Northeast Fisheries Science Center Reference Document 15-08

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60th Northeast Regional Stock Assessment Workshop (60th SAW) Assessment Report

by the Northeast Fisheries Science Center

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NOAA Fisheries, Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543

U.S. DEPARTMENT OF COMMERCE
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Northeast Fisheries Science Center
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Foreword

The Northeast Regional Stock Assessment Workshop (SAW) process has three parts: preparation of stock assessments by the SAW Working Groups and/or by ASMFC Technical Committees / Assessment Committees; peer review of the assessments by a panel of outside experts who judge the adequacy of the assessment as a basis for providing scientific advice to managers; and a presentation of the results and reports to the Region's fishery management bodies.

Starting with SAW-39 (June 2004), the process was revised in two fundamental ways. First, the Stock Assessment Review Committee (SARC) became smaller panel with panelists provided by the Independent System for Peer Review (Center of Independent Experts, CIE). Second, the SARC provides little management advice. Instead, Council and Commission teams (e.g., Plan Development Teams, Monitoring and Technical Committees, Science and Statistical Committee) formulate management advice, after an assessment has been accepted by the SARC. Starting with SAW-45 (June 2007) the SARC chairs were from external agencies, but not from the CIE. Starting with SAW-48 (June 2009), SARC chairs are from the Fishery Management Council's Science and Statistical Committee (SSC), and not from the CIE. Also at this time, some assessment Terms of Reference were revised to provide additional science support to the SSCs, as the SSC's are required to make annual ABC recommendations to the fishery management councils.

Reports that are produced following SAW/SARC meetings include: An *Assessment Summary Report* - a summary of the assessment results in a format useful to managers; an *Assessment Report* – a detailed account of the assessments for each stock; and the SARC panelist reports – a summary of the reviewer's opinions and recommendations as well as individual reports from each panelist. SAW/SARC assessment reports are available online at http://www.nefsc.noaa.gov/nefsc/publications/series/crdlist.htm. The CIE review reports and assessment reports can be found at *http://www.nefsc.noaa.gov/nefsc/saw/*".

The 59th SARC was convened in Woods Hole at the Northeast Fisheries Science Center, June 2-5, 2015 to review benchmark stock assessments of scup (*Stenotomus chrysops*) and bluefish (*Pomatomus saltatrix*). CIE reviews for SARC60 were based on detailed reports produced by NEFSC Assessment Working Groups. This Introduction contains a brief summary of the SARC comments, a list of SARC panelists, the meeting agenda, and a list of attendees (Tables 1 – 3). Maps of the Atlantic coast of the USA and Canada are also provided (Figures 1 - 5).

Outcome of the Stock Assessment Review Meeting:

Text in this section is based on SARC-60 Review Panel reports (available at http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "SARC 60 Panelist Reports").

For scup all of the ToRs were met and the assessment results can be used as a basis for management. The assessment was based on an age-structured population model (ASAP). In 2014 overfishing was not occurring and the stock was not overfished. The SARC Panel felt that the assessment represents a robust summary of scup population dynamics, but noted uncertainty regarding the steepness of the estimated rise in biomass since 2000, possible "cryptic" biomass, and in the accuracy of the Biological Reference Points. If trends in F or recruitment were to change in the medium term, further investigations are recommended to ensure that the stock does not become over-exploited. The Panel felt that attempts to incorporate environmental data into the assessment could be pursued further, and do not yet provide adequate predictions of scup habitat use.

For bluefish all of the ToRs were met and the assessment results can be used as a basis for management. The assessment was based on an age-structured population model (ASAP), with the NEFSC survey index split in 2008/2009 to account for the change in research survey vessels. In 2014 overfishing was not occurring and the stock was not overfished. The Panel noted improvements made since the previous assessment regarding quality of age data and the splitting of commercial and recreational fleets. The Panel noted that the model is strongly driven by one index (MRIP) which provides the majority of the information on older ages, and recommended that an attempt be made to develop additional informative indices. The Panel accepted the continued use of MSY proxy reference points, and recommended basing bluefish stock status determination on spawning stock biomass instead of total biomass.

Table 1. 60th Stock Assessment Review Committee Panel.

SARC Chairman (MAFMC SSC):

Dr. Cynthia Jones
Old Dominion University
Email: cjones@odu.edu

SARC Panelists (CIE):

Dr. Norm Hall
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Australia
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Dr. Sven Kupschus
Centre for Environment, Fisheries and Aquaculture Sciences (CEFAS)
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Dr. Kevin Stokes
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Khandallah, Wellington
New Zealand
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Table 2. Agenda, 60th Stock Assessment Review Committee Meeting.

June 2-5, 2015

Stephen H. Clark Conference Room – Northeast Fisheries Science Center
Woods Hole, Massachusetts

AGENDA* **(version: May 29, 2015)**

TOPIC	PRESENTER(S)	SARC LEADER	RAPPORTEUR

Tuesday, June 2

10 – 10:30 AM
Welcome — **James Weinberg**, SAW Chair
Introduction — **Cynthia Jones,** SARC Chair
Agenda
Conduct of Meeting

10:30 – 12:30 PM Assessment Presentation (A. Scup)
Mark Terceiro — **Larry Alade**

12:30 – 1:30 PM Lunch

1:30 – 3:30 PM Assesssment Presentation (A. Scup)
Mark Terceiro — **Chuck Adams**

3:30 – 3:45 PM Break

3:45 – 5:45 PM SARC Discussion w/ Presenters (A. Scup)
Cynthia Jones, SARC Chair — **Chuck Adams**

5:45 – 6 PM Public Comments

Wednesday, June 3

8:30 – 10:30 AM Assessment Presentation (B. Bluefish)
Tony Wood — **Jon Deroba**

10:30 – 10:45 AM Break

10:45 – 12:30 PM Assessment Presentation (B. Bluefish)
Tony Wood — **Jon Deroba**

12:30 – 1:30 PM Lunch

1:30 – 3:30 PM SARC Discussion w/presenters (B. Bluefish)
Cynthia Jones, SARC Chair — **Brian Linton**

3:30 – 3:45 PM Public Comments

3:45 -4 PM Break

4 – 6 PM Revisit with Presenters (A. Scup)
Cynthia Jones, SARC Chair **Toni Chute**

7 PM **(**Social Gathering**)**

TOPIC PRESENTER(S) SARC LEADER RAPPORTEUR

Thursday, June 4

8:30 – 10:30 Revisit with Presenters (B. Bluefish)
Cynthia Jones, SARC Chair **Anne Richards**

10:30 – 10:45 Break

10:45 – 12:15 Review/Edit Assessment Summary Report (A. Scup)
Cynthia Jones, SARC Chair **Alicia Miller**

12:15 – 1:15 PM Lunch

1:15 – 2:45 PM (cont.) Edit Assessment Summary Report (A. Scup)
Cynthia Jones, SARC Chair **Mike Palmer**

2:45 – 3 PM Break

3 – 6 PM Review/edit Assessment Summary Report (B. Bluefish)
Cynthia Jones, SARC Chair **TBD**

Friday, June 5

9:00 AM – 5:00 PM SARC Report writing

*All times are approximate, and may be changed at the discretion of the SARC chair. The meeting is open to the public. During the SARC report writing stage on June 5, the public should not engage in discussion with the SARC.

Table 3. 60th SAW/SARC List of Attendees

NAME	AFFILIATION	CONTACT INFO
Jim Weinberg	NEFSC	james.weinberg@noaa.gov
Paul Rago	NEFSC	paul.rago@noaa.gov
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Chris Legault	NEFSC	chris.legault@noaa.gov
Gary Shepherd	NEFSC	gary.shepherd@noaa.gov
Mark Terceiro	NEFSC	mark.terceiro@noaa.gov
Tony Wood	NEFSC	anthony.wood@noaa.gov
Kirby Rootes-Murdy	ASMFC	krootes-murdy@asmfc.org
Katie Drew	ASMFC	kdrew@asmfc.org
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Julia Beaty	MAFMC	jbeaty@mafmc.org
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David McElroy	NEFSC	dave.mcelroy@noaa.gov
John Manderson	NEFSC	john.manderson@noaa.gov
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Kiersten Curti	NEFSC	kiersten.curti@noaa.gov
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Loretta O'Brien	NEFSC	loretta.o'brien@noaa.gov
Paul Nitschke	NEFSC	paul.nitschke@noaa.gov

Research Area Maps

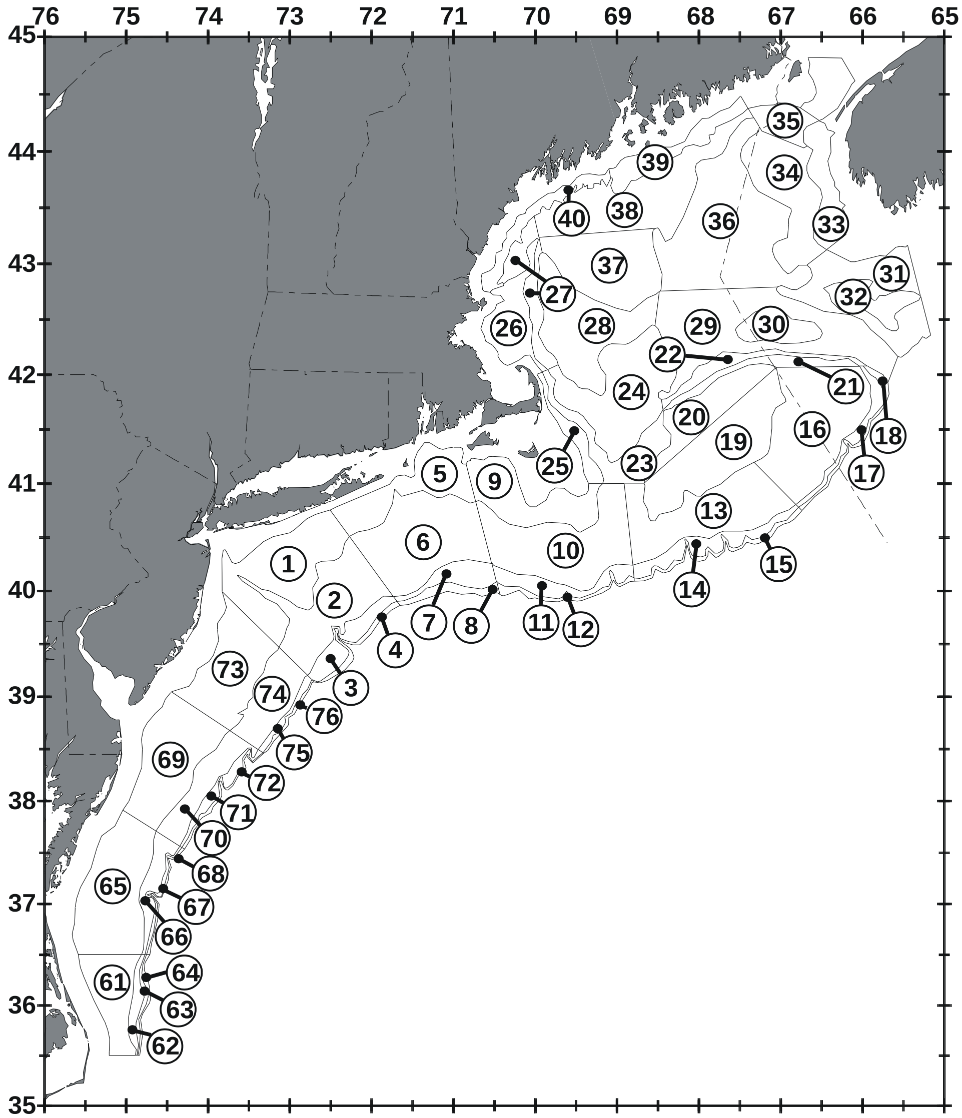

Figure 1. Offshore depth strata that have been sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.

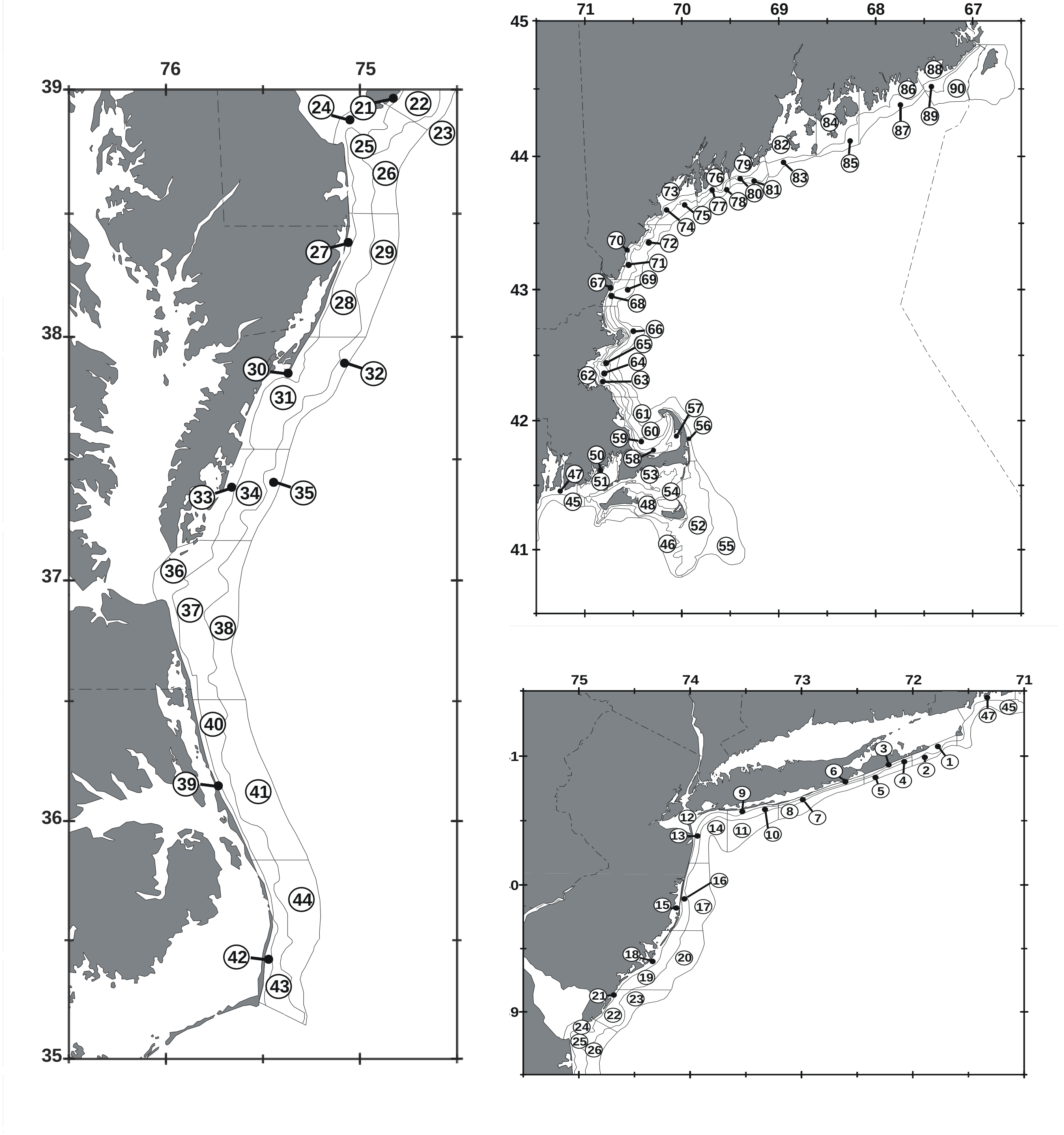

Figure 2. Inshore depth strata that have been sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.

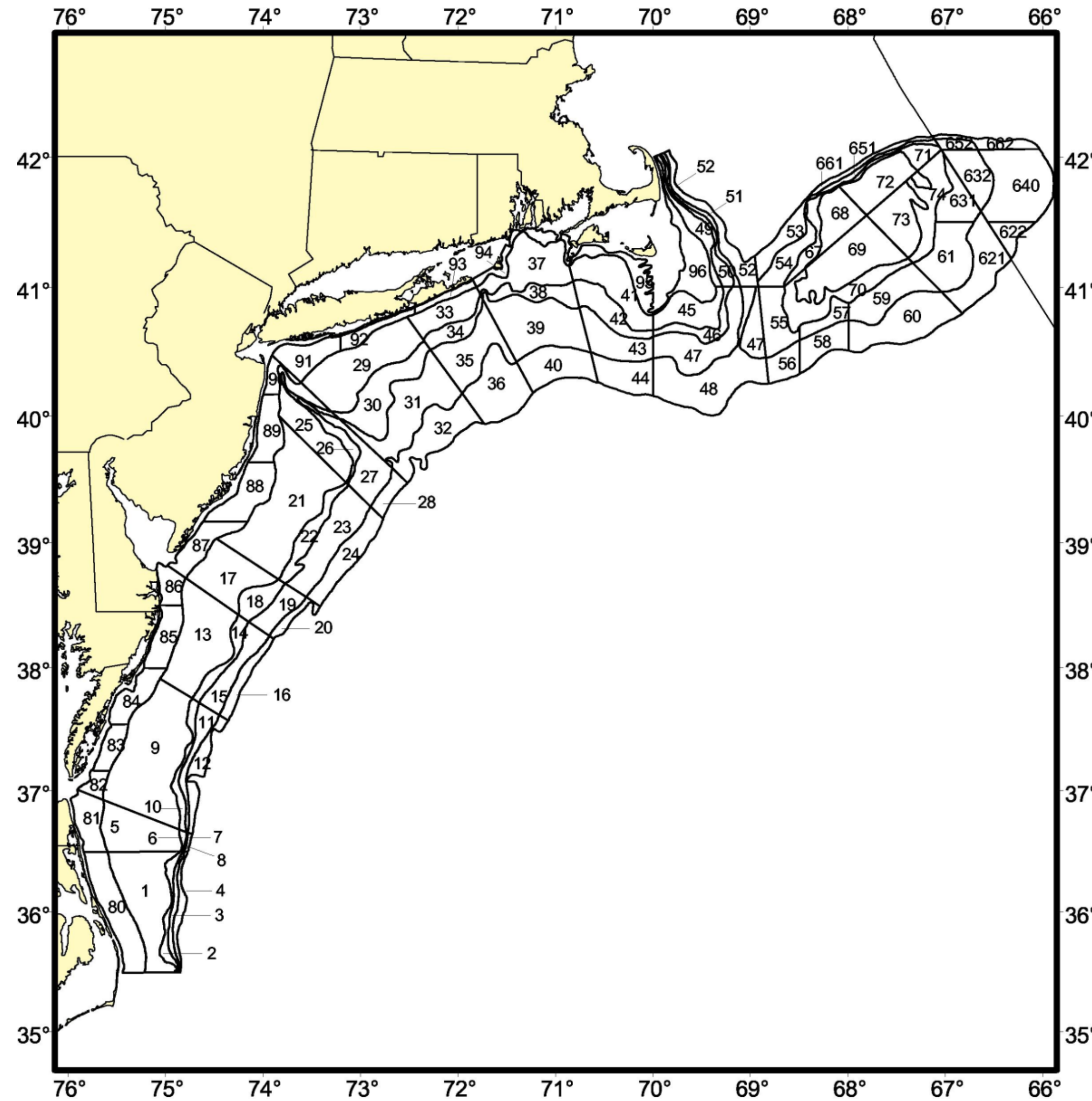

Figure 3. Depth strata sampled during Northeast Fisheries Science Center clam dredge research surveys.

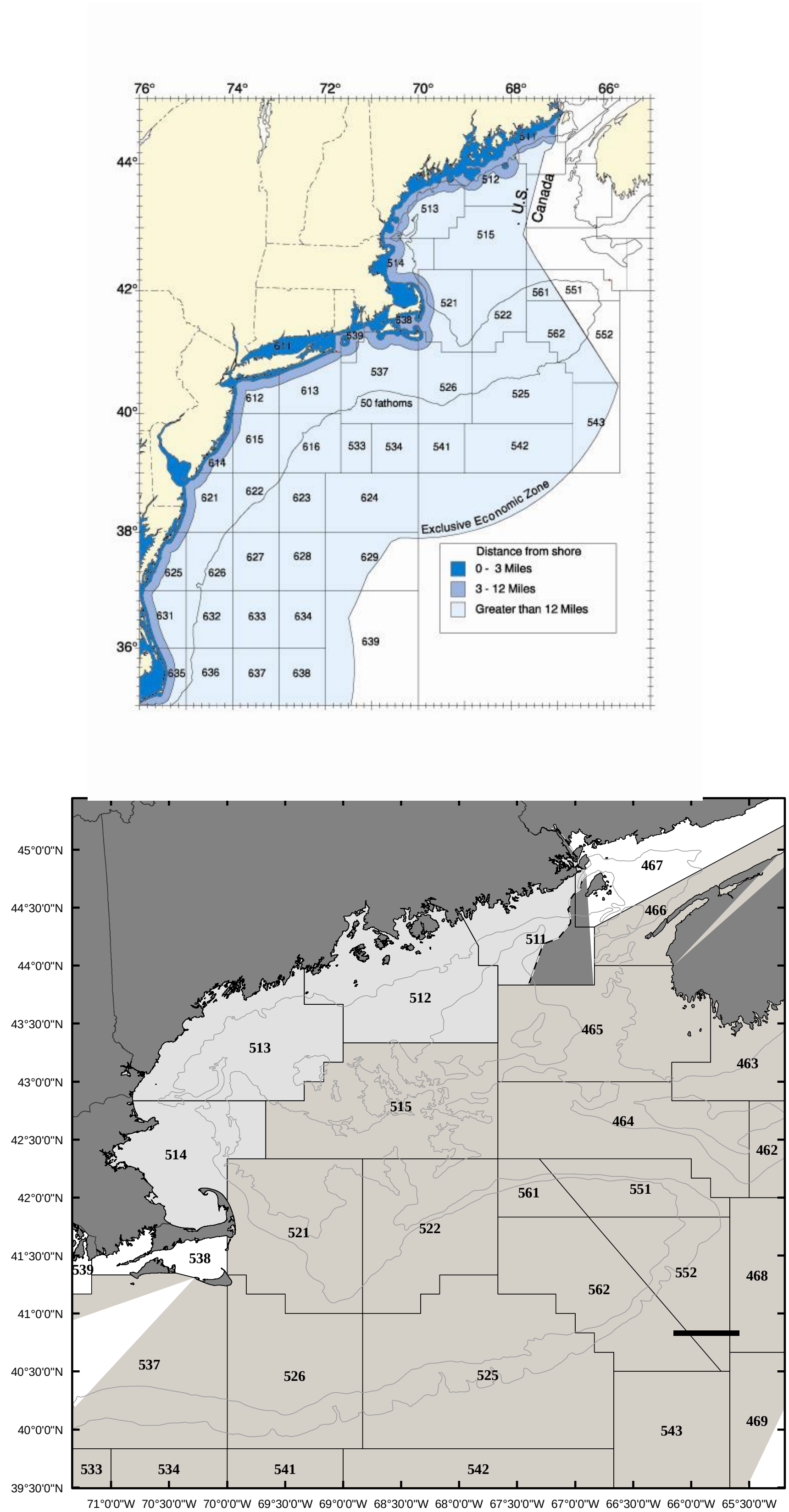

Figure 4. Statistical areas used for reporting commercial catches.

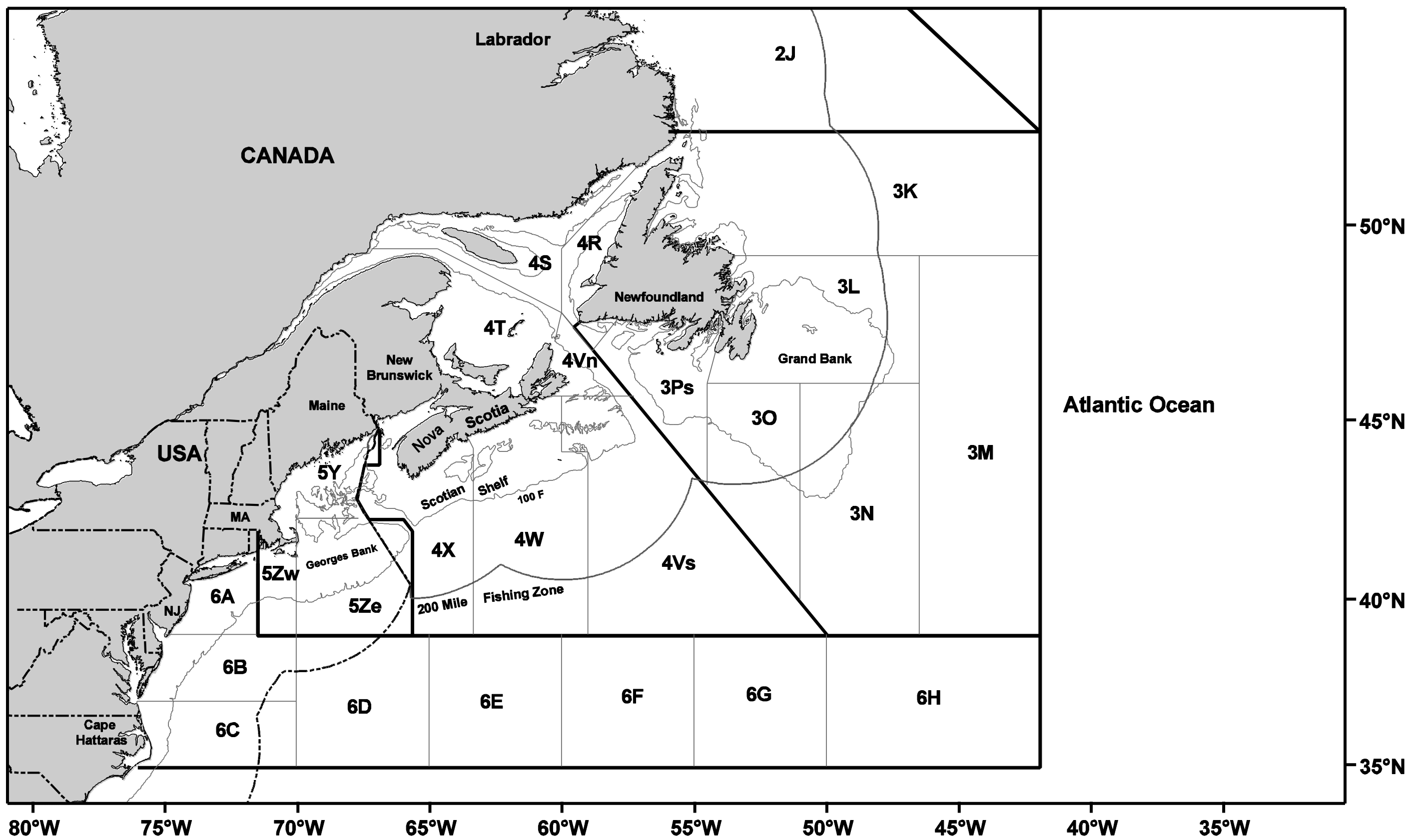

Figure 5. Catch reporting areas of the Northwest Atlantic Fisheries Organization (NAFO) for Subareas 3-6.

SCUP BENCHMARK STOCK ASSESSMENT FOR 2015

A1. Terms of Reference

1. Estimate catch from all sources including landings and discards. Include recreational discards, as appropriate. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize the uncertainty in these sources of data.

2. Present the survey data being used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.). Characterize the uncertainty and any bias in these sources of data.

3. Describe the thermal habitat and its influence on the distribution and abundance of scup, and attempt to integrate the results into the stock assessment.

4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results and previous projections.

5. State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY} and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

6. Evaluate stock status with respect to the existing model (from previous peer reviewed accepted assessment) and with respect to a new model developed for this peer review.
   a. When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the existing BRP estimates.
   b. Then use the newly proposed model and evaluate stock status with respect to "new" BRPs and their estimates (from TOR-5).

7. Develop approaches and apply them to conduct stock projections and to compute the statistical distribution (e.g., probability density function) of the OFL (overfishing level) (see Appendix to SAW TORs for definitions).
   a. Provide numerical annual projections (3 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment).
   b. Comment on which projections seem most realistic. Consider the major uncertainties in the assessment as well as sensitivity of the projections to various assumptions.
   c. Describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming overfished, and how this could affect the choice of ABC.

8. Review, evaluate and report on the status of the SARC, SSC, and Working Group research recommendations listed in most recent SARC reviewed assessment and review panel reports. Identify new research recommendations.

A2. Executive Summary

TOR 1. Estimate catch from all sources including landings and discards. Include recreational discards, as appropriate. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize the uncertainty in these sources of data.

The otter trawl is the principal commercial fishing gear. Commercial landings of scup peaked in 1960 at 22,200 mt, then decreased during the 1960s and ranged between 5,000 and 10,000 mt until the late 1980s. Commercial fishery quotas were implemented in 1997, and landings then ranged between 1,200 mt and 8,100 mt and averaged 4,000 mt during 1997-2014. Reported 2014 commercial fishery landings were 7,228 mt = 15.935 million lbs, about 77% of the commercial quota, and 68% of the total catch.

The NEFSC Northeast Fishery Observer Program (NEFOP) has collected information on landings and discards in the commercial fishery since 1989. In previous assessments, a method using the Geometric Mean Discards-to-Landings Ratio (GMDL) was been used to estimate scup discards. The Observer data have provided evidence that the Gear Restricted Areas (GRAs) implemented in 2000-2001 have been effective in reducing the scup discard percentage. The current assessment absolute estimates of scup discards using the GMDL approach, however, are produced on a temporal and spatial scale that is too coarse to directly evaluate the effectiveness of specific discard reduction measures (e.g., on a specific area or season basis). This prompted a re-examination of the methods used to estimate commercial fishery scup discards using the Standardized Bycatch Reporting Method (SBRM), which was implemented in February 2008 to address the requirements of the Magnuson-Stevens Fishery Conservation and Management Act. The SBRM for the estimation of discards has now been adopted for most NEFSC stock assessments that have been subject to a benchmark review since 2009. In this assessment, newly developed SBRM estimates of scup discards are compared the current GMDL estimates. The new SBRM discard estimate time series is used in the 2015 SAW 60 scup assessment. Estimated 2014 commercial fishery live discards were 1,140 mt = 2.513 million lbs (CV = 14%), about 11% of the total catch. The commercial discard mortality rate is assumed to be 100%.

Scup is the object of a major recreational fishery, with the greatest proportion of catches taken in the states of Massachusetts, Rhode Island, Connecticut and New York. Estimates of the recreational catch in numbers were obtained from the NMFS Marine Recreational Fishery Statistics Survey (MRFSS) for 1981-2011, and from the NMFS Marine Recreational Information Program (MRIP) for 2004-2014. The estimated recreational landings during 1981-2014 averaged 2,300 mt per year. Estimated 2014 recreational fishery landings were 2,025 mt = 4.464 million lbs (CV = 13%), about 64% of the recreational harvest limit, and 19% of the total catch.

The estimated recreational live discard during 1984-2011 ranged from 43 mt in 1999 to a high of 2,120 mt in 2010, averaging 600 mt per year. A discard mortality rate in the recreational fishery of 15% has been used in this and previous assessments, resulting in a time series average discard mortality of about 126 mt per year. Estimated 2014 recreational fishery dead discards were 227 mt = 0.500 million lbs (CV = 14%), about 2% of the total catch.

In response to fishing industry (both commercial and recreational) comments that the utility of fishery dependent catch per unit effort (CPUE) should be evaluated as indices of abundance for scup, a subset of the 2015 SAW 60 Scup Working Group (SWG) with an interest in fishery dependent CPUE compiled data and conducted analyses from a number of sources. The SWG noted generally that 1) the utility of the fishery dependent data as the basis for indices of abundance is limited in that some of them include only landings and not the total catch including discards, and so the resulting LPUE could be biased low relative to the true abundance of fish, 2) the use of only positive trips that catch scup may bias the LPUE or CPUE as well, and may be influenced by management regulations, and 3) the ratio of catch to effort has generally changed over time, and it is unclear how this change reflects real changes over time in fishing behavior due to fish abundance, management regulations, or changes in data reporting systems. The SWG concluded that further analysis beyond the scope of the assessment is needed to standardize the complexity of factors influencing fishery catch rates.

TOR 2. Present the survey data being used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.). Characterize the uncertainty and any bias in these sources of data.

Indices of stock abundance from the NEFSC winter, spring, and fall, Massachusetts DMF spring and fall, Rhode Island DFW spring and fall, University of Rhode Island Graduate School of Oceanography (URIGSO), Connecticut DEEP spring and fall, New York DEC, New Jersey DFW, and Virginia Institute of Marine Science (VIMS) Chesapeake Bay (ChesMMAP) and VIMS juvenile fish trawl surveys were used in the 2008 model calibration and in subsequent assessment updates through 2012. The NEAMAP spring and fall bottom trawl, RIDFW spring and fall survey age compositions, and RI Industry Cooperative trap survey data have been added to the 2015 SAW 60 assessment documentation. After a process of building the 2015 population model, the NEFSC spring, MADMF spring, RIDFW spring and fall, and VIMS ChesMMAP surveys were omitted from the model calibration.

TOR 3. Describe the thermal habitat and its influence on the distribution and abundance of scup and attempt to integrate the results into the stock assessment.

Some of the NEFSC winter, spring and fall trawl survey environmental data were summarized for the strata sets used for scup to investigate the correspondence between the environmental factors and the distribution of scup. The environmental factors were surface air temperature in degrees Celsius, surface and bottom water temperature in degrees Celsius, and bottom water salinity in parts per thousand (PPT). Examination of patterns in the survey catch, for spring and fall and day and night, confirms the irregular distributions of catch by temperature, salinity and depth and portend the difficulties of modeling the scup survey catch data. No well defined relationships are evident; i.e., small catches are as likely to be taken at shallow depths as large depths and at both warm and cold temperatures and large catches can occur over a relatively large range of depth and temperature (e.g, over a range of 70 meters or 10 degrees). Therefore, generalized linear model (GENMOD) and generalized additive model (GAM) based indices of abundance for the scup NEFSC seasonal survey data proved to be not useful, due to highly variable results owing from the inability of the models to adequately fit the variable and complex temporal and spatial properties of scup survey catches.

The NEFSC survey indices sometimes appear to mainly reflect the availability of scup to the survey, rather than true abundance, making it difficult to interpret large inter-annual changes in the indices. In particular, the spring 2002 and 2014 spring indices were unexpectedly much higher than adjacent indices, across all ages. In 2002, this 'availability event' appears to have been a response to higher than normal spring water temperatures, as large scup survey catches and bottom water with temperatures higher than 10^{o}C were distributed further inshore on the shelf than usual. Near 'normal' bottom conditions were present in 2014, but catches of large scup occurred near mid-shelf in large-area strata, and the 2014 indices were among the largest of the spring time series. These two sequences of potential 'availability events' make clear the difficulty that is encountered when interpreting survey indices for scup – do high survey indices indicate high availability, high abundance, or (more likely) some combination of both?

Estimates of proportions of thermal habitat surveyed in the NEFSC and NEAMAP surveys were developed that could be used to account for errors in survey observations related to temperature dependent changes in geographic distribution and seasonal migration. Time varying estimates of the proportion of thermal habitat suitability for scup surveyed on the Northeast US shelf were calculated for the NEFSC and NEAMAP bottom trawl surveys from 1975-2012. An average of 63 % of the thermal habitat suitability available to scup within the model domain (Cape Hatteras to Nova Scotia) was sampled from 1973-2012 by the fall NEFSC bottom trawl survey, while 50% was sampled in the spring. In the 2008-2012 NEAMAP surveys 14% of available thermal habitat suitability on the Northeast US continental shelf was sampled during the fall, while 11% was sampled in the spring. Yearly estimates of the proportion of thermal habitat suitability surveyed did not exhibit systematic trends.

Logit-transformed annual values of the 'proportion of suitable scup thermal habitat sampled' – i.e., availability - were used in a version of the final assessment model run to provide annually varying estimates of relative survey catchability (q), where q is the product of availability and survey gear efficiency (assumed = 1). The NEFSC survey qs were estimated to be variable without long term trend; NEAMAP survey qs were variable over the short 7-8 year time series. Given the similarity of results and still preliminary nature of the 'varying q' model version (the version of the model and associated documentation have not yet been released to the public), the 'varying q' version of the final model was not used for status evaluation.

TOR 4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results and previous projections.

The instantaneous natural mortality rate (M) for scup has been assumed to be 0.20 in all previous stock assessments. Given the historical maximum size and age of 41 cm and 15 years, recent observations of large fish (45 cm) up to age 12, the range of M (0.1 – 0.6) estimated by the empirical methods based on maximum age, and the likelihood profile of a preliminary assessment model run that indicated a best fit at 0.10 and of the final model at 0.15, the SARC decided there was no compelling reason to change from the previous assumption for M, and adopted a value of M = 0.20 for all ages and years in the 2015 SAW 60 assessment models.

The most recent benchmark peer review of the scup assessment was conducted by the 2008 Northeast Data Poor Stocks Working Group (DPSWG). The assessment model for scup changed in 2008 from a simple index-based model to a complex statistical catch at age model.
The fishery catch is modeled as four fleets: commercial landings, recreational landings, commercial discards and recreational discards. The time series of commercial discard and recreational catch estimates have been revised since the 2008 assessment.

Indices of stock abundance from NEFSC winter, spring, and fall, Massachusetts DMF spring and fall, Rhode Island DFW spring and fall, University of Rhode Island Graduate School of Oceanography (URIGSO), Connecticut DEEP spring and fall, New York DEC, New Jersey DFW, and Virginia Institute of Marine Science (VIMS) Chesapeake Bay (ChesMMAP) and VIMS juvenile fish trawl surveys were used in the 2008 model calibration and in subsequent assessment updates through 2012. The NEAMAP spring and fall bottom trawl, RIDFW spring and fall survey age compositions, and RI Industry Cooperative trap survey data have been added to the 2015 SAW 60 assessment documentation.

The ASAP model structural configuration and settings were significantly revised for the 2015 SAW 60 assessment. After a process of building the 2015 population model, the NEFSC spring, MADMF spring, RIDFW spring and fall, and VIMS ChesMMAP surveys were omitted from the model calibration. The general results (e.g., highest estimated stock size and low F in the last decade) are robust to all proposed alternative model configurations, including the length of the time series and a range of priors and likelihood component weightings. There is no consistent retrospective pattern in F, SSB, or recruitment evident in the scup assessment model. However, there are some indications of poor model fit from lack of correspondence among surveys (higher than expected variance when accounting for potential process error, some residual patterns), and there is uncertainty in the absolute magnitude of recent stock size estimates (although the terminal year estimates are calculated to be relatively precise with CVs less than or equal to 15%). Alternative survey catchabilities (e.g., relative, absolute using wing or door spread), starting years, commercial and recreational selectivity patterns (see note below), and time-varying survey catchability configurations can produce about a +/- 40% range of terminal year SSB. The SARC concluded, however, that the accepted model run provided the best balance between good retrospective diagnostics, acceptable fishery and survey fit diagnostics, and stability over most configurations, and recommended use of the ASAP model final run for status evaluation.

During the evaluation of the accepted model, sensitivities were examined which highlighted some additional risk. The main one of relevance to management is the choice of selectivity pattern. The base model has a strong domed selectivity pattern which could result in an increasing cryptic biomass given current stock trajectory. Conclusions regarding current stock status are robust to alternative selectivity patterns but decreased recruitment or increased F in the future could lead to divergence between domed and flattop selectivity model results.

Spawning stock biomass (SSB) decreased from about 68,000 mt in 1963 to about 5,000 mt in 1969, then increased to about 27,000 mt during the late 1970s. SSB declined through the 1980s and early 1990s to less than about 4,000 mt in the mid-1990s. With greatly improved recruitment and low fishing mortality rates since 1998, SSB increased to about greater than 100,000 mt = 220 million lbs since 2003. SSB was estimated to be 182,915 mt = 403 million lbs in 2014. There is a 90% probability that SSB in 2014 was between 153,000 and 222,000 mt (337 and 489 million lbs). Fishing mortality estimated at the 'apical' age 3 (model age 4) where full selection occurs varied between F = 0.5 and F = 2.0 during the 1960s and 1970s. Fishing mortality next peaked at about F = 1.5 in the 1990s. Fishing mortality decreased after 1994, falling to less than F = 0.15 since 2000, with F in 2014 = 0.127. There is a 90% probability that F in 2014 was between 0.093 and 0.149. Recruitment at age 0 averaged 98 million fish during 1963-1983, the period in which recruitment estimates are tightly constrained (CV = 0.1 on recruitment deviations and stock-recruitment scaler with fixed h =1) to ensure near constant recruitment before 1984, when fishery catch at age are not available. Since 1984, recruitment estimates from the model are influenced mainly by the fishery and survey catches at age, and averaged 109 million fish during 1984-2014. The 1999, 2006, and 2007 year classes are estimated to be the largest of the time series, at 222, 222, and 218 million age 0 fish. After below average recruitment in 2012 and 2013, the 2014 year class is estimated to be above average at 112 million age 0 fish.

Despite changes in model assumptions, configurations, and estimation procedures, the 'historical' retrospective analysis indicates that the general trends in stock biomass, recruitment, and fishing mortality have been consistent for the last decade. Estimates of SSB are in line with previous 2009-2012 projections, F is lower than from the 2011-2012 projections, and catch is lower than from the 2011-2012 projections, with the fishery in 2014 taking about 75% of the ACL.

TOR 5. State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY} and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

The 2008 Data Poor Stocks Working Group (DPSWG) Peer Review Panel accepted the ASAP model results as the basis for biological reference points and status determination for scup. Reference points were calculated using the non-parametric yield and SSB per recruit/long-term projection approach adopted for summer flounder and the New England groundfish stocks. For the estimation of MSY (Maximum Sustainable Yield) and SSBMSY (Spawning Stock Biomass at Maximum Sustainable Yield), the cumulative distribution function of the 1984-2007 recruitments (corresponding to the period of available fishery catches at age) was re-sampled to provide future recruitment estimates (mean = 117 million age 0 fish) for biomass reference point estimation. The existing reference points for scup are the 2008 DPSWG Peer Review Panel recommended F40% as the proxy for FMSY, and the corresponding SSBF40% as the proxy for SSBMSY. The F40% proxy for FMSY = 0.177, the proxy estimate for SSBMSY = SSB40% = 92,044 mt = 202.922 million lbs, and the proxy estimate for MSY = MSY40% = 16,161 mt = 35.629 million lbs (13,134 mt = 28.956 million lbs of landings and 3,027 mt = 6.673 million lbs of discards).

The SARC accepted the ASAP model S60_BASE_18 results as the basis for new biological reference points and status determination for scup. Reference points were again calculated using the non-parametric yield and SSB per recruit long-term projection approach. The cumulative distribution function of the 1984-2014 recruitments (corresponding to the period of available fishery catches at age) was re-sampled to provide future recruitment estimates (mean = 109 million age 0 fish) for biomass reference point estimation. The SARC recommended F40% as the proxy for FMSY, and the corresponding SSBF40% as the proxy for the SSBMSY biomass target. The F40% proxy for FMSY = 0.220; the proxy estimate for SSBMSY = SSB40% = 87,302 mt = 192.468 million lbs; the proxy estimate for the ½ SSBMSY biomass threshold = ½ SSB40% = 43,651 mt = 96.234 million lbs; and the proxy estimate for MSY = MSY40% = 11,752 mt = 25.909 million lbs (9,445 mt = 20.823 million lbs of landings and 2,307 mt = 5.086 million lbs of discards).

TOR 6. Evaluate stock status with respect to the existing model (from previous peer reviewed accepted assessment) and with respect to a new model developed for this peer review.
a. When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the existing BRP estimates.
b. Then use the newly proposed model and evaluate stock status with respect to "new" BRPs and their estimates (from TOR-5).

a) The existing model updated with new data indicated that the scup stock was not overfished and overfishing was not occurring in 2014 relative to the existing (old) biological reference points established in the 2008 Data Poor Stocks Working Group assessment (NEFSC 2009). The fishing mortality rate (F) was estimated to be 0.049 in 2014, below the fishing mortality threshold reference point = FMSY = F40% = 0.177. Spawning Stock Biomass (SSB) was estimated to be 219,066 metric tons (mt) = 483 million lbs in 2014, above the biomass target reference point = SSBMSY = SSB40% = 92,044 mt = 203 million lbs.

b) The scup stock was not overfished and overfishing was not occurring in 2014 relative to the new biological reference points recommended by the SARC. The fishing mortality rate (F) was estimated to be 0.127 in 2014, below the fishing mortality threshold reference point = FMSY = F40% = 0.220. Spawning Stock Biomass (SSB) was estimated to be 182,915 metric tons (mt) = 403 million lbs in 2014, above the biomass target reference point = SSBMSY = SSB40% = 87,302 mt = 192 million lbs.

TOR 7. Develop approaches and apply them to conduct stock projections and to compute the statistical distribution (e.g., probability density function) of the OFL (overfishing level) (see Appendix to SAW TORs for definitions).
a. Provide numerical annual projections (3 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment).
b. Comment on which projections seem most realistic. Consider the major uncertainties in the assessment as well as sensitivity of the projections to various assumptions.

c. Describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming overfished, and how this could affect the choice of ABC.

a) Stochastic projections were made to provide forecasts of stock size and overfishing level (OFL) catches in 2016-2018 consistent with the 2015 SAW 60 assessment biological reference points. The cumulative distribution function of the 1984-2014 recruitments (corresponding to the period of available fishery catches at age) was re-sampled to provide future recruitment estimates (mean = 109 million age 0 fish) for projections. The SWG conducted two sets of projections. Option A is proposed as the most realistic and assumes that given recent patterns in the fishery, it is likely that 75% of the 2015 ACL will be caught. Projection option B assumes that 100% of the 2015 ACL will be caught.

A) If the catch of scup in 2015 equals 75% of the specified ACL = 0.75 * 15,320 = 11,490 mt = 25.331 million lbs, the 2015 median (50% probability) landings are projected to be 10,058 mt = 22.174 million lbs and discards are projected to be 1,432 mt = 3.157 million lbs. The projected OFLs in 2016-2018 are 16,238, 14,556, and 13,464 mt (35.799, 32.090, and 29.683 million lbs).

B) If the catch of scup in 2015 equals 100% of the specified ACL = 15,320 mt = 33.775 million lbs, the 2015 median (50% probability) landings are projected to be 13,412 mt = 29.568 million lbs and discards are projected to be 1,908 mt = 4.206 million lbs. The projected OFLs in 2016-2018 are 15,745, 14,199, and 13,230 mt (34.712, 31.303, and 29.167 million lbs).

The biological inputs to the scup stock assessment are based on well-founded assumptions (e.g., for M, for discard mortality in the fisheries) and precisely estimated biological parameters (e.g., growth, age, maturity, and mean weights). Further, the research survey index CVs used in model calibration have been increased by 50-100% (depending on assessment model fit diagnostics) to account for process error. A broad set of model configurations produced a range about +/- 40% in the average estimate of terminal year SSB of about 180,000 mt (396 million lbs). The internal retrospective average error (for the terminal 7-years) of the assessment is low, at less than 10% for both SSB and F. The analytically derived CV for the 2014 SSB is 11%, the CV for the 2014 F is 15%, and the CV for the 2014 age 1 and older stock size total number is 15%. Given these properties of the 2015 scup stock assessment, it was concluded that an approximate doubling of the analytically derived 2016-2018 OFL CVs to 30% is a reasonable and sufficient adjustment to account for additional uncertainty in the assessment such as the magnitude of domed fishery selection, the magnitude of commercial fishery discards and recreational catch during the early part of the assessment model time series, and potential error in the aging process.

b) Both projection options have a realistic probability of being achieved and indicate there is zero percent chance that SSB will fall below the biomass threshold in 2016-2018 fishing at the OFL.

c) The scup stock has a low probability of becoming overfished in the short term (2016-2018) given recent trends in productivity and the responsiveness of the management regime.

TOR 8. Review, evaluate and report on the status of the SARC, SSC, and Working Group research recommendations listed in most recent SARC reviewed assessment and review panel reports. Identify new research recommendations.

Nine of the 12 previously identified research recommendations were either addressed in full or significant progress was made. No progress has been made on a) quantifying contemporary discard mortality rates, b) quantifying the degree of bias in landings reporting and discard estimation including non-compliance, or c) development of a management strategy evaluation of alternative approaches to setting quotas. Six new research recommendations were developed.

A3. Working Group Process

The Stock Assessment Workshop (SAW) Scup Working Group (SWG) met during April 20-22, 2015 at the Northeast Fisheries Science Center (NEFSC) to develop the benchmark stock assessment of scup through 2014. The following people provided data, participated in the preparation, and/or where present for discussion of the assessment in the 2015 SWG:

Gary Shepherd	NEFSC Coastal/Pelagic Resources Task Leader; SWG Chair
Mark Terceiro	NEFSC Demersal Resources Task Leader, Scup Assessment Lead
Julia Beaty	Mid-Atlantic Fishery Management Council (MAFMC)
Mike Bednarski	Massachusetts Division of Marine Fisheries (MADMF)
Chris Bonzek	Virginia Institute of Marine Science (VIMS)
Steve Cadrin	University of Massachusetts-Dartmouth, School of Marine Science and Technology(SMAST), Science Center for Marine Fisheries (SCeMFiS)
Kirsten Curti	NEFSC Population Dynamics Branch
Peter Clarke	New Jersey Division of Fish and Wildlife (NJDFW)
Kiley Dancy	Mid-Atlantic Fishery Management Council (MAFMC)
Meaghan Lapp	Seafreeze Ltd.
Robert Leaf	University of Southern Mississippi (USM), Science Center for Marine Fisheries (SCeMFiS)
Chris Legault	NEFSC, Assessment Methods Task Leader
Jean-Jacques McGuire	Science Center for Marine Fisheries (SCeMFiS)
John Manderson	NEFSC Cooperative Research Sandy Hook Laboratory
John Maniscalco	New York Dept. of Environ. Conservation (NYDEC); ASMFC Technical Committee Chair
Jason McNamee	Rhode Island Division of Fish and Wildlife (RIDFW),
Alicia Miller	NEFSC Population Dynamics Branch
Tim Miller	NEFSC Population Dynamics Branch
Loretta O’Brien	NEFSC Population Dynamics Branch
Mike Palmer	NEFSC Population Dynamics Branch
Paul Rago	NEFSC Population Dynamics Branch
Kirby Rootes-Murdy	Atlantic States Marine Fisheries Commission (ASMFC)
Gregory Wojcik	Connecticut Department of Energy and Environmental Protection (CTDEEP)

A4. Introduction

A4.1 Biology

Scup (*Stenotomus chrysops*) is a schooling continental shelf species of the Northwest Atlantic that is distributed primarily between Cape Cod and Cape Hatteras (Morse 1978). Scup undertake extensive migrations between coastal waters in summer and offshore waters in winter. Scup migrate north and inshore to spawn in spring, with larger fish (age 2 and older) tending to arrive in spring first, followed by smaller fish (Neville and Talbot 1964; Sisson 1974). Larger scup are found during the summer near the mouth of large bays and in the ocean within 20 fathoms (120 feet = 37 meters), and often inhabit rough bottom areas. Smaller scup are more likely to be found in shallow, smooth bottom areas of bays during summer (Morse 1978). Scup migrate south and offshore in the fall as the water temperature decreases, arriving in offshore wintering areas by December (Hamer 1970; Morse 1978).

Historical tagging studies in the 1930s and 1950s (e.g., Neville and Talbot 1964; Cogswell 1960, 1961; Hamer 1970, 1979) have indicated the possibility of two stocks of scup, one in Southern New England waters and another extending south from New Jersey waters. However, the lack of definitive locations for tag return data coupled with distributional data from the NEFSC bottom trawl surveys support the concept of a single unit stock extending from Cape Hatteras north to New England (Mayo 1982). The NEFSC conducted a scup tagging program in cooperation with commercial and recreational fishermen in MA, RI, CT, and NY during 2005, tagging over 5,600 fish. The recapture rate was low at only 70 fish (1%) through 2008, with recoveries ranging from inshore waters off Southern New England to the edge of the shelf around Hudson Canyon.

Love and Chase (2009) compared morphology among scup populations by means of a geometric, landmark-based analysis of morphological and meristic traits for 180 individuals sampled in 2005 that were sexed and staged to maturity. They found morphological differences between a North Atlantic Bight (north of Cape Hatteras, NC) population and two South Atlantic Bight (south of Cape Hatteras) populations, at extremes of the scup's range in the northwestern Atlantic Ocean.

A4.2 Age and Growth

Historical studies of scup age and growth with reliable data include those of Finkelstein (1969a, b), Hamer (1970, 1979), Campbell et al. (1982), Dery and Rearden (1979), and Pentilla et al. (1989). These studies indicated that scup are relatively slow growing fish with maximum lengths of 37-41 cm and maximum ages of 13-15 years. Finkelstein (1969a, b) found both males and females to age 15, and noted that scup do not exhibit sexual dimorphism.

Age and growth information is available for full calendar years from NEFSC commercial port sampling from 1984-2014 and from NEFSC seasonal bottom trawl surveys from 1977-2014. The largest and oldest fish sampled by the NEFSC were a 46 cm age 10 fish sampled in 1973 and a 45 cm age 12 fish sampled in 2014; and 38-41 cm age 14 fish sampled in 1973, 1976, 1978, and 2014. For the NEFSC bottom trawl survey ages during 2008-2014, overall scup ageing precision, based on sample-size weighted intra- and inter-reader ageing agreement, averaged 90% with an overall Coefficient of Variation (CV) of 3%. For the NEFSC commercial port sample ages during 2008-2014, overall scup ageing precision averaged 83% with an overall Coefficient of Variation (CV) of 2%.

Finkelstein (1969a) used data from 1,289 fish sampled from New York Bight in the 1960s to estimate the von Bertalanffy growth parameters for scup, finding Linf of about 34 cm for males and 37 cm for females, and k values of 0.27 and 0.22. Hamer (1979) used data from 1,429 fish sampled off New Jersey in the late 1950s and found a maximum age of 13 and estimated Linf for sexes combined to be about 34 cm and k to be 0.20.

The NEFSC trawl survey data for 1977-2014 were used to estimate growth parameters for males, females, and sexes combined. The full time series data provide parameters for males (n = 6,440) of Linf = 49.6 cm, k = 0.12, with maximum length of 38 cm and age of 10; parameters for females (n = 7,826) of Linf = 51.7 cm, k = 0.11, with maximum length of 41 cm and age of 14; and parameters for sexes combined (n = 20,197, including small fish of undetermined sex) of Linf = 46.6, k = 0.15, with maximum size of 41 cm and age of 14 (see table below). The growth curves are generally similar for all studies and sexes through about 30 cm and age 6, where they begin to diverge, due to the presence of larger fish of both sexes at ages 7 and older in the NEFSC survey data, compared to the same age fish in the Finkelstein (1969a) and Hamer (1970) data sets. In the most recent stock assessment update (Terceiro 2012), ages are grouped together for ages 7 and older (age 7+ 'plus group').

Study	N fish	Max age (M, F)	Linf (M, F, B)	k (M, F, B)
Finkelstein (1969a)	1,289	15,15	34.3,37.4	0.27,0.22
Hamer (1970)	1,429	13	34.1	0.29
NEFSC SVs	20,197	10,14	49.6, 51.7, 46.6	0.12, 0.11, 0.15

A4.3 Length-Weight Relationship

Morse (1978) used NEFSC trawl survey data from 2,234 New York Bight fish sampled during 1974-1975 to estimate the length weight parameters that are used for NEFSC commercial fishery length to weight conversions. Morse (1978) reported that an analysis of covariance showed no significant difference between males and females. Wigley *et al.* (2003) updated the length-weight parameters used in audits of the NEFSC trawl survey data, using individual length and weight information from 3,309 fish for 1992-1999. In the current work, individual length and weight information from 8,557 fish (3,572 males, 4,985 females) sampled during 1992-2013 were used to estimate length-weight parameters for comparison with the earlier studies to judge whether changing from the historical Morse (1978) parameters would be justified.

A comparison among these alternative compilations indicates very little difference in the estimated length-weight relationships from Morse (1978), Wigley *et al.* (2003), and the current examination for the NEFSC trawl survey data. The curves are virtually identical through a fork length of 30 cm at age 6, a threshold below which over 95% of the fishery catch has occurred. As noted earlier, larger fish of age 7 and older fish compose the assessment 'plus group.' Above 30 cm, the curves begin to diverge, with the Morse (1978) relationship providing mean weights at 35 cm and larger sizes that are about 10% higher than the current NEFSC survey combined relationship. Based on the consistency of these L-W relationships through 95% of the length range of the fishery catch, the Morse (1978) length-weight parameters were retained for this assessment.

A4.4 Condition Factor

Fulton's condition factor, K, is a measure of the relationship between fish length and weight that attempts to quantify the 'condition' of an individual or group of fish. Nash *et al.* (2006) note that it was Heincke (1908) who first used K as a measure of 'condition,' building on the 'cubic law' of growth in weight first introduced by Fulton (1904; K = x*weight / length**3, where x is a constant to scale K near 1). Nash *et al.* (2006) further point out that it was Ricker (1957) who first attributed the factor K to Fulton and coined the name 'Fulton's condition factor.' Froese (2006) reviewed the derivations of fish length-weight relationships and condition factors, and recommended use of a modern version of Fulton's K incorporating estimated length-weight relationship parameters as a better expression of 'relative condition factor.' The NEFSC spring and fall trawl survey sample data were examined for trends in relative condition factor by season and sex. Individual fish weight collection for scup began on NEFSC surveys in fall 1992. There are no long-term trends in condition factor by season or sex.

A4.5 Sex Ratio

The NEFSC winter, spring and fall trawl survey raw sample data were examined for trends in sex ratio by season and age, expressed as the proportion of females at age. The spring and fall series have sufficient data for the compilation beginning in 1977; the winter survey was conducted from 1992-2007. In all the series there are some years with no fish at ages older than 2.

In the winter survey, the proportion of females showed no trend for ages 1 and 2 and the proportion female generally varied from 0.4 to 0.8 (40 to 80% females), and the mean proportion was about 0.6. For age 3, the proportion increased from about 0.4 in the early 1990s to 1.0 by 1992, with a mean of about 0.6. For ages 4 to 6, the proportions are highly variable with no valid (i.e., ones that one would have confidence in, given the low sample sizes) trends due to low sample sizes.

In the spring survey, the proportion of females showed no trend for ages 1-3 and the mean proportion was about 0.6 for all three ages. For age 4, the proportion had an increasing trend, has been highly variable, and a mean of about 0.5. For ages 5 and 6, the proportions are highly variable with no valid trends, and mean proportions of 0.5-0.7.

In the fall survey, the proportion of females shows no trend for age 0 since 1981 and the mean proportion was 0.5. For age 1, the proportion has increased from about 0.5 in the 1980s to about 0.7 since the mid-2000s, with a mean of about 0.6. For age 2, the proportion has increased from about 0.5 in the 1980s to about 0.6 since the mid-2000s, with a mean of about 0.5. For age 3, the proportion was highly variable until about 2000, and has since varied from 0.4 to 0.7 with a mean of about 0.6. For ages 4 and 5, the proportions are highly variable with no valid trends, and mean proportions of about 0.6. Across all NEFSC surveys and ages, the proportion female has varied from 0.4 in 1981 to 0.7 in 2011, with a mean of 0.6.

A4.6 Maturity

Spawning occurs from May through August and peaks in June. Finkelstein (1969b) examined 849 male and 440 female scup and found the length and age at maturity for scup to be 16 cm and two years for both males and females, with spawning between May and July. Morse

(1978) found that about 50% of age-2 scup are sexually mature at about 17 cm total length while nearly all scup of age 3 and older are mature. O'Brien et al. (1993) used NEFSC spring trawl survey data for 1985 and 1987-1990 (516 total fish) and estimated L50% to be 15.6 cm for males and 15.5 cm for females.

For this benchmark assessment of scup, available maturity at age data from the NEFSC spring trawl survey for 1981-2013 (34 years) have been examined. The current data set consists of 1,472 males from age 1 to 10 and 1,828 females from age 1 to 11, for a total of 3,300 fish. The median length at maturity (50^{th} percentile, L_{50}) was estimated at 15.6 cm (95% CI from 13.5 to 18.0 cm) for males, 16.3 cm (95% CI from 14.0 to 18.6 cm) for females, close to the Finkelstein (1969b), Morse (1978), and O'Brien et al. (1993) estimates noted above.

For the 1981-2013 NEFSC time series, the observed percent mature of males is 12% at age 1, 81% at age 2, 96% at age 3, and 100% for age 4 and older. The observed percent mature of females is 12% at age 1, 76% at age 2, 97% for age 3, and 100% for age 4 and older. The observed percent mature of sexes combined for the time series is 12% at age 1, 76% at age 2, 97% at age 3, and 100% for age 4 and older. Estimated maturity ogives for the time series indicate the maturity of both males and females to be 4% at age 1, 76% at age 2, and 100% at ages 3 and older, and for sexes combined to be 4% at age 1, 71% at age 2, 99% at age 3, and 100% at ages 4 and older.

The NEFSC spring survey data were pooled into three year time blocks (except for the first [1981-1984] and last [2009-2013] blocks) to look for trends or abrupt changes in the observed proportions mature over time. For many of the blocks, the male and female patterns are very similar, generally with age 1 observed maturity at 0-10%, age 2 at 60-80%, and age 3 at 90-100%. For some of the blocks (1991-1993, 1994-1996, 1997-1999) there is more divergence between the sexes at age 2. The most recent 2009-2013 block shows the lowest observed proportion mature for both sexes at age 2, with males at 63% and females at 61%, and sexes combined at 62%.

The next step was to estimate maturity ogives for three-year moving windows, in an attempt to stabilize the inter-annual variability and improve precision. Estimated three-year proportions mature for ages 1, 2, and 3 by sex provided a relatively smooth inter-annual pattern. Finally, in keeping with the approach from the previous benchmark assessment (NEFSC 2009), a sexes combined three-year moving window ogive was compiled from the NEFSC 1981-2014 spring survey data to be used with the fishery catch at age to compute SSB in the assessment model. The three-year moving window approach provides a) well-estimated proportions mature at age, b) estimated maturities at age that transition smoothly over the course of the time series, and c) reflect the recent trend of decreasing maturity at ages 1 and 2 (see table below). The average of the values for 1981-1983 (i.e., maturity at ages 0 and 1 = 0.00, maturity at age 2 = 0.83, maturity at ages 3+ = 1.00) was used in subsequent modeling for years before 1981.

MAT3	0	1	2	3	4	5	6	7+
1981	0.00	0.00	0.89	1.00	1.00	1.00	1.00	1.00
1982	0.00	0.00	0.83	1.00	1.00	1.00	1.00	1.00
1983	0.00	0.00	0.78	1.00	1.00	1.00	1.00	1.00
1984	0.00	0.01	0.68	1.00	1.00	1.00	1.00	1.00
1985	0.00	0.25	0.83	1.00	1.00	1.00	1.00	1.00
1986	0.00	0.21	0.77	1.00	1.00	1.00	1.00	1.00
1987	0.00	0.21	0.78	1.00	1.00	1.00	1.00	1.00
1988	0.00	0.06	0.67	1.00	1.00	1.00	1.00	1.00
1989	0.00	0.01	0.83	1.00	1.00	1.00	1.00	1.00
1990	0.00	0.01	0.90	1.00	1.00	1.00	1.00	1.00
1991	0.00	0.03	0.76	1.00	1.00	1.00	1.00	1.00
1992	0.00	0.03	0.68	1.00	1.00	1.00	1.00	1.00
1993	0.00	0.06	0.55	1.00	1.00	1.00	1.00	1.00
1994	0.00	0.06	0.70	1.00	1.00	1.00	1.00	1.00
1995	0.00	0.08	0.73	1.00	1.00	1.00	1.00	1.00
1996	0.00	0.05	0.89	1.00	1.00	1.00	1.00	1.00
1997	0.00	0.02	0.86	1.00	1.00	1.00	1.00	1.00
1998	0.00	0.01	0.89	1.00	1.00	1.00	1.00	1.00
1999	0.00	0.01	0.85	1.00	1.00	1.00	1.00	1.00
2000	0.00	0.02	0.81	1.00	1.00	1.00	1.00	1.00
2001	0.00	0.05	0.80	1.00	1.00	1.00	1.00	1.00
2002	0.00	0.08	0.80	1.00	1.00	1.00	1.00	1.00
2003	0.00	0.08	0.74	1.00	1.00	1.00	1.00	1.00
2004	0.00	0.06	0.70	1.00	1.00	1.00	1.00	1.00
2005	0.00	0.02	0.64	1.00	1.00	1.00	1.00	1.00
2006	0.00	0.04	0.79	1.00	1.00	1.00	1.00	1.00
2007	0.00	0.05	0.59	1.00	1.00	1.00	1.00	1.00
2008	0.00	0.06	0.61	1.00	1.00	1.00	1.00	1.00
2009	0.00	0.03	0.54	1.00	1.00	1.00	1.00	1.00
2010	0.00	0.02	0.58	1.00	1.00	1.00	1.00	1.00
2011	0.00	0.02	0.58	1.00	1.00	1.00	1.00	1.00
2012	0.00	0.02	0.51	1.00	1.00	1.00	1.00	1.00
2013	0.00	0.01	0.58	1.00	1.00	1.00	1.00	1.00
2014	0.00	0.01	0.52	1.00	1.00	1.00	1.00	1.00

A4.7 Predators and Prey

The NEFSC trawl survey foods habits 1973-2013 database was investigated to identify the most frequent predators and prey of scup. Scup was identified to species as a prey item in 527 predator stomachs. Spiny dogfish was the predator in 127 cases (24%), followed by summer flounder (119 cases, 23%), bluefish (59 cases, 11%), monkfish (45 cases, 9%), smooth dogfish (38 cases, 7%), and weakfish (28 cases, 5%), with other fish species accounting for the other 111 cases and 21%, including mostly species of rays, skates, and sharks. The data are insufficient to calculate total absolute predator consumption of scup.

The current investigation confirmed the work of Bowman et al. (2000), which indicated that scup below 25 cm in length consume mainly cnidarians, amphipods, mysids, and annelid and polychaete worms, while scup above 25 cm consume mainly squids and small fish including silversides and butterfish.

A4.8 Fishery Management

The Mid-Atlantic Fishery Management Council (MAFMC) and Atlantic States Marine Fisheries Commission (ASMFC) jointly manage scup under Amendment 8 (1997) to the Scup, Scup, and Black Sea Bass Fishery Management Plan (FMP). The assessment and management unit includes all scup from Cape Hatteras, North Carolina north to the US-Canada border.

Amendment 8 to the FMP established a recovery plan for scup under which exploitation rates were to be reduced to 47% (F=0.72) during 1997-1999, to 33% (F=0.45) during 2000-2001, and to 21% (F=0.26) during 2002-2007. These goals were to be attained through implementation of a Total Allowable Catch (TAC) that included a commercial quota and a recreational harvest limit, commercial fishery trips limits, commercial fishery net minimum mesh sizes, fish trap minimum escape vent and fish sizes and closed areas, and recreational fishery minimum fish sizes, possession limits, and closed seasons.

Amendment 12 (1998) to the FMP established a biomass threshold (a proxy for one-half BMSY) for scup based on the three-year moving average of the NEFSC spring bottom trawl survey index of Spawning Stock Biomass (SSB) during 1977-1979, which was perceived to be a period when the stock was near one-half BMSY. The scup stock was considered to be overfished when the SSB index fell below a value of 2.77 SSB kg per tow. Amendment 12 defined overfishing for scup to occur when the fishing mortality rate exceeded the threshold fishing mortality of Fmax = 0.26 (as a proxy for FMSY).

Broad scale Gear Restricted Areas (GRAs) for scup were implemented in November 2000 under the framework provisions of the FMP to reduce discards of scup in the small mesh fisheries for *Loligo* squid and silver hake. Two Northern Areas off Long Island were implemented for November through January, while a Southern Area off the mid-Atlantic coast was implemented for January through April. The size and boundaries of the GRAs were modified in December 2000 and again in 2005 in response to commercial fishing industry recommendations.

Amendment 14 (2007) to the FMP defined the biomass target, implemented a stock rebuilding plan for scup, and made the GRAs modifiable through a framework adjustment. The stock was to fully rebuild to the biomass target by January 1, 2015. The proxy for BMSY was two times the 3-year moving average of the NEFSC spring index of SSB during 1977-1979 noted earlier, or 2*2.77 = 5.54 SSB kg per tow. A target fishing mortality rate of F = 0.10 was to be applied in each year of a 7 year rebuilding period beginning in 2008. A TAC of 4,491 mt = 9.901 million lbs and corresponding Total Allowable Landings (TAL) of 3,329 mt = 7.339 million lbs were established for 2008 to achieve the target F.

Amendment 15 (2011) established Annual Catch Limits (ACLs) and Accountability Measures (AMs) for scup to comply with the 2006 reauthorization of the Magnuson-Stevens Act (MSA); Amendment 16 (2013) revised the fishery AMs for each FMP species; Amendment 19 (2014) further modified the AMs for recreational fisheries.

The current overfished and overfishing definitions are based on revisions to the FMP through Framework 7 (2007) and use the values established in Amendments 12 (1998) and 14 (2007) as follows:

"The maximum fishing mortality threshold for each of the species under the FMP is defined as FMSY (the Fishing mortality producing Maximum Sustainable Yield or a reasonable proxy thereof) as a function of productive capacity, and based upon the best scientific information consistent with National Standards 1 and 2. Specifically, FMSY is the fishing mortality rate associated with MSY. The maximum fishing mortality threshold (FMSY) or a reasonable proxy may be defined as a function of (but not limited to): total stock biomass, spawning stock biomass, total egg production, and may include males, females, both, or combinations and ratios thereof which provide the best measure of productive capacity for each of the species managed under the FMP. Exceeding the established fishing mortality threshold constitutes overfishing as defined by the Magnuson-Stevens Act.

The minimum stock size threshold for each of the species under the FMP is defined as one-half BMSY (or a reasonable proxy thereof) as a function of productive capacity, and based upon the best scientific information consistent with National Standards 1 and 2. The minimum stock size threshold (one-half BMSY) or a reasonable proxy may be defined as a function of (but not limited to): total stock biomass, spawning stock biomass, total egg production, and may include males, females, both, or combinations and ratios thereof which provide the best measure of productive capacity for each of the species managed under the FMP. The minimum stock size threshold is the level of productive capacity associated with the relevant one-half MSY level. Should the measure of productive capacity for the stock or stock complex fall below this minimum threshold, the stock or stock complex is considered overfished. The target for rebuilding is specified as BMSY (or reasonable proxy thereof) at the level of productive capacity associated with the relevant MSY level, under the same definition of productive capacity as specified for the minimum stock size threshold."

A4.9 Previous Stock Assessments

A peer-reviewed assessment including an analytical population model was accepted in 1995 by SAW 19 (NEFSC 1995). The assessment featured a virtual population analysis (VPA) modeled in the ADAPT framework (Conser and Powers 1990), with commercial and recreational landings and discards at age estimates, and with state and NEFSC abundance indices used for calibration. The 1995 SAW 19 assessment indicated that F in 1993 was 1.3, and SSB was 4,600 mt = 10.141 million lbs. A yield per recruit (YPR) analysis indicated that Fmax = 0.236.

The VPA was updated through 1996 and reviewed by the 1997 SAW 25 (NEFSC 1997), but due to concerns over the low intensity of fishery length sampling in the 1990s, uncertainty about the magnitude of commercial discards in the late 1990s, and the ongoing high variability and imprecision of survey indices, the VPA was not accepted as a basis for management decisions. Assessment conclusions were therefore based primarily on trends in NEFSC and state agency survey indices and catch curve analyses using those survey data. The 1997 SAW 25 was able to conclude that in 1996 scup were over-exploited and near record low abundance levels.

The scup assessment was next updated through 1997 and reviewed by the 1998 SAW 27 (NEFSC 1998). Several configurations of a surplus production model (ASPIC; Prager 1994) were reviewed in addition to an updated VPA, but like the VPA, the production model results were not accepted due to concerns over the validity of the input fishery and survey data. An updated YPR analysis was accepted and indicated that Fmax = 0.26. The 1998 SAW 27 concluded that a VPA or other analytical model formulation for scup would not be feasible until the quality of the input data, particularly the precision of discard estimates, was significantly improved and that scup was over exploited and at a low biomass level.

The 1998 SAW 27 Panel recommended the scup assessment be based on the long-term time series of NEFSC trawl survey indices and fishery catches. The Panel noted that commercial landings were sustained at about 19,000 mt = 41.888 million lbs annually during the mid-1950s to mid-1960s, and concluded that the stock was likely near BMSY during that period (Figure A1). The nearest subsequent peak in NEFSC survey indices occurred in the late 1970s. Commercial and total fishery catches in the late 1970s were about one-half of those in the 1950s to 1960s, and so the late 1970s were identified as a period when the stock was likely to have been near one-half of BMSY. The Panel considered the NEFSC spring survey series to be most representative of SSB, since older ages were better represented in the age structure than in the NEFSC fall survey or other state agency surveys. The 1998 SAW 27 Panel recommended that the three-year moving average of the NEFSC spring bottom trawl survey index of SSB during 1977-1979 (2.77 SSB kg per tow) be used as the proxy biomass threshold (one-half BMSY) and that Fmax = 0.26 be used as the proxy fishing mortality threshold (FMSY). Those recommendations were subsequently adopted for the biological reference points in Amendment 12 to the FMP.

The scup assessment was next updated through 1999 and reviewed by the 2000 SAW 31 (NEFSC 2000). The assessment continued to be based on trends in research survey indices and fishery catches and indicated that the stock was overfished and that overfishing was occurring. The stock assessment was reviewed again by the 2002 SAW 35 and included fishery data through 2001 (NEFSC 2002). The assessment was again based on trends in research survey indices and fishery catches, but indicated that the stock was no longer overfished, although the 2002 SAW 35 Panel concluded that stock status with respect to the overfishing definition could not be evaluated due to the uncertainty of F estimates derived from research survey catch curve calculations. The 2002 SAW 35 Panel found sufficient evidence to conclude that the relative exploitation rates had declined in recent years and that survey observations indicated strong recruitment and some rebuilding of age structure.

During 2002-2008, the status of the stock was evaluated by the MAFMC Monitoring Committee using trends in research survey indices and fishery catches. A relative exploitation index based on the annual total fishery landings and the NEFSC spring three-year average SSB index was used as a proxy for F to monitor status with respect to overfishing and provide guidance to the specification of the annual TAC. A projection of the NEFSC spring survey SSB index using assumptions about maturity, partial recruitment to the survey, and the level of future recruitment as indexed by the NEFSC spring survey at age 1 was used in Amendment 14 to the FMP to forecast stock rebuilding and set the F target for 2008-2015. An update to the status monitoring metrics was completed in 2008 to aid in the specification of fishery regulations for 2009. The update indicated that while the stock was overfished in 2007, the exploitation rate was at about the F target, suggesting that overfishing was not occurring in 2007. However, the stock rebuilding progress was slower than forecast by the Amendment 14 projection, with the NEFSC spring 2007 SSB index (three-year average = 1.16 kg per tow) at only 56% of the projected 2007 index (2.08 kg per tow).

The most recent benchmark peer review of the scup assessment was conducted by the 2008 Northeast Data Poor Stocks Working Group (DPSWG) Peer Review Panel (NEFSC 2009), which accepted an ASAP (A Stock Assessment Program; Legault and Restrepo 1988, NFT 2008) statistical catch at age (SCAA) model as the basis for status determination, with fishery and survey catch data through 2007. The new model of scup population dynamics was expected to provide a more stable tool for monitoring stock status and specifying annual fishery regulations than the previous single index-based model. The assessment indicated that the stock was not overfished and overfishing was not occurring in 2007, relative to the revised biological reference points. Fishing mortality was estimated to have decreased rapidly after 1994, with F in 2007 = 0.054. With greatly improved recruitment and relatively low fishing mortality rates since 1998, SSB was estimated to have steadily increased to about 119,300 mt = 263 million lbs in 2007. There was no consistent retrospective pattern in F, SSB, or recruitment evident in the 2008 assessment model. Following the 2008 DPSWG stock assessment, the NMFS declared scup to be officially rebuilt in 2009.

The 2008 benchmark was last updated in 2012 (Terceiro 2012) using the same model configuration as the 2008 DPSWG (NEFSC 2009) benchmark and subsequent 2009-2011 assessment updates (Terceiro 2009, 2010, 2011). The updated population model included with fishery and survey catch information through 2011. The 2012 update found the stock was not overfished and overfishing was not occurring in 2011 relative to the 2008 biological reference points. The fishing mortality rate (F) was estimated to be 0.034 in 2011, below the fishing mortality threshold reference point = FMSY = F40% = 0.177. Spawning Stock Biomass (SSB) was estimated to be 190,424 metric tons (mt) = 420 million lbs in 2011, above the biomass target reference point = SSBMSY = SSB40% = 92,044 mt = 203 million lbs.

A5. TERM OF REFERENCE 1: Estimate catch from all sources including landings and discards. Include recreational discards, as appropriate. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize the uncertainty in these sources of data.

A5.1 Commercial Fishery Landings

Commercial landings of scup peaked in 1960 at 22,200 mt, then decreased during the 1960s and ranged between about 5,000 and 10,000 mt until the late 1980s. Commercial landings averaged 4,900 mt annually during 1987-1996. Commercial fishery quotas were implemented in 1997, and landings then ranged between 1,200 mt and 8,100 mt and averaged 4,000 mt during 1997-2014, about 54% of the total catch. Reported 2014 commercial fishery landings were 7,228 mt = 15.935 million lbs, about 77% of the commercial quota (Figure A1). About eighty percent of the commercial landings of scup since 1979 were landed in Rhode Island (38%), New Jersey (26%), and New York (16%; Table A1). The otter trawl is the principal commercial fishing gear, accounting for about 65%-90% of the annual total commercial landings since 1979 (Table A2). The remainder of the commercial landings is taken by floating trap (~10%), hand lines (~5%), and fish pots (~5%), with paired trawl, pound nets, and other types of pots and traps each contributing between 1 and 4%.

The distribution of commercial landings by 3-digit statistical area indicated that scup were taken from 43 different areas, but with just 12 accounting for more than 1% of the cumulative total since 1964, lead by area 616 (20%) off northern NJ and western Long Island NY in the Hudson Canyon area, areas 537 (16%), 538 (12%), and 539 (9%) off RI and MA, area 622 (15%) off southern New Jersey and Delaware Bay, and area 613 (9%) off Long Island NY (Figure A2). The distribution of commercial fishing effort for scup expressed as days fished has a similar pattern of concentration, but areas 537-539 off RI and MA account for higher percentages than in the reported landings (Figure A3). It should be noted that not all states routinely reported all landings and effort data to the federal Dealer reporting system until the late 1980s. The distribution of landings by tonnage class (TC) indicated that about 60% of the landings were taken by tonnage class 3 vessels.

A5.2 Fishery Dependent Data Indices of Abundance (LPUE and CPUE)

In response to fishing industry (both commercial and recreational) comments that the utility of fishery dependent catch per unit effort (CPUE) should be evaluated as indices of abundance for scup, a subset of the 2015 SAW 60 Scup Working Group (SWG) with an interest in fishery dependent CPUE compiled data and conducted analyses from a number of sources. These sources include 1) the commercial Dealer reported data for trawl gear, 2) the commercial fishing vessel trip reports (VTR) data for trawl gear, 3) the Northeast Fishery Observer Program (NEFOP) data for trawl gear, 4) the recreational for-hire fishing vessel VTRs for rod-and-reel gear, and 5) the Marine Recreational Fishery Statistics Survey / Marine Recreational Information Program (MRFSS/MRIP) data for rod-and-reel gear, and 6) commercial Study Fleet detailed catch per tow information. This information was reported in 6 separate working papers that were considered during the winter of 2014-2015 by the SWG.

The SWG evaluated the fishery dependent landings or catch per unit effort indices and their utility as indices of abundance in the scup stock assessment. The SWG noted generally that 1) the utility of the fishery dependent data as the basis for indices of abundance is limited in that some of them include only landings and not the total catch including discards, and so the resulting LPUE could be biased low relative to the true abundance of fish, 2) the use of only positive trips that catch scup may bias the LPUE or CPUE as well, and may be influenced by management regulations, and 3) the ratio of catch to effort has generally changed over time, and it is unclear how this change reflects real changes over time in fishing behavior due to fish abundance, management regulations, or changes in data reporting systems.

The SWG noted that over the long term, and especially since fishery quotas and harvest limits were instituted in 1997, there have been a number of associated regulatory changes, primarily seasonal trip limits and mesh regulations, which are different in timing and magnitude for each year. This information is not part of the fishery catch databases and must be developed independently and integrated within the Generalized Linear Models. This information generally could not be modeled adequately as classification variables within the generalized model framework (i.e., inability to develop a model which converges and produces valid parameter estimates).

At a conference call meeting in late March 2015, a subset of the SWG with an interest in fishery dependent CPUE recommended that the lead assessment scientist investigate the utility of ‘directed scup trips’ from the Dealer landings reports as the basis for an index of abundance. The SWG decided to move forward by using data for ‘75% scup trips’ LPUE (trips for which scup account for 75% or more of the reported landings) in the hope that these strongly ‘post-hoc directed’ trips would prove a better candidate for the development of a useful fishery dependent index of abundance. The removal of ~200,000 ‘bycatch’ trips for scup (those landing <75% scup) evidently increased the contrast of the cell means across classification strata sufficiently to allow successful estimation of classification effects for the management regulation effects of seasonal trip limits and mesh size. Thus, attempts to include the effects of management measures in the standardized of ’75% scup trips’ LPUE proved successful, from an estimation standpoint. The resulting ‘75% scup trip’ nominal and model-based indices indicate a nearly flat linear trend in LPUE over the time series.

The SWG decided that the Dealer report standardized LPUE from >75% scup trips was the most appropriate information from which to attempt development of an index of abundance. However, the SWG noted that the resulting LPUE series was different than all other survey and CPUE stock indicators (e.g., slight peak in LPUE in mid 1990s). Figure A4 compares the trends in the fishery dependent nominal and model indices of abundance compiled for this assessment (no Study fleet model indices were compiled). The SWG concluded that further analysis beyond the scope of the assessment is needed to standardize the complexity of factors influencing fishery catch rates.

A5.3 Commercial Fishery Discards

A5.3.1 Current Geometric Mean Discards-to-Landings Ratio Estimates

The NEFSC Northeast Fishery Observer Program (NEFOP) has collected information on landings and discards in the commercial fishery since 1989. Quantifying discards from the commercial fishery is necessary for a reliable scup assessment, but low sample sizes in the past have resulted in estimates of uncertain and relatively low precision. Concern regarding the uncertainty of discard estimates due to inadequate observer sampling has been expressed in previous SAW reviews of the scup assessment, and those reviews recommended increases in sampling intensity to increase the accuracy and precision of discard estimates (e.g., NEFSC 1995, 1997, 1998, 2000, 2002, 2009). Despite the uncertainty of the discard estimates, recent SAW panels have concluded that commercial discarding of scup has been high during most of the last 20 years, generally approaching or exceeding commercial landings, averaging 43% of the total commercial catch during 1989-2000. Since full implementation of the Gear Restricted Areas (GRAs) in 2001, estimated discards as a proportion of the total commercial catch have decreased, averaging about 33%.

In previous assessments, a method using the Geometric Mean Discards-to-Landings Ratio (GMDL) has been used to estimate scup discards for 1989 and later years. Data were sufficient to estimate directly discards for trawl gear only, and ratio of discards to landings was applied to total landings in order to get total commercial fishery discards. The ratios of discards to landings by trip landings level (for trip landings < 300 kg [661 lbs], the ‘bycatch’ fishery; or => 300 kg, the ‘directed’ fishery) and half year period are calculated and multiplied by the corresponding observed landings from the NEFSC Dealer report data to provide estimates of discards. Geometric mean rates (re-transformed, uncorrected, mean ln-transformed Discards to Landings [D/L] per trip) are used because the distributions of scup landings and discards and the ratio of discards to landings on a per-trip basis in the scup fishery are highly variable and positively skewed. Observed trips with both scup landings and discard are used to calculate the per-trip discards to landings ratios. Only trips with both non-zero landings and discards can be used for this approach to avoid division by zero. The number of trawl gear trips used to calculate the geometric mean discard-to-landings ratios (GMDL) by half year for 1997-2007 ranged from 1 to 104 for trips < 300 kg and from 1 to 35 for trips =>300 kg, with the best sampling occurring since 2003. No trawl gear trips were available for half year 2 in 1997 and 1999 for trips < 300 kg and for half year 2 in 1997-2001 for trips => 300 kg. The GMDL calculated for half year 1 was used to estimate discards for half year 2 when no trawl gear trips were available in half year 2. The GMDL ratios ranged from 0.03 in 2004 (half year 2, trips => 300 kg) to 121.71 in 1998 (half year 1, trips => 300 kg).

A large 1998 ‘directed’ fishery discard ratio and subsequent very high annual discard estimate (111,973 mt) was based on one trawl gear trip. About 93% of the discard from that trip was attributable to a single tow in which an estimated 68 mt (~150,000 lbs) of scup were captured. This tow was not lifted from the water and the captain of the vessel estimated the weight of the catch. There has been debate concerning the validity of the catch weight estimate and whether or not it was representative of other vessels or trips in the fishery. However, the observation was reported by a trained NEFSC observer and was therefore included in the initial calculation of the GMDL estimate of scup discards. The 1998 discard estimate was considered infeasible, and replaced by the mean of the 1997 and 1999 GMDL estimates (3,331 mt) in subsequent tabulations of catch and in subsequent modeling (Table A3).

Since 1998 the GMDL approach discard estimates have been adopted by SAW review panels (NEFSC 1998, 2000, 2002) and the MAFMC Monitoring Committee to monitor trends in fishery catch and evaluate the status of the stock. The GMDL approach was accepted by the Data Poor Stocks Workshop peer review of the 2008 assessment as the best method to estimate scup discards (NEFSC 2009). The GMDL estimates were used for all subsequent modeling approaches considered in the 2008 and later assessments.

Broad scale Gear Restricted Areas (GRAs) for scup were implemented in November

2000 to reduce discards of scup in the small mesh fisheries for *Loligo* squid and silver hake. Initially two Northern Areas off Long Island were implemented for November through January, while a Southern Area off the mid-Atlantic coast was implemented for January through April. The size, boundaries, and other measures of the GRAs were modified in December 2000 and again in 2001 and 2005 in response to commercial fishing industry recommendations. Currently a Northern GRA restricts the use of codend mesh less than 5.0 inches (127 mm) during November and December, while a Southern GRA is in effect from January 1 through March 15.

Both the observed discards (as a function of both increased fishing activity for scup and increased sampled trip number) and the current assessment GMDL estimated fishery discards (as a function of increased fishery quotas and therefore increased fishing activity for scup) have generally increased as the fishery quotas have increased since 2005, although the observed discard percentage of total commercial catch has decreased. Scup commercial fishery estimated discards remain an important component of the commercial fishery removals and averaged about 25% of the estimated total commercial catch during 2010-2014.

The distribution of observed discards varies by statistical area, season, and mesh size. Within the nine important GRA 3-digit statistical areas that account for 84% of observed scup discards over the time series, 24% was observed in ‘large’ mesh tows (codend or liner < 4.5 [114 mm] or 5.0 in [127 mm], 35% in ‘small’ mesh tows (larger than 2.125 in [54 mm] and smaller than 4.5 or 5.0 inch), and 41% in ‘squid’ mesh tows (equal to or less than 2.125 inch).

The Observer data have provided evidence that the GRAs have been effective in reducing the scup discard percentage. The current assessment absolute estimates of scup discards using the GMDL approach, however, are produced on a temporal and spatial scale that is too coarse to directly evaluate the effectiveness of specific discard reduction measures (e.g., on a specific area or season basis). This has prompted a re-examination of the methods used to estimate commercial fishery scup discards using the Standardized Bycatch Reporting Method (SBRM).

A5.3.2 New Standardized Bycatch Reporting Method Discard Estimates

The SBRM Omnibus Amendment to the fishery management plans of the Northeast region was implemented in February 2008 to address the requirements of the Magnuson-Stevens Fishery Conservation and Management Act to include standardized bycatch reporting methodology in all FMPs of the New England Fishery Management Council and Mid-Atlantic Fishery Management Council. The SBRM for the estimation of discards (Wigley et al. 2008, 2011) has now been adopted for most NEFSC stock assessments that have been subject to a benchmark review since 2009. In this assessment, newly developed SBRM estimates of scup landings and discards are compared with Dealer reported landings and the current GMDL estimation approach estimates of discards as part of a re-examination of the estimation of commercial fishery scup discards.

Data are still sufficient to estimate discards for trawl gear only, the major commercial gear which has accounted for about 83% of commercial landings since 1989. Based on comments received from fishery managers and industry advisors since the 2008 assessment (NEFSC 2009), under the SBRM approach the trawl gear ratios of discards to landings have not been used to ‘raise’ trawl discards to account for discards from other gears. The remainder of the commercial gear includes floating traps, hand lines, fish pots, pound nets, and other types of pots and traps. All of these other gears are assumed to either have very low discard rates (e.g., traps, pots, pound nets) and/or low discard mortality rates (e.g., hand lines), and so dead discards from those gears are assumed to be negligible.

In the SBRM, the sampling unit is an individual fishing trip. Live scup discards or landings were estimated using a stratified d/k ratio estimator (Cochran 1963) where *d* = observed discard or kept pounds of scup, and *k* = observed kept pounds of all species, raised by the trip landings of all species as reported by VTR or Dealer records, to provide estimates of scup discards or landings by stratum. Further computational details are provided in Wigley et al. (2011).

Three SBRM stratification alternatives were evaluated for scup discards and landings:

1) by calendar quarter for all areas and meshes, providing 4 strata annually (QTR4),

2) by calendar quarter for all areas and two mesh categories: 'large' (for codend or liner equal or larger than 4.5 [114 mm] or 5.0 inch [127 mm]) and 'small' (less than 4.5 or 5.0 inch, providing 8 strata (MESH8), and

3) by calendar quarter, statistical area, and three mesh categories: 'large' (for codend or liner equal or larger than 4.5 or 5.0 inch), 'small' (larger than 2.125 inch [54 mm] and less than 4.5 or 5.0 inch, and 'squid' (equal to or less than 2.125 inch), providing 240 strata (MESH240).

The three SBRM alternatives are compared with the current assessment GMDL estimates of discards for 1989-2013 in Table A4 and Figure A5 (note that 2014 data were not available when this work was conducted). Due to the influence of the 'infamous' 1998 tow, all 1998 estimates were replaced with the average of the adjacent years. Over the time series, the current GMDL estimates of discards have averaged 2,397 mt with PSE of 35%. The SBRM QTR4 estimates averaged 1,314 mt with PSE of 39%. The SBRM MESH8 estimates averaged 1,296 mt with PSE of 44%. The SBRM MESH240 estimates averaged 1,376 mt with PSE of 22%. Over the series, the three SBRM alternatives averaged about 1,300 mt, about 45% lower than the GMDL estimates.

The three SBRM alternatives are compared with the current assessment Dealer total and Trawl gear only landings as an additional means of evaluation (Figure A6). Over the 1989-2013 time series, the Dealer total landings have averaged 4,144 mt and the Trawl gear landings have averaged 3,245 mt. The SBRM QTR4 estimates averaged 2,529 mt (38% below the Dealer, 22% below the Trawl) with PSE of 35%. The SBRM MESH8 estimates averaged 1,757 mt (57% below the Dealer, 46% below the Trawl) with PSE of 44%. The SBRM MESH240 estimates averaged 1,831 mt (55% below the Dealer, 44% below the Trawl) with PSE of 18%. Over the series, the three SBRM alternatives averaged about 2,000 mt, about 50% lower than the Dealer landings and 35% lower than the Trawl gear landings. The SBRM MESH240 landings estimates correlate best with the Dealer total and Trawl gear reported landings, with a correlation coefficients (r) of 0.71 and 0.77 (df = 24, $p < 0.01$), compared to r values of 0.38 and 0.34 ($p < 0.5$) for the QTR4 estimates and 0.42 and 0.38 ($p < 0.5$) for the MESH8 estimates.

The final comparison made was for the SBRM MESH240 estimates apportioned to length and age (dead discards including the 100% discard mortality rate) with those using the current assessment GMDL estimates of discards. The SBRM estimates in absolute total numbers average 12.5 million fish per year during 1989-2013, about 62% of the GMDL estimate of 20.3

million. The largest difference in absolute total numbers was for 1992, with the GMDL estimate about 58.5 million fish larger than the SBRM estimate; the smallest difference in absolute total numbers was for 2005, with the SBRM estimate about 43,000 fish larger than the GMDL estimate. The largest difference in proportions at age was in 1993 at ages 0, 2, and 3, due to differences in the distribution of discards and subsequent allocation of lengths during the year. Comparable differences, generally at ages 0-2, were observed in 1990, 1992, 1993, 1994, 2001, and 2008.

The consideration of three SBRM discard estimators of scup discards and discards and comparison with the current GMDL method estimates indicates that the SBRM MESH240 estimator and stratification provides the best overall combination of feasible estimates of the scup discards and landings and good precision. The SBRM MESH240 discard estimator also provides the ability to evaluate the effectiveness management measures like the GRAs. The new SBRM MESH240 discard estimate time series (Table A5) is used in the 2015 SAW 60 scup assessment. The commercial fishery live discards of scup have averaged 1,375 mt during 1989-2014, the period for which direct estimates are available.

A5.4 Recreational Fishery Catch

Scup is the object of a major recreational fishery, with the greatest proportion of catches taken in the states of Massachusetts, Rhode Island, Connecticut and New York. Estimates of the recreational catch in numbers were obtained from the NMFS Marine Recreational Fishery Statistics Survey (MRFSS) for 1981-2011, and from the NMFS Marine Recreational Information Program (MRIP) for 2004-2014. These estimates were available for three categories: type A - fish landed and available for sampling, type B1 - fish landed but not available for sampling and type B2 - fish caught and released. The estimated recreational landings (types A and B1) in weight estimated by the programs during 1981-2014 averaged about 2,300 mt per year (Table A6). Since 1981, the recreational landings have averaged 32% of the commercial plus recreational landings total.

The commercial fishery VTR system provides an alternative set of reported recreational landings by the party/charter boat sector. A comparison of VTR reports and MRFSS estimates indicates that MRFSS estimates were on average about 57% higher over the 1995-2014 period, ranging from a factor of 0.34 in 1998 to 2.56 in 2013 (Table A7). It is unclear if this is due mainly to under-reporting of party/charter boat recreational landings in the VTR system, or a systematic positive bias of MRFSS landings estimates for the party/charter boat sector.

The estimated recreational live discard in weight during 1984-2011 ranged from 43 mt in 1999 to a high of 2,120 mt in 2010, averaging about 840 mt per year (Table A8). The weight of discards has been directly calculated only for those years (1984 and later) for which recreational catch at age has been compiled. In compilations of total fishery catch for earlier years, the recreational discards was assumed to be approximately 2% of the estimated recreational landings, based on the mean discard percentage for 1984-1996, the time period with catch at age estimates before the implementation of the FMP. The discard mortality rate in the recreational fishery has been reported to range from 0-15% (Howell and Simpson 1985) and from 0-14% (Williams, pers. comm.). Howell and Simpson (1985) found mortality rates were positively correlated with size, due mainly to the tendency for larger fish to take the hook deep in the esophagus or gills. Williams more clearly demonstrated increased mortality with depth of hook location, as well as handling time, but found no association with fish size. Based on these studies, a discard mortality rate in the recreational fishery of 15% has been used in this and previous assessments, resulting in a time series average discard mortality of about 100 mt per year.

A5.5 MRIP Estimates of Recreational Fishery Catch

The NMFS Marine Recreational Fishery Statistics Survey (MRFSS) was replaced by the Marine Recreational Information Program (MRIP) in 2012 to provide improved recreational fishing statistics. The MRIP implemented a new statistical method for calculating recreational catch estimates, with many survey elements related to both data collection and analysis updated and refined to address issues such as data gaps, bias, consistency, accuracy, and timeliness. As part of the implementation of the MRIP, MRFSS recreational fishery catch estimates for 2004-2011 have been directly replaced by those using the MRIP estimation methods. For earlier years, a constant "ratio of means" of the MRFSS and MRIP estimates has been used to adjust the recreational catch estimates (Tables A6 & A8).

For the recreational fishery harvest number (catch types A + B1), the largest change was for the commonwealth of MA, with a cumulative 2004-2011 increase of about 4 million fish, about +67% and also the largest cumulative percentage increase amongst the states. The largest absolute decrease was for the state of RI with a cumulative 2004-2011 decrease of about 289,000 fish, or about -7%. The state of MD had the largest cumulative percentage decrease at -67%; however, MD's cumulative harvest (now about 3,600 fish) is only 0.1% of the coastal total. Over all states, the cumulative harvest in numbers increased by about 5.3 million fish (about +19%), ranging from a decrease of 174,000 fish in 2007 (-5%) to an increase of 2.5 million fish in 2004 (+52%; Table A9). Therefore, for the years 1963-2003 recreational harvest numbers were increased by 19% for this assessment (see TOTAL FISHERY CATCH section below for discussion of estimates before 1981).

For the recreational fishery harvest weight (catch types A + B1, mt), the most important change was for the commonwealth of MA with a cumulative 2004-2011 increase of about 1,713 mt, or about +67%. The state of DE had the largest cumulative percentage increase at +112%; however, DE's cumulative harvest (now about 4 mt) is less than 0.1% of the coastal total. The largest absolute decrease was for the state of RI with a cumulative 2004-2011 decrease of about 108 mt, about -6%. The state of MD had the largest cumulative percentage decrease at -30%, a cumulative decrease of about 1 mt. Over all states, the cumulative harvest in weight (mt; metric tons) increased by about 2,433 mt (about +18%), ranging from a decrease of 122 mt in 2008 (-7%) to an increase of 1,356 mt fish in 2004 (+71%; Table A10). Therefore, for the years 1963-2003 recreational harvest weight was increased by 18% for this assessment.

For the recreational fishery live releases in numbers (catch type B2), the largest change was for the commonwealth of MA, with a cumulative 2004-2011 increase of about 3.1 million fish, about +38% and also the largest cumulative percentage increase amongst the states. The largest absolute decrease was for the state of NJ with a cumulative 2004-2011 decrease of about 410,000 fish, or about -12%. The state of MD had the largest cumulative percentage decrease at -47%, a cumulative decrease of about 45,000 million fish. Over all states, the cumulative live release in numbers increased by about 4.5 million fish (about +11%), ranging from a decrease of 239,000 fish in 2008 (-3%) to an increase of 1.7 million fish in 2004 (+36%; Table A11). Therefore, for the years 1963-2003 recreational live release and discard mortality estimates were increased by 11% for this assessment.

A5.6 Commercial Fishery Landings at Length and Age

The NER commercial fishery length frequency sampling is summarized in Table A12 and Figure A7. Annual sampling intensity has varied from 18 to 687 mt per 100 lengths, with sampling exceeding the informal threshold criterion of 200 mt per 100 lengths since 1995. For this assessment, commercial fishery landings at age beginning in 1984 have been updated through 2014, with samples for most of the series pooled by market category (pins/small, medium, large/mix, jumbo, and unclassified) and by half-year (January-June, July-December); samples were pooled on a regional (New England, Mid-Atlantic), quarterly basis (e.g., January-March) where possible since 2004. Estimates of commercial fishery landings at age (Figure A8) and mean weights at age are presented in Tables A13-A14.

A5.7 Commercial Fishery Discards at Length and Age

The intensity of length sampling of discarded scup from the NEFSC Fishery Observer Program declined in 1992-1995 relative to 1989-1991 (Table A15, Figure A7). Sampling intensity ranged from 489 to 335 mt per 100 lengths sampled in 1992-1995, failing to meet the informal criterion of 200 mt per 100 lengths. Sampling intensity improved to 100 mt per 100 lengths in 1996, but then declined to over 200 mt per 100 lengths in 1997-1999. Sampling intensity has generally met the 200 mt per 100 lengths threshold since 2000. The mean weight of the discard was estimated from length frequency data using a length-weight equation, total numbers discarded at length were then estimated by dividing total weight at length by mean weight at length. Discards at length were aged using a combination of commercial and survey age-length keys, with discards at age dominated by fish aged 0, 1, or 2, depending on the year under consideration. Estimated proportions at length and age for 1984-1988 (before the advent of the Observer sampling) were derived from irregularly collected NEFSC samples (NEFSC 1998) and the ratio of scup discards to scup landings during 1989-1991 (0.50 for the GMDL estimates; 0.46 for the SBRM estimates). Estimates of commercial fishery discards at age (Figure A9) and mean weights at age are presented in Tables A16-A17.

A5.8 Recreational Fishery Landings at Length and Age

For the recreational fishery, length sampling intensity has varied from 45 to 471 mt per 100 lengths. Sampling in all years except 1984 during 1981-1987 failed to meet the informal criterion of 200 mt per 100 lengths, but since 1988 the criterion has been met except for 1999-2000 (Table A6, Figure A7). Numbers at length for recreational landings were determined from recreational fishery length samples pooled by half-years (January-June; July-December) over all regions and fishing modes, and were converted to numbers at age by applying half-year age-length keys constructed from NEFSC commercial and survey samples. Age-length keys from spring surveys and first and second quarter commercial samples were applied to numbers at length from the first half of the year, while age-length keys from fall surveys and third and fourth quarter commercial samples were applied to numbers at length from the second half of the year. Estimates of recreational fishery landings at age (Figure A10) and mean weights at age are presented in Tables A18-A19.

A5.9 Recreational Fishery Discards at Length and Age

No length frequency samples of the scup discard were collected under the MRFSS program before 2005, so recreational discards were assumed to be fish aged 0 and 1, in the same relative proportions and with the same mean weight as the landed catch samples less than state regulated minimum fish sizes. An inspection of discard length frequency samples from the New York recreational fishery for 1989-1991 indicated that this assumption was reasonable. Since 2005, the MRFSS/MRIP For-Hire Survey discard samples have been used in concert with the MRFSS/MRIP sub-legal landed lengths to characterize the length frequency of the recreational discard. The informal sampling criterion of 200 mt per 100 lengths has been consistently met since 2007 (Table A8, Figure A7). Numbers at length were converted to numbers at age by applying half-year (January-June; July-December) age-length keys constructed from NEFSC commercial and survey samples. As noted earlier, a 15% discard mortality rate is assumed. Estimates of recreational fishery discards at age (Figure A11) and mean weights at age are presented in Tables A20-A21.

A5.10 Total Fishery Catch

Total commercial and recreational landings in 2014 were 9,253 mt = 20.399 million lbs and total commercial and recreational discards were 1,367 mt = 3.014 million lbs, for a total catch in 2014 of 10,620 mt = 23.413 million lbs (Table A22, Figure A12). Estimates of the total fishery catch at age and mean weights at age (Figure A13) for 1984-2014 (the time series is limited by the availability of sampled fishery ages) are presented in Tables A23-A24. An extended time series of the total catch of scup has been estimated to provide an historical perspective of the exploitation of scup in the years before a) the MRFSS/MRIP was implemented in 1981 to estimate recreational fishery catch, b) the Observer program was implemented in 1989 to provide estimates of commercial fishery discard, and c) fishery aging data became available in 1984 (Table A25). These estimates include commercial and recreational landings and discards. The recreational fishery catch for 2004-2014 has been estimated using the MRIP methods. For earlier years, a constant "ratio of means" of the MRFSS and MRIP estimates has been used to adjust the recreational catch estimates (see previous MRIP section).

The catches before 1981 are the less reliable due to uncertainty about a) the magnitude of domestic commercial fishery discards, b) the magnitude of the distant water fleet (DWF) catch and c) the uncertainty of assumptions made to estimate the recreational catch (50% reduction from estimates based on time-varying ratios to the commercial landings made in Mayo 1982 for 1960-1978; recreational discards assumed to be 2% of the adjusted recreational landings). For years in which no commercial fishery observer data were collected (1963-1988), commercial discards were computed using a constant "ratio of means" using landings and discards for 1989-2001 (0.50 for the GMDL estimates) as in previous assessments (NEFSC 2002; NEFSC 2009). This ratio for the SBRM estimates adopted for the 2015 SAW 60 assessment is 0.46.

A6.TERM OF REFERENCE 2: Present the survey data being used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.). Characterize the uncertainty and any bias in these sources of data.

A6.1 Research Suvey Indices of Abundance

A6.2 Northeast Fisheries Science Center

The NEFSC spring and fall bottom trawl surveys provide long time series of fishery-independent indices for scup. The NEFSC spring and fall surveys are conducted annually during March-May and September-November, ranging from just south of Cape Hatteras, NC to Canadian waters. NEFSC spring and fall abundance and biomass indices for scup exhibit considerable inter-annual variability (Table A26, Figure A14). NEFSC spring survey catches are characterized mainly by scup of ages 1 and 2 (Figure A15), while the fall survey often captures large numbers of age 0 and 1 fish (Figure A16).

The Fisheries Survey Vessel (FSV) *Albatross IV* (ALB) was replaced in spring 2009 by the FSV *Henry B. Bigelow* (BIG) as the main platform for NEFSC research surveys, including the spring and fall bottom trawl surveys. The size, towing power, and fishing gear characteristics of the BIG are significantly different from the ALB, resulting in different fishing power and therefore different survey catchability. Calibration experiments to estimate these differences were conducted during 2008 (Brown 2009), and the results of those experiments were peer reviewed by a Panel of three non-NMFS scientists during the summer of 2009 (Anonymous 2009, Miller et al. 2010). The terms of reference for the Panel were to review and evaluate the suite of statistical methods used to derive calibration factors by species before they were applied in a stock assessment context. Following the advice of the August 2009 Peer Review (Anonymous 2009), the methods proposed in Miller et al. (2010), and the precedents set in peer-reviews of stock assessments for haddock (Van Eeckhaute and Brooks 2010), yellowtail flounder (Legault et al. 2010), silver and red hake (NEFSC 2011a), and winter flounder (NEFSC 2011b), aggregate and length-based calibration factors were used to convert 2009-2014 spring and fall BIG survey catch number and weight indices to ALB equivalents for use in this stock assessment update (Tables A27-A30; Figure A14).

The NEFSC survey indices sometimes appear to mainly reflect the availability of scup to the survey, rather than true abundance, making it difficult to interpret large inter-annual changes in the indices. For example, the 2002 spring biomass index was about twice the second highest spring index, which was observed in 1977 (Figure A14). The spring numeric abundance indices are similar; the 2002 index is the highest observed in the series and about twice the 1970 index. These dramatic increases were evident across all ages in the estimated 2002 spring numbers at age (Table A31; Figure A15). However, the previous fall survey estimates of numbers at age in 2001 had not reflected relatively large values from which the corresponding 2002 spring numbers at age might have been expected to derive (Table A32, Figure A16) nor did they subsequently translate to exceptional indices of biomass in fall 2002 or spring 2003. A potentially similar ‘availability’ event appears to have occurred in spring 2014, with the largest biomass and numeric indices sampled since 2002, but with no follow-up apparent in the 2014 fall indices (Tables A26-A27).

The NEFSC winter survey was started in 1992 primarily as a flatfish survey, was conducted during February, and ranged from Cape Hatteras, NC to the southwestern part of Georges Bank. The winter survey 2002 abundance and biomass indices were, like the spring survey, the largest of the time series (Table A33, Figure A13). Similar to the spring estimates, numbers at age estimated for the 2002 winter survey were also exceptionally large (Table A34, Figure A17). The winter trawl series ended in 2007.

The large differences in the absolute magnitude of NEFSC survey catches of ages 0-2 compared to those of fish at ages 3 and older suggests a substantial difference in survey selection at age between these two aggregate age groups. In the 2008 DPS assessment (NEFSC 2009), aggregate biomass indices restricted to the lengths of fish ages 0-2 were constructed for calibration of those ages in the population model (maximum length of 22 cm in the winter, 20 cm in the spring, and 23 cm in the fall series). The 2009-2014 BIG values for these aggregate indices have also been converted to ALB equivalents using length calibration factors (Table A35). Both the NEFSC spring and fall indices indicate an increasing trend in scup abundance since the late 1990s.

Alternate NEFSC strata sets

Only about one-third (spring) to one-half (fall) of the 30 offshore strata included in the standard assessment long-term aggregate spring and fall (offshore strata 1-12, 23, 25, 61-76) strata sets account for large proportion of the scup catches. In the spring, these are the 'middle two' bands of offshore strata with depths from 56 to 185 meters (about 30 to 100 fathoms), and from North to South include strata 2, 3, 74, 75, 70, 71, 66, 67, 62, and 63. In the fall, these are the 'inner two' bands of offshore strata with depths from 27 to 110 meters (about 15 to 60 fathoms), and from North to South include strata 9, 10, 5, 6, 1, 2, 73, 74, 69, 70, 65, 66, 61, and 62. These two groups of seasonal strata were used to construct candidate 'Alternate' offshore strata sets for the long-term aggregate indices used for scup. The spring Alternate set of 10 strata includes 97.5% of the time series total catch, while the fall Alternate set of 14 strata includes 99.8% of the time series total catch. The goal of developing indices using the alternate sets was to explore if the inter-annual variability and occasional extreme 'outliers' (e.g., spring 2002) in the time series might be reduced, before attempting the development of model-based indices.

The alternate series indices for both seasons are, as expected, scaled higher as the strata that were omitted had low catches. When normalized to each respective time series mean, however, trends were very similar for both abundance and biomass indices for both seasons. The alternate series indices also had slightly higher variance, because the omitted strata catches generally had small or zero variance. The time series Proportional Standard Error (PSE: the ratio of the time series standard error to the time series mean) increased from 129% to 135% for the spring number per tow index, and from 95% to 97% for the fall. PSE magnitudes and changes were comparable for the seasonal biomass indices. More importantly, no significant reduction in inter-annual variation was realized. Given these results, the standard assessment NEFSC strata sets and stratified random indices of abundance were retained for use in the 2015 SAW 60 assessment.

Model-based NEFSC indices of abundance

Descriptive statistics indicate that the NEFSC survey scup catch distribution is highly contagious and overdispersed in relation to a normal distribution. For both spring and fall, examination of patterns in the survey catch, for both day and night, confirm the irregular distributions of catch by temperature, salinity and depth and portend the difficulties of modeling the survey scup catch data. No well defined relationships are evident; i.e., small catches are as likely to be taken at shallow depths as large depths and at both warm and cold temperatures and large catches can occur over a relatively large range of depth and temperature (e.g, over a range of 70 meters or 10 degrees). Generalized linear model (GENMOD) and generalized additive model (GAM) based indices of abundance for the scup NEFSC seasonal survey data proved to be not useful, due to highly variable results owing from the inability of the models to adequately fit the variable and complex temporal and spatial properties of scup survey catches.

A6.3 Massachusetts DMF

The Massachusetts Division of Marine Fisheries (MADMF) has conducted spring and fall bottom trawl surveys of Massachusetts territorial waters in May and September since 1978. Survey coverage extends from the New Hampshire to Rhode Island boundaries and seaward to three nautical miles, including Cape Cod Bay and Nantucket Sound. The study area is stratified into geographic zones based on depth and area. The MADMF spring survey catches are characterized mainly by scup of ages 1 and 2, while the fall survey often captures large numbers of age 0 fish. The spring biomass and abundance indices decreased sharply from a high in the early 1980s to relatively low levels through the 1990s, and have since exhibited a variable but increasing trend (Table A36, Figure A18). The MADMF fall abundance index can include large numbers of age 0 fish and therefore can be more variable as it reflects inter-annual variance in recruitment. The fall biomass index exhibits an increasing trend since the mid 1990s (Table A36, Figure A18).

A6.4 Rhode Island DFW

The Rhode Island Division of Fish and Wildlife (RIDFW) has conducted spring and fall bottom trawl surveys based on a stratified random sampling design since 1979. Three major fishing grounds are considered in the spatial stratification, including Narragansett Bay, Rhode Island Sound, and Block Island Sound. Stations are either fixed or randomly selected for each stratum. The spring index shows relatively low scup abundance and biomass through 1999 followed by a steep increase during 2000-2002, in common with the NEFSC and MADMF indices, and high variability since then (Table A37; Figure A19). The RIDFW spring survey catches a full age range of scup of ages 1 through 7+ (Table A38, Figure A20). The RIDFW fall survey indices show a general increase to a 1993 peak, followed by a steep decline until 1998, and a steady increase since then. The fall biomass series reached a time series peak in 2011 (Table A37, Figure A18). The RIDFW fall survey is dominated by age 0 scup (Table A39, Figure A21).

The RIDFW implemented a ventless trap survey in cooperation with commercial fishermen beginning in 2005 and ending in 2012 (Table A40, Figure A19). The cooperative trap survey has a fixed station format, and survey catches are expressed as catch per trap soak hour.

The RIDFW cooperative trap survey caught a full age range of scup of ages 1 through 7+ (Figure A22).

A6.5 University of Rhode Island Graduate School of Oceanography (URIGSO)

University of Rhode Island Graduate School of Oceanography (URIGSO) has conducted a standardized, year-round, weekly two-station trawl survey in Narragansett Bay and Rhode Island Sound since the 1950s, with consistent sampling since 1963. Irregular length-frequency samples for scup indicate that most of the survey catch is of fish from ages 0 to 2. The aggregate numbers-based index reached a peak in the late 1970s, was relatively low during the late 1990s, and has since generally increased. The 2014 index was the third highest of the time series, after the 1976 and 1989 indices (Table A41, Figure A23).

A6.6 Connecticut DEEP

The Connecticut Department of Energy and Environmental Protection (CTDEEP) trawl survey program was initiated in May 1984 and encompasses both the New York and Connecticut waters of Long Island Sound. The stratified random design survey is conducted in the spring (April-June) and fall (September-October). The CTDEEP spring index indicates relatively low abundance through most of the survey period, but has increased substantially since 1999 (Table A42, Figure A24). The CTDEEP fall survey, which often catches large numbers of age-0 scup, indicates that recruitment was relatively stable during most of the survey period, but the aggregate fall indices have also increased substantially since 1999. (Table A43, Figure A22) Due to vessel engine failure, a complete fall survey was not conducted in 2010. The CTDEEP spring and fall surveys catch scup from ages 0-7+ (Figures A25-A26).

A6.7 New York DEC

The New York Department of Environmental Conservation (NYDEC) initiated a small mesh trawl survey in 1985 to collect fisheries-independent data on the age and size composition of scup in local waters. This survey is conducted in the Peconic Bays, the estuarine waters which lie between the north and south forks of eastern Long Island. The NYDEC survey provides age 0, 1, and 2+ indices of scup abundance (Table A44). The index of age 2 and older fish indicates a substantial increase since the late 1990s (Figure A27). The age 0 indices indicate recruitment of strong cohorts since the late 1990s. In the early years of the survey, however, there often was not been a strong correspondence between the age 0 indices and age 1 and 2+ indices in the following years (Figure A28).

A6.8 New Jersey DFW

The New Jersey Department of Fish and Wildlife (NJDFW) conducts a stratified random bottom trawl survey of New Jersey coastal waters from Ambrose Channel south to Cape Henlopen Channel. Latitudinal strata boundaries correspond to those in the NEFSC trawl survey; longitudinal boundaries correspond to the 30, 60, and 90 foot isobaths. Each survey includes two tows per stratum plus one additional tow in each of nine larger strata for a total of 39 tows. The NJDFW survey indices exhibit variable patterns over the early part of the time series. The biomass index reached a minimum in 1996 and then generally increased, peaking in 2007, but has since decreased (Table A45; Figure A29).

A6.9 Virginia Institute of Marine Science (VIMS)

A6.9.1Juvenile Fish Trawl Survey

The Virginia Institute of Marine Science (VIMS) has conducted a juvenile fish trawl survey in lower Chesapeake Bay during June-September since 1988. The VIMS age-0 scup indices indicate a general decline in recruitment from relatively high levels with peaks in the late 1980s to early 1990s, to relatively low levels from the late 1990s to early 2000s, and the indication of several recent strong year classes (Table A45).

A6.9.2 ChesMMAP Trawl Survey

The VIMS Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP) trawl survey is designed to support stock assessment activities at both a single and multispecies scale. While no single gear or monitoring program can collect all of the data necessary for quantitative assessments, ChesMMAP was designed to fill data gaps by maximizing the biological and ecological data collected for several recreationally and commercially important species in the bay. Total abundance and biomass indices composed mainly of age 0 and 1 fish are available since 2002, and suggest strongest recruitment in 2005 and 2010 (Table A46, Figures A30-A31).

A6.9.3 NEAMAP Trawl Survey

The VIMS Northeast Area Monitoring and Assessment Program (NEAMAP) trawl survey was started in fall 2007, providing research survey samples in the spring and fall seasons along the Atlantic coast from Rhode Island to North Carolina in depths of 20-90 feet (9-43 meters). The NEAMAP survey data are included for the first time in the 2015 SAW60 scup assessment population model (Table A47-A48, Figures A29, A32-A33).

A6.10 Aggregate research survey trends

Figure A34 presents the trends in aggregate indices of numeric abundance for the 16 surveys used in the assessment (the 17th is the VIMS juvenile fish trawl survey). The historical peak in the 1970s is evident, as is the decrease to a minimum in the late 1990s. Most surveys indicate an increase in abundance since the late 1990s, some to historic highs.

Figure A35 presents the trends in scup recruitment at age 0 for the 8 surveys with significant catch of age 0 scup. Multiple surveys indicated good recruitment in the late 1980s, poor recruitment in the mid-1990s, and improved to historically high recruitment during the 2000s. Some surveys indicate decreased recruitment since about 2010.

A6.11 Integrated Indices of Abundance

A6.11.1 Aggregate and At-Age indices from General Linear Modeling (GLM)

Several of the Northeast United States fish stock assessments conducted by Northeast Regional Stock Assessment Workshop (SAW) Working Groups and Atlantic States Marine Fisheries Commission (ASMFC) Technical Committees incorporate abundance indices from several state and federal agency research survey programs (e.g., summer flounder, winter flounder, bluefish, black sea bass, striped bass, weakfish, tautog, scup, etc.). Typically, this information is provided to the assessment process as annual or seasonal aggregate indices of biomass or numbers, and sometimes as indices at age. These indices can be used in complex, age-structured analyses to calibrate population trends and relative cohort size.

The evaluation process of candidate indices for use in complex models has typically included looking for common trends (i.e., signal) by: a) examination of time series plots, b) analysis of correlation (of lack thereof) between survey indices and between survey indices and population dynamics model results, c) outlier analysis, and d) consideration of the magnitude and trend of residuals when indices are included in population dynamics models such as VPA and ASAP. Multiple analyses with different sets of indices are often conducted to examine the sensitivity of model results to inclusion of a given index series to determine the best analysis configuration to characterize stock status. Alternatively, all available abundance indices may be included in an analysis with the results most strongly influenced by those indices that statistically fit best within the analytical framework. Even given these approaches, with 50 or more indices of abundance at age from up to 15-20 surveys (as in this assessment of scup) to consider for inclusion in a complex age structured assessment, it can be difficult to qualitatively discern general trends in abundance from the battery of available indices. The decision to include a given index time series at age can therefore often be subjective, based on a loose set of decision rules that may vary from one assessment to another. SAW peer reviews have often recommended the investigation of methods to better integrate trends in stock abundance inferred from survey indices of abundance, prior to the inclusion of such indices in a population model calibration. A review of NEFSC data collection programs (NEFSC 2013a) recommended: "…better integration of NEFSC and state surveys. This could include planning efforts to standardize timing and methods, to improve comparability among surveys. On the stock assessment side, panelists questioned the appropriateness of giving equal weight to a survey covering the whole range, compared to a large set of geographically restricted surveys of unknown rigor."

The integration of survey indices collected by different research sampling programs can be viewed as analogous to the standardization of commercial fishing vessel catch rates in developing fishery-dependent indices of abundance (e.g., Robson 1960, Gavaris 1980, Kimura 1981, O'Brien and Mayo 1988). Viewed in that light, a Generalized Linear Model framework (GLM; Searle 1987, McCullaugh and Nelder 1989, SAS Institute 2011) or Generalized Additive Framework (GAM; Hastie and Tibshirani 1990, SAS Institute 2011) might be used in which deviations from the mean trend are modeled by defining various classification variables which are thought to account for the deviations. This general approach has been used in several North Atlantic Fisheries Organization (NAFO) groundfish stock assessments to integrate multiple fishery-independent survey indices of recruitment (e.g., Healey et al., MS 2001 and subsequent Greenland halibut assessments; Stansbury et al., MS 2001 and subsequent Grand Banks cod assessments).

For this scup assessment, the GLM approach using lognormal error was used to calculate 'integrated' indices of abundance at age for use in model calibration. As noted above, this analytical approach is analogous to a GLM standardization analysis of commercial fishing vessel catch per unit effort data: the 'year' main effect classification variable serves as the index of abundance, while the 'survey' classification variable is analogous to a 'vessel' classification variable, each with its' own time series of catch per unit effort that has some relationship to the underlying true abundance of the stock. The mean index of abundance is modeled as a log-linear function of the classification variables. The analysis could be expanded by including additional classification variables, such as the sampling gear type, tow duration, temporal variables (e.g., day/night) or environmental variables (e.g., water temperature anomalies). However, such details typically are not immediately available for most assessments, as indices are most often presented to the assessment working group process as aggregate annual or seasonal indices at age. As configured here, the analysis provides average, or 'integrated,' aggregate indices of abundance.

SAS software version 9 (SAS 2011) PROC GENMOD was used to develop models of the scup state and academic trawl survey data. The GENMOD procedure fits generalized linear models (GLM) that allow the mean of a population to depend on a linear predictor through a nonlinear link function, and allows the response probability distribution to be specified from a number of probability (error) distributions. These include the normal, lognormal, binomial, Poisson, gamma, negative binomial (negbin), and multinomial distributions (McCullagh and Nelder 1989). The GENMOD procedure fits the models by maximum likelihood estimation. There is generally no closed form solution for the maximum likelihood estimates of the parameters, so the procedure estimates the parameters of the model numerically through an iterative fitting process, with the covariances, standard errors, and p-values computed for the estimated parameters based on the asymptotic normality of maximum likelihood estimators (SAS 2011).

The time series of years for the scup ASAP model is 1963-2014, with fishery catch available for the entire series and fishery age compositions available for 1984 and later. The longest survey series is the University of Rhode Island Graduate School of Oceanography (URIGSO) aggregate index beginning in 1963; the shortest are the Northeast Monitoring and Assessment Program (NEAMAP) spring (2008) and fall (2007) trawl series, which have 'limited' age compositions. The state and academic survey series were grouped into spring and fall seasonal collections to develop seasonal standardized, or 'integrated,' aggregate indices. The spring collection includes the MADMF spring, RIDFW spring, CTDEP spring, and NEAMAP spring trawl survey aggregate numeric indices. The spring collection surveys index age 1 and older abundance. The fall collection includes summer and fall seasonal surveys; the MADMF fall, RIDFW fall, URIGSO, CTDEP fall, NYDEC, NJDFW, ChesMMAP, and NEAMAP fall trawl survey aggregate numeric indices. The fall collection surveys index age 0 and older abundance.

GLM main classification effects were limited to the year of sampling (1982, 1983...2014) and the identity of the survey (MASPR, RIFAL, etc.) The resulting year effect coefficients, corrected for lognormal-transformation bias and re-transformed to the original scale, serve as the seasonal indices of abundance. Models were constructed using lognormal, Poisson, negative binominal, and gamma error distributions with log-links where necessary. The estimates of- and changes in several goodness of fit statistics were used to evaluate the goodness of fit of the model and the significance of the classification factors: a) the ratio of the deviance (twice the difference between the maximum attainable log likelihood and the log likelihood of the model) to the degrees of freedom (DF) – this statistic is a measure of "dispersion" and of fit of the expected probability distribution to the data (closer to 1 is better), b) the value of the log-likelihood (a measure of model fit), c) the computed AIC (a measure of model fit and performance, valid for a sequence of models within each distribution), d) whether or not the model converged (whether the negative of the Hessian matrix was positive definite, allowing valid estimation of the parameters and their precision), and e) the significance of the classification factors as indicated by the log-likelihood ratio statistics at the 5% level. A Type III analysis was used since it does not depend on the order in which the classification factors (i.e., the survey ID) are specified (SAS 2011). The seasonal 'integrated' aggregate numeric indices were then used as calibration indices and results compared with the existing (2008 model updated through 2014) and preliminary SAW 60 scup model (new surveys with full age 0-7+ compositions) configurations. The GLM seasonal state/academic survey indices of aggregate numeric abundance are shown in Figure A36.

There are insufficient seasonal state/academic survey indices at age to construct integrated indices at age for both seasons for the full range of ages, 0 to 7+. For example, there are only two spring age 2 series (CTDEEP and NEAMAP), and only one spring series each for ages 3, 4, and 5-7+ (from the CTDEEP spring survey). Therefore, standardized integrated indices at age were constructed using indices for both seasons to construct independent annual index series for ages 0, 1, 2, 3, 4, and 5-7+. Main classification effects were limited to the year of sampling (1982, 1983...2004) and the identity of the survey (CTDEEP fall age 0, CTDEEP fall age 1...CTDEEP fall age 5:7+). The resulting year effect coefficients, corrected for lognormal-transformation bias and re-transformed to the original scale, were used as six independent indices of abundance at ages 0, 1, 2, 3, 4, and 5-7+ that were input to the model calibration in place of the original, multiple (28) state/academic survey series at age. Survey selection was set at 1 for each age series. The construction of the six independent, annual 'integrated' indices at age suggested it could be useful to have a corresponding annual 'integrated' aggregate index, analogous to the way the 2008 assessment model was configured; one was constructed using all state/academic spring and fall indices, as in the previous section. The six independent, annual 'integrated' indices at age and the annual 'integrated' aggregate numeric index were then used in sequential fashion as calibration indices in the existing 2008 and preliminary SAW 60 scup model configurations.

A model using only seasonal 'integrated' aggregate indices indicated lower SSB over the last decade, about 40% in 2014, and higher F by 50-100% in 2014, compared to the existing 2008 and preliminary SAW 60 models. The 'integrated' indices model provided more uncertain estimates of 2014 SSB and F than the existing/preliminary models, with comparable precision of recruitment at age 0. A model using an integrated aggregate index for both seasons plus 'integrated' indices at age' for ages 0-2 provided the closest agreement between the existing 2008 and preliminary SAW 60 models. As 'integrated' indices at ages 3 and older were added, the estimates of SSB for 2010 and later years increased above the existing/preliminary models. The SWG viewed this work as a useful 'sensitivity' analysis of the existing and preliminary model configurations.

A6.11.2 Hierarchical Analysis (Conn 2010) Indices of Abundance

The ‘hierarchical analysis’ approach demonstrated in Conn (2010) was applied to the same collections of scup spring and fall research survey data from state agencies and academic institutions as used in the GLM ‘integrated indices’ work described earlier. In his paper Conn (2010) concluded “…I have shown how hierarchical analysis can be used to estimate a common population trend from multiple indices. This framework separates components of index variation into process error and sampling error. In this manner, analysts can calculate a single, ‘‘most probable’’ index prior to stock assessment analyses. Such an index may be of interest in its own right or may be advantageous in model fitting because it reduces the dimensionality of the likelihood and precludes numerical problems that can arise when fitting data to multiple, conflicting indices. It also has the potential to reduce the number of subjective decisions that are typically made about which indices to include in the analysis.”

The result was construction of seasonal time series of relative abundance for use in scup model calibration. No hierarchical indices at age were constructed. The hierarchical seasonal indices of aggregate numeric abundance are shown in Figure A37.

A6.12 Comparative analysis and Conclusion

The ‘GLM Integrated’ and ‘Hierarchical’ spring and fall indices, with all 4 series scaled to their respective time series means, are shown in Figure A38. The ‘Hierarchical’ series are less variable, resulting in a stronger ‘smooth’ through the state and academic spring and index series. The ‘GLM Integrated’ and ‘Hierarchical’ seasonal indices of aggregate abundance were added to the preliminary SAW 60 ASAP model run referenced earlier in the GLM section, to examine the influence of each on the model results and compare to the preliminary SAW 60 ‘full’ model. The SWG viewed this work as a useful ‘sensitivity’ analysis of the existing and preliminary model configurations, but it has not been carried forward in the assessment.

This work for scup suggests there are ‘pros’ and ‘cons’ to the construction of ‘integrated’ indices and their use in the calibration of population models. ‘Pros’ include the idea that the standardization procedures serve as objective statistically based ‘smoothers’ of survey indices with high inter-annual variability and relatively low precision. The resulting indices then serve as temporally and spatially synoptic ‘integrated’ metrics of aggregate abundance. ‘Cons’ include the notion that use of ‘integrated’ indices as calibration data in a model means that much of the characteristic variability of the original survey indices has been ‘smoothed out’ by the standardization procedure, although there is a trade-off with the decrease in degrees of freedom (fewer ‘surveys’ used in the calibration). The SWG concluded that the ‘hierarchical’ approach held more promise for future development, but that considerably more work is needed before these indices could be used in the scup assessment.

A7. TERM OF REFERENCE 3: Describe the thermal habitat and its influence on the distribution and abundance of scup, and attempt to integrate the results into the stock assessment.

A7.1 NEFSC Trawl Survey Environmental Data

Some of the NEFSC winter, spring and fall trawl survey environmental data were summarized for the strata sets used for scup to investigate the correspondence between the environmental factors and the distribution of scup. The environmental factors were surface air temperature in degrees Celsius, surface and bottom water temperature in degrees Celsius, and bottom water salinity in parts per thousand (PPT). Valid surface and bottom temperature data on a per tow basis are generally available for the entire 1968-2014 time series for the scup survey strata (Great South Channel to Cape Hatteras) in both spring and fall, with the exception of fall 2008, for which large numbers of observations are missing. Air temperatures are generally missing during the 1970s and during 2012-2014 in both spring and fall. Bottom salinities are generally available for 1997 and later years, except for fall 2008.

First, the cumulative distributions of the scup survey catches by tow and the environmental factors were compiled for the spring (offshore strata 1-12, 23, 25, 61-76) and fall (offshore strata 1-12, 23, 25, 61-76, inshore strata 1-61) strata sets. For this simple compilation, the cumulative totals over tows are not weighted by stratum area. In the spring survey strata, over the full 1968-2014 time series, scup were in general caught at stations (tow sites) that had a warmer surface temperature (Figure A39; median [50^{th} %ile] catch at 8.5^{o}C, median tows at 6.3^{o}C), a warmer bottom temperature (Figure A40; median [50^{th} %ile] catch at 9.8^{o}C, median tows at 6.8^{o}C), higher bottom salinity (Figure A41; median catch at 34.8 PPT, median tows at 33.6 PPT), and warmer air temperature (Figure A42; median catch at 10.0^{o}C, median tows at 6.0^{o}C) than the median environment of the spring scup strata set. In the fall survey strata, scup were in general caught at stations (tow sites) that had a warmer surface temperature (Figure A43; median catch at 22.1^{o}C, median tows at 19.9^{o}C), a warmer bottom temperature (Figure A44; median catch at 21.0 median tows at 13.4^{o}C), lower bottom salinity (Figure A45; median catch at 31.9 PPT, median tows at 32.5 PPT), and slightly warmer air temperature (Figure A46; median [50^{th} %ile] catch at 19.0^{o}C, median tows at 18.7^{o}C) than the median environment of the fall scup strata set.

In a second compilation, the annual stratified mean values of the environmental factors for positive scup catch tows were compared with the annual stratified mean values of the environmental factors for all tows in the scup strata sets to investigate trends over time. Figure A46 shows that the mean surface temperature on NEFSC spring survey tows with positive scup catch (SCP_surftemp) was generally warmer than the mean surface temperature of all tows (All_surftemp) over the series. The solid trend lines show that the mean surface water temperature of both positive scup tows and all tows in the spring strata set has increased over time. Figure A48 shows the pattern for NEFSC fall survey tows, with the mean surface temperature on tows with positive scup catches generally close to the mean surface temperature of all tows over the series. The solid trend lines show that the mean surface water temperature of positive scup catch tows and all tows in the fall strata set has increased over time.

Figure A49 shows that the mean bottom temperature on NEFSC spring survey tows with positive scup catches (SCP_bottemp) was generally warmer than the mean bottom temperature of all tows (All_bottemp) over the series. The solid trend lines show that the mean bottom water temperature of both positive scup tows and all tows in the spring strata set has slightly increased over time. Figure A50 shows the pattern for NEFSC fall survey tows, with the mean bottom temperature on tows with positive scup catches generally warmer than the mean bottom temperature of all tows over the series. The solid trend lines show that the mean bottom water temperature of scup tows in the fall strata set has increased more over time than the bottom temperature in all tows.

Figure A51 shows that the mean bottom salinity on NEFSC spring survey tows with positive scup catches (FLK_botsalin) was generally higher than the mean salinity of all tows (All_botsalin) since 1997. The solid blue trend line shows that the mean bottom salinity of all tows in the spring strata set has increased since 1997. Figure A52 shows the pattern for NEFSC fall survey tows, with the bottom salinity on tows with positive scup catches generally lower than the mean salinity of all tows since 1997. The solid trend lines show that the mean salinity of all tows in the fall strata set has a similar trend as the spring.

Figure A53 shows the mean air temperature on NEFSC spring survey tows with positive scup catches (FLK_airtemp) was slightly higher than the mean air temperature of all tows (All_airtemp) over the series. The solid trend lines show that the mean air temperature of all tows in the spring strata set has decreased over time. Figure A54 shows the pattern for NEFSC fall survey tows, with the air temperature on tows with positive scup catches generally comparable to the mean air temperature of all tows. The solid red trend line shows that the air temperature of all tows in the fall strata set has increased over the series.

As noted in the NEFSC surveys section under TOR 2, examination of patterns in the survey catch, for spring and fall and day and night, confirms the irregular distributions of catch by temperature, salinity and depth and portend the difficulties of modeling the survey scup catch data. No well defined relationships are evident; i.e., small catches are as likely to be taken at shallow depths as large depths and at both warm and cold temperatures and large catches can occur over a relatively large range of depth and temperature (e.g, over a range of 70 meters or 10 degrees). Therefore, generalized linear model (GENMOD) and generalized additive model (GAM) based indices of abundance for the scup NEFSC seasonal survey data proved to be not useful, due to highly variable results owing from the inability of the models to adequately fit the variable and complex temporal and spatial properties of scup survey catches.

The NEFSC survey indices sometimes appear to mainly reflect the availability of scup to the survey, rather than true abundance, making it difficult to interpret large inter-annual changes in the indices. As noted in the description of the NEFSC trawl survey indices above, the spring 2002 and 2014 indices were unexpectedly much higher than adjacent indices (Figure A14), across all ages. In 2002, this ‘availability event’ appears to have been a response to higher than normal spring water temperatures, as large scup survey catches and bottom water with temperatures higher than 10^{o}C were distributed further inshore on the shelf than usual. Figures A55-A57 show the distribution of scup catches and temperatures during 2001-2003. In more recent years, the bottom temperature pattern in 2011 and 2013 was more ‘normal’ and large scup catches were restricted to the shelf edge (Figures A58 & A60). The bottom temperature in 2012 was similar to that in 2002, and scup catches were distributed across the shelf (Figure A59), resulting in a high biomass and abundance indices, although not as extreme as in 2002. Near ‘normal’ bottom conditions were present in 2014 (Figure A61), but catches of large scup occurred near mid-shelf in large-area strata, and the 2014 indices (especially in biomass per tow) were among the largest of the spring time series. These sequences of potential ‘availability events’ make clear the difficulty that is encountered when interpreting survey indices for scup – do high survey indices indicate high availability, high abundance, or (more likely) some combination of both? This issue has lead NEFSC investigators to pursue the work described in the next section.

A7.2 Modeling annually varying suitable thermal habitat

The working paper of Manderson et al. (MS 2015; Working Paper A11) describes the development of estimates of proportions of 'thermal habitat suitability' for scup (Figure A62) surveyed in the NEFSC and NEAMAP surveys that could be used to account for errors in survey observations related to temperature dependent changes in geographic distribution and seasonal migration. The working paper described the development and evaluation of time series of varying estimates of the proportion of thermal habitat suitability for scup surveyed on the Northeast US shelf by the NEFSC and NEAMAP bottom trawl surveys from 1975-2012 in a manner that accounted for thermal habitat occurring outside the surveys and the relative motions of habitat and the survey vessel. The working paper estimated that an average of ~63 % of the thermal habitat suitability available to scup within the model domain (Cape Hatteras to Nova Scotia) was sampled from 1973-2012 by the fall NEFSC bottom trawl survey, while ~50% was sampled in the spring. In the 2008-2012 NEAMAP surveys approximately 14% of available thermal habitat suitability on the Northeast US continental shelf was sampled during the fall, while 11% was sampled in the spring. Yearly estimates of the proportion of thermal habitat suitability surveyed did not exhibit systematic trends (Figures A63-A65).

A8. TERM OF REFERENCE 4: Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results and previous projections.

A8.1 Instantaneous Natural Mortality Rate (M)

The instantaneous natural mortality rate (M) for scup has been assumed to be 0.20 (Crecco *et al.* 1981, Simpson *et al.* 1990) in all previous stock assessments. Longevity based estimators of M are sensitive to critical underlying assumptions which include the value of p, or the small proportion of the population surviving to a given maximum age (tmax), and the maximum observed age under no exploitation conditions. Using a maximum age of 15 years for scup, the 'Rule of Thumb' method of 3/tmax noted in Quinn and Deriso (1999) and the methods of Hoenig (1983) and Hewitt and Hoenig (2005), longevity based estimates of M for combined sexes range from 0.20 to 0.28. Age-specific and size variable estimates of M, based on the work Lorenzen (1996, 2000) and Gislason et al. (2010) range from 0.18 to 1.72, with the highest values associated with age 0 fish (fish at smallest lengths and weights).

Then et al. (2014) recently conducted a review of the performance of the best known empirical estimators of natural mortality. Then et al. (2014) recommended use of the updated Hoenig (1983) estimator when an estimator of tmax is available, or the updated Pauly estimator when a reliable estimate of tmax is not available. For a scup tmax of 15 years, the updated Hoenig method provides an estimate of 0.41, and for Linf = 51.6 cm and K = 0.16, the updated Pauly method provides an estimate of 0.30.

Alternative estimates of M for scup are presented in the table below. Given the historical maximum size and age of 41 cm and 15 years, recent observations of large fish (45 cm) up to age 12, the range of M (0.1 – 0.6) estimated by the empirical methods based on maximum age, and the likelihood profile of a preliminary assessment model run that indicated a best fit at M = 0.10 and of the final model at 0.15, the SWG decided there was no compelling reason to change from the previous assumption for M, and adopted a value of M = 0.20 for all ages and years in the 2015 SAW 60 assessment models.

Age	3/tmax Rule of Thumb	Hoenig (1983), Hewitt and Hoenig (2005)	Gislason et al (2010)	Lorenzen (1996, 2000)	Lorenzen Scaled to Rule of Thumb	Lorenzen Scaled to Hewitt & Hoenig	Then et al. (2014): Pauly	Then et al. (2014): Hoenig
0	0.20	0.28	1.72	1.38	0.82	0.68	0.30	0.41
1	0.20	0.28	0.96	1.03	0.61	0.51	0.30	0.41
2	0.20	0.28	0.59	0.77	0.46	0.38	0.30	0.41
3	0.20	0.28	0.44	0.65	0.38	0.32	0.30	0.41
4	0.20	0.28	0.36	0.57	0.34	0.28	0.30	0.41
5	0.20	0.28	0.31	0.53	0.32	0.26	0.30	0.41
6	0.20	0.28	0.28	0.50	0.30	0.24	0.30	0.41
7	0.20	0.28	0.27	0.48	0.28	0.23	0.30	0.41
8	0.20	0.28	0.25	0.46	0.27	0.23	0.30	0.41
9	0.20	0.28	0.24	0.42	0.25	0.20	0.30	0.41
10	0.20	0.28	0.20	0.42	0.25	0.20	0.30	0.41
11	0.20	0.28	0.21	0.40	0.24	0.20	0.30	0.41
12	0.20	0.28	0.20	0.40	0.24	0.19	0.30	0.41
13	0.20	0.28	0.19	0.39	0.23	0.19	0.30	0.41
14	0.20	0.28	0.19	0.38	0.23	0.19	0.30	0.41
15	0.20	0.28	0.18	0.38	0.22	0.18	0.30	0.41
Mean	0.20	0.28	0.34	0.57	0.34	0.28	0.30	0.41

A8.2 2015 SAW 60 Model Building

A8.2.1 Existing 2008 Assessment Model Updated through 2012

The most recent benchmark peer review of the scup assessment was conducted by the 2008 Northeast Data Poor Stocks Working Group (DPSWG) panel (NEFSC 2009), which accepted an Age Structured Assessment Program (ASAP) statistical catch at age model (Legault and Restrepo 1998, NFT 2008) with fishery and survey catch data through 2007 as the basis for status determination. The assessment indicated that the stock was not overfished and overfishing was not occurring in 2007 relative to the corresponding biological reference points. There was no consistent retrospective pattern in F, SSB, or recruitment evident in the assessment model.

ASAP is an age-structured model that uses forward computations assuming the separability of fishing mortality into year and age components to estimate population sizes given observed catches, catch-at-age, and aggregate and at-age indices of abundance. The separability assumption is partially relaxed by allowing for fleet-specific computations and by allowing the selectivity-at-age to change in blocks of time. Weights (emphasis factors) are input for different components of the objective function which allows for configurations ranging from relatively simple age-structured production models to fully parameterized statistical catch-at-age models.

The objective function is the sum of the negative log-likelihood of the fit to estimable model components. Catch at age and survey at age compositions are generally modeled assuming a multinomial distribution, while most other model components are assumed to have lognormal error. Specifically, lognormal error distributions were assumed for the total catch in weight, research survey catch at age calibration indices, selectivity parameters, annual fishing mortality parameters, survey catchability parameters, estimated stock numbers at age, and Beverton-Holt stock-recruitment parameters, when estimated. Recruitment deviations are also assumed to follow a lognormal distribution, with annual deviations estimated as a bounded vector to force them to sum to zero, thus centering the predictions on the expected stock-recruitment relationship. In the 2008 assessment ASAP model an instantaneous natural mortality rate of M = 0.2 was assumed for all ages and years. Additional initial model settings included specification of the likelihood component emphasis factors (weights or Lambdas, L), the size of deviation factors expressed as standard deviations (i.e., ln-scale CV), and the penalty functions for extreme fishing mortality estimates. These were set at consensus values by the 2008 DPSWG (NEFSC 2009) after multiple sensitivity runs to evaluate a range of inputs.

The 2008 ASAP model built on earlier Virtual Population Analysis (VPA) models for scup (NEFSC 1998), and the 2008 scup assessment was one of the first uses of the ASAP model in Greater Atlantic Region stock assessments. As such, the survey indices at age were configured as in the earlier VPA model, with indices input to the model as individual time series (e.g., NEFSC fall survey Age 0, 1984-2007; CTDEEP spring survey age 6, 1984-2007; VIMS age 0, 1987-2007). During the model building process for the 2008 assessment, additional aggregate survey biomass series were added to the model to provide more and longer time series of survey data and explicitly model aggregate population trends (e.g., NEFSC winter, spring and fall biomass series, MADMF spring and fall biomass series, RIDFW spring and fall biomass series, and NJ biomass and URIGSO aggregate numeric series). The addition of the long-term aggregate series helped stabilize the model estimates and ensured consistent convergence. Winter, spring, and mid-year survey indices and all survey recruitment (age-0) indices were calibrated to population numbers of the same age at the beginning of the same year. Fall survey indices were calibrated to population numbers one year older at the beginning of the next year. Lognormal error distributions were assumed for the survey catch at age calibration indices. This survey index configuration was retained in the 2008 and subsequent assessment updates.

Four fishery fleets were modeled in aggregate (metric tons; Tables A22 & A27) and at-age (in thousands of fish at ages 0-7+): commercial landings (Table A13), commercial discards with mortality rate of 100% (Table A16), recreational landings (Table A18), and recreational discards with mortality rate of 15% (Table A20). In ASAP, a single catch numbers-weighted mean weight at age matrix (Table A24) serves as the basis for mid-year catch and extrapolated (Rivard method) SSB mean weights at age. Fleet CVs were set at 0.10, 0.32, 0.10, and 0.12 and Fleet Effective Sample Sizes (ESS) were set at 22, 9, 31, and 4. Fishery selectivity (S) was modeled as 'at-age' selectivity (estimate individual S at age) by fleet and time block. Two time blocks were set: 1963-1996, before the implementation of quotas, and 1997 and later, after implementation. Commercial and recreational landings S was set fixed at 1 for (true) age 4 for both time blocks with L = 1 and CV = 0.1. Commercial discards S was set fixed at 1 for (true) age 2 and recreational discards S was set fixed at 1 for (true) age 1 for both time blocks with L = 1 and CV = 0.1. Survey selectivity (S) was set fixed at 1 for each individual index at age.

Other 2008 assessment model settings included: total fishery catch weight lambda (L) = 1; fishing mortality (F) and stock size (N) in year 1 L = 1 and CV = 0.9; recruitment deviations L =

1, with CV = 0.1 during 1963-1983, and CV = 1.0 after 1983; S-R function and population scaler Ls = 1 with CV = 0.9, effectively ‘turning on’ the influence of the S-R function in the model and giving particular influence in years 1963-1983 before any fishery or survey age data were available; and survey catchability coefficients (q) estimated as a constant value (no deviations) with L = 1 and CV = 0.9.

Following the 2008 assessment, the NMFS declared scup to be officially rebuilt in 2009. The assessment was updated with new data under the same 2008 model configuration for 2009-2012. The 2012 update again found the stock was not overfished and that overfishing was not occurring in 2011 relative to the 2008 biological reference points (Terceiro 2012).

A8.2.2 Existing 2008 Assessment Model Updated through 2014

Model IAA-IND08 is the first of the 2015 SAW 60 models, with the same configuration and settings as the 2008-2012 models but with data updated through 2014. Surveys are configured as independent indices at age (IAA), the index set included in the model is the same as in the 2008-2012 models (IND08), and fishery and survey selection is modeled as ‘at-age.’ Model IAA-IND08 provides estimates appropriate to compare with the existing reference points, which are FMSY proxy = F40% = 0.177 and SSBMSY proxy = SSBMSY40% = 92,044 mt (TOR 6a). This model indicates that F in 2014 = 0.047 and SSB in 2014 = 232,673 mt, so the stock was not overfished and overfishing was not occurring (see TOR 6a). Summary results for 1984 and later years (the period when fishery age data are available and recruitment deviations can be estimated from fishery and survey catch at age) from the 2008 and 2012 assessments are compared with those from run IAA-IND08 in Figures A66-A68.

A8.2.3 2015 SAW 60 Assessment Model Updated through 2014

The subsequent model building occurred in three ‘phases.’ In phase 1, structural changes were made to the survey configurations (from individual indices-at-age modeled with lognormal error to catch-at-age matrices modeled with multinomial error, with full age compositions), several new survey series with full age compositions were added to the model, and new (revised) maturity and commercial discard estimates were added to the model. The end product of phase 1 was the BASE run with the most complete input data set to move forward.

In phase 2, the BASE run was tested to determine the likelihood components that are reliably estimable (e.g., starting N and F, fishery and survey selectivity, recruitment estimation, survey catchability, time series of F and N, etc.) , evaluate their statistical diagnostics (convergence, residuals, Root Mean Square Error [RMSE], etc.), and determine their influence on model results. Phase 2 determined the ‘best’ general model configuration to move forward.

In phase 3, the ‘best’ BASE run was ‘tuned’ by iterating survey CVs to allow RMSEs to approach the confidence intervals associated with a N(0,1) distribution (i.e., for a normal random variate) for that sample size, and by adjusting fishery and survey age composition ESS to near the time series means while accounting for ‘outliers.’ Subsequent ‘final run’ diagnostics included retrospective analyses, likelihood profiling over the assumptions for M and SSB0, sensitivity to the configuration of the NEFSC spring and fall survey series, and sensitivity to the length of the modeled time series.

A8.2.4 Model Building Phase 1

The 2015 SARC 60 model building process started with the 2012 updated assessment model run with data through 2011 (Terceiro 2012). The 2012 model differed from the previous 2008 DPSWG benchmark assessment ASAP model (NEFSC 2009) only in minor changes to the values of the fleet Effective Sample Sizes (ESS). As noted above, the 2012 model has been updated with fishery and survey data through 2014 to create model IAA-IND08, with results compared to the existing 2008 reference points, in response to TOR 6A.

Since the 2008 assessment, the survey index configuration widely accepted as 'standard' in the ASAP model has evolved. In general, survey indices at age are now input as a 'catch-at-age' matrix modeled with multinomial error to calibrate population proportions at age, along with a corresponding aggregate numeric or biomass index modeled with lognormal error to calibrate aggregate population trends. Stand-alone recruitment indices can continue to be modeled as single-age indices, as can aggregate numeric biomass or numeric survey series for which no associated age composition data are available. Each model configuration change (step) in phase 1 generally builds on the previous step, unless noted. The model was first transitioned to the now 'standard' ASAP model survey index configuration using the same suite of indices as in 2008 and 2012 and given the name MULTI_IND08.

In the next step, new surveys and new ages [i.e., full age range] from previous surveys are added to the model, creating model NEWSVS. 'Full-catch-number-at-age' survey indices are available for the NEFSC spring, fall, and winter (ages 0-7+; Tables A31-A32, A34) and CTDEEP spring and fall (ages 0-7+; Tables A42-A43). 'Limited-catch-number-at-age' surveys are available for the NYDEC (ages 0-2; Table A44) and VIMS ChesMMAP (ages 0-1; Table A46). Aggregate numeric indices (no age compositions) are available for the MADMF spring and fall (Table A36), URIGSO (Table A41) and NJDFW surveys (Table A45) . The VIMS index of age 0 abundance is input as a stand-alone numeric index at age (Table A45). New 'Full-catch-number-at-age' survey indices from the RIDFW Industry Cooperative Trap Survey (ages 0-7+; Table A40) and 'Limited-catch-number-at-age' indices the NEAMAP spring and fall surveys (ages 0-2; Table A48) are also added. Late in the assessment process, too late to be added to the NEWSVS configuration, 'full-catch-number-at-age' survey indices became available for the RIDFW spring and fall surveys (Tables A38-A39). These new RIDFW indices replaced the previous aggregate indices (Table A37) and were evaluated in a later, phase 3 run. Finally, the fishery fleet ESS values were 'rounded' from [22, 9, 29, 4] to [30, 10, 30, 5] to provide a new ESS starting point given the addition of new ages for previous surveys and survey data series (it was noted that the estimated ESS values were starting to drift away in both directions from the initial 2012 assessment values).

The next step was to revise the commercial fishery discard estimates as described above in the COMMERCIAL FISHERY DISCARDS section, creating model NEWDISC. The final step in phase 1 was to adopt the revised maturity schedule using the 3 year moving window estimates as described above in the MATURITY section, creating model NEWMAT. Results from models the 2008 DPSWG, 2012 Update, and 2015 SAW 60 IAA_IND08 through NEWMAT are summarized in Tables A49-A50 and Figures A69-A71. Table A49 provides a summary of the initial steps in building the model configuration and settings, while Table A50 provides summary results. Important changes in settings and estimates between modeling steps are highlighted with bold text. The largest changes occurred due to the use of the new survey configuration (MULTI_IND08) and the revision in commercial discards (NEWDISC). Retrospective analysis conducted for run NEWMAT found no pattern of large (i.e., > 30%) relative errors in SSB or F, which were both < 10%, with about +16% for age 0 (model age 1) recruitment.

A8.2.5 Model Building Phase 2

As in phase 1, each change in phase 2 generally builds on the previous step, unless noted. Model configuration NEWMAT was renamed S60_BASE_1 to begin phase 2. In addition to acceptance of survey indices at age input as a 'catch-at-age' matrix modeled with multinomial error as the standard ASAP configuration, a number of other settings have also became accepted as 'standard', mainly in the interest of allowing the input data to most strongly influence the model results and of reducing the influence of prior (initial) values, in the following general order:

1) Test the model sensitivity to the initial values of N in year 1 to minimize residuals and stabilize starting conditions, Ls set to 0 if possible

2) Test the model sensitivity to the initial values of F in year 1 (to minimize residuals and stabilize starting conditions) and F deviations in subsequent years; Ls set to 0 if possible

3) Ls for fishery and survey selectivity, Ls set to 0 if possible

4) If the internal S-R function will not be used for BRPs (e.g., if h ~1), 'turn off' S-R function (Ls set to 0)

5) Test the model for sensitivity to recruitment deviation priors, L set to 0 if possible

6) Test the model for sensitivity to use of likelihood constants, 'turn off' if possible

The first change was to iterate the initial guesses for N in year 1 from the very large values with exponential decline used in the 2008 assessment to values closer to the predicted 2008 values with simple deviations, creating run S60_BASE_2. This run provided results very close to S60_BASE_1.

The next change in phase 2 was to remove the prior (L=1 to L=0) for N in year 1 of the model, removing these parameters from the objective function. This run did not converge (no estimates), so the L was reset to 1, and the run continued to be called S60_BASE_2.

The next change in phase 2 was to remove the prior (L=1 to L=0) for F in year 1 of the model and for F deviations in subsequent years, removing these parameters from the objective function. The model performed somewhat better (more feasible F in year 1 estimate) when the L=1 for F in year 1 was retained, creating run S60_BASE_3. The changes from S60_BASE_1 to S60_BASE_3 resulting in only minor changes in the estimates of SSB, R, and F since 1984 (the first year in the model with both fishery and survey ages).

The next change was to remove the priors for fishery selectivities (L=1 to L=0), creating run

S60_BASE_4. Removing the constraint of the priors allowed the fishery landed catch selectivity patterns to become more domed, while the fishery discarded catch selectivity patterns became less domed. The landed catch dome in particular became extreme, to less than 10% selection for the plus group age in the second time block, which is likely not feasible. The overall effect on the general magnitude of SSB, R, and average F for adult fish (true ages 2 and older; model ages 3 and older) was relatively minor, however, for most of the time series.

The next change was to restore the priors for catch selectivities (L=0 to L=1) but increase the CV from 0.1 to 0.5, allowing moderate constraint, and creating run S60_BASE_5. This change provided intermediate results between runs 3 and 4, and was carried forward.

The next change was to remove the priors for survey selectivities (L=1 to L=0) for surveys with age compositions, creating run S60_BASE_6. Removing the constraint of the priors on survey selectivities allowed most of the selectivities to be estimated lower for ages 2 and older and to approach zero for ages 5 and older. This change had a relatively large effect. The overall effect on the general magnitude of R and SSB was an increase in recruitment during the 2000s and a stronger increase in SSB since 2000 which resulted in about a 20% increase in terminal year SSB compared to run S60_BASE_5 (Figures A72-A74). Some of the older age selectivities were imprecisely estimated or hit a boundary constraint. However, the run S60_BASE_6 survey selectivity settings were left as is until later in phase 2, where they would be re-examined.

Calculation of the S-R function parameters in runs 1-6 resulted in 'steepness' estimates ranging from 0.95 to 0.97, i.e., very close to 1.00. The next change was to change the Ls from 1 to 0 for 'Initial Steepness,' effectively 'turning off' the influence of the S-R function in the model, and thus relying only on the fishery and survey indices to estimate recruitment, constrained by L = 1 and CV = 0.1 during 1963-1983, increasing to CV = 1.0 during 1984-2014 for the annual recruitment deviations. These changes created run S60_BASE_7. 'Turning off' the S-R function mainly affected model estimates before 1984, which translated into about 10% lower F during the mid-1990s, but only very small changes in F or SSB since 2000 compared to run S60_BASE_6.

The next change was to remove the constraints on recruitment deviations, by changing L = 1 to L = 0, creating run S60_BASE_8. This resulted in an extremely variable pattern in estimated stock sizes at age in the years before 1984 (e.g., annual recruitment ranging from near 0 to about the post-1983 maximum of about 200 million), and infeasible estimates of F during the 1960s-1970s ranging to near the constraint of F = 5.0. With no apparent benefit to removing the recruitment deviations constraint that holds them near the mean for years before 1984, it was re-implemented by changing back to L = 1, and the S60_BASE_7 configuration was retained for moving forward.

The next change was to 'turn off' the 'likelihood constants' in the model, creating run S60_BASE_9. This change affects the way recruitment deviations are estimated in ASAP3. Ongoing ASAP model development work demonstrates that holding the value of the term constant can, in some cases, lead to underestimates of recruitment because the objective function can be reduced by lowering the estimated recruitment values, since one of the components sometimes is in fact not constant, with the degree of variation depending on the specific model configuration. For run 9, 'turning off' the likelihood constants resulted in a nearly uniform time series increase in recruitment of about 9% over the time series compared to run 7. One estimation difficulty re-emerged, however, as the run 9 model provided infeasible estimates of F during the 1960s-1970s ranging to near F = 3.0, due to the estimation of some transient but very large stock sizes at fully recruited ages early in the time series, similar to the DPSWG2008 assessment model and some of the earlier 2015 configurations. These ‘odd’ estimates do not generally persist for long, passing out of the population in 3-4 years, and so do not affect the population dynamics over the last 30 years when age compositions are available. ‘Turning off’ the ‘likelihood constants’ is now considered to be the preferred configuration for ASAP, so this change was retained in subsequent steps.

Some patterning in the fishery age composition residuals from the mid-2000s and later years had persisted through all the early S60_BASE run configurations. Run S60_BASE_10 built upon run 9, adding a third fishery selection block for 2006 and later years, with the fishery selection Ls = 1 and S = 1 for (true) age 4 for the landings and (true) age 2 for discards. This change slightly improved the fishery age composition residual magnitude and pattern, and the third selection block was retained.

Before moving to model ‘tuning’ in phase 3, a more detailed examination of diagnostics for run 10 was made, including those for fishery and survey selectivity parameter estimates, patterns in aggregate survey index residuals, and patterns in fishery and survey age composition residuals. Inspection of the estimated parameters of run S60_BASE_10 revealed that several of the fishery and survey selection parameters at age were poorly estimated (either constrained at a bound or with large standard error; although note that the survey selectivities are not part of the objective function as L = 0). In run S60_BASE_11, bounded fishery selection parameters at 1 were fixed at S = 1, generally true ages 4 or 5 adjacent to the S= 1 fixed at true age 3. Estimates from run S60_BASE_11 were nearly identical to those from run 10. Next, poorly estimated survey selection parameters at age (CV equal to or greater than 1.0), typically for the youngest or oldest ages, were fixed near the value of the nearest acceptably estimated age, resulting in run S60_BASE_12. Again, these change had little effect, and the results of S60_BASE_12 were nearly identical to those from run 11.

In summary, the largest changes in estimates over steps 1-12 of the BASE model were due to 1) changing the fishery selectivity prior CVs from 0.1 to 0.5 in run 5, 2) changing the survey selectivity Ls from 1 to 0 in run 6, 3) ‘turning off’ the recruitment likelihood constants in run 9, and 4) adding a third (2006 and later) fishery selectivity block in run 10. Except for the transient, starting condition-related extreme F early in the time series, the estimates change very little from run S60_BASE_9 through 12 (Tables A51-A52, Figures A75-A77).

A8.2.6 Model Building Phase 3

In phase 3, the following changes to the model configuration were made:

1) Iterate survey CVs to allow Root Mean Square Errors (RMSE) to approach the confidence intervals associated with a N(0,1) distribution for that sample size (i.e., +/- 2 se; see the ‘normal random variate’ diagnostic plot). For example, if RMSE is ‘too low,’ the CV can be reduced, while if the RMSE is ‘too high,’ the CV can be increased

2) Calibrate fleet ESSs to about the time series mean, one time, rather than Francis (2011) adjustment

3) Calibrate survey ESSs to about the time series mean, one time, rather than Francis (2011) adjustment

The first model 'tuning' step was undertaken in run S60_BASE_13. The input aggregate survey CVs, generally the means of the calculated time series averages, are intended to characterize the sampling error of those series. However, it is recognized that additional process (model) error may be present in the survey indices that are not reflected in the calculated CVs, as diagnosed by the distance of the Root Mean Square Error (RMSE) of each series from 1. Examination of the model diagnostics for the survey indices resulted in adjustments to the survey CVs, thereby allowing for larger deviations to bring their respective RMSEs within or close (sometimes) to the expected confidence intervals (CI) for the number of observations.

Most of the surveys included in the scup model have calculated CVs in the range of 0.2 to 0.9. Based on previous experience with winter (NEFSC 2011b) and summer (NEFSC 2013b) flounder assessment models in ASAP, the input CVs were initially set in the range of 0.5 to 0.6 to account for additional process error. Iterating survey SVs to reduce the RMSEs brought most of them to 0.8-0.9, but in some cases even a high CV of 1.2 still resulted in RMSE outside the N(0,1) confidence interval (RIDFW spring, MADMF spring, NEFSC spring, Figure A78). The next step might be to consider omission of some of those survey series from the model calibration. The input CVs and RMSEs for run S60_BASE_13 were as follows:

Index	Name	Initial CV	Adjusted CV	Run 13 RMSE
1	NECWIN	0.6	0.8	1.2
2	NECSPR	0.6	1.0	1.5
3	NECFAL	0.6	0.6	0.9
4	CTSPR	0.5	0.9	1.3
5	CTFAL	0.5	0.8	1.2
6	NYDEC	0.6	1.2	1.4
7	MASPRKG	0.5	1.2	1.4
8	MAFALKG	0.5	0.5	1.1
9	RISPRKG	0.5	1.2	1.6
10	RIFALKG	0.5	0.8	1.1
11	NJKG	0.5	0.8	1.3
12	URIGSO	0.5	0.7	1.2
13	ChesMMAP	0.6	1.0	1.4
14	VIMSYOY	0.6	1.2	1.2
15	NEAMAP SPR	0.5	0.7	1.3
16	NEAMAP FAL	0.5	0.5	1.2
17	RI Coop Trap	0.5	0.5	0.6
	Total			1.3

These adjustments in survey CVs resulted in lower recent stock sizes and higher recent F relative to the S60_ BASE_12 run (Figures A79-A81). The 'odd' large older age stock size estimates and corresponding unfeasible F estimates early in the time series were reduced. The larger survey CVs also resulted in more large residuals in the last 10-15 years of the model for the CTDEEP spring, NYDEC, RIDFW spring and fall, and URIGSO indices.

The next change was to ‘tune’ the 4 fishery fleet age composition ESSs to about their time series means, roughly ‘centering’ them in the time series pattern. The ESSs were adjusted from the initial run 1 values of [30, 10, 30, 5] to [50, 20, 50, 5]. These ‘centered’ ESSs for three of the fleets were fairly close to the calculated Francis (2011) ESS values for this run (50 to 69, 50 to 46, 5 to 5), but diverged from the Francis values for the commercial discard fleet (20 to 4). These changes provided run S60_BASE_14. The estimates for run 14 were very similar to those from run 13.

The final changes was to ‘tune’ the 10 survey age composition ESSs to about their time series means, roughly ‘centering’ them in the time series pattern. These ‘centered’ ESSs all were significantly higher than the calculated Francis values. These changes provided run S60_BASE_15; the estimates for run 15 were very similar to those from runs 13 and 14. Tables A53-A54 summarize the changes due to the phase 3 model building steps through run S60_BASE_15. Figures A82-A84 summarize the changes in model estimates from the 2008 model updated through 2014 (IAA_IND08) to the initial 2015 BASE run (S60_BASE_1) through the phase 3 ‘tuning’ steps (S60_BASE_15).

A8.2.7 Sensitivity to NEFSC trawl survey time series configuration

All the runs configured through S60_BASE_15 used continuous NEFSC trawl survey time series, with the years sampled by the FSV Albatross IV (ALB) and FSV Henry B Bigelow (BIG) joined by the use of length-based calibration factors. While the factors at length are constant over time, the ‘effective’ factors vary over time due to the inter-annual changes in the survey distribution at length. A sensitivity run of S60_BASE_15 was constructed by ending the ALB series in 2008 and adding two additional survey series for the BIG from spring 2009 onward (run S60_BASE_15_BIG).

The aggregate N q for the NEFSC spring survey ALB indices = 7.87e-5; the BIG spring indices q= 1.89e-4. The BIG spring aggregate N q is 2.40 times the ALB spring q. The spring effective calibration factor over all lengths has ranged from 0.89 to 2.36, averaging 1.59 (Table A29). The aggregate N q for the NEFSC fall survey ALB indices = 7.78e-4; the BIG fall indices q= 1.29e-3. The BIG fall aggregate N q is 1.66 times the ALB fall q. The fall effective calibration factor over all lengths has ranged from 2.08 to 4.33, averaging 3.05 (Table A30). Summary estimation results for the S60_BASE_15 and S60_BASE_15_BIG runs are presented in Figures A85-A87. The SWG concluded that the differences are minor, indicating that the NEFSC survey calibration factors are not a major source of uncertainty in the S60_BASE_15 model, and retained the NEFSC ALB-equivalent indices in subsequent runs.

A8.2.8 Sensitivity to Model Time Series Length

The 2008 DPSWG assessment (NEFSC 2009) adopted a model with a time series beginning in 1963, in spite of the need to extrapolate estimates of commercial fishery discards prior to 1989 and recreational fishery catches prior to 1981, in order to include the large catches of the early 1960s and peaks in survey indices in the late 1970s. Model configuration S60_BASE_15 (starting in 1963) was run with alternative time series lengths to evaluate the sensitivity of results to the model time series length. Three alternatives were considered 1) start in 1977, the year with the earliest available age data (NEFSC spring), 2) start in 1984, when the fishery catch at age starts, and 3) start in 1989, when the Observer commercial fishery data start, and therefore none of the catch estimates rely on extrapolation from ratios.

All three alternative time series length models converged successfully. The SSB, R, and F estimates for the 1963, 1997, and 1984 time series are very similar. The 1989 model series has the fishery and several survey age composition series considerably shortened, which results in lower estimates of stock size (e.g., about 15% lower average recruitment than the 1963 run since 1989) and translates to lower SSB (25% lower average than the 1963 run since 1989) and slightly higher F (5% higher average than the 1963 run since 1989). Figures A88-A90 compare the S60_BASE_15_1963 summary results with the three alternatives.

Seven year retrospective ‘peels’ were run for the three alternative models and compared with the S60_BASE_15 run. The Mohn’s rho (Mohn 1999, Legault at al. 2009) values expressed as average percent error are compared below. As the modeled time series is shortened, the retrospective error generally increases, although the differences are not large.

		Mohn’s rho	
Run ID	SSB	R	F
S60_BASE_15_1963	-5%	-45%	-2%
S60_BASE_15_1977	-5%	-45%	-3%
S60_BASE_15_1984	-8%	-48%	+1%
S60_BASE_15_1989	-11%	-52%	-5%

An initial 1963 run with Monte Carlo Markov Chain (MCMC) estimates of uncertainty indicated some diagnostic problems. One thousand iterations with a thinning rate of 1,000 (one million total iterations of which 1,000 are saved) were conducted for one chain (random number seed). Ideally, the ‘trace’ of the MCMC chain should not show any trending or patterning, and the correlation between successive values in the chain should be low (e.g., less than 0.1 after year 0).

For the 1963 run, however, uneven patterning was evident in SSB and F estimates, especially for the 1963 estimates (Figure A91-A92). There was also evidence of high correlation between successive estimates of the chain for several years (lags; Figures A93-A94). These diagnostics indicate a fairly high level of uncertainty of the model estimates, especially at the beginning of the series. The ‘transient’ high stock sizes in the initial years of the model and associated very high Fs are a symptom of these issues (e.g., see models S60_BASE_9 and subsequent). The autocorrelation is also reflective of the near-constant recruitment assumed for the years before 1984 when no fishery age data are available (tightly constrained [CV=0.1] recruitment deviations and stock-recruitment scaler with fixed h = 1, by definition resulting in autocorrelated recruitment during this early period). The autocorrelation may also reflect the sequence of consecutive very strong (>25% above the time series average) year classes estimated for 1999-2001 and 2005-2008 that are reflective of the fishery and survey catches. The degree of uncertainty results in the 1963 point estimates for SSB and F not being ‘centered’ in the distribution of 1963 MCMC estimates (Figures A95-A96).

Given these issues with the early year estimates, the MCMC distributions for runs starting in 1977, 1984, and 1989 were examined for the same number of total and saved iterations. For the 1977 run there was less patterning evident in the SSB and F estimates than in the 1963 run, although the pattern was still ‘noisy’ (Figures A97-A98). There was also still evidence of high correlation between successive estimates of the chain for several years (Figures A99-A100), although it is reduced compared to the 1963 run. The point estimates for SSB and F from the 1977 run are better ‘centered’ in the distribution of MCMC estimates than those from the 1963 run (Figures A101-A102).

For the 1984 and 1989 runs there was minor patterning evident in the SSB and F estimates, although the variability pattern was still ‘noisy’. There was also still evidence of high correlation between successive estimates of the chain for 1-2 year lags. The point estimates for SSB and F from the 1984 and 1989 runs are further from the MCMC distribution mode for 2014 SSB than the 1997 run point estimate, as terminal year precision slightly decreases with the shorter series. The precision of the 2014 SSB and F estimates for the four different time series length runs are compared in the table below. The SWG concluded that using the full time series model starting in 1963, given an understanding of why the autocorrelation coefficients are high, caused no major technical issues in the S60_BASE_15 run that would hinder the evaluation of the status of the stock from terminal year results of the model, and retained the full time series in subsequent model development.

Run ID	MCMC CV% SSB 2014	MCMC CV% F2014
S60_BASE_15_1963	10.8	14.4
S60_BASE_15_1977	9.7	13.7
S60_BASE_15_1984	11.1	14.5
S60_BASE_15_1989	12.6	15.5

A8.2.9 Post run S60_BASE_15 revisions made in the SWG meeting

As noted earlier, the RIDFW supplied new spring and fall trawl survey aggregate numeric and indices-at-age, replacing the aggregate biomass indices used previously. The inclusion of the new RIDFW indices created run S60_BASE_16. Run 16 provided estimates of SSB and R slightly higher and F slightly lower in the terminal year compared to run 15 (Table A54).

Revisions to the 2014 NEFSC commercial ages were also made. The latest available 2014 fishery catch and age data were included in the model to create run S60_BASE_17. Run 17 provided estimates of SSB (-7%) and R (-1%) slightly lower and F slightly higher (+3%) in the terminal year compared to run 16 (Table A54).

The effect of several configuration changes to run 17 was examined. As noted in the description of run S60_BASE_13, iterating survey SVs to reduce the RMSEs brought most of them to 0.8-0.9, but in some cases even a high CV of 1.2 still resulted in RMSE outside the N(0,1) 95% confidence interval. Run S60_BASE_18 omitted five of the indices from the model calibration (NEFSC spring, MADMF spring, RIDFW spring and fall, and VIMS ChesMMAP), and the results and diagnostics examined in comparison to run 17. The run 18 SSB estimates are about 5-10% lower than the run 17 estimates over the terminal 5 years; recruitment at age 0 estimates are 2-5% lower; run F estimates are 10-20% higher (Figures A103-A105). The ‘random normal variate’ diagnostic plot of survey RMSE indicated that most of the surveys included in run 18 were now close to or inside the confidence interval of the theoretical N(0,1) distribution (Figure A106), indicating better overall survey index fit in the model.

It was noted again that estimates of the recreational fishery landings and discards and commercial fishery discards were based on ratio extrapolation from the commercial fishery landings for all years prior to 1981 or 1989, and that the CVs on those catches was based on the empirical CVs ranging from 13-22%. The CVs on those catches were increased to 30% for years before 1981, creating run S60_BASE_19, to examine the sensitivity of the model run 17 to that setting. Model 19 results were within a few percent of the run 17 results for the entire time series.

Finally, a run including only indices with age composition data, run S60_BASE_20, was examined. The run 20 SSB estimates are about 15-25% higher than the run 17 estimates over the terminal 10 years; recruitment at age 0 estimates are 2-5% lower; run F estimates are 15-25% lower (Table A54).

It was noted that run 18 results were more sensitive to time series length (1989 run start 2014 SSB estimate about 40% lower than the 1963 run start estimate and 2014 F estimate about 50% higher) than run 17 (2014 SSB about 30% lower, F about 45% higher). Run 18 was also more sensitive to the use of BIG indices than run 17, with the 2014 SSB estimate 10% higher and 2014 F 12% lower than when using all LAB equivalent indices; comparable run 17 results were 2014 SSB 5% higher and 2014 F 4% lower.

The SARC concluded that run S60_BASE_18 provided the information needed to meet TOR4 (estimate annual fishing mortality, recruitment and stock biomass for the time series, and estimate their uncertainty). The general results (e.g., record high stock size and low F in the last decade) are robust to the proposed alternative model configurations including alternative time series length and a range of priors and likelihood component weightings. However, there are some indications of poor model fit from lack of correspondence among surveys (higher than expected variance when accounting for potential process error, some residual patterns), and there is some uncertainty in the absolute magnitude of recent stock size estimates (although the terminal year estimates are calculated to be relatively precise with CVs equal to or less than 15%). Alternative survey catchabilities (e.g., relative, absolute using wing or door spread), starting years, and time-varying survey catchability configurations can produce about a +/- 40% range of terminal year SSB.

During the evaluation of the accepted model, sensitivities were examined which highlighted some additional risk. The main one of relevance to management is the choice of selectivity pattern. The base model has a strong domed selectivity pattern which could result in an increasing cryptic biomass given current stock trajectory. Conclusions regarding current stock status are robust to alternative selectivity patterns but decreased recruitment or increased F in the future could lead to divergence between domed and flattop selectivity model results (see Appendix 1). The SARC concluded, however, that the accepted model run provided the best balance between good retrospective diagnostics, acceptable fishery and survey fit diagnostics, and stability over most configurations, and recommended use of ASAP model run S60_BASE_18 for status evaluation.

Figures A107-A109 summarize the 1984 and later SSB, R, and F estimates for runs S60_BASE_1 to S60_BASE_20. Terminal year estimates of SSB range from about 159,000 mt (run 4) to 239,000 mt (run 11), or -13% to +31% of the final run 18 estimate of 183,000 mt. Terminal year estimates of R range from about 49 million (run 2) to 174 million (run 8), or -56% to +55% of the final run 18 estimate of 112 million. Terminal year estimates of F range from about 0.06 (run 11) to 0.14 (run 4), or -54% to +8% of the final run 18 estimate of 0.13.

A8.3 Final Run S60_BASE_18 Diagnostics

A8.3.1 Model Fit Diagnostics (R plots)

Figure A110 shows the distribution of objective function components contribution to total likelihood. The aggregate landings and discards catch and age composition fit diagnostics and residuals are presented in Figures A111-A118. The aggregate survey index and age composition fit diagnostics and residuals are presented in Figures A119-A138.

A8.3.2 Retrospective Analyses

An 'internal' retrospective analysis for the S60_BASE_18 was conducted to examine the stability of the model estimates as data were removed from the end of the time series. Retrospective runs were made for terminal years back to 2007. The scup stock assessment has historically not exhibited a strong retrospective pattern for SSB, F, or recruitment at age 0 (model age 1; R). Over the last seven years, the annual retrospective change in SSB has ranged from -8% in 2009 to -3% in 2007, with an average of -5% (Mohn's rho; Figure A139). The annual retrospective change in recruitment has ranged from -58% in 2011 to +40% in 2012, with an average of -26% (Figure A140). The annual retrospective change in fishing mortality has ranged from -25% in 2007 to +7% in 2013, with an average of -3% (Figure A141). The SWG concluded that these diagnostics indicate that the S60_BASE_18 model run does not exhibit a significant retrospective pattern.

The 2008 DPSWG benchmark assessment (NEFSC 2009), the 2012 assessment update (Terceiro 2012), and model run S60_BASE_18 (2015 SAW 60) results for 1984 and later years are compared in Figures A142-A144 to provide an 'historical' retrospective. The ASAP model has been used in the assessment during the 2008-2015 period, but due to changes in fishery selectivity estimation, 'fully-recruited' F is reported for ages 3-7+ in the 2008-2012 assessments, but only for age 3 ('apical' F where S = 1) in the 2015 assessment, and so is somewhat higher due to increased 'domed' selectivity since 2006 in model run S60_BASE_18. Despite changes in model assumptions, configurations, and estimation procedures, the 'historical' retrospective analysis indicates that the general trends in stock biomass, recruitment, and fishing mortality have been consistent for the last decade.

The estimation results of run S60_BASE_18 are compared with previous 2009-2012 assessment projections of SSB, F, and fishery catch in Figures A145-A147. Final model run S60_BASE_18 estimates of SSB are in line with previous 2009-2012 projections, F is lower than from the 2011-2012 projections, and catch is lower than from the 2011-2012 projections, with the fishery in 2014 taking about 75% of the ACL.

A8.3.3 MCMC Estimates of Uncertainty

Monte Carlo Markov Chain (MCMC) is a common approach to estimate uncertainty in models. A simple MCMC resampling procedure is implemented in ASAP to provide additional estimates of model estimate uncertainty and an array of starting stock size in 2014 for future projections. For the S60_BASE_18 run, several chains of varying length and seed were examined, with the final one having 5 million iterations thinned by 5,000 to produce 1,000 final iterations for diagnostics and projections. Ideally, the 'trace' of the MCMC chain should not show any trending or patterning, and the correlation between successive values in the chain should be low (e.g., less than 0.1 after year 0).

For the S60_BASE_18 run, however (in fact, for all of the start in 1963 runs examined), uneven patterning was evident in SSB and F estimates, especially for the 1963 estimates (Figures A148-A149). There was also evidence of high correlation between successive estimates of the chain of the 1963 SSB and F for several years, although not for the 2014 estimates (lags; Figures A150-A151). These diagnostics indicate a fairly high level of uncertainty of the model estimates at the beginning of the series. The 'transient' high stock sizes in the initial years of the model and associated very high Fs are a symptom of these issues (e.g., see models S60_BASE_9 and subsequent). The autocorrelation is also reflective of the near-constant recruitment (tight constraint [CV = 0.1] on recruitment deviations and stock-recruitment scaler with fixed h =1 to ensure mean recruitment before 1984, by definition resulting in autocorrelated recruitment during this early period) assumed for the years when no fishery age data are available. The slight autocorrelation at the end of the time series may also reflect the sequence of consecutive very strong (>25% above the time series average) year classes from 1999-2001 and 2005-2008 that are indicated by the fishery and survey catches. The degree of uncertainty results in the point estimates for SSB and F not being 'centered' in the distribution of 1963 MCMC estimates (Figures A152-A153).

Estimates for 2014, in contrast, were well-centered. The 2014 SSB MCMC median was 186,000 mt, mean was 187,000 with CV = 11%, compared to the point estimate of 183,000 mt. The 2014 F MCMC median was 0.122, mean was 0.124 with CV = 15%, compared to the point estimate of 0.127.

Recognizing that these diagnostics in the early part of the series are due to the intentional model configuration and in the latter part of the series are due to stock sizes estimates that are well supported by the fishery and survey input data, it was concluded that there were no serious technical issues in the S60_BASE_18 run that would prevent its use in evaluation of the status of the stock.

A8.4 Profiles and Sensitivity Runs

A8.4.1 Likelihood Profile over assumptions for Natural Mortality (M)

Run S60_BASE_18 was run over a range of assumptions for M values from 0.05 to 0.50 (constant at all ages over time) to help judge which assumption for M fit best, given the diagnostic of total minimum log-likelihood (value of the total objective function). Figure A154 shows that likelihood was minimized for M = 0.15, with runs between 0.05 and 0.20 within 5 objective function total likelihood points. The current value of constant M= 0.20 was retained in the S60_BASE_18 model.

A8.4.2 Likelihood Profile over assumptions for unexploited SSB (SSB0)

A likelihood profile of run S60_BASE_18 over the population scaling parameter SSB0 (unexploited SSB with fixed steepness [h] = 1) with fixed values from 100 kmt to 300 kmt was constructed to help judge the behavior of other likelihood components of the model. Figure A155 indicates that the likelihood of most of the major objective function components is minimized at about 175 kmt (the calculated value for run S60_BASE_18 is 183 kmt with fixed h = 1). It was concluded that no further 'tuning' or other changes in likelihood component emphasis were necessary for the S60_BASE_18 model.

A8.4.3 Sensitivity to NEFSC and NEAMAP survey indices input as swept-area absolute estimates of abundance

All the runs configured through S60_BASE_15 used NEFSC and NEAMAP trawl survey time series of stratified mean numbers per tow with no efficiency assumption made (i.e., indices of relative abundance). In some New England groundfish assessments, assumptions about the efficiency of the trawl gear are made (typically 100%) and 'minimum swept-area numbers' based on area swept by the net wings and/or trawl doors are calculated and used as input to the assessment model (i.e., indices of absolute abundance). This does not result in changes to the estimates of population size and mortality, but does change the scaling of the catchability coefficients ('q') estimated for the surveys.

Some investigators prefer this treatment of the survey calibration data, contending that it serves as a 'check' of whether the scaling of the survey q in an assessment model is 'reasonable' or 'feasible'. Other investigators note that the validity of this 'check' rests on the validity of the assumptions behind the constants used in the simple swept-area calculation (i.e., the size of the trawl gear swept area, the assumption of trawl gear efficiency across lengths and ages, assumption about the uniform distribution of fish within strata, and assumptions about the total area included in the calculation). Experimental estimates of the NEFSC Albatross, NEFSC Bigelow, or NEAMAP trawl gear efficiency for scup are not available.

For the scup S60_BASE_18 model using relative indices for the NEFSC fall and NEAMAP spring and fall, the estimated aggregated N qs are 6.8e-4, 3.7e-5, and 2.4e-5, respectively. Using absolute indices based on wing spread (for NEFSC ALB specifications), the estimated aggregated N qs are 2.17, 0.02, and 0.08, respectively. Using absolute indices based on door spread, the estimated aggregated N qs are 1.02, 0.01, and 0.03, respectively. It was concluded that while it may be useful to look at q estimates using swept area indices to provide context for model estimates, the results should not be used to make reach conclusions about the accuracy of the 'scaling' of the assessment model until field experiments have been conducted to study the behavior of a particular species in reaction to the survey gear and better quantify survey catchability.

A8.4.4 Varying NEFSC and NEAMAP survey catchability

As described under TOR 3, the working paper of Manderson et al. (MS 2015; WP 11) provides time series of varying estimates of the proportion of thermal habitat suitability for scup surveyed on the Northeast US shelf by the NEFSC and NEAMAP bottom trawl surveys from 1975-2012 in a manner that accounts for thermal habitat occurring outside the surveys and the relative motions of habitat and the survey vessel. Logit-transformed annual values of the 'proportion of suitable scup thermal habitat sampled' – i.e., availability - were used in an ASAP4 version of run S60_BASE_18 to provide annually varying estimates of relative survey catchability (q), where q is the product of availability and survey gear efficiency (assumed = 1).

The NEFSC survey qs were estimated to be variable without long term trend; NEAMAP survey qs were variable over the short 7-8 year time series. Compared to the ASAP3 version of run S60_BASE_18, there were changes in some SV residual patterns, with RMSEs generally larger. ASAP4 run 18 estimation results for 2014 were close to the ASAP3 results, with 2014 SSB estimated to be 3% lower, R 23% higher, and F 4% lower. Given the similarity of results and still preliminary nature of the ASAP4 model (the model and documentation have not yet been released to the public), the ASAP4 version of run 18 was not used for status evaluation.

A8.5 Annual Fishing Mortality, Recruitment, and Stock Size Estimates

Summary SSB, recruitment, and F estimates, estimated January 1 stock size at age in numbers, and estimated fishing mortality (F) at age from the final model (S60_BASE_18) for 1984-2014 (the years with input fishery catches at age) are provided in Tables A55-A56. Spawning stock biomass (SSB) decreased from about 68,000 mt in 1963 to about 5,000 mt in 1969, then increased to about 27,000 mt during the late 1970s. SSB declined through the 1980s and early 1990s to less than about 4,000 mt in the mid-1990s. With greatly improved recruitment and low fishing mortality rates since the late 1990s, SSB increased to greater than 100,000 mt = 220 million lbs since 2003. SSB was estimated to be 182,915 mt = 403 million lbs in 2014 (Figures A156-A157). There is a 90% probability that SSB in 2014 was between 153,000 and 222,000 mt (337 and 489 million lbs; Figure A158). Fishing mortality estimated at the 'apical' age 3 (model age 4) where full selection occurs (S=1) varied between F = 0.5 and F = 2.0 during the 1960s and 1970s. Fishing mortality next peaked at about F = 1.5 in the 1990s. Fishing mortality decreased after 1994, falling to less than F = 0.15 since 2000, with F in 2014 = 0.127 (Figure A159). There is a 90% probability that F in 2014 was between 0.093 and 0.149 (Figure A160).

Recruitment at age 0 averaged 98 million fish during 1963-1983, the period in which recruitment estimates are tightly constrained (CV = 0.1 on recruitment deviations and stock-recruitment scaler with fixed h =1) to ensure near constant recruitment before 1984, when fishery catch at age are not available. Since 1984, recruitment estimates from the model are influenced mainly by the fishery and survey catches at age, and averaged 109 million fish during 1984-2014. The 1999, 2006, and 2007 year classes are estimated to be the largest of the time series, at 222, 222, and 218 million age 0 fish. After below average recruitment in 2012 and 2013, the 2014 year class is estimated to be above average at 112 million age 0 fish (Figures A156-A157).

A9. TERM OF REFERENCE 5: State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY} and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

A9.1 Existing: 2008 DSP Assessment Biological Reference Points

The 2008 DPSWG Peer Review Panel accepted the ASAP SCAA model results as the basis for biological reference points and status determination for scup (NEFSC 2009). Reference points were calculated using the non-parametric yield and SSB per recruit/long-term projection approach adopted for summer flounder (NEFSC 2008a) and the New England groundfish stocks (NEFSC 2008b). In the yield and SSB per recruit calculations, the most recent five year averages were used for mean weights and fishery partial recruitment pattern. For the estimation of MSY (Maximum Sustainable Yield) and SSBMSY (Spawning Stock Biomass at Maximum Sustainable Yield), the cumulative distribution function of the 1984-2007 recruitments (corresponding to the period of input fishery catches at age) was re-sampled to provide future recruitment estimates (mean = 117 million age 0 fish). The existing reference points for scup are the 2008 DPSWG Peer Review Panel recommended F40% as the proxy for FMSY, and the corresponding SSBF40% as the proxy for SSBMSY. The F40% proxy for FMSY = 0.177, the proxy estimate for SSBMSY = SSB40% = 92,044 mt = 202.922 million lbs, and the proxy estimate for MSY = MSY40% = 16,161 mt = 35.629 million lbs (13,134 mt = 28.956 million lbs of landings and 3,027 mt = 6.673 million lbs of discards).

A9.2 New: 2015 SAW 60 Biological Reference Points

The SARC accepted the ASAP SCAA model run S60_BASE_18 results as the basis for new biological reference points and status determination for scup. Reference points were again calculated using the non-parametric yield and SSB per recruit/long-term projection approach adopted for summer flounder (NEFSC 2008a) and the New England groundfish stocks (NEFSC 2008b). In the yield and SSB per recruit calculations, the most recent five year averages were used for mean weights and fishery partial recruitment pattern. For the estimation of MSY (Maximum Sustainable Yield) and SSBMSY (Spawning Stock Biomass at Maximum Sustainable Yield), the cumulative distribution function of the 1984-2014 recruitments (corresponding to the period of input fishery catches at age) was re-sampled to provide future recruitment estimates (mean = 109 million age 0 fish). The SARC recommended F40% as the proxy for FMSY, and the corresponding SSBF40% as the proxy for the SSBMSY biomass target. The F40% proxy for FMSY = 0.220. The proxy estimate for SSBMSY = SSB40% = 87,302 mt = 192.468 million lbs; the proxy estimate for the ½ SSBMSY biomass threshold = ½ SSB40% = 43,651 mt = 96.234 million lbs. The proxy estimate for MSY = MSY40% = 11,752 mt = 25.909 million lbs (9,445 mt = 20.823 million lbs of landings and 2,307 mt = 5.086 million lbs of discards).

A10. TERM OF REFERENCE 6: Evaluate stock status with respect to the existing model (from previous peer reviewed accepted assessment) and with respect to a new model developed for this peer review.

a. When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the existing BRP estimates.
b. Then use the newly proposed model and evaluate stock status with respect to "new" BRPs and their estimates (from TOR-5).

2015 UPDATED STOCK STATUS

a) The existing model updated with new data indicated that the scup stock was not overfished and overfishing was not occurring in 2014 relative to the existing (old) biological reference points established in the 2008 Northeast Data Poor Stocks Working Group (DPSWG; NEFSC 2009) assessment. The fishing mortality rate (F) was estimated to be 0.049 in 2014, below the fishing mortality threshold reference point = FMSY = F40% = 0.177. Spawning Stock Biomass (SSB) was estimated to be 219,066 metric tons (mt) = 483 million lbs in 2014, above the biomass target reference point = SSBMSY = SSB40% = 92,044 mt = 203 million lbs (Table A58).

b) The scup stock was not overfished and overfishing was not occurring in 2014 relative to the new biological reference points recommended by the 2015 SWG. The fishing mortality rate (F) was estimated to be 0.127 in 2014, below the fishing mortality threshold reference point = FMSY = F40% = 0.220. Spawning Stock Biomass (SSB) was estimated to be 182,915 metric tons (mt) = 403 million lbs in 2014, above the biomass target reference point = SSBMSY = SSB40% = 87,302 mt = 192 million lbs (Table A58, Figure A161).

A11. TERM OF REFERENCE 7: Develop approaches and apply them to conduct stock projections and to compute the statistical distribution (e.g., probability density function) of the OFL (overfishing level) (see Appendix to SAW TORs for definitions).

a. Provide numerical annual projections (3 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment).

b. Comment on which projections seem most realistic. Consider the major uncertainties in the assessment as well as sensitivity of the projections to various assumptions.

c. Describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming overfished, and how this could affect the choice of ABC.

A11.1 Numerical Annual Projections for 2016-2018

Stochastic projections were made to provide forecasts of stock size and overfishing level (OFL) catches in 2016-2018 consistent with the 2015 SAW 60 assessment biological reference points. The projections assume that recent (2010-2014) patterns of discarding will continue over the time span of the projections. Different patterns that could develop in the future due to different trip and bag limits and fishery closures have not been evaluated. One hundred projections were made for each of the 1000 MCMC (Markov Chain Monte Carlo) realizations of 2014 stock sizes from the updated assessment results using NFT AGEPRO version 4.0.5 (NFT 2011). Future recruitment at age 0 was generated randomly from a cumulative density function of the updated recruitment series for 1984-2014 (mean recruitment = 109 million fish).

Two sets of projections were conducted. Option A is proposed as the most realistic and assumes that given recent patterns in the fishery, it is likely that 75% of the 2015 Allowable Biological Catch (ABC) will be caught. Projection option B assumes that 100% of the 2015 ABC will be caught.

Option A) If the catch of scup in 2015 equals 75% of the specified ABC = 0.75 * 15,320 = 11,490 mt = 25.331 million lbs, the 2015 median (50% probability) landings are projected to be 10,058 mt = 22.174 million lbs and discards are projected to be 1,432 mt = 3.157 million lbs. The table below shows the projected biomass and catch for Option A in 2015 if the stock is then fished at the fishing mortality threshold = FMSY = F40% = 0.220 in 2016-2018. The projected OFLs in 2016-2018 are 16,238, 14,556, and 13,464 mt (35.799, 32.090, and 29.683 million lbs).

Option A: Total Catch (OFL), Landings, Discards, Fishing Mortality (F)
and Spawning Stock Biomass (SSB) in 2015-2018
Catches and SSB in metric tons

Year	Total Catch (OFL)	OFL CV (%)	Landings	Discards	F	SSB
2015	11,490	fixed	10,058	1,432	0.143	187,477
2016	16,238	14	13,840	2,398	0.220	170,002
2017	14,556	13	12,214	2,342	0.220	154,083
2018	13,464	13	11,156	2,308	0.220	141,077

Option B) If the catch of scup in 2015 equals 100% of the specified ABC = 15,320 mt = 33.775 million lbs, the 2015 median (50% probability) landings are projected to be 13,412 mt = 29.568 million lbs and discards are projected to be 1,908 mt = 4.206 million lbs. The table below shows the projected biomass and catch for Option B in 2015 if the stock is then fished at the fishing mortality threshold = FMSY = F40% = 0.220 in 2016-2018. The projected OFLs in 2016-2018 are 15,745, 14,199, and 13,230 mt (34.712, 31.303, and 29.167 million lbs).

Option B: Total Catch (OFL), Landings, Discards, Fishing Mortality (F)
and Spawning Stock Biomass (SSB) in 2015-2018
Catches and SSB in metric tons

Year	Total Catch (OFL)	OFL CV (%)	Landings	Discards	F	SSB
2015	15,320	fixed	13,412	1,908	0.194	185,916
2016	15,745	13	13,398	2,347	0.220	166,355
2017	14,199	12	11,883	2,316	0.220	150,702
2018	13,230	12	10,935	2,295	0.220	138,072

The biological inputs to the scup stock assessment are based on well-founded assumptions (e.g., for natural and discard mortality) and precisely estimated parameters (e.g., growth, age, maturity, and mean weights). Further, the research survey index CVs used in model calibration have been increased by 50-100% (depending on assessment model fit diagnostics) to account for process error. Twenty-five alternative configurations of the assessment base model were examined to evaluate robustness, including starting years, impact of NEFSC calibration factors, natural mortality, fishery selectivity, and time-varying survey catchability. This broad set of configurations produced a range about +/- 40% in the estimate of terminal year SSB of about 180,000 mt (= 396 million lbs). The internal retrospective average error (for the terminal 7-years) of the assessment is low, at less than 10% for both SSB and F. The analytically derived CV for the 2014 SSB is 11%, the CV for the 2014 F is 15%, and the CV for the 2014 age 1 and older stock size total number is 15%. Given these properties of the 2015 scup stock assessment, it was concluded that an approximate doubling of the analytically derived 2016-2018 OFL CVs to 30% is a reasonable and sufficient adjustment to account for additional uncertainty in the assessment such as the magnitude of domed fishery selection, the magnitude of commercial fishery discards and recreational catch during the early part of the assessment model time series, and potential error in the aging process.

A11.2 Most Realistic Projections

The commercial and recreational fisheries have landed about 75% of the landings quota over the last two years, suggesting that the 2015 ACL may not all be caught. The SWG concluded that a projection assuming that 75% of the 2015 ABC will be caught was more realistic than assuming 100% will be caught, and this scenario is identified as ‘Option A.’ An Option B projection assuming 100% of the 2015 ABC will be caught is also provided.

A11.3 Stock Vulnerability

The 2008 DPSWG Peer Review Panel (NEFSC 2009) advised that a gradual increase in the ABC toward the MSY level would facilitate an evaluation of the performance of the new assessment model and reference points in monitoring stock status, while reducing the risk to the stock due to rapidly increased catch.

The 2015 assessment indicates that the stock was well above the biomass target and being fished at well below the fishing mortality threshold in 2014. The high level of 2014 stock abundance is the result of historically low fishing mortality rates and historically high levels of recruitment since the late 1990s. The MSY proxy in terms of total catch is 11,752 mt (25.909 million lbs; CV = 19%), with total landings of 9,445 mt (20.823 million lbs) and total discards of 2,307 mt (5.086 million lbs). Total fishery catch is estimated to have averaged about 34,000 mt (~75 million lbs) during 1960-1965, while reported commercial landings alone averaged about 19,000 mt (~42 million lbs) in that period. Therefore, the MSY estimate appears feasible given historical evidence from the fishery.

Both projection options have a realistic probability of being achieved and indicate there is zero percent chance that SSB will fall below the biomass threshold in 2016-2018 fishing at the OFL. The scup stock has a low probability of becoming overfished in the short term (2016-2018) given recent trends in productivity and the responsiveness of the management regime.

A12. TERM OF REFERENCE 8: Review, evaluate and report on the status of the SARC, SSC, and Working Group research recommendations listed in most recent SARC reviewed assessment and review panel reports. Identify new research recommendations.

Nine of the 12 previously identified research recommendations were either addressed in full or significant progress was made. No progress has been made on a) quantifying contemporary discard mortality rates, b) quantifying the degree of bias in landings reporting and discard estimation including non-compliance, or c) development of a management strategy evaluation of alternative approaches to setting quotas. Six newly developed research recommendations are listed below.

A12.1 Previous Research Recommendations

A12.1.1 DPWG 2008 (NEFSC 2009)

Short term analytical tasks

1) Evaluation of indicators of potential changes in stock status that could provide signs to management of potential reductions of stock productivity in the future would be helpful.

Some progress in SSC work on 'rumble strip' analysis – used in 2013.

The 2015 assessment explored the potential use of the Conn (2010) hierarchical method to combine indices across time and space; more developmental work is needed.

2) A management strategy evaluation of alternative approaches to setting quotas would be helpful.

No progress.

Long term data and analytical needs

3) Current research trawl surveys are likely adequate to index the abundance of scup at ages 0 to 2. However, the implementation of new standardized research surveys that focus on accurately indexing the abundance of older scup (ages 3 and older) would likely improve the accuracy of the stock assessment.

The RI Industry Cooperative Trap survey was implemented during 2005-2012. This survey had a higher catch rate for larger and older fish of age 3+ than the bottom trawl surveys. A peer review indicated that some of the design elements should be modified and this advice was followed; however, funding was halted after 2012.

4) Continuation of at least the current levels of at-sea and port sampling of the commercial and recreational fisheries in which scup are landed and discarded is critical to adequately characterize the quantity, length and age composition of the fishery catches.

Adequate sampling has been maintained (see assessment tables and figures).

5) Quantification of the biases in the catch and discards, including non-compliance, would help confirm the weightings used in the model. Additional studies would be required to address this issue.

No progress.

6) The commercial discard mortality rate was assumed to be 100% in this assessment. Experimental work to better characterize the discard mortality rate of scup captured by different commercial gear types should be conducted to more accurately quantify the magnitude of scup discard mortality.

No progress.

A12.1.2 MAFMC SSC July 2012

1) Improve estimates of discards and discard mortality for commercial and recreational fisheries

SBRM estimates of commercial fishery discards, which exhibit a less variable time series pattern and improved precision compared to previous estimates, were developed and accepted for this assessment.

No progress on discard mortality rates.

2) Evaluate indices of stock abundance from new surveys

The RI Cooperative Trap (ended in 2012), NEAMAP spring and fall surveys, indices at age from the RIDFW spring and fall surveys, and indices at age from the NYDEC survey are now included in the assessment documentation.

3) Quantify the pattern of predation on scup

The limited NEFSC survey food habits data for scup were reviewed and it is not possible to calculate absolute estimates of consumption of scup by predators due to sample size considerations (~500 identifiable scup in the ~40 year time series).

4) Conduct biological studies to investigate maturity schedules and factors affecting annual availability of scup to research surveys

The NEFSC maturity schedule for scup was updated.

GLM and GAM modeling and GIS investigation of NEFSC bottom trawl survey data on scup distribution, temperature preference, and salinity preference did not reveal strong effects that could be directly linked to a trend in availability.

Changes in scup distributions with respect to bottom temperature, body size and abundance within the NEFSC survey were examined to identify potential effects on availability. A thermal habitat model was developed to estimate proportions thermal habitat suitability for scup sampled during fall and spring NEFSC and NEAMAP surveys. These habitat based estimates of availability were used to inform catchability in sensitivity evaluations of the final ASAP model.

5) Explore the utility of incorporating ecological relationships, predation, and oceanic events that influence scup population size on the continental shelf and its availability to resource surveys into the stock assessment mode

GLM and GAM modeling and GIS investigation of NEFSC bottom trawl survey data on scup distribution, temperature preference, and salinity preference did not reveal strong effects that could be directly linked to a trend in availability.

Changes in scup distributions with respect to bottom temperature, body size and abundance within the NEFSC survey were examined to identify potential effects on availability. A thermal habitat model was developed to estimate proportions thermal habitat suitability for scup sampled during fall and spring NEFSC and NEAMAP surveys. These habitat based estimates of availability were used to inform catch ability in sensitivity evaluations of the final ASAP model.

6) Evaluate alternate forms of survey selectivity in the assessment to inform indices of abundance at higher ages

The multinomial approach to inclusion of fishery and survey catch at age was used in the assessment model, allowing use of low and variable indices at older ages and, where possible, estimation of selectivity at age.

A12.2 New Research Recommendations

1) A standardized fishery dependent CPUE of scup targeted tows, from either NEFOP observer samples or the commercial study fleet, might be considered as an additional index of abundance to complement survey indices in future benchmark assessments

2) Explore additional sources of length/age data from fisheries and surveys in the early parts of the time series to provide additional context for model results

3) Explore experiments to estimate the catchability of scup in NEFSC and other research trawl surveys (side-by-side, camera, gear mensuration, acoustics, etc.)

4) Refine and update the Manderson et al. availability analysis when/if a new ocean model is available (need additional support). Explore alternative niche model parameterizations including laboratory experiments on thermal preference and tolerance.

5) Explore the Study fleet data in general for information that could provide additional context and/or input for the assessment

6) A scientifically designed survey to sample larger and older scup would likely prove useful in improving knowledge of the relative abundance of these large fish.

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Tables

Table A1. Commercial landings (metric tons; mt) of scup by state. One mt was landed in DE in 1995, included with MD 1995 total. Eight mt were landed in PA in 2004 included with MD 2004 total. Landings include revised Massachusetts landings for 1986-1997.

Year	ME	MA	RI	CT	NY	NJ	MD	VA	NC	Total
1979		782	3,123	92	1,422	2,159	21	397	589	8,585
1980	1	706	2,934	17	1,294	2,310	32	531	599	8,424
1981		523	2,959	44	1,595	2,990	9	1,054	682	9,856
1982		545	3,203	25	1,473	1,746	2	1,042	668	8,704
1983		672	2,583	49	1,103	2,536	13	536	302	7,794
1984		540	2,919	32	904	2,217	6	673	478	7,769
1985		387	3,583	41	861	1,493	17	74	271	6,727
1986		875	2,987	67	893	1,895	14	273	172	7,176
1987	5	735	2,162	301	911	1,817		232	113	6,276
1988	9	536	2,832	359	687	1,334	1	127	58	5,943
1989	32	579	1,401	89	603	1,219	1	45	15	3,984
1990	4	696	1,786	165	755	1,005	4	75	81	4,571
1991	16	553	2,902	287	1,223	1,960	15	56	69	7,081
1992		655	2,676	193	1,043	1,475	17	73	127	6,259
1993		556	1,332	148	729	1,822	10	76	53	4,726
1994		354	1,514	142	688	1,456	7	92	139	4,392
1995		310	1,045	90	511	1,084	2	20	11	3,073
1996		436	773	99	377	1,141	20	72	27	2,945
1997		676	486	50	376	596	1	2	1	2,188
1998		435	361	44	282	758	5	4	7	1,896
1999		300	581	44	206	361		13		1,505
2000		161	461	65	287	232		1		1,207
2001		149	734	45	297	479	1	24		1,729
2002		330	1,668	4	714	419		25	13	3,173
2003		407	1,730	64	839	1,033	21	253	58	4,405
2004		352	1,547	116	863	851	21	203	247	4,209
2005		515	1,553	149	989	325	1	130	50	3,711
2006		505	1,652	135	1,103	632	0	36	17	4,081
2007		513	1,766	116	1,059	714	1	10	13	4,193
2008		256	977	128	551	351	3	44	60	2,370
2009		326	1,641	90	839	693	5	110	16	3,721
2010		458	1,950	290	1,220	703	12	188	45	4,866
2011		574	2,874	292	1,689	892	25	360	113	6,819
2012		910	2,863	411	1,956	444	4	164	2	6,751
2013		636	3,332	547	2,075	923	143	447	7	8,110
2014		549	3,134	354	1,458	1,068	241	344	80	7,228

Table A2. Commercial landings (metric tons; mt) of scup by major gear types. Midwater paired trawl landings are combined with other gears during 1994 and later. Landings include revised Massachusetts landings for 1986-1997.

Year	Otter trawl	Paired trawl	Floating trap	Pound net	Pots and traps	Hand lines	Other gear	Total mt
1979	6,387	146	1,305	429	26	215	77	8,585
1980	6,192	160	1,559	194	8	303	8	8,424
1981	7,836	79	1,291	246	49	306	49	9,856
1982	6,563	104	1,514	244	9	226	44	8,704
1983	5,861	398	850	390	8	265	22	7,794
1984	5,617	272	1,266	295	8	287	24	7,769
1985	4,856	417	1,022	229	5	182	16	6,727
1986	5,163	540	629	332	9	493	10	7,176
1987	4,607	237	590	193	213	423	13	6,276
1988	4,142	166	1,052	53	44	396	90	5,943
1989	3,174	89	193	74	104	334	16	3,984
1990	3,205	200	505	60	239	340	22	4,571
1991	5,217	152	988	40	258	395	31	7,081
1992	4,371	94	934	67	303	450	40	6,259
1993	3,865	46	166	25	202	402	20	4,726
1994	3,416		331	79	76	340	150	4,392
1995	2,204		331	42	57	215	224	3,073
1996	2,196		229	8	120	374	18	2,945
1997	1,491		86	12	104	489	6	2,188
1998	1,379		11	4	98	390	14	1,896
1999	1,005		140	30	77	184	69	1,505
2000	773		56	0	78	205	95	1,207
2001	1,088		229	65	52	215	80	1,729
2002	2,084		220	0	221	450	198	3,173
2003	2,777		723	0	168	445	292	4,405
2004	3,716		20	0	127	222	124	4,209
2005	2,843		117	0	178	477	96	3,711
2006	3,390		106	0	215	323	47	4,081
2007	3,268		181	0	332	381	31	4,193
2008	1,953		103	0	125	177	12	2,370
2009	3,168		116	0	191	237	9	3,721
2010	4,359		82	0	184	223	18	4,866
2011	6,073		121	0	339	276	10	6,819
2012	5,980		8	0	293	445	25	6,751
2013	7,556		0	0	240	271	44	8,110
2014	6,747		0	0	174	277	30	7,228

Table A3. Summary of landings, existing estimates of commercial fishery live discards, and the aggregate geometric mean discards to landings ratio (GMDL). Geometric mean discards to landings ratios (GMDL; retransformed, mean ln-transformed discards to landings ratios [D/L], per trip) are stratified by half-year period and trip landings level (< 300 kg, => 300 kg). Catches are in metric tons (mt).

Year	Dealer Landings	GMDL Discards	D:L Ratio	GMDL Discards PSE (%)
1989	3,984	2,229	0.56	35
1990	4,571	3,909	0.86	35
1991	7,081	3,530	0.50	35
1992	6,259	5,668	0.91	35
1993	4,726	1,436	0.30	35
1994	4,392	807	0.18	35
1995	3,073	2,057	0.67	35
1996	2,945	1,522	0.52	35
1997	2,188	1,843	0.84	61
1998	1,896	3,331	1.76	32
1999	1,505	4,819	3.20	9
2000	1,207	2,352	1.95	48
2001	1,729	1,499	0.87	32
2002	3,173	5,636	1.78	95
2003	4,405	2,153	0.49	41
2004	4,231	893	0.21	25
2005	4,266	662	0.16	29
2006	4,062	1,387	0.34	27
2007	4,196	1,859	0.44	26
2008	2,351	2,879	1.22	31
2009	3,717	1,675	0.45	22
2010	4,855	2,108	0.43	31
2011	6,819	1,913	0.28	38
2012	6,751	2,152	0.32	15
2013	8,110	1,477	0.18	30
2014	7,228	1,122	0.15	31

Table A4. Comparison of estimated live discards (metric tons) and corresponding PSEs for the current assessment approach (GMDL) with new SBRM estimates using three alternative stratifications. Note that 2014 data were not available when this work was conducted.

Year	Current GMDL (mt)	Current GMDL PSE (%)	SBRM QTR4 (mt)	SBRM QTR4 PSE (%)	SBRM MESH8 (mt)	SBRM MESH8 PSE (%)	SBRM MESH240 (mt)	SBRM MESH240 PSE (%)
1989	2,229	35	3,059	38	2,960	47	1,277	7
1990	3,909	35	5,533	45	3,201	45	2,466	5
1991	3,530	35	5,319	24	3,006	26	3,388	11
1992	5,668	35	5,603	58	6,746	60	1,885	29
1993	1,436	35	1,890	53	2,228	51	1,510	1
1994	807	35	417	40	351	44	962	5
1995	2,057	35	439	51	621	51	974	1
1996	1,522	35	845	46	504	43	870	52
1997	1,843	61	947	47	669	48	675	40
1998	3,331	32	995	94	1,085	99	705	72
1999	4,819	9	1,042	72	1,500	78	735	9
2000	2,352	48	542	44	506	42	592	26
2001	1,499	32	662	58	248	71	1,671	63
2002	5,636	95	650	41	666	38	1,284	10
2003	2,153	41	181	47	434	50	436	18
2004	893	25	939	25	1,141	30	1,324	25
2005	662	29	118	28	151	27	565	47
2006	1,387	27	307	32	444	49	896	14
2007	1,859	26	229	27	488	34	1,363	31
2008	2,879	31	333	26	698	38	1,693	4
2009	1,675	22	856	18	936	22	3,189	18
2010	2,108	31	725	17	734	23	2,638	19
2011	1,913	38	401	19	487	22	1,234	13
2012	2,152	15	311	16	613	27	1,029	12
2013	1,477	30	516	17	546	27	1,279	13
mean	2,397	35	1,314	39	1,296	44	1,386	22

Table A5. Total Dealer reported landings, recommended SBRM MESH240 revised commercial fishery live discards (stratified by quarter, 3-digit statistical area, and 3 mesh sizes), recommended revised total commercial catch, and discard as a percentage of total catch for scup. Catches are in metric tons (mt).

Year	Dealer Landings	SBRM MESH240 Estimate	SBRM MESH240 PSE (%)	Total Catch	Live Discard: Catch (%)
1989	3,984	1,277	7	5,261	24%
1990	4,571	2,466	5	7,037	35%
1991	7,081	3,388	11	10,469	32%
1992	6,259	1,885	29	8,144	23%
1993	4,726	1,510	1	6,236	24%
1994	4,392	962	5	5,354	18%
1995	3,073	974	1	4,047	24%
1996	2,945	870	52	3,815	23%
1997	2,188	675	40	2,863	24%
1998	1,896	705	72	2,601	27%
1999	1,505	735	9	2,240	33%
2000	1,207	592	26	1,799	33%
2001	1,729	1,671	63	3,400	49%
2002	3,173	1,284	10	4,457	29%
2003	4,405	436	18	4,841	9%
2004	4,231	1,324	25	5,555	24%
2005	4,266	565	47	4,831	12%
2006	4,062	896	14	4,958	18%
2007	4,196	1,363	31	5,559	25%
2008	2,351	1,693	4	4,044	42%
2009	3,717	3,189	18	6,906	46%
2010	4,855	2,638	19	7,493	35%
2011	6,819	1,234	13	8,053	15%
2012	6,751	1,029	12	7,780	13%
2013	8,110	1,279	13	9,387	14%
2014	7,228	1,140	13	8,368	14%
mean	4,220	1,375	21	5,595	25%

Table A6. Summary of the landed fish length sampling for scup in the recreational fishery (includes MRFSS/MRIP and state agency sampling). Landings are in metric tons (mt). Sampling intensity based on MRFSS when available.

Year	No. of lengths	Estimated landings (A + B1; mt) MRFSS	Estimated landings (A + B1; mt) MRIP	Sampling intensity (mt/100 lengths)
1981	642	2,636	3,116	411
1982	1,057	2,361	2,791	223
1983	1,384	2,836	3,353	205
1984	943	1,096	1,296	116
1985	741	2,764	3.268	373
1986	2,580	5,264	6,223	204
1987	777	2,811	3,323	362
1988	2,156	1,936	2,289	90
1989	4,111	2,521	2,980	61
1990	2,698	1,878	2,220	70
1991	4,230	3,668	4,336	87
1992	4,419	2,001	2,366	45
1993	2,206	1,450	1,714	66
1994	1,374	1,192	1,409	87
1995	822	609	720	74
1996	526	978	1,156	186
1997	399	543	642	136
1998	286	397	469	139
1999	265	856	1,012	323

Table A6 continued.

Year	No. of lengths	Estimated landings (A + B1; mt) MRFSS	Estimated landings (A + B1; mt) MRIP	Sampling intensity (mt/100 lengths)
2000	524	2,469	2,919	471
2001	1,038	1,933	2,285	186
2002	1,006	1,644	1,944	163
2003	2,508	3,848	4,549	153
2004	1,802	1,923	3,278	107
2005	1,794	1,153	1,215	64
2006	2,217	1,334	1,681	60
2007	2,262	1,655	2,085	73
2008	2,426	1,834	1,713	76
2009	2,269	1,334	1,462	59
2010	2,710	2,516	2,715	93
2011	2,412	1,601	1,632	66
2012	2,476	n/a	1,842	74
2013	3,798	n/a	2,424	64
2014	3,927	n/a	2,025	52

Table A7. Comparison of Vessel Trip Report (VTR) reported landings of scup by Party (VTRPB) and charter (VTRCB) boats with landings estimated by the MRFSS/MRIP (MRS) for the Party/Charter boat (P/C Boat) sector. Catches are numeric landings in thousands of fish.

Year	VTRPB	VTRCB	VTR P/C Boat Total	MRS P/C Boat Total	Ratio MRS to VTR
1995	641	41	682	767	1.12
1996	280	39	319	573	1.80
1997	216	37	253	451	1.78
1998	447	43	490	165	0.34
1999	435	75	510	822	1.61
2000	609	116	725	1140	1.57
2001	892	129	1021	769	0.75
2002	542	92	634	1309	2.06
2003	769	132	901	1330	1.48
2004	392	91	483	958	1.98
2005	195	47	242	111	0.46
2006	292	54	346	531	1.53
2007	345	100	445	454	1.02
2008	237	62	299	567	1.90
2009	344	56	400	970	2.43
2010	375	80	455	1099	2.42
2011	330	85	415	655	1.58
2012	469	99	568	964	1.70
2013	533	105	638	1631	2.56
2014	451	124	575	1013	1.76
Mean	440	80	520	814	1.57

Table A8. Summary of the discard fish length sampling for scup in the recreational fishery (includes MRFSS/MRIP and state agency sampling). Live discards are in metric tons (mt) from MRFSS/MRIP.

Year	No. of lengths	Estimated Live Discards (B2; mt) MRFSS	Estimated Live Discards (B2; mt) MRIP	Sampling intensity (mt/100 lengths)
1984	n/a	199	221	n/a
1985	n/a	358	398	n/a
1986	n/a	578	643	n/a
1987	n/a	252	280	n/a
1988	n/a	208	232	n/a
1989	n/a	258	287	n/a
1990	n/a	256	284	n/a
1991	n/a	518	577	n/a
1992	n/a	314	349	n/a
1993	n/a	188	209	n/a
1994	n/a	245	273	n/a
1995	15	85	95	567
1996	6	133	148	2,217
1997	5	52	59	1,040
1998	6	96	107	1,600
1999	1	39	43	3,900

Table A8 continued.

Year	No. of lengths	Estimated Live Discards (B2; mt) MRFSS	Estimated Live Discards (B2; mt) MRIP	Sampling intensity (mt/100 lengths)
2000	15	367	408	2447
2001	146	1,098	1,222	752
2002	70	912	1,015	1303
2003	73	1,052	1,171	1441
2004	33	895	1,216	2712
2005	679	1,102	1,310	162
2006	109	1,232	1,337	1130
2007	1,869	1,044	1,144	56
2008	1,727	1,971	1,908	114
2009	1,780	1,275	1,409	72
2010	1,370	2,031	2,120	148
2011	836	942	1,156	113
2012	1,719	n/a	1,542	90
2013	2,959	n/a	1,508	51
2014	2,656	n/a	1,467	56

Table A9. TOP - Estimated total landings (catch types A + B1, number) of scup by recreational fishermen as estimated by the Marine Recreational Information Program (MRIP). Proportional Standard Error (PSE) is for the TOTAL landings estimate. BOTTOM - Percentage difference in estimated total landings (catch types A + B1, number) of scup by recreational fishermen as estimated by the MRSSS and MRIP ([MRIP-MRFSS]/MRFSS). Positive value indicates MRIP estimate is larger. MRFSS to MRIP comparisons are only available for 2004-2011.

STATE	2004	2005	2006	2007	2008	2009	2010	2011
CT	1,072,232	508,296	532,362	925,236	549,083	288,702	1,087,681	1,071,802
DE	518	3,870	319	2,365	1,338	821	0	50
MD	1,095	1,832	226	305	104	32	18	0
MA	3,312,973	656,524	424,968	1,769,960	761,612	1,069,275	925,222	1,011,190
NJ	60,141	118,667	327,202	99,320	87,186	174,809	739,901	41,825
NY	1,876,973	859,156	1,677,998	1,596,391	1,450,860	1,460,314	1,990,340	496,635
NC	1,710	3,714	14,444	5,268	13,843	3,989	7,580	26,257
RI	816,894	430,747	470,286	353,450	632,839	139,576	398,178	405,423
VA	10,999	8,507	0	586	3,920	527	5,284	7,500
TOTAL	7,153,535	2,591,313	3,447,806	4,752,881	3,500,785	3,138,045	5,154,203	3,060,683
PSE (%)	13	17	20	22	13	14	12	13

STATE	2004	2005	2006	2007	2008	2009	2010	2011	TOTAL
CT	90%	-30%	3%	34%	-18%	26%	8%	36%	16%
DE	-65%	1%	-50%	30%	27%	-15%		134%	-6%
MD	-83%	8%	-49%	16%	-20%	0%	-31%	-100%	-61%
MA	119%	65%	35%	143%	15%	38%	10%	39%	67%
NJ	-48%	-5%	31%	-11%	-34%	-38%	34%	-22%	2%
NY	19%	25%	31%	0%	-10%	11%	7%	-33%	7%
NC	-13%	9%	17%	-7%	-33%	37%	49%	-12%	-6%
RI	-10%	-3%	10%	-22%	11%	-19%	-9%	-23%	-7%
VA	26%	82%		-27%	42%	-75%	22%	-51%	-4%
TOTAL	52%	8%	23%	32%	-5%	13%	9%	6%	19%

Table A10. TOP - Estimated total landings (catch types A + B1, metric tons) of scup by recreational fishermen as estimated by the Marine Recreational Information Program (MRIP). Proportional Standard Error (PSE) is for the TOTAL landings estimate. BOTTOM - Percentage difference in estimated total landings (catch types A + B1, metric tons) of scup by recreational fishermen as estimated by the MRSSS and MRIP ([MRIP-MRFSS]/MRFSS). Positive value indicates MRIP estimate is larger. MRFSS to MRIP comparisons are only available for 2004-2011.

STATE	2004	2005	2006	2007	2008	2009	2010	2011
CT	512	249	353	487	261	163	611	627
DE	0	2	0	1	0	0	0	0
MD	0	1	0	0	0	0	0	0
MA	1,384	335	199	629	371	397	464	484
NJ	28	32	106	39	33	64	282	17
NY	998	398	760	786	757	770	1,191	258
NC	0	1	5	1	6	1	3	11
RI	354	194	259	141	284	66	161	235
VA	2	3	0	0	1	0	2	0
TOTAL	3,278	1,215	1,681	2,085	1,713	1,462	2,715	1,632
PSE (%)	12	16	19	20	14	13	12	14

STATE	2004	2005	2006	2007	2008	2009	2010	2011	TOTAL
CT	88%	-34%	6%	38%	-45%	23%	12%	37%	11%
DE	208%	4465%	-65%	27%	27%	-23%		177%	112%
MD	-63%	2%	-46%	-1%	-41%	18%	-50%	-100%	-30%
MA	154%	86%	100%	120%	23%	31%	4%	25%	67%
NJ	-45%	4%	48%	6%	-34%	-37%	35%	-28%	4%
NY	45%	16%	21%	0%	0%	8%	6%	-35%	9%
NC	174%	12%	24%	-7%	-33%	45%	45%	-16%	-8%
RI	-3%	-10%	25%	-26%	15%	-18%	-15%	-24%	-6%
VA	24%	37%		+9303%	36%	-74%	12%	-90%	-22%
TOTAL	71%	5%	25%	26%	-7%	10%	8%	2%	18%

Table A11. TOP - Estimated total live releases (catch type B2, number) of scup by recreational fishermen as estimated by the Marine Recreational Information Program (MRIP). Proportional Standard Error (PSE) is for the TOTAL landings estimate. BOTTOM - Percentage difference in estimated total live releases (catch type B2, number) of scup by recreational fishermen as estimated by the MRSSS and MRIP ([MRIP-MRFSS]/MRFSS). Positive value indicates MRIP estimate is larger. MRFSS to MRIP comparisons are only available for 2004-2011.

STATE	2004	2005	2006	2007	2008	2009	2010	2011
CT	538,241	752,749	739,778	1,006,174	974,212	1,204,388	1,192,329	576,941
DE	241	2,303	7,611	9,784	2,428	1,563	576	7
MD	5,279	1,531	34,790	1,742	6,322	586	24	161
MA	1,486,750	751,180	1,096,029	1,183,159	1,687,442	1,741,140	1,857,722	1,373,564
NJ	164,381	449,233	802,174	502,779	316,003	146,919	524,877	33,098
NY	3,514,103	1,737,255	2,621,812	1,963,724	2,838,176	2,124,306	1,864,138	929,213
NC	497	389	6,290	4,800	8,723	4,364	1,045	4,379
RI	517,673	689,788	801,281	613,147	1,386,018	332,505	536,204	765,426
VA	45,471	63,940	75,605	22,404	8,262	18,635	23,081	9,287
TOTAL	6,272,637	4,448,369	6,185,371	5,307,714	7,227,587	5,574,406	5,999,997	3,692,075
PSE (%)	15	18	15	12	11	11	11	14

STATE	2004	2005	2006	2007	2008	2009	2010	2011	TOTAL
CT	39%	5%	1%	16%	-14%	27%	4%	9%	8%
DE	-91%	-30%	-20%	11%	9%	-45%	103%	-99%	-21%
MD	-75%	-10%	-41%	-12%	-45%	-12%	-9%	28%	-47%
MA	74%	45%	18%	26%	43%	36%	21%	56%	38%
NJ	-36%	-17%	47%	-27%	-43%	-45%	14%	-8%	-12%
NY	40%	37%	5%	23%	-14%	-3%	-7%	-9%	8%
NC	11%	-32%	-17%	5%	-11%	46%	-26%	-19%	-7%
RI	0%	4%	-9%	-17%	8%	0%	-7%	45%	2%
VA	-33%	101%	143%	133%	-29%	3%	-20%	9%	29%
TOTAL	36%	19%	9%	10%	-3%	10%	4%	23%	11%

Table A12. Summary of the landings length sampling for scup in the NER (ME-VA) commercial fishery. Landings are in metric tons (mt).

Year	No. of samples	No. of lengths	NER Landings (mt)	Sampling rate (mt/100 lengths)
1979	10	1,250	8,585	687
1980	26	3,478	8,424	242
1981	16	2,005	9,856	492
1982	81	9,896	8,704	88
1983	72	7,860	7,794	99
1984	60	6,303	7,769	123
1985	31	3,058	6,727	220
1986	54	5,467	7,176	131
1987	61	6,491	6,276	97
1988	85	8,691	5,943	68
1989	46	4,806	3,984	83
1990	46	4,736	4,571	97
1991	31	3,150	7,081	225
1992	33	3,260	6,259	192
1993	23	2,287	4,726	207
1994	22	2,163	4,392	203
1995	22	2,487	3,073	124
1996	61	6,544	2,945	45
1997	37	3,732	2,188	59
1998	41	4,022	1,896	47
1999	56	6,040	1,505	25

Table A12 continued.

Year	No. of samples	No. of lengths	NER Landings (mt)	Sampling rate (mt/100 lengths)
2000	22	2,352	1,207	51
2001	40	3,934	1,729	44
2002	26	2,587	3,173	123
2003	78	6,681	4,405	66
2004	144	13,172	4,209	32
2005	124	9,324	3,711	40
2006	152	12,506	4,081	32
2007	198	15,704	4,193	27
2008	154	12,764	2,370	18
2009	112	9,694	3,721	38
2010	105	9,860	4,866	49
2011	99	9,660	6,819	71
2012	103	9,554	6,751	71
2013	133	13,159	8,110	62
2014	140	13,609	7,228	53

Table A13. Commercial fishery scup landings (000s) at age.

Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	1	2691	6114	7090	5793	1418	536	251	1	0	0	23895
1985	79	3245	6767	7696	2640	346	520	159	0	0	0	21452
1986	9	301	12321	4773	1004	75	106	337	5	0	0	18931
1987	2	1679	9952	10399	1725	177	124	21	18	0	1	24098
1988	17	423	7709	9526	2424	58	127	39	0	0	0	20323
1989	17	1484	4943	7071	685	22	69	24	0	0	0	14315
1990	0	247	10203	6781	1022	355	149	2	0	0	0	18759
1991	0	2412	12956	10202	2161	409	193	0	0	0	0	28334
1992	21	1577	10883	3737	3797	1243	138	0	0	0	0	21396
1993	1	230	6558	6877	1500	1143	124	0	0	0	0	16433
1994	0	1052	13544	6358	836	82	39	0	0	0	0	21911
1995	0	2198	8345	2878	891	248	31	0	0	0	0	14591
1996	0	346	6343	1640	770	469	62	0	0	0	0	9630
1997	0	131	2080	4089	732	84	97	0	0	0	0	7213
1998	0	340	1453	2373	1092	381	2	0	0	0	0	5641
1999	0	1	1148	2688	527	117	0	0	0	0	0	4481
2000	0	0	661	2144	511	15	0	0	0	0	0	3331
2001	0	31	1635	3033	695	46	6	1	1	0	0	5448
2002	0	124	1219	5051	2132	393	5	0	0	0	0	8922
2003	0	2	955	2974	4553	1131	121	41	5	14	0	9796
2004	0	1	844	2406	2826	2089	296	40	4	14	0	8520
2005	0	31	683	1558	2361	2515	807	92	3	3	0	8053
2006	0	89	2233	2231	1119	1477	1219	366	28	3	0	8765
2007	0	91	2787	2661	1390	680	940	590	124	12	0	9275
2008	0	36	1304	2411	1108	306	254	257	34	1	1	5712
2009	0	3	1305	4277	2592	818	220	206	125	10	0	9556
2010	0	34	1717	3788	3863	1791	259	146	97	16	1	11712
2011	0	57	1579	5363	4630	3269	691	178	112	29	2	15910
2012	0	134	2500	2362	5448	3404	1171	272	82	30	2	15405
2013	0	82	3197	4593	3380	4347	1523	695	207	101	12	18137
2014	0	0	1630	5747	4256	2713	1300	589	363	145	16	16759

Table A14. Commercial fishery scup landings mean weights (kg) at age.

Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	0.033	0.155	0.190	0.293	0.344	0.398	0.767	1.044	1.545	0.000	0.000	0.288
1985	0.043	0.134	0.197	0.293	0.409	0.517	0.739	1.042	0.000	0.000	0.000	0.272
1986	0.036	0.140	0.219	0.357	0.676	0.670	1.010	1.246	1.616	0.000	0.000	0.302
1987	0.034	0.136	0.203	0.244	0.407	0.544	0.747	1.194	1.068	0.000	0.000	0.237
1988	0.044	0.123	0.201	0.263	0.441	0.636	0.715	0.982	0.000	0.000	0.000	0.263
1989	0.025	0.144	0.188	0.275	0.367	0.651	0.721	1.036	0.000	0.000	0.000	0.240
1990	0.000	0.140	0.189	0.246	0.367	0.518	0.842	0.846	0.000	1.096	0.000	0.230
1991	0.000	0.187	0.194	0.263	0.389	0.511	0.729	0.000	0.000	0.000	0.000	0.241
1992	0.039	0.173	0.199	0.325	0.419	0.503	0.859	0.000	0.000	1.096	0.000	0.280
1993	0.031	0.140	0.197	0.261	0.442	0.510	0.782	0.000	0.000	0.000	0.000	0.272
1994	0.000	0.203	0.193	0.259	0.430	0.663	0.742	0.000	0.000	0.000	0.000	0.224
1995	0.000	0.161	0.209	0.295	0.396	0.480	0.724	0.000	0.000	0.000	0.000	0.236
1996	0.000	0.206	0.200	0.325	0.468	0.554	0.784	0.000	0.000	0.000	0.000	0.264
1997	0.000	0.227	0.253	0.300	0.386	0.529	0.749	0.000	0.000	0.000	0.000	0.303
1998	0.000	0.200	0.254	0.313	0.459	0.556	0.748	0.000	0.000	0.000	0.000	0.336
1999	0.000	0.075	0.220	0.323	0.497	0.748	0.000	0.000	0.000	0.000	0.000	0.328
2000	0.000	0.000	0.221	0.367	0.504	0.674	0.000	0.000	0.000	0.000	0.000	0.360
2001	0.000	0.229	0.265	0.346	0.476	0.562	0.779	1.003	1.003	0.000	0.000	0.340
2002	0.000	0.231	0.281	0.339	0.465	0.577	0.748	0.000	0.000	0.000	0.000	0.370
2003	0.000	0.187	0.285	0.362	0.471	0.659	0.859	0.884	1.241	0.000	0.000	0.448
2004	0.000	0.182	0.313	0.398	0.518	0.591	0.812	1.002	1.370	1.674	0.000	0.496
2005	0.000	0.196	0.269	0.362	0.471	0.652	0.809	1.044	1.099	1.311	0.000	0.529
2006	0.000	0.213	0.283	0.344	0.460	0.591	0.727	0.915	1.108	1.314	0.000	0.463
2007	0.000	0.217	0.265	0.353	0.470	0.646	0.768	0.894	1.077	1.697	0.000	0.452
2008	0.000	0.197	0.264	0.321	0.486	0.634	0.804	0.973	1.176	1.435	2.437	0.412
2009	0.000	0.177	0.252	0.29	0.439	0.59	0.821	0.958	1.086	1.36	1.815	0.389
2010	0.000	0.191	0.251	0.313	0.426	0.548	0.784	0.941	1.054	1.232	1.510	0.403
2011	0.000	0.198	0.255	0.309	0.432	0.566	0.803	0.992	1.128	1.252	1.525	0.428
2012	0.000	0.199	0.270	0.246	0.454	0.562	0.747	0.899	1.097	1.193	1.678	0.464
2013	0.000	0.202	0.259	0.324	0.428	0.528	0.701	0.840	1.011	1.198	1.532	0.445
2014	0.000	0.000	0.273	0.305	0.411	0.522	0.678	0.803	0.917	1.084	1.325	0.413

Table A15. Summary of discarded commercial catch length sampling for scup in the NEFSC Fishery Observer Program. OT =number of otter trawl trips sampled with scup discard lengths. H1 = first half year; H2 = second half year. SBRM estimated discards in metric tons (mt).

Year	OT trips	Lengths H1	Lengths H2	Lengths Total	Discards	Sampling Intensity (mt/100 lengths)
1989	61	4,449	2,910	7,359	1,277	17
1990	52	2,582	781	3,363	2,466	73
1991	91	1,237	1,780	3,017	3,388	111
1992	53	1,158	0	1,158	1,885	162
1993	29	275	154	429	1,510	352
1994	7	99	119	218	962	441
1995	18	162	383	556	974	175
1996	27	1,093	435	1,528	870	57
1997	45	750	1	751	675	90
1998	33	618	64	682	705	103
1999	35	586	89	675	735	109
2000	62	3,981	762	4,743	592	12
2001	67	1,231	229	1,460	1,671	114
2002	65	1,422	866	2,288	1,284	56
2003	72	925	284	1,209	436	36
2004	80	1,948	1,051	2,999	1,324	77
2005	73	797	1,159	1,956	565	29
2006	47	1,486	777	2,263	896	40
2007	59	1,313	1,058	2,371	1,363	57
2008	54	1,217	1,259	2,476	1,693	68
2009	111	3,498	2,788	6,286	3,189	51
2010	137	5,185	2,466	7,651	2,638	34
2011	113	4,232	2,317	6,549	1,234	19
2012	82	2,851	970	3,821	1,029	27
2013	152	4,163	969	5,132	1,279	25
2014	204	3,385	1,702	5,087	1,140	22

Table A16. Commercial fishery scup SBRM method discards (000s) at age.

Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	201	27990	16430	2384	54	0	0	0	0	0	0	47060
1985	21663	5375	2682	435	4	0	0	0	0	0	0	30159
1986	267	4044	48118	2063	10	0	0	0	0	0	0	54503
1987	280	24469	43864	4905	18	0	0	0	0	0	0	73536
1988	1979	2165	11786	1708	13	0	0	0	0	0	0	17651
1989	556	8134	5045	253	6	0	0	0	0	0	0	13994
1990	7645	7847	9275	666	0	0	0	0	0	0	0	25433
1991	1716	16748	4923	1423	132	103	172	0	0	0	0	25218
1992	3575	6887	5929	352	36	0	0	0	0	0	0	16780
1993	146	202	8051	1593	8	0	0	0	0	0	0	9999
1994	20372	4341	527	23	1	0	0	0	0	0	0	25264
1995	4660	8589	368	24	2	0	0	0	0	0	0	13643
1996	193	2159	3758	303	8	0	0	0	0	0	0	6421
1997	1	473	4211	275	9	0	0	0	0	0	0	4970
1998	1	4991	2067	223	62	3	0	0	0	0	0	7346
1999	38	885	4250	178	51	13	0	0	0	0	0	5415
2000	119	2658	1441	437	20	12	0	2	0	0	0	4688
2001	369	5262	3306	696	506	85	15	0	171	0	0	10410
2002	2111	4113	1426	966	300	18	6	0	0	0	0	8940
2003	235	416	767	138	156	83	28	2	0	0	0	1825
2004	467	1275	2716	1697	387	139	10	1	0	0	0	6693
2005	661	1383	1407	323	86	48	17	4	1	2	0	3932
2006	2468	5602	1741	505	25	3	1	4	0	0	0	10349
2007	529	3280	4242	965	111	29	18	3	0	0	0	9177
2008	1872	16160	19070	7925	1339	351	315	314	167	74	74	47660
2009	726	5986	5816	3716	1101	267	104	119	86	8	2	17932
2010	423	1436	7575	3427	1010	282	45	29	23	9	1	14259
2011	186	4572	2090	1967	423	126	35	12	2	0	0	9413
2012	218	3885	1734	542	298	106	54	13	5	3	0	6857
2013	689	1263	4605	1049	115	77	14	9	4	10	19	7854
2014	614	1126	4105	935	103	69	12	8	4	9	17	7002

Table A17. Commercial fishery scup SBRM method discards mean weights (kg) at age.

Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	0.033	0.108	0.125	0.198	0.222	0	0	0	0	0	0	0.118
1985	0.033	0.108	0.125	0.198	0.222	0	0	0	0	0	0	0.057
1986	0.033	0.108	0.125	0.198	0.222	0	0	0	0	0	0	0.126
1987	0.033	0.108	0.125	0.198	0.222	0	0	0	0	0	0	0.124
1988	0.033	0.108	0.125	0.198	0.222	0	0	0	0	0	0	0.120
1989	0.039	0.060	0.111	0.198	0.217	0	0	0	0	0	0	0.080
1990	0.026	0.121	0.137	0.187	0	0	0	0	0	0	0	0.100
1991	0.057	0.127	0.163	0.207	0.252	0	0	0	0	0	0	0.133
1992	0.033	0.078	0.136	0.243	0	0	0	0	0	0	0	0.092
1993	0.026	0.106	0.154	0.269	0	0	0	0	0	0	0	0.169
1994	0.024	0.068	0.122	0.198	0	0	0	0	0	0	0	0.034
1995	0.038	0.037	0.229	0.310	0.331	0	0	0	0	0	0	0.043
1996	0.033	0.110	0.169	0.240	0.268	0.532	0	0	0	0	0	0.149
1997	0.020	0.028	0.137	0.362	0.000	0.000	0	0	0	0	0	0.139
1998	0.092	0.069	0.147	0.224	0.418	0.564	0	0	0	0	0	0.099
1999	0.010	0.037	0.158	0.398	0.599	0.690	0	0	0	0	0	0.150
2000	0.044	0.076	0.195	0.299	0.486	0.768	0	0	0	0	0	0.136
2001	0.015	0.063	0.168	0.345	0.500	0.670	0.944	0	0	0	0	0.140
2002	0.035	0.064	0.201	0.361	0.524	0.757	1.071	0	0	0	0	0.129
2003	0.022	0.091	0.212	0.315	0.537	0.784	0.878	0	0	0	0	0.232
2004	0.029	0.109	0.166	0.268	0.371	0.453	0.750	0	0	0	0	0.190
2005	0.019	0.090	0.154	0.267	0.416	0.652	0.912	0	0	0	0	0.133
2006	0.026	0.086	0.166	0.217	0.313	0.549	0.755	0	0	0	0	0.092
2007	0.041	0.094	0.163	0.282	0.342	0.597	0.770	0	0	0	0	0.148
2008	0.039	0.096	0.182	0.294	0.495	0.742	0.884	1.078	1.442	0.000	0.000	0.193
2009	0.032	0.083	0.160	0.261	0.401	0.582	0.810	0.962	1.154	0.000	0.000	0.185
2010	0.027	0.096	0.147	0.240	0.340	0.516	0.780	0.967	1.144	1.302	1.503	0.188
2011	0.028	0.060	0.166	0.233	0.312	0.519	0.739	0.839	0.877	0.912	0.000	0.140
2012	0.037	0.054	0.183	0.257	0.337	0.516	0.715	0.843	1.287	1.294	1.549	0.130
2013	0.033	0.099	0.171	0.247	0.346	0.462	0.766	0.873	1.581	1.460	1.791	0.171
2014	0.033	0.099	0.171	0.247	0.346	0.462	0.766	0.873	1.581	1.460	1.791	0.171

Table A18. Recreational fishery scup landings (000s) at age.

Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	23	3036	1353	570	182	219	442	86	51	30	66	6058
1985	431	4478	3054	1330	788	441	137	33	0	0	115	10807
1986	538	4353	15570	2617	845	431	87	5	4	57	315	24822
1987	77	2299	4686	1261	824	598	112	0	0	11	46	9914
1988	9	1001	2229	1824	460	216	123	92	20	0	86	6060
1989	311	3978	3371	823	86	235	154	13	0	50	148	9169
1990	169	1352	5091	1102	147	112	36	7	2	3	22	8043
1991	299	4838	3797	3319	700	210	19	0	2	20	68	13272
1992	99	1850	4457	530	672	84	12	6	8	7	30	7755
1993	46	1245	3051	908	254	133	2	2	0	2	7	5650
1994	31	1473	1840	691	95	88	21	6	0	0	0	4245
1995	15	613	1399	225	89	20	3	3	0	0	0	2367
1996	9	351	1467	812	365	54	10	15	0	0	0	3083
1997	32	52	983	562	168	63	33	17	6	0	0	1916
1998	13	223	257	415	248	19	13	23	0	0	0	1211
1999	61	469	2169	359	182	11	0	0	0	0	0	3251
2000	6	912	3443	2113	641	129	0	0	0	0	0	7244
2001	0.3	514	1511	1705	806	244	101	218	0	0	0	5099
2002	7	70	688	1635	1005	179	24	39	0	0	0	3647
2003	0.3	75	1723	2655	3127	1407	350	115	0	0	0	9452
2004	0.9	45	284	1551	1441	1166	470	32	0	0	0	4990
2005	0	13	100	513	700	845	349	26	0	0	0	2546
2006	1	50	658	819	404	431	541	46	0	1	0	2951
2007	3	47	456	1347	775	378	605	206	26	1	0	3844
2008	2	52	732	1352	842	205	338	133	17	1	0	3674
2009	1	37	159	1007	1003	365	109	64	24	2	0	2771
2010	2	10	282	1221	1575	804	222	422	162	8	1	4709
2011	1	14	79	386	1029	897	290	142	48	13	1	2900
2012	1	43	213	425	1068	920	598	146	81	17	13	3525
2013	0	30	494	714	1244	1434	616	299	101	82	7	5021
2014	0	13	181	935	1207	1009	316	310	142	21	8	4142

Table A19 Recreational fishery scup landings mean weights (kg) at age.

Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	0.044	0.117	0.266	0.373	0.472	0.557	0.678	0.825	0.912	1.002	1.145	0.274
1985	0.038	0.125	0.253	0.340	0.573	0.718	0.913	1.087	0.000	0.000	1.673	0.270
1986	0.052	0.101	0.234	0.374	0.534	0.654	0.801	0.912	1.003	1.003	1.638	0.261
1987	0.029	0.105	0.242	0.381	0.548	0.698	0.737	0.000	0.000	1.003	3.808	0.302
1988	0.026	0.142	0.240	0.325	0.497	0.663	0.794	1.144	1.099	0.000	1.532	0.330
1989	0.035	0.123	0.234	0.376	0.433	0.653	0.696	0.657	0.000	1.003	1.332	0.235
1990	0.057	0.128	0.208	0.325	0.461	0.567	0.761	0.939	1.088	1.202	1.947	0.225
1991	0.064	0.150	0.275	0.361	0.474	0.714	0.675	0.000	1.003	1.003	1.305	0.271
1992	0.092	0.140	0.240	0.373	0.454	0.598	0.804	0.859	1.311	1.003	2.117	0.256
1993	0.087	0.135	0.226	0.336	0.460	0.524	0.912	0.827	0.000	1.026	1.100	0.242
1994	0.054	0.180	0.281	0.357	0.467	0.674	0.905	1.430	0.000	0.000	0.000	0.274
1995	0.065	0.155	0.279	0.450	0.557	0.756	1.044	1.311	0.000	0.000	0.000	0.279
1996	0.093	0.171	0.231	0.368	0.540	0.772	0.876	1.383	0.000	0.000	0.000	0.314
1997	0.083	0.110	0.253	0.299	0.510	0.684	0.819	1.342	0.779	0.000	0.000	0.318
1998	0.072	0.121	0.211	0.312	0.491	0.866	1.066	1.950	0.000	0.000	0.000	0.337
1999	0.095	0.173	0.274	0.451	0.635	0.900	0.000	0.000	0.000	0.000	0.000	0.298
2000	0.075	0.138	0.296	0.424	0.544	0.825	0.000	0.000	0.000	0.000	0.000	0.345
2001	0.092	0.220	0.344	0.485	0.637	0.776	0.875	1.127	0.000	0.000	0.000	0.490
2002	0.110	0.152	0.296	0.427	0.618	0.795	0.932	1.427	0.000	0.000	0.000	0.481
2003	0.092	0.161	0.314	0.416	0.536	0.720	0.908	1.499	0.000	0.000	0.000	0.512
2004	0.094	0.151	0.325	0.437	0.523	0.575	0.858	0.748	0.000	0.000	0.000	0.527
2005	0.000	0.112	0.270	0.384	0.516	0.679	0.881	1.098	0.000	0.000	0.000	0.588
2006	0.092	0.151	0.304	0.411	0.525	0.695	0.883	0.999	0.000	1.311	0.000	0.536
2007	0.111	0.152	0.313	0.418	0.509	0.672	0.882	0.935	1.056	1.322	0.000	0.551
2008	0.080	0.162	0.318	0.442	0.545	0.714	0.996	1.035	1.201	1.350	0.000	0.528
2009	0.064	0.127	0.279	0.419	0.539	0.666	0.918	1.035	1.085	1.409	0.000	0.523
2010	0.028	0.129	0.282	0.408	0.521	0.667	0.897	1.372	1.201	1.307	1.482	0.620
2011	0.041	0.119	0.279	0.377	0.512	0.626	0.823	1.084	1.129	1.219	1.549	0.594
2012	0.060	0.178	0.269	0.397	0.494	0.605	0.814	0.969	1.144	1.198	1.658	0.590
2013	0.000	0.147	0.283	0.359	0.461	0.550	0.754	0.981	1.046	1.238	1.488	0.545
2014	0.000	0.152	0.257	0.355	0.466	0.581	0.763	0.911	0.949	1.099	1.614	0.537

Table A20. Recreational fishery scup discards (000s) at age.

Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	2	255	0	0	0	0	0	0	0	0	0	257
1985	40	417	0	0	0	0	0	0	0	0	0	457
1986	100	807	0	0	0	0	0	0	0	0	0	907
1987	12	357	0	0	0	0	0	0	0	0	0	369
1988	2	219	0	0	0	0	0	0	0	0	0	221
1989	24	308	0	0	0	0	0	0	0	0	0	332
1990	36	284	0	0	0	0	0	0	0	0	0	320
1991	31	505	0	0	0	0	0	0	0	0	0	536
1992	17	325	0	0	0	0	0	0	0	0	0	342
1993	8	204	0	0	0	0	0	0	0	0	0	212
1994	4	203	0	0	0	0	0	0	0	0	0	207
1995	63	135	0	0	0	0	0	0	0	0	0	198
1996	44	222	0	0	0	0	0	0	0	0	0	266
1997	163	10	0	0	0	0	0	0	0	0	0	173
1998	80	139	0	0	0	0	0	0	0	0	0	219
1999	208	0	0	0	0	0	0	0	0	0	0	208
2000	20	561	25	0	0	0	0	0	0	0	0	606
2001	0.3	484	325	0	0	0	0	0	0	0	0	809
2002	14	199	381	55	0	0	0	0	0	0	0	649
2003	1	168	550	63	0	0	0	0	0	0	0	782
2004	7	232	242	211	0	0	0	0	0	0	0	692
2005	5	88	232	135	44	46	11	1	0	0	0	562
2006	1	143	644	66	0	0	0	0	0	0	0	854
2007	20	185	375	124	20	2	1	0	0	0	0	727
2008	24	230	511	282	50	9	5	8	1	0	0	1120
2009	11	137	307	247	46	6	1	1	1	0	0	757
2010	6	74	287	273	148	40	14	9	7	4	0	862
2011	3	40	125	163	97	23	1	1	0	0	0	453
2012	4	185	181	150	182	54	4	1	1	1	0	763
2013	2	69	325	167	133	59	4	1	1	1	0	762
2014	2	52	167	324	169	23	2	1	0	0	0	740

Table A21. Recreational fishery scup discards mean weights (kg) at age.

Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	0.044	0.117	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.116
1985	0.038	0.125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.117
1986	0.052	0.101	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.096
1987	0.029	0.105	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.103
1988	0.026	0.142	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.141
1989	0.035	0.123	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.117
1990	0.057	0.128	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.120
1991	0.064	0.150	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.145
1992	0.092	0.140	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.138
1993	0.087	0.135	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.133
1994	0.054	0.180	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.178
1995	0.063	0.065	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.064
1996	0.075	0.075	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.075
1997	0.043	0.075	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.045
1998	0.061	0.068	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.065
1999	0.028	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.028
2000	0.075	0.087	0.189	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.091
2001	0.092	0.194	0.218	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.204
2002	0.110	0.155	0.238	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.211
2003	0.092	0.141	0.215	0.251	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.202
2004	0.094	0.149	0.206	0.233	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.194
2005	0.035	0.114	0.215	0.311	0.481	0.698	0.810	1.110	0.000	0.000	0.000	0.294
2006	0.092	0.148	0.229	0.243	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.216
2007	0.067	0.127	0.220	0.322	0.408	0.567	0.000	0.000	0.000	0.000	0.000	0.215
2008	0.039	0.121	0.242	0.343	0.507	0.781	0.854	1.074	1.233	0.000	0.000	0.264
2009	0.048	0.125	0.226	0.313	0.432	0.662	0.937	0.980	1.093	0.000	0.000	0.253
2010	0.048	0.132	0.226	0.342	0.471	0.730	0.898	1.092	1.218	1.678	0.000	0.354
2011	0.047	0.122	0.243	0.331	0.408	0.474	0.732	0.807	0.827	0.000	0.000	0.312
2012	0.060	0.142	0.233	0.363	0.422	0.491	0.760	0.865	0.914	0.000	0.000	0.303
2013	0.045	0.145	0.233	0.333	0.395	0.446	0.653	0.845	1.103	1.427	1.514	0.297
2014	0.053	0.133	0.236	0.315	0.384	0.477	0.708	0.889	0.748	0.000	0.000	0.306

Table A22. Total catch (metric tons) of scup from Maine through North Carolina. Landings include revised Massachusetts landings for 1986-1997. Commercial discards for 1981-1988 calculated from the mean ratio of discards to landings for 1989-1991. Commercial discard estimate for 1998 is the mean of 1997 and 1999 estimates. Recreational catch from MRIP (2004-2014) and MRFSS adjusted by MRFSS to MRIP 2004-2011 ratio (1981-2003). Commercial discards are from the SBRM estimator.

Year	Commercial Landings	Commercial Discards	Recreational Landings	Recreational Discards	Total Catch
1981	9,856	4,495	3,116	59	17,526
1982	8,704	3,970	2,791	53	15,518
1983	7,794	3,555	3,353	63	14,765
1984	7,769	3,543	1,296	33	12,641
1985	6,727	3,068	3,268	60	13,123
1986	7,176	3,273	6,223	97	16,769
1987	6,276	2,862	3,323	42	12,503
1988	5,943	2,710	2,289	35	10,977
1989	3,984	1,277	2,980	43	8,285
1990	4,571	2,466	2,220	42	9,299
1991	7,081	3,388	4,336	87	14,892
1992	6,259	1,885	2,366	52	10,562
1993	4,726	1,510	1,714	31	7,981
1994	4,392	962	1,409	41	6,804
1995	3,073	974	720	14	4,781
1996	2,945	870	1,156	22	4,993
1997	2,188	675	642	9	3,514
1998	1,896	705	469	16	3,086
1999	1,505	735	1,012	7	3,259
2000	1,207	592	2,919	61	4,779
2001	1,729	1,671	2,285	184	5,869
2002	3,173	1,284	1,944	152	6,553
2003	4,405	436	4,549	176	9,566
2004	4,209	1324	3,278	182	8,993
2005	3,711	565	1,215	270	5,761
2006	4,081	896	1,681	426	7,084
2007	4,193	1,363	2,085	346	7,987
2008	2,370	1,693	1,713	287	6,062
2009	3,721	3,189	1,462	211	8,583
2010	4,866	2,638	2,715	318	10,537
2011	6,819	1,234	1,632	173	9,858
2012	6,751	1,029	1,842	231	9,853
2013	8,110	1,279	2,430	226	12,045
2014	7,228	1,140	2,025	227	10,620

Table A23. Total fishery scup catch (000s) at age.

Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	227	33972	23897	10044	6029	1637	978	337	52	30	66	77270
1985	22213	13515	12503	9461	3432	787	657	192	0	0	115	62875
1986	914	9505	76009	9453	1859	506	193	342	9	57	315	99163
1987	371	28804	58502	16565	2567	775	236	21	18	11	47	107917
1988	2007	3808	21724	13058	2897	274	250	131	20	0	86	44255
1989	908	13903	13359	8147	777	257	223	37	0	50	148	37810
1990	7850	9730	24569	8549	1169	467	185	9	2	3	22	52555
1991	2046	24503	21676	14944	2993	723	384	0	2	20	68	67360
1992	3712	10639	21269	4619	4505	1327	150	6	8	7	30	46273
1993	201	1881	17660	9378	1762	1276	126	2	0	2	7	32294
1994	20407	7069	15911	7072	932	170	60	6	0	0	0	51627
1995	4738	11535	10112	3127	982	268	34	3	0	0	0	30799
1996	246	3078	11568	2755	1143	523	72	15	0	0	0	19400
1997	196	666	7274	4926	909	147	130	17	6	0	0	14272
1998	94	5693	3777	3011	1402	403	15	23	0	0	0	14417
1999	307	1355	7567	3225	760	141	0	0	0	0	0	13355
2000	145	4131	5570	4694	1172	156	0	0	0	0	0	15867
2001	370	6291	6777	5434	2007	375	122	219	171	0	0	21767
2002	2132	4505	3714	7707	3436	590	35	39	0	0	0	22158
2003	237	661	3995	5830	7836	2621	499	158	5	14	0	21856
2004	475	1553	4086	5865	4654	3394	776	73	4	14	0	20895
2005	666	1515	2422	2529	3191	3454	1184	123	4	5	0	15093
2006	2470	5884	5276	3621	1548	1911	1761	416	28	4	0	22919
2007	552	3603	7860	5097	2296	1089	1564	799	150	13	0	23023
2008	1898	16478	21617	11970	3339	871	912	712	219	76	75	58166
2009	738	6163	7587	9247	4742	1456	434	390	236	20	2	31016
2010	431	1554	9861	8709	6596	2917	540	606	289	37	3	31542
2011	190	4683	3873	7879	6179	4315	1017	333	162	42	3	28676
2012	223	4247	4628	3479	6996	4484	1827	432	169	51	15	26550
2013	691	1444	8621	6523	4872	5917	2157	1004	313	194	38	31774
2014	616	1191	6083	7941	5735	3814	1630	908	509	175	41	28643

Table A24. Total fishery scup catch mean weights (kg) at age.

Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	0.034	0.113	0.150	0.275	0.347	0.419	0.727	0.988	0.924	1.002	1.145	0.183
1985	0.033	0.121	0.195	0.295	0.447	0.629	0.775	1.050	0.000	0.000	1.673	0.168
1986	0.046	0.105	0.163	0.327	0.609	0.656	0.916	1.241	1.344	1.003	1.638	0.193
1987	0.032	0.109	0.148	0.241	0.451	0.663	0.742	1.194	1.068	1.003	3.727	0.166
1988	0.033	0.121	0.164	0.263	0.449	0.657	0.754	1.096	1.099	0.000	1.532	0.214
1989	0.037	0.088	0.171	0.283	0.373	0.653	0.704	0.903	0.000	1.003	1.332	0.178
1990	0.027	0.123	0.173	0.252	0.379	0.530	0.826	0.918	1.088	1.195	1.947	0.166
1991	0.058	0.138	0.201	0.279	0.403	0.497	0.400	0.000	1.003	1.003	1.305	0.206
1992	0.035	0.105	0.190	0.324	0.421	0.509	0.854	0.859	1.311	1.004	2.117	0.207
1993	0.042	0.133	0.182	0.270	0.443	0.512	0.784	0.827	0.000	1.026	1.100	0.234
1994	0.024	0.115	0.201	0.268	0.433	0.669	0.799	1.430	0.000	0.000	0.000	0.135
1995	0.038	0.067	0.219	0.306	0.410	0.501	0.752	1.311	0.000	0.000	0.000	0.153
1996	0.043	0.125	0.194	0.328	0.490	0.577	0.796	1.327	0.000	0.000	0.000	0.231
1997	0.049	0.074	0.186	0.303	0.405	0.594	0.767	1.342	0.779	0.000	0.000	0.244
1998	0.063	0.079	0.193	0.306	0.463	0.571	1.024	1.950	0.000	0.000	0.000	0.211
1999	0.039	0.084	0.201	0.341	0.537	0.755	0.947	1.538	0.000	0.000	0.000	0.244
2000	0.050	0.091	0.260	0.386	0.526	0.806	0.947	1.538	0.000	0.000	0.000	0.277
2001	0.015	0.087	0.233	0.389	0.547	0.726	0.879	1.126	0.000	0.000	0.000	0.274
2002	0.036	0.074	0.249	0.360	0.515	0.649	0.932	1.427	0.000	0.000	0.000	0.286
2003	0.022	0.112	0.274	0.384	0.498	0.696	0.894	1.323	1.241	0.000	0.000	0.449
2004	0.030	0.116	0.210	0.365	0.507	0.580	0.839	0.878	1.340	1.674	0.000	0.396
2005	0.019	0.094	0.197	0.352	0.480	0.659	0.832	1.022	0.735	0.778	0.000	0.427
2006	0.026	0.090	0.240	0.340	0.475	0.614	0.775	0.915	1.108	1.313	0.000	0.296
2007	0.042	0.100	0.211	0.356	0.476	0.654	0.812	0.901	1.071	1.668	0.000	0.340
2008	0.039	0.097	0.193	0.317	0.505	0.698	0.903	1.032	1.381	0.037	0.033	0.237
2009	0.032	0.084	0.181	0.293	0.451	0.608	0.843	0.972	1.111	0.801	0.000	0.280
2010	0.027	0.100	0.171	0.299	0.437	0.580	0.833	1.245	1.148	1.313	1.499	0.336
2011	0.028	0.062	0.207	0.294	0.437	0.577	0.806	1.025	1.125	1.240	1.533	0.349
2012	0.038	0.064	0.236	0.271	0.454	0.569	0.768	0.921	1.124	1.177	1.661	0.380
2013	0.033	0.108	0.212	0.316	0.434	0.532	0.716	0.882	1.030	1.230	1.653	0.388
2014	0.033	0.101	0.203	0.304	0.421	0.536	0.695	0.841	0.931	1.105	1.575	0.377

Table A25. Extended series of total fishery catch. Commercial discards are from SBRM estimator. To estimate commercial discards for 1963-1988, D/L ratio for 1989-1991 = 0.46 was applied to commercial landings. To estimate recreational catch for 1963-1980, 50% of the Mayo 1982 estimates were included. Recreational catches are from MRFSS/MRIP. Catches are in metric tons (mt).

Year	Comm. Land.	Comm. Disc.	DWF Land.	Rec. Catch	Total Catch
1963	18,884	8,612	5,863	4,166	37,525
1964	17,204	7,846	459	3,945	29,454
1965	15,785	7,199	2,089	3,855	28,928
1966	11,960	5,455	823	2,921	21,159
1967	8,748	3,990	896	2,219	15,853
1968	6,630	3,024	2,251	1,738	13,643
1969	5,149	2,348	485	1,307	9,289
1970	4,493	2,049	288	1,183	8,013
1971	3,974	1,812	889	1,007	7,682
1972	4,203	1,917	1,647	940	8,707
1973	5,024	2,291	1,783	1,319	10,417
1974	7,106	3,241	958	1,639	12,944
1975	7,623	3,477	685	1,657	13,442
1976	7,302	3,330	87	1,397	12,116
1977	8,330	3,799	28	1,651	13,808
1978	8,936	4,075	3	1,482	14,496
1979	8,585	3,915	0	1,443	13,943
1980	8,424	3,842	16	3,745	16,027
1981	9,856	4,495	0	3,175	17,526
1982	8,704	3,970	0	2,844	15,518
1983	7,794	3,555	0	3,416	14,765
1984	7,769	3,543	0	1,329	12,641
1985	6,727	3,068	0	3,328	13,123
1986	7,176	3,273	0	6,320	16,769
1987	6,276	2,862	0	3,365	12,503
1988	5,943	2,710	0	2,323	10,976
1989	3,984	1,277	0	3,024	8,285
1990	4,571	2,466	0	2,262	9,299
1991	7,081	3,388	0	4,423	14,892
1992	6,259	1,885	0	2,418	10,562
1993	4,726	1,510	0	1,745	7,981
1994	4,392	962	0	1,450	6,804
1995	3,073	974	0	734	4,781
1996	2,945	870	0	1,178	4,993
1997	2,188	675	0	651	3,514
1998	1,896	705	0	485	3,086
1999	1,505	735	0	1,019	3,259

Table A25 continued.

Year	Comm. Land.	Comm. Disc.	DWF Land.	Rec. Catch	Total Catch
2000	1,207	592	0	2,980	4,779
2001	1,729	1,671	0	2,469	5,869
2002	3,173	1,284	0	2,096	6,553
2003	4,405	436	0	4,725	9,566
2004	4,209	1,324	0	3,460	8,993
2005	3,711	565	0	1,485	5,761
2006	4,081	896	0	2,107	7,084
2007	4,193	1,363	0	2,431	7,987
2008	2,370	1,693	0	1,999	6,062
2009	3,721	3,189	0	1,673	8,583
2010	4,866	2,638	0	3,033	10,537
2011	6,819	1,234	0	1,805	9,858
2012	6,751	1,029	0	2,073	9,853
2013	8,110	1,279	0	2,656	12,045
2014	7,228	1,140	0	2,252	10,620

Table A26. NEFSC spring and fall trawl survey indices for scup. Strata sets include only offshore strata 1-12, 23, 25 and 61-76 for closest consistency over entire time series (fall 1963-1966 did not sample 61-76). The fall strata set excludes inshore strata 1-61 that are included in the 1984 and later indices at age.

Year	Spring N/tow	Spring N CV	Spring Kg/tow	Spring Kg CV	Fall N/tow	Fall N CV	Fall Kg/tow	Fall Kg CV
1963					2.04	49.3	1.21	51.0
1964					118.59	96.3	2.29	60.4
1965					3.52	50.3	0.66	59.5
1966					1.17	50.0	0.41	44.2
1967					29.25	69.6	1.48	60.9
1968	59.21	92.1	2.26	66.0	14.27	52.7	0.55	44.2
1969	2.24	96.9	0.40	97.6	100.27	65.8	4.51	65.7
1970	70.87	79.1	3.40	60.9	10.27	84.1	0.22	57.7
1971	68.44	91.1	3.54	73.3	7.55	45.9	0.25	36.2
1972	49.73	58.4	2.60	50.2	39.73	47.5	2.34	43.3
1973	3.59	42.4	1.19	46.6	22.75	54.9	0.93	42.3
1974	30.26	55.0	3.24	34.3	9.75	41.6	1.00	39.4
1975	14.01	53.5	3.12	48.2	52.00	22.9	3.40	25.6
1976	4.04	29.2	0.63	30.7	161.09	51.2	7.35	47.0
1977	42.46	81.2	4.48	89.3	32.64	35.0	1.71	21.1
1978	39.85	71.1	3.49	90.0	12.17	24.0	1.32	24.0
1979	22.42	73.7	1.95	59.8	15.73	42.4	0.61	23.6
1980	9.31	64.7	1.31	69.8	11.04	42.9	0.92	51.4
1981	14.72	39.2	1.16	45.3	67.11	57.8	3.01	35.1
1982	7.88	30.0	1.16	34.7	25.47	52.5	1.17	43.7
1983	0.74	52.4	0.03	46.6	4.59	42.0	0.34	33.3
1984	8.51	77.6	0.51	70.5	24.02	62.3	1.22	59.7
1985	14.64	92.2	0.80	88.5	68.30	30.6	3.56	26.1
1986	11.74	56.3	1.30	56.7	46.19	61.3	1.66	62.5
1987	10.82	57.0	1.21	61.7	5.75	82.1	0.15	52.4
1988	25.41	66.9	1.26	63.3	5.75	84.1	0.09	64.8
1989	1.62	63.3	0.12	84.2	94.05	49.4	3.37	48.3
1990	1.15	42.3	0.39	53.5	16.53	40.9	0.83	39.9
1991	12.60	28.6	0.75	43.0	9.52	44.1	0.43	46.2
1992	6.71	46.7	0.40	34.0	16.17	24.6	1.12	44.4
1993	2.83	82.6	0.33	86.3	0.41	97.5	0.04	97.7
1994	1.50	85.4	0.09	76.7	3.52	71.3	0.11	66.3
1995	2.88	45.2	0.22	35.8	24.70	60.4	0.91	58.8
1996	0.52	74.9	0.03	42.3	4.46	55.6	0.23	59.2
1997	0.90	37.4	0.11	38.3	16.92	98.8	0.88	97.8
1998	40.04	32.4	0.87	22.7	25.35	41.8	0.69	31.6
1999	1.67	43.6	0.12	73.8	85.16	48.0	2.07	35.9
2000	6.62	77.3	0.33	34.9	99.31	65.9	4.79	50.8
2001	13.03	50.7	0.80	60.4	20.28	51.4	1.11	46.7
2002	154.86	71.8	13.46	52.4	95.62	38.5	3.79	41.9
2003	6.01	41.4	0.28	43.1	28.18	68.5	0.79	55.4
2004	57.58	59.0	2.84	69.6	10.38	52.8	0.27	70.4
2005	19.22	61.8	0.55	52.4	4.50	86.0	0.07	69.1
2006	5.71	56.9	2.10	85.8	96.41	40.0	1.92	35.4
2007	10.60	75.5	0.36	59.6	41.52	51.8	2.21	52.8
2008	9.68	76.7	1.44	61.5	38.49	67.7	1.38	69.2

Table A27. NEFSC spring and fall trawl survey indices for scup. Spring and fall strata sets include only offshore strata 1-12, 23, 25 and 61-76 for consistency over entire time series. FSV *Bigelow* (HBB) and **annual aggregate factor** calibrated indices for the FSV *Albatross IV* (ALB) time series. The annual aggregate catch number calibration factor is 1.705; the aggregate weight factor is 1.347. *Note that the 2014 spring survey was incomplete, failing to sample offshore strata 61-68 off central DelMarVa and south. The 2014 spring indices here in italics have been adjusted to reflect the spring 2013 distribution of catches (i.e., decrease by 16%).*

Year	Spring N/tow HBB	Spring N CV HBB	Spring Kg/tow HBB	Spring Kg CV HBB	Spring N/tow ALB	Spring N CV ALB	Spring Kg/tow ALB	Spring Kg CV ALB
2009	11.98	75.1	0.99	79.0	7.02	75.5	0.58	79.4
2010	31.82	35.8	4.62	56.0	18.66	37.5	2.71	56.8
2011	26.67	76.2	0.92	61.9	15.64	76.6	0.54	62.6
2012	58.65	55.1	2.44	40.2	34.39	56.0	1.43	41.6
2013	30.95	41.7	2.16	53.1	18.15	43.0	1.27	54.0
2014	82.40	90.1	23.14	94.3	48.32	90.2	13.57	94.4
2014	*69.22*	*90.1*	*19.44*	*94.3*	*40.59*	*90.2*	*11.40*	*94.4*

Year	Fall N/tow HBB	Fall N CV HBB	Fall Kg/tow HBB	Fall Kg CV HBB	Fall N/tow ALB	Fall N CV ALB	Fall Kg/tow ALB	Fall Kg CV ALB
2009	158.54	35.1	3.72	25.2	92.97	36.8	2.76	27.6
2010	64.18	35.2	6.08	35.3	37.63	36.9	4.51	37.0
2011	93.68	36.6	2.69	36.5	54.93	38.1	2.00	38.1
2012	147.59	31.7	6.62	37.0	86.54	33.5	4.91	38.5
2013	28.99	57.2	1.80	64.4	17.00	57.9	1.34	65.0
2014	112.82	41.9	2.62	47.3	66.16	43.2	1.95	48.4

Table A28. NEFSC trawl survey spring and fall survey indices from the FSV Henry B. Bigelow (HBB) and **length calibrated**, equivalent indices for the FSV Albatross IV (ALB) time series. Spring and fall strata sets include only offshore strata 1-12, 23, 25 and 61-76 for consistency over entire time series. Indices are the sum of the stratified mean numbers (n) at length. The length calibration factors are for the lengths observed in the 2008 calibration experiment and include a constant swept area factor of 0.579. Length calibration factors range from > 3.0 for fish < 10 cm, to about 0.8 for fish in the 21-25 cm interval, to > 1.0 for fish > 30 cm. The effective total catch number calibration factors (HBB/ALB ratios) therefore vary by year and season, depending on the characteristics of the HBB length frequency distributions. *Note that the 2014 spring survey was incomplete, failing to sample offshore strata 61-68 off central DelMarVa and south. The 2014 spring indices here in italics have been adjusted to reflect the spring 2013 distribution of catches (i.e., decrease by ~16%).*

Year	Spring (n) HBB	HBB CV	Spring (n) ALB	Effective Factor
2009	11.98	75.1	9.58	1.25
2010	31.82	35.8	27.30	1.17
2011	26.67	76.2	11.31	2.36
2012	58.65	55.1	26.46	2.22
2013	30.95	41.7	18.69	1.66
2014	82.40	90.1	92.31	0.89
2014	*69.22*	*90.1*	*77.79*	*0.89*

Year	Fall (n) HBB	HBB CV	Fall (n) ALB	Effective Factor
2009	158.54	34.8	50.79	3.17
2010	64.18	35.2	31.18	2.06
2011	93.68	36.3	29.47	3.18
2012	147.59	31.7	71.79	2.06
2013	28.99	57.2	10.96	2.65
2014	112.82	41.9	28.90	3.90

Table A29. NEFSC trawl survey spring survey indices at age from the FSV Henry B. Bigelow (HBB) and **length calibrated equivalent indices at age for the FSV Albatross IV (ALB) time series.** The strata set includes only offshore strata 1-12, 23, 25, and 61-76. The length calibration factors are for the lengths observed in the 2008 calibration experiment. Length calibration factors range from > 3.0 for fish < 10 cm, to about 0.8 for fish in the 21-25 cm interval, to > 1.0 for fish > 30 cm. The effective total catch number calibration factors (HBB/ALB ratios) therefore vary by year and season, depending on the characteristics of the HBB length frequency distributions.

Spring

2009	0	1	2	3	4	5	6	7+	Total
HBB	0.00	4.56	6.95	0.28	0.13	0.04	0.02	<0.01	11.98
ALB	0.00	2.35	6.69	0.33	0.15	0.01	0.03	0.01	9.58
HBB/ALB	0.00	1.94	1.04	0.85	0.87	4.00	0.67	0.40	1.25

2010	0	1	2	3	4	5	6	7+	Total
HBB	0.00	7.96	15.53	3.84	2.42	1.35	0.38	0.34	31.82
ALB	0.00	2.77	15.07	4.57	2.81	1.50	0.33	0.25	27.30
HBB/ALB	0.00	2.87	1.03	0.84	0.86	0.90	1.15	1.36	1.16

2011	0	1	2	3	4	5	6	7+	Total
HBB	0.00	25.41	0.58	0.35	0.25	0.08	0.01	<0.01	26.67
ALB	0.00	9.95	0.57	0.41	0.29	0.08	0.01	<0.01	11.31
HBB/ALB	0.00	2.55	1.02	0.85	0.86	1.00	1.00	1.00	2.36

2012	0	1	2	3	4	5	6	7+	Total
HBB	0.00	54.99	2.00	0.35	1.06	0.14	0.06	0.05	58.65
ALB	0.00	22.39	2.16	0.42	1.24	0.15	0.06	0.04	26.46
HBB/ALB	0.00	2.46	0.93	0.83	0.85	0.93	1.00	1.25	2.22

2013	0	1	2	3	4	5	6	7+	Total
HBB	0.00	21.05	7.65	1.62	0.20	0.28	0.12	0.03	30.95
ALB	0.00	8.28	7.79	1.94	0.24	0.33	0.10	0.01	18.69
HBB/ALB	0.00	2.54	0.98	0.84	0.83	0.85	1.20	3.00	1.66

2014	0	1	2	3	4	5	6	7+	Total
HBB	0.00	3.08	5.73	39.92	12.44	4.93	1.01	2.11	69.22
ALB	0.00	1.35	6.01	47.85	14.25	5.38	0.95	1.76	77.79
HBB/ALB	0.00	2.28	0.95	0.83	0.87	0.92	1.06	1.20	0.89

Table A30. NEFSC trawl survey fall survey indices at age from the FSV Henry B. Bigelow (HBB) and **length calibrated equivalent indices at age for the FSV Albatross IV (ALB) time series.** The strata set includes offshore strata 1-12, 23, 25, 61-76, and inshore strata 1-61. The length calibration factors are for the lengths observed in the 2008 calibration experiment. Length calibration factors range from > 3.0 for fish < 10 cm, to about 0.8 for fish in the 21-25 cm interval, to > 1.0 for fish > 30 cm. The effective total catch number calibration factors (HBB/ALB ratios) therefore vary by year and season, depending on the characteristics of the HBB length frequency distributions.

Fall

2009	0	1	2	3	4	5	6	7+	Total
HBB	194.94	17.79	2.36	0.38	0.15	0.02	0.00	0.00	215.64
ALB	57.08	14.55	2.74	0.45	0.17	0.02	0.00	0.00	75.01
HBB/ALB	3.42	1.22	0.86	0.84	0.88	1.00	1.00	1.00	2.88

2010	0	1	2	3	4	5	6	7+	Total
HBB	111.63	3.64	5.07	3.96	3.46	0.75	0.16	0.02	128.69
ALB	31.06	2.98	5.99	4.63	3.83	0.73	0.13	0.01	49.36
HBB/ALB	3.59	1.22	0.85	0.86	0.90	1.03	1.23	2.00	2.61

2011	0	1	2	3	4	5	6	7+	Total
HBB	128.28	8.99	0.25	0.67	0.50	0.51	0.05	0.03	139.28
ALB	33.02	6.26	0.29	0.80	0.55	0.54	0.04	0.02	41.52
HBB/ALB	3.88	1.44	0.86	0.84	0.91	0.94	1.25	1.50	3.35

2012	0	1	2	3	4	5	6	7+	Total
HBB	127.88	31.56	1.88	0.51	0.82	0.52	0.10	0.03	163.30
ALB	49.75	24.53	2.27	0.59	0.90	0.52	0.09	0.02	78.67
HBB/ALB	2.57	1.29	0.83	0.86	0.91	1.00	1.11	1.50	2.08

2013	0	1	2	3	4	5	6	7+	Total
HBB	58.52	0.64	2.36	0.77	0.87	0.29	0.09	0.03	63.57
ALB	15.18	0.53	2.81	0.91	0.97	0.30	0.08	0.02	20.81
HBB/ALB	3.86	1.21	0.84	0.85	0.91	0.997	1.13	1.00	3.05

2014	0	1	2	3	4	5	6	7+	Total
HBB	158.02	4.91	0.56	1.01	0.59	0.42	0.09	0.19	165.79
ALB	31.02	4.08	0.66	1.22	0.68	0.43	0.09	0.14	38.32
HBB/ALB	5.09	1.20	0.85	0.83	0.87	0.98	1.00	1.36	4.33

Table A31. NEFSC spring trawl survey stratified mean number of scup per tow at age. Strata set includes only offshore strata 1-12, 23, 25, and 61-76. No ages available for 1968-1976. HBB index lengths calibrated to ALB equivalents for 2009 and later years.

Spring						Age							
Year	0	1	2	3	4	5	6	7	8	9	10	11	Total
1968													59.21
1969													2.24
1970													70.87
1971													68.44
1972													49.73
1973													3.59
1974													30.26
1975													14.01
1976													4.04
1977		6.62	32.06	3.51	0.19	0.04	0.01	0.01					42.45
1978		27.20	4.37	6.50	1.31	0.32	0.12	0.03					39.85
1979		15.70	3.95	0.88	1.28	0.37	0.06	0.13	0.02				22.39
1980		2.44	5.55	0.57	0.17	0.25	0.15	0.08	0.07	0.01			9.29
1981		10.78	2.16	1.15	0.17	0.14	0.05	0.15	0.12				14.72
1982		3.80	1.77	1.39	0.38	0.15	0.13	0.03	0.09	0.13			7.87
1983		0.64	0.03	0.06				0.01					0.74
1984		6.18	1.92	0.24	0.13	0.04							8.51
1985		12.08	2.31	0.20	0.03	0.01							14.64
1986		1.06	10.42	0.26									11.74
1987		4.57	3.60	1.81	0.74	0.04	0.02	0.03	0.01				10.82
1988		16.74	8.36	0.17	0.03	0.01	0.03	0.07					25.41
1989		0.79	0.73	0.09	0.01								1.62
1990		0.09	0.30	0.30	0.18	0.09	0.13	0.06					1.15
1991		10.60	0.70	1.11	0.19								12.60
1992		5.64	0.88	0.07	0.05	0.06	0.01						6.71
1993		0.53	1.99	0.18	0.11	0.02							2.83
1994		1.36	0.10	0.04									1.50
1995		2.27	0.44	0.11	0.05	0.01							2.88
1996		0.42	0.05	0.03	0.02								0.52
1997		0.15	0.64	0.11									0.90
1998		39.90	0.12	0.02									40.04
1999		1.00	0.67										1.67
2000		5.84	0.71	0.07									6.62
2001		7.90	5.03	0.08		0.02							13.03
2002		109.01	15.60	26.67	3.27	0.31							154.86
2003		5.08	0.79	0.07	0.06								6.01
2004		38.69	16.15	1.31	0.82	0.60	0.01						57.58
2005		18.26	0.81	0.13	0.02								19.22
2006		1.56	0.51	0.80	0.35	0.70	1.69	0.10					5.71
2007		9.73	0.41	0.44		0.01	0.01						10.60
2008		0.40	5.82	2.92	0.18	0.09	0.15	0.05	0.07				9.68

Table A31 continued.

Spring						Age							
Year	0	1	2	3	4	5	6	7	8	9	10	11	Total
2009		2.35	6.69	0.33	0.15	0.01	0.01	0.01					9.58
2010		2.77	15.07	4.57	2.81	1.50	0.33	0.08	0.16	0.01			27.30
2011		9.95	0.57	0.41	0.29	0.08	0.01						11.31
2012		22.39	2.16	0.42	1.24	0.15	0.06	0.04					26.46
2013		8.28	7.79	1.94	0.24	0.33	0.10	0.01					18.69
2014		1.35	6.01	47.85	14.25	5.38	0.95	1.76					77.79

Table A32. NEFSC fall trawl survey stratified mean number of scup per tow at age. Strata set includes offshore strata 1-12, 23, 25, 61-76, and inshore strata 1-61. Inshore strata were not sampled until 1972; no ages available for 1972-1983. HBB index lengths calibrated to ALB equivalents for 2009 and later years.

Fall					Age					
Year	0	1	2	3	4	5	6	7	8	Total
1972										33.69
1973										26.74
1974										25.21
1975										48.45
1976										193.24
1977										85.91
1978										45.54
1979										14.76
1980										13.65
1981										75.22
1982										49.07
1983										26.84
1984	50.28	9.19	0.34	0.12	0.01					59.94
1985	61.71	11.53	1.10	0.26	0.06	0.05	0.01			74.71
1986	70.17	6.58	0.57		0.01					77.33
1987	50.11	29.85	0.46	0.01						80.43
1988	47.47	15.95	0.67	0.10						64.19
1989	176.36	25.92	0.66	0.04						202.98
1990	77.43	9.21	0.75	0.04	0.01	0.01				87.45
1991	151.62	12.51	0.08	0.02						164.23
1992	25.90	14.50	1.66	0.04	0.02					42.12
1993	46.70	9.81	0.32							56.83
1994	39.48	3.92	0.04	0.01	0.01					43.46
1995	33.01	2.61	0.08	0.01						35.71
1996	24.40	2.86	0.43	0.01	0.01					27.71
1997	46.89	0.71	0.02	0.02						47.64
1998	57.69	9.64	0.09	0.03	0.01					67.46
1999	95.99	9.77	1.36	0.07	0.01					107.21
2000	98.72	20.59	3.14	0.49	0.13	0.04				123.11
2001	85.28	10.24	1.78	0.12	0.04					97.46
2002	180.08	43.31	0.90	0.35	0.04	0.01				224.69
2003	53.66	5.69	2.30	1.33	0.82	0.20	0.02			64.02
2004	41.83	33.47	1.14	1.70	0.39	0.12	0.04	0.01		78.69
2005	27.26	7.94	1.02	0.13	0.04	0.04				36.43
2006	146.85	20.08	0.92	0.07	0.05	0.03	0.01			168.01
2007	113.95	40.28	0.60	0.23	0.05	0.03	0.05	0.02		155.21
2008	70.43	65.48	0.52	0.06	0.01					136.50

Table A32 continued.

Fall Year	Age 0	1	2	3	4	5	6	7	8	Total
2009	57.08	14.55	2.74	0.45	0.17	0.02				75.01
2010	31.06	2.98	5.99	4.63	3.83	0.73	0.13		0.01	49.36
2011	33.02	6.26	0.29	0.80	0.55	0.54	0.04	0.01	0.01	41.52
2012	49.75	24.53	2.27	0.59	0.90	0.52	0.09	0.02		78.67
2013	15.18	0.53	2.81	0.91	0.97	0.30	0.08	0.01	0.01	20.81
2014	31.02	4.08	0.66	1.22	0.68	0.43	0.09	0.04	0.14	38.32

Table A33. NEFSC 1992-2007 Winter trawl survey indices of abundance for scup, offshore survey strata 1-12 and 61-76. The winter survey ended in 2007.

Year	No./tow	No. CV	Kg/tow	Kg CV
1992	65.49	48	2.87	43
1993	25.63	80	2.73	86
1994	17.09	6	0.66	7
1995	69.47	71	2.26	65
1996	18.23	51	1.19	61
1997	13.87	74	0.32	54
1998	46.91	49	1.20	38
1999	15.04	41	0.71	48
2000	24.14	55	1.33	49
2001	55.37	61	1.58	39
2002	267.83	64	7.56	45
2003	24.16	67	0.49	63
2004	380.59	88	3.82	85
2005	84.74	40	1.96	41
2006	201.96	43	3.72	38
2007	101.08	61	2.95	66

Table A34. NEFSC 1992-2007 winter trawl survey stratified mean number of scup per tow at age, offshore survey strata 1-12 and 61-76. The 1992, 1993, and 1996 lengths are aged with the corresponding annual spring survey age-length key. The winter survey ended in 2007.

Winter					Age					
Year	0	1	2	3	4	5	6	7	8	Total
1992		59.72	4.97	0.16	0.13	0.53				65.49
1993		2.44	22.05	0.55	0.29	0.31				25.63
1994		16.30	0.73	0.04	0.01					17.09
1995		67.32	1.94	0.15	0.01	0.01	0.02	0.01		69.47
1996		12.98	5.17	0.03	0.01	0.04				18.23
1997		13.24	0.52	0.11						13.87
1998		45.61	0.75	0.22	0.21	0.08	0.03	0.01		46.91
1999		12.48	2.41	0.12	0.02	0.01				15.04
2000		20.21	3.21	0.68	0.03			0.01		24.14
2001		48.43	6.48	0.35	0.09	0.02				55.37
2002		257.08	7.44	2.96	0.33	0.01	0.01			267.83
2003		23.77	0.28	0.07	0.03		0.02			24.16
2004		380.23	0.29	0.07	0.01					380.59
2005		80.03	4.62	0.09						84.74
2006		198.52	2.64	0.66	0.03	0.04	0.08			201.96
2007		99.18	1.86	0.02	0.02					101.08

Table A35. NEFSC trawl survey winter, spring and fall survey **maximum-length restricted biomass indices** from the FSV Albatross IV (ALB) and **length calibrated**, ALB equivalent indices from the FSV Henry B. Bigelow (HBB) for the spring and fall time series. Spring and fall strata sets include only offshore strata 1-12, 23, 25 and 61-76 for consistency over entire time series. These are the aggregate biomass indices for approximate ages 0-2 used in the 2008 DPSWG stock assessment ASAP model calibration.

Year	Winter	Winter CV	Spring	Spring CV	Fall	Fall CV
1963					0.03	64.2
1964					2.19	86.7
1965					0.39	65.7
1966					0.05	49.0
1967					1.43	72.0
1968			1.58	81.7	0.55	46.4
1969			0.16	96.6	4.18	66.0
1970			2.78	71.4	0.30	66.5
1971			3.03	82.6	0.29	37.1
1972			2.12	57.3	2.47	41.4
1973			0.18	42.5	0.93	38.3
1974			1.52	54.4	0.77	34.4
1975			1.27	70.7	2.69	23.1
1976			0.24	35.0	7.43	50.1
1977			5.03	92.4	1.52	21.9
1978			1.92	80.0	0.73	23.0
1979			1.07	63.2	0.57	26.3
1980			0.84	82.1	0.90	50.2
1981			0.74	36.4	3.21	37.6
1982			0.37	41.3	1.04	50.7
1983			0.02	46.2	0.34	37.6
1984			0.56	70.2	1.35	62.0
1985			0.81	90.9	3.66	26.3
1986			1.42	58.9	1.86	60.9
1987			0.73	74.2	0.15	56.1
1988			1.48	68.6	0.10	69.8
1989			0.12	77.7	3.99	48.1
1990			0.06	38.0	0.97	40.5
1991			0.50	21.5	0.50	47.1
1992	2.86	45.2	0.35	37.7	1.16	39.2
1993	2.99	86.1	0.26	78.7	0.05	95.8
1994	0.67	8.6	0.08	83.6	0.09	68.3
1995	2.99	68.7	0.16	37.1	1.10	59.0
1996	1.22	62.3	0.03	62.5	0.26	57.0
1997	0.43	63.4	0.09	41.4	1.02	98.1
1998	1.48	45.2	1.31	22.9	0.90	36.1
1999	0.69	46.9	0.14	69.4	2.52	35.9
2000	1.64	55.1	0.41	45.6	5.01	56.0
2001	2.15	41.9	0.98	57.9	1.16	45.1
2002	10.78	54.1	7.53	68.0	4.65	40.7
2003	0.75	69.0	0.30	39.5	0.64	63.8
2004	6.42	83.9	3.13	65.1	0.17	45.6
2005	2.93	41.9	0.81	57.3	0.07	76.0
2006	6.36	39.7	0.18	63.7	2.68	38.1
2007	3.46	57.4	0.37	65.6	2.40	56.3
2008			1.02	90.7	1.74	67.5
2009			1.05	90.1	2.32	28.7
2010			2.32	46.4	2.42	36.1
2011			0.49	69.6	0.48	30.1

Table A36. MADMF trawl survey mean number of scup per tow and mean weight (kg) per tow for spring (survey regions 1-3) and fall (survey regions 1-5). CVs in percent.

Year	Spring No./tow	Spring No. CV	Spring Kg/tow	Spring Kg CV	Fall No./tow	Fall No. CV	Fall Kg/tow	Fall Kg CV
1978	89.21	74	31.63	82	1859.40	22	14.82	17
1979	72.93	46	17.31	50	1150.16	16	12.20	16
1980	189.80	87	41.39	94	1183.02	16	12.53	14
1981	298.53	44	17.63	40	971.83	38	14.34	28
1982	10.36	52	0.98	51	2153.75	36	9.17	24
1983	25.29	47	3.51	44	1623.11	30	12.90	32
1984	17.90	41	6.53	46	963.39	17	12.29	17
1985	67.02	48	3.40	35	647.59	17	12.09	42
1986	44.17	54	7.35	52	773.56	25	9.15	19
1987	6.03	29	1.38	30	579.73	13	7.91	16
1988	13.98	36	2.09	35	1396.86	19	14.15	16
1989	13.28	51	2.02	54	580.57	31	7.77	20
1990	144.06	55	21.45	61	1128.07	37	7.21	30
1991	28.71	89	6.05	92	1150.42	20	10.18	24
1992	14.49	70	2.52	63	2440.90	24	11.54	21
1993	19.13	38	4.23	38	1023.92	15	10.66	15
1994	9.69	66	2.85	74	820.25	19	9.84	19
1995	49.24	24	2.76	23	506.98	22	4.11	16
1996	5.06	66	0.68	66	1019.82	20	9.15	18
1997	3.21	44	0.71	57	920.78	21	7.25	21
1998	1.37	47	0.21	45	709.46	17	6.94	17
1999	11.61	47	1.93	46	1212.17	26	18.07	19
2000	306.98	23	18.02	41	866.81	15	11.63	14
2001	7.28	80	2.37	83	1205.59	27	9.89	17
2002	281.20	23	18.77	28	1137.62	15	8.32	12
2003	0.22	40	0.07	48	3209.47	20	14.87	15
2004	41.71	56	13.04	58	1483.55	30	10.07	27
2005	9.29	68	3.25	70	4005.88	18	21.53	10
2006	92.93	36	22.41	47	1231.27	25	9.46	15
2007	13.29	20	2.03	23	1774.20	12	11.65	12
2008	145.72	21	27.89	25	743.07	11	10.78	21
2009	82.69	49	16.02	45	1087.27	11	14.10	14
2010	72.22	29	12.66	31	1424.47	18	14.92	18
2011	8.65	31	2.42	38	1378.56	14	16.55	12
2012	556.34	21	38.46	22	639.70	17	11.02	18
2013	46.02	25	10.88	37	1135.19	20	13.10	15
2014	148.29	51	36.52	56	3546.61	13	29.29	12

Table A37. RIDFW trawl survey mean number of scup per tow and mean weight (kg) per tow for spring and fall.

	Spring		Fall	
Year	No./Tow	Kg/tow	No./Tow	Kg/Tow
1981	12.49	0.40	196.22	2.54
1982	0.43	0.04	63.87	0.70
1983	3.59	0.32	173.63	2.75
1984	13.24	0.88	589.68	10.57
1985	8.30	0.41	74.27	1.51
1986	1.78	0.33	340.06	4.20
1987	0.04	0.01	314.20	4.73
1988	0.23	0.04	804.00	7.10
1989	0.17	0.04	326.86	6.62
1990	0.64	0.15	527.31	5.66
1991	2.93	0.57	655.69	16.62
1992	1.88	0.61	1105.51	9.10
1993	1.12	0.06	1246.35	8.90
1994	2.08	0.53	236.12	3.66
1995	4.33	0.53	423.02	5.03
1996	0.52	0.07	184.73	3.83
1997	1.93	0.15	597.90	6.04
1998	0.15	0.03	150.38	1.89
1999	0.38	0.07	832.22	12.39
2000	84.05	3.54	588.73	9.11
2001	29.68	5.08	1139.17	11.07
2002	174.80	10.28	716.12	9.27
2003	0.00	0.00	1181.83	11.38
2004	2.59	0.45	1616.24	9.58
2005	2.95	1.63	2216.72	21.35
2006	53.12	3.90	765.90	11.26
2007	1.95	0.24	2410.00	23.76
2008	0.19	0.04	705.10	18.15
2009	1.14	0.39	1705.33	24.99
2010	2.14	0.56	760.14	17.39
2011	3.95	1.66	1167.58	30.60
2012	212.70	3.13	2312.70	39.77
2013	0.27	3.17	1159.23	18.45
2014	3.06	1.14	4411.39	38.83

Table A38. RIDFW spring trawl survey mean number of scup per tow at age.

Spring	0	1	2	3	4	5	6	7	8	9	Total
1979	0	37.08	0.92	0.31	0.92	0.31	0.07	0.19	0.00	0.03	39.83
1980	0	30.73	8.27	2.84	0.71	1.12	0.39	0.17	0.07	0.00	44.31
1981	0	10.14	0.66	0.16	0.01	0.00	0.00	0.01	0.00	0.00	10.98
1982	0	0.23	0.17	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.43
1983	0	2.08	1.13	0.30	0.04	0.02	0.00	0.00	0.00	0.00	3.56
1984	0	8.91	3.08	0.42	0.10	0.03	0.00	0.00	0.00	0.00	12.54
1985	0	6.85	1.10	0.09	0.01	0.00	0.00	0.00	0.00	0.00	8.05
1986	0	0.39	0.89	0.28	0.05	0.00	0.00	0.00	0.00	0.00	1.62
1987	0	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.04
1988	0	0.02	0.12	0.02	0.07	0.00	0.00	0.00	0.00	0.00	0.23
1989	0	0.00	0.05	0.11	0.01	0.00	0.00	0.00	0.00	0.00	0.17
1990	0	0.00	0.36	0.15	0.06	0.03	0.04	0.00	0.00	0.00	0.64
1991	0	0.58	0.60	1.31	0.19	0.00	0.00	0.00	0.00	0.00	2.67
1992	0	0.00	0.30	0.53	0.47	0.56	0.00	0.00	0.00	0.00	1.86
1993	0	0.82	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.12
1994	0	0.03	0.58	0.55	0.13	0.00	0.00	0.00	0.00	0.00	1.28
1995	0	2.36	1.42	0.35	0.16	0.00	0.00	0.00	0.00	0.00	4.29
1996	0	0.05	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55
1997	0	1.23	0.59	0.08	0.00	0.00	0.00	0.00	0.00	0.00	1.90
1998	0	0.00	0.10	0.00	0.04	0.01	0.00	0.00	0.00	0.00	0.15
1999	0	0.07	0.23	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.36
2000	0	81.65	1.76	0.85	0.02	0.00	0.00	0.00	0.00	0.00	84.29
2001	0	3.64	18.59	4.64	2.39	0.42	0.00	0.00	0.00	0.00	29.68
2002	0	143.75	21.98	6.41	2.28	0.33	0.05	0.00	0.00	0.00	174.80
2003	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	0	0.19	1.63	0.39	0.17	0.21	0.00	0.00	0.00	0.00	2.59
2005	0	0.00	0.00	0.90	0.39	0.31	0.05	0.00	0.00	0.00	1.65
2006	0	0.00	45.33	6.67	2.49	0.90	0.54	0.62	0.00	0.00	56.56
2007	0	0.05	0.75	0.17	0.02	0.12	0.00	0.00	0.00	0.00	1.12
2008	0	0.02	0.10	0.04	0.00	0.00	0.02	0.00	0.00	0.00	0.19
2009	0	0.00	0.02	0.45	0.24	0.02	0.00	0.00	0.00	0.00	0.74
2010	0	0.41	0.60	0.48	0.33	0.12	0.08	0.02	0.07	0.02	2.14
2011	0	0.00	0.26	0.89	1.22	1.34	0.06	0.00	0.00	0.00	3.77
2012	0	163.87	40.71	2.06	6.07	0.01	0.02	0.00	0.00	0.00	212.73
2013	0	0.00	0.05	0.02	0.10	0.00	0.02	0.01	0.00	0.00	0.20
2014	0	0.07	0.42	1.45	0.26	0.17	0.13	0.30	0.23	0.02	3.05

Table A39. RIDFW fall trawl survey mean number of scup per tow at age.

Fall	0	1	2	3	4	5	6	7	8	9	Total
1979	0.00	10.62	0.60	0.00	0.02	0.00	0.00	0.00	0.00	0.00	11.24
1980	0.00	18.97	0.99	0.07	0.00	0.00	0.00	0.00	0.00	0.00	20.02
1981	120.47	22.84	0.90	0.08	0.00	0.01	0.00	0.00	0.00	0.00	144.31
1982	59.02	2.38	0.06	0.05	0.01	0.00	0.00	0.00	0.00	0.00	61.51
1983	161.72	10.52	0.98	0.01	0.00	0.00	0.00	0.00	0.00	0.00	173.24
1984	472.15	45.46	2.94	0.48	0.19	0.00	0.00	0.00	0.00	0.00	521.23
1985	62.84	5.44	0.63	0.16	0.02	0.01	0.01	0.00	0.00	0.00	69.11
1986	262.62	54.59	1.88	0.00	6.40	0.00	0.00	0.00	0.00	0.00	325.49
1987	282.22	23.56	1.23	0.02	0.00	0.00	0.00	0.00	0.00	0.00	307.04
1988	730.20	44.34	0.35	0.02	0.00	0.00	0.00	0.00	0.00	0.00	774.90
1989	245.32	61.13	2.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	308.60
1990	476.52	13.58	1.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	491.16
1991	558.67	95.77	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	654.79
1992	1084.62	16.95	0.77	0.17	0.15	0.00	0.00	0.00	0.00	0.00	1102.66
1993	1232.34	9.83	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1242.82
1994	227.59	8.48	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	236.12
1995	374.70	18.83	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	393.74
1996	170.07	13.98	0.65	0.01	0.00	0.00	0.00	0.00	0.00	0.00	184.70
1997	595.39	2.34	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	597.79
1998	146.98	3.23	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	150.31
1999	799.60	7.01	0.87	0.03	0.00	0.00	0.00	0.00	0.00	0.00	807.51
2000	555.69	31.36	0.76	0.01	0.00	0.00	0.00	0.00	0.00	0.00	587.83
2001	1117.99	20.21	0.96	0.01	0.00	0.00	0.00	0.00	0.00	0.00	1139.17
2002	719.64	13.98	0.29	0.11	0.01	0.00	0.00	0.00	0.00	0.00	734.03
2003	1164.41	8.70	4.55	2.59	1.45	0.13	0.00	0.00	0.00	0.00	1181.83
2004	1608.78	6.94	0.25	0.24	0.01	0.00	0.00	0.00	0.00	0.00	1616.24
2005	2160.96	37.32	5.17	0.60	0.00	0.00	0.00	0.00	0.00	0.00	2204.05
2006	729.42	34.36	2.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	765.88
2007	2357.03	46.57	4.41	0.05	0.00	0.00	0.00	0.00	0.00	0.00	2408.05
2008	573.78	109.02	18.60	2.82	0.24	0.00	0.00	0.00	0.00	0.00	704.45
2009	1607.12	65.58	19.08	4.30	2.43	0.00	0.00	0.00	0.00	0.00	1698.50
2010	715.53	25.33	14.52	2.23	1.56	0.33	0.07	0.00	0.00	0.00	759.57
2011	1011.70	87.97	12.47	13.49	2.76	0.49	0.92	0.92	0.00	0.00	1130.72
2012	2122.37	151.72	12.17	5.49	4.48	1.52	0.00	0.00	0.00	0.00	2297.75
2013	787.66	33.69	24.99	2.24	1.25	0.48	0.24	0.06	0.00	0.00	850.61
2014	4335.64	59.82	8.46	3.91	2.09	1.14	0.28	0.06	0.00	0.00	4411.39

Table A40. RIDFW industry cooperative ventless trap survey: mean number of scup per trap per soak time. Survey ran from 2005-2012.

Age/Year	0	1	2	3	4	5	6	7	8+	Total
2005	0.014	0.306	0.904	0.980	0.352	0.391	0.071	0.026	0.003	3.047
2006	0.031	0.472	1.337	0.803	0.263	0.214	0.189	0.125	0.046	3.480
2007	0.041	0.661	1.397	2.204	0.385	0.199	0.628	0.170	0.051	5.736
2008	0.005	0.794	1.664	2.875	0.824	0.352	0.202	0.039	0.068	6.823
2009	0.028	1.557	2.313	3.840	1.150	0.578	0.436	0.068	0.051	10.021
2010	0.112	0.699	4.311	3.897	1.985	0.481	0.408	0.134	0.002	12.029
2011	0.018	0.413	1.551	2.080	1.421	0.710	0.164	0.092	0.010	6.458
2012	0.098	1.930	2.189	0.801	1.528	0.609	0.247	0.075	0.032	7.509

Table A41. University of Rhode Island Graduate School of Oceanography (URIGSO) trawl survey indices for scup (number per tow) Fox Island station.

Year	Fox Is	Year	Fox Is
1959	87.713	2000	279.488
1960	21.772	2001	108.717
1961	21.325	2002	109.125
1962	7.754	2003	51.953
1963	51.982	2004	58.358
1964	55.408	2005	141.163
1965	35.817	2006	187.940
1966	16.394	2007	257.338
1967	106.604	2008	298.097
1968	30.292	2009	330.836
1969	19.068	2010	227.854
1970	17.371	2011	274.779
1971	76.188	2012	294.500
1972	37.683	2013	96.863
1973	109.514	2014	339.046
1974	55.249		
1975	166.406		
1976	408.007		
1977	287.300		
1978	148.249		
1979	139.350		
1980	80.211		
1981	122.392		
1982	56.950		
1983	189.271		
1984	160.896		
1985	187.582		
1986	158.563		
1987	106.625		
1988	99.863		
1989	358.521		
1990	131.329		
1991	256.358		
1992	80.353		
1993	261.838		
1994	55.640		
1995	90.829		
1996	83.663		
1997	62.096		
1998	56.208		
1999	268.650		

Table A42. CTDEEP spring trawl survey mean number of scup per tow at age, total mean number per tow, and total mean weight (kg) per tow.

	Age														Total	Total
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	No./Tow	Kg/Tow
1984	0.49	1.31	0.59	0.30	0.08	0.00	0.00	0.00	0.00	0.03	0.02	0.00	0.00	0.00	2.80	0.64
1985	2.94	2.00	0.33	0.24	0.05	0.02	0.05	0.00	0.00	0.01	0.00	0.00	0.00	0.00	5.61	1.22
1986	4.44	1.65	0.99	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.40	0.78
1987	0.43	1.65	0.07	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.17	0.37
1988	1.18	0.30	0.51	0.05	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.11	0.32
1989	5.63	0.56	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.77	0.63
1990	2.56	2.06	0.21	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.25	0.61
1991	4.25	1.44	1.26	0.09	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.09	0.94
1992	0.39	1.21	0.09	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.75	0.48
1993	0.04	2.29	0.19	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32	0.49
1994	0.81	2.03	0.93	0.10	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.88	0.58
1995	12.94	0.39	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.24	0.65
1996	5.20	2.48	0.07	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.25	0.73
1997	3.16	2.61	1.68	0.06	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.23	0.75
1998	10.07	0.58	0.12	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.25	0.75
1999	2.71	1.75	0.16	0.07	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.22	0.56
2000	124.51	17.18	4.24	0.20	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.46	4.56
2001	1.65	18.99	1.57	0.25	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.20	2.85
2002	49.15	66.61	123.25	17.44	1.29	0.10	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	257.91	13.16
2003	0.14	4.05	3.28	4.96	0.61	0.07	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	13.12	2.28
2004	0.01	3.97	8.96	4.90	8.21	0.76	0.08	0.02	0.01	0.00	0.00	0.00	0.00	0.00	26.92	3.93
2005	1.16	1.28	1.06	1.51	1.27	1.94	0.22	0.05	0.00	0.00	0.00	0.00	0.00	0.00	8.49	1.65
2006	18.48	23.72	5.63	2.07	2.56	3.16	2.90	0.53	0.01	0.00	0.00	0.00	0.00	0.00	59.06	10.41
2007	7.51	15.86	5.84	1.49	0.55	0.54	0.54	0.39	0.07	0.01	0.00	0.00	0.00	0.00	32.80	3.35
2008	16.96	40.62	27.82	4.94	0.91	0.16	0.30	0.24	0.15	0.02	0.00	0.00	0.00	0.00	92.12	5.88
2009	31.61	28.23	28.41	12.49	2.50	0.61	0.21	0.13	0.25	0.00	0.00	0.00	0.00	0.00	104.44	6.40
2010	0.42	24.27	22.00	14.00	6.02	1.19	0.12	0.06	0.04	0.01	0.02	0.00	0.00	0.00	68.15	3.14
2011	2.13	3.29	11.39	9.83	4.12	3.38	1.41	0.24	0.07	0.10	0.08	0.06	0.01	0.00	36.11	9.55
2012	49.04	25.93	11.98	9.23	9.57	4.67	2.76	0.87	0.14	0.13	0.08	0.02	0.00	0.00	114.42	9.99
2013	4.61	29.42	8.72	3.15	4.98	4.45	1.55	0.76	0.17	0.12	0.06	0.03	0.00	0.02	58.04	6.47
2014	14.66	10.64	23.83	5.07	1.50	2.32	1.49	0.61	0.32	0.02	0.00	0.01	0.00	0.01	60.48	5.61

Table A43. CTDEEP fall trawl survey mean number of scup per tow at age, total mean number per tow, and total mean weight (kg) per tow. No survey in 2010.

	Age											Total	Total
Year	0	1	2	3	4	5	6	7	8	9	10+	No/Tow	Kg/Tow
1984	7.99	1.04	0.78	0.52	0.28	0.09	0.02	0.00	0.00	0.00	0.00	10.72	1.36
1985	25.01	4.71	0.40	0.59	0.19	0.04	0.03	0.00	0.00	0.00	0.00	30.97	2.50
1986	13.06	9.98	2.50	0.19	0.01	0.01	0.01	0.00	0.00	0.00	0.00	25.76	2.95
1987	12.47	4.17	1.25	0.58	0.06	0.01	0.01	0.00	0.00	0.00	0.00	18.55	1.79
1988	31.89	5.71	1.82	0.24	0.03	0.00	0.00	0.00	0.00	0.00	0.00	39.69	2.27
1989	40.88	22.60	1.51	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00	65.08	3.65
1990	54.34	7.74	6.95	0.40	0.03	0.01	0.01	0.00	0.00	0.01	0.00	69.49	5.00
1991	291.58	17.03	1.76	1.04	0.15	0.01	0.00	0.00	0.00	0.00	0.00	311.57	8.30
1992	50.91	26.58	5.54	0.40	0.29	0.01	0.01	0.00	0.00	0.00	0.00	83.74	4.96
1993	74.06	1.83	1.02	0.12	0.01	0.01	0.00	0.00	0.00	0.00	0.00	77.05	3.72
1994	90.76	1.12	0.46	0.18	0.01	0.00	0.00	0.00	0.00	0.00	0.00	92.53	3.33
1995	32.46	26.52	0.14	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	59.13	4.63
1996	51.50	8.56	1.37	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	61.47	3.68
1997	31.79	8.68	0.63	0.17	0.01	0.00	0.00	0.00	0.00	0.00	0.00	41.28	2.49
1998	90.40	12.24	0.54	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	103.27	4.50
1999	498.18	30.93	8.35	0.19	0.02	0.01	0.00	0.00	0.00	0.00	0.00	537.68	22.72
2000	250.39	261.45	8.32	0.79	0.14	0.01	0.00	0.00	0.00	0.00	0.00	521.10	30.76
2001	140.51	16.90	18.42	1.61	0.19	0.03	0.00	0.00	0.00	0.00	0.00	177.66	11.28
2002	259.90	47.62	23.32	16.81	0.67	0.33	0.05	0.00	0.01	0.00	0.00	348.71	23.69
2003	52.91	15.35	32.07	22.39	26.44	2.49	0.54	0.02	0.02	0.00	0.00	152.23	28.95
2004	251.05	4.13	8.34	15.08	5.98	6.25	0.53	0.07	0.01	0.02	0.00	291.46	16.31
2005	373.32	32.56	8.14	2.44	4.01	1.50	1.69	0.33	0.06	0.00	0.00	424.05	13.79
2006	52.16	51.02	9.52	2.34	0.26	0.35	0.38	0.68	0.04	0.00	0.00	116.75	10.49
2007	319.89	118.06	29.34	5.93	0.90	0.23	0.30	0.31	0.31	0.03	0.00	475.30	24.42
2008	243.68	35.10	11.92	7.04	3.56	1.05	0.50	0.14	0.12	0.14	0.00	303.25	16.53
2009	67.49	40.39	20.79	6.93	2.61	0.74	0.21	0.13	0.07	0.02	0.00	139.38	13.73
2010												n/a	n/a
2011	119.03	38.41	8.16	14.89	9.67	3.92	3.23	0.59	0.17	0.03	0.26	198.36	20.28
2012	153.24	54.31	9.96	2.85	2.06	0.57	0.14	0.32	0.08	0.01	0.00	223.54	13.54
2013	17.74	6.70	9.19	4.07	0.81	1.06	0.75	0.24	0.09	0.03	0.01	40.69	6.47
2014	144.70	23.88	4.33	6.51	1.19	0.43	0.81	0.48	0.19	0.05	0.03	182.60	10.71

Table A44. NYDEC small mesh trawl survey indices at ages 0, 1 and 2 and older (2+).

	NYDEC Trawl		
Year	Age 0	Age 1	Age 2+
1987	0.33	3.42	0.09
1988	1.23	1.89	0.05
1989	0.70	11.00	0.04
1990	5.31	1.31	0.14
1991	12.73	2.38	0.22
1992	14.87	1.59	0.06
1993	0.28	0.68	0.04
1994	6.28	0.35	0.06
1995	0.62	7.35	0.03
1996	0.49	0.99	0.15
1997	17.41	0.77	0.20
1998	68.86	1.46	0.05
1999	35.33	2.11	0.03
2000	192.27	16.75	1.00
2001	84.95	2.99	1.22
2002	346.37	5.51	6.01
2003	258.23	0.39	1.35
2004	40.87	0.85	0.70
2005	39.79	0.91	0.33
2006	126.32	3.06	0.34
2007	109.50	4.25	0.61
2008	246.92	5.15	0.30
2009	79.10	4.92	0.70
2010	7.86	2.17	3.84
2011	57.77	3.63	2.28
2012	156.99	16.34	2.37
2013	24.85	2.71	2.50
2014	246.35	5.87	1.58

Table A45. NJBMF trawl survey mean number of scup per tow and mean weight (kg) per tow; VIMS age 0 index.

	NJBMF Trawl		VIMS
Year	No/tow	Kg/tow	Age 0
1987			2.07
1988			3.06
1989	72.75	2.75	4.81
1990	74.72	3.77	1.90
1991	200.61	6.17	0.65
1992	227.70	7.16	3.30
1993	256.91	5.21	0.90
1994	86.45	3.30	0.39
1995	27.13	2.08	0.54
1996	30.81	1.04	0.21
1997	52.09	3.82	0.50
1998	220.05	4.88	0.27
1999	209.10	10.30	0.13
2000	262.66	6.56	1.34
2001	163.37	4.32	0.24
2002	568.07	25.65	0.96
2003	804.08	10.19	0.46
2004	449.12	11.70	1.11
2005	147.98	4.19	1.58
2006	943.63	16.52	2.99
2007	1185.54	38.27	0.20
2008	141.17	3.19	2.97
2009	205.66	6.04	4.11
2010	141.11	2.21	0.82
2011	101.74	5.13	0.22
2012	131.73	5.83	0.74
2013	12.72	0.50	0.16
2014	71.96	1.74	

Table A46. VIMS ChesMMAP trawl survey indices for scup. Indices are delta-lognormal model stratified geometric mean numbers (N) and biomass per tow. Aggregate indices are delta-lognormal model geometric means per tow. Aged indices are in numbers, are compiled independently, and are aged using a smoothed age-length key, and so do not total to the aggregate numeric indices.

Year	Number (CV %)	Biomass (CV %)
2002	3.47 (22)	0.90 (24)
2003	4.58 (20)	1.20 (21)
2004	13.11 (14)	2.34 (15)
2005	13.03 (18)	1.91 (18)
2006	11.09 (16)	2.15 (21)
2007	23.04 (16)	2.66 (19)
2008	1.31 (30)	0.44 (33)
2009	10.99 (17)	1.90 (19)
2010	27.84 (14)	4.06 (16)
2011	2.28 (26)	0.56 (28)
2012	0.49 (60)	0.15 (38)
2013	1.15 (64)	0.32 (50)
2014	1.08 (70)	0.37 (58)

Year	0	1+	Total
2002	0.73	2.77	3.50
2003	6.77	3.67	10.44
2004	1.81	10.07	11.88
2005	19.05	9.41	28.46
2006	6.28	9.04	15.32
2007	2.05	19.77	21.82
2008	0.55	1.16	1.71
2009	2.75	8.97	11.72
2010	15.37	20.31	35.68
2011	1.11	1.94	3.05
2012	0.00	0.45	0.45
2013	1.27	0.93	2.20
2014	1.11	0.92	2.03

Table A47. VIMS NEAMAP trawl survey indices for scup. Indices are delta-lognormal model stratified geometric mean numbers (N) and biomass per tow.

Season	Number/tow (CV %)	Kilogram/tow (CV %)
Fall 2007	117.65 (4.0)	7.63 (5.6)
Fall 2008	24.52 (5.1)	3.15 (6.6)
Fall 2009	40.86 (4.4)	3.94 (5.6)
Fall 2010	31.08 (4.9)	3.34 (7.5)
Fall 2011	13.67 (6.1)	2.29 (8.0)
Fall 2012	16.59 (16.1)	2.27 (12.0)
Fall 2013	4.52 (14.5)	0.40 (16.3)
Fall 2014	13.76 (15.3)	0.80 (10.6)
Spring 2008	32.86 (3.9)	2.37 (6.4)
Spring 2009	8.17 (6.3)	1.44 (10.8)
Spring 2010	2.26 (7.2)	0.79 (10.7)
Spring 2011	2.38 (7.8)	0.59 (14.6)
Spring 2012	20.64 (17.7)	1.68 (14.1)
Spring 2013	5.31 (14.4)	0.48 (14.5)
Spring 2014	3.47 (15.3)	0.36 (13.9)

Table A48. VIMS NEAMAP trawl survey indices at age for scup. Aged indices are in numbers, are compiled independently, and are aged using a smoothed age-length key, and so do not total to the aggregate numeric indices.

		Spring		
Year	0	1	2+	Total
2008	0	18.82	8.15	26.97
2009	0	3.27	5.47	8.74
2010	0	0.62	1.51	2.13
2011	0	0.91	1.40	2.31
2012	0	17.90	3.44	21.34
2013	0	2.21	2.37	4.58
2014	0	2.40	1.53	3.93

		Fall		
Year	0	1	2+	Total
2007	59.72	26.83	3.60	90.15
2008	11.86	11.96	2.30	26.12
2009	24.06	21.81	4.18	50.05
2010	21.19	8.41	3.10	32.70
2011	6.91	7.81	1.94	16.66
2012	9.99	4.82	0.71	15.52
2013	3.69	1.43	0.62	5.74
2014	11.73	3.74	1.28	16.75

Table A49. Model Building Phase 1 Specifications.

2015 SARC 60	**CODES:**	S60 = 2015 SARC 60	
ASAP for scup		IAA = Indices configured independently At Age	L = Lambda (scalar weighting factor)
Ages 0-8+ (coded ages 1-7+)		MULTI = Indices configured as Multinomials	ESS = Effective Sample Size
		IND08 = 2008 DPSWG index set	CV = Coefficeint of Variation
		NEWSVS = all available 2015 SARC 60 indices	Y1 = First year of model
		NEWMAT = New Maturity Schedule	
		NEWDISC = New Commercial Discards	

MODEL	**2008** DPSWG	**2012** Update	IAA-IND08	MULTI-IND08	NEWSVS	NEWDISC	NEWMAT
	terminal Y = **2007**	terminal Y = **2011**	terminal Y = **2014**	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014
Years	1963-2007	1963-2011	1963-2014	1963-2014	1963-2014	1963-2014	1963-2014
Mean M	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Fleets	4	4	4	4	4	4	4
FISH SELEX							
Time block start	1963; 1997	1963;1997	1963; 1997	1963;1997	1963; 1997	1963;1997	1963; 1997
L	1	1	1	1	1	1	1
CV	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Landings Models	F at Age	F at Age	F at Age	F at Age	F at Age	F at Age	F at Age
True Age Fixed S=1	4, 4; 4, 4	4, 4; 4, 4	4, 4; 4, 4	4, 4; 4, 4	4, 4; 4, 4	4, 4; 4, 4	4, 4; 4, 4
Selex L	1	1	1	1	1	1	1
Selex CV	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Discards Models	F at Age	F at Age	F at Age	F at Age	F at Age	F at Age	F at Age
True Age Fixed S=1	2, 1; 2, 1	2, 1; 2, 1	2, 1; 2, 1	2, 1; 2, 1	2, 1; 2, 1	2, 1; 2, 1	2, 1; 2, 1
Selex L	1	1	1	1	1	1	1
Selex CV	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Fishery							
Catch L	1	1	1	1	1	1	1
Comm Landings CV	0.10	0.10	0.10	0.10	0.10	**0.10**	0.10
Comm Discards CV	0.32	0.32	0.32	0.32	0.32	**0.22**	0.22
Recr Landings CV	0.10	0.10	0.10	0.10	0.10	**0.10**	0.10
Recr Discards CV	0.12	0.12	0.12	0.12	0.12	**0.12**	0.12
Comm Landings ESS	21	22	22	22	**30**	30	30
Comm Discards ESS	6	9	9	9	**10**	10	10
Recr Landings ESS	34	31	31	31	**30**	30	30
Recr Discards ESS	4	4	4	4	**5**	5	5
F,N,Q							
F in Y1 L	1	1	1	1	1	1	1
F in Y1 CV	0.9	0.9	0.9	0.9	0.9	0.9	0.9
F Dev L	1	1	1	1	1	1	1
F Dev CV	0.9	0.9	0.9	0.9	0.9	0.9	0.9
N in Y1 L	1	1	1	1	1	1	1
N in Y1 CV	0.9	0.9	0.9	0.9	0.9	0.9	0.9
All SVs L	1	1	1	1	1	1	1
SV q L	0	0	0	0	0	0	0
SV q CV	0.9	0.9	0.9	0.9	0.9	0.9	0.9
SV q Dev L	0	0	0	0	0	0	0
SV q Dev CV	0.9	0.9	0.9	0.9	0.9	0.9	0.9

Table A49 cont'd.

SV Selectivity							
SV Selex L	1	1	1	1	1	1	1
SV Selex CV	0.5	0.5	0.5	0.5	0.5	0.5	0.5
S-R Model							
Rec Dev L	1	1	1	1	1	1	1
Rec CV	0.1, 1.0	0.1, 1.0	0.1, 1.0	0.1, 1.0	0.1, 1.0	0.1, 1.0	0.1, 1.0
Steepness Dev L	1	1	1	1	1	1	1
Steepness CV	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Scaler Dev L	1	1	1	1	1	1	1
Scaler CV	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Likelihood Constants	1	1	1	1	1	1	1

Table A50. Model Building Phase 1 Results.

2015 SARC 60	**CODES:**	S60 = 2015 SARC 60	
ASAP for scup		IAA = Indices configured independently At Age	L = Lambda (scalar weighting factor)
Ages 0-8+ (coded ages 1-7+)		MULTI = Indices configured as Multinomials	ESS = Effective Sample Size
		IND08 = 2008 DPSWG index set	CV = Coefficeint of Variation
		NEWSVS = all available 2015 SARC 60 indices	Y1 = First year of model
		NEWMAT = New Maturity Schedule	
		NEWDISC = New Commercial Discards	

MODEL	**2008** DPSWG	**2012** Update	IAA-IND08	MULTI-IND08	NEWSVS	NEWDISC	NEWMAT
	terminal Y = **2007**	terminal Y = **2011**	terminal Y = **2014**	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014
Objective Function							
Total	8,965.57	8,695.49	*8,192.88*	*6,467.79*	*6,175.86*	*6,251.77*	*6,172.80*
Catch	1,123.11	1,225.54	*1,287.96*	*1,272.76*	*1,263.76*	*1,220.76*	*1,222.07*
Indices	5,437.39	4,774.09	*5,134.56*	*3,011.34*	*2,229.63*	*2,285.55*	*2,222.57*
Fish CAA	1,804.03	2,060.79	*1,059.65*	*1,034.94*	*1,129.58*	*1,114.03*	*1,141.94*
SV CAA	0.00	0.00	*0.00*	*454.90*	*862.73*	*911.55*	*871.12*
Fish Selex	-106.43	-99.94	*-103.41*	*-109.21*	*-94.53*	*-97.15*	*-97.11*
SV Selex	0.00	0.00	*0.00*	*29.15*	*86.48*	*94.18*	*90.12*
SV q in Y1	0.00	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
SV q Dev	0.00	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
F in Y1	29.45	28.68	*22.09*	*19.07*	*14.49*	*5.80*	*5.85*
F Dev	39.48	27.15	*33.35*	*33.38*	*29.83*	*24.12*	*24.46*
N in Y1	85.94	86.55	*125.43*	*82.93*	*41.03*	*82.63*	*82.72*
Rec Dev	537.87	577.98	*618.83*	*624.08*	*598.51*	*595.74*	*594.45*
S-R Steepness	0.48	0.48	*0.47*	*0.48*	*0.46*	*0.46*	*0.46*
S-R scaler	14.24	14.22	*13.96*	*13.98*	*13.91*	*14.09*	*14.13*
FISH SELEX							
Comm Landings (by block)							
Age 0	0.06, 0.04	0.06, 0.04	*0.04,0.04*	*0.04,0.04*	*0.04,0.04*	*0.04,0.04*	*0.04,0.05*
Age 1	0.17, 0.15	0.16, 0.15	*0.14,0.14*	*0.14,0.15*	*0.12,0.13*	*0.13,0.13*	*0.13,0.14*
Age 2	0.54, 0.47	0.56, 0.47	*0.63,0.48*	*0.59,0.49*	*0.61,0.46*	*0.60,0.46*	*0.60,0.47*
Age 3	0.95, 1.00	0.94, 1.00	*1.00,1.00*	*1.00,1.00*	*1.00,1.00*	*1.00,1.00*	*1.00,1.00*
Age 4	1.00, 1.00	1.00, 1.00	*1.00,1.00*	*1.00,1.00*	*1.00,1.00*	***1.00,1.00***	***1.00,1.00***
Age 5	1.00, 1.00	1.00, 1.00	*1.00,1.00*	*1.00,1.00*	*1.00,1.00*	***1.00,1.00***	***1.00,1.00***
Age 6	1.00, 1.00	1.00, 0.95	*1.00,0.94*	*1.00,0.93*	*0.97,0.93*	***1.00,0.93***	***1.00,0.93***
Age 7+	0.95, 0.93	0.89, 0.83	*0.97,0.77*	*1.00,0.76*	*0.99,0.75*	***1.00,0.75***	***1.00,0.75***
Comm Discards (by block)							
Age 0	0.23, 0.26	0.22, 0.22	*0.26,0.22*	*0.25,0.23*	*0.23,0.22*	*0.23,0.21*	*0.23,0.22*
Age 1	0.45, 0.71	0.42, 0.53	*0.55,0.54*	*0.50,0.53*	***0.48,0.53***	*0.51,0.52*	*0.51,0.53*
Age 2	1.00, 1.00	1.00, 1.00	*1.00,1.00*	*1.00,1.00*	***1.00,1.00***	*1.00,1.00*	*1.00,1.01*
Age 3	0.11, 0.10	0.12, 0.11	*0.10,0.11*	*0.10,0.11*	***0.10,0.12***	***0.10,0.12***	***0.10,0.12***
Age 4	0.11, 0.10	0.12, 0.10	*0.10,0.10*	*0.10,0.10*	***0.10,0.10***	***0.10,0.10***	***0.10,0.10***
Age 5	0.11, 0.10	0.12, 0.10	*0.10,0.10*	*0.10,0.10*	***0.10,0.10***	***0.10,0.10***	***0.10,0.10***
Age 6	0.12, 0.10	0.12, 0.10	*0.10,0.10*	*0.10,0.10*	***0.10,0.10***	***0.10,0.10***	***0.10,0.10***
Age 7+	0.12, 0.10	0.12, 0.10	*0.10,0.10*	*0.10,0.10*	***0.10,0.10***	***0.10,0.10***	***0.10,0.10***

Table A50 continued.

Recr Landings (by block)							
Age 0	0.06, 0.04	0.06, 0.04	*0.04,0.04*	*0.04,0.40*	*0.04,0.04*	*0.04,0.04*	*0.04,0.05*
Age 1	0.23, 0.15	0.23, 0.15	*0.22,0.15*	*0.22,0.15*	*0.21,0.15*	*0.22,0.15*	*0.22,0.16*
Age 2	0.56, 0.55	0.57, 0.53	*0.67,0.50*	*0.65,0.51*	*0.64,0.49*	*0.64,0.49*	*0.64,0.50*
Age 3	0.76, 1.00	0.77, 1.00	*0.91,1.00*	*0.88,1.00*	*0.90,1.00*	*0.88,1.00*	*0.88,1.01*
Age 4	1.00, 1.00	1.00, 1.00	*1.00,1.00*	*1.00,1.00*	*1.00,1.00*	***1.00,1.00***	***1.00,1.00***
Age 5	1.00, 1.00	1.00, 1.00	*0.97,1.00*	*1.00,1.00*	*1.00,1.00*	***1.00,1.00***	***1.00,1.00***
Age 6	1.00, 1.00	1.00, 1.00	*1.00,1.00*	*1.00,1.00*	*1.00,1.00*	***1.00,1.00***	***1.00,1.00***
Age 7+	0.78, 0.90	0.78, 0.81	*0.96,0.75*	*1.00,0.73*	*1.00,0.80*	***1.00,0.79***	***1.00,0.80***
Recr Discards (by block)							
Age 0	0.39, 0.47	0.39, 0.46	*0.44,0.45*	*0.44,0.45*	*0.43,0.44*	*0.43,0.44*	*0.43,0.45*
Age 1	1.00, 1.00	1.00, 1.00	*1.00,1.00*	*1.00,1.00*	***1.00,1.00***	*1.00,1.00*	*1.00,1.01*
Age 2	0.46, 0.54	0.45, 0.55	*0.47,0.56*	*0.46,0.56*	***0.46,0.57***	*0.46,0.57*	*0.46,0.58*
Age 3	0.11, 0.10	0.11, 0.11	*0.10,0.11*	*0.10,0.11*	*0.10,0.11*	***0.10,0.11***	***0.10,0.11***
Age 4	0.11, 0.10	0.11, 0.10	*0.10,0.10*	*0.10,0.10*	*0.10,0.10*	*0.10,0.10*	*0.10,0.10*
Age 5	0.11, 0.10	0.11, 0.10	*0.10,0.10*	*0.10,0.10*	*0.10,0.10*	*0.10,0.10*	*0.10,0.10*
Age 6	0.11, 0.10	0.11, 0.10	*0.10,0.10*	*0.10,0.10*	*0.10,0.10*	*0.10,0.10*	*0.10,0.10*
Age 7+	0.11, 0.10	0.11, 0.10	*0.10,0.10*	*0.10,0.10*	*0.10,0.10*	*0.10,0.10*	*0.10,0.10*
ESTIMATES							
F							
F 1963	0.24	0.28	*0.77*	*0.67*	***3.26***	***0.60***	***0.60***
F 1984	0.53	0.51	*0.60*	*0.67*	***0.74***	***0.71***	***0.71***
F 1994	1.12	1.11	*1.18*	*0.97*	***1.19***	***1.21***	***1.21***
F 2000	0.14	0.19	*0.18*	*0.15*	***0.22***	***0.21***	***0.21***
F 2007	0.05	0.06	*0.06*	*0.05*	*0.07*	***0.07***	***0.07***
F 2011		0.03	*0.05*	*0.04*	*0.06*	***0.06***	***0.06***
F 2014			*0.07*	*0.07*	*0.09*	***0.09***	***0.09***
Age 0							
Age 0 1963	81	91	*113*	*113*	*83*	*97*	*97*
Age 0 1984	108	110	*121*	*118*	*122*	*119*	*119*
Age 0 1994	76	79	*85*	*82*	*73*	*57*	*57*
Age 0 2000	311	226	*236*	*219*	*148*	*130*	*130*
Age 0 2007	308	172	*186*	*191*	*193*	***174***	***174***
Age 0 2011		154	*239*	*234*	*175*	***157***	***157***
Age 0 2014			*77*	*83*	*55*	***50***	***50***
SSB							
SSB 1963	102	107	*75*	*51*	*8*	*60*	***61***
SSB 1984	18	20	*15*	*12*	*12*	*13*	***12***
SSB 1994	4	4	*4*	*6*	*5*	***5***	***4***
SSB 2000	26	20	*21*	*28*	*20*	***19***	***18***
SSB 2007	119	134	*141*	*162*	*105*	***100***	***96***
SSB 2011		190	*200*	*234*	*178*	***162***	***160***
SSB 2014			*226*	*252*	*193*	*172*	*169*

Table A51. Model Building Phase 2 Specifications.

2015 SARC 60 **CODES:** S60 = 2015 SARC 60

ASAP for scup

Ages 0-8+ (coded ages 1-7+)

L = Lambda (scalar weighting factor)

ESS = Effective Sample Size

CV = Coefficeint of Variation

Y1 = First year of model

MODEL	S60_BASE_1	S60_BASE_2	S60_BASE_3	S60_BASE_4	S60_BASE_5	S60_BASE_6
	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014
Years	1963-2014	1963-2014	1963-2014	1963-2014	1963-2014	1963-2014
Mean M	0.20	0.20	0.20	0.20	0.20	0.20
Fleets	4	4	4	4	4	4
FISH SELEX						
Time block start	1963; 1997	1963; 1997	1963; 1997	1963; 1997	1963; 1997	1963; 1997
Landings Models	F at Age	F at Age	F at Age	F at Age	F at Age	F at Age
True Age Fixed S=1	4, 4; 4, 4	4, 4; 4, 4	4, 4; 4, 4	4, 4; 4, 4	4, 4; 4, 4	4, 4; 4, 4
Selex L	1	1	1	**0**	**1**	1
Selex CV	0.1	0.1	0.1	0.1	**0.5**	0.5
Discards Models	F at Age	F at Age	F at Age	F at Age	F at Age	F at Age
True Age Fixed S=1	2, 1; 2, 1	2, 1; 2, 1	2, 1; 2, 1	2, 1; 2, 1	2, 1; 2, 1	2, 1; 2, 1
Selex L	1	1	1	**0**	**1**	1
Selex CV	0.1	0.1	0.1	0.1	**0.5**	0.5
Fishery						
Catch L	1	1	1	1	1	1
Comm Landings CV	0.10	0.10	0.10	0.10	0.10	0.10
Comm Discards CV	0.22	0.22	0.22	0.22	0.22	0.22
Recr Landings CV	0.10	0.10	0.10	0.10	0.10	0.10
Recr Discards CV	0.12	0.12	0.12	0.12	0.12	0.12
Comm Landings ESS	30	30	30	30	30	30
Comm Discards ESS	10	10	10	10	10	10
Recr Landings ESS	30	30	30	30	30	30
Recr Discards ESS	5	5	5	5	5	5
F,N,Q		**N1 Settings**				
F in Y1 L	1	1	1	1	1	1
F in Y1 CV	0.9	0.9	0.9	0.9	0.9	0.9
F Dev L	1	1	**0**	0	0	0
F Dev CV	0.9	0.9	0.9	0.9	0.9	0.9
N in Y1 L	1	1	1	1	1	1
N in Y1 CV	0.9	0.9	0.9	0.9	0.9	0.9
All SVs L	1	1	1	1	1	1
SV q L	0	0	0	0	0	0
SV q CV	0.9	0.9	0.9	0.9	0.9	0.9
SV q Dev L	0	0	0	0	0	0
SV q Dev CV	0.9	0.9	0.9	0.9	0.9	0.9
SV Selectivity						
SV Selex L	1	1	1	1	1	**0**
SV Selex CV	0.5	0.5	0.5	0.5	0.5	0.5

Table A51 continued.

S-R Model						
Rec Dev L	1	1	1	1	1	1
Rec CV	0.1, 1.0	0.1, 1.0	0.1, 1.0	0.1, 1.0	0.1, 1.0	0.1, 1.0
Steepness Dev L	1	1	1	1	1	1
Steepness CV	0.9	0.9	0.9	0.9	0.9	0.9
Scaler Dev L	1	1	1	1	1	1
Scaler CV	0.9	0.9	0.9	0.9	0.9	0.9

Table A51 continued.

2015 SARC 60 **CODES:** S60 = 2015 SARC 60

L = Lambda (scalar weighting factor)

ASAP for scup

Ages 0-8+ (coded ages 1-7+)

ESS = Effective Sample Size

CV = Coefficeint of Variation

Y1 = First year of model

MODEL	S60_BASE_7	S60_BASE_8	S60_BASE_9	S60_BASE_10	S60_BASE_11	S60_BASE_12
	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014
Years	1963-2014	1963-2014	1963-2014	1963-2014	1963-2014	1963-2014
Mean M	0.20	0.20	0.20	0.20	0.20	0.20
Fleets	4	4	4	4	4	4
FISH SELEX						
Time block start	1963; 1997	1963; 1997	1963; 1997	**1963; 1997; 2006**	1963; 1997; 2006	1963; 1997; 2006
Landings Models	F at Age	F at Age	F at Age	F at Age	F at Age	F at Age
True Age Fixed S=1	4, 4; 4, 4	4, 4; 4, 4	4, 4; 4, 4; 4, 4	4, 4; 4, 4; 4, 4	4, 4; 4, 4; 4, 4	4, 4; 4, 4; 4, 4
Selex L	1	1	1	1	1	1
Selex CV	0.5	0.5	0.5	0.5	0.5	0.5
Discards Models	F at Age	F at Age	F at Age	F at Age	F at Age	F at Age
True Age Fixed S=1	2, 1; 2, 1	2, 1; 2, 1	2, 1; 2, 1; 2, 1	2, 1; 2, 1; 2, 1	2, 1; 2, 1; 2, 1	2, 1; 2, 1; 2, 1
Selex L	1	1	1	1	1	1
Selex CV	0.5	0.5	0.5	0.5	0.5	0.5
					Fishery S	
Fishery						
Catch L	1	1	1	1	1	1
Comm Landings CV	0.10	0.10	0.10	0.10	0.10	0.10
Comm Discards CV	0.22	0.22	0.22	0.22	0.22	0.22
Recr Landings CV	0.10	0.10	0.10	0.10	0.10	0.10
Recr Discards CV	0.12	0.12	0.12	0.12	0.12	0.12
Comm Landings ESS	30	30	30	30	30	30
Comm Discards ESS	10	10	10	10	10	10
Recr Landings ESS	30	30	30	30	30	30
Recr Discards ESS	5	5	5	5	5	5
F,N,Q						
F in Y1 L	1	1	1	1	1	1
F in Y1 CV	0.9	0.9	0.9	0.9	0.9	0.9
F Dev L	0	0	0	0	0	0
F Dev CV	0.9	0.9	0.9	0.9	0.9	0.9
N in Y1 L	1	1	1	1	1	1
N in Y1 CV	0.9	0.9	0.9	0.9	0.9	0.9
All SVs L	1	1	1	1	1	1
SV q L	0	0	0	0	0	0
SV q CV	0.9	0.9	0.9	0.9	0.9	0.9
SV q Dev L	0	0	0	0	0	0
SV q Dev CV	0.9	0.9	0.9	0.9	0.9	0.9
SV Selectivity						
SV Selex L	0	0	0	0	0	0
SV Selex CV	0.5	0.5	0.5	0.5	0.5	0.5
						Survey S

Table A51 continued.

S-R Model						
Rec Dev L	1	**0**	**1**	**1**	1	1
Rec CV	0.1, 1.0	0.1, 1.0	0.1, 1.0	0.1, 1.0	0.1, 1.0	0.1, 1.0
Steepness Dev L	**0**	0	0	0	0	0
Steepness CV	0.9	0.9	0.9	0.9	0.9	0.9
Scaler Dev L	**0**	0	0	0	0	0
Scaler CV	0.9	0.9	0.9	0.9	0.9	0.9
Likelihood Constants	1	1	**0**	0	0	0

Table A52. Model Building Phase 2 Results.

2015 SARC 60 **CODES:** S60 = 2015 SARC 60

ASAP for scup

Ages 0-8+ (coded ages 1-7+)

L = Lambda (scalar weighting factor)

ESS = Effective Sample Size

CV = Coefficeint of Variation

Y1 = First year of model

MODEL	S60_BASE_1	S60_BASE_2	S60_BASE_3	S60_BASE_4	S60_BASE_5	S60_BASE_6
	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014
Objective Function						
Total	*6,172.80*	*6,171.71*	*6,151.42*	*5,924.64*	*5,989.98*	*5,804.60*
Catch	*1,222.07*	*1,221.97*	*1,220.76*	*1,221.12*	*1,220.92*	*1,220.10*
Indices	*2,222.57*	*2,222.38*	*2,226.97*	*2,231.44*	*2,229.20*	*2,215.32*
Fish CAA	*1,141.94*	*1,141.91*	*1,141.36*	*834.36*	*884.99*	*884.98*
SV CAA	*871.12*	*871.11*	*871.15*	*861.27*	*864.21*	*778.98*
Fish Selex	*-97.11*	*-97.10*	*-96.93*	**0.00**	**9.31**	*8.08*
SV Selex	*90.12*	*90.09*	*90.39*	*87.14*	*88.03*	**0.00**
SV q in Y1	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
SV q Dev	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
F in Y1	*5.85*	*5.69*	*8.78*	*-0.27*	*4.27*	*4.24*
F Dev	*24.46*	*24.50*	**0.00**	*0.00*	*0.00*	*0.00*
N in Y1	*82.72*	*82.16*	*79.37*	*80.33*	*79.67*	*79.57*
Rec Dev	*594.45*	*594.40*	*595.04*	*594.51*	*594.76*	*598.74*
S-R Steepness	*0.46*	*0.46*	*0.46*	*0.47*	*0.46*	*0.47*
S-R scaler	*14.13*	*14.14*	*14.07*	*14.27*	*14.16*	*14.13*
FISH SELEX						
Comm Landings (by block)						
Age 0	*0.04,0.05*	*0.04,0.04*	*0.04,0.04*	*0.00,0.00*	***0.01,0.01***	*0.01,0.01*
Age 1	*0.13,0.14*	*0.13,0.13*	*0.13,0.13*	*0.04,0.01*	***0.05,0.02***	*0.05,0.03*
Age 2	*0.60,0.47*	*0.60,0.46*	*0.60,0.46*	*0.48,0.24*	***0.53,0.31***	*0.54,0.33*
Age 3	*1.00,1.00*	*1.00,1.00*	*1.00,1.00*	*1.00,0.91*	***1.00,1.00***	*1.00,1.00*
Age 4	***1.00,1.00***	***1.00,1.00***	***1.00,1.00***	*1.00,1.00*	***1.00,1.00***	*1.00,1.00*
Age 5	***1.00,1.00***	***1.00,1.00***	***1.00,1.00***	*0.69,0.91*	***0.83,1.00***	*0.82,0.96*
Age 6	***1.00,0.93***	***1.00,0.93***	***1.00,0.93***	*0.66,0.46*	***0.84,0.59***	*0.83,0.53*
Age 7+	***1.00,0.75***	***1.00,0.75***	***1.00,0.74***	*0.36,0.13*	***0.76,0.23***	*0.66,0.20*
Comm Discards (by block)						
Age 0	*0.23,0.22*	*0.23,0.21*	*0.23,0.21*	*0.16,0.12*	***0.16,0.13***	*0.16,0.14*
Age 1	*0.51,0.53*	*0.51,0.52*	*0.51,0.52*	*0.58,0.64*	***0.55,0.59***	*0.51,0.60*
Age 2	*1.00,1.00*	*1.00,1.00*	*1.00,1.00*	*1.00,1.00*	***1.00,1.00***	*1.00,1.00*
Age 3	***0.10,0.12***	***0.10,0.12***	***0.10,0.12***	*0.29,0.56*	***0.17,0.39***	*0.18,0.39*
Age 4	***0.10,0.10***	***0.10,0.10***	***0.10,0.10***	*0.09,0.27*	***0.10,0.17***	*0.10,0.16*
Age 5	***0.10,0.10***	***0.10,0.10***	***0.10,0.10***	*0.05,0.13*	***0.10,0.11***	*0.10,0.10*
Age 6	***0.10,0.10***	***0.10,0.10***	***0.10,0.10***	*0.16,0.06*	***0.10,0.10***	*0.10,0.09*
Age 7+	***0.10,0.10***	***0.10,0.10***	***0.10,0.10***	*0.43,0.03*	***0.10,0.08***	*0.10,0.07*
Recr Landings (by block)						
Age 0	*0.04,0.05*	*0.04,0.04*	*0.04,0.04*	*0.01,0.00*	***0.02,0.01***	*0.01,0.01*
Age 1	*0.22,0.16*	*0.22,0.15*	*0.22,0.15*	*0.22,0.03*	***0.24,0.05***	*0.25,0.05*
Age 2	*0.64,0.50*	*0.64,0.49*	*0.63,0.49*	*0.67,0.23*	***0.74,0.30***	*0.78,0.35*
Age 3	*0.88,1.00*	*0.88,1.00*	*0.89,1.00*	*0.70,0.58*	***0.78,0.71***	*0.81,0.76*
Age 4	***1.00,1.00***	***1.00,1.00***	*1.00,1.00*	*1.00,1.00*	***1.00,1.00***	*1.00,1.00*
Age 5	***1.00,1.00***	***1.00,1.00***	*1.00,1.00*	*1.00,1.00*	***1.00,1.00***	*1.00,1.00*
Age 6	***1.00,1.00***	***1.00,1.00***	*1.00,1.00*	*1.00,0.80*	***1.00,0.91***	*1.00,0.84*
Age 7+	***1.00,0.80***	***1.00,0.79***	*1.00,0.79*	*0.95,0.22*	***1.00,0.32***	*1.00,0.27*

Table A52 continued.

Recr Discards (by block)						
Age 0	*0.43,0.45*	*0.43,0.44*	*0.43,0.44*	*0.07,0.26*	***0.16,0.28***	*0.16,0.29*
Age 1	*0.88,1.00*	*1.00,1.00*	*1.00,1.00*	*1.00,1.00*	***1.00,1.00***	*1.00,1.00*
Age 2	*0.46,0.58*	*0.46,0.57*	*0.44,0.57*	*0.00,1.00*	***0.13,1.00***	*0.13,1.00*
Age 3	***0.10,0.11***	*0.10,0.11*	*0.10,0.11*	*0.00,0.95*	***0.08,0.43***	*0.08,0.41*
Age 4	*0.10,0.10*	*0.10,0.10*	*0.10,0.10*	*0.00,0.65*	***0.09,0.22***	*0.09,0.21*
Age 5	*0.10,0.10*	*0.10,0.10*	*0.10,0.10*	*0.00,0.35*	***0.10,0.13***	*0.10,0.13*
Age 6	*0.10,0.10*	*0.10,0.10*	*0.10,0.10*	*0.00,0.07*	***0.10,0.10***	*0.10,0.09*
Age 7+	*0.10,0.10*	*0.10,0.10*	*0.10,0.10*	*0.00,0.03*	***0.10,0.09***	*0.10,0.08*
ESTIMATES						
F						
F 1963	***0.60***	*0.59*	*0.72*	*0.65*	***0.71***	*0.70*
F 1984	***0.71***	*0.70*	*0.71*	*0.75*	***0.75***	***0.71***
F 1994	***1.21***	*1.21*	*1.22*	*1.27*	***1.32***	***1.18***
F 2000	***0.21***	*0.21*	*0.21*	*0.36*	***0.29***	***0.19***
F 2007	***0.07***	*0.07*	*0.07*	*0.09*	***0.08***	*0.06*
F 2011	***0.06***	*0.06*	*0.06*	*0.07*	***0.07***	*0.06*
F 2014	***0.09***	*0.09*	*0.09*	*0.14*	***0.12***	*0.11*
Age 0						
Age 0 1963	*97*	*98*	*101*	*89*	*96*	*98*
Age 0 1984	*119*	*119*	*120*	*117*	*119*	*117*
Age 0 1994	*57*	*57*	*57*	*51*	*53*	*54*
Age 0 2000	*130*	*130*	*131*	*132*	*133*	***171***
Age 0 2007	***174***	*173*	*177*	*167*	*171*	***192***
Age 0 2011	***157***	*156*	*160*	*156*	*157*	*157*
Age 0 2014	***50***	*49*	*51*	*71*	*68*	***86***
SSB						
SSB 1963	***61***	*62*	*45*	*49*	*47*	*45*
SSB 1984	***12***	*12*	*12*	*12*	*11*	*12*
SSB 1994	***4***	*4*	*4*	*4*	*4*	*4*
SSB 2000	***18***	*18*	*19*	*13*	*15*	***21***
SSB 2007	***96***	*96*	*99*	*96*	*98*	***136***
SSB 2011	***160***	*159*	*164*	*154*	*159*	***200***
SSB 2014	*169*	*169*	*174*	*159*	*165*	***196***

Table A52 continued.

2015 SARC 60 **CODES:** S60 = 2015 SARC 60

ASAP for scup

Ages 0-8+ (coded ages 1-7+)

L = Lambda (scalar weighting factor)

ESS = Effective Sample Size

CV = Coefficeint of Variation

Y1 = First year of model

MODEL	S60_BASE_7	S60_BASE_8	S60_BASE_9	S60_BASE_10	S60_BASE_11	S60_BASE_12
	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014		
Objective Function						
Total	5,798.58	**5,178.50**	**5,822.08**	**5,421.11**	5,382.10	5383.62
Catch	1,219.99	1,219.55	**1,218.70**	**-423.50**	-423.23	-423.23
Indices	2,220.57	**2,186.64**	**2,223.33**	**608.21**	613.38	613.56
Fish CAA	887.60	889.28	**894.00**	**3,318.39**	3,277.13	3277.14
SV CAA	779.30	779.30	**810.18**	**1,851.45**	1,843.75	1845.09
Fish Selex	6.81	9.05	**-15.13**	**18.64**	23.10	23.1
SV Selex	0.00	0.00	0.00	0.00	0.00	0
SV q in Y1	0.00	0.00	0.00	0.00	0.00	0
SV q Dev	0.00	0.00	0.00	0.00	0.00	0
F in Y1	4.04	5.74	4.41	5.55	5.62	5.63
F Dev	0.00	0.00	0.00	0.00	0.00	0
N in Y1	79.21	**90.63**	86.60	84.93	85.04	85.04
Rec Dev	601.06	**0.00**	**600.00**	**-42.57**	-42.69	-42.7
S-R Steepness	**0.00**	0.00	0.00	0.00	0.00	0
S-R scaler	**0.00**	0.00	0.00	0.00	0.00	0
FISH SELEX						
Comm Landings (by block)						
Age 0	0.01,0.01	0.01,0.01	0.01,0.01,0.02	0.01,0.01,0.02	0.01,0.01,0.02	0.01,0.01,0.02
Age 1	0.05,0.03	0.05,0.03	0.05,0.03,0.06	0.05,0.03,0.06	0.05,0.03,0.06	0.05,0.03,0.06
Age 2	0.56,0.33	0.54,0.33	0.53,0.26,0.50	0.53,0.26,0.51	0.52,0.26,0.51	0.52,0.26,0.51
Age 3	1.00,1.00	1.00,1.00	1.00,1.00,1.00	1.00,1.00,1.00	1.00,1.00,1.00	1.00,1.00,1.00
Age 4	1.00,1.00	1.00,1.00	**1.00,1.00,1.00**	1.00,1.00,1.00	1.00,1.00,1.00	1.00,1.00,1.00
Age 5	0.76,0.94	0.87,0.94	**0.80,0.98,1.00**	0.81,1.00,1.00	0.83,0.96,1.00	0.83,0.96,1.00
Age 6	0.76,0.52	0.78,0.52	**0.82,0.59,0.64**	0.82,0.57,0.63	0.89,0.57,0.63	0.89,0.57,0.63
Age 7+	0.63,0.19	0.50,0.19	**0.72,0.54,0.23**	0.64,0.52,0.22	0.78,0.52,0.22	0.78,0.52,0.22
Comm Discards (by block)						
Age 0	0.16,0.14	0.15,0.14	**0.16,0.13,0.17**	0.17,0.13,0.16	**0.22,0.10,0.16**	0.22,0.10,0.16
Age 1	0.51,0.60	0.49,0.60	**0.51,0.49,0.68**	0.53,0.49,0.68	**0.47,0.52,0.66**	0.47,0.52,0.66
Age 2	1.00,1.00	1.00,1.00	**1.00,1.00,1.00**	1.00,1.00,1.00	1.00,1.00,1.00	1.00,1.00,1.00
Age 3	0.18,0.39	0.19,0.39	**0.18,0.33,0.13**	**0.18,0.33,0.27**	**0.19,0.20,0.29**	0.19,0.20,0.29
Age 4	0.10,0.16	0.11,0.16	**0.10,0.15,0.10**	0.10,0.15,0.13	**0.09,0.12,0.12**	0.09,0.12,0.12
Age 5	0.10,0.10	0.11,0.10	**0.10,0.11,0.10**	0.10,0.11,0.10	0.10,0.11,0.09	0.10,0.11,0.09
Age 6	0.10,0.09	0.10,0.09	**0.10,0.10,0.09**	0.09,0.10,0.09	0.09,0.09,0.09	0.09,0.09,0.09
Age 7+	0.10,0.07	0.12,0.07	**0.10,0.10,0.07**	0.09,0.10,0.07	0.07,0.09,0.07	0.07,0.09,0.07
Recr Landings (by block)						
Age 0	0.02,0.01	0.02,0.01	0.02,0.01,0.02	0.02,0.01,0.02	0.02,0.01,0.02	0.02,0.01,0.02
Age 1	0.28,0.06	0.26,0.06	0.26,0.07,0.06	0.25,0.08,0.06	0.24,0.08,0.06	0.24,0.08,0.06
Age 2	0.84,0.36	0.81,0.36	0.80,0.47,0.28	0.79,0.49,0.28	0.75,0.48,0.28	0.75,0.48,0.28
Age 3	0.84,0.78	0.85,0.78	0.82,0.88,0.79	0.82,0.90,0.80	0.79,0.89,0.79	0.79,0.89,0.79
Age 4	1.00,1.00	1.00,1.00	**1.00,1.00,1.00**	1.00,1.00,1.00	1.00,1.00,1.00	1.00,1.00,1.00
Age 5	1.00,1.00	1.00,1.00	**0.95,1.00,1.00**	0.97,1.00,1.00	0.98,1.00,1.00	0.98,1.00,1.00
Age 6	1.00,0.84	1.00,0.84	**1.00,0.95,0.85**	1.00,0.93,0.84	1.00,0.93,0.84	1.00,0.93,0.84
Age 7+	1.00,0.27	0.58,0.27	**1.00,0.79,0.26**	1.00,0.75,0.25	1.00,0.77,0.25	1.00,0.77,0.25

Table A52 continued.

Recr Discards (by block)						
Age 0	*0.16,0.29*	*0.16,0.29*	***0.16,0.40,0.21***	*0.16,0.40,0.21*	*0.16,0.39,0.18*	*0.16,0.39,0.18*
Age 1	*1.00,1.00*	*1.00,1.00*	***1.00,1.00,1.00***	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*
Age 2	*0.13,1.00*	*0.17,1.00*	***0.17,0.81,1.00***	*0.17,0.81,1.00*	***0.17,0.81,0.50***	*0.17,0.81,0.50*
Age 3	*0.08,0.41*	*0.08,0.41*	***0.08,0.16,0.39***	*0.08,0.16,0.39*	*0.08,0.16,0.35*	*0.08,0.16,0.35*
Age 4	*0.09,0.21*	*0.09,0.21*	***0.09,0.10,0.23***	*0.09,0.10,0.23*	*0.09,0.10,0.22*	*0.09,0.10,0.22*
Age 5	*0.10,0.13*	*0.10,0.13*	***0.06,0.10,0.13***	*0.07,0.10,0.13*	*0.07,0.10,0.12*	*0.07,0.10,0.12*
Age 6	*0.10,0.09*	*0.10,0.09*	***0.10,0.10,0.09***	*0.10,0.10,0.09*	*0.10,0.10,0.09*	*0.10,0.10,0.09*
Age 7+	*0.10,0.08*	*0.10,0.08*	***0.10,0.10,0.08***	*0.10,0.10,0.08*	*0.10,0.10,0.08*	*0.10,0.10,0.08*
ESTIMATES						
F						
F 1963	*0.73*	***0.44***	***0.56***	*0.61*	*0.61*	***0.57***
F 1984	*0.68*	*0.66*	*0.71*	*0.73*	*0.77*	***0.81***
F 1994	*1.05*	*1.13*	*1.21*	*1.19*	***1.31***	***1.41***
F 2000	*0.17*	*0.18*	*0.19*	*0.16*	*0.17*	***0.20***
F 2007	*0.06*	*0.03*	*0.06*	*0.05*	*0.05*	***0.07***
F 2011	*0.06*	*0.05*	*0.06*	*0.05*	*0.05*	***0.06***
F 2014	*0.11*	*0.10*	*0.08*	*0.06*	*0.06*	***0.08***
Age 0						
Age 0 1963	***131***	***88***	*92*	***103***	*103*	*103*
Age 0 1984	*117*	*116*	*117*	***121***	*130*	*130*
Age 0 1994	*54*	*55*	*54*	***57***	*61*	*61*
Age 0 2000	*171*	***181***	*174*	***191***	*184*	*183*
Age 0 2007	*192*	***206***	*194*	***214***	*217*	*217*
Age 0 2011	*157*	***170***	*165*	***183***	***148***	***186***
Age 0 2014	*83*	***173***	*74*	***146***	***138***	***113***
SSB						
SSB 1963	*41*	***129***	***72***	***64***	*65*	*65*
SSB 1984	*12*	***16***	*13*	*13*	*12*	*12*
SSB 1994	*5*	*5*	*5*	*5*	*5*	*5*
SSB 2000	*23*	*23*	*22*	***25***	*25*	*25*
SSB 2007	*137*	***150***	*144*	***164***	*162*	*161*
SSB 2011	*201*	***223***	*209*	***239***	*238*	*237*
SSB 2014	*197*	***223***	*209*	***239***	*239*	*239*

Table A53. Model Building Phase 3 Specifications.

2015 SARC 60

ASAP for scup

Ages 0-8+ (coded ages 1-7+)

L = Lambda (scalar weighting factor)

ESS = Effective Sample Size

CV = Coefficeint of Variation

Y1 = First year of model

MODEL	S60_BASE_13	S60_BASE_14	S60_BASE_15	S60_BASE_16	S60_BASE_17	**S60_BASE_18**	S60_BASE_19	S60_BASE_20
	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	**terminal Y = 2014**	terminal Y = 2014	terminal Y = 2014
Years	1963-2014	1963-2014	1963-2014	1963-2014	1963-2014	1963-2014	1963-2014	1963-2014
Mean M	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Fleets	4	4	4	4	4	4	4	4
FISH SELEX								
Time block start	1963; 1997; 2006	1963; 1997; 2006	1963; 1997; 2006	1963; 1997; 2006	1963; 1997; 2006	1963; 1997; 2006	1963; 1997; 2006	1963; 1997; 2006
Landings Models	F at Age	F at Age	F at Age	F at Age	F at Age	F at Age	F at Age	F at Age
True Age Fixed S=1	4, 4; 4, 4; 4, 4	4, 4; 4, 4; 4, 4	4, 4; 4, 4; 4, 4	4, 4; 4, 4; 4, 4	4, 4; 4, 4; 4, 4	4, 4; 4, 4; 4, 4	4, 4; 4, 4; 4, 4	4, 4; 4, 4; 4, 4
Selex L	1	1	1	1	1	1	1	1
Selex CV	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Discards Models	F at Age	F at Age	F at Age	F at Age	F at Age	F at Age	F at Age	F at Age
True Age Fixed S=1	2, 1; 2, 1; 2, 1	2, 1; 2, 1; 2, 1	2, 1; 2, 1; 2, 1	2, 1; 2, 1; 2, 1	2, 1; 2, 1; 2, 1	2, 1; 2, 1; 2, 1	2, 1; 2, 1; 2, 1	2, 1; 2, 1; 2, 1
Selex L	1	1	1	1	1	1	1	1
Selex CV	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Fishery	**Survey CVs**	**Fishery ESS**	**Survey ESS**	**Add New RI aged Indices**	**Add Final 2014 Catch at Age**	**From 17 Omit High CV SVs**	**From 17 Early Cat CV = 0.3**	**From 17 Only Age Comp SVs**
Catch L	1	1	1	1	1	1	1	1
Comm Landings CV	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Comm Discards CV	0.22	0.22	0.22	0.22	0.22	0.22	**0.30**	0.22
Recr Landings CV	0.10	0.10	**0.13**	0.13	0.13	0.13	**0.30**	0.13
Recr Discards CV	0.12	0.12	**0.13**	0.13	0.13	0.13	**0.30**	0.13
Comm Landings ESS	30	**50**	50	50	50	50	50	50
Comm Discards ESS	10	**20**	20	20	20	20	20	20
Recr Landings ESS	30	**50**	50	50	50	50	50	50
Recr Discards ESS	5	**5**	5	5	5	5	5	5

Table A53 continued.

F,N,Q								
F in Y1 L	1	1	1	1	1	1	1	1
F in Y1 CV	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
F Dev L	0	0	0	0	0	0	0	0
F Dev CV	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
N in Y1 L	1	1	1	1	1	1	1	1
N in Y1 CV	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
All SVs L	1	1	1	1	1	1	1	1
SV q L	0	0	0	0	0	0	0	0
SV q CV	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
SV q Dev L	0	0	0	0	0	0	0	0
SV q Dev CV	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
SV Selectivity								
SV Selex L	0	0	0	0	0	0	0	0
SV Selex CV	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Survey CVs	**Fishery ESS**	**Survey ESS**					
S-R Model								
Rec Dev L	1	1	1	1	1	1	1	1
Rec CV	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Steepness Dev L	0	0	0	0	0	0	0	0
Steepness CV	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Scaler Dev L	0	0	0	0	0	0	0	0
Scaler CV	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Likelihood Constants	0	0	0	0	0	0	0	0

Table A54. Model Building Phase 3 Results.

2015 SARC 60

ASAP for scup

Ages 0-8+ (coded ages 1-7+)

L = Lambda (scalar weighting factor)

ESS = Effective Sample Size

CV = Coefficeint of Variation

Y1 = First year of model

MODEL	S60_BASE_13	S60_BASE_14	S60_BASE_15	S60_BASE_16	S60_BASE_17	**S60_BASE_18**	S60_BASE_19	S60_BASE_20
	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	terminal Y = 2014	**terminal Y = 2014**	terminal Y = 2014	terminal Y = 2014
Objective Function								
Total	***4,997.08***	***7,187.22***	***10,385.60***	*11,148.10*	*11,132.90*	***9,461.79***	*11,224.30*	*11075.30*
Catch	***-427.03***	*-425.99*	*-424.83*	*-406.81*	*-406.71*	*-407.04*	*-303.31*	*-407.68*
Indices	***245.41***	*246.69*	*250.59*	*315.83*	*316.01*	***104.56***	*313.81*	*261.28*
Fish CAA	***3,273.29***	***5,429.49***	*5,441.01*	*5,442.54*	*5,427.15*	*5,425.82*	*5,425.12*	*5428.45*
SV CAA	***1,837.95***	*1,840.72*	***5,020.24***	*5,697.64*	*5,696.37*	***4,239.54***	*5,695.17*	*5692.94*
Fish Selex	***22.79***	***51.28***	**53.44**	**52.19**	*53.14*	*54.52*	*53.42*	*53.27*
SV Selex	*0.00*	*0.00*	*0.00*	*0.00*	0.00	*0.00*	*0.00*	*0.00*
SV q in Y1	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
SV q Dev	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
F in Y1	*5.90*	*6.00*	*5.96*	*5.70*	*5.72*	*0.00*	*0.00*	*0.00*
F Dev	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
N in Y1	*85.39*	*85.41*	*85.35*	*85.06*	*85.12*	*85.24*	*81.01*	*84.72*
Rec Dev	*-46.60*	*-46.38*	*-46.19*	*-44.04*	*-43.95*	*-46.65*	*-44.46*	*-43.34*
S-R Steepness	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
S-R scaler	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
FISH SELEX								
Comm Landings (by block)								
Age 0	*0.01,0.01,0.02*	*0.01,0.01,0.02*	*0.01,0.02,0.02*	*0.01,0.01,0.02*	*0.01,0.01,0.02*	*0.01,0.01,0.02*	*0.01,0.01,0.02*	*0.01,0.01,0.02*
Age 1	*0.05,0.03,0.06*	*0.04,0.02,0.04*	*0.04,0.04,0.04*	*0.04,0.02,0.04*	*0.04,0.02,0.04*	*0.04,0.02,0.04*	*0.04,0.02,0.04*	*0.05,0.02,0.04*
Age 2	*0.53,0.26,0.50*	*0.52,0.24,0.48*	*0.51,0.50,0.50*	***0.52,0.24,0.50***	*0.51,0.24,0.47*	*0.50,0.25,0.46*	*0.51,0.24,0.47*	*0.53,0.24,0.48*
Age 3	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*
Age 4	*1.00,1.001.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*
Age 5	*0.82,0.98,1.00*	*0.79,0.97,1.00*	*0.80,1.00,1.00*	*0.79,0.94,1.00*	*0.78,0.94,1.00*	*0.80,0.91,1.00*	*0.80,0.95,1.00*	*0.78,0.93,1.00*
Age 6	*0.90,0.58,0.63*	*0.89,0.52,0.59*	***0.89,0.57,0.57***	***0.90,0.48,0.57***	*0.89,0.48,0.55*	*0.88,0.46,0.55*	*0.88,0.49,0.56*	*0.88,0.48,0.53*
Age 7+	*0.89,0.52,0.22*	***0.88,0.42,0.19***	***0.83,0.48,0.18***	***0.78,0.41,0.17***	*0.79,0.41,0.18*	*0.86,0.39,0.18*	*0.78,0.42,0.18*	*0.78,0.41,0.16*

Table A54 continued.

Comm Discards (by block)								
Age 0	*0.17,0.13,0.16*	***0.21,0.08,0.15***	*0.21,0.08,0.14*	*0.21,0.09,0.14*	*0.21,0.09,0.14*	*0.20,0.09,0.15*	*0.21,0.08,0.14*	*0.21,0.08,0.15*
Age 1	*0.53,0.49,0.68*	***0.44,0.51,0.69***	*0.44,0.52,0.68*	*0.43,0.52,0.69*	*0.43,0.52,0.69*	*0.43,0.52,0.70*	*0.43,0.52,0.69*	*0.43,0.52,0.71*
Age 2	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*
Age 3	*0.18,0.33,0.27*	***0.24,0.25,0.37***	*0.24,0.24,0.36*	*0.25,0.24,0.36*	*0.25,0.24,0.36*	*0.25,0.24,0.36*	*0.25,0.24,0.36*	*0.24,0.24,0.36*
Age 4	*0.10,0.15,0.13*	*0.09,0.14,0.12*	*0.09,0.13,0.12*	*0.09,0.13,0.12*	*0.09,0.13,0.12*	*0.09,0.13,0.12*	*0.09,0.13,0.12*	*0.09,0.13,0.12*
Age 5	*0.10,0.11,0.10*	*0.11,0.10,0.09*	*0.11,0.10,0.09*	*0.11,0.10,0.08*	*0.11,0.10,0.08*	*0.11,0.10,0.08*	*0.09,0.10,0.09*	*0.11,0.10,0.08*
Age 6	*0.09,0.10,0.09*	*0.10,0.09,0.08*	*0.10,0.09,0.08*	*0.10,0.09,0.08*	*0.10,0.09,0.08*	*0.10,0.09,0.08*	*0.10,0.09,0.08*	*0.11,0.09,0.07*
Age 7+	*0.09,0.10,0.07*	*0.05,0.10,0.06*	*0.05,0.10,0.06*	*0.05,0.10,0.05*	*0.05,0.10,0.05*	*0.05,0.10,0.05*	*0.05,0.10,0.05*	*0.05,0.10,0.05*
Recr Landings (by block)								
Age 0	*0.02,0.01,0.02*	*0.01,0.01,0.02*	*0.01,0.01,0.01*	*0.02,0.01,0.02*	*0.02,0.01,0.02*	*0.01,0.02,0.02*	*0.02,0.01,0.02*	*0.02,0.01,0.02*
Age 1	*0.25,0.08,0.06*	*0.23,0.07,0.04*	*0.23,0.06,0.05*	*0.24,0.07,0.05*	*0.24,0.07,0.05*	*0.22,0.07,0.04*	*0.24,0.07,0.05*	*0.25,0.07,0.05*
Age 2	*0.79,0.49,0.28*	*0.72,0.43,0.25*	*0.72,0.43,0.26*	*0.76,0.45,0.27*	*0.75,0.45,0.25*	*0.69,0.46,0.24*	*0.75,0.44,0.25*	*0.78,0.45,0.26*
Age 3	*0.82,0.90,0.80*	*0.76,0.82,0.75*	*0.76,0.83,0.75*	*0.78,0.84,0.76*	*0.78,0.83,0.78*	*0.74,0.85,0.78*	*0.76,0.83,0.78*	*0.79,0.84,0.80*
Age 4	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*
Age 5	*0.97,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*
Age 6	*1.00,0.93,0.84*	*1.00,0.90,0.80*	*1.00,0.85,0.78*	*1.00,0.84,0.77*	*1.00,0.84,0.75*	*1.00,0.82,0.74*	*1.00,0.85,0.75*	*1.00,0.84,0.72*
Age 7+	*1.00,0.75,0.25*	*1.00,0.70,0.23*	*1.00,0.70,0.21*	*1.00,0.68,0.20*	*1.00,0.68,0.21*	*1.00,0.65,0.21*	*1.00,0.69,0.21*	*1.00,0.69,0.20*
Recr Discards (by block)								
Age 0	*0.16,0.40,0.21*	*0.16,0.40,0.19*	*0.15,0.40,0.19*	*0.15,0.40,0.18*	*0.16,0.41,0.19*	*0.16,0.40,0.19*	*0.16,0.40,0.19*	*0.16,0.40,0.19*
Age 1	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*	*1.00,1.00,1.00*
Age 2	*0.17,0.81,1.00*	*0.17,0.80,0.50*	*0.17,0.80,0.50*	*0.17,0.80,0.50*	*0.17,0.80,0.50*	*0.17,0.80,0.50*	*0.17,0.80,0.50*	*0.16,0.81,0.50*
Age 3	*0.08,0.16,0.39*	*0.08,0.16,0.35*	*0.08,0.16,0.35*	*0.08,0.16,0.35*	***0.08,0.16,0.40***	*0.08,0.16,0.40*	*0.06,0.16,0.40*	*0.08,0.16,0.39*
Age 4	*0.09,0.10,0.23*	*0.09,0.10,0.22*	*0.09,0.10,0.22*	*0.09,0.10,0.22*	*0.09,0.10,0.22*	*0.09,0.10,0.22*	*0.09,0.10,0.22*	*0.09,0.10,0.22*
Age 5	*0.07,0.10,0.13*	*0.07,0.10,0.12*	*0.07,0.10,0.12*	*0.07,0.10,0.12*	*0.07,0.10,0.11*	*0.07,0.10,0.11*	*0.10,0.10,0.11*	*0.07,0.10,0.11*
Age 6	*0.10,0.10,0.09*	*0.10,0.10,0.09*	*0.10,0.10,0.09*	*0.10,0.10,0.09*	*0.10,0.10,0.09*	*0.10,0.10,0.09*	*0.10,0.10,0.09*	*0.10,0.10,0.09*
Age 7+	*0.10,0.10,0.08*	*0.10,0.10,0.08*	*0.10,0.10,0.08*	*0.10,0.10,0.08*	*0.10,0.10,0.08*	*0.10,0.10,0.08*	*0.10,0.10,0.08*	*0.10,0.10,0.08*

Table A54 continued.

ESTIMATES								
F								
F 1963	***0.54***	*0.55*	*0.56*	*0.58*	*0.58*	***0.65***	*0.53*	*0.61*
F 1984	***0.81***	*0.85*	*0.83*	*0.83*	*0.84*	***0.94***	*0.85*	*0.83*
F 1994	***1.41***	*1.46*	*1.46*	*1.39*	*1.40*	***1.53***	*1.39*	*1.36*
F 2000	***0.21***	*0.23*	*0.22*	*0.20*	*0.20*	***0.18***	*0.21*	***0.17***
F 2007	***0.08***	*0.08*	*0.08*	*0.08*	*0.08*	*0.09*	*0.08*	*0.07*
F 2011	***0.07***	*0.07*	*0.07*	*0.07*	*0.07*	*0.08*	*0.07*	*0.06*
F 2014	***0.10***	*0.11*	*0.11*	*0.11*	*0.11*	***0.13***	*0.11*	*0.10*
Age 0								
Age 0 1963	***96***	*95*	*96*	*100*	*99*	***97***	*99*	*104*
Age 0 1984	***135***	*138*	*130*	***137***	***142***	***132***	*139*	*142*
Age 0 1994	*59*	*58*	*61*	*63*	*61*	*61*	*63*	*61*
Age 0 2000	***148***	*148*	*149*	*152*	***149***	*146*	*146*	***175***
Age 0 2007	***203***	*203*	*211*	*214*	*215*	*218*	*211*	***244***
Age 0 2011	***155***	*151*	*153*	*154*	***161***	***142***	*158*	*174*
Age 0 2014	***112***	*110*	*104*	***142***	*140*	***112***	*137*	*138*
SSB								
SSB 1963	*70*	*70*	*69*	*66*	*66*	*68*	*61*	*62*
SSB 1984	*12*	*11*	*12*	*12*	*12*	*11*	*12*	*12*
SSB 1994	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*
SSB 2000	*23*	*22*	*24*	*25*	*26*	*28*	*25*	***30***
SSB 2007	*164*	*167*	***143***	*151*	*149*	*142*	*145*	***182***
SSB 2011	***203***	*203*	*212*	*222*	*221*	*209*	*215*	***265***
SSB 2014	***199***	*199*	*203*	*210*	***196***	*183*	*190*	***232***

Table A55. Summary assessment results; Spawning Stock Biomass (SSB) in metric tons (mt); Recruitment (R) at age 0 in millions; Fishing Mortality (F) for age of peak selection (S = 1) age 3.

Year	SSB	R	F
1984	11,479	132	0.936
1985	15,031	127	0.884
1986	14,341	82	1.054
1987	11,320	63	1.074
1988	8,602	118	1.101
1989	7,459	67	0.962
1990	10,361	100	0.812
1991	8,413	89	1.359
1992	6,949	36	1.355
1993	5,563	37	1.339
1994	4,202	61	1.527
1995	3,624	35	1.194
1996	5,412	29	1.013
1997	5,438	78	0.801
1998	6,592	97	0.510
1999	13,340	222	0.273
2000	27,792	146	0.177
2001	53,561	138	0.103
2002	80,358	84	0.081
2003	104,409	84	0.095
2004	110,325	127	0.089
2005	120,631	197	0.061
2006	130,122	222	0.084
2007	142,113	218	0.086
2008	163,555	185	0.053
2009	178,334	98	0.068
2010	208,869	107	0.079
2011	209,171	142	0.079
2012	205,496	75	0.086
2013	199,034	61	0.120
2014	182,915	112	0.127

Table A56. January 1 population number (N, 000s) estimates at age.

	Age							
	0	1	2	3	4	5	6	7+
1984	132,145	72,707	47,106	19,913	8,571	3,625	1,960	2,335
1985	127,048	99,215	47,336	16,528	6,394	2,849	1,397	1,583
1986	82,378	98,108	66,974	18,520	5,592	2,110	1,067	1,071
1987	63,329	63,288	62,666	22,289	5,283	1,472	631	613
1988	117,526	48,339	40,834	20,794	6,232	1,419	459	369
1989	67,313	89,323	31,241	13,379	5,661	1,665	446	246
1990	99,664	52,865	60,903	12,216	4,187	1,644	550	218
1991	88,934	77,415	36,292	25,429	4,441	1,485	655	293
1992	36,121	66,654	46,445	9,351	5,348	874	350	209
1993	37,481	27,786	43,464	14,066	1,974	1,082	219	129
1994	61,448	28,826	18,183	13,329	3,020	409	277	82
1995	34,697	47,415	18,705	5,131	2,370	510	88	70
1996	29,394	26,715	31,826	6,334	1,272	582	152	44
1997	78,245	22,979	18,430	12,374	1,882	365	196	62
1998	97,292	62,716	16,764	10,121	4,547	688	142	139
1999	221,646	78,535	47,583	10,627	4,976	2,235	352	179
2000	145,857	180,151	61,725	33,670	6,624	3,077	1,405	371
2001	137,641	118,880	143,964	45,745	23,093	4,468	2,088	1,276
2002	84,021	111,974	94,347	108,654	33,792	17,007	3,308	2,581
2003	84,103	68,421	89,374	72,542	82,034	25,510	12,905	4,608
2004	127,430	68,593	55,165	69,595	53,988	60,713	18,969	13,485
2005	197,175	103,556	54,218	41,653	52,129	40,471	45,768	25,254
2006	221,875	160,493	82,989	42,484	32,088	40,202	31,350	56,364
2007	217,652	180,438	127,536	64,110	31,984	24,216	30,402	69,858
2008	184,694	177,026	143,534	98,301	48,185	24,079	18,264	79,905
2009	98,308	150,283	140,918	111,936	76,356	37,577	18,811	79,258
2010	107,141	79,663	117,355	106,495	85,639	59,115	29,172	78,993
2011	141,523	86,802	62,159	88,502	80,586	65,439	45,302	86,619
2012	75,149	115,086	68,981	47,781	66,981	61,340	49,896	105,457
2013	60,549	61,129	91,605	53,072	35,898	50,528	46,351	123,923
2014	112,436	49,179	48,375	69,104	38,540	26,161	36,895	134,653

Table A57. Fishing mortality (F) estimates at age.

	Age							
	0	1	2	3	4	5	6	7+
1984	0.087	0.229	0.847	0.936	0.901	0.754	0.816	0.783
1985	0.058	0.193	0.738	0.884	0.909	0.782	0.836	0.812
1986	0.064	0.248	0.900	1.054	1.135	1.007	1.061	1.037
1987	0.070	0.238	0.903	1.074	1.115	0.966	1.029	1.001
1988	0.074	0.236	0.916	1.101	1.120	0.958	1.026	0.996
1989	0.042	0.183	0.739	0.962	1.036	0.908	0.963	0.944
1990	0.053	0.176	0.673	0.812	0.836	0.720	0.769	0.748
1991	0.088	0.311	1.156	1.359	1.425	1.245	1.321	1.287
1992	0.062	0.228	0.995	1.355	1.398	1.185	1.276	1.244
1993	0.063	0.224	0.982	1.339	1.375	1.164	1.254	1.222
1994	0.059	0.233	1.065	1.527	1.579	1.333	1.438	1.404
1995	0.061	0.199	0.883	1.194	1.204	1.008	1.091	1.061
1996	0.046	0.171	0.745	1.013	1.048	0.891	0.958	0.934
1997	0.021	0.115	0.399	0.801	0.806	0.747	0.436	0.365
1998	0.014	0.076	0.256	0.510	0.510	0.472	0.271	0.227
1999	0.007	0.041	0.146	0.273	0.281	0.264	0.166	0.138
2000	0.005	0.024	0.100	0.177	0.194	0.188	0.136	0.111
2001	0.006	0.031	0.081	0.103	0.106	0.101	0.070	0.057
2002	0.005	0.025	0.063	0.081	0.081	0.076	0.049	0.041
2003	0.004	0.015	0.050	0.095	0.101	0.096	0.064	0.053
2004	0.007	0.035	0.081	0.089	0.088	0.083	0.054	0.046
2005	0.006	0.021	0.044	0.061	0.060	0.055	0.033	0.028
2006	0.007	0.030	0.058	0.084	0.081	0.079	0.049	0.016
2007	0.007	0.029	0.060	0.086	0.084	0.082	0.051	0.017
2008	0.006	0.028	0.049	0.053	0.049	0.047	0.030	0.010
2009	0.010	0.047	0.080	0.068	0.056	0.053	0.034	0.012
2010	0.011	0.048	0.082	0.079	0.069	0.066	0.042	0.015
2011	0.007	0.030	0.063	0.079	0.073	0.071	0.043	0.014
2012	0.006	0.028	0.062	0.086	0.082	0.080	0.048	0.016
2013	0.008	0.034	0.082	0.120	0.116	0.114	0.069	0.022
2014	0.009	0.039	0.090	0.127	0.122	0.119	0.072	0.023

Table A58. Stock status of scup:
left- existing model and reference points from the previous 2008 DPSWG assessment with data through 2007 [2008_DPSWG_IAA_IND08];
center – existing model with data through 2014 [2015_SAW_60_IAA_IND08]);
right - new model and reference points with data through 2014 [2015_SAW_60_S60_BASE_18].

Assessment Model	**2008_DPSWG IAA_IND08**	**2015_SAW_60 IAA_IND08**	**2015_SAW_60 S60_BASE_18**
NON-PARAMETRIC	(deterministic)	(deterministic)	(deterministic)
	M=0.20	M=0.20	M=0.20
	Full F = age 3-7+	Full F = age 3-7+	Full F = age 3
FMSY or Proxy	**F40%**	**F40%**	**F40%**
FMSY	0.177	0.177	0.220
MSY (mt)	16,161	16,161	11,752
SSBMSY(mt)	92,044	92,044	87,302
Fterm	0.054	0.049	0.127
Yterm	7,867	10,620	10,620
SSBterm	119,343	218,990	182,915
Fterm/FMSY	0.31	0.28	0.58
Yterm/MSY	0.49	0.66	0.90
SSBterm/SSBMSY	1.30	2.38	2.10

Figures

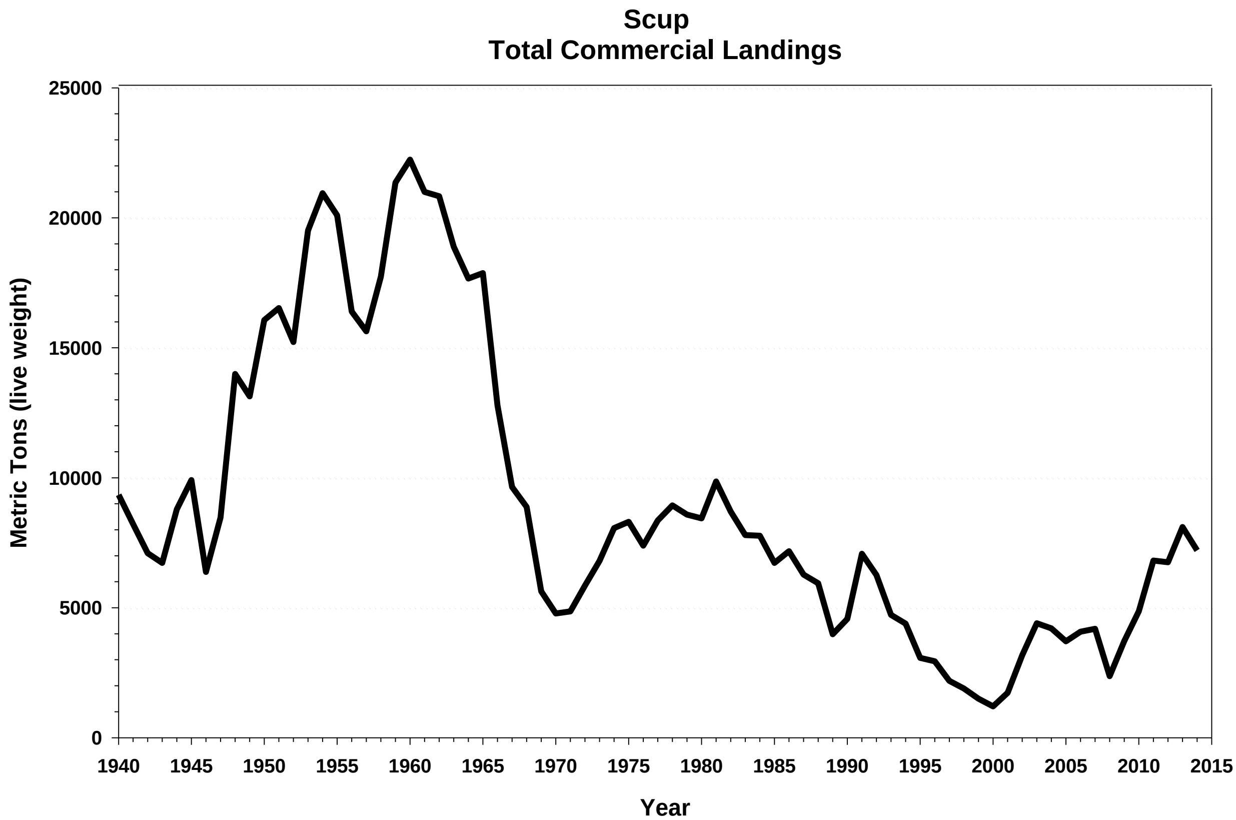


Figure A1. Total commercial fishery landings for scup.

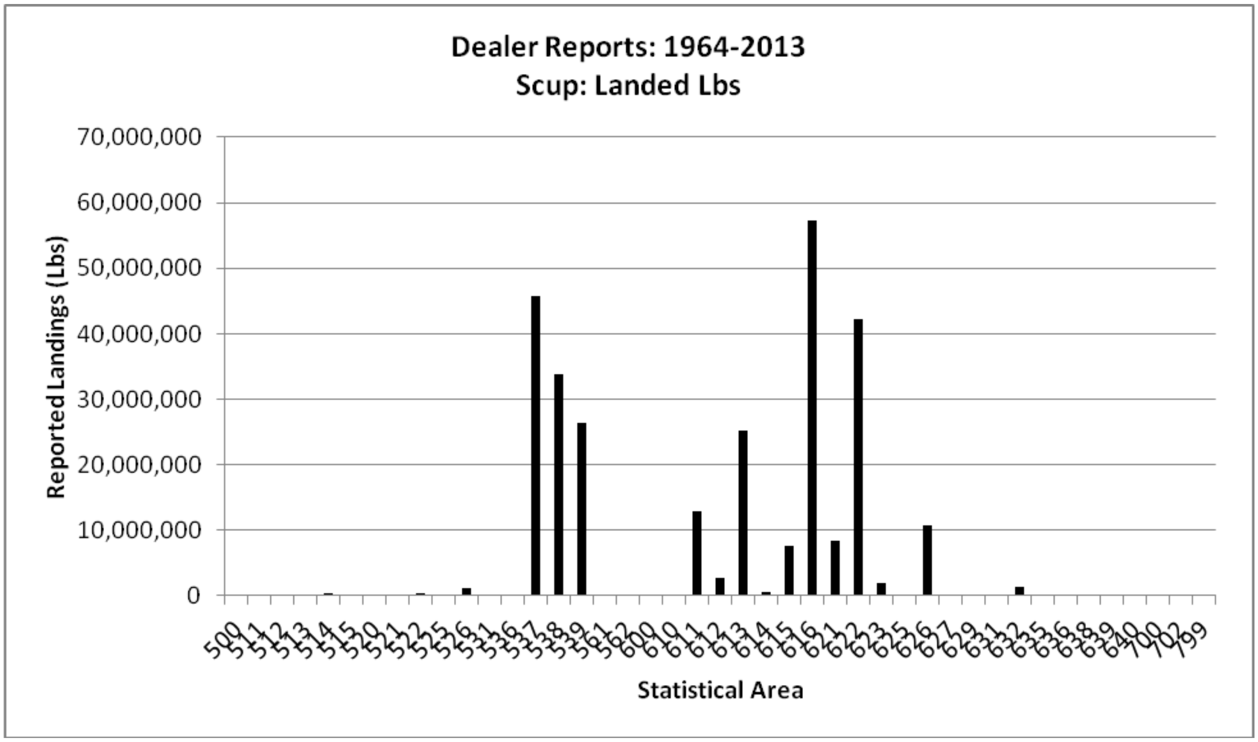


Figure A2. Commercial fishery dealer (port agent interviews before 1994; Vessel Trip Reports thereafter) reported distribution of scup landings by 3-digit statistical area.

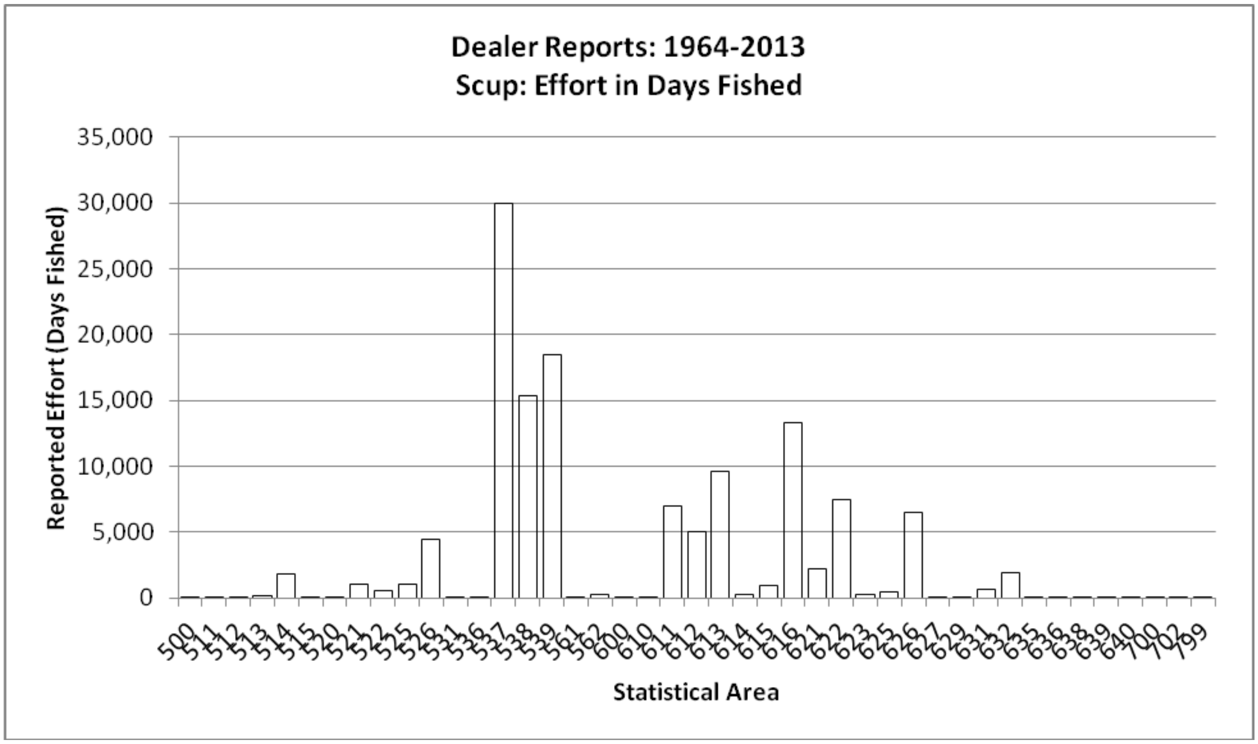


Figure A3. Commercial fishery dealer (port agent interviews before 1994; Vessel Trip Reports thereafter) reported distribution of scup fishing effort (days fished) by 3-digit statistical area.

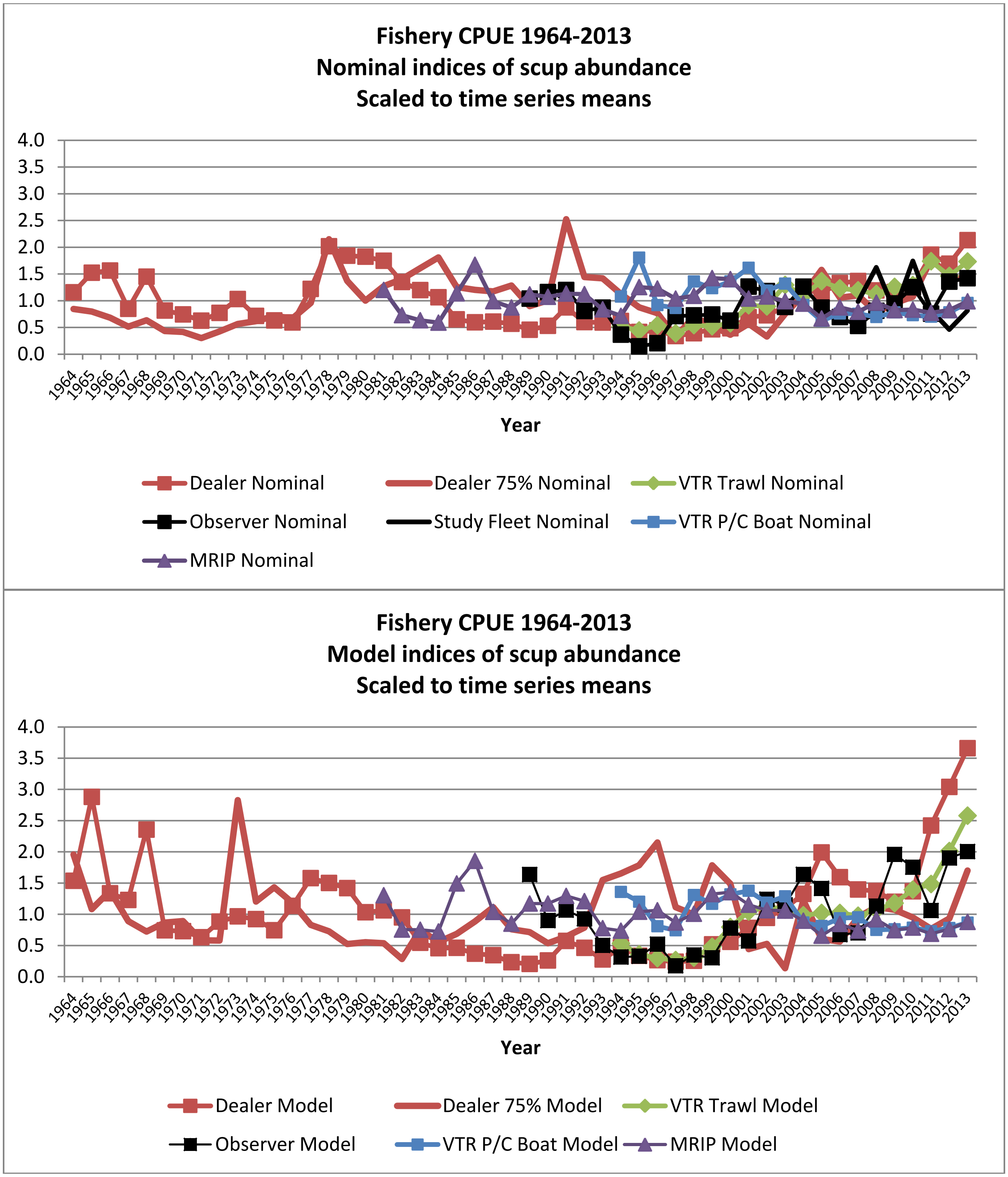


Figure A4. Fishery dependent indices of abundance for scup. Top panel are nominal (un-standardized) CPUE (total catch or landings) indices. Bottom panel are GLM standardized indices.

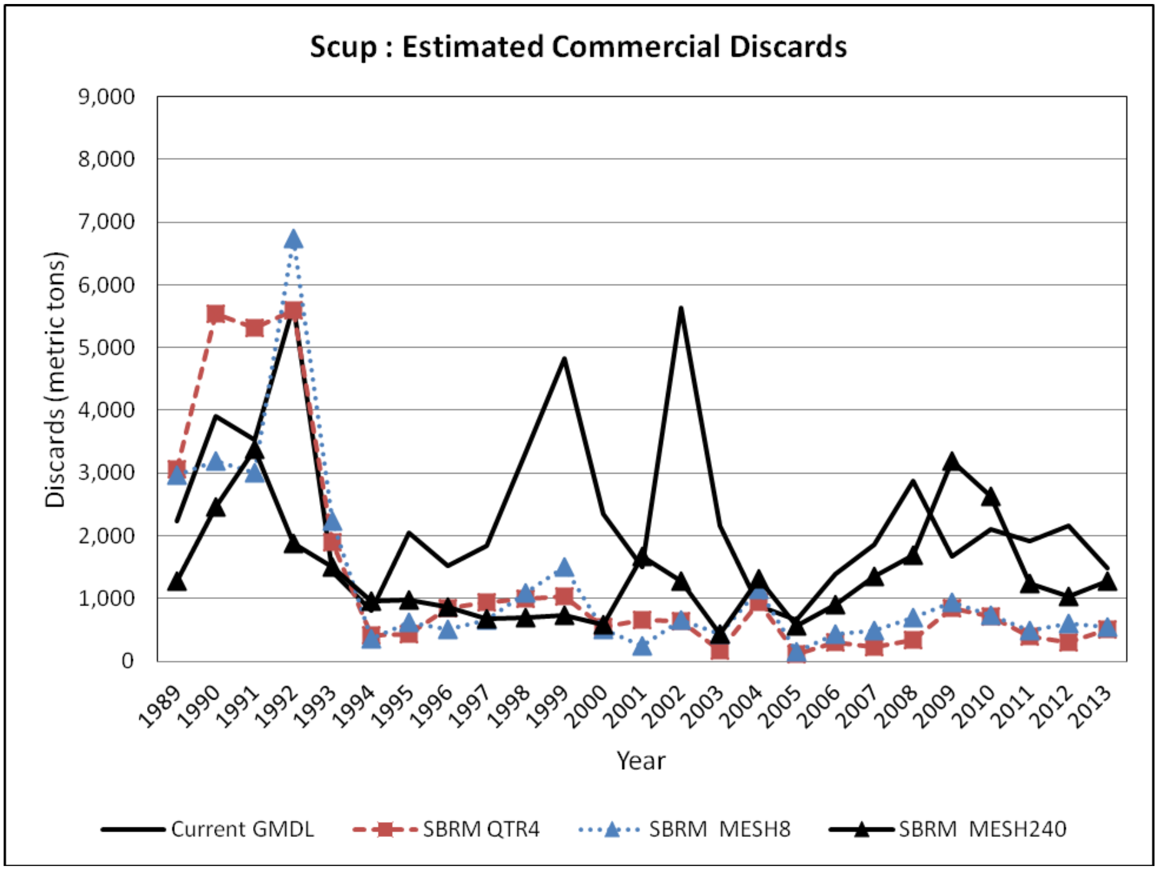


Figure A5. The three SBRM alternative estimates of discards compared with the current GMDL estimates of discards for 1989-2013.

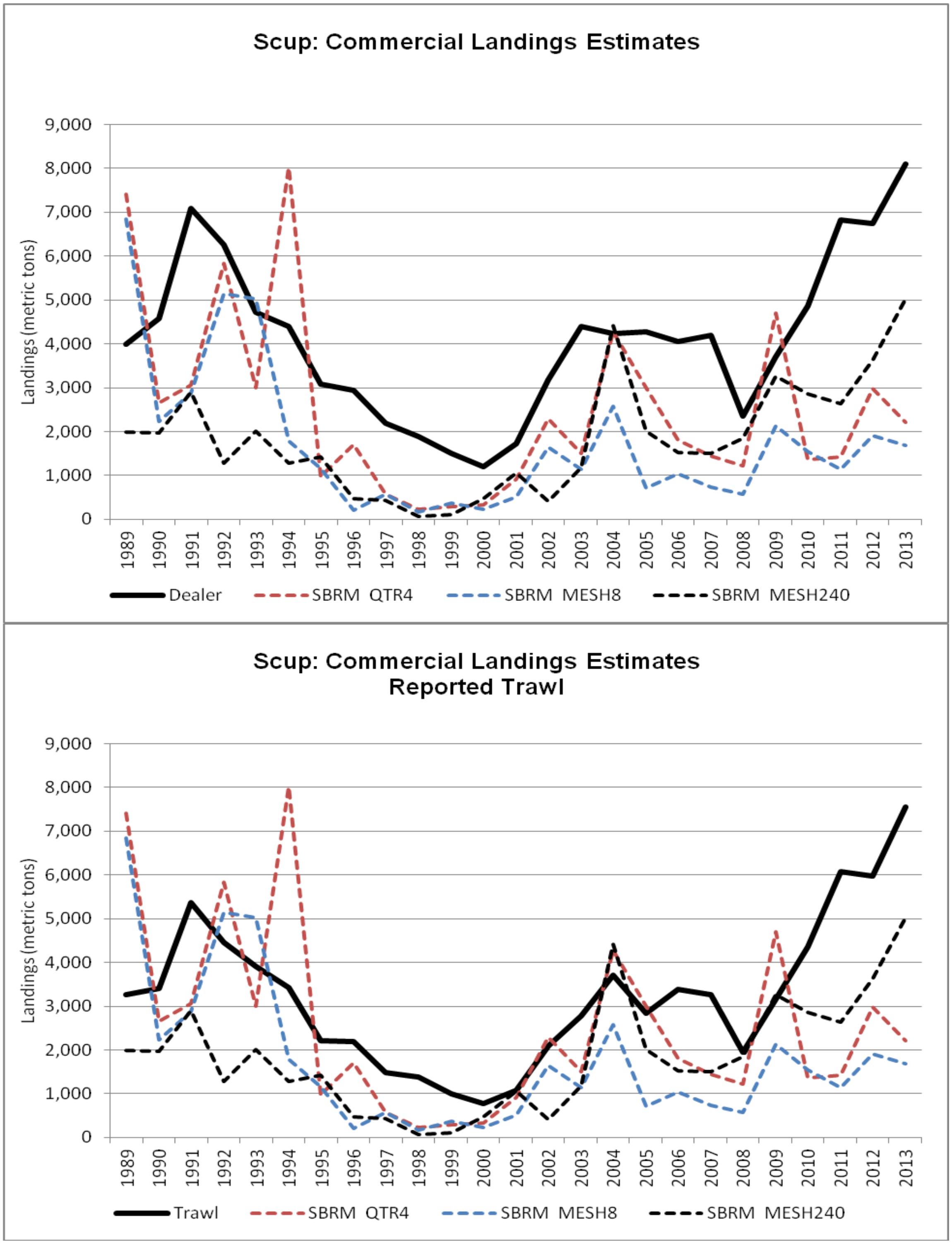


Figure A6. Top panel - the three SBRM alternative estimates of landings compared with the Dealer reported landings for 1989-2013; bottom panel - compared with the Dealer reported Trawl gear landings for 1989-2013

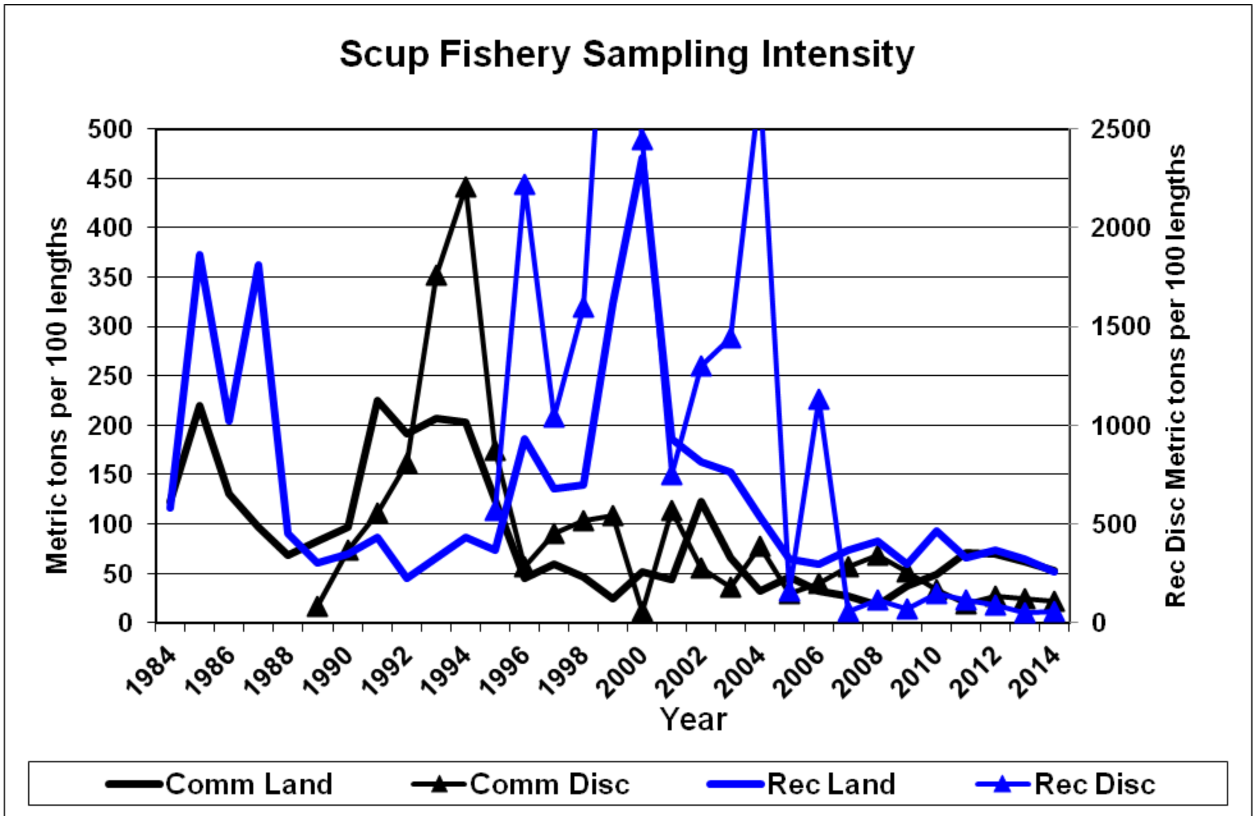


Figure A7. Summary fishery length sampling intensity expressed as metric tons of catch per 100 lengths sampled for consistency across fisheries.

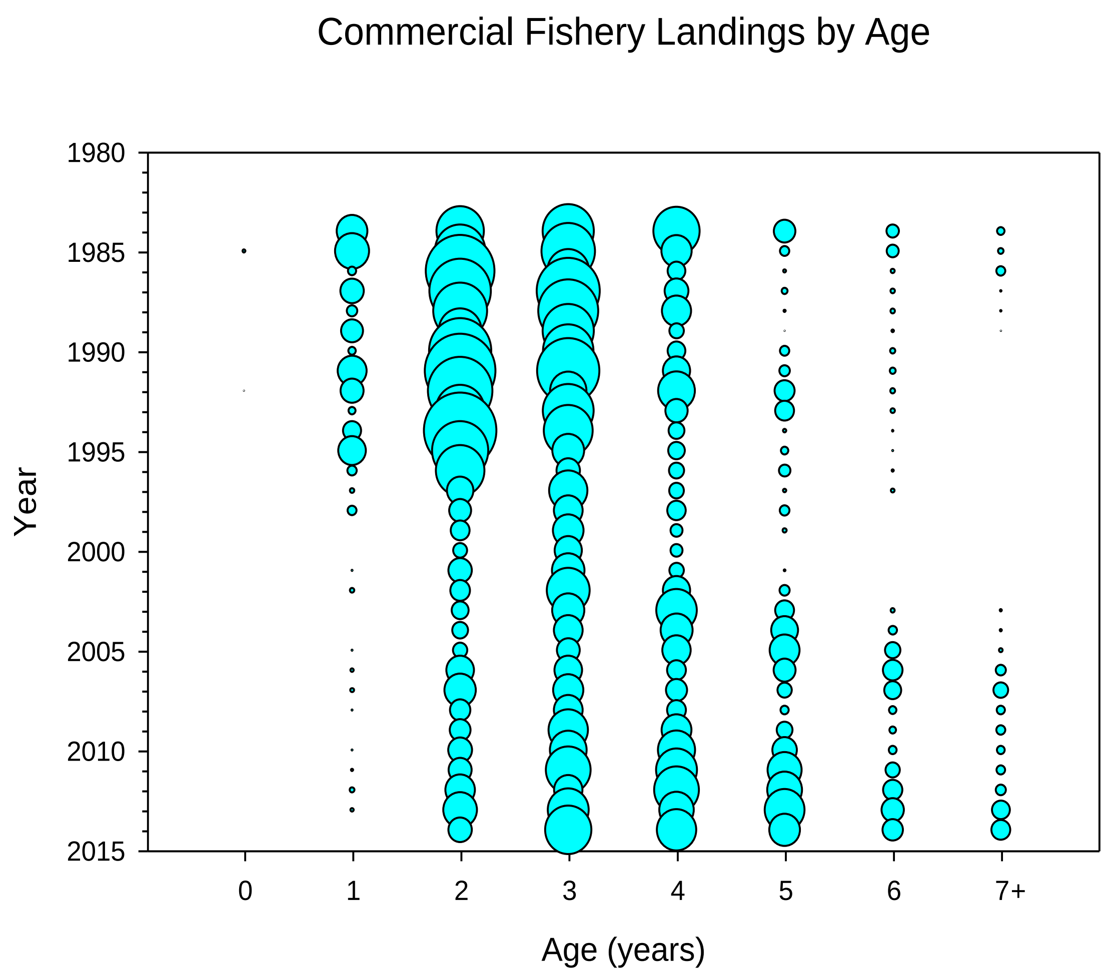


Figure A8. Commercial fishery landings by age for scup.

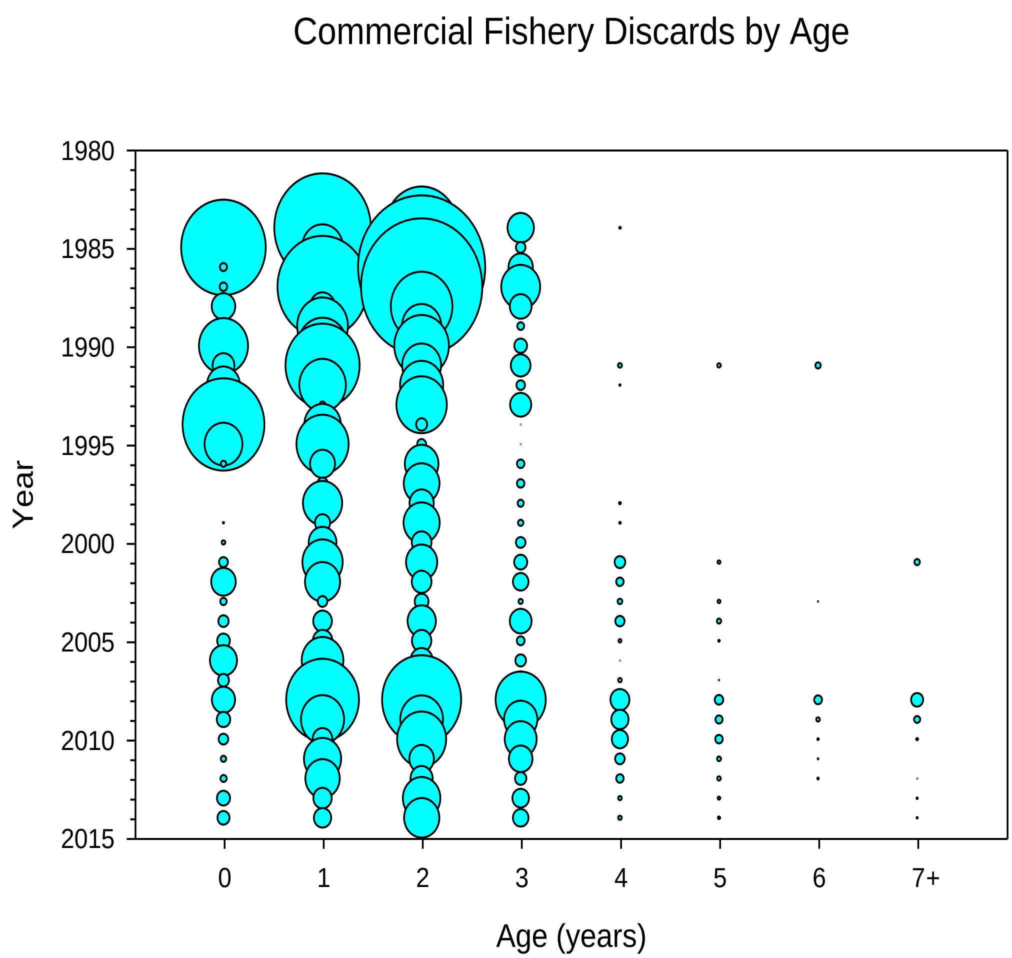


Figure A9. Commercial fishery discards by age for scup.

Figure A10. Recreational fishery landings by age for scup.

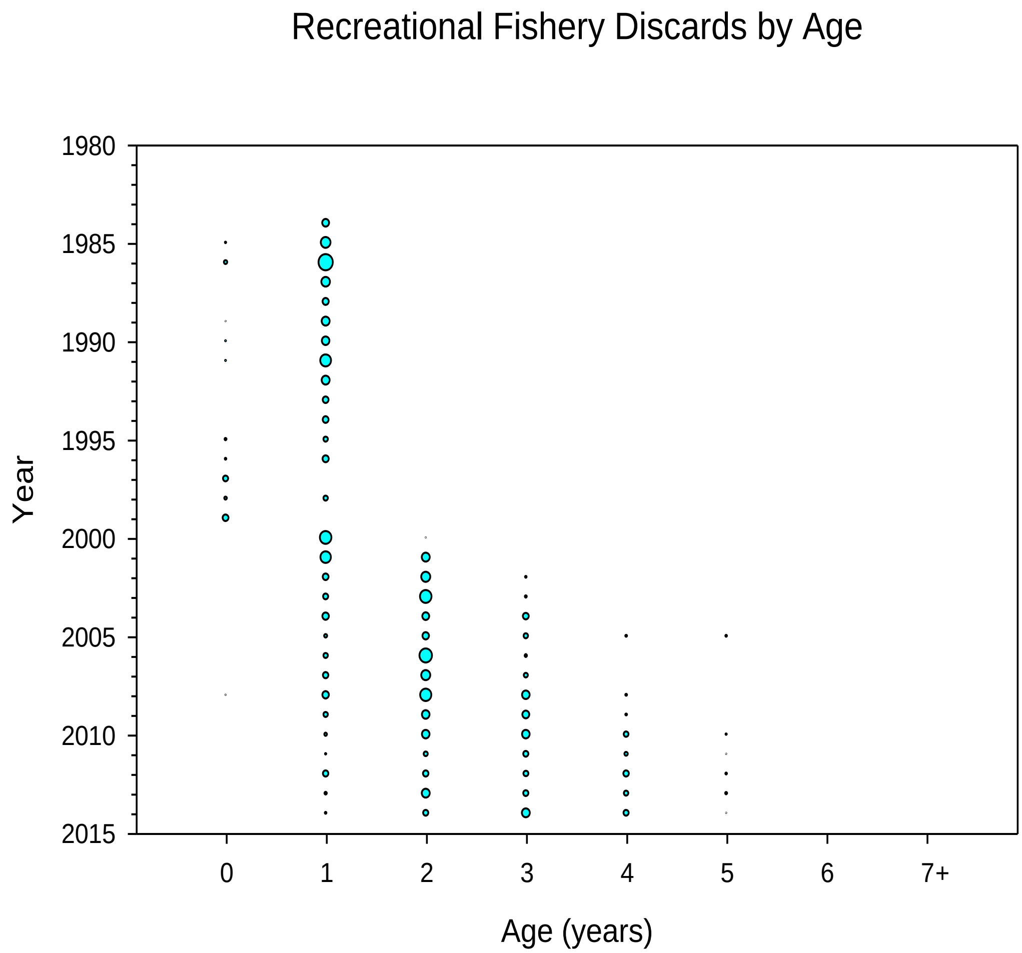


Figure A11. Recreational fishery discards by age for scup.

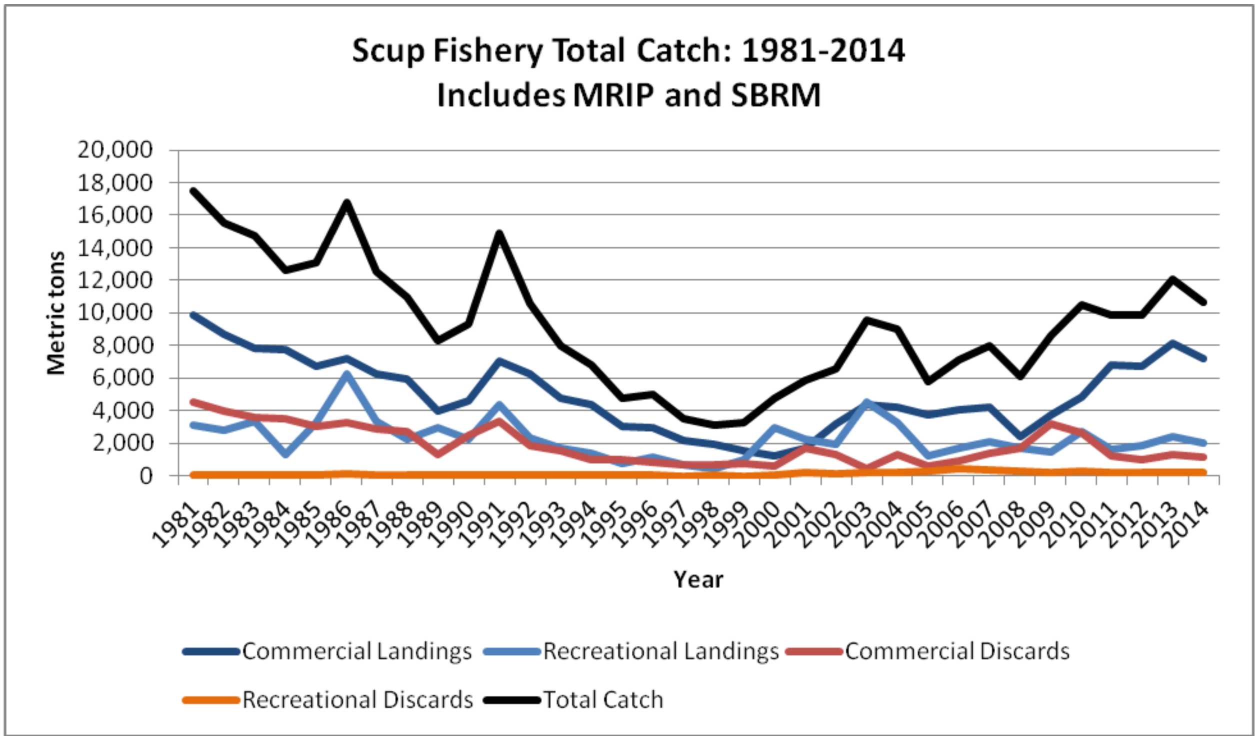


Figure A12. Scup fishery total catch. MRIP = Marine Recreational Information Program estimates of recreational catch; SBRM = Standardized Bycatch Reporting Method estimates of commercial fishery discards. Commercial landings are from Dealer reports.

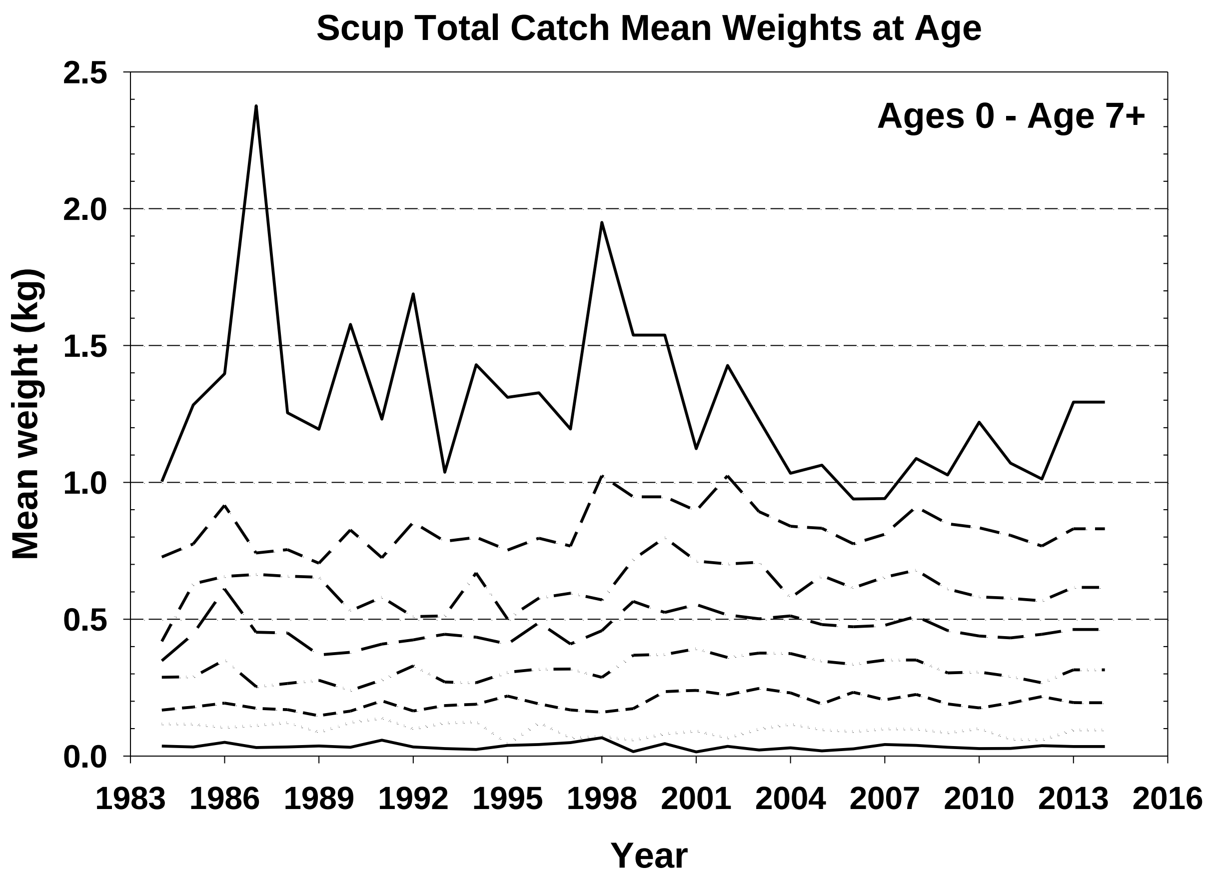


Figure A13. Scup fishery total catch mean weights at age.

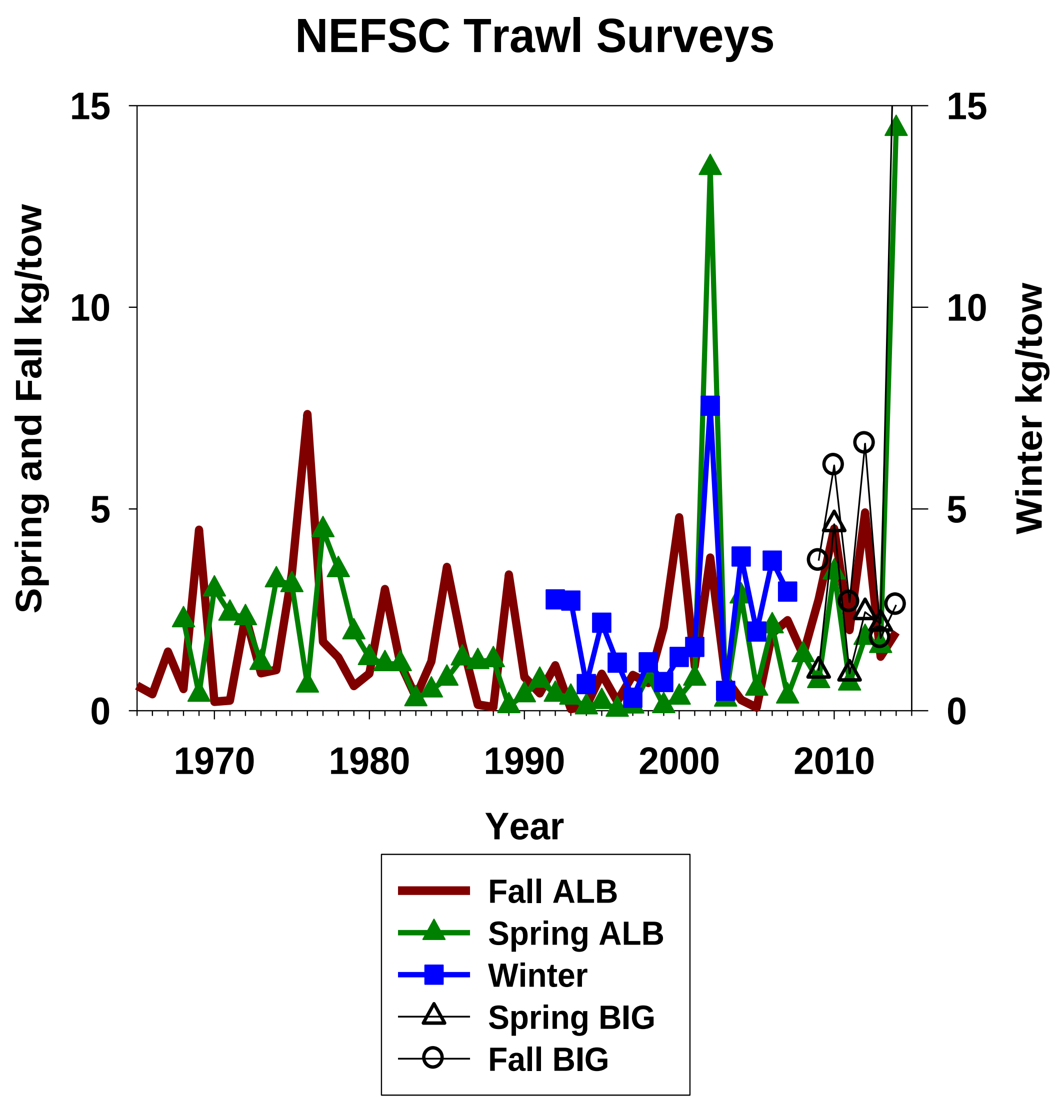


Figure A14. NEFSC winter, spring and fall biomass indices for scup, including FSV *Henry B. Bigelow* (BIG) indices and FSV *Albatross IV* (ALB) equivalents. Note spring 2014 BIG index is above the left hand y-axis scale.

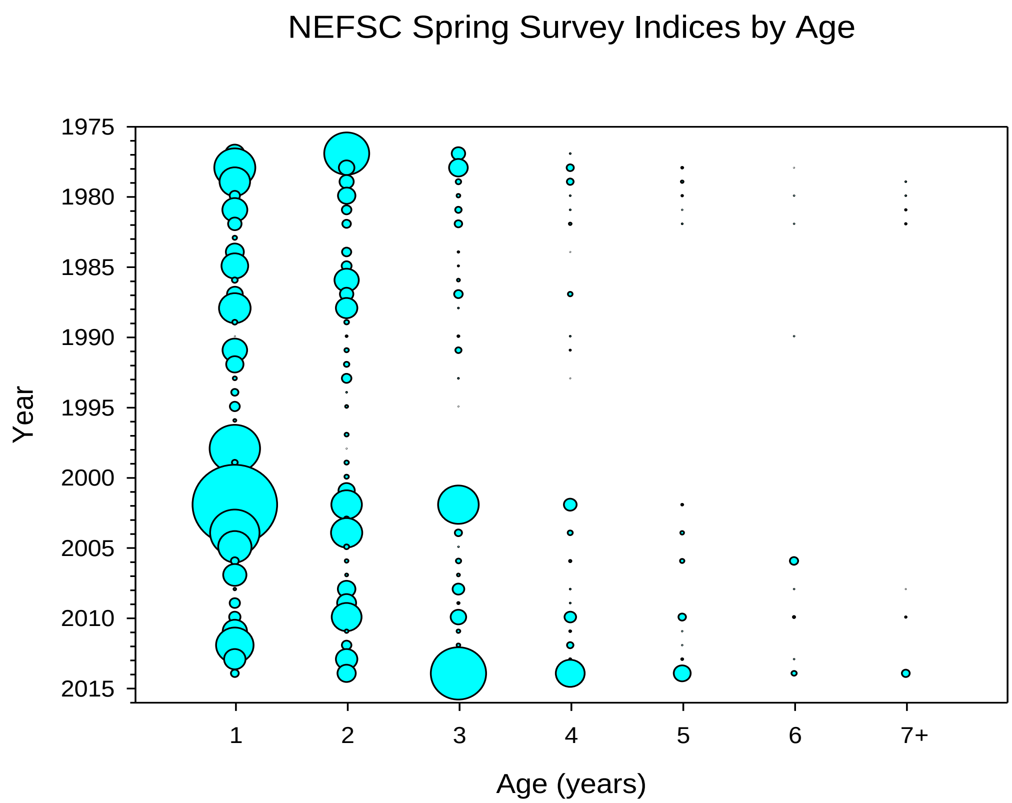


Figure A15. NEFSC spring survey indices by age for scup.

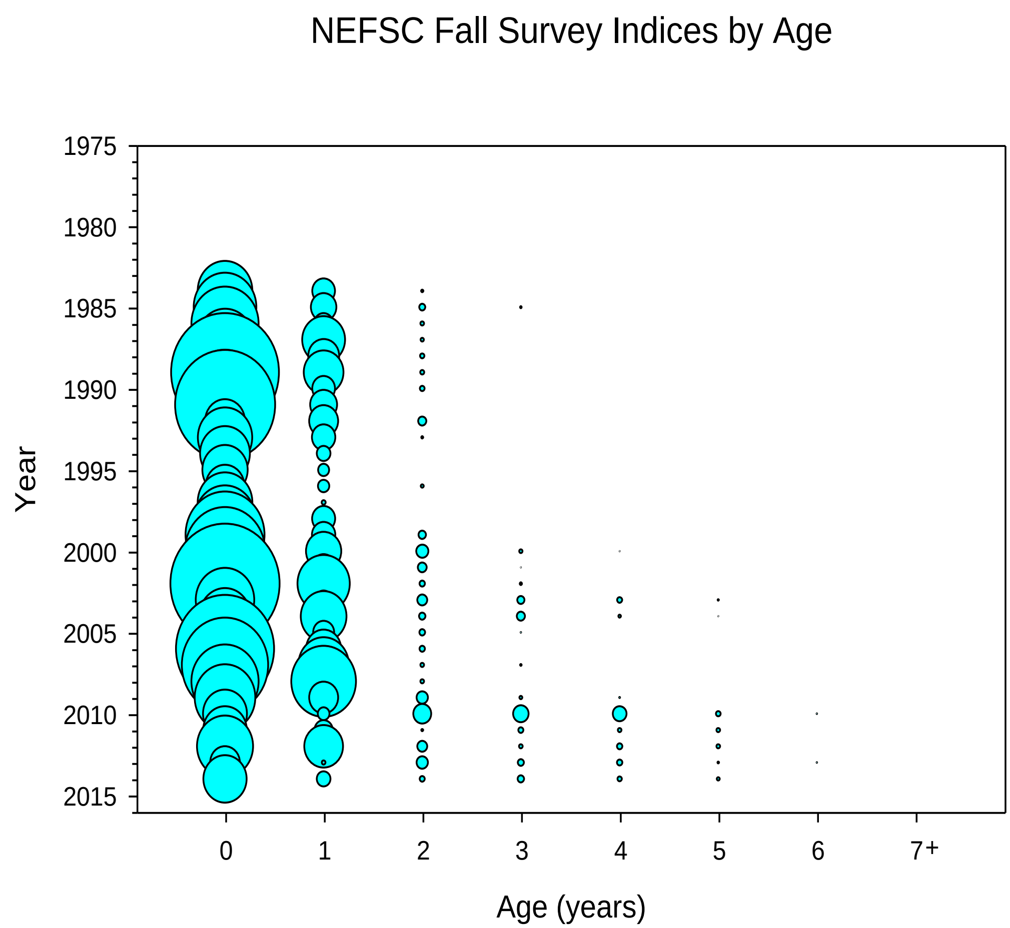


Figure A16. NEFSC fall survey indices by age for scup.

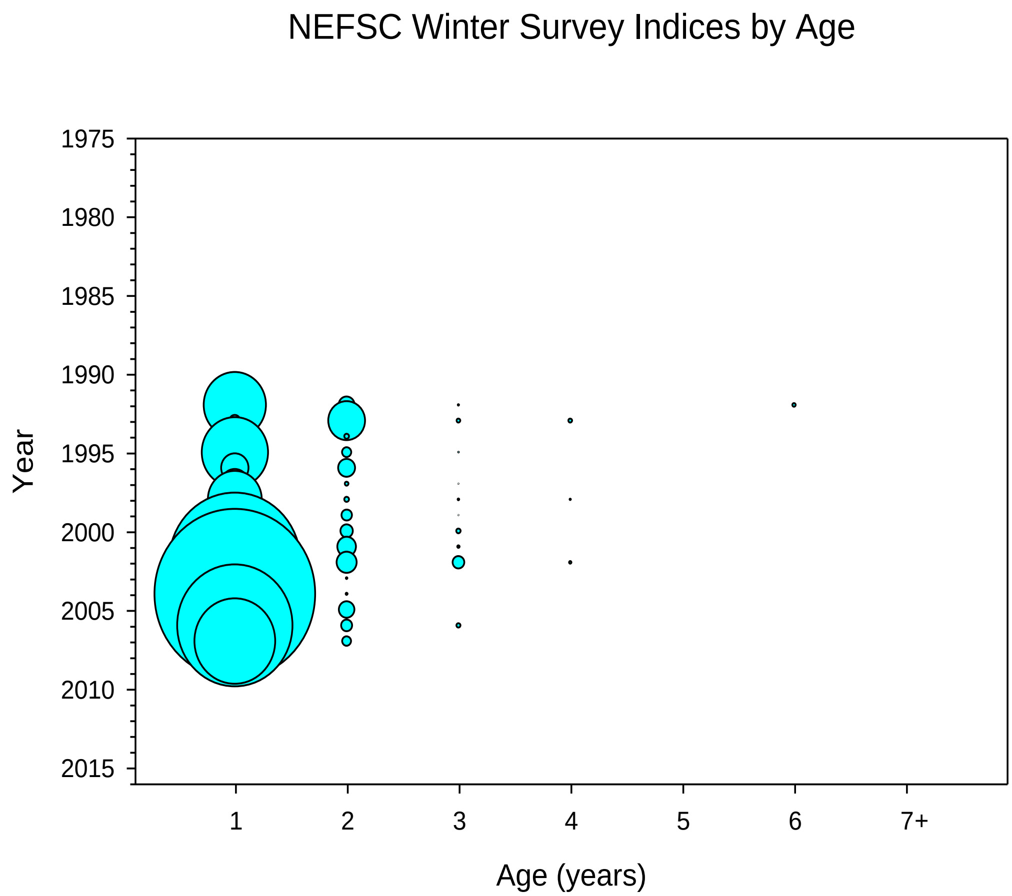


Figure A17. NEFSC winter survey indices by age for scup.

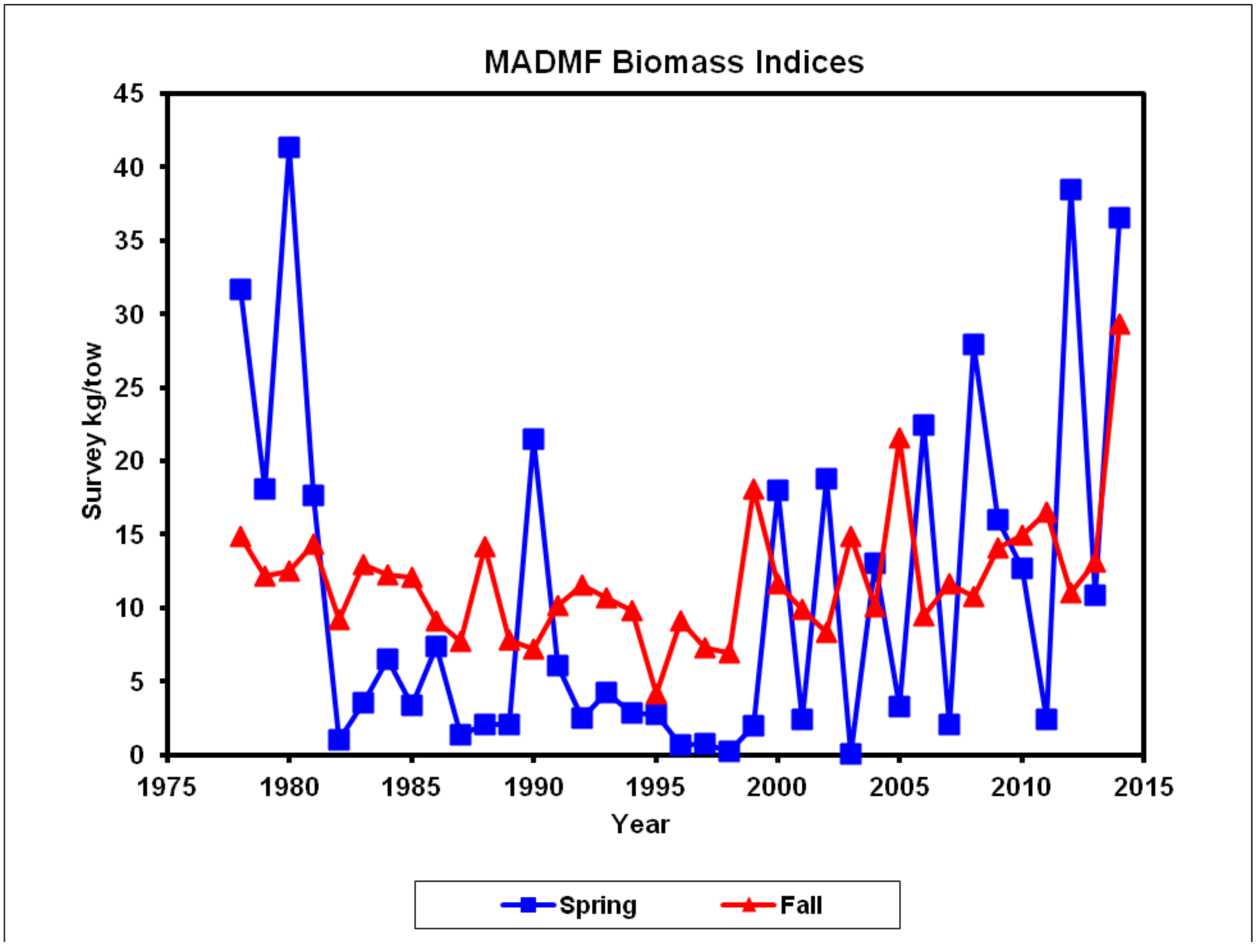


Figure A18. MADMF spring and fall survey aggregate biomass indices.

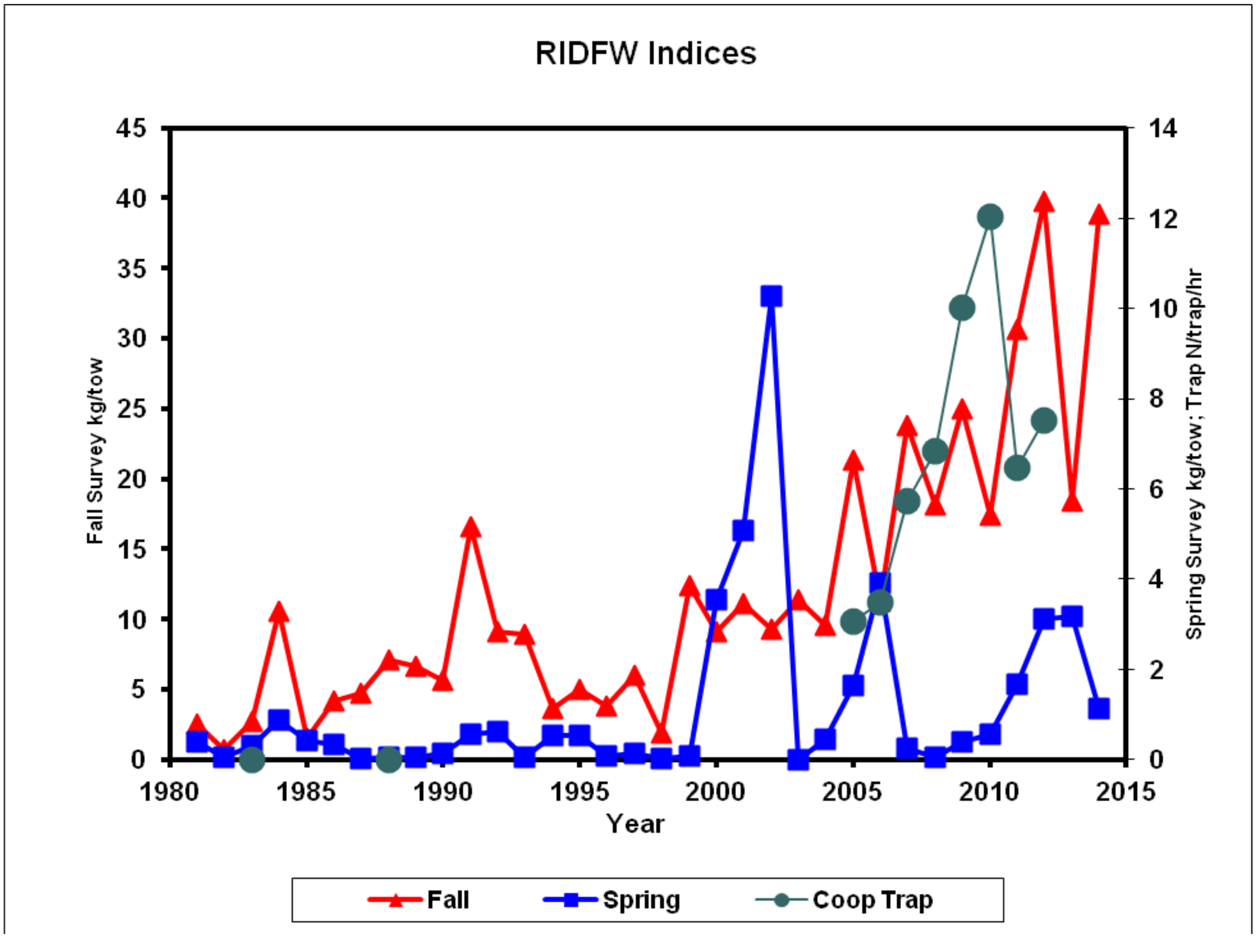


Figure A19. RIDFW spring and fall survey aggregate biomass indices.

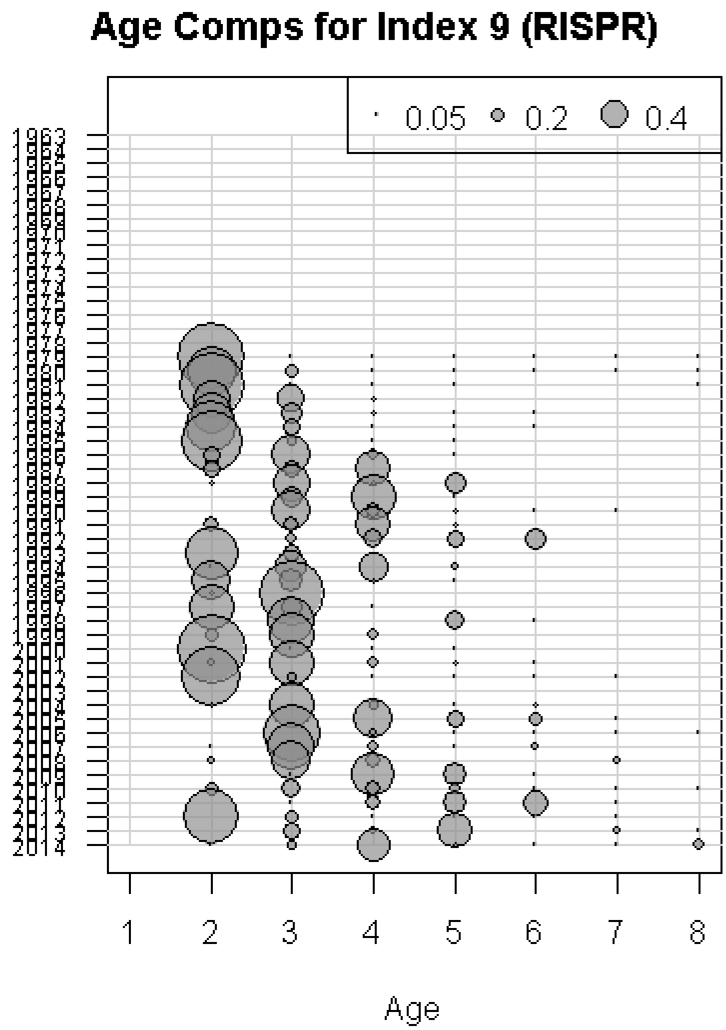


Figure A20. RIDFW spring survey indices by age for scup (plotted age 2 is true age 1, etc.).

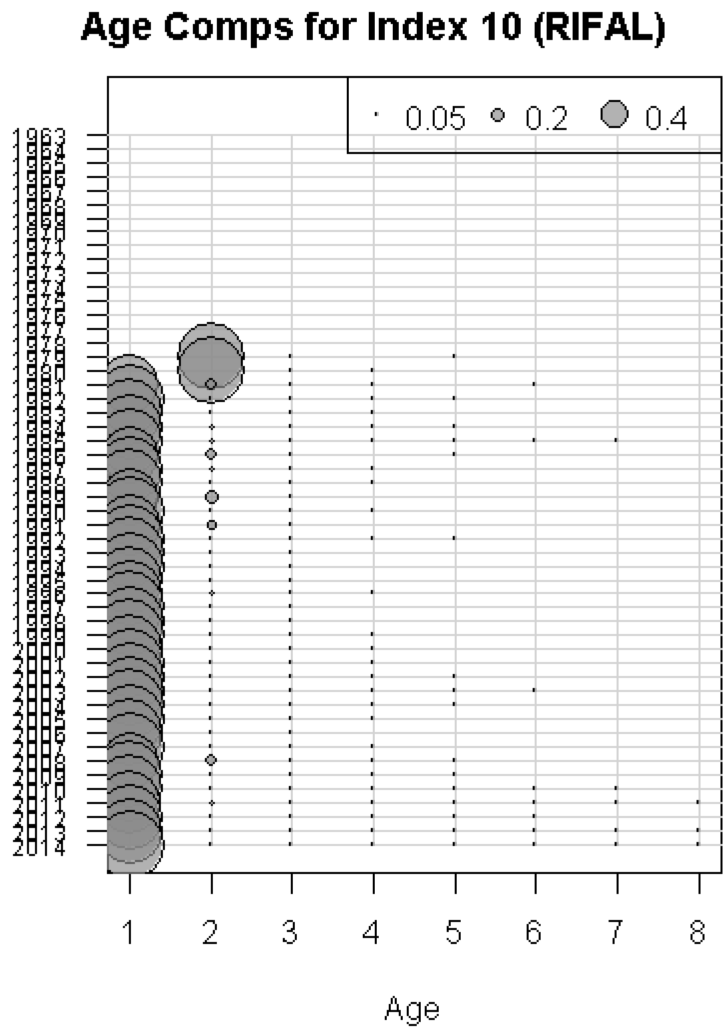


Figure A21. RIDFW fall survey indices by age for scup (plotted age 1 is true age 0, etc).

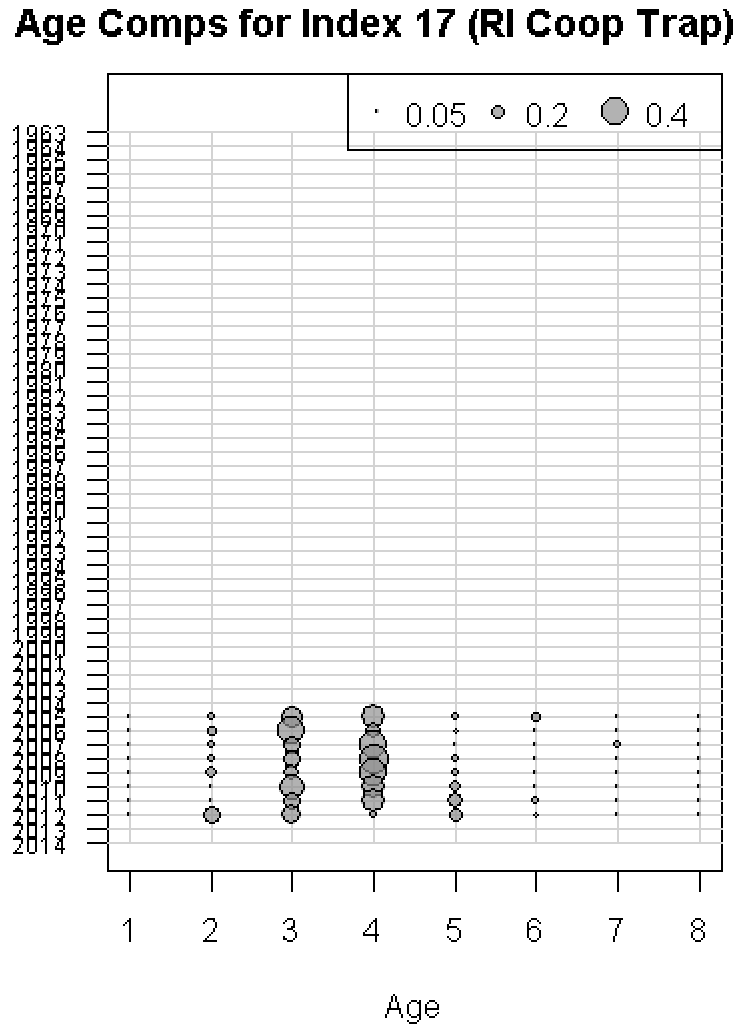


Figure A22. RIDFW cooperative trap survey indices by age for scup (plotted age 1 is true age 0, etc).

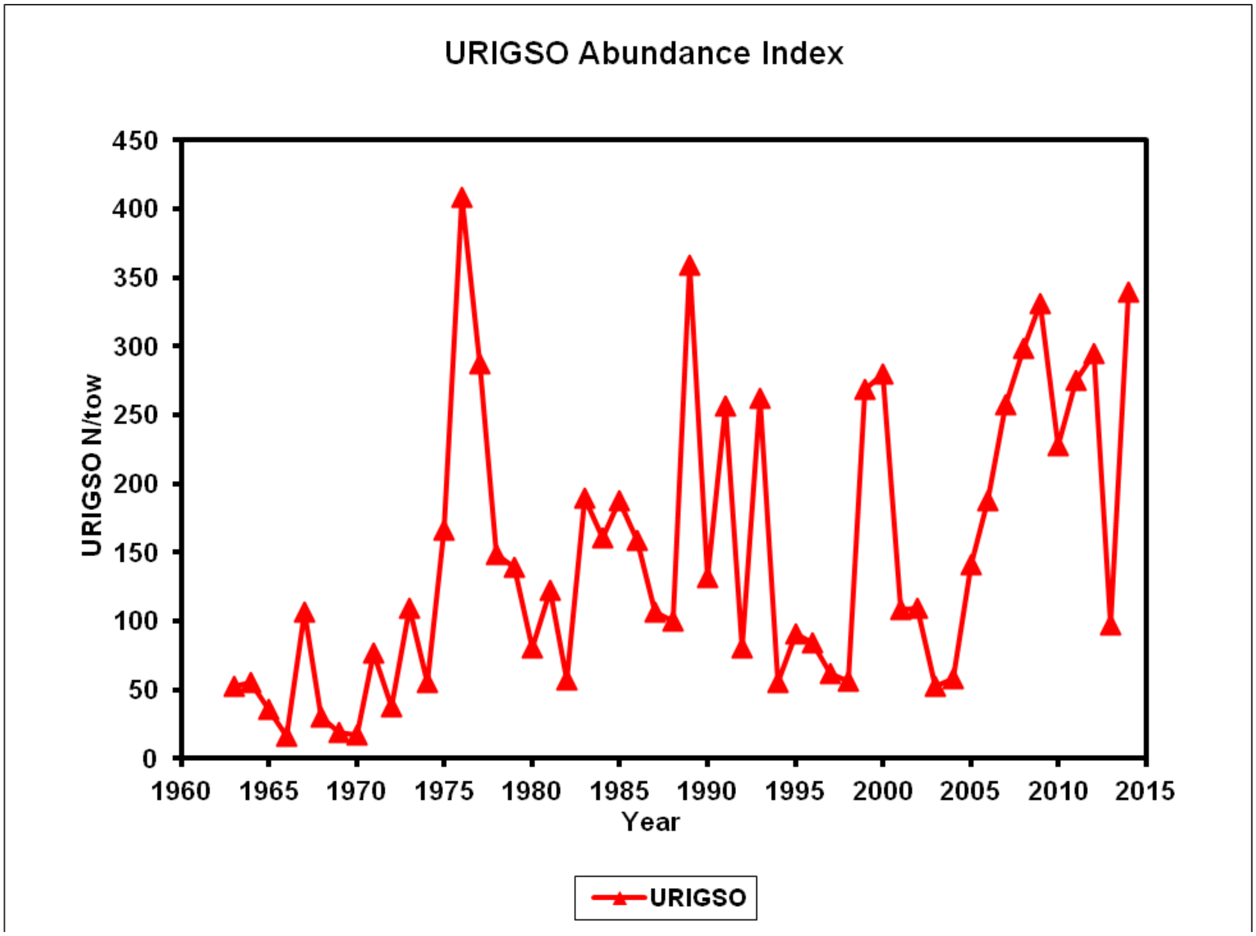


Figure A23. URIGSO survey aggregate abundance index.

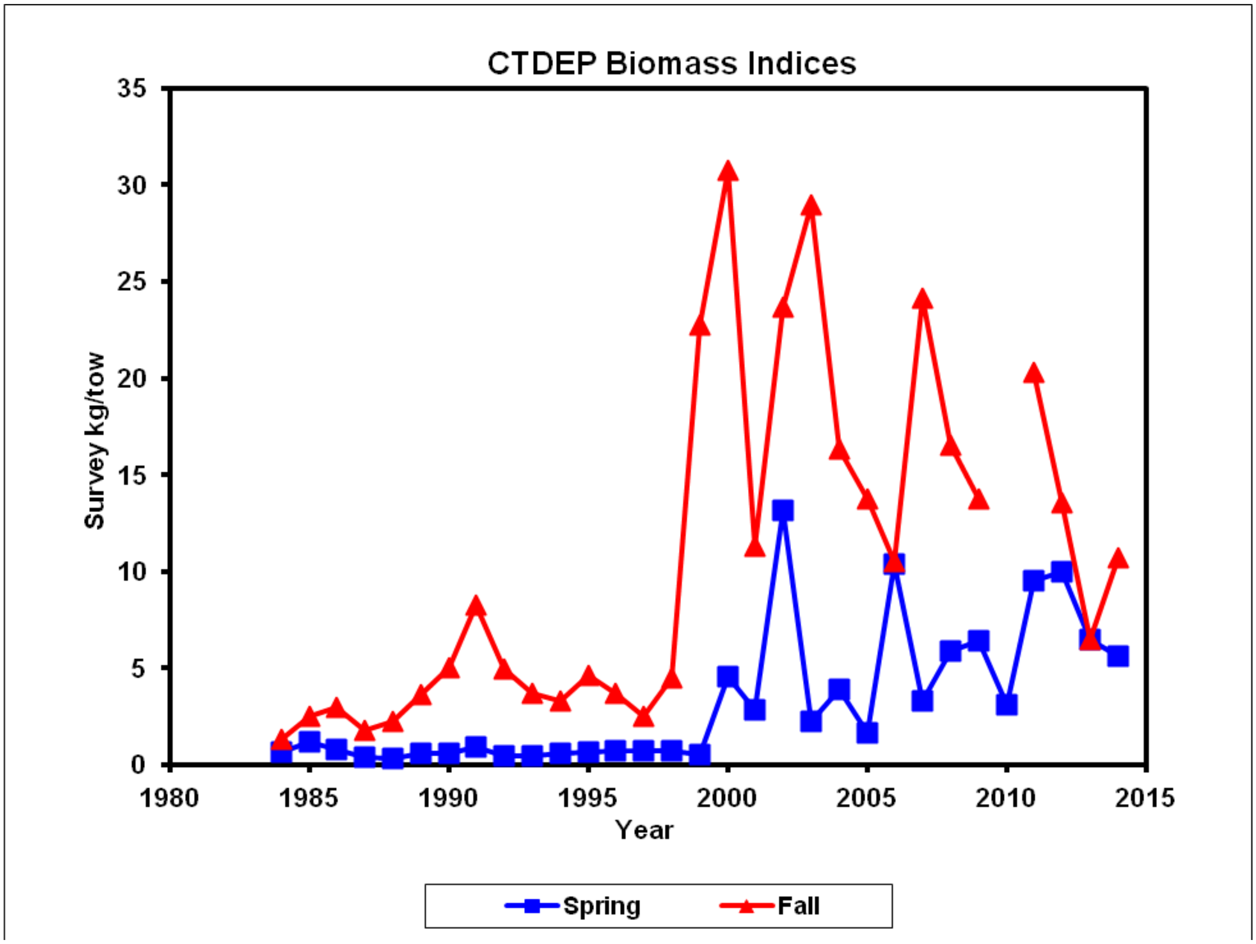


Figure A24. CTDEP spring and fall survey aggregate biomass indices.

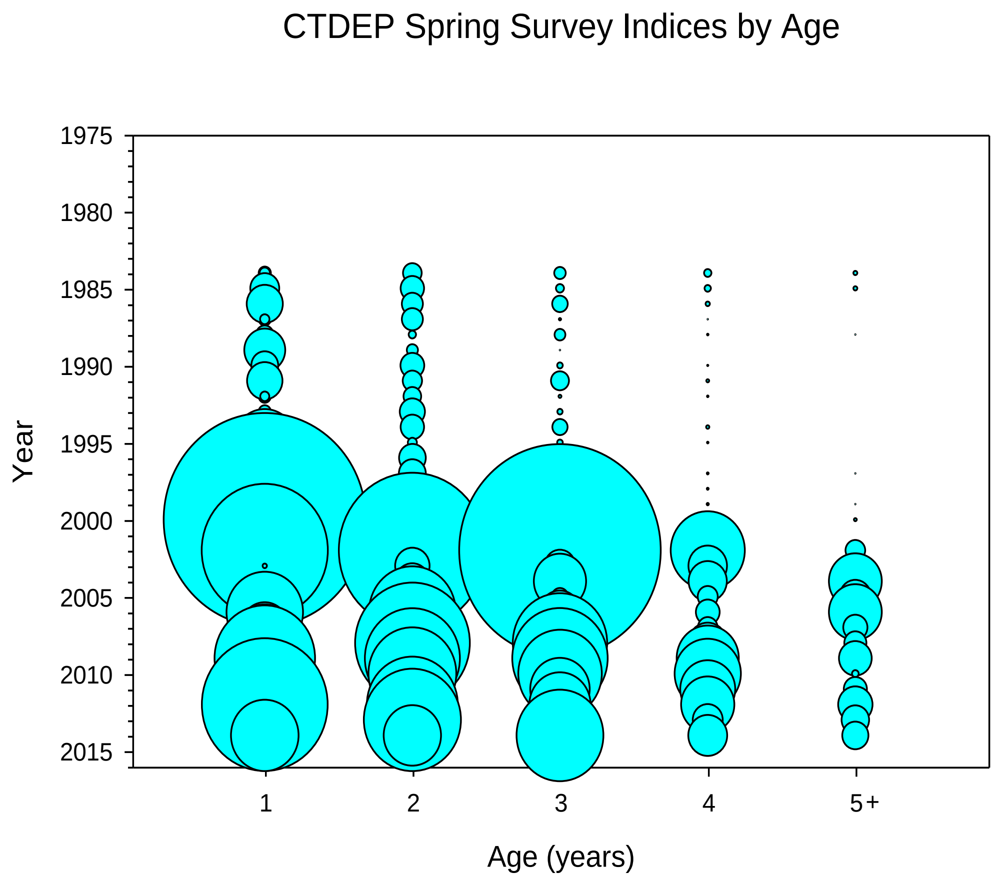


Figure A25. CTDEP spring survey indices by age for scup.

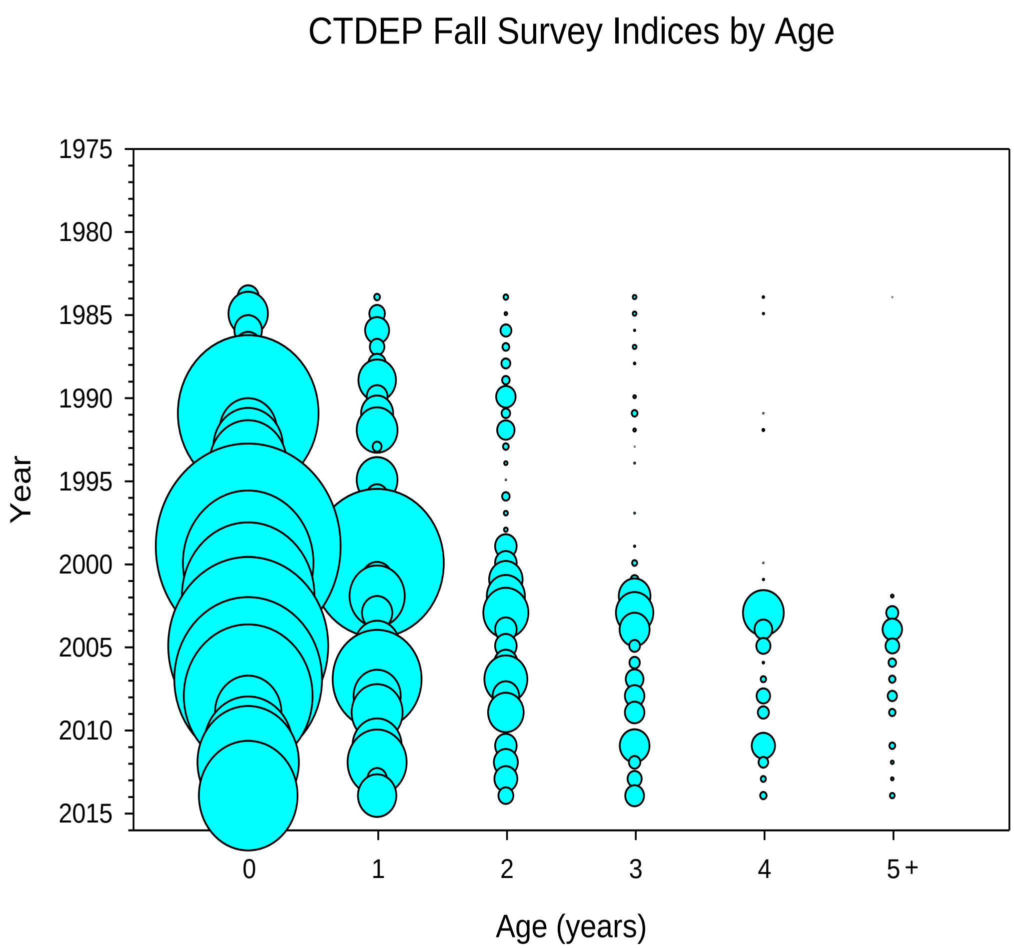


Figure A26. CTDEP fall survey indices by age for scup.

