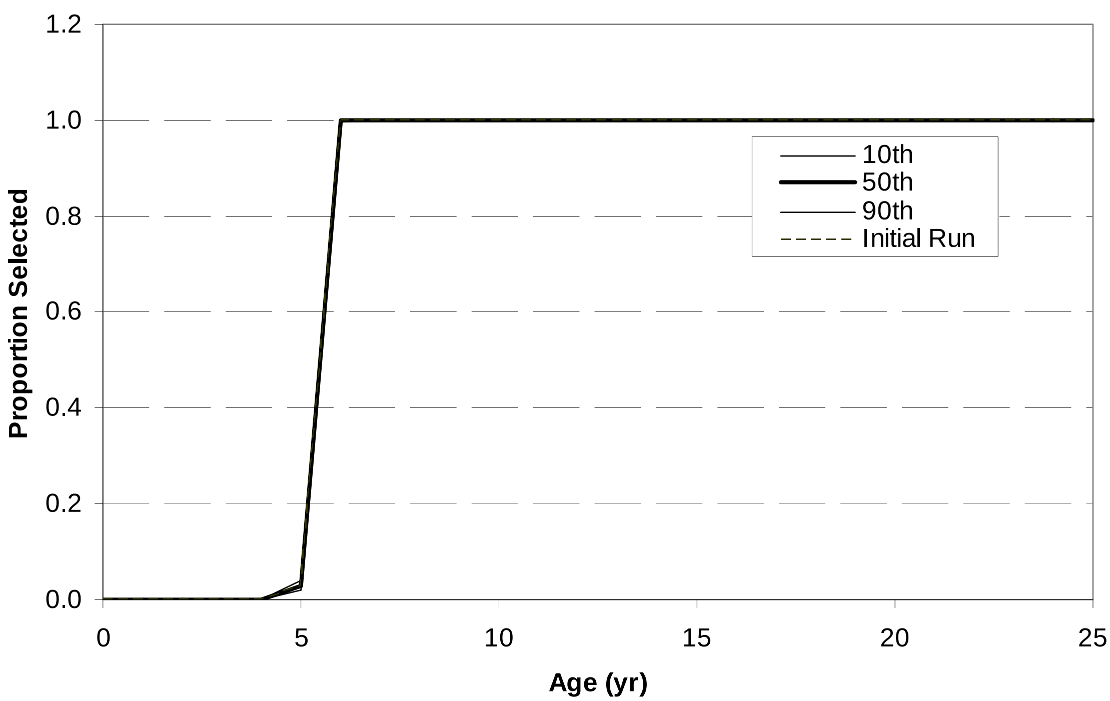


Figure 34: Commercial longline selectivity estimated in the tilefish model. Results shown are those of the initial run and the 10th, 50th (median), and 90th percentiles of the MCB runs.

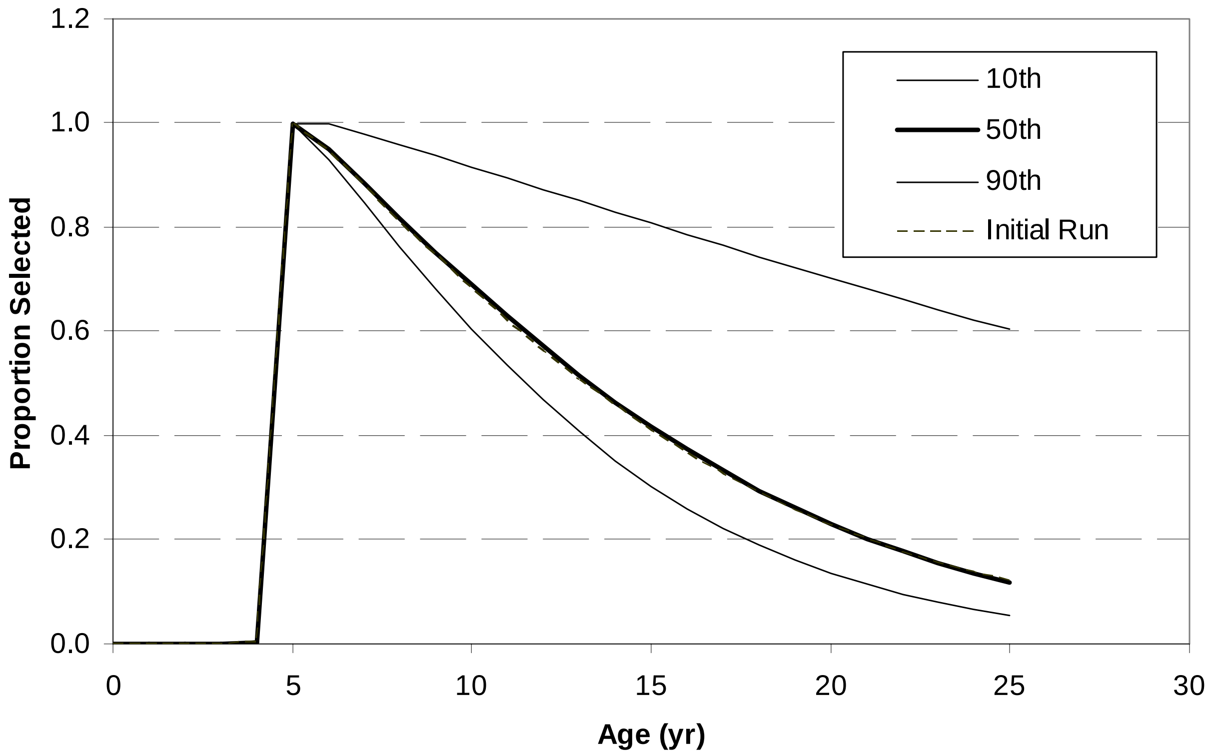


Figure 35: MARMAP horizontal longline selectivity estimated in the tilefish model. Results shown are those of the initial run and the 10th, 50th (median), and 90th percentiles of the MCB runs.

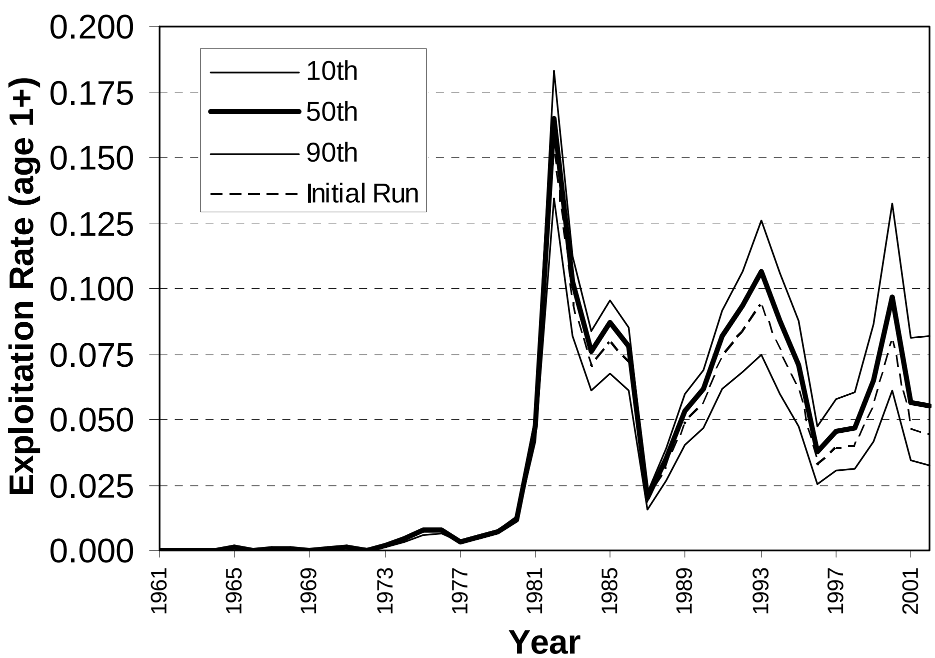


Figure 36: Exploitation rate (per yr) estimated by the tilefish model. Results shown are those of the initial run and the 10th, 50th (median), and 90th percentiles of the MCB runs.

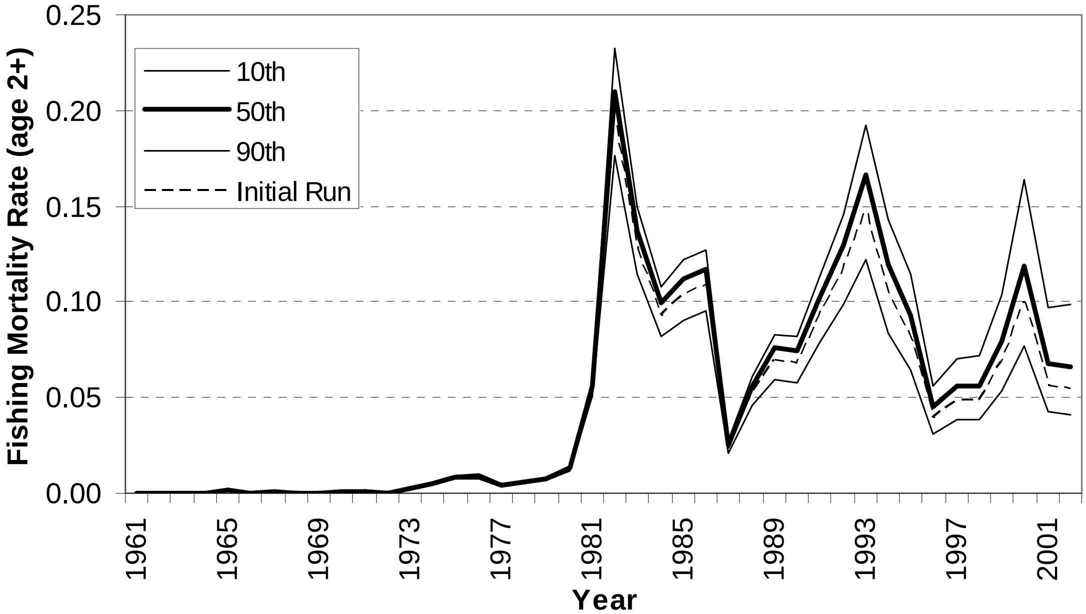


Figure 37: Fishing mortality rate (per yr) estimated by the tilefish model. Results shown are those of the initial run and the 10th, 50th (median), and 90th percentiles of the MCB runs.

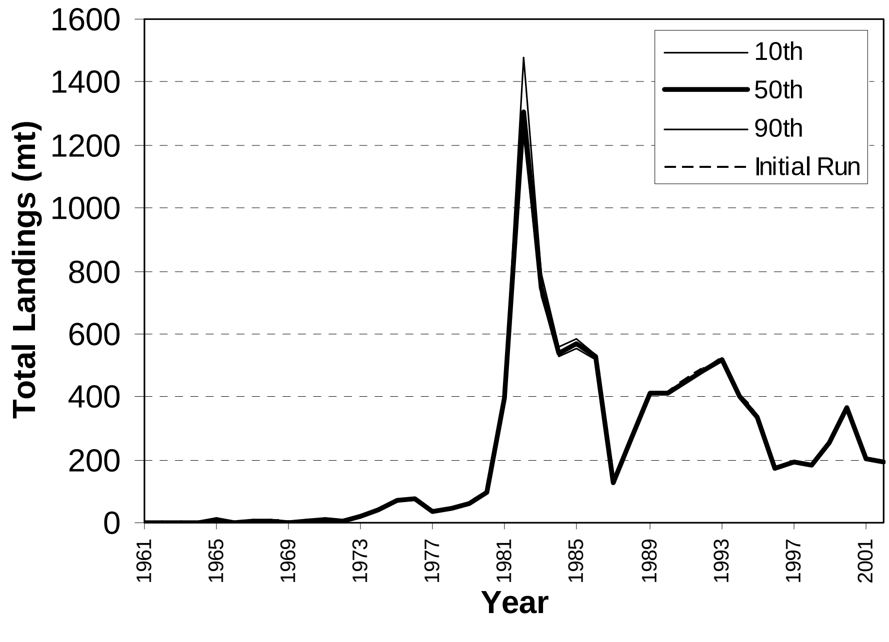


Figure 38: Total landings (mt) estimated by the tilefish model. Results shown are those of the initial run and the 10th, 50th (median), and 90th percentiles of the MCB runs.

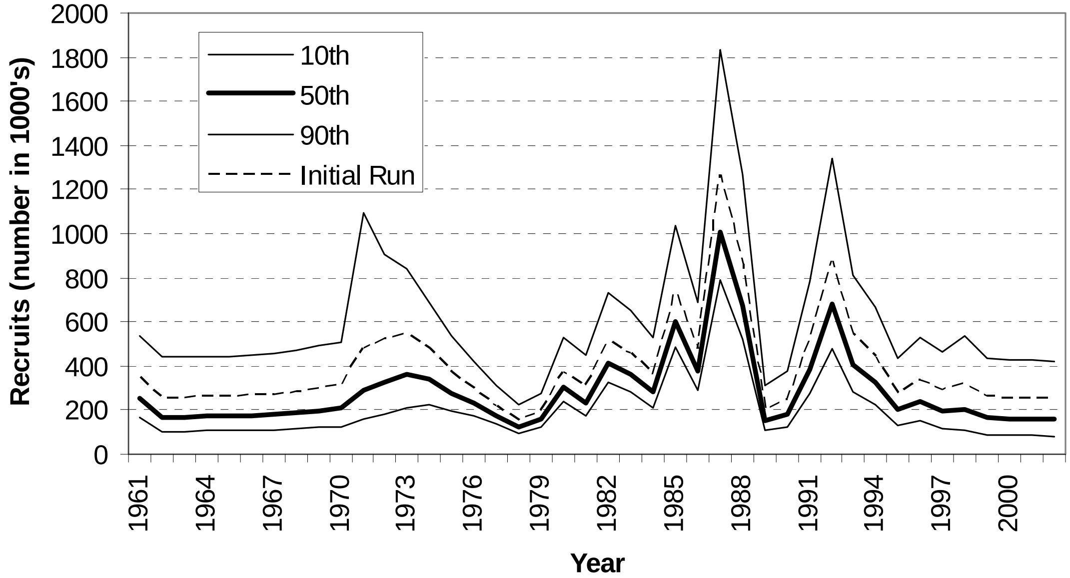


Figure 39: Number of recruits (1000s) estimated by the tilefish model. Results shown are those of the initial run and the 10th, 50th (median), and 90th percentiles of the MCB runs.

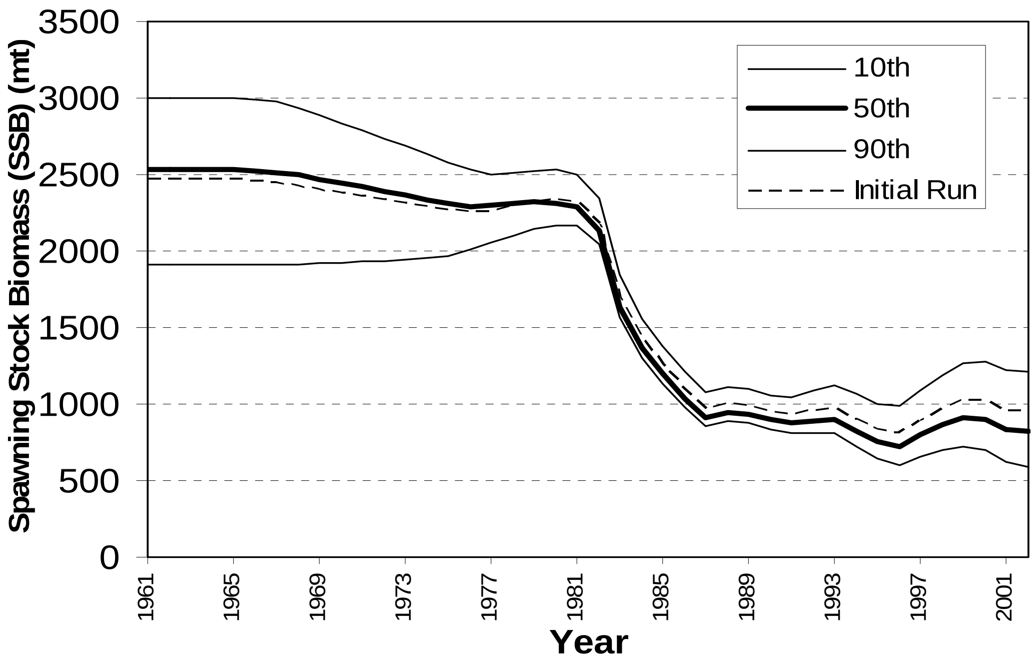


Figure 40: Spawning stock biomass (mt) estimated by the tilefish model. Results shown are those of the initial run and the 10th, 50th (median), and 90th percentiles of the MCB runs.

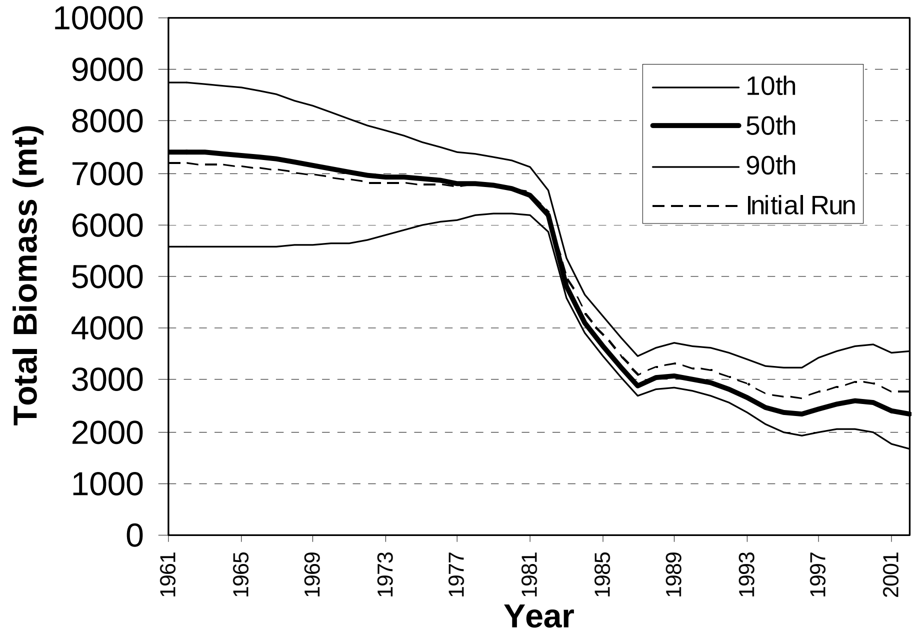


Figure 41: Total biomass (mt) estimated by the tilefish model. Results shown are those of the initial run and the 10th, 50th (median), and 90th percentiles of the MCB runs.

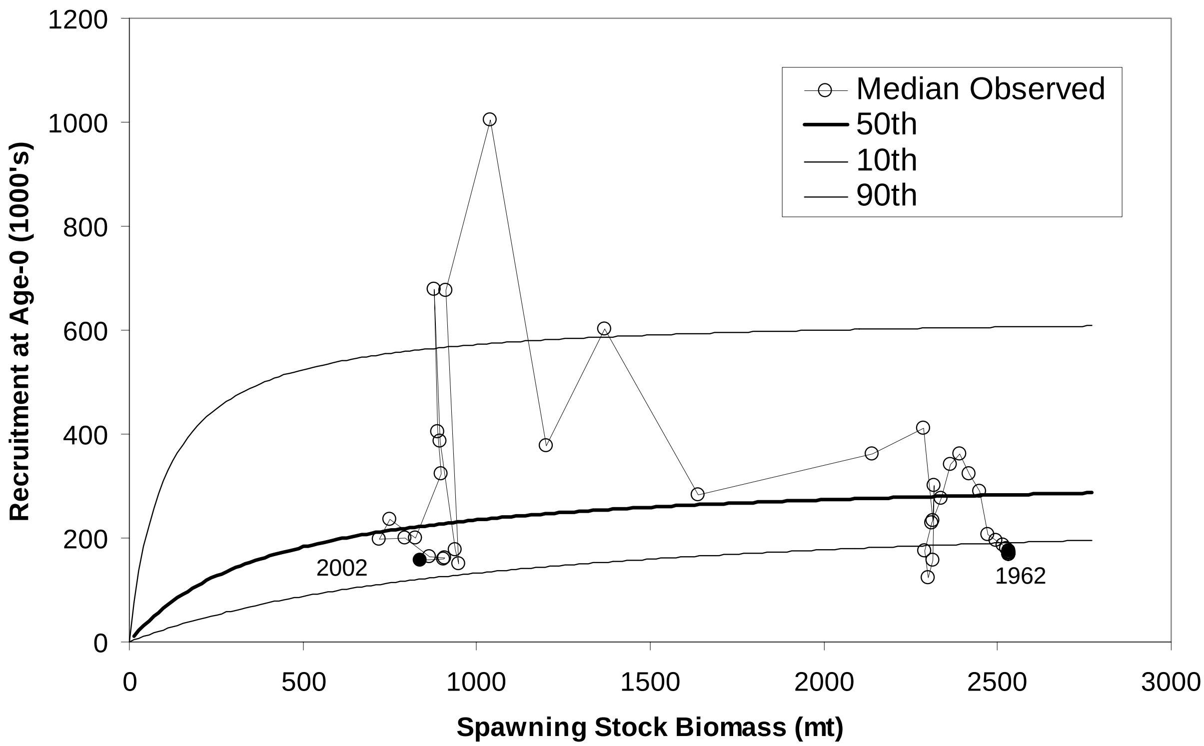


Figure 42: Stock-recruit curve estimated by the tilefish model, with the median stock-recruit time series overlaid (circles). Beginning (1962) and end (2002) of time series indicated by solid circles. Curves shown are the 10th, 50th (median), and 90th percentiles of the MCB runs.

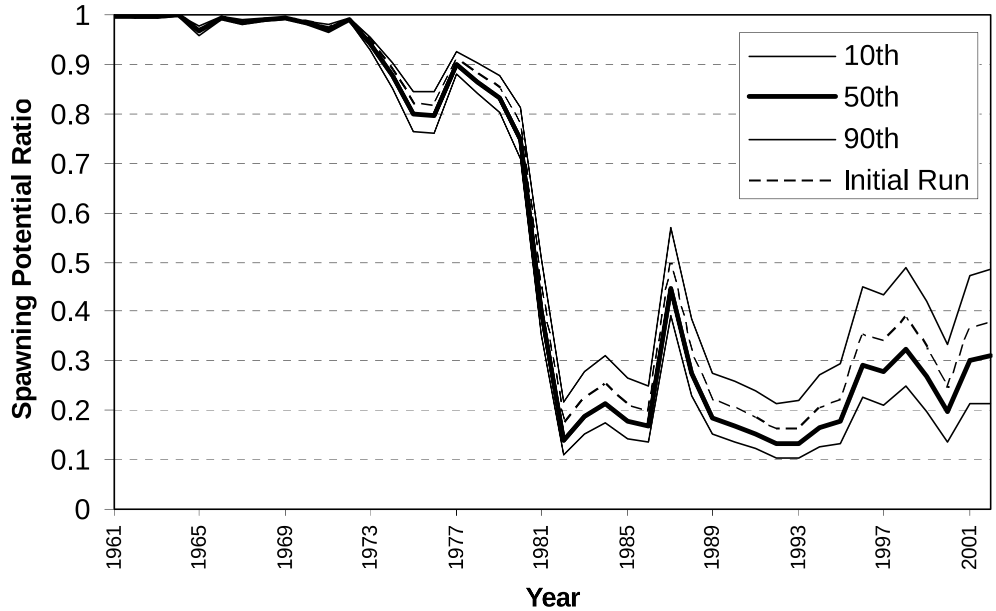


Figure 43: Static spawning potential ratio estimated by the tilefish model. Results shown are those of the initial run and the 10th, 50th (median), and 90th percentiles of the MCB runs.

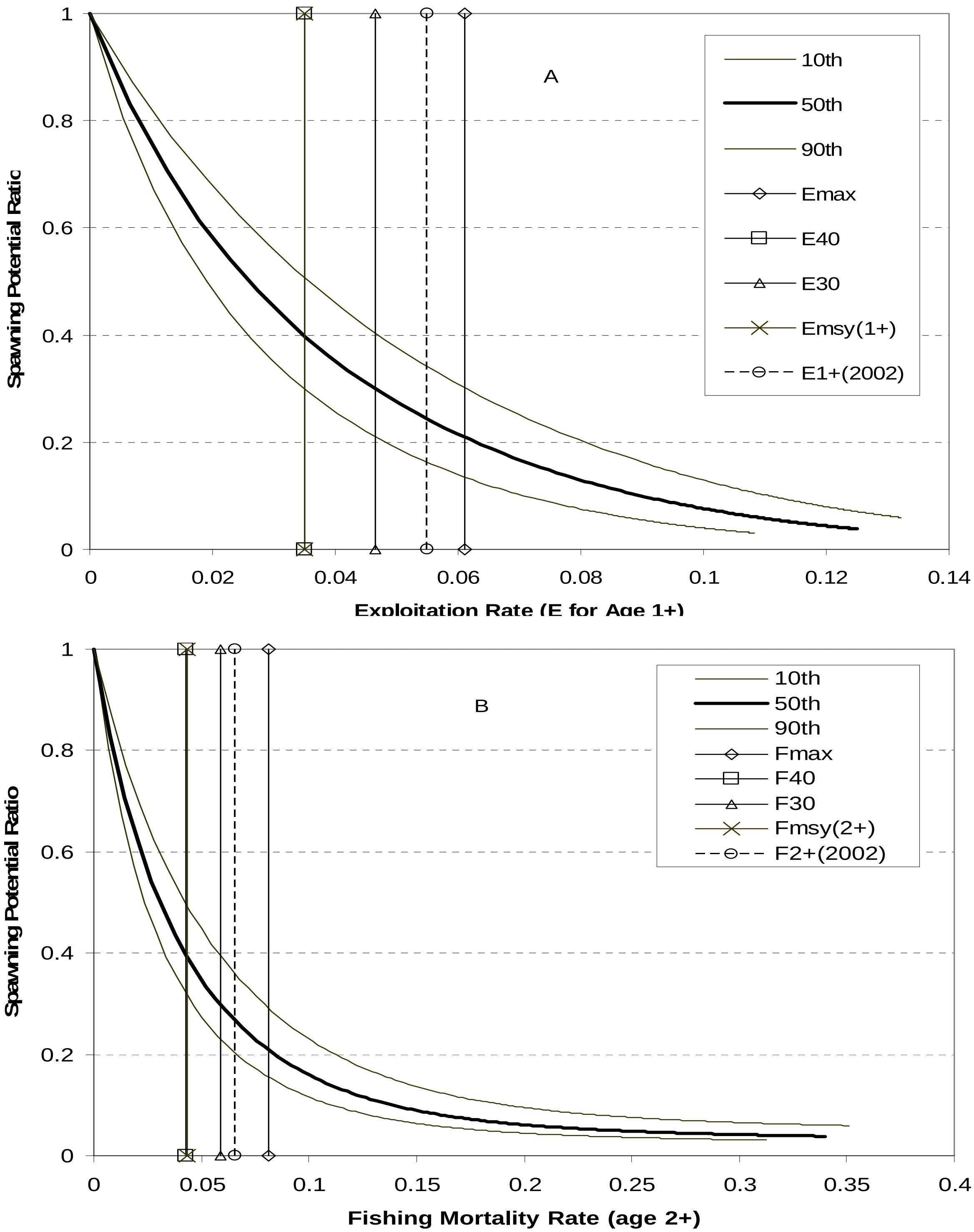
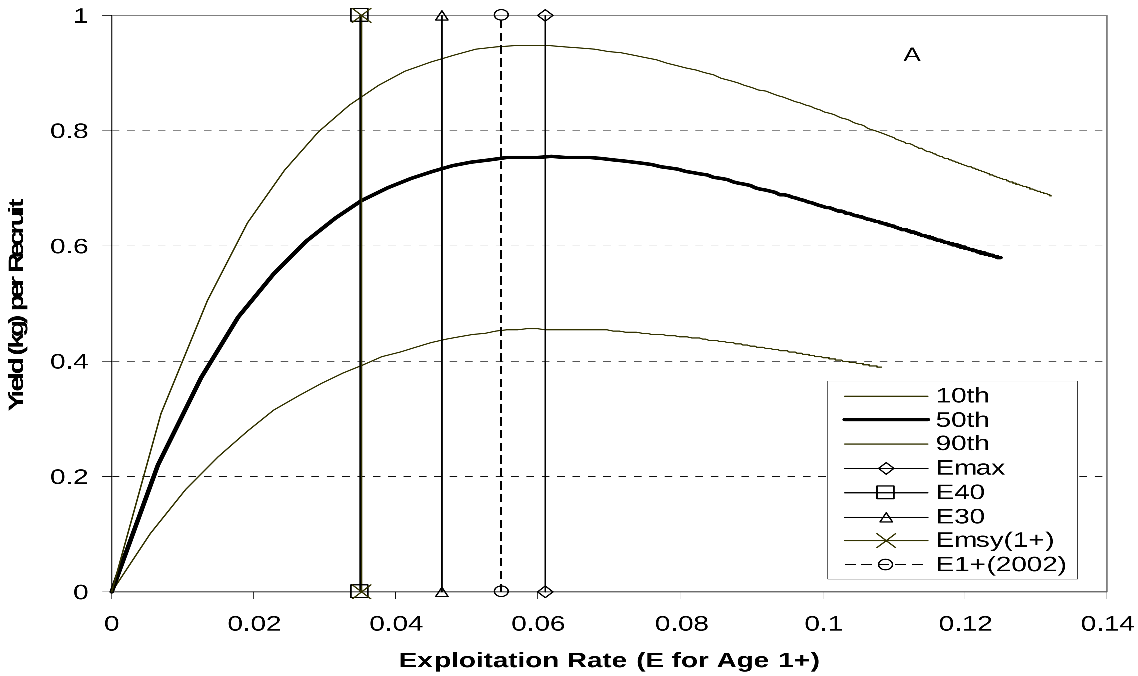


Figure 44: Spawning potential ratio (SSB-per-recruit relative to SSB-per-recruit at F=0) of tilefish as a function of a) exploitation rate or b) fishing mortality rate. Values are based on the average exploitation ratios among the three fisheries from the last three years (1999-2002) and their respective selectivity patterns. Results shown are the 10th, 50th (median), and 90th percentiles of the MCB runs, along with median benchmarks and median 2002 rate.



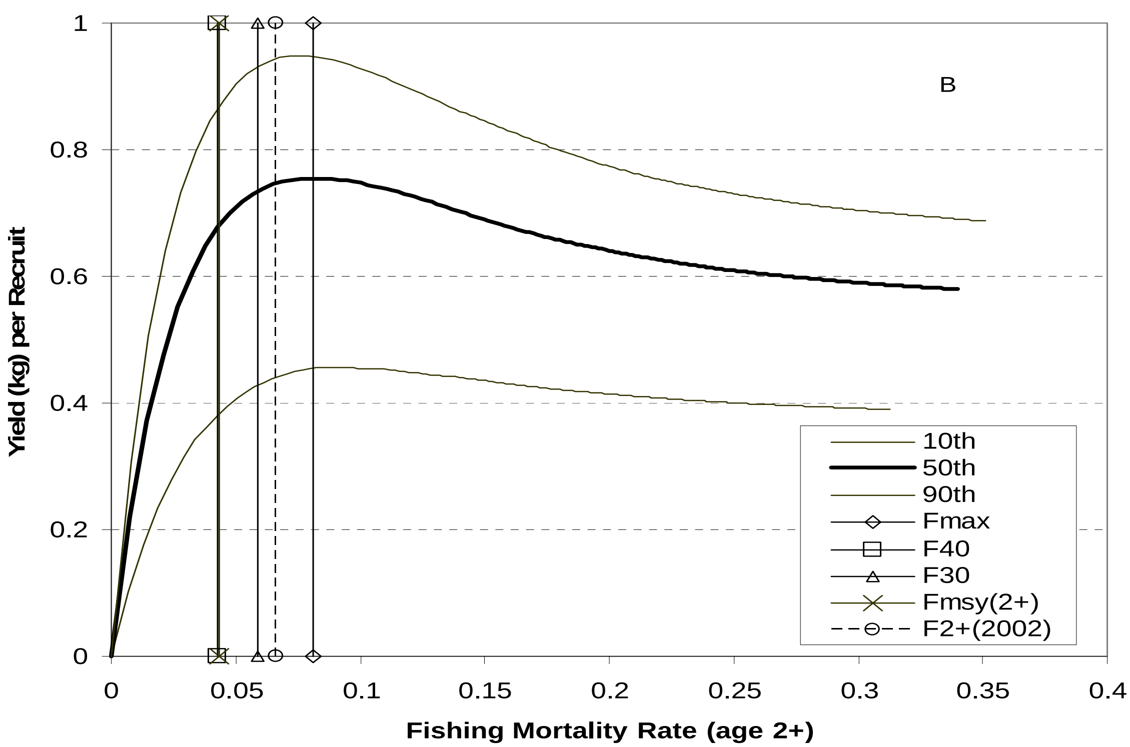


Figure 45: Yield(kg)-per-recruit of tilefish as a function of a) exploitation rate or b) fishing mortality rate. Values are based on the average exploitation ratios among the three fisheries from the last three years (1999-2002) and their respective selectivity patterns. Results shown are the 10th, 50th (median), and 90th percentiles of the MCB runs, along with median benchmarks and median 2002 rate.

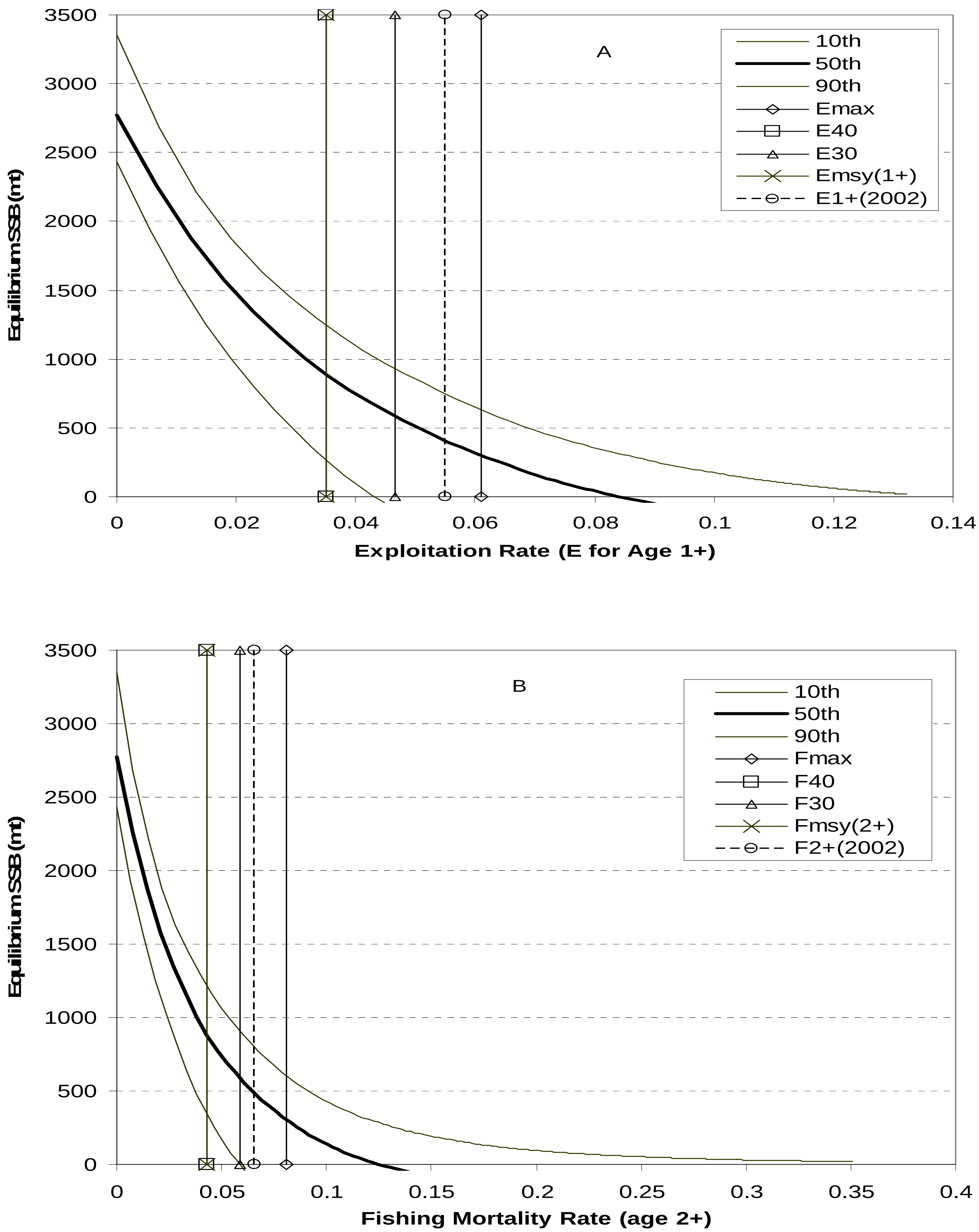


Figure 46: Equilibrium SSB (mt) of tilefish as a function of a) exploitation rate or b) fishing mortality rate. Values are based on the estimated stock-recruit curves and the average exploitation ratios among the three fisheries from the last three years (1999-2002) and their respective selectivity patterns. Results shown are the 10th, 50th (median), and 90th percentiles of the MCB runs, along with median benchmarks and median 2002 rate.

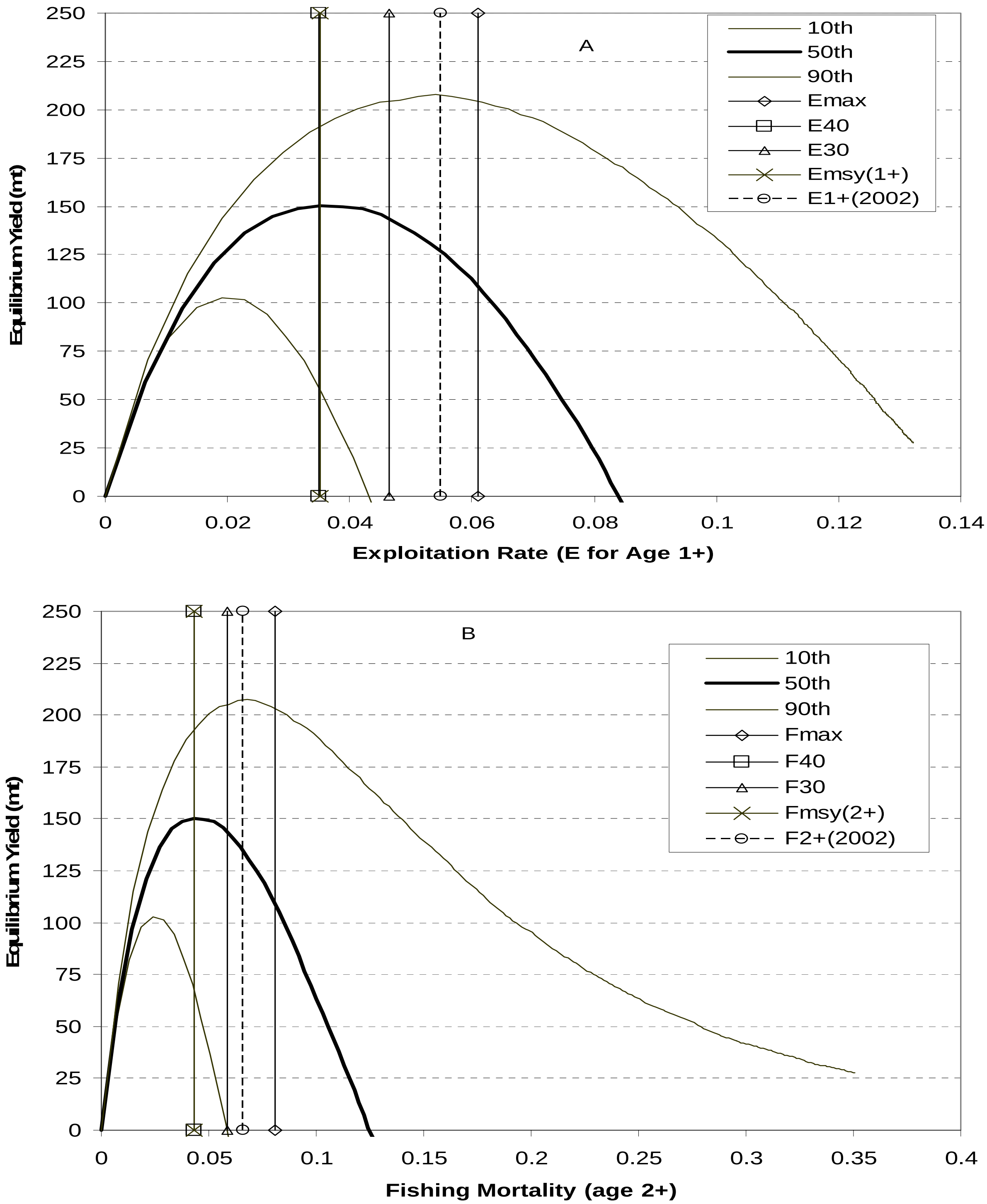
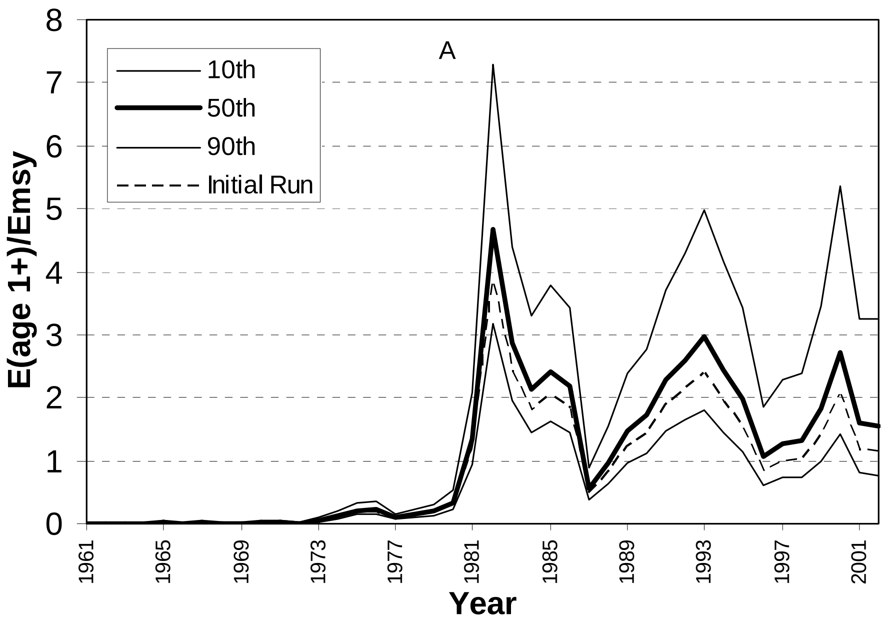


Figure 47: Equilibrium yield (mt) of tilefish as a function of a) exploitation rate or b) fishing mortality rate. Values are based on the estimated stock-recruit curves and the average exploitation ratios among the three fisheries from the last three years (1999-2002) and their respective selectivity patterns. Results shown are the 10^{th}, 50^{th} (median), and 90^{th} percentiles of the MCB runs, , along with median benchmarks and median 2002 rate.



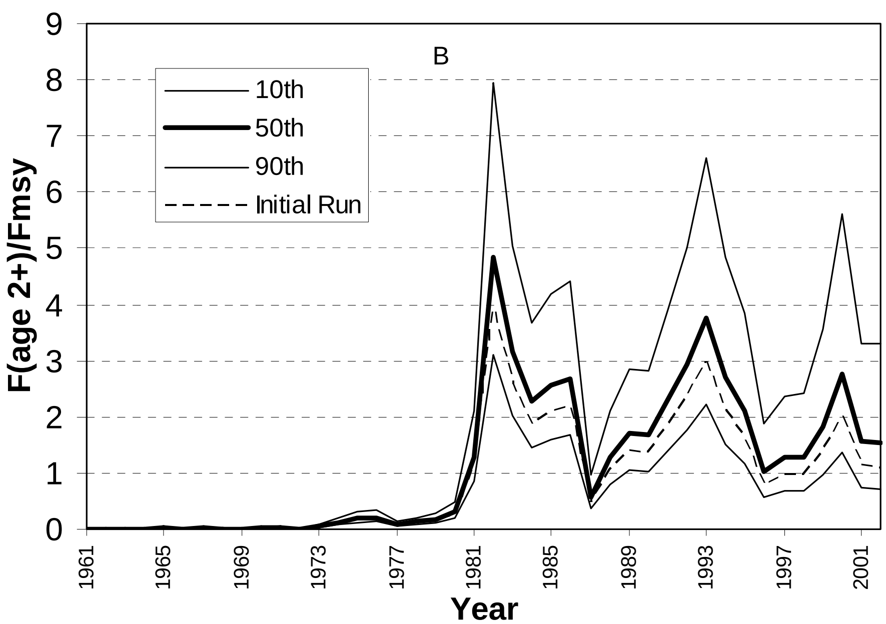


Figure 48: Time series of a) exploitation rate relative to Emsy and b) fishing mortality rate relative to Fmsy, as estimated by the tilefish model. Results shown are those of the initial run and the 10th, 50th (median), and 90th percentiles of the MCB runs.

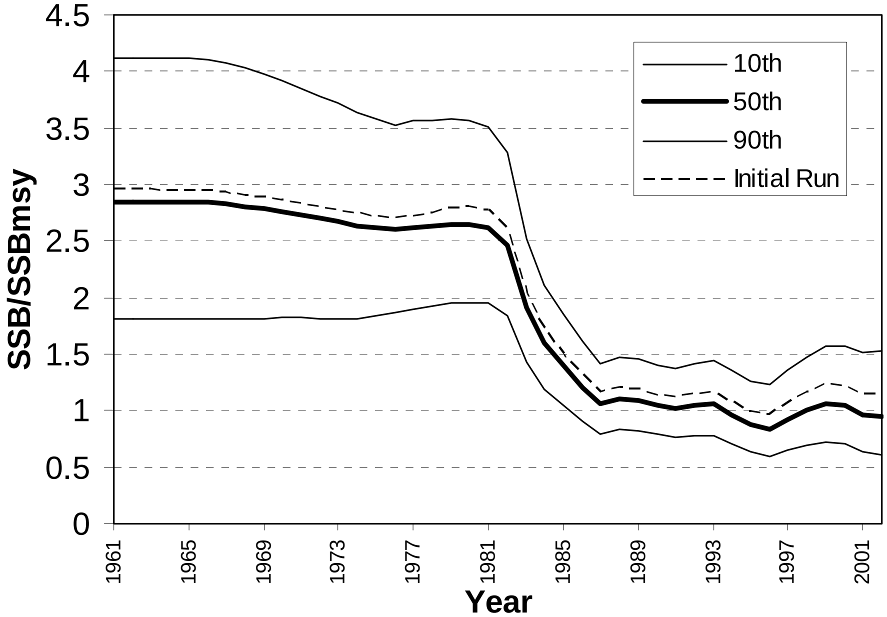


Figure 49: Time series of spawning stock biomass relative to SSBmsy, as estimated by the tilefish model. Results shown are those of the initial run and the 10th, 50th (median), and 90th percentiles of the MCB runs.

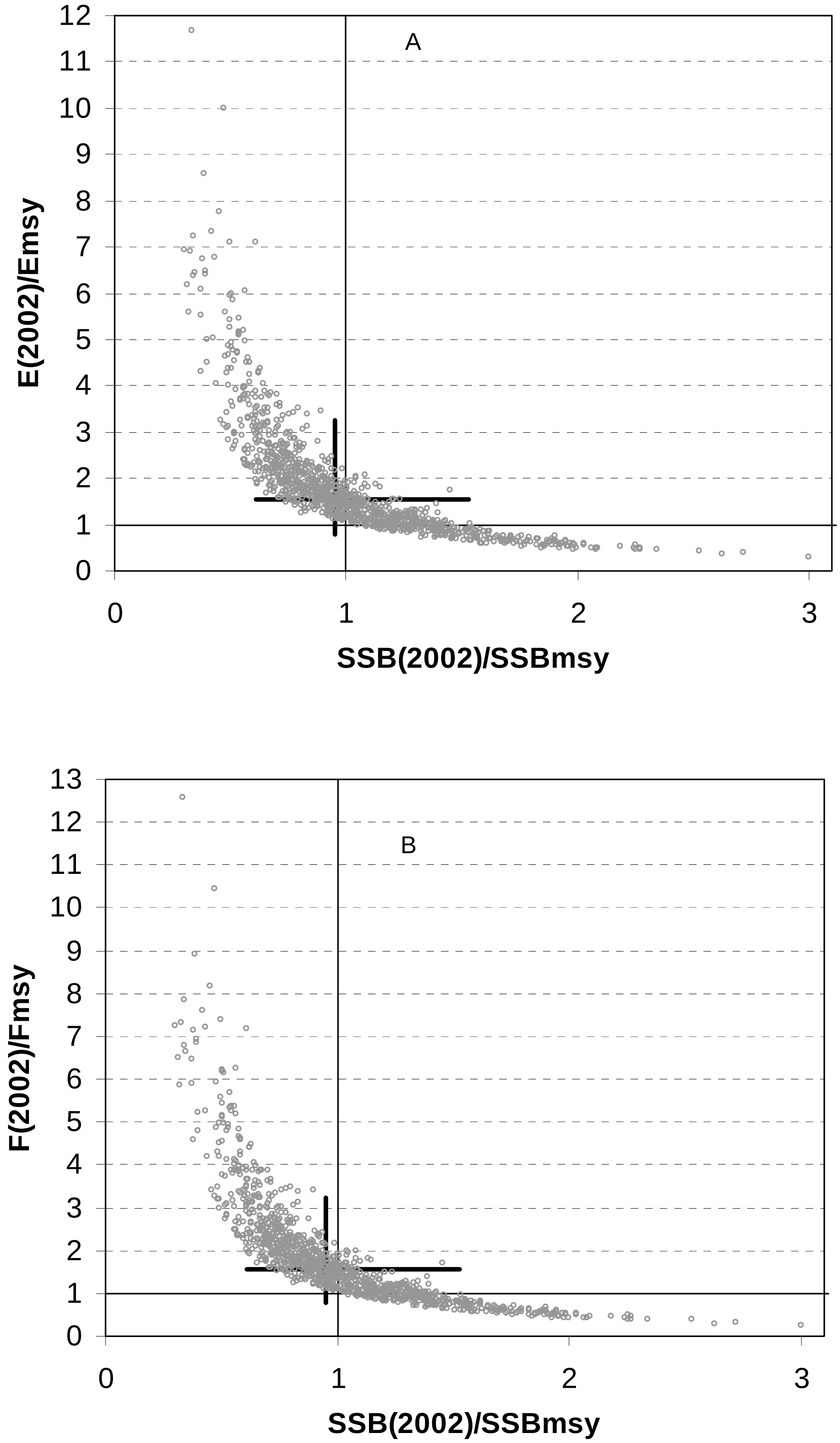


Figure 50: Estimated tilefish stock status in year 2002 relative to MSY benchmarks. Circles represent results from all MCB runs. Thick horizontal line spans the 10^{th} to 90^{th} percentiles of SSB(2002)/SSBmsy. In a) thick vertical line spans the 10^{th} to 90^{th} percentiles of E(2002)/Emsy; in b) thick vertical line spans the 10^{th} to 90^{th} percentiles of F(2002)/Fmsy. The thick lines intersect at the median values. E and Emsy are of age 1+; F and Fmsy are of age 2+.

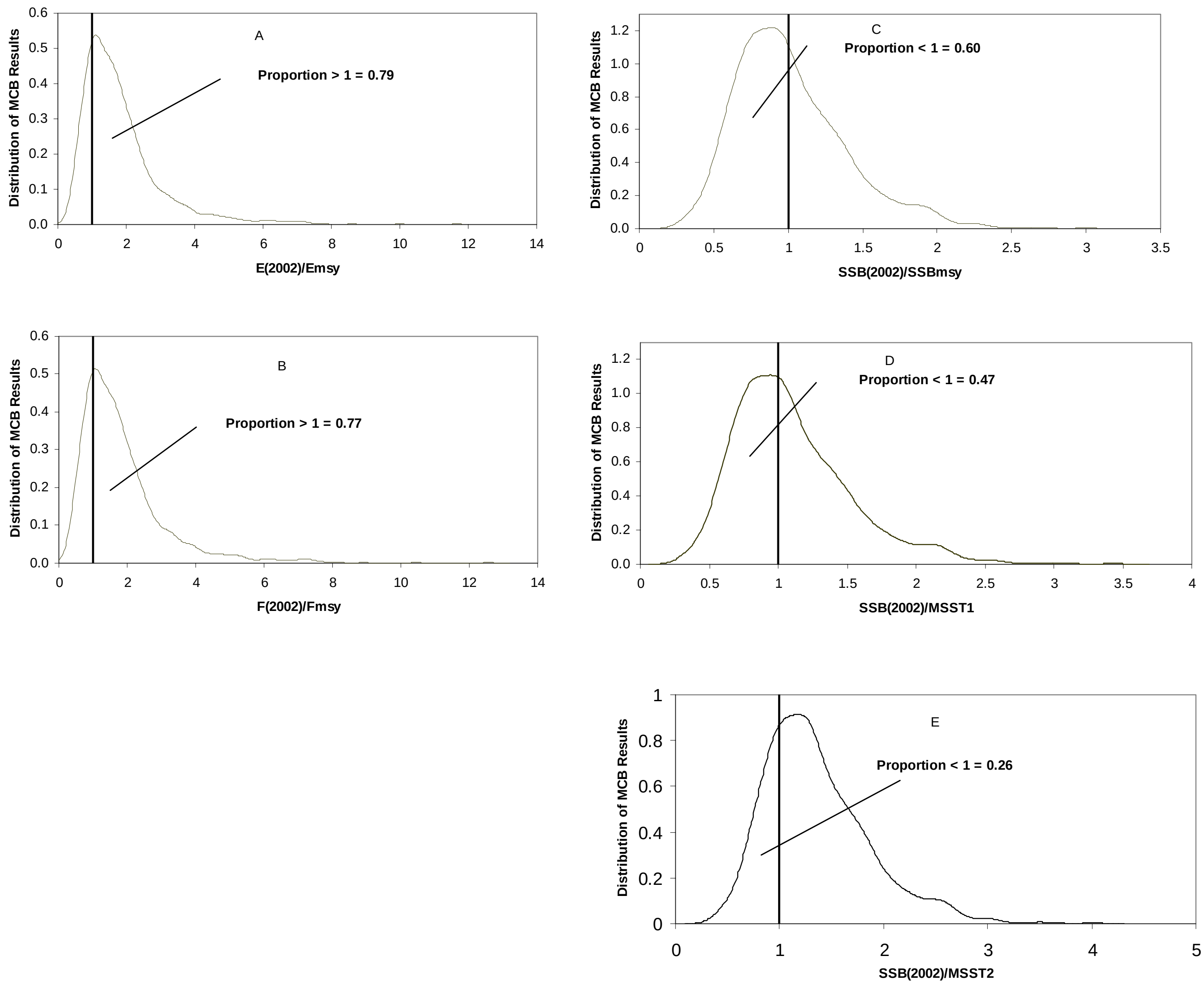


Figure 51: Distributions of 2002 stock status from MCB runs of the tilefish model. a) E(2002)/Emsy; b) F(2002)/Fmsy; c) SSB(2002)/SSBmsy; d) SSB(2002)/MSST1; e) SSB(2002)/MSST2. E and Emsy are of age 1+; F and Fmsy are of age 2+. MSST1 computed as (1-M)SSBmsy and MSST2 computed as 0.75SSBmsy (see section 2.6.8).

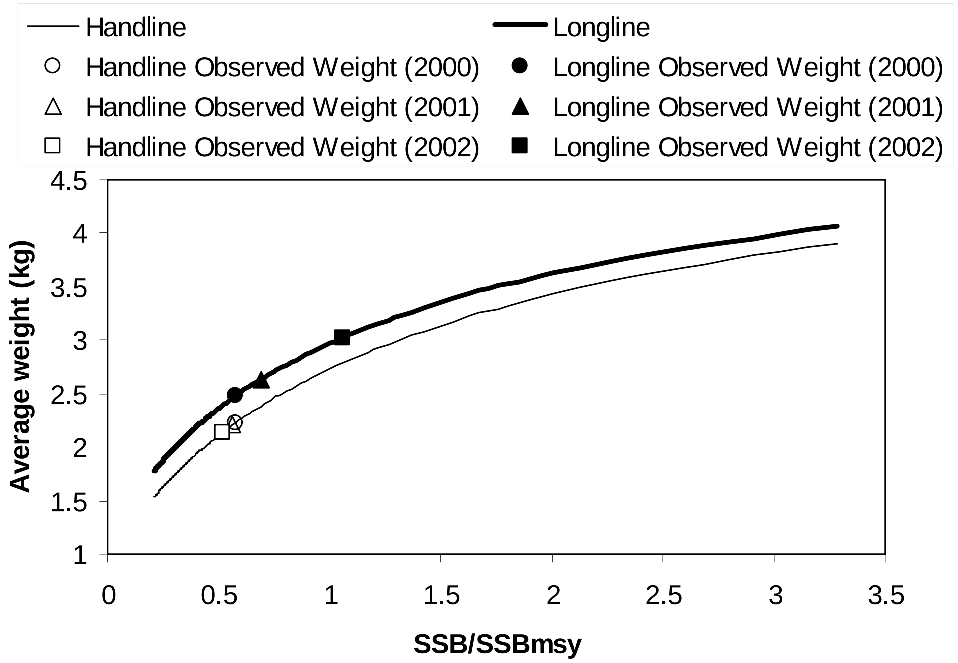
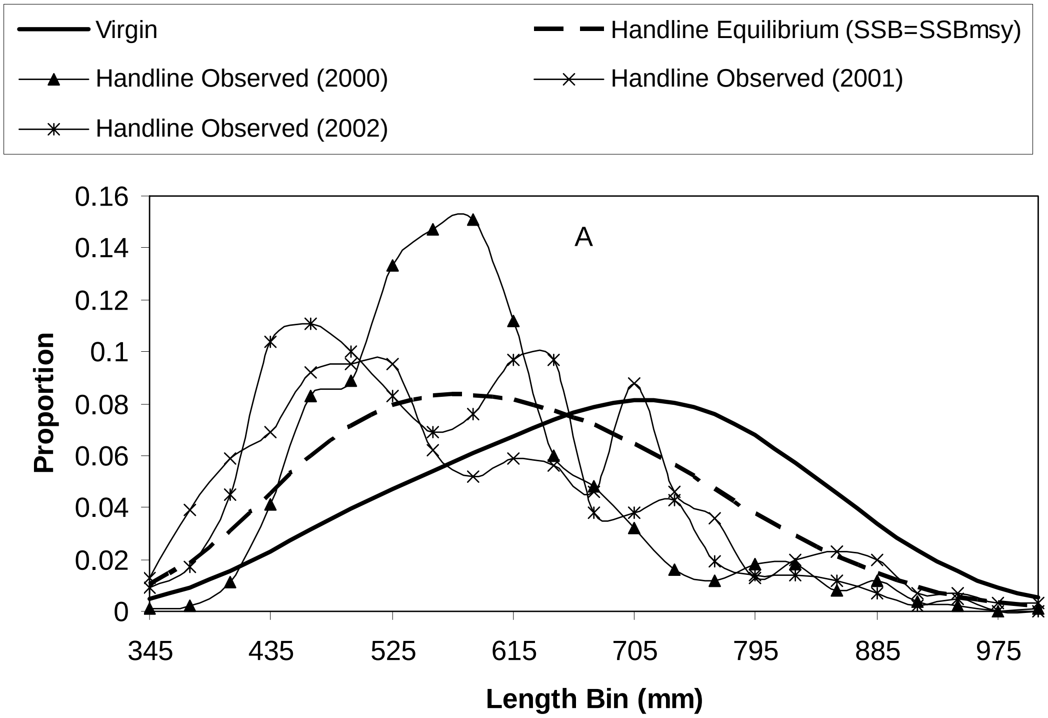


Figure 52: The average weight (kg) of landed fish from the commercial handline and longline fisheries relative to stock status (SSB/SSBmsy) for tilefish using the selectivity estimates from the initial run model and assuming an equilibrium age-structure.



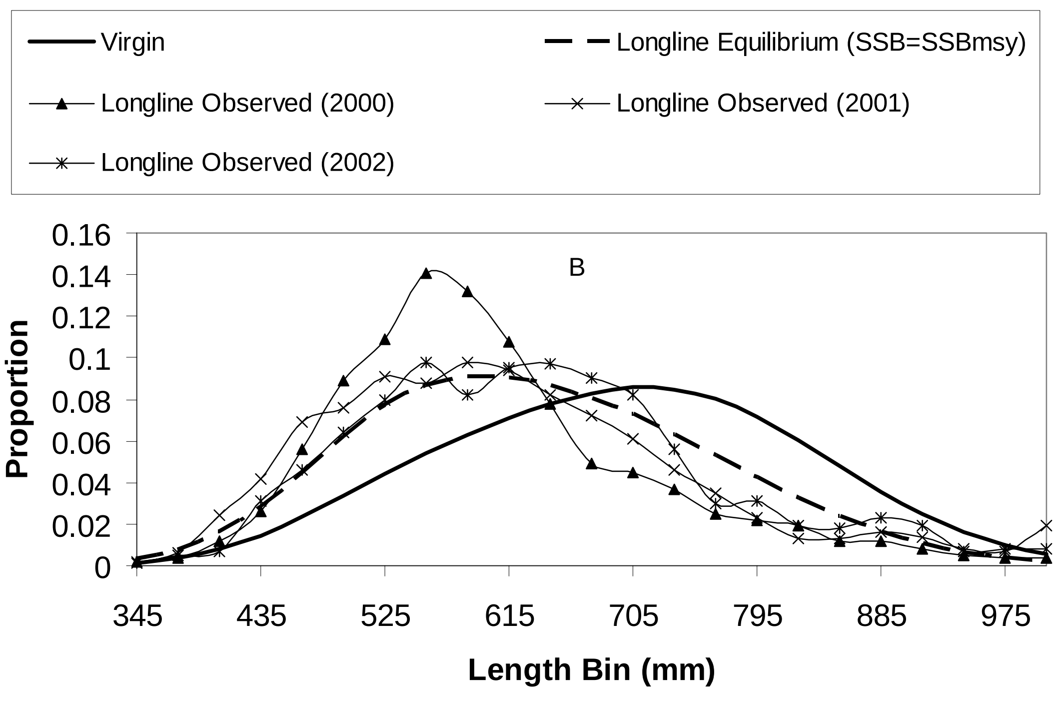


Figure 53: The hypothetical virgin length composition, equilibrium length composition at SSB=SSBmsy, and observed length compositions (years (2000–2002) of landed tilefish. A) commercial handline and B) longline fisheries for tilefish. Computations assume an equilibrium age-structure. Selectivity and SSBmsy estimates come from the initial run model.

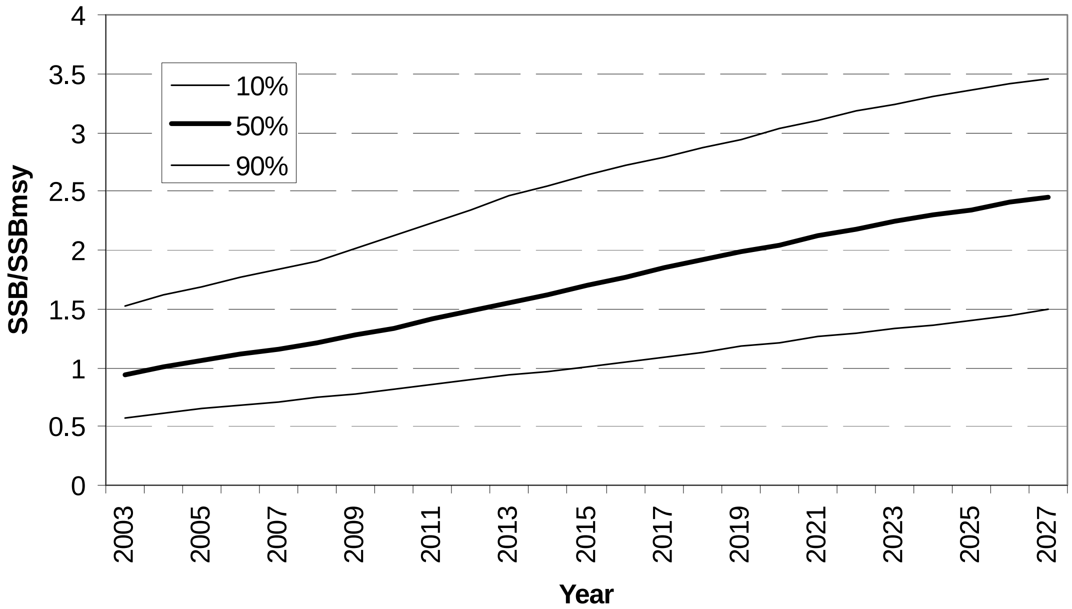
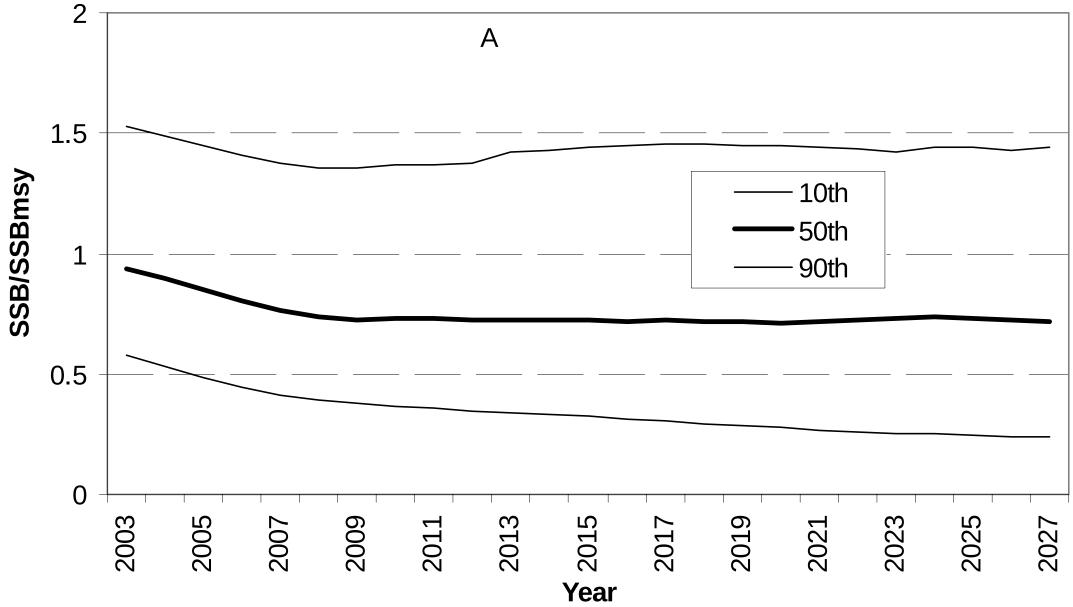


Figure 54: Projections of SSB/SSBmsy from tilefish model with F=0. Results shown are those of the 10th, 50th (median), and 90th percentiles of the MCB runs.



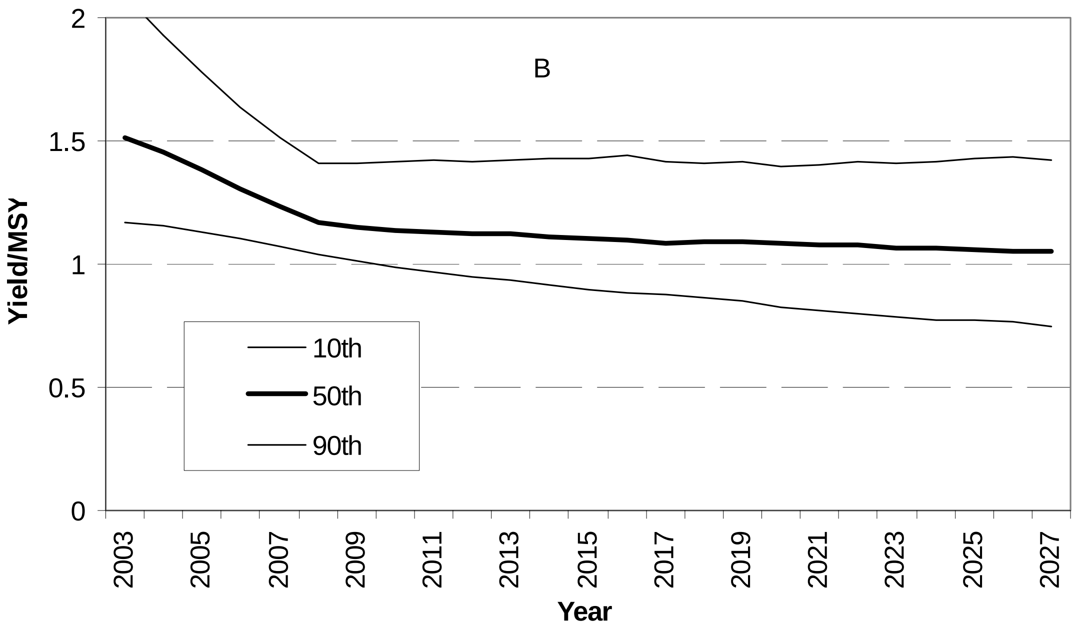
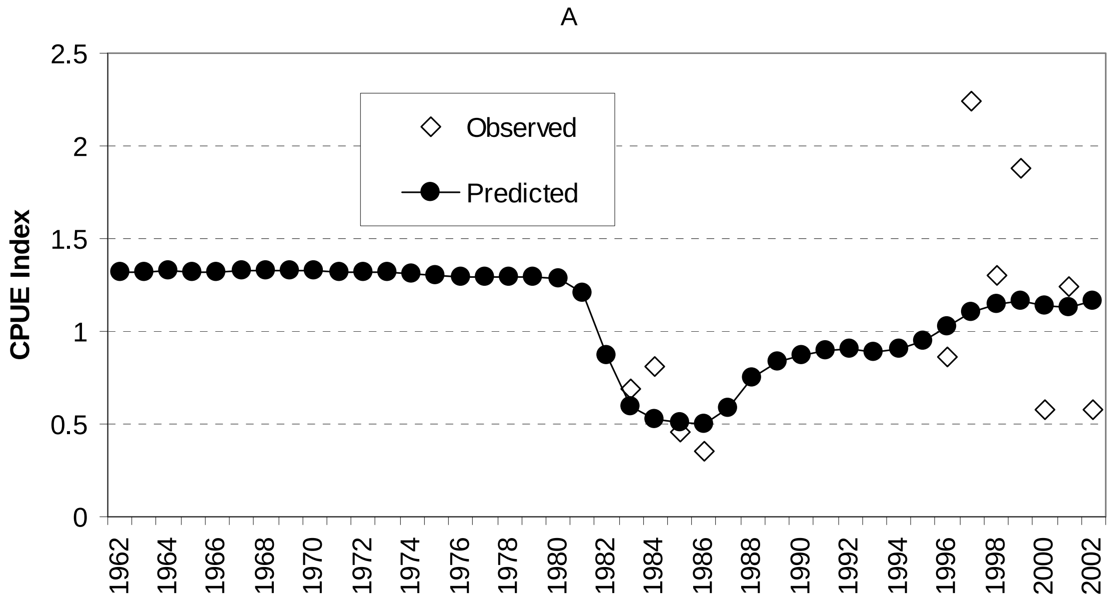


Figure 55: Projections of a) SSB/SSBmsy and b) yield/MSY from tilefish model with fishing mortality set at the current rate (F=Fnow). Results shown are those of the 10th, 50th (median), and 90th percentiles of the MCB runs. The current fishing mortality rate (Fnow) was defined as the geometric mean of the fully selected F's in the last three years of the assessment period (2000–2002). It was divided among the three fisheries, each with its estimated selectivity, according to their proportional contributions to Fnow.



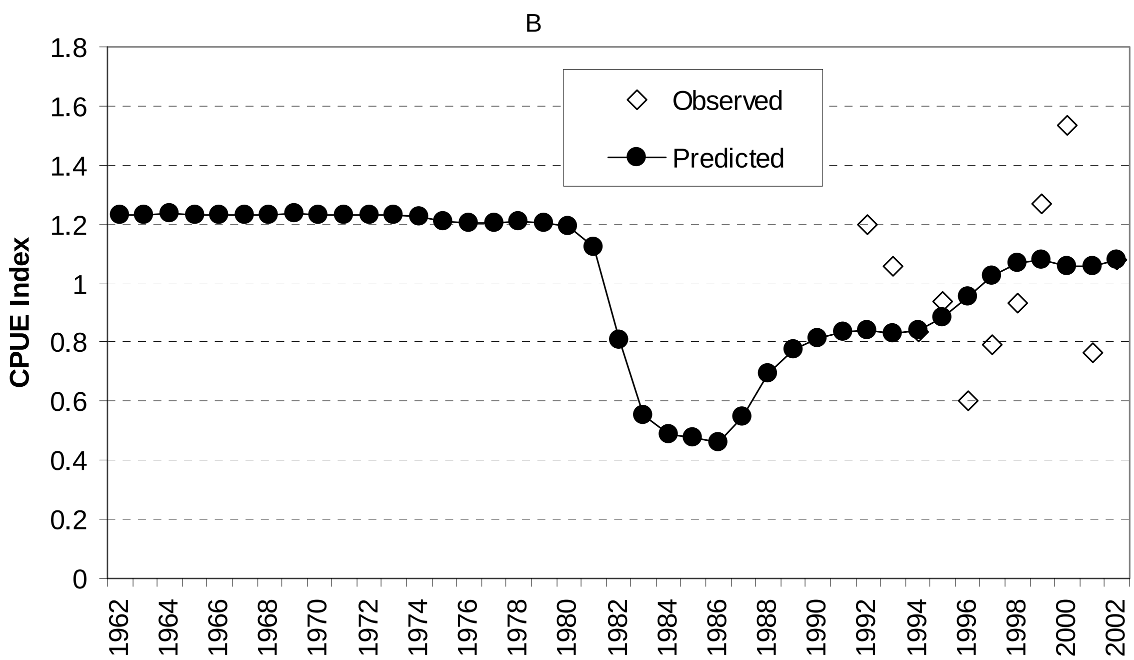


Figure 56: Fit of production model of tilefish to a) MARMAP horizontal longline index and to b) commercial logbook index.

