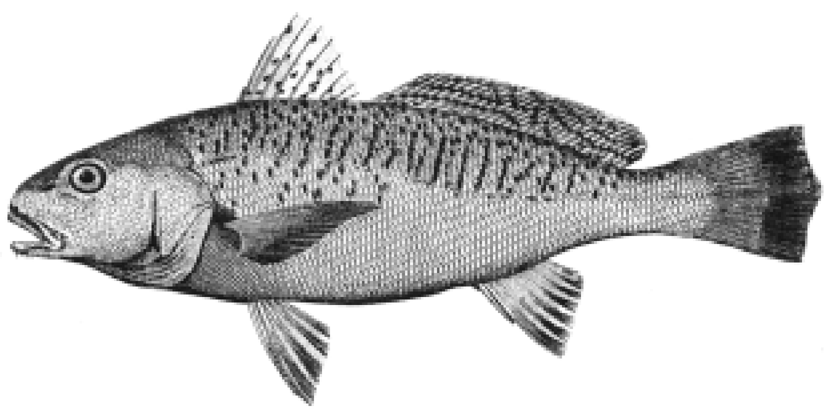
Stock Assessment Report No. 03-02
of the

Atlantic States Marine Fisheries Commission

Terms of Reference & Advisory Report
for the Atlantic Croaker Stock Assessment Peer Review



October 2003

Working towards healthy, self-sustaining populations for all Atlantic coast fish species
or successful restoration well in progress by the year 2015

Stock Assessment Report No. 03-02
of the

Atlantic States Marine Fisheries Commission

Terms of Reference & Advisory Report
for the Atlantic Croaker Stock Assessment Peer Review

Conducted on
October 8 & 9, 2003
Raleigh, North Carolina

A publication of the Atlantic States Marine Fisheries Commission pursuant to National Oceanic and Atmospheric Administration Award No. NA03NMF4740078.

Preface

Summary of the Commission Peer Review Process

The Stock Assessment Peer Review Process, adopted in October 1998 by the Atlantic States Marine Fisheries Commission, was developed to standardize the process of stock assessment reviews and validate the Commission's stock assessments. The purpose of the peer review process is to: (1) ensure that stock assessments for all species managed by the Commission periodically undergo a formal peer review; (2) improve the quality of Commission stock assessments; (3) improve the credibility of the scientific basis for management; and (4) improve public understanding of fisheries stock assessments. The Commission stock assessment review process includes evaluation of input data, model development, model assumptions, scientific advice, and review of broad scientific issues, where appropriate.

The Stock Assessment Peer Review Process report outlines four options for conducting a peer review of Commission managed species. These options are, in order of priority:

1. The Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC) conducted by the National Marine Fisheries Service (NMFS), Northeast Fisheries Science Center (NEFSC) or the Southeast Data and Assessment Review (SEDAR) conducted by the National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center (SEFSC).

2. A Commission stock assessment review panel composed of 3-4 stock assessment biologists (state, federal, university) will be formed for each review. The Commission review panel will include scientists from outside the range of the species to improve objectivity.

3. A formal review using the structure of existing organizations (i.e. American Fisheries Society, International Council for Exploration of the Sea, or the National Academy of Sciences).

4. An internal review of the stock assessment conducted through the Commission's existing structure (i.e. Technical Committee, Stock Assessment Committee).

Twice annually, the Commission's Interstate Fisheries Management Program (ISFMP) Policy Board prioritizes all Commission managed species based on species Management Board advice and other prioritization criteria. The species with highest priority are assigned to a review process to be conducted in a timely manner.

In November 2002, the Atlantic croaker stock assessment was prioritized for a SEDAR peer review. A review panel was convened of stock assessment biologists and representatives from the fishing community and non-government organizations. Panel members had expertise in Atlantic croaker life history and stock assessment methods. The SEDAR review for the Atlantic croaker stock assessment was conducted October 8-9, 2003 in Raleigh, North Carolina.

Purpose of the Terms of Reference and Advisory Report

The Terms of Reference and Advisory Report provides summary information concerning the Atlantic croaker stock assessment and results of the SEDAR review to evaluate the accuracy of the data and assessment methods for this species. Specific details of the assessment are documented in a supplemental report entitled Atlantic Croaker Stock Assessment Report for Peer Review. To obtain a copy of the supplemental report please contact the Commission at (202) 289-6400.

Acknowledgments

Thanks are due to the many individuals who contributed to the Commission's Atlantic croaker Stock Assessment Peer Review. Special thanks are extended to the Atlantic Croaker Peer Review Panel (Dr. Steve Bobco, Old Dominion University, William Goldsborough, Chesapeake Bay Foundation, Najih Lazar, Rhode Island Division of Environmental Management Marine Fisheries Section, Dr. Tom Miller, Chesapeake Biological Laboratory, Dr. Jim Nance, NOAA Fisheries NMFS SEFSC, Dr. Paul Nitschke, NOAA Fisheries, NMFS NEFSC, Lee Paramore, North Carolina Division of Marine Fisheries, Dr. Stephen Smith, Bedford Institute of Oceanography, Dr. Elizabeth Wenner, South Carolina Department of Natural Resources, Geoffrey White, Atlantic States Marine Fisheries Commission, William T. Windley, Jr., Maryland Saltwater Sportfish Association) for their hard work in reviewing the meeting materials and providing advice on improvements to the Commission's Atlantic croaker stock assessment. The Commission would like to extend its appreciation to the members of the Atlantic Croaker Technical Committee and Stock Assessment Subcommittee for development of the Atlantic Croaker Stock Assessment Report for Peer Review (Stock Assessment Peer Review Report 03-002 Supplement) and specifically to the following members for presenting this report at the Peer Review meeting: Dr. Janaka DeSilva (Florida Fish and Wildlife Commission), and Dr. Eric Williams (National Marine Fisheries Service, Beaufort Laboratory).

Special appreciation is given to the staff dedicated to the performance of the peer review and finalization of peer review reports, specifically – Dr. Lisa Kline, Dr. John Merriner, and Nancy Wallace.

Table of Contents

List of Figures

Terms of Reference for the Atlantic croaker Peer Review

1. **Evaluate the adequacy and appropriateness of fishery-dependent and independent data used in the assessments (i.e. was the best available data used in the assessment).**

The Atlantic croaker stock assessment used commercial and recreational landings data, the National Marine Fisheries Service (NMFS) Northeast Fisheries Science Center (NEFSC) bottom trawl indices, Marine Recreational Fisheries Statistics Survey (MRFSS) CPUE index, and Southeast Area Monitoring and Assessment Program (SEAMAP) nearshore trawl survey indices.

The commercial landings data used in the assessment did not include landings from aggregate, unculled ("scrap") bait fisheries nor were discard data estimated. Unculled bait landings data are only available from North Carolina and indicated that this fishery could account for a substantial amount (2-50%) of additional landings not accounted for in the directed fishery landings, particularly prior to 1996. The Panel expressed concern both over whether unculled bait landings data are available from other states and the magnitude of these landings for other states. The Panel recommends that the North Carolina unculled bait fishery data be evaluated and the landings updated to include these landings. The possibility of applying the North Carolina proportions to other states to estimate their unculled fish landings should also be explored. The unculled bait fishery consists of primarily small fish compared to other commercial landings and may require a revised or new selectivity curve in the model. The Panel also recommends that at-sea observer data be evaluated for inclusion of discard/bycatch data in the model.

The Panel agreed that the MRFSS recreational landings for the period 1981 to present were the best available data. The Panel noted that as the ratio of commercial to recreational landings for the period 1981-present was used to hindcast earlier recreational landings, changes in the commercial removals (see above) will require re-estimation of recreational landings for the 1973 to 1980 time period. The Panel agreed with the validity of the recreational landings and the method of extending these data back to 1973.

The model used NMFS NEFSC fall bottom trawl survey indices from 1982 to the present. The survey is a stratified random survey design extending back to 1963. The assessment used a survey index derived from the application of a delta lognormal model to the NEFSC bottom trawl data, as opposed to stratified mean estimates. A comparison of the delta lognormal estimates with stratified mean estimates on assessment results indicated substantial differences. The Panel noted that these differences were not addressed in the assessment report and was not confident in the use of the Delta lognormal model. The Panel recommends that the time series be extended back to 1973 and an evaluation be conducted to better understand the differences between the lognormal and stratified mean estimates.

The Panel accepted the SEAMAP nearshore trawl data and the MRFSS CPUE index as the best data available. The Panel accepted the definition of croaker trips as consisting of a suite of species.

The final stock assessment model did not include trawl survey data from the Virginia Institute of Marine Science (VIMS). The VIMS trawl survey is believed to reflect dynamics of young croaker. The Panel noted that although the inclusion of the VIMS trawl survey might not be appropriate in an unstructured surplus production model, the VIMS time series may provide important information for the current assessment model. The Panel recommends further investigation of the inclusion of the VIMS trawl survey in the model since this survey covers the full time period and areas not covered by other survey indices included in the model.

The assessment model uses a growth curve derived only from North Carolina data and applies this growth curve to all areas included in the model. The Panel agrees that the North Carolina growth curve is the best available. However, the Panel expressed concern that the North Carolina growth parameters were being applied across the entire latitudinal range of the stock and over the entire period of the assessment. Given the wide latitudinal range of this species, and the wide range of abundances observed in the stock, the Panel recommends the investigation of spatial and interannual variability in growth.

Several different methods of calculating natural mortality (M) were evaluated in the stock assessment. The model used a constant M of 0.3 from the mid-point of the range of estimates. The Panel accepted the approach for calculating M as the best available, but recommends the development of age-specific mortality estimates.

The Atlantic croaker stock assessment is not an age based method. Work is currently being conducted to standardize ageing methods for Atlantic croaker. The Panel recommends that the Commission conduct an ageing workshop to develop approved standard ageing protocols to improve coastwide consistency in ageing data. The Panel also support continued collection of age samples from fisheries-independent surveys and length samples from the MRFSS in order to improve future Atlantic croaker assessments.

2. **Evaluate the adequacy, appropriateness and application of models used to assess these species and to estimate population benchmarks.**

The model used was a forward projection age-structured production model with the age structure generated by the model and not included as input data to the model. The model was run separately for the mid-Atlantic region (North Carolina and north) and the south Atlantic region (South Carolina to Florida). The regions were separated due to a lack of observations of older fish (age 3+) in the southern region and differences in the temporal patterns in fishery-independent survey indices in the southern area, which indicated that dynamics may be different in the two regions. The Technical Committee indicated that performance of the mid-Atlantic model was acceptable, whereas that of the south Atlantic model was not wholly acceptable. There was extensive Panel discussion of the justification and implications of the separation of croaker into two management units. One view suggested the separation reflected a recognition of a lack of knowledge regarding the dynamics of croaker in the southern part of the species range. An extension of this view implies that the separation reflects a “culling” of the data so that the strength of the signal in the mid-Atlantic is not masked by differences in indices in the southern portion of the range. An alternative view is that there is indeed some functional stock structure that underlies the decision to develop separate models. An extension of this view implies the potential for different reference points in the two components. Overall, the Panel did not believe that data were available to support either view. The Panel recommends investigation of the distribution and movement of croaker by age and season, and a comparison of life history parameters over the full distribution of croaker to address these uncertainties and provide full justification for a spatially explicit model. The Panel recommends tagging (artificial tags or natural tags such as otolith microchemistry/genetics) studies be conducted to address the justification for regional assessments.

The model for the Mid-Atlantic region used commercial and recreational landings from 1973 to the present, while the survey indices used in the model only extended back to 1982. The Panel expressed concerns with starting the model in 1973 with landings data only and not taking advantage of the available survey tuning indices. During the review, the Panel requested a comparison model run using the NMFS NEFSC bottom trawl survey data from 1973 to the present. This analysis provided some indication of differences in scale between the full series and the partial series used in the assessment. The Panel recommends re-running the model using the full series of NMFS NEFSC fall bottom survey data. The Panel also recommends the evaluation and possible inclusion of the VIMS trawl survey data.

The base model assumed that the SSB in 1973 was equal to 0.75 SSB (virgin biomass) from the Beverton-Holt analysis. The Panel was concerned about the validity of this assumption. The Panel recommends that the assessment readdress this assumption once the full time series of survey data is included in the model.

The model assumes that the fisheries-independent survey indices are more precise than the fisheries-dependent data and recruitment deviation estimates and, therefore, provided higher weights to these surveys. The Panel did not find compelling evidence to support the weightings applied. The Panel noted that these weighting factors may not be optimum and could strongly impact model results. The Panel recommended an exploration of the consequences of different weighting factors.

The assessment included an age structured production model only. This required development of an algorithm to generate an age structure for the population. The Panel recommends a comparison of non-age assessment models, such as the Collie-Sissenwine catch-survey and a delay difference model, to understand the implications of this age structure on derived reference points and stock advice.

The Panel accepted selectivity curves used for both commercial and fisheries-independent indices as the best available. The Panel recommends the evaluation of culling the larger fish out of the survey indices to better match the assumed selectivity.

The Panel noted that the assessment model relies on a single renewal function – specifically a Beverton and Holt stock- recruit function. The Panel noted that there has been dramatic variation in croaker abundance over the time period. In weakfish, a related sciaenid fish, similar variation in abundance has induced density-dependent changes in fecundity. If similar biological changes, or environmentally induced changes to potential stock productivity have occurred in croaker, the assumption of a constant renewal function may be questionable. The Panel recommended an evaluation of changes in maturity and fecundity within the stock.

3. **Evaluate the adequacy and appropriateness of the Technical Committee's recommendations of current stock status based on biological reference points.**

The Atlantic Croaker Technical Committee had concerns with recommending and evaluating reference points for the south Atlantic model at this time. Given the lack of data to estimate movement between the two regions, and the poor model fits, estimates of Fmsy and SSBmsy for the South Atlantic may be incorrect. The Panel accepted this conclusion regarding the southern region.

The benchmarks for the mid-Atlantic region listed in the stock assessment report were corrected as follows:

F threshold - Fmsy
Biomass threshold - 0.7 SSBmsy
F target – 0.75 Fmsy
Biomass target – SSBmsy

These benchmarks are based on Restrepo et al. (1998) and are standard for other managed species. The Panel noted that these benchmarks are appropriate given the model.

Stock status determination was only provided for the Mid-Atlantic region, with F2001 = 0.98 Fmsy, and SSB2001 = 1.76 SSBmsy. Based upon the recent trends in survey indices, many members of the Panel accepted that the stock was not overfished; however, full consensus was not reached. However, given the lack of precision associated with the F estimates and the problems noted earlier with the model and landings data the Panel could not determine if overfishing is occurring. The Panel recommends that if the high degree of uncertainty in current F's continues, a more conservative target be evaluated so that management action to meet the target F may not place the stock in danger of simultaneously exceeding the limit F.

Given the major concerns with the landings data and abundance indices used in the model, the Panel expressed concern with use of the current Atlantic croaker stock assessment for management purposes. The Panel recommends that the Atlantic Croaker Technical Committee resolve the issues in research recommendations 1-7 and update the assessment.

4. **Develop recommendations for future research for improving data collection and the assessment.**

The Panel recommends that the Atlantic Croaker Technical Committee resolve the issues in research recommendations 1-7 during the development of an updated assessment.

1. Issue: Commercial landings did not include all removals from the population.
    - Evaluate North Carolina unculled bait ("scrap") fishery data and include in the commercial landings.

- Evaluate the potential of applying the North Carolina unculled bait fishery data to other states.
- Consider at-sea observer data for discards and bycatch.

2. Issue: The model used catch data from 1973 to the present but tuning indices were only used from 1981 to the present.
   - Extend the NMFS NEFSC bottom trawl survey data to 1973 for inclusion in the model.
   - Evaluate the difference between the Delta lognormal and stratified mean estimates from NMFS NEFSC bottom trawl survey.
   - Evaluate the VIMS survey data for possible inclusion in the model.

3. Issue: The base model assumed that the SSB in 1973 was equal to 0.75 SSB (virgin biomass) from the Beverton-Holt analysis.
   - Re-evaluate after inclusion of the full time series of NMFS NEFSC and VIMS trawl survey data.

4. Issue: The model assumes that the fisheries-independent survey indices are more precise than the fisheries-dependent data and model recruitment estimates and, therefore, provided higher weights to these surveys.
   - Evaluate the consequences of alternative weighting schemes.
   - Provide detailed justification for the final choice of weighting scheme.

5. Issue: Separate models were developed for the mid-Atlantic (North Carolina and north) and South Atlantic (South Carolina to Florida).
   - Investigate the distribution and movement of croaker by age and season.
   - Compare life history parameters over the full distribution of croaker.

6. Issue: The assessment included an age structured production model only. This required development of an algorithm to generate an age structure for the population.
   - Compare non-age assessment models, such as the Collie-Sissenwine catch-survey and a delay difference model, to understand the implications of this age structure on derived reference points and stock advice.

7. Issue: Determination of overfishing/overfished were based on point estimates only.

   - Estimate the error distribution for current estimates of F, and reference points.
   - Determine whether, given error distributions determined above, target F and threshold F could be distinguished from estimates derived from the assessment model.
   - Consider revising F target reference point relative to the previous bullet.

The following research recommendations are lower priority, long-term research issues. These recommendations will provide improvements to future assessments.

8. Issue: Separate models were developed for the mid-Atlantic (North Carolina and north) and South Atlantic (South Carolina to Florida).

- Conduct tagging and otolith microchemistry studies to address the justification for regional assessments.

9. Issue: Difficult to understand what component of the population the surveys were tracking.
   - Include maps of fishery and survey areas in future reports.

10. Issue: A single growth curve based on data from North Carolina was applied over all years and for whole area.
    - Evaluate the applicability of the North Carolina growth curve to all areas (spatial variability).
    - Investigate interannual variability in growth.

11. Issue: A single natural mortality estimate was used for all ages and years.
    - Develop age-specific M for inclusion in the model.

12. Issue: Trends in the recruitment deviations may indicate temporal bias in the recruitment model.
    - Assess whether changes in potential population reproductive capacities have changed by quantifying patterns in the maturity ogive and size- and age-dependent fecundity.
    - Assess whether density dependent shifts in age- or condition-dependent timing of age at maturity have occurred as in other sciaenids.
    - Assess whether temporal patterns in recruitment slope or asymptote have occurred.

13. Issue: There are no standard protocols for ageing of Atlantic croaker.
    - Conduct a workshop to develop and approve ageing standards for Atlantic croaker.
    - Continue collection of coastwide age samples from fisheries-independent surveys and length samples from the MRFSS.

14. Issue: Selectivity curves were used for both commercial and fisheries-independent indices.
    - Evaluate culling of the larger fish out of the survey indices to better match the assumed selectivity.

Atlantic Croaker Advisory Report

Status of Stocks

The Atlantic croaker stock status for the South Atlantic region is unknown at this time. The South Atlantic region makes up a relatively small component of the total stock biomass. Stock status determination in terms of overfishing is also unknown for the mid-Atlantic region. Given that the forward projection age-structured production model did not account for a likely significant source of removals by the scrap fishery along with questions on biomass indices noted in the full Peer Review Panel Terms of Reference Report, the Panel could not determine if overfishing is occurring. Based upon the recent trends in survey indices, many members of the Panel accepted that the stock was not overfished; however, full consensus was not reached.

Stock Identification and Distribution

Genetic studies indicate a single genetic stock of Atlantic croaker on the Atlantic coast and separate, weakly differentiated stocks in the Atlantic and Gulf of Mexico.

Management Unit

The management unit for Atlantic croaker is the entire Atlantic coast from Delaware to Florida.

Landings

Commercial landings for Atlantic croaker exhibited three periods of peak landings: 1955-1959, 1975-1980, and 1995 to the present (Figure 1). The highest landings were in 1977 at 13,532 mt. The current period of elevated landings is more than seven years. Low levels of harvest were evident during the 1960s and 1970s. The commercial harvest has been dominated by North Carolina and Virginia since 1950.

The commercial landings data did not include landings from aggregate, unculled ("scrap") bait fisheries or discard data. Unculled bait landings data are only available from North Carolina and indicated a substantial amount of additional landings not accounted for in the model (2-50%), particularly prior to 1996. There is uncertainty whether unculled bait landings data are available from other states and the magnitude of these landings.

Recreational landings are from the National Marine Fisheries Service Marine Recreational Fishery Statistics Survey (MRFSS). From 1981-2002, recreational landings of Atlantic croaker (Type A+B1 in numbers) from Massachusetts through Florida have varied between 2.8 million fish (1981) and 13.2 million fish (2001), with landings showing a strong linear increase over this period (Figure 2). Average landings for the period 1981 – 1990 were 6.0 million fish, while more recent landings averaged 10.8 million fish. The increased landings in recent years have been at the northern range of the fishery (Massachusetts to North Carolina).

Data and Assessment

The Atlantic croaker stock assessment used commercial landings from NOAA general canvas reports for all states, including the east coast of Florida. No data from the scrap fishery were included in the assessment model. No observer data were evaluated to quantify discards. Biological samples were from state surveys from North Carolina since 1982, Virginia since 1989, and limited age/weight data from Maryland since 1999. Recreational landings data from 1981 to the present were from the MRFSS. A fishery dependent survey index of the MRFSS CPUE index was also used in the assessment.

Fishery independent surveys included the National Marine Fisheries Service (NMFS) Northeast Fisheries Science Center (NEFSC) fall bottom trawl indices from 1982 to the present, and Southeast Area Monitoring and Assessment Program (SEAMAP) nearshore trawl survey indices from 1989 to the present.

The assessment model used a deterministic age-structured surplus production model to explain the population dynamics of Atlantic croaker, where the population in successive years was linked using a Beverton-Holt stock recruitment relationship. For modeling purposes, the Atlantic croaker population was divided into two geographic regions: mid-Atlantic (all states north of and including North Carolina) and south Atlantic (all states south of and including South Carolina).

Biological Reference Points

No biological reference points have been determined for the South Atlantic region. The benchmarks for the mid-Atlantic region listed in the stock assessment report were corrected as follows:

F threshold - F_{msy}
Biomass threshold - 0.7 SSB_{msy}
F target – 0.75 F_{msy}
Biomass target – SSB_{msy}

These benchmarks are based on Restrepo et al. (1998) and are standard for other managed species.

Fishing Mortality

The lack of inclusion of the landings in the scrap fishery in the assessment implies that removals were not fully accounted for in the model. Consequently, this suggests that estimates of F produced in the model have unknown biases. Given the lack of inclusion of all removal and questions on biomass indices, the Panel did not accept the fishing mortality estimates provided in the Atlantic Croaker Stock Assessment Report for Peer Review (include publication number here).

Recruitment

The lack of inclusion of the landings in the scrap fishery in the assessment implies that removals were not fully accounted for in the model. Consequently, this suggests that estimates of recruitment produced in the model have unknown biases. Given the lack of inclusion of all removal and questions on biomass indices, the Panel did not accept the recruitment estimates provided in the Atlantic Croaker Stock Assessment Report for Peer Review (include publication number here) and suggests that trends in recruitment estimated by the model should be interpreted in relative terms.

Spawning Stock Biomass

The lack of inclusion of the landings in the scrap fishery in the assessment implies that removals were not fully accounted for in the model. Consequently, this suggests that estimates of spawning stock biomass produced in the model have unknown biases. Given the lack of inclusion of all removals and questions on biomass indices, the Panel did not accept the spawning stock biomass estimates provided in the Atlantic Croaker Stock Assessment Report for Peer Review (include publication number here).

Bycatch

Bycatch and discard information was not included in this stock assessment for commercial fisheries. Recreational discards were accounted for in the assessment.

Sources of Information

Atlantic States Marine Fisheries Commission. 2003. Atlantic Menhaden Stock Assessment Report for Peer Review. ASMFC Stock Assessment Peer Review Report No. 03-02 (Supplemental). Washington, DC.

Restrepo, V.R., G.G. Thompson, P.M. Mace, W.L. Gabriel, L.L. Low, A.D. MacCall, R.D. Methot, J.E. Powers, B.L. Taylor, P.R. Wade, and J. F. Witzig. 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Tech. Memo. NMFS-F/SPO-31. 56 p.

Figure 1. Atlantic coastal commercial landings of Atlantic croaker (metric tons), 1950-2001.

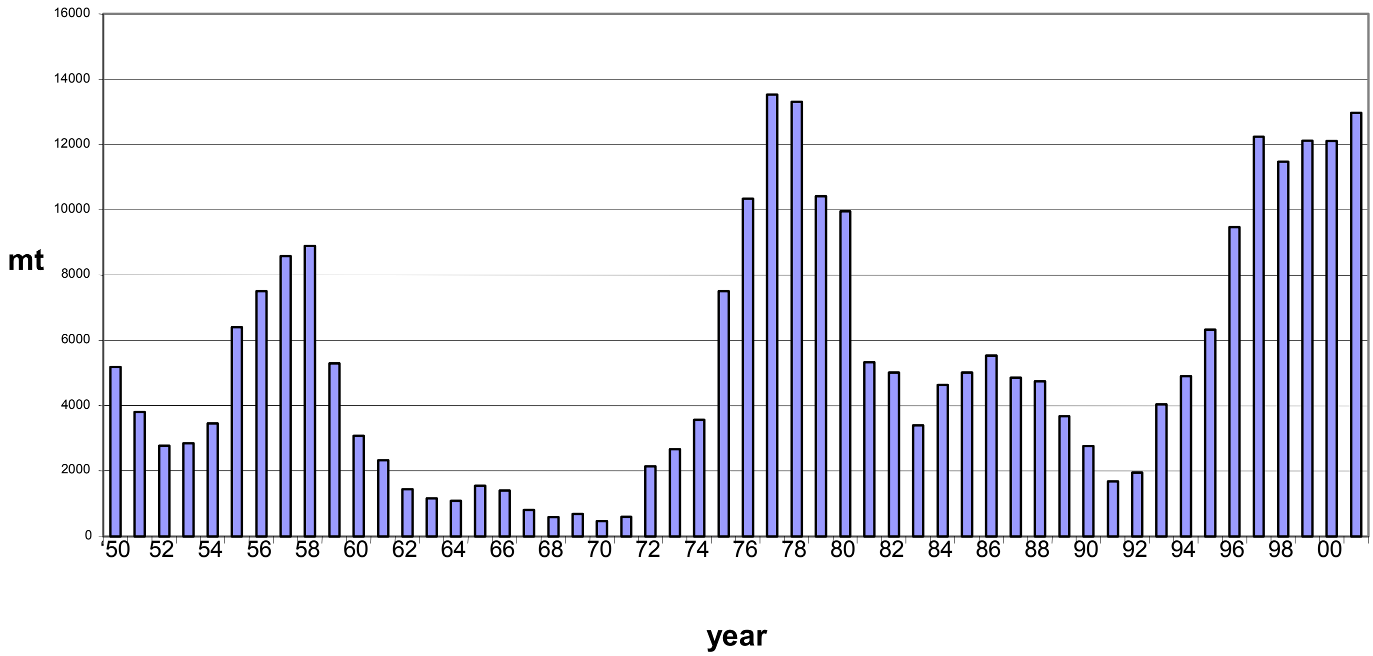
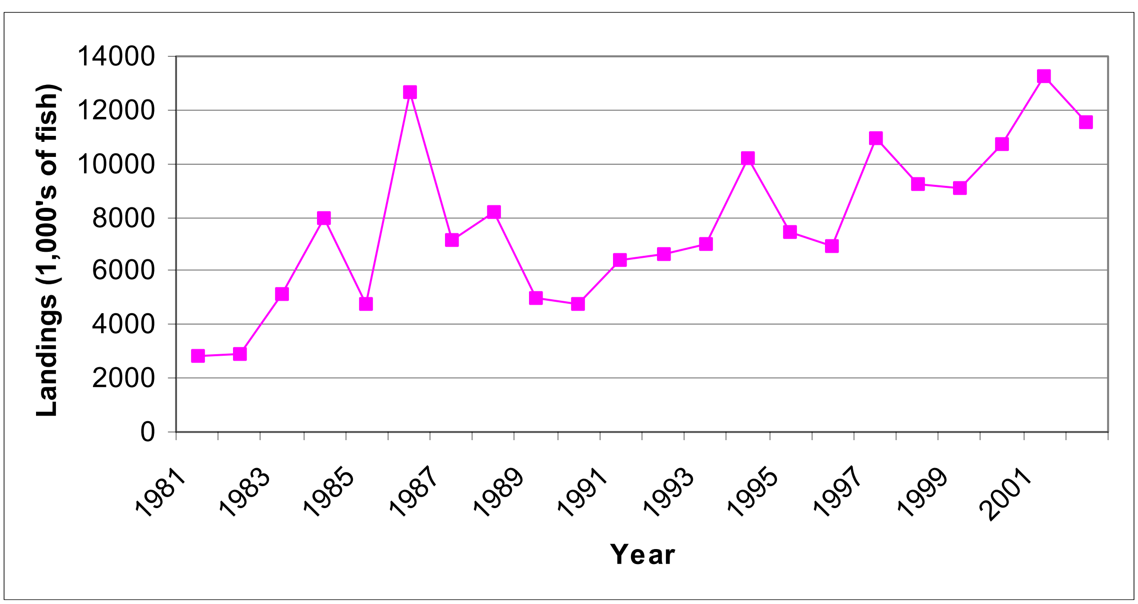


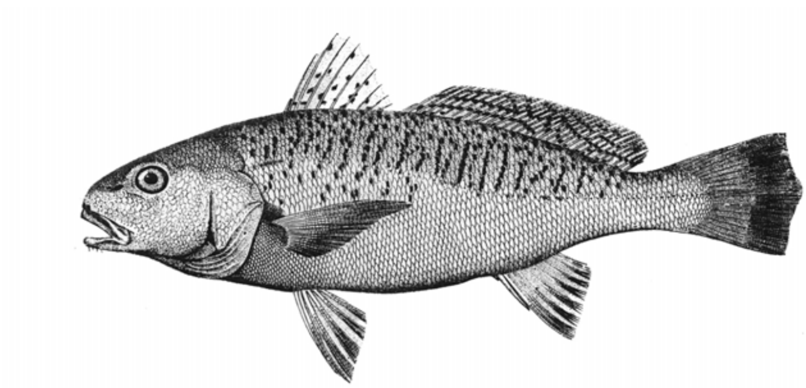
Figure 2. Recreational Landings (Type A+B1 in numbers) of Atlantic croaker



Atlantic States Marine Fisheries Commission

Atlantic Croaker 2004 Stock Assessment Supplement

DRAFT



May 2004

Working towards healthy, self-sustaining populations for all Atlantic coast fish species or successful restoration well in progress by the year 2015

Table of Contents

1.0 Introduction

In November 2002, the Atlantic croaker stock assessment was prioritized for a SEDAR peer review (ASMFC 2003; SEDAR report). A review panel was convened of stock assessment biologists and representatives from the fishing community and non-government organizations. Panel members had expertise in the Atlantic croaker life history and stock assessment methods. The SEDAR review for the Atlantic croaker stock assessment was conducted on October 8-9, 2003 in Raleigh, North Carolina.

The Atlantic croaker stock status for the South Atlantic region is unknown at this time. The South Atlantic region makes up a relatively small component of the total stock biomass. Stock status determination in terms of overfishing was also unknown for the mid-Atlantic region at the time of the October peer review. Given that the forward projection age-structured model did not account for a likely significant source of removals by the scrap fishery and there were questions on biomass indices noted in the full Peer Review Panel Terms of Reference Report, the Panel could not determine if overfishing was occurring. Based on the recent trends in survey indices, many members of the Panel accepted that the stock was not overfished; however, full consensus was not reached (ASMFC 2003; SEDAR report).

The Panel described in their report several major issues that required additional work by the Technical Committee (TC). There were seven short term issues the panel felt should be addressed to update the stock assessment. The South Atlantic State-Federal Fisheries Management Board directed the TC to address five of the short-term issues. These Five of these issues are presented in detail below. The other two issues; a coast wide versus regional stock assessment, and the exploration of additional models will be done at a later time. The TC has started looking into the issue of a coast wide versus a regional model through status of the stock identification (Appendix H). This issue will be addressed further at the time of the next benchmark assessment. The detailed descriptions below, and the updating of the assessment only refer to the mid-Atlantic model. The status of the South Atlantic stock remains unkown.

2.0 Addressing Panel Points on Data Inputs.

2.1 Commercial landings did not include all removals from the population
(Section 5.1.3 of original stock assessment report, pg 21)

2.1.1. Evaluate North Carolina unculled bait ("scrap") fishery data and include the commercial landings

For the revised assessment we have included the Atlantic croaker scrap estimates developed by the North Carolina Division of Marine Fisheries (NCDMF) from 1986-2002. For 1973-1985 we estimated North Carolina's scrap landings using a number of methods (see Appendix A). It was evident that no one method works for all gear types, owing to the quality of the available data. For example, developing estimates based on unclassified bait landings for ocean gill nets are low or do not exist, so the estimates are low or close to zero.

The regression models described in Appendix A, can produce very high and variable estimates. There was little justification, with the exception of the pound net fishery to suggest that scrap has any correlation to landings. In general the ratio method based on bait or total unclassified landings may be the most suitable. The unclassified finfish landings are likely to incorporate Atlantic croaker scrap. However, the proportion of Atlantic croaker scrap in these landings is unknown. Ratios based on estimates of Atlantic croaker scrap (from NCDMF) to the unclassified finfish landings from 1986 through 1990 are likely the most representative of North Carolina scrap estimates for the 1973-1985 period. North Carolina scrap estimates for 1973-1985 were based on the average ratio of scrap to total unclassified finfish landings (1986-1990) and included in this assessment.

2.1.2 Evaluate the potential of applying the North Carolina unculled bait fishery data to other states

Using data from North Carolina, four approaches to estimating Virginia's scrap landings were evaluated (see Appendix A for details). While estimates of Virginia's scrap landings can be made using data from North Carolina. There is little ancillary data to evaluate the validity of those assumptions. Trip based methods may be the most appropriate; however, the time series of the number of trips by gear is limited. This method assumes that scrap estimates per trip for North Carolina and Virginia are similar. An alternate method to estimate Virginia's scrap landings, using the bio-profile data collected by the Virginia Marine Resources Commission (VMRC) was also developed and evaluated by the technical committee (see Appendix B for details). The technical committee concluded that using the field sample of lengths from the Virginia harvest to estimate Virginia scrap was preferable to using data from North Carolina because there are distinct regional differences among the gear, area, and seasonal contributions to the Atlantic croaker landings and scrap. For example, the majority of the scrap in North Carolina stems from ocean trawl fisheries in coastal waters during late fall through winter, whereas the Virginia scrap primarily represents harvest from inside waters by pound net and haul seine fisheries during spring through late summer. The VMRC contacted long-time, high-volume seafood buyers (one on the western and one on the eastern shore) that wholesale Atlantic croaker from pound nets. The buyers indicated that Atlantic croaker less than 9 inches could generally be considered as scrap. However, both buyers and a middle peninsula buyer indicated that some small-size croaker (< 9 inches) was sold for food during years of low Atlantic croaker abundance. The buyers generally agreed that ½ of croaker within the 9-inch interval are sold as food fish, with a greater amount of this size category in the bait in recent years and less in earlier years. The technical committee endorsed using Atlantic croaker length data, collected by the VMRC, as the best method for estimating the scrap component of Atlantic croaker landings in Virginia.

2.1.3 Consider at-sea observer data for discards in ocean gill nets and ocean trawl and investigate the potential for developing bycatch estimates in the North Carolina shrimp trawl fishery.

The technical committee evaluated the use of the Northeast Fisheries Science Center (NEFSC) observer database to estimate at-sea discards of Atlantic croaker in the gill net and trawl fisheries (see Appendix D for details) The group also investigated the potential for developing bycatch estimates for the North Carolina shrimp fishery (see Appendix C for detailed methods and results). For the at-sea discards, both ratio and trip based estimators were developed for the gill net and trawl fisheries. The regression approach, based on the log-log transformation, produced very low discard estimates. For the trip-based approach, effort information for the otter trawl fishery for Virginia was unavailable and it had to be assumed that the discard ratios observed in the coastal waters of the Atlantic ocean are applicable to the inshore gill net trips for Virginia. At best, trip based estimates can be estimated for the period 1993-2002, for all other periods an alternate approach would need to be used. Since the average number of trips sampled per year is low (< 25 trips), estimates based on yearly samples by gear are poor, A ratio-based method would use a consistent methodology to estimate the entire time series, but the correlation between landings and discards is weak. The technical committee endorsed using estimates based on the ratio of discards to landings in the final model.

The technical committee also evaluated all available data on shrimp bycatch and made preliminary estimates of Atlantic croaker bycatch in the North Carolina shrimp fishery. Based on available size data, the majority of Atlantic croaker bycatch would be Age 0. Estimates of Atlantic croaker bycatch in the shrimp fishery are highly uncertain. The majority of data were collected in one year of the NMFS observer program (1994). Other available data sources were poor. The preliminary estimates of Atlantic croaker bycatch may not capture the inter-annual variability across the time series, as estimates for 1973-1991 are based on 39 tows, 1992-1998 on 685 tows and 1999-2002 on 56 tows (See Appendix C for details). By consensus, the technical committee had no confidence in the inter-annual magnitude of the shrimp bycatch, for an approximate estimate of 10 million pounds for the 1994-95 period,. A Monte Carlo simulation of using available data indicated a high variability in the estimates. While, the shrimp bycatch is likely to be an important source of mortality, there appears to be little data to evaluate its magnitude. The technical committee concluded further work needed to be carried out on estimating Atlantic croaker bycatch in the shrimp fishery and therefore did not include it in the assessment at this time. Evaluating the effectiveness of developing estimates of discards by combining available information on the effectiveness of bycatch reduction devices with estimates of the effective 'swept area' by the shrimp fishery and abundance estimates from the SEAMAP and NCDMF indices need to be explored in more detail. The shrimp fishery has undergone significant changes in efficiency with the introduction of bycatch reduction devices and turtle excluder devices. Given the potential magnitude of estimates known with reasonable confidence (1994), sensitivity of the biological reference points to the inclusion/non-inclusion of estimates from shrimp bycatch was examined.

2.2 Tuning indices.

(Section 6.2.1 of original stock assessment report, pg 38)

2.2.1 Extend the NMFS NEFSC bottom trawl survey data to 1973 for inclusion in the model.

The National Marine Fisheries Service (NMFS) NEFSC trawl survey was re-examined, and data from 1973 through 2002 was included in the revised model. In the re-analysis of the NEFSC trawl index, estimates were based on numbers, as the quality of weight data in the early part of the time series was poor (not always taken). A detailed analysis of the data set was carried out and annual estimates, based on the stratified means, were developed (CW-STRAT; see Appendix E for details). In addition, the data were used to develop estimates using the delta-lognormal distribution and compared to stratified mean estimates developed by NMFS (courtesy of P.Nitske, NEFSC). Correlation between the stratified mean estimates developed by NMFS and CW-STRAT were high (0.94) and both methods exhibited a similar trend (Table 2.2.2.1).

2.2.2 Evaluate the difference between the delta lognormal and stratified mean estimates from NMFS NEFSC bottom trawl survey.

Comparison of the delta-lognormal estimates to the NMFS and CW-STRAT indicated that estimates from the delta-lognormal method were not consistent with the estimates derived from the stratified means, with extremely high estimates associated with the delta-lognormal method, for the early part of the time series (Table 2.2.2.1). The delta-lognormal model, treated depth as a categorical variable consisting of five classes. Closer examination of the data revealed that poor sample sizes within the categories were the likely cause for differing results. Least square mean estimates using a General linear model, where the response variable was the log (number +1) and explanatory variables were year, stratum and water temperature, were also carried out. While the scale of the least square mean estimates differed from the stratified mean estimates, trends between the methods were similar, with the exception of estimates between 1991 and 1994 and those in 2002 where the least square mean estimates indicated lower than average estimates (Table 2.2.2.1). The technical committee evaluated the different methods and concluded that the stratified mean estimates (CW-Strat) were the most appropriate for use in the model. These estimates are only based on strata that were suitable Atlantic croaker habitat (see Appendix E for details).

Table 2.2.2.1. Estimates of mean number of Atlantic croaker/tow from the NEFSC-NMFS trawl survey based on stratified, least square and delta-lognormal means. CW = estimates based on using only strata considered Atlantic croaker habitat. NMFS = all strata suitable for comparison. STRAT= stratified mean estimates. LSM =Least square mean estimates from GLM. Delta = delta lognormal estimates.

Year	CW-Strat	NMFS-Strat	LSM-CW	LSM-NMFS	DEL-CW	DEL-NMFS
1973	38.07	40.98	4.52	7.63	1.38	1,158.68
1974	143.20	158.79	6.63	10.96	1.16	1,375.75
1975	638.21	792.47	18.95	36.12	12.60	6,767.31
1976	397.61	376.20	17.01	32.42	15.85	7,285.82
1977	119.35	116.99	7.28	12.50	2.48	1,237.61
1978	161.72	125.16	6.70	11.11	0.09	438.96
1979	15.64	15.64	2.73	4.17	0.06	157.43
1980	88.53	99.22	1.72	3.01	0.06	329.37
1981	31.77	42.82	1.67	2.72	0.02	104.19
1982	9.11	5.67	1.37	1.42	0.01	63.32
1983	231.94	337.63	3.70	6.13	0.10	621.32
1984	267.61	303.28	13.93	27.58	0.33	1,373.50
1985	213.97	237.34	8.06	16.67	5.59	2,574.77
1986	127.11	99.11	14.02	22.20	0.16	409.77
1987	111.96	156.77	1.54	2.63	0.03	173.95
1988	31.65	41.50	7.56	12.78	0.02	125.24
1989	99.64	142.55	7.39	13.26	0.06	329.24
1990	79.82	65.03	2.37	3.79	0.06	343.98
1991	260.53	315.41	3.35	5.18	0.06	453.06
1992	216.19	219.49	5.89	7.64	0.13	539.00
1993	140.88	90.27	4.10	6.08	0.04	334.14
1994	478.57	309.95	9.60	18.18	0.29	1,450.53
1995	189.36	212.36	8.96	19.22	0.34	1,015.76
1996	203.99	173.92	8.80	18.07	0.21	922.63
1997	159.14	134.91	4.29	6.75	0.09	464.58
1998	344.79	319.08	17.21	34.67	0.56	1,322.89
1999	734.45	685.19	34.54	84.92	2.41	3,238.18
2000	387.65	471.44	9.40	16.24	0.20	721.43
2001	177.64	162.09	8.61	10.30	0.12	448.11
2002	939.82	676.95	19.42	28.80	0.59	1,629.70

2.2.3. Evaluate the VIMS survey data for possible inclusion in the model.

The spring VIMS index was included in the revised model run. This index is a young of the year index and estimates are geometrical means in numbers. While this index is spatially limited to Chesapeake Bay, it extends across the time series (1973-2002). Preliminary analysis revealed that the pattern in recruitment deviations was closely associated with indices that had a strong age 0 component. The TC concluded that including the VIMS index into the revised model was beneficial, in that recruitment deviations would be more closely associated with the index and would improve the estimation of parameters in the Stock-Recruit relationship. Also, it improves data included earlier in the time series which reduces the overall variability.

2.3 Model Formulations

2.3.1 The base model assumed that the SSB in 1973 was equal to 0.75 SSB (virgin biomass) from the Beverton- Holt analysis. Re-evaluate after inclusion of the full time series of NMFS NEFSC and VIMS trawl survey

(Section 6.1.2 of the original stock assessment report, pg 33)

Preliminary analyses revealed that unless the model included abundance indices that covered the early part of the time series (~1973), the initial SSB: SSB virgin ratio was poorly estimated. This lead to deterministically fixing the ratio in the original version. In the revised model, two indices that cover the early part of the time series and enables the SSB 1973:SSB virgin ratio to be estimated by the model.

2.3.2 Evaluate the consequences of alternative weighting schemes. The model assumes that the fisheries-independent survey indices are more precise than the fisheries-dependent data and model recruitment estimates and, therefore, provided higher weights to these surveys.

(Section 6.2.2 of the original stock assessment report, pg 41)

In the original version of the age structured production model, we gave the fleets, recruitment deviations and MRFSS index a weight of $\lambda = 1$ and all fishery independent indices a weight of $\lambda=2$. In this iteration of the model, we explore alternate weighting schemes in more detail.

The likelihood components fall into three groups, the fleet, index and the recruitment deviation components. The fleet and index likelihood terms are based on the difference between the observed data and the predicted estimates. The recruitment deviation likelihood is based on differences from a mean of 0 (i.e. no deviation from the stock-recruit relationship). As such, weightings were treated in two groupings: 1.) weights for the fleets and indices and 2.) weights for the recruitment deviations. Weighting profiles for the fleets and indices were examined, while keeping the weight on the recruitment deviations constant at $\lambda=1$. All of the likelihood terms were estimated assuming a lognormal distribution (see Appendix F for detailed methods and results).Our examination of possible weighting options revealed a relatively flat response surface for the likelihood terms. It was evident that none of the weightings considered produced a fit better than the base model. Simulations indicated that increasing an individual weighting component (to > 5) produced relatively little reduction in the standard deviation of the residuals. There is no basis to objectively determine an appropriate weighting scheme. However, experience tells us that, the fishery independent indices should be given a higher weight than that of the fleets. The original weighting scheme appears to be a reasonable choice for the data (see Appendix F for details.)

3.0 Final Model Run

In the revised model the following changes were made:

1) Estimates of North Carolina and Virginia's scrap landings were included in the model. A model where scrap estimates were treated as a separate component was chosen over one where scrap landings were included as part of the commercial landings.
2) Using data from the NEFSC observer database, estimates of at-sea discards for the gill net and otter trawl fishery have been included.
3) The NEFSC trawl survey index has been extended to the entire time series, and the stratified mean estimates in numbers were used.
4) The VIMS spring index has been included in the model.
5) The model now estimates initial SSB: SBB virgin ratio.
6) The selectivity patterns used for the fleets has been refined using selectivity patterns estimated from an 'un-tuned' separable VPA by incorporating the length and age data for Virginia's and North Carolina's commercial fishery (1989-2002) and the recreational fishery's size distribution (1981-2002).
7) Commercial landings for 2002 were updated.

Details of the major changes and results for the revised model are presented in Appendix G. For the base model, the steepness (0.76), natural mortality (0.3), growth and length weight relationships used were similar to those in the original version. In the revised model, fishing mortality rates (F) are based on the average population weighted F for ages 1-10+. Fishing mortality rates for Atlantic croaker exhibit a cyclical trend over the time series. From 1977 to 1979, F rose rapidly reaching a maximum of 0.5 in 1979. From 1980 onwards, F rapidly declined reaching its lowest levels in 1992 (Appendix G; Figure G3; Table G8). Since 1993, F has gradually increased and between 1997 and 2002 remained relatively stable at around 0.11. For the base mid-Atlantic run, the trend in population abundance indicates a step-wise increase reaching a peak of 974 million fish in 1999. Population estimates from 1999 to 2002 have ranged from 663 to 974 million fish. The number of Age-0 fish in the population exhibit a series of periodic recruitment spikes in 1975, 1983, 1991, 1998, and 2002. Between 1999 and 2002 the number of age-0 fish have ranged between 100-375 million fish. Spawning stock biomass estimates (estimated as the proportion of mature females) exhibit a cyclical trend over the time series. From the early 1970's to 1983 spawning stock biomass declined to its lowest level (11,746 MT). Between 1999 and 2002 spawning stock biomass estimates have ranged between 80-91,000 metric tons (See Appendix G for detailed report).

Between 1973 and 2002 the relationship the different sources of removals has changed. In particular, estimates of scrap/discards reached their peak in 1979 (3,200 MT) and since then declined to their lowest levels in 2002 (425 MT). Between 1973 and 1995, scrap/discard removals averaged 1,687 MT per year, whereas between 1996-2002 scrap/discards averaged 595 MT per year. It appears that the significant reduction in removals of predominantly age-1 and younger fish may have contributed to relatively stable fishing mortality and spawning stock biomass estimates since the mid 1990's.

4.0 Management

4.1 Risk Analysis.

4.1.1 Determination of overfishing/overfished were based on point estimates only.

Burnham and Anderson (1998) define precision as " a property of an estimator related to the amount of variation among estimates from repeated samples". The model developed in excel, does not provide any estimates of precision. For models run using AD model builder, estimates of standard deviation are based on the delta method, which approximate the variance estimates. Variance estimates using the delta method are biased to the lower range of the spectrum when additional constraints are imposed on the model. Confidence bounds on the parameters can be estimated using bootstrap procedures. However, the estimates derived are likely to be biased (Hilborn and Walters, 1992). Ideally, the relative levels of confidence of the parameter estimates should be evaluated using methodology such as the "operating model concept" described in Hilborn and Walters (1992) or Bayesian methods; These are part of the long-term objectives in the model's development.

As an interim measure, uncertainty in the estimates of the status of the stock was examined at three levels through a series of simulations. These were: 1) the sensitivity of the base model to alternate weightings of the likelihood components; 2) sensitivity of the model to alternative steepness and natural mortality estimates based on a prior distribution and 3) the implications of not including shrimp bycatch estimates (See Appendix G for details).

4.1.2 Estimate the error distribution for current estimates of F, and reference points.

For both fishing mortality and spawning stock estimates, estimates determined from the base run appear to be more pessimistic (conservative) when compared to other potential weighting schemes. This assumes that 3,500 simulations capture a wide range of weightings. The inter quartile range (25-75th percentile) for F_{2002} from the simulations ranged from 0.015 to 0.11 (See Appendix G for details). For 2002, average fishing mortality rates from the base model was close to the 75th percentile of the simulation runs (average F=0.11). The inter quartile range for 2002 spawning stock biomass estimates from the simulation ranged between 71,000 and 120,000 MT. In comparison, estimates of spawning stock biomass in 2002 from the base model was 80,000 MT, close to the value of 25th percentile of the simulation runs. Trends in fishing mortality and spawning stock biomass under varying steepness and natural mortality rates indicate that for 2002, the inter quartile range of spawning stock biomass estimates was 80,000 and 110,000 metric tons and between 0.08 and 0.12 for F_{2002}. Based on the sensitivity runs, it appears that ~25% of the runs had higher fishing mortality estimates than those for the base run and ~25% of the sensitivity runs had spawning stock biomass estimates lower than the base run. Sensitivity analysis examining the inclusion of shrimp bycatch, indicated average fishing mortality rates (ages 0-10+) in 2002 ranged from 0.06 to 0.176 with 50% of the simulations having values less than 0.105. Spawning stock biomass estimates in 2002 from the simulation runs ranged from 77,000 to 149,000 MT with 50% of the values being less than 111,388 MT . In comparison, the average fishing mortality rate from the base run in 2002 was 0.11 (ages 1-10+) and the spawning stock biomass estimate in 2002 was 80,328 MT. Differences in Spawning stock biomass estimates are most likely a result of the model accounting for the increased removals as part of the shrimp bycatch by increasing the population estimates. (See Appendix G for details).

Estimates of F_{msy} from the base mid-Atlantic model was 0.39 and SSB_{msy} was equal to 28,932 MT. Estimates of average fishing mortality rates from the base mid-Atlantic model of 0.11 indicate that 2002 estimates were below the target and threshold levels (Appendix G). Recent estimates of SSB (~80,000 MT) are above both the proposed target and threshold levels. For 2002, $F{:}F_{msy}$ ratio was 0.263 and $SSB{:}SSB_{msy}$ ratio 2.78.

Based on the base run's sensitivity to weighting of the likelihood components, and the sensitivity of the model to alternate steepness and natural mortality estimates, estimates derived from the base run appear robust. From the sensitivity analysis on weighting of the likelihood terms, 90 % of the simulations had $F_{2002}{:}F_{msy}$ ratios less than 0.44 (Appendix G). Biomass reference points from the weighting analysis indicated that 10% of the runs had SSB_{2002}: SSB_{msy} ratios less than 2.27 (Appendix G). Model sensitivity to steepness and natural mortality estimates also indicated the stock was most likely below the fishing mortality targets and thresholds and above the biomass targets and thresholds; 90 % of the simulations had $F_{2002}{:}F_{msy}$ ratios less than 0.44 and 10% of the runs had SSB_{2002}:

SSB_{msy} ratios less than 2.16. When including estimates of Atlantic croaker caught as shrimp bycatch, simulations revealed that the current status of the stock was similar to the base run where shrimp bycatch were not included; the stock is not overfished or undergoing overfishing. However, biomass reference points from the simulation runs indicated higher SSB_{msy} values and the lower estimates of SSB_{2002}:SSB_{msy} than those obtained for the base model. The range of estimates for F_{msy} (~0.4) was similar to the base model (~ 0.39). SSB_{msy} estimates from the simulation (ranged from 48,000-67,000 MT with a median of 56,467 MT) and were much higher than those for the base run (28,932 MT). The ratio of F_{2002}:F_{msy} ranged from 0.14-0.43 with 50% of the runs having estimates below 0.26. In comparison F_{2002}:F_{msy} from the base model was 0.263 (based on ages 1-10+). The ratio of SSB_{2002}:SSB_{msy} for the simulations ranged from 1.55 to 2.27, with 50% of the runs having estimates less than 1.98.

5.0 Conclusions

5.1 Determine whether, given error distributions determined above, target F and threshold F could be distinguished from estimates derived from the assessment model.

While this analysis does not capture all of the sources of uncertainty, examination of the effects of alternate weightings of the likelihood components and alternate steepness and natural mortality estimates indicate that reference points derived from the base run are robust, and suggest that there was less than a 10% chance that the population is overfished or undergoing overfishing. Sensitivity analysis evaluating the inclusion/non-inclusion of shrimp bycatch estimates, indicate that SSB_{msy} estimates are sensitive to the inclusion of Atlantic croaker caught as shrimp bycatch. However, increased SSB_{msy} estimates are also accompanied by higher SSB estimates. The ratio of SSB_{2002}:SSB_{msy} when preliminary estimates of shrimp bycatch is included indicates that the stock is unlikely to be below the threshold estimates.

5.2 Consider revising F target reference point relative to the previous bullet

Based on the simulation analysis, there appears little need to revise the F target reference points. Of concern, would be management goals that define biomass reference points in absolute terms. Differences in Spawning stock biomass estimates are most likely a result of the model accounting for the increased removals as part of the shrimp bycatch by increasing the population estimates. There appears to be some justification for revising the reference points for the biomass target and threshold to relative terms until a more comprehensive evaluation of Atlantic croaker from shrimp bycatch can be carried out. Alternatively, we could use the biomass reference points from the analysis, with the understanding that they are based on a model that does not include shrimp bycatch.

APPENDIX A: Estimating the Scrap Component of Atlantic croaker on the Atlantic coast of the United States using data collected by the North Carolina Division of Marine Fisheries

Scrap landings of Atlantic croaker primarily occur in North Carolina and Virginia and are not accounted for in the NMFS commercial landings database. Scrap landings of Atlantic croaker are primarily small fish that are part of the landings and used for bait or animal food.

The North Carolina Division of Marine Fisheries (NCDMF) has developed scrap estimates of Atlantic croaker by gear type for the period 1986-2002 (NCDMF 2003). Scrap estimates of Atlantic croaker from Virginia are non-existent.

This report summarizes the available data on scrap landings and the results of using that information to:

1) Estimate scrap landings of Atlantic croaker for North Carolina from 1973 to 1985.
2) Estimate Atlantic croaker scrap landings for Virginia from 1973 to 2002 using data from North Carolina.

Data Sources from North Carolina

Since 1986, the state of North Carolina has estimated scrap landings of Atlantic croaker for the major commercial fisheries (NCDMF 2003). The North Carolina Division of Marine Fisheries (NCDMF) determined estimates of scrapfish landings for Atlantic croaker by applying the tri-annual ratio of marketable fish to scrapfish in the fish house samples to the reported tri-annual marketable landings (NCDMF 2003).

In addition to Atlantic croaker scrap estimates, the number of trips and landings of Atlantic croaker by gear were available from the North Carolina trip ticket database from 1994-2002.

Data Sources from Virginia

Scrap estimates of Atlantic croaker from Virginia are non-existent. However, from 1993 to 2002, the annual number of trips and landings of Atlantic croaker by gear were available from the Virginia trip ticket database. The size distribution of Atlantic croaker by gear, was available from 1989-2002 from the Virginia Marine Resources Commission sampling program.

Other Data Sources

While there are no estimates of scrap landings of Atlantic croaker in the NMFS commercial landings database, it does contain records for unclassified finfish by state and category. For state, year and gear specific information, data were available for four categories:

1) Unclassified finfish used as food
2) Unclassified finfish classified under the "general" category
3) Unclassified finfish spawn (fish roe; limited data for VA only) according to NMFS roe estimates .
4) Unclassified finfish used as bait or animal food.

Estimates of unclassified finfish most likely include a diverse range of species and the proportions of these categories that represent Atlantic croaker are unknown in recent times. Historic information on the composition of the North Carolina scrap landings from 1962-64 indicated that Atlantic croaker comprised between 30-42% by weight of scrap from the trawl fishery and less than 1% by weight from the pound and haul seine fisheries (Fahy, 1966).

The unclassified finfish estimates from the NMFS database could be considered as the upper bound of Atlantic croaker accounted for by scrap landings in North Carolina and Virginia. Any scrap estimates of Atlantic croaker would be expected to be less than the annual estimate of unclassified finfish in the NMFS commercial landings database.

Summary of North Carolina Scrap Landings 1986-2002

For North Carolina, estimates of the scrap component of Atlantic croaker landings were available from 1986 to 2002 (NCDMF 2003). Estimates of Atlantic croaker in the North Carolina scrap landings were highest between 1987-1990, ranging from 1,249 to 1,569 metric tons and equivalent to about 50% of annual Atlantic croaker landings. More recently, North Carolina's scrap landings have decreased as a result of a suite of regulations that mandated bycatch reduction devices in shrimp trawls (1992), eliminated fly net fishing south of Cape Hatteras (1994) and introduced culling panels in long haul seines (1999). , Estimates of scrap landings of Atlantic croaker from the North Carolina averaged 266 metric tons annually between 1997 and 2002, and were equivalent to 3% of that state's Atlantic croaker landings (Table A1). In North Carolina, the primary gears that produced scrap landings between 1986-1993 were haul seines, ocean trawls (flynets), and pound nets. More recently, greater than 90% of scrap landings were from the haul seine and ocean trawls fisheries (Table A2). Scrap estimates for ocean otter trawls are a composite of three trawl types; (1) Flounder trawls (Otter trawl-Bottom, Fish);(2) Shrimp trawls and; (3) Flynets (Otter trawl-Midwater). Flynets are responsible for the majority of the scrapfish component in ocean trawls brought to the dock and sold as scrapfish. Shrimp trawls mainly cull at sea finfish too small for usual market grades.

Estimating Atlantic croaker Scrap Landings in North Carolina and Virginia

North Carolina

For the period 1986-2002, Pearson correlation estimates between the scrap estimates and potential explanatory variables were developed by gear type (Table A3). Preliminary analyses revealed that for most of the gears, the unclassified finfish used for bait and animal feed were more closely correlated to scrap landings than total Atlantic croaker landings (Table A3). For the gill net fishery there was poor correlation between scrap landings and any of the explanatory variables examined.

To estimate North Carolina's Atlantic croaker scrap component from 1973 through 1985, estimates using three different methods were explored.

1) A stepwise regression approach was used. The response variable was the estimated scrap landings in pounds and explanatory variables were number of estimated trips (market landings *1,000 /cpue), Atlantic croaker landings, landings of unclassified finfish in the bait and animal food, unclassified finfish in the "general" category and unclassified finfish in the "food" category.
2) A linear regression approach where the log (scrap landings) was modeled, using either Atlantic croaker landings or the unclassified finfish landings for bait and animal food as explanatory variables. Using the parameter estimates and their associated standard errors, a Monte-Carlo simulation with 1,000 replicates was carried out to evaluate the error surrounding scrap estimates.
3) Using the last five years of available data (1986-1990) ratios of scrap landed to total croaker landings and scrap landed to total unclassified finfish used for bait and animal food and total unclassified finfish landings were developed for each gear type. These estimates were then used to apportion historic landings. Using the standard deviation estimates associated with these ratios, a Monte Carlo approach with 1,000 replications was carried out to estimate the error surrounding those estimates. A five-year interval was chosen to represent historic conditions, as it was the longest period where conditions were most likely to have been stable.

Stepwise Regression model

Prior to developing the appropriate model for each gear, a Box-Cox transformation was carried out to determine the appropriate transformation of the response variable. With the exception of ocean gill nets, the log transformation of the response variable was appropriate ($\lambda = 0$). For ocean gill nets an appropriate λ value was –1.0, equivalent to 1/response variable.

To determine the most appropriate suite of explanatory variables that best predicted the scrap estimates by gear type, a stepwise regression was employed using liberal p-values to determine inclusion into the final model (entry into model p=0.4 and to be kept p=0.1).

For the ocean gill net fishery a suitable regression model that met the minimum criteria could not be developed. For the otter trawl, pound net and haul seine fisheries adequate regression models that had R^2 values > 0.5 were developed (Tables A4 and A5).

Examination of the variables included in the final model indicated that for most gears, the number of trips was an important factor. However, data on the number of trips, for years where scrap landings need to be estimated, were unavailable and suitable proxies for effort are unavailable (NCDMF, personal communication). As such, the model was of little utility in estimating those missing years of scrap landings. Furthermore, for some of the other explanatory variables in the regression models, missing data limited their utility as a tool for estimating scrap landings for the missing years.

Given the limitations in using the stepwise regression model as a predictor, a simpler approach to estimating scrap landings was evaluated (methods 2 and 3).

Other Potential methods

A generalized additive model (GAM) using both LOESS smoothers and regression splines on the explanatory variable was briefly examined. For each gear type, log (scrap landed in pounds) was modeled using either Atlantic croaker landings or total unclassified finfish landings as explanatory variables. Preliminary evaluations revealed that the GAM approach added little to treating the Atlantic croaker landings as a linear function and also had a poor fit.

As a possible technique to estimate historical scrap landings for North Carolina multiple imputation methods were also examined. Multiple imputation is a Monte-Carlo technique in which missing values are replaced by M >1 simulated versions that represent the uncertainty about the correct value to impute. In this exploration, only the first phase of the imputation process, generating 20 complete data sets using the MCMC method was carried out. Analyses were performed using Proc MI in SAS. While multiple imputation techniques hold promise, further work needs to be carried out before applying these methods to estimating scrap landings. In the preliminary analyses, the posterior covariance matrix was singular and further work needs to be carried out in providing appropriate priors.

Estimates of North Carolina Scrap Landings 1973-1985

Table A6 summarizes the unclassified finfish landings by category and gear for North Carolina. Table A7 summarizes the scrap estimates of Atlantic croaker using the regression and ratio methods. It was evident that no one method works for all gear types. In part this has to do with the quality of the available data. For example, unclassified bait landings for ocean gill nets are low or do not exist, so the estimates turn out to be low or close to zero.

In general the ratio method based on bait or total unclassified landings may be the most suitable. The unclassified finfish landings are likely to incorporate Atlantic croaker scrap. However, the proportion of Atlantic croaker scrap in these landings is unknown. Ratios based on estimates of Atlantic croaker scrap (from NCDMF) to the unclassified finfish landings between 1986-1990 are most likely to be the most representative of North Carolina scrap estimates between 1973-1985. The regression models can produce very high and variable estimates. There is little justification, with the exception of the pound net fishery, to suggest that scrap has any correlation to landings. This is most likely due to regulations imposed in 1991, which limits the scrapfish catch to 5,000 pound per vessel per day.

Virginia

Given the lack of any data for scrap landings in Virginia, using the NC data to estimate scrap landings from Virginia was examined. To estimate Virginia's scrap landings from 1973 to 2002, we have used four approaches:

1) Use the parameter estimates from the stepwise regression (Table A4 and A5) to estimate Virginia's scrap landings. For some years and gear, data were not available, and estimates were not produced.
2) Apply the regression estimators developed using method 2 for North Carolina
3) Apply the ratio estimators developed using method 3 for North Carolina
4) Develop estimates, using the estimated Atlantic scrap per trip from the NCDMF study, and number of trips for the gear from the VA trip ticket program. Also, this method has no SE estimates and only included 1993-2002 data.

Estimates of Standard errors were produced using 1,000 Monte-Carlo trials as described earlier.

Estimates of Virginia Scrap Landings 1973-2002

Table A8 summarizes the unclassified finfish landings by category and gear for Virginia. Also included in Table A8 are Atlantic croaker landings by gear, trips, and the NCDMF scrap catch rate by year (in kgs). Table A9 summarizes the scrap estimates and their standard errors for Virginia using the different methods.

While estimates of Virginia's scrap landings can be made using data from North Carolina, there is little ancillary data to evaluate the validity of those assumptions. Trip based methods may be the most appropriate; however, the extent of the time series where the number of trips by gear exists is limited. This method also assumes that scrap estimates per trip for North Carolina and Virginia are similar. An alternate method to estimate Virginia's scrap landings, using the bio-profile data collected by the Virginia Marine Resources Commission was also developed (see Appendix B for details of method and results).

Literature Cited

Fahy, W.E. 1966. Species composition of the North Carolina industrial fish fishery. Commercial Fisheries Review 28(7): 1-8.

North Carolina Division of Marine Fisheries (NCDMF). 2004. Assessment of North Carolina Commercial Finfisheries, 2000-2002. Final Performance report for Award Number NA 76 FI 0286, 1-3. North Carolina Department of Environment and Natural Resources. North Carolina Division of Marine Fisheries.

Table A1. Estimates of bait (scrap) landings of Atlantic croaker from North Carolina for all fisheries combined. Source: NCDMF

			Total		Market		Bait (Scrap)	
Fishery	Year	Collections sampled	Landed (mt)	CPUE (kgs)	Landed (mt)	CPUE (kgs)	Landed (mt)	CPUE (kgs)
Fisheries	1986	333	4,598	1,601	4,033	1,318	565	283
combined	1987	338	4,280	1,208	2,995	886	1,286	321
	1988	366	5,066	1,414	2,601	905	1,465	509
	1989	327	4,469	1,382	2,900	843	1,569	538
	1990	346	3,685	1,564	2,436	1,020	1,249	545
	1991	381	2,456	611	1,462	372	992	239
	1992	407	1,872	1,410	1,183	995	689	415
	1993	273	1,996	4,451	1,428	3,428	527	1,022
	1994	204	2,924	9,871	2,026	8,462	899	1,409
	1995	193	3,800	7,615	2,643	6,659	1,157	956
	1996	253	4,840	8,547	4,411	7,841	476	706
	1997	229	5,146	11,623	4,802	11,207	344	416
	1998	207	5,020	4,787	4,845	4,660	175	127
	1999	256	4,953	13,118	4,559	12,793	394	325
	2000	302	4,845	12,187	4,543	11,885	301	302
	2001	299	5,593	8,951	5,375	8,620	218	332
	2002	259	4,722	12,178	4,559	11,781	163	398

Table A2. Estimates of bait (scrap) landings of Atlantic croaker from North Carolina by gear. Source: NCDMF.

Fishery	Year	Collections sampled	Total Landed (mt)	Total CPUE (kgs)	Market Landed (mt)	Market CPUE (kgs)	Bait (Scrap) Landed (mt)	Bait (Scrap) CPUE (kgs)
Long haul	1986	176	1,690	2,653	1,392	2,168	298	485
	1987	119	1,528	1,197	691	863	838	335
	1988	169	1,777	1,496	1,177	1,118	600	377
	1989	139	2,324	1,067	1,427	664	897	402
	1990	147	2,649	1,990	1,769	1,327	880	664
	1991	140	1,391	833	896	555	495	278
	1992	155	490	301	423	267	66	34
	1993	105	427	499	196	331	232	167
	1994	65	680	649	47	58	633	591
	1995	53	897	559	74	117	823	442
	1996	85	244	626	163	443	81	183
	1997	71	169	220	28	40	142	180
	1998	70	82	190	11	45	70	145
	1999	64	114	151	3	4	111	147
	2000	61	231	270	31	55	200	215
	2001	52	155	1,423	45	390	110	1,033
	2002	62	67	382	14	81	53	301
Sciaenid pound net	1986	57	368	681	233	431	135	250
	1987	59	666	667	499	533	167	135
	1988	54	733	358	466	235	267	124
	1989	53	505	543	266	289	239	254
	1990	61	420	598	220	306	200	291
	1991	59	207	318	81	123	126	195
	1992	43	52	80	14	20	38	60
	1993	33	90	38	7	3	83	35
	1994	22	9	100	3	43	7	57
	1995	53	15	12	6	4	9	8
	1996	33	100	18	5	1	95	17
	1997	26	6	11	<1	1	6	11
	1998	36	2	25	<1	<1	2	25
	1999	41	202	132	6	1	196	132
	2000	18	17	126	<1	<1	16	126
	2001	16	13	173	11	139	2	35
	2002	11	11	21	<1	<1	11	21

Table A2.. Continued.

Fishery	Year	Collections sampled	Total Landed (mt)	Total CPUE (kgs)	Market Landed (mt)	Market CPUE (kgs)	Bait (Scrap) Landed (mt)	Bait (Scrap) CPUE (kgs)
Ocean sink net	1986	75	1,415	22	1,415	22	<1	-
	1987	113	1,082	32	1,082	32	<1	-
	1988	94	1,110	107	1,110	107	<1	-
	1989	92	585	68	585	68	<1	<1
	1990	90	305	10	292	9	13	<1
	1991	136	356	21	349	21	6	<1
	1992	155	428	56	422	55	7	10
	1993	76	354	113	354	113	<1	<1
	1994	79	622	314	622	314	<1	1
	1995	68	872	242	872	242	<1	<1
	1996	95	1,859	541	1,859	541	<1	<1
	1997	71	1,274	370	1,274	370	<1	<1
	1998	69	2,547	713	2,544	713	3	1
	1999	122	1,770	402	1,770	402	<1	<1
	2000	182	1,734	306	1,726	305	8	1
	2001	190	2,372	525	2,372	525	<1	<1
	2002	160	1,911	325	1,909	325	2	<1
Ocean trawl (fish)	1986	25	1,125	4,612	993	3,794	132	818
	1987	47	1,004	4,200	723	3,020	281	1,181
	1988	49	1,446	3,606	848	2,244	598	1,363
	1989	43	1,055	3,672	622	2,205	433	1,467
	1990	48	311	942	155	399	156	542
	1991	46	502	80	136	205	365	597
	1992	54	902	4,638	324	3,184	578	1,455
	1993	59	1,125	7,134	871	5,496	234	1,637
	1994	38	1,613	14,599	1,354	12,512	259	2,087
	1995	19	2,016	11,750	1,691	10,275	325	1,475
	1996	40	2,639	15,485	2,337	14,180	302	1,305
	1997	61	3,697	15,810	3,500	15,241	197	569
	1998	32	2,389	9,335	2,290	9,068	99	266
	1999	29	2,867	21,255	2,780	20,722	88	532
	2000	41	2,863	19,678	2,786	19,188	77	489
	2001	41	3,053	15,882	2,947	15,293	106	589
	2002	26	2,733	20,830	2,636	20,143	97	686

Table A3. Pearson correlation coefficients between North Carolina's scrap landings (bait_landed_pnds) and potential explanatory variables by gear type. nc_trips= number of trips ; nc_pnds=landings of Atlantic croaker; nc_unc_bait= unclassified finfish laded for bait or animal food; nc_unc_gen= unclassified finfish landed under the general category; nc_unc_food= unclassified finfish landed as food fish; nc_unc_total = nc_unc_bait+nc_unc_food+nc_unc_gen;

Gear Type	Variable	nc_pnds	nc_trips	nc_unc_ food	nc_unc_ bait	nc_unc_ gen	nc_unc_ total
GILLNET	bait_landed _pnds	-0.30	0.14	-0.25	-0.25	-0.05	-0.07
HAUL_S	bait_landed _pnds	0.62	0.72	-0.12	0.67	0.23	0.67
OTTER_ TRAWL_F	bait_landed _pnds	-0.62	0.19	-0.19	0.41	0.40	0.46
POUND	bait_landed _pnds	0.72	0.28	-0.27	0.68	0.23	0.68

Table A4. Summary of Stepwise regression models to examining the relationship of Scrap landings to potential explanatory variables for North Carolina. nc_trips= number of trips ; nc_pnds=landings of Atlantic croaker; nc_unc_bait= unclassified finfish laded for bait or animal food; nc_unc_gen= unclassified finfish landed under the general category. nc_unc_total = nc_unc_bait+nc_unc_food+nc_unc_gen.

Gear Type	Dependent	Step	Var. Entered	Var. Removed	Number In	Partial R-Square	Model R-square	Cp	F Value	Prob F
HAUL_S	log_bait	1	nc_trips		1	0.476	0.476	4.633	13.650	0.002
HAUL_S	log_bait	2	nc_unc_bait		2	0.152	0.628	1.522	5.714	0.031
HAUL_S	log_bait	3	nc_pnds		3	0.029	0.657	2.552	1.091	0.315
HAUL_S	log_bait	4		nc_pnds	2	0.029	0.628	1.522	1.091	0.315
OTTER_ TRAWL_F	log_bait	1	nc_pnds		1	0.442	0.442	3.633	11.882	0.004
OTTER_ TRAWL_F	log_bait	2	NC_UNC_GEN		2	0.167	0.609	0.644	5.999	0.028
POUND	log_bait	1	nc_unc_total		1	0.457	0.457	8.173	12.621	0.003
POUND	log_bait	2	nc_trips		2	0.226	0.683	1.350	10.002	0.007
POUND	log_bait	3	nc_pnds		3	0.018	0.701	2.652	0.779	0.394
POUND	log_bait	4		nc_pnds	2	0.018	0.683	1.350	0.779	0.394
GILLNET	Inv_bait	1	nc_unc_bait		1	0.061	0.061	-0.944	0.976	0.339
GILLNET	Inv_bait	2		nc_unc_ bait	0	0.061	0.000	-2.159	0.976	0.339

Table A5. Parameter estimates for final stepwise regression model to estimate scrap landings of Atlantic croaker in North Carolina. nc_trips= number of trips ; nc_pnds=landings of Atlantic croaker; nc_unc_bait= unclassified finfish laded for bait or animal food; nc_unc_gen= unclassified finfish landed under the general category. nc_unc_total = nc_unc_bait+nc_unc_food+ nc_unc_gen.

Gear Type	Dep. Var	Step	Variable	Estimate	Std Err	TypeII SS	F-Value	Prob. F
HAUL_S	log_bait	4	Intercept	11.99726	0.33352	584.30	1293.96	0.000
HAUL_S	log_bait	4	nc_trips	0.000865	0.000332	3.07	6.79	0.021
HAUL_S	log_bait	4	nc_unc_ bait	3.41E-07	1.43E-07	2.58	5.71	0.031
OTTER_ TRAWL_F	log_bait	2	Intercept	13.29162	0.253261	546.53	2754.35	0.000
OTTER_ TRAWL_F	log_bait	2	nc_pnds	-1.6E-07	4.85E-08	2.27	11.46	0.004
OTTER_ TRAWL_F	log_bait	2	nc_unc_ gen	1.43E-06	5.83E-07	1.19	6.00	0.028
POUND	log_bait	4	Intercept	9.429383	0.428459	518.13	484.34	0.000
POUND	log_bait	4	nc_unc_ total	2.35E-06	4.96E-07	23.95	22.39	0.000
POUND	log_bait	4	nc_trips	0.000618	0.000196	10.70	10.00	0.007

Table A6. Unclassified Finfish landings for North Carolina (in MT) by gear. Also shown are the Landings of Atlantic croaker and the NCDMF estimated scrap landings for Atlantic croaker

		NC		Unclassified Landings			
Year	Gear type	Scrap Est	Landings	General	Food	Bait	Total
1973	Gill net		166	0	0	0	0
1974	Gill net		133	0	0	0	0
1975	Gill net		61	0	0	0	0
1976	Gill net		59	0	0	0	0
1977	Gill net		376	0	0	0	0
1978	Gill net		547	0	0	0	0
1979	Gill net		901	0	0	1	1
1980	Gill net		1,712	17	0	0	17
1981	Gill net		603	109	0	0	109
1982	Gill net		562	23	0	0	23
1983	Gill net		406	3	0	0	3
1984	Gill net		1,127	8	0	0	8
1985	Gill net		1,085	10	0	0	10
1986	Gill net	0.5	1,526	35	0	0	35
1987	Gill net	0.5	1,200	57	0	0	57
1988	Gill net	0.5	1,198	1	0	0	1
1989	Gill net	0.5	642	14	0	0	14
1990	Gill net	13	396	37	0	0	37
1991	Gill net	6	385	11	0	0	11
1992	Gill net	7	465	19	0	0	19
1993	Gill net	0.5	384	168	9	0	177
1994	Gill net	0.5	665	2	3	0	6
1995	Gill net	0.5	941	5	3	4	11
1996	Gill net	0.5	1,944	5	2	0	7
1997	Gill net	0.5	1,315	4	3	2	8
1998	Gill net	3	2,616	2	3	1	6
1999	Gill net	0.5	1,817	2	2	2	6
2000	Gill net	8	1,769	2	3	0	5
2001	Gill net	0.5	2,436	1	2	0	4
2002	Gill net	2	1,921	5	1	0	6

Table A6 continued.

Year	Gear type	NC Scrap Est.	Landings	Unclassified Landings General	Food	Bait	Total
1973	Haul Seine		1,114	0	0	902	902
1974	Haul Seine		1,616	0	0	960	960
1975	Haul Seine		2,941	0	0	1,406	1,406
1976	Haul Seine		2,000	0	0	1,170	1,170
1977	Haul Seine		3,510	0	0	1,336	1,336
1978	Haul Seine		3,165	0	0	2,150	2,150
1979	Haul Seine		4,190	0	0	2,524	2,524
1980	Haul Seine		3,720	31	0	2,870	2,901
1981	Haul Seine		2,487	42	0	1,940	1,982
1982	Haul Seine		2,175	19	0	1,954	1,973
1983	Haul Seine		1,951	21	0	2,065	2,085
1984	Haul Seine		1,490	59	0	2,054	2,113
1985	Haul Seine		1,117	29	0	1,164	1,193
1986	Haul Seine	298	1,399	41	0	1,424	1,465
1987	Haul Seine	838	708	10	0	1,393	1,403
1988	Haul Seine	600	1,203	12	0	1,078	1,090
1989	Haul Seine	897	1,461	29	0	1,122	1,151
1990	Haul Seine	880	1,771	7	0	1,557	1,565
1991	Haul Seine	495	899	30	0	856	886
1992	Haul Seine	66	426	9	0	195	204
1993	Haul Seine	232	202	15	1	108	124
1994	Haul Seine	633	55	9	0	45	54
1995	Haul Seine	823	79	2	0	65	67
1996	Haul Seine	81	208	4	0	38	42
1997	Haul Seine	142	38	3	0	49	51
1998	Haul Seine	70	17	6	0	16	22
1999	Haul Seine	111	14	4	0	11	15
2000	Haul Seine	200	32	6	0	6	12
2001	Haul Seine	110	49	7	0	0	7
2002	Haul Seine	53	15	6	0	2	8

Table A6 continued.

Year	Gear type	NC Scrap Est.	Landings	Unclassified Landings General	Food	Bait	Total
1973	Trawl		580	0	0	2,463	2,463
1974	Trawl		851	0	0	3,868	3,868
1975	Trawl		1,414	0	0	1,396	1,396
1976	Trawl		3,732	0	0	1,367	1,367
1977	Trawl		4,426	0	0	1,563	1,563
1978	Trawl		4,943	0	0	1,082	1,082
1979	Trawl		3,662	0	0	4,757	4,757
1980	Trawl		2,510	18	0	2,262	2,280
1981	Trawl		894	11	0	1,584	1,594
1982	Trawl		832	13	0	1,095	1,108
1983	Trawl		370	5	0	1,419	1,424
1984	Trawl		1,031	44	0	1,765	1,809
1985	Trawl		995	21	1	1,606	1,627
1986	Trawl	132	995	24	1	1,507	1,532
1987	Trawl	281	724	213	1	1,003	1,217
1988	Trawl	598	866	150	0	2,172	2,322
1989	Trawl	433	622	101	1	659	761
1990	Trawl	156	155	7	0	40	48
1991	Trawl	365	137	59	0	22	80
1992	Trawl	578	342	56	0	0	56
1993	Trawl	234	859	144	2	2	148
1994	Trawl	259	1,351	242	11	90	343
1995	Trawl	325	1,688	214	16	21	250
1996	Trawl	302	2,126	248	4	15	266
1997	Trawl	197	3,252	55	6	45	106
1998	Trawl	99	2,289	121	5	0	126
1999	Trawl	88	2,777	3	4	22	29
2000	Trawl	77	2,786	11	5	0	16
2001	Trawl	106	2,947	9	3	0	12
2002	Trawl	97	2,611	13	3	0	16

Table A6 continued.

Year	Gear type	NC Scrap Est.	Landings	General	Unclassified Landings Food	Bait	Total	
1973	Pound net		27	0	0	0	0	
1974	Pound net		42	0	0	0	0	
1975	Pound net		79	0	0	0	0	
1976	Pound net		961	0	0	0	0	
1977	Pound net		176	0	0	0	0	
1978	Pound net		213	0	0	362	362	
1979	Pound net		274	0	0	277	277	
1980	Pound net		1,142	5	0	453	458	
1981	Pound net		865	1	0	465	466	
1982	Pound net		928	5	0	557	562	
1983	Pound net		341	5	0	410	416	
1984	Pound net		448	1	0	551	551	
1985	Pound net		616	71	0	678	749	
1986	Pound net	135	251	5	0	261	265	
1987	Pound net	167	636	103	0	448	550	
1988	Pound net	267	505	5	0	445	450	
1989	Pound net	239	277	0	0	456	456	
1990	Pound net	200	232	4	0	681	685	
1991	Pound net	126	84	3	0	613	616	
1992	Pound net	38	18	3	0	400	402	
1993	Pound net	83	10	3	0	108	111	
1994	Pound net	7	12	1	4	76	82	
1995	Pound net	9	10	0	1	102	104	
1996	Pound net	95	7	3	0	43	46	
1997	Pound net	6	2	2	0	54	55	
1998	Pound net	2	0	1	0	59	60	
1999	Pound net	196	6	1	1	61	63	
2000	Pound net	16	1	2	0	23	25	
2001	Pound net	2	12	1	0	5	5	
2002	Pound net	11	1	0	0	13	13	

Table A7. Estimated Scrap landings for North Carolina Commercial Fisheries by gear. NC Estimates=NCDMF scrap estimates. reg=regression method. ratio=ratio method. land=based on landings. bait=based on unclassified finfish laded as bait or animal food. uncl= total unclassified fin fishes. All estimates are in MT.

		NC	Scrap Estimates					Standard Error				
Year	Gear type	Estimates	reg -land	reg-bait	ratio-land	ratio-bait	ratio-uncl	reg -land	reg-bait	ratio-land	ratio-bait	ratio-uncl
1973	Gillnet		2	1	1	0	0	0.05	0.02	0.02	0.00	0.00
1974	Gillnet		2	1	0	0	0	0.05	0.02	0.01	0.00	0.00
1975	Gillnet		2	1	0	0	0	0.05	0.02	0.01	0.00	0.00
1976	Gillnet		2	1	0	0	0	0.05	0.02	0.01	0.00	0.00
1977	Gillnet		2	1	1	0	0	0.06	0.02	0.04	0.00	0.00
1978	Gillnet		2	1	2	0	0	0.06	0.02	0.05	0.00	0.00
1979	Gillnet		2	1	3	0	0	0.10	0.02	0.08	0.00	0.00
1980	Gillnet		3	1	5	0	2	0.35	0.02	0.16	0.00	0.05
1981	Gillnet		2	1	2	0	11	0.07	0.02	0.06	0.00	0.29
1982	Gillnet		2	1	2	0	2	0.07	0.02	0.05	0.00	0.06
1983	Gillnet		2	1	1	0	0	0.08	0.02	0.04	0.00	0.01
1984	Gillnet		2	1	4	0	1	0.13	0.02	0.11	0.00	0.02
1985	Gillnet		2	1	3	0	1	0.11	0.02	0.10	0.00	0.03
1986	Gillnet	0.5	2	1	5	0	4	0.13	0.02	0.14	0.00	0.10
1987	Gillnet	0.5	2	1	3	0	6	0.10	0.02	0.11	0.00	0.16
1988	Gillnet	0.5	2	1	4	0	0	0.09	0.02	0.11	0.00	0.00
1989	Gillnet	0.5	2	1	2	0	1	0.07	0.02	0.06	0.00	0.04
1990	Gillnet	13.0	2	1	1	0	4	0.06	0.02	0.04	0.00	0.10
1991	Gillnet	6.0	2	1	1	0	1	0.06	0.02	0.04	0.00	0.03
1992	Gillnet	7.0	2	1	1	0	2	0.07	0.02	0.04	0.00	0.05
1993	Gillnet	0.5	2	1	1	0	18	0.06	0.02	0.04	0.00	0.49
1994	Gillnet	0.5	2	1	2	0	1	0.06	0.01	0.06	0.00	0.02
1995	Gillnet	0.5	2	1	3	0	1	0.10	0.02	0.09	0.00	0.03
1996	Gillnet	0.5	3	1	6	0	1	0.21	0.02	0.19	0.00	0.02
1997	Gillnet	0.5	2	1	4	0	1	0.16	0.02	0.12	0.00	0.02
1998	Gillnet	3.0	3	1	8	0	1	0.34	0.02	0.26	0.00	0.02
1999	Gillnet	0.5	3	1	6	0	1	0.22	0.02	0.17	0.00	0.02
2000	Gillnet	8.0	3	1	6	0	1	0.24	0.02	0.17	0.00	0.01
2001	Gillnet	0.5	3	1	7	0	0	0.26	0.02	0.23	0.00	0.01
2002	Gillnet	2.0	2	1	6	0	1	0.17	0.01	0.17	0.00	0.02

Table A7. Continued.

Year	Gear type	NC Estimates	Scrap Estimates reg-land	reg-bait	ratio-land	ratio-bait	ratio-uncl	Standard Error reg-land	reg-bait	ratio-land	ratio-bait	ratio-uncl
1973	Haul Seine		590	468	604	485	478	13.21	8.42	3.95	2.70	2.70
1974	Haul Seine		1,149	508	874	516	509	36.94	9.97	5.82	2.93	2.92
1975	Haul Seine		7,201	904	1,580	751	740	440.07	22.83	10.78	4.36	4.35
1976	Haul Seine		1,840	650	1,069	623	613	69.33	14.26	7.30	3.61	3.60
1977	Haul Seine		18,081	820	1,880	712	701	1491.06	21.18	12.79	4.12	4.11
1978	Haul Seine		9,628	2,495	1,698	1,148	1,131	566.08	88.62	11.21	6.45	6.43
1979	Haul Seine		49,601	4,239	2,232	1,339	1,319	6750.51	206.79	15.21	7.75	7.73
1980	Haul Seine		25,536	7,522	2,006	1,539	1,532	3170.59	488.30	13.15	8.58	8.65
1981	Haul Seine		3,746	1,904	1,340	1,039	1,046	186.47	64.58	8.93	5.89	6.00
1982	Haul Seine		2,154	1,778	1,158	1,036	1,031	83.96	56.24	7.41	5.63	5.67
1983	Haul Seine		1,729	2,230	1,047	1,103	1,097	61.52	76.33	7.05	6.31	6.36
1984	Haul Seine		963	2,276	808	1,106	1,121	29.42	88.30	5.20	6.07	6.23
1985	Haul Seine		561	630	597	619	625	12.22	12.99	3.85	3.40	3.47
1986	Haul Seine	298.0	801	888	745	756	766	21.41	22.05	4.93	4.25	4.36
1987	Haul Seine	838.0	336	835	375	736	730	5.72	20.42	2.46	4.09	4.11
1988	Haul Seine	600.0	646	579	647	576	574	16.12	12.15	4.22	3.20	3.23
1989	Haul Seine	897.0	875	599	777	594	601	24.51	12.67	5.36	3.48	3.56
1990	Haul Seine	880.0	1,437	1,156	965	843	834	48.16	31.56	6.23	4.64	4.65
1991	Haul Seine	495.0	439	431	483	457	466	8.51	7.48	3.18	2.56	2.65
1992	Haul Seine	66.0	252	190	230	105	108	3.49	1.94	1.55	0.60	0.63
1993	Haul Seine	232.0	190	169	108	58	65	2.01	1.49	0.71	0.32	0.37
1994	Haul Seine	633.0	161	156	29	24	28	1.59	1.40	0.21	0.14	0.17
1995	Haul Seine	823.0	168	162	43	35	35	1.68	1.46	0.29	0.21	0.21
1996	Haul Seine	81.0	193	156	112	20	22	2.17	1.32	0.76	0.12	0.13
1997	Haul Seine	142.0	159	158	20	26	27	1.45	1.34	0.13	0.15	0.15
1998	Haul Seine	70.0	156	152	9	9	12	1.41	1.26	0.06	0.05	0.07
1999	Haul Seine	111.0	154	151	7	6	8	1.32	1.19	0.05	0.03	0.04
2000	Haul Seine	200.0	159	151	17	3	6	1.52	1.28	0.12	0.02	0.04
2001	Haul Seine	110.0	162	150	27	0	4	1.53	1.22	0.18	0.00	0.02
2002	Haul Seine	53.0	155	149	8	1	4	1.39	1.21	0.05	0.00	0.02

Table A7 Continued.

		NC	Scrap Estimates					Standard Error				
Year	Gear type	Estimates	reg-land	reg-bait	ratio-land	ratio-bait	ratio-uncl	reg-land	reg-bait	ratio-land	ratio-bait	ratio-uncl
1973	Trawl		327	658	276	733	671	3.15	18.60	2.60	6.88	5.88
1974	Trawl		293	1,566	403	1,143	1,047	3.13	66.00	3.82	10.81	9.23
1975	Trawl		241	359	680	419	384	3.06	6.09	6.13	3.77	3.22
1976	Trawl		113	366	1,819	416	380	2.74	6.39	16.94	3.86	3.30
1977	Trawl		81	380	2,082	459	421	2.28	7.13	19.64	4.32	3.69
1978	Trawl		71	302	2,363	323	296	2.04	4.28	22.13	3.01	2.57
1979	Trawl		112	3,175	1,771	1,437	1,314	2.61	185.86	16.12	13.03	11.13
1980	Trawl		169	625	1,213	683	629	3.36	18.54	11.68	6.55	5.64
1981	Trawl		290	392	425	470	433	3.10	7.23	4.03	4.44	3.82
1982	Trawl		290	293	386	318	295	3.10	4.33	3.83	3.14	2.71
1983	Trawl		350	351	174	417	383	2.99	5.94	1.63	3.89	3.33
1984	Trawl		279	446	495	530	497	3.26	9.84	4.56	4.86	4.26
1985	Trawl		280	401	473	477	443	3.23	8.02	4.51	4.53	3.93
1986	Trawl	132.0	279	376	473	448	417	3.13	6.95	4.40	4.15	3.60
1987	Trawl	281.0	313	293	347	301	334	3.21	4.09	3.33	2.87	2.97
1988	Trawl	598.0	293	549	411	644	630	3.17	13.73	3.89	6.08	5.55
1989	Trawl	433.0	320	241	295	196	207	3.06	2.62	2.72	1.79	1.77
1990	Trawl	156.0	384	180	74	12	13	2.93	1.08	0.68	0.11	0.11
1991	Trawl	365.0	384	177	64	6	22	2.99	1.07	0.62	0.06	0.19
1992	Trawl	578.0	362	178	164	0	15	3.12	1.05	1.55	0.00	0.13
1993	Trawl	234.0	294	177	409	1	40	3.13	1.03	3.83	0.01	0.35
1994	Trawl	259.0	244	184	645	27	93	2.87	1.13	5.76	0.24	0.78
1995	Trawl	325.0	217	179	807	6	68	2.96	1.04	7.37	0.06	0.58
1996	Trawl	302.0	186	178	1,012	4	72	3.16	1.10	9.83	0.04	0.65
1997	Trawl	197.0	126	181	1,560	13	29	2.50	1.10	14.54	0.13	0.25
1998	Trawl	99.0	176	177	1,098	0	34	2.91	1.02	10.12	0.00	0.30
1999	Trawl	88.0	148	179	1,328	6	8	2.85	1.07	12.39	0.06	0.07
2000	Trawl	77.0	149	178	1,337	0	4	2.87	1.04	12.60	0.00	0.04
2001	Trawl	106.0	133	175	1,384	0	3	2.50	0.98	12.61	0.00	0.03
2002	Trawl	97.0	154	176	1,231	0	4	2.87	1.05	12.02	0.00	0.04

Table A7. Continued

		NC	Scrap Estimates					Standard Error				
Year	Gear type	Estimates	reg-land	reg-bait	ratio-land	ratio -bait	ratio-uncl	reg-land	reg-bait	ratio -land	ratio-bait	ratio-uncl
1973	Pound net		25	13	14	0	0	0.38	0.20	0.10	0.00	0.00
1974	Pound net		29	13	23	0	0	0.49	0.21	0.17	0.00	0.00
1975	Pound net		37	14	43	0	0	0.72	0.21	0.30	0.00	0.00
1976	Pound net		23,130	13	509	0	0	2766.23	0.19	3.64	0.00	0.00
1977	Pound net		64	13	93	0	0	1.72	0.20	0.66	0.00	0.00
1978	Pound net		85	112	113	159	152	2.78	5.02	0.82	0.74	0.76
1979	Pound net		128	66	146	122	116	4.22	1.97	1.04	0.56	0.57
1980	Pound net		138,724	179	593	197	189	28782.04	8.26	4.45	0.94	0.97
1981	Pound net		17,001	216	460	205	195	4282.51	12.37	3.32	0.95	0.97
1982	Pound net		23,748	378	492	245	235	4642.46	22.37	3.55	1.13	1.17
1983	Pound net		214	156	181	181	174	9.93	7.11	1.35	0.86	0.89
1984	Pound net		477	394	240	244	232	23.95	19.51	1.75	1.15	1.17
1985	Pound net		1,574	836	325	297	312	110.89	50.84	2.47	1.45	1.63
1986	Pound net	135.0	102	56	132	114	110	3.20	1.61	0.95	0.53	0.55
1987	Pound net	167.0	1,780	186	339	198	231	121.10	7.25	2.46	0.92	1.16
1988	Pound net	267.0	659	181	267	195	188	39.04	7.69	1.96	0.92	0.95
1989	Pound net	239.0	127	194	146	200	191	4.58	9.10	1.07	0.94	0.96
1990	Pound net	200.0	98	993	124	301	288	3.56	105.82	0.90	1.41	1.45
1991	Pound net	126.0	35	593	44	267	255	0.77	59.21	0.33	1.29	1.33
1992	Pound net	38.0	24	143	10	177	169	0.36	6.12	0.07	0.82	0.85
1993	Pound net	83.0	23	24	5	48	46	0.33	0.51	0.04	0.23	0.24
1994	Pound net	7.0	23	20	6	33	34	0.35	0.42	0.05	0.16	0.18
1995	Pound net	9.0	23	24	5	45	44	0.34	0.51	0.04	0.22	0.23
1996	Pound net	95.0	22	17	4	19	19	0.30	0.28	0.03	0.09	0.09
1997	Pound net	6.0	22	18	1	24	23	0.30	0.31	0.01	0.11	0.12
1998	Pound net	2.0	22	19	0	26	25	0.30	0.34	0.00	0.12	0.13
1999	Pound net	196.0	22	18	3	27	26	0.30	0.33	0.02	0.12	0.13
2000	Pound net	16.0	22	15	1	10	11	0.29	0.24	0.00	0.05	0.05
2001	Pound net	2.0	23	14	6	2	2	0.35	0.22	0.05	0.01	0.01
2002	Pound net	11.0	21	14	1	6	5	0.30	0.23	0.00	0.03	0.03

Table A8. Unclassified Finfish landings for Virginia (in MT) by gear. Also shown are the Landings of Atlantic croaker and the NCDMF scrap cpue (per trip in Kg) and where available the number of commercial trips for Atlantic croaker.

Year	Gear type	Landings	General	Spawn	Food	Bait	Total	Trips	NC bait/trip (kgs)
1973	Gill net	115	0	0	7	343	350		0
1974	Gill net	94	0	0	4	14	18		0
1975	Gill net	303	0	0	1	26	27		0
1976	Gill net	701	0	0	1	5	6		0
1977	Gill net	936	0	0	4	25	29		0
1978	Gill net	566	0	0	7	102	109		0
1979	Gill net	167	0	0	6	53	59		0
1980	Gill net	54	0	0	2	20	22		0
1981	Gill net	18	0	0	1	10	10		0
1982	Gill net	11	0	0	3	46	49		0
1983	Gill net	13	0	0	2	29	31		0
1984	Gill net	58	0	0	1	64	65		0
1985	Gill net	195	0	0	2	67	68		0
1986	Gill net	206	0	0	1	47	48		0
1987	Gill net	175	0	0	0	96	96		0
1988	Gill net	264	0	0	1	42	43		0
1989	Gill net	164	0	0	22	32	54		0.5
1990	Gill net	47	26	0	2	53	81		0.5
1991	Gill net	55	5	0	7	53	65		0.5
1992	Gill net	332	4	0	4	57	65		10
1993	Gill net	1342	0	0	2	62	64	2166	0.5
1994	Gill net	1441	1	0	1	153	155	1677	1
1995	Gill net	1284	0	0	0	237	237	1598	0.5
1996	Gill net	1736	2	0	1	217	220	1390	0.5
1997	Gill net	2323	6	0	1	175	182	1813	0.5
1998	Gill net	2177	13	0	1	296	310	1943	1
1999	Gill net	1578	37	0	0	121	158	1541	0.5
2000	Gill net	2710	58	0	0	160	218	1770	1
2001	Gill net	2356	0	0	1	84	84	1528	0.5
2002	Gill net	2112	4	0	0	150	153	1598	0.5

Table A8. continued.

Year	Gear type	Landings	General	Spawn	Food	Bait	Total	Trips	NC bait/trip (kgs)
1973	Haul Seine	201	0	0	0	31	32		0
1974	Haul Seine	45	0	0	0	9	10		0
1975	Haul Seine	179	0	0	0	85	85		0
1976	Haul Seine	284	0	0	0	14	15		0
1977	Haul Seine	422	0	0	5	14	20		0
1978	Haul Seine	302	0	0	2	46	48		0
1979	Haul Seine	183	0	0	0	299	299		0
1980	Haul Seine	21	0	0	0	67	67		0
1981	Haul Seine	29	0	0	0	77	77		0
1982	Haul Seine	0	0	0	0	36	37		0
1983	Haul Seine	5	0	0	0	54	54		0
1984	Haul Seine	81	0	0	0	84	84		0
1985	Haul Seine	504	0	0	1	129	130		0
1986	Haul Seine	598	0	0	0	137	137		485
1987	Haul Seine	807	0	0	0	35	36		335
1988	Haul Seine	315	0	0	0	10	10		377
1989	Haul Seine	126	0	0	0	88	88		402
1990	Haul Seine	5	0	0	0	43	43		664
1991	Haul Seine	7	0	0	0	160	160		278
1992	Haul Seine	205	0	0	0	290	290		34
1993	Haul Seine	384	0	0	0	274	274	399	167
1994	Haul Seine	484	0	0	0	330	330	378	591
1995	Haul Seine	581	0	0	0	257	257	324	442
1996	Haul Seine	695	5	0	0	238	243	358	183
1997	Haul Seine	1438	0	0	0	138	138	490	180
1998	Haul Seine	1060	0	0	1	418	419	522	145
1999	Haul Seine	1287	0	0	0	319	319	512	147
2000	Haul Seine	955	0	0	0	215	215	397	215
2001	Haul Seine	1006	0	0	0	117	117	402	1033
2002	Haul Seine	1237	1	0	0	168	169	370	301

Table A8. Continued.

Year	Gear type	Landings	General	Spawn	Food	Bait	Total	Trips	NC bait/trip (kgs)
1973	Trawl	140	0	0	2	0	2		0
1974	Trawl	218	0	0	2	5	7		0
1975	Trawl	606	0	0	4	1	5		0
1976	Trawl	420	0	0	12	0	12		0
1977	Trawl	295	0	0	9	2	11		0
1978	Trawl	379	0	0	7	0	7		0
1979	Trawl	99	0	0	1	0	1		0
1980	Trawl	29	0	0	1	3	5		0
1981	Trawl	11	0	0	1	0	1		0
1982	Trawl	11	0	0	0	20	21		0
1983	Trawl	7	0	0	0	3	3		0
1984	Trawl	48	0	0	1	2	3		0
1985	Trawl	62	0	0	2	0	2		0
1986	Trawl	36	0	0	0	0	0		818
1987	Trawl	34	0	0	0	5	6		1181
1988	Trawl	10	0	0	0	1	1		1363
1989	Trawl	26	0	0	0	20	20		1467
1990	Trawl	0	0	0	0	0	1		542
1991	Trawl	3	0	0	1	1	3		597
1992	Trawl	10	0	0	0	1	1		1455
1993	Trawl	62	0	0	0	0	0		1637
1994	Trawl	62	0	0	0	0	0		2087
1995	Trawl	112	1	0	18	0	19		1475
1996	Trawl	193	776	0	15	0	792		1305
1997	Trawl	425	734	0	2	0	736		569
1998	Trawl	311	636	0	0	0	636		266
1999	Trawl	612	289	0	9	0	298		532
2000	Trawl	515	27	0	0	0	27		489
2001	Trawl	480	0	0	3	0	3		589
2002	Trawl	439	1	0	0	0	1		686

Table A8. Continued.