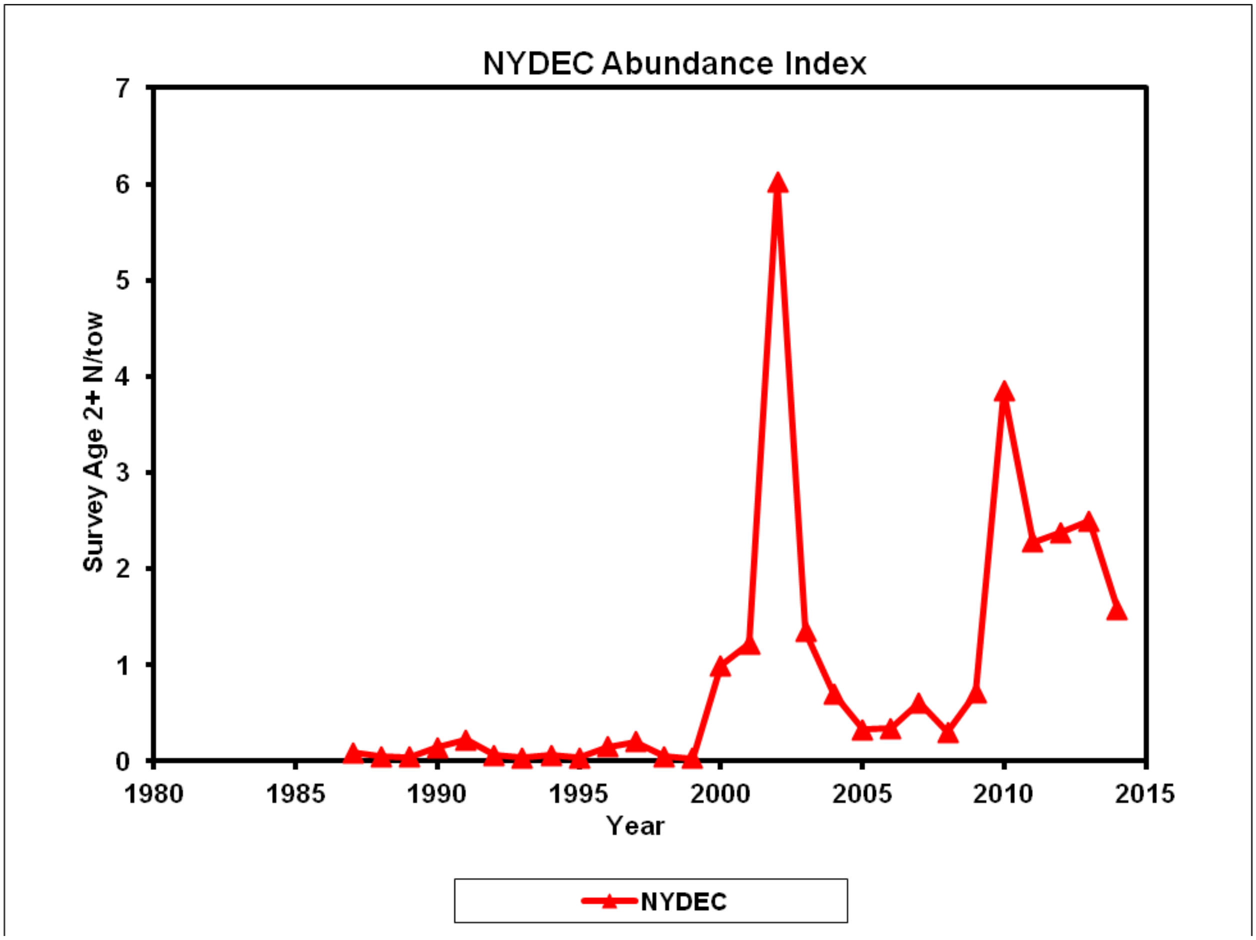


Figure A27. NYDEC survey aggregate numeric index, ages 2+.

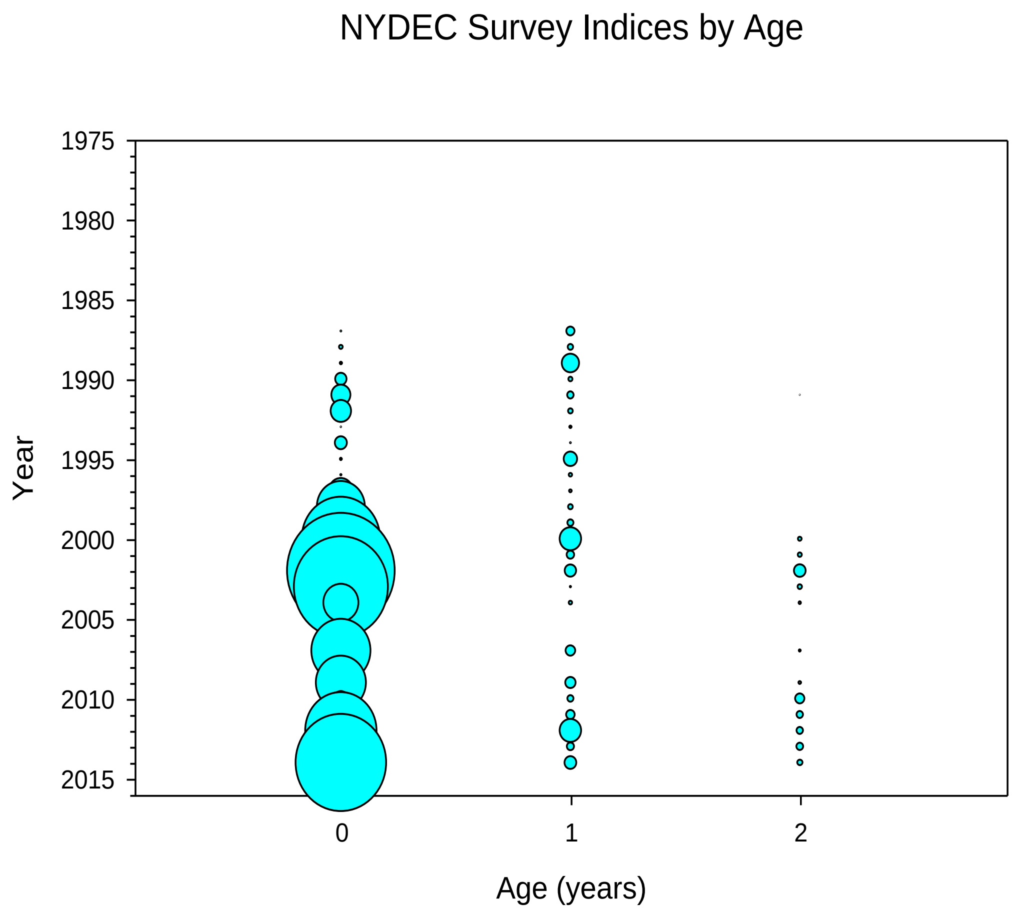


Figure A28. NYDEC survey indices by age for scup.

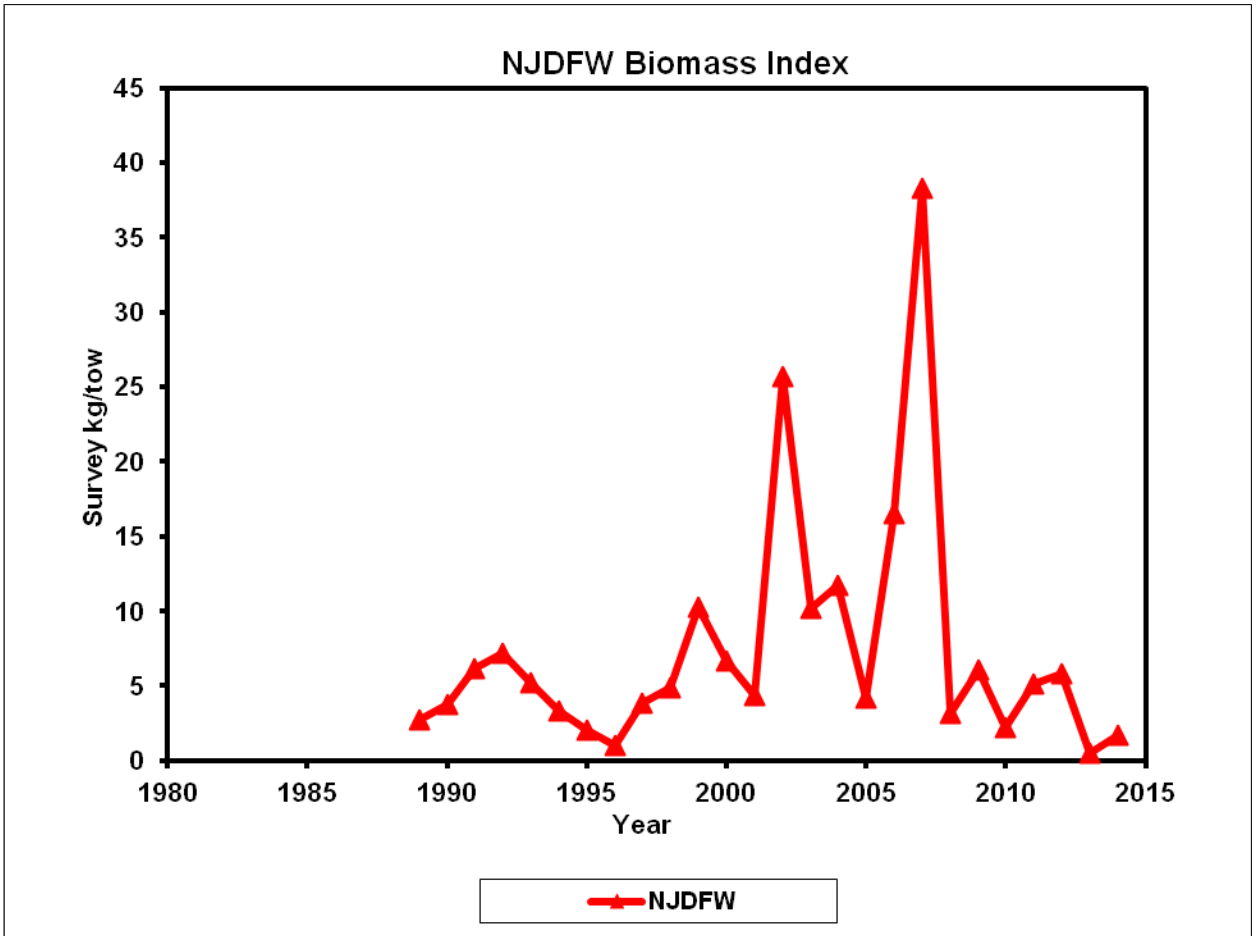


Figure A29. NJBMF survey biomass index.

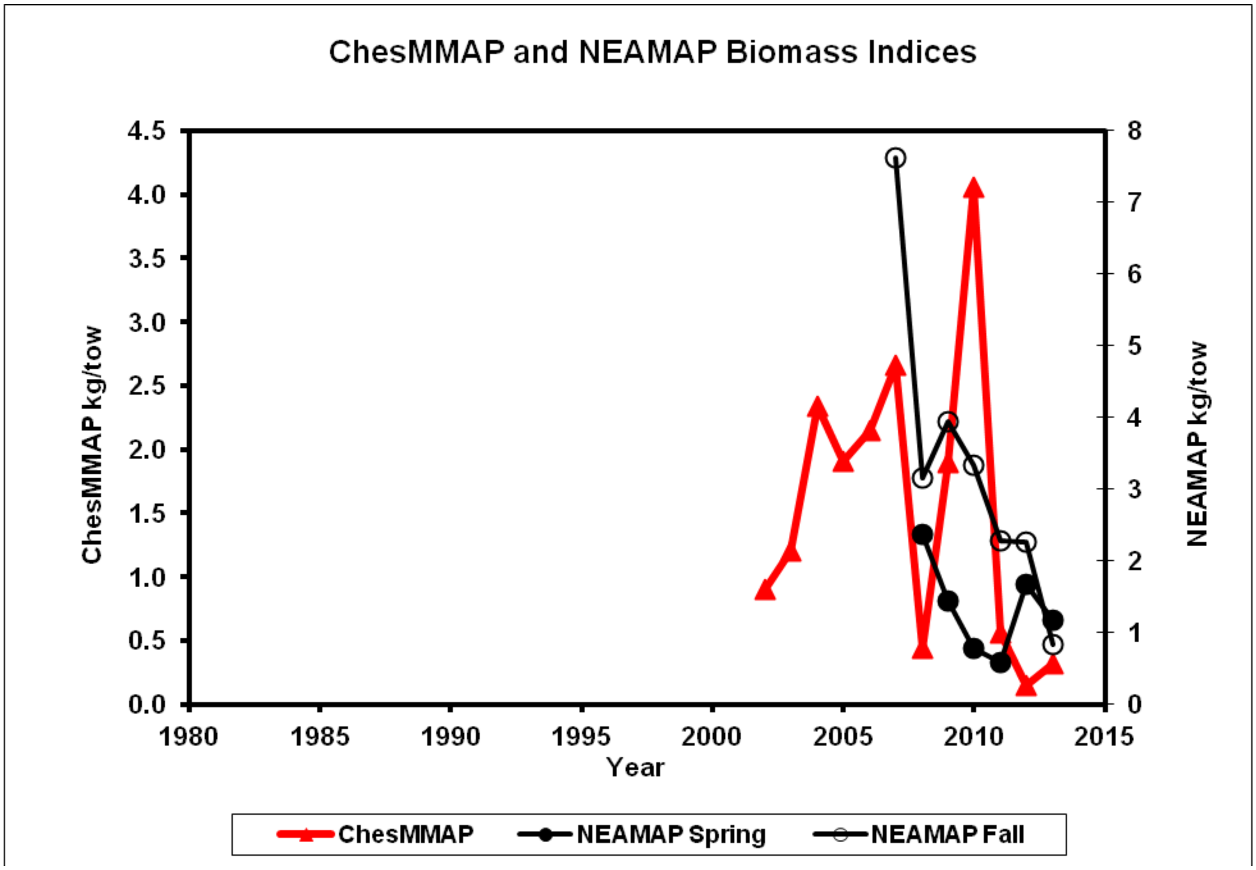


Figure A30. VIMS ChesMMap and NEAMAP spring and fall survey biomass indices.

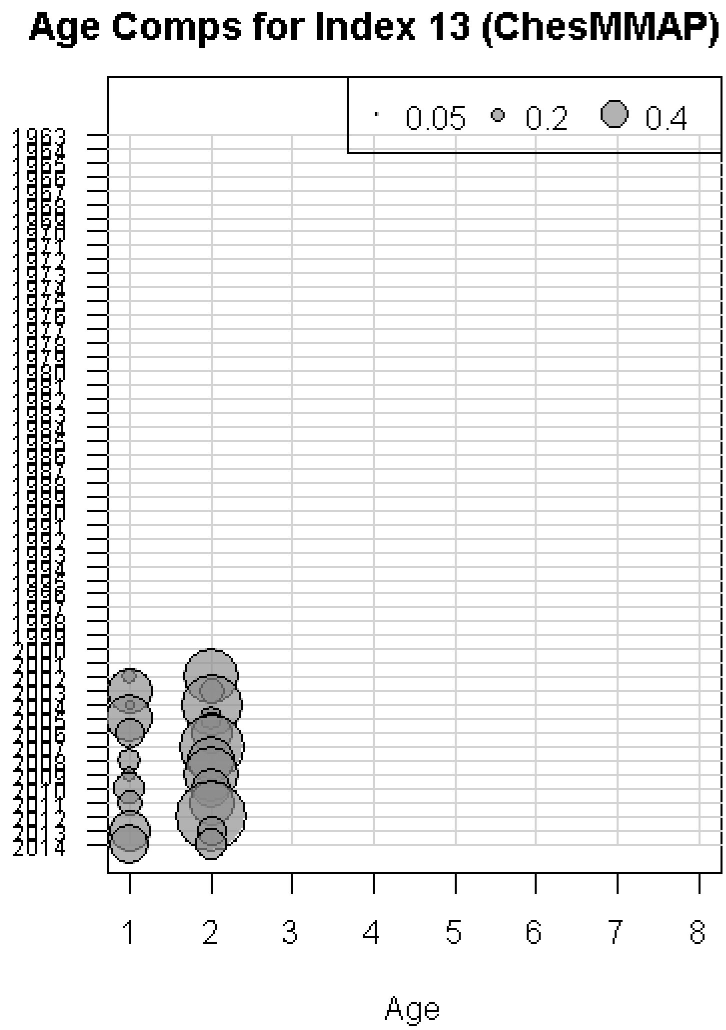


Figure A31. VIMS ChesMMAP survey indices at age (plotted age 1 is true age 0, etc.).

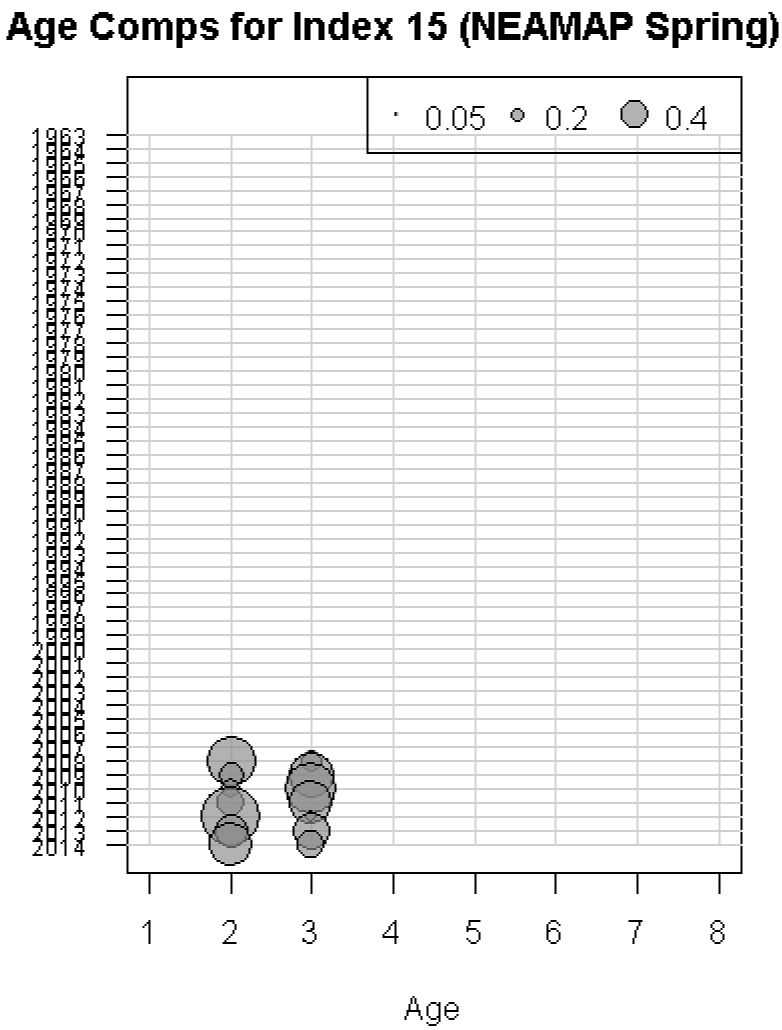


Figure A32. VIMS NEAMAP spring survey indices at age (plotted age 1 is true age 0, etc.).

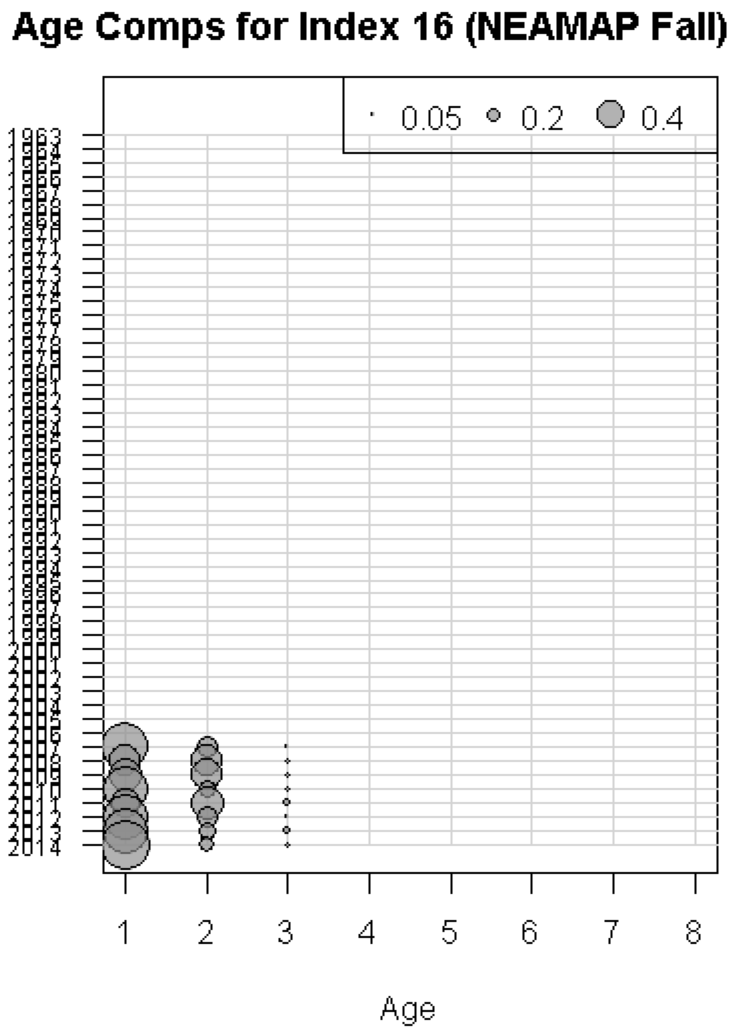


Figure A33. VIMS NEAMAP fall survey indices at age (plotted age 1 is true age 0, etc.).

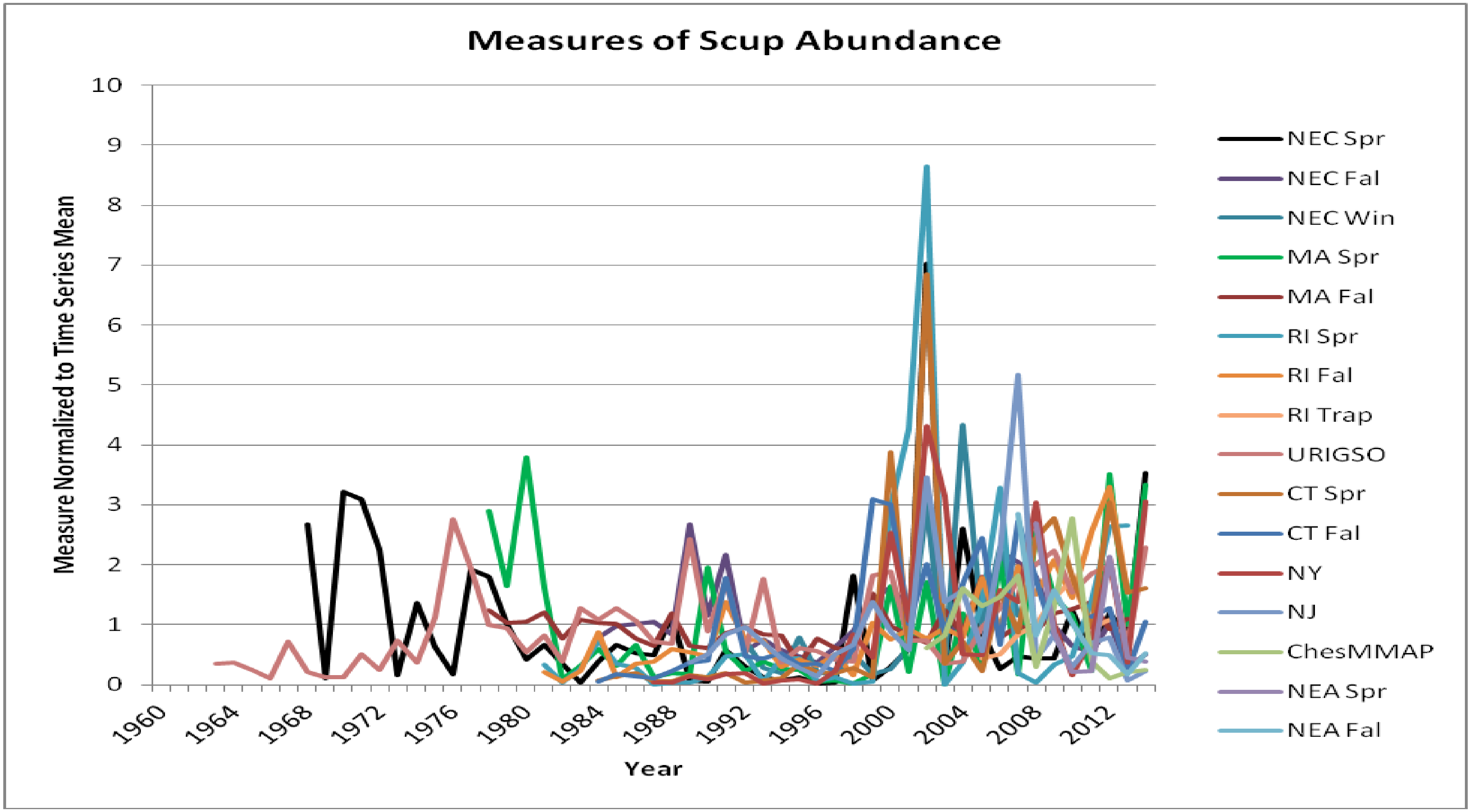


Figure A34. Trends in survey aggregate indices of scup abundance.

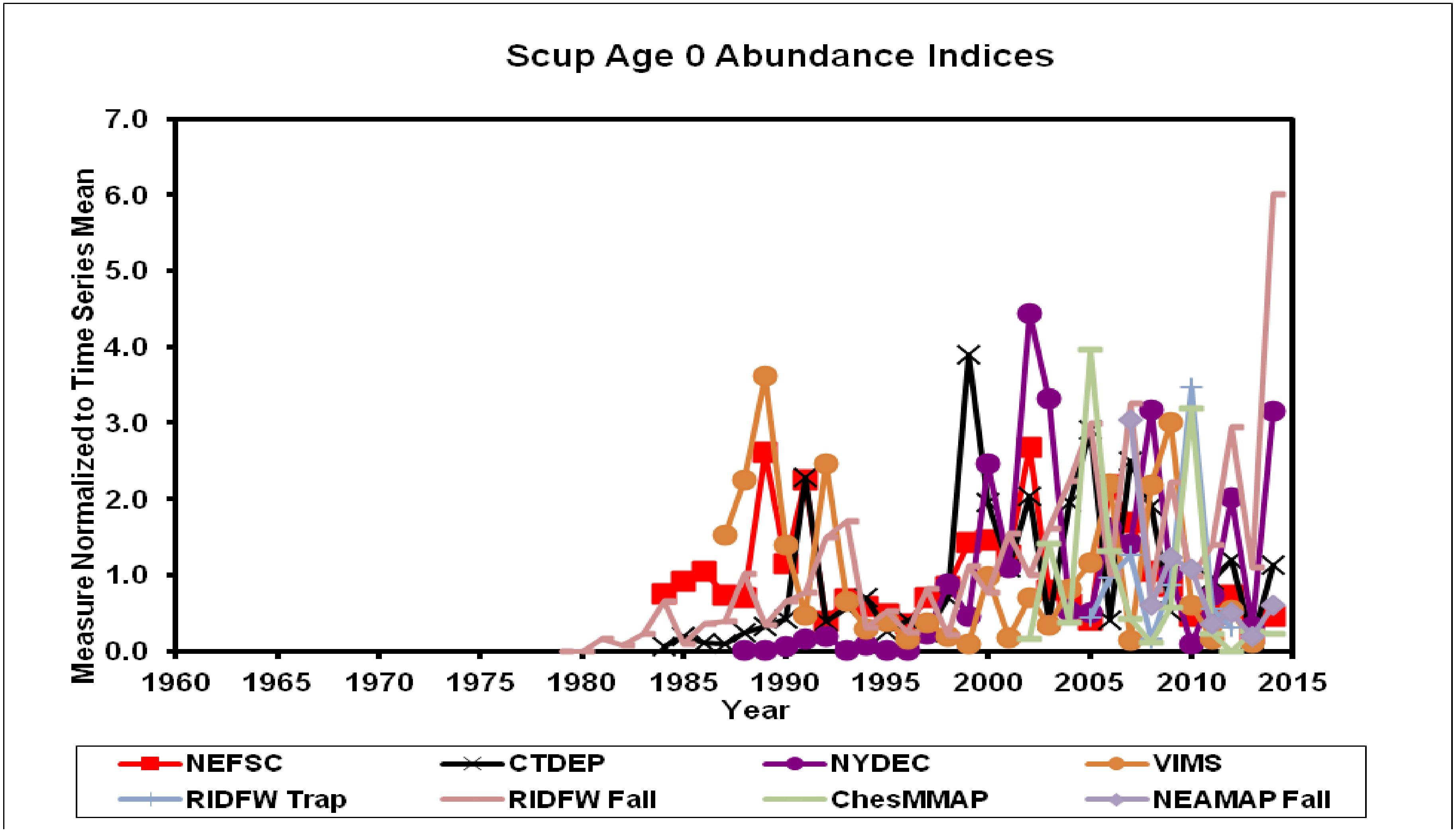


Figure A35. Trends in survey indices of scup recruitment at age 0.

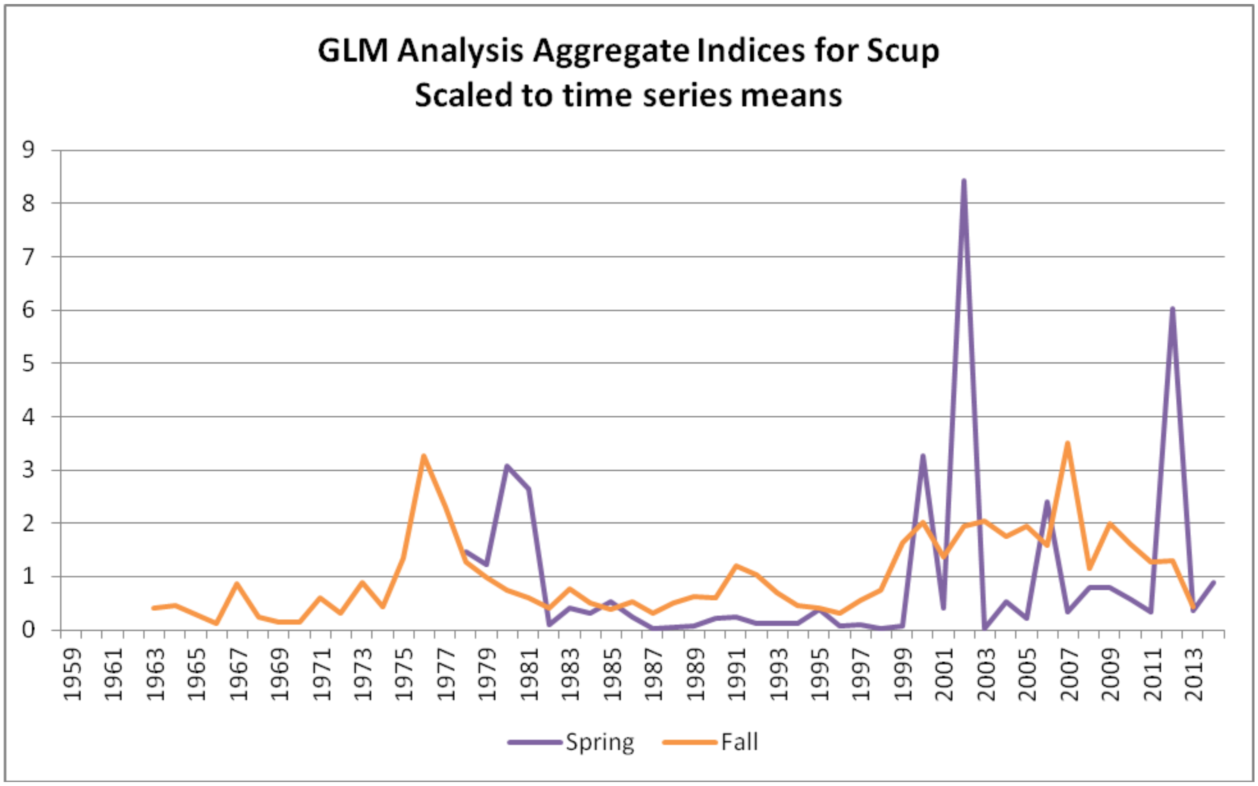


Figure A36. 'GLM Integrated' model aggregate indices of scup abundance based on state agency and academic instituion spring and fall research surveys.

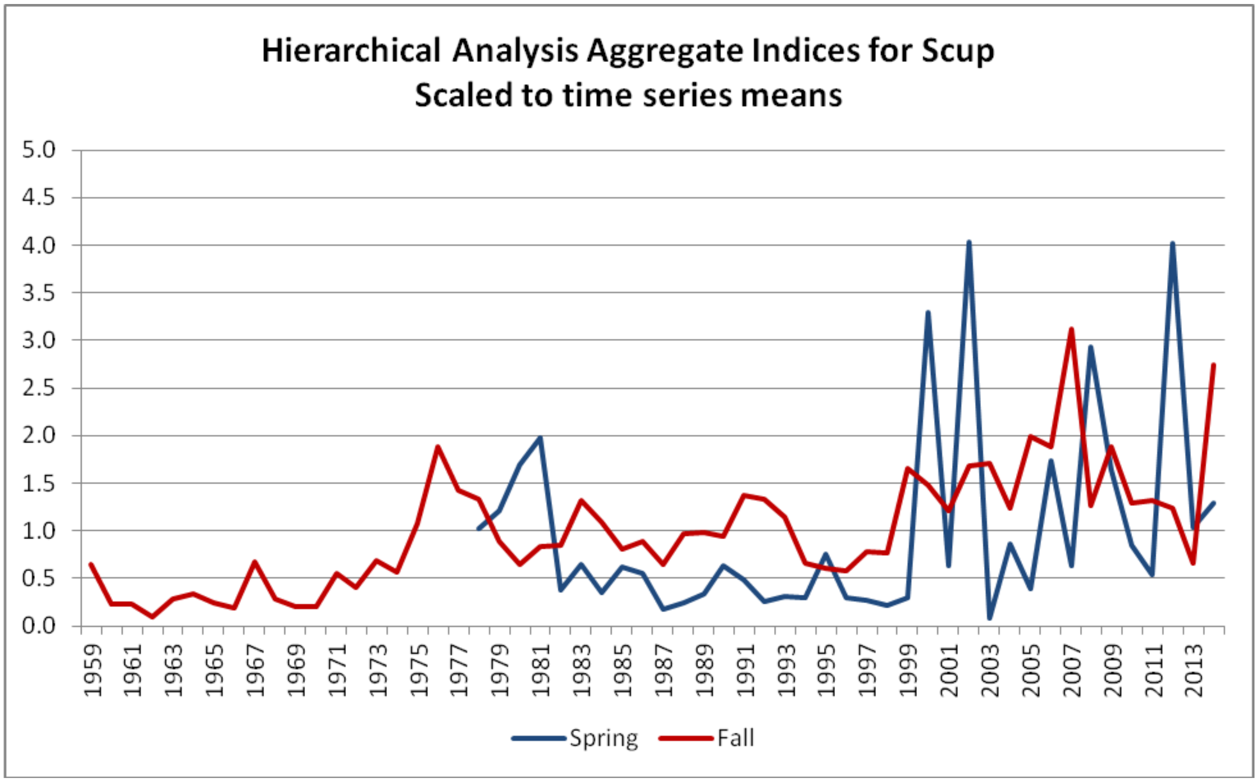


Figure A37. ‘Hierarchical’ model aggregate indices of scup abundance based on state agency and academic instituion spring and fall research surveys.

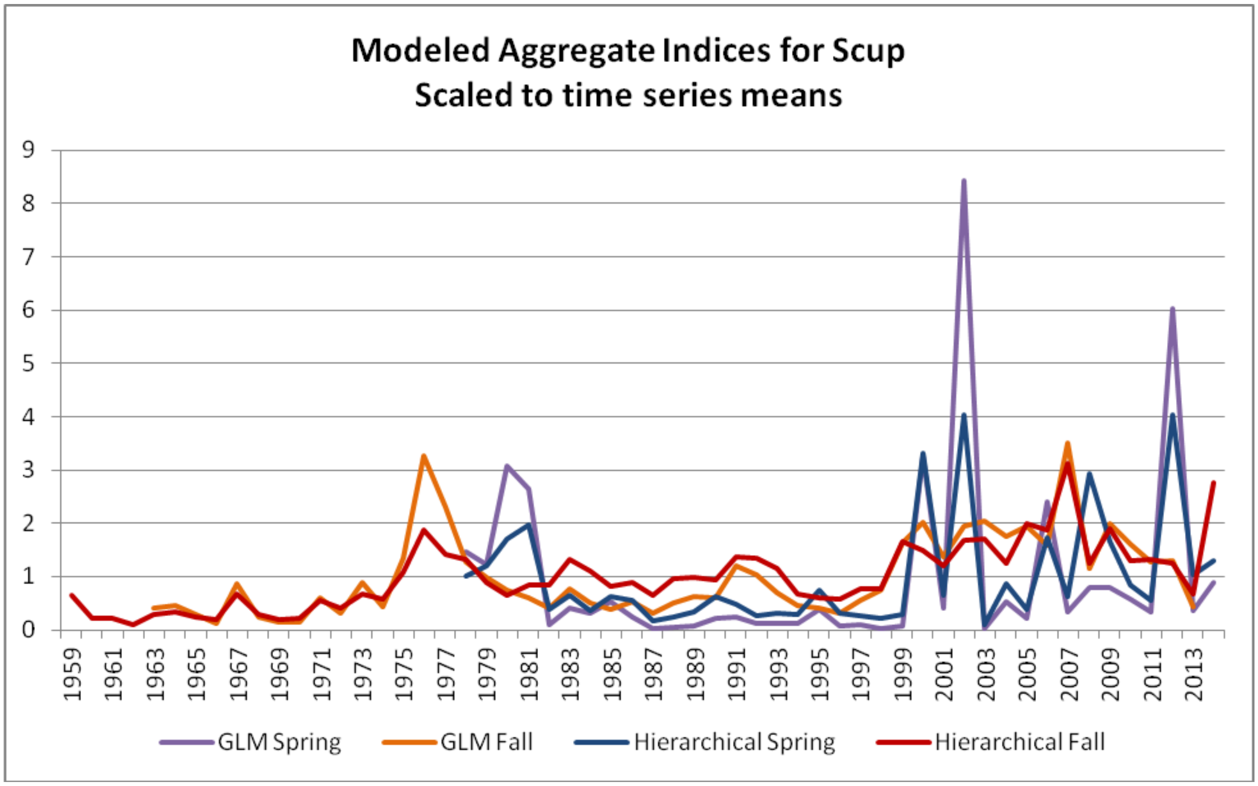


Figure A38. 'GLM Integrated' and 'Hierarchical' model seasonal indices of aggregate abundance based on state agency and academic instituion spring and fall research surveys.

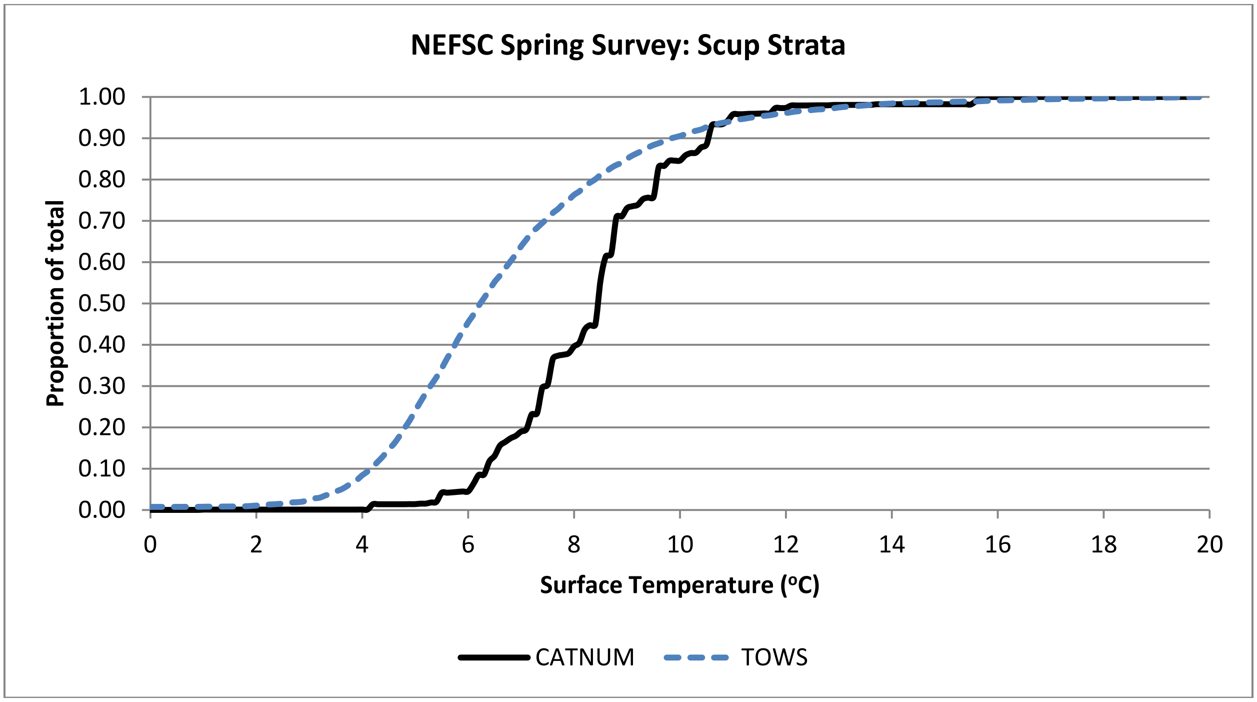


Figure A39. Cumulative proportion of total (expanded catch number per tow or number of tows) by surface temperature for survey stations in the NEFSC spring survey strata set (1968-2014).

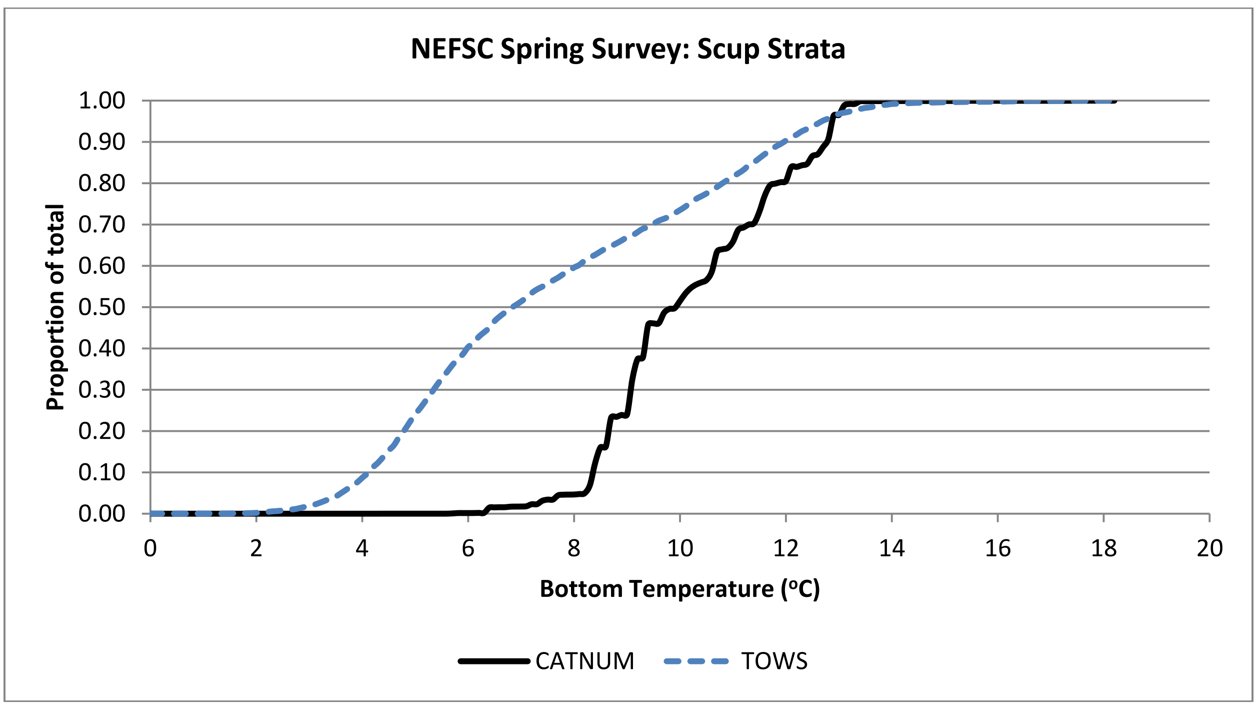


Figure A40. Cumulative proportion of total (expanded catch number per tow or number of tows) by bottom temperature for survey stations in the NEFSC spring survey strata set (1968-2014).

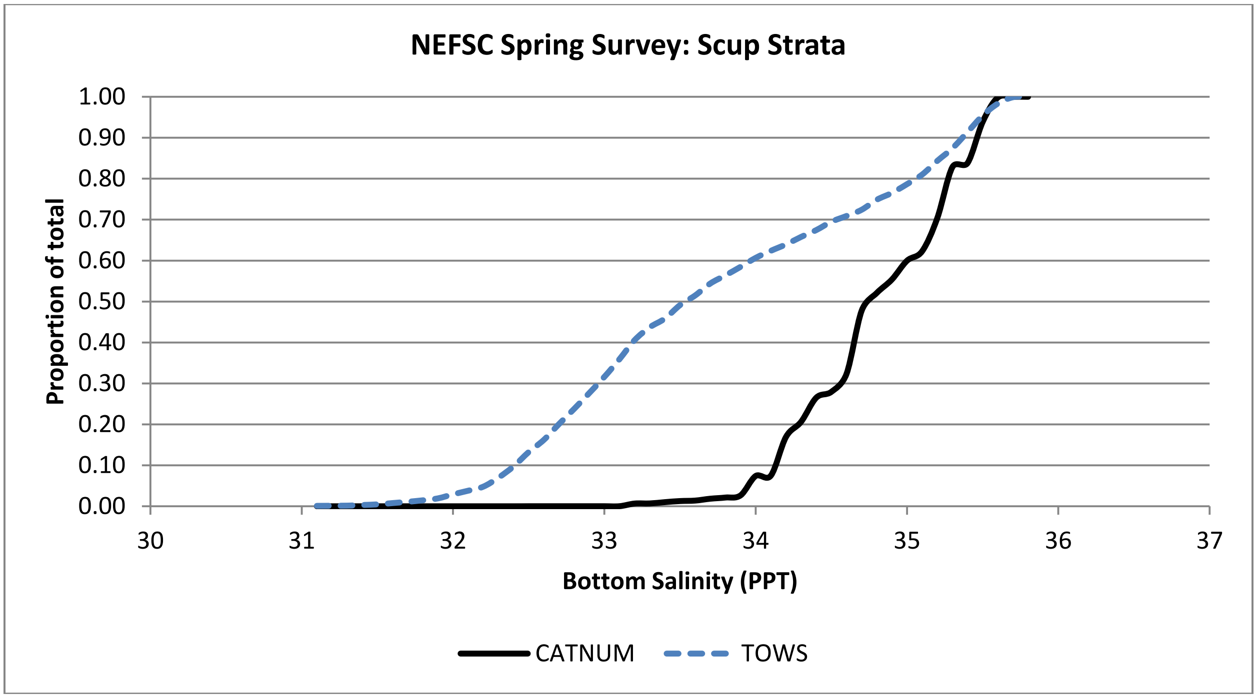


Figure A41. Cumulative proportion of total (expanded catch number per tow or number of tows) by bottom salinity for survey stations in the NEFSC spring survey strata set (1997-2014).

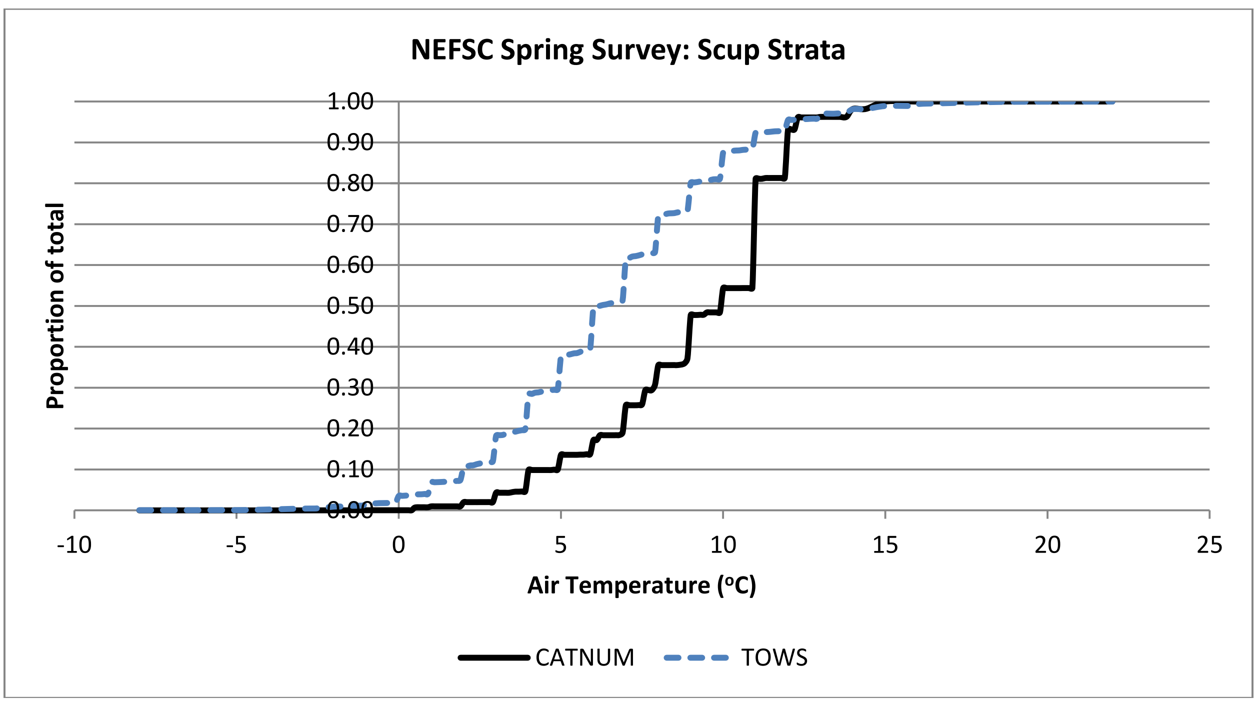


Figure A42. Cumulative proportion of total (expanded catch number per tow or number of tows) by air temperature for survey stations in the NEFSC spring survey strata set (1968-2014).

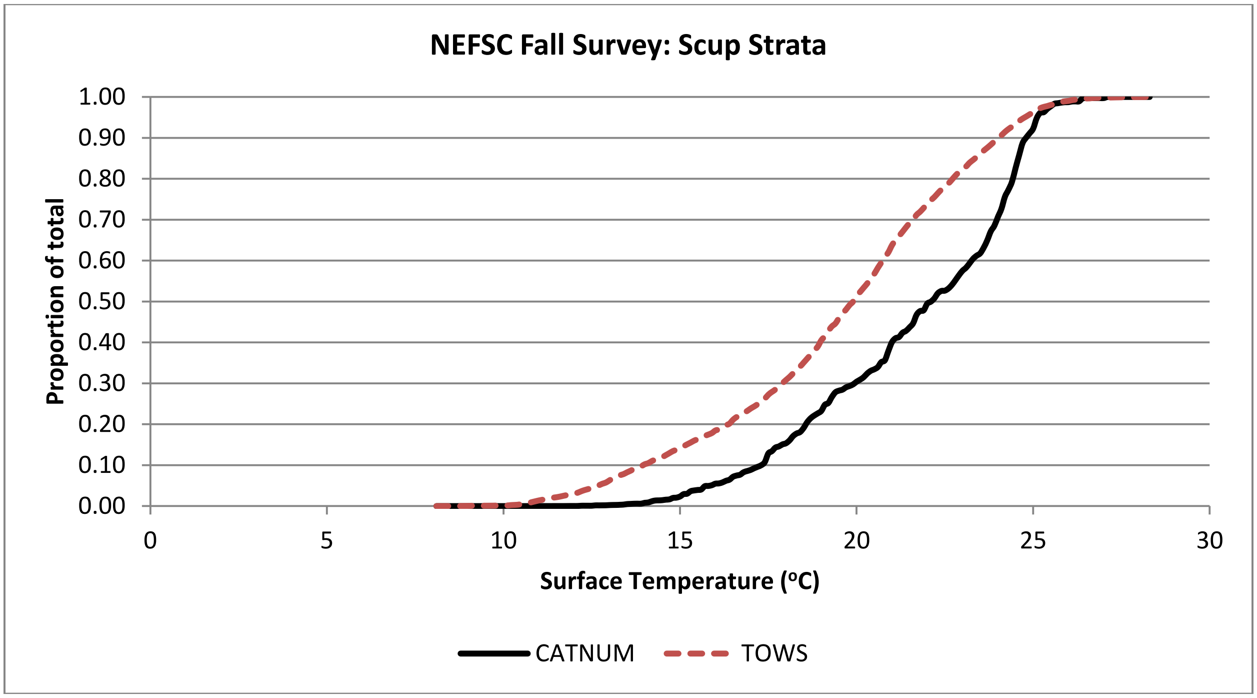


Figure A43. Cumulative proportion of total (expanded catch number per tow or number of tows) by surface temperature for survey stations in the NEFSC fall survey strata set (1968-2013).

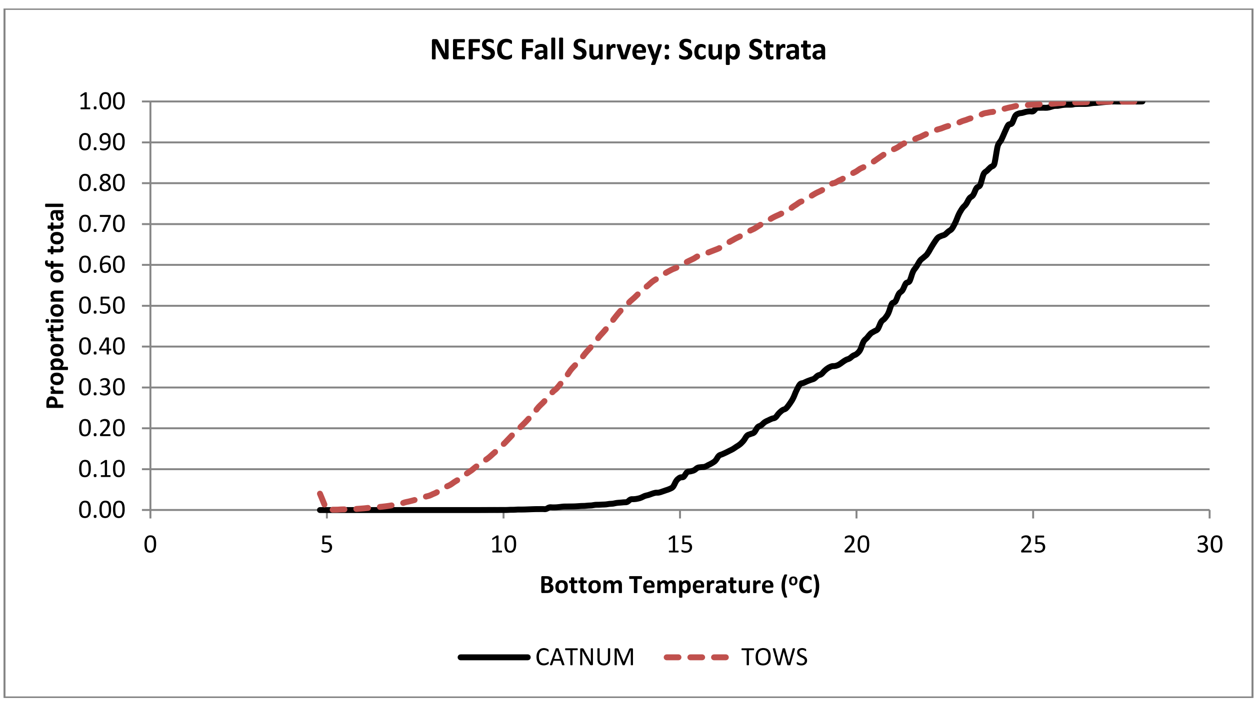


Figure A44. Cumulative proportion of total (expanded catch number per tow or number of tows) by surface temperature for survey stations in the NEFSC fall survey strata set (1968-2013).

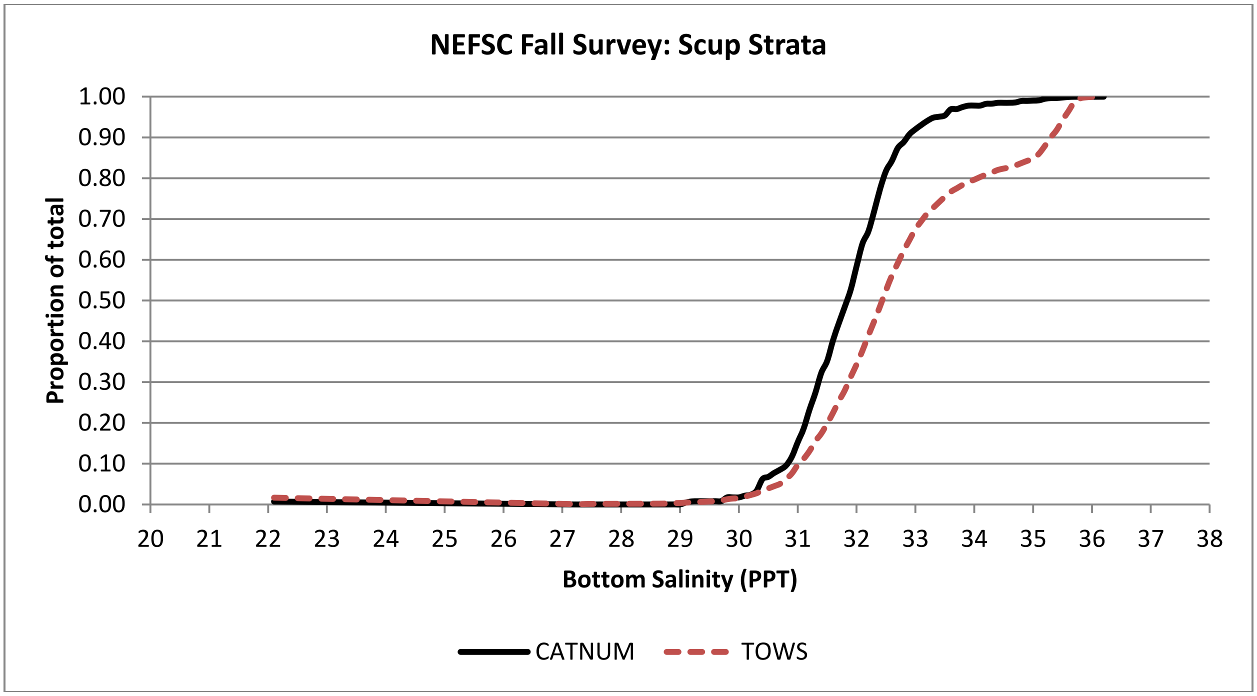


Figure A45. Cumulative proportion of total (expanded catch number per tow or number of tows) by bottom salinity for survey stations in the NEFSC fall survey strata set (1997-2013).

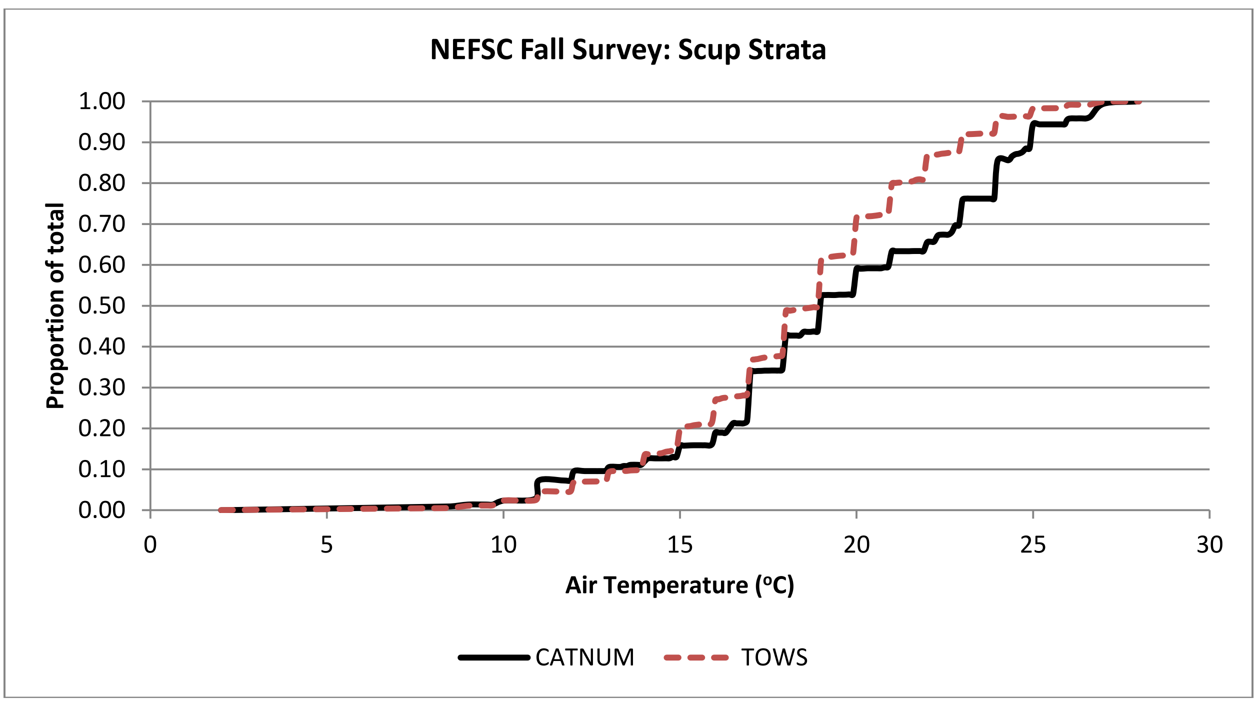


Figure A46. Cumulative proportion of total (expanded catch number per tow or number of tows) by air temperature for survey stations in the NEFSC fall survey strata set (1968-2013).

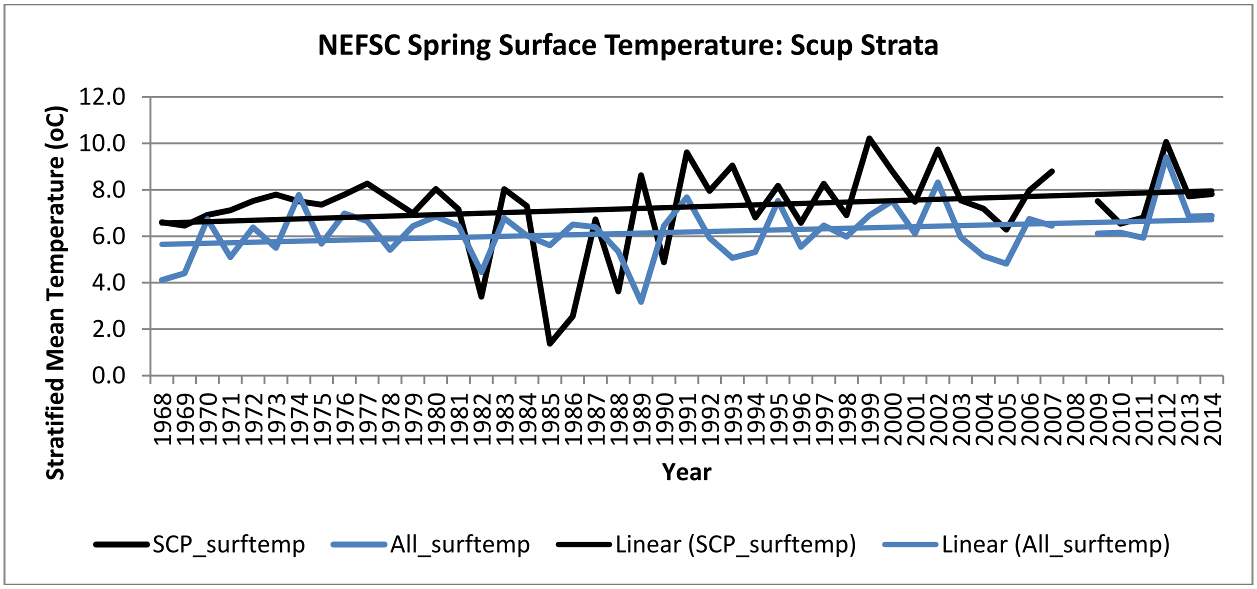


Figure A47. Annual stratified mean values of the surface temperature for spring positive scup catch tows (expcatchnum > 0; SCP_bottemp) was compared with the annual stratified mean values for all tows (All_bottemp).

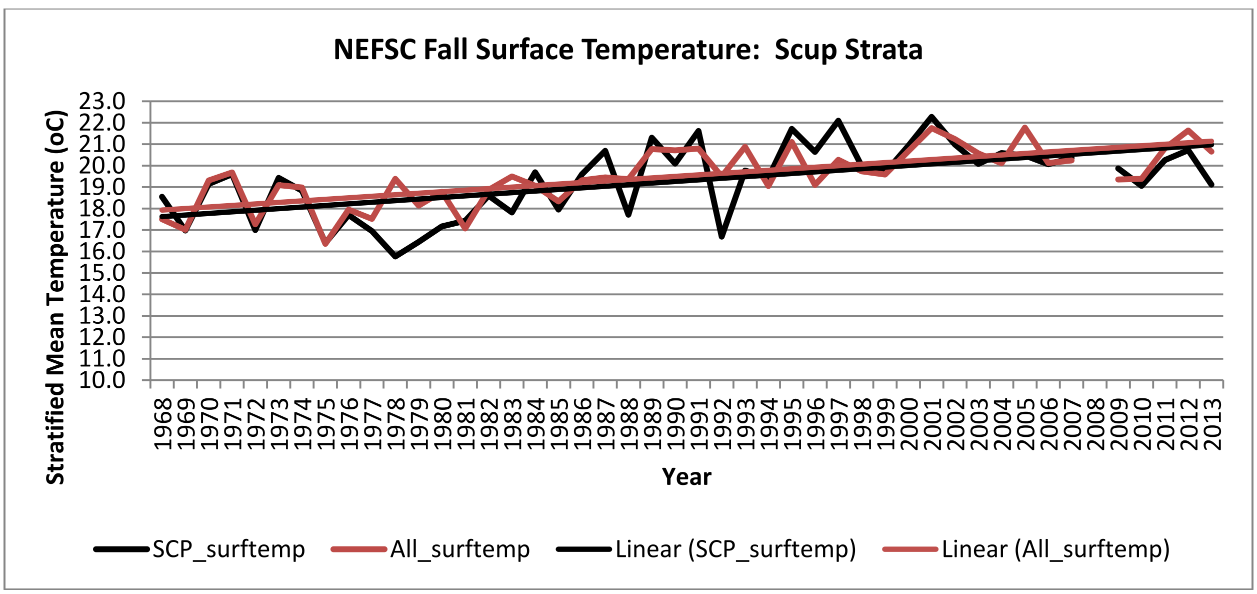


Figure A48. Annual stratified mean values of the surface temperature for fall positive scup catch tows (expcatchnum > 0; SCP_bottemp) was compared with the annual stratified mean values for all tows (All_bottemp).

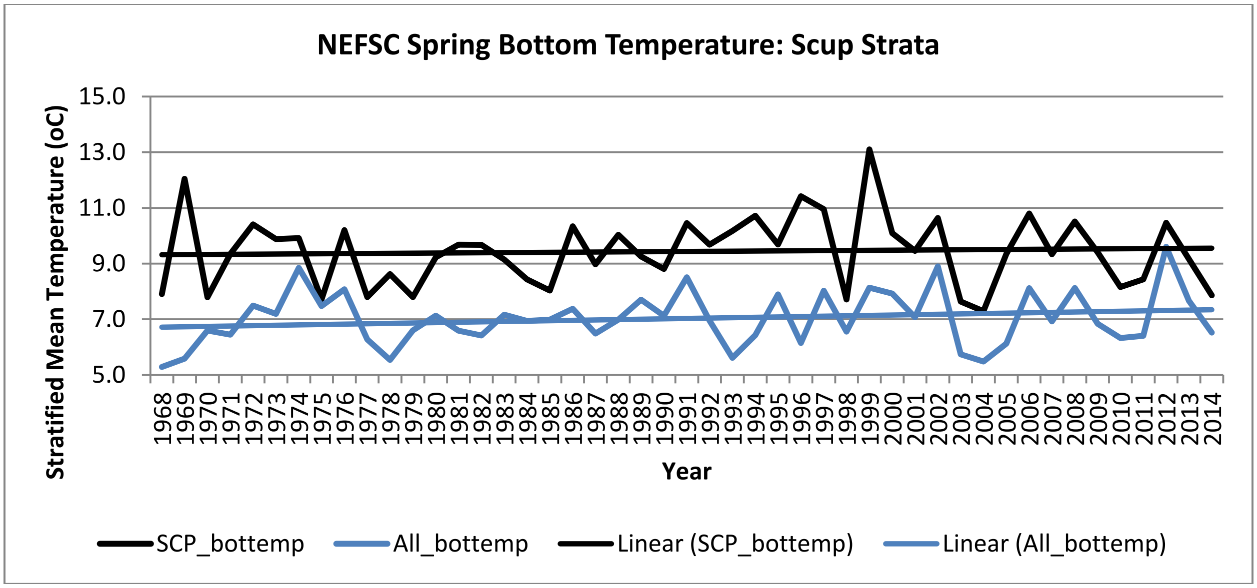


Figure A49. Annual stratified mean values of the bottom temperature for spring positive scup catch tows (expcatchnum > 0; SCP_bottemp) was compared with the annual stratified mean values for all tows (All_bottemp).

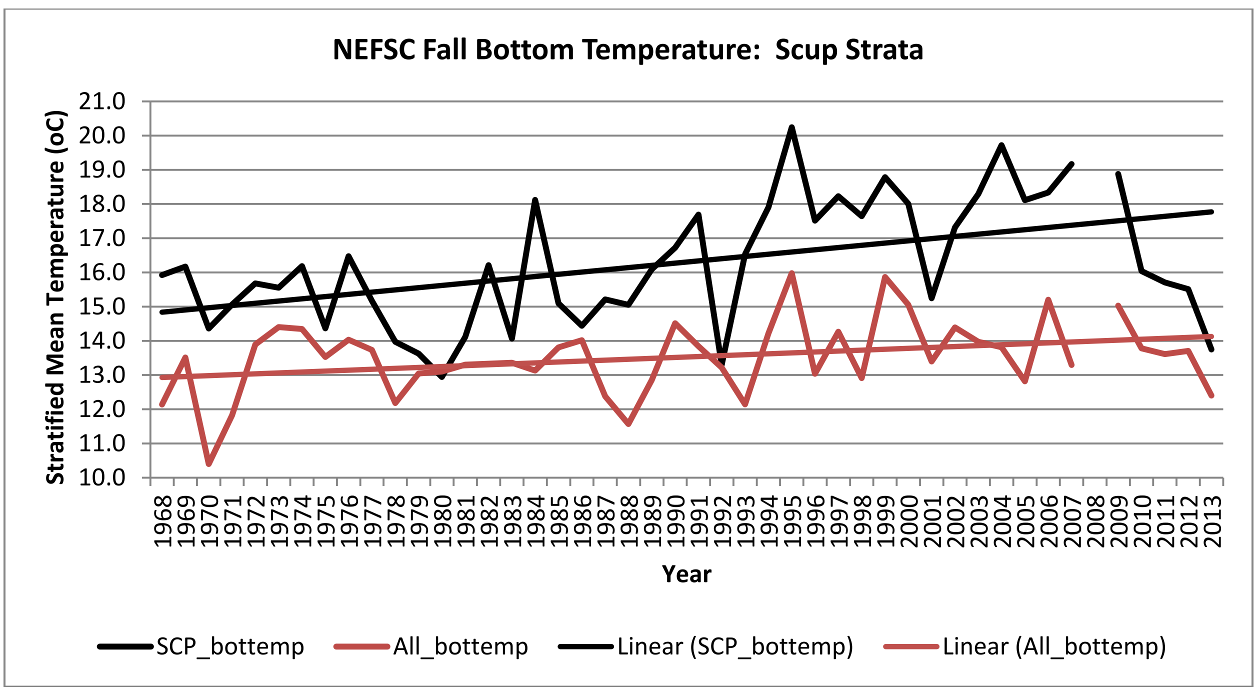


Figure A50. Annual stratified mean values of the bottom temperature for fall positive scup catch tows (expcatchnum > 0; SCP_bottemp) was compared with the annual stratified mean values for all tows (All_bottemp).

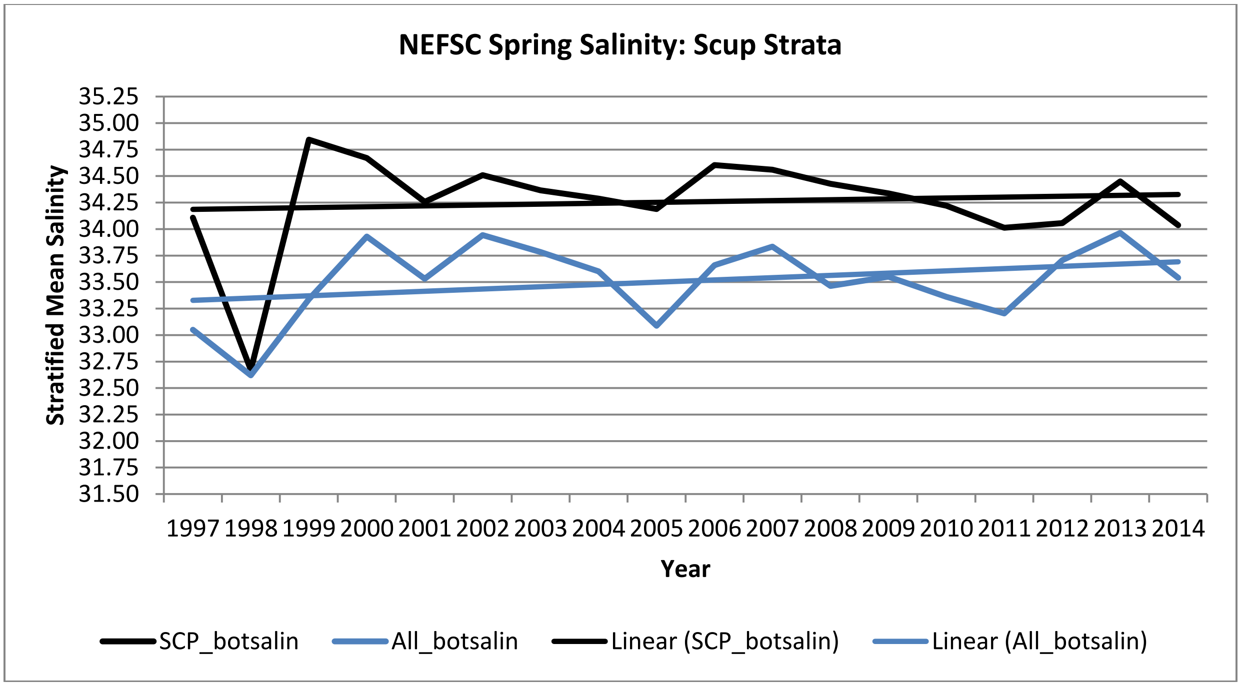


Figure A51. Annual stratified mean values of the bottom salinity for spring positive scup catch tows (expcatchnum > 0; SCP_botsalin) was compared with the annual stratified mean values for all tows (All_botsalin).

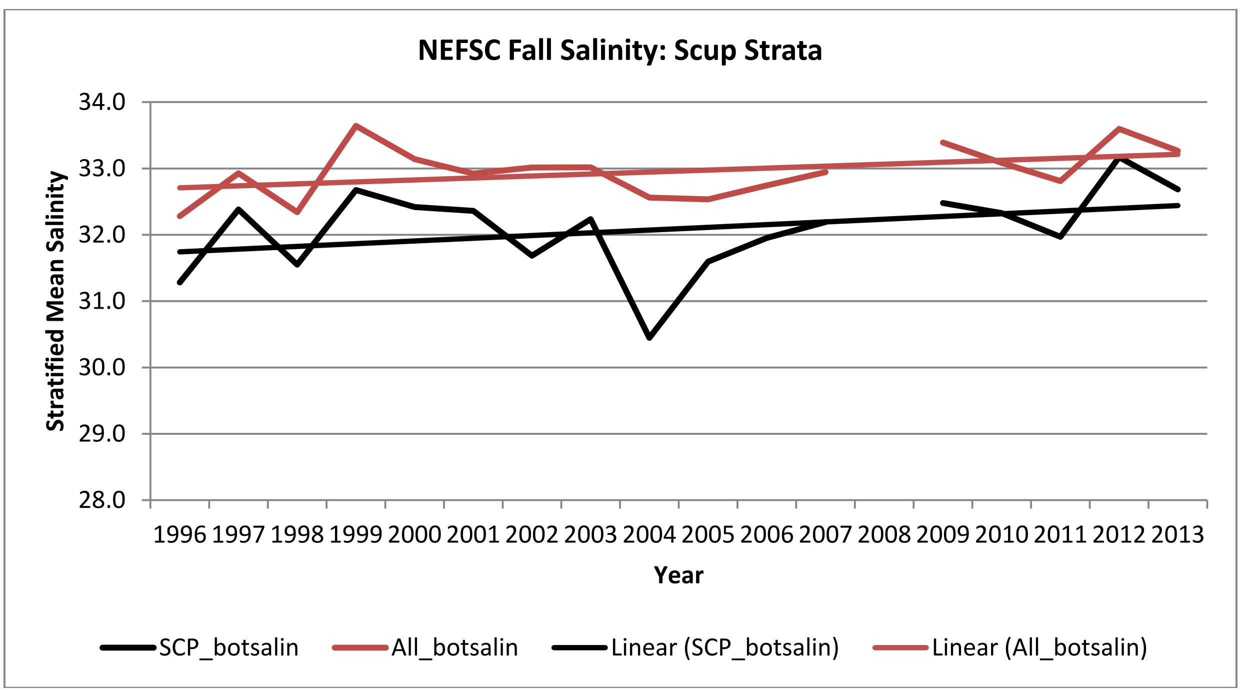


Figure A52. Annual stratified mean values of the bottom salinity for fall positive scup catch tows (expcatchnum > 0; SCP_botsalin) was compared with the annual stratified mean values for all tows (All_botsalin).

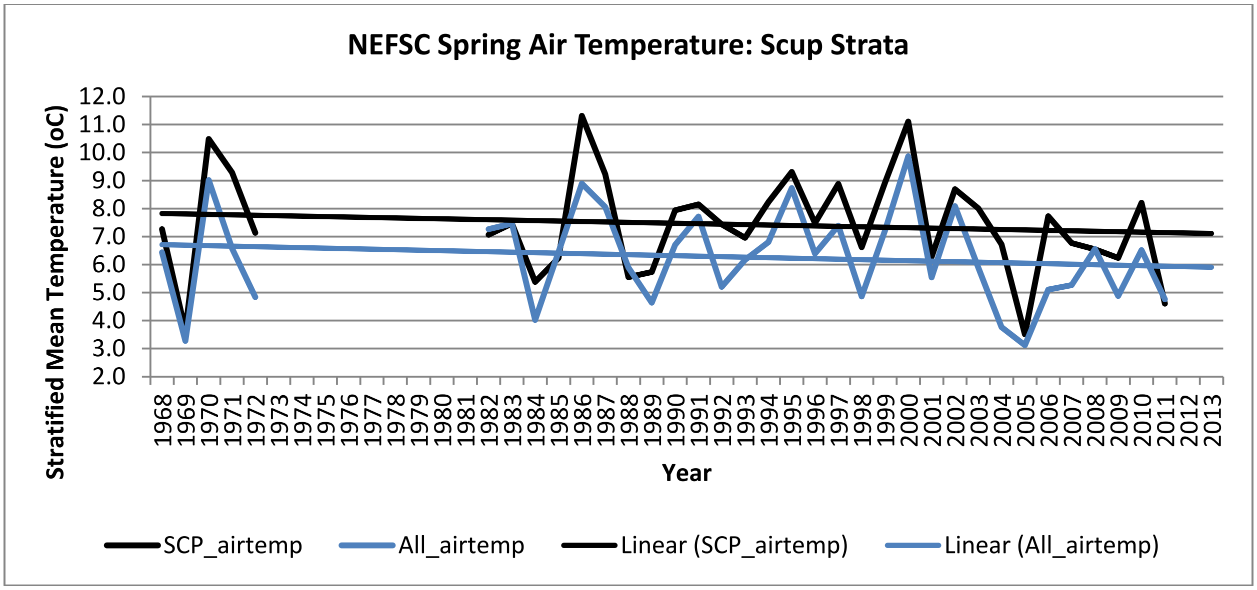


Figure A53. Annual stratified mean values of the air temperature for spring positive scup catch tows (expcatchnum > 0; SCP_airtemp) was compared with the annual stratified mean values for all tows (All_airtemp).

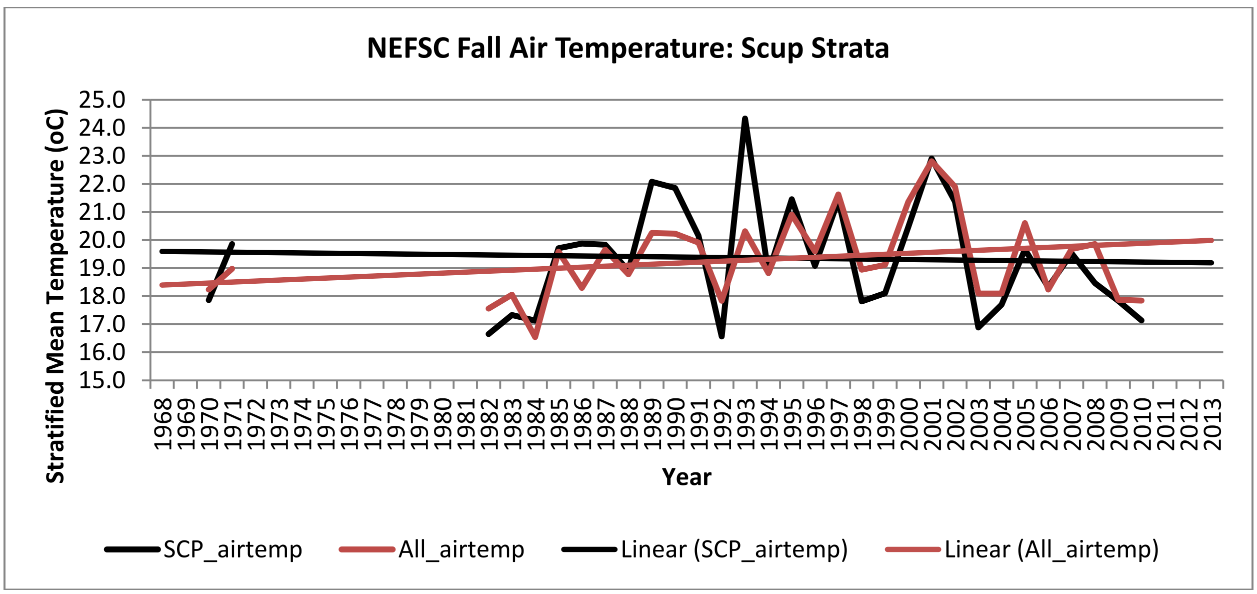


Figure A54. Annual stratified mean values of the air temperature for fall positive scup catch tows (expcatchnum > 0; SCP_airtemp) was compared with the annual stratified mean values for all tows (All_airtemp).

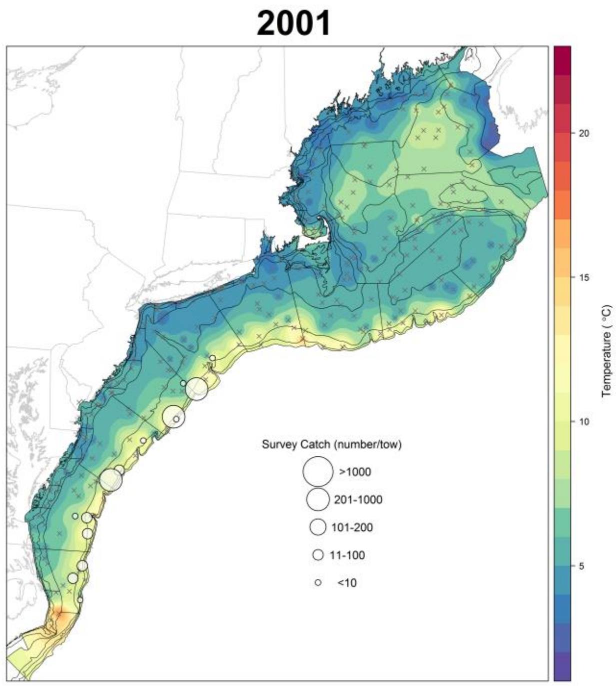


Figure A55. NEFSC spring trawl survey 2001: distribution of scup catch and bottom temperature.

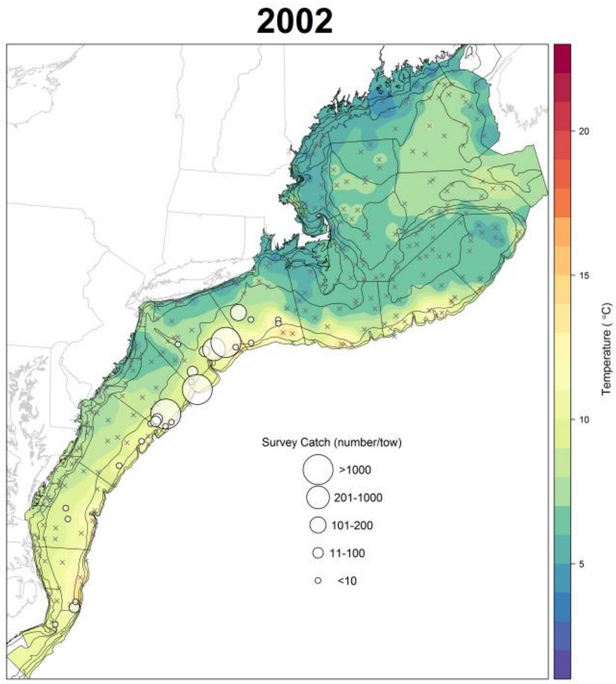


Figure A56. NEFSC spring trawl survey 2002: distribution of scup catch and bottom temperature.

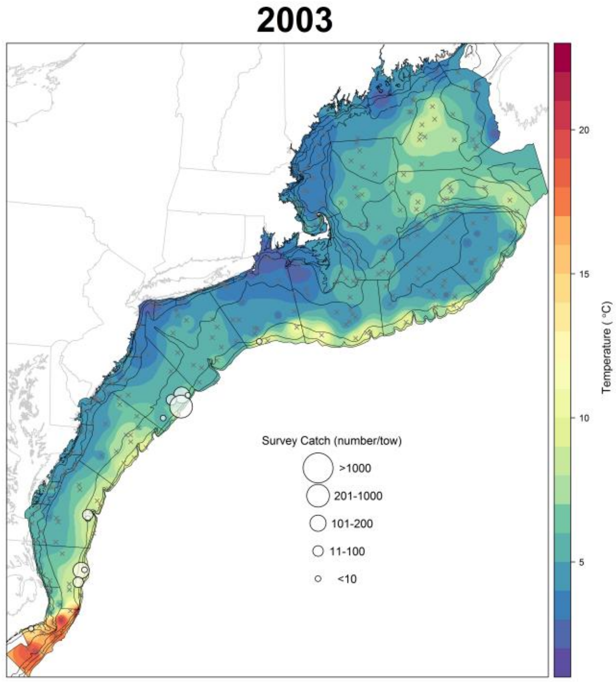


Figure A57. NEFSC spring trawl survey 2003: distribution of scup catch and bottom temperature.

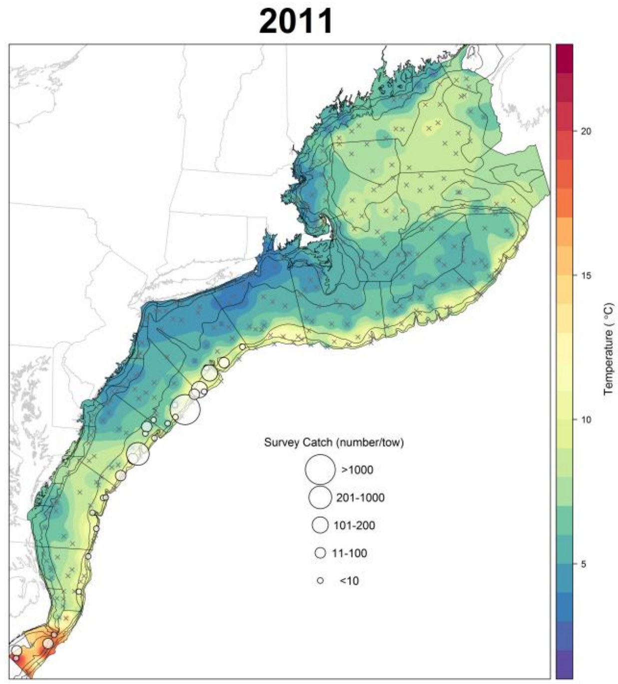


Figure A58. NEFSC spring trawl survey 2011: distribution of scup catch and bottom temperature.

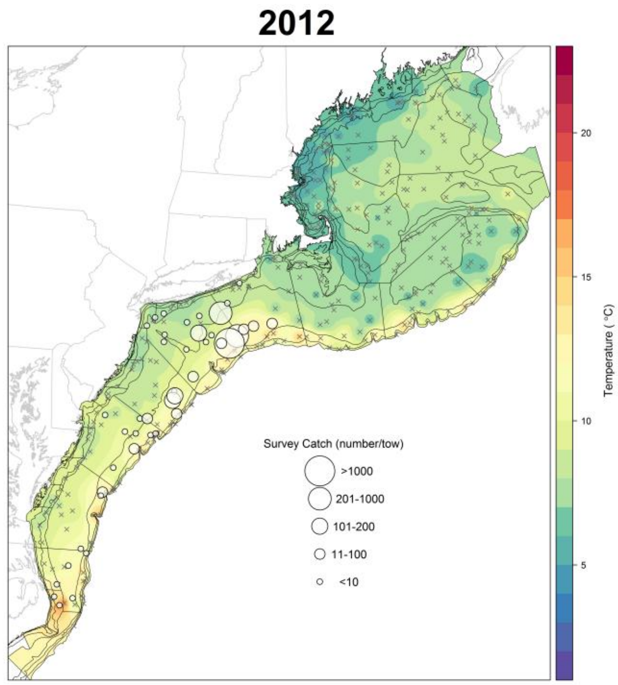


Figure A59. NEFSC spring trawl survey 2012: distribution of scup catch and bottom temperature.

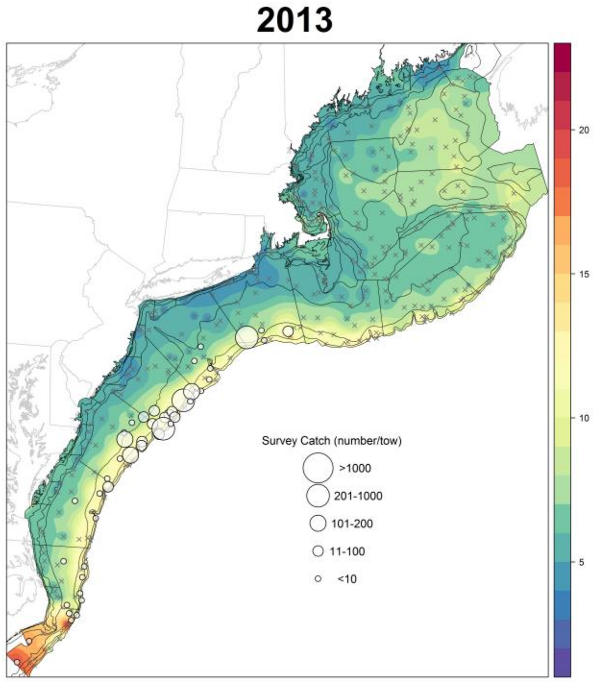


Figure A60. NEFSC spring trawl survey 2013: distribution of scup catch and bottom temperature.

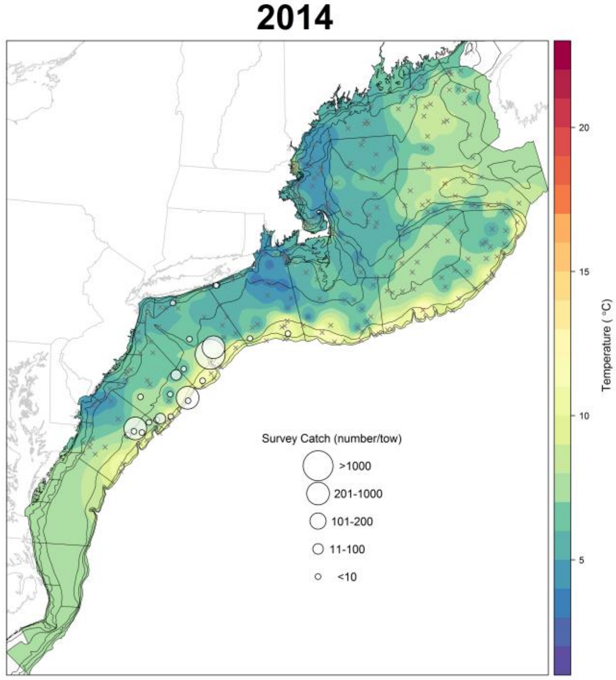


Figure A61. NEFSC spring trawl survey 2014: distribution of scup catch and bottom temperature.

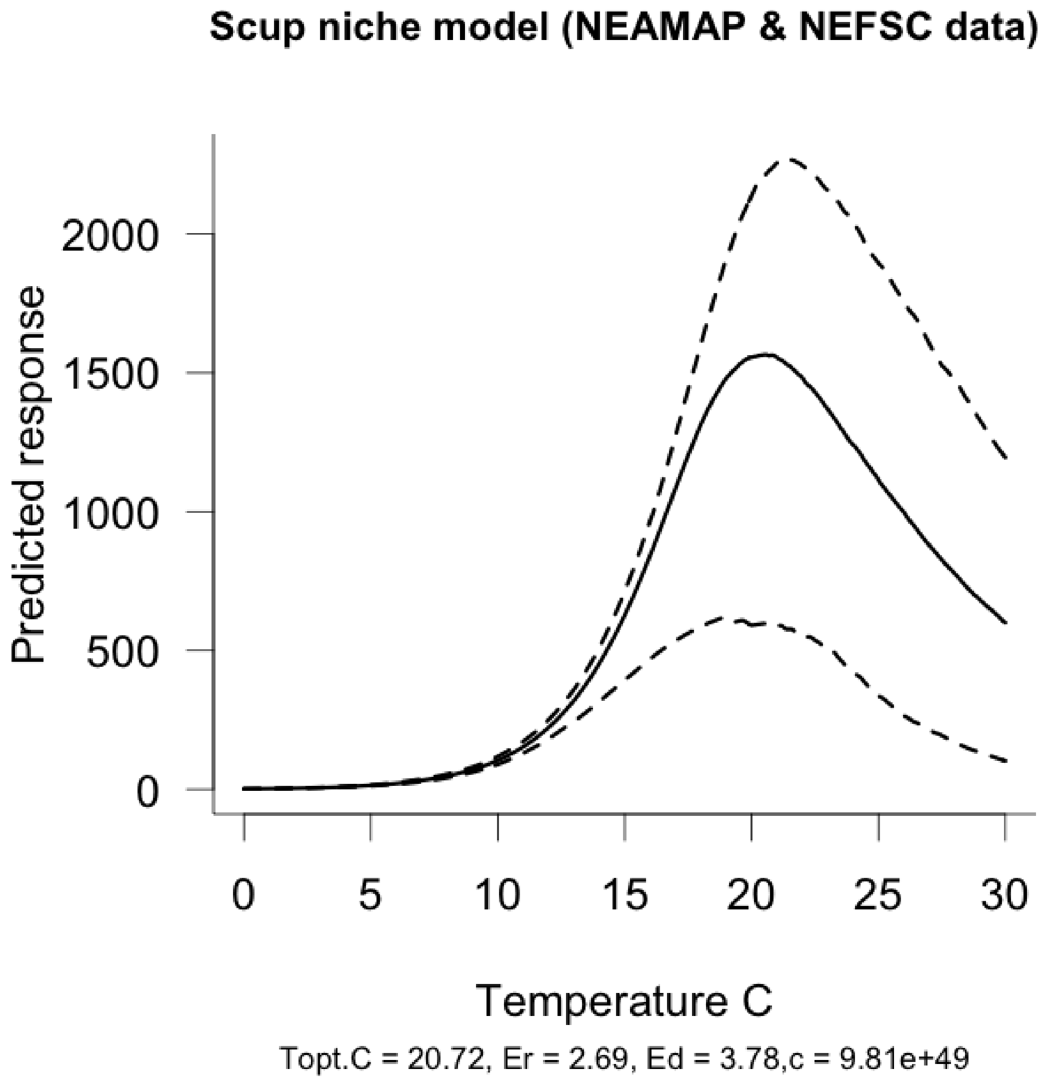


Figure A62. Plot of the thermal response curve for scup constructed by estimating parameters of the Johnson and Lewin equation (solid black line) minimizing negative binomial likelihood using catch as the response and bottom water temperature as the independent variable. Calibration data was from spring and fall bottom trawl surveys of the Northwest Atlantic conducted by the Northeast Fisheries Science Center and NEAMAP from 2008-2014. Dashed lines are 2.5% and 97.5% population prediction intervals developed using parameter estimates and the variance covariance matrix in the method described in Lande et al. (2003) and Bolker (2008). Mean maximum likelihood estimates of parameter values are indicated under the X axis label.

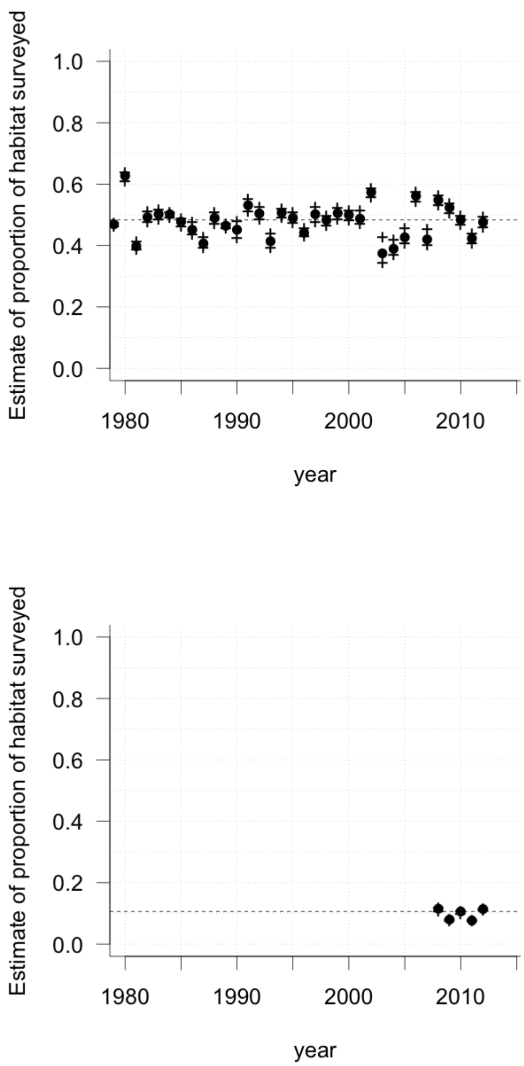


Figure A63. Estimates of the proportion of thermal habitat suitability for scup surveyed in the spring estimated in NEFSC offshore strata (*top panel*) and NEAMAP strata (*bottom panel*) using the niche model coupled to the debiased bottom temperature hindcast. Means (filled circle) and 2.5% and 97.5% population prediction intervals (+) are shown.

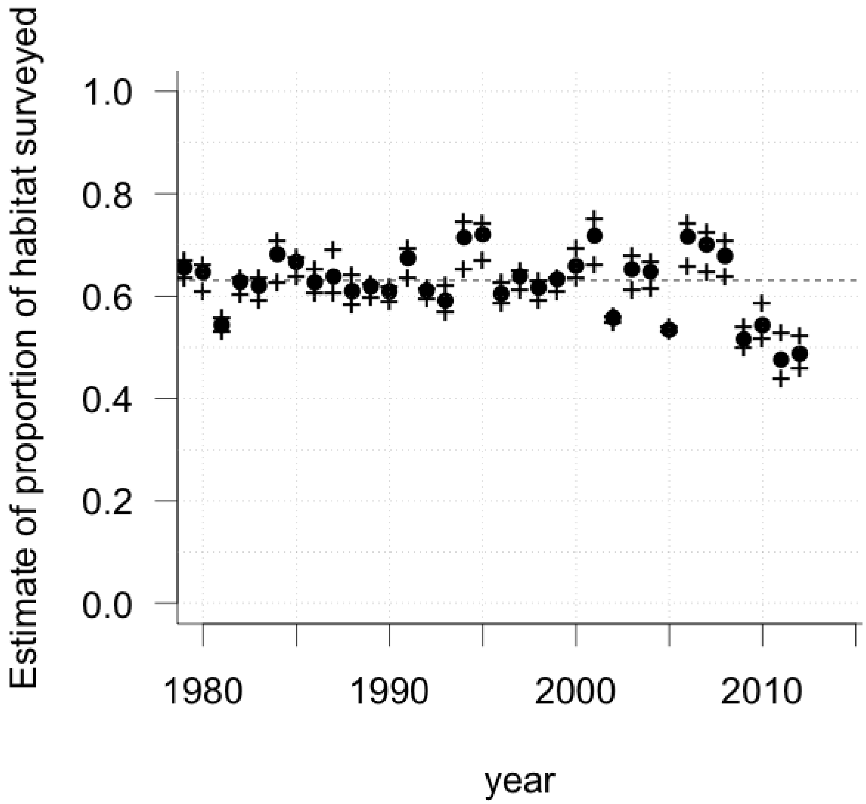


Figure A64. Estimates of the proportion of thermal habitat suitability surveyed for scup estimated using the niche model coupled to the debiased bottom temperature hindcast for NEFSC fall inshore + offshore strata. Means (filled circle) and 2.5% and 97.5% population prediction intervals (+) are shown.

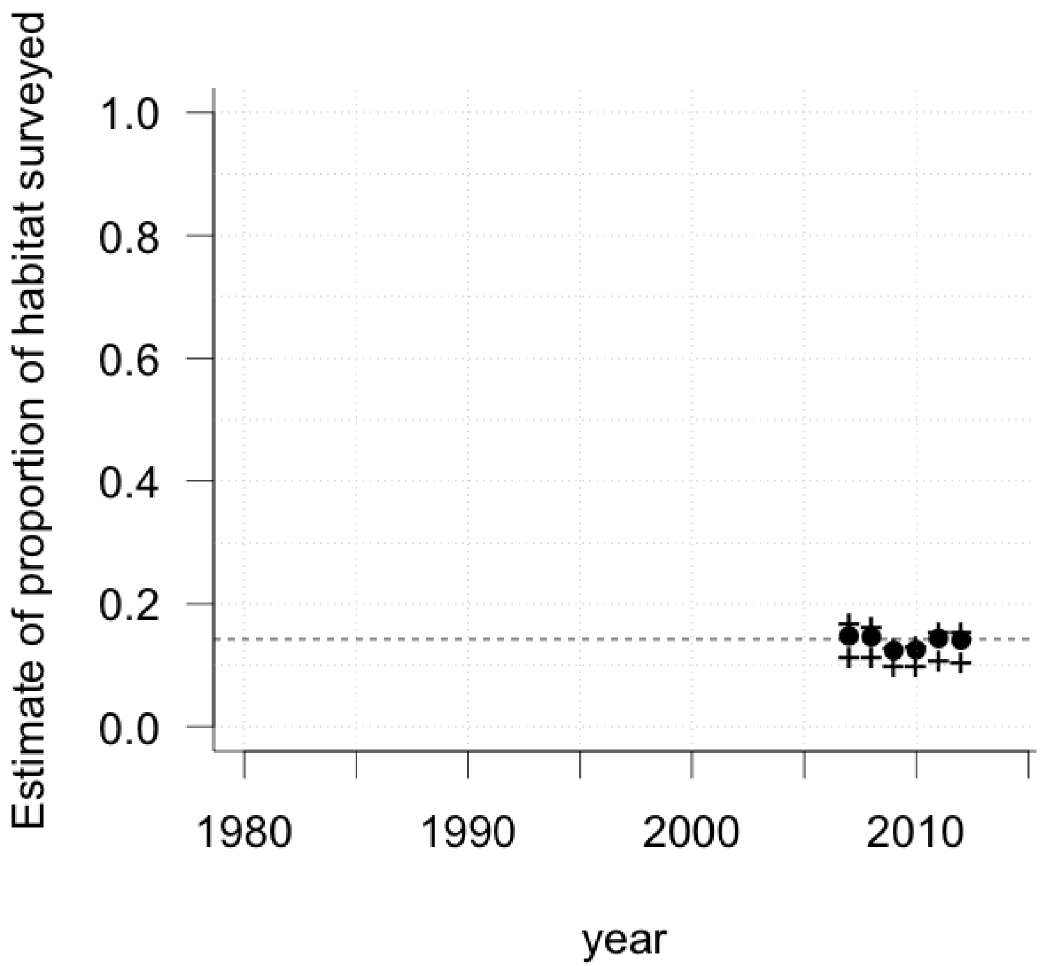


Figure A65. Estimates of the proportion of thermal habitat suitability for scup surveyed in the fall for the NEAMAP survey developed using the niche model coupled to the debiased bottom temperature hindcast. Means (filled circle) and 2.5% and 97.5% population prediction intervals (+) are shown.

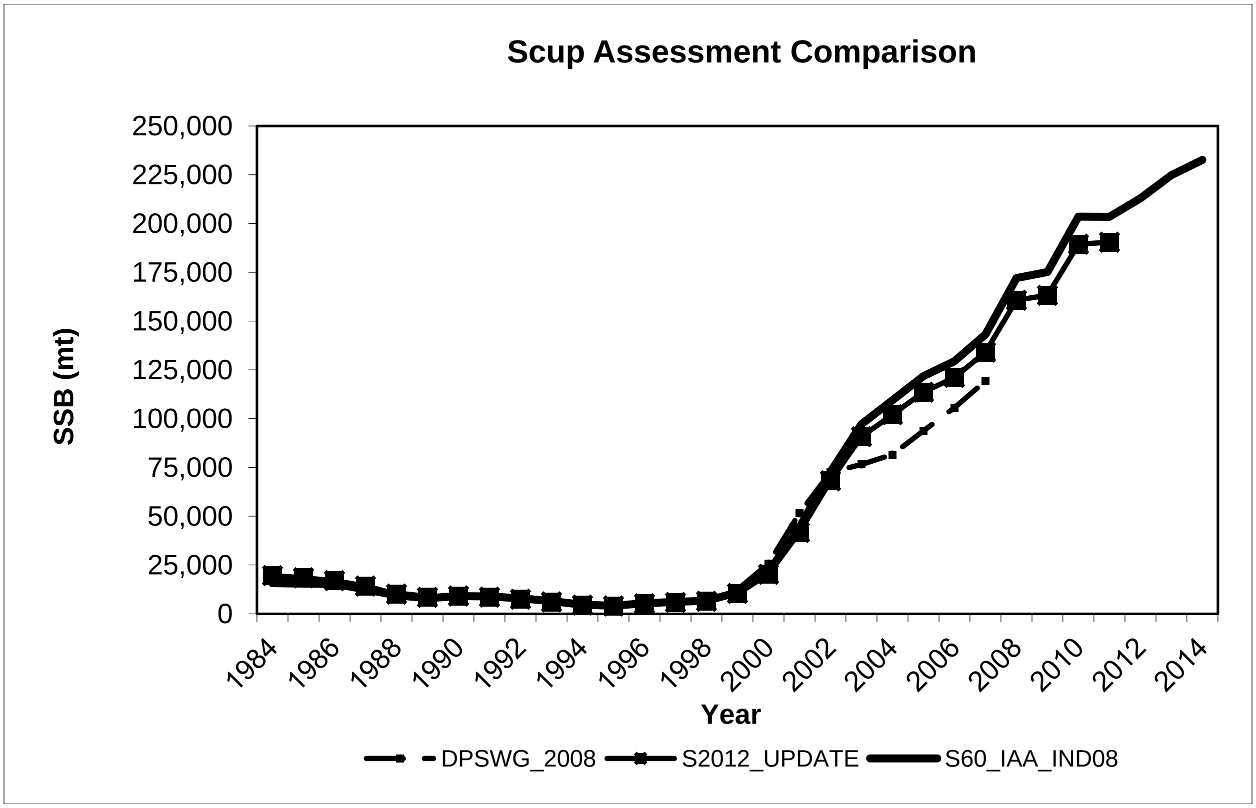


Figure A66. Comparison of 2008 DPSWG, 2012 Model Update, and 2015 SAW 60 IAA_IND08 (2008 model updated with data through 2014) estimates of SSB.

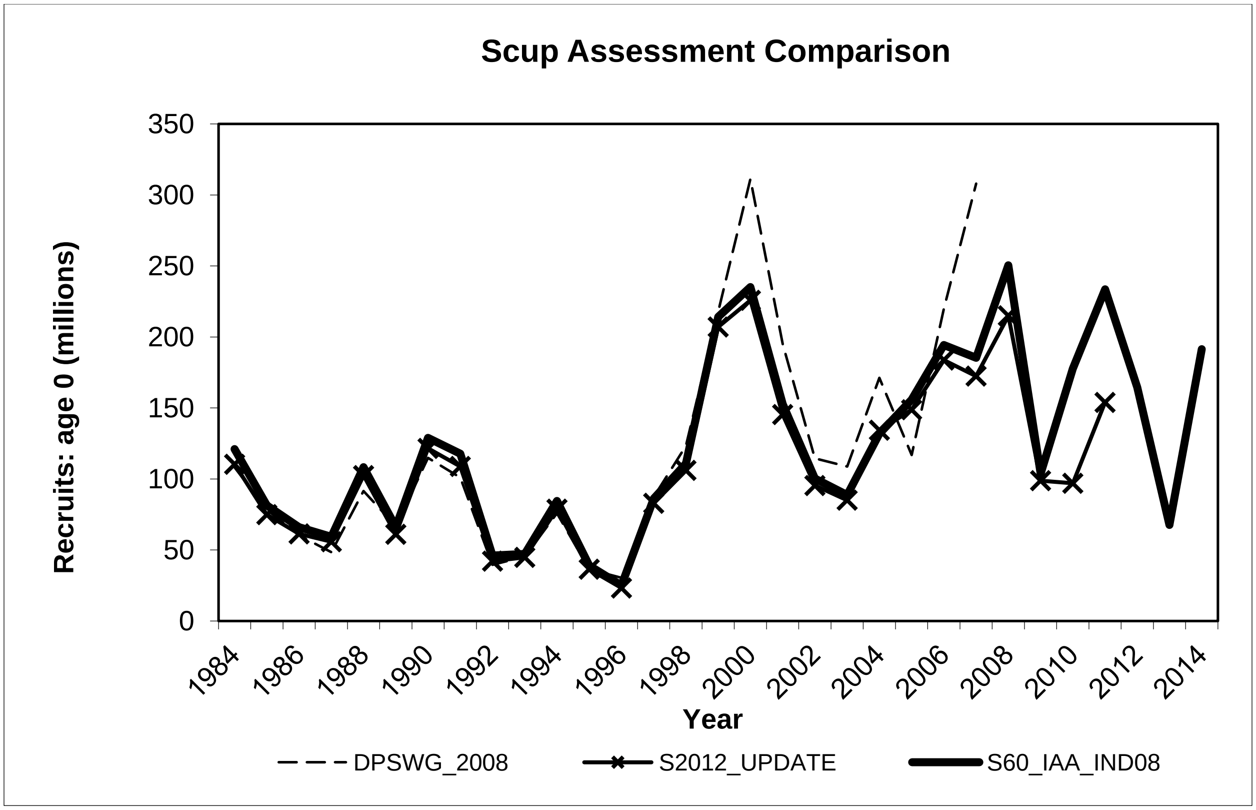


Figure A67. Comparison of 2008 DPSWG, 2012 Model Update, and 2015 SAW 60 IAA_IND08 (2008 model updated with data through 2014) estimates of R.

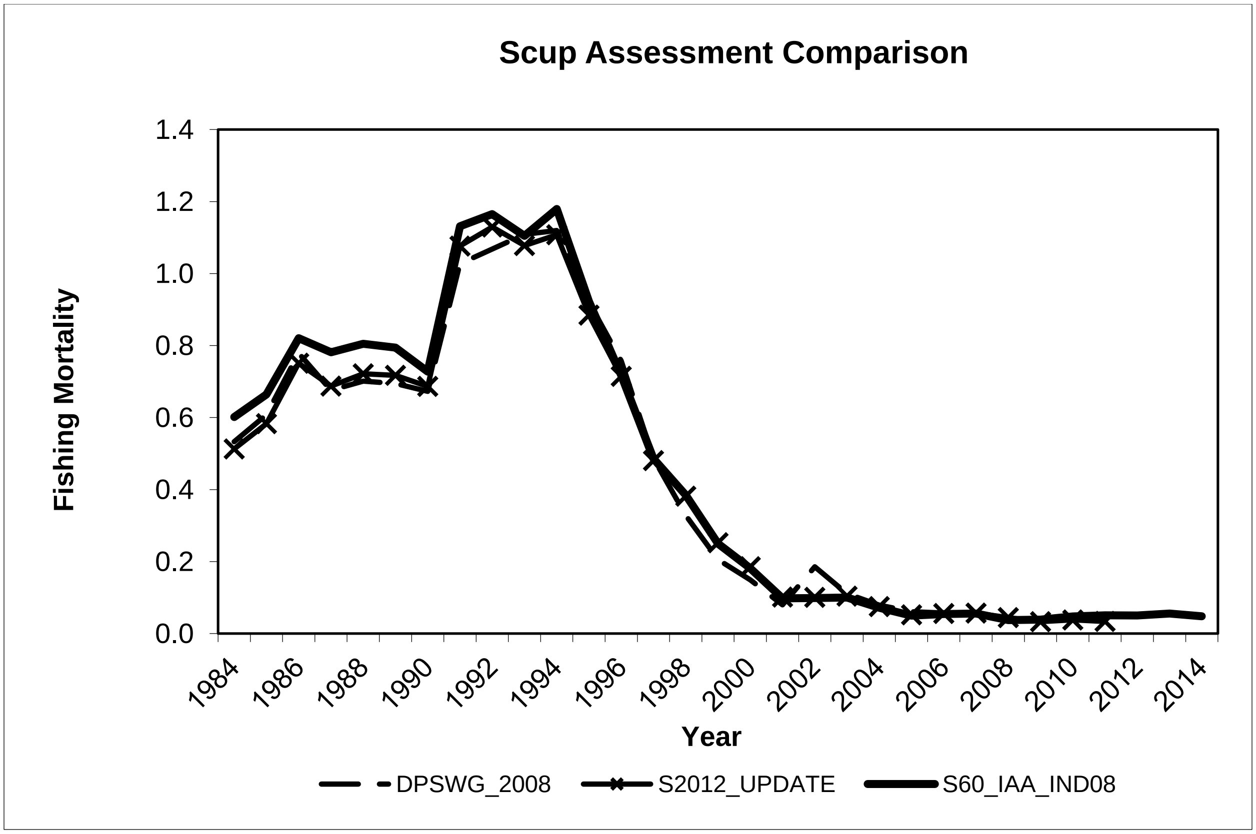


Figure A68. Comparison of 2008 DPSWG, 2012 Model Update, and 2015 SAW 60 IAA_IND08 (2008 model updated with data through 2014) estimates of F.

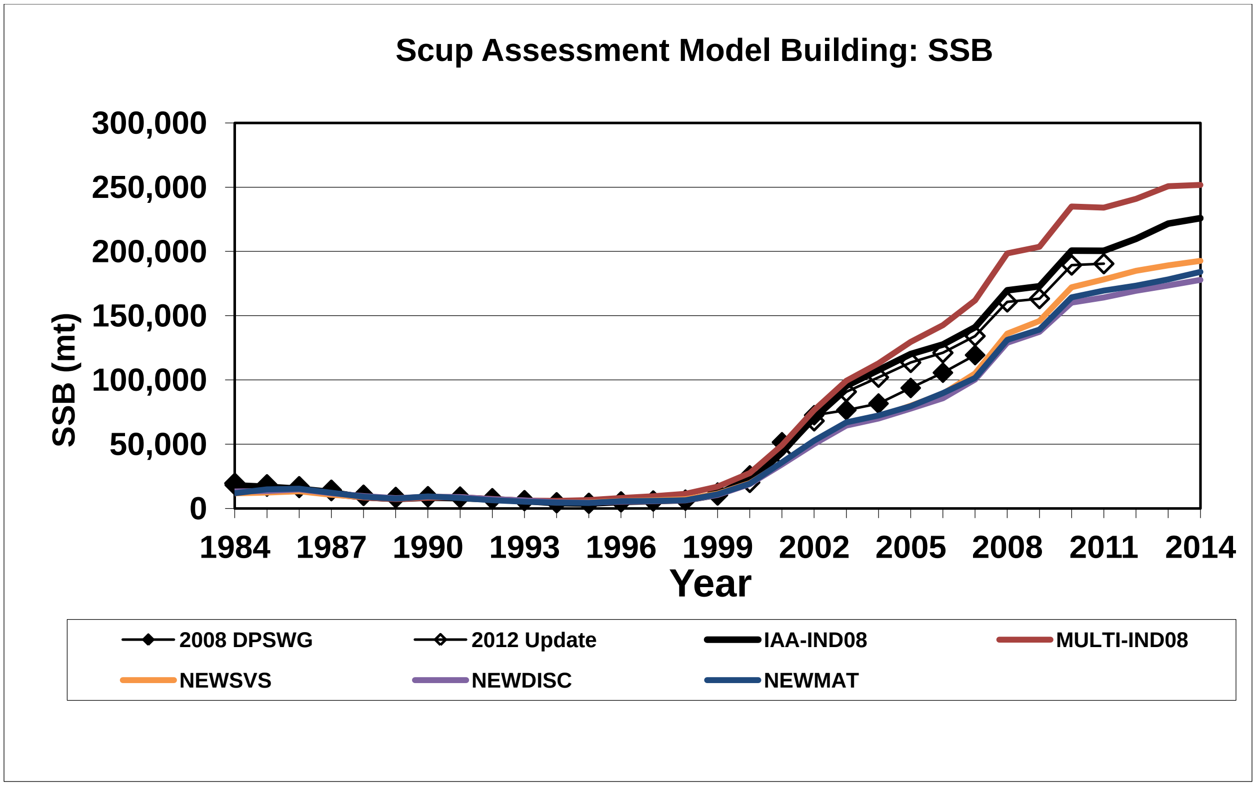


Figure A69. Comparison of 2008 DPSWG, 2012 Model Update, and 2015 SAW 60 IAA_IND08 through NEWMAT model estimates of SSB.

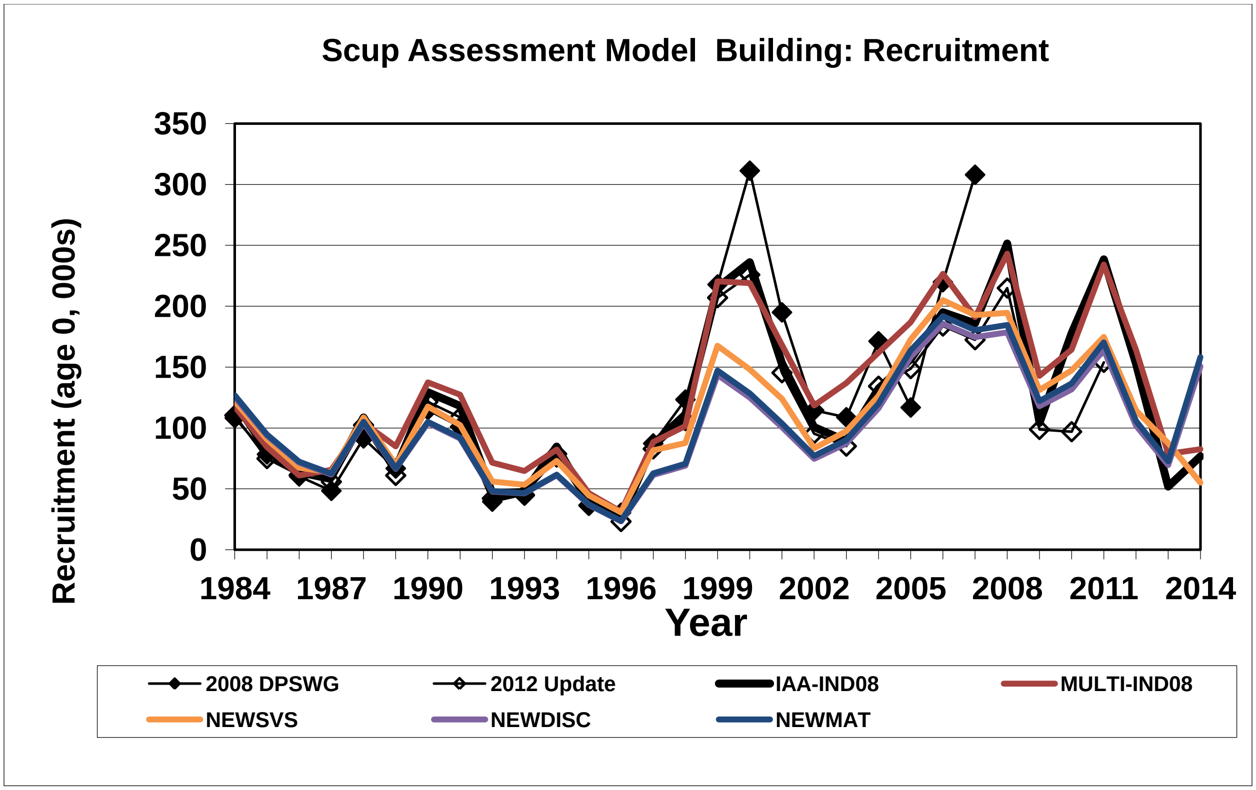


Figure A70. Comparison of 2008 DPSWG, 2012 Model Update, and 2015 SAW 60 IAA_IND08 through NEWMAT model estimates of R.

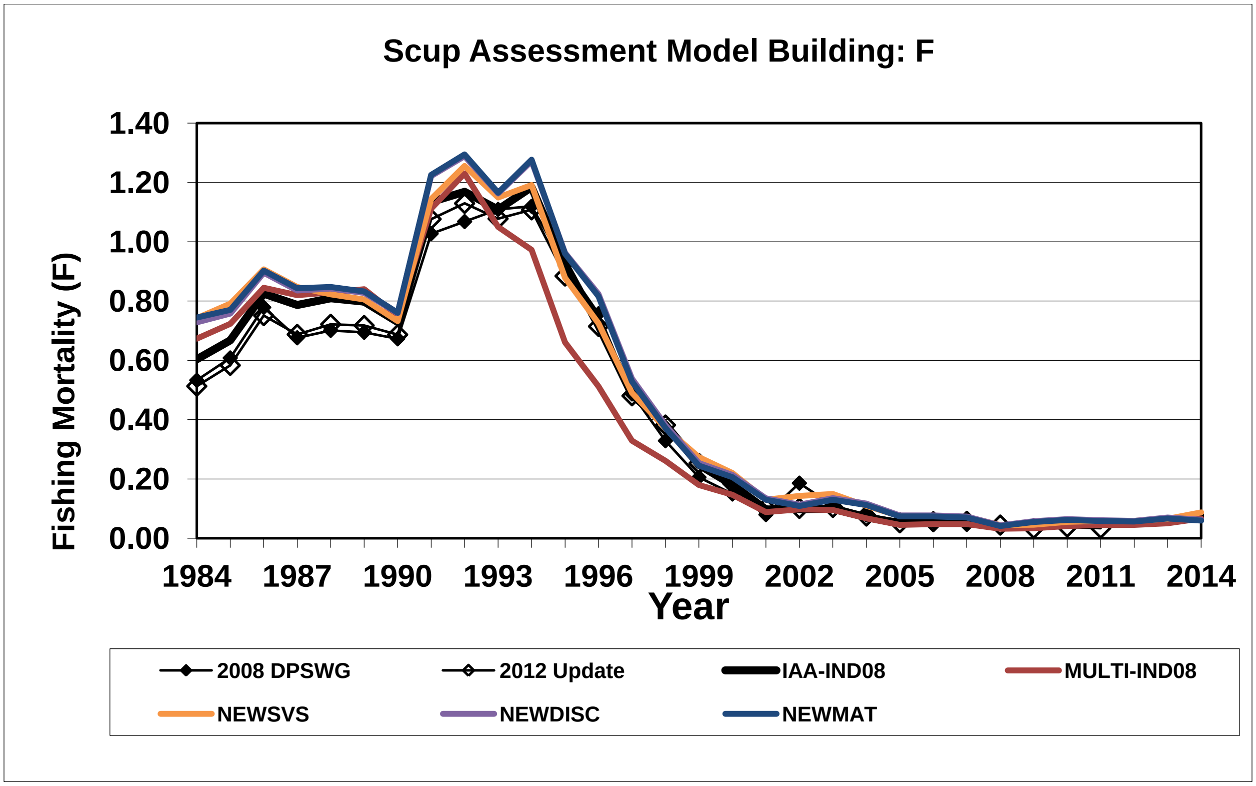


Figure A71. Comparison of 2008 DPSWG, 2012 Model Update, and 2015 SAW S60_IAA_IND08 through NEWMAT model estimates of F.

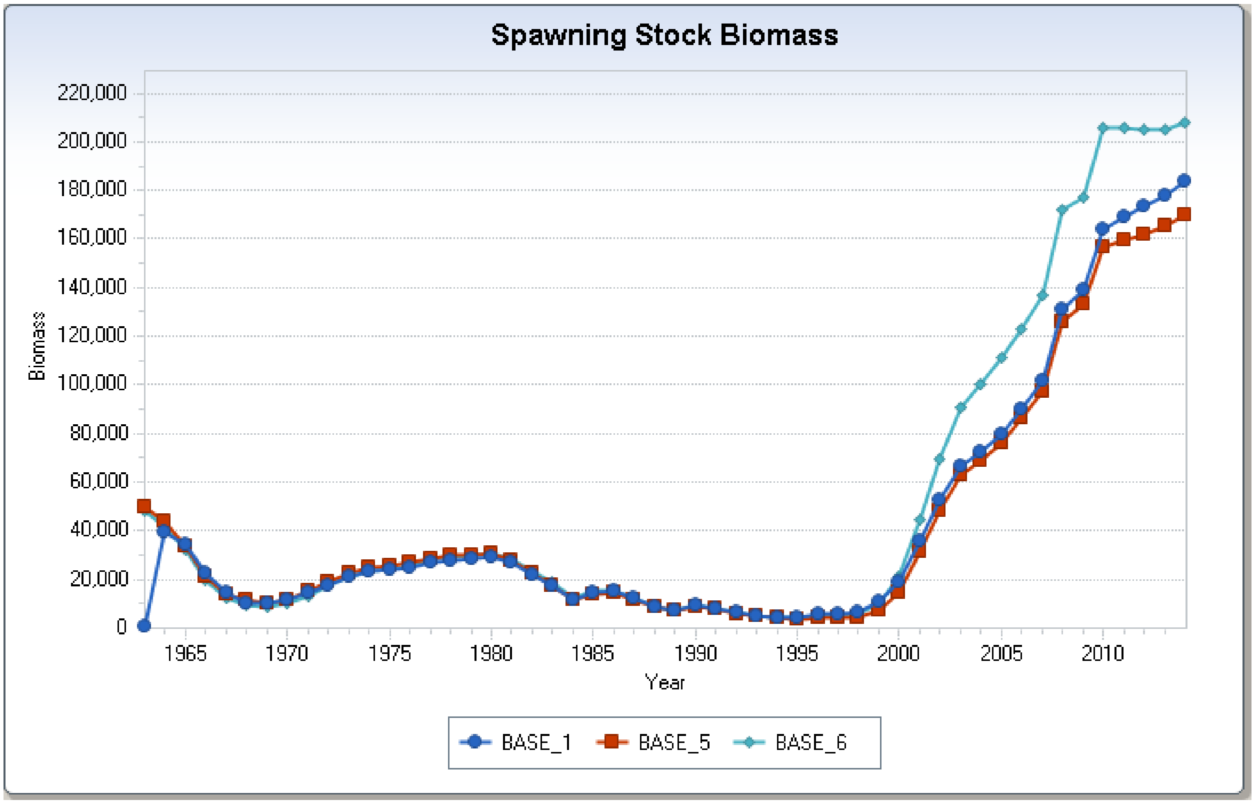


Figure A72. Comparison of 2015 SAW 60 models BASE_1, BASE_5, and BASE_6 estimates of SSB.

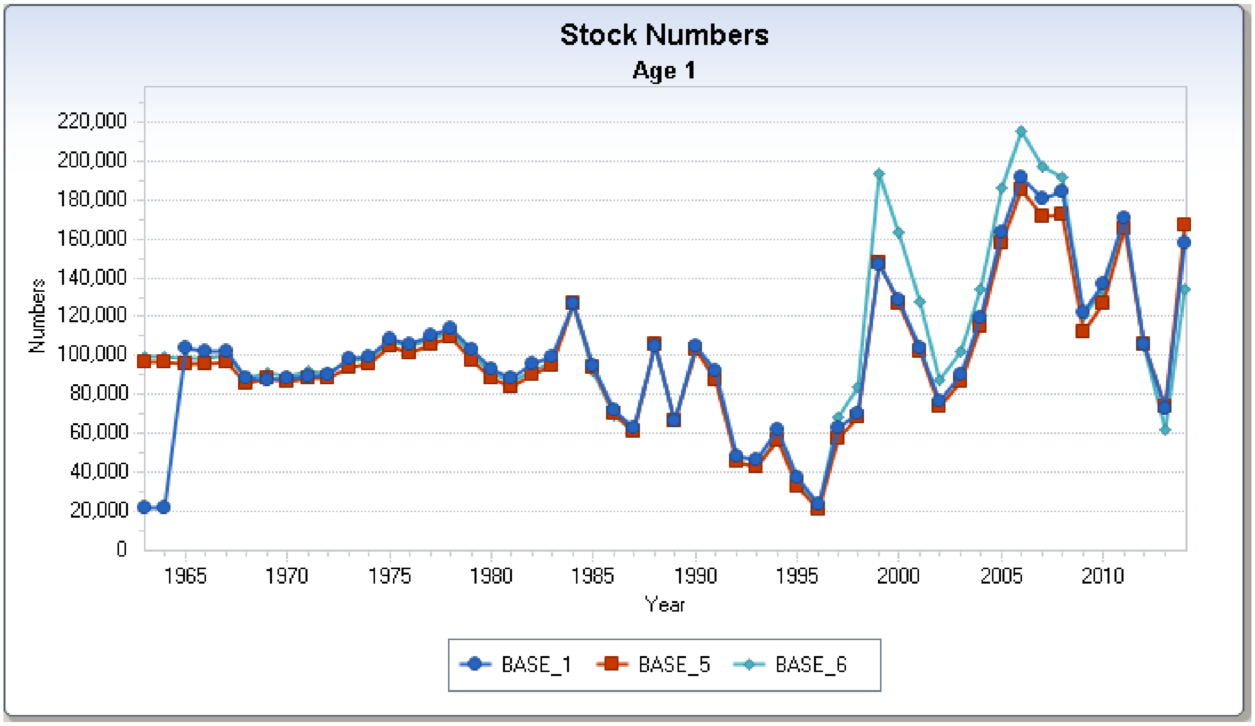


Figure A73. Comparison of 2015 SAW 60 models BASE_1, BASE_5, and BASE_6 estimates of R (recruitment at true age 0, model age 1).

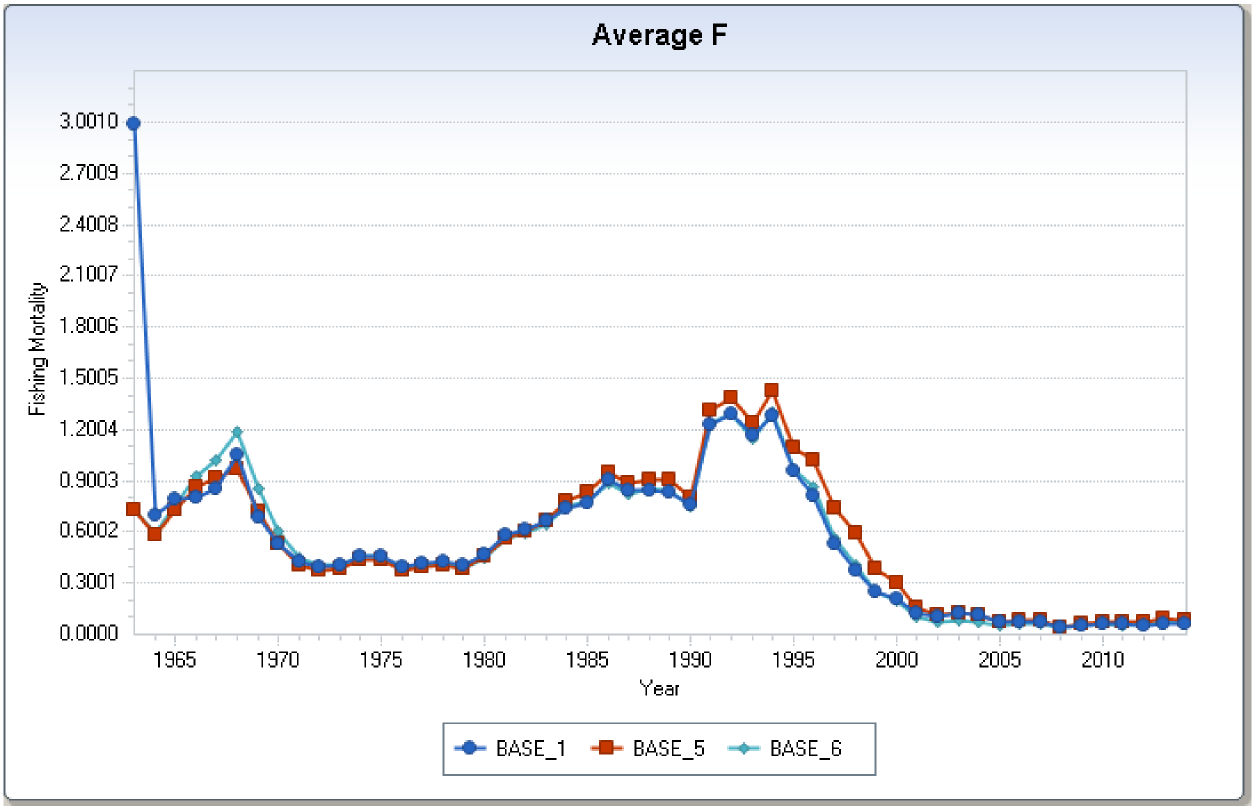


Figure A74. Comparison of 2015 SAW 60 models BASE_1, BASE_5, and BASE_6 estimates of F.

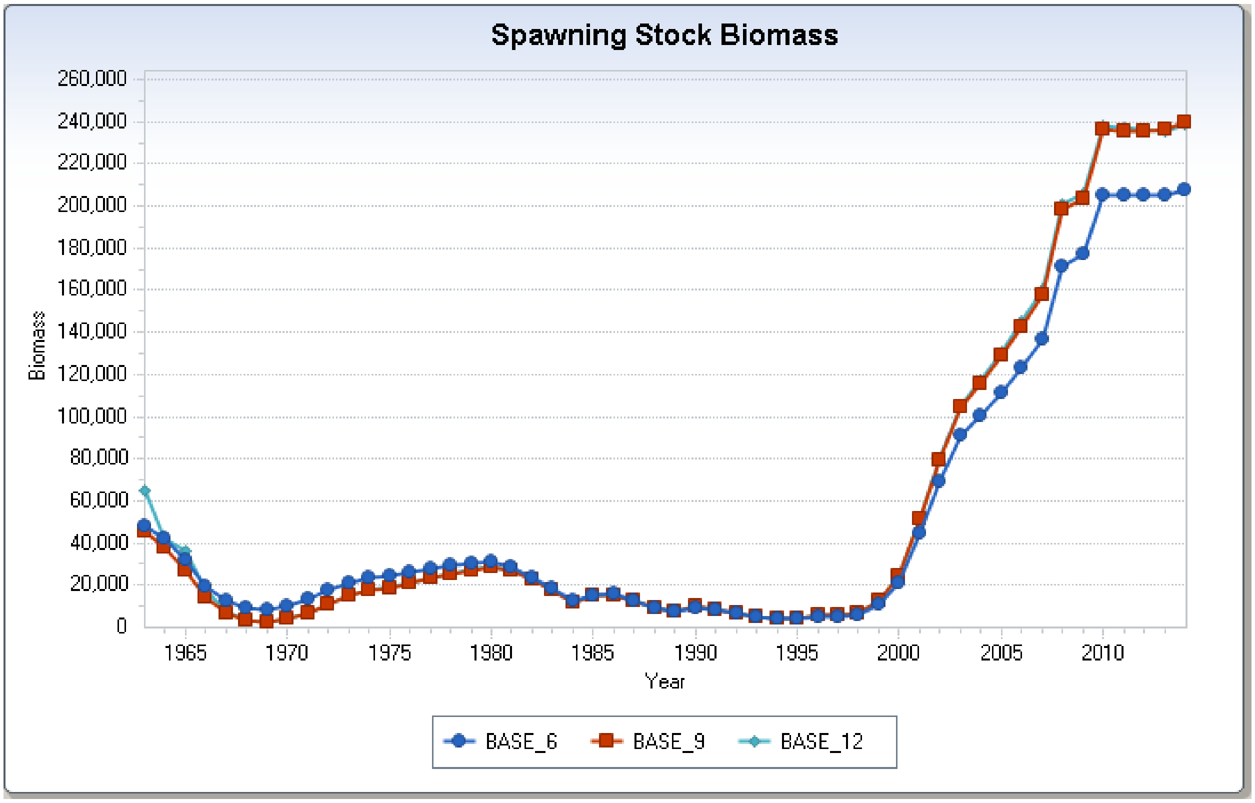


Figure A75. Comparison of 2015 SAW 60 models BASE_6, BASE_9, and BASE_12 estimates of SSB.

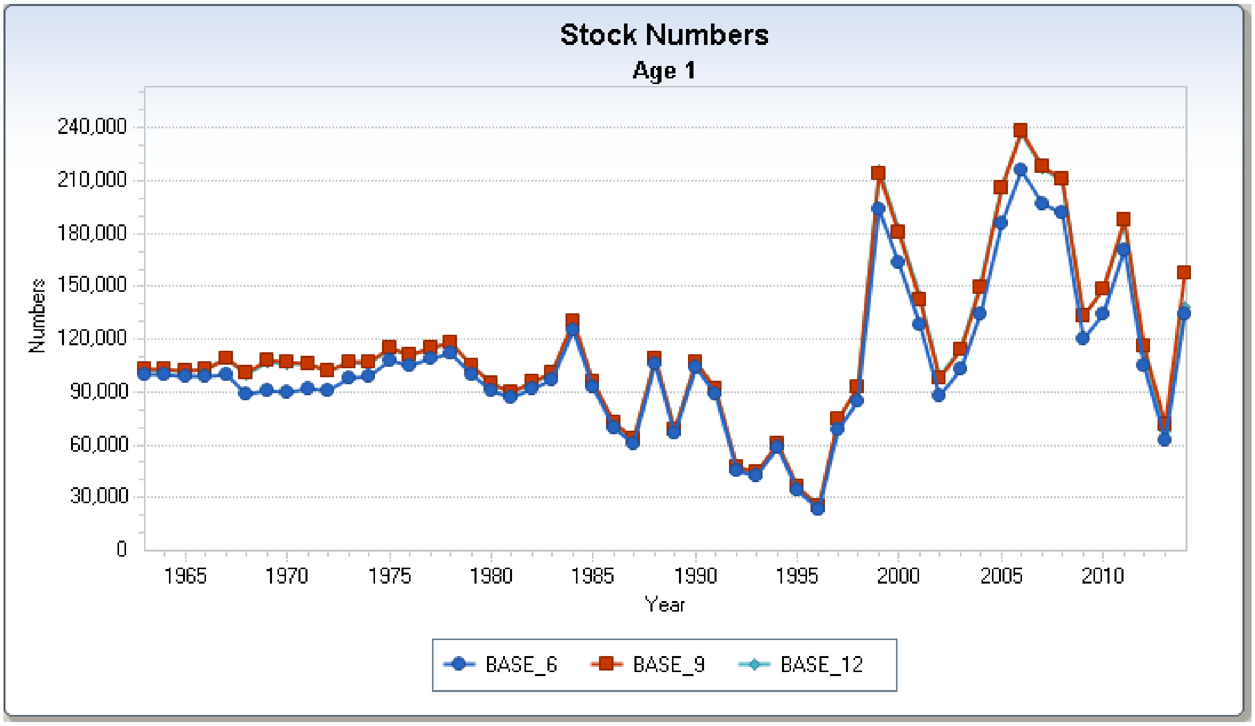


Figure A76. Comparison of 2015 SAW 60 models BASE_6, BASE_9, and BASE_12 estimates of R (recruitment at true age 0, model age 1).

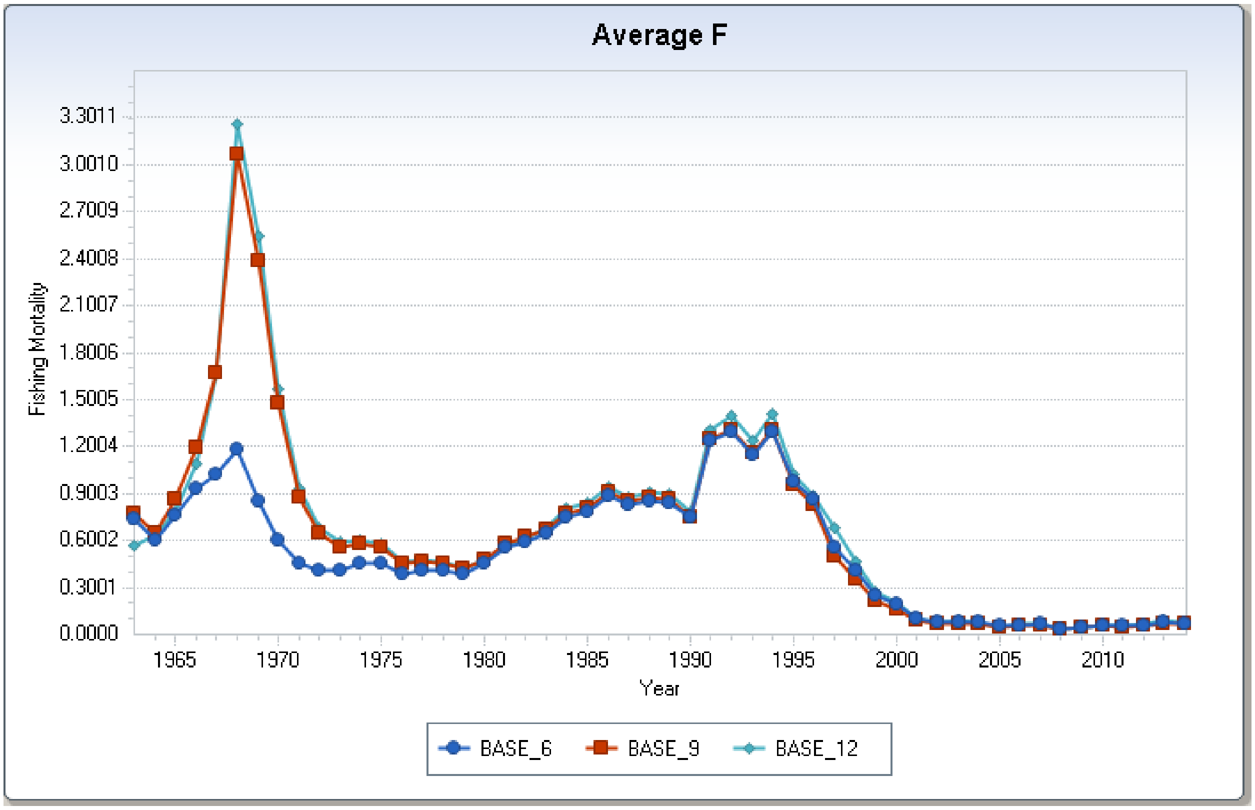


Figure A77. Comparison of 2015 SAW 60 models BASE_6, BASE_9, and BASE_12 estimates of F.

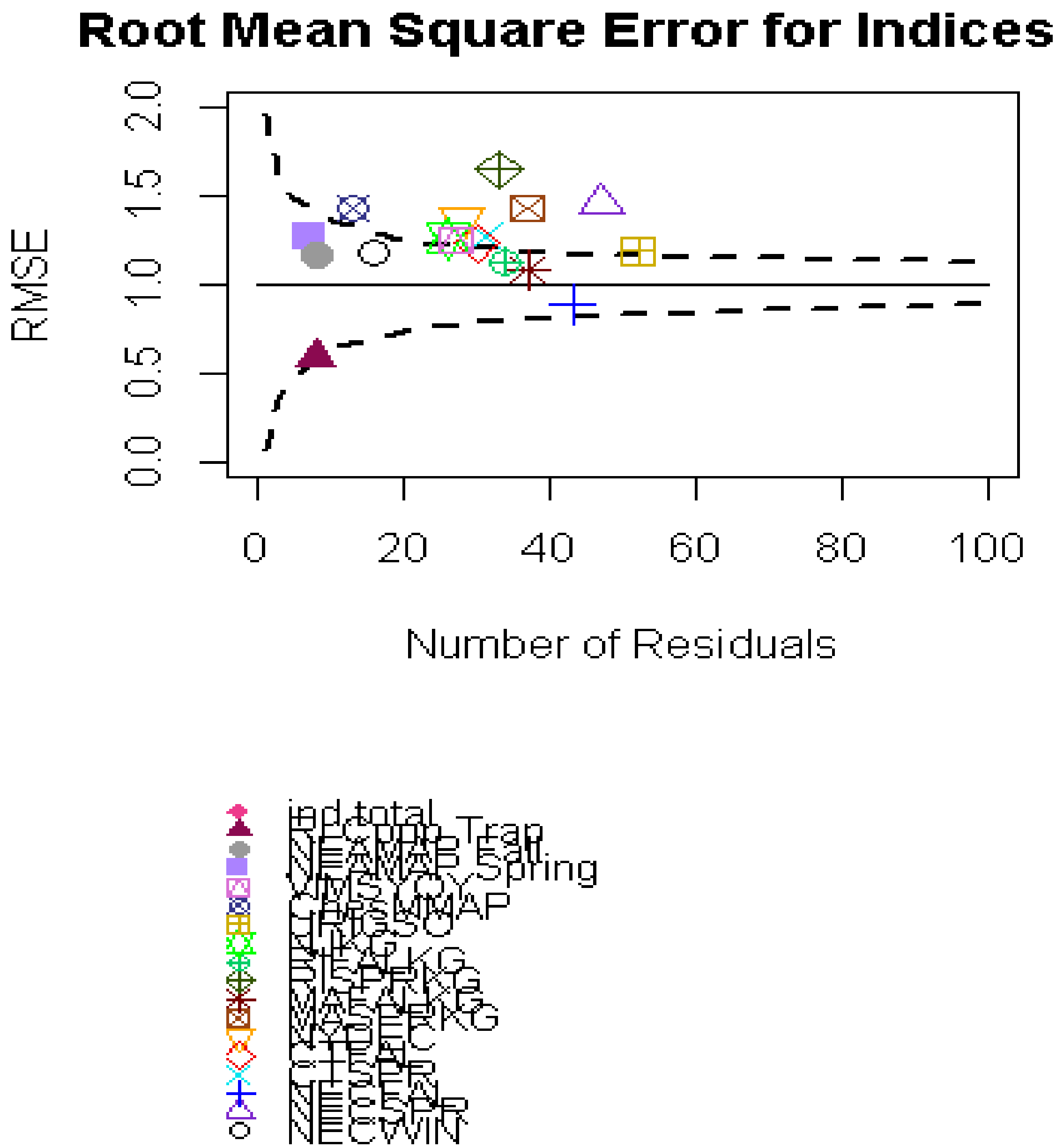


Figure A78. RMSE plot for run S60_BASE_13.

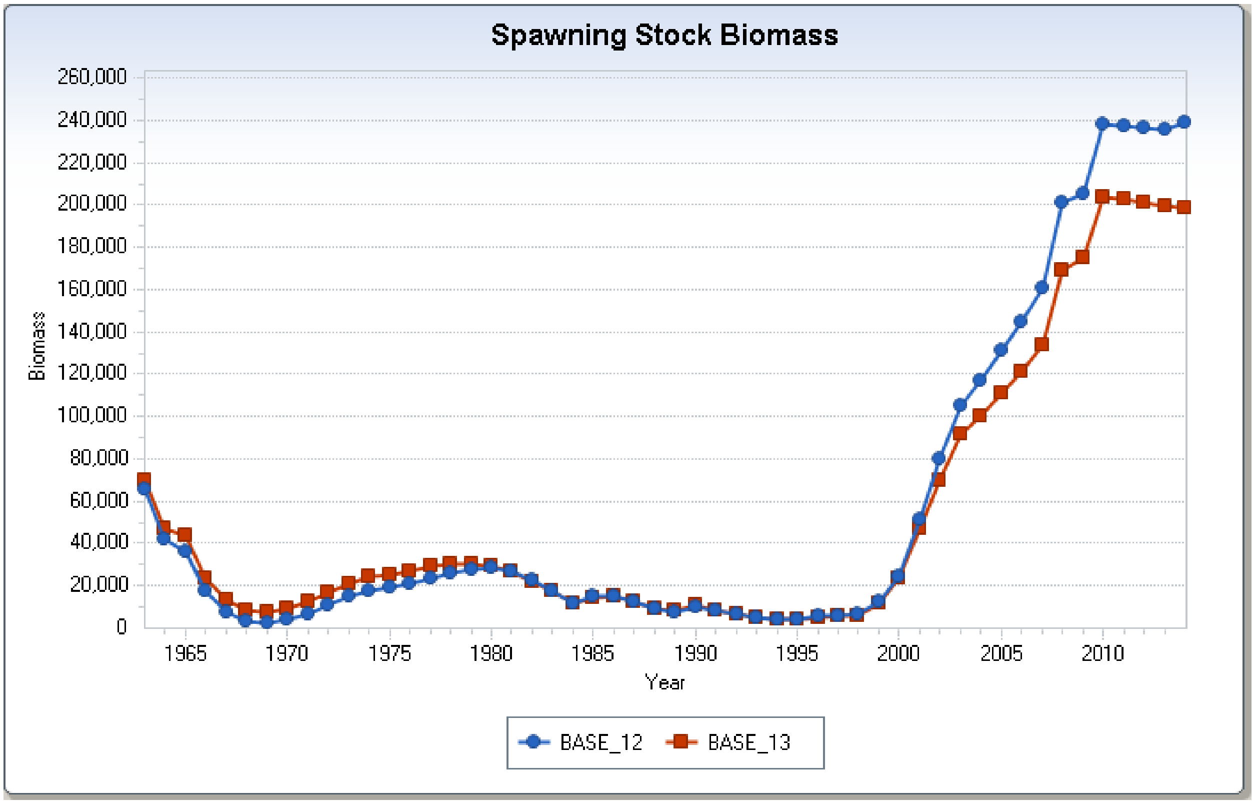


Figure A79. Comparison of 2015 SAW 60 models BASE_12 and BASE_13 estimates of SSB.

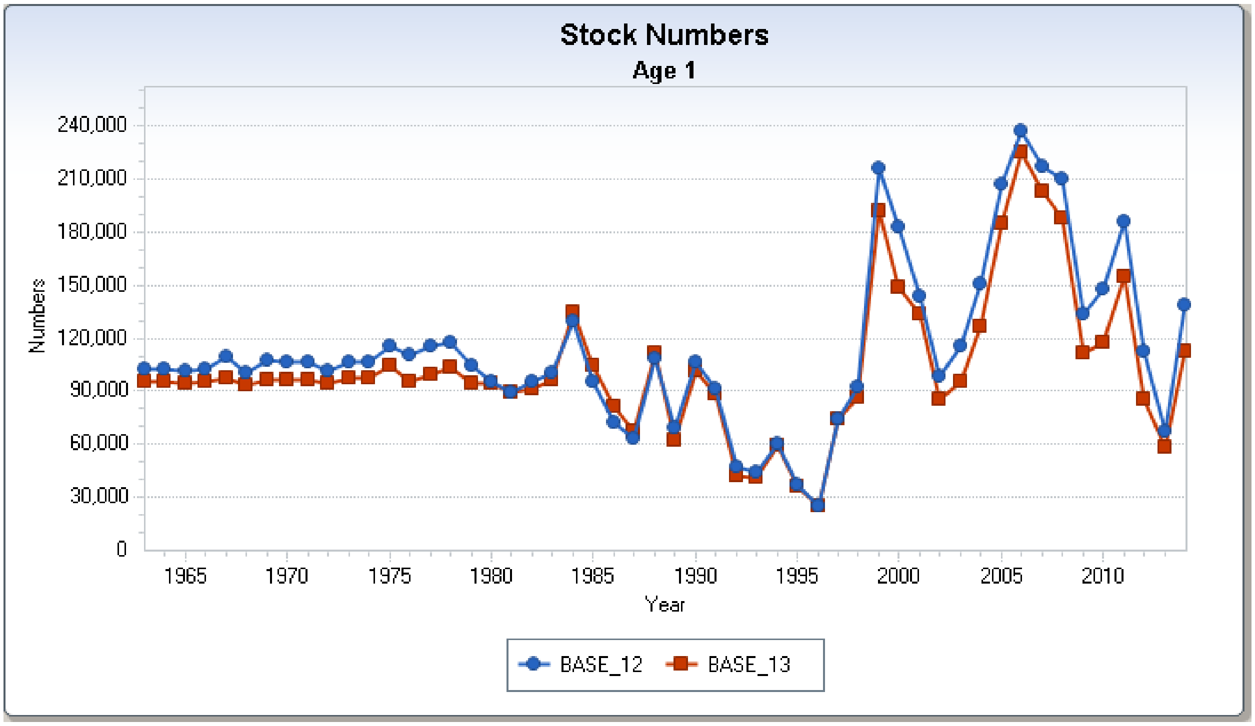


Figure A80. Comparison of 2015 SAW 60 models BASE_12 and BASE_13 estimates of R (recruitment at true age 0, model age 1).

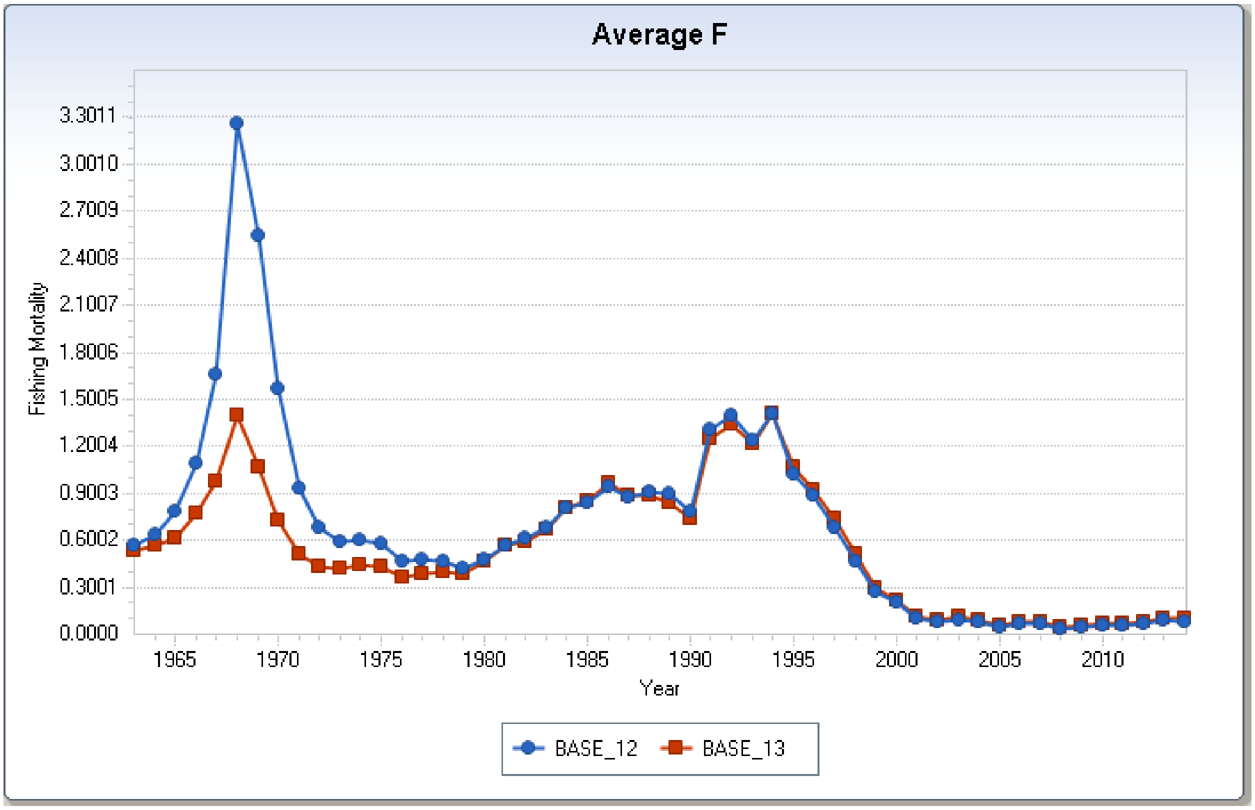


Figure A81. Comparison of 2015 SAW 60 models BASE_12 and BASE_13 estimates of F.

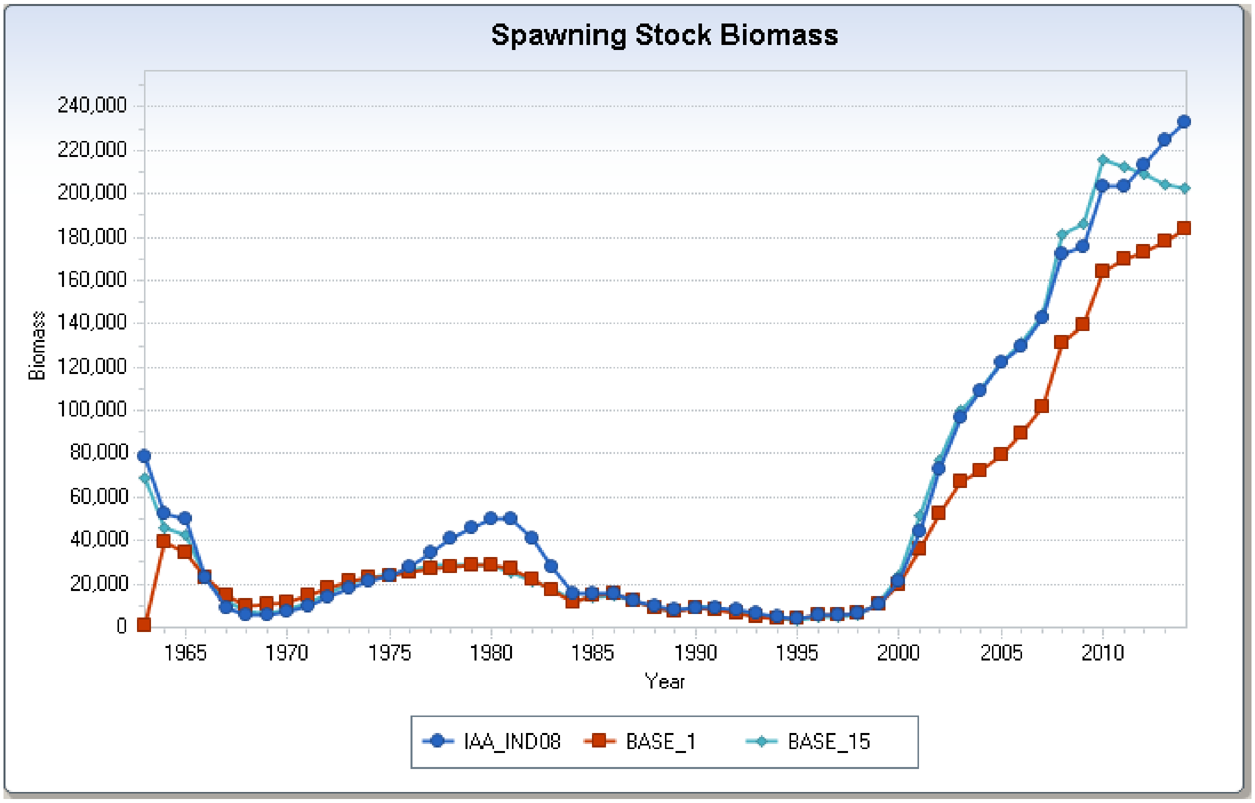


Figure A82. Comparison of 2015 SAW 60 models IAA_IND08, BASE_1 and BASE_15 estimates of SSB.

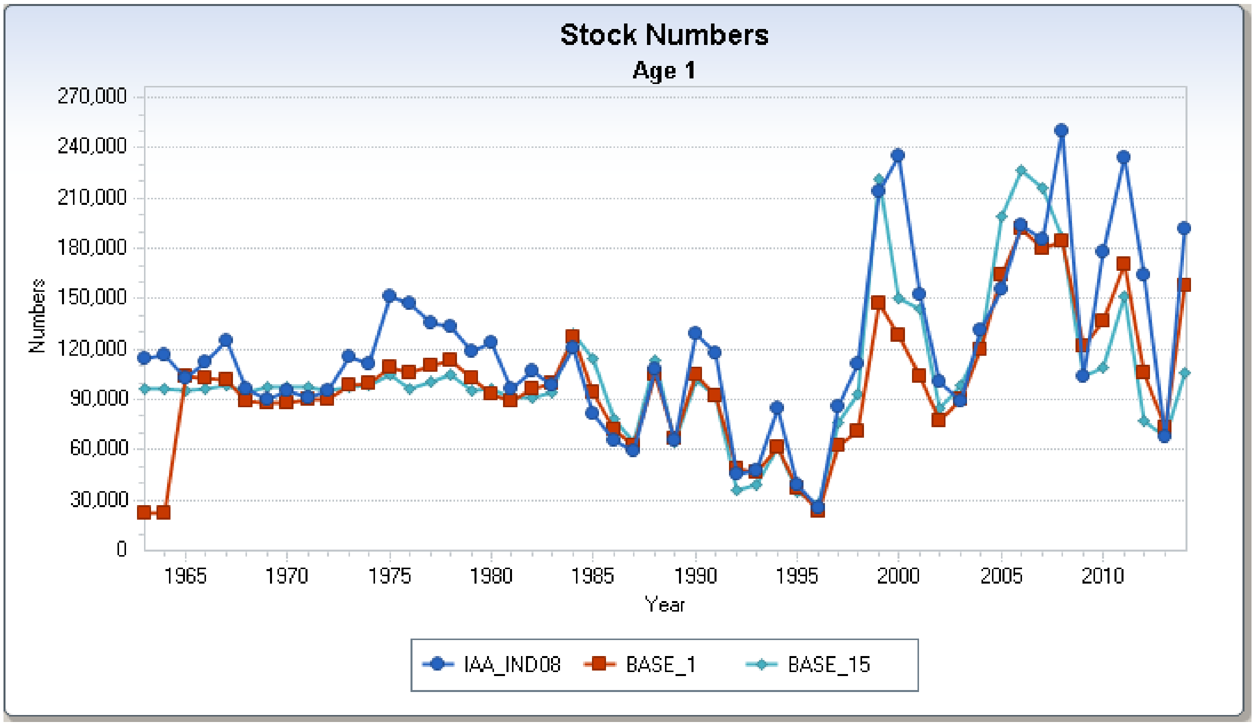


Figure A83. Comparison of 2015 SAW 60 models IAA_IND08, BASE_1 and BASE_15 estimates of R (recruitment at true age 0, model age 1).

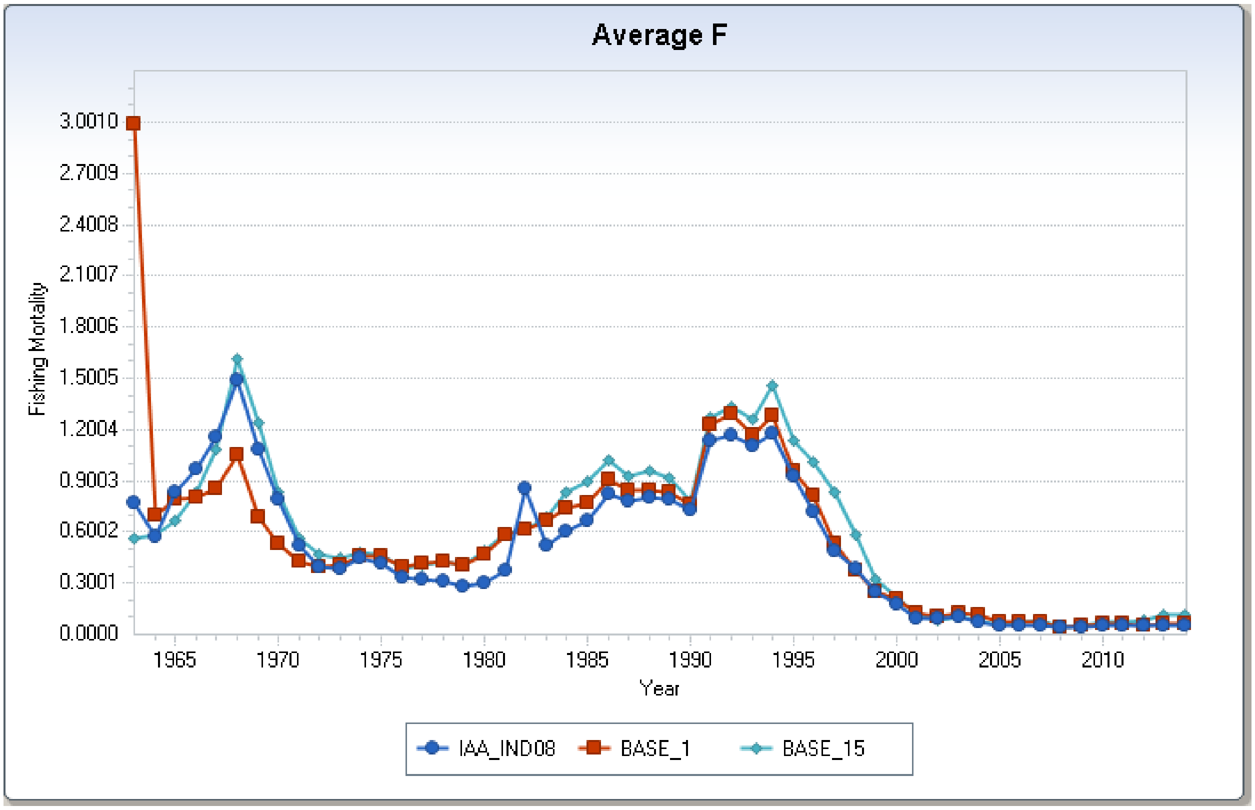


Figure A84. Comparison of 2015 SAW 60 models IAA_IND08, BASE_1 and BASE_15 estimates of F.

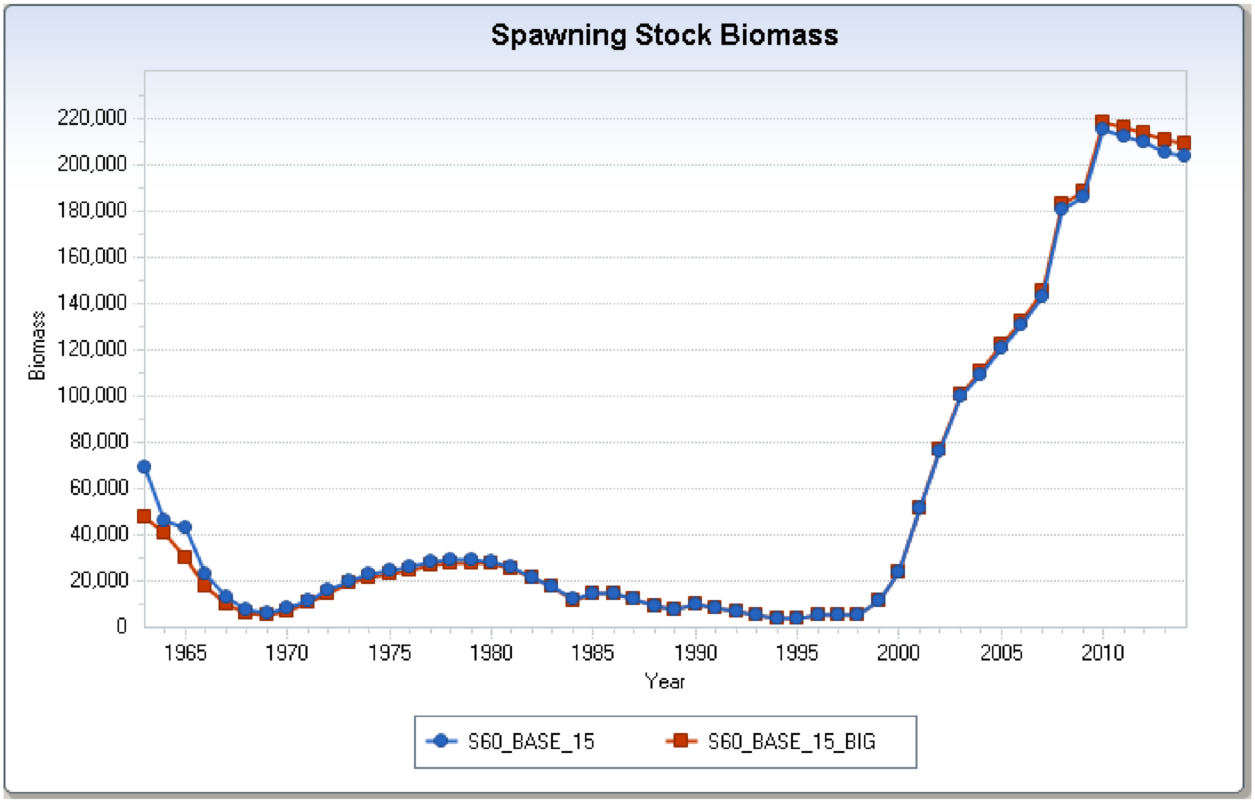


Figure A85. Comparison of run S60_BASE_15 (all calibrated ALB indices) with S60_BASE_15_BIG (ALB indices for 1968/1972 -2008; BIG indices for 2009-2014): SSB.

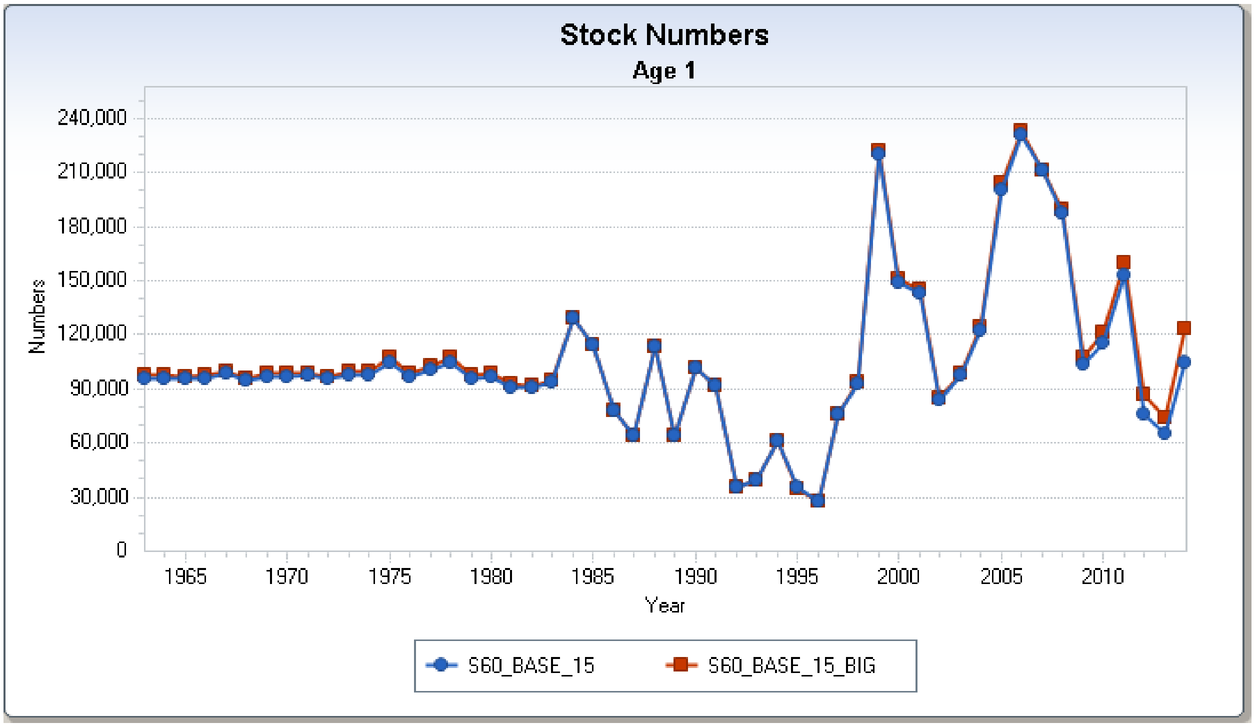


Figure A86. Comparison of run S60_BASE_15 (all calibrated ALB indices) with S60_BASE_15_BIG (ALB indices for 1968/1972 -2008; BIG indices for 2009-2014): R (recruitment at true age 0, model age 1).

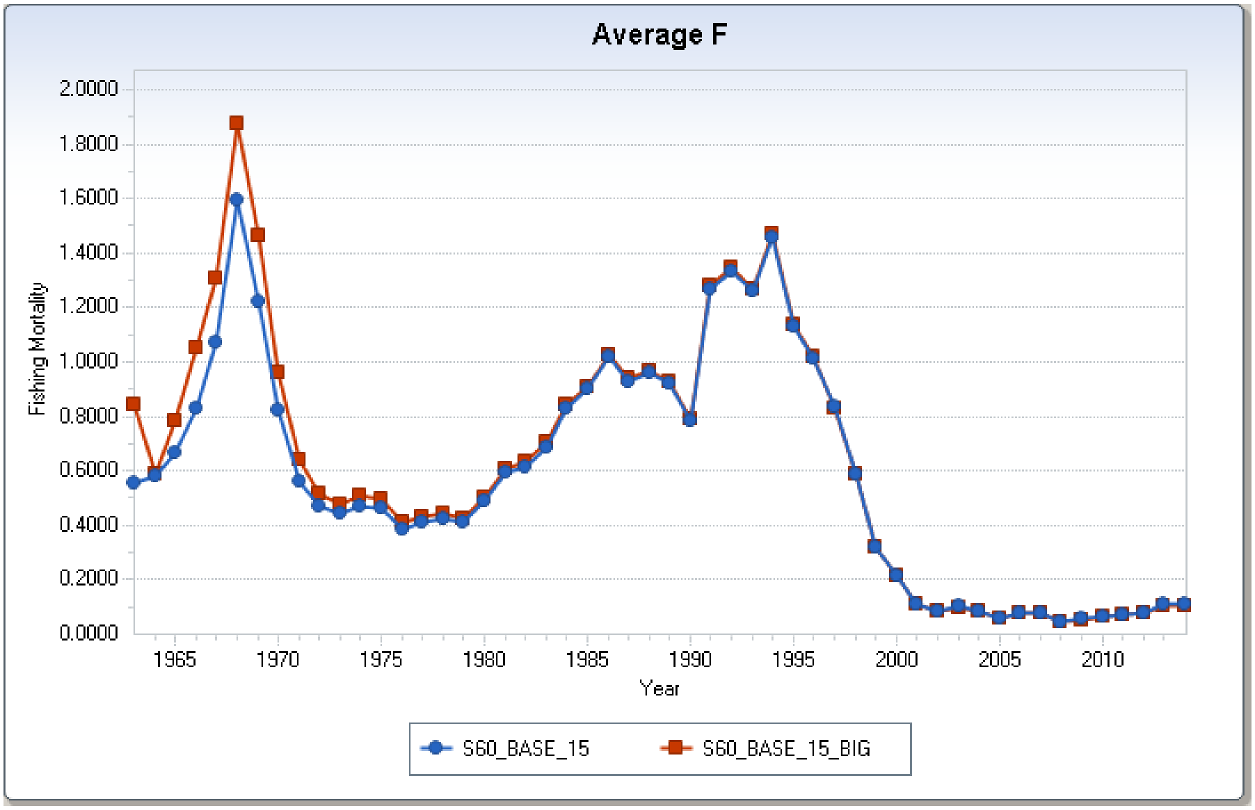


Figure A87. Comparison of run S60_BASE_15 (all calibrated ALB indices) with S60_BASE_15_BIG (ALB indices for 1968/1972 -2008; BIG indices for 2009-2014): F.

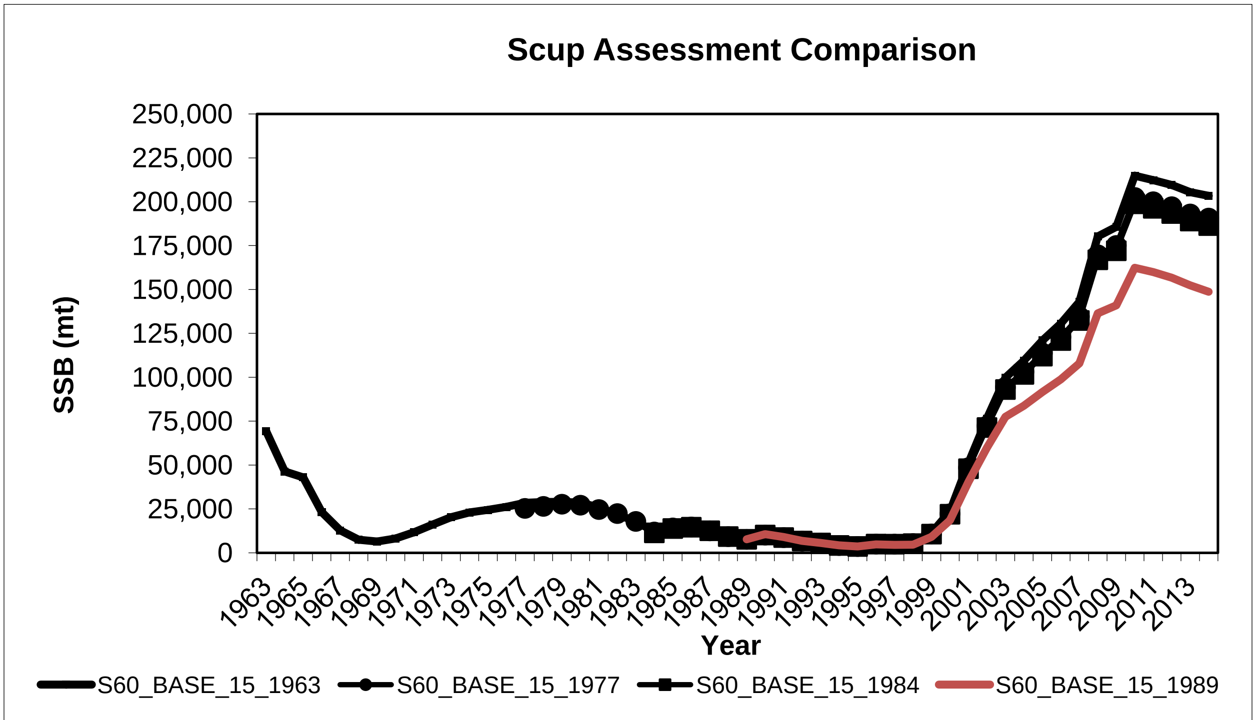


Figure A88. Comparison of the S60_BASE_15 run starting in 1963, with 3 alternatives starting in 1977, 1984, and 1989: SSB.

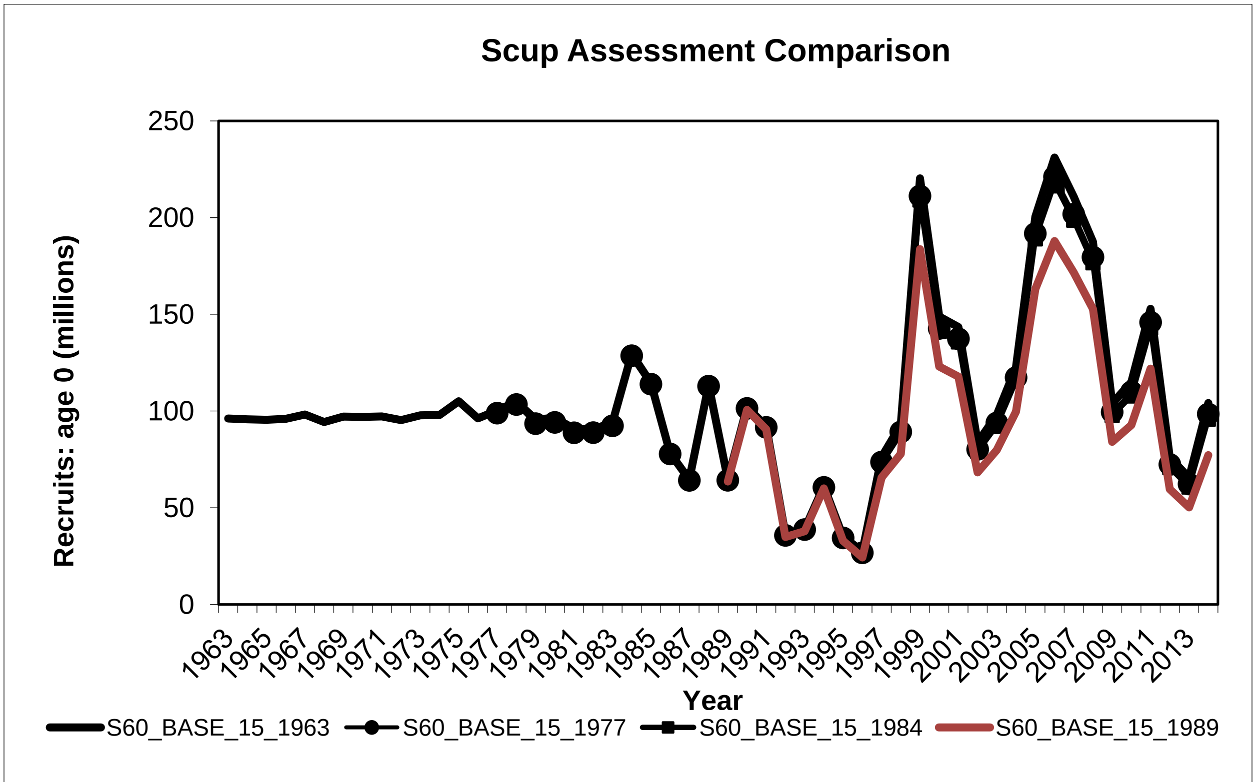


Figure A89. Comparison of the S60_BASE_15 run starting in 1963, with 3 alternatives starting in 1977, 1984, and 1989: R (recruitment at age 0, model age 1).

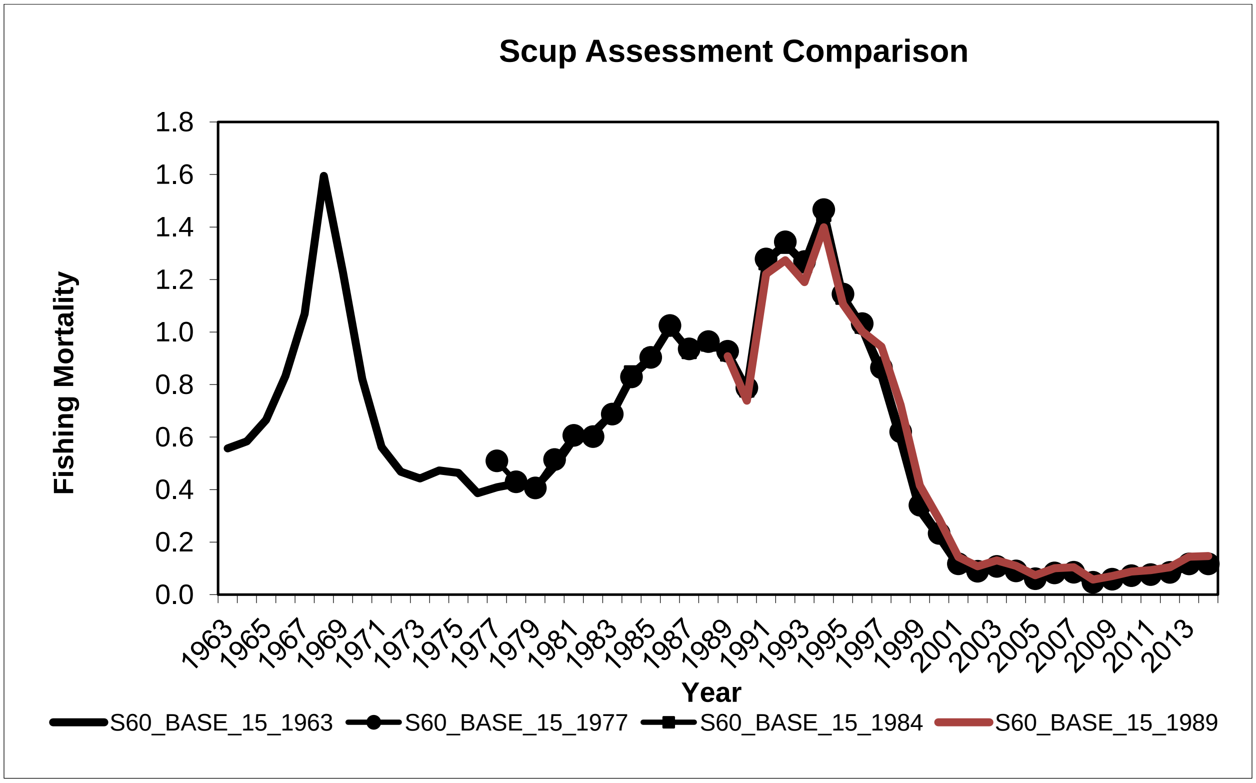
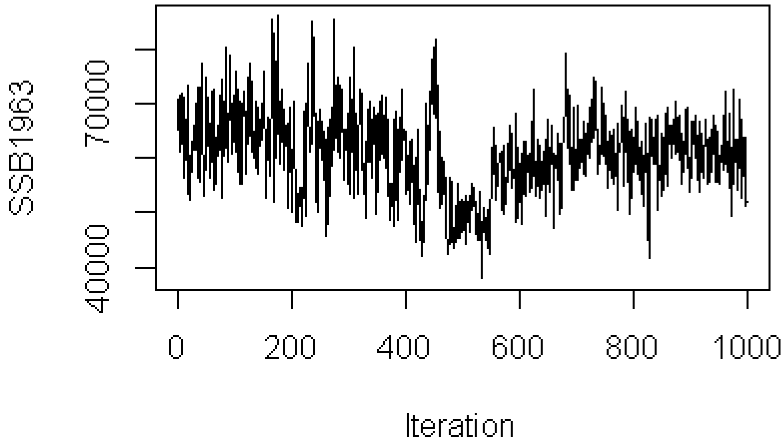


Figure A90. Comparison of the S60_BASE_15 run starting in 1963, with 3 alternatives starting in 1977, 1984, and 1989: F.



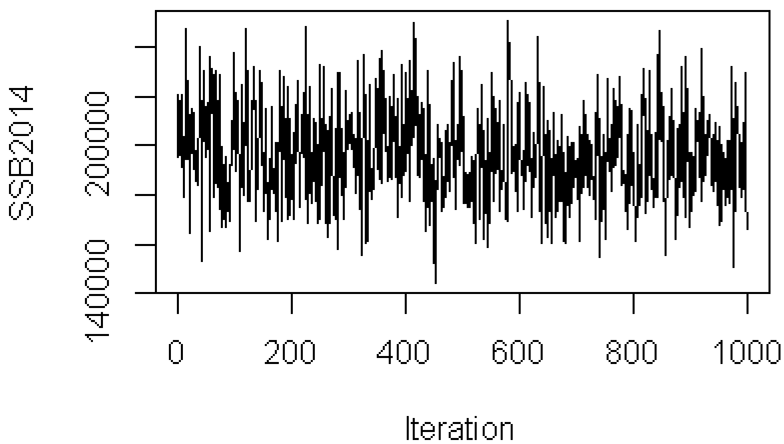


Figure A91. Run S60_BASE_15_1963 MCMC chains for SSB.

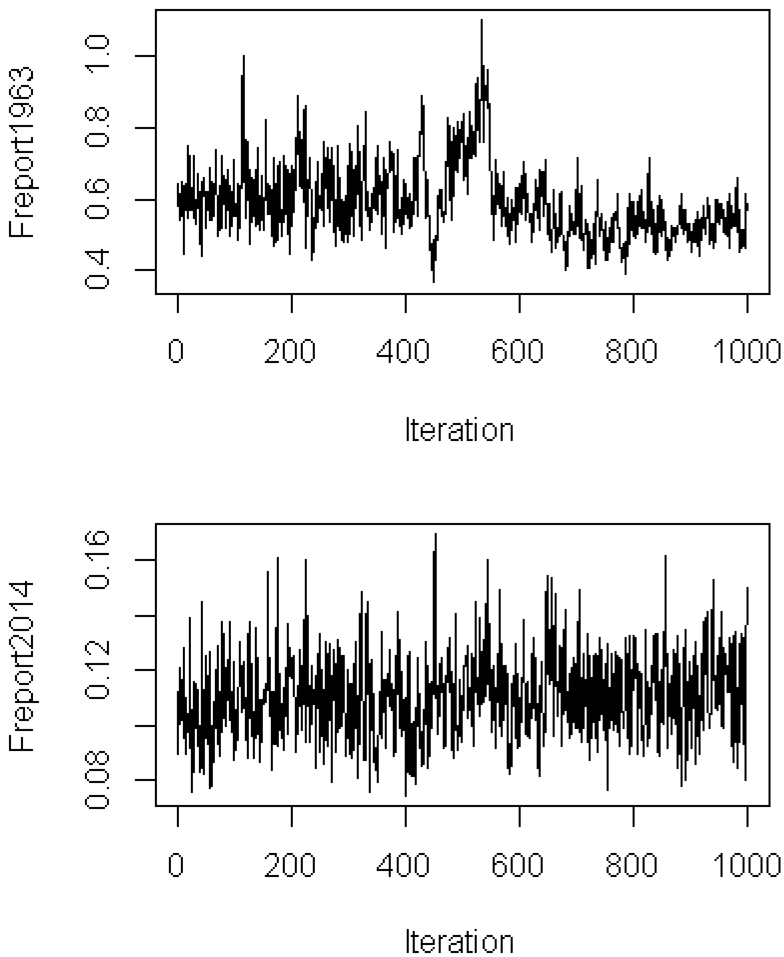


Figure A92. Run S60_BASE_15_1963 MCMC chains for F.

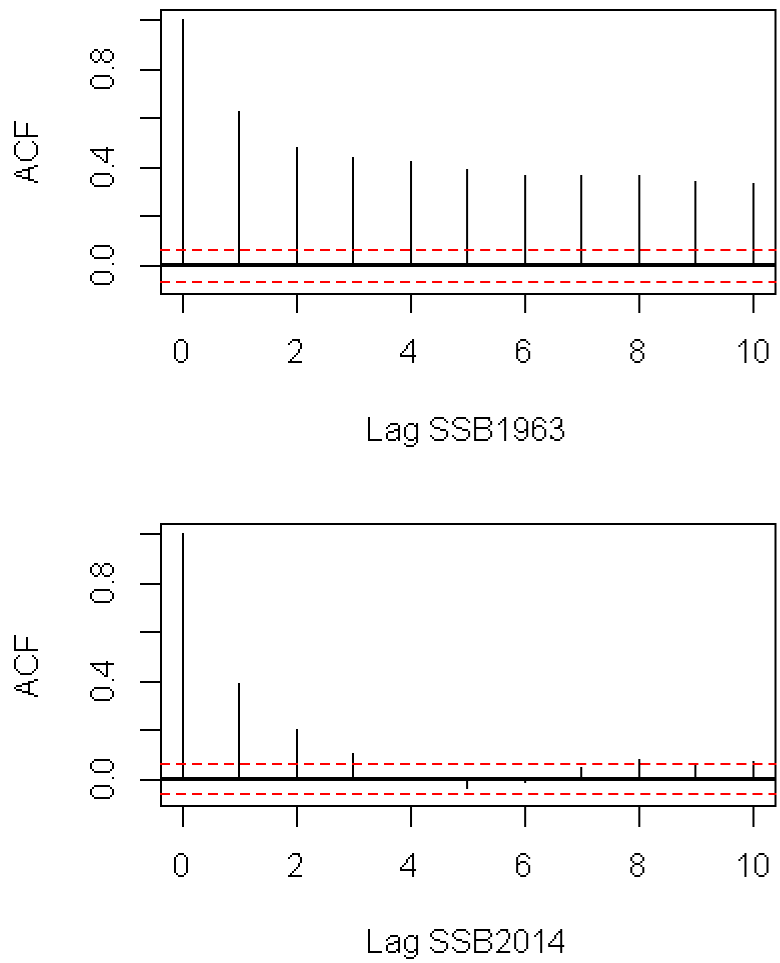


Figure A93. Autocorrelation plot for run S60_BASE_15_1963 MCMC estimates: SSB.

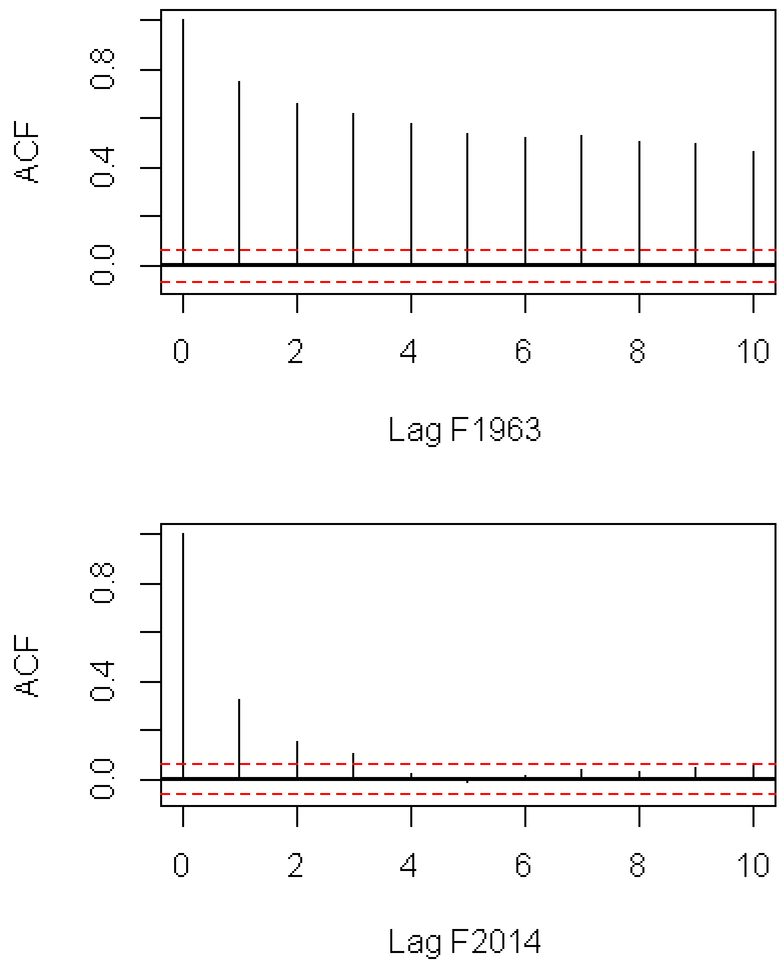


Figure A94. Autocorrelation plot for run S60_BASE_15_1963 estimates: F.

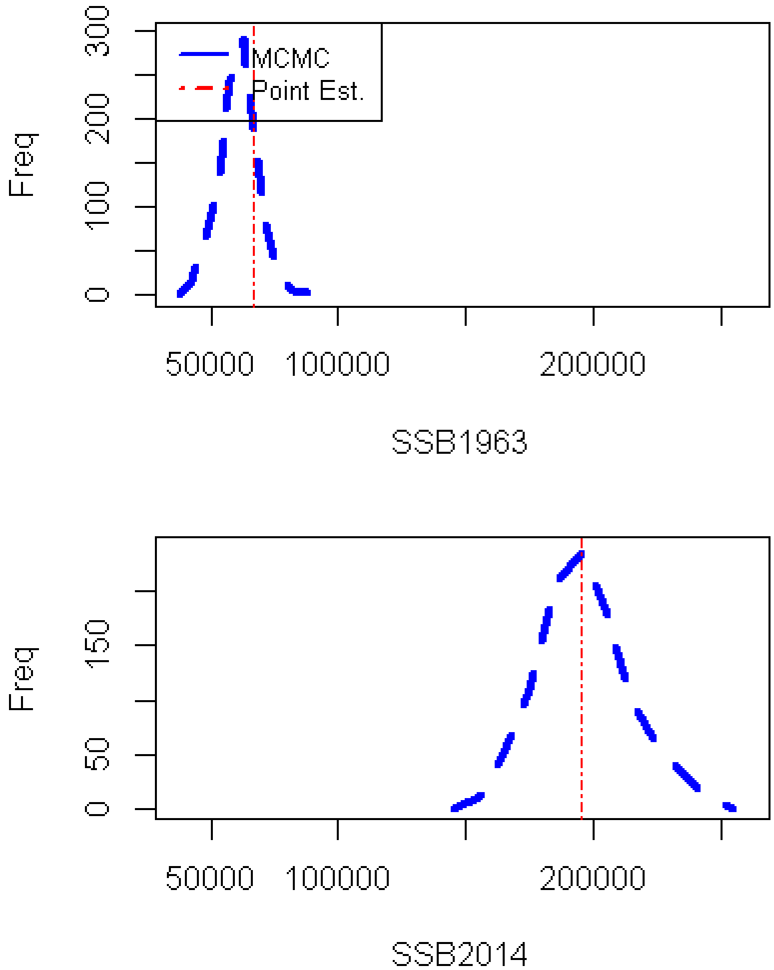


Figure A95. Run S60_BASE_15_1963 point estimates and MCMC distributions: SSB.

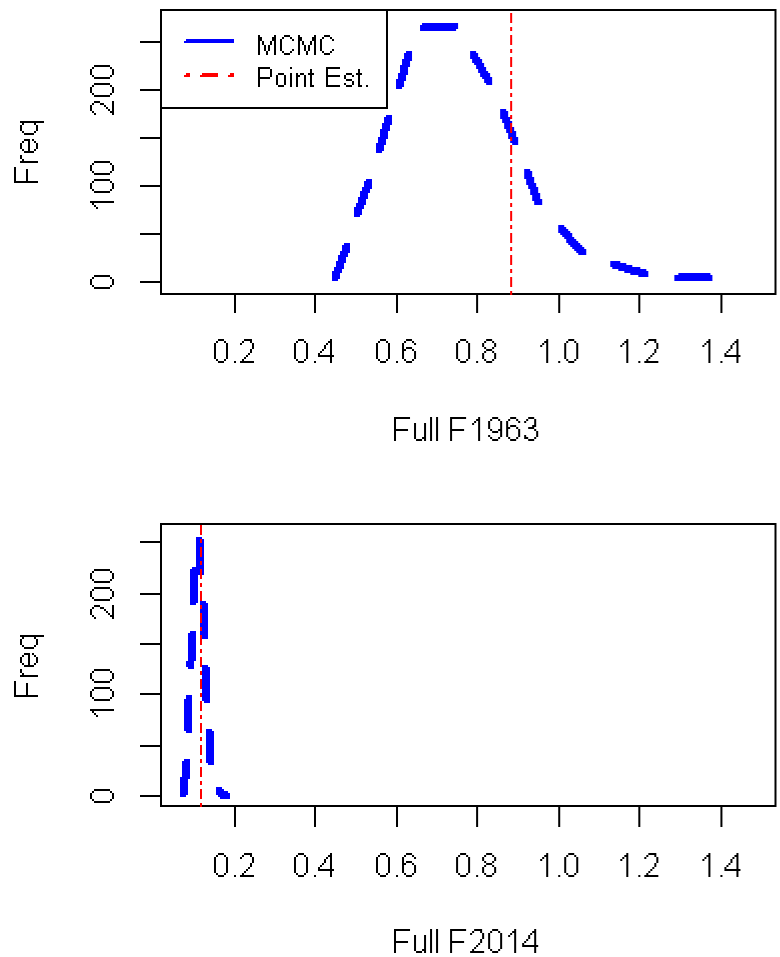
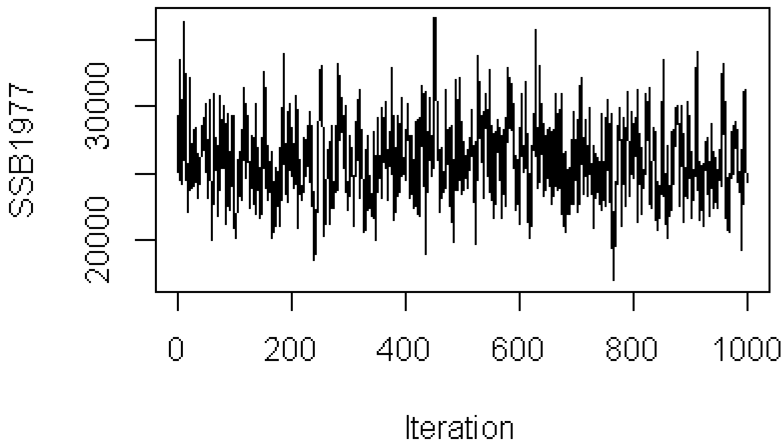


Figure A96. Run S60_BASE_15_1963 point estimates and MCMC distributions: F.



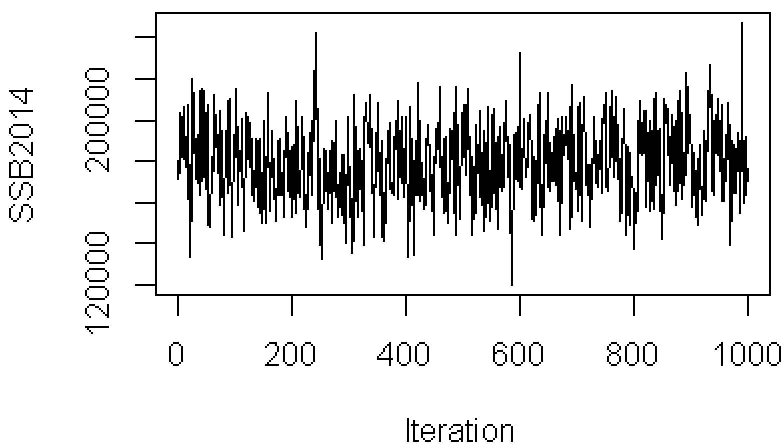


Figure A97. Run S60_BASE_15_1977 MCMC chains for SSB.

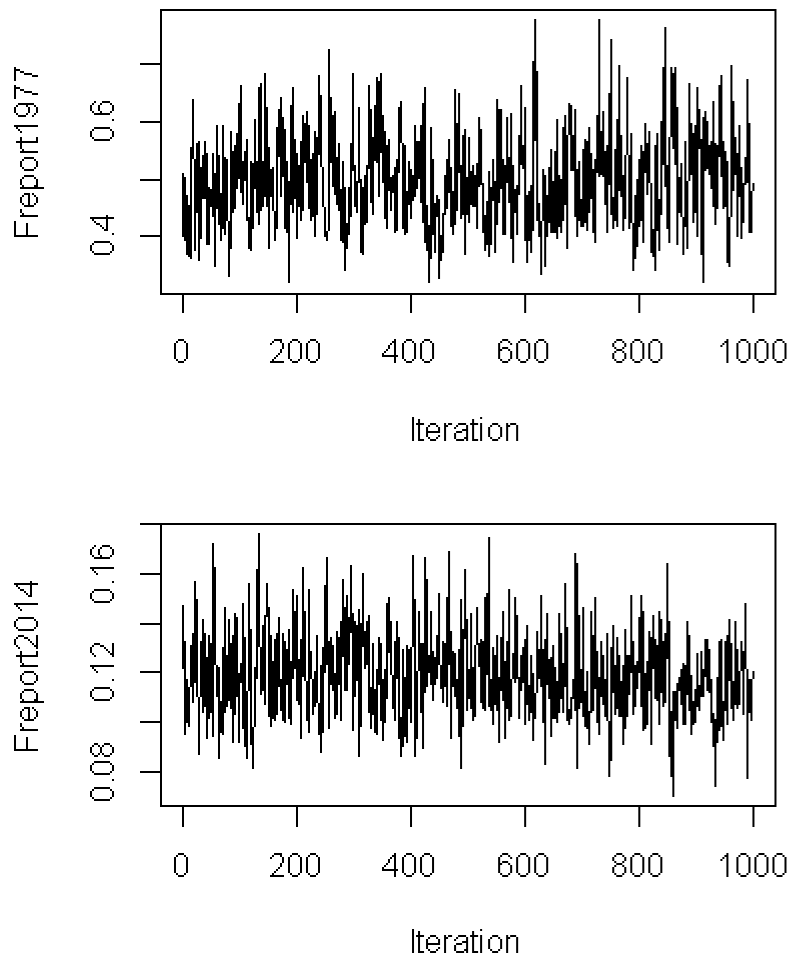
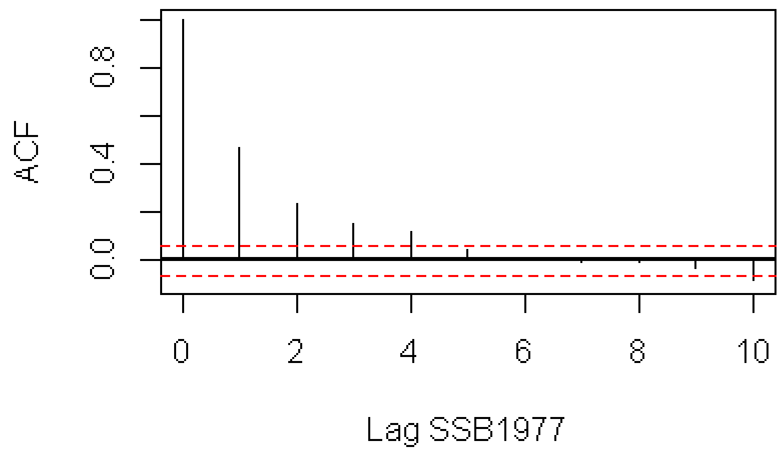


Figure A98. Run S60_BASE_15_1977 MCMC chains for F.



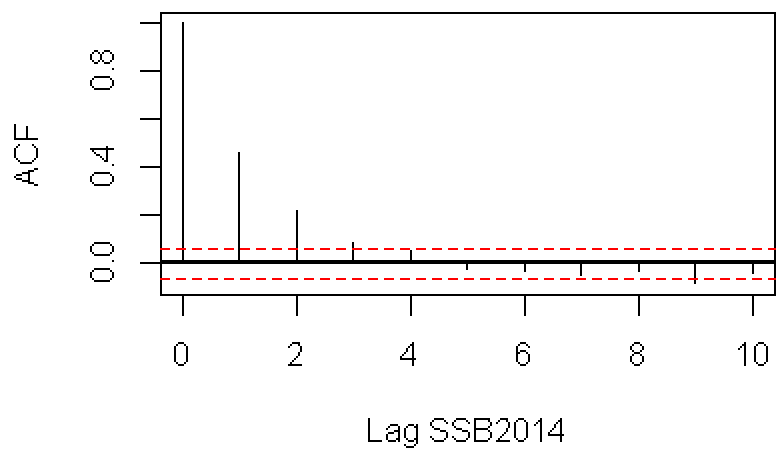


Figure A99. Autocorrelation plot for run S60_BASE_15_1977 MCMC estimates: SSB.

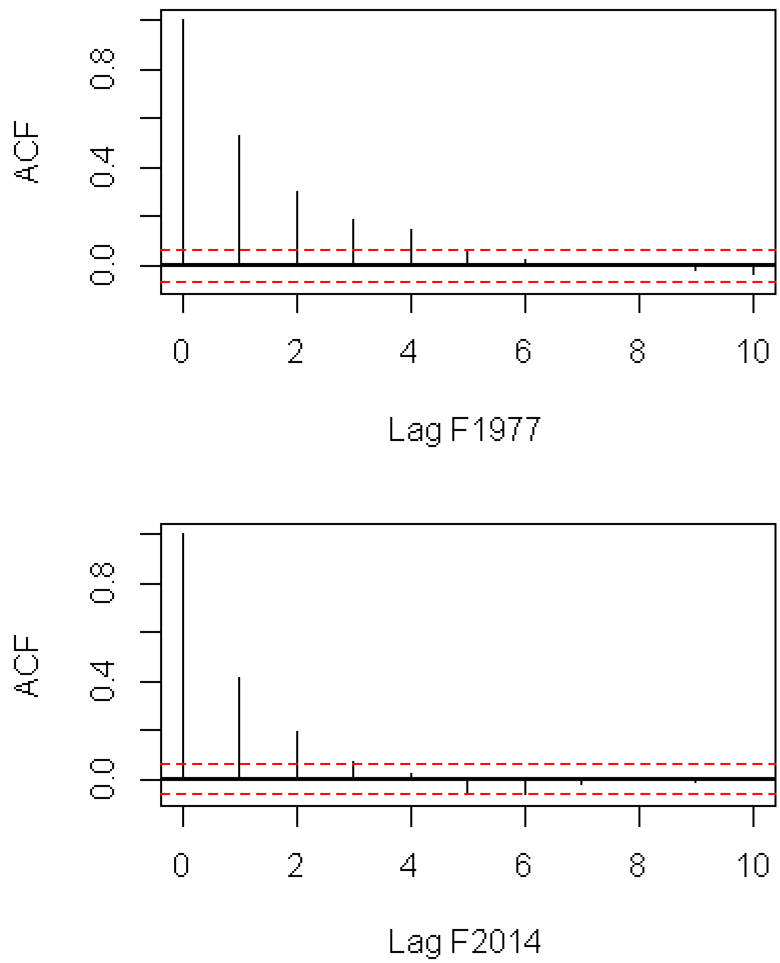


Figure A100. Autocorrelation plot for run S60_BASE_15_1977 MCMC estimates: F.

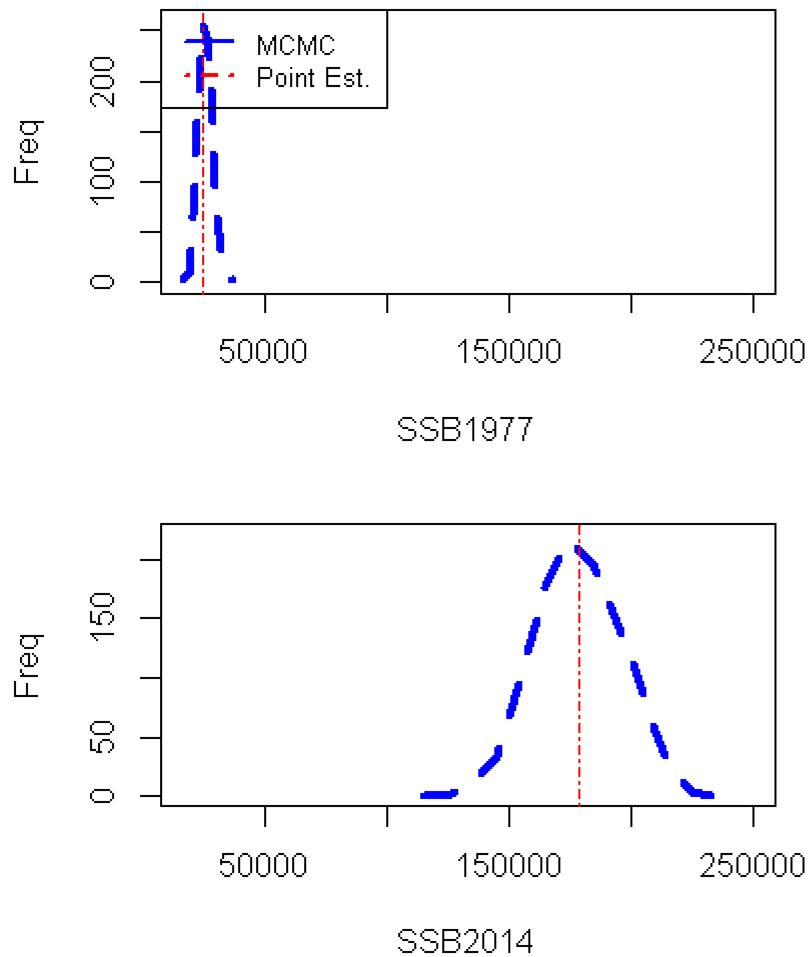


Figure A101. Run S60_BASE_15_1977 point estimates and MCMC distributions: SSB.

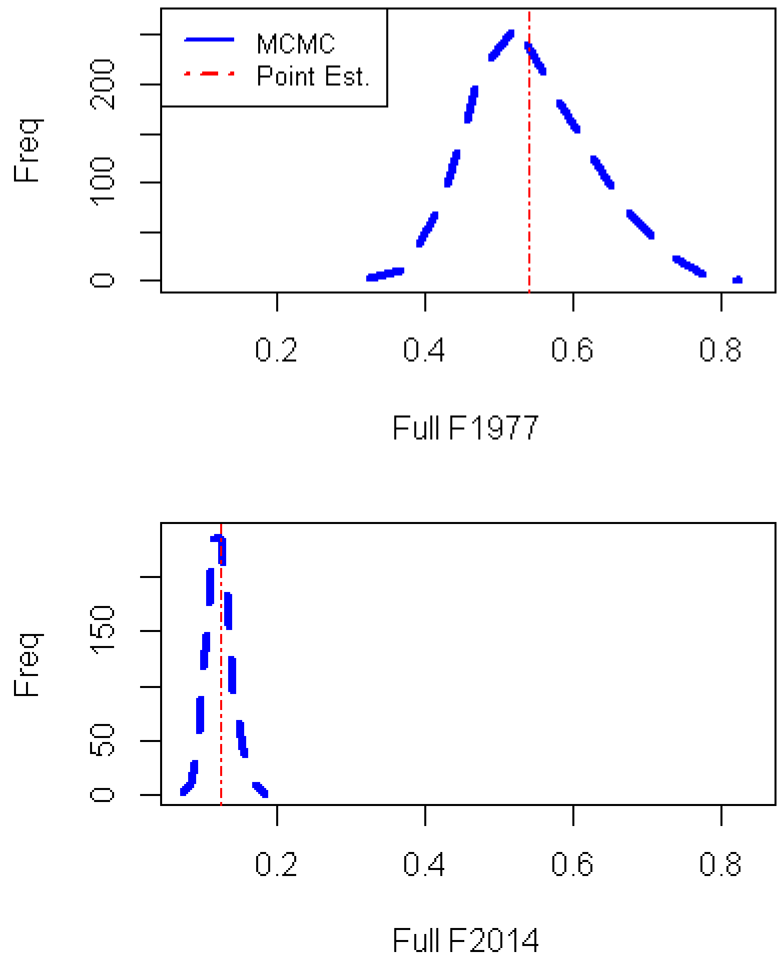


Figure A102. Run S60_BASE_15_1977 point estimates and MCMC distributions: F.

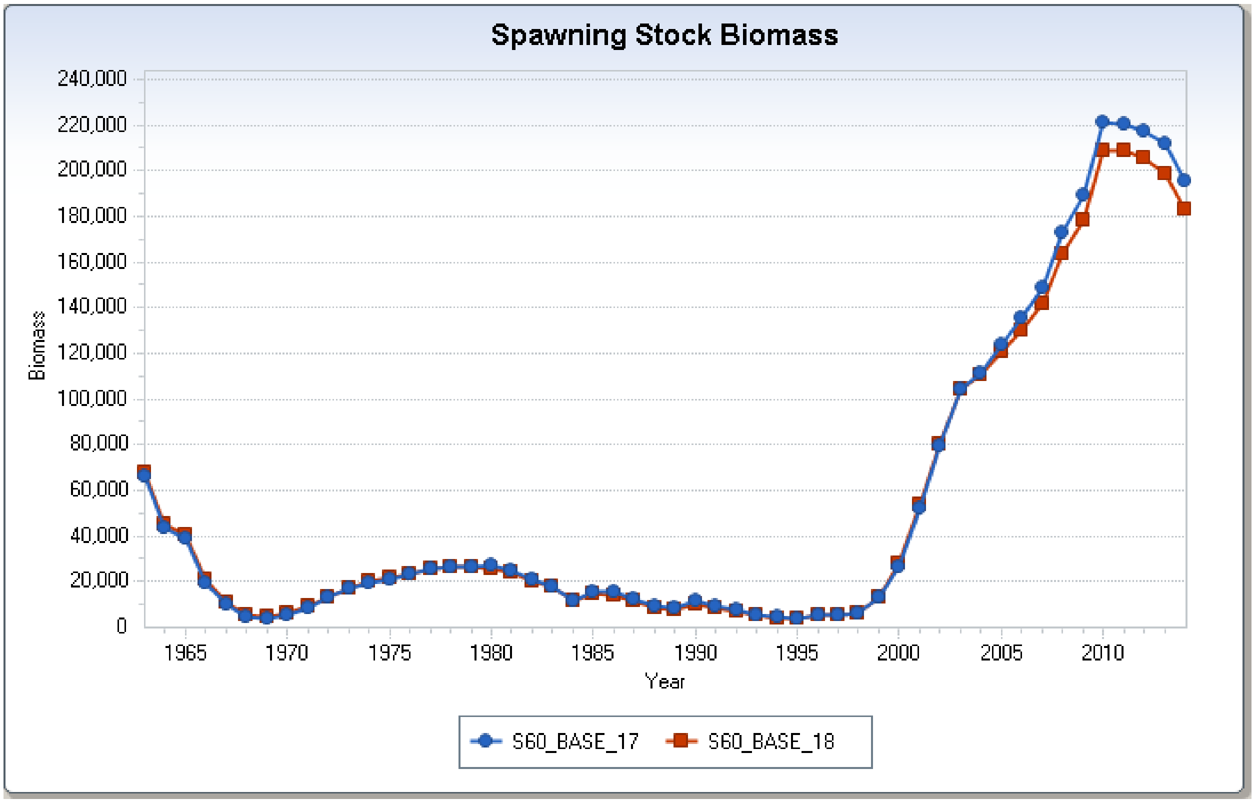


Figure A103. Comparison of run S60_BASE_17 (all indices) with S60_BASE_18 (high RMSE indices omitted): SSB.

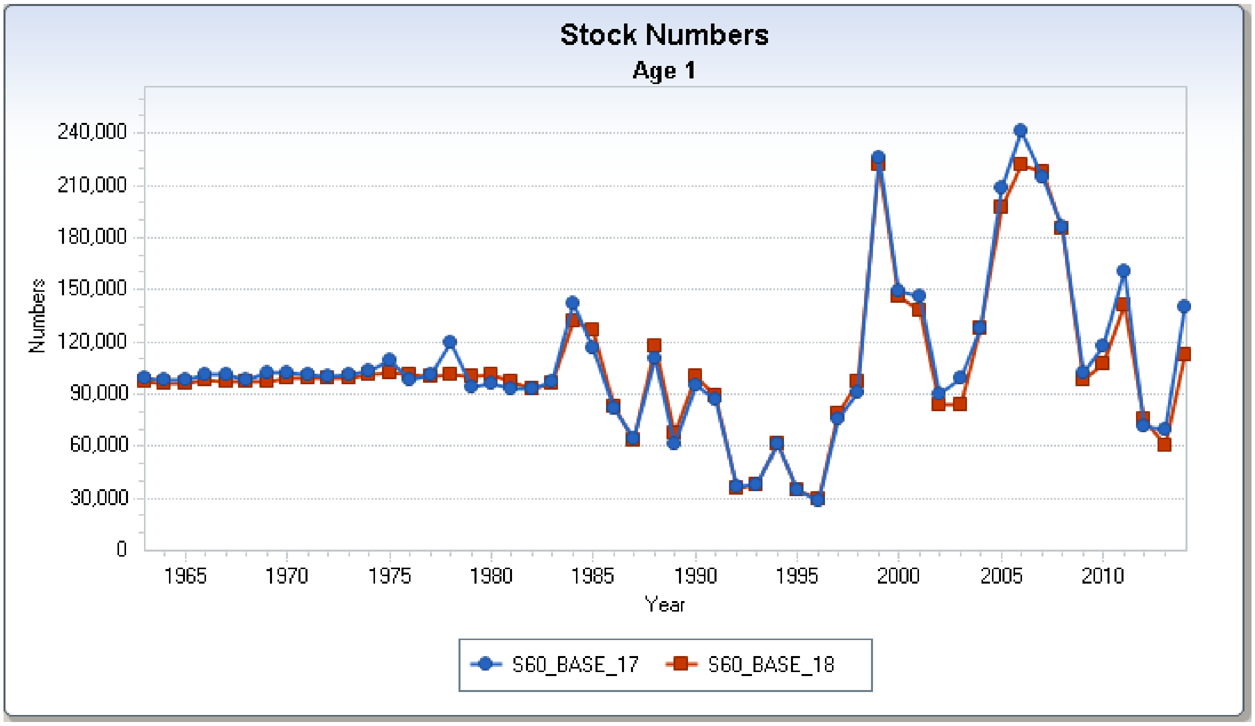


Figure A104. Comparison of run S60_BASE_17 (all indices) with S60_BASE_18 (high RMSE indices omitted): R (recruitment at true age 0, model age 1).

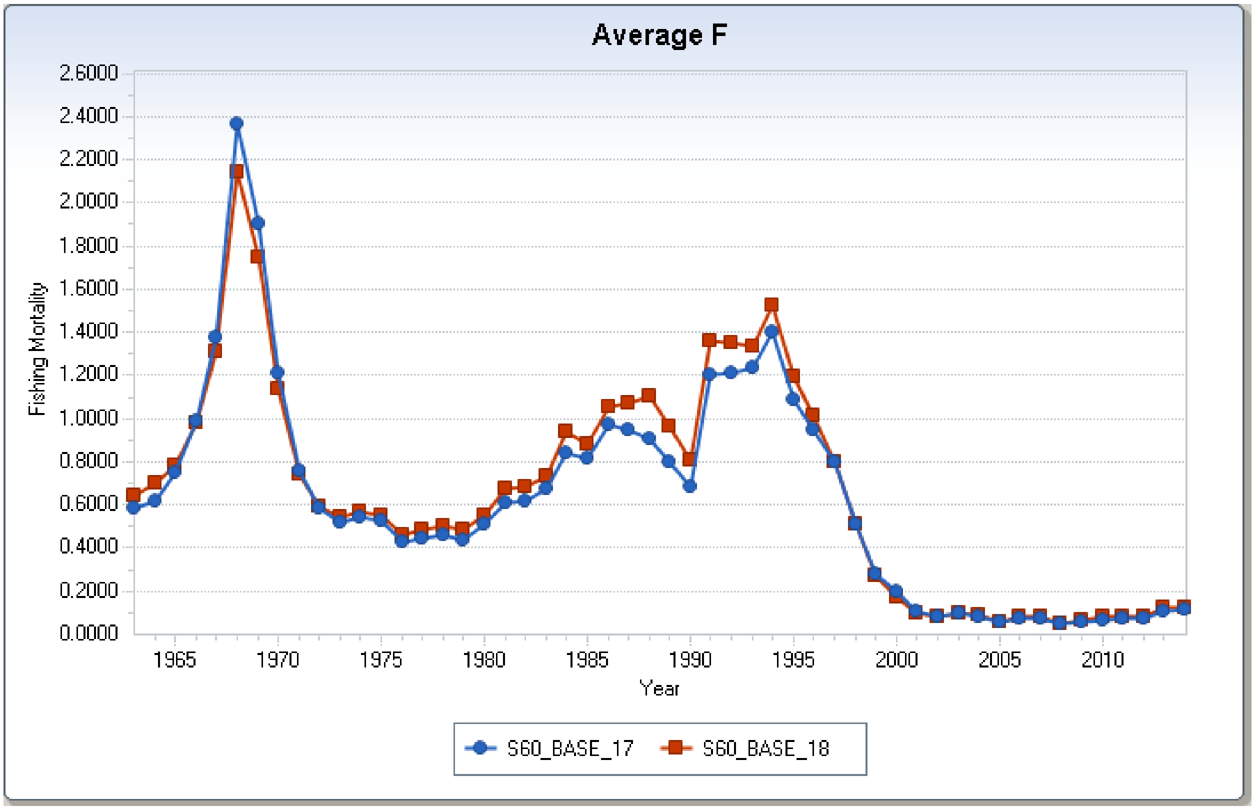


Figure A105. Comparison of run S60_BASE_17 (all indices) with S60_BASE_18 (high RMSE indices omitted): F.

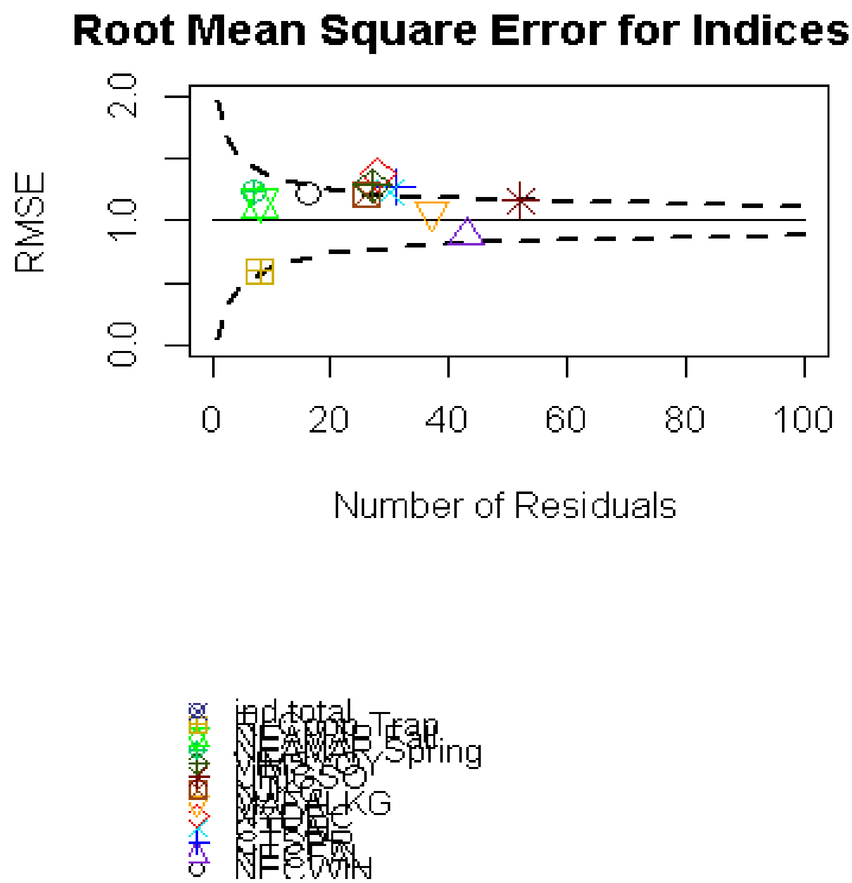


Figure A106. RMSE plot for run S60_BASE_18 indices.