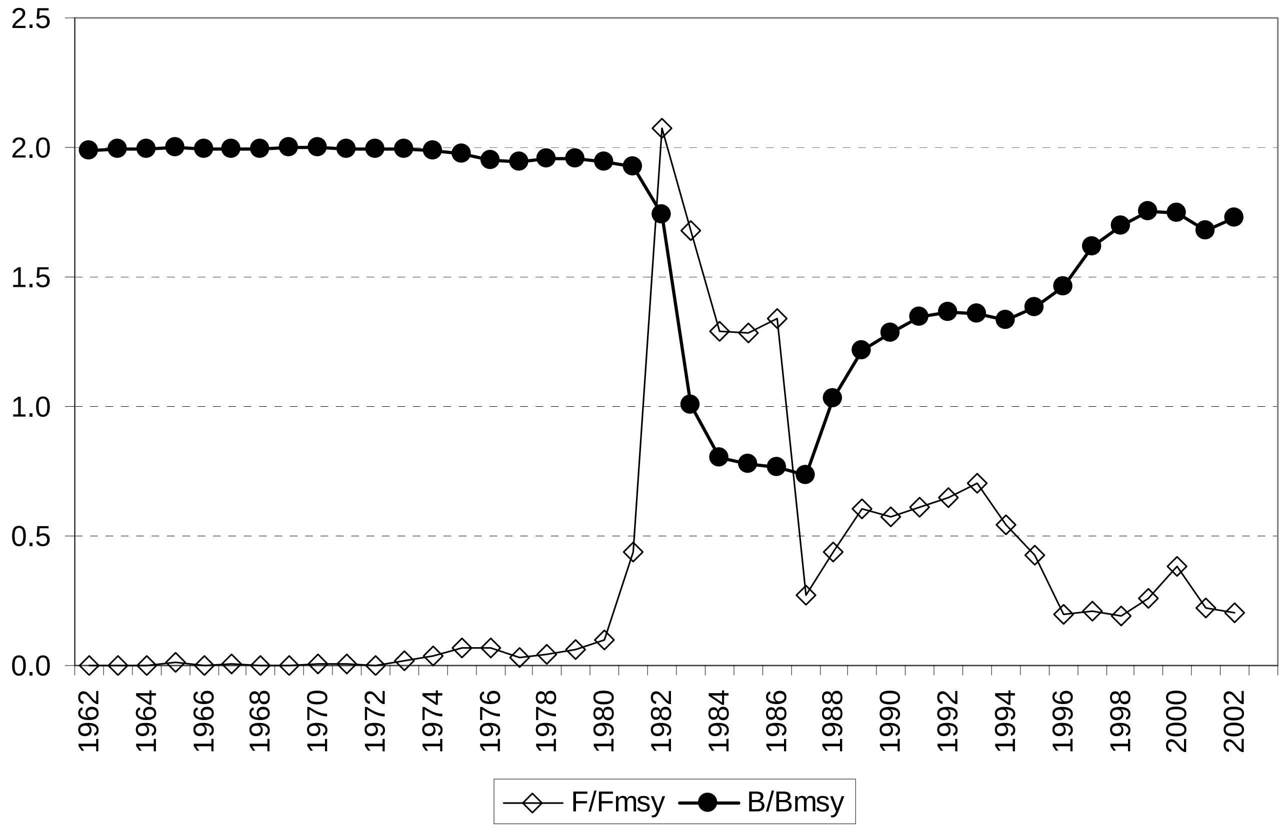


Figure 57: Estimates of relative biomass (filled circles) and relative fishing mortality rate (open diamonds) from production model of tilefish.

7. Appendices

Appendix A. Abbreviations and Symbols.

Symbol	Description
AW	Assessment workshop
B	Total biomass of stock
Bmsy	Total biomass at which MSY could be attained
CPUE	Catch per unit effort
CV	Coefficient of variation
DW	Data workshop
E	Exploitation rate; proportion of stock caught
E30%	Exploitation rate at which the spawning potential ratio is 30%
E40%	Exploitation rate at which the spawning potential ratio is 40%
Emax	Exploitation rate that maximizes the yield-per-recruit
Emsy	Exploitation rate at which MSY could be attained
F	Instantaneous rate of fishing mortality
F30%	Fishing mortality rate at which the spawning potential ratio is 30%
F40%	Fishing mortality rate at which the spawning potential ratio is 40%
Fmax	Fishing mortality rate that maximizes the yield-per-recruit
Fmsy	Fishing mortality rate at which MSY could be attained
h	Steepness parameter of the Beverton-Holt stock-recruit function
K	Carrying capacity; average size of stock when not exploited by man
M_a	Age-specific instantaneous rate of natural (non-fishing) mortality
MARMAP	Marine Resource Monitoring, Assessment, and Prediction Program, a fishery-independent data collection program of SCDNR
MCB	Monte Carlo and bootstrap approach to quantifying uncertainty
MFMT	Maximum fishing mortality threshold; a limit reference point used in U.S. fishery management; often set to Fmsy
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
MSY	Maximum sustainable yield
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
q	Catchability coefficient
R	Recruitment
SAFMC	South Atlantic Fishery Management Council
SEDAR	SouthEast Data, Assessment, and Review
SCDNR	South Carolina Department of Natural Resources
SSB	Spawning-stock biomass
SSBmsy	Spawning-stock biomass at which MSY could be attained
T	Generation time
TIP	Trip Interview Program, a fishery-dependent bio-data collection program of NMFS
TL	Total length, as opposed to fork length

Appendix B. SEDAR 4 Data Workshop Documents.

Document	Title	Author(s)
SEDAR4-DW-01	Indices of Abundance from Commercial Logbook Data: South Atlantic stocks	Shertzer, K.; McCarthy, K.
SEDAR4-DW-02	MRFSS Landings and Length Data Summary for the South Atlantic	Vaughan, D. S.
SEDAR4-DW-03	General Canvass Landings Statistics for the South Atlantic Region	Poffenberger, J.
SEDAR4-DW-12	Discard Estimates for the South Atlantic Region.	Poffenberger, J.
SEDAR4-DW-13	Size Frequency Data from the Trip Interview Program, South Atlantic Region	Poffenberger, J.
SEDAR4-DW-16	Preliminary analysis of some deepwater species in the South Atlantic headboat survey data.	Williams, E.; Dixon, B.
SEDAR4-DW-17	Age, growth and reproductive biology of the blueline tilefish, *Caulolatilus microps*, along the southeastern coast of the United States, 1982-99.	Harris, P. J.; Wyanski, D.M.; Powers, P.T.
SEDAR4-DW-18	Age, growth and reproduction of tilefish, Lopholatilus chamaeleonticeps, along the southeast Atlantic coast of the United States, 1980-87 and 1996-98.	Palmer, S.M.; Harris, P.J.; Powers, P. T.
SEDAR4-DW-19	Deep-water species report. South Carolina and Georgia.	Low, B.
SEDAR4-DW-20	South Atlantic Snapper-Grouper Regulatory Overview	Carmichael, J.
SEDAR4-DW-21	Summary of MARMAP sampling	Anon.
SEDAR4-DW-22	Blueline tilefish life history; How to assess reef fish stocks: Excerpts from NMFS-SEFC-80	various
SEDAR4-DW-25	Yellowedge Grouper age-length key	Bullock & Godcharles
SEDAR4-DW-26	Estimating catches and fishing effort of the southeast united states headboat fleet, 1972-1982	Dixon & Huntsman
SEDAR4-DW-27	Trends in Catch Data and Estimated Static SPR Values for Fifteen Species of Reef Fish Landed along the Southeastern United States, February 1998.	Potts, Burton & Manooch
SEDAR4-DW-28	Trends in Catch Data and Estimated Static SPR Values for Fifteen Species of Reef Fish Landed along the Southeastern United States, February 2001.	Potts & Brennan
SEDAR4-DW-29	Description of the Southeast Fisheries Science Center's Logbook Program for Coastal Fisheries	Poffenberger, J.

Appendix C. AD Model Builder code for tilefish statistical catch-at-age model.

```
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--
//
//  Southeast U.S. Tilefish Assessment Model
//
//  Kyle W. Shertzer, NMFS, Beaufort Lab
//  (kyle.shertzer@noaa.gov)
//  Last Modified: June 16, 2004 (KWS)
//
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--

DATA_SECTION
//--Monte Carlo stuff-----------------------------------------------------------------------------------------------------
init_int MCcount;                                          //counter for Monte Carlo runs, if 0 then R output file created instead
!!CLASS ofstream MCreport1("montecarlofile1.dat",ios::app);  //create file for Monte Carlo output
!!CLASS ofstream MCreport2("montecarlofile2.dat",ios::app);  //create file for Monte Carlo output
!!CLASS ofstream MCreport3("montecarlofile3.dat",ios::app);  //create file for Monte Carlo output
!!CLASS ofstream MCreport4("montecarlofile4.dat",ios::app);  //create file for Monte Carlo output

//--model set up stuff----------------------------------------------------------------------------------------------------
init_int styr;                    // Starting year of the data
init_int endyr;                   // Ending year of the data
init_int nages;                   // Number of ages
init_ivector agebins(1,nages);    // Vector of ages for age bins
init_int nlenbins;                // Number of length bins
init_ivector lenbins(1,nlenbins); // Vector of length bin midpoints
int nyrs;                         // Number of years of data
int styr_eq;                      // Starting year for recruitment estimates
//this section MUST BE INDENTED!!!
 LOCAL_CALCS
   nyrs=endyr-styr+1;
   styr_eq=styr-1;
 END_CALCS

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

//--observed landings data (mt)-------------------------------------------------------------------------------------------
init_int L_handline_styr;                                    //starting year of data
init_int L_handline_endyr;                                   //ending year of data
init_vector L_handline_obs(L_handline_styr,L_handline_endyr);  //vector of observed landings by year
init_vector L_handline_cv(L_handline_styr,L_handline_endyr);   //vector of CV of landings by year

init_int L_longline_nyrs;                                    //number of years of data
init_ivector L_longline_yrs(1,L_longline_nyrs);              //vector of years of data
init_vector L_longline_obs(1,L_longline_nyrs);               //vector of observed landings by year
init_vector L_longline_cv(1,L_longline_nyrs);                //vector of CV of landings by year

!!cout << "L_longline_cv=" << L_longline_cv << endl;

//--observed catch data (1000s)-------------------------------------------------------------------------------------------

init_int C_MRFSS_styr;                                       //starting year of data
init_int C_MRFSS_endyr;                                      //ending year of data
init_vector C_MRFSS_obs(C_MRFSS_styr,C_MRFSS_endyr);         //vector of observed landings by year
init_vector C_MRFSS_cv(C_MRFSS_styr,C_MRFSS_endyr);          //vector of CV of landings by year

!!cout << "C_MRFSS_cv=" << C_MRFSS_cv << endl;

//--observed length composition data--------------------------------------------------------------------------------------
init_int lc_handline_nyrs;                                    //number of years of data
```

```
init_ivector lc_handline_yrs(1,lc_handline_nyrs);                //vector of years of data                                                                          //ending year of
data
init_vector lc_handline_ss(1,lc_handline_nyrs);              //vector of samples sizes by year
init_matrix lc_handline_obs(1,lc_handline_nyrs,1,nlenbins);  //matrix of observed data, year by length

!!cout << "lc_handline_ss=" << lc_handline_ss << endl;

init_int lc_longline_styr;                                                          //starting year of data
init_int lc_longline_endyr;                                                         //ending year of data
init_vector lc_longline_ss(lc_longline_styr,lc_longline_endyr);                     //vector of samples sizes by year
init_matrix lc_longline_obs(lc_longline_styr,lc_longline_endyr,1,nlenbins);  //matrix of observed data, year by length

!!cout << "lc_longline_ss=" << lc_longline_ss << endl;

init_int lc_MMlongline_nyrs;                                          //number of years of data
init_ivector lc_MMlongline_yrs(1,lc_MMlongline_nyrs);                    //vector of years of data                                                                          //ending year
of data
init_vector lc_MMlongline_ss(1,lc_MMlongline_nyrs);              //vector of samples sizes by year
init_matrix lc_MMlongline_obs(1,lc_MMlongline_nyrs,1,nlenbins);  //matrix of observed data, year by length

!!cout << "lc_MMlongline_ss=" << lc_MMlongline_ss << endl;

//--observed age composition data------------------------------------------------------------------------------------------
init_int ac_handline_nyrs;                                 //number of years of data
init_ivector ac_handline_yrs(1,ac_handline_nyrs);          //vector of years of data
init_vector ac_handline_ss(1,ac_handline_nyrs);            //vector of sample sizes by year
init_matrix ac_handline_obs(1,ac_handline_nyrs,1,nages);  //matrix of observed data, year by age
!!cout << "ac_handline_ss=" << ac_handline_ss << endl;

init_int ac_longline_nyrs;                                 //number of years of data
init_ivector ac_longline_yrs(1,ac_longline_nyrs);          //vector of years of data
init_vector ac_longline_ss(1,ac_longline_nyrs);            //vector of sample sizes by year
init_matrix ac_longline_obs(1,ac_longline_nyrs,1,nages);  //matrix of observed data, year by age
!!cout << "ac_longline_ss=" << ac_longline_ss << endl;

//--observed abundance indices-----------------------------------------------------------------------------------------------

init_int I_MMlongline_nyrs;                                          //starting year of data
init_ivector I_MMlongline_yrs(1,I_MMlongline_nyrs);                                            //ending year of data
init_vector I_MMlongline_obs(1,I_MMlongline_nyrs);  //vector of observed index by year
init_vector I_MMlongline_cv(1,I_MMlongline_nyrs);   //vector of CV of index by year
!!cout << "I_MMlongline_obs=" << I_MMlongline_obs << endl;

init_int I_logbook_styr;                                             //starting year of data
init_int I_logbook_endyr;                                            //ending year of data
init_vector I_logbook_obs(I_logbook_styr,I_logbook_endyr);           //vector of observed index by year
init_vector I_logbook_cv(I_logbook_styr,I_logbook_endyr);            //vector of CV of index by year

!!cout << "I_logbook_obs=" << I_logbook_obs << endl;

//--selectivity parameter values---------------------------------------------------------------------------------------------
//-element 1 = slope for logistic
//-element 2 = 50% for logistic
//-element 3 = slope for descending part of double logistic
//-element 4 = 50% for descending part of double logistic
init_vector set_sel_handline(1,4);    //parameter values for selectivity function
init_vector set_sel_longline(1,4);    //parameter values for selectivity function
init_vector set_sel_MMlongline(1,4);  //parameter values for selectivity function
!!cout << "mmlongline sel=" << set_sel_MMlongline << endl;

//--biologicals--------------------------------------------------------------------------------------------------------------
init_number set_Linf;              // vonBertalanffy asymptotic length (mm)
init_number set_K;                 // Browdy growth coefficient
init_number set_t0;                // vonBertalanffy parameter, age at length=0
init_number set_len_CV;            // Coefficient of variation of length at age
init_vector set_wgt_age(1,nages);  // Weight-at-age (mt) of both sexes combined, based on von Bert fit with fixed t0
```

```
init_vector set_wgt_age_female(1,nages);  // Weight-at-age (mt) of females only
init_vector set_mat_age(1,nages);  // Proportion females mature at age
init_vector set_sex_age(1,nages);  // Proportion female at age
init_vector set_M_age(1,nages);    // Natural mortality at age

//--stock-recruit stuff------------------------------------------------------------------------------------------------
init_number SRswitch;                   //Stock-recruit function (1=Bev-Holt,2=Ricker)
init_number set_logR0;                  //Virgin log-recruitment
init_number set_steep;                  //Stock-Recruit steepness (0.2-1.0)
init_number set_S1dS0;                  //Reproductive capacity relative to virgin in first year
init_number set_SenddS0;                //Reproductive capacity relative to virgin in last year
init_vector set_logR_dev(styr,endyr);   //Annual log-recruitment deviations (nyrs)

!!cout << "S1dS0=" << set_S1dS0 << endl;

//--fishing mortality--------------------------------------------------------------------------------------------------
init_number set_mulogF_handline;                                 //Mean F (log)
init_vector set_logF_handline(L_handline_styr,L_handline_endyr);  //F deviations (log) by year
init_number set_mulogF_longline;                                 //Mean F (log)
init_vector set_logF_longline(1,L_longline_nyrs);                //F deviations (log) by year
init_number set_mulogF_MRFSS;                                    //Mean F (log)
init_vector set_logF_MRFSS(C_MRFSS_styr,C_MRFSS_endyr);          //F deviations (log) by year

!!cout << "muF_handline=" << set_mulogF_handline;
!!cout << " muF_longline=" << set_mulogF_longline;
!!cout << " muF_MRFSS=" << set_mulogF_MRFSS << endl;

//--index catchability-------------------------------------------------------------------------------------------------
init_number set_logq_MMlongline;  //catchability coefficient (log) for the MARMAP longline gear index
init_number set_logq_logbook;     //catchability coefficient (log) for the logbook index

!!cout << " q_MMlongline=" << set_logq_MMlongline << " q_logbook=" << set_logq_logbook << endl;

//--weights for likelihood components----------------------------------------------------------------------------
init_number set_w_L;
init_number set_w_lc;
init_number set_w_ac;
init_number set_w_I_MMlongline;
init_number set_w_I_logbook;
init_number set_w_R;
init_number set_w_S1;
init_number set_w_Send; //not used: set to zero, no influence on fit

!!cout << "set_w_S1" << set_w_S1 << endl;

//--Lorenzen M stuff, only used in MC output files -----------------------------------------------------------
init_number M_scale;
init_number M_Mmu;
init_number M_b;

//--future projection set-up-------------------------------------------------------------------------------------------
init_int nyrs_fut;      //number of years for future projections
init_int project_type;  //switch for stochastic (1) versus deterministic (2) recruitment projections
init_int seed;          //random number seed for stochastic projections
int styr_fut;           //starting year of future projections
int endyr_fut;          //ending year of future projections
 LOCAL_CALCS
   styr_fut=endyr+1;
   endyr_fut=endyr+nyrs_fut;
 END_CALCS

!!cout << "seed=" << seed << endl;

//--indices for year(y), age(a), and length(l)-------------------------------------------------------------------------
int y;
int a;
```

```
int l;

PARAMETER_SECTION
//--parameters/fixed variables which have values read in to data section-------------------------------------------------------
//--[init_] prefix declares a parameter to be estimated--------------------------------------------------------------------------
init_bounded_number par_sel1_handline(1,10);
init_bounded_number par_sel2_handline(0.05,15);
init_bounded_number par_sel3_handline(0,10,3);
init_bounded_number par_sel4_handline(1,nages,3);
init_bounded_number par_sel1_longline(1,10);
init_bounded_number par_sel2_longline(0.05,15);
number par_sel3_longline;
number par_sel4_longline;
init_bounded_number par_sel1_MMlongline(1,10);
init_bounded_number par_sel2_MMlongline(0.05,15);
init_bounded_number par_sel3_MMlongline(0,10,3);
init_bounded_number par_sel4_MMlongline(1,nages,3);
number par_Linf;
number par_K;
number par_t0;
number par_len_CV;
vector wgt_age(1,nages);
vector wgt_age_female(1,nages);
vector mat_age(1,nages);
vector sex_age(1,nages);
vector M_age(1,nages);
init_bounded_number par_logR0(1,20);
//init_bounded_number par_steep(0.25,0.95,2);
number par_steep;
//init_bounded_number par_S1dS0(0.1,0.99,2);
number par_S1dS0;
number par_SenddS0;
init_bounded_dev_vector par_logR_dev(styr,endyr,-2,2);
init_bounded_number par_mulogF_handline(-10,0);
init_bounded_dev_vector par_logF_handline(L_handline_styr,L_handline_endyr,-4,4);
init_bounded_number par_mulogF_longline(-10,0);
init_bounded_dev_vector par_logF_longline(1,L_longline_nyrs,-4,4);
init_bounded_number par_mulogF_MRFSS(-10,0);
init_bounded_dev_vector par_logF_MRFSS(C_MRFSS_styr,C_MRFSS_endyr,-4,4);
init_bounded_number par_logq_MMlongline(-10,0);
init_bounded_number par_logq_logbook(-10,0);
//------------------------------------------------------------------------------------------------------------------------------

//--length stuff---------------------------------------------------------------------------------------------------------------
vector meanlen_age(1,nages);         //Mean length at age
vector stdlen_age(1,nages);          //Standard deviation of length at age (computed from par_len_CV)
matrix age2len(1,nages,1,nlenbins);  //Age to length conversion matrix

//--selectivity at age---------------------------------------------------------------------------------------------------------
vector sel_handline(1,nages);                                //Handline fisheries selectivity at age
vector sel_longline(1,nages);                                //Longline fisheries selectivity at age
vector sel_MRFSS(1,nages);                                   //Recreational MRFSS fisheries selectivity at age, borrowd from handline
vector sel_MMlongline(1,nages);                              //MARMAP longline selectivity at age
matrix sel_logbook(I_logbook_styr,I_logbook_endyr,1,nages);  //Logbook selectivity at age (catch-weighted by year)

//--fishing stuff--------------------------------------------------------------------------------------------------------------
vector F_full(styr_eq,endyr);                     //Total fully selected fishing mortality by year
vector F_age2plus(styr_eq,endyr);                 //Population weighted fishing mortality (age 2+)
vector E(styr_eq,endyr);                          //Exploitation rate by year
matrix F_age_total(styr_eq,endyr,1,nages);        //Total fishing mortality at age
matrix C_age_total(styr_eq,endyr,1,nages);        //Total catch (numbers) at age
matrix L_age_total(styr_eq,endyr,1,nages);        //Total landings (mt) at age
matrix Z_age(styr_eq,endyr,1,nages);              //Total mortality at age
matrix F_age_handline(styr_eq,endyr,1,nages);     //Fishing mortality at age, handline fishery
matrix F_age_longline(styr_eq,endyr,1,nages);     //Fishing mortality at age, longline fishery
matrix F_age_MRFSS(styr_eq,endyr,1,nages);        //Fishing mortality at age, recreational MRFSS fishery
```

```
matrix C_age_handline(styr_eq,endyr,1,nages);  //Catch (numbers) at age, handline fishery
matrix C_age_longline(styr_eq,endyr,1,nages);  //Catch (numbers) at age, longline fishery
matrix C_age_MRFSS(styr_eq,endyr,1,nages);     //Catch (numbers) at age, recreational MRFSS fishery
matrix L_age_handline(styr_eq,endyr,1,nages);  //Landings (mt) at age, handline fishery
matrix L_age_longline(styr_eq,endyr,1,nages);  //Landings (mt) at age, longline fishery
matrix L_age_MRFSS(styr_eq,endyr,1,nages);     //Landings (mt) at age, recreational MRFSS fishery
number F_avg;                                  //temporary storage for average F used in calculations

//--miscellaneous stuff---------------------------------------------------------------------------------------------
vector reprod(1,nages);              //Product of weight, sex ratio, and maturity by age
vector N_spr_F0(1,nages);            //Numbers storage vector for computing spr_F0
number spr_F0;                       //Reproduction-per-recruit at F=0
number R0;                           //Virgin recruitment
number R1_eq;                        //Equilibrium recruitment estimate for first year in model
number S0;                           //Virgin reproductive potential
matrix N_age(styr_eq,endyr,1,nages); //Population numbers by year at age (beginning of year)
matrix B_age(styr_eq,endyr,1,nages); //Total biomass by year at age (beginning of year)
vector SSB(styr_eq,endyr);           //Reproductive potential by year
number SenddS0                       //Reproductive potential ratio in last year

//--predicted data objects-------------------------------------------------------------------------------------------
vector L_handline_pred(L_handline_styr,L_handline_endyr);
vector L_longline_pred(1,L_longline_nyrs);
vector C_MRFSS_pred(C_MRFSS_styr,C_MRFSS_endyr);
matrix lc_handline_pred(1,lc_handline_nyrs,1,nlenbins);
matrix lc_longline_pred(lc_longline_styr,lc_longline_endyr,1,nlenbins);
matrix lc_MMlongline_pred(1,lc_MMlongline_nyrs,1,nlenbins);
matrix ac_handline_pred(1,ac_handline_nyrs,1,nages);
matrix ac_longline_pred(1,ac_longline_nyrs,1,nages);
vector I_MMlongline_pred(1,I_MMlongline_nyrs);
vector I_logbook_pred(I_logbook_styr,I_logbook_endyr);

//--MSY objects-------------------------------------------------------------------------------------------------------
number F_handline_prop;  //proportion of F_full attributable to handline, last three yrs
number F_longline_prop;  //proportion of F_full attributable to longline, last three yrs
number F_MRFSS_prop;     //proportion of F_full attributable to MRFSS, last three yrs
number F_temp_sum;       //sum of geom mean full Fs in last yrs, used to compute F_fishery_prop
vector F_msy(1,3);           //average F last 3 years
vector L_msy(1,3);           //landings (mt)
vector C_msy(1,nages);       //catch (numbers)
matrix Z_msy(1,3,1,nages);   //total mortality
matrix N_msy(1,3,1,nages);   //numbers at age (beginning of year)
vector spr_msy(1,3);         //reproductive potential per recruit
vector R_eq(1,3);            //equilibrium recruitment
number msy_pred;             //MSY
number F_msy_pred;           //fully selected fishing mortality at MSY
number F_msy_age2plus;       //population weighted fishing mortality (age 2+) at MSY
number R_msy_pred;           //recruitment at MSY
number SSB_msy_pred;         //reproductive potential at MSY
number B_msy_pred;           //biomass at MSY
number E_msy_pred;           //exploitation rate at MSY
number diff;                 //difference value to use in Newton's method
number dy;                   //first derivative approximation
number ddy;                  //second derivative approximation

//--per-recruit objects---------------------------------------------------------------------------------------------
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(styr_eq,endyr);  //vector of static SPR values by year
vector F_spr(1,201);               //values of full F to be used in per-recruit and equilibrium calculations
vector spr_spr(1,201);             //reporductive capacity-per-recruit values corresponding to F values in F_spr
vector L_spr(1,201);               //landings(mt)-per-recruit values corresponding to F values in F_spr
vector R_spr_eq(1,201);            //equilibrium recruitment values corresponding to F values in F_spr
vector L_spr_eq(1,201);            //equilibrium landings(mt) values corresponding to F values in F_spr
vector SSB_spr_eq(1,201);          //equilibrium reproductive capacity values corresponding to F values in F_spr
```

```
vector B_spr_eq(1,201);             //equilibrium biomass values corresponding to F values in F_spr
vector E_spr(1,201);                //exploitation rate values corresponding to F values in F_spr
vector F_spr_age2plus(1,201);       //fishing mortality (age2+) values corresponding to F values in F_spr

//--future projection objects-----------------------------------------------------------------------------------------------
vector logR_dev_fut(styr_fut,endyr_fut);        //recruitment(log) deviations in future
matrix N_age_fut(styr_fut,endyr_fut,1,nages);   //numbers at age by year in future
vector SSB_fut(styr_fut,endyr_fut);             //reproductive capacity by year in future
vector Z_age_fut(1,nages);                      //total mortality at age in future
number F_fut;                                   //fully selected fishing mortality in future
vector L_fut(styr_fut,endyr_fut);               //landings(mt) by year in future
!!CLASS random_number_generator rng(seed);      //random number declaration
number nyrs_num;                                //double precision number of years
number rand_draw;                               //storage for random number draw
number nyr_bins;                                //temporary bin for parsing random draw

//--negative log-likelihood components------------------------------------------------------------------------------------------
number f_L_handline;
number f_L_longline;
number f_C_MRFSS;
number f_lc_handline;
number f_lc_longline;
number f_lc_MMlongline;
number f_ac_handline;
number f_ac_longline;
number f_I_MMlongline;
number f_I_logbook;
number f_R_constraint;
number f_S1_constraint;
number f_Send_constraint;

//--negative log-likelihood weights-------------------------------------------------------------------------------------------------
number w_L;
number w_lc;
number w_ac;
number w_I_MMlongline;
number w_I_logbook;
number w_R;
number w_S1;
number w_Send;

number sqrt2pi;

//init_number play;

objective_function_value f;


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

RUNTIME_SECTION

maximum_function_evaluations 10000;
convergence_criteria 1e-8;

PRELIMINARY_CALCS_SECTION
 sqrt2pi=sqrt(2.0*3.14159265);  //square root of 2 pi
 diff=1e-5;                     //differencing value to use in Newton's method
//--set likelihood weightings-------------------------------------------------------------------------------------------------
 w_L=set_w_L;
 w_lc=set_w_lc;
 w_ac=set_w_ac;
 w_I_MMlongline=set_w_I_MMlongline;
 w_I_logbook=set_w_I_logbook;
```

```
 w_R=set_w_R;
 w_S1=set_w_S1;
 w_Send=set_w_Send;

//-----------------------------------------------------------------------------------------------------------------------------

//--fix value of parameters-----------------------------------------------------------------------------------------
 par_sel1_handline=set_sel_handline(1);
 par_sel2_handline=set_sel_handline(2);
 par_sel3_handline=set_sel_handline(3);
 par_sel4_handline=set_sel_handline(4);
 par_sel1_longline=set_sel_longline(1);
 par_sel2_longline=set_sel_longline(2);
 par_sel3_longline=set_sel_longline(3);
 par_sel4_longline=set_sel_longline(4);
 par_sel1_MMlongline=set_sel_MMlongline(1);
 par_sel2_MMlongline=set_sel_MMlongline(2);
 par_sel3_MMlongline=set_sel_MMlongline(3);
 par_sel4_MMlongline=set_sel_MMlongline(4);
 par_Linf=set_Linf;
 par_K=set_K;
 par_t0=set_t0;
 par_len_CV=set_len_CV;
 wgt_age=set_wgt_age*1000;  //set this to kilograms to match numbers in 1000's
 wgt_age_female=set_wgt_age_female*1000;
 mat_age=set_mat_age;
 sex_age=set_sex_age;
 M_age=set_M_age;
 par_logR0=set_logR0;
 par_steep=set_steep;
 par_S1dS0=set_S1dS0;
 par_SenddS0=set_SenddS0;
 par_logR_dev=set_logR_dev;
 par_mulogF_handline=set_mulogF_handline;
 par_logF_handline=set_logF_handline;
 par_mulogF_longline=set_mulogF_longline;
 par_logF_longline=set_logF_longline;
 par_mulogF_MRFSS=set_mulogF_MRFSS;
 par_logF_MRFSS=set_logF_MRFSS;

 par_logq_MMlongline=set_logq_MMlongline;
 par_logq_logbook=set_logq_logbook;

TOP_OF_MAIN_SECTION

 arrmblsize=2000000;
 gradient_structure::set_MAX_NVAR_OFFSET(1600);
 gradient_structure::set_GRADSTACK_BUFFER_SIZE(15000000);
 gradient_structure::set_CMPDIF_BUFFER_SIZE(100000000);
 gradient_structure::set_NUM_DEPENDENT_VARIABLES(1000);

PROCEDURE_SECTION

 reprod=elem_prod(elem_prod(sex_age,mat_age),wgt_age_female);  //product of stuff going into reproductive capacity calcs

 get_length_stuff();

 get_selectivity();

 get_mortality();

 get_spr_F0();

 get_numbers_at_age();

 get_catch_and_landings();
```

```
 get_predicted_stuff();

 //evaluate_the_objective_function_play();
 evaluate_the_objective_function();


//FUNCTION evaluate_the_objective_function_play
//    f=square(play-2.0);

//----------------------------------------------------------------------------------------------------------------------------------------------
--------------------------------
FUNCTION get_length_stuff
//compute mean length at age from vonBertalanffy equation
  meanlen_age=par_Linf*(1-mfexp(-par_K*(agebins-par_t0)));
//compute standard deviation of length at age based on constant CV
  stdlen_age=meanlen_age*par_len_CV;
//compute age to length probability conversion matrix
  for (a=1;a<=nages;a++)
  {
    for (l=1;l<=nlenbins;l++)
    {
      age2len(a,l)=(mfexp(-(square(lenbins(l)-meanlen_age(a))/(2.*square(stdlen_age(a)))))/(sqrt2pi*stdlen_age(a)));
    }
    age2len(a)/=sum(age2len(a));
  }

//----------------------------------------------------------------------------------------------------------------------------------------------
--------------------------------
FUNCTION get_selectivity
//compute selectivity at age using double logistic equation (reduces to logistic with last 2 parameters = 0)
  for (a=1; a<=nages; a++)
  {
    sel_handline(a)=(1./(1.+mfexp(-1.*par_sel1_handline*(double(agebins(a))-par_sel2_handline))))*(1-(1./(1.+mfexp(-1.*par_sel3_handline*(double(agebins(a))
(par_sel2_handline+par_sel4_handline))))));
    sel_longline(a)=(1./(1.+mfexp(-1.*par_sel1_longline*(double(agebins(a))-par_sel2_longline))))*(1-(1./(1.+mfexp(-1.*par_sel3_longline*(double(agebins(a))
(par_sel2_longline+par_sel4_longline))))));
    sel_MMlongline(a)=(1./(1.+mfexp(-1.*par_sel1_MMlongline*(double(agebins(a))-par_sel2_MMlongline))))*(1-(1./(1.+mfexp(-
1.*par_sel3_MMlongline*(double(agebins(a))-(par_sel2_MMlongline+par_sel4_MMlongline))))));
  }
  sel_handline=sel_handline/max(sel_handline);
  sel_longline=sel_longline/max(sel_longline);
  sel_MMlongline=sel_MMlongline/max(sel_MMlongline);

  sel_MRFSS=sel_handline;

//----------------------------------------------------------------------------------------------------------------------------------------------
--------------------------------
FUNCTION get_mortality
//compute fishing mortality-at-age for all years
//use median of first 3 years to fill in earlier years
  F_full=0.0;
  for (y=1; y<=L_longline_nyrs; y++)
  {
    F_age_longline(L_longline_yrs(y))=sel_longline*mfexp(par_mulogF_longline+par_logF_longline(y));
    F_full(L_longline_yrs(y))+=mfexp(par_mulogF_longline+par_logF_longline(y));
  }

  for (y=styr_eq; y<=endyr; y++)
  {
    if(y>=L_handline_styr)
    {
      F_age_handline(y)=sel_handline*mfexp(par_mulogF_handline+par_logF_handline(y));
      F_full(y)+=mfexp(par_mulogF_handline+par_logF_handline(y));
    }
    else
```

```
    {
      F_age_handline(y)=sel_handline*mfexp((3.0*par_mulogF_handline+sum(par_logF_handline(L_handline_styr,L_handline_styr+2)))/3);
      F_full(y)+=mfexp((3.0*par_mulogF_handline+sum(par_logF_handline(L_handline_styr,L_handline_styr+2)))/3);
    }

    if(y>=C_MRFSS_styr)
    {
      F_age_MRFSS(y)=sel_MRFSS*mfexp(par_mulogF_MRFSS+par_logF_MRFSS(y));
      F_full(y)+=mfexp(par_mulogF_MRFSS+par_logF_MRFSS(y));
    }
    else
    {
      F_avg=mfexp((3.0*par_mulogF_MRFSS+sum(par_logF_MRFSS(C_MRFSS_styr,C_MRFSS_styr+2)))/3);
      F_age_MRFSS(y)=sel_MRFSS*F_avg*(y-styr_eq)/(C_MRFSS_styr+1-styr_eq);
      F_full(y)+=F_avg*(y-styr_eq)/(C_MRFSS_styr+1-styr_eq);
    }

    F_age_total(y)=F_age_handline(y)+F_age_longline(y)+F_age_MRFSS(y);
    Z_age(y)=F_age_total(y)+M_age;
  }

//---------------------------------------------------------------------------------------------------------------------------------------------
---------------------------------
FUNCTION get_spr_F0
  //compute reproductive capacity-per-recruit at F=0
  N_spr_F0(1)=1.0;
  for(a=2; a<=nages; a++)
  {
    N_spr_F0(a)=N_spr_F0(a-1)*mfexp(-1.*M_age(a-1));
  }
  N_spr_F0(nages)=N_spr_F0(nages-1)*mfexp(-1.*M_age(nages-1))/(1-mfexp(-1.*M_age(nages)));
  spr_F0=sum(elem_prod(N_spr_F0,reprod));

//---------------------------------------------------------------------------------------------------------------------------------------------
---------------------------------
FUNCTION get_numbers_at_age
//compute the numbers-at-age, reproductive capacity, biomass, and recruitment
  R0=mfexp(par_logR0);
  S0=spr_F0*R0;
  //recruitment for first year in model (1 year prior to start of data)
  R1_eq=mfexp(par_logR0+log(par_S1dS0));
//age-structure for first year in model (assumes equilibrium age-structure)
  N_age(styr_eq,1)=R1_eq;
  for (a=2; a<=nages; a++)
  {
    N_age(styr_eq,a)=N_age(styr_eq,a-1)*mfexp(-1.*Z_age(styr_eq,a-1));
  }
  N_age(styr_eq,nages)=N_age(styr_eq,nages-1)*mfexp(-1.*Z_age(styr_eq,nages-1))/(1.-mfexp(-1.*Z_age(styr_eq,nages)));
  SSB(styr_eq)=sum(elem_prod(N_age(styr_eq),reprod));
  B_age(styr_eq)=elem_prod(N_age(styr_eq),wgt_age);
  //subsequent years in model
  for (y=styr_eq; y<endyr; y++)
  {
    if(SRswitch<2)//Beverton-Holt stock-recruit function
    {
      N_age(y+1,1)=mfexp(log(((0.8*R0*par_steep*SSB(y))/(0.2*R0*spr_F0*(1-par_steep)+(par_steep-0.2)*SSB(y)))+0.00001)+par_logR_dev(y+1));
    }
    if(SRswitch>1)//Ricker stock-recruit function
    {
      N_age(y+1,1)=mfexp(log((SSB(y)/spr_F0)*mfexp(log((par_steep*4)/(1-par_steep))*(1-SSB(y)/(R0*spr_F0)))+0.00001)+par_logR_dev(y+1));
   }
    N_age(y+1)(2,nages)=++elem_prod(N_age(y)(1,nages-1),(mfexp(-1.*Z_age(y)(1,nages-1))));
    N_age(y+1,nages)+=N_age(y,nages)*mfexp(-1.*Z_age(y,nages));
    SSB(y+1)=sum(elem_prod(N_age(y+1),reprod));
    B_age(y+1)=elem_prod(N_age(y+1),wgt_age);
  }
```

```
  SenddS0=SSB(endyr)/S0;

//----------------------------------------------------------------------------------------------------------------------------------------------------------------
---------------------------------
FUNCTION get_catch_and_landings
  //compute catch-at-age and landings by year for each fishery
  for (y=styr_eq; y<=endyr; y++)
  {
    for(a=1; a<=nages; a++)
    {
      C_age_handline(y,a)=N_age(y,a)*F_age_handline(y,a)*(1.-mfexp(-1.*Z_age(y,a)))/Z_age(y,a);
      C_age_longline(y,a)=N_age(y,a)*F_age_longline(y,a)*(1.-mfexp(-1.*Z_age(y,a)))/Z_age(y,a);
      C_age_MRFSS(y,a)=N_age(y,a)*F_age_MRFSS(y,a)*(1.-mfexp(-1.*Z_age(y,a)))/Z_age(y,a);
    }
    L_age_handline(y)=elem_prod(C_age_handline(y),wgt_age);
    L_age_longline(y)=elem_prod(C_age_longline(y),wgt_age);
    L_age_MRFSS(y)=elem_prod(C_age_MRFSS(y),wgt_age);
  }

//----------------------------------------------------------------------------------------------------------------------------------------------------------------
---------------------------------
FUNCTION get_predicted_stuff
  //predicted landings
  for (y=L_handline_styr; y<=L_handline_endyr; y++)
  {
    L_handline_pred(y)=sum(L_age_handline(y));
  }
  for (y=1; y<=L_longline_nyrs; y++)
  {
    L_longline_pred(y)=sum(L_age_longline(L_longline_yrs(y)));
  }
  for (y=C_MRFSS_styr; y<=C_MRFSS_endyr; y++)
  {
    C_MRFSS_pred(y)=sum(C_age_MRFSS(y));
  }
  //predicted length compositions
  for (y=1; y<=lc_handline_nyrs; y++)
  {
    lc_handline_pred(y)=C_age_handline(lc_handline_yrs(y))*age2len;
    lc_handline_pred(y)=lc_handline_pred(y)/sum(lc_handline_pred(y));
  }
  for (y=lc_longline_styr; y<=lc_longline_endyr; y++)
  {
    lc_longline_pred(y)=C_age_longline(y)*age2len;
    lc_longline_pred(y)=lc_longline_pred(y)/sum(lc_longline_pred(y));
  }
  for (y=1; y<=lc_MMlongline_nyrs; y++)
  {
    lc_MMlongline_pred(y)=elem_prod(N_age(lc_MMlongline_yrs(y)),sel_MMlongline)*age2len;
    lc_MMlongline_pred(y)=lc_MMlongline_pred(y)/sum(lc_MMlongline_pred(y));
  }
  //predicted age compositions
  for (y=1; y<=ac_handline_nyrs; y++)
  {
    ac_handline_pred(y)=C_age_handline(ac_handline_yrs(y))/sum(C_age_handline(ac_handline_yrs(y)));
  }
  for (y=1; y<=ac_longline_nyrs; y++)
  {
    ac_longline_pred(y)=C_age_longline(ac_longline_yrs(y))/sum(C_age_longline(ac_longline_yrs(y)));
  }
  //predicted indices
  for (y=1; y<=I_MMlongline_nyrs; y++)
  {
    I_MMlongline_pred(y)=mfexp(par_logq_MMlongline)*N_age(I_MMlongline_yrs(y))*sel_MMlongline;
  }
```

```
  for (y=I_logbook_styr; y<=I_logbook_endyr; y++)
  {
    //selectivity of longline is catch-weighted selectivities of the two gears
    sel_logbook(y)=(sum(C_age_handline(y))*sel_handline + sum(C_age_longline(y))*sel_longline) / (sum(C_age_handline(y))+sum(C_age_longline(y)));
    //sel_logbook(y)=(sum(L_age_handline(y))*sel_handline + sum(L_age_longline(y))*sel_longline) / (sum(L_age_handline(y))+sum(L_age_longline(y)));
    sel_logbook(y)=sel_logbook(y)/max(sel_logbook(y));
    I_logbook_pred(y)=mfexp(par_logq_logbook)*B_age(y)*sel_logbook(y);
  }

//---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
---------------------------------
FUNCTION get_msy
  //compute MSY statistics
  //compute proportion F's attributable to each fishery, based on arithmetic mean across fisheries of geometric means in last three years within fisheries

  F_temp_sum=mfexp((3.0*par_mulogF_handline+sum(par_logF_handline(endyr-2,endyr)))/3)+mfexp((3.0*par_mulogF_longline+sum(par_logF_longline(endyr-
2,endyr)))/3)+mfexp((3.0*par_mulogF_MRFSS+sum(par_logF_MRFSS(endyr-2,endyr)))/3);
  F_handline_prop=mfexp((3.0*par_mulogF_handline+sum(par_logF_handline(endyr-2,endyr)))/3)/F_temp_sum;
  F_longline_prop=mfexp((3.0*par_mulogF_longline+sum(par_logF_longline(endyr-2,endyr)))/3)/F_temp_sum;
  F_MRFSS_prop=mfexp((3.0*par_mulogF_MRFSS+sum(par_logF_MRFSS(endyr-2,endyr)))/3)/F_temp_sum;

  //do Newton's method for 10 iterations
  F_msy(1)=M_age(nages)*0.5;  //initial guess
  for (int i=1; i<=20; i++){
    L_msy=0.0;
    C_msy=0.0;
    F_msy(2)=F_msy(1)-diff;
    F_msy(3)=F_msy(1)+diff;
    Z_msy(1)=M_age+F_msy(1)*F_handline_prop*sel_handline+F_msy(1)*F_longline_prop*sel_longline+F_msy(1)*F_MRFSS_prop*sel_MRFSS;
    Z_msy(2)=M_age+F_msy(2)*F_handline_prop*sel_handline+F_msy(2)*F_longline_prop*sel_longline+F_msy(2)*F_MRFSS_prop*sel_MRFSS;
    Z_msy(3)=M_age+F_msy(3)*F_handline_prop*sel_handline+F_msy(3)*F_longline_prop*sel_longline+F_msy(3)*F_MRFSS_prop*sel_MRFSS;

    N_msy(1,1)=1.0;
    N_msy(2,1)=1.0;
    N_msy(3,1)=1.0;
    for (a=2; a<=nages; a++)
    {
      N_msy(1,a)=N_msy(1,a-1)*mfexp(-1.*Z_msy(1,a-1));
      N_msy(2,a)=N_msy(2,a-1)*mfexp(-1.*Z_msy(2,a-1));
      N_msy(3,a)=N_msy(3,a-1)*mfexp(-1.*Z_msy(3,a-1));
    }
    N_msy(1,nages)=N_msy(1,nages-1)*mfexp(-1.*Z_msy(1,nages-1))/(1.-mfexp(-1.*Z_msy(1,nages)));
    N_msy(2,nages)=N_msy(2,nages-1)*mfexp(-1.*Z_msy(2,nages-1))/(1.-mfexp(-1.*Z_msy(2,nages)));
    N_msy(3,nages)=N_msy(3,nages-1)*mfexp(-1.*Z_msy(3,nages-1))/(1.-mfexp(-1.*Z_msy(3,nages)));
    spr_msy(1)=sum(elem_prod(N_msy(1),reprod));
    spr_msy(2)=sum(elem_prod(N_msy(2),reprod));
    spr_msy(3)=sum(elem_prod(N_msy(3),reprod));
    if(SRswitch<2) //Beverton-Holt
    {
      R_eq(1)=(R0/((5*par_steep-1)*spr_msy(1)))*(4*par_steep*spr_msy(1)-spr_F0*(1-par_steep));
      R_eq(2)=(R0/((5*par_steep-1)*spr_msy(2)))*(4*par_steep*spr_msy(2)-spr_F0*(1-par_steep));
      R_eq(3)=(R0/((5*par_steep-1)*spr_msy(3)))*(4*par_steep*spr_msy(3)-spr_F0*(1-par_steep));
    }
    if(SRswitch>1) //Ricker
    {
      R_eq(1)=(R0/(spr_msy(1)/spr_F0))*(1+log(spr_msy(1)/spr_F0)/log((par_steep*4)/(1-par_steep)));
      R_eq(2)=(R0/(spr_msy(2)/spr_F0))*(1+log(spr_msy(2)/spr_F0)/log((par_steep*4)/(1-par_steep)));
      R_eq(3)=(R0/(spr_msy(3)/spr_F0))*(1+log(spr_msy(3)/spr_F0)/log((par_steep*4)/(1-par_steep)));
    }

    N_msy(1)*=R_eq(1);
    N_msy(2)*=R_eq(2);
    N_msy(3)*=R_eq(3);
    for(a=1; a<=nages; a++){
      C_msy(a)=N_msy(1,a)*((Z_msy(1,a)-M_age(a))/Z_msy(1,a))*(1.-mfexp(-1.*Z_msy(1,a)));
      L_msy(1)+=N_msy(1,a)*((Z_msy(1,a)-M_age(a))/Z_msy(1,a))*(1.-mfexp(-1.*Z_msy(1,a)))*wgt_age(a);
```

```
      L_msy(2)+=N_msy(2,a)*((Z_msy(2,a)-M_age(a))/Z_msy(2,a))*(1.-mfexp(-1.*Z_msy(2,a)))*wgt_age(a);
      L_msy(3)+=N_msy(3,a)*((Z_msy(3,a)-M_age(a))/Z_msy(3,a))*(1.-mfexp(-1.*Z_msy(3,a)))*wgt_age(a);
    }
    dy=(L_msy(3)-L_msy(2))/(2.*diff);
    ddy=(L_msy(3)-2.*L_msy(1)+L_msy(2))/square(diff);
    if(square(ddy)>1e-12){
      F_msy(1)-=(dy/ddy);
    }
    if(F_msy(1)<=diff){
      F_msy(1)=diff;
    }
  }
  msy_pred=L_msy(1);
  F_msy_pred=F_msy(1);
  E_msy_pred=sum(C_msy(2,nages))/sum(N_msy(1)(2,nages));
  F_msy_age2plus=((Z_msy(1)-M_age)(3,nages)*N_msy(1)(3,nages))/sum(N_msy(1)(3,nages));
  R_msy_pred=R_eq(1);
  SSB_msy_pred=sum(elem_prod(N_msy(1),reprod));
  B_msy_pred=sum(elem_prod(N_msy(1),wgt_age));

//-----------------------------------------------------------------------------------------------------------------------------------------------
---------------------------------
FUNCTION get_miscellaneous_stuff
  //compute total catch-at-age and landings
  C_age_total=C_age_handline;
  C_age_total+=C_age_longline;
  C_age_total+=C_age_MRFSS;
  //compute exploitation rate and population-weighted F(age2+)
  for(y=styr_eq; y<=endyr; y++)
  {
    L_age_total(y)=elem_prod(C_age_total(y),wgt_age);
    E(y)=sum(C_age_total(y)(2,nages))/sum(N_age(y)(2,nages));
    F_age2plus(y)=((F_age_handline(y)(3,nages)+F_age_longline(y)(3,nages)+F_age_MRFSS(y)(3,nages))*N_age(y)(3,nages))/sum(N_age(y)(3,nages));
  }

//-----------------------------------------------------------------------------------------------------------------------------------------------
---------------------------------
FUNCTION get_per_recruit_stuff
  //static per-recruit stuff
  for(y=styr_eq; y<=endyr; y++)
  {
    N_age_spr(1)=1.0;
    for(a=2; a<=nages; a++)
    {
      N_age_spr(a)=N_age_spr(a-1)*mfexp(-1.*Z_age(y,a-1));
    }
    N_age_spr(nages)=N_age_spr(nages-1)*mfexp(-1.*Z_age(y,nages-1))/(1-mfexp(-1.*Z_age(y,nages)));
    spr_static(y)=sum(elem_prod(N_age_spr,reprod))/spr_F0;
  }

  //fill in F's for per-recruit stuff
  F_spr.fill_seqadd(0,.01);
  //compute SSB/R and YPR as functions of F
  for(int ff=1; ff<=201; ff++)
  {
    //uses fishery-weighted F's, same as in MSY calculations
    Z_age_spr=M_age+F_spr(ff)*F_handline_prop*sel_handline+F_spr(ff)*F_longline_prop*sel_longline+F_spr(ff)*F_MRFSS_prop*sel_MRFSS;

    N_age_spr(1)=1.0;
    for (a=2; a<=nages; a++)
    {
      N_age_spr(a)=N_age_spr(a-1)*mfexp(-1.*Z_age_spr(a-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));
    L_spr(ff)=0.0;
```

```
    for (a=1; a<=nages; a++)
    {
      C_age_spr(a)=N_age_spr(a)*((Z_age_spr(a)-M_age(a))/Z_age_spr(a))*(1.-mfexp(-1.*Z_age_spr(a)));
      L_spr(ff)+=C_age_spr(a)*wgt_age(a);
    }
    E_spr(ff)=sum(C_age_spr(2,nages))/sum(N_age_spr(2,nages));
    F_spr_age2plus(ff)=((Z_age_spr-M_age)(3,nages)*N_age_spr(3,nages))/sum(N_age_spr(3,nages));

    //Compute equilibrium values of R, SSB and Yield at each F
    if(SRswitch<2) //Beverton-Holt
    {
      R_spr_eq(ff)=(R0/((5*par_steep-1)*spr_spr(ff)))*(4*par_steep*spr_spr(ff)-spr_F0*(1-par_steep));
    }
    if(SRswitch>1) //Ricker
    {
      R_spr_eq(ff)=(R0/(spr_spr(ff)/spr_F0))*(1+log(spr_spr(ff)/spr_F0)/log((par_steep*4)/(1-par_steep)));
    }
    N_age_spr*=R_spr_eq(ff);
    SSB_spr_eq(ff)=sum(elem_prod(N_age_spr,reprod));
    B_spr_eq(ff)=sum(elem_prod(N_age_spr,wgt_age));
    L_spr_eq(ff)=sum(elem_prod(C_age_spr*R_spr_eq(ff),wgt_age));
  }

//----------------------------------------------------------------------------------------------------------------------------------
--------------------------------
FUNCTION evaluate_the_objective_function
  f=0;
  //landings data (lognormal)
  f_L_handline=0.0;
  for (y=L_handline_styr; y<=L_handline_endyr; y++)
  {
    f_L_handline+=square(log(L_handline_obs(y)+.001)-log(L_handline_pred(y)+.001))/(2.0*square(L_handline_cv(y)));
  }
  f+=w_L*f_L_handline;
  f_L_longline=0.0;
  for (y=1; y<=L_longline_nyrs; y++)
  {
    f_L_longline+=square(log(L_longline_obs(y)+.001)-log(L_longline_pred(y)+.001))/(2.0*square(L_longline_cv(y)));
  }
  f+=w_L*f_L_longline;
  f_C_MRFSS=0.0;
  for (y=C_MRFSS_styr; y<=C_MRFSS_endyr; y++)
  {
    f_C_MRFSS+=square(log(C_MRFSS_obs(y)+.001)-log(C_MRFSS_pred(y)+.001))/(2.0*square(C_MRFSS_cv(y)));
  }
  f+=w_L*f_C_MRFSS;
  //length composition data (multinomial)
  f_lc_handline=0.0;
  for (y=1; y<=lc_handline_nyrs; y++)
  {
    f_lc_handline+=-lc_handline_ss(y)*sum(elem_prod((lc_handline_obs(y)+.001),log(lc_handline_pred(y)+.001))-
elem_prod((lc_handline_obs(y)+.001),log(lc_handline_obs(y)+.001)));
  }
  f+=w_lc*f_lc_handline;
  f_lc_longline=0.0;
  for (y=lc_longline_styr; y<=lc_longline_endyr; y++)
  {
    f_lc_longline+=-lc_longline_ss(y)*sum(elem_prod((lc_longline_obs(y)+.001),log(lc_longline_pred(y)+.001))-
elem_prod((lc_longline_obs(y)+.001),log(lc_longline_obs(y)+.001)));
  }
  f+=w_lc*f_lc_longline;
  f_lc_MMlongline=0.0;
  for (y=1; y<=lc_MMlongline_nyrs; y++)
  {
    f_lc_MMlongline+=-lc_MMlongline_ss(y)*sum(elem_prod((lc_MMlongline_obs(y)+.001),log(lc_MMlongline_pred(y)+.001))-
elem_prod((lc_MMlongline_obs(y)+.001),log(lc_MMlongline_obs(y)+.001)));
```

```
  }
  f+=w_lc*f_lc_MMlongline;
  //age composition data (multinomial)
  f_ac_handline=0.0;
  for (y=1; y<=ac_handline_nyrs; y++)
  {
    f_ac_handline+=-ac_handline_ss(y)*sum(elem_prod((ac_handline_obs(y)+.001),log(ac_handline_pred(y)+.001))-
elem_prod((ac_handline_obs(y)+.001),log(ac_handline_obs(y)+.001)));
  }
  f+=w_ac*f_ac_handline;
  f_ac_longline=0.0;
  for (y=1; y<=ac_longline_nyrs; y++)
  {
    f_ac_longline+=-ac_longline_ss(y)*sum(elem_prod((ac_longline_obs(y)+.001),log(ac_longline_pred(y)+.001))-
elem_prod((ac_longline_obs(y)+.001),log(ac_longline_obs(y)+.001)));
  }
  f+=w_ac*f_ac_longline;
  //indices data (lognormal)
  f_I_MMlongline=0.0;
  for (y=1; y<=I_MMlongline_nyrs; y++)
  {
    f_I_MMlongline+=square(log(I_MMlongline_obs(y)+.001)-log(I_MMlongline_pred(y)+.001))/(2.0*square(I_MMlongline_cv(y)));
  }
  f+=w_I_MMlongline*f_I_MMlongline;
  f_I_logbook=0.0;
  for (y=I_logbook_styr; y<=I_logbook_endyr; y++)
  {
    f_I_logbook+=square(log(I_logbook_obs(y)+.001)-log(I_logbook_pred(y)+.001))/(2.0*square(I_logbook_cv(y)));
  }
  f+=w_I_logbook*f_I_logbook;
  //recruitment deviations (lognormal)
  f_R_constraint=norm2(par_logR_dev);
  f+=w_R*f_R_constraint;
  //stock size deviations
  //f_Send_constraint=square(SenddS0-par_SenddS0);
  //f+=w_Send*f_Send_constraint;
  f_S1_constraint=square(SSB(styr_eq)/S0-par_S1dS0);
  f+=w_S1*f_S1_constraint;


//-------------------------------------------------------------------------------------------------------------------------------------------------------------------------
--------------------------------
FUNCTION project_into_the_future
  //do future projections (1=stochastic,2=deterministic)
  //compute future random recruitment (if stochastic option chosen)
  if(project_type<2)
  {
    int counter;
    nyrs_num=nyrs;
    for(y=styr_fut; y<=endyr_fut; y++)
    {
      rand_draw=randu(rng);
      counter=0;
      for(int y2=0; y2<=nyrs; y2++)
      {
        nyr_bins=y2/nyrs_num;
        if(rand_draw>nyr_bins)
        {
          counter+=1;
        }
      }
      logR_dev_fut(y)=par_logR_dev(styr+counter-1);
    }
  }
  //set future F equal to median of last 3 years
  //F_fut=mfexp(sum(log(F_full(endyr-2,endyr)))/3);
```

```
  F_fut=0.0;
  //use selectivity from MSY calcs
  Z_age_fut=M_age+F_fut*F_handline_prop*sel_handline+F_fut*F_longline_prop*sel_longline+F_fut*F_MRFSS_prop*sel_MRFSS;
  //project age-structure into future
  for (y=styr_fut-1; y<endyr_fut; y++)
  {
    if(y<=endyr)
    {
      if(SRswitch<2)//Beverton-Holt stock-recruit function
      {
        N_age_fut(y+1,1)=mfexp(log(((0.8*R0*par_steep*SSB(y))/(0.2*R0*spr_F0*(1-par_steep)+(par_steep-0.2)*SSB(y)))+0.00001)+logR_dev_fut(y+1));
      }
      if(SRswitch>1)//Ricker stock-recruit function
      {
        N_age_fut(y+1,1)=mfexp(log((SSB(y)/spr_F0)*mfexp(log((par_steep*4)/(1-par_steep))*(1-SSB(y)/(R0*spr_F0)))+0.00001)+logR_dev_fut(y+1));
      }
      N_age_fut(y+1)(2,nages)=++elem_prod(N_age(y)(1,nages-1),(mfexp(-1.*Z_age(y)(1,nages-1))));
      N_age_fut(y+1,nages)+=N_age(y,nages)*mfexp(-1.*Z_age(y)(nages));
    }
    else
    {
      if(SRswitch<2)//Beverton-Holt stock-recruit function
      {
        N_age_fut(y+1,1)=mfexp(log(((0.8*R0*par_steep*SSB_fut(y))/(0.2*R0*spr_F0*(1-par_steep)+(par_steep-0.2)*SSB_fut(y)))+0.00001)+logR_dev_fut(y+1));
      }
      if(SRswitch>1)//Ricker stock-recruit function
      {
        N_age_fut(y+1,1)=mfexp(log((SSB_fut(y)/spr_F0)*mfexp(log((par_steep*4)/(1-par_steep))*(1-SSB_fut(y)/(R0*spr_F0)))+0.00001)+logR_dev_fut(y+1));
      }
      N_age_fut(y+1)(2,nages)=++elem_prod(N_age_fut(y)(1,nages-1),(mfexp(-1.*Z_age_fut(1,nages-1))));
      N_age_fut(y+1,nages)+=N_age_fut(y,nages)*mfexp(-1.*Z_age_fut(nages));
    }
    SSB_fut(y+1)=sum(elem_prod(N_age_fut(y+1),reprod));
    L_fut(y+1)=0;
    for (a=1; a<=nages; a++)
    {
      L_fut(y+1)+= wgt_age(a)*N_age_fut(y+1,a)*((Z_age_fut(a)-M_age(a))/Z_age_fut(a))*(1.-mfexp(-1.*Z_age_fut(a)));
    }
  }

//----------------------------------------------------------------------------------------------------------------------------------------------------------------------
---------------------------------
FUNCTION append_MC_output_file1
  //this file contains all estimated parameters
  if(MCcount==1)
  {
    MCreport1 << "MCcount";
    MCreport1 << " par_sel1_handline";
    MCreport1 << " par_sel2_handline";
    MCreport1 << " par_sel3_handline";
    MCreport1 << " par_sel4_handline";
    MCreport1 << " par_sel1_longline";
    MCreport1 << " par_sel2_longline";
    MCreport1 << " par_sel3_longline";
    MCreport1 << " par_sel4_longline";
    MCreport1 << " par_sel1_MMlongline";
    MCreport1 << " par_sel2_MMlongline";
    MCreport1 << " par_sel3_MMlongline";
    MCreport1 << " par_sel4_MMlongline";
    MCreport1 << " par_Linf";
    MCreport1 << " par_K";
    MCreport1 << " par_t0";
    MCreport1 << " par_len_CV";

    MCreport1 << " par_mulogF_handline";
    for(y=L_handline_styr; y<=L_handline_endyr; y++)
```

```
    {
      MCreport1 << " par_logF_handline_" << y;
    }
    MCreport1 << " par_mulogF_longline";
    for(y=1; y<=L_longline_nyrs; y++)
    {
    MCreport1 << " par_logF_longline_" << y;
    }
    MCreport1 << " par_mulogF_MRFSS";
    for(y=C_MRFSS_styr; y<=C_MRFSS_endyr; y++)
    {
      MCreport1 << " par_logF_MRFSS_" << y;
    }
    MCreport1 << " par_logq_MMlongline";
    MCreport1 << " par_logq_logbook";

    for(a=1; a<=nages; a++)
    {
       MCreport1 << " M_age_" << agebins(a);
    }
    MCreport1 << " par_logR0";
    MCreport1 << " par_steep";
    MCreport1 << " par_S1dS0";
    MCreport1 << " par_SenddS0";
    for(y=styr; y<=endyr; y++)
    {
      MCreport1 << " par_logR_dev_" << y;
    }
    MCreport1 << endl;
  }
  MCreport1 << MCcount << " ";
  MCreport1 << par_sel1_handline << " ";
  MCreport1 << par_sel2_handline << " ";
  MCreport1 << par_sel3_handline << " ";
  MCreport1 << par_sel4_handline << " ";
  MCreport1 << par_sel1_longline << " ";
  MCreport1 << par_sel2_longline << " ";
  MCreport1 << par_sel3_longline << " ";
  MCreport1 << par_sel4_longline << " ";
  MCreport1 << par_sel1_MMlongline << " ";
  MCreport1 << par_sel2_MMlongline << " ";
  MCreport1 << par_sel3_MMlongline << " ";
  MCreport1 << par_sel4_MMlongline << " ";
  MCreport1 << par_Linf << " ";
  MCreport1 << par_K << " ";
  MCreport1 << par_t0 << " ";
  MCreport1 << par_len_CV << " ";

  MCreport1 << par_mulogF_handline << " ";
  MCreport1 << par_logF_handline(L_handline_styr,L_handline_endyr) << " ";
  MCreport1 << par_mulogF_longline << " ";
  MCreport1 << par_logF_longline(1,L_longline_nyrs) << " ";
  MCreport1 << par_mulogF_MRFSS << " ";
  MCreport1 << par_logF_MRFSS(C_MRFSS_styr,C_MRFSS_endyr) << " ";
  MCreport1 << par_logq_MMlongline << " ";
  MCreport1 << par_logq_logbook << " ";

  MCreport1 << M_age(1,nages) << " ";
  MCreport1 << par_logR0 << " ";
  MCreport1 << par_steep << " ";
  MCreport1 << par_S1dS0 << " ";
  MCreport1 << par_SenddS0 << " ";
  MCreport1 << par_logR_dev(styr,endyr) << " ";
  MCreport1 << endl;

//----------------------------------------------------------------------
```

```
FUNCTION append_MC_output_file2
  if(MCcount==1)
  {
    MCreport2 << "MCcount";
    for(y=styr_eq; y<=endyr; y++)
    {
      MCreport2 << " spr_static_" << y;
    }
    for(y=1; y<=201; y++)
    {
      MCreport2 << " F_spr";
    }
    for(y=1; y<=201; y++)
    {
      MCreport2 << " E_spr";
    }
    for(y=1; y<=201; y++)
    {
      MCreport2 << " F_spr_age2plus";
    }
    for(y=1; y<=201; y++)
    {
      MCreport2 << " spr_spr";
    }
    for(y=1; y<=201; y++)
    {
      MCreport2 << " L_spr";
    }
    for(y=1; y<=201; y++)
    {
      MCreport2 << " SSB_spr_eq";
    }
    for(y=1; y<=201; y++)
    {
      MCreport2 << " B_spr_eq";
    }
    for(y=1; y<=201; y++)
    {
      MCreport2 << " L_spr_eq";
    }
    MCreport2 << endl;
  }
  MCreport2 << MCcount << " ";
  for(y=styr_eq; y<=endyr; y++)
  {
    MCreport2 << spr_static(y) << " ";
  }
  MCreport2 << F_spr << " ";
  MCreport2 << E_spr << " ";
  MCreport2 << F_spr_age2plus << " ";
  MCreport2 << spr_spr << " ";
  MCreport2 << L_spr << " ";
  MCreport2 << SSB_spr_eq << " ";
  MCreport2 << B_spr_eq << " ";
  MCreport2 << L_spr_eq << " ";
  MCreport2 << endl;

//--------------------------------------------------------------------------------------------------------------------------------------------------------------------
---------------------------------
FUNCTION append_MC_output_file3
  //this file contains recruitment, SSB, biomass, F, F(age2+), and E time series
  if(MCcount==1)
  {
    MCreport3 << "MCcount";
    for(y=styr_eq; y<=endyr; y++)
    {
```

```
      MCreport3 << " R_" << y;
    }
    for(y=styr_eq; y<=endyr; y++)
    {
      MCreport3 << " SSB_" << y;
    }
    for(y=styr_eq; y<=endyr; y++)
    {
      MCreport3 << " B_" << y;
    }
    for(y=styr_eq; y<=endyr; y++)
    {
      MCreport3 << " Ffull_" << y;
    }
    for(y=styr_eq; y<=endyr; y++)
    {
      MCreport3 << " Fage2+_" << y;
    }
    for(y=styr_eq; y<=endyr; y++)
    {
      MCreport3 << " Eage1+_" << y;
    }
    MCreport3 << endl;
  }
  MCreport3 << MCcount << " ";
  for(y=styr_eq; y<=endyr; y++)
  {
    MCreport3 << N_age(y)(1) << " ";
  }
  MCreport3 << SSB << " ";
  for(y=styr_eq; y<=endyr; y++)
  {
    MCreport3 << sum(B_age(y)) << " ";
  }
  MCreport3 << F_full << " ";
  MCreport3 << F_age2plus << " ";
  MCreport3 << E << " ";
  MCreport3 << endl;

//------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
---------------------------------
FUNCTION append_MC_output_file4
  //this file contains total landings, spr.F0, MSY stuff, projection stuff, and likelihood components
  if(MCcount==1)
  {
    MCreport4 << "MCcount";
    for(y=styr_eq; y<=endyr; y++)
    {
      MCreport4 << " L_total_" << y;
    }
    MCreport4 << " spr_F0";
    MCreport4 << " Fmsy";
    MCreport4 << " F2002.Fmsy";
    MCreport4 << " Fmsy_age2+";
    MCreport4 << " Emsy";
    MCreport4 << " MSY";
    MCreport4 << " Rmsy";
    MCreport4 << " SSBmsy";
    MCreport4 << " SSB2002.SSBmsy";
    MCreport4 << " Bmsy";
    MCreport4 << " rnd_seed";
    MCreport4 << " project_type";
    MCreport4 << " F_fut" << " ";
    for(y=styr_fut; y<=endyr_fut; y++)
    {
      MCreport4 << " R_fut_" << y;
```

```
  }
  for(y=styr_fut; y<=endyr_fut; y++)
  {
    MCreport4 << " L_fut_" << y;
  }
  for(y=styr_fut; y<=endyr_fut; y++)
  {
    MCreport4 << " SSB_fut_" << y;
  }
  MCreport4 << " f_L_handline";
  MCreport4 << " f_L_longline";
  MCreport4 << " f_C_MRFSS";
  MCreport4 << " f_lc_handline";
  MCreport4 << " f_lc_longline";
  MCreport4 << " f_lc_MMlongline";
  MCreport4 << " f_ac_handline";
  MCreport4 << " f_ac_longline";
  MCreport4 << " f_I_MMlongline";
  MCreport4 << " f_I_logbook";
  MCreport4 << " f_R_constraint";
  MCreport4 << " f_S1_constraint";
  MCreport4 << " f_Send_constraint";
  MCreport4 << " w_L";
  MCreport4 << " w_lc";
  MCreport4 << " w_ac";
  MCreport4 << " w_I_MM";
  MCreport4 << " w_I_logbook";
  MCreport4 << " w_R";
  MCreport4 << " w_S1";
  MCreport4 << " f_total";
  MCreport4 << " M_scale";
  MCreport4 << " M_Mmu";
  MCreport4 << " M_b";
  MCreport4 << endl;
}
MCreport4 << MCcount << " ";
for(y=styr_eq; y<=endyr; y++)
{
  MCreport4 << sum(L_age_total(y)) << " ";
}
MCreport4 << spr_F0 << " ";
MCreport4 << F_msy_pred     << " ";
MCreport4 << F_full(endyr)/F_msy_pred     << " ";
MCreport4 << F_msy_age2plus << " ";
MCreport4 << E_msy_pred     << " ";
MCreport4 << msy_pred       << " ";
MCreport4 << R_msy_pred     << " ";
MCreport4 << SSB_msy_pred   << " ";
MCreport4 << SSB(endyr)/SSB_msy_pred   << " ";
MCreport4 << B_msy_pred     << " ";
MCreport4 << seed << " ";
MCreport4 << project_type << " ";
MCreport4 << F_fut << " ";
for(y=styr_fut; y<=endyr_fut; y++)
{
  MCreport4 << N_age_fut(y)(1) << " ";
}
for(y=styr_fut; y<=endyr_fut; y++)
{
  MCreport4 << L_fut(y) << " ";
}
for(y=styr_fut; y<=endyr_fut; y++)
{
  MCreport4 << SSB_fut(y) << " ";
}
MCreport4 << f_L_handline << " ";
```

```
  MCreport4 << f_L_longline << " ";
  MCreport4 << f_C_MRFSS << " ";
  MCreport4 << f_lc_handline << " ";
  MCreport4 << f_lc_longline << " ";
  MCreport4 << f_lc_MMlongline << " ";
  MCreport4 << f_ac_handline << " ";
  MCreport4 << f_ac_longline << " ";
  MCreport4 << f_I_MMlongline << " ";
  MCreport4 << f_I_logbook << " ";
  MCreport4 << f_R_constraint << " ";
  MCreport4 << f_S1_constraint << " ";
  MCreport4 << f_Send_constraint << " ";
  MCreport4 << w_L << " ";
  MCreport4 << w_lc << " ";
  MCreport4 << w_ac << " ";
  MCreport4 << w_I_MMlongline << " ";
  MCreport4 << w_I_logbook << " ";
  MCreport4 << w_R << " ";
  MCreport4 << w_S1 << " ";
  MCreport4 << f << " ";
  MCreport4 << M_scale << " ";
  MCreport4 << M_Mmu << " ";
  MCreport4 << M_b << " ";
  MCreport4 << endl;

//----------------------------------------------------------------------------------------------------------------------------------------------------
--------------------------------



FINAL_SECTION
 get_msy();
 cout << "SSBstart.S0 = " << SSB(styr_eq)/S0 << endl;
 cout << "SSBend.S0 = " << SenddS0 << endl;
 cout << "steepness = " << par_steep << endl;
 cout << "dy = " << dy << endl;
 cout << "Fmsy = " << F_msy_pred << endl;

 get_miscellaneous_stuff();
 get_per_recruit_stuff();
 project_into_the_future();
 if(MCcount>0)
 {
   append_MC_output_file1();  //appends the Monte Carlo file
   append_MC_output_file2();  //appends the Monte Carlo file
   append_MC_output_file3();  //appends the Monte Carlo file
   append_MC_output_file4();  //appends the Monte Carlo file
 }
 if(MCcount<1)
 {
   #include "s-report-tile-4.cxx"   // ADMB code to write the S-compatible report
 }
```

Appendix D. Samples of exploratory weighting schemes leading to the initial run.