Year	Gear type	Landings	General	Spawn	Food	Bait	Total	Trips	NC bait/trip (kgs)
1973	Pound net	160	0	0	17	4261	4278		0
1974	Pound net	322	0	0	77	1943	2020		0
1975	Pound net	1053	0	0	6	2980	2986		0
1976	Pound net	1262	0	0	5	3715	3721		0
1977	Pound net	2236	0	0	8	4383	4391		0
1978	Pound net	2424	0	0	6	6618	6624		0
1979	Pound net	516	0	0	17	5208	5224		0
1980	Pound net	218	0	0	5	1806	1812		0
1981	Pound net	137	0	0	2	915	917		0
1982	Pound net	32	0	0	2	1189	1191		0
1983	Pound net	43	0	0	1	1810	1811		0
1984	Pound net	183	0	0	0	894	895		0
1985	Pound net	225	0	0	1	766	767		0
1986	Pound net	233	0	0	1	396	397		250
1987	Pound net	218	0	0	2	465	467		135
1988	Pound net	204	0	0	2	214	216		124
1989	Pound net	112	0	0	4	909	913		254
1990	Pound net	37	0	0	3	507	510		291
1991	Pound net	9	0	0	3	685	689		195
1992	Pound net	60	0	0	5	848	852		60
1993	Pound net	595	0	0	31	2405	2436	1580	35
1994	Pound net	615	0	0	0	2769	2769	1607	57
1995	Pound net	1178	0	0	0	3351	3352	2228	8
1996	Pound net	1642	9	0	0	2835	2844	2113	17
1997	Pound net	1592	12	0	0	3310	3322	2502	11
1998	Pound net	1852	5	0	3	1422	1430	3234	25
1999	Pound net	2324	6	0	0	1539	1545	2781	132
2000	Pound net	1638	4	0	6	1909	1920	2614	126
2001	Pound net	1997	0	0	0	1347	1348	2236	35
2002	Pound net	1617	5	0	3	1246	1255	2238	21

Table A9. Estimated Scrap landings from Virginia commercial Fisheries by gear. reg=regression method. ratio=ratio method. land=based on landings. bait=based on unclassified finfish laded as bait or animal food. uncl= total unclassified fin fishes. step=based on stepwise regression. va-cpue/trip= using NCDMF scrap cpue/trip * number of trips from trip ticket database. Note 2[nd] column has different number of trips (see text) . All estimates in MT.

		Estimate							Std Error					
Year	gear type	reg -land	reg-bait	ratio-land	ratio-bait	ratio-uncl	reg-step	va-cpue/trip	reg -land	reg-bait	ratio-land	ratio-bait	ratio-uncl	reg-step
1973	Gill net	2	22	0		37			0.05	6.02	0.01	0.00	0.98	
1974	Gill net	2	1	0		2			0.04	0.02	0.01	0.00	0.05	
1975	Gill net	2	1	1		3			0.05	0.02	0.03	0.00	0.07	
1976	Gill net	2	1	2		1			0.09	0.02	0.07	0.00	0.02	
1977	Gill net	2	1	3		3			0.10	0.03	0.09	0.00	0.08	
1978	Gill net	2	1	2		11			0.06	0.07	0.05	0.00	0.29	
1979	Gill net	2	1	0		6			0.05	0.04	0.02	0.00	0.16	
1980	Gill net	2	1	0		2			0.05	0.03	0.01	0.00	0.06	
1981	Gill net	2	1	0		1			0.05	0.02	0.00	0.00	0.03	
1982	Gill net	2	1	0		5			0.05	0.04	0.00	0.00	0.14	
1983	Gill net	2	1	0		3			0.05	0.03	0.00	0.00	0.08	
1984	Gill net	2	1	0		7			0.05	0.05	0.01	0.00	0.18	
1985	Gill net	2	1	1		7			0.05	0.05	0.02	0.00	0.19	
1986	Gill net	2	1	1		5			0.05	0.03	0.02	0.00	0.13	
1987	Gill net	2	1	0		10			0.05	0.06	0.02	0.00	0.26	
1988	Gill net	2	1	1		4			0.05	0.03	0.02	0.00	0.12	
1989	Gill net	2	1	0		5			0.05	0.03	0.02	0.00	0.15	
1990	Gill net	2	1	0		8			0.05	0.04	0.00	0.00	0.22	
1991	Gill net	2	1	0		7			0.05	0.04	0.01	0.00	0.18	
1992	Gill net	2	1	1		7			0.06	0.04	0.03	0.00	0.18	
1993	Gill net	2	1	4		7		1	0.13	0.04	0.13	0.00	0.18	
1994	Gill net	2	2	4		15		2	0.09	0.10	0.13	0.00	0.42	
1995	Gill net	2	5	4		25		1	0.13	0.92	0.12	0.00	0.66	
1996	Gill net	3	4	6		24		1	0.18	0.47	0.17	0.00	0.61	
1997	Gill net	3	3	7		19		1	0.47	0.40	0.22	0.00	0.49	
1998	Gill net	3	7	6		31		2	0.22	2.01	0.21	0.00	0.88	
1999	Gill net	3	2	5		17		1	0.17	0.11	0.15	0.00	0.44	
2000	Gill net	5	3	8		23		2	0.66	0.27	0.26	0.00	0.61	
2001	Gill net	3	1	7		9		1	0.24	0.05	0.22	0.00	0.23	
2002	Gill net	3	2	6		15		1	0.20	0.13	0.19	0.00	0.40	

Table A9. Continued.

		Estimate							Std Error					
Year	gear type	reg -land	reg-bait	ratio-land	ratio-bait	ratio-uncl	reg-step	va-cpue/trip	reg -land	reg-bait	ratio-land	ratio-bait	ratio-uncl	reg-step
1973	Haul Seine	194	156	109	17	17			2.10	1.28	0.71	0.09	0.09	
1974	Haul Seine	162	152	24	5	5			1.51	1.25	0.16	0.03	0.03	
1975	Haul Seine	187	165	96	45	45			2.04	1.49	0.66	0.26	0.26	
1976	Haul Seine	210	151	152	8	8			2.56	1.24	1.04	0.04	0.04	
1977	Haul Seine	247	151	226	8	10			3.55	1.27	1.54	0.04	0.06	
1978	Haul Seine	214	157	162	24	25			2.61	1.32	1.07	0.14	0.14	
1979	Haul Seine	185	212	97	159	157			2.03	2.42	0.66	0.92	0.92	
1980	Haul Seine	156	162	11	36	35			1.39	1.40	0.07	0.20	0.20	
1981	Haul Seine	158	164	16	41	40			1.43	1.45	0.10	0.23	0.23	
1982	Haul Seine	150	153	0	19	19			1.24	1.22	0.00	0.11	0.11	
1983	Haul Seine	153	159	3	29	29			1.34	1.36	0.02	0.17	0.17	
1984	Haul Seine	168	166	44	45	45			1.60	1.46	0.28	0.25	0.25	
1985	Haul Seine	268	172	269	69	68			3.78	1.55	1.74	0.38	0.38	
1986	Haul Seine	299	173	319	73	72			4.69	1.61	2.11	0.41	0.41	
1987	Haul Seine	378	152	428	19	19			6.92	1.24	2.80	0.10	0.10	
1988	Haul Seine	218	151	169	5	5			2.72	1.21	1.11	0.03	0.03	
1989	Haul Seine	173	164	67	47	46			1.78	1.48	0.46	0.27	0.27	
1990	Haul Seine	156	159	3	23	23			1.35	1.33	0.02	0.13	0.13	
1991	Haul Seine	153	180	4	85	84			1.32	1.72	0.03	0.48	0.48	
1992	Haul Seine	194	214	111	155	153			2.17	2.41	0.75	0.89	0.89	
1993	Haul Seine	235	206	206	146	144	149	67	2.96	2.17	1.34	0.81	0.81	2.85
1994	Haul Seine	265	221	258	175	173	146	223	4.10	2.73	1.82	1.05	1.05	2.64
1995	Haul Seine	304	205	313	138	136	136	143	5.03	2.31	2.15	0.81	0.80	2.43
1996	Haul Seine	345	199	373	127	128	143	66	6.02	2.12	2.52	0.73	0.75	2.53
1997	Haul Seine	883	176	774	74	73	144	88	26.43	1.67	5.08	0.41	0.41	2.71
1998	Haul Seine	546	250	571	224	221	189	76	12.62	3.21	3.86	1.29	1.29	4.09
1999	Haul Seine	711	219	692	170	168	178	75	17.29	2.43	4.52	0.95	0.95	3.82
2000	Haul Seine	485	195	514	115	114	145	85	10.69	2.13	3.63	0.69	0.69	2.74
2001	Haul Seine	517	173	544	63	62	128	415	11.27	1.63	3.67	0.36	0.36	2.14
2002	Haul Seine	680	183	664	90	89	127	111	16.77	1.81	4.55	0.52	0.52	2.08

Table A9. Continued

		Estimate							Std Error					
Year	gear type	reg -land	reg-bait	ratio-land	ratio-bait	ratio-uncl	reg-step	va-cpue/trip	reg -land	reg-bait	ratio-land	ratio-bait	ratio-uncl	reg-step
1973	Trawl	387	177	67	0	1	267		3.03	1.04	0.63	0.00	0.00	2.29
1974	Trawl	374	176	103	2	2	261		3.04	1.04	0.98	0.01	0.02	2.38
1975	Trawl	326	178	291	0	1	228		3.06	1.01	2.63	0.00	0.01	2.39
1976	Trawl	356	179	205	0	3	240		3.23	1.07	1.91	0.00	0.03	2.36
1977	Trawl	360	175	139	1	3	251		2.99	1.02	1.31	0.01	0.03	2.40
1978	Trawl	354	177	181	0	2	244		3.04	1.02	1.70	0.00	0.02	2.31
1979	Trawl	398	178	48	0	0	266		3.01	1.03	0.44	0.00	0.00	2.30
1980	Trawl	410	179	14	1	1	276		3.22	1.12	0.13	0.01	0.01	2.27
1981	Trawl	406	176	5	0	0	278		2.94	1.03	0.05	0.00	0.00	2.29
1982	Trawl	400	176	5	6	6	273		2.96	1.07	0.05	0.06	0.05	2.13
1983	Trawl	403	175	3	1	1	277		2.88	1.01	0.03	0.01	0.01	2.27
1984	Trawl	404	178	23	1	1	276		3.04	1.05	0.21	0.01	0.01	2.27
1985	Trawl	399	177	30	0	0	269		3.04	1.05	0.28	0.00	0.00	2.18
1986	Trawl	402	176	17	0	0	271		2.95	1.02	0.16	0.00	0.00	2.22
1987	Trawl	406	178	16	2	2	270		3.04	1.07	0.16	0.02	0.01	2.18
1988	Trawl	406	176	5	0	0	277		2.98	1.04	0.04	0.00	0.00	2.26
1989	Trawl	403	178	13	6	5	272		2.90	1.05	0.12	0.05	0.05	2.28
1990	Trawl	408	176	0	0	0	283		2.87	1.01	0.00	0.00	0.00	2.30
1991	Trawl	404	175	2	0	1	277		2.93	1.03	0.02	0.00	0.01	2.23
1992	Trawl	411	178	5	0	0	278		3.00	1.05	0.05	0.00	0.00	2.32
1993	Trawl	399	177	30	0	0	271		2.97	1.03	0.28	0.00	0.00	2.19
1994	Trawl	399	177	30	0	0	270		2.79	0.97	0.26	0.00	0.00	2.40
1995	Trawl	392	177	54	0	5	270		2.91	1.00	0.49	0.00	0.04	2.42
1996	Trawl	380	177	92	0	216	6,681		3.15	1.07	0.89	0.00	1.95	433.30
1997	Trawl	349	177	204	0	202	5,250		3.03	1.02	1.90	0.00	1.75	352.61
1998	Trawl	365	177	149	0	174	3,403		3.05	1.02	1.37	0.00	1.49	175.25
1999	Trawl	324	177	292	0	81	672		3.15	1.03	2.73	0.00	0.71	15.69
2000	Trawl	338	178	247	0	7	260		3.16	1.05	2.33	0.00	0.06	3.10
2001	Trawl	334	175	225	0	1	239		2.92	0.98	2.06	0.00	0.01	2.41
2002	Trawl	342	1.8E+02	207	0	0	241		3.13	1.05	2.02	0.00	0.00	2.40

Table A9 continued.

Year	gear type	Estimate reg -land	reg-bait	ratio-land	ratio-bait	ratio-uncl	reg-step	va-cpue/trip	Std Error reg -land	reg-bait	ratio-land	ratio-bait	ratio-uncl	reg-step
1973	Pound net	56	1.4E+16	84	1,858	1,774			1.45	8.87E+15	0.62	8.79	9.03	
1974	Pound net	190	3.2E+07	172	859	850			8.60	1.48E+07	1.29	4.16	4.43	
1975	Pound net	104,741	3.2E+11	572	1,333	1,272			2.06E+04	1.68E+11	4.05	6.10	6.25	
1976	Pound net	311,105	2.3E+13	668	1,633	1,556			5.95E+04	1.58E+13	4.78	7.49	7.67	
1977	Pound net	1.6E+10	1.1E+17	1,186	1,929	1,838			1.13E+10	9.88E+16	8.43	8.79	9.00	
1978	Pound net	1.8E+12	6.0E+28	1,291	2,920	2,781			1.71E+12	6.01E+28	9.37	13.61	13.93	
1979	Pound net	742	7.8E+18	275	2,301	2,197			41.38	4.08E+18	1.96	10.55	10.82	
1980	Pound net	81	4.0E+06	113	784	748			2.49	1.12E+06	0.85	3.74	3.84	
1981	Pound net	51	5,203	73	403	384			1.25	890.50	0.52	1.87	1.91	
1982	Pound net	26	35,607	17	523	499			0.40	6.90E+03	0.12	2.42	2.48	
1983	Pound net	28	7.4E+06	23	798	759			0.49	2.17E+06	0.17	3.79	3.88	
1984	Pound net	71	4,203	98	396	377			1.93	315.79	0.72	1.86	1.90	
1985	Pound net	90	1,522	118	336	320			2.67	104.91	0.90	1.64	1.67	
1986	Pound net	90	126	122	173	165			2.70	4.86	0.88	0.80	0.82	
1987	Pound net	86	207	116	205	196			2.36	8.30	0.84	0.96	0.98	
1988	Pound net	77	44	108	94	90			2.17	1.17	0.79	0.44	0.46	
1989	Pound net	43	4,190	59	399	381			0.91	466.96	0.43	1.86	1.92	
1990	Pound net	27	296	20	224	214			0.46	20.08	0.14	1.05	1.08	
1991	Pound net	22	992	5	298	285			0.34	119.22	0.03	1.44	1.48	
1992	Pound net	31	2,987	32	374	358			0.56	307.31	0.23	1.75	1.80	
1993	Pound net	1,398	7.5E+08	315	1,057	1,019	7.1E+08	55	105.74	3.49E+08	2.34	5.04	5.22	2.29E+08
1994	Pound net	1,842	4.5E+10	325	1,216	1,157	4.5E+09	92	176.60	1.96E+10	2.46	5.89	6.03	1.40E+09
1995	Pound net	250,996	2.2E+12	631	1,484	1,412	1.7E+12	18	3.77E+04	7.99E+11	4.77	7.22	7.38	6.80E+11
1996	Pound net	1.8E+07	3.0E+10	874	1,250	1,193	9.5E+10	36	6.99E+06	1.53E+10	6.16	5.66	5.81	3.59E+10
1997	Pound net	9.1E+06	1.1E+12	847	1,459	1,394	9.6E+11	28	2.37E+06	4.71E+11	6.27	6.94	7.12	3.21E+11
1998	Pound net	3.1E+08	241,188	988	628	601	1.6E+06	81	2.06E+08	6.52E+04	7.26	2.96	3.05	3.37E+05
1999	Pound net	1.8E+10	473,857	1,231	677	647	2.9E+06	367	7.51E+09	9.33E+04	8.80	3.10	3.18	6.27E+05
2000	Pound net	2.9E+07	1.4E+07	871	841	805	4.9E+07	329	1.85E+07	7.63E+06	6.11	3.79	3.90	1.67E+07
2001	Pound net	3.1E+09	162,623	1,061	594	565	231,969	78	2.43E+09	4.89E+04	7.99	2.87	2.93	3.82E+04
2002	Pound net	1.9E+07	56,157	851	546	523	177,427	47	7.26E+06	9.31E+03	6.54	2.68	2.76	3.63E+04

APPENDIX B: **Estimating Virginia's Scrap Landings: Using Virginia field sampling data**

Scrap or bait landings in Virginia comprise small-size croaker harvested primarily from small-mesh haul seine and pound net fisheries. However, gill net, out-of-state trawl fisheries (Virginia has prohibited trawling in its state waters, since 1989), and other non-directed gear types (e. g. pots, dredges) that harvest a minor amount of Atlantic croaker also contribute to the scrap component of croaker landings.

The Virginia Marine Resource Commission (VMRC) has collected samples size (length, weight) data from its commercial fisheries since 1989, by gear and market category. Though not differentiated, these data include information on both the marketable and scrap component. Classification of Virginia Atlantic croaker landings by market grade (unclassified, small, medium and large) was initiated in 1989. Atlantic croaker landings from all gear types combined show a decline in small-grade Atlantic croaker and corresponding general increase in large-grade Atlantic croaker over time, 1989-2003 (Table B1). This decline in small-grade Atlantic croaker is tied to the general population increase in numbers across ages, evident since the mid-1990s. Additionally, of the major gears responsible for landing small-grade Atlantic croaker (haul seine and pound net), the number of active pound nets has declined by 45%, since 1994. Haul seine trips during the last 10 years have fluctuated but are similar. Based on mesh size characteristics, haul seine and pound net gears in Virginia, are responsible for the majority of small (< 9 inches) Atlantic croaker harvested. By extension, these two gear types can be expected to contribute the most to the scrap (or bait) component of Atlantic croaker landings, and landings from each gear type show a decline in the proportion of small-grade Atlantic croaker during the 1989-2003 period (Tables B2 and B3).

The market grade classification system of landings allowed for a proportional expansion of Atlantic croaker lengths (converted to weights) vs. Atlantic croaker landings to estimate total scrap (pounds), for the 1989 – 2002 period. It was decided that any Atlantic croaker less than 9 inches would be considered as potential scrap, and that ½ of the Atlantic croaker within a 9 to 9.99-inch length interval would also contribute to the scrap component (crab bait or other uses). Lengths of Atlantic croaker that satisfied their inclusion in the scrap category were converted to weights, using a length weight relationship. Total scrap landings were determined by using the proportion of scrap to total weight by year, gear and market grade were used to apportion the Atlantic croaker landings by year gear and market category (Table B4). Scrap estimates for the period 1973 to 1988 were estimated using an average ratio of estimated scrap to landings by gear from 1989-1993 and applying it to total landings by gear. These data was also used to develop estimates in numbers and a size distribution in 20mm length classes (Table B5).

Using the field sample of lengths from the Virginia harvest to estimate Virginia scrap is preferable to using data from North Carolina because there are distinct regional differences among the gear, area, and seasonal contributions to the Atlantic croaker landings and scrap. For example, the majority of the scrap in North Carolina stems from ocean trawl fisheries in coastal waters during late fall through winter, whereas the Virginia scrap primarily represents harvest from inside waters by pound net and haul seine fisheries during spring through late summer. The other approach to estimating the Virginia scrap component of Atlantic croaker landings used the ratio of North Carolina's scrap to NMFS unclassified (all species) bait category to apportion Virginia's NMFS unclassified (all species) bait category. However, using this method assumes that the relationship estimated for North Carolina is also appropriate for Virginia, which may not be a suitable assumption given the regional gear differences between the states.

Potential limitations in using Virginia sample data to determine scrap include a potential for not sampling some small (< 7 inches) Atlantic croaker that are immediately set aside at the dock by the harvester for bait use. Also, the choice of assigning ½ of Atlantic croaker in the 9-inch interval (average weight ranged from 0.35 to of 0.42 pounds during 1989 – 2002) to the scrap component was initially based on the VMRC understanding of the marketing factors that change over time and within a season. The VMRC contacted long-time, high-volume seafood buyers (one on the western and one on the eastern shore) that wholesale Atlantic croaker from pound nets. The buyers indicated that Atlantic croaker less than 9 inches could generally be considered as scrap. However, both buyers and a middle peninsula buyer indicated that some small-size Atlantic croaker (< 9 inches) was sold for food during years of low Atlantic croaker abundance. The buyers generally agreed that ½ of Atlantic croaker within the 9-inch interval are sold as food fish, with a greater amount of this size category in the bait in recent years and less in earlier years.

Recommendation:

The technical committee endorsed using Atlantic croaker length data, collected by the VMRC, as the best method for estimating the scrap component of Atlantic croaker landings in Virginia.

Table B1. Pounds landed and percentages of total landings (pounds) of Atlantic croaker, by market category and year, for all gear types combined.

	Jumbo		Large		Medium		Small		Unclassified		
Year	Pounds	%	Pounds	%	Pounds	%	Pounds	%	Pounds	%	Total
1989			27,266	2.87%	280,111	29.50%	252,854	26.63%	389,418	41.01%	949,649
1990			135	0.07%	48,706	24.19%	20,556	10.21%	131,956	65.53%	201,353
1991			3,031	1.85%	12,319	7.51%	40,243	24.52%	108,533	66.13%	164,126
1992			39,190	2.93%	144,618	10.80%	522,894	39.04%	632,651	47.24%	1,339,353
1993			236,537	4.50%	1,012,462	19.25%	875,599	16.65%	3,135,589	59.61%	5,260,187
1994			219,803	3.82%	1,078,449	18.72%	851,764	14.79%	3,609,959	62.67%	5,759,975
1995			399,929	5.75%	1,126,052	16.20%	934,840	13.45%	4,488,818	64.59%	6,949,639
1996			760,685	8.08%	1,375,274	14.62%	786,297	8.36%	6,487,648	68.94%	9,409,904
1997			1,562,283	12.15%	2,153,049	16.74%	1,236,503	9.61%	7,908,809	61.50%	12,860,644
1998			2,849,047	23.59%	2,315,277	19.17%	991,497	8.21%	5,920,847	49.03%	12,076,668
1999			3,036,692	23.60%	2,691,293	20.91%	1,175,712	9.14%	5,964,722	46.35%	12,868,419
2000			3,379,066	25.88%	2,086,243	15.98%	1,467,594	11.24%	6,121,281	46.89%	13,054,184
2001			3,299,005	25.32%	2,423,227	18.60%	1,072,696	8.23%	6,232,927	47.84%	13,027,855
2002	76,790	0.63%	3,149,279	25.87%	2,591,993	21.29%	568,846	4.67%	5,786,789	47.54%	12,173,697
2003	32,118	0.29%	3,208,629	29.34%	2,957,566	27.04%	492,252	4.50%	4,246,076	38.82%	10,936,641

Table B2 Virginia landings of Atlantic croaker from pound net, by market grade and year (1973-2003). Included are percentages of total pound net landings, by market grade.

Year	Jumbo pounds	% Total	Large pounds	% Total	Medium pounds	% Total	Small pounds	% Total	Unclassified pounds	% Total	Total
1973									349,343	100%	349,343
1974									704,081	100%	704,081
1975									2,281,840	100%	2,281,840
1976									2,560,877	100%	2,560,877
1977									4,024,832	100%	4,024,832
1978									4,990,645	100%	4,990,645
1979									1,081,930	100%	1,081,930
1980									480,617	100%	480,617
1981									300,560	100%	300,560
1982									70,477	100%	70,477
1983									94,476	100%	94,476
1984									365,394	100%	365,394
1985									486,751	100%	486,751
1986									431,690	100%	431,690
1987									402,005	100%	402,005
1988									436,950	100%	436,950
1989			21,506	9%	80,764	33%	55,564	22%	89,632	36%	247,466
1990			10	0.01%	2,078	3%	2,220	3%	77,546	95%	81,854
1991			379	2%	34	0.2%	576	3%	18,477	95%	19,466
1992			4,985	4%	10,179	8%	23,981	18%	93,666	71%	132,811
1993			89,721	7%	144,555	11%	190,638	15%	886,752	68%	1,311,666
1994			125,171	9%	218,734	16%	222,516	16%	787,194	58%	1,353,615
1995			284,552	11%	315,033	12%	296,226	11%	1,699,673	65%	2,595,484
1996			238,236	7%	343,748	9%	289,587	8%	2,756,253	76%	3,627,824
1997			265,269	8%	331,873	9%	261,446	7%	2,649,690	76%	3,508,278
1998			999,749	25%	770,925	19%	383,323	9%	1,926,149	47%	4,080,146
1999			862,337	17%	861,181	17%	301,980	6%	3,076,727	60%	5,102,225
2000			519,006	14%	378,486	10%	283,090	8%	2,426,960	67%	3,607,542
2001			808,369	18%	565,293	13%	245,176	5%	2,874,422	64%	4,493,260

Table B3. Virginia landings of Atlantic croaker from haul seine, by market grade and year (1973-2003).
Included are percentages of total haul seine landings, by market grade.

YEAR	Jumbo Pounds	% Total	Large Pounds	% Total	Medium Pounds	% Total	Small Pounds	% Total	Unclassified Pounds	% Total	Total Pounds
1973									442,201	100%	442,201
1974									99,716	100%	99,716
1975									394,682	100%	394,682
1976									625,722	100%	625,722
1977									930,088	100%	930,088
1978									665,752	100%	665,752
1979									403,315	100%	403,315
1980									45,655	100%	45,655
1981									64,158	100%	64,158
1982									188	100%	188
1983									10,596	100%	10,596
1984									177,621	100%	177,621
1985									1,110,437	100%	1,110,437
1986									1,302,181	100%	1,302,181
1987									1,778,874	100%	1,778,874
1988									694,972	100%	694,972
1989			2,475	1%	101,327	36%	122,836	44%	52,182	19%	278,820
1990			2,475	15%	98	1%	6,124	38%	7,352	46%	16,049
1991			2,475	13.5%	153	1%	15,654	85%	83	0%	18,365
1992				4%	34,068	8%	403,818	89%	13,624	3%	451,510
1993			17,830	1%	169,145	20%	472,564	56%	186,056	22%	845,595
1994			8,879	2%	196,214	18%	477,394	45%	384,130	36%	1,066,617
1995			18,965	11%	362,295	28%	422,373	33%	476,274	37%	1,279,907
1996			136,670	16%	599,442	39%	195,490	13%	599,818	39%	1,531,420
1997			244,199	17%	1,059,130	33%	528,106	17%	1,338,487	42%	3,169,922
1998			552,139	36%	838,135	35%	280,575	12%	726,940	30%	2,397,789
1999			871,837	8%	784,507	28%	253,320	9%	928,186	33%	2,837,850
2000			222,963	9%	486,269	23%	531,970	25%	890,721	42%	2,131,923
2001			197,843	2%	810,614	37%	376,472	17%	833,221	38%	2,218,150
2002	8,460	0.3%	49,109	2%	1,028,992	38%	279,576	10%	1,360,777	50%	2,726,914
2003	847	0.03%	66,999	2%	1,598,710	53%	174,012	6%	1,200,188	39%	3,040,756

Table B4. Estimated Scrap Landings from Virginia in metric tons

Year	Scrap estimates
1973	119.36
1974	101.22
1975	341.81
1976	464.71
1977	767.32
1978	736.51
1979	202.79
1980	64.29
1981	44.51
1982	8.64
1983	13.16
1984	77.38
1985	248.85
1986	285.27
1987	352.29
1988	183.66
1989	44.64
1990	14.06
1991	14.69
1992	141.62
1993	330.56
1994	266.51
1995	193.88
1996	48.40
1997	103.20
1998	66.40
1999	31.10
2000	19.80
2001	24.14
2002	15.82

Table B5. Size distribution of Virginia scrap component in 20 mm intervals

	Size class (mm)							
Year	120	140	160	180	200	220	240	Grand total
1989	0	0	3,815	7,696	90,966	323,070	57,921	483,468
1990	0	0	100	3,058	42,342	85,127	13,592	144,219
1991	64	64	0	8,385	44,054	95,715	14,922	163,204
1992	0	0	854	23,375	347,810	1,104,836	286,543	1,763,418
1993	0	0	0	12,606	430,501	2,664,577	1,009,569	4,117,253
1994	0	0	24,407	230,550	270,564	2,229,771	754,107	3,509,399
1995	0	0	29,422	366,644	705,240	1,156,509	265,687	2,523,502
1996	0	0	0	2,498	22,371	294,867	197,647	517,383
1997	0	0	0	0	108,811	799,504	321,222	1,229,537
1998	0	0	0	2,030	30,485	499,216	244,078	775,809
1999	0	0	0	0	26,377	207,362	149,219	382,958
2000	0	3,861	0	0	10,886	130,101	102,988	247,836
2001	0	0	0	0	2,493	91,558	99,377	193,428
2002	0	0	0	41,042	24,542	86,583	41,674	193,841
Grand total	64	3,925	58,598	697,884	2,157,442	9,768,796	3,558,546	16,245,255

APPENDIX C: Estimates of annual Atlantic croaker bycatch in the North Carolina shrimp trawl fishery, 1973-2002, based on a simple fish: shrimp ratio approach

Annual estimates of Atlantic croaker bycatch-at-age in the North Carolina shrimp trawl fishery were produced for 1973 through 2002. Given the lack of detailed effort data and limited bycatch characterization data, estimates were produced using a fish catch to shrimp catch ratio method. Annual estimates in weight were converted to bycatch-at-age in numbers using length frequencies from the available bycatch data and the length-weight relationship and growth model derived from the North Carolina Division of Marine Fisheries (NCDMF) dataset in the current assessment. Ages present in the bycatch estimates ranged from 0 to 2. Over 99% of bycatch was age 0, which equated to 264 million fish, in 1994 (most reliable estimate in time series). Annual bycatch was on the order of millions of fish for age 1 and tens of thousands for age 2. These estimates must be considered extremely crude.

Data sources:

NC commercial shrimp trawl landings, 1973-2002

Annual landings, in pounds, from the shrimp trawl fishery were provided by NCDMF for Atlantic croaker and penaeid shrimp from 1973-2002. Over the time series, shrimp landings have averaged 6.5 million pounds ranging from 2.4 million (1981) to 11.4 million (1985) with no strong temporal trend (Figure C1). Catches made in Inside waters (sounds, coastal rivers, etc.) account for approximately 75% of annual shrimp landings, with the remaining 25% coming from Ocean waters.

From 1973-2002, landings of Atlantic croaker from the NC shrimp trawl fishery have averaged 208,000 pounds. Landings declined steadily from 820,336 pounds in 1982, to 1,693 pounds in 2002 (Figure C2). In marked contrast to the overall decline, landings in 1996 and 1997 were both over 500,000 pounds. The spike in landings was attributed to a brief change in fishing behavior that was quickly modified by regulation (Tina Moore, pers. comm.[1]).

Wolff, 1972 (Wolff)

From June through August 1970, 39 trawl tows were sampled to determine discard ratios of finfish to commercially valuable shrimp by weight. Of the 39 tows, 4 were classified as “Ocean”, 18 as “Core Sound”, and 17 as “Pamlico Sound”. In addition to general location, day vs. night, total finfish catch weight, total shrimp catch weight, and the resulting fish:shrimp ratio were reported for each sampled trawl tow. Finfish species composition and percent by weight were reported for all tows combined. No length data were available from the 39 tows.

[1] Tina Moore, North Carolina Division of Marine Fisheries
943 Washington Square Mall, Washington, NC 27889

NMFS bycatch characterization, 1992-1994 (NMFS)

From 1992-1994, approximately 685 trawl tows were sampled during a NMFS bycatch characterization study. Data available from each sample included location, tow duration, gear information, total weight of penaeid shrimp by species, total weight and total number of Atlantic croaker. Lengths (TL mm) were recorded for Atlantic croaker from approximately 288 tows. Of the 685 tows, 17 were made in 1992, 146 in 1993, and 522 in 1994. By area, 36 were in Ocean waters, 629 were in Inside waters, and 20 had missing or erroneous location information. These data are summarized in Nance et al., 1997.

Johnson, 2003 (Johnson)

From June, 1999 through July, 2000, 56 trawl tows were sampled during a University of North Carolina shrimp trawl discard study (Johnson, 2003). Data available from each sample included location, tow duration, gear information, total weight of penaeid shrimp by species, total weight and total number of Atlantic croaker. Lengths (TL mm) were recorded from the 54 tows that caught Atlantic croaker. By year, 34 tows were sampled in 1999, 22 in 2000. Tows were made in two Inside water areas: the Neuse River and Core Sound. No tows from Ocean waters were sampled during this study.

Methods and estimates:

Atlantic croaker:shrimp ratios

For each of the three bycatch and discard datasets described above, Atlantic croaker:shrimp ratios were calculated by dividing Atlantic croaker catch weight summed across all tows by shrimp catch weight summed across all tows (Table C1). Since tow duration was not available from Wolff, differences in duration among tows were not taken into account. While not desirable, this decision was made to keep ratio estimation consistent among the three datasets. For the Wolff and NMFS datasets, ratios were also calculated by area: Inside and Ocean. For NMFS and Johnson, tow catches were summed across years.

For Wolff, the fish:shrimp ratio for all 39 tows was 5.38:1. Atlantic croaker made up 24.2% by weight of the total finfish catch from all tows. 24.2% of 5.38 is approximately 1.30, so the overall Atlantic croaker:shrimp ratio was 1.30:1. The fish:shrimp ratio was 14.0:1 for Ocean tows pooled, 1.6:1 for Core Sound, and 12.5:1 for Pamlico Sound. For Core and Pamlico Sounds combined, the ratio was 3.9:1. As species composition and percent by weight were not available for each tow, Atlantic croaker:shrimp ratios could only be calculated by area using 24.2% reported for all tows combined. The resulting Atlantic croaker:shrimp ratios by area were 3.4:1 for Ocean, 0.4:1 for Core Sound, 3.0:1 for Pamlico Sound, and 0.9:1 for Inside waters (Core and Pamlico Sounds combined).

For NMFS, the Atlantic croaker:shrimp ratio for all years, areas combined was 1.66:1. By area, the ratio was 0.25:1 for Ocean waters and 1.81:1 for Inside waters. While not used in subsequent calculations, ratios by year (pooled over area) were 1.83:1 in 1992, 1.07:1 in 1993, and 1.77:1 in 1994.

For Johnson, the Atlantic croaker:shrimp ratio for both years combined was 0.60:1. Ratios could not be calculated by area as all sampled tows were made in Inside waters. While not used in subsequent calculations, ratios by year were 0.37:1 in 1999, and 1.01:1 in 2000.

The three ratios (one from each bycatch dataset) based on Atlantic croaker and shrimp catches pooled over years and areas were considered to be the base case for subsequent calculations. Ratios by area were calculated and carried forward as one possible alternative.

Annual Atlantic croaker bycatch by weight

The first step in estimating total annual bycatch of Atlantic croaker was deciding how to apply the ratios from the three datasets to the time series, 1973-2002. The Wolff ratio was used for years 1972 through 1991. The NMFS ratio was used for 1992-1998, and the Johnson ratio was used for 1999-2002. In this method, a ratio was used from the first year in which the underlying data were collected until the year preceding the next available ratio. There are serious shortcomings to this method, and numerous alternatives could be employed. This issue is revisited in the Discussion section.

After allocating the years in the time series among the three ratios, annual Atlantic croaker bycatch was calculated by multiplying annual shrimp landings by the appropriate Atlantic croaker:shrimp ratio and then subtracting the reported Atlantic croaker landings:

$$Croaker\,Bycatch_{year} = ShrimpLandings_{year} \times Croaker:Shrimp\,ratio - ReportedLandings_{year}$$

with all landings from the NC commercial shrimp trawl fishery (Table C2). Annual Atlantic croaker bycatch from 1973-2002 averaged 8.04 million pounds with a range of 2.73 million in 1981 to 14.56 million in 1985. While there was no clear trend over the entire time series, there appeared to be a decline in bycatch estimates from the early 1990's through 2002 (Figure C3a).

Annual Atlantic croaker bycatch was estimated by area, as well. Bycatch estimates for Inside and Ocean waters were calculated separately and then summed to produce total annual estimates (Table C3). The NMFS Ocean waters Atlantic croaker:shrimp ratio was used for 1992-2002 since all Johnson samples were from Inside waters. The by area estimate generally exceeded the area pooled estimate from 1972-1991 (Figure C3a). The by area estimate was less than the area pooled estimate from 1992-2002. This switch is most readily explained by the large decrease in the Ocean waters Atlantic croaker:shrimp ratio from 3.40:1, 1972-1991, to 0.25:1 for 1992-2002.

Length Frequency Distributions

Weighted length frequency distributions were calculated for the NMFS and Johnson datasets separately. Observed numbers-at-length from each sampled net were expanded to the tow level and then summed across all tows with Atlantic croaker catch to produce weighted length frequency distributions.

Length frequency distributions were somewhat different between the two datasets (Figure C4). Both had a minimum length of about 30mm. However, the NMFS distribution had a mode of 120mm and a maximum of about 250mm compared to Johnson with a mode of 90mm and a maximum of about 180mm.

For NMFS, separate length frequencies were calculated for Inside and Ocean waters. The Inside distribution ranged from 30mm to 250mm with a mode of 120mm (Figure C5). The Ocean distribution was truncated in comparison, with a range of 90-180mm and a mode of 110mm.

Mean weight per fish

Mean weight per fish was calculated for the NMFS and Johnson datasets separately. Lengths (mm) from the weighted length frequencies were converted to weights (kg) using the length weight relationship from the current assessment:

$\text{Weight} = a(\text{Length})^b$,

where $a = 5.49 \times 10^{-9}$, $b = 3.13$. Individual weights were then summed and divided by the total number to produce a mean. The mean weight for NMFS was 0.02 kg (0.043 lbs.). Mean weight for Johnson was smaller at 0.013 kg (0.028 lbs.).

Mean weights were also calculated by area for NMFS. For Ocean waters, the mean was 0.021 kg (0.047 lbs.). Inside waters mean was slightly smaller at 0.02 kg (0.044 lbs.).

Annual Atlantic Croaker Bycatch By Number

To convert bycatch from weight to numbers, annual Atlantic croaker bycatch by weight was divided by mean weight per fish. The NMFS mean weight estimate was used for 1973-1998 since there was no length or individual fish weight information available from Wolff. Johnson mean weight was used for 1999-2002. As landings were in pounds, mean weight estimates were converted from kilograms to pounds prior to calculations.

Estimates of bycatch by number were two orders of magnitude greater than estimates by weight. The average number of Atlantic croaker in shrimp trawl bycatch over the time series was 194 million, annually, ranging from 63.2 million, 1981, to 337 million, 1985 (Table C2). There was a similar decline in bycatch estimates by number from the early 1990's through 2002 (Figure C3b). However, the decline in numbers did not exactly match the decline in weight due to the smaller mean weight per fish estimate from Johnson used in years 1999-2002.

Annual bycatch in numbers was also estimated by area. As before, estimates were produced separately for Ocean and Inside waters, then summed to produce total annual estimates. Mean weight per fish for Ocean waters from NMFS was used for 1973 through 2002. For Inside waters, NMFS was used for 1973-1998, and Johnson was used for 1999-2002. Calculated by area, average annual bycatch in numbers was 192 million, 1973-2002 (Table C3). As with weight estimates, bycatch in numbers by area were generally greater than the area pooled estimates from 1973-1991 and less than area pooled from 1992-2002 (Figure C3b).

Age Composition

For NMFS and Johnson, age compositions were produced by converting the weighted numbers-at-length, pooled over years and areas, to numbers-at-age using the growth model from the current assessment. The von Bertalanffy equation:

$L = L_{\infty}(1\text{-}\exp^{(-k(Age - t_0))})$,

where $L_{\infty} = 434.6$mm, $k = 0.2415$, $t_0 = -1.9572$, was rearranged to solve for age:

$Age = (\ln(1 - (L / L_{\infty}))) / (-k) + t_0$.

Calculated ages less than zero were set to age 0. Non-negative ages were rounded to the nearest whole age.

Age compositions for both NMFS and Johnson were comprised primarily or entirely of age 0 fish. For NMFS, age 0 made up the overwhelming majority at just over 99.32%. Age 1 made up about 0.67%, and age 2 made up slightly more than 0.01%. Age 0 fish made up 100% of the Johnson age composition.

Age compositions by area could only be calculated for NMFS. Inside waters age composition was virtually identical to the area pooled composition: 99.32% - age 0, 0.67% - age 1, 0.01% - age 2. Ocean waters fish were 100% age 0.

Bycatch-at-age

Annual estimates of bycatch by number were multiplied by each age percentage in the appropriate age composition to produce bycatch-at-age in numbers. NMFS age composition was used for years 1973-1998. Johnson was used for 1999-2002. The resulting estimates are given in Table C4 and Figure C6. The average number of age 0 fish caught annually was approximately 193 million ranging from 62.8 million, in 1981, to 334.8 million, 1985. Age 1 and age 2 annual bycatch in numbers averaged 1.14 million and 19,130, respectively. However, it must be noted that ages 1 and 2 were absent from estimates for years 1999-2002 due to the smaller length frequency distribution of Johnson. As before, this issue will be expanded upon in the Discussion section.

While overall patterns in bycatch-at-age calculated by area were very similar to area pooled, annual estimates by area were consistently smaller for ages 1 and 2 (Table C5, Figure C6). The annual averages for ages 1 and 2 were 734,080 and 12,273, respectively, both considerably less than the area pooled averages of 1.14 million and 19,130. Conversely, age 0 averaged 191 million annually which was quite similar to the area pooled average of 193 million. As with area pooled, ages 1 and 2 were absent from the by area estimates for years 1999-2002. For these years, the Johnson age composition (100% age 0) was used for Inside and the NMFS Ocean waters age composition (100% age 0) was used for Ocean.

Discussion:

Due to the scarcity of information concerning Atlantic croaker bycatch in the North Carolina shrimp trawl fishery relative to the time series of the current assessment, numerous subjective decisions were made to produce this initial set of estimates. The rationale for, along with possible alternatives to, these decisions are provided below. Undoubtedly, significant changes will need to be made to the methodology and resulting estimates presented in this report.

Fish: Shrimp ratio bycatch estimation approach

At the heart of this approach are at least two key assumptions. First, Atlantic croaker abundance and shrimp abundance are related, or more correctly, the catchability of Atlantic croaker in the North Carolina shrimp trawl fishery and the catchability of shrimp in said fishery are directly, linearly related. The second assumption is that available bycatch information is sufficient to produce ratio estimates representative of the fishery over the time series considered. It is beyond the capabilities of the author to address these assumptions other than to provide several references on the subject (Peuser 1996; Nance et al. 1997; Diamond 2003) and to state that 6 years of bycatch characterization data (5 of which are from 1992-2000) are being applied to a 30 year time series.

Ratio calculations

One of the goals in producing these initial estimates was to incorporate all bycatch information that was readily available. Because the three bycatch datasets had different levels of detail, all methods and estimates were standardized to the lowest level. The Wolff dataset had the lowest level of detail providing most information at the tow level (general area, total weight of shrimp and total weight of fish per trawl tow) and one critical piece of information at the study level (proportional fish species composition of total fish landings summed over all tows). Shrimp and Atlantic croaker catches from NMFS and Johnson datasets were expanded, as needed, to the tow level and then summed across all tows to produce a base case Atlantic croaker:shrimp ratio for each of the two datasets consistent with the Wolff base case ratio. This method ignores all ancillary information from NMFS and Johnson that could have been used to calculate ratios by strata such as year or season, based on catches standardized to a consistent unit of effort (e.g. tow hour).

The "by area" method was one alternative to pooling all information for each study. Unfortunately, this method had serious flaws. Only Wolff and NMFS datasets had observations from Ocean waters, and of those Wolff had only four. Since there were no Ocean tows in the Johnson dataset, the NMFS Ocean ratio was used for 1999-2002. Producing Atlantic croaker:shrimp ratios by area for Wolff required the assumption that the Atlantic croaker proportion of total fish landings (0.242) was not significantly different from what that proportion might have been for Inside and Ocean tows considered separately.

Discards vs. Landings

Reported landings of Atlantic croaker must be considered when producing bycatch estimates. Sampling in the three bycatch studies was conducted at sea, meaning that any ratios calculated from these data would reflect Atlantic croaker to be discarded as well as Atlantic croaker to be landed. For this reason, annual reported landings from the shrimp trawl fishery were subtracted from the total bycatch estimate to produce a discard bycatch estimate.

This method assumes that reported landings come from the total bycatch indiscriminately. It is more likely that reported landings are comprised of the largest fish in the bycatch, disproportionate to their numbers. If this were the case, the bycatch-at-age estimates presented here would be biased high for Ages 1 and 2, and low for Age 0. Some other method for allocating the reported landings by size or age group should be evaluated.

Length Information

Length information was only available from NMFS and Johnson datasets. For this reason, mean size and age composition from NMFS were used in calculations for years 1973-1991 when the Wolff ratio was used to produce the annual bycatch estimate by weight. Starting in 1992, the first year of the NMFS dataset, BRD's were being implemented in North Carolina. Undoubtedly, BRD's have affected the size distribution of Atlantic croaker present in bycatch. However, this size distribution has to be applied to years prior to BRD implementation.

Possible Alternatives

The following paragraphs provide alternative ratio approaches using the current datasets, with advantages, disadvantages and potential changes in the estimates relative to the base case, area pooled.

Consider only NMFS dataset: This is the most extensive bycatch characterization dataset currently available. It includes hundreds of observed tows providing the largest spatial and temporal coverage. The NMFS mean size and age composition are already being applied to most of the time series, 1973-1998. Disadvantages include applying three consecutive years of data to the remaining 27 and applying a ratio based on BRD impacted catches to years prior to BRD implementation. Likely changes to the estimates include ages 1 and 2 being present for years 1999-2002 and a slight increase in annual bycatch overall.

Pool all datasets: Given the limited information available and realizing that over a 30 year time series many aspects of the Atlantic croaker population(s), shrimp population(s), and the shrimp fishery are subject to change, pooling all available information might produce an average set of estimates for the time series. This approach would require some weighting scheme among the datasets or the resulting estimates would still be dominated by the NMFS. Pooling all datasets will not address the lack of length distribution data prior to 1992 and BRD implementation. Effects on bycatch estimates would depend heavily on the weighting scheme with the exception that Ages 1 and 2 are likely to be present for years 1999-2002.

Smooth transitions between datasets: The current stepwise approach produces dramatic changes across the time series, most notably the sudden disappearance of ages 1 and 2 from bycatch in 1999, continuing through 2002. A smoothing function would allow for less abrupt changes that might be more realistic. This approach would not address the lack of length information prior to 1992 and would require some means of evaluating the smoothing function. Ages 1 and 2 would likely reappear for some portion of the 1999-2002 time series with other changes being less noticeable.

Calculate ratios using different methodologies appropriate to the level of coverage in each dataset: This approach might improve estimates for the latter part of the time series, 1992-2002, as separate ratios could be calculated for more spatial, temporal strata. Coverage in terms of length information would have to be evaluated, and two-thirds of the time series will still have relatively less precise estimates based on length data impacted by BRD's. Likely impacts on the estimates would be minimal prior to 1992.

Literature Cited:

Diamond, S.L. 2003. Estimation of bycatch in shrimp trawl fisheries: a comparison of estimation methods using field data and simulated data. Fish. Bull. 101:484-500.

Johnson, G. 2003. The role of trawl discards in sustaining blue crab production. Fishery Resource Grant 99-EP-07. 127 pp.

Nance, J., E. Scott-Denton, E. Martinez, J. Watson, A. Shah, and D. Foster. 1997. Bycatch in the southeast shrimp trawl fishery. A data summary report, SFA Task N-10.03.

Peuser, R. (ed.) 1996. Estimates of finfish bycatch in the South Atlantic shrimp fishery. Prepared by the SEAMAP South Atlantic Committee, Shrimp Bycatch Work Group, Final Report. Atlantic States Marine Fisheries Commission, April 1996, 64 pp.

Wolff, M. 1972. A study of North Carolina scrap fishery. NC Department of Natural and Economic Resources, Special Scientific Report 20, 29 pp.

Table C1. Summary of Atlantic croaker:shrimp ratios by weight. Atlantic croaker and shrimp total weights are in pounds for Wolff, and kilograms for NMFS and Johnson. Sample sizes for NMFS Inside and NMFS Ocean do not sum to NMFS Pooled as 20 observations had missing tow coordinates.

Dataset	WOLFF	WOLFF	WOLFF	NMFS	NMFS	NMFS	JOHNSON
N	39	35	4	685	629	36	56
Area	POOLED	INSIDE	OUTSIDE	POOLED	INSIDE	OUTSIDE	INSIDE ONLY
Atlantic croaker total weight	265.97	164.25	101.72	23832.69	23367.48	264.22	586.38
Shrimp Total Weight	204.33	174.33	30.00	14294.80	12915.34	1061.86	976.24
C:S Ratio	1.30	0.94	3.39	1.67	1.81	0.25	0.60

Table C2. Reported annual shrimp and Atlantic croaker landings from the North Carolina shrimp trawl fishery, with estimated Atlantic croaker bycatch and number. C:S ratios and Atlantic croaker mean weights were calculated using the area pooled approach.

Year	Shrimp landed (lbs.)	Atlantic croaker landed (lbs.)	C:S ratio	Total croaker (lbs.)	Discard Atlantic croaker bycatch (lbs.)	Atlantic croaker mean Weight (lbs)	Discard Atlantic croaker bycatch (No.)
1970	4,918,000	34,500	1.30	6,401,552	6,367,052	0	147,412,069
1971	7,408,900	29,700	1.30	9,643,850	9,614,150	0	222,589,963
1972	5,445,100	73,001	1.30	7,087,655	7,014,654	0	162,405,578
1973	4,864,700	163,146	1.30	6,332,173	6,169,027	0	142,827,344
1974	8,227,700	255,596	1.30	10,709,648	10,454,052	0	242,035,631
1975	4,962,200	330,061	1.30	6,459,085	6,129,024	0	141,901,172
1976	6,490,500	137,927	1.30	8,448,408	8,310,481	0	192,406,985
1977	5,578,900	254,361	1.30	7,261,817	7,007,456	0	162,238,923
1978	2,880,331	188,699	1.30	3,749,204	3,560,505	0	82,433,991
1979	4,613,389	376,698	1.30	6,005,052	5,628,354	0	130,309,509
1980	9,210,911	447,142	1.30	11,989,452	11,542,310	0	267,231,336
1981	2,432,165	435,374	1.30	3,165,846	2,730,472	0	63,216,780
1982	6,666,224	820,336	1.30	8,677,141	7,856,805	0	181,903,317
1983	5,884,672	425,522	1.30	7,659,828	7,234,306	0	167,491,015
1984	4,682,496	105,667	1.30	6,095,006	5,989,339	0	138,667,144
1985	11,397,253	277,047	1.30	14,835,320	14,558,273	0	337,057,913
1986	5,969,024	215,283	1.30	7,769,625	7,554,342	0	174,900,603
1987	4,207,170	80,473	1.30	5,476,294	5,395,821	0	124,925,828
1988	7,869,873	118,500	1.30	10,243,879	10,125,379	0	234,426,104
1989	8,643,154	205,161	1.30	11,250,426	11,045,265	0	255,723,607
1990	7,538,761	101,216	1.30	9,812,885	9,711,669	0	224,847,744
1991	10,163,807	114,765	1.30	13,229,796	13,115,031	0	303,643,495
1992	5,200,780	36,319	1.67	8,670,889	8,634,570	0	199,910,400
1993	6,144,215	40,836	1.67	10,243,811	10,202,975	0	236,222,622
1994	6,893,428	14,821	1.67	11,492,920	11,478,100	0	265,744,725
1995	7,911,321	19,013	1.67	13,189,981	13,170,968	0	304,938,573
1996	4,876,299	505,599	1.67	8,129,905	7,624,306	0	176,520,436
1997	6,451,887	549,275	1.67	10,756,770	10,207,495	0	236,327,284
1998	4,271,323	9,197	1.67	7,121,272	7,112,075	0	164,661,089
1999	8,109,944	6,987	0.60	4,871,247	4,864,260	0	174,299,249
2000	9,443,835	1,180	0.60	5,672,450	5,671,270	0	203,216,566
2001	4,747,112	2,257	0.60	2,851,358	2,849,101	0	102,090,800
2002	8,834,301	1,693	0.60	5,306,333	5,304,640	0	190,079,219

Table C3. Reported annual shrimp and Atlantic croaker landings from the North Carolina shrimp trawl fishery, with estimated Atlantic croaker bycatch by weight and number. C:S ratios and Atlantic croaker mean weights were calculated using the alternative by area approach.

	INSIDE						
Year	Shrimp landed (lbs.)	Atlantic croaker landed (lbs.)	C:S Ratio	Total Atlantic croaker (lbs.)	Discarded Atlantic croaker bycatch (lbs.)	Atlantic croaker mean weight (lbs)	Discarded Atlantic croaker bycatch (No.)
1972	3,326,912	25,483	1	3,134,458	3,108,975	0.0435	71,462,820
1973	2,975,106	83,241	1	2,803,003	2,719,762	0.0435	62,516,383
1974	6,258,665	146,232	1	5,896,615	5,750,383	0.0435	132,178,181
1975	3,051,935	116,365	1	2,875,387	2,759,022	0.0435	63,418,827
1976	4,635,186	75,168	1	4,367,051	4,291,883	0.0435	98,653,124
1977	4,667,283	145,440	1	4,397,291	4,251,851	0.0435	97,732,955
1978	1,787,660	169,967	1	1,684,248	1,514,281	0.0435	34,807,226
1979	3,121,182	297,881	1	2,940,629	2,642,748	0.0435	60,746,138
1980	7,646,578	381,136	1	7,204,241	6,823,105	0.0435	156,835,729
1981	1,929,037	407,151	1	1,817,447	1,410,296	0.0435	32,417,022
1982	5,087,026	772,272	1	4,792,753	4,020,481	0.0435	92,414,685
1983	4,283,091	374,028	1	4,035,324	3,661,296	0.0435	84,158,463
1984	3,025,281	80,307	1	2,850,275	2,769,968	0.0435	63,670,429
1985	10,016,284	211,253	1	9,436,864	9,225,611	0.0435	212,059,697
1986	4,768,243	160,096	1	4,492,411	4,332,315	0.0435	99,582,492
1987	3,035,150	46,482	1	2,859,573	2,813,091	0.0435	64,661,655
1988	6,015,313	85,970	1	5,667,341	5,581,371	0.0435	128,293,260
1989	6,569,740	171,442	1	6,189,695	6,018,253	0.0435	138,335,435
1990	6,155,089	81,536	1	5,799,031	5,717,495	0.0435	131,422,210
1991	8,812,513	93,316	1	8,302,729	8,209,413	0.0435	188,701,380
1992	4,232,962	23,020	2	7,658,616	7,635,596	0.0435	175,511,639
1993	4,344,978	7,471	2	7,861,284	7,853,813	0.0435	180,527,578
1994	5,242,490	8,392	2	9,485,136	9,476,744	0.0435	217,832,226
1995	5,729,196	11,735	2	10,365,724	10,353,989	0.0435	237,996,566
1996	3,054,886	6,620	2	5,527,146	5,520,527	0.0435	126,894,704
1997	4,911,723	4,152	2	8,886,685	8,882,533	0.0435	204,173,698
1998	2,019,600	8,031	2	3,654,023	3,645,992	0.0435	83,806,694
1999	5,275,158	1,744	1	3,168,530	3,166,786	0.0279	113,474,275
2000	7,847,702	999	1	4,713,731	4,712,732	0.0279	168,869,623
2001	3,493,218	2,161	1	2,098,205	2,096,044	0.0279	75,106,797
2002	7,511,154	1,083	1	4,511,583	4,510,500	0.0279	161,623,104

Table C3. Continued.

Year	OCEAN Shrimp landed (lbs.)	Atlantic croaker landed (lbs.)	C:S ratio	Total Atlantic croaker (lbs.)	Discarded Atlantic croaker bycatch (lbs.)	Atlantic croaker mean weight (lbs)	Discarded Atlantic croaker bycatch (No.)	Total discard Atlantic croaker bycatch (lbs.)	Total discard Atlantic croaker bycatch (No.)
1972	2,118,190	47,518	3	7,182,237	7,134,719	0.0473	150,935,553	10,243,694	222,398,374
1973	1,889,582	79,905	3	6,407,086	6,327,181	0.0473	133,852,025	9,046,943	196,368,408
1974	1,969,214	109,364	3	6,677,098	6,567,734	0.0473	138,940,935	12,318,117	271,119,115
1975	1,910,234	213,696	3	6,477,112	6,263,416	0.0473	132,503,063	9,022,438	195,921,890
1976	1,855,285	62,759	3	6,290,794	6,228,035	0.0473	131,754,577	10,519,918	230,407,701
1977	911,933	108,921	3	3,092,130	2,983,209	0.0473	63,110,027	7,235,060	160,842,982
1978	1,093,067	18,732	3	3,706,309	3,687,577	0.0473	78,010,983	5,201,858	112,818,210
1979	1,494,932	78,817	3	5,068,930	4,990,113	0.0473	105,566,232	7,632,860	166,312,370
1980	1,580,401	66,006	3	5,358,733	5,292,727	0.0473	111,968,064	12,115,832	268,803,793
1981	505,898	28,223	3	1,715,370	1,687,147	0.0473	35,691,728	3,097,442	68,108,749
1982	1,601,111	48,064	3	5,428,955	5,380,891	0.0473	113,833,186	9,401,372	206,247,871
1983	1,601,956	51,494	3	5,431,821	5,380,327	0.0473	113,821,237	9,041,622	197,979,700
1984	1,647,793	25,360	3	5,587,242	5,561,882	0.0473	117,662,058	8,331,850	181,332,486
1985	1,381,502	65,794	3	4,684,318	4,618,524	0.0473	97,705,239	13,844,135	309,764,936
1986	1,173,063	55,187	3	3,977,555	3,922,368	0.0473	82,978,003	8,254,683	182,560,494
1987	1,168,458	33,991	3	3,961,940	3,927,949	0.0473	83,096,082	6,741,041	147,757,738
1988	1,826,134	32,530	3	6,191,950	6,159,420	0.0473	130,303,031	11,740,791	258,596,291
1989	2,073,275	33,719	3	7,029,942	6,996,223	0.0473	148,005,655	13,014,476	286,341,090
1990	1,381,184	19,680	3	4,683,240	4,663,560	0.0473	98,657,973	10,381,054	230,080,183
1991	1,341,367	21,449	3	4,548,230	4,526,781	0.0473	95,764,420	12,736,194	284,465,800
1992	967,602	13,299	0	240,766	227,467	0.0473	4,812,087	7,863,063	180,323,726
1993	1,799,000	33,365	0	447,641	414,276	0.0473	8,764,045	8,268,090	189,291,623
1994	1,643,201	6,429	0	408,874	402,445	0.0473	8,513,760	9,879,189	226,345,986
1995	2,181,634	7,278	0	542,851	535,573	0.0473	11,330,091	10,889,562	249,326,657
1996	1,811,952	498,980	0	450,864	-	0.0473	-	5,520,527	126,894,704
1997	1,539,725	545,123	0	383,126	-	0.0473	-	8,882,533	204,173,698
1998	2,250,604	1,166	0	560,013	558,847	0.0473	11,822,446	4,204,839	95,629,141
1999	2,834,540	5,243	0	705,312	700,069	1.0473	668,471	3,866,855	114,142,745
2000	1,596,695	181	0	397,302	397,121	2.0473	193,976	5,109,853	169,063,599
2001	1,256,792	96	0	312,725	312,629	3.0473	102,593	2,408,673	75,209,390
2002	1,370,572	610	0	341,036	340,426	4.0473	84,113	4,850,926	161,707,217

Table C4. Estimates of annual croaker bycatch by age group, in weight and numbers, from the North Carolina shrimp trawl fishery, 1973-2002. Estimates were calculated using the area pooled approach.

	Bycatch at age (Number)						
	Discard Atlantic croaker bycatch	Age proportions			Bycatch at age		
Year	(No.)	Age0	Age1	Age2	Age0	Age1	Age2
1972	162,405,578	0.993226	0.006662	0.000111	161,305,482	1,082,007	18,090
1973	142,827,344	0.993226	0.006662	0.000111	141,859,866	951,569	15,909
1974	242,035,631	0.993226	0.006662	0.000111	240,396,139	1,612,532	26,960
1975	141,901,172	0.993226	0.006662	0.000111	140,939,968	945,399	15,806
1976	192,406,985	0.993226	0.006662	0.000111	191,103,666	1,281,887	21,432
1977	162,238,923	0.993226	0.006662	0.000111	161,139,955	1,080,896	18,071
1978	82,433,991	0.993226	0.006662	0.000111	81,875,603	549,206	9,182
1979	130,309,509	0.993226	0.006662	0.000111	129,426,823	868,171	14,515
1980	267,231,336	0.993226	0.006662	0.000111	265,421,175	1,780,395	29,766
1981	63,216,780	0.993226	0.006662	0.000111	62,788,565	421,174	7,042
1982	181,903,317	0.993226	0.006662	0.000111	180,671,147	1,211,908	20,262
1983	167,491,015	0.993226	0.006662	0.000111	166,356,471	1,115,888	18,656
1984	138,667,144	0.993226	0.006662	0.000111	137,727,846	923,852	15,446
1985	337,057,913	0.993226	0.006662	0.000111	334,774,763	2,245,606	37,544
1986	174,900,603	0.993226	0.006662	0.000111	173,715,868	1,165,253	19,482
1987	124,925,828	0.993226	0.006662	0.000111	124,079,611	832,303	13,915
1988	234,426,104	0.993226	0.006662	0.000111	232,838,158	1,561,834	26,112
1989	255,723,607	0.993226	0.006662	0.000111	253,991,396	1,703,726	28,484
1990	224,847,744	0.993226	0.006662	0.000111	223,324,680	1,498,020	25,045
1991	303,643,495	0.993226	0.006662	0.000111	301,586,686	2,022,986	33,822
1992	199,910,400	0.993226	0.006662	0.000111	198,556,255	1,331,878	22,267
1993	236,222,622	0.993226	0.006662	0.000111	234,622,507	1,573,803	26,312
1994	265,744,725	0.993226	0.006662	0.000111	263,944,634	1,770,491	29,601
1995	304,938,573	0.993226	0.006662	0.000111	302,872,992	2,031,615	33,966
1996	176,520,436	0.993226	0.006662	0.000111	175,324,729	1,176,045	19,662
1997	236,327,284	0.993226	0.006662	0.000111	234,726,459	1,574,501	26,324
1998	164,661,089	0.993226	0.006662	0.000111	163,545,715	1,097,034	18,341
1999	174,299,249	1	0	0	174,299,249	0	0
2000	203,216,566	1	0	0	203,216,566	0	0
2001	102,090,800	1	0	0	102,090,800	0	0
2002	190,079,219	1	0	0	190,079,219	0	0

Table C4. Continued.

	Bycatch at age (lbs.)						
	Discard Atlantic croaker bycatch	Age proportions			bycatch at age		
Year	(lbs.)	Age0	Age1	Age2	Age0	Age1	Age2
1972	7,014,654	0.993226	0.006662	0.000111	6,967,139	46,734	781
1973	6,169,027	0.993226	0.006662	0.000111	6,127,240	41,100	687
1974	10,454,052	0.993226	0.006662	0.000111	10,383,238	69,649	1,164
1975	6,129,024	0.993226	0.006662	0.000111	6,087,507	40,834	683
1976	8,310,481	0.993226	0.006662	0.000111	8,254,188	55,368	926
1977	7,007,456	0.993226	0.006662	0.000111	6,959,989	46,686	781
1978	3,560,505	0.993226	0.006662	0.000111	3,536,387	23,721	397
1979	5,628,354	0.993226	0.006662	0.000111	5,590,229	37,498	627
1980	11,542,310	0.993226	0.006662	0.000111	11,464,125	76,899	1,286
1981	2,730,472	0.993226	0.006662	0.000111	2,711,976	18,191	304
1982	7,856,805	0.993226	0.006662	0.000111	7,803,584	52,345	875
1983	7,234,306	0.993226	0.006662	0.000111	7,185,302	48,198	806
1984	5,989,339	0.993226	0.006662	0.000111	5,948,769	39,903	667
1985	14,558,273	0.993226	0.006662	0.000111	14,459,659	96,993	1,622
1986	7,554,342	0.993226	0.006662	0.000111	7,503,171	50,330	841
1987	5,395,821	0.993226	0.006662	0.000111	5,359,271	35,949	601
1988	10,125,379	0.993226	0.006662	0.000111	10,056,792	67,459	1,128
1989	11,045,265	0.993226	0.006662	0.000111	10,970,447	73,588	1,230
1990	9,711,669	0.993226	0.006662	0.000111	9,645,884	64,703	1,082
1991	13,115,031	0.993226	0.006662	0.000111	13,026,193	87,377	1,461
1992	8,634,570	0.993226	0.006662	0.000111	8,576,082	57,527	962
1993	10,202,975	0.993226	0.006662	0.000111	10,133,862	67,976	1,136
1994	11,478,100	0.993226	0.006662	0.000111	11,400,350	76,471	1,279
1995	13,170,968	0.993226	0.006662	0.000111	13,081,751	87,750	1,467
1996	7,624,306	0.993226	0.006662	0.000111	7,572,661	50,796	849
1997	10,207,495	0.993226	0.006662	0.000111	10,138,352	68,006	1,137
1998	7,112,075	0.993226	0.006662	0.000111	7,063,899	47,383	792
1999	4,864,260	1.000000	0.000000	0.000000	4,864,260	0	0
2000	5,671,270	1.000000	0.000000	0.000000	5,671,270	0	0
2001	2,849,101	1.000000	0.000000	0.000000	2,849,101	0	0
2002	5,304,640	1.000000	0.000000	0.000000	5,304,640	0	0

Table C5. Estimates of annual Atlantic croaker bycatch by age group, by number and by weight, from the North Carolina shrimp trawl fishery. Estimates were calculated using the alternative by area approach.

	Inside							Ocean							Total		
		Age proportions			Bycatch at age (No.)				Age proportions			Bycatch at age (No.)			Bycatch at age (No.)		
Year	Discards Atlantic croaker bycatch (No.)	Age0	Age1	Age2	Age0	Age1	Age2	Discards Atlantic croaker bycatch (No.)	Age0	Age1	Age2	Age0	Age1	Age2	Age0	Age1	Age2
1972	71,462,820	0.9929	0.0069	0.0001	70,957,955	496,563	8,302	150,935,553	1	0	0	150,935,553	0	0	221,893,509	496,563	8,302
1973	62,516,383	0.9929	0.0069	0.0001	62,074,722	434,398	7,263	133,852,025	1	0	0	133,852,025	0	0	195,926,747	434,398	7,263
1974	132,178,181	0.9929	0.0069	0.0001	131,244,378	918,447	15,355	138,940,935	1	0	0	138,940,935	0	0	270,185,313	918,447	15,355
1975	63,418,827	0.9929	0.0069	0.0001	62,970,790	440,669	7,367	132,503,063	1	0	0	132,503,063	0	0	195,473,854	440,669	7,367
1976	98,653,124	0.9929	0.0069	0.0001	97,956,166	685,497	11,461	131,754,577	1	0	0	131,754,577	0	0	229,710,743	685,497	11,461
1977	97,732,955	0.9929	0.0069	0.0001	97,042,499	679,103	11,354	63,110,027	1	0	0	63,110,027	0	0	160,152,525	679,103	11,354
1978	34,807,226	0.9929	0.0069	0.0001	34,561,323	241,860	4,044	78,010,983	1	0	0	78,010,983	0	0	112,572,306	241,860	4,044
1979	60,746,138	0.9929	0.0069	0.0001	60,316,983	422,098	7,057	105,566,232	1	0	0	105,566,232	0	0	165,883,215	422,098	7,057
1980	156,835,729	0.9929	0.0069	0.0001	155,727,728	1,089,781	18,220	111,968,064	1	0	0	111,968,064	0	0	267,695,792	1,089,781	18,220
1981	32,417,022	0.9929	0.0069	0.0001	32,188,004	225,251	3,766	35,691,728	1	0	0	35,691,728	0	0	67,879,732	225,251	3,766
1982	92,414,685	0.9929	0.0069	0.0001	91,761,801	642,148	10,736	113,833,186	1	0	0	113,833,186	0	0	205,594,987	642,148	10,736
1983	84,158,463	0.9929	0.0069	0.0001	83,563,906	584,780	9,777	113,821,237	1	0	0	113,821,237	0	0	197,385,144	584,780	9,777
1984	63,670,429	0.9929	0.0069	0.0001	63,220,615	442,417	7,397	117,662,058	1	0	0	117,662,058	0	0	180,882,672	442,417	7,397
1985	212,059,697	0.9929	0.0069	0.0001	210,561,554	1,473,508	24,635	97,705,239	1	0	0	97,705,239	0	0	308,266,792	1,473,508	24,635
1986	99,582,492	0.9929	0.0069	0.0001	98,878,969	691,954	11,569	82,978,003	1	0	0	82,978,003	0	0	181,856,971	691,954	11,569

Table C5. Continued.

	Inside							Ocean							Total		
		Age proportions			Bycatch at age				Age proportions			Bycatch at age			Bycatch at age		
Year	Discards Atlantic croaker bycatch (No.)	Age0	Age1	Age2	Age0	Age1	Age2	Discards Atlantic croaker bycatch (No.)	Age0	Age1	Age2	Age0	Age1	Age2	Age0	Age1	Age2
1987	64,661,655	0.9929	0.0069	0.0001	64,204,838	449,305	7,512	83,096,082	1	0	0	83,096,082	0	0	147,300,921	449,305	7,512
1988	128,293,260	0.9929	0.0069	0.0001	127,386,903	891,453	14,904	130,303,031	1	0	0	130,303,031	0	0	257,689,934	891,453	14,904
1989	138,335,435	0.9929	0.0069	0.0001	137,358,133	961,231	16,071	148,005,655	1	0	0	148,005,655	0	0	285,363,788	961,231	16,071
1990	131,422,210	0.9929	0.0069	0.0001	130,493,748	913,194	15,268	98,657,973	1	0	0	98,657,973	0	0	229,151,721	913,194	15,268
1991	188,701,380	0.9929	0.0069	0.0001	187,368,257	1,311,202	21,922	95,764,420	1	0	0	95,764,420	0	0	283,132,676	1,311,202	21,922
1992	175,511,639	0.9929	0.0069	0.0001	174,271,697	1,219,552	20,390	4,812,087	1	0	0	4,812,087	0	0	179,083,785	1,219,552	20,390
1993	180,527,578	0.9929	0.0069	0.0001	179,252,201	1,254,406	20,972	8,764,045	1	0	0	8,764,045	0	0	188,016,245	1,254,406	20,972
1994	217,832,226	0.9929	0.0069	0.0001	216,293,301	1,513,619	25,306	8,513,760	1	0	0	8,513,760	0	0	224,807,061	1,513,619	25,306
1995	237,996,566	0.9929	0.0069	0.0001	236,315,186	1,653,732	27,648	11,330,091	1	0	0	11,330,091	0	0	247,645,277	1,653,732	27,648
1996	126,894,704	0.9929	0.0069	0.0001	125,998,228	881,735	14,742	0	1	0	0	0	0	0	125,998,228	881,735	14,742
1997	204,173,698	0.9929	0.0069	0.0001	202,731,267	1,418,712	23,719	0	1	0	0	0	0	0	202,731,267	1,418,712	23,719
1998	83,806,694	0.9929	0.0069	0.0001	83,214,623	582,335	9,736	11,822,446	1	0	0	11,822,446	0	0	95,037,069	582,335	9,736
1999	113,474,275	1.0000	0.0000	0.0000	113,474,275	0	0	668,471	1	0	0	668,471	0	0	114,142,745	0	0
2000	168,869,623	1.0000	0.0000	0.0000	168,869,623	0	0	193,976	1	0	0	193,976	0	0	169,063,599	0	0
2001	75,106,797	1.0000	0.0000	0.0000	75,106,797	0	0	102,593	1	0	0	102,593	0	0	75,209,390	0	0
2002	161,623,104	1.0000	0.0000	0.0000	161,623,104	0	0	84,113	1	0	0	84,113	0	0	161,707,217	0	0

Table C5. Continued.

	Inside							Ocean							Total		
		Age proportions			Bycatch at age				Age proportions			Bycatch at age			Bycatch at age		
Year	Discarded Atlantic croaker bycatch (lbs.)	Age0	Age1	Age2	Age0	Age1	Age2	Discarded Atlantic croaker bycatch (lbs.)	Age0	Age1	Age2	Age0	Age1	Age2	Age0	Age1	Age2
1972	3,108,975	0.9929	0.0069	0.0001	3,087,011	21,603	361	7,134,719	1	0	0	7,134,719	0	0	10,221,730	21,603	361
1973	2,719,762	0.9929	0.0069	0.0001	2,700,547	18,898	316	6,327,181	1	0	0	6,327,181	0	0	9,027,729	18,898	316
1974	5,750,383	0.9929	0.0069	0.0001	5,709,758	39,957	668	6,567,734	1	0	0	6,567,734	0	0	12,277,492	39,957	668
1975	2,759,022	0.9929	0.0069	0.0001	2,739,531	19,171	321	6,263,416	1	0	0	6,263,416	0	0	9,002,947	19,171	321
1976	4,291,883	0.9929	0.0069	0.0001	4,261,562	29,822	499	6,228,035	1	0	0	6,228,035	0	0	10,489,597	29,822	499
1977	4,251,851	0.9929	0.0069	0.0001	4,221,813	29,544	494	2,983,209	1	0	0	2,983,209	0	0	7,205,022	29,544	494
1978	1,514,281	0.9929	0.0069	0.0001	1,503,583	10,522	176	3,687,577	1	0	0	3,687,577	0	0	5,191,160	10,522	176
1979	2,642,748	0.9929	0.0069	0.0001	2,624,077	18,363	307	4,990,113	1	0	0	4,990,113	0	0	7,614,190	18,363	307
1980	6,823,105	0.9929	0.0069	0.0001	6,774,901	47,411	793	5,292,727	1	0	0	5,292,727	0	0	12,067,628	47,411	793
1981	1,410,296	0.9929	0.0069	0.0001	1,400,332	9,800	164	1,687,147	1	0	0	1,687,147	0	0	3,087,479	9,800	164
1982	4,020,481	0.9929	0.0069	0.0001	3,992,077	27,937	467	5,380,891	1	0	0	5,380,891	0	0	9,372,969	27,937	467
1983	3,661,296	0.9929	0.0069	0.0001	3,635,430	25,441	425	5,380,327	1	0	0	5,380,327	0	0	9,015,756	25,441	425
1984	2,769,968	0.9929	0.0069	0.0001	2,750,399	19,247	322	5,561,882	1	0	0	5,561,882	0	0	8,312,281	19,247	322
1985	9,225,611	0.9929	0.0069	0.0001	9,160,435	64,105	1,072	4,618,524	1	0	0	4,618,524	0	0	13,778,959	64,105	1,072
1986	4,332,315	0.9929	0.0069	0.0001	4,301,708	30,103	503	3,922,368	1	0	0	3,922,368	0	0	8,224,076	30,103	503
1987	2,813,091	0.9929	0.0069	0.0001	2,793,218	19,547	327	3,927,949	1	0	0	3,927,949	0	0	6,721,167	19,547	327
1988	5,581,371	0.9929	0.0069	0.0001	5,541,940	38,782	648	6,159,420	1	0	0	6,159,420	0	0	11,701,360	38,782	648
1989	6,018,253	0.9929	0.0069	0.0001	5,975,736	41,818	699	6,996,223	1	0	0	6,996,223	0	0	12,971,959	41,818	699
1990	5,717,495	0.9929	0.0069	0.0001	5,677,102	39,728	664	4,663,560	1	0	0	4,663,560	0	0	10,340,662	39,728	664
1991	8,209,413	0.9929	0.0069	0.0001	8,151,416	57,044	954	4,526,781	1	0	0	4,526,781	0	0	12,678,197	57,044	954
1992	7,635,596	0.9929	0.0069	0.0001	7,581,653	53,056	887	227,467	1	0	0	227,467	0	0	7,809,120	53,056	887
1993	7,853,813	0.9929	0.0069	0.0001	7,798,328	54,573	912	414,276	1	0	0	414,276	0	0	8,212,604	54,573	912
1994	9,476,744	0.9929	0.0069	0.0001	9,409,793	65,850	1,101	402,445	1	0	0	402,445	0	0	9,812,239	65,850	1,101
1995	10,353,989	0.9929	0.0069	0.0001	10,280,841	71,945	1,203	535,573	1	0	0	535,573	0	0	10,816,414	71,945	1,203
1996	5,520,527	0.9929	0.0069	0.0001	5,481,526	38,360	641	0	1	0	0	0	0	0	5,481,526	38,360	641

Table.C5. Continued.

	Inside							Ocean								Total		
	Age proportions				Bycatch at age			Age proportions				Bycatch at age				Bycatch at age		
Year	Discarded Atlantic croaker bycatch (lbs.)	Age0	Age1	Age2	Age0	Age1	Age2	Discarded Atlantic croaker bycatch (lbs.)	Age0	Age1	Age2	Age0	Age1	Age2		Age0	Age1	Age2
1997	8,882,533	0.9929	0.0069	0.0001	8,819,780	61,721	1,032	0	1	0	0	0	0	0		8,819,780	61,721	1,032
1998	3,645,992	0.9929	0.0069	0.0001	3,620,234	25,334	424	558,847	1	0	0	558,847	0	0		4,179,081	25,334	424
1999	3,166,786	1.0000	0.0000	0.0000	3,166,786	0	0	700,069	1	0	0	700,069	0	0		3,866,855	0	0
2000	4,712,732	1.0000	0.0000	0.0000	4,712,732	0	0	397,121	1	0	0	397,121	0	0		5,109,853	0	0
2001	2,096,044	1.0000	0.0000	0.0000	2,096,044	0	0	312,629	1	0	0	312,629	0	0		2,408,673	0	0
2002	4,510,500	1.0000	0.0000	0.0000	4,510,500	0	0	340,426	1	0	0	340,426	0	0		4,850,926	0	0

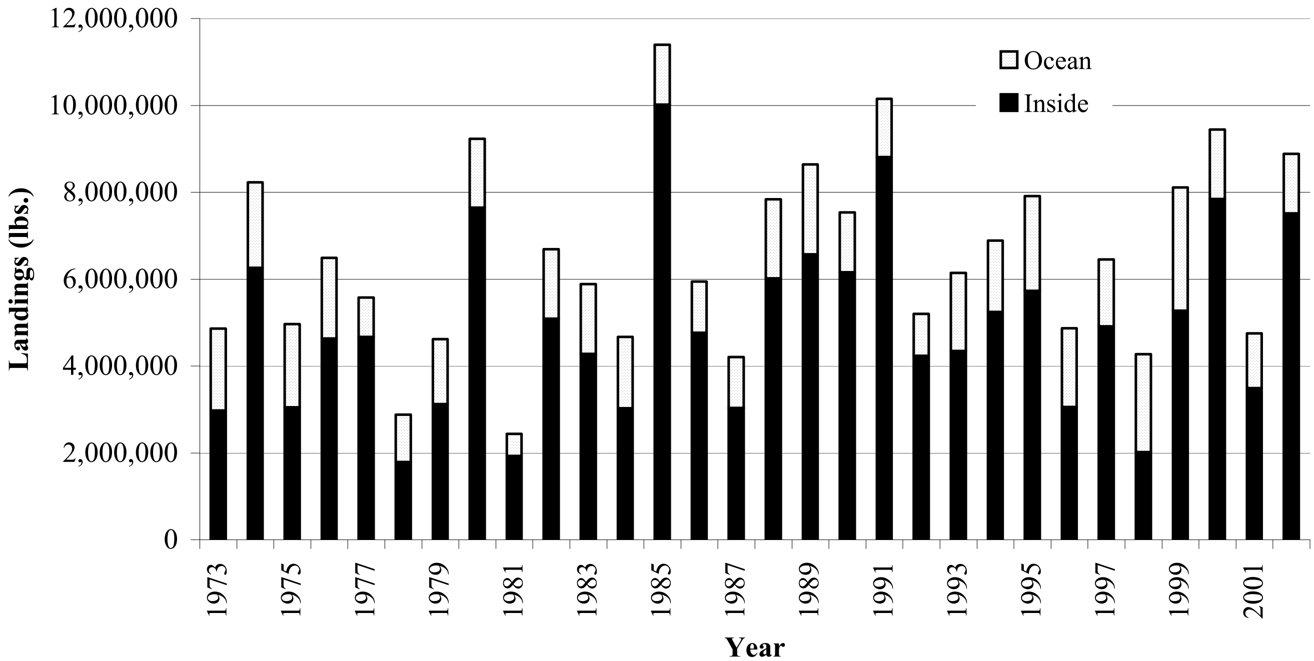


Figure C1. Annual landings of Penaeid shrimp from North Carolina shrimp trawl fishery by general area, 1973-2002.

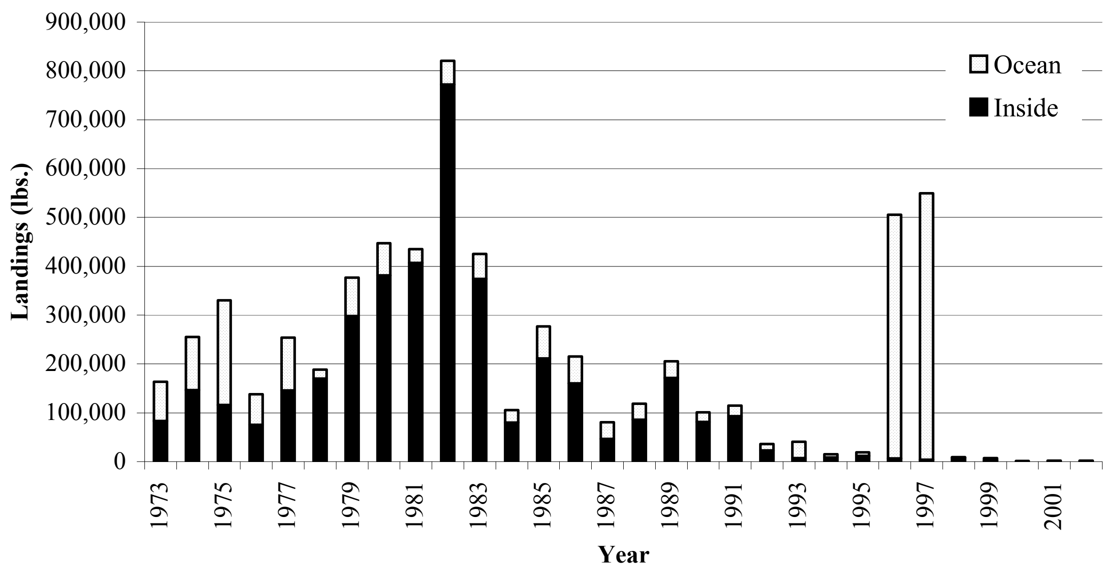
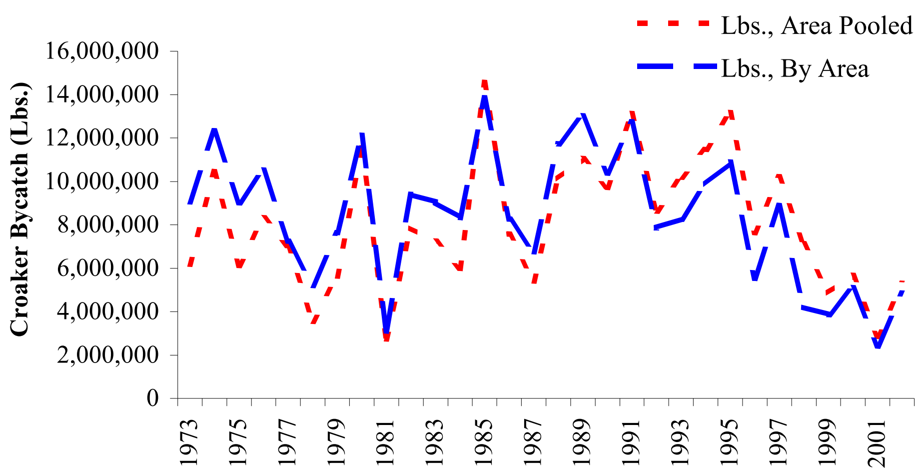


Figure C2. Annual landings of Atlantic croaker from North Carolina shrimp trawl fishery by general area, 1973-2002. Landings in 1996 and 1997 reflect a brief change in fishing behavior that was modified by regulation.

a.



b.

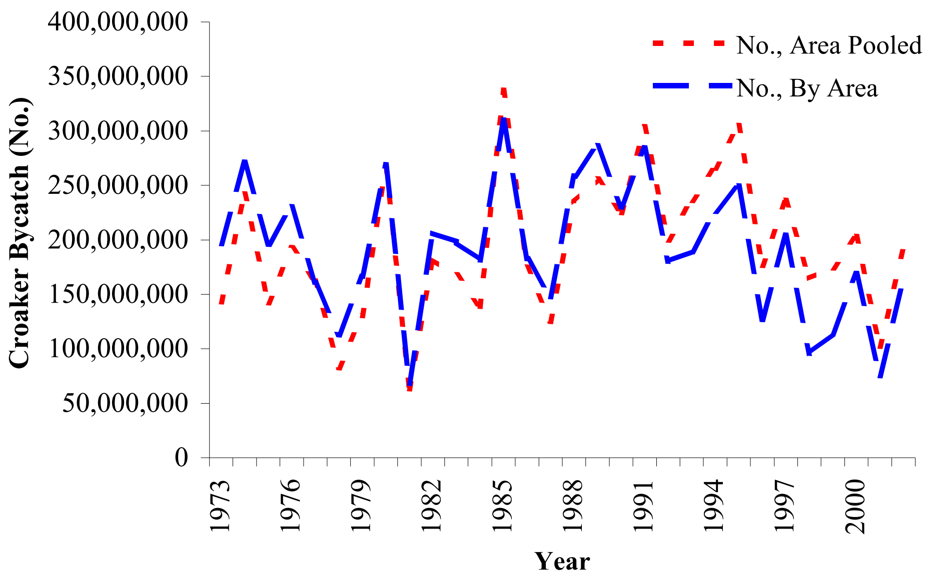


Figure C3. Annual discarded Atlantic croaker bycatch from the North Carolina shrimp trawl fishery, 1973-2002. Bycatch in weight (a) and number (b) are plotted for both the area pooled and alternative by area approaches.

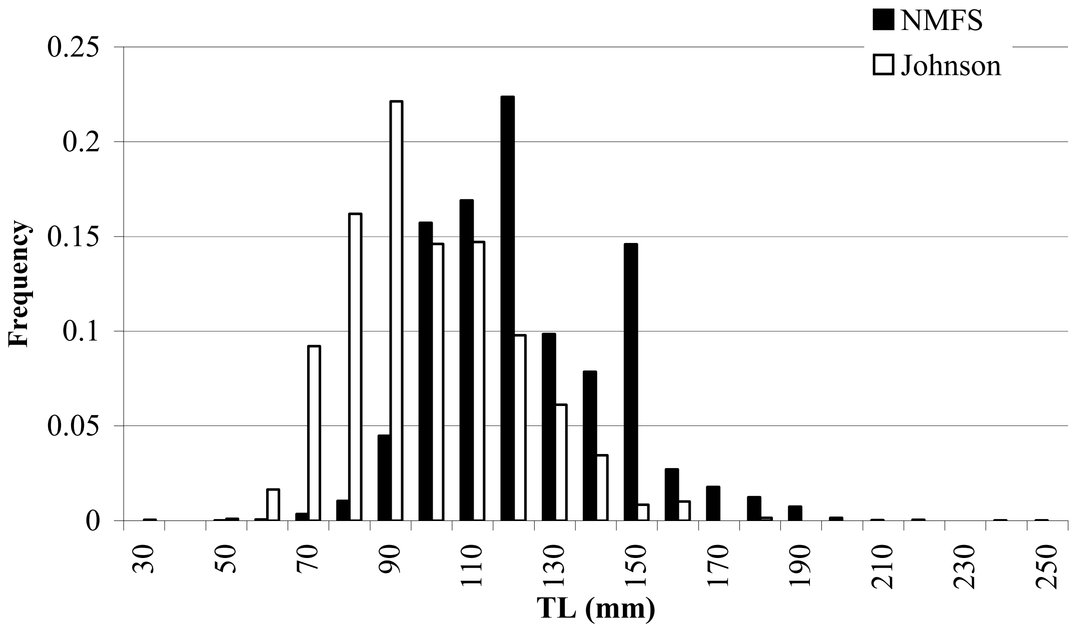


Figure C4. Weighted length frequencies for NMFS and Johnson datasets by 10mm size intervals.

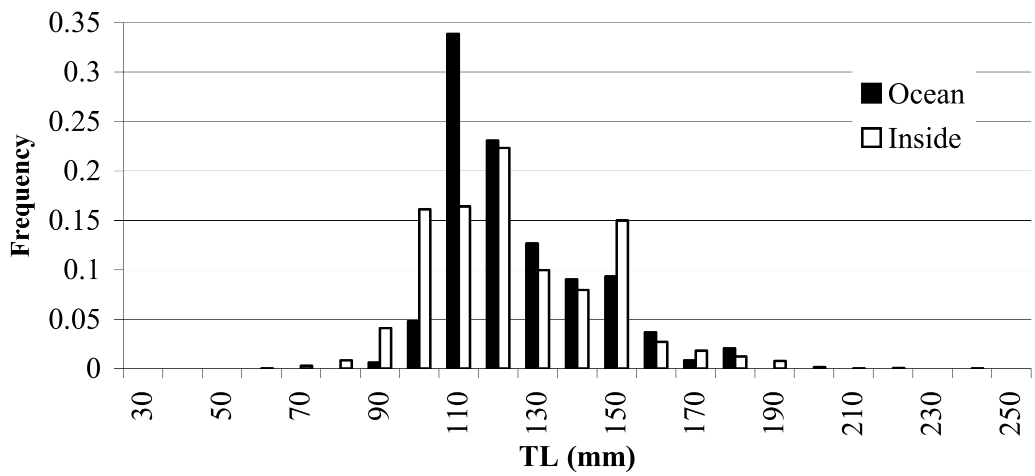


Figure C5. Weighted length frequencies for NMFS Ocean and Inside waters considered separately, by 10mm size intervals.

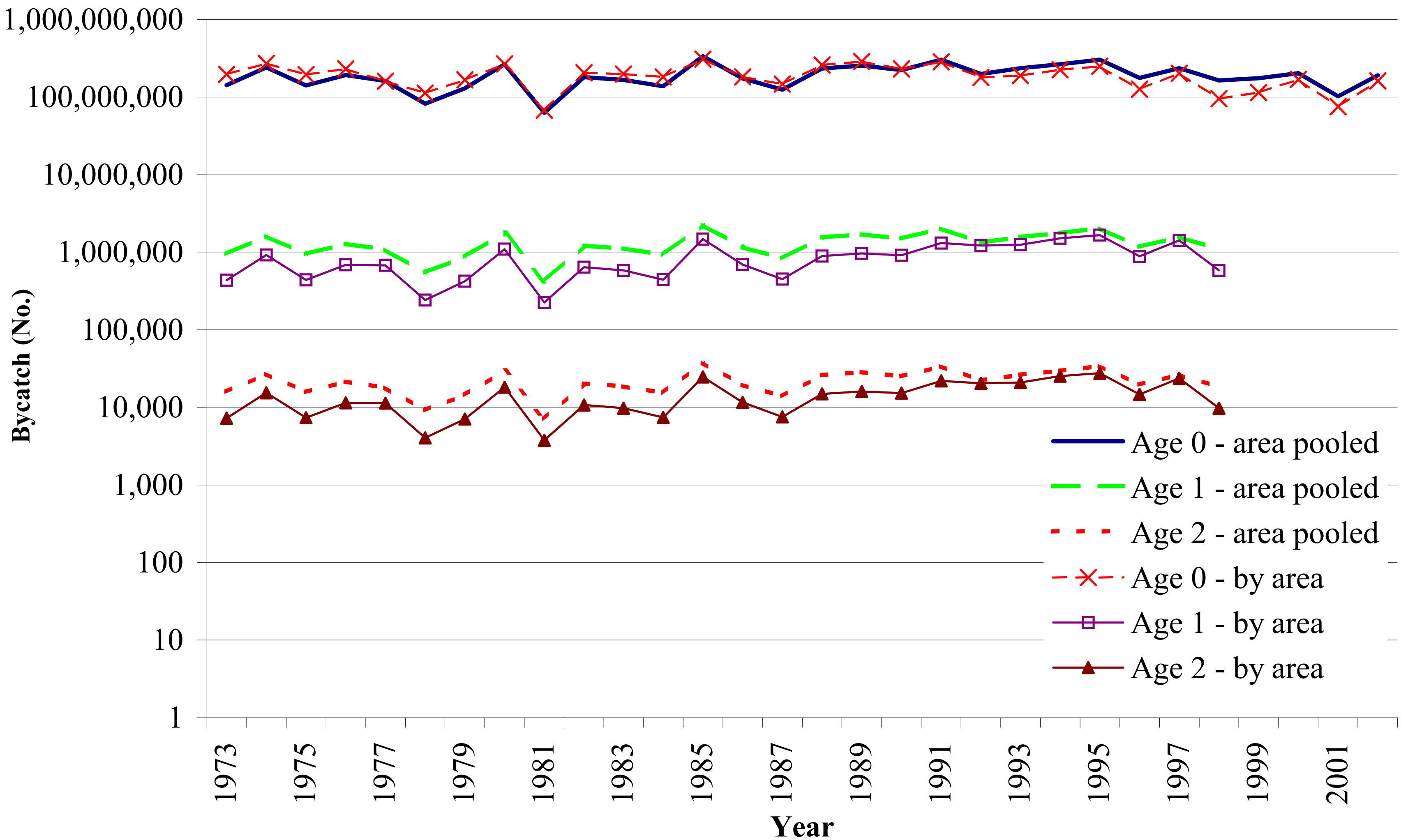


Figure C6. Atlantic croaker bycatch-at-age (No.) in the North Carolina shrimp trawl fishery, 1973-2002. Estimates are plotted for the area pooled and alternative by area approaches. Bycatch is plotted on log scale.

APPENDIX D: An Evaluation of the NEFSC observer data to estimate Atlantic croaker discards

"The Northeast Domestic Fisheries Observer Program collects, maintains and distributes data for scientific and management purposes in the northwest Atlantic Ocean (NEFSC Web Site). Since implementation in 1989, the Program has deployed an average of 35 observers a year in various commercial fisheries" (NEFSC Web Site). The Northeast Fisheries Science Center (NEFSC) observer data set contains information on Atlantic croaker discards from 1989 to 2002. This report provides a summary the available data and its potential use in estimating Atlantic croaker discards.

Summary of the Data Set

Between 1989 and 2002, a total of 1,267 observer-sampling trips caught or discarded Atlantic croaker. However, for 960 trips, discard records were not kept (G. Reppucci, NMFS NEFSC) and the data set was reduced to observations made on 306 trips. The majority of those sea days for the discarded trips were funded through Protected Species monies and data collection protocols required the observer to watch for mammal/turtle takes to ensure they don't miss 'fall outs' leading to incomplete discard data (G. Reppucci, NMFS NEFSC). Gill nets and fish otter trawls accounted for the majority of sampled trips (306 of 307 trips) and this analysis only evaluates these two gears.

For most years and both gears, discards were observed on less than 25 trips/year; gill nets accounted for 234 trips and fish otter trawls 72 trips over the entire time series (Table D1). The majority of observer sampling was carried out on vessels that landed their catch in Virginia and North Carolina (Table D2). In terms of target species, the majority of gill net trips targeted Atlantic croaker, with weakfish and spot being species of secondary species (Table D3). In general, kept landings of Atlantic croaker, weakfish and spot were likely to co-occur on the same trip. For otter trawls, the majority of sampled trips landed their catch in Maryland (Table D2) and targeted summer flounder (Table D3). Given the co-occurrence of the major target species and to avoid the possibility of "double counting" if estimates were based on species-specific targets, we developed discard estimates based on the landings of Atlantic croaker by gear type.

A comparison of the Atlantic croaker discarded to those kept by trip revealed weak relationships for the untransformed and transformed variables for both gears (Table D4). Linear regression on the log transformed variables revealed that the linear relationship between log (discards) and log (Landings) had R^2 values of 0.12 and 0.03 for gillnets and otter trawls respectively (Figures D1 and D2). Linear regressions on discards to landings were also weak, with R^2 values of 0.04 and 0.18 for gill nets and otter trawls respectively. Discard estimators were developed using a ratio approach and trip based approach. The ratio-based approach consisted of:

1) Developing discard ratios by gear type using all years of data. In addition, ratio estimators, by gear type and year were also estimated.

Discard ratios were estimated using Proc Survey means in SAS®, which uses the Taylor series expansion method to estimate the variance of the ratio estimator.

2) A regression approach where discards were estimated as a function of landings was also developed for each gear. Given the small sample size by year, regression estimators by year and gear were not developed. The linear regression estimators were based on log transformed discards and landings.

Trip based estimators were developed using two approaches:

1) Estimating the mean discards/trip and their variance by gear type and year, and by gear type across all years.
2) Developing a general linear model (GLM) to estimate the mean discards per trip. Mean discards per trip and their standard error by year were estimated using the least squares mean approach in SAS. The response variable was log discards and the explanatory variables were year, target species and number of hauls.

Estimates of total Atlantic croaker discards and their variance were determined for the gill net fishery and otter trawl fishery using a Monte-Carlo approach using the estimators discussed earlier. For the ratio-based estimators, annual estimates were based on the mean of 1,000 runs derived from the annual landings * an estimate based on a random value generated from the mean and standard error of the estimator (Table D5 and D6).

In order to develop a trip-based estimate, the annual number of trips by gear type was obtained from the Virginia and North Carolina trip ticket databases. For North Carolina, the annual number of gill nets and otter trawl trips were available from 1994-2002. For Virginia, only the numbers of gill net trips between 1993 and 2002 were available. As such, trip based estimates could only be developed for periods where trip data existed. Annual estimates of discards by state, gear and year were based on a Monte-Carlo approach where the mean of 1,000 runs were derived from the annual number of trips * a discard estimate based on a random value generated from the mean and standard error of the estimator (Table D7-D8).

Initial Observations

1) For the ratio-based method, the regression approach based on the log-log transformation produce very low estimates. While not presented here, we first looked at a regression model where the response variable log (discards+1) and the explanatory variable were landings. This was a poor model. The 1,000 Monte-Carlo runs produced estimates ranging from infinity to zero.
2) For the trip-based approach, we do not have effort information for the otter trawl-fishery for Virginia and it also assumes that the discard ratios observed in the coastal waters of the Atlantic ocean are applicable to the inshore gill net trips for Virginia. At best, trip based estimates can be estimated for the period 1993-2002, for all other periods an alternate approach would need to be used.

3) A ratio-based method would use a consistent methodology to estimates the entire time series, but the correlation between landings and discards is weak at best.
4) Estimates based on yearly samples by gear are poor, since the average number of trips sampled per year is low (< 25 trips).

Table D1. Summary of Atlantic croaker discard trips and associated hauls sampled in the NEFSC observer database for gill nets and otter trawls. Discards and landings in pounds.

Gear	Year	Croaker Kept	Croaker Discarded	Hauls	Trips
Gill net	1993	2,701	95	56	8
Gill net	1994	53,730	824	162	28
Gill net	1995	71,915	403	211	24
Gill net	1996	121,313	1,012	248	28
Gill net	1997	111,052	318	167	20
Gill net	1998	91,871	77	207	36
Gill net	1999	14,557	55	82	20
Gill net	2000	50,520	205	156	30
Gill net	2001	41,436	667	115	22
Gill net	2002	23,958	24	92	18
Gill net	Total	583,053	3,680	1496	234
Other	1995	0	31	9	1
Other	Total	0	31	9	1
Trawl	1989	416	353	45	5
Trawl	1990	5	20	3	2
Trawl	1991	15	123	6	3
Trawl	1992	25	1,418	14	2
Trawl	1993	62	1,231	28	6
Trawl	1994	53,809	2,775	38	6
Trawl	1995	21,382	5,081	86	11
Trawl	1996	62,345	838	28	6
Trawl	1997	76,562	541	24	2
Trawl	1998	46,718	5,106	25	2
Trawl	1999	20,551	483	30	8
Trawl	2000	9,483	8	8	6
Trawl	2001	31,059	1,425	30	6
Trawl	2002	299	94	24	7
Trawl	Total	322,731	19,496	389	72
Grand Total		905,784	23,206	1894	307

Table D2. Sampling trips of Atlantic croaker discards by location of state of landing.