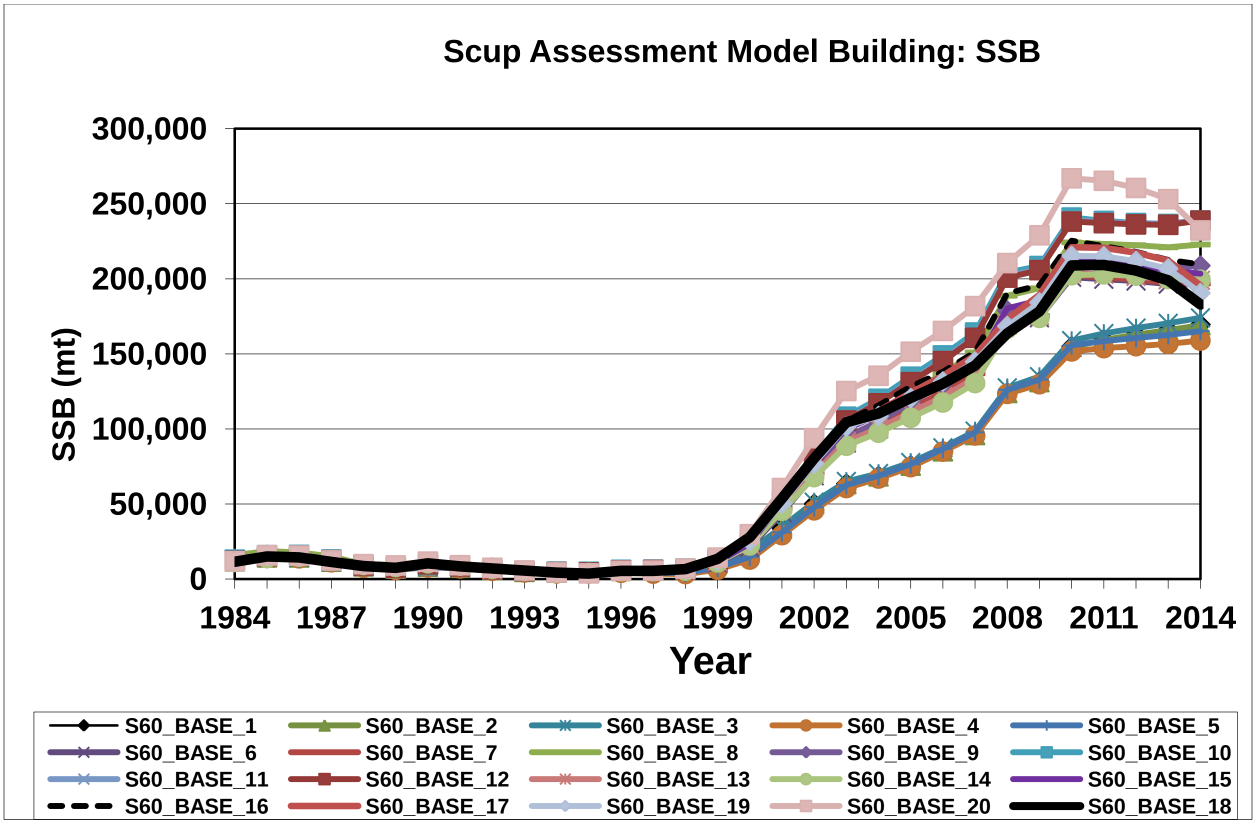


Figure A107. Comparison of results from the 2015 SAW 60 model building. Run S60_BASE_18 that was selected for final status evaluation is plotted in the heavy black line: SSB.

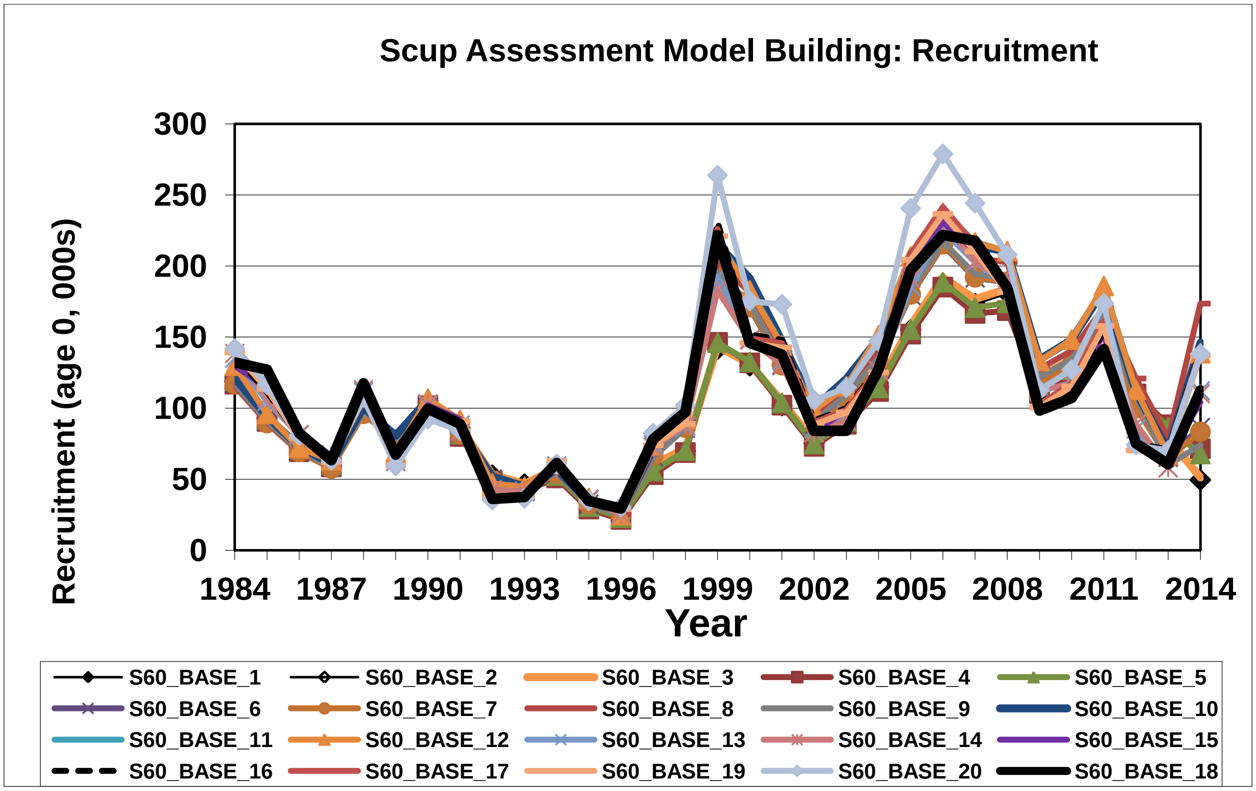


Figure A108. Comparison of results from the 2015 SAW 60 model building. Run S60_BASE_18 that was selected for final status evaluation is plotted in the heavy black line: R (recruitment at true age 0, model age 1).

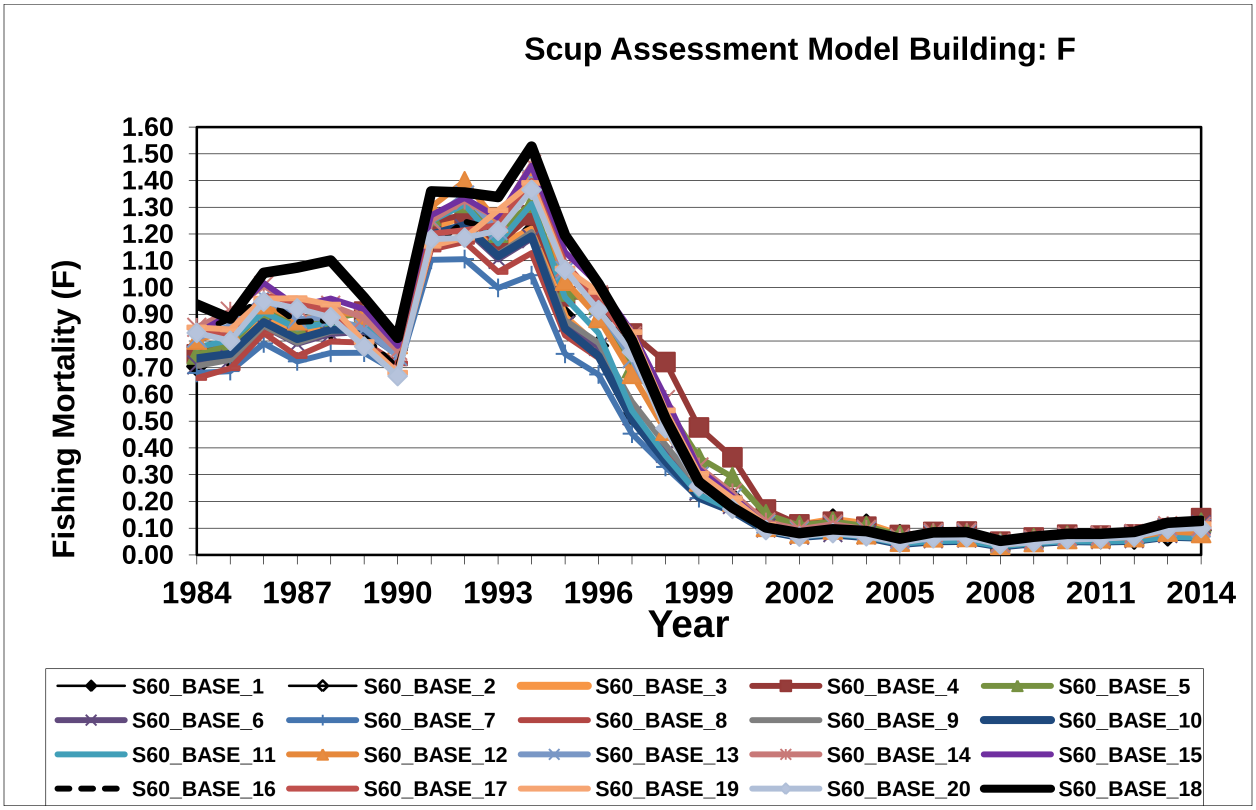


Figure A109. Comparison of results from the 2015 SAW 60 model building. Run S60_BASE_18 that was selected for final status evaluation is plotted in the heavy black line: F.

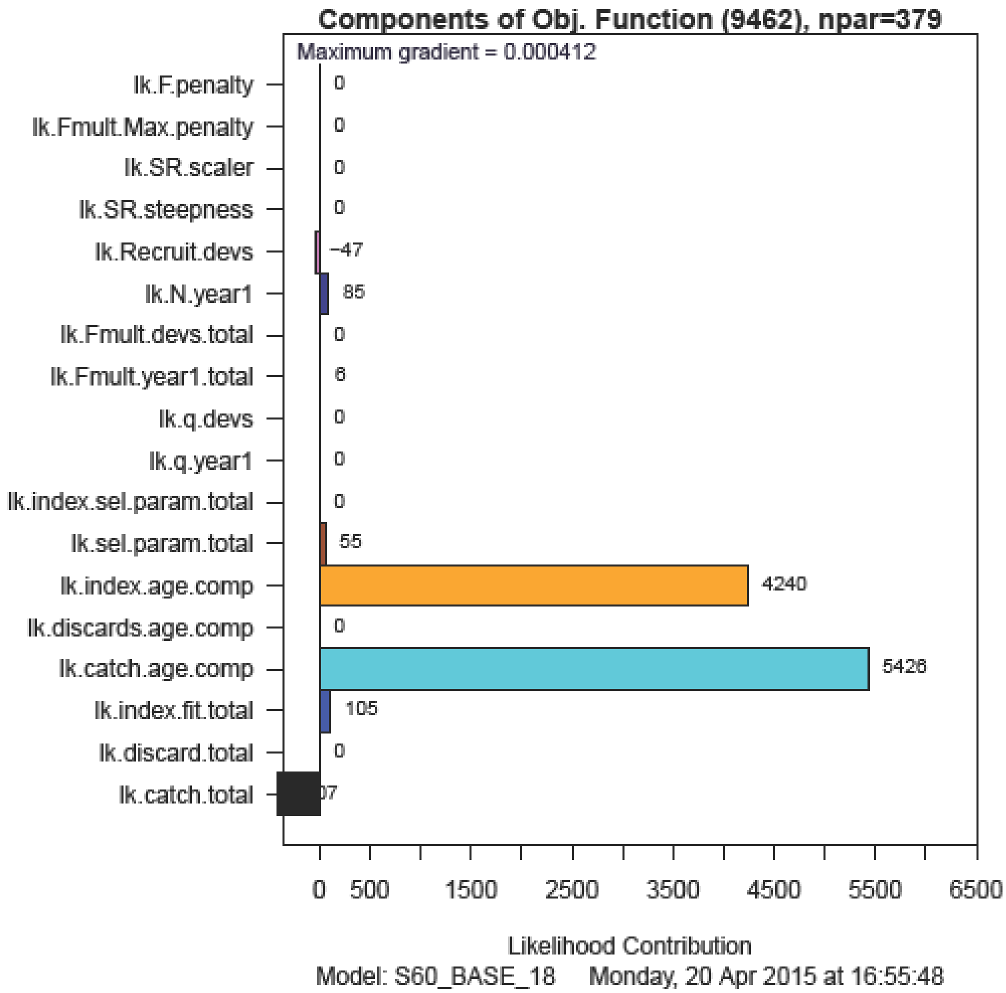


Figure A110. Objective function components contribution to the total likelihood for final run S60_BASE_18.

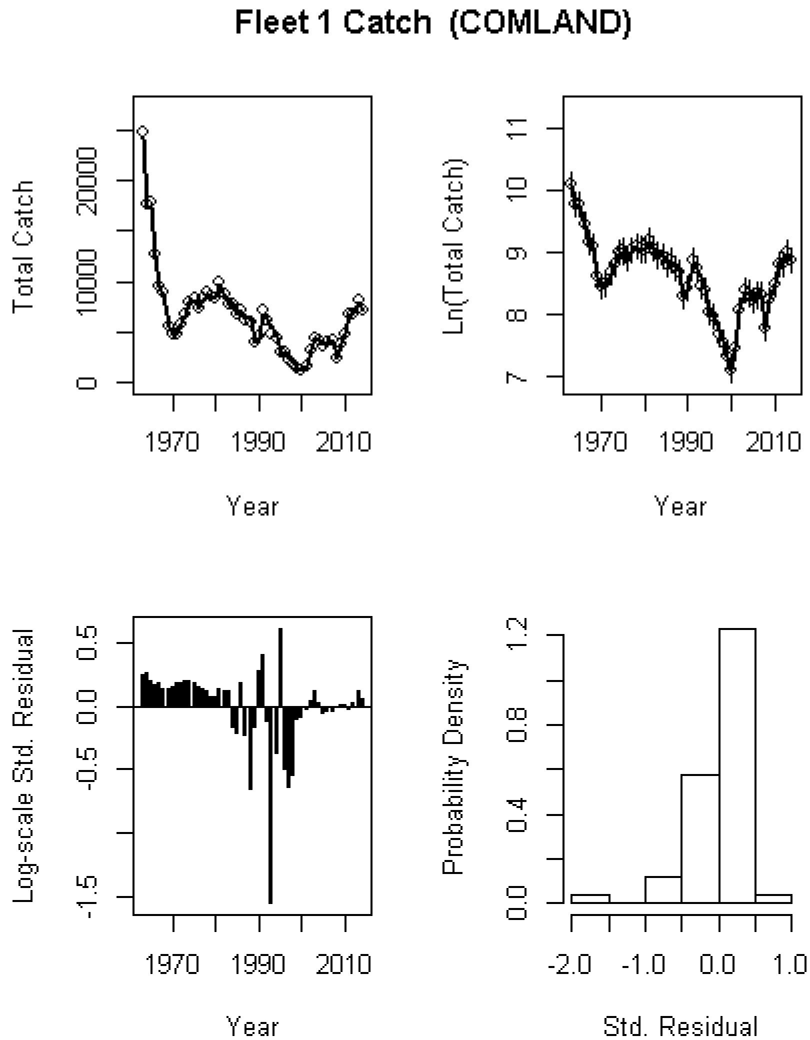


Figure A111. Residuals from the final run S60_BASE_18: commercial landings.

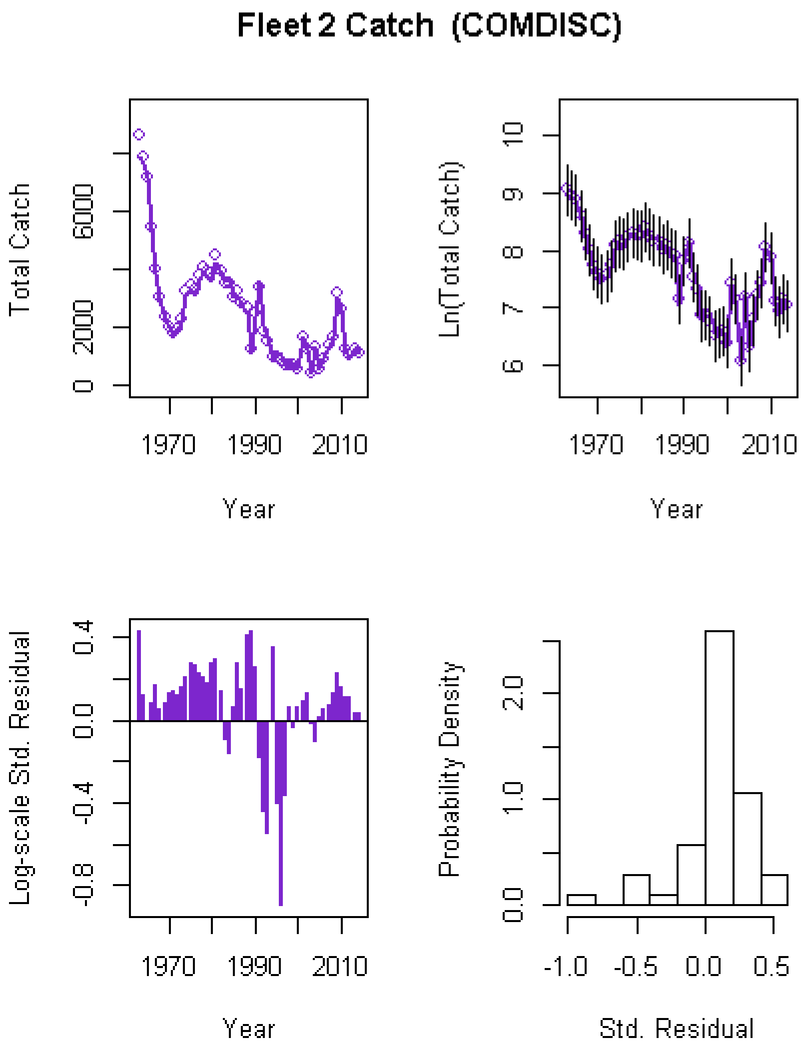


Figure A112. Residuals from the final run S60_BASE_18: commercial discards.

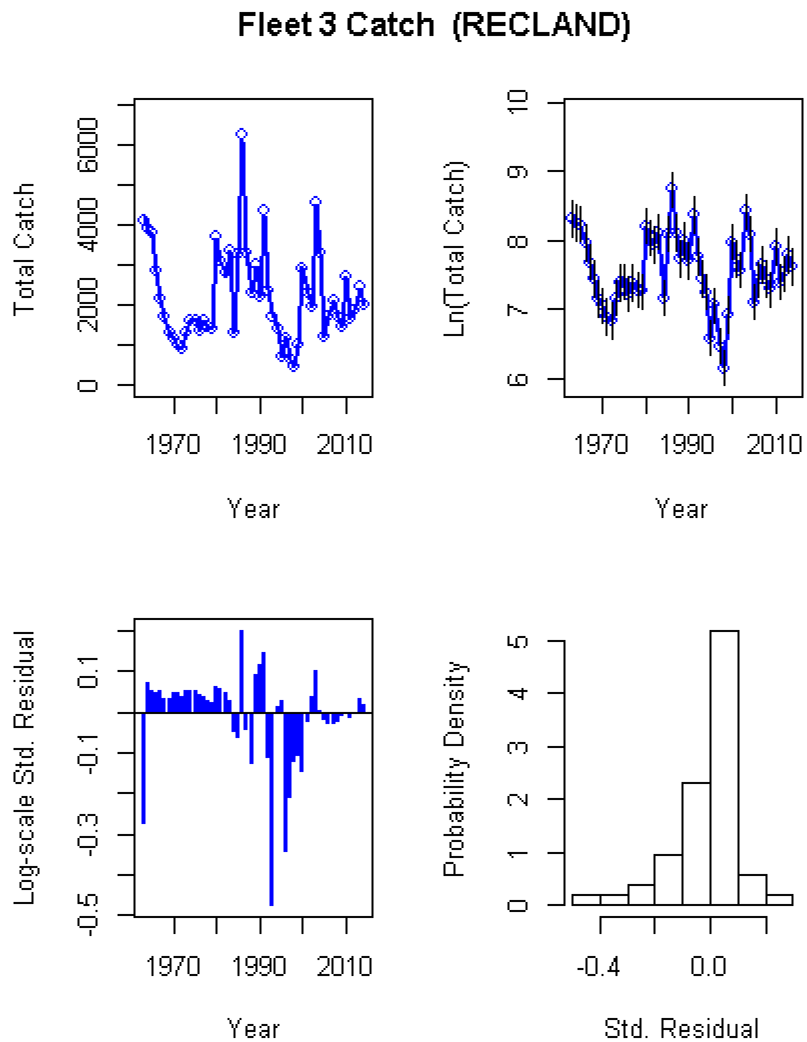


Figure A113. Residuals from the final run S60_BASE_18: recreational landings.

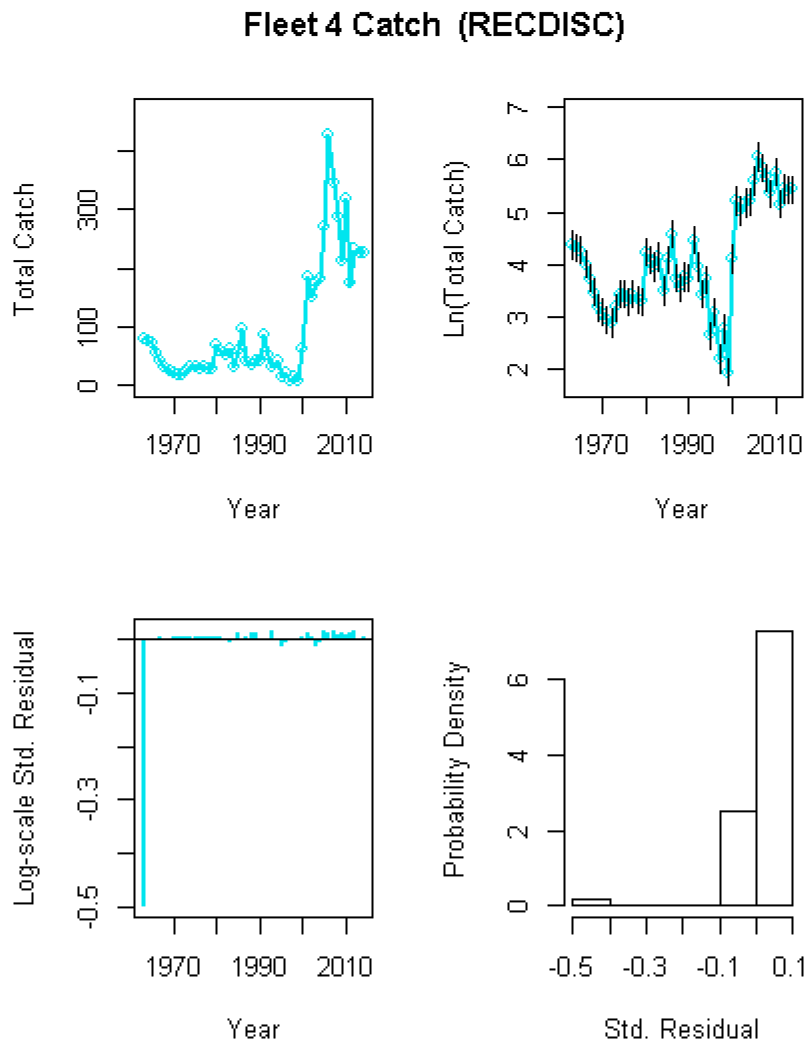


Figure A114. Residuals from the final run S60_BASE_18: recreational discards.

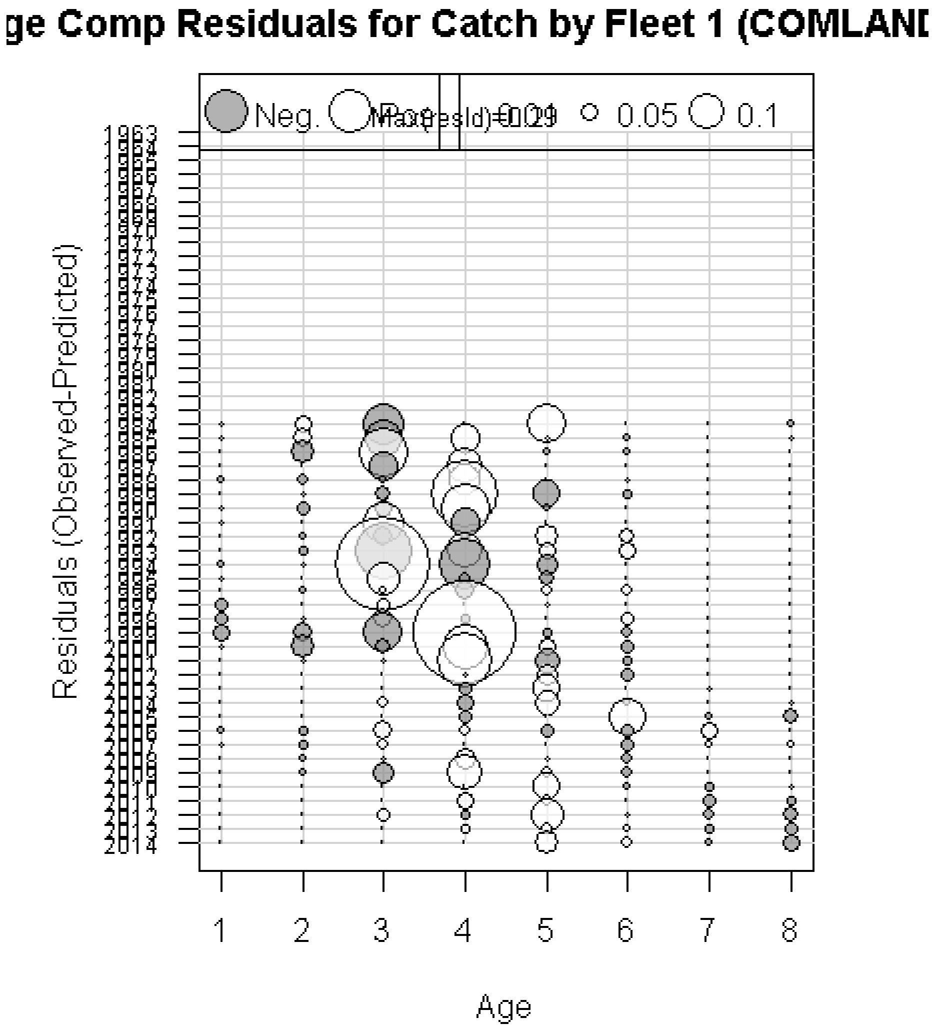


Figure A115. Age composition residuals for final run S60_BASE_18: commercial landings.

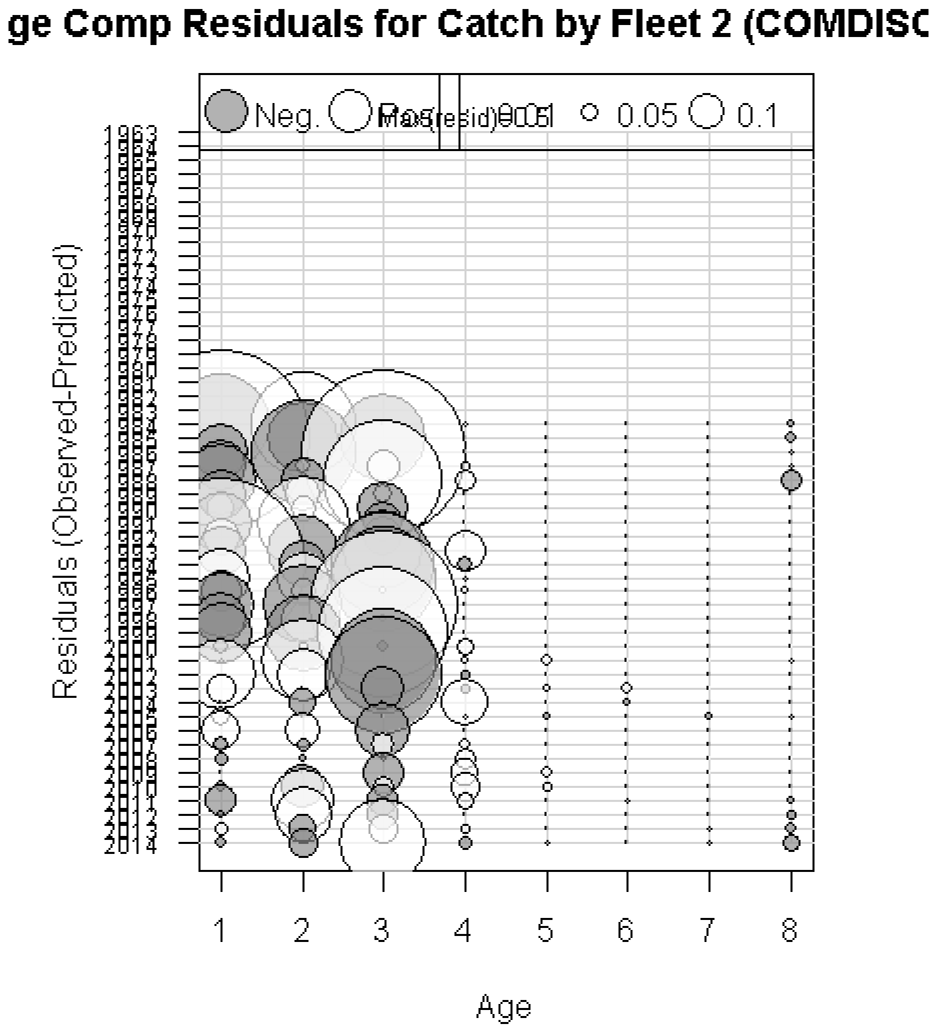


Figure A116. Age composition residuals for final run S60_BASE_18: commercial discards.

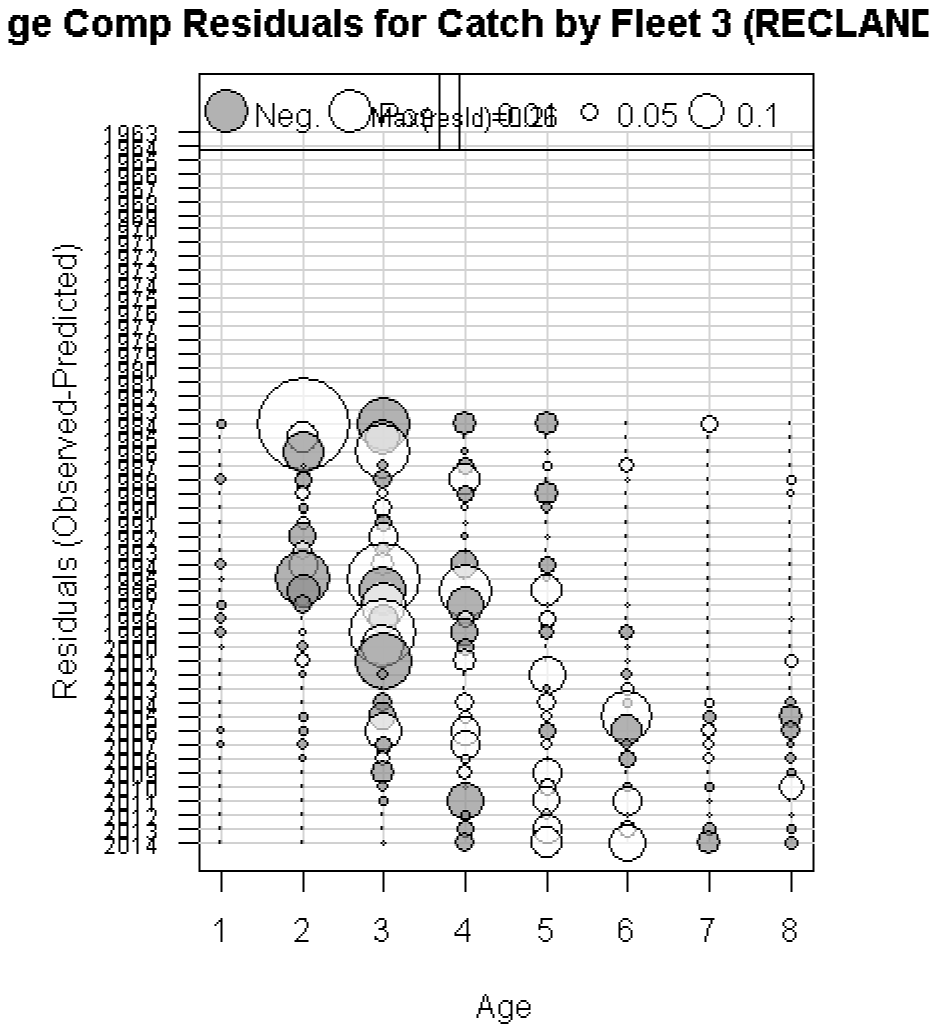


Figure A117. Age composition residuals for final run S60_BASE_18: recreational landings.

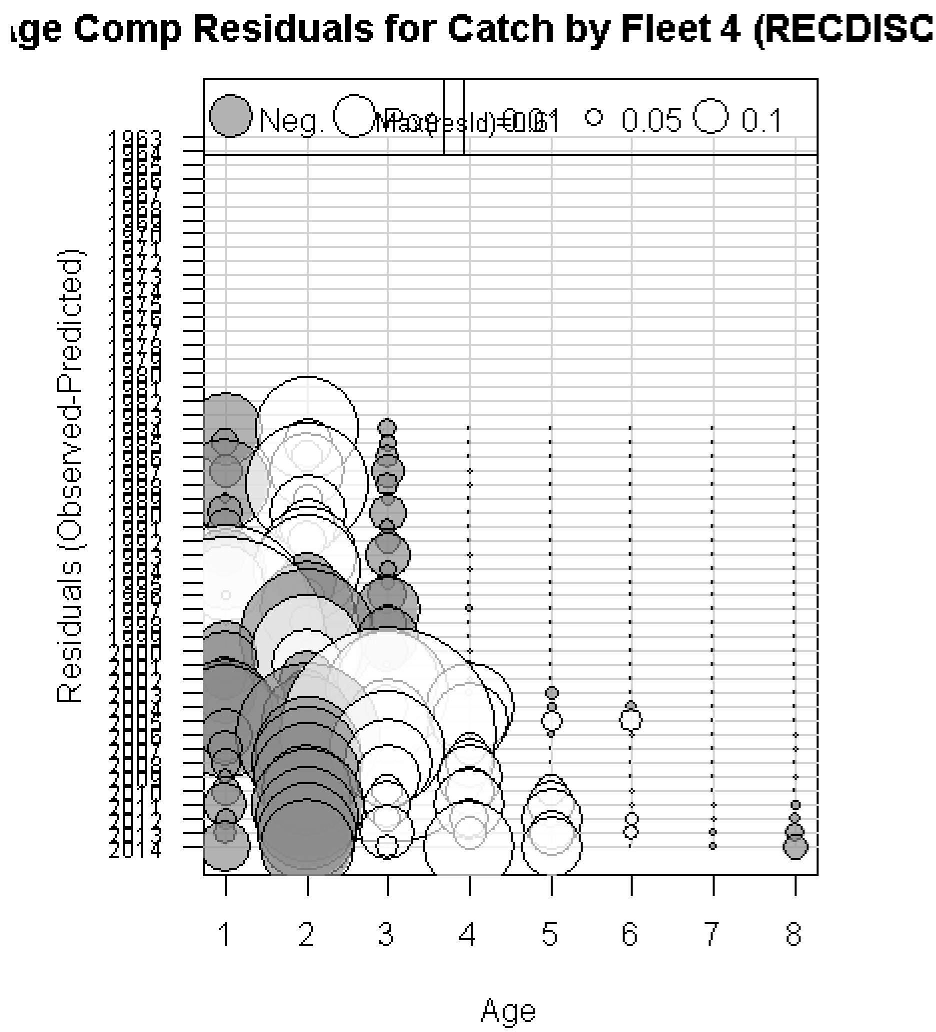


Figure A118. Age composition residuals for final run S60_BASE_18: recreational discards.

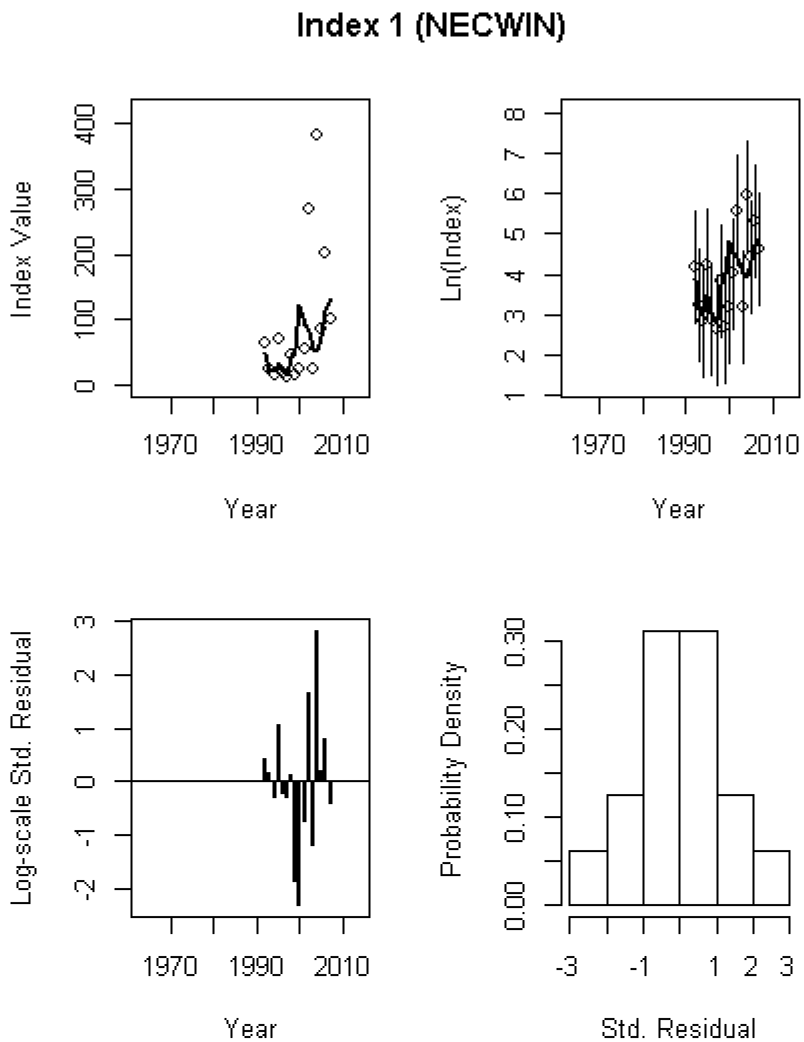


Figure A119. Residuals for final run S60_BASE_18: NEFSC winter survey.

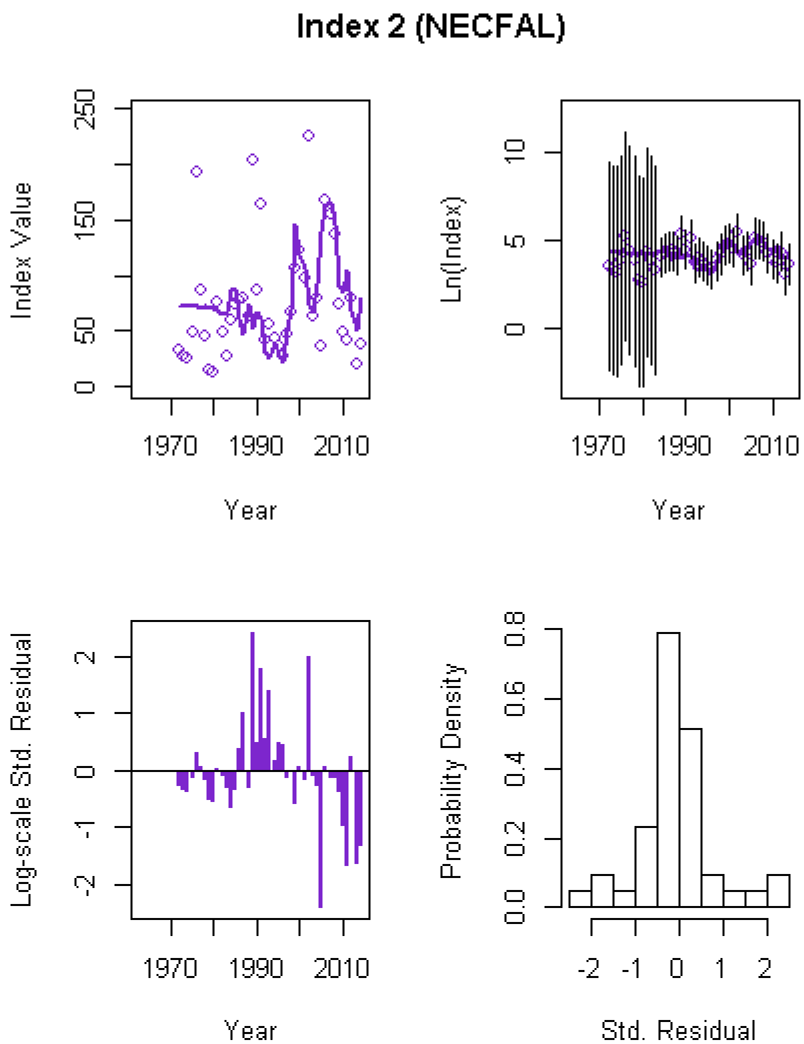


Figure A120. Residuals for final run S60_BASE_18: NEFSC fall survey.

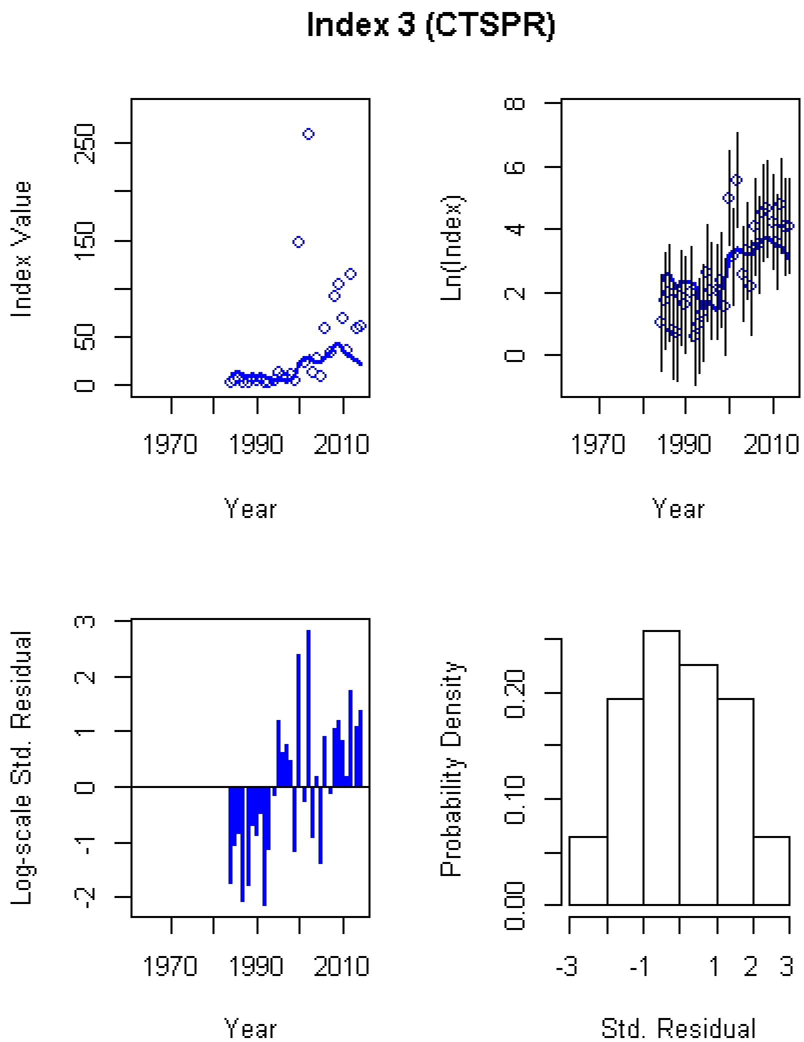


Figure A121. Residuals for final run S60_BASE_18: CTDEEP spring survey.

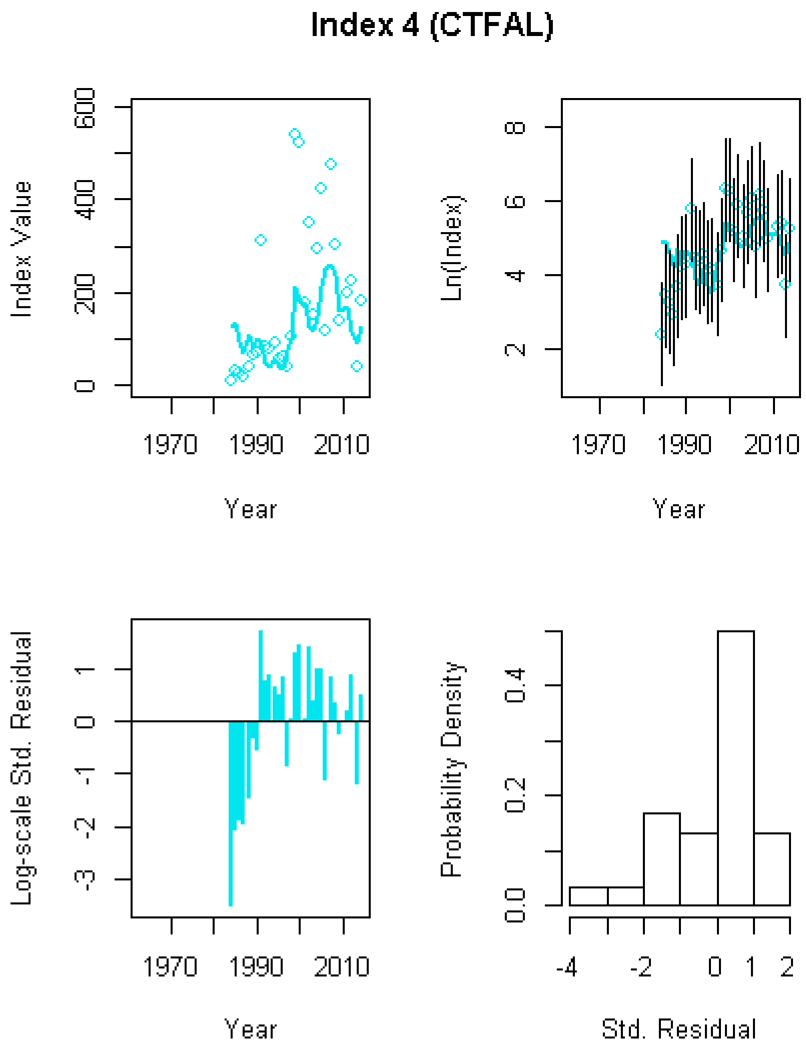


Figure A122. Residuals for final run S60_BASE_18: CTDEEP fall survey.

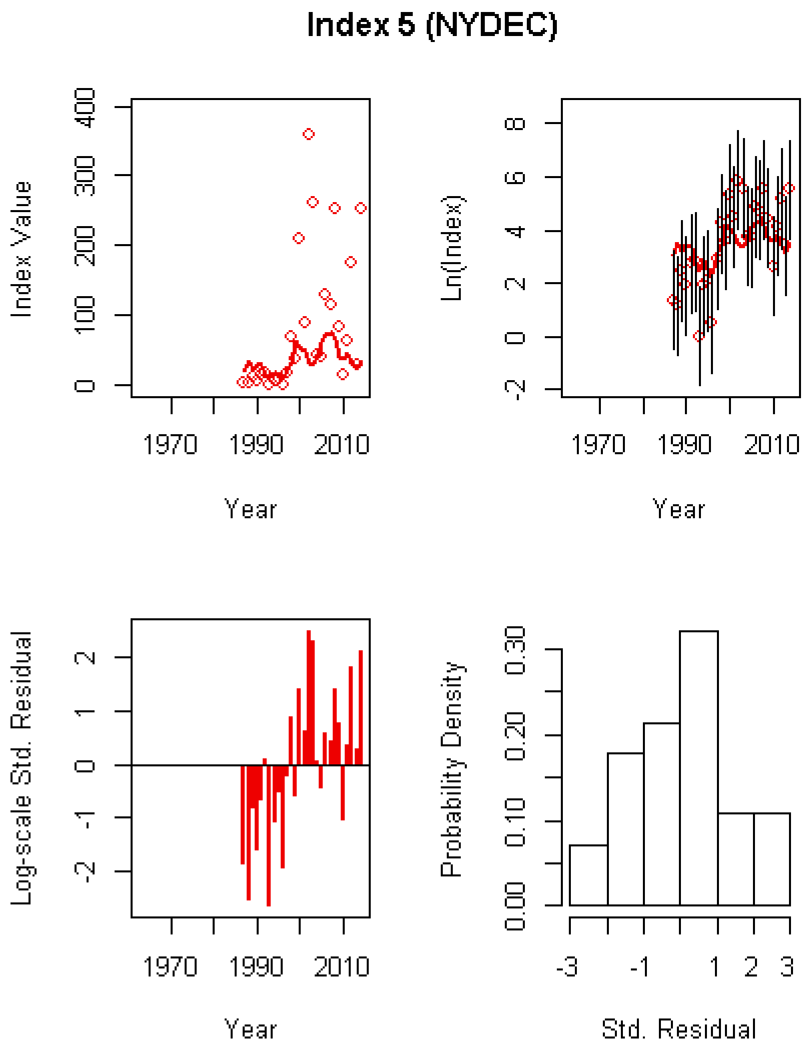


Figure A123. Residuals for final run S60_BASE_18: NYDEC survey.

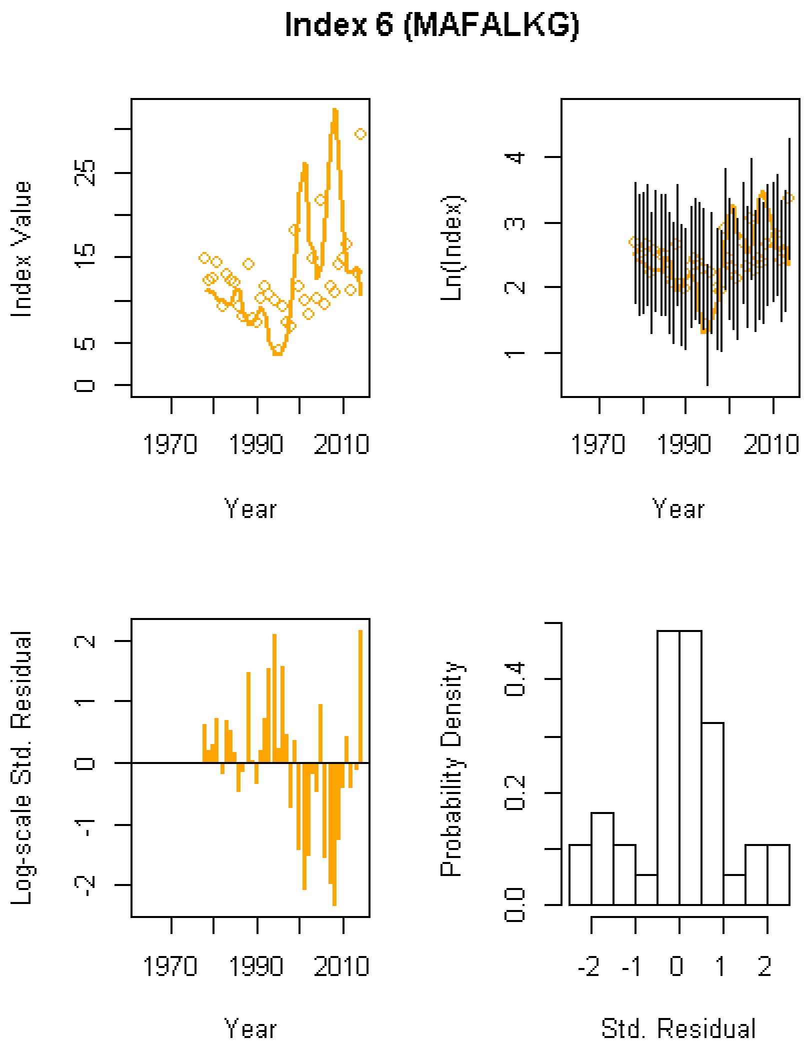


Figure A124. Residuals for final run S60_BASE_18: MADMF fall survey.

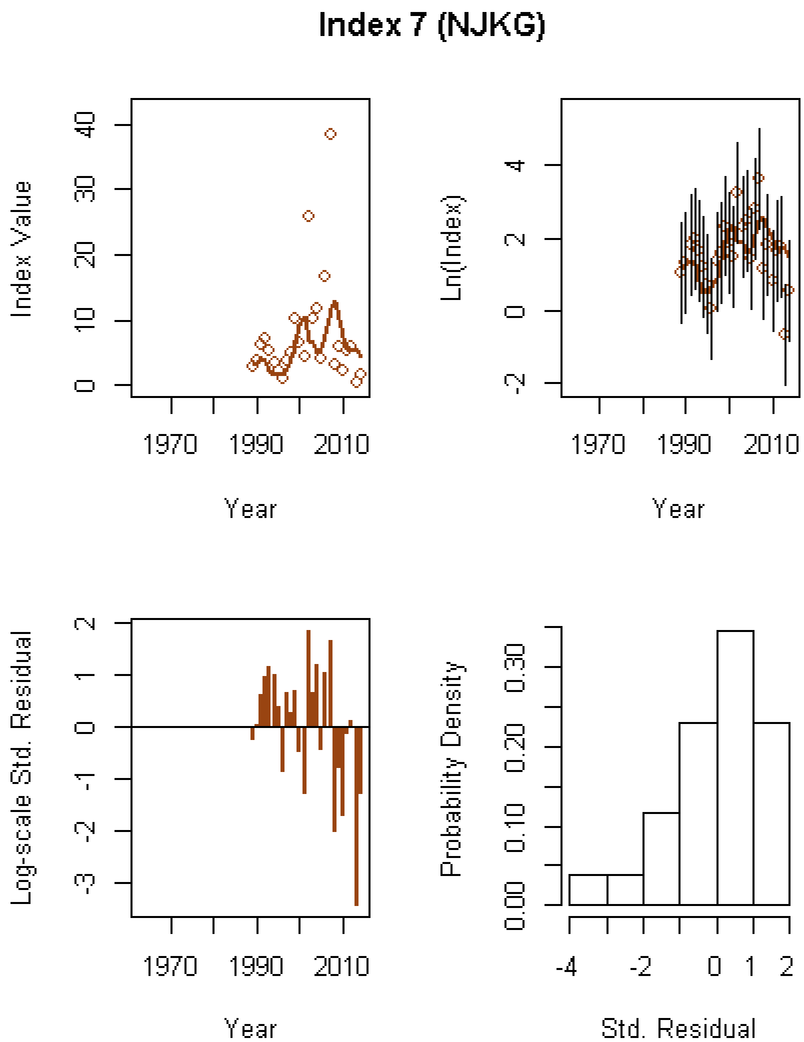


Figure A125. Residuals for final run S60_BASE_18: NJDFW survey.

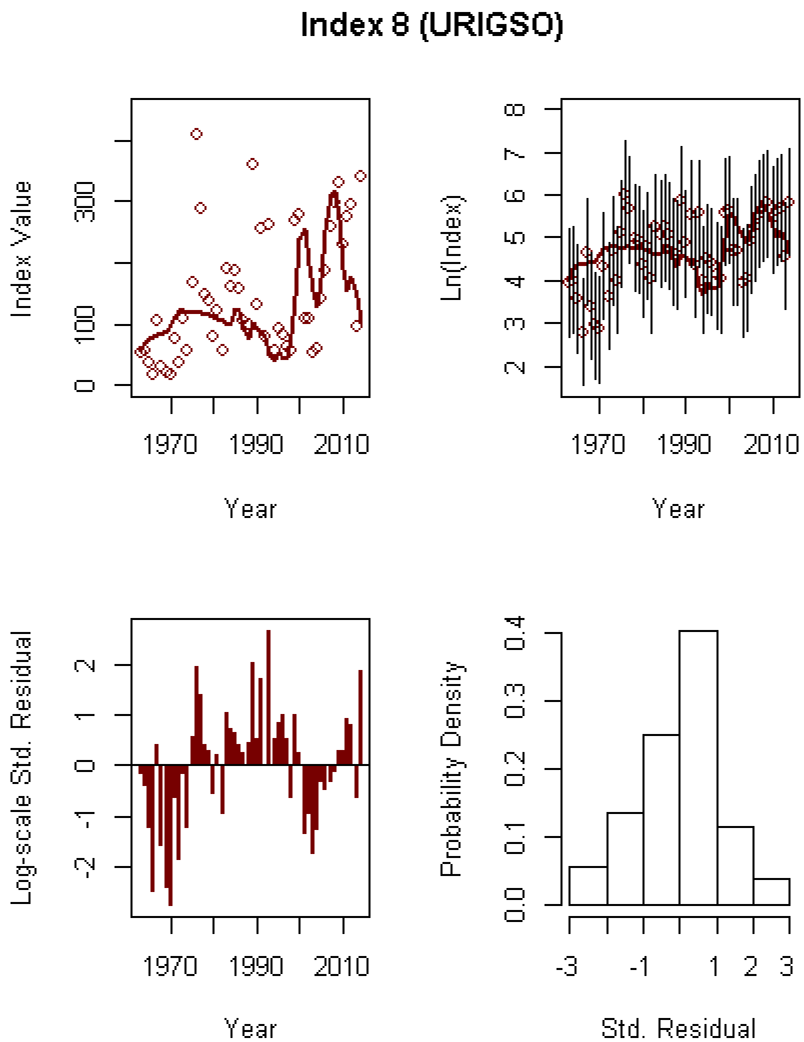


Figure A126. Residuals for final run S60_BASE_18: URIGSO survey.

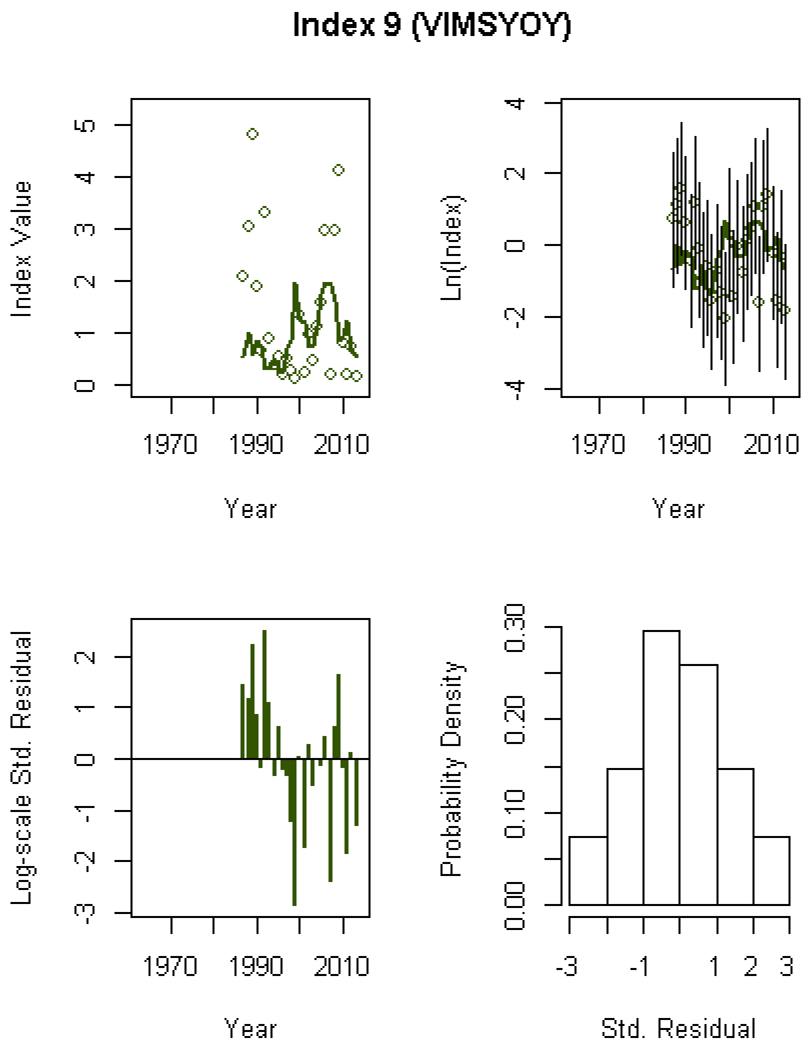


Figure A127. Residuals for final run S60_BASE_18: VIMS juvenile fish (YOY = Young-Of-the-Year) survey.

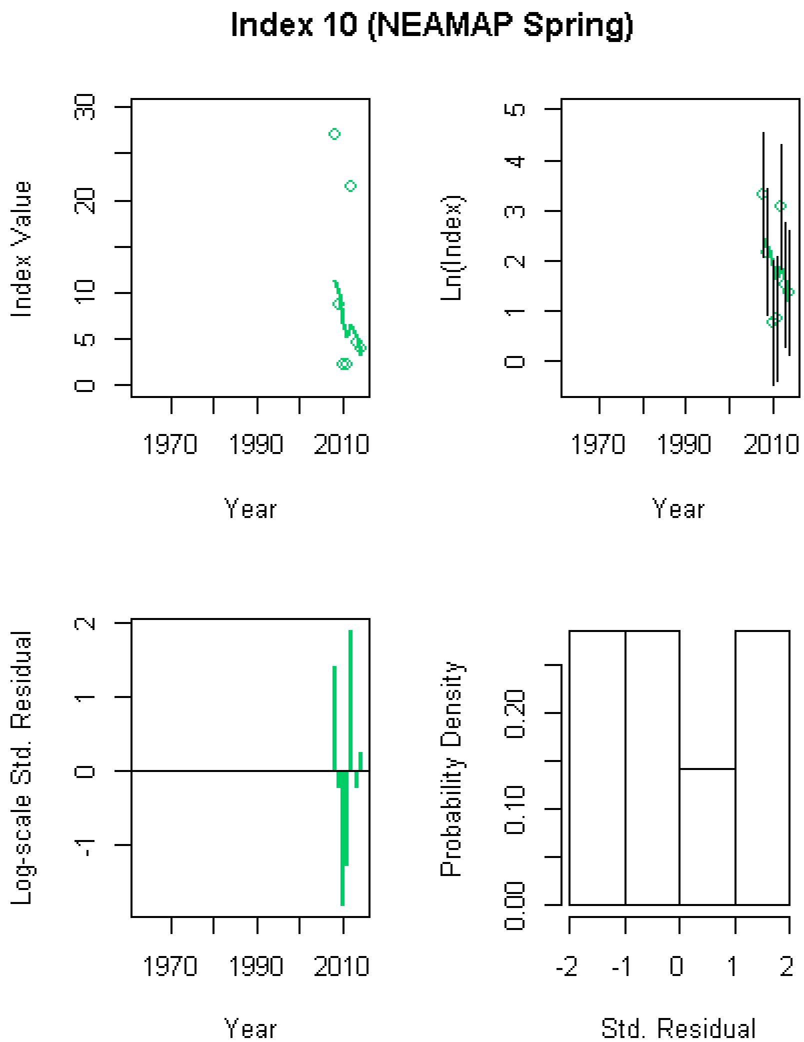


Figure A128. Residuals for final run S60_BASE_18: VIMS NEAMAP spring survey.

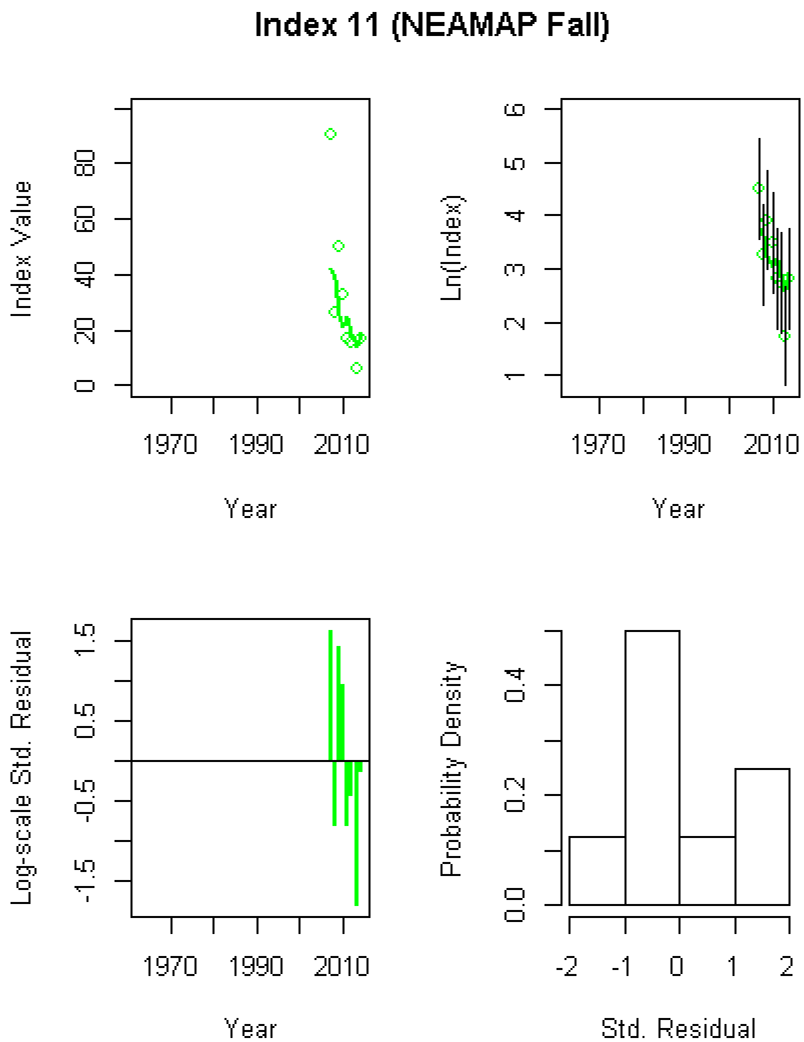


Figure A129. Residuals for final run S60_BASE_18: VIMS NEAMAP fall survey.

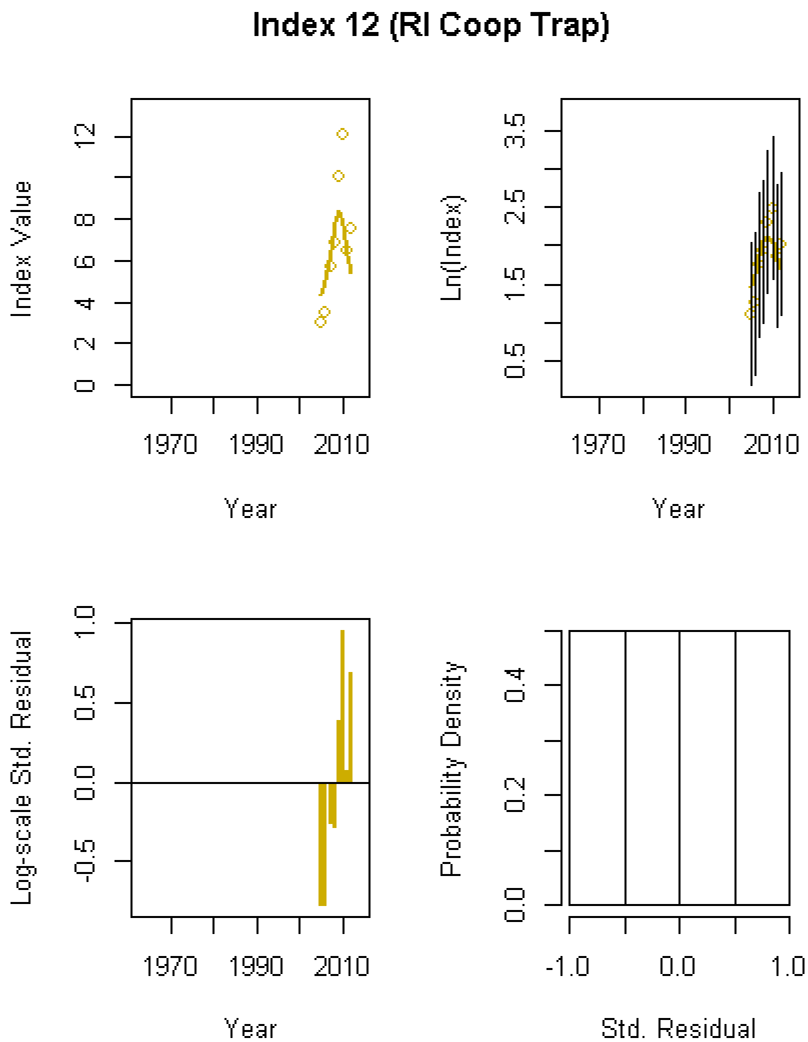


Figure A130. Residuals for final run S60_BASE_18: RIDFW cooperative trap survey.

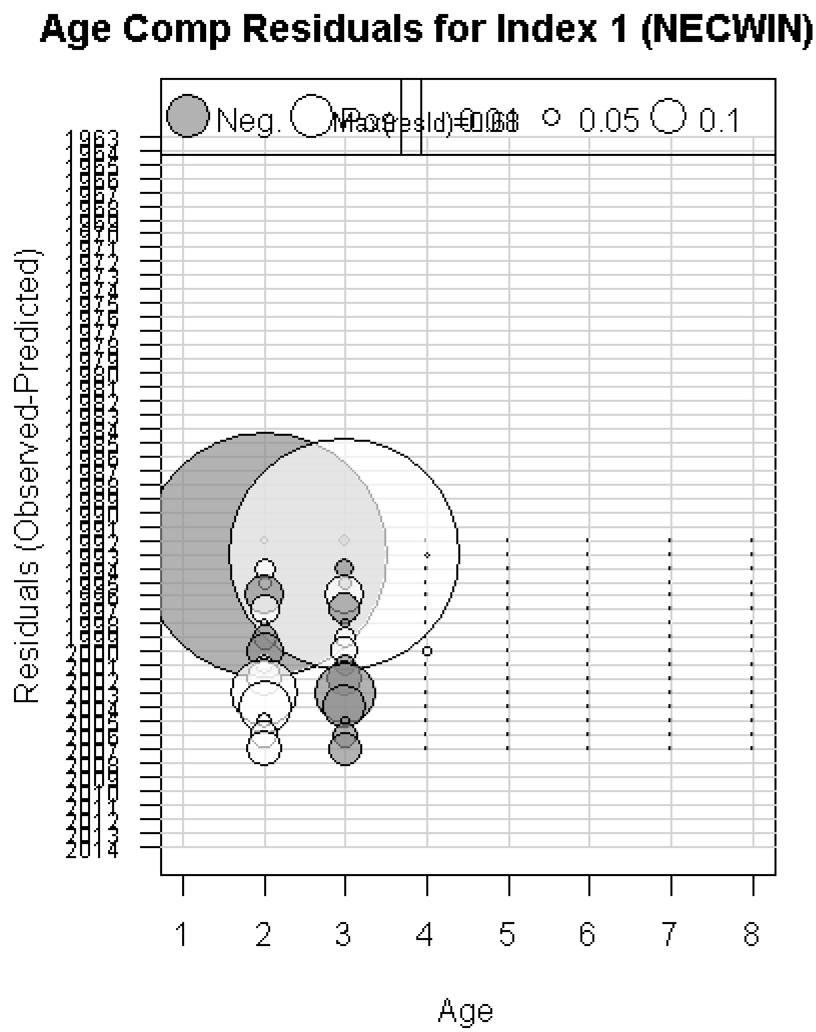


Figure A131. Age composition residuals for final run S60_BASE_19: NEFSC winter survey.

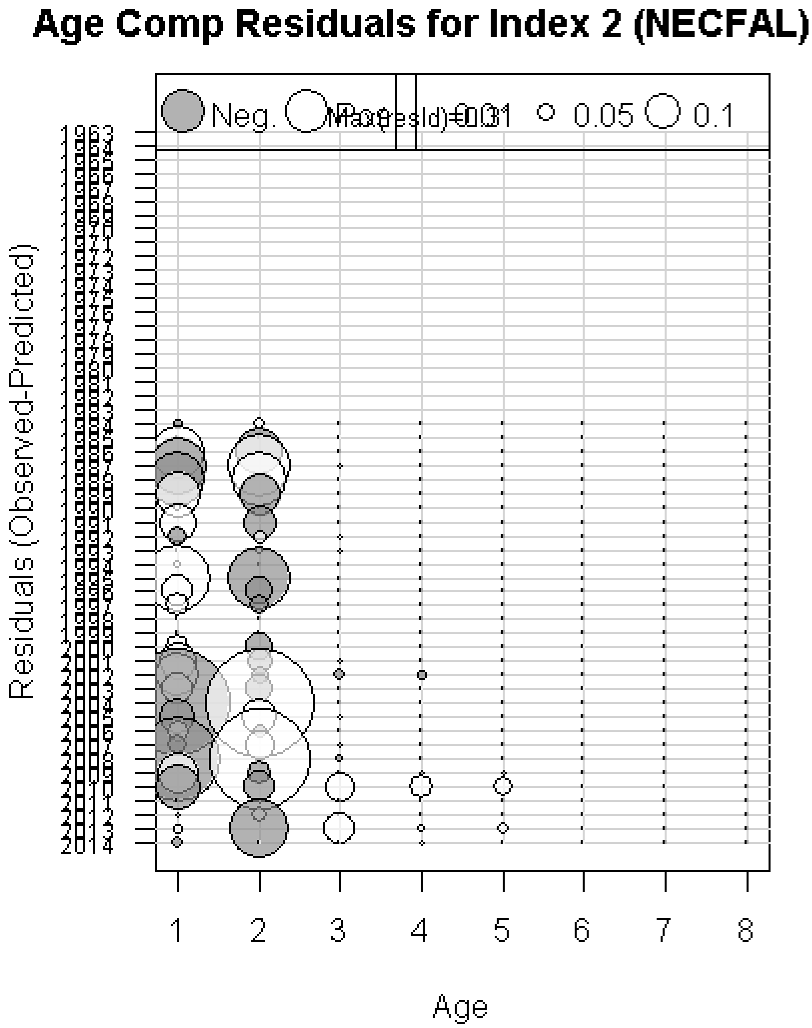


Figure A132. Age composition residuals for final run S60_BASE_19: NEFSC fall survey.

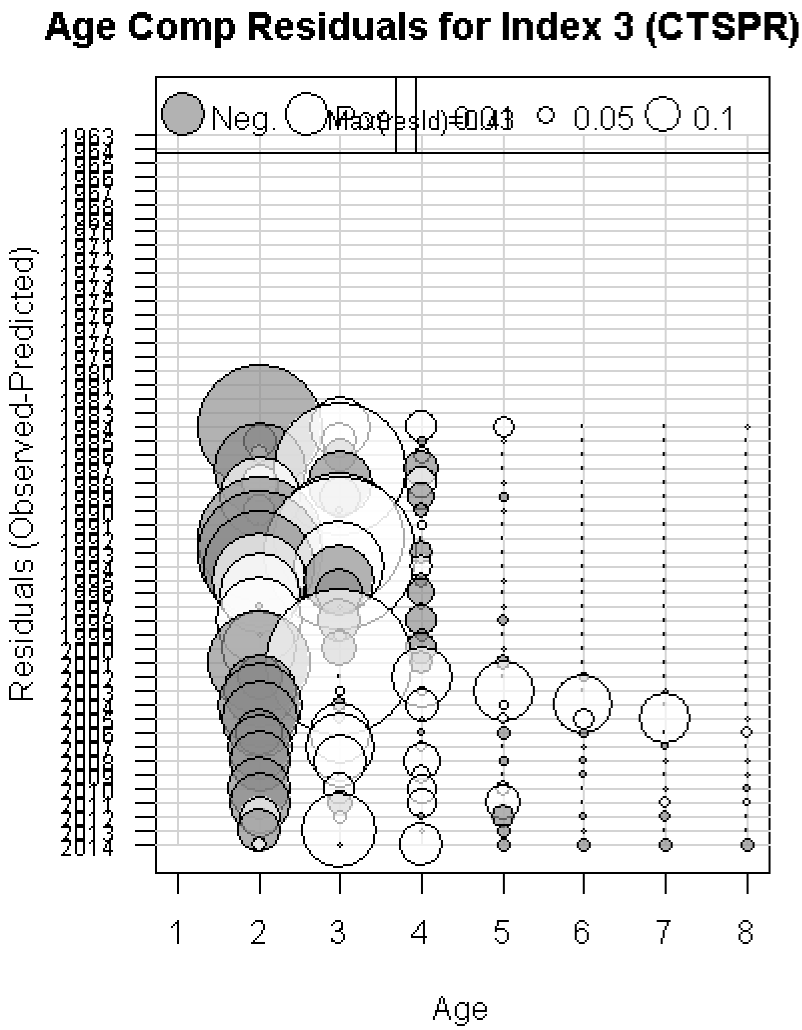


Figure A133. Age composition residuals for final run S60_BASE_19: CTDEEP spring survey.

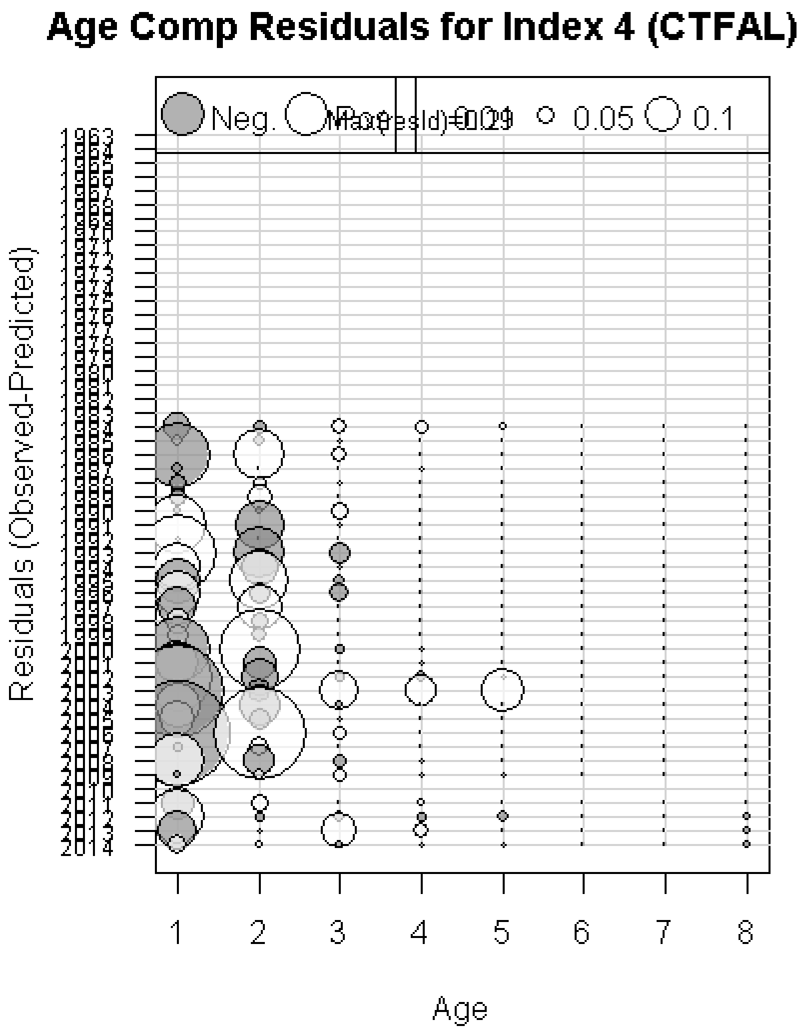


Figure A134. Age composition residuals for final run S60_BASE_19: CTDEEP fall survey.

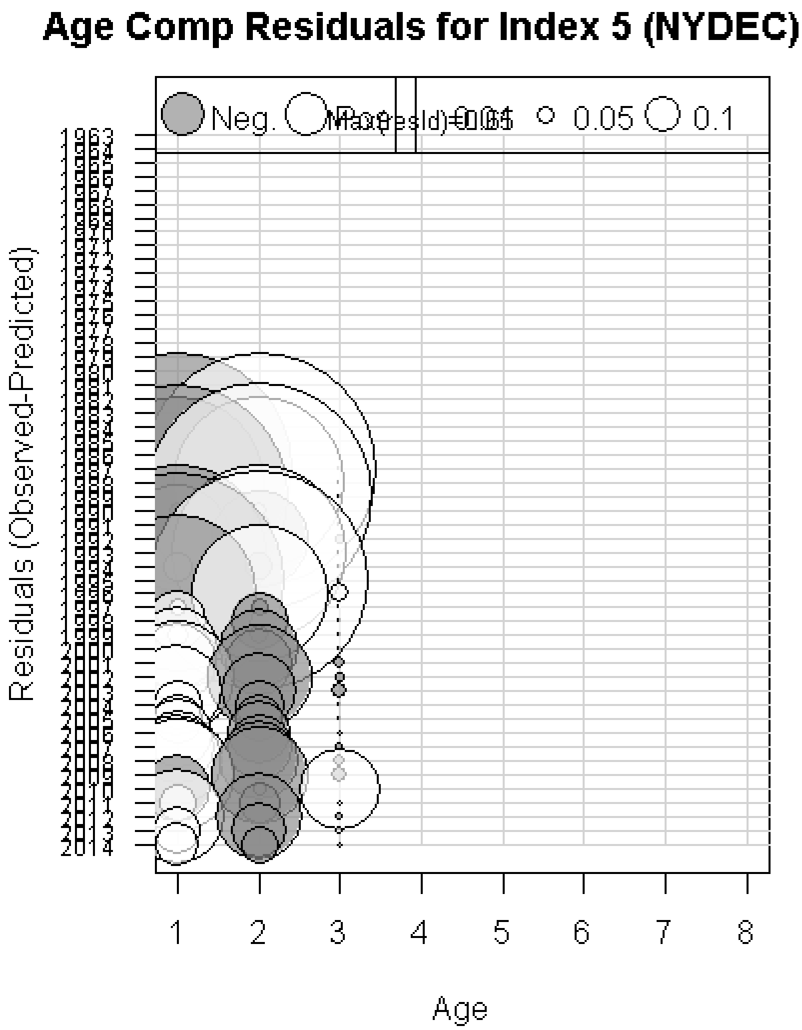


Figure A135. Age composition residuals for final run S60_BASE_19: NYDEC survey.

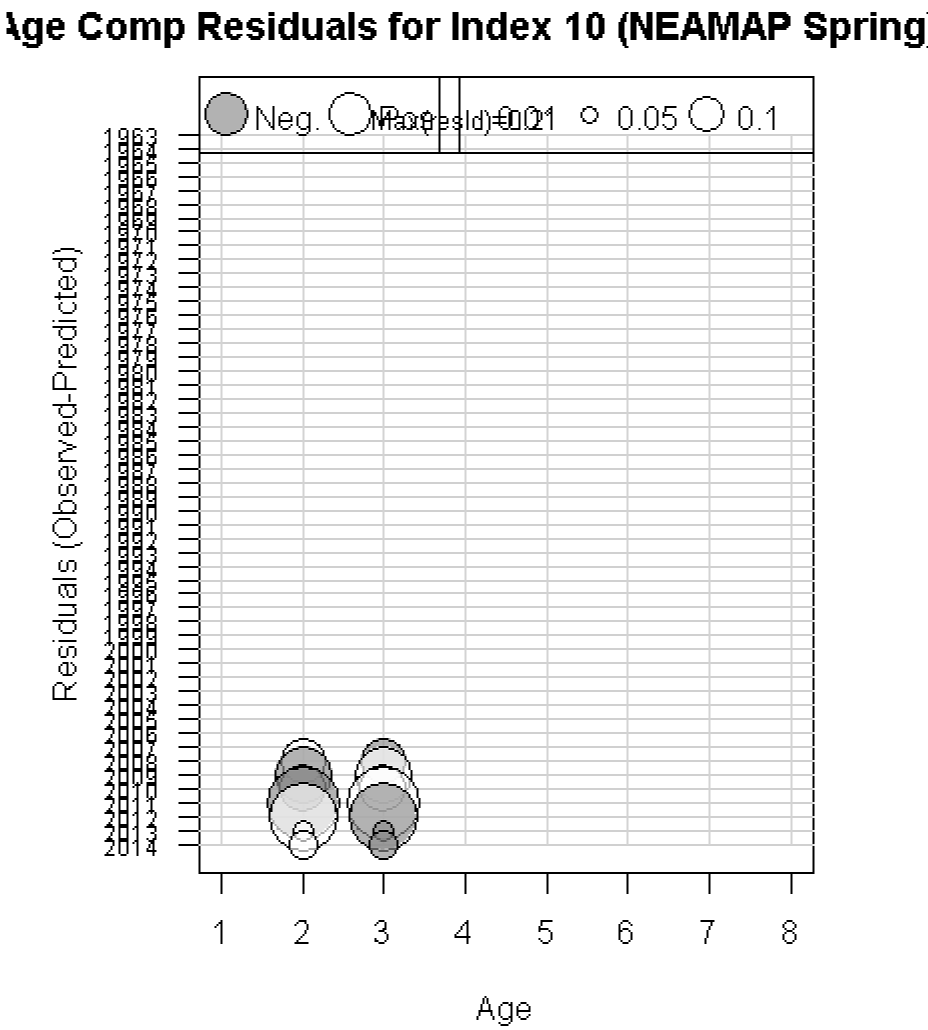


Figure A136. Age composition residuals for final run S60_BASE_19: VIMS NEAMAP spring survey.

Age Comp Residuals for Index 11 (NEAMAP Fall)

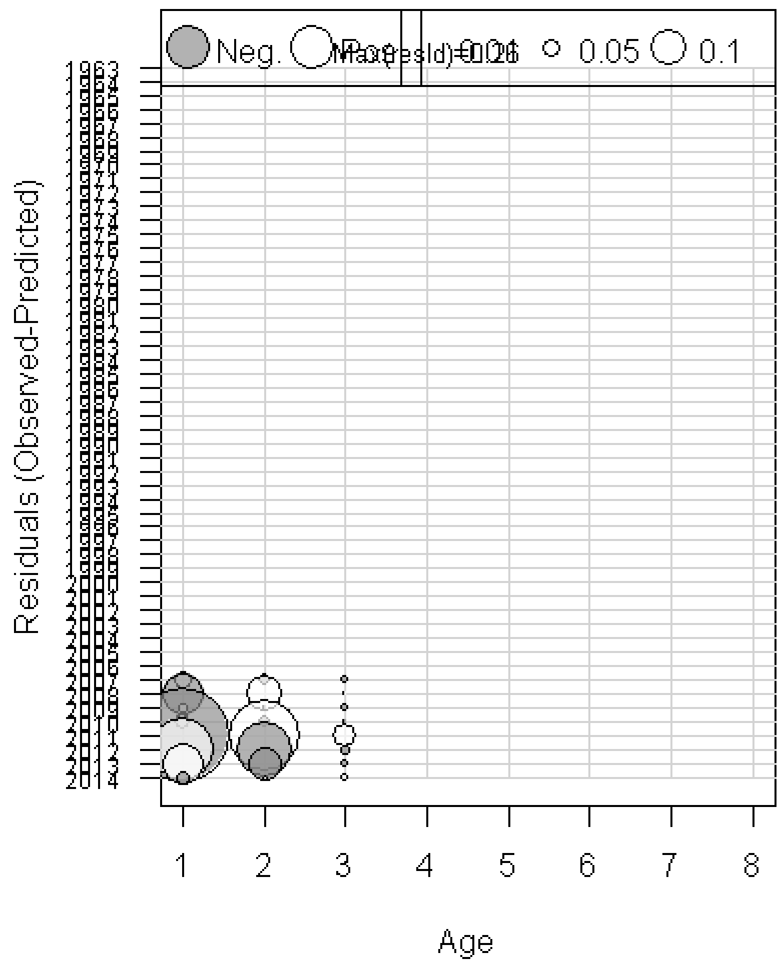


Figure A137. Age composition residuals for final run S60_BASE_19: VIMS NEAMAP fall survey.

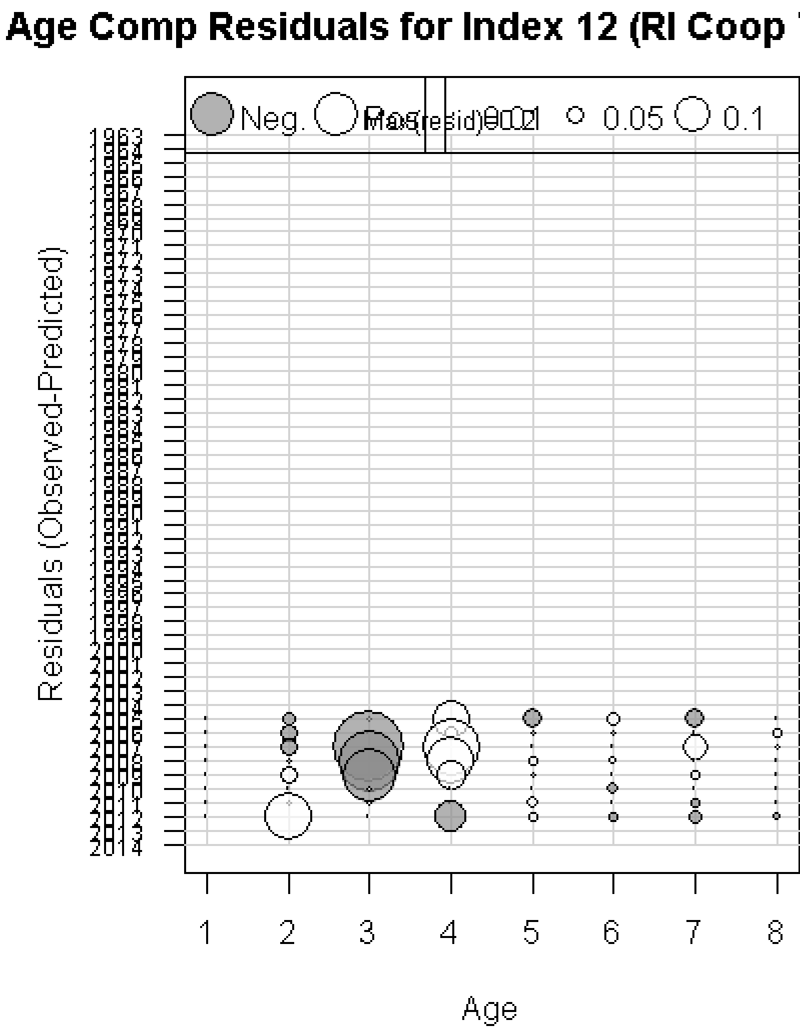


Figure A138. Age composition residuals for final run S60_BASE_19: RIDFW cooperative trap survey.

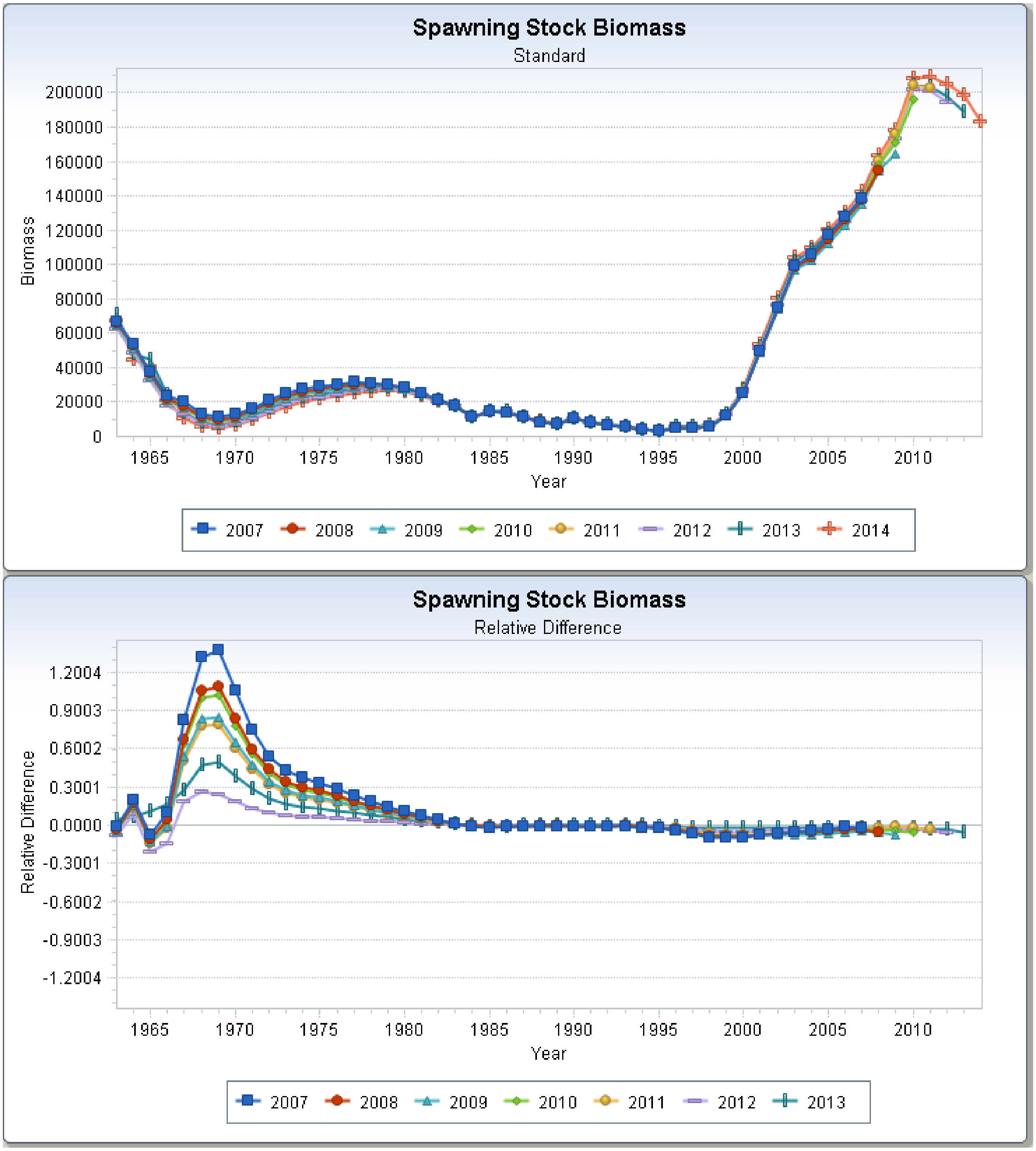


Figure A139. Retrospective analysis for run S60_BASE_18: top panel is absolute difference, bottom panel is relative difference - SSB.

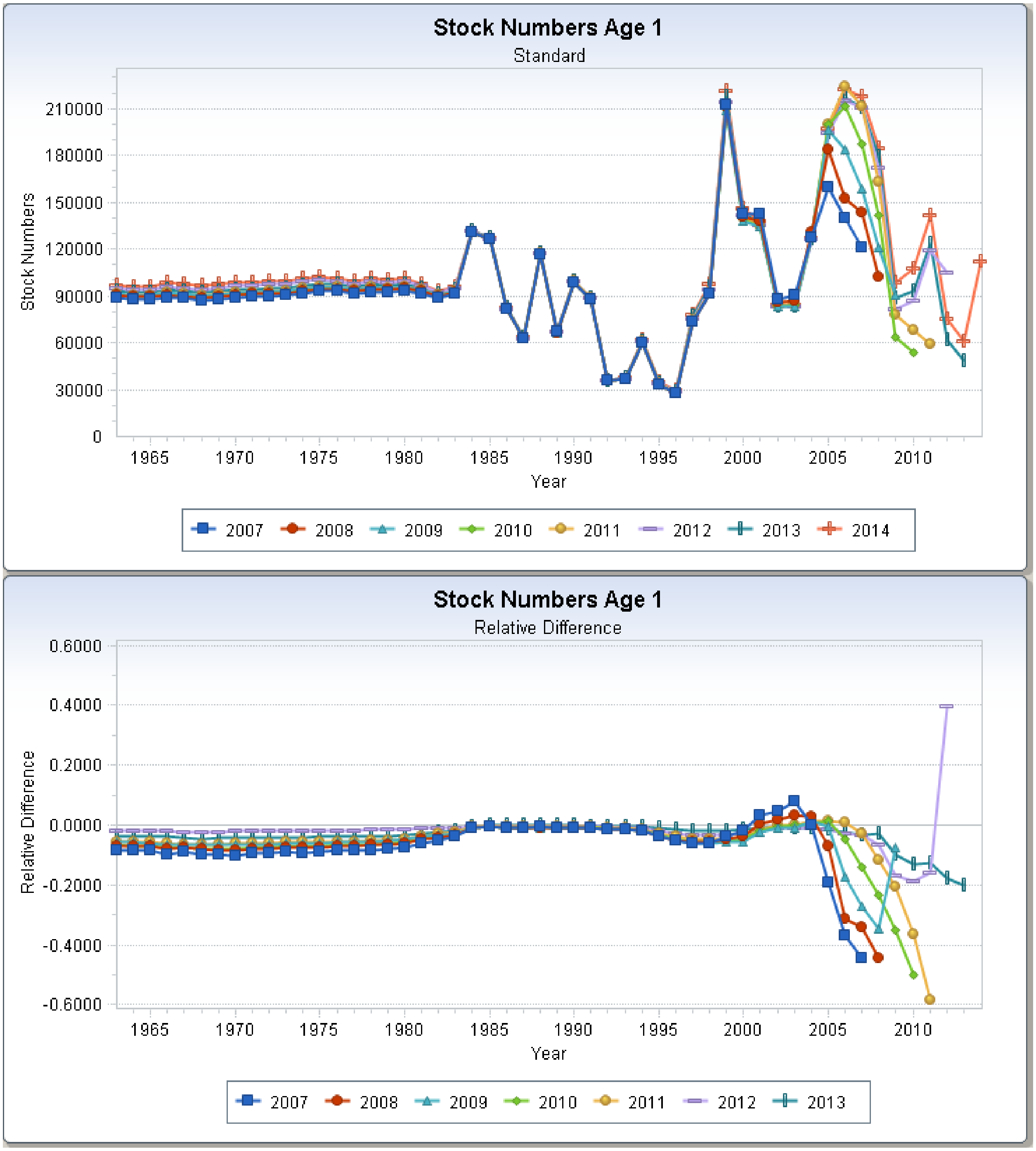


Figure A140. Retrospective analysis for run S60_BASE_18: top panel is absolute difference, bottom panel is relative difference - R (recruitment at true age 0, model age 1).

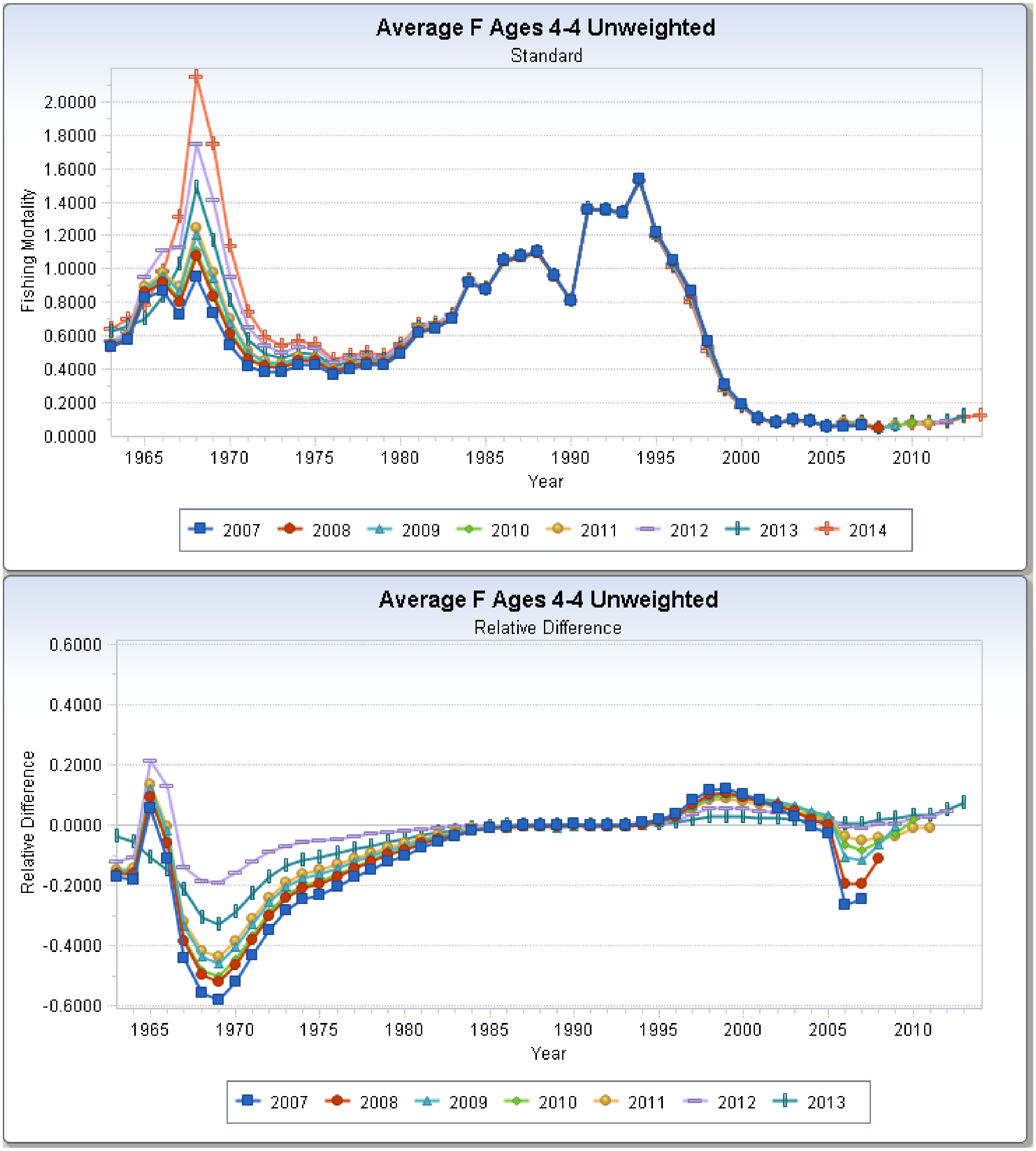


Figure A141. Retrospective analysis for run S60_BASE_18: top panel is absolute difference, bottom panel is relative difference – F (peak F at true age 3, model age 4).

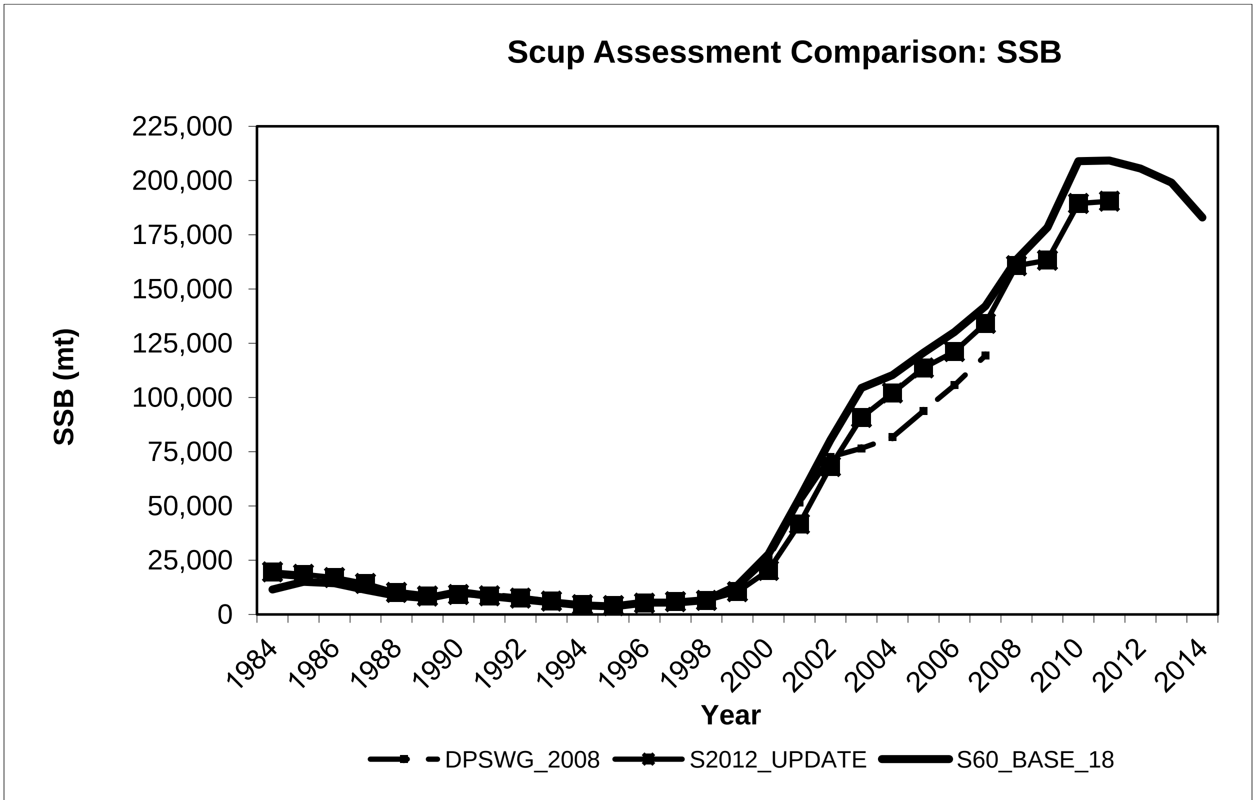


Figure A142. 'Historical' retrospective comparison of the 2008 DPSWG, 2012 update, and 2015 SAW 60 assessments: estimates of SSB.

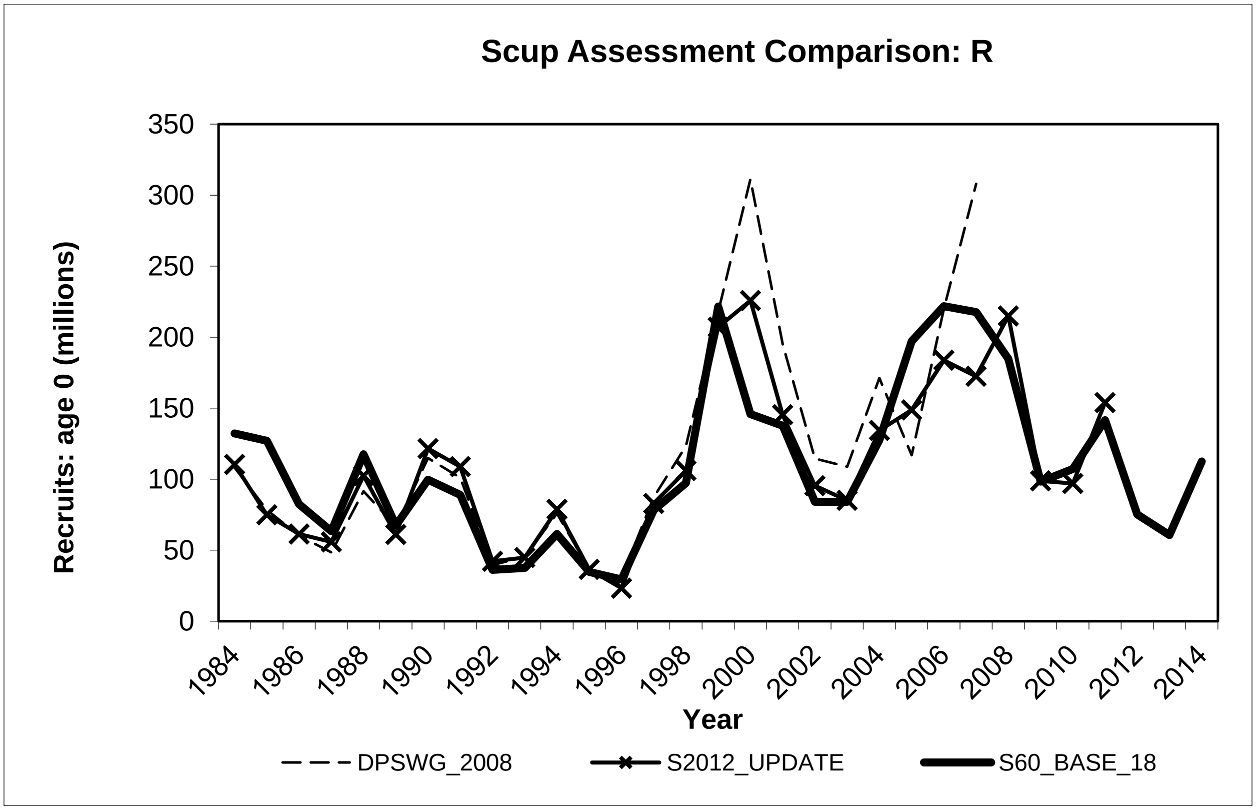


Figure A143. ‘Historical’ retrospective comparison of the 2008 DPSWG, 2012 update, and 2015 SAW 60 assessments: estimates of R (recruitment at age 0).

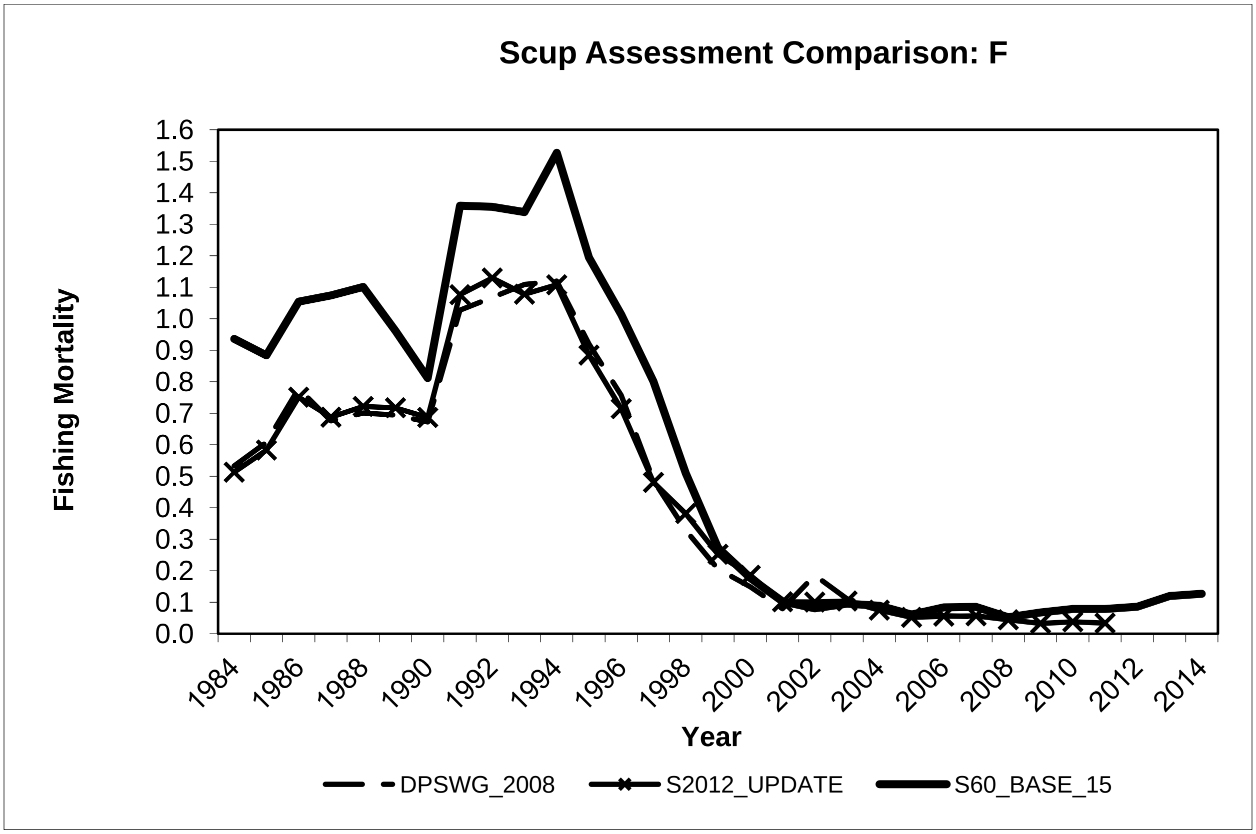


Figure A144. 'Historical' retrospective comparison of the 2008 DPSWG, 2012 update, and 2015 SAW 60 assessments: estimates of F.

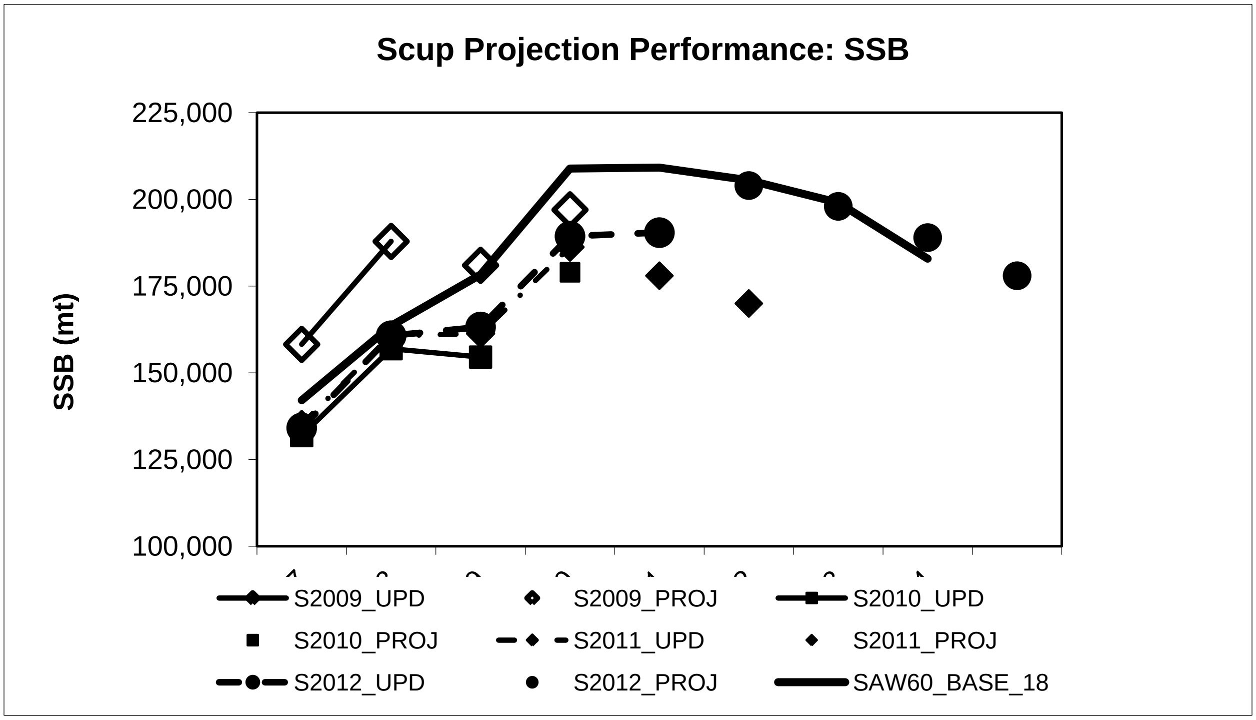


Figure A145. Performance of the 2009-2012 assessment estimates and projections when compared to 2015 SAW 60 final run S60-BASE_18 results: SSB.

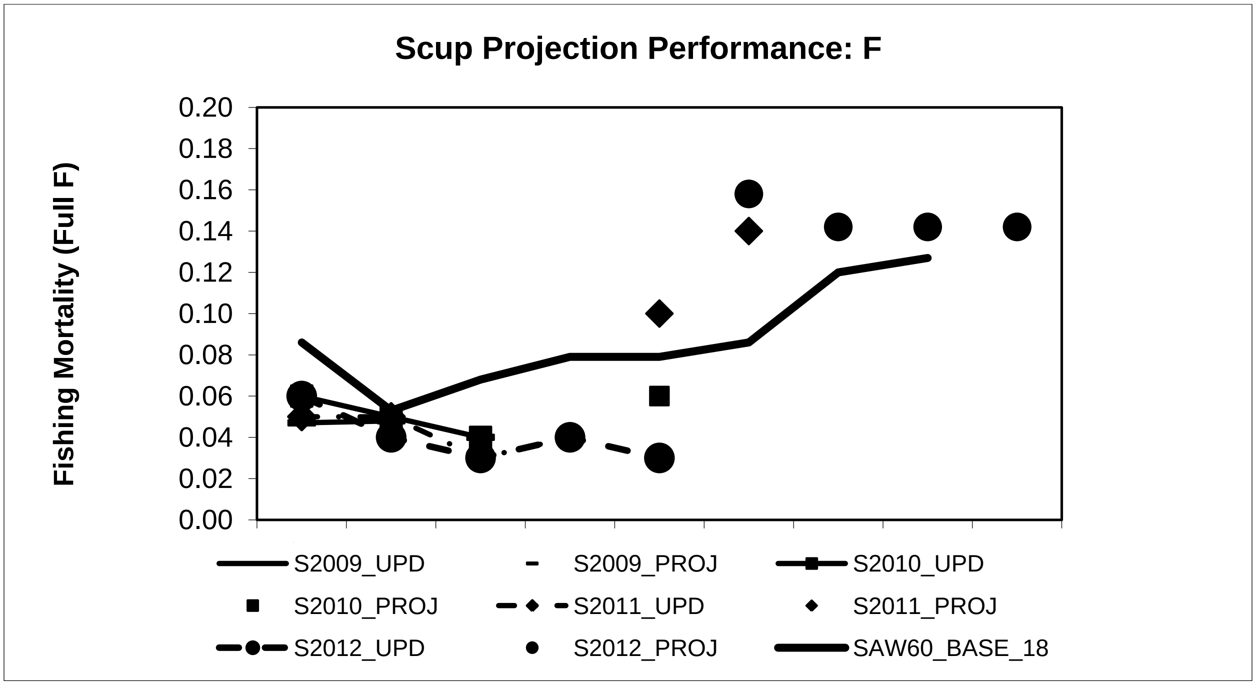


Figure A146. Performance of the 2009-2012 assessment estimates and projections when compared to 2015 SAW 60 final run S60-BASE_18 results: F.

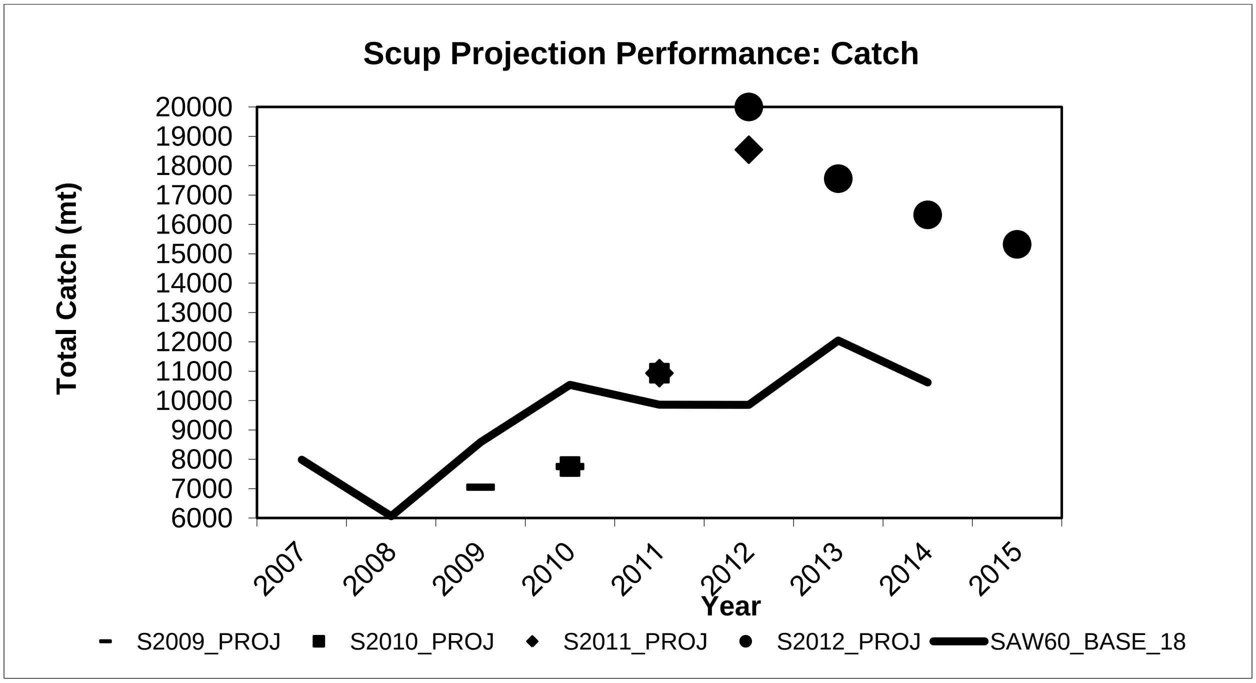


Figure A147. Performance of the 2009-2012 assessment estimates and projections when compared to 2015 SAW 60 final run S60-BASE_18 results: total fishery catch.

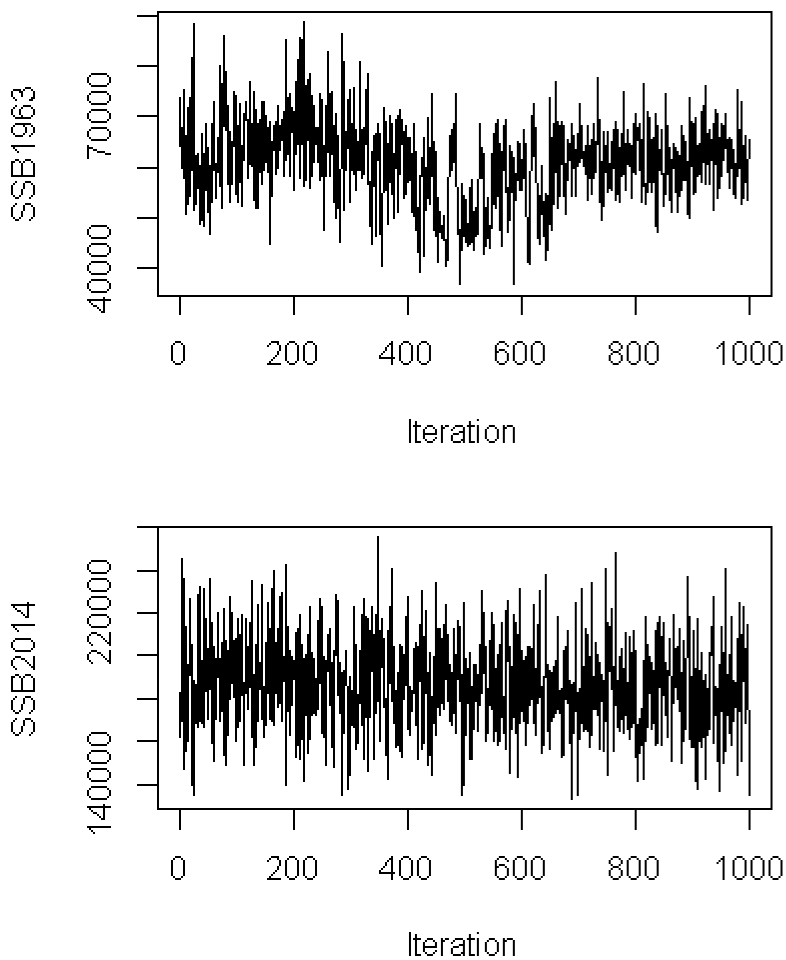


Figure A148. Run S60_BASE_18 MCMC chains for SSB.

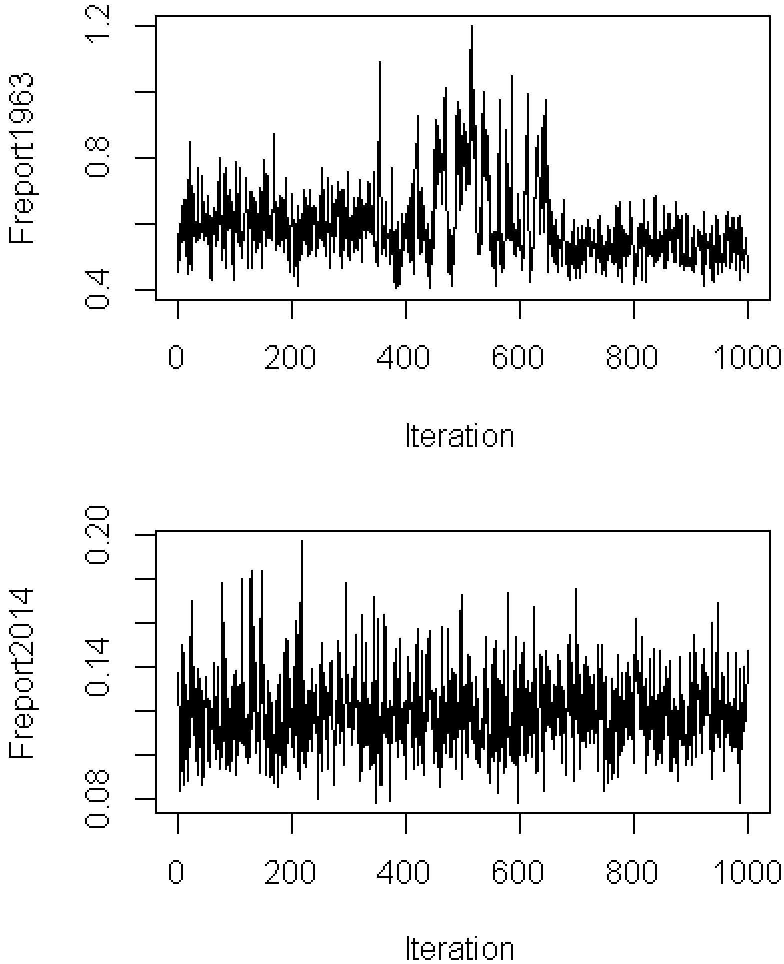


Figure A149. Run S60_BASE_18 MCMC chains for F.

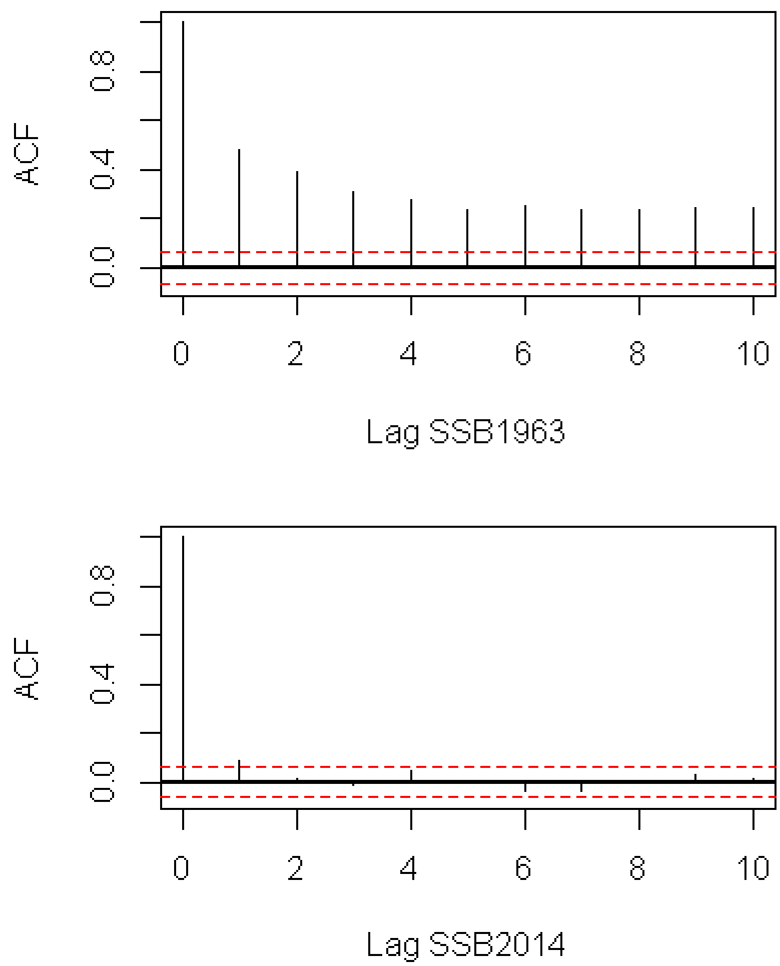


Figure A150. Autocorrelation plot for run S60_BASE_18 MCMC estimates: SSB.

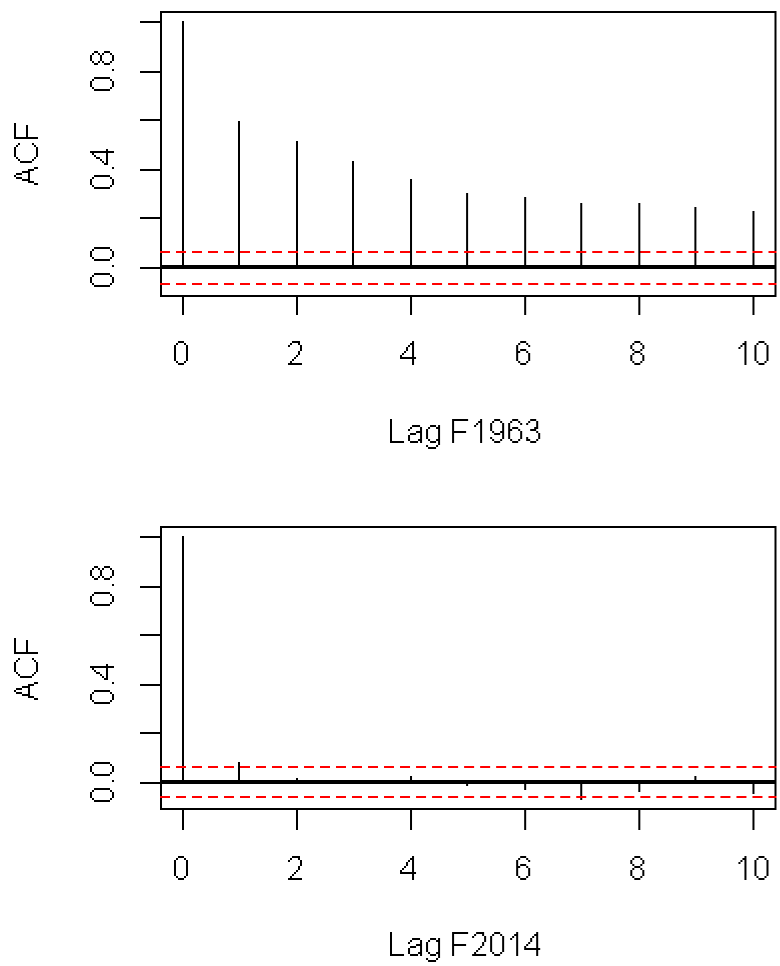


Figure A151. Autocorrelation plot for run S60_BASE_18 MCMC estimates: F.

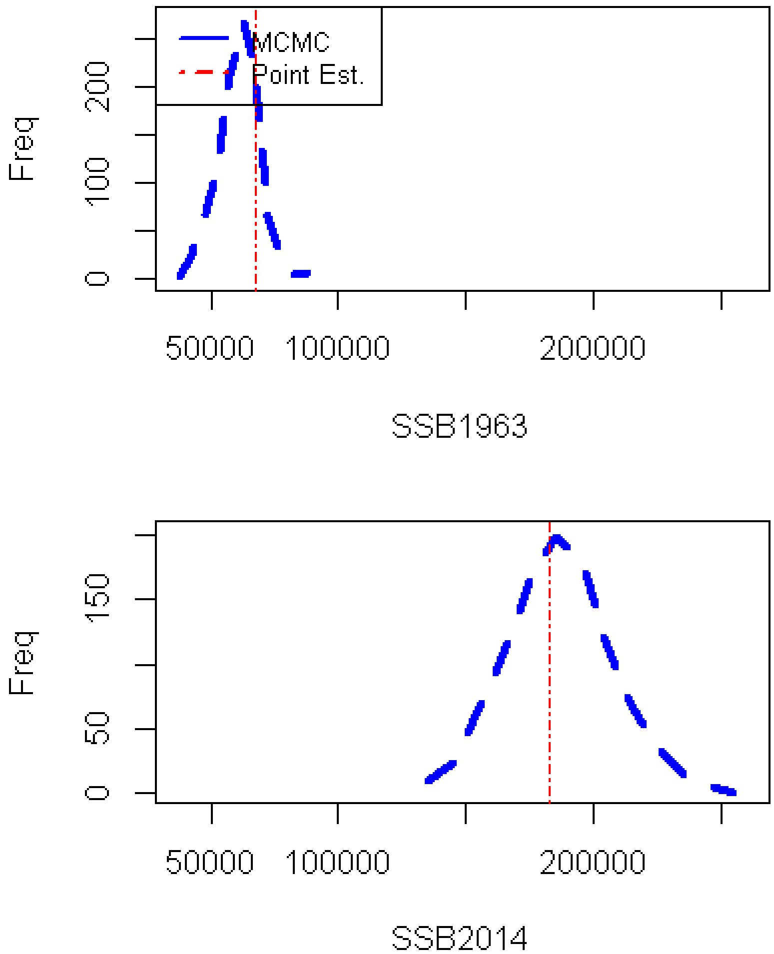


Figure A152. Run S60_BASE_18 point estimates and MCMC distributions: SSB.

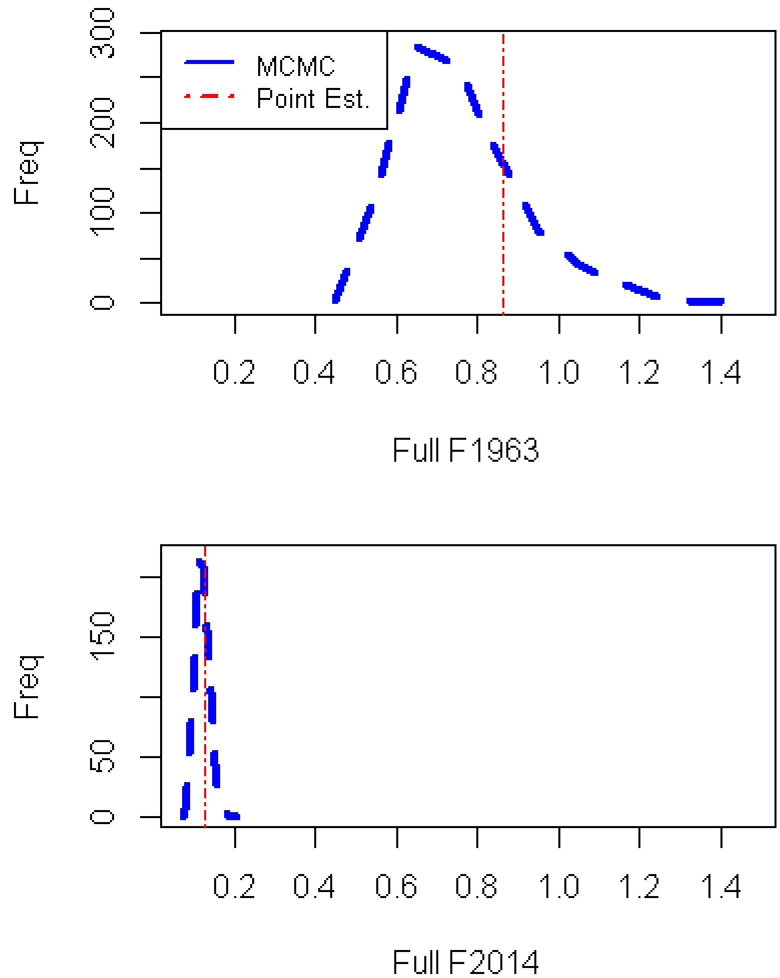


Figure A153. Run S60_BASE_18 point estimates and MCMC distributions: F.

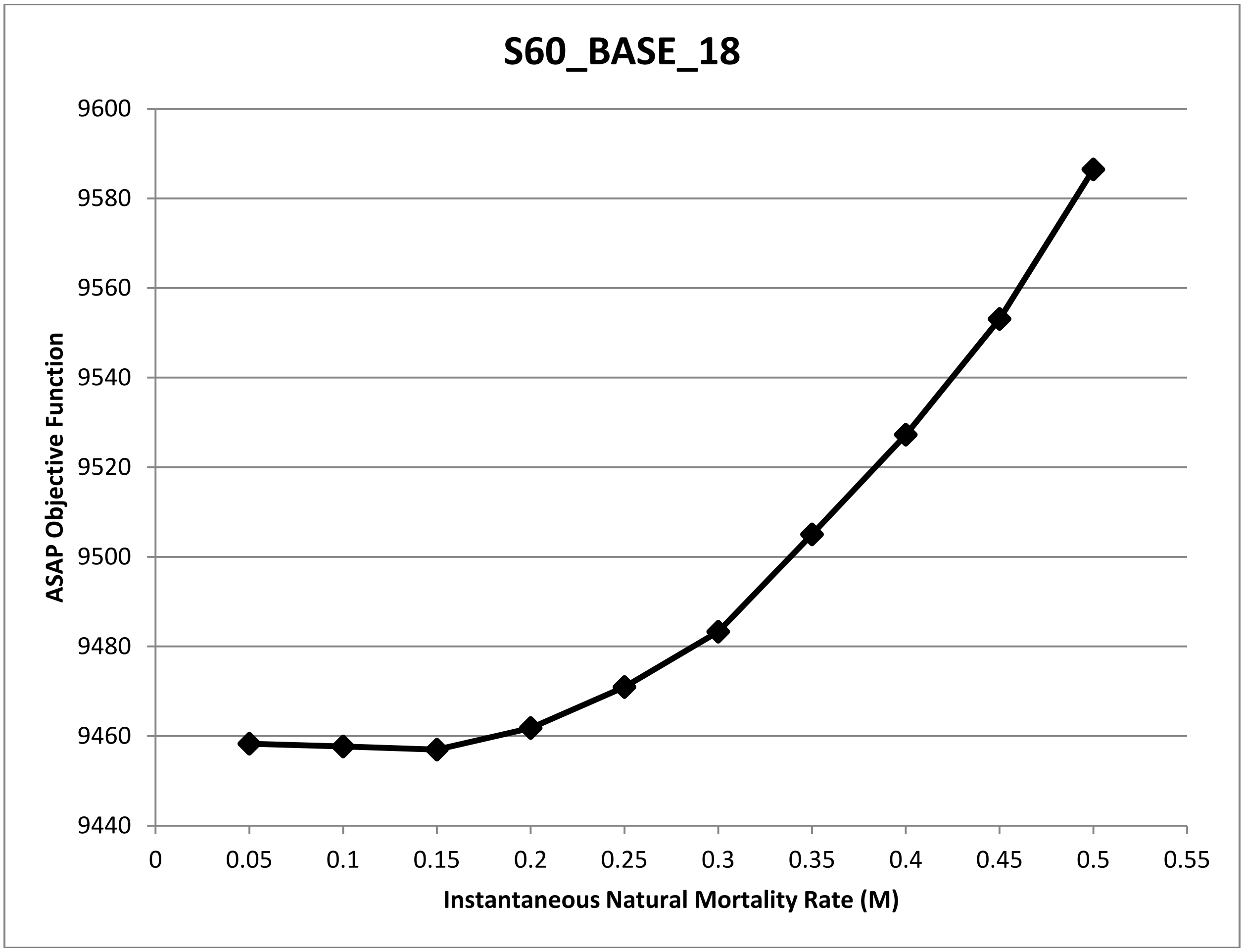


Figure A154. Likelihood profile of run S60_BASE_18 for fixed values of M.

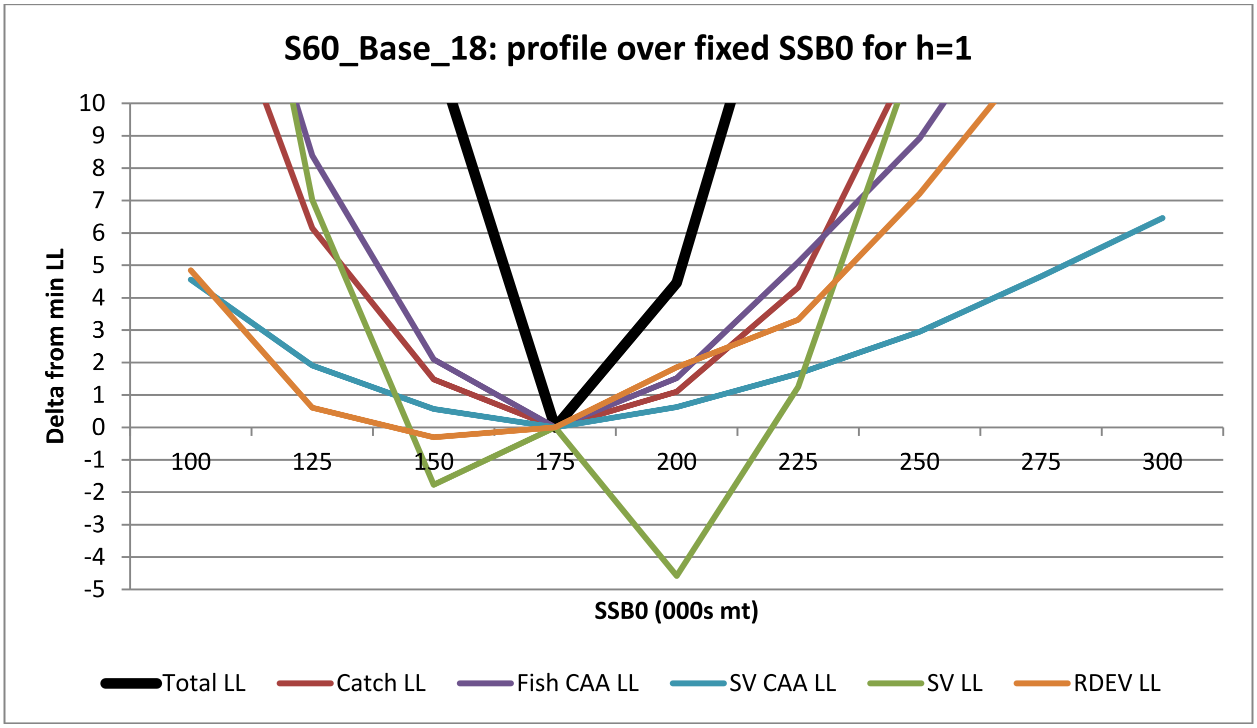


Figure A155. Likelihood profile of run S60_BASE_18 for fixed values of SSB0 given fixed steepness (h =1). The plot shows the difference (delta) from the Total LL at 175 mt for all components to show both the minimum LL for each and to help judge whether differences are likely to be significant.

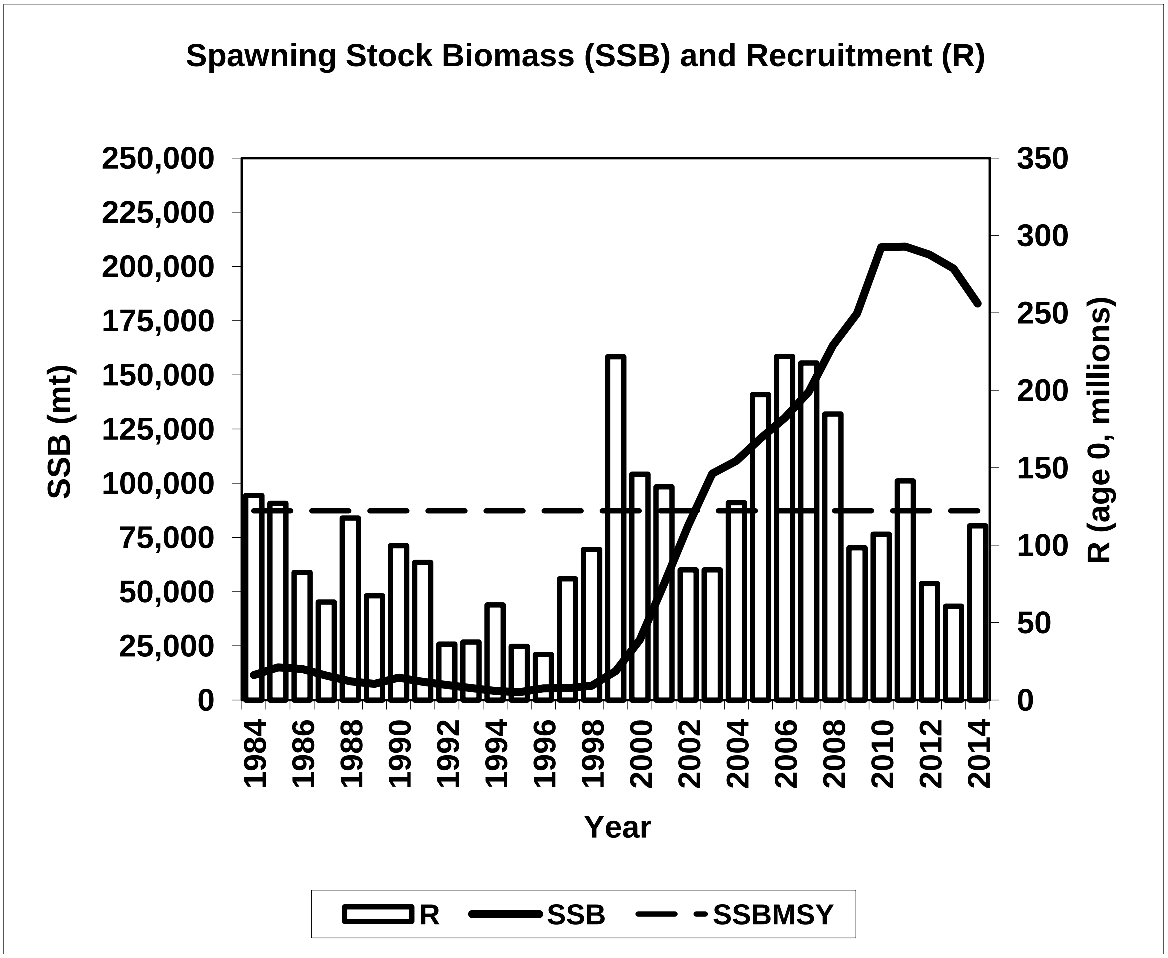


Figure A156. Spawning Stock Biomass (SSB; solid line) and R (Recruitment at age 0; vertical bars). The horizontal dashed line is the SSBMSY proxy = SSB40% = 87,302 mt. Note these plots show only years where fishery age data are available in the model.

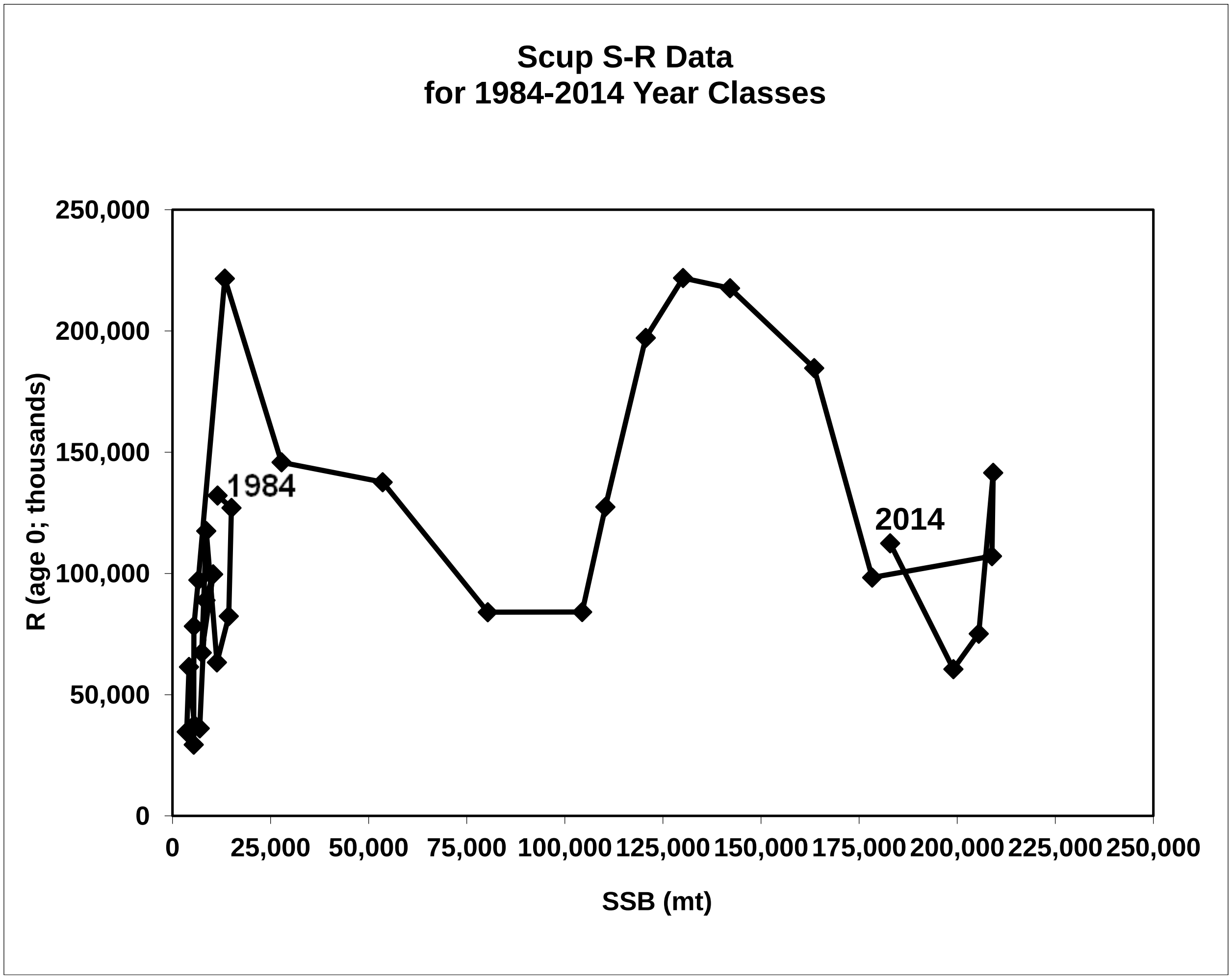


Figure A157. Spawning Stock Biomass (SSB) and Recruitment (R) scatter plot for scup. Note this plot shows only years where fishery age data are available in the model.

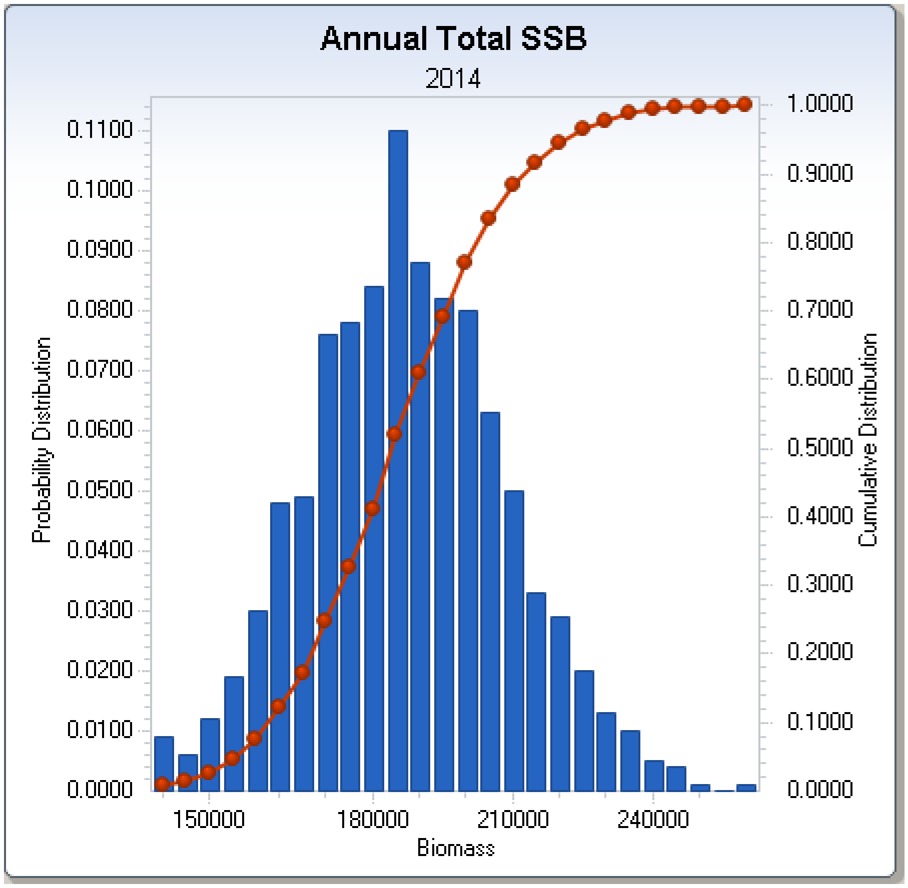


Figure A158. MCMC distribution plot for the 2014 estimate of SSB.

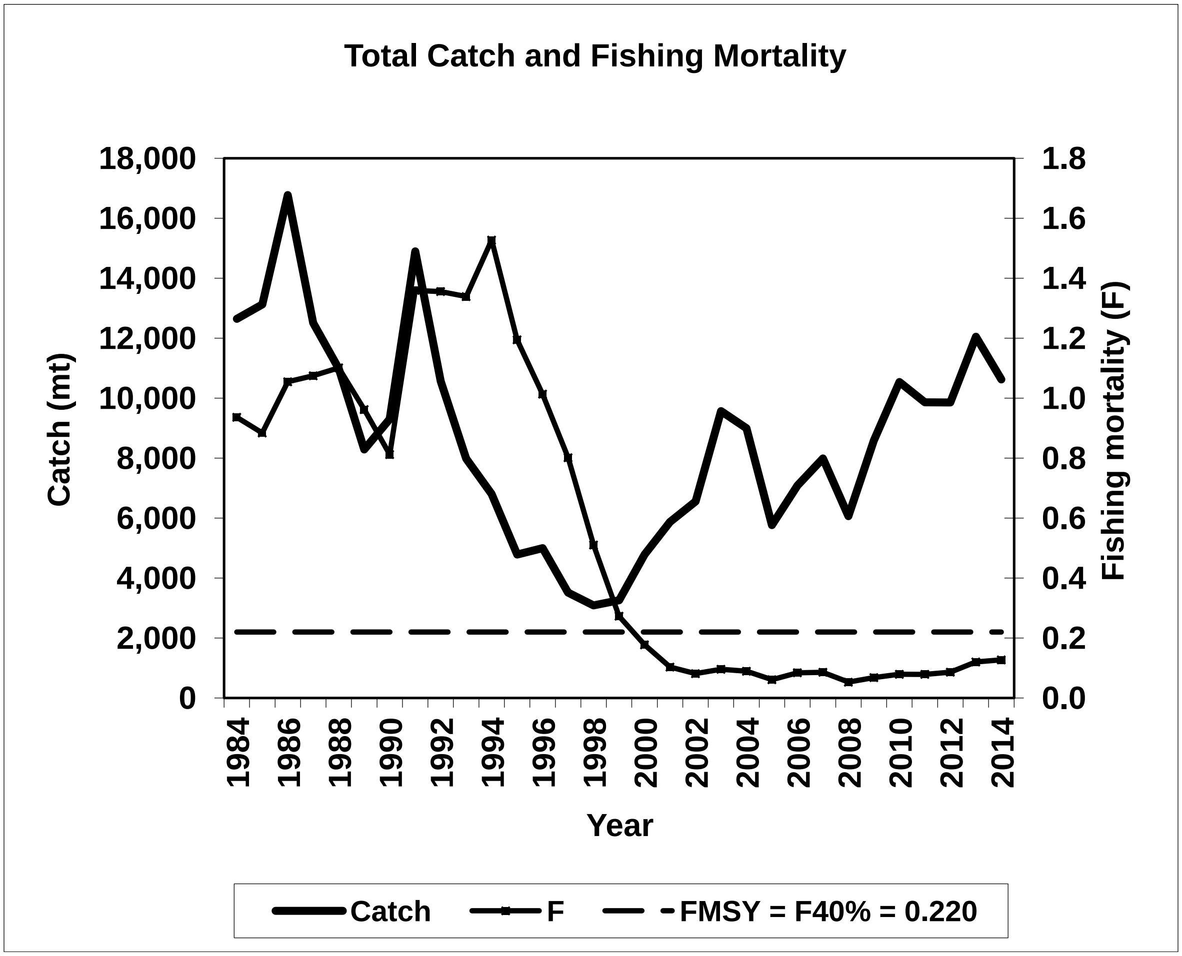


Figure A159. Total fishery catch and fishing mortality (F, peak at age 3). The horizontal dashed line is the FMSY proxy = F40% = 0.220. Note these plots show only years where fishery age data are available in the model.

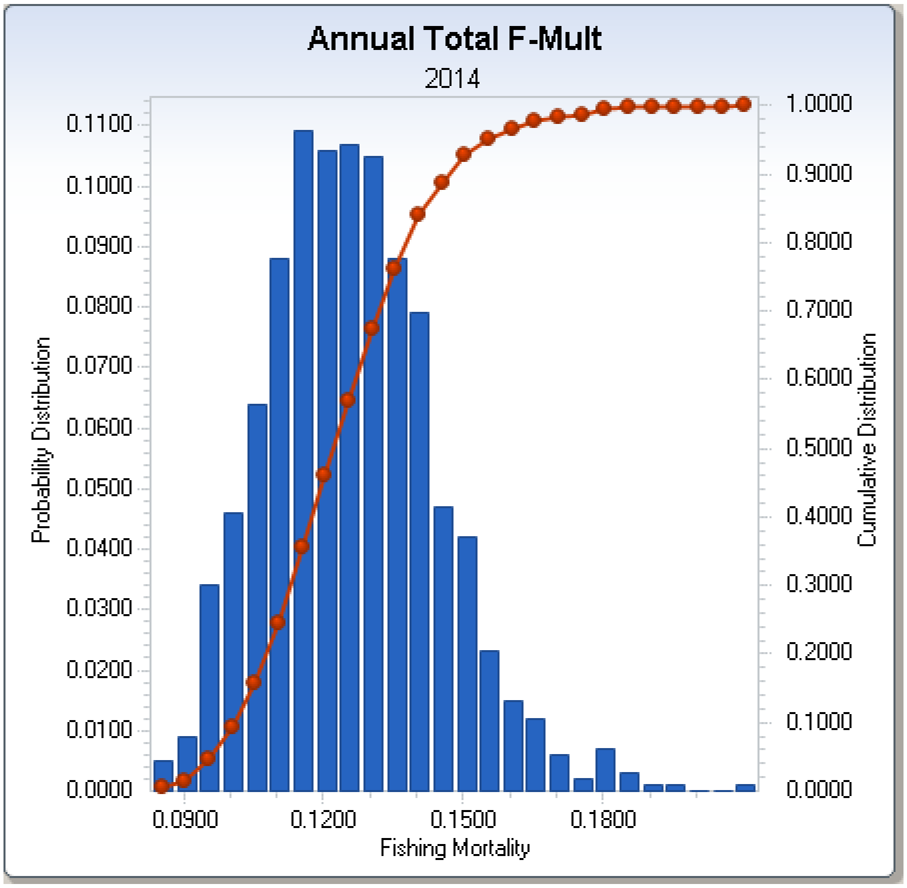


Figure A160. MCMC distribution plot for the 2014 estimate of fishing mortality (F).

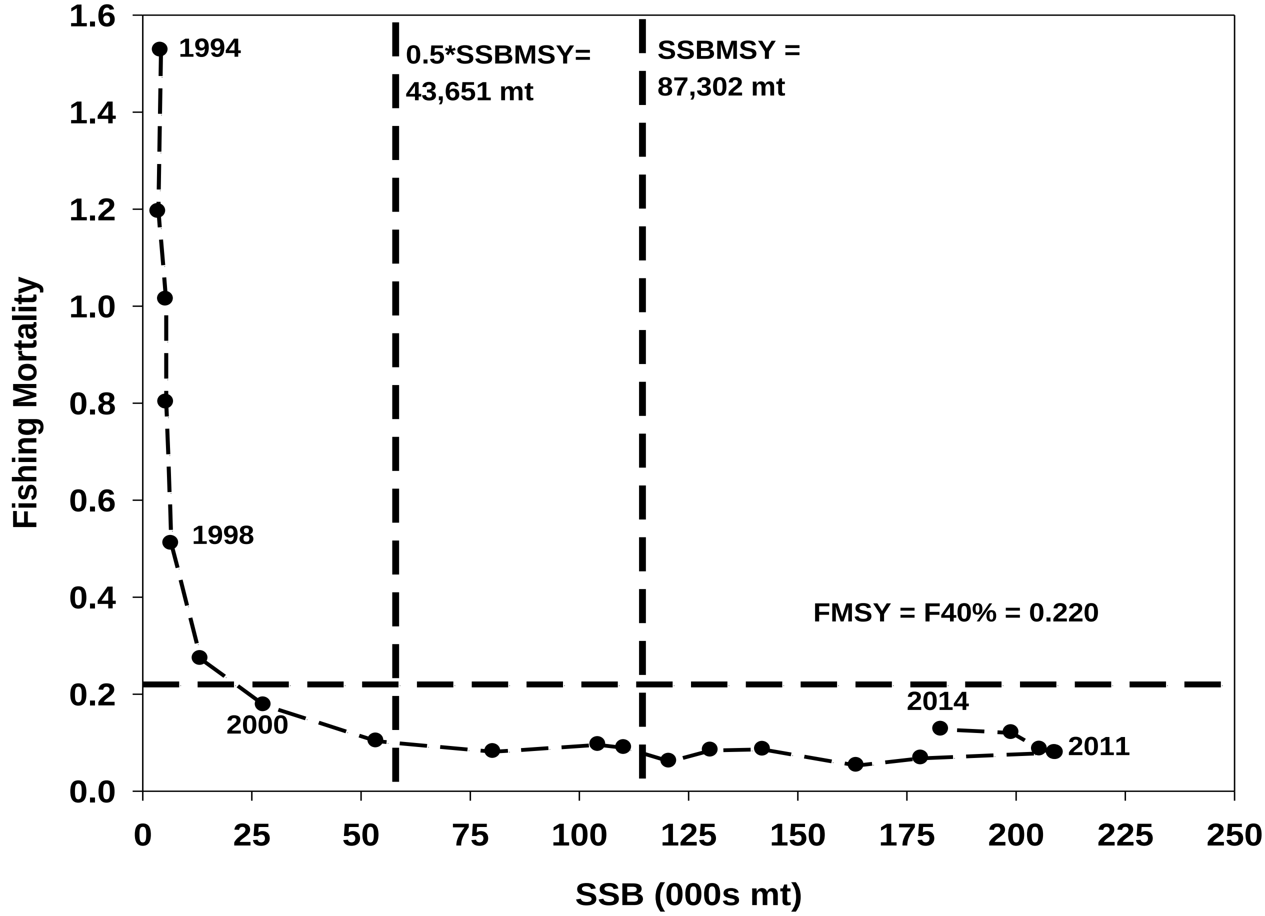


Figure A161. Status determination plot for scup: spawning stock biomass (SSB) and fully-recruited fishing mortality (F) relative to the 2015 SAW 60 biological reference points.

Appendix

Appendix 1: Additional work requested by the SARC

Model result sensitivity to the assumption for M

The SARC requested a fuller examination of the sensitivity of the model run S60_BASE_18 results to a range of values assumed for the instantaneous natural mortality rate (M). The model results changed in a predictable way, with stock sizes through model age 5 (true age 4) generally scaled upward as M was increased from 0.1 to 0.3 (0.2 was assumed for run 18; Figures 1-5). The pattern changes for model ages 6-8+ (true ages 5-7+) as the relative importance of M and F changes with the increase in M due to the domed fishery selection pattern. This changing pattern over ages of the relationship between M and F is also why the SSB (which by weight is composed mostly of true age 3 and older) is lower for higher M (Figure 6). Recent fishing mortality (F) estimates increase by about 10% for each increase in M (Figure 7).

Fishing mortality and SSB reference points were calculated for each M assumption and stock status determined for each assumption. Under all three assumptions for M, the stock was not overfished and overfishing was not occurring, as F in 2014 was below the F threshold and SSB was above the SSB target (Figure 8). These results indicated to the SARC that the status evaluation for scup was robust to the assumption for M.

Model result sensitivity to the length of included time series

The SARC requested a fuller examination of the sensitivity of the model run S60_BASE_18 results to the length of the time series included in the model, given the model configuration (i.e., Lambda settings, selectivity settings, catch and survey CV settings). The 2014 SSB estimate for the model run starting in 1963 was about 40% higher than the estimate for the model run starting in 1989 (Figure 9); the 2014 total stock numbers (N) estimate was about 50% higher (Figure 10); the 2014 fishing mortality (F) estimate was about 65% lower (Figure 11). Patterns were similar for estimated stock sizes at age (Figures 12-15).

Model fit to survey data

Given the need to set priors on starting conditions, set priors on fishery selectivity, and adjust survey CVs to account for additional process error, the SARC reviewed a plot of normalized survey time series of aggregate and true age 0 survey indices compared with normalized model estimates of total stock size. These plots indicated that, even given the influence of prior (Lambda) settings and the fishery catch data, the model estimates were still in general following the trends indicated by the survey data (Figures 16-17).

Model result sensitivity to the configuration of fishery selectivity

The SARC requested a fuller examination of the sensitivity of the model run S60_BASE_18 results to assumptions for and estimation of the fishery selectivity. The selectivity (S) for the commercial and recreational landings was initially set fixed at S = 1 for model age 4 (true age 3) in all three time blocks (1963-1996, 1997-2005, 2006-2014). In subsequent ‘tuning’ of the model, S at some adjacent ages and /or older ages were also fixed at 1 for the landings if the estimated parameters were constrained at the upper bound of S = 1. The total fishery estimated selectivity pattern for run S60_BASE_18 was:

0.07, 0.31, 0.71, 1.00, 0.96, 0.94, 0.57, and 0.18 for model ages 1-8+ (true ages 0-7+).

In run S60_BASE_18_FLATL, the commercial and recreational landings selectivities were set at S = 1 for model ages 4-8+ (true ages 3-7+) in all three time blocks. The total fishery estimated selectivity pattern for run S60_BASE_18_FLATL was:

0.06, 0.40, 0.83, 1.00, 0.91, 0.88, 0.88, and 0.87 for model ages 1-8+ (true ages 0-7+).

The resulting pattern estimated in the sensitivity run both rises more steeply and is flatter at older ages than in the accepted model.

Comparative results are provided in Figures 18-20. This sensitivity run of the choice of selectivity pattern used in the accepted model highlighted some additional risk. The accepted model has a strong domed selectivity pattern which could result in an increasing cryptic biomass given current stock trajectory. Conclusions regarding current stock status are robust to alternative selectivity patterns but decreased recruitment or increased F in the future could lead to divergence between domed and flattop selectivity model results.

Appendix 1: Figures

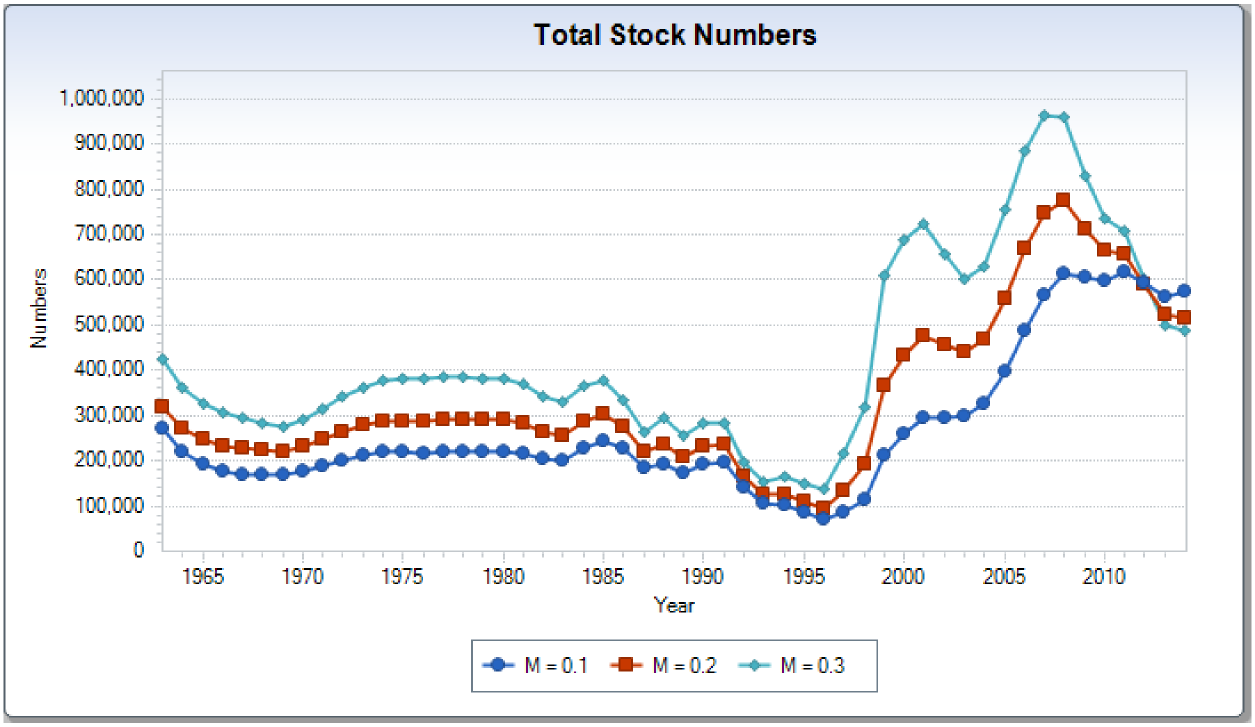


Figure 1. Comparison of run S60_BASE_18 estimates of total stock numbers for three values of M.

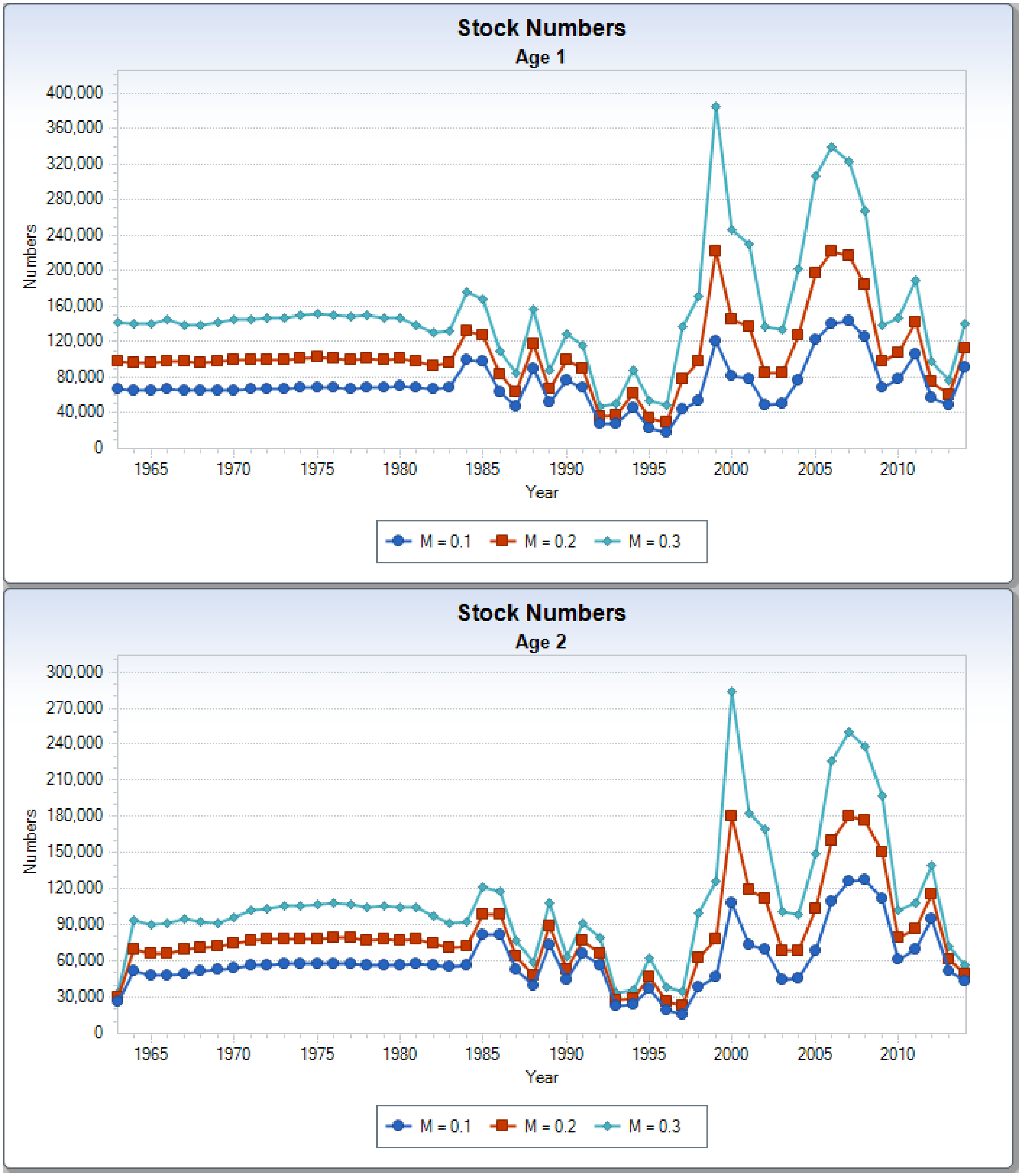


Figure 2. Comparison of run S60_BASE_18 estimates of model ages 1 and 2 (true ages 0 and 1) stock numbers for three values of M.

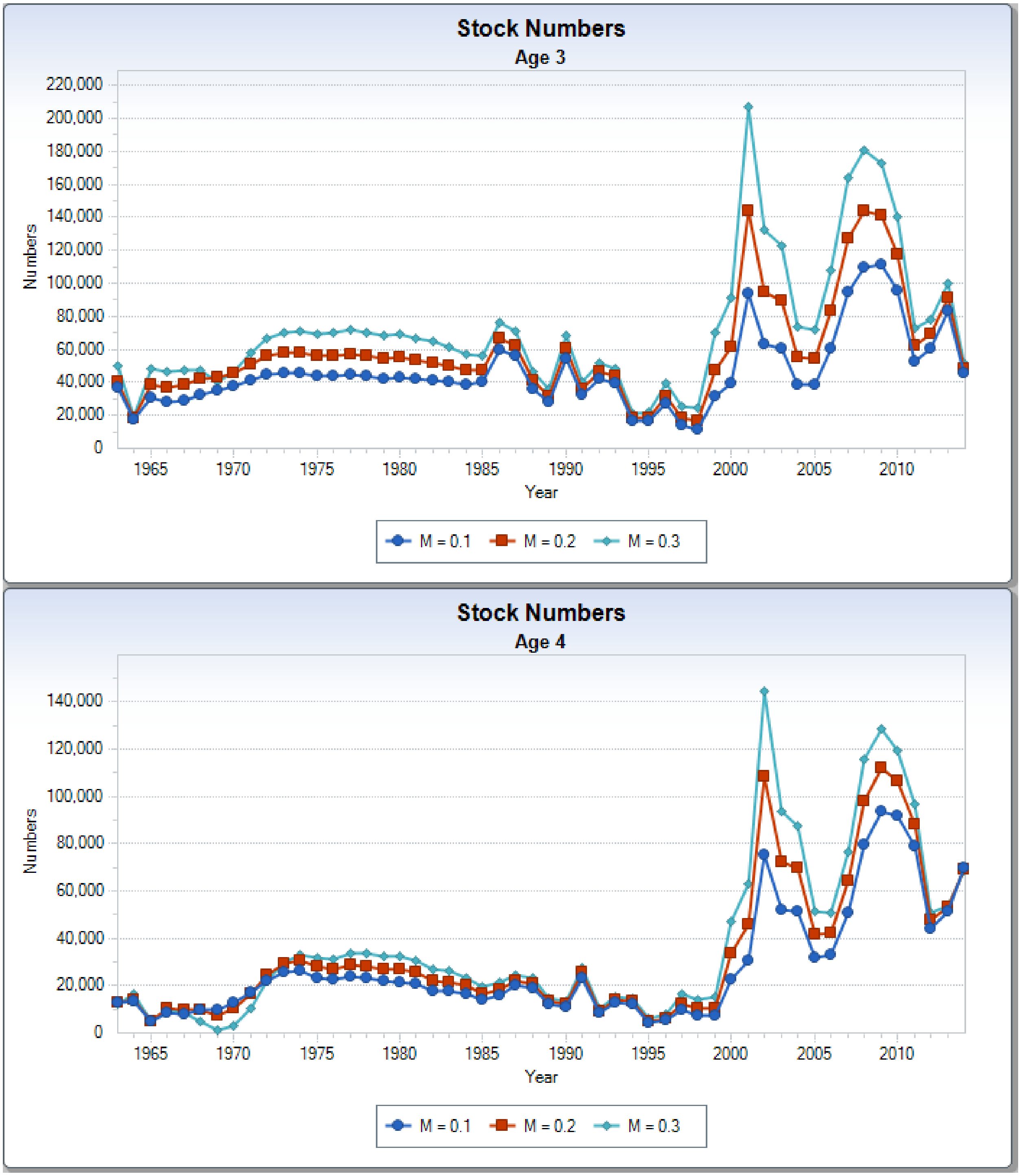


Figure 3. Comparison of run S60_BASE_18 estimates of model ages 3 and 4 (true ages 2 and 3) stock numbers for three values of M.

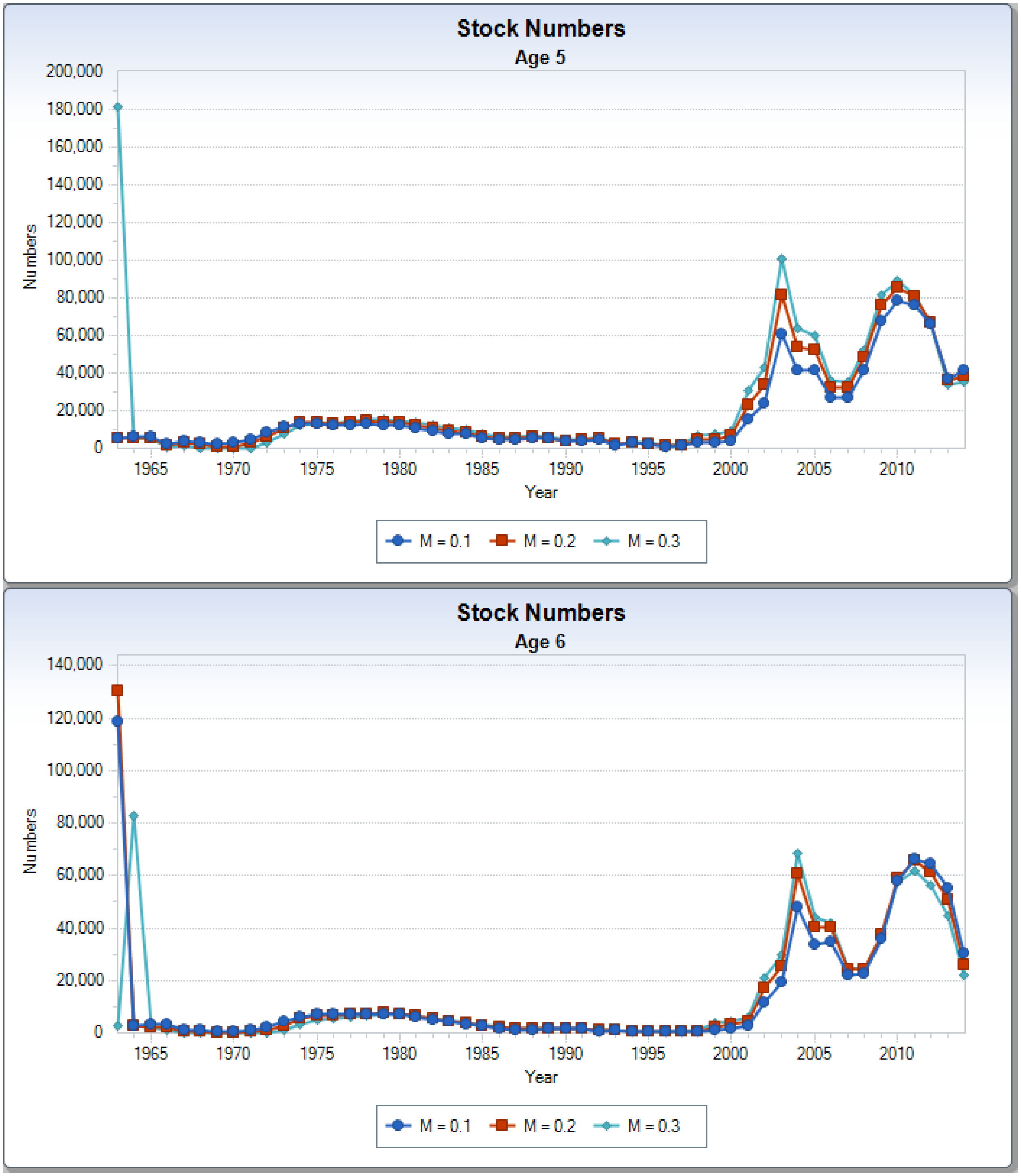
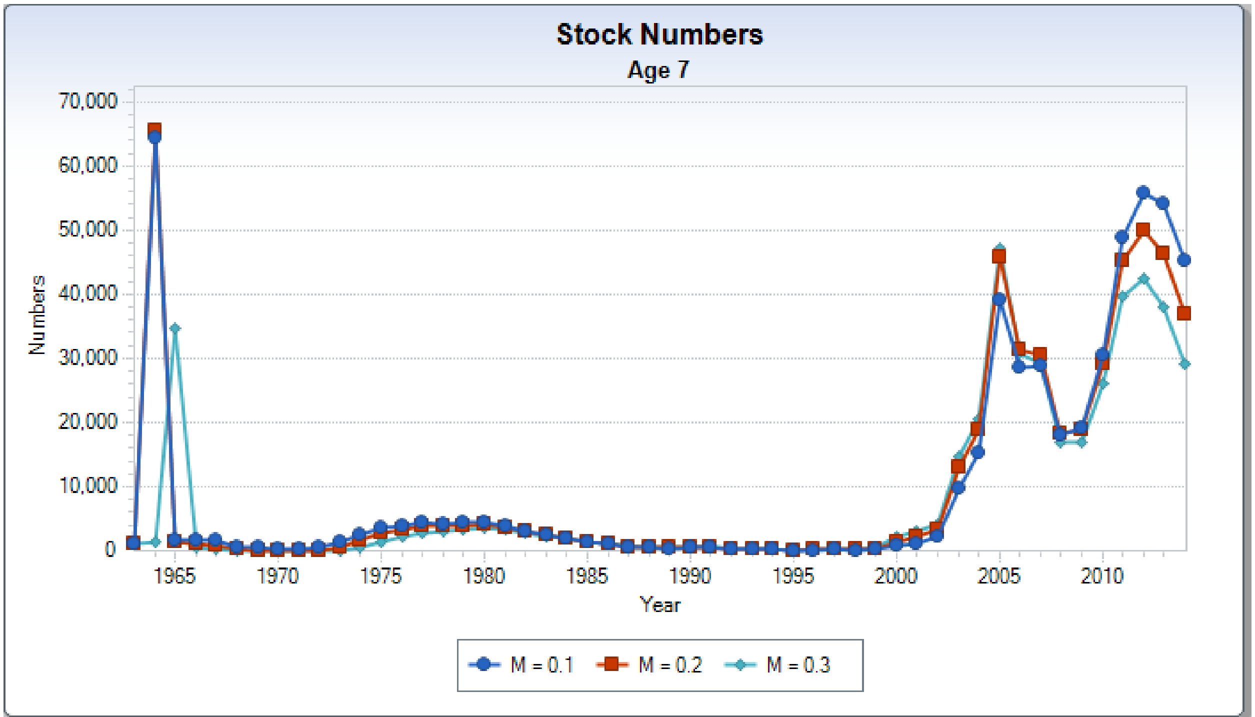


Figure 4. Comparison of run S60_BASE_18 estimates of model ages 5 and 6 (true ages 4 and 5) stock numbers for three values of M.



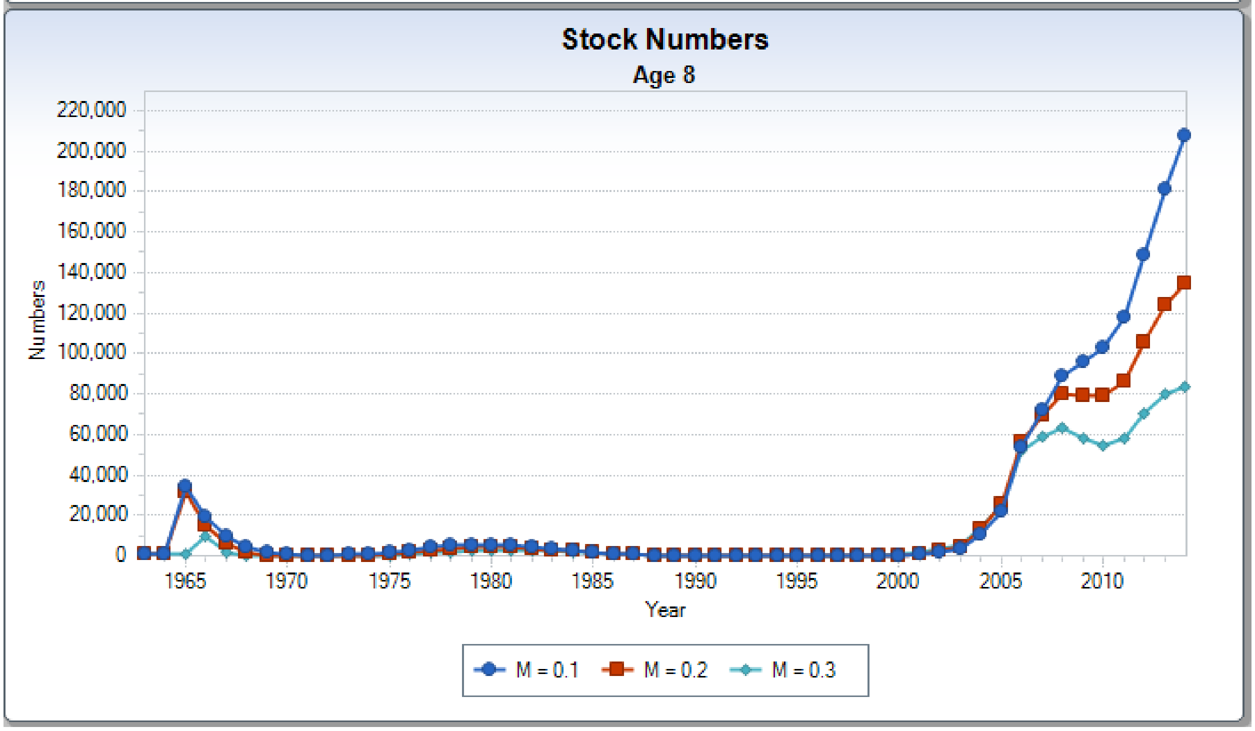


Figure 5. Comparison of run S60_BASE_18 estimates of model ages 7 and 8+ (true ages 6 and 7+) stock numbers for three values of M.

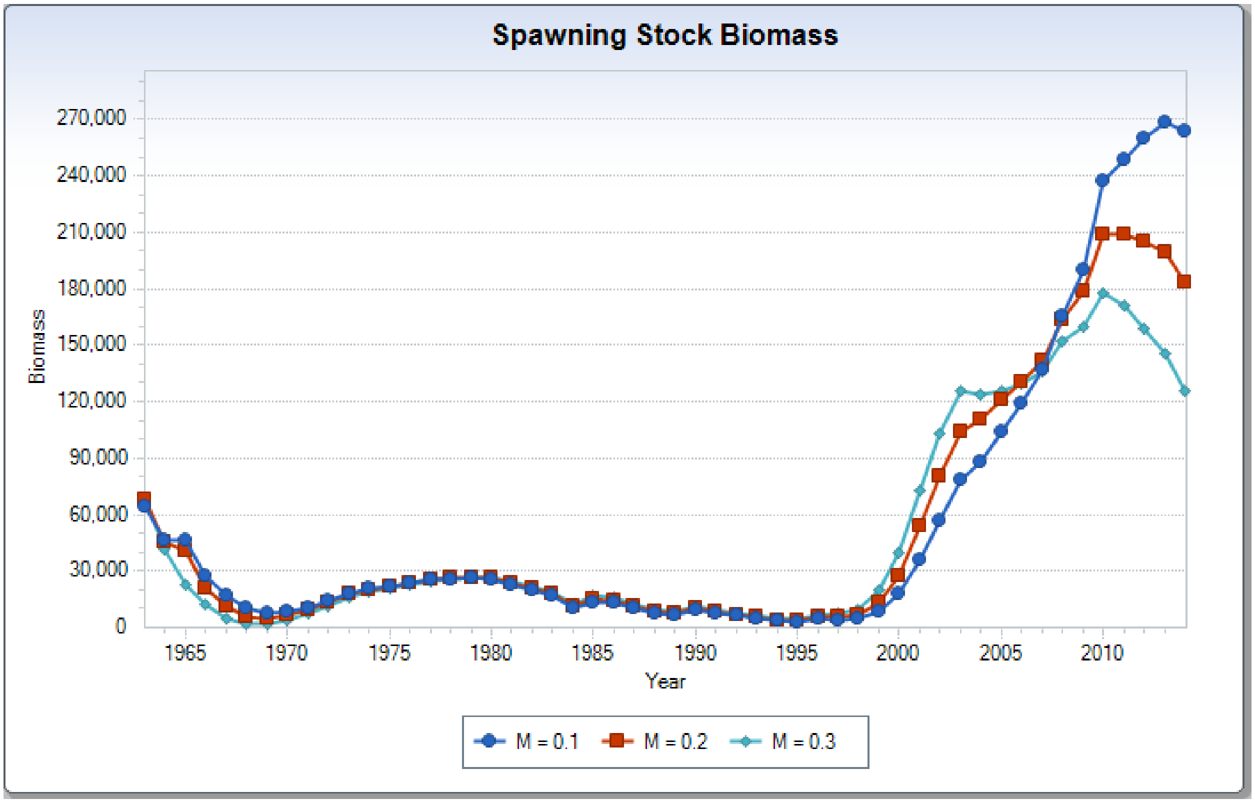


Figure 6. Comparison of run S60_BASE_18 estimates of Spawning Stock Biomass (SSB) for three values of M.

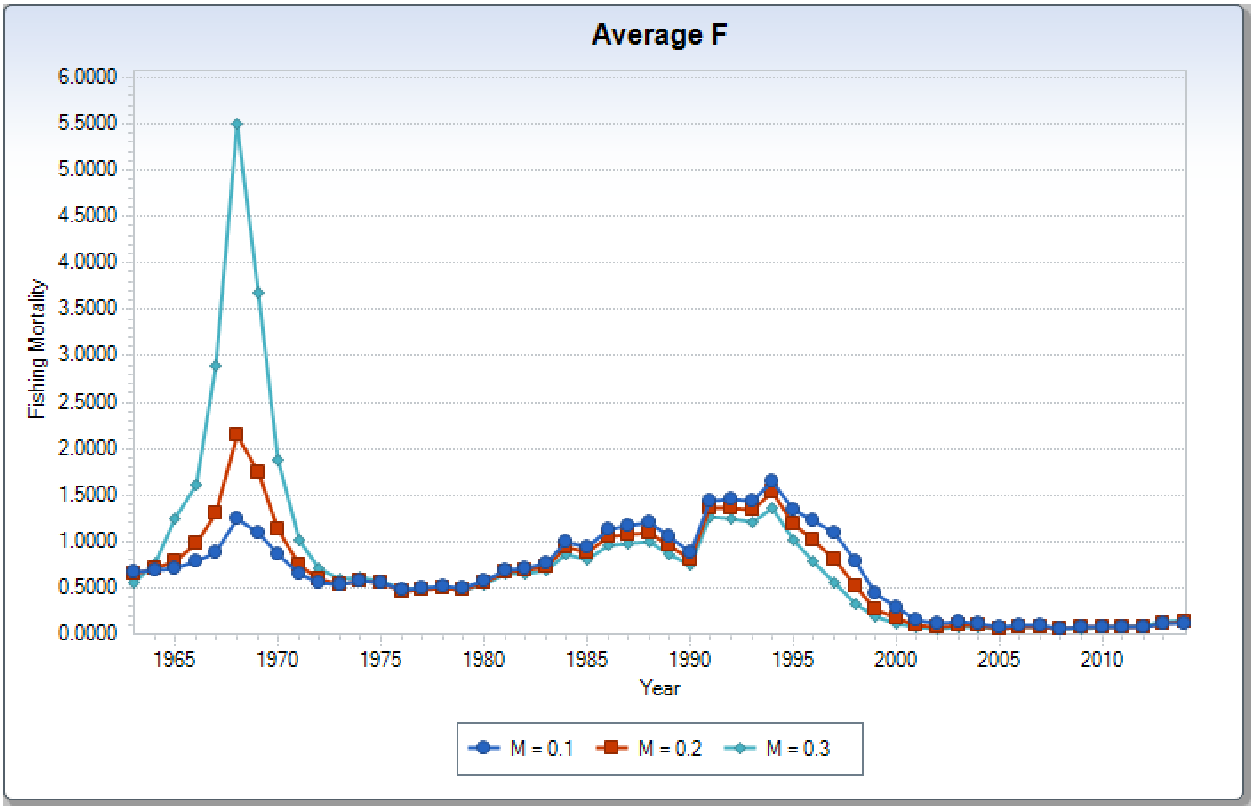


Figure 7. Comparison of run S60_BASE_18 estimates of peak Fishing Mortality (F) at model age 4 (true age 3) for three values of M.

SARC Work: Run 18 Sensitivity to M
Reference Points

M = 0.1: F40 = 0.172, F2014 = 0.111
M = 0.2: F40 = 0.220, F2014 = 0.127
M = 0.3: F40 = 0.261, F2014 = 0.146

M = 0.1: SSB40 = 194 kmt, SSB2014 = 264 kmt
M = 0.2: SSB40 = 87 kmt, SSB2014 = 183 kmt
M = 0.3: SSB40 = 56 kmt, SSB2014 = 126 kmt

M = 0.1: MSY40 = 13 kmt, CAT2014 = 11 kmt
M = 0.2: MSY40 = 12 kmt, CAT2014 = 11 kmt
M = 0.3: MSY40 = 11 kmt, CAT2014 = 11 kmt

Figure 8. Comparison of the proxy reference points and model estimates for three assumptions for M in the S60_BASE_18 model. For all three assumptions the stock is not overfished and overfishing is not occurring in 2014. Maximum sustainable yield (MSY40) is similar for the three assumptions

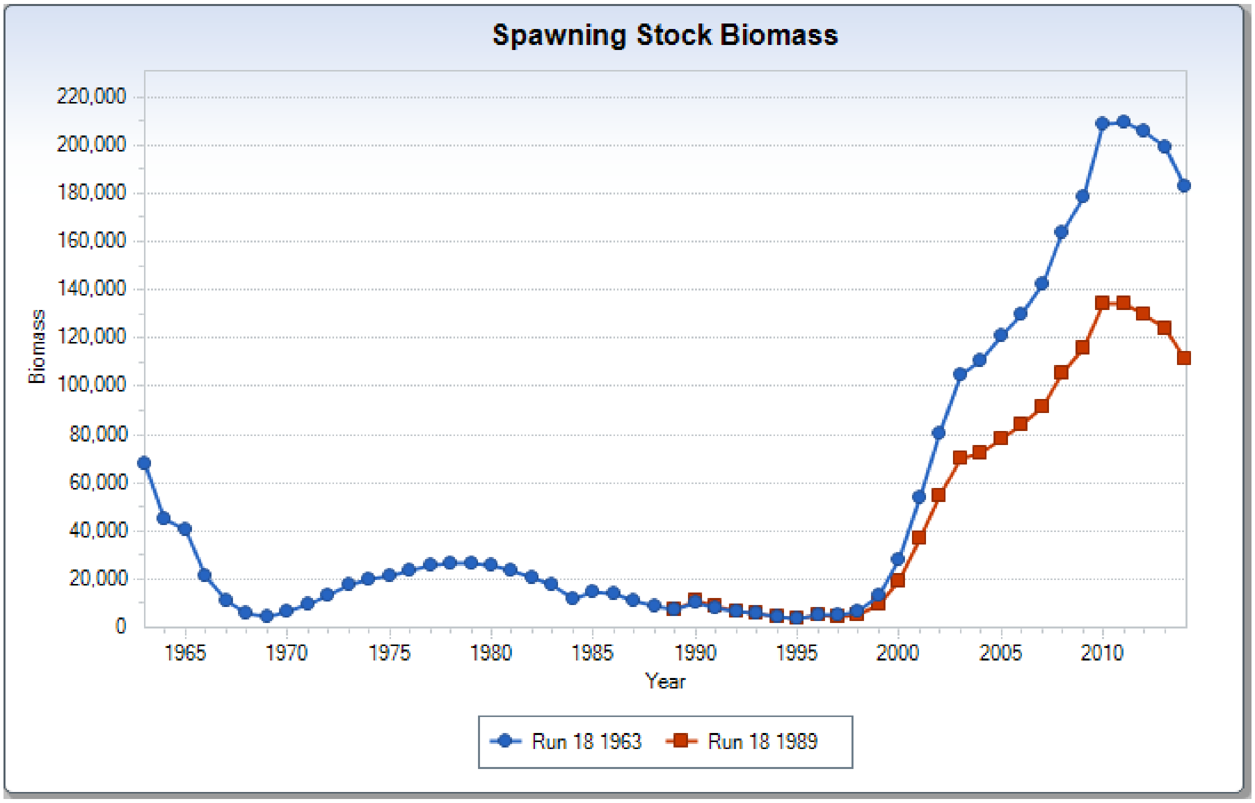


Figure 9. Comparison of results for versions of model S60_BASE_18 starting in 1963 and 1989: Spawning Stock Biomass.

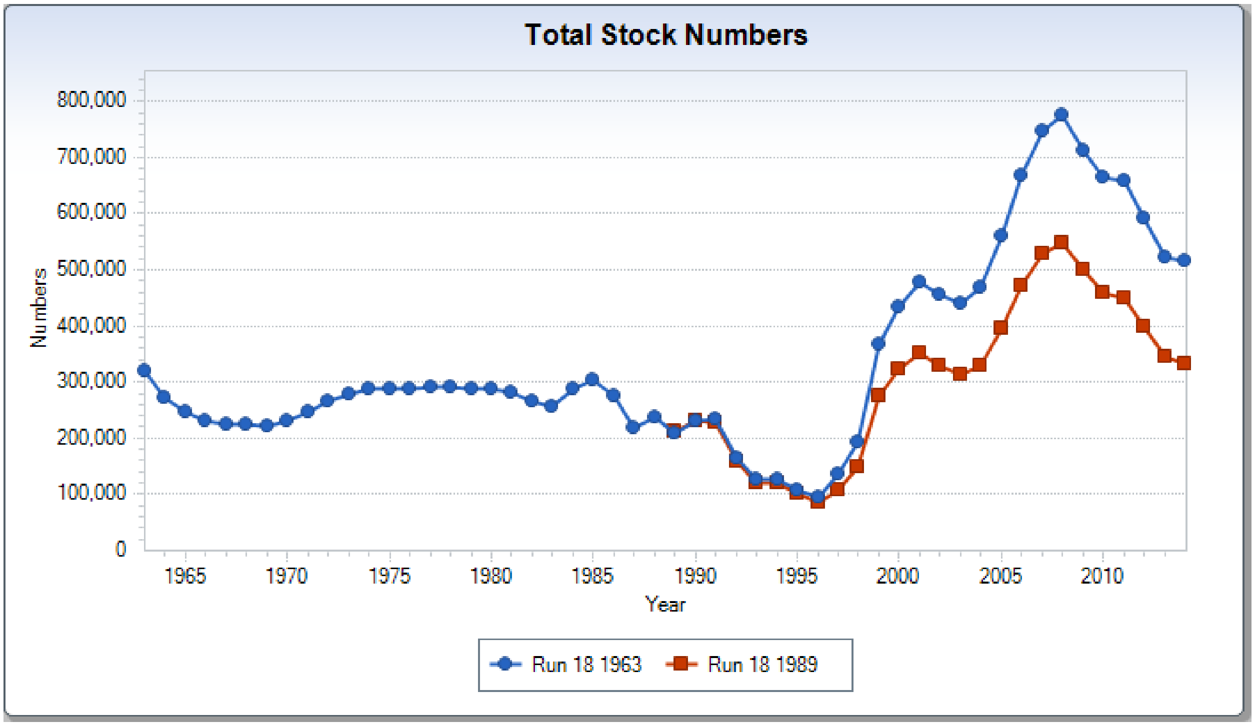
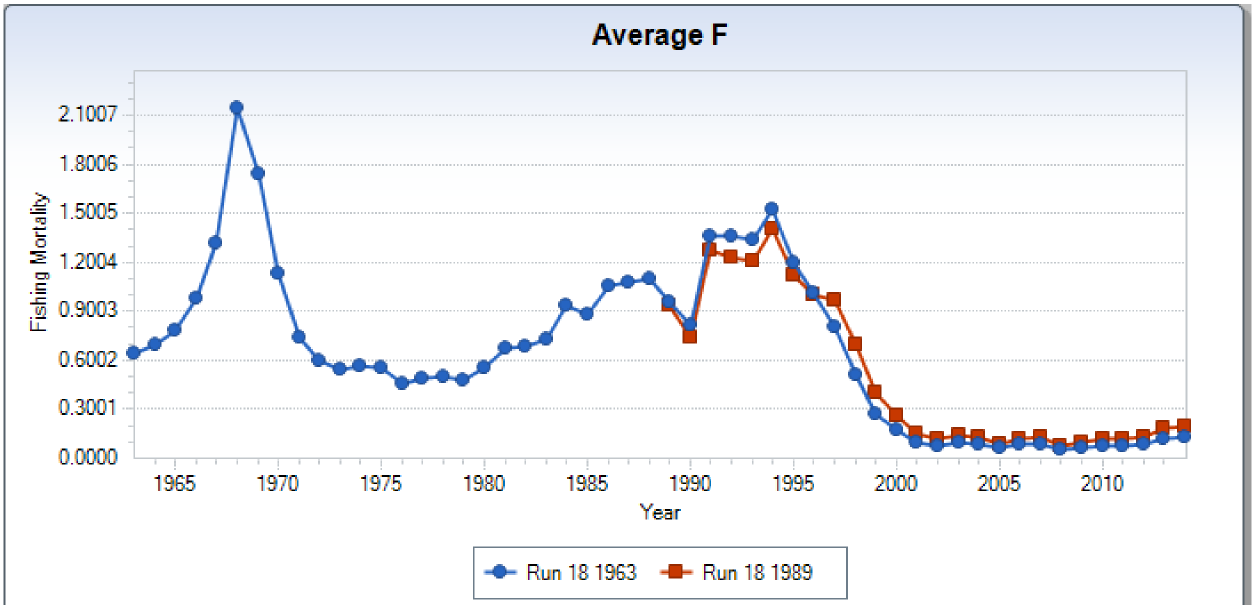


Figure 10. Comparison of results for versions of model S60_BASE_18 starting in 1963 and 1989: total stock numbers.



	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Run 18 1963	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	0.1028	0.0810	0.0954	0.0890	0.0609	0.0839	0.0856	0.0526	0.0678	0.0788	0.0786	0.0860	0.1200	0.1270
Run 18 1989	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	0.1496	0.1162	0.1361	0.1277	0.0878	0.1231	0.1256	0.0768	0.0978	0.1145	0.1162	0.1282	0.1810	0.1965

Figure 11. Comparison of results for versions of model S60_BASE_18 starting in 1963 and 1989: peak F at model age 4 (true age 3).

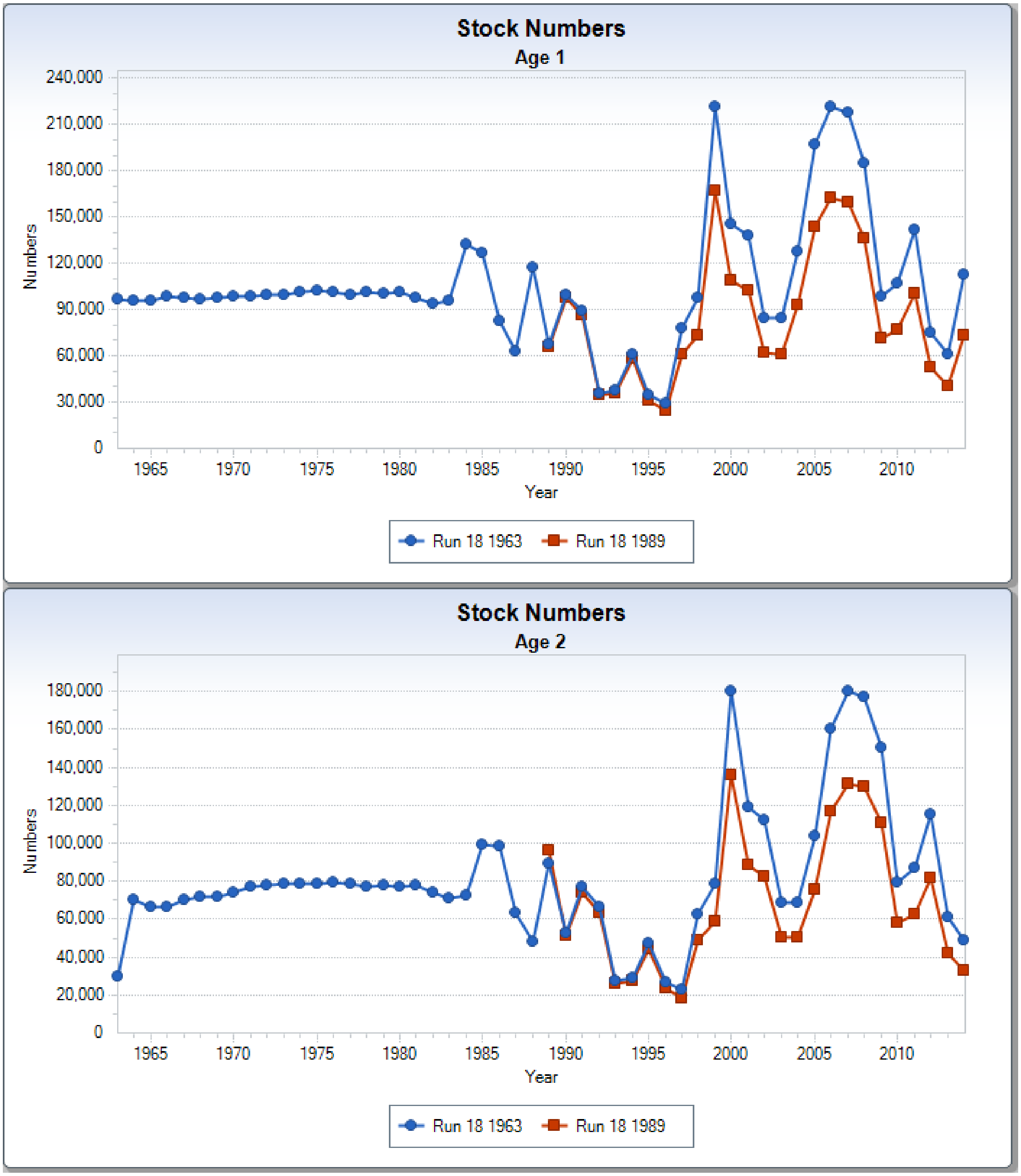


Figure 12. Comparison of results for versions of model S60_BASE_18 starting in 1963 and 1989: stock size at model ages 1 and 2 (true ages 0 and 1).

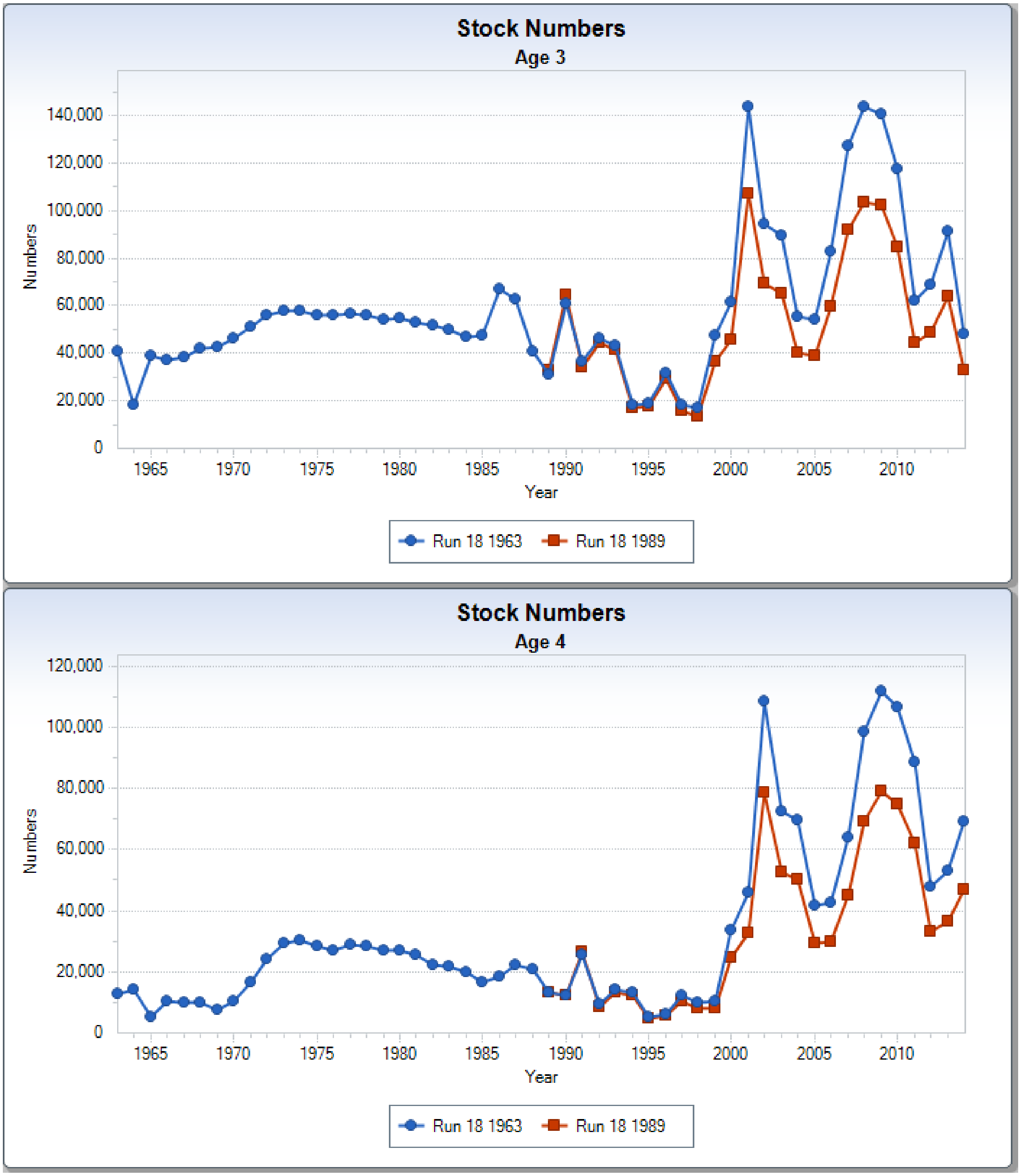
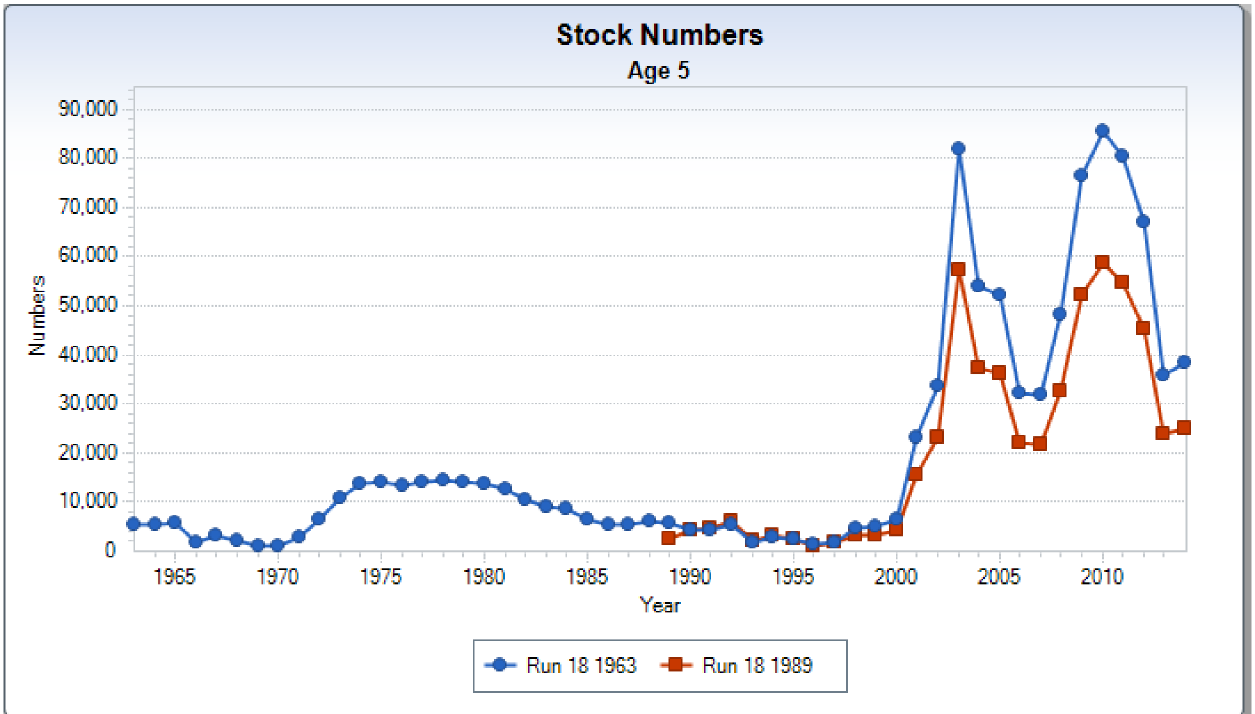


Figure 13. Comparison of results for versions of model S60_BASE_18 starting in 1963 and 1989: stock size at model ages 3 and 4 (true ages 2 and 3).



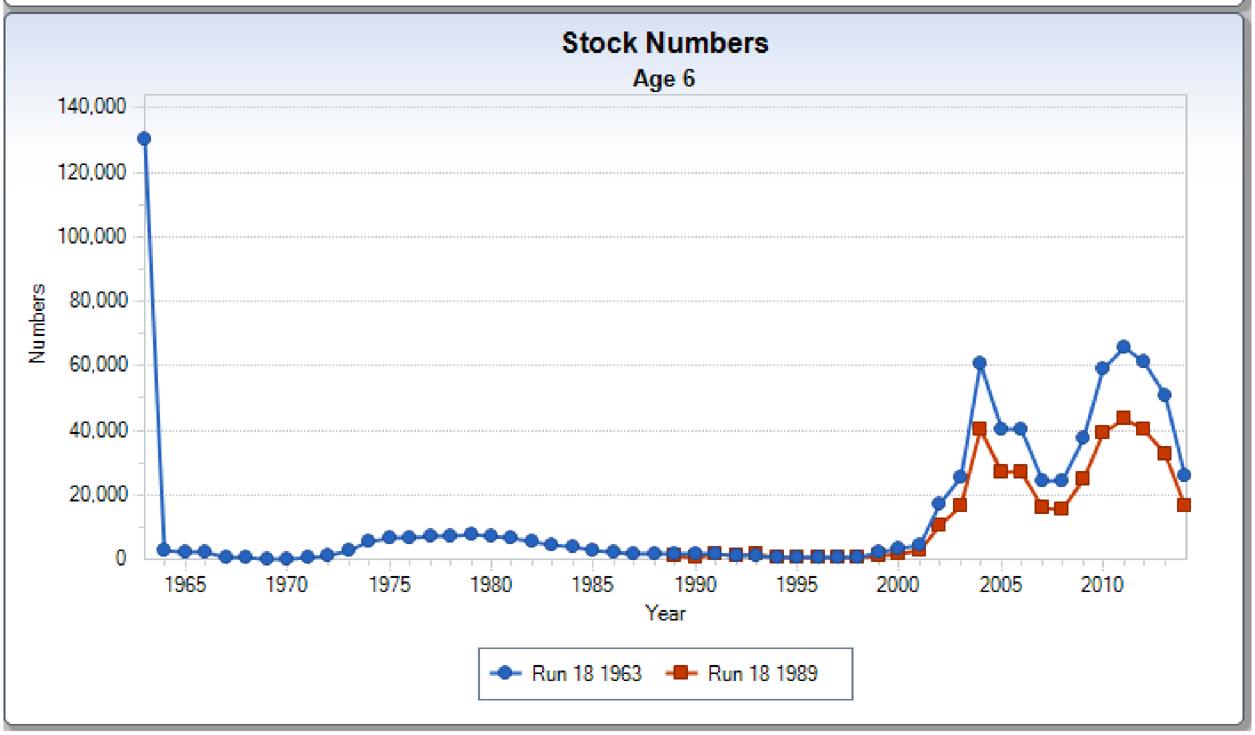
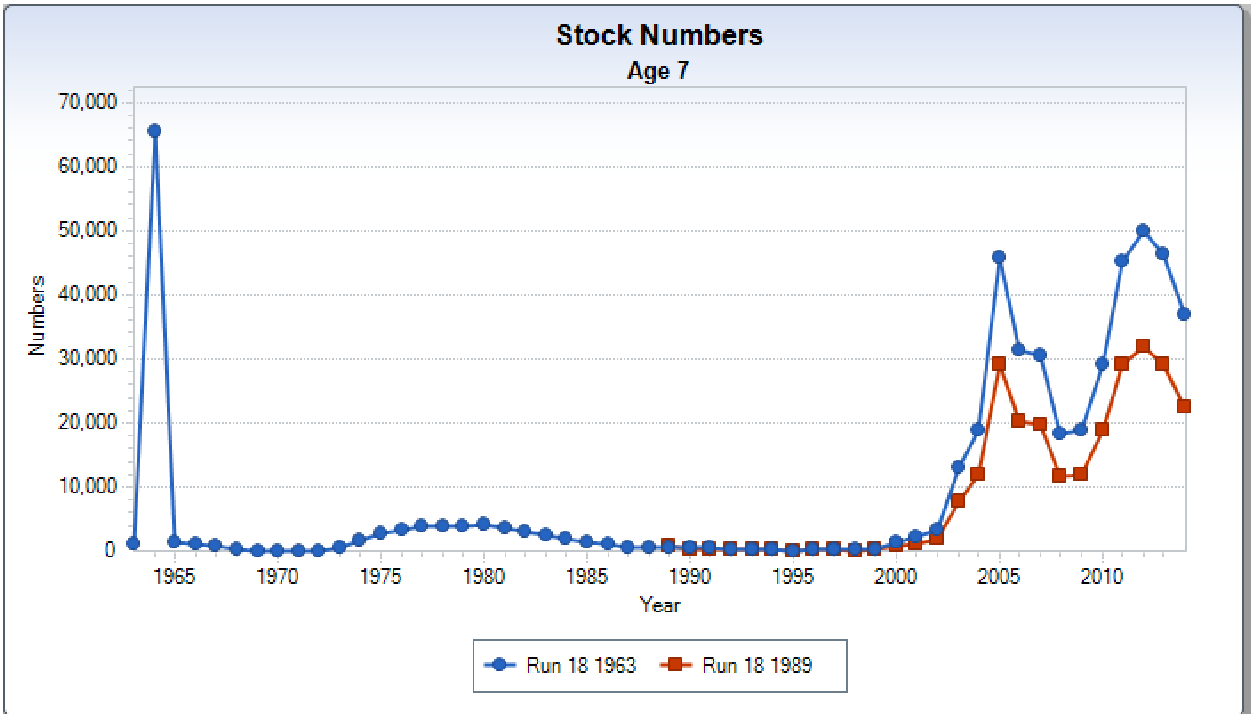


Figure 14. Comparison of results for versions of model S60_BASE_18 starting in 1963 and 1989: stock size at model ages 5 and 6 (true ages 4 and 5).



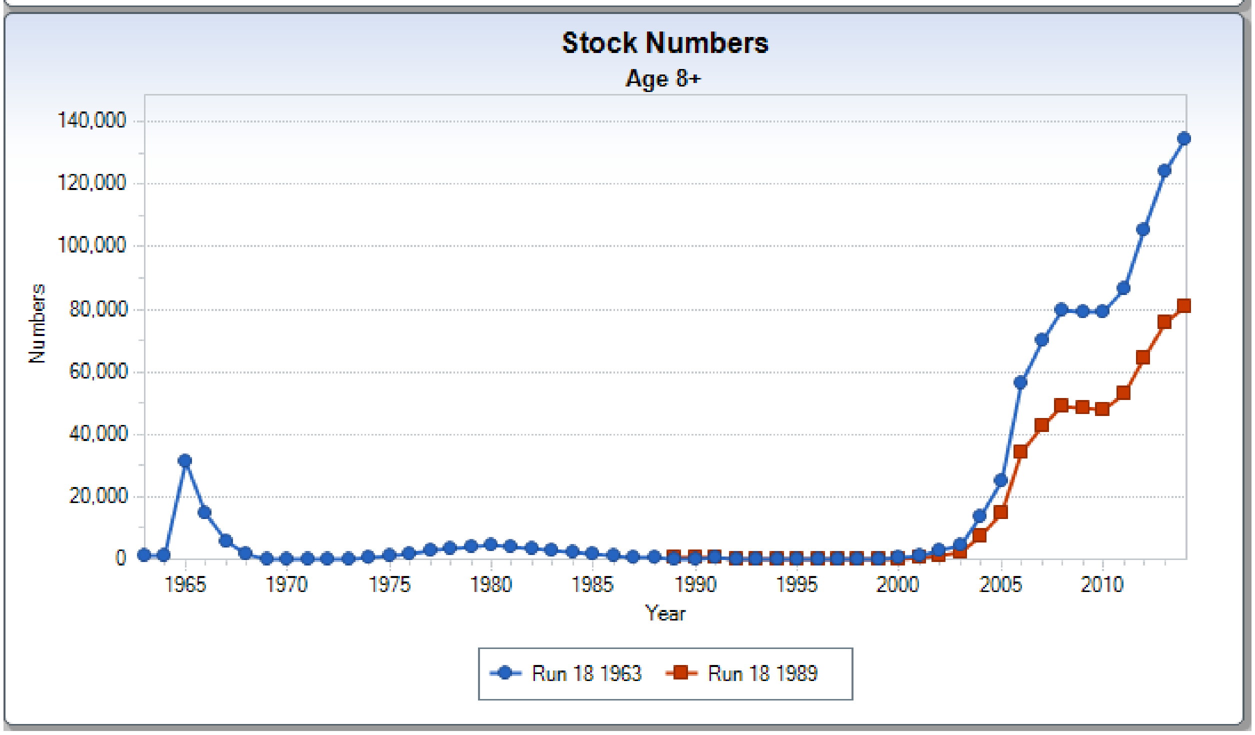


Figure 15. Comparison of results for versions of model S60_BASE_18 starting in 1963 and 1989: stock size at model ages 7 and 8+ (true ages 6 and 7+).

SARC Work: Run 18 'Feasibility'
How does the model fit the survey data?
Comparison to SV Index Trends – Total Stock N

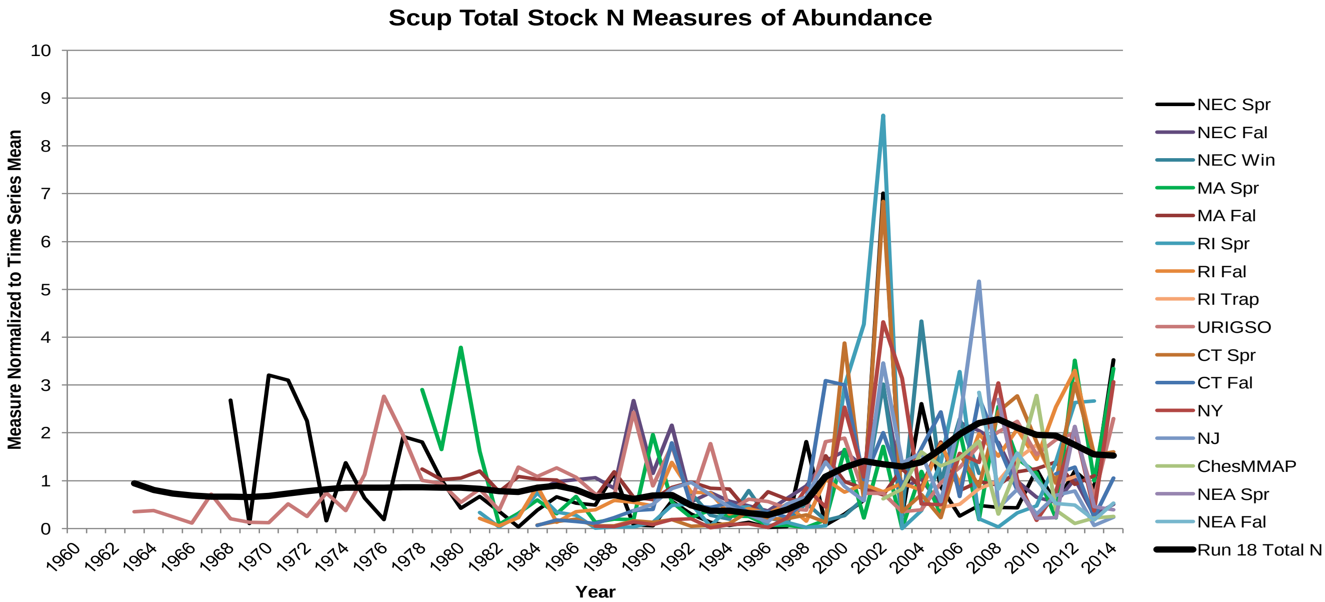


Figure 16. Trends in normalized aggregate survey indices in numbers with normalized run S60_BASE_18 total stock size numbers (N) estimates. Note that some of the indices (NEC Spr, MA Spr, RI Spr, RI Fal, ChesMMAP) were not included in the final model.