Run	Landings	Length Comps	Age Comps	MARMAP Index	Logbook Index	Recruitment Deviations	Comments
1	10	10	10	10	10	50	Poor fit to landings
2	100	10	10	10	10	50	Poor fits to indices, unrealistic selectivities
3	30	10	10	10	10	50	Poor fit to MARMAP index
4	10	10	10	100	100	50	Poor fit to landings
5	10	10	2	5	5	50	Poor fit to landings
6	10	10	10	20	5	50	Poor fit to landings
7	10	10	10	1	10	50	Poor fit to landings and indices
8	20	10	10	20	40	50	Two q's estimated for MARMAP index; Poor fit to landings
9	20	10	10	10	40	50	Normal likelihood on landings; two q's estimated for MARMAP index; Good fits but very slow convergence.
10	1000	10	10	10	10	50	Poor fit to MARMAP index; unrealistic spikes in recruitment
11,12	1000	10	10	100	100	200,300	Unrealistic spikes in recruitment
13	1000	10	10	100	100	400	Acceptable – Initial run

Appendix E. Parameter estimates from the initial run (ADMB output file).

```
# Number of parameters = 147
# par_sel1_handline:
2.48524
# par_sel2_handline:
4.88216
# par_sel3_handline:
1.00000e-10
# par_sel4_handline:
14.5604
# par_sel1_longline:
10.0000
# par_sel2_longline:
5.36813
# par_sel1_MMlongline:
10.0000
# par_sel2_MMlongline:
4.63415
# par_sel3_MMlongline:
0.228293
# par_sel4_MMlongline:
11.0960
# par_logR0:
5.27245
# par_logR_dev:
 -0.668751 -0.663205 -0.654382 -0.641769 -0.624146 -0.600030 -0.567109 -0.518535 -0.464383 -0.255324
 -0.124371 0.0663011 0.203317 0.102140 -0.0433091 -0.293515 -0.697053 -0.394160 0.290170 -0.102201
 0.632022 0.439229 0.147712 1.20787 0.635689 1.77212 1.42493 -0.361277 -0.176643 0.694338 1.29686
 0.701384 0.531754 -0.0452058 0.166215 -0.00687528 -0.297002 -0.507515 -0.535009 -0.535137 -0.535151
# par_mulogF_handline:
-5.34581
# par_logF_handline:
 -3.32829 -3.32823 -4.20616 -1.28755 -2.96088 -2.09273 -2.57309 -2.76237 -2.06225 -1.42801 -2.58383
 -0.624733 0.205960 0.782092 0.752329 -1.58454 -1.07446 -0.988160 -0.278628 0.975354 2.24385 1.65484
 1.48963 1.62443 1.78326 0.320255 1.12231 1.73350 1.70152 1.90833 1.73711 2.38240 1.93934 1.98741
 1.10575 0.971323 0.891108 0.940267 1.49804 0.219400 1.19409
# par_mulogF_longline:
-2.45397
# par_logF_longline:
 -4.40144 -3.07588 -2.77666 -2.45776 -1.98465 -0.466166 1.00634 0.680342 0.545700 0.613688 0.826666
 -0.474810 0.226191 0.731262 0.887418 1.00651 1.25707 1.20565 1.01152 0.987774 0.434669 0.486499
 0.389638 0.711405 1.15114 0.739849 0.738034
# par_mulogF_MRFSS:
-7.43559
# par_logF_MRFSS:
 -2.27775 -4.12670 -0.577555 1.14884 3.85265 -2.25987 -2.33502 0.754212 -3.75642 -1.88170 -1.86420
 1.40438 0.350399 1.94538 -4.12670 1.24364 3.05612 0.211348 1.76324 2.60337 2.59475 2.27759
# par_logq_MMlongline:
-6.27380
# par_logq_logbook:
-7.34617
```

Appendix F. Surplus–production model results (ASPIC output file).

```
Tilefish - June, 2004 - SEDAR AW                                                                     Page 1
                                                                           Wednesday, 09 Jun 2004 at 11:51:51
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 5.05)
                                                                                             FIT program mode
Author:     Michael H. Prager; NOAA Center for Coastal Fisheries and Habitat Research         LOGISTIC model mode
            101 Pivers Island Road; Beaufort, North Carolina  28516  USA                     YLD conditioning
            Mike.Prager@noaa.gov                                                             SSE optimization

Reference:  Prager, M. H. 1994. A suite of extensions to a nonequilibrium           ASPIC User's Manual is available
            surplus-production model.  Fishery Bulletin 92: 374-389.                         gratis from the author.

CONTROL PARAMETERS USED (FROM INPUT FILE)                                                 Input file: til003.inp
------------------------------------------------------------------------------------------------------------------------
Operation of ASPIC:  Fit logistic (Schaefer) model by direct optimization.
Number of years analyzed:                      41           Number of bootstrap trials:                            0
Number of data series:                          2           Lower bound on MSY:                            2.000E+01
Objective function:                 Least squares           Upper bound on MSY:                            1.000E+03
Relative conv. criterion (simplex):     1.000E-08           Lower bound on K:                              3.000E+01
Relative conv. criterion (restart):     3.000E-08           Upper bound on K:                              5.000E+04
Relative conv. criterion (effort):      1.000E-04           Random number seed:                              4120359
Maximum F allowed in fitting:              10.000           Monte Carlo search mode, trials:       0               0
Identical convergences required in fitting:     8


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.
Number of restarts required for convergence:      7


CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
------------------------------------------------------------------------------------------------------------------------
                                       |
 1  TIL MARMAP Horiz LL Idx, Total L...|   1.000
                                       |      11
                                       |
 2  TIL Commercial Logbook Idx         |  -0.242   1.000
                                       |       7      11
                                       --------------------------------------------------
                                              1       2


GOODNESS-OF-FIT AND WEIGHTING (NON-BOOTSTRAPPED ANALYSIS)
------------------------------------------------------------------------------------------------------------------------
                                                     Weighted            Weighted      Current     Inv. var.    R-squared
Loss component number and title                           SSE       N         MSE       weight        weight      in CPUE

Loss(-1)  SSE in yield                              0.000E+00
Loss(0)   Penalty for B1 > K                        0.000E+00       1         N/A    1.000E+00           N/A
Loss(1)   TIL MARMAP Horiz LL Idx, Total Landings   2.083E+00      11   2.315E-01    1.000E+00     5.338E-01        0.282
Loss(2)   TIL Commercial Logbook Idx                7.586E-01      11   8.429E-02    1.000E+00     1.466E+00       -0.044
.........................................................................................
TOTAL OBJECTIVE FUNCTION, MSE, RMSE:           2.84206906E+00           1.672E-01    4.089E-01
Estimated contrast index (ideal = 1.0):                0.6304           C* = (Bmax-Bmin)/K
Estimated nearness index (ideal = 1.0):                1.0000           N* = 1 - |min(B-Bmsy)|/K
```

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	User/pgm guess	2nd guess	Estimated	User guess
B1/K	Starting relative biomass (in 1962)	9.924E-01	8.000E-01	4.155E-01	1	1
MSY	Maximum sustainable yield	5.500E+02	4.100E+02	2.057E+02	1	1
K	Maximum population size	2.797E+03	2.050E+03	1.234E+03	1	1
phi	Shape of production curve (Bmsy/K)	0.5000	0.5000	----	0	1
---------	Catchability Coefficients by Data Series ---------------					
q(1)	TIL MARMAP Horiz LL Idx, Total Landings	4.743E-04	5.000E-04	4.750E-02	1	1
q(2)	TIL Commercial Logbook Idx	4.417E-04	5.000E-04	4.750E-02	1	1

MANAGEMENT and DERIVED PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	Logistic formula	General formula
MSY	Maximum sustainable yield	5.500E+02	----	----
Bmsy	Stock biomass giving MSY	1.398E+03	K/2	K*n**(1/(1-n))
Fmsy	Fishing mortality rate at MSY	3.933E-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(2003)/Bmsy	1.764E+00	----	----
F./Fmsy	Ratio: F(2002)/Fmsy	2.018E-01	----	----
Fmsy/F.	Ratio: Fmsy/F(2002)	4.955E+00	----	----
Y.(Fmsy)	Approx. yield available at Fmsy in 2003	9.701E+02	MSY*B./Bmsy	MSY*B./Bmsy
	...as proportion of MSY	1.764E+00	----	----
Ye.	Equilibrium yield available in 2003	2.292E+02	4*MSY*(B/K-(B/K)**2)	g*MSY*(B/K-(B/K)**n)
	...as proportion of MSY	4.167E-01	----	----
---------	Fishing effort rate at MSY in units of each CE or CC series ---------			
fmsy(1)	TIL MARMAP Horiz LL Idx, Total Landings	8.293E+02	Fmsy/q(1)	Fmsy/q(1)

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	0.001	2.775E+03	2.781E+03	1.430E+00	1.430E+00	1.205E+01	1.307E-03	1.985E+00
2	1963	0.001	2.786E+03	2.789E+03	1.430E+00	1.430E+00	6.296E+00	1.304E-03	1.992E+00
3	1964	0.000	2.791E+03	2.793E+03	1.700E-01	1.700E-01	3.267E+00	1.548E-04	1.996E+00
4	1965	0.004	2.794E+03	2.790E+03	1.097E+01	1.097E+01	4.898E+00	9.995E-03	1.998E+00
5	1966	0.001	2.788E+03	2.790E+03	2.060E+00	2.060E+00	5.463E+00	1.877E-03	1.994E+00
6	1967	0.002	2.791E+03	2.791E+03	4.880E+00	4.880E+00	4.480E+00	4.445E-03	1.996E+00
7	1968	0.001	2.791E+03	2.791E+03	2.990E+00	2.990E+00	4.117E+00	2.723E-03	1.996E+00
8	1969	0.001	2.792E+03	2.792E+03	2.440E+00	2.440E+00	3.336E+00	2.222E-03	1.997E+00
9	1970	0.002	2.793E+03	2.792E+03	4.840E+00	4.840E+00	3.586E+00	4.407E-03	1.997E+00
10	1971	0.003	2.792E+03	2.790E+03	8.960E+00	8.960E+00	5.531E+00	8.166E-03	1.996E+00
11	1972	0.001	2.788E+03	2.790E+03	2.780E+00	2.780E+00	5.498E+00	2.534E-03	1.994E+00
12	1973	0.007	2.791E+03	2.785E+03	1.922E+01	1.922E+01	9.057E+00	1.754E-02	1.996E+00
13	1974	0.015	2.781E+03	2.769E+03	4.281E+01	4.281E+01	2.172E+01	3.931E-02	1.989E+00
14	1975	0.027	2.760E+03	2.742E+03	7.343E+01	7.343E+01	4.218E+01	6.809E-02	1.974E+00
15	1976	0.026	2.728E+03	2.721E+03	7.098E+01	7.098E+01	5.792E+01	6.632E-02	1.951E+00
16	1977	0.013	2.715E+03	2.726E+03	3.548E+01	3.548E+01	5.428E+01	3.309E-02	1.942E+00
17	1978	0.018	2.734E+03	2.734E+03	4.914E+01	4.914E+01	4.843E+01	4.570E-02	1.955E+00
18	1979	0.023	2.733E+03	2.727E+03	6.352E+01	6.352E+01	5.307E+01	5.921E-02	1.955E+00
19	1980	0.039	2.723E+03	2.703E+03	1.056E+02	1.056E+02	7.090E+01	9.927E-02	1.947E+00
20	1981	0.171	2.688E+03	2.543E+03	4.359E+02	4.359E+02	1.799E+02	4.357E-01	1.923E+00
21	1982	0.816	2.432E+03	1.832E+03	1.495E+03	1.495E+03	4.736E+02	2.075E+00	1.739E+00
22	1983	0.659	1.411E+03	1.254E+03	8.272E+02	8.272E+02	5.423E+02	1.677E+00	1.009E+00
23	1984	0.507	1.126E+03	1.107E+03	5.616E+02	5.616E+02	5.261E+02	1.290E+00	8.050E-01
24	1985	0.505	1.090E+03	1.078E+03	5.440E+02	5.440E+02	5.211E+02	1.283E+00	7.796E-01
25	1986	0.527	1.067E+03	1.048E+03	5.519E+02	5.519E+02	5.154E+02	1.339E+00	7.632E-01
26	1987	0.107	1.031E+03	1.234E+03	1.324E+02	1.324E+02	5.386E+02	2.726E-01	7.371E-01
27	1988	0.172	1.437E+03	1.577E+03	2.714E+02	2.714E+02	5.394E+02	4.376E-01	1.028E+00
28	1989	0.239	1.705E+03	1.755E+03	4.195E+02	4.195E+02	5.139E+02	6.075E-01	1.219E+00
29	1990	0.226	1.799E+03	1.842E+03	4.161E+02	4.161E+02	4.946E+02	5.744E-01	1.287E+00
30	1991	0.239	1.878E+03	1.893E+03	4.528E+02	4.528E+02	4.811E+02	6.081E-01	1.343E+00
31	1992	0.255	1.906E+03	1.902E+03	4.859E+02	4.859E+02	4.786E+02	6.494E-01	1.363E+00
32	1993	0.278	1.899E+03	1.879E+03	5.218E+02	5.218E+02	4.850E+02	7.060E-01	1.358E+00
33	1994	0.213	1.862E+03	1.902E+03	4.050E+02	4.050E+02	4.785E+02	5.413E-01	1.332E+00
34	1995	0.168	1.936E+03	1.997E+03	3.347E+02	3.347E+02	4.487E+02	4.260E-01	1.384E+00
35	1996	0.079	2.050E+03	2.165E+03	1.706E+02	1.706E+02	3.835E+02	2.003E-01	1.466E+00
36	1997	0.083	2.263E+03	2.326E+03	1.927E+02	1.927E+02	3.077E+02	2.106E-01	1.618E+00
37	1998	0.076	2.378E+03	2.418E+03	1.840E+02	1.840E+02	2.573E+02	1.934E-01	1.700E+00
38	1999	0.103	2.451E+03	2.445E+03	2.520E+02	2.520E+02	2.417E+02	2.620E-01	1.753E+00
39	2000	0.151	2.441E+03	2.391E+03	3.615E+02	3.615E+02	2.726E+02	3.844E-01	1.745E+00
40	2001	0.087	2.352E+03	2.389E+03	2.072E+02	2.072E+02	2.740E+02	2.205E-01	1.682E+00
41	2002	0.079	2.419E+03	2.445E+03	1.941E+02	1.941E+02	2.418E+02	2.018E-01	1.730E+00
42	2003		2.466E+03						1.764E+00

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED) TIL MARMAP Horiz LL Idx, Total Landings

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
1	1962	*	1.319E+00	0.0005	1.430E+00	1.430E+00	0.00000
2	1963	*	1.323E+00	0.0005	1.430E+00	1.430E+00	0.00000
3	1964	*	1.325E+00	0.0001	1.700E-01	1.700E-01	0.00000
4	1965	*	1.323E+00	0.0039	1.097E+01	1.097E+01	0.00000
5	1966	*	1.323E+00	0.0007	2.060E+00	2.060E+00	0.00000
6	1967	*	1.324E+00	0.0017	4.880E+00	4.880E+00	0.00000
7	1968	*	1.324E+00	0.0011	2.990E+00	2.990E+00	0.00000
8	1969	*	1.324E+00	0.0009	2.440E+00	2.440E+00	0.00000
9	1970	*	1.324E+00	0.0017	4.840E+00	4.840E+00	0.00000
10	1971	*	1.323E+00	0.0032	8.960E+00	8.960E+00	0.00000
11	1972	*	1.323E+00	0.0010	2.780E+00	2.780E+00	0.00000
12	1973	*	1.321E+00	0.0069	1.922E+01	1.922E+01	0.00000
13	1974	*	1.313E+00	0.0155	4.281E+01	4.281E+01	0.00000
14	1975	*	1.300E+00	0.0268	7.343E+01	7.343E+01	0.00000
15	1976	*	1.290E+00	0.0261	7.098E+01	7.098E+01	0.00000
16	1977	*	1.293E+00	0.0130	3.548E+01	3.548E+01	0.00000
17	1978	*	1.296E+00	0.0180	4.914E+01	4.914E+01	0.00000
18	1979	*	1.294E+00	0.0233	6.352E+01	6.352E+01	0.00000
19	1980	*	1.282E+00	0.0390	1.056E+02	1.056E+02	0.00000
20	1981	*	1.206E+00	0.1714	4.359E+02	4.359E+02	0.00000
21	1982	*	8.689E-01	0.8162	1.495E+03	1.495E+03	0.00000
22	1983	6.910E-01	5.949E-01	0.6595	8.272E+02	8.272E+02	-0.14974
23	1984	8.130E-01	5.249E-01	0.5074	5.616E+02	5.616E+02	-0.43747
24	1985	4.590E-01	5.113E-01	0.5046	5.440E+02	5.440E+02	0.10783
25	1986	3.540E-01	4.970E-01	0.5267	5.519E+02	5.519E+02	0.33931
26	1987	*	5.854E-01	0.1072	1.324E+02	1.324E+02	0.00000
27	1988	*	7.479E-01	0.1721	2.714E+02	2.714E+02	0.00000
28	1989	*	8.326E-01	0.2390	4.195E+02	4.195E+02	0.00000
29	1990	*	8.734E-01	0.2259	4.161E+02	4.161E+02	0.00000
30	1991	*	8.978E-01	0.2392	4.528E+02	4.528E+02	0.00000
31	1992	*	9.021E-01	0.2554	4.859E+02	4.859E+02	0.00000
32	1993	*	8.911E-01	0.2777	5.218E+02	5.218E+02	0.00000
33	1994	*	9.020E-01	0.2129	4.050E+02	4.050E+02	0.00000
34	1995	*	9.473E-01	0.1676	3.347E+02	3.347E+02	0.00000
35	1996	8.600E-01	1.027E+00	0.0788	1.706E+02	1.706E+02	0.17734
36	1997	2.245E+00	1.103E+00	0.0828	1.927E+02	1.927E+02	-0.71058
37	1998	1.306E+00	1.147E+00	0.0761	1.840E+02	1.840E+02	-0.12992
38	1999	1.879E+00	1.160E+00	0.1030	2.520E+02	2.520E+02	-0.48258
39	2000	5.760E-01	1.134E+00	0.1512	3.615E+02	3.615E+02	0.67739
40	2001	1.241E+00	1.133E+00	0.0867	2.072E+02	2.072E+02	-0.09113
41	2002	5.760E-01	1.160E+00	0.0794	1.941E+02	1.941E+02	0.69973

* Asterisk indicates missing value(s).

```
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 1
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1962     0.0000                                             |
1963     0.0000                                             |
1964     0.0000                                             |
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983    -0.1497                                       ======|
1984    -0.4375                            =================|
1985     0.1078                                             |====
1986     0.3393                                             |==============
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.0000                                             |
1990     0.0000                                             |
1991     0.0000                                             |
1992     0.0000                                             |
1993     0.0000                                             |
1994     0.0000                                             |
1995     0.0000                                             |
1996     0.1773                                             |=======
1997    -0.7106                 ============================|
1998    -0.1299                                        =====|
1999    -0.4826                          ===================|
2000     0.6774                                             |===========================
2001    -0.0911                                         ====|
2002     0.6997                                             |============================
                   ------------------------------------------------------------------------------------
```

RESULTS FOR DATA SERIES # 2 (NON-BOOTSTRAPPED) TIL Commercial Logbook Idx

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
1	1962	0.000E+00	0.000E+00	--	*	1.229E+00	0.00000
2	1963	0.000E+00	0.000E+00	--	*	1.232E+00	0.00000
3	1964	0.000E+00	0.000E+00	--	*	1.234E+00	0.00000
4	1965	0.000E+00	0.000E+00	--	*	1.233E+00	0.00000
5	1966	0.000E+00	0.000E+00	--	*	1.232E+00	0.00000
6	1967	0.000E+00	0.000E+00	--	*	1.233E+00	0.00000
7	1968	0.000E+00	0.000E+00	--	*	1.233E+00	0.00000
8	1969	0.000E+00	0.000E+00	--	*	1.234E+00	0.00000
9	1970	0.000E+00	0.000E+00	--	*	1.233E+00	0.00000
10	1971	0.000E+00	0.000E+00	--	*	1.232E+00	0.00000
11	1972	0.000E+00	0.000E+00	--	*	1.232E+00	0.00000
12	1973	0.000E+00	0.000E+00	--	*	1.230E+00	0.00000
13	1974	0.000E+00	0.000E+00	--	*	1.223E+00	0.00000
14	1975	0.000E+00	0.000E+00	--	*	1.211E+00	0.00000
15	1976	0.000E+00	0.000E+00	--	*	1.202E+00	0.00000
16	1977	0.000E+00	0.000E+00	--	*	1.204E+00	0.00000
17	1978	0.000E+00	0.000E+00	--	*	1.208E+00	0.00000
18	1979	0.000E+00	0.000E+00	--	*	1.205E+00	0.00000
19	1980	0.000E+00	0.000E+00	--	*	1.194E+00	0.00000
20	1981	0.000E+00	0.000E+00	--	*	1.123E+00	0.00000
21	1982	0.000E+00	0.000E+00	--	*	8.093E-01	0.00000
22	1983	0.000E+00	0.000E+00	--	*	5.541E-01	0.00000
23	1984	0.000E+00	0.000E+00	--	*	4.889E-01	0.00000
24	1985	0.000E+00	0.000E+00	--	*	4.762E-01	0.00000
25	1986	0.000E+00	0.000E+00	--	*	4.629E-01	0.00000
26	1987	0.000E+00	0.000E+00	--	*	5.453E-01	0.00000
27	1988	0.000E+00	0.000E+00	--	*	6.966E-01	0.00000
28	1989	0.000E+00	0.000E+00	--	*	7.755E-01	0.00000
29	1990	0.000E+00	0.000E+00	--	*	8.135E-01	0.00000
30	1991	0.000E+00	0.000E+00	--	*	8.363E-01	0.00000
31	1992	1.000E+00	1.000E+00	--	1.199E+00	8.403E-01	0.35553
32	1993	1.000E+00	1.000E+00	--	1.055E+00	8.300E-01	0.23992
33	1994	1.000E+00	1.000E+00	--	8.330E-01	8.402E-01	-0.00857
34	1995	1.000E+00	1.000E+00	--	9.400E-01	8.824E-01	0.06326
35	1996	1.000E+00	1.000E+00	--	6.010E-01	9.565E-01	-0.46465
36	1997	1.000E+00	1.000E+00	--	7.910E-01	1.027E+00	-0.26155
37	1998	1.000E+00	1.000E+00	--	9.350E-01	1.068E+00	-0.13323
38	1999	1.000E+00	1.000E+00	--	1.267E+00	1.080E+00	0.15953
39	2000	1.000E+00	1.000E+00	--	1.533E+00	1.056E+00	0.37252
40	2001	1.000E+00	1.000E+00	--	7.640E-01	1.055E+00	-0.32294
41	2002	1.000E+00	1.000E+00	--	1.080E+00	1.080E+00	-0.00008

* Asterisk indicates missing value(s).

```
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 2
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1962     0.0000                                             |
1963     0.0000                                             |
1964     0.0000                                             |
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.0000                                             |
1985     0.0000                                             |
1986     0.0000                                             |
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.0000                                             |
1990     0.0000                                             |
1991     0.0000                                             |
1992     0.3555                                             |==============
1993     0.2399                                             |==========
1994    -0.0086                                             |
1995     0.0633                                             |===
1996    -0.4646                          ===================|
1997    -0.2615                                   ==========|
1998    -0.1332                                        =====|
1999     0.1595                                             |======
2000     0.3725                                             |===============
2001    -0.3229                               =============|
2002    -0.0001                                             |
                   ------------------------------------------------------------------------------------
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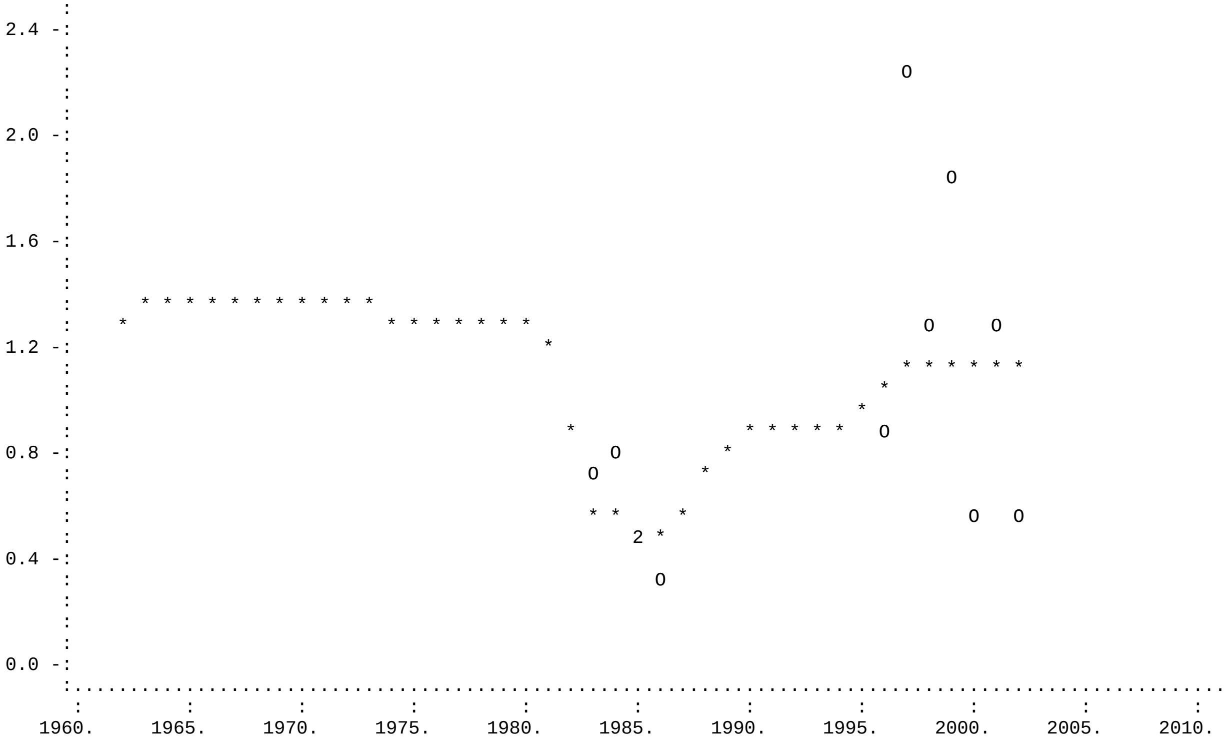
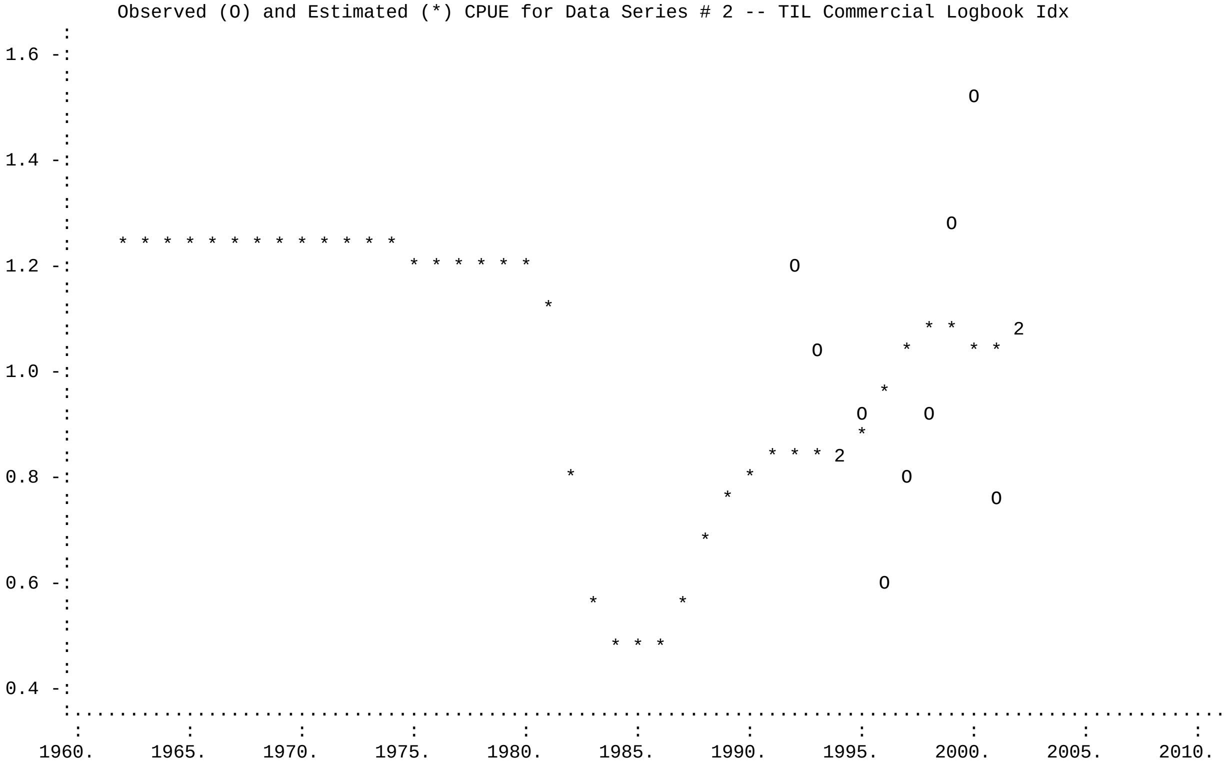
Observed (O) and Estimated (*) CPUE for Data Series # 1 -- TIL MARMAP Horiz LL Idx, Total Landings



Observed (O) and Estimated (*) CPUE for Data Series # 2 -- TIL Commercial Logbook Idx



```
                                   Time Plot of Estimated F/Fmsy and B/Bmsy (dashed line = 1.0)
         :
   2.4 -:
         :
         :
         :
         :                                                       F
   2.0 -:    B B B B B B B B B B B B B B
         :                                B B B B B B
         :
         :                                                       B                                     B B   B B
         :                                                         F                                 B     B
   1.6 -:                                                                                          B
         :
         :                                                                                       B
         :                                                             F          B B B B B
         :                                                         F F          B
   1.2 -:                                                                     B
         :
         :                                                         B         B
         :- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
         :
   0.8 -:                                                         B B B
         :                                                               B           F
         :                                                                   F   F F
         :                                                                     F       F
         :
   0.4 -:                                                     F             F             F         F
         :
         :                                                               F                 F F   F   F F
         :                                                                                     F
         :                              F F   F F F
   0.0 -:    F F F F F F F F F F F F F      F
         :.....................................................................................................
          :         :         :         :         :         :         :         :         :         :         :
        1960.     1965.     1970.     1975.     1980.     1985.     1990.     1995.     2000.     2005.     2010.
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SEDAR 4 Advisory Reports

Snowy Grouper

Tilefish

SEDAR 4
Stock Assessment Advisory Report
Snowy Grouper in SAFMC Management Area
August 18, 2004

Prepared by members of the SEDAR Assessment Workshop

1. Introduction

This document summarizes the recent SEDAR assessment of snowy grouper (*Epinephelus niveatus*) in the management area of the South Atlantic Fishery Management Council. Except where other sources are noted, material in this report is abstracted from the full report, entitled "Stock Assessment of the Deepwater Snapper–Grouper Complex in the South Atlantic" and designated SEDAR 4 Stock Assessment Report 1, 2004. Those desiring further detail are referred to the full Assessment Report.

2. Data

Data sets for assessment of snowy grouper were developed at a SEDAR Data Workshop (DW), which was held in Charleston, November 3–7, 2003. Data included basic biological information (e.g., natural mortality rate, maturity rate, size at age, and sex ratio at age), commercial and recreational landings by fishery and area, and indices of abundance developed from commercial logbooks and Marine Resources Monitoring, Assessment, and Prediction Program (MARMAP) fishery-independent surveys (Fig. 1). The fishery-dependent index for this stock was rejected during the Assessment Workshop (AW) because such indices of highly aggregating species, like snowy grouper, are often misleading. No estimates of discards are available from any fishery, and discards are believed to be negligible.

State and Federal specialists dedicated many man-months to data preparation before, during, and after the Data Workshop; without those efforts, the assessment would not have been possible. A full description of the resulting data are found in sections II and IIIA of the Assessment Report.

3. Stock Identification and Distribution

Young snowy grouper are found on shallow coral reefs, rocky areas and hard bottom. The fish move into very deep waters (up to 450 m [1,500 ft]) as they grow. The species is long-lived and slow-growing, and such species are relatively vulnerable to impacts of fishing. The stock assessed here is defined as extending from the North Carolina–Virginia border to the southern tip of Florida.

4. Landings

Snowy grouper are taken mainly by two commercial gears, handline and longline, with the former taking the bulk of the commercial landings (Table 1, Fig. 2). Recreational fishing in most years has taken considerably less than commercial fishing. Among recreational sectors, the headboat fishery is minimal, compared to the private boat/charter boat sector sampled by the Marine Recreational Fisheries Statistics Survey (MRFSS). The peak in total landings was over 400 mt/yr in the mid 1980s; in the last 10 years, landings have declined to about 150–200 mt/yr.

5. Assessment Model

The stock was assessed using a statistical model of catch-at-age similar to those used in recent SEDAR assessments of red porgy and black seabass. A stock–recruitment relationship was estimated simultaneously with stock status and trends. This arrangement provides estimates of maximum sustainable yield (MSY) and related benchmarks as part of the assessment procedure.

An initial run of the assessment model was determined by careful consideration of fits to all data sources in accordance with their information content. A resampling procedure was then applied to the initial run to characterize uncertainty in the assessment results. Median estimates from this procedure were taken as best estimates, with 10^{th} and 90^{th} percentiles used to describe ranges of uncertainty. Projections of future stock sizes and yields were obtained through an age-structured population model with stochastic (variable) recruitment.

6. Assessment Results

6.1. Exploitation Rate

Exploitation rate is defined as the fraction of fish, by number, taken during a year's fishing. That is, if the number of fish at the start of the year is N and the catch is C, the exploitation rate is $E = C/N$. The exploitation rate is generally similar in magnitude to the instantaneous rate of fishing mortality F when F and the natural mortality rate M are both small. As F increases, the exploitation rate becomes smaller in magnitude than F. Exploitation rate is used here and in the Assessment Report as a less technical measure of fishing pressure than F. All exploitation rates reported here are for the aggregate of ages 1 and older. They would be markedly higher if they were expressed as fractions of an older population (e.g., 2+).

Exploitation rates in this stock rose steadily from 1961 (the start of the assessment period) to about 1980. Since then, they have varied widely with no apparent trend (Fig.

3). The range since 1980 has been roughly 0.06/yr to 0.18/yr. The median estimate of the exploitation rate at MSY (under the current gear pattern) is E_{MSY} = 0.037/yr. Exploitation rates have consistently exceeded this value since the mid 1970s (Fig. 4).

Exploitation over time expressed as spawning potential ratio (SPR) is estimated to have varied inversely with exploitation rate, as expected (Fig. 5). During the last 25 years, the estimated %SPR has generally been below 10%.

6.2. Overfishing Status

The Assessment Workshop (AW) estimated that the stock was experiencing overfishing during 2002, the final year of the assessment period (Fig. 4). The median estimate of the degree of overfishing was E_{2002}/E_{MSY} = 3.06, which suggests that fishing pressure should be reduced by about 67% to meet SFA requirements.

6.3 Biomass

The stock's spawning-stock biomass (SSB), computed as total mature biomass, is estimated to have decreased markedly since the start of the assessment period (Fig. 6).

6.4 Overfished Status

The Assessment Workshop did not specifically estimate overfished status of the stock, which depends on the Council's definition of MSST. However, as the median estimate of SSB/SSB_{MSY} in 2002 (the end of the assessment period) was only 18%, the stock would be overfished under any conventional definition of MSST, and certainly under the Council's default definition of $0.75 \cdot SSB_{MSY}$.

6.5 Stock and Recruitment

The snowy grouper stock does not appear to have a strong stock–recruitment relationship. Nonetheless, the last few years have exhibited low recruitment levels, as would be expected at low stock sizes (Fig. 8).

7. Projections

The stock was projected for 35 years beyond the assessment period (2003–2037) under F=0 (no fishing). The projections used the same resampling techniques as the assessment. Projected recruitment was stochastic, but assumed that future recruitment would be similar to past recruitment.

The projections depict population recovery to SSB_{MSY} in 13 years with no fishing (Fig. 9). However, the last year of the assessment was 2002, and management of snowy grouper has not changed significantly (as of August, 2004). Thus, the stock status may well be lower than was estimated by the assessment workshop, and if so, recovery is likely to take longer than estimated.

8. Special Comments

This species changes sex from female to male as it reaches older ages. The relative importance of females and males to spawning success is not known, and is expected to vary with variations in population size. This phenomenon adds additional uncertainty when trying to estimate recovery rates and optimal spawning stock biomass levels.

The abundance indices (Fig. 1) used in this assessment were considered relatively uninformative by the Assessment Workshop. This observation was made because the indices show no definite trend; because they vary considerably from one year to the next and thus seem noisy; and because they are short. Given the relative lack of information from abundance indices, much of the information to estimate stock history comes from size and age composition data (in this case, from size composition data). In the course of the assessment, it was estimated that if the population were in steady state at SSB_{MSY}, it's length distribution would include a larger proportion of larger fish than is observed now (Fig. 10).

Table 1. Commercial landings of snowy grouper by year and gear.

Year	Handline	Longline	Trawl	Traps	Other	Total
1962	33.09	0.00	0.03	0.00	0.00	33.12
1963	45.33	1.88	0.00	0.14	0.00	47.35
1964	47.23	0.19	0.00	0.69	0.00	48.11
1965	39.32	0.00	0.00	0.89	0.00	40.21
1966	31.85	0.00	0.00	0.83	0.00	32.68
1967	58.92	0.00	1.37	0.90	0.00	61.19
1968	74.15	0.00	0.24	2.75	0.00	77.14
1969	57.12	0.04	0.00	2.26	0.00	59.41
1970	79.63	0.00	0.00	3.68	0.00	83.31
1971	81.91	0.00	0.01	3.38	0.00	85.29
1972	54.21	0.00	0.00	0.85	0.00	55.06
1973	72.64	0.00	0.00	0.10	0.00	72.74
1974	99.62	0.00	0.00	0.02	0.00	99.64
1975	116.68	0.00	0.02	1.00	0.00	117.70
1976	152.64	0.00	0.03	2.77	0.46	155.90
1977	100.14	35.81	0.33	0.03	0.08	136.38
1978	182.60	43.98	0.03	0.03	0.09	226.73
1979	168.05	37.76	0.14	0.03	0.08	206.06
1980	134.15	31.52	0.00	0.02	0.06	165.75
1981	276.11	41.58	0.11	0.03	0.08	317.92
1982	203.08	70.64	1.97	0.03	0.08	275.79
1983	246.39	171.03	0.74	0.03	0.08	418.26
1984	171.55	133.55	0.18	0.03	0.08	305.39
1985	105.78	70.77	0.00	0.02	0.06	176.63
1986	133.06	86.47	0.09	0.02	0.06	219.71
1987	91.19	88.09	0.00	0.03	0.03	179.34
1988	60.67	71.56	0.00	0.02	0.02	132.27
1989	138.53	89.64	0.00	0.01	0.03	228.21
1990	174.17	109.66	0.00	0.60	0.03	284.46
1991	149.59	79.19	0.00	1.69	0.09	230.57
1992	176.48	101.53	0.00	0.01	0.24	278.27
1993	134.24	76.07	0.00	0.01	0.48	210.81
1994	81.38	41.47	0.00	0.01	10.37	133.23
1995	124.19	34.74	0.25	0.81	9.78	169.78
1996	108.07	29.72	0.00	0.04	3.48	141.31
1997	148.62	81.66	0.00	0.09	4.19	234.55
1998	97.70	40.95	0.20	0.26	1.95	141.06
1999	143.45	44.11	0.00	0.05	2.60	190.20
2000	117.58	47.09	0.00	0.43	0.37	165.46
2001	84.04	52.08	0.00	0.06	0.84	137.02
2002	80.00	39.80	0.01	0.12	0.94	120.87

Table 2. Recreational landings of snowy grouper by fishery and year.

	Headboat		MRFSS (A+B1+B2)	
Year	**Numbers**	**Weight (mt)**	**Numbers**	**Weight (mt)**
1972	1035	5.12		
1973	636	4.98		
1974	1793	9.58		
1975	1039	6.16		
1976	2486	11.16		
1977	1157	3.47		
1978	797	4.58		
1979	1142	4.48		
1980	2664	9.00		
1981	3046	7.65	17647	62.12
1982	2243	7.52	5017	2.51
1983	3895	10.65	7602	22.73
1984	570	1.10	1648	0.82
1985	1108	1.96	0	0.00
1986	1338	1.92	0	0.00
1987	1134	2.00	5354	11.31
1988	953	1.49	2430	1.67
1989	1118	1.83	0	0.00
1990	677	1.29	1601	0.80
1991	529	0.99	97	0.13
1992	238	0.40	2388	9.02
1993	325	0.49	8567	40.34
1994	438	0.33	867	0.75
1995	395	0.33	8554	9.00
1996	722	1.55	1567	1.02
1997	411	1.00	18018	103.66
1998	172	0.59	570	2.64
1999	142	0.23	8095	12.70
2000	178	0.23	2419	7.45
2001	411	0.43	10254	19.05
2002	200	0.26	2148	4.78

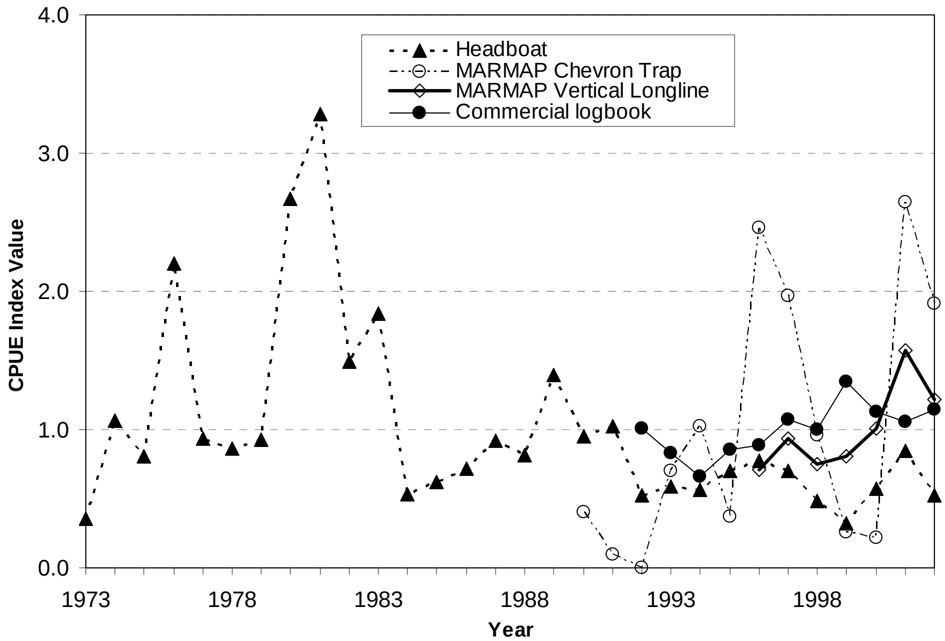

Figure 1. Snowy grouper indices of abundance derived from MARMAP vertical longline and chevron traps, headboat fishery, and commercial logbooks. Values are scaled to their respective means. Logbook index for this species was rejected by the Assessment Workshop.

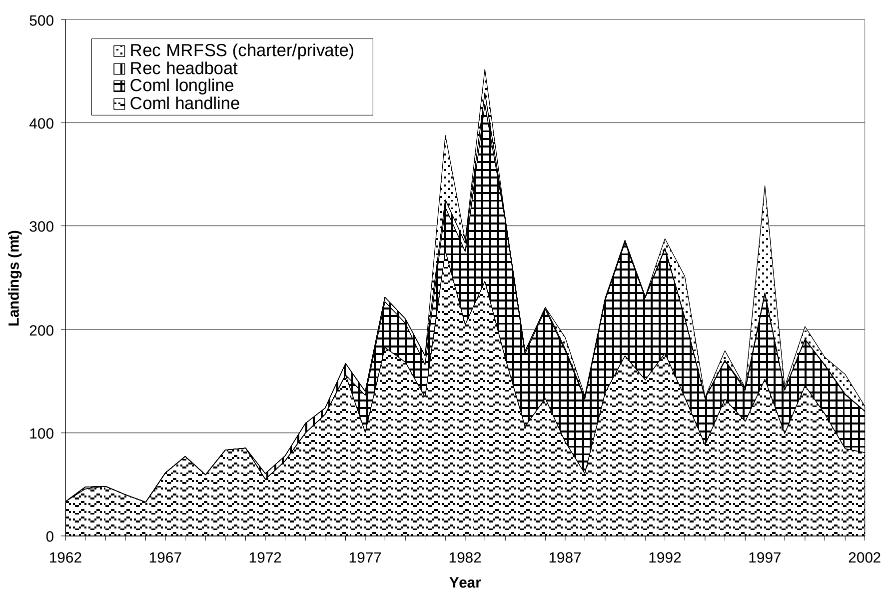

Figure 2. Annual landings (mt) of snowy grouper by fishery sector.

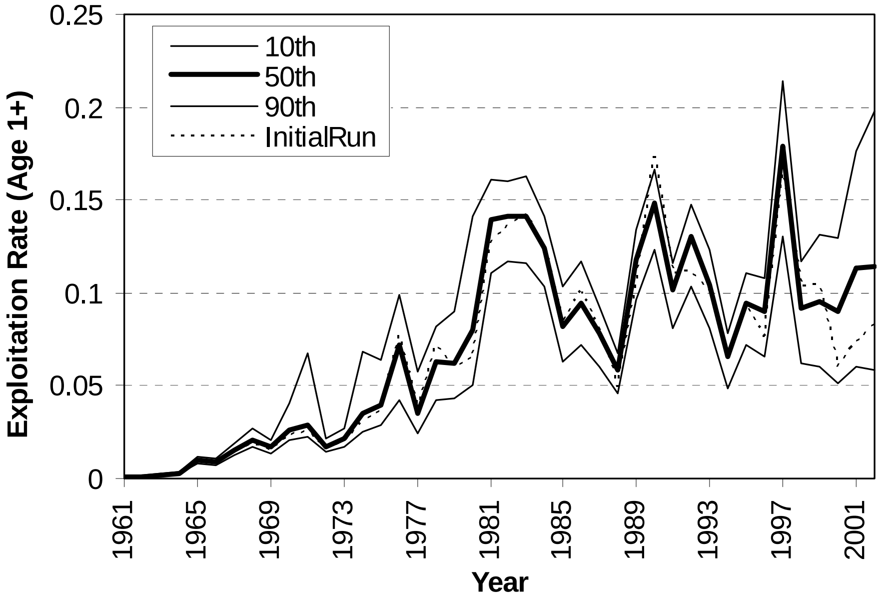

Figure 3. Estimated exploitation rate (per yr) of snowy grouper. Results shown are the initial run and the 10th, 50th (median), and 90th percentiles. The median is considered the best estimate.

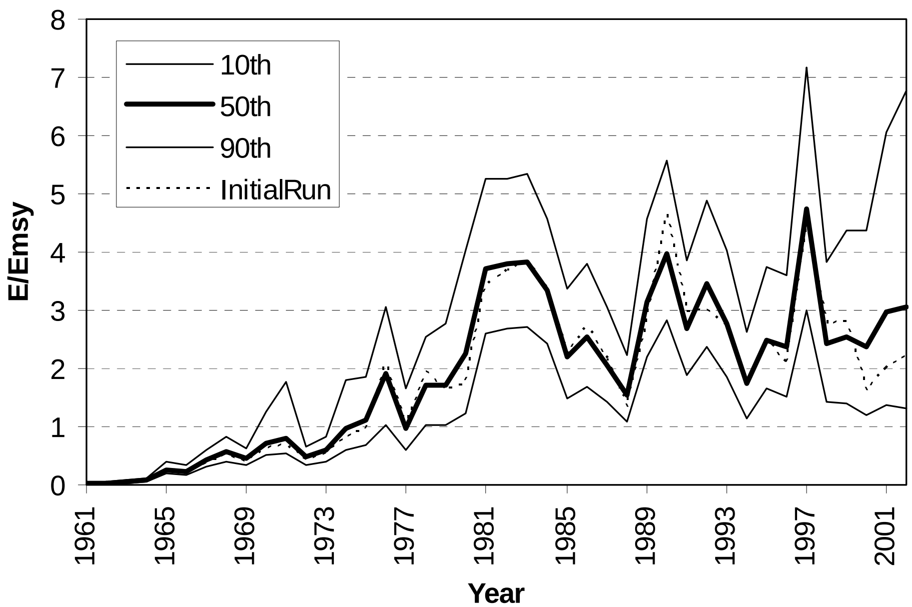

Figure 4. Estimated exploitation rate relative to E_{MSY}. Median is considered the best estimate.

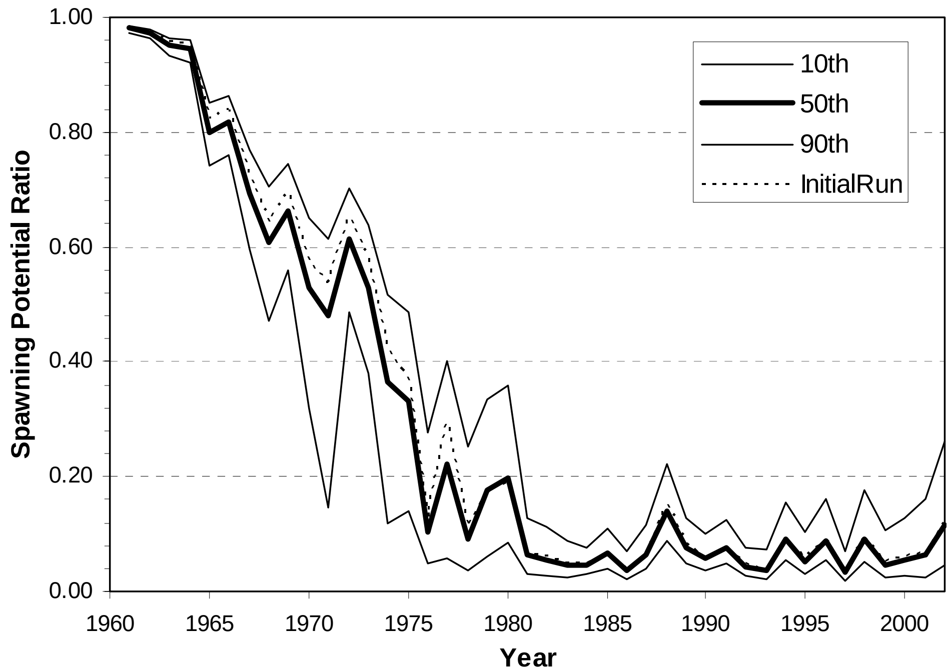

Figure 5. Estimated SPR of snowy grouper. The median is considered the best estimate.

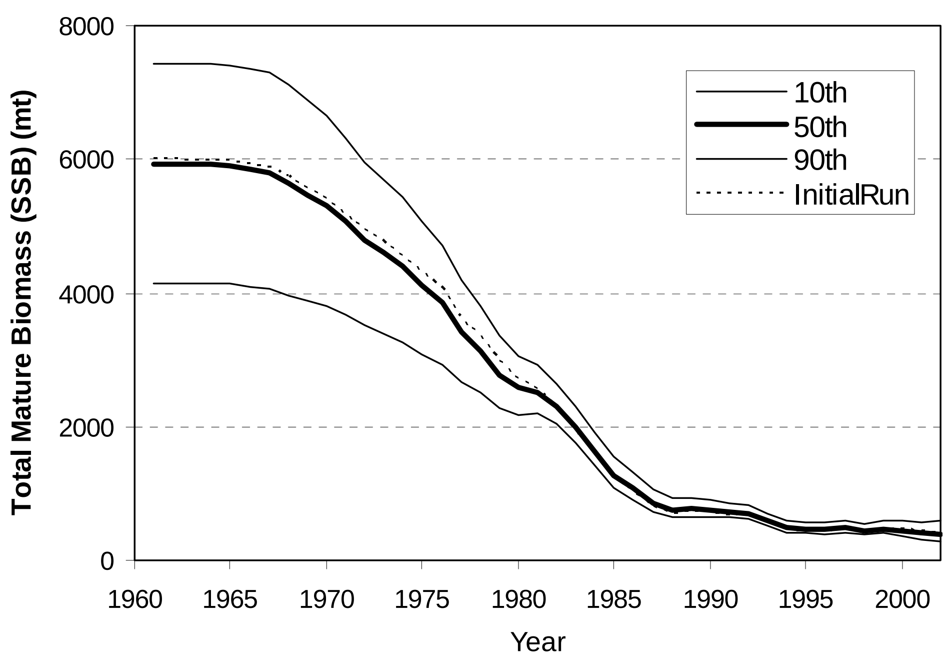

Figure 6. Estimated spawning-stock biomass (total mature biomass, mt) of snowy grouper. The median is considered the best estimate.

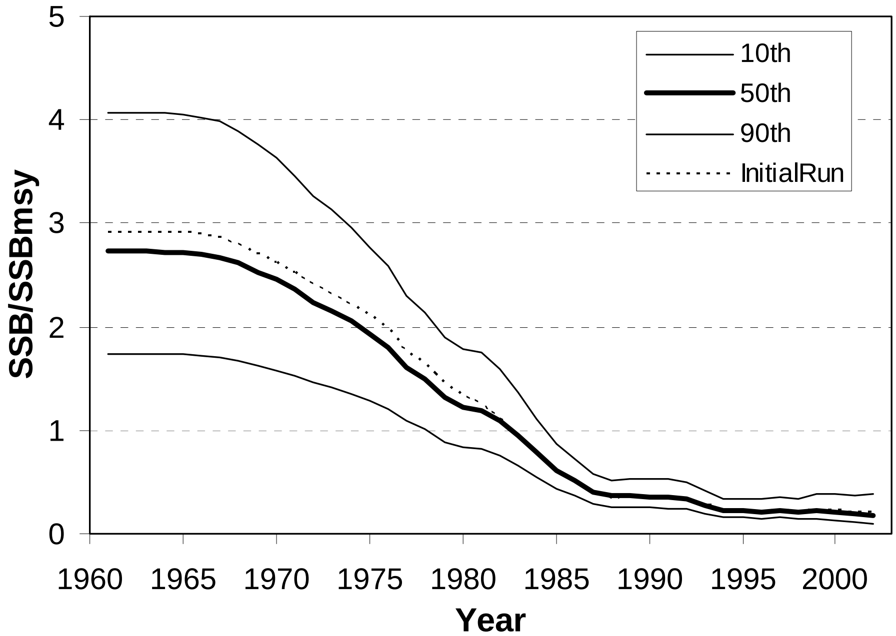

Figure 7. Estimated spawning stock biomass of snowy grouper relative to SSBmsy. Median is considered the best estimate.

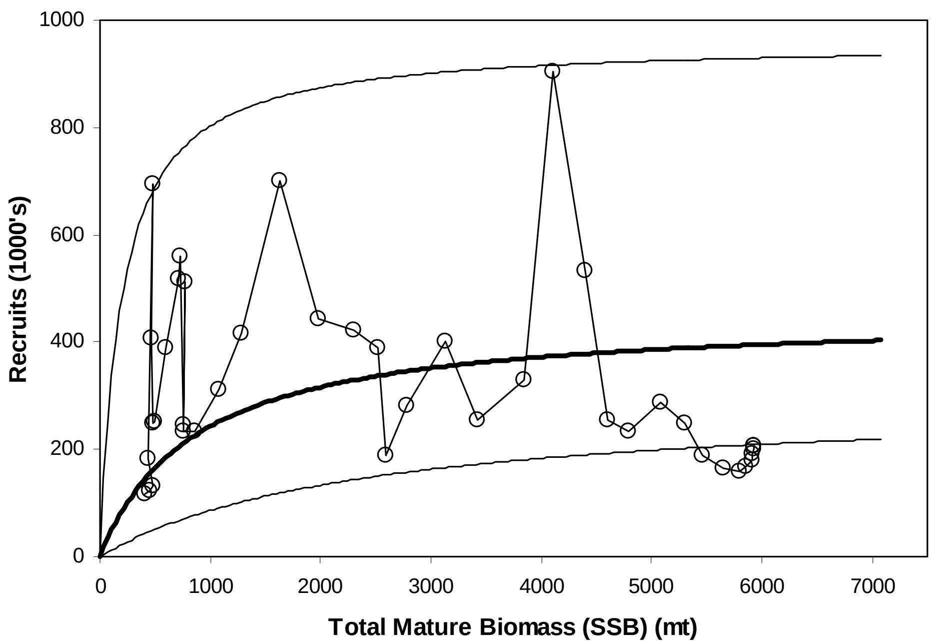

Figure 8. Estimated stock–recruit relationship of snowy grouper with median S–R time trajectory. Annual estimates in trajectory are open circles, with first year (1962) on the right. For S–R relationship, median plus 10th and 90th percentiles shown. Median line is considered the best estimate of the S–R relationship.

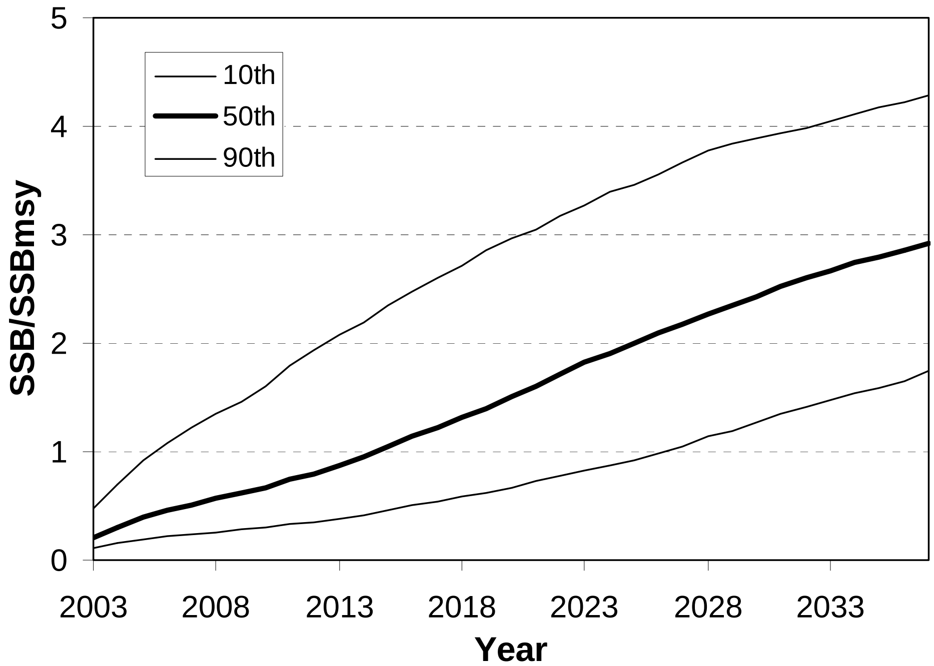

Figure 9. Projections of snowy grouper SSB/SSB$_{MSY}$ with no fishing. Shown: 10th, 50th (median), and 90th percentiles. The median is considered the best estimate.

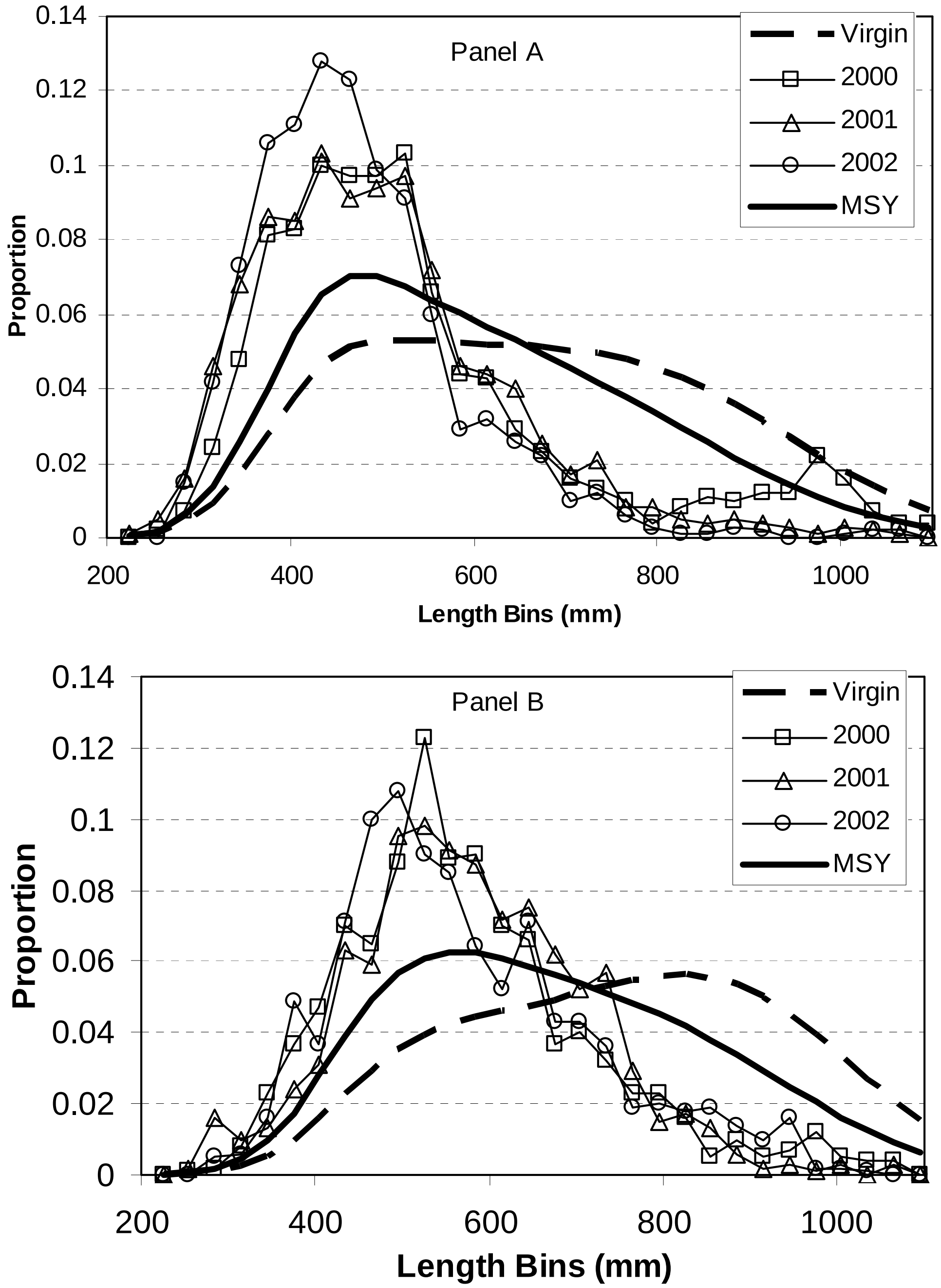

Figure 10: Steady-state length distributions of snowy grouper at various population sizes. B=virgin (unexploited), B=B_{MSY}, and observed (years 2000–2002) length compositions (landed fish) from the commercial handline (A) and longline (B) fisheries. Curves use selectivity estimates from initial run model.

SEDAR 4
Stock Assessment Advisory Report
Tilefish in SAFMC Management Area
August 18, 2004

Prepared by members of the SEDAR Assessment Workshop

1. Introduction

This document summarizes the recent SEDAR assessment of tilefish (*Lopholatilus chamaeleonticeps*) in the management area of the South Atlantic Fishery Management Council. Except where other sources are noted, material in this report is abstracted from the full report, entitled "Stock Assessment of the Deepwater Snapper-Grouper Complex in the South Atlantic" and designated SEDAR 4 Stock Assessment Report 1, 2004. Those desiring further detail are referred to the full Assessment Report.

2. Data

Data sets for assessment of tilefish were developed at a SEDAR Data Workshop (DW), which was held in Charleston, November 3–7, 2003. Data included basic biological information (e.g., natural mortality rate, maturity rate, size at age, and sex ratio at age), commercial and recreational landings by fishery and area, and indices of abundance developed from commercial logbooks and MARMAP fishery-independent surveys (Fig. 1). Though no estimates of discards are available, the discard rate was believed to be negligible.

State and Federal specialists dedicated many man-months to data preparation before, during, and after the Data Workshop; without those efforts, the assessment would not have been possible. A full description of the resulting data are found in sections II and IIIB of the Assessment Report.

3. Stock Identification and Distribution

Tilefish are found on sandy bottoms at depths of approximately 100–400 meters (300–1300 feet). The stock is defined as extending from the North Carolina–Virginia border to the southern tip of Florida.

4. Landings

Tilefish are taken mainly by commercial fishermen, with recreational components taking relatively little (Table 1, Table 2, Fig. 2). Although the commercial handline fishery has been prosecuted longer, the longline fishery has had greater landings since the late 1970s. The peak in total landings was over 1400 mt in the early 1980s. Landings have declined since then, to about 200–400 mt/yr in the last 15 years.

5. Assessment Model

The stock was assessed using a statistical model of catch-at-age similar to those used in recent SEDAR assessments of red porgy and black seabass. A stock–recruitment relationship was estimated simultaneously with stock status and trends. This arrangement provides estimates of maximum sustainable yield (MSY) and related benchmarks as part of the assessment procedure.

An initial run of the model was fit, based on careful consideration of fits to the data sources and their information content. Then, a resampling procedure was used to characterize uncertainty in the assessment results. Median estimates from this procedure were taken as best estimates, with 10th and 90th percentiles used to describe ranges of uncertainty. Projections of future stock sizes and yields were obtained through an age-structured population model with stochastic (variable) recruitment.

6. Assessment Results

6.1. Exploitation Rate

Exploitation rate is defined as the fraction of fish, by number, taken during a year's fishing. That is, if the number of fish at the start of the year is N and the catch is C, the exploitation ratio is $E = C/N$. The exploitation rate is generally similar in magnitude to the instantaneous rate of fishing mortality F when F and the natural mortality rate M are both small. As F increases, the exploitation rate becomes smaller in magnitude than F. Exploitation rate is used here and in the Assessment Report as a less technical measure of fishing pressure than F. All exploitation rates reported here are for the aggregate of ages 1 and older. They would be markedly higher if expressed as fractions of an older population (e.g., 2+).

Exploitation rates in this stock rose rapidly in the early 1980s. Since about 1985, they have varied in the range of roughly 0.02/yr to 0.10/yr (Fig. 3). The median estimate of the exploitation rate at which MSY can be attained under the current gear pattern is $E_{MSY} = 0.035$/yr. Exploitation rates have exceeded this value in many recent years (Fig. 4).

Exploitation over time expressed as the spawning potential ratio (SPR) is estimated to have varied inversely with exploitation rate, as expected (Fig. 5). In the last 15 years, the SPR has generally been below 30%.

6.2. Overfishing Status

The Assessment Workshop (AW) estimated that the stock was experiencing overfishing during 2002, the final year of the assessment period (Fig. 4). The median estimate of the degree of overfishing was $E_{2002}/E_{MSY} = 1.55$, which suggests that fishing pressure should be reduced by about 35% to meet SFA requirements.

6.3 Biomass

The stock's total biomass is estimated to have decreased by over 50% since 1980 (and earlier), as has the spawning-stock biomass (Fig. 6, Fig. 7).

6.4 Overfished Status

Whether the stock was in an overfished status in 2002 depends on the value of the limit reference point in biomass (MSST) chosen. Under the default SAFMC definition,

$$MSST = (1–M)\ SSB_{MSY} \approx 0.92\ SSB_{MSY}$$

slightly fewer than half the runs from the resampling procedure concluded the stock is overfished (thus by definition the median estimate is not overfished). However, the Assessment Workshop noted that defining MSST so close to SSB_{MSY} could result in difficulty distinguishing between the rebuilt and overfished states, and thus the Assessment Workshop examined results under an alternative definition

$$MSST = 0.75\ SSB_{MSY}$$

which also estimates that the stock is not in the overfished state.

6.5 Stock and Recruitment

The current stock level appears to be benefiting from unusually high recruitments in 1987, 1988, and 1992 (Fig. 8). The influence of those years is being felt now, because the species is relatively long lived (up to about 40 years), and fishing takes place mainly on ages 5+. Those recent large recruitments apparently account for the stock's relatively minor degree of depletion in the face of substantial recent overfishing. If future years are not above average in recruitment, the stock biomass is expected to decline unless reductions in fishing pressure are made.

7. Projections

The stock was projected for 25 years beyond the assessment period (2003–2027) using the same resampling techniques used for the assessment. Projected recruitment was stochastic but assumed that future recruitment would be similar to past recruitment.

The stock was projected under two different levels of exploitation, either zero or the current rate, based on the geometric mean of the last three years of the assessment period (2000–2002). Exploitation was divided among the three fisheries according to their current proportions.

The median projection under no fishing is of a stock that will attain SSB_{MSY} within one year (Figure 9). The median projection under current fishing is of a declining SSB that reaches about 72% of SSB_{MSY} in 2027. The annual yield in 2027 is slightly higher than MSY (Figure 10), which implies slow and continued stock decline.

8. Special Comments

The abundance indices (Fig. 1) used in this assessment were considered relatively uninformative by the Assessment Workshop. This observation was made because the indices show no definite trend; because they vary considerably from one year to the next and thus seem noisy; and because they are short. In the relative absence of information from abundance indices, much of the information to estimate stock history comes from size and age composition data (in this case, from size composition data). In the course of the assessment, it was estimated that the steady-state length distribution at the MSY level would include a larger proportion of larger fish (Fig. 11).

TABLES

Table 1. Commercial landings (mt) of tilefish by year and gear.

Year	Handline	Longline	Other	Total
1962	1.43	0.00	0.00	1.43
1963	1.43	0.00	0.00	1.43
1964	0.17	0.00	0.00	0.17
1965	10.97	0.00	0.00	10.97
1966	2.06	0.00	0.00	2.06
1967	4.88	0.00	0.00	4.88
1968	2.99	0.00	0.00	2.99
1969	2.44	0.00	0.00	2.44
1970	4.84	0.00	0.00	4.84
1971	8.96	0.00	0.00	8.96
1972	2.78	0.00	0.00	2.78
1973	19.22	0.00	0.00	19.22
1974	42.81	0.00	0.00	42.81
1975	73.44	0.02	0.05	73.51
1976	70.39	0.84	0.34	71.57
1977	7.86	31.01	4.53	43.40
1978	11.03	38.10	0.00	49.14
1979	11.87	51.65	0.00	63.52
1980	23.78	81.78	0.00	105.56
1981	79.73	355.93	0.00	435.66
1982	237.01	1258.36	0.00	1495.37
1983	103.59	722.19	0.00	825.79
1984	72.64	488.63	0.00	561.27
1985	70.54	452.51	0.00	523.05
1986	69.28	482.49	0.05	551.82
1987	14.80	117.50	0.00	132.30
1988	32.78	236.85	0.00	269.64
1989	56.08	363.41	0.00	419.49
1990	49.89	366.15	0.00	416.03
1991	57.01	395.70	0.00	452.71
1992	45.79	436.48	0.00	482.27
1993	84.69	435.66	0.00	520.36
1994	45.59	324.06	28.09	397.73
1995	41.46	268.40	24.84	334.70
1996	16.58	142.66	9.57	168.82
1997	15.46	154.90	9.18	179.54
1998	15.56	162.70	4.68	182.94
1999	16.57	228.71	3.04	248.32
2000	26.11	326.22	2.41	354.74
2001	6.39	188.01	0.65	195.05
2002	15.57	173.57	0.06	189.21

Table 2. Recreational landings of tilefish by fishery and year.

	Headboat		MRFSS (A+B1+B2)	
Year	Number	Metric tons	Number	Metric tons
1981	94	0.2	0	0.0
1982	12	0.0	0	0.0
1983	0	0.0	367	1.5
1984	0	0.0	1648	0.3
1985	0	0.0	20960	21.0
1986	0	0.0	46	0.1
1987	10	0.0	33	0.0
1988	0	0.0	900	1.8
1989	10	0.0	0	0.0
1990	14	0.0	48	0.1
1991	0	0.0	65	0.1
1992	20	0.0	1768	3.6
1993	0	0.0	700	1.4
1994	8	0.0	2607	7.2
1995	0	0.0	0	0.0
1996	0	0.0	1114	1.8
1997	190	0.4	6915	12.7
1998	0	0.0	472	1.0
1999	5	0.0	1952	3.6
2000	0	0.0	3896	6.8
2001	0	0.0	3150	12.2
2002	0	0.0	2036	4.9

FIGURES

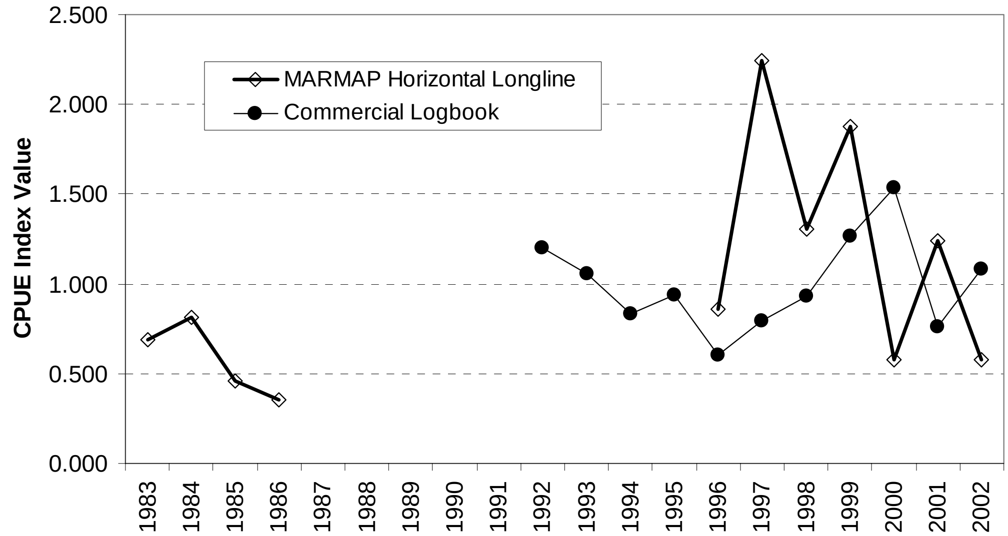

Figure 1. Abundance indices used in assessment of tilefish.

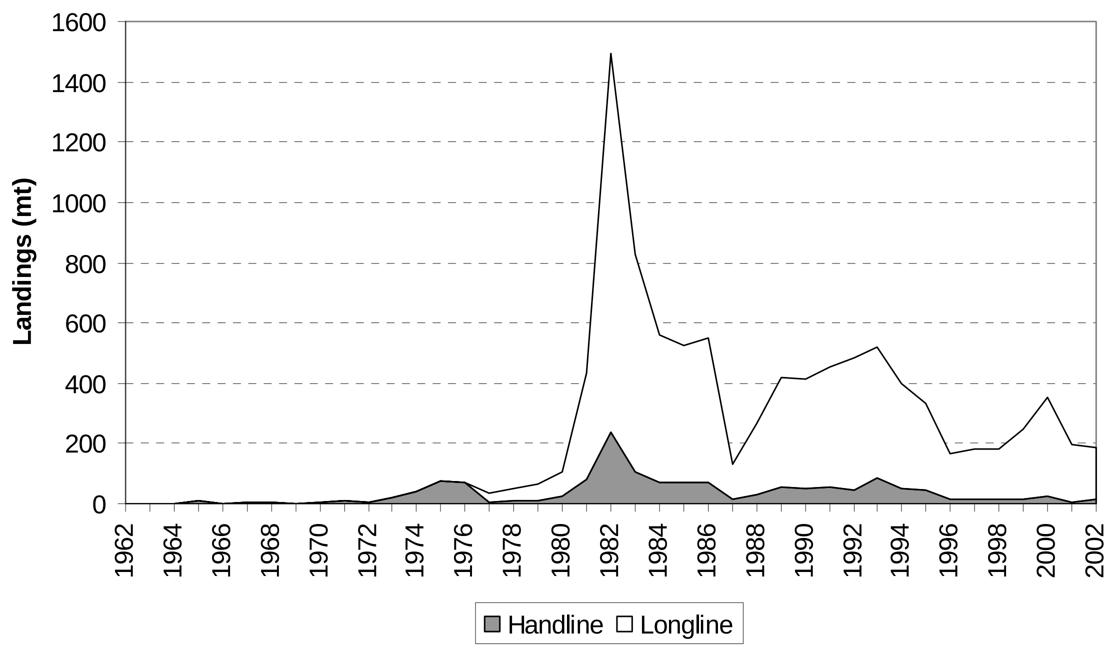

Figure 2. Commercial landings of tilefish (mt) by year and gear

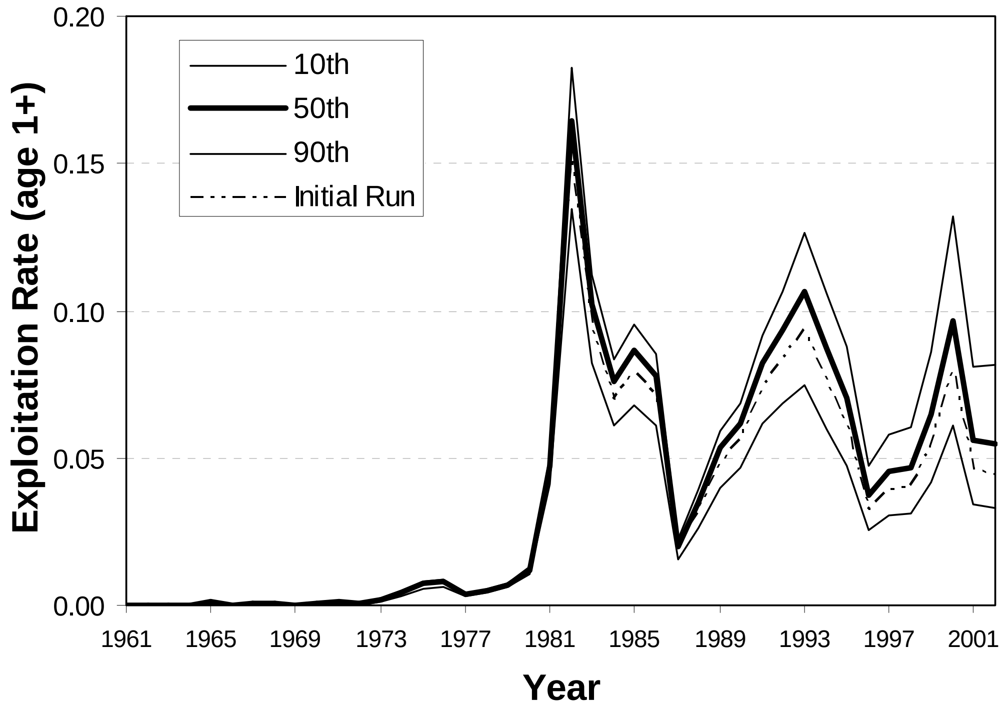

Figure 3. Exploitation rate (per yr) estimated by the tilefish model. Results shown are the initial run and the 10th, 50th (median), and 90th percentiles. The median is considered the best estimate.