Year	MA	MD	NC	NJ	NY	VA	Grand Total
1989	0	4	0	1	0	0	5
1990	0	2	0	0	0	0	2
1991	0	2	0	0	0	1	3
1992	0	2	0	0	0	0	2
1993	0	6	2	0	0	6	14
1994	0	3	21	1	1	8	34
1995	1	5	11	5	1	13	36
1996	0	2	13	4	0	15	34
1997	0	0	7	1	0	14	22
1998	0	0	19	1	0	18	38
1999	0	0	12	1	1	14	28
2000	0	0	12	5	1	18	36
2001	0	3	9	4	0	12	28
2002	0	3	3	5	0	14	25
Grand Total	1	32	109	28	4	133	307

Table D3. Summary of sampling trips by target species is the species identified by fisher as his/her primary target on trip.

	Gill net		Trawl		Total	
Species	Hauls	Trips	Hauls	Trips	Hauls	Trips
ALL COMBINED	2	1	0	0	2	1
BASS, STRIPED	27	7	0	0	27	7
BLUEFISH	24	6	0	0	24	6
BUTTERFISH	6	1	0	0	6	1
CRAB, HORSESHOE	0	0	31	4	31	4
CRAB,NK	0	0	7	1	7	1
CROAKER, ATLANTIC	763	98	74	11	837	109
DOGFISH, SPINY	46	8	0	0	46	8
DOGFISH,NK	2	1	0	0	2	1
FINFISH,NK	21	4	11	4	32	8
FLOUNDER, NK	2	1	0	0	2	1
FLOUNDER, SUMMER (FLUKE)	0	0	38	10	38	10
FLOUNDER,MIXED	0	0	6	1	6	1
FLOUNDER,SUMMER/FLUKE	0	0	185	33	185	33
GROUNDFISH,MIXED	7	1	1	1	8	2
KINGFISH, NK	9	3	0	0	9	3
MACKEREL, SPANISH	46	11	0	0	46	11
MENHADEN, ATLANTIC	7	1	0	0	7	1
MENHADEN/POGY	13	3	0	0	13	3
OTHER	14	3	8	1	22	4
SHARK,NK	4	1	0	0	4	1
SOUTHERN FLOUNDER	2	2	0	0	2	2
SPOT	178	23	0	0	178	23
WEAKFISH (SQUETEAGUE SEA TROUT)	23	6	0	0	23	6
WEAKFISH/BLUEFISH	9	2	0	0	9	2
WEAKFISH/CROAKER	31	5	20	1	51	6
WEAKFISH/GRAY SEA TROUT	260	46	8	5	268	51
Grand Total	1496	234	389	72	1885	306

Table D4. Correlation between Atlantic croaker discards and landings from the NEFSC Observer database.

Gill net

	Landings	Discards	Log (Discards+1)	Log(Landings+1)
Landings	1			
Discards	0.201066	1		
Log (Discards+1)	0.373964	0.616753	1	
Log(Landings+1)	0.696137	0.205805	0.347876	1

Otter Trawl

	Landings	Discards	Log (Discards+1)	Log(Landings+1)
Landings	1			
Discards	0.424636	1		
Log (Discards+1)	0.246803	0.622602	1	
Log(Landings+1)	0.654923	0.364162	0.185773	1

Table D5. Discard estimates of Atlantic croaker from the gill net fishery. Estimates in pounds. ratio_allyr= ratio estimator based on all years combined. reg_allyr= estimator based on log-log regression model. ratio_indyr=ratio estimator based on individual year.

	Gill net	Total Discards			Std Err		
Year	landings	ratio_allyr	reg_allyr	ratio_indyr	ratio_allyr	reg_allyr	ratio_indyr
1972	243,200	1,536	12		13	0	
1973	619,300	3,848	14		31	0	
1974	499,800	3,139	14		25	0	
1975	802,700	5,039	16		42	0	
1976	1,685,600	10,660	18		85	0	
1977	2,934,600	18,419	20		144	0	
1978	2,496,590	15,684	20		125	1	
1979	2,363,480	15,010	20		122	1	
1980	3,892,493	24,609	22		196	1	
1981	1,369,646	8,622	18		71	0	
1982	1,268,144	8,053	18		64	0	
1983	924,657	5,881	17		48	0	
1984	2,613,152	16,572	20		133	1	
1985	2,821,276	17,816	20		144	0	
1986	3,821,447	23,761	21		194	1	
1987	3,037,713	19,072	20		153	0	
1988	3,239,778	20,297	21		168	1	
1989	1,784,728	11,204	18		90	0	
1990	977,347	6,142	16		51	0	
1991	975,819	6,213	17		50	0	
1992	1,758,254	11,076	19		91	0	
1993	3,816,993	23,645	20	130,650	191	0	1,540
1994	4,672,895	29,472	23	71,643	243	1	623
1995	4,917,110	31,561	24	28,344	254	1	390
1996	8,130,019	51,373	26	68,041	410	1	1,308
1997	8,056,062	50,171	25	22,540	428	1	331
1998	10,713,447	67,935	28	8,980	557	1	103
1999	7,837,131	49,919	27	30,482	413	1	790
2000	10,610,535	66,685	27	42,967	539	1	330
2001	11,236,025	70,130	26	173,953	551	1	4,876
2002	9,548,509	60,894	27	9,718	487	1	272

Table D6. Discard estimates of Atlantic croaker from the otter trawl fishery. Estimates in pounds. ratio_allyr= ratio estimator based on all years combined. reg_allyr= estimator based on log-log regression model. ratio_indyr=ratio estimator based on individual year.

	Trawl	Total Discards			Std Err		
Year	Landings	ratio_allyr	reg_allyr	ratio_indyr	ratio_allyr	reg_allyr	ratio_indyr
1972	3,225,400	197,458	322		2,395	37	
1973	1,661,100	100,378	243		1,255	25	
1974	2,522,900	151,248	261		1,898	26	
1975	5,966,800	358,442	382		4,483	43	
1976	10,872,000	655,587	376		7,941	34	
1977	12,519,500	745,146	431		9,369	70	
1978	12,948,089	787,861	506		9,431	96	
1979	8,483,004	515,441	393		6,277	48	
1980	5,615,381	333,831	269		3,945	27	
1981	2,021,126	121,998	242		1,505	20	
1982	1,859,491	114,232	279		1,338	40	
1983	831,819	49,789	169		591	12	
1984	2,439,191	145,237	235		1,774	21	
1985	2,384,824	140,685	223		1,708	20	
1986	2,500,141	151,267	275		1,808	29	
1987	2,121,088	125,756	233		1,604	20	
1988	2,017,540	125,205	277		1,464	25	
1989	1,638,547	98,918	220	1,389,308	1,196	17	20,700
1990	343,752	20,943	159	1,411,653	258	11	53,320
1991	339,505	20,454	134	2,775,374	245	8	38,663
1992	828,181	49,346	217	46,656,967	641	22	298,145
1993	2,215,984	134,804	306	44,260,991	1,695	33	473,521
1994	3,225,941	195,164	304	166,356	2,417	36	166
1995	4,305,209	261,321	349	1,035,900	3,135	48	32,214
1996	5,781,415	350,658	378	78,779	4,335	49	3,277
1997	10,231,066	618,572	351	72,321	7,409	36	369
1998	6,809,853	412,814	419	745,530	5,332	46	4,625
1999	9,562,721	584,455	426	232,899	7,182	48	8,521
2000	8,913,884	538,543	377	7,523	6,753	37	311
2001	8,615,978	521,200	379	397,002	6,357	45	14,843
2002	7,990,650	479,083	329	2,470,228	5,894	28	68,263

Table D7. Estimated Atlantic croaker discards in the gill net fishery using trip based estimators. trip_lsm_va= discard estimates for Virginia using the annual least squares estimates. trip_lsm_nc = discard estimates for North Carolina using the annual least squares estimates. trip_ind_va= discard estimates for Virginia based on the average annual discard weight per trip. trip_ind_nc= discard estimates for North Carolina based on the average annual discard weight per trip. trip_all_va= discard estimates for Virginia based on the average discards per trip based across all years sampled. trip_all_nc= discard estimates for North Carolina based on the average discards per trip based across all years sampled. All estimates are in pounds.

		Discard Estimates (Trip based in Pounds)						Standard Error					
Year	Gill net Landings	trip_lsm_va	trip_lsm_nc	trip_ind_va	trip_ind_nc	trip_all_va	trip_all_nc	trip_lsm_va	trip_lsm_nc	trip_ind_va	trip_ind_nc	trip_all_va	trip_all_nc
1993	3,816,993	63,937		110,431		147,666		971		1,359		1,191	
1994	4,672,895	104,765	107,400	313,262	321,143	167,409	171,621	883	905	4,503	4,617	1,381	1,416
1995	4,917,110	39,047	57,025	172,312	251,647	159,788	233,357	348	508	2,253	3,291	1,288	1,880
1996	8,130,019	27,356	41,013	312,144	467,981	135,545	203,216	224	336	5,881	8,817	1,083	1,624
1997	8,056,062	39,950	41,635	190,967	199,021	190,211	198,233	395	412	2,458	2,562	1,624	1,693
1998	10,713,447	22,169	18,083	24,491	19,977	180,973	147,619	162	132	264	215	1,483	1,210
1999	7,837,131	19,437	23,311	26,166	31,382	146,727	175,978	196	235	673	807	1,215	1,457
2000	10,610,535	32,437	30,346	74,135	69,355	170,503	159,510	254	238	787	736	1,380	1,291
2001	11,236,025	26,911	31,439	270,533	316,046	144,025	168,255	237	277	7,223	8,438	1,133	1,324
2002	9,548,509	15,538	11,537	13,985	10,384	164,832	122,388	159	118	342	254	1,318	979

Table D8. Estimated Atlantic croaker discards in the otter trawl fishery using trip based estimators. trip_lsm_va= discard estimates for Virginia using the annual least squares estimates. trip_lsm_nc = discard estimates for North Carolina using the annual least squares estimates. trip_ind_va= discard estimates for Virginia based on the average annual discard weight per trip. trip_ind_nc= discard estimates for North Carolina based on the average annual discard weight per trip. trip_all_va= discard estimates for Virginia based on the average discards per trip based across all years sampled. trip_all_nc= discard estimates for North Carolina based on the average discards per trip based across all years sampled. All estimates are in pounds.

		Discard Estimates (Trip Based in Pounds)						Standard Error					
Year	Landings	trip_lsm_va	trip_lsm_nc	trip_ind_va	trip_ind_nc	trip_all_va	trip_all_nc	trip_lsm_va	trip_lsm_nc	trip_ind_va	trip_ind_nc	trip_all_va	trip_all_nc
1994	3,225,941		12,684		104,901		61,283		552		3,274		732
1995	4,305,209		5,920		112,019		65,287		170		2,917		756
1996	5,781,415		6,016		40,062		77,200		237		1,215		921
1997	10,231,066		17,393		108,172		108,128		1,659		3,364		1,250
1998	6,809,853		170,390		1,507,144		158,938		16,986		50,317		1,981
1999	9,562,721		24,463		24,300		108,168		994		467		1,283
2000	8,913,884		4,342		405		82,325		195		9		996
2001	8,615,978		2,368		61,915		70,495		91		1,446		830
2002	7,990,650		1,303		3,065		61,827		50		38		734

Figure D1. Linear relationship between the log transformed discards and log transformed landings for gill net samples.

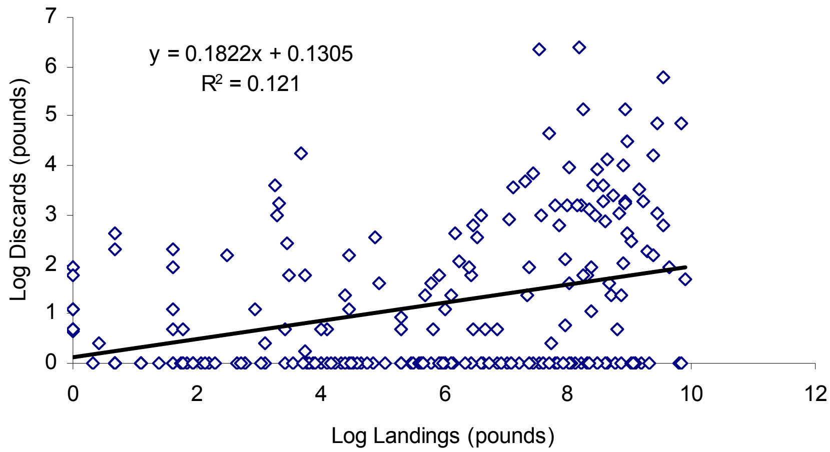


Figure D2. Linear relationship between the log transformed discards and log transformed landings for otter trawls samples.

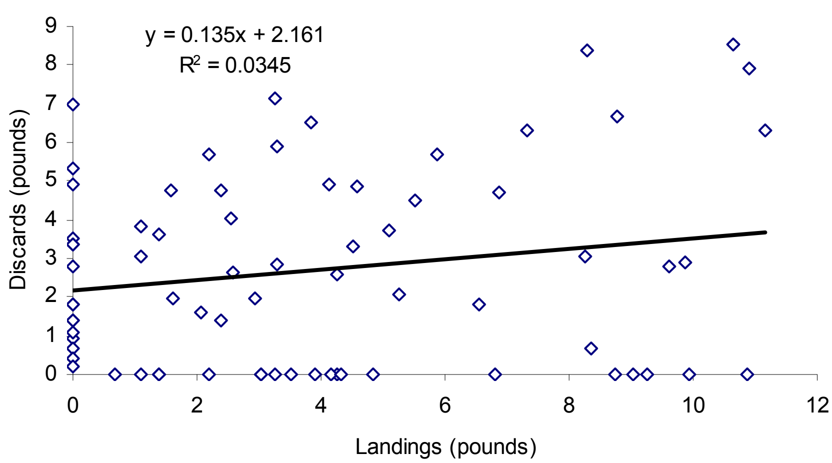


Figure D3. Linear relationship between the discards and landings for gill net samples.

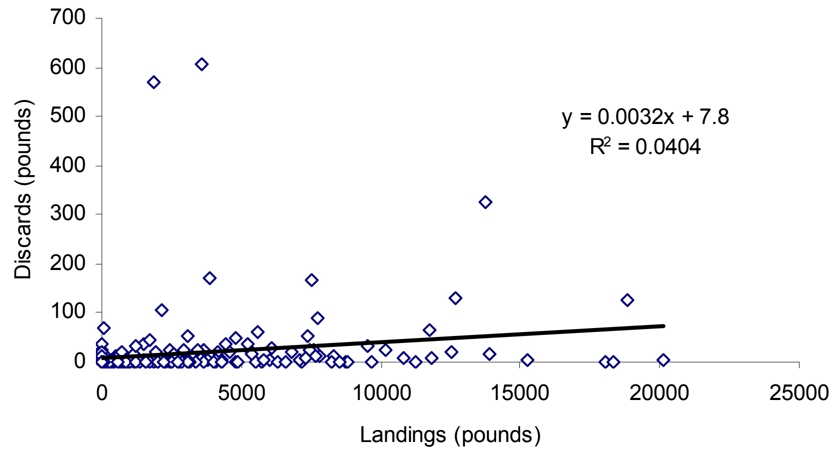
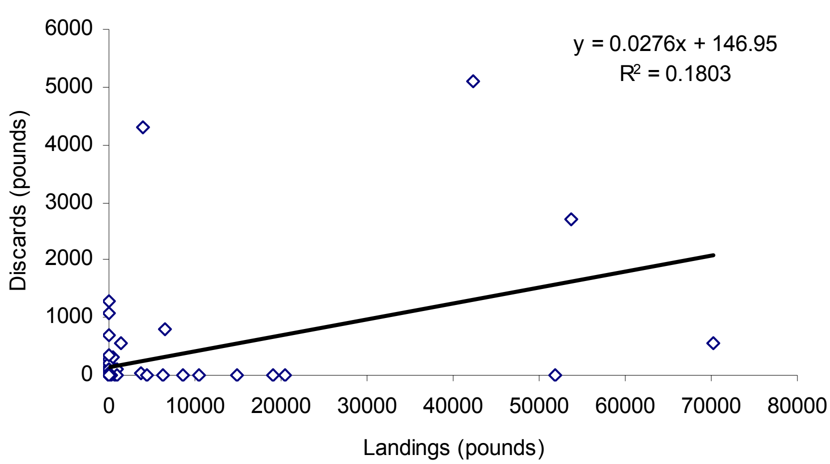


Figure D4. Linear relationship between the discards and landings for otter trawls samples



APPENDIX E: Using the NMFS-Woods Hole Fall Groundfish Survey off the East Coast of the United States: 1972-2002 to develop indices of abundance for Atlantic croaker

The Woods Hole laboratory of the National Marine Fisheries Service has been conducting stratified random surveys of fishes from Long Island to Cape Hatteras since 1982. The division of the region into a series of depth zones (0 – 9 m; 9 – 18 m; 18 – 27 m; 27 – 55 m; 55 – 110 m; 110 – 188 m; 188 – 366 m) provides the framework for the erection of strata based on latitude and depth. The area within each stratum is subdivided into one-nautical mile blocks that are selected randomly prior to the sampling trip (see Azarovitz, 1994 for a review of the survey; see also Grosslein, 1969).

At each randomly selected station, a trawl tow was made according to a standardized format. A #36-Yankee otter trawl rigged with rollers, 5 fathom legs and 1000 pound polyvalent door was fished for 30-minutes. The cod end and upper belly were lined with 0.5-inch mesh to retain young-of-year fish. The data recorded at each station (excluding the catch itself) are in Table E1.

Table E1. Data recorded at each station during a groundfish survey cruise.

Variable	Columns	Definition
Cruise code	1-4	First two digits are the year; second two digits sequentially assigned to indicate the order in which the cruise were coded
Station	5-8	Sequential station number
Stratum	9-13	Strata identification numbers
Tow number	14-16	Number of tow within a given stratum
Station value	17	Station type – [1] survey haul; [2] non-random haul; [3] special random add-on station haul [4] comparison haul; [5] no trawl – other gear; [6] site=specific; [7] systematic grid; [8] depletion site; [9] systematic parallel tracts; [0] systematic zigzag transects.
	18	Relative success of haul [1] good tow – no gear or tow duration problems; [2] representative but with some problems due to gear or tow time; [3] problem tow – may or may not be representative due to gear or tow time; [4] not representative due to gear or time; [5] no trawl tow – other gear used
	19	Gear condition – [1] no damage to insignificant damage; [2] twisted wing small tears in belly; [3] hang with no to minor damage; [4] parted legs, sweep or headrope; [5] tear-up. But not total; [6] obstruction in net; [7] crossed doors; [8] open gear; [9] hang with major damage
Statistical area	20-22	International statistical area where tow made
Vessel	23-24	AL = Albatross IV; AT = Atlantic Twin; DE = Delaware II
Cruise	25-26	Assigned vessel cruise number
Time	27	[1] = Eastern standard time; [2] = eastern daylight savings time
Yr-mo-day	28-33	First two = year; second two = month; last two = day
Gear code	34-35	Type of gear used (numerous code values)
Time	36-39	Local time with 24-hour clock
Minutes out	40-42	Actual time for gear out to with tenths of minutes
Depth start/end	43-50	First four digits = start depth; last four digits = end depth
Min/max	51-58	First four digits = minimum depth; second four digits = maximum depth

Table E1. Continued.

Variable	Columns	Definition
Lat/long	59-66	Replace by GPS reading in 1999; prior to that, first four digits = beginning latitude last four digits beginning longitude; both rounded to whole minutes
Loran	67-98	Loran readings
Cable	99-102	Cable in water measured in meters at the water's surface
Pitch	103-105	Pitch of prop if applicable
Heading	106-108	Vessel's heading in degrees
Course	109-111	Actual course the vessel made good in degrees
Rpm	112-114	Average shaft rpm under tow
Doppler bottom	115-117	Speed over bottom
Doppler water	118-120	Used on special occasions
Des speed	121-122	Designated towing speed for a particular gear to 0.1 knots
Gear id	123-124	Gear id number (each net has it's own number)
Door id	125-126	Door id number
Head-rope height	127-129	Not used leave blank
Other gear	130-131	Code for other gear (hydro, plankton, etc)
Air temp	134-136	Air temp to nearest whole degree
Cloud cover	137-138	Code for cloud cover
Insol	139-142	Not used – blank
Bar	143-146	Barometric pressure to nearest millibar
Wind dir & speed	147-151	Wind direction in degrees; wind velocity in knots
Weather	152-153	Weather codes
Wave height	154-155	Height of waves to nearest tenth of meter
Swell direction & hgt	156-160	First three digits swell direction in degrees, second two digits = swell height in tenths of meters
Surf temp	161-163	Surface temp in tenths of degrees C
Surf salinity	164-167	Salinity parts per 1000
Wingspread	168-171	Not used – blank
Sal depth	172-175	Not used leave blank
Xbt	176	Type of temperature profiler used
Surf & bot temp	177-182	First three digits = surface degrees c to tenths; second three digits = bottom from xbt or ctd
Coded species	183-184	Number of species caught and coded at station
Trash	185-188	Amount of trash in liters
Fullness of dredge	189-191	Mot used leave blank
Sed type	192-194	Not used leave blank
Trash by %	195-203	Not used leave blank
Ave depth	203-207	Average depth in meters between start and end of tow
Calc speed	208-210	Calculated speed of tow derived from navigational instruments
Surf sal	214-218	Surface salinity (0.001)
Bot sal	219-223	Bottom salinity (0.001)
Total weight	224-229	Total weight of species to 0.1 kg
Total number	230-235	Total number of animals at station

Trawl surveys are used to generate abundance estimates, distributional patterns, hydrographic data and specimens for life history studies do not have the experimental rigidity of laboratory studies. For example, severe weather, mechanical problems with the vessel, and at sea illnesses are just a few of the difficulties that are encountered during a cruise. There are a considerable number of strata in the Mid-Atlantic area surveyed over the past 20+ years. Periods of equipment failure as well as poor weather resulted in some strata not being sampled with the same intensity through time. Indeed, in the early years, the cruise only sampled a single station in the shallowest depth stratum. Other depth zones on other occasions had a limited number of tows so that the within stratum variance either could not be calculated or was based on a few observations.

The problems of insufficient sampling intensity within various strata are not new. When summarizing the Marine Resources Monitoring Assessment and Prediction (MARMAP) trawl survey data for the South Atlantic Bight (Cape Hatteras, NC to Cape Canaveral, FL), examination of the distribution of the tows within a stratum during a particular survey indicated that it was unrealistic to calculate stratum means and variances with existing sample sizes. After considering alternatives, it was decided that the strata could be collapsed within a depth zone. This resulted in a reasonable number of tows available for estimates of the mean catch per standard tow and its variance within a depth zone. Since the areas of each stratum was known, a stratified mean catch per tow with its associated standard error could be calculated for the number and weight of the catch (see Wenner et al. 1979).

In addition to within stratum sample size, additional problems are frequently encountered in trawl survey data. What constitutes an acceptable tow? When should a tow be eliminated from the data set because of problems? The NMFS groundfish survey of the eastern Atlantic coast has established a series of coded observations that include the time a net is towed at a station in comparison to the standard tow time of 30-minutes, and the condition of the trawl net at the end of the haul (see Table E1). This is recorded as the variable "SHG" in the data set. The inclusion of a specific tow is a judgment made by investigators during the analysis of the data. Some have not included tows that had an shg greater than 136 [= a stratified random trawl tow (first digit =1); that may or may not be representative of the site due to tow time as short as 20-25 minutes or a long as 35-40 minutes (second digit = 3) and the condition of the gear (third digit less than 6).

Method for the present analysis

Station, catch, and length frequency data for Atlantic croaker were obtained for the Groundfish Survey Unit of the National Marine Fisheries Service Science Center at Woods Hole, MA. The area requested were trawl tows made between southern Long Island, NY south to Cape Hatteras, NC in the three shallowest depth zones (0 – 9m; 9 – 18m; 18 – 27m) for the fall survey (generally completed in September) from 1982 to 2002.

These data were edited for appropriateness for inclusion in the analysis. The criteria used were:

Inclusion criteria	Rationale
Tow made in depths less than 27 m	Atlantic croaker are extremely rare in samples deeper than 27 m along the east coast of the US; inclusion of deeper tows would provide no additional information
Tows made in strata from 3180 to 3440	Atlantic croaker were taken in only 3.8% of the 343 tows made in adjacent strata to the North (Table 2)
Tows that had an shg value (= tow conditions) less than 125	Based on the Woods Hole code, it was felt that the inclusion of only these tows would be a conservative approach

The use of more stringent criteria for tow condition resulted in the elimination of 33 tows from the original data set for the included strata. This was in contrast to the exclusion of 10 tows with the more liberal shg value of 136.

As previously mentioned, not all strata were sampled each year and when sampled, often the intensity was low. Two approaches could be taken in the calculation of an index of relative abundance from these data. First, those strata that were not sampled consistently through the time series could be eliminated from the data set. Second, strata within depth zones could be collapsed so that each zone could be treated as a large stratum with trawl sites occupied throughout

Table E2. Presence-absence of Atlantic croaker in strata from near New York south to Cape Hatteras with the average latitude for all tows in that stratum. *Old #* refers to historical identification number of strata by NMFS-Woods Hole; *New #* refers to present identification number of strata.

Stratum Old #	New #	Mean latitude	Tows with Atlantic croaker	Total number of tows
12	3120	40.6	2	34
13	3130	40.5	1	70
14	3140	40.5	1	81
15	3150	40.0	2	21
16	3160	40.0	5	69
17	3170	40.0	2	68
18	3180	39.5	6	27
19	3190	39.5	12	70
20	3200	39.5	7	69
21	3210	39.1	5	25
22	3220	39.1	18	64
23	3230	39.1	9	63
24	3240	38.9	22	44
25	3250	38.8	38	67
26	3260	38.8	31	63
27	3270	38.3	18	24
28	3280	38.3	50	69
29	3290	38.4	37	64
30	3300	38.0	25	30
31	3310	37.9	60	69
32	3320	37.9	40	62
33	3330	37.5	26	27
34	3340	37.4	51	67
35	3350	37.4	44	63
36	3360	37.0	34	44
37	3370	37.0	43	70
38	3380	36.9	43	66
39	3390	36.3	28	31
40	3400	36.3	58	65
41	3410	36.3	49	69
42	3420	35.7	24	29
43	3430	35.6	54	64
44	3440	35.7	45	67
45	3450	41.4	Out of area	
46	3460	41.1	Out of area	
52	3520	41.0	Out of area	
55	3550	41.2	Out of area	

The analysis of the frequency of tows made in strata by year indicated that the shallowest strata (0 – 9m) would be eliminated because of either missing years or a year with a single tow. In 1987 and 1988, no tows were made in any of the shallow strata. Over the time series, Atlantic croaker were taken in 67% of the 274 tows made in 0 – 9m, 64% of those in 9 – 18m (n = 595) and 52% of the 570 tows in the deepest zone retained in the data set. The overall catch per tow of Atlantic croaker in numbers was also higher (404) in the 0 – 9m depth zone than those in the 9 –18m (262) or 18 – 27m (153) zones.

During each of the surveys, most strata had only two tows (Table E2). This would result in estimates of the within stratum variances being very large and having only a single degree of freedom. For this reason, I determined that the best approach would be to collapse the strata within a given depth zone into a large stratum that would include the heart of the species distribution along the Middle Atlantic Coast. The resultant distribution of stations within the depth zones is in Table E3. The locations of the various strata are in Figure E1.

The stratified mean catch per tow for the three depth "strata" were calculated for each cruise using the following formula (Krebs,1989):

$$\overline{y_{st}} = \left(\sum_{h=1}^{L} N_h \overline{x_h} \right) / N$$

where $\overline{y_{st}}$ = the stratified mean catch per tow

N_h = size of stratum h

$\overline{x_h}$ = mean catch per tow for the h stratum

N = total population size = $\sum N_h$

The variance for each of the three strata (= collapsed depth zones) was determined with the equation

$$\mathrm{var}iance\left(\overline{y_{st}}\right) = \sum_{h=1}^{L} \left(\left(\left(w_h^2 * s_h^2 \right) / n_h \right) \left(1 - f_h \right) \right)$$

where w_h = stratum weight = N_h/N

s_h^2 = observed variance of stratum h

n_h = number of tows in stratum h

f_h = sampling fraction in stratum h = n_h/N_h

The standard error of the stratified mean is

standard error of $\overline{y_{st}}$ = $\sqrt{\mathrm{var}iance\left(\overline{y_{st}}\right)}$

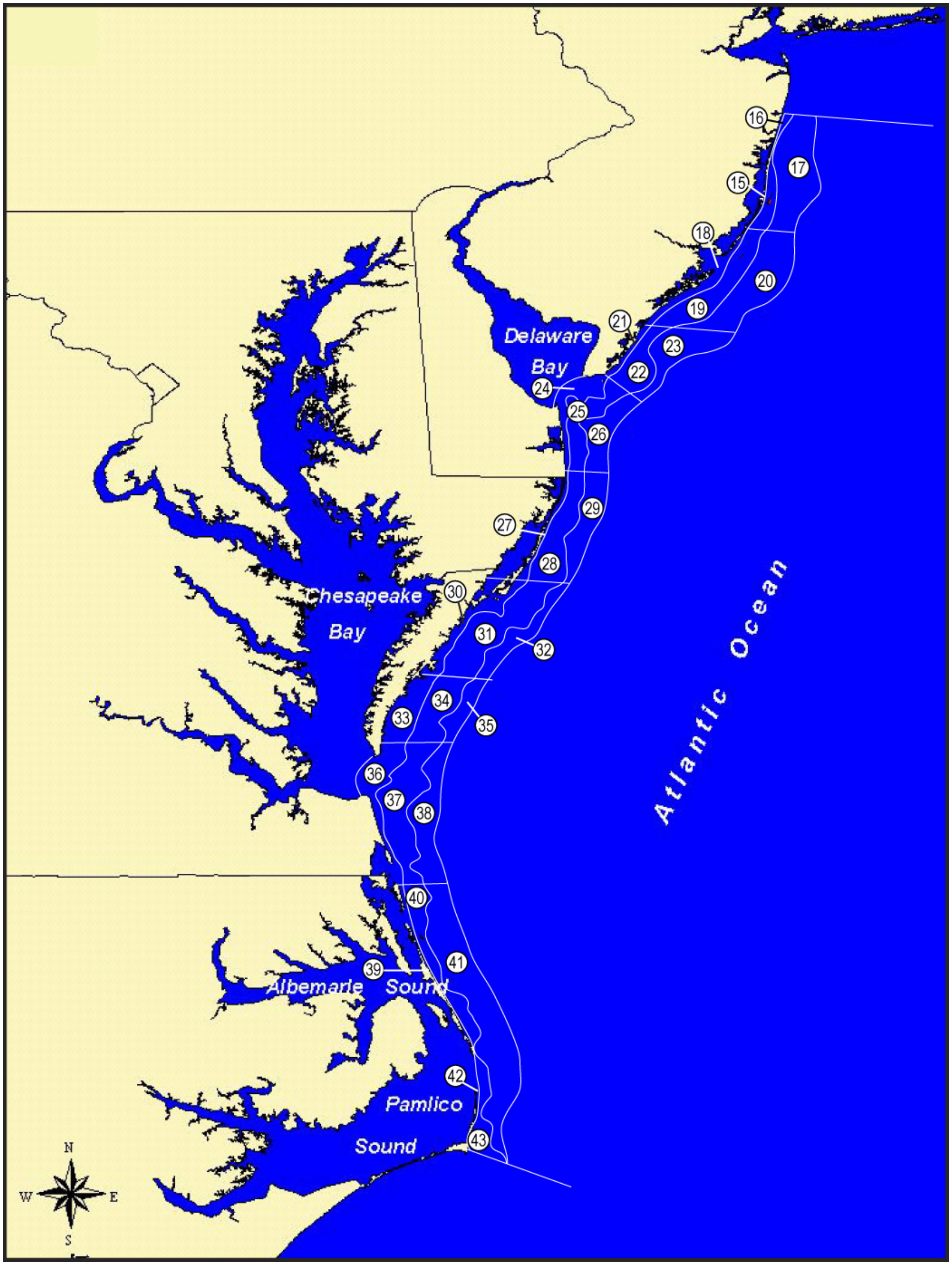
Table E3. Number of tows made in each of the strata include in the analysis for each year's survey.

	Year																														
Stratum	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02
3180	2	3	0	2	1	1	1	1	1	1	0	0	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	0	0	1	1
3190	4	3	2	3	2	2	2	2	2	2	3	2	2	2	2	2	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2
3200	3	4	4	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2
3210	3	2	0	2	1	0	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	1	0	0	0	0	0	1	1
3220	3	2	3	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3230	3	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3240	3	2	0	2	1	1	1	1	1	1	1	1	1	1	1	0	0	2	2	2	1	2	1	2	2	2	2	1	2	2	2
3250	4	3	3	2	2	2	2	2	2	2	0	2	2	2	2	2	2	2	3	2	2	2	2	2	1	2	2	2	2	2	2
3260	3	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2
3270	1	2	0	2	1	1	1	1	1	1	0	0	1	1	0	0	0	1	0	1	1	1	1	1	1	0	1	1	0	0	1
3280	3	3	3	2	2	2	2	2	2	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	2
3290	3	2	3	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2
3300	4	2	0	2	1	1	1	0	1	1	0	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3310	3	4	3	3	2	2	2	2	2	2	3	3	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3320	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3330	2	1	0	2	1	1	1	1	1	1	0	1	1	1	1	0	0	1	1	1	1	1	1	1	0	1	1	1	0	1	1
3340	3	3	3	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	3	2	2
3350	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2
3360	3	2	2	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	2	2	1	2	2	2	1	2	2	2	2	2	2
3370	4	4	4	3	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	1	2	2	2	2	2	2	2	2	2	2
3380	3	3	4	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3390	2	2	0	2	1	1	1	1	1	1	0	1	1	1	2	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3400	3	3	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2
3410	4	4	4	2	2	2	2	2	2	2	0	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2
3420	2	2	0	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	1	1	0	1	1	0	1	1	1
3430	3	2	0	4	2	2	2	2	2	2	1	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2
3440	2	4	4	3	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Total	77	70	52	58	45	44	45	44	45	45	35	45	45	44	42	35	36	47	46	47	43	47	44	47	41	44	45	43	45	46	47

Table E4. The number of stations occupied in each of the three shallow depth

	Depth Zone		
Year	0 – 9 m	9 – 18 m	18 – 27 m
1972	22	30	25
1973	18	27	25
1974	2	23	27
1975	16	23	19
1976	9	18	18
1977	8	18	18
1978	9	18	18
1979	8	18	18
1980	9	18	18
1981	9	18	18
1982	3	13	19
1983	6	20	19
1984	9	18	18
1985	9	18	17
1986	8	17	17
1987	0	18	17
1988	0	18	18
1989	8	21	18
1990	9	20	17
1991	11	18	18
1992	9	16	18
1993	11	18	18
1994	9	18	17
1995	11	18	18
1996	7	17	17
1997	9	17	18
1998	10	18	17
1999	7	18	18
2000	7	20	18
2001	10	19	17
2002	11	18	18

Figure E1. Chart of strata mentioned or used in this report. The older stratum numbers are used in order to save space. See Table E2 for the recent designations of these strata. Strata not drawn exactly as indicated on nautical charts because of space considerations.



Results

Means, variances, and weighting factors for strata collapsed into depth zones for each year are in Table E5. The stratified mean catch per tow with the associated standard error for each year of the time series is in Table E6.

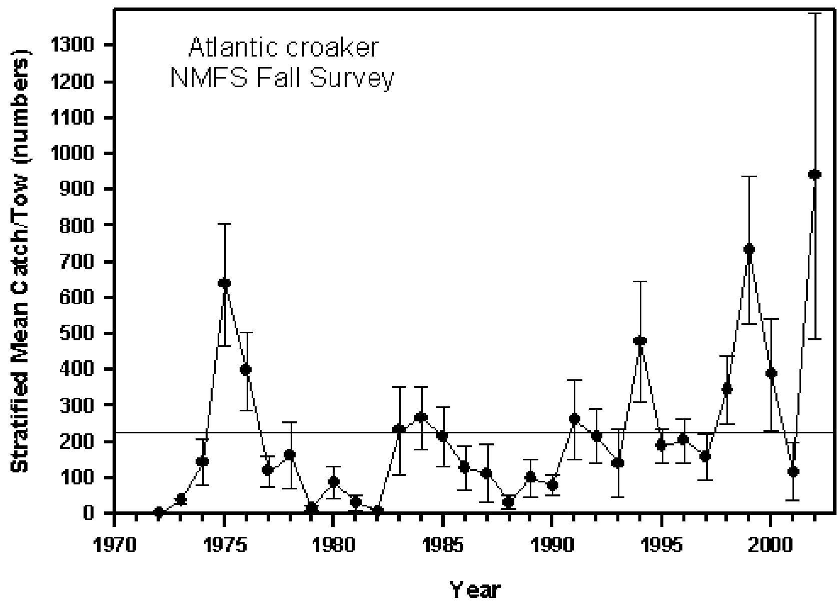


Figure E2. The stratified mean catch per tow +/- one standard error of the mean for the number of Atlantic croaker caught during the southern leg of the fall groundfish survey conducted by NMFS-Woods Hole. Strata included are from mid-New Jersey to Cape Hatteras (see figure E1). These were collapsed into three depth zones. Solid horizontal line is the mean of the time series.

During the earlier period of the time series, the stratified mean catch per tow peaked in 1975 and then fell to some of the lowest values observed during the early 1980's. A slight increase in the catches in relation to the long-term mean was followed by another decline in the mid-1980's. Since then, the catches of Atlantic croaker in the groundfish survey have shown variability between years with a general upward trend. The two highest estimates have been during survey made during the last four years.

Table E5. Mean catch per tow, variance and number of tows by depth zone and year.

Year	Zone	Mean number $\left(\overline{y_{st}}\right)$	Variance number s_h^2	Number of tows n_h	Number tows with Atlantic croaker	Area (nautical miles[2]) (N_h)	Area surveyed $\left(\sum N_h\right)$	Stratum weight $w_h = (N_h / N)$	$w_h * \overline{y_h}$	$\left[\left(w_h^2 * s_h^2\right)/n_h\right]*$ $(1-f_h)$
1972	0-9	9.82	778.7	22	12	568	4423	0.128	1.26	0.56
1972	9–18	2.17	50.1	30	5	1888	4423	0.427	0.92	0.30
1972	18-27	0.32	1.5	25	3	1967	4423	0.445	0.14	0.01
1973	0-9	48.7	5263.6	18	11	568	4423	0.128	6.25	4.67
1973	9–18	50.7	5226.6	27	19	1888	4423	0.427	21.64	34.77
1973	18-27	22.9	1833.8	25	10	1967	4423	0.445	10.18	14.32
1974	0-9	446.5	171112.5	2	2	119	3802	0.031	13.98	82.41
1974	9–18	232.9	454037.0	23	15	1716	3802	0.451	105.12	3967.47
1974	18-27	46.6	7530.9	27	13	1967	3802	0.517	24.11	73.63
1975	0-9	2076.8	13544942.4	16	10	568	4423	0.128	266.70	13567.84
1975	9–18	767.4	1915637.4	23	16	1888	4423	0.427	327.57	14991.06
1975	18-27	98.8	50510.5	19	8	1967	4423	0.445	43.93	520.70
1976	0-9	583.8	390166.4	9	7	568	4423	0.128	74.97	703.61
1976	9–18	625.2	903084.6	18	13	1888	4423	0.427	266.88	9054.53
1976	18-27	125.4	182967.1	18	9	1967	4423	0.445	55.76	1991.97
1977	0-9	209.5	79438.6	8	6	546	4401	0.124	25.99	150.60
1977	9–18	141.3	128091.9	18	13	1888	4401	0.429	60.61	1297.15
1977	18-27	73.3	26946.9	18	10	1967	4401	0.447	32.75	296.31
1978	0-9	729.3	4251475.2	9	7	568	4423	0.128	93.66	7666.96
1978	9–18	105.5	32588.6	18	13	1888	4423	0.427	45.03	326.74
1978	18-27	51.8	30912.4	18	11	1967	4423	0.445	23.03	336.54
1979	0-9	26.7	1628.2	8	5	493	4348	0.113	3.03	2.57
1979	9–18	21.2	4222.7	18	10	1888	4348	0.434	9.19	43.81
1979	18-27	7.6	288.4	18	10	1967	4348	0.452	3.42	3.25
1980	0-9	50.0	5808.0	9	4	568	4423	0.128	6.42	10.47
1980	9–18	96.3	64416.9	18	6	1888	4423	0.427	41.12	645.86
1980	18-27	92.2	131456.3	18	8	1967	4423	0.445	40.99	1431.17
1981	0-9	9.0	670.5	9	2	568	4423	0.128	1.16	1.21
1981	9–18	4.1	85.5	18	10	1888	4423	0.427	1.73	0.86

Table E5. Continued.

Year	Zone	Mean number $(\overline{y_{st}})$	Variance number s_h^2	Number of tows n_h	Number tows with Atlantic croaker	Area (nautical miles^2) (N_h)	Area surveyed $(\sum N_h)$	Stratum weight $w_h = (N_h / N)$	$w_h * \overline{y_h}$	$[(w_h^2 * s_h^2)/n_h]*$ $(1 - f_h)$
1981	18-27	64.9	34372.5	18	10	1967	4423	0.445	28.88	374.22
1982	0-9	0.3	0.3	3	1	194	3494	0.056	0.019	0.0
1982	9–18	5.5	87.8	19	10	1716	3494	0.491	2.71	1.10
1982	18-27	14.1	1784.2	13	3	1584	3494	0.453	6.38	27.98
1983	0-9	690.0	1033048.4	6	5	361	4216	0.086	59.08	1241.38
1983	9–18	355.3	1334961.8	20	9	1888	4216	0.448	159.11	13243.92
1983	18-27	29.5	5333.2	19	9	1967	4216	0.467	13.75	60.51
1984	0-9	278.1	389360.8	9	6	568	4423	0.128	35.71	702.16
1984	9–18	356.8	615286.3	18	14	1888	4423	0.427	152.29	61.69.00
1984	18-27	179.0	91768.7	18	13	1967	4423	0.445	79.61	991.09
1985	0-9	72.7	8489.3	9	7	568	4423	0.128	9.33	15.31
1985	9–18	338.5	555703.0	18	13	1888	4423	0.427	144.49	5571.60
1985	18-27	135.2	91759.6	17	12	1967	4423	0.445	60.14	1058.30
1986	0-9	84.7	17395.1	8	5	414	4269	0.097	8.22	20.05
1986	9–18	137.0	233906.3	17	12	1888	4269	0.442	60.59	2666.96
1986	18-27	126.5	80048.5	17	11	1967	4269	0.461	58.30	991.04
1987	9–18	57.5	16121.1	18	10	1888	3855	0.490	28.16	212.77
1987	18-27	164.2	414321.1	17	8	1967	3855	0.510	83.80	6290.40
1988	9–18	50.6	25459.2	18	10	1888	3855	0.490	24.76	366.02
1988	18-27	13.5	581.8	18	9	1967	3855	0.510	6.89	8.34
1989	0-9	41.0	5156.6	8	3	431	4286	0.101	4.12	6.40
1989	9–18	43.7	8852.0	21	14	1888	4286	0.441	19.26	80.88
1989	18-27	166.2	222314.1	18	11	1967	4286	0.458	76.26	2577.55
1990	0-9	168.6	191049.0	9	5	436	4291	0.102	17.13	214.63
1990	9–18	58.1	14697.5	20	9	1888	4291	0.440	25.56	140.76
1990	18-27	81.0	38598.5	17	9	1967	4291	0.458	37.13	472.98
1991	0-9	677.0	2984745.6	11	7	568	4423	0.128	86.94	4388.18
1991	9–18	403.7	797433.9	18	12	1888	4423	0.427	172.33	7995.25
1991	18-27	2.8	68.1	18	5	1967	4423	0.445	1.26	0.74

Year	Zone	Mean Number	Variance Number	Number of Tows	Number tows with Atlantic croaker	Area (nautical miles^2	Area surveyed	Stratum Weight	$w_h * \overline{y_h}$	$\left[\left(w_h^2 * s_h^2\right)/n_h\right]*(1-f_h)$
1992	9–18	354.8	399059.0	16	12	1888	4423	0.427	151.46	4506.00
1992	18-27	22.2	4601.5	18	8	1967	4423	0.445	9.88	50.10
1993	0-9	940.7	5912807.0	11	7	568	4423	0.128	120.81	8693.02
1993	9–18	41.1	9944.5	18	9	1888	4423	0.427	17.52	99.71
1993	18-27	5.7	397.6	18	3	1967	4423	0.445	2.54	4.33
1994	0-9	239.9	224953.1	9	6	546	4401	0.124	29.76	336.02
1994	9–18	153.3	78652.8	18	10	1888	4401	0.429	65.76	796.49
1994	18-27	857.1	2286676.9	17	9	1967	4401	0.447	383.06	26637.42
1995	0-9	245.7	380558.6	11	7	568	4423	0.128	31.56	559.50
1995	9–18	210.2	120550.0	18	14	1888	4423	0.427	89.71	1208.66
1995	18-27	153.1	45159.9	18	16	1967	4423	0.445	68.09	491.66
1996	0-9	305.6	288085.6	7	5	414	4269	0.097	29.63	380.51
1996	9–18	161.0	157272.7	17	13	1888	4269	0.442	71.20	1793.20
1996	18-27	223.9	137513.4	17	12	1967	4269	0.461	103.16	1702.48
1997	0-9	414.7	566242.7	9	6	511	4366	0.117	48.53	846.68
1997	9–18	159.4	213930.1	17	13	1888	4366	0.432	68.91	2332.01
1997	18-27	92.6	60556.4	18	9	1967	4366	0.451	41.70	676.61
1998	0-9	395.1	242933.4	10	9	546	4401	0.124	49.02	367.06
1998	9–18	476.1	638218.6	18	16	1888	4401	0.429	204.22	6463.05
1998	18-27	204.8	161720.1	17	13	1967	4401	0.447	91.54	1883.87
1999	0-9	451.3	349764.2	7	6	409	4264	0.096	43.29	451.85
1999	9–18	651.5	916928.7	18	16	1888	4264	0.443	288.47	9891.73
1999	18-27	872.9	2694278.1	18	15	1967	4264	0.461	402.69	31561.07
2000	0-9	662.0	1204226.6	7	7	322	4177	0.077	51.03	1000.11
2000	9–18	136.0	36312.7	20	15	1888	4177	0.452	61.47	367.01
2000	18-27	584.3	1882474.3	18	12	1967	4177	0.471	275.14	22979.67
2001	0-9	110.1	31728.5	10	8	533	4388	0.121	13.37	45.94
2001	9–18	327.8	657566.5	19	14	1888	4388	0.430	141.06	6342.55
2001	18-27	51.8	18676.4	17	8	1967	4388	0.448	23.20	218.85
2002	0-9	1314.1	8270889.2	11	10	568	4423	0.128	168.76	12159.88
2002	9–18	1606.3	19006251.7	18	16	1888	4423	0.427	685.66	190560.90
2002	18-27	192.1	136963.3	18	11	1967	4423	0.445	85.41	1491.13

Table E6. Stratified mean catch per tow in number of Atlantic croaker with frequency of occurrence in samples and the standard error of the stratified mean.

Year	*Number of Tows*	*Number of Tows with Atlantic croaker*	*Stratified mean Number /tow*	*Standard error stratified mean number/tow*
1972	77	20	2.33	0.93
1973	70	40	38.07	7.33
1974	52	30	143.20	64.21
1975	58	34	638.21	170.53
1976	45	29	397.61	108.40
1977	44	29	119.35	41.76
1978	45	31	161.72	91.27
1979	44	25	15.64	7.05
1980	45	18	88.53	45.69
1981	45	22	31.77	19.40
1982	35	14	9.11	5.39
1983	45	23	231.94	120.61
1984	45	33	267.61	88.71
1985	44	32	213.97	81.52
1986	42	28	127.11	60.65
1987	35	18	111.96	80.64
1988	36	19	31.65	18.56
1989	47	28	99.64	51.62
1990	46	23	79.82	28.78
1991	47	24	260.53	111.28
1992	43	27	216.19	74.90
1993	47	19	140.88	93.79
1994	44	25	478.57	166.77
1995	47	37	189.36	47.54
1996	41	30	203.99	62.26
1997	44	28	159.14	62.09
1998	45	38	344.79	93.35
1999	43	37	734.45	204.71
2000	45	34	387.65	156.03
2001	46	30	177.64	81.29
2002	47	37	939.82	451.90

After looking at the index of abundance (stratified mean catch per tow), the data was examined to determine, within the core strata used in the analysis, where did Atlantic croaker occur more frequently, where was the greatest abundance over the time series, and were there any spatial differences in size of the fishes caught during the survey. The catch data was pooled, by both number per tow and number of occurrences, as well as the length frequencies over the time series by stratum. The stratum used were the Woods Hole designations of strata, not the depth zones used to calculate the stratified means.

The highest mean catches for the 1972-2002 period were in strata 3390 (39) where tows yielded over 800 Atlantic croakers per haul (Table E7). In general, the largest catches were in the lower latitudes and in the shallower strata. The frequency of occurrence also increased with decreasing latitude (Table E8).

Table E7. Mean number per tow with appropriate statistic for Atlantic croaker taken in the southern leg of the fall groundfish survey in core strata. Data pooled over all years to derive values.

Stratum	***N***	***Mean***	***Std. Error***	***Minimum***	***Maximum***
3180	26	379.42	370.66	0	9644
3190	69	49	34.071	0	2265
3200	67	2.03	1.808	0	121
3210	25	127.76	106.153	0	2617
3220	63	27.97	13.513	0	766
3230	62	14.23	9.337	0	562
3240	43	137.88	54.942	0	1872
3250	64	119.69	66.785	0	4070
3260	61	62.05	21.017	0	931
3270	23	433.52	138.246	0	2268
3280	69	186.26	48.987	0	2508
3290	62	127.65	40.413	0	1404
3300	30	368.57	133.273	0	3323
3310	68	250.1	64.473	0	2643
3320	62	227.02	87.371	0	4429
3330	27	481.93	230.442	0	5758
3340	66	618.27	294.656	0	18616
3350	60	354.13	134.229	0	6301
3360	43	595.86	317.35	0	13306
3370	69	320.43	104.254	0	5161
3380	65	85	40.192	0	2467
3390	31	849.45	370.736	0	8380
3400	64	355.17	84.332	0	3215
3410	65	313.32	108.876	0	5074
3420	26	537.04	246.343	0	6225
3430	63	379.76	109.415	0	5459
3440	66	158.71	43.931	0	2071
Total	**1439**	**247.11**	**24.93**	**0**	**18616**

Table E8. Presence – absence of Atlantic croaker in trawl tows made during the southern leg of the NMFS – Woods Hole fall groundfish survey in the core strata as previously defined. Data pooled across all years (1972 – 2002).

Southern Leg Fall Groundfish Survey - NMFS			
	Atlantic Croaker		
	Presence-Absence		
Stratum	Absent in tow	Present in tow	Total tows
3180	21	5	26
3190	57	12	69
3200	61	6	67
3210	20	5	25
3220	45	18	63
3230	53	9	62
3240	22	21	43
3250	27	37	64
3260	30	31	61
3270	5	18	23
3280	19	50	69
3290	26	36	62
3300	5	25	30
3310	9	59	68
3320	22	40	62
3330	1	26	27
3340	15	51	66
3350	18	42	60
3360	10	33	43
3370	26	43	69
3380	22	43	65
3390	3	28	31
3400	7	57	64
3410	19	46	65
3420	4	22	26
3430	9	54	63
3440	21	45	66
Total	**577**	**862**	**1439**

The pooled arcsine transformed values of the percent frequency of occurrence were correlated with the mean catch per tow for a given stratum (Figure E2). As abundance increases (the catch/tow is elevated), the species becomes more widely distributed in the core strata.

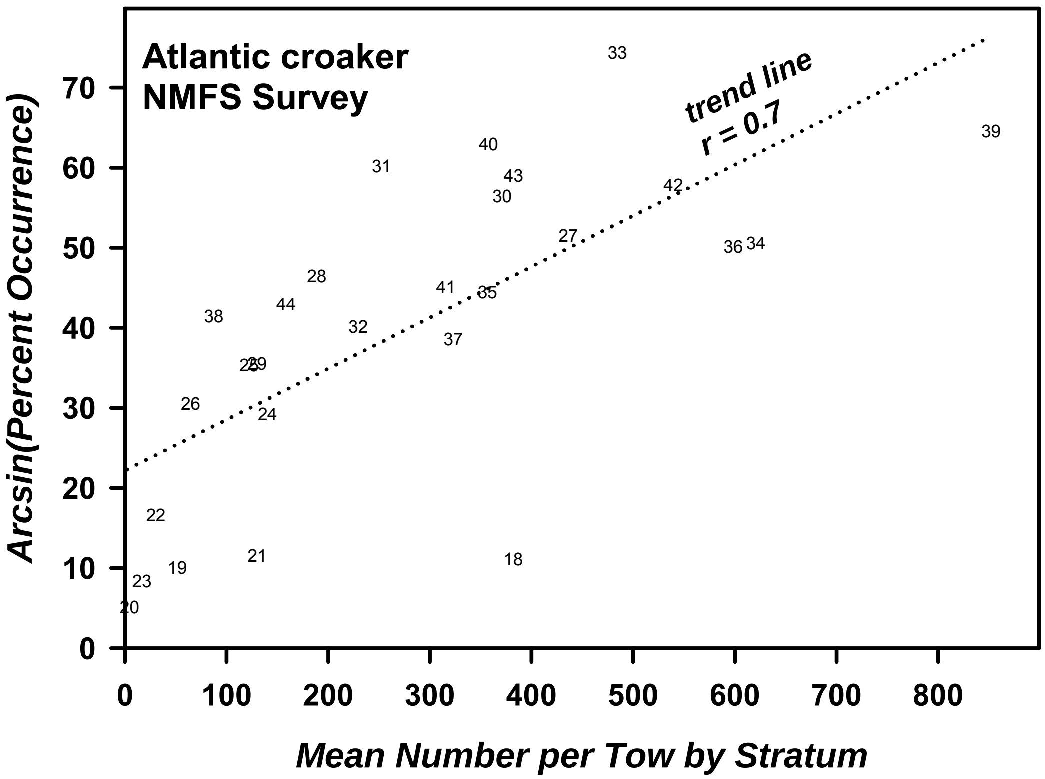


Figure E3 Relationship of the arcsine transformed frequency of occurrence and the mean catch per tow for Atlantic croaker taken during the southern leg of the NMFS-Woods Hole groundfish survey. Data derived from values pooled for each stratum over the time series. Numbers refer to stratum designations under old system, i.e., 38 = 3380.

Examination of the length frequency distribution of the Atlantic croaker by strata for the time series showed that smaller individuals (<5-cm TL) were consistently taken in a limited area within the core section. The average size of the Atlantic croaker in the individual strata was smallest in the same general area along the coast where the smallest size classes were most abundant (Tables E9 and E10). Their distribution would suggest that the origin of these small fishes off the eastern shore of Maryland and Virginia was Delaware Bay.

Table E9. Length frequency (total length in cm) distribution of Atlantic croaker by stratum for the southern leg of the NMFS-Woods Hole groundfish survey. Data pooled by stratum across all years. Note most small fishes <6 cm TLs were taken in strata 3270, 3280, 3300 and 3320. These are the two shallowest strata south of Delaware Bay off the eastern shore of Virginia and Maryland.

										Stratum																	
TL	***3180***	***3190***	***3200***	***3210***	***3220***	***3230***	***3240***	***3250***	***3260***	***3270***	***3280***	***3290***	***3300***	***3310***	***3320***	***3330***	***3340***	***3350***	***3360***	***3370***	***3380***	***3390***	***3400***	***3410***	***3420***	***3430***	***3440***
1										5	210																
2							6			2668	1870	70	1865	1782		144											
3	1						16			1314	600	28	3039	1480		532			11				1			6	
4							10			368	25		566	78		51			33							1	
5							3			99			157	9		1			13								
6							3			36			22	10		1											
7										12			5	3		3											
8										1			6			1									1		
9												1															
10																						9			2		
11										1	1		3							4					8		
12				4			3			1			16									254	6	1	57	14	
13				7			1	2	1	7			38		16	8			11	5		2243	21		835	75	
14				15					1	21	2		21			19			166	18		4699	172	12	1155	379	29
15				74			6	44		112	19		47	10		4			1577	18		3120	323	15	1356	604	103
16	34			468			37	260	13	224	21	1	76	8		5	246	2	3079	105	5	2265	349	84	1091	1215	346
17	34			762			80	814	92	263	7		81	19		103	2405	12	4583	1051	35	1466	1056	334	621	2718	615
18	448		1	706			137	1002	120	167	17		70	84		955	7366	101	3549	2786	98	1630	1845	972	587	4141	1253
19	1654	2	2	382			98	504	155	124	45	45	337	256	62	2476	8267	599	2910	4072	220	1933	2615	1756	635	4692	1800
20	2381	1	2	134			105	373	177	229	180	249	690	1332	445	3449	5363	1785	3512	2678	813	2441	4285	2661	542	3685	1954
21	1864	4	1	27			52	173	108	668	787	329	875	1928	1361	1689	4747	2945	2930	1145	1187	2956	4063	2808	601	2643	1674
22	1833	2	1	43			60	153	125	748	1320	503	645	1810	2462	1541	3943	3317	1867	1754	1287	1329	2485	4149	1381	1325	951
23	594	2	1		2	4	151	143	201	892	1445	375	444	1674	2572	1000	3221	3811	715	2125	767	772	1783	3850	1895	837	873
24	138	4	1	1	50		328	183	275	618	1636	478	541	1321	2252	527	2483	2450	162	2285	406	524	1101	2266	1366	353	348
TL	***3180***	***3190***	***3200***	***3210***	***3220***	***3230***	***3240***	***3250***	***3260***	***3270***	***3280***	***3290***	***3300***	***3310***	***3320***	***3330***	***3340***	***3350***	***3360***	***3370***	***3380***	***3390***	***3400***	***3410***	***3420***	***3430***	***3440***

25	140	5	2	9	135		641	192	309	465	1352	865	649	1311	1469	254	1014	2286	427	1584	307	221	706	909	817	393	160
26	74	46	3	12	264	17	982	248	431	332	1110	827	421	1078	1175	141	662	1384	42	1090	125	143	565	312	479	316	73
27	47	211	7	32	256	53	927	419	448	255	736	852	152	1205	877	62	396	958	18	682	84	65	409	113	355	100	79
28	80	300	15	53	189	102	650	478	466	123	525	863	152	728	454	17	287	510	19	402	53	101	309	35	76	205	84
29	54	472	21	85	230	78	534	545	231	85	341	700	45	417	253	6	178	337	36	162	39	15	210	19		90	31
30	64	523	26	89	176	90	387	573	214	59	320	668	54	237	153	4	109	289	7	41	27	69	185	23	51	47	47
31	18	599	15	98	112	108	277	309	194	32	116	248	11	110	106	5	30	153	1	63	12	63	52	17	51	55	33
32	83	469	19	93	134	102	222	396	66	21	78	274	21	40	65	5	16	89		5	19	4	66	9		1	9
33	111	415	11	51	97	97	97	305	55	14	39	209	3	24	89	6	25	48		8	17	10	45	6		13	28
34	140	134	2	26	45	64	44	219	29	4	45	121	3	38	65	1	18	69	1	4	4		37	12		14	1
35	36	98	2	13	28	37	39	191	30	2		76	1	1	42		11	31		18	9		21	5		3	4
36	1	77	2	6	20	41	17	34	16	1	5	29	1	5	43		7	13		3	6	1	13	2			
37		4		1	6	27	7	43	9			44		1	19	1	8	10	1	2	5		4				
38	35				9	25	3	24	4			26		2	21		2	23									
39					3	18	1	25	3			13		4	17			6					4				
40				1	3	4	4		2			20			32	1	2	1			1						
41			2	1	1	9	1		2			1			5			3							1		
42	1	13		1	2				2						7												
43						2		8	3						3												
44						1			2					1	6												
45						1			1					1													
46															1			1									
47															3			15									
48						2																					

Table E10. Mean total length (cm) of Atlantic croaker taken in the southern leg of the fall groundfish survey conducted by NMFS-Woods Hole. Data pooled over the time series by stratum within the core area.

Stratum	*Number*	***Mean TL*** cm	*std error*	***95% Confidence Interval*** lower	upper
3180	9865	21.4	0.033	21.4	21.5
3190	3381	30.7	0.041	30.6	30.8
3200	136	29.7	0.298	29.1	30.3
3210	3194	19.9	0.092	19.7	20.1
3220	1762	28.8	0.071	28.7	28.9
3230	882	31.7	0.118	31.5	31.8
3240	5929	26.5	0.052	26.4	26.6
3250	7660	24.7	0.071	24.5	24.8
3260	3785	25.8	0.069	25.6	25.9
3270	9971	13.5	0.103	13.3	13.7
3280	12852	19.9	0.084	19.7	20
3290	7915	26.5	0.052	26.4	26.6
3300	11057	12.4	0.096	12.2	12.6
3310	17007	19.6	0.068	19.4	19.7
3320	14075	24.1	0.026	24.1	24.2
3330	13012	19.6	0.04	19.6	19.7
3340	40806	20.5	0.013	20.4	20.5
3350	21248	23.4	0.02	23.4	23.5
3360	25670	18.7	0.016	18.7	18.7
3370	22110	21.5	0.021	21.4	21.5
3380	5526	22.2	0.033	22.1	22.2
3390	26333	17.5	0.022	17.5	17.6
3400	22731	21.1	0.021	21	21.1
3410	20370	21.7	0.015	21.7	21.7
3420	13963	19.8	0.037	19.7	19.9
3430	23925	19.4	0.018	19.4	19.4
3440	10495	20.3	0.026	20.3	20.4
total	**355660**	**20.6**	**0.009**	**20.6**	**20.6**

Age determination and age composition

In sciaenids (drums and croakers), the major problem in the determination of ages from otoliths is the definition of the first annulus. This becomes more difficult when the species either has a protracted spawning season over its geographical range or spawns in the late summer-early fall. For example, the red drum (*Sciaenops ocelatus*) is a late summer spawner in South Carolina waters. The young enter the tidal creeks for a two to three month period and move to deeper waters in the winter at a size of 3 to 5 cm TL. When the waters warm in the spring, the young move back into the shallow tidal creeks where they feed on a variety of crustaceans such as grass shrimp. They reach a size of 15 to 20 cm TL by June when they leave this habitat and form schools of like sized individuals in various shallow water areas of the estuary. By their second winter, they reach a size of 30 to 40 cm TL. During the cold weather period, feeding is reduced and the growth is essentially zero. The following spring (April – early May) these individuals deposit the first well defined mark on the edge of their sagittae. These fishes are from 20 to 21 months of age at the time of formation of the first well-defined annulus. Careful examination of the otolith's core in transverse sections frequently shows a series of ill-defined, hazy concentric rings near the core. This probably is a combination of the settlement mark as well as passage through the first winter. The distance from the center of the core to the position of these rings is highly variable, and in some individuals, the area (the diffuse rings) is entirely absent. Since the annual rings on the otoliths of red drum are very distinct, we ignore the ill-defined "marks" near the core and designate the first well defined ring as the first annulus. Red drum, as previously mentioned, are ~20 – 21 months old at this time.

The situation is even more complex in the Atlantic croaker. I followed the embedding and sectioning procedures outlined for this species in a draft document dealing with age determination of fishes in the Gulf of Mexico produced by the Gulf States Marine Fisheries Commission (Table 9). Ootliths (sagittae) were removed, stored dry and later sectioned (~0.5-mm) with a low speed saw after embedding in expoxide resin. Transverse sections were examined under a binocular microscope and the ages determined.

Table E11. Methodology for the determination of the ages of Atlantic croaker used in the present report. Extracted from GSMFC manual dealing with age determination of fishes in the Gulf of Mexico. Description directly copied from manual.

. Atlantic croaker *Micropogonias undulatus*
Highlights
_ Otoliths relatively easy to locate and extract.
_ Multiple sectioning techniques successful.
_ Rings easily discernable.
_ First distinct opaque ring forms at approximately 1.5 years of age.
_ Generally less than ten rings.

Otolith description
The sagittae in Atlantic croaker are very thick and shield shaped, often with a shelf or flange on the outer surface or on the dorsal margin (Figure 5.75). The ostium of the sulcus is large, pear-shaped, and its expanded part does not reach the anterior margin. The 'J' shaped cauda of the sulcus acousticus is sharply bent, and its dorsal edge extends further into the ostium than its ventral edge.

Otolith processing
Due to the robust nature of the otoliths in this species, multiple techniques are acceptable and usually reflect available equipment. Generally, Atlantic croaker sections are processed at approximately 0.5 mm. The following techniques have been used

successfully throughout the Gulf.
Low Speed Wafering Saw Techniques
Embedded Whole Otoliths (Section 3.4.2.1)
LDWF, GCRL, MDMR, FMRI
1. Embed the otolith with the long axis parallel to the long axis of the mold.
2. Locate core and position block in chuck.
3. Adjust arm weight and speed. Make successive 0.5 mm cuts to obtain the core region.
4. Mount the core sections.

Mounted whole otoliths (Section 3.4.2.2)FMRI
1. Mount whole otolith to slide, concave side down with the long axis parallel to the long side of the slide using thermoplastic.
2. Locate core and position slide in chuck.
3. Adjust arm weight (50-75 g) and speed (8- 10). Make successive 0.5 mm cuts to obtain the core region.
4. Mount the core sections.

High speed wafering saw techniques
Embedded Whole Otoliths (Section 3.4.2.1) TPWD
1. Embed the whole otolith with the long axis parallel to the long axis of the mold.
2. Locate core and position block in chuck.
3. Adjust load (1,000 g) and speed (3,000 rpm). Make successive 0.5 mm cuts to obtain the core region.
4. Mount the core sections.

Thin section machine
Free-Hand whole otolith sectioning (Section 3.4.3) LSU, AMRD
1. Firmly grasping both ends of the otolith, make initial cut adjacent to the core.
2. Hand grind additional material until core is visible.
3. Mount otolith half with core on labeled slide.
4. Place slide in chuck and section off remaining material.
5. Place slide into precision grinder arm and adjust caliper to 0.5 mm.

Age Determination

Transverse otolith sections of Atlantic croaker show very clear, easily identified marks that can be used for aging. Typical sections have an opaque core surrounded by a blurred opaque band, composed of fine opaque and translucent zones. This band represents the first annulus. Because of Atlantic croaker’s spawning season, the width of the first annulus varies among individuals.

Spawning typically occurs from November through January while annuli deposition occurs from December through May. Late-spawned fish have a very narrow band that is almost continuous with the core; early spawned fish have a wide, well-defined band clearly separated from the core. Because of this variation in width and proximity to the core, the first annulus is sometimes difficult to identify. Figure 5.80 Otolith section of an age-8 Atlantic croaker. Black arrows indicate annuli. Note first annulus appears as a blur or smudge. Subsequent annuli are represented by easily identified, narrow, opaque bands that alternate with wider translucent bands outside the proximal margin of the first annulus.

For regional stock assessment purposes, three minimal parameters are recorded: number of rings, presence or absence of an opaque ring at the margin, and month of capture. Based on these three parameters, cohort and biological ages can be determined.

Other aging methods

Whole otoliths have not been used successfully in the Gulf region. The usefulness of break and burn techniques for Atlantic croaker has not been determined, however; this species may be a good candidate for the technique. Atlantic croaker scales have not been demonstrated to be useful in the Gulf yet (Figure E4) Birthdate assignment timeline for Atlantic croaker. Age or year group based on biological birthdate (January 1), number of rings, and January 1 to December 31 year.

In our estimates of the ages of Atlantic croaker, we used the methodology as described above for the embedding and sectioning (low speed). There is still a problem with the determination (using the GSMFC definition) of the first annulus. Near the core of many individuals (they define them as early spawned fish), a faint ring can be seen that is of variable location and size as well as clarity. From the description in the aging manual "Spawning typically occurs from November through January while annuli deposition occurs from December through May (Figure E5). Late-spawned fish have a very narrow band that is almost continuous with the core; early spawned fish have a wide, well-defined band clearly separated from the core. Because of this variation in width and proximity to the core, the first annulus is sometimes difficult to identify. Otolith section of an age-8 Atlantic croaker. Black arrows indicate annuli. Note first annulus appears as a blur or smudge. Subsequent annuli are represented by easily identified, narrow, opaque bands that alternate with wider translucent bands outside the proximal margin of the first annulus."

We have not included this area (blur or smudge) in the counts of the annuli because it is not present in all fish from either the Middle or South Atlantic. Photomicrographs of Atlantic croaker sectioned otoliths used in our analysis are in Figures E4 and E5.

Spawning season and origin of problems in age determination

The confusion in the designation of the first annulus results from the extended spawning season for this species along the eastern United States. In the Chesapeake Bay region, the spawning dates for larval and juvenile Atlantic croakers were from early July to early February with an estimated 82% of spawning occurring from August to October (Nixon and Jones 1997). In the Cape Lookout area of North Carolina, Warlen and Burke (1990) found Atlantic croaker move from coastal to estuarine waters over a six-month period from November through April. They defined two pulses of larval ingress. The first occurred in the fall (November-December) and the second was in mid-February to mid-April. Plankton samples taken during the six weeks between these two peaks had a much lower abundance of Atlantic croaker (Warlen and Burke 1990).

In the South Atlantic Bight, data are available for the Cape Fear River estuary (Weinstein 1979), South Carolina (McGovern and Wenner 1990; Wenner, unpublished data). In the Cape Fear River, Weinstein sampled the shallow tidal creeks that meander through the vegetated marsh systems up a salinity gradient. Atlantic croaker ingress to the shallow creeks peaked in November, but generally the catches were low. He indicated that the species preferred the deeper waters of the estuarine system over a muddy bottom rather than the shallow tidal creek system (Weinstein 1979). In a subsequent study in that same area, Weinstein et al. (1980) determined that ingressing Atlantic croaker were most concentrated in the near bottom waters of the Cape Fear River. These fishes ranged in size from 7 to 30 mm SL with a modal size of 11 mm. The interesting fact about these collections was that they were made over a three two-day periods in 1977 (March 14-15, April 5-6, April 11-12) and they contained a number of larval and early juvenile Atlantic croaker that were not seen in the samples from the shallow marsh habitat of the same river system. They failed to give any indication as the period of peak ingress (summer-fall; winter)

Further south in the North Inlet estuarine system, Bozeman and Dean (1980) sampled an intertidal creek with a blocknet thereby capturing all fishes that had moved into the area on the high tide. These collections were made from October 21, 1974 to February 22, 1975. Atlantic croaker were present in all collections except the final sample taken on May 25, 1975. Although no lengths were presented for the fishes, the number and weight of each species was taken (Table E12).

As can be seen from the average weights in the right hand column of Table E12, these were small fishes suggesting that recruitment of Atlantic croaker into this system occurs over an extended period from October through February. In this same system with another gear type (epibenthic sled), Allen and Barker (1990) found increases in abundance in late fall and early spring with more Atlantic croaker in the latter. The average size of these fishes was from 9 to ~15 mm SL. In the Charleston Harbor estuarine system, plankton samples caught Atlantic croaker from October through May. Greatest catches were in January, and the late winter-early spring tows were far higher than those in the fall (Wenner, unpublished data). These were small fishes with most being less than 15 mm TL.

Table E12. Total number and weight and mean weight of Atlantic croaker in samples from North Inlet, SC as reported in Bozeman and Dean

Date	Number	Weight	Average weight
3 October	2,532	31.4	0.012
2 November	166	2.5	0.015
14 December	92	1.9	0.021
4 January	4	0.1	0.025
7 January	3,425	92.4	0.027
16 January	10	0.4	0.040
30 January	2,187	67.7	0.031
22 February	323	12.2	0.038
8 March	410	16.8	0.041
15 March	124	4.8	0.039
17 March	86	3.2	0.037
20 April	14	0.7	0.050
25 May	0	0	

In yet another plankton study, McGovern and Wenner (1990) indicated that Atlantic croaker showed a "protracted period of recruitment to the creek habitat, with larvae and small juveniles found in collections from September through May".

This extended period of larval ingress that varies latitudinally is the source of the difficulty in the determination of the first annulus. The first well defined ring outside of the core area (with its concentric, multiple rings and 'smudges') is designated as the first annulus. This is deposited in the spring (April-May in South Carolina). Hence, the age at the first well defined ring is from 13 to 18 months. By ignoring the noise near the core, much of the confusion is eliminated as the remainder of the marks on the structure are readily interpretable.

The purpose of this lengthy description of larval ingress into the nursery habitat is to describe the origin of the problems with the designation of the first annulus. By ignoring the noise around the core and using only well defined rings as an interpretation of the age, the ages can be determined more accurately. Since there is recruitment to east coast estuaries over an extended period with peaks dependent upon latitude, by ignoring the core and designating January 1 (the approximate mid-point of the spawning season) as the birthdate, age determination for this species is standardized.

Fishes sampled during the NMFS-Woods Hole fall groundfish survey (length based subsample of fishes in each tow) were aged and placed in 1-cm size intervals. An age-length key was constructed for the survey. Note that the available ages were survey specific but not cruise specific, i.e., ages were not available for every cruise. We have unprocessed otoliths from the last four years. The methodology used assumes that there are not yearly changes in the lengths at age.

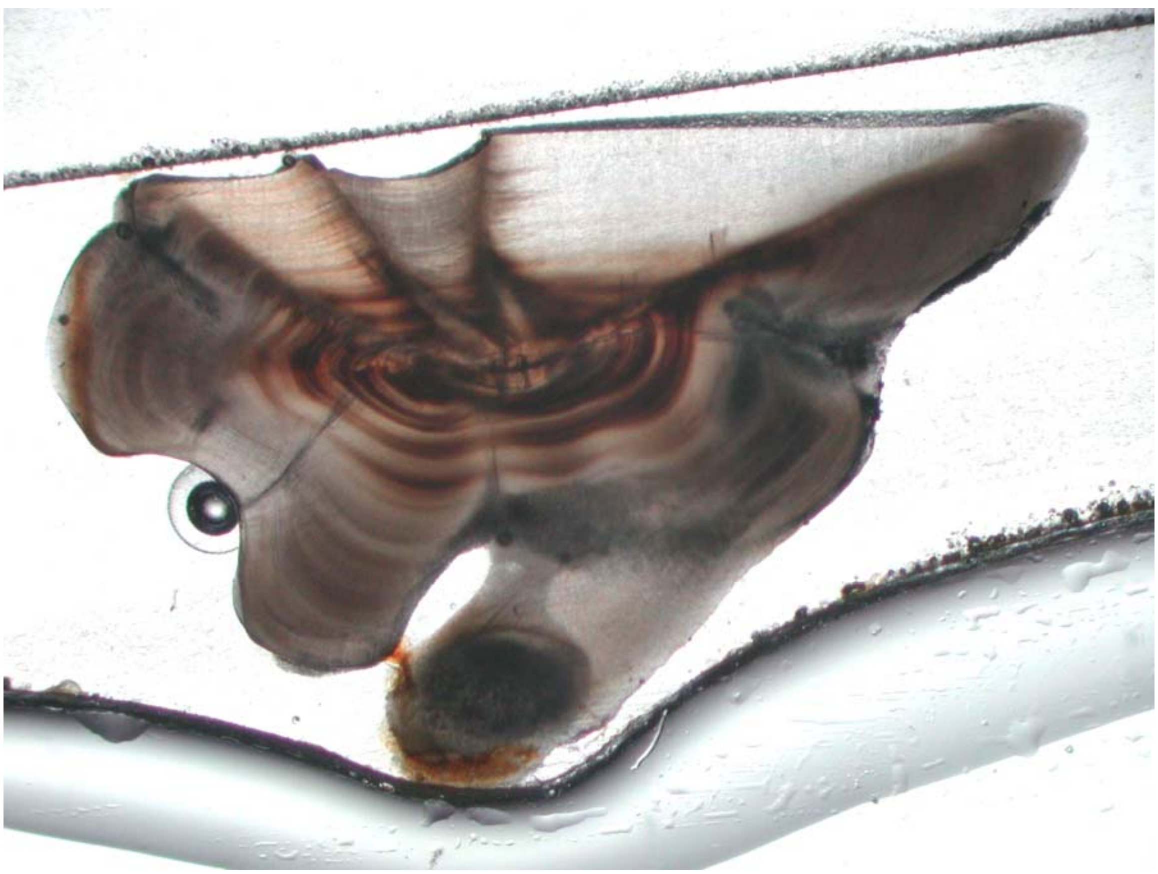
In the photomicrograph figures, the characteristics of the rings near the core are visible. In Figure E4, there is a translucent "ring" near the center. This is surrounded by a series of rings that are of variable clarity. In our age determinations, the "ring" was not included in the counts of the annuli. This fish was designated as being age 4 +. Figure 5 shows what we call an age 0 fish taken during the fall groundfish survey along the Middle Atlantic Coast during September. It would have deposited its first well defined ring the following spring.

Figure E4. Photomicrograph of a transverse section of a sagittal otolith from an Atlantic croaker collected during the southern leg of the fall groundfish survey of the Middle Atlantic coast. We have interpreted the age of this fish as 4+. The ring close to the core and the smudge near it were not included in the count in contrast to methodology in GSMFC handbook on age determination.

The construction of the age-length key for the NMFS fall survey was based on the ages of fishes captured with the survey gear during regular cruises in the mid to late 1990's. No data are available for the prior years. Otoliths are available, but as yet have not been read, from cruises made from 1999 through 2003. Analysis is planned on these otoliths in the near future as well as participating in the fall surveys of 2004 and 2005. The following results are based on keys produced from a few years merged together and applied to the time series of catches and lengths from 1972 through 2002.

The resulting estimates of the age composition of the catch during the NMFS fall survey are in Table E12. The oldest fishes (age 9 – 10) were present only in the mid-1970's and recent years. The periods of expanded age distributions coincided with peaks in the commercial landing along the east coast of the United States. In addition, the NMFS-Woods Hole fall survey estimates of abundance as indicated by the stratified mean catch per tow of the core strata were high during the same periods. Given the habit of young-of-year Atlantic croaker (resulting from late summer spawning events) over-wintering

Figure E5. Photomicrographs of a cross section of a sagittal otolith from and Atlantic croaker collected during the fall groundfish survey along the Mid-Atlantic coast. The multiple rings near the center were not defined as the first annulus. The fish was designated as age 0. Magnification greater than Figure 4.



in some estuaries such as Chesapeake Bay, the abundance estimates of the age 0 fish do not show the same trends, i.e., fails to track with the commercial landings, because of the unavailability to the survey gear. Perhaps the indices of abundance derived from other surveys inside the various estuaries during the fall and winter could provide a much better estimate of yearclass strength. The values could be lagged for a year and then compared to the abundance of say, age 1 fish in the NMFS survey.

The contributions of the various age groups to the stratified mean catch per tow for a species year's survey are in Table 11. Higher values of the older age groups (age 4+) are in the more recent year and in the 1970's.

Future Work

The SCDNR plans to complete the age determinations from the NMFS-fall survey off the Mid-Atlantic coast as well as complete the gathering and analysis of the SEAMAP South Atlantic data. The project has taken fish for age analysis for the past five or more years, so at least for the most recent period, there are cruise specific age-length keys.

Table E13. Age composition of the southern leg of the fall groundfish survey conducted by NMFS-Woods Hole. Ages estimated by the application of an age-length key (determined by sections of sagittae) to the expanded length frequency distributions of each cruise. Reading procedures of the sections followed those of the Gulf.

cruise	*age 0*	*age 1*	*age 2*	*age 3*	*age 4*	*age 5*	*age 6*	*age 7*	*age 8*	*age 9*	*age 10*	*total*
197208	276	9	3									**288**
197308	661	1333	527	212	53	22	8	2				**2818**
197411	396	2766	2026	1446	501	226	90	50	5	1	3	**7510**
197512	29277	17258	3683	1779	383	218	76	53	9	1	3	**52740**
197609	1860	9856	3683	2215	596	310	114	63	12	1	1	**18711**
197712	214	2048	1302	1192	350	211	114	59	26	1	4	**5521**
197806	471	4372	2193	1403	484	274	130	74	34	3	5	**9443**
197910	308	287	66	46	14	8	5	2	2			**738**
198007	557	2423	580	206	43	18	9	5	3			**3844**
198106	227	717	230	105	28	10	6	1				**1324**
198206	6	110	81	62	15	7	4	1				**286**
198306	5382	5592	687	132	9	2						**11804**
198405	1310	7366	2373	782	190	75	25	3				**12127**
198508	9118	3722	4291	839	244	57	22	9	2			**1275**
198606	737	2772	1027	375	89	61	11	7				**5079**
198705	245	2321	869	211	65	19	3					**3733**
198803	66	701	279	77	22	1	1					**1147**
198904	1779	1916	412	104	18	5	1					**4235**
199004	2367	1299	205	42	3							**3916**
199105	6144	7397	968	204	28	4	6	1				**14752**
199206	3463	5269	885	275	24	5	0	0				**9921**
199306	8600	1942	478	135	26	5	1					**11187**
199406	4626	10291	3052	1098	239	111	28	12				**19457**
199507	5072	3108	749	232	50	21	7					**9239**
199604	1650	2481	1801	1697	512	310	128	70	3	1	1	**8654**
199706	4329	2176	704	577	152	100	40	24	1			**8103**
199804	5388	7019	2154	986	257	123	60	25	5	1	2	**16018**
199908	4958	14831	5959	3137	890	498	183	109	18	5	4	**30592**
200005	4109	7655	3285	1849	512	287	111	56	9	1	1	**17875**
200109	951	2128	1057	2175	841	547	261	184	43	3	14	**8204**
200209	20780	17952	3544	2874	1000	643	302	193	44	9	18	**46825**

Table E14 . Percent of the number of Atlantic croaker caught during the southern leg of the fall groundfish survey in each age group; $\overline{y_{st}}$ is the stratified mean catch per tow in numbers, total number is the total number of Atlantic croaker caught during the cruise; % - 0 = the percent of the total number of Atlantic croaker at age 0 and so on; % - 4+ is the percent of the total that is greater or equal to age 5.

cruise	*Total Number*	$\overline{y_{st}}$	*% - 0*	*% - 1*	*% - 2*	*% - 3*	*% - 4*	*% - 4+*
197208	288	2.33	95.83	3.13	1.04	0.00	0.00	0.00
197308	2818	38.07	23.46	47.30	18.70	7.52	1.88	1.14
197411	7510	143.20	5.27	36.83	26.98	19.25	6.67	4.99
197512	52740	638.21	55.51	32.72	6.98	3.37	0.73	0.68
197609	18711	397.61	9.94	52.67	19.68	11.84	3.19	2.68
197712	5521	119.35	3.88	37.09	23.58	21.59	6.34	7.52
197806	9443	161.72	4.99	46.30	23.22	14.86	5.13	5.51
197910	738	15.64	41.73	38.89	8.94	6.23	1.90	2.30
198007	3844	88.53	14.49	63.03	15.09	5.36	1.12	0.91
198106	1324	31.77	17.15	54.15	17.37	7.93	2.11	1.28
198206	286	9.11	2.10	38.46	28.32	21.68	5.24	4.20
198306	11804	231.94	45.59	47.37	5.82	1.12	0.08	0.02
198405	12127	267.61	10.81	60.76	19.57	6.45	1.57	0.85
198508	1275	213.97	49.81	20.33	23.44	4.58	1.33	0.49
198606	5079	127.11	14.51	54.58	20.22	7.38	1.75	1.56
198705	3733	111.96	6.56	62.18	23.28	5.65	1.74	0.59
198803	1147	31.65	5.75	61.12	24.32	6.71	1.92	0.17
198904	4235	99.64	42.01	45.24	9.73	2.46	0.43	0.14
199004	3916	79.82	60.44	33.17	5.23	1.07	0.08	0.00
199105	14752	260.53	41.65	50.14	6.56	1.38	0.19	0.07
199206	9921	216.19	34.91	53.11	8.92	2.77	0.24	0.05
199306	11187	140.88	76.87	17.36	4.27	1.21	0.23	0.05
199406	19457	478.57	23.78	52.89	15.69	5.64	1.23	0.78
199507	9239	189.36	54.90	33.64	8.11	2.51	0.54	0.30
199604	8654	203.99	19.07	28.67	20.81	19.61	5.92	5.93
199706	8103	159.14	53.42	26.85	8.69	7.12	1.88	2.04
199804	16018	344.79	33.63	43.81	13.45	6.15	1.60	1.35
199908	30592	734.45	16.21	48.48	19.48	10.25	2.91	2.67
200005	17875	387.65	22.99	42.83	18.38	10.34	2.86	2.60
200109	8204	177.64	11.59	25.94	12.88	26.51	10.25	12.82
200209	46825	939.82	44.57	37.78	7.10	5.96	2.04	2.55

Literature cited

ALLEN,D.M. AND D.L. BARKER. 1990.
Interannual variations in larval fish recruitment to estuarine epibenthic habitats. Mar. Ecol. Prog. Ser. 63: 113-125.

AZAROVITZ, T.R. 1994.
Northeast Fisheries Science Center Bottom Trawl Surveys. In Proceedings of the workshop on the collection and use of trawl survey data for fisheries management, p. 4-7. ASMFC Special ReptNo.35

BOZEMAN, E.L.,Jr. AND JM. DEAN. 1980.
The abundance of estuarine larval and juvenile fish in a South Carolina intertidal creek. Estuaries 3: 89-97.

GROSSLEIN, M.G. 1969.
Groundfish survey program of BCF Woods Hole. Commercial Fisheries Rev. (8-9) 22-35.

KREBS, C.J..1989.
Ecological Methodology. Harper Collins, N.Y., N.Y., 654 p.

McGOVERN, J.C. AND C.A. WENNER. 1990.
Seasonal recruitment of larval and juvenile fishes into impounded and non-impounded marshes. Wetlands 10: 203-221.

NIXON, s.w. AND C.M. JONES. 1997.
Age and growth of larval and juvenile Atlantic croaker, *Micropogonias undulatus,* from the Middle Atlantic Bight and estuarine waters of Virginia. Fish. Bull. 95: 773-784.

WARLEN, S.M. 1982.
Age and growth of larvae and spawning time of Atlantic croaker in North Carolina. Proc. Annual Conf. South eastern Assoc. Fish & Wildl Agencies. 34: 204-214.

WARLEN,S.M. AND J.S. BURKE. 1990.
Immigration of larvae of fall/winter spawning marine fishes into a North Carolina estuary. Estuaries 13: 453-461.

WEINSTEIN, M.P. 1979.
Shallow marsh habitats as primary nurseries for fish and shellfish, Cape Fear River, North Carolina. Fish. Bull. 78: 419-436.

WEINSTEIN, M.P., S.L. WEISS, R.G. HODSON, AND L.R. GERRY. 1980. Retention of three species of postlarval fishes in an intensely flushed tidal estuary, Cape Fear River, North Carolina. Fish. Bull. 78:419-436.

WENNER, C.A., C.A. BARANS, B.W. STENDER, AND F.H. BERRY 1979. Results of MARMAP otter trawl investigations in the South Atlantic Bight. I. Fall, 1973. Tech. Rept. 33, S.C. Mar. Resour. Cent., Charleston, SC 29412, 78 p.

Appendix F: An Evaluation of Weighting the Likelihood terms in an Age Structured Production Model for Atlantic croaker

Data weighting has been identified as a crucial problem in modern stock assessments (NRC 1998). One of the recommendations of the review panel for Atlantic croaker was to examine the weighting of the likelihood components in greater detail. Weighting of the likelihood components has the potential to have a significant influence of the model outcome. In this report we examine possible weighting options for the Atlantic croaker model and attempt to objectively determine a suitable suite of likelihood weightings for use in the model implementation.

In the original version of the age structured production model, we gave the fleets, recruitment deviations and MRFSS index a weight of λ =1, and all fishery independent indices a weight of λ=2. In this iteration of the model we explore alternate weighting schemes in more detail.

The likelihood components fall into three groups, the fleet, index, and the recruitment deviation components. The fleet and index likelihood terms are based on the difference between the observed data and the predicted estimates. The recruitment deviation likelihood is based on differences from a mean of 0 (i.e. no deviation from the stock-recruit relationship). As such, weightings were treated in two groupings: 1) weights for the fleets and indices; and 2) weights for the recruitment deviations. Weighting profiles for the fleets and indices were examined while keeping the weight on the recruitment deviations constant at λ=1. All of the likelihood terms were estimated assuming a lognormal distribution.

To determine suitable weights for the fleets and indices we used a set of criteria to rank the relative importance/reliability of each fleet to each other and each index relative to the other indices. For the fleets, we ranked each fleet on two criteria:

1) The number of years for which data were available.
2) An estimated proportion of total landings that was determined using the available data.

For the indices we ranked each of the indices on three criteria:

1) Number of years sampled.
2) Sampling design (fishery independent/dependent)/geographical coverage.
3) Seasonal coverage of sampling within a year.

We chose three base weights that were used in a combinatorial design, to evaluate 16 weighting combinations. The four base weights were λ =3.37 (~c.v. = 0.4), λ =4.33 (~c.v. =0.35), λ =5.8 (~c.v. =0.3) and λ = 8.25 (~c.v. =0.25). In addition, we also ran the model where all weights were set to λ =1, one where the indices were set to λ =2, and the weighting method used in the previous assessment (fishery independent indices λ =2, fleet and fishery dependent indices λ=1). Table F1 summarizes the relative rankings and the weighting schemes evaluated.

To evaluate the influence of weighting, the performance statistics used were the standard deviations of the residuals for each of the indices and fleets, the total un-weighted likelihood of each of these terms, the recruitment deviation likelihood and the total un-weighted likelihood (Tables F3 and F4). We did not consider using the parameter estimates of the model (e.g. fishing mortality rates) as good indicators as it would be difficult to evaluate them objectively.

In our ranking system, the NEFSC, SEAMAP, and VIMS index received similar relative weightings and the MRFSS index ranked the lowest. In general, increasing the weight on a likelihood component resulted in a reduction in the standard deviation of the residuals. However, with the exception of the SEAMAP index the observed reductions were relatively small (Figures F1 to F4).

For the fleets, the commercial and recreational fishery received the highest relative rankings, with the scrap/discard and shrimp bycatch having low relative rankings. For the fleets, increasing λ resulted in a more marked reduction in the standard deviation of the residuals (Figures F5 to F8), indicating a better fit to those terms could be obtained.

When examining the effects of weighting options on the total likelihood, it was readily apparent that increasing the weighting on all four indices had a similar effect (Figures F9-F12). The similar trends are to be expected as the weighting of the indices are tied together through their relative rankings. In general, increasing the weightings, reduces the likelihood terms for the indices (these are the un-weighted values), but is compensated by an increase in the recruitment deviation and fleet likelihood terms. For the NEFSC and SEAMAP indices weightings > 4 appear to produce relatively small reductions in the total likelihood of the indices (Figures F9 and F11). Trends in the relationship between the un-weighted likelihood and weightings among the different fleets were similar (they too were linked by their relative ranking). For the fleets, increasing the weighting on the likelihood results lowering the fleet likelihood, with the recruitment deviation and index likelihood terms remaining relatively flat across most weighting combinations. It should be noted that for each of the fleets, the model estimates 30 parameters (a fully selected F for each year), whereas for the indices the model estimates one parameter per index (a catchability coefficient). As such, one would expect the fleets to provide a better fit, irrespective of weighting. This is reflected in the standard deviation of the residuals (Table F3).

Comparing the total un-weighted likelihood terms for the 19 model runs suggests that for most runs the total likelihood's were similar (Figure F17). In fact, the base run where all components were weighted λ=1, and the original weighting used in the previous version, produced the lowest un-weighted total likelihood. Model runs 15, 10, 5, 14, 9, 13, 'Original' and 'index x 2' had likelihood terms that were at most 15 % greater than the model run with the lowest total likelihood (the base run). With the exception of the 'Original' and 'index x 2' runs, all other runs had weighting schemes that favored the fleets over indices.

There appears little evidence to suggest that any of our weighting schemes make a meaningful reduction in the total un-weighted likelihood. However, increasing the weighting on an index or fleet will reduce the standard deviation of that component and its respective likelihood component. For the indices, it appears that forcing the model to fit the indices better results in compensation through adjusting the recruitment residuals to account for the greater confidence in those indices. It is possible that the upper bound for our weighting choices were too low. We re-did the analysis using higher base weights (λ= 10, 15 and 20). The results of that analysis were similar to the weighting scheme described in the text.

One of the disadvantages of the relative ranking of the fleets and indices is that it ties them together. A combinatorial type design, where all possible combinations of a set of weights are examined, would be an appropriate method to explore for the future. As an alternative, we ran a simulation of 5,000 runs where each weighting term was randomly and independently assigned a weight between 0 to 20 using a uniform random number generator. The results of the 5,000 simulations were enlightening. None of the 5,000 simulations had a total un-weighted likelihood less than the "base" and "original" models. There also appears to be a strong indication of a flat response surface, 60% of runs had very similar total likelihood's (Figure F18). Increasing the weighting terms reduced the standard deviation of the residuals for the NEFSC, SEAMAP and VIMS index and had less influence on he MRFSS index and fleets (Figures F19-F26).

In our examination of weighting terms, we have treated the recruitment deviations separate to the other likelihood terms. It is apparent that increasing the weight on an index is compensated by increased recruitment deviations. Preliminary runs suggest that the recruitment deviations show a correlation with those indices that have a large age 0 component. Furthermore, it is difficult to objectively determine an appropriate weighting. Maunder and Deriso (2003) through a series of simulations noted that for New Zealand snapper that a standard deviation of 0.6 was appropriate. In terms of λ, a standard deviation of 0.6 ~ 1.39, which is relatively close to our weighting of 1. Maunder and Deriso (2003) note that Beddington and Cooke (1983) found that the standard deviation of recruitment residuals for many species of fish was around 0.6. However, none of species noted in Beddington and Cooke (1983) had similar life history characteristics to Atlantic croaker. We examined the effects of increasing the weighting of the recruitment residuals on two fleet-index weighting combinations. For the fleet-index weight combinations, we chose the base run (all λ =1) and the 'original' weight combination (fishery independent indices had a λ =2 and all other terms λ =1). For the recruitment deviation weights we chose six weights. The base case was a λ =1, Other choices were λ =1.39 ~ sd=0.6 and similar to that of Maunder and Deriso (2003), λ = 3.37, 4.33, 5.8 and 8.25, values that were used for evaluating the fleet and index weighting options. Tables F4 and F5 summarize the affects of increasing the recruitment deviation weights. To summarize, increasing the weighting on the recruitment deviations, results in increasing the index and fleet likelihood's (poorer fit) and thus the total likelihood. Increasing the recruitment deviation weights constrains the model more closely to the stock-recruitment relationship. Weighting values similar to that suggested by the literature produced similar results to weightings used in the 'original' run. Choosing an appropriate weighting for the recruitment residuals should be based on our interpretation on how closely the model should follow the stock-recruitment relationship. In this version of the model, steepness is a fixed value. Preliminary runs that estimated steepness using the revised data produced steepness estimates of 1, much higher than the base case of 0.76 used.

Conclusions

Our examination of possible weighting options revealed a relatively flat response surface for the likelihood terms. It was evident that none of the weightings considered produced a fit better than the base model. Simulations indicated that increasing an individual weighting component > 5 produced relatively little reduction in the standard deviation of the residuals. We were not able to objectively determine an appropriate weighting scheme. However, subjectively, we believe that, the fishery independent indices should be given a higher weight that the fleets. Our original weighting scheme appears to be a reasonable choice for the data.

Literature Cited

Beddington, J.R. and Cooke , J.G. 1983. The potential yield of fish stocks. FAO Fish. Tech. Paper, 242: 1-47.

Maunder, M.N. and R. B. Deriso. 2003. Estimation of recruitment in catch-at-age-models. Can. J. Fish. Aquat. Sci. 60: 1204-1216.

National Research Council. 1999. Improving fish stock assessments. National Academy Press.

Table F1. Relative rankings and weighting schemes explored for fleet and index likelihood terms.

	LANDINGS				INDICES				Rec dev
	Commercial	Recreational	Scrap/discard	Shrimp bycatch	NEFSC	MRFSS	SEAMAP	VIMS	
Relative. Rank	1.00	0.59	0.19	0.13	1.00	0.37	0.93	0.75	
Base	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
Index x 2	1.00	1.00	1.00	1.00	2.00	2.00	2.00	2.00	1
Original	1.00	1.00	1.00	1.00	2.00	1.00	2.00	2.00	1
run 1	3.37	1.98	0.65	0.45	3.37	1.24	3.14	2.53	1
run 2	3.37	1.98	0.65	0.45	4.33	1.59	4.04	3.25	1
run 3	3.37	1.98	0.65	0.45	5.80	2.13	5.41	4.35	1
run 4	3.37	1.98	0.65	0.45	8.25	3.02	7.70	6.19	1
run 5	4.33	2.54	0.83	0.58	3.37	1.24	3.14	2.53	1
run 6	4.33	2.54	0.83	0.58	4.33	1.59	4.04	3.25	1
run 7	4.33	2.54	0.83	0.58	5.80	2.13	5.41	4.35	1
run 8	4.33	2.54	0.83	0.58	8.25	3.02	7.70	6.19	1
run 9	5.80	3.40	1.11	0.77	3.37	1.24	3.14	2.53	1
run 10	5.80	3.40	1.11	0.77	4.33	1.59	4.04	3.25	1
run 11	5.80	3.40	1.11	0.77	5.80	2.13	5.41	4.35	1
run 12	5.80	3.40	1.11	0.77	8.25	3.02	7.70	6.19	1
run 13	8.25	4.84	1.58	1.10	3.37	1.24	3.14	2.53	1
run 14	8.25	4.84	1.58	1.10	4.33	1.59	4.04	3.25	1
run 15	8.25	4.84	1.58	1.10	5.80	2.13	5.41	4.35	1
run 16	8.25	4.84	1.58	1.10	8.25	3.02	7.70	6.19	1

Table F2 Summary of Likelihood terms for model weighting schemes evaluated. Filled cells indicate lowest likelihood for term.

	Index likelihood				Fleet likelihood				Total likelihood		
Run	NEFSC	MRFSS	SEAMAP	VIMS	COMM	REC	Scrap/disc	Shrimp	Fleet + Index	Rec. dev	Total
Base	10.69	4.25	2.93	12.14	0.19	0.02	0.45	1.00	31.67	9.60	41.27
Index x 2	9.96	4.08	2.64	9.90	0.27	0.04	0.87	1.14	28.91	13.73	42.64
Original	9.95	4.75	2.55	9.68	0.27	0.04	1.09	1.04	29.37	13.31	42.68
run 1	7.56	4.94	2.42	10.32	0.05	0.02	3.37	6.32	35.01	13.92	48.94
run 2	7.21	4.94	2.39	9.57	0.07	0.03	3.81	9.85	37.86	15.59	53.45
run 3	6.90	4.91	2.35	8.74	0.09	0.04	4.48	14.76	42.27	17.73	60.00
run 4	6.14	5.37	2.35	7.65	0.17	0.07	16.90	16.37	55.02	20.41	75.43
run 5	7.92	4.85	2.42	10.56	0.03	0.01	2.42	3.73	31.94	14.35	46.29
run 6	7.49	4.87	2.39	9.94	0.04	0.02	2.96	6.34	34.06	15.79	49.85
run 7	7.08	4.89	2.36	9.11	0.06	0.03	3.42	11.15	38.10	17.82	55.92
run 8	6.74	4.87	2.32	8.19	0.10	0.04	4.36	17.84	44.45	20.50	64.95
run 9	8.32	4.70	2.41	10.68	0.02	0.01	1.41	2.09	29.64	15.03	44.67
run 10	7.98	4.70	2.38	10.23	0.02	0.01	1.88	3.19	30.39	16.32	46.72
run 11	7.43	4.79	2.36	9.60	0.04	0.02	2.54	6.67	33.44	17.90	51.33
run 12	6.99	4.84	2.34	8.64	0.06	0.03	3.15	12.83	38.88	20.30	59.18
run 13	8.61	4.60	2.40	10.77	0.01	0.00	0.70	1.22	28.30	15.78	44.08
run 14	8.43	4.54	2.36	10.35	0.01	0.00	0.92	1.55	28.17	17.14	45.31
run 15	8.13	4.54	2.34	9.95	0.02	0.01	1.37	2.47	28.81	18.51	47.33
run 16	7.40	4.71	2.34	9.30	0.03	0.01	2.20	7.00	32.99	20.16	53.15

Table F3. Summary of residual standard deviations for model weighting runs

Run	NEFSC	MRFSS	SEAMAP	VIMS	COMM	REC	Scrap/Disc	Shrimp
	Resid Std Dev				Resid Std Dev			
Base	0.607	0.450	0.475	0.647	0.067	0.023	0.124	0.181
Index x 2	0.586	0.441	0.451	0.584	0.084	0.032	0.172	0.194
Original	0.586	0.475	0.442	0.578	0.085	0.035	0.192	0.187
run 1	0.511	0.485	0.432	0.596	0.037	0.024	0.335	0.456
run 2	0.499	0.485	0.429	0.574	0.042	0.028	0.357	0.567
run 3	0.488	0.483	0.425	0.549	0.049	0.033	0.389	0.690
run 4	0.460	0.506	0.425	0.513	0.066	0.044	0.744	0.736
run 5	0.522	0.480	0.431	0.604	0.029	0.019	0.284	0.351
run 6	0.508	0.482	0.429	0.586	0.035	0.023	0.315	0.457
run 7	0.494	0.483	0.426	0.561	0.041	0.028	0.340	0.603
run 8	0.482	0.482	0.423	0.531	0.050	0.034	0.385	0.759
run 9	0.536	0.473	0.430	0.607	0.022	0.015	0.218	0.264
run 10	0.525	0.473	0.428	0.594	0.026	0.017	0.251	0.325
run 11	0.506	0.477	0.426	0.575	0.032	0.022	0.293	0.470
run 12	0.491	0.480	0.424	0.546	0.041	0.027	0.327	0.647
run 13	0.545	0.468	0.430	0.609	0.016	0.010	0.153	0.201
run 14	0.539	0.465	0.426	0.597	0.018	0.012	0.177	0.227
run 15	0.529	0.465	0.424	0.586	0.022	0.015	0.215	0.287
run 16	0.505	0.474	0.425	0.566	0.030	0.020	0.273	0.482

Table F4. Likelihood estimates for individual indices and fleets under different recruitment-deviation weights.
Model runs 1 to 6 represent all fleets and indices with λ =1. Model runs 7-12 represent the 'original' index weighting scheme where all the fleets and MRFSS index had λ =1 and the fishery independent indices had λ=2.