SARC Work: Run 18 'Feasibility'
Does the model fit the data?
Comparison to SV Index Trends – Age 0 N

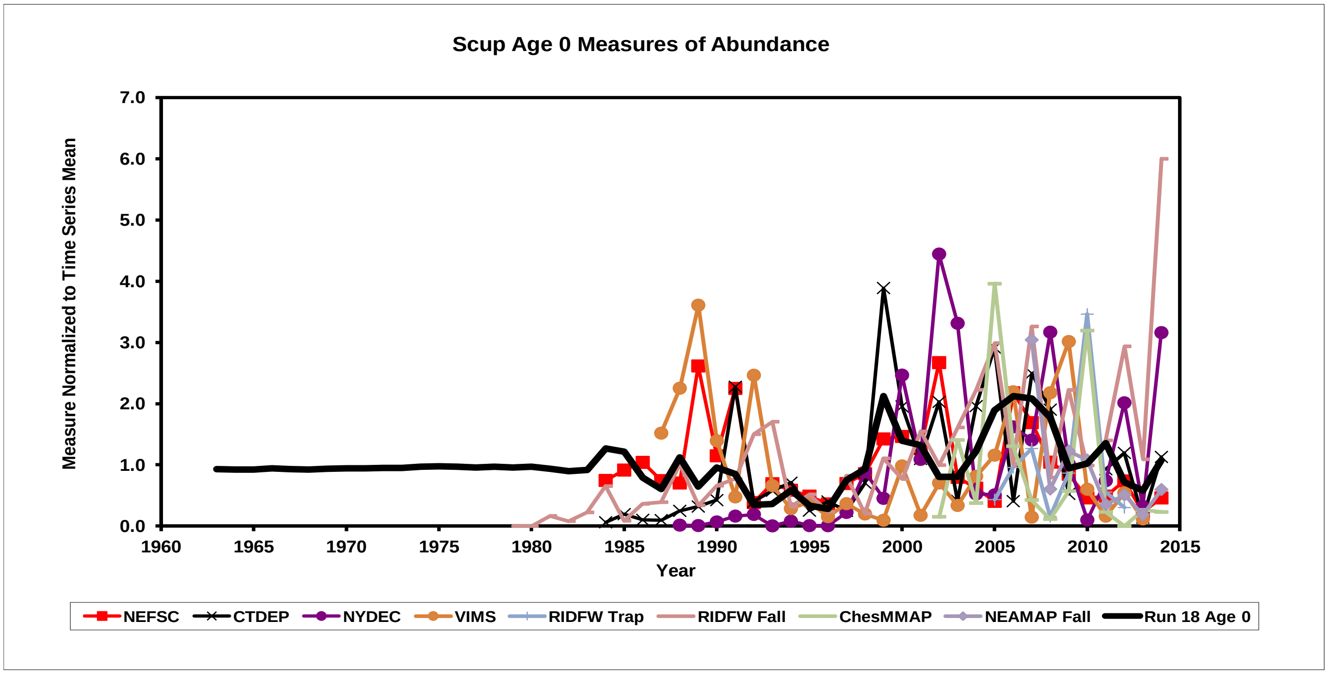


Figure 17. Trends in normalized survey true age 0 indices in numbers with normalized run S60_BASE_18 true age 0 stock size estimates. Note that some of the indices (RIDFW Fall, ChesMMAP) were not included in the final model.

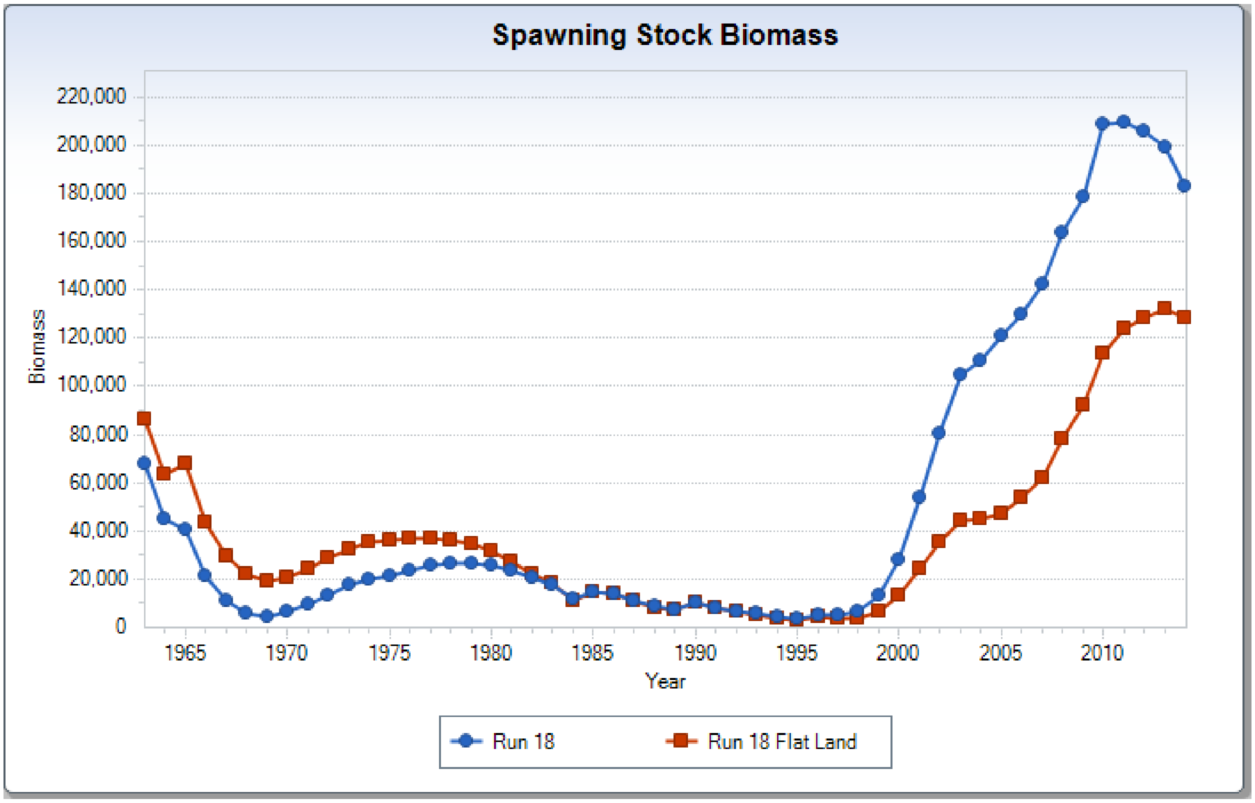


Figure 18. Comparison of estimates from the accepted model (Run 18) with a model with a fixed flattop fishery landings selection pattern (Run 18 Flat Land): Spawning Stock Biomass.

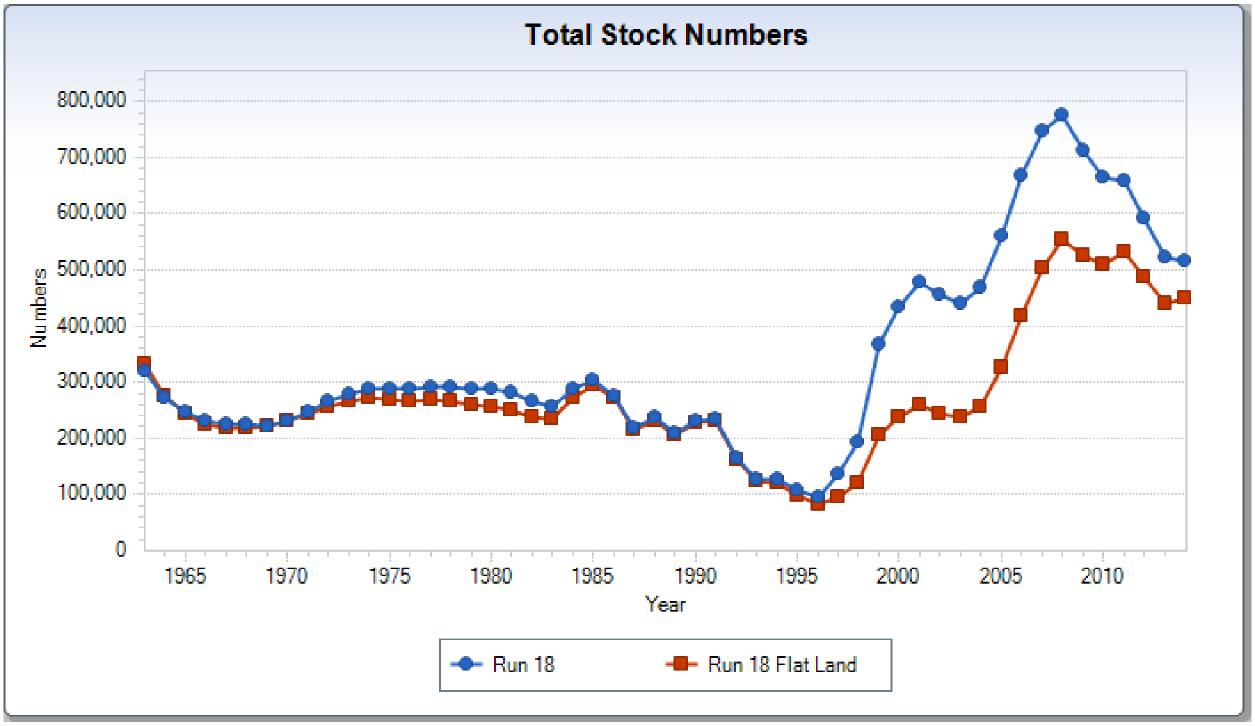
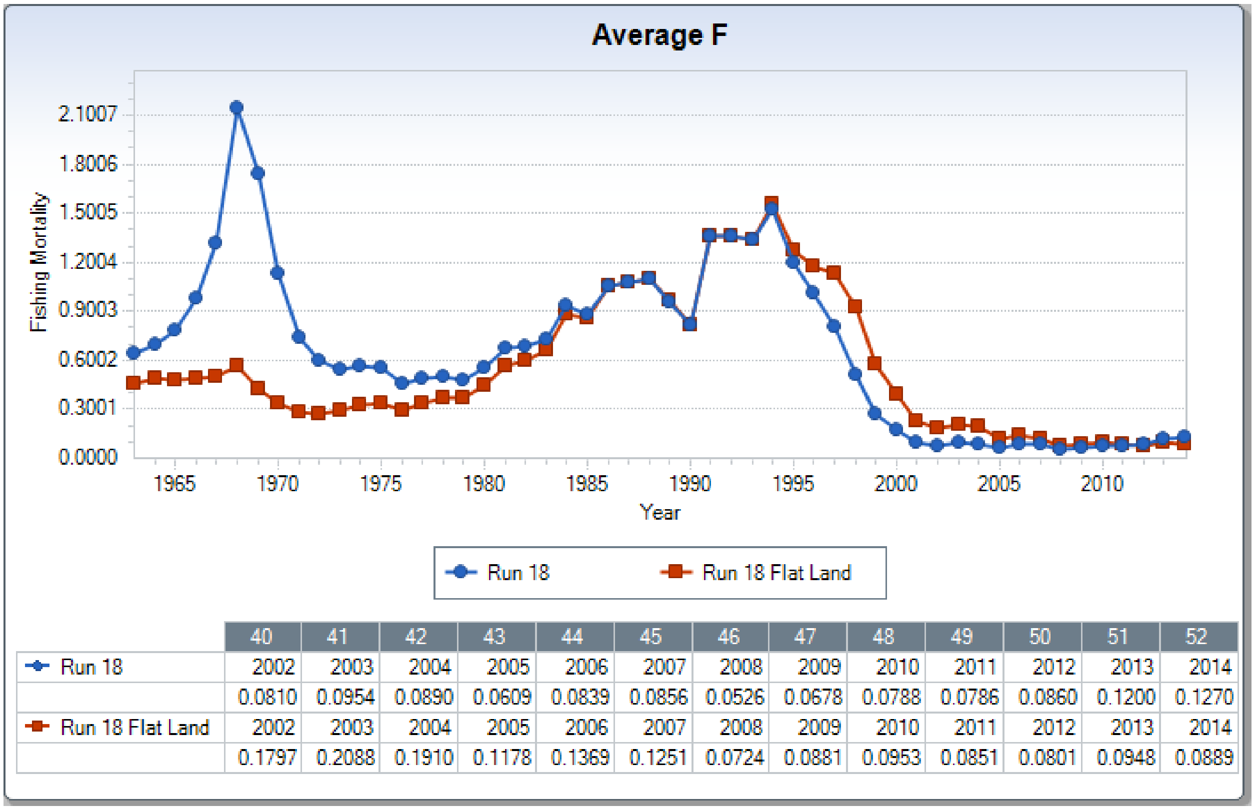


Figure 19. Comparison of estimates from the accepted model (Run 18) with a model with a fixed flattop fishery landings selection pattern (Run 18 Flat Land): Total Stock Numbers.



	40	41	42	43	44	45	46	47	48	49	50	51	52
Run 18	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	0.0810	0.0954	0.0890	0.0609	0.0839	0.0856	0.0526	0.0678	0.0788	0.0786	0.0860	0.1200	0.1270
Run 18 Flat Land	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	0.1797	0.2088	0.1910	0.1178	0.1369	0.1251	0.0724	0.0881	0.0953	0.0851	0.0801	0.0948	0.0889

Figure 20. Comparison of estimates from the accepted model (Run 18) with a model with a fixed flattop fishery landings selection pattern (Run 18 Flat Land): peak F at model age 4 (true age 3).

BLUEFISH BENCHMARK STOCK ASSESSMENT FOR 2015

BLUEFISH WORKING GROUP MEMBERS

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B1. Executive Summary

TERM OF REFERENCE #1: Estimate catch from all sources including landings and discards. Evaluate and if necessary update the discard mortality estimate. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize the uncertainty in these sources of data.

Since 1982, fishery removals of bluefish have ranged from 9,617 mt (1999)to 54,091 (1986) mt. Fishery removals over the past five years have ranged from 14,320 mt (2010) to 9,817 mt (2014). Prior to 1981 there are no direct estimates of recreational removals and no attempt was made to hindcast recreational catch pre-1981. Over the assessment time series, recreational harvest has been the dominant source of fishery removals, constituting 37-80% of the total catch. Commercial landings have been a smaller component of fishery removals. Information on commercial discards was limited. There have been few regulatory changes (e.g. seasonal closures, trip limits, etc) that would induce high rates of discards. Based on the uncertainty in the discard estimates and the low level of commercial landings relative to total removals the SAW 60 WG chose not to include commercial discards in the SAW 60 assessment models.

Currently, both the commercial and recreational fisheries are primarily concentrated in the mid-Atlantic region. Historically, the recreational harvest was more broadly distributed between the Mid and South Atlantic.

The SAW 60 Working Group (WG) evaluated standardized catch per unit effort (CPUE) indices from the recreational fishery and considered its utility as an index of abundance. The MRIP index covers the entire range of the Atlantic coast stock of bluefish and includes information on older age classes that are poorly sampled by standard fishery independent surveys, so the SAW 60 WG chose to include it as an index of abundance.

TERM OF REFERENCE #2: Present and evaluate data and trends on life history information including, age, growth, natural mortality, food habits, and maturity.

Bluefish, Pomatomus saltatrix, is a coastal, pelagic species found in temperate and tropical marine waters throughout the world and inhabits both inshore and offshore waters along the east coast of the United States.

Bluefish spawn offshore in the western North Atlantic Ocean, from approximately Massachusetts to Florida. Bluefish are characterized as iteroparous spawners with indeterminate fecundity and spawn continuously during their spring migration. In addition to distinctive spring and summer cohorts, a fall-spawned cohort has been identified, demonstrating the potential of an extended bluefish spawning season.

The working group (WG) expended considerable time and effort tracking down all original sources of age data used at SAW41 as well as new sources of data. The WG recovered NC scale and otolith data from 1983-2000, VA/ODU age data from 1998-2005, and age data from a wide variety of east coast states from 2006 forward. With the expansion of a coast wide biological collection program, bluefish age data have become considerably more robust relative to pre-

SAW41. As in the previous SAW, age data were truncated to a 6+ category to reduce ageing error associated with scale ages.

Bluefish grow nearly one-third of their maximum length in their first year. von Bertalanfy growth curves were fit to data available from 1985-2014. Values for L∞ matched closely with both published estimates (87-128 cm FL) and to the largest individuals in the available catch data. The results from the sex based growth examination confirm the results of previous studies that growth rates do not differ between sexes. Although there was not enough data available from older fish in the south to do a comparison between northern and southern fish, there were data available to compare growth rates between ageing structures. Scale ages typically over-estimate younger ages and underestimate the age of older fish. Changes in the primary age structure for bluefish over the time series makes it difficult to determine if there has been a change in growth rates.

In past stock assessments, a value of 0.20 has been assumed as the instantaneous natural mortality (M) for bluefish over all ages and years. The WG used longevity and life-history based equations to estimate different possible values for age constant and age varying M. Based on the results of all the methods explored to estimate natural mortality for bluefish, the WG reasoned that the assumption of M = 0.2 was justifiable and was maintained for SAW60.

During oceanic larval development, bluefish diets are composed primarily of copepods and fish eggs in the smaller size classes (<30mm) expanding to amphipods, and crab larvae above this size. An onset to piscivory occurs for early juveniles, primarily inhibited by mouth-gape size, in estuarine waters leading to rapid increases in growth rates. Cannibalism has also been documented. Both seasonal and inter-annual differences in diet have been observed and are likely attributed to changes in prey availability, but also due to inter-annual variability in timing of estuarine arrival. The WG also evaluated diet data from three fishery independent surveys and found that overall, the diet of bluefish both in the Chesapeake Bay and the coastal ocean, from Cape Cod to Cape Canaveral, is dominated by fishes, regardless of the index by which the diet is quantified. These findings correspond with those of past studies that have sought to characterize bluefish diet in estuarine and ocean environments.

The WG evaluated maturity at length for all available fish, northern and southern fish, and males and females. The most accurate source of maturity at age for bluefish involved a histological examination of 1,437 female fish. However, because this maturity information did not apply to the entire bluefish stock (females only), the proportion mature at age for all fish was used as the input maturity for the catch-at-age model used in the benchmark assessment.

TERM OF REFERENCE #3: Present the survey data available for use in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.), evaluate the utility of the age-length key for use in stock assessment, and explore standardization of fishery- independent indices. Investigate the utility of recreational LPUE as a measure of relative abundance. Characterize the uncertainty and any bias in these sources of data, including exploring environmentally driven changes in availability and related changes in size structure. Explore the spatial distribution of the stock over time, and whether there are consistent distributional shifts.

States and agencies provided indices from fisheries-dependent and fisheries-independent sources that were assumed to reflect trends in bluefish relative abundance. Bayesian hierarchical modeling was used to combine YOY indices into a single composite index, using the method developed by Conn (2010) that represents the coast wide recruitment dynamics of bluefish. Surveys included in the composite index were from NH Juvenile Finfish Seine Survey, RI Narragansett Bay Juvenile Finfish Beach Seine Survey, NY Western Long Island Seine Survey, NJ Delaware Bay Seine Survey, MD Juvenile Striped Bass Seine Survey, and VIMS Juvenile Striped Bass Seine Survey. In addition, the bluefish working group decided on 8 additional representative indices of bluefish abundance for the SAW60 assessment:

1. *NEFSC Fall inshore strata: 1985-2008 (age-0 – age-6+)*
2. *NEFSC Fall outer inshore strata (FSV Bigelow): 2009-2014 (age-0 – age-6+)*
3. *Marine Recreational Information Program CPUE: 1985-2014 (age-0 – age-6+)*
4. *NEAMAP Fall Inshore trawl survey: 2007-2014 (age-0 – age-6+)*
5. *Connecticut Long Island Sound Trawl Survey: 1985-2014 (age-0 – age-6+)*
6. *Pamlico Sound Independent Gillnet Survey; 2001-2014 (age-0 – 6+)*
7. *New Jersey Ocean Trawl Survey: 1990-2014 (age-0 – age-2)*
8. *SEAMAP Fall Inshore trawl survey: 1989-2014 (age-0)*

The WG thoroughly investigated age length data and evaluated the utility of age length keys for use in this assessment. NC scale and otolith data from early in the time series (1985-2000) required adjustments prior to their eventual use in this assessment. Some additional age data for the middle part of the time series (1997-2005) was available and was incorporated. NC, MA, and NJ resumed or began collecting age data after SAW41, and Addendum to Amendment 1 to the bluefish fishery management plan required additional states to collect age data and this has greatly improved the age length keys for use in this assessment.

Within the NEFSC survey, age 0 and age 1+ bluefish shifted distribution from 1973 through 2014 but not in a systematic direction. Analysis of the centers of biomass (COB) indicated that COB positions were correlated with variations in body size and abundance, but not temperature.

TERM OF REFERENCE #4: Estimate relative fishing mortality, annual fishing mortality, recruitment, total abundance, and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Explore inclusion of multiple fleets in the model. Include both internal and historical retrospective analyses to allow a comparison with previous assessment results and previous projections. Explore alternative modeling approaches if feasible.

The final model configuration included a number of notable changes since the previous peer reviewed model, including the addition of multiple fleets (one commercial, one recreational), updated maturity ogive, model estimated selectivities (two selectivity blocks), addition of new indices, changes to the way indices are fit in the model, and changes to model weighting factors and reduction in model penalties (lambdas and input CVs).

At the SARC review of bluefish the review panel discovered a model misspecification in the selectivity parameters for the MRIP index. A parameter in the function describing the curve for selectivity was fixed when it was intended to have been freely estimated by the model. This was causing patterning in the age composition residuals for this index. The final revised model corrects this misspecification. The values presented in this report reflect the output from the revised model as accepted at the review; for the original model results and diagnostics presented in the draft report, see Appendix B7.

The maximum F at age in 2014 was 0.157 on ages 1 and 2. Average F (age 2) has generally declined since its high in 1987 and in 2014 represents the lowest level in the time series. Recruitment in 2014 was 29.6 million fish, a value that is well above the median for time series. Recruitment has fluctuated over the time series without trend. Total bluefish abundance in 2014 was 82.0 million fish. Abundance was at its highest at the start of the time series at 124.3 million fish. Abundance declined to a low of 53.3 million fish in 1993 then abundance rose steadily through 2006. Abundance declined after 2006 until 2012, and has since risen to levels above the median for the time series. Total biomass in 2014 was 94,328 mt. Total biomass was at its highest at the start of the time series and declined to a low in 1997 and has steadily increased since. SSB in 2014 was estimated at 86,534 mt and trends mimic those of total biomass.

Retrospective patterns suggest that F is underestimated in the model, and that total and spawning stock biomass are overestimated. No clear retrospective pattern appears in model estimates of recruitment.

The working group was able to explore alternate modelling approaches that did not depend on age data (Depletion Corrected Average Catch and Depletion Based Stock Reduction Analysis) both of which suggested that recent harvest of bluefish in the terminal 3 years of the assessment was sustainable.

TERM OF REFERENCE #5. State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY} and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

The current biological reference points for bluefish were determined in SARC 41 and are F_{MSY} (0.19) and B_{MSY} (147,052 mt). The basis for the reference points was the Sissenwine-Shepherd method using the Beverton-Holt stock recruitment parameters and SSB per recruit results generated by the SARC 41 ASAP model results. Overfishing of a stock occurs if F exceeds F_{MSY} and a stock is considered overfished if total biomass is less than half of B_{MSY} ($B_{THRESHOLD}$). The existing definition of overfishing is $F > 0.19$ and $B < 73,526$ mt.

The BTC and the SAW 60 WG concluded that new reference points were required because of the uncertainty present in the stock recruitment relationship estimated by the current model, as the time series of spawning stock biomass and recruitment does not contain any information about recruitment levels at low stock sizes. As a proxy for F_{MSY}, the BTC and the SAW 60 WG *recommend $F_{40\% SPR}$. To calculate the associated proxy for B_{MSY}, the population was projected forward for one hundred years under current conditions with fishing mortality set at the F_{MSY} proxy and recruitment drawn from the observed time series. The resulting equilibrium biomass is the recommended B_{MSY} proxy, with the overfishing threshold set at ½ B_{MSY}.*

The new reference points are $F_{MSY\ proxy}$ = F40% = 0.170 and $B_{threshold}$ = ½ $SSB_{MSY\ proxy}$ = 55,614 mt. The MSY_{proxy} = 13,967 mt.

TERM OF REFERENCE #6: Evaluate stock status with respect to the existing model (from previous peer review accepted assessment) and with respect to a new model developed for this peer review.

When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the existing BRP estimates.

The existing reference points are F_{MSY} = 0.19 and B_{MSY} = 147,052 mt (½ B_{MSY} = 73,526 mt). The 2014 F estimate (0.141) is well below F_{MSY} and the 2014 estimate of B is 92,755 mt, below B_{MSY} but well above ½ B_{MSY}. This indicates that overfishing is not occurring and that the stock is not overfished.

a. **Then use the newly proposed model and evaluate stock status with respect to "new" BRPs and their estimates (from TOR-5).**

The new reference points are F_{MSY} proxy = F40% = 0.170 and SSB_{MSY} proxy = 111,228 mt (½ SSB_{MSY} = 55,614 mt). The 2014 F estimate (0.157) is below $F_{40\%}$ and the 2014 SSB estimate (86,534 mt) is greater than ½ SSB_{MSY}, indicating that overfishing is not occurring and that the stock is not overfished.

Reference Point	**SARC 41**		**Updated**	
	Definition[1]	Value	Definition[1]	Value
$F_{Threshold}$	F_{MSY}	0.19	$F_{MSY\ proxy} = F_{40\%SPR}$	0.170
B_{Target}	B_{MSY}	147,052 mt	Equilibrium SSB under $F_{40\%SPR}$	111,228 mt
$B_{Threshold}$	½ B_{MSY}	73,526 mt	½ $SSB_{MSY\ Proxy}$	55,614 mt

[1]: Note that the SARC 41 biomass reference points refer to total biomass, while the updated biomass reference points refer to spawning stock biomass.

TERM OF REFERENCE #7: Develop approaches and apply them to conduct stock projections and to compute the statistical distribution (e.g., probability density function) of the OFL (overfishing level; see Appendix to the SAW TORs).

a. **Provide annual projections (3 years). For given catches, each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment).**

Short-term projections were conducted using AGEPRO v.4.2.2 (available from the NOAA Fisheries Toolbox, http://nft.nefsc.noaa.gov/AGEPRO.html).

Removals in 2015 were assumed to be equal to the 2015 quota (9,772 mt). For 2016-2018, a constant level of fishing mortality was applied. The population was projected forward under six different F levels (F_{low} = 0.100, F_{2014} = 0.157, $F_{0.1}$ = 0.187, F_{TARGET} = 90% $F_{MSY\ Proxy}$ = 0.153, $F_{MSY\ Proxy}$ = $F_{40\%SPR}$ = 0.170, $F_{35\%SPR}$ = 0.191).

Uncertainty was incorporated into the projections primarily via estimates of recruitment and initial abundance-at-age.

Estimates of recruitment were drawn from the 1985-2014 time-series of observed recruitment from the preferred ASAP model. Initial abundance-at-age estimates were drawn from distributions of terminal abundance-at-age developed from the MCMC runs of the preferred ASAP model. A small amount of uncertainty was incorporated into biological parameters such as weight-at-age, maturity-at-age, and natural mortality; estimates of these parameters were drawn from lognormal distributions with mean values used in the last three years of the assessment and a CV of 0.01.

A sensitivity analysis approach was used to determine the effects of major sources of model uncertainty that could not be encompassed through the MCMC runs of the base model. This included: limiting the empirical recruitment distribution to the CDF of observed recruitment for 2006-2014 (the years of the best available age data), higher M (M=0.26), increased uncertainty in biological parameters (CV of 0.1 instead of 0.01), using the upper and lower 95% confidence intervals for recreational catch, and using the continuity run instead of the new model configuration.

None of the fishing mortality scenarios resulted in total spawning stock biomass going below the biomass threshold (½ $SSB_{MSY\ Proxy}$) in any year of the projection; total spawning stock biomass remained above the SSB threshold with 100% probability in all years.

The overfishing limit (OFL) for 2016 was estimated to be 10,528 mt with a CV of 0.10. A qualitative inflation was applied for known sources of uncertainty that are not adequately captured in the projection process, including retrospective bias and uncertainty in the F_{MSY} proxy estimate, resulting in a recommended CV of 0.15.

   a. **Comment on which projections seem most realistic. Consider the major uncertainties in the assessment as well as sensitivity of the projections to various assumptions.**

The WG considers the base model configuration the most realistic projection scenario. While estimates of recruitment in the most recent 10 years of the time-series (derived in part from the best age information) are likely more reliable than the estimates from the beginning of the time-series, the median recruitment and projection time-series are virtually indistinguishable.

b. Describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming overfished, and how this could affect the choice of ABC.

Bluefish are a fast-growing, fast-maturing species with a moderately long life span. Although they recruit to the fishery before they are fully mature, larger, older fish are considered unpalatable, reducing demand for those sizes in the commercial market and encouraging the release of those size classes in the recreational fishery. The resulting dome-shaped selectivity of the fleets offers protection to the spawning stock biomass. Although they are a popular gamefish, demand for this species is not extreme and the quota is rarely met or exceeded.

Bluefish are opportunistic predators that do not depend on a single prey species. Their range covers the whole of the Atlantic coast, and their spawning is protracted both temporally and geographically. As a result, they are not as vulnerable as many other species to major non-fishery drivers such as climate change that would result in the loss of critical forage or nursery habitat.

This assessment indicates bluefish are near their target biomass and well above their overfished threshold. Short-term projections indicate no risk of driving the biomass below the overfished threshold while fishing at or near the F_{MSY} proxy. Overall, bluefish have a low degree of vulnerability to becoming overfished, and the ABC can be set on the basis of the F_{MSY} proxy without risk of causing the stock to become overfished.

TERM OF REFERENCE #8: Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in most recent SARC reviewed assessment and review panel reports, as well as MAFMC SSC model recommendations from 2005 and the research recommendations contained in its 23 September 2013 report to the MAFMC. Identify new research recommendations.

The SAW 60 WG reviewed the status of previous research recommendations and proposed new ones to address issues raised during WG meetings. The 2011 bluefish ageing workshop lead directly to the development of Addendum I to the Bluefish FMP (2012), with both items addressing research recommendations from SAW 41. Addendum I has resulted in increased sampling of commercial and recreational biological data (e.g., age, sex, weights) that was utilized by the SAW 60 WG in the assessment. Additionally the SAW 60 WG explored the application of two models designed to provide catch guidance in data poor situations: Depletion Corrected Average Catch Model (DCAC) and Depletion-Based Stock Reduction Analysis.

Lastly, the SAW 60 WG proposed eight new research recommendations to better understanding bluefish dynamics and assessing the population through the current or future models. These included some of the following: developing additional adult bluefish indices of abundance;

investigate species associations with recreational angler trips targeting bluefish; explore age- and time-varying natural mortality from predator-prey relationships; quantify effects of age- and time-varying natural mortality in the assessment model; and continue to evaluate the spatial, temporal, and sector-specific trends in bluefish growth and quantify their effects in the assessment model.

B2. Terms of Reference

1. Estimate catch from all sources including landings and discards. Evaluate and if necessary update the discard mortality estimate. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize the uncertainty in these sources of data.

2. Present and evaluate data and trends on life history information including, age, growth, natural mortality, food habits, and maturity.

3. Present the survey data available for use in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.), evaluate the utility of the age-length key for use in stock assessment, and explore standardization of fishery independent indices. Investigate the utility of recreational LPUE as a measure of relative abundance. Characterize the uncertainty and any bias in these sources of data, including exploring environmentally driven changes in availability and related changes in size structure. Explore the spatial distribution of the stock over time, and whether there are consistent distributional shifts.

4. Estimate relative fishing mortality, annual fishing mortality, recruitment, total abundance, and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Explore inclusion of multiple fleets in the model. Include both internal and historical retrospective analyses to allow a comparison with previous assessment results and previous projections. Explore alternative modeling approaches if feasible.

5. State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for BMSY, BTHRESHOLD, FMSY and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

6. Evaluate stock status with respect to the existing model (from previous peer review accepted assessment) and with respect to a new model developed for this peer review.

    a. When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the existing BRP estimates.
    b. Then use the newly proposed model and evaluate stock status with respect to "new" BRPs and their estimates (from TOR-5).

7. Develop approaches and apply them to conduct stock projections and to compute the statistical distribution (e.g., probability density function) of the OFL (overfishing level; see Appendix to the SAW TORs).

a. Provide annual projections (3 years). For given catches, each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment).
b. Comment on which projections seem most realistic. Consider the major uncertainties in the assessment as well as sensitivity of the projections to various assumptions.
c. Describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming overfished, and how this could affect the choice of ABC.

8. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in most recent SARC reviewed assessment and review panel reports, as well as MAFMC SSC model recommendations from 2005 and the research recommendations contained in its 23 September 2013 report to the MAFMC. Identify new research recommendations.

B3. Introduction

The 60th Stock Assessment Workshop Working Group (SAW 60 WG) prepared the assessment report. The ASMFC Bluefish Technical Committee (TC) and the SAW 60 WG met February 18th - 20th, 2015 in Providence, RI to evaluate data sources in preparation for the SAW 60 WG assessment meeting held April 27-29th, 2015 at the Northeast Fisheries Science Center (NEFSC) in Woods Hole, MA. A complete list of technical committee and working group participants can be found in Appendix B.1 and B.2.

B3.1 Assessment History

Bluefish was assessed through SAW23 (1997) using the CAGEAN model, a catch-at-age model that used commercial and recreational catch tuned by recreational CPUE and survey catch-at-age data. The assessment found that bluefish were at historically low levels of spawning stock biomass and over-exploited. It recommended that fishing mortality should be reduced to halt the decline in SSB.

In 2004, the SAW WG put forward an ASPIC surplus production model at SARC-39. This assessment was not accepted as a basis for fishery management because the recreational CPUE did not correctly handle live-release data, creating a “severe” bias, the NEFSC data used as an index of fishable biomass represent only age-0 and age-1 fish, and the residuals in the commercial catch rate data showed strong autocorrelation, indicating model misspecification

The TC and WG continued work on the assessment, returning in 2005 with an age-structured assessment at SARC 41. The NFT ADAPT version of VPA was used as an initial model. The committee felt that the VPA model produced satisfactory results, but the assumption of no error in the catch-at-age matrix and the ADAPT method of modeling selectivity could produce misleading results. Therefore, a catch-at-age model, ASAP from the NFT models, was used as the primary assessment tool. Many of the results coming out of the ADAPT VPA model were used as input starting value for a statistical catch-at-age model (ASAP). The ASAP model was brought to review and was accepted by 2 out of 3 reviewers. The third reviewer was extremely critical of the way the model had been configured and the way some inputs and assumptions were handled.

The ASAP model from SAW/SARC 41 currently forms the basis of bluefish management advice.

B3.2. Fishery Management History

The Atlantic States Marine Fisheries Commission (ASMFC) and Mid-Atlantic Fishery Management Council (MAFMC) jointly developed the Fishery Management Plan (FMP) for the bluefish fishery and adopted the plan in 1989 (ASMFC 1989, MAFMC 1990). The Secretary of Commerce approved the FMP in March 1990. The FMP defines the management unit as bluefish (*Pomatomus saltatrix*) in U.S. waters of the western Atlantic Ocean.

The ASMFC and MAFMC approved Amendment 1 to the FMP in October 1998 and the National Marine Fisheries Service (NMFS) published the final rule to implement the Amendment 1 measures in July 2000 (MAFMC and ASMFC 1998). Amendment 1 implemented an annual coastwide quota to control bluefish landings. The ASMFC and MAFMC adjust the quota and harvest limit annually using the specification setting process detailed in Amendment 1. The recreational fishery is allocated 83% of the entire quota. Coastwide, the commercial fishery is limited to 17% of the total allowable landings each year. If the commercial quota is less than 10.5 million lbs, the quota can be increased up to 10.5 million lbs if it is anticipated that the recreational fishery will not land their entire allocation for the upcoming year. The coastwide commercial quota is divided into individual state-by-state quotas based on landings from 1981-1989 (Table B3.1). State by state management measures are included in table (Table B3.2)

In 2007, the MAFMC approved Amendment 2 which standardized bycatch reporting methodology (SBRM). The approval of Amendment 2 satisfies the requirement for all federal fisheries management plans that SBRM be included in those plans, as stipulated by the Magnuson-Stevens Act (MAFMC 2007).

In 2011, the MAFMC approved Amendment 3 (effective 1/1/2012) which incorporated the development of annual catch limits (ACLs) and accountability measures (AMs) into the specification process. This specified for Bluefish specifications that ACLs are annually set equal to the acceptable biological catch (ABC) (MAFMC 2011).

In 2012, ASMFC approved Addendum I (ASMFC 2012) that stipulated States that account for more than 5% of total coastwide bluefish harvest (recreational and commercial combined) for the 1998 – 2008 period are required to collect a minimum of 100 bluefish ages (50 from January through June, 50 from July through December). These states are: Massachusetts, Rhode Island, Connecticut, New York, New Jersey, and North Carolina. Virginia was required to continue its sampling regime for bluefish and provide that same minimum 100 samples as the other states.

In 2014, the MAFMC approved Amendment 4 which modified recreational accountability measures to accommodate uncertainty in recreational management and catch estimation. NOAA Fisheries disapproved the use of a 3-yr moving average of the lower confidence limit of the recreational catch estimate to determine whether an ACL overage has occurred. By doing so, the status quo (as stipulated in Amendment 3) of a single-year point estimate from MRIP for the Atlantic bluefish fisheries remains as the mechanism to determine whether the recreational fishing ACL was exceeded in a given year (78 FR 76759).

B3.3. Current Assessment Approach

The current assessment model for bluefish has provided management advice since 2005 and was accepted at the Stock Assessment Workshop 41 review (NEFSC 2005). After reviewing several model types including a modified Delury model, a surplus production model, a VPA and catch-at-age models, the bluefish Technical Committee concluded that a statistical-catch-at-age (ASAP) model was the most appropriate for the bluefish assessment.

B3.4 Biology

B3.4.1 Life History

Bluefish, *Pomatomus saltatrix*, is a coastal, pelagic species found in temperate and tropical marine waters throughout the world (Goodbred and Graves 1996; Juanes et al. 1996). Inhabiting both inshore and offshore waters along the east coast of the United States, spawning takes place offshore (Kendall and Walford 1979; Kendall and Naplin 1981) and subsequent to larval development in continental shelf waters, juveniles eventually move to estuarine and nearshore shelf habitats (Marks and Conover 1993; Hare and Cowen 1995; Able and Fahay 1998; Able et al. 2003). Traveling in loose groups of fish aggregated by size, bluefish typically migrate north in the spring/summer and south in the fall/winter (Wilk 1977; Klein-MacPhee 2002). Their range during these periods of migration can extend as far north as Maine and as far south as Florida in the Unites States (Shepherd et al. 2006).

B3.4.2 Growth

Bluefish grow nearly one-third of their maximum length in their first year (Richards 1976, Wilk 1977). Variation in growth rates or sizes-at-age among young bluefish is evident from the appearance of intra-annual cohorts. Lassiter (1962) identified a spring-spawned cohort and a summer-spawned cohort from the bimodal appearance of size at Annulus I for fish aged from North Carolina and found the seasonal cohorts can differ in age by two to three months. Hare and Cowen (1993) however, suggest the bimodal length at age observed in bluefish is not the result of two distinct spawning events but rather a consequence of continuous spawning (March-September) with the summer spawned offspring having a lower probability of recruitment. Previous research suggests different growth rates at age with summer-spawned larvae and juveniles growing faster than spring-spawned larvae and juveniles (McBride and Conover 1991) with size differences at annual age diminishing greatly after three to four years (Lassiter 1962).

B3.4.3 Reproduction

Bluefish spawn offshore in the western North Atlantic Ocean, from approximately Massachusetts to Florida (Norcross et al. 1974; Kendall and Walford 1979; Kendall and Naplin 1981; Collins and Stender 1987). Bluefish are characterized as iteroparous spawners with indeterminate fecundity and spawn continuously during their spring migration (Robillard et al. 2008). In addition to distinctive spring and summer cohorts, Collins and Stender (1987) identified a fall-spawned cohort, demonstrating the potential of an extended bluefish spawning season. Bluefish mature quickly, with approximately half of the population mature at age 1 and close to one hundred percent mature (97%) by age 2.

B3.4.4 Stock Definition

Bluefish in the western North Atlantic are managed as a single stock (NEFSC 1997; Shepherd and Packer 2006). Genetic data support a unit stock hypothesis (Graves et al. 1992; Goodbred and Graves 1996; Davidson 2002). For management purposes, the ASMFC and MAFMC define the management unit as the portion of the stock occurring along the Atlantic Coast from Maine to the east coast of Florida.

B3.4.5 Habitat Description

Adult and juvenile bluefish are found primarily in waters less than 20 meters (m) deep along the Atlantic coast (Shepherd and Packer 2006). Adults use both inshore and offshore areas of the coast and favor warmer water temperatures although they are found in a variety of hydrographic environments (Ross 1991; Shepherd and Packer 2006). Bluefish can tolerate temperatures ranging from 11.8°-30.4°C, however they exhibit stress, such as an increase in swimming speed, at both extremes (Olla and Studholme 1971; Klein-MacPhee 2002). Temperature and photoperiod are the principal factors directing activity, migrations, and distribution of adult bluefish (Olla and Studholme 1971).

B3.5 Description of Fisheries

B3.5.1 Commercial Fishery

Over the last 33 years, commercial landings from the bluefish fishery ranged from a high of 7,162 mt (1983) (15.8 million pounds) to a low of 1,974 mt (2013) (4.4 million pounds). Gill nets are the dominant commercial gear used to target bluefish and account for over 40% of the bluefish commercial landings from 1982 to 2014, with primary use in the Mid-Atlantic and Florida. Other commercial gears including hook & line, pound nets, seines, and trawls, collectively account for approximately 50% of the commercial landings.

B3.5.2 Recreational Fishery

Recreational harvest estimates of bluefish has averaged over 14,000 mt (30.9 million pounds) annually since 1981. There has been an overall decline since 2007 to roughly 5,000-5,400 mt (11-11.9 million pounds) in 2011 and 2012. Harvest estimates for 2014 show a decrease to approximately 4,700 mt (10.4 million pounds). In 2014, recreational anglers along the Atlantic Coast caught 5.8 million bluefish, a 7.4% increase from 2013. The majority of recreational activity occurred from May to October, with the peak activity in July and August.

B4. TERM OF REFERENCE #1: Estimate catch from all sources including landings and discards. Evaluate and if necessary update the discard mortality estimate. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize the uncertainty in these sources of data.

B4.1. Commercial Data

Historical commercial landings (1950 to present) for all species on the Atlantic coast are maintained in the Atlantic Coastal Cooperative Statistics Program (ACCSP) Warehouse. The Data Warehouse is an online database of fisheries dependent data provided by the ACCSP state and federal partners. The Data Warehouse was queried on 11 March 2015 for all commercial bluefish landings (monthly summaries by state, gear and market category) from 1982-2014 for Florida (east coast), Georgia, South Carolina, North Carolina, Virginia, Maryland, Delaware, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, and Maine (ACCSP, 2014). Data sources and collection methods are illustrated by state in Figure B4.1, and annual landings summaries were used when trip level data or monthly summaries were not available. The gear categories were decided upon by the working group based on knowledge of the fisheries and reporting tendencies. The specific ACCSP gears included in each category can be found in Table B4.1.

After review of the commercial landings data by ACCSP state partners, differences in the annual landings from 1996-2014 were identified between the Virginia Fishery Mandatory Reporting Program Trip (FSMRPT) historical landings database and the ACCSP data warehouse. Issues such as duplicate state and federal reporting of landings, and failure to sync data across programs when records are updated in local databases, may be responsible for the discordance across the federally reported and state reported commercial bluefish landings, and the Potomac River Fisheries Commission (PRFC) data, between the Virginia historical landings database and the ACCSP data warehouse. The difference in total commercial bluefish landings between the ACCSP data warehouse and Virginia historical landings database was approximately 1.5% from 1982-2014. It was decided that ACCSP would provide two datasets as options to be used in the assessment model for the Virginia commercial landings data for bluefish. Option 1 consists of commercial bluefish landings where each year of data from 1982-2014 was chosen from either the ACCSP data warehouse or the VA historical landings database, depending on which of these two had the greater annual landings total. The data sources for Option 1 can be seen in Table B4.2. Option 2 consists of commercial bluefish landings where the annual federal dealer landings, the annual state dealer landings, and the PRFC data were compared separately for each year from 1982-2014, and the greater selected from either the ACCSP data warehouse or the VA historical landings database. The data sources for Option 2 can be seen in Table B4.3. Both options are intended to err towards the creation of larger datasets in order to avoid underrepresenting the Virginia commercial bluefish landings data in the assessment. At the 27-29 April 2015 Working Group (WG) Modelling Workshop, the WG elected to use Option 1 since model output using the two Options were nearly identical, and Option 1 is less complex and hence less prone to error.

Prior to the SARC 60, the commercial landings data had been provided by the Northeast Fisheries Science Center (NEFSC) Commercial Fisheries Database (CFDBS), and supplemented with state data supplied directly from several local state collection programs. For past bluefish assessment updates, the NEFSC CFDBS was queried for the federal dealer reported landings and length data from Maine to Maryland, and occasionally for Virginia landings data for some years. However, the NEFSC CFDBS does not capture the commercial bluefish landings which are reported by state dealers who do not have federal reporting requirements. Therefore, it was necessary that additional state dealer reported landings and length data would be supplied by the Virginia Marine Resources Commission (VMRC), the North Carolina Department of Marine Fisheries (NCDMF) trip ticket program, and the Florida Fish and Wildlife Conservation Commission (FWC). To improve on the consistency and reproducibility of the data collection for future bluefish assessments, it was decided for SARC 60 that the commercial bluefish landings would be supplied by the ACCSP data warehouse, which maintains fisheries dependent data for all Atlantic coast species across all ACCSP state and federal partners. A comparison of the commercial bluefish landings across the NEFSC CFDBS, the ACCSP data warehouse, and the local state collection programs can be seen in Tables B4.4 and B4.5 for Virginia, North Carolina, and Florida.

Commercial fisheries landings data for states between North Carolina and Maine are collected via the NMFS dealer mandatory reporting system. Beginning in June 2004, an electronic dealer reporting was initiated in the northeast. The states of Florida, Georgia, and South Carolina use a trip ticket system.

B4.1.1 Commercial Landings

Over the last 33 years, commercial landings from the bluefish fishery (Table B4.6) ranged from a high of 7,162 mt (1983) (15.8 million pounds) to a low of 1,974 mt (2013) (4.4 million pounds). During this time landings have been consistently lower than the recreational catch (Figure B4.2). Gill nets are the dominant commercial gear used to target bluefish and account for over 40% of the bluefish commercial landings from 1982 to 2014, with primary use in the Mid-Atlantic and Florida. Other commercial gears including hook & line, pound nets, seines, and trawls, collectively account for approximately 50% of the commercial landings (Table B4.7).

Regional variations in commercial fishing activity are linked to the seasonal migration of bluefish. The majority of commercial fishing activity in the North and Mid-Atlantic occurs from late spring to early fall when bluefish are most abundant in these areas. As water temperatures decrease in late fall and winter, bluefish migrate south. Peak landings in the South Atlantic occur in late fall and winter. The majority of commercial landings over the time series (1950-present) have been taken in the Mid-Atlantic region (New York, New Jersey, and North Carolina), with the exception of Florida which accounted for a larger percent historically (early 1980s) and a diminishing proportion of landings over time (Table B4.6). Since 1982, approximately 64% of the coastwide total landings have been taken in this region.

Commercial landings decreased steadily from 4,819 mt (10.6 million pounds) in 1993 to 3,359 mt (7.4 million pounds) in 2003, and continued to declined less sharply to 1,974 mt (4.4 million pounds) in 2013 (Table B4.6). Commercial landings have been regulated by quota since implementation of Amendment 1 in 2000. Commercial landings for 2014 increased to 2,242 mt (4.94 million pounds).

The top commercial landings ports for bluefish in 2013 are shown in Table B4.8. Ten ports qualified as "top bluefish ports", i.e., those ports where 45.4 mt (100,000 pounds) or more of bluefish were landed. Wanchese, NC was the most important commercial bluefish port with over 272.2 mt (600,000 pounds) landed.

The Northeast Region is divided into 46 statistical areas for Federal fisheries management. According to VTR data, bluefish were commercially harvested in 36 statistical areas in 2013 (Figure B4.3). Six statistical areas, however, collectively accounted for more than 75 % of VTR-reported landings in 2013, with individual areas contributing 6% to 18% of the total. This trend is supported through time by VTR data over the last 20 years (Figure B4.4). These areas also represented 70% of the trips that landed bluefish suggesting that resource availability as expressed by catch per trip is fairly consistent through the range were harvest occurs.

B4.1.2 Revenue

In 2014, commercial vessels landed about 2,242 mt (4.94 million pounds) of bluefish valued at approximately $3.0 million. Average coastwide ex-vessel price of bluefish was $0.61/lb ($1.33/kg) in 2014, a descrease from the previous years (2012 price = $0.65/lb; $1.43/kg; 2013 price =$0.67/lb; $1.48/kg). The relative value of bluefish is very low among commercially landed species, approximately 0.17 % of the total value, respectively of all finfish and shellfish landed along the U.S. Atlantic coast in 2013. A time series of bluefish revenue and price is provided in Figure B4.5.

B4.1.3 Commercial Biological Sampling

Maine to Virginia

Commercial fisheries from Maine to Virginia were sampled as part of the NEFSC data collection program. In addition, the Virginia Marine Resources Commission's (VMRC) Stock Assessment Program (SAP) has collected finfish biological data (length, weight, sex, and age) since 1988. At most sites, bluefish are sampled from 50-pound boxes of landed fish that have been graded, boxed, and iced. At sites associated with pound net or haul seine landings, bluefish are intercepted after they have been graded by market category and weighed. A 50-pound box (or partial box) of graded fish from all available species market categories (i.e. small, medium, large, and unclassified) are chosen for determination of length, weight, and sex information. In most cases, the entire 50-pound box of fish graded by species market category is sampled to account for within-box variation (see Chittenden and Barbieri 1990).

Each fish is measured for size (total length and usually weight). Weight is measured to the nearest 0.1 lbs; total length is measured to the nearest millimeter (mm), accurate to 2.5 mm, using electronic Limnoterra Fish Measuring Boards. Fork length is measured on a subsample basis. All fish, except those with damaged tails, are measured for total length from the tip of the snout to the end of the tail fin.

For ME-VA bluefish, the numbers of fish sampled has ranged from a low in 1995 of 189 fish to a maximum of 10912 fish in 2012 (Table B4.9). Sampling has averaged just over 6000 fish per year since the year 2000. ME-VA length sampling intensity per 100 lbs landed is presented in Tables B4.10-20. Expansion of length data was completed by market category and quarter of the year, with the results merged into half year periods. Market category/quarters with inadequate length samples were filled with length information from adjacent quarters within the same market category. Market category/quarters with landings and no associated lengths were combined with landings information from adjacent quarters.

North Carolina

Commercial bluefish landings are monitored through the North Carolina trip ticket program (1994-present). Under this program, licensed fishermen can only sell commercial catch to licensed North Carolina Division of Marine Fisheries (NCDMF) fish dealers. The dealer is required to complete a trip ticket every time licensed fishermen land fish. Trip tickets capture data on gears used, area fished, species harvested, and total weights of each individual species landed, by market grade. Trip tickets are submitted to NCDMF monthly.

Fishery-dependent sampling of NC commercial fisheries has been ongoing since 1982. Predominant gears sampled include: ocean sink nets, estuarine gill nets, winter trawls, long haul seines/swipe nets, beach haul seines, and pound nets. From the fishery-dependent data, NCDMF derives length and weight estimates by market grade for almost all of the commercial landings except catches by shrimp trawls, pots, long line, gigs, fyke nets, hand harvest, trolling, and rod & reel. Landings from these unsampled or ‘other’ commercial gears combined represent 0.2-1.1% of the 1997-2004 landings. Length frequency distributions from all sampled commercial gear were combined to represent landings by these other gears.

Bluefish length frequency samples, by gear, market category and year were obtained from dealers with a sample representing the landings from an individual trip. Sampling was done by market category as fish were culled at the dealers. Length distributions (and aggregate weights) from sampled trips by gear and market grade were expanded by respective landings, gear, and market grade. Length frequency distributions were combined to represent total landings, market grade, quarter, and year.

The number of bluefish sampled by NCDMF has ranged from a low in 1995 of 1820 fish to a maximum of 11112 fish in 2001 (Table B4.9). Sampling has averaged almost 8000 fish per year since the year 2000. NC length sampling intensity per 100 lbs landed is presented in Tables B4.13-20. Expansion of length data was completed by market category and quarter of the year, with the results merged into half year periods. Market category/quarters with inadequate length samples were filled with length information from adjacent quarters within the same market category. Market category/quarters with landings and no associated lengths were combined with landings information from adjacent quarters. NCDMF has completed aging bluefish otoliths from years 2006 through 2014. There were a total of 792 bluefish otoliths collected in 2014. Each fish was measured for fork and total length, total weight and sex were recorded, as well as sexual maturity and ovary weight for females.

Florida

Biological data collection for the bluefish fishery from Florida to North Carolina is sparse. FWC has collected an average of around 400 lengths per year from 1992 to 2014. However, there is a large range of values depending on year, from a minimum of 25 fish in 2003, to a maximum of 1618 fish in 1992. There is market category or quarter information associated with the FL lengths and lengths are provided by half year. FL length sampling and sampling intensity is presented in Tables B4.13-20. Expansion of FL length data was completed by half year. If half year information for length or landings were inadequate, expansion was carried out at an annual level.

B4.1.4 Commercial Length Frequency Distribution

The length frequency distribution from the commercial fisheries is characterized by a bi-modal distribution for much of the time-series (Figure B4.6). In the most recent years, a skewed distribution is present, lacking the multi-modal distribution seen in previous years; however, in 2014 the bi-modal distribution is present again. This bi-modal pattern has also been observed in recreational landings length frequencies (Figure B4.10A), and to a lesser degree the recreational discard length frequencies (Figure B4.10B). The bi-modal pattern is a result of an apparent low availability to the fisheries of age 3 to age 4 bluefish. Bluefish are known to school by size class and it is likely that unobserved movement dynamics at this age/size range affects availability of the population. It is possible a larger portion of the population at these sizes are staying south or offshore each year. Since the dominant fisheries for bluefish are coastal and north of Cape Hatteras, North Carolina this would account for a reduced available of this size/age class.

B4.1.5 Commercial Discards

Previous TCs and WGs have concluded that commercial discards for the Atlantic coast were minimal. The SAW60 TC and WG agreed, given: the comparatively small amount of discards relative to landings (1.5-10.7% of landings in any given year; Figure B4.2); the total commercial quota has not been landed for any of the years between 2000 and 2014. The bluefish FMP allows states with a surplus quota to transfer a portion or the entire quota to a state that has or will reach its quota; Amendment 1 to the FMP allows quota transfer from the recreational fishery to the commercial fishery; the need for a discard mortality rate where presently none are available; the need for commercial discard length frequency data where presently none are available; and high CVs around the discard estimates. For these reasons the TC and WG agreed that commercial discards are minimal relative to landings and their use would likely introduce more error than they would resolve.

B4.2 Recreational Data (MRFSS/MRIP)

The main source of information on catch, harvest, release numbers, harvest weights, and sizes for bluefish in the recreational fishery come from the National Marine Fisheries Service's Marine Recreational Information Program (MRIP), which was formerly the Marine Recreational Fisheries Statistical Survey (MRFSS). The MRFSS data collection program began in 1979, though estimates of recreationally caught Bluefish are not available until 1981. In 2005, the National Academy of Sciences' Natural Research Council was commissioned to review the MRFSS and provide recommendations for improving recreational fishing estimates. A major finding of the Council was that intercept methods resulted in a non-representative sample of recreational anglers and their catch-per-trip was not accounted for in the estimation methodology, resulting in potentially biased catch estimates and overestimated precision (MRIP website). Interviewers were instructed to maximize the number of intercepts made and site selection was at the interviewer's discretion. Interviewers were more likely to obtain intercepts from high pressure sites and disregard low pressure sites and the catch-per-trip at the low pressure sites was not adequately represented. The Council's review contributed to the implementation of the MRIP and a new estimation methodology. MRIP uses the same basic data as MRFSS but implements a new catch estimate methodology that better matches the sampling design used in the dockside intercept survey. The MRIP methodology is intended to account for the clustered sample design and the non-equal weighting used to select sample sites.

MRFSS/MRIP contain estimates for number of trips anglers are taking, the total amount of fish harvested (numbers or weight), total amount discarded, catch rates, and biological information. The survey is conducted coastwide and usually by state agency employees or contractors. In MRFSS/MRIP, anglers that fish from private boats and from shore are sampled using random dockside intercepts and telephone calls. During a dockside intercept, anglers are interviewed about their trip and the catch is counted, measured, and weighed. Angler access points are randomly selected in proportion to their expected fishing activity. To estimate effort, coastal households are randomly called and anglers are interviewed about the fishing trips taken during the previous 2 months. Similarly, a for-hire telephone survey is used to collect trip information directly from for-hire operators. Angler participation in MRIP surveys is voluntary. For details in addition to the description provided here, visit the NOAA recreational fisheries statistics website (www.st.nmfs.noaa.gov/recreational-fisheries).

Angler Catch Surveys (dockside intercepts) are interviews of anglers intercepted at public fishing access sites (e.g., marinas, piers) that collect information on the catch and fishing trip (see example questionnaire here http://www.st.nmfs.noaa.gov/Assets/recreational/pdf/append_a.pdf). Sampling is stratified by state, mode of fishing, and wave (bimonthly period) and is conducted continuously during the sampled wave. Recreational fishing estimates are provided for four major modes of fishing: private boats (including rentals), shoreline (e.g., pier, jetty, etc.), charter boats, and headboats (party boats). From 1981-1985 all for-hire boats (charter and party boats) were sampled as one category, producing a single mode that was undifferentiated. From 1986-2004 the party/charter mode was continued in the northeast states (Maine to Virginia), while in the southeast states (North Carolina to Florida) charter boats (only; as separate mode) were sampled by MRIP. Party boats are surveyed by the Southeast Head Boast Logbook Program which began in 1986. From 2005-to present the charter and party boats are sampled independently by the for-hire survey and stratified angler intercept survey; as such separate charter and party boat estimates are produced. Each shoreline angler is treated as being on an independent fishing trip whereas boat modes are treated as fishing parties under the assumption that all anglers on a boat are fishing the same. Sampling is conducted in six waves, each wave being two consecutive calendar months starting with wave 1 (January and February) and ending with wave 6 (November and December). Sampling is conducted during all six waves in Florida (except wave 1 in 1981) and during waves 2-6 in Georgia to Maine (with the exception of pilot studies during some years in GA and NC). Prior to 1993 sampling was divided evenly between the two months in a wave. Beginning in 1993, sampling was divided proportional to expected fishing pressure during each month. There are a minimum of 30 intercepts in each stratum for the shore and private boat modes and at least 45 intercepts in each stratum for the party and charter boat modes (to account for clustering effect). Sampling beyond the minimum is allocated

proportional to expected fishing pressure in each stratum based on the previous three year period. The number of Bluefish caught is recorded as harvested fish observed by the interviewer in whole form (type A), fish reported as harvested by the angler but not observed by the interviewer (bait, filleted, discarded dead) (type B1), and fish released alive (type B2).
Estimation of the variances associated with the average catch and weight of catch estimates obtained from the intercept survey is based on the assumptions that the primary sampling unit is a fishing trip by an individual angler and that there is no clustering effect due to the collection of groups of interviews at each visited site. These assumptions have been empirically verified in pilot surveys. Therefore, the variance is estimated using the standard variance equation for a stratified random sample.

The sampling variance of the estimated total catch is calculated in terms of the expected values and sampling variance the average catch and the total number of trips for each stratum. Total catch is not normally distributed and therefore direct examination of the precision of the estimates is difficult. However, simulation experiments indicate that a normal approximation is satisfactory for constructing 95 percent confidence intervals around the estimated total catch.

The proportional standard error (PSE) expresses that standard error as a percentage of the estimate. It provides an alternative measure of precision and is useful in comparing the relative precision of two estimates. A small PSE indicates a more precise estimate than does a large PSE.

Effort data are collected with the Coastal Household Telephone Survey (CHTS). The CHTS is a stratified random digit dialing telephone survey that includes only households in coastal counties (generally counties within 25-50 miles of coastline, depending on state). The CHTS is stratified by county and wave. Sampling is conducted over a two week period at the end of each wave (last week of the wave and first week of the next wave) and is allocated proportional to county population. Information is collected on the number of trips in the previous wave and details about those trips (see example CHTS questionnaire http://www.st.nmfs.noaa.gov/Assets/recreational/pdf/append_a.pdf). Outliers in effort (number of trips during the particular wave) recorded from telephone surveys are reduced to the 95th percentile of the distribution of effort for the last five years for the particular stratum being sampled.

Evaluation of the CHTS indicated that for-hire modes were being underrepresented due to the nature of these fisheries (out of state clients, etc.). Beginning in 2005, angler effort on charter boats and headboats has been sampled through the For-Hire Survey (FHS) and several overlapping sampling programs. The CHTS was replaced by the FHS for charter boats and headboats (the CHTS is still used for private boats and shoreline modes). The FHS is also a random dial telephone survey that uses a vessel directory as a sampling frame. Other overlapping programs include the Vessel Trip Report (VTR) Program for Maine through Virginia (census logbook), the Southeast Headboat Survey (since 1986) for North Carolina though Florida (census logbook), and state census logbook programs in South Carolina, Florida, and Maryland.

MRFSS vs. MRIP Estimates

Estimates of catch using the MRIP methodology are available from 2004 to the present.

However, prior to 2004, only catch estimates using the MRFSS methodology are available, since the site weight information needed to produce the MRIP estimates is not readily available for the older data. For some species, MRIP estimates were consistently higher or lower than MRFSS estimates, usually when catch rates at low pressure sites were significantly different from catch rates at high pressure sites.

However, for bluefish, there was not a consistent trend in the difference between MRFSS and MRIP estimates, and MRFSS estimates were within the 95% confidence intervals calculated from the MRIP PSEs (Figure B4.7). The TC and WG used the method developed by the MRIP calibration working group to calibrate pre-2004 MRFSS estimates. Difference between the two time-series were minimal.

B4.2.1 Recreational Catch and Harvest

Recreational harvest estimates of bluefish has averaged over 14,000 mt (30.9 million pounds) annually since 1981 (Table B4.23). From the early 1980s to the early 1990s, recreational harvest declined by about 70% [avg. 1981-1983 = 40,433 mt (89.1 million pounds); avg. 1991-1993 = 11,713 mt (25.8 million pounds)]. Recreational harvest estimates continued to decline at a somewhat slower rate until reaching their lowest level at 3,310 mt (7.3 million pounds) in 1999, but since have grown to a peak of 10,204 mt (22.5 million pounds) in 2007. There has been an overall decline since 2007 to roughly 5,000-5,400 mt (11-11.9 million pounds) in 2011 and 2012. Though harvest increased to approximately 7,000 mt (15.4 million pounds) in 2013, harvest estimates for 2014 show a decrease to approximately 4,700 mt (10.4 million pounds). In 2014, recreational anglers along the Atlantic Coast caught 5.8 million bluefish, a 7.4% increase from 2013 (Table B4.24). Recreational harvest has generally increased from a low of 3.6 million fish in 1999, the lowest harvest in the time series. Since then, recreational harvest averaged over 6.2 million fish annually. The majority of recreational activity occurred from May to October, with the peak activity in July and August. Most of the recreational activity occurs from July to October, when almost 70% of the bluefish harvest is taken.

Trends in recreational trips associated with targeting or harvesting bluefish from 1991 to 2013 are provided in Table B4.25. The lowest annual estimate of bluefish trips was 1.727 million trips in 1999, but last year (2013) was also very low with 1.733 million trips. The highest annual estimate of bluefish trips in this timeframe was 5.9 million trips in 1991. Relative to total angler effort in 2013, bluefish were the primary target of recreational trips only about 4.7% of the time.

Recreational Catches by Mode

Figure B4.8 reflects MRFSS/MRIP-based estimates of total removals by mode and indicates that the primary catch modes for bluefish are private boats and shore-based fishing. Less than 10 % of the catch came from for-hire boats over the same time period.

Recreational Catches by Area

MRIP classifies catch into three fishing areas: inland, nearshore ocean (< 3 mi), and offshore ocean (> 3 mi). About 54% of the catch of bluefish on a coastwide basis came from inland waters, followed by nearshore ocean (39%) (Figure B4.9). Offshore ocean is only about 7% of the total catch.

B4.2.2 Recreational Releases

MRFSS/MRIP Recreational release estimates have ranged from a low of 3.2 million fish (1985) to a high of 15 million fish (2007) from 1981-2014 (Table B4.26). Recreational release estimates have generally increased in proportion to harvested fish over the time series, increasing from approximately 4% of the total coastwide catch in 1981 to over approximately 60% in 2014. Recreational discards in 2014 were estimated at 2,808.4 mt and after adjusting for a 15% mortality rate the resulting discard loss was 421.4 mt.

B4.2.3 Recreational Discard Mortality

Since the 1997 assessment (23rd SAW), recreational discard mortality has been estimated at 15%. This was based on estimates calculated in a study by Malchoff (1995), and modified by the ASMFC Bluefish Technical Committee. Prior estimates used in 1994 (18th SAW), estimated a hooking mortality rate of 25% and was based on analogy with species such as striped bass (Diodati 1991), black sea bass (Bugley and Shepherd 1991), and Pacific halibut (IPHC 1988). The Technical Committee thoroughly reviewed the bluefish discard mortality literature (working paper B1) for SAW60. Four methods to calculate a point estimate of post release mortality were conducted, resulting in a range of estimates between 14% and 17%. The TC and WG approved a 15% (SD=0.143%) discard mortality estimate for use in SAW60 based on bluefish specific estimates from five known studies using Bartholomew and Bohnsack (2005) meta-analysis methodology. Supporting analysis using 70 studies and 21 different species from Bartholomew and Bohnsack (2005) (16% post release mortality) and an equal weighted estimate from bluefish specific papers (14% post release mortality) assisted the decision by the WG and TC. For more details see working paper B1.

B4.2.4 Recreational Biological Sampling

Recreational landings are sampled for length as part of the MRIP program. The MRIP length samples were used to expand recreational landings per half year. Recreational discards were characterized using lengths from bluefish tagged and released in the American Littoral Society tagging program (by definition B2 catches), as well as information provided by volunteer angler programs in RI, CT, and NJ.

Rhode Island Volunteer Angler Survey

The Rhode Island Department of Environmental Management Division of Fish and Wildlife (RIDFW) implemented a voluntary on-line angler logbook (eLOGBOOK) in 2010. The eLOGBOOK application, housed by the Atlantic Coastal Cooperative Statistics Program (ACCSP), enables recreational fishers to enter complete trip level catch and effort data online. Information collected includes trip date, fishing mode (party, charter, private, shore), area fished, number of fishers, number of lines, gear type, hours fished, species, disposition, length and quantity.

Connecticut Volunteer Angler Survey

The Connecticut DEEP Marine Fisheries Division has conducted a Volunteer Angler Survey (VAS) since 1979. This survey supplements the National Marine Fisheries Service, Marine Recreational Information Program (MRIP) by providing additional length measurement data particularly for fish that are released. The survey's initial objective was to collect marine recreational fishing information concerning finfish species with special emphasis on striped bass. In 1994, the collection of bluefish length measurements was added to the survey to enhance understanding of the bluefish fishery in Connecticut. In 1997, length measurement information for other marine finfish was added to the survey design.

The CT VAS is designed to collect trip and catch information from marine recreational (hook and line) anglers who volunteer to record their fishing activities by logbook. The logbook format consists of recording fishing effort, target species, fishing mode (boat and shore), area fished (subdivisions of Long Island Sound and adjacent waters), catch information concerning finfish kept (harvested) and released, and length measurements of striped bass (since 1979), bluefish (since 1994), and other common species (since 1997). Instructions for volunteers are provided on the inside cover of all postage paid logbooks. Each participating angler is assigned a personal numeric code for confidentiality purposes. After the logbook data are entered into a database, logbooks are returned to each volunteer for their own personal records.

New Jersey Programs

Recreational discard data were available from several New Jersey programs: the New Jersey volunteer angler survey (VAS) is an online, open access survey that began in 2006. The intent of the survey is to complement and supplement the MRIP survey. Two main objectives of the VAS are to allow anglers to submit data to increase buy-in to management measures as well as address sample size concerns of MRIP, and to collect additional length frequency data of discarded fish. The survey was designed based on the MRIP intercept survey, collecting effort, catch, and length information from marine recreational (hook and line) anglers in New Jersey waters. The survey is available online at http://www.njfishandwildlife.com/marinesurvey.htm.

The NJ Tournament and Party/Charter Boat biological sampling program is designed to collect marine recreational (hook and line) fishing information concerning finfish species. Tournament sampling consists of staff collecting biological data (length, weight, age, sex) of finfish kept (harvested) and released during fishing tournaments. In 2014, logbooks were created for tournament anglers who volunteered to record their fishing activities. The logbook format consists of recording fishing location, number of hours fished, fishing mode (surf or boat), number of anglers reporting on log, water temperature, catch information concerning finfish kept and released, and length measurements.

NJ Party/charter boat sampling consists of staff collecting biological data of finfish kept and released during fishing trips aboard party/charter boats. Party/charter boats can submit trip and catch information by logbook when staff are not present. The logbook format consists of recording fishing location, number of hours fished, number of fisherman, water temperature, weather conditions, catch information concerning finfish kept and released, and length measurements.

Length frequencies from the recreational catch and discards show a similar trend to the commercial length frequency. While previous years were characterized by a bimodal distribution, more recent years reveal a skewed distribution, with a main peak around 28 cm and a flat/slightly-decreasing distribution out to 90 cm (Figure B4.10A & B). Total length frequency distribution by season of the recreational landings and discards are presented in Figure B4.11. The average size of the recreationally released bluefish is larger than the average size of retained fish, an uncommon pattern most likely due to bluefish's unpalatability at larger sizes.

B5. TERM OF REFERENCE #2: Present and evaluate data and trends on life history information including, age, growth, natural mortality, food habits, and maturity.

B5.1 Life History
Bluefish, *Pomatomus saltatrix*, is a coastal, pelagic species found in temperate and tropical marine waters throughout the world (Goodbred and Graves 1996; Juanes et al. 1996). Inhabiting both inshore and offshore waters along the east coast of the United States, spawning takes place offshore (Kendall and Walford 1979; Kendall and Naplin 1981) and subsequent to larval development in continental shelf waters, juveniles eventually move to estuarine and nearshore shelf habitats (Marks and Conover 1993; Hare and Cowen 1995; Able and Fahay 1998; Able et al. 2003). Traveling in loose groups of fish aggregated by size, bluefish typically migrate north in the spring/summer and south in the fall/winter (Wilk 1977; Klein-MacPhee 2002). Their range during these periods of migration can extend as far north as Maine and as far south as Florida in the Unites States (Shepherd et al. 2006).

B5.2 Age Data
The working group (WG) expended considerable time and effort tracking down all original sources of age data used at SAW41, new sources of data, as well as constructing and reconstructing age length keys. The WG recovered NC scale data files from 1983-1996 and NC otolith data from 1996 to 2000 (scale and otolith samples were collected from the same fish in 1996; the WG elected to use 1996 otolith data only). Samples were primarily from commercial gears. Of note, the raw NC ages included many spring age 0 fish, which are uncommon in biological age samples (WP B5; ASMFC 2011). Exploration of spring NC data suggested, contrary to SAW41 (NEFSC 2005) language, that those data do not use a January 1 birthdate, making them incompatible with all other age data1. The WG initially considered using the raw data (with model adjustments), but at the modeling workshop quantitatively re-assigned NC spring scale ages based on the size and age of known samples from across the time series; for otolith ages, only spring age 0 samples (1996-2000) were adjusted to age 1. See WP B6 and TOR 3 for more details.

Additional data from this general time period (1984-19952) that were recovered included CT Long Island Sound Trawl Survey (LISTS) scale ages, NEFSC trawl scale ages, and NMFS commercial port sampling scale ages (Table B5.1, Figure B5.1). For SAW41, these data were used to age fishery independent or commercial landings only. The SAW60 WG reasoned that bringing all of these data into the ALKs was desirable as it lead to more complete ALKs. Given the limited age data from 1982-1984 the WG elected to start the model in 1985.

The WG recovered VA age length keys from 1998-2004 used at SAW 41. In 1997, VMRC established a cooperative fish ageing lab with Old Dominion University's Center for Quantitative Fisheries Ecology (CQFE) laboratory. The CQFE Lab ages fish harvested from Virginia's marine fisheries and provides the data to VMRC for management purposes. Collection of age samples was based on a quota by inch interval. The Virginia time series (1998-2004) contains

1 Fall samples would not have suffered from a birthday concern, and so were used at SAW41, and also retained for SAW60 (WP B6).
2 NMFS port samples and NEFSC trawl samples were also available for 1996 but were inadvertently omitted from ALKs.

age information by gear, sex, market category, and location from approximately 2,700 samples, from sectioned otoliths only. The SAW60 WG augmented the VA spring ALKs with NC spring otoliths after adjusting the age 0s to age 1 (WP B6). This augmentation allowed for disaggregation of the previously combined 1998-2001 spring ALK into ALKs for 1998, 1999, and 2000-2001 (Table B5.2). With this exception, age keys from 1997-2004 were reconstructed according to the protocol specified at SAW41 (Table B5.2).

New sources of age data acquired since SAW41 include otolith ages from MA, RI, CT, NY, NJ, ChesMMAP, NC, NEAMAP, and SEAMAP (Figure B5.1). The Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP) Trawl Survey samples the main stem of the Chesapeake Bay, from Poole's Island, MD to the Virginian Capes at the mouth of the bay since 2002. ChesMMAP conducts 5 cruises annually, during the months of March, May, July, September, and November. This survey is designed to sample the late juvenile and adult stages of the living marine resources in Chesapeake Bay, and as such the timing of sampling is meant to coincide with the seasonal residency of these life stages in the estuary. The NEAMAP and SEAMAP programs are described in TOR 3. With the addition of these new data sources, age keys since 2005 average a minimum of approximately 30 fish per age (Table B5.3, WP B5).

Several studies document the problems with bluefish ageing information, specifically problems with using scales to accurately age bluefish. False annuli, rejuvenated scales, identifying annuli on scales from larger fish, different annuli counts between scales from the same fish, and the timing of the first annulus formation can all cause inaccuracies (Lassiter 1962; Richards 1976; NCDMF 2000; Robillard et al. 2009). The divergence between scale ages and otolith ages occurs beyond age-6 (E. Robillard, CQFE, pers. comm. 2005). Therefore the catch-at-age matrices were truncated to a 6+ category to reduce ageing error associated with scale ages in the 1985-1995 time period.

The SAW-23 review expressed concern that use of a single age key collected in NC may not be representative of the coastal stock (NEFSC 1997). The SAW-41 review expressed concerns that ALKs have been combined across areas and years. Salerno et al. (2001) examined age data collected along the Atlantic coast in the NEFSC autumn trawl survey and compared the scale ages with the North Carolina commercial ages and concluded that the NC ages were representative of Atlantic coast bluefish. Other studies have used age at length information from commercial and recreational fisheries as well as fishery-independent surveys and have shown similar bluefish growth parameter estimates from Maine to North Carolina, providing further evidence that North Carolina age data are representative of the Atlantic Coast (VMRC 1999, 2000, 2001). Regional trends in age data are available in Figure B5.2A-B (and WP B5) and suggest similarities and differences.

The WG explicitly evaluated borrowing age data across years (WP B8), and the results suggested that this should generally be avoided. The SAW-60 WG accounted for historical borrowing and sparse ALKs (1997-2005) through model considerations (see TOR 4).

The SAW-41 review expressed concerns regarding gaps in sampling age 3, 4, and 5-year old fish (Jones 2005). In response to concerns about the adequacy of bluefish biological data, in February 2012 the Bluefish Management Board passed Addendum I to Amendment 1 to the bluefish fishery management plan that required states that accounted for >5% of total coast-wide bluefish harvest to collect a minimum of 100 bluefish ages (50 from January - June; 50 from July - December). A number of states implemented this program prior to 2012, including NC (2006+), MA (2009+), and NJ (2010+); and as noted above, VA has maintained an ageing program in conjunction with ODU since 1997. With the expansion of the biological collection program, bluefish age length keys have become considerably more robust relative to the time series described above (Figure B5.3 and B5.4). Working paper B5 describes the biological collection program in greater detail. See WP B5, B7, and B8 for more information on trends on age data.

B5.3 Growth and Reproduction
Bluefish spawn offshore in the western North Atlantic Ocean, from approximately Massachusetts to Florida (Norcross et al. 1974; Kendall and Walford 1979; Kendall and Naplin 1981; Collins and Stender 1987). Bluefish are characterized as iteroparous spawners with indeterminate fecundity and spawn continuously during their spring migration (Robillard et al. 2008). In addition to distinctive spring and summer cohorts, Collins and Stender (1987) identified a fall-spawned cohort, demonstrating the potential of an extended bluefish spawning season.

Bluefish grow nearly one-third of their maximum length in their first year (Richards 1976, Wilk 1977). Variation in growth rates or sizes-at-age among young bluefish is evident from the appearance of intra-annual cohorts. Lassiter (1962) identified a spring-spawned cohort and a summer-spawned cohort from the bimodal appearance of size at Annulus I for fish aged from North Carolina and found the seasonal cohorts can differ in age by two to three months. Hare and Cowen (1993) however, suggest the bimodal length at age observed in bluefish is not the result of two distinct spawning events but rather a consequence of continuous spawning (March-September) with the summer spawned offspring having a lower probability of recruitment. Previous research suggests different growth rates at age with summer-spawned larvae and juveniles growing faster than spring-spawned larvae and juveniles (McBride and Conover 1991) with size differences at annual age diminishing greatly after three to four years (Lassiter 1962).

To further explore differences in growth, von Bertalanfy growth curves were fit to data available from 1985-2014 (Table B5.4, Figures B5.5 and B5.6). Historically, scale ages have been used to estimate von Bertalanffy growth parameters (Lassiter 1962; Barger 1990; Terceiro and Ross 1993; Salerno et al. 2001) however more recent research validated otolith ages for bluefish and re-examined growth (Robillard et al. 2008). The values for $L\infty$ from all of these studies (87-128 cm FL) match closely to the largest individuals in the available catch data and are similar to the estimates presented here (Table B5.4).

The results from the sex based growth examination confirm the results of previous studies that growth rates do not differ between sexes (Hamer 1959; Salerno et al. 2001, Robillard et al. 2008) (Figure B5.6, Table B5.4). Although there was not enough data available from older fish in the south to do a comparison between northern and southern fish, there were data available to compare growth rates between ageing structures. Scale ages typically over-estimate younger ages and underestimate the age of older fish. The growth curve for scales from this study had more data to fit at older ages, and asymptotes at a much smaller L-infinity value (92.4cm) than the otolith ages (120 cm). The otolith ages seem to provide more realistic VBL growth parameter estimates (Table B5.4). Finally, the differences in growth curves by time block can be explained by the age structures. From 1985-1994 all of the age data is derived from scales, 1995-2004 age data comes from a mixture of scales and otoliths, and 2005-2014 data is otoliths only. Changes in the primary age structure for bluefish over the time series makes it difficult to determine if there has been a change in growth rates.

B5.4 Natural Mortality
In past stock assessments, a value of 0.2 has been assumed as the instantaneous natural mortality (M) for bluefish over all ages and years. To investigate the validity of this estimate, longevity and life-history based equations were used to estimate different possible values for M. Taking the maximum age for bluefish to be 14 years (observed age in the data used in these analyses), the 'Rule of thumb' method (3/tmax) gives a natural mortality estimate of 0.21. Additional longevity based estimates derived from equations in Hoenig (1983) and Hewitt and Hoenig (2005) give values of 0.32 and 0.3, respectively. Estimates based on equations that use growth parameters from Then et al. (2014) and Jensen (1996) give values of 0.20 and 0.195, respectively. The mean value for natural mortality using the estimates from these 5 approaches is 0.245.

Age-specific estimates were calculated based on the work of Lorenzen (1996, 2000) and Gislason et al. (2010). These values ranged from 1.70-0.17 over the age range of 0-14 (Table B5.5). The WG was concerned with the use of age-specific M estimates due to uncertainty in M particularly for younger ages of bluefish (Table B5.5; e.g., range of M for age 0 = 0.54-1.70). Based on the results of all the methods explored to estimate natural mortality for bluefish, the WG reasoned that the assumption of M = 0.2 was justifiable and was maintained for SAW60.

B5.6 Food habits
During oceanic larval development, bluefish diets are composed primarily of copepods and fish eggs in the smaller size classes (<30mm) expanding to amphipods, and crab larvae above this size (Marks and Conover 1993). An onset to piscivory occurs for early juveniles, primarily inhibited by mouth-gape size, in estuarine waters leading to rapid increases in growth rates with maximum rates reaching 2 mm/day (Juanes and Conover 1994). Cannibalism has also been documented, and therefore bluefish predation may influence recruitment of conspecifics (Bell et al. 1999). Increased predation on commercially important invertebrates such as blue crabs (*Callinectes sapidus*) may occur when fish prey are less available (Scharf et al. 2004). Both seasonal and inter-annual differences in diet have been observed and are likely attributed to changes in prey availability, but also due to inter-annual variability in timing of estuarine arrival (Nyman and Conover 1988). To confirm the findings of previous research and further investigate the diet of bluefish, data on diet composition collected from four surveys were evaluated.

Data from the NEFSC bottom trawl survey from the Mid-Atlantic and Southern New England regions was analyzed in 10 year blocks to look at bluefish diet composition. The proportion of empty stomachs ranged from 20-40% and in each ten year period, around 60-70 bluefish prey items were identified. Anchovies were a significant prey of bluefish across all time periods, as were butterfish and squids (Figure B5.7). Other prey have different levels of importance across time, including sandlances, herrings, bluefish, and scup (which has increased in the past two decades). Drums have also recently increased in bluefish diets. Prey composition percent by weight as shown in Figure B5.7 was calculated using the methods of Link and Almeida (2000).

Since 2007, the NEAMAP survey has sampled a total of 4,250 bluefish for diet from the Mid-Atlantic Bight and Southern New England. Of these, 56.0% (2,379 fish) have had prey in their stomach comprising 86 prey items. Percent by weight (%W) of each prey type was calculated following Bogstad et al. (1995) and Buckel et al. (1999). This data showed that fishes comprised greater than 96% of the bluefish diet by weight, with bay anchovy (53.9%), butterfish (7.4%), and striped anchovy (6.2%) accounting for the bulk of the prey consumed. For the invertebrates, the longfin inshore squid was the main identifiable prey type. Percent by number (%N) of each prey type was calculated following the same %W equation by replacing the biomass values with count data. These calculations presented a similar picture of bluefish diet, with fishes contributing 92.6% of the diet and the same three fishes dominating the diets of bluefish. Invertebrates were shown to be slightly more important in the bluefish diet using %N, likely due the large numbers of small-bodied invertebrates (e.g., crab megalope and mysid shrimps) that were encountered on several occasions.

The ChesMMAP survey has collected a total of 443 bluefish stomachs since 2002, and 54.0% of these have had prey items in their stomach. Of these 239 bluefish stomachs, 34 prey types were identified with fishes again dominating the diet of bluefish collected from Chesapeake Bay, as measured using the %W index. Fishes comprised approximately 87.7% of the bluefish diet by weight, with bay anchovy (39.9%), spot (18.8%), and Atlantic menhaden (9.1%) accounting for the bulk of the fishes consumed by bluefish. Silver perch and weakfish each accounted for 2.4% of the diet by weight. Of the invertebrates, the mysid shrimp was the main identifiable prey type. Fishes comprised nearly the same percentage of the bluefish diet when measured by the %N index. Fishes contributed 84.6% of the diet by number, while invertebrates accounted for 13.7%. The remainder was unidentifiable items.

The SEAMAP trawl survey sampling from Cape Hatteras, North Carolina to Cape Canaveral, Florida has collected 644 stomachs from 2011-2013. A total of 49 different types of prey were identified with the diet composition by weight consisting primarily of fishes (93.5%), most significantly anchovies (49.8%), Atlantic bumper (3.2%), and sciaenid fishes (1.2%). Penaeid shrimp, loliginid squids and cubozoan jellyfish contributed in highest proportions among the invertebrates. A similar composition is depicted in the %N calculations (WP B3).

Overall, the diet of bluefish both in the Chesapeake Bay and the coastal ocean, from Cape Cod to Cape Canaveral, is dominated by fishes, regardless of the index by which the diet is quantified. These findings correspond with those of past studies that have sought to characterize bluefish diet in estuarine and ocean environments. For more information see WP B3.

B5.7 Maturity

Bluefish maturity at age and length has been investigated in previous studies (Salerno et al. 2001, Robillard et al. 2008). To confirm these results and further investigate bluefish maturity, maturity at length is presented for all fish, northern and southern fish, and males and females (Figure B5.8 and B5.9).

This study presents maturity at length all fish, northern and southern fish, and males and females (Figure B5.8 and B5.9). The length estimate at 50% maturity for all fish (29.87 cm) was found to be smaller than the mean value of 33.65 cm estimated in Salerno et al. (2001)(Table B5.6). Given the larger sample size (N = 13,722 vs N = 3,334) and broader geographic region of the data presented here, these differences can be expected. Although it appears that southern fish mature at a smaller length than northern fish, this may also be an artifact of sampling (N = 12,909 fish in north, N = 813 fish in south). The length at maturity for males versus females was found to be slightly smaller for males (Table B5.6 A). Similarly, the data also indicate that female fish mature at an older age than male fish (Table B5.6, Figure B5.10). This is consistent with the maturity information from Robillard et al (2008). Finally, comparing maturity at age for otoliths to scales shifts the maturity ogive to slightly younger ages (Figure B5.10).

The most accurate source of maturity at age for bluefish involved a histological examination of 1,437 female fish (Robillard et al. 2008). However, because this maturity information does not apply to the entire bluefish stock, the proportion mature at age for all fish (estimated via logistic regression: A50 = 1.10, A95 = 1.85) was used as the input maturity for the catch-at-age model used in the benchmark assessment (Table B5.7, Figure B5.11). These estimates are nearly identical to the results from Salerno et al. (2001) (Table B5.7).

B5.8 Stock Definition

Bluefish in the western North Atlantic are managed as a single stock (NEFSC 1997; Shepherd and Packer 2006). Genetic data support a unit stock hypothesis (Graves et al. 1992; Goodbred and Graves 1996; Davidson 2002). For management purposes, the ASMFC and MAFMC define the management unit as the portion of the stock occurring along the Atlantic Coast from Maine to the east coast of Florida.

B5.9 Habitat Description

Bluefish eggs have been collected across the continental shelf from southern New England to Cape Hatteras from May through August, and their depth distribution during those months ranged from 30-70 m, with the majority at 30 m (Shepherd and Packer 2006). Larvae occur near the edge of the continental shelf in the south Atlantic Bight, in open oceanic waters in the mid-Atlantic Bight, and over mid-shelf depths farther north (Shepherd and Packer 2006). Spring spawned larvae are subject to advection to northern waters by the Gulf Stream (Shepherd and Packer 2006). Adult and juvenile bluefish are found primarily in waters less than 20 meters (m) deep along the Atlantic coast Shepherd and Packer 2006). Adults use both inshore and offshore areas of the coast and favor warmer water temperatures although they are found in a variety of hydrographic environments (Ross 1991; Shepherd and Packer 2006). Bluefish can tolerate temperatures ranging from 11.8°-30.4°C, however they exhibit stress, such as an increase in swimming speed, at both extremes (Olla and Studholme 1971; Klein-MacPhee 2002). Temperature and photoperiod are the principal factors directing activity, migrations, and distribution of adult bluefish (Olla and Studholme 1971).

B6. TERM OF REFERENCE #3: Present the survey data available for use in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.), evaluate the utility of the age-length key for use in stock assessment, and explore standardization of fishery- independent indices. Investigate the utility of recreational CPUE as a measure of relative abundance. Characterize the uncertainty and any bias in these sources of data, including exploring environmentally driven changes in availability and related changes in size structure. Explore the spatial distribution of the stock over time, and whether there are consistent distributional shifts.

B6.1 Fishery-Independent Surveys

Fishery-independent surveys from Florida to New Hampshire were reviewed for this assessment (Figure B6.1). Survey methods include estuarine and nearshore bottom trawl and beach seine surveys. The surveys caught predominantly age-0 and age-1 bluefish (<30 cm FL). Indices of relative abundance were calculated based on constraints of catch size, time, and location of sampling. Several surveys sample monthly or bi-monthly. The working group evaluated the timing of each survey and chose the period that had the highest availability of bluefish to the survey gear.

B6.1.1. NH Fish and Game Department, Marine Division Juvenile Finfish Seine Survey

The New Hampshire Fish and Game Department's Juvenile Finfish Seine Survey was initiated in 1997 and has sampled continuously since. The Survey is a fixed station survey. Fifteen fixed stations were chosen through sampling several sites within New Hampshire bays and estuaries in the years before 1997 and selected based on habitat type, depth of less than six feet (1.8 m), and with low enough tidal current to allow for the net to be pulled through the site. The stations, four of which are in the Hampton/Seabrook Estuary, three in Little Harbor, three in the Piscataqua River and five in Little Bay/Great Bay (Figure B6.2), are representative of juvenile finfish nursery habitat along New Hampshire's coastal waters. The beach seine used for this survey is a bag seine, 30.5 m long by 1.8 m high, with 6.4 mm mesh.

A single seine haul is performed at each station each month from June through November, resulting in 90 tows per year. Seine hauls are performed between two hours before and two hours after low tide, and always in daylight. Seine hauls are set by boat about 15-25 m from the beach and, ideally, in water depths less than 2 m, in order to prevent the foot rope of the seine from lifting off of the bottom.

All captured finfish are identified to the lowest possible taxon, measured in total length to the nearest millimeter (with a maximum of 25 individual lengths recorded per species per seine haul), and then enumerated. Water surface temperature (°C), salinity (ppt) and substrate type are recorded at each fixed station for each seine haul. Sampling occurs annually from June to November. All fifteen stations within all four areas (Great Bay, Hampton Harbor, Little Harbor, Piscataqua River) are sampled within each month. This sampling design results in a total of 15 seine hauls being collected monthly and 90 seine hauls being collected annually.

The annual geometric mean catch per tow from the New Hampshire Finfish Seine Survey is used as a measure of relative abundance (Table B6.1). In calculating the index, the full dataset between 1997 and 2014 was used and all survey months (June through November) were included. All fish encountered during time series of the survey ranged between 23 mm and 220 mm. A size cutoff of 250 mm is an assumed level at which bluefish would be classified as age 1 based on discussions of the technical committee, and therefore all bluefish used in the analysis are classified as young-of-the-year.

B6.1.2 Northeast Fisheries Science Center (NEFSC) Fall Inshore Trawl Survey

The NEFSC has conducted bottom trawl surveys over a large portion of the Atlantic shelf since 1963 (Avarovitz 1981). Sampling sites are randomly selected from within depth-defined strata; both inshore and offshore strata are sampled. The surveys run in the spring and fall and cover areas from 5 to 200 fathoms (9.1-365.8 m) deep, from Cape Hatteras, North Carolina to Canadian waters. Trawling locations are allocated according to a stratified-random sampling design. The research vessels F/RV Albatross IV and the F/RV Delaware II were used to conduct these surveys from 1963 to 2008. In 2009 the F/RV Albatross IV was decommissioned and the FSV Henry B. Bigelow took over as the permanent NEFSC survey vessel. This vessel change resulted in changes to the trawl gear and survey protocol (Table B6.2, adapted from Brooks et al. 2010 and NEFSC 2012).

Bluefish are predominantly caught in the fall, and in inshore waters. NEFSC fall inshore strata from Cape Hatteras to Cape Cod were used to build two indices for bluefish (Figures B6.3A-B). An F/RV Albatross index based on all inshore strata (1-46) was constructed from 1985 to 2008. F/RV Albatross tows were 30 minutes in duration and utilized a codend mesh liner of 1.27 cm to retain pre-recruits. An additional NEFSC index representing the current survey vessel, the FSV Henry B. Bigelow, was constructed from 2009 to 2014. The Bigelow is only able to sample the outer inshore band of strata and not able to sample as close to shore as previous vessels. FSV Bigelow tows are 20 minutes long and use a larger codend liner at 2.54 cm. Stratified mean numbers of bluefish per tow for both indices with associated CV estimates are presented in Table B6.1.

Mean number per tow at length were aged using age length keys from 1985 to 2014 developed for the assessment (see TOR 2 for details). The majority of bluefish caught in the fall are age-0 or age-1. The Albatross index shows large cohorts early in the time series in 1986, 1989, and to a lesser degree, later in the time series in 1999, 2003, and 2005 (Figure B6.3A). It is difficult to discern trends from the Bigelow index due to the short (6 year) time series. However, the SAW60 WG decided that while the Bigelow time series was short, it was important to separately include this index in the assessment. Previously, Albatross and Bigelow data were used in a combined index, with Bigelow numbers converted to Albatross units using a conversion factor of 1.16 (Miller et al. 2010). Bluefish have not had a benchmark assessment since 2005 and there will likely be an extended period of time before the next benchmark. The separate Bigelow index will continue to add value, without the need to apply conversion factors, as additional years are added.

B6.1.3 RI DEM Narragansett Bay Juvenile Finfish Beach Seine Survey

The Rhode Island Department of Environmental Management Division of Fish and Wildlife

(DEM) Narragansett Bay juvenile finfish survey began in 1988 to monitor the relative abundance and distribution of the juvenile life history stage of commercial and recreationally important species in Narragansett Bay. These are used to evaluate short and long term annual changes in juvenile population dynamics, to provide data for stock assessments, and to develop Fishery Management Plans. Additionally, the fish community data collected by this survey is used to continue to identify, characterize, and map essential juvenile finfish habitat in Narragansett Bay.

The survey encompasses 18 fixed stations throughout Rhode Island's Narragansett Bay (Figure B6.4. The survey began in 1986 with fifteen stations. The data represented begins in 1988 as the period of time when the survey began using consistent methodology with 15 stations, and then station 16 (Dyer Is.) was added in June 1990, station 17 (Warren R.) was added in July of 1993, and station 18 (Wickford) was added in July of 1995.

Finfish are collected using a 61 meter (200') x 3.05 meter (10'), 6.4 mm stretched (¼") mesh beach seine. The seine has a bag at its midpoint and a weighted footrope. The beach seine is set in a semi-circle, away from the shoreline and back again using an outboard powered 23' (7 m) boat. The net is then hauled toward the beach by hand and the bag is emptied into large water-filled totes. Area swept was calculated, to determine the area covered by an average set (5,837 sq ft; 542.3 sq m).

Physical parameters such as weather conditions, water temperature, dissolved oxygen, salinity, are taken at each station. Fish are sorted by species, measured and counted. If over 50 individuals of one species are collected a sub-sample is taken. Fish collected in the sub-sample are measured and counted. The fish are released immediately after measurements are taken. Relative abundances of invertebrates and aquatic vegetation are also noted. Finfish are sampled monthly, from June through October of each year (all months used in index). The index of abundance used a 25 cm YOY cutoff. Index of abundance is provided in Table B6.1.

The Rhode Island index was standardized using the delta lognormal model approach (Lo et al. 1992). Two generalized linear model (GLM) analyses are used to construct a single index. The first GLM procedure of proportion positive trips assumed a binomial error distribution while the procedure for catch rates on successful trips assumed a lognormal error distribution. The five factors included were year, month, station, temperature (^{o}C), and salinity (ppt).The standardization was accomplished using R statistical software package.

B6.1.4 CT DEEP Long Island Sound Trawl Survey

The Connecticut Department of Energy and Environmental Protection's (CTDEEP) Marine Fisheries Division has conducted the Long Island Sound Trawl Survey (LISTS) since 1984. The LISTS provides fishery independent monitoring of important recreational species, as well as annual total counts and biomass for all finfish taken in the Survey. The LISTS employs a stratified-random sampling and is conducted from longitude 72° 03' (New London, Connecticut) to longitude 73° 39' (Greenwich, Connecticut). The sampling area includes Connecticut and New York waters of Long Island Sound and is divided into 1.85 x 3.7 km (1 x 2 nautical miles) sites (Figure B6.5), with each site assigned to one of 12 strata defined by depth interval design using strata based on depth interval (0-9.0 m, 9.1-18.2 m, 18.3-27.3 m or, 27.4+ m) and bottom type (mud, sand, or transitional as defined by Reid et al. 1979. Sampling is divided into spring (April-June) and fall (Sept-Oct) periods, with 40 sites sampled monthly for a total of 200 sites annually. Species are sorted, weighed, and counted and all or a sub-sample of primary species are measured to nearest cm FL. Some species are sorted and subsampled by length group; so that all large individuals are measured and a subsample of small (often young-of-year) specimens is measured. The length frequency of each group is estimated by the proportion of individuals in each centimeter interval of the subsample expanded across the total number of individuals caught in the length group. The estimated length frequencies of each size group are then appended to complete the length frequency for that species (Gottschall & Pacileo, 2013).

Length sampling for bluefish began in 1984. LISTS bluefish length frequency since 1984 includes 167,132 fish. Connecticut initiated a biological sampling program for bluefish in 2012 as part of implementing Addendum I to Amendment I of the bluefish fishery management plan. Since 2012, the majority of the fish collected for this program have come from LISTS. All bluefish samples have been aged by otolith cross section methodologies approved during the May 2011 bluefish ageing workshop.

LISTS generates a spring and fall geometric mean catch per tow, however, few bluefish are taken in the spring. The current bluefish assessment uses LISTS fall index consisting of September and October samples to generate a geometric mean catch/tow (Table B6.1, Figure B6.5). LISTS employs a stratified-random sampling design. The bluefish index used is an age 0 through age 6+ design based index (non-standardized). The average fall geometric mean over the time series is 22.63 fish/tow, with an average of 91.8% positive tows.

B6.1.5 NY DEC Beach Seine Survey (NYSDEC WLIS)

The New York Department of Environmental Conservation's (NYSDEC) Western Long Island Beach Survey started in 1984, has employed a consistent methodology starting in 1987. The survey uses a 200 x 10 ft (61 m x 3 m) beach seine with ¼ inch (6.4 mm) square mesh to sample sites at fixed stations within western Long Island bays: Little Neck and Manhasset Bay on the north shore of Long Island, and Jamaica Bay on the south shore (1984-present). Oyster Bay has been sampled consistently since 2001, and Hempstead Harbor since 2006. Other bays have been sampled on a shorter time frame. Sites are sampled May through October. Pre-2000 sampling was conducted 2 times per month during May and June, once a month July through October. Now, Little Neck Bay, Manhasset Bay, and Jamaica Bay are sampled 2 times per month (bi-weekly) from May through October. Hempstead Harbor and Oyster Bay are sampled 1 time each month. Generally 5-10 seine sites are sampled in each Bay on each sampling trip.

All finfish species caught identified and counted. As many finfish as possible were measured at each station until 2000 when either all, if less than 30, or a subset of 30 individuals were measured for each species. Environmental information (air and water temperature, salinity, dissolved oxygen, tide stage, wind speed and direction, and wave height) has been recorded at each station. Bottom type, vegetation type, and percent cover have been recorded qualitatively since 1988. Young-of-the-year (YOY) vs. older bluefish have always been recorded, with more species being differentiated over time. 99% of bluefish caught by this survey are YOY, as defined by a 30 cm fork length size cutoff.

The index of abundance (Table B6.1, Figure B6.6) was standardized using a negative binomial GLM with bottom water temperature and bottom dissolved oxygen levels as significant covariates and included sampling during the months of June through October. Bay was not a significant factor.

B6.1.6 NJ DFW Ocean Trawl Survey

The New Jersey Division of Fish and Wildlife (NJDFW) Bureau of Marine Fisheries Ocean Trawl Survey is a multispecies trawl survey that started in August 1988 to monitor the abundance and distribution of marine recreational fishes in the state's nearshore coastal waters. The survey samples from the entrance of the New York Harbor south, to the entrance of the Delaware Bay five times per year in January, April, June, August, and October.

There are 15 strata (five strata assigned to three different depth regimes: inshore – 5.5 to 9 m, mid-shore – 9 to 18 m, and offshore – 18 to 28 m). Stations are randomly selected, and station allocation per stratum is proportional to stratum size. Samples are collected with a three-in-one trawl, so named because all the tapers are three to one. The net is a two-seam trawl with forward netting of 12 cm (4.7 inches) stretch mesh and rear netting of 8 cm (3.0 inches) and is lined with a 6.4 mm (0.25 inch) bar mesh liner. The headrope is 25 m (82 feet) long and the footrope is 30.5 m (100 feet) long.

A consistent protocol has been in place with 20 minute tows and 5 annual cruises since 1990. Exploratory analyses indicated the most consistently high catches (and often the plurality of catches) are from the October cruise. Consequently, the index of abundance is from the October cruise from 1990+. Catches are dominated by young of the year fish, but 7% of the catch over the time series consists of age 1+ fish. The index of abundance is a stratified geometric mean catch per tow of ages 0-2 (Table B6.1, Figure B6.7).For standard catches, the total weight of each species is measured (in kilograms) and the fork length of all individuals is measured to the nearest centimeter. For large catches, a subsample is also weighed and measured (nearest cm), and an expansion factor (total weight / subsample weight) is then applied to each frequency of the length-frequency distribution from the subsample. Each of 39 stations are sampling every October.

B6.1.7 NJ DFW Delaware River Seine Survey

Since 1980, the NJDFW Bureau has conducted a striped bass young-of-year (YOY) seine survey in the Delaware River. This survey collects a variety of other species of fish and invertebrates, with moderate numbers of bluefish collected, over 2,900, since its inception.

The Delaware River is divided into three regions based on habitat; region 1 includes brackish, tidal water extending from the springtime saltwater/freshwater interface to the Delaware Memorial Bridge; region 2 includes brackish to tidal fresh water extending from the Delaware memorial Bridge to the Schuylkill River at the Philadelphia Naval Yard; region 3 includes tidal freshwater from Philadelphia to the fall line at Trenton. In the history of the survey no bluefish have been collected in region 3 and so that region was excluded for purposes of a bluefish abundance index. The region 1 shoreline is dominated by saltmarsh vegetation while region 2 is primarily urban with a shoreline heavily developed for commerce and industry.

The sampling scheme has been modified over the years but the core survey area and station locations have remained consistent. In 2002, the second two weeks of June and first two weeks of July were added to the sampling protocol; exploratory analyses indicated that comparatively large numbers of bluefish are collected during that time, and so the index of abundance includes those months (and consequently starts in 2002).

Field sampling employed a bagged, 30.5 m (100-feet) long, by 2 m (6-feet) deep, with a 6 mm (1/4-inch) mesh beach seine. The seine is deployed as follows: one end of the seine is held fixed at the waterline while a vessel backs off the beach in a half-circle or elliptical pattern before returning to the beach with the other end of the seine. The two ends of the seine are drawn together and hauled on shore at which point all fish are identified to species level, quantified and a sub-sample of up to 30 lengths (FL cm) are recorded for each species from each seine haul; the total size range is also recorded. A size cutoff of less than or equal to 25 cm was used to distinguish young of the year bluefish. Basic water quality parameters, including water temperature, salinity and dissolved oxygen, were also recorded at each station. The geometric mean young-of-year index is reported as the number of young-of-year bluefish per seine haul (Table B6.1, Figure B6.8). The full survey takes place between the 2nd week in June and the last week in October, but exploratory analyses indicated a substantive drop in catch after September, and so the bluefish abundance index includes only the 2nd week of June through the end of September. During this timeframe, each of 24 stations are sampled twice per month (every two weeks).

B6.1.8 MD DNR Juvenile Striped Bass Seine Survey

The Maryland Department of Natural Resources' (MD DNR) Juvenile Striped Bass Seine Survey has documented annual year-class success and relative abundance of many fish species in Chesapeake Bay since 1954. Juvenile striped bass indices are developed from sampling at 22 fixed stations located in major spawning areas in Maryland's portion of the Chesapeake Bay. A subset of 13 sample sites was selected for the development of a juvenile bluefish index from 1981 to present. Other sites were excluded on the basis that bluefish were rarely, if ever, captured there. Each site is visited monthly, from July to September, and up to two samples are collected at each visit.

Fixed sample sites are located in three areas of Maryland's Chesapeake Bay: the Choptank and Potomac rivers and the Upper Chesapeake Bay region north of the Chesapeake Bay Bridge. Sites have occasionally been lost due to erosion, bulkheading, or proliferation of submerged grasses. When necessary, replacement sites are located as close as possible to the original site. Effort was slightly variable prior to 1998, with sample sizes ranging from 72 to 80 seine hauls per year. From 1998 to present effort was standardized and sample size has been constant at n=75.Samples are collected with a 30.5 m x 1.24 m bagless beach seine of untreated 6.4 mm bar mesh set by hand. One end of the net is held on shore, while a biologist pulls the other end of the net perpendicular from shore to the 1.2 m depth contour or the net's full extension, whichever comes first. The net is then pulled parallel to shore to sweep the largest area possible and returned to the beach. All fish captured are sorted and counted by species.

A random subsample of up to 30 individuals is measured for species of interest. Select species are separated into age 0 and age 1+ groups. Ages are assigned from length frequencies and verified by direct examination of scales. Additional data collected at each site include: time of first haul, maximum distance from shore, surface water temperature, surface salinity, primary and secondary substrates types, percent submerged aquatic vegetation, dissolved oxygen, pH, and turbidity.

Annual indices of relative abundance were calculated as the non-stratified Geometric Mean catch per haul of YOY bluefish using data from July-September (Table B6.1, Figure B6.9). Age was assigned by length frequency, with 250 mm FL used as a cutoff for age 0 fish. Attempts at index standardization did not improve indices, so the design-based survey index was recommended.

B6.1.9 NEAMAP Mid-Atlantic/Southern New England Nearshore Trawl Survey

The Northeast Area Monitoring and Assessment Program, Mid-Atlantic/Southern New England Nearshore Trawl Survey (hereafter, NEAMAP) has been sampling the coastal ocean from Martha's Vineyard, MA to Cape Hatteras, NC since the fall of 2007 (Figure B6.10). NEAMAP conducts two cruises per year, one in the spring and one in the fall, mirroring the efforts of the Northeast Fisheries Science Center (NEFSC) Bottom Trawl Surveys offshore. Spring cruises begin during the third week in April and conclude around the end of May, while the fall surveys span from the third week in September until the beginning of November. Sampling progresses from south to north in the spring and in the opposite direction in the fall, so as to follow the general migratory pattern of the living marine resources of these regions.

The survey area is stratified by both latitudinal/longitudinal region and depth. Depth strata between Montauk, NY and Cape Hatteras are 6.1m-12.2m and 12.2m-18.3m, while those in Block Island Sound and Rhode Island Sound are 18.3m-27.4m and 27.4m-36.6m. It is worth noting that, between Montauk and Hatteras, the outer boundary of the NEAMAP Survey any the inner boundary of the NEFSC Survey align. Both programs sample in Block Island Sound and Rhode Island Sound.

Sampling sites are selected for each cruise using a stratified random design; site allocation for a given stratum is proportional to the surface area of that stratum. A total of 150 sites are sampled per cruise, except 160 sites were sampled in the spring and fall of 2009 as part of an investigation into the adequacy of the program's stratification approach. A four-seam, three-bridle, 400x12cm bottom trawl is towed for 20 minutes at each sampling site with a target speed-over-ground of 3.0kts. The gear is of the same size as and nearly identical in design to that used by the NEFSC survey, only sweep configuration and trawl door type differ between the two programs. Tow times and tow speeds are consistent between the two programs. The net is outfitted with a 2.54cm knotless nylon liner to retain the early life stages of the various fishes and invertebrates sampled by the trawl. Trawl wingspread, doorspread, headline height, and bottom contact are measured during each tow, and those in which net performance falls outside of defined acceptable ranges are either re-towed or excluded from analyses in an effort to maintain sampling consistency. A number of hydrographic variables (profiles of water temperature, salinity, dissolved oxygen, and photosynthetically active radiation [PAR]), atmospheric data, and station identification information are recorded at each sampling site.

Following each tow, the catch is sorted by species and, if appropriate, by size group within a species. Size groups are not predetermined for each species, but rather are defined relative to the size composition of that species for that tow. As such, size designations and ranges of small, medium, and large for a species may vary somewhat among tows. Such an approach facilitates representative subsampling, and therefore proper catch characterization, for each tow.

A subsample of five bluefish is selected from each size group from each tow for full processing. Specifically, individual fork length (mm), whole and eviscerated weight (kg), sex, and maturity stage are recorded. Stomachs are removed for diet analysis and otoliths are removed for age determination. For specimens not taken for full processing, aggregate weight and individual fork length measurements (mm) are recorded by size group.

While bluefish are sampled during both spring and fall cruises, catches are more sporadic during the spring survey. Specifically, bluefish have been encountered on only 6.5% of tows on average during the spring cruises, with cruise-specific encounter rates ranging from 4.6% to 9.4%. Although a relatively broad size (106 mm FL to 770 mm FL) and age (age-1 to age-9) range of bluefish have been sampled over the course of the NEAMAP spring surveys, individual catches are typically very small, with 97.8% of tows comprised of two or fewer bluefish. In contrast, bluefish have been encountered on 70.5% of fall tows overall, and this rate has ranged from 62.7% to 79.3% among cruises. Spatially, the percentage of tows in which bluefish were collected by survey region has varied between approximately 53.7% and 91.1%. The size and age ranges sampled during fall cruises are similar to those seen on spring surveys (65 mm FL to 785 mm FL; age-0 to age-10, respectively), but the fall cruises typically yield a greater number of bluefish per tow than do the spring surveys. While only 2.2% of spring tows were comprised of greater than two bluefish, 53.8% of fall tows yielded more than 2 specimens, by comparison.

Bluefish abundance indices as measured by the NEAMAP survey included all ages, all strata, but were limited to fall surveys only. Specifically, a geometric mean catch per standard area swept (Table B6.1) was determined for each year (fall only) by:

$$\hat{N} = \exp\left(\sum_{s=1}^{n_s} \hat{A}_s \hat{\bar{N}}_s \right)$$

where n_s is the total number of strata in which the species was captured, $\hat{A}_s$ is an estimate of the proportion of the total survey area in stratum *s*, and $\hat{\bar{N}}_s$ is an estimate of the $\log_e$ transformed mean catch (number or biomass) of the species per standard area swept in stratum *s* during that cruise. The latter term is calculated using:

$$\hat{\bar{N}}_s = \frac{\sum_{t=1}^{n_{t,s}} \log_e \left(\frac{c_{t,s}}{\hat{a}_{t,s}/25000} \right)}{n_{t,s}}$$

where $\hat{a}_{t,s}$ is an estimate of the area swept by the trawl (generated from wing spread and tow track data) during tow *t* in stratum *s*, 25,000m^2 is the approximate area swept on a typical tow (making the quantity [$\hat{a}_{t,s}$ / 25000] approximately 1), $n_{t,s}$ is the number of tows *t* in stratum s that produced the species of interest, and $c_{t,s}$ is the catch of the species from tow *t* in stratum *s*.

B6.1.10 VIMS Juvenile Striped Bass Seine Survey

The Virginia Institute of Marine Science (VIMS) initiated a seine survey in 1967 designed to monitor the abundance of juvenile striped bass in the James, York, and Rappahannock Rivers, as well as in the main tributaries of these systems (Figure B6.11). While primarily designed to collect striped bass in the shore zones, this survey also has consistently sampled bluefish throughout its time series. Specifically, sampling of fixed sites has occurred twice per month during the months of July, August, and September from 1967-1973 and again from 1980 to the present.

At each site, a 30.5m long by 1.2m deep bagless seine (0.64cm bar mesh) is deployed perpendicular to the shore and then swept back to the land, resulting in the sampling of a quarter-circle quadrant. Two tows are made at each "index" sampling site, while a single sweep is made at auxiliary locations. The two index tows are separated by a minimum of a half hour. Length measurements (mm, fork length) are recorded for up to 25 bluefish per tow. If greater than 25 specimens are collected, the remainder are counted.

In developing an index of abundance (Table B6.1) for young-of-the-year (YOY) bluefish from this survey, areas in which this species have never been encountered (i.e., freshwater reaches of tributaries) were removed from the dataset. All months were included, and bluefish less than 260 mm FL were considered YOY. Overall, since 1981, bluefish have been encountered on 5.5% of the seine tows. This encounter rate varied between 0% and 17.5% across years, and 4.7% and

6.5% among the bi-monthly sampling rounds. Catches ranged from 0 to 19 bluefish. The YOY index of abundance was calculated as geometric mean catch-per-tow and, while variable throughout the time series, seem to show relatively few instances of large recruitment after 1997.

B6.1.11 NC Pamlico Sound Independent Gill Net Survey

The North Carolina Division of Marine Fisheries (DMF) Pamlico Sound Independent Gill Net Survey was initiated on March 1, 2001 and field sampling began in May 2001. The primary objective of the project is to provide independent relative abundance indices for key estuarine species in Pamlico Sound and adjacent rivers.

A stratified random sampling design is used, based on area and water depth. The SAS procedure PLAN was used to randomly select sampling grids within each area (SAS Institute 1985). Sampling gear consists of an array of nets consisting of 30-yard (27.4 m) segments of 3, 3½, 4, 4½, 5, 5½, 6, and 6½ inch (7.6, 8.9, 10.2, 11.4, 14.0, 15.2, 16.5 cm) stretched mesh webbing [240 yards (219.5 m) of gill net per sample]. Gear was typically deployed within an hour of sunset and fished the following morning to keep all soak times at a standard 12 hours.

For every random grid selected, both a deep (1.8 m contour) and shallow array of nets are set. Some deep grids outside the 1.8 m contour were dropped in 2005 due sea turtle interactions and low catch rates of target species. The PSIGNS study is divided into two regions that includes eastern Pamlico Sound and western Pamlico Sound.

Floating gill nets are used to sample shallow strata while sink nets are fished in deep strata. Catches from an array of gill nets comprised a single sample and two samples (one shall, one deep), totaling 480 yards (438.9 m) of gill nets fished, are completed in each field trip.

Sampling initially occurred during all 12 months of the year. This was changed in 2002 and sampling no longer occurs between December 15 - February 14 due to extremely low catches and unsafe working conditions (limited daylight hours and cold temperatures) for the technicians.

Each area within a region is sampled twice monthly during most of the year. This sampling design results in a total of approximately 32 gill net samples (16 deep and 16 shallow samples) being collected per month in each the PSIGNS areas. Beginning in 2011, Area 1 of Region 1 is not sampled during the months of June through August. This reduction in sampling results in loss of 12 samples per year.

Catch rates of bluefish are calculated annually and expressed as an overall CPUE along with corresponding length class distributions. The overall CPUE provides a relative index of abundance showing availability of each species to the study, while the length distribution and age CPUE estimates show the size structure of each species for a given year. The overall CPUE was defined as the number of a species of fish captured per sample and was further expressed as the number of a species of fish at length per sample, with a sample being one array of nets fished for 12 hours. Due to disproportionate sizes of each stratum and region, the final CPUE estimate was weighted. The total area of each region by stratum was quantified using the one-minute by one-minute grid system and then used to weight the observed catches for calculating the abundance indices. Based on these modifications, uniform weighting factors by region and strata were applied to all years and were as follows:

Eastern Pamlico 1: Shallow water - 134.5 square nautical miles (461.9 square km)
Eastern Pamlico1: Deep water - 70.5 square nautical miles (242.1 square km)
Western Pamlico 2: Shallow water - 82.5 square nautical miles (283.3 square km)
Western Pamlico 2: Deep water - 54.5 square nautical miles (187.2 square km)

The CPUE for each age is calculated as an arithmetic mean weighted by strata (Table B6.1, Figure B6.12). The length frequency was determined for both seasons (spring, February – June, and fall July – December), and all four strata. The seasonal Catch-at-age (CAA) was estimated for both seasons using the seasonal length frequencies with seasonal age-length-keys (ALKs). The annual CAA was calculated by number of fish at each age for spring and fall. The annual CAA, in each stratum was multiplied by the stratum weight, and added across stratum to produce the weighted estimate for each age. The weighted estimate for each age is then divided by the total number of samples summed across all strata, producing a weighted annual CPUE for each age. All ages and sizes available were used to calculate the CPUE.

B6.1.12 SEAMAP

The Southeast Area Monitoring and Assessment Program (SEAMAP) fishery-independent trawl survey has sampled the coastal zone of the South Atlantic Bight between Cape Hatteras, North Carolina and Cape Canaveral, Florida since 1989. Its primary intent is to sample the coastal zone of the South Atlantic Bight (SAB) between Cape Hatteras, NC, to Cape Canaveral, FL.

A stratified random sampling design is used, based on area and water depth. For this design, coastal waters of the SAB are divided into 24 coastal latitudinal strata bounded inshore and offshore by the 4 m and 10 m depth contours, respectively. During each sampling season, a random subset of stations within each strata are selected for sampling using paired 75-ft (22.9 m) mongoose-type Falcon trawl nets towed for 20 minutes at 4.6 km/hr (2.5 knots).

Since the inception of the program the SEAMAP-SA Coastal Trawl Survey has used the R/V Lady Lisa to conduct annual surveys of finfish and invertebrate species. During each season, at each randomly selected station the SEAMAP-SA Coastal Trawl Survey deploys paired 75-ft (22.9 m) mongoose-type Falcon trawl nets to conduct bottom trawl surveys. At each randomly selected station, a bottom trawl is conducted by deploying the paired nets for 20 minutes at a constant speed of 4.6 km/hr (2.5 knots). Data elements include numbers caught by species, individual fork lengths (FL; nearest cm), and a suite of environmental information including bottom and sea surface water temperature, depth, and salinity.

The survey is conducted seasonally, with a spring (mid-April to mid-May), summer (mid-July to mid-August), and fall (late-September to mid-November) cruise annually. During each cruise, 52-112 stations between North Carolina and Florida (Figure B6.13) are selected for sampling via optimal allocation among strata for a total of approximately 158-336 stations sampled annually. The proportion of positive tows for age-0 Bluefish averaged approximately 27% across the time series for the fall survey. Index values are provided in Table B6.1.

B6.2 General Survey Results
Correlations among survey indices at age are shown in Figure B6.15. Of 131 comparisons (pairwise n > 0), 89 were positive and 40 were negative. Positive correlations outnumbered negative correlations for all ages except age 0.

Biases

All surveys were designed to sample either species in addition to bluefish or species other than bluefish. However, the BCT set a minimum for % positive tows and minimum for consecutive years of sampling (to eliminate intermittent sampling), consistent with other species (e.g., black sea bass, Atlantic menhaden, tautog), to help ensure surveys were representative of bluefish abundance. In several instance indices were standardized (e.g., RI and SEAMAP), but biases could result if important factors that affect standardization were not included. In most cases, the standardized index and the design-based index resulted in nearly identical trends.

B6.3 Composite YOY Index
States from New Hampshire to Virginia conduct seine surveys for juvenile finfish that capture YOY bluefish (Figure B6.14). These surveys are noisy and cover small geographical areas, compared to the range of bluefish. Bayesian hierarchical modeling was used to combine these indices into a single composite index, using the method developed by Conn (2010), that represents the coast wide recruitment dynamics of bluefish. Surveys included in the composite index were from NH Juvenile Finfish Seine Survey, RI Narragansett Bay Juvenile Finfish Beach Seine Survey, NY Western Long Island Seine Survey, NJ Delaware Bay Seine Survey, MD Juvenile Striped Bass Seine Survey, and VIMS Juvenile Striped Bass Seine Survey (Figure B6.16).

Conn’s (2010) method assumes that all indices are tracking the abundance of recruits, but are also influenced by sampling error and process error (e.g., sampling different components of the coastwide recruit population).

$$\log(U_t) = Normal(\log(\mu_t) + \log(q_{it}), (\sigma_{it}^{p})^2 + (\sigma_{it}^{p})^2)$$

A Bayesian analysis was performed to estimate the true trend in relative abundance of recruits as well as the process error and catchability associated with each survey. The input parameters and priors were chosen to be the same as Conn (2010) and the Atlantic Menhaden assessment (SEDAR 2015) used.

A Normal(log(100), 1) distribution was chosen for $\nu_t = \log(\mu_t)$ The mean of this distribution, log(100), was chosen so that the mean of the relative abundance time series would be approximately 100. This number is arbitrary, since we are interested in the trends in relative abundance, not the actual number.

For catchability, which is assumed constant and estimated in log-space, χ_i was set as χ_i = Normal(log(0.01), 0.5), which gives reasonable support to plausible parameter values.

Finally, for process error, Gelman (2006) suggests that a Uniform(0,m) distribution may outperform other choices when there is a small number of group effects. We specified a Uniform(0, 5) prior distribution for σ^p, which gives equal weight to all plausible precision values.

The observed CVs from the surveys was used as the input sampling error. Zero observations were treated as missing data.

All posterior simulation was performed using the software package WinBUGS (Lunn et al. 2000), with the package R2WinBUGS (Sturtz et al. 2005) used to pass data sets between WinBUGS and the R programming environment (R Development Core Team 2007). Standard Bayesian diagnostics were used to assess convergence and stability of results.

The final composite index (Table B6.3) tracked several consistently strong recruitment events that were registered by multiple surveys, and smoothed out the noise somewhat in years with weaker signals (Figure B6.16).

B6.4 MRIP CPUE

The MRIP intercept data was queried to develop a set of directed bluefish trips, defined as any trip that caught bluefish (regardless of disposition) or where the angler reported targeting bluefish. This resulted in a total of 208,947 trips with the complete suite of explanatory variables, of which 46.2% were positive bluefish trips (Figure B6.17 and B6.18).

Factors considered for standardization included:

- Year
- Wave
- Mode (Shore, For Hire, Private/Rental Boat)
- Area Fished (Inshore, Offshore)
- State (Maine – Florida)
- Avidity (number of days that the angler reported fishing in the past year)

An interaction term between State and Wave was also considered, but the model did not converge with that included. The log of effort (number of contributing anglers) was treated as an offset in the models. GLMs using a Poisson distribution and a negative binomial distribution were explored, as well as a zero-inflated model.

Initial model comparisons suggest a negative binomial distribution is more appropriate than a Poisson distribution. (Dispersion = 1.62 with the negative binomial distribution vs. 9.76 with the Poisson distribution; likelihood ratio test of overdispersion of count data was significant at $p < 0.0001$). The zero-inflated model did not converge. The negative binomial was chosen as the final standardization approach, although there is still some overdispersion in the data (Figure B6.19).

All factors were significant for the negative binomial model. However, Area Fished reduced the deviance by less than 5% (Table B6.4) and was dropped from the model. This also resulted in a lower AIC value compared to the full model. The final GLM-standardized estimates of catch-per-unit-effort from the MRIP survey are provided in Table B6.5.

The MRIP CPUE shows a decline in catch per trip during the 1980s and mid-1990s, before rebounding in the late 1990s to fairly stable levels since 2000 (Figure B6.20).

B6.5 Spatial distribution of stock over time

For SAW60 Manderson et al. (2015; WP B4) investigated bluefish distributions and the degree to which spatial distribution shifts were statistically related to changes in ocean temperature, abundance and body size. Manderson et al. (2015) also described the development and evaluation of time varying estimates of the proportion of thermal habitat suitability for bluefish sampled on the NEAMAP & NEFSC bottom trawl surveys that could be used to account for effects of ocean temperature on the availability of the population to surveys in the stock assessment. The details are available in WP B4.

Within the NEFSC survey, age 0 (≤ 28 cm) and age 1+ bluefish (> 28 cm) shifted distribution from 1973 through 2014 but not in a systematic direction. Analysis of the centers of biomass (COB) indicated that COB positions were correlated with variations in body size and abundance, but not temperature. A parametric thermal niche model for bluefish using data from the NEFSC and NEAMAP bottom trawl surveys from 2008-2014 was used to evaluate with data collected by NEFSC before 2008 and 6 inshore surveys performed on along the US east coast at locations ranging from Jacksonville, Florida to Massachusetts. The model estimated that ~44% of thermal habitat suitability available from Cape Hatteras to Nova Scotia was sampled by the NEFSC inshore and “offshore” inshore strata to be used in the 2015 assessment. In the NEAMAP survey ~20% of available thermal habitat suitability on the northeast US shelf was sampled. Yearly estimates of the proportion of thermal habitat suitability surveyed did not exhibit consistent trends (Figure B6.21).

B6.6 Age-length data and utility of age data for stock assessment

As noted elsewhere in this document (TOR 2), the WG expended considerable effort investigating age length data and evaluating the utility of age length keys for use in this assessment. The WG could not recover any age data from 1982 (the first year in the SAW41 model) and determined that age data were too sparse from 1983 and 1984 to be considered reliable. Consequently, the WG elected to start the model in 1985.

NC scale and otolith data from early in the time series (1985-2000) required adjustments prior to their eventual use in this assessment. The SAW41 assessment document suggested that the raw spring NC data used a January 1 birthday and that other sources of spring data were incompatible with the NC data, but the WG determined that the reverse situation existed. The WG graphically demonstrated that a birthday problem existed with the spring early NC scale and otolith data (Figure B6.22, Figure B6.23), subsequently demonstrated that a birthday problem did not exist in other sources of spring data, and ultimately used all sources of age data with a January 1 birthday to inform a reclassification of spring NC age data (see WP B6 for more details).

In response to concerns expressed at SAW41 about sharing data across time, the WG conducted an analysis (WP B8) and quantitatively determined that in general sharing age data across time should be avoided. This put the WG in the position to have to either reclassify spring NC age data on an annual basis where sample sizes were small, not use spring NC age data (which would have truncate the time series considerably), or pool spring January 1 birthday data to inform reclassifying spring NC data. The WG felt comfortable that the adjustment algorithm3 provided reliable results (Figure B6.24) and was a superior outcome to the alternatives of further truncating the times series (especially in light of available data from 1997-2005) or using the raw data. It is important to note that all fall data used a January 1 birthday and therefore required no adjustments.

Age data from 1997-2004 garnered a lot of attention from reviewers at SAW41 (Jones 2005). An additional source of age data from this time period was evaluated by the SAW60 WG and used for the present assessment. As noted above, NC otolith data from 1996-2000 was considered incompatible with existing data for SAW41; but the SAW60 WG determined that with the exception of spring age 0 fish (Figure B6.23), which were changed to age 1 based on biological considerations, those data could be used for this assessment. This addition allowed for some disaggregation of multi-year spring keys (Table B5.2), however, since no additional sources of fall data were available for the same years, the SAW60 WG was not in a superior position with respect to the age data for this general time period. In terms of utility for stock assessment, the WG elected to set effective sample sizes to a low value for this time period (1997-20044) in acknowledgement of the data uncertainty. See TOR4 for more details.

The situation for age data in the years following SAW41 is very good. Beginning in 2006 NC resumed a bluefish biological collection program. Substantial numbers of bluefish otoliths have been collected as part of this program (Table B6.6). In an effort to further improve coast wide age length keys, MA initiated its own biological collection program in 2009, and NJ followed in 2010. In 2012, Addendum to Amendment 1 to the bluefish fishery management plan required additional states (those that accounted for >5% of total coast-wide bluefish harvest) to collect a minimum of 100 bluefish ages (50 from January - June; 50 from July - December), further improving the quality of age length keys. These additions to the coast wide biological collection program have greatly improved the age length keys for use in this assessment (Figure B5.3 and B5.4 and WP B5).

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3 Briefly, based on biological considerations, all NC spring age 0 fish were changed to age 1. For all other ages, save 6+ which would not require any adjustments, from all data (by age) known to have a January 1 birthday, use the mean + $t_{0.05(2)}$ * SD (~ 2 * SD) of age i fish as the criterion to determine whether NC spring fish become age i+1. That is, for example, if the length of an age 1 NC fish was > the mean + $t_{0.05(2)}$ * SD of all other data sources of age 1 spring fish, the NC fish age would change to 2.
4 The WG also used a low ESS for 1995, which had a very sparse spring ALK (Table B5.3).

B7. TERM OF REFERENCE #4: Estimate relative fishing mortality, annual fishing mortality, recruitment, total abundance, and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Explore inclusion of multiple fleets in the model. Include both internal and historical retrospective analyses to allow a comparison with previous assessment results and previous projections. Explore alternative modeling approaches if feasible.

B7.1 Bluefish SAW 60 Assessment model

B7.1.1 History of the current (SAW41) bluefish assessment model

The current assessment model for bluefish has provided management advice since 2005 and was accepted at the Stock Assessment Workshop 41 review (NEFSC 2005). After reviewing several model types including a modified Delury model, a surplus production model, a VPA and catch-at-age models, the bluefish Technical Committee concluded that age-based models such as a VPA or catch-at-age were the most appropriate for the bluefish assessment. The bluefish data were truncated to an age-6+ category to reduce the influence of ageing error. In addition, the catch-at-age distribution in past assessments was bimodal, which was reduced with inclusion of more ages into a plus group.

The NFT ADAPT version of VPA was used as an initial model with a catch-at-age matrix from 1982 to 2004 through age-6+. The SAW-17 review of a bluefish assessment suggested that values of M should range from 0.2-0.25 instead of M=0.35 (NEFSC 1994a). Since the oldest aged bluefish is 14, an M of 0.2 was appropriate, using M=3/oldest age. The initial input PR was bimodal with a maximum value at age-1 of 1.0 and age-5 value of 0.74. The F ratio was set at 1.4 to create a higher F in the age-6+ group, forcing the model towards a bimodal F pattern. Full F was calculated as an average of F from age-2 to age-4.

Maturity at age was held constant over time as 0 at age-0, 0.25 at age-1, 0.75 at age-2 and 1.0 thereafter. Following initial runs including all available indices, the tuning indices were truncated based on proportional variance contributions to the overall model variance. The final tuning indices were limited to those with adults present:

1. NEFSC inshore (age-0 – age-6+)
2. CT trawl indices (age-0 – age-6+)
3. NJ trawl indices (age-0 – age-2)
4. DE adult trawl indices (age-0 – age-2)
5. Recreational CPUE (age-0 – age-6+)
6. SEAMAP series to include an age-0 recruitment series from the South Atlantic Bight.

Tuning was made to mid-year population size.

The Technical Committee concluded that although the VPA produced satisfactory results, the assumption of no error in the catch-at-age matrix and the way ADAPT handles selectivity may produce misleading results. Therefore, a catch-at-age model, ASAP from the NFT models, was chosen as the primary assessment tool. The ability of the ASAP model to allow error in the catch-at-age as well as the assumption of separability into year and age components makes it better suited to handle the selectivity patterns and catch data from the bluefish fishery.

The input values from ADAPT were used as initial values for the ASAP model. ASAP allows selectivity and catchability patterns to vary over time. The model was structured to allow greater deviations from the indices than from the catch-at-age data. A selectivity pattern was fitted to the data and held constant for the periods 1982-1990, 1991-1998 and 1999-2004. Recruitment was allowed to deviate from the fitted model after the 4th year. Full details of the SAW41 model characteristics and settings are provided in the 'SAW60 Model Building' section under 'Update the current model.'

The Bluefish Technical Committee concluded that the results of the ASAP model were the best representation of the Atlantic coast bluefish population. There was some tradeoff in the goodness of fit between the catch-at-age and survey indices in the model, but the overall model results were considered acceptable. The results also corresponded well to ADAPT model results. Although the agreement between models did not validate either model, it indicates that there was some signal in the data that could produce consistent output in two models with different assumptions. The model results lead to the conclusion that the Atlantic stock of bluefish was not experiencing overfishing nor was it overfished.

B7.2 SAW60 Model Building Introduction

The SAW60 model building procedure for bluefish was accomplished over multiple steps. The first step was to carry out a continuity run, which updated the current assessment model with data through 2014. A base model was then constructed by adding new data (CAA, WAA, and maturity) and indices to the continuity run, keeping the same model settings and weights. A model bridge was then built from the base model to a final model by changing model settings, weights, and data. In total, about 75 models were explored during this bridge building procedure. The model steps with the most important changes that provide a linear path from the base model to the final model are presented below. Table B7.1 provides a brief model description and a summary of the important parameters at each step.

The SAW60 working group maintained ASAP as the model for assessing bluefish. ASAP is an age-structured model that uses forward computations assuming separability of fishing mortality into year and age components to estimate population sizes given observed catches, catch-at-age, and indices of abundance. The separability assumption is partially relaxed by allowing for fleet-specific computations and by allowing the selectivity-at-age to change in blocks of years. Weights (Lambda and input CVs) are input for different components of the objective function which allows for configurations ranging from relatively simple age-structured production models to fully parameterized statistical catch-at-age models. The objective function is the sum of the negative log-likelihood of the fit to various model components. Catch-at-age and survey age composition are modeled assuming a multinomial distribution, while most other model components are assumed to have lognormal error. Specifically, lognormal error is assumed for: total catch in weight by fleet, survey indices, stock recruit relationship, and annual deviations in fishing mortality. Recruitment deviations are also assumed to follow a lognormal distribution, with annual deviations estimated as a bounded vector to force them to sum to zero (this centers the predictions on the expected stock recruit relationship). For more technical details, the reader is referred to the technical manual (Supporting documentation: ASAP manual, Legault 2012).

B7.3 Building a model bridge from the current model to the final model

B7.3.1 Update the current model through 2014: Model B001: Continuity Run

The current model for bluefish is heavily weighted towards the catch. Recreational landings, recreational discards, and commercial landings are input into the model as a single fleet. The input CV around catch is set at 0.01 and the effective sample size is constant at a value of 30. The model weighting parameter (lambda) for the catch is set at twice the value of the indices. Selectivities are fixed for both catch and the indices and multiple penalties constrain different estimates included in the objective function. These include penalties on recruitment deviations, FMult in the first year, index catchabilities, and numbers in the first year. A stock recruitment relationship is not fit in the model and steepness is fixed at a value of 1. The weighting factors and penalties in the continuity run result in a very constrained model.

Model B001, the continuity run, is the first model explored in the model building process for SAW 60. The continuity run was carried out as update of the SAW41 final model. Total catch, catch-at-age, weight-at-age, and indices-at-age were updated for 2014. The fishery was modeled as a single fleet with selectivity fixed as a bimodal pattern with full recruitment at age 1 (selectivity values = 0.338, 1.0, 0.942, 0.476, 0.343, 0.694, and 0.914, for ages 0-6+, respectively). In addition, 6 indices of abundance were updated for 2014:

1. NEFSC inshore (age-0 – age-6+)
2. CT trawl indices (age-0 – age-6+)
3. NJ trawl indices (age-0 – age-2)
4. DE adult trawl indices (age-0 – age-2)
5. Recreational CPUE (age-0 – age-6+)
6. SEAMAP series to include an age-0 recruitment series from the South Atlantic Bight.

Indices were input at age with full selectivity (1.0) fixed on the input age. Natural mortality was kept constant at 0.2 for all ages and all years. Maturity was fixed across years at a value of 0 for Age 0, 0.25 for Age 1, 0.75 for Age 2, and full maturity at Age 3+. Complete model specifications and weightings for model B001 are presented in Table B7.2.

The component contribution of the objective function for model B001 show how the model is weighted very heavily towards the single catch fleet (Figure B7.1). Estimates from the model show a decrease in total abundance since 2006, declining from 83.6 million to 57.7 million fish (Figure B7.2). Following a peak in recruitment in 2006 of 30.8 million fish, recruitment has remained below the time series average of 20.5 million, and stays below average in 2014 at an estimate of 14.7 million fish (Figure B7.3). Total biomass in 2014 (Jan 1) equaled 92,755 mt, a slight decrease from the 2013 estimate of 107,443. Corresponding spawning stock biomass (SSB) in 2014 was 84,800 mt, a slight decrease from the 2013 estimate of 98,070 mt (Figure B7.4).

The 2014 F_{MULT} value equals 0.141. Fishing mortality steadily declined from 0.35 in 1987 to 0.12 in 2012 and has increased over the past two years (Figure B7.5).

Retrospective bias for the continuity run was examined for F, SSB, and recruitment (Figure B7.6). The analysis shows consistent but minor bias in the estimates of F and SSB, with Mohn's rho values of -0.09 and 0.10, respectively. A more prominent retrospective bias is present in the recruitment estimates going back to the early 2000's (Figure B7.6). This bias has been increasing in recent years, and has flipped from a positive bias early on to negative bias more recently (Mohn's rho avlue = -0.19). The variation in the final continuity model estimates for F and SSB was determined using a Monte Carlo Markov Chain with 1000 iterations and a thinning factor of 100. The MCMC distribution for SSB ranged from 74,656 to 98,154 mt, with an 80% CI between 79,384 mt and 89,590 mt. (Figure B7.7). The MCMC results of variation around F ranged from 0.12 to 0.161, with the 80% CI between 0.132 and 0.150 (Figure B7.8).

Model B002: Cropping the continuity run to start in 1985

The working group re-built catch-at-age and weight-at-age information back to 1985 using all available age data and length samples. The working group was unable to find original age length keys and was unable to find raw age data from 1982-1984. Instead of using the current CAA and WAA information from those years (carried over from SAW41) the working group made the decision to start the new model in 1985. Model run B002 examines the effects of cropping off data from 1982-1984 on the continuity run. The main effect of starting the model in 1985 was to shift recruitment and total stock numbers upwards. F, SSB, and TSB increased minimally while TSN (000s) increased from 57,671 to 70,867, and recruitment (000s) increased from 14,696 to 21,528 (Table B7.1).

B7.3.2 Moving from the continuity run to a final model

Model B004: Base Model

The base model run uses continuity model specifications with newly calculated CAA, WAA, and total landings data from 1985-2014, and new survey indices of abundance. The new indices of abundance are input at age to maintain consistency with the continuity run. The bluefish working group decided on 9 representative indices of bluefish abundance for the SAW60 assessment:

1. NEFSC Fall inner inshore strata: 1985-2008 (age-0 – age-6+)
2. NEFSC Fall outer inshore strata: 1985-2014 (age-0 – age-6+)
3. Marine Recreational Information Program CPUE: 1985-2014 (age-0 – age-6+)
4. NEAMAP Fall Inshore trawl survey: 2007-2014 (age-0 – age-6+)
5. Connecticut Long Island Sound Trawl Survey: 1985-2014 (age-0 – age-6+)
6. Pamlico Sound Independent Gillnet Survey; 2001-2014 (age-0 – 6+)
7. New Jersey Ocean Trawl Survey: 1990-2014 (age-0 – age-2)
8. SEAMAP Fall Inshore trawl survey: 1989-2014 (age-0)

9. Composite YOY seine survey: 1985-2014 (age-0)

In past stock assessments, the instantaneous natural mortality (M) for bluefish has been assumed constant over all ages and years at a value of 0.2. This study used longevity and life-history based equations to estimate different possible values for M. Taking the maximum age for bluefish to be 14 years (observed age in the data used in these analyses), the ‘Rule of thumb’ method (3/tmax) give a natural mortality estimate of 0.21. Additional longevity based estimates from equations in Hoenig (1983) and Hewitt and Hoenig (2005) give values of 0.32 and 0.3, respectively. Estimates based on equations that use growth parameters from Then et al. (2014) and Jensen (1996) give values of 0.20 and 0.195, respectively. The mean value for natural mortality using the estimates from these 5 approaches is 0.245. Age-specific estimates were calculated using based on the work of Lorenzen (1996, 2000) and Gislason et al. (2010). These values ranged from 1.70-0.17 over the age range of 0-14 (Table B5.5). Based on the results of all the methods explored to estimate natural mortality for bluefish, the assumption of M = 0.2 is reasonable and is maintained for the benchmark assessment.

The results from the base model are very similar to the continuity run (B001), and differ in total number and recruitment estimates when compared to model B002. Using the newly calculated data and new indices in model B004 resulted in almost no change in the 2014 F between model B002 (F = 0.145) and model B004 (F = 0.146). However, estimates of F from model B004 were consistently higher from 2002 to 2013 (Figure B7.9). Total stock numbers (000s) decreased from 70,867 to 57,534, and recruitment estimates (000s) decreased from 21,528 to 15,731. These changes are driven by lower estimates of Age 0 through Age 2 numbers from the new data (Table B7.1 and Figure B7.10).

Model B006: Change indices from at-age to estimate age composition

The preferred approach for including survey indices of abundance in ASAP has shifted from at-age input to a catch-at-age matrix input. In this model run, the new input survey indices are shifted from at-age to a catch-at-age matrix, and are modeled with multinomial error to estimate proportions at age. The total numerical index for each survey is modeled with lognormal error to estimate overall population trend. Young of the year indices (SEAMAP and the composite YOY index) are still input at-age.

Estimating age composition for each of the survey indices in model B006 resulted in a noticeable increase in all 2014 model estimates except for F. The objective function increased considerably and while a direct comparison cannot be made to the objective function from model B004, the increased contribution of the index fit and index age composition is important to note. This model, while still heavily weighted towards the catch is now being driven more by the indices (Figure B7.11). The estimate of F decreased to 0.119, and estimates for total stock numbers, spawning stock biomass, total stock biomass, and recruitment all increased considerably. The scale of total biomass and spawning stock biomass was shifted downwards at the beginning of the time series resulting in flatter trends from 1985-2014 (Table B7.1, Figure B7.12). Figure B7.13 shows the estimates for index selectivity from model B006.

Model B007: From single catch fleet to two fleets: Commercial and Recreational

The fishery for bluefish is predominantly a recreational fishery (80+%) and the recreational data on landings, lengths, and discards are collected very when compared to the commercial fishery data. There is enough information for both fisheries to build separate catch-at-age, weight-at-age and total landings time series. Model B007 separates the single fleet fishery into a commercial and recreational fleet. Incorporating multiple fleets addresses a specific portion in term of reference 4 which tasks the working group to "Explore inclusion of multiple fleets in the model." In addition, it is more appropriate method for modeling the bluefish stock because of the differences between the fisheries.

Separating the fleet data into two fisheries scaled up the entire time-series of fishing mortality estimates and decreased estimates of total stock numbers and biomass (Table B7.1, Figure B7.14). The recruitment time-series from model B007 is similar to model B006 but seems to be smoothed at the end of the time series (Figure B7.15).

Model B008: Update maturity information

Maturity-at-age was updated from a preliminary analysis of data presented in the section and working paper for TOR2. Estimates of maturity-at-age for bluefish have persisted from the 2005 ADAPT VPA model (modeling work prior to the final SAW41 ASAP model) where values were (arbitrarily?) chosen to be: 0, 0.25, 0.75, and 1.00 for ages 0 to 3+, respectively. For this model run a maturity ogive was fit using logistic regression to a preliminary bluefish age/maturity dataset and the estimates of: 0, 0.41, 0.86, and 1.00 for ages 0 to 3+, respectively, were used. It should be noted that further along in the model building process final estimates for the maturity ogive were used (model B023). At this step, the new maturity information was not that different from the maturity-at-age previously used, and only resulted in a slight increase in spawning stock biomass (Table B7.1, Figure B7.14).

Model B011: Change from fixed fleet selectivities to estimated

Prior to model B011, fleet selectivity has been fixed assuming a bi-model selectivity at-age carried over from SAW41. The bi-modal selectivity pattern for the bluefish fishery has been present since the beginning of the assessment time-series. This pattern has been observed in both commercial and recreational length frequencies and as a result in the CAA matrix input to the model. There is a dynamic of the bluefish population that occurs at age 3 – age 4 that is unobserved and likely affects availability of the population at these ages. Bluefish carry out sized based migrations so a larger portion of the population at these ages may be staying south or offshore each year. Since the main fisheries for bluefish are coastal and operate north of Cape Hatteras, North Carolina this would result in reduced available of this size/age class.

Model B011 estimates fleet selectivites and assumes starting values equal to the previously fixed values. Full selectivity is fixed at age 1 in both the commercial and recreational fleet. Estimated selectivities for both fleets maintain a bi-modal pattern, with the recreational fleet having higher selectivity at all ages (Figure B7.16). Estimates of F slightly increased in model B011 to a value of 0.145. Total stock numbers, recruitment, and biomass estimates increased at a larger scale as a result of estimating fleet selectivities (Table B7.1).

Model B020: Estimate 2 selectivity blocks per fleet

A number of model iterations were conducted that investigated different selectivity blocks for each fleet between model B011 and B020. The working group decided to continue the model building process with two selectivity blocks per fleet: 1985-2005, 2006-2014. These blocks were chosen based on data quality assumptions associated with age data early on in the time series (scale age data) versus later in the time series (otolith age data). The working group put a great deal of effort into uncovering, addressing and resolving these issues. A full write up on the age data can be found in TOR 2 and 3 sections of this document.

Changing the model to include two estimated selectivity blocks per fleet resulted in significant shifts in all estimates (Table B7.1). Selectivity in block 1 for both fleets was estimated assuming bi-modal selectivity-at-age with full selectivity fixed at age-1. Selectivity in block 2 for both fleets was estimated assuming a bi-modal selectivity-at-age with full selectivity at age-2. The shift to full selectivity at age-2 was made after multiple iterations and fitting both at-age selectivity and assuming a double logistic fit. Commercial and recreational fleet selectivity in time block 2 are dome shaped with a single mode, unlike the bi-modal selectivities estimated in the early time block (Figure B7.17). The domed selectivity at older ages in block two is resulting in the large increase in biomass estimates from Model B011 to B020 (Figure B7.18).

Model B020A: ESS = 0 in middle time-block (1997-2005)

The age keys used from 1997-2005 have the least amount of year specific information. As described in TOR 2 and 3 of this document many of the seasonal keys borrow across years during this time period. Previous reviews (SAW41) highlighted the negatives of this approach and the how it is likely inappropriate to borrow across years or seasons to fill in the sparse age keys. A number of analyses were carried out and confirm that borrowing across years is not valid for bluefish (WP B8). Unfortunately, the keys are too sparse during this time period and borrowing is unavoidable. To mitigate the effects of borrowed keys model B020A sets the effective sample size for these years equal to 0, and does not fit to the age composition. This has a minimal effect on the model estimates when compared to model B020A (Table B7.1 and Figure B7.18).

Model B021: Change weighting factor input style. Set Lambdas = 0 or 1.

Model B021 was an important step in the model building process. Up until this point, model weighting factors (lambdas) were consistent with the inputs used in the continuity run (Table B7.1). The method of weighting used in the continuity run is not the preferred method, and in some cases was emphasizing portions of the objective function more than expected. The preferred method is to use the lambda values as a switch to turn on or off portions of the objective function (0 = off, 1 = 0). When these weighting factors are switched on, the input value and input CV act as a prior during the minimization of the associated portion of the objective function. In the continuity run, and all models in the bridge up to this point, many of the lambda values were > 1 and acting as both a switch, and a weight. This resulted in very constrictive priors around the associated portions of the objective function.

The switch in weighting style for this model gave equal weight to the two catch fleets, and the 9 survey indices. This equal weighting is reflected in the likelihood contribution for each of the components in the objective function (Figure B7.19). Estimates of F did not significantly change from Model B020A, however the entire scale of total population numbers and biomass time-series decreased dramatically. Surprisingly, recruitment estimates remained almost identical to model B020A (Table B7.1).

Model B021A: Turn likelihood constants off in the objective function

Recently, an issue with constants in likelihood function of ASAP has been uncovered. The specific issue has to do with a constant that depends on recruitment parameters. The lognormal distribution with notation specified for application to recruitment deviations is:

$$\frac{1}{R_{y,v}\sqrt{2\pi}\sigma} e^{-\frac{\left(\ln\left(R_{y,v}\right)-\ln\left(R_{y,e}\right)\right)^2}{2\sigma^2}}$$

where $R_{y,v}$ is the recruitment value estimated in year y, σ is the user supplied standard deviation of the recruitment deviations, and $R_{y,e}$ is the recruitment expected from the underlying stock-recruit curve. The negative log likelihood, $-\ln(L)$, which is what is used in the objective function for most applications, equals:

$$-\ln(L) = n_{rec}\frac{ln(2\pi)}{2} + \sum ln\left(R_{y,v}\right) + n_{rec}\,ln(\sigma) + \frac{1}{2}\sum\frac{\left(\ln\left(R_{y,v}\right) - \ln\left(R_{y,e}\right)\right)^2}{\sigma^2}$$

where n_{rec} is the number of recruitment deviations. The first three terms on the right hand side of the equation are often referred to as constants (assuming σ is not an estimated parameter) that do not affect model estimation and so are often dropped from the likelihood. However, in this case, the term $\sum \ln(R_{y,v})$ is not a constant and depends on model parameters. Consequently, ignoring this term as a constant is technically incorrect, while retaining the term may have unintended consequences for model fit. Preliminary work demonstrates that including this term can, in some cases, lead to underestimates of recruitment because the objective function can be reduced by lowering the estimated recruitment values.

Model B021A turns off the likelihood constants in the objective function, the current preferred method for dealing with the above issues. All estimates from the model increased when these likelihood constants were turned off (Table B7.1). The recruitment estimates are no longer being lowered by the specific likelihood constant which is likely resulting in the increased estimates.

Model B022: No penalty on numbers in the first year deviations

Model B022 removes one of the two remaining penalties on numbers in the first year deviations. Lambda for these values was switched on in all previous model runs and the input CV was set at 0.9. This penalty served to scale the initial population biomass by assuming a prior distribution around the numbers in the first year. We do not have any prior information relating to initial stock numbers so it is preferable to allow the model complete flexibility around these estimates. Turning off this penalty reduced the estimates of F from model B021A, and caused numbers and biomass estimates to scale up again (Table B7.1 and Figure B7.20).

Model B023: Finalized maturity-at-age data

Maturity-at-age was updated from a final analysis of data presented in TOR 2 and WP B2. In previous models, the estimates of maturity-at-age were from an analysis of a preliminary bluefish age/maturity dataset: 0, 0.41, 0.86, and 1.00 for ages 0 to 3+, respectively, were used. After compiling a final dataset of all available bluefish maturity-at-age information a logistic regression was refit to estimate a maturity ogive. The final values used in model B023 were: 0, 0.40, 0.97, and 1.00 for ages 0 to 3+, respectively. Spawning stock biomass estimates were the only minor change resulting from this new maturity ogive (Table B7.1).

Model B 024: Increase the CV around recruitment deviations from 0.5 to 1.0

Model B024 increased the CV around the recruitment deviations from 0.5 to 1.0 to give the model more flexibility around these estimates. This causes very little change in estimates from the previous model (Table B7.1). It should be noted that sensitivity runs were carried out in an attempt to remove this penalty completely; however, the resulting models had issues with convergence and scale.

Model B025 and Model B027: Change some selectivities

Model B025 and B027 shifted selectivities on time block 2 of the fleets from selectivity-at-age to double logistic, and from double logistic to selectivity-at-age for the NEFSC survey indices. These changes were to better match the selectivity patterns coming out of the previous models. Making these changes resulted in very little differences in model estimates from previous model runs (Table B7.1).

Figure B7.21 shows the differences in model estimates from model B022 and B027 to gauge the impacts of the various minor changes between these model steps. The total effect was to minimally decrease the main estimates coming out the model.

Model B028: Revert back to 1 selectivity block per fleet

During the model meeting for the SAW60 bluefish assessment the working group discovered an issue with the early spring scale age data coming from North Carolina. The working group was always aware of a disparity between the scale age data in the early time series (1985-1996) and the otolith age data later (2006-2014). The reason for the disparity was pinpointed to spring North Carolina ages and the likelihood that some of these ages represent a biological birth date as opposed to assuming a Jan 1 birth date (the accepted ageing protocol practice for bluefish). A very detailed description of the analyses and the correction the working group made to these scale ages can be found in the TOR3 age section of this document and WP B6.

Model B028 was run in anticipation of including corrected data in the model. The working group's initial justification for splitting the fleets into selectivity blocks was the disparity in age data between time blocks. Having corrected these data, there was no longer justification to split the fleet selectivities into two blocks. It should be noted there have been no specific fishery changes or management changes for bluefish over the time series that would result in a fishery selectivity change.

Fleet selectivity was estimated at-age for both fleets assuming starting values equal to the fixed selectivity values from SAW41. Shifting back to one selectivity block per fleet had a small effect on the model estimates and shifted the scale of all estimates down (Table B7.1).

Model B029: Change the NEFSC surveys to split off the Bigelow survey

For model runs previous to this model, the NEFSC fall survey has been split into inner inshore strata and outer inshore strata. The inner inshore strata time-series was sampled by F/V Albatross IV from 1985-2008. The sampling of these strata has been taken over by the NEAMAP survey, which is included as an index of abundance from 2007-2014. The outer inshore strata were sampled by F/V Albatross IV from 1985-2008, and from the NEFSC new research vessel the R/V Bigelow from 2009-2014. The Bigelow is not able to sample the shallower inner inshore band which the NEAMAP survey now samples. For the outer inshore survey, a conversion factor has always been applied to Bigelow units to correct them to Albatross equivalents. The value used in past update assessments was 1.16 and comes from an extensive calibration study between the vessels (Miller et al. 2010).

At the model meeting for SAW60, the working group decided to shift the NEFSC indices and move forward with the Bigelow split off a separate time series. It has been a decade since the last benchmark assessment for bluefish and it is likely there will be an extended period before the next benchmark. While the Bigelow time series is currently only 6 years, the value of this time series to the model, without having to use a conversion factor, will increase over the next few years.

In model run B029, an NEFSC inshore survey using all inshore strata (all Albatross data) and a Bigelow survey representing the outer inshore band of strata were used as indices of abundance. Splitting off the Bigelow time-series and changing the input indices for the NEFSC fall survey had very minor impacts on the model estimates. The estimates of fishing mortality, total stock numbers, recruitment and biomass all decreased very slightly from the previous model run (Table B7.1).

Model B030: Switch MRIP selectivity to match fleet 2

Model B030 is a result of questions raised at the bluefish SAW60 model meeting. Previous to Model B030, the MRIP index assumed different starting values for selectivity than the recreational fleet. The question was raised as to why the two selectivities did not match even though the time series of landings and the CPUE index are derived from the same data. This fact is not entirely true, and the working group has addressed that in a later model run (B042).

The comparison to the selectivity of fleet 2 was not the only issue discovered with the input selectivity for the MRIP Index. The previous selectivity was not fixed at any age and the model was free to estimate all parameters. Previous model runs should have had a fully selected age for this index and without it the biomass estimates from these models were biased low. The MRIP index is the most important index in the bluefish assessment as it drives age composition estimates for the older ages. Most of the other surveys do not catch many older fish.

Model B030 changes the starting values for the MRIP index selectivity to match the starting values for the selectivity of fleet 2. Fish are fully selected at age one and the input matches the previously described bi-modal pattern. Figure B7.22 presents the model B029 selectivity estimates for the MRIP index, as well as model B030 selectivity estimates for both the MRIP index and Fleet 2. The MRIP index has higher selectivity at older ages than Fleet 2. See the write up for B042 for an explanation of why the selectivities are different, and why at-age selectivity for MRIP is probably not appropriate.

Switching the input selectivity patterns for the MRIP index significantly increased biomass estimates. As mentioned previously, MRIP is the most important index in the model, especially for tracking older ages. The doming of the selectivity estimates at older ages seemed to create a lot of cryptic biomass in model run B030. Estimates of fishing mortality declined slightly from previous models and estimates of total stock numbers, and recruitment increased (Table B7.1 and Figure B7.23).

Model B033: Early NC scale ages corrected and data were re-calculated

Model B033 has the same model specifications as Model B030 except revised data are used. In this model issues with NC scale age data from 1985 to 1996 have been corrected (see TOR 2 and 3 of this document and WP B6 for a detailed explanation). The implemented correction decided up on by the working group bumped groups of scales up 1 age. This had a predictable outcome of decreasing F, and increasing the estimates of numbers and biomass when compared to model B030 (Table B7.1, Figure B7.23).

Model B035: Switch PSIGN selectivity from double logistic to at-age

This model made minor change to the PSIGN selectivity which was being estimated as a double logistic selectivity curve. The selectivity for this index was switched to at-age and the resulting changes to the model estimates were minor increases in stock numbers and biomass (Table B7.1).

This model was final model formulation coming out of the SAW60 model meeting. Plans were to make minor changes to input CVs, and effective sample size changes to finalize the model. The working group was concerned about the inflated biomass estimates and the problem of cryptic biomass. However, no cause or resolution was determined prior to the end of the meeting. Part of the finalization of the model involved running a retrospective analysis. The results indicated somewhat severe retrospective bias in all of the estimates (Figure B7.24). In order to determine the cause of the retrospective patterns, retrospective analyses were carried out in a stepwise manner, for each previous model in the model building process. It was determined that the dome in MRIP selectivity was causing the retrospective patterns as well as the cryptic biomass.

Model B042: Change MRIP selectivity to single logistic and increase fleet 2 input CV

In model B042, a flat-top, single logistic curve was input for the MRIP selectivity. This fixed both the retrospective patterns seen in model B033 and removed the cryptic biomass being estimated by the model.

Re-visiting an earlier question: Why is the selectivity of the MRIP index different from Fleet 2 (the recreational catch) if they are developed from the same data? For the recreational catch the working group assumed a 15% mortality rate for the recreational discards. However, to calculate the MRIP index at-age, all of discard data were used. This is important because there is a very noticeable difference in the size distributions of landed fish versus discarded fish. Bluefish are a unique recreational species in that the size distribution of the discards is much larger than the landed fish (Figure B4.11). This can be attributed to the fact that bluefish are a very oily fish, more so at larger sizes, and for many people large bluefish are unpalatable. This leads to a domed selectivity for the recreational catch because most of the larger sized fish are released. However, it is safe to assume these ages are fully selected by the discards and should be fully selected for the MRIP index since 100% of the discards are used to calculate the age proportions. The working group used this reasoning to justify shifting the selectivity for MRIP from a selectivity-at-age to a flat-top, single logistic curve, that fully selects the older ages.

The estimates from model B042 are have shifted drastically from prior model runs. Fishing mortality increased, and total stock numbers, recruitment, and biomass estimates have decreased. As mentioned previously, the new selectivity estimates for MRIP eliminated the cryptic biomass being estimated by earlier models and greatly reduced the retrospective bias in the estimates. Total biomass and spawning stock biomass estimates from model B042 were around 50% of the estimates from the previous model (Table B7.1 and Figure B7.25).

Model B043: adjustments to input CVs and effective sample sizes

One of the final changes in the model building process was iterative adjustments to the input CV of each index to account for additional process error. The model was re-run and adjustments were made for each index until the root mean square error of the index was close to a value of 1.0. In addition to fine tuning the input CVs of the surveys, a low effective sample size was assigned to the middle period time block 1997-2005. The working group decided while the age information in this time block was poor (because of pooled age keys and borrowing across years) a small effective sample size should be input to generate some information about age composition in these years.

Model B043 had similar estimates to model B042 with slightly greater fishing mortality, total stock number, and recruitment estimates, and slightly decreased estimates of biomass (Table

B7.1).

<u>Please note, this model was the final SAW60 WG model that was taken to the SARC60 review. For full diagnostics and results from this model please see appendix B7.</u>

B7.3.3 A Final Model

Model B044 (BFINAL): Final model after SARC60 review

Model B044 is the new final bluefish model resulting from the SARC60 benchmark review. At the review, the review panel discovered a model misspecification in the selectivity parameters for the MRIP index. A parameter in the function describing the curve for selectivity was fixed when it was intended to have been freely estimated by the model. This was causing patterning in the age composition residuals for this index. The final revised model corrects this misspecification. The values presented in this report reflect the output from the revised model as accepted at the review.

Final model data summary: Catch proportions for the recreational fleet ranged from 66% to 84% of the total catch (Figure B7.26). Catch-at-age for both fleets is predominantly age 0 to age 3, with the recreational fleet catching more age 0, and both fleets catching lesser numbers at older ages (Figures B7.27 and B7.28). Overall survey index trends are generally flat, with noticeable peaks for some of the indices early in the time series, and around 2005 (Figure B7.29). Input age composition for the indices are presented in Figures B7.30 through B7.35. Final model inputs for weight-at-age of the fleets, natural mortality, and maturity-at-age are presented in Figures B7.36 through B7.41.

The main contributions to the objective function were from the likelihood components of the index and catch age compositions (Figure B7.42). Compared to the previous assessment model from SAW41, which was heavily weighted towards the single catch fleet, model BFINAL gives equal weight to all components.

B7.4 Final Model Diagnostics

BFINAL model diagnostic plots for the fit to the two catch fleets are presented in Figures B7.44 through B7.51. Diagnostic plots for the 9 survey indices are presented in Figures B7.52 through B7.81. For reference when viewing some of the plots:

Fleet 1 = Commercial
Fleet 2 = Recreational
Index 1 = NEFSC Inshore trawl
Index 2 = NEFSC Bigelow trawl
Index 3 = MRIP recreational CPUE
Index 4 = NEAMAP trawl
Index 5 = SEAMAP Age 0
Index 6 = PSIGN gillnet

Index 7 = CT LISTS trawl
Index 8 = NJ Ocean trawl
Index 9 = Composite YOY seine

The final model estimated higher fishing mortality and lower abundance and biomass than model B043 (Table B7.1). Selectivity at-age estimates for the two catch fleets were both domed, with a bi-modal pattern still evident in the commercial fleet (Figures B7.82 and B7.83). Fishing mortality for the recreational fleet has always been higher than the commercial fleet, in some year two to three times as much. Fishing mortality estimates in 2014 for the commercial and recreational fleets were 0.049 and 0.108, respectively (Figure B7.84). Final model estimates for the index selectivities show a rapid decrease in selectivity after age 0. A few of the indices have higher selectivity towards larger/older fish, the most important being MRIP and PSIGNS, and to a lesser extent the Bigelow survey (Figure B7.85). Observed and predicted catch-at-age for the two fleets and nine indices are presented in Figures B7.86 through B7.103. Estimates of age composition at older ages are poorly predicted for some of the components.

B7.5 Final Model Results

Average F for from 1985 to 2014 from the final model was 0.284 and average SSB was 79,449 mt (Table B7.4). Spawning stock biomass dipped from a high of 154,633 mt in 1985 to a low of 52,775 mt in 1997 and has steadily increased to a value of 86,534 mt in 2014 (Table B7.4, Figure B7.104). The majority of the spawning stock biomass (50-60%) is in the age 6+ group for the entire time-series (Figure B7.105). Estimates of F have remained below average since 1997 and the 2014 estimate of 0.157 is well below the time series average (Table B7.4, Figure B7.104). There has been a steady decline in fishing mortality since 2007.

Estimates from model BFINAL showed a decrease in total abundance since 2006, declining from 91.5 million to 65.2 million fish in 2012 (Table B7.5, Figure B7.106). Total abundance increased in 2013, and 2014, to 72.1 and 82.0 million, respectively. Age 0 and age 1 fish collectively average around 50% of abundance for the time-series. Below average (24.0 million) recruitment began in 2008 with an estimate of 23.1 million fish (Table B7.4, Figure B7.107). Low recruitment persisted through 2012 to the lowest estimate of the time-series at 16.7 million. Recruitment for 2013 and 2014 have increased above the average to 25.1 and 29.6 million fish, respectively. Throughout the time series the plus group contains the majority of the biomass (Table B7.6). Biomass estimates for 6-plus bluefish have remained above the time series average of 41,600 mt since 2010. Total mean biomass in 2014 equaled 94,328 mt, a slight decrease from the 2013 estimate of 96,922 mt (Table B7.6, Figure B7.108).

Retrospective bias for the final model was examined for F, spawning stock biomass, recruitment, total biomass, exploitable biomass, total abundance, and abundance-at-ages 1 through 6. The analysis shows small bias in the estimates of F (Mohn's rho = -0.12), SSB (Mohn's rho = 0.19), and recruitment (Mohn's rho = 0.05) (Figure B7. 109). Similarly, there is little retrospective bias in estimates of total biomass (Mohn's rho = 0.18), exploitable biomass (Mohn's rho = 0.10) and total abundance (Mohn's rho = 0.06) (Figure B7.110). There does appear to be minor retrospective bias in some of the estimates of abundance-at-age, particularly numbers at age 5 (Mohn's rho = 0.19) and numbers at age 6 (Mohn's rho = 0.23) (Figures B7.111 and B7.112).

The variation in the final model results for F and SSB was determined using a Monte Carlo Markov chain with 1000 iterations and a thinning factor of 1000 (1,000,000 iterations). Trace plots for both SSB and F show little to no patterning (Figures B7.113 and B7.114).There is no significant autocorrelation in the F chain (Figure B7.115). Autocorrelation plots show minor autocorrelation in the SSB (both 1985 and 2014) chain at a lag of 1, with no autocorrelation at a lag greater than 2 (Figure B7.116). The MCMC results of SSB for 2014 ranged from 50,804 mt to 112,588 mt, with a median estimate of 76,062 mt, and 80% confidence interval ranging from 65,078 mt to 86,752 mt. The 2014 SSB point estimate from the final model (86,534 mt) is greater than the median estimate from the MCMC distribution (Figure B7.117 and B7.118). Variation around F ranged from 0.110 to 0.282, with the 80% CI between 0.139 and 0.202. The point estimate from the final model (0.157) is less than the median estimate (0.166) from the MCMC distribution (Figure B7.119 and B7.120).

B7.6 Final model sensitivity runs

A number of sensitivity runs were carried out by changing data inputs to the final model.

Changes to the recreational data

The first group of sensitivities explored different changes made to the estimation of various components of the recreational catch. A total of 5 sensitivity runs were conducted for the recreational data: 1. Assume recreational landings (AB1) lengths apply to the recreational discards (B2), 2. Assume recreational catch at the upper 95% CI of estimates, 3. Assume recreational catch at the lower 95% CI of the estimates, 4. Use MRFSS numbers prior to 2004 (no conversion to MRIP equivalents), and 5. Assume 17% recreational discard mortality instead of 15%. Comparisons between final model and sensitivity run estimates of F, total stock numbers, recruitment, and SSB are presented in Figures B7.121 through B7.125.

Changes to data structure and inputs

Additional final model sensitivity runs were conducted that changed other components of the input data: 1, A regional sensitivity run was explored that used northern and southern regional age-length keys to age the fleets and surveys from 2006 to 2014, 2. Length-weight coefficients were varied over time by three time blocks, 1985-1994, 1995-2004, 2005-2014, 3. Virginia landings date were calculated using a different methodology (VA set 2). Comparisons between final model and sensitivity run estimates of F, total stock numbers, recruitment, and SSB for these sensitivity runs are presented in Figures B7.126 through B7.128.

Sensitivity runs were also carried out the final model assuming different input values for natural mortality. A profile of the objective function was calculated over a range of natural mortality estimates, and the objective function was minimized at a value of 0.263 (Table B7.7 and Figures B7.129 and B7.130). Age-based inputs for natural mortality were also explored (Table 1.50 and Figure B7.131). The estimates assuming age-based M derived from equations in Gislason et al. 2010 resulted in unrealistic model estimates (Table B7.8).

Changes to the survey indices

Sensitivity of the final model to individual survey indices was also tested by removing each index and re-running the model (Table B7.9). The model is fairly insensitive to the removal of all the indices except for the MRIP recreational CPUE index, which is driving the model along with the two catch fleets. The reason this index is so important is because it provides most of the information for model estimates at older ages. Removing the MRIP index and re-running the final model results in a significant decrease in fishing mortality estimates and an increase in abundance and biomass estimates (Table B7.9 and Figure B7.132). An additional model run using just the two catch fleets and the single MRIP index was also conducted. Without the other indices the model loses some information to inform estimates of younger ages and recruitment is scaled up. However, the overall trend and scale of biomass and fishing mortality estimates are not that different from the final model (Figure B7.132).

Investigating habitat suitability indices

Habitat suitability information was also investigated for the NEFSC surveys as well as the NEAMAP survey. Annual estimates of habitat suitability were input as a covariate on availability in the ASAP model (catchability = availability*efficiency, where efficiency was assumed = 1). The use of the habitat suitability indices did not improve the fit of the model to the respective indices. This is not surprising, since the annual estimates of available thermal habitat sampled by the NEFSC and NEAMAP surveys did not show significant trends which would cause a bias in trends of relative abundance (Figure B6.21). In addition, these indices used a hindcasted estimate of sea bottom temperature to derive estimates of bluefish habitat suitability. The ocean model used to hindcast these temperatures was not available for 2013 and 2014 and as a result no index of habitat suitability was available for these years (See WP B4 for full details). The working group decided to go forward without incorporating habitat suitability in the model. There was concern because recent information was not available, as well concern for the ocean model that was used to develop the indices. A habitat suitability index developed from an ocean model using real-time or forecasted sea-surface temperature would be more appropriate for bluefish. This is included as a research recommendation and could be developed for future bluefish assessments.

B7.7 Historical retrospective analysis

Historical retrospective comparisons between the final model and both the continuity run, and the SAW41 assessment show fairly consistent results among estimates (Figure B7.133). Over time, annual updates of the SAW41 model shifted model estimates of total stock numbers, recruitment and fishing mortality. The shift can be observed in comparisons of the continuity run and the SAW41 model. The SAW60 final model for bluefish brings these estimated time-series back in line with the SAW41 model estimates.

B7.8 Alternative Model Runs

B7.8.1 Depletion Corrected Average Catch Model

As an alternative to the base model run using the statistical catch-at-age (SCAA) framework detailed above, we estimated sustainable yield using MacCall's (2009) Depletion-Corrected Average Catch (DCAC). The sum of landings from 1985-2014 is approximately 550,000 mt with an annual average of 18,325 mt (Table B7.10). DCAC requires an estimate of fractional depletion ("delta," which is the change in relative biomass, in units of unfished relative biomass). Our delta estimate is based on preliminary model runs and results of the last update (47.1%; http://www.asmfc.org/uploads/file/552ea3fe2014BluefishStockAssessmentUpdate.pdf) that suggested approximately a 50% depletion in spawning stock biomass over the catch period. Our point estimate for natural mortality (M) was based on the work of Then et al. (2015) and their $\text{Pauly}_{\text{nls-T}}$ estimator ($M = 4.118k^{0.73}L_{\infty}^{-0.33}$; $k = 0.311$ and $L_{\infty} = 815.3$ from Robillard et al. 2009). This is very similar to the M estimate assumed in ASAP SCAA base model. Other DCAC parameters were set to be consistent with MacCall (2009) and Dick and MacCall (2011) (Table B7.10; Figure B7.134). DCAC was implemented with software available from the NMFS toolbox (DCAC V2.1.1; http://nft.nefsc.noaa.gov/DCAC.html). The median of the DCAC distribution was 13,479 mt (Figure B7.135). The average harvest of bluefish throughout the region during the period 2012-2014 was 10,618 mt, with no year exceeding 11,254 mt. This suggests that recent annual harvests were at sustainable levels.

We performed a number of DCAC sensitivity analyses to look at the impact assumed model parameters had on sustainable yield estimates (Table B7.11). All possible combinations of input parameters were investigated, resulting in a total of 192 individual model runs (including the base run presented above). Results of all runs suggested that recent average harvest of bluefish in the terminal 3 years of the assessment (10,618 mt) were sustainable as median sustainable yield levels from all DCAC runs exceeded this value (Figure B7.136).

B7.7.2 Depletion Based Stock Reduction Analysis (DBSRA)

Depletion-based stock reduction analysis (DBSRA) is a technique proposed by Dick and MacCall (2010, 2011) to generate sustainable yield reference points for data-poor groundfish stocks in the Pacific Northwest. It is a variation on stochastic stock reduction analysis (Walters *et al.*, 2006) that uses a production model rather than an age-structured model to describe the underlying population dynamics.

$$B_{t+1} = B_t + \gamma \cdot m \cdot \left(\frac{B_t}{K}\right) - \gamma \cdot m \cdot \left(\frac{B_t}{K}\right)^n - C_t$$

We can select reasonable values to describe the productivity of the population, and then ask the question: if the population sustains *y* years of observed catch, what did the virgin population size have to be in order to both (1) sustain those catches without being driven to extinction and (2) end up at some known fraction of *K* at the end of the time series?

Similar to DCAC, input parameters (Table B7.12, Figure B7.137) are drawn from distributions based on expert opinion about bluefish and meta-analysis of similar stocks. Uncertainty about these parameters is incorporated into the final estimates of *K* and the management parameters of interest (MSY, OFL). DBSRA requires as complete a time-series of catch as possible, so harvest from 1950-2014 was used. Estimates of commercial landings were available from 1950 onwards through ACCSP. Recreational harvest estimates are available from MRFSS/MRIP from 1982 onwards. To hindcast recreational landings, the average ratio of recreational to commercial harvest from 1982-2014 was used to scale the commercial landings up from 1950-1982. Dick and MacCall (2011) assume that catch is known without error, which is not the case with a recreationally important species like bluefish. To incorporate some of that uncertainty into this analysis, the catch history was also drawn from a series of lognormal distributions that used each year of the observed time-series of catch as the median. Natural mortality was assumed to be 0.2, consistent with the ASAP model runs. The ratio of F_{MSY} to M and B_{MSY} to K followed distributions recommended by MacCall (2009), as was done with the DCAC runs. The ratio of B_{2014} to K was based on the estimates of B_{2014} to B_{MSY} from the most recent update of the ASAP model where a stock-recruitment model was used to estimate MSY-based reference points.

DBSRA estimated a median MSY for bluefish of 19,954 mt, with an OFL for 2015 of 20,0245 mt (Table B7.13, Figure B7.138). This method cannot be used to assess stock status (i.e., overfished or experiencing overfishing), because status relative to K is one of the inputs to the model. However, the management parameters (MSY, OFL) derived from this model are robust to assumptions about stock status. Results of all runs suggested that recent average harvest of bluefish in the terminal 3 years of the assessment (10,618 mt) were sustainable, as they are below the estimated MSY from the DBSRA.

B7.7.3 Model Comparisons

The data poor models corroborate the scale of the ASAP model and agree with the determination that harvest in recent years has been sustainable.

All three models produced roughly similar estimates of sustainable harvest for bluefish, and indicate that recent harvest has been below the maximum sustainable yield. DBSRA estimated the highest MSY, but encompasses the estimates of the other two models in the 5^{th} and 95^{th} percentiles of the estimate.

B8. TERM OF REFERENCE #5: State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY}, and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

The current biological reference points for bluefish were determined in SARC 41 and are F_{MSY} (0.19) and B_{MSY} (147,052 mt). The basis for the reference points was the Sissenwine-Shepherd method using the Beverton-Holt stock recruitment parameters and SSB per recruit results generated by the SARC 41 ASAP model results. B_{MSY} was calculated using mean weights at age and is therefore comparable to mean biomass in year *t*. Overfishing of a stock occurs if F exceeds F_{MSY} and a stock is considered overfished if total biomass is less than half of B_{MSY} ($B_{THRESHOLD}$). The existing definition of overfishing is F > 0.19 and B < 73,526 mt.

The TC and WG concluded that new reference points were required because of the uncertainty present in the stock recruitment relationship estimated by the current model. The time series of spawning stock biomass and recruitment does not contain any data about recruitment levels at low stock sizes (Figure B8.1), and the BTC and the SAW 60 WG did not believe the fitted parameters adequately described the stock-recruitment relationship for bluefish.

Because MSY based reference points require a stock recruitment relationship, MSY proxies are required. As a proxy for F_{MSY}, the BTC and the SAW 60 WG recommend $F_{40\%\ SPR}$. The input maturity and composite selectivity curves are shown in Figure B8.2. The resulting YPR and SPR curves are shown in Figure B8.3.

To calculate the associated target and threshold for biomass, the population was projected forward for one hundred years under current conditions with fishing mortality set at the F_{MSY} proxy and recruitment drawn from the observed time series. The WG originally proposed that the biomass threshold be based on total biomass, to be consistent with the previous assessment and current management, but the SARC panel determined that spawning stock biomass was a more appropriate reference point. The resulting equilibrium spawning stock biomass is the recommended SSB_{MSY} proxy, with the overfishing threshold set at ½ SSB_{MSY}. Similarly, the equilibrium landings under projected under F_{MSY} proxy = $F_{40\%SPR}$ were set as the MSY proxy.

The revised reference points are F_{MSY} proxy = F40% = 0.170 and B_{MSY} proxy = 111,228 mt (½ SSB_{MSY} = 55,614 mt). The MSY proxy is 13,967 mt.

The usage of these proxies has been accepted in many other assessments and is considered adequate in cases where a stock recruitment relationship is not estimable. Recent SAW assessments where MSY proxies have been used include the Gulf of Maine haddock (2014), summer flounder (2013), and white hake (2013).

SPR-based reference points are not sensitive to uncertainty in the stock-recruitment relationship, but do not link future recruitment to spawning stock biomass. The projection approach used to establish the B_{MSY} proxy incorporates the observed variability in recruitment, but assumes that recruitment is independent of SSB. This assumption is not unreasonable over the observed high levels of bluefish abundance, and maintaining the stock close to the proposed target should minimize the risk of this assumption.

B9. TERM OF REFERENCE #6: Evaluate stock status with respect to the existing model (from previous peer review accepted assessment) and with respect to a new model developed for this peer review.

B9.1 Stock status from the continuity run

a. When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the existing BRP estimates.

The existing reference points are F_{MSY} = 0.19 and B_{MSY} = 147,052 mt (½ B_{MSY} = 73,526 mt). The 2014 F estimate (0.141) is well below F_{MSY} and the 2014 estimate of B is 92,755 mt, below B_{MSY} but well above ½ B_{MSY}. This indicates that overfishing is not occurring and that the stock is not overfished (Figure B9.1).

B9.2 Stock status for the current assessment

b. Then use the newly proposed model and evaluate stock status with respect to "new" BRPs and their estimates (from TOR-5).

The new reference points are F_{MSY} proxy = F40% = 0.170 and SSB_{MSY} proxy = 111,228 mt (½ SSB_{MSY} = 55,614 mt). The 2014 F estimate (0.157) is below $F_{40\%}$ and the 2014 SSB estimate (86,534 mt) is greater than ½ SSB_{MSY}, indicating that overfishing is not occurring and that the stock is not overfished (Figure B9.2 and B9.3).

Reference Point	**SARC 41** Definition[1]	Value	**Updated** Definition[1]	Value
$\mathbf{F_{Threshold}}$	F_{MSY}	0.19	$F_{MSY\ proxy} = F_{40\%SPR}$	0.170
$\mathbf{B_{Target}}$	B_{MSY}	147,052 mt	Equilibrium SSB under $F_{40\%SPR}$	111,228 mt
$\mathbf{B_{Threshold}}$	½ B_{MSY}	73,526 mt	½ $SSB_{MSY\ Proxy}$	55,614 mt

[1]: Note that the SARC 41 biomass reference points refer to total biomass, while the updated biomass reference points refer to spawning stock biomass.

B10. TERM OF REFERENCE #7: Develop approaches and apply them to conduct stock projections and to compute the statistical distribution (e.g., probability density function) of the OFL (overfishing level; see Appendix to the SAW TORs).

B10.1 Provide annual projections (3 years). **For given catches, each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment)**

Short-term projections were conducted using AGEPRO v.4.2.2 (available from the NOAA Fisheries Toolbox, http://nft.nefsc.noaa.gov/AGEPRO.html).

Removals in 2015 were assumed to be equal to the 2015 quota (9,722 mt). For 2016-2018, a constant level of fishing mortality was applied. The population was projected forward under five different F levels:

- F_{low} = 0.100
- $F_{status\ quo}$ = 0.136
- $F_{0.1}$ = 0.203
- F_{TARGET} = 90%$F_{MSY\ Proxy}$ = 0.163
- $F_{MSY\ Proxy}$ = $F_{40\%SPR}$ = 0.181

Uncertainty was incorporated into the projections primarily via estimates of recruitment and initial abundance-at-age.

Estimates of recruitment were drawn from the 1985-2014 time-series of observed recruitment from the preferred ASAP model. Initial abundance-at-age estimates were drawn from distributions of terminal abundance-at-age developed from the MCMC runs of the preferred ASAP model. A small amount of uncertainty was incorporated into biological parameters such as weight-at-age, maturity-at-age, and natural mortality; estimates of these parameters were drawn from lognormal distributions with mean values used in the terminal year of the assessment and a CV of 0.01.

The projections were conducted with a single fleet. Selectivity was calculated by summing the commercial and recreational F-at-age for each age from the preferred ASAP model over the last three years of the model and dividing by the maximum F-at-age to develop a composite selectivity curve. A CV of 0.01 was also applied to the selectivity-at-age estimates.

The model exhibited a minor retrospective pattern. Estimates of retrospective bias-adjusted SSB and F were within the credible intervals from the MCMC runs of the accepted model estimates Figure B10.1), so a retrospective adjustment was not deemed necessary.

None of the fishing mortality scenarios resulted in total biomass going below the biomass threshold (½ $SSB_{MSY\ Proxy}$) in any year of the projection; spawning stock biomass remained above the biomass threshold with 100% probability in all years (Table B10.1, Figure B10.2).

The overfishing limit (OFL) for 2016 was estimated to be 10,528 mt (23.2 million lbs) with a CV of 0.10 (Table B10.1, Figure B10.3). A qualitative inflation was applied for known sources of uncertainty that are not adequately captured in the projection process, including retrospective bias and uncertainty in the F_{MSY} proxy estimate, resulting in a recommended CV of 0.15.

A sensitivity analysis approach was used to determine the effects of major sources of model uncertainty that could not be encompassed through the MCMC runs of the base model. This included:

- Limiting the empirical recruitment distribution to the CDF of observed recruitment for 2006-2014 (the years of the best available age data)
- Higher M (M=0.26)
- Increased uncertainty in selectivity-at-age, weight-at-age, and maturity-at-age (CV of 0.1 instead of 0.01)

Please note: these sensitivity runs were carried out with the results of Model B043, not the revised BFINAL model.

Using the more limited recruitment time series did not significantly change the estimates of landings or biomass from the projections (Table B10.2, Figure B10.4). This is not surprising, since the median recruitment of the 2005-2014 period (26.4 million fish) is not significantly different from the median recruitment of the entire time series (24.5 million fish). Higher M values resulted in higher estimates of landings and biomass, but did not change the probability of going below the biomass threshold (0% in all years). Increasing the CV on the biological parameters did not significantly change the median of the distributions for biomass or landings in each year, but did increase the confidence intervals. The probability of being above the biomass threshold remained 100%.

B10.2 Comment on which projections seem most realistic. Consider the major uncertainties in the assessment as well as sensitivity of the projections to various assumptions.

The WG considers the base model configuration the most realistic projection scenario. While estimates of recruitment in the most recent 10 years of the time-series (derived in part from the best age information) are likely more reliable than the estimates from the beginning of the time-series, the median recruitment and projection time-series are virtually indistinguishable.

B10.3 Describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming overfished, and how this could affect the choice of ABC.
Bluefish are a fast-growing, fast-maturing species with a moderately long life span. Although they recruit to the fishery before they are fully mature, larger, older fish are considered unpalatable, reducing demand for those sizes in the commercial market and encouraging the release of those size classes in the recreational fishery. The resulting dome-shaped selectivity of the fleets offers protection to the spawning stock biomass. Although they are a popular gamefish, demand for this species is not extreme and the quota is rarely met or exceeded.

Bluefish are opportunistic predators that do not depend on a single prey species. Their range covers the whole of the Atlantic coast, and their spawning is protracted both temporally and geographically. As a result, they are not as vulnerable as many other species to major non-fishery drivers such as climate change that would result in the loss of critical forage or nursery habitat.

This assessment indicates bluefish are near their target biomass and well above their overfished threshold. Short-term projections indicate no risk of driving the biomass below the overfished threshold while fishing at or near the FMSY proxy. Overall, bluefish have a low degree of vulnerability to becoming overfished, and the ABC can be set on the basis of the FMSY proxy without risk of causing the stock to become overfished.

B11. TERM OF REFERENCE #8: Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in most recent SARC reviewed assessment and review panel reports, as well as MAFMC SSC model recommendations from 2005 and the research recommendations contained in its 23 September 2013 report to the MAFMC. Identify new research recommendations.

B11.1 Progress Made in Addressing Previous Research Recommendations.

Commercial Data

- Increase sampling of size and age composition by gear type and statistical area

- Target landings for biological data collection and increase intensity of sampling for biological data.

Addendum I to the Bluefish FMP has resulted in additional commercial biological data (e.g., age, sex, weights) being available (e.g., from NC and NY). Prior to Addendum I, the NC biological collection program targeted commercial landings for biological data (e.g., 2006-2011, age, sex, weight).

Recreational Data

- Increase sampling of size and age composition by gear type and statistical area

- Target landings for biological data collection and increase intensity of sampling for biological data

Addendum I to the Bluefish FMP has resulted in additional recreational biological data (e.g., age, sex, weights) being available from all participating states; in addition, volunteer recreational angler surveys from several states (CT, RI, and NJ) are now providing recreational discard data for use in the bluefish stock assessment.

Ageing Data

- Complete a scale-otolith comparison study

Both independent research and an inter-agency bluefish ageing workshop confirmed that the use of sectioned otoliths is the preferred method by which to age this species (Robillard et al. 2009; ASMFC 2011). Further, each agency follows the standard otolith processing, reading, and age-assignment protocols developed by ODU. Some variations do exist with respect to processing, but these are relatively minor (e.g., baking before or after sectioning, mounting sections using various adhesives, etc.) and allowable as determined by the 2011 Bluefish Ageing Workshop. In response, all organizations that currently are involved with efforts to age bluefish for the purposes of informing the stock assessment for this species do so using sectioned otoliths and the 2011 protocol. The WG determined at the model meeting (WP B6) that historic age scale ages (excluding NC spring scales) were comparable to otolith ages and hence historic scale age data were retained for model runs.

- Conduct study or workshop to address discrepancies between estimated bluefish age from scales and otoliths and the chronological age. Examine issues of inter- and intra-reader variation in interpretation of ages

It was unclear to the WG exactly what this research recommendation was suggesting (especially in light of the previous research recommendation). To the extent that this research recommendation is related to a non-January 1 birthday for early NC spring age data, at the model meeting the WG made adjustments to the NC spring scale and otolith data (WP B6); those corrected spring ages were incorporated into the final assessment.

For the second part of the research recommendation, an ageing workshop was held in 2011 to produce guidelines for future aging work on bluefish. Intra-agency measures of ageing precision are available for nearly all of the organizations currently collecting age data (WP B5). The few organizations that were unable to provide estimates of precision due to staffing limitations (i.e., no second reader), will likely will be able to do so in the future as ageing programs develop further and assuming additional resources become available. Based on inter-agency measures and the 2011 Workshop, the WG felt comfortable using the expanded sources of age data.

- Examine the feasibility of each state collecting samples of hard parts for ageing, with one or two laboratories interpreting the annuli for consistency

The 2011 workshop resulted in Addendum I to the bluefish fishery management plan, which required all states that capture a substantial portion of bluefish landings to collect and age a minimum of 100 bluefish samples per year. Inter-agency comparability of age data is currently maintained through the adherence to standardized processing and ageing protocols for bluefish, while the digital reference collection developed by the states and maintained by the ASMFC also promotes this consistency by serving as a training tool and reference collection. Formal ageing exchanges meant to quantify inter-agency precision and bias have yet to occur for bluefish. It should be noted, however, that recent exchanges for other species, including black sea bass and summer flounder have shown that standard exchange practices are effort-intensive and often suffer from serious design flaws (ASMFC 2013). The latter issue results in measures of inter-agency precision and bias from the exchange that are not representative of the quality of age data provided by the participating organizations to the assessment process, and are therefore wholly uninformative. Further, discussions regarding the consolidation of all processing and ageing of bluefish under a single agency have determined that the current multi-agency approach is the superior design (WP B5). Gains in consistency that are realized using a single set of processors/readers are offset by increases in bias that arise due to lack of localized knowledge regarding life history and growth.

Fishery-Independent Data

- Continue research on species interactions and predator-prey relationships

No progress made on this item beyond development of working paper summarizing diet information (WP B3) for bluefish derived from NEFSC, NEAMAP, ChesMMAP, and SEAMAP which addressed portions of TOR #2.

- Examine alternative weighting schemes for the available fishery-independent surveys (area, inverse variance, N, etc.)

The Conn (2010) hierarchical approach which implicitly weights surveys by uncertainty was applied to combine multiple noisy state YOY indices that were criticized during the previous review as being unrepresentative of coastwide recruitment due to their individual limited spatial and temporal extent. The WG did not have time to explore model runs using weighting schemes alternative to this.

Finally, the WG adjusted fishery independent survey input CVs in the assessment model to get the RMSEs near 1, and ESS for fishery independent surveys to reflect confidence in age data over different time periods.

- Investigate the feasibility of alternative survey methods that target bluefish across all age classes to create a more representative fishery-independent index of abundance

No specific progress made on this item regarding survey gear types. However, the TC included additional fishery independent surveys (e.g., PSIGNS) that do target a wider age range (0-6+) in the current assessment.

- Initiate sampling of offshore populations in winter months

No progress made on this recommendation.

- Conduct research on influences on recruitment including pathways of larval bluefish

Research has been conducted on recruitment dynamics of bluefish (e.g., multiple cohorts; see paragraph below) however, time constraints prevented the WG from incorporating cohort-specific indices in the model.

Recent research has focused on the factors that influence bluefish survival from the young-of-year stage to age-1. Taylor et al. (2006) concluded that young of year bluefish almost exclusively utilize habitats on the inner continental shelf. Scharf et al. (2006) quantified the inter cohort dynamics of young of year bluefish. Taylor and Able (2006) provide additional information on cohort hatch date and differences in growth between spring and summer cohorts. Morely et al. (2007) explored how energy storage influenced juvenile young of year survival. Taylor et al. (2007) provide further information on fine scale habitat selection of young of year bluefish. Wuenschel et al. (2012) synthesized coastwide data to develop a conceptual model of the processes underlying bluefish recruitment. Morely et al. (2013) documented size selective overwinter mortality of young of year bluefish.

- Initiate coastal surf zone seine study to provide more complete indices of juvenile abundance

Research suggests that the coastal surf zone is important habitat (Able et al. 2013). No progress made on this item.

Models, Inputs, and Outputs

- Explore a tag based assessment and associated costs compared to age based assessments

No progress made on this recommendation. The WG determined that this item is no longer relevant given the potential costs and limited benefits.

- Determine if a tag based assessment could supplement or replace other assessment techniques

No progress made on this recommendation. The WG determined that this item is no longer relevant given the potential costs and limited benefits.

- Continue to examine alternative models including a forward projection catch-at-age model

The intent of this item was not entirely clear to the WG since the previous assessment model was a forward projecting catch at age model. This notwithstanding, the SAW 60 WG explored the application of two models designed to provide catch guidance in data poor situations: Depletion Corrected Average Catch Model (DCAC) and Depletion-Based Stock Reduction Analysis. (See Section B7.3 and Appendices for more details.) Both methods suggest that recent annual harvests were at sustainable levels.

B11.2 New Research Recommendations

High Priority

- Determine whether NC scale data from 1985-1995 are available for age determination; if available, re-age based on protocols outlined in ASMFC (2011); if re-aging results in changes to age assignments, quantify the effects of scale data on the assessment
    - Would allow for validation of the adjustments to the early NC spring age data made by WG at model meeting (WP B6)
- Develop additional adult bluefish indices of abundance (e.g., broad spatial scale longline survey or gillnet survey)
    - Given the limited information on older (e.g., age 2+) bluefish collected by existing fishery independent surveys this item addresses the need to adequately characterize dynamics of older fish that are currently not well sampled by fishery independent trawl surveys.
- Expand age structure of SEAMAP index

    - Given patterns of bluefish migration and recruitment (Shepherd et al. 2006, Wuenschel et al. 2012), it is important to monitor bluefish abundance in SAB; currently, the SEAMAP index used in the assessment indexes age 0 abundance only, but recent age data from SEAMAP suggests collection of age 1 and 2 fish that would help inform the SAB age structure

Moderate priority

- Investigate species associations with recreational angler trips targeting bluefish (on a regional and seasonal basis) to potentially modify the MRIP index used in the assessment model
    - Given the importance of the MRIP index in the assessment model, this addresses a need to accurately estimate effort for of the MRIP index (reduce risk of hyperstability)
- Explore age- and time-varying natural mortality from, for example, predator prey relationships; quantify effects of age- and time-varying natural mortality in the assessment model
    - This addresses the issue of predation on bluefish by, for example, coastal sharks and/or limited prey resources (top down effects, bottom up effects, and/or environmental effects)
- Continue to evaluate the spatial, temporal, and sector-specific trends in bluefish growth and quantify their effects in the assessment model
    - Addresses appropriateness of WG pooling age data spatially (and temporally) for potential changes regarding the efficiency of the biological collection program
- Continue to examine alternative models that take advantage of length-based assessment frameworks. Evaluate the source of bimodal length frequency in the catch (e.g., migration, differential growth rates);
    - This item would address a source of uncertainty in the assessment with age data from different hard parts & provide means to examine the appearance of bimodal length frequency in the catch data
- Modify thermal niche model to incorporate water temperature data more appropriate for bluefish in a timelier manner [e.g., sea surface temperature data & temperature data that cover the full range of bluefish habitat (SAB and estuaries)].

- This addresses the current limitations of the habitat suitability model for bluefish (limited to hindcast bottom temps, in the MAB).

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Table B3.1 State shares of Commercial Quota as specified in Amendment 1.

State	% of Federal Quota
Maine	0.6685
New Hampshire	0.4145
Massachusetts	6.7167
Rhode Island	6.8081
Connecticut	1.2663
New York	10.3851
New Jersey	14.8162
Delaware	1.8782
Maryland	3.0018
Virginia	11.8795
North Carolina	32.0608
South Carolina	0.0352
Georgia	0.0095
Florida	10.0597
Coastwide Total	**100**

Table B3.2 State by state Recreational and Commercial Management Measures

State	Recreational Bag Limit	Recreational Season	Recreational Size Limit	Commercial Trip Limit	Commercial Open Season
ME	3 fish	All year	None		
NH	10 fish	All year	None		JUL 1 – SEP 30
MA	10 fish	All year	None	5,000 lbs/day	
RI	15 fish	All year	None		
CT	10 fish	All year	None	750 lbs/day between 1/1-4/30 until 30% of the state quota is landed; 500 lbs/day	JAN 1 – DEC 31
NY	15 fish	All year	No more than 10 under 12” TL	Varies based on available quota	
NJ	15 fish	All year	None		Gear-specific
DE	10 fish	All year	None		
MD	10 fish	All year	8” minimum		
PRFC	10 fish	All year	None	Daily limits when 80% of VA and MD quotas are met	
VA	10 fish	All year	None		
NC	15 fish	All year	Only 5 greater than 24” TL		
SC	15 fish	All year	None		
GA	15 fish	MAR 16 – NOV 30	12” minimum FL	15 fish	MAR 16 – NOV 30
FL	10 fish	All year	12” minimum FL	7,500 lbs/day	

Table B4.1 ACCSP Gears included in each of the SAW 60 Assessment Gear Categories

SARC 60	ACCSP Gear Types	
Gear Category	**Type Code**	**Gear Type**
Gill Nets	006	GILL NETS
Hook and Line	014	BY HAND
Hook and Line	013	HAND LINE
Hook and Line	007	HOOK AND LINE
Pound Nets	003	FIXED NETS
Seines	001	HAUL SEINES
Seines	002	PURSE SEINES
Trawls	004	TRAWLS
Other	010	DIP NETS AND CAST NETS
Other	009	DREDGE
Other	008	LONG LINES
Other	015	OTHER GEARS
Other	005	POTS AND TRAPS
Other	011	RAKES, HOES, AND TONGS
Other	012	SPEARS AND GIGS
Not Coded	000	NOT CODED

Table B4.2 Data sources for the Virginia bluefish commercial landings data used in Option 1. The greater annual landings were chosen from either the ACCSP data warehouse (ACCSP DW) and the Virginia historical landings database (VA FSMRPT).

YEAR	Database Source
1982	ACCSP DW
1983	ACCSP DW
1984	ACCSP DW
1985	ACCSP DW
1986	ACCSP DW
1987	ACCSP DW
1988	ACCSP DW
1989	ACCSP DW
1990	ACCSP DW
1991	ACCSP DW
1992	ACCSP DW
1993	ACCSP DW
1994	ACCSP DW
1995	ACCSP DW
1996	ACCSP DW
1997	ACCSP DW
1998	ACCSP DW
1999	VA FSMRPT
2000	VA FSMRPT
2001	VA FSMRPT
2002	VA FSMRPT
2003	VA FSMRPT
2004	ACCSP DW
2005	ACCSP DW
2006	VA FSMRPT
2007	ACCSP DW
2008	VA FSMRPT
2009	ACCSP DW
2010	ACCSP DW
2011	VA FSMRPT
2012	VA FSMRPT
2013	VA FSMRPT
2014	ACCSP DW

Table B4.3 Data sources for the Virginia bluefish commercial landings data used in Option 2. The greater annual landings for state dealer reported data, federal dealer reported data, and Potomac River Fisheries Commission (PRFC) were each chosen from either the ACCSP data warehouse (ACCSP) and the Virginia FSMRPT database (VA).

YEAR	STATE	FED	PRFC
1982	ACCSP	ACCSP	ACCSP
1983	ACCSP	ACCSP	ACCSP
1984	ACCSP	ACCSP	ACCSP
1985	ACCSP	ACCSP	ACCSP
1986	ACCSP	ACCSP	ACCSP
1987	ACCSP	ACCSP	ACCSP
1988	ACCSP	ACCSP	ACCSP
1989	ACCSP	ACCSP	ACCSP
1990	ACCSP	ACCSP	ACCSP
1991	ACCSP	ACCSP	ACCSP
1992	ACCSP	ACCSP	ACCSP
1993	ACCSP	ACCSP	ACCSP
1994	ACCSP	ACCSP	ACCSP
1995	ACCSP	ACCSP	ACCSP
1996	VA	ACCSP	ACCSP
1997	VA	ACCSP	ACCSP
1998	ACCSP	ACCSP	ACCSP
1999	VA	ACCSP	ACCSP
2000	VA	VA	ACCSP
2001	VA	ACCSP	ACCSP
2002	VA	ACCSP	ACCSP
2003	VA	ACCSP	ACCSP
2004	ACCSP	VA	ACCSP
2005	VA	ACCSP	ACCSP
2006	VA	ACCSP	VA
2007	ACCSP	ACCSP	VA
2008	VA	VA	VA
2009	ACCSP	ACCSP	ACCSP
2010	VA	VA	ACCSP
2011	VA	VA	ACCSP
2012	VA	VA	ACCSP
2013	VA	VA	ACCSP
2014	ACCSP	ACCSP	VA

Table B4.4 Comparison of commercial bluefish landings data (in pounds) from the NEFSC database, the ACCSP data warehouse, and the local state records. State data supplied by Florida Department of Environmental Protection, North Carolina Department of Marine Fisheries trip ticket program, and the Virginia Marine Resources Commission.

	2011			2012			2013		
	NEFSC	**State**	**ACCSP**	**NEFSC**	**State**	**ACCSP**	**NEFSC**	**State**	**ACCSP**
FL	203,000	244,447	245,868	?	178,197	181,491	110,489	142,199	151,958
NC	1,613,585	1,901,143	1,897,408	569,275	746,720	758,858	952,307	1,135,481	1,159,580
VA	255,250	256,889	252,854	516,062	183,861	514,220	315,954	300,310	282,482

Table B4.5 Percent difference in commercial bluefish landings data between the NEFSC database, or the ACCSP data warehouse, and the local state records. State data supplied by Florida Department of Environmental Protection, North Carolina Department of Marine Fisheries trip ticket program, and the Virginia Marine Resources Commission.

	2011		**2012**		**2013**	
	NEFSC	**ACCSP**	**NEFSC**	**ACCSP**	**NEFSC**	**ACCSP**
FL	-17%	1%	-100%	2%	-22%	7%
NC	-15%	0%	-26%	-1%	-16%	2%
VA	-1%	-2%	181%	180%	5%	-6%

Table B4.6 Bluefish Atlantic coast commercial landings (mt) by state. Asterisks indicate confidential data. Data Source ACCSP

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC	SC	GA	FL	Total
1982	74.8	30.3	406.1	270.4	136.2	781.4	898.5	231.8	131.0	1,176.2	1,946.3	4.2	1.0	910.8	6,999.2
1983	77.1	13.8	453.8	235.5	31.5	765.3	872.9	131.7	149.9	689.4	3,060.4	5.1	0.1	679.8	7,166.5
1984	22.0	8.0	318.3	462.3	45.4	742.1	767.5	71.3	83.9	525.2	1,614.8	0.9	0.1	719.1	5,381.0
1985	41.0	10.3	362.1	767.8	82.5	967.6	902.1	85.3	231.0	749.8	1,634.9	0.8	0.1	288.5	6,123.9
1986	46.9	27.7	708.8	518.4	86.2	733.6	1,362.2	181.5	207.1	686.4	1,565.0	3.8	1.0	528.5	6,657.2
1987	47.9	58.1	361.5	537.4	79.7	709.7	1,148.5	160.8	165.0	536.2	2,068.9	1.5	1.2	702.0	6,578.6
1988	3.9	10.4	365.7	464.3	46.3	510.4	1,126.5	94.9	467.7	1,186.5	2,285.7	1.6	1.3	596.8	7,162.1
1989	34.6	62.2	562.4	549.6	88.0	256.1	717.9	47.3	125.1	349.5	1,493.0	1.2	0.2	453.0	4,740.0
1990	24.4	89.4	546.1	537.4	81.3	731.3	984.7	65.2	129.5	495.1	2,076.6	0.5	0.2	488.3	6,250.3
1991	56.6	57.7	343.0	676.1	116.8	716.0	1,110.3	153.1	105.8	373.8	1,778.0	0.6	0.1	650.1	6,138.2
1992	39.3	103.4	376.3	703.1	121.9	677.1	997.1	42.0	93.6	269.1	1,287.8	0.9	0.4	495.6	5,207.7
1993	8.3	73.8	288.6	542.1	61.0	702.7	994.0	13.4	60.6	294.8	1,227.1	0.2	0.2	551.8	4,818.6
1994	24.5	124.9	543.0	409.1	68.9	667.6	858.3	15.7	74.8	284.7	808.5	3.0	0.3	423.1	4,306.2
1995	8.8	84.8	253.0	350.2	53.2	590.2	384.6	16.5	48.9	243.8	1,365.6	*	0.5	228.6	3,628.8
1996	5.5	72.5	409.2	291.2	45.9	719.8	731.0	62.5	37.3	279.4	1,496.2	1.0	0.2	60.9	4,212.8
1997	1.2	28.4	197.0	270.5	32.7	682.4	559.2	13.3	44.3	335.4	1,815.8	0.2	0.3	128.8	4,109.5
1998		7.6	164.8	258.9	25.6	716.0	627.5	12.6	84.1	360.5	1,327.2	1.1	0.3	154.7	3,740.8
1999	*	5.5	186.4	272.3	24.1	644.7	490.0	8.9	65.9	217.2	1,252.4	0.3	0.2	157.1	3,325.1
2000	0.1	10.9	128.1	157.6	15.2	843.9	608.4	13.2	38.2	252.1	1,528.2	0.1	0.4	64.0	3,660.3
2001		5.3	158.1	219.2	20.8	624.3	583.6	8.5	59.2	366.4	1,844.3	0.1	0.2	62.7	3,952.8
2002	0.4	2.4	184.5	254.6	24.6	669.1	600.9	20.8	51.5	216.0	1,054.1		0.2	36.9	3,115.9
2003	0.3	3.9	150.2	189.6	20.3	707.6	459.2	13.9	24.0	171.6	1,574.0	*	0.4	44.3	3,359.3
2004	0.3	11.3	209.3	267.9	19.1	652.7	485.7	12.2	21.1	217.9	1,707.7	0.1	0.9	54.8	3,661.1
2005	0.1	2.4	214.6	248.9	17.7	516.6	543.6	20.1	55.4	233.5	1,287.1	0.1	0.2	70.5	3,210.8
2006	0.1	13.1	231.5	268.7	18.8	535.4	475.4	18.8	31.8	347.0	1,266.0	0.1	0.0	45.1	3,251.8
2007	2.2	5.3	260.2	267.8	10.3	666.0	636.4	8.9	66.3	329.4	1,056.7	0.1	0.2	76.2	3,386.1
2008	0.4	4.0	231.6	180.6	17.0	572.1	463.5	10.3	40.6	267.0	875.6	0.2	*	67.3	2,730.3
2009	0.5	1.7	174.8	225.6	21.6	587.4	649.5	10.1	74.3	206.0	1,070.5	0.1	0.1	97.1	3,119.2
2010	0.1	1.4	265.8	159.3	19.0	379.8	627.0	8.7	55.8	184.5	1,458.8	0.2	0.1	143.4	3,303.7
2011		1.9	262.4	185.7	21.0	531.5	321.8	5.3	36.5	115.3	860.6	0.2	0.1	110.9	2,453.3
2012	0.6	14.0	311.3	285.1	38.8	500.3	312.7	7.3	83.3	233.7	344.2	*		80.8	2,212.1
2013	*	0.1	268.3	207.5	14.5	572.1	157.2	4.6	22.6	136.5	526.0	*	*	67.9	1,977.4
2014		1.4	213.8	229.0	14.1	427.4	230.9	1.5	36.1	92.3	915.8	*		74.1	2,236.5

Table B4.7 Bluefish Atlantic coast commercial landings (mt) by gear category. Data source: ACCSP.

Year	GILL NETS	HOOK-N-LINE	NOT CODED	OTHER GEARS	POUND NETS	SEINES	TRAWLS	Percentage of landings by gillnets
1982	2,513.7	512.3		912.5	947.7	494.3	1,618.5	35.9%
1983	2,307.7	532.6		682.4	728.9	427.2	2,487.5	32.2%
1984	1,988.6	440.0		719.5	573.4	379.9	1,279.2	37.0%
1985	2,184.5	454.1		391.0	822.0	588.1	1,684.2	35.7%
1986	2,801.6	436.0	528.5	13.7	782.4	575.5	1,519.4	42.1%
1987	3,306.2	512.9	702.0	14.7	678.4	282.9	1,081.5	50.3%
1988	3,129.7	481.5	596.8	5.1	1,395.2	331.9	1,221.8	43.7%
1989	2,509.9	295.0	453.0	1.9	232.3	169.7	1,078.1	53.0%
1990	3,408.5	440.6	488.3	5.9	514.9	309.6	1,082.4	54.5%
1991	3,129.0	384.3	586.5	5.6	382.9	443.1	1,206.7	51.0%
1992	2,637.3	350.1	87.7	30.3	375.9	275.7	1,450.6	50.6%
1993	2,902.4	372.5	13.7	16.7	438.0	189.9	885.4	60.2%
1994	2,575.7	168.5	301.3	24.1	285.8	129.6	821.1	59.8%
1995	2,215.8	144.8	83.5	21.4	307.9	98.7	756.6	61.1%
1996	2,611.4	388.6	27.7	11.5	243.5	90.3	839.9	62.0%
1997	2,789.1	150.7	26.6	12.7	241.4	114.9	777.9	67.8%
1998	2,427.2	168.8	42.1	32.0	291.4	80.1	699.1	64.9%
1999	2,084.4	167.0	11.5	16.1	224.0	145.0	687.0	62.5%
2000	2,572.5	129.8	12.0	7.6	219.8	58.8	659.8	70.3%
2001	2,821.5	148.5	28.4	12.5	363.3	54.8	526.6	71.3%
2002	2,022.9	158.0	17.7	18.0	325.0	43.8	533.3	64.9%
2003	2,413.4	170.1	0.2	31.6	311.2	42.7	392.0	71.8%
2004	2,273.5	157.1	651.1	164.3	99.2	33.7	294.6	61.9%
2005	1,683.8	140.7	653.7	151.1	196.3	56.7	333.0	52.4%
2006	1,942.5	172.1	686.8	36.8	150.2	49.5	247.7	59.1%
2007	1,816.0	165.7	812.6	39.3	347.5	69.5	139.4	53.6%
2008	1,463.6	136.4	624.3	37.7	181.4	56.5	230.3	53.6%
2009	1,782.1	145.9	760.1	45.4	128.1	64.5	193.0	57.1%
2010	2,116.8	235.0	522.5	57.3	147.3	35.0	189.8	64.1%
2011	1,343.8	175.7	630.5	29.4	43.8	26.9	203.2	54.8%
2012	910.6	190.2	725.1	35.6	63.3	23.9	263.4	41.2%
2013	906.6	174.4	634.4	35.5	63.8	11.8	150.8	45.9%
2014	1,204.3	219.2	539.7	12.5	140.1	16.5	116.0	53.6%

Table B4.8 Top ports of bluefish landings (in metric tons), based on NMFS 2013 dealer data. Since this table includes only the "top ports" (ports where landings of bluefish were > 45.4 mt), it does not include all of the landings for the year.

Port[a]	**Metric Tons**	**# Vessels**
WANCHESE, NC	277.7	15
POINT JUDITH, RI	181.7	90
MONTAUK, NY	160.8	84
HAMPTON BAYS, NY	156.8	30
HATTERAS, NC	79.0	13
AMAGANSETT, NY	69.0	4
POINT PLEASANT, NJ	56.6	67
CHATHAM, MA	56.5	24
BELFORD, NJ	52.3	13
SHINNECOCK, NY	48.9	-

Table B4.9 Commercial landings (mt) by state grouping used in length expansions.

Year	State Groupings Landings (mt)			Total	State Groupings Lengths			Total
	ME - VA	NC	SC-FL		ME - VA	NC	SC-FL	
1985	4,199.6	1,635.0	289.4	**6,124.0**	1,581	5,243		**6,824**
1986	4,558.8	1,565.0	533.3	**6,657.1**	1,838	3,748		**5,586**
1987	3,804.9	2,068.9	704.7	**6,578.5**	1,105	3,576		**4,681**
1988	4,276.6	2,285.7	599.7	**7,162.0**	1,961	3,831		**5,792**
1989	2,792.7	1,493.0	454.4	**4,740.1**	590	5,149		**5,739**
1990	3,684.4	2,076.6	489.0	**6,250.0**	201	7,447		**7,648**
1991	3,709.2	1,778.0	650.8	**6,138.0**	201	5,540		**5,741**
1992	3,422.9	1,287.8	496.9	**5,207.6**	400	6,004	1,618	**8,022**
1993	3,039.3	1,227.1	552.2	**4,818.6**	200	3,613	1,445	**5,258**
1994	3,071.5	808.5	426.4	**4,306.4**	763	1,983	463	**3,209**
1995	2,034.0	1,365.6	229.1	**3,628.7**	189	1,820	258	**2,267**
1996	2,654.4	1,496.2	62.1	**4,212.7**	1,321	2,253	966	**4,540**
1997	2,164.6	1,815.8	129.3	**4,109.7**	1,520	4,086	278	**5,884**
1998	2,257.7	1,327.2	156.1	**3,741.0**	4,107	4,222	341	**8,670**
1999	1,915.0	1,252.4	157.6	**3,325.0**	3,183	6,608	48	**9,839**
2000	2,067.8	1,528.2	64.5	**3,660.5**	1,779	8,163	76	**10,018**
2001	2,045.4	1,844.3	63.0	**3,952.7**	2,964	11,112	139	**14,215**
2002	2,024.9	1,054.1	37.1	**3,116.1**	4,579	7,979	95	**12,653**
2003	1,740.6	1,574.0	44.7	**3,359.3**	4,636	7,663	25	**12,324**
2004	1,897.5	1,707.7	55.8	**3,661.0**	6,134	9,495	48	**15,677**
2005	1,853.0	1,287.1	70.8	**3,210.9**	5,955	9,277	92	**15,324**
2006	1,940.6	1,266.1	45.2	**3,251.9**	8,520	9,995	437	**18,952**
2007	2,252.8	1,056.8	76.5	**3,386.1**	5,942	8,184	128	**14,254**
2008	1,787.1	875.6	67.5	**2,730.2**	7,244	7,463	81	**14,788**
2009	1,951.5	1,070.5	97.3	**3,119.3**	7,038	7,184	660	**14,882**
2010	1,701.5	1,458.8	143.7	**3,304.0**	6,556	6,671	706	**13,933**
2011	1,481.4	860.7	111.2	**2,453.3**	8,390	5,722	261	**14,373**
2012	1,787.1	344.2	80.8	**2,212.1**	10,912	7,007	603	**18,522**
2013	1,383.4	526.0	67.9	**1,977.3**	5,388	6,920	383	**12,691**
2014	1,246.5	915.8	74.1	**2,236.4**	4,371	6,333	207	**10,911**

Table B4.10 Landings (lbs), lengths sampled, and sampling intensity (lengths/100 lbs landed) for ME-VA and NC-FL by quarter and market category from 1985-1987.

	1985				1986				1987			
	ME-VA Landings (lbs)				**ME-VA Landings (lbs)**				**ME-VA Landings (lbs)**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	0	0	9896307	0	0	0	11226201	0	0	0	9942058
Large	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Small	0	0	0	0	0	0	0	0	0	0	0	0
	NC-FL Landings (lbs)				**NC-FL Landings (lbs)**				**NC-FL Landings (lbs)**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	1216531	685832	0	1702082	1591089	398486	641679	818976	1548739	966302	535134	1510926
Large	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Small	0	0	0	0	0	0	0	0	0	0	0	0
	ME-VA LENGTHS				**ME-VA LENGTHS**				**ME-VA LENGTHS**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	0	0	1581	0	0	0	1838	0	0	0	1105
Large	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Small	0	0	0	0	0	0	0	0	0	0	0	0
	NC LENGTHS				**NC LENGTHS**				**NC LENGTHS**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	1622	1506	0	2115	2477	180	58	1033	2270	394	5	907
Large	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Small	0	0	0	0	0	0	0	0	0	0	0	0
	LENGTHS/100 LBS ME-VA				**LENGTHS/100 LBS ME-VA**				**LENGTHS/100 LBS ME-VA**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0.000	0.000	0.000	0.016	0.000	0.000	0.000	0.016	0.000	0.000	0.000	0.011
Large	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Medium	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Small	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	LENGTHS/100 LBS NC-FL				**LENGTHS/100 LBS NC-FL**				**LENGTHS/100 LBS NC-FL**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0.133	0.220	0.000	0.124	0.156	0.045	0.009	0.126	0.147	0.041	0.001	0.060
Large	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Medium	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Small	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table B4.11 Landings (lbs), lengths sampled, and sampling intensity (lengths/100 lbs landed) for ME-VA and NC-FL by quarter and market category from 1988-1990.

	1988				1989				1990			
	ME-VA Landings (lbs)				**ME-VA Landings (lbs)**				**ME-VA Landings (lbs)**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	0	0	10750523	0	0	0	7158323	0	2215473	0	6985824
Large	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Small	0	0	0	0	0	0	0	0	0	0	0	0
	NC-FL Landings (lbs)				**NC-FL Landings (lbs)**				**NC-FL Landings (lbs)**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	2577962	1115345	412704	933028	1192144	383105	405966	1310253	1668557	652815	566638	1690162
Large	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Small	0	0	0	0	0	0	0	0	0	0	0	0
	ME-VA LENGTHS				**ME-VA LENGTHS**				**ME-VA LENGTHS**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	0	0	1961	0	0	0	590	0	104	0	97
Large	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Small	0	0	0	0	0	0	0	0	0	0	0	0
	NC LENGTHS				**NC LENGTHS**				**NC LENGTHS**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	2719	151	643	318	2144	784	19	2202	1151	843	357	5096
Large	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Small	0	0	0	0	0	0	0	0	0	0	0	0
	LENGTHS/100 LBS ME-VA				**LENGTHS/100 LBS ME-VA**				**LENGTHS/100 LBS ME-VA**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0.000	0.000	0.000	0.018	0.000	0.000	0.000	0.008	0.000	0.005	0.000	0.001
Large	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Medium	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Small	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	LENGTHS/100 LBS NC-FL				**LENGTHS/100 LBS NC-FL**				**LENGTHS/100 LBS NC-FL**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0.105	0.014	0.156	0.034	0.180	0.205	0.005	0.168	0.069	0.129	0.063	0.302
Large	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Medium	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Small	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table B4.12 Landings (lbs), lengths sampled, and sampling intensity (lengths/100 lbs landed) for ME-VA and NC-FL by quarter and market category for 1991

1991				
ME-VA Landings (lbs)				
Market	1	2	3	4
Uncl	0	0	0	9612438
Large	0	0	0	0
Medium	0	0	0	0
Small	0	0	0	0
NC-FL Landings (lbs)				
Market	1	2	3	4
Uncl	1565142	1066933	437117	850594
Large	0	0	0	0
Medium	0	0	0	0
Small	0	0	0	0
ME-VA LENGTHS				
Market	1	2	3	4
Uncl	0	0	0	201
Large	0	0	0	0
Medium	0	0	0	0
Small	0	0	0	0
NC LENGTHS				
Market	1	2	3	4
Uncl	1681	2877	554	428
Large	0	0	0	0
Medium	0	0	0	0
Small	0	0	0	0
LENGTHS/100 LBS ME-VA				
Market	1	2	3	4
Uncl	0.000	0.000	0.000	0.002
Large	0.000	0.000	0.000	0.000
Medium	0.000	0.000	0.000	0.000
Small	0.000	0.000	0.000	0.000
LENGTHS/100 LBS NC-FL				
Market	1	2	3	4
Uncl	0.107	0.270	0.127	0.050
Large	0.000	0.000	0.000	0.000
Medium	0.000	0.000	0.000	0.000
Small	0.000	0.000	0.000	0.000

Table B4.13 Landings (lbs), lengths sampled, and sampling intensity (lengths/100 lbs landed) for ME-VA and NC and FL by quarter and market from 1992-1994

	1992				1993				1994			
	ME-VA Landings (lbs)				**ME-VA Landings (lbs)**				**ME-VA Landings (lbs)**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	0	0	7546329	0	0	0	6700454	0	0	0	6771230
Large	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Small	0	0	0	0	0	0	0	0	0	0	0	0
	NC-FL Landings (lbs)				**NC-FL Landings (lbs)**				**NC-FL Landings (lbs)**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	1119651	760851	367899	590656	1053609	708245	207112	736312	0	22791	4169	4652
Large	0	0	0	0	0	0	0	0	953853	223986	0	118162
Medium	0	0	0	0	0	0	0	0	12174	96908	0	197038
Small	0	0	0	0	0	0	0	0	6265	75054	39326	27971
	FL Landings (lbs)				**FL Landings (lbs)**				**FL Landings (lbs)**			
Market	1	2			1	2			1	2		
ALL	886286	209119			911803	305561			751367	188513		
	ME-VA LENGTHS				**ME-VA LENGTHS**				**ME-VA LENGTHS**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	0	0	400	0	0	0	200	0	0	0	763
Large	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Small	0	0	0	0	0	0	0	0	0	0	0	0
	NC LENGTHS				**NC LENGTHS**				**NC LENGTHS**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
	1580	3687	74	664	1706	1667	9	232	0	223	152	22
	0	0	0	0	0	0	0	0	117	69	0	4
	0	0	0	0	0	0	0	0	2	53	0	366
	0	0	0	0	0	0	0	0	14	868	1	91
	FL LENGTHS				**FL LENGTHS**				**FL LENGTHS**			
Market	1	2			1	2			1	2		
ALL	1534	84			1064	381			339	124		

Table B4.13 continued

LENGTHS/100 LBS ME-VA					LENGTHS/100 LBS ME-VA				LENGTHS/100 LBS ME-VA			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.011
Large	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Medium	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Small	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

LENGTHS/100 LBS NC-FL					LENGTHS/100 LBS NC-FL				LENGTHS/100 LBS NC-FL			
Market	1	2	3	4	1	2	3	4	1	2	3	4
	0.141	0.485	0.020	0.112	0.162	0.235	0.004	0.032	0.000	0.979	3.650	0.480
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.031	0.000	0.003
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.019	0.055	0.000	0.186
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.221	1.157	0.003	0.326

LENGTHS/100 LBS FL			LENGTHS/100 LBS FL		LENGTHS/100 LBS FL	
Market	1	2	1	2	1	2
ALL	0.173	0.040	0.117	0.125	0.045	0.066

Table B4.14 Landings (lbs), lengths sampled, and sampling intensity (lengths/100 lbs landed) for ME-VA and NC and FL by quarter and market from 1995-1997

	1995				1996				1997			
	ME-VA Landings (lbs)				ME-VA Landings (lbs)				ME-VA Landings (lbs)			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	0	0	4484236	0	0	0	4022405	0	549995	1663339	929822
Large	0	0	0	0	0	436711	0	397946	0	230725	134306	198149
Medium	0	0	0	0	0	311974	220725	162051	22291	155799	312025	279245
Small	0	0	0	0	0	0	0	300320	0	0	0	295935
	NC-FL Landings (lbs)				NC-FL Landings (lbs)				NC-FL Landings (lbs)			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	16025	5887	4193	36676	6226	1258	20537	683	2236	3251	16886
Large	1362944	309057	0	377058	0	1807659	4150	808059	1617501	133168	15645	1150077
Medium	352888	201006	141958	98275	32294	270928	107081	58020	180629	286555	161528	277247
Small	7498	55519	24521	53822	16695	81983	17949	29064	0	77853	29417	50486
	FL Landings (lbs)				FL Landings (lbs)				FL Landings (lbs)			
Market	1	2			1	2			1	2		
ALL	481975	23158			47042	89692			143374	141728		
	ME-VA LENGTHS				ME-VA LENGTHS				ME-VA LENGTHS			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	0	0	189	0	0	0	198	0	161	97	185
Large	0	0	0	0	0	94	0	100	0	200	104	59
Medium	0	0	0	0	0	100	100	229	100	83	69	156
Small	0	0	0	0	0	0	0	500	0	0	0	306
	NC LENGTHS				NC LENGTHS				NC LENGTHS			
Market	1	2	3	4	1	2	3	4	1	2	3	4
	0	109	1295	2	1	300	76	15	22	475	78	27
	32	43	0	19	0	556	5	16	154	4	1	231
	8	2	20	89	42	138	63	109	212	686	155	602
	10	18	17	155	10	100	28	794	0	896	102	442
	FL LENGTHS				FL LENGTHS				FL LENGTHS			
Market	1	2			1	2			1	2		
ALL	253	5			247	719			196	82		

Table B4.14 continued.

LENGTHS/100 LBS ME-VA					LENGTHS/100 LBS ME-VA				LENGTHS/100 LBS ME-VA			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.005	0.000	0.029	0.006	0.020
Large	0.000	0.000	0.000	0.000	0.000	0.022	0.000	0.025	0.000	0.087	0.077	0.030
Medium	0.000	0.000	0.000	0.000	0.000	0.032	0.045	0.141	0.449	0.053	0.022	0.056
Small	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.166	0.000	0.000	0.000	0.103

LENGTHS/100 LBS NC-FL					LENGTHS/100 LBS NC-FL				LENGTHS/100 LBS NC-FL			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0.000	0.679	22.005	0.053	0.002	4.814	6.071	0.073	3.251	21.234	2.388	0.160
Large	0.002	0.014	0.000	0.005	0.000	0.031	0.116	0.002	0.010	0.003	0.006	0.020
Medium	0.002	0.001	0.014	0.091	0.130	0.051	0.059	0.188	0.117	0.239	0.096	0.217
Small	0.132	0.033	0.067	0.289	0.061	0.122	0.156	2.730	0.000	1.151	0.346	0.876

LENGTHS/100 LBS FL			LENGTHS/100 LBS FL		LENGTHS/100 LBS FL	
Market	1	2	1	2	1	2
ALL	0.052	0.022	0.525	0.802	0.137	0.058

Table B4.14 continued.

Table B4.15 Landings (lbs), lengths sampled, and sampling intensity (lengths/100 lbs landed) for ME-VA, NC and FL by qtr and mkt from 1998-2000

	1998				1999				2000			
	ME-VA Landings (lbs)				**ME-VA Landings (lbs)**				**ME-VA Landings (lbs)**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	633916	1E+06	993435	30497	662807	1E+06	813393	0	735574	1283634	748623
Large	0	197731	199747	277190	0	220623	113921	338687	0	0	0	1052196
Medium	0	296007	212184	325364	0	146088	115502	167659	0	109380	112652	196955
Small	0	62723	288506	147584	0	47842	133366	87347	0	22488	181189	115596
	NC-FL Landings (lbs)				**NC-FL Landings (lbs)**				**NC-FL Landings (lbs)**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	32222	18298	3031	3178	1781	40725	1106	618	785	7776	2850	12439
Large	1253323	156499	7399	251938	1383951	267491	2982	63114	1877721	604071	0	109261
Medium	265311	530196	80354	208319	540410	323717	55285	25387	33943	164704	146149	333541
Small	16167	55664	9115	34920	6551	30192	6658	11123	6678	32515	19485	17256
	FL Landings (lbs)				**FL Landings (lbs)**				**FL Landings (lbs)**			
Market	1	2			1	2			1	2		
ALL	261535	82568			216411	131167			82395.89	59538.65		
	ME-VA LENGTHS				**ME-VA LENGTHS**				**ME-VA LENGTHS**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	361	556	242	5	807	292	139	0	131	231	100
Large	0	117	295	65	0	454	58	94	0	0	0	19
Medium	0	582	241	570	0	27	378	66	0	316	389	94
Small	0	201	857	20	0	168	543	152	0	120	252	127
	NC LENGTHS				**NC LENGTHS**				**NC LENGTHS**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
	31	53	118	24	26	164	22	22	338	131	92	100
	386	160	0	252	1175	191	30	200	1528	739	0	410
	297	1484	226	146	3260	546	205	33	64	1537	752	2120
	3	236	84	723	2	45	5	682	57	99	10	186
FL LENGTHS					**FL LENGTHS**				**FL LENGTHS**			
Market	1	2			1	2			1	2		
ALL	176	165			31	17			27	49		

Table B4.15 continued

LENGTHS/100 LBS ME-VA					**LENGTHS/100 LBS ME-VA**				**LENGTHS/100 LBS ME-VA**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0.000	0.057	0.041	0.024	0.016	0.122	0.022	0.017	0.000	0.018	0.018	0.013
Large	0.000	0.059	0.148	0.023	0.000	0.206	0.051	0.028	0.000	0.000	0.000	0.002
Medium	0.000	0.197	0.114	0.175	0.000	0.018	0.327	0.039	0.000	0.289	0.345	0.048
Small	0.000	0.320	0.297	0.014	0.000	0.351	0.407	0.174	0.000	0.534	0.139	0.110

LENGTHS/100 LBS NC-FL					**LENGTHS/100 LBS NC-FL**				**LENGTHS/100 LBS NC-FL**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0.096	0.288	3.900	0.740	1.472	0.403	1.954	3.619	43.110	1.684	3.237	0.803
Large	0.031	0.102	0.000	0.100	0.085	0.071	1.007	0.316	0.081	0.122	0.000	0.375
Medium	0.112	0.280	0.281	0.070	0.603	0.169	0.371	0.129	0.189	0.933	0.515	0.635
Small	0.020	0.425	0.917	2.071	0.031	0.150	0.078	6.128	0.860	0.303	0.053	1.076

LENGTHS/100 LBS FL			**LENGTHS/100 LBS FL**		**LENGTHS/100 LBS FL**	
Market	1	2	1	2	1	2
ALL	0.067	0.200	0.014	0.013	0.033	0.082

Table B4.16 Landings (lbs), lengths sampled, and sampling intensity (lengths/100 lbs landed) for ME-VA and NC and FL by quarter and market from 2001-2003

	2001				2002				2003			
	ME-VA Landings (lbs)				**ME-VA Landings (lbs)**				**ME-VA Landings (lbs)**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	805131	1E+06	778394	0	678907	1E+06	625413	0	662155	1013769	701414
Large	0	463262	199838	232986	0	478070	116171	163468	0	232833	241607	220684
Medium	0	276613	159410	139296	0	459751	133368	130594	0	207303	185263	267065
Small	0	9611	93506	104163	6747	24477	217447	177921	0	16998	48405	39659
	NC-FL Landings (lbs)				**NC-FL Landings (lbs)**				**NC-FL Landings (lbs)**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	10405	43284	7894	2359	1691	16439	6636	4495	5127	45489	11192	13896
Large	1830585	461745	0	431941	1106634	142963	24559	426592	1273604	426179	0	606910
Medium	694884	340755	100816	49511	249271	97726	78640	108361	449807	388971	106195	78996
Small	16829	35303	18921	20770	9658	20105	10821	19381	25251	30074	4256	4155
	FL Landings (lbs)				**FL Landings (lbs)**				**FL Landings (lbs)**			
Market	1	2			1	2			1	2		
ALL	65955.5	72971			41290.42	40426.75			51507.94	47117.09		
	ME-VA LENGTHS				**ME-VA LENGTHS**				**ME-VA LENGTHS**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	546	506	126	0	397	591	115	0	967	527	78
Large	0	5	102	276	0	311	6	22	0	342	353	112
Medium	0	438	242	104	0	376	1414	305	0	914	318	538
Small	0	92	513	14	29	174	427	412	0	94	277	116
	NC LENGTHS				**NC LENGTHS**				**NC LENGTHS**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
	4	311	50	22	578	37	107	64	11	284	110	22
	1307	741	0	208	884	628	532	482	1460	1429	0	851
	5429	918	281	39	1709	962	523	216	1255	724	369	184
	252	974	174	403	19	372	37	829	96	589	19	259
	FL LENGTHS				**FL LENGTHS**				**FL LENGTHS**			
Market	1	2			1	2			1	2		
ALL	97	42			67	28			16	9		

Table B4.16 continued.