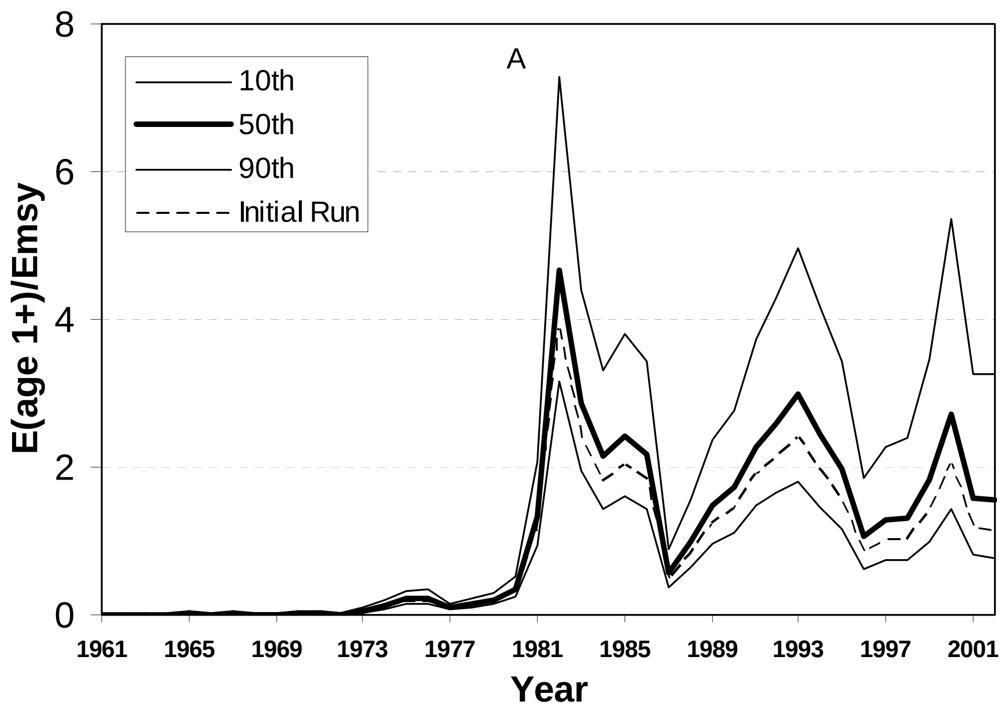

Figure 4. Estimated exploitation rate relative to E_{MSY}. The median is considered the best estimate.

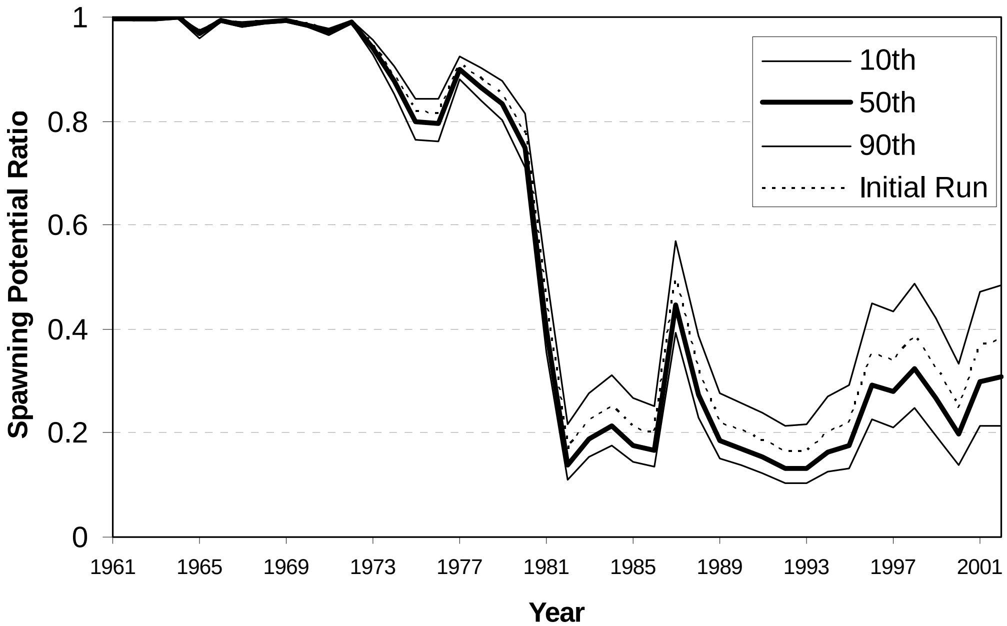

Figure 5. Estimated SPR of tilefish. The median is considered the best estimate.

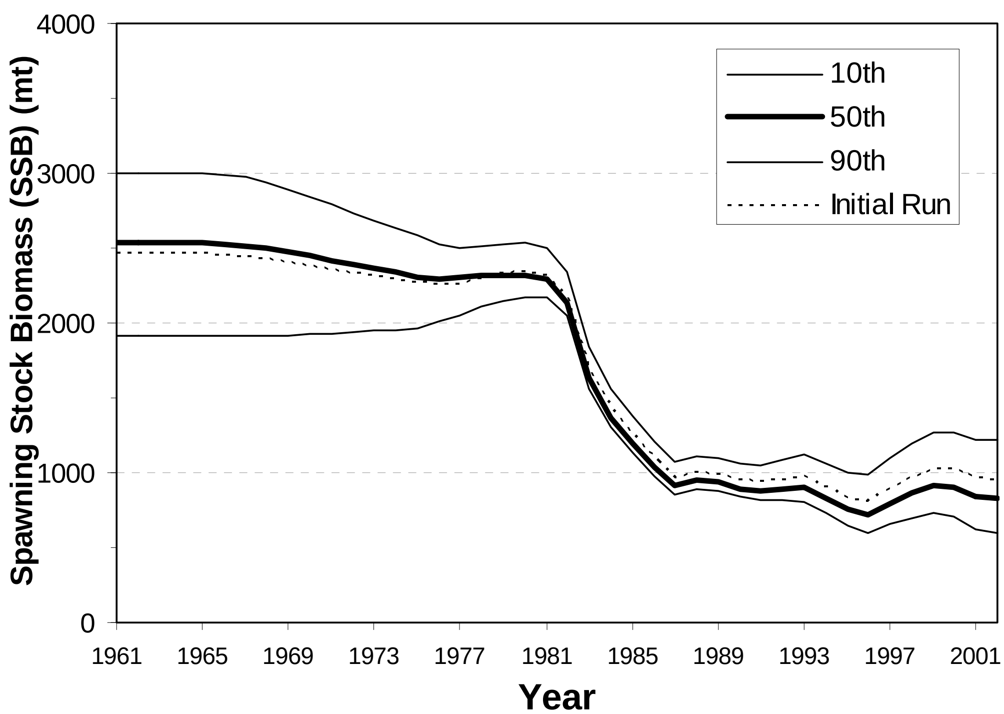

Figure 6. Estimated total stock biomass (mt) of tilefish. The median is considered the best estimate.

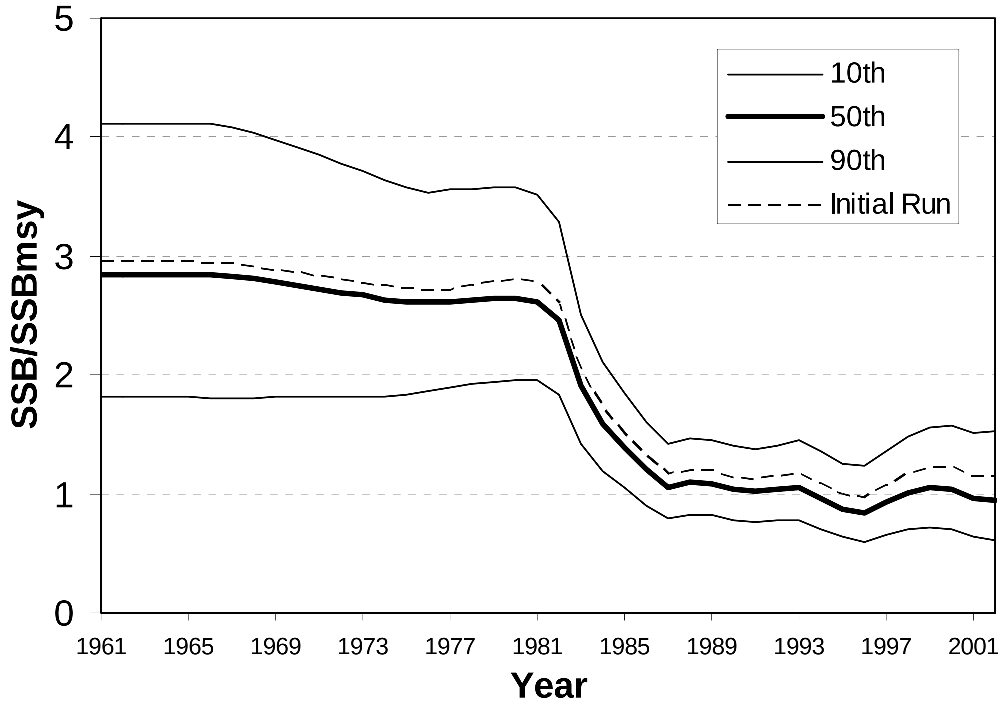

Figure 7. Estimated spawning stock biomass of tilefish relative to SSBmsy. The median is considered the best estimate.

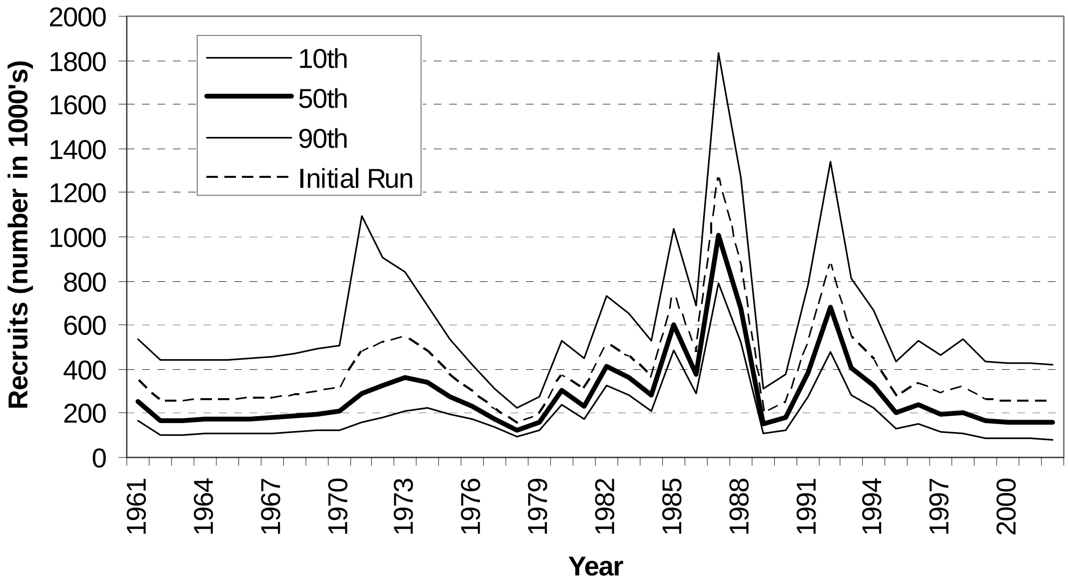

Figure 8. Estimated recruitment of tilefish. The median line is considered the best estimate.

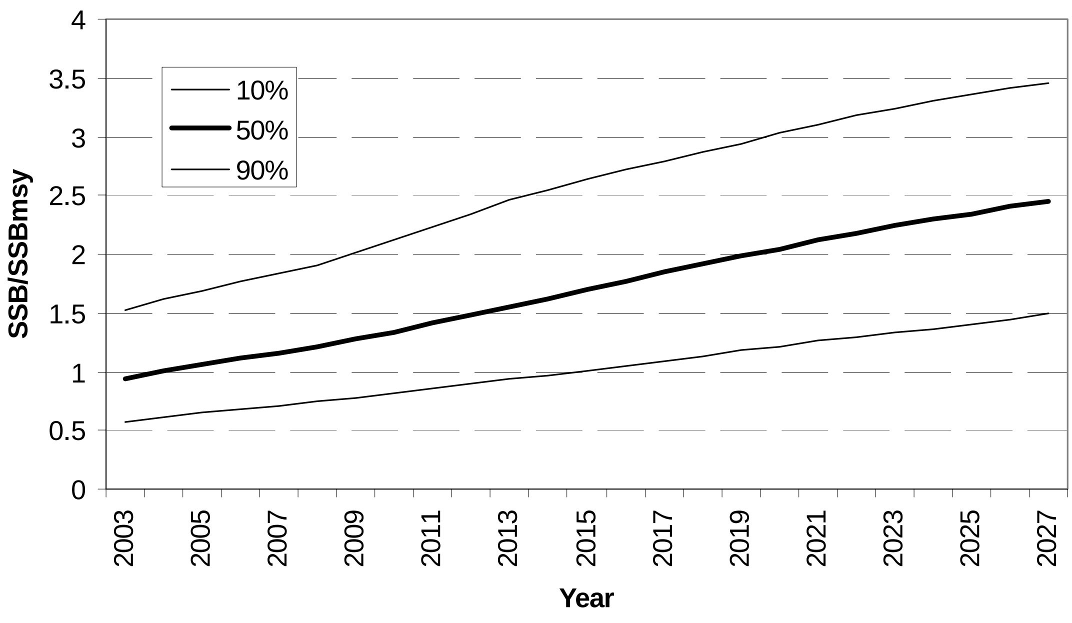

Figure 9. Projections of tilefish SSB/SSBmsy with no fishing. Shown: 10^{th}, 50^{th} (median), and 90^{th} percentiles. The median is considered the best estimate.

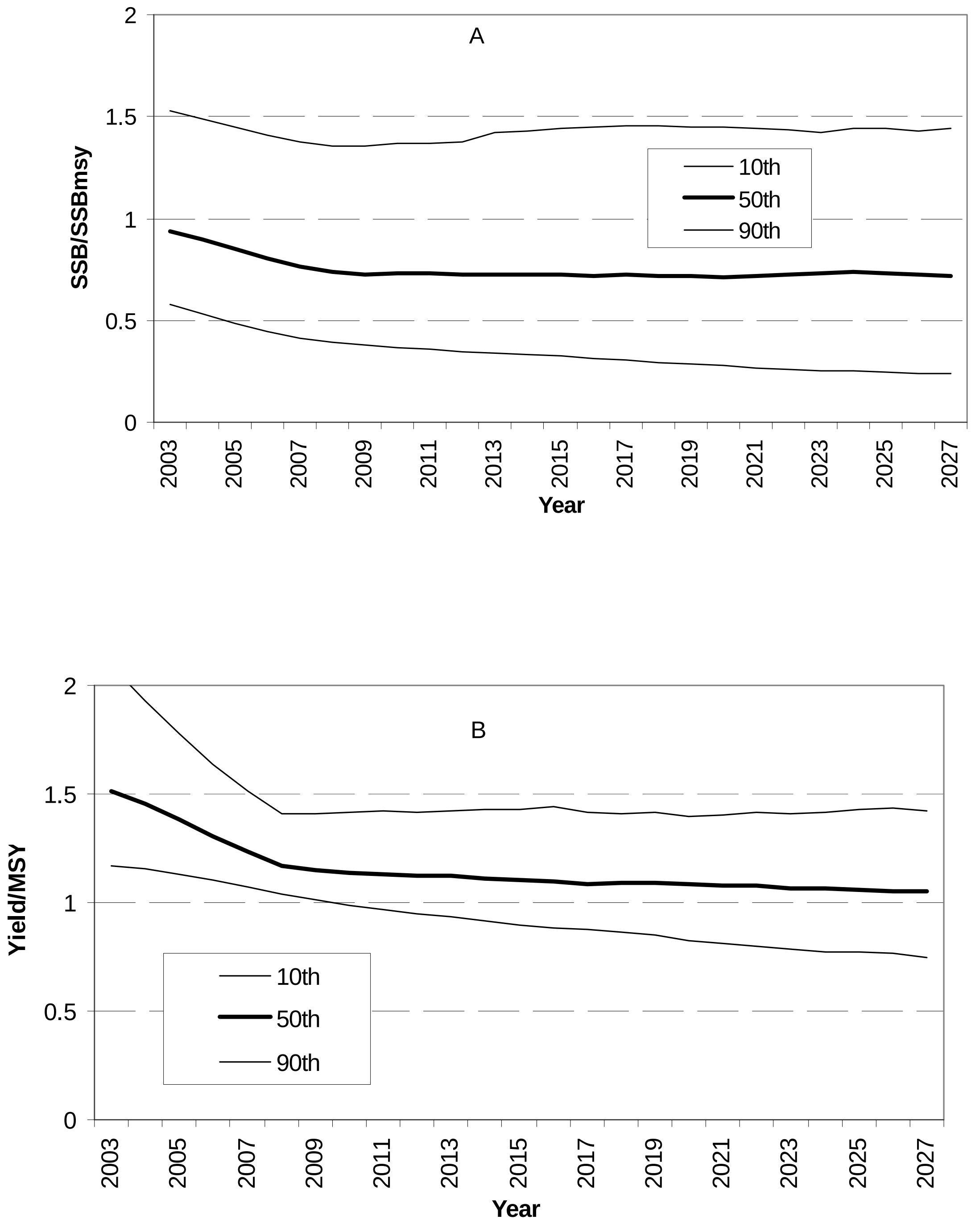

Figure 10. Projections of (A) SSB/SSBmsy and (B) yield/MSY of tilefish with fishing set at the current rate. Results shown are 10th, 50th (median), and 90th percentiles. The median is considered the best estimate.

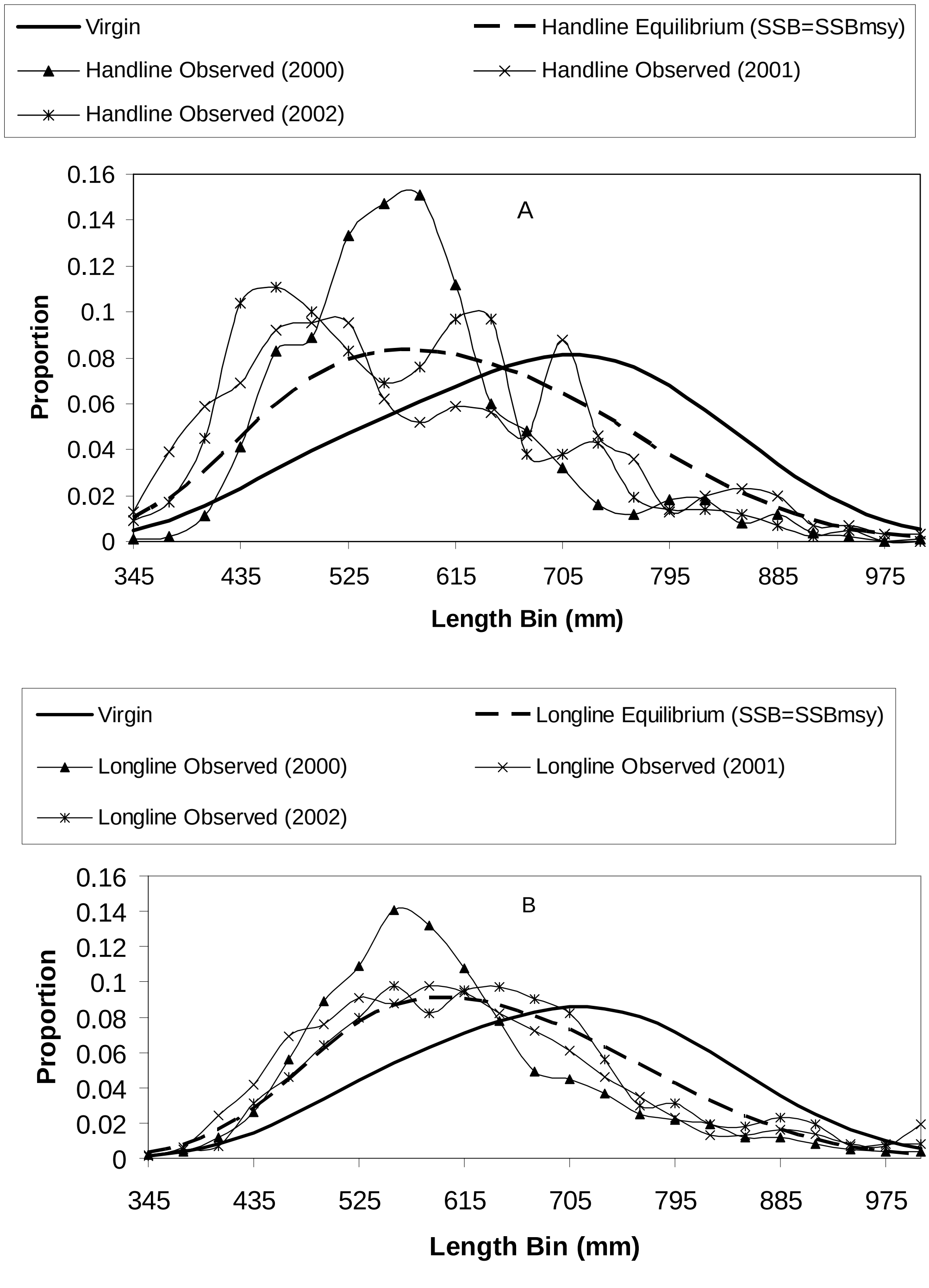

Figure 11. Current length distributions of tilefish from (A) the handline fishery and (B) the longline fishery, compared to length distributions expected from a virgin stock or one at MSY level. Note reduced proportion of larger fish in recent observed distributions.

SEDAR

Southeast Data, Assessment, and Review

SEDAR 4

Stock Assessment Report 1

SECTION IV. Review Consensus

Prepared by:
SEDAR 4 Review Workshop Panel
July, 2004

Charlotte, NC

Snowy Grouper and Tilefish
Peer Review Consensus Summary

Report prepared for the
South Atlantic Fishery Management Council
National Marine Fisheries Service

Edited by R. Mohn for the
Southeast Data and Assessment Review
July 26 – 29, 2004
Charlotte, NC

Executive summary

The Southeast Data, Assessment and Review (SEDAR) is a sequence of three workshops. The fist is a Data Workshop (DW) which is charged with compiling and evaluating data that may be used for resource assessment. Its products, if judged to be adequate, are passed on to the Assessment Workshop (AW) where models are developed and assessment advice produced. The third step is an independent peer review workshop which assesses the technical merits of the data, analysis, stock status and prognosis. This Review Workshop (called the Panel hereafter) assures quality and transparency in the generation of the biological basis of management advice.

The Data Workshop reviewed eight deepwater species and concluded that there were sufficient data and personnel resources to assess two of them, snowy grouper (*Epinephelus niveatus*) and tilefish (*Lopholatilus chamaeleonticeps*. Neither of these stocks had been assessed before. The Panel concluded that the data were weaker than those generally expected in fisheries assessments, especially for the tilefish. For both species the model chosen was forward-projecting statistical catch-at-age model. The models and analysis were well developed and presented. The population benchmarks are scientifically sound considering the limitation of the data.

The Panel also accepted, with some additional comments, the recommendations from both the DW and AW.

Introduction.

The format of this report requires some explanation. Because the Panel's terms of reference (Appendix A) included the reviews of both the Data Workshop (DW) and Assessment Workshop's (AW) terms of reference care has been taken to assure that all of the items were addressed. For this reason, the portion of report dealing with the DW follows their terms of reference in order form rather than narrative to facilitate the tracking the essentially hierarchical terms of reference. For convenience, the Panel's specific terms of reference are in the text and are in italics. The data and models used for snowy grouper and tilefish were quite similar, so the Panel decided to address each under each term of reference. When the observation was not applicable to both species, than the appropriate species was named.

Review of The Panel's Deliberations.

1. Evaluate the adequacy and appropriateness of all data used in the assessment and state whether or not the data are scientifically sound;

The terms of reference for the Data Workshop are given in Appendix C. The following section follows them in order.

A clear unit stock definition was not provided for either species from the data workshop. A single South Atlantic stock is apparently assumed for snowy grouper and for tilefish. This assumption is considered reasonable, based on the likelihood of restricted movement of adults in or out of the region, as well as the likely broad dispersal of their planktonic larvae. Modeling of the dispersal of other snapper and grouper larvae has suggested both local and long-distance transport of larvae prior to settlement. Future assessments should consider whether to include the snowy grouper and tilefish from the Gulf of Mexico or Mid-Atlantic because of possible larval diffusion.

> DW2. Evaluate the quality and reliability of life-history information (Age, growth, natural mortality, reproductive characteristics); develop models to describe growth, maturation, and fecundity by age, sex, or length as appropriate.

The Data workshop report provided life history data for eight deepwater species. The Panel only considered information related to snowy grouper and tilefish.

<u>Age and growth</u>

Aging differences between MARMAP and the NMFS Beaufort Lab indicate questions remain regarding age determination protocols, the validity of age-related data, and their use in age-structured models. Ages from bomb-radiocarbon indicate that the MARMAP ages are likely too low. However, the Assessment workshop concluded that NMFS' ages used in the assessments were preferable for determining von Bertalanffy growth curves.

Snowy Grouper: While age composition data were limited, they were important in determining selectivities by fishing sector, but were downweighted in the fitting process to account for the uncertainty involved.

Tilefish: Tilefish age compositions do not appear consistent with the length compositions, and are not fit well by the model. The RW recommended a sensitivity run in which tilefish age composition data are not included in the fitting process (objective function).

<u>Natural mortality</u>

The Assessment workshop used the shape coefficient for ocean fish (-0.305), and it's associated confidence interval (-0.351,-0.257), from Lorenzen (1996) and scaled the series such that the proportion surviving at the oldest observed age (35 and 54 years for snowy grouper and tilefish, respectively) was 1.4%. This value of 1.4% came from a re-analysis of Hoenig's (1983) earlier work with total mortality and maximum ages. The Review Panel acknowledges that this approach is a proper step towards capturing the idea that it is unlikely that natural mortality is constant across all ages. However, the Panel noted that the confidence intervals used in the Lorenzen model for ocean fish regarding the shape coefficient may be too narrow when applied to a specific species. Literature supports the use in the sensitivity analysis of values ranging from 0.1% to 5% surviving to the observed maximum age. The Panel noted that it would be more appropriate to calculate Hoenig's total mortality taking sample size into account, but the analyst responded that the dome-shaped recruitment to sampling gear means selectivity confounds natural mortality, so one cannot tease them apart when looking at the descending limb of the curve. Panel members questioned the resulting distributions of natural mortality at age, especially the relatively narrow range of values at older ages. Lorenzen's method may be more realistic in capturing the variation in natural mortality by age; however, the question as to whether the added realism outweighs the additional assumptions and complexity needs to be investigated. Moreover, total mortality (Z) and natural mortality (M) are confounded when estimated from an observed maximum age derived from a fished stock.

The Panel conducted a simulation exercise to examine the maximum age expected to be observed from a population following a Lorenzen natural mortality pattern versus a population following a constant natural mortality pattern because of differences in the implied number of fish still alive after the maximum observed age in the two populations. The constant natural mortality was set such that the two equilibrium populations had the same proportion of fish alive at age 54. Samples of 100 fish were randomly sampled from each population and the maximum age in each sample determined. There were 10,000 random samples collected from each population. Comparison of the distribution of maximum age from the samples of the two populations showed that the Lorenzen population had a larger maximum age than the constant M population. This implies that the Lorenzen M cannot be scaled to the same proportion alive at a given age as the constant M to produce an equivalent expected maximum age observed. The Panel recommends further analyses be conducted to determine an appropriate scaling for Lorenzen M vectors to produce an estimated maximum age equivalent to the constant M assumption.

The Panel asked NMFS staff to conduct a trial run of the model using constant mortality, in order to assess the impact of the Lorenzen-based natural mortality assumption on model performance. The results suggested that the model was relatively robust to any error in this assumption. Overall, the Panel did not consider the possible inaccuracy of the Lorenzen approach at the lower ages to be of much importance, given the high age of selectivity to the fishery.

Reproduction and sex ratios

A maturity ogive by age was developed with a logistic regression using MARMAP data after adjusting the ages to be consistent with NMFS' aging. The fit was not particularly good -- possibly due to the low numbers of older fish -- but the equation was deemed adequate for determining spawning biomass at age.

Snowy Grouper: Snowy grouper is a protogynous hermaphrodite, changing from female to male with age; hence, it is important to estimate the proportion of females by age. Age-specific sex ratios were calculated from a logistic regression.

Tilefish: Tilefish are gonochoristic, but sexually dimorphic, with sex-specific growth curves. The use of female weights is therefore appropriate; use of female only weights in SSB calculations required an assumption regarding age-specific sex ratios; all were set to 0.5 for all ages.

The Panel recommended that better information should be collected related to sex ratios at age, and that the fisheries implications of protogynous hermaphroditism in snowy grouper be more fully evaluated in future assessments.

The Data workshop provided fishery-independent (MARMAP) and fishery-dependent (headboat and commercial logbook) abundance indices.

Snowy Grouper: The Data Workshop identified four time series of information that could be used as indices of abundance for snowy grouper: MARMAP trap and longline surveys, commercial logbook reports, and the headboat catch rates. The Assessment Workshop did not use the commercial logbook index in the snowy grouper analysis because they thought that the index did not track abundance because of fishers shifting to areas of greater abundance, concerns for identifying directed trips, regulatory changes, technology creep, etc. The Assessment Workshop used the other three indices in their analyses. Pairwise correlations between indices were not significant.

The fishery-independent indices came from the MARMAP survey. The Panel noted the poor fits in the model and expressed concern regarding the zero value in 1992 in the MARMAP chevron trap series and questioned how that was handled in the analyses. Because these indices were assumed to follow a log-normal distribution, the concern regarded the extra value added to the zero. They also questioned why the coefficients of variation (CVs) for the chevron traps were similar to those used for longlines even though the longline index was less variable. The analysts responded that the CVs are used to provide estimates of inter-annual variation within an index. The MARMAP chevron trap series is considered an index of younger fish (ages 2 to 5 approximately) because the sampling only goes to 100 m which is shallow for snowy grouper. MARMAP's deeper longline sampling is more appropriate for snowy grouper at older ages. Neither of these indices had much of an influence the model's outcome. However, the Panel thought that these indices will be more valuable as the time series increases.

The only fishery-dependent index used in the analysis was the headboat index. The Panel questioned its use as a true measure of abundance, because headboats are fishing at the very edge of the distribution and changed their fishing from deeper waters in the early years to shallower waters of 100 m or less where snowy groupers are not a commonly caught species. Headboat trips were sub-set to those trips that caught deep-water species and effort was expressed in angler-hook days. The Assessment Workshop addressed these concerns by allowing selectivity to vary over time. Results showed that selectivity shifted toward younger ages over time, which is consistent with perceived changes in the fishery and expected availability by area. The model fit to this index was poor in the early years and better after 1984.

Tilefish: The Data Workshop identified two time series of information that could be used as indices of abundance for tilefish: MARMAP's fishery-independent, horizontal longline survey and commercial logbook CPUE. Although the MARMAP sampling was discontinuous, both time periods (1983-1986 and 1996-2002) were assumed to have the same catchability rate. As expected with the short time series of relatively noisy data, the model fits were poor.

The commercial logbook index was considered appropriate for tilefish because the logbook data had a large tilefish sample size and broad spatial coverage. The fit was as good as could be expected.

> DW6. Evaluate the quality and reliability of commercial and recreational fishery-dependent data for determining harvest and discard by species; develop estimates of total annual catch including both landings and discard removals by species.

Prior to 1985, the commercial landings of both of these species were reported only in aggregated categories and so the historical species landings had to be estimated. The Commercial Statistics subcommittee of the Data Workshop used the landings data from 1985-1993 to estimate the average ratio of snowy groupers to unclassified groupers or tilefish to unclassified tilefish by state then applied these ratios to the aggregate to extend the time series back to 1962. Similarly, if gear was missing, the average ratio of gears was applied. An underlying assumption is that these ratios from the later years were constant back into the earlier years. The results were time series of landings by state and gear from 1962 through 2002 for both snowy grouper and tilefish. The Assessment Workshop captured some of the uncertainty in the early commercial landings by setting the commercial coefficient of variation (CV) for the early years at 50% until 1983 and then decreased the CV linearly until 1994 when the CV was set to 10%. There was some discussion as to whether this use of CVs is the best approach to address the uncertainty in landings, given that it is believed the uncertainty is a bias and not random error. An alternative approach worth evaluating would be to include a bias parameter in the model that is estimated.

Snowy Grouper: The snowy grouper commercial fishery began in Florida and expanded northward to South Carolina and North Carolina in the early 1980s. Handlines are the dominant gear in this fishery. Commercial discards were reported to be negligible for snowy grouper.

Tilefish: The tilefish commercial fishery began in Florida and expanded north to South Carolina and North Carolina in the early 1980s, but Florida remains the dominant state for landings. Longlines are the dominant gear. While the same approach used to estimate historical tilefish landings, the smaller number of species and large proportion due to tilefish reduced the uncertainty imposed by this approach. A similar decreasing function for CV of landings was applied, which the RW felt was not appropriate given the reported greater confidence in tilefish landings than in snowy grouper landings. However, since landings were matched closely in the model such changes in CV were not considered worth changing. Commercial discards are also reported to be negligible for tilefish.

Because snowy grouper and tilefish are caught in deep water, the recreational landings are small coming mostly from NMFS's Marine Recreational Fisheries Statistics Survey (MRFSS) charterboat and private boats and an even smaller amount comes from headboats. Again because of the deeper water, it is assumed that none of the released fish estimated by MRFSS survive and so these released fish are included as recreational catch. Proportional standard errors estimated by MRFSS are used as CVs for this sector. The headboat survey does not estimate CVs because it is assumed to be a census but Dixon and Huntsman (SEDAR4-DW-26) note that approximately 40% of headboat landings aren't reported and have to be estimated. The headboat CVs were 10% for 1972-1995 and higher (25%) afterwards because some boats operate in Florida waters not in federal waters offshore and they claim they don't have to report, so from 1996 on has a higher CV to account for it. As with commercial landings, the recreational CVs are not believed to be very important in what the model predicts because the model is configured to fit the landings. Some Panel members thought that since the headboat coverage has changed over time the CVs should be higher in the earlier years. Concern was expressed regarding the poor fits to the landings in the early years which suggested that the differences are not just random error but bias. Recreational fishing for tilefish is limited with landings less than 20 t annually.

Snowy Grouper: The only length data for snowy grouper prior to 1983 came from the headboat survey, and those data did not encompass the entire region. The fishery expanded north from Florida, while the headboat sampling began in North Carolina. Therefore, the early length samples may not be representative of the bulk of the fishery. Length sampling in the commercial handline and longline sectors after 1983 was deemed adequate, especially in the handline portion. There was an apparent contradiction from expectation in that the sizes of fish caught by longlines decreased after the longlines were restricted to fishing in 100 m or greater depths.

Tilefish: Length data for tilefish were only available beginning in 1983. The dominant source of length data was the commercial longline fishery, which has been well sampled each year since 1984, with more than 2,000 length measurements for most years. Length distributions for the commercial handline fishery and the MARMAP survey contained many fewer fish -- less than 200 length measurements for most years.

Age sampling

There was a lot of concern for the small number of age samples for both species, and for possible effects of clumped sampling, which would make the 'effective' sample size even smaller. The Stock Assessment Workshop did not include age composition data for years where there were fewer than 25 age samples. This cutoff meant that few years were included in the analyses, e.g. only 1981 and 1986 could be included for the headboat/recreational sector in the snowy grouper assessment. On the commercial side, only data from 1997 and later could be included in the snowy grouper analyses. A question was raised as to whether 25 age samples were adequate, and whether such limited sampling enabled tracking of cohorts. The response was that age data actually served only to aid in determining selectivities. A suggestion was made to model selectivities based on size instead of age. The analysts said that they would move in that direction in future SEDAR assessments.

The length distribution of the tilefish age samples did not appear representative of the length samples from which they were chosen. The Panel recommended that these age composition data not be used within the model because of this lack of representativeness. To test the importance of this recommendation, a sensitivity run was performed, and this omission did not affect model results. Therefore, the Panel was satisfied with the model as configured, but recommenced that value of retaining these data be considered in future assessments.

In summary, the Review Panel believed that an extensive amount of data had been introduced through the Data Workshop, but that the Data Workshop had provided little written evaluation of quality and reliability. The Review Panel considers the data were scientifically sound and used appropriately. However, the Panel and the Assessment report both note a number of data limitations, and conclude that the data were adequate, but allowed only limited inference as to population status.

2. *Evaluate the adequacy, appropriateness, and application of the methods used to estimate population parameters such as abundance, biomass, and exploitation and state whether or not the methods are scientifically sound.*

This section reviews the Assessment Workshop in light of its terms of reference; see Appendix D.

The Review Panel considered the terms of reference applied to the assessment workshop, and concluded that in general they were addressed adequately. The one problem noted that several arguments and rationales for the inclusion and exclusion of models were not well represented in the AW documents. A specific example would be the determination of the “initial runs”. In each assessment, the initial run is the configuration was deemed to be good enough to act as a basis for diagnostics and upon which the MCB replicates were based. As is noted below, the initial run was not used to directly determine stock status.

The model used for both species was a forward projecting, age-structured model that fit gear-specific landings, indices, age and length compositions to produce numbers of fish by age and fishing mortalities. The weights for the components of the likelihood functions were adjusted during the stock assessment workshop until the results were deemed reasonable and that run was labeled ‘initial run’. Uncertainty was evaluated through a Monte Carlo/Bootstrap (MCB) approach

The Panel supports the assessment teams’ use of MCB technique as a pragmatic method of characterizing uncertainty in the assessments. This technique addresses two types of uncertainty. The first derives from model parameters (such as natural mortality and steepness) that were held fixed in the initial run. The second type is associated with the data inputs (such as CPUE indices of length compositions). All data inputs include a random error component arising from sampling variation (e.g., the length compositions inputs would have been different had different landings been sampled). MCB answers the question “how different might the assessment results have been if different (but plausible) values had been used for the fixed parameters and if the sampling error had been different?".

Care should be taken in interpreting MCB results. For each model output the assessment teams presented the 10th and 90th percentile from the MCB analysis (e.g., for tilefish the 10th and 90th percentiles were 1792 mt and 3644 mt). These should be treated as indicating the approximate range of the uncertainty associated with each output. However, they should not be interpreted probabilistically. That is, we should not say that we can have 80% confidence that the true MSY for tilefish lies between 1792 mt and 3644 mt. There are two main reasons for this. First, consider the initial SSB, which was allowed to take any value between 0.5SSB(virgin) and 1.3SSB(virgin). This defines the range of uncertainty for SSB(initial) but it is not probabilistic because it is not true that all values in this range are equally likely. A similar comment applies to uncertainty in natural mortality. The second reason is that it is not appropriate to treat all MCB runs as having equal weight. In some runs, the randomly chosen parameter values will not produce a good fit to the data. For a formal probabilistic interpretation these runs would need to receive less weight than those for which the data are fitted well.

There was one type of probabilistic interpretation which the Panel felt was acceptable (although not strictly correct). Consider, for example, the forward projections with no fishing for snowy grouper (Figure 60). Here, the median line crosses 1 in about 2015. From this we can say that there is a more than 50% chance that snowy grouper would not rebuild to MSY in less than 10 years.

The Review Panel considered that the statistical catch-at-age model used for both snowy grouper and tilefish was appropriate for the available data and, within the limits of the data, adequately addressed questions of exploitation and relative abundance. It also believed that the median MCB values provide the best estimates of model outputs, but that it is useful, for comparative purposes, to include results from the initial run in all plots except for those from projections. The initial run is also important because it provides important diagnostic plots, such as those illustrating model fit to the data.

There is not a single median run as such chosen from the MCB replicates. For each parameter or model product (SSB2002, MSY etc) there is a median. Some of the products are expressed as ratios, (Figure 56 of snowy grouper report SSB2002/SSBmsy) in which case the median of the ratios is chosen and not the ratio of the medians. Thus, it may be that the median ratio will not be the ratio of the median SSB2002 and SSBmsy and such a discrepancy is not an error. The Panel did not have these results in tabular form so an example could not be presented.

The Panel suggested that a reduced-parameter run, with simpler assumptions, be made for both species. In these runs the effective number of parameters estimated was substantially reduced (from 204 to 24 for snowy grouper and from 147 to 13 for tilefish) by making recruitment deterministic and forcing the model to fit the landings exactly. This made the model into an age-structured production model.

The Panel concurred with the AW decision not to include the surplus production model results for either species.

Snowy Grouper: The snowy grouper assessment suggested that fishing mortality first exceeded Fmsy in the mid 1970s and has fluctuated around 3Fmsy since the early 1980s. This high fishing mortality rate caused the population biomass to decrease below SSBmsy in the early 1980s and it has continued to decline ever since. The Panel concluded that the main information on population trends was coming from the length composition data rather than the abundance data.

Unfortunately, outputs from the 2316 MCB runs fell into two main groups: 1) a realistic group (1470 outcomes) in which population biomass was on the order of a few thousand tons and recent fishing mortalities were about 3Fmsy and 2) an unrealistic group (846 outcomes) with very high population biomasses (on the order of 1million tons) and very low exploitation (F essentially zero). See Figure 1 which shows a scatterplot of the runs relative to SSBmsy and Emsy. The Panel concurred with the AW's decision that the latter group was unrealistic, primarily because it implies that fishing mortality has had no impact on the population, but also because the biomass estimates appear highly implausible given known landings, perceptions of general grouper biomass/productivity, and perceptions of available habitat.

The Panel attempted to more objectively define the implausibility of the biomass estimates based on available habitat, but quantification of available habitat could not be provided at the meeting. The Panel recommends using estimates of available habitat and stock productivity to set reasonable upper bounds on biomass estimates when possible. The initial run fell in the realistic low population and high fishing mortality domain.

The Panel attempted to determine from the MCB results if there were combinations of parameter values that were associated with the unrealistic group. No such combinations were evident when the outcomes in ratio of spawning biomass to spawning biomass at MSY (SSB/SSBmsy) were plotted against relevant parameters. The bimodality of model estimates for stock condition probably is indicative that these data can only weakly be used to estimate the condition of the underlying stock. A suggestion was to run the model in more phases in the hopes that the high abundance/low mortality result would not occur. However, increasing the number of phases did not cause the model to avoid the unrealistic high abundance/low mortality domain.

The reduced-parameter model resulted in the high abundance/low mortality scenario when initial biomass ratio was set high (0.9) but more closely reproduced the initial run when the initial biomass ratio was estimated. However, the estimated initial biomass ratio was extremely low (0.2) given the low level of catches assumed to have occurred prior to 1961. From this it was inferred that the population decline implied by the length composition data was clearly greater than could have been caused by the observed landings in the early years, suggesting that these landings must have been substantially under-estimated.

The model for snowy grouper showed a sharp decline in biomass beginning in the late 1970s which was before the length composition data were available except for the headboat sector or any age data. The Panel recommends that in such cases of limited age or size composition data in the early years, a sensitivity analysis should be conducted which starts in the year that age or size composition data is available. Due to time constraints and the complexity of the requisite modeling, this recommendation could not be met at the meeting.

Tilefish: The tilefish assessment indicated that fishing mortality first exceeded Fmsy in the early 1980s and has remained there since. This high fishing mortality rate caused the population biomass to decrease to near MSY levels in the mid 1980s, where it has remained ever since. Fishing mortality in recent years has exceeded Fmsy, but the population has been maintained at Bmsy because of better than average recruitment. As with snowy grouper, the main information on population trends appeared to be coming from the length composition data.

In contrast to the two clusters of MCB results seen snowy grouper assessment, only two of the 1100 MCB runs were unsatisfactory (and so were not included in summary statistics). They were rejected because for these two the model did not converge.

The reduced-parameter run produced a biomass trajectory that was similar to that from the initial run, except that the biomass continued to decline below Bmsy in the most recent years. This revealed how much the initial run's assessment of stock status depends on the parts of the length composition data which indicate above average recruitment in recent years. More comprehensive age data would have strengthened the model's inferences about these recruitments.

3. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population benchmarks (e.g., MSY, Fmsy, Bmsy, MSST, MFMT, or their proxies) and state whether or not the methods are scientifically sound.

The Panel recommended using the median benchmarks.

Methods were considered appropriate and adequate for estimating benchmarks.

4. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound.

The Panel concludes that the methods used in the projections are appropriate, adequate, and scientifically sound, and recommends using the median of projection results. As mentioned above, the 10^{th} and 90^{th} percentiles shown in the projections are indicators of the range on uncertainty and are not to be taken as confidence limits.

5. Ensure that all available required assessment results (as listed in the SEDAR Stock Assessment Report Outline) are clearly presented in the Stock Assessment Report and consistent with the Panel's decisions regarding adequacy, appropriateness, and application of the data and methods.

Assessment results were clearly and adequately presented by the tables and figures in the Assessment Reports for snowy grouper and tilefish. Several members of the Panel found the complete documentation of equations and the inclusion of model code particularly informative, and recommend that such information become a standard component of SEDAR assessment reports. Further, it is recommended that model input data files also be included in future reports.

The Review Panel noted several minor errors and omissions in figures; these will be corrected by the analysts. The Review Panel suggests that two additional pieces of information be provided in future reports: 1) a table of model parameter estimates, and 2) a thorough documentation of the process that led to the initial model configuration. The Review Panel requested details of the seasonal and spatial coverage of the length and age samples.

6. Evaluate the performance of the Data and Assessment Workshops with regards to their respective Terms of Reference, and state whether or not the Terms of Reference for those previous workshops are adequately addressed in the Stock Assessment Report.

The Review Panel found it helpful to address the Data Workshop Terms of Reference during deliberations of TOR 1 above. The Review Panel concluded that all but one of the Data

Workshop Terms of Reference were addressed adequately for snowy grouper and tilefish in the Data Workshop Report. The one TOR that was not addressed is TOR 1, which required identifying the unit stock. The Review Workshop also recommends that future data workshop reports provide greater evaluation of input data. In many instances data are provided with little consideration of the ‘evaluation of quality and reliability’ as required in the Terms of Reference.

The Review Panel concluded that the assessment reports adequately addressed the AW Terms of Reference.

The Review Panel suggests for future SEDARs that confusion may be reduced by providing a brief description of the process that leads to assessing only a subset of those species addressed in the Data Workshop.

7. Review the assessment workshop’s recommendations of future research for improving data collection and the assessment, and make any additional recommendations warranted.

The Panel supports the research recommendations included in the snowy grouper and tilefish assessment reports. However, the Panel felt it was important to provide some specific additional detail.

Regarding ageing methods, the Review Panel recommends that ageing validation should be accomplished prior to addressing concerns over differences in age determinations between the various labs.

Regarding age sampling, the Panel recommends that the suggested initial sampling rate for age structures be clarified to avoid the suggestion of age as a sampling strata. The intent is to establish an initial age sample of 20 times the number of ages in the population. The Review Workshop also recommends that stratification by length and development of appropriate age-length keys be considered as a possibly more effective and economical approach to inferring age composition than attempting random age sampling. Regardless of the method ultimately chosen, it is most important to provide adequate age and length sampling through a rigorous and statistically valid sampling program.

The Panel recommends exploring the relative importance of age sampling in models of the type used here to assess snowy grouper and tilefish. Such analysis could help identify the best allocation of limited monitoring resources.

The Panel supports the snowy grouper recommendation # 7 regarding research into the implication of sex change. The Review Workshop adds that future assessment models addressing species which undergo sex change should provide model results that incorporate sex-specific information.

8. Prepare a Consensus Peer Review of Assessments summarizing the peer review panel’s evaluation of the tilefish and snowy grouper stock assessments and addressing the Terms of Reference. (Drafted during the Assessment Review Panel workshop with a final report due three weeks after the workshop ends.).

A draft was prepared during the meeting and a final version was circulated to the Panel afterwards.

9. Prepare a Stock Advisory Report summarizing the stock assessments. (Drafted during the Assessment Review Panel workshop with a final report due three weeks after the workshop ends.).

The Review Panel was advised that the Stock Advisory Report will be prepared by the analytical team reflecting the assessment results endorsed during the Review Workshop.

II. Additional Comments

During the Review, several requests were made by the Panel for additional explanation or analysis. See Appendix E. These requests were always dealt with promptly, professionally and reported clearly.

Simulations to examine the distribution of the initial to unfished biomass ratios:
The Panel conducted a simulation exercise to examine the distribution of the starting year biomass, given recruitment variability. The starting year biomass is modeled as the ratio of biomass in the first year to the unfished biomass (B1 ratio). The B1 ratio is one of the distributions assumed in the MCB approach. The Panel's simulation assumed tilefish biological parameters and projected a population for 100 years given only uncertainty in the annual recruitment deviations. The biomass in the final year of the projection was compared to the deterministic value of unfished biomass. Repeating this 100 year projection 10,000 times allowed formation of the distribution of the B1 ratio. This distribution was approximately lognormal in shape and ranged from approximately 0.8 to 1.5. The Panel recommends a similar simulation approach to determine appropriate distributions for MCB approaches requiring a distribution for the B1 ratio.

Rebuilding time frame:

The Panel observed that the median of the MCB projections for snowy grouper crossed quite close to SSBmsy in 2015. The decision whether or not to invoke the rebuilding rule is well within the distribution of projections. Although the Panel did not consider this issue in any detail, concern was mentioned about the difficulty caused by the abrupt transition from one harvest strategy to another when the trigger is the probable state of the resource which is poorly defined.

3. Stakeholder Comments

The stakeholder present commented that this SEDAR Review was an improvement in its openness to discuss ecological issues.

Given the weakness of the data, and that these were new assessments, it would have been useful to have had industry representation to respond to the assessments and their results.

4. Recommendations for Future Workshops

The Panel considered that the lack of representation by fisherman limited the scope of input and the points of view that were considered. A number of questions arose regarding selectivity and fishery practices that may have been addressed by industry participation.

Appendix A Terms of reference for SEDAR 4 Review: Tilefish and Snowy Grouper

The SEDAR Assessment Review Panel will evaluate the tilefish and snowy grouper stock assessments, input data, assessment methods, and model results as put forward in stock assessment reports. The Assessment Review Panel will:

A1. Evaluate the adequacy and appropriateness of all data used in the assessment and state whether or not the data are scientifically sound;

A2. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population parameters such as abundance, biomass, and exploitation and state whether or not the methods are scientifically sound;

A3. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population benchmarks (*e.g., MSY, Fmsy, Bmsy, MSST, MFMT, or their proxies*) and state whether or not the methods are scientifically sound;

A4. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound;

A5. Ensure that all available required assessment results (*as listed in the SEDAR Stock Assessment Report Outline*) are clearly and accurately presented in the Stock Assessment Report and that such results are consistent with the Panel’s decisions regarding adequacy, appropriateness, and application of the data and methods;

A6. Evaluate the performance of the Data and Assessment Workshops with regards to their respective Terms of Reference, and state whether or not the Terms of Reference for those previous workshops are adequately addressed in the Stock Assessment Report;

A7. Review the assessment workshop’s recommendations of future research for improving data collection and the assessment, and make any additional recommendations warranted;

A8. Prepare a Peer Review Consensus Summary summarizing the Panel’s evaluation of the tilefish and snowy grouper stock assessments and addressing each Term of Reference. (Drafted by the Panel during the Review Workshop with a final report due three weeks after the workshop ends.);

A9. Prepare a Stock Advisory Report summarizing the stock assessments. (Drafted during the Assessment Review Panel workshop with a final report due three weeks after the workshop ends.).

Appendix B : Attendees at SEDAR4 Assessment Review Panel Workshop

CIE Participants

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Appendix C: Terms of Reference for the Data Workshop.

DW1.   Evaluate stock structure and develop a unit stock definition.

DW 2.   Evaluate the quality and reliability of life-history information (Age, growth, natural mortality, reproductive characteristics); develop models to describe growth, maturation, and fecundity by age, sex, or length as appropriate.

DW 3.   Evaluate the quality and reliability of fishery-independent measures of abundance; develop indices by appropriate strata (e.g., age, size, and fishery) for use in assessment modeling.

DW 4. Evaluate the quality and reliability of fishery-dependent measures of abundance; develop indices for use in assessment modeling.

DW 5. Evaluate the adequacy of the NMFS logbook data as a fishery-dependent measure of effort and catch rates; develop indices of abundance for use in assessment modeling.

DW 6. Evaluate the quality and reliability of commercial and recreational fishery-dependent data for determining harvest and discard by species; develop estimates of total annual catch including both landings and discard removals by species.

DW 7. Evaluate the quality and reliability of data available for characterizing the size and age distribution of the catch (landings and discard); characterize commercial, recreational, and headboat landings and discard by size and age.

DW 8. Evaluate the quality and reliability of available data for estimating the impacts of management actions.

DW 9. Recommend assessment methods and models that are appropriate given the quality and scope of the data sets reviewed and management requirements.

DW 10. If data are not adequate for assessment modeling of each species listed in the complex, evaluate the feasibility of (1) using specific members of the stock complex as indicator species, or (2) using other metrics to evaluate stock status.

DW 11. Provide recommendations for future research (research, sampling, monitoring, and assessment).

DW 12. Prepare complete documentation of workshop actions and decisions, and generate introductory, descriptive, and research needs sections (1-4, 9) of the stock assessment report.

Appendix D: Terms of Reference for the Assessment Workshop.

AW1. Select several appropriate modeling approaches, based on available data sources, parameters and values required to manage the stock, and recommendations of the Data Workshop.

AW2. Develop and solve the chosen population models, incorporating data that are the best available, the most recent and up-to-date, and scientifically sound.

AW3. Provide measures of model performance, reliability, and goodness of fit.

AW4. Estimate values and provide tables of relevant stock parameters (abundance, biomass, fishery selectivity, stock-recruitment relationship, etc; by age and year).

AW5. Consider sources of uncertainty related to input data, modeling approach, and model configuration. Provide appropriate and representative measures of precision for stock parameter estimates.

AW6. Provide Yield-per-Recruit and Stock-Recruitment analyses.

AW7. Provide complete SFA criteria: evaluate existing SFA benchmarks; estimate alternative SFA benchmarks if appropriate; estimate SFA benchmarks (MSY, Fmsy, Bmsy, MSST, and MFMT) if not previously estimated; develop stock control rules.

AW 8. Provide declarations of stock status relative to SFA benchmarks: MSY, Fmsy, Bmsy, MSST, MFMT.

AW 9. Estimate the Allowable Biological Catch (ABC) for each stock.

AW 10. Estimate probable future stock conditions and develop rebuilding schedules if warranted; include estimates of generation time.

AW 11. Evaluate the impacts of current management actions, with emphasis on determining progress toward stated management goals.

AW 12. Provide recommendations for future research and data collection (field and assessment); be as specific as possible in describing sampling design and sampling intensity.

AW 13. Provide thorough justification for any deviations from recommendations of the Data Workshop or subsequent modification of data sources provided by the Data Workshop.

AW 14. Fully document all activities: Draft Section III of the SEDAR Stock Assessment Report; Provide tables of estimated values; Prepare a first draft of the Advisory Report based on the Assessment Workshop's recommended base assessment run for consideration by the Review Panel. Reports are to be finalized within 3 weeks of the conclusion of the Assessment Workshop.

Appendix E. requests for additional analysis during Workshop.

With one exception, these were all performed in a prompt and complete fashion. That one exception was the request to start the model at a time in 1982 to more closely match the available data. At the time when the request was made, NMFS personnel explained that it would probably be too difficult to do in the time available.

These are still in the point form used in presentation and are included to chronicle the events at the Review. For more detail, the reader is referred to the Assessment Workshop
.
The Review Panel made three successive requests from Snowy grouper assessment team:

1)

- Add MSY length compositions to Figure 58
- Observed and predicted catch differences
- Model output by sex
- Scatter plots of input versus MCB criteria
- Example of "bad" run
- Initial model run with increased weight on landings
- Initial model run with constant M=0.12
- Initial model run starting in 1982

2)

- Add deterministic initial run projections to projection figures
- Try fitting "bad" MCB run with more phases

3)

- Run age-structured production model (called reduced parametric model above)

Tilefish

- Distribution of SSB/MSST, where MSST=0.75SSBmsy

- Distributions of M at age
- Model run: SSB(1961)=SSBvirgin
- Model run: Drop age comps
- Model run: Logistic selectivity for MARMAP survey
- Model run: Age-structured production model equivalent

Citations

Hoenig, John. 1983. Empirical use of longevity data to estimate mortality rates. U.S. Fish. Bull. 81:898-903.

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

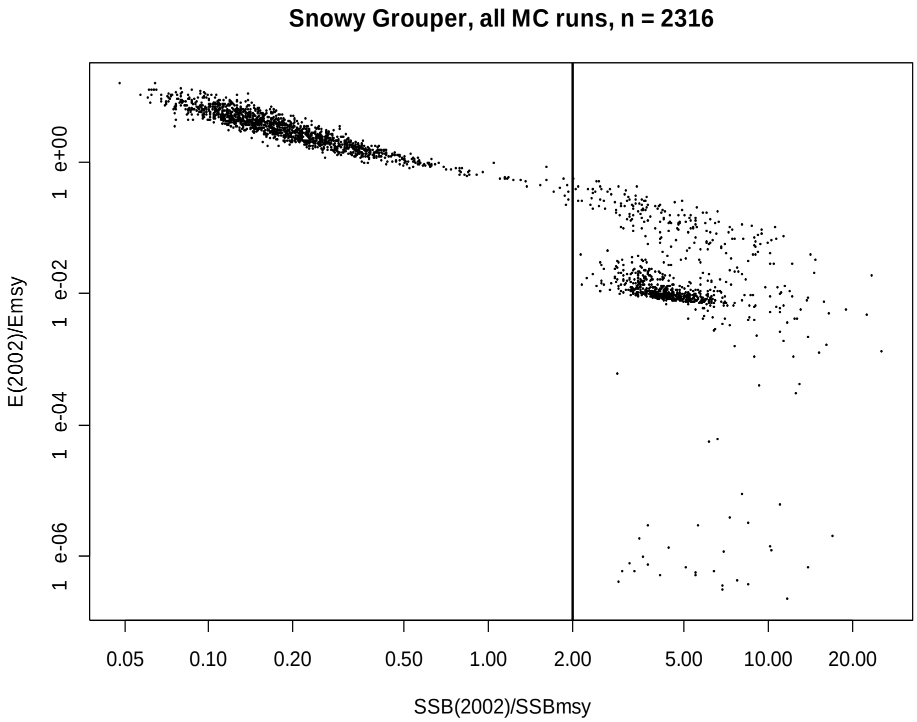


Figure 1. Scatter plot of the MCB replicates showing the two clouds of solutions. The region the Panel called “realistic” cloud is the on concentrated in the upper left corner.

IV.A Additional Information Provided for the Review Workshop

Table. Annual sample size for snowy grouper lengths from commercial fishery by gear, state and season:

		Florida					Georgia					North Carolina					South Carolina					Grand Total
Gear	Year	Win	Spr	Sum	Fall	Total	Win	Spr	Sum	Fall	Total	Win	Spr	Sum	Fall	Total	Win	Spr	Sum	Fall	Total	
Handline	1983													83	12	95						95
	1984								114	7	121	321	355	472	249	1397	27	100	129		256	1774
	1985	4	82	9	6	101	26	89	58	7	180	447	1303	819	418	2987	77	2	86	35	200	3468
	1986	1				1		24	47	110	181	326	293	499	65	1183	11	3	56		70	1435
	1987						79	103	170	25	377	15	120	291	241	667	2	27	230	3	262	1306
	1988	6	44	16		66	23	20	40	17	100	167	115	74	149	505	25	41	1	2	69	740
	1989				24	24	55	97	42		194	144	524	327	101	1096	11	5	5		21	1335
	1990		82	83		165						484	523	104	118	1229		1	124	24	149	1543
	1991	4	76	75	228	383	5	59	77	41	182	431	232	93	140	896	4	54	113	12	183	1644
	1992	53	477	366	756	1652	13	30	108	39	190	306	336	198	60	900	54	26	153	8	241	2983
	1993	282	407	314	216	1219	16	55	28		99	456	133	219	28	836	18	140	60	20	238	2392
	1994	3	80	278	181	542		23	63		86	114	534	391	121	1160	52	45	26		123	1911
	1995		1118	1071	60	2249		31	18	1	50	484	430	576	155	1645	1	135	2	13	151	4095
	1996	123	321	71	343	858	26	32	2		60	92	317	219	30	658	41	134	210	141	526	2102
	1997	6	176	72	94	348		40		4	44	197	3	80	52	332	110	143	32	37	322	1046
	1998	91	207	23	60	381			5		5	72	325	242	72	711	171	164	193	31	559	1656
	1999	24	249	95	64	432		15			15	244	482	312	123	1161	112	69	378	38	597	2205
	2000	98	116	91	23	328		73		3	76	638	582	174	32	1426	216	24	52	43	335	2165
	2001	13	135	98	20	266	16	1		2	19	449	253	191	38	931	91	62	243	74	470	1686
	2002	10	41	39	6	96						263	345	202	23	833	167	46	14	28	255	1184
Total		718	3611	2701	2081	9111	259	692	772	256	1979	5650	7205	5566	2227	20648	1190	1221	2107	509	5027	36765
Longline	1984									26	26	15	302	19	2	338	309	203	69	125	706	1070
	1985		179	136	8	323								51	3	54	175	334	61	41	611	988
	1986			9		9						9				9	400	273	556	45	1274	1292
	1987											171	104		3	278	33	140	41		214	492
	1988											58	17	98	63	236			225		225	461
	1989											83		71		154						154
	1990			56	15	71						164	40	118	85	407			61		61	539
	1991	7	1		20	28			4	1	5	218	229	205	25	677		51	136		187	897
	1992	165	354	110	136	765		2	13		15	193	210	201	19	623		50	112	39	201	1604
	1993	1108	1197	706	168	3179		40	61		101	186	582	94	101	963	51	6	82	45	184	4427
	1994	35	46		40	121	5		31		36	139	84	21		244	49		71		120	521
	1995	88	493	383	262	1226			46		46			90	45	135						1407
	1996	67	119	183		369													18		18	387
	1997	223	175	47	66	511							5			5	166	74	339	272	851	1367
	1998	6	56	150	5	217											41	155		30	226	443
	1999	4	59	125	71	259						330				330	159	310	2	186	657	1246
	2000	33	70	126	22	251							156			156	128	200	97		425	832
	2001	12	206	54	5	277						209				209		72	313		385	871
	2002	81	118			199											380	67	21	164	632	831
Total		1829	3073	2085	818	7805	5	42	155	27	229	1775	1729	968	346	4818	1891	1935	2204	947	6977	19829
Grand Total		2547	6684	4786	2899	16916	264	734	927	283	2208	7425	8934	6534	2573	25466	3081	3156	4311	1456	12004	56594

Table. Annual sample size for snowy grouper ages from commercial and headboat fisheries by gear, state and season:

Gear	Year	Florida					North Carolina				South Carolina				Grand Total
		Win	Spr	Sum	Fall	Total	Spr	Sum	Fall	Total	Win	Spr	Sum	Total	
Handline	1992			27	11	38									38
	1993		2			2									2
	1995		1			1									1
	1996		5			5									5
	1997		15	32		47									47
	1998	1	27	1	32	61									61
	1999	12		38	17	67									67
	2000	34	27	28	11	100									100
	2001	8	29	32	1	70									70
	2002	10	26	12	5	53									53
Total		65	132	170	77	444									444
Longline	1992			1		1									1
	1997		26	38	35	99									99
	1998	17	22	40	5	84									84
	1999		53	15	27	95									95
	2000	21	26	26	22	95									95
	2001	11	51	44	3	109									109
	2002	54	73			127									127
Total		103	251	164	92	610									610
Headboat	1980			6		6						15		15	21
	1981	1	28	9		38	4			4		7		7	49
	1982	1				1									1
	1983	1				1						12	4	16	17
	1984		1	4		5			1	1			6	6	12
	1985	1		1		2						1	3	4	6
	1986	2	1			3						16	10	26	29
	1989											3	1	4	4
	1990						1			1		1		1	2
	1991							1		1	1			1	2
	1992						2	1		3	2			2	5
	1993						1			1		2		2	3
	1994						2			2					2
	1995						1			1					1
	1996						4	2	1	7					7
	1997			1		1			1	1					2
Total		6	30	21		57	15	4	3	22	3	57	24	84	163
Grand Total		174	413	355	169	1111	15	4	3	22	3	57	24	84	1217

Table. Annual sample size for tilefish lengths from commercial fishery by gear, state and season:

		Florida					Georgia					North Carolna					South Carolna					Grand Total
Gear	Year	Win	Spr	Sum	Fall	Total	Win	Spr	Sum	Fall	Total	Win	Spr	Sum	Fall	Total	Win	Spr	Sum	Fall	Total	
Handline	1984											3				3						3
	1985							3			3	5	5		1	11						14
	1986												1			1						1
	1988			3		3																3
	1989												63	5		68						68
	1990												6	5		11			3		3	14
	1991				10	10	5	7			12			1		1		47			47	70
	1992																	84	82		166	166
	1993	2				2								52		52						54
	1994				68	68												30	72		102	170
	1996				7	7																7
	1997		41	92		133																133
	1998		46		46	92																92
	1999		40	10	66	116													3		3	119
	2000	24	257	239	314	834							2			2						836
	2001	13	103	138	52	306																306
	2002	104	106	187	25	422																422
Total		143	593	669	588	1993	5	10			15	8	77	63	1	149		161	160		321	2478
Longline	1984								246	559	805		180	53	55	288	290	657	103	209	1259	2352
	1985	201	1554	1974	1091	4820	24		38		62			98		98		32	16	9	57	5037
	1986	930		185	620	1735						171			1	172	851	1317	1295	44	3507	5414
	1987								58		58	134	38			172			312		312	542
	1988	253				253						13	494	84		591			213		213	1057
	1989											125		140	501	766						766
	1990			23		23							118	175	67	360			355		355	738
	1991	473	641	1032	1494	3640		28	215	341	584	369	9	791	302	1471	75	25	242	51	393	6088
	1992	262	1996	1818	4582	8658		47	120	25	192	380	437	365	105	1287	371	236	477	368	1452	11589
	1993	5764	5585	7925	8280	27554		21	37		58	197	225	54	66	542	158	121	41	243	563	28717
	1994	4233	2470	1076	2943	10722	1		40		41	225	40	86		351	125				125	11239
	1995	116	1588	4392	2015	8111			33		33			89	56	145						8289
	1996	498	550	380	374	1802						5		16		21			312		312	2135
	1997	298	379	514	120	1311							79			79	100	290	539	313	1242	2632
	1998	22	326	366	408	1122											41	329		221	591	1713
	1999	81	516	1045	1129	2771											234	231	264	222	951	3722
	2000	499	1192	1080	676	3447							303			303	371	493	159	179	1202	4952
	2001	90	147	455	608	1300						307				307		228	192	161	581	2188
	2002	284	692	26		1002											281	141	176	330	928	1930
Total		14004	17636	22291	24340	78271	25	96	787	925	1833	1926	1923	1951	1153	6953	2897	4100	4696	2350	14043	101100
Grand Total		14147	18229	22960	24928	80264	30	106	787	925	1848	1934	2000	2014	1154	7102	2897	4261	4856	2350	14364	103578

Table. Annual sample size for tilefish ages from commercial fishery by gear, state and season:

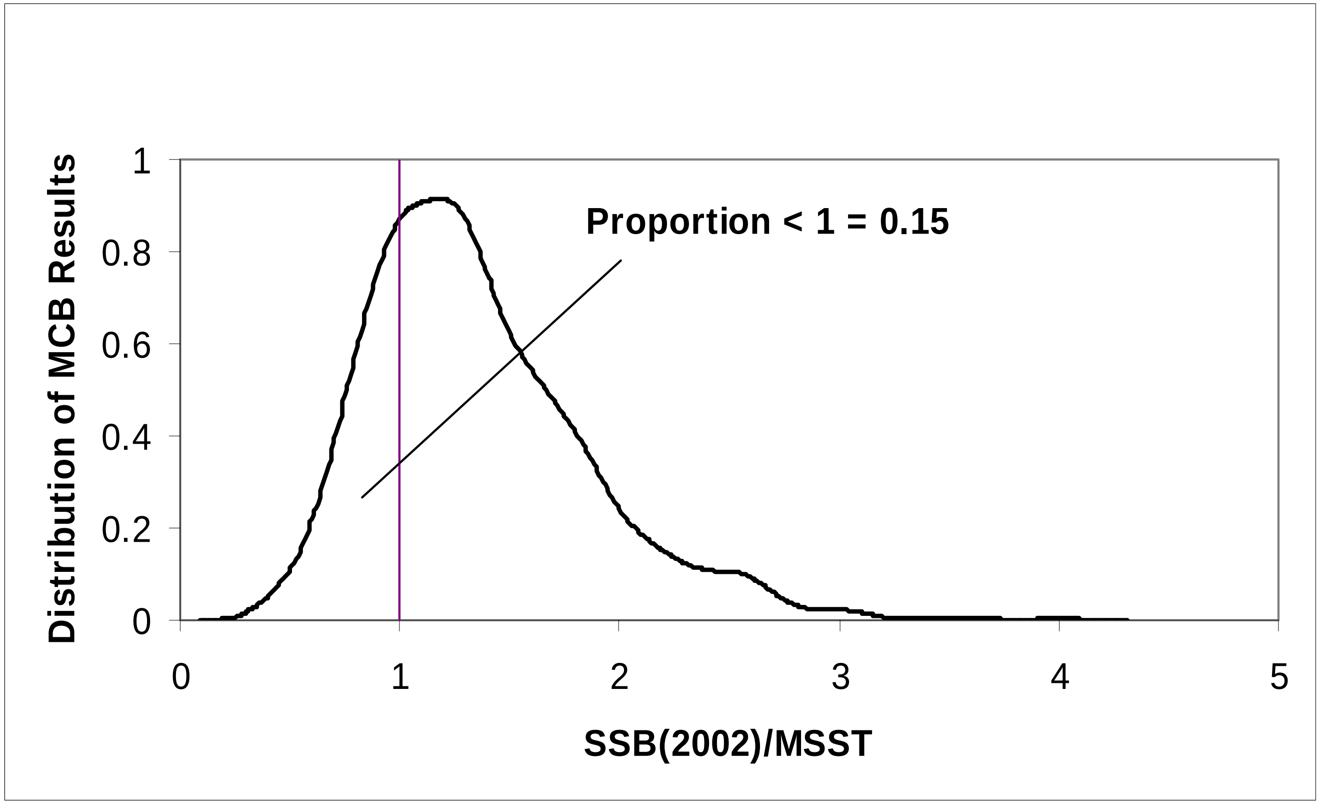
		Florida				
Gear	Year	Winter	Spring	Summer	Fall	Total
Handline	1992			6		6
	1993	1				1
	1995		12			12
	1997		8	26	6	40
	1998	21	5		32	58
	1999		15	8	9	32
	2000	42	129	39	30	240
	2001	13	7		23	43
	2002	14	50	38	96	198
	2003	9			11	20
Total		100	226	117	207	650
Longline	1992			46	51	97
	1993	34	23	68	63	188
	1994	8				8
	1995		31	255	57	343
	1996	46	70	65		181
	1997			94	40	134
	1998		51	74	13	138
	1999	23	47	50	67	187
	2000		155	39	87	281
	2001	28	34	127		189
	2002	30				30
	2003		77	12		89
Total		169	488	830	378	1865
Grand Total		269	714	947	585	2515

Summary Presentation of Tilefish Stock Assessment Sensitivity Requests

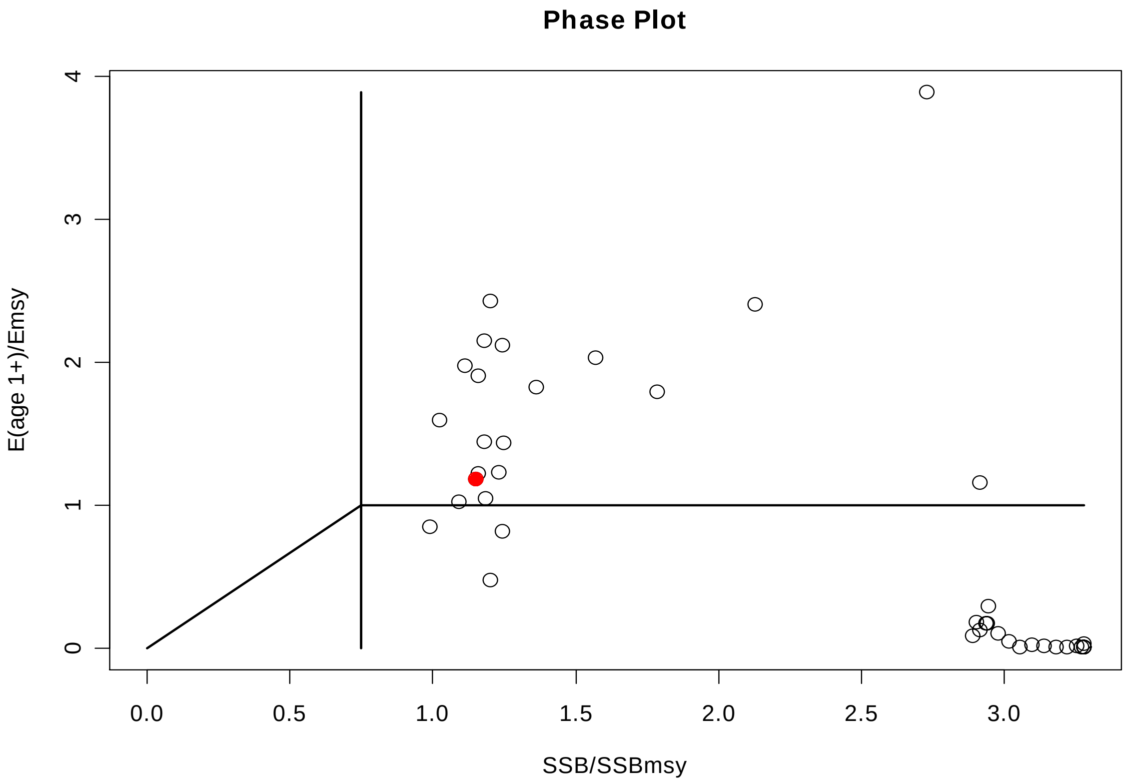
Tilefish - RW requests

- Distribution of SSB/MSST, where MSST=0.75SSBmsy
- Distributions of M at age
- Model run: SSB(1961)=SSBvirgin
- Model run: Drop age comps
- Model run: Logistic selectivity for MARMAP survey
- Model run: Age-structured production model equivalent