		Likelihood Individual Index				Likelihood Individual Fleet			
Run	Rec_Dev Wt	NEFSC	MRFSS	SEAMAP	VIMS	COMM	REC	Scrap/Disc	Shrimp
1	1	10.69	4.25	2.93	12.14	0.19	0.02	0.45	1.00
2	1.39	11.07	4.28	3.14	13.49	0.27	0.03	0.64	1.38
3	3.37	12.26	4.11	3.94	18.06	0.61	0.04	1.55	3.03
4	4.33	12.56	4.03	4.21	19.48	0.72	0.05	1.92	3.65
5	5.8	12.99	3.88	4.54	21.19	0.81	0.05	2.18	4.46
6	8.25	13.47	3.71	4.92	23.17	0.91	0.06	2.54	5.45
7	1	9.95	4.75	2.55	9.68	0.27	0.04	1.09	1.04
8	1.39	10.01	4.92	2.65	10.50	0.39	0.06	1.58	1.33
9	3.37	10.73	4.93	3.13	13.74	0.79	0.09	2.54	2.96
10	4.33	11.03	4.81	3.33	14.99	0.91	0.09	2.71	3.69
11	5.8	11.39	4.63	3.59	16.58	1.05	0.10	2.97	4.65
12	8.25	11.84	4.40	3.94	18.57	1.22	0.11	3.33	5.88

Table F5. Total likelihood components for indices fleets and recruitment deviations different recruitment-deviation weights. Model runs 1 to 6 represent all fleets and indices with λ =1. Model runs 7-12 represent the 'original' index weighting scheme where all the fleets and MRFSS index had λ =1 and the fishery independent indices had λ=2.

	Weightings									Un-weighted Likelihood			
Run	Rec_Dev	NEFSC	MRFSS	SEAMAP	VIMS	COMM	REC	Scrap /Discard	Shrimp	Rec Dev	Fleet	Index	Total
1	1	1	1	1	1	1	1	1	1	9.60	1.66	30.00	41.27
2	1.39	1	1	1	1	1	1	1	1	7.37	2.32	31.98	41.67
3	3.37	1	1	1	1	1	1	1	1	3.02	5.24	38.38	46.63
4	4.33	1	1	1	1	1	1	1	1	2.23	6.34	40.29	48.85
5	5.8	1	1	1	1	1	1	1	1	1.53	7.51	42.60	51.64
6	8.25	1	1	1	1	1	1	1	1	0.93	8.95	45.27	55.15
7	1	2	1	2	2	1	1	1	1	13.31	2.45	26.92	42.68
8	1.39	2	1	2	2	1	1	1	1	10.72	3.35	28.09	42.16
9	3.37	2	1	2	2	1	1	1	1	5.21	6.38	32.52	44.11
10	4.33	2	1	2	2	1	1	1	1	4.06	7.41	34.15	45.62
11	5.8	2	1	2	2	1	1	1	1	2.93	8.77	36.19	47.89
12	8.25	2	1	2	2	1	1	1	1	1.90	10.55	38.75	51.20

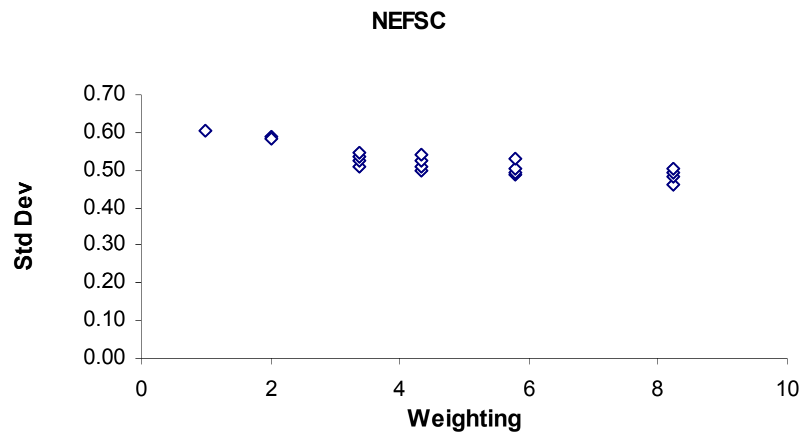


Figure F1. Comparison of standard deviation of residuals to weight applied to the NEFSC trawl index

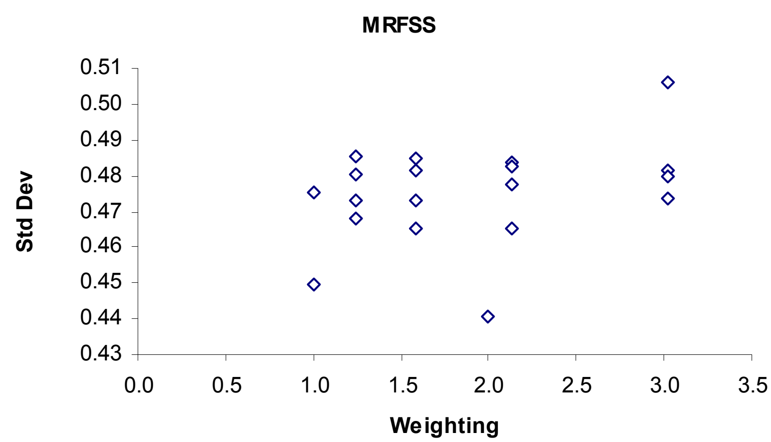


Figure F2. Comparison of standard deviation of residuals to weight applied to the MRFSS index

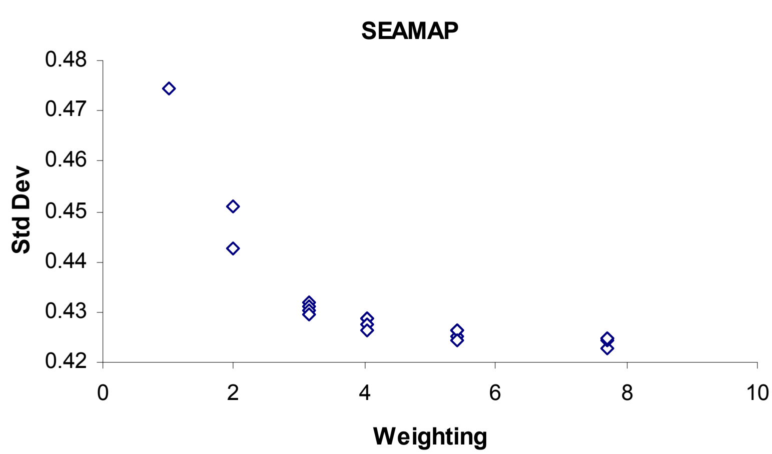


Figure F3. Comparison of standard deviation of residuals to weight applied to the SEAMAP index

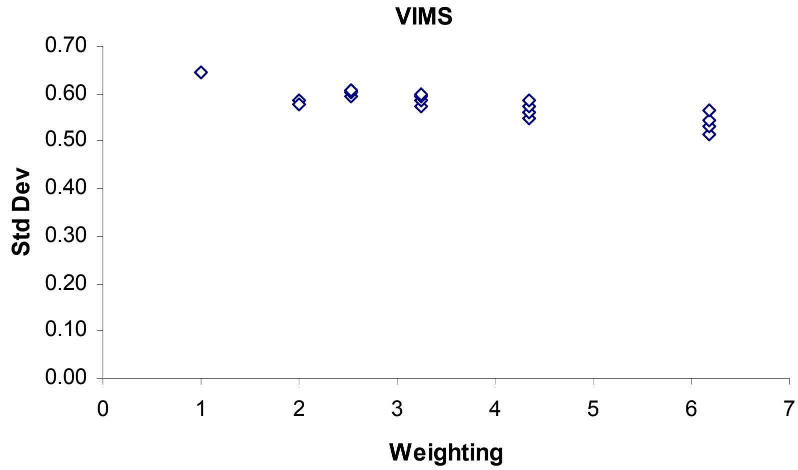


Figure F4. Comparison of standard deviation of residuals to weight applied to the VIMS index.

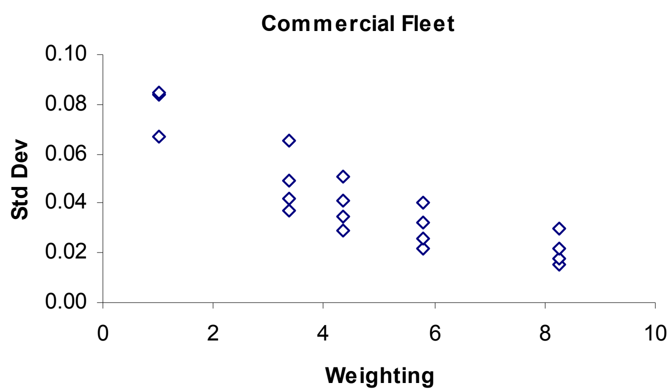


Figure F5. Comparison of standard deviation of residuals to weight applied to the Commercial fleet.

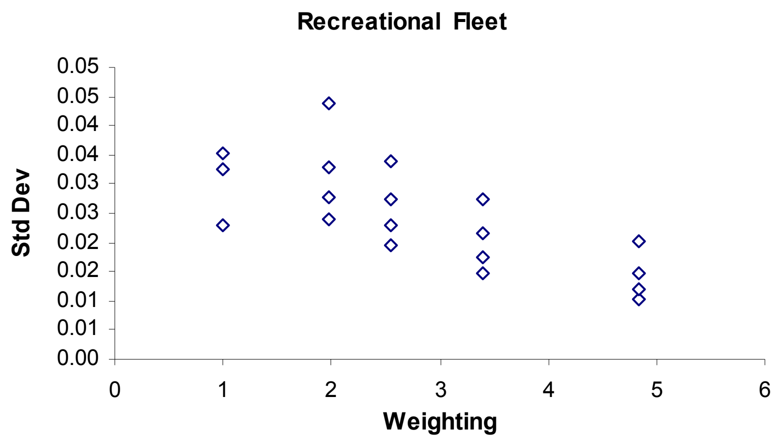


Figure F6. Comparison of standard deviation of residuals to weight applied to the recreational fleet.

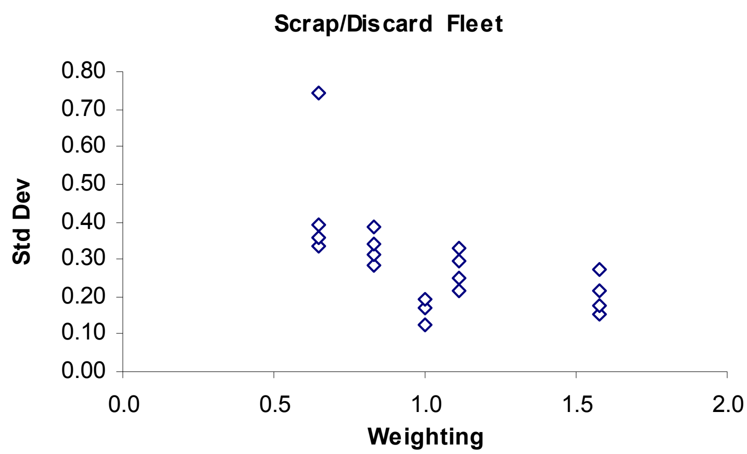


Figure F7. Comparison of standard deviation of residuals to weight applied to the scrap/discard fleet.

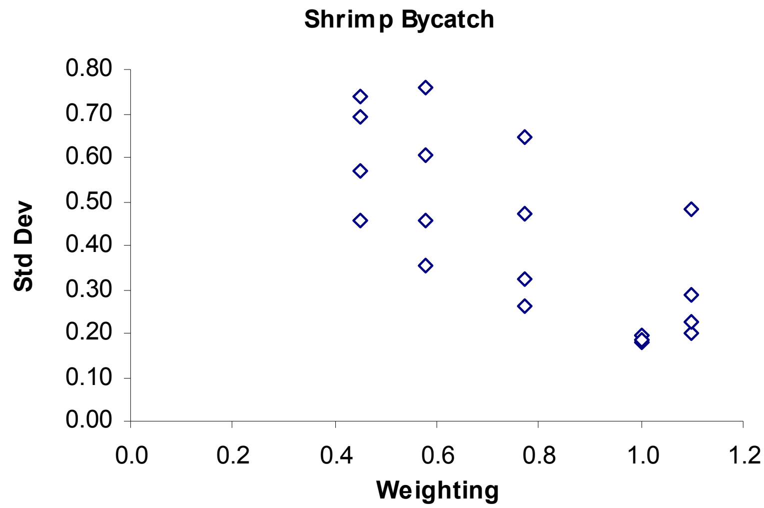


Figure F8. Comparison of standard deviation of residuals to weight applied to the shrimp bycatch fleet.

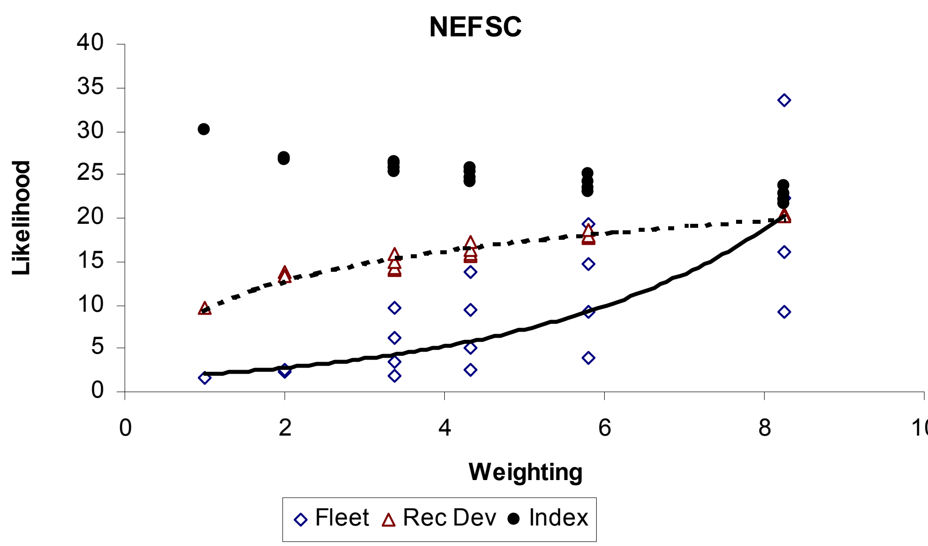


Figure F9. The influence of weighting of the NEFSC index on the likelihood components. Fleet= total likelihood of the fleets. Rec Dev = recruitment deviation component. Index= total likelihood of all indices. The dotted line represents a trend line for the recruitment deviations and the solid line the trend line for the fleets

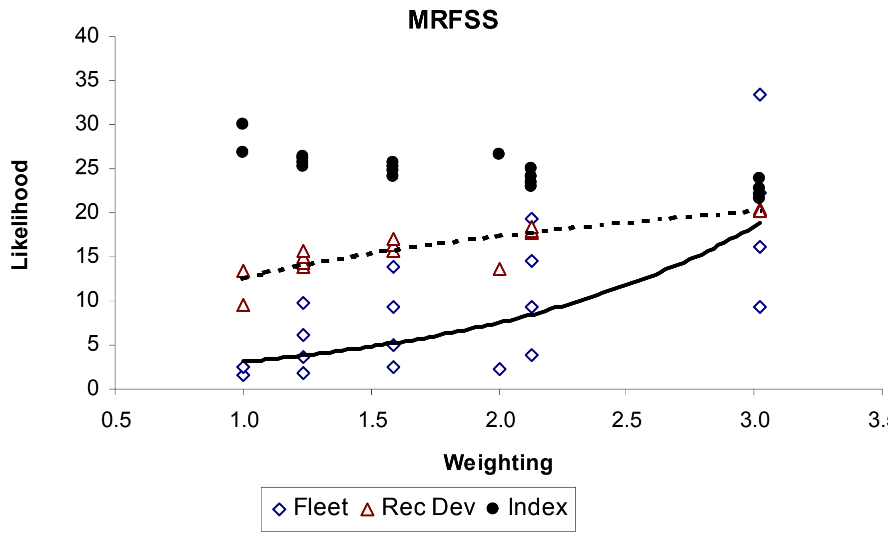


Figure F10. The influence of weighting of the MRFSS index on the likelihood components. Fleet= total likelihood of the fleets. Rec Dev = recruitment deviation component. Index= total likelihood of all indices. The dotted line represents a trend line for the recruitment deviations and the solid line the trend line for the fleets.

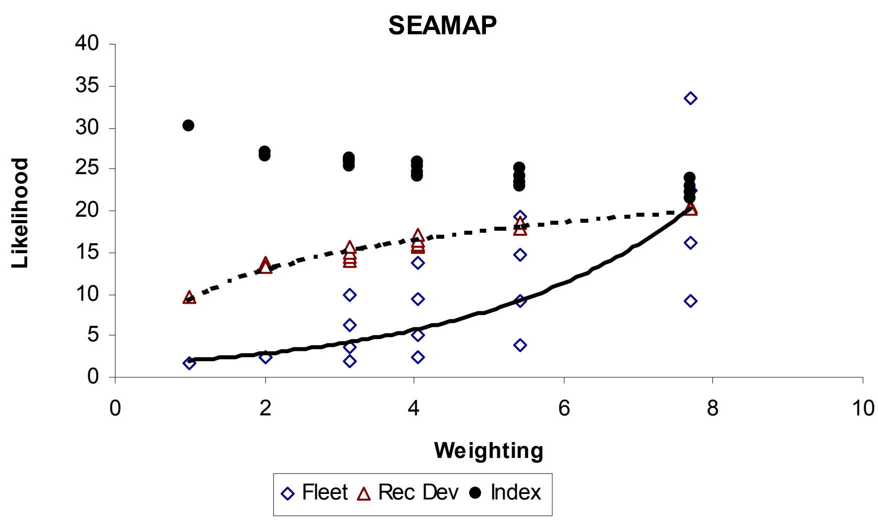


Figure F11. The influence of weighting of the SEAMAP index on the likelihood components. Fleet= total likelihood of the fleets. Rec Dev = recruitment deviation component. Index= total likelihood of all indices. The dotted line represents a trend line for the recruitment deviations and the solid line the trend line for the fleets.

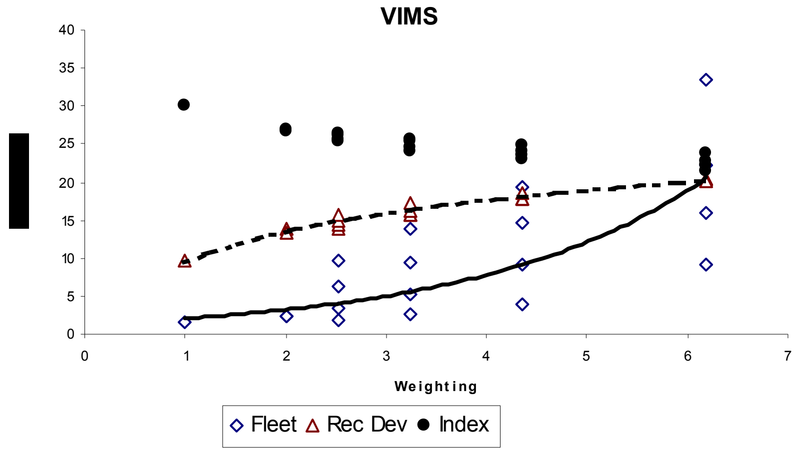


Figure F12. The influence of weighting of the VIMS index on the likelihood components. Fleet= total likelihood of the fleets. Rec Dev = recruitment deviation component. Index= total likelihood of all indices. The dotted line represents a trend line for the recruitment deviations and the solid line the trend line for the fleets.

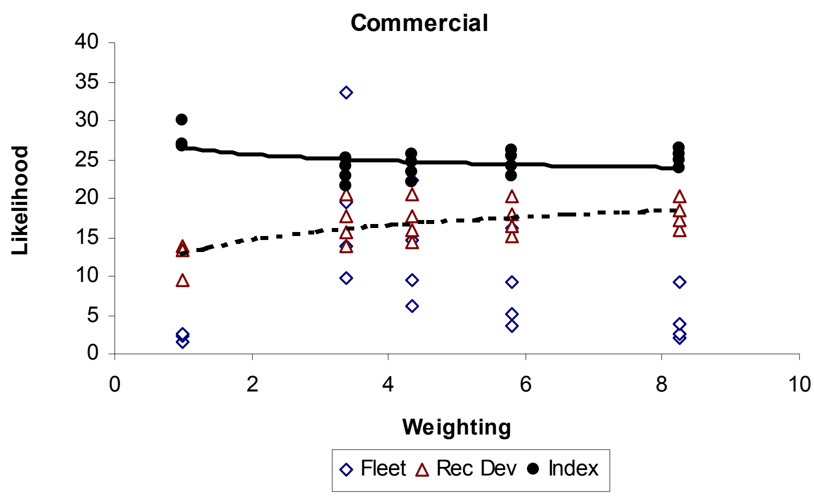


Figure F13. The influence of weighting of the commercial fleet on the likelihood components. Fleet= total likelihood of the fleets. Rec Dev = recruitment deviation component. Index= total likelihood of all indices. The dotted line represents a trend line for the recruitment deviations and the solid line the trend line for the indices.

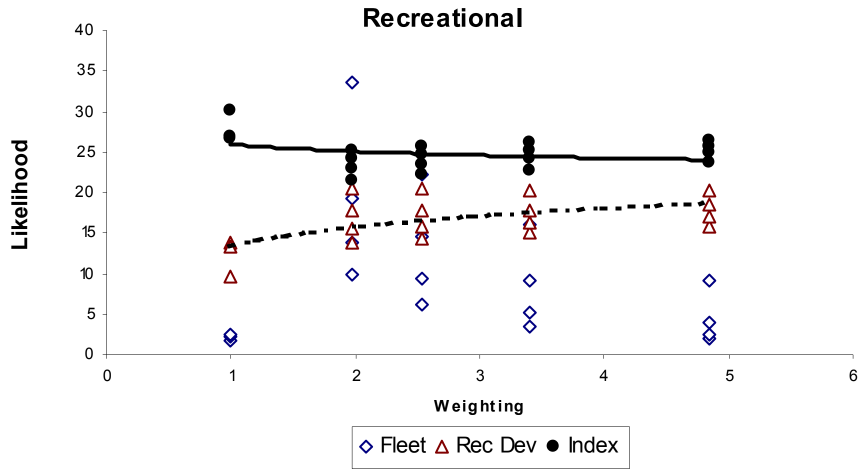


Figure F14. The influence of weighting of the recreational fleet on the likelihood components. Fleet= total likelihood of the fleets. Rec Dev = recruitment deviation component. Index= total likelihood of all indices. The dotted line represents a trend line for the recruitment deviations and the solid line the trend line for the indices.

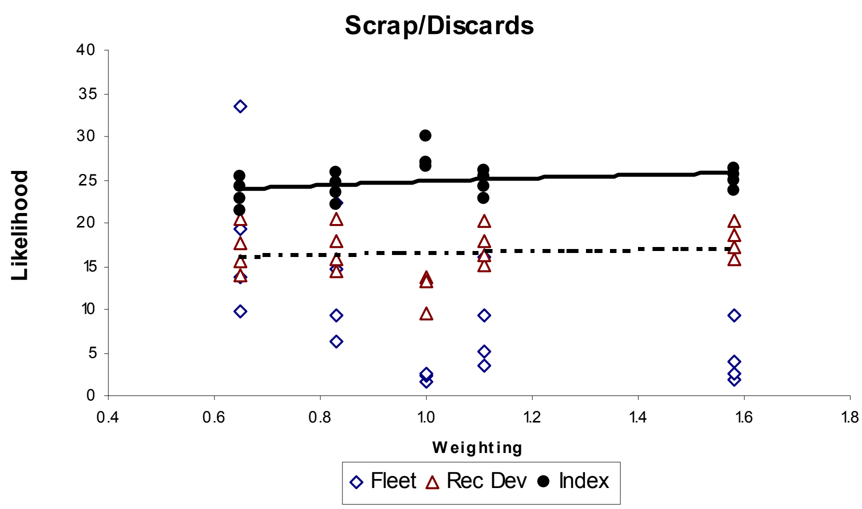


Figure F15. The influence of weighting of the scrap/discards on the likelihood components. Fleet= total likelihood of the fleets. Rec Dev = recruitment deviation component. Index= total likelihood of all indices. The dotted line represents a trend line for the recruitment deviations and the solid line the trend line for the indices.

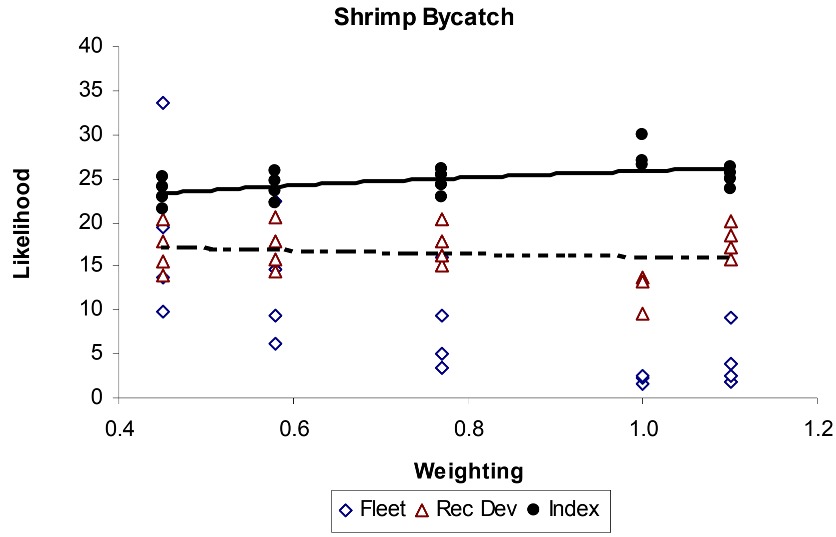


Figure F16. The influence of weighting of the shrimp bycatch on the likelihood components. Fleet= total likelihood of the fleets. Rec Dev = recruitment deviation component. Index= total likelihood of all indices. The dotted line represents a trend line for the recruitment deviations and the solid line the trend line for the indices.

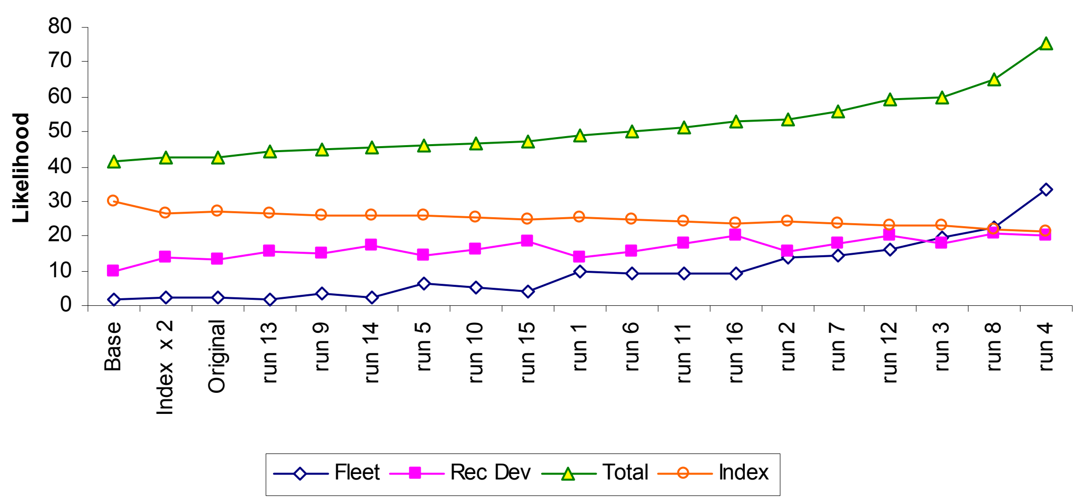


Figure F17. Total likelihood and major likelihood components across model runs.

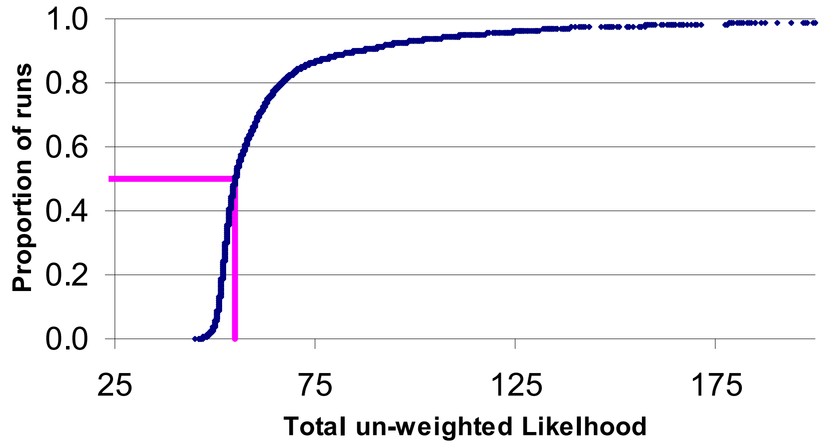


Figure F18. The cumulative proportion of 5,000 simulations relative to the total un-weighted likelihood of each run. The solid line indicates the median likelihood of the 5000 simulations (55.07).

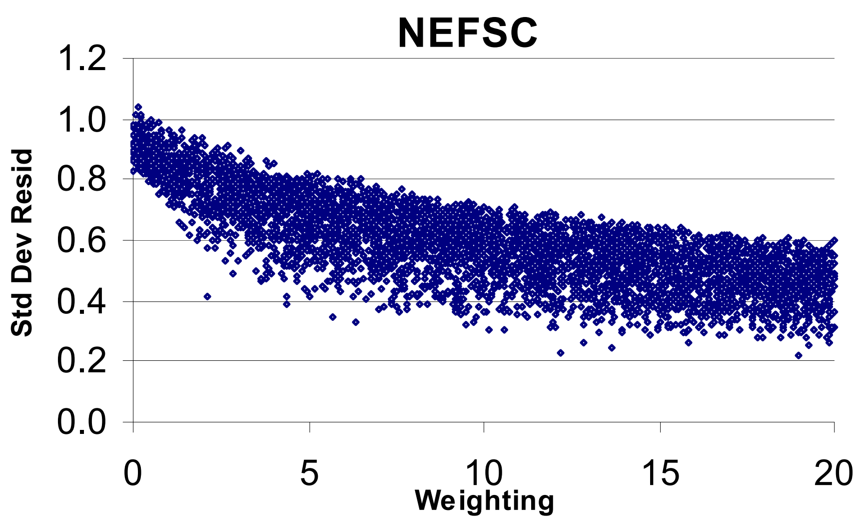


Figure F19. The association between the standard deviation of the residuals and weighting (λ) for the NEFSC index based on 5,000 simulations.

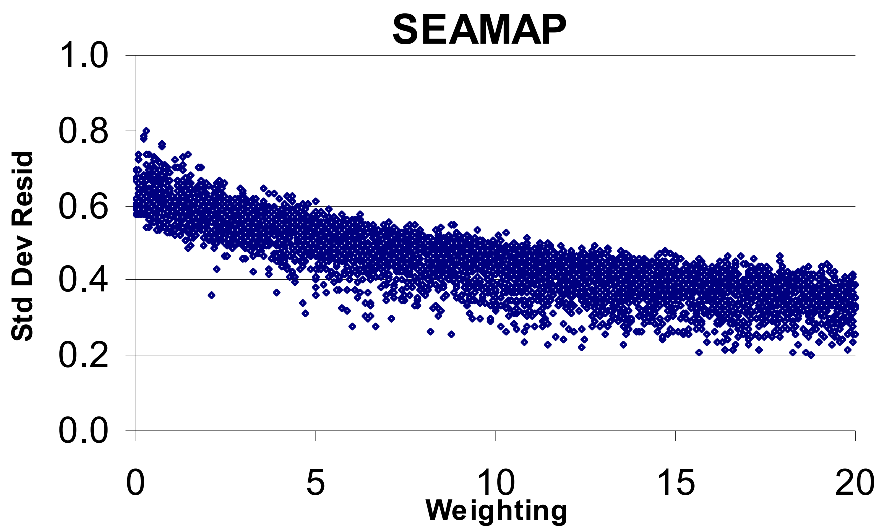


Figure F20. The association between the standard deviation of the residuals and weighting (λ) for the SEAMAP index based on 5,000 simulations.

.

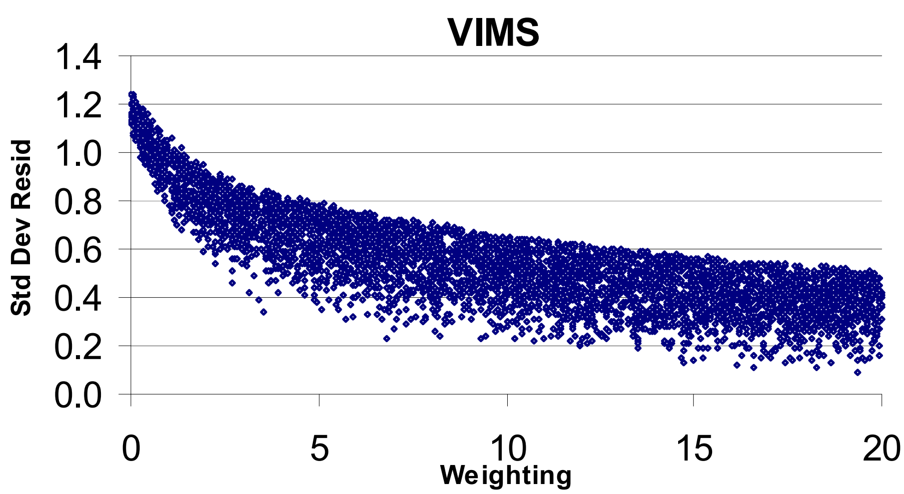


Figure F21. The association between the standard deviation of the residuals and weighting (λ) for the VIMS index based on 5,000 simulations

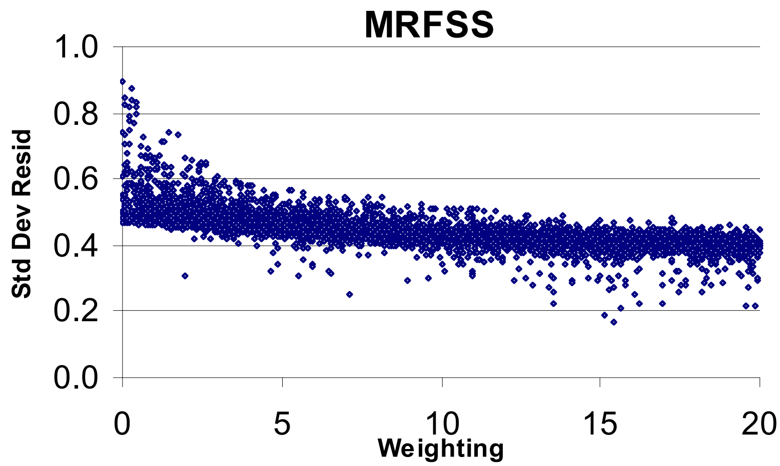


Figure F22. The association between the standard deviation of the residuals and weighting (λ) for the MRFSS index based on 5,000 simulations.

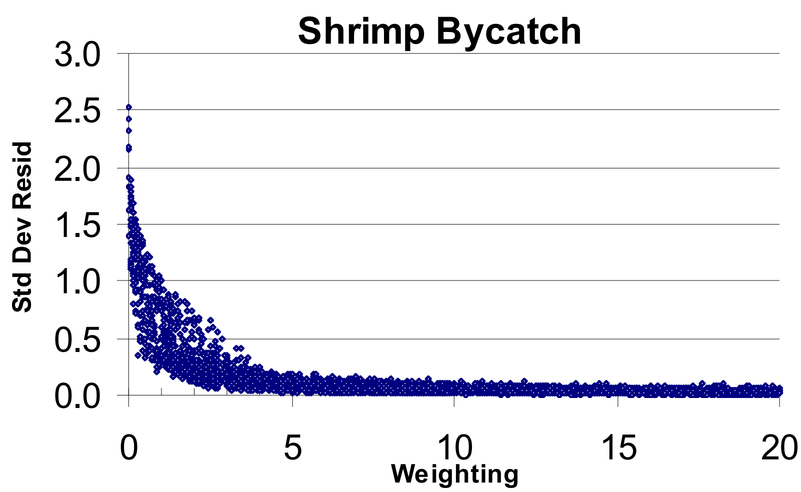


Figure F23. The association between the standard deviation of the residuals and weighting (λ) for the shrimp bycatch based on 5,000 simulations

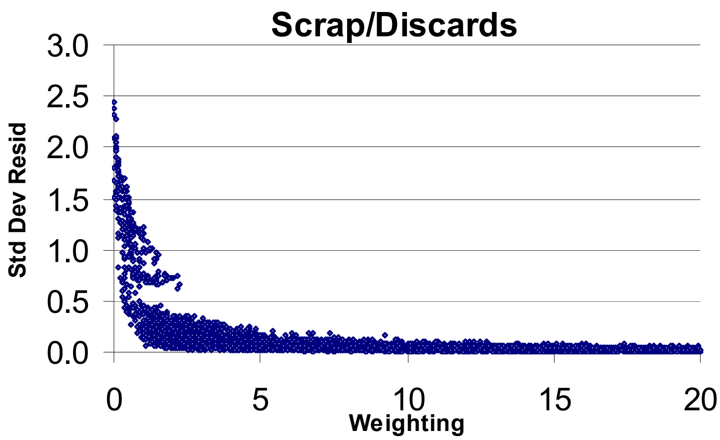


Figure F24. The association between the standard deviation of the residuals and weighting (λ) for the scrap/discards based on 5,000 simulations.

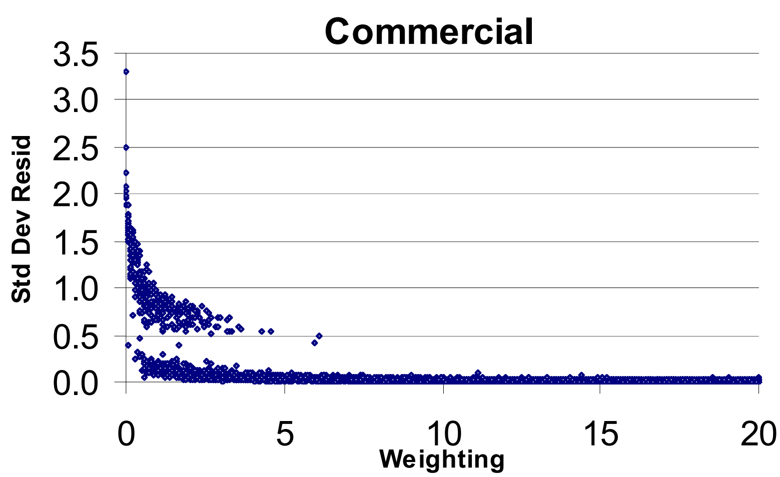


Figure F25. The association between the standard deviation of the residuals and weighting (λ) for the commercial landings based on 5,000 simulations.

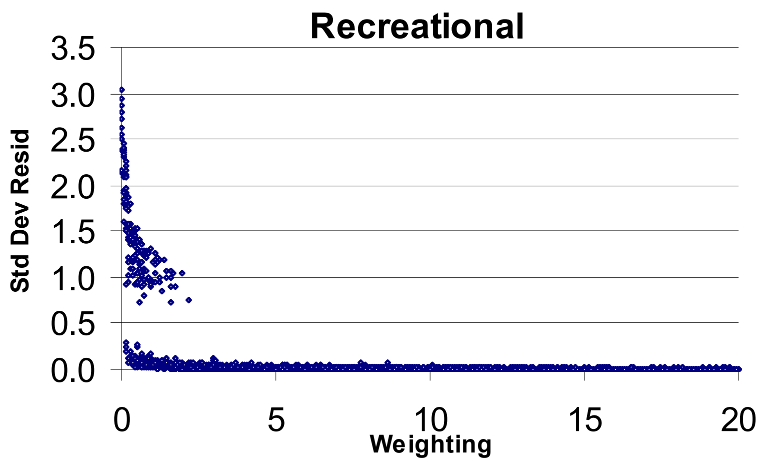


Figure F26. The association between the standard deviation of the residuals and weighting (λ) for the recreational landings based on 5,000 simulations.

Appendix G. A re-assessment of the status of the Atlantic croaker population in the Mid-Atlantic (New York to North Carolina).

The recent review of the Atlantic States Marine Fisheries Commission (ASMFC) Atlantic croaker stock assessment identified seven areas of concern. The ASMFC Atlantic croaker management board prioritized the recommendations of the peer review panel and identified four issues that the Atlantic croaker technical committee (TC) needed to address immediately. The management board also made the decision to use an analytical model that only incorporated data from the mid-Atlantic (North Carolina to New York) but requested the TC to evaluate the basis for this at a later date (Issue 5 – review panel recommendations). This report does not address developing alternate modeling approaches such as the Collie-Sissenwine catch survey and delay-difference models (Issue 6 of review panel recommendations).

We summarize the changes made to the age structured production model and the results from the revised version.

Summary of Changes

In this revision of the model the following changes were made:

1) Estimates of North Carolina and Virginia's scrap landings were included in the model. A model where scrap estimates were treated as a separate component was chosen over one where scrap landings were included as part of the commercial landings.
2) Using data from the NEFSC observer database, estimates of at-sea discards for the gill net and otter trawl fishery have been included.
3) The NEFSC trawl survey index has been extended to the entire time series, and the stratified mean estimates in numbers were used.
4) The VIMS spring index has been included in the model.
5) The model now estimates initial SSB: SBB virgin ratio.
6) The selectivity patterns used for the fleets has been refined using selectivity patterns estimated from an 'un-tuned' separable VPA by incorporating the length and age data for Virginia's and North Carolina's commercial fishery (1989-2002) and the recreational fishery's size distribution (1981-2002).
7) Commercial landings for 2002 were updated.

Data changes

Harvest and discards

The major changes in landings data were the inclusion of scrap estimates from North Carolina and Virginia and at-sea discards from the gill net and trawl fishery. The technical committee also evaluated the potential inclusion of shrimp bycatch estimates, but decided the data quality was poor and had little confidence in the estimates. However, the implications of not including estimates of Atlantic croaker bycatch in the shrimp fishery were evaluated through sensitivity analysis. For the scrap landings, the model includes estimates developed by the North Carolina Division of Marine Fisheries (NCDMF) of Atlantic croaker scrap (bait) for 1986 to 2002 (see Appendix A for detailed report). For estimates of North Carolina's scrap landings from 1973-1985, the technical committee evaluated estimates created using a variety of methods and determined the most appropriate estimates were those based on the average ratio of scrap to unclassified finfish landings from the NMFS database between 1986-1990 (see Appendix A for details). In the model, scrap landings and discards have been combined. It was assumed that the selectivity pattern and size distribution of the discards would be similar to the scrap landings. Commercial landings for 2002 were updated from the NMFS database. Landings estimates used in the revised model are presented in Table G1.

Between 1973 and 2002 the relationship the different sources of removals has changed. From 1973 and 1995 scrap/discards accounted for an average 20% of the annual removals (ranged between 14-30 %). From 1996-2002, scrap/discards accounted for an average 3% of the removals. Estimates of scrap/discards reached their peak in 1979 (3,200 MT) and since then shown declined to their lowest levels in 2002 (425 MT). Between 1973 and 1995, scrap/discard removals averaged 1,687 MT per year, whereas between 1996-2002 scrap/discards averaged 595 MT per year.

Indices

In the revised model, data from the NEFSC trawl survey was re-examined (see Appendix E for details). Estimates used in the model are based on the stratified means in numbers from 1973 to 2002 (Appendix E).

In addition, the Virginia Institute of Marine Science (VIMS) spring trawl index was included in the revised model. This index is a young-of -year (YOY) index and estimates are the geometrical mean in numbers. While this index is spatially limited to Chesapeake Bay, it extends across the time series (1973-2002). Preliminary analysis revealed that the pattern in recruitment deviations were closely associated with indices that had a strong age 0 component. The TC concluded that including the VIMS index into the revised model was beneficial, in that recruitment deviations would be more closely associated with an additional index and would also help in the estimation of parameters in the stock-recruit relationship. Preliminary analyses revealed that unless the model included abundance indices that covered the early part of the time series (~1973), the initial SSB: SSB virgin ratio was poorly estimated. Indices used in the revised model are presented in Table G2.

Model changes

The technical committee considered the options available for incorporating the scrap/discard landings into the model. The two options were:

1) Including the scrap landings as a "pseudo fleet" with its unique selectivity pattern.
2) Incorporating the scrap landings into the commercial landings and adjusting the selectivity pattern accordingly.

The technical committee evaluated the advantages and disadvantages of the two model configurations. For the two fleet model, where scrap/discards were included with the commercial landings, advantages include a model with fewer parameters. Including the scrap/discards with the commercial fleet is intuitively pleasing, as it is a component of the commercial landings. However, the scrap/discards tend to be small fish, with a different selectivity pattern to that of the landings (see selectivity section). In addition, there was evidence that the relationship between scrap and landings has not been constant across the time series. This was clearly evident for data from North Carolina. As such, the TC concluded treating the scrap/discards as a 'pseudo fleet' was the most appropriate way to include the data in the model. The two model configurations produced similar parameter estimates and fishing mortality rates for the recent time series. However, estimates of the fully selected fishing mortality rates for the commercial fishery in the two fleet model, reached the upper bound for some years in the early part of the time series. To account for different selectivity patterns among the fleets, the fishing mortality rates are expressed as the average fishing mortality rate from ages 1 to 10+, weighted by population size.

In addition, the revised model estimates the initial SSB: SSB Virgin ratio. In the original version, the initial SSB:SSB virgin ratio was set to 0.75 and included as a term in the sensitivity runs.

For the base model, the steepness (0.76), natural mortality (0.3), growth, and length-weight relationships used were similar to those in the original version.

Selectivity

An important deterministic component of the age structured production model is the selectivity pattern used for each of the fleets and indices. As this re-analysis included estimates of at-sea discards and the scrap landings from Virginia and North Carolina, which comprise of the majority of landings, the available data from these two states were re-evaluated and used to describe the selectivity components of the fleets.

Data and methods for estimating selectivity of fleets

For North Carolina, landings of the marketable Atlantic croaker and scrap by gear type and year in numbers had been estimated by the NCDMF (NCDMF 2003). In addition, the NCDMF had also estimated the length composition of the marketable landings and scrap by gear type from 1986 to 2002 (NCDMF 2003).

For Virginia, the Virginia Marine Resources Commission (VMRC) collected length-weight data characterizing the commercial fishery from 1989 to 2002 by gear and market category. In addition, landings by gear type and market category (in pounds) were also available from the VMRC from 1989-2002. Landings in numbers and size-class were estimated from 1989-2002 by gear and market category using the VMRC bio-profile data on length and weight (in 20 mm size classes). Using the length-weight data for each market and gear category, the landings in numbers were then estimated using the size-weight relationship. For Virginia's scrap component, the truncated size distribution (all fish less than 8 inches and 50% of fish of 9 inches TL) was used to estimate the scrap component (see section on estimating Virginia Scrap landings).

For the recreational fishery, an annual weighted size distribution had been developed for the mid-Atlantic from 1981 –2002 (see section 5.2.1.6 in original report).

As North Carolina and Virginia account for more than 90 % of the commercial landings of Atlantic croaker, using a catch-at-age matrix based on the data from these states would provide a reasonable description of selectivity patterns for the commercial fishery. Using the North Carolina otolith age database, an age-length key was developed combining data from all years and gear types in 20 mm intervals. Using the available bio-profile data, a set of catch-at-age matrices for the Virginia's and North Carolina's market and scrap landings were developed for the period 1989 to 2002 and the mid-Atlantic recreational landings from 1981-2002. In developing the catch at age matrices length classes of 20 mm were used as some of the length data was in 20mm increments. Given the lack of length data prior to the mid-1980's it was assumed that the selectivity pattern based on the period 1989-2002 would be applicable to the early part of the time series (1973-1988).

Three composite catch-at-age matrices were developed for the commercial landings.

1) An annual market grade catch-at-age matrix for landings from North Carolina and Virginia was developed (1989-2002).
2) An annual scrap grade catch-at-age matrix for estimates from North Carolina and Virginia was developed (1989-2002).
3) Market and scrap catch-at-age matrices from North Carolina and Virginia were combined to produce an annual catch-at-age matrix for scrap and market grades combined (1989-2002).

Catch-at-age matrices for the commercial, scrap, and recreational fishery are shown in Tables G3 to G5.

An 'un-tuned' separable VPA (Clay 1990) was used to estimate the selectivity patterns for each of the three composite commercial catch at age matrices and the recreational catch at age matrix. The separable VPA uses Pope and Shepard's (1982) method for estimating selectivity. Input parameters for the model include a catch-at-age matrix, an estimate of a fully selected age, shape of selectivity curve (dome or flat), and terminal fishing mortality rate. In estimating selectivity patterns for the different components, a series of terminal fishing mortality rates between 0.1-0.3 were used. Selectivity patterns were insensitive to the choice of terminal fishing mortality rate. For the combined market and scrap catch-at age-matrix, market catch-at-age matrix and recreational catch-at-age, a flat-topped selectivity pattern was used where the ascending limb was estimated. For these components, a fully selected age of four was used. For the scrap catch-at-age component, a dome shaped selectivity pattern was used, and a fully selected age of one was used. Based on the model output, choices used for the fully selected ages for each of the components appeared to be appropriate.

The selectivity patterns for the four fleet components are presented in Table G6. The selectivity patterns for the MRFSS and NEFSC indices were also revised. For the NEFSC index, the age composition of the index (see Appendix E) was used to revise the original selectivity pattern. The selectivity pattern for the MRFSS index was used to model the recreational fleets. Since the VIMS index is an age 0 index, age 0 was considered fully selected (1), and all other ages were set at 0 (Table G7).

Output/results

Goodness of fit of model used

The goodness of fit of statistical model is judged by how well the predicted estimates match the observed estimates. In general, the base model appeared to fit the data well, with few outliers. Examination of the standardized residuals for each of the fleet components indicates few data points exceeded an absolute value of 2.0 (Figure G1). However, for the commercial and recreational fleets, predicted estimates slightly underestimated landings in recent years. For the indices, standardized residuals also indicated few outliers (absolute values > 2), and there appeared to be little sign of serial correlation in the error terms. However, for the NEFSC trawl survey, while the model captured the general trend of the index, it poorly fitted the peak estimates of 1975, 1994, 1999, and 2002. For these years, estimates were on average two times greater than estimates in adjacent years (Table G2). The predicted estimates of the other indices also captured the general trends of their respective indices adequately. However, as with the NEFSC trawl index, peak estimates for 1999 in the MRFSS, 1992 in the SEAMAP, and 1983-86 in the VIMS index were underestimated. For the period

1983-86 the VIMS index indicated higher than average estimates, whereas the NEFSC and MRFSS indices indicated relatively low estimates during this period.

Parameter estimates

In the revised model, 125 parameters were estimated. The estimated parameters include the initial SSB: SSB virgin ratio, the number of virgin recruits (R_0), a catchability coefficient for each of the indices (4), an annual recruitment deviation from the stock-recruit relationship for 1974-2002 (29), and a fully selected fishing mortality rate for each of the fleets (90). For the base model estimated R_0 at 170 million fish, the initial SSB: SSB virgin ratio at 0.296, the catchability coefficient for the NEFSC index at 6.53778E-07, the catchability coefficient of the MRFSS index at 2.71784E-09, the catchability coefficient of the SEAMAP index at 2.54743E-06 and the catchability coefficient of the VIMS index at 6.71846E-09. Estimates of the fully recruited fishing mortality estimates and recruitment deviations from the base model are presented in Table G8.

Exploitation rates

In the revised model, fishing mortality rates (F) are based on the average population weighted F for ages 1-10+. Exploitation rates (*u*) are expressed as the predicted catch (in numbers)/ population estimate (in numbers). Unless, otherwise noted fishing mortality rates referred to in the text are to the average instantaneous fishing mortality rate.

Fishing mortality rates for Atlantic croaker exhibit a cyclical trend over the time series. From 1977 to 1979, F rose rapidly reaching a maximum of 0.5 in 1979. From 1980 onwards, F rapidly declined reaching its lowest levels in 1992 (Figure G3; Table G8). Since 1993, F has gradually increased and between 1997 and 2002 remained relatively stable at around 0.11 (Figure G3; Table G8). Exploitation rates followed a similar trend to F, reaching it's maximum in 1979 (*u*=0.25; Table G8). Exploitation rates in recent years (1997-2002) have been low ranging between 0.05 and 0.08 (Table G8).

Abundance estimates

For the base mid-Atlantic run, the trend in population abundance indicates a step-wise increase reaching a peak of 974 million fish in 1999 (Table G9). Population estimates from 1999 to 2002 have ranged from 663 to 974 million fish. The number of age 0 fish in the population exhibited a series of periodic spikes in 1975, 1983, 1991, 1998, and 2002 (Figure G4; Table G9). Between 1999 and 2002 the number of age 0 fish have ranged between 100-375 million fish. Spawning stock biomass estimates (estimated as the proportion of mature females) exhibit a cyclical trend over the time series. From the early 1970's to 1983 spawning stock biomass declined to its lowest level (11,746 MT). Since 1984, spawning stock biomass has increased in three distinct phases, with estimates reaching a maximum in 1996 (Figure G4, Table G9). Between 1999 and 2002 spawning stock biomass estimates have ranged between 80-91,000 metric tons (Table G9).

Precision of parameter estimates

Burnham and Anderson (1998) define precision as " a property of an estimator related to the amount of variation among estimates from repeated samples". The model developed in excel, does not provide any estimates of precision. For models run using AD model builder, estimates of standard deviation are based on the delta method, which approximate the variance estimates. Variance estimates using the delta method are biased to the lower range of the spectrum when additional constraints are imposed on the model (ASMFC 2003). Confidence bounds on the parameters can be estimated using bootstrap procedures. However, the estimates derived are likely to be biased (Hilborn and Walters 1992). Ideally, the relative levels of confidence of the parameter estimates should be evaluated using methodology such as the "operating model concept" described in Hilborn and Walters (1992) or Bayesian methods. These are part of the long-term objectives in the model's development.

Examination of alternate weighting strategies of the likelihood components revealed that selecting a weighting profile using an objective set of criteria were difficult (see Appendix F). However, the influence of alternative weighting criteria on selected performance statistics may be a useful method to characterize the uncertainty around those estimates. For the base model, we ran a simulation of 3,500 runs, where a random and independent weight (λ) ranging between 0-20 was selected from a uniform distribution for each of the fleet and index terms. The performance statistics evaluated were the average fishing mortality rate per year (ages 1-10+), spawning stock biomass estimates per year, and the ratios of average fishing mortality rate to F_{msy} and spawning stock biomass to SSB_{msy} in 2002.

Average fishing mortality rates from 1973–2002 from the simulation were consistent with patterns observed for the base model. The inter quartile range (25-75th percentile) for F_{2002} from the simulations ranged from 0.015 to 0.11 (Figure G5). For 2002, average fishing mortality rates from the base model was close to the 75th percentile of the simulation runs (Figure G5a) (average F=0.11). Spawning stock biomass trends from the simulation runs also show a similar trend to estimates derived from the base run (Figure G6). The inter quartile range for spawning stock biomass estimates from the simulation in 2002 ranged between 71,000 and 120,000 MT. In comparison, estimates of spawning stock biomass in 2002 from the base model was 80,000 MT, close to the value of 25th percentile of the simulation runs. For both fishing mortality and spawning stock estimates, estimates determined from the base run appear to be more pessimistic (conservative) when compared to other potential weighting schemes. This assumes that 3,500 simulations capture a wide range of weightings.

Sensitivity analysis

In the original model, the TC identified five deterministic inputs that the parameter estimates were likely to be sensitive to. These parameters were in the initial SSB:SSB virgin ratio, selectivity patterns for the early age classes for the commercial and recreational fishery, steepness, and natural mortality. In the revised version, the initial SSB: SSB virgin ratio is estimated and the selectivity patterns for the fleets are based on estimates derived from an 'un-tuned' separable VPA. As such, sensitivity analysis for the revised model examined the effects of varying steepness and natural mortality estimates on the parameter estimates and biological reference points. Choice of steepness estimates can have a large impact on stock status. The TC identified a subjective weighting for a range of natural mortality estimates (see section 6.1 in original document). These weightings were used to create a probability distribution for natural mortality. For steepness, the prior distribution developed by Myers et al. (2002) was used (see section 7.4 of original report for distributions). Steepness and natural mortality estimates were selected from the probability distributions and the model was run 2,500 times. While this method, does not capture all of the uncertainty associated with the model, it does capture two of the major sources of uncertainty based on an assigned distribution for each of the parameters.

Examination of the likelihood profile of the 2,500 runs shows a strong correlation between the total likelihood and steepness (Pearson Corr. =-0.7; Figure G7). The best-fitting models were associated with steepness estimates ~1. There appears to be little correlation between the total likelihood and natural mortality estimates used (Pearson Corr =0.3). Fishing mortality rates from the sensitivity runs indicate that estimates up to the early 1980's were associated with a high degree of variability. Fishing mortality estimates from recent years have been relatively stable and show low variability across runs (Figure G8; Table G10). For 2002, the inter quartile range of fishing mortality estimates were between 0.08 and 0.12. F_{2002} from the base run was 0.11. Spawning stock biomass estimates from the sensitivity runs are presented in Table G11. Trends in spawning stock biomass under varying steepness and natural mortality rates show greater variability in recent years than those for the early part of the time series (Figure G9). For 2002, the inter quartile range of spawning stock biomass estimates was 80,000 and 110,000 Metric tons. Spawning stock biomass estimates for 2002 from the base run was 80,000 MT. Based on the sensitivity runs, it appears that ~25% of the runs had higher fishing mortality estimates than those for the base run and ~25% of the sensitivity runs had spawning stock biomass estimates lower than the base run.

Biological reference points

As part of the model configuration, a Beverton and Holt stock recruitment relationship re-parameterized in terms of steepness is included. Estimates of the virgin recruitment for the base mid-Atlantic were 169 million fish. The stock recruitment curves for the base mid-Atlantic are presented in Figure 10. For the base mid-Atlantic model a wide scatter between recruits and spawning stock was evident, and estimates for the recent part of the time series are scattered around the region where the replacement line meets the stock-recruit curve (Figure G10).

Overfishing definition

The benchmarks for the mid-Atlantic region are:

F threshold - Fmsy
Biomass threshold - 0.7 SSBmsy
F target – 0.75 Fmsy
Biomass target – SSBmsy

Estimates of F_{msy} from the base mid-Atlantic model was 0.39 and SSB_{msy} was equal to 28,932 MT. Estimates of average fishing mortality rates from the base mid-Atlantic model of 0.11 indicate that 2002 estimates were below the target and threshold levels (Figure G11). Estimates of SSB from the base mid-Atlantic model relative to the proposed target and threshold SSB levels are shown in Figure G12. Recent estimates of SSB (~80,000 MT) are above both the proposed target and threshold levels. For 2002, $F:F_{msy}$ ratio was 0.263 and $SSB:SSB_{msy}$ ratio 2.78.

Uncertainty in the estimates of the current status of the stock (in 2002) were examined at three levels; 1) the sensitivity of the base model to alternate weightings of the likelihood components; 2) sensitivity of the model to alternative steepness and natural mortality estimates; and 3) the implications of not including shrimp bycatch estimates.

Based on the base run's sensitivity to weighting of the likelihood components, and the sensitivity of the model to alternate steepness and natural mortality estimates, estimates derived from the base run appear robust. From the sensitivity analysis on weighting of the likelihood terms, 90 % of the simulations had $F_{2002}:F_{msy}$ ratios less than 0.44 (Table G12; Figure G13a). Biomass reference points from the weighting analysis indicated that 10% of the runs had SSB_{2002}: SSB_{msy} ratios less than 2.27 (Table G12; Figure G13b). Model sensitivity to steepness and natural mortality estimates also indicated the stock was most likely below the fishing mortality targets and thresholds and above the biomass targets and thresholds; 90 % of the simulations had $F_{2002}:F_{msy}$ ratios less than 0.44 (Table G12; Figure G14a) and 10% of the runs had SSB_{2002}: SSB_{msy} ratios less than 2.16 (Table G12; Figure G14b).

The TC discussed the quality of estimates of Atlantic croaker discards from the shrimp fishery in depth. The TC concluded further work needed to be carried out on estimating Atlantic croaker bycatch in the shrimp fishery. Evaluating the effectiveness of developing estimates of discards by combining available information on the effectiveness of bycatch reduction devices with estimates of the effective 'swept area' by the shrimp fishery and abundance estimates from the SEAMAP indices need to be explored in more detail. The shrimp fishery has undergone significant changes in efficiency with the introduction of bycatch reduction devices and turtle excluder devices. Based on the available length data, the majority of Atlantic croaker caught as shrimp bycatch were age 0 fish. The preliminary estimates of Atlantic croaker bycatch may not capture the inter-annual variability across the time series, as estimates for 1973-1991 are based on 39 tows, 1992-1998 on 685 tows, and 1999-2002 on 56 tows (See appendix C for details). While the uncertainty surrounding the estimates across years is high, estimates for 1994 are likely to be good since they were based on 522 tows (67% of the available data). Estimates of Atlantic croaker from the shrimp fishery in 1994 were 5,200 MT of age 0 fish. Given the potential magnitude of estimates known with reasonable confidence, sensitivity of the biological reference points to the inclusion/non-inclusion of estimates from shrimp bycatch was examined. This analysis assumes that the preliminary estimates of Atlantic croaker bycatch are the best available and that the standard error estimates associated with the three ratios used, capture the inter-annual variability. For the analysis, the estimates of Atlantic croaker from the shrimp bycatch were treated as a separate fleet with a selectivity pattern that treated all age 0 fish as fully selected (1) and all other age classes as not being selected (0). Average fishing mortality estimates evaluated were age 0-10+ weighted by the population. Using the standard error estimates for the three ratio estimators, annual estimates of Atlantic croaker from the shrimp fishery were determined using:

$$Estimate = ShrimpLand \times \left(AC : Shrimp\ ratio + rand\ norm\ dev \times SEratio \right) - AC\ Land\ \ from\ Shrimp\ Fishery$$

The simulation was run 1,000 times and the range of Atlantic croaker bycatch estimates evaluated are shown in Figure G15. Estimates of F_{msy}, SSB_{msy}, and the current status of the stock were used as performance statistics (Table G13). Average fishing mortality rates (ages 0-10+) in 2002 ranged from 0.06 to 0.176 with 50% of the simulations having values less than 0.105 (Figure G16a). Spawning stock biomass estimates in 2002 from the simulation runs ranged from 77,000 to 149,000 MT with 50% of the values being less than 111,388 MT (Figure G16b). In comparison, the average fishing mortality rate from the base run in 2002 was 0.11 (ages 1-10+) and the spawning stock biomass estimate in 2002 was 80,328 MT.

When including estimates of Atlantic croaker caught as shrimp bycatch, simulations revealed that the current status of the stock was similar to the base run where shrimp bycatch were not included; the stock is not overfished or undergoing overfishing. However, biomass reference points from the simulation runs indicated higher SSB_{msy} values and the lower estimates of SSB_{2002}:SSB_{msy} than those obtained for the base model. The range of estimates for F_{msy} (~0.4; Figure G17a) was similar to the base model (~ 0.39). SSB_{msy} estimates from the simulation (ranged from 48,000-67,000 MT with a median of 56,467 MT; Table 13; Figure G17b) and were much higher than those for the base run (28,932 MT). Differences in Spawning stock biomass estimates are most likely a result of the model accounting for the increased removals as part of the shrimp bycatch by increasing the population estimates. The ratios of F_{2002}:F_{msy} and SSB_{2002}:SSB_{msy} for the sensitivity runs are summarized in Table G13. The ratio of F_{2002}:F_{msy} ranged from 0.14-0.43 with 50% of the runs having estimates below 0.26 (Figure G18a). In comparison F_{2002}:F_{msy} from the base model was 0.263 (based on ages 1-10+). The ratio of SSB_{2002}:SSB_{msy} for the simulations ranged from 1.55 to 2.27, with

50% of the runs having estimates less than 1.98 (Figure G18b). In comparison, the SSB_{2002}:SSB_{msy} ratio for the base run was 2.78.

Recommendations and findings

The mid-Atlantic model, which is the core of the population, indicates fishing mortality rates were high in the mid 1970's, abruptly declined, and has been low and stable since the mid 1990's. Between 1973 and 2002 the relationship between the different sources of removals has changed. In particular, estimates of scrap/discards reached their peak in 1979 (3,200 MT) and since then declined to their lowest levels in 2002 (425 MT). Between 1973 and 1995, scrap/discard removals averaged 1,687 MT per year, whereas between 1996-2002 scrap/discards averaged 595 MT per year. It appears that the significant reduction in removals of predominantly age 1 and younger fish may have contributed to relatively stable fishing mortality and spawning stock biomass estimates since the mid 1990's. In relation to the proposed reference points the Atlantic croaker population is not overfished or undergoing overfishing. The commercial and recreational catch-at-age data from recent years also shows an increasing age distribution, with a few fish of 12 years being observed in the commercial landings. Anecdotal evidence from the mid-Atlantic indicates an expansion of the population at the northern part of the range. For example, in Delaware, fishery independent indices indicate a recent increase in abundance of Atlantic croaker in the region (D. Kahn, personal communication). In addition, both commercial and recreational landings from New Jersey and Delaware have increased recently. The population has benefited from good recruitment in recent years, which may also be tied to the regulatory changes that have affected some of the fisheries that indirectly target Atlantic croaker (see Section 3.2 of original report).

While this analysis does not capture all of the sources of uncertainty, examination of the effects of alternate weightings of the likelihood components and alternate steepness and natural mortality estimates indicate that reference points derived from the base run are relatively robust. The reference points suggest that there was less than a 10% chance that the population is overfished or undergoing overfishing. Sensitivity analysis evaluating the inclusion/non-inclusion of shrimp bycatch estimates, indicate that SSB_{msy} estimates are sensitive to the inclusion of Atlantic croaker caught as shrimp bycatch. However, increased SSB_{msy} estimates are also accompanied by higher SSB estimates. The ratio of SSB_{2002}:SSB_{msy} when shrimp bycatch is included indicates that the stock is unlikely to be below the threshold estimates. Of concern, would be management goals that define biomass reference points in absolute terms. There appears to be some justification for revising the reference points for the biomass target and threshold to relative terms until a more comprehensive evaluation of Atlantic croaker from shrimp bycatch can be carried out.

Literature cited

ASMFC.2003. Atlantic menhaden 2003 stock assessment report. Atlantic States Marine Fisheries Commission.

Burnham, K. P. and R.D. Anderson. 1998. Model selection and inference. A practical information-theoretic approach. Springer-Verlag. New York.

Clay, D. 1990. TUNE: a series of fish stock assessment computer programs written in FORTRAN for microcomputers (MS DOS). Internat. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap. 32:443-460.

Hilborn, R and C.J. Walters. 1992. Quantitative Fisheries Stock Assessment. Choice dynamics and uncertainty. Kluwer Academic Publishers.

Myers, R.A., N.J. Barrowman, R. Hilborn, D.G. Kehler. 2002. Inferring Bayesian priors with limited directed data: Applications to risk analysis. North American Journal of Fisheries Management 22:351-364.

North Carolina Division of Marine Fisheries (NCDMF). 2003 Assessment of North Carolina Commercial Finfisheries, 1997-2002. Final Performance report for Award Number NA 76 FI 0286, 1-3. North Carolina Department of Environment and Natural Resources. North Carolina Division of Marine Fisheries.

Pope, J.G. and Shepard, J.G. 1982. A simple method for the consistent interpretation of catch-at-age data. *Journal du Conseil International pour l'Exploration de la Mer* 40:176-184.

Table G1. Landings estimates used in revised model (metric tons)

Year	Commercial	Recreational	Scrap/Discards
1973	2,611	1,027	1,316
1974	3,515	1,284	1,727
1975	7,484	2,325	1,631
1976	10,300	3,292	1,761
1977	13,506	3,547	2,236
1978	13,292	3,211	2,680
1979	10,385	2,036	3,193
1980	9,923	1,019	2,579
1981	5,289	449	1,790
1982	4,967	366	1,627
1983	3,357	432	1,693
1984	4,570	619	2,002
1985	4,955	546	1,702
1986	5,459	1,067	930
1987	4,756	880	1,705
1988	4,678	1,958	1,715
1989	3,628	938	1,664
1990	2,709	614	1,275
1991	1,651	1,004	1,019
1992	1,905	1,005	858
1993	4,017	1,375	952
1994	4,866	2,116	1,268
1995	6,309	1,713	1,484
1996	9,452	1,821	710
1997	12,231	3,460	753
1998	11,471	3,533	459
1999	12,113	3,134	715
2000	12,091	4,375	596
2001	12,970	4,955	511
2002	11,717	4,170	424

Table G2. Indices and estimates used in revised model

YEAR	NEFSC (Numbers)	MRFSS (Numbers)	SEAMAP (Weight)	VIMS (Numbers)
1973	38.07			0.12
1974	143.20			2.04
1975	638.21			2.63
1976	397.61			1.08
1977	119.35			0.15
1978	161.72			0.08
1979	15.64			2.18
1980	88.53			0.52
1981	31.77	0.235		0.07
1982	9.11	0.228		0.11
1983	231.94	0.674		6.59
1984	267.61	0.648		1.63
1985	213.97	0.397		4.98
1986	127.11	0.616		2.97
1987	111.96	0.690		4.24
1988	31.65	0.807		0.32
1989	99.64	0.860	16.35	0.60
1990	79.82	0.625	15.03	0.43
1991	260.53	0.899	79.44	4.41
1992	216.19	0.795	150.26	1.28
1993	140.88	0.957	26.54	2.17
1994	478.57	1.287	65.90	0.90
1995	189.36	0.855	60.84	1.06
1996	203.99	0.855	31.91	0.19
1997	159.14	1.232	10.19	1.47
1998	344.79	1.424	59.02	1.19
1999	734.45	2.108	87.86	1.50
2000	387.65	1.517	25.63	0.60
2001	177.64	1.371	21.73	0.36
2002	939.82	1.135	25.53	1.59

Table G3. Catch at age matrix for Atlantic croaker commercial landings from Virginia and North Carolina used to determine selectivity pattern

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10+
1989	1,913,896	8,284,718	4,878,422	2,571,310	1,060,693	308,536	153,695	45,575	20,674	5,194	4,834
1990	3,001,525	8,024,342	4,093,361	1,596,628	492,309	72,574	38,989	5,071	1,193	178	198
1991	1,591,819	5,681,592	2,814,373	1,039,527	316,941	43,376	23,218	2,047	481	50	49
1992	1,066,981	5,443,807	3,218,412	1,347,402	428,387	68,260	33,679	5,271	1,273	223	224
1993	1,462,614	9,117,384	6,716,731	3,302,396	1,131,509	222,095	102,459	26,749	6,617	1,205	1,249
1994	1,537,251	9,236,310	7,036,738	3,666,462	1,362,637	338,939	174,281	82,920	23,638	6,706	4,896
1995	1,191,361	7,488,001	6,369,830	4,486,040	2,280,852	874,727	480,024	321,302	95,570	25,996	21,493
1996	544,320	5,548,422	6,801,258	6,058,676	3,774,520	1,803,504	1,096,841	877,463	265,582	83,821	57,238
1997	463,771	5,196,638	6,513,139	5,976,257	3,796,729	1,895,439	1,179,833	980,822	300,052	104,244	64,298
1998	326,055	4,025,199	5,838,981	6,282,436	4,763,891	2,646,459	1,713,539	1,451,298	450,857	148,517	99,255
1999	236,740	3,283,204	4,977,617	5,630,503	4,616,605	2,845,188	1,995,907	1,913,074	586,656	214,108	135,878
2000	298,992	3,591,152	5,078,611	5,428,259	4,420,446	2,741,790	1,974,824	1,879,379	582,600	206,648	134,384
2001	281,031	3,236,220	4,614,524	5,156,565	4,506,946	3,001,980	2,207,830	2,251,971	692,983	269,526	152,094
2002	191,636	3,023,454	4,733,488	5,403,268	4,306,672	2,605,232	1,778,150	1,668,526	513,716	193,680	112,311

Table G4. Catch-at-age matrix for Atlantic croaker scrap from Virginia and North Carolina used to determine selectivity pattern.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10+
1,989	3,084,834	10,419,742	3,205,238	662,641	166,240	6,613	14,550	21	7	0	0
1,990	4,204,683	7,546,689	2,059,344	427,228	105,592	4,072	9,630	117	29	0	0
1,991	3,120,426	8,135,978	1,978,838	316,430	78,965	1,733	6,720	36	9	0	0
1,992	2,542,800	8,242,979	2,169,508	440,018	111,592	6,055	9,925	467	67	67	67
1,993	2,559,385	5,930,994	2,087,439	568,524	144,932	9,508	12,858	99	17	11	11
1,994	5,029,502	9,273,672	1,933,851	487,346	119,883	7,369	10,760	118	28	2	2
1,995	4,018,781	9,100,379	1,962,377	435,327	108,533	6,644	9,405	190	44	5	5
1,996	568,967	2,290,915	1,075,225	410,810	131,689	22,087	11,571	2,260	579	55	76
1,997	899,437	2,434,017	905,559	303,971	86,870	9,905	6,610	443	118	29	29
1,998	848,224	856,254	403,006	146,077	42,455	5,532	3,919	568	162	19	29
1,999	2,219,998	2,832,170	459,603	150,838	44,668	7,695	4,436	933	240	27	27
2,000	1,175,057	2,267,978	487,748	144,718	43,550	6,493	3,623	671	190	25	33
2,001	386,140	1,134,278	399,721	136,608	42,470	6,470	3,402	511	133	14	14
2,002	178,416	668,908	271,092	125,459	45,467	10,393	4,720	1,559	357	73	86

Table G5. Recreational catch-at-age matrix used to determine selectivity pattern.

Year	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10+
1,981	212,633	1,007,408	474,407	222,291	106,742	43,123	26,313	12,453	6,560	2,705	1,157
1,982	99,066	433,047	194,312	105,260	53,425	22,923	14,939	14,778	3,752	1,495	8,892
1,983	1,514,569	2,007,776	446,687	136,410	58,064	22,374	17,641	7,245	4,320	1,391	1,108
1,984	448,335	2,288,610	1,124,814	479,917	193,841	57,935	37,124	11,969	5,941	885	1,714
1,985	359,281	1,624,282	812,758	351,399	135,355	36,809	21,500	6,239	3,110	612	812
1,986	651,207	3,430,795	1,841,266	774,127	289,262	79,239	49,136	16,132	9,808	3,420	1,727
1,987	321,474	1,861,768	1,264,185	684,409	297,092	97,083	53,158	17,761	9,948	3,008	2,031
1,988	518,828	2,718,699	1,767,141	1,211,467	688,538	302,130	175,665	74,724	41,137	13,777	8,380
1,989	410,214	2,046,026	1,163,752	585,118	246,291	74,482	39,286	11,690	6,681	1,578	1,220
1,990	590,312	2,085,115	863,083	319,217	134,549	41,594	26,248	8,398	5,300	837	801
1,991	857,974	3,424,106	1,306,488	449,741	147,001	27,645	15,913	3,772	1,778	711	351
1,992	534,263	2,960,468	1,541,923	631,302	222,035	49,557	27,648	6,449	2,910	475	679
1,993	532,829	3,218,301	2,064,341	1,045,897	442,964	135,546	73,202	23,994	12,459	3,111	2,719
1,994	802,548	4,485,852	2,717,809	1,453,372	664,828	229,411	124,384	44,503	23,932	7,979	5,420
1,995	434,499	2,701,277	1,995,879	1,280,593	665,278	259,816	144,684	55,503	30,284	8,403	6,886
1,996	284,596	2,081,852	1,854,836	1,466,609	870,358	403,111	237,378	101,414	56,838	20,823	13,806
1,997	355,958	2,846,298	2,741,614	2,273,194	1,518,477	798,598	543,824	257,624	146,653	46,102	35,930
1,998	186,691	1,709,738	1,983,000	2,015,324	1,591,306	961,818	674,205	349,447	203,445	75,899	43,396
1,999	314,461	2,284,113	2,136,974	1,871,915	1,311,272	742,332	529,421	256,414	155,978	56,235	34,188
2,000	165,964	1,638,777	2,123,191	2,408,398	2,125,559	1,341,381	956,664	456,514	287,609	98,578	63,972
2,001	276,053	2,427,922	2,769,453	2,860,242	2,329,382	1,377,722	954,574	467,770	272,837	86,322	65,129
2,002	308,909	2,612,711	2,774,499	2,534,875	1,864,685	1,020,896	688,551	310,252	187,810	59,341	42,672

Table G6. Selectivity patterns for the commercial and recreational fishery determined using the 'un-tuned' separable VPA.

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10+
Com S(J)	0.036	0.383	0.606	0.809	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Rec S(J)	0.083	0.737	0.863	0.972	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Scrap S(J)	0.286	1.000	0.508	0.209	0.082	0.010	0.015	0.010	0.000	0.000	0.000
Com/Scrap S(J)	0.110	0.614	0.717	0.855	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table G7. Selectivity patterns for the indices used in the revised model.

	Age										
	0	1	2	3	4	5	6	7	8	9	10+
NEFSC Trawl	0.79	1.00	0.40	0.34	0.11	0.12	0.00	0.00	0.00	0.00	0.00
MRFSS	0.08	0.74	0.86	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SEAMAP North	1.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
VIMS	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table G8. Recruitment deviations, fully selected fishing mortality rates, average fishing mortality rate (ages 1-10) and exploitation rate for Atlantic croaker in the mid-Atlantic. Estimates are for the base model (steepness=0.76; natural mortality=0.3).

Year	Recruitment deviations	Commercial (Age 4)	Recreational (Age 4)	Scrap/Discard (Age 1)	Average F Ages 1-10	Exploitation Rate
1973		0.10	0.04	0.13	0.17	0.10
1974	0.933	0.21	0.06	0.18	0.28	0.09
1975	1.433	0.35	0.08	0.06	0.27	0.09
1976	0.284	0.30	0.06	0.04	0.22	0.13
1977	-1.079	0.31	0.06	0.07	0.27	0.19
1978	-1.585	0.30	0.06	0.16	0.33	0.22
1979	-0.132	0.36	0.05	0.55	0.50	0.25
1980	-0.464	0.34	0.03	0.28	0.41	0.21
1981	-1.775	0.23	0.02	0.22	0.28	0.19
1982	-1.505	0.27	0.02	0.36	0.35	0.22
1983	1.395	0.19	0.02	0.18	0.23	0.07
1984	0.434	0.19	0.02	0.06	0.15	0.09
1985	0.683	0.14	0.01	0.05	0.12	0.06
1986	0.299	0.11	0.01	0.02	0.09	0.06
1987	0.278	0.07	0.01	0.05	0.08	0.05
1988	-0.914	0.06	0.02	0.06	0.09	0.06
1989	-0.403	0.04	0.01	0.08	0.06	0.05
1990	-0.620	0.03	0.01	0.07	0.05	0.04
1991	1.256	0.02	0.01	0.05	0.04	0.02
1992	0.143	0.02	0.01	0.02	0.03	0.02
1993	0.476	0.04	0.01	0.02	0.04	0.03
1994	0.340	0.04	0.01	0.03	0.05	0.03
1995	0.414	0.05	0.01	0.03	0.06	0.04
1996	-1.091	0.06	0.01	0.02	0.06	0.05
1997	0.070	0.09	0.02	0.03	0.10	0.06
1998	0.867	0.09	0.03	0.02	0.10	0.05
1999	0.799	0.09	0.02	0.02	0.09	0.05
2000	-0.224	0.10	0.03	0.01	0.09	0.06
2001	-0.504	0.10	0.03	0.01	0.11	0.08
2002	0.686	0.10	0.03	0.02	0.11	0.05

Table G9. Population estimates for the base mid-Atlantic model (steepness=0.76, natural mortality=0.3).

	Population estimates		
	Numbers (millions)		Biomass (metric tons)
Year	Age 0	Total	Spawning stock biomass
1973	50.31	145.10	13,196
1974	297.37	392.17	13,196
1975	489.01	748.66	21,261
1976	181.15	677.65	38,338
1977	52.53	478.51	45,165
1978	32.46	311.33	39,883
1979	135.57	307.21	30,057
1980	93.08	255.17	22,389
1981	23.44	166.07	18,566
1982	29.28	125.13	15,387
1983	500.84	570.42	11,746
1984	175.21	565.68	27,920
1985	287.40	663.85	37,804
1986	207.52	664.10	49,070
1987	210.79	671.51	57,373
1988	65.43	534.06	63,800
1989	109.91	476.13	62,221
1990	88.40	422.25	60,099
1991	572.80	871.25	57,085
1992	187.78	818.23	73,274
1993	270.26	862.02	82,924
1994	238.21	856.89	90,023
1995	258.43	868.30	94,131
1996	57.35	672.92	96,686
1997	183.93	654.18	89,624
1998	403.39	853.69	81,590
1999	375.06	974.35	84,412
2000	135.18	817.37	91,040
2001	103.10	663.92	88,773
2002	338.55	786.87	80,328

Table G10. Summary statistics of average fishing mortality estimates from 2,500 simulations examining model sensitivity to steepness and natural mortality estimates. Percentile represents the estimate at the n^{th} percentile

Year	Percentile						
	100	90	75	50	25	10	0
1973	0.454	0.246	0.190	0.149	0.118	0.092	0.001
1974	0.800	0.400	0.305	0.244	0.194	0.147	0.002
1975	0.487	0.319	0.282	0.249	0.212	0.169	0.002
1976	0.302	0.238	0.228	0.215	0.192	0.157	0.002
1977	0.358	0.286	0.276	0.261	0.230	0.187	0.002
1978	0.451	0.358	0.344	0.322	0.278	0.218	0.002
1979	0.911	0.627	0.561	0.488	0.381	0.267	0.002
1980	0.834	0.530	0.464	0.394	0.311	0.225	0.002
1981	0.771	0.385	0.325	0.262	0.199	0.139	0.001
1982	1.539	0.524	0.412	0.314	0.225	0.150	0.001
1983	1.272	0.323	0.252	0.196	0.144	0.098	0.001
1984	0.824	0.184	0.158	0.134	0.106	0.079	0.001
1985	0.941	0.142	0.125	0.107	0.086	0.065	0.001
1986	0.861	0.109	0.097	0.084	0.069	0.054	0.001
1987	0.578	0.094	0.084	0.074	0.062	0.049	0.001
1988	0.547	0.101	0.091	0.080	0.067	0.053	0.001
1989	0.339	0.075	0.068	0.060	0.051	0.040	0.001
1990	0.246	0.061	0.054	0.048	0.041	0.032	0.000
1991	0.157	0.046	0.041	0.036	0.030	0.024	0.000
1992	0.089	0.033	0.031	0.027	0.024	0.019	0.000
1993	0.121	0.050	0.046	0.041	0.035	0.029	0.000
1994	0.128	0.061	0.056	0.050	0.043	0.035	0.001
1995	0.138	0.070	0.063	0.056	0.049	0.040	0.001
1996	0.149	0.080	0.072	0.064	0.056	0.046	0.001
1997	0.242	0.131	0.114	0.100	0.086	0.070	0.001
1998	0.236	0.127	0.109	0.095	0.081	0.066	0.001
1999	0.215	0.117	0.103	0.091	0.078	0.064	0.001
2000	0.222	0.118	0.104	0.092	0.079	0.064	0.001
2001	0.272	0.140	0.122	0.106	0.091	0.072	0.001
2002	0.295	0.144	0.123	0.105	0.088	0.071	0.001

Table G11. Summary statistics of spawning stock biomass estimates (MT) from 2,500 simulations examining model sensitivity to steepness and natural mortality estimates. Percentile represents the estimate at the n^{th} percentile

Year	Percentile						
	100	90	75	50	25	10	0
1973	2,419,230	28,912	21,440	16,605	12,844	9,577	4,783
1974	2,419,230	28,912	21,440	16,605	12,844	9,577	4,783
1975	3,093,457	39,208	30,776	25,395	21,937	19,239	11,660
1976	4,541,037	61,215	50,452	44,161	40,545	37,928	25,768
1977	5,432,598	70,584	58,264	51,450	47,654	44,870	30,792
1978	5,585,148	65,219	52,325	45,409	41,998	39,873	27,062
1979	5,279,292	53,741	41,120	34,635	31,285	29,194	19,140
1980	5,087,160	46,082	33,171	26,201	22,642	20,045	11,328
1981	4,812,990	41,174	28,831	22,077	18,476	15,875	8,125
1982	4,317,903	36,221	24,815	18,570	14,938	12,228	5,125
1983	3,780,529	30,646	20,267	14,536	10,952	8,329	1,976
1984	5,102,710	53,377	40,201	32,421	28,050	24,871	10,944
1985	5,996,611	68,314	52,752	43,529	38,157	34,222	11,519
1986	7,024,952	85,115	67,147	56,134	49,620	44,762	12,735
1987	7,771,811	97,734	77,506	65,372	57,975	52,773	12,126
1988	8,328,488	107,573	85,783	72,610	64,653	58,648	13,958
1989	8,144,911	105,810	84,049	71,235	62,962	56,836	11,816
1990	7,760,380	102,403	81,606	69,064	60,675	54,172	12,323
1991	7,216,889	97,654	77,812	66,011	57,442	50,129	13,185
1992	8,674,023	121,609	98,370	84,198	74,912	67,897	23,814
1993	9,401,115	135,410	110,356	95,004	85,005	77,282	32,194
1994	10,012,997	146,305	119,179	103,082	92,233	83,566	38,727
1995	10,422,803	152,437	124,758	107,967	96,198	86,788	43,428
1996	10,764,486	157,121	128,480	111,105	98,679	88,307	46,685
1997	10,220,093	148,710	120,302	103,480	90,871	79,154	42,315
1998	9,767,586	137,817	111,400	94,527	81,721	69,805	36,095
1999	10,260,406	143,059	114,989	97,877	85,076	73,766	38,244
2000	11,102,100	152,708	123,121	105,119	92,305	81,803	42,796
2001	11,105,390	150,927	120,797	102,647	89,550	78,558	40,309
2002	10,530,092	139,937	110,900	93,237	80,103	68,660	33,410

Table G12. Summary of sensitivity of reference point estimates in 2002 to varying weightings of likelihood components and alternate steepness and natural mortality estimates. For weighting sensitivity, the table summarizes the range of estimates from 3,500 runs. For the steepness and natural mortality sensitivity, the table summarizes the range of estimates from 2,500 runs. See text for details.

Sensitivity to	Statistic	Percentile						
		100	90	75	50	25	10	0
Weighting	F_{2002}: Fmsy	0.96	0.44	0.28	0.14	0.04	0.002	0.002
Weighting	SSB_{2002}: SSBmsy	5.54	5.12	4.93	4.52	2.93	2.27	0.80
Steep & M	F_{2002}: Fmsy	27.83	0.44	0.37	0.31	0.27	0.23	0.011
Steep & M	SSB_{2002}: SSBmsy	8.13	2.97	2.78	2.61	2.41	2.16	1.50

Table G13. Sensitivity of reference point estimates and status of population in 2002 when estimates of Atlantic croaker bycatch from the shrimp fishery are included in the model. See text for details. Based on 1,00 runs. Percentile represents the proportion of run that had estimate equal to the estimate. e.g. For F_{msy} , 90% of the runs had an F_{msy} estimate <= 0.410.

	Percentile						
	100	90	75	50	25	10	0
F_{msy}	0.415	0.410	0.408	0.407	0.405	0.403	0.400
F_{2002}	0.176	0.129	0.118	0.105	0.094	0.082	0.057
SSB_{msy} (MT)	67,121	60,034	58,055	56,467	54,678	53,388	48,673
SSB_{2002} (MT)	149,450	124,851	118,090	111,388	105,297	100,196	77,539
F_{2002}:F_{msy}	0.43	0.32	0.29	0.26	0.23	0.20	0.14
SSB_{2002}:SSB_{msy}	2.27	2.10	2.04	1.98	1.91	1.86	1.55

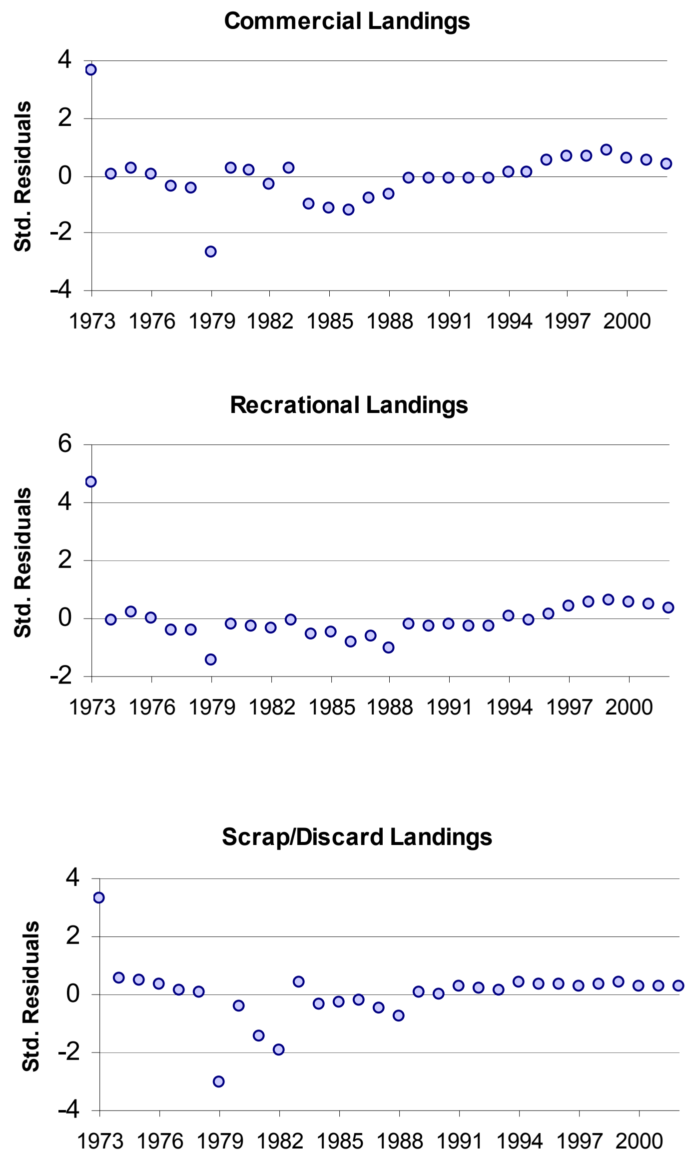


Figure G1. Standardized residuals for the commercial , recreational and scrap/discard landings for the mid-Atlantic base model (steepness=0.76 , natural mortality=0.3).

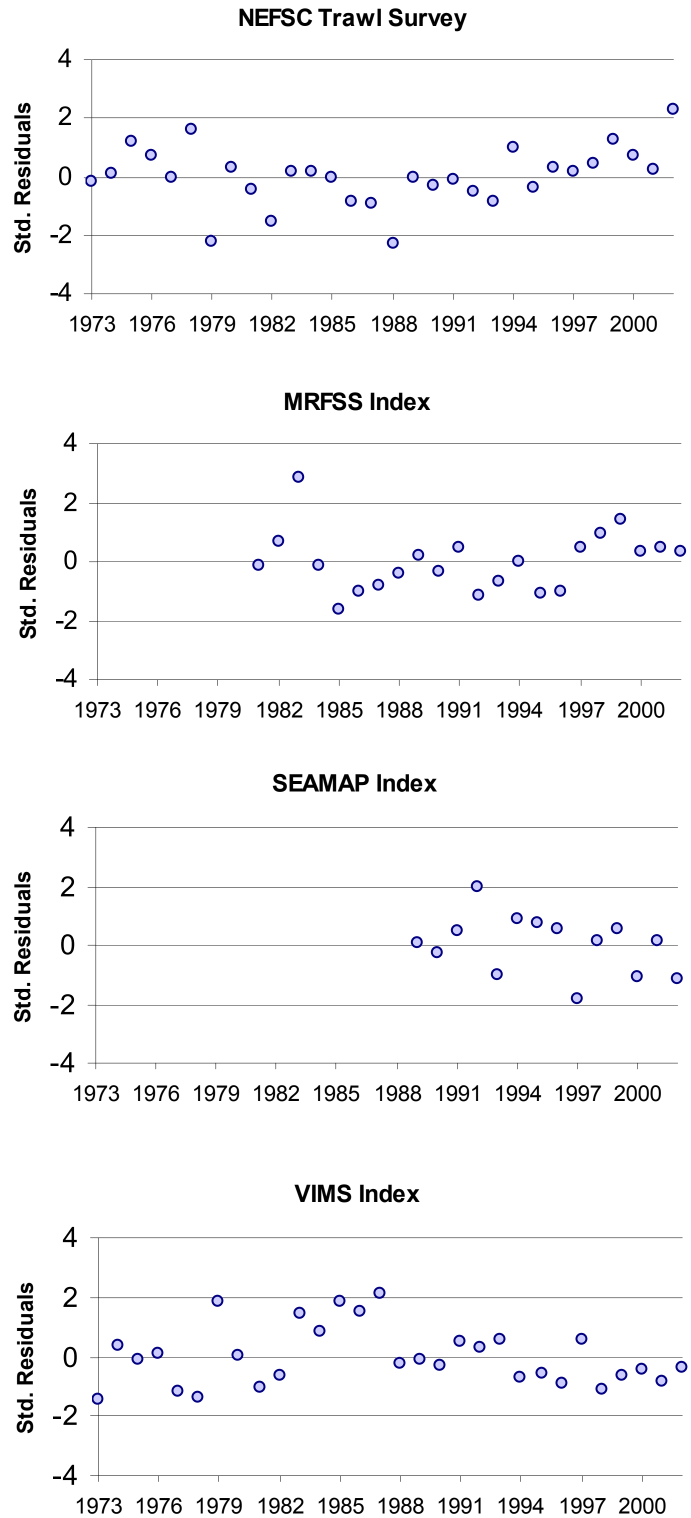


Figure G2. Standardized residuals for the indices used in the mid-Atlantic base model (steepness=0.76, natural mortality=0.3).

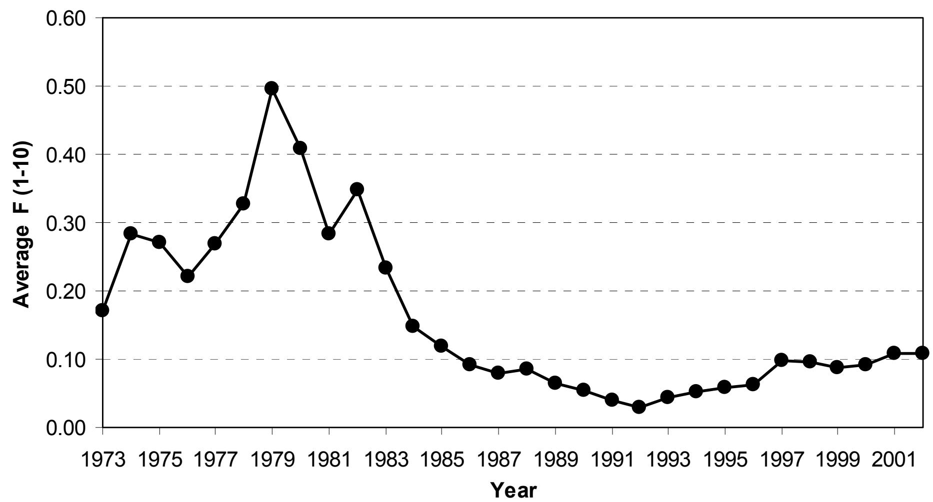


Figure G3. Average fishing mortality rates (ages 1 –10) for Atlantic croaker in the mid-Atlantic.

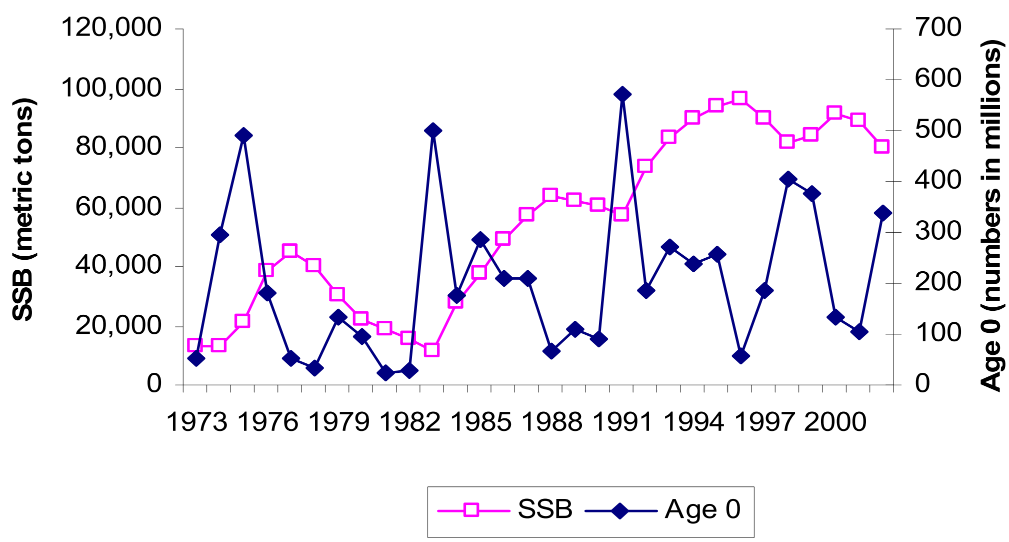
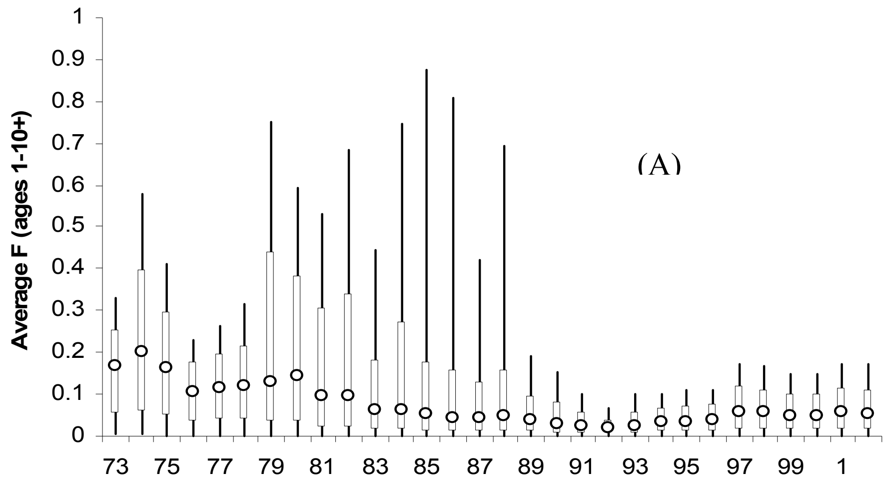


Figure G4. Spawning stock biomass (metric tons) and age 0 recruits (millions of fish) estimates from the base mid-Atlantic model (steepness=0.76, natural mortality =0.3).

.