LENGTHS/100 LBS ME-VA					LENGTHS/100 LBS ME-VA				LENGTHS/100 LBS ME-VA			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0.000	0.068	0.041	0.016	0.000	0.058	0.047	0.018	0.000	0.146	0.052	0.011
Large	0.000	0.001	0.051	0.118	0.000	0.065	0.005	0.013	0.000	0.147	0.146	0.051
Medium	0.000	0.158	0.152	0.075	0.000	0.082	1.060	0.234	0.000	0.441	0.172	0.201
Small	0.000	0.957	0.549	0.013	0.430	0.711	0.196	0.232	0.000	0.553	0.572	0.292
LENGTHS/100 LBS NC-FL					**LENGTHS/100 LBS NC-FL**				**LENGTHS/100 LBS NC-FL**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0.035	0.717	0.633	0.914	34.186	0.223	1.613	1.418	0.222	0.625	0.980	0.161
Large	0.071	0.160	0.000	0.048	0.080	0.439	2.165	0.113	0.115	0.335	0.000	0.140
Medium	0.781	0.269	0.279	0.078	0.686	0.984	0.665	0.199	0.279	0.186	0.347	0.233
Small	1.495	2.759	0.918	1.942	0.197	1.852	0.342	4.277	0.381	1.959	0.450	6.222
LENGTHS/100 LBS FL					**LENGTHS/100 LBS FL**				**LENGTHS/100 LBS FL**			
Market	1	2			1	2			1	2		
ALL	0.147	0.058			0.162	0.069			0.031	0.019		

Table B4.17 Landings (lbs), lengths sampled, and sampling intensity (lengths/100 lbs landed) for ME-VA and NC and FL by quarter and market from 2004-2006

	2004				2005				2006			
	ME-VA Landings (lbs)				**ME-VA Landings (lbs)**				**ME-VA Landings (lbs)**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	298155	835685	704000	0	294102	771819	683274	0	319591	889968	1047738
Large	0	405767	434333	340119	0	269187	402303	313423	0	459678	355681	245392
Medium	0	316733	355258	319993	0	476997	338647	425710	0	316411	300782	214663
Small	0	25732	92369	55319	0	54610	34022	20870	0	23816	67187	37137
	NC-FL Landings (lbs)				**NC-FL Landings (lbs)**				**NC-FL Landings (lbs)**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	31115	9208	4320	19356	6088	14823	5028	13595	467	8132	4074	13161
Large	1492357	420338	11737	721649	973177	391382	3858	588585	1518621	181056	8768	107665
Medium	392065	308445	103907	203167	268925	300991	150863	73184	360414	248423	131789	170221
Small	4466	20910	10923	10830	1570	29532	8216	7801	0	22834	7255	8283

	2004		2005		2006	
	FL Landings (lbs)		**FL Landings (lbs)**		**FL Landings (lbs)**	
Market	1	2	1	2	1	2
ALL	60418.6	62611	71433.66	84448.1	42083.76	57529.35

	2004				2005				2006			
	ME-VA LENGTHS				**ME-VA LENGTHS**				**ME-VA LENGTHS**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	823	1595	1099	0	456	1450	630	0	887	1392	423
Large	0	422	365	240	0	232	570	159	0	220	370	399
Medium	0	206	193	273	0	385	338	809	0	558	1173	1196
Small	0	112	687	119	0	178	519	229	0	268	1043	591
	NC LENGTHS				**NC LENGTHS**				**NC LENGTHS**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
	23	131	106	27	18	159	43	390	7	103	90	150
	1773	792	25	921	2539	971	18	925	3139	505	3	26
	2378	578	138	1859	649	1822	269	431	1703	969	644	1387
	22	380	7	335	16	439	2	587	0	661	53	556

	2004		2005		2006	
	FL LENGTHS		**FL LENGTHS**		**FL LENGTHS**	
Market	1	2	1	2	1	2
ALL	6	42	39	53	17	420

Table B4.17 continued.

LENGTHS/100 LBS ME-VA					LENGTHS/100 LBS ME-VA				LENGTHS/100 LBS ME-VA			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0.000	0.276	0.191	0.156	0.000	0.155	0.188	0.092	0.000	0.278	0.156	0.040
Large	0.000	0.104	0.084	0.071	0.000	0.086	0.142	0.051	0.000	0.048	0.104	0.163
Medium	0.000	0.065	0.054	0.085	0.000	0.081	0.100	0.190	0.000	0.176	0.390	0.557
Small	0.000	0.435	0.744	0.215	0.000	0.326	1.525	1.097	0.000	1.125	1.552	1.591
LENGTHS/100 LBS NC-FL					**LENGTHS/100 LBS NC-FL**				**LENGTHS/100 LBS NC-FL**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0.075	1.420	2.456	0.140	0.301	1.069	0.845	2.871	1.415	1.263	2.209	1.140
Large	0.119	0.188	0.216	0.128	0.261	0.248	0.456	0.157	0.207	0.279	0.032	0.024
Medium	0.607	0.187	0.132	0.915	0.241	0.605	0.178	0.589	0.472	0.390	0.488	0.815
Small	0.499	1.818	0.061	3.091	0.997	1.485	0.021	7.525	0.000	2.895	0.728	6.715
LENGTHS/100 LBS FL					**LENGTHS/100 LBS FL**				**LENGTHS/100 LBS FL**			
Market	1	2			1	2			1	2		
ALL	0.010	0.067			0.055	0.063			0.040	0.730		

Table B4.18 Landings (lbs), lengths sampled, and sampling intensity (lengths/100 lbs landed) for ME-VA and NC and FL by quarter and market from 2007-2009

	2007				2008				2009			
	ME-VA Landings (lbs)				ME-VA Landings (lbs)				ME-VA Landings (lbs)			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	465365	1E+06	548862	22008	327421	751174	543981	0	269608	598791	394198
Large	65689	904730	392156	366176	7541	728030	582739	226150	0	567637	824265	584772
Medium	0	418065	249503	313920	2996	187301	299217	192331	53251	328039	336058	196535
Small	0	15494	58743	0	0	3971	56070	8983	6712	11821	26950	103524
	NC-FL Landings (lbs)				NC-FL Landings (lbs)				NC-FL Landings (lbs)			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	367	10210	9639	9577	3667	13037	4717	8610	4769	13723	13148	5735
Large	804366	260947	29271	345664	531879	275869	10541	74647	931732	460649	9076	20080
Medium	216473	311792	128549	114460	455107	239747	106767	113300	232061	202218	235373	101714
Small	12479	24438	13427	38066	34227	27240	15438	15604	0	46454	66454	16897
	FL Landings (lbs)				FL Landings (lbs)				FL Landings (lbs)			
Market	1	2			1	2			1	2		
ALL	67723	100976			87619.44	61223			111982.79	102311.58		
	ME-VA LENGTHS				ME-VA LENGTHS				ME-VA LENGTHS			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	691	1324	372	32	765	1517	620	0	314	1342	776
Large	35	691	89	301	201	326	158	325	0	628	270	553
Medium	0	481	792	393	6	627	985	583	467	368	804	819
Small	0	285	488	0	0	146	400	553	33	95	102	467
	NC LENGTHS				NC LENGTHS				NC LENGTHS			
Market	1	2	3	4	1	2	3	4	1	2	3	4
	190	636	438	260	19	90	45	250	11	133	1222	152
	1408	684	125	34	2222	383	13	3	1733	281	1	3
	407	2149	470	333	1472	702	993	390	1343	671	634	124
	21	481	27	522	184	242	25	430	0	252	4	621
	FL LENGTHS				FL LENGTHS				FL LENGTHS			
Market	1	2			1	2			1	2		
ALL	68	60			21	60			3	657		

Table B4.18 continued

LENGTHS/100 LBS ME-VA					LENGTHS/100 LBS ME-VA				LENGTHS/100 LBS ME-VA			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0.000	0.148	0.113	0.068	0.145	0.234	0.202	0.114	0.000	0.116	0.224	0.197
Large	0.053	0.076	0.023	0.082	2.665	0.045	0.027	0.144	0.000	0.111	0.033	0.095
Medium	0.000	0.115	0.317	0.125	0.200	0.335	0.329	0.303	0.877	0.112	0.239	0.417
Small	0.000	1.839	0.831	0.000	0.000	3.677	0.713	6.156	0.492	0.804	0.378	0.451

LENGTHS/100 LBS NC-FL					LENGTHS/100 LBS NC-FL				LENGTHS/100 LBS NC-FL			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	51.653	6.233	4.543	2.717	0.514	0.689	0.958	2.902	0.230	0.970	9.294	2.644
Large	0.175	0.262	0.425	0.010	0.418	0.139	0.123	0.004	0.186	0.061	0.013	0.012
Medium	0.188	0.689	0.365	0.291	0.324	0.293	0.930	0.344	0.579	0.332	0.269	0.122
Small	0.171	1.967	0.200	1.372	0.537	0.890	0.164	2.755	0.000	0.543	0.005	3.677

LENGTHS/100 LBS FL			LENGTHS/100 LBS FL		LENGTHS/100 LBS FL	
Market	1	2	1	2	1	2
ALL	0.100	0.059	0.024	0.098	0.003	0.642

Table B4.19 Landings (lbs), lengths sampled, and sampling intensity (lengths/100 lbs landed) for ME-VA and NC and FL by quarter and market from 2010-2012

	2010				2011				2012			
	ME-VA Landings (lbs)				**ME-VA Landings (lbs)**				**ME-VA Landings (lbs)**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	237692	618572	308954	42503	349938	466963	382370	146624	451638	568411	443292
Large	26636	717445	767847	398163	6473	335076	527652	388626	40891	448697	396498	509195
Medium	17057	183256	212521	154476	41928	231137	216890	194785	65092	260851	248729	191214
Small	3015	27140	55531	22491	5909	10628	43734	21346	23469	26539	63109	55486
	NC-FL Landings (lbs)											
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	41	5436	1290	2581	129	3145	937	1213	175	4609	14176	12842
Large	1198520	462031	8851	513023	684156	145537	3326	2075	0	72822	5217	1958
Medium	146810	306739	255907	229495	204295	426733	315047	47882	32403	197746	259299	115494
Small	0	42099	15530	27671	1595	43235	12727	5384	4236	15509	15375	7001
	FL Landings (lbs)				**FL Landings (lbs)**				**FL Landings (lbs)**			
Market	1	2			1	2			1	2		
ALL	191790	124812			133662.4	111432			82186.47	96103.7		
	ME-VA LENGTHS				**ME-VA LENGTHS**				**ME-VA LENGTHS**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0	390	1261	836	208	489	1735	1006	362	1059	1522	903
Large	43	460	763	577	13	645	758	800	204	702	651	807
Medium	1	533	241	389	88	358	163	854	293	494	1138	919
Small	26	52	367	617	134	12	264	863	99	697	675	387
	NC LENGTHS				**NC LENGTHS**				**NC LENGTHS**			
Market	1	2	3	4	1	2	3	4	1	2	3	4
	5	240	61	102	51	195	11	70	174	537	147	323
	1634	74	1	587	471	169	2	2	0	29	1	2
	773	1134	700	695	986	2644	829	87	574	2773	1883	151
	0	537	33	95	1	101	33	68	36	99	5	271
	FL LENGTHS				**FL LENGTHS**				**FL LENGTHS**			
Market	1	2			1	2			1	2		
ALL	637	69			92	169			373	230		

Table B4.19 continued

LENGTHS/100 LBS ME-VA					LENGTHS/100 LBS ME-VA				LENGTHS/100 LBS ME-VA			
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	0.000	0.164	0.204	0.271	0.489	0.140	0.372	0.263	0.247	0.234	0.268	0.204
Large	0.161	0.064	0.099	0.145	0.201	0.192	0.144	0.206	0.499	0.156	0.164	0.158
Medium	0.006	0.291	0.113	0.252	0.210	0.155	0.075	0.438	0.450	0.189	0.458	0.481
Small	0.862	0.192	0.661	2.743	2.268	0.113	0.604	4.043	0.422	2.626	1.070	0.697

LENGTHS/100 LBS NC-FL												
Market	1	2	3	4	1	2	3	4	1	2	3	4
Uncl	11.725	4.409	4.727	3.940	39.818	6.213	1.191	5.779	99.447	11.662	1.036	2.519
Large	0.136	0.016	0.011	0.114	0.069	0.116	0.066	0.117	0.000	0.040	0.027	0.100
Medium	0.526	0.370	0.274	0.303	0.483	0.620	0.263	0.181	1.773	1.403	0.726	0.131
Small	0.000	1.277	0.215	0.345	0.053	0.233	0.261	1.272	0.854	0.637	0.032	3.875

LENGTHS/100 LBS FL			LENGTHS/100 LBS FL		LENGTHS/100 LBS FL	
Market	1	2	1	2	1	2
ALL	0.332	0.055	0.069	0.152	0.454	0.239

Table B4.20 Landings (lbs), lengths sampled, and sampling intensity (lengths/100 lbs landed) for ME-VA and NC and FL by quarter and market from 2013-2014

	2013				2014			
	ME-VA Landings (lbs)				**ME-VA Landings (lbs)**			
Market	1	2	3	4	1	2	3	4
Uncl	74489	429754	735891	242154	12776	302644	541012	183442
Large	3783	113071	409792	283111	5415	273359	347966	460803
Medium	32736	266550	265895	108906	0	199598	238909	114482
Small	23059	34376	18162	8156	0	14929	23986	28753
	NC-FL Landings (lbs)				**NC-FL Landings (lbs)**			
Market	1	2	3	4	1	2	3	4
Uncl	47	22781	6905	3180	100	7751	2033	2817
Large	208502	50108	7711	12568	774680	296359	0	16488
Medium	41515	366361	183875	200098	242259	172269	280088	179284
Small	0	33537	12390	10008	0	21422	8543	14960
	FL Landings (lbs)				**FL Landings (lbs)**			
Market	1	2			1	2		
ALL	62430.1	80232			163413.5	0		
	ME-VA LENGTHS				**ME-VA LENGTHS**			
Market	1	2	3	4	1	2	3	4
Uncl	285	283	959	486	1	493	1140	1004
Large	51	145	371	350	3	267	121	279
Medium	344	550	576	342	0	132	270	284
Small	17	304	303	22	0	104	69	204
	NC LENGTHS				**NC LENGTHS**			
Market	1	2	3	4	1	2	3	4
	1	83	7	25	1	44	6	6
	98	65	2	102	1066	110	0	287
	85	3199	951	2176	1285	1110	1220	1072
	0	4	32	90	0	63	13	50
	FL LENGTHS				**FL LENGTHS**			
Market	1	2			1	2		
ALL	216	167			207	0		

Table B4.20 continued

. LENGTHS/100 LBS ME-VA					LENGTHS/100 LBS ME-VA			
Market	1	2	3	4	1	2	3	4
Uncl	0.383	0.066	0.130	0.201	0.008	0.163	0.211	0.547
Large	1.348	0.128	0.091	0.124	0.055	0.098	0.035	0.061
Medium	1.051	0.206	0.217	0.314	0.000	0.066	0.113	0.248
Small	0.074	0.884	1.668	0.270	0.000	0.697	0.288	0.709
LENGTHS/100 LBS NC-FL					**LENGTHS/100 LBS NC-FL**			
Market	1	2	3	4	1	2	3	4
Uncl	2.128	0.363	0.096	0.781	1.000	0.570	0.289	0.226
Large	0.047	0.129	0.028	0.815	0.138	0.037	0.000	1.742
Medium	0.206	0.873	0.517	1.087	0.531	0.644	0.436	0.598
Small	0.000	0.013	0.259	0.899	0.000	0.292	0.155	0.337
LENGTHS/100 LBS FL					**LENGTHS/100 LBS FL**			
Market	1	2			1	2		
ALL	0.346	0.208			0.127	0.000		

Table B4.21 Commercial catch-at-age for bluefish from 1985 to 2014

	Age						
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**
1985	607.2	3297.1	432.6	168.2	82.3	151.6	359.0
1986	599.0	2297.6	729.8	197.3	295.0	285.6	278.0
1987	209.2	1837.1	793.3	696.3	157.7	179.1	240.6
1988	173.8	905.6	476.5	221.2	433.2	345.4	497.9
1989	655.4	1505.7	163.6	182.6	193.9	326.1	162.0
1990	1354.6	1267.6	2827.6	215.4	80.9	155.8	114.2
1991	468.9	5026.4	425.3	16.1	48.9	62.9	798.6
1992	89.1	8150.2	1014.7	95.6	24.8	24.4	71.0
1993	572.0	1238.2	3001.7	74.2	31.6	22.1	86.9
1994	34.1	1388.3	359.1	51.4	157.6	229.4	300.0
1995	296.3	3761.3	704.0	7.0	6.5	49.3	132.2
1996	178.7	1126.9	726.0	317.6	137.9	88.4	266.0
1997	112.7	1096.9	509.7	183.2	134.2	75.2	402.9
1998	192.4	2383.4	1360.2	178.4	31.3	120.6	82.9
1999	495.0	1549.9	1106.4	183.4	15.4	124.3	129.6
2000	284.4	2736.9	1013.6	143.5	20.7	283.5	46.5
2001	68.7	851.7	1445.5	300.9	40.8	303.3	67.4
2002	52.6	1575.2	708.4	136.7	137.7	123.0	149.8
2003	37.8	966.4	704.2	222.7	168.2	142.5	176.6
2004	30.9	1216.6	790.2	225.5	119.0	183.1	191.1
2005	225.5	787.9	1112.0	224.7	167.1	90.4	55.5
2006	143.2	924.6	563.3	352.2	133.2	159.6	251.9
2007	242.7	648.4	1006.8	233.5	187.0	108.0	250.8
2008	137.7	470.7	744.1	279.5	137.2	116.5	124.0
2009	50.2	417.6	585.7	558.4	152.5	89.8	232.2
2010	46.5	338.0	513.2	514.7	275.1	151.1	220.5
2011	40.0	294.3	461.3	557.6	288.0	75.9	166.4
2012	59.8	301.3	625.3	498.6	163.5	47.1	119.1
2013	190.3	536.9	729.6	241.4	96.4	57.5	64.2
2014	259.9	848.2	608.6	134.9	130.7	79.2	116.0

Table B4.22 Commercial weight-at-age (kg) for bluefish from 1985 to 2014

	Age						
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**
1985	0.29	0.55	1.49	2.23	3.34	4.67	5.99
1986	0.29	0.57	1.16	2.60	3.83	4.26	5.24
1987	0.29	0.65	1.35	2.29	3.56	4.43	5.44
1988	0.25	0.70	1.03	2.42	3.28	4.15	5.22
1989	0.23	0.65	1.29	3.11	3.60	4.12	4.86
1990	0.15	0.47	1.23	2.12	3.55	4.11	5.13
1991	0.15	0.14	0.72	2.67	3.36	4.31	5.70
1992	0.13	0.45	0.76	1.92	3.39	4.23	5.27
1993	0.15	0.41	1.14	1.95	2.80	4.23	5.37
1994	0.26	0.45	0.80	2.64	3.48	4.19	5.82
1995	0.18	0.54	0.85	1.84	3.82	4.35	5.22
1996	0.16	0.62	1.09	1.88	3.09	4.18	4.88
1997	0.19	0.47	0.93	1.78	2.77	3.72	5.26
1998	0.20	0.49	0.80	2.00	3.25	4.14	5.83
1999	0.19	0.44	0.77	1.88	3.48	3.98	6.12
2000	0.19	0.42	0.69	2.86	2.96	3.62	5.72
2001	0.18	0.42	0.82	2.28	3.39	3.92	5.70
2002	0.18	0.49	0.94	1.67	2.52	3.37	4.53
2003	0.16	0.53	1.01	1.96	2.56	3.43	4.41
2004	0.20	0.51	1.06	1.87	2.77	3.47	4.26
2005	0.30	0.57	0.88	2.19	3.48	4.18	4.86
2006	0.24	0.46	0.78	1.54	2.54	3.23	3.80
2007	0.18	0.39	0.84	1.54	2.42	3.66	4.15
2008	0.19	0.50	0.96	1.68	2.80	3.36	4.11
2009	0.19	0.47	1.03	1.10	2.49	3.40	4.35
2010	0.20	0.39	1.01	0.90	2.19	3.58	4.72
2011	0.20	0.42	0.82	0.79	1.24	3.89	5.11
2012	0.19	0.45	0.72	0.90	2.12	3.98	5.31
2013	0.21	0.49	0.75	1.31	2.48	3.84	5.42
2014	0.24	0.41	0.72	1.61	2.81	3.55	4.48

Table B4.23 Recreational Harvest (A+B1) Total Weight (mt) 1982-2014. Data source: MRFSS/MRIP

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC	SC	GA	FL	Total
1982	10.0	7.2	1,662.8	8,864.6	8,155.0	5,399.5	4,959.1	179.6	3,114.3	2,213.5	1,649.9	141.8	15.4	1,278.2	37,650.9
1983	140.7	23.5	3,718.4	10,268.4	1,265.6	4,317.8	7,531.7	580.8	3,552.9	1,448.9	6,485.4	61.0	23.6	1,006.1	40,425.0
1984	0.3	13.5	2,155.3	1,241.8	5,200.5	5,380.1	8,816.9	395.0	2,203.3	471.0	3,566.6	80.3	34.9	1,036.7	30,596.2
1985	146.3	0.0	1,309.8	2,661.9	3,686.3	3,919.6	2,978.6	118.1	4,405.7	1,432.3	2,424.8	154.0	6.2	576.6	26,289.7
1986	439.0	303.2	6,039.4	5,306.3	5,474.2	7,880.6	9,303.8	156.3	3,034.4	1,719.3	1,853.8	183.7	8.0	430.7	45,576.8
1987	1,074.5	319.5	3,225.5	1,141.7	3,732.5	9,056.0	8,765.4	140.5	3,210.7	784.4	2,393.3	102.1	113.8	709.3	38,613.1
1988	302.3	132.7	2,212.9	931.0	1,739.8	2,815.2	4,495.3	245.7	3,543.4	1,599.1	3,054.8	51.1	17.4	732.7	21,508.4
1989	145.1	100.6	1,522.5	1,299.8	2,072.1	3,368.3	4,948.0	294.1	1,374.9	530.6	1,405.5	150.2	1.9	594.4	18,953.1
1990	230.9	120.1	1,278.9	626.0	2,501.0	3,251.9	2,961.0	114.4	660.7	585.9	1,189.2	35.9	18.3	286.1	14,002.2
1991	225.7	123.0	1,998.7	766.1	2,419.9	3,421.1	2,394.3	188.5	1,283.8	727.9	751.0	30.9	14.7	621.6	14,509.2
1992	421.1	77.9	888.1	560.1	1,869.5	2,663.7	2,739.0	143.3	332.0	184.3	496.8	57.2	14.7	563.4	11,738.1
1993	110.8	167.2	1,534.0	432.8	1,932.4	2,597.4	861.9	192.5	247.9	62.5	461.4	28.9	4.1	570.5	9,811.5
1994	290.7	80.9	1,727.1	200.5	1,327.9	1,501.8	888.0	66.2	307.6	86.7	266.5	46.1	1.1	258.1	7,972.6
1995	33.5	49.6	1,197.5	230.8	1,278.1	1,134.0	1,493.8	89.1	285.8	140.3	206.8	72.8	4.8	272.5	7,322.7
1996	7.7	7.9	806.4	229.5	1,074.1	723.3	1,504.6	132.7	235.2	126.3	335.6	13.6	1.2	129.9	5,689.8
1997	35.1	109.3	1,053.4	370.9	645.4	566.7	1,670.4	70.0	415.9	648.7	602.3	41.0	2.0	256.1	6,918.9
1998	6.7	14.0	705.2	422.3	510.4	638.5	1,898.6	91.5	381.9	173.8	417.2	50.8	10.4	273.4	6,048.1
1999	12.8	15.0	317.9	380.0	413.2	516.0	1,433.2	41.8	162.4	96.4	191.0	9.2	3.9	150.7	3,310.6
2000	0.0	4.1	646.8	779.1	327.1	821.4	1,225.0	99.0	204.5	74.5	324.0	28.4	6.4	270.3	4,940.6
2001	55.0	24.0	842.9	490.9	563.7	863.1	1,680.5	86.1	287.1	211.1	531.2	40.9	3.5	320.9	6,743.4
2002	57.5	62.5	587.0	406.5	570.5	1,077.7	1,182.1	81.1	237.3	63.9	338.5	32.9	1.0	459.4	5,199.0
2003	21.9	23.2	590.1	420.5	917.5	1,177.6	1,580.5	74.4	154.7	147.5	370.2	24.7	0.7	454.9	7,116.3
2004	44.4	35.2	819.5	522.4	1,049.9	2,458.1	1,513.0	46.2	177.9	158.1	568.3	52.4	0.2	408.8	8,513.9
2005	82.6	53.1	1,114.4	379.9	586.5	1,690.0	3,510.6	106.6	205.8	327.6	578.6	75.7	1.7	296.5	9,654.4
2006	13.2	20.9	1,546.5	461.2	1,020.4	1,424.5	1,498.7	110.1	284.5	377.5	477.7	32.4	1.7	284.5	7,890.9
2007	102.5	87.5	1,223.5	394.1	1,326.7	3,205.0	1,936.2	70.5	461.8	142.0	576.9	52.8	3.0	288.0	10,204.7
2008	76.2	16.5	1,358.6	437.1	1,681.4	2,410.3	1,565.9	37.8	246.7	144.5	673.4	42.4	2.4	284.9	9,865.5
2009	4.6	0.9	896.7	159.3	670.4	2,073.9	1,392.3	51.3	334.2	49.2	434.6	56.5	0.6	440.1	6,736.4
2010	23.6	6.2	1,223.2	54.8	1,195.0	1,825.2	1,551.2	17.4	174.3	196.2	432.3	161.4	4.4	546.0	7,971.5
2011	1.5	8.3	532.9	236.2	795.0	1,411.9	1,192.2	26.0	141.9	24.3	453.2	72.5	0.8	318.3	5,720.4
2012	7.6	14.5	588.8	106.8	1,118.8	1,491.2	1,217.4	18.5	55.5	54.9	458.4	66.2	1.2	171.7	5,863.5
2013	28.4	0.0	971.2	626.9	1,901.7	1,671.4	831.5	11.9	29.7	124.6	448.5	49.5	1.7	234.2	7,062.9
2014	0.3	2.4	751.2	157.9	549.6	851.2	1,411.2	56.0	109.6	38.9	436.0	47.8	5.5	326.8	4,772.1

Table B4.24 Recreational harvest (A+B1) by state (numbers of fish) 1982-2014. Data Source: MRFSS/MRIP

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC	SC	GA	FL	Total
1982	9,028	1,323	666,541	2,869,064	5,451,071	3,128,211	2,935,851	235,461	2,165,924	1,078,140	2,926,732	475,530	36,962	1,743,831	23,723,669
1983	39,041	5,118	1,450,528	3,741,228	1,207,856	5,426,404	3,952,550	340,839	2,124,159	577,478	4,310,991	148,062	100,217	1,459,072	24,883,543
1984	136	5,771	795,041	745,651	3,271,917	5,821,703	2,941,418	203,356	1,737,086	454,614	2,196,749	278,736	179,994	2,165,749	20,797,921
1985	45,986	0	430,804	1,478,197	3,134,579	3,760,052	2,682,711	120,191	3,642,442	649,555	1,754,375	430,927	20,153	1,095,752	19,245,724
1986	148,542	66,261	2,243,859	1,873,890	2,514,539	6,914,320	4,808,361	161,429	2,064,470	849,833	1,679,049	156,624	19,436	940,237	24,440,850
1987	289,408	74,178	1,420,481	825,341	2,534,984	5,386,239	4,726,822	99,808	2,241,352	564,701	1,737,660	164,392	43,928	966,996	21,076,290
1988	62,840	31,625	692,553	440,261	663,699	1,453,538	1,754,447	255,122	1,228,546	437,135	1,821,847	87,164	8,012	968,222	9,905,011
1989	37,520	22,647	411,504	486,802	1,467,939	3,984,450	2,888,757	323,562	711,110	707,077	1,605,431	226,047	16,235	710,857	13,599,938
1990	47,294	26,782	416,331	446,687	1,034,237	2,737,554	2,176,865	242,129	707,293	743,031	2,228,907	76,037	42,898	439,313	11,365,358
1991	114,909	41,060	840,326	441,074	1,729,165	3,471,086	2,011,959	147,079	953,321	666,051	820,536	39,078	24,441	642,522	11,942,607
1992	94,690	23,518	345,096	249,797	1,184,831	1,195,920	1,907,876	188,684	366,588	163,359	681,805	33,253	7,535	714,803	7,157,755
1993	29,083	27,622	510,703	188,254	825,333	1,440,297	656,435	137,934	217,055	65,856	722,668	81,249	5,179	817,688	5,725,356
1994	65,584	18,343	434,172	296,726	512,044	1,605,331	941,152	120,327	472,915	231,183	451,718	118,314	3,595	496,547	5,767,951
1995	8,937	11,745	404,748	126,146	608,269	1,041,725	1,242,904	183,141	285,231	212,501	386,623	154,037	14,732	487,240	5,167,979
1996	9,638	3,449	285,239	361,211	624,072	545,273	957,039	136,241	345,912	323,679	298,588	54,815	4,197	255,751	4,205,104
1997	13,151	25,329	316,398	412,091	518,809	816,331	942,127	158,807	432,616	446,772	742,424	89,242	5,129	493,811	5,413,037
1998	1,735	2,856	237,168	193,900	386,501	767,789	817,361	149,749	284,445	223,304	527,061	170,529	21,797	417,916	4,202,111
1999	8,020	3,830	196,605	329,615	440,444	710,399	809,040	84,247	166,535	133,679	517,744	34,462	12,036	235,184	3,681,840
2000	0	1,372	221,400	280,394	389,715	718,078	1,235,628	131,815	344,249	149,737	877,586	87,807	20,252	438,974	4,897,007
2001	15,449	8,029	357,242	364,597	716,477	1,005,457	1,430,605	101,503	428,589	260,817	1,265,790	118,264	9,672	580,746	6,663,237
2002	24,163	19,147	228,530	324,557	569,340	750,577	1,321,223	116,616	198,527	130,898	777,396	78,625	1,980	758,610	5,300,189
2003	13,980	7,730	374,327	334,257	457,759	1,146,759	1,570,656	89,387	214,414	171,573	952,694	66,269	1,222	644,036	6,045,063
2004	15,665	14,148	355,500	257,455	588,833	1,894,833	1,530,834	126,224	366,454	221,352	1,231,782	133,013	321	513,991	7,250,405
2005	37,383	20,583	550,213	345,310	247,360	1,683,647	2,367,766	127,120	167,545	323,856	1,382,613	246,643	4,410	444,731	7,949,180
2006	7,477	8,940	652,516	470,758	506,812	1,832,376	1,183,300	96,982	419,856	368,269	917,634	133,707	3,246	433,306	7,035,179
2007	49,329	34,412	682,528	295,213	450,500	2,150,532	1,654,412	153,056	675,638	313,792	1,257,420	175,372	10,543	471,152	8,373,899
2008	30,189	6,019	519,490	281,773	623,183	1,483,713	1,027,640	68,592	551,105	384,359	1,176,983	127,399	7,198	376,509	6,664,152
2009	2,716	426	343,453	64,956	261,998	1,293,144	813,980	97,912	591,214	137,088	827,788	134,899	1,596	623,072	5,194,242
2010	13,660	1,662	473,946	103,020	590,844	1,026,392	910,018	32,365	272,764	318,197	1,104,077	444,340	12,563	786,982	6,090,830
2011	481	2,118	224,501	124,143	306,858	927,493	1,149,558	45,786	259,286	85,092	1,152,105	225,058	2,742	556,172	5,061,393
2012	4,341	9,446	336,552	672,541	480,079	1,149,529	1,190,391	35,596	113,698	151,233	888,888	206,361	6,312	278,318	5,523,285
2013	19,542	0	371,734	312,040	875,068	983,041	740,335	24,391	55,544	188,367	1,183,627	298,451	3,408	409,076	5,464,624
2014	112	950	385,754	136,089	315,788	1,419,801	1,350,919	129,813	170,228	161,233	1,080,853	172,561	20,277	525,631	5,870,009

Table B4.25 Number of bluefish recreational fishing trips, recreational harvest limit, and recreational landings from 1991 to 2013.

Year	Number of Bluefish Trips[a]	Recreational Landings (N)	Recreational Landings per "Bluefish" Trip
1991	5,948,808	11,942,608	2.0
1992	4,549,536	7,157,754	1.6
1993	4,269,162	5,725,355	1.3
1994	3,587,131	5,767,953	1.6
1995	3,608,325	5,167,979	1.4
1996	2,820,059	4,205,103	1.5
1997	2,384,133	5,413,036	2.3
1998	2,180,471	4,202,111	1.9
1999	1,727,175	3,681,841	2.1
2000	2,041,450	4,897,008	2.4
2001	2,661,032	6,663,237	2.5
2002	2,324,253	5,300,189	2.3
2003	2,647,840	6,045,062	2.3
2004	2,898,679	7,250,407	2.5
2005	3,233,133	7,949,179	2.5
2006	2,781,357	7,035,179	2.5
2007	3,620,374	8,373,899	2.3
2008	3,024,787	6,664,150	2.2
2009	2,088,857	5,194,242	2.5
2010	2,468,273	6,090,830	2.5
2011	2,128,166	5,061,391	2.4
2012	2,394,988	5,523,282	2.3
2013	1,733,408	5,464,623	3.2

[a]Estimated number of recreational fishing trips where the primary target was bluefish or bluefish were harvested regardless of target, Maine – Florida's East Coast. Source: MRFSS (1991-2003)/MRIP (2004 fwd).

Table B4.26 Recreational Releases by state (numbers of fish) 1982-2014. Data Source: MRFSS/MRIP

Year	MA	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC	SC	GA	FL	Total
1982	2,526	0	58,662	151,692	885,850	197,039	346,279	46,666	690,368	452,410	301,407	106,967	52,725	204,229	3,496,820
1983	1,869	1,357	636,226	42,406	63,887	1,743,414	783,690	36,255	710,716	170,376	765,433	16,833	67,142	214,243	5,253,847
1984	0	0	354,473	55,112	257,048	2,570,029	709,282	88,522	512,129	137,656	241,685	76,673	37,048	670,670	5,710,327
1985	8,009	1,436	159,512	123,111	326,913	954,786	536,572	34,052	257,457	118,007	333,415	181,773	37,918	155,181	3,228,142
1986	24,524	22,791	1,317,955	70,619	154,507	1,852,425	1,161,718	44,113	287,291	315,260	449,139	48,390	28,596	192,331	5,969,659
1987	190,933	7,710	639,358	267,972	290,633	1,879,441	1,697,153	63,898	477,607	181,407	544,698	46,986	32,881	206,404	6,527,081
1988	22,683	2,032	298,163	70,265	26,995	735,486	437,364	34,551	266,401	715,455	550,135	64,029	6,982	229,433	3,459,974
1989	4,994	16,815	265,861	86,237	130,858	1,474,146	1,084,233	190,685	445,682	293,665	750,152	144,811	21,930	127,248	5,037,317
1990	35,875	5,651	307,904	316,809	228,175	1,261,626	1,061,846	103,942	388,238	279,760	728,228	65,675	132,154	164,937	5,080,820
1991	327,363	23,818	579,410	195,279	552,421	1,367,011	1,545,379	58,518	369,022	450,673	551,446	17,359	65,760	245,757	6,349,216
1992	66,824	12,812	451,273	234,709	415,060	783,716	535,540	121,771	98,748	277,874	796,444	15,999	43,968	387,567	4,242,305
1993	18,464	21,650	389,842	153,377	260,932	974,737	561,092	105,346	194,429	163,020	784,495	55,550	22,434	494,532	4,199,900
1994	52,002	8,181	350,282	200,649	281,574	1,171,234	894,344	46,181	246,091	461,658	1,480,854	140,081	20,395	798,748	6,152,274
1995	4,962	6,868	585,071	69,858	170,633	719,237	637,486	126,899	273,367	417,066	1,200,514	220,576	84,948	808,418	5,325,903
1996	57,386	2,604	467,296	439,224	366,885	661,066	959,185	82,525	464,609	420,224	735,622	85,814	25,869	547,497	5,315,806
1997	82,858	2,857	644,331	320,201	293,238	898,423	849,370	193,056	891,449	661,907	1,149,328	197,452	19,566	956,476	7,160,512
1998	0	515	510,309	203,146	404,953	588,706	701,638	274,589	492,406	404,793	534,295	200,317	71,385	615,103	5,002,155
1999	19,584	5,094	397,468	784,301	744,419	1,156,348	1,823,535	322,548	604,763	228,200	986,417	58,598	13,728	660,842	7,805,845
2000	3,520	955	595,606	496,896	863,248	2,629,264	1,906,915	303,491	1,150,171	321,013	1,630,426	181,600	79,385	1,200,887	11,363,377
2001	39,774	13,877	947,782	892,975	1,429,180	2,543,456	2,055,555	220,644	1,074,250	625,089	2,328,952	152,378	48,454	1,376,402	13,748,768
2002	41,753	13,965	628,185	801,379	662,319	1,017,366	2,168,272	435,157	576,603	381,997	1,609,804	162,644	25,597	1,391,963	9,917,004
2003	22,747	16,964	1,018,898	931,770	541,938	1,304,618	1,913,100	119,732	517,975	340,331	1,416,064	215,426	22,800	621,877	9,004,240
2004	42,112	8,710	1,294,329	801,789	979,185	2,529,207	2,225,662	408,033	593,724	548,400	1,761,560	386,264	16,120	498,806	12,093,901
2005	48,536	48,327	1,813,373	526,790	575,611	3,381,001	2,292,400	190,721	236,084	540,719	2,043,699	316,726	21,147	368,768	12,403,902
2006	49,690	22,911	1,843,798	554,255	1,167,223	2,378,930	1,803,840	288,995	777,916	449,250	1,836,657	622,242	22,335	718,402	12,536,444
2007	73,780	17,877	1,240,404	685,758	887,907	2,650,325	2,735,060	538,156	1,171,858	915,930	2,376,886	677,031	103,088	932,359	15,006,419
2008	55,667	2,568	1,301,663	491,213	1,143,879	3,224,070	1,476,829	167,326	1,631,409	711,317	2,136,350	333,028	116,329	498,919	13,290,567
2009	25,900	1,978	952,521	159,523	295,061	1,792,884	1,476,248	167,083	670,494	349,936	1,553,376	252,310	72,398	680,521	8,450,233
2010	9,680	562	1,028,388	94,021	714,853	1,471,387	1,885,821	57,496	161,424	359,451	2,221,130	318,430	107,709	1,620,958	10,051,310
2011	7,603	1,360	597,774	327,849	996,737	1,598,098	1,910,805	127,519	408,323	197,276	1,923,767	551,024	69,915	912,206	9,630,256
2012	126,096	4,970	713,753	427,449	678,733	1,809,011	1,995,812	117,951	138,495	207,798	1,036,297	168,650	51,646	1,110,650	8,587,311
2013	22,184	85	457,740	622,771	724,547	1,007,911	876,798	70,335	260,957	220,068	1,871,916	309,021	7,375	1,492,011	7,943,719
2014	0	1,556	2,185,959	114,222	436,605	1,506,963	1,864,489	325,357	144,742	187,617	1,537,352	297,608	118,547	1,456,688	10,177,705

Table B4.27 Recreational catch-at-age for bluefish from 1985 to 2014

	Age						
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**
1985	5731.8	6903.4	3542.6	915.2	631.9	461.2	1665.5
1986	5466.7	3977.4	6494.3	2917.3	1517.4	1176.6	3084.5
1987	4225.1	3783.6	3732.0	4642.1	1906.8	1012.2	1923.2
1988	1319.6	1482.5	1260.3	1077.1	1589.0	913.6	1662.9
1989	4945.8	2582.7	1582.1	571.3	370.8	902.3	1500.0
1990	1665.4	5356.3	1462.8	430.2	259.5	469.5	1160.7
1991	4111.3	2583.2	3827.4	545.5	233.5	288.8	1376.4
1992	714.7	2178.3	1941.2	1641.0	433.9	219.2	788.3
1993	757.7	1603.9	1178.6	935.7	1123.7	134.9	616.8
1994	1569.6	2567.8	559.3	554.0	384.2	420.0	632.9
1995	702.7	2869.9	923.4	326.9	289.3	341.2	553.3
1996	933.4	1353.1	907.3	540.1	262.1	196.6	647.9
1997	1146.8	2477.1	902.1	352.4	221.4	229.1	943.0
1998	644.5	1458.6	1180.9	951.5	154.1	132.0	380.3
1999	1333.1	1290.4	1041.7	560.3	150.4	88.0	261.4
2000	418.8	2817.1	1583.9	975.0	226.2	295.7	244.2
2001	1161.9	2780.0	2271.5	1117.9	163.7	318.1	380.8
2002	445.7	3448.6	1505.1	327.2	138.7	202.3	433.1
2003	580.0	2564.5	2447.6	689.9	311.1	304.9	504.6
2004	554.0	4020.8	2485.3	783.0	329.7	407.6	484.1
2005	1986.7	1844.5	3043.6	1623.1	521.9	391.8	398.2
2006	1922.3	2258.7	1704.0	1307.1	388.5	571.6	743.5
2007	1283.8	2187.9	3189.1	1501.6	1397.2	413.8	651.5
2008	1290.9	1997.7	2616.8	1076.4	541.8	428.4	705.7
2009	390.1	1509.2	1906.0	1520.6	479.7	188.9	467.3
2010	961.8	1480.8	1758.8	1471.2	935.2	442.4	548.5
2011	1028.3	1503.0	1199.5	1219.4	607.0	388.9	559.7
2012	1537.6	1283.6	1407.7	1195.5	759.9	212.7	414.4
2013	1342.6	1269.9	1674.9	1144.3	619.6	305.4	299.6
2014	2290.1	2134.0	1275.6	736.1	343.2	240.0	306.4

Table B4. 28 Recreational weight-at-age (kg) for bluefish from 1985 to 2014

	Age						
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**
1985	0.10	0.58	1.30	2.31	3.58	4.57	6.83
1986	0.07	0.59	1.34	2.24	3.28	4.42	6.24
1987	0.08	0.59	1.30	2.17	3.50	4.46	6.19
1988	0.15	0.52	1.16	2.29	3.04	3.89	5.90
1989	0.10	0.62	1.60	2.92	3.55	4.31	5.85
1990	0.15	0.51	1.12	2.50	4.10	4.48	6.31
1991	0.10	0.51	1.15	2.06	3.36	4.13	5.80
1992	0.06	0.50	1.18	2.12	3.18	4.28	5.89
1993	0.15	0.50	1.08	2.37	2.92	3.99	6.21
1994	0.10	0.50	1.25	2.04	3.31	4.13	7.03
1995	0.16	0.51	1.14	2.21	3.44	4.52	6.10
1996	0.12	0.62	0.94	1.74	2.84	4.43	5.84
1997	0.09	0.50	1.07	2.06	2.75	3.68	5.93
1998	0.11	0.53	0.98	2.72	3.79	3.94	6.28
1999	0.11	0.51	1.07	2.56	3.70	4.05	6.38
2000	0.14	0.41	0.96	2.87	3.66	4.09	6.30
2001	0.12	0.41	1.08	2.82	4.15	4.48	5.96
2002	0.12	0.51	1.16	2.00	2.95	3.80	5.25
2003	0.09	0.52	1.15	1.81	2.70	3.77	5.10
2004	0.11	0.48	1.35	2.23	2.90	3.71	4.95
2005	0.15	0.52	0.96	2.23	3.38	4.35	5.48
2006	0.11	0.50	0.98	1.88	2.83	3.10	4.17
2007	0.15	0.42	1.00	1.54	2.13	3.72	4.33
2008	0.16	0.47	1.37	1.98	3.23	3.61	5.01
2009	0.15	0.40	1.17	1.39	2.64	3.37	4.70
2010	0.12	0.37	1.02	0.95	2.59	3.73	5.36
2011	0.13	0.34	0.95	1.09	2.08	4.16	5.45
2012	0.11	0.35	0.90	1.23	2.68	4.24	5.51
2013	0.14	0.42	1.10	1.89	2.66	3.77	5.89
2014	0.13	0.41	1.08	1.92	2.92	3.98	5.39

Table B4.29 Total weight-at-age (kg) for bluefish from 1985 to 2014

	Age						
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**
1985	0.12	0.57	1.32	2.30	3.55	4.59	6.68
1986	0.09	0.59	1.32	2.27	3.37	4.39	6.16
1987	0.09	0.61	1.31	2.18	3.51	4.45	6.10
1988	0.16	0.59	1.13	2.31	3.09	3.96	5.74
1989	0.12	0.63	1.57	2.97	3.57	4.26	5.75
1990	0.15	0.50	1.19	2.37	3.97	4.39	6.21
1991	0.10	0.27	1.11	2.08	3.36	4.16	5.76
1992	0.07	0.46	1.04	2.11	3.19	4.28	5.84
1993	0.15	0.46	1.13	2.34	2.92	4.02	6.11
1994	0.10	0.48	1.07	2.10	3.36	4.15	6.64
1995	0.17	0.53	1.02	2.20	3.45	4.50	5.93
1996	0.13	0.62	1.01	1.79	2.93	4.36	5.56
1997	0.10	0.49	1.02	1.97	2.76	3.69	5.73
1998	0.13	0.51	0.88	2.61	3.70	4.04	6.20
1999	0.14	0.47	0.92	2.40	3.68	4.01	6.29
2000	0.16	0.41	0.86	2.87	3.60	3.86	6.21
2001	0.13	0.41	0.98	2.70	3.64	4.20	5.92
2002	0.13	0.50	1.09	1.90	2.74	4.01	5.07
2003	0.09	0.52	1.12	1.84	2.65	3.67	4.92
2004	0.11	0.48	1.28	2.15	2.87	3.63	4.75
2005	0.17	0.54	0.94	2.23	3.13	4.08	5.40
2006	0.12	0.49	0.93	1.81	2.76	3.40	4.32
2007	0.15	0.42	0.96	1.54	2.17	3.71	4.28
2008	0.16	0.48	1.28	1.92	3.14	3.56	4.87
2009	0.15	0.41	0.94	1.31	2.60	3.38	4.58
2010	0.12	0.37	1.00	1.14	2.50	3.69	5.18
2011	0.13	0.36	0.92	1.14	1.81	4.11	5.37
2012	0.11	0.37	0.84	1.13	2.58	4.19	5.46
2013	0.15	0.44	1.00	1.79	2.64	3.78	5.80
2014	0.14	0.41	0.96	1.87	2.89	3.87	5.14

Table B4.30 Jan-1 weight-at-age (kg) for bluefish from 1985 to 2014

	Age						
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**
1985	0.05	0.37	1.01	1.90	3.19	4.04	6.68
1986	0.03	0.27	0.87	1.73	2.78	3.95	6.16
1987	0.04	0.23	0.88	1.70	2.82	3.87	6.10
1988	0.08	0.23	0.83	1.74	2.60	3.73	5.74
1989	0.06	0.32	0.96	1.83	2.87	3.63	5.75
1990	0.11	0.24	0.87	1.93	3.43	3.96	6.21
1991	0.05	0.20	0.75	1.57	2.82	4.06	5.76
1992	0.03	0.21	0.53	1.53	2.58	3.79	5.84
1993	0.08	0.18	0.72	1.56	2.48	3.58	6.11
1994	0.04	0.27	0.70	1.54	2.80	3.48	6.64
1995	0.09	0.23	0.70	1.53	2.69	3.89	5.93
1996	0.07	0.32	0.73	1.35	2.54	3.88	5.56
1997	0.04	0.25	0.80	1.41	2.22	3.29	5.73
1998	0.07	0.23	0.66	1.63	2.70	3.34	6.20
1999	0.08	0.25	0.69	1.45	3.10	3.85	6.29
2000	0.10	0.24	0.64	1.62	2.94	3.77	6.21
2001	0.07	0.26	0.63	1.52	3.23	3.89	5.92
2002	0.07	0.26	0.67	1.36	2.72	3.82	5.07
2003	0.04	0.26	0.75	1.42	2.24	3.17	4.92
2004	0.05	0.21	0.82	1.55	2.30	3.10	4.75
2005	0.10	0.24	0.67	1.69	2.59	3.42	5.40
2006	0.06	0.29	0.71	1.30	2.48	3.26	4.32
2007	0.08	0.22	0.69	1.20	1.98	3.20	4.28
2008	0.10	0.27	0.73	1.36	2.20	2.78	4.87
2009	0.10	0.26	0.67	1.29	2.23	3.26	4.58
2010	0.07	0.24	0.64	1.04	1.81	3.10	5.18
2011	0.08	0.21	0.58	1.07	1.44	3.21	5.37
2012	0.06	0.22	0.55	1.02	1.72	2.75	5.46
2013	0.09	0.22	0.61	1.23	1.73	3.12	5.80
2014	0.08	0.25	0.65	1.37	2.27	3.20	5.14

Table B5.1 Table of age sample sizes by geographic origin (all seasons combined). Note that NEAMAP and SEAMAP samples have been assigned to states from which they were collected (as were nmfsPort samples for 2013). NNCNcomb = combined nmfsPort, nefscTrawl, CT, and NC scale data from spring samples (see working paper B6 for more details). nmfsPort = commercial NMFS samples; nefscTrawl = NEFSC trawl scale ages. Note too that data are shared among some years between 1997-2004. CB = Chesapeake Bay (ChesMMAP); CB samples prior to 2005 were inadvertently omitted from ALKs, as were nmfsPort and nefscTrawl samples from 1996.

Year	nmfsPort	nefscTrawl	MA	RI	CT	NY	NJ	DE	MD	CB	VA	NNCNcomb	NC	SC	GA	FL
1985	159	404	0	0	799	0	0	0	0	0	0	399	193	0	0	0
1986	225	271	0	0	572	0	0	0	0	0	0	360	244	0	0	0
1987	132	281	0	0	448	0	0	0	0	0	0	264	128	0	0	0
1988	186	174	0	0	270	0	0	0	0	0	0	311	158	0	0	0
1989	49	316	0	0	0	0	0	0	0	0	0	198	145	0	0	0
1990	12	271	0	0	0	0	0	0	0	0	0	171	220	0	0	0
1991	66	164	0	0	0	0	0	0	0	0	0	213	104	0	0	0
1992	15	260	0	0	0	0	0	0	0	0	0	426	288	0	0	0
1993	9	145	0	0	0	0	0	0	0	0	0	378	352	0	0	0
1994	41	389	0	0	0	0	0	0	0	0	0	316	247	0	0	0
1995	11	358	0	0	0	0	0	0	0	0	0	311	341	0	0	0
1996	214	273	0	0	0	0	0	0	0	0	0	0	230	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	446	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	399	0	658	0	0	0
1999	0	0	0	0	0	0	0	0	0	0	0	0	442	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	412	0	291	0	0	0
2002	0	0	0	0	0	0	0	0	0	34	1442	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	74	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	26	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	70	332	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	22	327	0	89	0	0	0
2007	0	0	0	12	50	86	183	43	69	50	487	0	469	0	0	0
2008	0	0	0	32	45	95	48	40	40	27	519	0	713	0	0	0
2009	0	0	13	29	37	153	120	37	50	11	513	0	553	0	0	0
2010	0	0	70	50	45	88	290	23	29	29	529	0	564	0	0	0
2011	0	0	69	18	35	72	326	41	43	7	533	0	744	47	37	83
2012	0	0	113	114	169	260	253	75	40	8	648	0	999	58	39	13
2013	0	0	133	296	282	339	406	28	24	32	495	0	859	68	70	35
2014	0	0	113	116	224	572	236	40	18	39	418	0	929	55	74	45

Table B5.2 Age sample sizes used to develop age length keys. All 1997 from NC otoliths. Spring 1998-2004 VA and NC otoliths; fall 1999-2000 includes VA and NC otoliths; fall 2001+ from VA otoliths only. Note that at SAW41 all spring 2001 samples were applied to springs of 1998-2001. Shading is added to help illustrate where data were shared. Dotted lines surrounding 1998-2001 added to illustrate previously shared years of data. Empty cells = 0.

Spring	A0	A1	A2	A3	A4	A5	A6+		Total
1997		202	153	38	18	14	32		457
1998		155	126	28	9	15	28		0
1999		140	90	7	13	13	26		0
2000		145	4			1	1		0
2001		12	32	2	2	3	11		62
2002		103	85	6	8	42	38		282
2003			147	4	13	17	45		226
2004		82	131	23		3	2		241

Fall	A0	A1	A2	A3	A4	A5	A6+		Total
1997	65	128	14	1			9		217
1998									0
1999	85	134	59	7	1	2	49		337
2000	21	108	10				1		140
2001		116	109		2	5	40		272
2002	7	319	56	5	1	2	5		395
2003	34	51	12		6	41	70		214
2004		66	14	3					83

Table B5.3Age length key sample size by year, age, and season from post-SAW41. See Figure B5.1 for the source (state or sampling program of origin) of age data by year.

Spring							
Year	**A0**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6+**
2005	0	20	87	8	3	2	1
2006	0	39	73	26	2	5	41
2007	0	82	217	29	10	15	82
2008	0	197	267	51	11	20	45
2009	0	99	106	63	18	20	66
2010	0	105	142	165	85	38	68
2011	0	209	166	181	91	22	72
2012	2	344	277	205	124	43	133
2013	4	301	467	335	177	44	63
2014	1	291	205	115	130	68	125
Avg	1	169	201	118	65	28	70
Median	0	151	186	89	52	21	67

Fall							
Year	**A0**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6+**
2005	89	93	54	9	9	10	17
2006	40	94	65	11	10	3	29
2007	494	253	162	63	13	8	21
2008	518	244	132	31	8	6	29
2009	580	205	142	150	39	10	18
2010	471	250	116	138	58	32	49
2011	589	300	123	126	51	49	76
2012	673	288	273	201	119	29	78
2013	847	281	244	148	66	49	41
2014	674	462	259	190	132	103	124
Avg	498	247	157	107	51	30	48
Median	549	252	137	132	45	20	35

Table B5.4 Von Bertalanfy growth parameters for multiple groupings of bluefish data

	ALL	NORTH	SOUTH	MALES	FEMALES	OTOLITHS	SCALES	1985-1994	1995-2004	2005-2014
Linf	112.998	93.618	742.365	114.614	129.600	120.303	92.377	91.272	105.811	130.907
K	0.126	0.196	0.011	0.118	0.094	0.109	0.214	0.222	0.143	0.0944
t0	-1.604	-1.149	-3.055	-1.630	-1.881	-1.661	-1.245	-1.204	-1.614	-1.708

Table B5.5 Estimates of natural mortality for bluefish based on methodologies using longevity and life history characteristics.

Age	3/tmax Rule of Thumb	Hoenig (1983)	Hewitt and Hoenig (2005)	Then et al. (2014): Pauly	Jensen 1996	Gislason et al. (2010)	Lorenzen (1996, 2000)	Lorenzen Scaled to Rule of Thumb	Lorenzen Scaled to Hoenig	Lorenzen Scaled to H&H
0	0.21	0.30	0.32	0.20	0.195	1.70	0.94	0.54	0.78	0.83
1	0.21	0.30	0.32	0.20	0.195	0.87	0.64	0.37	0.53	0.56
2	0.21	0.30	0.32	0.20	0.195	0.53	0.48	0.28	0.40	0.42
3	0.21	0.30	0.32	0.20	0.195	0.40	0.40	0.23	0.33	0.36
4	0.21	0.30	0.32	0.20	0.195	0.30	0.34	0.20	0.28	0.30
5	0.21	0.30	0.32	0.20	0.195	0.24	0.30	0.17	0.25	0.26
6	0.21	0.30	0.32	0.20	0.195	0.21	0.28	0.16	0.23	0.25
7	0.21	0.30	0.32	0.20	0.195	0.20	0.27	0.16	0.23	0.24
8	0.21	0.30	0.32	0.20	0.195	0.20	0.27	0.16	0.22	0.24
9	0.21	0.30	0.32	0.20	0.195	0.19	0.26	0.15	0.22	0.23
10	0.21	0.30	0.32	0.20	0.195	0.18	0.26	0.15	0.21	0.23
11	0.21	0.30	0.32	0.20	0.195	0.17	0.25	0.14	0.21	0.22
12	0.21	0.30	0.32	0.20	0.195	0.17	0.25	0.14	0.21	0.22
13	0.21	0.30	0.32	0.20	0.195	0.17	0.24	0.14	0.20	0.22
14	0.21	0.30	0.32	0.20	0.195	0.17	0.24	0.14	0.20	0.22
Mean	**0.21**	**0.30**	**0.32**	**0.20**	**0.195**	**0.38**	**0.36**	**0.21**	**0.3**	**0.32**

Table B5.6 Bluefish length (A) and age (B) at 50% and 95% maturity for different groupings

A.

	ALL	NORTH	SOUTH	MALES	FEMALES
L50	29.87	30.42	24.04	29.49	30.11
L95	44.33	44.69	33.08	43.96	44.34

B.

	ALL	OTOLITH	SCALES	MALES	FEMALES
A50	1.1	1.07	1.13	1.05	1.14
A95	1.85	1.79	1.92	1.72	2.01

Table B5. 7 Bluefish maturity at age for two previous studies and this study using all fish. The values from this study were used as final input values for the benchmark assessment.

Age	Robillard et al. 2009**	Salerno et al. 2001	ALL Fish this study
0	0.00	0.00	0.00
1	0.21	0.41	0.40
2	0.86	0.98	0.97
3	0.92	1.00	1.00
4	1.00	1.00	1.00
5	1.00	1.00	1.00
6+	1.00	1.00	1.00

** Maturity based on histology not gross maturity and females only

Table B6.1 Survey indices used in final model configuration. Note:YOY indices from NH, RI, NY-NJ, MD , and VA were combined.

NH YOY		RI YOY			CT, geoMean								
Year	**YOY**	**Year**	**YOY**	**CV**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6+**	**Total**
1985		1985			1985	16.98	0.95	0.63	0.25	0.15	0.02	0.04	19.01
1986		1986			1986	10.82	1.18	1.17	0.19	0.13	0.09	0.08	13.66
1987		1987			1987	12.17	1.01	0.51	0.38	0.13	0.06	0.07	14.32
1988		1988	7.93	0.42	1988	14.27	0.21	0.49	0.14	0.17	0.13	0.09	15.49
1989		1989	9.29	0.36	1989	25.00	0.58	0.46	0.04	0.02	0.07	0.09	26.25
1990		1990	7.06	0.36	1990	19.37	2.97	0.93	0.16	0.13	0.12	0.20	23.88
1991		1991	17.81	0.33	1991	28.49	1.28	3.27	0.12	0.06	0.05	0.16	33.43
1992		1992	1.48	0.48	1992	18.87	1.76	2.79	1.32	0.18	0.06	0.23	25.22
1993		1993	1.05	0.36	1993	16.78	0.11	1.03	0.32	0.57	0.03	0.08	18.92
1994		1994	7.30	0.45	1994	30.52	0.76	0.24	0.16	0.14	0.17	0.07	32.06
1995		1995	2.93	0.32	1995	21.70	1.96	0.60	0.06	0.05	0.04	0.07	24.46
1996		1996	6.29	0.38	1996	19.81	0.22	0.41	0.25	0.01	0.03	0.08	20.80
1997	0.00	1997	11.07	0.29	1997	36.59	0.60	0.48	0.07	0.07	0.03	0.06	37.90
1998	0.00	1998	7.61	0.40	1998	29.87	0.97	0.38	0.16	0.01	0.00	0.01	31.41
1999	0.20	1999	46.86	0.28	1999	41.88	2.89	0.22	0.20	0.05	0.01	0.06	45.31
2000	0.04	2000	3.30	0.40	2000	17.28	2.03	1.07	0.15	0.00	0.03	0.02	20.57
2001	0.12	2001	7.99	0.37	2001	21.47	1.13	1.40	0.18	0.02	0.01	0.02	24.24
2002	0.01	2002	3.87	0.36	2002	14.01	3.79	0.64	0.09	0.02	0.08	0.12	18.75
2003	0.01	2003	2.64	0.52	2003	27.34	0.43	0.60	0.07	0.02	0.03	0.04	28.53
2004	0.00	2004	7.51	0.41	2004	21.45	5.52	1.46	0.33	0.07	0.16	0.15	29.13
2005	0.02	2005	14.06	0.31	2005	17.77	0.09	0.66	0.21	0.09	0.05	0.04	18.89
2006	0.09	2006	6.76	0.40	2006	14.24	0.49	0.55	0.29	0.06	0.01	0.02	15.66
2007	0.06	2007	7.45	0.52	2007	27.26	1.98	0.72	0.43	0.11	0.07	0.09	30.66
2008	0.17	2008	11.02	0.37	2008	11.83	0.56	1.09	0.37	0.12	0.15	0.16	14.28
2009	0.32	2009	1.19	0.34	2009	15.69	0.52	0.43	0.81	0.30	0.07	0.30	18.11
2010	0.10	2010	3.67	0.38	2010								
2011	0.08	2011	1.95	0.45	2011	10.21	0.23	0.21	0.17	0.16	0.05	0.06	11.10
2012	0.35	2012	4.24	0.46	2012	14.34	0.27	0.19	0.13	0.08	0.02	0.03	15.06
2013	0.41	2013	3.91	0.35	2013	8.89	0.03	0.41	0.19	0.09	0.04	0.06	9.71
2014	0.05	2014	1.38	0.52	2014	18.14	0.21	0.07	0.06	0.07	0.04	0.02	18.61

Table B6.1 continued

NY YOY		
Year	YOY	CV
1985		
1986		
1987	36.9525	0.23554
1988	23.9299	0.32567
1989	40.7855	0.27558
1990	15.1449	0.28677
1991	8.45391	0.27238
1992	11.6167	0.26606
1993	1.62819	0.27099
1994	1.38648	0.3095
1995	1.85487	0.30232
1996	0.93605	0.54367
1997		
1998	1.65264	0.33874
1999	4.03057	0.30377
2000	6.39818	0.23123
2001	17.4834	0.26251
2002	4.98182	0.24177
2003	2.7814	0.22905
2004	10.2012	0.23079
2005	8.88195	0.23202
2006	15.0959	0.24829
2007	9.72859	0.23067
2008	18.393	0.227
2009	5.89022	0.23852
2010	9.06616	0.26044
2011	7.75543	0.23713
2012	5.38529	0.24329
2013	21.1646	0.23184
2014	12.2976	0.24793

NJ Ocean trawl			
Year	0	1	2
1985			
1986			
1987			
1988			
1989			
1990	1.437	0.084	0.001
1991	1.087	0.010	0.014
1992	1.561	0.237	0.025
1993	0.844	0.037	0.032
1994	2.238	0.008	0.002
1995	3.163	0.153	0.058
1996	1.835	0.077	0.007
1997	0.901	0.025	0.010
1998	1.013	0.153	0.077
1999	0.637	0.103	0.013
2000	0.493	0.092	0.035
2001	0.293	0.028	0.063
2002	2.762	1.068	0.027
2003	2.676	0.070	0.019
2004	1.546	0.448	0.249
2005	3.606	0.130	0.098
2006	2.760	0.078	0.025
2007	3.307	0.585	0.148
2008	2.888	0.082	0.011
2009	1.624	0.029	0.005
2010	0.868	0.018	0.008
2011	4.562	0.835	0.020
2012	2.732	0.195	0.044
2013	1.269	0.020	0.000
2014	3.155	0.268	0.010

NJ YOY	
Year	YOY
1985	
1986	
1987	
1988	
1989	
1990	
1991	
1992	
1993	
1994	
1995	
1996	
1997	
1998	
1999	
2000	
2001	
2002	0.454
2003	0.279
2004	0.264
2005	0.869
2006	0.495
2007	0.707
2008	0.604
2009	0.385
2010	0.749
2011	0.265
2012	0.274
2013	0.428
2014	0.587

Table B6.1 continued.

MD YOY		
Year	**Index**	**CV**
1985	0.37429	2.114
1986	0.05744	2.793
1987	0.1246	2.808
1988	0.10251	2.068
1989	0.30574	2.163
1990	0.47125	4.342
1991	0.05733	2.209
1992	0.08233	3.719
1993	0.01143	4.541
1994	0.03101	3.507
1995	0.03446	2.293
1996	0.0188	2.643
1997	0.25664	2.087
1998	0.04181	2.407
1999	0.08692	2.032
2000	0.12554	3.485
2001	0.07519	3.290
2002	0.02739	2.830
2003	0.09015	2.542
2004	0.07413	2.424
2005	0.02608	2.834
2006	0.16223	2.504
2007	0.16629	2.665
2008	0.15423	2.110
2009	0.42171	3.783
2010	0.01932	3.181
2011	0.06433	2.251
2012	0.09245	5.185
2013	0.10367	2.818
2014	0.0558	2.840

NEAMAP									
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6+**	**Total**	**CV**
1985									
1986									
1987									
1988									
1989									
1990									
1991									
1992									
1993									
1994									
1995									
1996									
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007	3.878	0.318	0.063	0.015	0.009	0.004	0.002	4.290	0.076
2008	4.779	0.362	0.055	0.020	0.007	0.003	0.003	5.230	0.073
2009	5.095	0.090	0.024	0.013	0.004	0.002	0.002	5.230	0.068
2010	3.081	0.112	0.028	0.027	0.019	0.007	0.006	3.280	0.080
2011	3.471	0.439	0.052	0.047	0.005	0.003	0.004	4.020	0.072
2012	5.174	0.413	0.087	0.043	0.009	0.001	0.003	5.730	0.062
2013	3.617	0.054	0.023	0.012	0.002	0.000	0.002	3.710	0.082
2014	2.505	0.189	0.009	0.007	0.004	0.005	0.002	2.720	0.093

Table B6.1 continued.

VIMS	
Year	**YOY**
1985	0.160
1986	0.033
1987	0.169
1988	0.059
1989	0.091
1990	0.114
1991	0.093
1992	0.014
1993	0.126
1994	0.006
1995	0.045
1996	0.009
1997	0.167
1998	0.042
1999	0.042
2000	0.053
2001	0.011
2002	0.030
2003	0.032
2004	0.040
2005	0.034
2006	0.018
2007	0.070
2008	0.048
2009	0.035
2010	0.035
2011	0.006
2012	0.053
2013	0.021
2014	

PSIGNS								
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6+**	**Total**
1985								
1986								
1987								
1988								
1989								
1990								
1991								
1992								
1993								
1994								
1995								
1996								
1997								
1998								
1999								
2000								
2001	0.13	2.99	2.16	0.00	0.00	0.00	0.00	5.28
2002	0.13	2.86	1.29	0.01	0.00	0.00	0.00	4.29
2003	0.16	1.84	2.74	0.03	0.00	0.01	0.00	4.78
2004	0.16	2.99	1.99	0.05	0.00	0.00	0.00	5.19
2005	1.08	2.24	3.02	0.04	0.01	0.00	0.01	6.40
2006	0.53	2.97	1.85	0.44	0.10	0.05	0.11	6.05
2007	0.44	2.33	4.78	0.81	0.04	0.01	0.05	8.46
2008	1.21	2.89	2.31	0.23	0.01	0.03	0.04	6.72
2009	0.38	2.04	1.48	1.96	0.29	0.06	0.13	6.34
2010	0.47	1.57	1.36	1.84	0.39	0.04	0.00	5.67
2011	0.24	0.95	1.65	2.04	0.92	0.04	0.04	5.88
2012	0.21	1.11	1.62	0.91	0.16	0.01	0.04	4.06
2013	1.69	1.65	1.90	0.39	0.05	0.01	0.01	5.70
2014	0.74	2.28	1.29	0.10	0.00	0.00	0.02	4.44

SEAMAP	
Year	**YOY**
1985	
1986	
1987	
1988	
1989	3.238
1990	0.140
1991	1.151
1992	0.614
1993	0.306
1994	1.225
1995	1.270
1996	1.151
1997	0.106
1998	0.387
1999	0.670
2000	0.181
2001	1.711
2002	1.246
2003	4.772
2004	0.654
2005	1.26
2006	0.24
2007	0.14
2008	1.25
2009	1.31
2010	0.80
2011	1.04
2012	0.65
2013	0.37
2014	0.13

Table B6.1 continued.

NEFSC Inshore bands 1985-2008									
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6+**	**Total**	**CV**
1985	15.34	1.95	0.24	0.13	0.04	0.01	0.04	17.74	0.15
1986	38.84	1.51	0.17	0.09	0.05	0.04	0.06	40.75	0.43
1987	5.64	1.25	0.13	0.19	0.10	0.05	0.10	7.45	0.31
1988	30.04	0.19	0.03	0.03	0.07	0.04	0.07	30.47	0.57
1989	90.17	0.95	0.05	0.02	0.02	0.03	0.04	91.27	0.19
1990	5.91	3.29	0.01	0.02	0.01	0.02	0.06	9.32	0.22
1991	15.29	0.33	0.11	0.05	0.01	0.00	0.00	15.80	0.23
1992	16.06	1.66	0.06	0.05	0.01	0.01	0.02	17.87	0.07
1993	1.63	0.19	0.08	0.02	0.05	0.01	0.01	1.98	0.21
1994	11.10	1.13	0.03	0.03	0.05	0.04	0.01	12.38	0.12
1995	6.80	2.45	0.06	0.01	0.01	0.03	0.02	9.39	0.19
1996	9.12	1.42	0.17	0.09	0.02	0.02	0.02	10.86	0.23
1997	4.76	0.45	0.32	0.14	0.01	0.01	0.02	5.70	0.16
1998	9.51	0.78	0.11	0.12	0.00	0.00	0.00	10.52	0.32
1999	22.93	1.45	0.08	0.10	0.00	0.00	0.01	24.57	0.32
2000	2.84	1.56	0.15	0.03	0.00	0.01	0.00	4.59	0.23
2001	17.82	1.27	0.29	0.05	0.00	0.01	0.00	19.43	0.15
2002	16.01	2.35	0.06	0.05	0.01	0.02	0.00	18.51	0.06
2003	32.93	2.58	0.16	0.00	0.01	0.02	0.02	35.72	0.17
2004	5.42	4.85	0.23	0.05	0.01	0.01	0.03	10.59	0.14
2005	34.50	0.68	0.13	0.15	0.04	0.06	0.02	35.59	0.07
2006	22.98	1.41	0.64	0.16	0.04	0.05	0.01	25.27	0.14
2007	12.43	2.21	0.53	0.03	0.01	0.00	0.01	15.23	0.13
2008	10.94	1.72	0.40	0.09	0.03	0.01	0.03	13.20	0.18
2009									
2010									
2011									
2012									
2013									
2014									

Table B6.1 continued.

NEFSC Bigelow 2009-2014									
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6+**	**Total**	**CV**
1985									
1986									
1987									
1988									
1989									
1990									
1991									
1992									
1993									
1994									
1995									
1996									
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009	2.39	3.60	0.95	0.43	0.10	0.03	0.03	7.52	0.49
2010	3.87	2.08	0.38	0.38	0.18	0.06	0.09	7.03	0.23
2011	5.64	1.99	0.29	0.30	0.15	0.03	0.04	8.44	0.16
2012	2.57	1.37	0.69	0.44	0.08	0.01	0.01	5.17	0.20
2013	2.70	0.26	0.04	0.02	0.02	0.00	0.00	3.05	0.58
2014	2.63	1.20	0.05	0.02	0.01	0.00	0.00	3.91	0.24

Table B6.2 NEFSC vessel gear and tow characteristics.

Measure	*FSV* Henry B. Bigelow	*FSV* Albatross IV
Tow Speed	3.0 knots SOG	3.8 knots SOG
Tow Duration	20 minutes	30 minutes
Headrope Height	3.5 to 4m	1 to 2m
Ground Gear	Rockhopper Sweep Total Length: 25.5m Center: 8.9m with 16 inch rockhoppers Wings: 8.2m each 14 inch rockhoppers	Roller Sweep Total Length: 24.5m Center: 5m with 16 inch rollers Wings: 9.75m each with 4 inch cookies
Mesh	Poly webbing Forward portion of trawl: 12cm, 4mm Square aft to codend: 6cm, 2.5mm Codend: 12cm, 4mm dbl. Codend liner: 2.54cm, knotless	Nylon webbing Body of Trawl: 12.7cm Codend: 11.5cm Codend and top-belly liner: 1.27cm, knotless
Net Design	4 Seam, 3 Bridle	Yankee 36 (recent years)
Door type	550 kg PolyIce oval	450 kg Polyvalent
Other	Wing End to Door length: 36.5m	Wing End to Door length: 9m

Table B6.3 Composite Young of Year (YOY) Index 1981-2014.

Year	Base Model	95% LCI	95% UCI	CV
1981	0.94	0.15	3.18	0.90
1982	1.66	0.32	5.12	0.80
1983	2.18	0.37	7.27	0.89
1984	1.46	0.22	5.12	0.99
1985	1.64	0.31	5.19	0.83
1986	0.77	0.13	2.60	0.90
1987	2.24	0.63	5.29	0.55
1988	1.41	0.49	3.09	0.48
1989	2.12	0.72	4.67	0.50
1990	1.33	0.49	2.96	0.48
1991	1.15	0.42	2.60	0.50
1992	0.67	0.21	1.53	0.52
1993	0.26	0.10	0.59	0.51
1994	0.39	0.12	1.00	0.61
1995	0.35	0.13	0.82	0.51
1996	0.35	0.10	0.89	0.59
1997	1.52	0.44	3.87	0.60
1998	0.47	0.15	1.15	0.57
1999	1.22	0.35	3.28	0.65
2000	0.63	0.24	1.36	0.47
2001	1.14	0.41	2.45	0.46
2002	0.50	0.20	1.03	0.44
2003	0.39	0.15	0.85	0.47
2004	0.88	0.34	1.84	0.45
2005	0.92	0.37	1.93	0.44
2006	1.03	0.40	2.14	0.44
2007	0.94	0.38	1.96	0.43
2008	1.29	0.52	2.61	0.42
2009	0.53	0.20	1.15	0.46
2010	0.68	0.27	1.43	0.44
2011	0.53	0.20	1.12	0.46
2012	0.65	0.26	1.40	0.46
2013	1.06	0.39	2.26	0.46
2014	0.68	0.23	1.50	0.49

Table B6.4 Deviance table for standardization of MRIP CPUE.

	Df	Deviance	Resid. Df	Resid. Dev	Pr(>Chi)	Percent Deviance Explained
NULL	NA	NA	208946	199775	NA	NA
YEAR	33	3827.811	208913	195947.2	0.00E+00	23.75
MODE	2	3791.219	208911	192156	0.00E+00	23.52
AVIDITY	1	2091.646	208910	190064.3	0.00E+00	12.98
STATE	13	5198.157	208897	184866.2	0.00E+00	32.25
WAVE	5	988.7111	208892	183877.5	1.67E-211	6.13
AREA	1	218.4265	208891	183659	1.99E-49	1.36

Table B6.5 GLM-standardized estimates of catch-per-unit-effort from the MRIP survey.

Year	Continuity Run	Standard Error	Benchmark	Standard Error
1981	1.12	0.02	1.73	0.09
1982	1.00	0.02	1.76	0.10
1983	0.77	0.02	1.34	0.07
1984	0.97	0.02	1.57	0.09
1985	1.09	0.02	1.62	0.08
1986	0.98	0.02	1.67	0.09
1987	0.98	0.02	1.65	0.09
1988	0.50	0.02	0.97	0.05
1989	0.76	0.01	1.31	0.06
1990	0.67	0.01	1.22	0.06
1991	0.63	0.01	1.18	0.06
1992	0.48	0.01	0.93	0.05
1993	0.30	0.02	0.74	0.04
1994	0.43	0.02	0.89	0.04
1995	0.39	0.02	0.86	0.04
1996	0.44	0.02	0.96	0.05
1997	0.67	0.02	1.12	0.06
1998	0.53	0.02	0.95	0.05
1999	0.76	0.02	1.28	0.07
2000	0.75	0.02	1.30	0.07
2001	0.87	0.02	1.49	0.08
2002	0.79	0.02	1.18	0.06
2003	0.73	0.02	1.27	0.07
2004	0.85	0.02	1.44	0.07
2005	0.77	0.02	1.32	0.07
2006	0.80	0.02	1.42	0.08
2007	0.81	0.02	1.31	0.07
2008	0.74	0.02	1.29	0.07
2009	0.62	0.02	1.15	0.06
2010	0.70	0.02	1.20	0.06
2011	0.77	0.02	1.28	0.07
2012	0.74	0.02	1.36	0.07
2013	0.74	0.02	1.25	0.07
2014	0.72	0.02	1.32	0.07

Table B6.6 Age data sample sizes by state or agency from post-SAW41.

Year	MA	RI	CT	NY	NJ	CB	VA	NEAMAP	NC	SEAMAP
2005	0	0	0	0	0	70	332	0	0	0
2006	0	0	0	0	0	22	327	0	89	0
2007	0	0	0	0	0	50	383	584	432	0
2008	0	0	0	0	0	27	326	550	656	0
2009	13	0	0	0	0	11	354	650	488	0
2010	70	0	0	0	201	29	401	489	527	0
2011	69	0	0	0	196	7	441	483	552	307
2012	113	86	124	131	167	8	514	609	811	226
2013	133	252	227	290	340	32	378	404	737	274
2014	113	92	190	518	169	39	343	361	792	262

Table B7.1 Bluefish model building starting with continuity run and ending at final model. The models shown highlight the important changes in the progression from one model to the next. 2014 estimates of F, F40%, total stock numbers, spawning stock biomass, total stock biomass and recruitment are presented for each model step.

MODEL	DESCRIPTION	Obj Func	#pars	2014 Estimates					
				F	F40%	TSN (000s)	SSB (mt)	TSB (mt)	Rec (000s)
B001	Continuity run. Update SAW2005 model through 2014.	3094.79	101	0.141	0.171	57,671	84,800	92,755	14,696
B002	Continuity run cropped to start in 1985: No age data for 1982-1984 found.	2637.25	95	0.145	0.200	70,867	84,551	91,808	21,528
B004	Base model run. SAW2005 model with new CAA, WAA, and Indices.	2282.17	114	0.146	0.172	57,534	81,241	90,381	15,731
B006	Changed indices from index-at-age to estimating age composition.	7692.99	108	0.119	0.175	76,803	105,632	103,359	23,573
B007	Changed from one catch fleet to two: Recreational and commercial.	8546.78	138	0.143	0.172	64,470	83,839	91,462	16,174
B008	New maturity ogive based on preliminary analyses of maturity data.	8546.78	138	0.143	0.175	64,470	85,738	91,462	16,174
B011	Change from fixed fleet selectivities-at-age estimated selectivities.	8480.29	148	0.145	0.202	78,047	117,234	125,019	18,723
B020	Change to two selectivity blocks per fleet: 1985-2005, 2006-2014	7748.80	155	0.105	0.146	109,651	182,995	193,733	23,828
B020A	No estimated age composition for fleets in middle time period 1997-2005: ESS = 0	7559.01	155	0.103	0.148	112,281	189,369	200,420	24,194
B021	Set Lambdas to 0 or 1 to act as a switch for CV and inclusion in Obj Func. Needed to adjust fleet ESS and CV to get model to converge.	2719.28	164	0.111	0.128	82,875	102,157	110,871	24,289
B021A	Turn Likelihood constant off in objective function.	8134.61	164	0.155	0.224	102,891	142,077	152,889	28,581
B022	Turn number in the first year deviation penalty off	7937.38	164	0.136	0.230	117,420	174,184	186,480	31,335

Table B7.1 continued. *SAW60 WG final model (B043) results and diagnostics can be found in appendix B7.

MODEL	DESCRIPTION	Obj Func	#pars	2014 Estimates					
				F	F40%	TSN (000s)	SSB (mt)	TSB (mt)	Rec (000s)
B023	New maturity ogive based on final analyses of maturity data.	7937.38	164	0.136	0.230	117,420	174,888	186,480	31,334
B024	Increase CV on recruitment from 0.5 to 1.0.	7950.68	164	0.137	0.230	117,082	174,284	185,906	31,286
B025	Switch from selectivity-at-age to double logistic in time block 2.	7951.81	159	0.134	0.223	115,067	169,754	181,167	30,933
B027	Switch from double logistic selectivity to selectivity-at-age for NEFSC surveys.	7942.52	164	0.135	0.221	113,697	167,409	178,658	30,509
B028	Switch back to one selectivity block per fleet before including corrected data.	8014.38	155	0.126	0.191	101,276	153,752	164,139	27,028
B029	Switch NEFSC surveys to split off Bigelow: Inshore bands 1985-2008, Bigelow (Outer Inshore band) 2009-2014.	7641.45	155	0.128	0.189	99,476	149,216	159,673	26,856
B030	Switch MRIP selectivity to match starting values at-age of Rec fleet.	7649.17	154	0.113	0.194	114,851	184,961	197,207	29,543
B033	New data that corrects North Carolina scale ages from 1985-1996.	7425.96	154	0.094	0.204	142,050	243,972	258,068	34,263
B035	Switched PSIGN from double logistic selectivity to selectivity-at-age.	7427.21	156	0.091	0.205	147,082	256,007	270,667	35,152
B042	Switch MRIP selectivity from at-age to single logistic. Increased CV around recreational fleet from 0.1 to 0.15.	7464.98	151	0.124	0.178	90,014	126,802	135,011	24,583
B043*	Final adjustments to index input CV and ESS. Low ESS in middle block: 1997-2005.	8593.52	151	0.136	0.181	94,202	117,827	127,061	31,054
B044 (BFINAL)	Final model from SARC60 review: Fixed a misspecification in the A50 selectivity parameter for the MRIP index	8581.45	152	0.157	0.170	82,031	86,534	94,328	29,607

Table B7.2. Model specifications for Model B001, the continuity run.

	Age						
Time Frame: All Years	0	1	2	3	4	5	6+
Natural Mortality	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Maturity	0.00	0.25	0.75	1.00	1.00	1.00	1.00
Fleet Selectivity: Fixed	0.338	1	0.942	0.476	0.343	0.694	0.914

Fleet 1		
CV	0.01	All Years
ESS	30	All Years

Recruitment Deviations		
CV	0.5	All Years
Lambda	1	--

Lambda for Catch weight	10
Lambda for Fmult Year 1	0.5
CV Fmult Year 1	0.9
Lambda Fmult Deviations	0
CV Fmult Deviations	0.9

	Lambda	CV
N in First Year Deviations	1	0.9
Deviation from initial Steepness	0	0.6
Deviation from initial SR Scaler	0	0.6

Indices		
	1	2 to 28
Lambda	10	5
Lambda for Catchability	0.01	0.01
CV for Catchability	0.9	0.9
Lambda for Catchability Deviations	100	100
CV for Catchability Deviations	0.9	0.9
Index Selectivities	Input at-age: Fixed	

Phases	
Fmult in year 1	2
Fmult deviations	3
Recruitment Devs	3
N in year 1	4
Catchability in year 1	1
Catchability Devs	-5
SR Scaler	2
Steepness	-4

Table B7.3. Model specifications for Model B044, the final model.

	Age						
Time Frame: All Years	0	1	2	3	4	5	6+
Natural Mortality	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Maturity	0.00	0.40	0.97	1.00	1.00	1.00	1.00
Fleet 1 Selectivity: Input	0.338	-1	0.942	0.476	0.343	0.694	0.914
Fleet 2 Selectivity: Input	0.338	-1	0.942	0.476	0.343	0.694	0.914

Fleets			
	1	2	Time Block
CV	0.1	0.15	All Years
ESS	30	50	1985-1996
ESS	20	25	1997-2005
ESS	50	100	2006-2014

Recruitment Deviations		
CV	1.0	All Years
Lambda	1	--

	Lambda	CV
N year 1	0	0.9
Steepness	0	0.6
SR Scaler	0	0.6

	Fleet 1	Fleet 2
Lambda for Catch weight	1	1
Lambda for Fmult Year 1	0	0
CV Fmult Year 1	0.9	0.9
Lambda Fmult Deviations	0	0
CV Fmult Deviations	0.9	0.9

Indices	
	ALL
Lambda	1
Lambda for Catchability	0
CV for Catchability	0.9
Lambda for Catchability Deviations	0
CV for Catchability Deviations	0.9

Phases	
Fmult in year 1	2
Fmult deviations	3
Recruitment Devs	1
N in year 1	1
Catchability in year 1	1
Catchability Devs	-5
SR Scaler	1
Steepness	-5

Table B7.3 continued

Input Index Selectivities (-1 = fixed full selectivity)							
Index	Age						
	0	1	2	3	4	5	6+
NEFSC Inshore	-1	0.25	0.1	0.1	0.1	0.05	0.05
NEFSC Bigelow	-1	0.25	0.1	0.1	0.1	0.05	0.05
MRIP	Single Logistic: A50 = 1, Slope = 0.5						
NEAMAP	-1	0.25	0.1	0.1	0.1	0.05	0.05
SEAMAP	-1						
PSIGN	0.338	-1	0.942	0.476	0.343	0.694	0.914
CT LISTS	-1	0.25	0.1	0.1	0.1	0.05	0.05
NJ OCEAN	-1	0.5	0.1				
COMPOSITE YOY	-1						

Table B7.4 Annual SSB (mt), recruitment (000s), total abundance (000s), and F from the ASAP model updated through 2013.

Year	SSB	Recruitment	F
1985	191,476	36,743	0.246
1986	172,059	28,771	0.400
1987	147,048	18,084	0.450
1988	114,649	24,369	0.421
1989	106,535	50,212	0.344
1990	99,809	24,293	0.345
1991	87,241	29,153	0.403
1992	82,983	14,284	0.342
1993	80,624	17,023	0.325
1994	80,088	25,342	0.274
1995	77,967	17,817	0.243
1996	72,796	22,581	0.248
1997	72,173	24,542	0.290
1998	81,296	21,778	0.219
1999	85,940	33,833	0.162
2000	96,940	19,205	0.196
2001	102,797	28,505	0.220
2002	93,860	23,700	0.169
2003	96,980	36,430	0.197
2004	104,483	21,891	0.200
2005	115,988	33,629	0.200
2006	99,731	35,477	0.205
2007	97,077	27,160	0.238
2008	118,635	25,661	0.182
2009	105,828	19,474	0.162
2010	114,135	20,560	0.187
2011	114,025	19,666	0.161
2012	119,665	18,354	0.151
2013	126,473	27,184	0.150
2014	117,827	31,054	0.136
Average	**105,904**	**25,892**	**0.249**

Table B7.5 Abundance at age (000s) for bluefish from the final SAW60 model, B044.

Year	Age							**Total**
	0	1	2	3	4	5	6+	
1985	34,564	40,376	16,902	8,067	5,733	3,382	15,262	**124,286**
1986	26,963	25,856	25,430	10,645	5,180	3,810	13,121	**111,005**
1987	17,036	18,924	13,843	13,616	5,834	2,998	10,747	**82,998**
1988	23,544	11,748	9,612	7,032	7,111	3,240	8,471	**70,758**
1989	48,104	16,609	6,102	4,992	3,807	4,089	7,341	**91,043**
1990	23,162	34,626	9,321	3,425	2,885	2,311	7,416	**83,146**
1991	27,509	16,827	19,315	5,200	1,991	1,766	6,406	**79,012**
1992	13,464	19,569	8,750	10,044	2,841	1,156	5,187	**61,011**
1993	16,164	9,762	10,827	4,841	5,799	1,729	4,181	**53,304**
1994	23,972	11,784	5,484	6,083	2,836	3,573	3,892	**57,624**
1995	16,905	17,792	7,012	3,264	3,751	1,825	5,010	**55,560**
1996	21,365	12,694	10,998	4,334	2,081	2,485	4,765	**58,722**
1997	22,575	16,072	7,812	6,768	2,762	1,379	5,025	**62,395**
1998	20,113	16,674	9,402	4,570	4,112	1,756	4,346	**60,973**
1999	30,628	15,271	10,578	5,964	2,992	2,787	4,320	**72,540**
2000	17,326	23,791	10,365	7,179	4,155	2,139	5,214	**70,170**
2001	25,488	13,218	15,511	6,758	4,798	2,864	5,276	**73,912**
2002	21,503	19,236	8,371	9,823	4,393	3,228	5,713	**72,267**
2003	32,848	16,569	12,930	5,627	6,749	3,100	6,510	**84,333**
2004	19,679	24,963	10,781	8,413	3,741	4,627	6,859	**79,064**
2005	30,560	14,929	16,183	6,989	5,572	2,556	8,140	**84,930**
2006	32,190	23,094	9,677	10,489	4,610	3,790	7,630	**91,480**
2007	24,533	24,327	14,832	6,215	6,883	3,124	8,076	**87,991**
2008	23,123	18,228	14,992	9,141	3,914	4,499	7,737	**81,634**
2009	17,626	17,544	11,976	9,850	6,101	2,689	8,735	**74,521**
2010	18,595	13,572	11,840	8,082	6,779	4,309	8,375	**71,550**
2011	17,815	14,160	8,882	7,748	5,403	4,669	9,077	**67,753**
2012	16,738	13,693	9,568	6,001	5,326	3,810	10,020	**65,155**
2013	25,149	12,904	9,372	6,548	4,169	3,788	10,180	**72,109**
2014	29,607	19,363	8,847	6,425	4,547	2,962	10,280	**82,031**

Table B7.6. Jan-1 Biomass at age (mt) for bluefish as estimated from the final SAW60 model, B044.

Year	Age 0	1	2	3	4	5	6+	**Total**
1985	1,870	15,125	17,013	15,328	18,301	13,653	101,950	**183,239**
1986	933	6,880	22,058	18,427	14,422	15,040	80,825	**158,584**
1987	600	4,434	12,170	23,096	16,467	11,612	65,559	**133,937**
1988	1,898	2,707	7,980	12,232	18,455	12,081	48,623	**103,976**
1989	2,828	5,273	5,872	9,146	10,932	14,836	42,209	**91,097**
1990	2,589	8,480	8,071	6,606	9,906	9,150	46,053	**90,855**
1991	1,282	3,386	14,389	8,180	5,617	7,175	36,899	**76,929**
1992	368	4,197	4,637	15,371	7,318	4,384	30,293	**66,568**
1993	1,356	1,751	7,806	7,553	14,394	6,192	25,548	**64,600**
1994	1,040	3,162	3,848	9,371	7,952	12,439	25,844	**63,655**
1995	1,505	4,096	4,906	5,008	10,097	7,098	29,710	**62,419**
1996	1,431	4,122	8,046	5,857	5,285	9,636	26,493	**60,870**
1997	1,000	4,057	6,212	9,547	6,140	4,535	28,796	**60,287**
1998	1,376	3,765	6,174	7,457	11,101	5,864	26,943	**62,680**
1999	2,505	3,775	7,246	8,668	9,273	10,735	27,175	**69,377**
2000	1,733	5,700	6,590	11,666	12,214	8,061	32,382	**78,346**
2001	1,690	3,385	9,832	10,297	15,510	11,135	31,232	**83,081**
2002	1,398	4,905	5,596	13,404	11,948	12,333	28,967	**78,551**
2003	1,281	4,308	9,675	7,968	15,145	9,830	32,027	**80,234**
2004	976	5,187	8,795	13,056	8,598	14,351	32,579	**83,542**
2005	3,059	3,638	10,870	11,808	14,455	8,746	43,957	**96,535**
2006	2,063	6,665	6,858	13,682	11,438	12,364	32,962	**86,032**
2007	2,058	5,461	10,173	7,437	13,641	9,997	34,567	**83,335**
2008	2,312	4,890	10,992	12,409	8,607	12,505	37,679	**89,396**
2009	1,683	4,493	8,044	12,755	13,633	8,759	40,008	**89,375**
2010	1,289	3,197	7,581	8,367	12,267	13,346	43,380	**89,427**
2011	1,374	2,942	5,182	8,273	7,761	14,965	48,741	**89,238**
2012	921	3,003	5,261	6,119	9,134	10,492	54,708	**89,638**
2013	2,281	2,839	5,701	8,029	7,200	11,830	59,042	**96,922**
2014	2,339	4,802	5,750	8,786	10,341	9,469	52,841	**94,328**

Table B7.7 Final model objective function profiled over different estimates of natural mortality.

M	Objective Function	F40%
0.10	8594.98	0.114
0.15	8588.11	0.145
0.20	8581.45	0.17
0.25	8576.89	0.189
0.26	8576.37	0.192
0.27	8576.00	0.195
0.28	8575.78	0.198
0.29	8575.70	0.201
0.30	8575.76	0.204
0.35	8578.03	0.217
0.40	8582.85	0.229

Table B7.8 Final model (B044) sensitivity runs at different age-based estimates of natural mortality.

MODEL	DESCRIPTION	Obj Func	#pars	2014 Estimates					
				F	F40%	TSN (000s)	SSB (mt)	TSB (mt)	Rec (000s)
B044	Final bluefish model estimates	8581.45	152	0.157	0.170	82,031	86,534	94,328	29,607
B044_M_LROT	M at age: Lorenzen scaled to Rule of Thumb (0.21)	8605.99	152	0.152	0.144	100,052	80,906	90,010	42,259
B044_M_L29	M at age: Lorenzen scaled to minimum objective function M (0.29)	8659.71	152	0.061	0.200	297,237	289,278	321,098	140,027
B044_M_LGIS	M at age: Gislason et al 2010	8686.76	152	0.075	0.17	518,498	155,860	204,324	397,560

Table B7.9 Sensitivity of the final model to removal of individual indices.

MODEL	DESCRIPTION	Obj Func	#pars	2014 Estimates					
				F	F40%	TSN (000s)	SSB (mt)	TSB (mt)	Rec (000s)
B044	Final bluefish model estimates	8581.45	152	0.157	0.170	82,031	86,534	94,328	29,607
B044-1	Remove NEFSC inshore survey	8097.87	145	0.158	0.170	81,550	85,539	93,283	29,496
B044-2	Remove NEFSC Bigelow survey	8209.91	145	0.155	0.170	81,820	86,894	94,268	30,011
B044-3	Remove MRIP rec CPUE	6965.31	150	0.087	0.215	179,828	305,764	326,698	50,254
B044-4	Remove NEAMAP survey	8372.90	145	0.157	0.170	84,229	86,274	94,302	31,896
B044-5	Remove SEAMAP age 0 index	8569.90	151	0.157	0.170	83,155	86,548	94,430	30,527
B044-6	Remove PSIGN survey	8269.00	145	0.158	0.169	81,788	82,014	89,381	30,031
B044-7	Remove CT LISTS survey	7918.29	145	0.151	0.170	83,944	89,998	97,853	29,403
B044-8	Remove NJ Ocean Trawl survey	8352.91	149	0.159	0.170	80,812	85,269	93,104	29,381
B044-9	Remove composite YOY index	8588.93	151	0.157	0.170	82,936	86,309	94,158	30,691
B044MRIP	All removed except MRIP rec CPUE	6323.18	112	0.151	0.168	93,742	83,384	91,128	41,835

Table B7.10 DCAC based model run assumed parameter estimates and error distributions.

Parameter	Value	Source	SD	Source	Distribution
CV of $\sum C$	0.2	–	–	–	normal
M	0.192	Then et al. (2015) $\text{Pauly}_{\text{nls-T}}$ estimator	0.5	MacCall (2009)	lognormal
F_{MSY}/M	0.8	MacCall (2009); Dick & MacCall (2011)	0.2	MacCall (2009)	lognormal
B_{MSY}/B_0	0.4	MacCall (2009); Dick & MacCall (2011)	0.1	MacCall (2009); Dick & MacCall (2011)	bounded beta
Δ	0.5	Preliminary SCAA model runs	0.1	–	lognormal

Table B7.11 DCAC alternative assumed parameter estimates.

		Alternative 1		Alternative 2	
Variable	**Value**	**Value**	**Source**	**Value**	**Source**
CV of $\sum C$	0.2	0.1	–	–	–
M	0.192	0.437	Then et al. (2015) $Hoenig_{nls}$	–	–
SD of M	0.5	–	–	–	–
F_{MSY}/M	0.8	1.0	MacCall (2009)	–	–
SD of F_{MSY}/M	0.2	0.1	Lower variance estimate	–	–
B_{MSY}/B_0	0.4	0.5	MacCall (2009)	–	–
SD of B_{MSY}/B_0	0.1	0.2	–	–	–
Δ	0.5	0.424	B_0: 1.5xSSB in 1982*	0.636	B_0: SSB in 1982*

* – based on the 2014 update stock assessment based on the 41st SAW/SARC benchmark stock assessment of bluefish.

Table B7.12 Drawn parameters and their distributions for the DBSRA model

Parameter	Value	Source	SD	Source	Distribution
Annual harvest	–	ACCSP, MRIP	0.1	MRIP PSEs	lognormal
M	0.2	2015 Assessment	0.5	MacCall (2009)	lognormal
F_{MSY}/M	0.8	MacCall (2009); Dick & MacCall (2011)	0.2	MacCall (2009)	lognormal
B_{MSY}/K	0.4	MacCall (2009); Dick & MacCall (2011)	0.1	MacCall (2009); Dick & MacCall (2011)	bounded beta
B_{2014}/K	0.4	2014 Assessment Update	0.2	–	bounded beta

Table B7.13 Median management benchmarks (and 5th and 95th quantiles) from DBSRA model.

	U_{MSY}	K	MSY	B_{MSY}
Base run	0.12 (0.05 - 0.21)	432,049 mt (277,232 – 831,884 mt)	19,954 mt (14,905 – 24,943 mt)	172,010 mt (110,510 – 324,853 mt)

Table B10.1. Short-term projections of catch and biomass for bluefish under various F scenarios, with the associated probability that biomass in 2018 will be above the biomass threshold.

	Catch (mt)			Spawning Stock Biomass (mt)			$P(SSB_{2018}) > SSB_{threshold}$
F Scenario	2016	2017	2018	2016	2017	2018	
$F_{MSY\ proxy} = 0.170$	**10,528***	10,578	11,023	83,936	82,200	85,400	1.00
90% $F_{MSY\ proxy} = 0.153$	9,533	9,698	10,218	84,448	83,736	88,045	1.00
$F_{2014} = 0.157$	9,768	9,908	10,413	84,327	83,371	87,416	1.00
$F_{low} = 0.100$	6,351	6,716	7,326	86,064	88,715	96,865	1.00
$F_{0.1} = 0.187$	11,510	11,423	11,772	83,426	80,701	82,839	1.00
$F_{35\%SPR} = 0.191$	11,740	11,617	11,941	83,307	80,352	82,247	1.00

*: The OFL for 2016, derived from catch projections under the F_{MSY} proxy.

Table B10.2 Sensitivity analysis for short-term projections for bluefish

	Landings (mt)			Total Biomass (mt)		
F = Fmsy	2016	2017	2018	2016	2017	2018
Base model	12,752	12,332	12,420	114,731	112,758	111,347
Increased CVs	12,984	12,599	12,615	114,699	112,497	110,765
M=0.26	18,122	16,513	15,891	147,636	137,192	128,747
2006-2014 recruitment	12,743	12,279	12,313	114,670	112,483	110,758
High rec landings	13,285	12,902	13,038	120,611	118,971	117,867
Low rec landings	11,500	11,104	11,271	108,055	106,100	104,870
Continuity model	12,641	12,055	11,641	90,271	86,258	84,003
F = F 2014	2016	2017	2018	2016	2017	2018
Base model	9,725	9,691	10,031	114,731	115,922	117,645
Increased CVs	9,904	9,905	10,198	114,699	115,712	117,161
M=0.26	9,187	8,969	9,166	147,636	146,276	146,042
2006-2014 recruitment	9,717	9,651	9,944	114,670	115,645	117,029
High rec landings	10,668	10,624	10,980	120,611	121,710	123,335
Low rec landings	7,899	7,927	8,333	108,055	109,868	112,427
Continuity model	10,006	9,846	9,747	90,271	88,955	89,055

Note: these sensitivity runs were conducted with Model B043, not the revised final model.

Figures

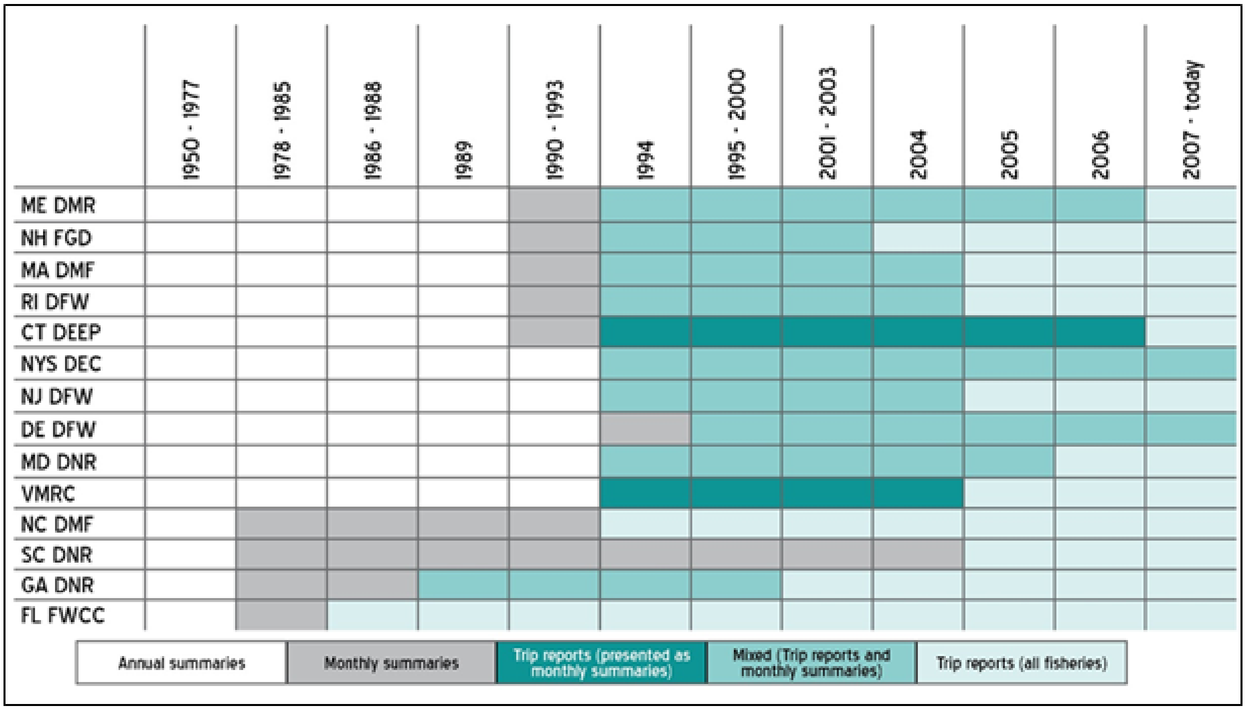


Figure B4.1. ACCSP data sources and collection methods.

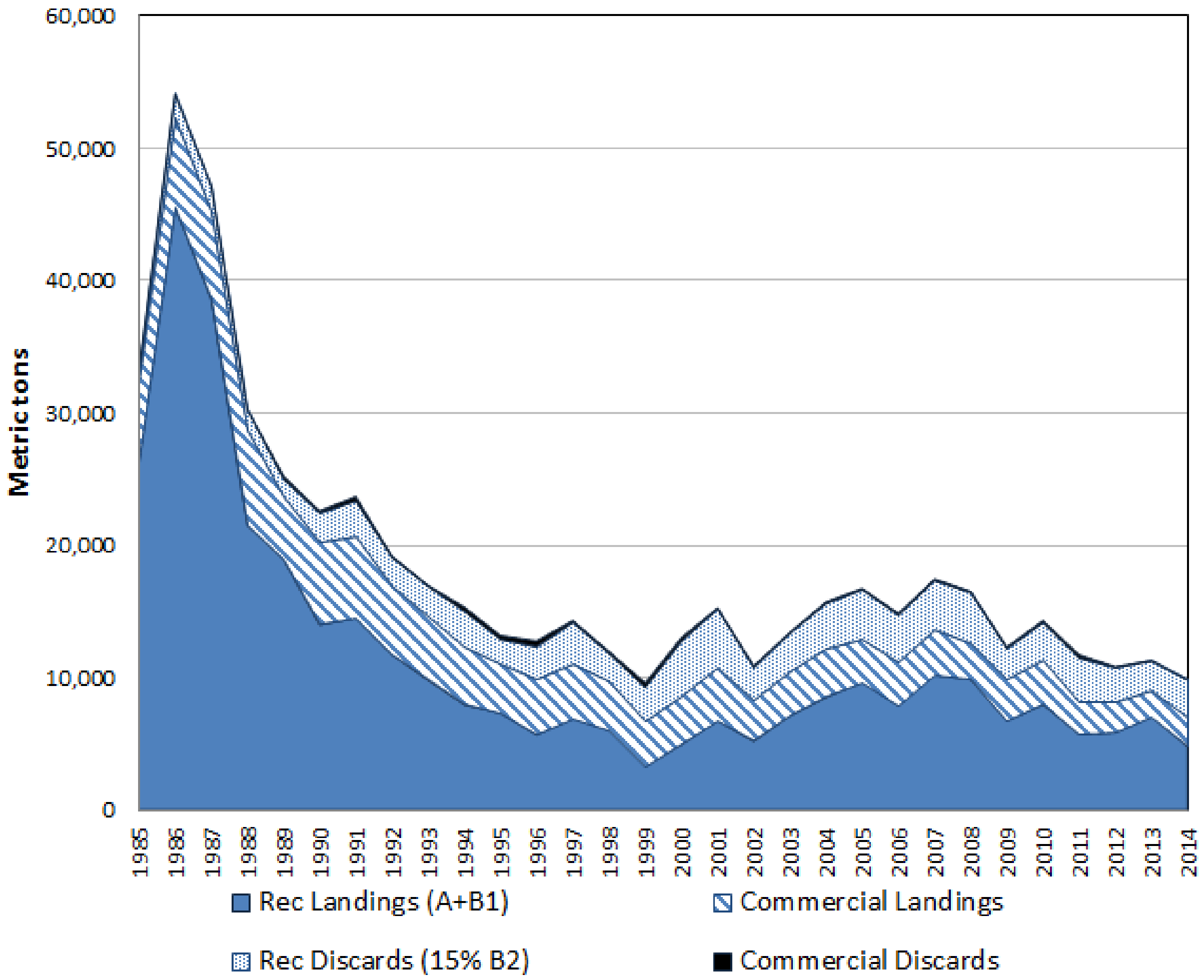


Figure B4.2. Bluefish landings by fleet and disposition.

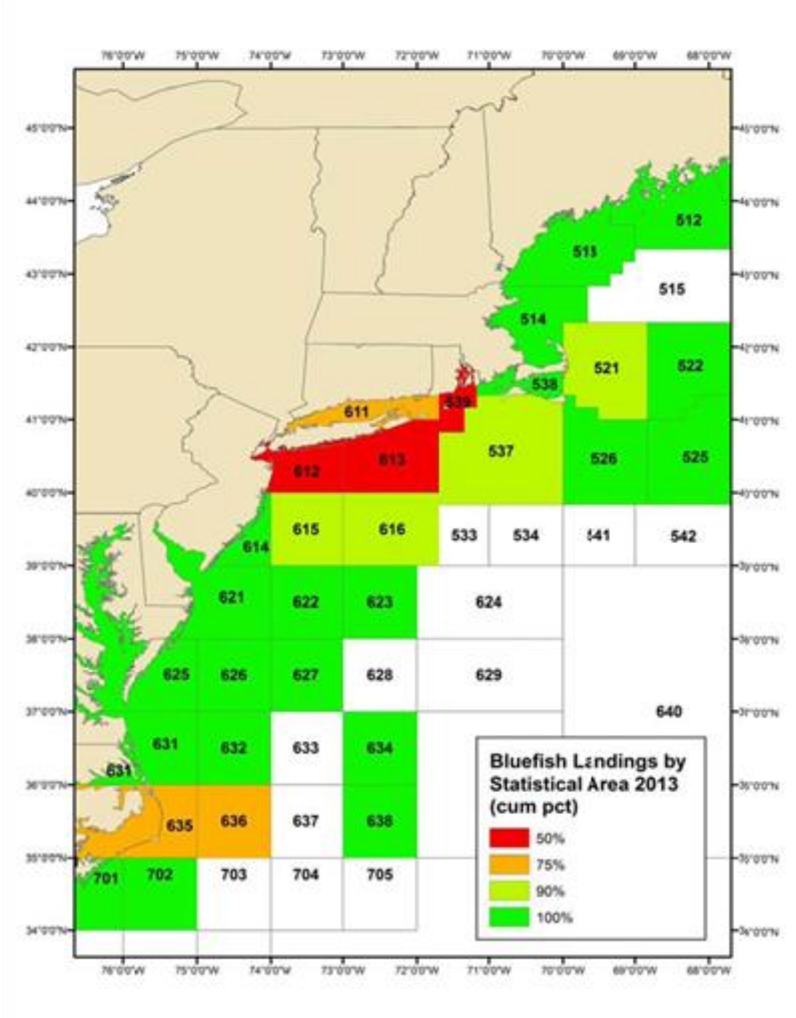


Figure B4.3. Bluefish landings by NMFS statistical areas. Shading reflects the cumulative percentage of landings with red and orange being the primary areas where the commercial landings are taken.

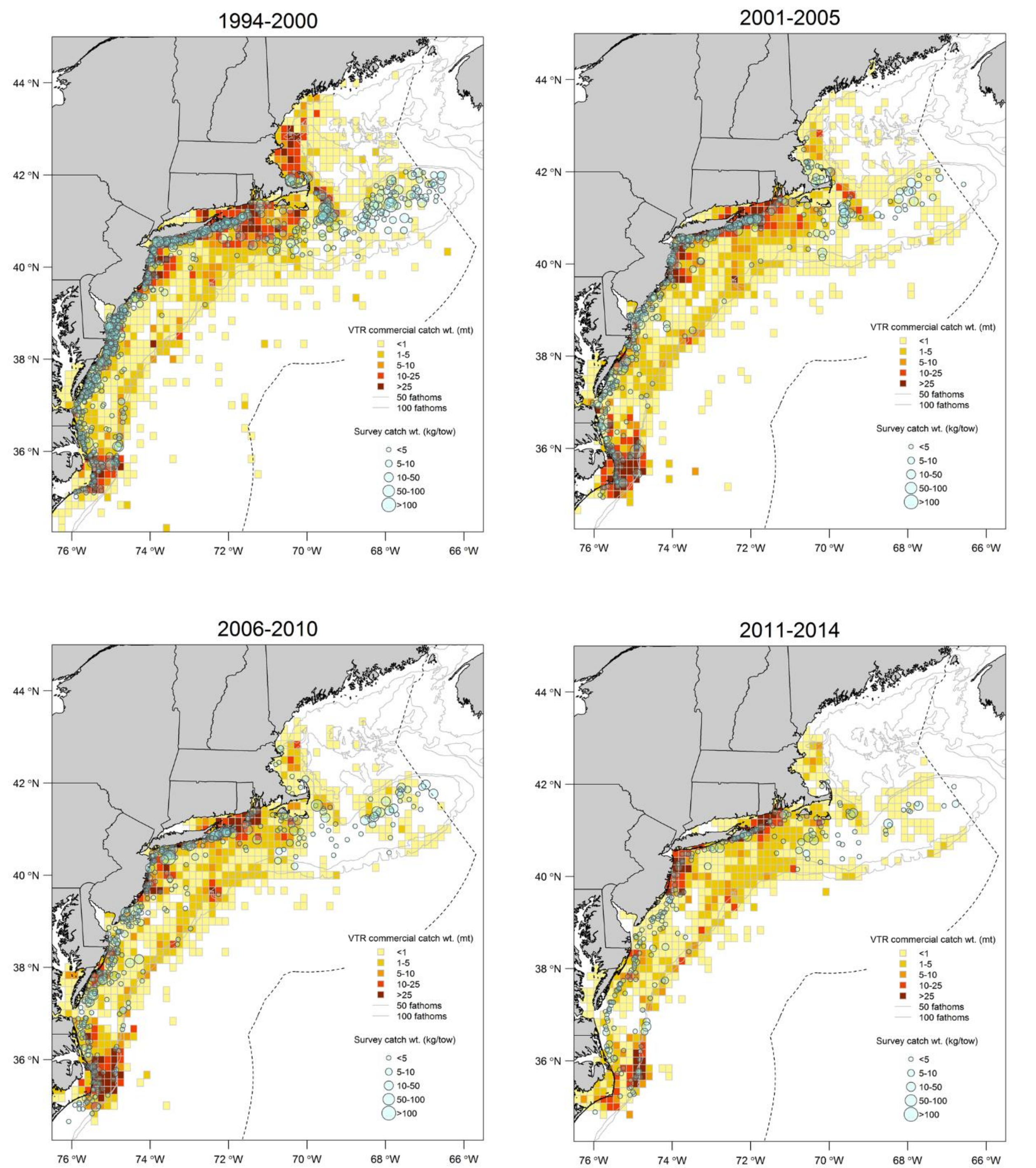


Figure B4.4. Spatial distribution of bluefish commercial catch by time period as reported through Vessel Trip Reports (VTR). Source: NEFSC.

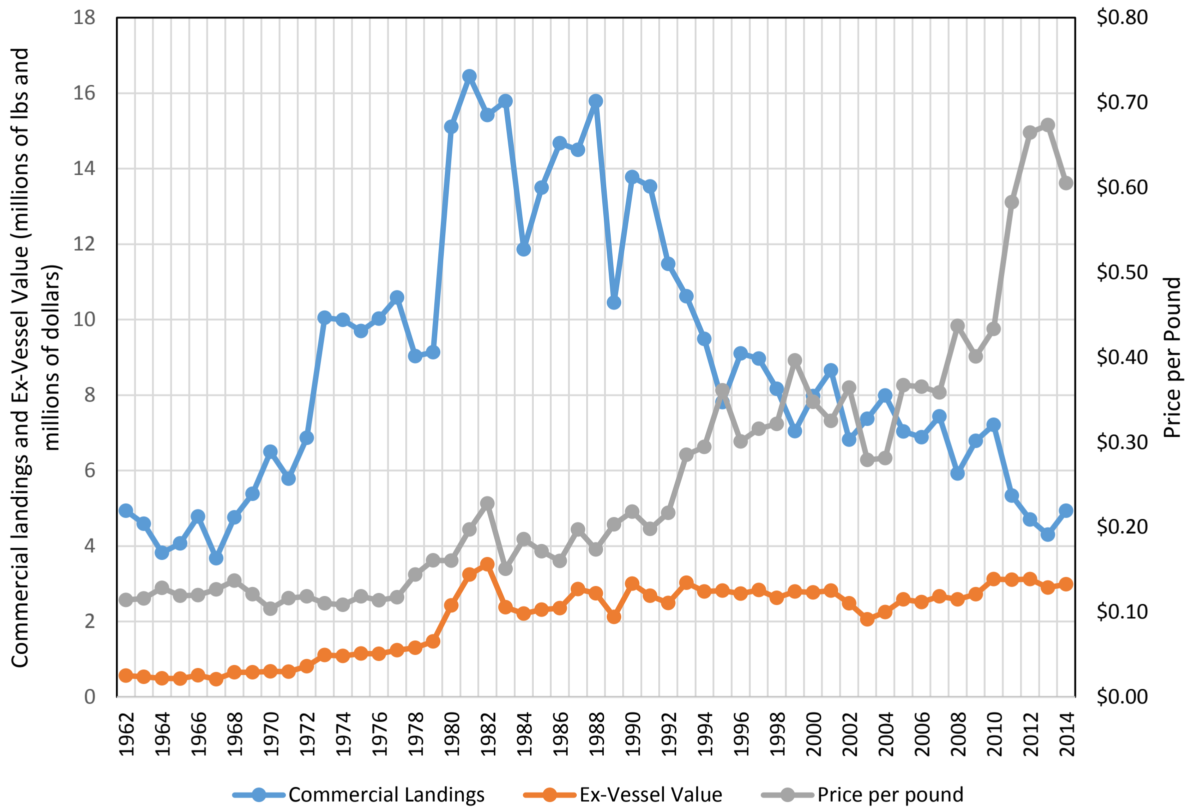


Figure B4.5. Landings, ex-vessel value, and price for bluefish, 1960 - 2014. Source: ACCSP Data Warehouse. Prices are not adjusted for inflation.

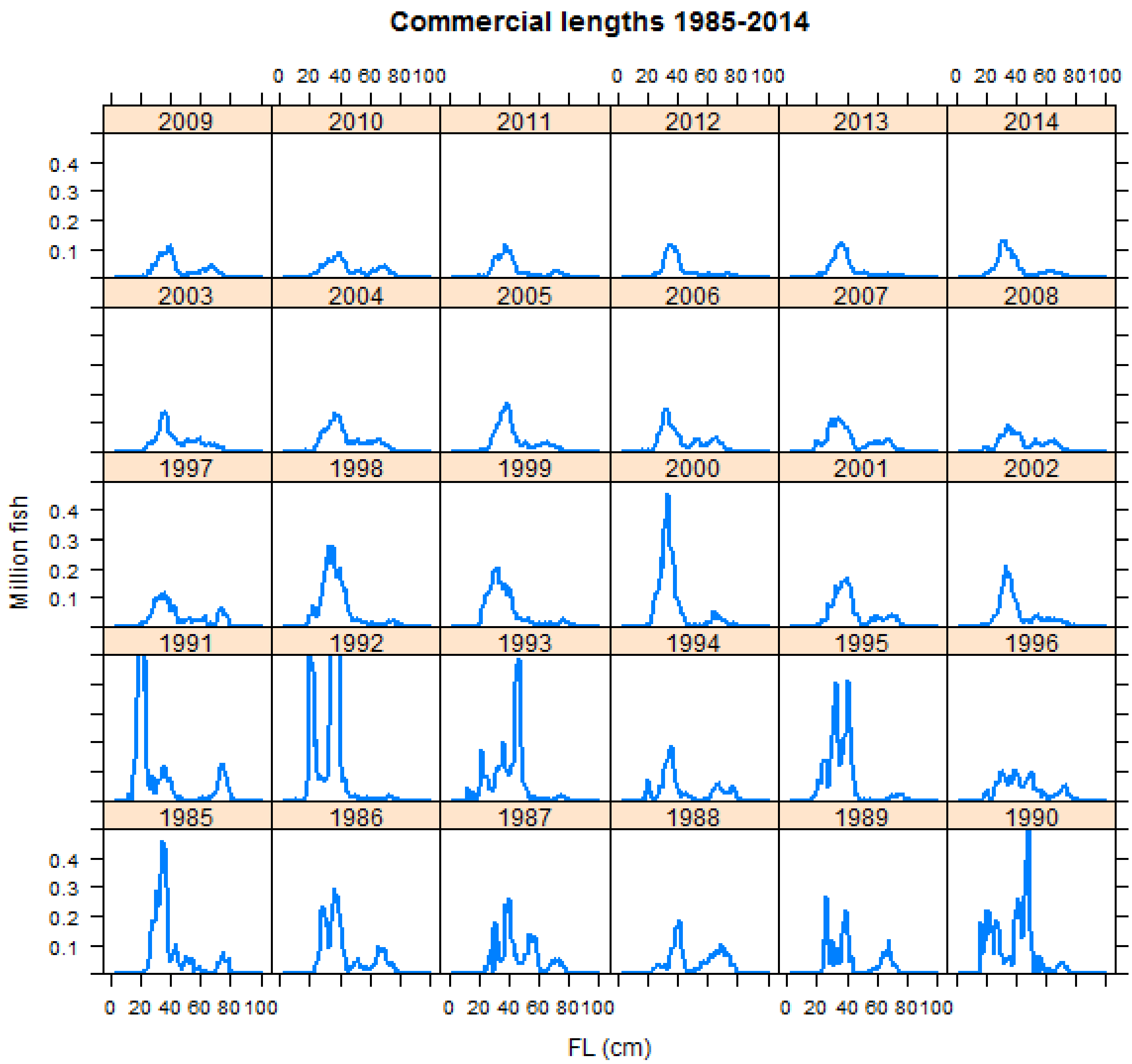


Figure B4.6. Length frequency distributions of commercial bluefish landings from Maine to Florida.

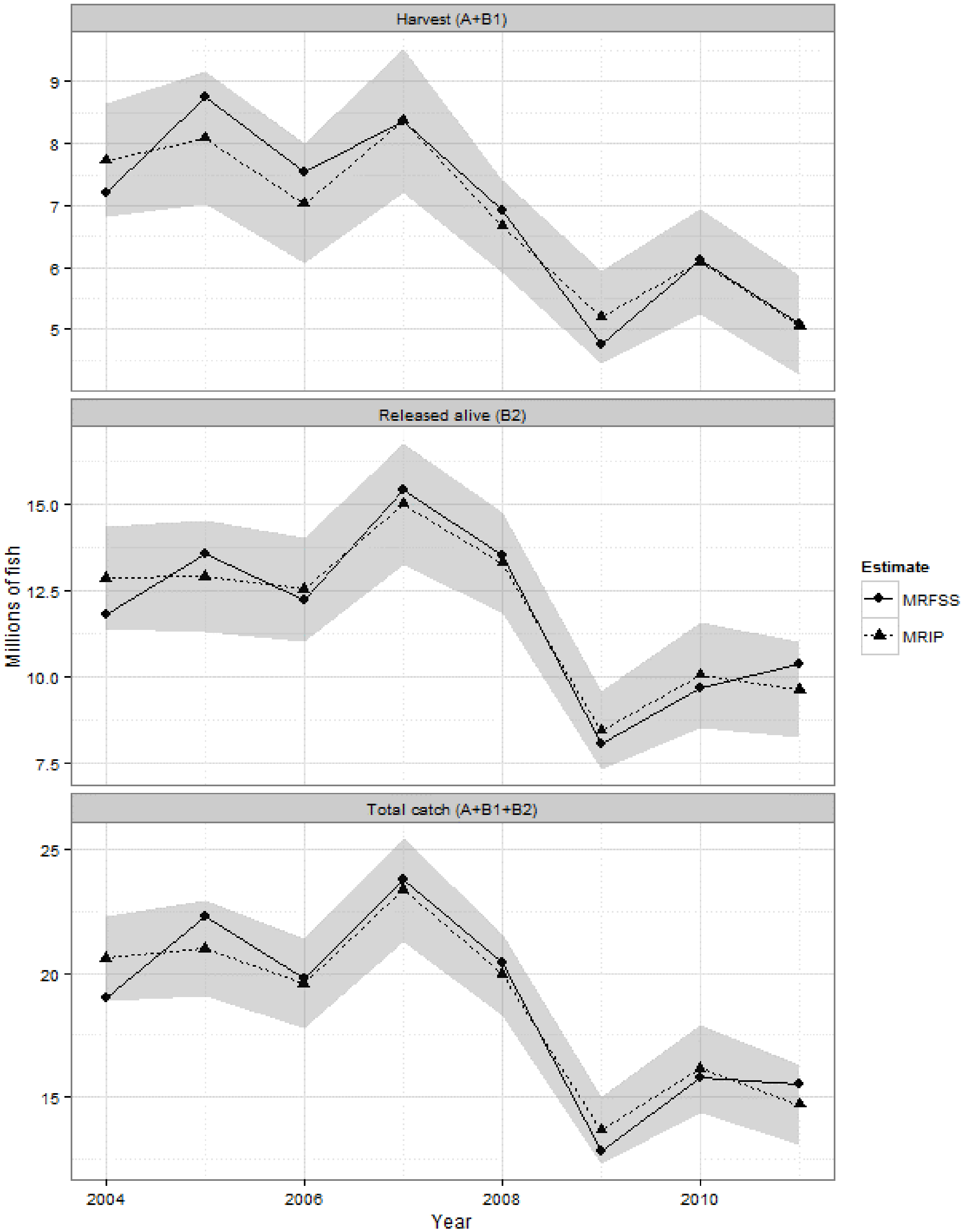
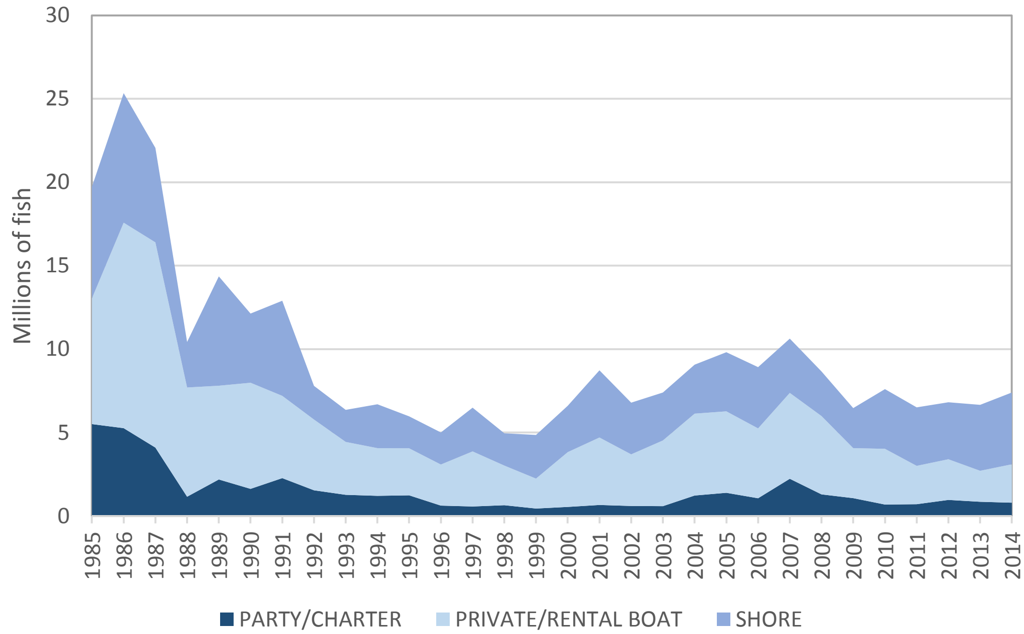


Figure B4.7. Comparison of MRFSS and MRIP estimates of bluefish catch for 2004 - 2011. Shaded bands indicate 95% confidence intervals calculated from MRIP PSEs.



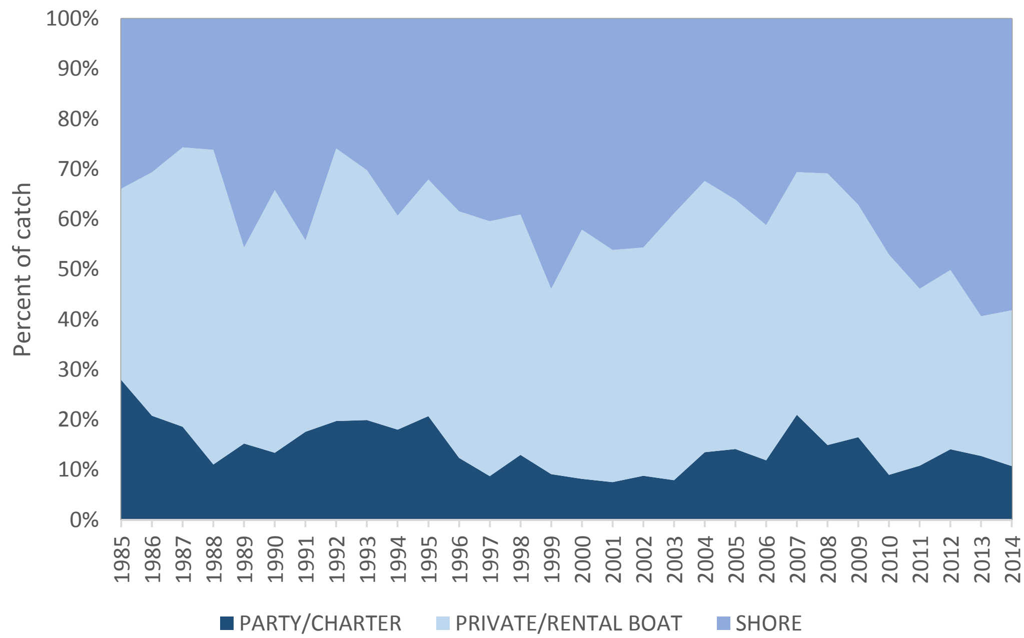
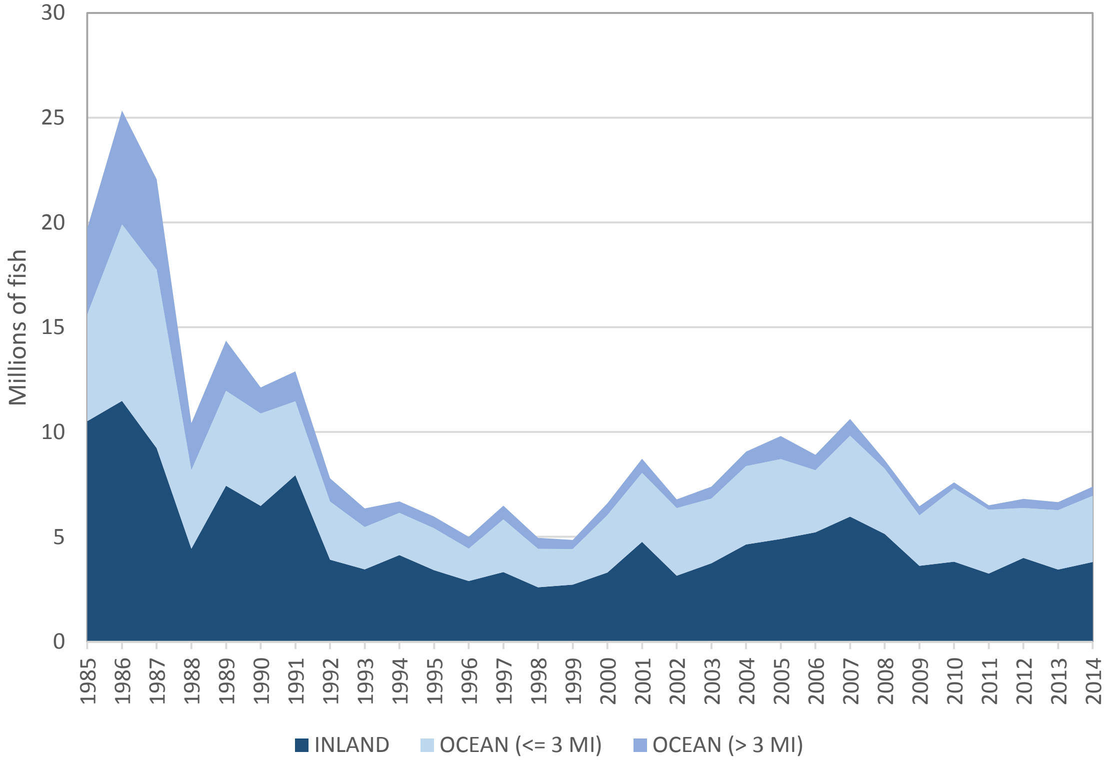


Figure B4.8. Bluefish recreational removals by mode for the Atlantic coast, shown in numbers of fish (top) and percent of catch (bottom.).



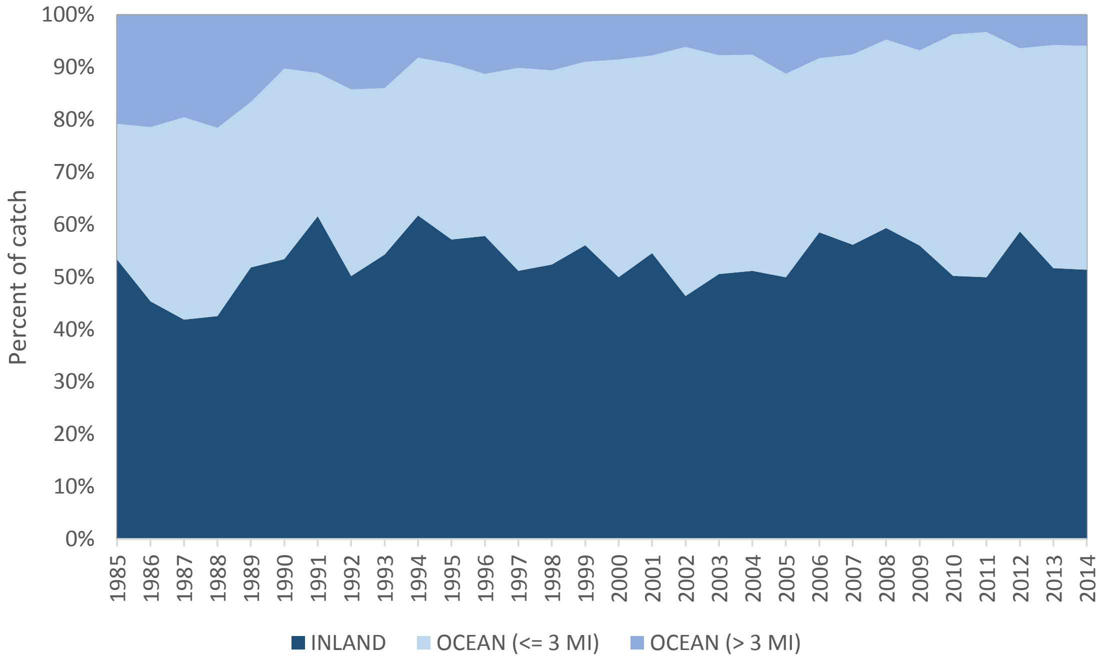


Figure B4.9. Bluefish recreational removals by area fished for the Atlantic coast, shown in numbers of fish (top) and percent of catch (bottom).

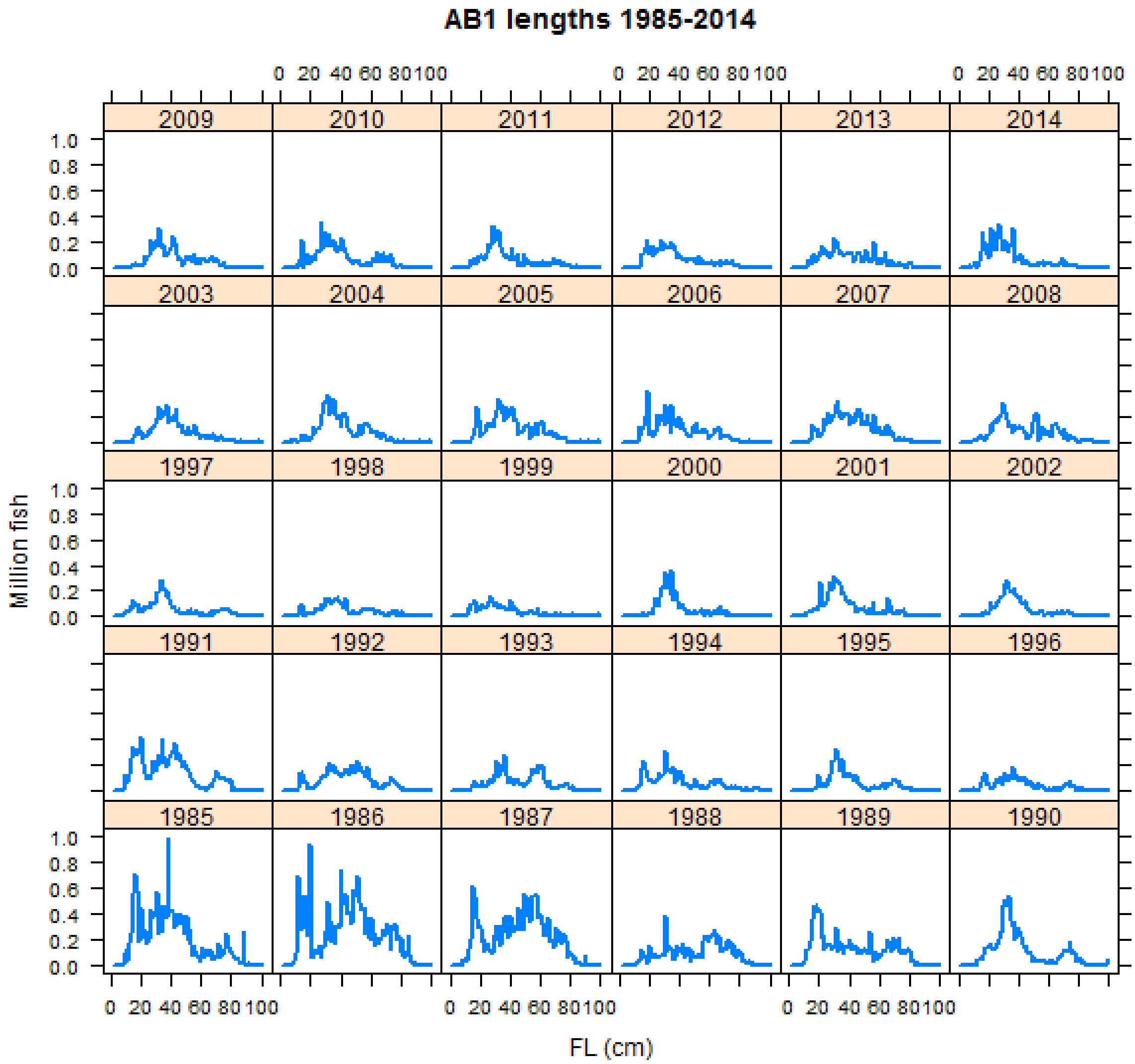


Figure B4.10A. Length frequency distributions of recreational landings for the Atlantic coast.

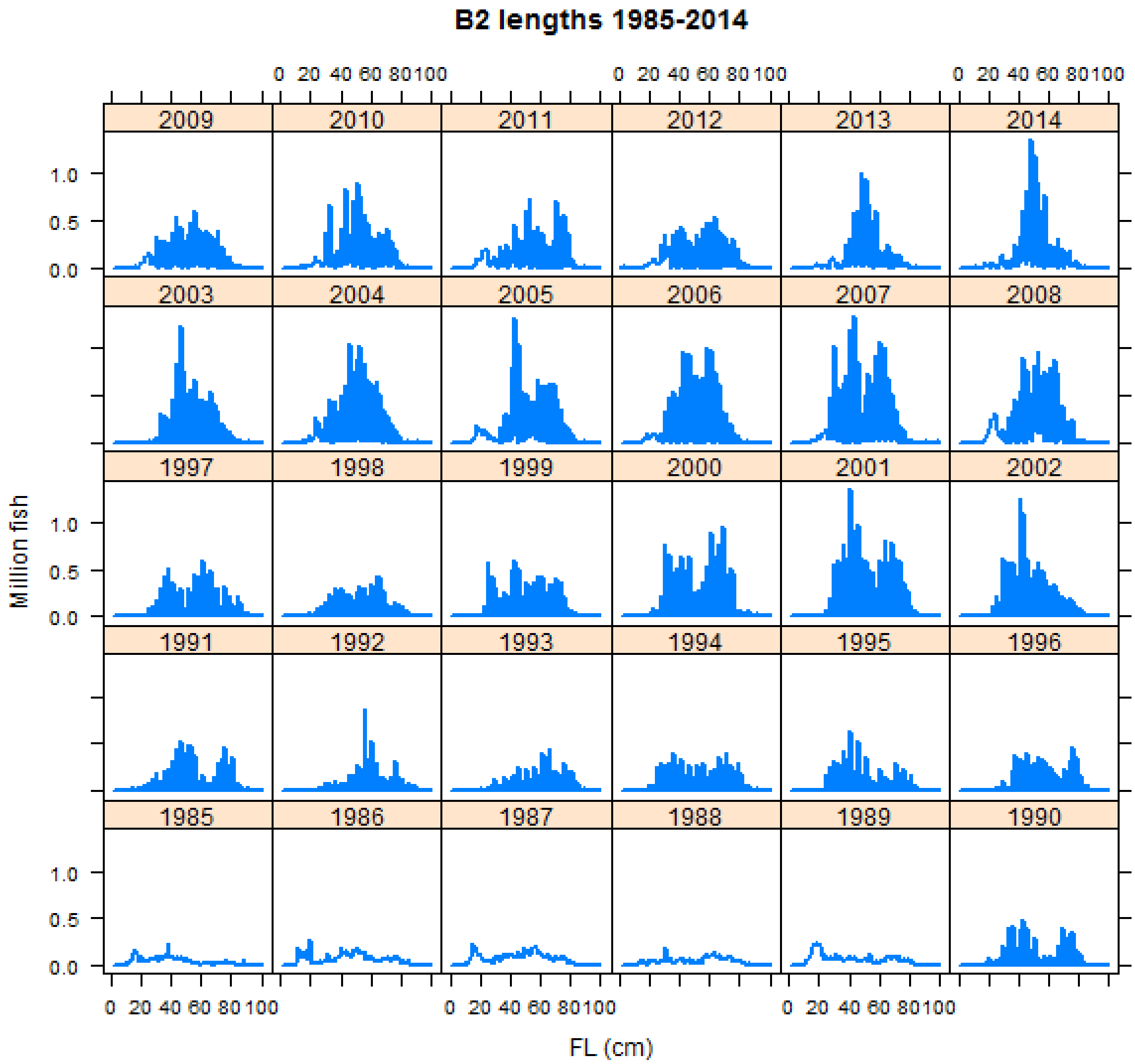
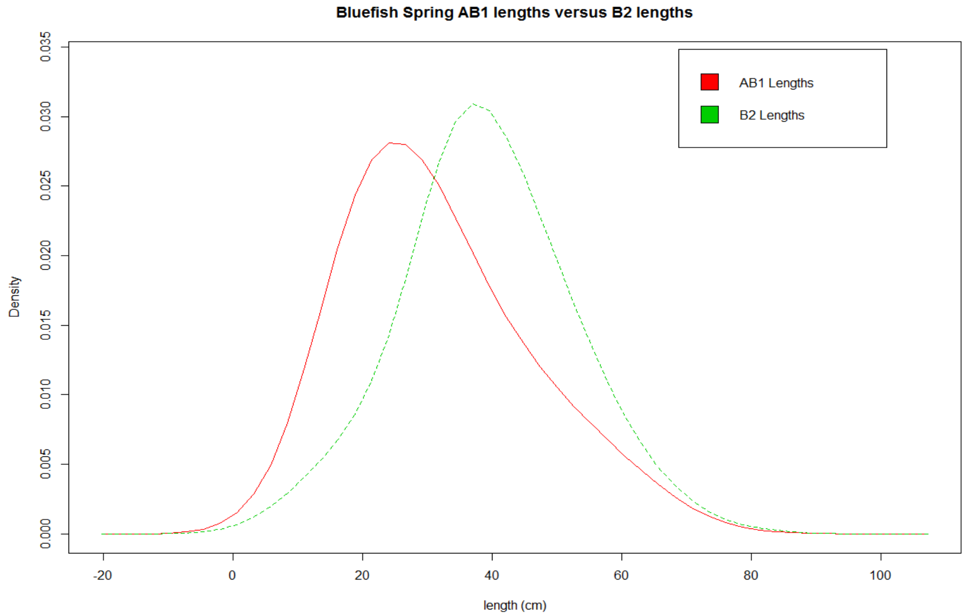


Figure B4.10B. Length frequency distributions of recreational discards for the Atlantic coast.



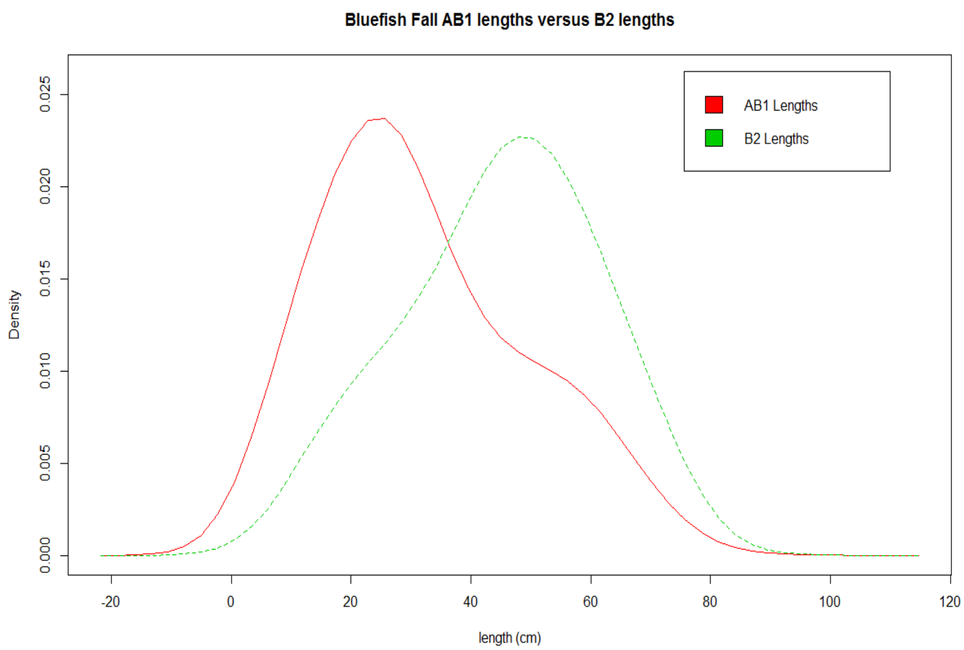


Figure B4.11. Density plots of the length frequency distributions of recreational landings (A+B1) versus discards (B2) for bluefish in the spring (top) and fall (bottom).

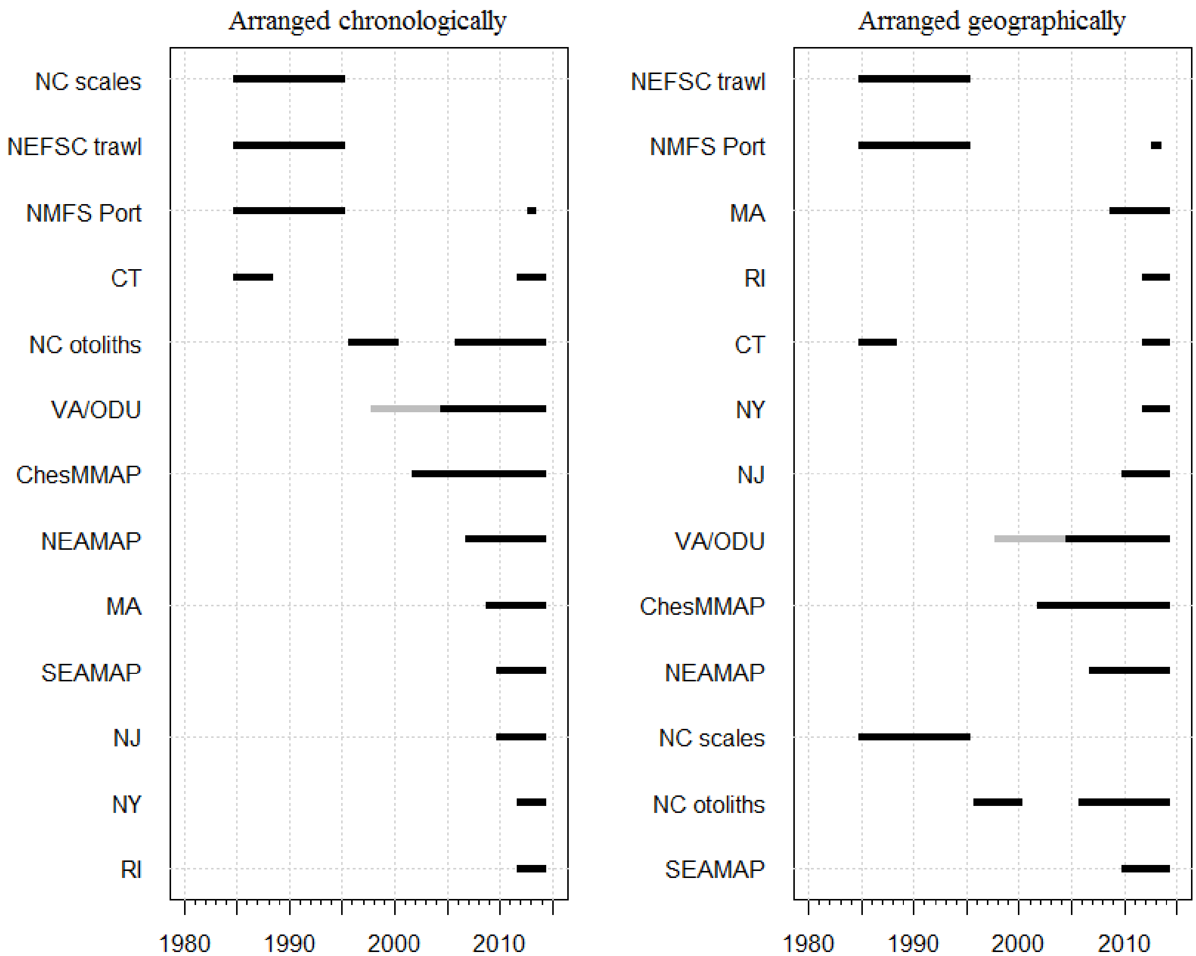


Figure B5.1. Depiction of available bluefish age data arranged chronologically (left) and geographically (right). Samples from 1985-1995 are scales, all others are otoliths. NMFS Port samples in 2013 came from RI, NY, and NJ (state of origin not retrievable prior to 2013); NEAMAP samples came from states between MA/RI and NC, inclusive; SEAMAP samples came from states between NC and FL, inclusive. Grey bar at VA/ODU represents years where age data were shared across some years.

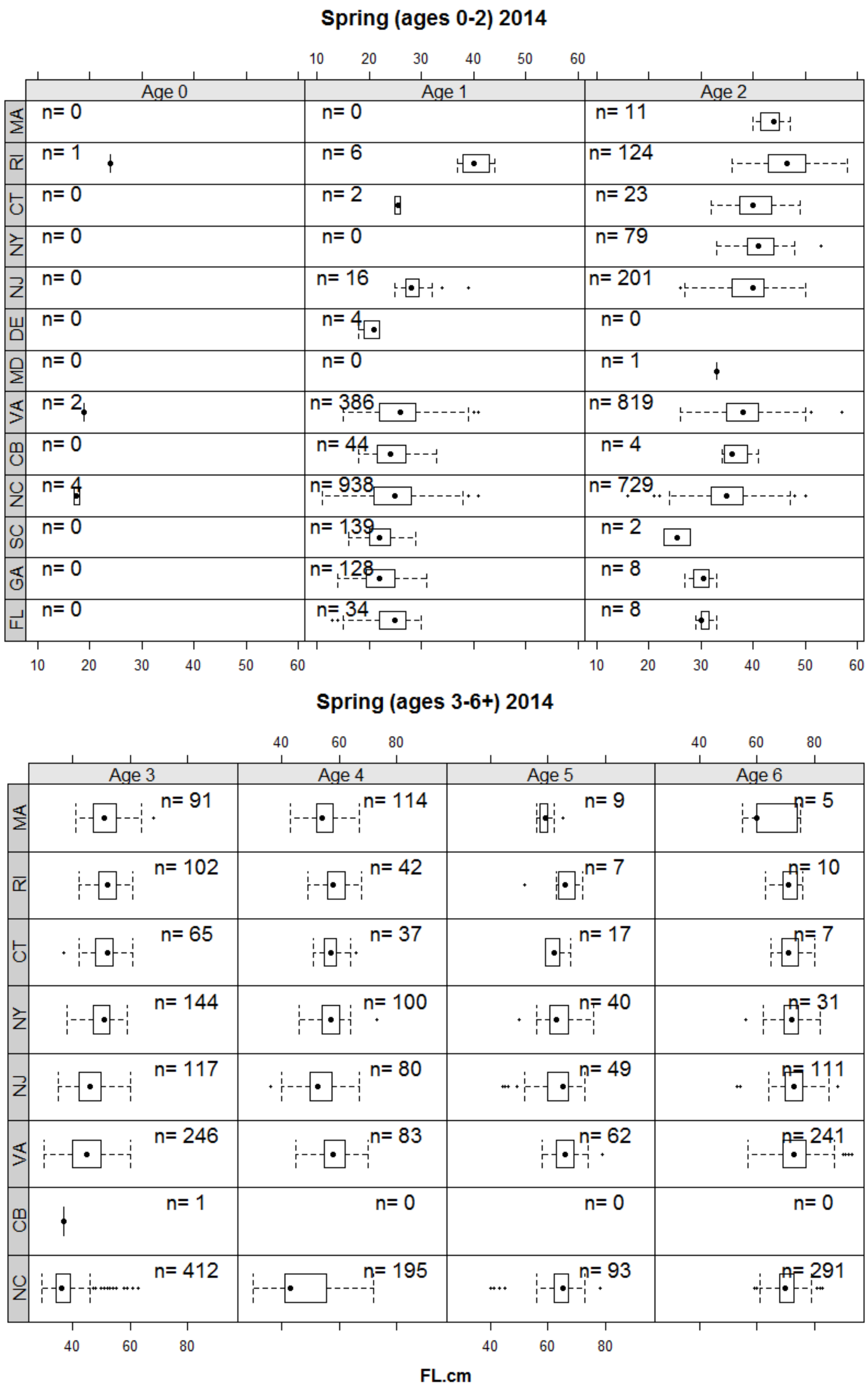


Figure B5.2A. Boxplots of size at age by state in spring 2014.

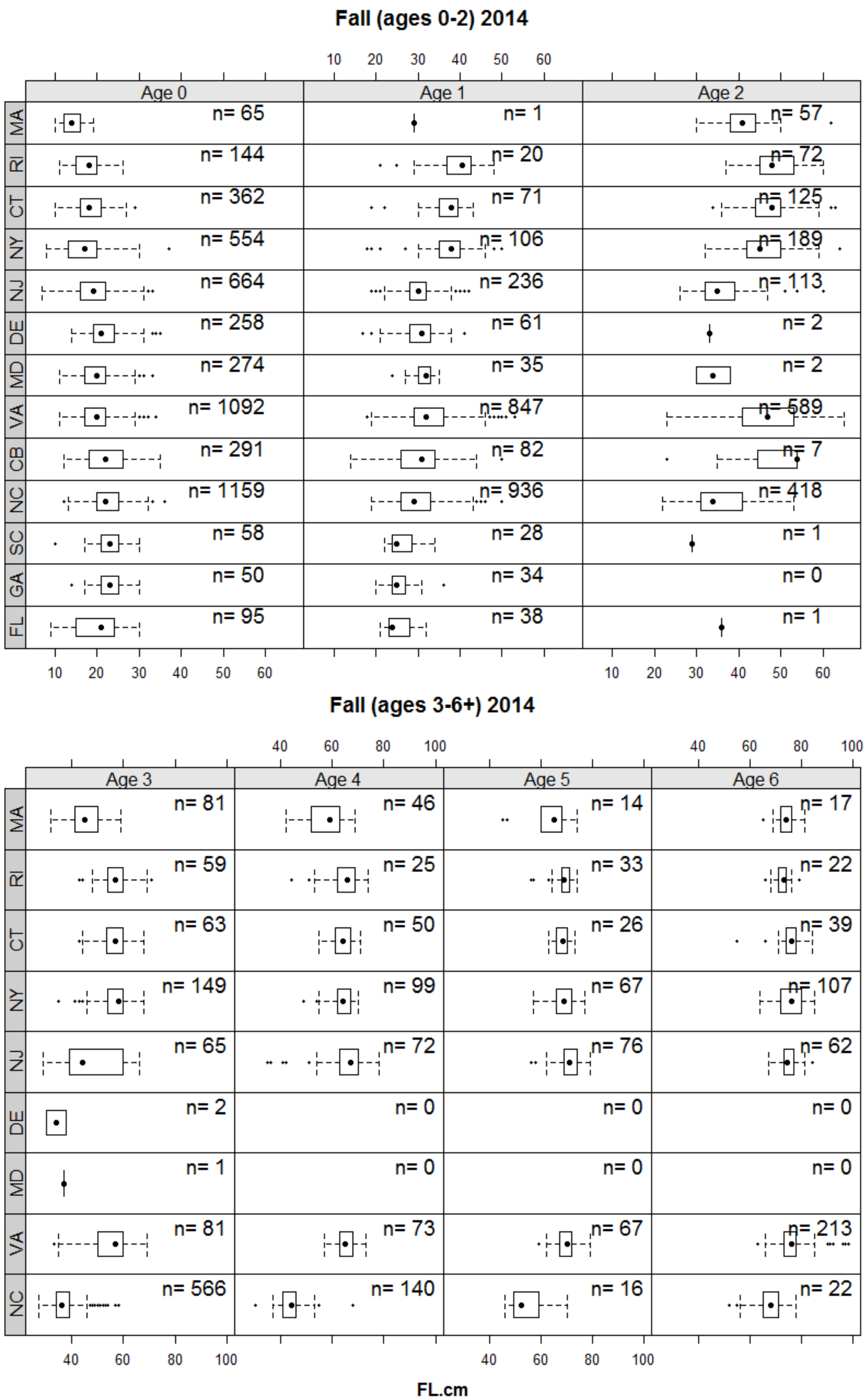


Figure B5.2B. Boxplots of size at age by state in fall 2014.

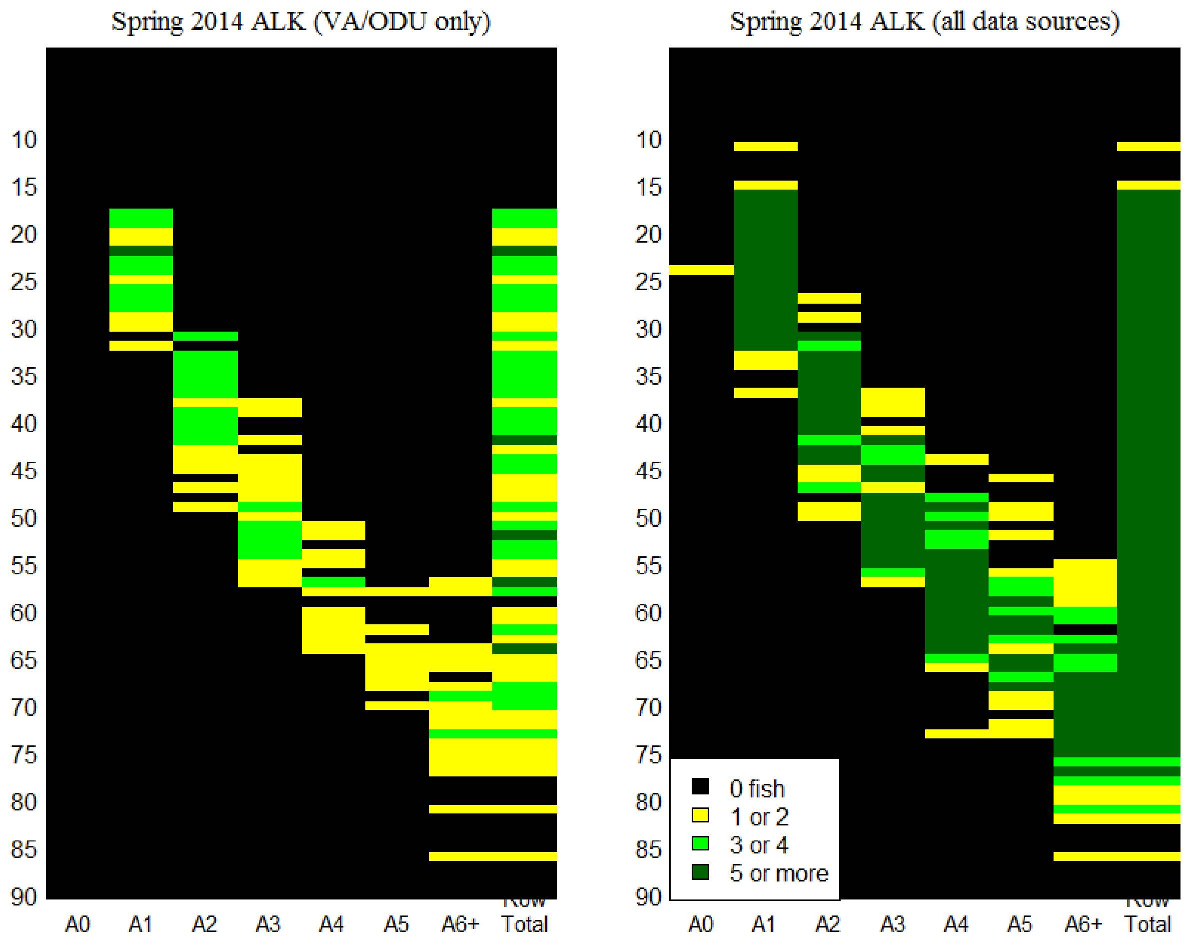


Figure B5.3. Comparison of age-length keys derived from VA/ODU versus all data sources ALK for spring 2014. Column on far right of each plot depicts the row total. Y-axis is FL (cm).

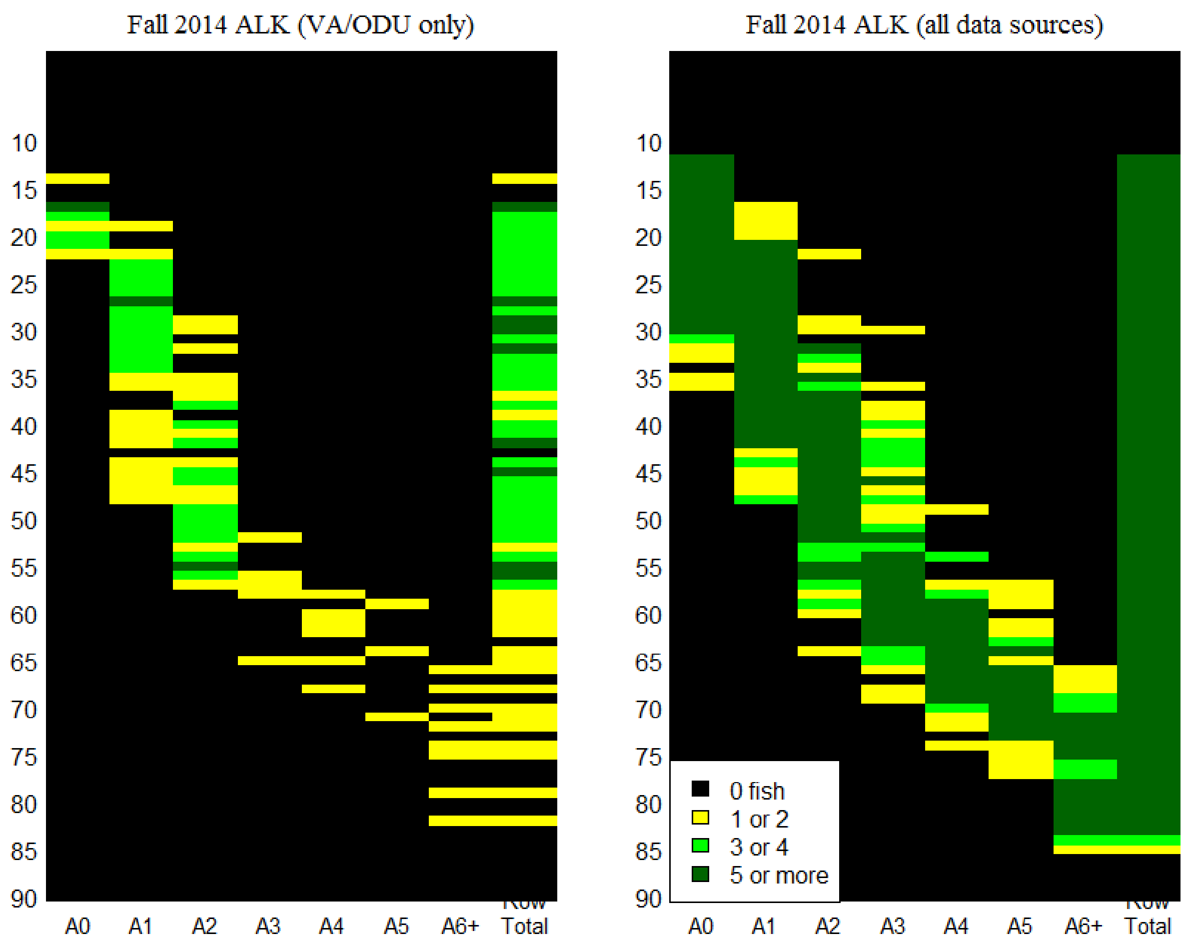


Figure B5.4. Comparison of age-length keys derived from VA/ODU versus all data sources ALK for fall 2014. Column on far right of each plot depicts the row total. Y-axis is FL (cm).

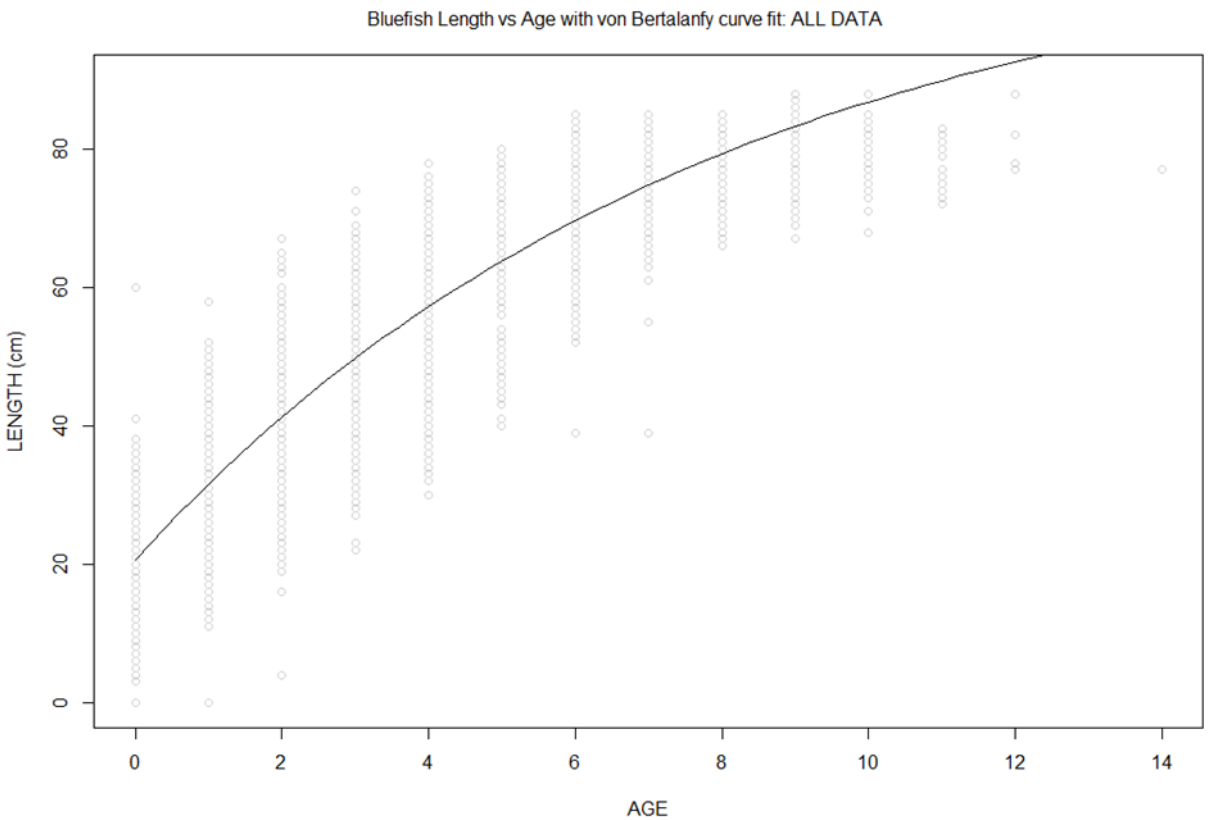


Figure B5.5. Von Bertalanffy growth curve fit to all bluefish data.

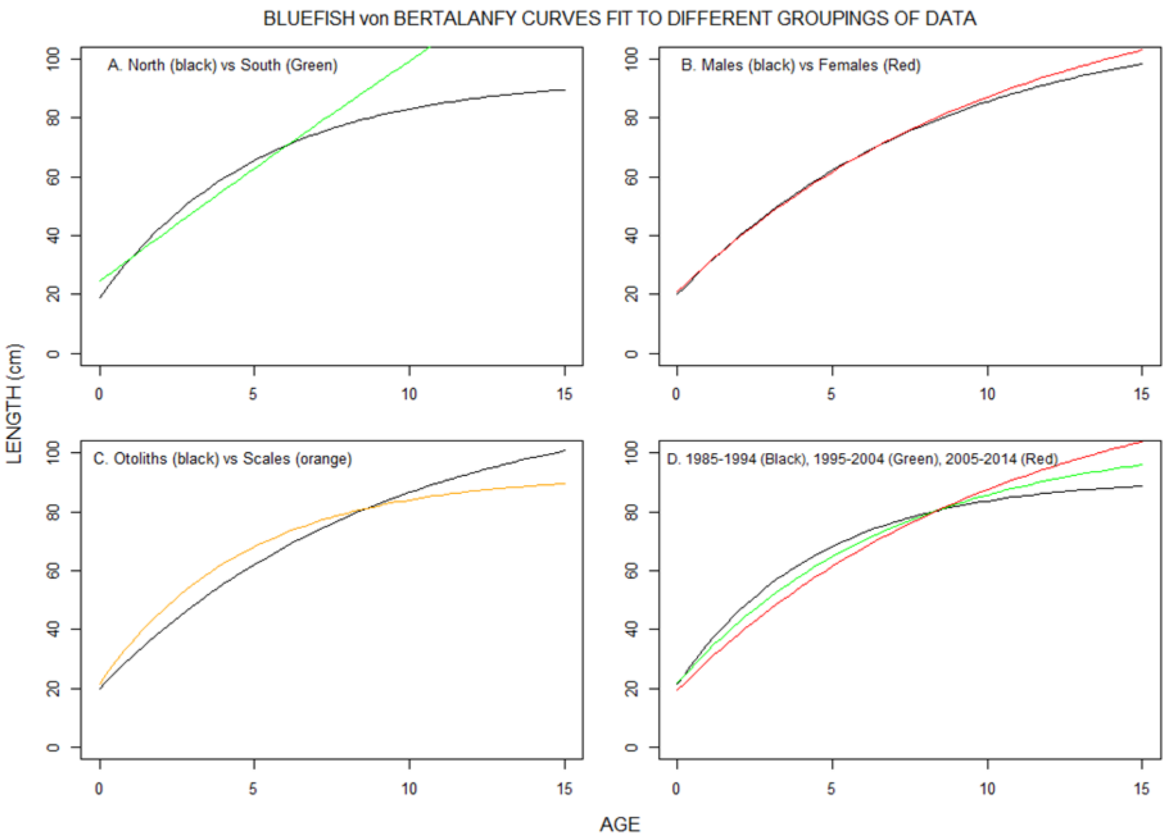


Figure B5.6. Von Bertalanfy growth curves fit to different groupings of data. (A) Northern and Southern fish, (B) Male and Females, (C) Otolith Ages and Scale Ages, and (D) Three time blocks.

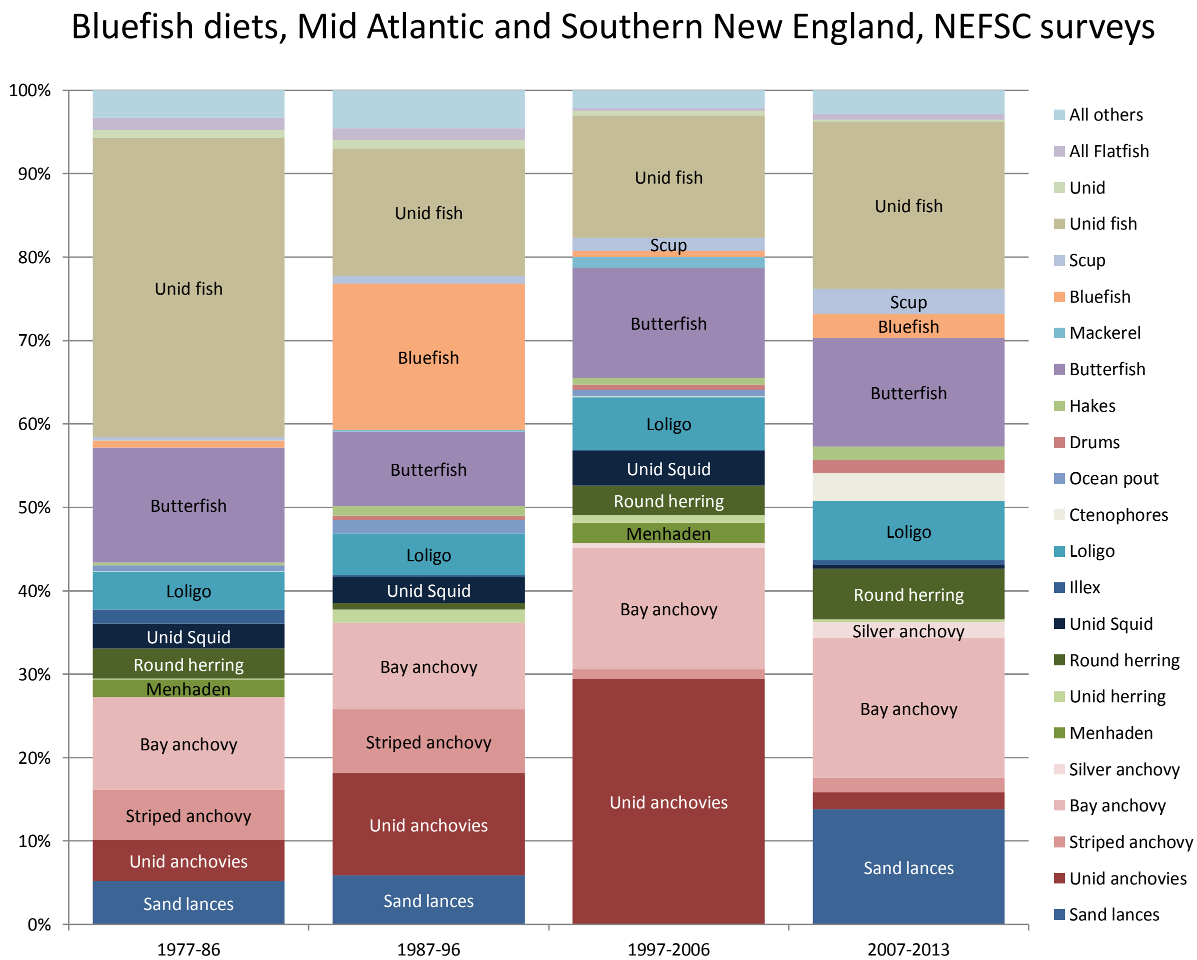


Figure B5.7. Bluefish historic diet composition: prey proportion by weight in 10-year intervals.

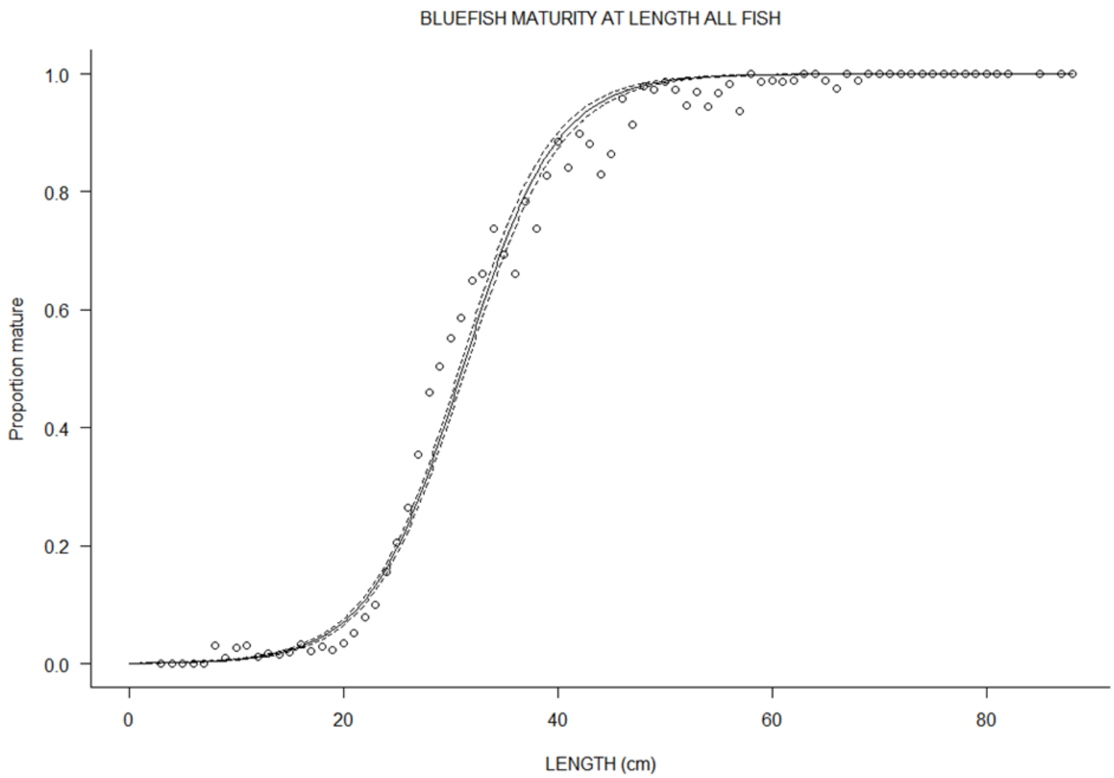


Figure B5.8. Bluefish maturity at length for all fish in the study. (L50 = 29.9 cm, L95 = 44.3 cm).

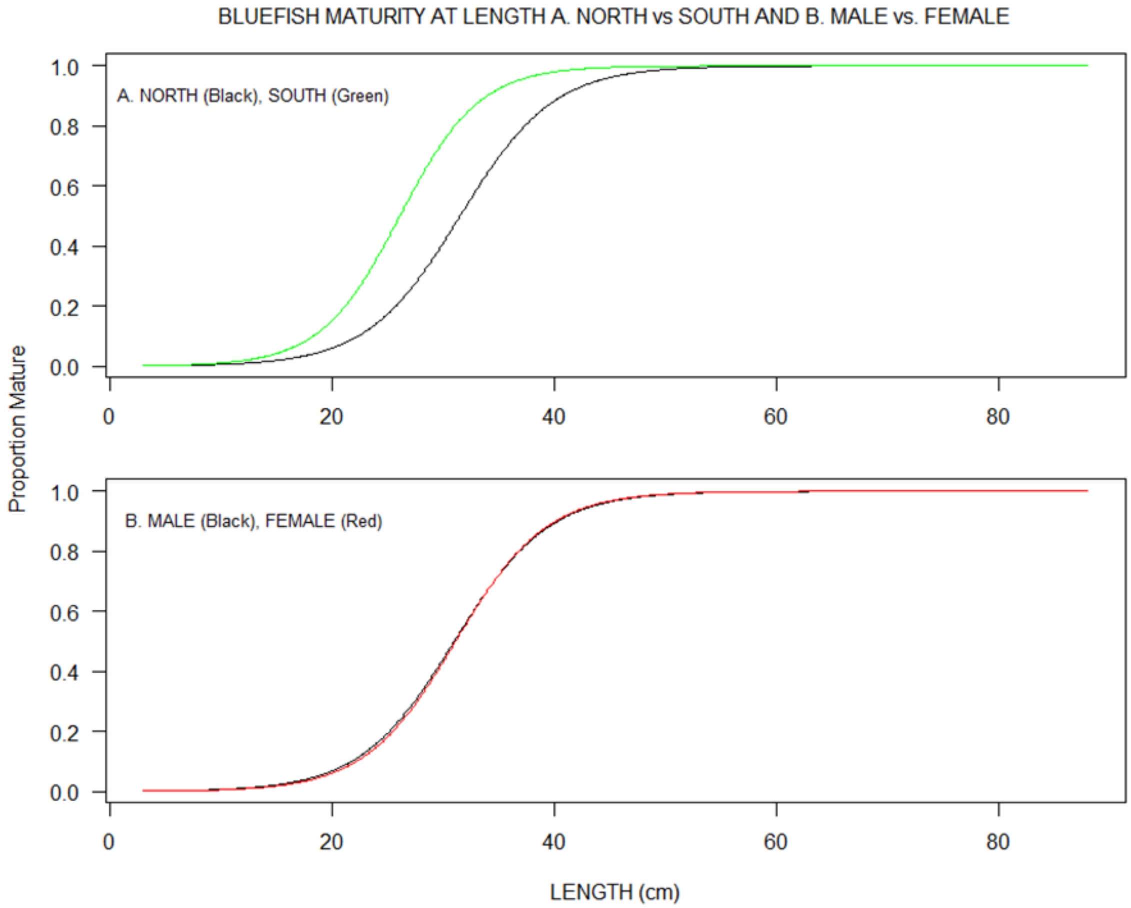


Figure B5.9. Bluefish maturity at length by region (A) and sex (B).

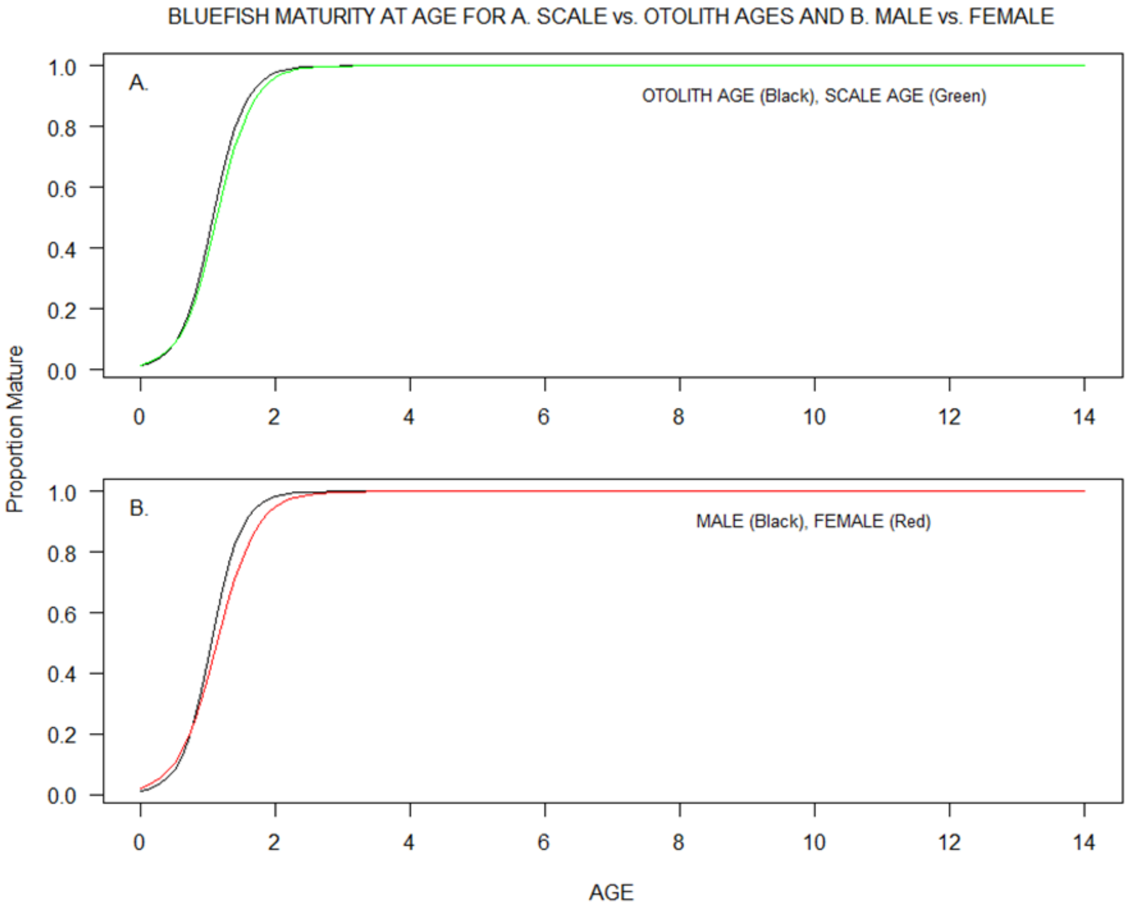


Figure B5.10. Bluefish maturity at age by ageing structure (A) and sex (B).

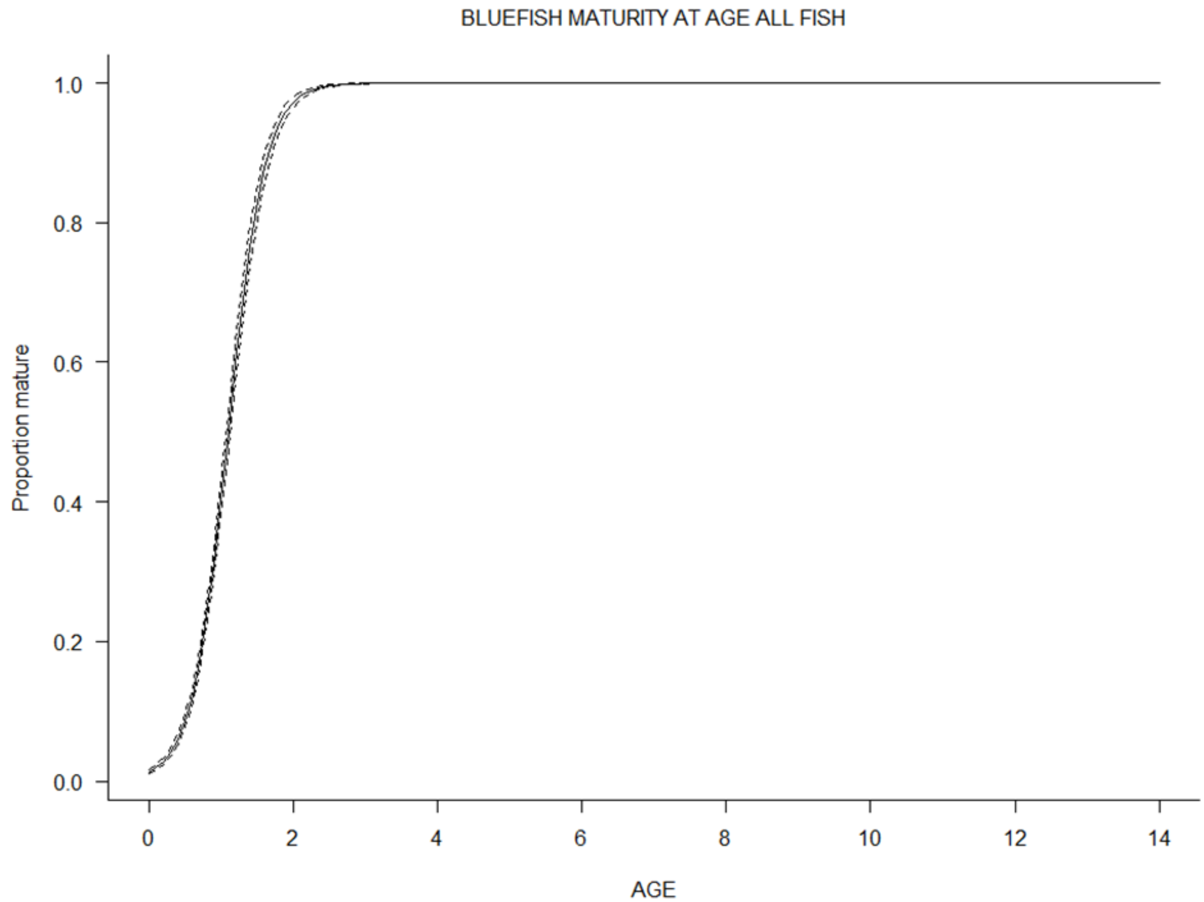


Figure B5.11. Bluefish maturity at age for all fish in the study. (A50 = 1.1 years, A95 = 1.84 years)

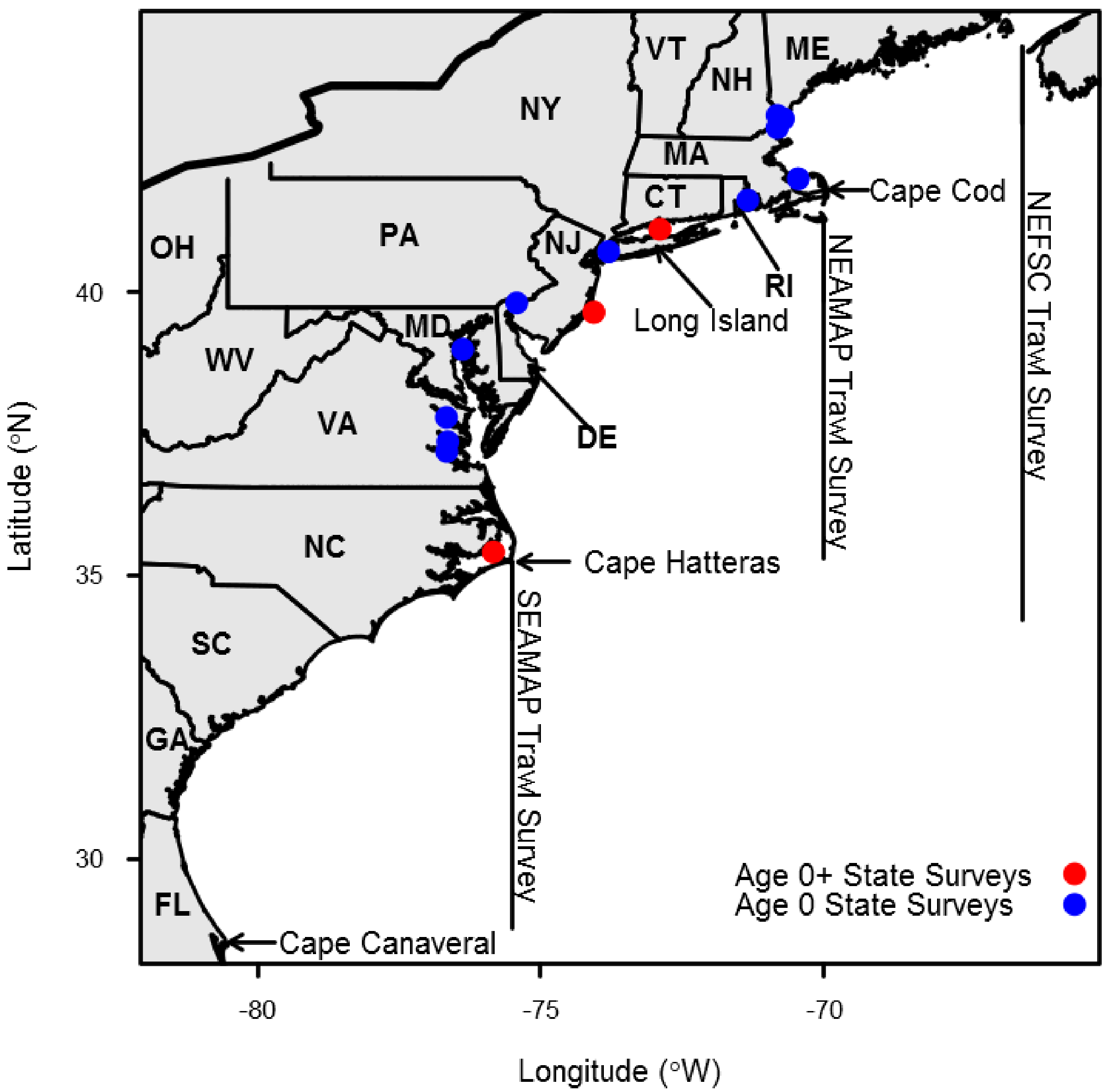


Figure B6.1. Map of available regional and state specific surveys. Regional surveys include SEAMAP Fall Trawl Survey Age-0 Index, NEAMAP Trawl Survey, and NEFSC Fall Trawl Surveys (R/V Albatross and R/V Bigelow). Vertical lines associated with regional surveys represent their latitudinal extent. State surveys include New Hampshire Juvenile Finfish Survey, Massachusetts Inshore Bottom Trawl Survey (not included in final base run), Rhode Island Seine Survey, Connecticut Long Island Sound Trawl Survey, New York Western Long Island Sound Seine Survey, New Jersey Delaware River Seine Survey, New Jersey Ocean Trawl Survey, Maryland Juvenile Striped Bass Survey, VIMS Juvenile Striped Bass Survey, and North Carolina PSIGNS.

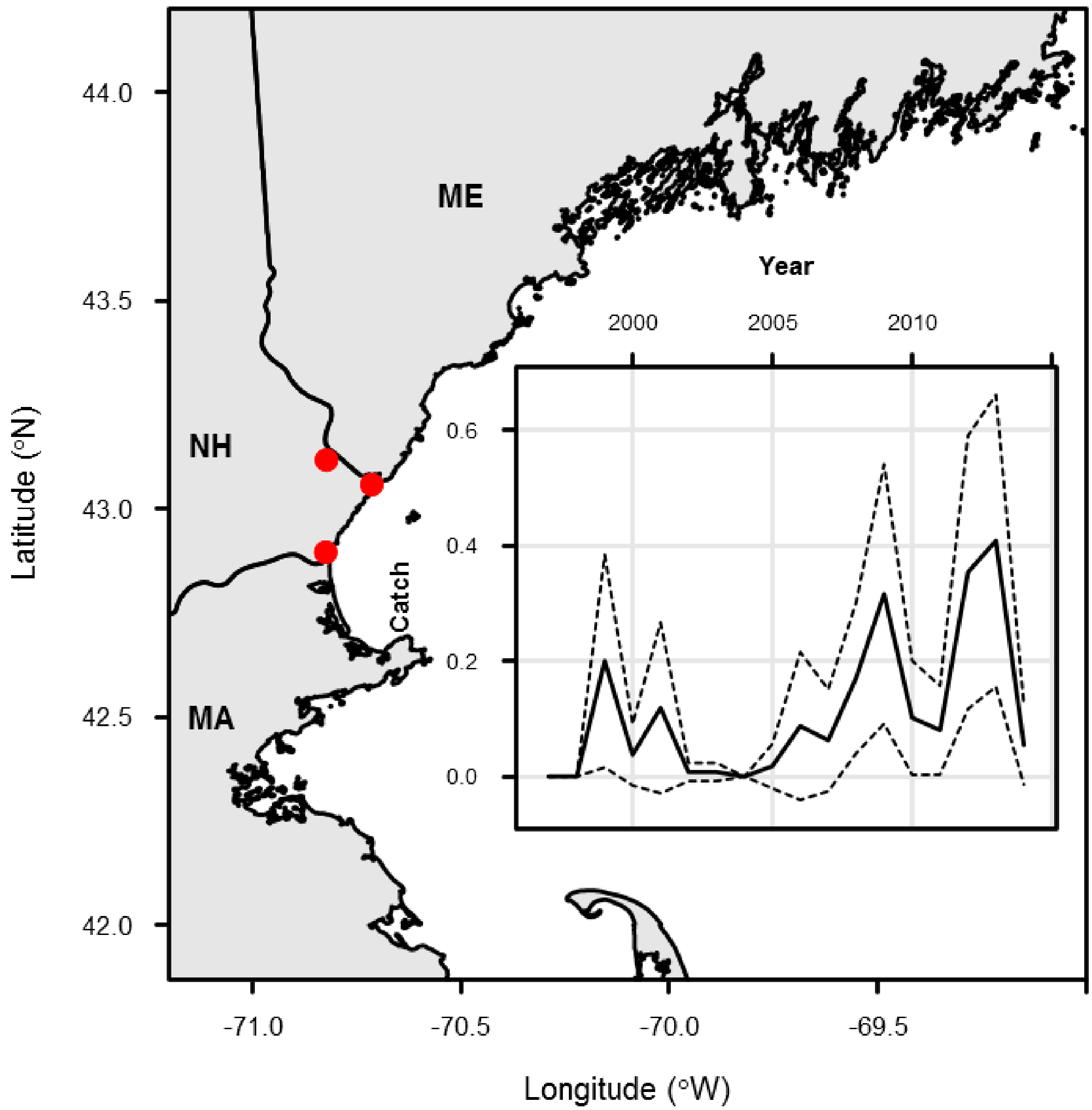


Figure B6.2. Map of the New Hampshire Juvenile Finfish Seine Survey area and resulting index of abundance (inset). Red dot indicates the center point in each of the three river systems surveyed.

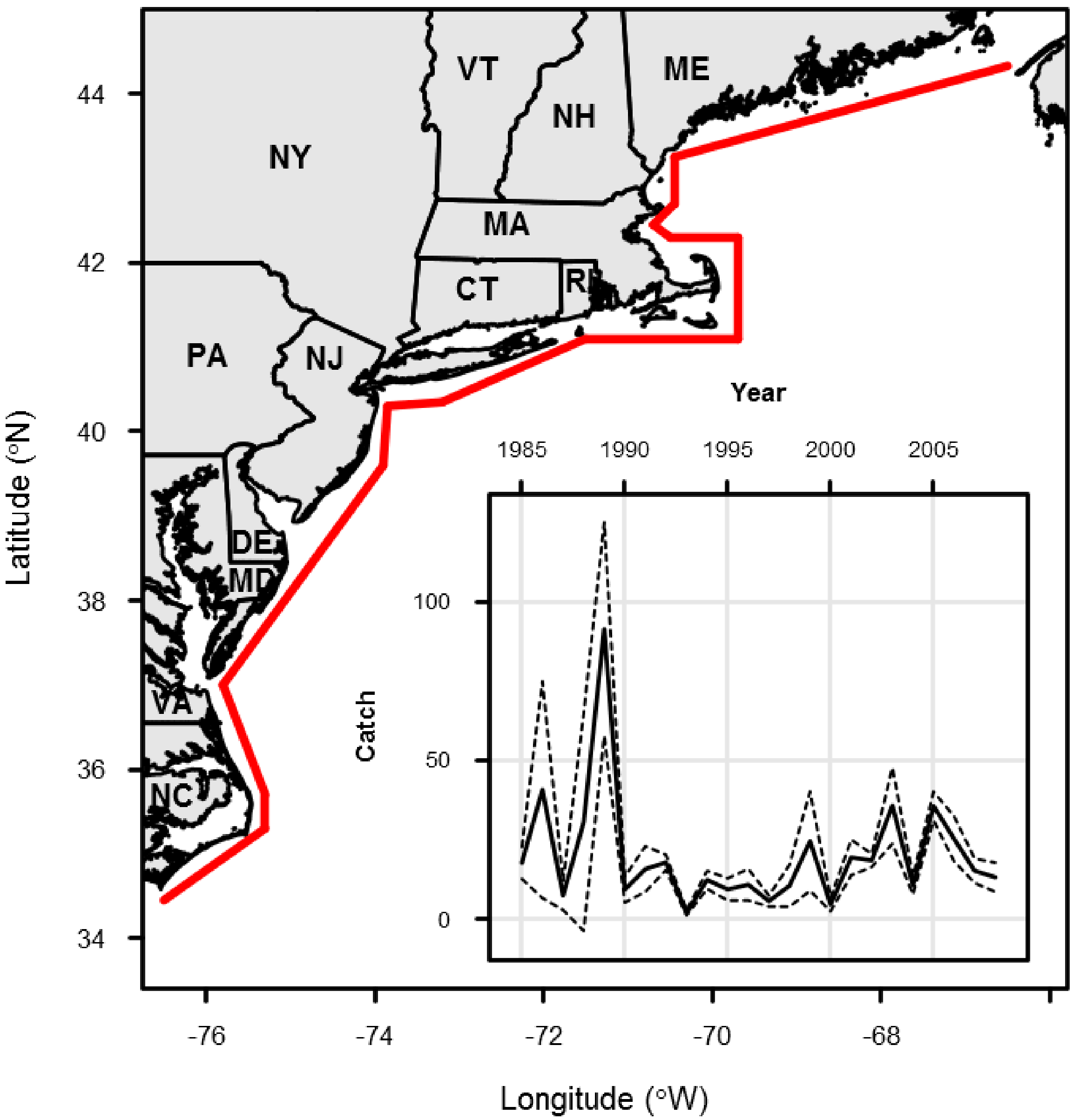


Figure B6.3A. Map of the NEFSC Fall Bottom Trawl Survey area and resultant index from the R/V Albatross years (inset). Red line represents extent of the survey area.

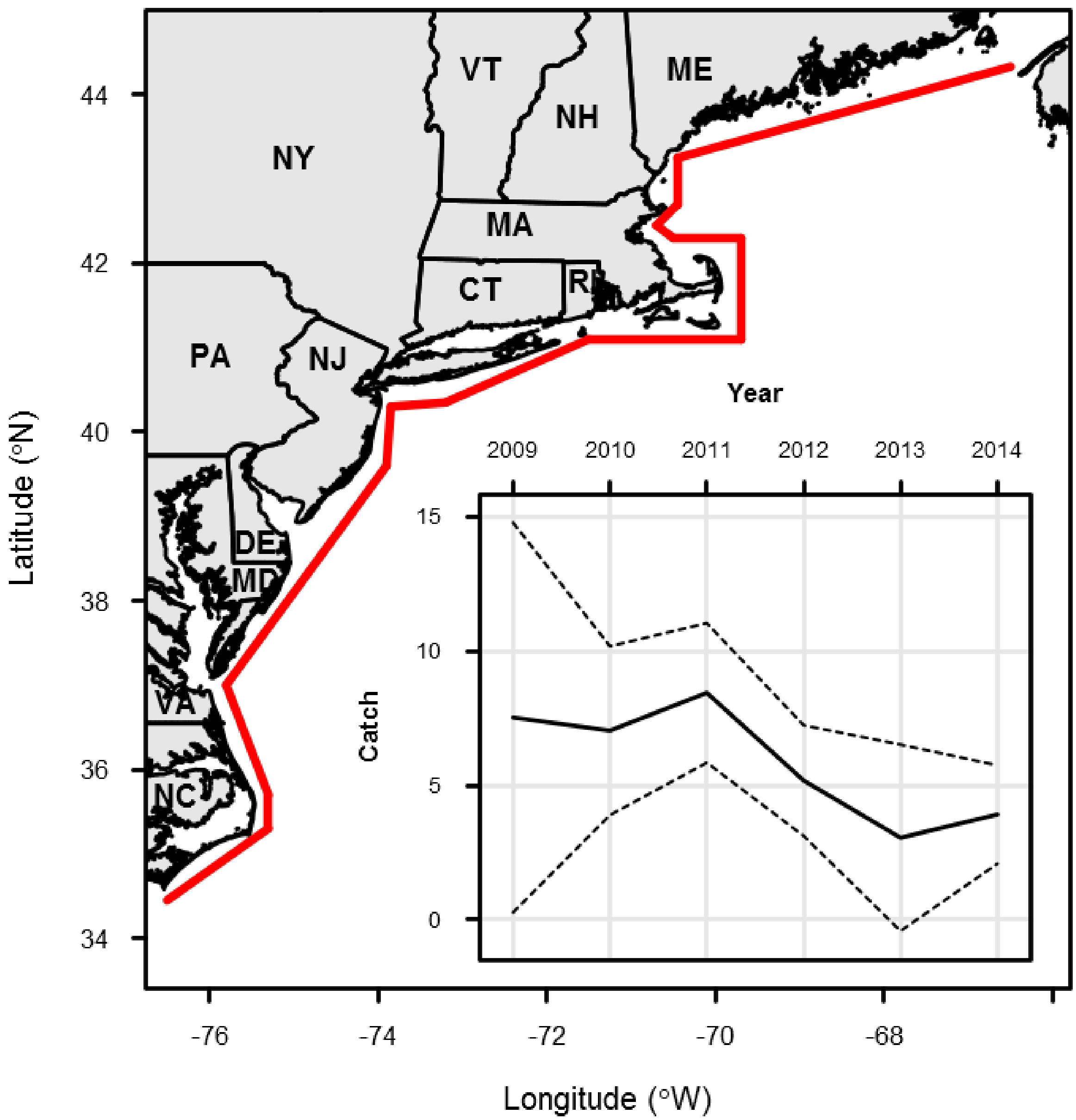


Figure B6.3B. Map of the NEFSC Fall Bottom Trawl Survey area and resultant index from the R/V Bigelow years (inset). Red line represents extent of the survey area.

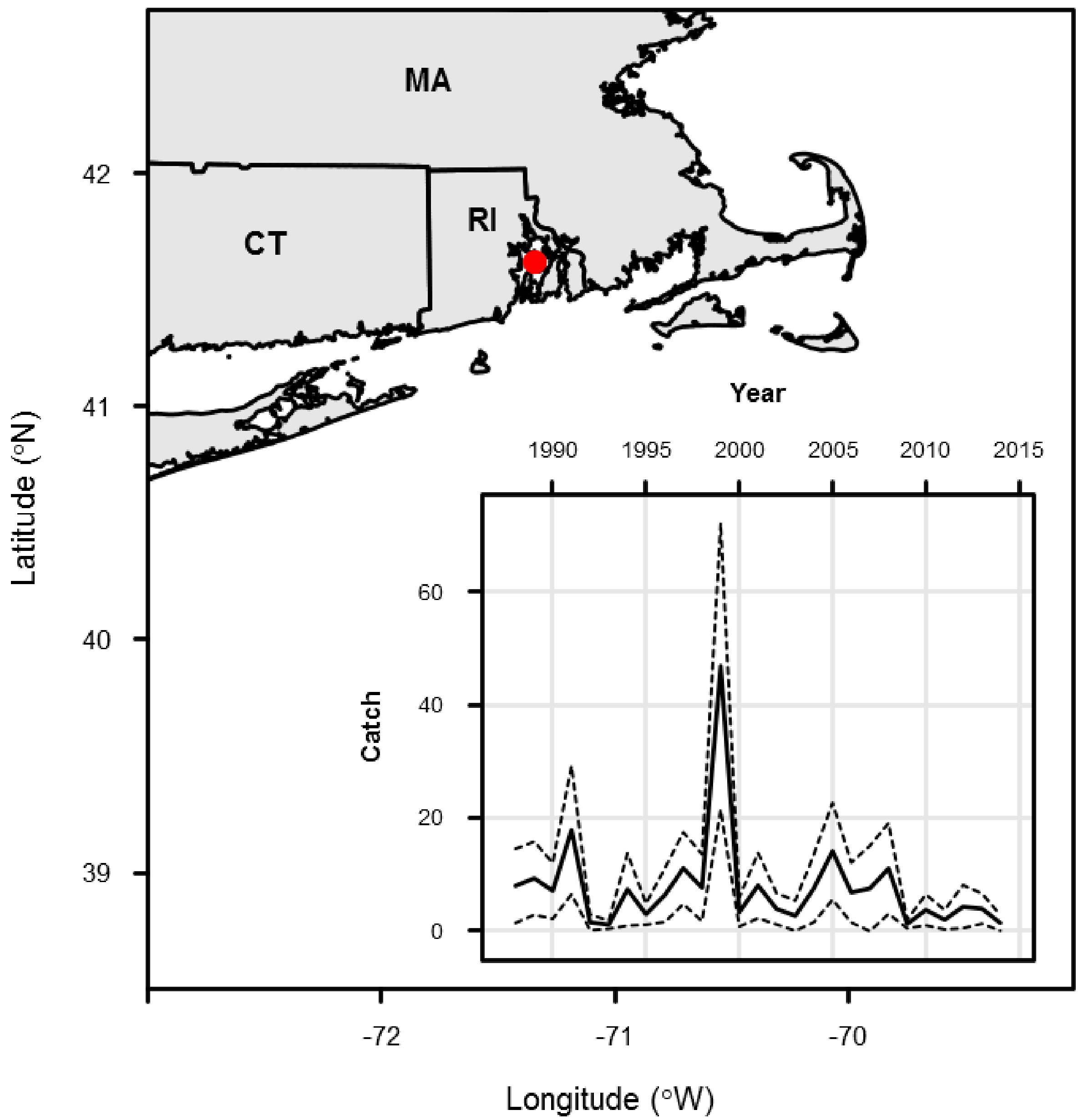


Figure B6.4. Map of the Rhode Island Narragansett Bay Juvenile Finfish Beach Seine Survey and resultant index of abundance (inset). Red dot indicates center point of survey area.

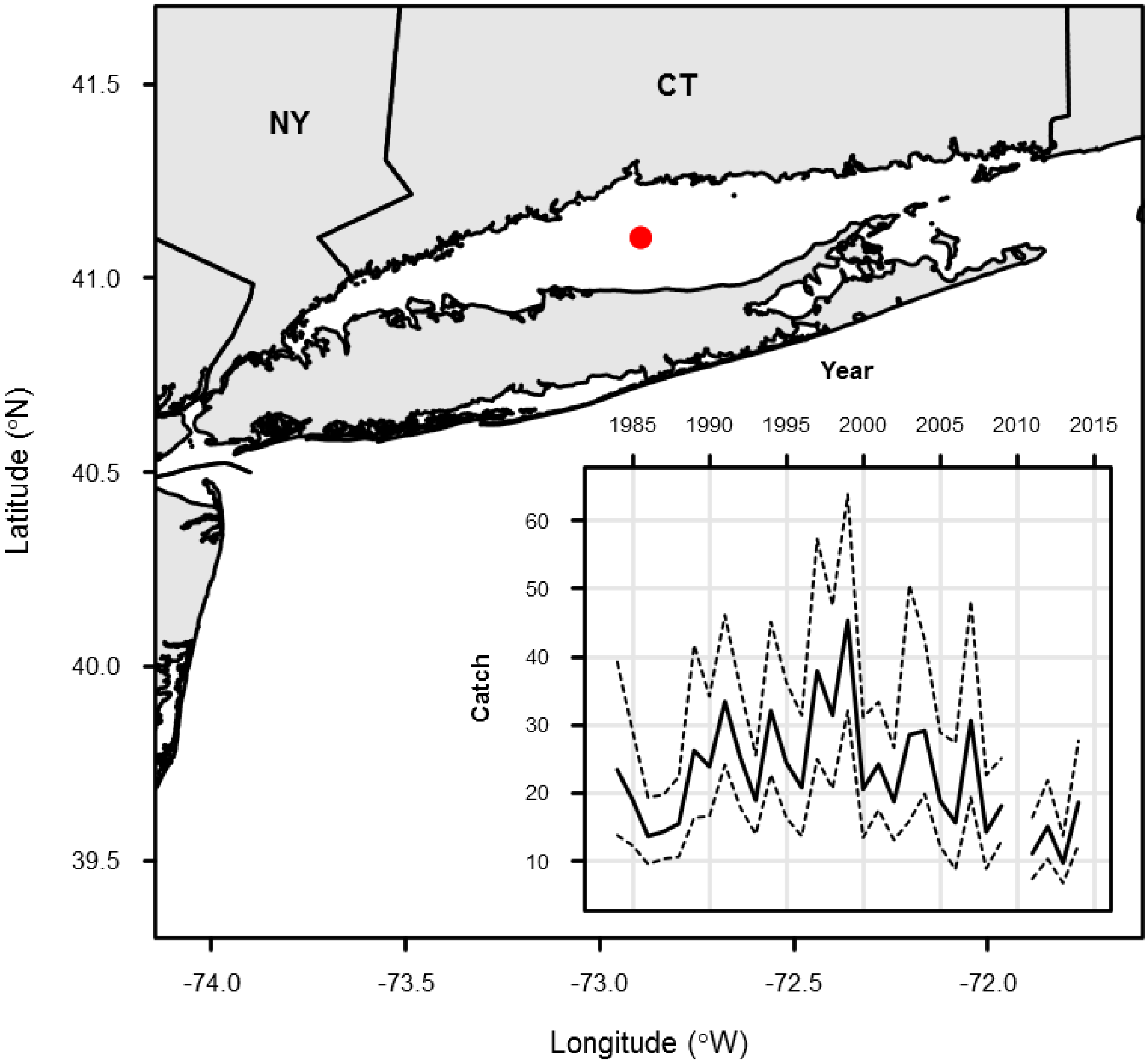


Figure B6.5. Map of the Connecticut Long Island Sound Bottom Trawl Survey and resultant index of abundance (inset). Red dot indicates center point of survey area.

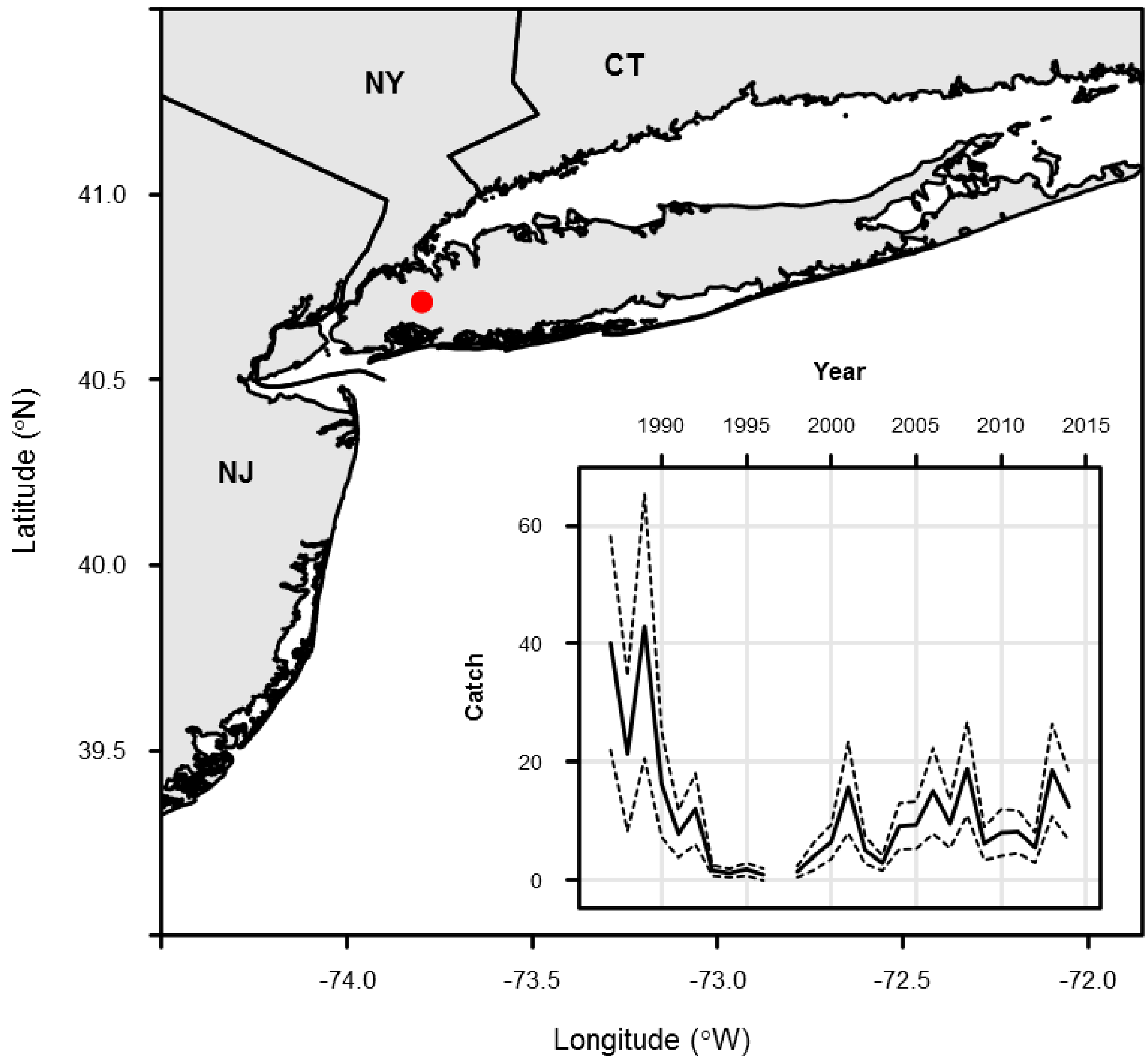


Figure B6.6. Map of the New York Western Long Island Sound Beach Seine Survey and resultant index of abundance (inset). Red dot indicates center point of survey area.

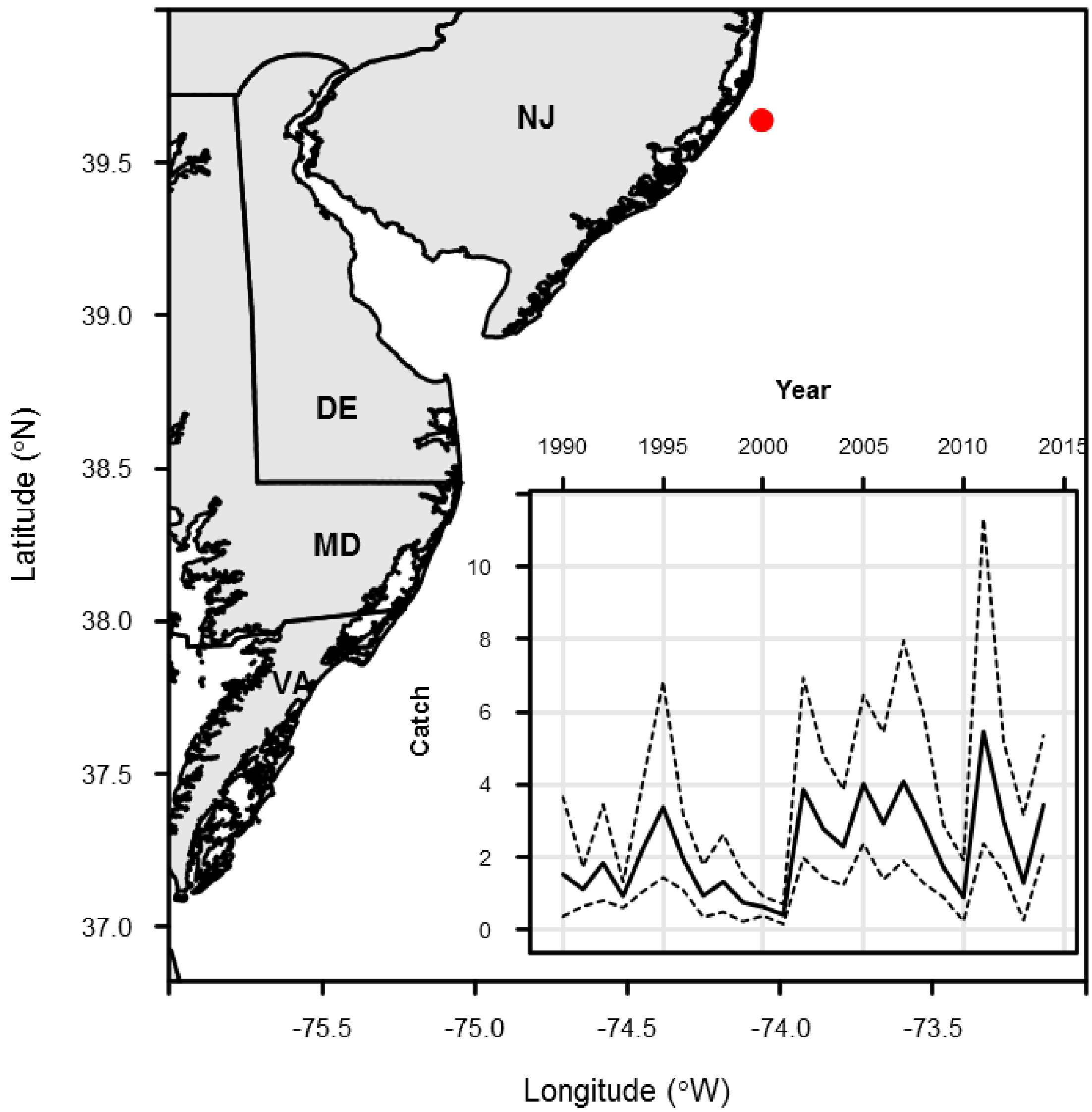


Figure B6.7. Map of the New Jersey Ocean Bottom Trawl Survey and resultant index of abundance (inset). Red dot indicates center point of survey area.

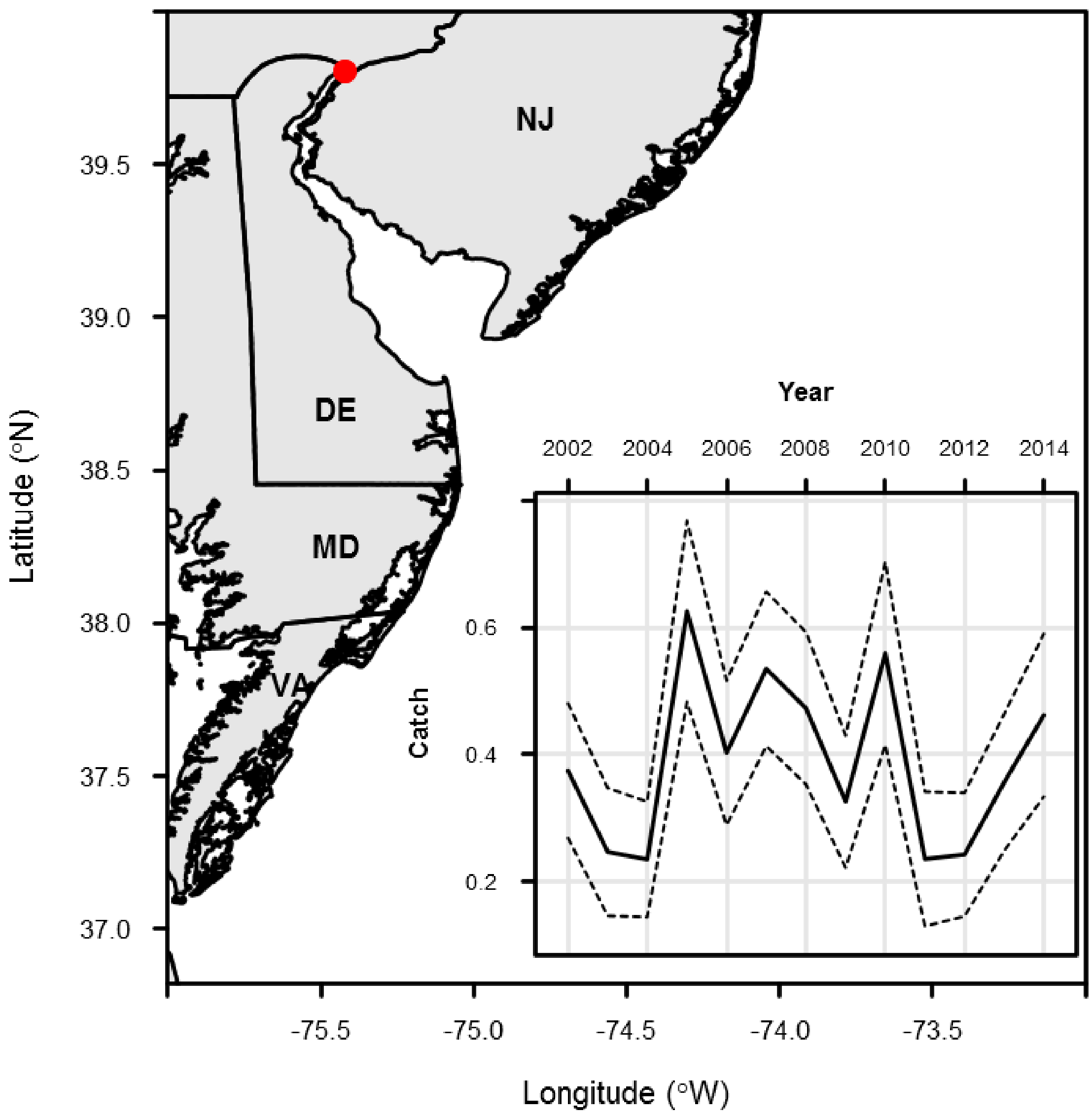


Figure B6.8. Map of the New Jersey Delaware River Seine Survey and resultant index of abundance (inset). Red dot indicates center point of survey area.

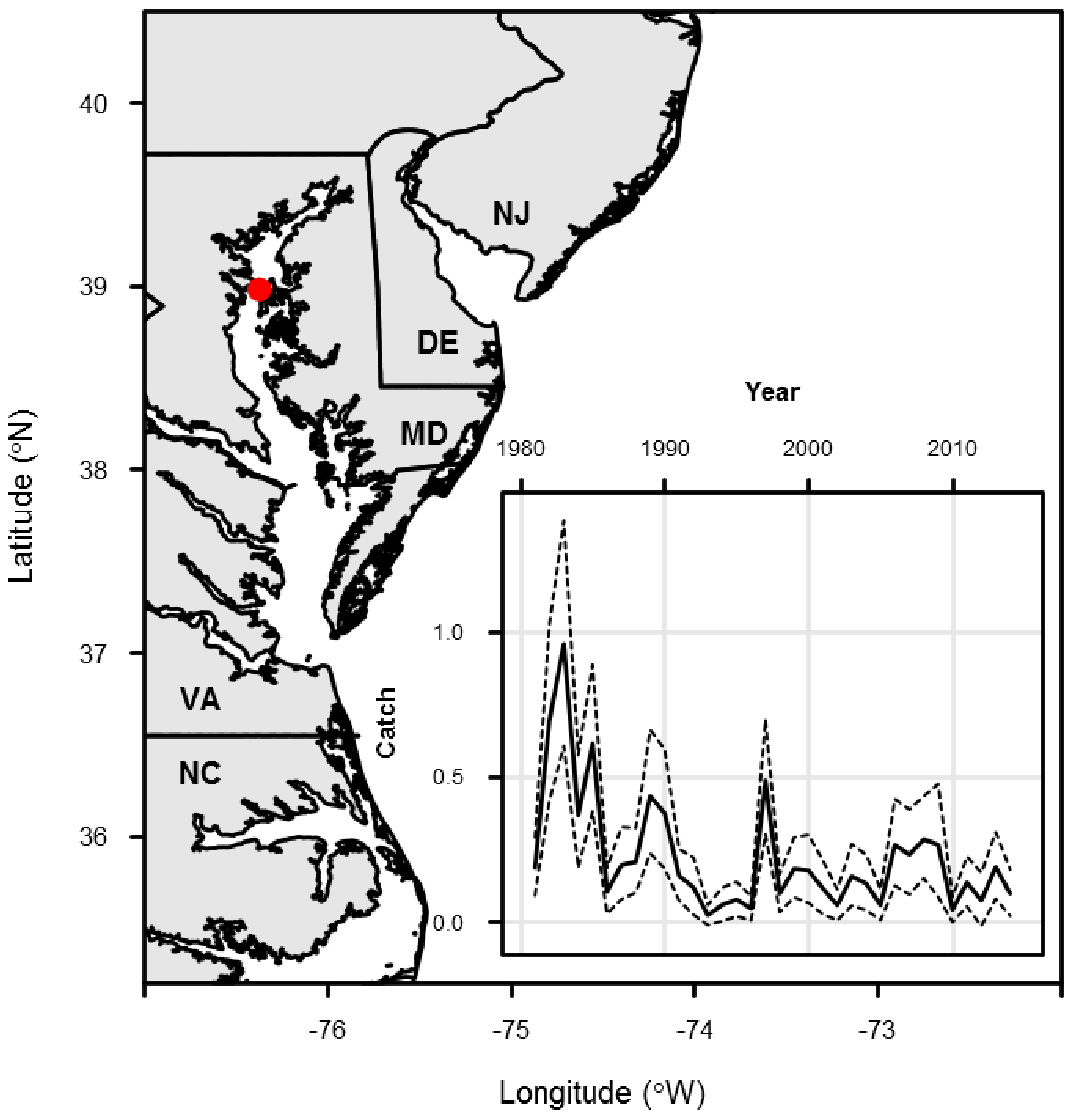


Figure B6.9. Map of the Maryland Juvenile Striped Bass Seine Survey and resultant index of abundance (inset). Red dot indicates center point of survey area.