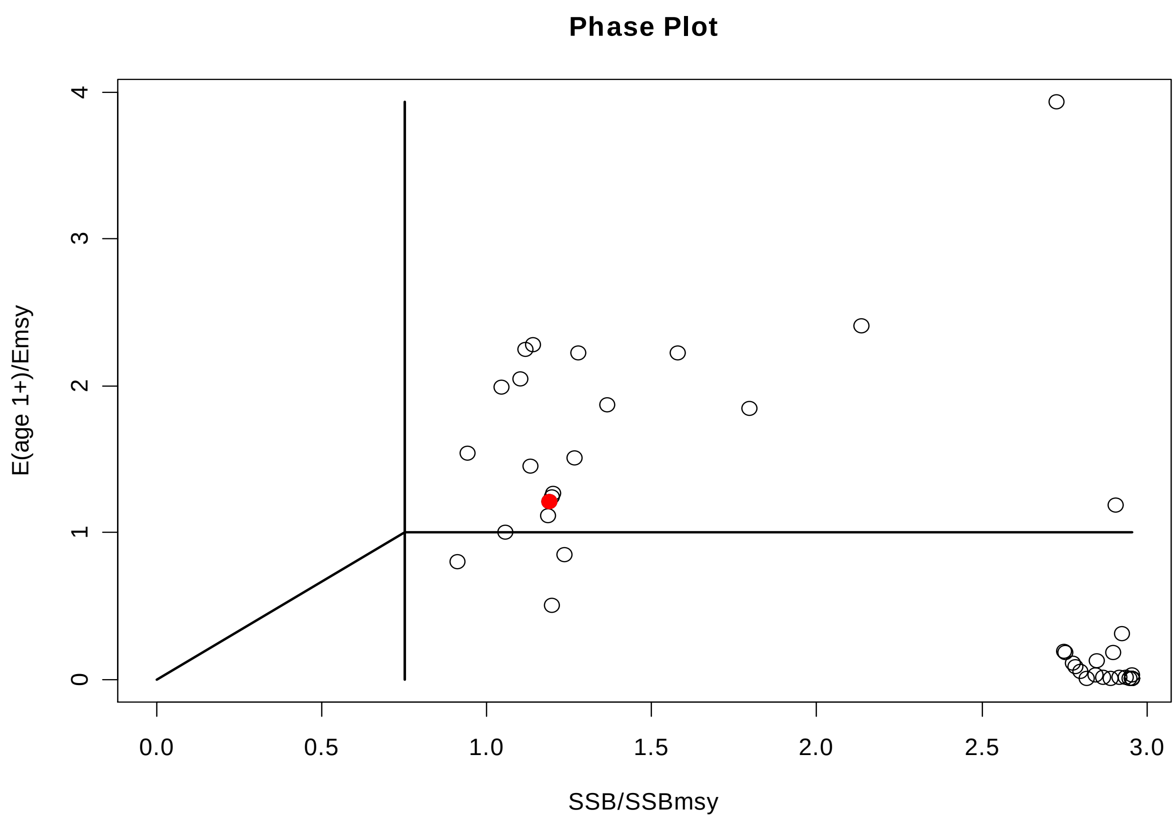
Estimated 2002 Status (MSST=0.75SSBmsy



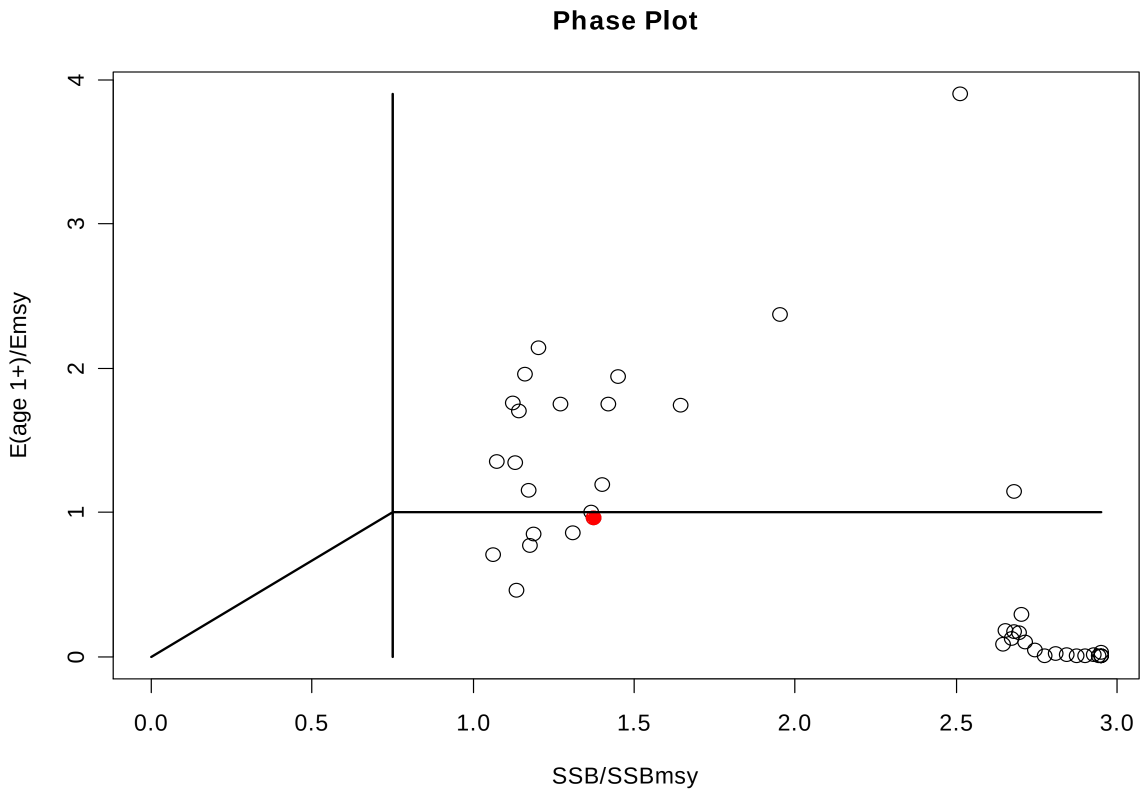
Model run: SSB(1961)=SSBvirgin
Stock status (red dot is 2002)



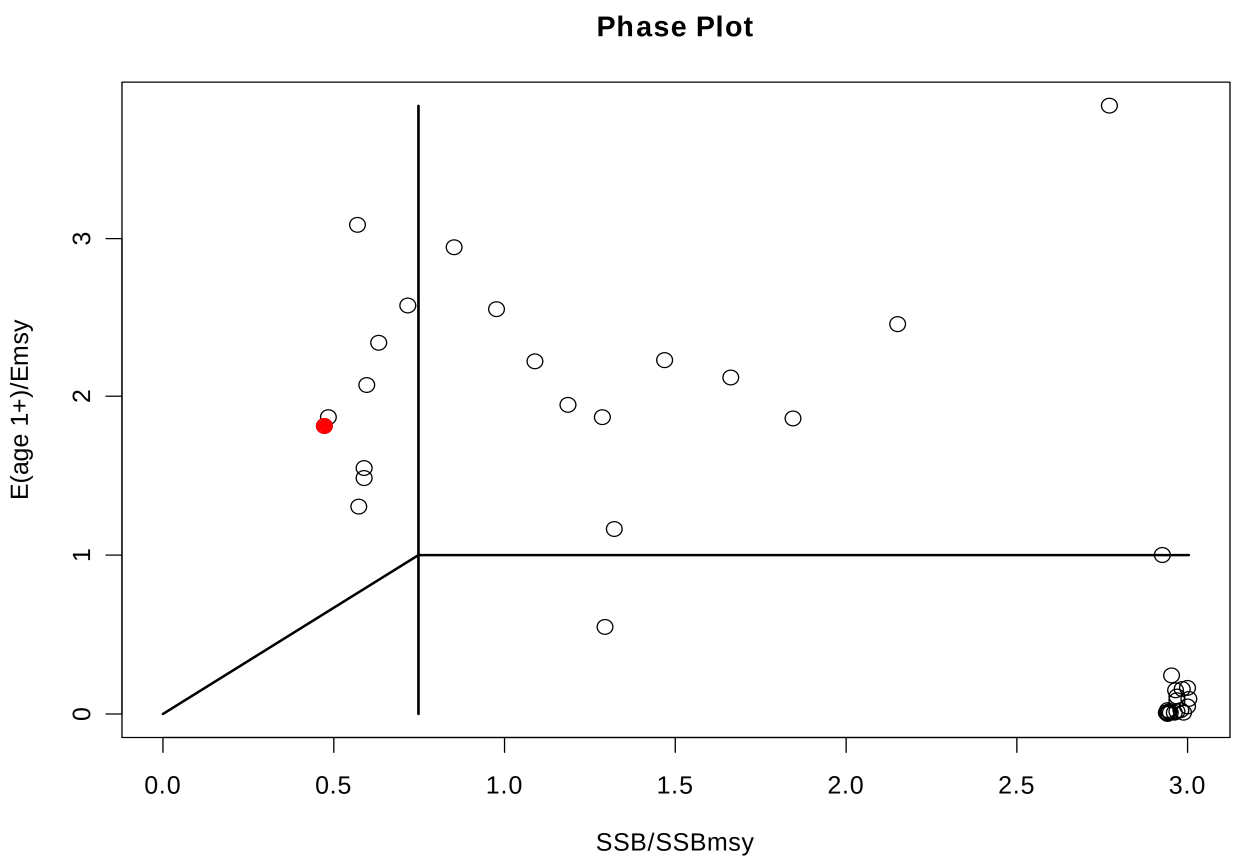
Model run: Drop age comps
Stock status (red dot is 2002)



Model run: Logistic selectivity for MARMAP survey
Stock status (red dot is 2002)

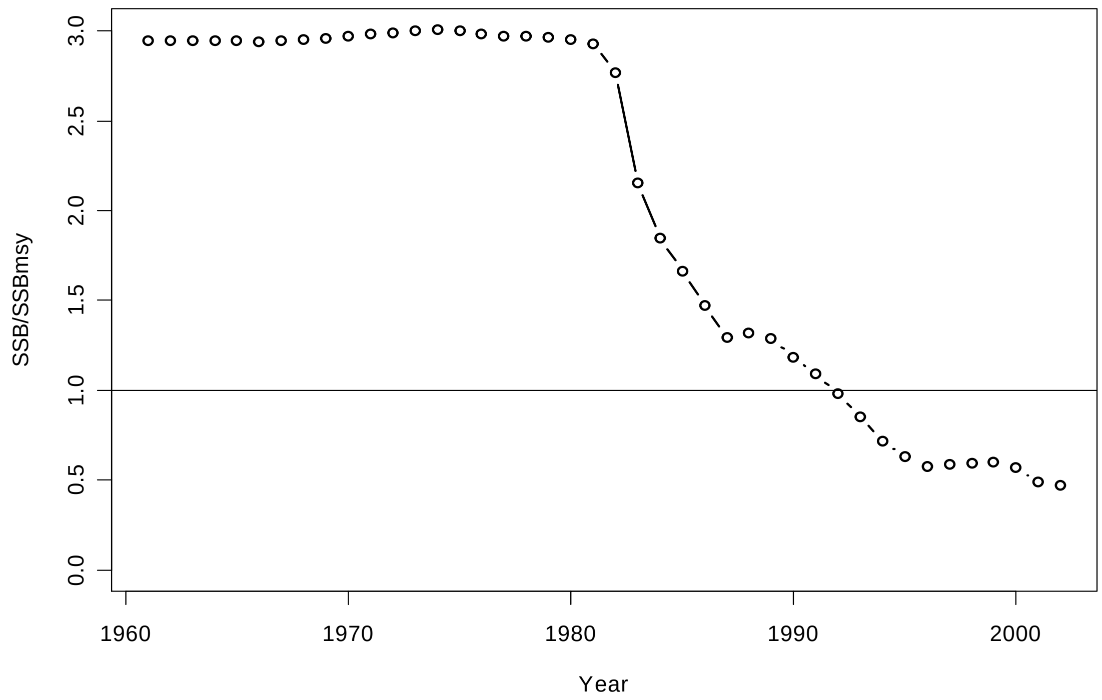


Model run: Age-structured production model equivalent
Stock status (red dot is 2002)



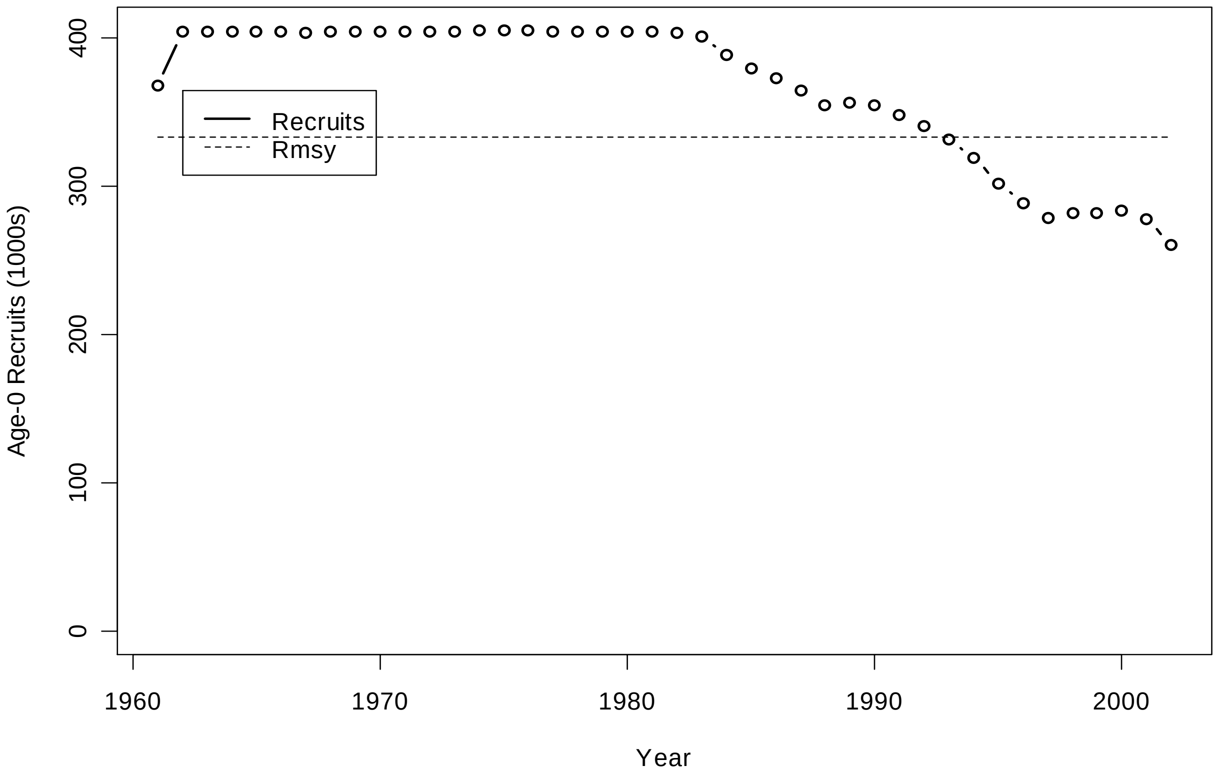
Tilefish - Review Workshop
Requests Summary

Model run: Age-structured production model equivalent



Model run: Age-structured production model equivalent

Model run: Age-structured production model equivalent



Summary Presentation of Snowy Grouper Stock Assessment Sensitivity Requests

Snowy Grouper (*Epinephelus niveatus*) Stock Assessment

Erik H. Williams
NOAA Fisheries
Beaufort Laboratory
Beaufort, North Carolina

Snowy Grouper Model

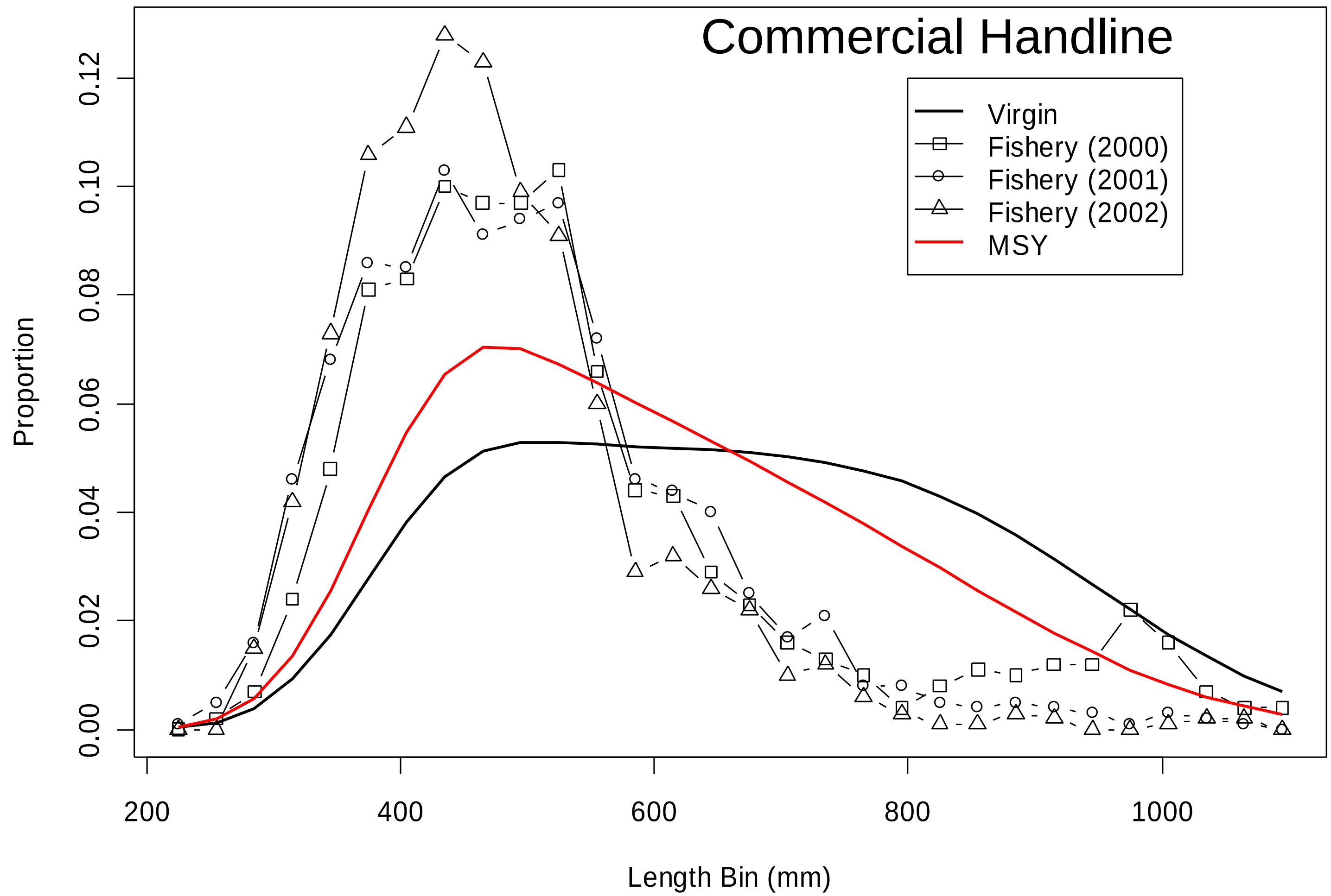
Review Panel Requests

- Add MSY length compositions to Figure 58
- Observed and predicted catch differences
- Model output by sex
- Scatter plots of input versus MCB criteria
- Example of “bad” run
- Initial model run with increased weight on landings
- Initial model run with constant M=0.12
- Initial model run starting in 1982

Snowy Grouper Model

Review Panel Requests

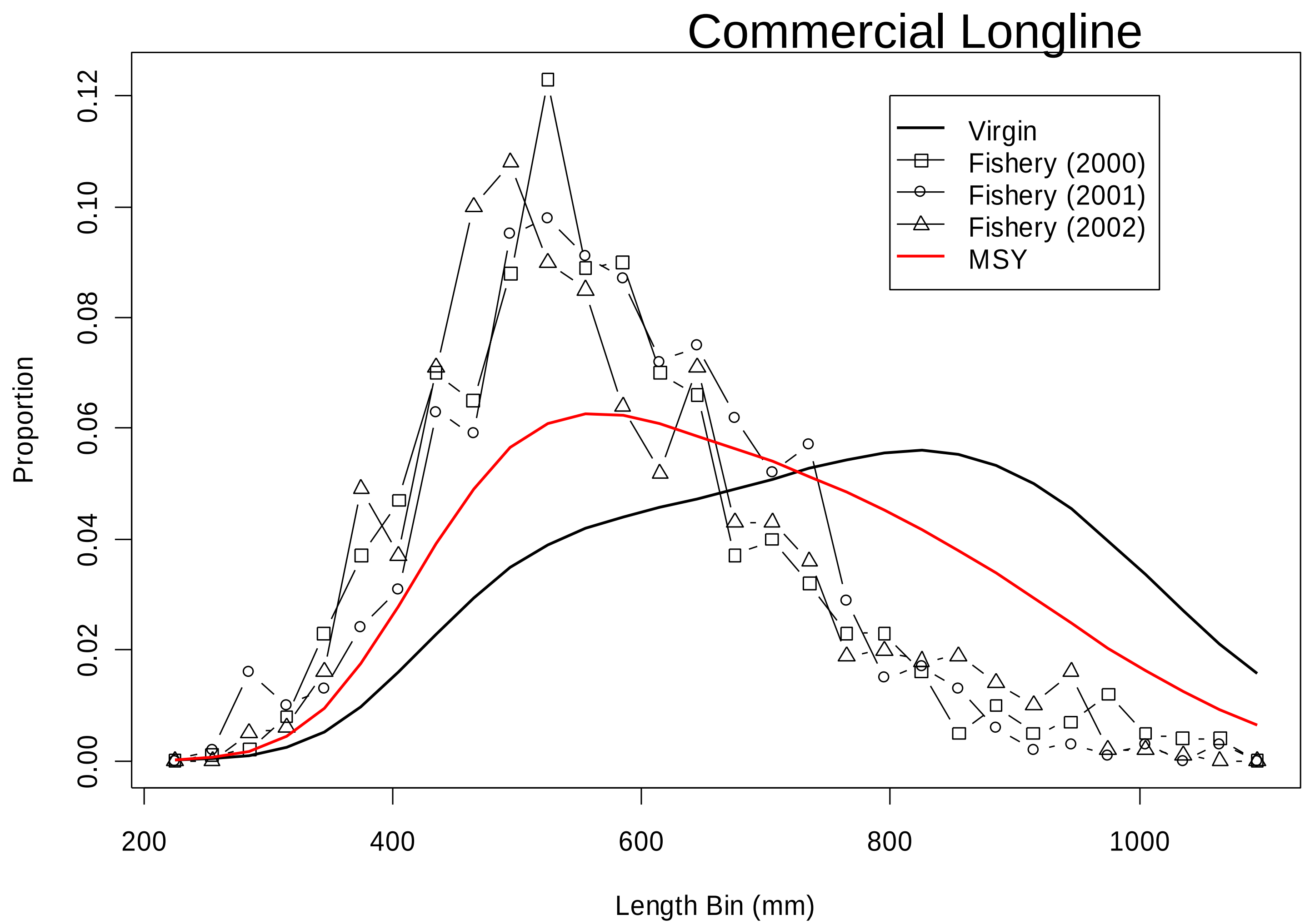
- Add MSY length compositions to Figure 58



Snowy Grouper Model

Review Panel Requests

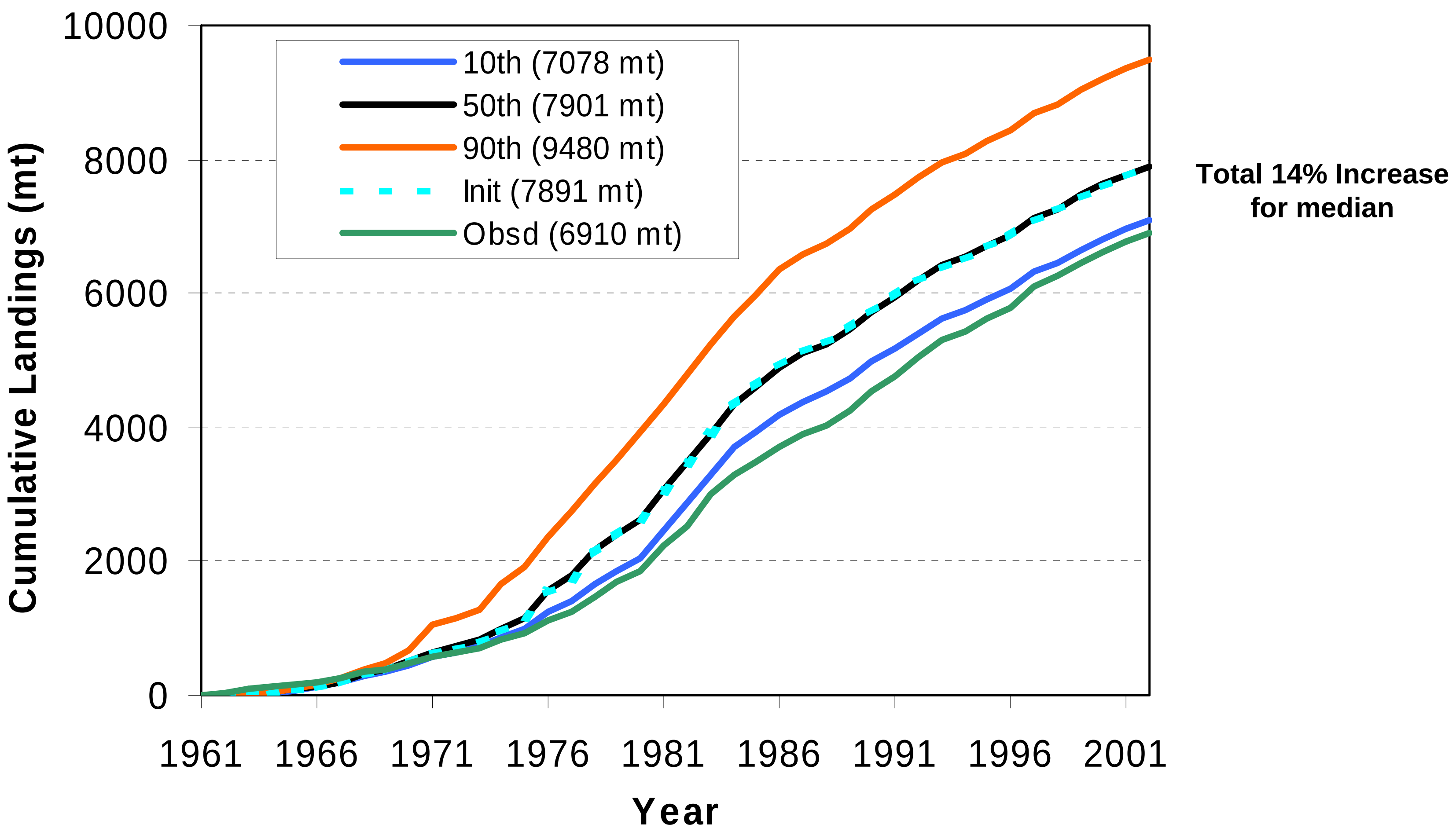
- Add MSY length compositions to Figure 58



Snowy Grouper Model

Review Panel Requests

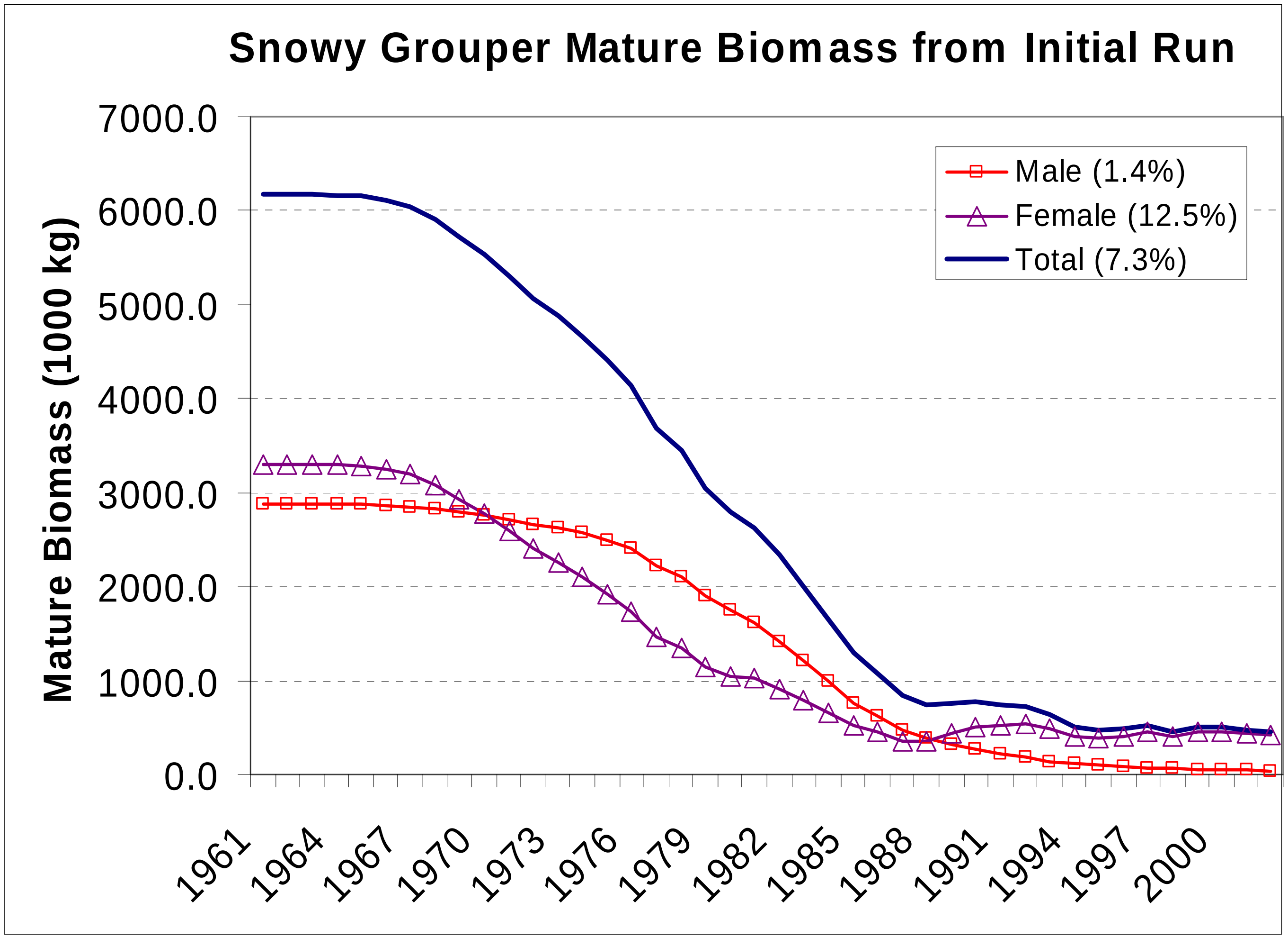
- Observed and predicted catch differences



Snowy Grouper Model

Review Panel Requests

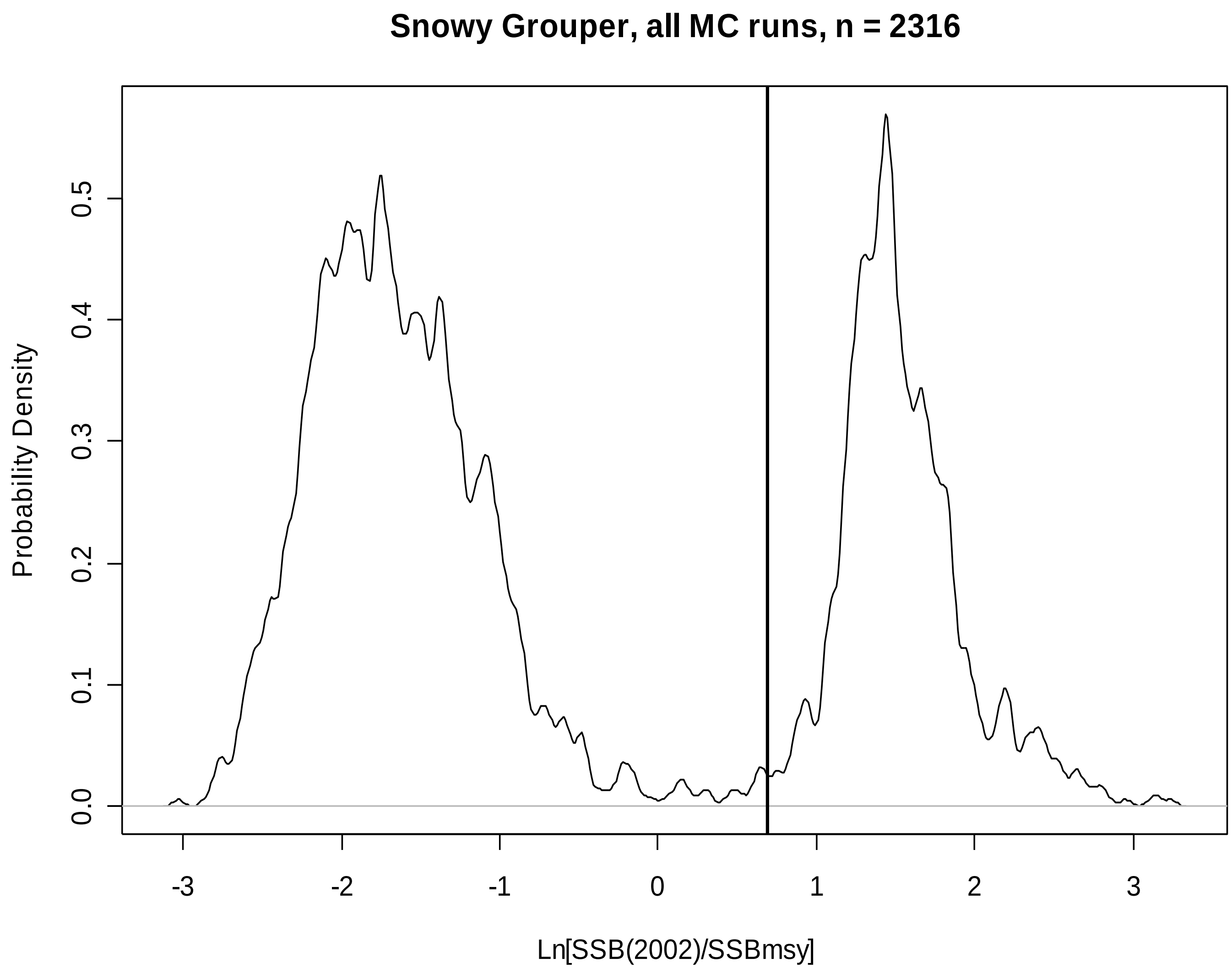
- Model output by sex



Snowy Grouper Model

Review Panel Requests

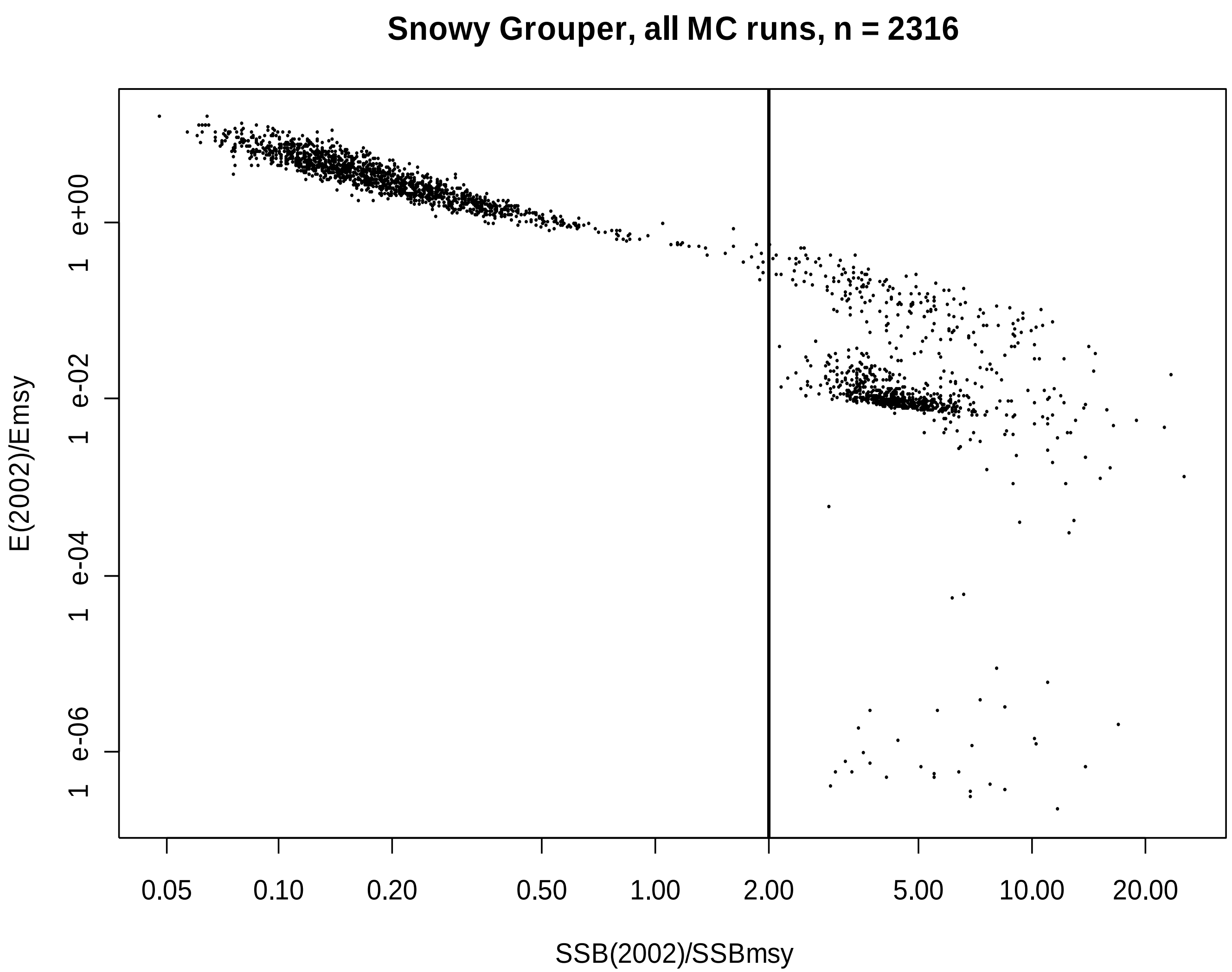
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

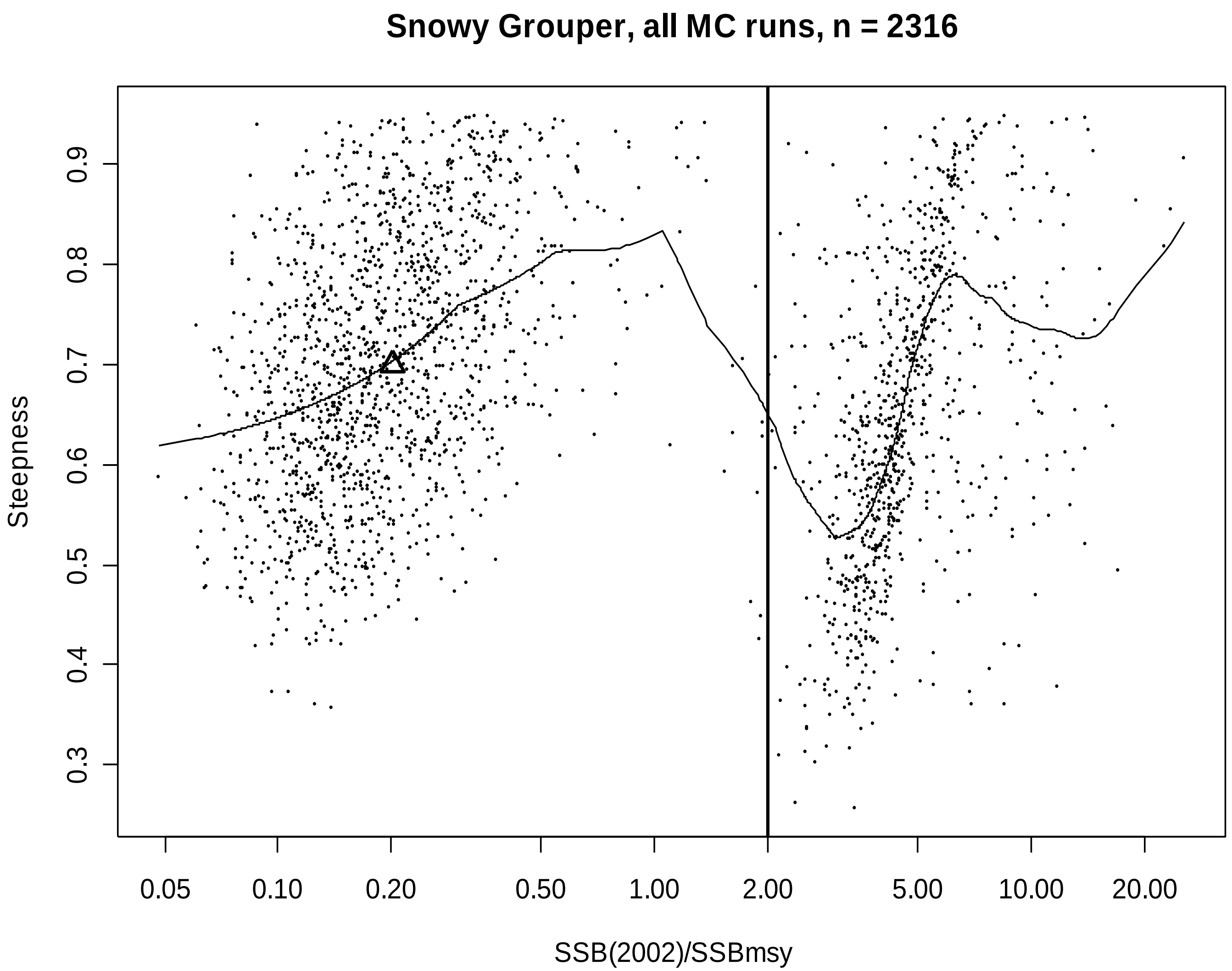
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

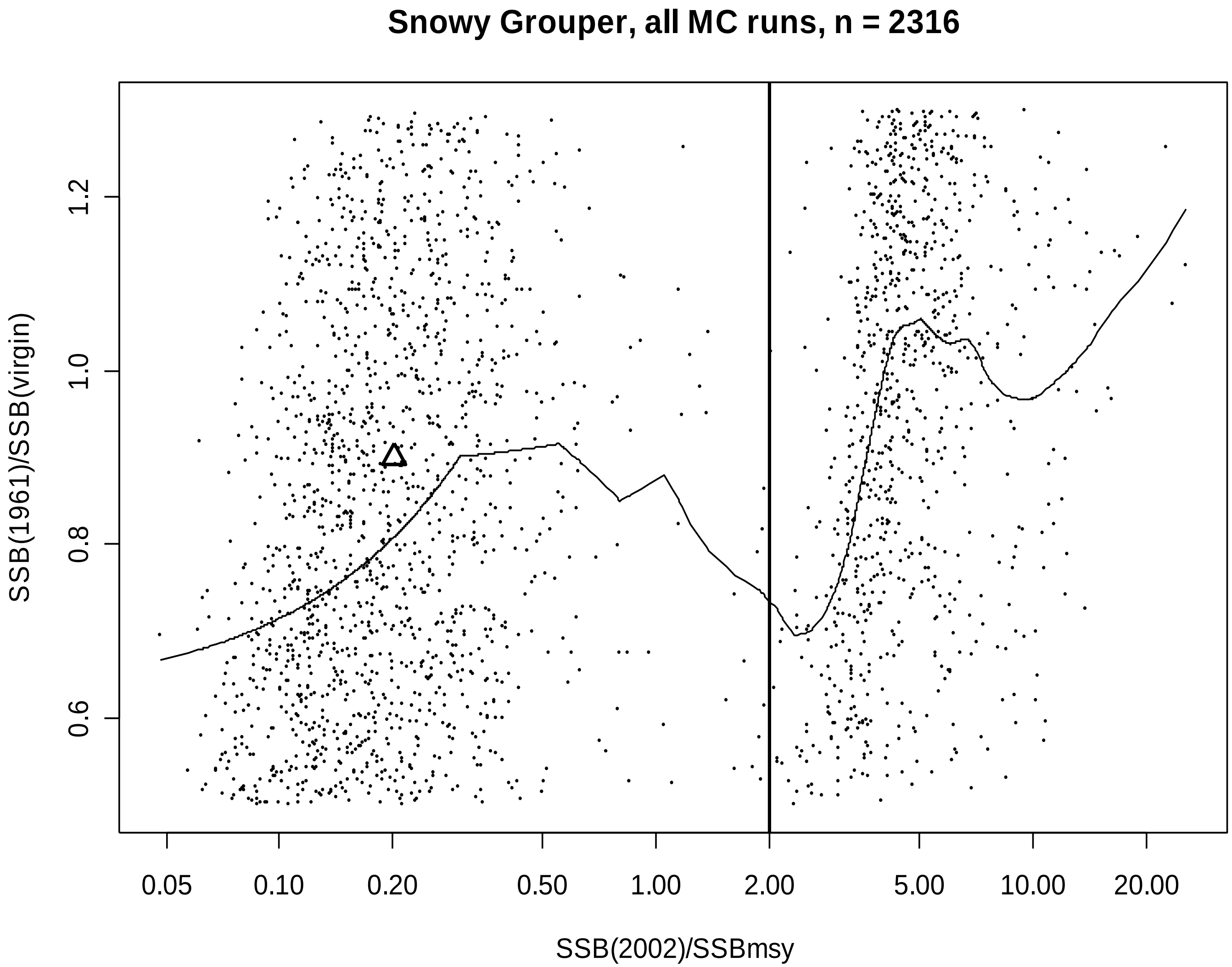
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

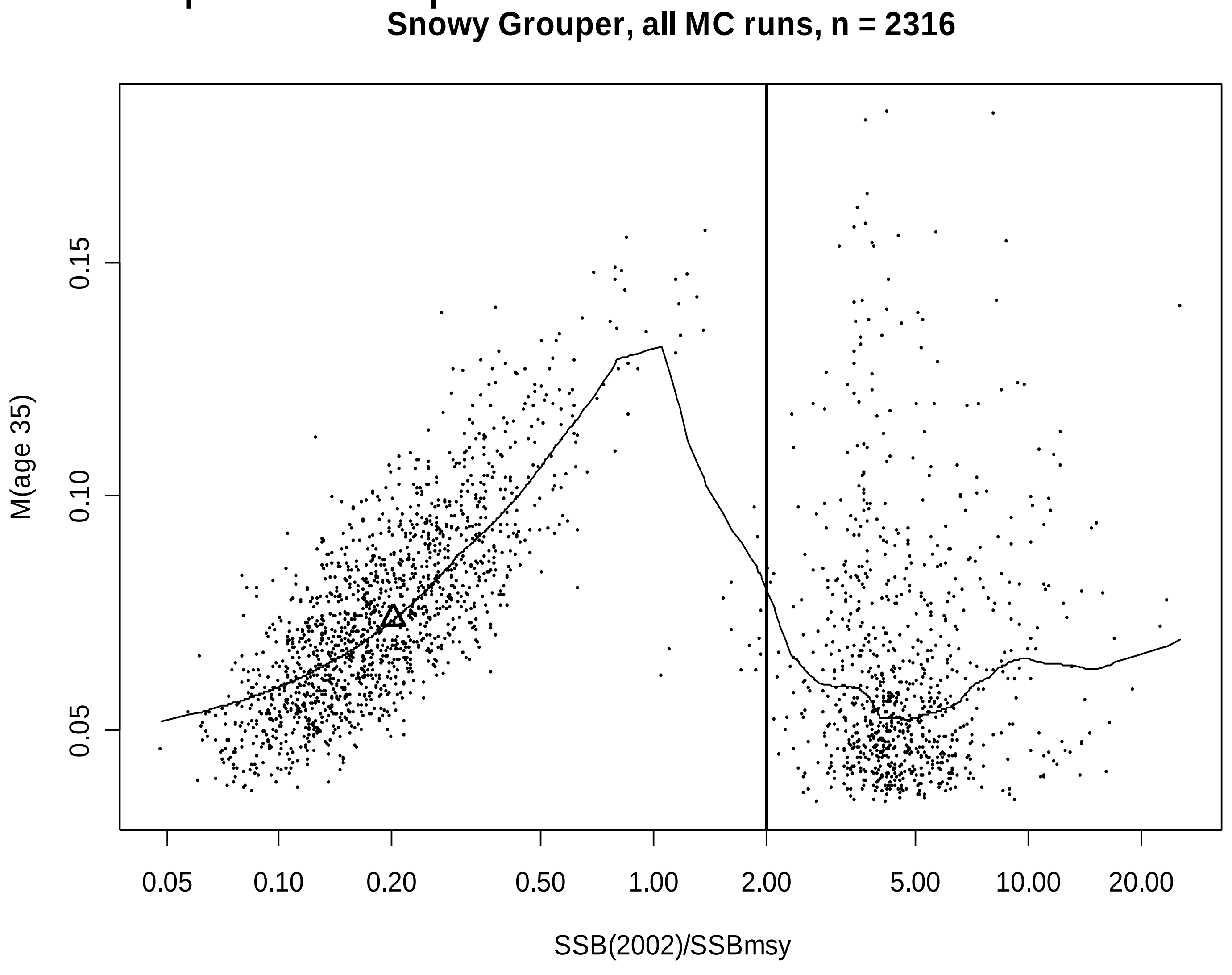
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

- Scatter plots of input versus MCB criteria

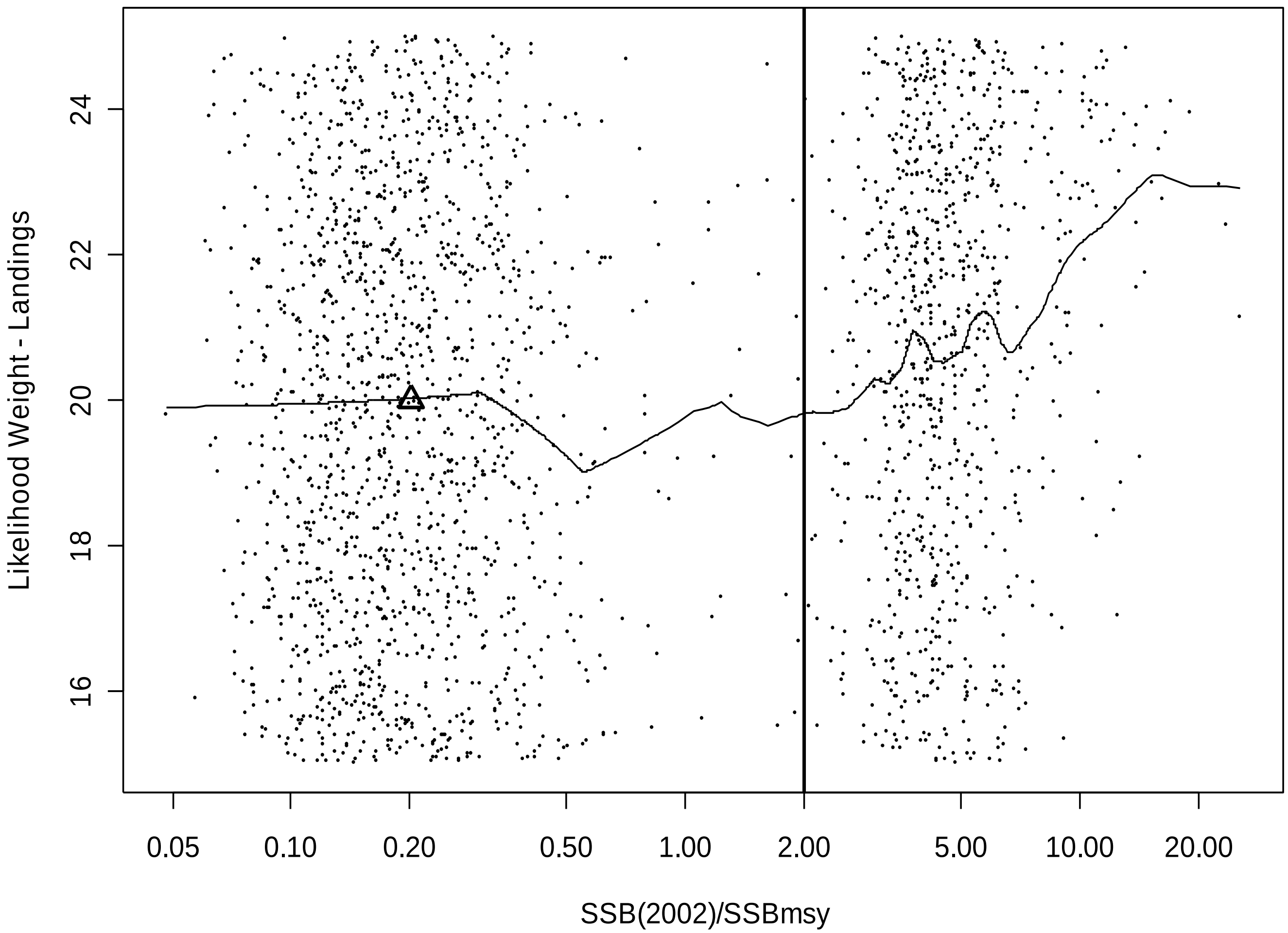


Snowy Grouper Model

Review Panel Requests

- Scatter plots of input versus MCB criteria

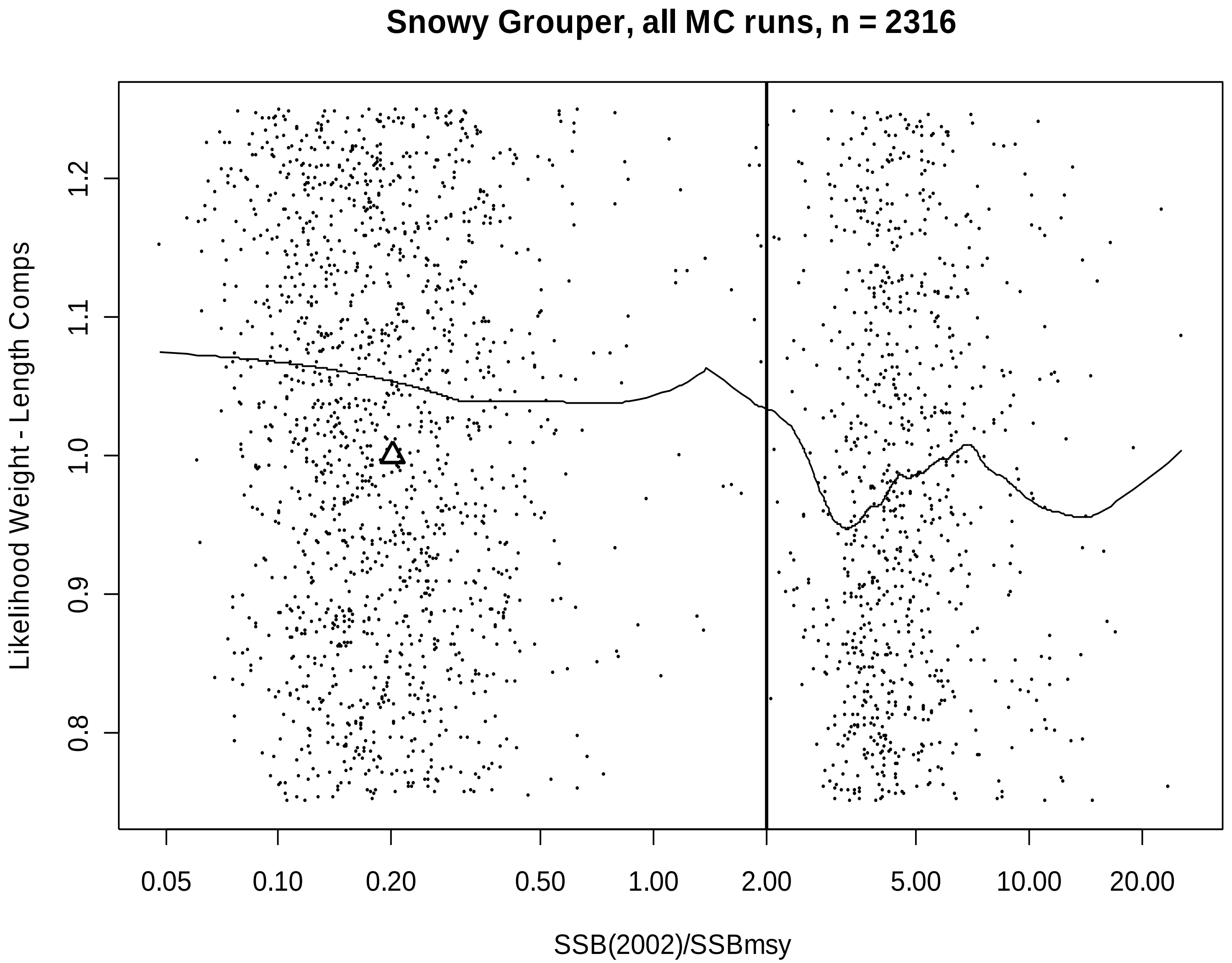
Snowy Grouper, all MC runs, n = 2316



Snowy Grouper Model

Review Panel Requests

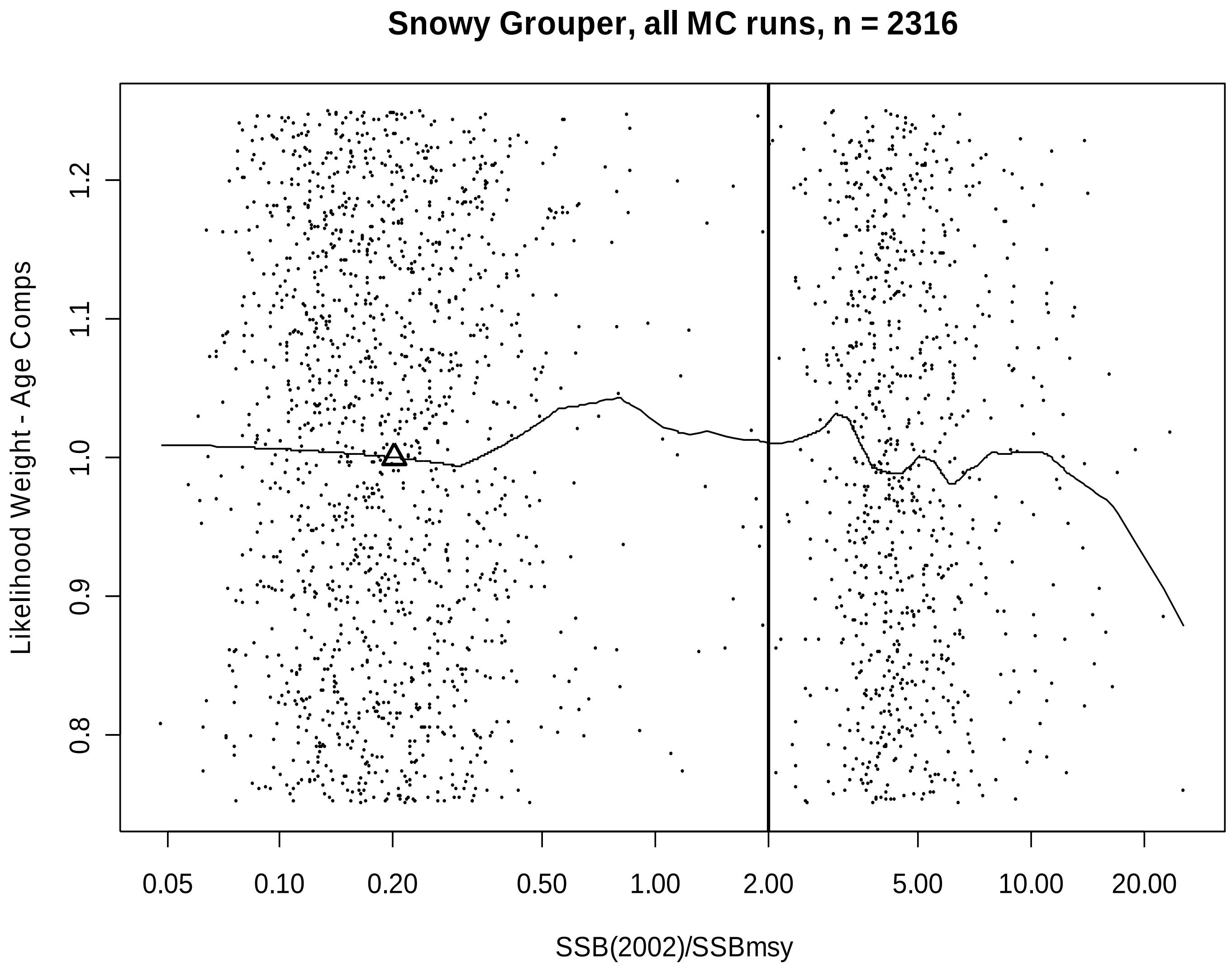
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

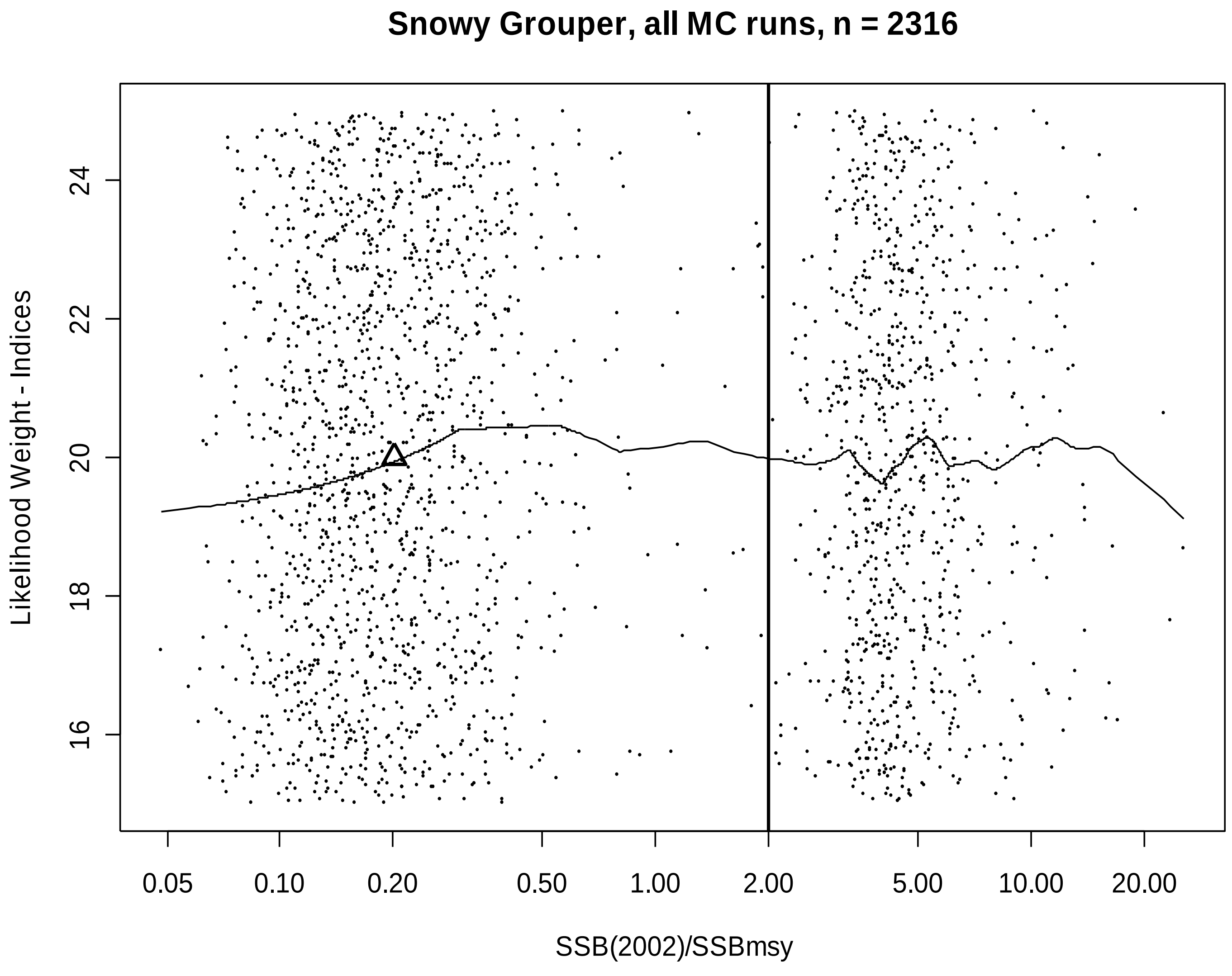
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

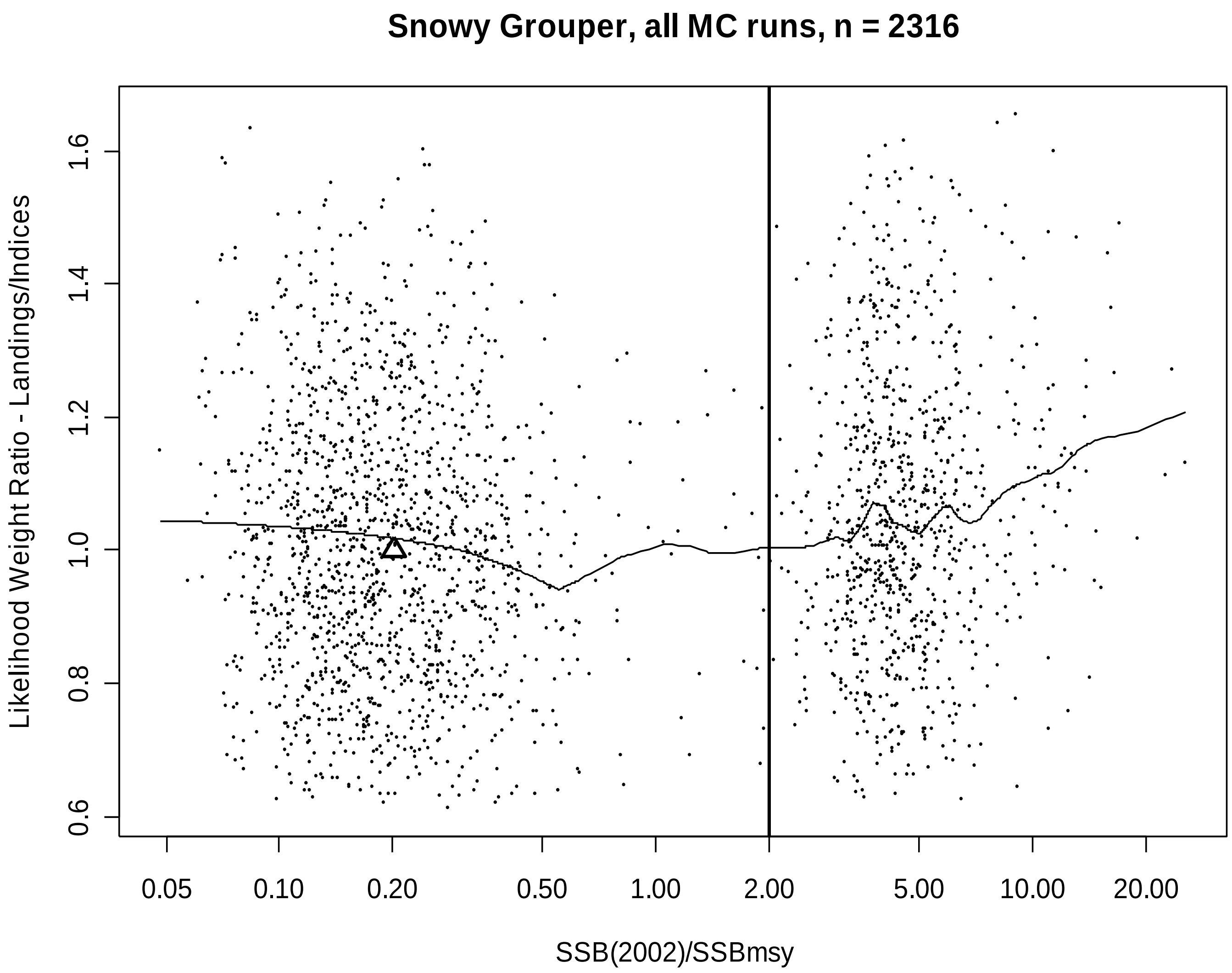
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

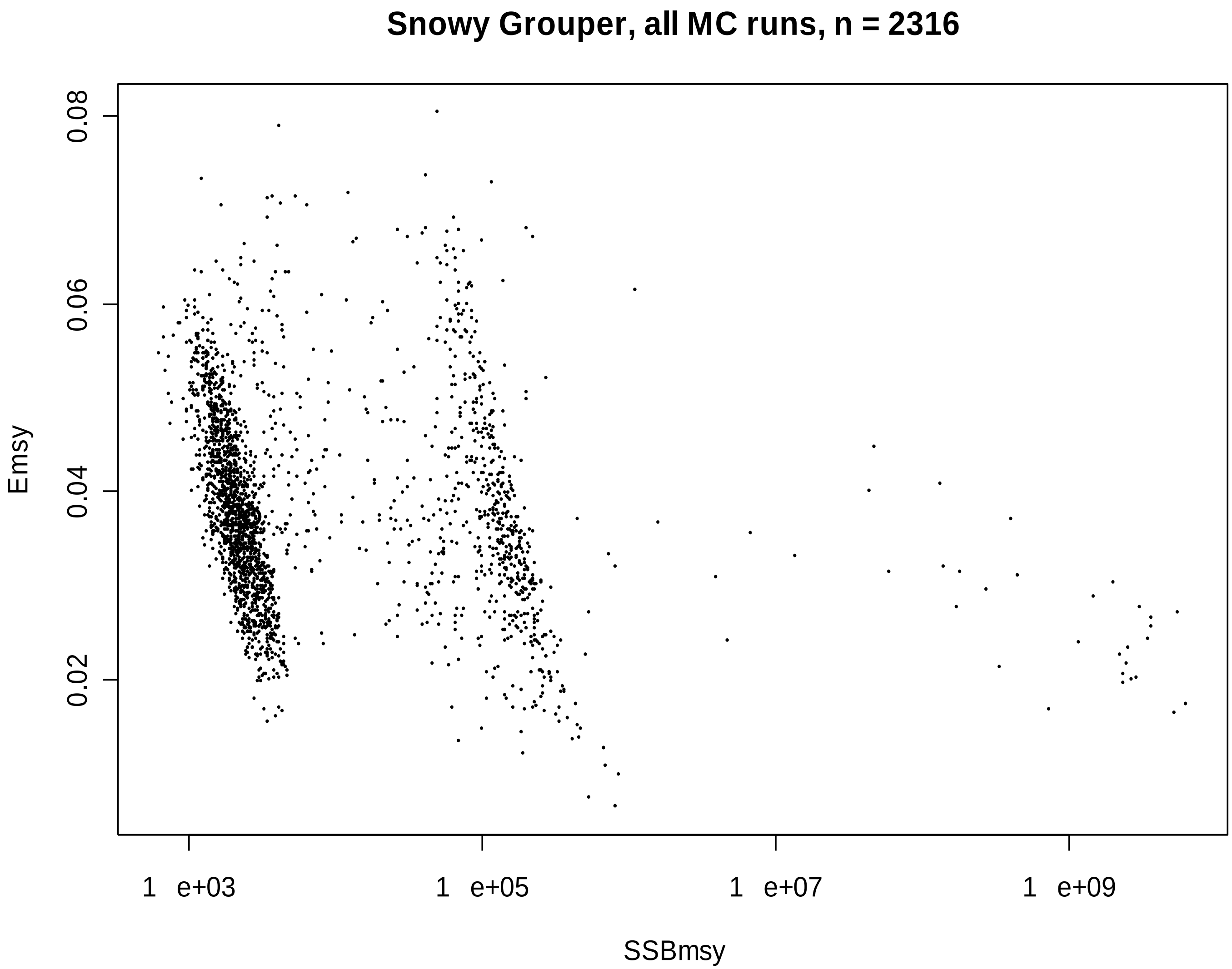
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