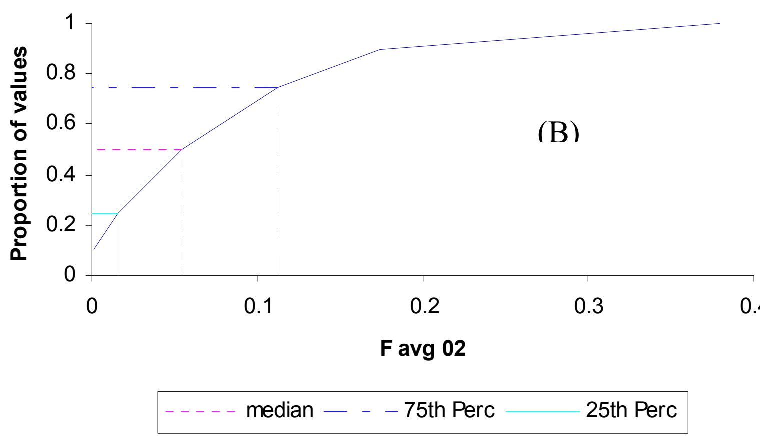
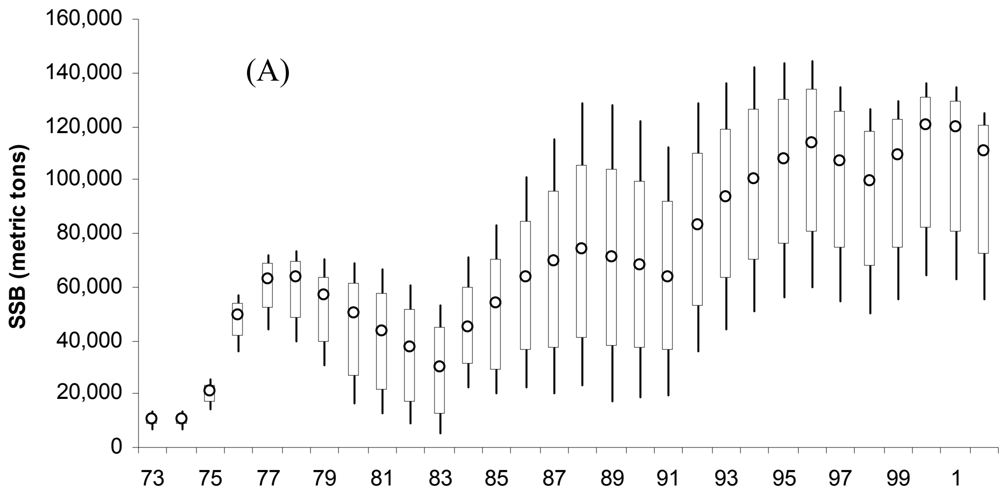


Figure G5. (A). Average fishing mortality rates (ages 1-10+), from a simulation of the base model (steepness=0.76, natural mortality=0.3) using alternate weightings of the likelihood components (λ = 0 to 20, n=3,500). Circle represents median, box = inter-quartile range and lines 10-90th percentile. (B) Estimates for 2002, figure show the cumulative proportion of samples that had estimates at the 25th, 50 and 75th percentiles.



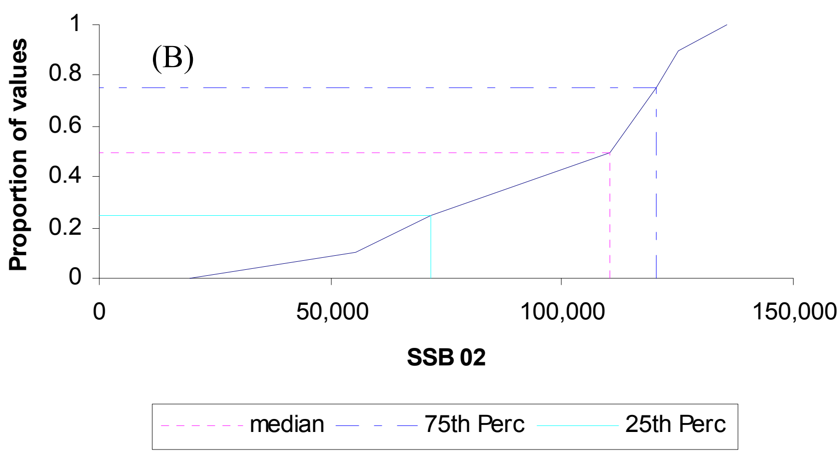
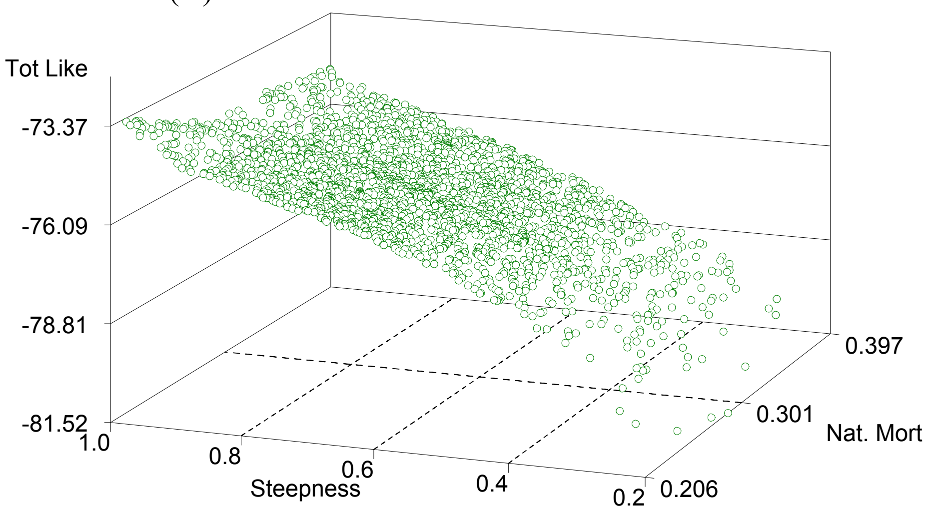


Figure G6. (A) Spawning stock biomass estimates (MT) from a simulation of the base model (steepness=0.76, natural mortality=0.3) using alternate weightings of the likelihood components (λ = 0 to 20, n=3,500). Circle represents median, box = inter-quartile range and lines 10-90th percentile. (B) Estimates for 2002, figure show the cumulative proportion of samples that had estimates at the 25th, 50 and 75th percentiles.

(A)



(B)

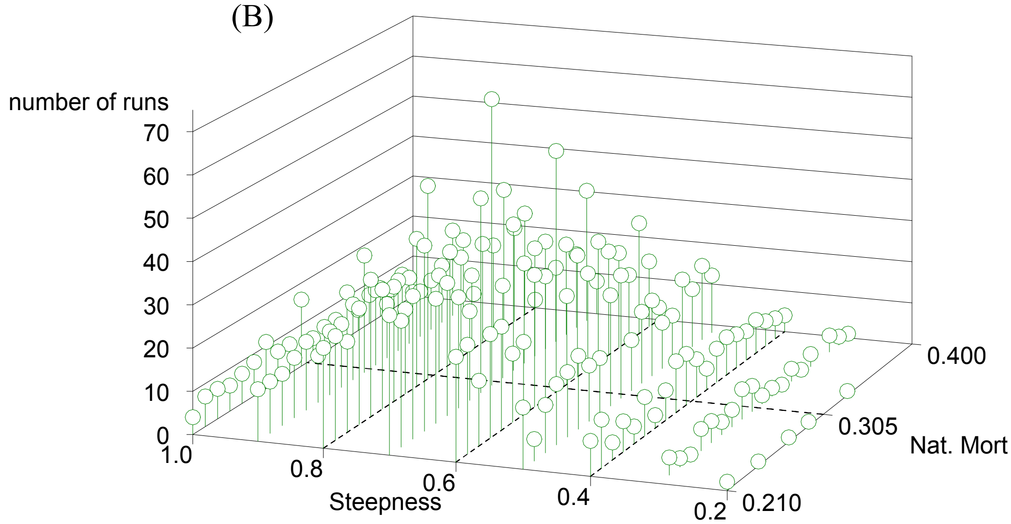
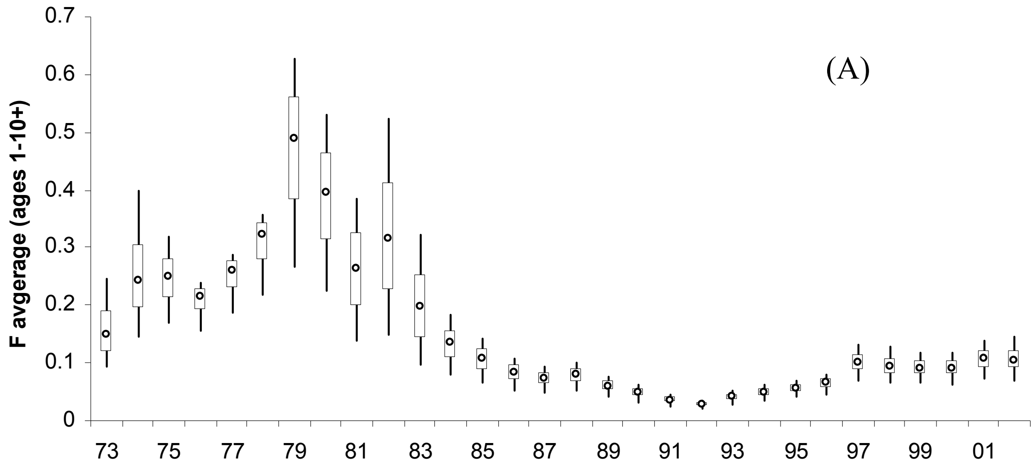


Figure G7. Sensitivity of model to varying steepness and natural mortality estimates: (A) Response surface of total likelihood estimates from 2,500 runs. Values towards low negative values (~ -73.37) represent the best fitting runs. (B) Sample size of steepness and natural mortality estimates evaluated. Steepness is binned in 0.1 intervals and natural mortality in 0.01 intervals.



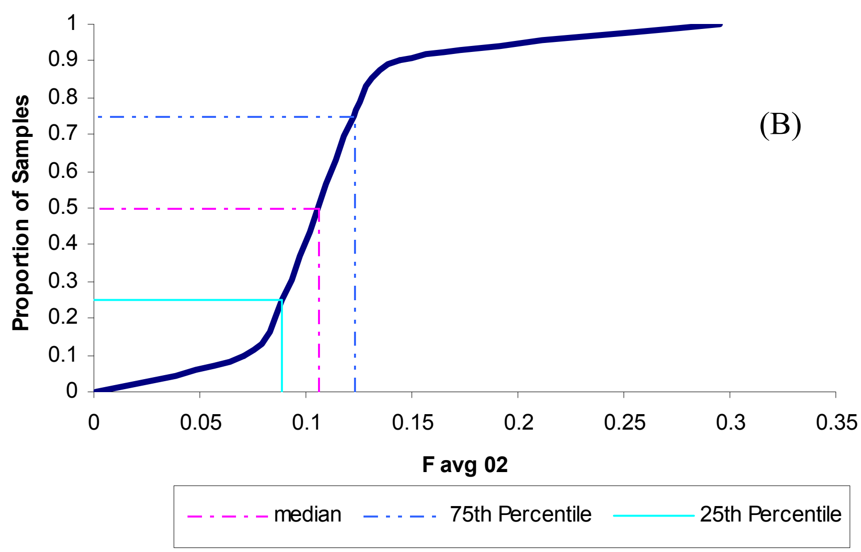


Figure G8. (A) Average fishing mortality rates (ages 1-10+), from the 2,500 runs examining model sensitivity to steepness and natural mortality estimates. Circle represents median, box = inter-quartile range and lines 10-90th percentile. Steepness and natural mortality estimates were based on prior distributions from Myers et al (2002) for steepness and that developed by the TC for natural mortality. (B) Estimates for 2002, figure show the cumulative proportion of samples that had estimates at the 25th, 50 and 75th percentiles.

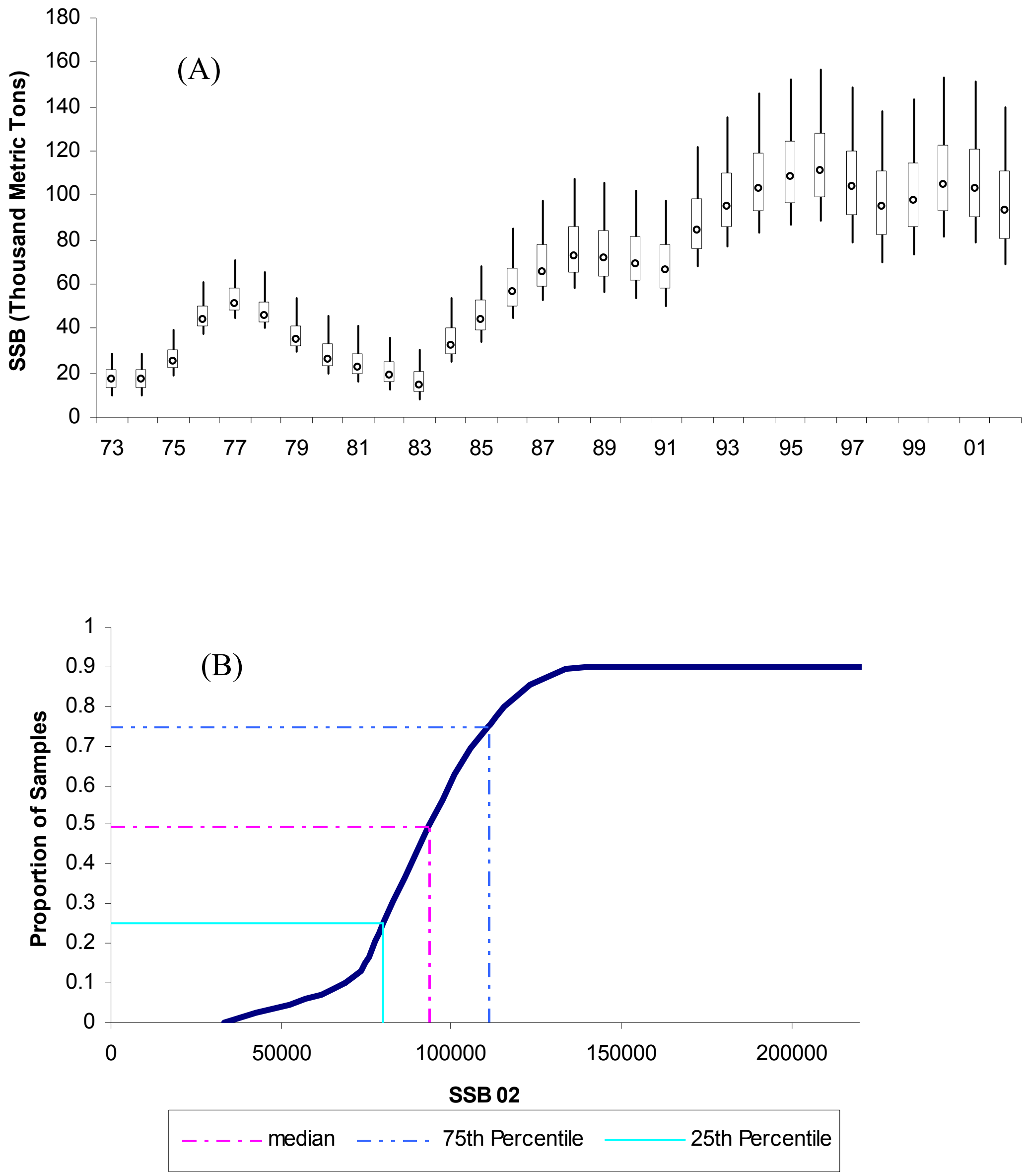


Figure G9. (A) Spawning stock biomass estimates (MT) from the 2,500 runs examining model sensitivity to steepness and natural mortality estimates. Circle represents median, box = inter-quartile range and lines 10-90th percentile. Steepness and natural mortality estimates were based on prior distributions from Myers et al. (2002) for steepness and that developed by the TC for natural mortality. (B) Estimates for 2002, figures show the cumulative proportion of samples that had estimates at the 25th, 50 and 75th percentiles.

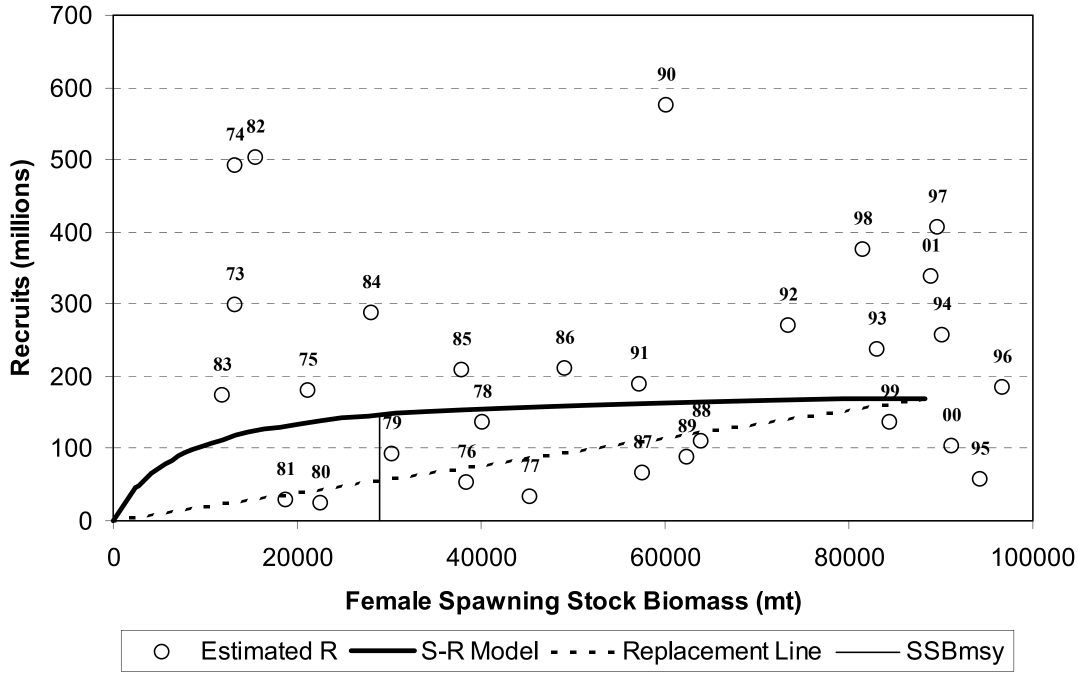


Figure G10. Stock –Recruit relationship fro Atlantic croaker using base model (steepness=0.76, natural mortality=0.3).

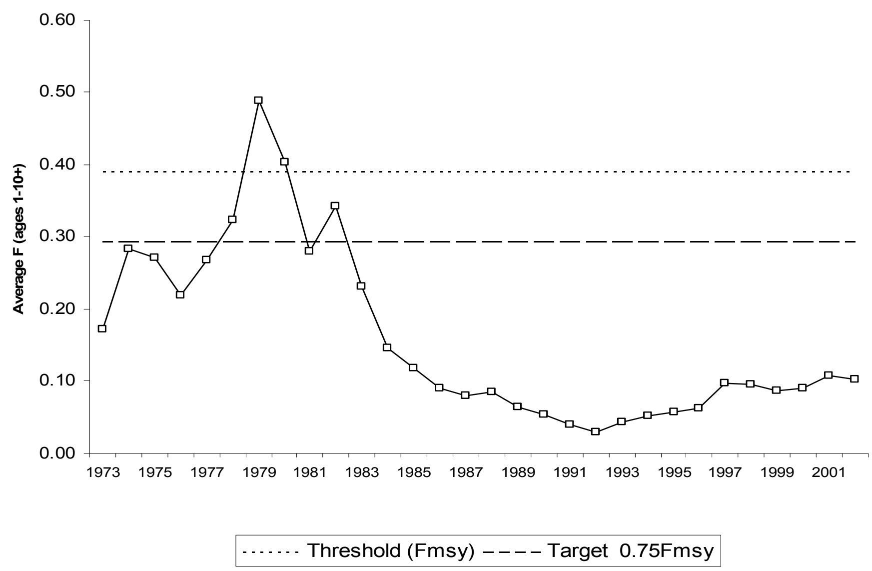


Figure G11. Fishing mortality reference points relative to average fishing mortality rates across the time series for mid-Atlantic base model (steepness=0.76, natural mortality=0.3). F_{msy}=0.39.

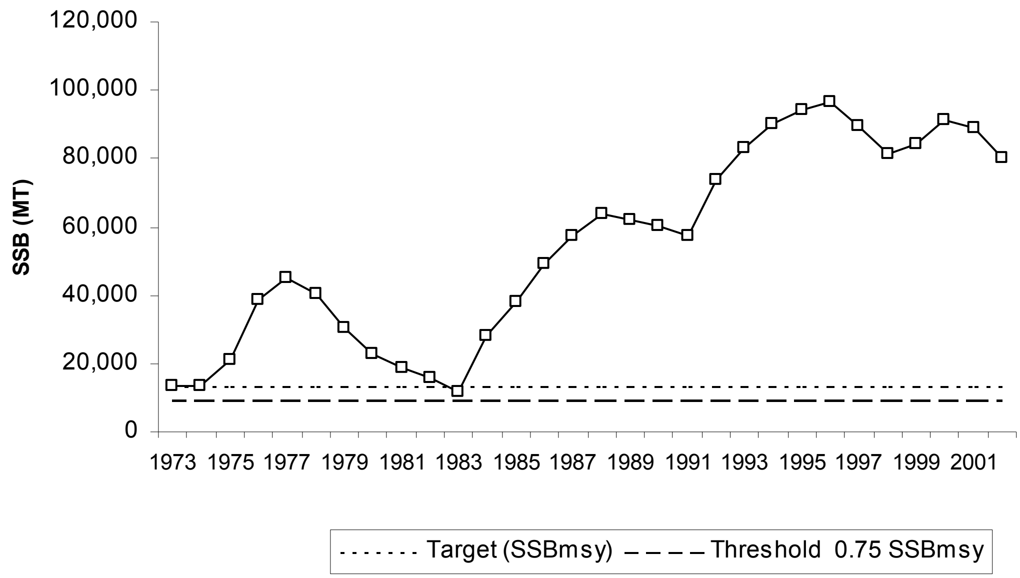
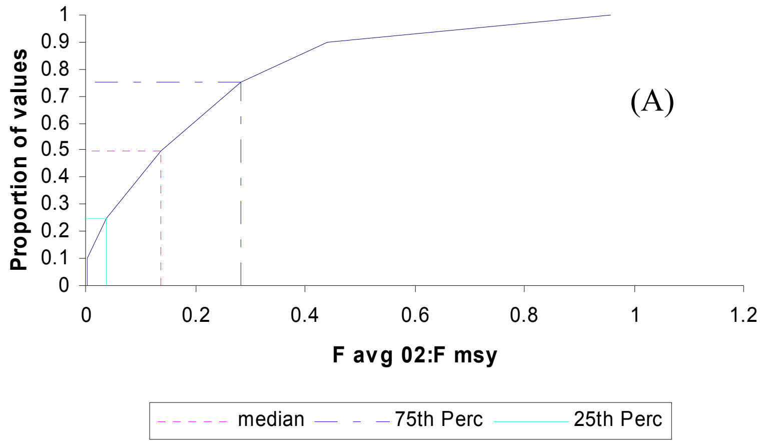


Figure G12. Biomass reference points relative to SSB estimates for the mid-Atlantic base model (steepness=0.76, natural mortality=0.3). SSB_{msy}= 28,932 MT.



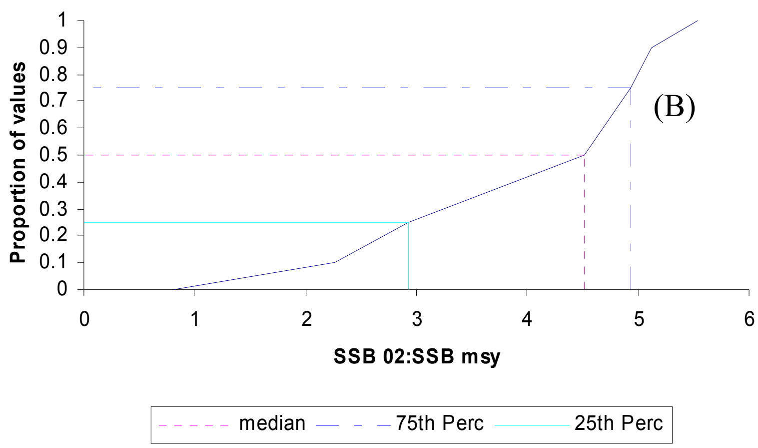
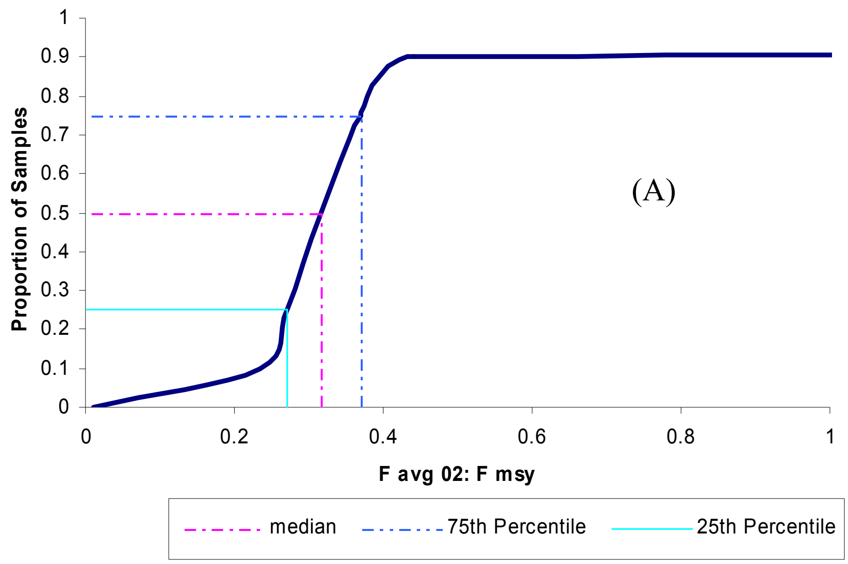


Figure G13. Sensitivity of biological reference points (in 2002) to varying the weighting of the likelihood components for the base run (steepness=0.76, natural mortality=0.3). N= 3,500 runs. Figures show the cumulative proportion of samples that had estimates at the 25th, 50 and 75th percentiles.



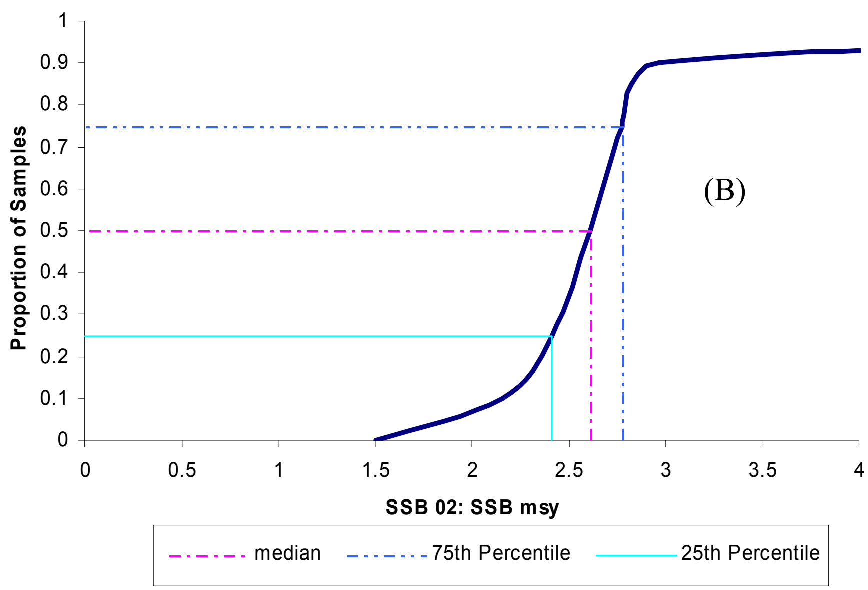


Figure G14. Sensitivity of biological reference points (in 2002) to varying the steepness and natural mortality estimates used in model. N= 2,500 runs. Figures show the cumulative proportion of samples that had estimates at the 25th, 50 and 75th percentiles.

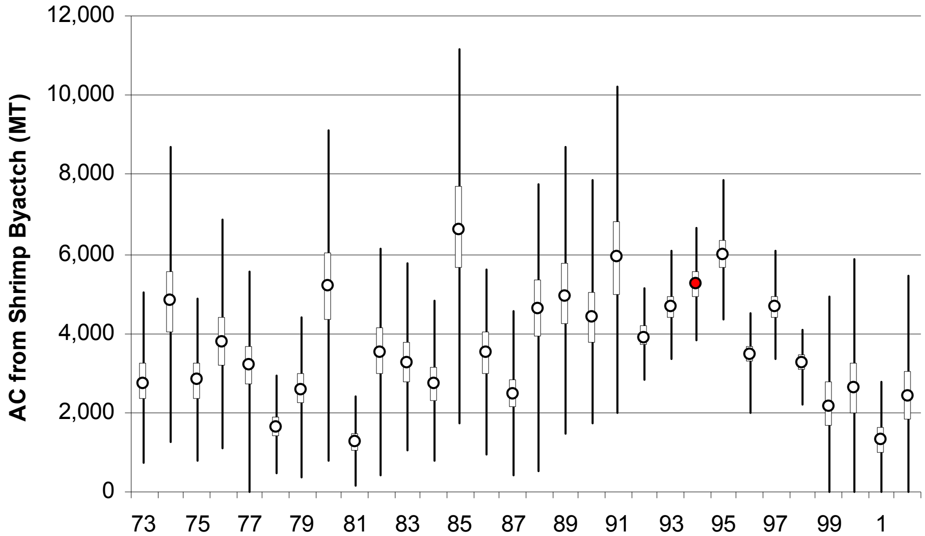
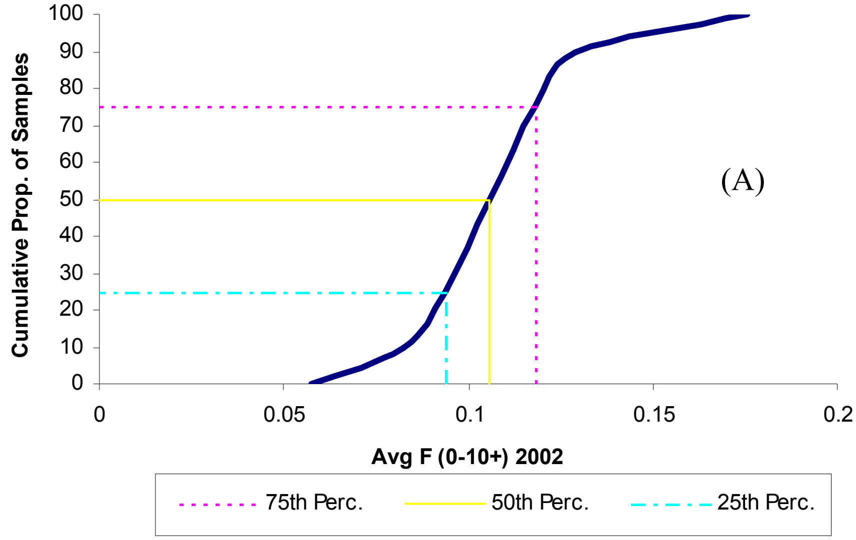


Figure G15. Estimates of Atlantic croaker bycatch from the shrimp fishery used in the simulation analysis. The circle represents the median estimate of all runs, the box the inter-quartile range and the whiskers the range of estimates. The dark circle represents estimates from 1994.



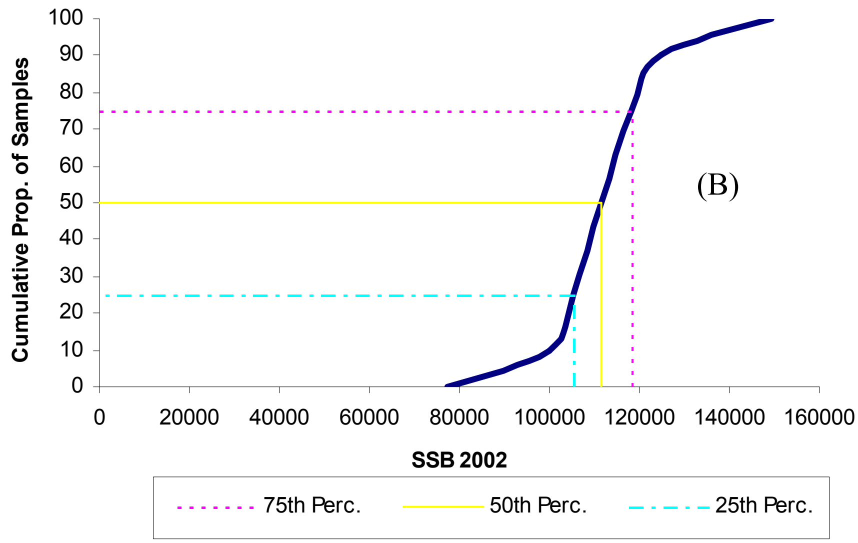
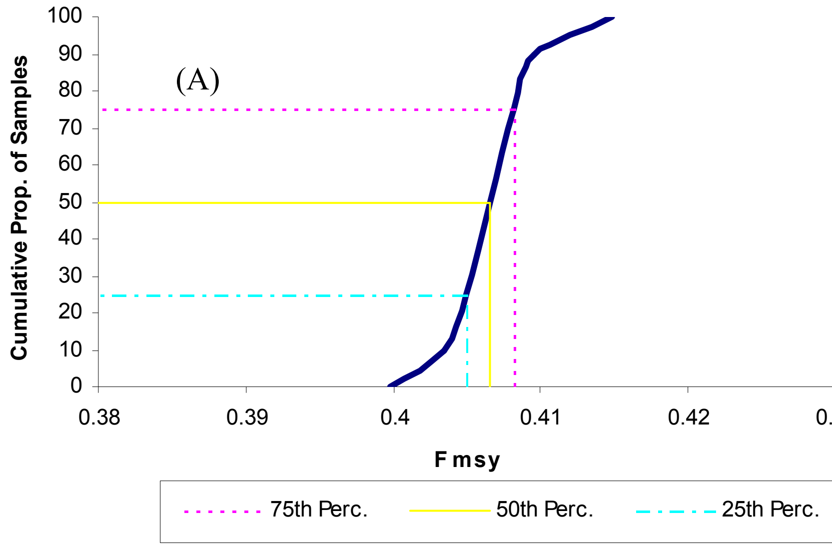


Figure G16. (A): Estimates of average fishing mortality rates (Ages 0-10+) and (B): spawning stock biomass (MT) for 2002 from sensitivity analysis where estimates of Atlantic croaker bycatch from the shrimp fishery are included in the model. Figures show the cumulative proportion of samples that had estimates at the 25^{th}, 50, and 75^{th} percentiles.



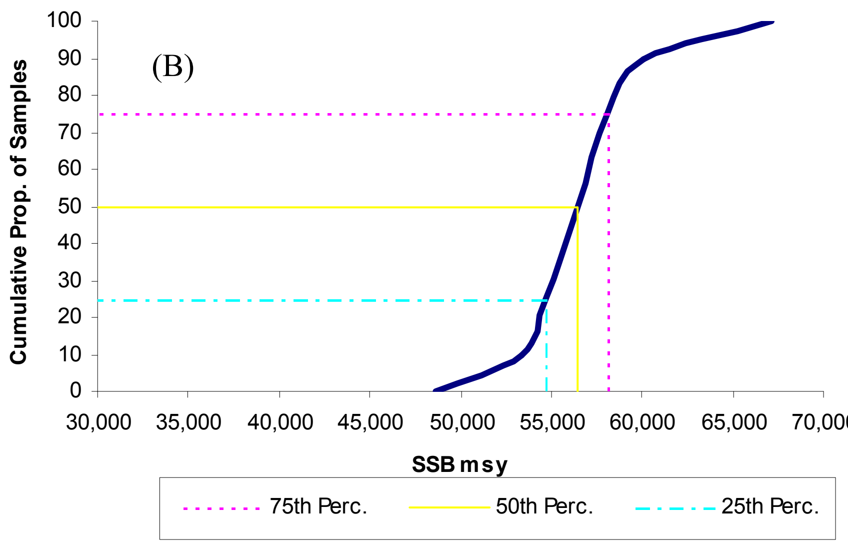


Figure G17. (A): Estimates of F_{msy} and (B) :SSB_{msy} from sensitivity analysis where estimates of Atlantic croaker bycatch from the shrimp fishery are included in the model. Figures show the cumulative proportion of samples that had estimates at the 25^{th}, 50, and 75^{th} percentiles.

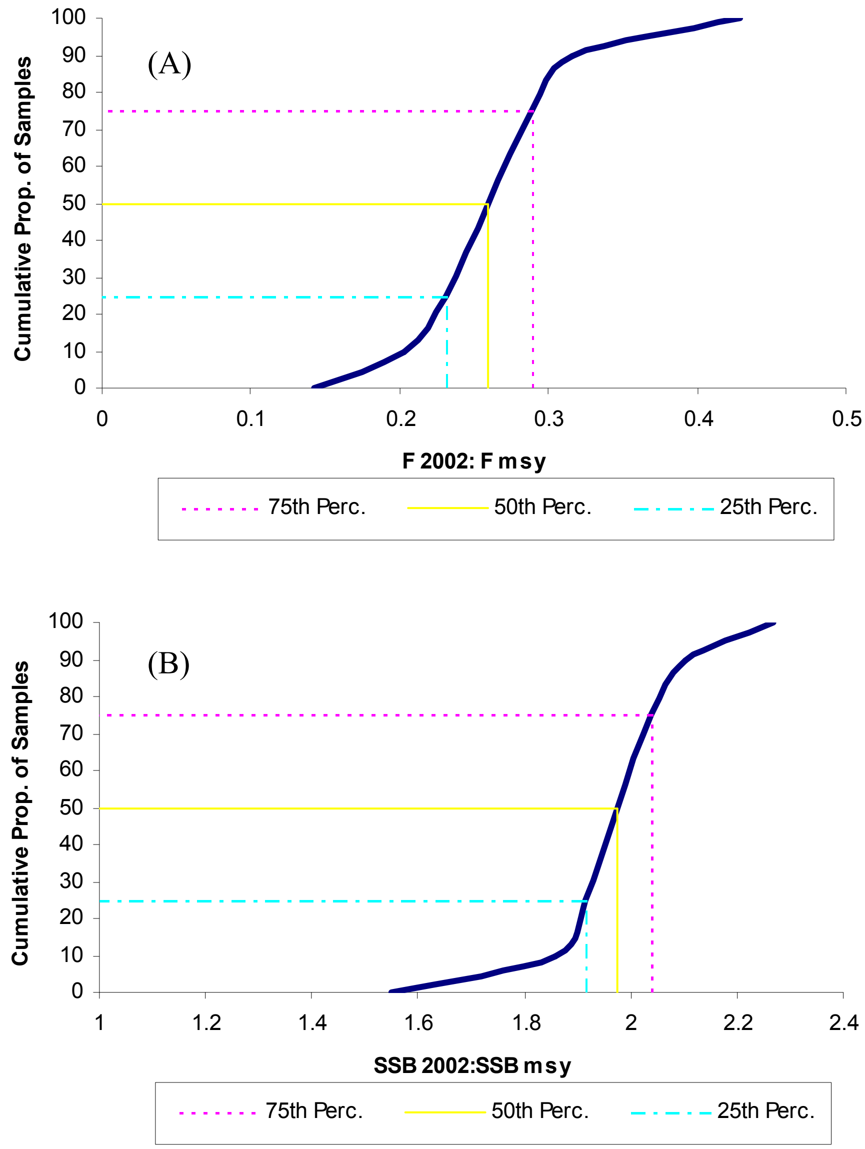


Figure G18. Estimates of F_{2002}: Fmsy and SSB_{2002}: SSB_{msy} ratios from sensitivity analysis where estimates of Atlantic croaker bycatch from the shrimp fishery are included in the model. Figures show the cumulative proportion of samples that had estimates at the 25^{th}, 50, and 75^{th} percentile.

Appendix H: Status of stock identification of Atlantic croaker along the east coast on the U.S.

A realistic population assessment has as its basis the correct identity of the species. Historically, there have been problems in the specific identification of exploited fishes. For example, redfish of the genus *Sebastes* occur in the deeper waters off the New England states and Canada, across the North Atlantic to Norway and the Barents Sea. Initially redfish were assigned to the species *Sebastes marinus*. Subsequent taxonomic studies found that there were two species: *S. mentella* and *S. fasciatus*. Because of this systematic problem, published and unpublished studies of "*S. marinus*" are suspect and may apply to either species. It is even more problematical in that they co-occur and also have been shown to hybridize (see Marcogliese et al., 2003).

For a valid species with a broad distributional range, the next problem is to determine if, within its range, that species is a unit stock. This term has a variety of definitions. Ricker (1975) called it "a part of a fish population which is under consideration from the point of view of actual or potential utilization". This definition is quite vague and has not been considered as the most appropriate. One of the most complete and understandable explanations of the term is that of Sparre and Venema (1992). From their perspective, a "stock is a sub-set of one species having the same growth and mortality parameters, and inhabiting a particular geographical area". Stocks show little mixing with the adjacent group, and since they possess the same growth and mortality parameters over their distribution, they can undergo modeling of their population. According to Hilborn and Walters (1992) "a unit stock is an arbitrary collections of populations of fish that is large enough to be essentially self-reproducing (abundance changes are not dominated by immigration or emigration), with members of the collection showing similar patterns of growth, migration and dispersal".

Methods to determine the unity of a stock of fishes include tag-recapture, meristics and morphometrics, parasite studies, scale and/or otolith pattern analysis, and genetic analysis including blood protein electrophoresis and DNA analysis. Recently, advances in the chemical composition (elemental composition) of otoliths have provided a method to determine the estuarine origin as well as a check for fidelity of the early life stages to a given estuary. In addition, investigators have compared life history traits such as growth, maturity schedules, and physiological tolerance ranges to determine if these vary between areas within the species geographic range.

Tag-recapture

There are numerous articles and reviews of the problems associated with and the use of tag-recapture experiments on fishes. Fish are caught with the least 'offensive' gear, handled as delicately as possible and marked with tags that are of the proper size and construction. By the latter, we mean that the tag should be made of materials that last. I have marked fish with a type of tag (T-bar) in the proper place (locked in the pterygiophores of the dorsal fin) and had them fail in a very short time. The plastic shaft with the "T" separated from the part of the tag that had the sequential number as well as the information for reporting the tag. To investigate the stock structure (or lack of structure) of Atlantic croaker along the US east coast, the tagging would occur to the south and north of the North Carolina coast to see if there is exchange between the two areas. If a sufficient number of fish were tagged and there was a reasonable reporting rate of the captured tagged fish, one could determine if there were northern and southern 'stocks' of Atlantic croaker.

The Georgia Department of Natural Resources conducted a study of the inshore fish species of importance to recreational anglers (Music and Pafford 1984). The Atlantic croaker was included in the species list. Fishes were collected with a variety of gear, studied for biological characteristics and tagged and released in an attempt to get information on movements. They tagged 3,456 Atlantic croaker from April 3, 1979 through June 28, 1982. Only 2.5% of the tags were returned (n = 87). Returns were made by recreational anglers (n = 50), commercial fishermen (n = 13) as well as recaptures by project personnel (n = 24). Time at large (period between marking and return) ranged from 2 to 416 days with an average of 63 days. The longest distance traveled from the tagging to the recapture location was 179 km with an average of 10.9 km. Over half of the returns (50.6%) were from fish caught in the same general location as where marked and released. Most of the recaptures came from either the creek systems or the Georgia Sounds. Of the three fish that moved over 100 km, two moved south to the St. Johns River in Florida and one moved north to Cane Island South Carolina. The remaining recaptures were less than 50 km from the release location.

A longterm study of the biota of the Cape Fear River, North Carolina estuarine system was conducted by Swartz et al. (1979). One aspect of this work was to examine movements of fishes within and between areas by tagging. Over the study period (1973 – 1977), 28,231 Atlantic croaker were tagged and released. Approximately 2% of the tags (n = 563) were returned to the investigators. Only 14 of the returns showed significant movement along the coast from 75 to ~300 km. Six fish were taken between the Cape Fear system and Cape Lookout, NC; seven fish between Cape Lookout and Ocracoke Island, NC; a single fish was caught between Ocracoke Island and Cape Hatteras. No fishes were caught at significant distances to the south of Cape Fear. Thus, some fishes tagged in the areas around Cape Fear moved as far north as the area around Cape Hatteras indicating that there was the potential for movement into the Mid-Atlantic region.

Although there may be other studies conducted by various states and agencies, we could find no other results for the east coast of the United States.

Morphometrics and meristics

In the recent literature, a study by Ross (1988) suggested that the growth rates of Atlantic croaker from the coastal areas of North Carolina showed differences. The more northerly group (northern North Carolina to Chesapeake Bay) lived longer and had a different growth curve than the more southerly group (south of Pamlico Sound, North Carolina). He suggested that the two groups over-lapped off North Carolina. It is difficult to determine from his paper whether he considered these “groups” as separate stocks. He did suggest, however, that the northern “group” had differing life history traits such as a longer life span, a later age at sexual maturity than the southern group. The latter was characterized by faster growth, early maturation, a shorter life span, and smaller size.

Two comments concerning this work. First, ages of the Atlantic croaker used in his study were determined from the analysis of scales. Second, the maturity schedules based on scale ages are suspect and those reports from the literature need to be re-evaluated. The last sentence in his paper is “Population dynamics and resulting fishery management in North Carolina may be confounded by a mixing of Atlantic croaker stocks until adequate separation techniques are developed.” I argue that he has not provided a sufficiently detailed analysis of the species throughout its distributional range along the east coast of the United States to define two “groups” or stocks.

Genetic analysis

Recent advances in analytical techniques to determine the composition of the genetic materials of species and individuals within species has led to a blossoming of studies attempting to determine the stock structure of marine fishes. Lankford et al. (1999) applied the analysis of mitochondrial DNA to investigate the possible stock structure of Atlantic croaker in U.S. waters. Their main finding was “MtDNA analysis provided no evidence that *M. undulatus* is subdivided by Cape Hatteras into discrete genetic stocks. Frequency and distance-based analyses both suggested a single, panmictic population of Atlantic croaker on the U.S. Atlantic coast.” Lankford et al. (1999) did find differences between fishes from the eastern Atlantic coast and those from the Gulf of Mexico. As is the case of most genetic analyses, the paper concluded with the following statement: “Mark-recapture studies designed to quantify the level of adult migration across Cape Hatteras, combined with otolith-microchemical analyses to examine larval dispersal patterns, could provide valuable information on the level of mixing between the MAB and South Atlantic Bight (SAB) areas and clarify the extent to which *M. undulatus* in these regions constitute self-recruiting groups.”

The use of modern, genetic analyses has failed to prove that the Atlantic croaker along the east coast of the United States forms “group” or stocks. Lankford et al. (1999) also state that “Because low levels of gene flow may produce mtDNA homogeneity between otherwise self-recruiting stocks, mtDNA is incapable of distinguishing between low (1%) and moderate (50%) amounts of mixing.”

No doubt, some new more sensitive technique will come into vogue and all these studies will be repeated.

Elemental composition of otoliths

Thorrold et al. (1997) applied laser ablation inductively coupled plasma mass spectrometry (LA – ICPMS) to the sagittae of wild caught Atlantic croaker juveniles. These fish originated from the Neuse River, NC and the Elizabeth River, VA. The technique basically vaporizes a very small area of the otolith and passes the resulting gas through a mass spectrometer to determine the concentrations and presence of specific elements. The investigator is then able to compare the elemental composition between areas or across different regions of the otolith section to determine ontogenetic changes in the elements and their concentrations. Since the elements are absorbed from seawater and incorporated into the structure of the otolith as it grows, the elemental composition of the otolith reflects the characteristics of the water body where the fish was at that time.

Thorrold et al. (1997) tested the sagittae of fishes from the above areas and found no differences in the chemical make up of the core area of the sagittae. The Atlantic croaker spawns off-shore on shelf and near-shore waters during the late summer and fall off the Middle Atlantic states and in off-shore waters primarily in late-fall and winter in the South Atlantic Bight. Their test fishes were caught in March and April 1994 and ranged between 20 and 45-mm standard length. The analyses showed that the chemical signatures of the central regions of the otoliths from the two areas could not be separated. The centers are deposited in the first days of the larval fishes' life and indicate the water mass within which the spawning event took place. The signatures suggested that they all originated from the same area. The authors stated "We were, however, unable to reject the hypothesis that Atlantic croaker larvae from north and south of Cape Hatteras originated from different spawning sites. This may indicate that the larvae were spawned in close geographical proximity, and strengthens arguments that Atlantic croaker in the MAB and SAB represent a single spawning stock."

Thus, the use of highly sophisticated analytical techniques were able to define "groups" of Atlantic croaker along the east coast of the U.S. One question jumps to mind from the paper. The Neuse River can not be referred to as 'north of Cape Hatteras" since the North Carolina Sounds are all connected and the juveniles may have gained access to the sounds from the inlets north of the Cape, i.e., Oregon Inlet. Secondly, even if the Neuse River is considered to be "south of Cape Hatteras", it would have been very helpful to substitute fishes from the Cape Fear River, North Carolina or some estuarine system further to the south. The stock definition issue is clouded between Atlantic croaker found south of Cape Fear, NC to near Cape Canaveral, FL and those of the Middle Atlantic such as Chesapeake Bay, VA and Delaware Bay.

Analysis of the parasitic fauna

The analysis of the parasitic fauna on fishes has been used for quite some time to study populations and movements of marine fishes (see MacKenzie 1983 for a review). When a fish becomes infected with a parasite, it contacts the parasite's infective phase. This may occur when a fish swallows food items that act as vectors, the parasite attaches to the body of the host, or when the fish becomes inoculated by a tissue feeder such as a leech (Lester 1990). A particular parasite generally has a restrictive distribution over the host's range because there are temporal and spatial limitations when a host is in proximity to the infective stage. As Lester (1993) so aptly points out "As fish move into the exchange points, they become infected, and as they move out, they carry a legacy of their occupancy of the points.".

The use of parasites as indicators of population structure and fish movement is not without limitations. Sinderman (1957) presented the following as contributing to these limitations: (1) the variability of parasitic infection with season and location; (2) does a parasitic infection cause differential mortality so that the resulting sampled group of fish is not representative to the real population; (3) the distribution of the parasite within a host may reflect variations in the distributions or abundance of intermediate or alternate hosts; (4) environmental factors such as temperature, salinity, etc.; and (5) longterm fluctuations may not be apparent in short term studies.

To be used in movement and population studies the following factors need to be addressed: (1) host specificity – does the parasite infect the target species and how specific is this parasite to the host; (2) what is the geographic distribution of the host as well as the parasite; (3) what is the sex of the host; (4) what is the size of the host; (5) what is the season of examination of the potential host for the presence of the parasite; and (6) what is the location of infection on the host.

In a comparison of the parasitic fauna infecting Atlantic croaker from various latitudes along the east coast of the US, Thoney (1993) reports some differences in the abundance of a suite of parasites in Atlantic croaker. The specimens were taken during the spring and fall groundfish surveys conducted along the east coast of the US by the National Marine Fisheries Service, Woods Hole. A weakness in this specific work resulted from the design of the research. Fishes were taken in two seasons, however, during the cooler months (i.e., spring), Atlantic croaker are in the warmer waters of the southern part of the survey's range. As water temperatures warm, this species moves north and inshore. Essentially, this study compared the parasites of the same "groups" of fish and the resulting differences may have been seasonal, size, or age related and hence could not form a solid foundation for stock determination. The distributional range of the samples was restricted to the northern and central part of the range along the east coast.

Researchers at the College of Charleston and the South Carolina Department of Natural Resources (SCDNR) are investigating whether the parasitic fauna of Atlantic croaker can be used to group the Atlantic coast population into discrete units. Fishes are collected during the groundfish survey of the Northeast Fisheries Science Center of the NMFS. These are frozen and shipped to the laboratory in Charleston, SC. Fishes are measured, weighed, sexed, assigned a reproductive condition, and aged by thin sections of sagittal otoliths. A variety of tissues and organ systems are examined for infection. The parasites are identified to the lowest possible taxon, counted and the within host distribution is documented.

Preliminary results are promising, however, the study has been on-going for one year and has two additional years to completion. Below is the general summary of the parasite information to date. The data will be presented at a scientific meeting. Remember, these are preliminary and fishes from other seasons need to be analyzed.

Abstract - presentation for SSP - April 04

In order to identify potential stock populations of the Atlantic croaker, *Micropogonias undulatus*, on the eastern coast of the United States, SCDNR initiated the study of the macroparasite fauna of this fish species to determine if some of its parasites could be used as biological tags. This is a three year project (2002-2005) and results presented herein are restricted to findings generated from the dissection of 111 Atlantic croakers collected from the New Jersey coast through Cape Canaveral FL in the Fall of 2002. Of all the macroparasite species collected, 2 acanthocephalans (*Pomphorhynchus rocci* and *Serrasentis sagittifer*), 1 nematode (*Spirocamallanus cricotus*), 1 cestode (*Scolex polymorphus unilocularis*), 1 copepod (*Lernaeenicus radiatus*), 1 digenean (*Diplomonorchis leistomi*), and 1 gastric monogenean (species yet to be identified and described) showed differences in occurrence north and south of Cape Hatteras, N.C., and are thus considered to be good candidates to act as natural tags marking potential Atlantic croaker stocks. Funded by a MARFIN grant NA17FF2885.

Comparison of life history traits

Several researchers have suggested that there are two stocks of Atlantic croaker along the east coast of the US with Cape Hatteras forming the breaking point between these stocks. They have indicated that the fish north of Hatteras have a longer life span, later age and size at sexual maturity, and differing mortality schedules and growth rates. The problem was that in these studies, the basis for comparison was suspect. Maturity schedules, mortality rates, longevity, and growth all require the proper determination of age. The initial work was based on the analysis of scales (see Ross 1988). Subsequent work has used otoliths, however, the location and description of the first annulus was difficult to reproduce and requires standardization (see Barbieri et al. 1994). Also, the latter work was based on specimens from only the Chesapeake Bay area and renders the discussion and the interpretation of the findings comparing other geographical locations as questionable.

Lankford and Targett (2001) conducted a series of tests on age-0 Atlantic croaker to determine their environmental tolerances and make comparisons along a latitudinal gradient along the east coast of the US. The initial work established the rates of survival at different temperatures. It ranged from 0% at 1^{o}C to 99.3% at 7^{o}C. The survival rate dramatically increased between 3 ^{o}C (1.3%) and 5^{o}C (86.8%). They also found that size had an impact on survival with smaller individuals being able to survive longer than larger individuals. Also, at higher salinities, survival increased. The next series of experiments compared these findings from age-0 Atlantic croakers collected in different Atlantic Coast estuaries (Lankford and Targett 2001). The sites were Delaware Bay, DE, Cape Fear River, NC, and Indian River Lagoon, FL. Growth capacity, feeding rate, growth efficiency, and cold tolerance were similar across geographic locations. This provided supporting evidence of a single genetic stock of Atlantic croakers along the US east coast.

Summary

One stock, two stock, three stock, four stock

The growth data as well as other life history comparisons on a latitudinal gradient along the east coast of the U.S. are suspect because of age problems (scales against otolith sections; differing interpretations of the first check mark on the sections). The tagging data from in the lower portion of the SAB suggests that although there is movement between states, no long-distance movements north of Cape Romain, SC were noted. On the other hand, the tagging information from the Cape Fear River, NC study shows movement from Cape Fear to the area around Cape Hatteras, NC indicating that the movement of fishes from the SAB may occur, but its significance is not known. The use of genetics has failed to show any differences between fishes in different areas along the east coast. Only a small amount of interchange obscures population differences. So far, the Atlantic croaker found along the east coast of North America may form two separate stocks; those of the Gulf of Mexico differ genetically from those along the east coast of the US and analytical techniques are not sophisticated enough to determine if there indeed are separate groups along the east coast. The parasite data are incomplete and require more locations, sizes and sexes to fill out the various sampling categories. The temperature tolerances, i.e., survival at low temperatures, are similar along the east coast for young-of-year (YOY). Growth parameters for YOY are also consistent throughout the region.

Future studies of various traits should examine fishes from the limits of their distributional range along the east coast of the US, and then examine those between the extremes to determine if there are indeed two stocks of Atlantic croaker.

Literature Cited

BARBIERI, L.R., M.E. CHITTENDEN,JR., AND C.M. JONES.
1994. Age, growth and mortality of Atlantic croaker, *Micropogonias undulatus*, in the Chesapeake Bay region with a discussion of apparent geographic changes in population dynamics. Fish. Bull. 92:1-12.

HILBORN, R. AND C.J. WALTERS.
1992. Quantitative Fisheries Stock Assessment. Chapman and Hall, NY, NY. 570p.

LANKFORD, T.E., JR., AND T.E. TARGETT.
2001. Low-temperature tolerance of age-0 Atlantic croakers: recruitment implications for U.S. Mid-Atlantic estuaries. Trans. Amer. Fish. Soc. 130:236-249.

LANKFORD, T.E., JR., AND T.E. TARGETT.
2001. physiological performance of young-of-year Atlantic croakers from different Atlantic coast estuaries: implications for stock structure. Trans. Amer. Fish. Soc. 130: 367-375.

LANKFORD,T.E.,Jr, T.E. TARGETT AND P.M.GAFFNEY.
1999. Mitochondrial DNA analysis of population structure in the Atlantic croaker, *Micropogonias undulatus* (Perciformes: Sciaenidae). Fish. Bull. 97: 884-890.

LESTER, J.G.
1990. Reappraisal of the use of fish parasites for fish stock identification. Aust. J. Mar. Freshwater Res. 41:855-864.

MacKENZIE,K.
1983. Parasites as biological tags in fish population studies. Advances in Appl. Biol. 7:251-331.

MARCOGLIESE,D.J., E. ALBERT, P. GAGNON, J. SEVIGNY.
2003. Use of parasites in stock identification of the deepwater redfish (*Sebastes mentella*) in the Northwest Atlantic. Fish. Bull. 101:183-188.

MUSIC, J.L.,JR AND J.M. PAFFORD.
1984. Population dynamics and life history aspects of major marine sportfishes in Georgia's coastal waters. GA DNR, Coastal Resources Dic., Contri. Ser. No. 38, 382p.

RICKER, W.E.
1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Bd. Canada Bull. 191, 382 p.

ROSS,S.W.
1988. Age, growth, and mortality of Atlantic croaker in North Carolina, with comments on population dynamics. Trans. Amer. Fish. Soc. 117: 461-473.

SINDERMAN,C.J.
1983. parasites as natural tags for marine fish: a review. Northwest Atlantic Fish. Org. Sci. Council Ser. 6: 63-71.

SPARRE, P. AND S.C. VENEMA.
1992. Introduction to tropical fish stock assessment. Part 1. Manual. FAO

Rome, 376p.

SWARTZ, F.J., L. DAVIDSON, C. SIMPSON, M. McADAMS,K. SANDOY, J. DUNCAN AND D. MASON.
1979. An ecological study of fishes and invertebrate macrofauna utilizing the Cape Fear River, Carolina Beach Inlet, and adjacent Atlantic Ocean. Inst. Mar. Sci. Univ. North Carolina. Final Report to Carolina Power and Light Company, Raleigh, N.C.,571 p.

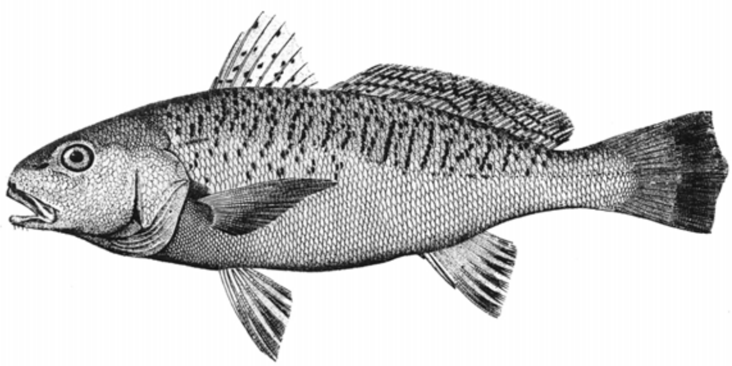
THONEY, D.A.
1993. community ecology of the parasites of adult spot, *Leiostomus xanthurus,* and Atlantic croaker, *Miscropogonias undulatus* (Sciaenidae) in the Cape Hatteras region. J. Fish. Biol. 43: 781-804.

THORROLD,S.R.,C.M.JONES, AND S.E. CAMPANA.
1997. response of otolith microchemistry to environmental variations experienced by larval and juvenile Atlantic croaker (*Micropogonias undulatus).* Limnol. Oceanog. 42: 102-111.

Atlantic States Marine Fisheries Commission

Atlantic Croaker 2003 Stock Assessment Report

DRAFT



October 2003

Working towards healthy, self-sustaining populations for all Atlantic coast fish species or successful restoration well in progress by the year 2015

Table of Contents

List of Tables

List of Figures

Terms of Reference

1. Evaluate adequacy and appropriateness of fishery-dependent and fishery- independent data used in the assessment (i.e. was the best available data used in the assessment).

2. Evaluate adequacy, appropriateness, and application of models used to assess the species and to estimate population benchmarks.

3. Evaluate adequacy and appropriateness of the Technical Committee's recommendations of current stock status based on biological-reference points.

4. Develop recommendations for future research for improving data collection and the assessment.

5. Prepare a report summarizing the peer review panel's evaluation of the stock assessment. (Drafted during the Review Workshop; Final report due October 23, 2003.)

6. Prepare a summary stock status report including research recommendations. (Drafted during the Review Workshop, Final report due October 23, 2003.)

1.0 Introduction

The Fishery Management Plan (FMP) for Atlantic croaker, adopted in 1987, included the states from Maryland through Florida. After a review of early results of the Interstate Fisheries Management Process, the Atlantic States Marine Fisheries Commission (ASMFC) determined that the plan for Atlantic croaker should possibly be revised. . A Wallop-Breaux grant from U.S. Fish and Wildlife Service provided fiscal support for a workshop for this species as well as spot. The results would provide the foundation for a major amendment to the 1987 FMP. The October 1993 workshop at the Virginia Institute of Marine Science was attended by university and state agency representatives from six states. Presentations on fishery-dependent and fishery-independent data, population dynamics and bycatch reduction devices were made and discussed. The results and a set of recommendations were included in the workshop report (ASMFC 1993).

Subsequent to the workshop and independent of it, the South Atlantic State/Federal Fisheries Management Board of the ASMFC reviewed the status of several plans to define those compliance issues to be enforced under the Atlantic Coast Fisheries Cooperative Management Act (ACFCMA). The Board found the Atlantic Croaker FMP was vague and no longer valid; they recommended an amendment to define management measures necessary to achieve the goals of the FMP. In the final schedule for compliance under the ACFCMA, the Interstate Fisheries Management Program (ISFMP) Policy Board adopted the finding that the current Atlantic Croaker FMP does not contain any management measures that states are required to implement (ASMFC 2002).

A Technical Committee appointed in 1997, compiled data during the summer of 1998. This was the first step in the preparation of a stock assessment. The proceedings of the 1993 workshop as well as data collected by the states and federal agencies since then provided the basis for an amendment to the plan (ASMFC 2002). However, no amendment has been drafted, to date.

2.0 Life History

General Information

Atlantic croaker (*Micropogonias undulates* Linnaeus) occur in coastal waters from the Gulf of Maine to Argentina (Lee et al. 2001). Although not common north of New Jersey, this species is one of the most abundant inshore demersal fish of the Atlantic Coast of the United States (ASMFC 1987). The Atlantic croaker is an opportunistic bottom-feeder on benthic epifauna and infauna and consumes a variety of invertebrates, including polychaetes, mollusks, ostracods, copepods, amphipods, mysids, and decapods, and occasionally fish (ASMFC 1987). Differences in spatial and temporal distribution, as well as differences in feeding behavior, reduce competition between juvenile sciaenids, such as Atlantic croaker and spot, and allow them to coexist in the same area (both spot and Atlantic croaker frequently co-occur in the same habitats – including juveniles). Predators of Atlantic croaker are larger piscivourous species such as striped bass, southern flounder, bluefish, weakfish, and spotted seatrout (ASMFC, 1987).

Larvae have been collected from near the edge of the continental shelf to within estuaries of the Mid- and South Atlantic coast (ASMFC 1987). Croaker larvae move from offshore spawning grounds to estuarine areas by mechanisms that are not well understood, but are likely influenced by both behavior of the larvae and physical processes (Barbieri et al. 1994a).

Recruitment of young-of-the-year (YOY) croaker to estuarine areas occurs over an extended period of time. Movement into the nursery areas generally peaks in the fall north of Cape Hatteras, North Carolina and in the winter and early spring to the south. Young –of-the-year were collected in October in the Delaware River, October to February in a Virginia Atlantic coast estuary, and July to November in Chesapeake Bay. Recruitment of early life stages to estuaries south of Chesapeake Bay took place from August to April with maximum ingress in December through February for North Carolina, South Carolina, Georgia and Florida (ASMFC 1987).

Early life history stages of Atlantic croaker exhibit ontogenetic shifts in prey items and habitat preferences. Larval and post larval Atlantic croaker are primarily zooplantivourous, while detritus appears to be a major component of the juvenile diet. The detritus may be a result of the foraging on benthic infauna and epifauna rather than a source of energy. Post-larval and very young Atlantic croaker occupy estuarine nursery areas, where they are often associated with the shallow marsh habitat over a broad range of estuarine salinities (ASMFC 1987).

Temperature induced winter mortality may be an important factor limiting recruitment in the mid-Atlantic bight. Lankford and Targett (2001) determined winter water temperatures at or below 3^{o} C drastically reduced survival of YOY Atlantic croaker. Laboratory experiments indicated 0% survival at 1^{o} C and 1.3% survival at 3^{o} C. There was a size-dependent factor where smaller individuals survived at higher rates than larger individuals (Lankford and Targett, 2001).

2.1 Age

Initial studies of the age of Atlantic croaker in the Gulf of Mexico were based on the analysis of marks on scales (White and Chittenden 1977). These researchers found few age groups and concluded that this species has a short life span, early age at maturity and could withstand considerable exploitation. Barger (1985) found that transverse sections of sagittal otoliths gave the most repeatable age estimates of Atlantic croaker from the Gulf of Mexico. Marginal increment analysis indicated that a single mark was deposited annually on the sagittae. Also, eight age groups were found suggesting that scales underestimate the true age of the fish in that area.

Ross (1988) aged Atlantic croakers from North Carolina waters also by scale analysis. Subsequently, Barbieri et al. (1994b) used sections of sagittae to age fish from the Chesapeake Bay during 1988-1991. A single annulus formed each year during April and May for all age classes (8); precision of the estimates was very good (99%). Their maximum age was 8 years from Chesapeake Bay collections (Barbieri et al. 1994b). Since this study, the population has expanded and maximum observed age has increased to 12 from fishes landed in Virginia and North Carolina in 2001 (Bobko et al. 2003 and NCDMF 2002). Sections of Atlantic croaker otoliths removed from archeological excavations near St. Augustine, Florida indicated that coastal Indians from the First Spanish period captured fish with a maximum age of 15 years (Hales and Reitz 1992).

Since Atlantic croaker have an extended spawning season and recruit to the estuarine nursery areas over an extended period, there are some problems associated with the assignment of ages to fish taken along the Atlantic coast of the U.S. As previously stated, the fish may move into the estuaries north of North Carolina as early as July. This would result in these croakers being approximately seven to ten months of age during their first spring. Along the southeast coast (North Carolina and south), most Atlantic croaker recruit to the estuaries from January through March. These fish would be from two to five months of age during their initial spring. The YOY north of Cape Hatteras form a rather indistinct mark near the core of the otolith that has been designated as the first annulus by some researchers, e.g., Barbieri et al. (1994b). The problem lies in the fact that this mark is not seen in the transverse sections of the sagittae of all fish. In those fish with the ring proximate to the core, the indistinct mark is designated as the first annulus. If the mark is absent and the distance to the first well-defined increment is relatively large, one is added to the number of annuli.

South of Chesapeake Bay, some fish do have the hazy area near the core, but many fish lack it. Ages of the fish from North Carolina and south have been determined by designating the first well defined, distinct ring as the first annulus. The ages may be made comparable by either subtracting one from the northern estimates by Virginia researchers or adding one to the counts from North Carolina and South Carolina biologists.

It should be noted that a workshop is planned by South Carolina Department of Natural Resources to attempt to standardize procedures for aging east coast sciaenids, including the Atlantic croaker.

Age data were available from five sources, and all surveys used sectioned otoliths to age specimen. These were as follows: (1) the Virginia Marine Resources Commission/ Old Dominion University (Virginia commercial landings from 1998-2002); (2) The North Carolina Division of Marine Fisheries (NCDMF) (fishery independent and dependent sources from 1996-2002), (3) Virginia Institute of Marine Science Age and Growth study (1998-2000); (4) South Carolina DNR aging of SEAMAP samples (2001-2002); and from commercial landings from Maryland (1999-2001) (Tables 2.1.1 and 2.1.2).

2.2 Growth

The size-at-age for Atlantic croaker is highly variable (Chittenden et al. 1994). Croaker grow rapidly during the first year; but the rate decreases during the second year and remains comparatively low thereafter. Barbieri et al. 1993 found on average, 64% of the cumulative total observed growth in length occurred in the first year and 84% was completed after two years. There was no difference found in the total length-total weight relationship between sexes (Chittenden et al. 1994).

Given the uncertainty associated with ages determined using scales, only those from sectioned otoliths were included. Growth parameters derived from the available otolith age data were compared with the literature (Table 2.2.1). The increased number of older fish in recent samples from Virginia and North Carolina result in larger von Bertalanffy estimates of theoretical maximum size ($L_{\infty)}$ than those of Barbieri et al. 1994a. Estimates of the growth parameter, K appear to be lower for data in the recent time series than those of Barbieri (1994a). There also appears to be a similarity in the recent von Bertalanffy estimates to those estimated by Hales and Reitz (1992) for Atlantic croaker from archeological sites (Table 2.2.1).

2.3 Reproduction

Atlantic croaker are multiple spawners with asynchronous oocyte development and indeterminate fecundity. At a population level, spawning extends over a six month period (July-December, could extend into January). Some authors suggest that individual fish spawn for only 2-3 months (Chittenden et al. 1994). Atlantic croaker spawn in the lower Chesapeake Bay as well as in coastal oceanic waters (Chittenden et al. 1994). Apparently, spawning starts in Chesapeake Bay and continues offshore and south as Atlantic croaker migrate out of the estuary. However, the occurrence during the fall of some regressing and resting females in Chesapeake Bay indicates that at least some individuals may complete their spawning in estuarine waters. A re-examination of the historical ichthyoplankton studies of the Chesapeake Bay would provide an indication of the magnitude of estuarine spawning for this species.

2.3.1 Sex ratio

Atlantic croaker in the Chesapeake Bay region showed temporal changes in sex ratio (Chittenden et al. 1994). In 1990-1991, Chittenden et al. 1994 found the contribution of the males in the Chesapeake Bay decreased at the beginning of the spawning season (June-July) and reached a minimum in September-October Males became more abundant again during November-December. Between 1989 and 2002 the annual proportion of females for the Virginia commercial fishery range between 0.54 and 0.8 with an average of 0.67.

2.3.2 Size and Age at Maturity

Based on samples of the commercial catches in the Chesapeake Bay and the Virginia and North Carolina coastal waters (n = 3091) during 1990 to 1991, Barbieri et al. (1994b) determined that Atlantic croaker mature at a small size and early age. Males and females started to mature at 170 and 150 mm total length, respectively. At larger sizes, the percentages of mature fish in the samples increased rapidly. Estimated mean length at first maturity was 182 mm TL for males and 173 mm TL for females. All individuals greater than or equal to 250-260mmTL were mature, regardless of sex. They also indicated that the same general pattern held for the maturity schedule by age. More than 85% of both males and females were sexually mature by the end of their first year.

2.4 Stock definitions

Genetic population structure in Atlantic croaker (*Micropogonias undulatus*) was examined by using the polymerase chain reaction (PCR) and restriction fragment length polymorphism (RFLP) analysis of mitochondrial DNA (mtDNA) (Lankford et al. 1999).

Juvenile croaker from three U.S. Atlantic localities (Delaware, North Carolina, and Florida) and one Gulf of Mexico locality (Louisiana) were screened to document the magnitude and spatial distribution of mtDNA variation in this species. The objectives were to evaluate the integrity of Cape Hatteras, North Carolina, as a genetic stock boundary; and to estimate levels of gene flow among Atlantic localities to provide an improved basis for future decisions regarding coastwide management of this fishery resource (Lankford et al. 1999). There was significant heterogeneity between Atlantic and Gulf of Mexico samples, suggesting restricted gene flow between these two regions. Analysis of molecular variance also indicated regional (Atlantic versus Gulf) population structure, but provided no evidence that Cape Hatteras represents a genetic stock boundary. These findings are consistent with: 1) a single genetic stock of *M. undulatus* on the Atlantic coast, and 2) separate, weakly differentiated stocks in the Atlantic and Gulf of Mexico (Lankford et al. 1999)

3.0 Fishery Description

3.1 Brief overview of Fisheries

Earlier records of commercial landings exist for some states, but because the data are incomplete we used records from 1950 to the present in this report. North Carolina commercial landings were low throughout the 1950s in comparison to Virginia. Sustained levels of high landings (greater than 5 million pounds) occurred in North Carolina from 1974-1990 and 1995-2001 and in Virginia from 1954-1959, 1976-1978, and 1993-2002.

The recreational catch statistics collected by the National marine Fisheries Service (Marine Recreational Fishery Statistics Survey, MRFSS) provided the data for the recreational landings component of this assessment. Data from 1981 through 2002 was used in. Recreational landings of Atlantic croaker (Type A + B1 in numbers), from Massachusetts through the Atlantic coast of Florida, have varied between 2.8 million fish (1981) and 13.2 million fish (2001), with landings showing a strong linear increase over this period (Table 5.2.2.1).

3.1.1 Commercial Fishery

Commercial landings of Atlantic croaker varied from one million pounds in 1970 to nearly 30 million pounds in 1976 and 1977 along the Atlantic coast. From 1996 to 2001, commercial landings have exceeded 20 million pounds annually. Annual landings consistently increased from a low of 3.7 million pounds in 1991 to 27 million pounds in 1997 (Table 3.1.1.1). North Carolina landings have continued to grow since 1993, to a maximum in 2001. However, the largest increase in landings was in Virginia, where only 164,000 pounds were reported in 1991, and more than 12 million pounds have been landed annually in Virginia since 1997. Coastwide landings of Atlantic croaker have remained steady at 25 to 28 million pounds from 1997 to 2001. This species is a major component of the commercial catches of Virginia, North Carolina, and Maryland. Gill nets, haul seines, trawls and pound nets accounted for most of those landings. (ASMFC 2002). In 2001, the total commercial value of croaker landings was $7,274,111(Table 3.1.1.2).

Atlantic croaker is the major component of the North Carolina “scrap fishery”. A number of regulations instituted by North Carolina, (the elimination of flynet fishing south of Cape Hatteras (1994); the introduction of BRDs in shrimp trawls (1992, by proclamation authority); limits on the incidental catch of finfish by shrimp and crab trawls in inside waters (since 1970s); and culling panels in long haul seines (1999) may have indirectly reduced catches of juvenile croaker and changed the size and age distributions of the harvest. In Georgia, trawl-caught croaker is sold as unsorted mixed fish along with spot, whiting, and small flounder; therefore, commercial landings are a tenuous measurement there. Small Atlantic croaker were previously a major part of the bycatch of the south Atlantic shrimp trawl fishery, however the use of TED’s and BRD’s has reduced this bycatch by an unquantifiable amount (ASMFC 2002).

3.1.2 Recreational Fishery

Between 1981 and 1990 annual average recreational landings (in numbers) amounted to 6.0 million fish, while more recently, between 1997 and 2002, recreational landings have ranged from a minimum of 9.1 million fish to a maximum of 13.2 million fish with average annual landings of 10.8 million fish. The increased landings in recent years have been at the northern range of the fishery (Massachusetts to North Carolina) particularly in New Jersey, Delaware, Maryland, and Virginia (Figures 5.2.2.1 and 5.2.2.2, Tables 5.2.2.1 and 5.2.2.2). During the past 10 years, recreational landings in Virginia, accounted for an average of 69 and-67 % of the total landings in numbers and weight, respectively. Landings from states north of Delaware accounted for sporadic and negligible landings of Atlantic croaker. Recreational landings at the southern range of the fishery (South Carolina through the Atlantic coast of Florida) have remained relatively stable, since 1997, with an annual average of 4.6 million fish and 2.5 million pounds (1997 – 2002). Recreational landings from the southern range of the fishery accounted for approximately 4.5 % of annual coast-wide landings between 1997-2002. The majority of landings in the southern region of the fishery were made on the Atlantic coast of Florida (Tables 5.2.2.1 and 5.2.2.2)

3.2 Regulations and Management History

The 1987 FMP for Atlantic croaker identified the following management measures for implementation:

1) Promote the development and use of bycatch reduction devices through demonstration and application in trawl fisheries.

2) Promote increases in yield per recruit through delaying entry to croaker fisheries to age one and older.

Although the ISFMP Policy Board judged that the FMP management recommendations were too vague and did not furnish objective compliance criteria, progress has been made on developing bycatch reduction devices (BRD's). The October 1993 workshop proceedings summarized experimental bycatch reduction work and examined the implications of bycatch reduction on the populations of Atlantic croaker and spot (ASMFC 1993). It was clear that there were economically viable shrimp gears that reduce finfish bycatch. North Carolina closed ocean waters south of Cape Hatteras to the South Carolina state line for flynets in 1994. These actions may indirectly affect the fishing impact on croaker (ASMFC 2002).

Table 3.2.1 summarizes the current state regulations for Atlantic croaker. Currently no regulations directly govern fishing practices for Atlantic croaker in North Carolina. However, the regulation, limiting the scrapfish catch to 5,000 pound per vessel per day, has an indirect effect since Atlantic croaker comprise a large percentage by weight landed by NC commercial fishing gears. BRDs were required in all North Carolina shrimp trawls in the fall of 1992 by proclamation. Restrictions such as a minimum mesh size (3" square or 3.5" diamond) in 1991 and the closure of ocean waters south of Cape Hatteras to flynets in 1994, also moderated the exploitation of croaker. Initial studies in long haul seines in 1996 produced a reduction in the average catch of the scrap fish species. The NCDMF adopted a permanent rule in April 1999 to require escape panels in long haul seines in the southern areas of the state. Some preliminary work has been done with sciaenid pound net fishermen along the Outer Banks to test a similar panel design in this fishery. A reduction of sub-adult croaker harvested should increase both spawning stock biomass and yield per recruit.

The Potomac River Fisheries Commission promotes the use of large mesh bycatch reduction panels in all pound nets, but use is voluntary (fishermen who use the escape panels are allowed to keep a by-catch of weakfish). It is estimated that the panels allow the release of 100% of captured croaker below the minimum legal size of nine (9) inches (ASMFC 2002).

The states of Florida through North Carolina have promoted and required the use of TED's (turtle excluder devices) and BRD's for trawls in state waters. Direct finfish trawling in inside estuarine waters has been banned in North Carolina since 1931. Finfish bycatch limits have been set since 1970s for non-finfish targeting trawls (i.e.: shrimp and crab) in inside estuarine waters and presently allows for only 500 pounds of finfish from December 1 to February 28 and 1,000 pounds of finfish from March 1 to November 30. North Carolina has implemented minimum stretch mesh size restrictions in shrimp trawls (1 1/2" tailbag) and crab trawls (to take hard crabs-3"; to take soft or "peeler" crabs-2") since 1991. Ocean trawls or flynets in ocean state waters have a minimum stretch mesh size since 1997 (4" main body, 3" extension, and 1 3/4" tail bag). Florida has a maximum shrimp trawl size. A ban on trawling in Virginia waters has been in effect, since 1989. Before you target a reduction, you need to measure the magnitude of the bycatch of this species, presently we lack good estimates for many of the South Atlantic states. Size limits that are in place in the states have been there for several years and do not represent a response to the FMP. In order to minimize recreational discard mortality, a new amendment may evaluate the concept of encouraging the use of hook types, which minimize such mortality (ASMFC 2002).

4.0 Habitat Description

The estuarine nursery areas for Atlantic croaker populations differ considerably among locations, possibly in response to tidal range. Where the range is less than 0.5m (20 inches), shallow open water areas at the landward extremities of large bays, as are shallow creeks, ponds, and lakes intimately associated with marsh are of major importance to juveniles. Where the tidal influence is stronger, large numbers of small juveniles have been collected from small tidal streams in the spring (ASMFC 1987); however, most reports indicate shallow areas are avoided and juvenile croakers are concentrated in the deep, main channels of estuaries as in the Delaware River, Chesapeake Bay, and the Cape Fear River. Apparently, shallow areas become less suitable for juvenile croakers as daily fluctuations of water level increase (ASMFC 1987).

Atlantic croakers are eurythermal with the early life stages more cold tolerant than adults. Juvenile croakers have been caught at water temperatures ranging from 0^{o} to $32^{o}C$ (ASMFC 1987). Atlantic croaker are also euryhaline being taken at salinities from 0 ppt to 70 ppt. More juveniles are associated with salinities in the oligohaline and mesohaline range (0.5 to 18 ppt) and the 0 to 70 ppt are the extremes (ASMFC 1987). As Atlantic croaker grow, they are much more likely to be found at high salinities (ASMFC 1987).

5.0 Data Sources

5.1 Commercial

Commercial landings data were taken from NOAA general canvas reports for all states, including the east coast of Florida. No observer data were available to quantify discard levels.

Biological samples were from state surveys. Age, length, and weight data of the Atlantic croaker commercial fishery have been sampled at fish houses by NCDMF since 1982, and VMRC since 1989. Maryland DNR has had a pound net survey in Chesapeake Bay since 1993. Limited age and weight data from MD are available since 1999.

5.1.1 Data Collection Methods

5.1.1.1 Survey Methods

NCDMF
The NCDMF has sampled major commercial fisheries since 1982. Atlantic croaker were sampled by gear, market category (in culled catches only), and area fished at local fish houses. Fishes were measured to the nearest mm (TL) and sample weights as well as total weights were taken to expand the sample data to the entire catch. Beginning in 1994, NCDMF instituted a trip ticket system to track commercial landings. Total catch by gear, area and market category were used to expand these data. To obtain overall annual distributions or mean landed CPUE in a fishery, the expanded values were weighted by the tri-annual commercial landings of the respective fishery in order to account for seasonal and between fishery differences in the magnitude of the landings. In 1994, the landings collection method changed from a voluntary dealer reporting system to a mandatory trip ticket system. Therefore, data may not be comparable between pre-1994 and post-1994 landings.

Scrapfish sampling was initiated in 1986. Total weight of a species in the scrapfish samples was calculated by determining the proportion of a species in the subsample and expanding that to the respective species proportional weight of the total scrapfish for the trip. The number of individuals per species in the scrapfish component was calculated by expanding the number of individuals in the sample to represent the total weight of the species for the scrapfish in the samples. Estimates of scrapfish landings for individual species were determined by applying the tri-annual ratio of marketable fish to scrapfish in the fish house samples to the reported tri-annual marketable landings. These trends are only from 1986 on, due to the lack of bait sampling prior to 1986.

Sub samples of Atlantic croaker were purchased to excise otoliths for age determination across the major commercial fisheries.

VMRC
At seafood dealers and buyers, commercially caught Atlantic croaker were sampled from 50-pound boxes of the graded catch. These were measured (mm TL) and weighed (0.1 lb). Market category, harvest area, gear type and total catch were noted. Beginning in 1999, samples were purchased to excise otoliths for age determination. All aging studies (processing and reading) were done at Old Dominion University's Center for Quantitative Fisheries Ecology.

MD DNR
Since 1993, commercial pound nets were surveyed during June through September. Atlantic croaker were sampled for length data. Beginning in 1999, limited age, sex and weight data were collected. All otoliths were processed and read by SC DNR.

5.1.1.2 Sampling intensity

Sampling intensity, relative to the magnitude of the catch, was generally low especially in MD, VA, and NC in the late 1990's as harvests increased. No other length data were available from other states. Sampling for length from the MD commercial fishery ranged from 0.7 lengths/mt in 2000 to 10.8 lengths/mt in 1994 (average 1993 – 2001 = 3.9 length / mt). Virginia's sampling intensity ranged from 0.47 lengths / mt in 2000 to 63 lengths / mt in 1991 (average 1989 – 2001 = 14.0 lengths / mt). North Carolina's sampling intensity ranged from 0.2 lengths/ mt in 1977 to 18.5 lengths / mt in 1992 (average 1977 – 2001 = 7.4 lengths / mt).

5.1.1.3 Biases

Substantial biases may exist in the Atlantic croaker sampling programs among the states collecting biological data. There are distinct seasonal and gear differences (selectivity) among the fisheries. The rapid growth of Atlantic croaker also makes it necessary to sample the catch throughout the year. Initially, the Stock Assessment Subcommittee attempted to segregate the biological data by trimesters, but available information was inadequate to characterize the commercial catch at such a resolution. The Subcommittee then decided that aggregating the biological data to broader time periods would introduce too much bias.

5.1.1.4 Aging methods

North Carolina

Atlantic croaker sagittal otolith samples were collected monthly from the winter trawl, long haul seine, pound net, sink net, recreational hook and line fisheries, and NCDMF independent programs. Sagittal otoliths have been collected since 1996. Each month, samples (n=15) are distributed across the size range in 15-mm size classes starting at 100 mm total length. Sagittal otoliths were removed, cleaned and stored dry. Total length to the nearest millimeter, weight to the nearest 0.01 kg, date, gear, and water location were recorded for each sample.

A transverse section through the focus on a plane perpendicular to the horizontal axis of the left otolith was prepared using a Hillquist thin-sectioning machine as described by Cowan et al. (1995). The system was calibrated with an ocular micrometer before each reading session. Sections were viewed under reflected light at 21X magnification. Annuli, marginal increment, and otolith size were measured (mm) on an image projected on a high resolution monitor from a video camera mounted on a microscope. Ages were assigned on the number of otolith annuli viewed. Sections were read and annuli measured by the aging lab biologist then independently read by the species lead biologist. Any differences were resolved or the data were not included.

A three-year report is compiled for species specific (seasonal based within a calendar year; winter January-March and October-December; summer April-September) age-length keys and applied to expanded length-frequency data to determine length at age for landed catches on an annual basis (NCDMF 2001).

South Carolina

In the laboratory, the left sagittae were viewed under low magnification with a binocular microscope (10X) and marked with a soft lead pencil on the core. These were then embedded in epoxide resin in silicon molds. After the resin had polymerized, the embedded otoliths were glued to a card held in a jig attached to the arm of a low speed saw. The otolith was positioned so that a transverse section ~0.5-mm thick could be taken through the core. The Isomet Saw was equipped with a pair of diamond wafering blades, separated by a plastic washer so that the section could be taken with a single cut. The resulting section was mounted on a labeled microscope slide with Cytoseal-XLY. After polymerization of the mounting medium, slides were stored in boxes until viewing. These were examined with a Nikon SMZU microscope equipped with a Supercircuits model PC – 23C high resolution camera with transmitted light. The video image was captured by a frame grabber board in a personal computer and was subsequently analyzed with the OPTIMAS® image analysis software. The following measurements were taken on each otolith section: (1) radius – distance in mm from the center of the core to the edge of the section as measured along the sulcus acousticus; (2) a_1 – distance in mm from the center of the core to the distal edge of the first annulus; (3) a_2 – distance in mm from the center of the core to the distal edge of the second annulus; (4) a_3 to a_n – distance from the center of the core to the distal edge of the third annulus and from the core to the distal edge of the n^{th} annulus; (5) marginal increment – distance from the distal edge of the last annulus to the edge of the otolith section.

Some Atlantic croaker otoliths varied with respect to diffuse, undefined marking near the core of the otolith. These diffuse areas were not interpreted as being a ring. We called the first annuli the first well defined opaque band that could be traced around the entire section.

5.1.2 Commercial landings

Atlantic state's commercial landings of Atlantic croaker exhibited three periods of peak landings: 1955 – 1959, 1975 – 1980, and 1995 - present (Figure 5.1.2.1). The highest landings were in

1977 at 13,532 mt. The current period of elevated landings is more than seven years. Conspicuously low levels of harvest were evident during the 1960's and early 1970's.

Three gear types have historically accounted for 95% of the harvest (Table 5.1.2.1). Haul seine and trawl fisheries accounted for an average of 31% and 35% of total Atlantic croaker harvest since 1950, respectively. Pound net and haul seine fisheries each accounted for an average of 16% of total landings, 1950 – 2001.

The commercial harvest has been dominated by NC and VA since 1950 (Table 5.1.2.2). North Carolina averaged 59% of the annual commercial landings among Atlantic coast states since 1950 and Virginia had a mean of 33.2%. Recently, (1997 – 2001) the mid-Atlantic states (NJ, MD, VA) had a higher proportion of the total commercial catch than their historic average. For example, New Jersey landings comprised 6.4% of the coastal catch during 1997 – 2001 (long term average = 1.6%), Maryland averaged 6.0% (long term average = 3.7%) and Virginia averaged 47.3% (long term average = 33.2%).

5.1.3 Commercial discards and bycatch

Quantifying bycatch and discard of Atlantic croaker is difficult. North Carolina maintains a regulated scrap fishery. However, the scrap fishery is not accounted for in the NOAA general canvas data.

The incidental catch of Atlantic croakers in the shrimp trawl fishery (predominately NC and south) is a major source of bycatch and discard mortality. Bycatch of Atlantic croaker was estimated at 5.8 mt to 12.7 mt (NC to FL) from 1973 to 1975, and 611 mt and 2283 mt (SC to FL) in 1992 and 1993, respectively (Diamond et al. 1999). Beginning in 1992, BRDS were mandated for the shrimp trawl fishery in North Carolina. No estimates of bycatch were available post-implementation of BRD mandates.

5.1.4 Commercial catch rates

Data were insufficient (spatially and temporally) to calculate CPUE from the commercial fishery.

5.1.5 Commercial catch at age

The subcommittee investigated using length and age data to compile a catch at age matrix for Atlantic croaker in four month intervals. However, the quality of the length and age data were not sufficient to complete this task.

5.2. Recreational

Two sources of recreational landings data for Atlantic croaker examined; the recreational catch statistics collected by the National Marine Fisheries Service (Marine Recreational Fishery Statistics Survey, MRFSS) and the National Marine Fisheries Service's headboat survey. On the Atlantic coast, the headboat survey collects data from headboats operating South of the Virginia-North Carolina border to Florida. However, examination of the data set revealed that species-specific information on Atlantic croaker was not available from the headboat survey.

5.2.1 Data Collection Methods

The MRFSS survey monitors fishing activity by recreational anglers by state, wave (two-month periods), mode of fishing and area fished. The recreational catch statistics from 1981-2002 and related materials were obtained from the MRFSS web site at http://www.st.nmfs.gov/st1/recreational/.

5.2.1.1 Survey Methods

A detailed description of the MRFSS survey methods is available at http://www.st.nmfs.gov/st1/recreational/pubs/data_users/index.html. To summarize, the survey consists of two independent and complementary parts: 1) a random telephone survey of households in the coastal counties of the eastern United State which is used to determine the number of recreational fishing trips conducted by the three modes during two-month time periods. 2) Angler interviews which collect information on the number of fish seen by the samplers, the number of fish that were caught and were unavailable to the sampler (Type B) because the fish could have been eaten, used for bait, or released and information on length and weights of fish available for inspection. The data from the two components are combined with U.S. Bureau of Census data to produce estimates of recreational catch, effort by state, wave, mode of fishing and area fished.

5.2.1.2 Sampling Intensity

The allocation of sampling for the telephone survey within a state is proportionally allocated based on the square root of the number of full-time occupied households in each county (MRFSS, 1999). For the intercept survey, sampling is stratified by state, mode, and wave with a minimum of 30 intercepts per stratum. Samples are allocated beyond the minimum in proportion to a 3-year average of fishing pressure (MRFSS 1999). For the intercept data, the number of interviews conducted in which Atlantic croaker were reported and the number of fish measured are presented in Table 5.2.1.2.

5.2.1.3 Biases

MRFSS estimates are designed to be unbiased and are based on a stratified random sampling design of fishers, which are combined with a random telephone survey. However, potential bias in the estimates could arise if the sampler were to have selected interviewees non-randomly. On occasion, there have been instances when the random telephone survey was found to be unrepresentative and an average estimate of trips has been substituted. Most recently, the 2002 telephone survey data were discarded for waves 2 and 3 and effort estimates based on a three-year average (1999-2001) for those waves was used.

5.2.1.4 Biological Sampling

As part of the intercept survey, MRFSS samplers also collect information on length and weights of fish measured. For Atlantic croaker, there is no other biological information from the MRFSS.

5.2.1.5 Aging Methods

Not Applicable

5.2.1.6 Development of Estimates

Estimates of landings in numbers and weight (Type A +B1), released landings (Type B2) and the total recreational trips are those published in the MRFSS. The trip estimates are for all recreational trips for the strata (i.e. by state, year wave, mode, area). An estimate of the number croaker trips within the strata was calculated by weighting the MRFSS trip estimates by the proportion of potential croaker trip intercepts to total intercept trips for the strata. See Section 5.2.4 for details on how potential croaker trips were identified. Total intercept trips were the number of unique angler trips for a given strata from the MRFSS intercept data set.

Recreational landings by size were determined using the length measurements from the intercept data set and the MRFSS landings estimates in numbers (Type A+B1). Examination of the data indicated that lengths samples were adequate (at best) to work at the state-year-wave level. Size distributions, based on 10 mm increments at the state-year-wave level were applied to the landings and released landings separately. However, there were many cells that had fewer than 50 length measurements per cell. For those cells that had less than 50 measurements, a size distribution based on a collapsed group of cells was used in a hierarchical manner. The levels of "collapsed length distributions " were:

1) If the number of length measurements were 50 or greater, those lengths were used to represent the state-year-wave cell.
2) If the number of length measurements were < 50, the size distribution applied to the cell were based on state-year- wave group. Two wave groups used were; waves 1 to 3 collapsed and waves 4 to 6 collapsed.
3) If, after using the collapsed size distribution the number of measurements for the cell was < 50, the length distribution used to fill the cell was based a size distribution at the state-year level.
4) If, after using the previous collapsed size distribution, the sample size was < 50, a size distribution based on measurements at a region-year level were applied. The fishery was divided into three regions; 1) Northeast - Virginia and North. 2) North Carolina and 3) Southeast -South Carolina and south. After using this final criteria there were a small number of cells (4) with less than 50 measurements, which were not collapsed further.

Once the landings were assigned a size distribution, the type A+B1 landings were appropriately apportioned among the size ranges representing the cell.

For the stock assessment, recreational discard mortality was estimated at 10% of Type B2 (released fish) estimates by numbers. Given the lack of information on discard mortality estimates, the estimate used was based on a consensus of the stock assessment-working group, but may not represent the true discard rate for the fishery. Recreational discards are those fish caught and released alive, but assumed to die as result of such factors such as hooking mortality and improper handling. As there are no weight estimates for recreational discards, the weighted size distribution of released estimates was used with a length-weight relationship (see section 6.2.2) to estimate the weight of the recreational discards.
.

In order to determine the weight of the discards, a weighted size distribution for the Type B2 estimates was required. As there was no information on the size of released fish (Type B2) three approaches to assigning a size distribution were evaluated. The first approach was based on assigning a size distribution similar to those assigned for the Type A+B1 landings. The second approach used the median size class for a given cell and using the length-weight relationship determined the landings for the cell. Since there are no size regulations on Atlantic croaker, except in Maryland and Georgia (PRFC has no size limit but does have a 25-croaker limit), the third approach was based on the assumption that released fish are likely to be representative of the lower range of the size distribution of those fish measured. The size at the 10, 15,20, 25 and 50th percentiles of fish measured within a cell was used to truncate the size distribution used for the released landings (Table 5.2.1.6). The truncated size distributions were used to determine the weight of the discards using the length-weight relationship.

5.2.2 Recreational Landings

From 1981-2002, recreational landings of Atlantic croaker (Type A+B1 in numbers), from Massachusetts through the Atlantic coast of Florida, have varied between 2.8 million fish (1981) and 13.2 million fish (2001), with landings showing a strong linear increase over this period (Table 5.2.2.1). Between 1981 and 1990 annual average recreational landings (in numbers) amounted to 6.0 million fish, while more recently, between 1997 and 2002, recreational landings have ranged from a minimum of 9.1 million fish to a maximum of 13.2 million fish with average annual landings of 10.8 million fish. The increased landings in recent years have been at the northern range of the fishery (Massachusetts to North Carolina) particularly in New Jersey, Delaware, Maryland, and Virginia (Figures 5.2.2.1 and 5.2.2.2, Tables 5.2.2.1 and 5.2.2.2). During the past 10 years, recreational landings in Virginia, accounted for an average of 69 and-67 % of the total landings in numbers and weight, respectively. Landings from states north of Delaware accounted for sporadic and negligible landings of Atlantic croaker. Recreational landings at the southern range of the fishery (South Carolina through the Atlantic coast of Florida) have remained relatively stable, since 1997, with an annual average of 4.6 million fish and 2.5 million pounds (1997 – 2002). Recreational landings from the southern range of the fishery accounted for approximately 4.5 % of annual coast-wide landings between 1997-2002. The majority of landings in the southern region of the fishery were made on the Atlantic coast of

Florida (Tables 5.2.2.1 and 5.2.2.2).

The precision of recreational landings is expressed as proportional standard error (PSE), which describes the standard error of the estimate relative to the estimate (MRFSS 1999). MRFSS (1999) noted that PSE estimates less than 20% are commonly observed for commonly caught sport fishes. For Atlantic croaker, the PSE by state varies over the time series, with the major mid-Atlantic states (North Carolina and Maryland) being associated with PSE values between 8 –12 % (Table 5.2.2.3). Estimates of Atlantic croaker landings from the south-Atlantic states (South Carolina, Georgia and Florida) were associated with PSE values between 15-30% in recent years (Table 5.2.2.3).

Atlantic croaker were primarily caught in inland waters by fishermen in private or rental boats or fishing from the shore. Fishermen in private/rental boats fishing in inland waters represent on average 71% of landings by numbers since 1993 (Table 5.2.2.4). Landings from offshore waters account for a small portion of the recreational landings (Figure 5.2.2.3). Private/rental boats accounted for the majority of Atlantic croaker landings (Figure 5.2.2.4). During the early to mid 1980's, shore fishing accounted for a relatively large portion of the landings. However, more recently landings by shore fishers and charter/party boats have remained low and stable (Figure 5.2.2.4). Recreational fishing for Atlantic croaker occurs mostly in the summer (Figure 5.2.2.5) and the majority of landings take place in waves 3 and 4 (May-August). However, at the southern range of the fishery, the landings occur over a slightly extended period from May-October.

Between 1981 and 2002 total recreational effort in state-wave-mode-area combinations where Atlantic croaker were caught has increased in a linear trend from a low of 7.7 to a high of 25 million trips (Table 5.2.2.5; Figure 5.2.2.6). Total recreational effort in the northern range of the fishery (North of North Carolina) accounted for on average 59% of total trips between 1997 and 2002. Estimates of targeted Atlantic croaker trips also show a linear increase between 1981 and 2002 from a low of 3.0 to a high of 14.2 million trips (Table 5.2.2.5; Figure 5.2.2.6). The majority of targeted croaker trips occurred in the northern range of the fishery with an annual average of 80% of total trips in the fishery in recent years (1997-2002).

The size distribution of Atlantic croaker weighted by Type A+B1 landings indicate that at the northern region of the fishery, an increase in the modal size in recent years was evident (Table 5.2.2.6) with the median size increasing from 245 in 1981 to 335 mm TL in 2002 (Figure 5.2.2.7). At the southern range of the fishery the modal size of Atlantic croaker landed has remained relatively stable, fluctuating between 265 and 295 mm TL (Table 5.2.2.7; Figure 5.2.2.8).

5.2.3 Recreational Discards

Recreational discards are included in the MRFSS estimates as the number of fish released alive (Type B2). In 1981, Atlantic croaker released by fishermen amounted to 1.2 million fish, and by 2002 the number of released fish had increased almost tenfold (Table 5.2.3.1). At the northern range of the fishery, which accounts for the majority of landings, the ratio of fish released alive to those landed has remained relatively stable over last 10 years, with an average of 1.2 fish being released for every fish that was kept (Figure 5.2.3.1). At the southern range of the fishery, the ratio of Atlantic croaker released to those kept in recent years (1998 onwards) has been similar to those observed for the northern range of the fishery. Prior to 1998, the ratio of fish released to those kept were lower for the southern range of the fishery than those observed for the northern range of the fishery (Figure 5.2.3.1). The estimated numbers and weight of recreational discards based on the different methods used are presented in Table 5.2.3.2.

5.2.4 Recreational Catch Rates

In developing a MRFSS catch rate index for Atlantic croaker, an important factor is defining a sampling unit. Based on the discussions at the data workshop an Atlantic croaker trip was identified using three methods. These were:

1) Original: defined a croaker intercept-sampling unit as one where either croaker was caught or where the angler recorded croaker as a targeted species, but did not catch any.
2) Jacquard: Used a binary similarity index to identify a suite of species with which Atlantic croaker were associated, and defined a sampling unit as one where any of those species were caught. This was based on a Jacquard type index (Krebs 1989) and was determined for each state. The species that had the six highest coefficients (this included croaker) were used to identify a sampling unit. Jacquard's index can be defined as:

$$S_j = \frac{a}{a+b+c}$$

Where:
a = no of samples where Atlantic croaker and species j was present
b = no of samples where Atlantic croaker were present and species j was not present (unique Croaker samples)
c= no of samples where species j was present but Atlantic croaker was not present.

3) Strata: identified all state-year-wave-area-mode strata where Atlantic croaker were caught and used all sampling units within those identified strata as potential Atlantic croaker trips.