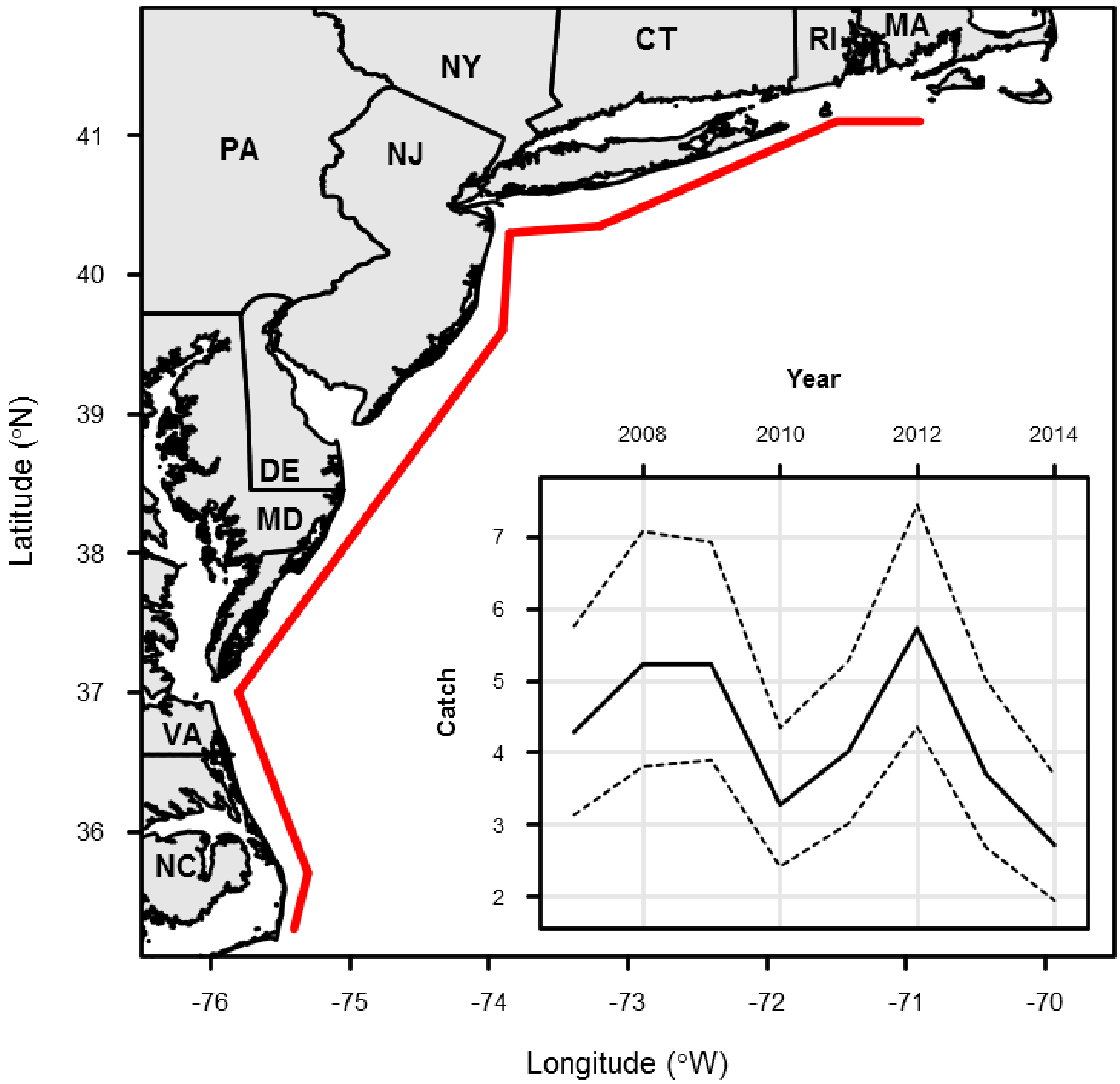


Figure B6.10. Map of the NEAMAP Fall Bottom Trawl survey area and resultant index (inset). Red line represents extent of the survey area.

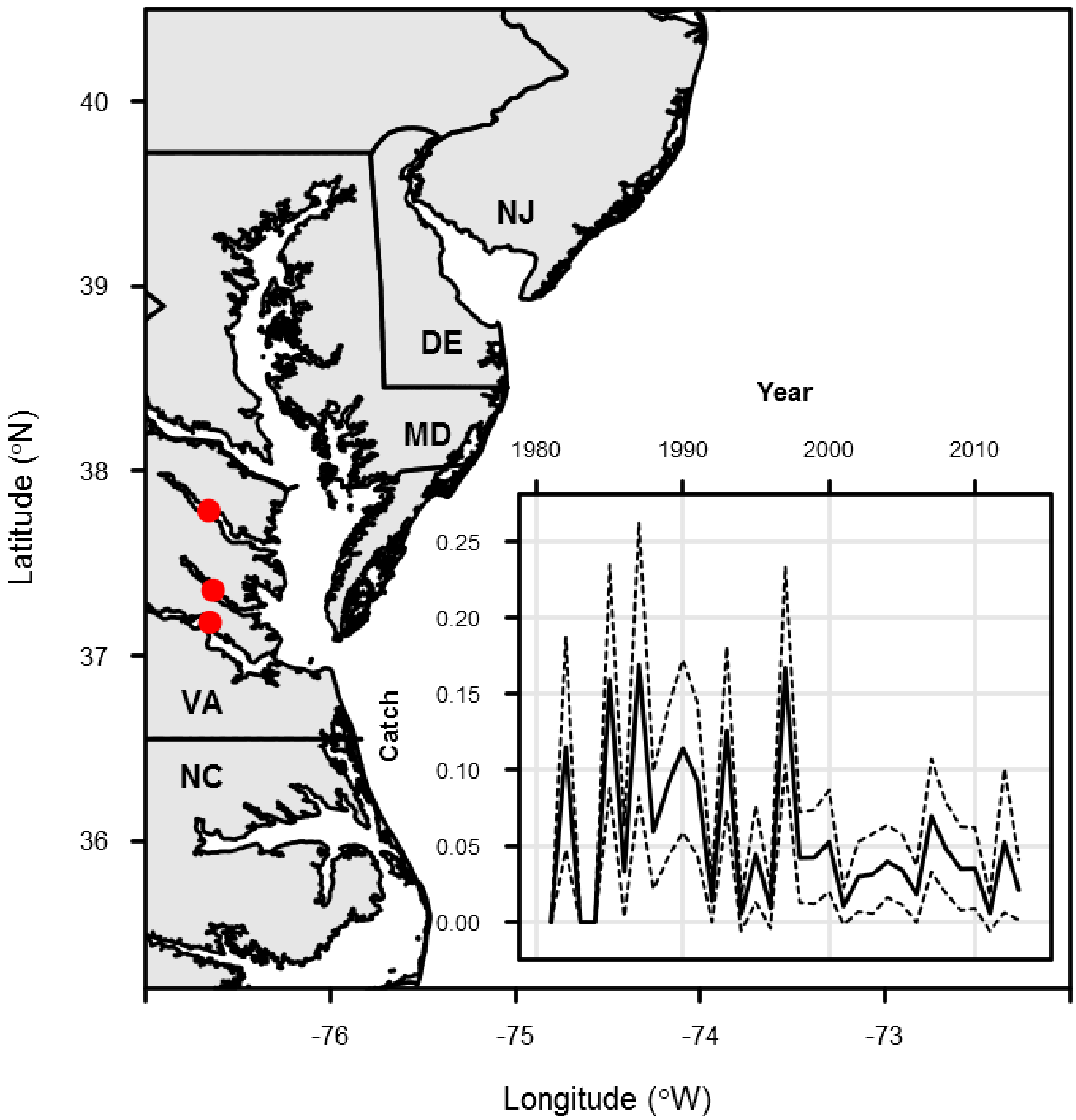


Figure B6.11. Map of the VIMS Juvenile Striped Bass Seine Survey area and resulting index of abundance (inset). Red dot indicates the center point in each of the three river systems surveyed.

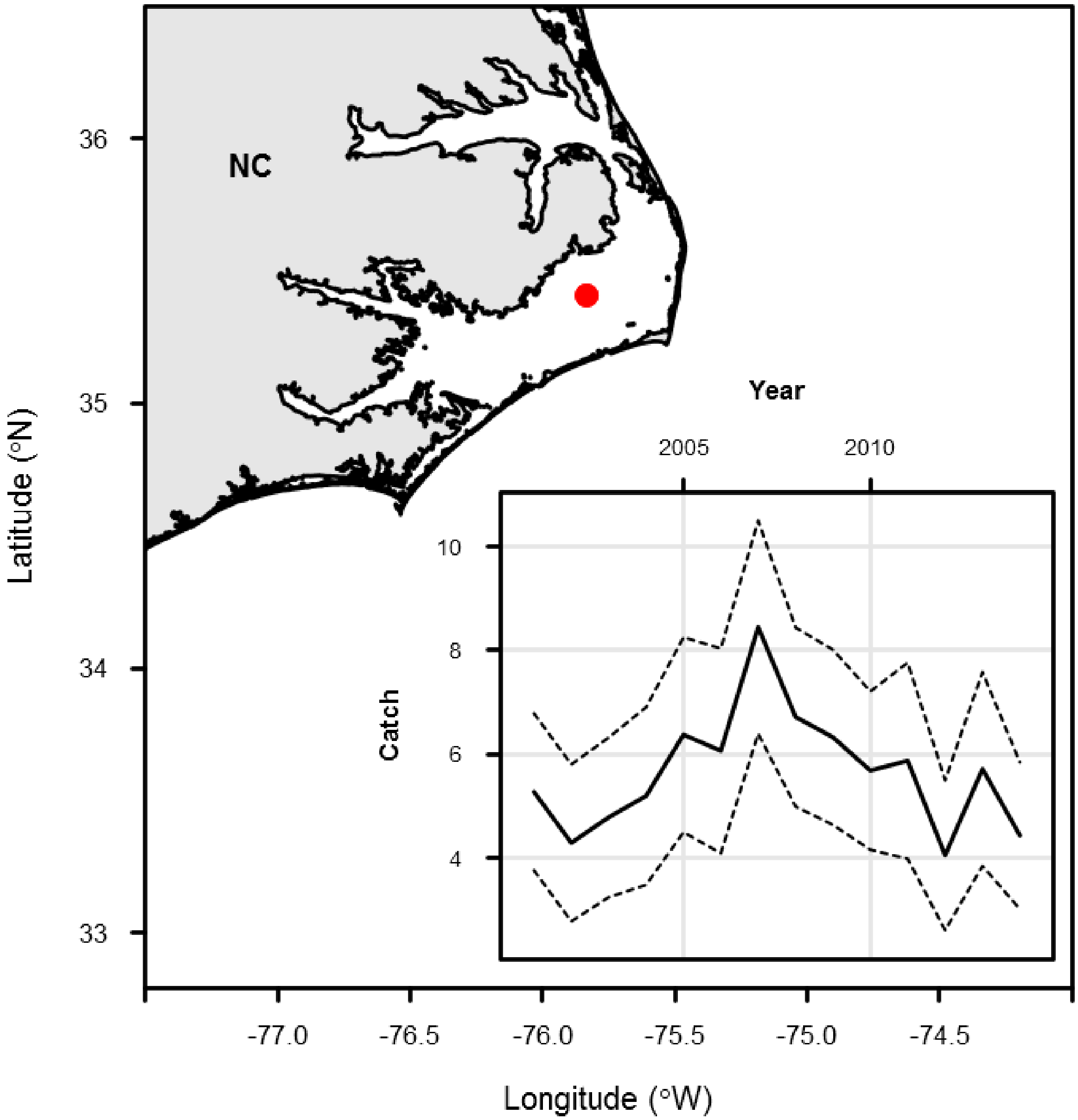


Figure B6.12. Map of the North Carolina Pamlico Sound Independent Gillnet Survey and resultant index of abundance (inset). Red dot indicates center point of survey area.

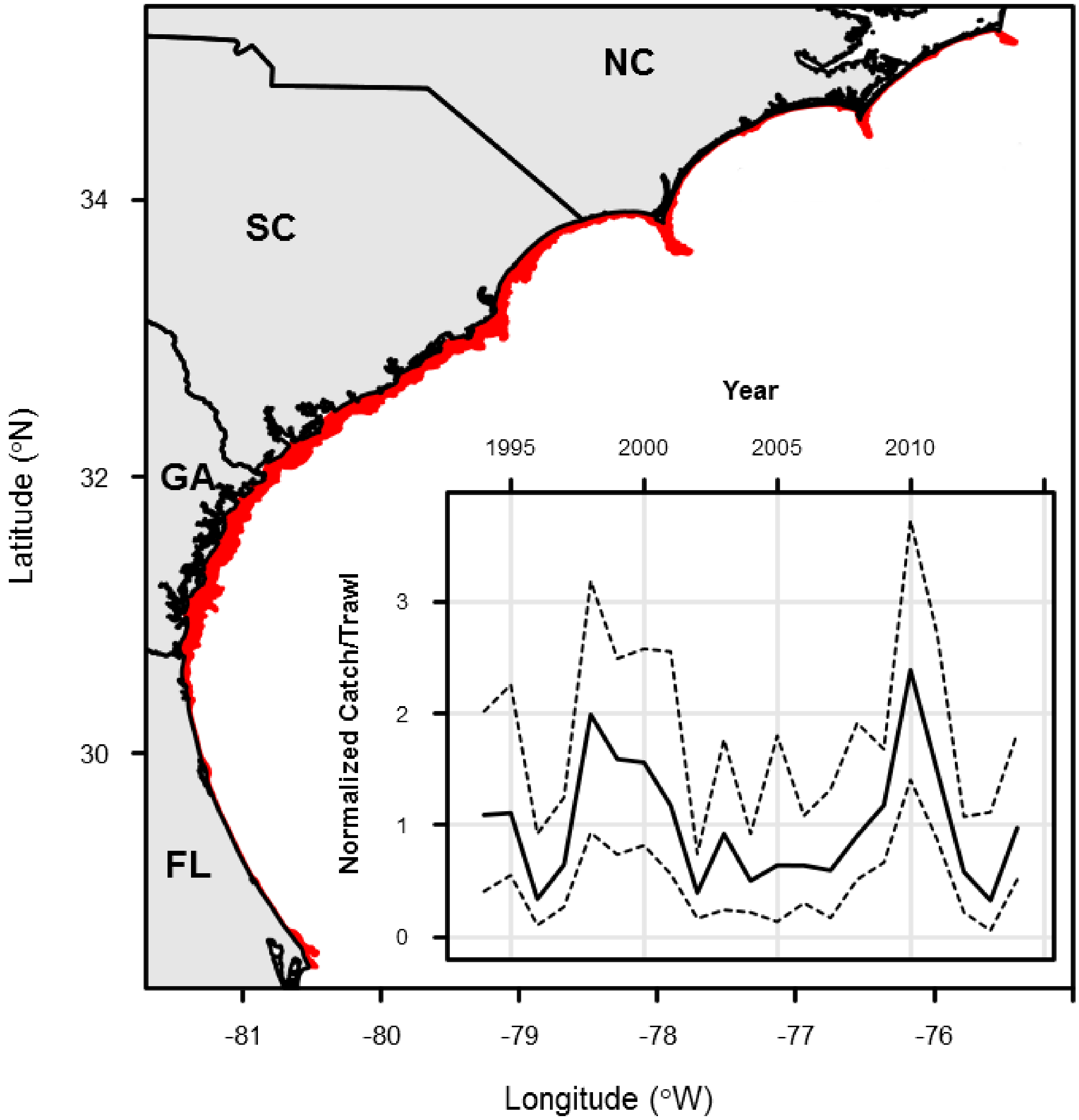


Figure B6.13. Map of the SEAMAP-SA Fall Bottom Trawl survey area and resultant index (inset). Red area represents total survey area.

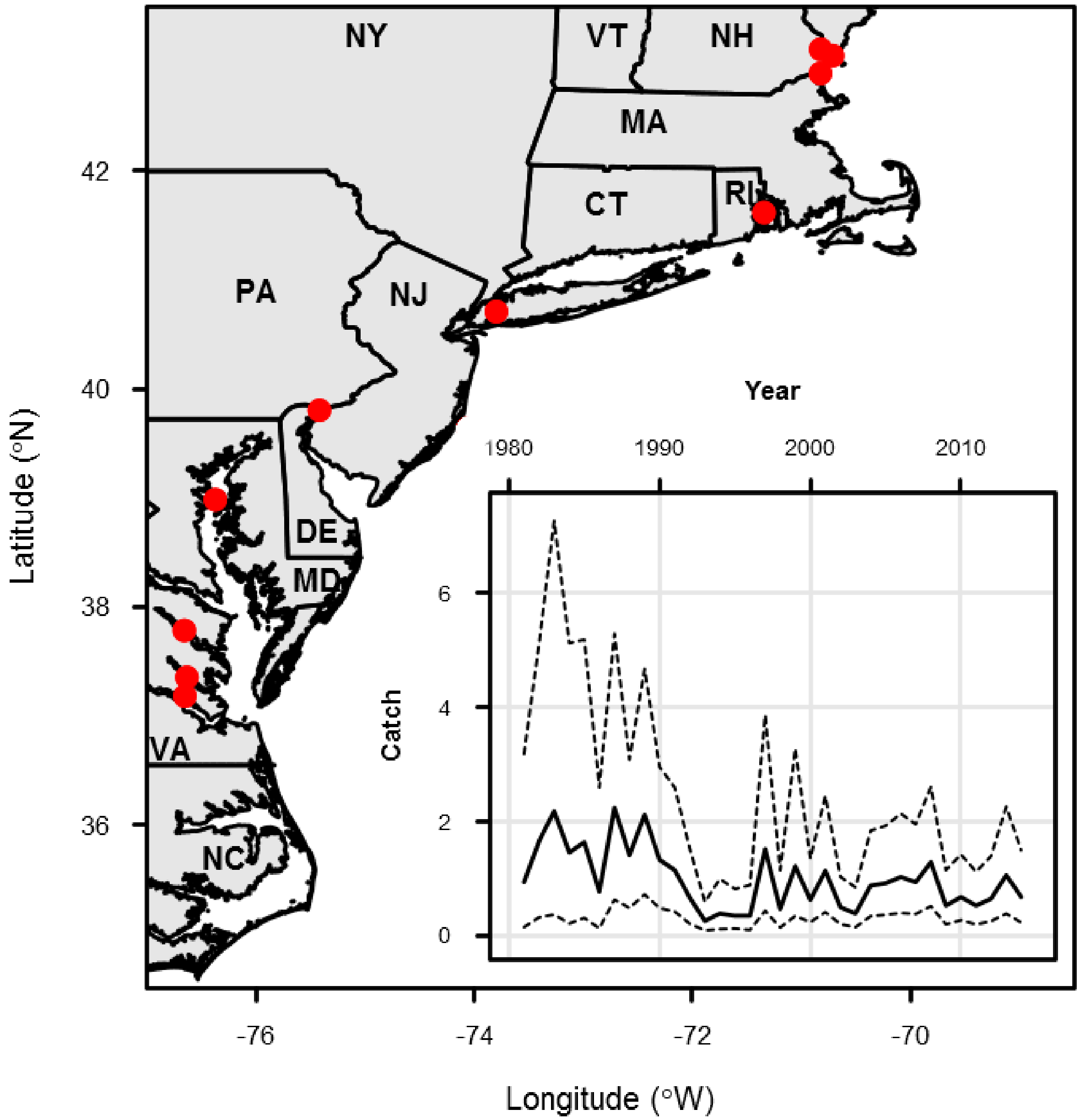


Figure B6.14. Map of all state seine surveys included in the composite young-of-year index with resultant index (inset).

Age 0

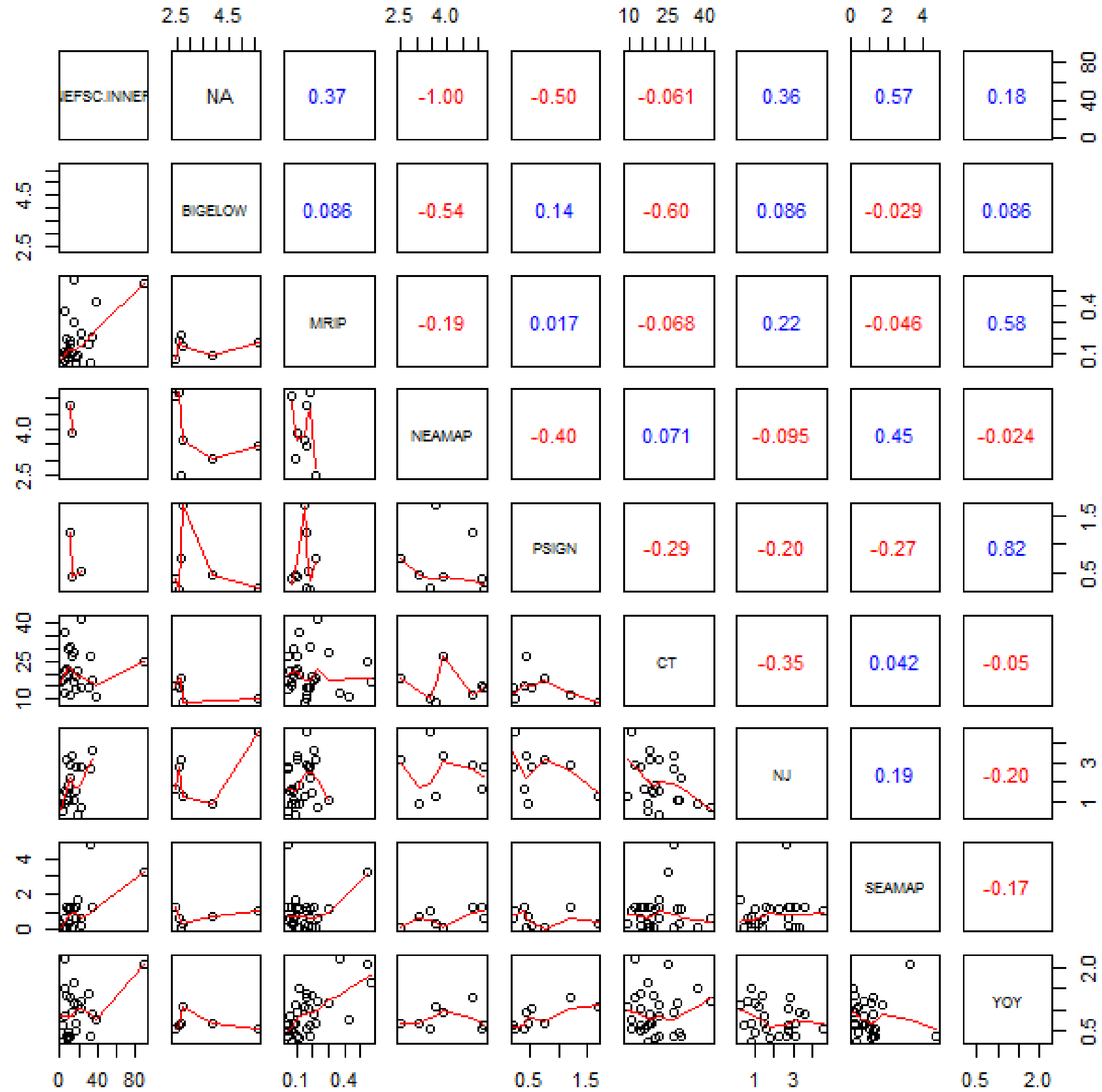


Figure B6.15. Correlation matrices of age specific indices. A locally-weighted polynomial regression smoother (lowess) trend line (red) is added to each pairwise comparison. Spearman correlation coefficients are indicated in the upper half of the matrix (red for negative correlations, blue for positive)

Age 1

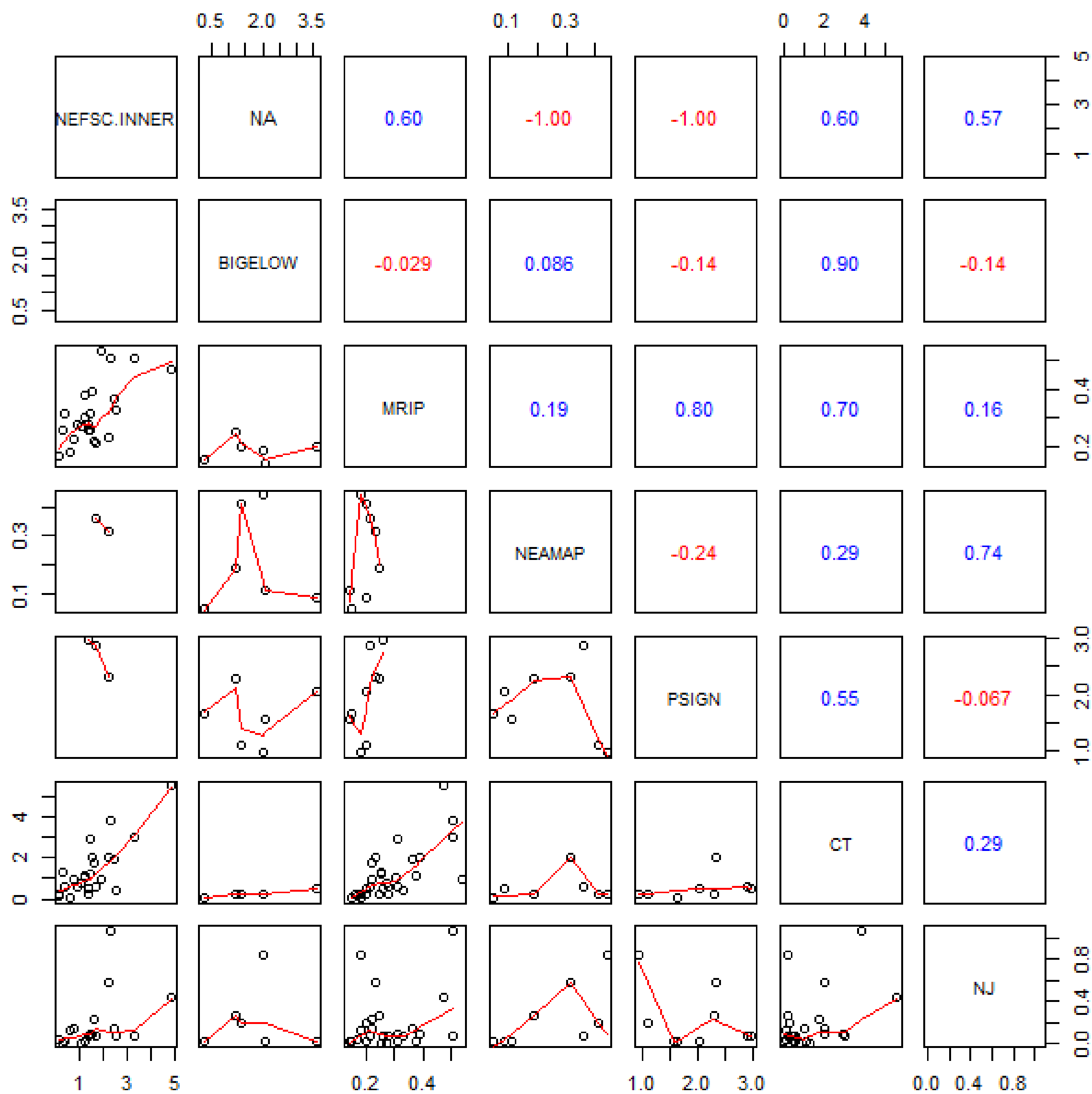


Figure B6.15 (cont.)

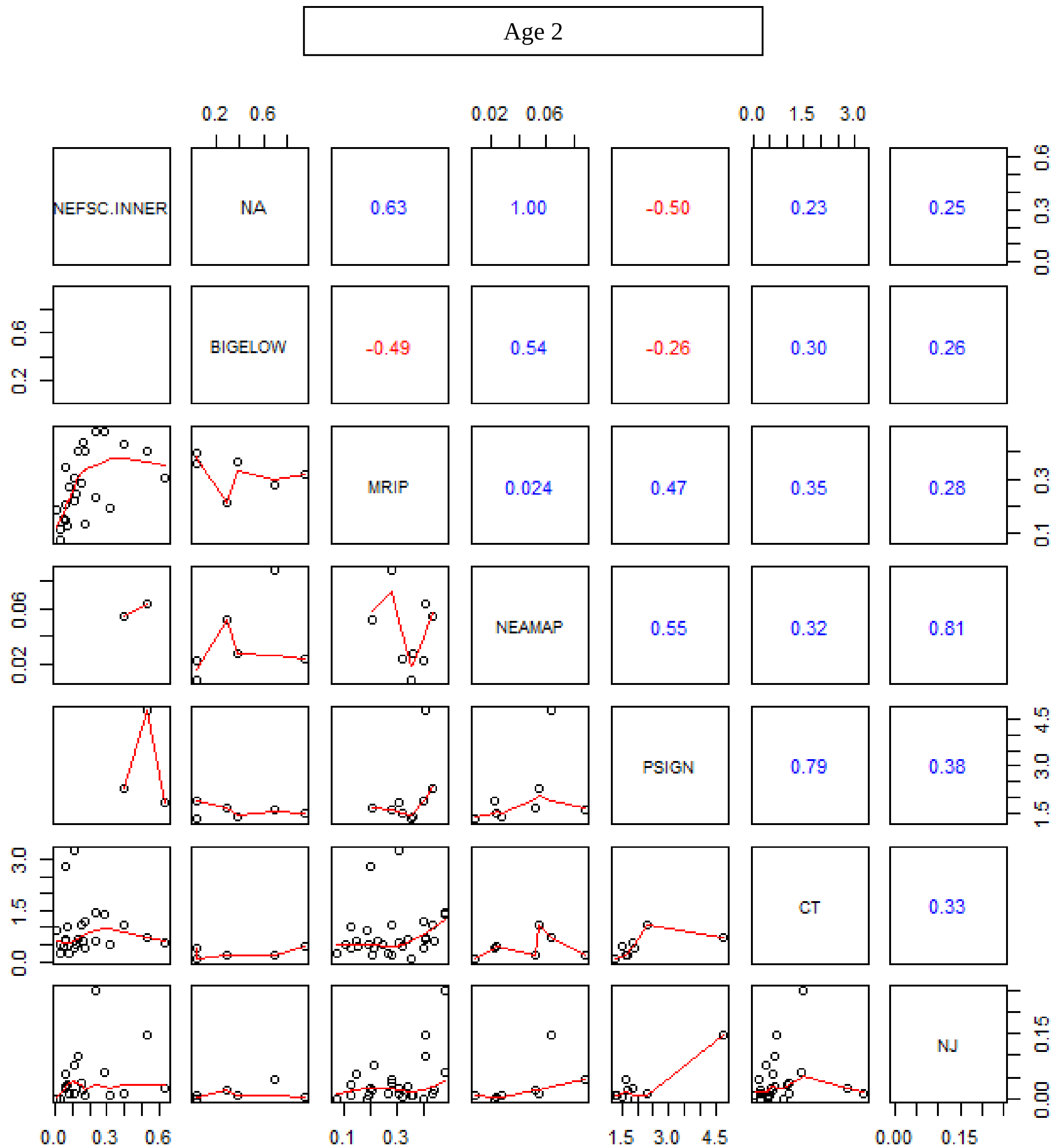


Figure B6.15 (cont.)

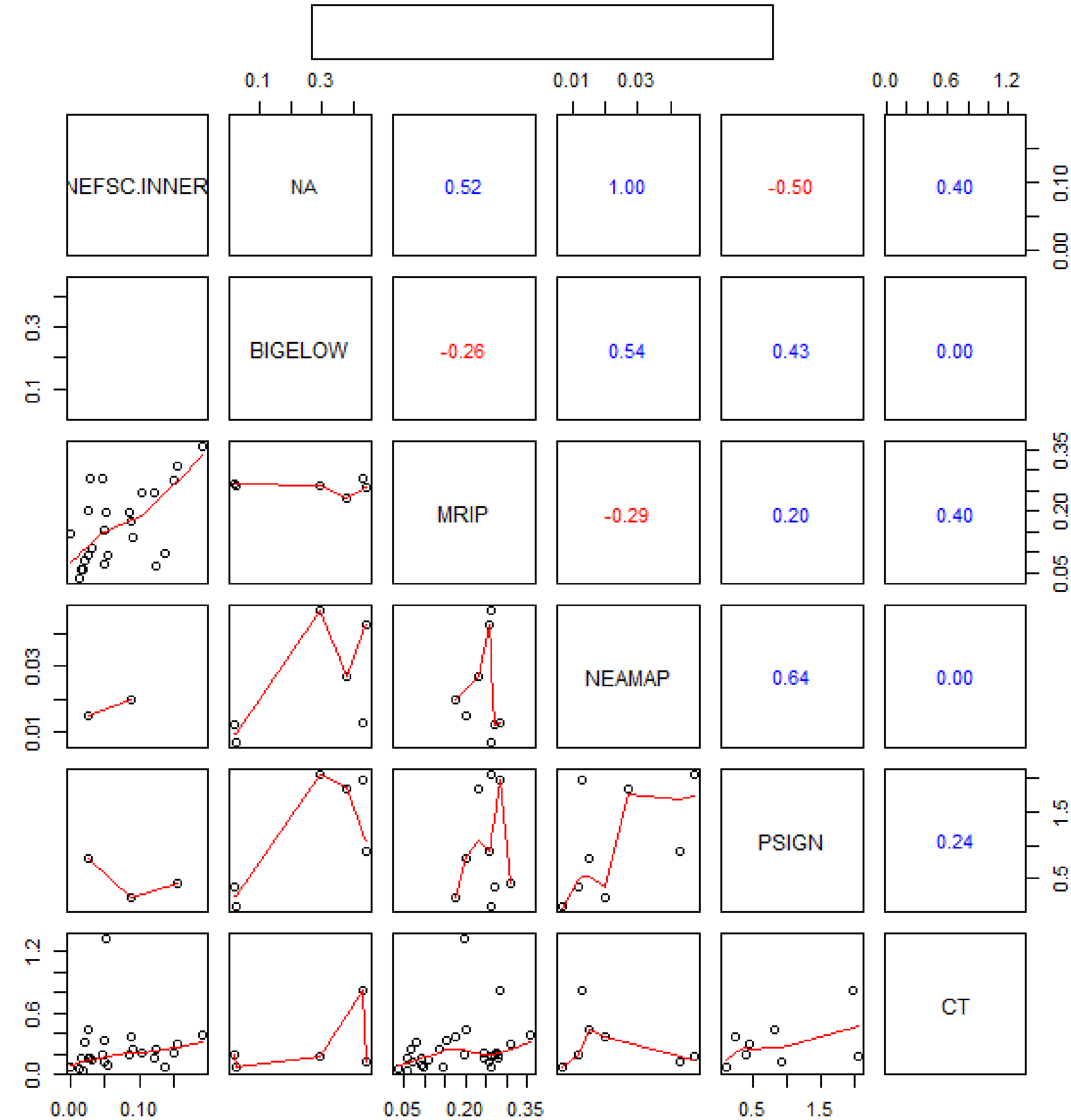


Figure B6.15 (cont.)

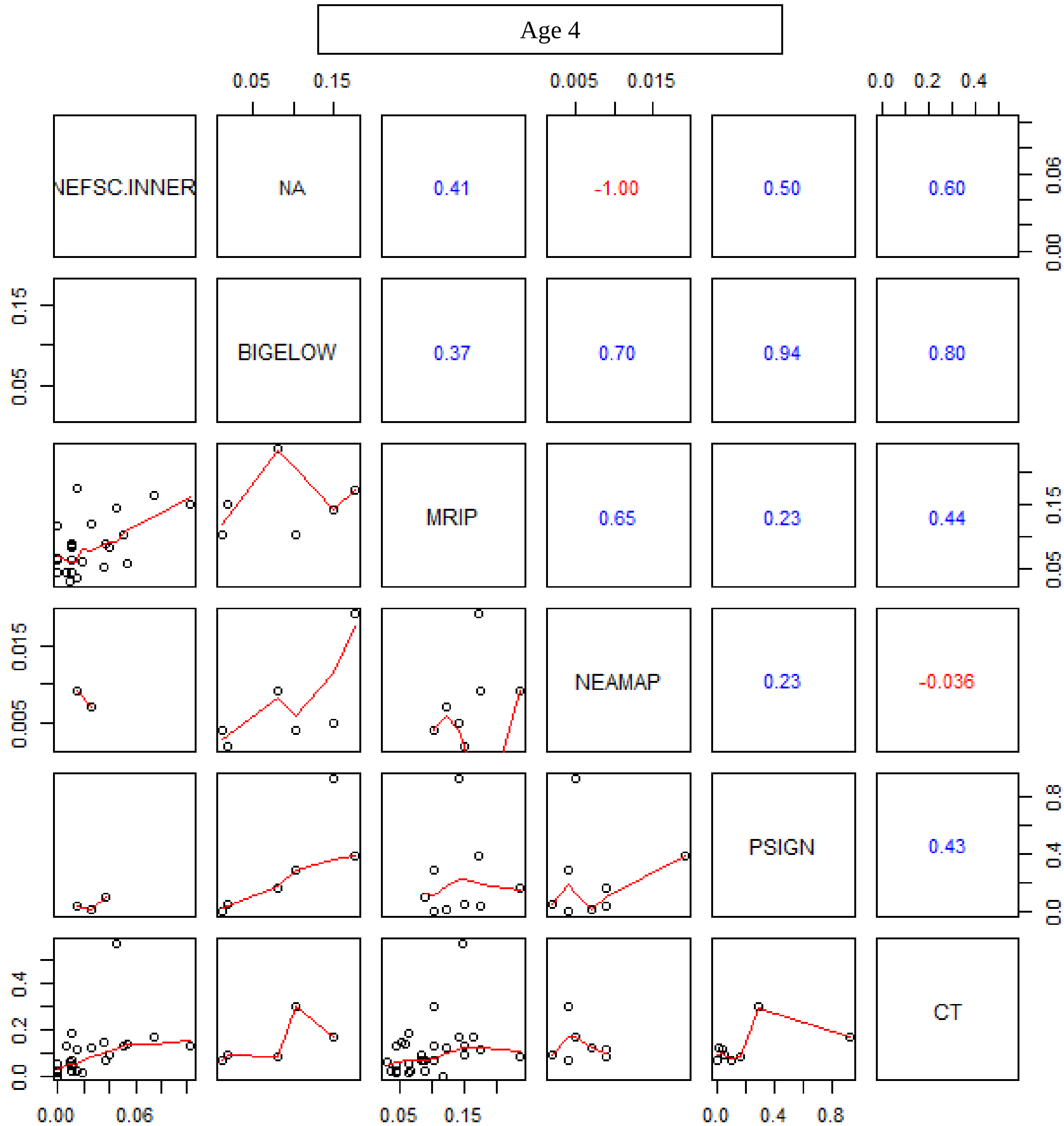


Figure B6.15 (cont.)

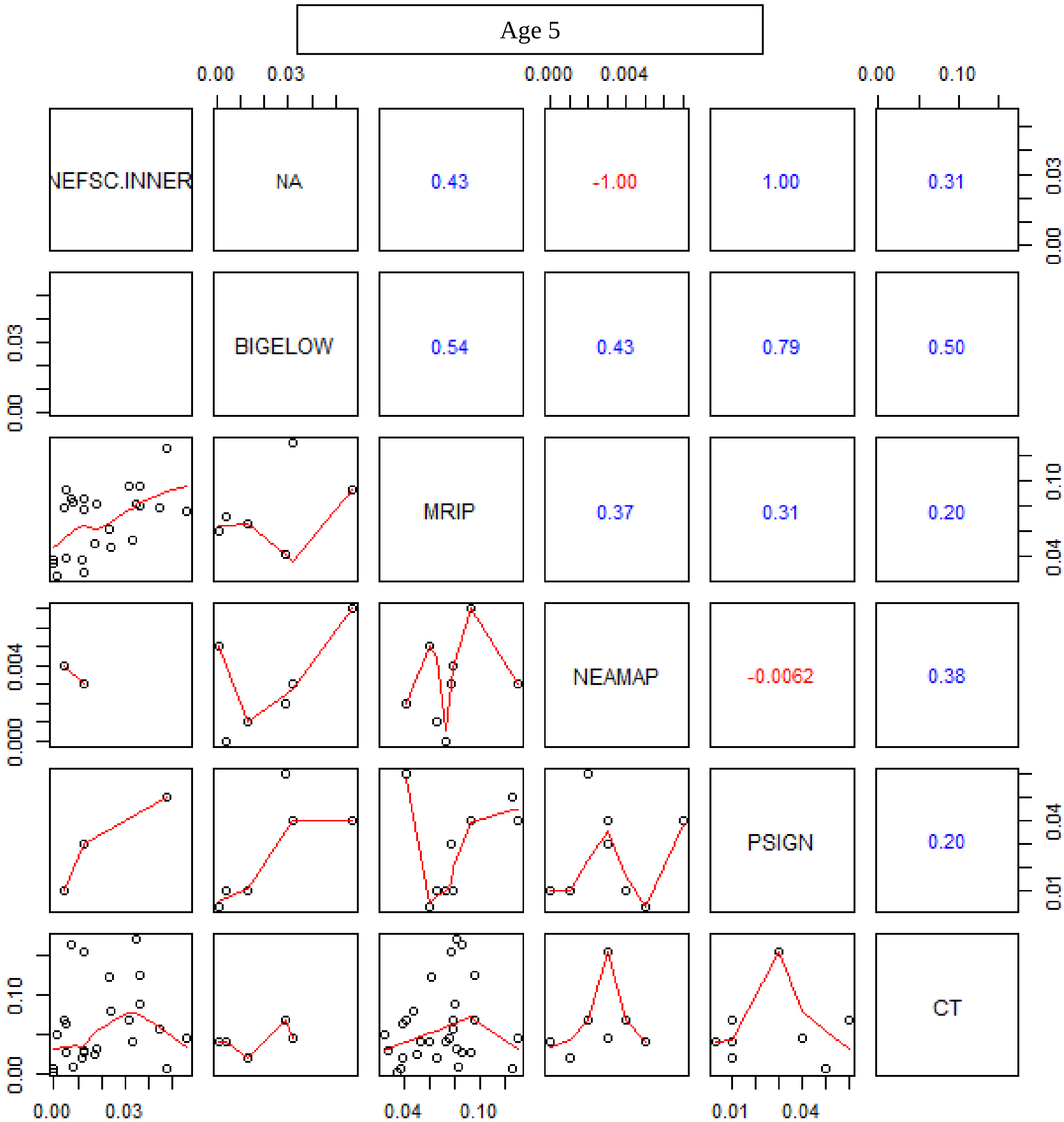


Figure B6.15 (cont.)

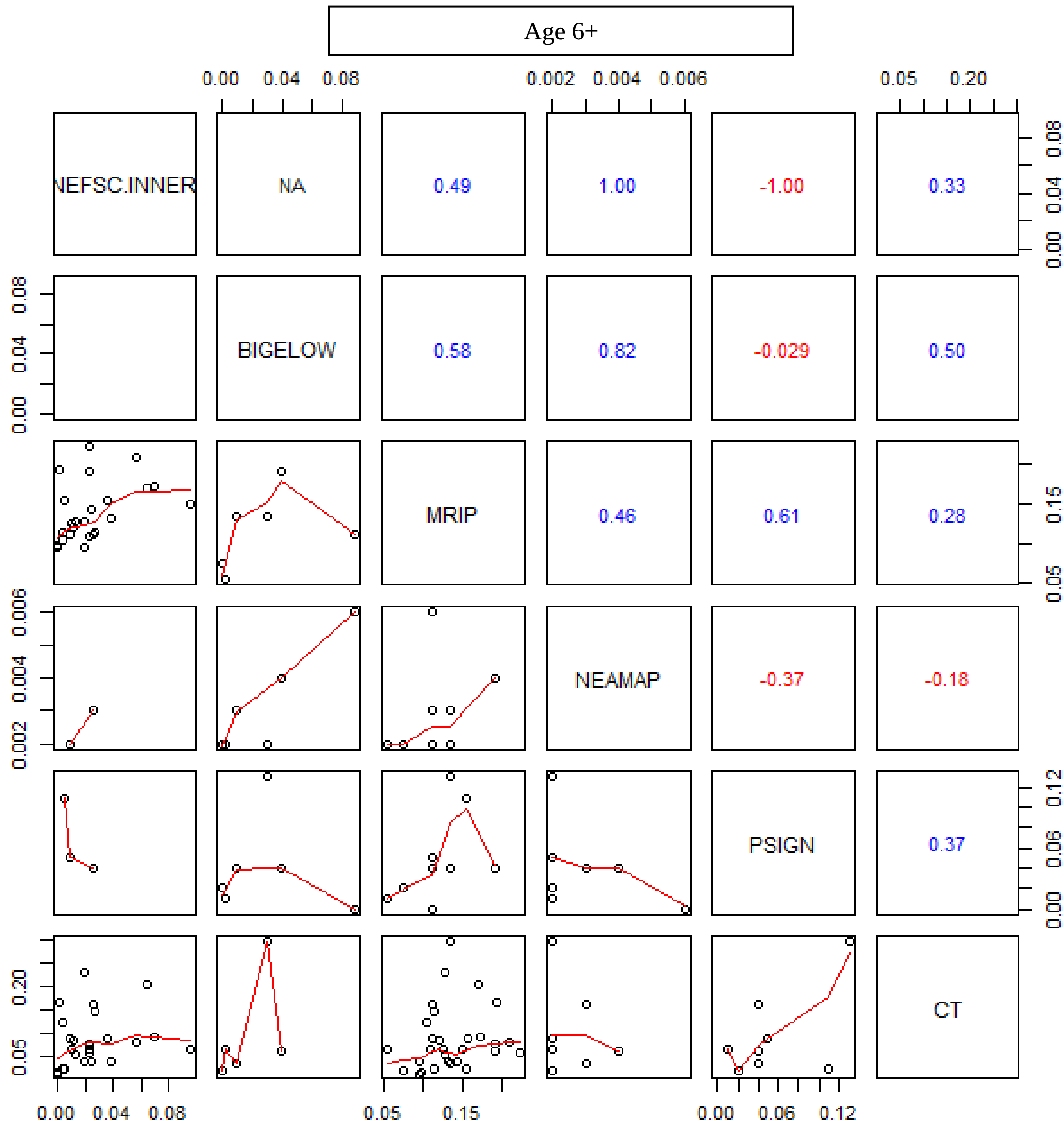


Figure B6.15 (cont.)

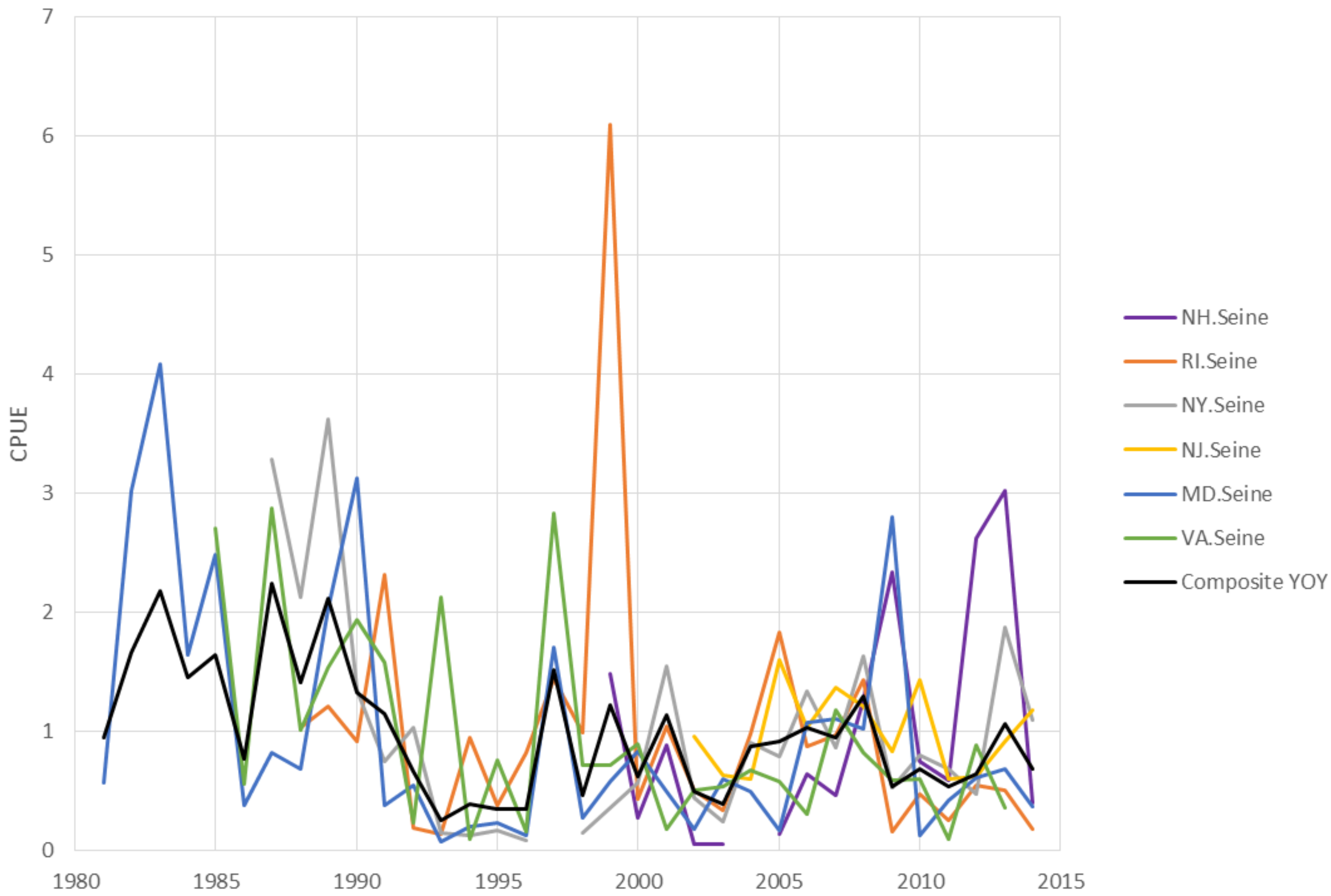


Figure B6.16. Composite young-of-year index plotted with component state indices. All indices are scaled to their mean.

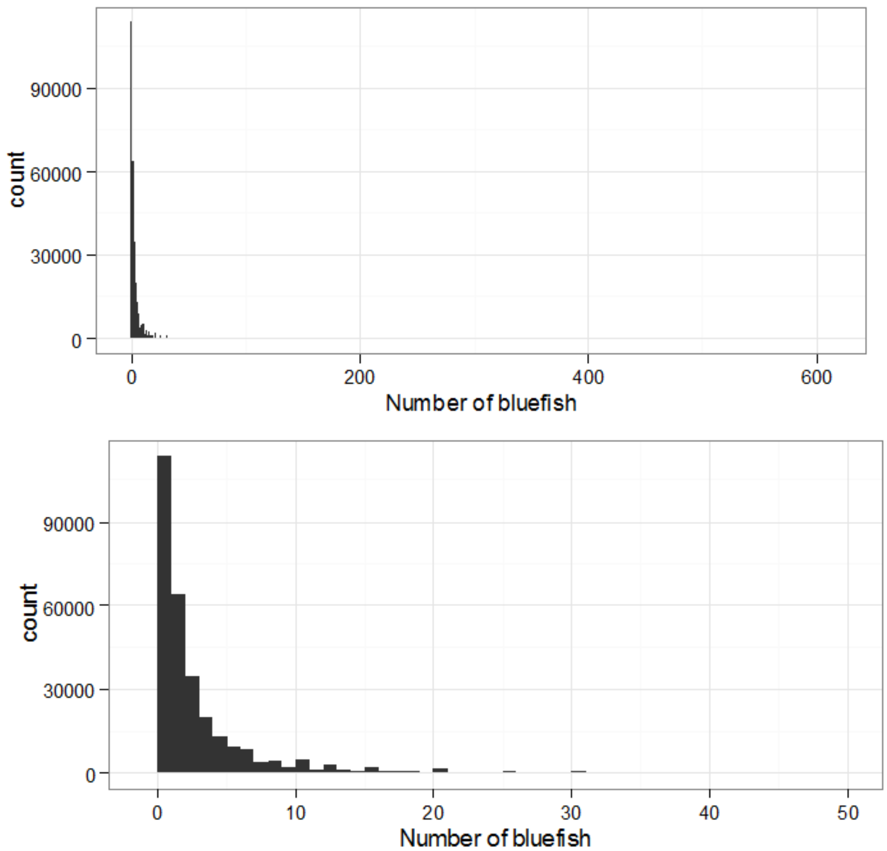


Figure B6.17. Distribution of observed catch-per-trip of bluefish. Lower figure has been truncated to trips with less than 50 bluefish per trip to improve readability.

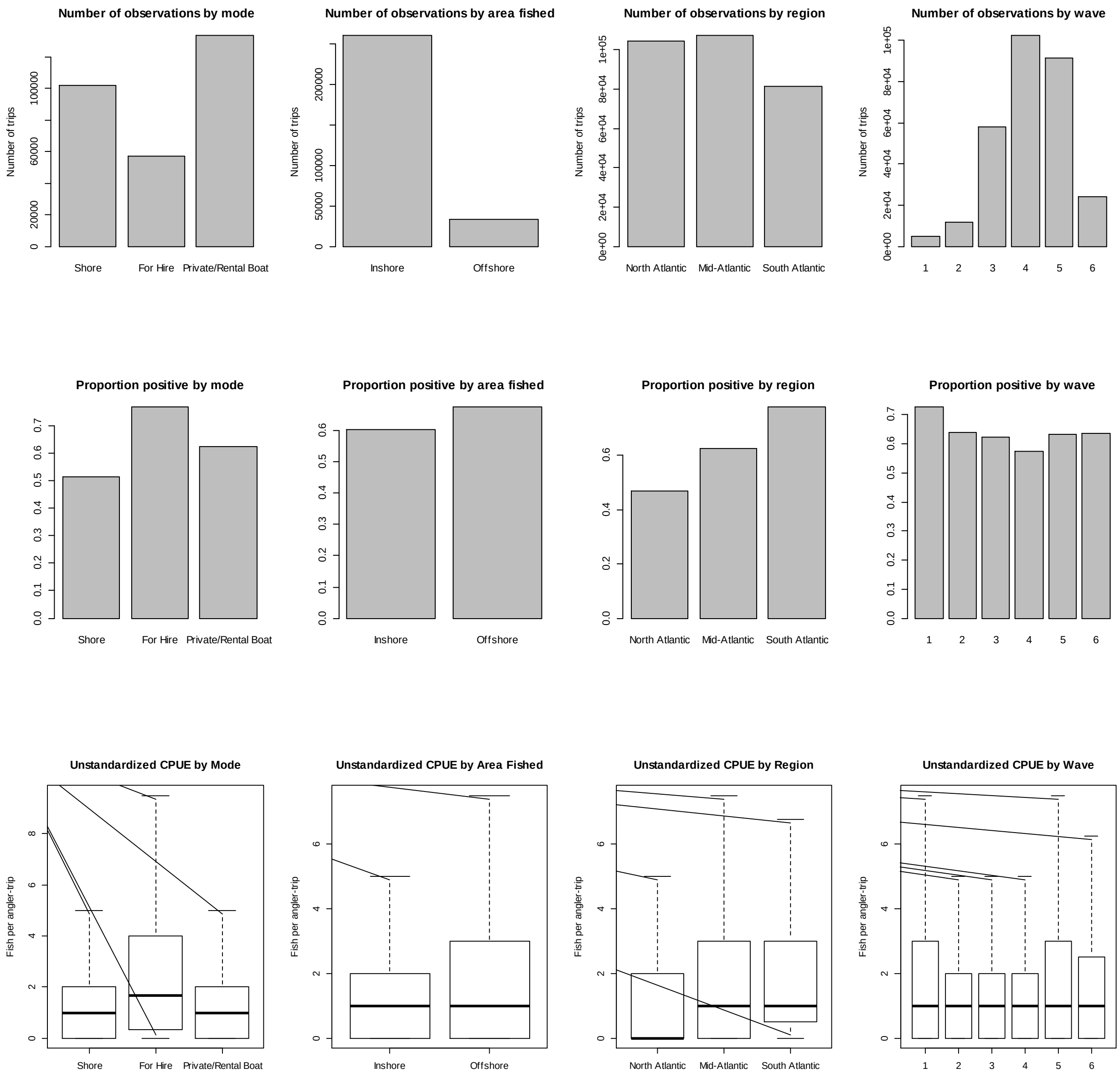


Figure B6.18. Number of observations (top), proportion positive trips (middle), and unstandardized CPUE (bottom) by factor for MRIP intercept data.

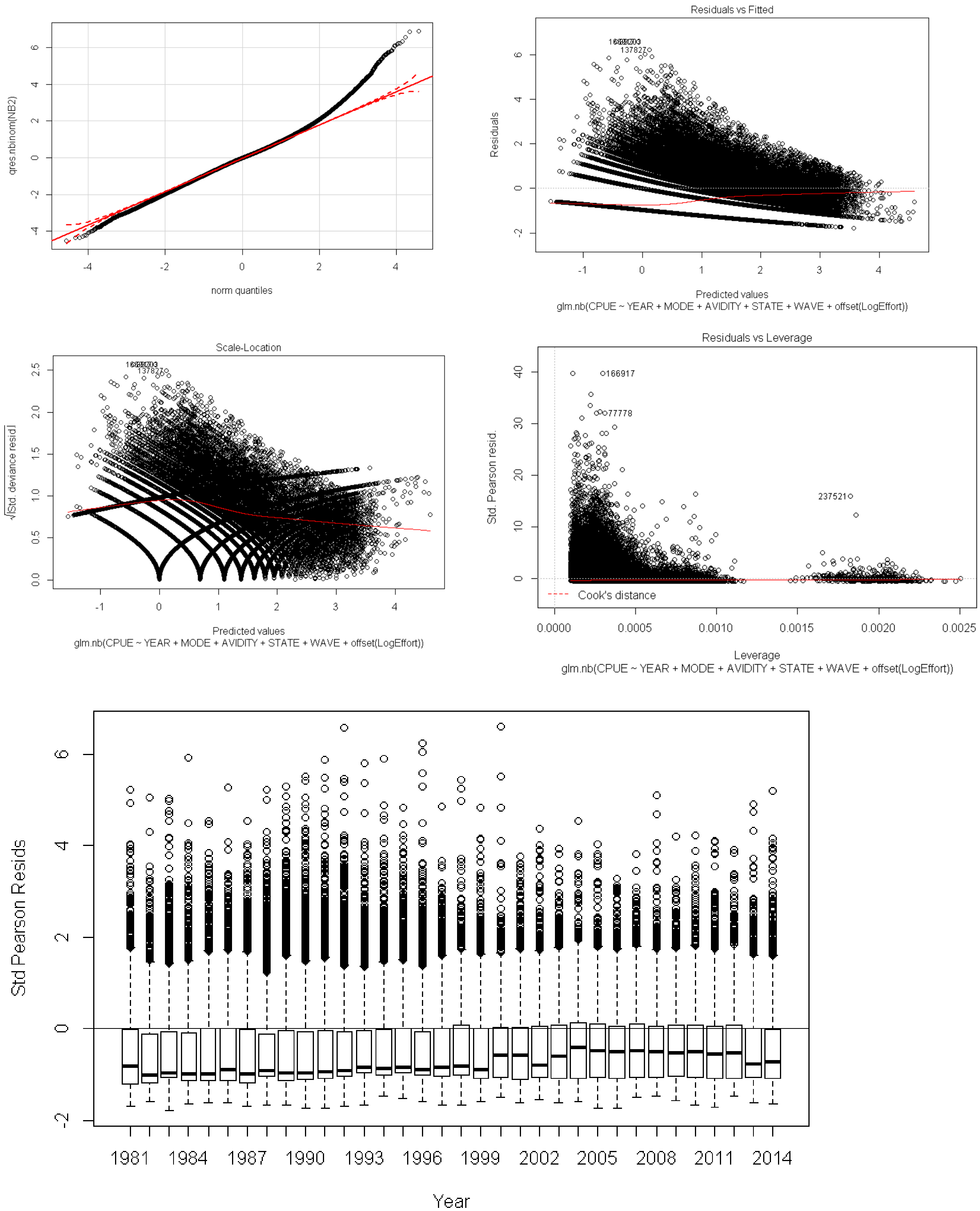


Figure B6.19.Diagnostic plots for GLM standardization of MRIP CPUE.

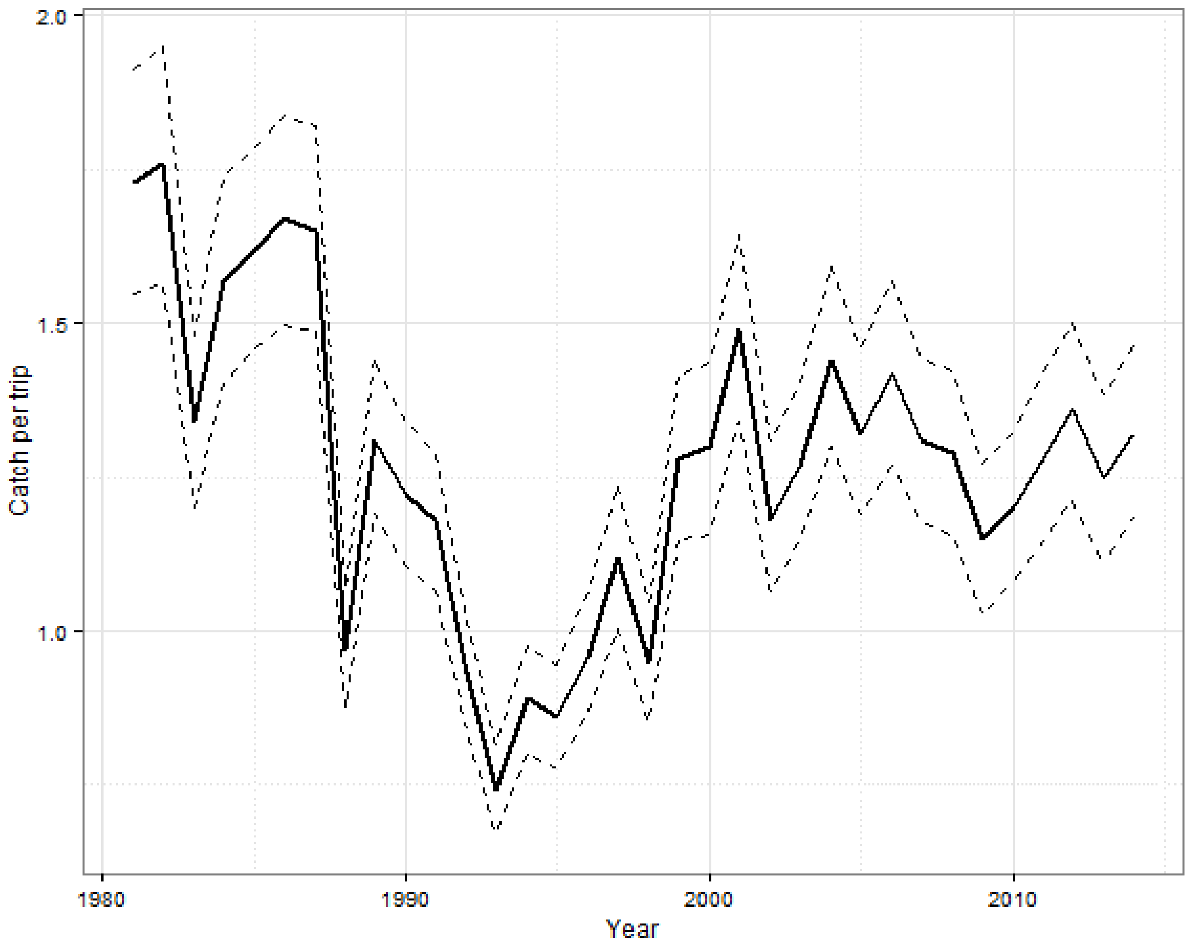


Figure B6.20.Standardized MRIP CPUE with 95% confidence intervals.

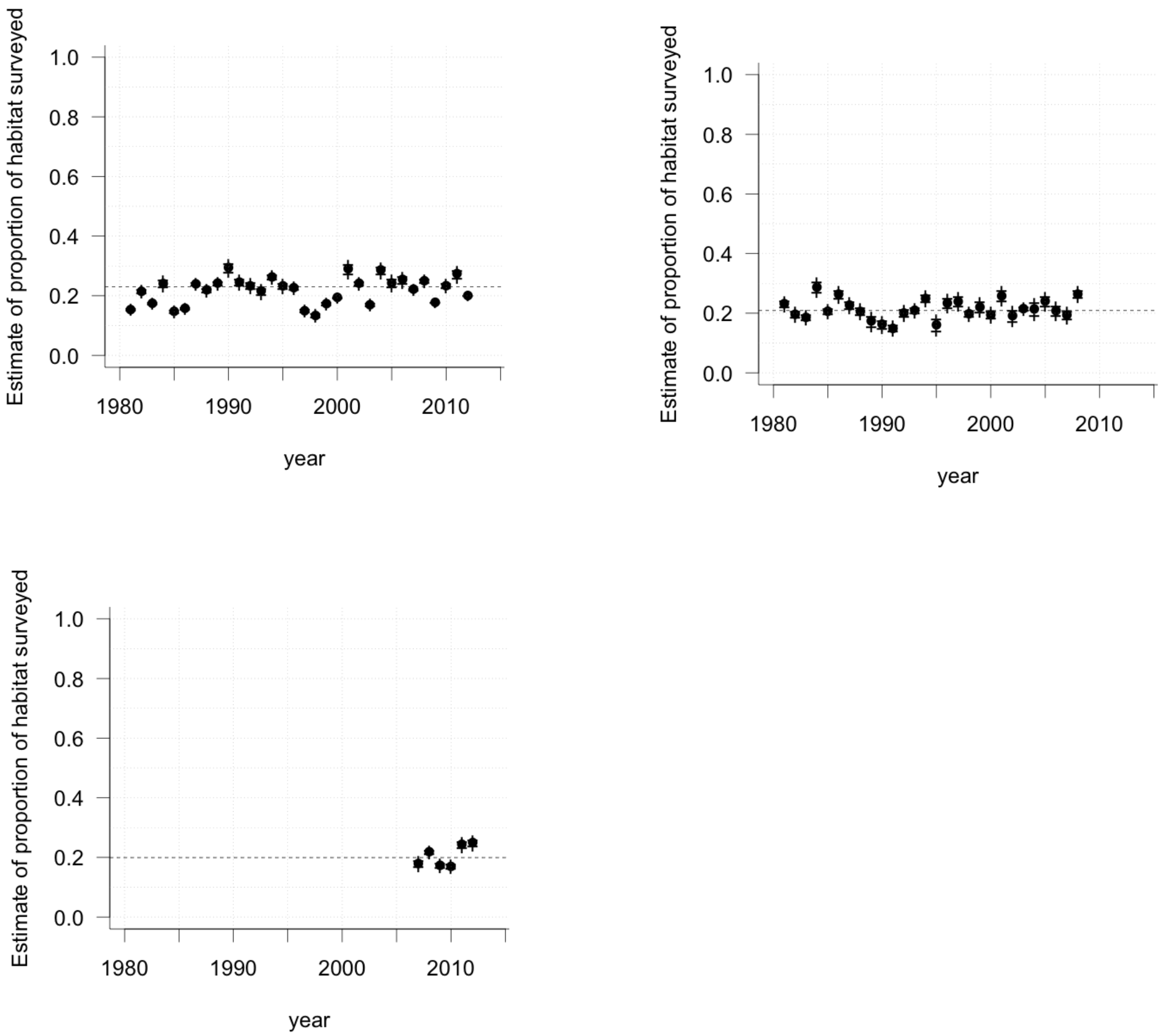


Figure B6.21 Estimates of the proportion of thermal habitat suitability surveyed for bluefish estimated using the niche model coupled to the debiased bottom temperature hindcast for NEFSC "offshore" inshore strata (top left), NEFSC "inshore" inshore strata and NEAMAP survey strata during the fall.

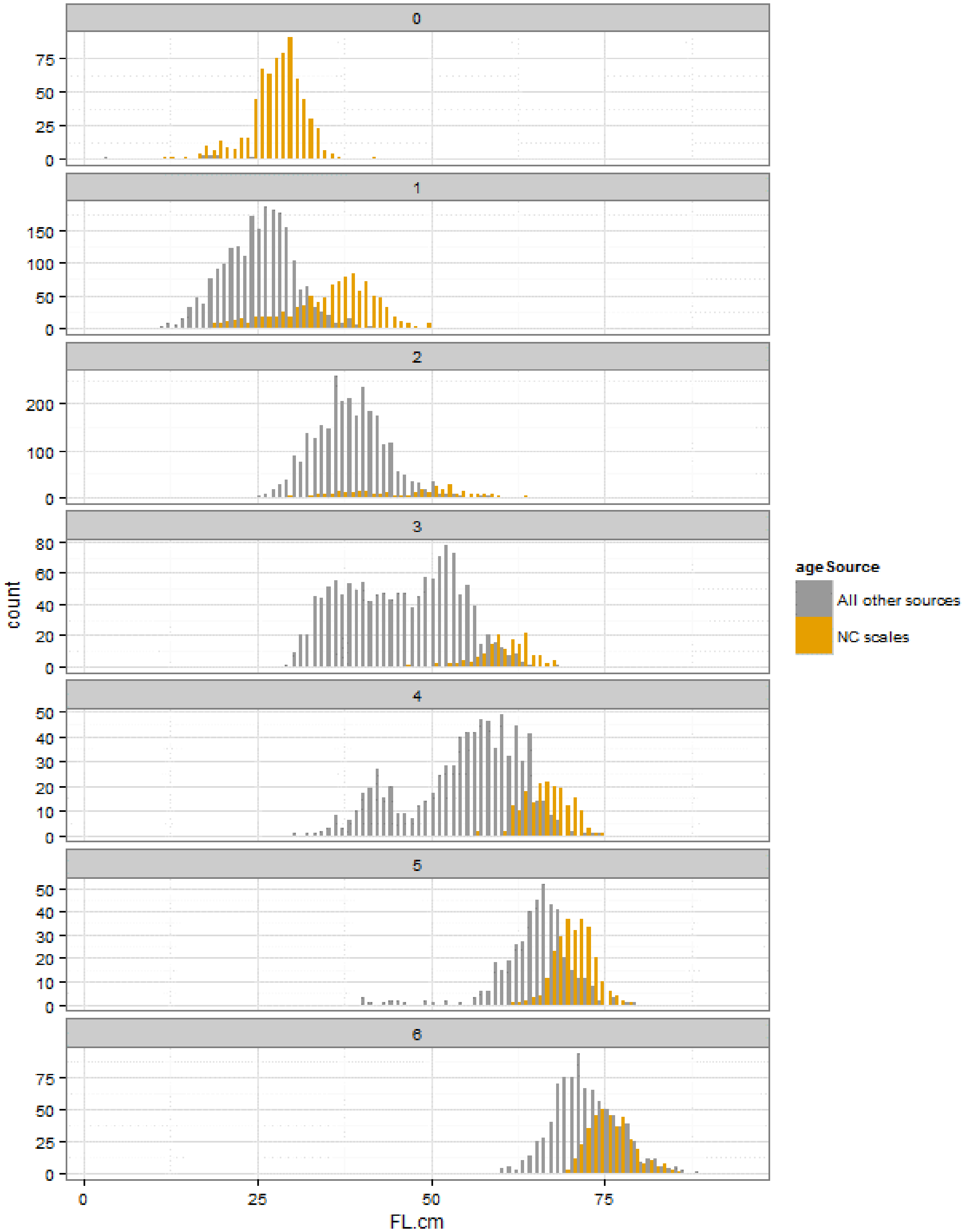


Figure B6.22. Length frequency of spring age data by age and source.

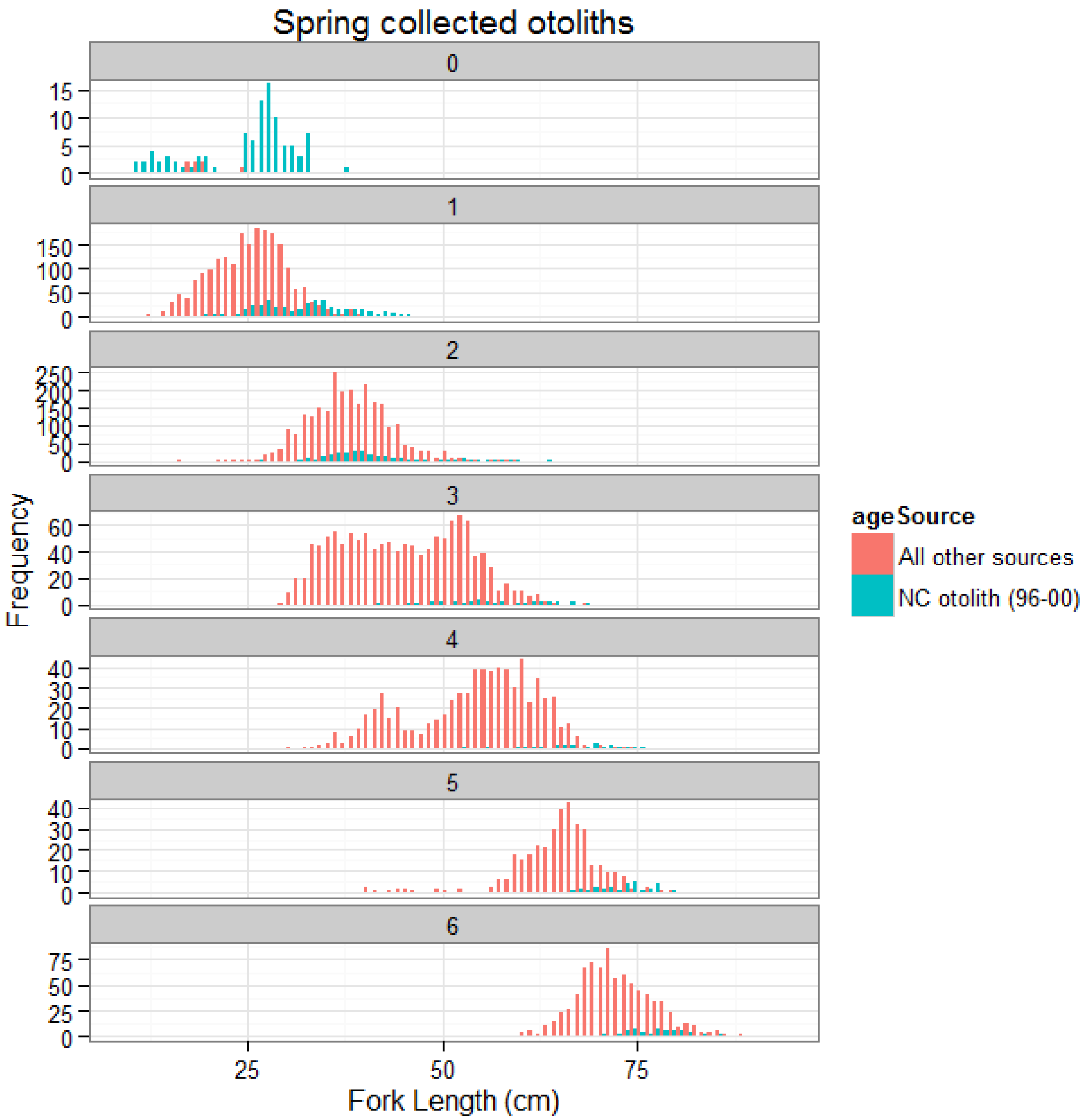


Figure B6.23. Length frequency of spring collected otolith data by age and source.

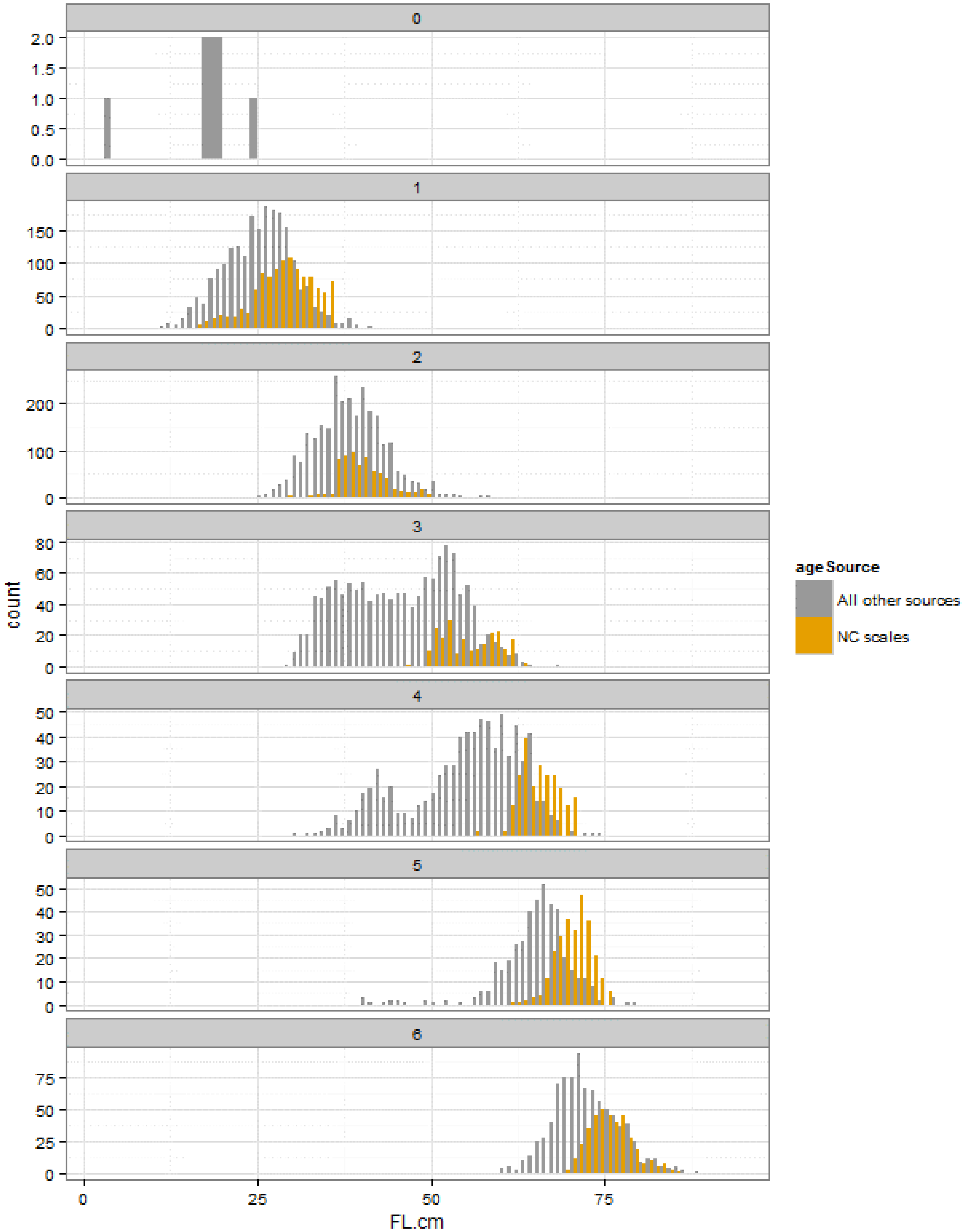


Figure B6.24. Length frequency of spring collected fish by age and source, with NC scales corrected for the birthday issue.

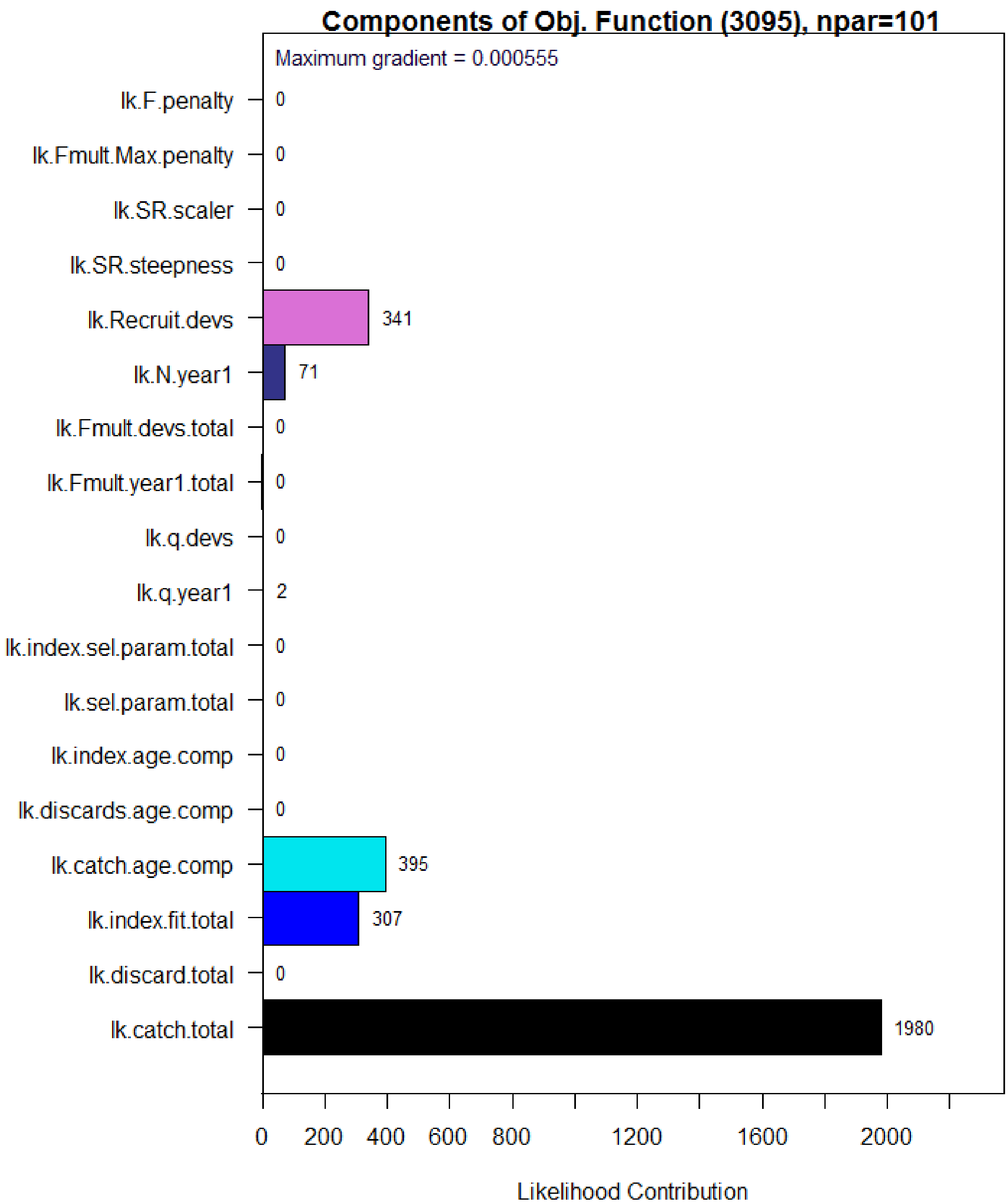


Figure B7.1. Likelihood components from the bluefish continuity model run (B001) showing the relative contribution of each component to the objective function.

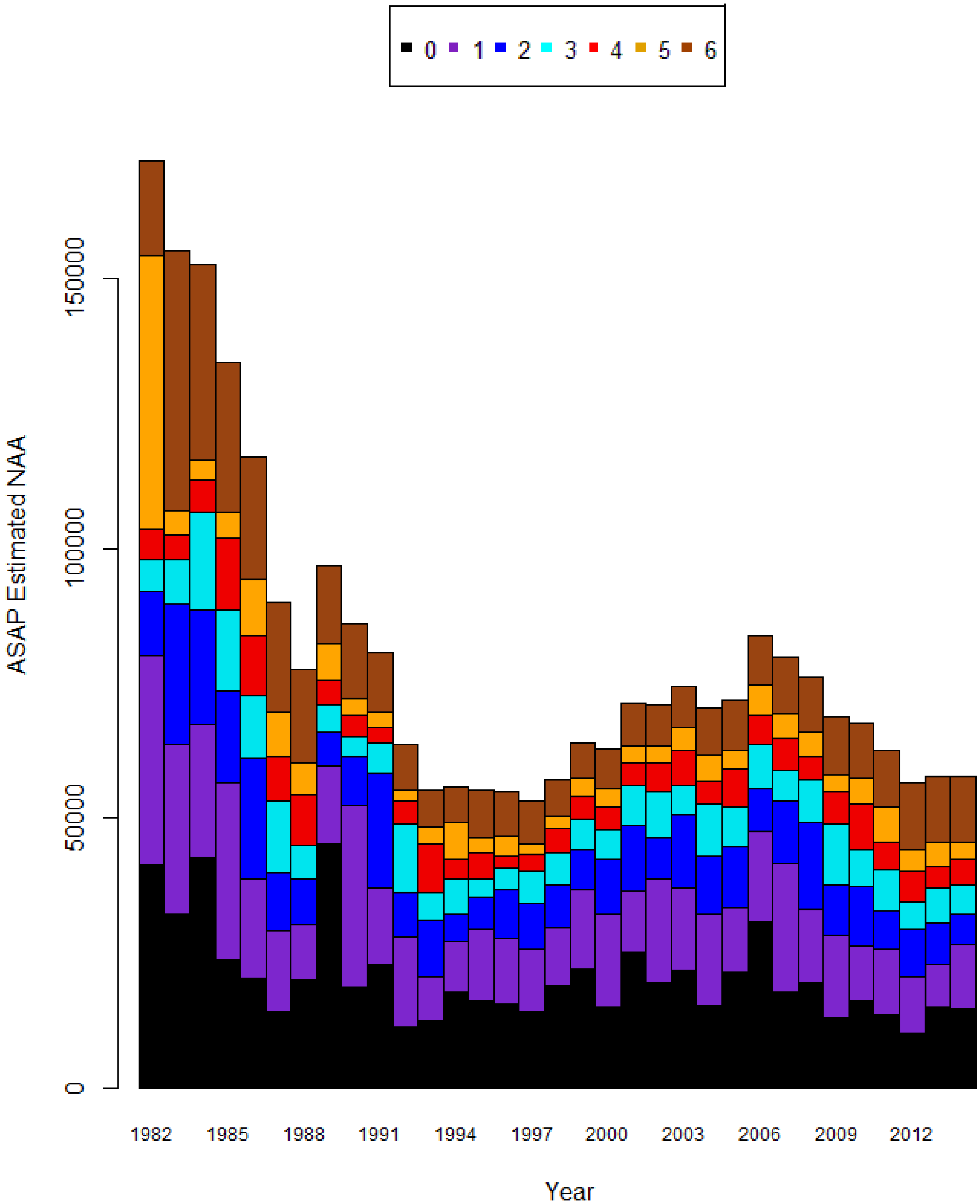


Figure B7.2. Bluefish numbers at age from 1982-2014 estimated from the continuity model run (B001).

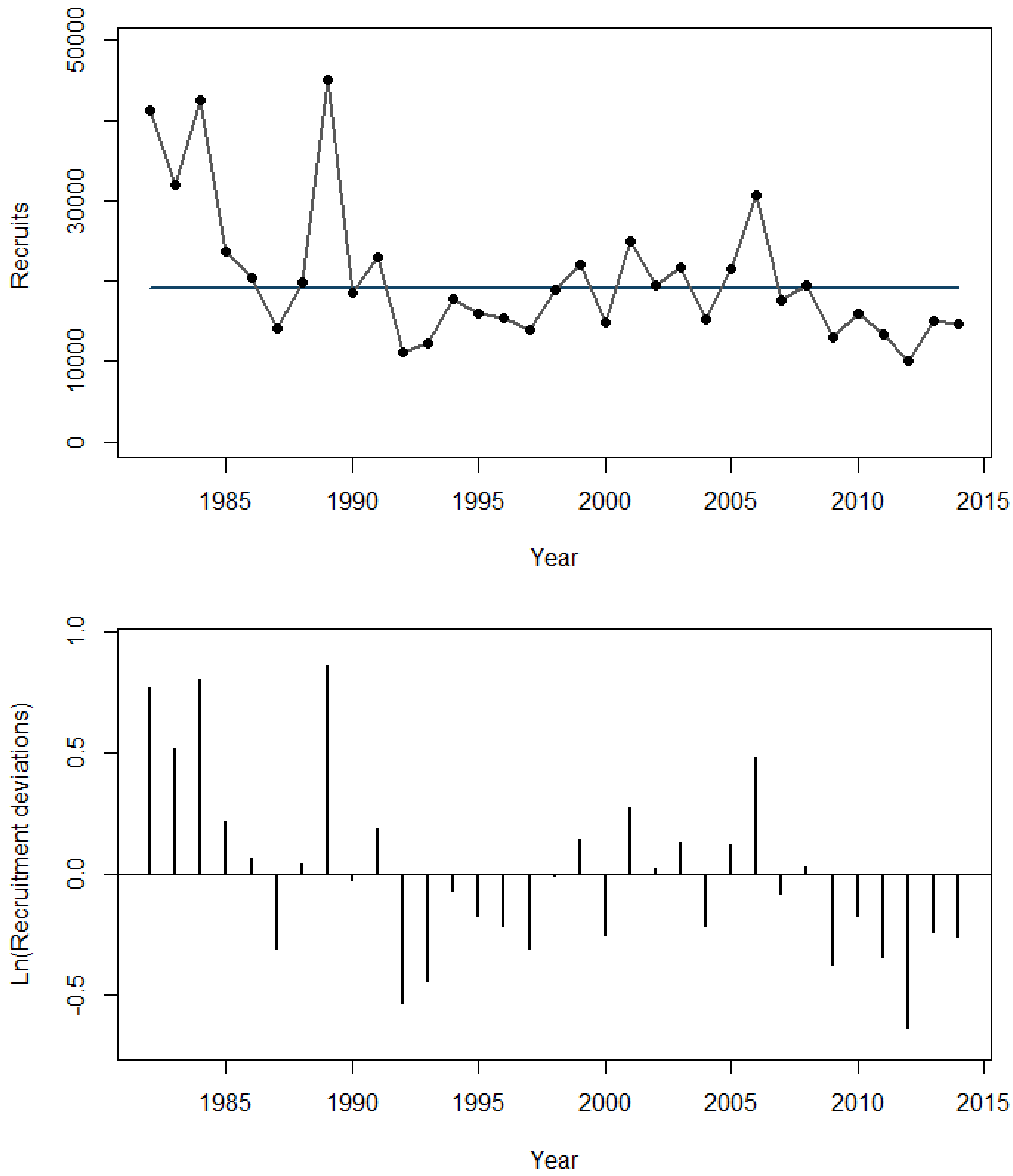


Figure B7.3. Bluefish recruitment, average recruitment over the time series (horizontal line), and recruitment deviations from the continuity model run (B001).

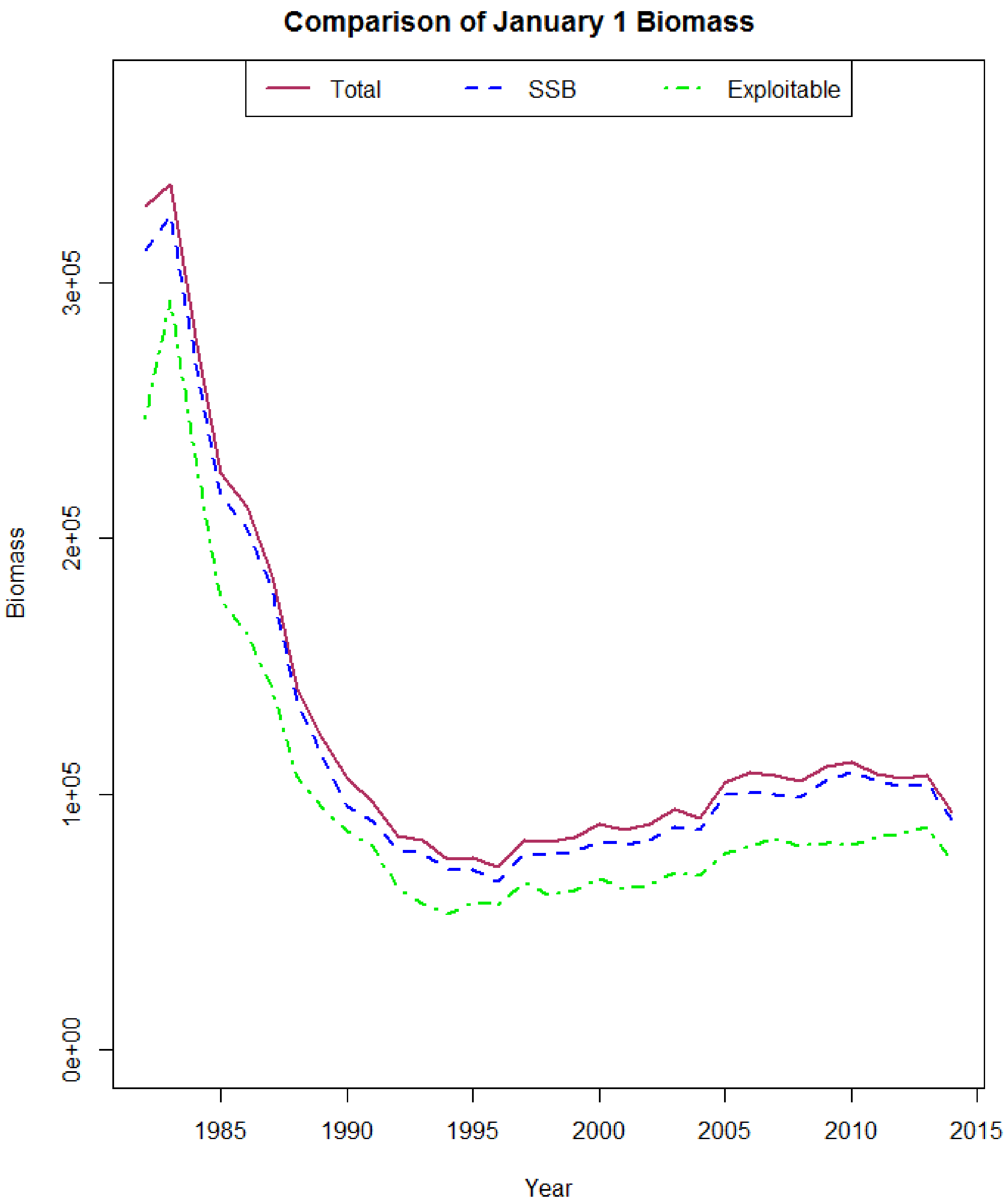


Figure B7.4. A comparison of bluefish total biomass (Jan-1), spawning stock biomass, and exploitable biomass estimated from the continuity model run (B001).

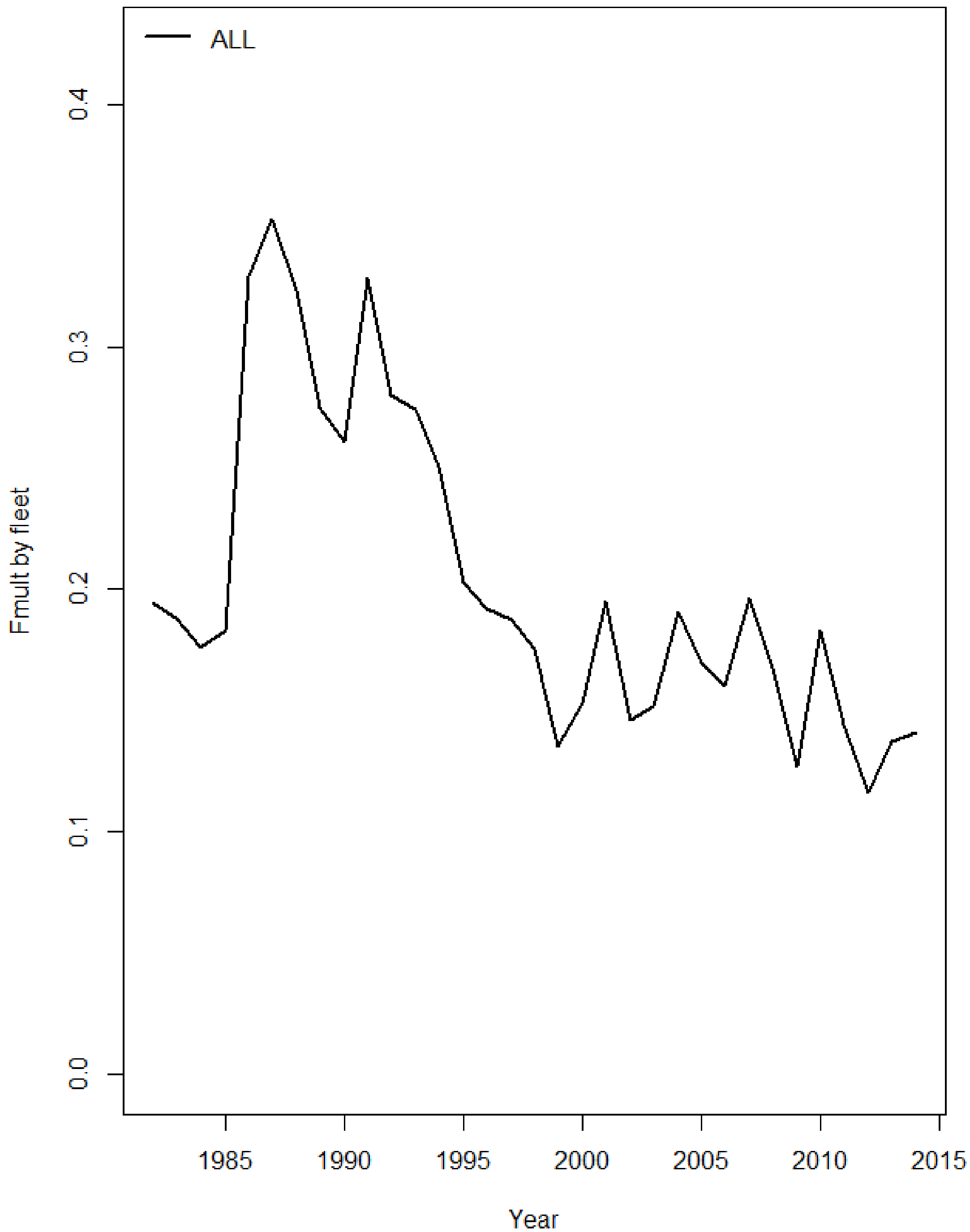


Figure B7.5. Estimates of fishing mortality for bluefish from 1982 to 2014 from model B001, the continuity run.

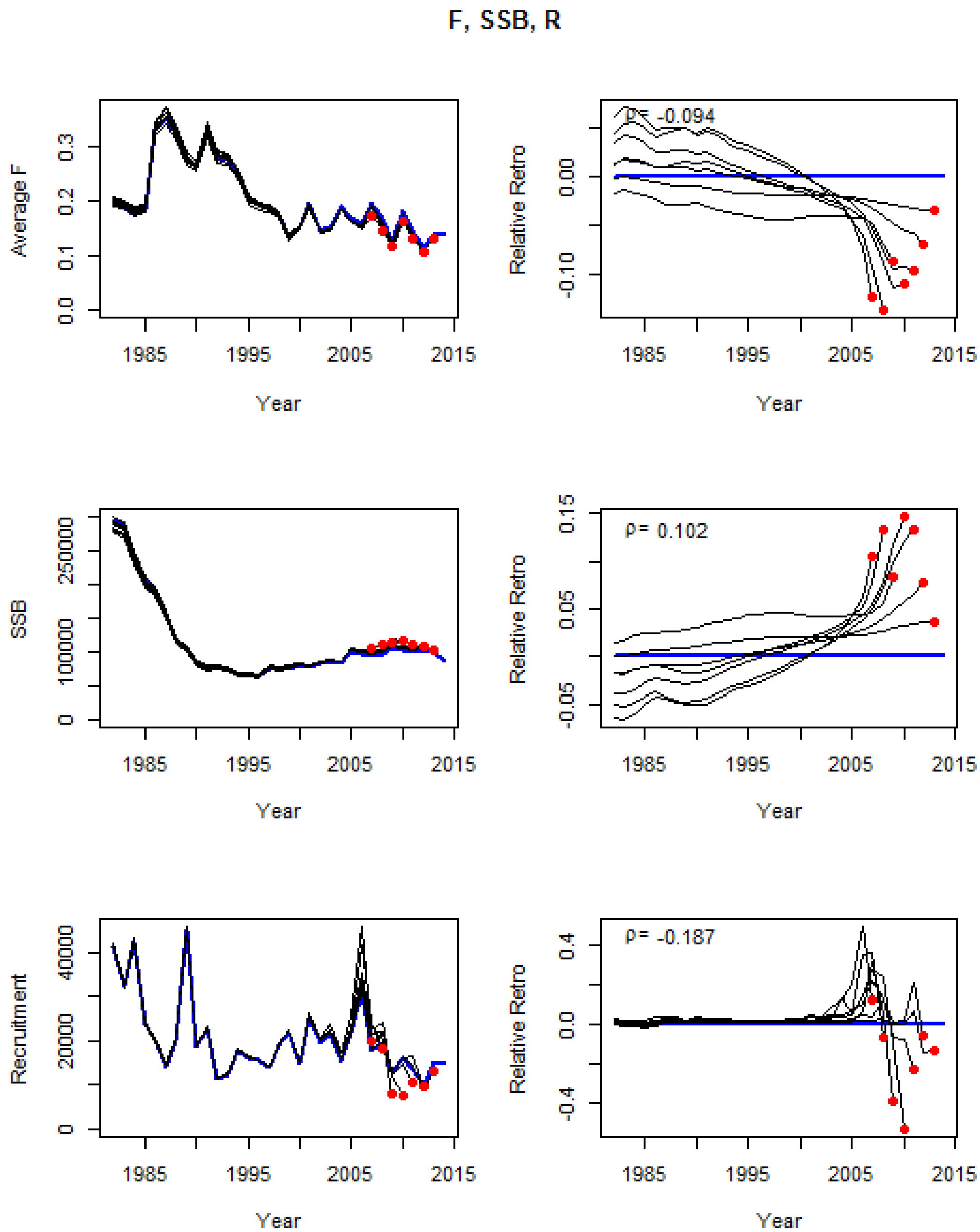


Figure B7.6. Retrospective bias for F, SSB, and Recruitment estimated from the bluefish model continuity run (B001).

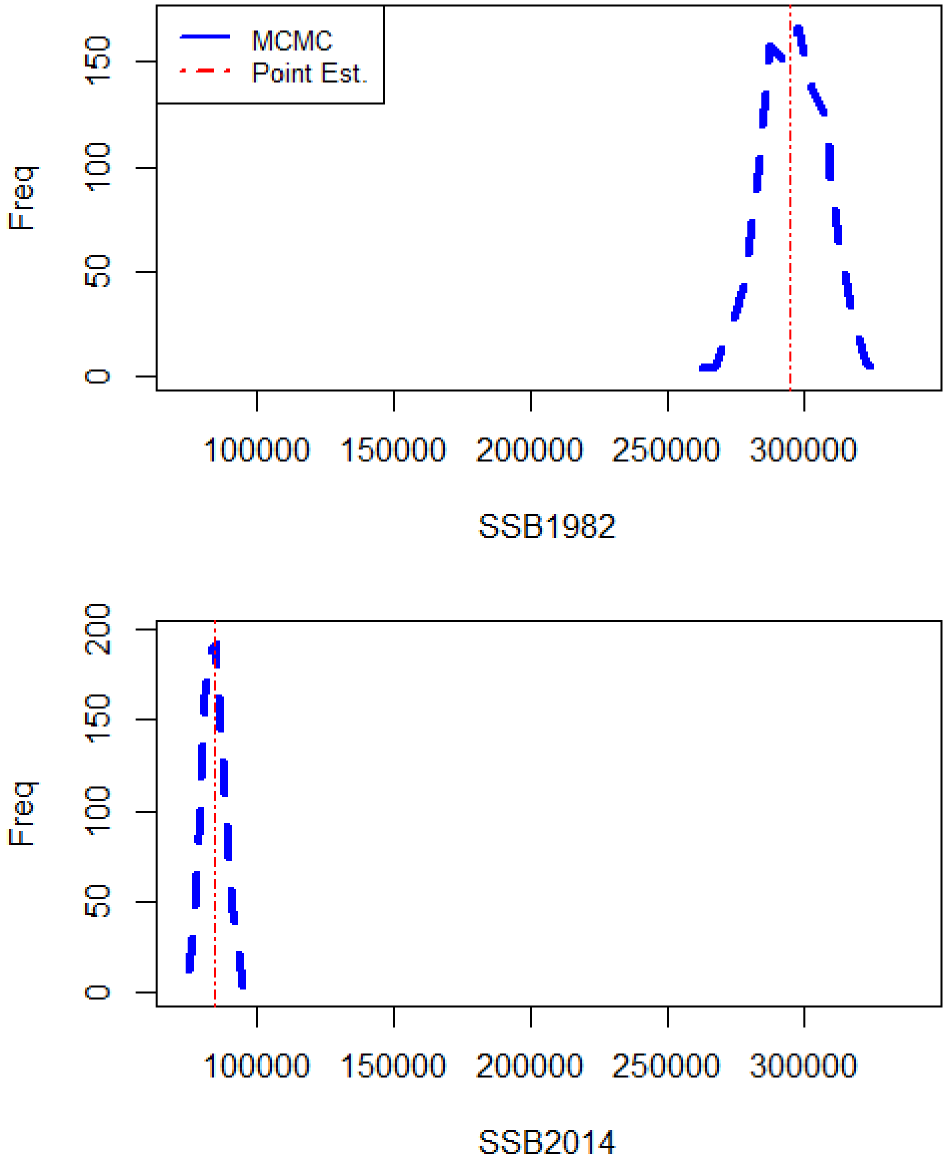


Figure B7.7. MCMC distribution of bluefish spawning stock biomass in 1982 and 2014 from 1000 iterations (thinning factor of 1000) of the continuity model (B001).

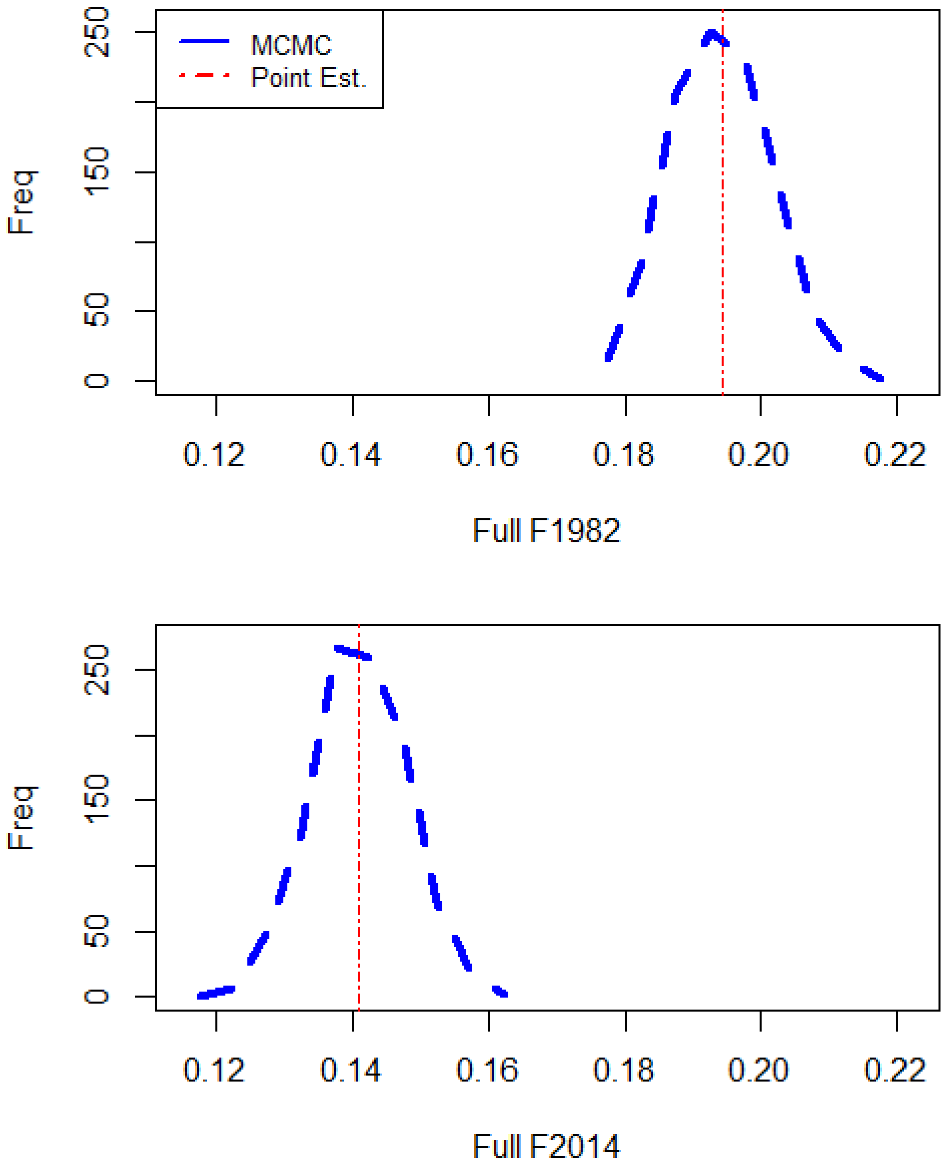


Figure B7.8. MCMC distribution of bluefish fishing mortality in 1982 and 2014 from 1000 iterations (thinning factor of 1000) of the continuity model (B001).

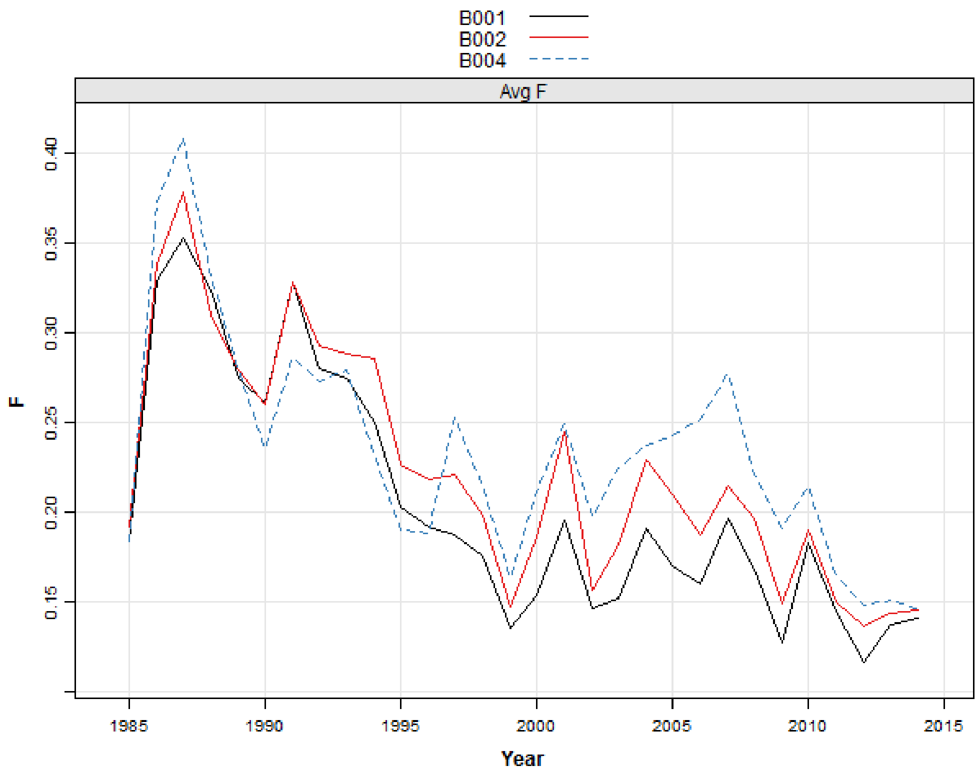


Figure B7.9. A comparison of bluefish fishing mortality estimates between the continuity run (B001: 1982-2014), the cropped continuity run (B002: 1985-2014), and the base model run (B004: 1985-2014).

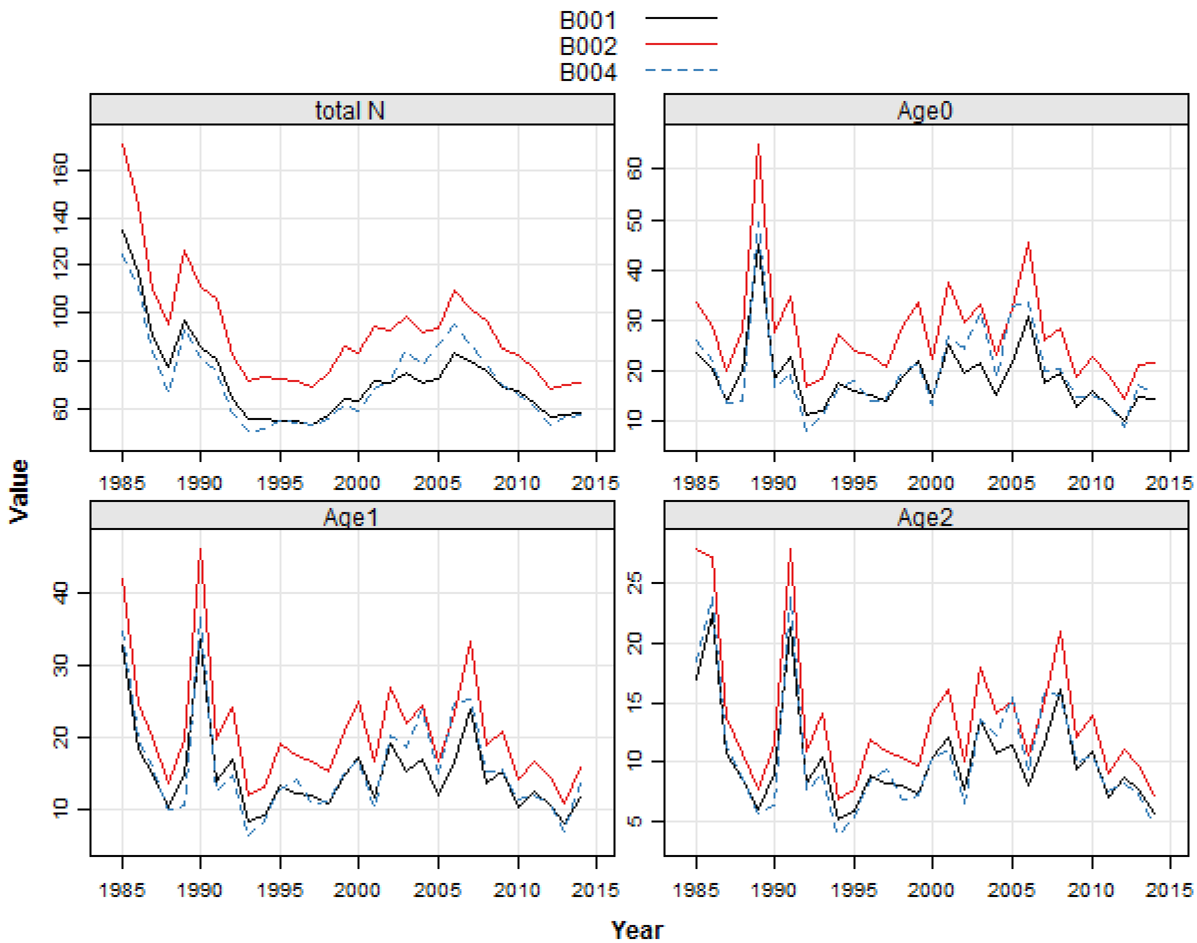


Figure B7.10. A comparison of bluefish total stock numbers and numbers at age for age 0 – age 2. Consistently lower estimates for numbers at age 0 to age 2 for model B004 are driving the differences in total stock numbers and recruitment from model B002.

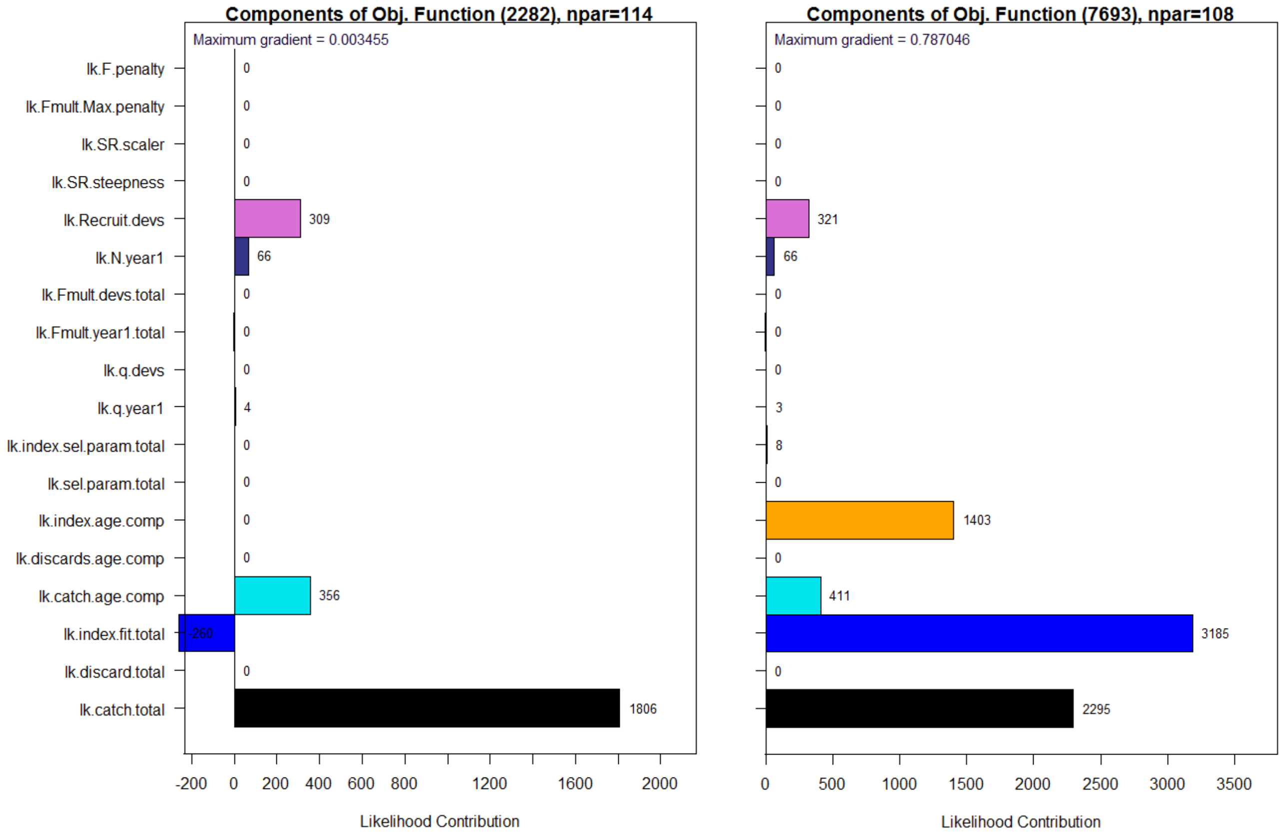


Figure B7.11. Overall contributions to the likelihood for components of model B004 (left) and B006 (right). Indices for model B006 are now input in catch-at-age format and age composition is estimated. The model is still heavily weighted to the catch, but the indices are now the majority of the objective function.

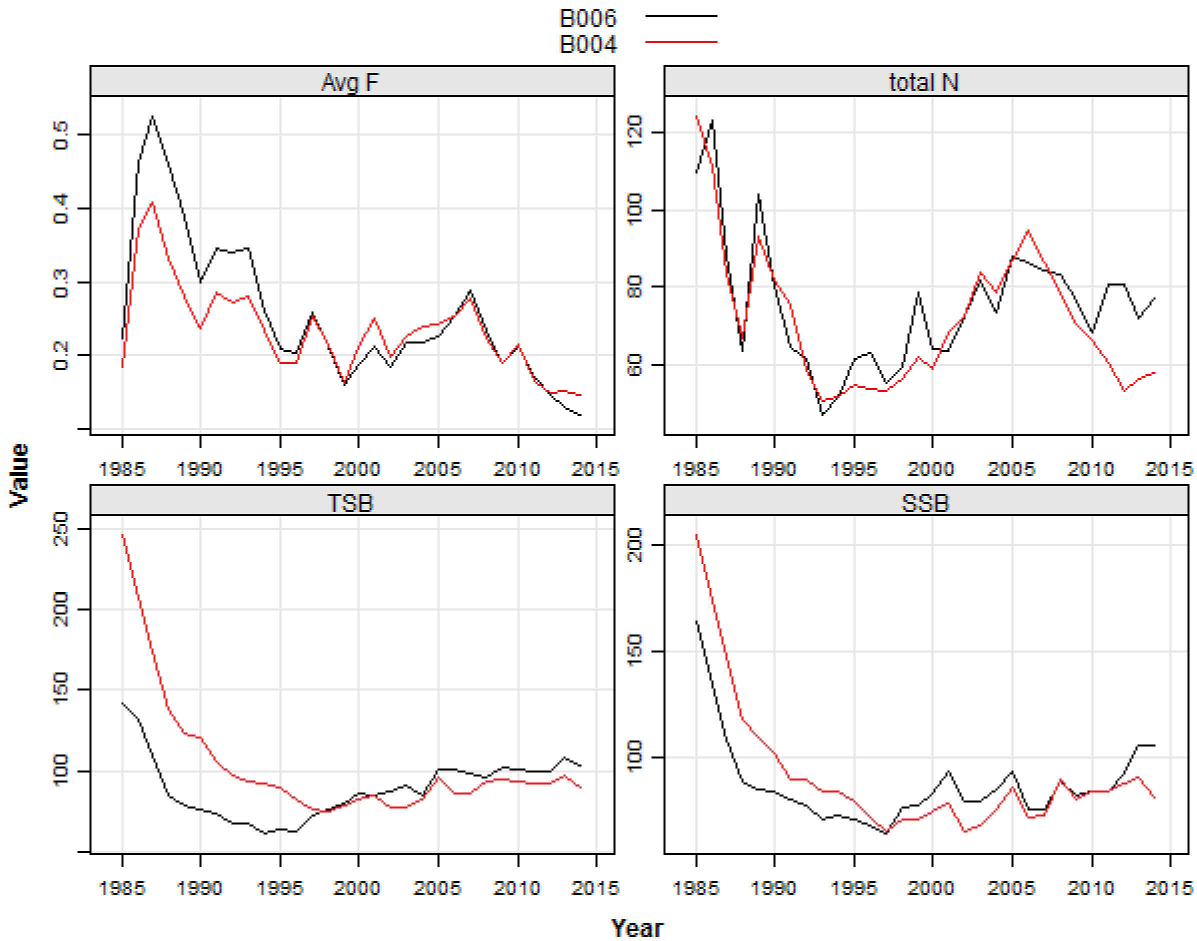


Figure B7.12. A comparison of bluefish fishing mortality, total stock numbers, total biomass, and spawning stock biomass between models B004 and B006. Estimating age composition for the survey indices results in a lower F, and higher 2014 estimates of TSN, TSB, and SSB. In addition, fitting to the age composition of the surveys decreases the scale of biomass at the beginning of the time series.

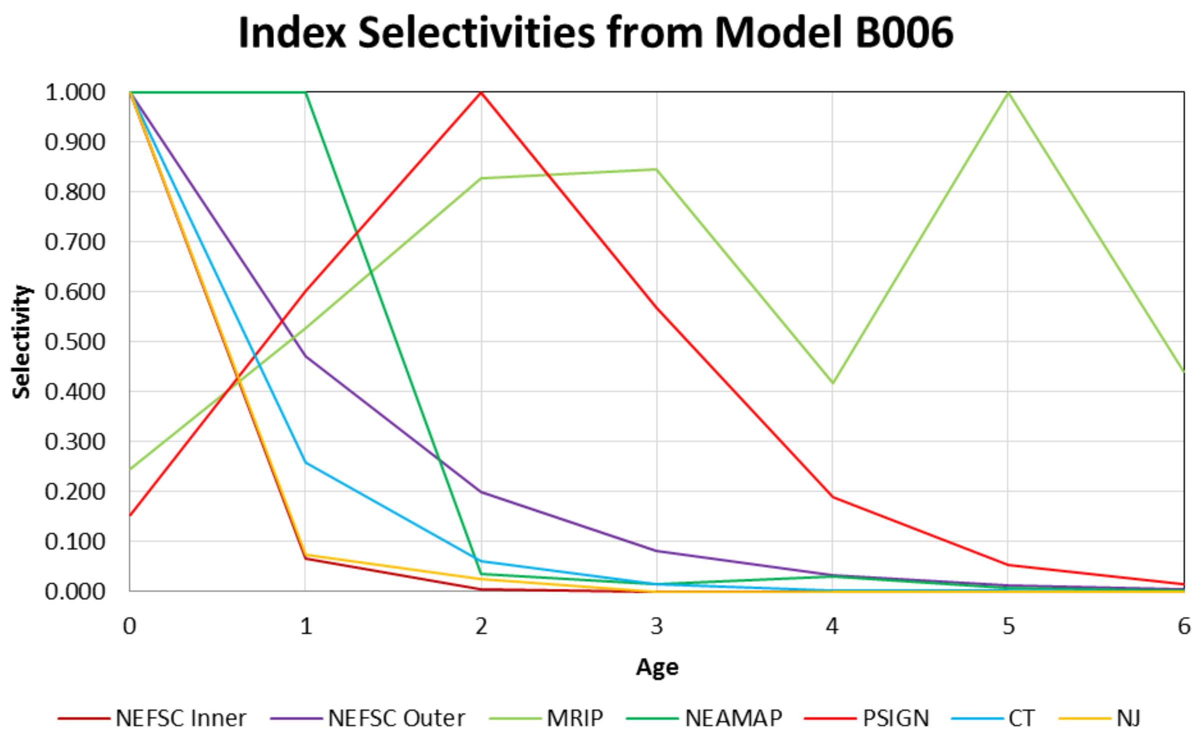


Figure B7.13. Index selectivity estimates from model B006, where the indices were input in a catch-at-age format to estimate age composition.

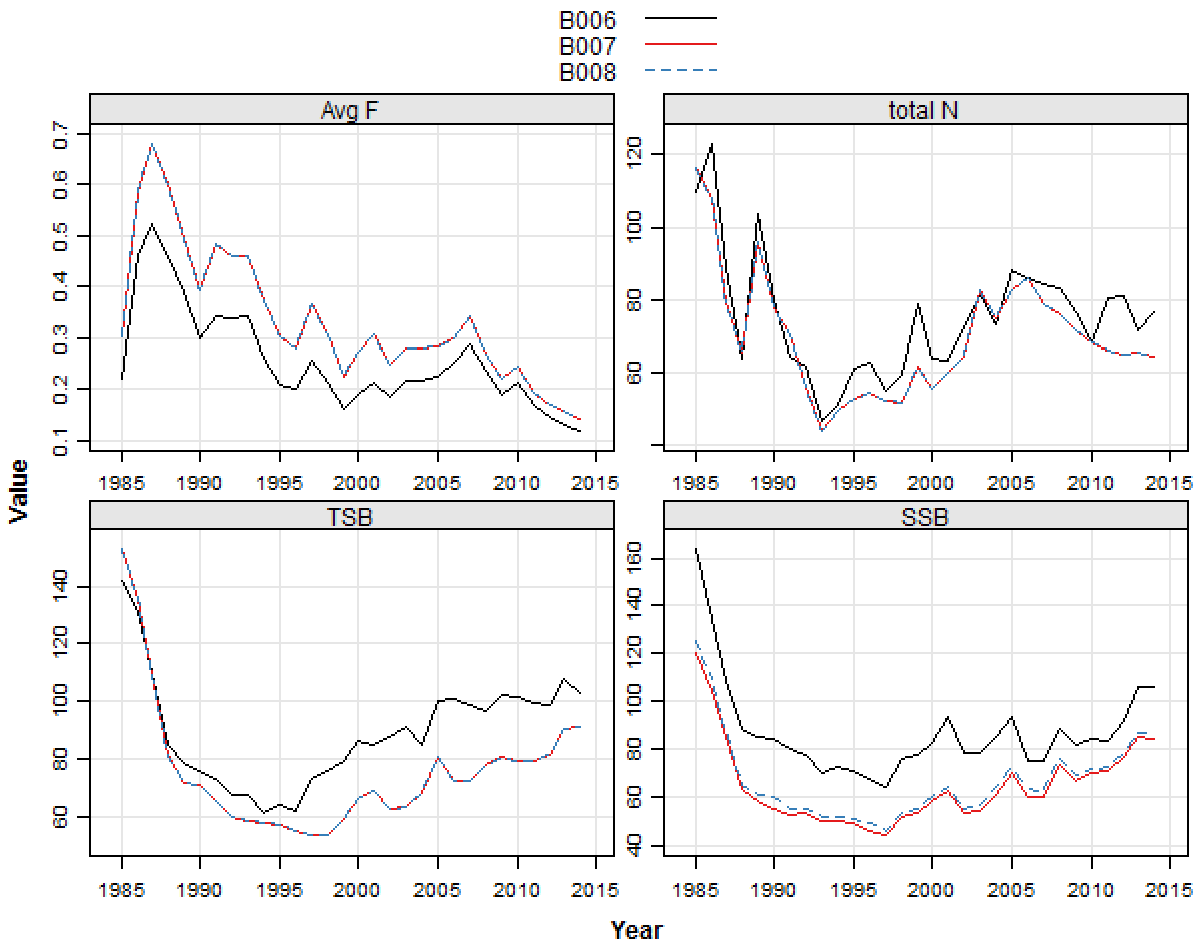


Figure B7.14. A comparison of bluefish fishing mortality, total stock numbers, total biomass, and spawning stock biomass between models B006, B007 (2 fleets) and B008 (new maturity-at-age). Separating the input data into separate commercial and recreational fleets increased the scale of fishing mortality and scaled down the time-series of total numbers and biomass. New maturity information in model B008 resulted in only a slight increase in SSB.

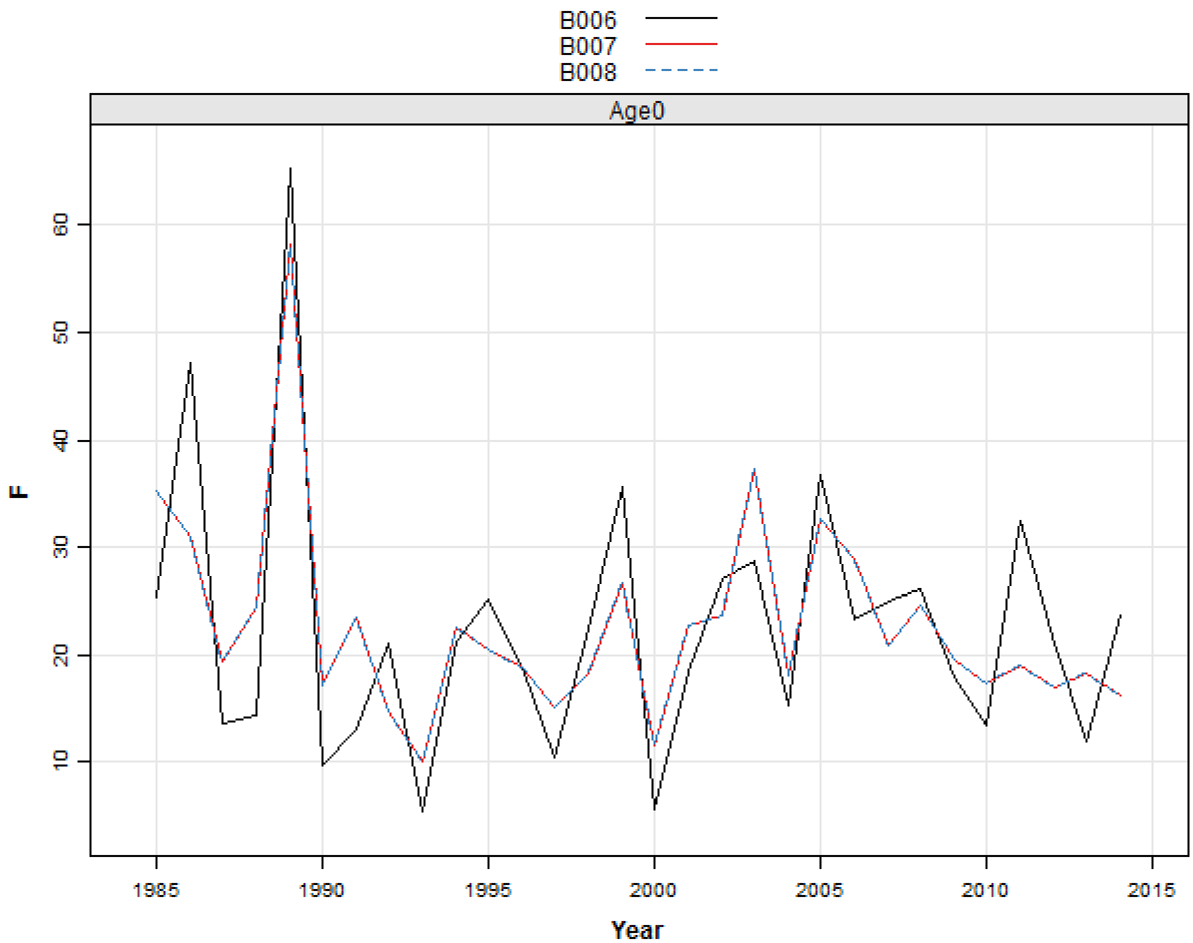


Figure B7.15. The separation of data into a commercial and recreational fleet did not change the recruitment time-series significantly but resulted in a smoother trend at the end of the B007 time-series.

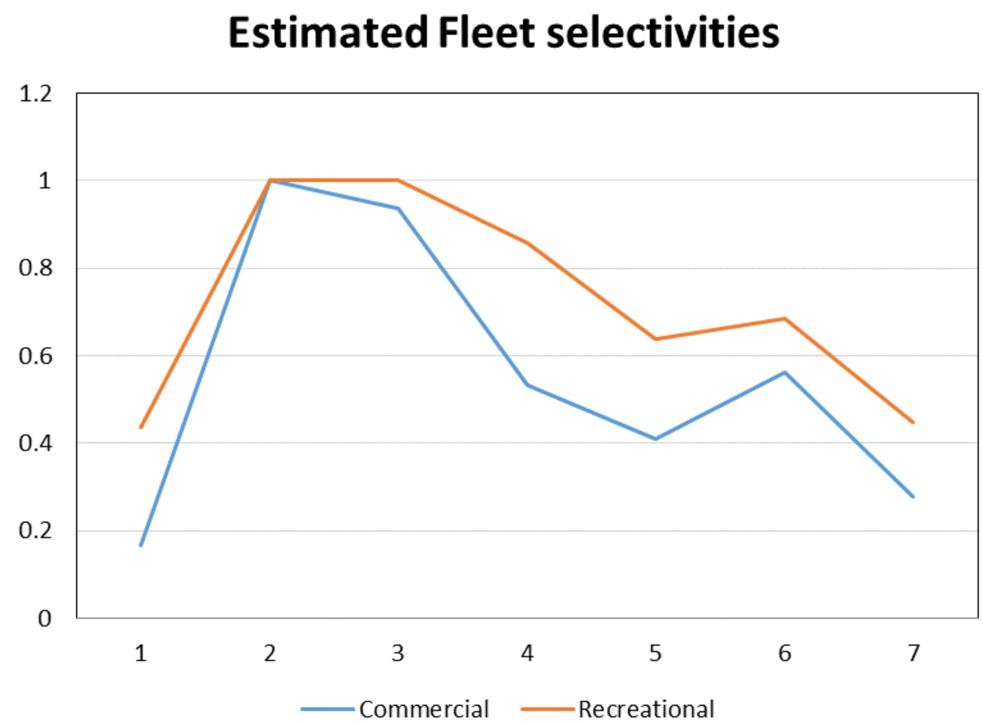


Figure B7.16. Estimated commercial and recreational fleet selectivities from model B011. Note that age class labels are 1 greater than the modeled age class, so that “age-1” corresponds to age 0, “age-2” corresponds to age 1, etc.

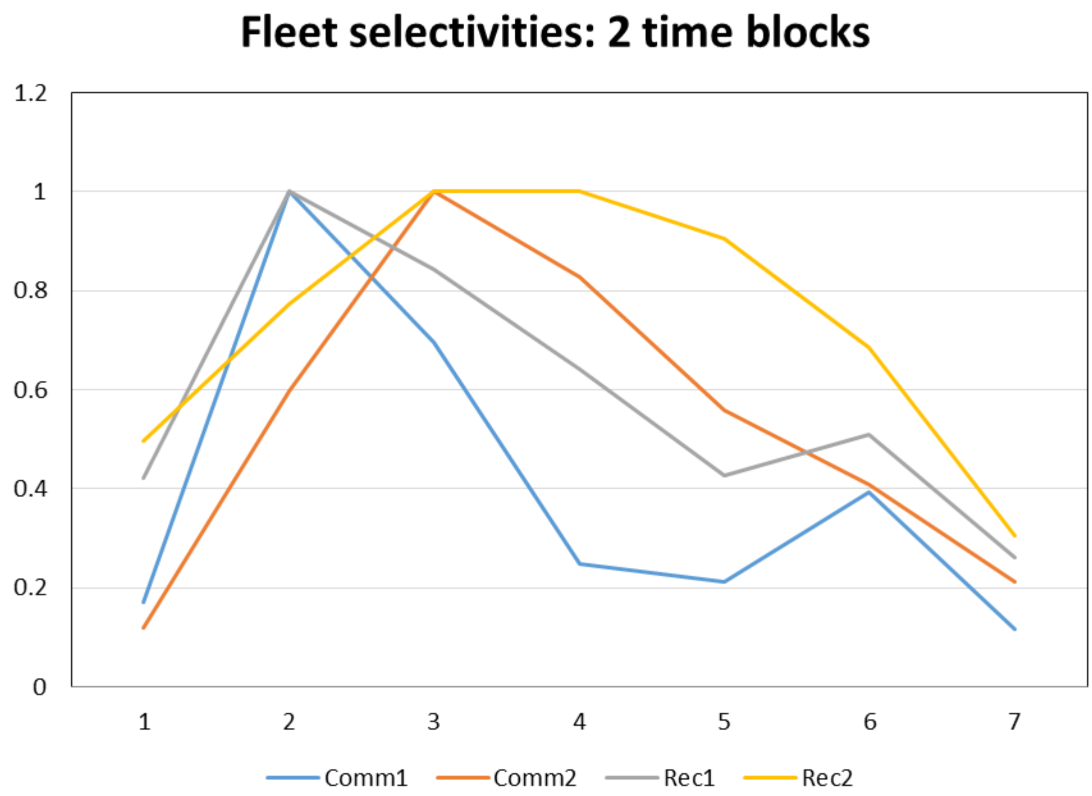


Figure B7.17. Estimated commercial and recreational fleet selectivities in two time blocks (1985-2005 and 2006-2014) from model B020. Note that age class labels are 1 greater than the modeled age class, so that “age-1” corresponds to age 0, “age-2” corresponds to age 1, etc.

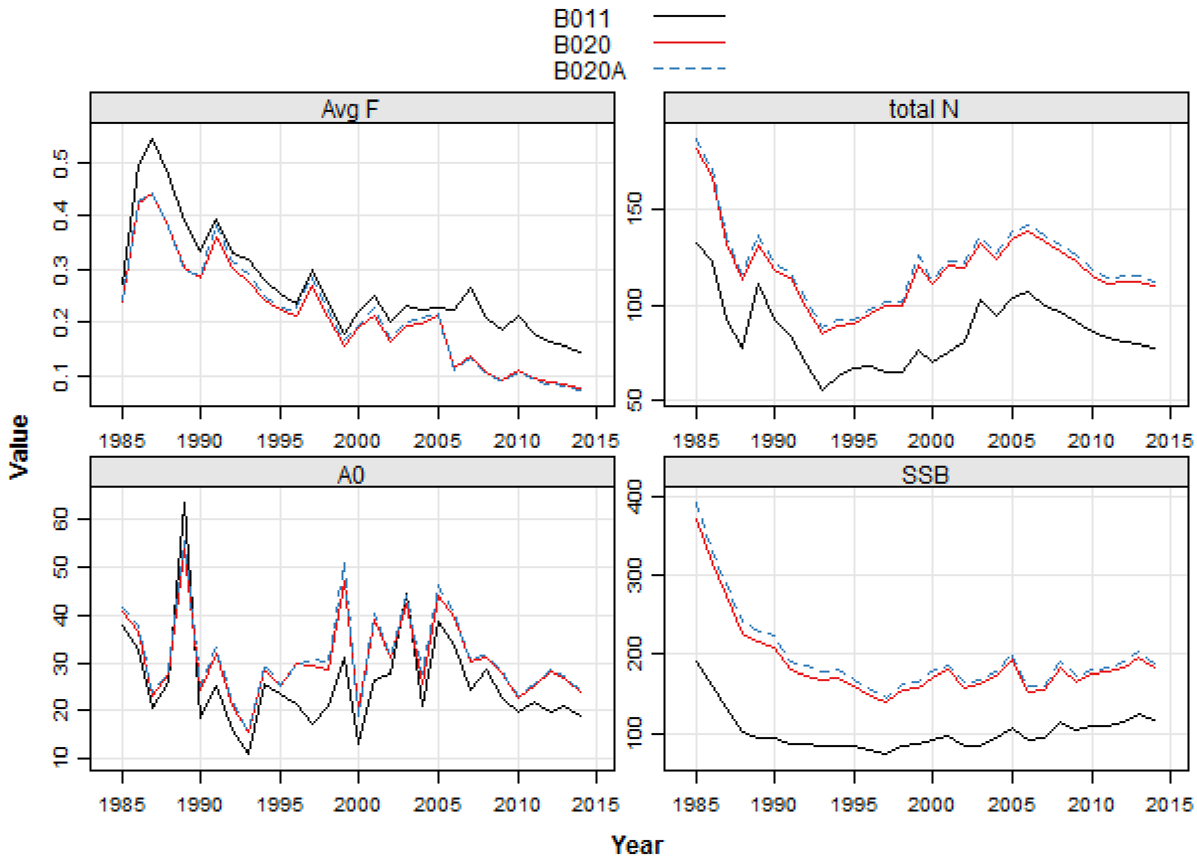


Figure B7.18. A comparison of bluefish fishing mortality, total stock numbers, recruitment, and spawning stock biomass between models B011, B020 (2 fleet selectivity blocks) and B020A (ESS = 0 for 1997-2005). Adding 2 selectivity blocks to the fleets decreases fishing mortality estimates and increases stock numbers, recruitment, and biomass estimates.

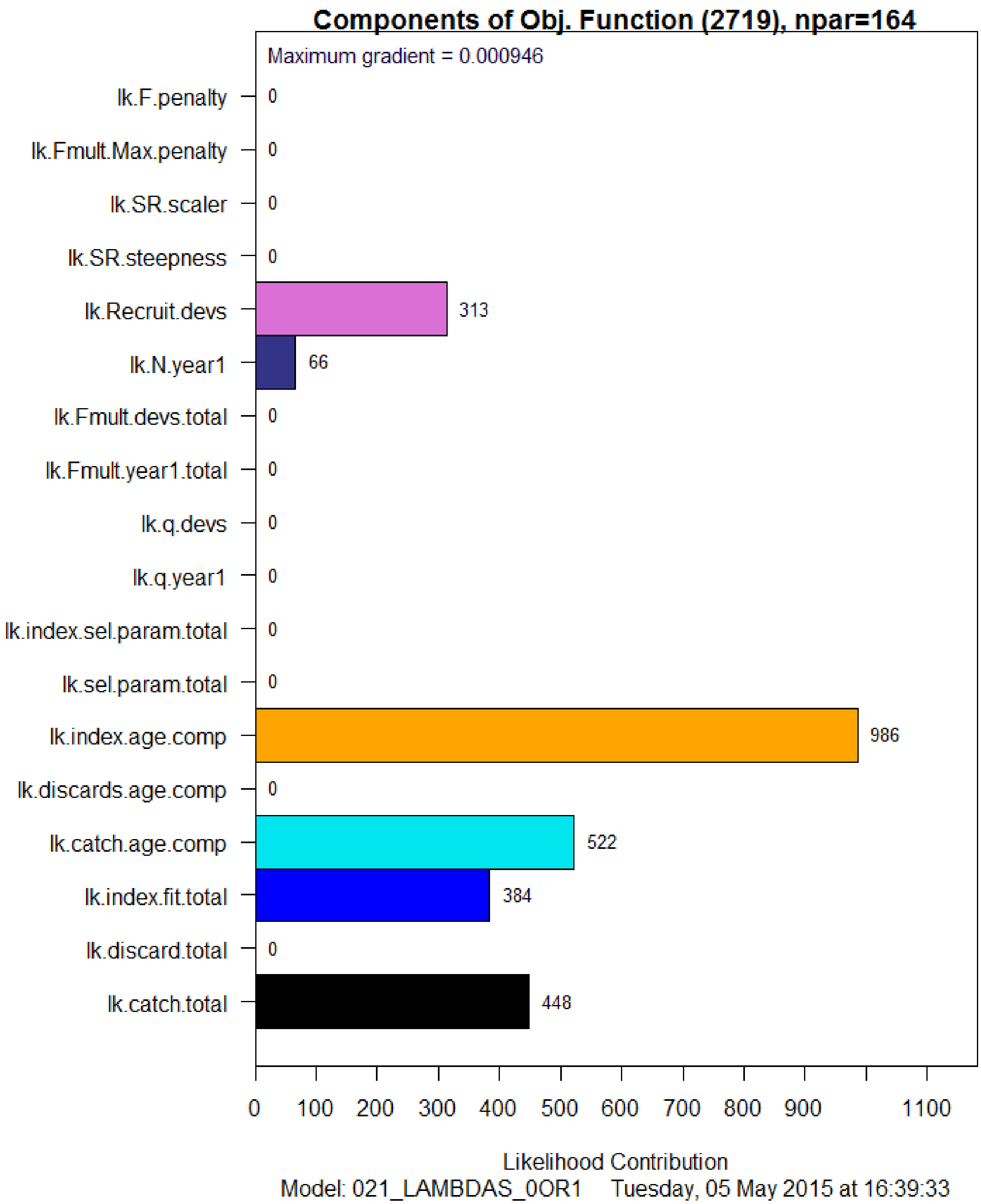


Figure B7.19. Overall contributions to the likelihood for components of model B021. This model shifted the lambdas to 1's or 0's, acting as switches to turn on or off the components of the objective function. If lambda is turned on for a component it is then included in the objective function and associated input CV is used as a weight (acting like a prior).

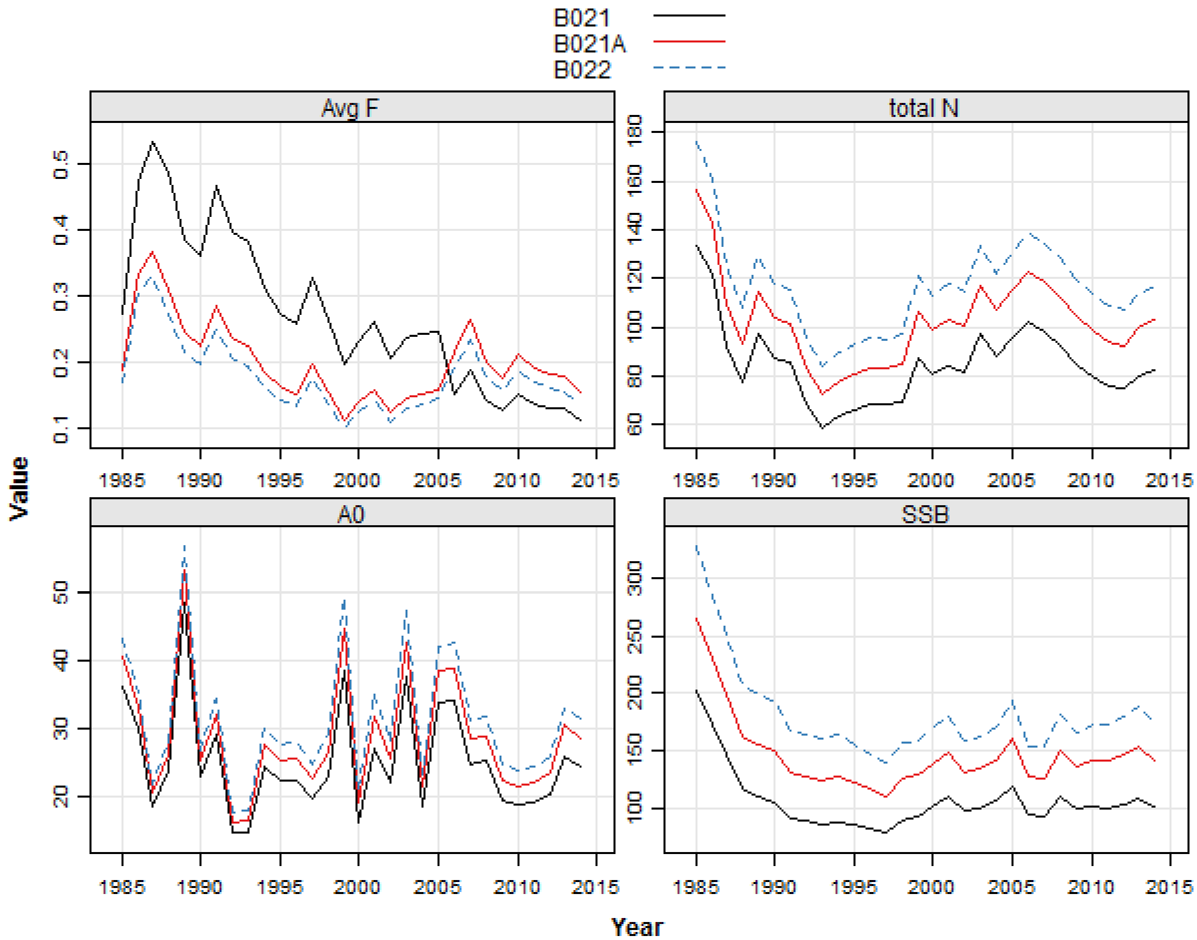


Figure B7.20. A comparison of bluefish fishing mortality, total stock numbers, recruitment, and spawning stock biomass between models B021 (new model weighting: Lambdas = 0 or 1), B021A (Likelihood constants off) and B022 (penalty on Nyear1 off).

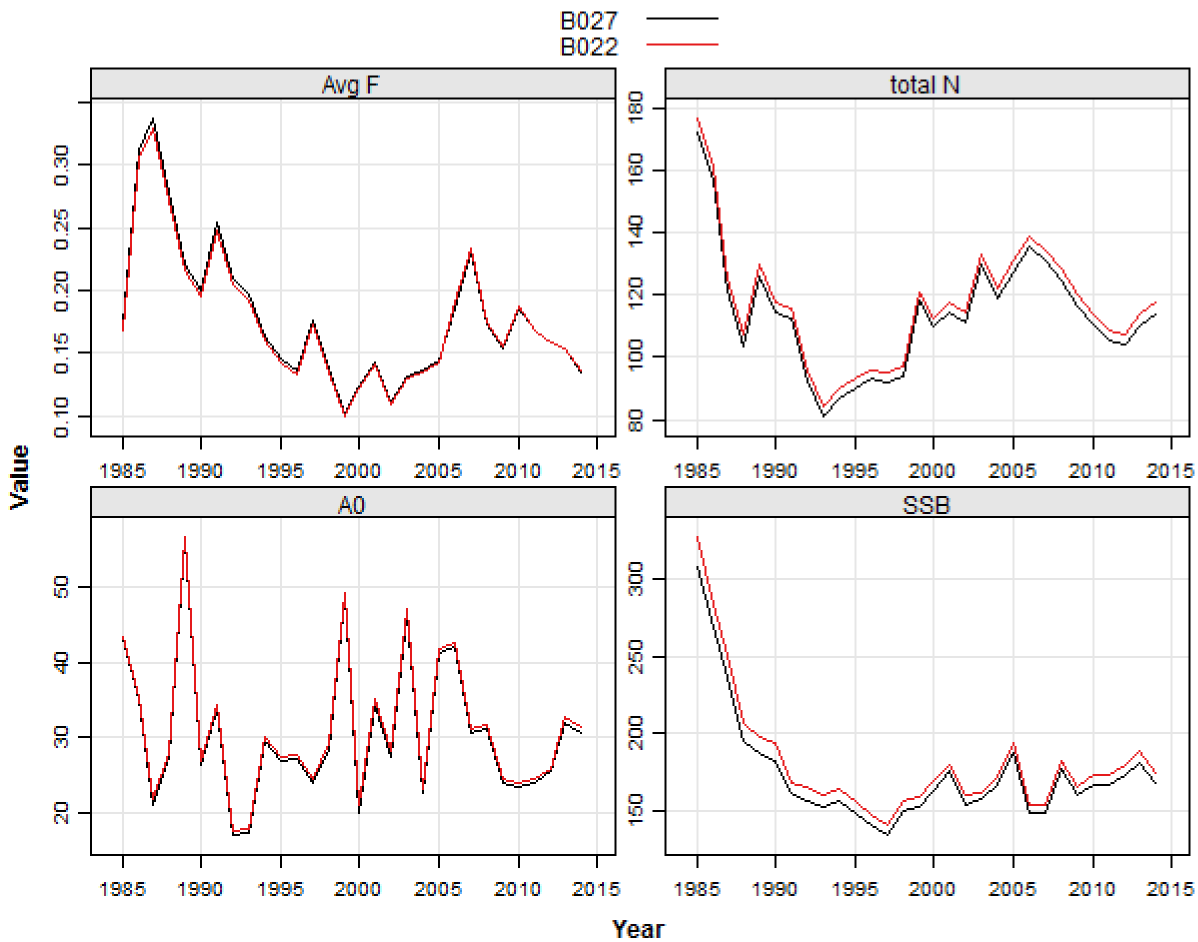


Figure B7.21. Minor changes were made to input CVs and selectivity estimates between model B022 and B027. The result of these changes was very little difference in the estimates of fishing mortality, total stock numbers, recruitment, and spawning stock biomass.

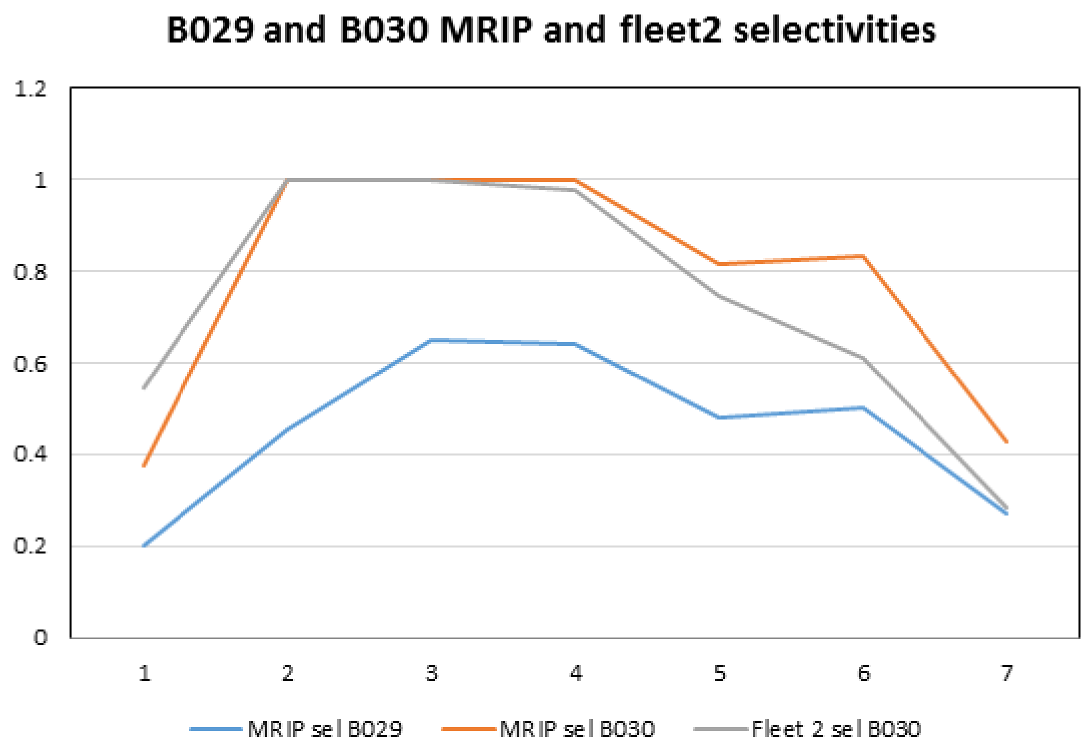


Figure B7.22. MRIP index selectivities and fleet 2 selectivity coming out of model B029 and B030. Note that age class labels are 1 greater than the modeled age class, so that “age-1” corresponds to age 0, “age-2” corresponds to age 1, etc.

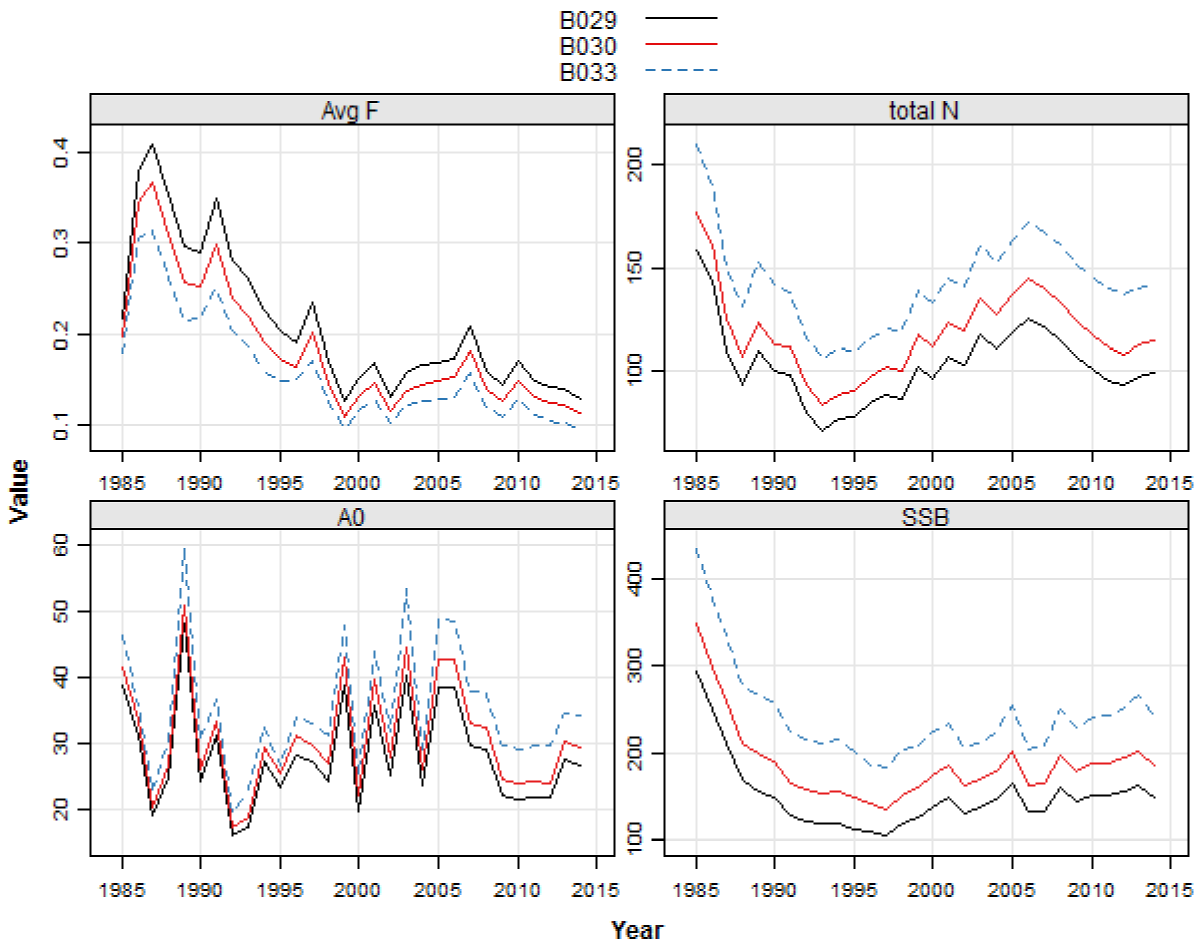


Figure B7.23. A comparison of bluefish fishing mortality, total stock numbers, recruitment, and spawning stock biomass between models B029 (Split off Bigelow survey), B030 (MRIP index selectivity to match fleet 2) and B033 (Corrected NC scale data).

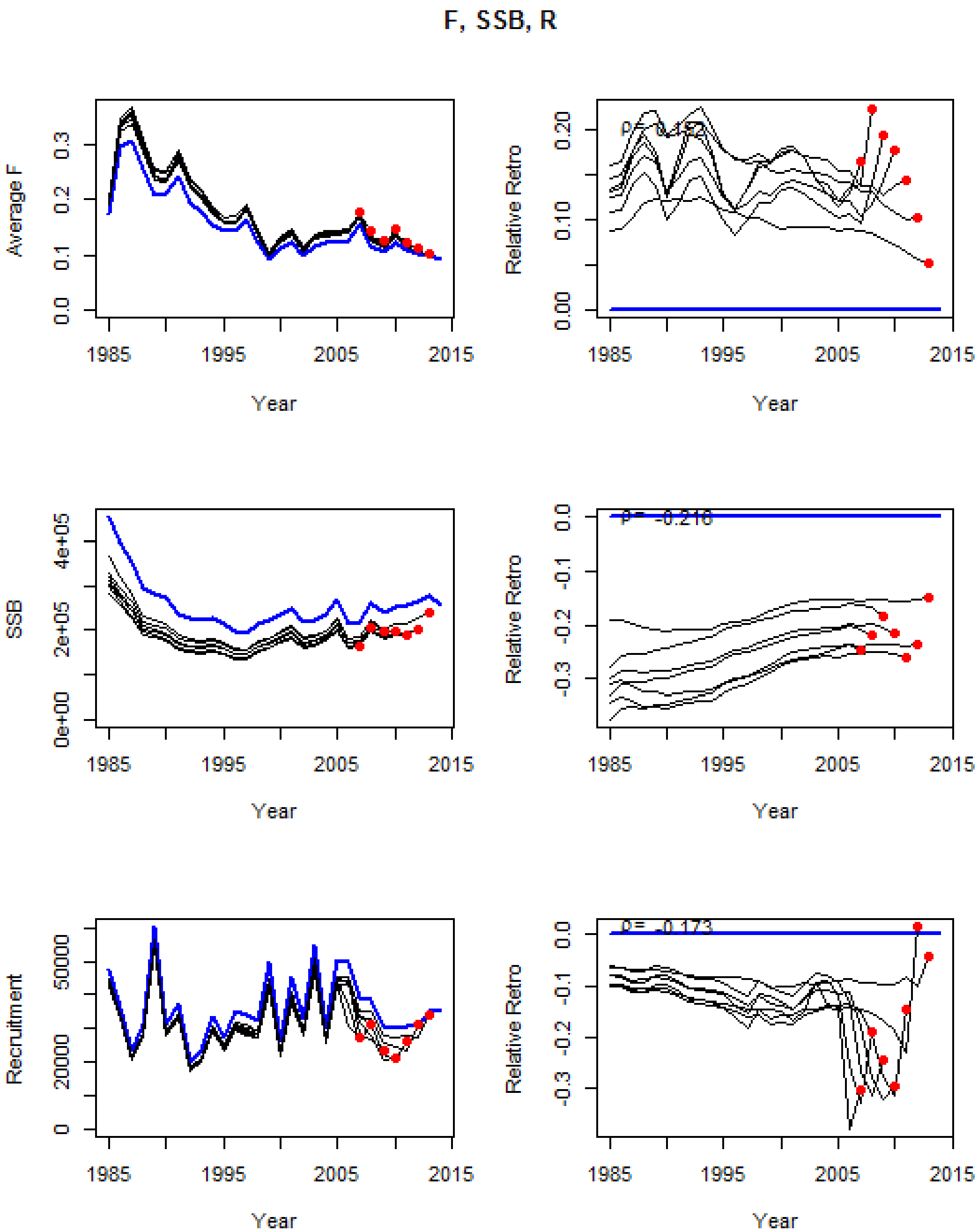


Figure B7.24. Significant retrospective bias in estimates of fishing mortality, spawning stock biomass and recruitment from model B035.

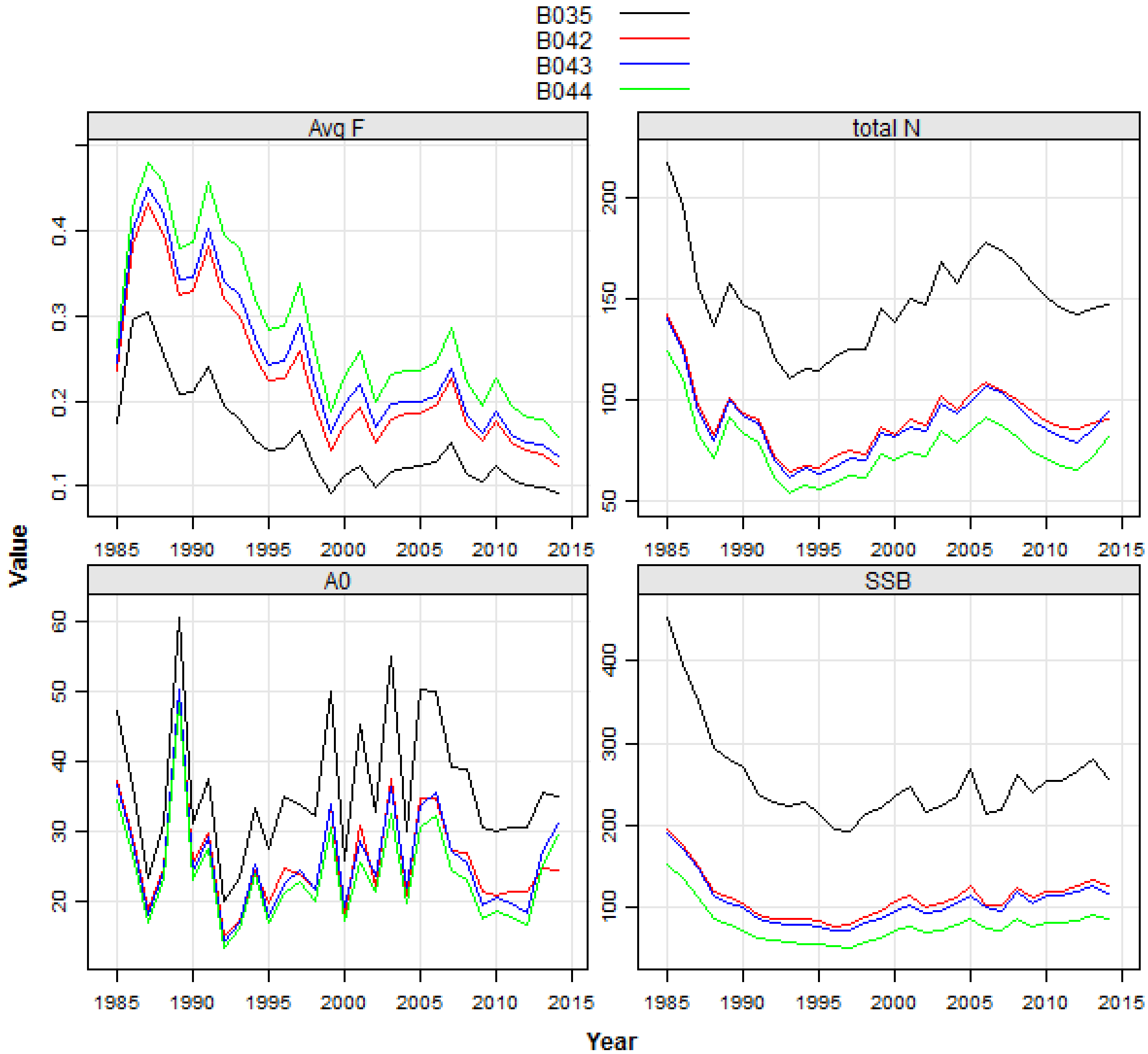
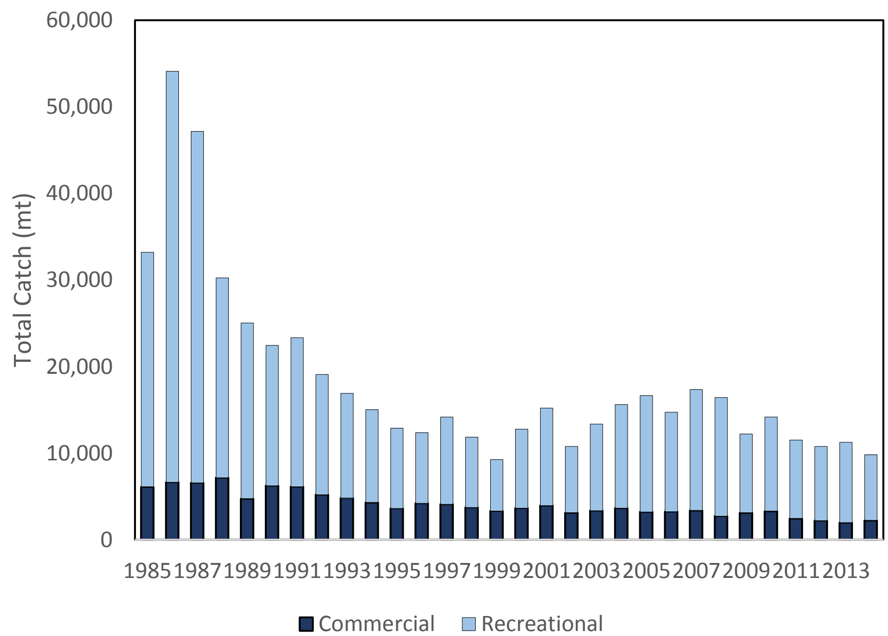


Figure B7.25. A comparison of bluefish fishing mortality, total stock numbers, recruitment, and spawning stock biomass between models B035 (PSIGN to sel-at-age), B042 (MRIP index selectivity to single logistic), B043 (adjustments to CVs and ESS), and B044 (final model accepted by SARC panel).



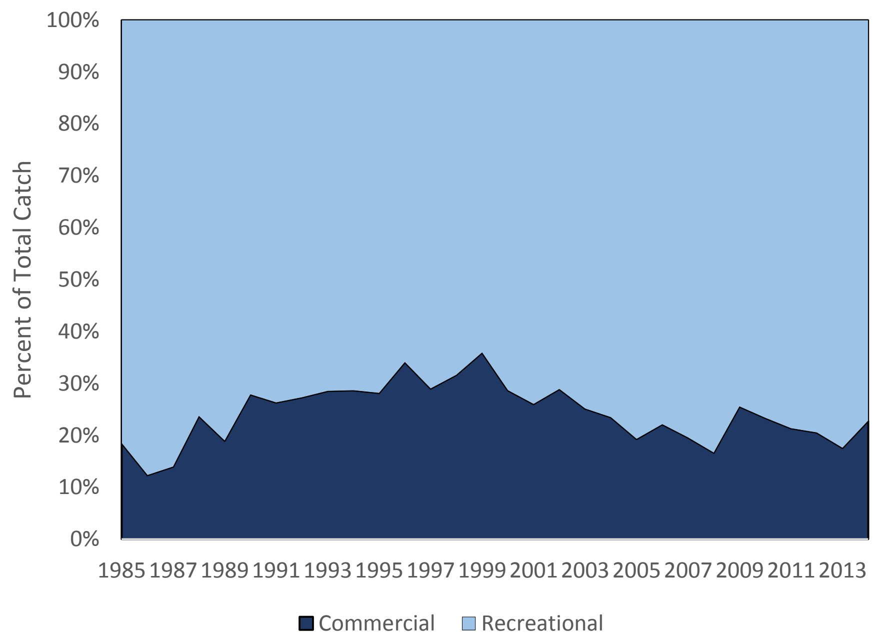


Figure B7.26. Bluefish catch by fleet in metric tons (top) and percent of total catch (bottom) from 1985 to 2014.

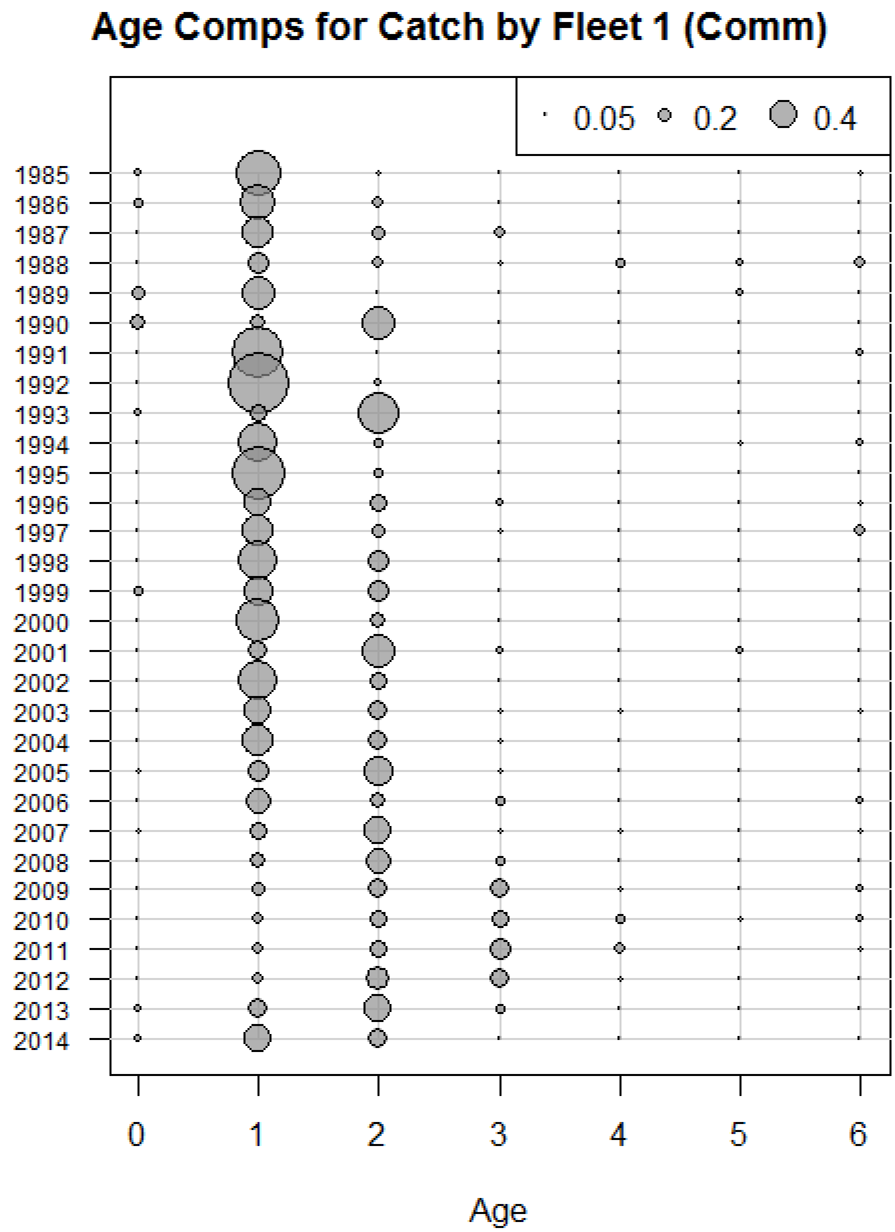


Figure B7.27. Bluefish age composition (catch-at-age) for the commercial fleet input into the final model run.

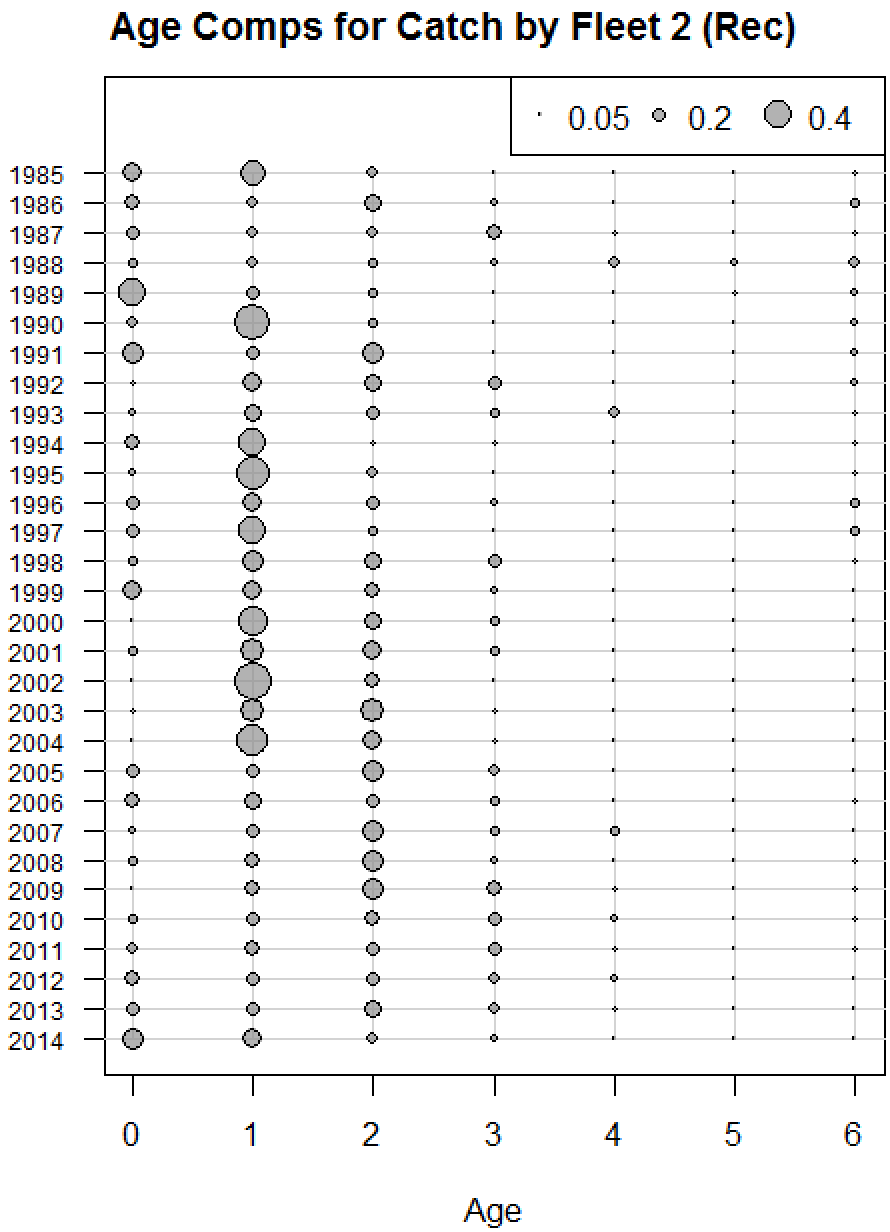


Figure B7.28. Bluefish age composition (catch-at-age) for the recreational fleet input into the final model run.

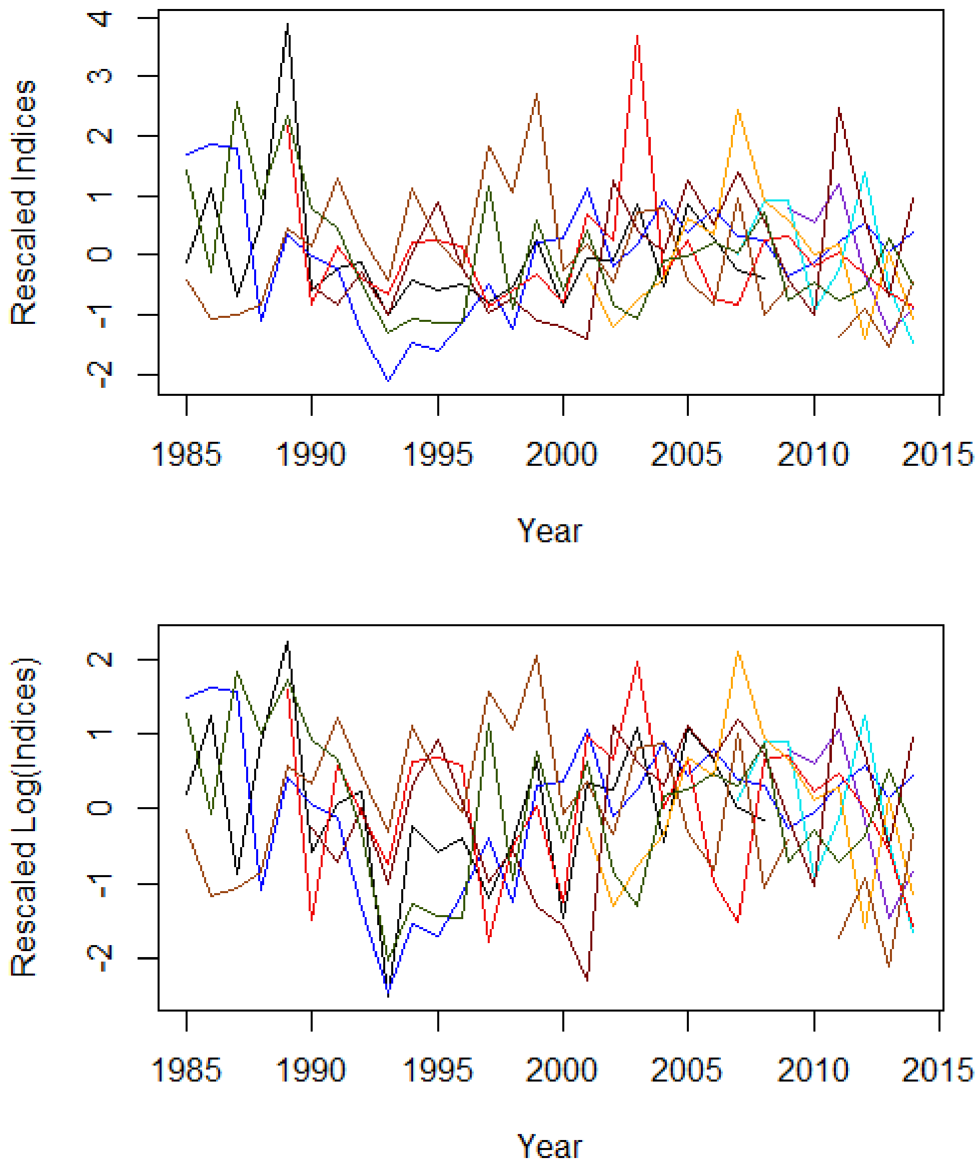


Figure B7.29. Bluefish survey indices re-scaled to their mean values and log-survey indices rescaled to their mean values.

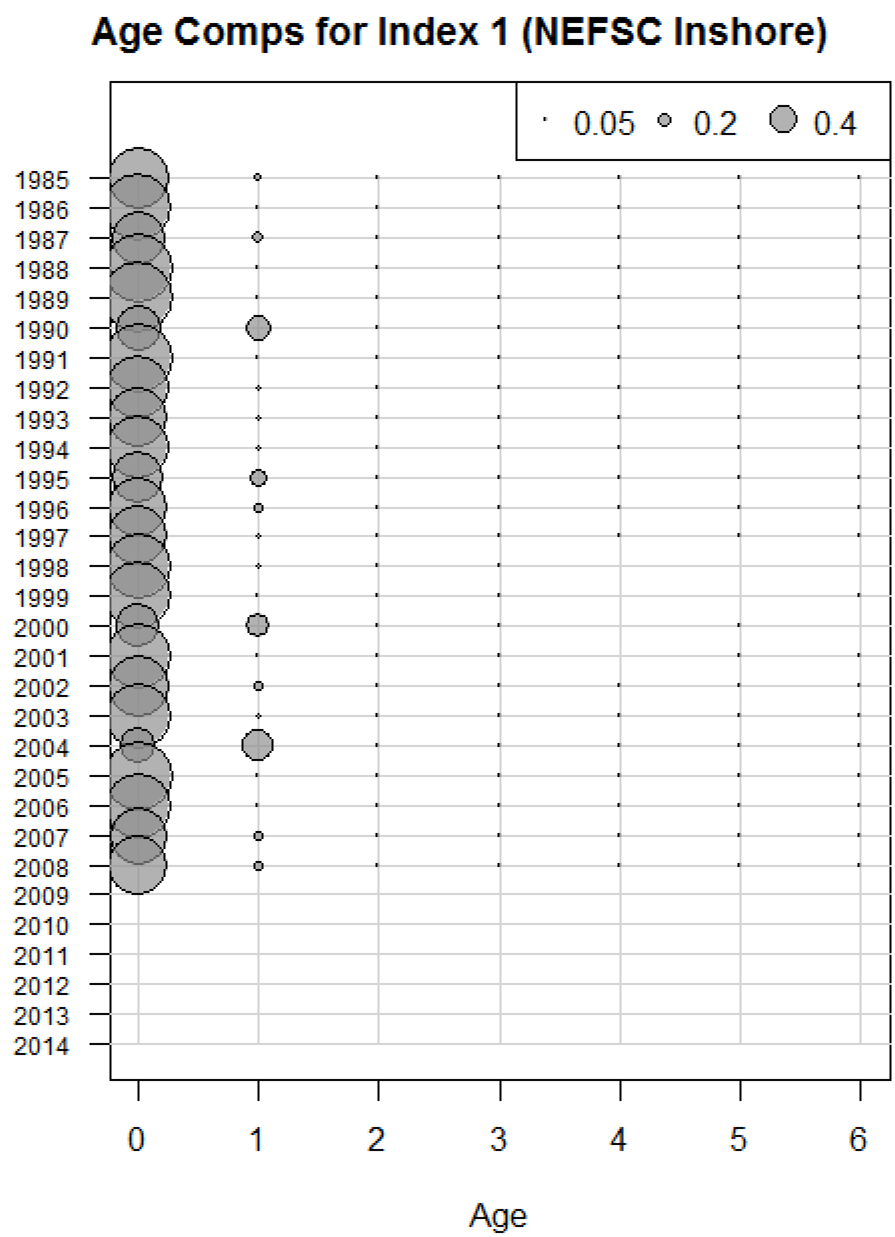


Figure B7.30. Input age composition for the NEFSC Inshore survey (Albatross survey from 1985 to 2008).

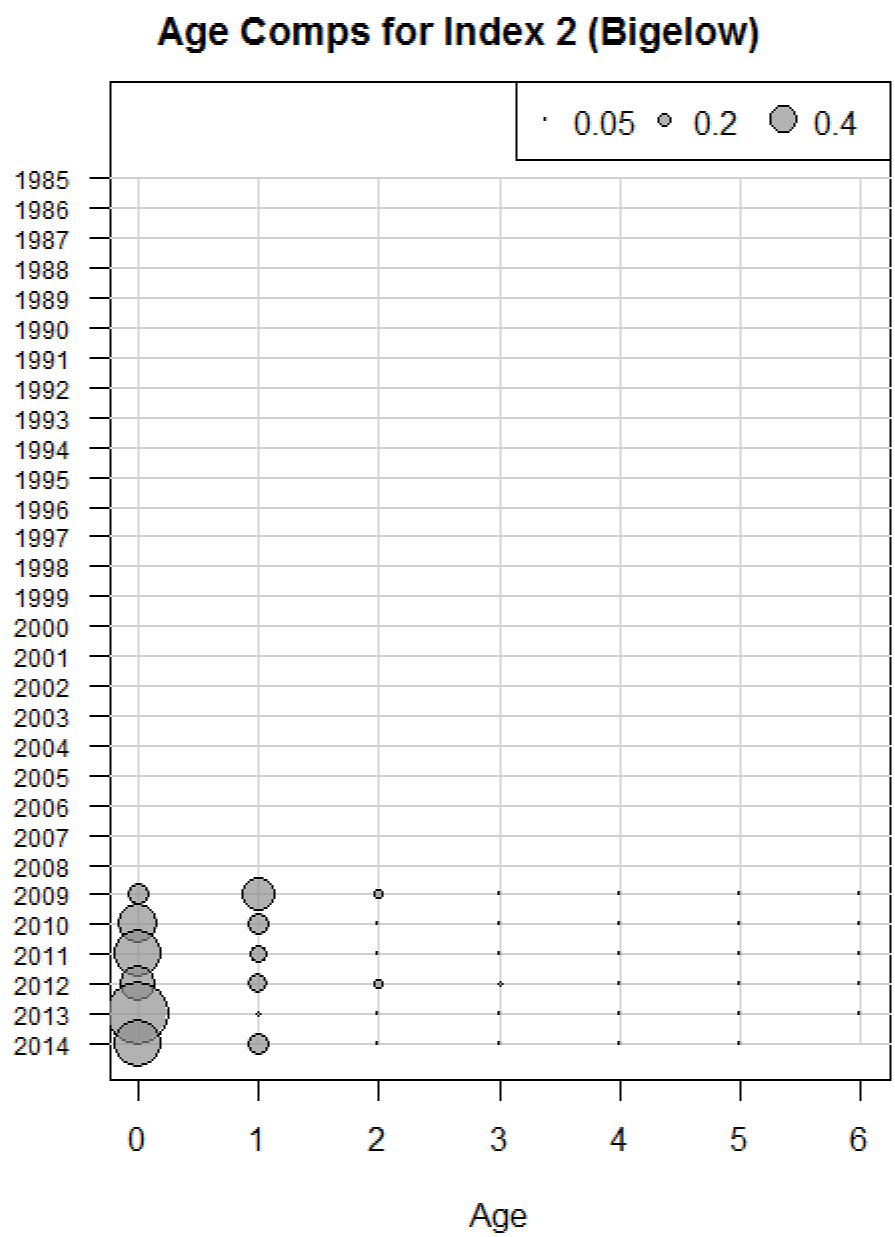


Figure B7.31. Input age composition for the NEFSC Bigelow survey (2009 to 2014).

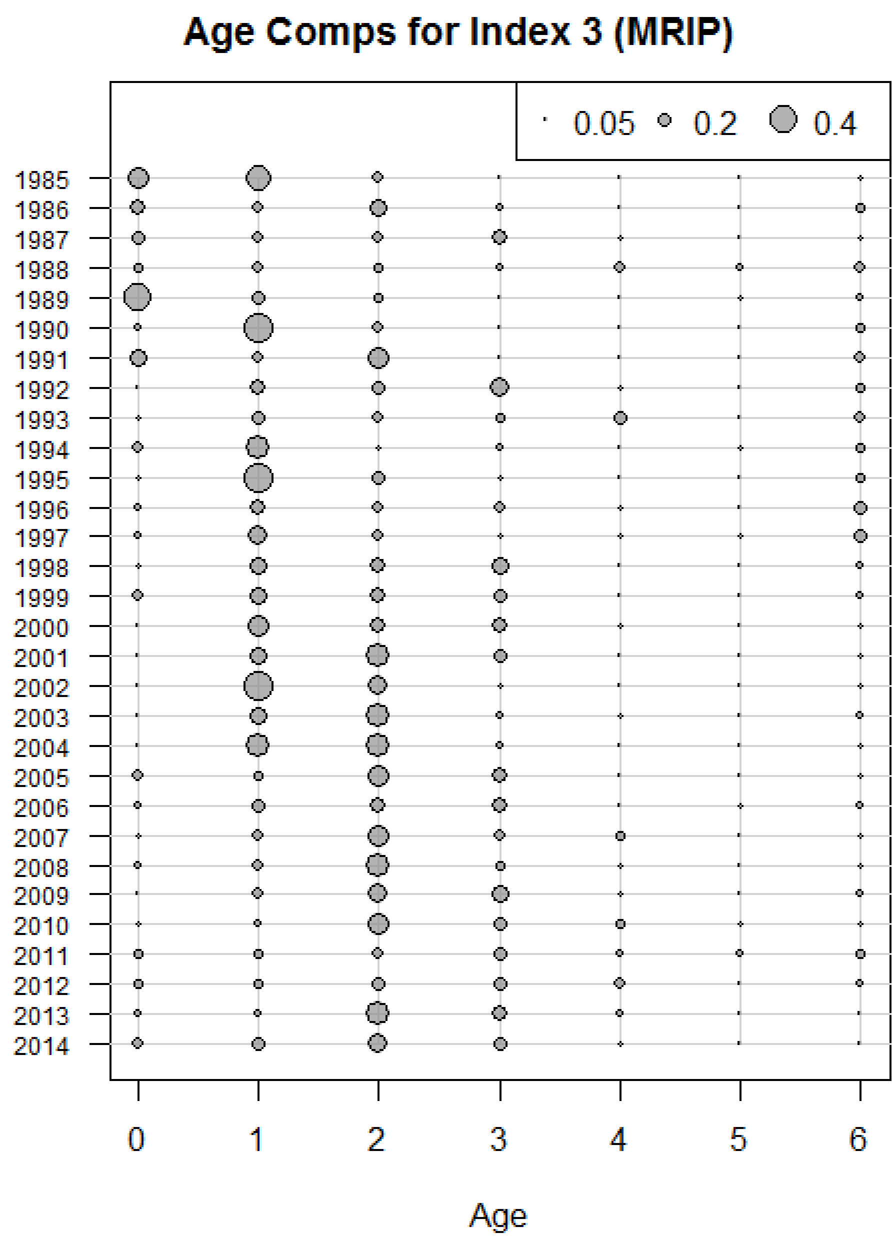


Figure B7.32. Input age composition for the MRIP recreation CPUE index from 1985 to 2014.

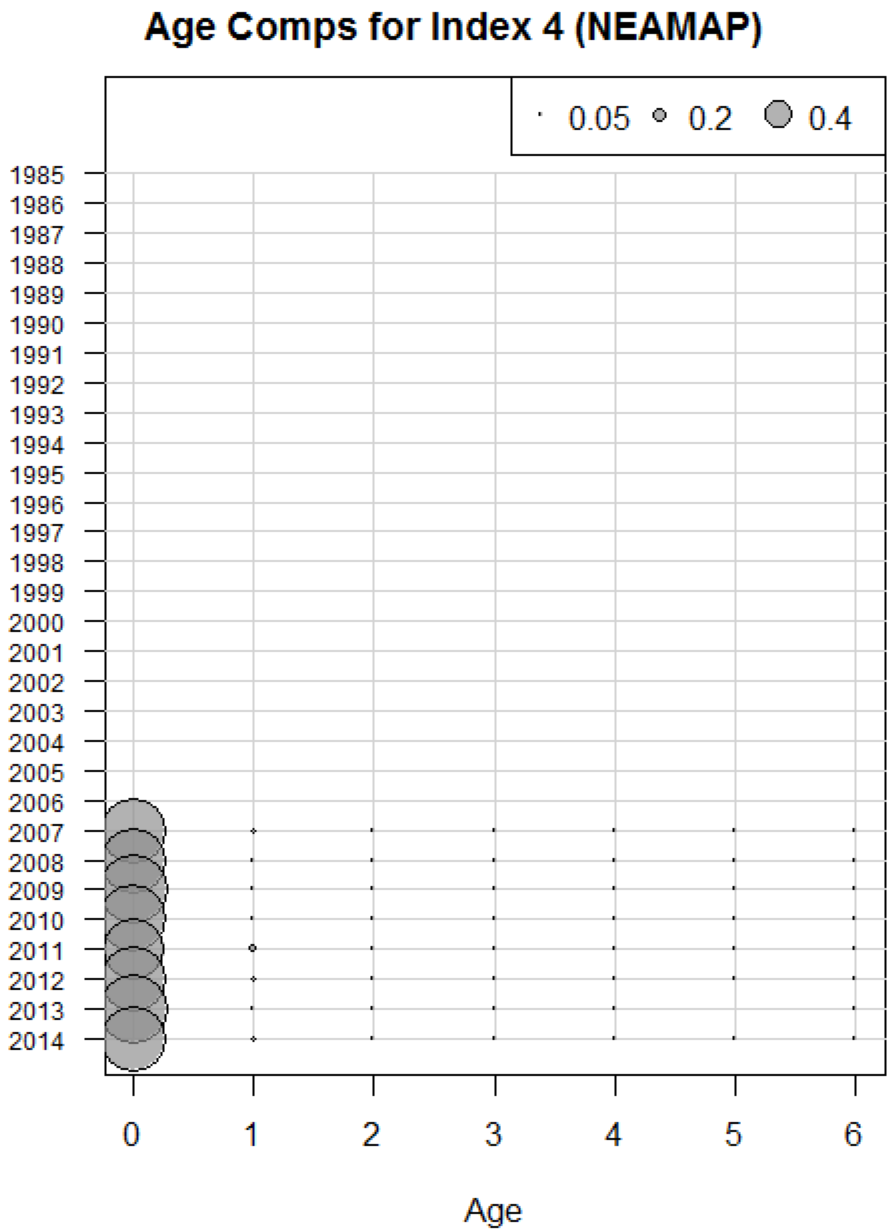


Figure B7.33. Input age composition for the NEAMAP trawl survey index from 2007 to 2014.

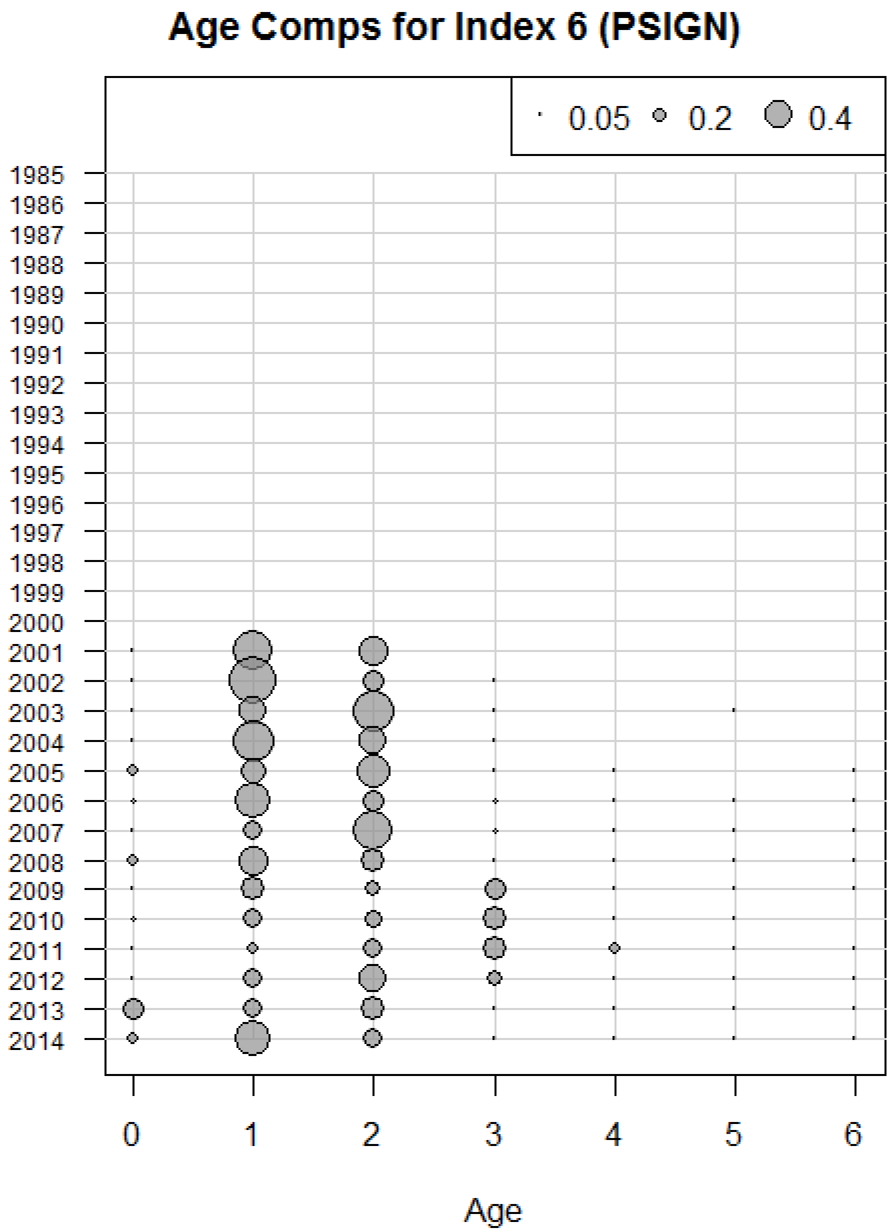


Figure B7.34. Input age composition for the PSIGN gillnet survey index from 2001 to 2014.

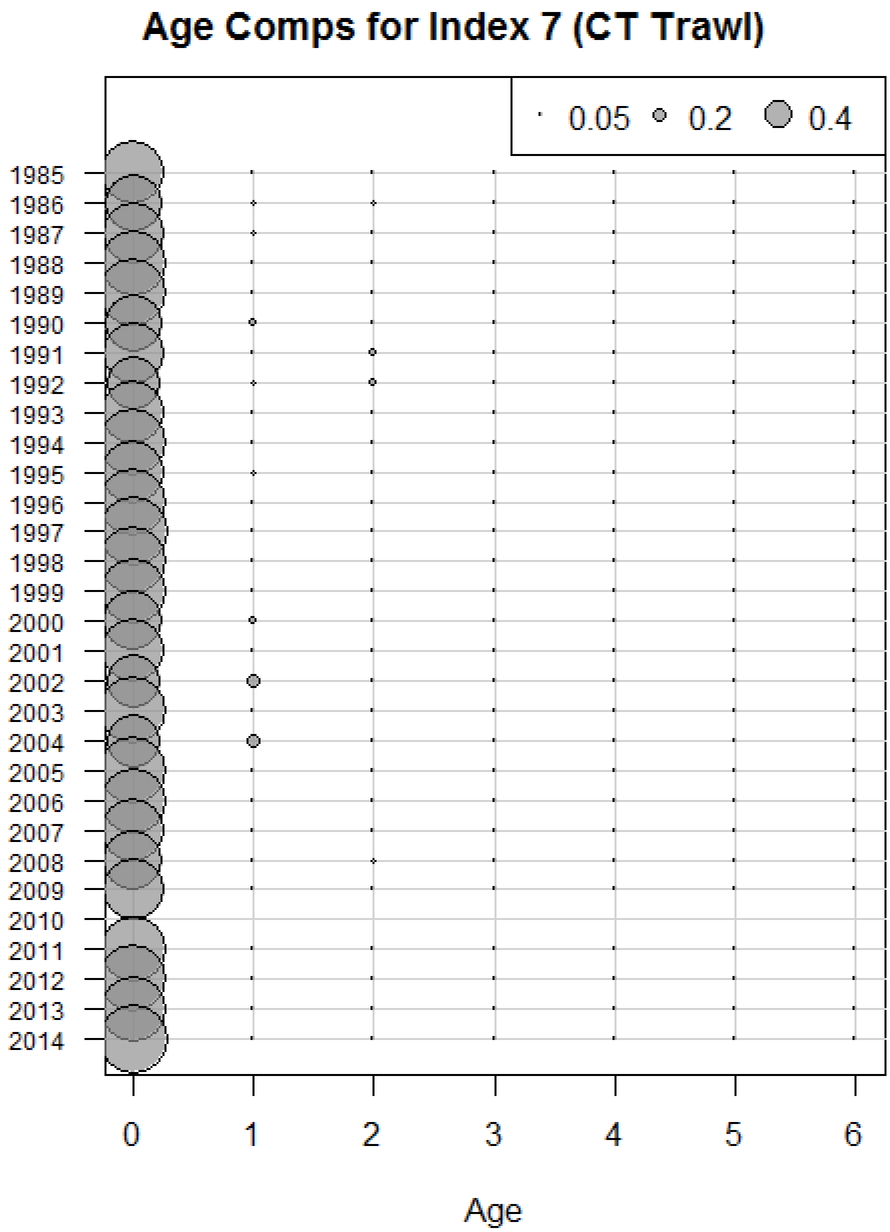


Figure B7.35. Input age composition for the CT LISTS trawl survey index from 1985 to 2014.

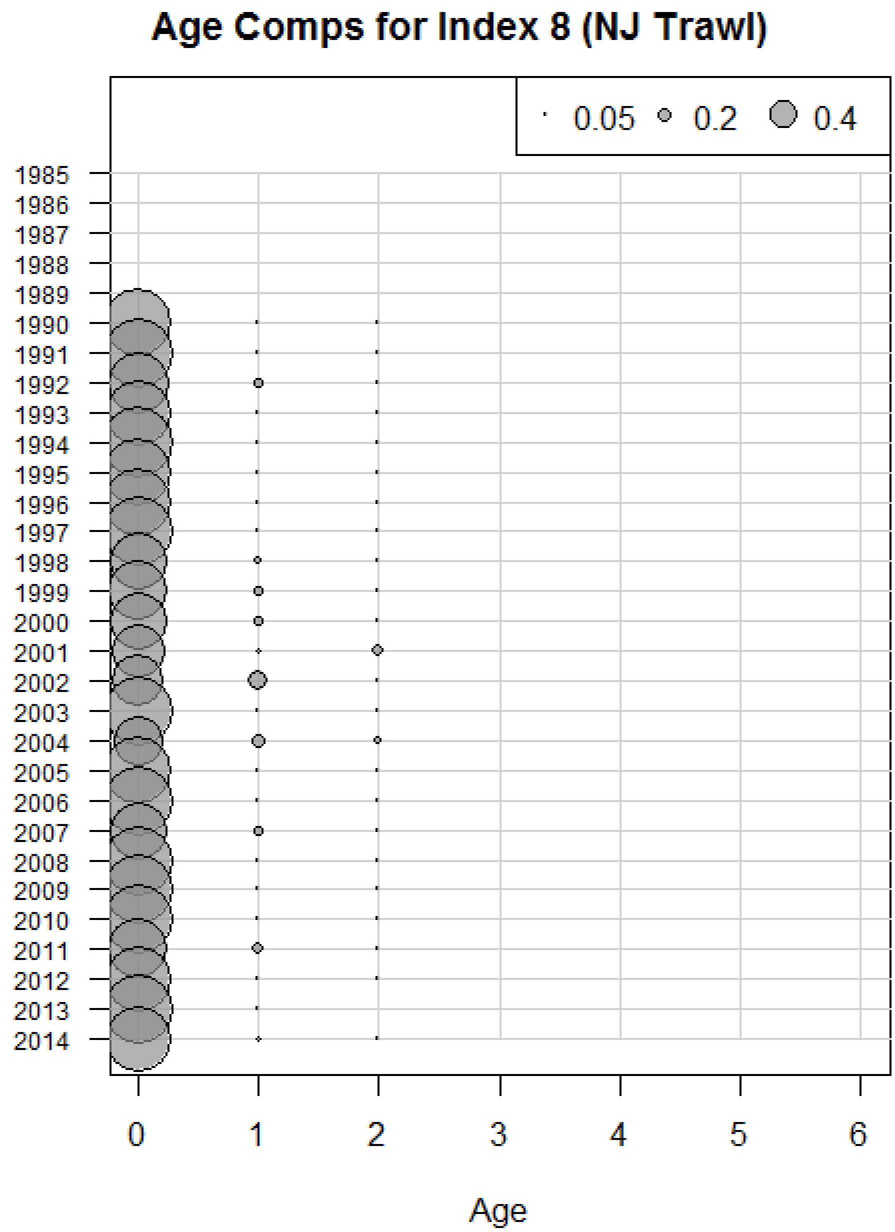


Figure B7.35A. Input age composition for the NJ Ocean trawl survey index from 1990 to 2014.

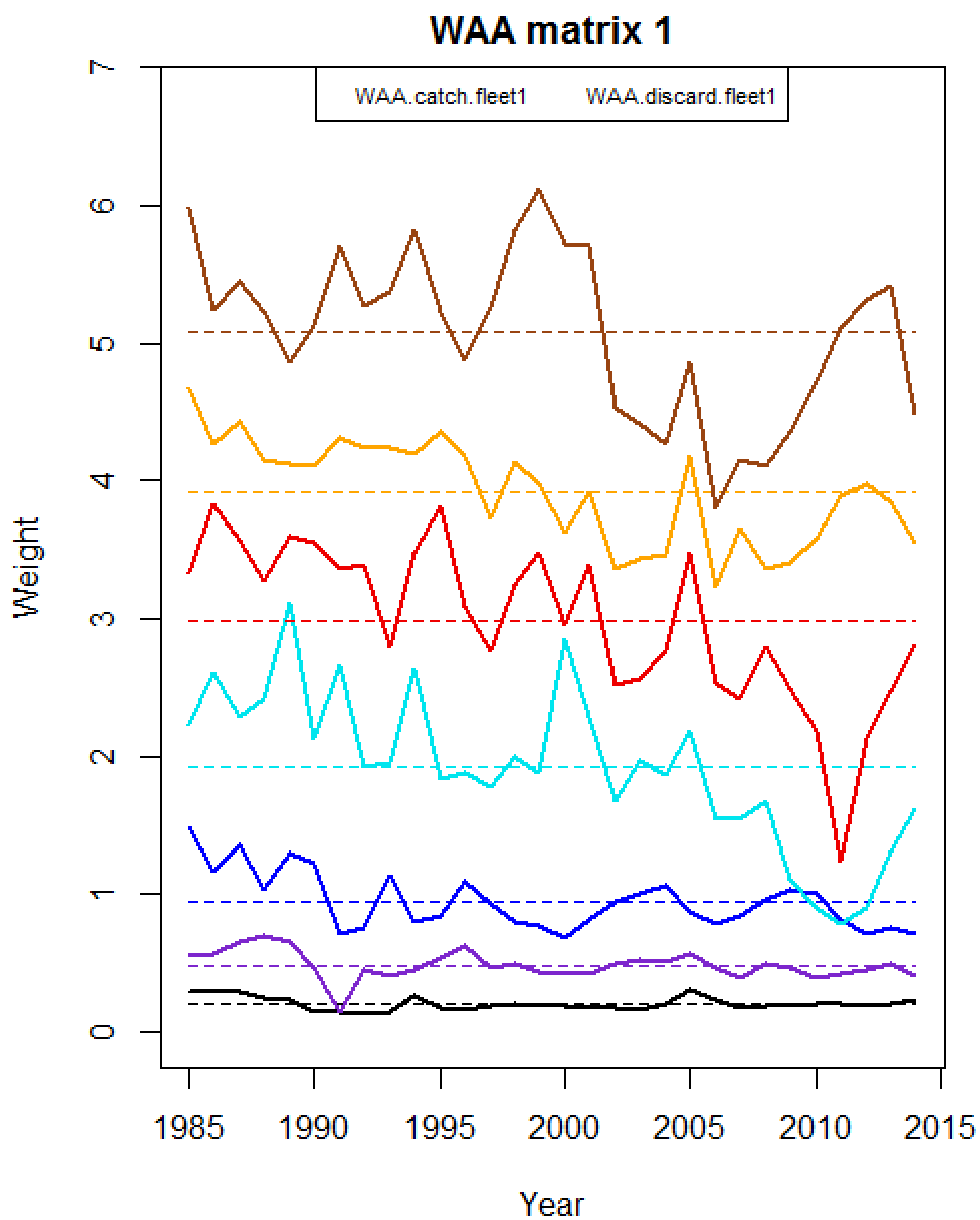


Figure B7.36. Bluefish weight-at-age (Ages 0-6+) for the commercial fleet from 1985 to 2014.

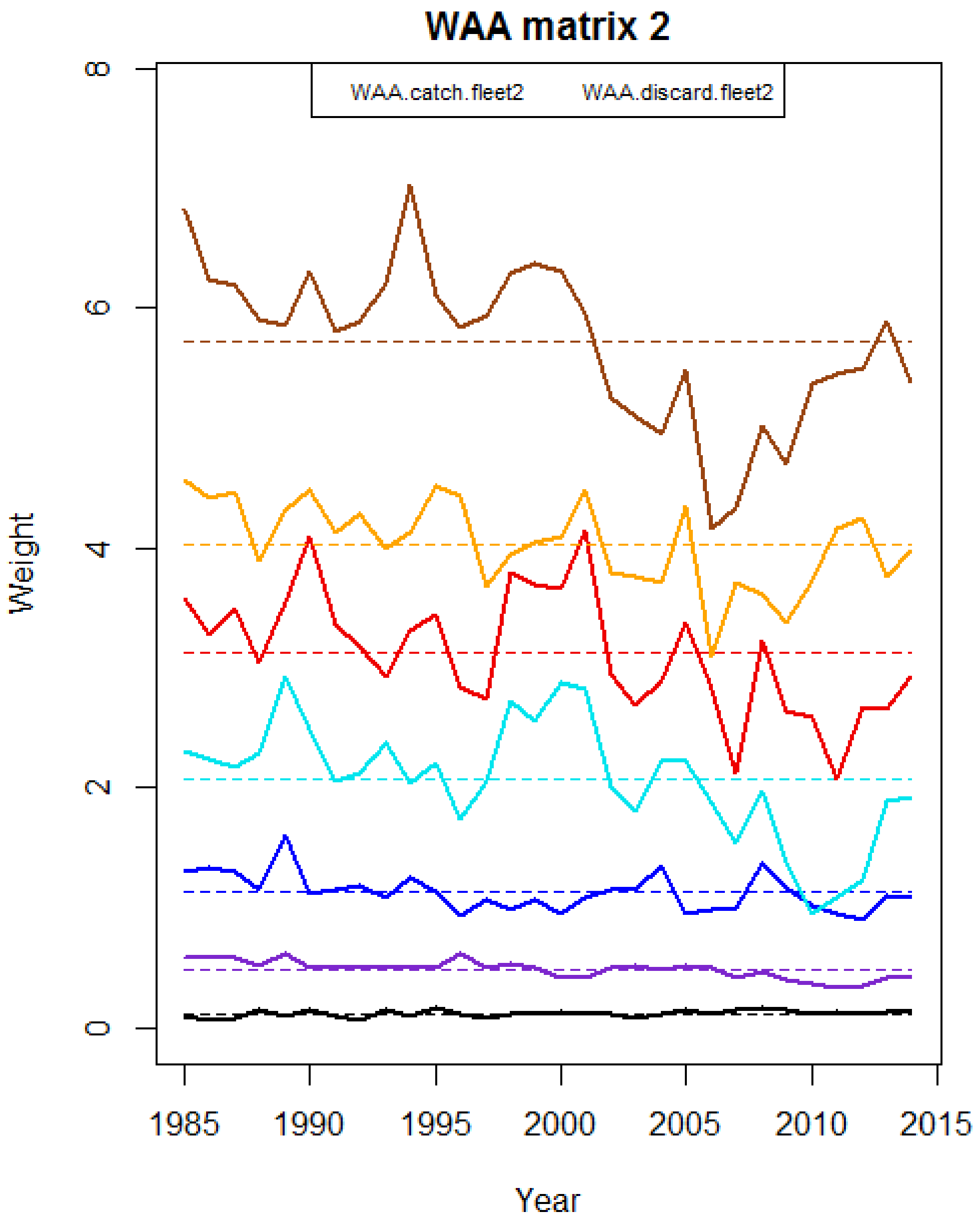


Figure B7.37. Bluefish weight-at-age (Ages 0-6+) for the recreational fleet from 1985 to 2014.

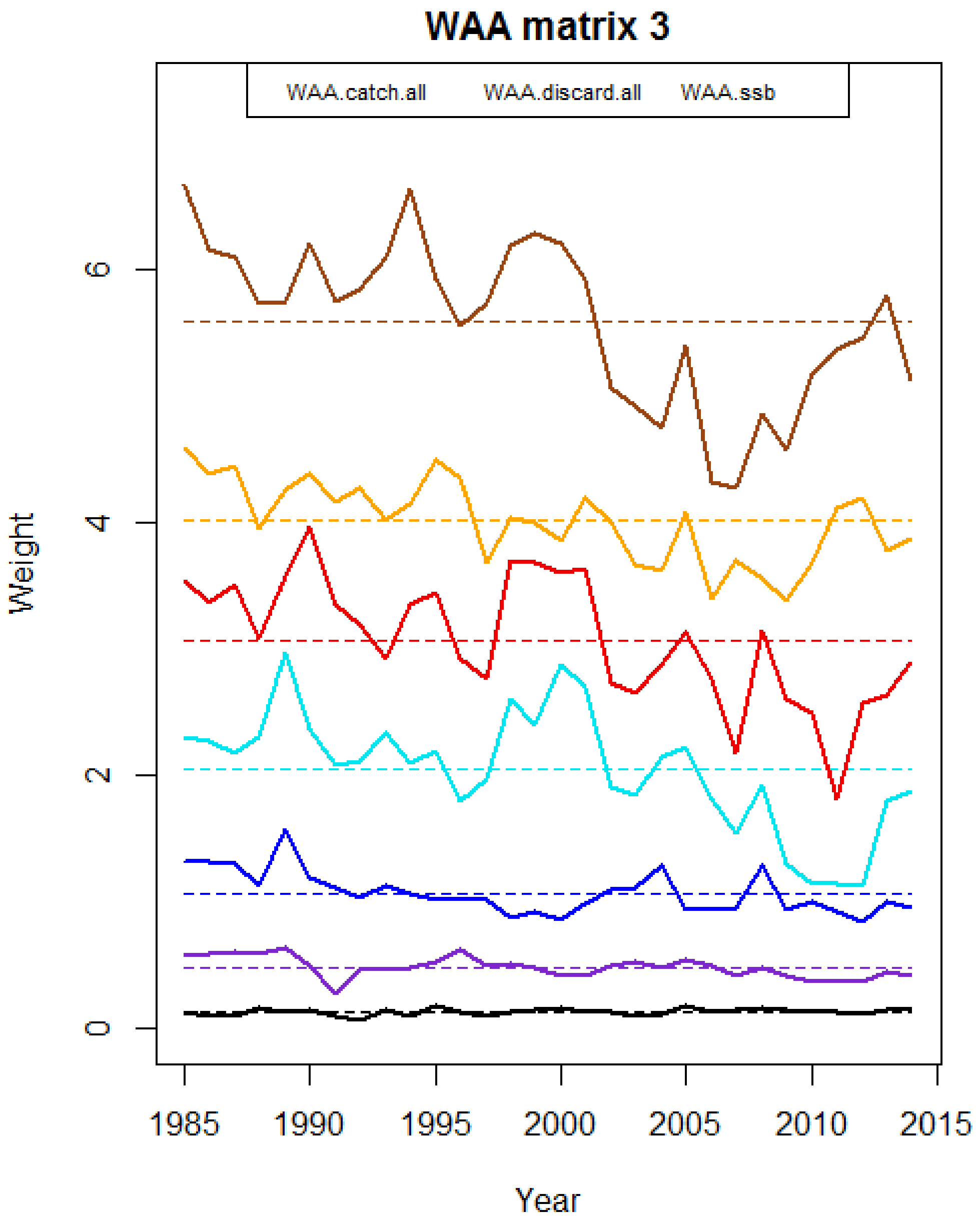


Figure B7.38. Bluefish weight-at-age (Ages 0-6+) for the catch (all fleets) from 1985 to 2014.

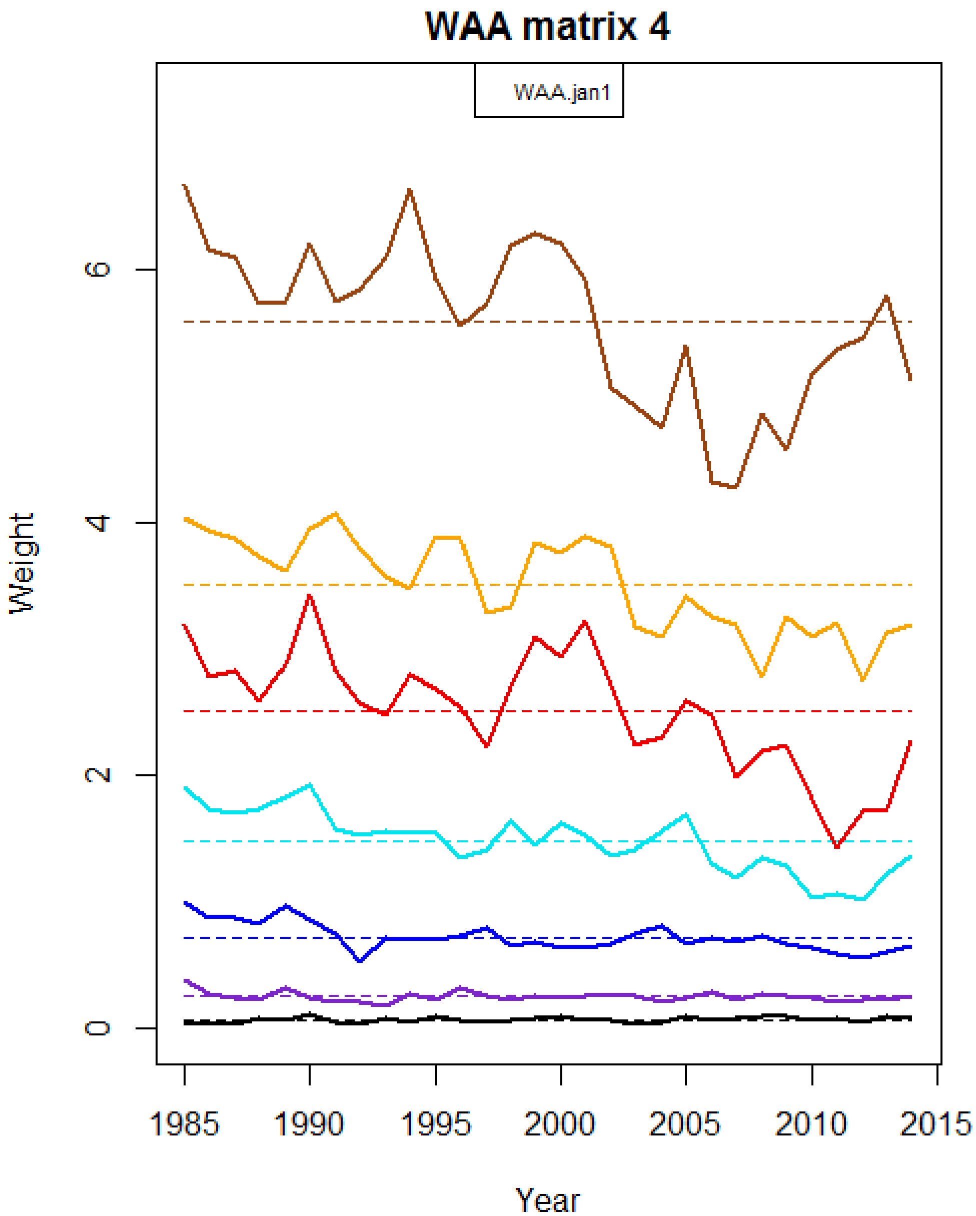


Figure B7.39. Bluefish Jan-1 weight-at-age (Ages 0-6+) for all fleets from 1985 to 2014.

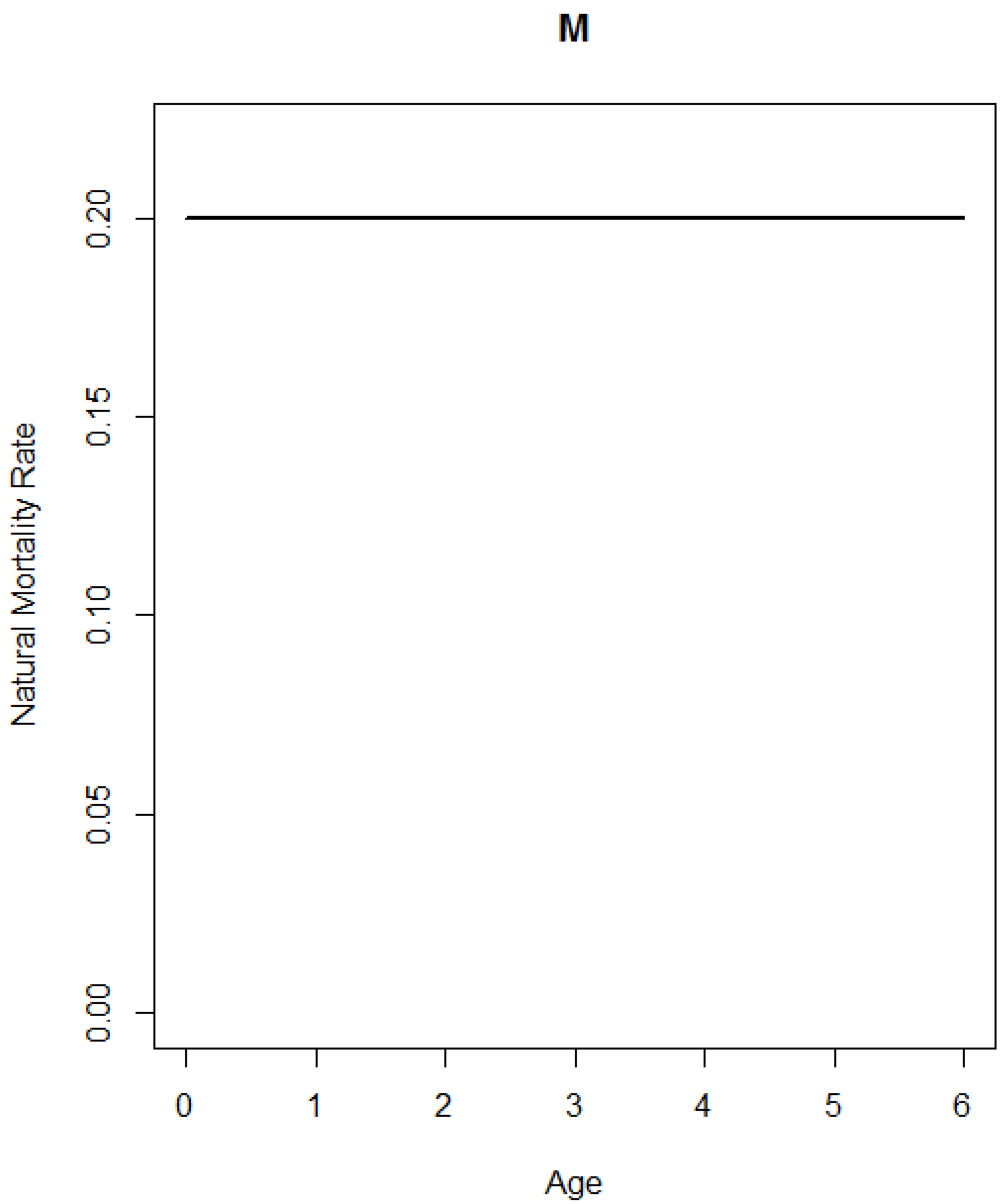


Figure B7.40. Bluefish natural mortality for the final model, kept constant at 0.2 for all ages across all years.

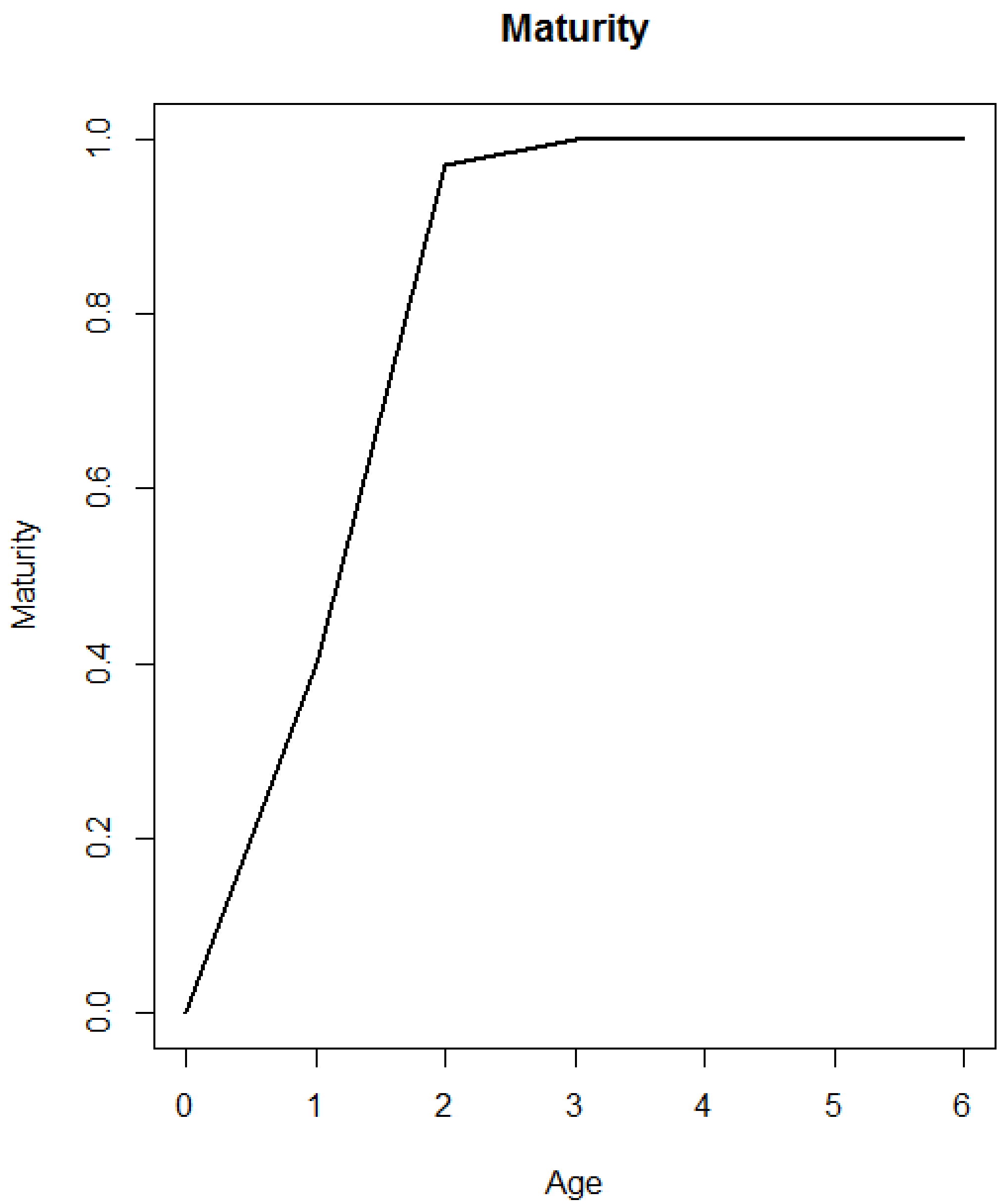


Figure B7.41. Bluefish maturity-at-age for the final model, kept constant across all years.