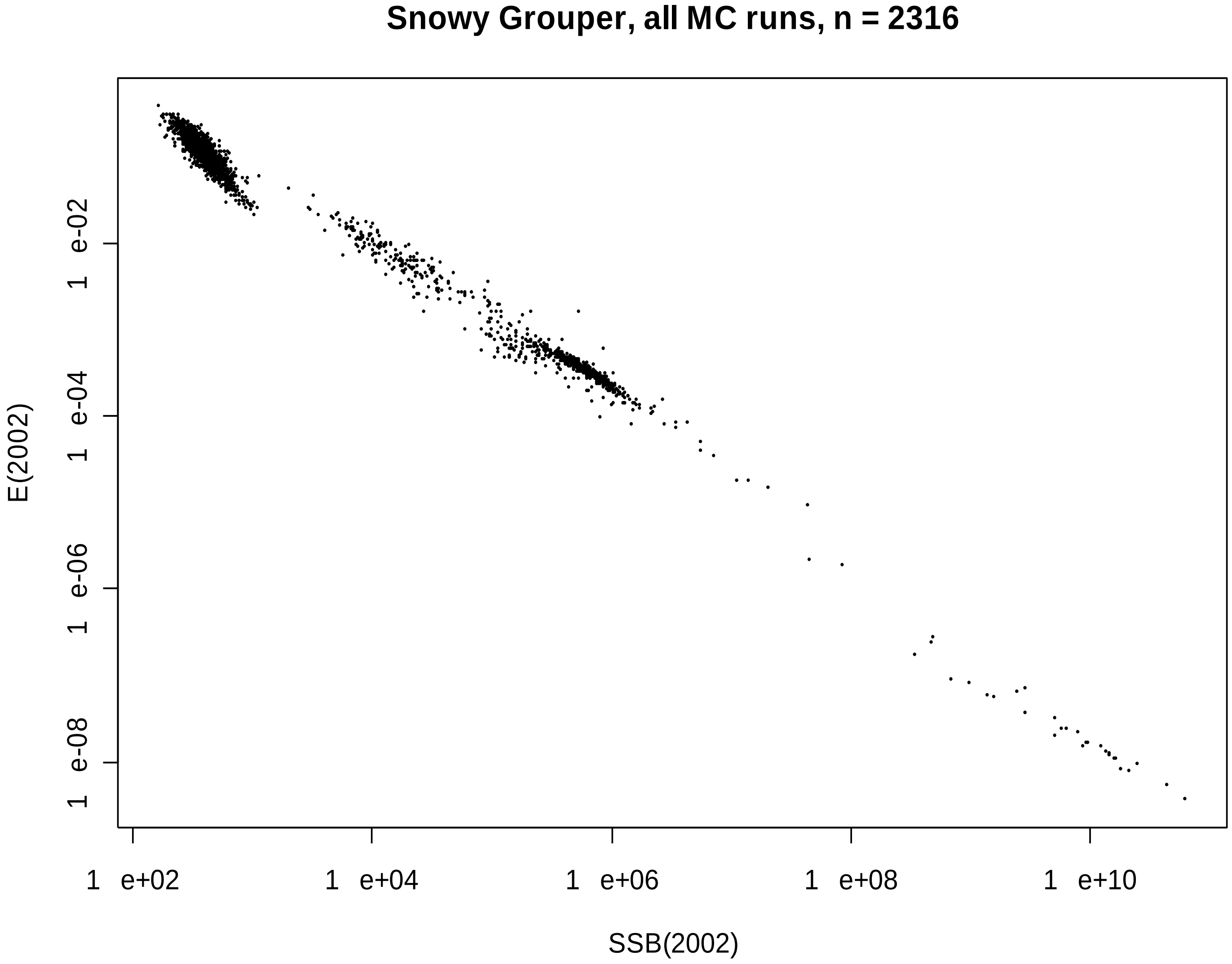
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

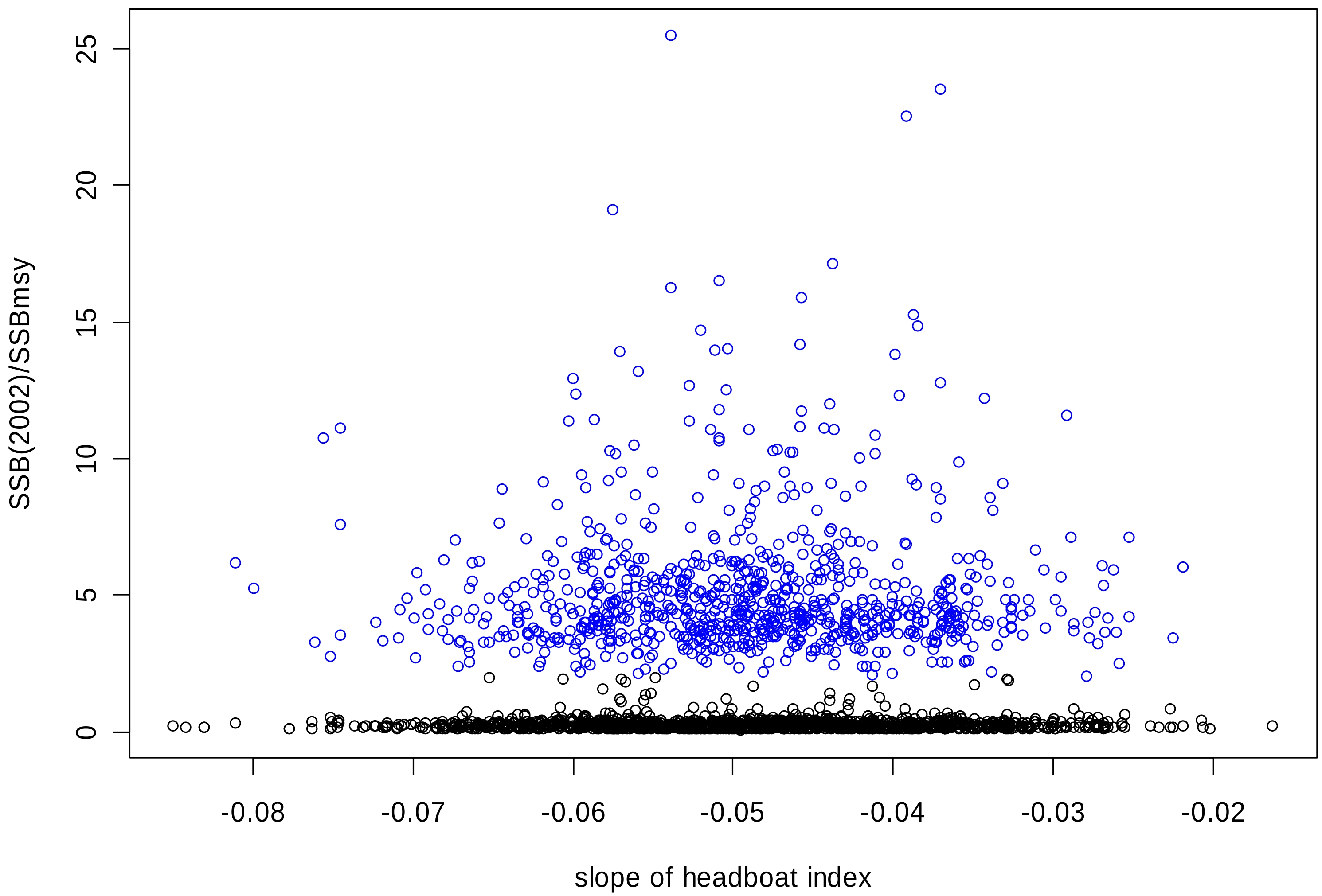
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

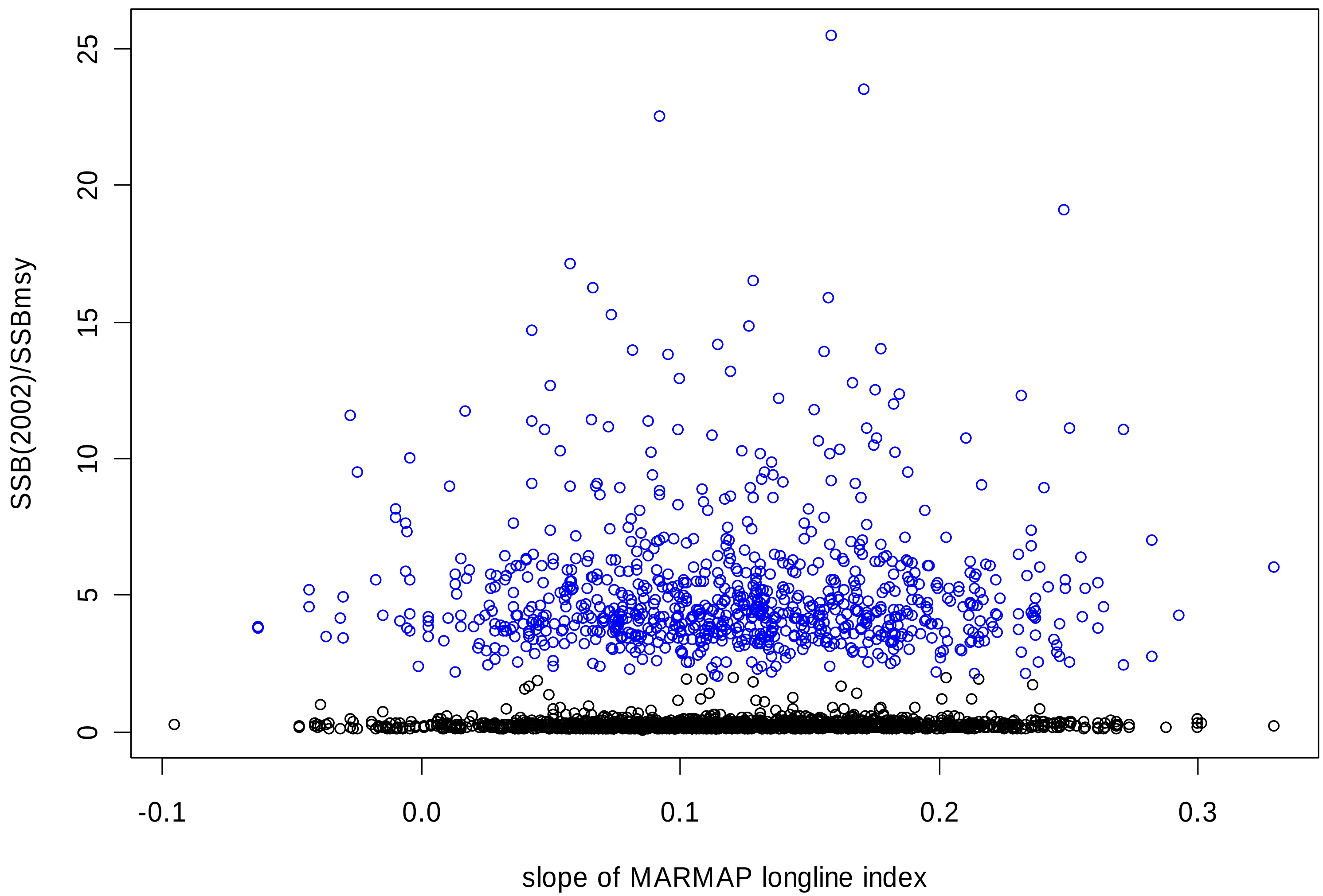
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

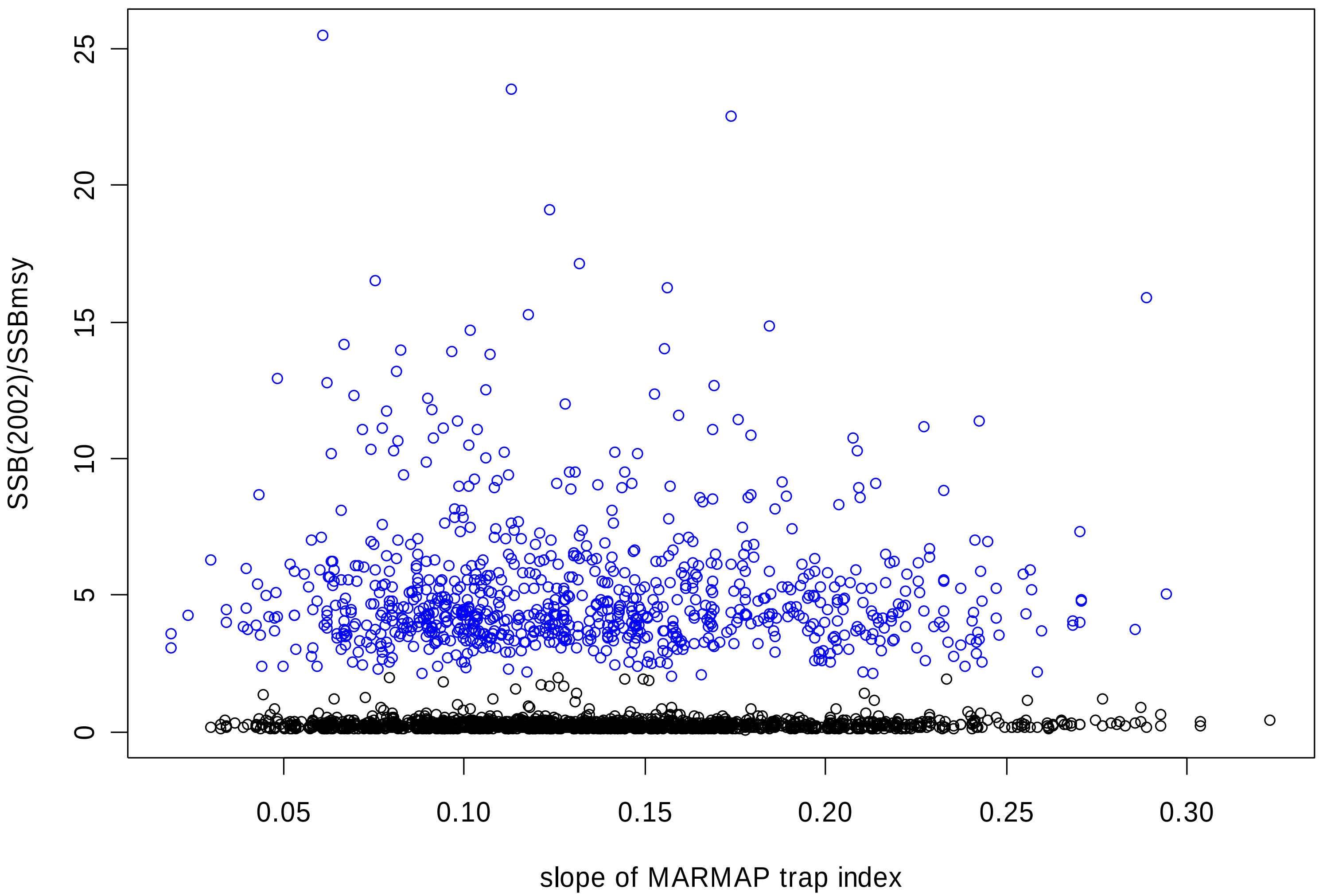
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

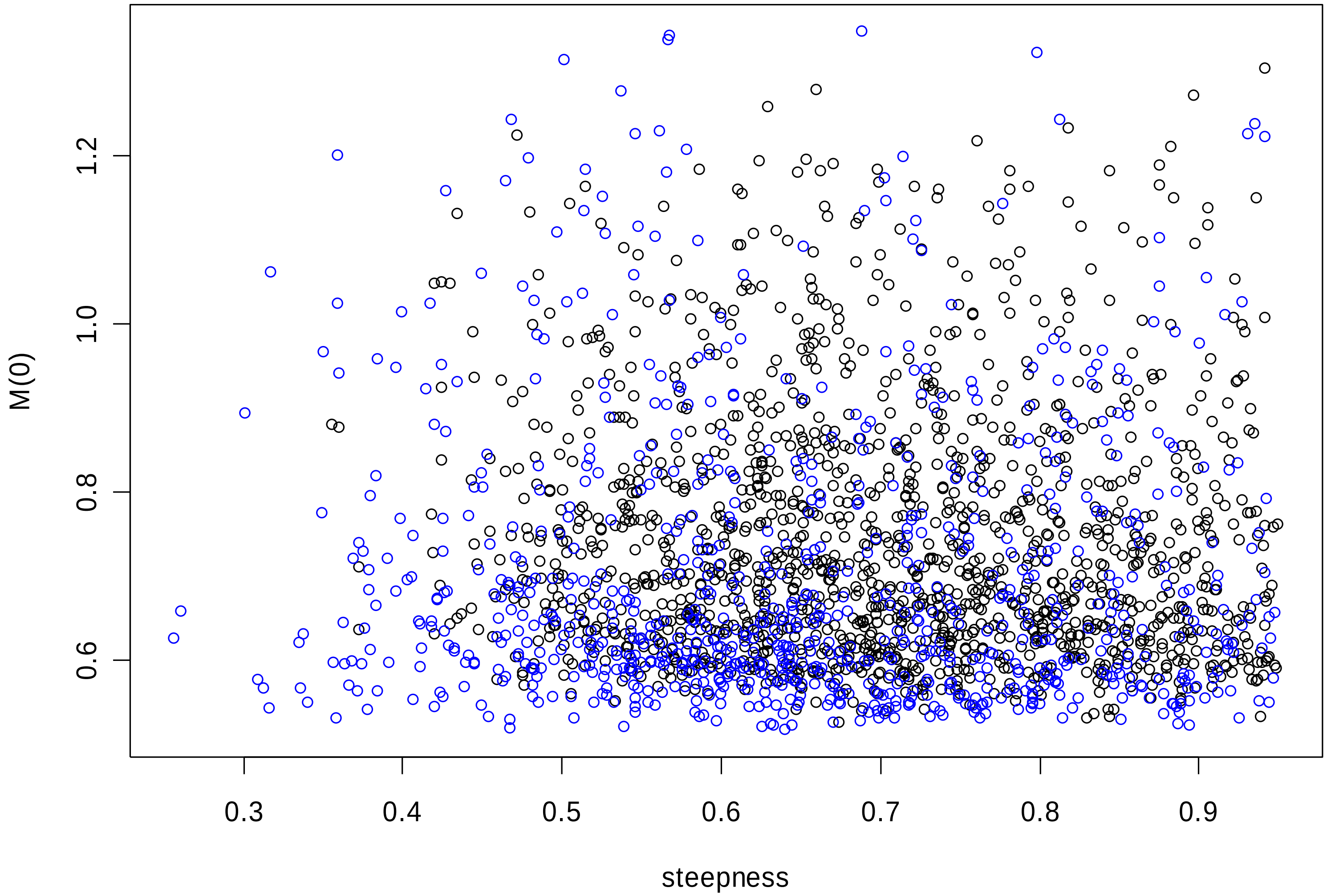
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

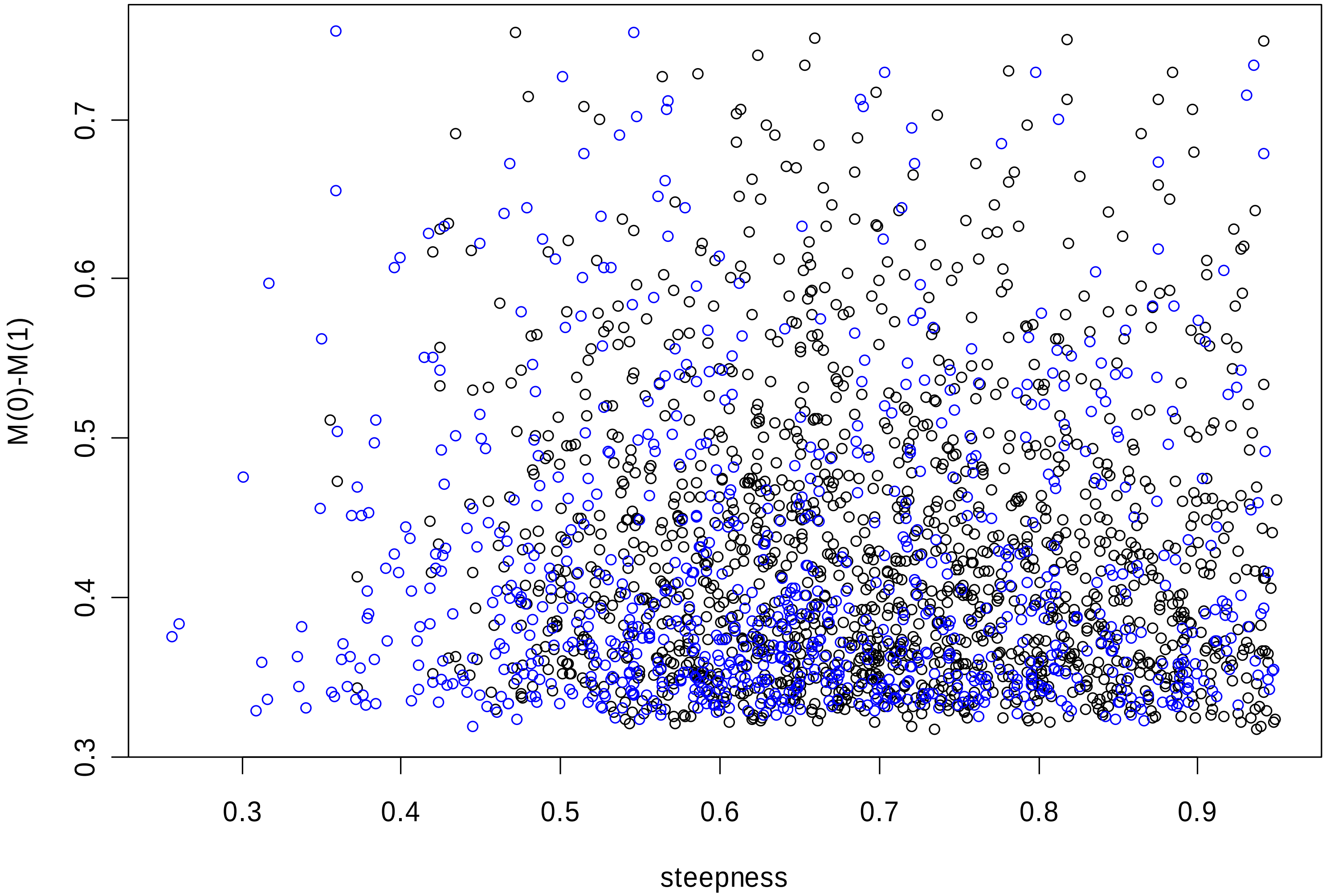
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

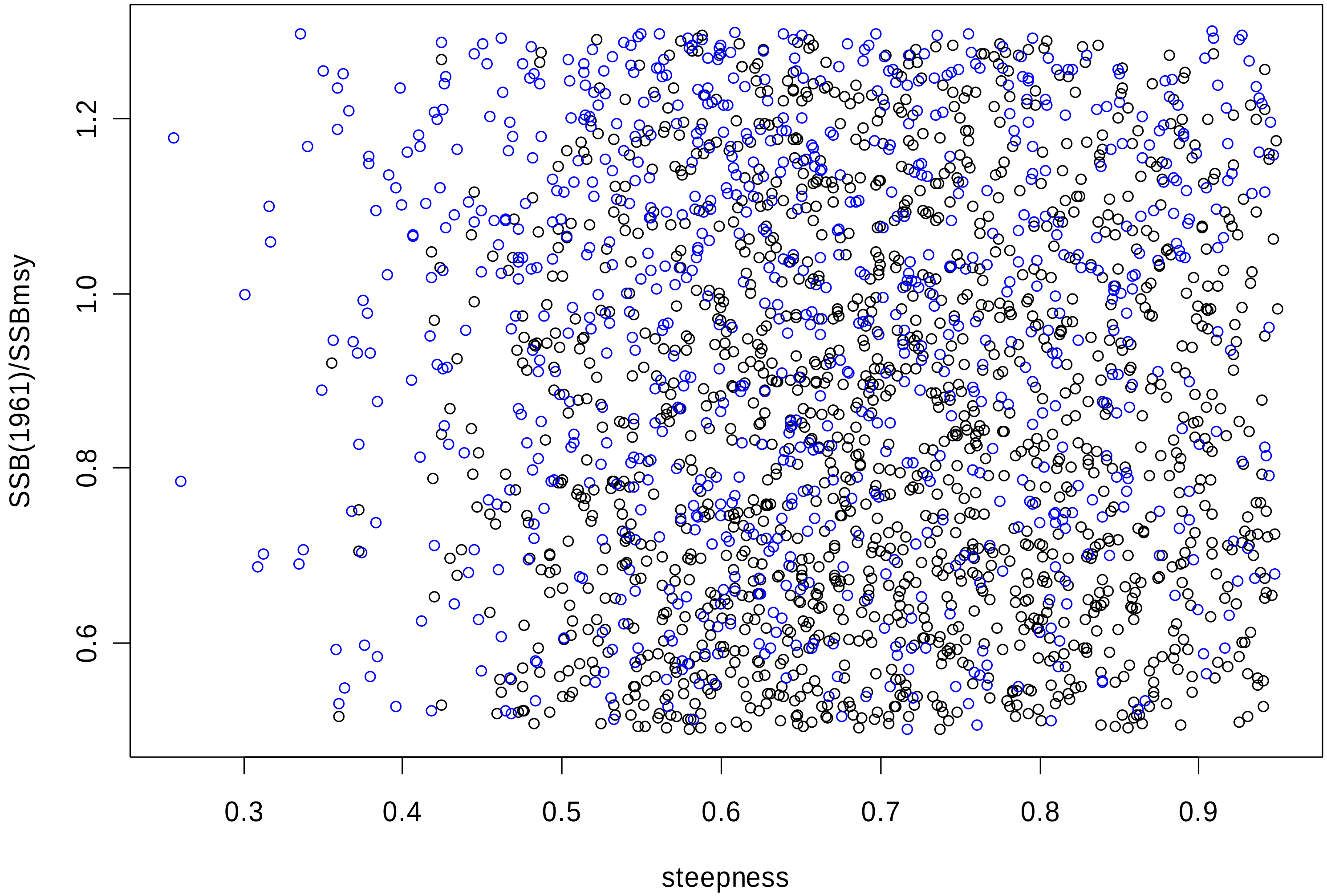
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

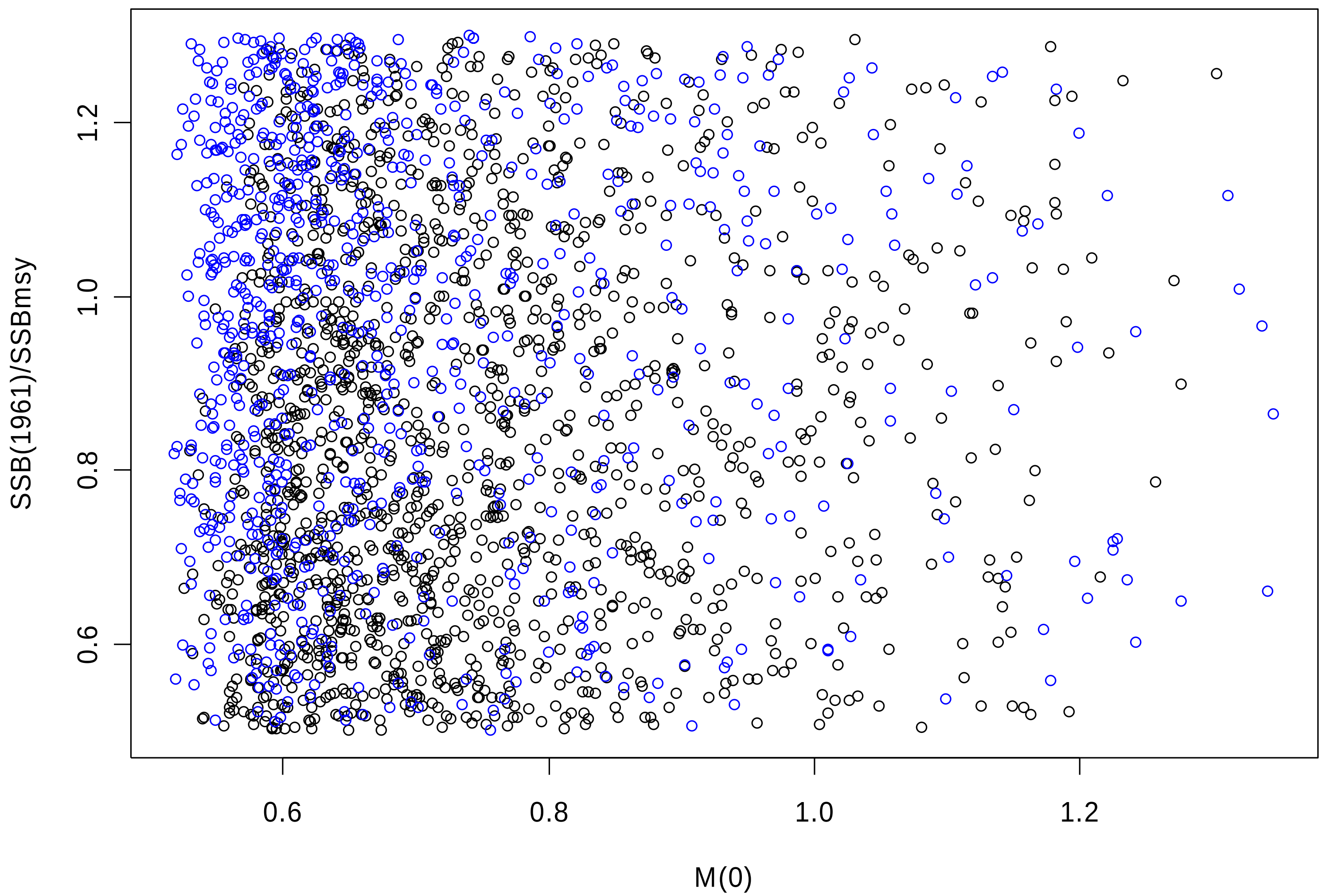
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

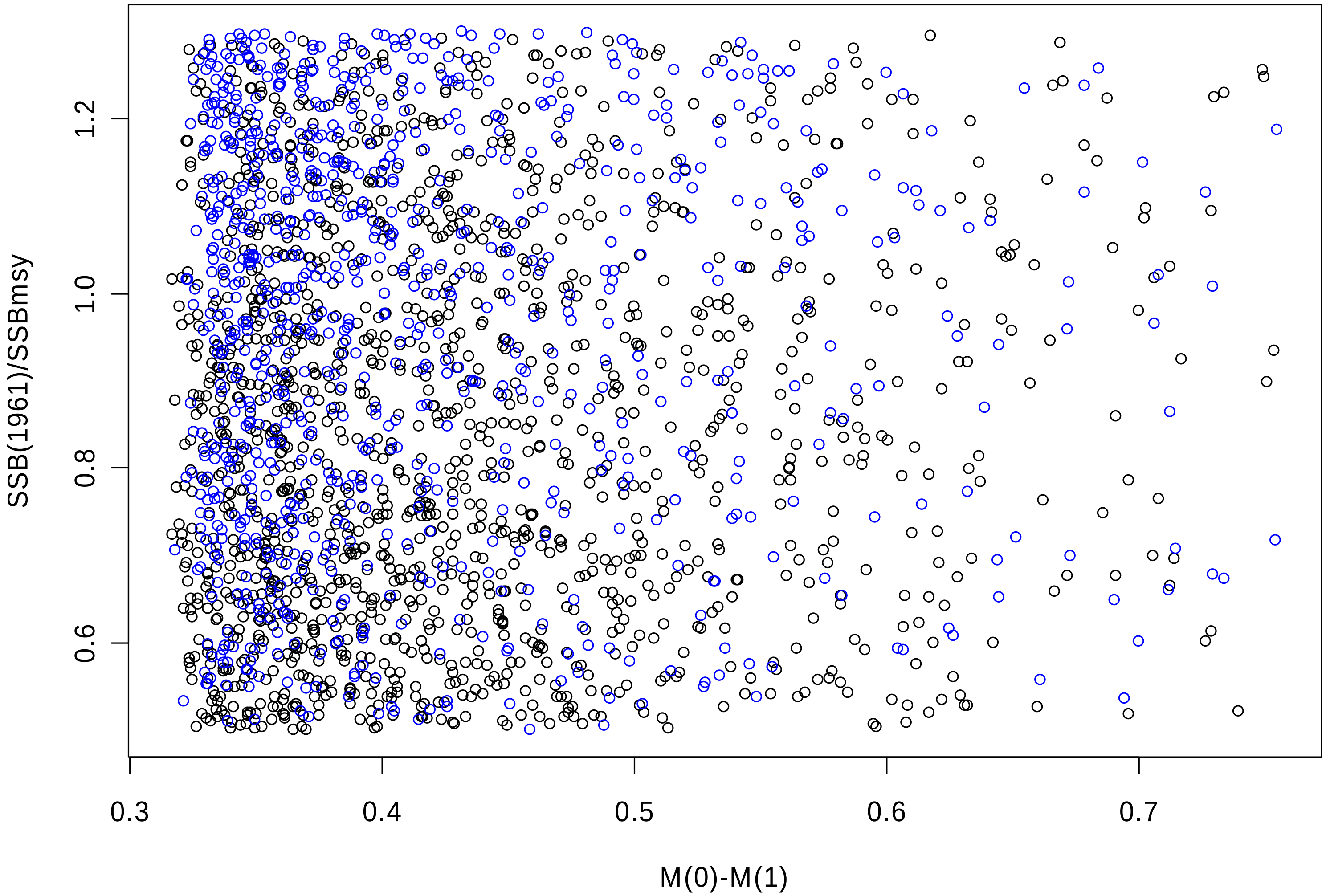
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

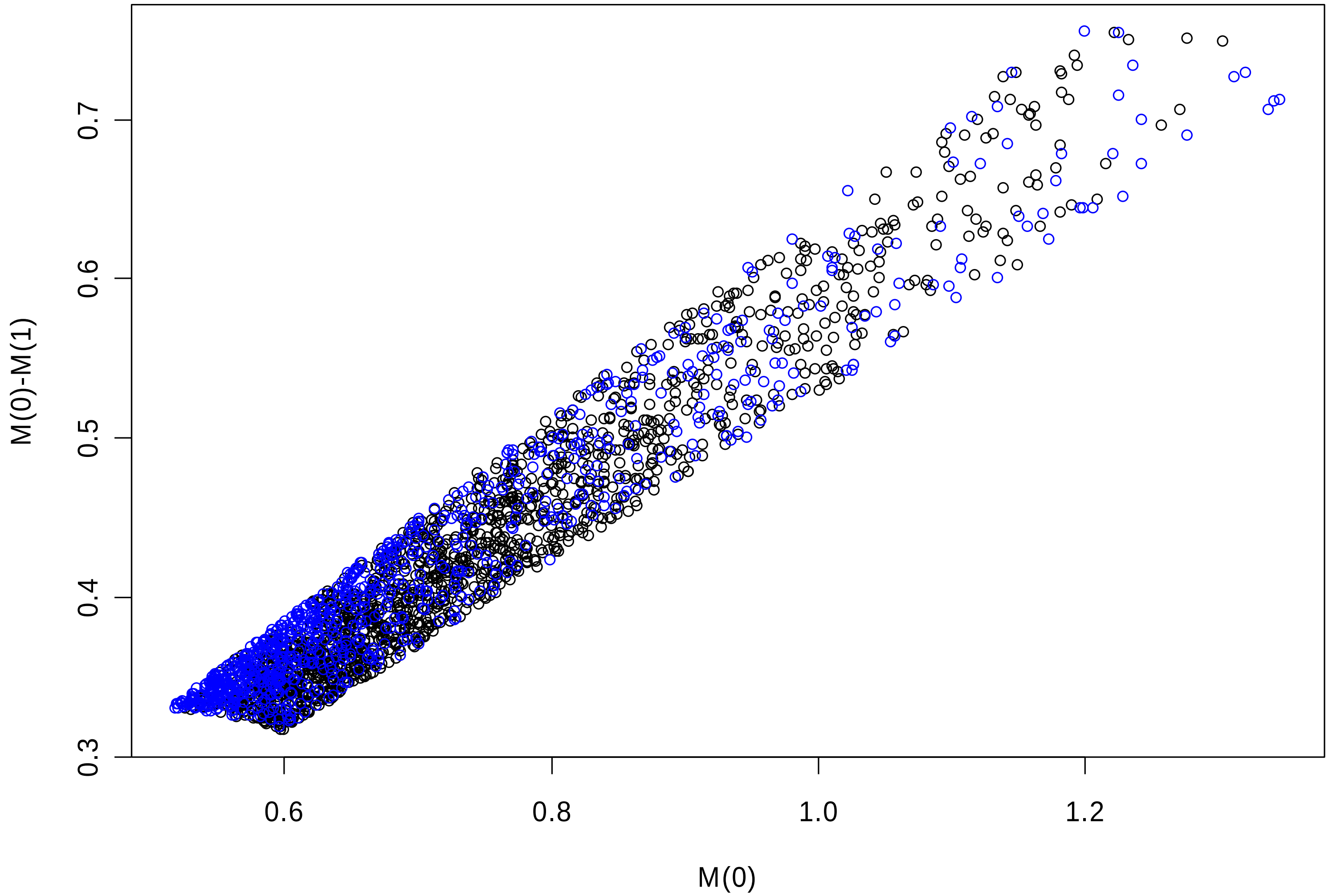
- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

- Scatter plots of input versus MCB criteria



Snowy Grouper Model

Review Panel Requests

- Example of “bad” run

User glitch, need to re-do

Snowy Grouper Model

Review Panel Requests

- Initial model run with increased weight on landings

Snowy Grouper Model

Review Panel Requests

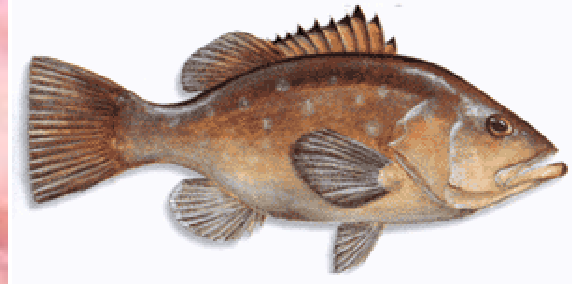
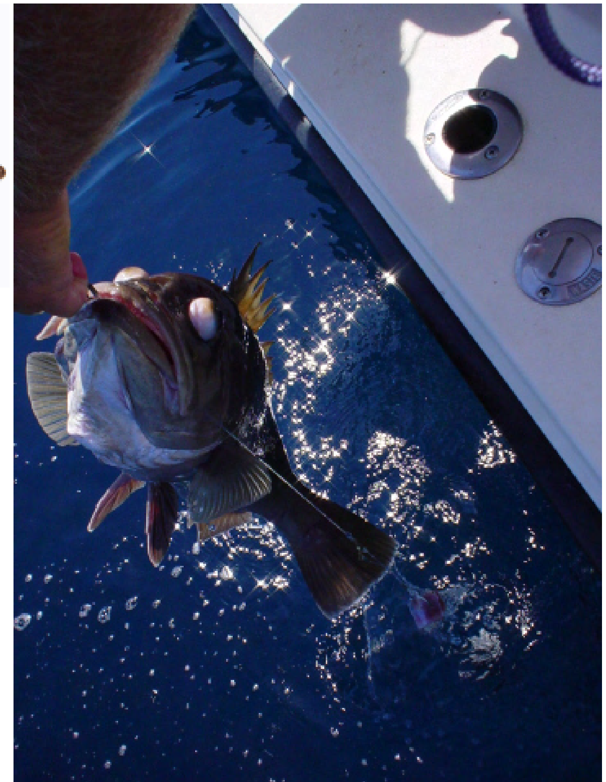
- Initial model run with constant M=0.12

Snowy Grouper Model

Review Panel Requests

- Initial model run starting in 1982

Unable to comply due to time constraints

T H E

E N D


Snowy Grouper (*Epinephelus niveatus*) Stock Assessment

Erik H. Williams
NOAA Fisheries
Beaufort Laboratory
Beaufort, North Carolina

Snowy Grouper Model

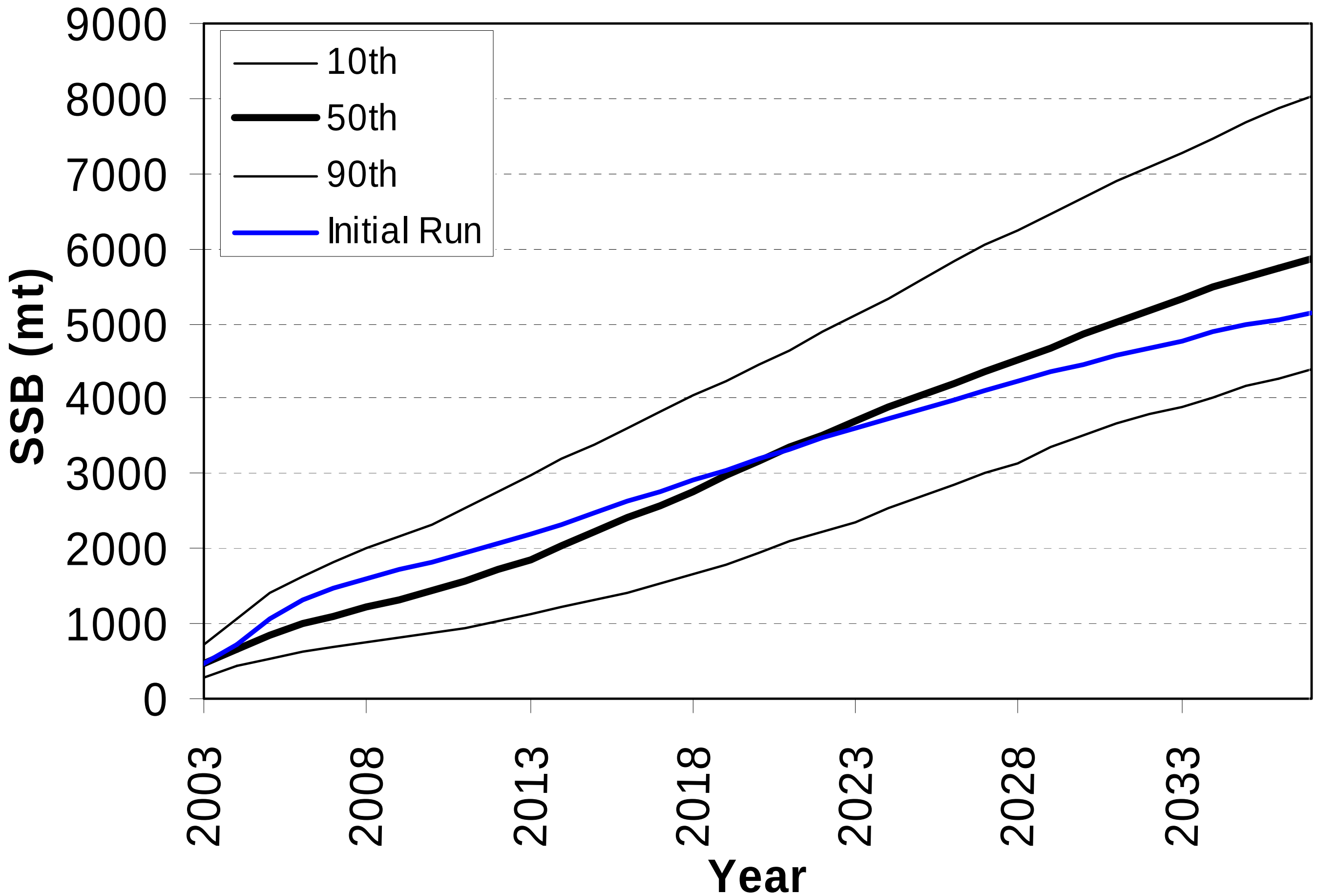
Review Panel Requests

- Add deterministic final run projections to projection figures
- Try fitting “bad” MCB run with more phases

Snowy Grouper Model

Review Panel Requests

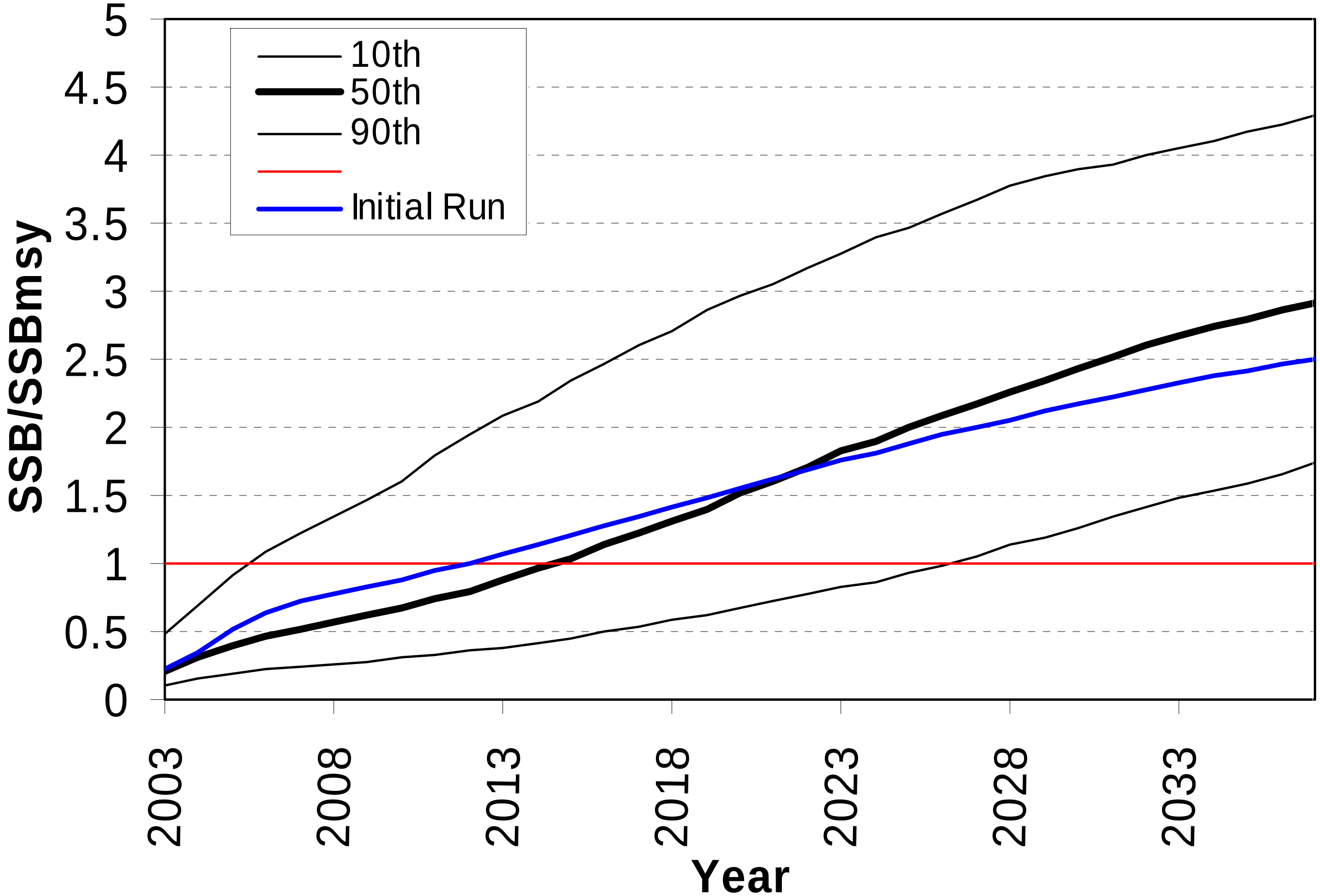
- Add deterministic final run projections to projection figures

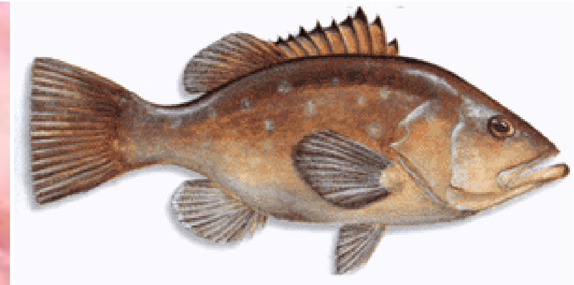


Snowy Grouper Model

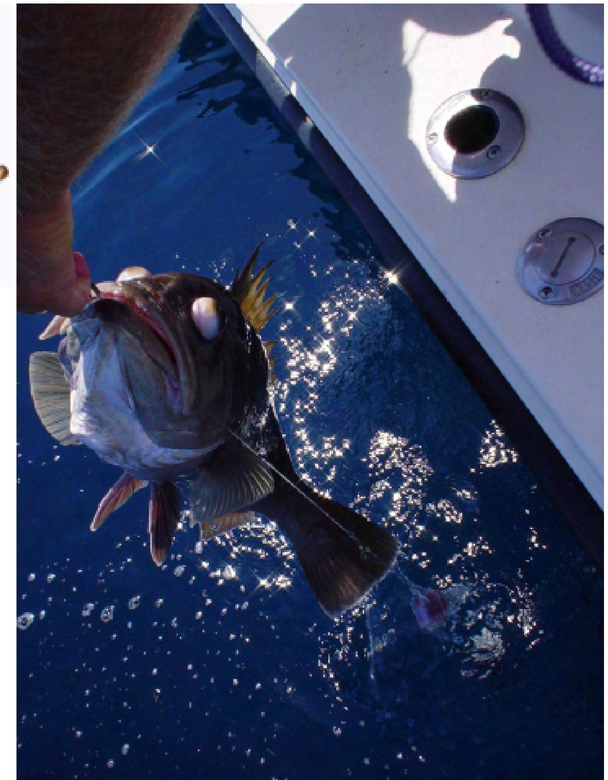
Review Panel Requests

- Add deterministic final run projections to projection figures





THE END



Snowy Grouper (*Epinephelus niveatus*) Stock Assessment

Erik H. Williams
NOAA Fisheries
Beaufort Laboratory
Beaufort, North Carolina

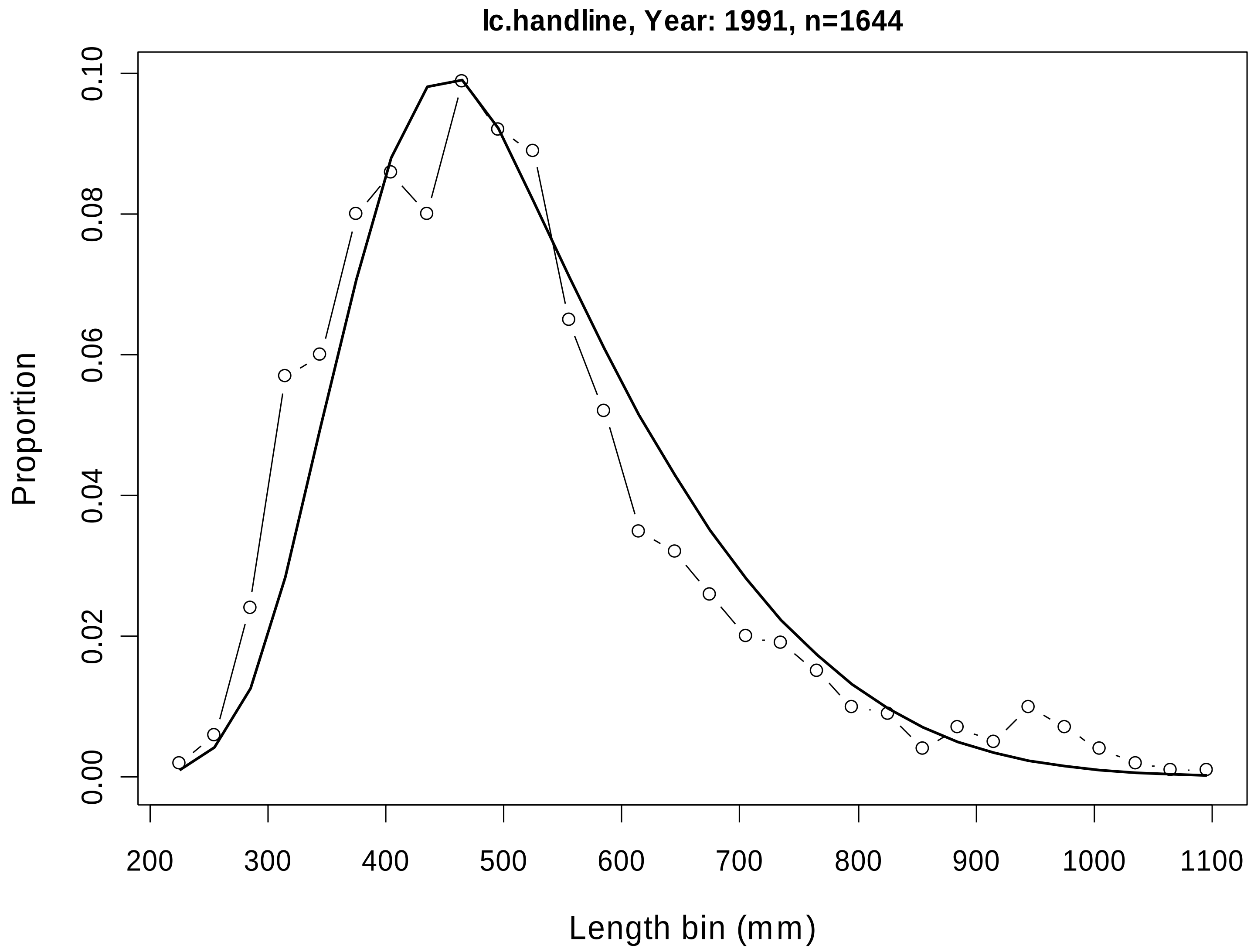
Snowy Grouper Model

Review Panel Requests

- Run age-structured production model

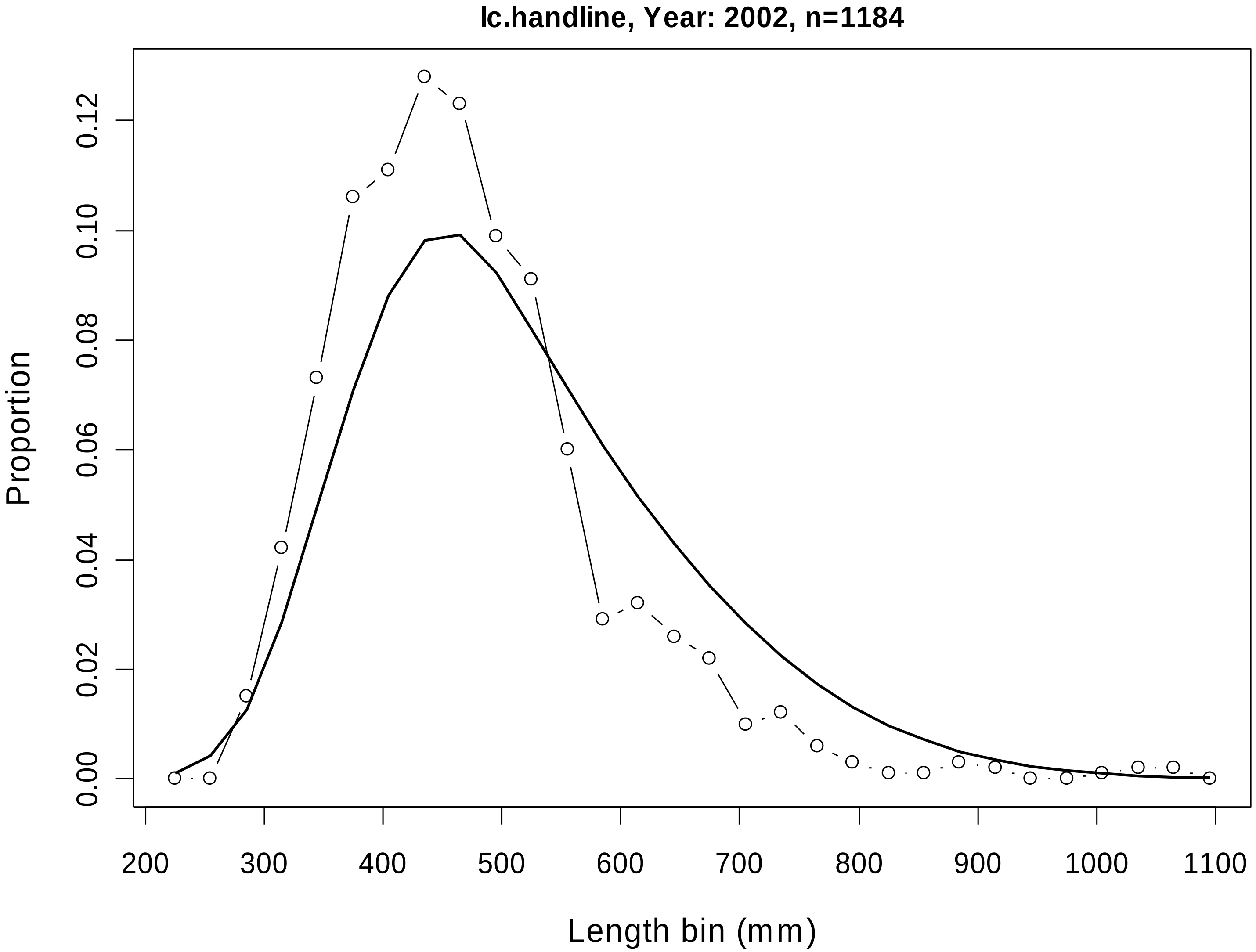
Snowy Grouper Model

ASPM Model with fixed initial biomass ratio (0.9)



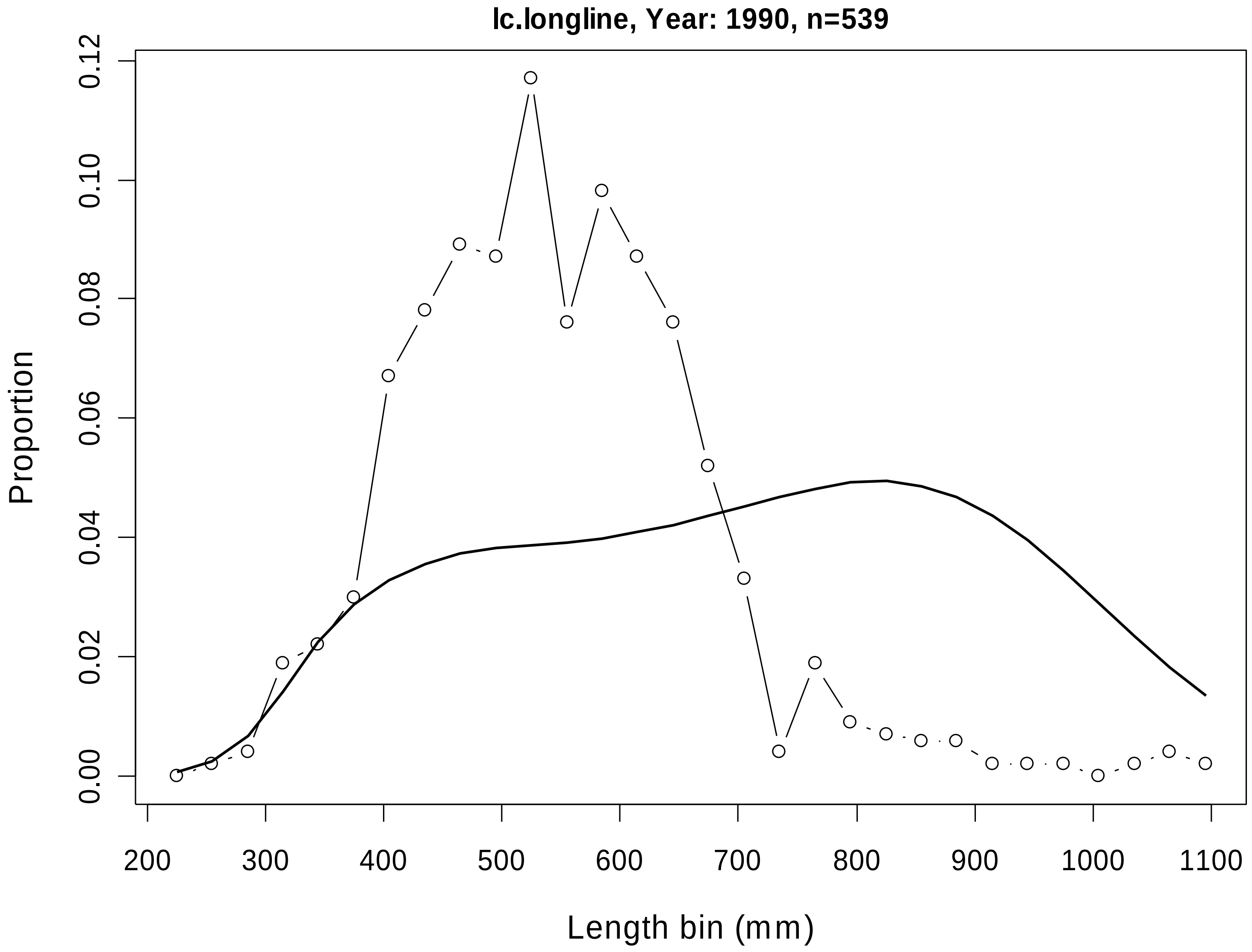
Snowy Grouper Model

ASPM Model with fixed initial biomass ratio (0.9)



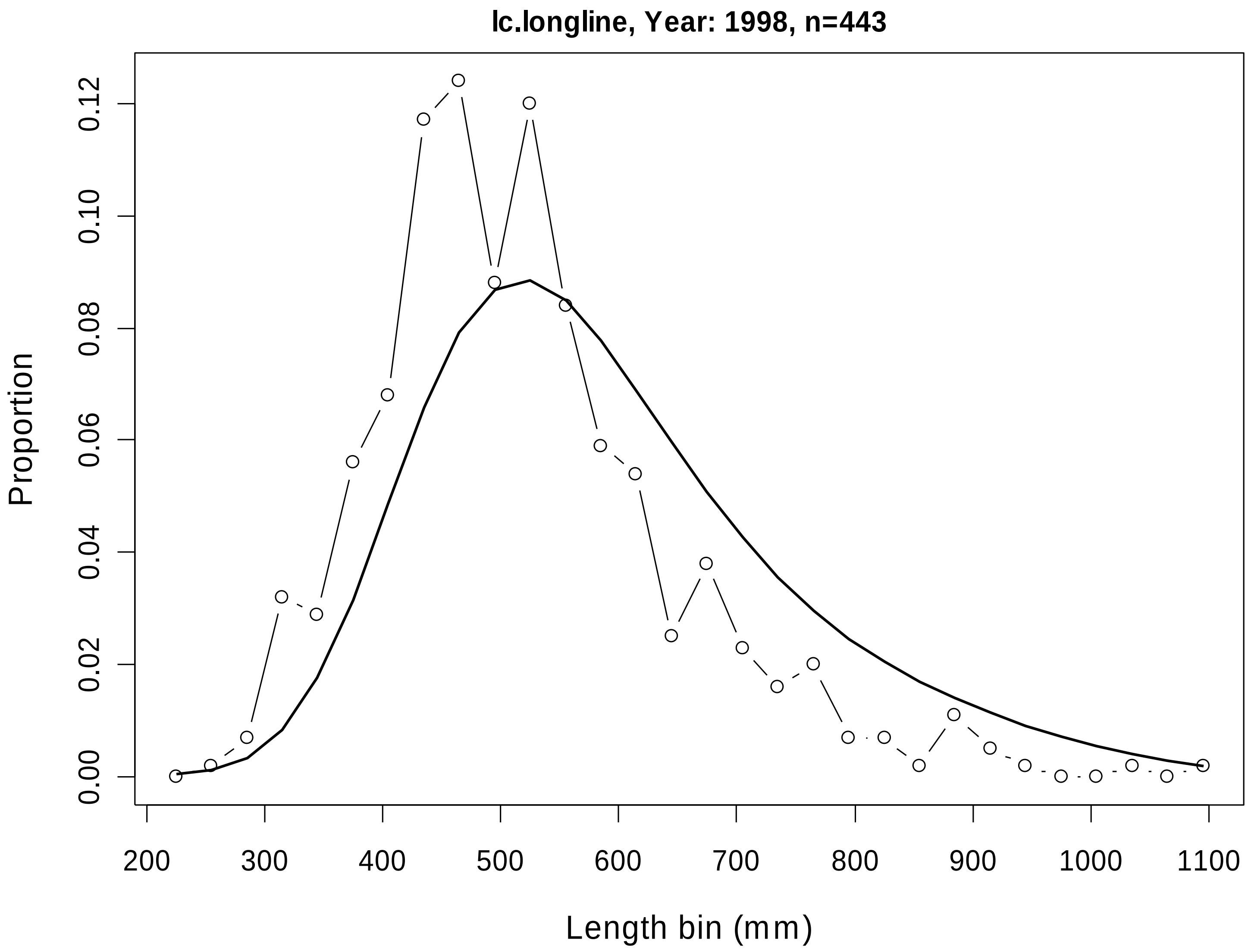
Snowy Grouper Model

ASPM Model with fixed initial biomass ratio (0.9)



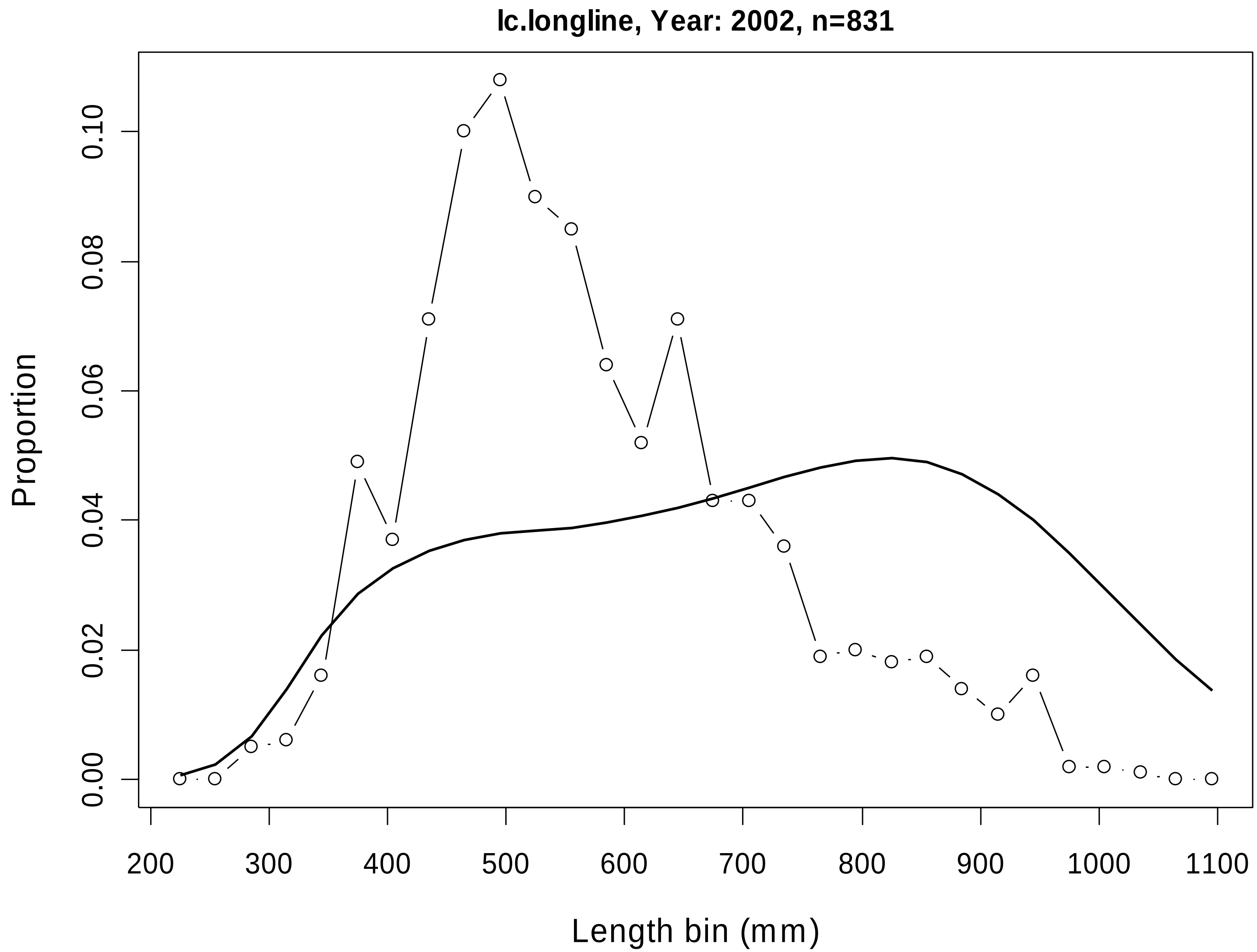
Snowy Grouper Model

ASPM Model with fixed initial biomass ratio (0.9)



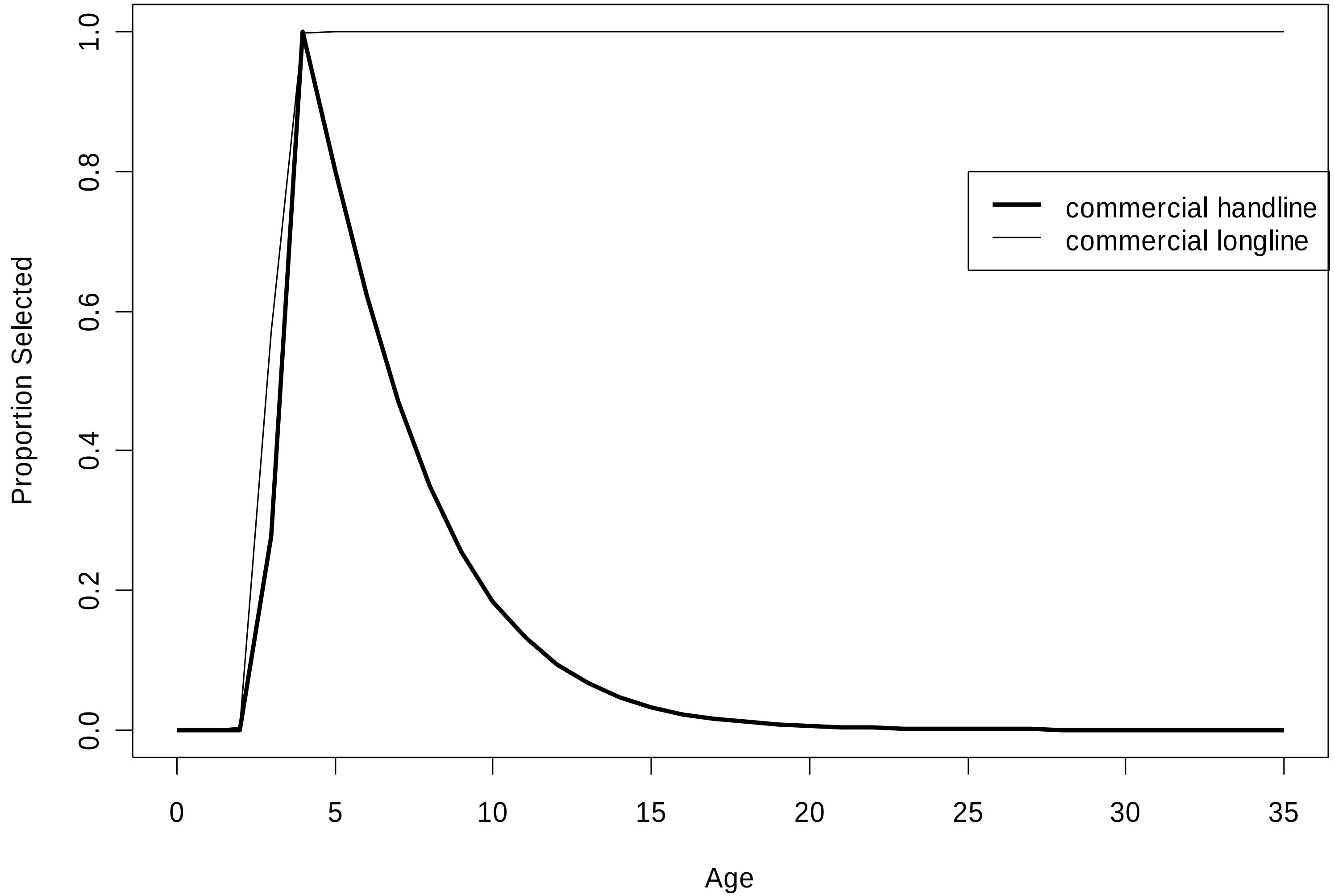
Snowy Grouper Model

ASPM Model with fixed initial biomass ratio (0.9)



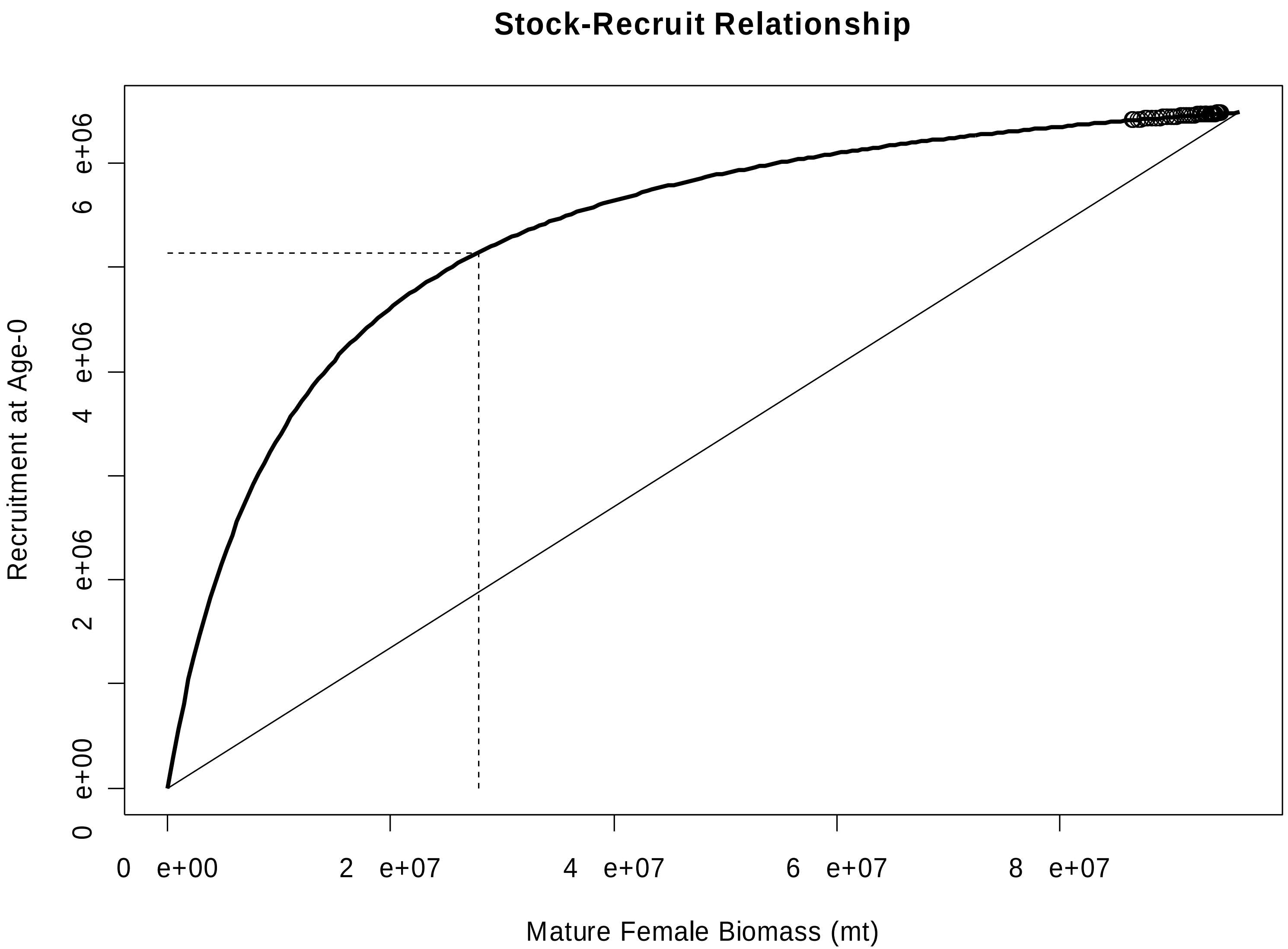
Snowy Grouper Model

ASPM Model with fixed initial biomass ratio (0.9)