In general, these three methods made changes to the number of zero cells added. Comparing the preliminary results using the three methods indicated that:

1) As Atlantic croakers are not commonly listed as a targeted species, the number of zero samples added to method 1 (original) was relatively small. This is probably the least appropriate method.
2) In states where the species occurred rarely in the early years (e.g. NJ and DE) the strata method cannot add samples. It is dependent on the species being present.
3) For some states, the differences between strata and the jaccard method reflect that within the strata there are different target species groups. However, for some states the strata and jaccard methods provide similar estimates.

Statistical Analysis of Catch-Rates

The base data set used for estimating the MRFSS catch rates was determined using the potential croaker sets identified using method 2 (jaccard). Table 5.2.4.1 shows the species included in defining a croaker set for each of the states used in the analysis. Due to small sample sizes, data from Massachusetts, Rhode Island and New York were excluded. The data were further reduced to only include hook and line sets. The response variable used in the analyses was based on total number of Atlantic croaker per trip (Type A+B1+B2). Two statistical models were used to estimate MRFSS catch rates. These were:

1) A general linear model where log (total number of croaker catch +1) was the response variable. Explanatory variables used in the full model were state year, wave area and mode (treated as classes) and hours fished and contributors, which were, treated as continuous explanatory variables. A state by year interaction term was also included in the full model.
2) A generalized linear model using a negative binomial distribution, using a log link was also carried out. The response variable was the number of croaker per trip (A+B1+B2). The explanatory variables used were similar to the general linear model. However, as the model would not converge within the allotted trials, a state by year interaction term-was not included.

Preliminary evaluation of both statistical models revealed that all explanatory variables were statistically significant ($P < 0.01$). Given the significant year by state interaction term for the log transformed GLM, both models was re-run by state. A comparison of the normalized catch rates by state revealed that the fishery could be broadly categorized into a northern and southern region. These two groups were the region Virginia and North and the region South Carolina and south. Catch rate trends in North Carolina were intermediate to those seen for the northern and southern regions. For the northern states, the recent time trend indicates higher catch rates than normal while for the southern states, catch rates appear to be fluctuating around or just below their normal levels in recent years.

Based on an evaluation of abundance trends in the fishery independent indices, participants at the stock assessment workshop (see section 6.2), concluded that developing separate MRFSS indices for the northern and southern range of the fishery was the most appropriate approach to evaluating catch rates. As such, the data were partitioned into the mid-Atlantic (North Carolina, Virginia, Maryland, Delaware and New Jersey) and the south-Atlantic (South Carolina, Georgia and the Atlantic coast of Florida) and analyses were conducted separately using the protocol described for the preliminary evaluation. Back transformed least square means by year were used as estimates of the catch rate.

Summary statistics for the models are presented in Table 5.2.4.2. For the negative binomial generalized linear model, all explanatory variables were statistically significant ($P < 0.01$). As such, a reduced model was not developed. For the general linear model, explanatory variables included for both regions were statistically significant with the exception of the number of hours fished in the southern model (Table 5.2.4.2).

Catch rates developed using the two statistical models are presented in Table 5.2.4.3. In general the catch trends from the negative binomial generalized linear model and log-transformed general linear model were similar. For the mid-Atlantic region in 1981/82, the log transformed GLM produced negative estimates that were not significantly different from 0. This was in part because of the low number of trips in which Atlantic croaker were caught.

For the northern range of the fishery, catch rates appear to have steadily increased over the time series with a peak in 1999 (Figure 5.2.4.1). For the southern region catch rates appear to be more stable over the time series, except between 1990-1992, when the catch rates were much higher (Figure 5.2.4.2).

5.2.5 Recreational Catch-at-Age

No information.

5.3 Fishery- Independent Survey data

For this analysis eight fishery independent surveys were available. An inspection of the fishery independent indices revealed that they primarily targeted juveniles to Age 1, though older age classes were evident in some indices (NMFS and SEAMAP). The eight fishery independent indices were the NMFS fall trawl survey, SEAMAP trawl survey, VIMS trawl survey, North Carolina DMF juvenile estuarine and sound surveys, Maryland DNR juvenile index, and the Florida FWC fishery independent trawl and seine surveys. However, of the available indices the NMFS trawl survey and SEAMAP indices were identified for use in this assessment (see section 6.2.1) together with the possible use of the VIMS trawl survey. As such, detailed descriptions of the available surveys were confined to the SEAMAP, NMFS and VIMS survey.

5.3.1 SEAMAP

5.3.1.1 Sampling Intensity

Samples were taken by trawl from the coastal zone of the South Atlantic Bight (SAB) between Cape Hatteras, North Carolina, and Cape Canaveral, Florida. Multi-legged cruises were conducted in spring (early April - mid-May), summer (mid-July - early August), and fall (October - mid-November).

Stations were randomly selected from a pool of stations within each stratum. The number of stations sampled in each stratum was determined by optimal allocation. A total of 102 stations were sampled each season within twenty-four shallow water strata, representing an increase from 78 stations previously sampled in those strata by the trawl survey (1990-2000). Strata were delineated by the 4 m depth contour inshore and the 10 m depth contour offshore. In previous years, stations were sampled in deeper strata with station depths ranging from 10 to 19 m in order to gather data on the reproductive condition of commercial penaeid shrimp. Those strata were abandoned in 2001 in order to intensify sampling in the shallower depth-zone.

The R/V *Lady Lisa*, a 75-ft (23-m) wooden-hulled, double-rigged, St. Augustine shrimp trawler owned and operated by the South Carolina Department of Natural Resources (SCDNR), was used to tow paired 75-ft (22.9-m) mongoose-type Falcon trawl nets without TED's. The body of the trawl was constructed of #15 twine with 1.875-in (47.6-mm) stretch mesh. The cod end of the net was constructed of #30 twine with 1.625-in (41.3-mm) stretch mesh and was protected by chafing gear of #84 twine with 4-in (10-cm) stretch "scallop" mesh.

Trawls were towed for twenty minutes, excluding wire-out and haul-back time, exclusively during daylight hours (1 hour after sunrise to 1 hour before sunset). Contents of each net were sorted separately to species, and total biomass and number of individuals were recorded for all species of finfish, elasmobranchs, decapod and stomatopod crustaceans, cephalopods, sea turtles, xiphosurans, and cannonball jellies. Only total biomass was recorded for all other miscellaneous invertebrates (excluding cannonball jellies) and algae, which were treated as two separate taxonomic groups. Published characteristics of the fishing gear (sweep, headrope height) can be found in Stender and Barans (1994).

5.3.1.2 Biological Sampling

In every collection, each of the priority species was weighed collectively and individuals were measured to the nearest centimeter. For large collections of the priority species, a random sub-sample consisting of thirty to fifty individuals was weighed and measured. Depending on the species, measurements were recorded as total length, fork length, or carapace width.

Additional data were collected on individual specimens of penaeid shrimp (total length in mm, sex, female ovarian development, male spermatophore development, occurrence of mated females), blue crabs (carapace width in mm, individual weight, sex, presence and developmental stage of eggs), sharks (total and fork lengths in cm, individual weight, sex), horseshoe crabs (prosomal width and length in mm, individual weight, sex), and sea turtles (curved and straight lengths and widths in cm, individual weight, PIT and flipper tag numbers). Marine turtles were released in good condition according to NMFS permitting guidelines.

Gonad and otolith specimens were also collected during seasonal cruises. A representative sample of specimens from each centimeter size range within each stratum were measured to the nearest mm (TL and SL), weighed to the nearest gram, and assigned a sex and maturity code (Wenner et al. 1998). Sagittal otoliths and a representative series of gonadal tissue were removed, preserved, and transported to the laboratory at MRRI, where samples were processed.

Hydrographic data collected at each station included surface and bottom temperature and salinity measurements taken with a Seabird SBE-19 CTD profiler, sampling depth, and an estimate of wave height. Additionally, atmospheric data on air temperature, barometric pressure, precipitation, and wind speed and direction was also noted at each station.

5.3.1.3 Aging Methods

A detailed description of the aging methods used for Atlantic croaker from the SEAMAP collections is described in Wenner (2003).

5.3.1.4 Development of Estimates

Standardized estimates were determined using a delta-lognormal General Linear Model (Lo et al. 1992; Williams 2001). The proportion of positive tows was modeled using a binomial GLM and the positive tows using a lognormal GLM. Explanatory terms used in the model were year, season, and strata. Error estimates were obtained from a bootstrap procedure which re-samples residuals from the lognormal GLM model of the positive values and randomly draws values from the binomial distribution based on the observed and predicted positive data (Williams, 2001). Coast-wide estimates and regional estimates were developed for the SEAMAP index (see section 6.2. for rationale). Regional estimates consisted of a northern region and southern region, which split the survey into north of North Carolina-South Carolina border.

5.3.2 NMFS Northeast Trawl Survey

5.3.2.1 Sampling Intensity

The NMFS Northeast Trawl Survey is the longest running continuous time series of research vessel sampling in the world and comprises of two seasonal surveys; Spring and Fall. The fall survey was initiated in 1963; the spring in 1968. These surveys cover the ocean environment from 5 to 200 fathoms deep, from Cape Hatteras, North Carolina to well beyond the Canadian border. About 300 half-hour trawl sets are made at sites randomly chosen prior to the beginning of each survey. The distribution of trawling locations is allocated according to a statistical method that divides the region into a number of smaller areas with similar depth characteristics. Detailed descriptions of the survey and annual survey reports can be obtained at:
http://www.nefsc.noaa.gov/femad/ecosurvey/mainpage/survey.htm

5.3.2.2 Biases

Recently it was found that the marks on the cable attaching scientific survey gear to the vessel Albatross IV were not at the 50 m length intervals they intended to indicate. The vessel crew used these marks to determine how much cable is deployed. The cable was most recently replaced in February 2000, and used in eight bottom trawl surveys, beginning with Winter 2000 and ending with Spring 2002, which may have an impact on estimates in these years, by affecting the "catchability". Details of the problem can be found at: http://www.nefsc.noaa.gov/survey_gear/ .

5.3.2.3 Aging Methods

Not Applicable.

5.3.2.4 Development of Estimates

Estimates for Atlantic croaker were developed using the fall survey (Table 5.3.2.4.1). Standardized estimates were determined using a delta-lognormal General Linear Model (Lo et al. 1992; Williams 2001). The proportion of positive tows was modeled using a binomial GLM and the positive tows using a lognormal GLM. Explanatory terms used in the model were year, depth and latitude. Error estimates were obtained from a bootstrap procedure which re-samples residuals from the lognormal GLM model of the positive values and randomly draws values from the binomial distribution based on the observed and predicted positive data (Williams 2001).

5.3.3 Virginia Institute of Marine Sciences (VIMS) Trawl Survey.

The VIMS trawls survey began in 1955. It a young of the year survey that samples "…. from the mouth of the Chesapeake Bay up to the freshwater interface at the fall line of the James, York, and Rappahannock Rivers". For Atlantic croaker, the spring index is considered a more reliable measure of young of the year abundance and is representative of fish up to 100 mm (VIMS, Personal Communication). It is believed that Atlantic croaker are very sensitive to cold winter temperatures are susceptible to winter die-offs (VIMS, Personal Communication). As such, the spring index is considered a better indicator of young-of-the-year. Details of the survey can be found at
http://www.fisheries.vims.edu/trawlseine/mainpage.htm

5.3.3.1 Sampling Intensity

The VIMS index has a long time series of over 40 years. An annual sample size for the spring index ranged between 106 and 591 for the time period 1973-2002. The average annual number of samples was 295 samples/year. These samples include bay and river stations.

5.3.3.2 Biases

Unknown

5.3.3.3 Biological Sampling

Unknown

5.3.3.4 Aging Methods

Not Applicable

5.3.3.5 Development of Estimates

Data were provided by VIMS. Estimates presented are those based on the geometric mean, and takes into account gear conversion factors (Table 5.3.3.5.1).

5.3.4 Length/Weight/ Catch-at-Age

See section 6.2.2 for use of length-weight data. A catch at age matrix was not developed for this assessment.

5.3.5 Abundance Indices

No population abundance indices were available. See section 6.2.1 for indices used in the assessment and the assumptions made on the portion of the population they represented.

5.3.6 Biomass Indices

At present there are no biomass indices that represent the Atlantic croaker population.

5.3.7 Natural Mortality Estimates

A key parameter in a stock assessment is the natural mortality (M). However, it is also a parameter that is difficult to ascertain for species that have been exploited. Estimates of M are usually obtained using life history analogies, which have been expressed in terms of equations or rules of thumb (e.g. Pauly (1980), Hoenig (1983), Gabriel et al. (1989)).

In the early to mid 1990's (Barbieri et al. 1994b) and in the previous assessment of Atlantic croaker (Lee et al. 2001), the maximum observed age based on available information was considered to be between 7-8 years. Lee et al. (2001) used an M=0.35 for their base model. However, recent data indicate a maximum observed age of 12 years from commercial landings in Virginia and North Carolina. Otoliths collected from Indian mounds ~ 1400-1700 indicate a maximum age of 15 years for Atlantic croaker during a period in which, presumably, the exploitation was much lower than in recent times. Mortality estimates using these different data sources indicate that the estimates using the archeological data were the lowest, with data from the mid-1990's producing the highest estimates (Table 5.3.7.1). In general, adjusting for a fishing mortality rate of 0.1 for data collected in recent times, an estimated natural mortality rate range would be 0.15-0.4 and 0.2-.28 for the archeological data using Hoenig's (1983) method or 3/maximum age rule of thumb. Estimates using Pauly's (1980) and Alverson and Carney's method (Quinn and Deriso 1999) produced higher natural mortality estimates between 0.2-0.7. In addition, the total mortality, Z necessary to result in the observed proportion at the oldest age for each year was estimated for the North Carolina and VIMS/ODU data. Z estimates between 1998-2002 ranged from 0.78-0.44 for the North Carolina data and 0.59-0.39 for the VIMS/ODU data set.

6.0 Methods

6.1 Model(s)

For this analysis the primary data sources considered were the commercial and recreational landings, a selection of fishery independent juvenile to age 2 indices, the MRFSS index, together with age data from North Carolina (1996-2002) and Virginia (1998-2002).

Based on the available data, two model approaches were identified for a detailed evaluation. For this assessment we used a non-equilibrium surplus production model (ASPIC, Prager 1994) and age-structured surplus production model (Punt et al. 1995) to evaluate the population status of Atlantic croaker.

6.1.1. Surplus Production Model

The non-equilibrium surplus production model was implemented using ASPIC (Prager 1994). The foundation of the non-equilibrium surplus production can be described by the equation:

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

Where B_t = population biomass at time t; F_t= fishing mortality at time t; r = the stocks intrinsic rate of increase and K= maximum population size (carrying capacity). In the model, the fishing mortality rate for each fishery at time t is defined as:

$$F_{jt} = q_j f_{jt}$$

Where F_{jt} = Fishing mortality for fishery j at time t, q_j = the catchability coefficient for fishery j, and f_{jt} = effort for fishery j at time t. The data required for fitting the model are catch, effort, or yield for each time period, and can include population biomass indices for the time periods. The model estimates the initial biomass, r, K, and a catchability coefficient for each fishery that is included. Details of the objective function can be found in Prager (1994).

6.1.2. Age Structured Production Model.

The age-structured model we used is similar in structure to a forward-projection catch-at-age-model, with the exception that the some of the parameters are deterministic and based on available information.

The model uses a deterministic age-structured model to explain the population dynamics of a species where the population in successive years was linked using a Beverton and Holt stock recruitment relationship re-parameterized in terms of steepness. The major deterministic components in the model were parameters that characterized the growth, fecundity, and morphometrics of the species and; selectivity patterns for all of the fisheries and indices included in the model. To obtain a solution, the model minimizes the objective function by estimating a fully recruited fishing mortality rate of each year and fishery, catchability coefficients for the indices, virgin recruitment R_0 and a set of annual recruitment deviations from the stock-recruit relationship.

The population abundance for the model is estimated using the following equations:

For the initial year:

$$
\begin{cases}
N_{a,y} = R_0 \; SSB_{init:virgin\ ratio} & where\ a = 0 \\
N_{a,y} = N_{a-1,y} \exp^{-(M+F_{a-1,y})} & where\ 1 < a < 9 \\
N_{a,y} = N_{a-1,y} \dfrac{\exp^{-(M+F_{a-1,y})}}{1-\exp^{-(M+F_{a-1,y})}} & where\ a = 10
\end{cases}
$$

R_0 represents the virgin recruitment estimated by the model; M = natural mortality and F = fishing mortality at age, *a* in year*, y*. $SSB_{init:virgin\ ratio}$ is the ratio of the spawning stock biomass in the initial year to the virgin spawning biomass and was user defined as 0.75 in the base model.

For all other years:

$$
\begin{cases}
N_{a,y} = \dfrac{0.8 R_o h S_{y-1}}{0.2 R_o SSB_{y-1} SSBR_{F=0}(1-h) + SSB_{y-1}(h-0.2)} \exp^{\eta_y} & where\ a = 0 \\
N_{a,y} = N_{a-1,y-1} \exp^{-(M+F_{a-1,y-1})} & where\ 1 < a < 9 \\
N_{a,y} = N_{a-1,y-1} \exp^{-(M+F_{a-1,y-1})} + \quad N_{a,y} \exp^{-(M+F_{a,y-1})} & where\ a = 10
\end{cases}
$$

R_0 represents the virgin recruitment estimated by the model; *h* is the steepness parameter (defined as the proportion of virgin-stock recruitment production that occurs at 20% of the virgin spawning stock size); SSB_{y-1} represents the spawning stock biomass during the previous year and $SSBR_{F=0}$ is the calculated spawning stock biomass per recruit under no fishing. η_y represents the recruitment deviation from the Beverton and Holt stock recruitment relationship in year, *y*; M = natural mortality and F = fishing mortality at age, *a* in year*, y.*

The spawning stock biomass for a given year was estimated by:

$$
SSB_y = \sum_{a=0}^{a=10} 0.5 N_{a,y} Maturity_{a,y} Wt_{a,y}
$$

Where $N_{a,y}$= numbers at age in year *y*; $Maturity_{a,y}$ = proportion of mature fish at age a in year, y; $Wt_{a,y}$= weight at age in year y in Kg.

The spawning stock biomass per recruit under no fishing ($SSBR_{F=0}$) was estimated as:

$$SSBR_{F=0} = \sum_{a=0}^{a=10} SSBR_a Maturity_a Wt_a$$

$$where \begin{cases} SSBR_a = 1 & where\ a = 0 \\ SSBR_a = SSBR_{a-1} \exp^{-M} & where\ 1 < a < 9 \\ SSBR_a = SSBR_{a-1} \dfrac{\exp^{-M}}{1-\exp^{-M}} & where\ a = 10 \end{cases}$$

The predicted total catch for a given year was estimated using the Barnov catch equation, summed across fleets and ages.

$$\hat{Catch}_y = \sum_{fleet=1}^{fleet=n} \sum_{a=0}^{a=10} N_{a,y} \frac{F_{a,y}}{Z_{a,y}} (1-\exp^{-z_{a,y}})\, Wt_{a,y}$$

Where, Na,y = estimated population numbers at age a in year y. $F_{a,y}$ = fishing mortality at age, *a* in year*, y.* $Z_{a,y}$ = total mortality at age, *a* in year*, y.* $Wt_{a,y}$= individual weight at age in year y in metric tons.

The predicted estimates for the indices were:

$$\begin{cases} I_y = \sum_{a=0}^{a=10} q_{index} N_{a,y} Selectivity_{a,index} \exp^{(-partyr_{index}\ Z_{a,y})} & where\ index\ is\ in\ numbers \\ I_y = \sum_{a=0}^{a=10} q_{index} N_{a,y} Wt_{a,y} Selectivity_{a,index} \exp^{(-partyr_{index}\ Z_{a,y})} & where\ index\ is\ in\ weight \end{cases}$$

Where $N_{a,y}$ = estimated population numbers at age a in year y. $Z_{a,y}$ = total mortality at age, *a* in year*, y.* $Wt_{a,y}$= individual weight at age in year y in Kg. $Selectivity_{a,index}$= selectivity for age a in index. $Partyr_{\ index}$= the proportion of the year that has passed at the mid-point of the survey's measurement represented as a fraction of the year. q_{index} is the estimated catchability coefficient for the index.

The Objective function in the model was constructed of components representing the differences between observed and predicted catches and indices, together with a component that accounted for the amount of recruitment deviation from the spawner-recruit relationship. The total likelihood was described by:

$$L_{total} = L_{catch} + L_{index} + L_{rec-dev}$$

The likelihood components for the catch were defined as:

$$L_{catch} = \sum_{fleet=1}^{fleet=n} (\log(landings_{n,y}) - \log(Predicted\ landings_{n,y}))^2 \lambda_n$$

Where $landings_{n,y}$ =observed landings for fishery n in year y. $Predicted\ landings_{n,y}$ =predicted landings for fishery n in year y. λ_n= user assigned weighting component for fleet n (where the weighting component could be configured to represent $1/2\sigma^2$)

The likelihood component for the indices were defined as:

$$L_{index} = \sum_{index=1}^{index=n} (\log(Observed\ Index_{n,y}) - \log(Predicted\ Index_{n,y}))^2 \lambda_n$$

Where $Observed\ index_{n,y}$ =observed estimate for index n in year y. $Predicted\ Index_{n,y}$ =predicted estimate for index n in year y. λ_n= user assigned weighting component for index n (where the weighting component could be configured to represent $1/2\sigma^2$)

The likelihood component for the constraint recruitment deviations from the Beverton and Holt spawner-recruit curve were defined as:

$$L_{rec-dev} = \sum_{y=1973}^{y=2002} (RecDev_y)^2 \lambda$$

Where $RecDev_y$= the estimated log recruitment deviations in year, y with a mean=0 and λ = a user assigned weight (where the weighting component could be configured to represent $1/2\sigma^2$).

6.2 Model Calibration

Examination of the two major coast-wide fishery independent indices revealed differing trends (Figure 6.2.1.) For the NMFS survey, a relatively flat trend with a recent spike was observed, while for the SEAMAP index, the general annual trend revealed relatively high values in the early 1990's followed by a relatively flat trend in recent years. A more detailed examination of the two indices by strata revealed that the divergent patterns reflected the geographical regions where sampling occurred (Figure 6.2.2). At the southern range of the species (Florida to South Carolina) the catch trend revealed higher estimates between 1989-1992 followed by a relatively flat pattern in recent times. For the northern range of the species (North Carolina to New York) normalized estimates by strata appear to be higher in recent times (1998-2002) with relatively low estimates in the early part of the time series. The working group identified three possible alternatives to splitting the analysis into two regions: 1) splitting the region at Cape Hatteras NC, where all data north of Cape Hatteras, NC were included in a mid-Atlantic model and all data south of Cape Hatteras were included in a south-Atlantic model; 2) including North Carolina's ocean landings with the northern range and North Carolina's bay (sounds) landings with landings from South Carolina to east Florida; 3) Splitting the region at the North Carolina- South Carolina border. Based on a consensus of the stock assessment-working group, it was decided to evaluate the population status of Atlantic croaker using two independent models for the northern region of the species (North Carolina and North) and the southern range of the species (South Carolina to Florida). Examination of the MRFSS recreational index also revealed a north-south split (Section 5.2.4). While there are no genetic differences between the northern and southern range of the

Atlantic croaker population, the dynamics of the regions may be different. At the southern range of species, the fishery is predominantly a small recreational fishery. In the south, the commercial fishery, only occurs in Florida, and was affected by the constitutional amendment than banned the use entangling fishing gear in state waters in the mid 1990's.

For years prior to 1981, when recreational landings were unavailable, total annual landings were estimated for each state using an adjustment factor derived from the ratios of annual commercial landings to annual total landings from 1981-2001. The state-specific adjustment factors were derived in one of two ways. For North Carolina and Florida – East Coast, the ratio of commercial to total landings appeared to be relatively stable (or at least did not exhibit marked trends) over time. For these states, the adjustment factor was the average of the commercial fraction of the total annual landings. In North Carolina for example, the average commercial fraction of total annual landings was 0.95 (i.e. commercial landings accounted for 95% of total annual landings, on average). To hind-cast total annual landings for North Carolina prior to 1981, the annual commercial landings was divided by 0.95. For New Jersey, Maryland, and Virginia, a temporal pattern was present that suggested when commercial landings were relatively large the commercial fraction of total annual landings was larger than in years when commercial landings were relatively small. For these states, two separate adjustment factors were calculated as (1) the average of the commercial fraction of the total annual landings in high commercial landings years (1984-1989,1993-2001), and (2) the average of the commercial fraction of the total annual landings in low commercial landings years (1981-1983,1990-1992). For these three states, total annual landings were calculated by first classifying years prior to 1981 as high or low based on their annual commercial landings and then dividing the year's annual commercial landings by the respective high or low adjustment factor.

Commercial landings data were unavailable for 2002. For each state, total annual landings were estimated as annual recreational landings divided by (1 – commercial adjustment factor). For New Jersey, Maryland, and Virginia, 2002 was classified as a high year based on the relatively high commercial landings in recent years (1997-2001).

In this analysis, commercial discards have not been taken into consideration for the reasons outlined in Section 5.1.3. Estimates of recreational discards by weight were based on assuming that discarded fish were likely to be representative of fish equal to or lower than the 10^{th} percentile of the size distribution of those fish measured (see section 5.2.1.6).

As part of the preliminary analysis, a series of model runs were carried out. These comprised of two types. The first, were a set of core models for each of the regions (Mid-Atlantic and South-Atlantic). The core group of model runs consisted of a base run and eleven sensitivity runs for each region based on a set of natural mortality and steepness estimates. The base runs for each of the regional models, used a natural mortality rate of 0.3 and a steepness values associated with the 50^{th} percentile of the posterior probability distribution for steepness (Figures 6.2.3 – 6.2.4). The second set of models evaluated the model sensitivity to configuration and input data. Some of the factors evaluated included: use of a two-fleet coast-wide model with the mid-Atlantic indices; the effects of increased weighting of the likelihood terms for the indices; effects of assuming alternate biological characteristics; use of alternate indices; and sensitivity to missspecification of selectivity in the commercial fishery. A summary document describing the results of these preliminary runs is available on the FTP site.

Based on the preliminary analyses, the Atlantic croaker technical committee (ACTC) concluded that while, there was no genetic evidence to suggest two separate stocks, the population trends seen in the two regions differed, and the best way to capture those differences were through two separate models for the northern (mid-Atlantic model) and the southern regions of the stock (south-Atlantic model; Figure 6.2.5). The south Atlantic model represents the stock at its southern boundary. Personal observations of some members of the ACTC indicate that larger and older Atlantic croaker were rare in the South Atlantic. The lack of larger older fish could be the result of higher mortality rates or movement of older fish out of the region. The trends and estimates from a coast-wide model done in the preliminary analysis revealed that the estimates from the coast-wide model were almost identical to those of the mid-Atlantic model.

Based on the preliminary analysis, the ACTC also identified four major factors that the model was sensitive to. These were: the natural mortality estimate, steepness parameter, the ratio of spawning stock biomass in 1973 relative to virgin conditions, selectivity estimates of Age 0-1 Atlantic croaker in the commercial fishery, and age 0 fish in the recreational fishery. The sensitivity of the model to these factors were examined through a series of Monte Carlo trials over a range of estimates (Table 6.2.1).

6.2.1 Tuning Indices

For this analysis eight fishery independent surveys and two fishery dependent indices were available. An inspection of the fishery independent indices revealed that they were primarily targeting juveniles to Age 1. The eight fishery independent indices were the NMFS fall trawl survey, SEAMAP trawl survey, VIMS trawl survey, North Carolina DMF juvenile estuarine and sound surveys, Maryland DNR juvenile index, and the Florida FWC fishery independent trawl and seine surveys. The fishery dependent surveys were the MRFSS total catch index and the North Carolina DMF commercial CPUE index. Table 6.2.1.1 and Figures 6.2.1.1-6.2.1.3 summarize the annual estimates for the available fishery independent and dependent indices. For the SEAMAP index, estimates for the North, South, and combined estimates are included.

For this analysis, our choice of indices was based on those that had the best spatial representation of the region over the time period. As such, for the mid-Atlantic region, the core indices considered were the NMFS trawl survey, SEAMAP survey, and MRFSS index. The VIMS spring juvenile index was included in one of the runs in the preliminary analysis, as it covered the entire time period 1973-2002. For the south-Atlantic region we used the SEAMAP and MRFSS indices.

6.2.2. Input Parameters and Specifications

The input parameters required for implementing the model are:

1) Selectivity patterns for each of the indices used and the commercial and recreational fisheries.

2) Biological characteristics of the species described by the von Bertalanffy parameters (L_∞, k, t_0), length-weight relationship and maturity schedule.
3) Estimates of natural mortality, steepness, and the ratio of the initial years spawning stock biomass to the virgin spawning stock biomass.
4) Weightings for the likelihood components.
5) Bounds for parameters estimated by the model

Selectivity

Estimated selectivity patterns for the fisheries and indices were initially determined by examining the available information on size and age range of the respective fisheries/indices, together with input from the members of the stock assessment-working group. The selectivity pattern for each fishery and index was specified by assigning a probability of capture for each age class in the model.

For the commercial fishery, selectivity patterns were based on an examination of the size and age distribution of the fishery in the mid-Atlantic. Over the time series, the majority of commercial landings ranged between 220 –400 mm TL (Figure 6.2.2.1) and based on the North Carolina growth parameters, this size range would most likely have compromised of fish between Age 1 to 5 years (Figure 6.2.2.2.). An overlay of the 200-400 mm size range on the North Carolina age data is shown in Figure 6.2.2.3.

In the early model runs a semi-observed catch-at-age matrix was used to iteratively tune age-specific selectivity estimates for the mid-Atlantic commercial fishery on a gross scale. Sufficient age data were available from Virginia's commercial fishery to construct annual age-length keys for years 1998-2001. The observed catch-at-age matrix for Virginia's commercial fishery, which included ages 1-10, was scaled to represent the mid-Atlantic region by multiplying each cell in the matrix by a year-specific expansion factor. The annual expansion factor was the ratio of the mid-Atlantic region annual commercial landings (NJ + MD + VA + NC) to Virginia's annual commercial landings. The resulting semi-observed catch-at-age matrix for the mid-Atlantic region was used to calculate catch-at-age residuals ([semi-observed catch-at-age matrix] – [predicted catch-at-age matrix]) from initial model runs. Consistent patterns in the residuals indicated that the selectivity estimates were high for ages 1-2 (negative residuals, predicted catches too large), reasonable for ages 3-4 (residuals near 0), and low for ages 5-10 (positive residuals, predicted catches too small). Selectivity estimates were adjusted, and residuals were re-examined graphically after subsequent model runs. Formal optimization of selectivity parameters was not performed given the order-of-magnitude accuracy level of the semi-observed catch-at-age matrix. Based on the evaluations, a flat-topped selectivity pattern was used for the commercial fishery in all runs. Given, the lack of information of size for the south Atlantic fishery, the mid-Atlantic selectivity pattern was also used for the south Atlantic model.

Based on the preliminary analyses, the ACTC concluded that there was much uncertainty on the selectivity estimates for Age 0 – 1 and modified the selectivity pattern accordingly. The available commercial data did not fully capture the size and age ranges of Atlantic croaker captured by the trawl fisheries. The ACTC concluded that as a base case for both models, a selectivity of 0.1 for age 0, 0.55 for Age 1 and 1.0 for all other ages was appropriate (Table 6.2.2.1).

The size distribution of Atlantic croaker caught by the recreational fishery was similar between for the mid-Atlantic and south Atlantic. However, larger fish between 295- 395 mm TL were less well represented in the south Atlantic fishery. However, the differences did not warrant a separate selectivity patterns for the regions. In general fish between 180 and 380 mm TL are well represent in the fishery (Figure 6.2.2.4). When the size estimates were converted to ages, fish age 1-8 are likely to be well represented in the fishery (Figures 6.2.2.5 and 6.2.2.6). For the recreational fishery, the ACTC modified the initial estimates of selectivity to include a selectivity estimate of 0.05 for age 0 fish and 1.0 for all other ages.

For the NMFS trawl and SEAMAP trawl surveys the majority of Atlantic croaker caught was between 120-240 mm TL and 110 –230 mm TL respectively (Figure 6.2.2.7; Figure 6.2.2.10). It appears that both these indices are good indicators of Age 0-1 Atlantic croaker and the selectivity patterns chosen reflect this (Figures 6.2.2.8, 6.2.2.9, 6.2.2.11, 6.2.2.12; Table 6.2.2.1). For 2001 and 2002 age data from the SEAMAP survey also indicate that the majority of Atlantic croaker were age 0-1.

Biological characteristics

Age information on Atlantic croaker was available form five data sources. Based on an examination of the growth curves from those data sets, and estimates in the literature, the stock assessment-working group concluded the most appropriate growth model to assign an estimated length at age was that based on the North Carolina DMF data set on pooled sexes. As such, length at age was estimated using:

$$Length - at - Age = L_{\infty}(1 - \exp^{(-k(Age - t_0))})$$
$$where\ L_{\infty} = 434.6mm,\ k = 0.2415,\ t_0 = -1.9572$$

Weight at age (kg) was estimated using:

$$Weight - at - Age = a\ (Length - at - Age)^{b}$$
$$where\ a = 5.49 \times 10^{-9},\ b = 3.13$$

Based on Barbieri et al. (1994a) we assigned Atlantic croaker a maturity schedule where Age 0 fish were considered immature (0% maturity), by Age 1, 90% were mature and from Age 2 onwards, 100% were considered mature.

Natural mortality and steepness

Given the large range of natural mortality estimates derived using the traditional methods of approximation (~ 0.15-0.6), a range of natural mortality rates was chosen for the preliminary analyses (0.2 to 0.4). For the base models presented in the assessment, M=0.30.

Steepness, *h* is a measure of recruitment when the spawning stock biomass is reduced to 20% of the stock when no fishing is present. Steepness is an indicator of the ability of a fish stock to withstand high fishing mortality rates; high steepness values indicate a resilient species, as recruitment is high even when the spawning stock biomass is reduced to low levels.

The choice of steepness values is an important factor in the model implementation, and is important in assessing the additional mortality a population can sustain over the long term (Myers et al. 2002). One solution to using appropriate estimates of steepness is to use a Bayesian approach in the model formulation. However, one of the most important considerations in using the Bayesian approach is having an informative prior distribution. Myers et al. (2002), have addressed this for Atlantic croaker by developing a series of prior distributions for the species using an empirical Bayesian approach. For this assessment we initially developed a posterior distribution for steepness for each of the regions using the Myers et al. (2002) prior distribution for Atlantic croaker (derived from their covariate analysis). The prior distribution was described using a beta distribution where α_1=4.7728 and α_2=2.2201(Figure 6.2.2.13).

In the preliminary analyses, steepness values at various percentiles of the posterior distribution were used for the model runs. An examination of the steepness estimates from the posterior probability distribution indicated a median estimate of 0.5 for both regional models. On further inspection, the ACTC concluded that the data provided little to no information for steepness. As such, it was decided to use the modal estimate from Myers et al (2002) prior as the base value of steepness (0.76).

Weighting of the likelihood components

Weighting of the likelihood components can have an important effect on the outcome on the estimates of the parameters. The main likelihood components in the model are based on a lognormal distribution. For all analyses we gave all components, except the fishery independent indices, a weighting (λ) of 1. This was equivalent to assigning the residuals in each data set a coefficient of variation (C.V.) of 0.8. (Where C.V.= $\sqrt{(\exp(\sigma^2)-1)}$ as λ is equivalent to $1/2\sigma^2$. For the fishery independent indices the weightings were increased to 2.0 (equivalent to a C.V. of 0.5). The ACTC felt that the residuals of the fishery independent indices were likely to be associated with less variability than the other terms in the objective function.

Bounds for parameters estimated by the model

For models implemented in Excel, the fishing mortality rate per fleet was bound between 0 and 1.5. The parameter bounds for all models implemented in AD model Builder were similar, and are summarized in Table 6.2.2.2.

7.0 Outputs/Results

The preliminary runs for the surplus production model revealed it was unstable. The model was highly sensitive to the model inputs, with the estimates of MSY and B1/K approaching the bounds. As such, the stock assessment group decided not to move further with this model. In addition, there were some other concerns with this model, as the available indices did not represent the population biomass, as they predominantly represented juveniles to Age 1. Results presented in this analysis were based on the model implemented in AD model builder and Excel. The results of the EXCEL based model were similar to those produced using the AD model builder version (See Appendix A for a comparison of similarly configured models).

7.1 Goodness of Fit of Model Used

The goodness of fit of a statistical model is judged by how well the predicted estimates match the observed estimates. The residuals for recreational and commercial landings indicated a good fit for the mid-Atlantic and south Atlantic models (Figures 7.1.1-7.1.4; Table 7.1.1). However, for the south Atlantic model, the high recreational landings in 1984 and 1986 were poorly estimated. Residuals were associated with low standard deviations; the mean and standard deviation of the residuals for each of the fleets and their standardized-residuals for the mid-Atlantic and south Atlantic base models are presented in Table 7.1.1.

Estimates of the standard deviation of the residuals and the standardized residuals indicated that for the mid-Atlantic, the MRFSS index was associated with best fit (residual mean=0 and standard deviation=0.52 for base model) and appears to be an important index influencing the model. The residuals standard deviations for the SEAMAP index were in a similar range to the MRFSS index (mean=0 and standard deviation =0.65). The NMFS trawl survey was associated with the greatest variability (Figures 7.1.5-7.1.7; Table 7.1.2). For the south-Atlantic model, the model appeared to fit the data reasonably well, except for the high points associated with both indices (Figures 7.1.8-7.1.9; Table 7.1.2). Based on the standard deviation of the residuals, the MRFSS and SEAMAP index appeared to have influenced the model in approximately equal proportions. In general, few data points exceeded an absolute value of 2.0 for the standardized residuals in either the mid-Atlantic or south-Atlantic base models.

7.2 Parameter Estimates

The model estimates a total of 93 parameters for the mid-Atlantic model and 92 parameters for the south-Atlantic model. The estimated parameters include an annual fully selected fishing mortality rate for each fishery, an annual recruitment deviation from the stock-recruitment relationship, the number of virgin recruits (R_0) and a catchability coefficient for each of the indices.

7.2.1 Exploitation Rates (should include both F and *u*)

Unless otherwise noted, fishing mortality rates referred to in the document are the combined fully selected fishing mortality rate for the commercial and recreational fishery. Exploitation rates were estimated using the fully selected fishing mortality rate for the commercial and recreational fishery combined.

For the mid-Atlantic region, a cyclical trend in fishing mortality rates is apparent, with the highest fishing mortality rates occurring in the mid 1970’s, followed by a cyclical peak in the mid 1980’s and again between 1997 and 1998 (Figure 7.2.1.1). However, the most recent peak in fishing mortality appears to be lower than those observed in the past, ranging around 0.5 per year (Table 7.2.1.1). For the mid-Atlantic fishery, the recreational fishery accounts for a relatively small proportion of the total fishing mortality (Table 7.2.1.1).

In the south-Atlantic region, a cyclical pattern to fishing mortality rates was also observed, with the highest peak between 1986-87 (Figure 7.2.1.2). More recently, fishing mortality rates have peaked in 2000-2001 (Table 7.2.1.1). For the south-Atlantic fishery, the recreational fishery accounted for the largest proportion of the total fishing mortality during the time series. In the model, fishing mortality estimates were limited to a maximum of 1.5. Estimates of recreational fishing mortality for the south-Atlantic model frequently hit this upper bound (Table 7.2.1.1)

Exploitation rates for the base mid-Atlantic and south-Atlantic models are presented in Tables 7.2.1.2. In general, the trends in exploitation rates mirror those of the fishing mortality rates. For the base mid-Atlantic model, the exploitation rate between 1999 and 2002 has been at around 0.25 (Table 7.2.1.2). For the base south-Atlantic model, exploitation rates between 1999 and 2002 have ranged between 0.33 and 0.59.

7.2.2 Abundance Estimates

Estimates of abundance in numbers for the base runs for the mid-Atlantic and south –Atlantic models are presented in Tables 7.2.2.1. For the mid-Atlantic region, the trend in population abundance indicates a step-wise increase in population size reaching a peak in 1998. For the base mid-Atlantic run, population estimates from 1999 to 2002 have ranged around 500 million fish (Table 7.2.2.1). For the south-Atlantic model, the population trend is an inverse to that observed for the mid-Atlantic model. Estimated population sizes were high in mid 1980’s and during the recent part of the time series have been relatively stable and low. For the base south-Atlantic run, population estimates between 1999 and 2002 have range between 3-4 million fish.

For the mid-Atlantic model, spawning stock biomass (expressed as the proportion of mature females) shows a sharp decline from the early 1970’s up to the early 1980’s. From 1981 to 1991, estimates of spawning stock biomass shows relatively flat trend up to the early 1990’s (Figure 7.2.2.1). From the early 1990’s spawning stock biomass has increased sharply and since 1999 has been relatively stable and high at around 30,000 metric tons (Table 7.2.2.1). For the south-Atlantic model, spawning stock biomass was highest in the early part of the time series, decreased in a stepwise pattern and remained relatively stable since 1995 (Figure 7.2.2.2). For the base south-Atlantic model spawning stock biomass estimates between 1999-2002 have ranged between 130-170 metric tons (Table 7.2.2.1).

The recruitment trend for the base mid-Atlantic model reveals a relatively flat recruitment period up to the early 1980’s. From the early 1980’s onwards, periodic spikes in recruitment in 1983, 1991, 1994, and 1998 occurred (Figure 7.2.2.1). Between 1999 and 2002 the estimated number Age 0 recruits for the mid-Atlantic base model has ranged between 390 and 526 million fish (Table 7.2.2.1). For the base south-Atlantic models the recruitment trend also reveals a cyclical pattern over the time series (Figure 7.2.2.2). Between 1999 and 2002 the number of Age 0 recruits for the base south-Atlantic model ranged between 1.3 and 2.4 million fish.

7.2.3 Precision of Parameter Estimates

For models run using AD model builder, estimates of standard deviation are based on the delta method, which approximate the variance estimates. Variance estimates using the delta method are biased to the lower range of the spectrum when additional constraints are imposed on the model (ASMFC, in preparation). As such, a Monte-Carlo re-sampling scheme was used to examine the uncertainty surrounding the parameter estimates and described more completely in Section 7.4.

7.3 Projection Estimates

No stock projections were carried out .

7.4 Sensitivity Analyses

To evaluate the sensitivity of the mid-Atlantic model to the deterministic inputs (see section 6.2), the ACTC identified a subjective weighting for each of the sensitivity inputs. These weightings were used to create a probability distribution for all parameters, except steepness (Figure 7.4.1). For steepness, the prior distribution developed by Myers et al (2002) was used (Figure 6.2.2.13). Using the probability distributions, 1,299 runs were carried out using the re-sampling procedure and are summarized in Table 7.4.1.

Commercial fishing mortality rates show a broad range of estimates over much of the time series (Figure 7.4.2 a). The effects of constraining the fishing mortality estimate to a maximum of 1.5 per year are clearly evident on some model permutations for the period 1978-1980. From 1997 onwards a declining trend in commercial fishing mortality rates is evident for all permutations examined. Fishing mortality rates in the recent part of the time series also appear to have less variability than estimates from the early years. Recreational fishing mortality rates per year indicate a close correspondence among the different trials (Figure 7.4.2. b).

Spawning stock biomass estimates suggest a relatively broad range of estimates during certain periods (Figure 7.4.3). Examination of the trials indicates that the low SSB estimates were associated with high steepness values, (0.8-0.9) and the high estimates were associated with low steepness estimates (0.2- 0.4). Trends in Age 0 recruits among the trials suggest that recruitment patterns were consistent over the majority of trials (Figure 7.4.4). Low recruitment estimates were associated with high steepness values and high recruitment estimates were associated with low steepness values.

7.5 Retrospective Analyses

To date, a traditional retrospective analysis, where the last few years in the data series were sequentially deleted and its effect evaluated, has not been done.

8.0 Biological Reference Points

Currently, there are no established biological reference points for Atlantic croaker. Based on the current model, the ACTC concluded that the most appropriate reference points would be those based on MSY criteria. The ACTC noted that, as more data become available and the assessment model evolves, alternate reference points should be considered. The ACTC also discussed the need for different reference points for the northern (mid-Atlantic model) and southern (south-Atlantic model) regions of the stock. However, the ACTC had concerns on recommending and evaluating reference points for the south-Atlantic model at this time. Personal observations of some members of the ACTC indicate that larger and older Atlantic croaker were rare in the South Atlantic. The lack of larger older fish could be the result of higher mortality rates or movement of older fish out of the region. Given the lack of information on movement rates of Atlantic croaker between the two regions, estimates of Fmsy and SSB_{msy} for the south Atlantic may be incorrect.

8.1 Overfishing Definition

Restrepo et al. (1998) describe a set of biological reference points or benchmarks that are based on fishing mortality (maximum fishing mortality threshold) and spawning stock biomass (minimum stock size threshold) that relate to implementing National Standard 1 of the Mangnuson-Stevens Fishery Conservation and Management Act. The national standards guidelines identifies thresholds that are necessary to maintain a stock within safe levels and are used to determine if a stock is being overfished or is in a overfished state. Currently, there are no established definitions of over fishing for Atlantic croaker. As such, the ACTC believe that adoption of the default criteria suggested by Restrepo et al (1998) would be appropriate for the mid-Atlantic region.

1) Fishing mortality threshold, F_{msy}
2) Fishing mortality target, 0.75 F_{msy}
3) Biomass threshold, 0.5 SSB_{msy}
4) Biomass target, (1-M) SSB_{msy} =0.7 SSB_{msy}

Examination of the phase plots of the ratio of F_{2001}/ F_{msy} with SSB_{2001}/SSB_{msy} and those based on average estimates between 1999-2001 from the Monte-Carlo simulations suggest that SSB/ SSBmsy ratios for a large proportion of the runs were greater than 1.0 (Figures 8.1.1-8.1.2;Table 8.1.1). F / F_{msy} ratios for 50% of the runs were less than 1.04 (Table 8.1.1). Estimates from the base model were close to the median estimates from the Monte-Carlo trials. For the base mid-Atlantic model, fishing mortality rates in recent years have been close to F_{msy} levels and above the proposed threshold level (Figure 8.1.3). Annual spawning stock biomass estimates from the base mid-Atlantic model in recent years has been above the proposed target and threshold levels (Figure 8.1.4).

8.2 Stock Recruitment Analysis

As part of the model configuration, a Beverton and Holt stock recruitment relationship re-parameterized in terms of steepness is included. Estimates of the Virgin recruitment for the base mid-Atlantic and south-Atlantic models were 114 and 5.8 million fish respectively. The stock recruitment curves for the base mid-Atlantic and south-Atlantic model are presented in Figures 8.2.1 and 8.2.2. For the base mid-Atlantic model a wide scatter between recruits and spawning stock is evident; whereas for the south-Atlantic model the scatter implies a downward trend in recruitment over the time series. The limitations of using two independent models to estimate the stock of Atlantic croaker over its range should be noted when evaluating these plots.

8.3 Yield and SSB per Recruit

Yield per recruit and SSB per recruit were estimated for the base mid-Atlantic and south Atlantic models. The selectivity pattern used was based on the average catch weighted selectivity over the last three years. In general, for both base models, the yield per recruit curve is flat (Figures 8.3.1 and 8.3.2). For the base mid-Atlantic model the average SPR over the last four years was 35 %, while for the base south-Atlantic model, the average SPR was13 %.

8.4 Stock Production Model

The stock production model was found to be unstable, and its use in this assessment was discontinued.

9.0 Recommendations and Findings

The mid-Atlantic model, which is the core of the population, indicates fishing mortality rates were high in the mid 1970’s, abruptly declined, and has shown a cyclical trend in the mid 1990’s, and appear to have stabilized. A preliminary catch curve analysis using the North Carolina and VMRC/ODU age data suggest that total mortality rates from 1998 to 2002 have declined from around 0.6-0.8 in 1998 to 0.31-0.4 in 2002. Using an M=0.3, these estimates of total mortality compare favorably to the base mid-Atlantic model (Full-F=0.5 in 1998 and 0.26 in 2002). The commercial age data from recent years also shows an increasing age distribution, with fish of 12 years being observed in the commercial landings. The mid-Atlantic model is primarily driven by MRFSS and SEAMAP index, which describe an increasing abundance trend in recent years. In addition, the NEFC trawl index also lends support to increasing trends of juveniles. Anecdotal evidence from the mid-Atlantic range of the population in Delaware, suggests an abundance of Atlantic croaker in the region (D. Kahn, personal communication). The population has benefited from good recruitment in recent years, which may also be tied to the regulatory changes that have affected some of the fisheries that indirectly target Atlantic croaker (see Section 3.2).

The southern region of the stock appears to have a different set of dynamics than that of the northern range. It is evident that the recent increases in recruitment seen in the mid-Atlantic have not been observed in the south. While the results of the model suggest high exploitation rates in the south, the migratory nature of the stock is not addressed in either of the models. Further, the role of the environment on the region is also poorly understood. It has been suggested that the recent and prolonged drought may have had some impact on the local population. Furthermore, the MRFSS estimates for Atlantic croaker in the South-Atlantic are also relatively imprecise, with landings being associated with high PSE values (Table 5.2.2.3). More effort needs to be spent on evaluating the south-Atlantic model, before appropriate management benchmarks are developed for the region. In this assessment we examined the population in two independent models. Linking the two models into one, with the incorporation of additional data on movement patterns should be goal for future assessments. Treating the population as one by combining the landings together masks the dynamics of the southern range of the species.

9.1 Evaluation of current status based on biological reference points

Based on the proposed reference points for the mid-Atlantic model, fishing mortality rates in recent years have been close to F_{msy} levels and above the proposed threshold level (Figure 8.1.3). Annual spawning stock biomass estimates for the mid-Atlantic recent years has been above the proposed target and threshold levels (Figure 8.1.4).

9.2 Research Recommendations

The technical committee provided a prioritized listing of research recommendations, as shown below:

1. Need for more movement data from the south region, including tagging information from Cape Fear south. Examine otolith microchemistry data available and continue research in this area.

2. Need for bycatch and discard estimates from the commercial and recreational fisheries (i.e. shrimp fishery). Characterization of scrap fishery.

3. Standardize ageing procedures for Atlantic croaker and standardize current age data sets. Need for Coast wide collection of bio-profile information and add standardized protocols for those data.

4. Produce a general fishery independent index using state survey information. Develop a coast wide and or regional CPUE index.

5. Investigate including climatic factors in the model.

6. Need for an updated maturity schedule.

7. Examine socio-economic aspects of the fishery.

10.0 Literature Cited

Atlantic States Marine Fisheries Commission (ASMFC). 1987. Fishery Management Plan for Atlantic Croaker. Fisheries Management Report No. 10, Oct 1987.

ASMFC. 1993. Proceedings of a Workshop on Spot (Leiostomus xanthurus) and Atlantic Croaker (Micropogonias undulates), L. Kline and H. Speir, eds. ASMFC, Washington DC. 160pp.

ASMFC. 2002. 2002 Review of the Fishery Management Plan for Atlantic Croaker, Washington DC.

ASMFC. In Preparation. Atlantic menhaden 2003 stock assessment report. Atlantic States Marine Fisheries Commission.

Barbieri, L. R. 1993. Life history, population dynamics and yield-per-recruit modeling of Atlantic croaker, *Micropogonias undulatus*, in the Chesapeake Bay area PhD Dissertation College of William and Mary, Williamsburg, VA. 140 p.

Barbieri, L.R., M.E. Chittenden Jr., and S.K. Lowerre-Barbieri. 1994a. Maturity, spawning, and ovarian cycle of Atlantic croaker, *Micropogonias undulates*, in the Chesapeake Bay and adjacent coastal waters. Fishery Bulletin 92: 671-685.

Barbieri, L.R., M.E. Chittenden Jr., and C.M. Jones. 1994b. Age, growth and mortality of Atlantic croaker, *Micropogonias undulates*, in the Chesapeake bay region, with a discussion of apparent geographic changes in population dynamics. Fishery Bulletin 92:1-12.

Barger, L.E. 1985. Age and growth of Atlantic croakers in the Northern Gulf of Mexico, based on otolith sections. Transactions of the American Fisheries Society 114: 847-850.

Bobko, S.J., C.M. Jones and E.M. Robillard. 2003. Results of 2001 Virginia-Chesapeake Bay Finfish Ageing. VMRC/ODU Age and Growth Lab. Old Dominion University, Norfolk, VA. 67 pp.

Chittenden Jr., M.E., L.R. Barbieri, and C.M Jones. 1994. Development of Age Determination Methods, Life History/Population Dynamics Information, and Yield-per-Recruit Simulation Modeling to Evaluate the Potential for Growth and Recruitment Overfishing of Atlantic Croaker, *Micropogonias undulates*, in the Chesapeake Bay.

Cowan, J.H., Jr., R.L. Shipp, H.K. Bailey IV, and D.W. Haywick. 1995. Procedure for rapid processing of large otoliths. Trans. Am. Fish. Soc. 124:280-282.

Diamond, S.L., L.B. Crowder, and L. Cowell. 1999. Catch and Bycatch: The qualitative effects of fisheries on population vital rates of Atlantic croaker. Transactions of the American Fisheries Society 128: 1085-1105.

Gabriel, W.L. M.P. Sissenwine and W.J. Overholtz. 1989. Analysis of Spawning Stock Biomass per recruit: An example for Georges bank haddock. North American Journal of Fisheries Management 9:383-391

Hales Jr., H.L. and E.J. Reitz. 1992. Historical changes in age and growth of Atlantic croaker, *Micropogonias undulatus* (Perciformes: Sciaenidae). Journal of Archaeological Science:19:73-99

Hoenig, J.M. 1983. Estimating total mortality rate from longevity data. Ph.D. Dissertation. University of Rhode Island

Krebs, C.J. 1989. Ecological Methodology. Harper Collins Publishers. 654 pp.

Lankford, T.E., Jr., T.E. Targett and P.M. Gaffney. 1999. Mitochondrial DNA analysis of population structure in the Atlantic croaker, *Micropogonias undulatus* (Perciformes: Sciaenidae). Fishery Bulletin 97:884-890

Lankford, T.E. Jr., and T.E. Targett. 2001. Low-temperature tolerance of age-1 Atlantic croakers: Recruitment implications for US Mid-Atlantic estuaries. Transactions of the American Fisheries Society 130: 236-249

Lee, Laura M., J.E. Hightower and P.S. Rand. 2001. Population dynamics of Atlantic croaker occurring along the U.S. east coast, 1981-1998.

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

MRFSS 1999. MRFSS user's manual. A guide to use of the National Marine Fisheries Service Marine Recreational Fisheries Statistics Survey Database. Atlantic Marine Fisheries Commission in cooperation with the National marine Fisheries Service and U.S. Fish and Wildlife Service. March 1999.

Myers, R.A., N.J. Barrowman, R. Hilborn, D.G. Kehler. 2002. Inferring Bayesian priors with limited directed data: Applications to risk analysis. North American Journal of Fisheries Management 22:351-364.

North Carolina Division of Marine Fisheries (NCDMF). 2001. Assessment of North Carolina Commercial Finfisheries, 1997-2000. Final Performance report for Award Number NA 76 FI 0286, 1-3. North Carolina Department of Environment and Natural Resources. North Carolina Division of Marine Fisheries..

North Carolina Division of Marine Fisheries (NCDMF). 2002. Survey of population parameters of marine recreational fishes in North Carolina. Annual Progress Report. Segment 11. North Carolina Department of Environment and Natural Resources. North Carolina Division of Marine Fisheries. 36 pp.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons.Int.Explor.Mer 39:175-92.

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

Punt. A.E. , Butterworth, D.S. and J. Penny. 1995. Stock assessment and risk analysis for the South Atlantic population of Albacore *Thunnus alalunga* using an age-structured production model. South African Journal of Marine Science 16: 287-310.

Reststrepo, V.L., G.G. Thompson, P.M. Mace, W.L. Gabriel, L.L. Low, A.D. MacCall, R.D. Methot, J.E. Powers, B.L. Taylor, P.R. Wade, J.F. Witzig. 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. U.S. Dept. of Commerce. NOAA Technical Memorandum, NMFS-F/SPO-31.

Ross, S.W. 1988. Age, growth and mortality of the Atlantic croaker. Transactions of the American Fisheries Society 117: 461-

Stender, B. and C.A. Barans. 1994. Comparisons of the catch from tongue and 2-seam shrimp nets off South Carolina. North American Journal of Fish. Mgmt. 14: 178-195.

Quinn, T.J. and R.B. Deriso. 1999. Quantitative fish dynamics. Oxford University Press.

Wenner, C.A., C. Walton, M. Brouwer and E.L. Wenner. 1998. Age, growth and reproductive biology of selected species taken incidentally to the penaeid shrimp fisheries along the southeastern coast of the U.S. Final Report for MARFIN Grant Number NA57FF0297.

Wenner, C.A. 2003. Atlantic croaker, *Micropogonias undulatus*, along the middle Atlantic and southeast coast of the United States. A research proposal submitted to MARFIN. South Carolina Department of Natural Resources 21 pp.

White, M.L., M.E. Chittenden Jr. 1977. Age determination, reproduction, and population dynamics of the Atlantic croaker, Micropogonias undulatus. Fishery Bulletin 75: 109-122.

Williams, E.H. 2001. Assessment of cobia, *Rachycentron canadum*, in the waters of the U.S. Gulf of Mexico. NOAA Technical Memorandum NMFS-SEFC-469.

11.0 Tables

Table 2.1.1. Summary of available age data for Atlantic croaker (only samples based on otolith readings were considered).

Source	NC DMF	VAMRC/ODU	VIMS	SEAMAP	MARYLAND	TOTAL
Type	FI/FD	FD	FI/FD	FI	FD	
1989	96					96
1990	32					32
1991-1995						0
1996	836					836
1997	428					428
1998	1,071	221	2,100			3,392
1999	671	317	2,260		180	3,428
2000	815	311	499		145	1,770
2001	793	364		797	38	1,992
2002	605	360		548		1,513

NC DMF -North Carolina Department of Marine Fisheries

VAMRC/ODU - Virginia Marine Resources Commission/ Old Dominion University

VIMS - Virginia Institute of Marine Science

SEAMAP- SEAMAP/South Carolina Department of Natural Resources

MARYLAND - Maryland DNR/ South Carolina Department of Natural Resources

FI - Fishery Independent FD- Fishery Dependent

Table 2.1.2. Summary of age structure of Atlantic croaker obtained from the available data sets

Program	Birthdate	Type	Year	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Total
VIMS/ODU	1-Jan	FD	1998	0	15	32	29	46	42	23	18	15	1				221
			1999	0	3	34	31	19	64	29	57	38	40	2			317
			2000	0	1	22	63	36	15	41	25	40	29	37	2		311
			2001	0	1	2	19	97	72	17	35	31	45	26	18	1	364
			2002	0	10	13	23	63	110	61	12	20	17	17	6	8	360
NC/DMF	Not Adjusted	FI/FD	1989	0		16	80										96
			1990			1	31										32
			1996	117	186	204	130	133	55	11							836
			1997	35	156	76	47	58	43	12			1				428
			1998	271	310	77	87	118	83	97	25	2	1				1,071
			1999	111	204	55	32	42	75	76	57	18	1				671
			2000	111	249	176	51	46	58	68	27	24	5				815
			2001	86	113	151	142	67	43	46	57	50	23	14		1	793
			2002	52	154	110	94	103	38	9	12	13	10	5	5		605
SEAMAP	1-Jan	FI	2001	361	315	76	41	1	3	0	0	0	0	0			797
			2002	338	138	37	21	13	0	1	0	0	0	0			548
VIMS	1-Jul	FI/FD ?	1998	0	90	297	238	309	362	420	250	125	8	1	0		2,100
			1999	0	26	278	203	146	240	438	396	378	143	9	3		2,260
			2000	0	5	107	119	22	39	45	81	29	50	1	1		499
Maryland/SCI	Not Adjusted	FD	1999		37	38	6	21	10	39	15	13	1				180
			2000	3	39	24	9	5	13	21	10	13	8				145
			2001			3	29	6									38

Table 2.2.1. Summary of Von Bertalanffy Growth parameters examined for use in this assessment. Only studies base on age determination made using sectioned otoliths were considered.

Program	NC-DMF	VMRC	VMRC	VMRC		
Collection Period	1996-2002	1998-2002	1998-2002	1998-2002	1988-1991	~1450-1765
Citation			ODU	ODU	Barbieri et al. 1994b	Hales&Rietz
Method	1	2	3	4	4	1
L infinity	434	558	505	479	312	422
K	0.242	0.093	0.135	0.157	0.360	0.180
to	-1.957	-4.135	-2.713	-3.260	-3.260	-2.360

1 Simple. Straight observed data from age dataset.
2 Adjusted for month age, weighted sample size (1/count age group)
3 Adjusted for month age, not sample size weighted
4 Based on Bio age in months.

Table 3.1.1.1: Commercial Landings of Atlantic Croaker in Pounds by Atlantic Coastal States, 1950-2001

YEAR	E FL	GA	SC	NC	VA	MD	DE	NJ	NY	RI	MA	NH	TOTAL
1950	60,400	1,000	29,100	2,095,800	6,673,900	2,517,900	6,100	37,900					11,422,100
1951	121,300		22,000	2,102,100	4,223,400	1,850,600	4,900	50,000					8,374,300
1952	151,200		23,000	1,346,300	3,641,200	850,300	8,300	82,700					6,103,000
1953	94,000		6,900	1,433,900	4,060,100	462,400	43,300	156,700					6,257,300
1954	124,700		5,100	1,015,500	5,124,500	912,900	60,100	369,200					7,612,000
1955	201,600		32,200	992,600	9,752,100	1,704,600	667,200	741,300					14,091,600
1956	138,400		73,500	4,828,800	9,667,900	1,748,700	27,200	76,800					16,561,300
1957	131,200		1,700	2,915,900	14,197,600	1,400,000	166,900	103,500					18,916,800
1958	157,600	100	9,700	6,920,600	11,856,000	658,500	3,200	400					19,606,100
1959	85,500		9,000	3,056,600	7,655,400	838,300	8,700	1,800					11,655,300
1960	140,700	300	20,500	2,092,800	3,932,700	586,000	200	8,100					6,781,300
1961	142,700		13,300	1,753,500	3,082,300	48,900		56,900					5,097,600
1962	161,300	600	33,300	1,662,800	1,293,700	11,100		4,300					3,167,100
1963	113,700	700	36,200	2,275,700	122,400	1,500							2,550,200
1964	101,200	400	10,400	1,866,900	394,200	2,400							2,375,500
1965	106,800	2,100	3,400	1,753,400	1,531,700	400							3,397,800
1966	330,700	5,100	1,300	1,267,000	1,463,200	800							3,068,100
1967	143,800	6,000		1,282,800	323,500	1,200							1,757,300
1968	70,000			1,200,800	6,200	100							1,277,100
1969	49,900	1,800	200	1,368,700	63,200	400							1,484,200
1970	66,900	9,400	2,700	806,800	127,900	100		200					1,014,000
1971	89,800	500	1,500	948,200	264,900	200		100					1,305,200
1972	101,100	2,400	400	4,108,600	484,100	500		400				17,700	4,715,200
1973	102,900	14,900	3,100	4,324,100	1,358,300	37,300		37,100	100				5,877,800
1974	65,100	8,500	39,900	6,081,700	1,501,700	120,300		45,100					7,862,300
1975	61,500	4,000	3,500	10,251,700	4,721,300	639,700	1,300	885,100					16,568,100

1976	78,400	13,600	1,300	15,038,000	5,897,600	1,069,100	2,600	700,600			100		22,801,300
1977	49,500	7,000	600	18,994,800	8,600,600	692,300	8,900	1,478,600		400			29,832,700
1978	39,470	563	730	19,945,471	8,099,100	597,000	7,300	654,900		100			29,344,634
1979	38,646	19,137	7,082	20,558,193	2,136,600	97,400	3,700	91,000	6,200	2,600			22,960,558
1980	50,911	4,721	5,438	21,146,798	711,600	7,100		12,000	900				21,939,468
1981	72,112	1,038	2,441	11,205,342	429,800	2,100		23,500	200				11,736,533
1982	95,357	2,177	386	10,824,953	119,300	7,000		100					11,049,273
1983	81,737	1,097	3,200	7,249,680	150,400	500		200			200		7,487,014
1984	131,375		3,793	9,170,160	817,700	27,100		57,700	3,000	100			10,210,928
1985	115,641		1,256	8,695,544	2,171,821	9,500	100	48,800			400		11,043,062
1986	177,414		924	9,424,828	2,367,000	137,500	500	106,000					12,214,166
1987	217,932	553	698	7,289,191	2,719,500	119,300	800	357,600					10,705,574
1988	140,242	304	2,614	8,434,415	1,749,200	98,700	200	30,100					10,455,775
1989	96,534		1,950	6,824,088	947,300	89,500		137,100					8,096,472
1990	104,402	32	1,190	5,769,512	198,195	3,584		644		20			6,077,579
1991	56,761			3,436,960	164,126	6,183	700	31,292		10			3,696,032
1992	73,369	210		2,796,612	1,339,388	10,685	800	51,600					4,272,664
1993	51,465			3,267,652	5,264,974	158,062	2,500	183,414					8,928,067
1994	96,018			4,615,791	5,773,430	218,744	3,000	117,256					10,824,239
1995	22,879			6,021,326	6,991,044	549,716	13,000	334,654					13,932,619
1996	26,045			9,961,862	9,442,959	810,435		621,889	1				20,863,191
1997	36,572			10,711,704	12,790,922	1,455,707	10,509	1,994,446	1,309				27,001,169
1998	26,418			10,865,928	12,006,988	1,375,646	10,368	1,029,332	31				25,314,711
1999	26,441			10,185,535	12,849,954	1,584,412	14,729	2,071,046	2	4			26,732,123
2000	34,441			10,122,634	12,889,406	1,501,655	11,121	2,130,465	285	40			26,690,047
2001	14,857			12,017,459	12,929,191	2,233,160	22,736	1,389,837	315				28,607,555
Grand Total	**5,068,939**	**108,232**	**415,502**	**334,328,038**	**227,081,498**	**27,257,189**	**1,110,963**	**16,311,675**	**12,343**	**3,274**	**700**	**17,700**	**611,716,053**

Table 3.1.1.2 Commercial value of landings by state of Atlantic croaker

Year	DE	E FL	GA	MD	MA	NH	NJ	NY	NC	RI	SC	VA	Total
1950	1,040	2,099	50	351,283			3,250		103,406		1,455	1,210,225	1,672,808
1951	783	12,130		264,763			3,343		112,531		1,100	655,990	1,050,640
1952	1,238	14,969		155,614			16,540		66,325		920	424,816	680,422
1953	5,198	10,340		76,162			20,095		69,118		276	402,822	584,011
1954	4,212	13,717		116,446			29,732		50,593		204	508,383	723,287
1955	43,456	20,979		200,107			62,545		53,636		3,864	798,522	1,183,109
1956	2,197	15,224		238,479			9,770		289,728		7,350	801,002	1,363,750
1957	18,430	15,744		134,390			12,304		219,543		89	1,541,111	1,941,611
1958	384	15,760	9	72,273			62		530,542		499	1,091,817	1,711,346
1959	1,324	8,550		172,667			392		228,331		430	1,215,370	1,627,064
1960	50	18,291	27	156,437			1,519		158,029		1,005	642,507	977,865
1961		18,551		13,980			14,533		143,774		532	564,620	755,990
1962		21,455	48	3,014			1,274		145,544		1,332	293,777	466,444
1963		17,394	84	385					152,442		1,473	30,420	202,198
1964		15,335	48	527					139,066		521	62,899	218,396
1965		18,394	248	76					107,913		167	154,090	280,888
1966		45,767	609	166					62,549		76	193,703	302,870
1967		24,940	480	204					65,101			57,337	148,062
1968		14,520		16					59,836			1,290	75,662
1969		11,445	191	62					62,089		20	9,567	83,374
1970		15,525	954	29			30		37,875		219	15,491	70,123
1971		19,578	48	36			14		53,605		143	33,463	106,887
1972		18,364	253	105		2,119	45		227,052		27	67,868	315,833
1973		23,815	1,570	5,765			7,388	8	372,198		426	160,774	571,944
1974		14,150	917	18,477			6,463		600,375		4,027	205,209	849,618
1975	317	16,997	559	52,973			64,382		904,219		404	512,906	1,552,757
1976	832	25,074	2,149	117,317	21		59,152		1,577,235		238	789,279	2,571,297
1977	1,841	16,009	1,606	68,468			123,431		2,076,370	74	110	910,279	3,198,188
1978	1,934	13,329	159	147,107			128,001		2,735,282	38	146	1,410,445	4,436,441
1979	1,558	11,223	5,562	40,614			27,745	3,236	4,345,433	949	1,424	493,772	4,931,516

1980		17,998	1,423	3,474			4,092	418	5,213,755		1,232	212,490	5,454,882
1981		28,731	446	612			5,097	90	3,944,643		762	124,866	4,105,247
1982		26,672	967	1,191			17		4,031,186		122	49,441	4,109,596
1983		35,065	513	214	16		47		2,842,139		959	45,353	2,924,306
1984		51,200		12,004			17,553	3,191	3,027,015	6	1,345	267,690	3,380,004
1985	30	53,754		3,818	357		12,619		2,936,732		429	554,191	3,561,930
1986	157	68,578		50,422			37,110		3,088,174		355	576,640	3,821,436
1987	260	90,786	185	40,552			112,445		2,956,025		283	1,060,709	4,261,245
1988	80	81,586	175	42,482			8,031		3,542,549		1,203	899,327	4,575,433
1989		48,001		52,379			49,911		3,380,041		1,044	533,036	4,064,412
1990		64,540	24	2,667			150		2,959,259	8	511	110,740	3,137,899
1991	245	33,571		5,141			8,653		1,518,888	1		90,735	1,657,234
1992	198	49,575	211	5,722			12,504		1,010,646			428,793	1,507,649
1993	575	39,029		80,800			39,711		990,961			1,846,467	2,997,543
1994	844	36,682		129,508			29,575		1,451,218			2,012,748	3,660,575
1995	4,494	17,190		288,575			70,648		2,002,495			2,527,690	4,911,092
1996		21,471		291,324			122,339	1	3,642,763			3,345,400	7,423,298
1997	2,985	26,309		497,880			401,910	564	4,116,610			3,567,206	8,613,464
1998	3,980	20,458		453,055			203,363	23	3,450,044			4,161,655	8,292,578
1999	4,896	23,714		482,034			413,019	1	3,120,036	2		3,499,416	7,543,118
2000	4,423	39,496		569,224			609,845	112	2,987,064	16		5,598,277	9,808,457
2001	6,651	13,568		675,770			371,411	173	3,080,386			3,126,152	7,274,111
Total	114,612	1,397,642	19,515	6,096,790	394	2,119	3,122,060	7,817	81,042,369	1,094	36,722	49,898,776	141,739,910

Table 3.2: Summary of current regulations for Atlantic croaker

State/Agency	Recreational	Commercial	Other
New York	None	none	
New Jersey	none	none	Trawling prohibited from 0-2 miles from shore
Delaware	8”	none	
Maryland	9”,25fish limit	9”	Trawling restricted in Ches. Bay; closed 1/1-3/15
PRFC	25per person/day		
Virginia	none	none	Trawling prohibited in state waters
North Carolina			Flynets excluded south of C. Hatteras and mesh size restrictions; culling panels required in long haul seines; TEDs required in flounder trawls in most state waters; TED/BRD requirements and minimum mesh restrictions in shrimp trawls.
South Carolina	none	none	Gear-related restrictions; TED/BRD requirements; license to land/sell
Georgia	8” 25 fish limit	8” 25 fish limit	BRD requirement; no trawling in sounds
Florida	none	None	Net ban in state waters

Table 5.1.2.1 Percent landings by gear for Atlantic coast commercial Atlantic croaker harvest

Year	Gill Net	Haul Seine	Trawl	Pound Net	Total
1950	2.4	59.6	17.6	20.1	99.7
1951	2.5	52.2	29.2	15.8	99.7
1952	2.5	45.4	26.8	24.9	99.7
1953	1.4	36.0	34.6	27.1	99.0
1954	3.2	39.1	27.7	29.5	99.6
1955	6.4	40.7	26.8	26.0	99.8
1956	3.1	29.7	41.6	25.0	99.4
1957	4.1	39.5	26.7	29.3	99.6
1958	2.7	37.3	38.6	20.8	99.4
1959	4.6	44.0	25.3	25.7	99.6
1960	9.8	44.1	27.5	18.0	99.4
1961	4.4	30.8	27.0	35.9	98.1
1962	7.0	33.7	39.4	18.9	99.1
1963	5.2	21.6	65.9	6.6	99.3
1964	5.5	21.5	58.8	13.6	99.4
1965	6.8	19.0	41.6	32.2	99.6
1966	12.7	23.4	40.3	22.1	98.4
1967	9.3	23.0	56.8	9.5	98.6
1968	7.0	15.6	74.6	1.7	99.0
1969	3.4	12.1	82.1	1.7	99.3
1970	7.4	18.7	63.8	8.6	98.4
1971	7.8	24.1	55.4	12.0	99.4
1972	6.1	17.1	70.2	6.0	99.4
1973	11.5	49.8	31.4	7.0	99.7
1974	6.8	47.2	35.6	10.2	99.8
1975	5.0	41.7	38.1	15.1	99.9
1976	7.6	22.3	48.4	21.5	99.8
1977	10.0	29.1	43.0	17.9	99.9
1978	8.5	26.0	45.5	19.8	99.8
1979	10.3	42.0	39.9	7.6	99.8
1980	17.7	37.6	30.7	13.7	99.8
1981	11.7	47.3	21.6	18.8	99.3
1982	11.5	43.4	25.1	19.1	99.1
1983	12.4	57.6	17.6	11.3	98.9
1984	25.6	34.1	25.3	13.7	98.7
1985	25.6	32.4	24.2	16.8	98.9
1986	31.3	36.0	22.4	8.9	98.5
1987	28.4	31.3	20.6	17.6	98.0
1988	31.0	32.0	20.5	15.0	98.5
1989	22.0	43.2	22.8	10.7	98.8
1990	16.1	64.4	8.0	9.8	98.3
1991	26.4	54.1	12.4	5.6	98.4

1992	41.2	32.6	20.3	4.1		98.1
1993	42.9	14.6	25.3	16.2		99.0
1994	43.2	11.0	29.9	14.1		98.2
1995	35.3	10.4	31.1	19.2		96.1
1996	39.0	9.5	30.1	17.4		96.1
1997	29.8	12.1	40.0	15.1		96.9
1998	42.3	9.4	26.9	17.5		96.2
1999	29.3	10.7	35.8	23.6		99.5
2000	39.8	8.2	33.4	17.8		99.2
2001	39.3	8.2	30.2	21.8		99.4
2002	15.9	31.3	35.3	16.5		99.0

Table 5.1.2.2 Percent Commercial landings of Atlantic croaker, by state, 1950 - 2001 for Atlantic coast states

	DE	E FL	MD	NJ	NC	SC	VA
1950	0.1	0.5	22.0	0.3	18.3	0.3	58.4
1951	0.1	1.4	22.1	0.6	25.1	0.3	50.4
1952	0.1	2.5	13.9	1.4	22.1	0.4	59.7
1953	0.7	1.5	7.4	2.5	22.9	0.1	64.9
1954	0.8	1.6	12.0	4.8	13.3	0.1	67.3
1955	4.7	1.4	12.1	5.3	7.0	0.2	69.2
1956	0.2	0.8	10.6	0.5	29.2	0.4	58.4
1957	0.9	0.7	7.4	0.5	15.4	0.0	75.1
1958	0.0	0.8	3.4	0.0	35.3	0.0	60.5
1959	0.1	0.7	7.2	0.0	26.2	0.1	65.7
1960	0.0	2.1	8.6	0.1	30.9	0.3	58.0
1961	0.0	2.8	1.0	1.1	34.4	0.3	60.5
1962	0.0	5.1	0.3	0.1	52.5	1.1	40.8
1963	0.0	4.5	0.1	0.0	89.3	1.4	4.8
1964	0.0	4.3	0.1	0.0	78.6	0.4	16.6
1965	0.0	3.1	0.0	0.0	51.6	0.1	45.1
1966	0.0	10.8	0.0	0.0	41.3	0.0	47.7
1967	0.0	8.2	0.1	0.0	73.0	0.0	18.4
1968	0.0	5.5	0.0	0.0	94.0	0.0	0.5
1969	0.0	3.4	0.0	0.0	92.2	0.0	4.2
1970	0.0	6.6	0.0	0.0	79.5	0.3	12.6
1971	0.0	6.9	0.0	0.0	72.6	0.1	20.3
1972	0.0	2.1	0.0	0.0	87.1	0.0	10.3
1973	0.0	1.8	0.6	0.6	73.6	0.1	23.1
1974	0.0	0.8	1.5	0.6	77.4	0.5	19.1
1975	0.0	0.4	3.9	5.3	61.9	0.0	28.5
1976	0.0	0.3	4.7	3.1	66.0	0.0	25.9
1977	0.0	0.2	2.3	5.0	63.7	0.0	28.8
1978	0.0	0.1	2.0	2.2	68.0	0.0	27.6
1979	0.0	0.2	0.4	0.4	89.5	0.0	9.3
1980	0.0	0.2	0.0	0.1	96.4	0.0	3.2
1981	0.0	0.6	0.0	0.2	95.5	0.0	3.7
1982	0.0	0.9	0.1	0.0	98.0	0.0	1.1
1983	0.0	1.1	0.0	0.0	96.8	0.0	2.0
1984	0.0	1.3	0.3	0.6	89.8	0.0	8.0
1985	0.0	1.0	0.1	0.4	78.7	0.0	19.7
1986	0.0	1.5	1.1	0.9	77.2	0.0	19.4
1987	0.0	2.0	1.1	3.3	68.1	0.0	25.4
1988	0.0	1.3	0.9	0.3	80.7	0.0	16.7
1989	0.0	1.2	1.1	1.7	84.3	0.0	11.7
1990	0.0	1.7	0.1	0.0	94.9	0.0	3.3
1991	0.0	1.5	0.2	0.8	93.0	0.0	4.4

1992	0.0	1.7	0.2	1.2	65.5	0.0	31.3
1993	0.0	0.6	1.8	2.1	36.5	0.0	59.1
1994	0.0	0.9	2.0	1.1	42.6	0.0	53.3
1995	0.1	0.2	3.9	2.4	43.2	0.0	50.2
1996	0.0	0.1	3.9	3.0	47.7	0.0	45.3
1997	0.0	0.1	5.4	7.4	39.7	0.0	47.4
1998	0.0	0.1	5.4	4.1	42.9	0.0	47.4
1999	0.1	0.1	5.9	7.7	38.1	0.0	48.1
2000	0.0	0.1	5.6	8.0	37.9	0.0	48.3
2001	0.1	0.1	7.8	4.9	42.0	0.0	45.2

Table 5.2.1.2 . Number of Intercept Trips in which Atlantic croaker could have been potentially caught but were not caught (zero trips), the number of intercepts where Atlantic croaker were caught (Positive Trips) and the number of Atlantic croaker measured by Region.

Mid Atlantic = North Carolina and states north. South= South Carolina and states south. See section 5.2.4. for methods used to identify a Table potential Atlantic croaker trip.

		Mid Atlantic			South Atlantic	
	Zero trips*	**Positive Trips**	**Fish Measured**	**Zero trips***	**Positive Trips**	**Fish Measured**
1981	1,141	126	403	188	127	206
1982	1,277	115	150	488	315	780
1983	2,628	456	709	503	247	470
1984	1,190	276	704	687	320	663
1985	3,387	1,006	1,951	1,096	509	1,041
1986	3,019	1,134	4,297	1,282	285	431
1987	1,885	702	2,364	1,540	310	472
1988	2,274	707	2,257	969	202	275
1989	4,098	1,433	2,497	1,031	269	296
1990	3,670	847	1,425	410	329	295
1991	5,079	1,319	1,463	691	291	151
1992	4,707	1,247	1,800	1,171	516	457
1993	4,357	1,341	1,916	1,005	231	113
1994	6,106	3,092	5,228	1,175	299	132
1995	5,895	1,970	2,747	1,217	226	86
1996	6,391	1,936	2,806	1,482	204	77
1997	7,071	2,318	3,161	1,684	248	108
1998	6,930	2,704	3,405	1,750	478	265
1999	5,390	2,855	3,049	2,485	438	269
2000	6,040	2,453	3,109	2,407	430	276
2001	7,944	2,709	5,133	2,619	364	284
2002	6,491	2,849	6,470	2,551	371	142

Table 5.2.1.6. Size categories used to determine recreational discard weights

			Length class at *n* th percentile				
Region	State	Year	10	15	20	25	50
Mid Atlantic	Delaware	1986	200	210	210	220	230
		1987	220	220	230	230	240
		1988	200	210	210	220	250
		1989	210	220	220	230	250
		1990	190	200	200	200	220
		1991	190	190	200	200	220
		1992	200	210	210	210	230
		1993	210	210	220	220	240
		1994	200	200	210	220	240
		1995	240	250	250	250	270
		1996	270	270	270	280	300
		1997	260	270	280	280	300
		1998	230	240	240	250	270
		1999	230	240	240	240	270
		2000	250	250	250	260	280
		2001	280	280	290	290	310
	Maryland	1981	210	210	220	230	250
		1983	170	170	180	180	210
		1984	210	220	230	230	260
		1985	200	210	210	210	230
		1986	270	290	300	300	320
		1987	280	300	300	300	310
		1988	260	270	270	270	280
		1989	210	220	220	230	250
		1990	190	200	200	200	220
		1991	190	190	200	210	230
		1992	250	250	250	250	250
		1993	240	250	250	250	270
		1994	230	230	240	250	260
		1995	250	250	250	260	280
		1996	280	280	280	290	310
		1997	260	270	290	300	320
		1998	250	260	270	280	310
		1999	240	250	250	260	290
		2000	270	280	290	300	320
		2001	290	300	300	310	320
	New Jersey	1987	220	220	230	230	240
		1991	180	190	190	200	220
		1992	200	210	210	210	230
		1993	210	210	220	220	240
		1994	200	200	210	220	240
		1995	210	220	220	230	250
		1996	220	220	220	230	270
		1997	240	250	250	260	290
		1998	250	250	260	260	300
		1999	270	270	280	290	310
		2000	280	290	300	300	320

		2001	290	290	300	300	320
	North Carolina	1981	180	180	190	190	210
		1982	190	190	210	210	240
		1983	170	170	180	180	190
		1984	190	190	190	200	220
		1985	180	180	190	190	220
		1986	210	220	220	230	230
		1987	180	190	190	190	220
		1988	190	190	200	200	210
		1989	190	190	190	200	220
		1990	180	180	190	190	210
		1991	170	180	180	190	210
		1992	190	190	190	200	210
		1993	180	180	190	190	210
		1994	180	180	190	190	210
		1995	190	190	200	200	230
		1996	220	220	230	240	270
		1997	190	200	200	200	220
		1998	200	210	210	210	230
		1999	200	210	220	220	240
		2000	200	210	210	220	240
		2001	210	210	220	220	250
	Virginia	1981	200	210	220	220	240
		1982	170	180	190	190	200
		1983	140	140	150	150	170
		1984	200	200	200	210	220
		1985	200	200	210	210	220
		1986	190	200	210	210	230
		1987	210	210	220	220	240
		1988	190	200	210	220	240
		1989	210	220	230	230	250
		1990	180	190	200	200	220
		1991	180	190	190	190	210
		1992	200	200	210	210	230
		1993	210	210	220	220	240
		1994	200	210	210	210	240
		1995	210	210	220	220	240
		1996	210	220	220	230	260
		1997	230	240	240	250	280
		1998	230	240	250	260	300
		1999	220	220	220	230	270
		2000	240	240	260	260	300
		2001	230	240	250	250	290
South Atlantic	Florida	1981	210	220	230	230	260
		1982	190	200	200	210	230
		1983	200	200	210	210	230
		1984	180	190	200	210	230
		1985	160	170	170	180	210
		1986	200	210	210	220	280
		1987	200	200	210	210	230
		1988	210	230	230	230	240

		1989	230	230	240	270	310
		1990	180	190	190	200	220
		1991	220	220	230	230	240
		1992	230	230	240	250	270
		1993	230	230	230	230	260
		1994	220	230	230	240	260
		1995	220	220	240	260	320
		1996	180	190	200	210	240
		1997	220	230	230	240	250
		1998	240	240	260	260	300
		1999	180	190	190	200	230
		2000	220	230	240	240	270
		2001	230	230	240	240	270
	Georgia	1981	170	180	180	190	230
		1982	180	180	190	190	210
		1983	170	180	180	190	220
		1984	190	190	200	210	230
		1985	170	180	180	180	200
		1986	180	180	180	190	200
		1987	180	190	190	190	210
		1988	180	180	190	190	200
		1989	180	180	180	180	190
		1990	190	190	190	200	220
		1991	210	220	220	220	240
		1992	180	180	180	190	210
		1993	230	230	230	230	250
		1994	200	210	210	220	240
		1995	200	210	220	220	270
		1996	180	190	200	210	240
		1997	220	230	230	240	250
		1998	160	180	190	200	230
		1999	170	180	180	200	250
		2000	210	220	230	240	260
		2001	220	230	230	240	270
	South Carolina	1981	170	180	180	190	230
		1982	180	190	190	200	220
		1983	200	200	210	210	230
		1984	180	190	190	190	200
		1985	130	140	140	150	180
		1986	200	200	200	210	230
		1987	190	200	200	210	230
		1988	190	190	200	210	240
		1989	180	180	180	190	200
		1990	180	190	190	200	220
		1991	210	220	220	220	240
		1992	180	190	200	210	220
		1993	230	230	230	230	250
		1994	200	210	210	220	240
		1995	200	210	220	220	270
		1996	180	190	200	210	240
		1997	220	220	230	230	250
		1998	210	220	220	220	230

		1999	170	180	180	200	250
		2000	210	220	230	240	260
		2001	220	230	230	240	270

Table 5.2.2.1. Recreational Landings (Type A+B1 in numbers) of Atlantic croaker

YEAR	DE	FL	GA	MD	MA	NJ	NY	NC	RI	SC	VA	TOTAL
1981	3,003	598,897	35,591	0	0	1,054	0	1,043,240	0	165,743	964,014	2,811,542
1982	0	1,682,619	169,749	10,452	0	0	0	596,494	0	193,553	273,039	2,925,906
1983	0	1,148,227	75,173	108,354	0	0	0	1,620,909	0	60,811	2,154,134	5,167,608
1984	0	2,781,742	202,365	211,035	0	0	0	2,147,870	0	588,114	2,047,720	7,978,846
1985	0	1,306,954	144,341	21,276	0	0	0	723,934	0	260,266	2,284,334	4,741,105
1986	4,694	5,118,553	69,886	123,578	0	0	0	356,741	0	599,442	6,384,967	12,657,861
1987	0	2,580,727	44,782	208,487	0	0	0	904,028	0	166,977	3,234,223	7,139,224
1988	1,186	685,778	64,093	1,005,452	0	0	0	2,256,128	0	144,057	4,048,690	8,205,384
1989	478	359,418	72,598	22,872	0	0	0	2,131,762	0	217,023	2,203,505	5,007,656
1990	281	304,063	585,380	100,674	0	0	0	1,063,452	0	346,632	2,374,679	4,775,161
1991	37,499	1,030,115	184,436	288,471	0	16,235	0	434,067	0	100,816	4,298,541	6,390,180
1992	9,855	754,596	440,185	117,426	0	0	0	723,822	0	74,051	4,524,040	6,643,975
1993	19,353	304,067	89,734	805,560	0	2,552	0	755,998	0	32,701	4,990,098	7,000,063
1994	5,718	599,031	102,974	1,633,582	0	1,567	0	1,179,736	0	188,521	6,494,691	10,205,820
1995	136,865	438,076	100,825	827,184	0	15,185	0	850,605	0	75,423	5,029,708	7,473,871
1996	235,389	116,574	61,956	775,115	0	35,037	0	662,240	0	37,465	4,997,022	6,920,798
1997	385,586	235,430	64,050	1,053,233	0	342,088	0	661,115	0	118,428	8,066,926	10,926,856
1998	391,234	234,360	64,953	1,126,058	1,477	143,404	0	387,425	0	170,528	6,730,182	9,249,621
1999	662,724	403,982	104,439	1,209,572	0	357,260	0	442,185	0	54,761	5,881,670	9,116,593
2000	517,885	455,871	128,922	2,674,881	0	1,023,442	0	391,057	0	32,333	5,486,159	10,710,550
2001	312,005	426,263	21,503	1,319,929	0	1,177,814	0	635,554	0	19,801	9,335,312	13,248,181
2002	261,635	177,751	36,496	1,223,385	0	253,473	0	408,943	0	66,409	9,129,061	11,557,153

Table 5.2.2.2. Recreational Landings (Type A+B1 in pounds) of Atlantic croaker

YEAR	DE	FL	GA	MD	MA	NJ	NY	NC	RI	SC	VA	Grand Total
1981	2,317	305,547	9,666	0	0	582	0	426,241	0	67,283	535,298	1,346,934
1982	0	754,958	45,160	70,276	0	0	0	264,606	0	67,013	455,250	1,657,263
1983	0	510,599	25,411	32,055	0	0	0	395,404	0	14,159	486,005	1,463,633
1984	0	1,856,599	80,685	86,462	0	0	0	584,660	0	161,663	634,872	3,404,941
1985	0	684,451	40,419	17,168	0	0	0	278,213	0	72,781	843,417	1,936,449
1986	2,595	2,783,651	21,503	116,541	0	0	0	126,887	0	173,028	2,034,334	5,258,539
1987	0	1,005,055	14,949	191,631	0	0	0	352,347	0	64,697	1,306,817	2,935,496
1988	827	316,900	20,313	926,397	0	0	0	935,460	0	54,313	2,390,572	4,644,782
1989	284	268,335	21,139	19,189	0	0	0	658,569	0	80,580	1,329,681	2,377,777
1990	113	127,525	205,352	37,870	0	0	0	347,183	0	123,797	875,430	1,717,270
1991	10,970	460,455	54,117	117,210	0	4,266	0	157,660	0	16,171	1,728,019	2,548,868
1992	3,294	407,670	132,595	53,557	0	0	0	233,537	0	28,512	1,768,964	2,628,129
1993	9,639	180,517	55,605	476,865	0	844	0	282,907	0	18,008	1,993,912	3,018,297
1994	2,892	337,475	34,051	991,169	0	818	0	351,231	0	128,307	3,024,117	4,870,060
1995	82,863	301,920	20,860	567,149	0	9,515	0	326,135	0	25,386	2,675,378	4,009,206
1996	205,527	50,038	21,797	702,035	0	39,101	0	346,500	0	14,481	2,716,759	4,096,238
1997	340,198	113,094	26,272	1,117,998	0	278,758	0	309,457	0	53,863	5,522,196	7,761,836
1998	293,559	141,755	30,968	1,150,461	1,790	135,733	0	161,116	0	76,824	5,920,432	7,912,638
1999	522,202	231,695	32,374	1,024,400	0	301,958	0	212,989	0	26,356	4,969,279	7,321,253
2000	483,964	242,912	62,390	2,672,999	0	1,125,729	0	201,310	0	13,457	4,888,906	9,691,667
2001	304,125	320,490	7,844	1,278,701	0	1,132,216	0	355,011	0	10,749	7,674,758	11,083,894
2002	250,899	117,880	10,619	1,162,279	0	268,424	0	242,187	0	29,345	7,075,127	9,156,760

Table 5.2.2.3. Percent standard error (PSE) estimates for MRFSS landings (Type A+B1 weight) by State and Year

Year	DE	FL	GA	MD	MA	NJ	NC	SC	VA
1981	100	23.6	38	0	0	99.9	27.7	40	19.6
1982	0	24.1	20.3	53.1	0	0	26.6	24	67
1983	0	18.5	23.7	23.5	0	0	43.3	45.5	26.9
1984	0	27	21.8	56.6	0	0	15.2	24	17.6
1985	0	20.2	17.2	31.4	0	0	26.6	23.8	12.9
1986	89.2	32.2	23.3	40.7	0	0	19.8	22.7	11.5
1987	0	25.6	16.5	39.5	0	0	10.5	23.4	8.9
1988	46.8	38.3	22.2	34.8	0	0	15.6	26.1	12.4
1989	60.1	27.9	24.2	41.6	0	0	10	31.1	7.9
1990	69.3	26.1	19	31.2	0	0	8.4	41.3	13.2
1991	22.3	16.3	23.2	27.1	0	41.1	8.3	50.3	11.7
1992	25.9	12	13	20.1	0	0	8.5	22.2	10.8
1993	29.9	18.5	29.2	15.3	0	63.5	8.1	32.8	10.5
1994	25.3	16.7	25.3	12.1	0	66.7	6.9	33.8	7.4
1995	26.7	41.2	47.9	21.5	0	49.8	10.4	51.6	9.9
1996	21.4	47.3	36.4	20.7	0	54.1	10.9	34	12.1
1997	13.4	31.7	50.9	17.4	0	62.7	15.6	21.5	12.2
1998	11.9	27.7	23.3	13.2	100	26.3	11.2	26	10.4
1999	12.7	20.6	33.3	12.7	0	18.3	12.1	61	11.1
2000	16.7	16.7	31.1	11	0	17.5	13	35.8	11.5
2001	14.7	18.9	32.2	10.8	0	11.9	14.4	51.6	7.4
2002	16.4	21.6	39.7	8.8	0	19.7	16.9	32.3	6.1

Table 5.2.2.4. Percentage of recreational landings by area and mode fished and total landings (numbers)

AREA	INLAND			OCEAN (<= 3 MI)			OCEAN (> 3 MI)		Grand Total
MODE	PARTY/CHARTER	PRIVATE/RENTAL	SHORE	PARTY/CHARTER	PRIVATE/RENTAL	SHORE	PARTY/CHARTER	PRIVATE/RENTAL	
1981	0%	30%	9%	1%	25%	25%	0%	11%	2,811,542
1982	0%	32%	38%	1%	5%	23%	0%	1%	2,925,906
1983	0%	38%	23%	0%	1%	27%	1%	9%	5,167,608
1984	6%	51%	11%	1%	7%	19%	2%	2%	7,978,846
1985	4%	53%	18%	0%	12%	9%	1%	3%	4,741,105
1986	3%	50%	40%	0%	2%	3%	1%	1%	12,657,861
1987	1%	46%	32%	0%	10%	5%	0%	7%	7,139,224
1988	2%	60%	8%	0%	9%	9%	2%	11%	8,205,384
1989	1%	64%	9%	0%	9%	13%	0%	3%	5,007,656
1990	1%	85%	8%	0%	4%	2%	0%	0%	4,775,161
1991	1%	78%	16%	0%	3%	2%	0%	1%	6,390,180
1992	3%	68%	13%	0%	3%	10%	0%	2%	6,643,975
1993	7%	68%	15%	0%	2%	4%	0%	3%	7,000,063
1994	6%	70%	11%	0%	5%	6%	0%	2%	10,205,820
1995	6%	62%	14%	0%	5%	6%	2%	4%	7,473,871
1996	4%	68%	9%	0%	6%	5%	1%	6%	6,920,798
1997	5%	72%	4%	3%	4%	3%	7%	2%	10,926,856
1998	4%	75%	9%	0%	3%	5%	2%	3%	9,249,621
1999	5%	67%	7%	1%	7%	4%	2%	6%	9,116,593
2000	8%	69%	10%	1%	2%	3%	2%	6%	10,710,550
2001	5%	78%	7%	1%	3%	3%	1%	2%	13,248,181
2002	5%	83%	5%	0%	3%	2%	1%	1%	11,557,153

Table 5.2.2.5. Estimated total recreational effort and targeted croaker trips by region.

Mid Atlantic = North Carolina and states north. South= South Carolina and states south.

	TOTAL TRIPS			TARGETED CROAKER TRIPS		
YEAR	Mid Atlantic	South Atlantic	TOTAL	Mid Atlantic	South Atlantic	TOTAL
1981	3,691,520	3,990,963	7,682,483	2,329,911	661,654	2,991,565
1982	3,396,824	7,173,834	10,570,658	1,983,758	1,507,711	3,491,468
1983	7,375,083	5,494,638	12,869,720	5,260,926	1,170,281	6,431,207
1984	5,051,370	8,559,747	13,611,118	3,223,967	2,487,146	5,711,113
1985	5,242,377	8,742,788	13,985,165	3,185,154	2,328,634	5,513,787
1986	5,525,108	7,971,801	13,496,910	3,823,570	2,143,462	5,967,032
1987	5,695,083	6,685,151	12,380,233	3,385,338	2,242,932	5,628,270
1988	6,091,459	7,538,628	13,630,087	3,492,146	1,562,828	5,054,974
1989	6,078,078	6,520,230	12,598,309	3,313,537	1,299,427	4,612,963
1990	6,399,454	6,619,192	13,018,646	3,648,991	1,407,813	5,056,804
1991	8,715,745	8,881,602	17,597,347	5,352,227	1,967,682	7,319,909
1992	8,631,710	10,078,812	18,710,522	5,058,166	1,930,748	6,988,914
1993	9,602,187	9,037,958	18,640,146	6,047,580	1,701,791	7,749,371
1994	10,313,392	12,071,012	22,384,404	7,133,688	2,212,994	9,346,682
1995	12,498,094	9,892,382	22,390,476	7,895,199	1,737,344	9,632,543
1996	9,941,977	8,760,298	18,702,275	6,578,210	1,643,307	8,221,517
1997	11,824,784	10,063,415	21,888,198	7,960,976	2,108,066	10,069,042
1998	13,433,755	9,581,675	23,015,431	9,072,299	2,082,834	11,155,134
1999	11,529,623	8,022,066	19,551,690	7,029,247	1,890,377	8,919,624
2000	17,246,924	12,093,782	29,340,706	10,565,856	2,622,408	13,188,264
2001	18,628,548	12,378,025	31,006,573	11,410,046	2,780,393	14,190,439
2002	15,316,012	9,794,446	25,110,458	8,956,822	2,154,108	11,110,929

Table 5.2.2.6. Size distribution of Atlantic croaker weighted by landings (numbers) for the Mid Atlantic region of the fishery (North Carolina and north). Size class in 10 mm intervals is the lower bound.