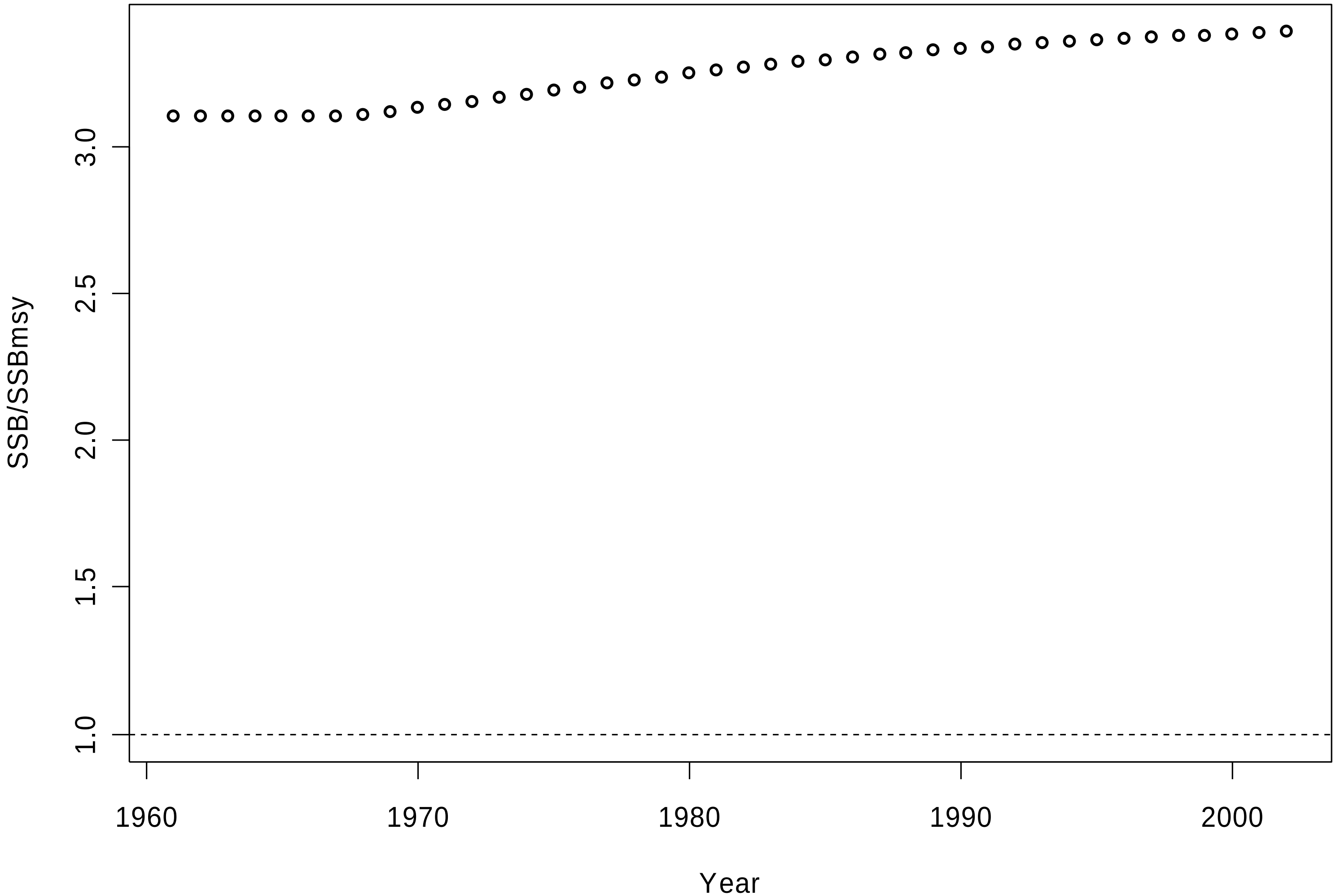
Snowy Grouper Model

ASPM Model with fixed initial biomass ratio (0.9)



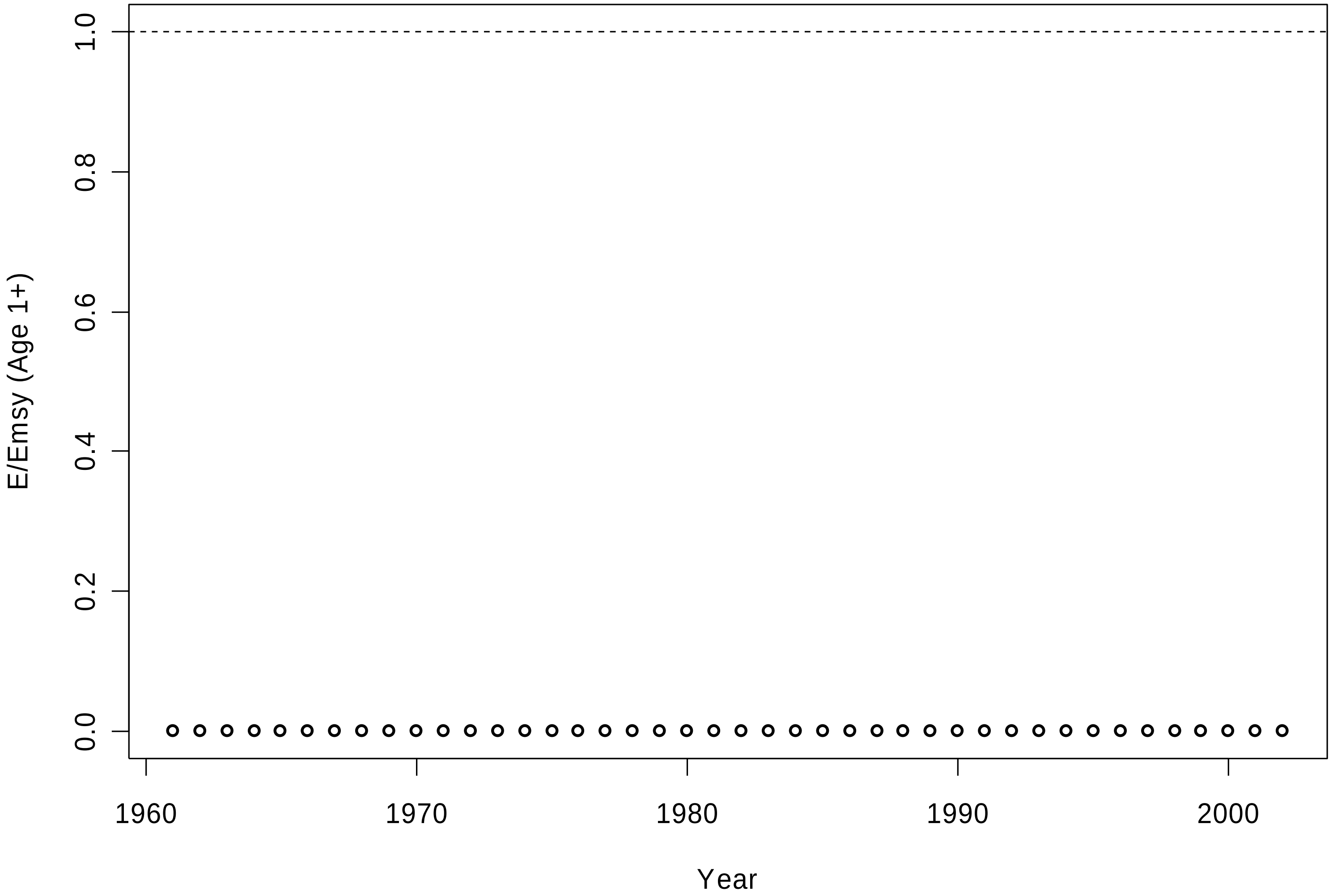
Snowy Grouper Model

ASPM Model with fixed initial biomass ratio (0.9)



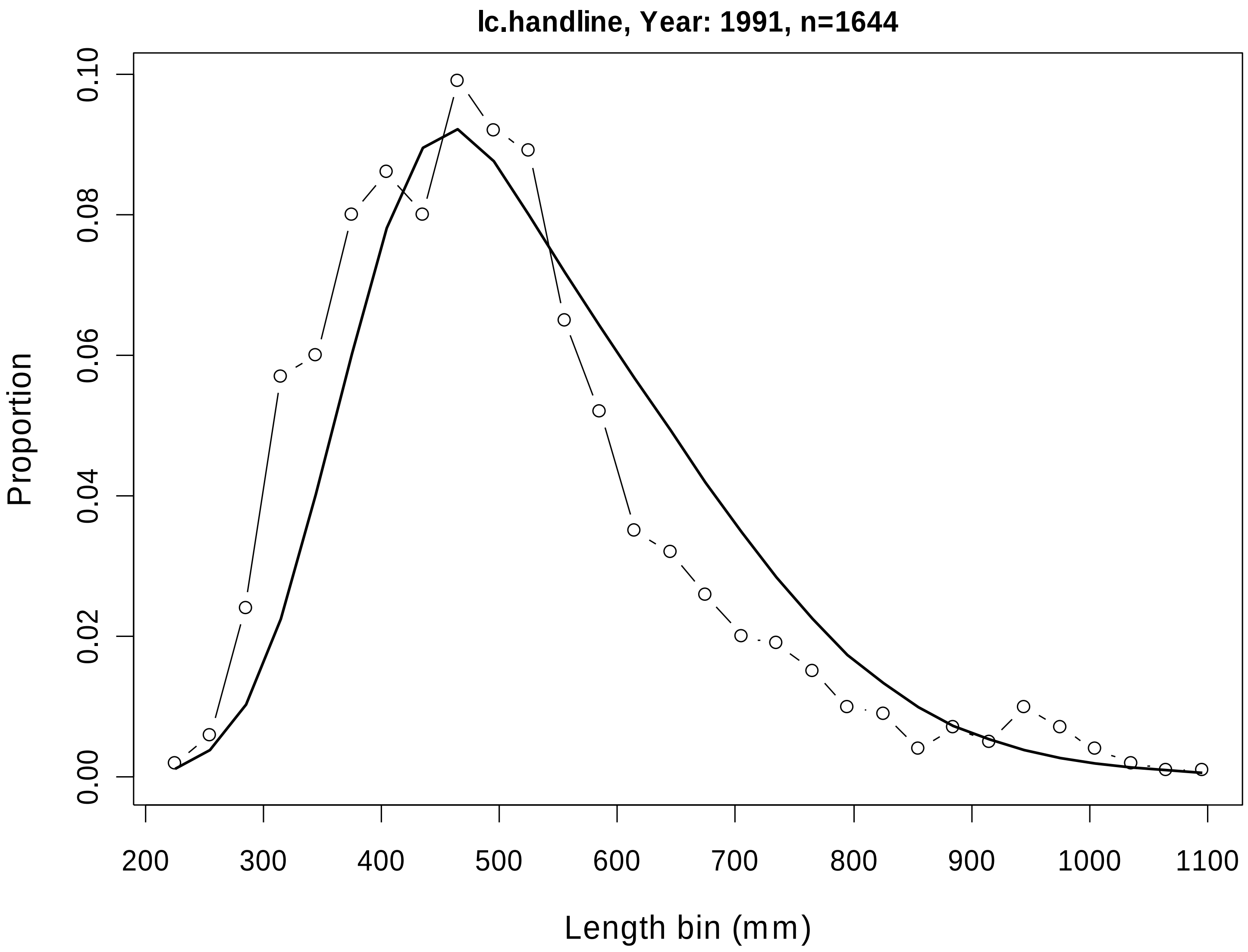
Snowy Grouper Model

ASPM Model with fixed initial biomass ratio (0.9)



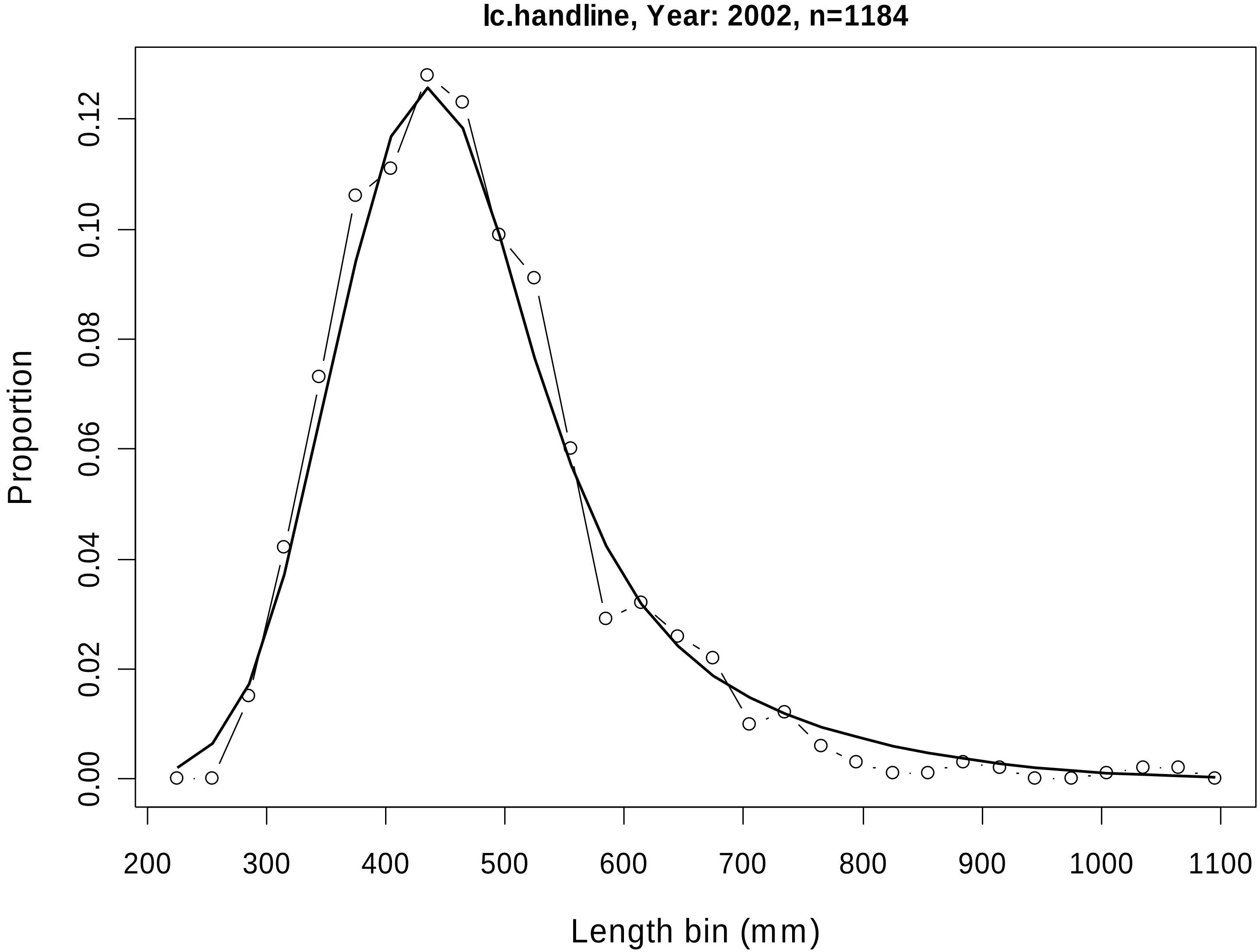
Snowy Grouper Model

ASPM Model with estimated initial biomass ratio



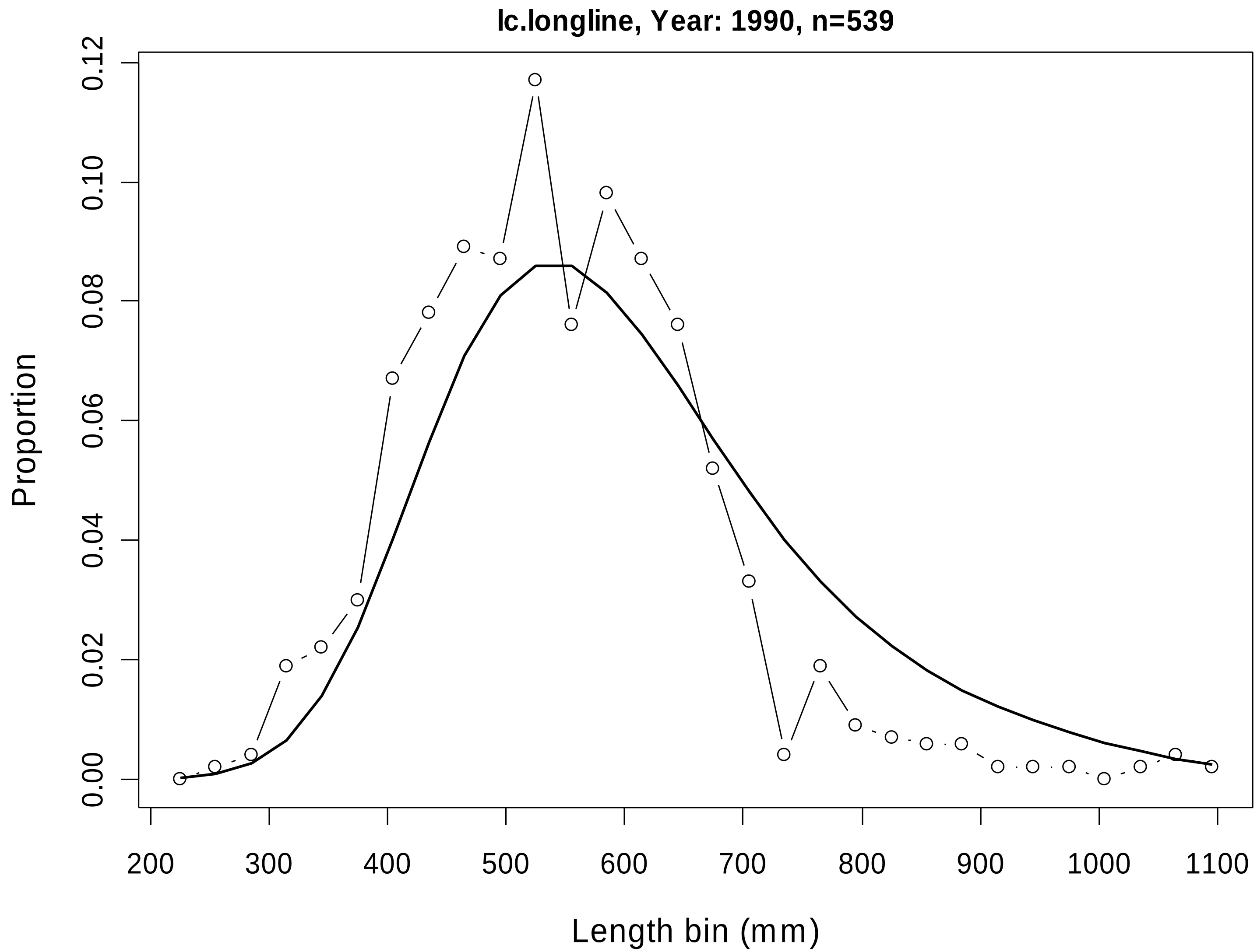
Snowy Grouper Model

ASPM Model with estimated initial biomass ratio



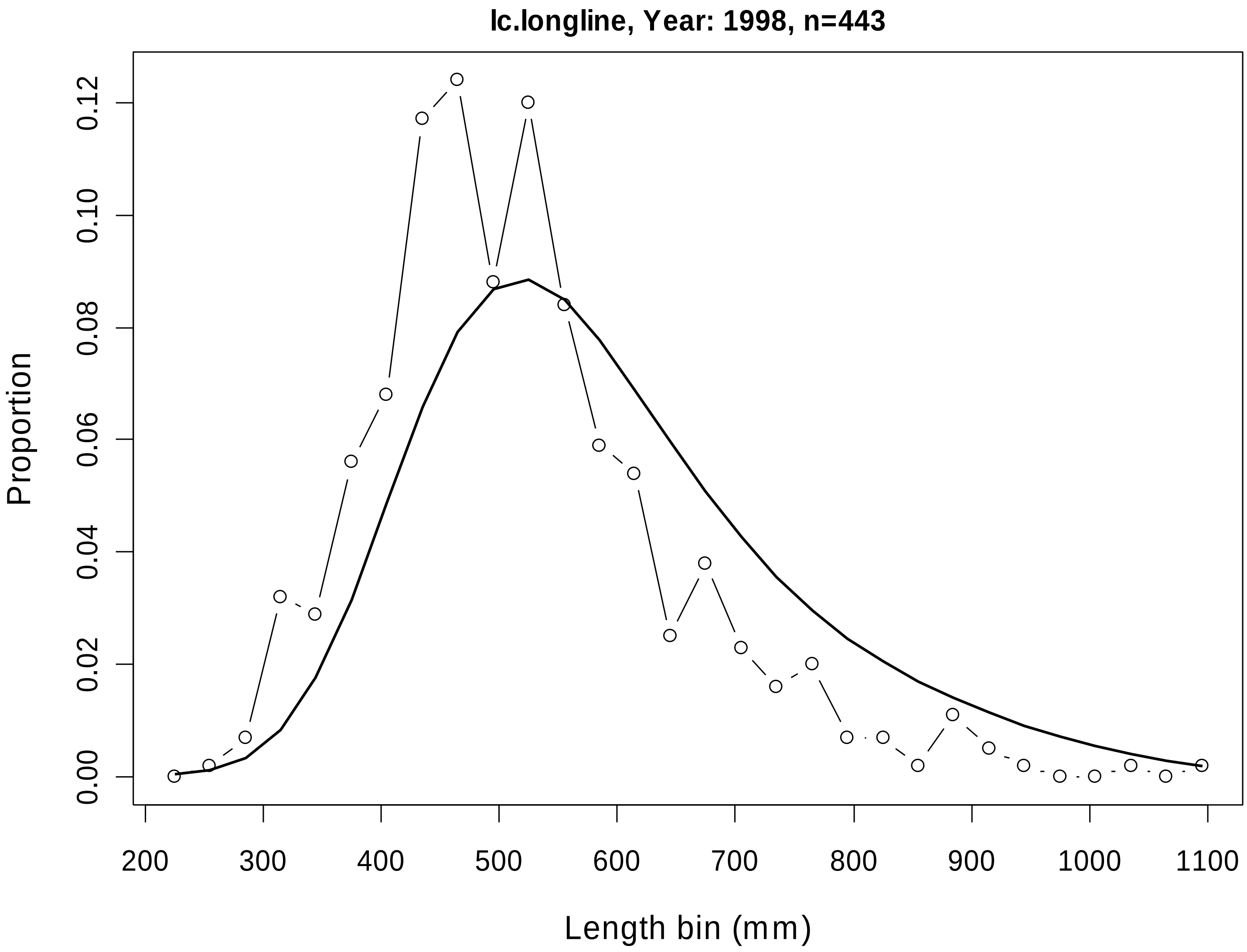
Snowy Grouper Model

ASPM Model with estimated initial biomass ratio



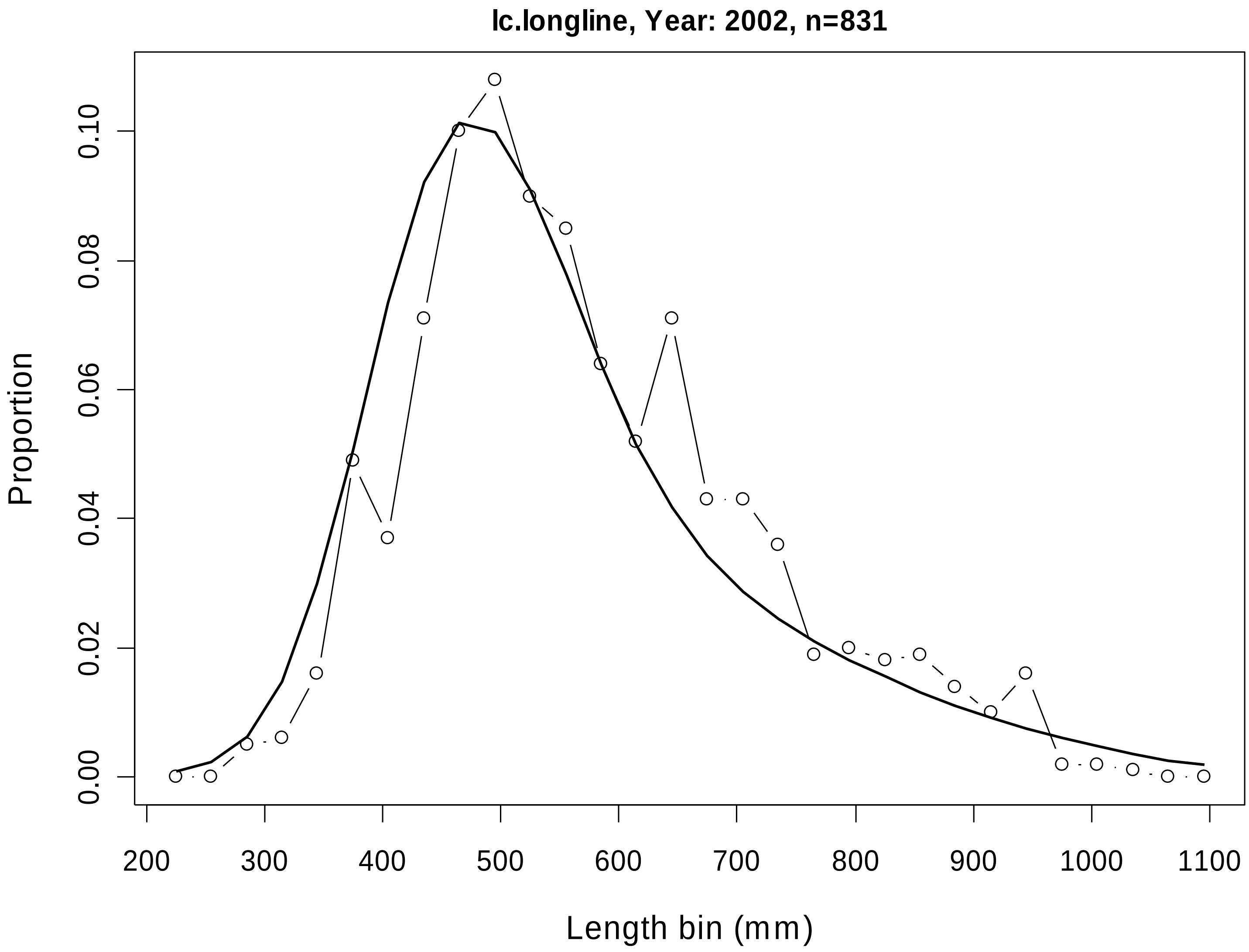
Snowy Grouper Model

ASPM Model with estimated initial biomass ratio



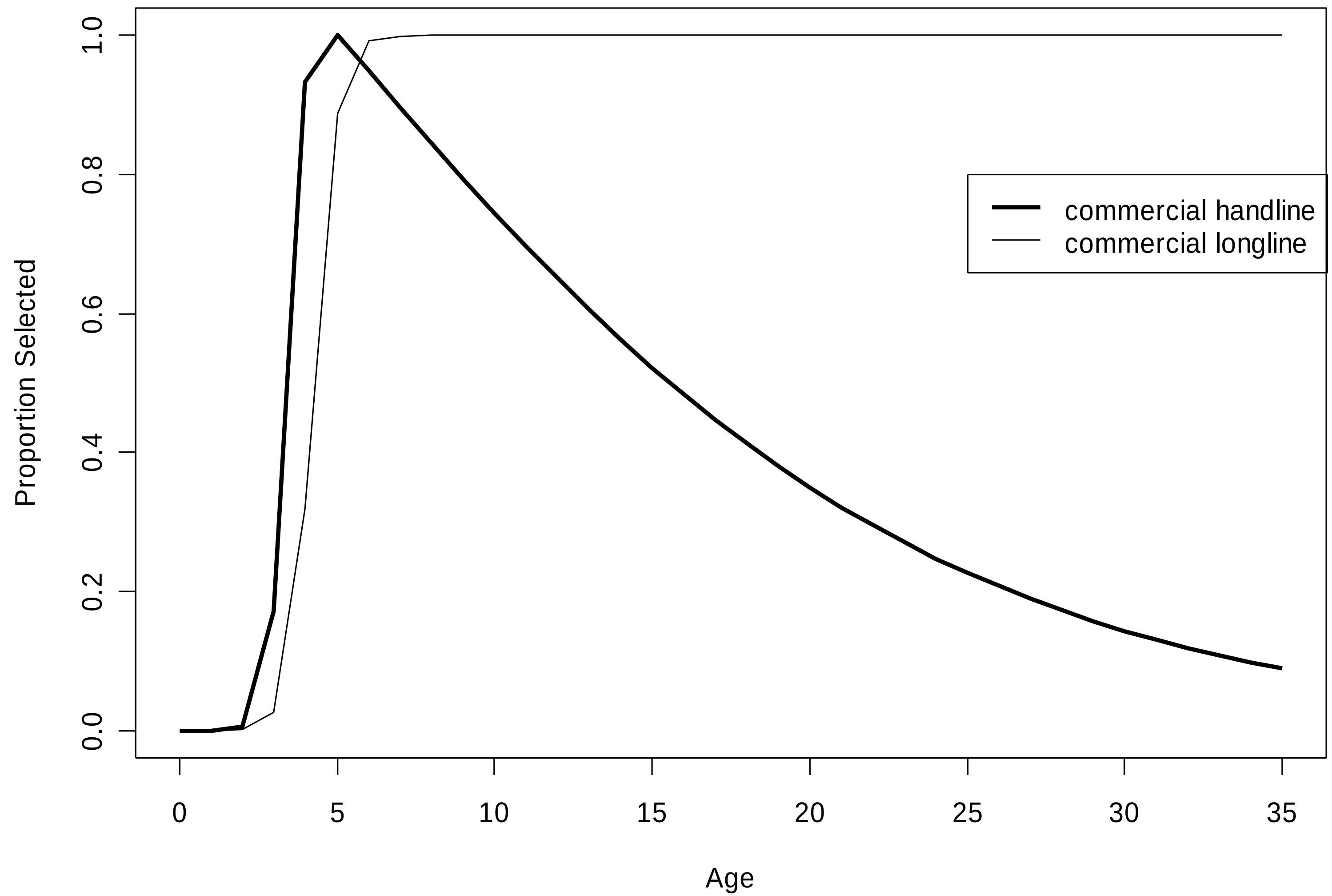
Snowy Grouper Model

ASPM Model with estimated initial biomass ratio



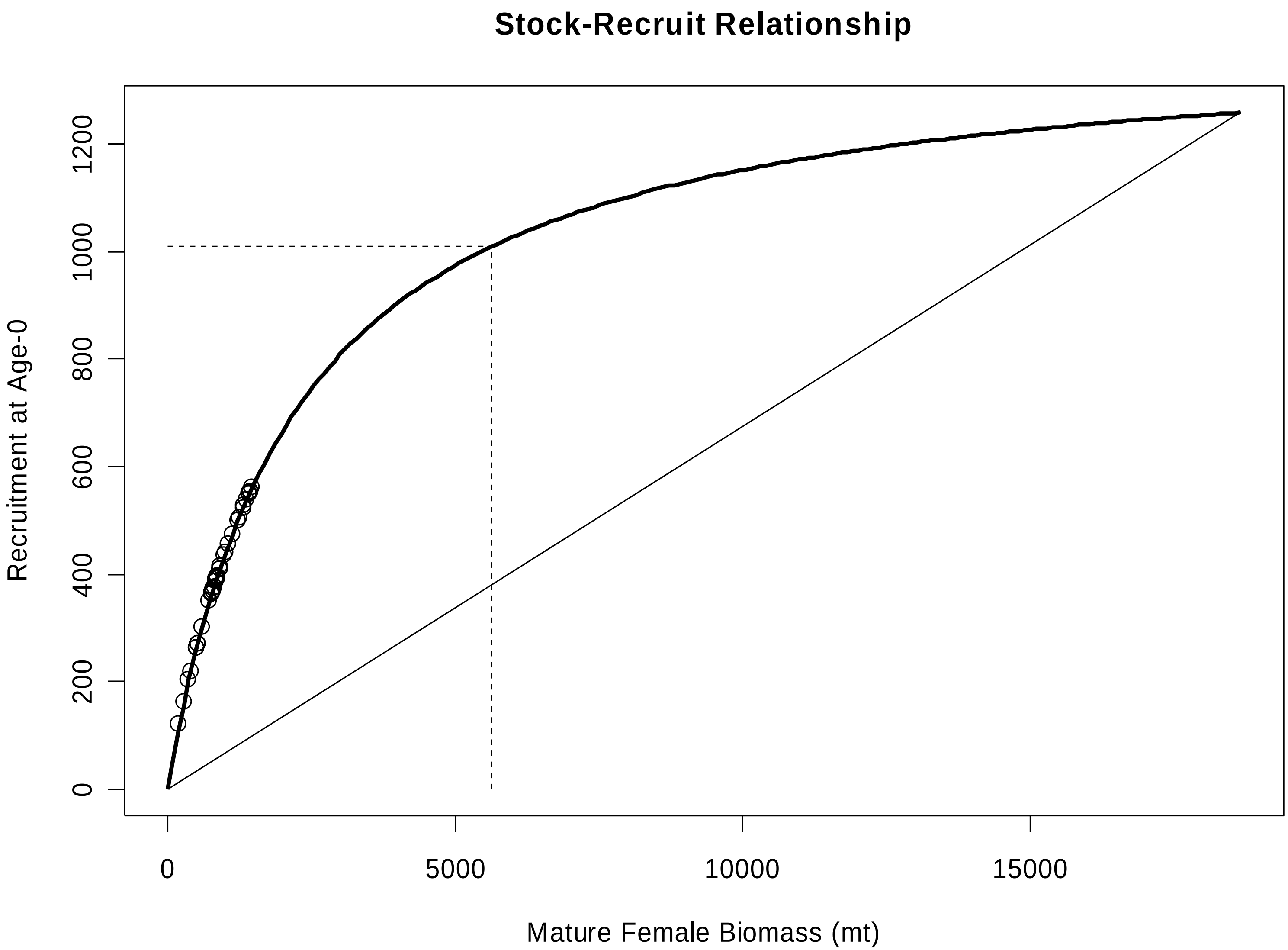
Snowy Grouper Model

ASPM Model with estimated initial biomass ratio



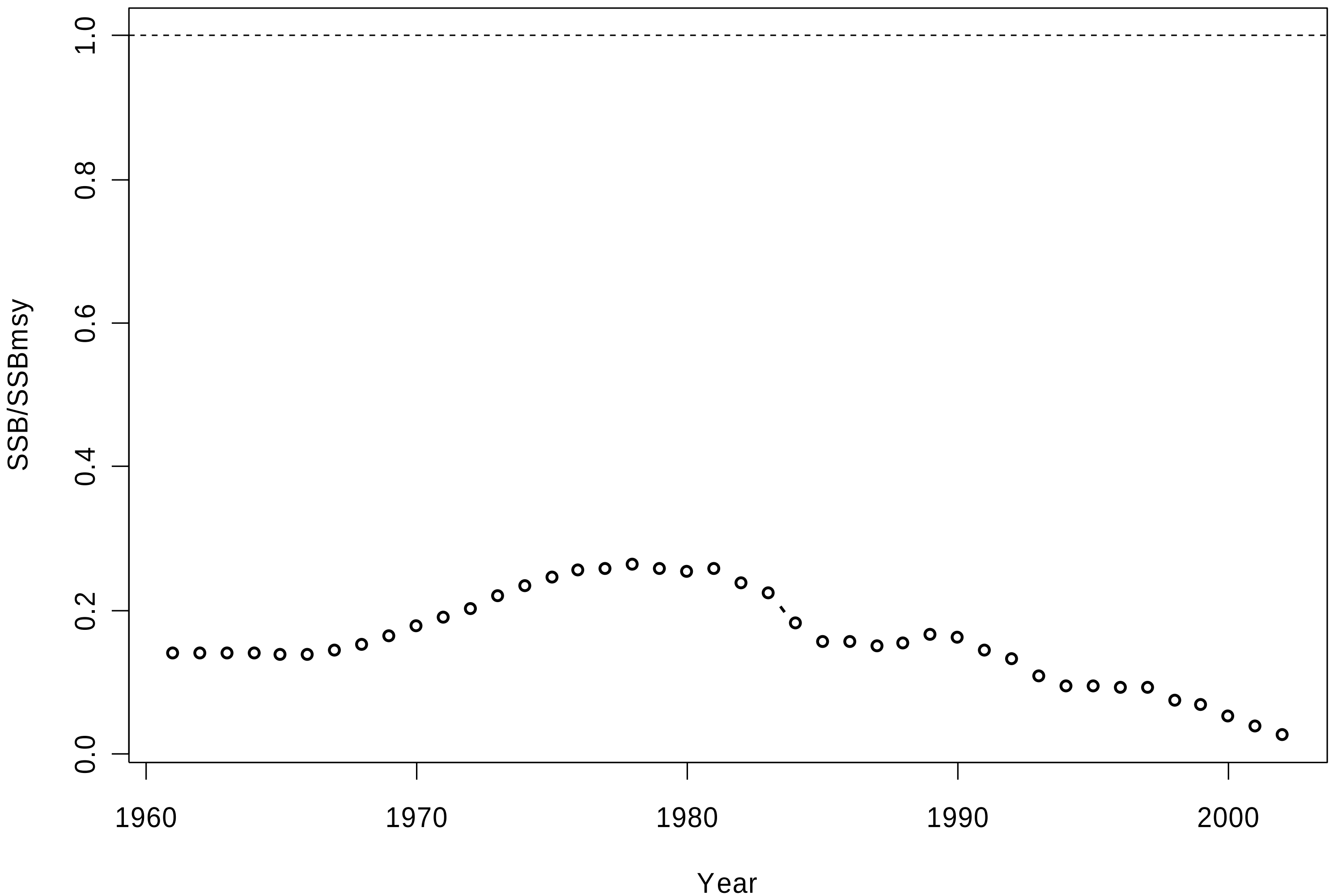
Snowy Grouper Model

ASPM Model with estimated initial biomass ratio



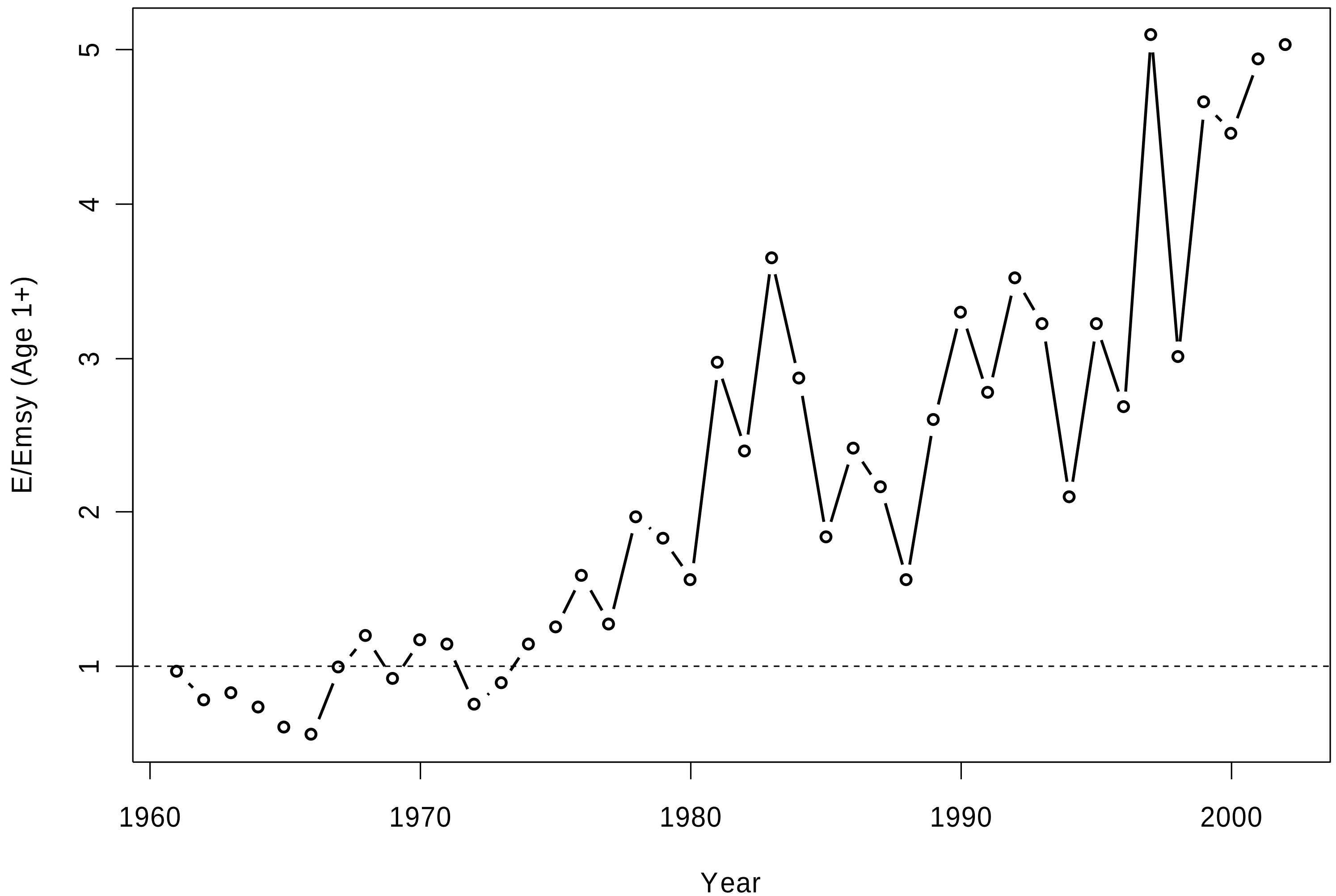
Snowy Grouper Model

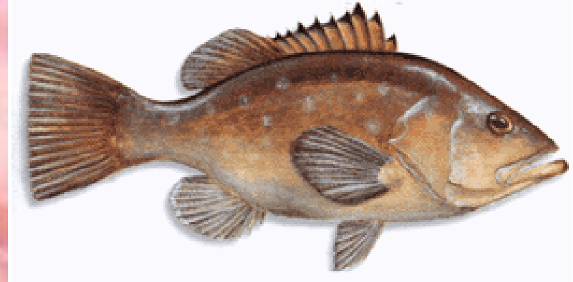
ASPM Model with estimated initial biomass ratio



Snowy Grouper Model

ASPM Model with estimated initial biomass ratio





THE END

SEDAR 4

Stock Assessment Report 1

Atlantic Deepwater Snapper - Grouper Complex

SECTION V. CIE Contractor Reports

Chair's Report of SEDAR 4 Review Panel
South Atlantic Snowy Grouper and Tilefish
July 26 – 29, 2004
Charlotte, NC

R. K. Mohn

Prepared for

CIE
University of Miami

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Synopsis/summary of Meeting

The Southeast Data, Assessment and Review (SEDAR) is a sequence of three workshops. This report is of the third of these, which is a technical, peer review of the previous two. The first workshop reviews and assembles the available data, while the second assesses the resource(s) and produces standard population parameters and benchmarks. The purpose of the third workshop is to assure quality and provide transparency.

The Review Workshop commenced on July 26, 2004. After introductions and opening remarks from John Carmichael (SEDAR Coordinator), the agenda was approved. Before commencing with the review, NMFS personnel provided an introduction to reference points and legal requirements within U.S. Fishery Management.

As neither of these stocks (snowy grouper and tilefish) had been fully assessed before, a fair amount of time was spent on the underlying data. The data for snowy grouper that were available, especially abundance indices, were limiting, which is weaker than the norm for assessments. The Panel’s discussion on the data focused on stock definition, aging and natural mortality. A presentation of the assessment model and results followed. The model chosen was a statistical catch-at-age model that fit length frequency, age frequency, gear selectively and abundance indices. Uncertainty in the results was assessed using a Monte Carlo/Bootstrap (MCB) approach. Clarifications and some additional analyses were requested. The requests that were feasible within the meeting were done promptly and well.

The data and analysis for tilefish were then presented to the Panel. Because the data and model were very similar in nature to the snowy grouper, fewer questions were posed. The tilefish data were weaker both in terms of quality and quantity than seen for the snowy grouper.

The Panel accepted both assessments as they were formulated in the Assessment Workshop. The snowy grouper was seen to have been fished down to some degree at successive locations and is currently estimated (median values) to be at less than 20% of SSBmsy. The tilefish SSB is slightly below SSBmsy.

Views on the Meeting Process

Process

The Review flowed well because of NMFS staff preparedness and the quality of the personnel in attendance. The dedication and application of the NMFS staff, Panel and observers meant that the Review concluded one day early. As well as performing review roles, the Panel provided technically innovative ideas and performed some analyses. The decision to adjourn a day early was reached early enough on Thursday that most of the attendees could leave that day. The few that could not stayed and worked on the draft Summary Report, for which I, as the Chair, am thankful.

The Panel was small which meant that it progressed fairly rapidly. It also contained sufficient technical expertise that the approach, data, model and analysis were easily assimilated. Although a small panel can move relatively quickly, it does not present the breadth of criticism and interpretation that a larger panel would. The details of the fishery and the implications of the assessments would have benefited from wider participation, especially from members of the industry. Wider participation would have meant that the data and models, as well as their assumptions and results, could have been put in the context of experience as a form of "ground truthing". This would have addressed the question "Do these results make sense?" from a number of points of view. It would also have meant that a wider variety of relevant questions might have been brought forward to direct future research and analyses. In summary, the Panel, NMFS personnel, and observers knew what was to be done and did it. The Panel did not become bogged down in back and forth argumentation or re-iteration of points of view.

During the review the Panel requested three sets of further analyses for snowy grouper and one set for tilefish. These requests were mostly exploratory into the models' behavior. Having a second meeting room available adjacent to the Review facilitated such analyses. As two stocks were being reviewed, one could be worked on while the other was being discussed, which provided the efficiency of some degree of parallel processing. Of course the downside is that fewer participants were available for the review.

Outcome

The outcome in terms of population status and biological advice was as good as could be expected given the data, and to a much lesser degree, analytical limitations. The implications of analytical limitations were not in terms of the stock status, but rather in terms of confidence in the stock status. Although not likely to affect the outcome, the diagnostics and arguments used in the selection of models and of the "initial" run could have been better developed and communicated. The outcome as described in the recommendations for future data and analysis was based on those provided by the Data and Assessment Workshops. The recommendations had been well thought out, although the Panel did add some observations and expanded detail.

The Data and Assessment documents were sufficiently well prepared that their outcomes were not amended in the Review. Reruns and related analyses suggested by the Panel were mainly to diagnose model performance.

The Panel's, and that of subsequent readers', ability to review the Workshop Reports was compromised in that details of analysis and discussion were lost through the multi-step process. One example is the definition of the "initial" runs for both stocks. During discussion at the Review, it was obvious that care had been taken in defining the initial runs, but the arguments were not captured in the written documentation. A second, and related, example was the determination of the parameter ranges used in the MCB analysis.

Materials provided

Background materials (Appendix B) in the forms of e-mailed files, a CD-ROM, and reprints were distributed before the Review. The SEDAR coordinator was helpful in assuring that the materials were received and readable. The reprints were about three inches thick, and many were never referred to during the review. Although the Data Workshop Report was received on a CD-ROM, a second edition of the Data Workshop Report was handed out at the Review, and it became the official version.

Some small confusion was occasioned by duplicate terms of reference for the Review Panel and the presence of two Data Workshop Summaries. Such updates are not surprising given the time constraints in this many-step process. The duplications did not materially affect the performance of the review.

Guidance provided

Guidance was provided in three manners: 1) printed material from SEDAR and CIE, 2) input from the SEDAR coordinator during the meeting, and 3) comments from various Panel members and observers. Both the formal and informal guidance were of the expected quality, i.e. focused and useful. The attendance of the SEDAR coordinator for the entire Review was valuable.

Other Observations

Technical

There are number of interrelated technical issues that deserve further comment. They are based on questions as to how the resource and fishery are qualitatively understood to act, how they are modeled, and what data are available to quantify this understanding.

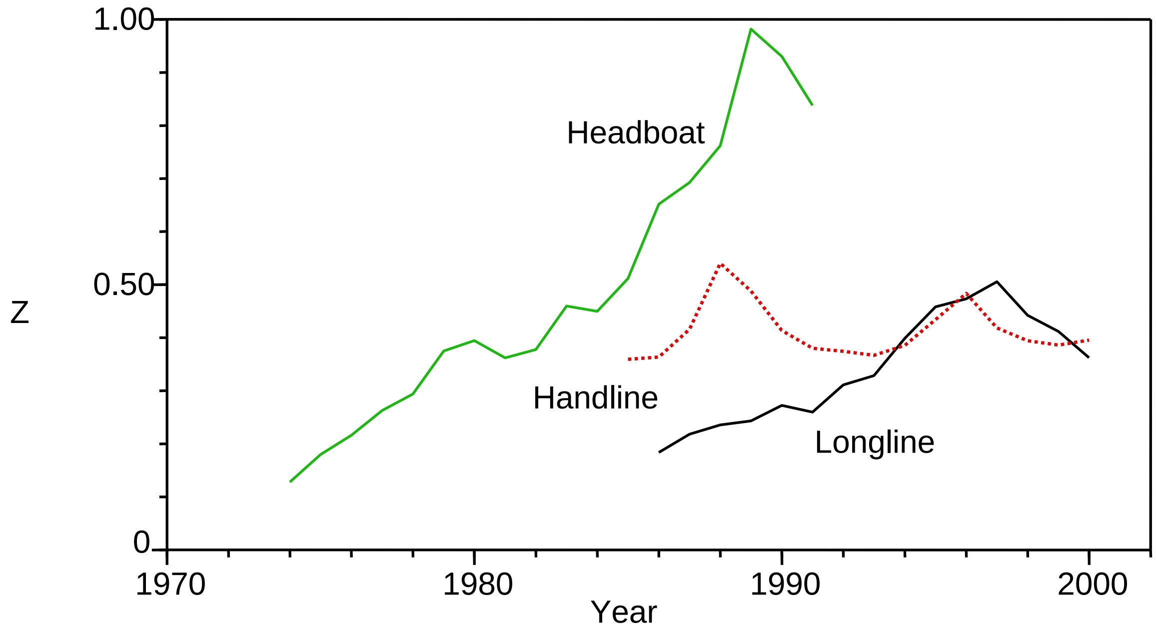
One example regards information on the spatial distribution of the resource. About a third of MCB runs for snowy grouper were clustered in a (parameter) region characterized by high biomass and low fishing mortality (refer to the figure in Appendix C). The Assessment Workshop, and subsequently the Review Panel, both deemed these results to be unrealistic. Data were not available for the Panel to take this qualitative definition of "unrealistic" to a quantitative basis. Furthermore, it was suggested that the snowy grouper was successively fished out as new concentrations were found. If plotted by decade, for instance, aggregated, MARMAP data with expanding symbols might provide a stronger basis for this assertion. If this could be done, the length frequency and abundance data might be open to different interpretation. I do not know what other geo-referenced data are available to aid in this sort of exploration.

When embarking on new assessments such as these, a wide variety of modeling approaches is desirable; it is also expensive in terms of time needed to perform the analysis. Conflicts between divergent approaches stimulate debate and allow one interpretation to be compared to another. Resources that have a history have winnowed out inappropriate analyses and they need not be reported. The snowy grouper and tilefish assessments focused on one modeling framework. The model chosen for both assessments was a highly parameterized (relative to the data available) statistical catch-at-age model. The snowy grouper model had just over 200 parameters while the tilefish had about 150 parameters. More parametrically parsimonious models should have been developed as well. Besides serving as a contrast to the bigger model, they often focus on a single aspect of the resource and are more easily communicated to clients. At the end of the day, the best description must be chosen, but the insights given by several models adds value to the analysis and a broader understanding of the uncertainty.

Furthermore, the highly parameterized model space meant that it was difficult to interpret the cause of the bimodal clusters of the MCB runs for snowy grouper. Panel requests for simpler runs, having about one-tenth the number of parameters, aided the understanding of the bimodal results.

It is noted that simpler production models had been attempted at the Assessment Workshops for both stocks but had (correctly) been dismissed. As these production models depend upon abundance data, which were not considered to be highly informative, they could not be expected to perform well.

Within the snowy grouper catch-at-age model, a conflict was seen between the length frequency data, which suggested a reduced stock in which the resource, especially older fish, had been significantly depleted, and the abundance data, which suggested some degree of recovery since about 1990 (see Figure 13 of the Assessment Report III.A). In order to illustrate the utility of simpler models of the data, I tried a catch curve analysis and presented it to the Panel. The results are summarized in the following figure below. The data were the headboat, handline and longline length frequency data for snowy grouper. The data were binned into 4-year blocks to smooth the results. It is reiterated that the results of this crude analysis are just meant as illustrations and are not an alternative analysis to the Assessment Workshop Report.



The longest time series, headboats, shows a low Z initially that continues to increase until about 1990. Recent headboat data were too sparse to continue the analysis past the early 1990s. This could be interpreted as the fishing down of a virgin resource. In most fishery models there is an implicit assumption that the resource is homogenous; local dynamics are assumed to average out. However, when the handline data were introduced, it was mentioned that they were affected by the discovery of two hot spots, known as Adrian's Mark and Snowy Wreck. The reduction in the early 1990s and again in the late 1990s in the handline Z's is consistent with the timing of the discoveries. Finally, the longline Z's start low in the late 1980s and peak a decade later, again suggesting a fishing down process. I believe that simpler analyses of this type are a constructive complement to the full model. When I presented these results, NMFS staff mentioned that a similar analysis had been done, but that it had been dropped. A record of these sorts of analyses would help readers and future assessors of snowy grouper. The development of a spatially heterogeneous model is probably well beyond what the available data could support, even in the sense of scenario sensitivity.

Other Comments

The Panel was advised that it did not need to prepare an Advisory Document. The reasons for this were not clear. Is it meant to be a precedent and review panels will be similarly instructed in the future? While it does represent a time savings for a process having non-trivial costs, it can mean that subtleties and nuances may be lost between the technical review and the Advisory Summary.

As chair, I greatly appreciated the participation of the second CIE reviewer, especially one as experienced and statistically sophisticated as Dr. Chris Francis. As well as participation in the review, having a second independent panelist aided the chair with both the flow of the meeting and some specifics of summary document preparation.

Finally, I would like to commend the developers of and participants within the SEDAR framework. I happened to have chaired the first assessment review for this region and am impressed at how rapidly SEDAR has attained a mature and operational assessment process.

Appendix A. Statement of Task

Note that the Terms of Reference in this Appendix differ slightly from those provide by the SEDAR Coordinator which are presented in Appendix B. The Panel was informed that those in Appendix B were drafted after those listed below, and the more recent Terms were followed.

Consulting Agreement between the University of Miami and Dr. Robert Mohn

General

South East Data, Assessment, and Review (SEDAR) is a joint process for stock assessment and review of the South Atlantic, Gulf of Mexico, and Caribbean Fishery Management Councils; NOAA Fisheries, SEFSC and SERO; and the Atlantic and Gulf States Marine Fisheries Commissions. SEDAR is organized around three workshops: data, assessment, and review. Input data are compiled during the data workshop, population models are developed during the assessment workshop, and an independent peer review of the data and assessment models is provided by the review workshop. The peer review panel is composed of stock assessment experts, other scientists, and representatives of council, fishing industries, and non-governmental conservation organizations. Final SEDAR documents include a stock assessment report produced by the data and assessment workshops, a review panel report evaluating the assessment (drafted during the review panel workshop), a review panel report that summarizes the peer-reviewed assessment results, and collected stock assessment documents considered in the SEDAR process.

NMFS-SEFSC requests the assistance of two assessment scientists from the CIE: one to serve as Chair and one to serve as a technical reviewer for the SEDAR 4 Review Panel that will consider assessments for two species from the South Atlantic deepwater snapper-grouper complex: tilefish and snowy grouper.

These species are within the jurisdiction of the South Atlantic Fishery Management Council and respective southeastern states. The review workshop for SEDAR 4, South Atlantic deepwater complex stock assessments, will take place at the Holiday Inn Center City, Charlotte, NC from July 26 (beginning at 2:00 pm) through July 30, 2004 (ending at 1:00 pm). Meeting materials will be forwarded electronically and in hard copy. Please contact John Carmichael (SEDAR Coordinator; 843-571-4366 or John.Carmichael@safmc.net) for additional details.

Hotel arrangements

Holiday Inn Center City, 230 N. College Street, Charlotte, NC 28202. Phone: (704) 335-5400, (800) 465-4329; Fax (704) 376-4921. Please make reservations by June 16 and to receive the ‘SEDAR Workshop’ group rate of $91.94 (including tax).

SEDAR Assessment Review Panel Tasks

The SEDAR Assessment Review Panel will evaluate the tilefish and snowy grouper stock assessments, input data, assessment methods, and model results as put forward in stock assessment reports. The Assessment Review Panel will:

1. Evaluate the adequacy and appropriateness of all data used in the assessment, and state whether or not the data are scientifically sound and the best available.
2. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population parameters such as abundance, biomass, and exploitation; state whether or not the methods are scientifically sound and the best available;
3. Recommend appropriate or best estimated values of population parameters such as abundance, biomass, and exploitation.
4. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population benchmarks (MSY, Fmsy, Bmsy, MSST, MFMT, etc.). State whether or not the methods are scientifically sound and the best available,
5. Recommend appropriate values for population benchmark criteria.
6. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound and the best available.
7. Recommend probable values of future population condition and status.
8. Develop recommendations for future research for improving data collection and the assessment.
9. Prepare a Peer Review Panel Consensus Summary summarizing the peer review panel's evaluation of the tilefish and snowy grouper stock assessments and addressing the Terms of Reference. (Drafted during the Assessment Review Panel workshop with a final report due three weeks after the workshop ends.)
10. Prepare a Stock Advisory Report summarizing the stock assessments. (Drafted during the Assessment Review Panel workshop with a final report due three weeks after the workshop ends.)

The Assessment Review Panel's primary duty is to review the assessments presented. In the course of this review, the Chair may request a reasonable number of sensitivity runs, additional details of the existing assessments, or similar items from technical staff. However, the review panel is not authorized to conduct an alternative assessment or to request an alternative assessment from the technical staff present. If the review panel finds that an assessment does not meet the standards outlined in Items 1 through 4, above, the panel will outline in its report the remedial measures that the panel proposes to rectify those shortcomings.

The Review Panel Report is a product of the overall Review Panel, and is NOT a CIE product. The CIE will not review or comment on the Panel's report, but shall be provided a courtesy copy, as described below under "Specific Tasks." The CIE product to be generated is the Chair's report, also discussed under Specific Tasks.

Specific Tasks

The CIE designee shall serve as Chair of a SEDAR Stock Assessment Review Panel workshop for SEDAR 4, South Atlantic tilefish and snowy grouper, July 26 - 30, 2004 (See attached agenda.). The workshop panel shall review stock assessments for South Atlantic tilefish and snowy grouper in the jurisdiction of the South Atlantic Fishery Management Council and applicable southeastern states.

It is estimated that the Chair's duties will occupy a total of 17 days - several days prior to the Review Panel meeting for document review; four days at the SEDAR meeting; several days following the meeting to ensure that the final documents are completed, and several days to complete a Chair's report for the CIE.

Roles and responsibilities:

(1) Prior to the Assessment Review Panel workshop the Chair shall be provided with the stock assessment reports and associated documents for South Atlantic tilefish and snowy grouper. The Chair shall read and review all documents to gain an in-depth understanding of the stock assessments under consideration and the data and information considered in the assessments.

(2) During the Assessment Review Panel workshop the Chair shall control and guide the meeting, including the coordination of presentations, discussions, and document flow.

(3) The Chair shall facilitate the preparation and writing of the Peer Review Panel Consensus Summary (Item 9 above) and a Stock Advisory Report (Item 10 above). Review panel members, SEFSC staff and stock assessment scientists present at the meeting will assist the Chair as needed. The Chair shall be responsible for the editorial content of the two review panel reports, and the Chair shall be responsible for overseeing that both reports are produced and distributed to appropriate contacts on schedule (see "Final Reports" below).

(4) The SEDAR coordinator shall assist the Assessment Review Panel Chair prior to, during and after the meeting to ensure that all final documents with results are distributed in a timely fashion.

(5) No later than August 20, 2004, the Chair shall submit a written Chair's Report[1] addressed to the "University of Miami Independent System for Peer Review," and sent to Dr. David Sampson, via e-mail to David.Sampson@oregonstate.edu, and to Mr. Manoj Shivlani, via e-mail to mshivlani@rsmas.miami.edu. See Annex 1 for the contents of the Chair's report.

Workshop Final Reports

The Chair shall send final review workshop reports to the University of Miami Independent System for Peer Review, Dr. David Die via email to ddie@rsmas.miami.edu.

Final workshop reports (in Word or WordPerfect format and in hardcopy) shall also be sent to:

Nancy Thompson, NMFS Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, FL 33149 (email, Nancy.Thompson@NOAA.gov)

Larry Massey, 101 Nina Drive #302, Virginia Beach, VA 23462 (email, Larry.Massey@NOAA.gov)

John Carmichael, SAFMC, One Southpark Circle, Suite 306, Charleston, SC 29407 (email, John.Carmichael@safmc.net)

[1] The written Chair's report will undergo an internal CIE review before it is considered final. After completion, the CIE will create a PDF version of the Chair's report that will be submitted to NMFS and the consultant.

Robert Mahood, South Atlantic Fishery Management Council, One Southpark Circle, Suite 306, Charleston, SC 29407 (email, Robert.Mahood@safmc.net)

For Additional Information or Emergency:

SEDAR contact: John Carmichael, One Southpark Circle, Suite 306, Charleston, SC 29407. Phone: 843-571-4366; cell phone (843) 224-4559. Email: John.Carmichael@safmc.net.

Draft Agenda
SEDAR 4: South Atlantic tilefish and snowy grouper
Review Workshop
July 26-30, 2004
Holiday Inn Center City, Charlotte NC

<u>Monday, July 26, 2004</u>		
2:00 – 5:30	1. Introduction	SEDAR Coordinator
	2. Review of Agenda	SEDAR Coordinator
	3. Tilefish Assessment	
	3.1 Assessment Presentation	AW Representatives
<u>Tuesday, July 27, 2004</u>		
8:30 – 12:00	3.2 Assessment Discussion	Chair
12:00 – 1:30	Lunch	
1:30 – 5:30	3.2 (Continued) Assessment Discussion	Chair
<u>Wednesday, July 28, 2004</u>		
8:30 – 12:00	4. Snowy Grouper Assessment	
	4.1 Assessment Presentation	AW Representatives
12:00 – 1:30	Lunch	
1:30 – 5:30	5. Draft Panel Reports – Advisory Report	Chair
<u>Thursday, July 29, 2004</u>		
8:30 -12:00	5. Draft Final Reports – Consensus Summary	
12:00 – 1:30	Lunch	
1:30 – 5:30	5. Draft Final Reports – Advisory Report	
<u>Friday, July 30, 2004</u>		
8:30 – 1:00	Final Review of Panel Reports	Chair
1:00	Adjourn	Chair

ANNEX I: Contents of Chair Report

1. Synopsis/summary of the meeting – to provide context for the comments rather than to rewrite the summary report, which is a product of the meeting and not a CIE product.

2. Views on the meeting process, including recommendations for improvements on:
   - The meeting process itself;
   - The outcome of the meeting;
   - Materials provided for the meeting, including timeliness, relevance, content, and quality;
   - The guidance provided to run the meeting.

3. Other observations on the meeting process.

4. Appendices, including:
   - Statement of Work;
   - Bibliography of the materials provided for the meeting;
   - Summary report (if available at the time of report submission).

Appendix B. Materials Provided

The following materials by the SEDAR Coordinator. Both paper copies and a CD-ROM were provided

1. Terms of Reference and Panel Instructions for SEDAR 4 Review Workshop, Atlantic Deepwater Snapper-Grouper: Tilefish and Snowy Grouper (see below)
2. SEDAR 4 Data Workshop Summary, Deep Water Complex, November 3-7, 2003
3. Assessment of Snowy Grouper (*Epinephelus niveatus*) in the South Atlantic Fishery Management Council Management Area. Section III.A of SEDAR Stock Assessment Report.
4. Assessment of Tilefish, *Lopholatilus chamaeleonticeps,* in the South Atlantic Fishery Management Council Management Area. Section III.B of SEDAR Stock Assessment Report.
5. Documents from SEDAR4 Atlantic and Caribbean Deepwater Snapper Grouper (see below)
6. Reference papers from SEDAR4 Atlantic and Caribbean Deepwater Snapper Grouper (see below)

Terms of Reference and Instructions for the Review Panel

I. Terms of Reference

The SEDAR Assessment Review Panel will evaluate the tilefish and snowy grouper stock assessments, input data, assessment methods, and model results as put forward in stock assessment reports. The Assessment Review Panel will:

1. Evaluate the adequacy and appropriateness of all data used in the assessment and state whether or not the data are scientifically sound;
2. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population parameters such as abundance, biomass, and exploitation and state whether or not the methods are scientifically sound;
3. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population benchmarks (*e.g., MSY, Fmsy, Bmsy, MSST, MFMT, or their proxies*) and state whether or not the methods are scientifically sound;
4. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound;

5. Ensure that all available required assessment results (*as listed in the SEDAR Stock Assessment Report Outline*) are clearly and accurately presented in the Stock Assessment Report and that such results are consistent with the Panel's decisions regarding adequacy, appropriateness, and application of the data and methods;

6. Evaluate the performance of the Data and Assessment Workshops with regards to their respective Terms of Reference, and state whether or not the Terms of Reference for those previous workshops are adequately addressed in the Stock Assessment Report;

7. Review the assessment workshop's recommendations of future research for improving data collection and the assessment, and make any additional recommendations warranted;

8. Prepare a Peer Review Consensus Summary summarizing the Panel's evaluation of the tilefish and snowy grouper stock assessments and addressing each Term of Reference. (Drafted by the Panel during the Review Workshop with a final report due three weeks after the workshop ends.);

9. Prepare a Stock Advisory Report summarizing the stock assessments. (Drafted during the Assessment Review Panel workshop with a final report due three weeks after the workshop ends.).

II. Review Panel Instructions

The Assessment Review Panel is charged with reviewing the technical aspects of the presented stock assessment and making judgements regarding the assessment that are based solely upon scientific merit. At no point during the deliberations should the Review Panel consider the implications that the assessment and its results may have upon management decisions or resource users. This is not to imply in any way that such considerations are not important, but rather to acknowledge several important facts: (1) consideration of management impacts is beyond the scope of the charge to the Review Panel, (2) SEDAR specifically strives to separate management considerations from assessment decisions, (3) Review Panel participants are selected based on technical, biological, and assessment knowledge, not social and economic knowledge of a fishery, (4) consideration of social and economic consequences is specifically mandated to the Council and various Council Committees composed of experts qualified to evaluate the social and economic consequences of management actions.

The Assessment Review Panel is discouraged from holding formal votes. Decisions should be based upon the unanamious consenus of the entire panel. In the event that the Chair feels that all avenues for agreement have been exhausted and unanimous consensus is not achievable, the Chair may instruct that the majority opinion be reflected in the report and allow the minority opinon holders to prepare and submit a minority report.

The Assessment Review Panel's primary duty is to review the assessments presented. In the course of this review, the Chair may request a reasonable number of sensitivity runs, additional details of the existing assessments, or similar items from technical staff. However, the review panel is not authorized to conduct an alternative assessment nor to request an alternative assessment from the technical staff present.

If the review panel finds that an assessment does not meet the standards outlined in Items 1 through 6, above, the panel will outline in its report the remedial measures to be taken by the assessment analysts to rectify those shortcomings.

Review Panel members are expected to participate in the entire workshop from start to finish. The supporting Council's strongly discourage panel members from leaving early. Panelists should expect that the Workshop will require the entire time alloted and plan travel accordingly. To this end, workshops are scheduled for an afternoon start and early adjournment to reduce the need for weekend travel.

Documents from SEDAR4 Data Workshop

#	Title	Author(s)
SEDAR4-DW-01	Indices of Abundance from Commercial Logbook Data: South Atlantic stocks	Shertzer, K.; McCarthy, K.
SEDAR4-DW-02	MRFSS Landings and Length Data Summary for the South Atlantic	Vaughan, D. S.
SEDAR4-DW-03	General Canvass Landings Statistics for the South Atlantic Region	Poffenberger, J.
SEDAR4-DW-04	Summary information on commercial fishing operations in Puerto Rico from 1969-2001 and reporting rates needed to adjust commercial landings.	Cummings, N. Matos-Caraballo, D.
SEDAR4-DW-05	Summarized reported commercial landings in Puerto Rico from 1969-2001 with specific notes on the silk snapper landing category.	Cummings, N. Matos-Caraballo, D.
SEDAR4-DW-06	Not used	
SEDAR4-DW-07	Information on the general biology of silk and queen snapper in the Caribbean.	Cummings, N
SEDAR4-DW-08	Preliminary Estimation of Reported Landings, Expansion Factors and Expanded Landings for the Commercial Fisheries of the United States Virgin Islands**.**	Valle-Esquivel, M. Diaz, G.A.
SEDAR4-DW-09	Preliminary species composition estimates of TIP samples from commercial landings in the U.S. Virgin Islands.	Diaz, G. A. ; Valle-Esquivel, M.
SEDAR4-DW-10	Standardized Catch Rates of Silk Snapper, Lutjanus vivanus, from the St. Croix .S.Virgin Islands Handline Fishery during 1984 - 1997.	Cass-Calay, S.L.; Valle-Esquivel, M.
SEDAR4-DW-11	Standardized Catch Rates of Queen Snapper, Etelis oculatus, from the St. Croix U.S. irgin Islands Handline Fishery during 1984 – 1997	Cass-Calay, S.L.; Valle-Esquivel, M.
SEDAR4-DW-12	Discard Estimates for the South Atlantic Region.	Poffenberger, J.
SEDAR4-DW-13	Size Frequency Data from the Trip Interview Program, South Atlantic Region	Poffenberger, J.
SEDAR4-DW-14	Size frequency distributions of silk snapper and queen snapper from dockside sampling of commercial landings in the U.S. VI	Diaz, G. A.; Valle-Esquivel, M.
SEDAR4-DW-15	Preliminary information on the recreational catch of silk, queen, and blackfin snapper, from 2000 through 2002 in Puerto Rico with additional notes on sand tilefish	Cummings, N.; Slater, B.; Turner, S.
SEDAR4-DW-16	Preliminary analysis of some deepwater species in the South Atlantic headboat survey data.	Williams, E.; Dixon, B.
SEDAR4-DW-17	Age, growth and reproductive biology of the blueline tilefish, *Caulolatilus microps*, along the southeastern coast of the United States, 1982-99.	Harris, P. J.; Wyanski, D.M.; Powers, P.T.
SEDAR4-DW-18	Age, growth and reproduction of tilefish, Lopholatilus chamaeleonticeps, along the southeast Atlantic coast of the United States, 1980-87 and 1996-98.	Palmer, S.M.; Harris, P.J.; Powers, P. T.

SEDAR4-DW-19	Deep-water species report. South Carolina and Georgia.	Low, B.
SEDAR4-DW-20	South Atlantic Snapper-Grouper Regulatory Overview	Carmichael, J.
SEDAR4-DW-21	Summary of MARMAP sampling	Anon.
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SEDAR4-DW-23	Preliminary size frequency information for silk, queen, and blackfin snapper from the Puerto Rico commercial fisheries from 1985 through 2002 with additional notes on sand tilefish	Cummings, N.J. Phares, P
SEDAR4-DW-24	Brief summary of SEAMAP data collected in the Caribbean Sea from 1975 to 2002	Ingram, W.
SEDAR4-DW-25	Yellowedge Grouper age-length key	Bullock & Godcharles
SEDAR4-DW-26	Estimating catches and fishing effort of the southeast united states headboat fleet, 1972-1982	Dixon & Huntsman
SEDAR4-DW-27	Trends in Catch Data and Estimated Static SPR Values for Fifteen Species of Reef Fish Landed along the Southeastern United States, February 1998.	Potts, Burton & Manooch
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Appendix C. Panel Consensus Report

Snowy Grouper and Tilefish
Peer Review Consensus Summary

Report prepared for the
South Atlantic Fishery Management Council
National Marine Fisheries Service

Edited by R. Mohn for the
Southeast Data and Assessment Review
July 26 – 29, 2004
Charlotte, NC

Executive summary

The Southeast Data, Assessment and Review (SEDAR) is a sequence of three workshops. The fist is a Data Workshop (DW) which is charged with compiling and evaluating data that may be used for resource assessment. Its products, if judged to be adequate, are passed on to the Assessment Workshop (AW) where models are developed and assessment advice produced. The third step is an independent peer review workshop which assesses the technical merits of the data, analysis, stock status and prognosis. This Review Workshop (called the Panel hereafter) assures quality and transparency in the generation of the biological basis of management advice.

The Data Workshop reviewed eight deepwater species and concluded that there were sufficient data and personnel resources to assess two of them, snowy grouper (*Epinephelus niveatus*) and tilefish (*Lopholatilus chamaeleonticeps*. Neither of these stocks had been assessed before. The Panel concluded that the data were weaker than those generally expected in fisheries assessments, especially for the tilefish. For both species the model chosen was forward-projecting statistical catch-at-age model. The models and analysis were well developed and presented. The population benchmarks are scientifically sound considering the limitation of the data.

The Panel also accepted, with some additional comments, the recommendations from both the DW and AW.

Introduction.

The format of this report requires some explanation. Because the Panel's terms of reference (Appendix A) included the reviews of both the Data Workshop (DW) and Assessment Workshop's (AW) terms of reference care has been taken to assure that all of the items were addressed. For this reason, the portion of report dealing with the DW follows their terms of reference in order form rather than narrative to facilitate the tracking the essentially hierarchical terms of reference. For convenience, the Panel's specific terms of reference are in the text and are in italics. The data and models used for snowy grouper and tilefish were quite similar, so the Panel decided to address each under each term of reference. When the observation was not applicable to both species, than the appropriate species was named.

Review of The Panel's Deliberations.

1. *Evaluate the adequacy and appropriateness of all data used in the assessment and state whether or not the data are scientifically sound*;

The terms of reference for the Data Workshop are given in Appendix C. The following section follows them in order.

A clear unit stock definition was not provided for either species from the data workshop. A single South Atlantic stock is apparently assumed for snowy grouper and for tilefish. This assumption is considered reasonable, based on the likelihood of restricted movement of adults in or out of the region, as well as the likely broad dispersal of their planktonic larvae. Modeling of the dispersal of other snapper and grouper larvae has suggested both local and long-distance transport of larvae prior to settlement. Future assessments should consider whether to include the snowy grouper and tilefish from the Gulf of Mexico or Mid-Atlantic because of possible larval diffusion.

> DW2. Evaluate the quality and reliability of life-history information (Age, growth, natural mortality, reproductive characteristics); develop models to describe growth, maturation, and fecundity by age, sex, or length as appropriate.

The Data workshop report provided life history data for eight deepwater species. The Panel only considered information related to snowy grouper and tilefish.

<u>Age and growth</u>
Aging differences between MARMAP and the NMFS Beaufort Lab indicate questions remain regarding age determination protocols, the validity of age-related data, and their use in age-structured models. Ages from bomb-radiocarbon indicate that the MARMAP ages are likely too low. However, the Assessment workshop concluded that NMFS' ages used in the assessments were preferable for determining von Bertalanffy growth curves.

Snowy Grouper: While age composition data were limited, they were important in determining selectivities by fishing sector, but were downweighted in the fitting process to account for the uncertainty involved.

Tilefish: Tilefish age compositions do not appear consistent with the length compositions, and are not fit well by the model. The RW recommended a sensitivity run in which tilefish age composition data are not included in the fitting process (objective function).

<u>Natural mortality</u>
The Assessment workshop used the shape coefficient for ocean fish (-0.305), and it's associated confidence interval (-0.351,-0.257), from Lorenzen (1996) and scaled the series such that the proportion surviving at the oldest observed age (35 and 54 years for snowy grouper and tilefish, respectively) was 1.4%. This value of 1.4% came from a re-analysis of Hoenig's (1983) earlier work with total mortality and maximum ages. The Review Panel acknowledges that this approach is a proper step towards capturing the idea that it is unlikely that natural mortality is constant across all ages. However, the Panel noted that the confidence intervals used in the Lorenzen model for ocean fish regarding the shape coefficient may be too narrow when applied to a specific species. Literature supports the use in the sensitivity analysis of values ranging from 0.1% to 5% surviving to the observed maximum age. The Panel noted that it would be more appropriate to calculate Hoenig's total mortality taking sample size into account, but the analyst responded that the dome-shaped recruitment to sampling gear means selectivity confounds natural mortality, so one cannot tease them apart when looking at the descending limb of the curve. Panel members questioned the resulting distributions of natural mortality at age, especially the relatively narrow range of values at older ages. Lorenzen's method may be more realistic in capturing the variation in natural mortality by age; however, the question as to whether the added realism outweighs the additional assumptions and complexity needs to be investigated. Moreover, total mortality (Z) and natural mortality (M) are confounded when estimated from an observed maximum age derived from a fished stock.

The Panel conducted a simulation exercise to examine the maximum age expected to be observed from a population following a Lorenzen natural mortality pattern versus a population following a constant natural mortality pattern because of differences in the implied number of fish still alive after the maximum observed age in the two populations. The constant natural mortality was set such that the two equilibrium populations had the same proportion of fish alive at age 54. Samples of 100 fish were randomly sampled from each population and the maximum age in each sample determined. There were 10,000 random samples collected from each population. Comparison of the distribution of maximum age from the samples of the two populations showed that the Lorenzen population had a larger maximum age than the constant M population. This implies that the Lorenzen M cannot be scaled to the same proportion alive at a given age as the constant M to produce an equivalent expected maximum age observed. The Panel recommends further analyses be conducted to determine an appropriate scaling for Lorenzen M vectors to produce an estimated maximum age equivalent to the constant M assumption.

The Panel asked NMFS staff to conduct a trial run of the model using constant mortality, in order to assess the impact of the Lorenzen-based natural mortality assumption on model performance. The results suggested that the model was relatively robust to any error in this assumption. Overall, the Panel did not consider the possible inaccuracy of the Lorenzen approach at the lower ages to be of much importance, given the high age of selectivity to the fishery.

<u>Reproduction and sex ratios</u>
A maturity ogive by age was developed with a logistic regression using MARMAP data after adjusting the ages to be consistent with NMFS' aging. The fit was not particularly good -- possibly due to the low numbers of older fish -- but the equation was deemed adequate for determining spawning biomass at age.

Snowy Grouper: Snowy grouper is a protogynous hermaphrodite, changing from female to male with age; hence, it is important to estimate the proportion of females by age. Age-specific sex ratios were calculated from a logistic regression.

Tilefish: Tilefish are gonochoristic, but sexually dimorphic, with sex-specific growth curves. The use of female weights is therefore appropriate; use of female only weights in SSB calculations required an assumption regarding age-specific sex ratios; all were set to 0.5 for all ages.

The Panel recommended that better information should be collected related to sex ratios at age, and that the fisheries implications of protogynous hermaphroditism in snowy grouper be more fully evaluated in future assessments.

The Data workshop provided fishery-independent (MARMAP) and fishery-dependent (headboat and commercial logbook) abundance indices.

Snowy Grouper: The Data Workshop identified four time series of information that could be used as indices of abundance for snowy grouper: MARMAP trap and longline surveys, commercial logbook reports, and the headboat catch rates. The Assessment Workshop did not use the commercial logbook index in the snowy grouper analysis because they thought that the index did not track abundance because of fishers shifting to areas of greater abundance, concerns for identifying directed trips, regulatory changes, technology creep, etc. The Assessment Workshop used the other three indices in their analyses. Pairwise correlations between indices were not significant.

The fishery-independent indices came from the MARMAP survey. The Panel noted the poor fits in the model and expressed concern regarding the zero value in 1992 in the MARMAP chevron trap series and questioned how that was handled in the analyses. Because these indices were assumed to follow a log-normal distribution, the concern regarded the extra value added to the zero. They also questioned why the coefficients of variation (CVs) for the chevron traps were similar to those used for longlines even though the longline index was less variable. The analysts responded that the CVs are used to provide estimates of inter-annual variation within an index. The MARMAP chevron trap series is considered an index of younger fish (ages 2 to 5 approximately) because the sampling only goes to 100 m which is shallow for snowy grouper. MARMAP's deeper longline sampling is more appropriate for snowy grouper at older ages. Neither of these indices had much of an influence the model's outcome. However, the Panel thought that these indices will be more valuable as the time series increases.

The only fishery-dependent index used in the analysis was the headboat index. The Panel questioned its use as a true measure of abundance, because headboats are fishing at the very edge of the distribution and changed their fishing from deeper waters in the early years to shallower waters of 100 m or less where snowy groupers are not a commonly caught species. Headboat trips were sub-set to those trips that caught deep-water species and effort was expressed in angler-hook days. The Assessment Workshop addressed these concerns by allowing selectivity to vary over time. Results showed that selectivity shifted toward younger ages over time, which is consistent with perceived changes in the fishery and expected availability by area. The model fit to this index was poor in the early years and better after 1984.

Tilefish: The Data Workshop identified two time series of information that could be used as indices of abundance for tilefish: MARMAP's fishery-independent, horizontal longline survey and commercial logbook CPUE. Although the MARMAP sampling was discontinuous, both time periods (1983-1986 and 1996-2002) were assumed to have the same catchability rate. As expected with the short time series of relatively noisy data, the model fits were poor.

The commercial logbook index was considered appropriate for tilefish because the logbook data had a large tilefish sample size and broad spatial coverage. The fit was as good as could be expected.

> DW6. Evaluate the quality and reliability of commercial and recreational fishery-dependent data for determining harvest and discard by species; develop estimates of total annual catch including both landings and discard removals by species.

Prior to 1985, the commercial landings of both of these species were reported only in aggregated categories and so the historical species landings had to be estimated. The Commercial Statistics subcommittee of the Data Workshop used the landings data from 1985-1993 to estimate the average ratio of snowy groupers to unclassified groupers or tilefish to unclassified tilefish by state then applied these ratios to the aggregate to extend the time series back to 1962. Similarly, if gear was missing, the average ratio of gears was applied. An underlying assumption is that these ratios from the later years were constant back into the earlier years. The results were time series of landings by state and gear from 1962 through 2002 for both snowy grouper and tilefish. The Assessment Workshop captured some of the uncertainty in the early commercial landings by setting the commercial coefficient of variation (CV) for the early years at 50% until 1983 and then decreased the CV linearly until 1994 when the CV was set to 10%. There was some discussion as to whether this use of CVs is the best approach to address the uncertainty in landings, given that it is believed the uncertainty is a bias and not random error. An alternative approach worth evaluating would be to include a bias parameter in the model that is estimated.

Snowy Grouper: The snowy grouper commercial fishery began in Florida and expanded northward to South Carolina and North Carolina in the early 1980s. Handlines are the dominant gear in this fishery. Commercial discards were reported to be negligible for snowy grouper.

Tilefish: The tilefish commercial fishery began in Florida and expanded north to South Carolina and North Carolina in the early 1980s, but Florida remains the dominant state for landings. Longlines are the dominant gear. While the same approach used to estimate historical tilefish landings, the smaller number of species and large proportion due to tilefish reduced the uncertainty imposed by this approach. A similar decreasing function for CV of landings was applied, which the RW felt was not appropriate given the reported greater confidence in tilefish landings than in snowy grouper landings. However, since landings were matched closely in the model such changes in CV were not considered worth changing. Commercial discards are also reported to be negligible for tilefish.

Because snowy grouper and tilefish are caught in deep water, the recreational landings are small coming mostly from NMFS's Marine Recreational Fisheries Statistics Survey (MRFSS) charterboat and private boats and an even smaller amount comes from headboats. Again because of the deeper water, it is assumed that none of the released fish estimated by MRFSS survive and so these released fish are included as recreational catch. Proportional standard errors estimated by MRFSS are used as CVs for this sector. The headboat survey does not estimate CVs because it is assumed to be a census but Dixon and Huntsman (SEDAR4-DW-26) note that approximately 40% of headboat landings aren't reported and have to be estimated. The headboat CVs were 10% for 1972-1995 and higher (25%) afterwards because some boats operate in Florida waters not in federal waters offshore and they claim they don't have to report, so from 1996 on has a higher CV to account for it. As with commercial landings, the recreational CVs are not believed to be very important in what the model predicts because the model is configured to fit the landings. Some Panel members thought that since the headboat coverage has changed over time the CVs should be higher in the earlier years. Concern was expressed regarding the poor fits to the landings in the early years which suggested that the differences are not just random error but bias. Recreational fishing for tilefish is limited with landings less than 20 t annually.

Snowy Grouper: The only length data for snowy grouper prior to 1983 came from the headboat survey, and those data did not encompass the entire region. The fishery expanded north from Florida, while the headboat sampling began in North Carolina. Therefore, the early length samples may not be representative of the bulk of the fishery. Length sampling in the commercial handline and longline sectors after 1983 was deemed adequate, especially in the handline portion. There was an apparent contradiction from expectation in that the sizes of fish caught by longlines decreased after the longlines were restricted to fishing in 100 m or greater depths.

Tilefish: Length data for tilefish were only available beginning in 1983. The dominant source of length data was the commercial longline fishery, which has been well sampled each year since 1984, with more than 2,000 length measurements for most years. Length distributions for the commercial handline fishery and the MARMAP survey contained many fewer fish -- less than 200 length measurements for most years.

<u>Age sampling</u>
There was a lot of concern for the small number of age samples for both species, and for possible effects of clumped sampling, which would make the 'effective' sample size even smaller. The Stock Assessment Workshop did not include age composition data for years where there were fewer than 25 age samples. This cutoff meant that few years were included in the analyses, e.g.

only 1981 and 1986 could be included for the headboat/recreational sector in the snowy grouper assessment. On the commercial side, only data from 1997 and later could be included in the snowy grouper analyses. A question was raised as to whether 25 age samples were adequate, and whether such limited sampling enabled tracking of cohorts. The response was that age data actually served only to aid in determining selectivities. A suggestion was made to model selectivities based on size instead of age. The analysts said that they would move in that direction in future SEDAR assessments.

The length distribution of the tilefish age samples did not appear representative of the length samples from which they were chosen. The Panel recommended that these age composition data not be used within the model because of this lack of representativeness. To test the importance of this recommendation, a sensitivity run was performed, and this omission did not affect model results. Therefore, the Panel was satisfied with the model as configured, but recommenced that value of retaining these data be considered in future assessments.

In summary, the Review Panel believed that an extensive amount of data had been introduced through the Data Workshop, but that the Data Workshop had provided little written evaluation of quality and reliability. The Review Panel considers the data were scientifically sound and used appropriately. However, the Panel and the Assessment report both note a number of data limitations, and conclude that the data were adequate, but allowed only limited inference as to population status.

2. *Evaluate the adequacy, appropriateness, and application of the methods used to estimate population parameters such as abundance, biomass, and exploitation and state whether or not the methods are scientifically sound.*

This section reviews the Assessment Workshop in light of its terms of reference; see Appendix D.

The Review Panel considered the terms of reference applied to the assessment workshop, and concluded that in general they were addressed adequately. The one problem noted that several arguments and rationales for the inclusion and exclusion of models were not well represented in the AW documents. A specific example would be the determination of the “initial runs”. In each assessment, the initial run is the configuration was deemed to be good enough to act as a basis for diagnostics and upon which the MCB replicates were based. As is noted below, the initial run was not used to directly determine stock status.

The model used for both species was a forward projecting, age-structured model that fit gear-specific landings, indices, age and length compositions to produce numbers of fish by age and fishing mortalities. The weights for the components of the likelihood functions were adjusted during the stock assessment workshop until the results were deemed reasonable and that run was labeled ‘initial run’. Uncertainty was evaluated through a Monte Carlo/Bootstrap (MCB) approach

The Panel supports the assessment teams’ use of MCB technique as a pragmatic method of characterizing uncertainty in the assessments. This technique addresses two types of uncertainty. The first derives from model parameters (such as natural mortality and steepness) that were held fixed in the initial run. The second type is associated with the data inputs (such as CPUE indices of length compositions). All data inputs include a random error component arising from sampling variation (e.g., the length compositions inputs would have been different had different landings been sampled). MCB answers the question “how different might the assessment results have been if different (but plausible) values had been used for the fixed parameters and if the sampling error had been different?".

Care should be taken in interpreting MCB results. For each model output the assessment teams presented the 10th and 90th percentile from the MCB analysis (e.g., for tilefish the 10th and 90th percentiles were 1792 mt and 3644 mt). These should be treated as indicating the approximate range of the uncertainty associated with each output. However, they should not be interpreted probabilistically. That is, we should not say that we can have 80% confidence that the true MSY for tilefish lies between 1792 mt and 3644 mt. There are two main reasons for this. First, consider the initial SSB, which was allowed to take any value between 0.5SSB(virgin) and 1.3SSB(virgin). This defines the range of uncertainty for SSB(initial) but it is not probabilistic because it is not true that all values in this range are equally likely. A similar comment applies to uncertainty in natural mortality. The second reason is that it is not appropriate to treat all MCB runs as having equal weight. In some runs, the randomly chosen parameter values will not produce a good fit to the data. For a formal probabilistic interpretation these runs would need to receive less weight than those for which the data are fitted well.

There was one type of probabilistic interpretation which the Panel felt was acceptable (although not strictly correct). Consider, for example, the forward projections with no fishing for snowy grouper (Figure 60). Here, the median line crosses 1 in about 2015. From this we can say that there is a more than 50% chance that snowy grouper would not rebuild to MSY in less than 10 years.

The Review Panel considered that the statistical catch-at-age model used for both snowy grouper and tilefish was appropriate for the available data and, within the limits of the data, adequately addressed questions of exploitation and relative abundance. It also believed that the median MCB values provide the best estimates of model outputs, but that it is useful, for comparative purposes, to include results from the initial run in all plots except for those from projections. The initial run is also important because it provides important diagnostic plots, such as those illustrating model fit to the data.

There is not a single median run as such chosen from the MCB replicates. For each parameter or model product (SSB2002, MSY etc) there is a median. Some of the products are expressed as ratios, (Figure 56 of snowy grouper report SSB2002/SSBmsy) in which case the median of the ratios is chosen and not the ratio of the medians. Thus, it may be that the median ratio will not be the ratio of the median SSB2002 and SSBmsy and such a discrepancy is not an error. The Panel did not have these results in tabular form so an example could not be presented.

The Panel suggested that a reduced-parameter run, with simpler assumptions, be made for both species. In these runs the effective number of parameters estimated was substantially reduced (from 204 to 24 for snowy grouper and from 147 to 13 for tilefish) by making recruitment deterministic and forcing the model to fit the landings exactly. This made the model into an age-structured production model.

The Panel concurred with the AW decision not to include the surplus production model results for either species.

Snowy Grouper: The snowy grouper assessment suggested that fishing mortality first exceeded Fmsy in the mid 1970s and has fluctuated around 3Fmsy since the early 1980s. This high fishing mortality rate caused the population biomass to decrease below SSBmsy in the early 1980s and it has continued to decline ever since. The Panel concluded that the main information on population trends was coming from the length composition data rather than the abundance data.

Unfortunately, outputs from the 2316 MCB runs fell into two main groups: 1) a realistic group (1470 outcomes) in which population biomass was on the order of a few thousand tons and recent fishing mortalities were about 3Fmsy and 2) an unrealistic group (846 outcomes) with very high population biomasses (on the order of 1million tons) and very low exploitation (F essentially zero). See Figure 1 which shows a scatterplot of the runs relative to SSBmsy and Emsy. The Panel concurred with the AW's decision that the latter group was unrealistic, primarily because it implies that fishing mortality has had no impact on the population, but also because the biomass estimates appear highly implausible given known landings, perceptions of general grouper biomass/productivity, and perceptions of available habitat.

The Panel attempted to more objectively define the implausibility of the biomass estimates based on available habitat, but quantification of available habitat could not be provided at the meeting. The Panel recommends using estimates of available habitat and stock productivity to set reasonable upper bounds on biomass estimates when possible. The initial run fell in the realistic low population and high fishing mortality domain.

The Panel attempted to determine from the MCB results if there were combinations of parameter values that were associated with the unrealistic group. No such combinations were evident when the outcomes in ratio of spawning biomass to spawning biomass at MSY (SSB/SSBmsy) were plotted against relevant parameters. The bimodality of model estimates for stock condition probably is indicative that these data can only weakly be used to estimate the condition of the underlying stock. A suggestion was to run the model in more phases in the hopes that the high abundance/low mortality result would not occur. However, increasing the number of phases did not cause the model to avoid the unrealistic high abundance/low mortality domain.

The reduced-parameter model resulted in the high abundance/low mortality scenario when initial biomass ratio was set high (0.9) but more closely reproduced the initial run when the initial biomass ratio was estimated. However, the estimated initial biomass ratio was extremely low (0.2) given the low level of catches assumed to have occurred prior to 1961. From this it was inferred that the population decline implied by the length composition data was clearly greater than could have been caused by the observed landings in the early years, suggesting that these landings must have been substantially under-estimated.

The model for snowy grouper showed a sharp decline in biomass beginning in the late 1970s which was before the length composition data were available except for the headboat sector or any age data. The Panel recommends that in such cases of limited age or size composition data in the early years, a sensitivity analysis should be conducted which starts in the year that age or size composition data is available. Due to time constraints and the complexity of the requisite modeling, this recommendation could not be met at the meeting.

Tilefish: The tilefish assessment indicated that fishing mortality first exceeded Fmsy in the early 1980s and has remained there since. This high fishing mortality rate caused the population biomass to decrease to near MSY levels in the mid 1980s, where it has remained ever since. Fishing mortality in recent years has exceeded Fmsy, but the population has been maintained at Bmsy because of better than average recruitment. As with snowy grouper, the main information on population trends appeared to be coming from the length composition data.

In contrast to the two clusters of MCB results seen snowy grouper assessment, only two of the 1100 MCB runs were unsatisfactory (and so were not included in summary statistics). They were rejected because for these two the model did not converge.

The reduced-parameter run produced a biomass trajectory that was similar to that from the initial run, except that the biomass continued to decline below Bmsy in the most recent years. This revealed how much the initial run's assessment of stock status depends on the parts of the length composition data which indicate above average recruitment in recent years. More comprehensive age data would have strengthened the model's inferences about these recruitments.

3. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population benchmarks (e.g., MSY, Fmsy, Bmsy, MSST, MFMT, or their proxies) and state whether or not the methods are scientifically sound.

The Panel recommended using the median benchmarks.

Methods were considered appropriate and adequate for estimating benchmarks.

4. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound.

The Panel concludes that the methods used in the projections are appropriate, adequate, and scientifically sound, and recommends using the median of projection results. As mentioned above, the 10^{th} and 90^{th} percentiles shown in the projections are indicators of the range on uncertainty and are not to be taken as confidence limits.

5. Ensure that all available required assessment results (as listed in the SEDAR Stock Assessment Report Outline) are clearly presented in the Stock Assessment Report and consistent with the Panel's decisions regarding adequacy, appropriateness, and application of the data and methods.

Assessment results were clearly and adequately presented by the tables and figures in the Assessment Reports for snowy grouper and tilefish. Several members of the Panel found the complete documentation of equations and the inclusion of model code particularly informative, and recommend that such information become a standard component of SEDAR assessment reports. Further, it is recommended that model input data files also be included in future reports.

The Review Panel noted several minor errors and omissions in figures; these will be corrected by the analysts. The Review Panel suggests that two additional pieces of information be provided in future reports: 1) a table of model parameter estimates, and 2) a thorough documentation of the process that led to the initial model configuration. The Review Panel requested details of the seasonal and spatial coverage of the length and age samples.

6. Evaluate the performance of the Data and Assessment Workshops with regards to their respective Terms of Reference, and state whether or not the Terms of Reference for those previous workshops are adequately addressed in the Stock Assessment Report.

The Review Panel found it helpful to address the Data Workshop Terms of Reference during deliberations of TOR 1 above. The Review Panel concluded that all but one of the Data

Workshop Terms of Reference were addressed adequately for snowy grouper and tilefish in the Data Workshop Report. The one TOR that was not addressed is TOR 1, which required identifying the unit stock. The Review Workshop also recommends that future data workshop reports provide greater evaluation of input data. In many instances data are provided with little consideration of the 'evaluation of quality and reliability' as required in the Terms of Reference.

The Review Panel concluded that the assessment reports adequately addressed the AW Terms of Reference.

The Review Panel suggests for future SEDARs that confusion may be reduced by providing a brief description of the process that leads to assessing only a subset of those species addressed in the Data Workshop.

7. Review the assessment workshop's recommendations of future research for improving data collection and the assessment, and make any additional recommendations warranted.

The Panel supports the research recommendations included in the snowy grouper and tilefish assessment reports. However, the Panel felt it was important to provide some specific additional detail.

Regarding ageing methods, the Review Panel recommends that ageing validation should be accomplished prior to addressing concerns over differences in age determinations between the various labs.

Regarding age sampling, the Panel recommends that the suggested initial sampling rate for age structures be clarified to avoid the suggestion of age as a sampling strata. The intent is to establish an initial age sample of 20 times the number of ages in the population. The Review Workshop also recommends that stratification by length and development of appropriate age-length keys be considered as a possibly more effective and economical approach to inferring age composition than attempting random age sampling. Regardless of the method ultimately chosen, it is most important to provide adequate age and length sampling through a rigorous and statistically valid sampling program.

The Panel recommends exploring the relative importance of age sampling in models of the type used here to assess snowy grouper and tilefish. Such analysis could help identify the best allocation of limited monitoring resources.

The Panel supports the snowy grouper recommendation # 7 regarding research into the implication of sex change. The Review Workshop adds that future assessment models addressing species which undergo sex change should provide model results that incorporate sex-specific information.

8. Prepare a Consensus Peer Review of Assessments summarizing the peer review panel's evaluation of the tilefish and snowy grouper stock assessments and addressing the Terms of Reference. (Drafted during the Assessment Review Panel workshop with a final report due three weeks after the workshop ends.).

A draft was prepared during the meeting and a final version was circulated to the Panel afterwards.

9. Prepare a Stock Advisory Report summarizing the stock assessments. (Drafted during the Assessment Review Panel workshop with a final report due three weeks after the workshop ends.).

The Review Panel was advised that the Stock Advisory Report will be prepared by the analytical team reflecting the assessment results endorsed during the Review Workshop.

II. Additional Comments

During the Review, several requests were made by the Panel for additional explanation or analysis. See Appendix E. These requests were always dealt with promptly, professionally and reported clearly.

Simulations to examine the distribution of the initial to unfished biomass ratios:
The Panel conducted a simulation exercise to examine the distribution of the starting year biomass, given recruitment variability. The starting year biomass is modeled as the ratio of biomass in the first year to the unfished biomass (B1 ratio). The B1 ratio is one of the distributions assumed in the MCB approach. The Panel's simulation assumed tilefish biological parameters and projected a population for 100 years given only uncertainty in the annual recruitment deviations. The biomass in the final year of the projection was compared to the deterministic value of unfished biomass. Repeating this 100 year projection 10,000 times allowed formation of the distribution of the B1 ratio. This distribution was approximately lognormal in shape and ranged from approximately 0.8 to 1.5. The Panel recommends a similar simulation approach to determine appropriate distributions for MCB approaches requiring a distribution for the B1 ratio.

Rebuilding time frame:

The Panel observed that the median of the MCB projections for snowy grouper crossed quite close to SSBmsy in 2015. The decision whether or not to invoke the rebuilding rule is well within the distribution of projections. Although the Panel did not consider this issue in any detail, concern was mentioned about the difficulty caused by the abrupt transition from one harvest strategy to another when the trigger is the probable state of the resource which is poorly defined.

3. Stakeholder Comments

The stakeholder present commented that this SEDAR Review was an improvement in its openness to discuss ecological issues.

Given the weakness of the data, and that these were new assessments, it would have been useful to have had industry representation to respond to the assessments and their results.

4. Recommendations for Future Workshops

The Panel considered that the lack of representation by fisherman limited the scope of input and the points of view that were considered. A number of questions arose regarding selectivity and fishery practices that may have been addressed by industry participation.

Appendix A Terms of reference for SEDAR 4 Review: Tilefish and Snowy Grouper

The SEDAR Assessment Review Panel will evaluate the tilefish and snowy grouper stock assessments, input data, assessment methods, and model results as put forward in stock assessment reports. The Assessment Review Panel will:

A1. Evaluate the adequacy and appropriateness of all data used in the assessment and state whether or not the data are scientifically sound;

A2. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population parameters such as abundance, biomass, and exploitation and state whether or not the methods are scientifically sound;

A3. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population benchmarks (*e.g., MSY, Fmsy, Bmsy, MSST, MFMT, or their proxies*) and state whether or not the methods are scientifically sound;

A4. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound;

A5. Ensure that all available required assessment results (*as listed in the SEDAR Stock Assessment Report Outline*) are clearly and accurately presented in the Stock Assessment Report and that such results are consistent with the Panel's decisions regarding adequacy, appropriateness, and application of the data and methods;

A6. Evaluate the performance of the Data and Assessment Workshops with regards to their respective Terms of Reference, and state whether or not the Terms of Reference for those previous workshops are adequately addressed in the Stock Assessment Report;

A7. Review the assessment workshop's recommendations of future research for improving data collection and the assessment, and make any additional recommendations warranted;

A8. Prepare a Peer Review Consensus Summary summarizing the Panel's evaluation of the tilefish and snowy grouper stock assessments and addressing each Term of Reference. (Drafted by the Panel during the Review Workshop with a final report due three weeks after the workshop ends.);

A9. Prepare a Stock Advisory Report summarizing the stock assessments. (Drafted during the Assessment Review Panel workshop with a final report due three weeks after the workshop ends.).

Appendix B : Attendees at SEDAR4 Assessment Review Panel Workshop

CIE Participants

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Appendix C: Terms of Reference for the Data Workshop.

DW1. Evaluate stock structure and develop a unit stock definition.

DW 2. Evaluate the quality and reliability of life-history information (Age, growth, natural mortality, reproductive characteristics); develop models to describe growth, maturation, and fecundity by age, sex, or length as appropriate.

DW 3. Evaluate the quality and reliability of fishery-independent measures of abundance; develop indices by appropriate strata (e.g., age, size, and fishery) for use in assessment modeling.

DW 4. Evaluate the quality and reliability of fishery-dependent measures of abundance; develop indices for use in assessment modeling.

DW 5. Evaluate the adequacy of the NMFS logbook data as a fishery-dependent measure of effort and catch rates; develop indices of abundance for use in assessment modeling.

DW 6. Evaluate the quality and reliability of commercial and recreational fishery-dependent data for determining harvest and discard by species; develop estimates of total annual catch including both landings and discard removals by species.

DW 7. Evaluate the quality and reliability of data available for characterizing the size and age distribution of the catch (landings and discard); characterize commercial, recreational, and headboat landings and discard by size and age.

DW 8. Evaluate the quality and reliability of available data for estimating the impacts of management actions.

DW 9. Recommend assessment methods and models that are appropriate given the quality and scope of the data sets reviewed and management requirements.

DW 10. If data are not adequate for assessment modeling of each species listed in the complex, evaluate the feasibility of (1) using specific members of the stock complex as indicator species, or (2) using other metrics to evaluate stock status.

DW 11. Provide recommendations for future research (research, sampling, monitoring, and assessment).

DW 12. Prepare complete documentation of workshop actions and decisions, and generate introductory, descriptive, and research needs sections (1-4, 9) of the stock assessment report.

Appendix D: Terms of Reference for the Assessment Workshop.

AW1. Select several appropriate modeling approaches, based on available data sources, parameters and values required to manage the stock, and recommendations of the Data Workshop.

AW2. Develop and solve the chosen population models, incorporating data that are the best available, the most recent and up-to-date, and scientifically sound.

AW3. Provide measures of model performance, reliability, and goodness of fit.

AW4. Estimate values and provide tables of relevant stock parameters (abundance, biomass, fishery selectivity, stock-recruitment relationship, etc; by age and year).

AW5. Consider sources of uncertainty related to input data, modeling approach, and model configuration. Provide appropriate and representative measures of precision for stock parameter estimates.

AW6. Provide Yield-per-Recruit and Stock-Recruitment analyses.

AW7. Provide complete SFA criteria: evaluate existing SFA benchmarks; estimate alternative SFA benchmarks if appropriate; estimate SFA benchmarks (MSY, Fmsy, Bmsy, MSST, and MFMT) if not previously estimated; develop stock control rules.

AW 8. Provide declarations of stock status relative to SFA benchmarks: MSY, Fmsy, Bmsy, MSST, MFMT.

AW 9. Estimate the Allowable Biological Catch (ABC) for each stock.

AW 10. Estimate probable future stock conditions and develop rebuilding schedules if warranted; include estimates of generation time.

AW 11. Evaluate the impacts of current management actions, with emphasis on determining progress toward stated management goals.

AW 12. Provide recommendations for future research and data collection (field and assessment); be as specific as possible in describing sampling design and sampling intensity.

AW 13. Provide thorough justification for any deviations from recommendations of the Data Workshop or subsequent modification of data sources provided by the Data Workshop.

AW 14. Fully document all activities: Draft Section III of the SEDAR Stock Assessment Report; Provide tables of estimated values; Prepare a first draft of the Advisory Report based on the Assessment Workshop's recommended base assessment run for consideration by the Review Panel. Reports are to be finalized within 3 weeks of the conclusion of the Assessment Workshop.

Appendix E. requests for additional analysis during Workshop.

With one exception, these were all performed in a prompt and complete fashion. That one exception was the request to start the model at a time in 1982 to more closely match the available data. At the time when the request was made, NMFS personnel explained that it would probably be too difficult to do in the time available.

These are still in the point form used in presentation and are included to chronicle the events at the Review. For more detail, the reader is referred to the Assessment Workshop
.
The Review Panel made three successive requests from Snowy grouper assessment team:

1)

- Add MSY length compositions to Figure 58
- Observed and predicted catch differences
- Model output by sex
- Scatter plots of input versus MCB criteria
- Example of "bad" run
- Initial model run with increased weight on landings
- Initial model run with constant M=0.12
- Initial model run starting in 1982

2)

- Add deterministic initial run projections to projection figures
- Try fitting "bad" MCB run with more phases

3)

- Run age-structured production model (called reduced parametric model above)

Tilefish

- Distribution of SSB/MSST, where MSST=0.75SSBmsy

- Distributions of M at age
- Model run: SSB(1961)=SSBvirgin
- Model run: Drop age comps
- Model run: Logistic selectivity for MARMAP survey
- Model run: Age-structured production model equivalent

Citations

Hoenig, John. 1983. Empirical use of longevity data to estimate mortality rates. U.S. Fish. Bull. 81:898-903.

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

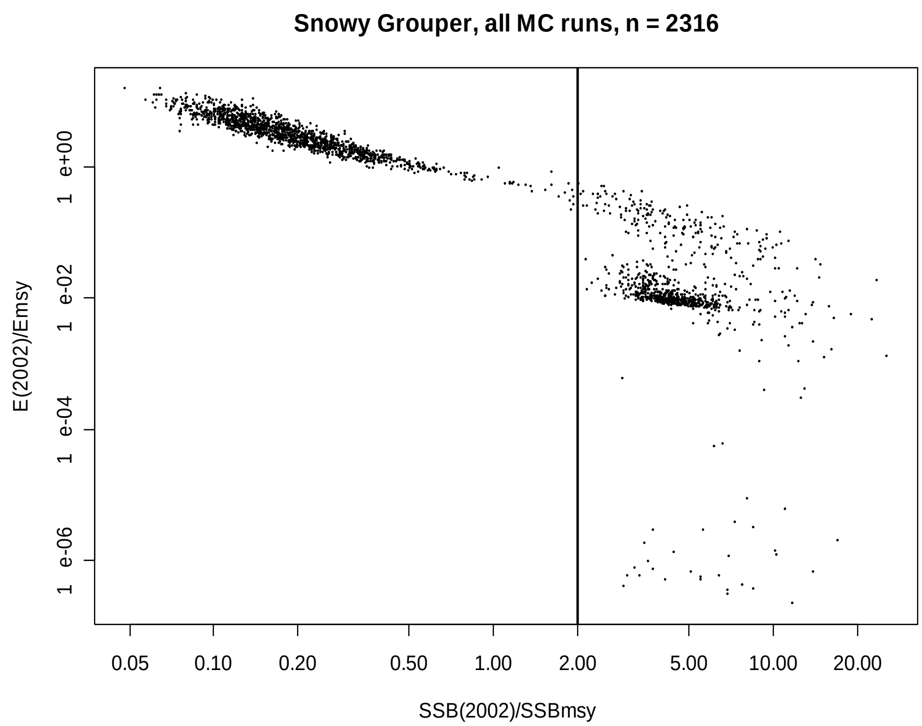

Figure 1. Scatter plot of the MCB replicates showing the two clouds of solutions. The region the Panel called “realistic” cloud is the on concentrated in the upper left corner.

Report on the 2004 Assessments of South Atlantic Tilefish and Snowy Grouper

NIWA Client Report: WLG2004-51
August 2004

NIWA Project: ERI05901

Report on the 2004 Assessments of South Atlantic Tilefish and Snowy Grouper

R.I.C.C. Francis

Prepared for

University of Miami

Independent System for Peer Review

NIWA Client Report: WLG2004-51
August 2004

NIWA Project: ERI05901

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Reviewed and approved for release by:

Executive Summary

The 2004 assessments of tilefish and snowy grouper in the southeast United States were reviewed as part of the SEDAR (South East Data, Assessment and Review) process. The Assessment Review Panel met 26-29 July 2004 at the Holiday Inn in Charlotte, North Carolina. The data and assessments were presented to the Panel, additional analyses were requested and carried out, and the Panel discussed the results and wrote its Consensus Report.

The data used were not strong, but were the best available, adequate for use in the assessments and, with minor exceptions, used appropriately. Given that these were first-time assessments for both stocks, the assessment techniques were sound and the results should be valuable to fishery managers. The presentation and documentation of the assessments was generally clear and detailed with only one significant exception: that the derivation of the likelihood weights was insufficiently explained.

Suggestions are given for the consideration of those charged with future assessments of these stocks.

1. BACKGROUND

This report reviews the 2004 assessments of tilefish (*Lopholatilus chamaeleonticeps*) and snowy grouper (*Epinephelus niveatus*) in the management area of the South Atlantic Fisheries Management Council, at the request of the University of Miami (see Appendix 1). In terms of recent catches, these species are the two most important of a group of eight snapper-groupers known as the South Atlantic Deep Water Complex. The author was provided with the assessment reports for both species, the report from the associated Data Workshop, and supporting documents (Appendix 2), and participated in the SEDAR 4 (South East Data, Assessment, and Review) Assessment Review Panel Workshop that considered these assessments. This workshop constituted the last of the three phases of the SEDAR 4 process, with the earlier phases being a Data Workshop (3-7 November 2003) and an Assessment Workshop (7-11 June 2004).

2. REVIEW ACTIVITIES

The Assessment Review Panel Workshop was held 26-29 July 2004 at the Holiday Inn in Charlotte, North Carolina (see Appendix 3 for the Panel membership and a list of other attendees).

The Review Panel's terms of reference, as provided by the SEDAR Coordinator (Appendix 2.1), differed somewhat from those given to the author as part of his Statement of Work (Appendix 1). The Panel followed the former, except that the last term was deleted at the instruction of the SEDAR Coordinator (i.e., the Panel was not required to compile a Stock Advisory Report).

Mike Prager gave a useful introductory talk outlining some features of U.S Fisheries Management. Doug Vaughan then discussed the data available for snowy grouper and Erik Williams presented the assessment. The panel discussed the assessment and requested some additional analyses. These were done and the results presented to the Panel (see below). The same sequence was followed for tilefish, with the data presented by Doug Vaughan and the assessment by Kyle Shertzer. The Panel then drafted their Consensus Report with input from others present.

The Panel's task was simplified because the assessments were very similar in terms of the data available, the analytical techniques, and the method of presentation.

This, and the fact that the Panel was not required to write a Stock Advisory Report, allowed the Workshop to finish a day earlier than scheduled.

2.1 Assessment structure and results

In this section I give a brief description of the two assessments in order to provide a context for the rest of this report.

In terms of data and structure, the two assessments were very similar. The observations comprised the landings by fishery, several time series of abundance indices from CPUE (catch per unit effort), and several time series of length and age frequencies (LFs and AFs). In an initial run, these observations were fitted by weighted maximum likelihood to predictions from an age-structured population model. The weights applied to each likelihood component in this run were derived subjectively after a series of preliminary model runs (not presented) which explored many alternative sets of weights. Constraints were applied to force the initial spawning stock biomass ($SSB_{initial}$) to be close to 0.9 of the virgin value (SSB_{virgin}) and to discourage extreme variation in recruitment deviations. The estimated parameters (204 for snowy grouper and 147 for tilefish) fell into five groups: virgin recruitment (1 parameter); CPUE catchabilities (3 for snowy grouper and 2 for tilefish); selectivities (20 and 20); fishing mortalities (139 and 93); and recruitment deviations (41 each). Natural mortality was modelled as age-dependent (varying as an exponential function of body weight) following Lorenzen (1996).

For some runs requested by the Panel the model was simplified substantially into what is sometimes called an age-structured production model (ASPM). This was done by increasing the likelihood weights associated with the landings to force the model to fit the landings almost exactly and making recruitment deterministic. This greatly reduced the effective number of parameters estimated (from 204 to 24 for snowy grouper and from 147 to 13 for tilefish).

In order to characterise uncertainty in the assessments a large number of Monte Carlo bootstrap (MCB) runs were done for each stock. These runs differed from the initial run in that some model inputs were randomly varied from run to run. Three types of inputs were "randomised": some of the parameters that were held fixed in the initial run (concerning natural mortality, $SSB_{initial}$, and stock-recruitment steepness), the likelihood weights (within a range of ±25%), and some of the observations (the CPUE indices). After discarding unsatisfactory runs, the 10th, 50th, and 90th percentiles of selected model outputs were calculated. The

50th percentile (i.e., the median) was treated as the best estimate and the other two percentiles were treated as indicating an approximate range of uncertainty.

The snowy grouper assessment suggested that fishing mortality first exceeded F_{msy} (the fishing mortality that will produce the maximum sustainable yield) in the mid 1970s and has fluctuated around $3F_{msy}$ since the early 1980s. This high fishing mortality rate caused the population biomass to decrease below SSB_{msy} in the early 1980s and it has continued to decline ever since. A feature of this assessment was that the MCB runs fell into two quite distinct groups: 1) a realistic group (1470 outcomes) in which population biomass was on the order of a few thousand tonnes and recent fishing mortalities were about $3F_{msy}$ and 2) an unrealistic group (846 outcomes) with very high population biomasses and very low fishing mortality. The latter group was discarded.

The tilefish assessment suggested that fishing mortality first exceeded F_{msy} in the early 1980s and has remained there since. This high fishing mortality rate caused the population biomass to decrease to near MSY levels in the mid 1980s, where it has remained ever since. Fishing mortality in recent years has exceeded F_{msy}, but the population has been maintained at B_{msy} because of above average recruitment. Only two of the 1100 MCB runs were deemed unsatisfactory and this was simply because the model failed to converge.

Some of the additional analyses requested by the Panel, and the results from these, are described briefly in the rest of this section.

2.2 Additional analyses for snowy grouper

A comparison of total observed and predicted landings showed that the latter exceeded the former by 14% overall, and by more (I calculated 33%) in the period before 1990. This degree of under-estimation of landings was not considered implausible.

A plot of estimated SSB by sex showed that males were estimated to be much more depleted than the females and that the current population was strongly dominated by females.

Attempts were made to understand the bipartite nature of the MCB runs by seeking combinations of the random components which would typically produce either satisfactory or unsatisfactory runs. No such explanation was found.

A run in which the model was forced to fit the landings almost exactly produced an output like one of the unrealistic MCB runs. The results of two ASPM runs depended on what was done with $SSB_{initial}$. When it was constrained to be equal to $0.9SSB_{virgin}$ (as in the initial run) the result was like one of the unrealistic MCB runs. When it was unconstrained it was estimated to be very low (about $0.2SSB_{virgin}$) but the estimated exploitation rates were more realistic (like those in the initial run). These runs were interpreted as showing that the population decline implied by the length composition data was clearly greater than could have been caused by the observed landings in the early years, so these landings must have been substantially under-estimated.

A model run in which natural mortality was independent of age produced results similar to those from the initial run. This suggests that although natural mortality undoubtedly varies with age it may not be important to model it thus.

2.3 Additional analyses for tilefish

An ASPM run produced a biomass trajectory that was similar to the initial run except that it led to lower biomass in the last 5-10 years. This showed the importance, in the initial run, of the positive recruitment residuals in the last few years. This is why, in the initial run, SSB is near SSB_{msy} in the final years although the fishing mortality exceeds F_{msy}.

3. FINDINGS

I was impressed by these assessments and the way they were presented to the Panel. They were mostly well documented. I particularly appreciated the inclusion of model equations and source code. Verbal descriptions of such complicated analyses are inevitably imprecise so it is good to be able to turn to the equations, or source code, for clarification of details. Presentations to the Panel were always clear and the assessment team was unfailingly helpful in response to requests for clarification or further analyses.

In the remainder of this section I first present my findings in relationship to each of the first four tasks of the Review Panel (as stated in Appendix 1) and then make some suggestions for future assessments.

3.1 Task 1: The data

The data used for both species were scientifically sound and appropriate for use in stock assessments (with minor exceptions), adequate to make useful inferences about stock status, and the best available for this purpose.

The exceptions concern the AFs for tilefish (and possibly snowy grouper) and one snowy grouper CPUE index. These exceptions are minor because these data sets had very little influence on the outcomes of the assessments. The problem with the tilefish AFs was that they appeared not to be representative of the catch (the LFs from the longline fishery seemed different from those for the fish from which otoliths were collected, though no formal statistical comparison was made). This is a common problem when AFs are estimated directly (rather than via an age-length key). It arises because such AFs are often constructed from many small samples and it is difficult to select a small sample that is random (and thus representative). Given the small sample sizes for the snowy grouper AFs it is quite possible that these data sets were not representative either. The existence of a zero in the 1992 MARMAP chevron trap CPUE index for snowy grouper was problematic because the lognormal error structure assumed for CPUE indices does not allow zeroes. This zero appears to have led to the estimation of a completely implausible selectivity for the MARMAP traps (Figure 43A) and thus a consistently poor fit to the associated AFs (Figure 39). The trap CPUE time series may not be an appropriate index for the assessment because its substantial oscillations (Figure 13) suggest that it may be indexing fluctuations in the availability of fish to this gear rather than changes in abundance.

Although the data were adequate to allow some useful inferences about stock status it should be stressed that these inferences are not strong, and there are substantial weaknesses in the data. For both stocks the assessments depended primarily on the LFs. But the stock assessment models could use the LFs only by assuming that the relationship between age and length was well known and that the associated selectivities had not changed over time (except for headboat LFs for snowy grouper). Age estimates for both species are unvalidated and uncertain, and any long-term changes in selectivities (which could be caused either by changes in gear or changes in the times and places that fishers choose to fish) would be likely to bias model estimates. The CPUE indices were not influential, but they would not be expected to be unless they covered long periods during which abundance had changed substantially. Another data weakness concerned the landings, which were known to be unreliable in the early years.

3.2 Tasks 2 and 4: Estimation of population parameters and benchmarks

I evaluated the estimation techniques used in these assessments in the knowledge that this was the first time that either stock had been fully assessed. It is not a simple task to assess a stock for the first time with models as complex as those used here. Every stock presents a different suite of problems to detect, consider, and solve. The first time it is assessed we can expect most major problems to be addressed and the general form of the model to be set. However it is normal that there should be other problems that are merely identified and, for lack of time or information, set aside to be dealt with in subsequent assessments. In this context I believe that the methods used to estimate population parameters and benchmarks in these assessments (weighted maximum likelihood and MCB runs of an age-structured population model) were adequate, appropriate, scientifically sound, and the best available.

I agree with the assessment team's conclusion that simple surplus-production models were not useful for these stocks.

3.3 Task 3: Best population parameters

With one reservation, I agree with the assessment team's decision that the best estimates of population parameters from these assessments are the median values from the MCB runs.

My reservation concerns the setting of the initial likelihood weights. The values assigned to these weights can have a profound effect on the estimated stock status so it is important that the rationale for this assignment be well documented. I did not feel that this was done in sufficient detail to allow me to judge whether or not I agreed with the chosen weights. Thus my acceptance of the conclusions of the assessments must be contingent on the assumption that I would find the weights acceptable. I should add that I have no grounds to doubt this assumption – it's just that I feel I had insufficient information to test it. Many preliminary model runs were done in setting the weights and I am not suggesting that all should have been presented. That would have swamped the Panel and not helped much. What I think *was* possible (and desirable) was that a narrative be constructed that described a sequence of decisions, with supporting reasons, leading to the accepted weights.

3.4 Suggestions for future assessments

The comments and suggestions given below are intended for the consideration of those charged with future assessments of these stocks. They should not be taken as criticisms of the current assessments. As I have said above, it is not a simple task to assess a stock for the first time, and we should not expect that all problems will be solved in the first assessment. I know that the assessment team had already identified some of the issues raised below and had flagged them for future consideration.

I first discuss issues common to both assessments and then those that were specific to just one.

3.4.1 Length and Age Frequencies

The acceptance criteria for LFs and AFs could be improved. Each LF or AF was accepted if its sample size exceeded a threshold (usually 25, sometimes 50). This doesn't make sense. A strength of maximum-likelihood estimation is that it automatically compensates for the loss of information as sample size decreases, so there is no theoretical lower limit on sample size. Acceptance criteria should be based on whether each LF or AF is representative of the catch. My suggestion is that an LF or AF should be acceptable only if it provides sufficient information to calculate an effective sample size.

How can we calculate an effective sample size for an LF (say)? By a simulation exercise in which the data are repeatedly resampled (bootstrapped) to generate a set of simulated LFs from which we can calculate the standard error (SE) of each proportion in the observed LF. The effective sample size, N_{eff}, is the number which minimises the difference between the bootstrap SEs and the theoretical values given by $[p(1-p)/N_{\mathrm{eff}}]^{0.5}$. So one requirement for acceptance is that there must be a non-trivial sample collected from each stratum of the catch. The strata must, of course, be constructed before sampling. How we might define 'non-trivial' depends on the sample structure and the nature of variability within a stratum, but one idea would be to require a minimum number of landings per stratum. The other requirement is for randomness at each stage of sampling (e.g., landings to be sampled selected at random, fish to be selected at random from the landing). Of course some judgement is necessary in deciding what is sufficiently random because the logistics of fisheries sampling usually preclude full formal randomness. However, when otoliths are taken from a subset of fish measured for an LF it is easy (and desirable) to test whether this has been done randomly by comparing lengths of otolithed fish with those in the LF, as was done for tilefish.

An example of a formal test for randomness in this context is given in Appendix 3 of Francis (2002).

It may be worth considering using length-mediated estimation for AFs (i.e, using age-length keys rather than direct estimation). Direct estimation of AFs (as used in these assessments) is very difficult because it usually requires many small samples, and the smaller the sample the harder it is to make sure it is randomly selected. The point is that age-length keys don't require that otoliths selection be random (as long as it is random within each length class, which is much easier to acheive). During the Workshop it was suggested that the degree of overlap between the length distributions of adjacent age classes for snowy grouper and tilefish precludes the use of age-length keys. I don't think this is true. However, it requires only a simple simulation experiment to determine which method produces, for a given sampling cost, the more precise AFs. Of course, it is not worth considering direct estimation of AFs unless random selection of otoliths can be assured.

3.4.2 Landings as observations

I think the way landings were modelled in these assessments could be improved. Each year's landing from a fishery was treated as an independent unbiased observation with a lognormal error distribution and a specified CV (coefficient of variation). However, the discussion of sources of error in these landings suggested to me that the primary concern was with bias. The likely direction and extent of bias was not known but it seemed probable, given its source, that it would be similar in groups of adjacent years. Thus a better model would be to divide the landings into blocks of adjacent years and assume constant bias within each block: say $L_{ij,\mathrm{obs}} = b_j L_{ij,\mathrm{true}} + e_{ij}$, where L_{ij} denotes the landing (observed or true) from the ith year in the jth block, b_j is a multiplicative bias, and the e_{ij} are the random error components. In principle we can, with sufficient information, estimate both the bias and the random error. However, I suggest that, given the data available for these assessments, we have virtually no ability to estimate the random components. Thus, a better approach would be to ignore the random components (assuming they will cancel each other out) and set $L_{ij,\mathrm{obs}} = b_j L_{ij,\mathrm{true}}$. This would substantially reduce the number of parameters to be estimated (by perhaps 137 for snowy grouper and 91 for tilefish, assuming two blocks of years) and avoid misleading the model with erroneous assumptions (the independence of errors in the assessments where the assumed model was $L_{i,\mathrm{obs}} = L_{i,\mathrm{true}} + e_i$). It also avoids the need to fabricate arbitrary CVs for the landings. Note that in the snowy grouper assessment there is strong autocorrelation in the landings residuals (Figure 31), which supports the above model of bias in blocks.

3.4.3 Length-based selectivities

It is generally believed that selectivity is much more a function of length than of age. Therefore, I think it would be better to estimate selectivities as functions of length, rather than of age. This requires the model to convert each length-based selectivity to an age-based one (using the estimated distribution of length at each age), which has two advantages. First, it avoids age-based selectivities that are implausibly steep, which was the case for almost all of those estimated in the present assessments (it is not possible for the selectivity to change greatly from one age to the next when there is a great deal of overlap in the length distributions for adjacent ages). Second, when growth differs between males and females it provides a more realistic way of modelling selectivity.

3.4.4 The desirability of being more statistical

Statistical models, like those used here, provide a powerful tool for dealing with uncertainty. They allow us to assign appropriate weights to different sources of information and they tell us how certain we can be about our inferences. In practice it is impossible to gain the full power of these models because we are unable to correctly specify all the statistical components of the model and so are often forced to add arbitrary non-statistical components. I suggest that our aim should be to minimise these non-statistical components, and in this section I suggest some ways in which I think this might be achieved for snowy grouper and tilefish.

The first thing is to avoid, as much as possible, non-statistical terms in the objective function. For example, if we treat the recruitment deviations as being lognormally distributed then the arbitrary (non-statistical) weight applied to the sum of squares of log recruitment deviations (to avoid extreme variation) is effectively an inverse variance. So why not specify it as such? There are quite a lot of published estimates of σ_R (the standard deviation of log recruitment) that can be used to provide a reasonable default value (e.g., Beddington and Cooke (1983), Myers et al (draft)). Also, given a value of σ_R, a simple simulation exercise (such as was done by Chris Legault during the Workshop) can be used to determine how much SSB can be expected to vary from year to year in an unfished population. This would allow the non-statistical constraint that was applied to SSB(initial) to be recast as a (statistical) prior distribution.

To deal with the likelihood components associated with the observations we need to discuss the nature of error. An approach that I have found useful is to write $(X_{obs}-X_{pred}) = (X_{obs}-X_{true}) + (X_{true}-X_{pred})$, where X_{obs} is our observation of some quantity, X_{true} is the true value of the quantity, and X_{pred} is the model's prediction of it. Thus the total error $(X_{obs}-X_{pred})$, which is modelled in our likelihood, is the sum of an observation error $(X_{obs}-X_{true})$ and what I call a process error $(X_{true}-X_{pred})$, this last being caused by all the simplifying assumptions (e.g., time-invariant selectivities and natural mortality) that we are forced to make in formulating our model. We can often estimate observation error outside the stock-assessment model (e.g., the CVs calculated for the CPUE indices measure observation error, as do the above-mentioned bootstrap-derived effective sample sizes for AFs and LFs). Process error is much more difficult, but becomes a bit easier if we assume, as seems reasonable, that all observations of the same type have the same sized process error. Thus, since CVs add as squares, we might say that $c_{ij,\mathrm{total}}^2 = c_{\mathrm{process}}^2 + c_{ij,\mathrm{observation}}^2$, where c_{ij} denotes a CV of the ith observation in the jth series of CPUE indices and c_{process} is the common process-error CV. This allows us to use a statistically interpretable quantity like c_{process} rather than a non-statistical likelihood weight. Of course it's still not easy to find an appropriate value for c_{process} (one approach that I've used for trawl surveys and CPUE is given in Francis et al 2003). Things don't work so easily with multinomial distributions (such as are use for LFs and AFs) but a pragmatic solution is to assume that $N_{\mathrm{total}}^{-1} = N_{\mathrm{observation}}^{-1} + N_{\mathrm{process}}^{-1}$.

Although there are still difficulties in deciding how large a process error term should be we do have an objective measure of how well we have done: by comparing the size of the residuals with that which is expected from the likelihood function. For example, with a normal or lognormal error distribution we can calculate the standard deviation of the normalised residuals, which should be about 1. Much smaller (or larger) values indicate that the total error CV is too large (or too small).

What is needed to make the MCB analysis more statistical is to devise probability distributions that best describe the uncertainty in the parameters that are being randomised. I acknowledge that this appears a daunting task but point out that these distributions are analogous to Bayesian priors, and there is an extensive literature on the problem of eliciting prior distributions. The advantage of making the MCB analysis more statistical is that it would allow a probabilistic interpretation of the MCB outputs (e.g., we could say that we are 80% confident that an estimated quantity (like SSB or MSY) lies between the 10th and 90th percentile of the MCB estimates).

There are two other issues associated with the MCB runs. First, all the observations should be randomised, and not just the CPUE. Given that the present assessments appeared to be driven by the LFs, and not much affected by the CPUE indices, it is regrettable that it was only the latter that were randomised. Second, it made no sense to me to scale the CPUE CVs to a maximum of 0.3 in randomising these observations. Given any CV, *c*, we can construct a lognormal variate *Y* with mean 1 and CV = *c* by setting $\sigma^2 = \log(1+c^2)$ and $Y = \exp(\sigma Z - 0.5\sigma^2)$, where *Z* is a standard normal variate.

3.4.5 Age data

There is clearly a need for validation of the ageing of both species so that we can have more confidence in the AFs and the age-length conversion matrix. This matrix is very important in an assessment in which LFs are influential. Since it is sensitive to the assumption that is made about how the variance of length at age varies with age this assumption should be checked carefully. Replicate age estimates of the same otoliths (preferably by different readers) can be used to generate an age misclassification matrix (in which the *i*th row gives the likely distribution of estimated ages for a fish of true age *i*) which can be used to modify the likelihood components associated with LFs and AFs.

3.4.6 Other general matters

The MCB analyses are a good way to replace one type of sensitivity analysis whose aim is to quantify uncertainty. Another type of sensitivity analysis which could have been useful in the Workshop would have been to rerun the initial run several times, each time dropping one type of data, thus showing the extent to which the assessments depended on each data type.

There were several small problems in both assessments, mostly in the documentation. It should be made clear that the calculation of generation time involves only female fish (I understand that this was how the calculations were made, but that was not clear to me from the reports). In fitting the von Bertalanffy equation the assumption used was clearly that the *standard deviation* of length at age was proportional to the mean length (not the *variance*, as stated). In the formula for the age-length conversion matrix the superscript 2 is misplaced. Equations should be given for the per-recruit calculations. It might be worth checking the method of fitting the maturity ogives for both species because the fitted curve is to the right of all data points for which the proportion mature is not near 0 or 1 (see Figure 5 for snowy grouper and Figure 8 for tilefish). In the tables documenting the model it might avoid confusion if a clear distinction were made between fixed parameters (e.g., growth parameters, LF sample sizes), estimated parameters (e.g., selectivity parameters, fishing mortalities), derived quantities (e.g., length at age, selectivity at age) and observations (which are characterised by having an associated likelihood component, e.g., CPUE, LFs).

3.4.7 Snowy Grouper

I think it might be useful to try some more sophisticated techniques (e.g., GAMs or tree-based regression) to seek an explanation of the unrealistic MCB runs. This may be informative. It might be worth dropping the Chevron trap CPUE index (for reasons given above). It seems a matter of some concern that more than half the catch is of immature fish. It is worth considering explicitly modelling the three categories of fish: immature, mature female, mature male (i.e., keeping track of numbers of fish by age and category)

3.4.8 Tilefish

I think it would be worthwhile to explicitly model sex (i.e., to keep track of numbers by sex, as well as by age — the assessment report stated that this was not possible because the landings and LFs were not sex-specific, but I don't see why). As females are smaller at age than males they probably do not have the same selectivity at age as males do, so modelling selectivity as length-based would be better.

4. CONCLUSIONS

I believe that the assessments of snowy grouper and tilefish that were presented to the Panel provide information that should be very useful to fishery managers. The assessment team did a good job of dealing with the available data and constructing sound first-time assessments.

5. REFERENCES

Beddington, J.R.; Cooke, J.G. (1983). The potential yield of fish stocks. *FAO Fisheries Technical Paper 242*. 50 p.

Francis, R.I.C.C. (2002). Estimating catch at age in the Chatham Rise hoki fishery. *New Zealand Fisheries Assessment Report 2002/9*. 22 p.

Francis, R.I.C.C.; Hurst, R.J.; Renwick, J.A. (2003). Quantifying annual variation in catchability for commercial and research fishing. *Fishery Bulletin 101*: 293-304.

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

Myers, R.A.; Bowen, K.G.; Zouros, I.A. (draft). Recruitment variability of fish and aquatic invertebrates. Draft paper available in pdf form from http://fish.dal.ca/~myers/papers.html.

APPENDIX 1: Statement of Work

This appendix contains the Statement of Task that formed part of the consulting agreement between the University of Miami and the author.

Consulting Agreement between the University of Miami and NIWA (Dr. Chris Francis)

General

South East Data, Assessment, and Review (SEDAR) is a joint process for stock assessment and review of the South Atlantic, Gulf of Mexico, and Caribbean Fishery Management Councils; NOAA Fisheries, SEFSC and SERO; and the Atlantic and Gulf States Marine Fisheries Commissions. SEDAR is organized around three workshops: data, assessment, and review. Input data are compiled during the data workshop, population models are developed during the assessment workshop, and an independent peer review of the data and assessment models is provided by the review workshop. The peer review panel is composed of stock assessment experts, other scientists, and representatives of council, fishing industries, and non-governmental conservation organizations. Final SEDAR documents include a stock assessment report produced by the data and assessment workshops, a review panel report evaluating the assessment (drafted during the review panel workshop), a review panel report that summarizes the peer-reviewed assessment results, and collected stock assessment documents considered in the SEDAR process.

NMFS-SEFSC requests the assistance of two assessment scientists from the CIE: one to serve as Chair and one to serve as a technical reviewer for the SEDAR 4 Review Panel that will consider assessments for two species from the South Atlantic deepwater snapper-grouper complex: tilefish and snowy grouper.

These species are within the jurisdiction of the South Atlantic Fishery Management Council and respective southeastern states. The review workshop for SEDAR 4, South Atlantic deepwater complex stock assessments, will take place at the Holiday Inn Center City, Charlotte, NC from July 26 (beginning at 2:00 pm) through July 30, 2004 (ending at 1:00 pm). Meeting materials will be forwarded electronically and in hard copy. Please contact John Carmichael (SEDAR Coordinator; 843-571-4366 or John.Carmichael@safmc.net) for additional details.

Hotel arrangements

Holiday Inn Center City, 230 N. College Street, Charlotte, NC 28202. Phone: (704) 335-5400, (800) 465-4329; Fax (704) 376-4921. Please make reservations by June 16 and to receive the ‘SEDAR Workshop’ group rate of $91.94 (including tax).

SEDAR Assessment Review Panel Tasks

The SEDAR Assessment Review Panel will evaluate the tilefish and snowy grouper stock assessments, input data, assessment methods, and model results as put forward in stock assessment reports. The Assessment Review Panel will:

1. Evaluate the adequacy and appropriateness of all data used in the assessment, and state whether or not the data are scientifically sound and the best available.
2. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population parameters such as abundance, biomass, and exploitation; state whether or not the methods are scientifically sound and the best available;
3. Recommend appropriate or best estimated values of population parameters such as abundance, biomass, and exploitation.
4. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population benchmarks (MSY, Fmsy, Bmsy, MSST, MFMT, etc.). State whether or not the methods are scientifically sound and the best available,
5. Recommend appropriate values for population benchmark criteria.
6. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound and the best available.
7. Recommend probable values of future population condition and status.
8. Develop recommendations for future research for improving data collection and the assessment.
9. Prepare a Peer Review Panel Consensus Summary summarizing the peer review panel's evaluation of the tilefish and snowy grouper stock assessments and addressing the Terms of Reference. (Drafted during the Assessment Review Panel workshop with a final report due three weeks after the workshop ends.)
10. Prepare a Stock Advisory Report summarizing the stock assessments. (Drafted during the Assessment Review Panel workshop with a final report due three weeks after the workshop ends.)

The Assessment Review Panel's primary duty is to review the assessments presented. In the course of this review, the Chair may request a reasonable number of sensitivity runs, additional details of the existing assessments, or similar items from technical staff. However, the review panel is not authorized to conduct an alternative assessment or to request an alternative assessment from the technical staff present. If the review panel finds that an assessment does not meet the standards outlined in Items 1 through 4, above, the panel will outline in its report the remedial measures that the panel proposes to rectify those shortcomings.

The Review Panel Report is a product of the overall Review Panel, and is NOT a CIE product. The CIE will not review or comment on the Panel's report, but shall be provided a courtesy copy, as described below under "Specific Tasks." The CIE product to be generated is the Chair's report, also discussed under Specific Tasks.

Specific Tasks

The CIE designee shall serve as review panelist of a SEDAR Stock Assessment Review Panel workshop for SEDAR 4, South Atlantic tilefish and snowy grouper, July 26 - 30, 2004 (See attached agenda.). The workshop panel shall review stock assessments for South Atlantic tilefish and snowy grouper in the jurisdiction of the South Atlantic Fishery Management Council and applicable southeastern states.

It is estimated that the review panelist's duties will occupy a maximum of 14 workdays; several days prior to the meeting for document review; five days at the SEDAR meeting, and several days following the meeting to ensure that final review comments on documents are provided to the Chair and to complete a CIE review report.

Roles and responsibilities:

1. Prior to the meeting the CIE reviewer shall be provided with the stock assessment reports and associated documents for South Atlantic tilefish and snowy grouper. The reviewer shall read these documents to gain an in-depth understanding of the stock assessment and the resources and information considered in the assessment.
2. During the Review Panel meeting, the reviewer shall participate, as a peer, in panel discussions on assessment validity, results, recommendations, and conclusions. The reviewer also shall participate in the development of the Peer Review Panel Consensus Summary and Stock Advisory Report;
3. Following the Review Panel meeting, the reviewer shall review and provide comments to the Panel Chair on the Peer Review Panel Consensus Summary and Stock Advisory Report.
4. No later than August 20, 2004, the reviewer shall submit a written CIE review report[1] consisting of the findings, analysis, and conclusions, addressed to the "University of Miami Independent System for Peer Review," and sent to Dr. David Sampson, via email to David.Sampson@oregonstate.edu, and to Mr. Manoj Shivlani, via email to mshivlani@rsmas.miami.edu. The report shall address points 1-4 under the above heading: SEDAR Assessment Review Panel Tasks. See Annex I for details on the report outline.

Workshop Final Reports

The Chair shall send final review workshop reports to the University of Miami Independent System for Peer Review, Dr. David Die via email to ddie@rsmas.miami.edu.

Final workshop reports (in Word or WordPerfect format and in hardcopy) shall also be sent to:

Nancy Thompson, NMFS Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, FL 33149 (email, Nancy.Thompson@NOAA.gov)

Larry Massey, 101 Nina Drive #302, Virginia Beach, VA 23462 (email, Larry.Massey@NOAA.gov)

John Carmichael, SAFMC, One Southpark Circle, Suite 306, Charleston, SC 29407 (email, John.Carmichael@safmc.net)

Robert Mahood, South Atlantic Fishery Management Council, One Southpark Circle, Suite 306, Charleston, SC 29407 (email, Robert.Mahood@safmc.net)

[1] The written Reviewer report will undergo an internal CIE review before it is considered final. After completion, the CIE will create a PDF version of the Reviewer report that will be submitted to NMFS and the consultant.

For Additional Information or Emergency:

SEDAR contact: John Carmichael, One Southpark Circle, Suite 306, Charleston, SC 29407. Phone: 843-571-4366; cell phone (843) 224-4559. Email: John.Carmichael@safmc.net.

ANNEX I: Contents of CIE Reviewer Report

1. The reviewer report shall be prefaced with an executive summary of findings and/or recommendations.

2. The main body of the reviewer report shall consist of a background, description of review activities, summary of findings, and conclusions/recommendations.

3. The reviewer report shall also include as separate appendices the bibliography of materials provided by the Center of Independent Experts and a copy of the Statement of Work.

APPENDIX 2: Materials Provided

The author was provided with the following materials by the SEDAR Coordinator.

1. Terms of Reference and Panel Instructions for SEDAR 4 Review Workshop, Atlantic Deepwater Snapper-Grouper: Tilefish and Snowy Grouper (see Appendix 2.1)

2. SEDAR 4 Data Workshop Summary, Deep Water Complex, November 3-7, 2003

3. Assessment of Snowy Grouper (*Epinephelus niveatus*) in the South Atlantic Fishery Management Council Management Area. Section III.A of SEDAR Stock Assessment Report.

4. Assessment of Tilefish, *Lopholatilus chamaeleonticeps,* in the South Atlantic Fishery Management Council Management Area. Section III.B of SEDAR Stock Assessment Report.

5. South Atlantic Deepwater Snapper Grouper Document List. Appendix A of SEDAR Stock Assessment Report

6. AD Model Builder code for tilefish statistical catch-at-age model. Appendix B of SEDAR Stock Assessment Report

7. Documents from SEDAR4 Atlantic and Caribbean Deepwater Snapper Grouper (listed in Appendix 2.2).

8. Reference papers from SEDAR4 Atlantic and Caribbean Deepwater Snapper Grouper (listed in Appendix 2.3).

9. A CD containing items 1-4, 7 and 8 above.

APPENDIX 2.1: Terms of Reference and Instructions for the Review Panel

I. Terms of Reference

The SEDAR Assessment Review Panel will evaluate the tilefish and snowy grouper stock assessments, input data, assessment methods, and model results as put forward in stock assessment reports. The Assessment Review Panel will:

1. Evaluate the adequacy and appropriateness of all data used in the assessment and state whether or not the data are scientifically sound;

2. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population parameters such as abundance, biomass, and exploitation and state whether or not the methods are scientifically sound;

3. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population benchmarks (*e.g., MSY, Fmsy, Bmsy, MSST, MFMT, or their proxies*) and state whether or not the methods are scientifically sound;

4. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound;

5. Ensure that all available required assessment results (*as listed in the SEDAR Stock Assessment Report Outline*) are clearly and accurately presented in the Stock Assessment Report and that such results are consistent with the Panel's decisions regarding adequacy, appropriateness, and application of the data and methods;

6. Evaluate the performance of the Data and Assessment Workshops with regards to their respective Terms of Reference, and state whether or not the Terms of Reference for those previous workshops are adequately addressed in the Stock Assessment Report;

7. Review the assessment workshop's recommendations of future research for improving data collection and the assessment, and make any additional recommendations warranted;

8. Prepare a Peer Review Consensus Summary summarizing the Panel's evaluation of the tilefish and snowy grouper stock assessments and addressing each Term of Reference. (Drafted by the Panel during the Review Workshop with a final report due three weeks after the workshop ends.);

9. Prepare a Stock Advisory Report summarizing the stock assessments. (Drafted during the Assessment Review Panel workshop with a final report due three weeks after the workshop ends.).

II. Review Panel Instructions

The Assessment Review Panel is charged with reviewing the technical aspects of the presented stock assessment and making judgements regarding the assessment that are based solely upon scientific merit. At no point during the deliberations should the Review Panel consider the implications that the assessment and its results may have upon management decisions or resource users. This is not to imply in any way that such considerations are not important, but rather to acknowledge several important facts: (1) consideration of management impacts is beyond the scope of the charge to the Review Panel, (2) SEDAR specifically strives to separate management considerations from assessment decisions, (3) Review Panel participants are selected based on technical, biological, and assessment knowledge, not social and economic knowledge of a fishery, (4) consideration of social and economic consequences is specifically mandated to the Council and various Council Committees composed of experts qualified to evaluate the social and economic consequences of management actions.

The Assessment Review Panel is discouraged from holding formal votes. Decisions should be based upon the unanamious consenus of the entire panel. In the event that the Chair feels that all avenues for agreement have been exhausted and unanimous consensus is not achievable, the Chair may instruct that the majority opinion be reflected in the report and allow the minority opinon holders to prepare and submit a minority report.

The Assessment Review Panel's primary duty is to review the assessments presented. In the course of this review, the Chair may request a reasonable number of sensitivity runs, additional details of the existing assessments, or similar items from technical staff. However, the review panel is not authorized to conduct an alternative assessment nor to request an alternative assessment from the technical staff present.

If the review panel finds that an assessment does not meet the standards outlined in Items 1 through 6, above, the panel will outline in its report the remedial measures to be taken by the assessment analysts to rectify those shortcomings.

Review Panel members are expected to participate in the entire workshop from start to finish. The supporting Council's strongly discourage panel members from leaving early. Panelists should expect that the Workshop will require the entire time alloted and plan travel accordingly. To this end, workshops are scheduled for an afternoon start and early adjournment to reduce the need for weekend travel.

APPENDIX 2.2: Documents from SEDAR4 Data Workshop

#	Title	Author(s)
SEDAR4-DW-01	Indices of Abundance from Commercial Logbook Data: South Atlantic stocks	Shertzer, K.; McCarthy, K.
SEDAR4-DW-02	MRFSS Landings and Length Data Summary for the South Atlantic	Vaughan, D. S.
SEDAR4-DW-03	General Canvass Landings Statistics for the South Atlantic Region	Poffenberger, J.
SEDAR4-DW-04	Summary information on commercial fishing operations in Puerto Rico from 1969-2001 and reporting rates needed to adjust commercial landings.	Cummings, N. Matos-Caraballo, D.
SEDAR4-DW-05	Summarized reported commercial landings in Puerto Rico from 1969-2001 with specific notes on the silk snapper landing category.	Cummings, N. Matos-Caraballo, D.
SEDAR4-DW-06	Not used	
SEDAR4-DW-07	Information on the general biology of silk and queen snapper in the Caribbean.	Cummings, N
SEDAR4-DW-08	Preliminary Estimation of Reported Landings, Expansion Factors and Expanded Landings for the Commercial Fisheries of the United States Virgin Islands**.**	Valle-Esquivel, M. Diaz, G.A.
SEDAR4-DW-09	Preliminary species composition estimates of TIP samples from commercial landings in the U.S. Virgin Islands.	Diaz, G. A. ; Valle-Esquivel, M.
SEDAR4-DW-10	Standardized Catch Rates of Silk Snapper, Lutjanus vivanus, from the St. Croix .S.Virgin Islands Handline Fishery during 1984 - 1997.	Cass-Calay, S.L.; Valle-Esquivel, M.
SEDAR4-DW-11	Standardized Catch Rates of Queen Snapper, Etelis oculatus, from the St. Croix U.S. irgin Islands Handline Fishery during 1984 – 1997	Cass-Calay, S.L.; Valle-Esquivel, M.
SEDAR4-DW-12	Discard Estimates for the South Atlantic Region.	Poffenberger, J.
SEDAR4-DW-13	Size Frequency Data from the Trip Interview Program, South Atlantic Region	Poffenberger, J.
SEDAR4-DW-14	Size frequency distributions of silk snapper and queen snapper from dockside sampling of commercial landings in the U.S. VI	Diaz, G. A.; Valle-Esquivel, M.
SEDAR4-DW-15	Preliminary information on the recreational catch of silk, queen, and blackfin snapper, from 2000 through 2002 in Puerto Rico with additional notes on sand tilefish	Cummings, N.; Slater, B.; Turner, S.
SEDAR4-DW-16	Preliminary analysis of some deepwater species in the South Atlantic headboat survey data.	Williams, E.; Dixon, B.
SEDAR4-DW-17	Age, growth and reproductive biology of the blueline tilefish, *Caulolatilus microps*, along the southeastern coast of the United States, 1982-99.	Harris, P. J.; Wyanski, D.M.; Powers, P.T.
SEDAR4-DW-18	Age, growth and reproduction of tilefish, Lopholatilus chamaeleonticeps, along the southeast Atlantic coast of the United States,	Palmer, S.M.; Harris, P.J.; Powers, P. T.

	1980-87 and 1996-98.	
SEDAR4-DW-19	Deep-water species report. South Carolina and Georgia.	Low, B.
SEDAR4-DW-20	South Atlantic Snapper-Grouper Regulatory Overview	Carmichael, J.
SEDAR4-DW-21	Summary of MARMAP sampling	Anon.
SEDAR4-DW-22	Blueline tilefish life history; How to assess reef fish stocks: Excerpts from NMFS-SEFC-80	various
SEDAR4-DW-23	Preliminary size frequency information for silk, queen, and blackfin snapper from the Puerto Rico commercial fisheries from 1985 through 2002 with additional notes on sand tilefish	Cummings, N.J. Phares, P
SEDAR4-DW-24	Brief summary of SEAMAP data collected in the Caribbean Sea from 1975 to 2002	Ingram, W.
SEDAR4-DW-25	Yellowedge Grouper age-length key	Bullock & Godcharles
SEDAR4-DW-26	Estimating catches and fishing effort of the southeast united states headboat fleet, 1972-1982	Dixon & Huntsman
SEDAR4-DW-27	Trends in Catch Data and Estimated Static SPR Values for Fifteen Species of Reef Fish Landed along the Southeastern United States, February 1998.	Potts, Burton & Manooch
SEDAR4-DW-28	Trends in Catch Data and Estimated Static SPR Values for Fifteen Species of Reef Fish Landed along the Southeastern United States, February 2001.	Potts & Brennan
SEDAR4-DW-29	Description of the Southeast Fisheries Science Center's Logbook Program for Coastal Fisheries	Poffenberger, J.

APPENDIX 2.3: References from the SEDAR4 Data Workshop

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APPENDIX 3: Attendees at SEDAR4 Assessment Review Panel Workshop

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