Len. Class (mm)	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Grand Total
110	0	0	1,479	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,479
120	0	0	1,479	0	0	0	0	0	0	0	0	1,361	0	2,465	1,076	0	0	0	0	0	0	0	6,381
130	0	0	74,734	0	0	0	0	0	9,155	0	0	1,361	610	10,279	1,281	0	0	0	0	0	0	0	97,420
140	0	0	274,218	11,459	0	3,409	0	0	7,302	0	13,433	0	4,707	7,925	12,221	0	0	1	0	0	0	0	334,673
150	4,400	0	525,197	11,459	0	10,066	4,981	13,902	18,559	115,748	28,457	0	6,365	7,035	4,176	0	0	0	0	0	0	0	750,344
160	8,799	0	220,101	0	57,369	33,385	21,825	23,231	10,312	67,933	57,759	2,299	15,850	18,663	7,176	368	0	0	25,218	0	3,151	4,975	578,413
170	23,918	32,710	248,288	24,009	82,299	82,497	51,660	107,760	38,284	71,011	188,873	11,300	16,997	38,514	31,016	37,901	16,499	9,711	33,789	1,796	4,392	16,753	1,169,979
180	144,959	54,725	378,004	122,718	121,415	245,174	59,033	188,215	118,219	182,006	460,616	120,424	65,675	145,755	82,574	42,826	30,784	2,283	43,732	8,224	31,166	31,054	2,679,580
190	148,724	99,291	519,472	242,445	87,095	236,993	119,073	389,466	270,771	256,758	454,443	291,133	115,377	288,105	101,752	42,667	49,348	5,404	42,866	28,191	18,769	56,619	3,864,763
200	203,201	56,307	511,883	342,424	116,101	371,879	140,045	366,330	320,784	429,128	605,325	423,067	404,690	1,197,789	335,160	121,853	112,579	118,189	84,749	133,819	119,977	73,622	6,588,901
210	217,199	86,163	372,048	736,204	477,804	566,758	254,422	545,338	458,211	442,949	539,308	812,534	636,977	660,149	432,857	198,141	395,846	118,615	206,178	79,788	297,576	161,935	8,696,999
220	194,588	92,929	250,575	717,588	553,936	1,253,295	365,301	641,178	461,248	586,088	722,741	933,574	1,154,676	1,016,816	719,861	976,825	497,917	299,843	939,289	341,173	547,893	785,889	14,053,223
230	193,398	100,884	134,317	626,894	362,234	1,479,820	765,461	572,795	474,322	445,670	857,136	720,301	771,088	1,046,206	691,448	329,243	760,478	436,294	446,971	176,411	546,866	491,317	12,429,557
240	214,637	51,022	9,948	477,345	231,785	860,639	631,748	520,906	470,206	225,394	369,385	671,464	756,064	954,411	552,495	420,967	706,550	475,775	385,575	297,446	444,746	615,700	10,344,208
250	199,696	33,549	100,532	224,115	383,703	572,266	514,151	340,383	449,473	273,898	335,653	520,990	708,241	817,058	667,215	350,201	956,924	409,162	579,380	407,216	789,761	931,705	10,565,272
260	101,348	53,774	93,912	208,301	153,080	399,804	400,022	561,341	389,073	163,837	208,604	280,463	592,058	834,254	650,647	452,719	873,216	417,084	504,848	468,666	595,410	780,013	9,182,474
270	76,411	52,490	54,655	180,009	107,998	228,975	266,959	671,262	277,441	51,193	100,729	214,511	384,125	494,897	594,658	672,492	893,081	453,226	458,268	562,988	632,851	917,513	8,346,733
280	47,765	43,501	3,335	229,514	84,364	166,145	208,892	547,361	195,494	46,643	49,369	161,441	325,344	461,552	448,551	565,748	770,479	619,903	695,326	636,560	931,414	636,609	7,875,309
290	50,333	4,655	49,052	51,113	80,845	67,197	145,434	314,094	117,691	19,480	14,216	91,507	125,757	330,430	319,154	465,247	673,212	738,155	627,631	710,950	865,076	846,646	6,707,876
300	41,320	41,896	0	32,978	54,193	76,478	95,570	311,349	63,467	16,365	27,674	51,681	151,409	393,384	430,522	739,503	663,544	915,303	675,238	819,026	1,032,298	748,821	7,382,020
310	17,599	4,655	0	36,827	11,072	43,288	98,553	338,420	63,259	6,947	14,774	16,534	99,441	185,171	145,558	293,532	528,938	538,697	488,055	717,107	925,463	710,390	5,284,278
320	13,199	4,976	0	0	15,259	40,247	30,023	240,622	35,707	96,297	16,833	9,988	95,993	143,594	182,494	235,786	462,506	463,025	291,164	927,771	1,179,379	911,358	5,396,220
330	35,714	9,631	0	34,377	14,062	34,302	87,150	207,575	73,690	17,846	0	16,112	58,001	85,595	195,718	133,185	363,779	702,539	364,425	800,150	831,554	574,053	4,639,456
340	13,199	13,965	13,333	33,822	30,647	10,875	17,994	140,087	16,197	15,860	0	23,098	11,896	57,500	97,152	193,520	586,949	362,485	357,368	619,768	817,470	724,919	4,158,105
350	10,826	4,655	27,887	63,024	1,384	25,485	22,218	47,979	0	1,959	0	0	39,679	16,366	51,600	91,190	365,270	382,159	364,052	613,620	572,727	274,656	2,976,735
360	17,599	0	13,943	0	47	21,663	18,199	77,128	8,237	3,586	2,728	0	22,066	53,098	25,117	159,089	261,046	243,081	238,543	525,195	451,061	267,826	2,409,253
370	0	9,310	0	0	2,768	15,214	16,893	30,965	11,517	0	0	0	8,035	9,998	35,819	47,804	94,019	193,417	122,032	373,433	405,644	232,134	1,609,002
380	0	4,655	0	0	35	13,782	3,712	95,299	0	0	6,759	0	0	4,930	23,709	45,558	145,055	298,436	144,728	219,603	179,781	165,643	1,351,686
390	32,479	0	0	0	0	5,194	7,425	0	0	2,491	0	0	1,219	9,147	12,436	41,843	70,615	161,150	110,021	140,291	109,551	91,294	795,155
400	0	9,310	5,003	0	24	1,594	0	13,902	0	0	0	0	0	19,055	0	10,033	47,735	176,046	76,567	118,836	131,126	103,511	712,742
410	0	0	0	0	0	0	0	4,568	0	0	0	0	0	5,152	0	20,156	33,225	76,196	140,539	131,040	63,507	32,559	506,942
420	0	0	0	0	24	0	0	0	0	0	0	0	0	0	6,102	14,575	29,784	73,193	24,131	91,084	40,946	24,565	304,404
430	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31,355	28,291	23,791	62,331	32,404	23,088	201,259
440	0	0	0	0	0	3,188	0	0	0	0	0	0	0	0	0	1,832	12,690	26,581	18,341	39,211	59,460	5,106	166,409
450	0	0	0	0	0	366	0	0	0	0	0	0	0	0	0	0	14,927	23,897	28,239	22,272	10,131	9,231	109,063
460	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21,236	0	0	8,338	20,604	6,270	56,448
470	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,880	12,359	3,554	15,088	17,088	51,969
480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7,760	0	7,566	43,731	0	59,057
490	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25,381	0	0	0	3,705	3,635	32,720
510	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,114	0	11,114
520	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14,819	0	14,819
530	0	0	0	0	0	0	0	0	0	0	0	0	1,219	0	0	0	0	0	0	0	0	0	1,219
540	0	14,928	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14,928
800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13,979	0	0	0	0	0	13,979

Table 5.2.2.7. Size distribution of Atlantic croaker weighted by landings (numbers) for the South Atlantic region of the fishery (South Carolina and south). Size class in 10 mm intervals is the lower bound.

Length Class (mm)	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Grand Total
90	0	0	0	0	0	0	0	0	0	0	0	0	1,083	0	0	2,805	0	0	0	0	0	0	3,889
100	0	0	259	0	0	0	0	0	0	0	10,837	0	0	0	0	0	0	0	0	0	0	0	11,096
110	0	0	0	0	3,521	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,521
120	0	0	0	24,731	48,518	0	0	0	0	0	0	0	0	0	10,014	5,610	0	0	0	0	0	0	88,874
130	0	2,221	0	24,731	77,540	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	104,491
140	13,565	0	0	0	71,503	0	0	0	0	0	0	1,157	0	0	0	0	0	0	0	0	0	0	86,225
150	13,258	2,221	1,131	44,755	35,327	0	702	0	0	0	5,667	6,439	0	0	0	0	0	0	17,867	0	0	0	127,367
160	6,841	5,834	5,990	57,765	60,153	1,362	2,284	15,563	0	8,382	0	8,753	2,369	11,637	0	5,610	0	8,406	16,243	0	0	0	217,190
170	11,912	10,413	11,137	102,589	43,761	5,596	70,595	2,698	18,295	32,676	3,778	21,815	0	0	0	5,610	0	764	25,988	0	0	0	367,627
180	24,987	176,337	22,353	92,088	54,165	100,967	200,841	18,797	52,877	92,015	0	36,971	0	7,711	8,198	2,805	0	3,057	25,107	3,835	2,342	725	926,177
190	23,886	258,406	25,948	117,308	72,118	93,124	109,739	20,626	66,471	111,111	1,889	50,512	0	13,214	2,049	16,831	9,490	8,816	12,994	8,729	2,342	725	1,026,328
200	11,181	249,650	151,110	177,542	61,839	476,674	96,578	19,176	40,957	202,320	11,334	71,924	1,083	28,181	8,198	14,026	0	18,066	22,403	8,949	2,633	2,174	1,675,997
210	44,606	195,115	151,527	278,609	234,685	753,214	225,550	65,139	13,314	114,918	88,588	90,566	0	24,291	12,296	5,610	2,773	938	11,521	27,819	6,429	5,104	2,352,613
220	26,885	182,699	130,568	242,155	178,480	316,845	435,296	23,167	37,739	175,411	132,070	94,846	24,664	59,130	86,263	14,026	48,251	39,822	35,515	24,429	18,130	22,179	2,348,572
230	74,306	133,437	151,943	232,563	112,746	458,967	650,934	160,188	50,571	165,142	270,935	96,965	84,178	82,895	4,099	28,051	40,363	47,770	31,776	24,985	46,166	15,083	2,964,062
240	109,870	157,821	105,826	249,360	130,568	181,711	362,206	148,896	14,736	61,952	171,010	138,315	42,031	55,380	44,156	16,831	59,879	69,511	28,932	40,413	57,821	12,655	2,259,881
250	63,918	102,527	76,038	392,813	110,514	334,564	135,533	109,283	14,882	65,050	92,366	75,473	33,449	55,380	2,049	16,831	59,343	18,655	56,367	62,516	29,528	16,573	1,923,654
260	18,882	106,805	60,735	351,019	68,903	159,679	58,839	58,534	17,751	57,682	119,211	128,140	25,662	114,614	30,043	8,415	24,526	29,849	30,817	84,588	44,254	21,069	1,620,018
270	28,293	100,863	77,068	278,015	101,448	98,760	91,323	56,919	3,500	77,099	249,260	54,302	51,814	153,485	8,198	16,831	22,554	28,917	20,006	87,336	41,626	21,322	1,668,936
280	85,732	132,904	51,823	213,316	42,880	910,671	30,615	25,044	6,035	26,582	43,350	43,614	64,156	69,820	30,043	11,221	5,546	37,543	35,460	36,040	36,166	50,079	1,988,641
290	37,764	57,576	83,606	205,386	64,089	997,048	143,262	2,738	48,276	23,679	0	98,457	9,953	23,273	40,058	5,610	37,960	18,475	48,644	35,944	18,417	19,977	2,020,192
300	12,588	44,528	44,929	115,381	11,767	25,935	170,968	18,137	47,192	0	54,187	9,800	6,416	20,470	14,113	8,415	21,383	23,878	36,479	31,280	26,312	13,168	757,327
310	9,410	26,597	60,208	98,391	12,448	137,661	0	57,078	84,483	6,617	0	27,377	0	34,910	2,049	8,415	9,490	16,696	3,968	17,563	16,392	27,874	657,627
320	37,764	17,966	20,098	78,372	776	91,446	0	45,296	18,104	2,206	17,532	61,075	11,153	11,637	190,274	5,610	45,478	6,167	32,994	11,209	22,572	3,046	730,774
330	15,704	30,506	10,822	3,367	12,448	323,798	2,105	5,188	0	4,411	0	44,189	1,083	11,637	0	2,805	14,235	9,251	5,622	18,052	22,523	16,573	554,321
340	34,587	20,704	6,139	54,601	0	90,462	0	15,563	18,104	6,617	0	35,387	7,499	34,910	0	5,610	0	6,167	15,241	7,642	29,548	6,718	395,498
350	6,233	19,172	4,683	0	0	90,462	0	10,375	10,701	2,206	0	33,142	19,247	14,931	0	0	0	9,251	3,653	17,333	20,837	1,344	263,570
360	31,470	1,041	4,683	78,372	0	0	0	10,375	0	0	0	0	2,167	0	30,043	0	11,092	15,418	8,103	1,278	10,038	1,344	205,425
370	18,882	0	2,342	58,779	0	0	0	0	0	0	43,350	5,838	0	0	0	0	0	24,670	1,654	35,537	2,342	6,718	200,110
380	6,233	5,378	2,342	0	0	90,462	1,280	1,287	7,685	0	0	11,677	19,247	23,273	22,078	0	5,546	9,251	13,821	11,588	5,947	6,805	243,898
390	0	0	0	213	18,194	0	3,840	3,860	15,369	0	0	0	6,416	0	60,086	0	0	0	7,276	0	0	0	115,254
400	0	0	9,193	0	20,752	0	0	0	18,104	0	0	0	0	23,273	0	0	0	18,502	2,826	6,153	471	2,687	101,961
410	0	5,205	0	0	0	45,231	0	0	6,035	0	0	22,095	12,831	0	0	0	0	0	0	0	2,206	2,687	96,289
420	0	0	0	0	0	0	0	0	37,857	0	0	0	0	0	0	0	0	0	0	0	2,526	4,031	44,414
430	0	0	4,683	0	62,420	0	0	0	0	0	0	0	0	0	10,014	0	0	0	0	0	0	0	77,118
440	0	0	7,025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,903	2,318	0	0	21,246
450	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,588	0	0	11,588
460	0	0	0	0	0	3,245	0	0	0	0	0	0	0	16,473	0	8,415	0	0	0	0	0	0	28,134
510	31,470	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31,470

Table 5.2.3.1. Numbers of Atlantic croaker released alive by recreational fishermen (Type B2).

Mid Atlantic =North Carolina and states north and South=South Carolina and states south.

	Mid Atlantic	South Atlantic	TOTAL
1981	1049345	227414	1276759
1982	719083	407245	1126328
1983	3341899	568556	3910455
1984	2444691	1020911	3465602
1985	3226084	1451908	4677992
1986	2761265	443468	3204733
1987	2651742	1955970	4607712
1988	2090314	332921	2423235
1989	2277220	149097	2426317
1990	5363671	596726	5960397
1991	11606571	813394	12419965
1992	6025611	456338	6481949
1993	9818050	239025	10057075
1994	12447451	572275	13019726
1995	7235644	339686	7575330
1996	6868219	251077	7119296
1997	10712099	280013	10992112
1998	10144925	578741	10723666
1999	11399028	1142286	12541314
2000	15731849	694437	16426286
2001	11068063	590107	11658170
2002	11287097	504026	11791123

Table. 5.2.3.2. Estimates number and weight of recreational discards. Discard weight (pounds) were estimated using seven methods described in the text.

REGION	YEAR	NUMBERS	lf_50	lf_p10	lf_p15	lf_p20	lf_p25	med	orig
Mid Atlantic	1981	731,311	23,484	16,631	18,137	19,117	20,141	29,734	38,839
	1982	503,358	18,561	12,014	12,300	13,975	15,197	29,629	38,185
	1983	2,339,328	42,911	29,115	31,890	36,219	36,636	61,577	90,922
	1984	1,711,283	59,029	45,199	49,336	49,343	53,030	72,412	84,415
	1985	2,258,259	72,182	48,596	54,064	55,306	61,333	94,895	100,057
	1986	1,932,886	75,941	49,345	54,538	64,658	65,473	89,965	99,915
	1987	1,856,219	79,498	58,241	60,720	68,568	69,647	98,363	106,169
	1988	1,463,220	66,214	45,041	47,020	51,999	54,011	87,774	101,594
	1989	1,594,057	64,218	41,642	46,015	48,455	50,554	83,427	89,218
	1990	3,754,570	115,372	67,887	76,622	89,138	91,465	148,276	165,852
	1991	8,124,600	241,410	176,523	181,190	196,692	203,285	307,729	337,556
	1992	4,217,927	168,409	138,307	140,633	144,621	152,711	197,063	216,576
	1993	6,872,636	309,696	237,540	263,832	267,099	271,928	375,221	416,617
	1994	8,713,218	343,744	255,699	258,630	274,382	288,441	440,129	498,133
	1995	5,064,950	227,013	155,741	165,720	187,587	190,439	290,582	337,371
	1996	4,807,752	253,099	189,738	190,875	196,557	203,770	328,735	378,803
	1997	7,498,469	467,309	308,109	337,249	359,971	384,678	608,293	742,907
	1998	7,101,449	512,674	319,410	339,843	372,522	406,377	697,554	798,893
	1999	7,979,319	478,114	335,113	347,338	364,757	387,360	663,574	793,299
	2000	11,012,294	932,122	611,176	653,687	727,430	739,493	1,227,414	1,322,053
	2001	7,747,643	573,284	391,245	412,904	452,144	461,452	757,788	869,307
South Atlantic	1981	159,189	5,571	3,324	3,988	4,012	4,562	8,538	13,209
	1982	285,072	9,609	6,343	6,816	7,576	7,771	12,977	15,433
	1983	397,989	14,941	10,553	10,896	12,068	12,169	19,287	24,015
	1984	714,637	22,504	14,073	17,191	17,760	18,507	27,769	31,393
	1985	1,016,337	18,718	13,065	13,947	14,007	15,148	29,775	43,400
	1986	310,429	14,995	8,962	9,273	9,289	9,714	22,299	21,597
	1987	1,369,179	50,353	29,298	32,840	37,123	37,495	62,278	67,356
	1988	233,045	9,791	6,433	7,682	7,874	8,439	12,597	15,398
	1989	104,367	5,623	3,328	3,328	3,396	3,938	7,375	9,080
	1990	417,708	12,298	8,833	9,648	9,648	10,348	15,853	17,223
	1991	569,376	24,774	19,391	20,124	22,654	22,654	29,683	35,659
	1992	319,437	14,664	11,012	11,141	11,989	12,862	19,221	22,301
	1993	167,318	8,719	7,226	7,226	7,454	7,454	11,174	14,386
	1994	400,593	20,161	13,173	14,533	14,735	16,003	26,417	33,848
	1995	237,781	14,861	6,887	7,451	8,619	9,094	23,497	25,004
	1996	175,754	6,048	2,277	3,223	3,755	3,977	9,162	12,512
	1997	196,009	9,685	7,332	7,693	7,948	8,478	12,195	15,070
	1998	405,118	18,872	13,592	14,112	14,719	15,137	25,356	29,099
	1999	799,600	26,046	16,372	18,092	18,561	19,255	37,462	50,418
	2000	486,105	27,450	17,733	18,966	20,266	21,615	36,346	44,630
	2001	413,075	22,714	15,883	17,342	17,861	18,847	30,914	37,489

Table 5.2.4.1. Species used to identify a potential Atlantic croaker intercept by state. The species most likely to be associated with an Atlantic croaker target trip were determined using a jaccard type index.

See text for details

SPECIES/GROUP	NJ	DE	MD	VA	NC	SC	GA	FL
BLACK SEA BASS	X	X		X				X
CLEARNOSE SKATE	X							
DUSKY SMOOTH-HOUND	X	X						
OYSTER TOADFISH	X							X
PIGFISH				X	X			
PINFISH					X	X		
RED DRUM						X	X	X
ROCKFISH			X					
SOUTHERN FLOUNDER						X	X	
SOUTHERN KINGFISH						X	X	
SPOT		X	X	X	X	X	X	
SPOTTED SEATROUT							X	
SUMMER FLOUNDER		X	X	X				
WEAKFISH	X	X	X	X	X			X
WHITE PERCH			X					
ATLANTIC CROAKER	X	X	X	X	X	X	X	X
STINGRAY SPP								X
SUMMER FLOUNDER SPP					X			

Table 5.2.4.2. Summary statistics for the negative binomial generalized linear model and log transformed general linear models used to estimate recreational catch rates

Model Type		**Negative Binomial GLM**		**Log transformed GLM**	
Region		**North**	**South**	**North**	**South**
Scaled Deviance		211,741	64,706	NA	NA
Degrees of Freedom		130,000	35,000	NA	NA
Mean Square Error		NA	NA	0.8869	0.4049
R-Square		NA	NA	0.1756	0.0948
Response Variable (numbers)		catch	catch	log (catch +1)	log (catch +1)
Explanatory Variables:					
	Year	<.0001	<.0001	<.0001	<.0001
	Wave	<.0001	<.0001	<.0001	<.0001
	Mode	<.0001	<.0001	<.0001	<.0001
	Area	0.0002	<.0001	<.0001	<.0001
	Hours Fished	<.0001	<.0001	<.0001	0.2595
	Contributors	<.0001	<.0001	<.0001	<.0001
	State	<.0001	<.0001	<.0001	<.0001

Table 5.2.4.3. Estimates of recreational catch rates and 95% confidence intervals for Atlantic croaker in the Mid Atlantic (North Carolina and North) and South Atlantic regions (South Carolina and south)

MODEL			Negative Binomial GLM						Log Transformed GLM			
REGION	Mid Atl.			South Atl.			Mid Atl.			South Atl.		
YEAR	Lower 95%	Estimate	Upper 95%	Lower 95%	Estimate	Upper 95%	Lower 95%	Estimate	Upper 95%	Lower 95%	Estimate	Upper 95%
1981	0.1541	0.2349	0.3581	0.4096	0.5860	0.8383	-0.1527	-0.0374	0.0936	0.3398	0.4386	0.5447
1982	0.1499	0.2282	0.3474	0.4555	0.5740	0.7232	-0.1343	-0.0175	0.1151	0.4087	0.4745	0.5433
1983	0.4552	0.6738	0.9974	0.2990	0.3814	0.4866	-0.0523	0.0699	0.2079	0.2559	0.3157	0.3782
1984	0.4302	0.6475	0.9746	0.3795	0.4684	0.5782	0.0367	0.1760	0.3341	0.2765	0.3288	0.3833
1985	0.2696	0.3968	0.5841	0.4846	0.5766	0.6861	-0.0330	0.0902	0.2291	0.3349	0.3795	0.4255
1986	0.4185	0.6161	0.9069	0.3699	0.4421	0.5284	0.0352	0.1673	0.3162	0.1449	0.1836	0.2237
1987	0.4656	0.6904	1.0237	0.2423	0.2876	0.3414	0.1347	0.2821	0.4485	0.0819	0.1165	0.1522
1988	0.5458	0.8073	1.1941	0.2100	0.2583	0.3177	0.2349	0.3942	0.5741	0.0852	0.1275	0.1715
1989	0.5863	0.8602	1.2621	0.2649	0.3222	0.3919	0.1389	0.2824	0.4440	0.1249	0.1667	0.2101
1990	0.4247	0.6254	0.9208	1.1335	1.4417	1.8336	0.1362	0.2807	0.4436	0.7221	0.8060	0.8939
1991	0.6133	0.8988	1.3172	0.5349	0.6632	0.8223	0.1740	0.3219	0.4885	0.3315	0.3879	0.4467
1992	0.5421	0.7950	1.1660	0.5961	0.7086	0.8423	0.1676	0.3151	0.4812	0.3882	0.4338	0.4809
1993	0.6520	0.9567	1.4037	0.2057	0.2511	0.3066	0.2261	0.3813	0.5560	0.0464	0.0862	0.1276
1994	0.8803	1.2871	1.8818	0.2500	0.3000	0.3599	0.4193	0.5974	0.7978	0.0930	0.1314	0.1710
1995	0.5839	0.8545	1.2506	0.2374	0.2850	0.3422	0.2237	0.3776	0.5508	0.0224	0.0585	0.0960
1996	0.5842	0.8547	1.2504	0.1245	0.1497	0.1799	0.1556	0.3009	0.4643	-0.0133	0.0192	0.0528
1997	0.8431	1.2324	1.8016	0.1930	0.2289	0.2716	0.2520	0.4090	0.5857	0.0370	0.0694	0.1028
1998	0.9747	1.4242	2.0810	0.2955	0.3458	0.4047	0.3179	0.4831	0.6690	0.1299	0.1630	0.1971
1999	1.4417	2.1079	3.0819	0.2997	0.3451	0.3974	0.5829	0.7817	1.0055	0.0532	0.0807	0.1088
2000	1.0377	1.5173	2.2183	0.2370	0.2734	0.3154	0.3829	0.5565	0.7519	0.0486	0.0765	0.1051
2001	0.9385	1.3708	2.0022	0.1720	0.1989	0.2301	0.2523	0.4091	0.5854	-0.0119	0.0140	0.0406
2002	0.7780	1.1352	1.6565	0.2258	0.2603	0.3000	0.3505	0.5196	0.7099	0.0126	0.0391	0.0663

Table 5.3.2.4.1 Estimates of catch per tow in numbers and weight for the NMFS trawl survey using the delta-log normal GLM.

	Numbers			Weight	
Year	**CPUE**	**StdErr**		**CPUE**	**StdErr**
1982	3.894219	2.453887		1.004295	0.6843551
1983	58.59242	35.75971		9.532017	5.887758
1984	307.2359	137.7837		47.19537	20.83276
1985	140.9434	52.47678		23.84431	9.097177
1986	70.75209	30.68178		12.5425	5.179898
1987	20.59788	13.66391		4.516468	3.134929
1988	14.48075	10.52384		3.482267	1.990745
1989	47.52855	29.2228		8.06636	4.274117
1990	38.40878	21.77061		5.39454	3.129935
1991	51.34846	29.45326		7.770463	3.988954
1992	100.6933	62.01083		12.21884	6.485378
1993	29.2586	19.75414		4.332819	3.073844
1994	228.9248	136.2203		29.3999	15.69074
1995	299.7379	133.462		41.69413	18.70153
1996	210.4528	98.66762		37.87971	17.75633
1997	70.35722	41.53354		13.38749	7.814934
1998	444.6383	204.7653		78.14807	35.38722
1999	1164.209	467.5473		182.4884	76.78962
2000	260.3665	112.7817		52.49517	23.69217
2001	282.5288	132.7705		61.3016	27.84747
2002	875.687	354.9882		162.6298	62.05909

Table 5.3.3.5.1 Spring Atlantic Croaker (Recruit) Indices. Estimates of catch per tow in numbers for the VIMS trawls survey (spring). Data courtesy of VIMS.

SPRING ATLANTIC CROAKER (RECRUITS) INDICES											
	Converted Index (RSCI)			Unconverted Index (RSI)				Original Index			
Year	Geo. Mean	95% C.I.'s	C.V.	Geo. Mean	95% C.I.'s	C.V.	N	Bay & River (BRI)	N	River Only	N
1955	0.31	0.17-0.45	20.15	0.45	0.3-0.61	14.47	20				
1956	3.28	1.2-7.3	22.81	4.92	2.05-10.48	18.66	48				
1957	13.62	0.11-191.83	48.08	11.70	0.15-139.59	47.30	28				
1958	0.30	0-0.88	71.25	0.40	0-1.22	68.83	59				
1959	0.04	0-0.88	46.61	0.04	0.01-0.07	41.19	48				
1960	0.24	0-0.6	57.76	0.35	0-0.97	62.28	54				
1961	0.36	0-1.05	67.92	0.24	0-0.62	63.83	28				
1962	0.79	0.56-1.05	11.74	0.67	0.47-0.91	12.66	28				
1963	0.01	0-0.04	86.67	0.01	0-0.03	70.15	28				
1964	0.35	0.16-0.57	25.21	0.32	0.18-0.48	20.50	55				
1965	4.01	1.98-7.4	16.06	2.93	1.58-4.98	15.33	48				
1966	0.00	0-0.01	-332.05	0.00	0-0.01	100.00	66				
1967	0.34	0.19-0.5	19.83	0.26	0.15-0.38	19.42	83				
1968	0.11	0.03-0.2	35.79	0.07	0.02-0.14	39.09	87				
1969	0.26	0.15-0.39	20.62	0.18	0.1-0.26	21.44	91				
1970	0.06	0-0.12	52.38	0.03	0-0.06	49.09	92				
1971	0.23	0.12-0.34	21.94	0.15	0.08-0.24	24.38	228				
1972	4.37	0-31.89	53.90	3.63	0-24.42	55.62	210				
1973	0.12	0.09-0.16	14.60	0.09	0.07-0.13	14.98	417				
1974	2.04	1.2-3.19	14.45	1.68	1.03-2.54	14.09	241				
1975	2.63	1.64-3.98	12.28	2.00	1.29-2.94	12.40	334				
1976	1.08	0.84-1.37	8.65	0.78	0.6-0.97	9.00	591				
1977	0.15	0.1-0.2	16.42	0.11	0.06-0.15	20.39	530				
1978	0.08	0.05-0.11	16.61	0.05	0.03-0.07	17.94	413				
1979	2.18	1.44-3.14	11.43	1.30	0.9-1.79	11.44	119			2.06	117
1980	0.52	0.39-0.66	10.98	0.44	0.34-0.55	10.12	152			1.85	137
1981	0.07	0.04-0.1	19.67	0.07	0.04-0.1	20.36	140			0.24	132
1982	0.11	0.07-0.14	14.68	0.11	0.07-0.14	15.05	168			1.23	148
1983	6.59	4.94-8.71	6.06	6.67	4.98-8.84	6.10	156			9.49	156
1984	1.63	0.83-2.77	18.72	1.61	0.83-2.73	18.59	140			1.23	144
1985	4.98	4.18-5.92	4.05	5.33	4.4-6.42	4.31	106			4.07	106
1986	2.97	2.25-3.84	7.18	3.33	2.52-4.32	7.03	142			3.19	142
1987	4.24	3.47-5.14	4.81	4.24	3.47-5.14	4.80	139			5.47	139
1988	0.32	0.21-0.44	15.52	0.36	0.23-0.49	16.05	234	0.38	234	2.22	84
1989	0.60	0.38-0.85	15.51	0.65	0.41-0.93	15.63	252	0.78	252	4.63	84
1990	0.43	0.23-0.67	21.19	0.48	0.26-0.74	20.56	252	0.52	252	2.98	85
1991	4.41	3.08-6.18	8.36	4.41	3.08-6.18	8.36	307	4.35	238	12.87	83
1992	1.28	0.87-1.78	12.10	1.28	0.87-1.78	12.10	309	1.34	240	10.26	84
1993	2.17	1.5-3.02	10.34	2.17	1.5-3.02	10.34	301	2.21	240	19.40	84
1994	0.90	0.6-1.26	13.54	0.90	0.6-1.26	13.54	300	0.95	240	2.98	84
1995	1.06	0.77-1.39	10.40	1.06	0.77-1.39	10.40	306	0.93	246	5.55	90
1996	0.19	0.11-0.28	19.63	0.19	0.11-0.28	19.63	405	0.16	242	0.36	88
1997	1.47	1.15-1.85	7.78	1.47	1.15-1.85	7.78	419	0.87	255	7.78	100
1998	1.19	0.95-1.47	7.51	1.19	0.95-1.47	7.51	374	0.48	214	6.21	96
1999	1.50	1.05-2.05	10.83	1.50	1.05-2.05	10.83	397	1.28	232	4.08	100
2000	0.60	0.42-0.80	12.68	0.60	0.42-0.80	12.68	413	0.44	245	1.39	97
2001	0.36	0.24-0.49	14.65	0.36	0.24-0.49	14.65	420	0.32	253	1.18	98
2002	1.59	1.07-2.22	11.59	1.59	1.07-2.22	11.59	361	1.10	195	4.59	98

Table 5.3.7.1. Mortality estimates for Atlantic croaker based on different studies and methods

Method	Source	Virginia MRC/ ODU	North Carolina DMF	Foster/VIMS	Hales&Reitz	Barbieri
	Type	Stratified random commercial samples	Mixed fishery independent/ dependent Stratified random samples ?	Large fish from Commercial	Archeological samples	Com & FI
	Location	Virginia	North Carolina	Virginia ?	Florida	MD-NC
	Time Period	1998-2002	1989-2002	1998-2000	~1450-1765	1988-1991
	Max Age	12	12	11	15	8
	Full -Rec Age	5	1	5	3	2
	Sample Size	1573	5347	4589	183	1027
	k	0.2415	0.135431303	0.2415	0.18	0.36
	Linfinity	505	434	505	422	312.43
Hoenig	exp(1.46-1.01Ln(MaxAge)	0.350023244	0.350023244	0.38217593	0.279394448	0.52716802
	-LN(0.05)/max age	0.249644356	0.249644356	0.272339298	0.199715485	0.374466534
	-LN(0.01)/max age	0.383764182	0.383764182	0.418651835	0.307011346	0.575646273
Gabriel et al.	3/MaxAge	0.25	0.25	0.272727273	0.2	0.375
Alverson and Carney in Deriso and Quninn	3k/(exp(0.38MaxAge*k)-1)	0.36082591	0.475525535	0.415389482	0.301695537	0.543426382
Pauly	Pauly	0.573010624	0.409413756	0.573010624	0.497050956	0.850728539

Table 6.2.1 Deterministic parameter estimates used to develop criteria for sensitivity runs. For each regional model, all possible combinations of these estimates were examined (N=243). Age 1 commercial selectivity was estimated as (1 + estimate of Age 0)/2 in all runs.

Steepness (h)	Natural Mortality (M)	SSB initial Ratio	Commercial Age 0 Selectivity	Recreational Age 0 Selectivity
0.6	0.2	0.25	0	0
0.76	0.3	0.75	0.1	0.05
0.85	0.4	1	0.25	0.2

.

Table 6.2.1.1. Summary Table of Available fishery Independent and dependent indices

	SEAMAP-ALL	SEAMAPS	SeamapN	NMFS	NC CPUE	MRFSS_NO	MRFSS SO	VIMS	NCDMF 120	NCDMF 195	MD DNR	FL FWCC Trawl	FLFWCC (Seine)
Year	weight	weight	weight	weight	weight	numbers	numbers	numbers	numbers	numbers	numbers	numbers	numbers
1973	x	x	x	x	x	x	x	0.12	x	x	x	x	x
1974	x	x	x	x	x	x	x	2.04	x	x	x	x	x
1975	x	x	x	x	x	x	x	2.63	x	x	x	x	x
1976	x	x	x	x	x	x	x	1.08	x	x	x	x	x
1977	x	x	x	x	x	x	x	0.15	x	x	x	x	x
1978	x	x	x	x	x	x	x	0.08	x	x	x	x	x
1979	x	x	x	x	x	x	x	2.18	22.50	x	x	x	x
1980	x	x	x	x	x	x	x	0.52	36.03	x	x	x	x
1981	x	x	x	x	x	0.23	0.59	0.07	6.55	x	x	x	x
1982	x	x	x	1.04	x	0.23	0.57	0.11	20.83	x	x	x	x
1983	x	x	x	9.92	x	0.67	0.38	6.59	38.95	x	0.40	x	x
1984	x	x	x	48.41	x	0.65	0.47	1.63	21.94	x	0.00	x	x
1985	x	x	x	26.25	x	0.40	0.58	4.98	8.53	x	0.39	x	x
1986	x	x	x	13.57	x	0.62	0.44	2.97	6.30	x	0.83	x	x
1987	x	x	x	4.49	x	0.69	0.29	4.24	8.78	12.12	0.17	x	x
1988	x	x	x	3.35	x	0.81	0.26	0.32	6.40	37.60	x	x	x
1989	5.19	2.06	16.35	8.02	x	0.86	0.32	0.60	5.18	63.35	0.43	x	x
1990	15.91	14.70	15.03	5.39	x	0.63	1.44	0.43	6.50	119.92	0.19	0.43	x
1991	42.51	25.42	79.44	8.05	x	0.90	0.66	4.41	2.99	21.41	0.08	0.27	x
1992	25.61	6.34	150.26	12.95	x	0.80	0.71	1.28	5.67	141.19	0.79	1.03	x
1993	8.72	3.65	26.54	4.26	x	0.96	0.25	2.17	13.60	64.64	1.92	1.00	x
1994	12.95	3.67	65.90	31.01	108.78	1.29	0.30	0.90	8.04	80.82	1.59	0.41	x
1995	11.78	3.00	60.84	44.64	115.90	0.85	0.28	1.06	11.89	52.62	0.74	0.87	x
1996	7.00	1.89	31.91	40.22	176.31	0.85	0.15	0.19	3.47	134.14	1.61	0.93	0.07
1997	4.78	2.54	10.19	13.81	101.94	1.23	0.23	1.47	13.90	85.16	1.65	0.03	0.07
1998	10.93	2.69	59.02	84.25	97.68	1.42	0.35	1.19	28.58	492.92	3.48	x	-0.02
1999	10.09	1.52	87.86	192.01	152.70	2.11	0.35	1.50	5.54	133.53	1.43	x	0.05
2000	5.98	1.98	25.63	54.50	126.87	1.52	0.27	0.60	20.89	39.42	1.39	x	0.16
2001	9.93	5.44	21.73	66.94	234.02	1.37	0.20	0.36	5.07	34.91	0.87	x	0.40
2002	6.45	2.13	25.53	170.60	141.27	1.14	0.26	1.59	6.86	x	1.51	x	x

Table 6.2.2.1. Selectivity estimates used in the base age structured production model

Selectivity	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10
Commercial	0.1	0.55	1	1	1	1	1	1	1	1	1
Recreational	0.05	1	1	1	1	1	1	1	1	1	1
NMFS Survey	1	1	0.59	0	0	0	0	0	0	0	0
MRFSS Survey	0.05	1	1	1	1	1	1	1	1	1	1
SEAMAP Survey	1	0.4	0	0	0	0	0	0	0	0	0

Table 6.2.2.2. Parameter bounds used in the AD model Builder version of the age structured production model .

Parameter	Upper bound	Lower bound	
Virgin recruitment (R0)	10	25	(log space)
Recruitment deviations from S/R curve	7.5	-7.5	(log space)
Catchability coefficeints (q)	-3	-25	(log space)
Fully selected Fishing mortality (by fleet)	0	1.5	
Steepness (when estimated)	0.2	1	

Table 7.1.1. Standardized residuals for the commercial and recreational landings for the Mid Atlantic and South Atlantic base models

(m=0.30, steepness=0.76, SSB initial: virgin ratio=0.75). Mean and standard deviation of the residuals are also included

	Mid-Atlantic		South-Atlantic	
	Com	Rec	Com	Rec
mean	0.00	0.00	0.00	0.00
s.d	0.20	0.06	0.03	0.29
N	30	30	30	30
1973	-0.627	-0.769	1.344	0.992
1974	-0.169	-0.173	-0.215	-0.054
1975	-0.411	-0.383	-0.173	-0.018
1976	-0.645	-0.614	-0.175	-0.019
1977	-0.950	-0.707	-0.153	-0.001
1978	-0.959	-0.651	-0.140	0.010
1979	-0.359	-0.192	-0.114	0.032
1980	0.949	0.163	-0.126	0.020
1981	0.291	0.083	-0.038	0.062
1982	0.615	-1.470	0.086	0.208
1983	1.759	1.109	0.282	0.273
1984	1.202	0.769	1.109	1.472
1985	-0.356	-0.062	1.291	0.916
1986	-0.880	-0.500	1.678	2.451
1987	-1.786	-0.987	1.849	1.172
1988	-0.038	-0.276	1.678	0.586
1989	0.703	0.761	1.039	0.373
1990	-1.130	-0.832	0.747	0.512
1991	-0.397	-0.822	-1.004	-1.393
1992	-0.708	-1.308	-1.851	-3.156
1993	-2.731	-2.280	-1.970	-1.749
1994	0.488	0.839	-1.183	-0.688
1995	0.444	0.537	-0.603	-0.683
1996	0.848	0.684	-1.554	-0.688
1997	0.459	0.340	-0.493	-0.232
1998	1.302	1.652	0.001	0.232
1999	1.073	1.299	-0.146	-0.030
2000	0.045	0.124	-0.330	-0.236
2001	0.930	1.799	-0.164	0.097
2002	1.040	1.864	-0.674	-0.459

Table 7.1.2. Standardized residuals for the indices used in the base models for the Mid-Atlantic and South Atlantic models

(m=0.30, steepness=0.76, SSB initial: virgin ratio=0.75). Mean and standard deviation of the residuals are also included

	Mid-Atlantic			South-Atlantic	
	NMFS	MRFSS	SEAMAP	MRFSS	SEAMAP
mean	0.00	0.00	0.00	0.00	0.00
s.d.	0.81	0.52	0.65	0.39	0.44
N	21	22	14	22	14
1981		-0.3260		-0.1931	
1982	-1.5045	0.0969		-0.1739	
1983	-0.2110	0.9647		-0.5889	
1984	0.9877	-0.2570		-0.2280	
1985	0.4770	-0.5843		-0.1712	
1986	0.1742	-0.0595		-0.1338	
1987	-0.6863	0.3728		-0.0520	
1988	-0.8371	0.8216		-0.4722	
1989	-0.0951	0.7908	0.0408	-0.2367	-0.7224
1990	-0.5355	0.4215	0.0040	1.2206	0.5493
1991	-0.5949	0.6114	1.0053	-0.1027	0.9180
1992	-0.4830	-0.1743	1.5313	0.3146	0.2570
1993	-1.4764	0.0171	0.1194	-0.2730	-0.1300
1994	0.1909	0.3560	0.2227	0.2637	0.0154
1995	0.2287	-0.7161	0.1233	0.4150	0.1415
1996	0.2498	-0.6671	0.0707	-0.3625	-0.2663
1997	-0.2011	0.0138	-0.6880	-0.0064	-0.0493
1998	0.7100	0.2909	-0.5883	0.2752	-0.0514
1999	1.1204	-0.4350	-0.0048	0.3012	-0.4587
2000	0.0779	-0.4870	-0.4484	0.3557	-0.2678
2001	0.7810	-0.4324	-0.7997	0.0241	0.4478
2002	1.6271	-0.6188	-0.5884	-0.1757	-0.3830

Table 7.2.1.1. Fully recruited fishing mortality estimate for Atlantic croaker from the base Mid-Atlantic and South Atlantic models.

Rec=recreational fishery; Comm=Commercial fishery. (m=0.30, steepness=0.76, SSB initial: virgin ratio=0.75).

	Mid-Atlantic			South-Atlantic		
F per Yr	Comm	Rec	Total	Comm	Rec	Total
1973	0.06	0.02	0.08	0.14	0.66	0.80
1974	0.07	0.02	0.09	0.16	0.96	1.12
1975	0.17	0.05	0.21	0.11	0.63	0.74
1976	0.29	0.08	0.37	0.15	0.89	1.05
1977	0.56	0.12	0.67	0.09	0.55	0.65
1978	0.95	0.18	1.13	0.05	0.30	0.35
1979	1.26	0.19	1.45	0.06	0.40	0.46
1980	1.50	0.14	1.64	0.05	0.34	0.39
1981	1.21	0.08	1.30	0.06	0.26	0.31
1982	1.50	0.11	1.61	0.07	0.55	0.62
1983	0.80	0.12	0.92	0.07	0.36	0.43
1984	0.50	0.05	0.55	0.13	1.12	1.25
1985	0.46	0.04	0.51	0.12	0.54	0.66
1986	0.59	0.09	0.68	0.22	1.50	1.72
1987	0.77	0.09	0.87	0.51	1.50	2.01
1988	0.78	0.28	1.06	0.33	0.56	0.88
1989	0.59	0.14	0.73	0.17	0.48	0.65
1990	0.57	0.09	0.67	0.16	0.54	0.69
1991	0.25	0.13	0.37	0.07	0.71	0.78
1992	0.19	0.07	0.26	0.10	1.50	1.60
1993	0.44	0.09	0.53	0.11	0.74	0.85
1994	0.27	0.11	0.38	0.28	1.44	1.72
1995	0.25	0.06	0.31	0.10	1.39	1.49
1996	0.26	0.05	0.31	0.11	0.33	0.43
1997	0.39	0.11	0.50	0.10	0.51	0.62
1998	0.38	0.13	0.51	0.07	0.51	0.58
1999	0.28	0.06	0.34	0.06	0.63	0.69
2000	0.24	0.08	0.32	0.10	0.94	1.04
2001	0.23	0.09	0.31	0.06	1.03	1.09
2002	0.19	0.07	0.26	0.08	0.39	0.47

Table 7.2.1.2. Exploitation rates for Atlantic croaker from the base mid-Atlantic and South-Atlantic models

(m=0.30, steepness=0.76, SSB initial: virgin ratio=0.75)

	Mid Atlantic	South Atlantic
1973	0.06	0.49
1974	0.08	0.60
1975	0.17	0.46
1976	0.27	0.57
1977	0.43	0.42
1978	0.60	0.26
1979	0.69	0.32
1980	0.72	0.28
1981	0.65	0.23
1982	0.72	0.41
1983	0.53	0.30
1984	0.37	0.63
1985	0.35	0.43
1986	0.43	0.74
1987	0.51	0.78
1988	0.58	0.52
1989	0.46	0.42
1990	0.43	0.44
1991	0.27	0.48
1992	0.20	0.72
1993	0.36	0.51
1994	0.27	0.74
1995	0.23	0.69
1996	0.23	0.31
1997	0.35	0.41
1998	0.35	0.38
1999	0.25	0.44
2000	0.24	0.57
2001	0.23	0.59
2002	0.20	0.33

Table 7.2.2.1. Population estimates for Atlantic croaker from the base mid-Atlantic and South-Atlantic models.

	Mid-Atlantic				South-Atlantic			
	Age 0 (millions)	SSB (MT) MT	Population (millions)	Population MT	Age 0 (millions)	SSB (MT) MT	Population (millions)	Population MT
1973	85.00	32,134	287.68	68,996	3.90	345	8.12	906
1974	93.96	29,287	296.65	69,415	3.34	345	7.55	880
1975	93.08	29,214	300.05	69,205	3.35	269	6.74	724
1976	93.51	26,600	288.07	63,261	3.02	292	6.63	755
1977	92.99	22,068	264.87	52,945	3.14	246	6.23	663
1978	91.68	15,516	228.72	38,114	2.90	285	6.38	733
1979	87.74	9,481	190.03	24,504	3.08	362	7.02	894
1980	59.21	6,498	141.74	16,626	3.24	390	7.33	959
1981	36.06	4,446	93.23	11,068	3.46	433	7.88	1,056
1982	34.94	3,394	75.57	8,717	3.41	500	8.35	1,191
1983	147.18	2,392	178.70	11,930	4.69	438	9.13	1,125
1984	55.30	6,963	167.56	17,721	5.22	512	10.79	1,310
1985	68.60	8,851	166.23	21,378	5.70	372	10.54	1,055
1986	48.10	9,334	144.13	21,502	4.29	469	10.27	1,189
1987	46.23	7,859	121.43	18,284	4.21	268	7.94	767
1988	55.70	5,861	114.99	14,707	2.59	204	5.79	563
1989	49.23	4,722	105.50	12,201	2.36	228	5.28	589
1990	47.54	5,057	105.89	12,749	6.30	247	9.17	808
1991	117.20	5,322	176.37	16,522	5.84	396	11.41	1,119
1992	83.67	9,119	200.10	23,169	2.43	467	8.51	1,097
1993	66.30	12,517	197.76	28,891	2.56	211	5.15	562
1994	225.02	11,651	334.93	34,402	2.44	212	5.10	559
1995	119.34	17,943	339.57	43,439	1.52	139	3.54	370
1996	69.02	21,928	285.21	48,148	1.29	99	2.68	272
1997	59.11	21,376	231.98	46,155	1.64	137	3.27	362
1998	506.56	16,285	630.09	56,808	1.58	155	3.42	398
1999	109.53	29,920	526.86	69,382	1.29	168	3.20	411
2000	129.52	34,544	453.77	76,195	1.74	151	3.38	395
2001	157.16	33,120	429.22	74,926	2.37	130	4.03	385
2002	124.07	32,313	390.36	72,032	1.38	146	3.46	376

Table 7.4.1. Summary of 1000 Monte-Carlo Trials to evaluate uncertainty surrounding the mid-Atlantic model. Estimates from the base mid-Atlantic model are included for comparative purposes.

Percentile	100	97.5	80	75	50	Base Case	25	40	2.5	0
Total Likelihood	53.644	51.230	49.705	49.503	48.876	51.509	48.179	48.602	46.737	45.811
M	0.40	0.39	0.35	0.34	0.30	0.30	0.26	0.28	0.20	0.20
steepness	0.99	0.95	0.84	0.81	0.70	0.76	0.58	0.66	0.34	0.21
Comm Age-0 Sel	0.25	0.24	0.19	0.18	0.13	0.10	0.08	0.11	0.02	0.00
Rec Age-0 Sel	0.20	0.20	0.15	0.14	0.10	0.05	0.06	0.08	0.01	0.00
SSB1/SSB0	1.00	1.00	0.84	0.80	0.65	0.75	0.45	0.58	0.26	0.25
R0	21.23	19.51	18.93	18.88	18.69	18.55	18.50	18.62	18.19	17.97
NMFS q	-12.84	-12.93	-13.03	-13.06	-13.32	-13.22	-13.54	-13.41	-14.45	-16.48
MRFSS q	-18.05	-18.15	-18.35	-18.40	-18.84	-18.42	-19.18	-19.01	-20.45	-22.33
SEAMAP q	-11.89	-11.99	-12.12	-12.14	-12.25	-12.21	-12.47	-12.32	-13.25	-15.38
Comm F 1973	1.43	0.61	0.09	0.09	0.06	0.06	0.05	0.06	0.03	0.01
Comm F 1974	0.38	0.25	0.12	0.11	0.08	0.07	0.06	0.07	0.03	0.01
Comm F 1975	0.66	0.42	0.26	0.24	0.18	0.17	0.15	0.16	0.07	0.01
Comm F 1976	0.79	0.59	0.41	0.38	0.30	0.29	0.25	0.28	0.11	0.02
Comm F 1977	1.16	0.96	0.72	0.69	0.55	0.56	0.46	0.52	0.17	0.03
Comm F 1978	1.50	1.50	1.20	1.15	0.93	0.95	0.74	0.85	0.19	0.03
Comm F 1979	1.50	1.50	1.50	1.50	1.18	1.26	0.78	1.02	0.15	0.02
Comm F 1980	1.50	1.50	1.50	1.50	1.43	1.50	0.78	1.07	0.14	0.02
Comm F 1981	1.50	1.50	1.38	1.27	0.85	1.21	0.47	0.66	0.08	0.01
Comm F 1982	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	0.09	0.01
Comm F 1983	1.50	1.50	1.20	1.13	0.83	0.80	0.59	0.73	0.06	0.01
Comm F 1984	0.81	0.72	0.58	0.55	0.38	0.50	0.29	0.34	0.06	0.01
Comm F 1985	0.99	0.84	0.65	0.61	0.32	0.46	0.22	0.27	0.05	0.01
Comm F 1986	1.42	1.28	1.03	0.94	0.38	0.59	0.23	0.30	0.05	0.01
Comm F 1987	1.50	1.50	1.34	1.21	0.39	0.77	0.22	0.30	0.04	0.01
Comm F 1988	1.50	1.50	1.38	1.22	0.38	0.78	0.22	0.30	0.04	0.01
Comm F 1989	1.49	1.29	0.93	0.83	0.30	0.59	0.17	0.23	0.03	0.01
Comm F 1990	1.50	1.50	1.05	0.93	0.28	0.57	0.15	0.21	0.03	0.00
Comm F 1991	0.79	0.66	0.46	0.42	0.14	0.25	0.08	0.11	0.02	0.00
Comm F 1992	0.46	0.37	0.29	0.27	0.12	0.19	0.08	0.10	0.02	0.00
Comm F 1993	1.50	1.50	1.50	1.50	0.27	0.44	0.15	0.21	0.03	0.01
Comm F 1994	0.74	0.68	0.58	0.56	0.19	0.27	0.13	0.16	0.03	0.01
Comm F 1995	0.49	0.47	0.41	0.40	0.19	0.25	0.14	0.16	0.04	0.01
Comm F 1996	0.51	0.47	0.40	0.38	0.22	0.26	0.16	0.19	0.04	0.01
Comm F 1997	0.91	0.83	0.70	0.67	0.33	0.39	0.24	0.29	0.06	0.01
Comm F 1998	0.92	0.73	0.60	0.57	0.30	0.38	0.21	0.25	0.05	0.01
Comm F 1999	0.43	0.40	0.36	0.35	0.22	0.28	0.17	0.20	0.05	0.01
Comm F 2000	0.36	0.33	0.30	0.29	0.19	0.24	0.14	0.16	0.04	0.01
Comm F 2001	0.32	0.31	0.29	0.28	0.18	0.23	0.13	0.16	0.04	0.01
Comm F 2002	0.28	0.27	0.24	0.23	0.15	0.19	0.11	0.13	0.03	0.01

Table 7.4.1 continued.

Percentile	100	97.5	80	75	50	Base Case	25	40	2.5	0
Rec F 1973	0.17	0.08	0.04	0.03	0.02	0.02	0.02	0.02	0.01	0.00
Rec F 1974	0.14	0.10	0.04	0.04	0.03	0.02	0.02	0.02	0.01	0.00
Rec F 1975	0.21	0.14	0.08	0.07	0.05	0.05	0.04	0.05	0.02	0.00
Rec F 1976	0.27	0.20	0.13	0.12	0.09	0.08	0.07	0.08	0.03	0.01
Rec F 1977	0.35	0.27	0.19	0.17	0.13	0.12	0.10	0.12	0.04	0.01
Rec F 1978	0.49	0.38	0.28	0.27	0.20	0.18	0.15	0.18	0.04	0.01
Rec F 1979	0.47	0.37	0.31	0.30	0.22	0.19	0.15	0.19	0.03	0.00
Rec F 1980	0.29	0.25	0.21	0.21	0.17	0.14	0.09	0.13	0.02	0.00
Rec F 1981	0.15	0.14	0.12	0.12	0.08	0.08	0.05	0.06	0.01	0.00
Rec F 1982	0.22	0.20	0.17	0.16	0.10	0.11	0.06	0.08	0.01	0.00
Rec F 1983	0.28	0.25	0.20	0.19	0.14	0.12	0.10	0.12	0.01	0.00
Rec F 1984	0.14	0.13	0.11	0.10	0.07	0.05	0.05	0.06	0.01	0.00
Rec F 1985	0.08	0.07	0.06	0.06	0.04	0.04	0.03	0.03	0.01	0.00
Rec F 1986	0.19	0.18	0.15	0.14	0.07	0.09	0.05	0.06	0.01	0.00
Rec F 1987	0.25	0.24	0.19	0.17	0.06	0.09	0.04	0.05	0.01	0.00
Rec F 1988	0.89	0.80	0.63	0.57	0.17	0.28	0.10	0.13	0.02	0.00
Rec F 1989	0.41	0.37	0.30	0.27	0.09	0.14	0.05	0.07	0.01	0.00
Rec F 1990	0.27	0.24	0.19	0.17	0.06	0.09	0.03	0.04	0.01	0.00
Rec F 1991	0.43	0.36	0.27	0.25	0.08	0.13	0.05	0.07	0.01	0.00
Rec F 1992	0.20	0.17	0.14	0.13	0.06	0.07	0.04	0.05	0.01	0.00
Rec F 1993	0.26	0.23	0.19	0.18	0.07	0.09	0.04	0.06	0.01	0.00
Rec F 1994	0.37	0.34	0.29	0.28	0.09	0.11	0.06	0.07	0.01	0.00
Rec F 1995	0.16	0.14	0.12	0.12	0.06	0.06	0.04	0.05	0.01	0.00
Rec F 1996	0.11	0.10	0.09	0.08	0.05	0.05	0.03	0.04	0.01	0.00
Rec F 1997	0.27	0.24	0.20	0.20	0.09	0.11	0.07	0.08	0.02	0.00
Rec F 1998	0.37	0.31	0.24	0.23	0.11	0.13	0.07	0.09	0.02	0.00
Rec F 1999	0.14	0.13	0.12	0.11	0.07	0.06	0.05	0.06	0.01	0.00
Rec F 2000	0.14	0.13	0.11	0.11	0.07	0.08	0.05	0.06	0.01	0.00
Rec F 2001	0.16	0.14	0.13	0.12	0.08	0.09	0.06	0.07	0.01	0.00
Rec F 2002	0.14	0.12	0.11	0.10	0.06	0.07	0.05	0.05	0.01	0.00

Table 7.4.1 continued.

Percentile	100	97.5	80	75	50	Base Case	25	40	2.5	0
SSB 1973	321,747	70,121	38,671	37,178	29,634	32,134	20,998	26,260	9,607	6,481
SSB 1974	321,747	70,121	38,671	37,178	29,634	29,287	20,998	26,260	9,607	6,481
SSB 1975	316,445	68,828	38,372	36,664	29,817	29,214	22,367	26,781	13,093	9,675
SSB 1976	306,565	65,765	34,897	33,140	27,361	26,600	21,417	24,877	13,938	11,163
SSB 1977	294,606	60,546	29,053	27,588	22,804	22,068	18,419	20,959	13,133	11,117
SSB 1978	281,736	52,202	20,924	19,920	16,275	15,516	13,349	14,974	10,333	9,032
SSB 1979	271,152	44,707	13,442	12,705	9,962	9,481	8,484	9,253	6,954	6,397
SSB 1980	266,476	41,764	10,541	9,825	7,050	6,498	5,963	6,559	5,155	4,666
SSB 1981	257,657	38,320	8,282	7,653	5,426	4,446	4,400	4,710	3,988	3,662
SSB 1982	250,606	35,734	7,447	6,795	4,651	3,394	3,104	3,693	2,539	2,374
SSB 1983	242,039	32,601	3,102	2,947	2,382	2,392	1,861	2,060	1,600	1,466
SSB 1984	289,608	48,631	11,484	10,892	8,396	6,963	5,743	6,614	4,645	4,258
SSB 1985	360,964	59,449	14,791	13,860	10,811	8,851	7,704	8,421	7,051	6,639
SSB 1986	386,312	64,659	16,351	15,291	11,624	9,334	7,706	8,592	6,992	6,638
SSB 1987	377,912	64,859	15,700	14,720	10,441	7,859	5,679	7,021	4,759	4,351
SSB 1988	365,251	63,075	14,494	13,566	8,868	5,861	4,028	5,320	3,221	2,989
SSB 1989	358,172	60,699	13,338	12,271	7,703	4,722	3,282	4,364	2,592	2,394
SSB 1990	351,500	59,799	13,423	12,453	7,943	5,057	3,965	4,852	3,242	2,986
SSB 1991	347,169	60,170	14,073	13,075	8,406	5,322	3,676	4,781	2,777	2,489
SSB 1992	404,299	71,988	18,895	17,978	12,639	9,119	7,134	8,472	5,755	5,265
SSB 1993	463,650	80,615	23,289	22,216	16,257	12,517	10,490	12,038	8,749	7,994
SSB 1994	481,565	84,700	24,047	22,866	15,925	11,651	5,556	7,311	4,679	4,318
SSB 1995	655,621	105,252	32,790	31,408	23,057	17,943	12,859	14,739	11,146	10,232
SSB 1996	744,453	119,305	38,208	36,603	27,290	21,928	16,317	18,465	14,481	13,385
SSB 1997	749,638	123,868	37,601	35,871	26,336	21,376	15,543	18,009	13,333	12,442
SSB 1998	707,321	120,504	31,717	29,896	20,592	16,285	9,942	12,652	7,693	6,695
SSB 1999	1,061,017	158,891	49,968	47,433	35,730	29,920	23,792	26,709	20,688	19,074
SSB 2000	1,184,458	179,638	57,311	54,570	41,606	34,544	28,181	31,556	25,020	23,201
SSB 2001	1,224,356	193,001	58,222	55,585	41,238	33,120	26,595	30,567	23,068	21,933
SSB 2002	1,241,446	200,955	58,839	55,835	41,361	32,313	26,101	30,568	22,389	21,154

Table 7.4.1 continued.

Percentile	100	97.5	80	75	50	Base Case	25	40	2.5	0
Age 0 -1973	976	163	107	101	79	85	62	73	40	27
Age 0 -1974	908	158	120	117	101	94	85	95	65	54
Age 0 -1975	907	153	120	117	102	93	85	95	65	54
Age 0 -1976	903	161	122	119	103	94	86	97	67	55
Age 0 -1977	899	161	121	118	102	93	86	96	67	55
Age 0 -1978	917	152	117	114	99	92	84	94	66	55
Age 0 -1979	1,038	139	110	107	96	88	84	91	68	57
Age 0 -1980	438	102	75	72	61	59	50	57	33	21
Age 0 -1981	364	68	38	37	32	36	27	30	21	18
Age 0 -1982	470	62	32	31	27	35	24	26	20	19
Age 0 -1983	3,311	414	255	242	185	147	143	164	116	105
Age 0 -1984	1,862	210	87	76	48	55	35	42	23	17
Age 0 -1985	1,031	123	84	81	71	69	60	66	47	40
Age 0 -1986	741	85	62	59	50	48	41	47	29	25
Age 0 -1987	765	83	57	55	47	46	39	44	29	25
Age 0 -1988	1,007	109	69	67	58	56	49	55	37	32
Age 0 -1989	1,093	114	68	66	56	49	47	53	36	31
Age 0 -1990	1,060	121	60	56	46	48	40	44	33	30
Age 0 -1991	3,291	345	168	157	130	117	115	124	97	87
Age 0 -1992	1,966	210	112	108	92	84	78	87	62	55
Age 0 -1993	1,331	159	83	80	70	66	61	66	50	44
Age 0 -1994	6,156	653	326	309	270	225	235	254	193	171
Age 0 -1995	2,451	267	154	144	117	119	99	110	79	70
Age 0 -1996	1,579	168	93	88	75	69	63	71	50	43
Age 0 -1997	1,317	150	78	74	62	59	54	58	44	38
Age 0 -1998	12,615	1,368	718	675	557	507	483	524	393	364
Age 0 -1999	2,539	269	150	144	118	110	98	110	78	67
Age 0 -2000	3,582	398	189	177	139	130	121	132	97	87
Age 0 -2001	3,997	409	226	211	173	157	147	162	119	105
Age 0 -2002	3,156	318	166	158	132	124	109	122	83	68

Table 8.1.1. Biological Reference Points for Mid-Atlantic region.

Quartiles describe the distribution of Monte-Carlo simulation across varying deterministic inputs. Base model estimates are highlighted in bold. Note that (1-M) SSB_{msy} estimates for the simulation runs are based on the natural mortality estimate used in the individual

	SSBmsy	F msy	MSY	Fmax	F40%	F35%	F30%	F2001 / F msy	SSB01 /SSB msy	F avg / F msy	SSB avg /SSB msy	0.75 Fmsy	(1-M) SSB msy	0.5 SSB msy
Maximum	396,261	0.79	62,974	1.00	0.46	0.58	0.75	1.78	7.12	1.88	6.53	0.59	273,420	198,131
97.5 Percentile	69,520	0.56	14,201	0.84	0.42	0.52	0.66	1.47	4.22	1.62	4.04	0.42	48,083	34,760
75th Percentile	30,303	0.36	10,527	0.65	0.34	0.42	0.53	1.17	2.07	1.24	1.99	0.27	22,140	15,152
Median	23,401	0.28	9,010	0.54	0.30	0.36	0.45	1.04	1.71	1.09	1.65	0.21	16,443	11,701
Base Case	**18,783**	**0.32**	**8,663**	**0.54**	**0.29**	**0.36**	**0.44**	**0.98**	**1.76**	**1.02**	**1.73**	**0.24**	**13,148**	**9,392**
25th Percentile	18,676	0.20	8,086	0.44	0.25	0.30	0.37	0.89	1.37	0.94	1.32	0.15	12,745	9,338
2.5th Percentile	12,695	0.08	6,462	0.34	0.20	0.24	0.29	0.30	0.85	0.31	0.81	0.06	8,109	6,348
Minimum	9,992	0.01	1,974	0.31	0.19	0.23	0.28	0.03	0.65	0.04	0.61	0.00	6,095	4,996
Num Trials	1299	1299	1299	1299	1299	1299	1299	1299	1299	1299	1299	1299	1299	1299

12.0 Figures

Figure 5.1.2.1 Atlantic coastal commercial landings of Atlantic croaker (metric tons), 1950-2001.

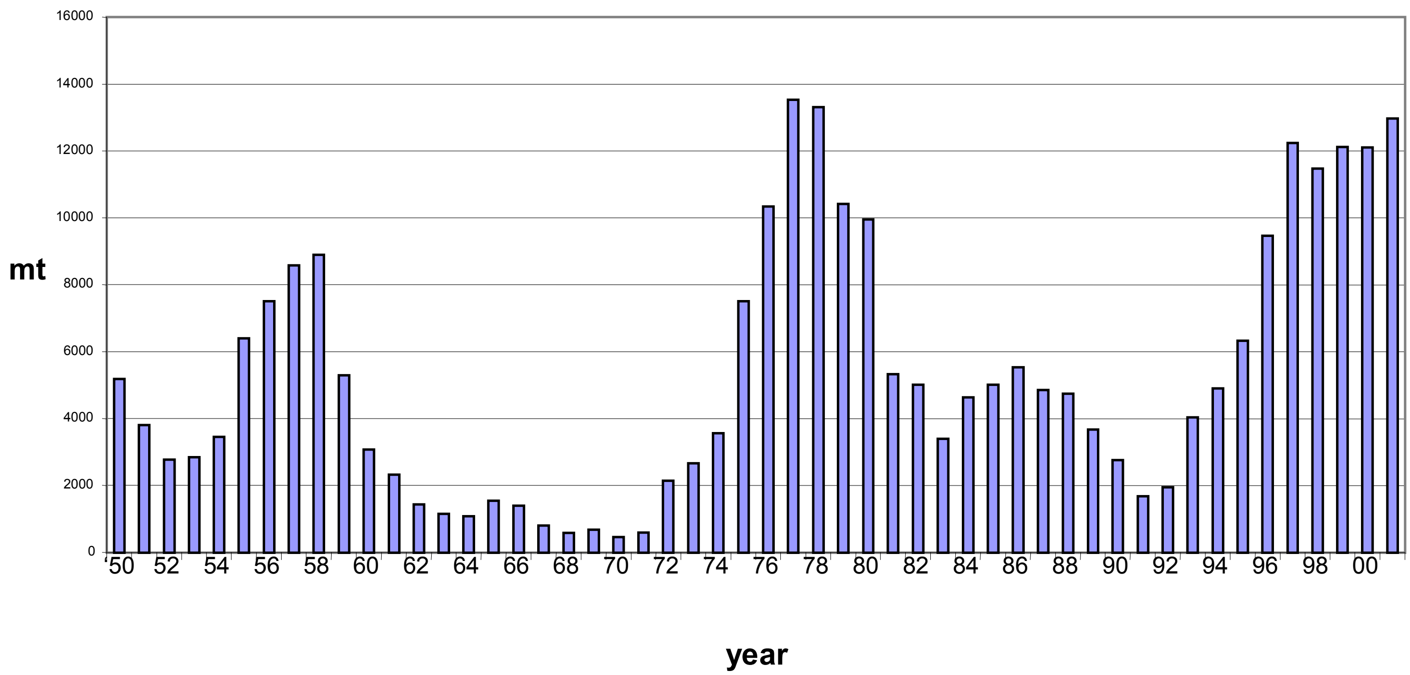


Figure 5.2.2.1. Recreational landings of Atlantic croaker (numbers) by region.

Mid Atlantic includes North Carolina and all states north. South Atlantic includes South Carolina and all states south.

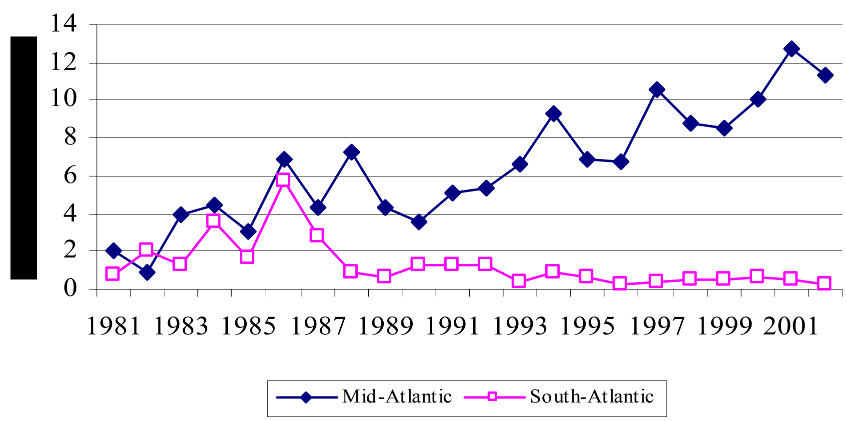


Figure 5.2.2.2. Recreational landings of Atlantic croaker (pounds) by region.

Mid Atlantic includes North Carolina and all states north. South Atlantic includes South Carolina and all states south.

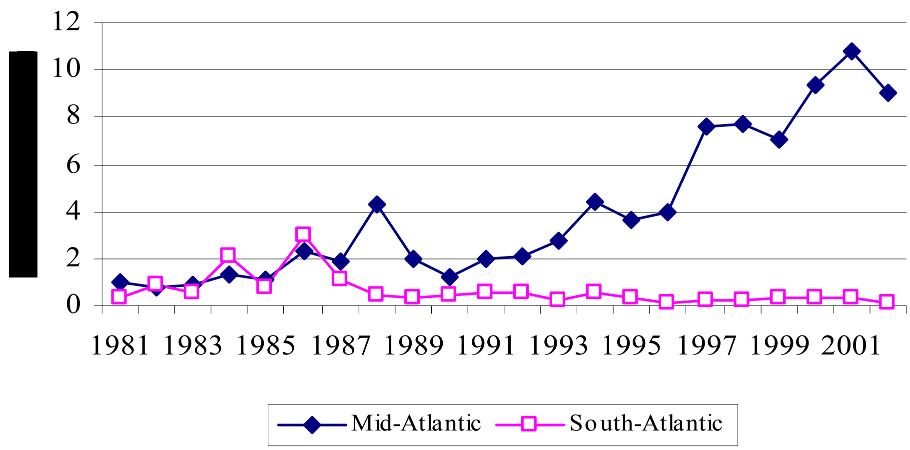


Figure 5.2.2.3.   Recreational landings by area fished and total landings (numbers)

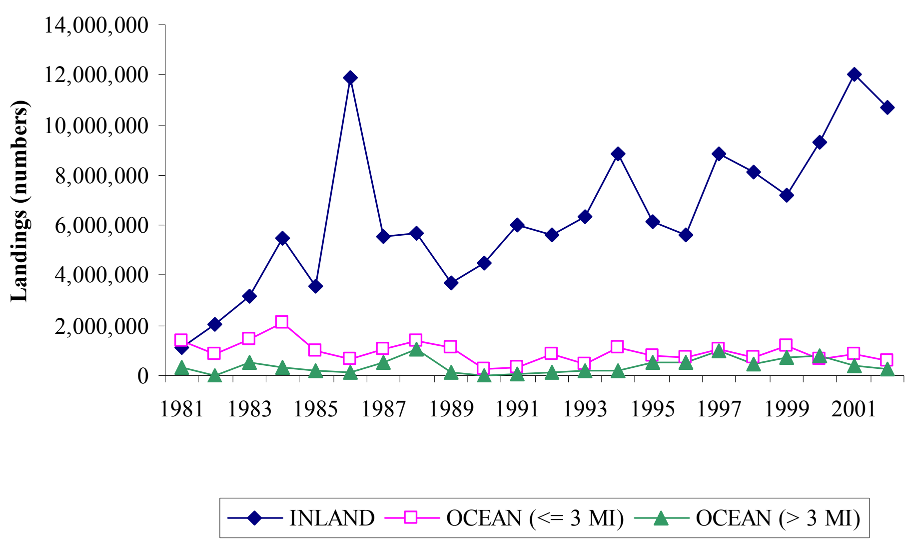


Figure 5.2.2.4. Recreational landings by mode fished and total landings (numbers)

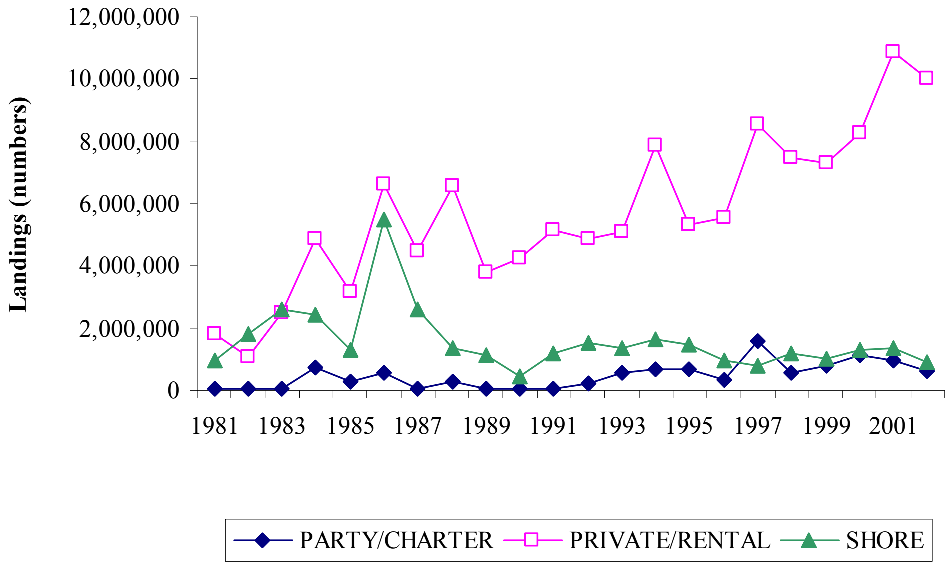


Figure 5.2.2.5. Proportion of Atlantic croaker landings by Wave and year.

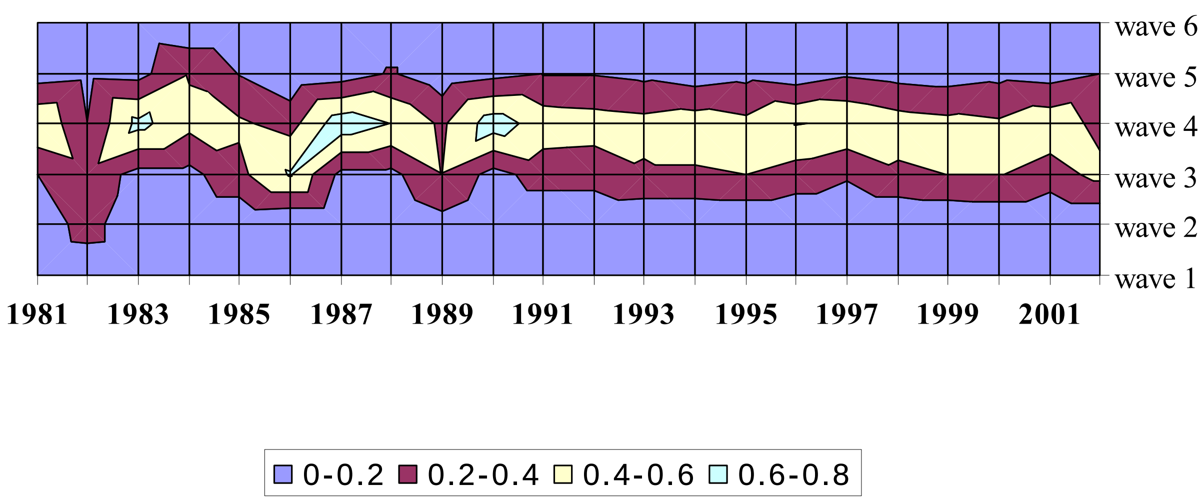


Figure 5.2.2.6. Estimated number of total recreational trips and trips targeting Atlantic croaker by region.

Mid-Atl= all states including and north of North Carolina. South-Atl= all states including and south of South Carolina.

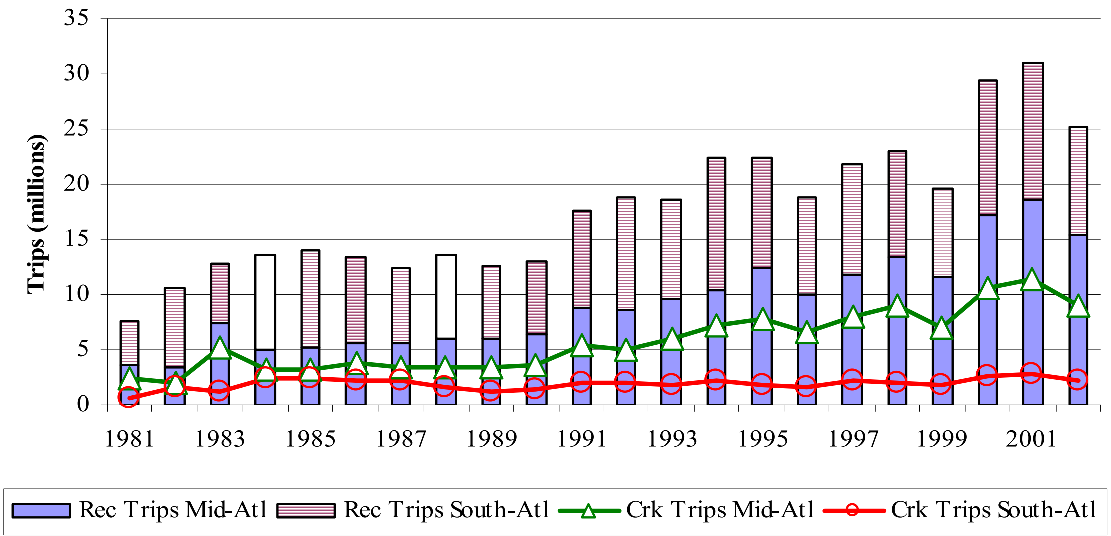


Figure 5.2.2.7. Size distribution of Atlantic croaker for the northern region (North Carolina and North).

The circle represent the median length class, the box represent the 25th to 75 percentile and whiskers the 2.5 to 97.5 percentile of size class

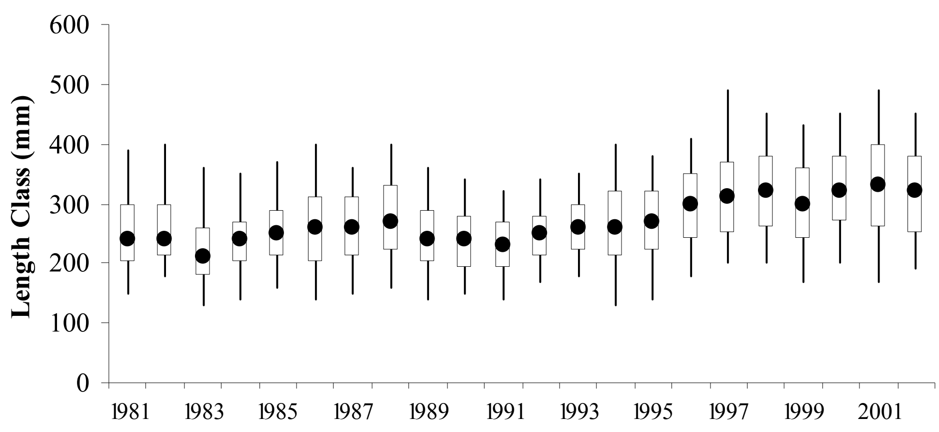


Figure 5.2.2.8. Size distribution of Atlantic croaker for the southern region (South Carolina and South).

The circle represent the median length class, the box represent the 25th to 75 percentile and whiskers the 2.5 to 97.5 percentile of size class

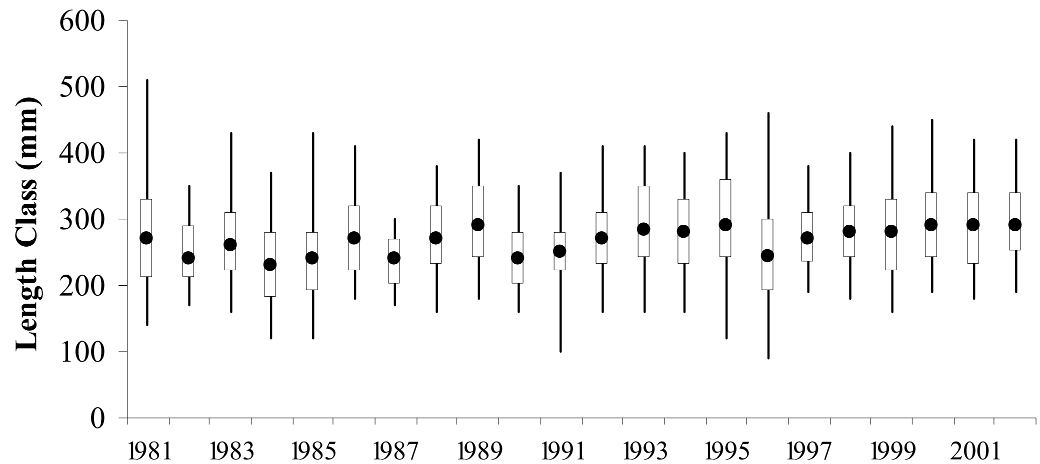


Figure 5.2.3.1. Ratio of Atlantic croaker released by anglers to those landed.

Mid Atlantic= North Carolina and North. South Atlantic= South Carolina and South.

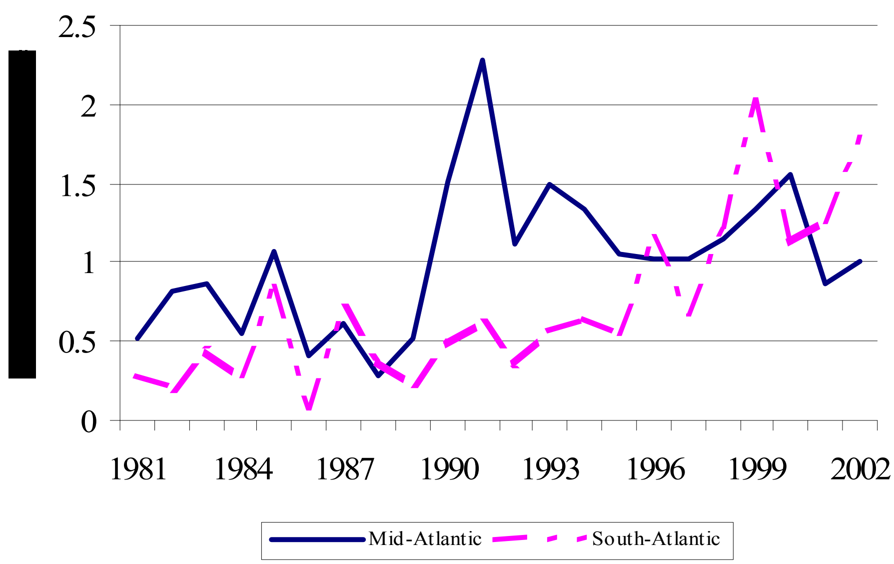


Figure 5.2.4.1. Recreational catch rates and 95% confidence intervals for Atlantic croaker in the Mid Atlantic region (North Carolina and North) using a negative binomial generalized linear model and log transformed general linear model.

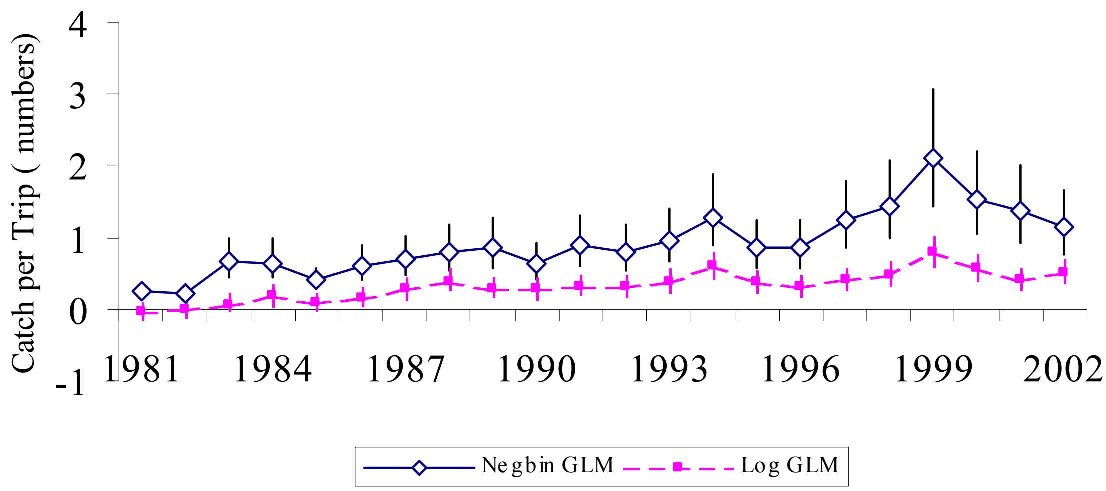


Figure 5.2.4.2. Recreational catch rates and 95% confidence intervals for Atlantic croaker in the South Atlantic region (South Carolina and South) using a negative binomial generalized linear model and log transformed general linear model.

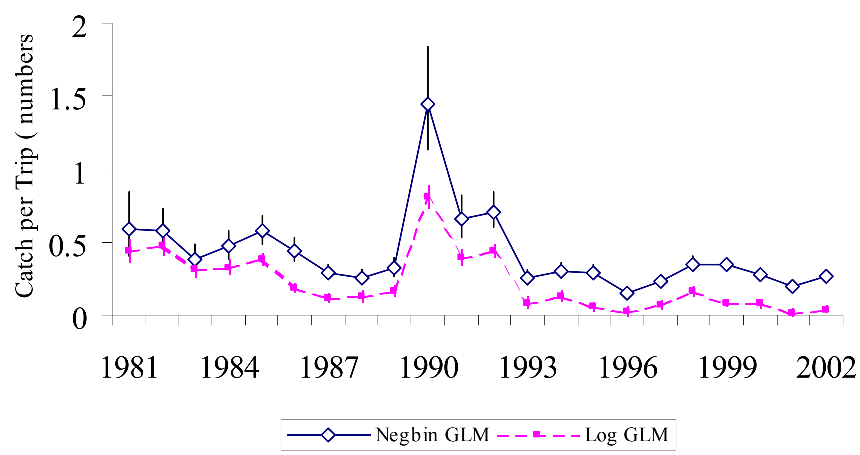


Figure 6.2.1.Normalized estimates for the two major fishery independent indices . NMFS=NEFFC trawl survey, SEAMAP= SEAMAP trawl survey.

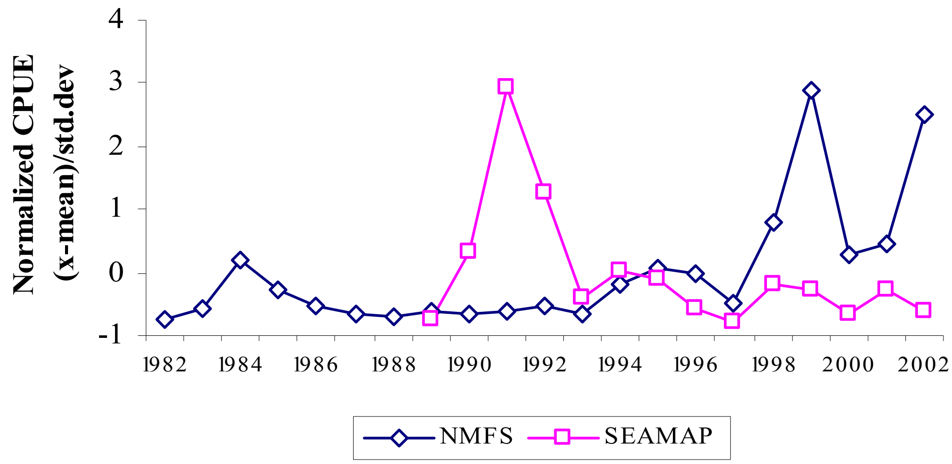


Figure 6.2.2 Normalized fishery independent CPUE estimates (by Strata).

Strata 21-67 represent the SEMAP data set from the Atlantic coast of Florida to Cape Hatteras, North Carolina. NMFS strata represent the strata grouped inboxes of one degree latitude. The North Carolina -South Carolina border is between strata 51 and 53. Cape Hatteras, N.C. is between strata 65 and 67.

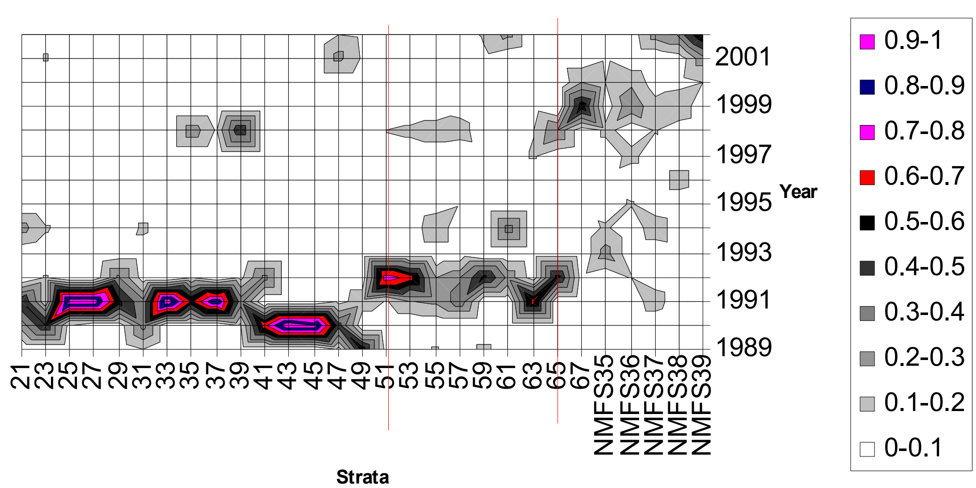


Figure 6.2.3. Posterior probability distributions for steepness at varying level of natural mortality used in the core models for the Mid Atlantic region (North). Prior probability distribution based on Myers et al . (2002) is also included.

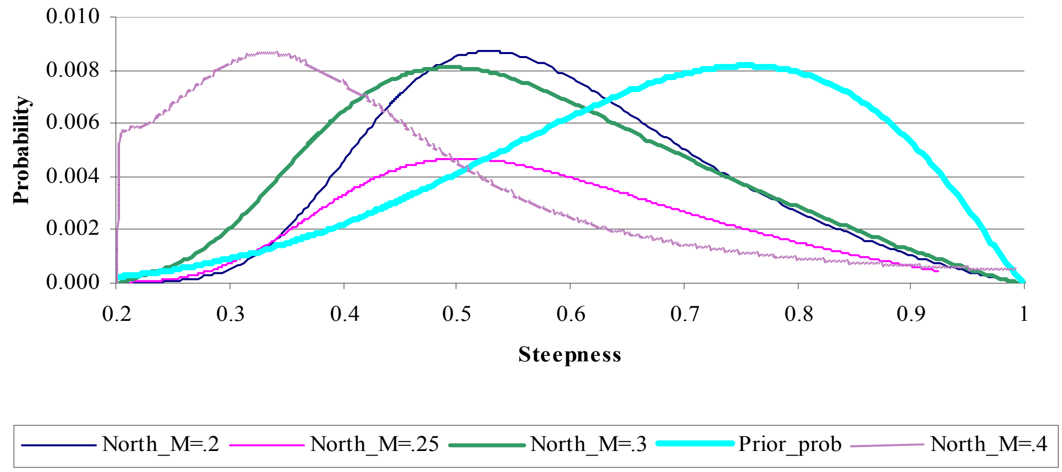


Figure 6.2.4. Posterior probability distributions for steepness at varying level of natural mortality used in the preliminary models for the South Atlantic region. Prior probability distribution based on Myers et al . (2002) is also included.

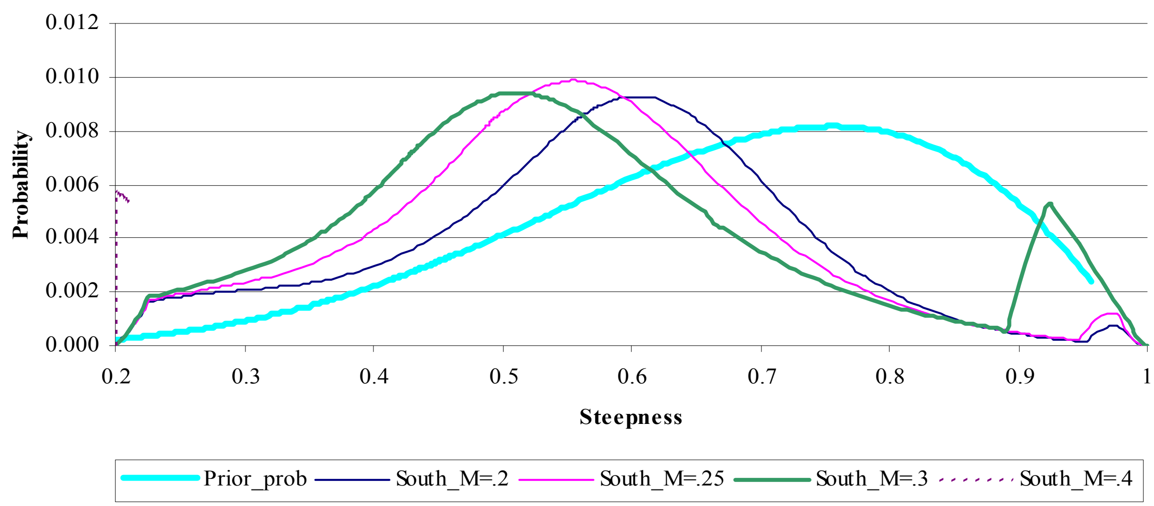


Figure 6.2.5 Map showing geographical boundaries used to define the mid-Atlantic and south-Atlantic models used in the assessment.

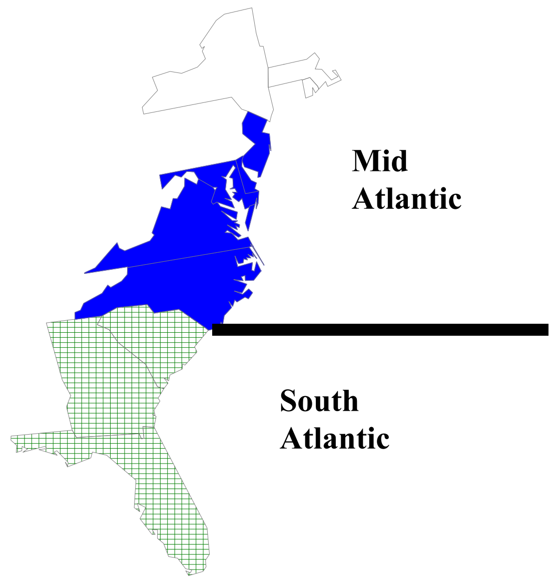
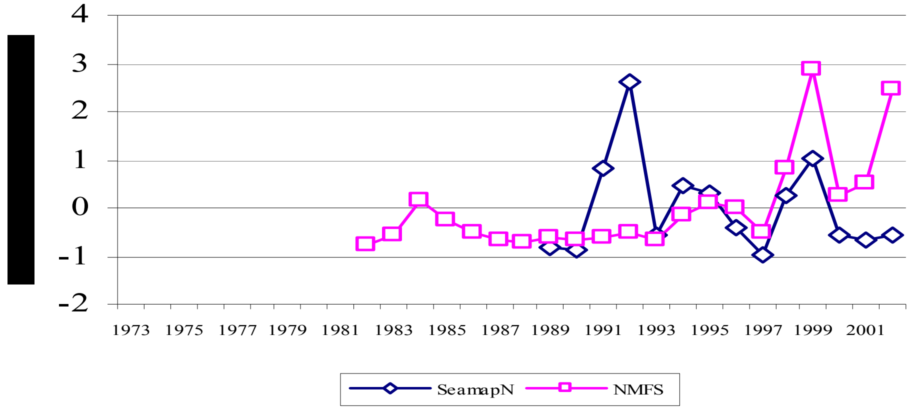
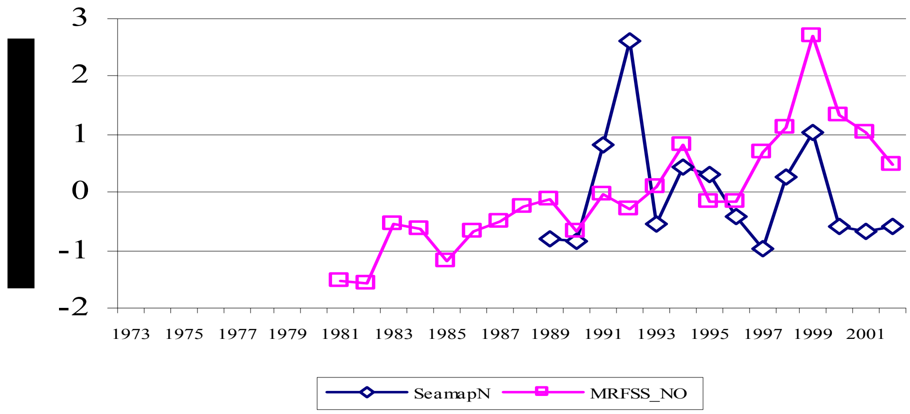


Figure 6.2.1.1. Comparison of Standardized estimates [(obs-mean)/std.dev] for the three major indices used in the Mid-Atlantic model.





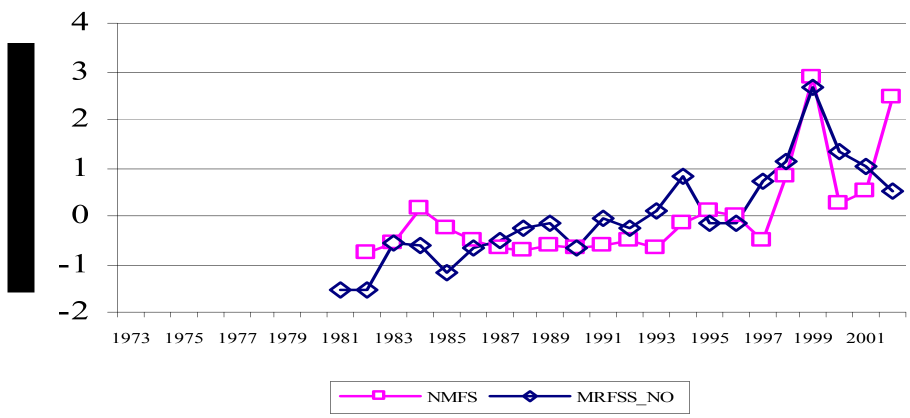


Figure 6.2.1.2. Comparison of Standardized estimates [(obs-mean)/std.dev] of the three major indices used in the mid-Atlantic model to the VIMS spring juvenile index and North Carolina Indices.

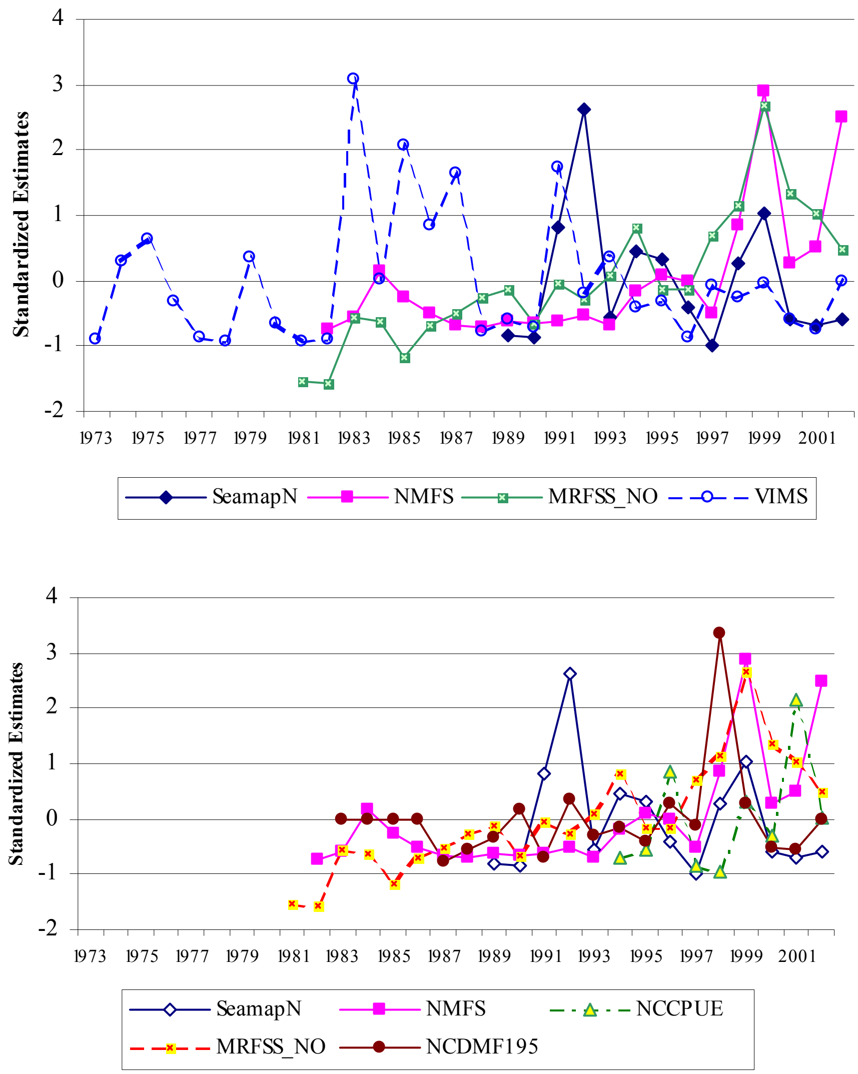


Figure 6.2.1.3. Comparison of Standardized estimates [(obs-mean)/std.dev] for the two major indices used in the South-Atlantic model with other available indices for the region.

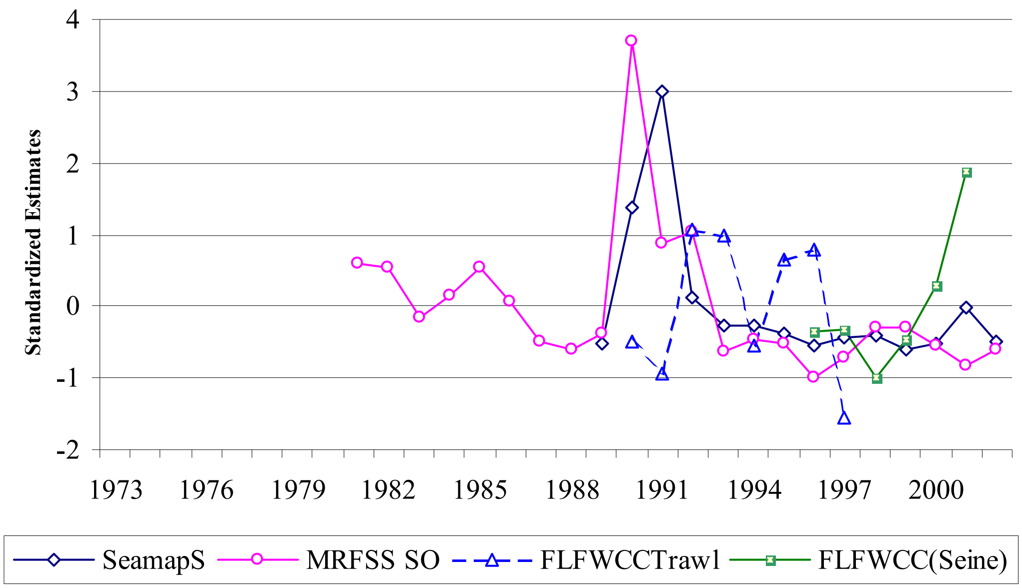


Figure 6.2.2.1 Proportion of commercial landings by size .

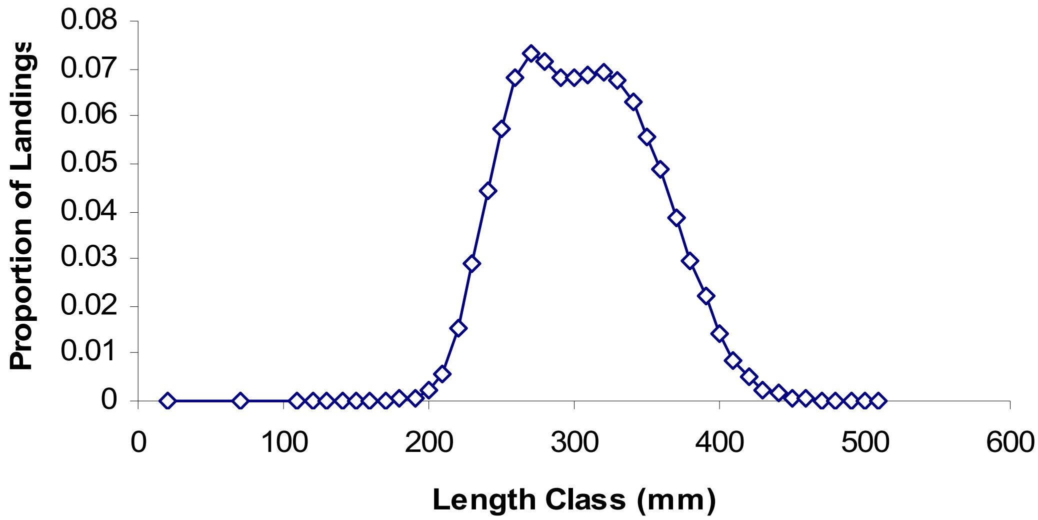


Figure 6.2.2.2. Proportion of commercial landings by estimated age (1973?-2002)

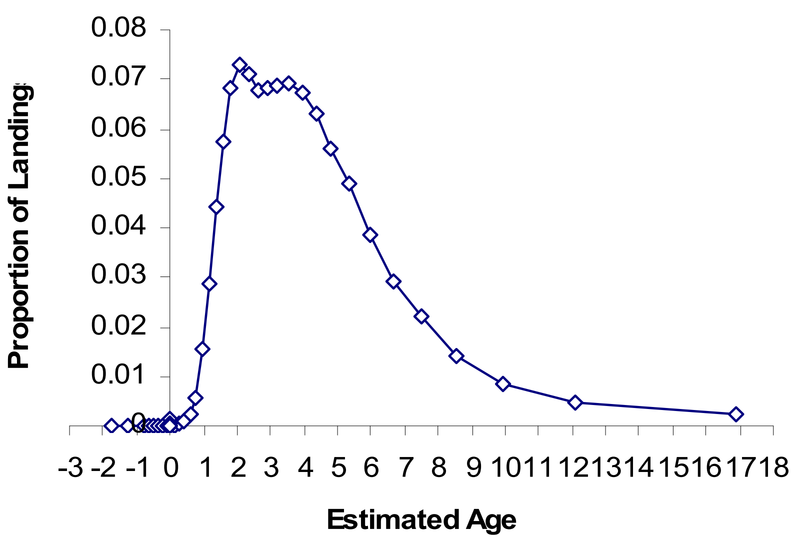


Figure 6.2.2.3. Predominant size range of Atlantic croaker in the commercial landings overlaid on combined age-length data.

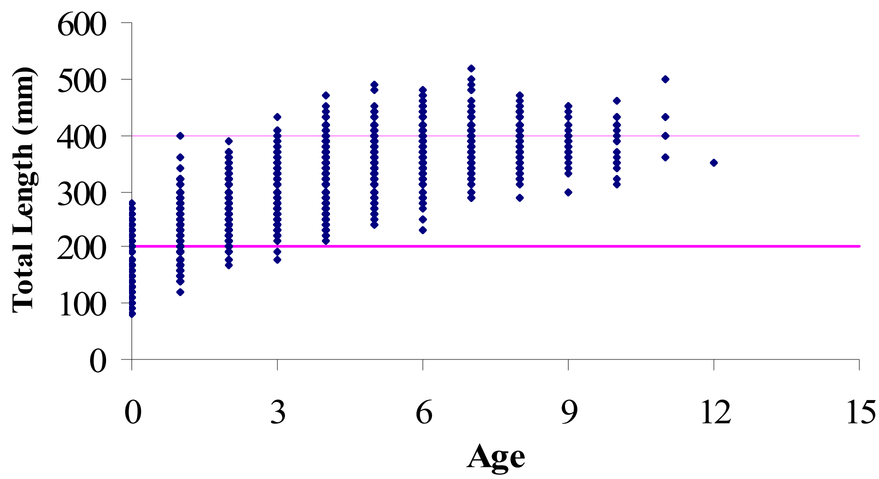


Figure 6.2.2.4. Proportion of recreational landings by size (1981-2002)

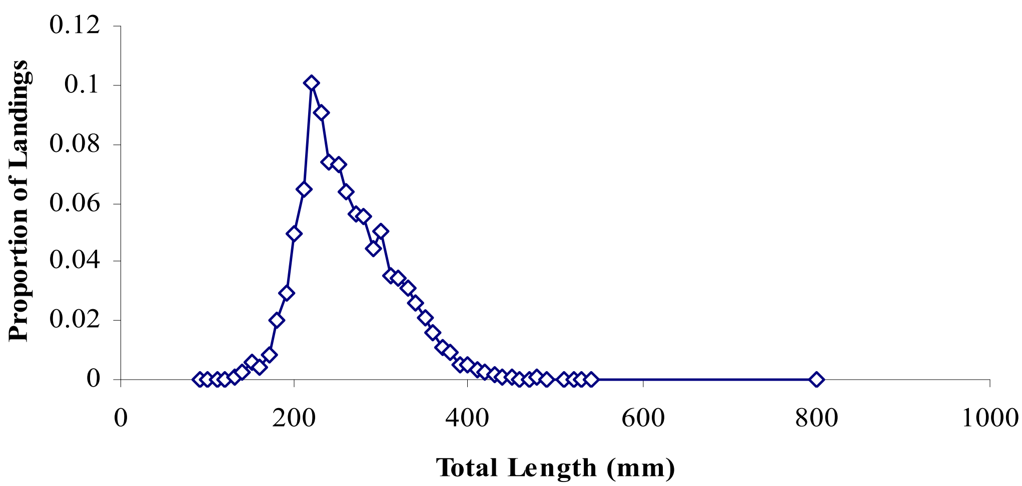


Figure 6.2.2.5 Proportion of recreational landings by estimated age (1981-2002)

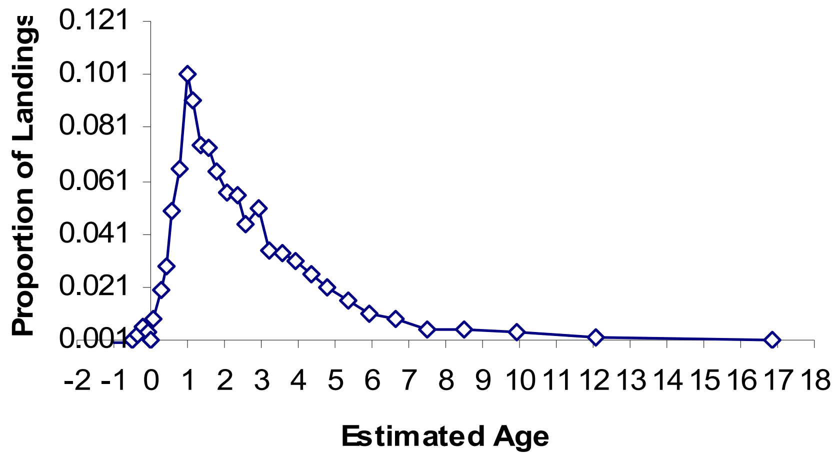


Figure 6.2.2.6. Predominant size range of Atlantic croaker in the recreational landings overlaid on combined age-length data.

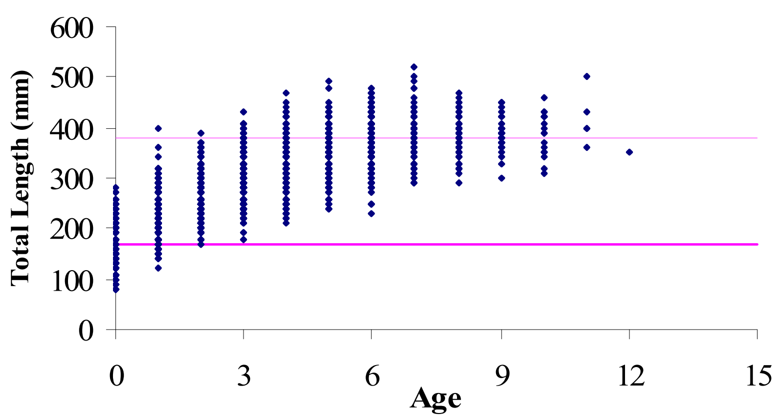


Figure 6.2.2.7. Proportion of SEAMAP catches by size class

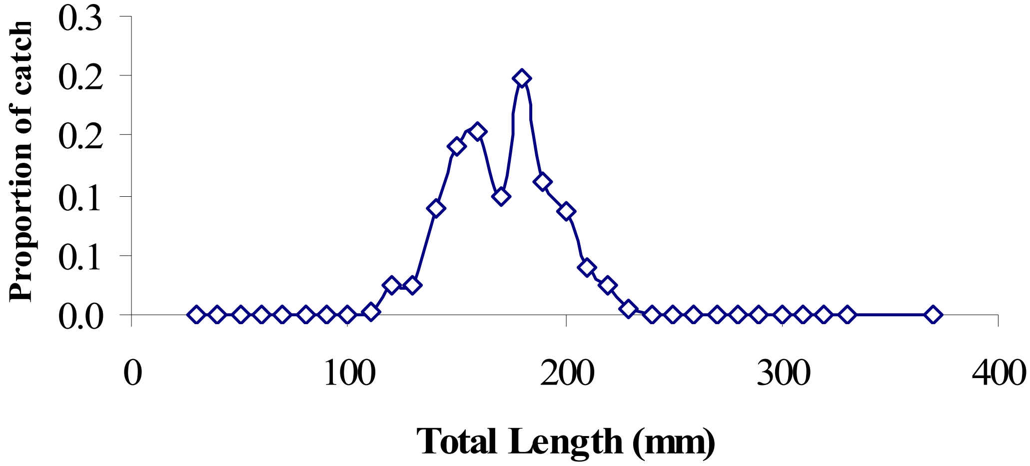


Figure 6.2.2.8. Proportion of SEAMAP catches by age

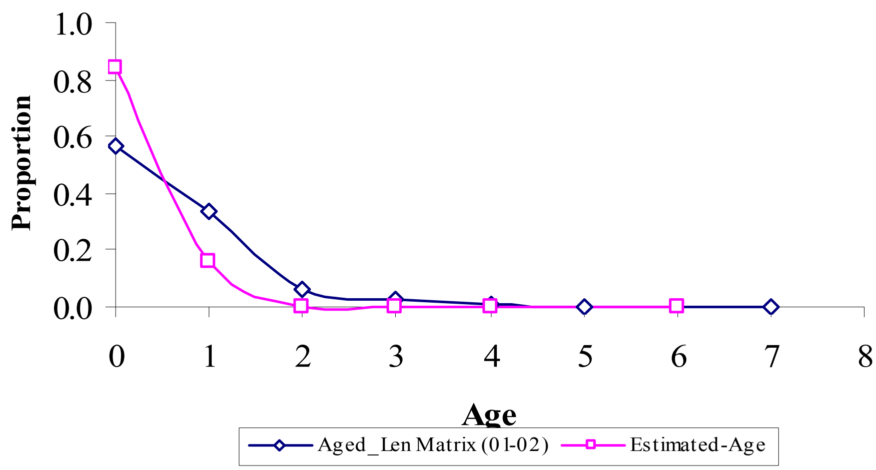


Figure 6.2.2.9. Predominant size range of Atlantic croaker in the SEAMAP catch overlaid on combined age-length data.

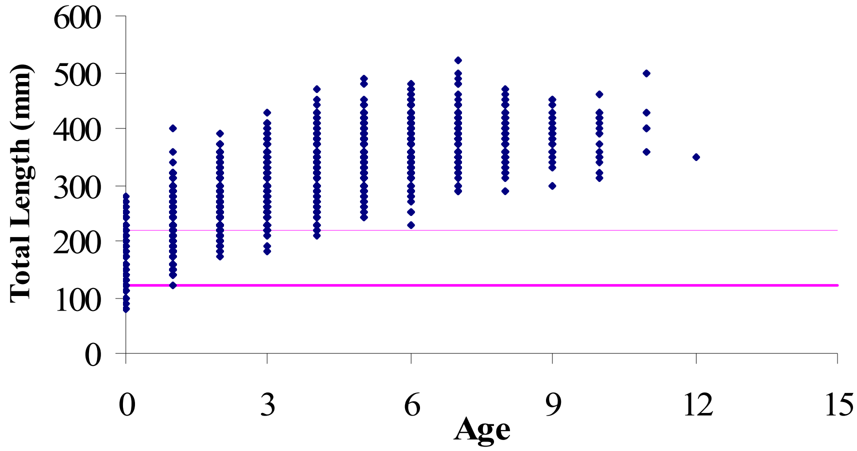


Figure 6.2.2.10. Proportion of NMFS survey catches by size class

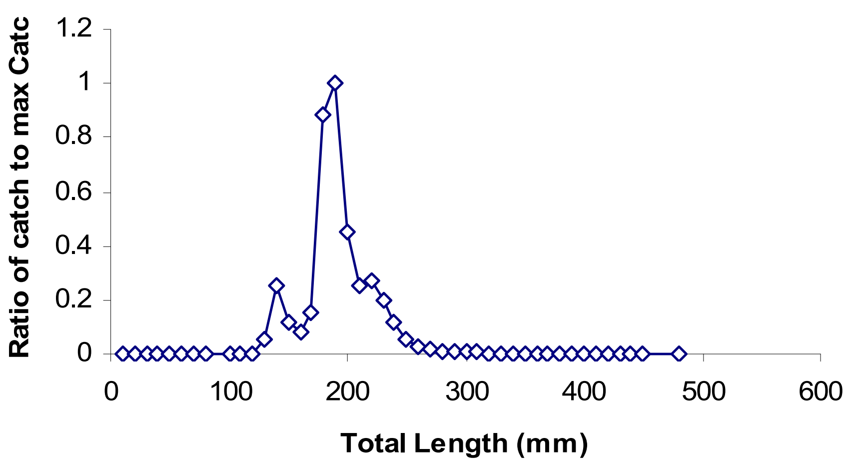


Figure 6.2.2.11. Proportion of NMFS survey catches by estimated age

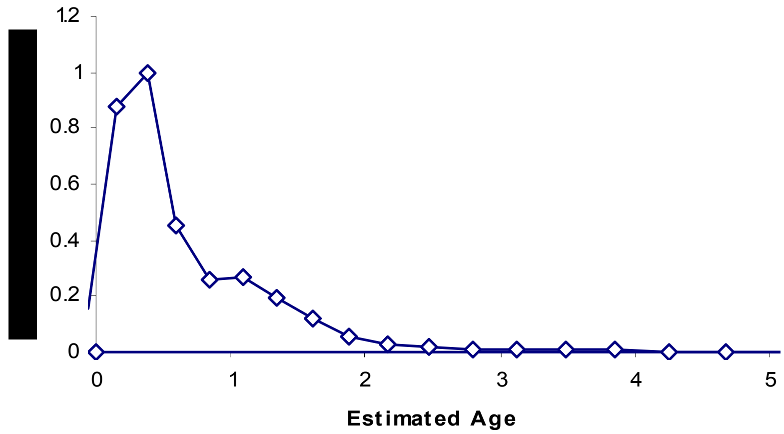


Figure 6.2.2.12. Predominant size ranges of Atlantic croaker in the NMFS trawl catch overlaid on combined age-length data.

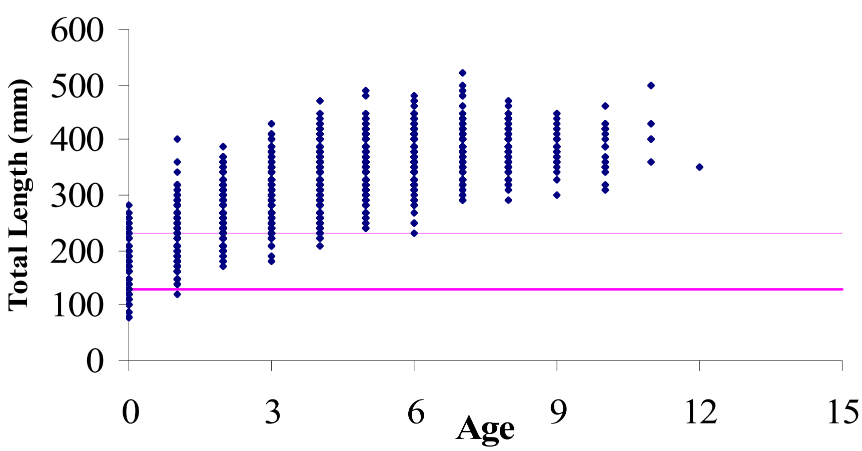


Figure. 6.2.2.13. Maximum likelihood profile for the prior distribution for the steepness parameter, h, from the covariate analysis of Myers et al.(2002)

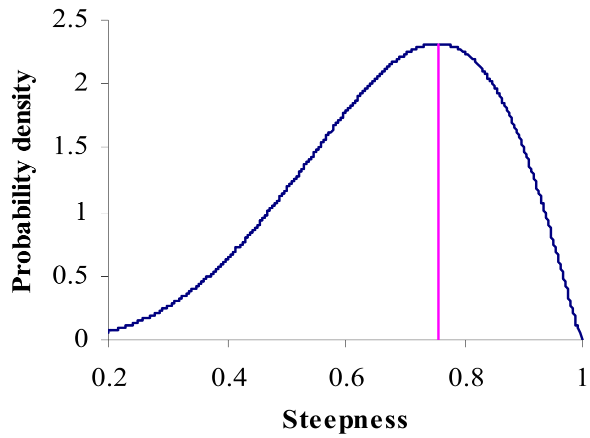


Figure 7.1.1. Observed and predicted commercial landings from base Mid-Atlantic model

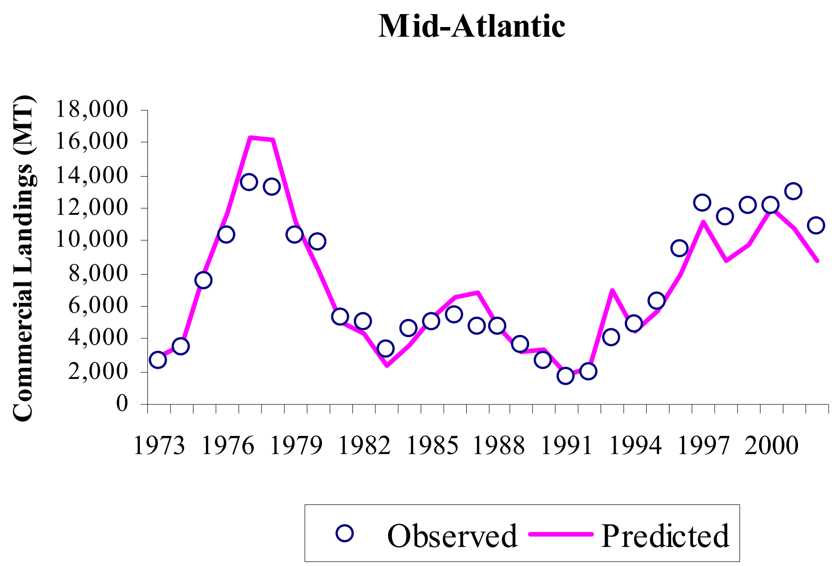


Figure 7.1.2. Observed and predicted recreational landings from base Mid-Atlantic model

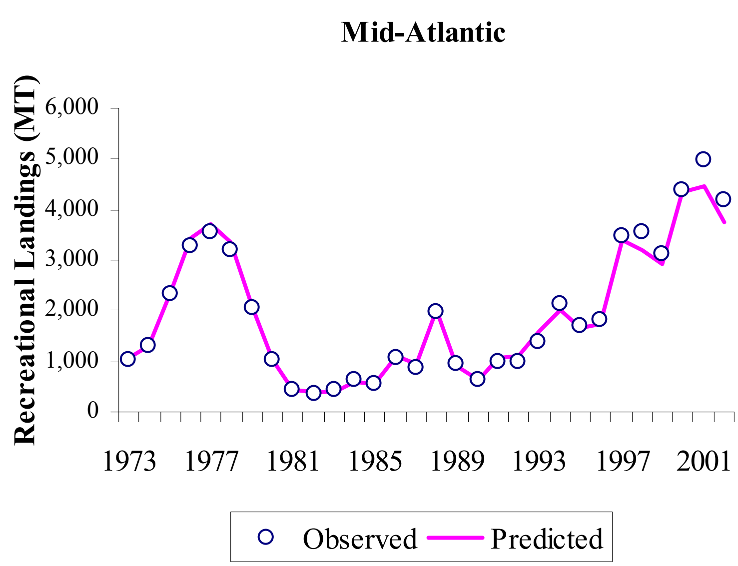


Figure 7.1.3. Observed and predicted commercial landings from base South-Atlantic model

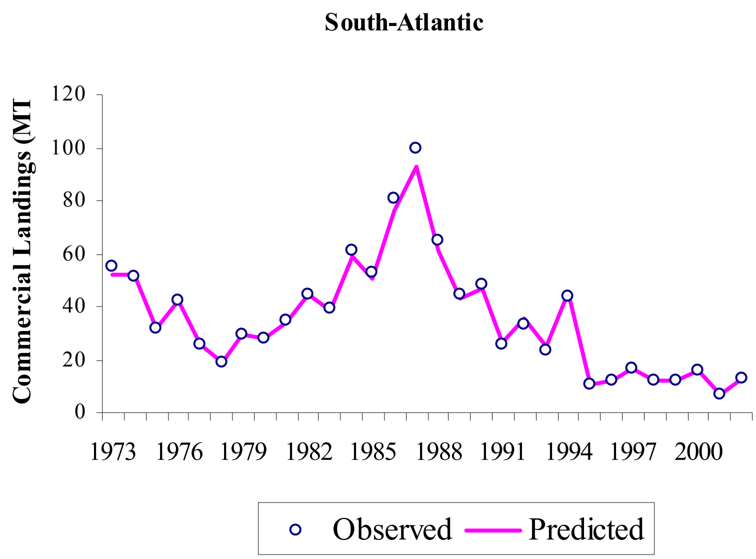


Figure 7.1.4. Observed and predicted recreational landings from base South-Atlantic model

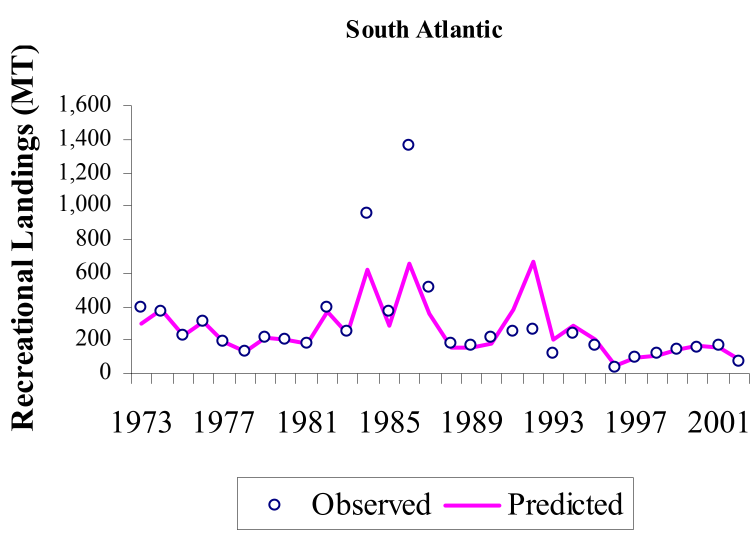


Figure 7.1.5. Observed and predicted estimates for the NMFS trawl survey for the base mid-Atlantic model

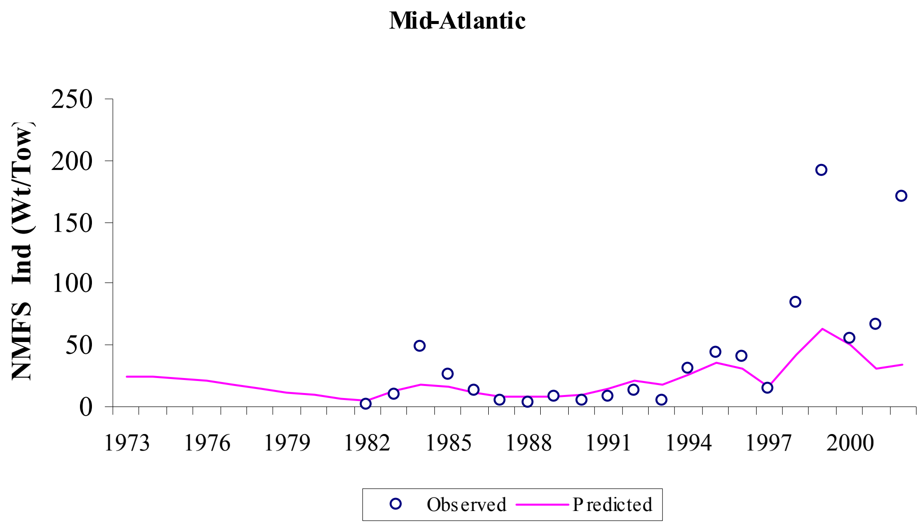


Figure 7.1.6. Observed and predicted estimates for the MRFSS index for the base mid-Atlantic model

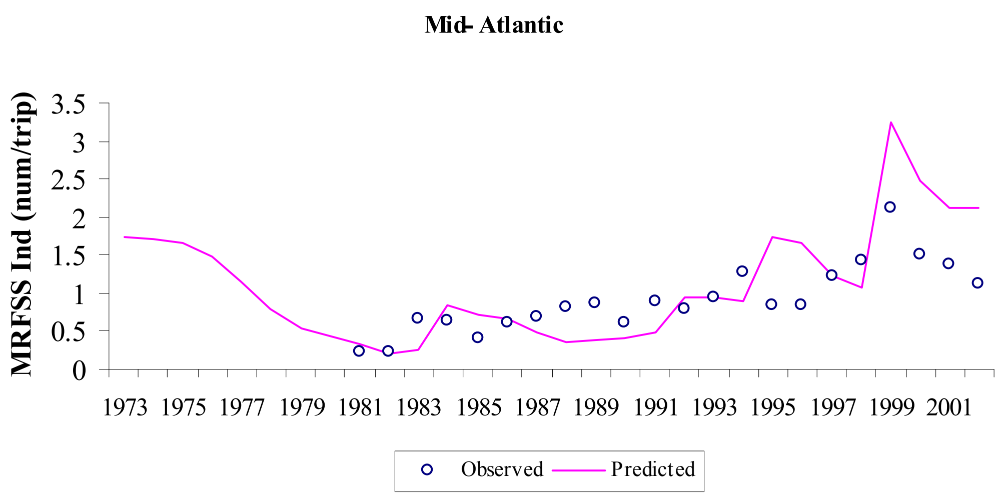


Figure. 7.1.7. Observed and predicted estimates for the SEAMAP index for the base mid-Atlantic model

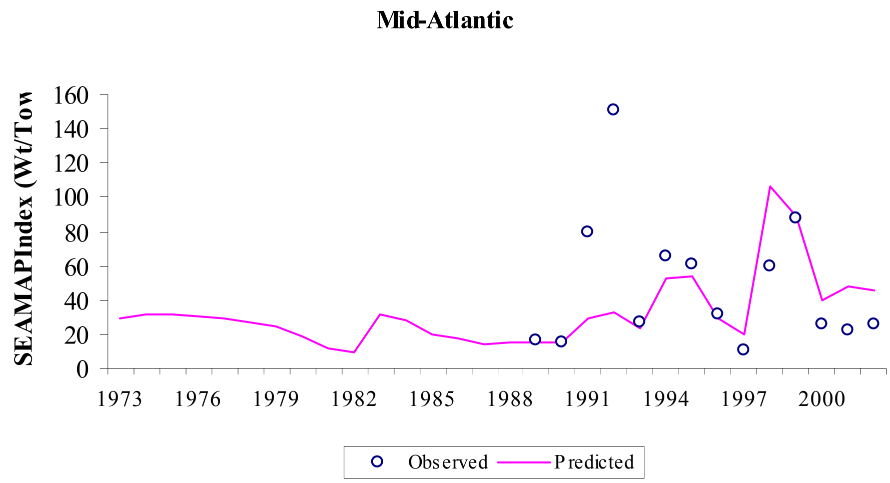


Figure 7.1.8. Observed and predicted estimates for the MRFSS index for the base south-Atlantic model

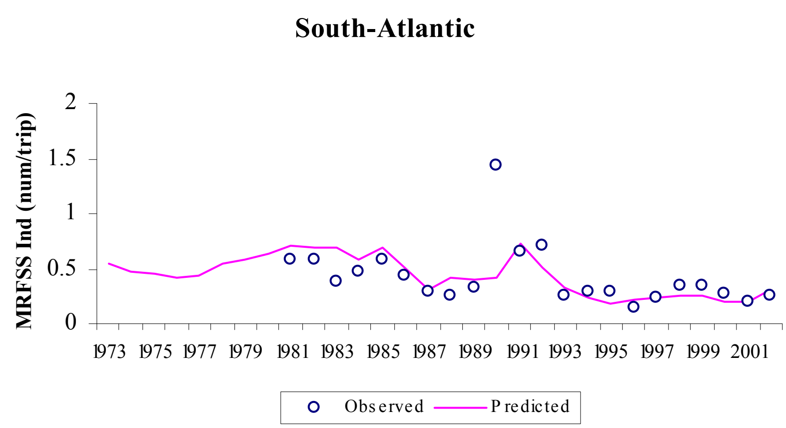


Figure 7.1.9. Observed and predicted estimates for the SEAMAP index for the base south-Atlantic model

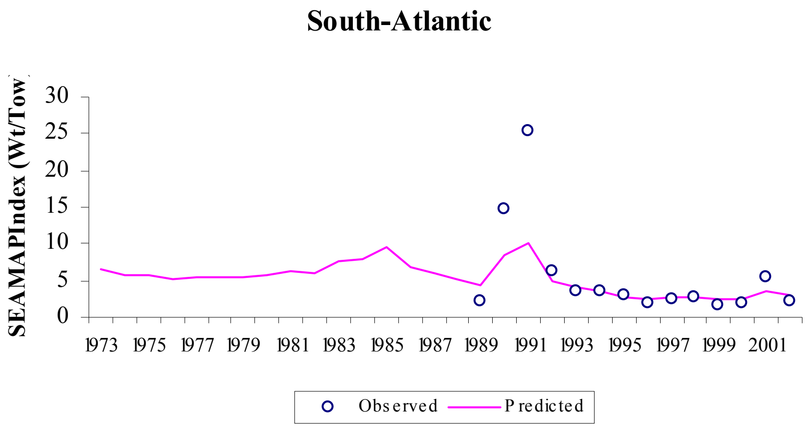


Figure 7.2.1.1. Fully recruited fishing mortality estimates for Atlantic croaker from the base mid-Atlantic model.

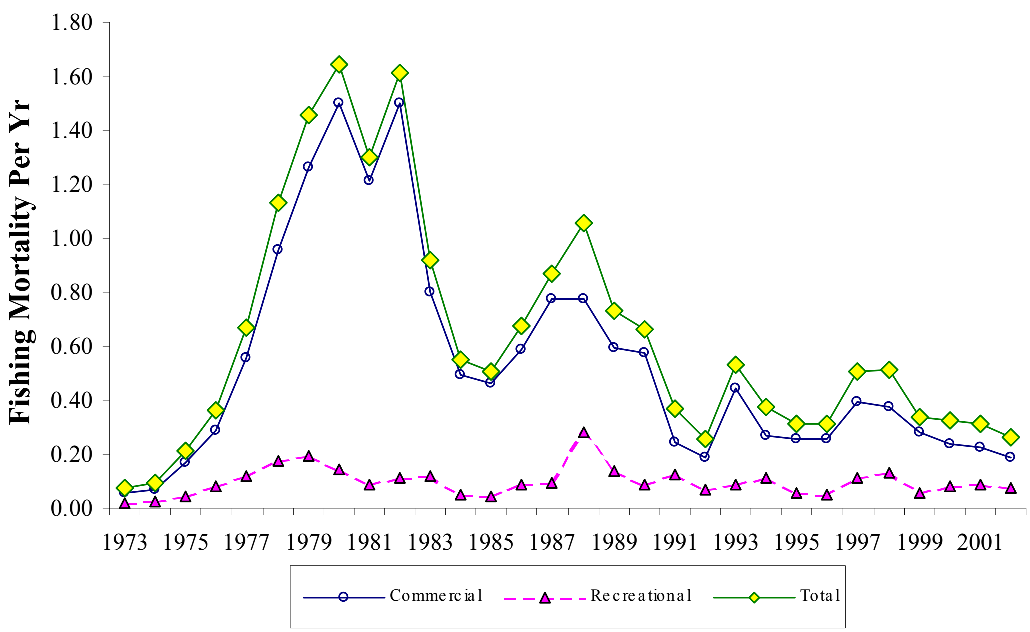


Figure 7.2.1.2. Fully recruited fishing mortality estimates for Atlantic croaker from the base South-Atlantic model.

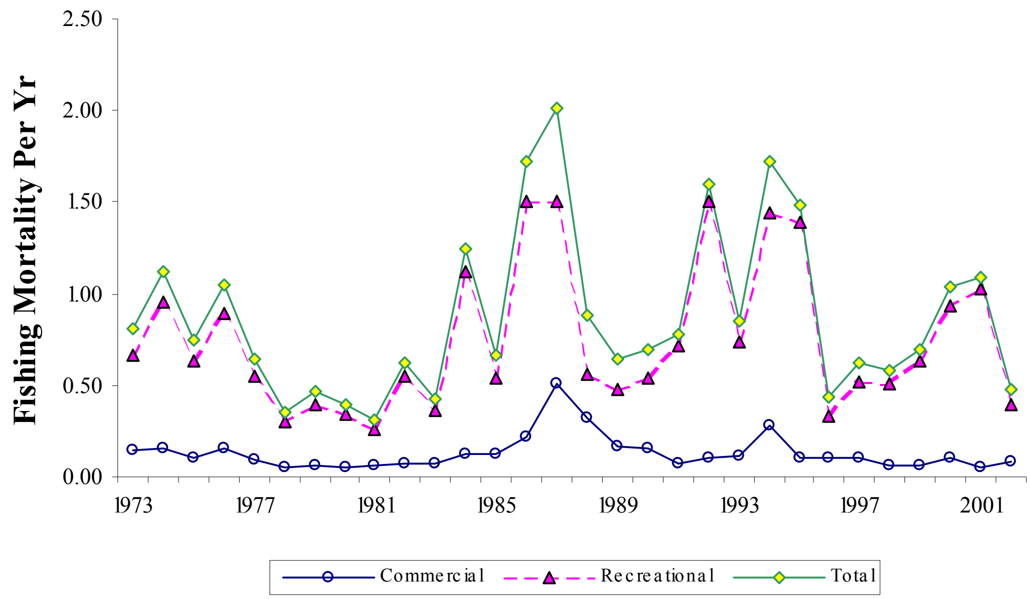


Figure 7.2.2.1. Spawning Stock Biomass and Age 0 estimates for Atlantic croaker from the base mid-Atlantic model.

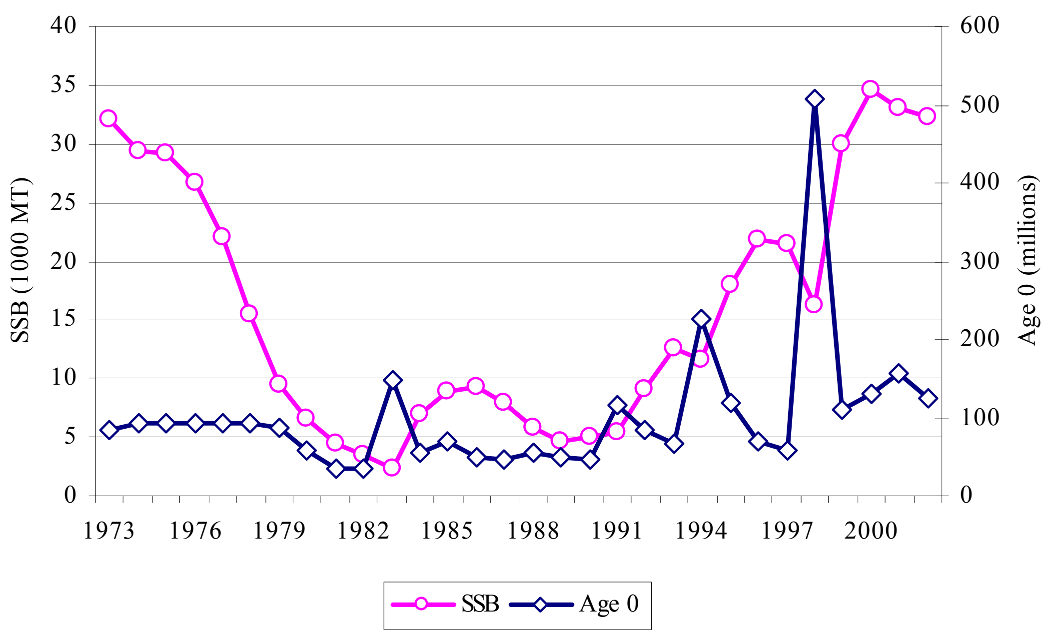


Figure 7.2.2.2. Spawning Stock Biomass and Age 0 estimates for Atlantic croaker from the base south-Atlantic model.

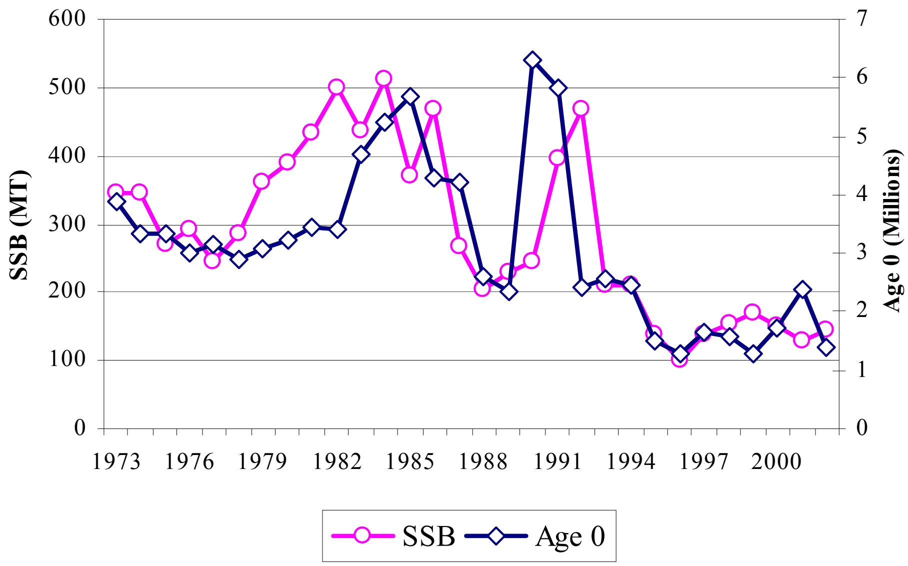
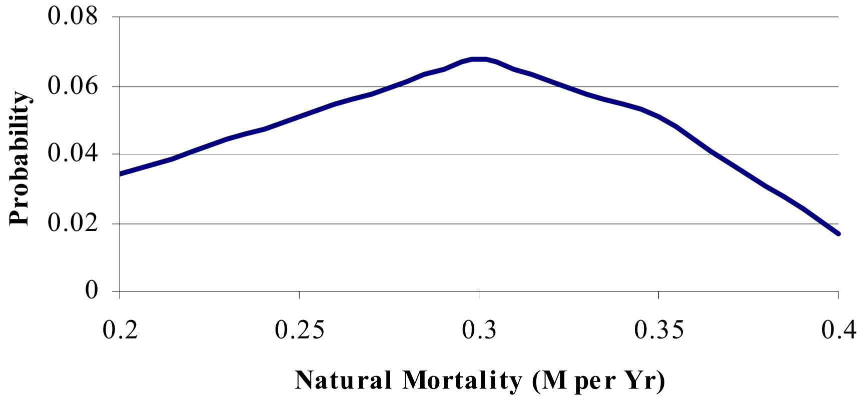
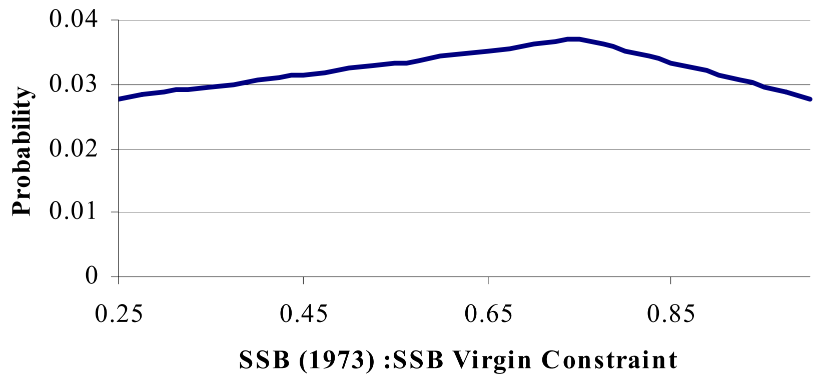


Figure 7.4.1. Probability profiles used for the deterministic estimates evaluated in the Mote-Carlo sensitivity analysis. For steepness, see Figure 6.2.2.13.





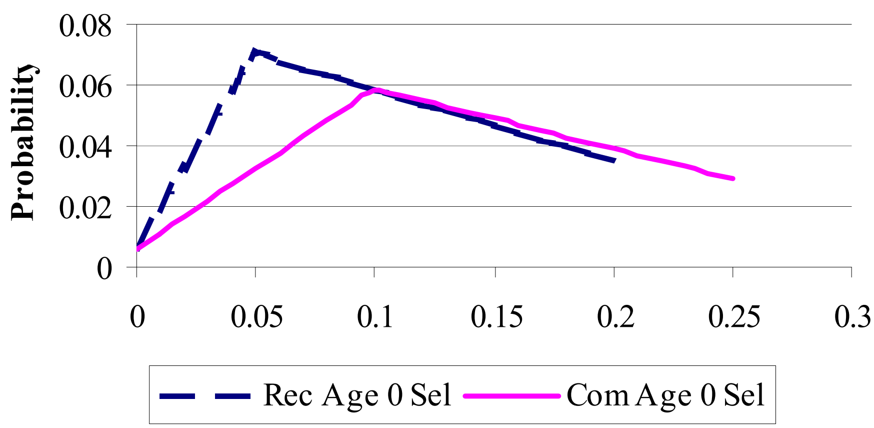
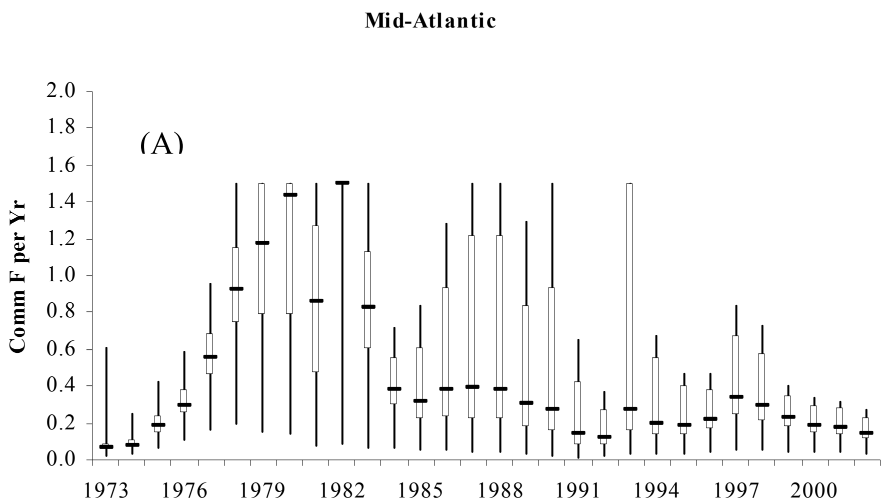


Figure 7.4.2. Distribution of commercial (A) and recreational (B) fishing mortality rates per year determined using 1,299 Mote-Carlo trails.

The dark horizontal line represents the median value, the box represents the 25th-75th percentiles and the vertical line extends from the 2.5th-97.5th percentile. Each trial represented a unique set of five deterministic input parameters.



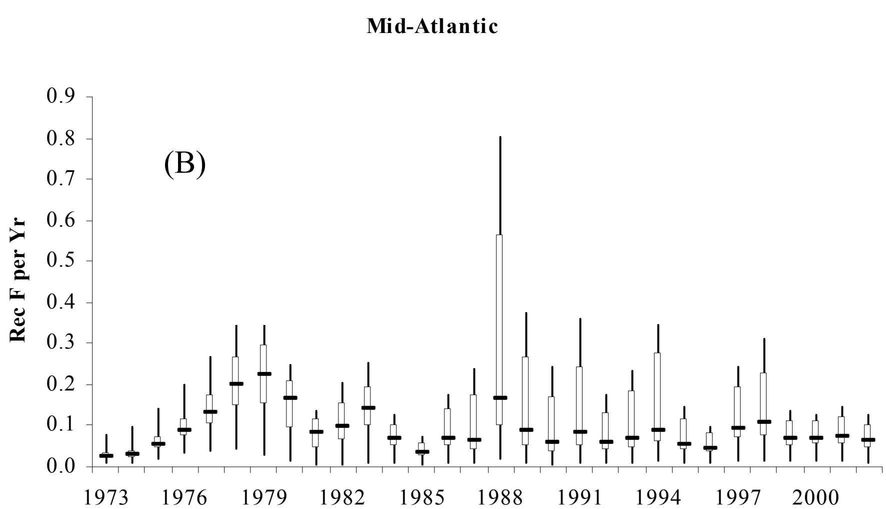


Figure. 7.4.3. Distribution of spawning stock biomass estimates determined using 1,299 Mote-Carlo trails.

The dark horizontal line represents the median value, the box represents the 25th-75th percentiles and the vertical line extends from the 2.5th-97.5th percentile. Each trial represented a unique set of five deterministic input parameters. Note: SSB estimates are on log scale.

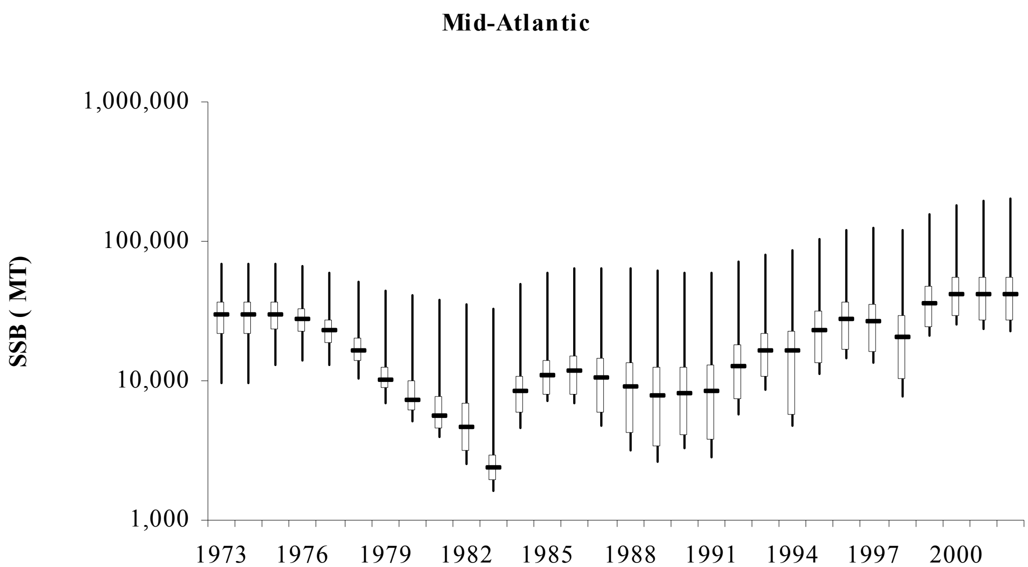


Figure. 7.4.4. Distribution of Age 0 estimates determined using 1,299 Mote-Carlo trails.

The dark horizontal line represents the median value, the box represents the 25th-75th percentiles and the vertical line extends from the 2.5th-97.5th percentile. Each trial represented a unique set of five deterministic input parameters. Note: SSB estimates are on log scale.

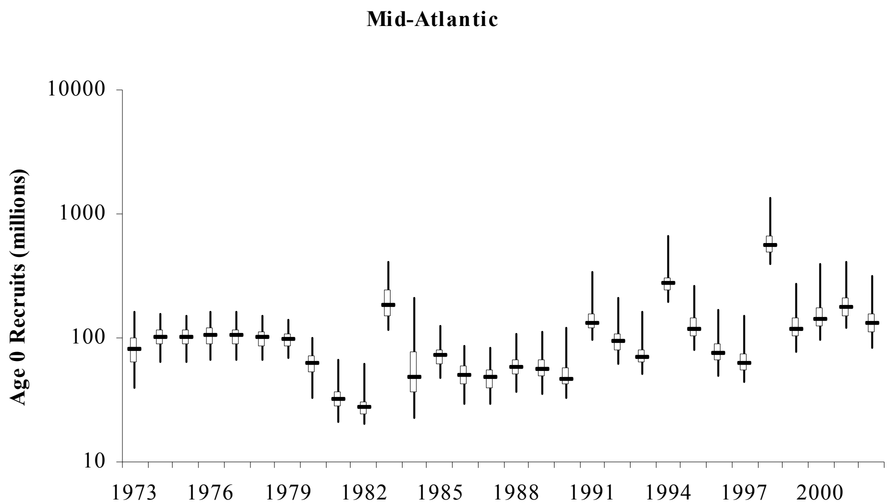


Figure. 8.1.1. Phase plot of the ratio of F_{2001}/F_{msy} with SSB_{2001}/SSB_{msy} for the Monte-Carlo simulations.

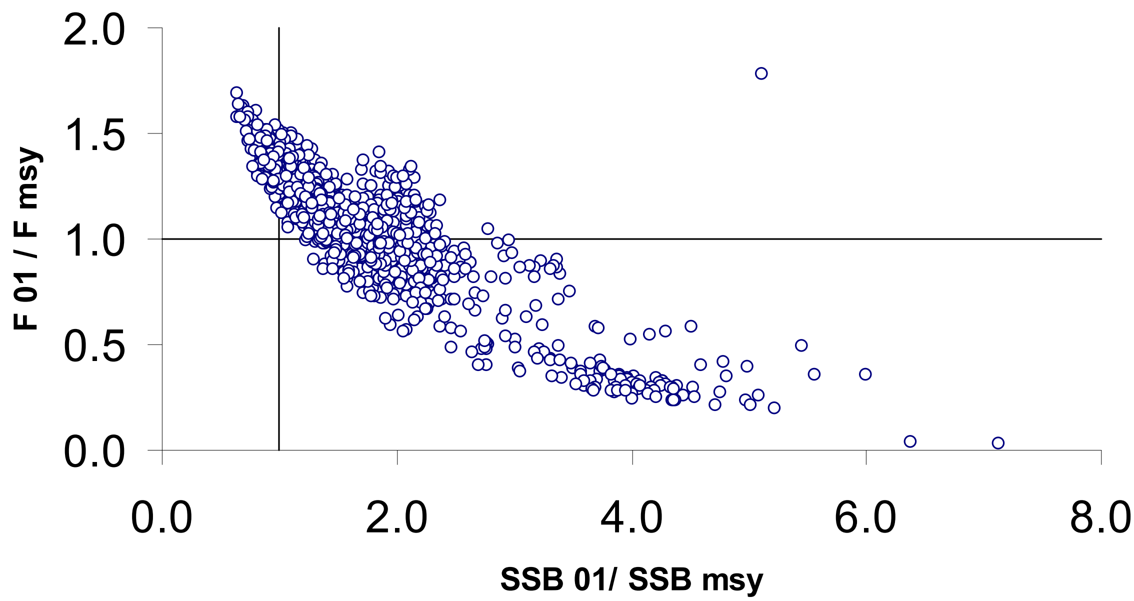


Figure 8.1.2. Phase plot of the ratio of F $_{avg1999-2001}$/ F$_{msy}$ with SSB$_{avg\ 1999-2001}$/SSB$_{msy}$ for the Monte-Carlo simulations.

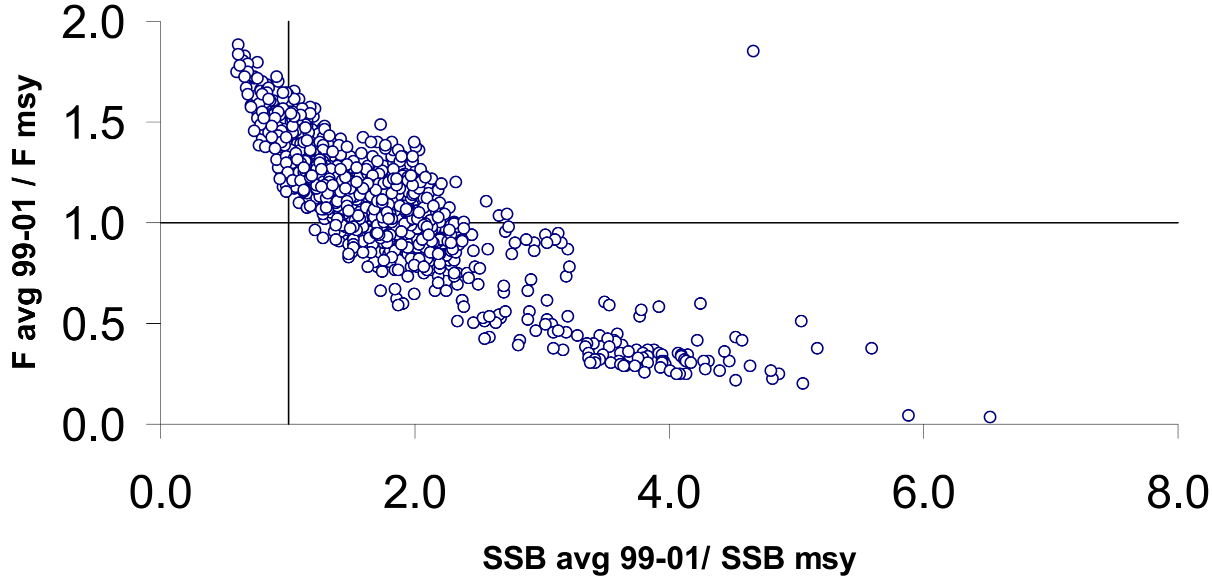


Figure 8.1.3. Estimated fishing mortality rates from the base mid-Atlantic model relative to proposed benchmarks.

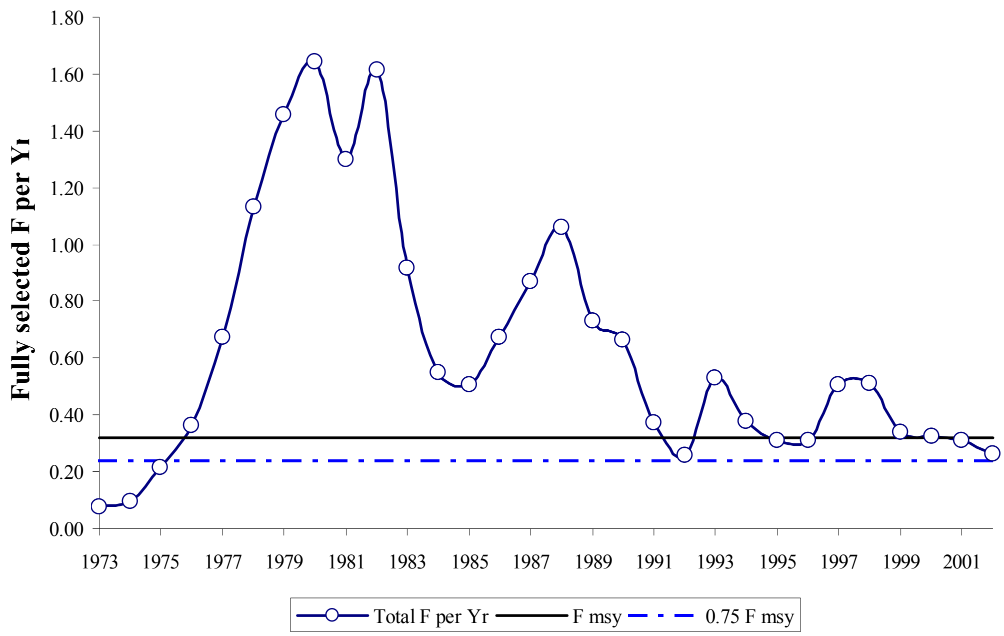


Figure 8.1.4. Estimated spawning stock biomass from the base mid-Atlantic model relative to proposed benchmarks.

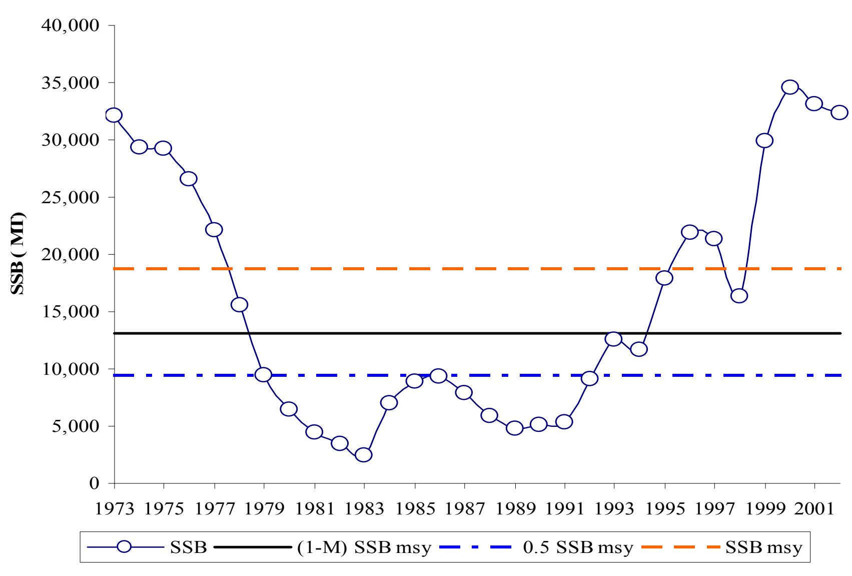


Figure 8.2.1 Beverton and Holt stock recruitment curve and stock recruit scatter for the base mid-Atlantic model. Vertical line represent SSB(MSY)

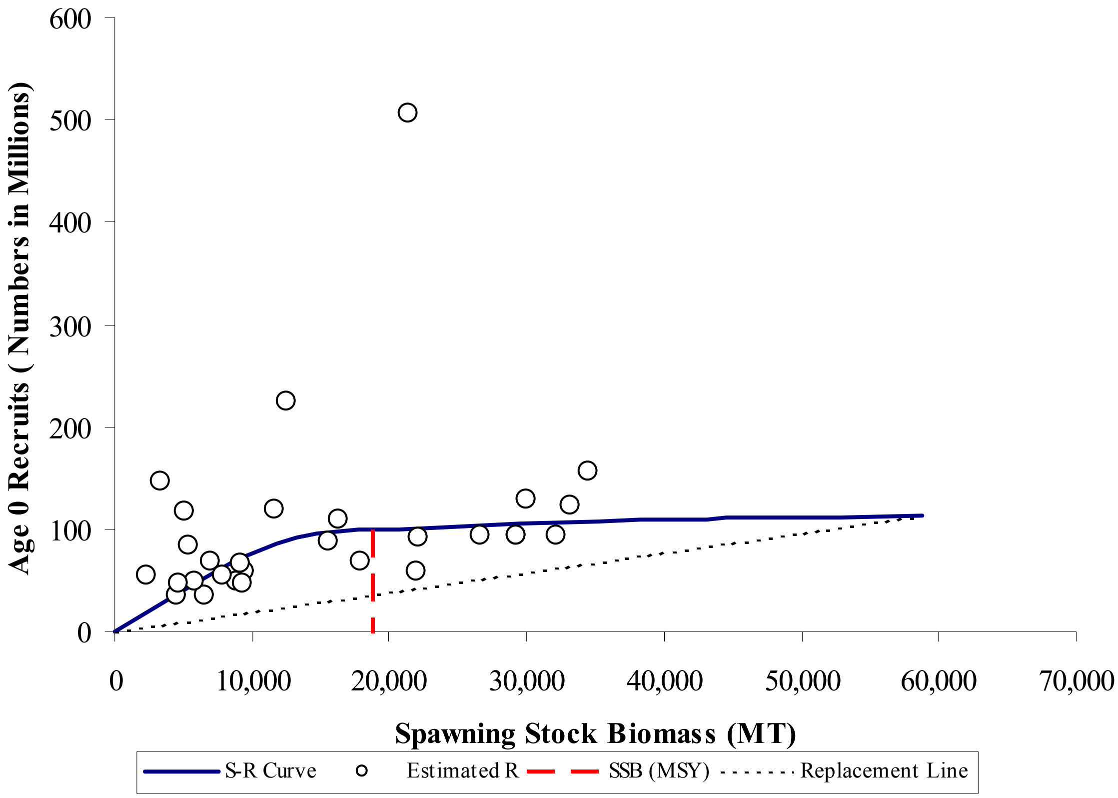


Figure 8.2.2 Beverton and Holt stock recruitment curve and stock-recruit scatter for the base south-Atlantic model. Vertical line represents SSB(MSY)

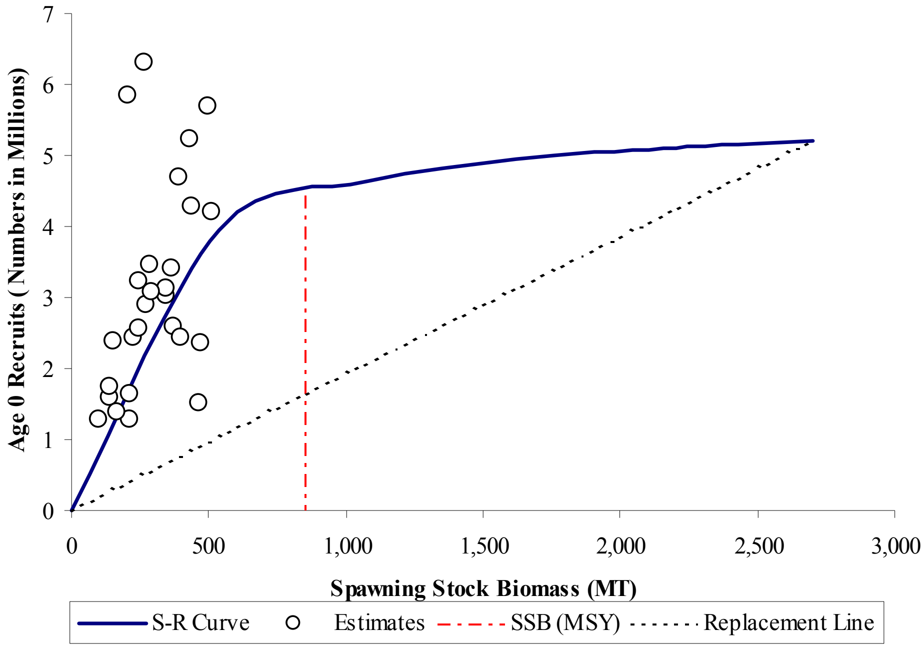


Figure 8.3.1 Yield per recruit and spawning potential ratio curve for the base mid-Atlantic model (m=0.3). Avg represents average SPR from 1999-2002

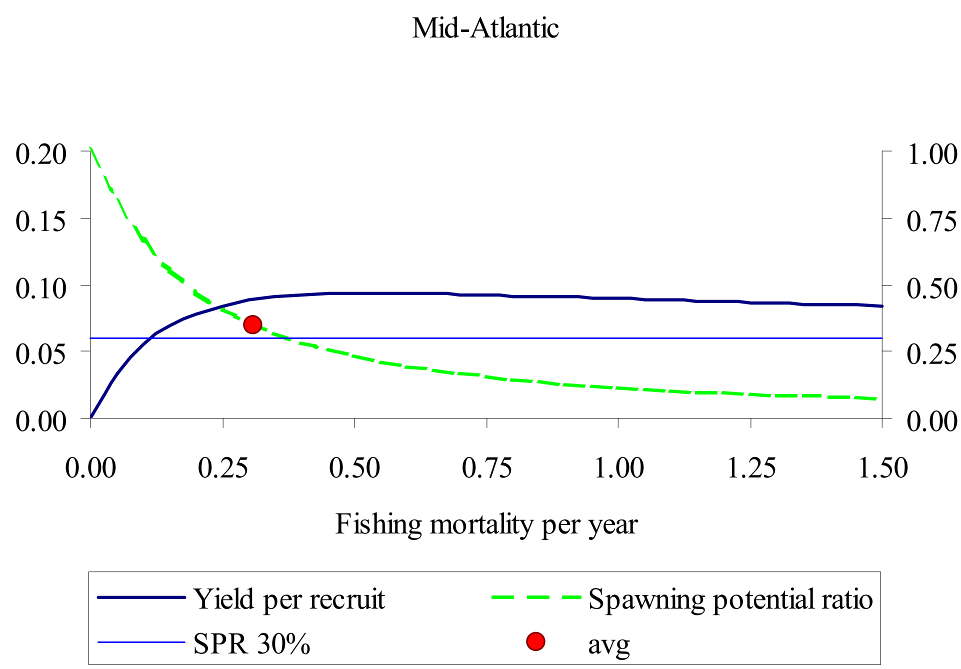
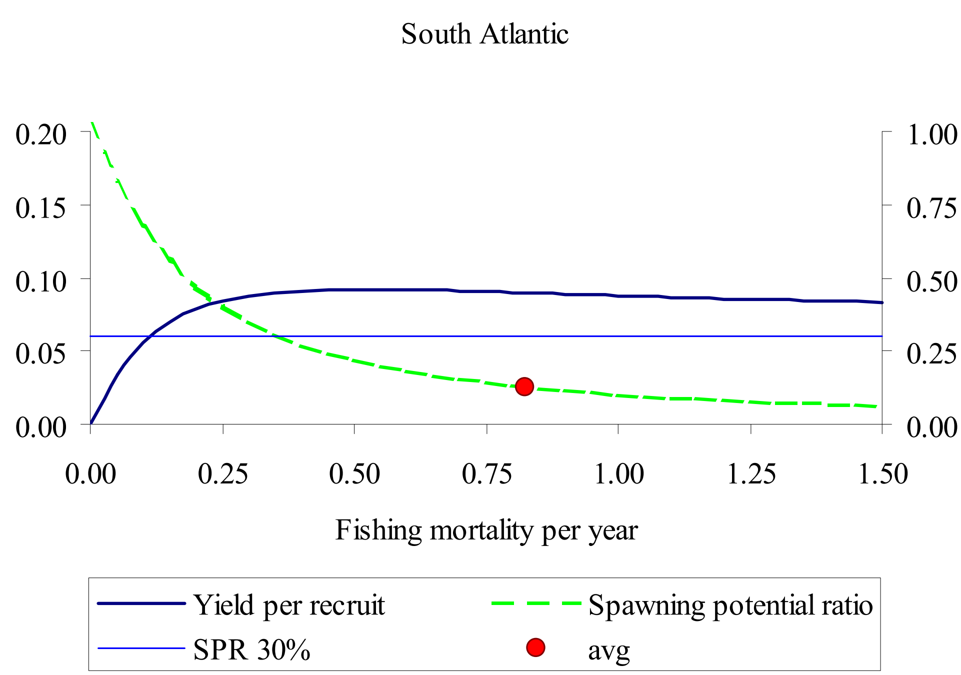


Figure 8.3.2 Yield per recruit and spawning potential ratio curve for the base south-Atlantic model (m=0.3). Avg represents average SPR from 1999-2002



Appendix A.

Comparison of Estimates using the Excel and AD model Builder age structured production model when similarly configured (base Mid-Atlantic model)

Likelihood Components	Weight	ADMB	EXCEL
Commercial Landings	1	1.169	1.570
Recreational Landings	1	0.105	0.134
Total Fleet		1.274	1.705
NEFSC Fall Trawl CPUE	2	13.020	12.697
MRFSS CPUE	1	5.607	5.818
SEAMAP North CPUE	2	5.440	5.476
Total Indices		42.527	42.163
Recruitment constraint	1	7.734	7.489
TOTAL		51.535	51.357

Estimated Parameters	ADMB	EXCEL
NEFSC Fall Trawl CPUE	-13.228	-13.142
MRFSS CPUE	-18.427	-18.291
SEAMAP North CPUE	-12.215	-12.166
Virgin Recruitment (R0)	18.540	18.550

	Commercial F per Yr		Rec F per yr		Rec Deviations	
	ADMB	EXCEL	ADMB	EXCEL	ADMB	EXCEL
1973	0.06	0.06	0.02	0.02		
1974	0.07	0.07	0.02	0.02	-0.122	-0.129
1975	0.17	0.17	0.05	0.05	-0.119	-0.126
1976	0.29	0.29	0.08	0.08	-0.114	-0.120
1977	0.56	0.57	0.12	0.12	-0.103	-0.109
1978	0.97	0.98	0.18	0.18	-0.083	-0.090
1979	1.28	1.33	0.20	0.20	-0.052	-0.030
1980	1.50	1.50	0.14	0.14	-0.306	-0.234
1981	1.21	1.15	0.08	0.08	-0.652	-0.765
1982	1.50	1.50	0.11	0.11	-0.499	-0.584
1983	0.79	0.84	0.12	0.12	1.092	1.005
1984	0.49	0.53	0.05	0.06	0.336	0.309
1985	0.46	0.53	0.04	0.05	-0.042	-0.019
1986	0.58	0.70	0.08	0.10	-0.495	-0.423
1987	0.75	0.96	0.09	0.11	-0.554	-0.475
1988	0.76	0.96	0.28	0.35	-0.303	-0.234
1989	0.58	0.72	0.13	0.16	-0.303	-0.217
1990	0.56	0.74	0.09	0.11	-0.229	-0.179
1991	0.24	0.31	0.12	0.16	0.641	0.674
1992	0.18	0.23	0.07	0.08	0.276	0.349
1993	0.43	0.65	0.09	0.11	-0.179	-0.151
1994	0.26	0.33	0.11	0.14	0.945	0.950
1995	0.25	0.30	0.06	0.07	0.330	0.352
1996	0.26	0.29	0.05	0.06	-0.329	-0.313
1997	0.39	0.45	0.11	0.13	-0.524	-0.535
1998	0.37	0.44	0.13	0.16	1.632	1.609
1999	0.28	0.31	0.06	0.06	0.155	0.151
2000	0.24	0.27	0.08	0.09	0.213	0.169
2001	0.22	0.25	0.09	0.10	0.387	0.349
2002	0.19	0.21	0.07	0.08	0.151	0.150

Appendix B. Ad model builder template file used in analysesDATA_SECTION

```
 !!USER_CODE ad_comm::change_datafile_name("aspm_dummy.txt");

//  define cells

  init_int nfleets     // number of separate fisheries operating
  init_int firstyr     // first year of data considered for each fishery (same for all)
  init_int lastyr      // last year of data considered for each fishery (same for all)
  init_int firstage    // first age in data considered for each fishery (same for all)
  init_int lastage     // last age in data considered for each fishery (same for all)
  init_int no_ndx      // total number of indices



// basic fishery inputs

  init_matrix land(1,nfleets,firstyr,lastyr)
  init_matrix index(1,no_ndx,firstyr,lastyr)

  init_matrix sel_fish(1,nfleets,firstage,lastage)
  init_matrix sel_index(1,no_ndx,firstage,lastage)

  init_ivector ndx_type(1,no_ndx) // (=1 if weight 0 if numbers)
  init_vector  part_yr(1,no_ndx) // part of year when index takes place


  // weighting components

  init_vector  ndx_wt(1,no_ndx)
  init_vector  fleet_wt(1,nfleets)
  init_number  ssbc_wt
  init_number  rec_wt
  init_number  prior_wt

  // biological parameters

  init_number linf
  init_number m
  init_number k
  init_number to
  init_number lw_a
```

```
  init_number lw_b
  init_vector mat_sch(firstage,lastage)

  // stock recruit inputs
  init_number  ssb_ratio   //SSB1/SSB0 constraint
  init_number h_st
  //init_number r_init

  // setting up ranges


  int ifleet
  int iyr
  int iage
  int indx
  int i

INITIALIZATION_SECTION

  //steep h_st
  //init_logr r_init
   //full_f 0.01

PARAMETER_SECTION
  number steep
  //init_bounded_number steep(0.2,1.0,2)
  //number steep_prior
  //vector steep_priors(1,5000)
  //vector steeps(1,5000)




  init_bounded_vector log_recdev(firstyr+1,lastyr,-7.5,7.5,1)

  //init_bounded_number init_logr(10,25,1)

  init_bounded_number log_ro(10,25,1)
  number init_logr
  init_bounded_matrix full_f(1,nfleets,firstyr,lastyr,0.0,1.50,1)
  init_bounded_vector ndx_logq(1,no_ndx,-25,-3,1)

  matrix len_at_age(firstyr,lastyr,firstage,lastage)
  matrix wt_at_age(firstyr,lastyr,firstage,lastage)
  matrix sb_per_r(firstyr,lastyr,firstage,lastage)
  matrix mat_ogive(firstyr,lastyr,firstage,lastage)
```

```
vector wgt(firstage,lastage)

matrix n_at_age(firstyr,lastyr,firstage,lastage)
matrix popwt_at_age(firstyr,lastyr,firstage,lastage)


matrix ind_pop_n(1,no_ndx,firstyr,lastyr)
matrix ind_pop_wt(1,no_ndx,firstyr,lastyr)


matrix pred_totcatch(1,nfleets,firstyr,lastyr)
matrix pred_ndx(1,no_ndx,firstyr,lastyr)

matrix resid_ndx(1,no_ndx,firstyr,lastyr)
matrix resid_catch(1,nfleets,firstyr,lastyr)
number ssb_fo

3darray f_by_age(1,nfleets,firstyr,lastyr,firstage,lastage)
3darray c_at_age(1,nfleets,firstyr,lastyr,firstage,lastage)
matrix tot_f(firstyr,lastyr,firstage,lastage)
matrix z_at_age(firstyr,lastyr,firstage,lastage)

vector SSB(firstyr,lastyr)
sdreport_vector f_by_yr(firstyr,lastyr);

number lik_ndx
number lik_catch
number lik_ssbc
number lik_recc
number temp

// items used to calculate the std dev of residuals


vector obs_ndx(1,no_ndx);
vector obs_fleet(1,nfleets);
vector sd_res_ndx(1,no_ndx);
vector sd_res_fleet(1,nfleets);
vector mean_res_indx(1,no_ndx);
vector mean_res_fleet(1,nfleets);


//MSY stuff swiped from erik's red porgy
  number avg_land;
  vector sel_msy(firstage,lastage);
  matrix N_msy(1,3,firstage,lastage);
```

```
  vector SSB_msy(1,3);
  //likeprof_number SSB_msy_out;
  sdreport_number SSB_msy_out;
  //likeprof_number SdSSB_msy_end;
  //sdreport_number SdSSB_msy_end;
  //likeprof_number FdF_msy_end;
  //sdreport_number FdF_msy_end;
  //likeprof_number msy_out;
  vector msy_outx(1,400);
  vector xx(1,400);
  sdreport_number msy_out;
  //likeprof_number F_msy_out;
  sdreport_number F_msy_out;
  vector F_msy(1,3);
  matrix Z_msy(1,3,firstage,lastage);
  vector L_msy(1,3);
  vector spr_msy(1,3);
  vector R_eq(1,3);
  //sdreport_vector FdF_msy(firstyr,lastyr);
  //sdreport_vector SdSSB_msy(firstyr,lastyr);
  number df;
  number dmsy;
  number ddmsy;
  number R0;


 //likeprof_number profile_steep;
 likeprof_number profile_ro;
 objective_function_value f


PRELIMINARY_CALCS_SECTION

 profile_ro.set_stepnumber(20);
 profile_ro.set_stepsize(0.15);


PROCEDURE_SECTION
 //profile_steep=steep;
 profile_ro=log_ro;

 cal_bio_parms();
 cal_fmort();
 cal_numbers_at_age();
 cal_pred_catch();
 cal_ndx_abund();
```

```
  cal_pred_index();
  cal_msy();
  cal_ssqcatch();
  cal_ssqndx();
  cal_resid_sd();
  evaluate_the_objective_function();


FUNCTION cal_bio_parms
     steep=h_st;
     //R0=mfexp(log_ro);
    // create length at age wt at age and ssb_r
    len_at_age=0.0;
    for (iyr=firstyr;iyr<=lastyr;iyr++)
         {
          for (iage=firstage;iage<=lastage;iage++)
            {
            len_at_age(iyr,iage)= linf*(1- mfexp(-k *((iage-1)- to)));
            }
         }
     mat_ogive=0.0;
     for (iyr=firstyr;iyr<=lastyr;iyr++)
             {
              for (iage=firstage;iage<=lastage;iage++)
                {
                mat_ogive(iyr,iage)= mat_sch(iage);
                }
             }

     wt_at_age=0.0;
     for (iyr=firstyr;iyr<=lastyr;iyr++)
             {
              for (iage=firstage;iage<=lastage;iage++)
                {
                wt_at_age(iyr,iage)= lw_a*pow(len_at_age(iyr,iage),lw_b);
                }
         }

     wgt=0.0;
       for (iage=firstage;iage<=lastage;iage++)
                {
                 wgt(iage)=wt_at_age(firstyr,iage);
                }


     sb_per_r=0.0;
```

```
for (iyr=firstyr;iyr<=lastyr;iyr++)
   {
    for (iage=firstage;iage<=firstage;iage++)
          {
          sb_per_r(iyr,iage) = 1;
       }
    for (iage=firstage+1;iage<lastage;iage++)
         {
      sb_per_r(iyr,iage)= sb_per_r(iyr,iage-1)*mfexp(-m);
         }
        for (iage=lastage;iage<=lastage;iage++)
         {
          sb_per_r(iyr,iage)= sb_per_r(iyr,iage-1)*(mfexp(-m)/(1-mfexp(-m)));
         }
    }

ssb_fo=0.0;
for (iyr=firstyr;iyr<=firstyr;iyr++)
     {
     for (iage=firstage;iage<=lastage;iage++)
         {
         ssb_fo += sb_per_r(firstyr,iage)*wt_at_age(firstyr,iage)*mat_sch(iage)*0.5;
      }
    }


FUNCTION cal_fmort

 for (ifleet=1;ifleet<=nfleets;ifleet++)
   {
    f_by_age(ifleet)=0.0;
    for (iyr=firstyr;iyr<=lastyr;iyr++)
      {
       for (iage=firstage;iage<=lastage;iage++)
         {
         f_by_age(ifleet,iyr,iage) = full_f(ifleet,iyr)*sel_fish(ifleet,iage);
         }
      }
    }


tot_f=0.0;
  for (iyr=firstyr;iyr<=lastyr;iyr++)
    {
     for (iage=firstage;iage<=lastage;iage++)
       {
```

```
            for (ifleet=1;ifleet<=nfleets;ifleet++)
            {
            tot_f(iyr,iage) += f_by_age(ifleet,iyr,iage);
            }
        }
      }

  z_at_age=0.0;

             for (iyr=firstyr;iyr<=lastyr;iyr++)
              {
                for (iage=firstage;iage<=lastage;iage++)
                  {
                   z_at_age(iyr,iage) = tot_f(iyr,iage)+m;
                  }
              }

   f_by_yr=0.0;

          for (iyr=firstyr;iyr<=lastyr;iyr++)
            {
             for (iage=2;iage<=lastage;iage++)
                 {
                 f_by_yr(iyr) += tot_f(iyr,iage);
                 }
                f_by_yr(iyr) = f_by_yr(iyr)/(nfleets*(lastage-1.0));
            }


FUNCTION cal_numbers_at_age

 // note: numbers are normal estimators are in log space

 // fill the first yr of population
   n_at_age=0.0;

   n_at_age(firstyr,firstage)=mfexp(log_ro +log(ssb_ratio));

    for (iage=firstage+1;iage<lastage;iage++)
      {
      n_at_age(firstyr,iage)=n_at_age(firstyr,iage-1.0)*mfexp(-(m+ tot_f(firstyr,iage-1)));
      }

   n_at_age(firstyr,lastage)=n_at_age(firstyr,lastage-1)*(mfexp(-(m+ tot_f(firstyr,lastage-
1)))/(1-mfexp(-(m+ tot_f(firstyr,lastage-1))))) ;
```

```
 // ssb for first year


  SSB = 0.0;


     for (iage=firststage;iage<=lastage;iage++)
      {
      SSB(firstyr) += 0.5 *(n_at_age(firstyr,iage) * mat_ogive(firstyr,iage)
*wt_at_age(firstyr,iage));
      }



  //----calculate the age structure each year filling forward and using SSB-R relation for
next year's recruits
    for (iyr=firstyr+1;iyr<=lastyr;iyr++)
        {
        for (iage=firststage;iage<=firststage;iage++)
              {
       n_at_age(iyr,firststage)=mfexp( log( (0.8*mfexp(log_ro)*steep*SSB(iyr-1)) /
(0.2*mfexp(log_ro)*ssb_fo*(1-steep)+SSB(iyr-1)*(steep-0.2))+0.000001 ) +
log_recdev(iyr)  );
 SSB(iyr) += 0.5 * (n_at_age(iyr,iage) * mat_ogive(iyr,iage) * wt_at_age(iyr,iage));

             }
         for (iage=firststage+1;iage<lastage;iage++)
              {
              n_at_age(iyr,iage)=n_at_age(iyr-1,iage-1)* mfexp( -(m+ tot_f(iyr-1,iage-1)));
              SSB(iyr) += 0.5 * (n_at_age(iyr,iage) * mat_ogive(iyr,iage) *
wt_at_age(iyr,iage));
              }
        for (iage=lastage;iage<=lastage;iage++)
              {
        n_at_age(iyr,lastage)=n_at_age(iyr-1,lastage-1)* mfexp( -(m+ tot_f(iyr-1,lastage-
1))) +
                            n_at_age(iyr-1,lastage)* mfexp( -(m+ tot_f(iyr-1,lastage)));
SSB(iyr) += 0.5 * (n_at_age(iyr,iage) * mat_ogive(iyr,iage) * wt_at_age(iyr,iage));

               }


        }
```

```
  // population weight at age matrix
    popwt_at_age=0.0;


      popwt_at_age = elem_prod(n_at_age,wt_at_age);



FUNCTION cal_pred_catch
  pred_totcatch=0.0;
     for (ifleet=1;ifleet<=nfleets;ifleet++)
       {
        c_at_age(ifleet)=0.0;
       for (iyr=firstyr;iyr<=lastyr;iyr++)
         {
          for (iage=firstage;iage<=lastage;iage++)
            {
            pred_totcatch(ifleet,iyr)+= (popwt_at_age(iyr,iage)/1000.0) *
(f_by_age(ifleet,iyr,iage)/ z_at_age(iyr,iage)) * (1- mfexp(-(z_at_age(iyr,iage))));
            c_at_age(ifleet,iyr,iage) = n_at_age(iyr,iage) * (f_by_age(ifleet,iyr,iage)/
z_at_age(iyr,iage)) * (1- mfexp(-(z_at_age(iyr,iage))));
            }
         }
      }


FUNCTION cal_ndx_abund

  ind_pop_n=0.0;
  ind_pop_wt=0.0;
  for (indx=1;indx<=no_ndx;indx++)
     {
       for (iyr=firstyr;iyr<=lastyr;iyr++)
          {
           for (iage=firstage;iage<=lastage;iage++)
                 {
                  ind_pop_n(indx,iyr) += n_at_age(iyr,iage) * sel_index(indx,iage) *mfexp(-
1. * part_yr(indx)* (tot_f(iyr,iage)+m)) ;
                  ind_pop_wt(indx,iyr) +=
popwt_at_age(iyr,iage)*sel_index(indx,iage)*mfexp(-1. * part_yr(indx)*
(tot_f(iyr,iage)+m));
                 }

            }
      }
```

```
FUNCTION cal_pred_index

        for (indx=1;indx<=no_ndx;indx++)
                {
                 for (iyr=firstyr;iyr<=lastyr;iyr++)
                      {
                       for (iage=firstage;iage<=lastage;iage++)
                          {
                             if (ndx_type(indx)==1)
                             {
                             pred_ndx(indx,iyr) =ind_pop_n(indx,iyr)*mfexp(ndx_logq(indx));
                             }
                             else
                             {
                             pred_ndx(indx,iyr) =mfexp(ndx_logq(indx))*ind_pop_wt(indx,iyr) ;
                             }
                          }
                      }
                }



FUNCTION cal_msy //swiped from Erik's red porgy and modified
  //get ratio of F's from last 3 years not used in final anlyses
  R0=mfexp(log_ro);
   df=0.0000001;

   avg_land=0.0;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
         {
         for (iyr=lastyr-2;iyr<=lastyr;iyr++)
                      {
                     avg_land +=land(ifleet,iyr);
                     }
          }

  sel_msy=0.0;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
         {
    for (iage=firstage; iage<=lastage; iage++)
              {
               for (iyr=lastyr-2;iyr<=lastyr;iyr++)
                      {
                      sel_msy(iage) +=sel_fish(ifleet,iage)*land(ifleet,iyr)/avg_land;
```

```
            }
        }
    }


 //use Newton's method to get Fmsy, MSY, and Smsy
 F_msy(1)=0.05;
 for (i=1; i<=10; i++)

   {
    F_msy(2)=F_msy(1)-df;
    F_msy(3)=F_msy(1)+df;
    L_msy=0.0;
    Z_msy(1)=sel_msy*F_msy(1)+m;
    Z_msy(2)=sel_msy*F_msy(2)+m;
    Z_msy(3)=sel_msy*F_msy(3)+m;
   //Initial age
    N_msy(1,1)=1.0;
    N_msy(2,1)=1.0;
    N_msy(3,1)=1.0;
     for (iage=2; iage<=lastage;iage++)
       {
       N_msy(1,iage)=N_msy(1,iage-1)*mfexp(-1.*Z_msy(1,iage-1));
       N_msy(2,iage)=N_msy(2,iage-1)*mfexp(-1.*Z_msy(2,iage-1));
       N_msy(3,iage)=N_msy(3,iage-1)*mfexp(-1.*Z_msy(3,iage-1));
       }
   //last age is pooled
   N_msy(1,lastage)=N_msy(1,lastage-1)*mfexp(-1.*Z_msy(1,lastage-1))/(1.-mfexp(-
1.*Z_msy(1,lastage)));
   N_msy(2,lastage)=N_msy(2,lastage-1)*mfexp(-1.*Z_msy(2,lastage-1))/(1.-mfexp(-
1.*Z_msy(2,lastage)));
   N_msy(3,lastage)=N_msy(3,lastage-1)*mfexp(-1.*Z_msy(3,lastage-1))/(1.-mfexp(-
1.*Z_msy(3,lastage)));
   spr_msy(1)=sum(elem_prod(elem_prod(N_msy(1),wgt),mat_sch));
   spr_msy(2)=sum(elem_prod(elem_prod(N_msy(2),wgt),mat_sch));
   spr_msy(3)=sum(elem_prod(elem_prod(N_msy(3),wgt),mat_sch));
   R_eq(1)=(R0/((5*steep-1)*spr_msy(1)))*(4*steep*spr_msy(1)-ssb_fo*(1-steep));
   R_eq(2)=(R0/((5*steep-1)*spr_msy(2)))*(4*steep*spr_msy(2)-ssb_fo*(1-steep));
   R_eq(3)=(R0/((5*steep-1)*spr_msy(3)))*(4*steep*spr_msy(3)-ssb_fo*(1-steep));

   //Initial age
   N_msy(1)=R_eq(1);
   N_msy(2)=R_eq(2);
   N_msy(3)=R_eq(3);
   for (iage=2; iage<=lastage; iage++)
   {
```

```
    N_msy(1,iage)=N_msy(1,iage-1)*mfexp(-1.*Z_msy(1,iage-1));
    N_msy(2,iage)=N_msy(2,iage-1)*mfexp(-1.*Z_msy(2,iage-1));
    N_msy(3,iage)=N_msy(3,iage-1)*mfexp(-1.*Z_msy(3,iage-1));
   }
   //last age is pooled
   SSB_msy=0.0;
   N_msy(1,lastage)=N_msy(1,lastage-1)*mfexp(-1.*Z_msy(1,lastage-1))/(1.-mfexp(-
1.*Z_msy(1,lastage-1)));
   N_msy(2,lastage)=N_msy(2,lastage-1)*mfexp(-1.*Z_msy(2,lastage-1))/(1.-mfexp(-
1.*Z_msy(2,lastage-1)));
   N_msy(3,lastage)=N_msy(3,lastage-1)*mfexp(-1.*Z_msy(3,lastage-1))/(1.-mfexp(-
1.*Z_msy(3,lastage-1)));
   SSB_msy(1)=0.5*sum(elem_prod(elem_prod(N_msy(1),wgt),mat_sch));
   SSB_msy(2)=0.5*sum(elem_prod(elem_prod(N_msy(2),wgt),mat_sch));
   SSB_msy(3)=0.5*sum(elem_prod(elem_prod(N_msy(3),wgt),mat_sch));

   L_msy=0.0;
   for(iage=firstage; iage<=lastage; iage++)
    {
    L_msy(1)+=N_msy(1,iage)*((Z_msy(1,iage)-m)/Z_msy(1,iage))*(1.-mfexp(-
1.*Z_msy(1,iage)))*wgt(iage);
    L_msy(2)+=N_msy(2,iage)*((Z_msy(2,iage)-m)/Z_msy(2,iage))*(1.-mfexp(-
1.*Z_msy(2,iage)))*wgt(iage);
    L_msy(3)+=N_msy(3,iage)*((Z_msy(3,iage)-m)/Z_msy(3,iage))*(1.-mfexp(-
1.*Z_msy(3,iage)))*wgt(iage);
    }
   dmsy=(L_msy(3)-L_msy(2))/(2.*df);
   ddmsy=(L_msy(3)-2.*L_msy(1)+L_msy(2))/square(df);
   if(square(ddmsy)<=1e-12)
    {
    F_msy(1)=F_msy(1);
    }
   if(square(ddmsy)>1e-12)
    {
    F_msy(1)-=(dmsy/ddmsy);
    }
   if(F_msy(1)<=df)
    {
    F_msy(1)=df;
    }
  }
  msy_out=L_msy(1);
  F_msy_out=F_msy(1);
  SSB_msy_out=SSB_msy(1);
```

```
FUNCTION cal_ssqcatch

    resid_catch=0.0;
    for (ifleet=1;ifleet<=nfleets;ifleet++)
      {
      for (iyr=firstyr;iyr<=lastyr;iyr++)
        {
        if(land(ifleet,iyr) > 0.0)
        {
        resid_catch(ifleet,iyr)=log(land(ifleet,iyr)) - log(pred_totcatch(ifleet,iyr));
        }
        else
              {
              resid_catch(ifleet,iyr)=0.0;
          }
        }
       }
FUNCTION cal_ssqndx

      for(indx=1;indx<=no_ndx;indx++)
             {
             for (iyr=firstyr;iyr<=lastyr;iyr++)
            {
            if(index(indx,iyr)>0.0)
             {
             resid_ndx(indx,iyr)= log(index(indx,iyr))-log(pred_ndx(indx,iyr));
             }
             else
             {
             resid_ndx(indx,iyr)=0.0;
             }
            }
          }



FUNCTION cal_resid_sd


   sd_res_ndx=0.0;
   obs_ndx=0.0;
   mean_res_indx=0.0;
  for(indx=1;indx<=no_ndx;indx++)
         {
         for (iyr=firstyr;iyr<=lastyr;iyr++)
```

```
           {
           if(index(indx,iyr)>0.0)
             {
             obs_ndx(indx) += 1.;
            }
                    }
           mean_res_indx(indx)= sum(resid_ndx(indx))/obs_ndx(indx);

        }

    for(indx=1;indx<=no_ndx;indx++)
           {
           for (iyr=firstyr;iyr<=lastyr;iyr++)
           {
            sd_res_ndx(indx) += square(resid_ndx(indx,iyr) - mean_res_indx(indx))/
(obs_ndx(indx)-1);

                 }
                sd_res_ndx(indx) =sqrt(sd_res_ndx(indx) );
        }




   sd_res_fleet=0.0;
   obs_fleet=0.0;
   mean_res_fleet=0.0;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
         {
          for (iyr=firstyr;iyr<=lastyr;iyr++)
          {
          if(land(ifleet,iyr) > 0.0)
            {
            obs_fleet(ifleet) += 1.0;
            }

          }
          mean_res_fleet(ifleet) =sum(resid_catch(ifleet))/obs_fleet(ifleet);
        }

   for (ifleet=1;ifleet<=nfleets;ifleet++)
         {
          for (iyr=firstyr;iyr<=lastyr;iyr++)
          {
```

```
            sd_res_fleet(ifleet) += square(resid_catch(ifleet,iyr) - mean_res_fleet(ifleet))/
(obs_fleet(ifleet)-1);
             }

             sd_res_fleet(ifleet)=sqrt(sd_res_fleet(ifleet));
            }

FUNCTION evaluate_the_objective_function


  lik_ndx=0.0;
   for(indx=1;indx<=no_ndx;indx++)
      {
      for (iyr=firstyr;iyr<=lastyr;iyr++)
      {
       lik_ndx +=square(resid_ndx(indx,iyr))*ndx_wt(indx);
      }
    }

  lik_catch=0.0;
   for (ifleet=1;ifleet<=nfleets;ifleet++)
        {
         for (iyr=firstyr;iyr<=lastyr;iyr++)
           {
           lik_catch += square(resid_catch(ifleet,iyr))*fleet_wt(ifleet);
           }
         }

  lik_recc=0.0;
    for (iyr=firstyr+1;iyr<=lastyr;iyr++)
        {
        lik_recc += pow(log_recdev(iyr),2)*rec_wt;
        }

  //lik_ssbc = ssbc_wt*square((mfexp(init_logr))/(mfexp(log_ro))- ssb_ratio);



  f += lik_catch + lik_ndx  +lik_recc ;


RUNTIME_SECTION
 maximum_function_evaluations 10000
 convergence_criteria 1.e-9
```

```
REPORT_SECTION
  report <<" ASPM output" << endl;
  report <<"   "<< endl;
  report <<"input landings"<<endl;
  report <<" first year  "<< endl;
  report <<    firstyr  <<endl;
  report <<"   "<< endl;
  report <<" last year  "<< endl;
  report <<    lastyr   <<endl;
  report <<"   "<< endl;
  report <<" first age  "<< endl;
  report <<    firstage <<endl;
  report <<"   "<< endl;
  report <<" last age  "<< endl;
  report <<    lastage <<endl;
  report <<"   "<< endl;
  report <<" number of indices  "<< endl;
  report <<    no_ndx           <<endl;
  report <<"   "<< endl;
  report <<" landings  "<< endl;
  report <<    land     <<endl;
  report <<"   "<< endl;
  report <<" index values note: -1= no data  "<< endl;
  report <<    index   <<endl;
  report <<"   "<< endl;
  report <<" fishery selectivities  "<< endl;
  report <<    sel_fish <<endl;
  report <<"   "<< endl;
  report <<" index selectivities  "<< endl;
  report <<    sel_index <<endl;
  report <<"   "<< endl;
  report <<" index type numbers =0 weight=1  "<< endl;
  report <<    ndx_type <<endl;
  report <<"   "<< endl;
  report <<" index weight for likelihood  "<< endl;
  report <<    ndx_wt           <<endl;
  report <<"   "<< endl;
  report <<" fleet weight for likelihood  "<< endl;
  report <<    fleet_wt <<endl;
  report <<"   "<< endl;
  report <<" ssb ratio weight for likelihood  "<< endl;
  report <<    ssbc_wt <<endl;
  report <<"   "<< endl;
  report <<" rec wt for likelihood  "<< endl;
  report <<    rec_wt <<endl;
  report <<"   "<< endl;
```

```
report <<" prior wt for likelihood  "<< endl;
report <<    prior_wt          <<endl;
report <<"   "<< endl;
report <<"  l inf "<< endl;
report <<    linf      <<endl;
report <<"   "<< endl;
report <<"  m "<< endl;
report <<    m         <<endl;
report <<"   "<< endl;
report <<"  k "<< endl;
report <<    k         <<endl;
report <<"   "<< endl;
report <<"  to "<< endl;
report <<    to        <<endl;
report <<"   "<< endl;
report <<"  lw a "<< endl;
report <<    lw_a    <<endl;
report <<"   "<< endl;
report <<"  lw b "<< endl;
report <<    lw_b    <<endl;
report <<"   "<< endl;
report <<" maturity schedule  "<< endl;
report <<    mat_sch          <<endl;
report <<" estimated parameters  "<< endl;
report <<"   "<< endl;
report <<" steepness  "<< endl;
report << steep<< endl;
    report <<"recruit deviations"<< endl;
report <<    log_recdev      << endl;
report <<"inital log recruit   "<< endl;
report <<    init_logr         << endl;
report <<" log ro   "<< endl;
report <<    log_ro  << endl;
report <<" full f  "<< endl;
report <<    full_f   << endl;
report <<" log q for indices  "<< endl;
report <<    ndx_logq        << endl;
report <<" calculated parameters  "<< endl;
report <<"   "<< endl;
report <<" length at age  "<< endl;
report <<    len_at_age       << endl;
report <<" weight at age  "<< endl;
report <<    wt_at_age       << endl;
report <<" spawning biomass per recruit  "<< endl;
report <<    sb_per_r         << endl;
report <<" maturity ogive   "<< endl;
```

```
report <<    mat_ogive       << endl;
report <<" ssb per r at F=0   "<< endl;
report <<    ssb_fo  << endl;
report <<" population estimates  "<< endl;
report <<"   "<< endl;
report <<" numbers at age  "<< endl;
report <<    n_at_age        << endl;
report <<"pop weight at age   "<< endl;
report <<    popwt_at_age  << endl;
report <<" index pop num  "<< endl;
report <<    ind_pop_n       << endl;
report <<" index pop wt    "<< endl;
report <<    ind_pop_wt     << endl;
report <<" predicted total landings  "<< endl;
report <<    pred_totcatch  << endl;
report <<" predicted indices  "<< endl;
report <<    pred_ndx        << endl;
report <<" Residuals  "<< endl;
report <<"   "<< endl;report <<" residuals of index  "<< endl;
report <<    resid_ndx       << endl;
report <<" residuals of catch  "<< endl;
report <<    resid_catch      << endl;


report << " std deviations of residuals" <<endl;
report << "   " << endl;
report << " number of obs for indices residuals   " << endl;
report << obs_ndx << endl;
report << "   " << endl;
report << " mean of residuals for indices" << endl;
report << mean_res_indx << endl;
report << "   " << endl;
report << " std deviation of index residuals  " << endl;
report <<  sd_res_ndx   << endl;
report << " number of obs for fleet residuals   " << endl;
report << obs_fleet << endl;
report << "   " << endl;
report << " mean of residuals for fleets" << endl;
report << mean_res_fleet << endl;
report << "   " << endl;
report << " std deviation of fleet residuals  " << endl;
report <<  sd_res_fleet   << endl;
```

```
report <<" Fishing mortality estimates  "<< endl;
report <<"   "<< endl;
report <<" F by age and fishery  "<< endl;
report <<    f_by_age        << endl;
report <<" total F by fishery  "<< endl;
report <<    tot_f    << endl;
report <<" total Z by age by fishery  "<< endl;
report <<    z_at_age         << endl;

report <<" ssb by year  "<< endl;
report <<    SSB     << endl;


report <<" likelihood terms  "<< endl;\
report <<"   "<< endl;
report <<" index likelihood  "<< endl;
report <<    lik_ndx          << endl;
report <<" catch likelihood  "<< endl;
report <<    lik_catch        << endl;
report <<" ssb ratio likelihood  "<< endl;
report <<    lik_ssbc         << endl;
report <<" recruitment deviation likelihood  "<< endl;
report <<    lik_recc         << endl;
report << " " <<endl;
report << " " <<endl;
report <<" total likelihood  "<< endl;
report <<    f          << endl;


report <<" blank line   "<< endl;
report << "blank line " << endl;
report <<" blank line  "<< endl;
report <<" blank line  "<< endl;
report << "blank line "<< endl;



report << " reference points " << endl;
report <<"  MSY  "<< endl;
report << msy_out << endl;
report <<" F MSY  "<< endl;
report <<   F_msy_out << endl;
report <<" SSB MSY  "<< endl;
report << SSB_msy_out << endl;
report <<" sel_msy  "<< endl;
```

```
  report << sel_msy << endl;
  report <<" average landings in last 3 yrs  "<< endl;
  report << avg_land << endl;


  report << "  "  <<endl;
  report << "catch at age" << endl;
  report << c_at_age << endl;

  report << "  "  <<endl;
  report << "f by yr avg 1-11" << endl;
  report << f_by_yr << endl;
////////////////////////////////////////////////////////////////////////////////////
```