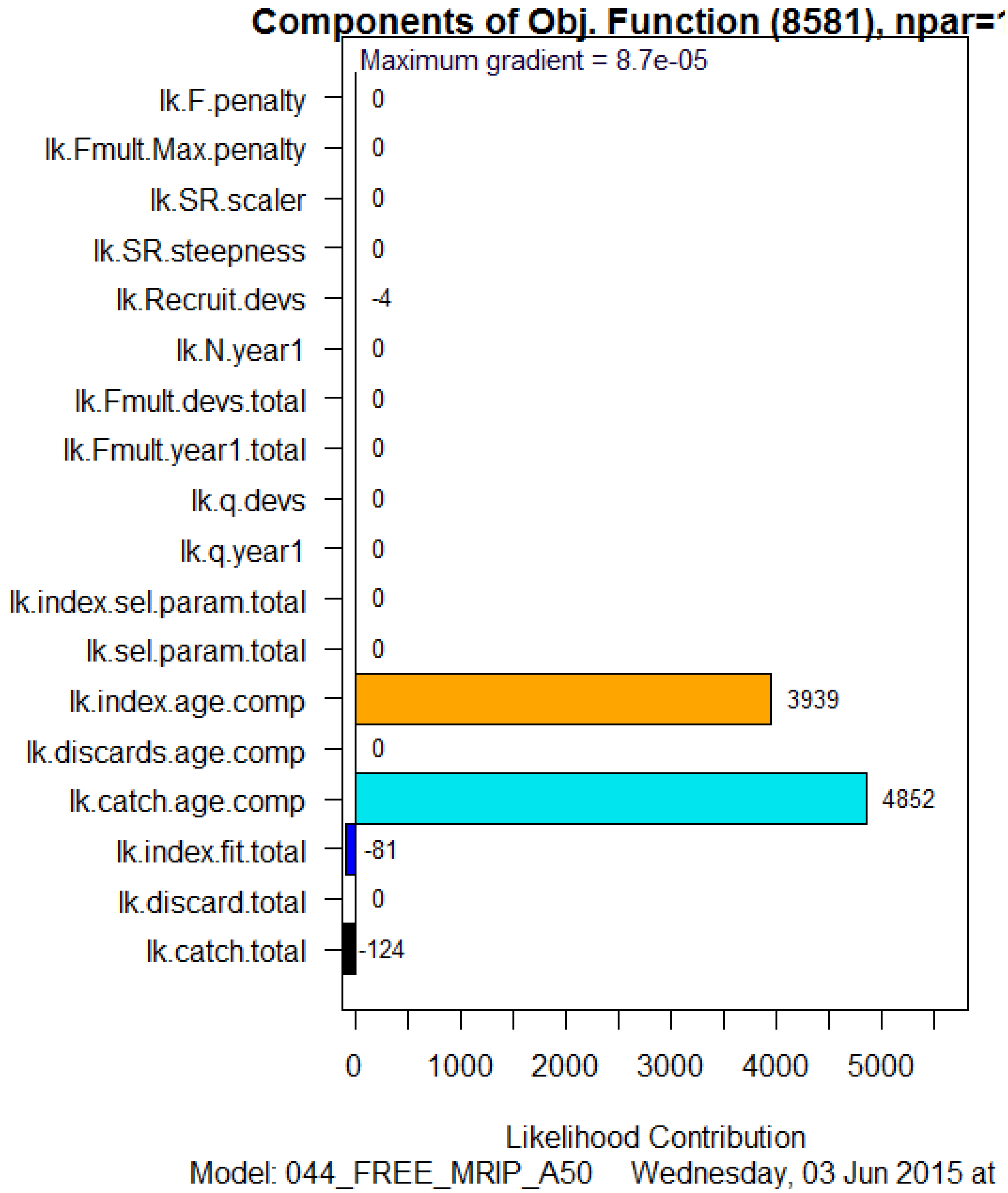


Figure B7.42. Objective function components of model BFINAL.

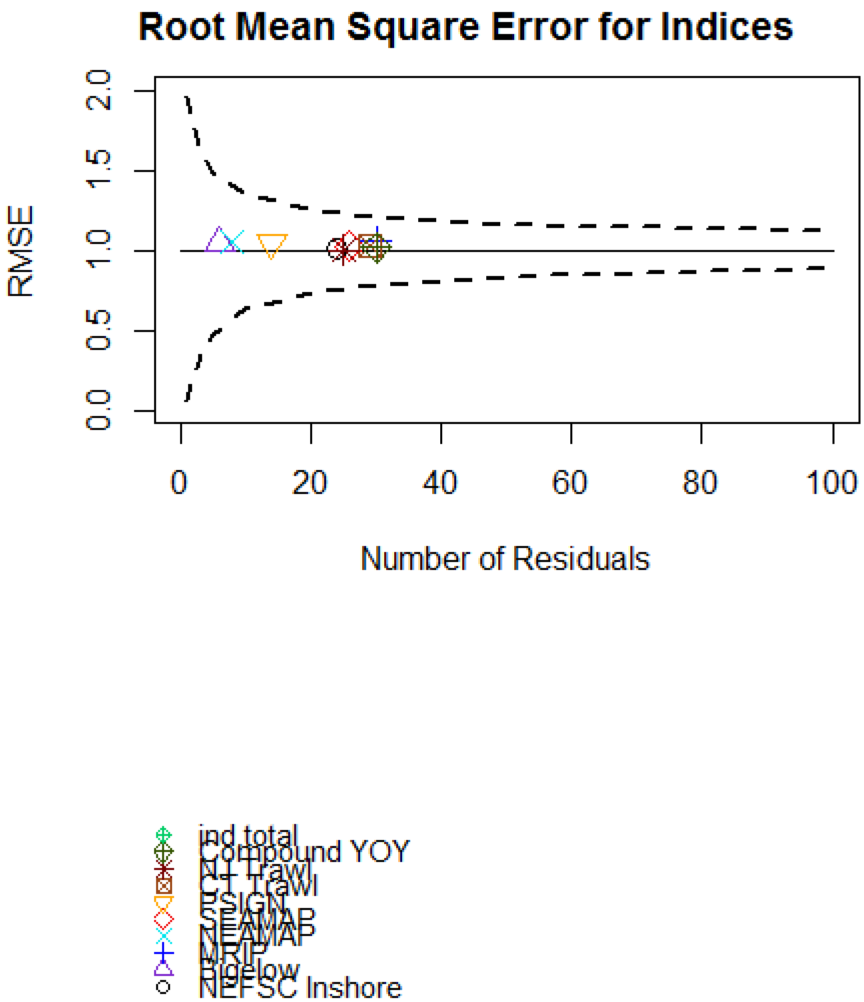


Figure B7.43. RMSE of the final indices after iterative adjustment of the input CVs.

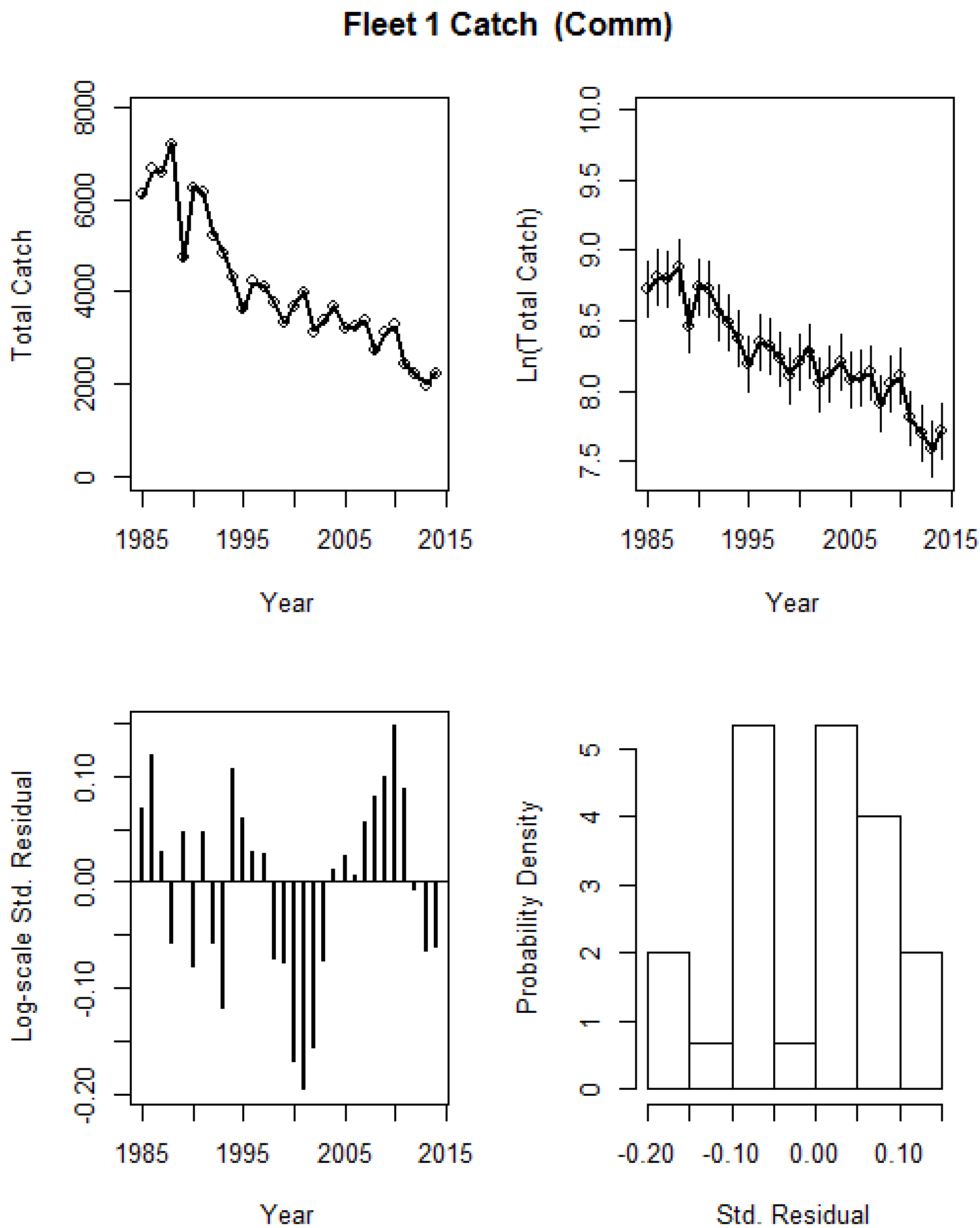


Figure B7.44. Final model fit to the commercial catch fleet with log-scale standardized residuals and residual probability density.

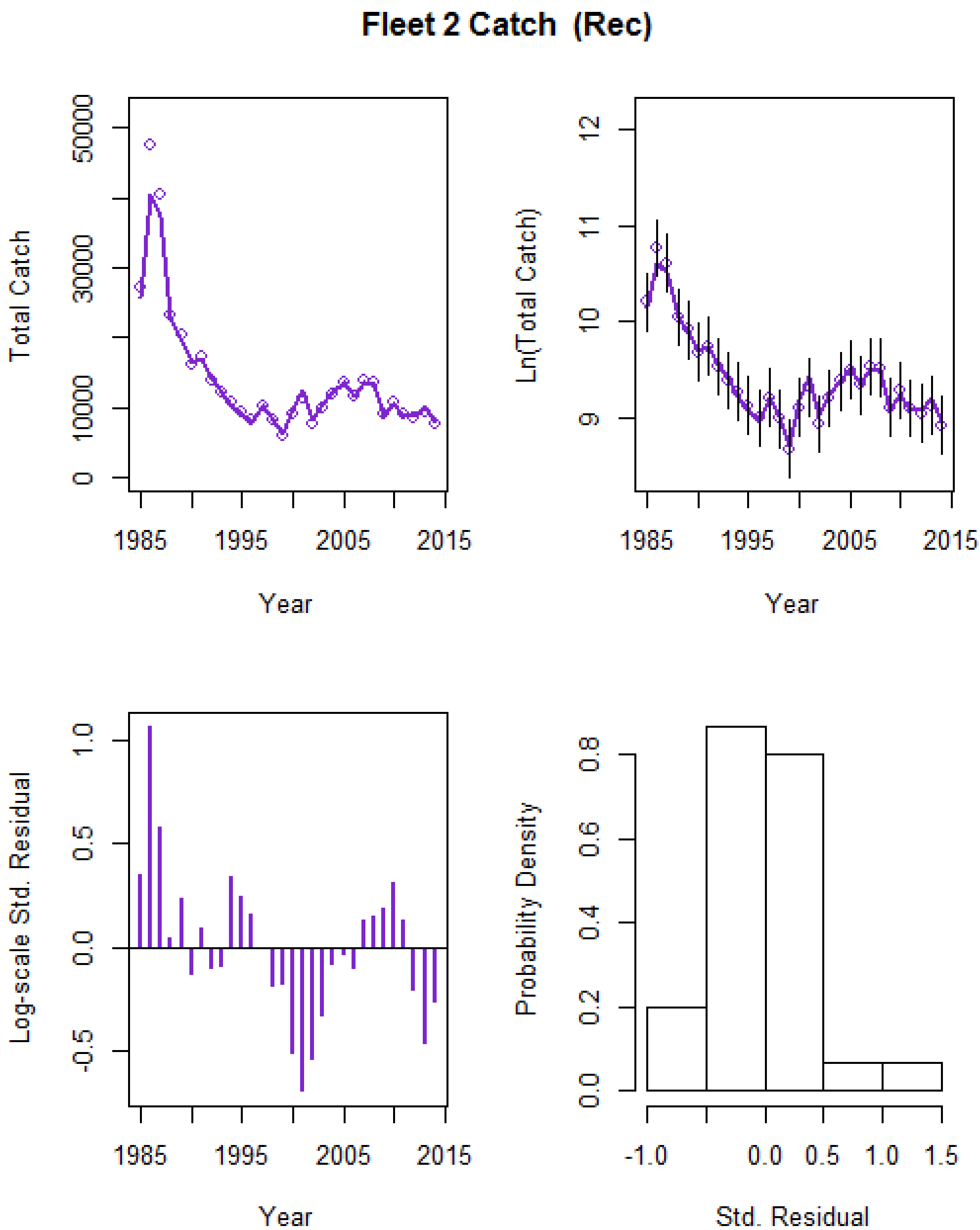


Figure B7.45. Final model fit to the recreational catch fleet with log-scale standardized residuals and residual probability density.

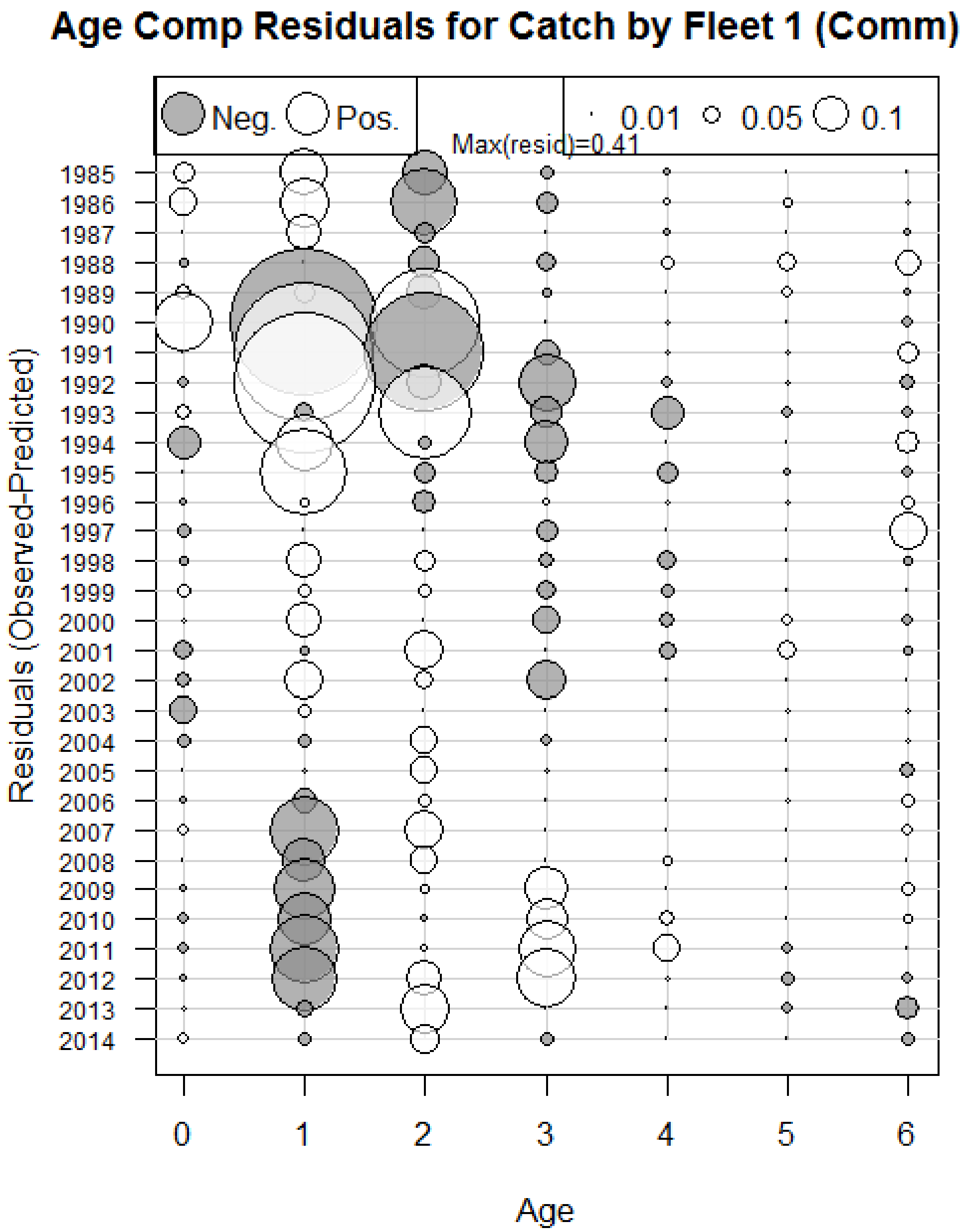


Figure B7.46. Age-composition residuals for the commercial catch fleet.

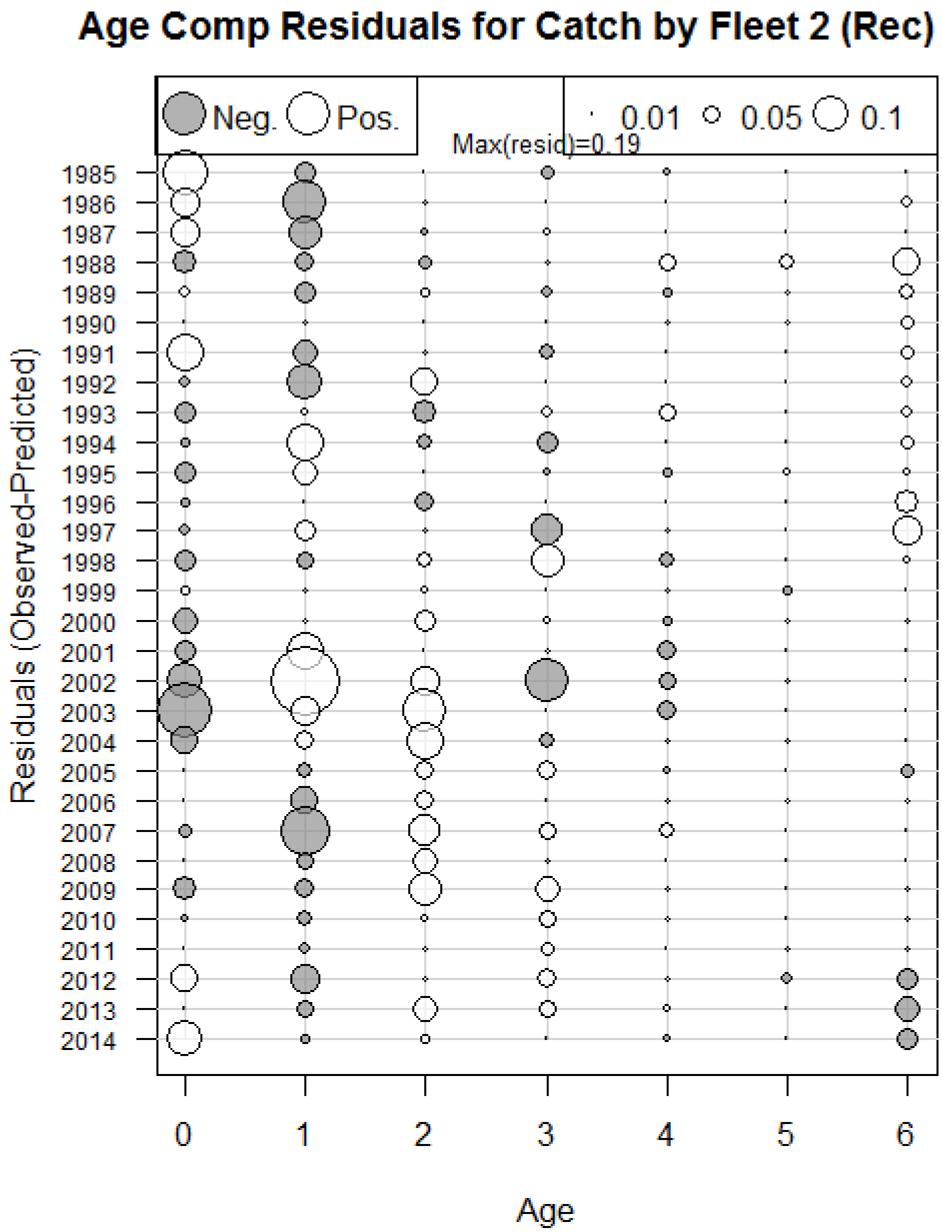


Figure B7.47. Age composition residuals for the recreational catch fleet.

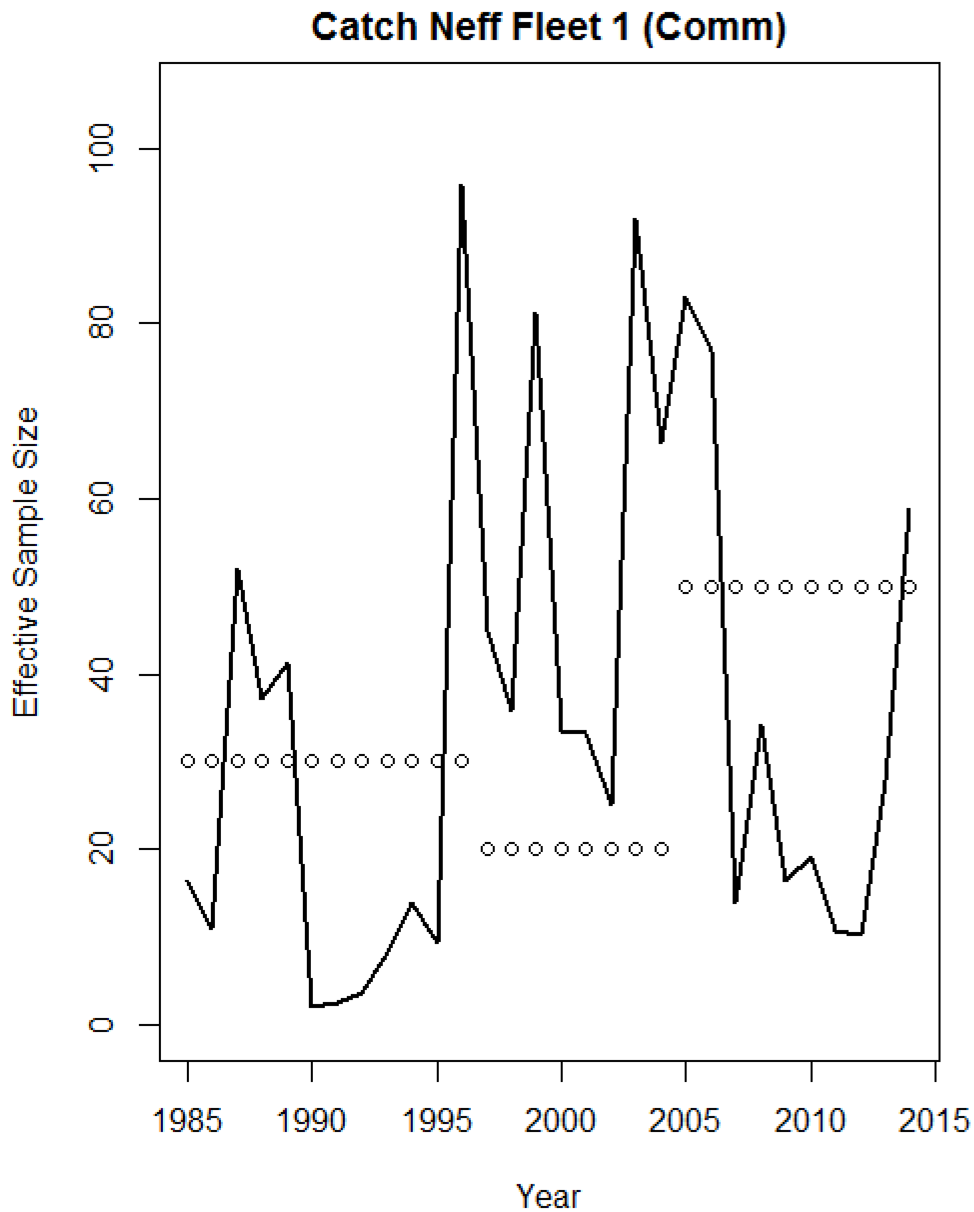


Figure B7.48. Input and estimated effective sample size for the commercial catch fleet.

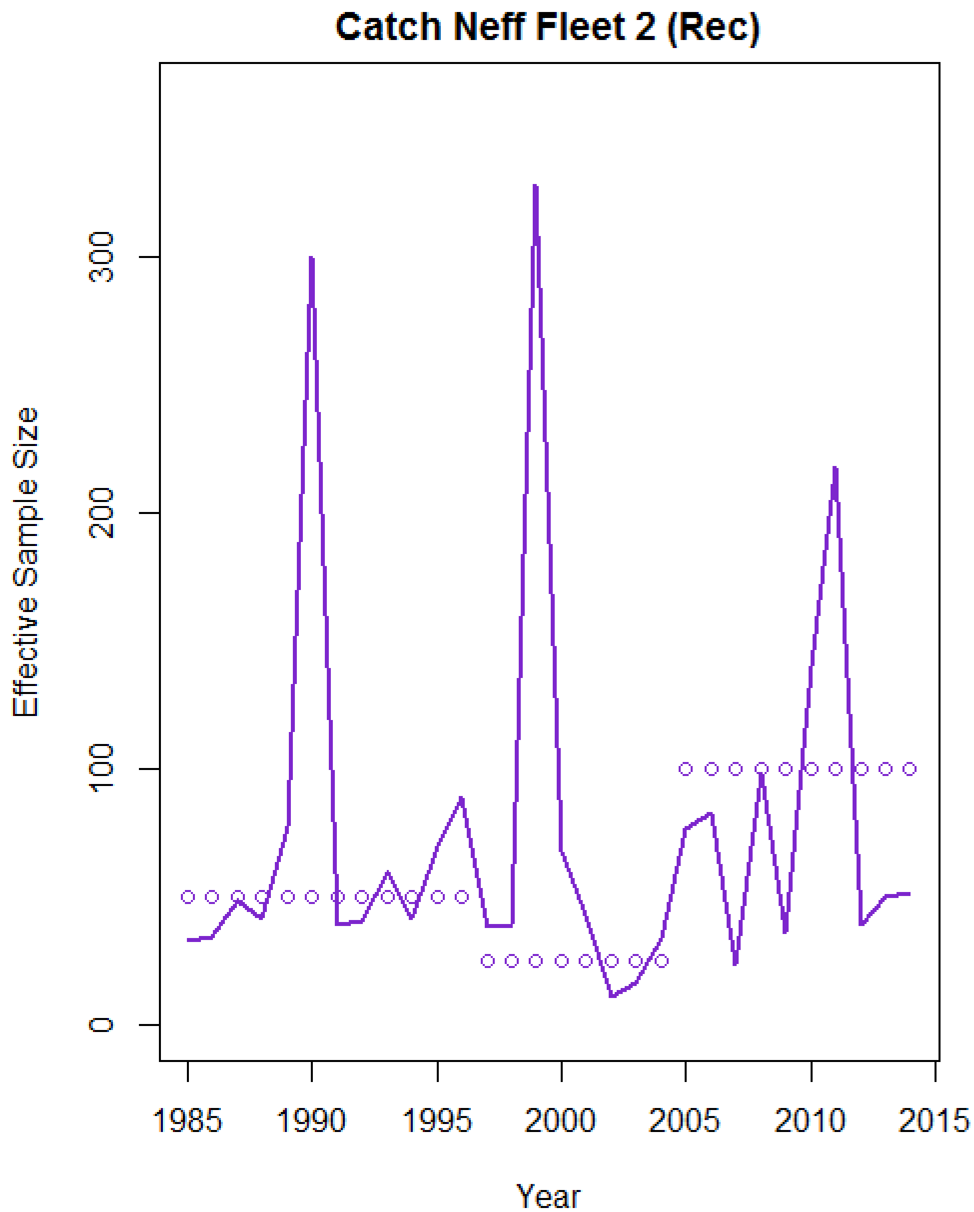


Figure B7.49. Input and estimated effective sample size for the recreational catch fleet.

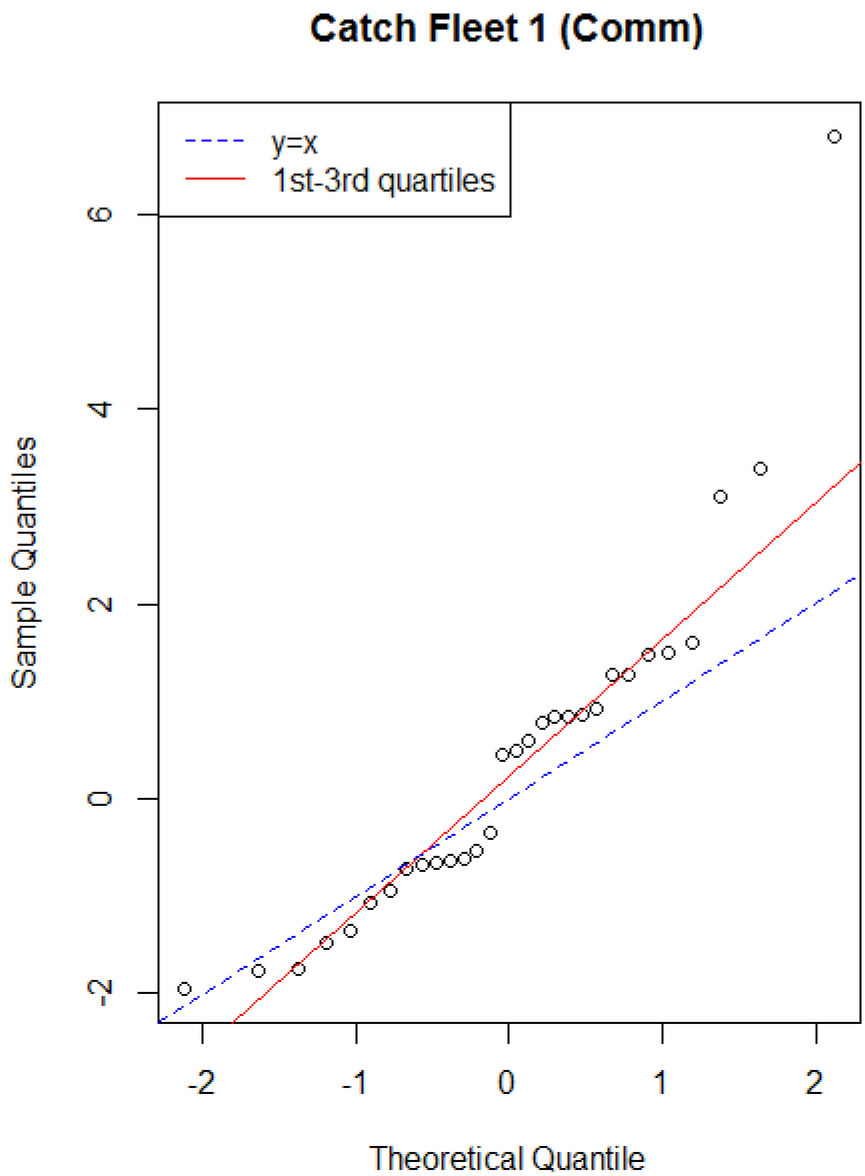


Figure B7.50. QQ-plot for the observed versus predicted mean catch for the commercial catch fleet.

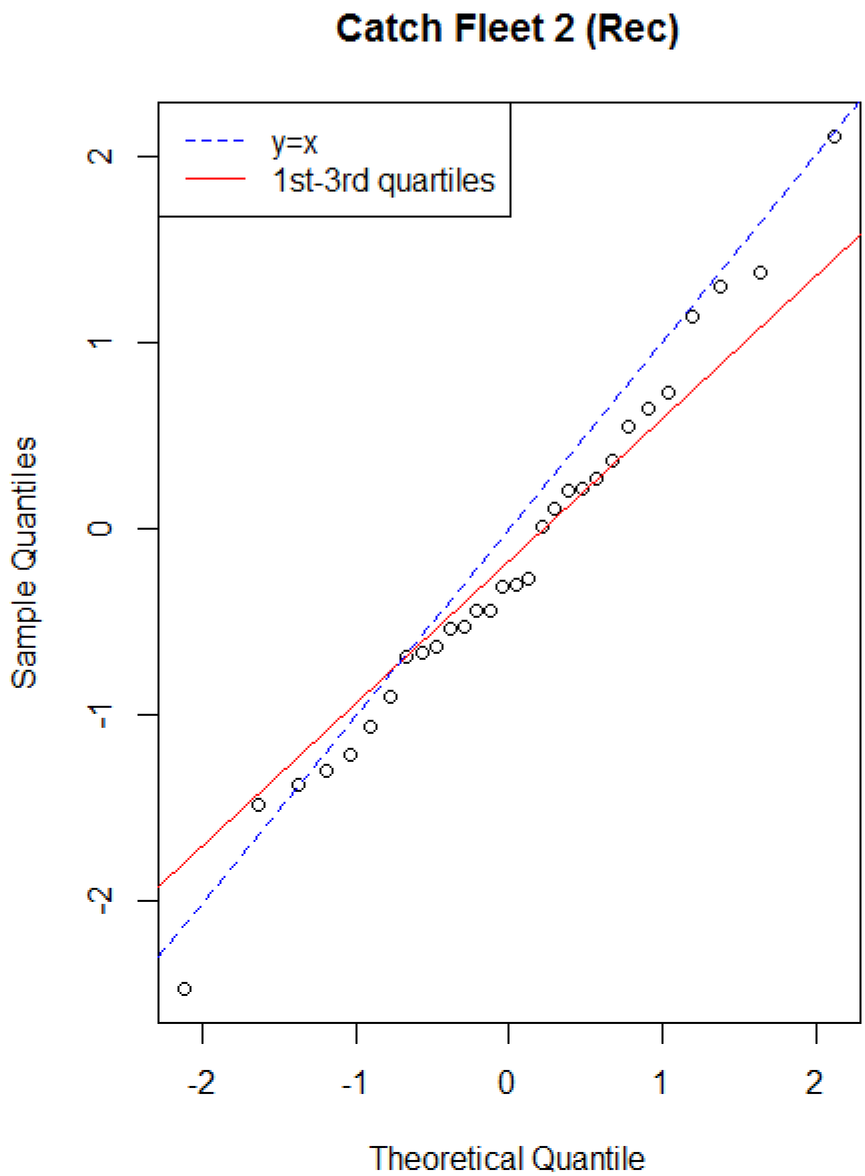


Figure B7.51. QQ-plot for the observed versus predicted mean catch for the recreational catch fleet.

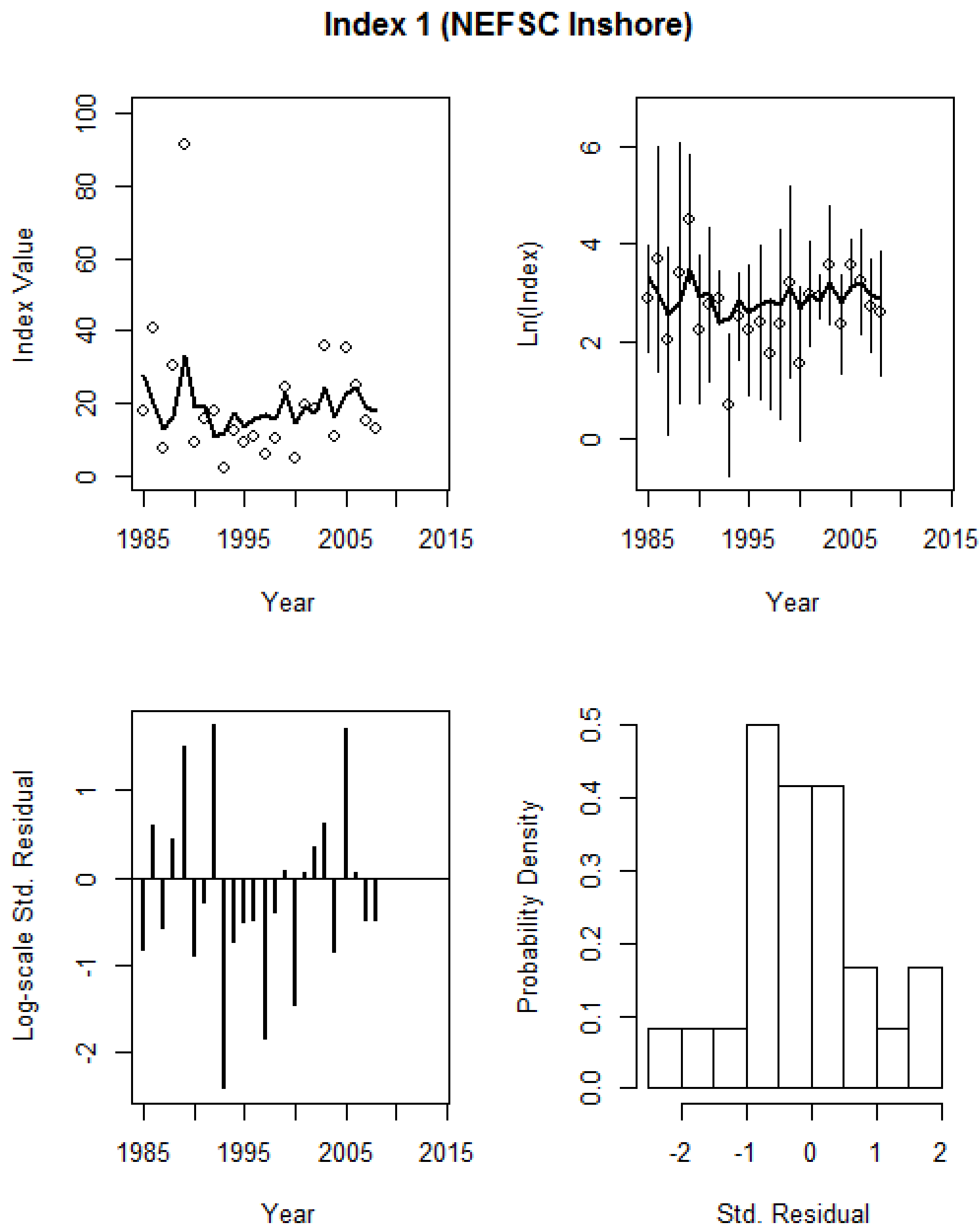


Figure B7.52. Final model fit to the NEFSC Inshore survey with log-scale standardized residuals and residual probability density.

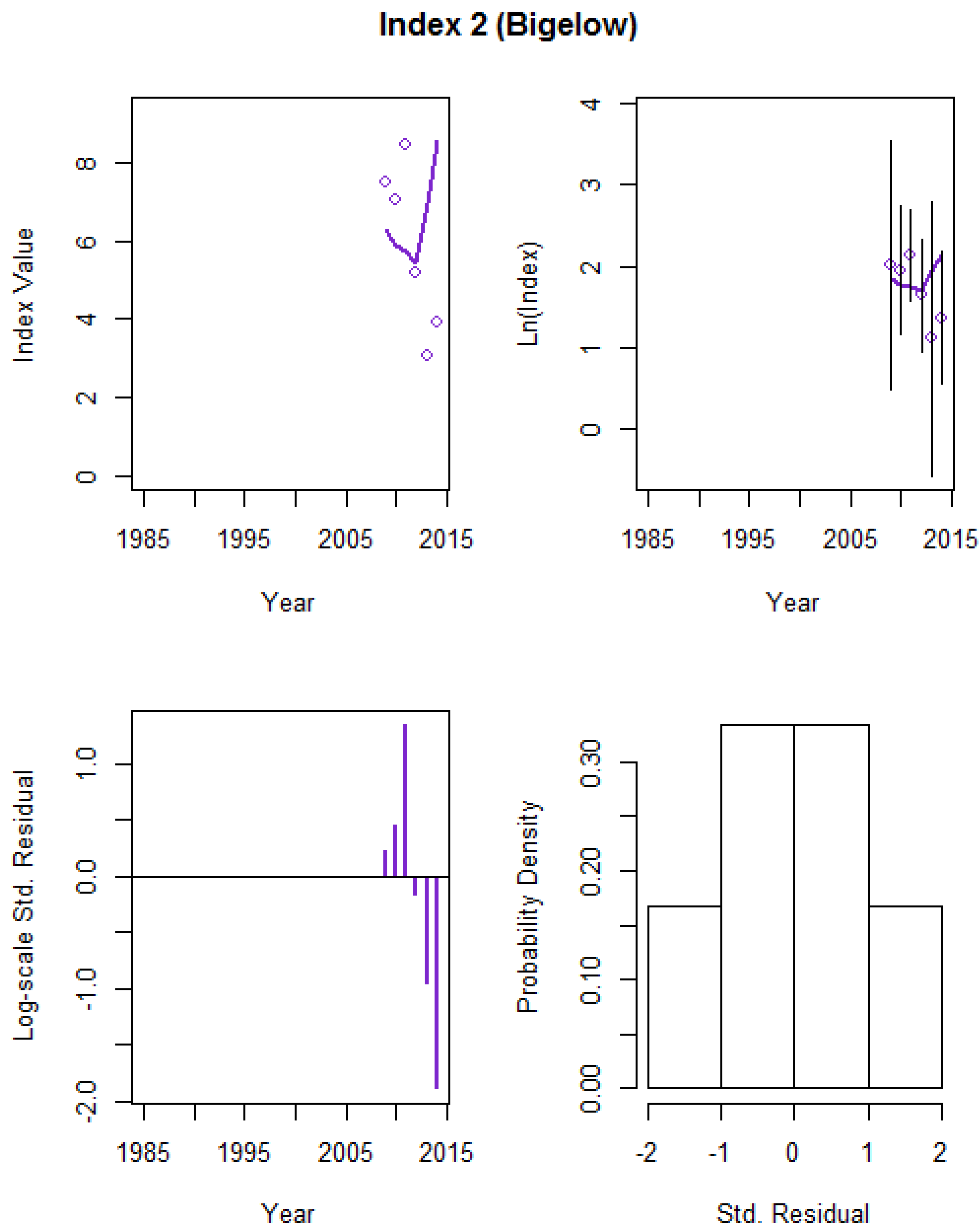


Figure B7.53. Final model fit to the NEFSC Bigelow survey with log-scale standardized residuals and residual probability density.

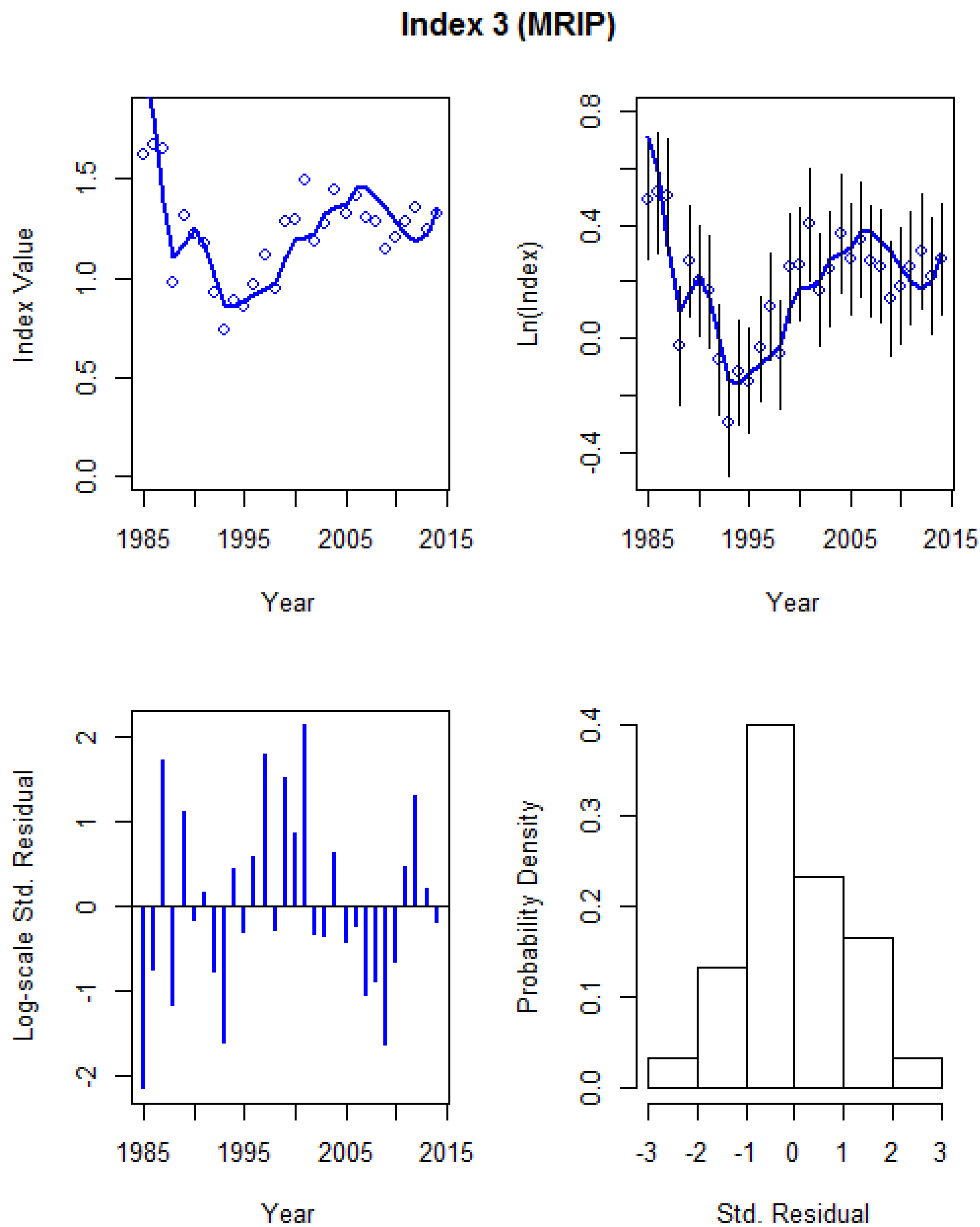


Figure B7.54. Final model fit to the MRIP recreational CPUE index with log-scale standardized residuals and residual probability density.

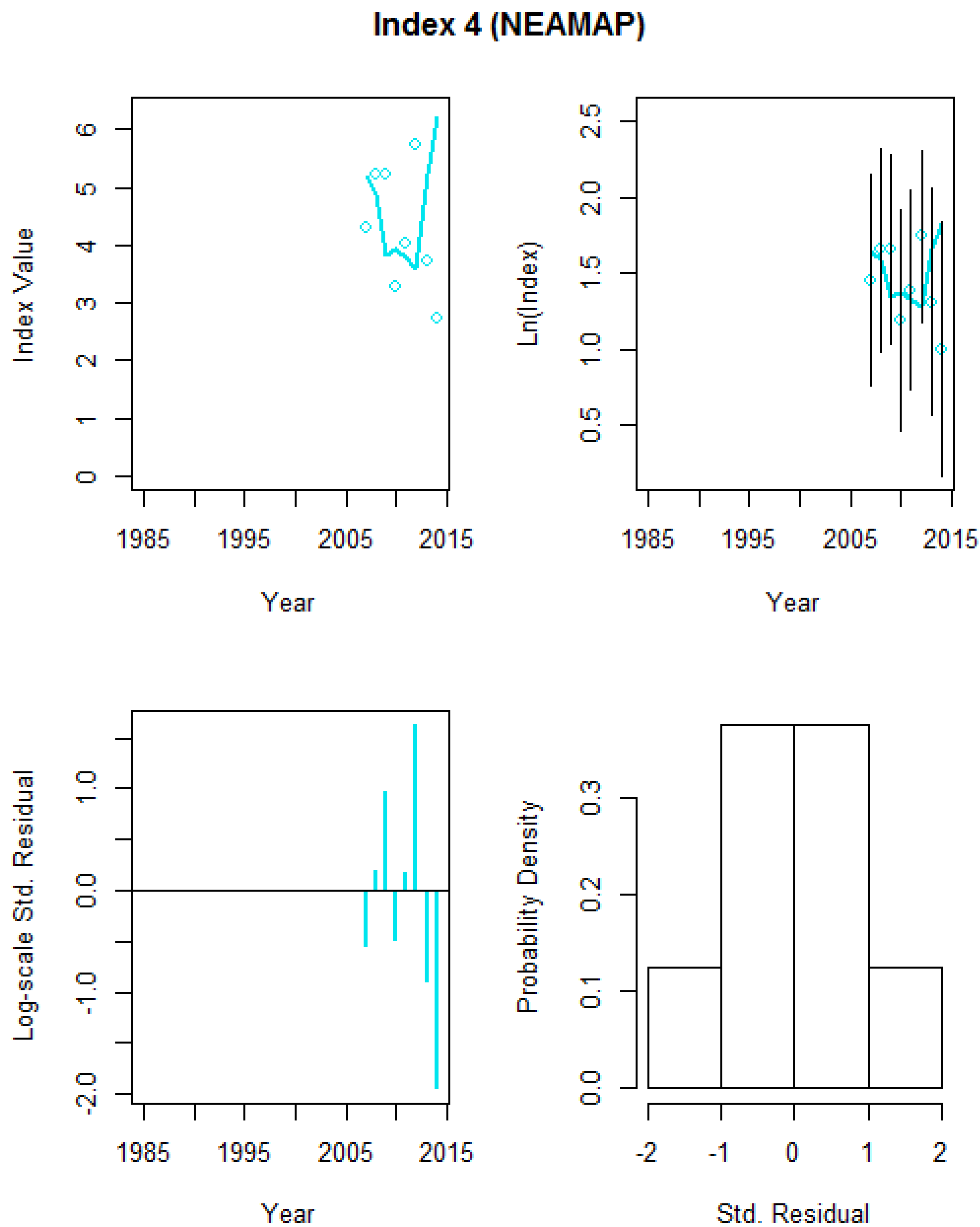


Figure B7.55. Final model fit to the NEAMAP survey with log-scale standardized residuals and residual probability density.

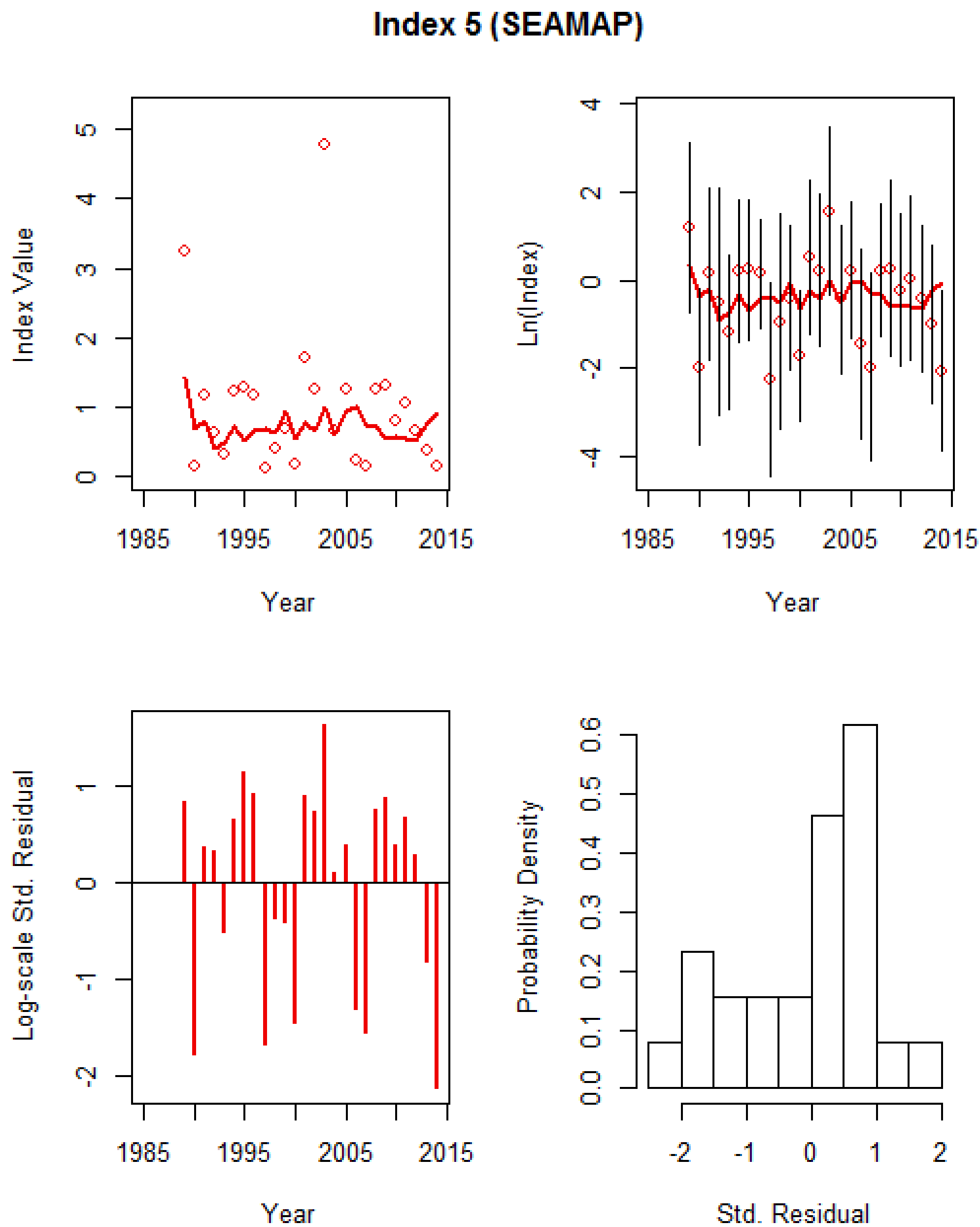


Figure B7.56. Final model fit to the SEAMAP Age 0 index with log-scale standardized residuals and residual probability density.

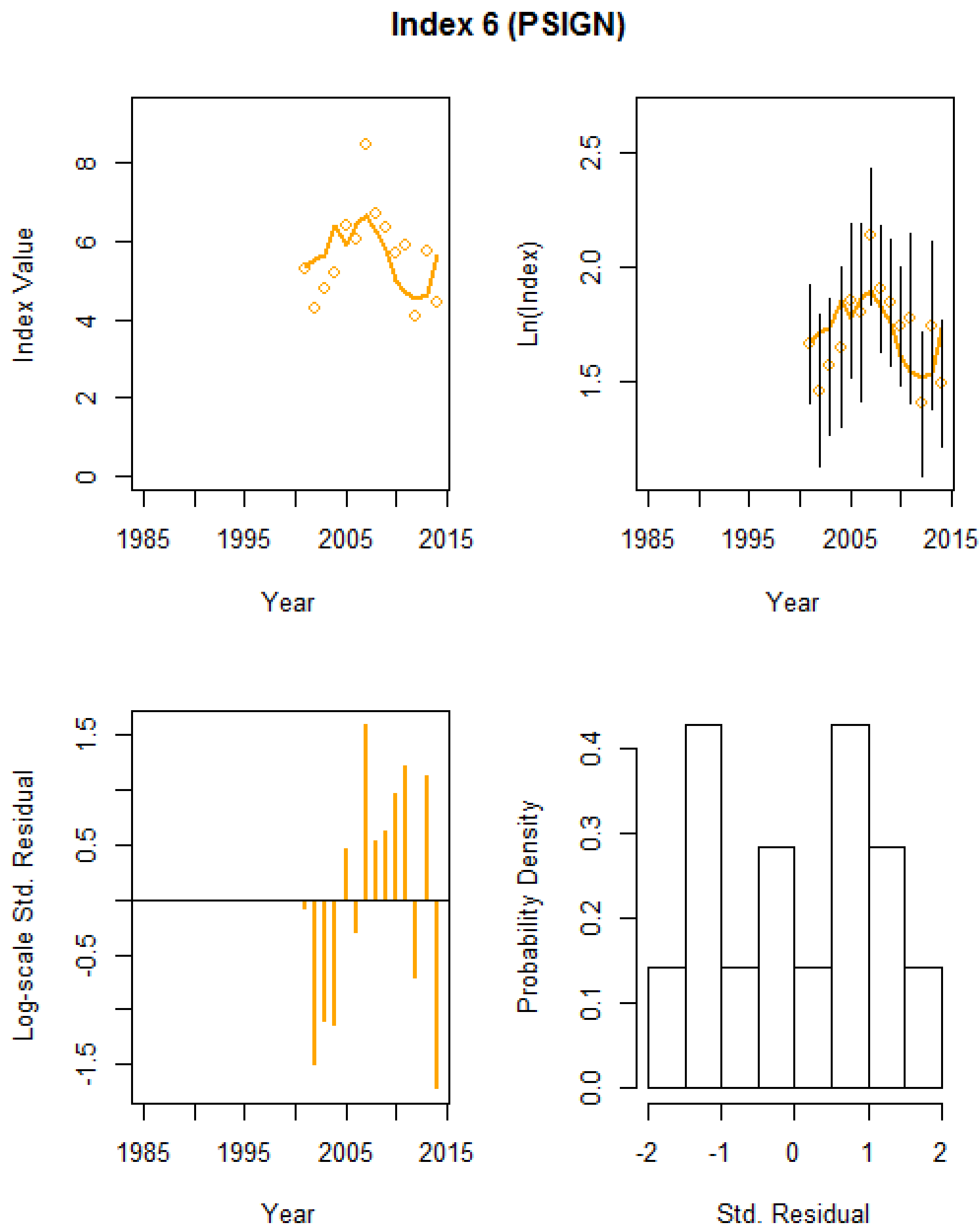


Figure B7.57. Final model fit to the PSIGNS gillnet survey with log-scale standardized residuals and residual probability density.

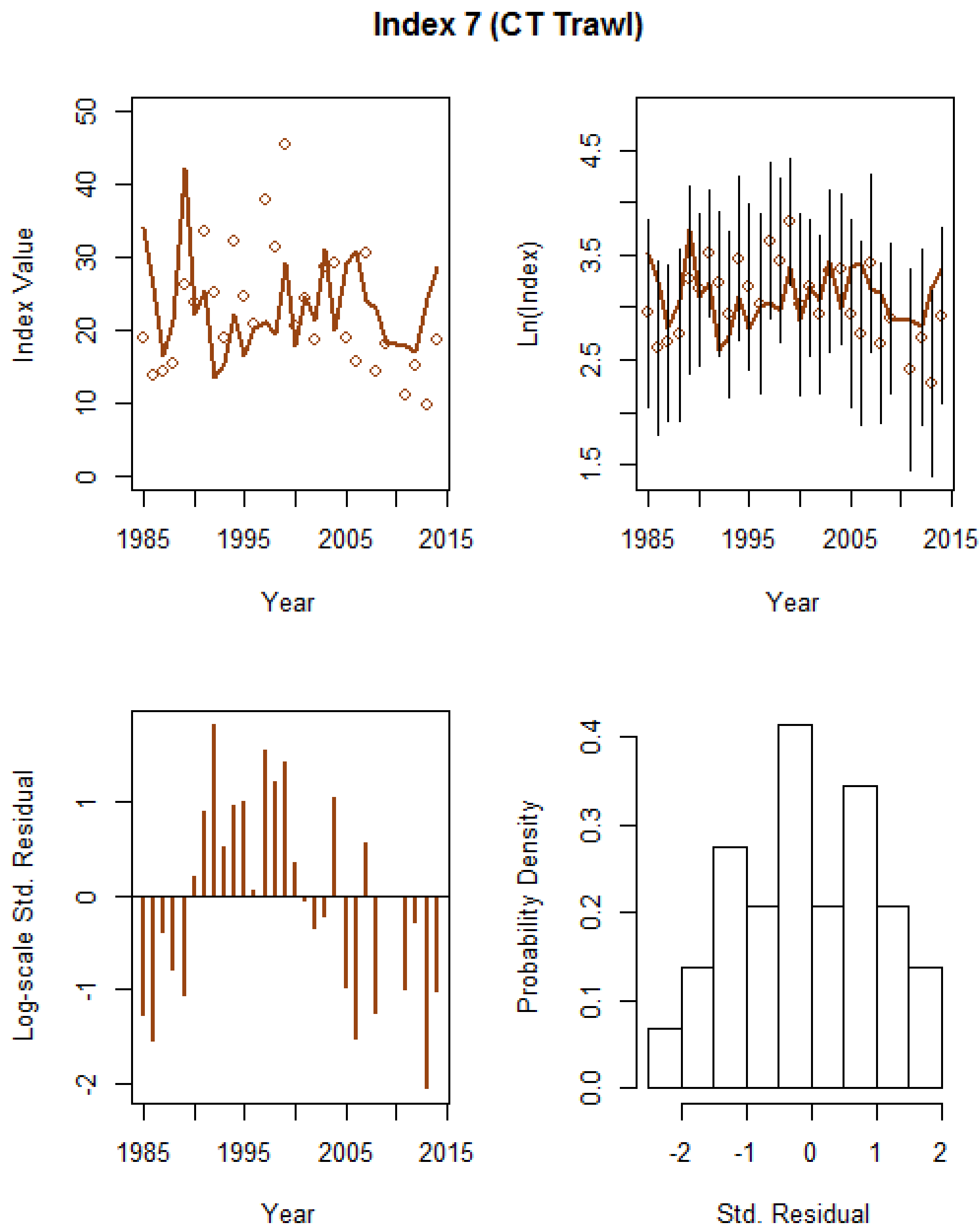


Figure B7.58. Final model fit to the CT LISTS trawl survey with log-scale standardized residuals and residual probability density.

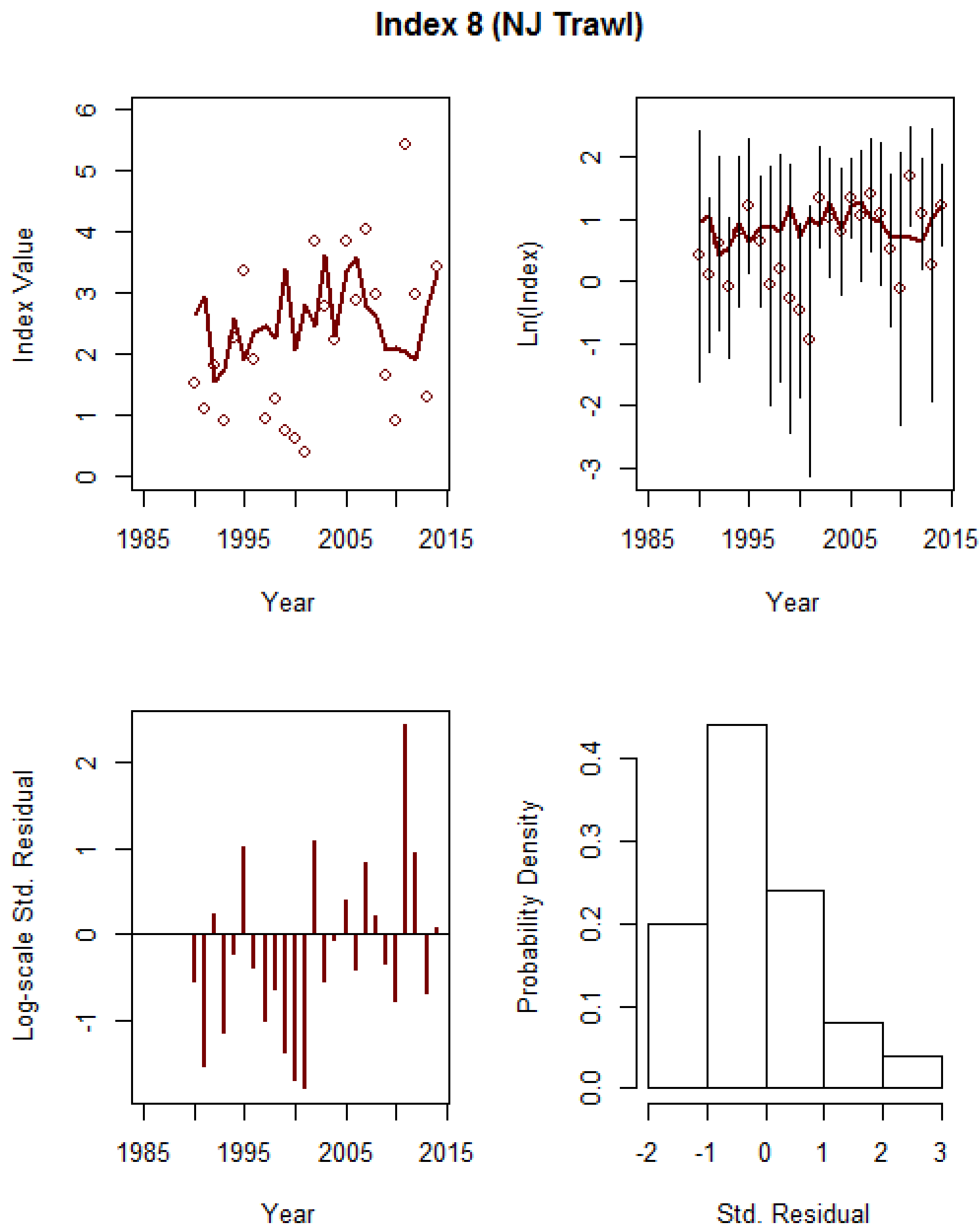


Figure B7.59. Final model fit to the NJ ocean trawl survey with log-scale standardized residuals and residual probability density.

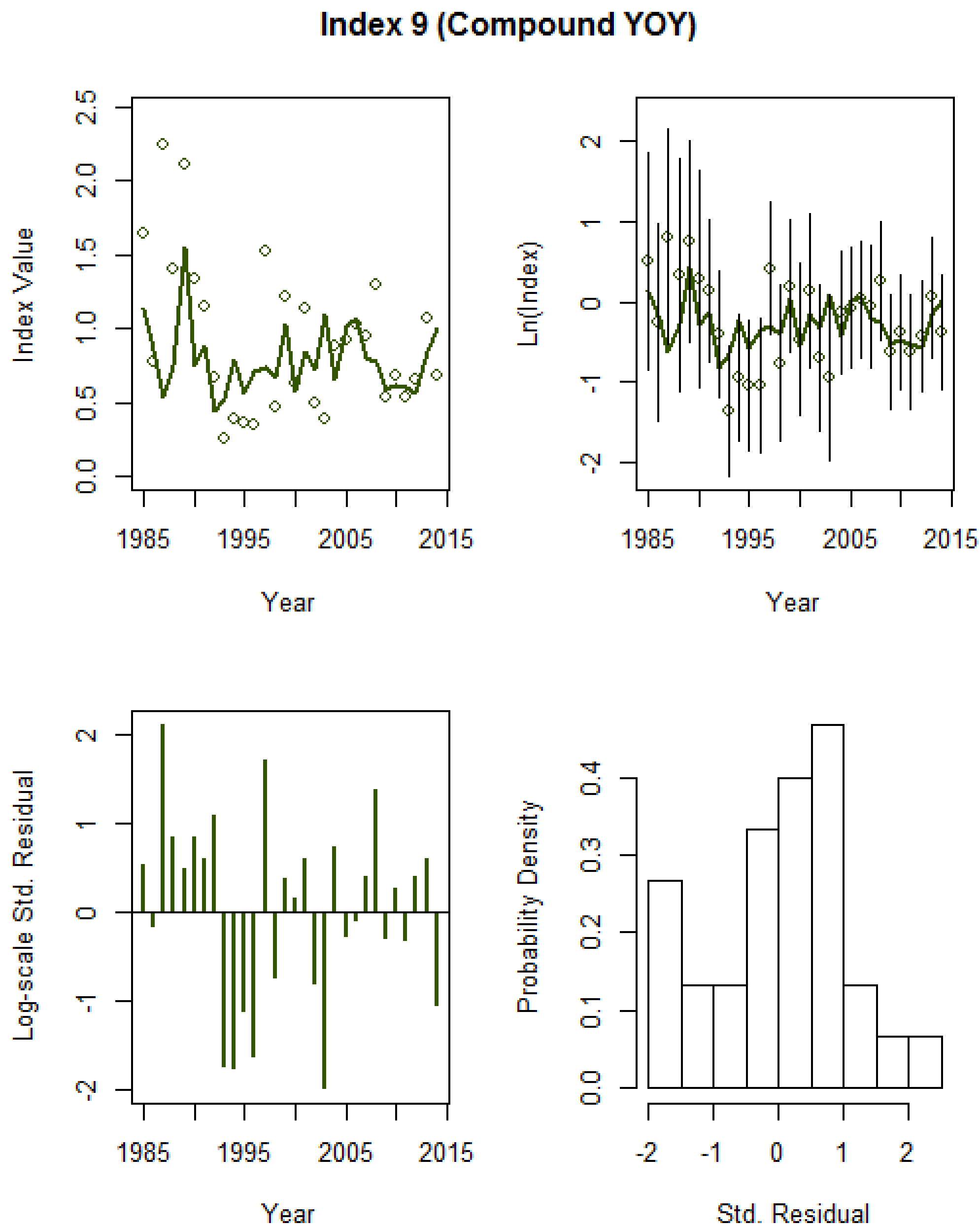


Figure B7.60. Final model fit to the composite YOY seine survey with log-scale standardized residuals and residual probability density.

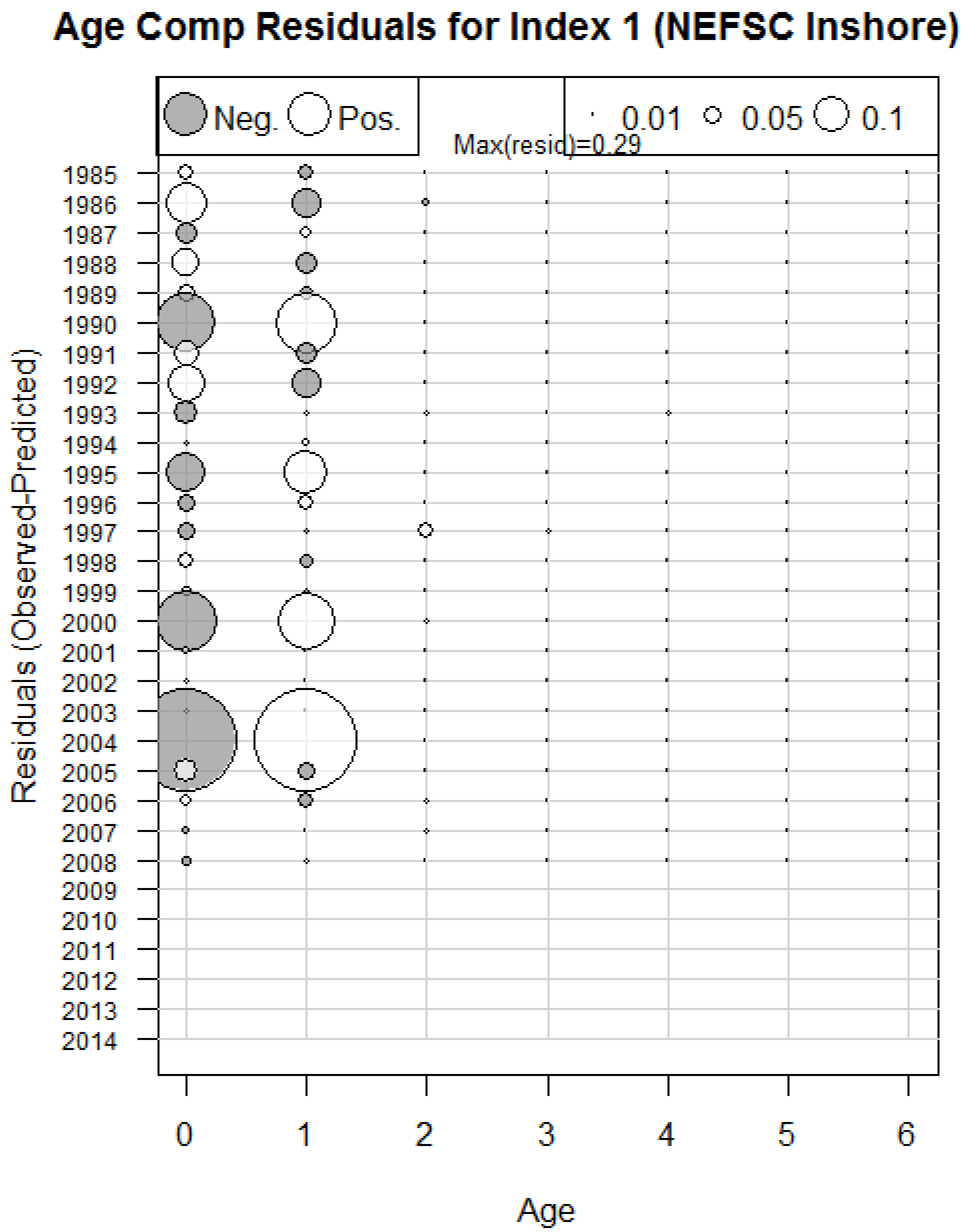


Figure B7.61. Age composition residuals for the NEFSC Inshore survey.

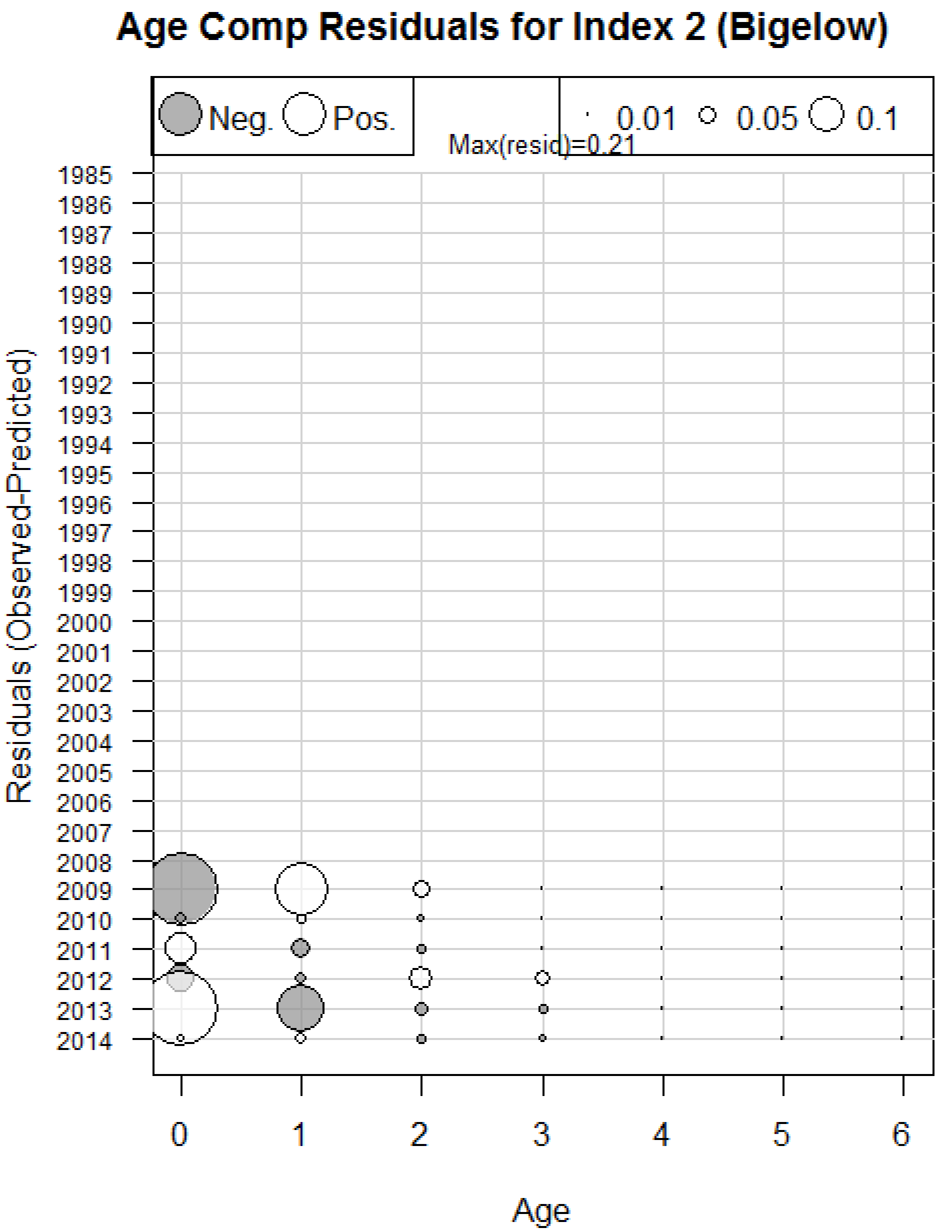


Figure B7.62. Age composition residuals for the NEFSC Bigelow survey.

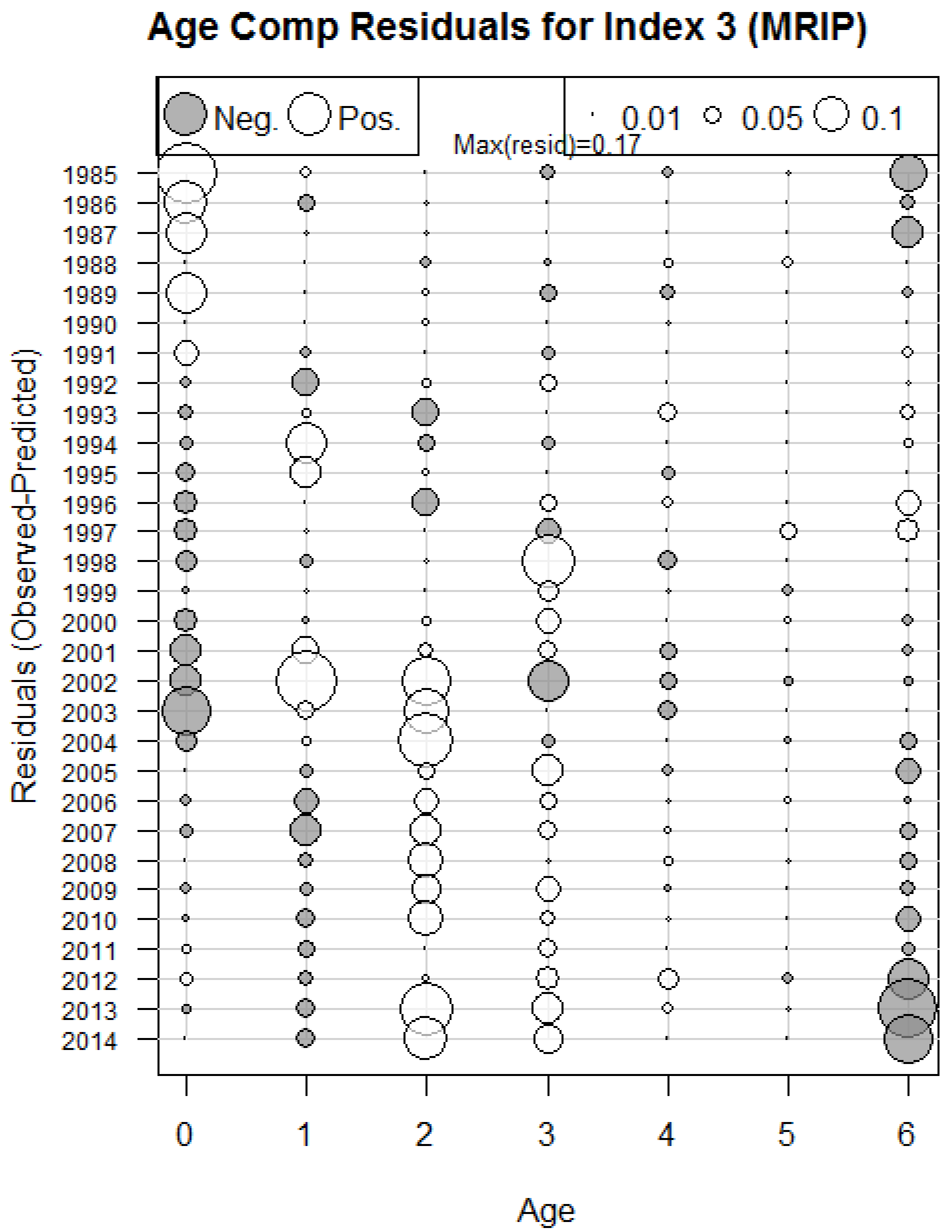


Figure B7.63. Age composition residuals for the MRIP recreational CPUE index.

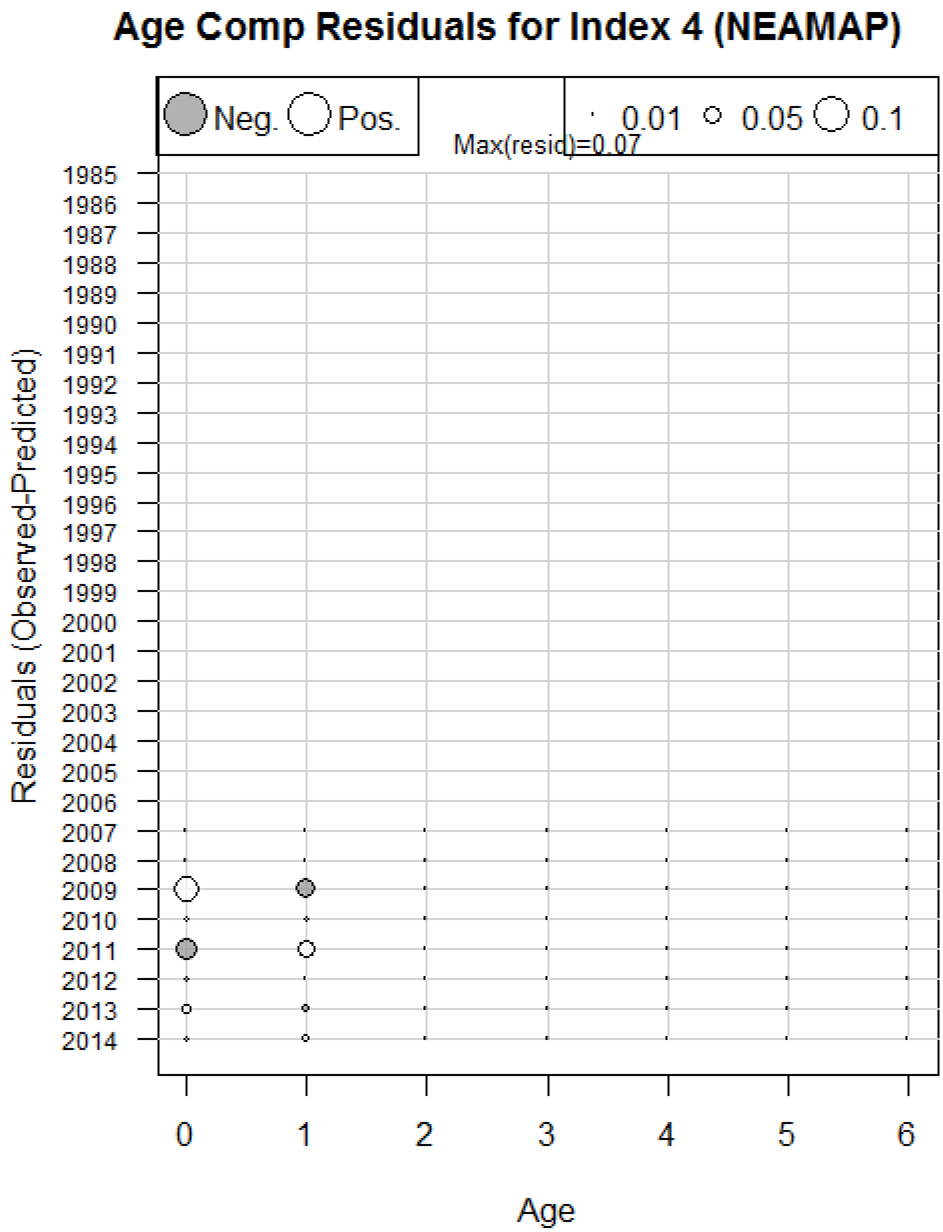


Figure B7.64. Age composition residuals for the NEAMAP survey.

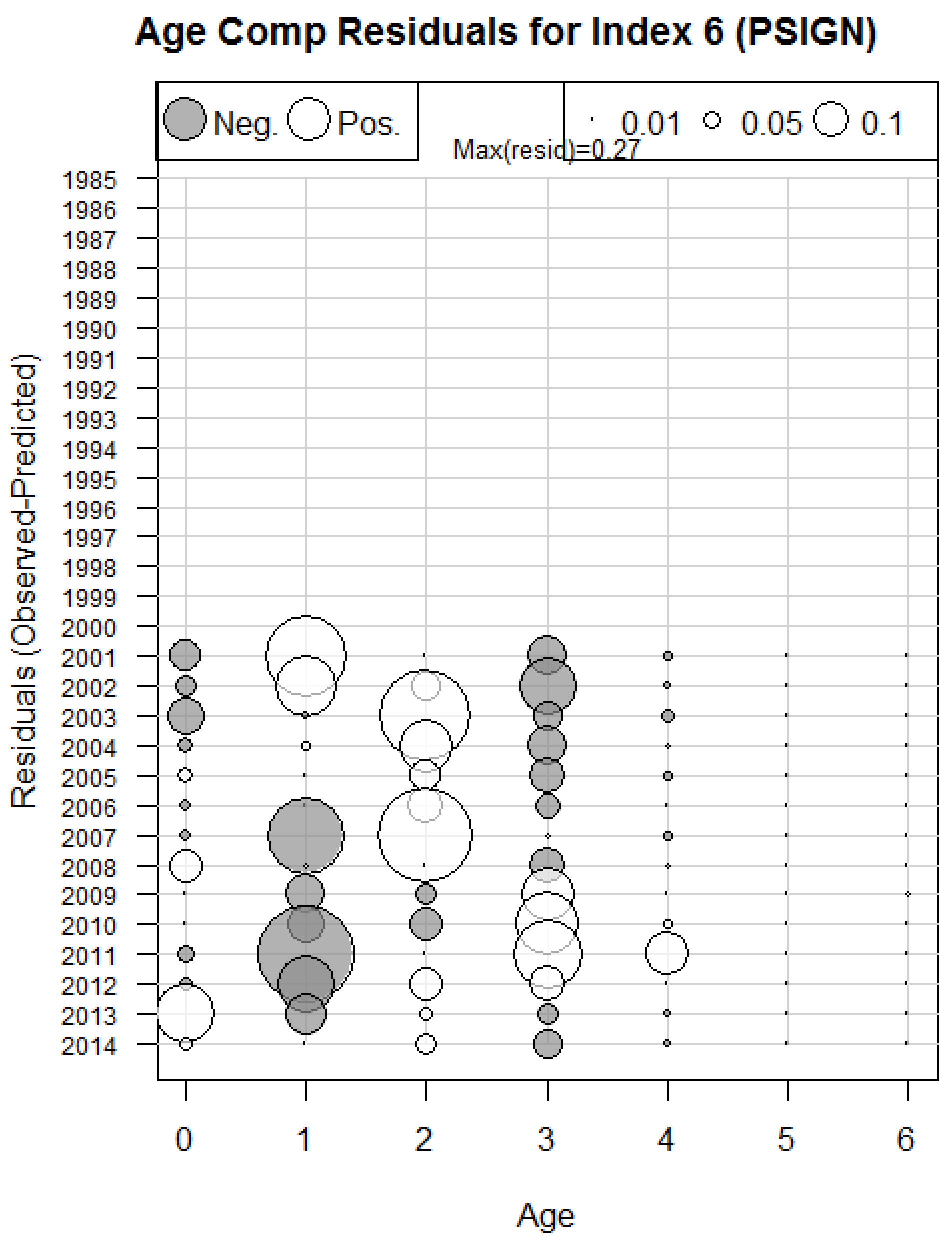


Figure B7.65. Age composition residuals for the PSIGNS gillnet survey.

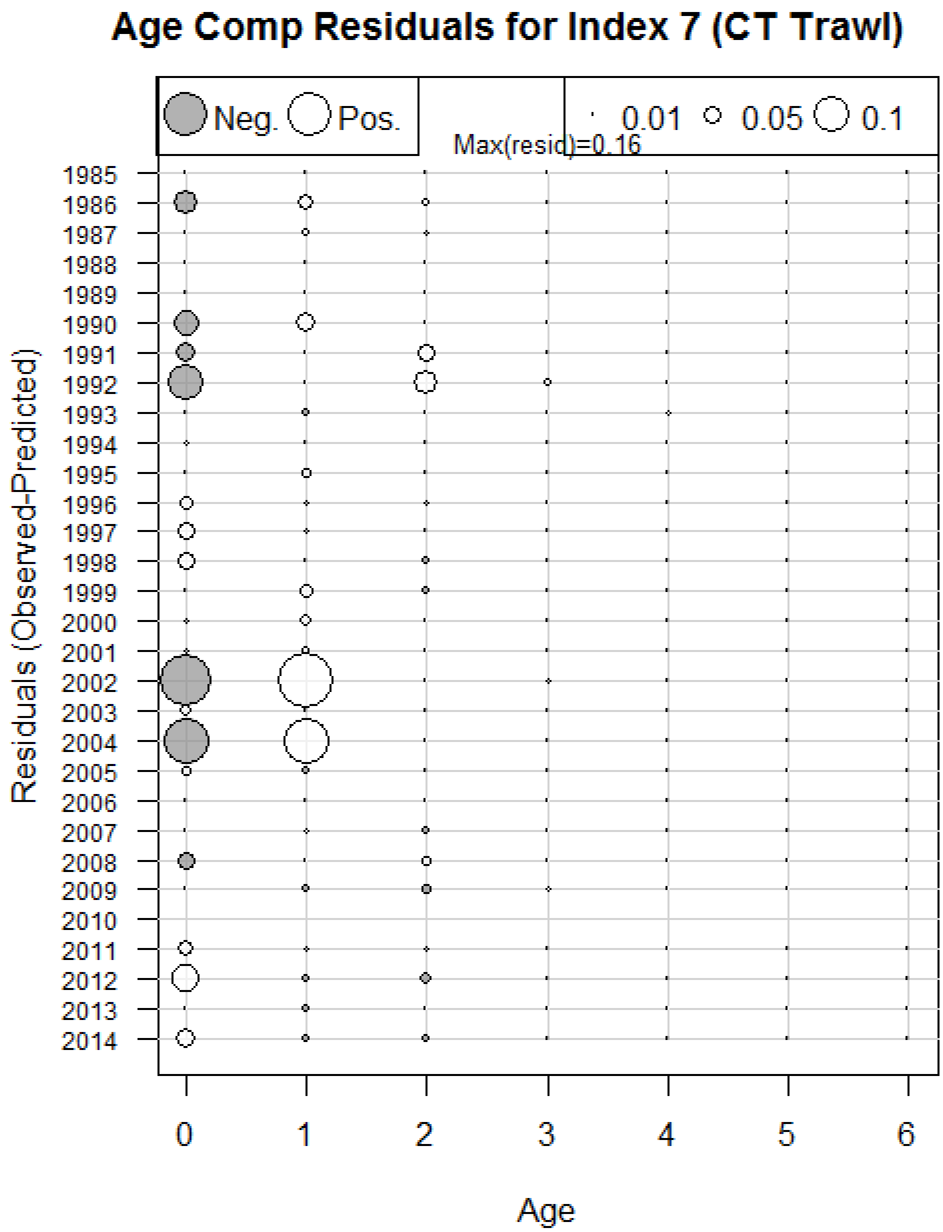


Figure B7.66. Age composition residuals for the CT LISTS trawl survey.

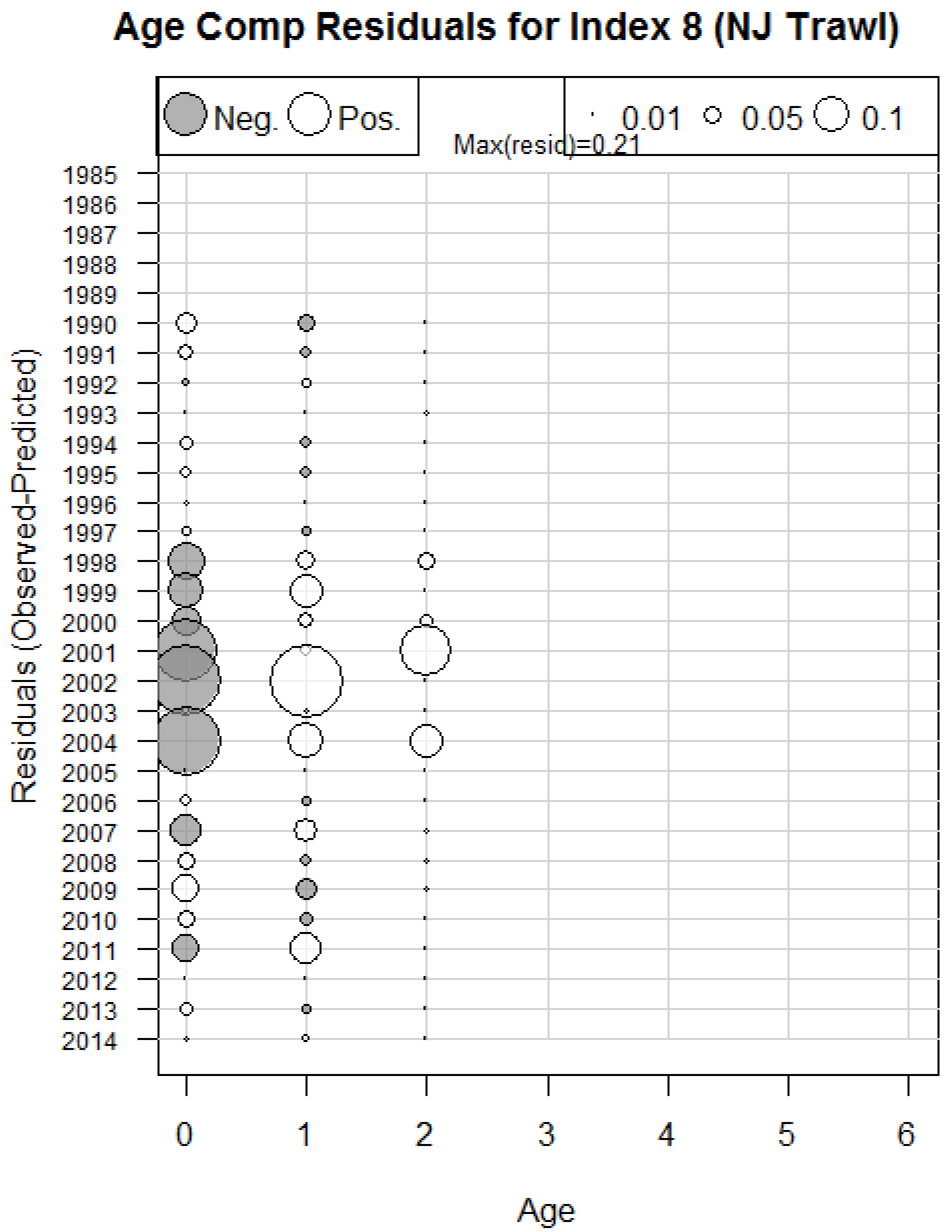


Figure B7.67. Age composition residuals for the NJ ocean trawl survey.

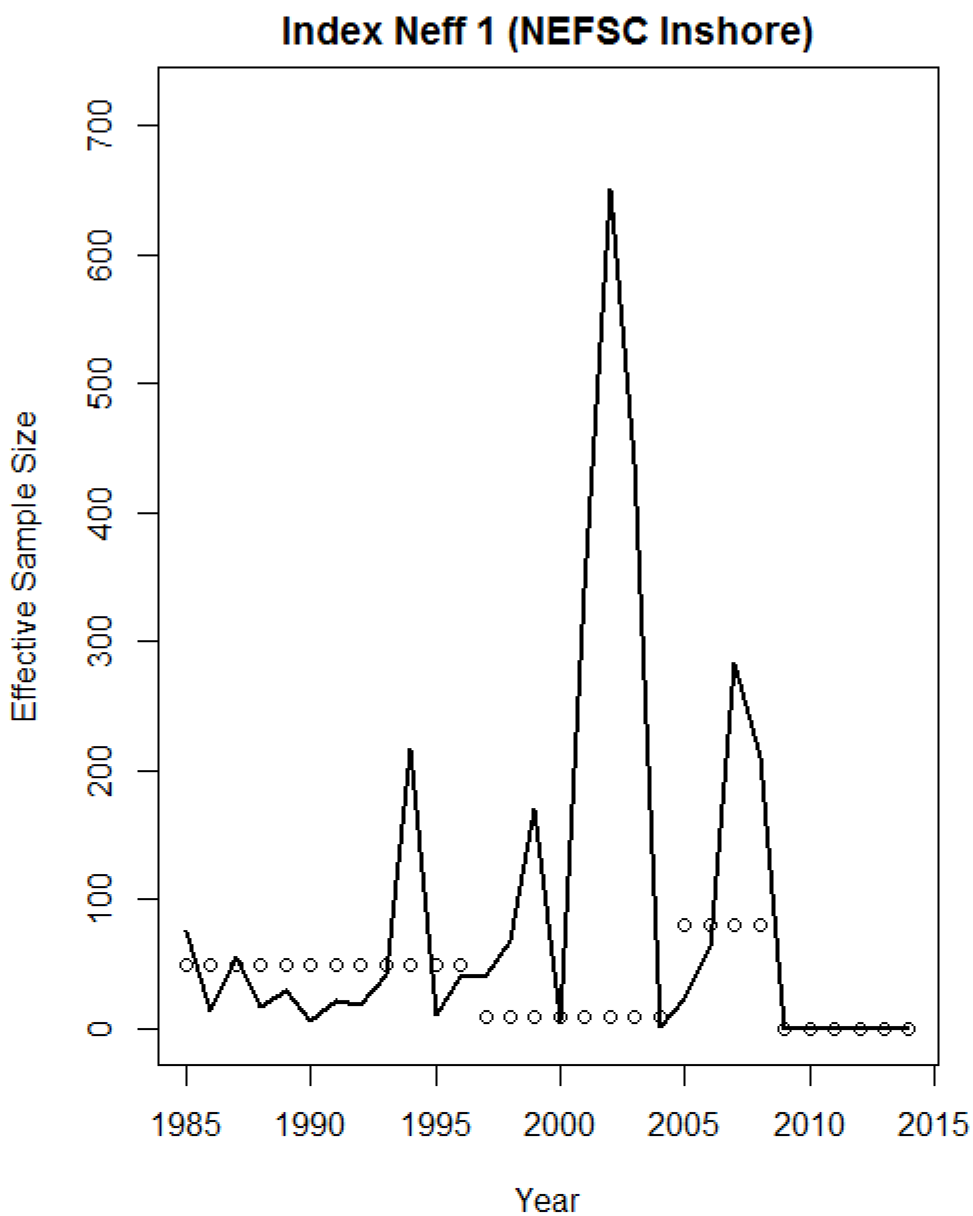


Figure B7.68. Input and estimated effective sample size for the NEFSC Inshore survey.

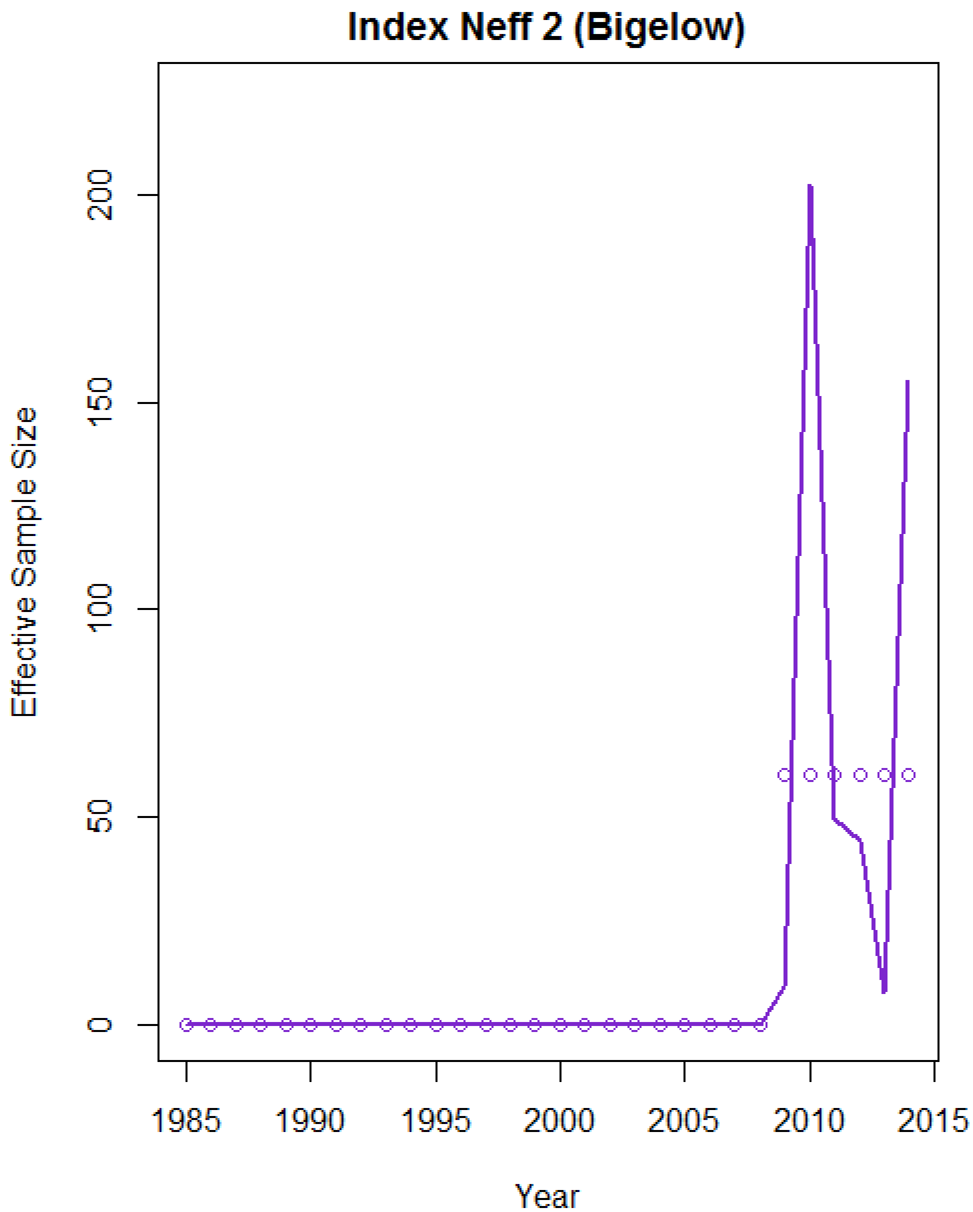


Figure B7.69. Input and estimated effective sample size for the NEFSC Bigelow survey.

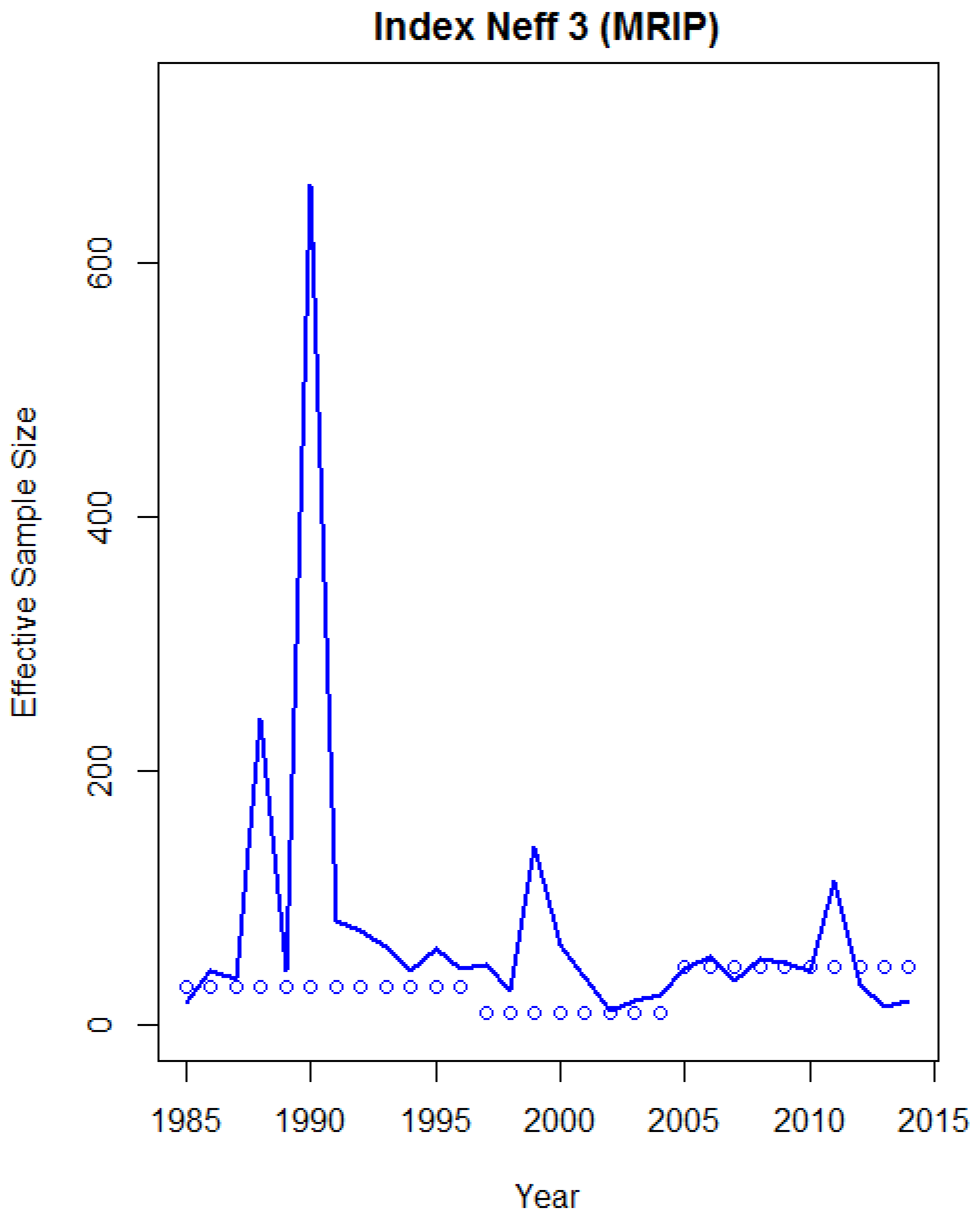


Figure B7.70. Input and estimated effective sample size for the MRIP recreational CPUE index.

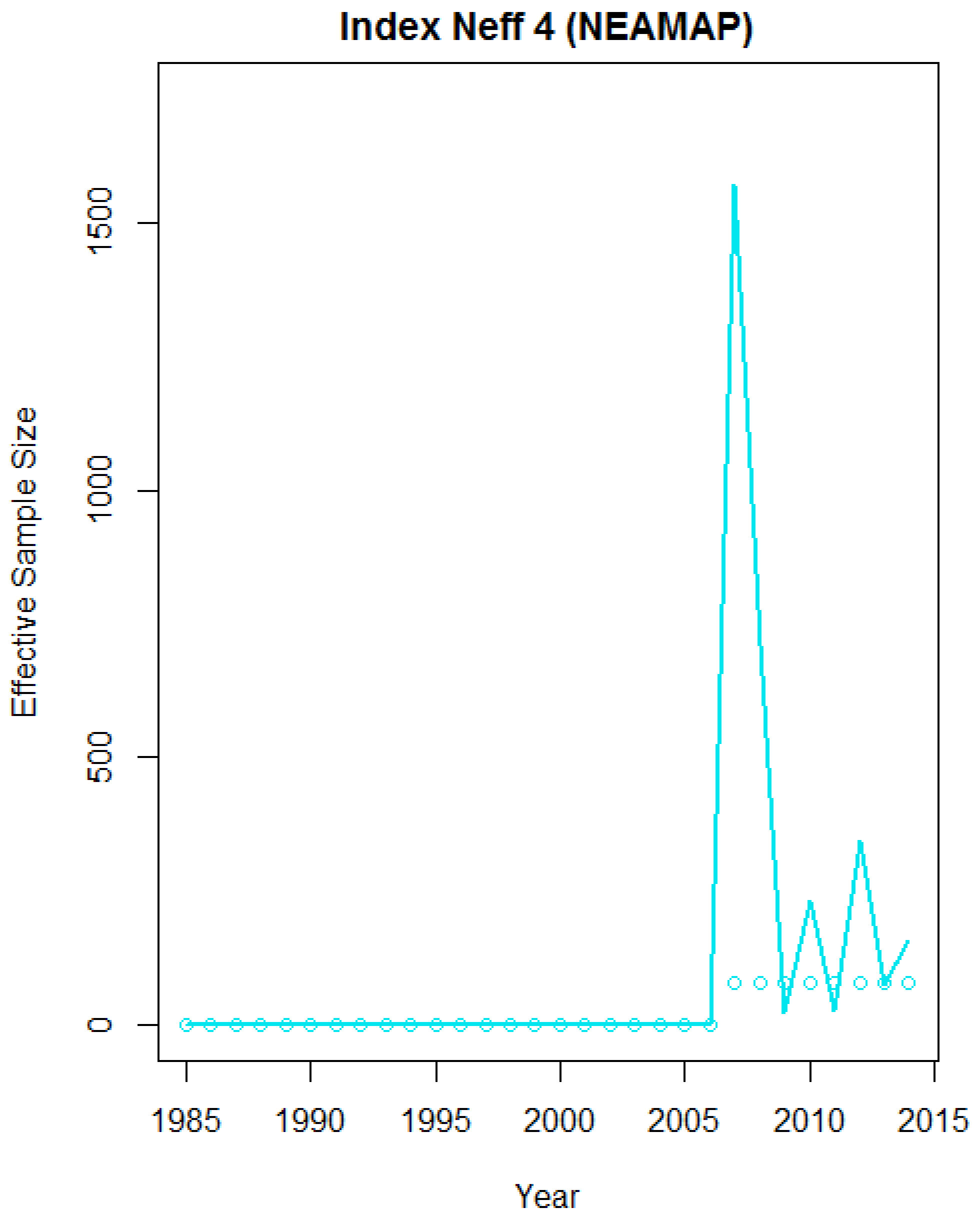


Figure B7.71. Input and estimated effective sample size for the NEAMAP survey.

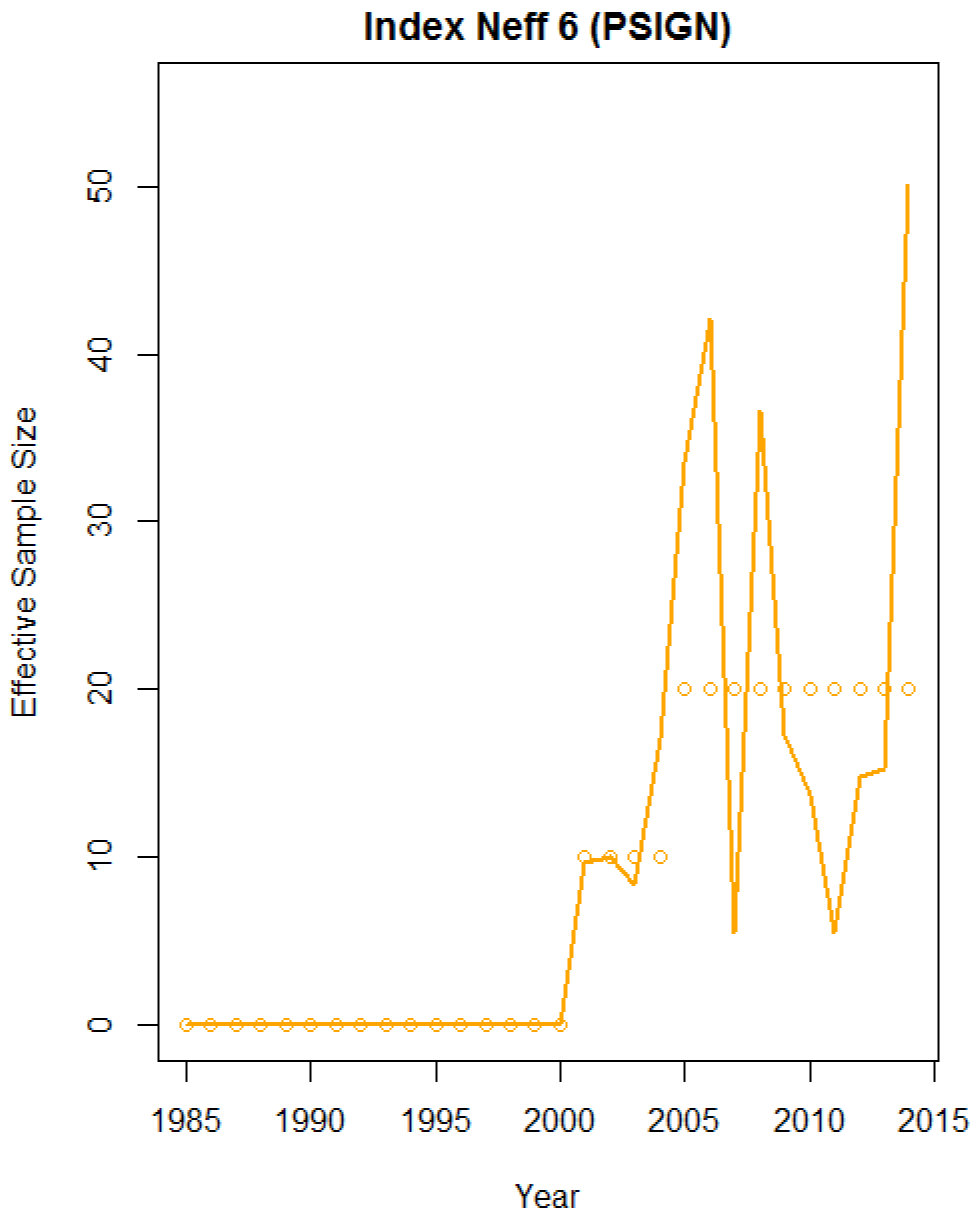


Figure B7.72. Input and estimated effective sample size for the PSIGNS gillnet survey.

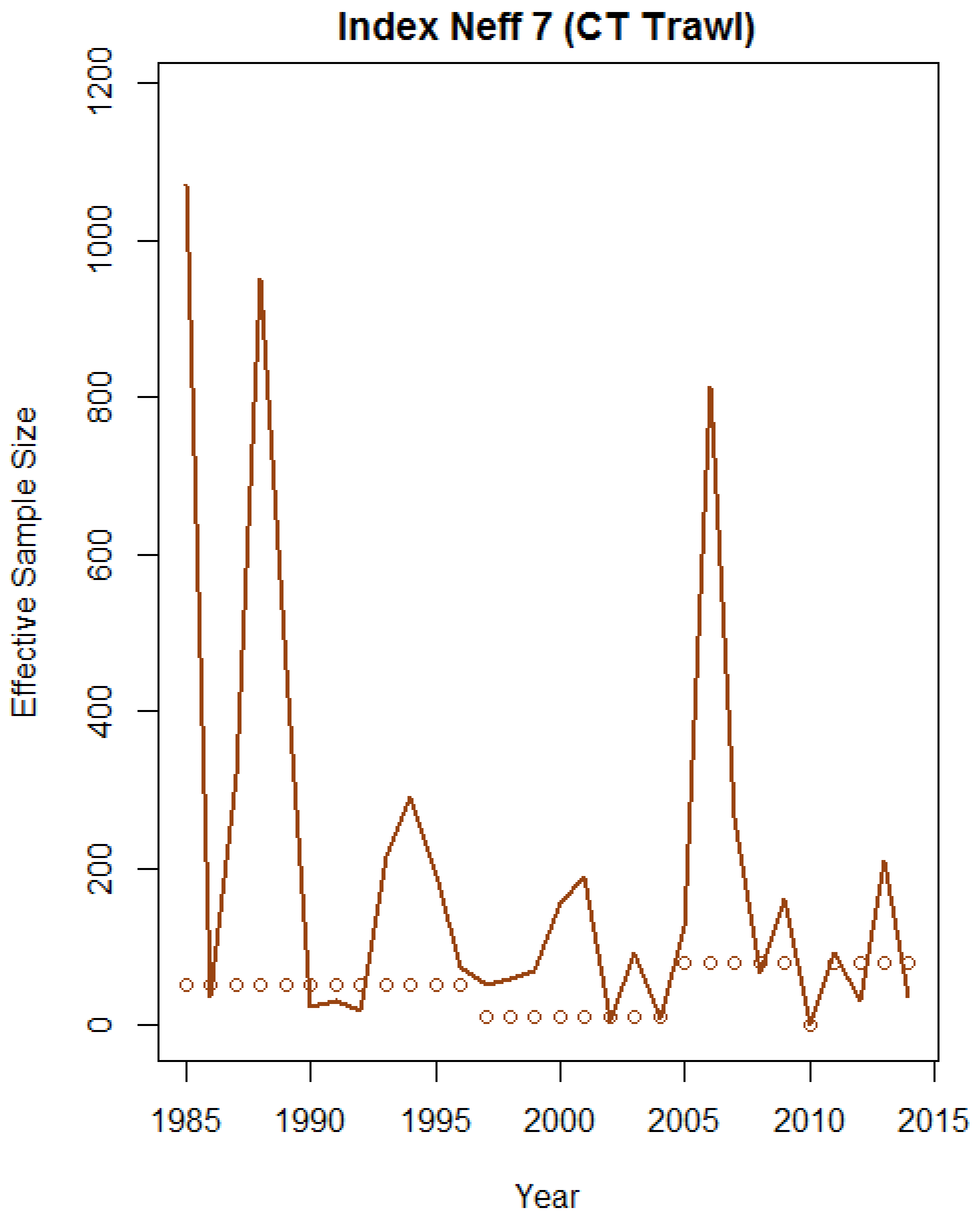


Figure B7.73. Input and estimated effective sample size for the CT LISTS trawl survey.

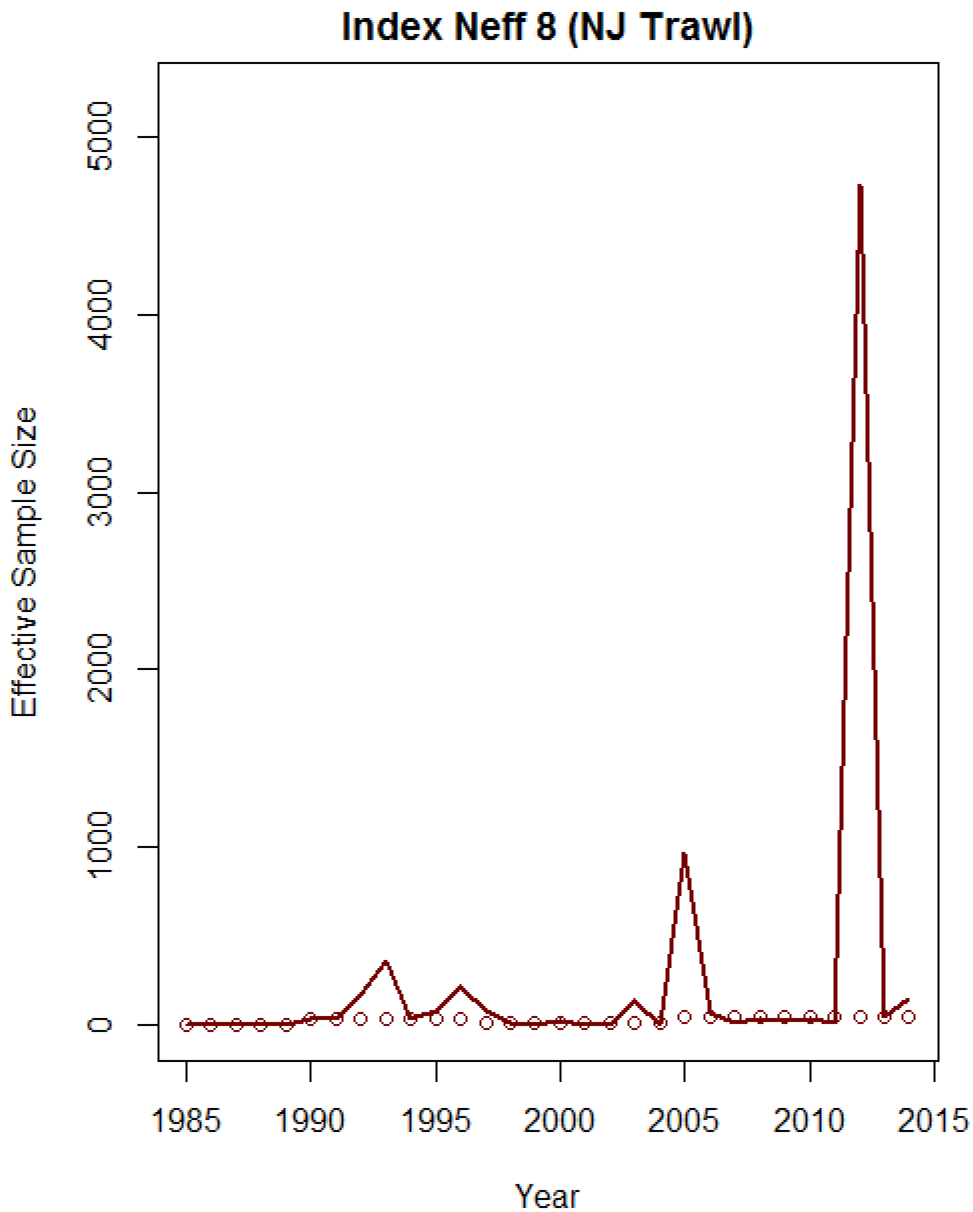


Figure B7.74. Input and estimated effective sample size for the NJ ocean trawl survey.

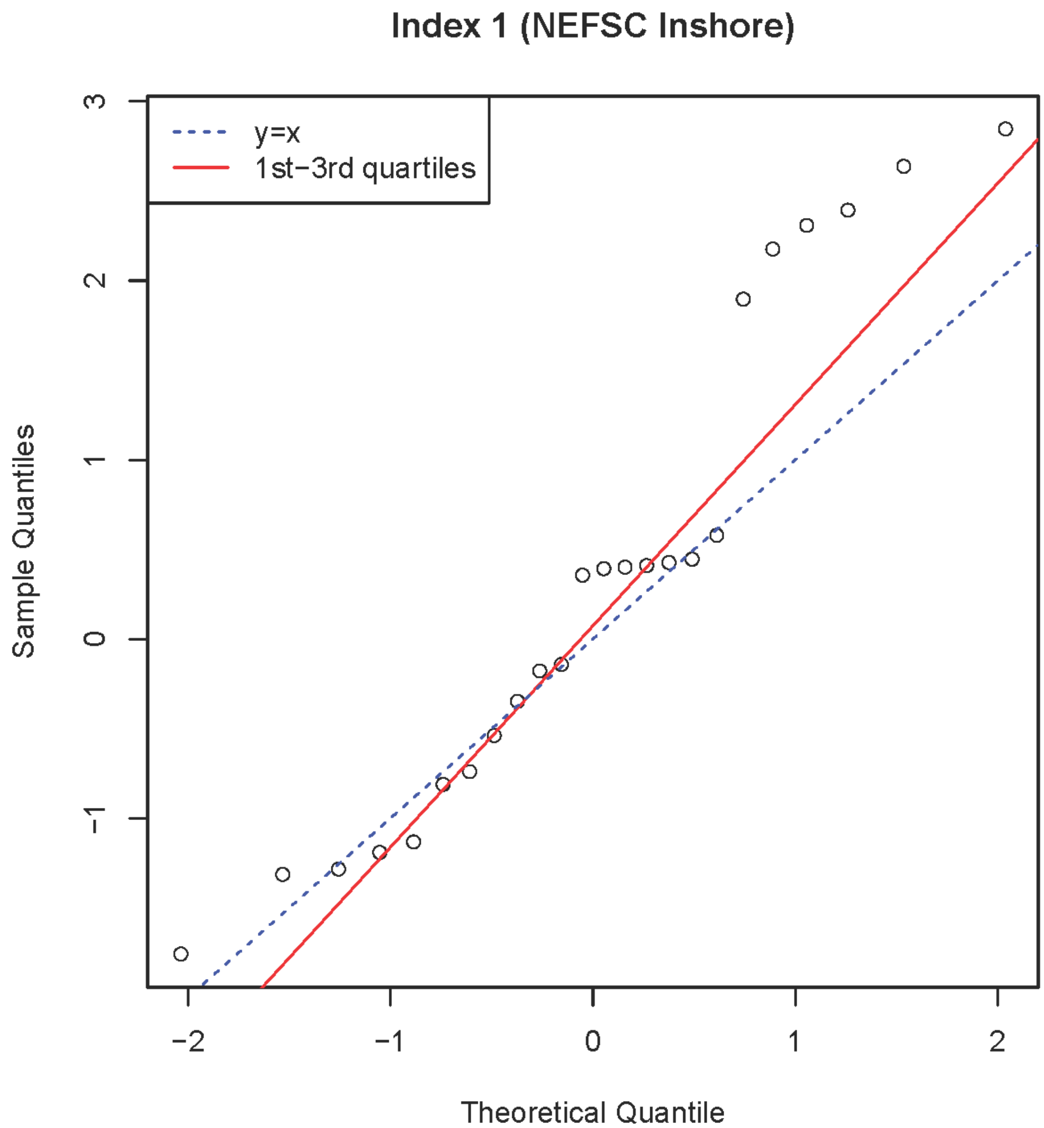


Figure B7.75. QQ-plot for the observed versus predicted mean catch for the NEFSC Inshore survey.

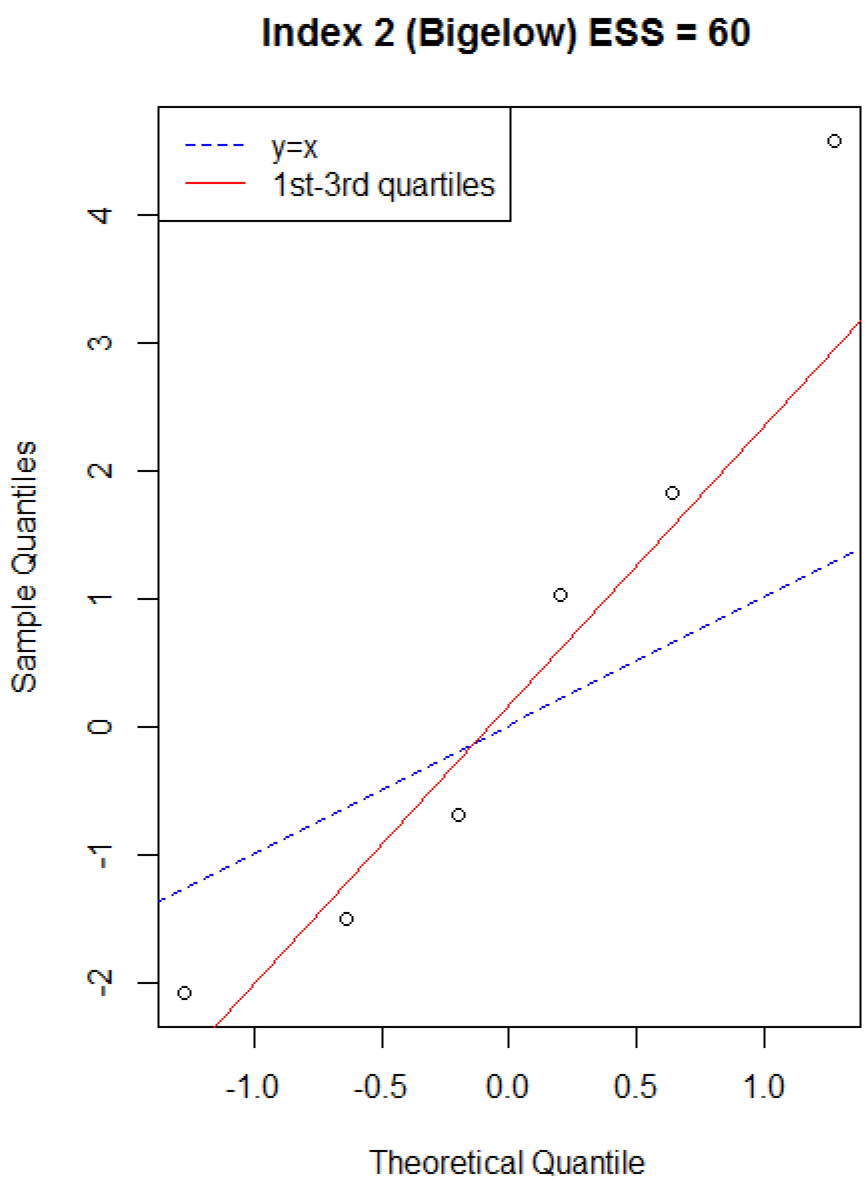


Figure B7.76. QQ-plot for the observed versus predicted mean catch for the NEFSC Bigelow survey.

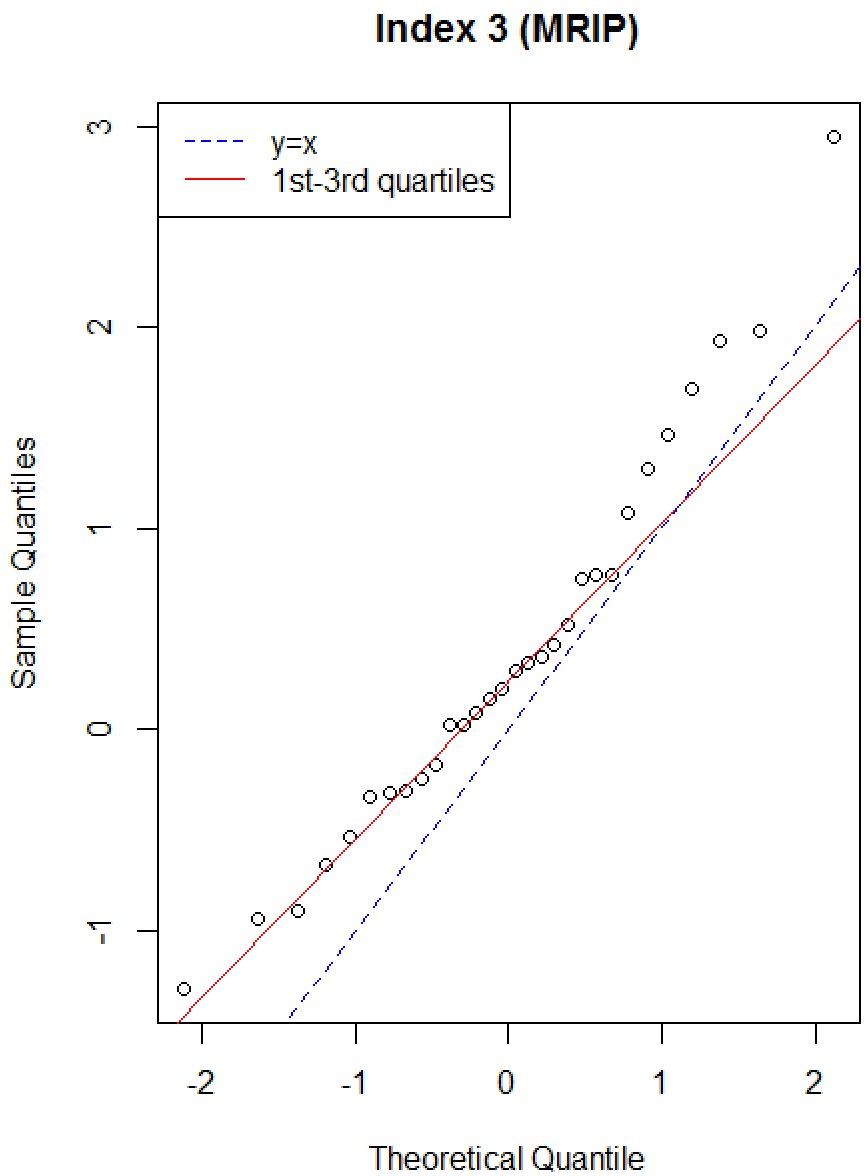


Figure B7.77. QQ-plot for the observed versus predicted mean catch for the MRIP recreational CPUE index.

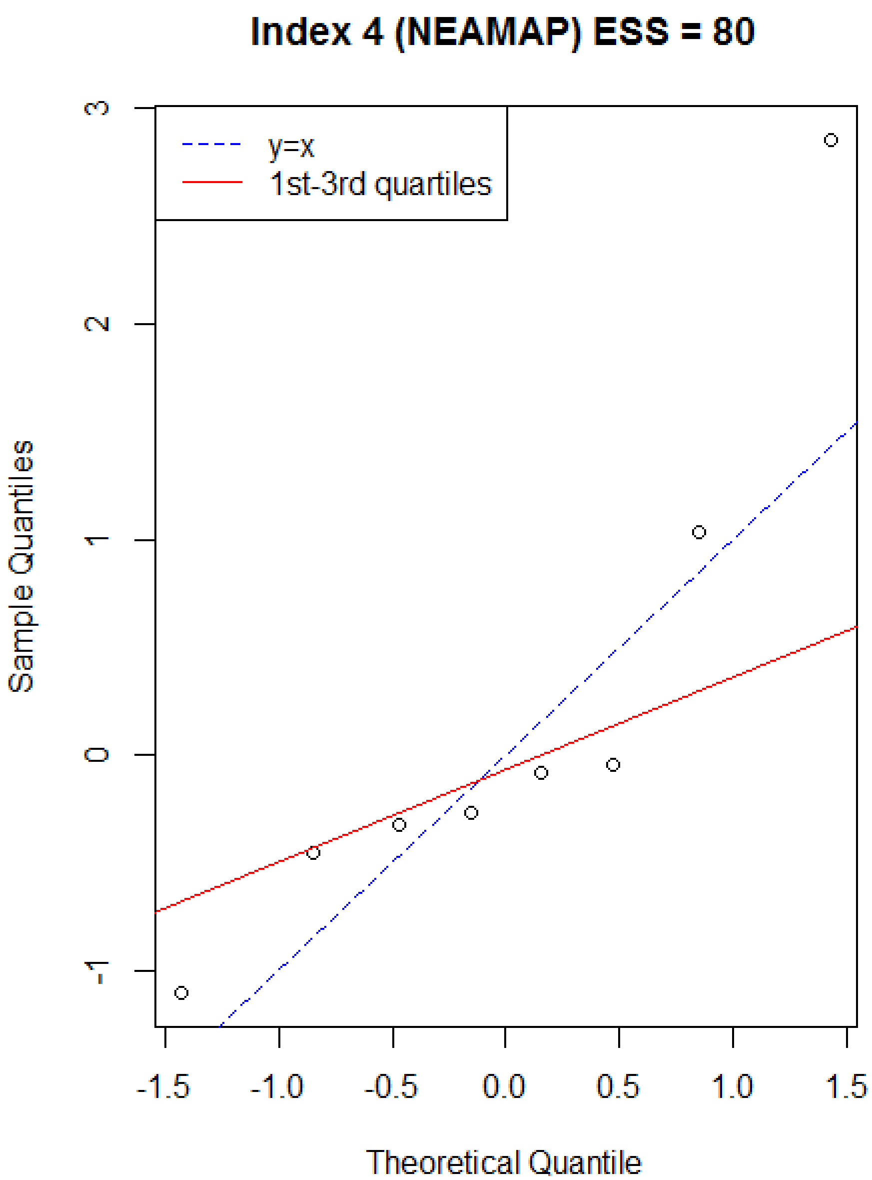


Figure B7.78. QQ-plot for the observed versus predicted mean catch for the NEAMAP survey.

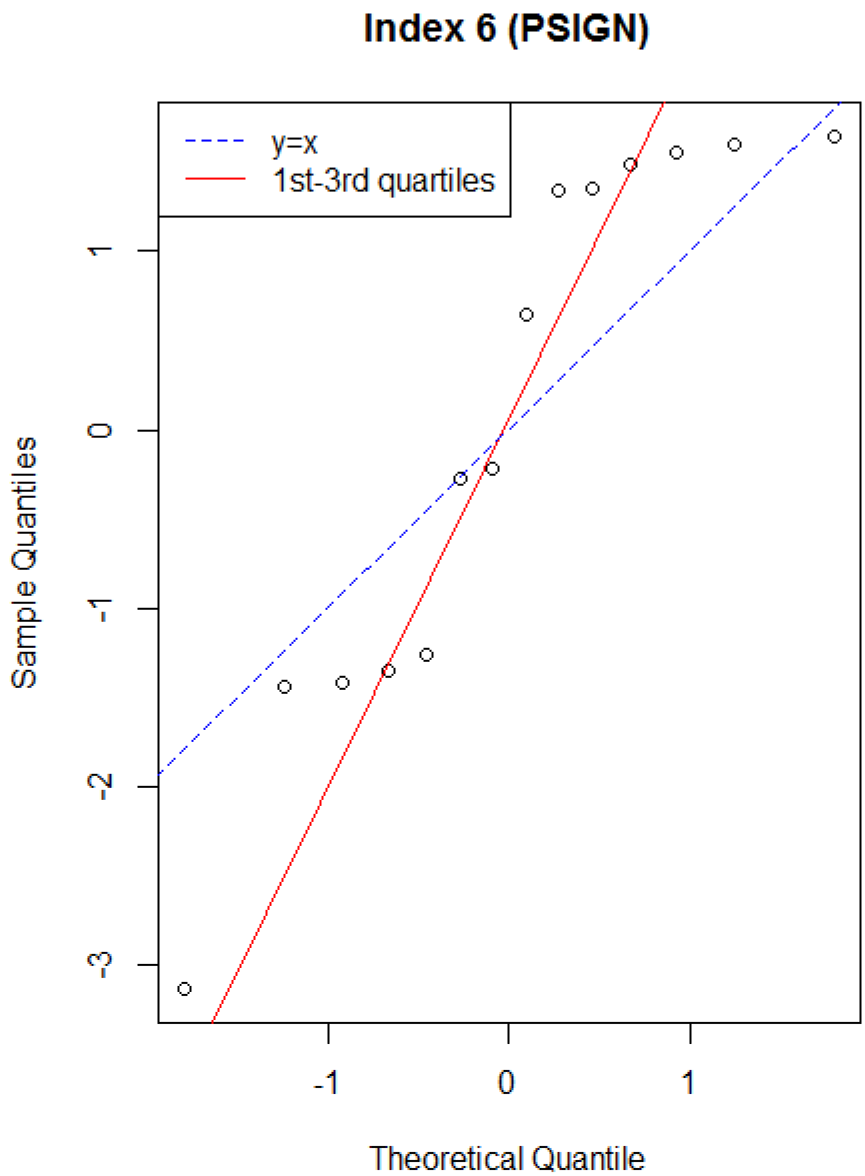


Figure B7.79. QQ-plot for the observed versus predicted mean catch for the PSIGNS gillnet survey.

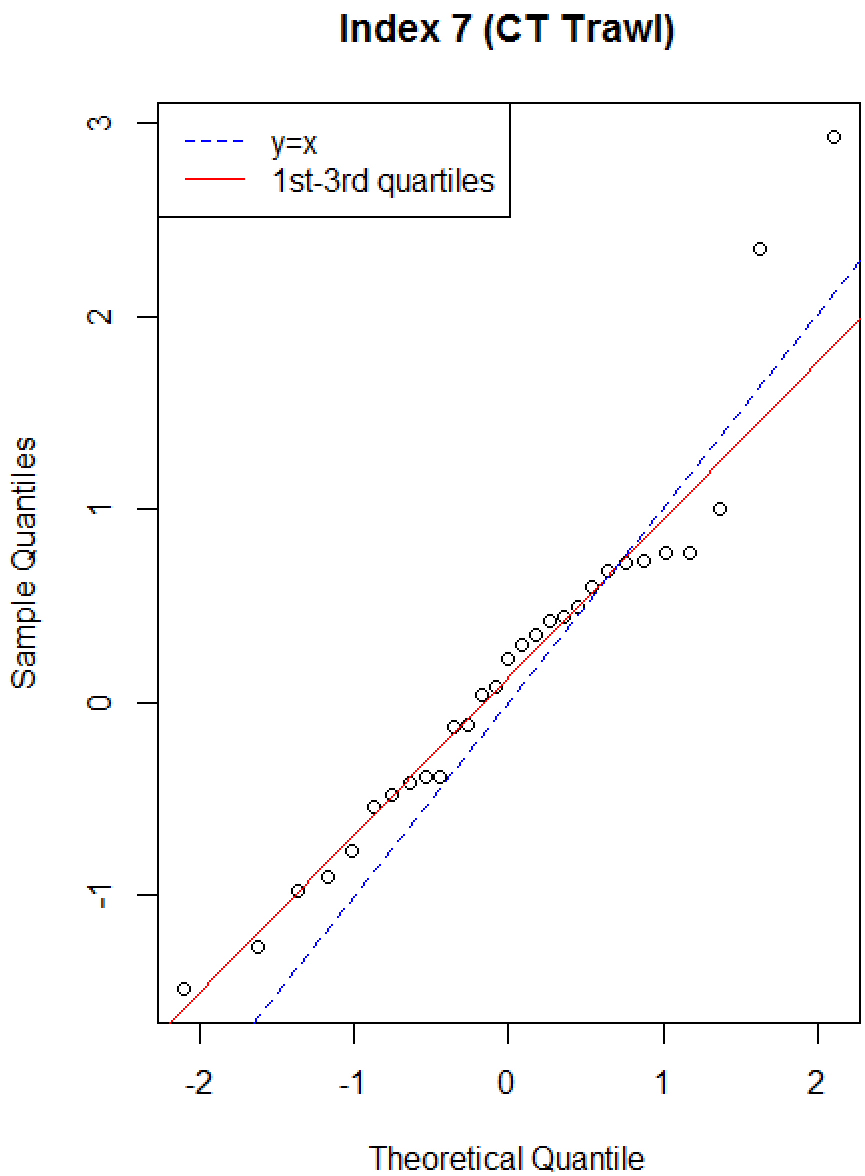


Figure B7.80. QQ-plot for the observed versus predicted mean catch for the CT LISTS trawl survey.

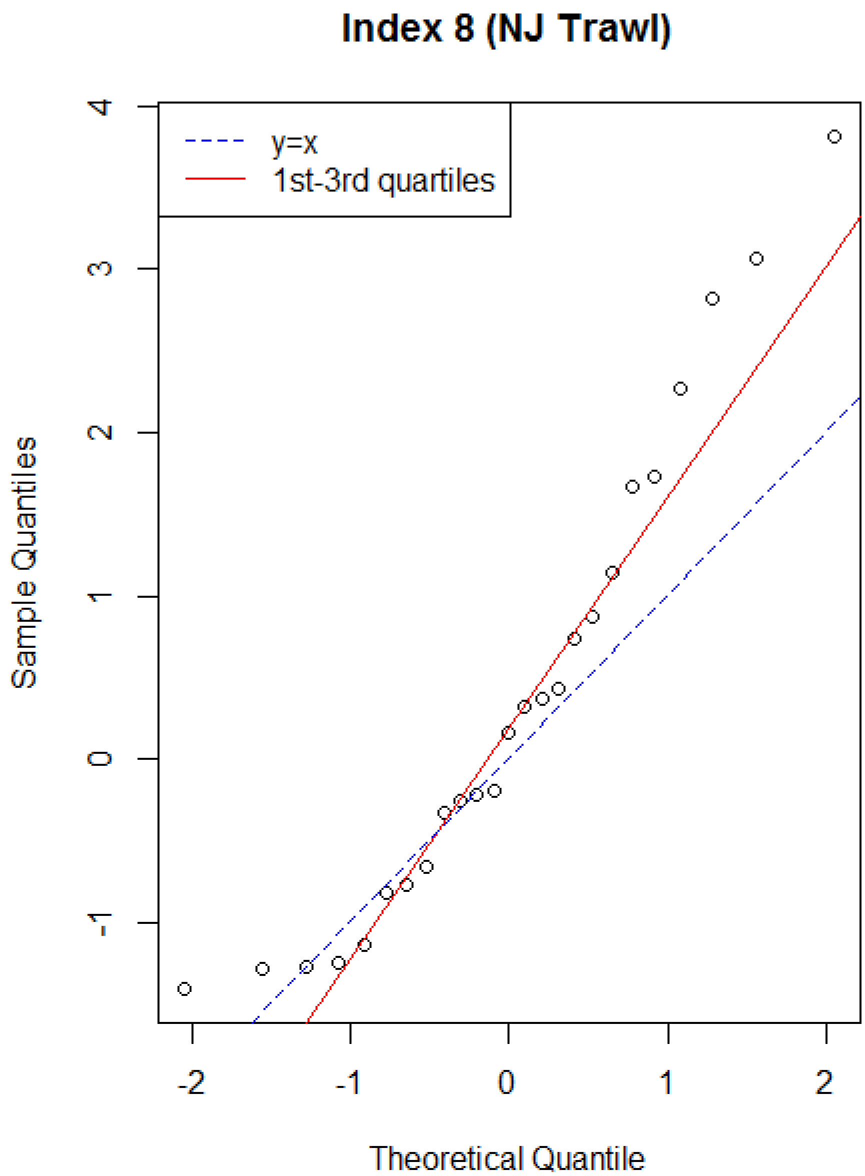


Figure B7.81. QQ-plot for the observed versus predicted mean catch for the NJ ocean trawl survey.

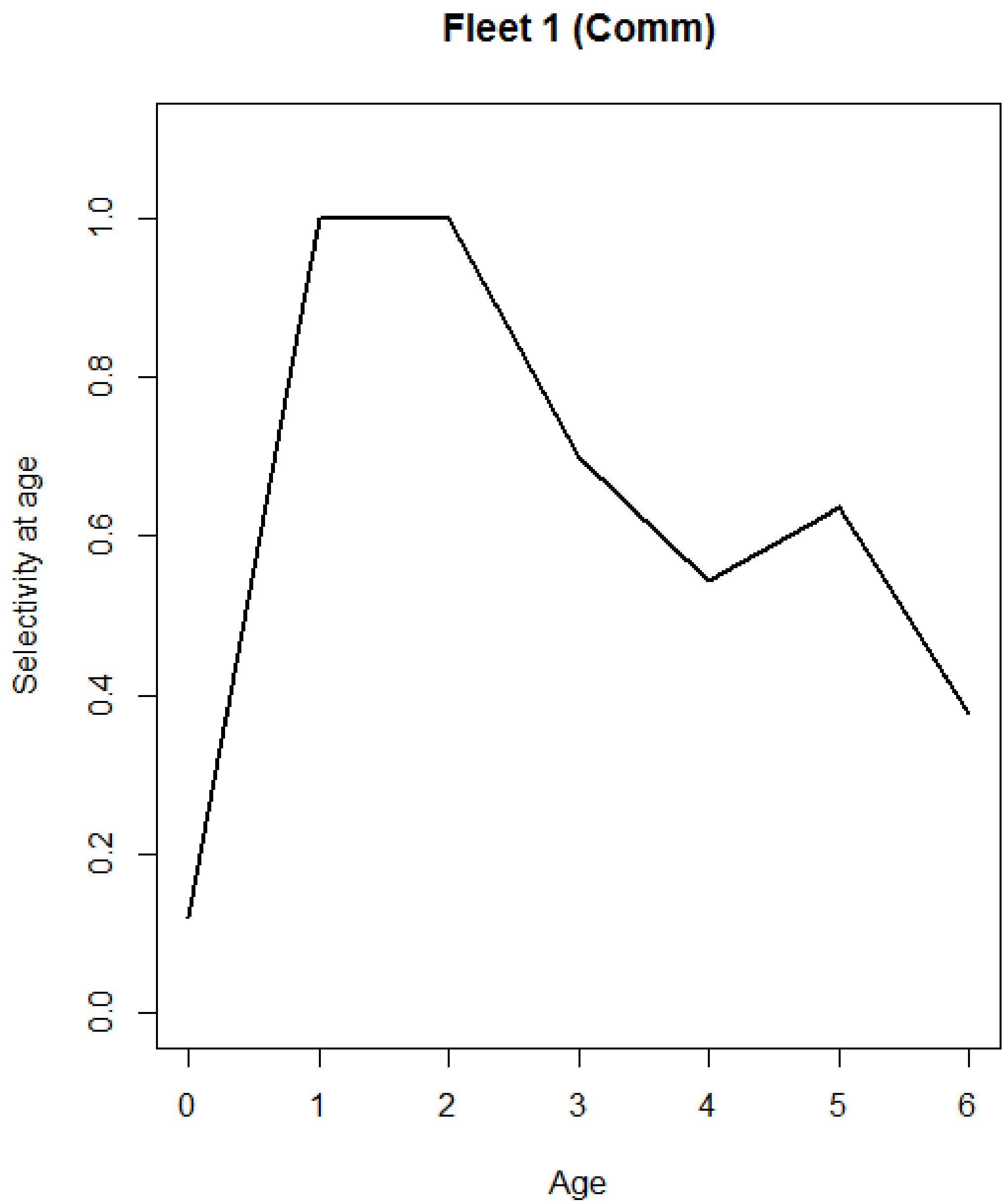


Figure B7.82. Estimated selectivity for the commercial fleet from the final model

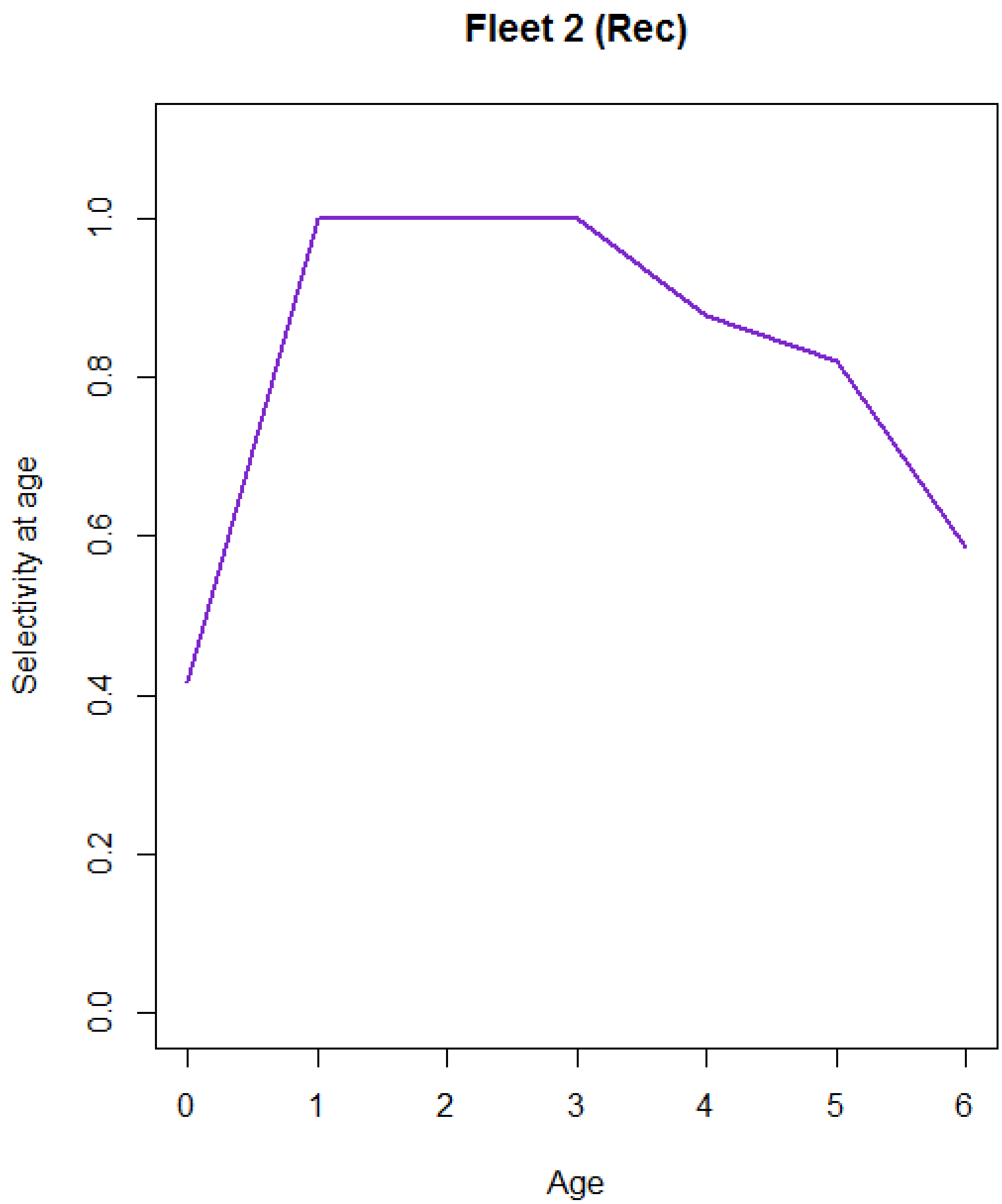


Figure B7.83. Estimated selectivity for the recreational fleet from the final model.

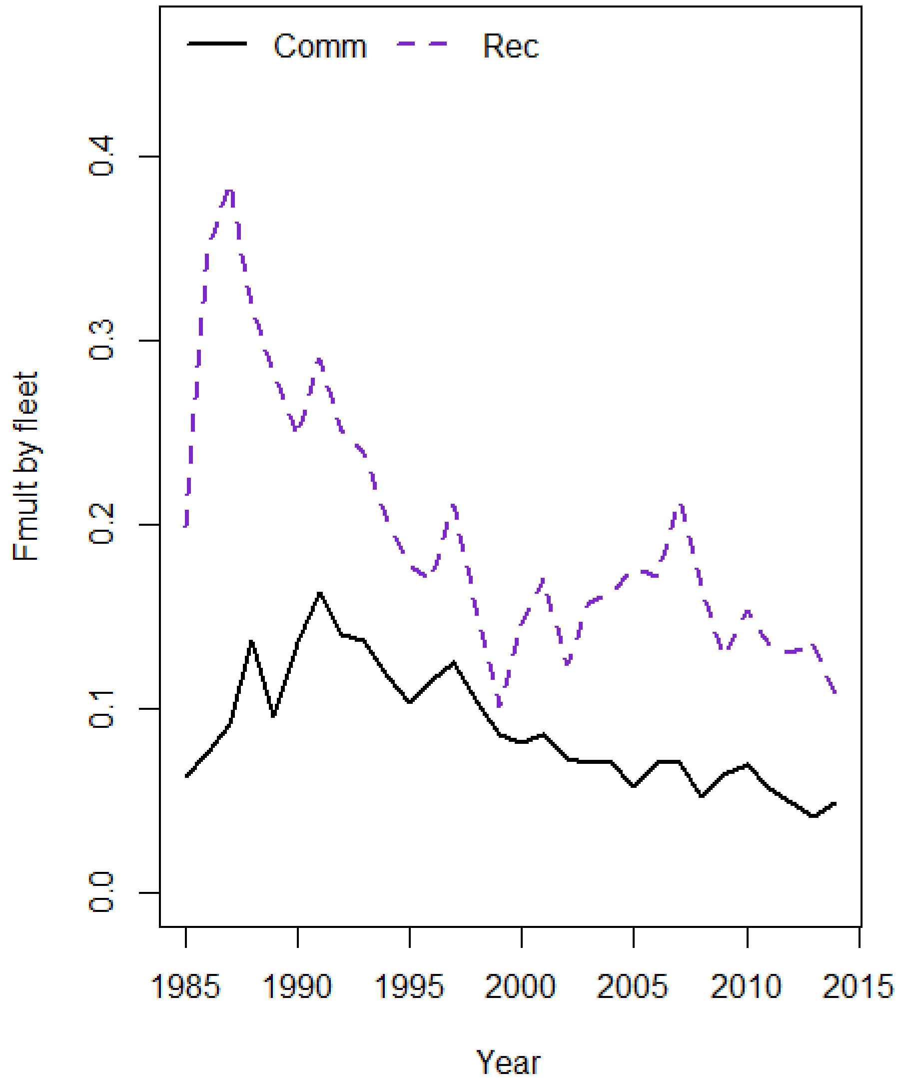


Figure B7.84. Full F (F_{mult}) estimates for the commercial (fleet 1) and recreational (fleet 2) fleets.

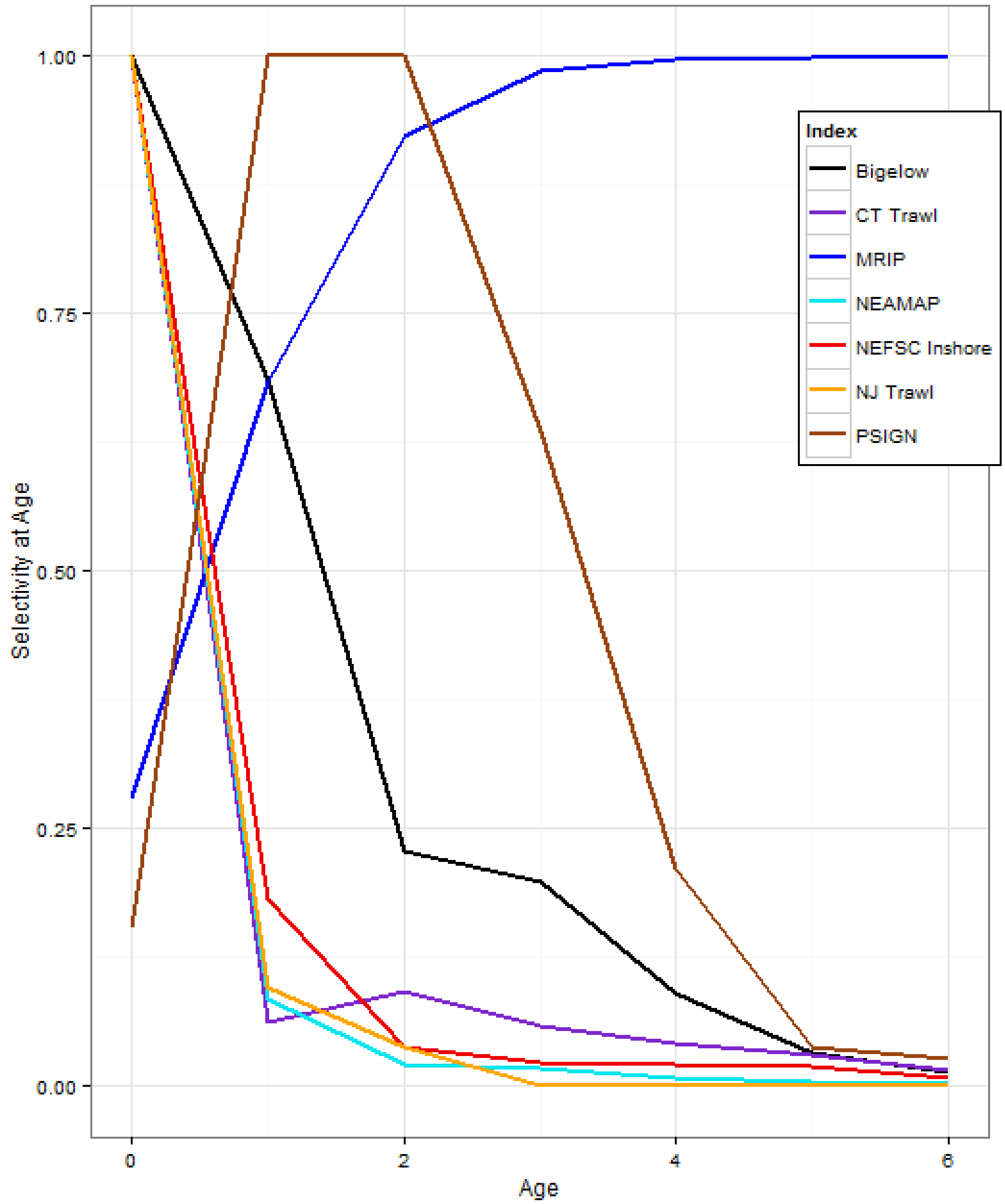


Figure B7.85. Estimated selectivities for the indices from the final model. Note the two age 0 indices are not plotted so only 7 selectivities are shown.

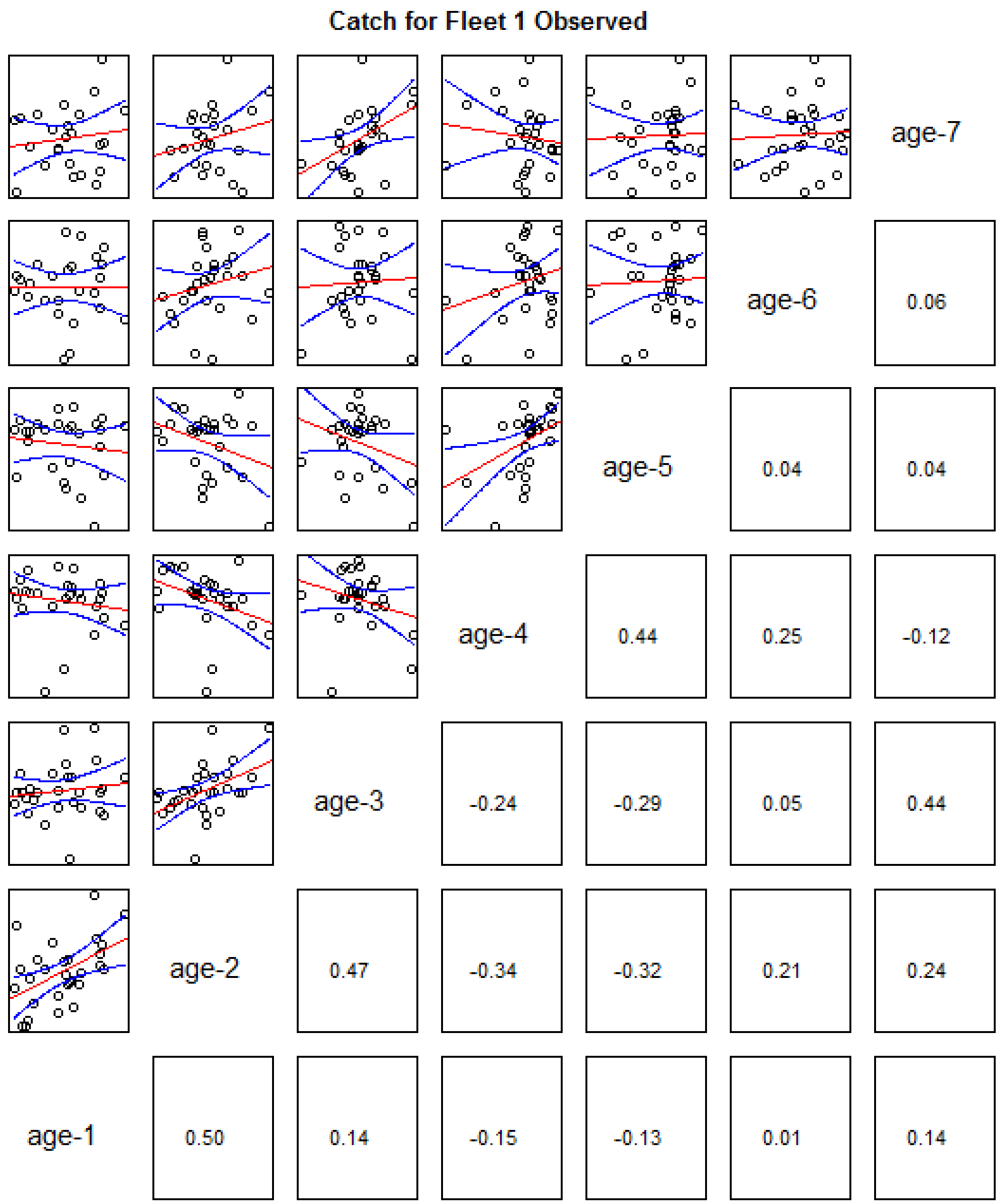


Figure B7.86. Observed catch for the commercial fleet. Note that age class labels are 1 greater than the modeled age class, so that "age-1" corresponds to age 0, "age-2" corresponds to age 1, etc.

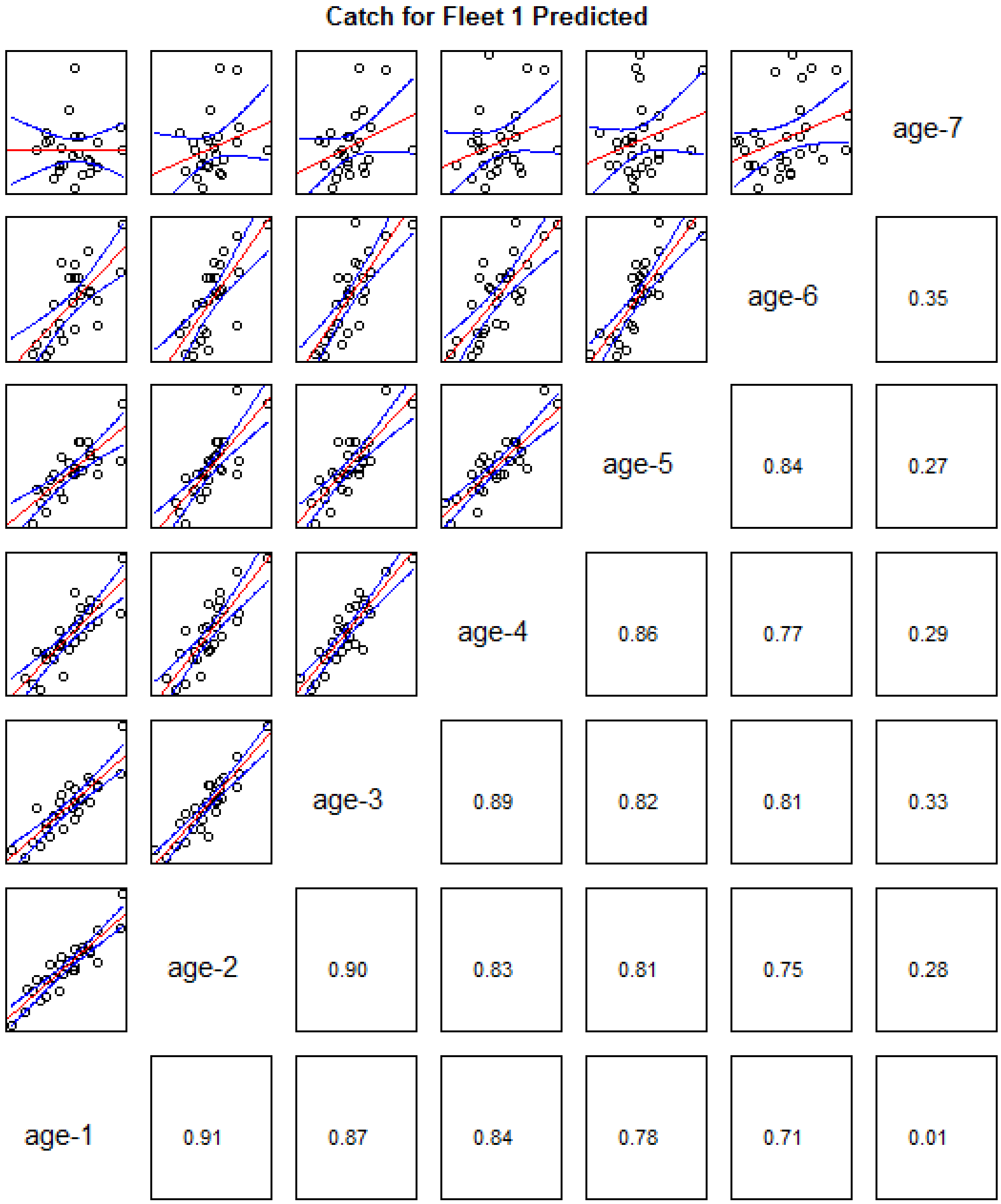


Figure B7.87. Predicted catch for the commercial fleet.
Note that age class labels are 1 greater than the modeled age class, so that "age-1" corresponds to age 0, "age-2" corresponds to age 1, etc.

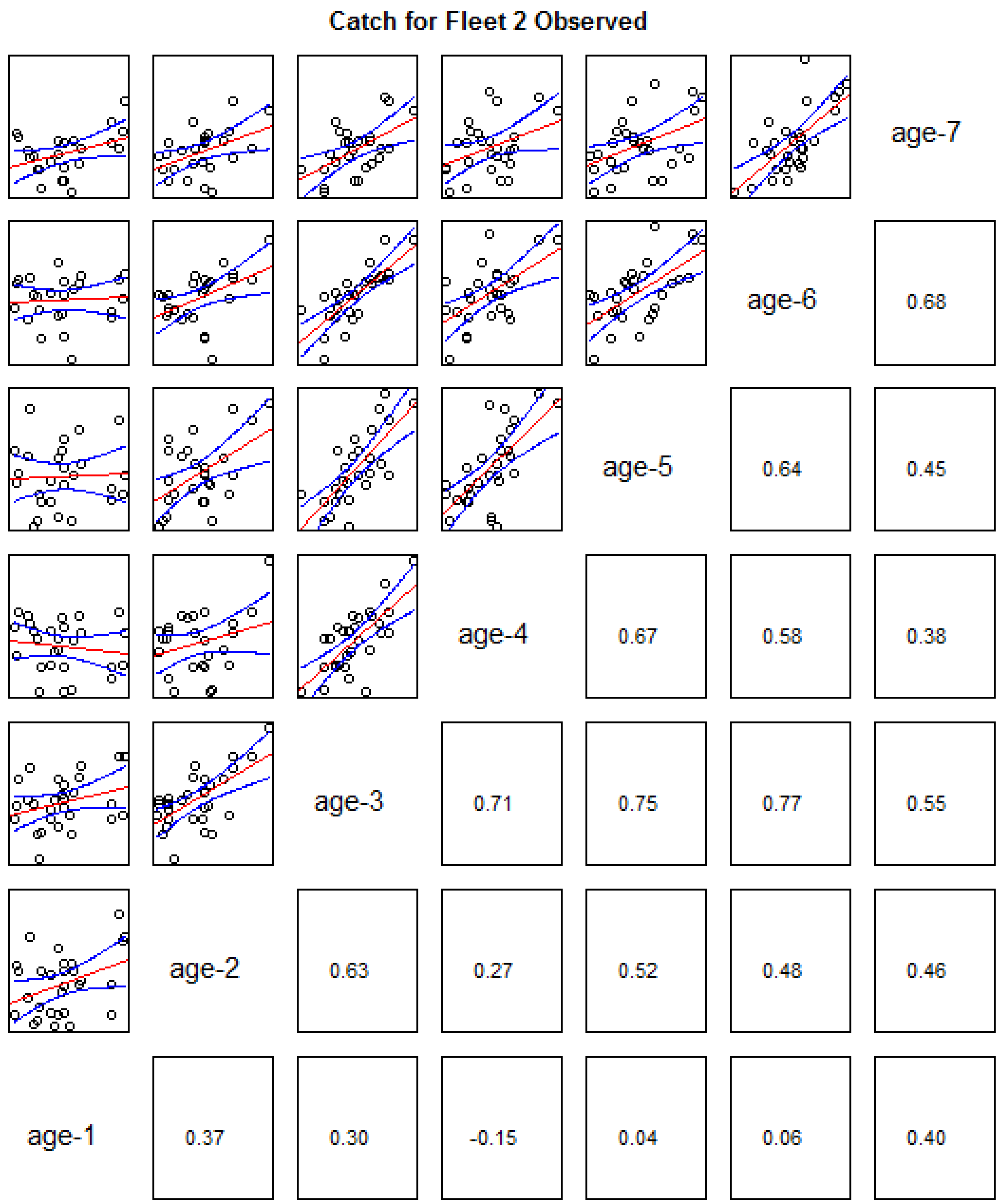


Figure B7.88. Observed catch for the recreational fleet. Note that age class labels are 1 greater than the modeled age class, so that “age-1” corresponds to age 0, “age-2” corresponds to age 1, etc.

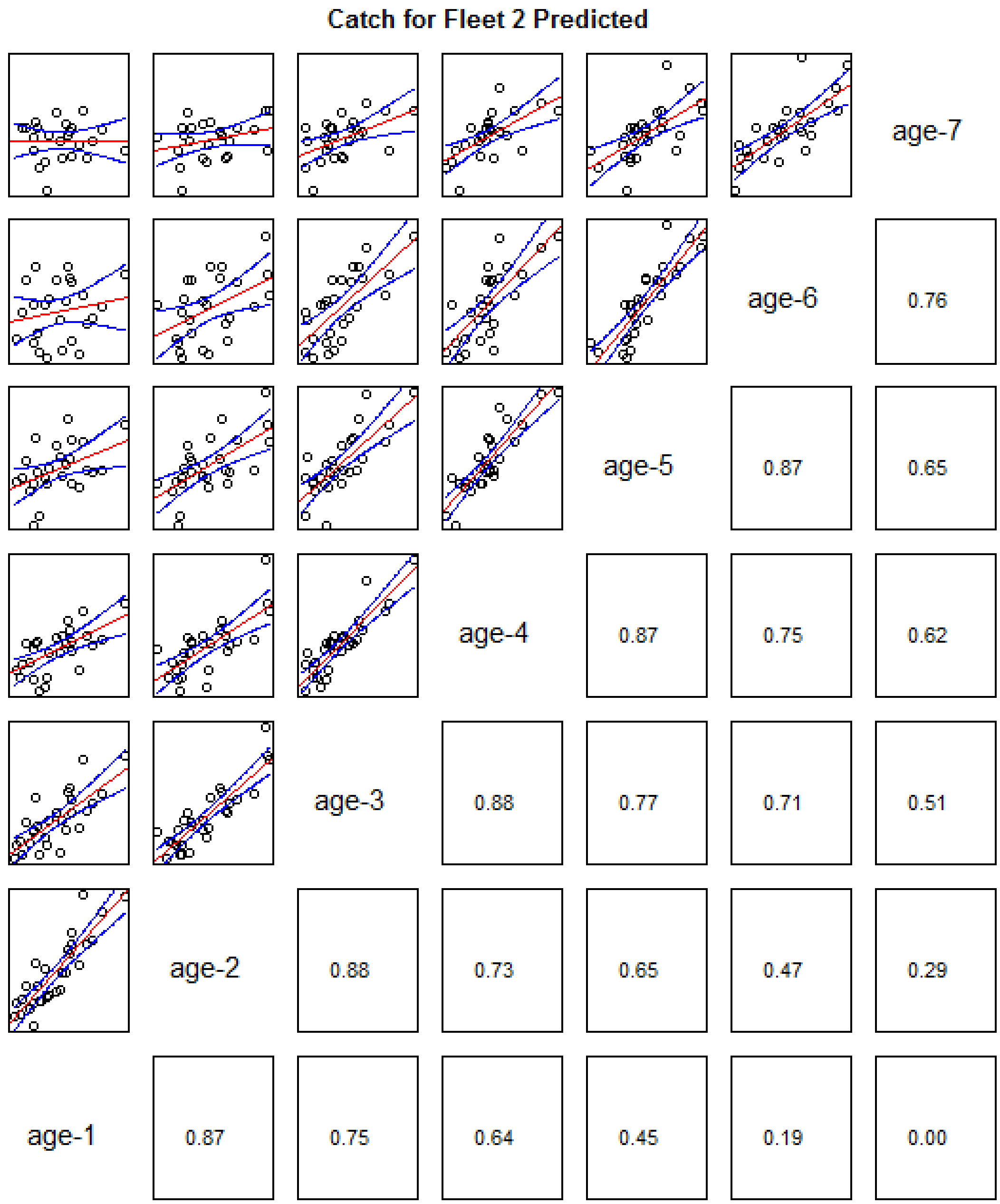


Figure B7.89. Predicted catch for the recreational fleet. Note that age class labels are 1 greater than the modeled age class, so that "age-1" corresponds to age 0, "age-2" corresponds to age 1, etc.

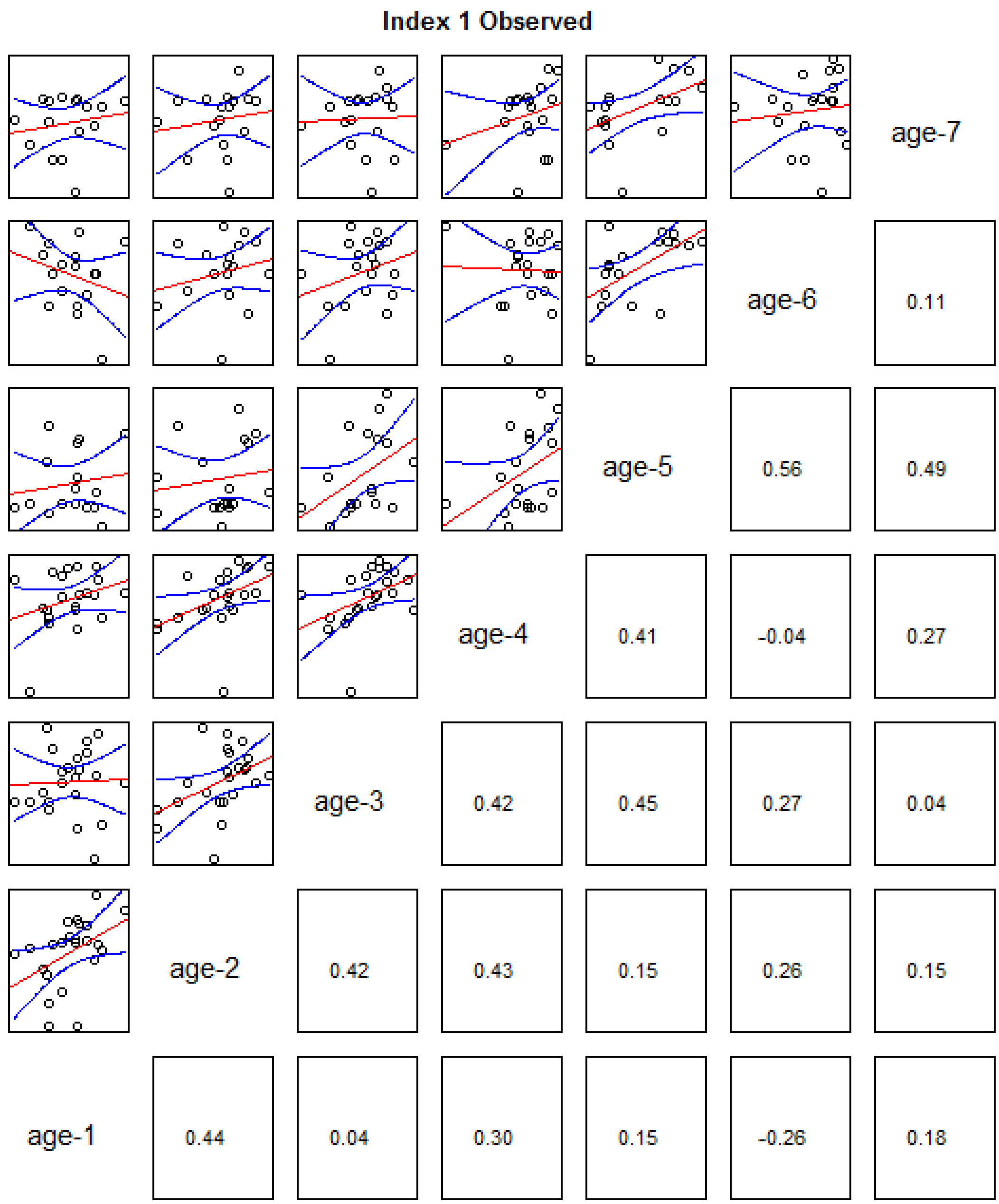


Figure B7.90. Observed catch for the NEFSC Inshore survey. Note that age class labels are 1 greater than the modeled age class, so that "age-1" corresponds to age 0, "age-2" corresponds to age 1, etc.

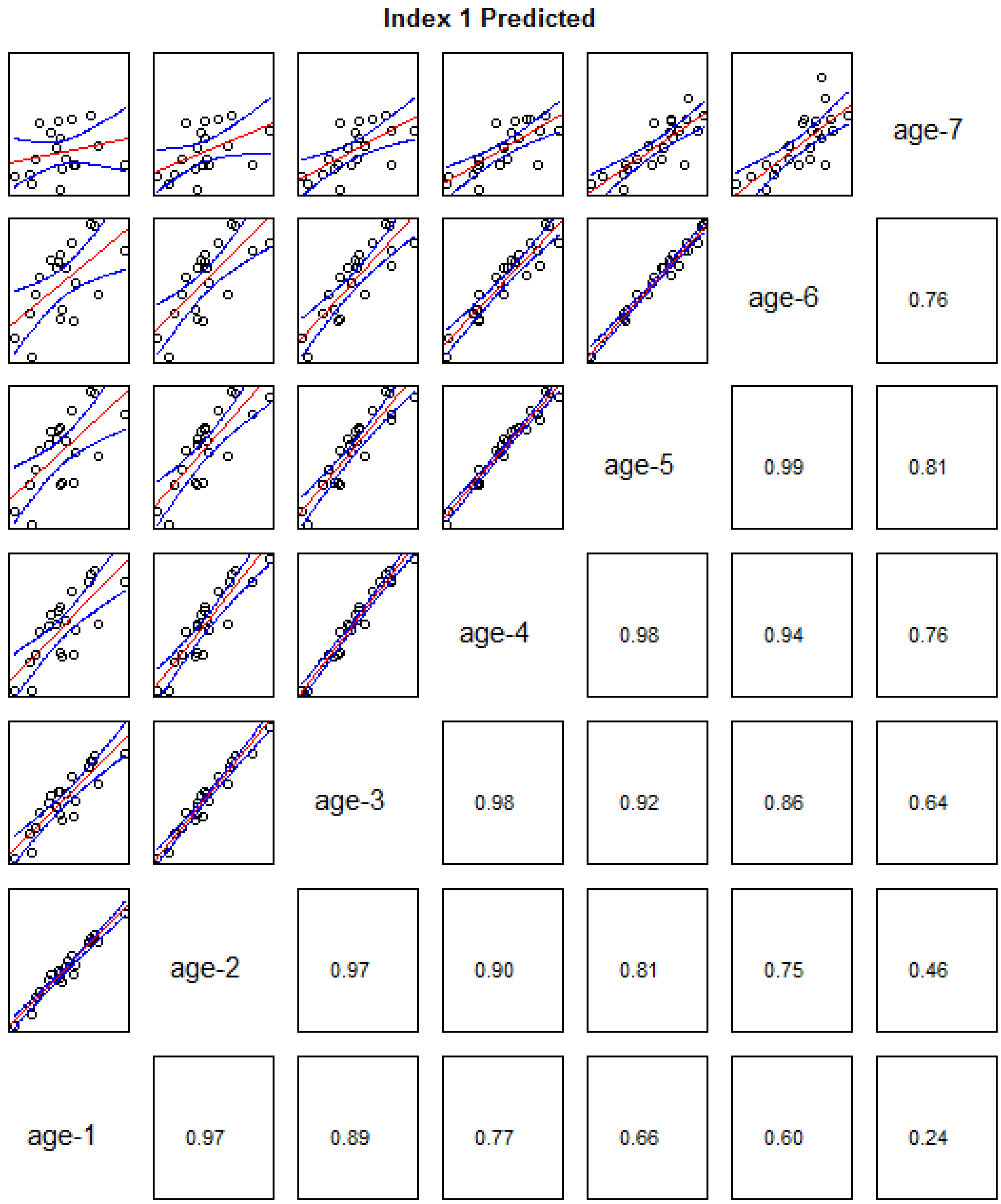


Figure B7.91. Predicted catch for the NEFSC Inshore survey. Note that age class labels are 1 greater than the modeled age class, so that "age-1" corresponds to age 0, "age-2" corresponds to age 1, etc.

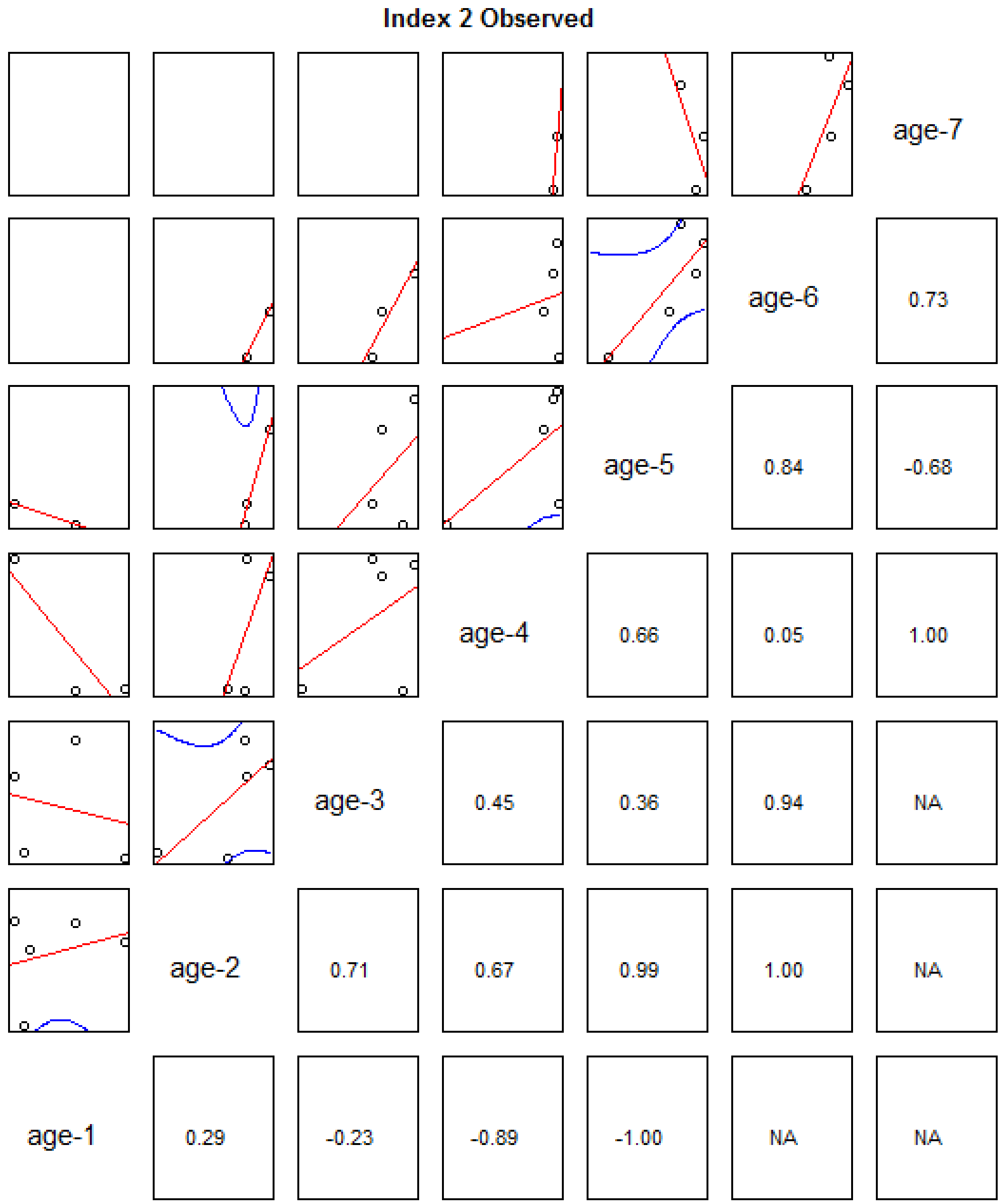


Figure B7.92. Observed catch for the NEFSC Bigelow survey. Note that age class labels are 1 greater than the modeled age class, so that "age-1" corresponds to age 0, "age-2" corresponds to age 1, etc.

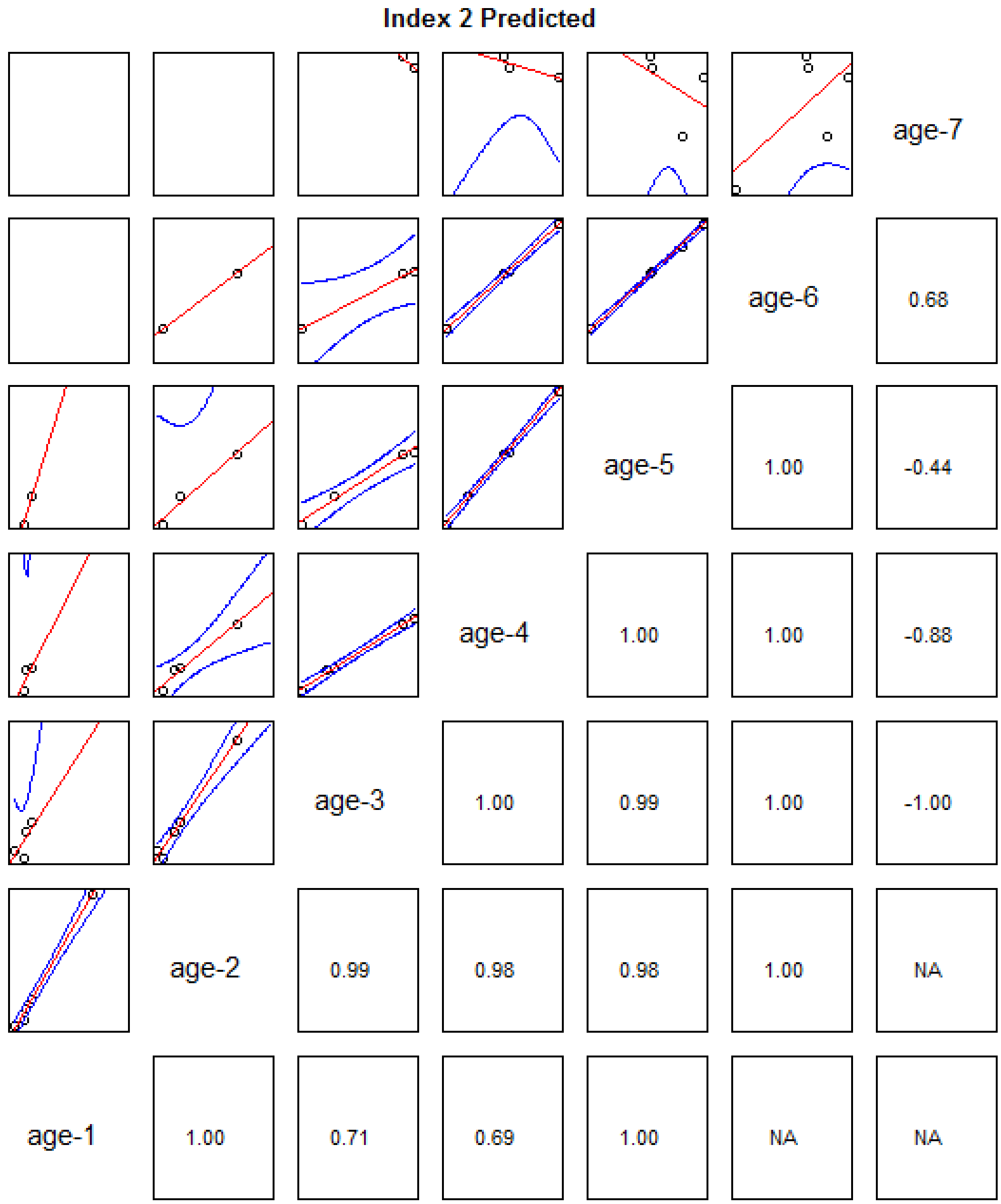


Figure B7.93. Predicted catch for the NEFSC Bigelow survey. Note that age class labels are 1 greater than the modeled age class, so that "age-1" corresponds to age 0, "age-2" corresponds to age 1, etc.

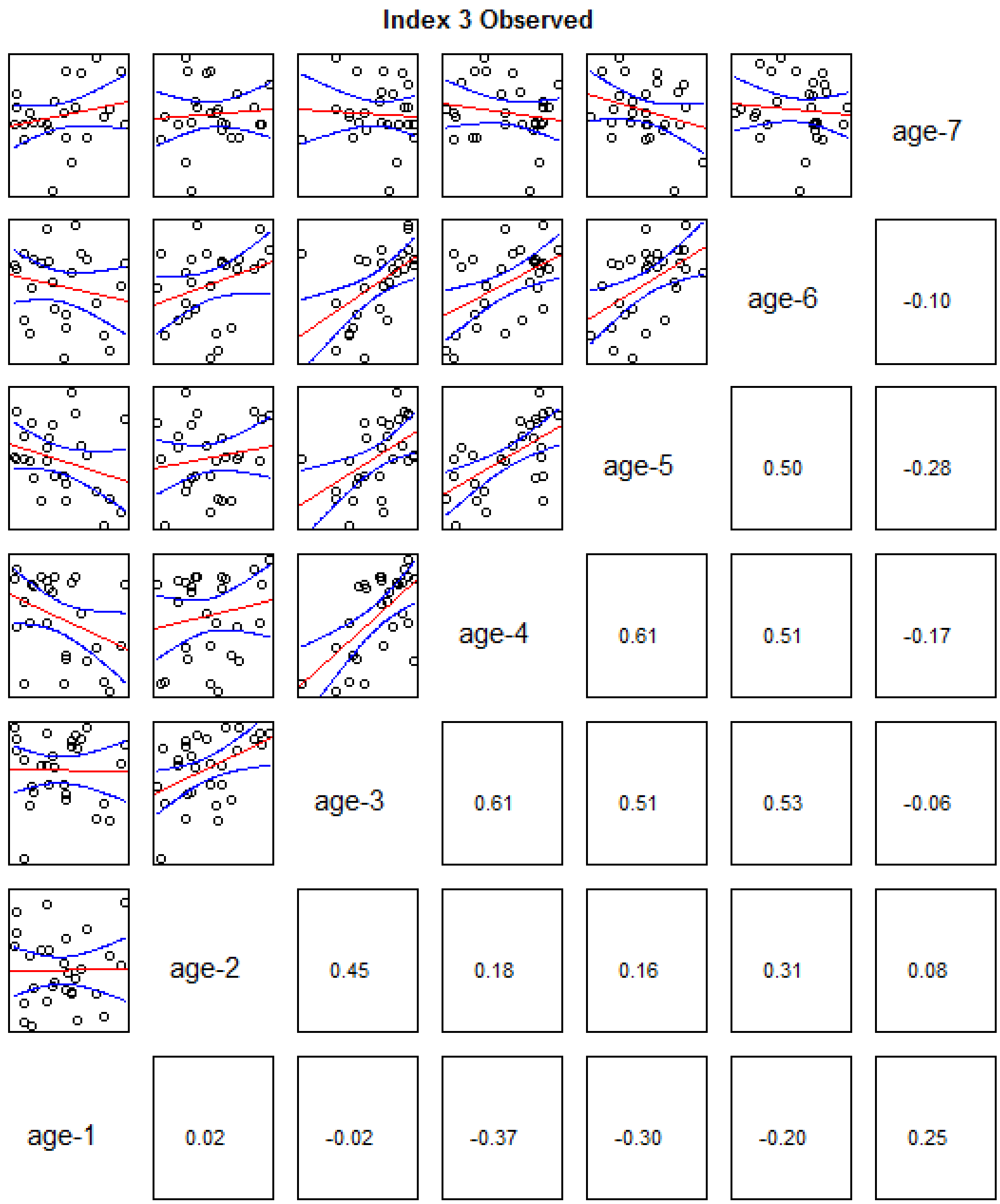


Figure B7.94. Observed catch for the MRIP recreational CPUE index. Note that age class labels are 1 greater than the modeled age class, so that “age-1” corresponds to age 0, “age-2” corresponds to age 1, etc.

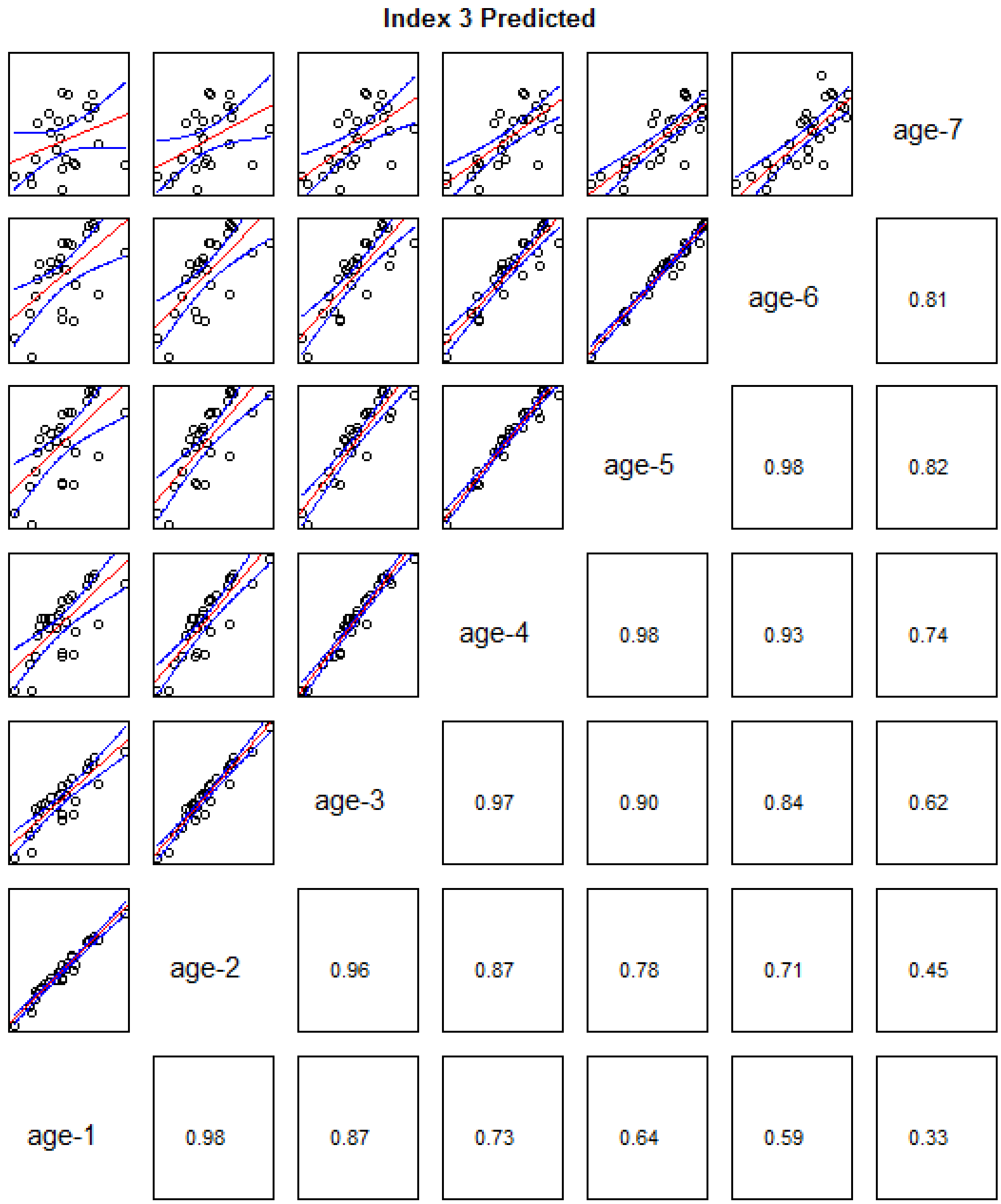


Figure B7.95. Predicted catch for the MRIP recreational CPUE index. Note that age class labels are 1 greater than the modeled age class, so that "age-1" corresponds to age 0, "age-2" corresponds to age 1, etc.

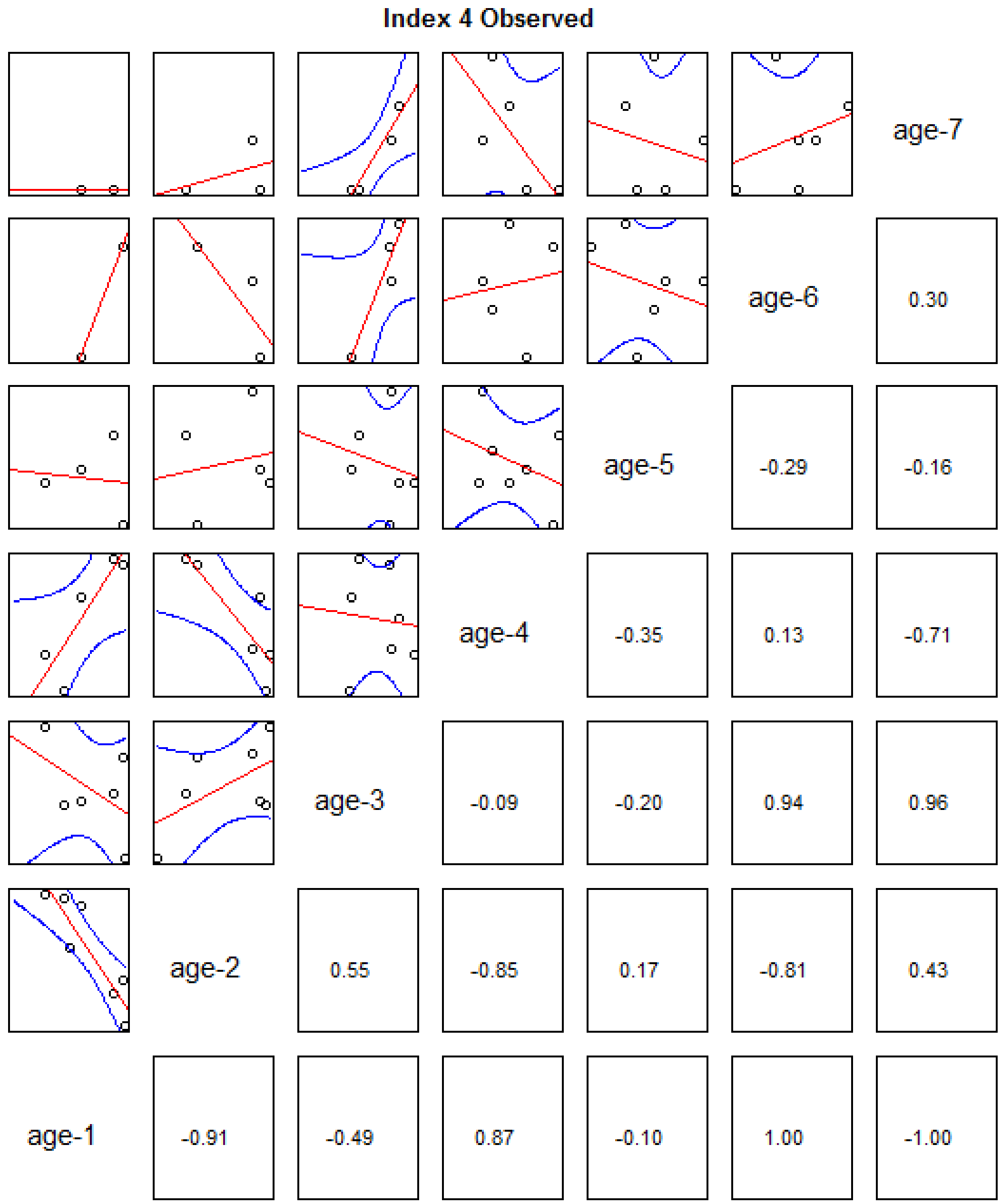


Figure B7.96. Observed catch for the NEAMAP survey. Note that age class labels are 1 greater than the modeled age class, so that "age-1" corresponds to age 0, "age-2" corresponds to age 1, etc.

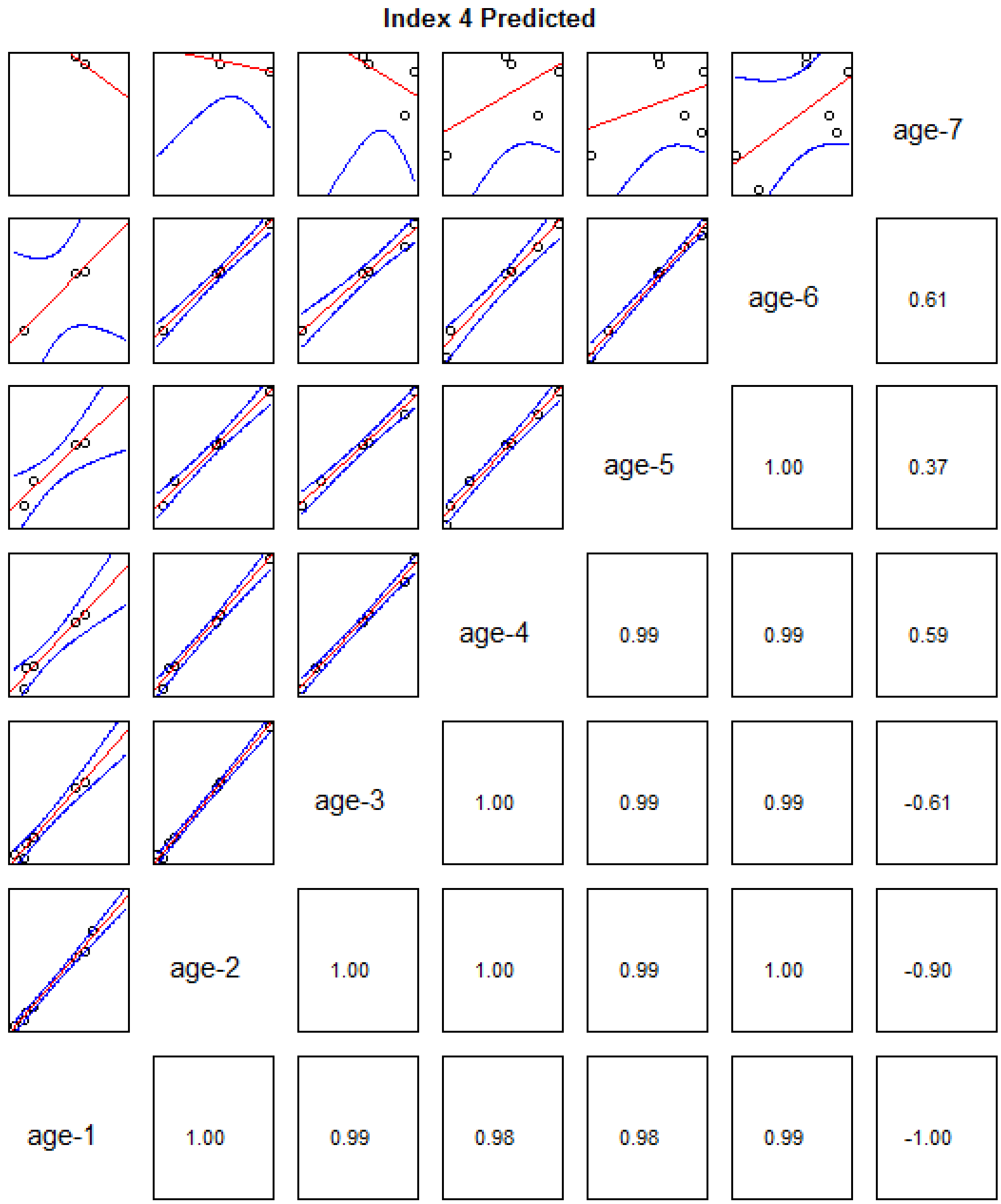


Figure B7.97. Predicted catch for the NEAMAP survey. Note that age class labels are 1 greater than the modeled age class, so that “age-1” corresponds to age 0, “age-2” corresponds to age 1, etc.

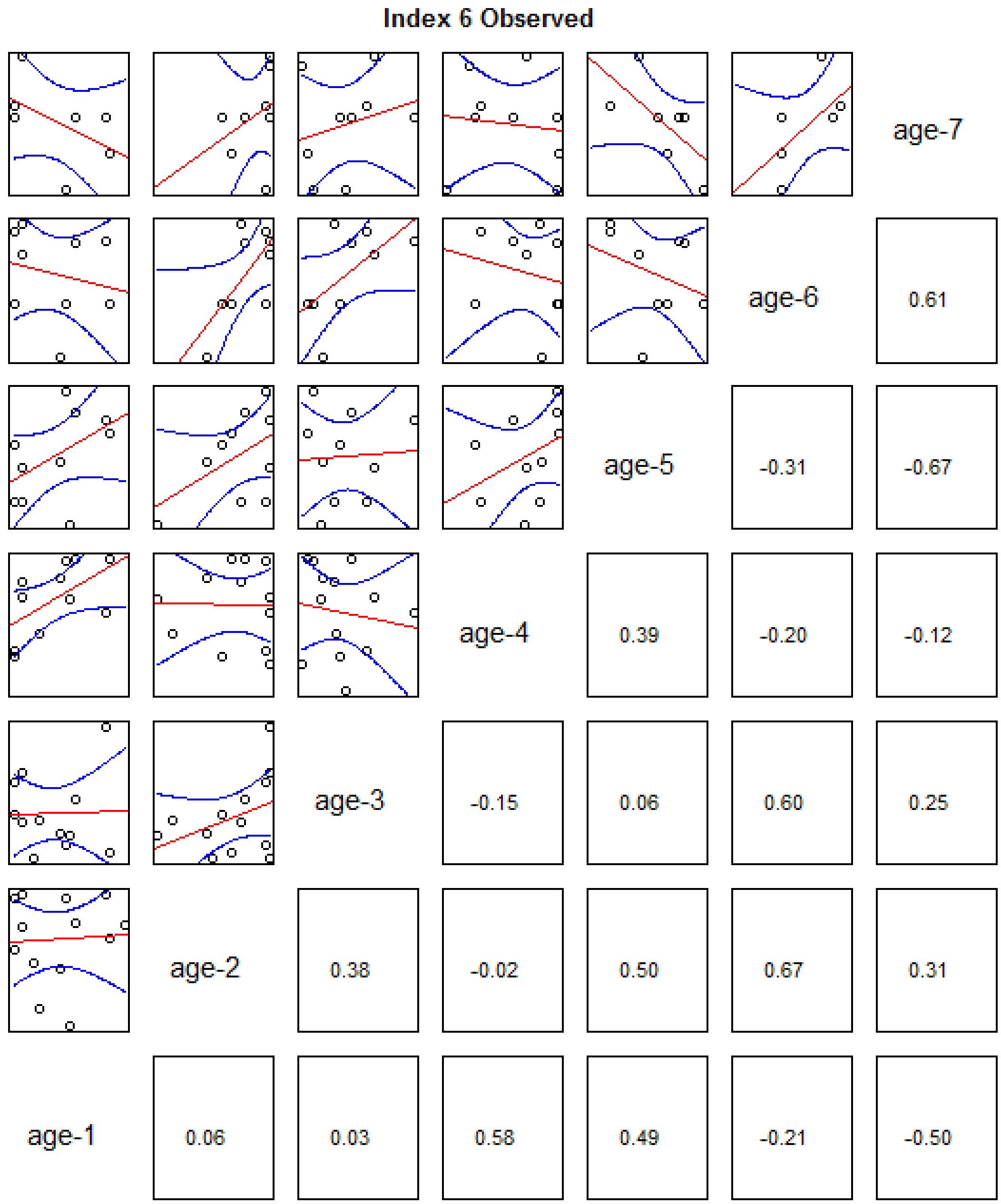


Figure B7.98. Observed catch for the PSIGNS gillnet survey. Note that age class labels are 1 greater than the modeled age class, so that “age-1” corresponds to age 0, “age-2” corresponds to age 1, etc.

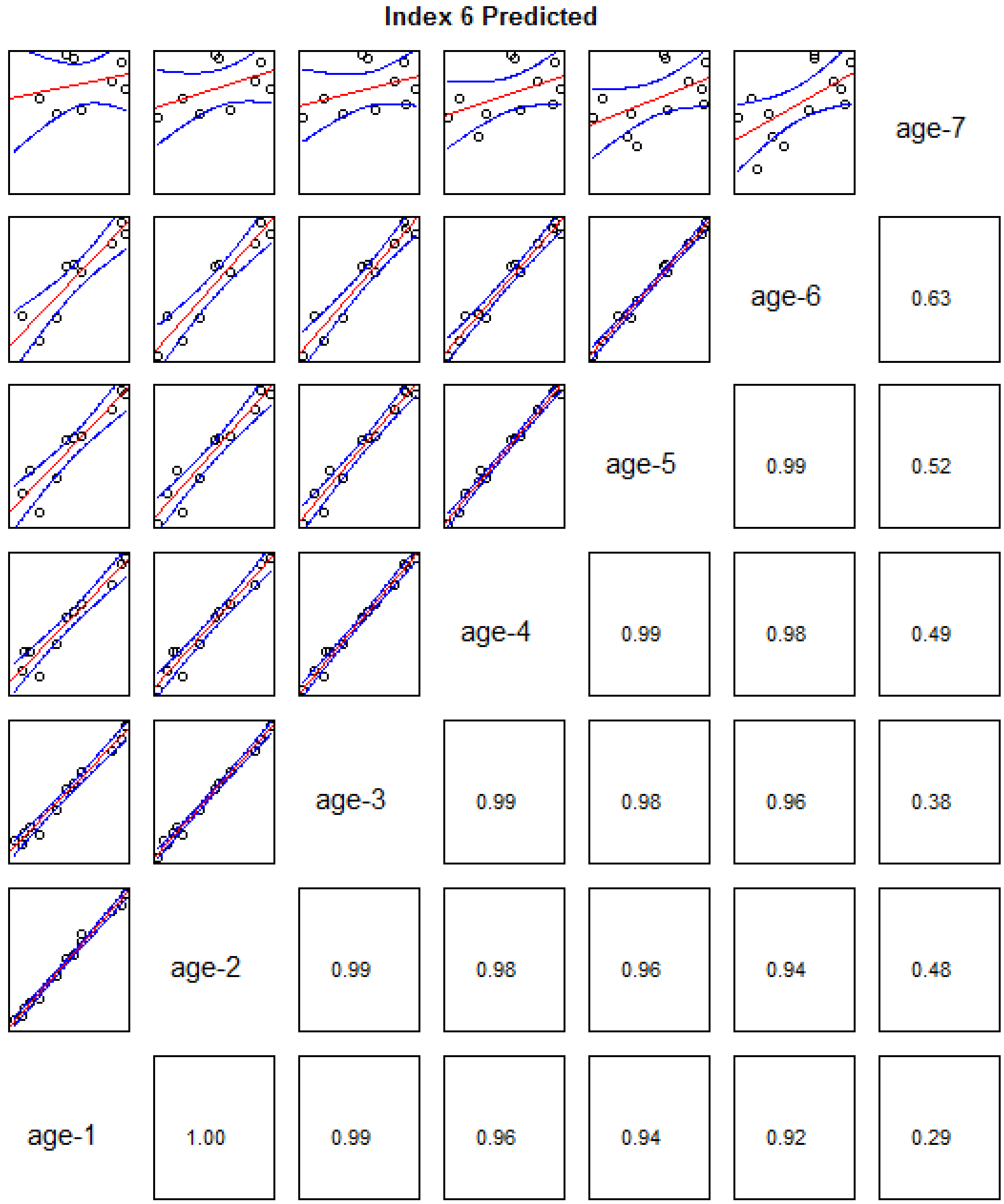


Figure B7.99. Predicted catch for the PSIGNS gillnet survey. Note that age class labels are 1 greater than the modeled age class, so that “age-1” corresponds to age 0, “age-2” corresponds to age 1, etc.

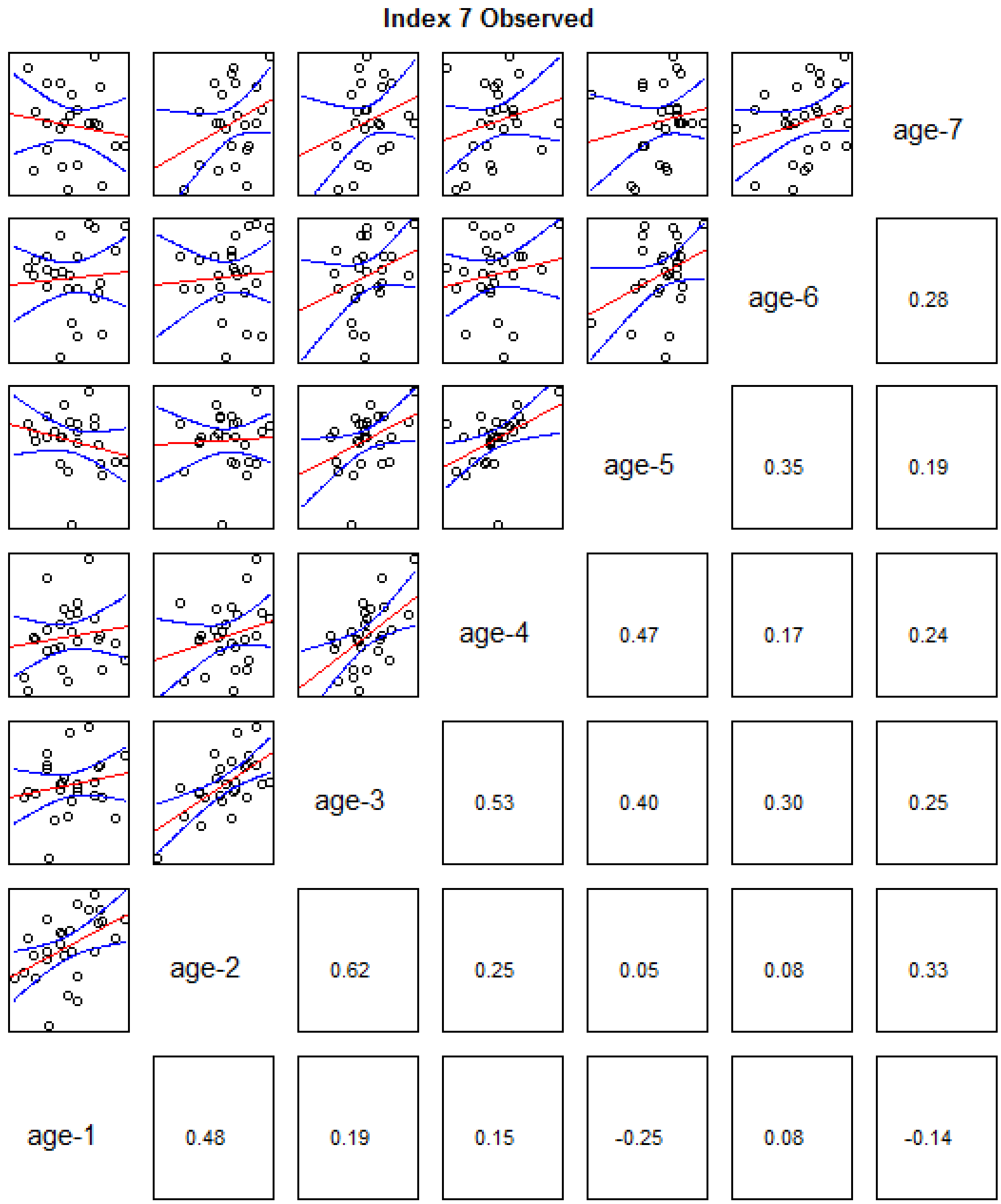


Figure B7.100. Observed catch for the CT LISTS trawl survey. Note that age class labels are 1 greater than the modeled age class, so that "age-1" corresponds to age 0, "age-2" corresponds to age 1, etc.

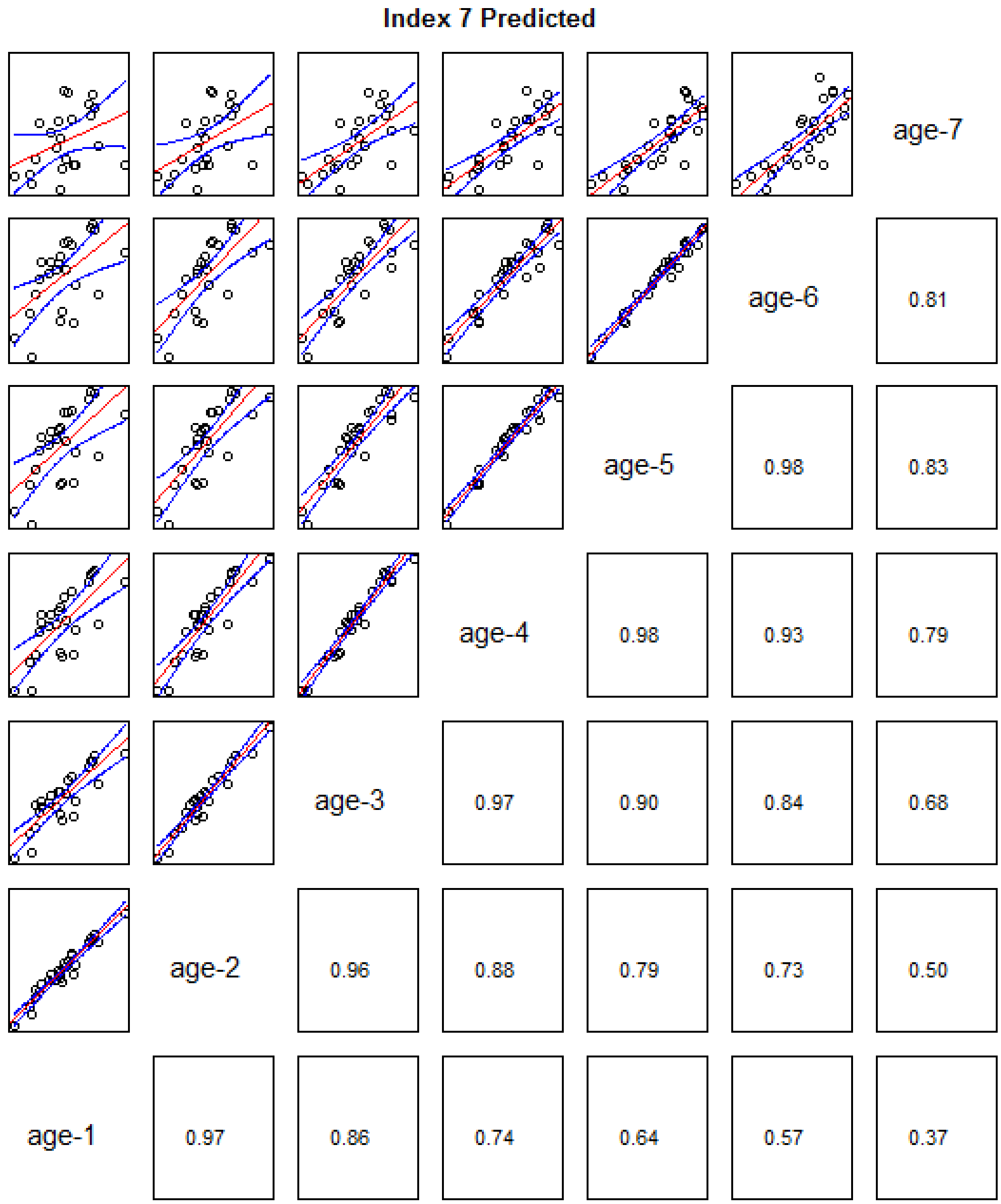


Figure B7.101. Predicted catch for the CT LISTS trawl survey. Note that age class labels are 1 greater than the modeled age class, so that “age-1” corresponds to age 0, “age-2” corresponds to age 1, etc.

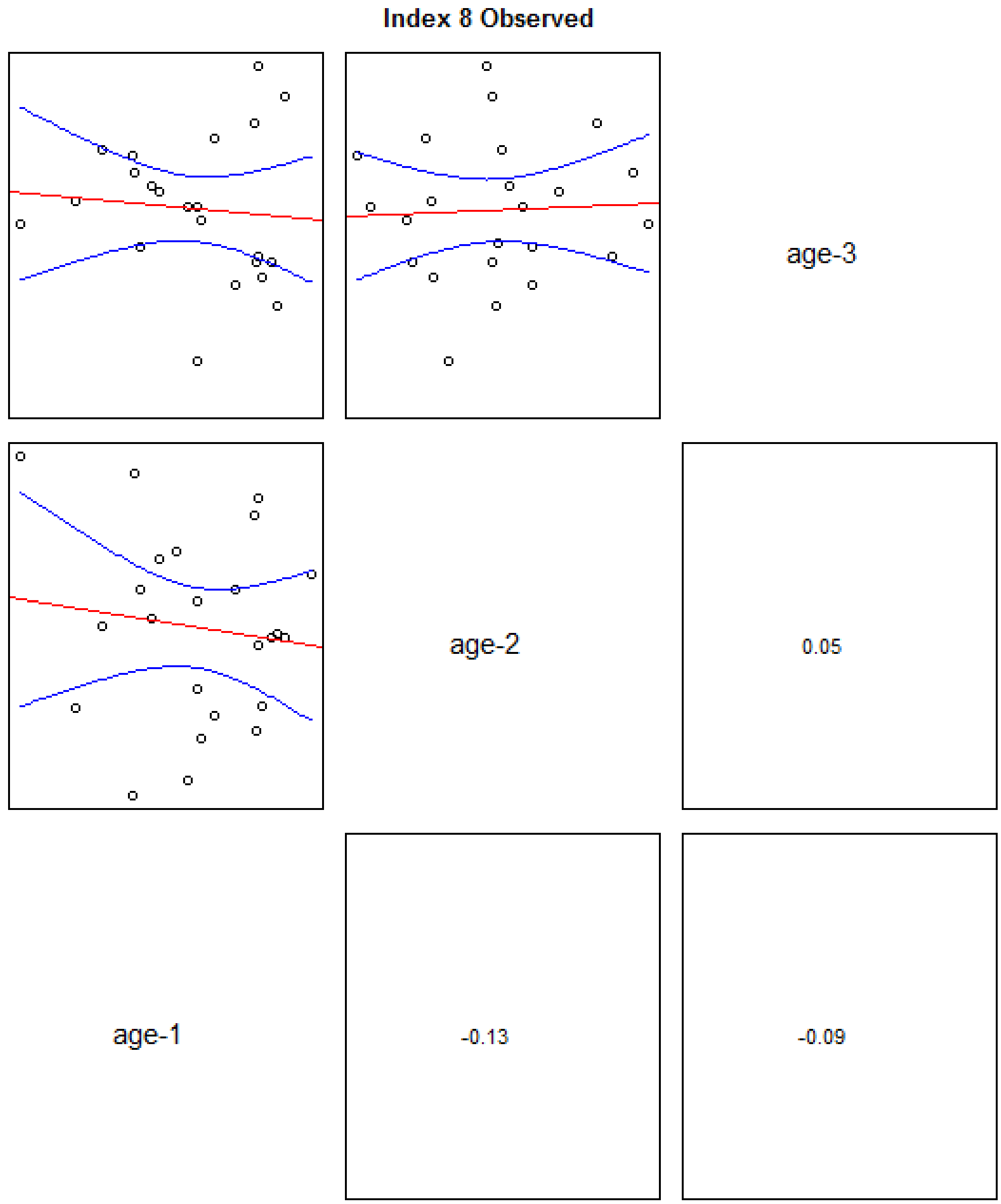


Figure B7.102. Observed catch for the NJ ocean trawl survey. Note that age class labels are 1 greater than the modeled age class, so that “age-1” corresponds to age 0, “age-2” corresponds to age 1, etc.

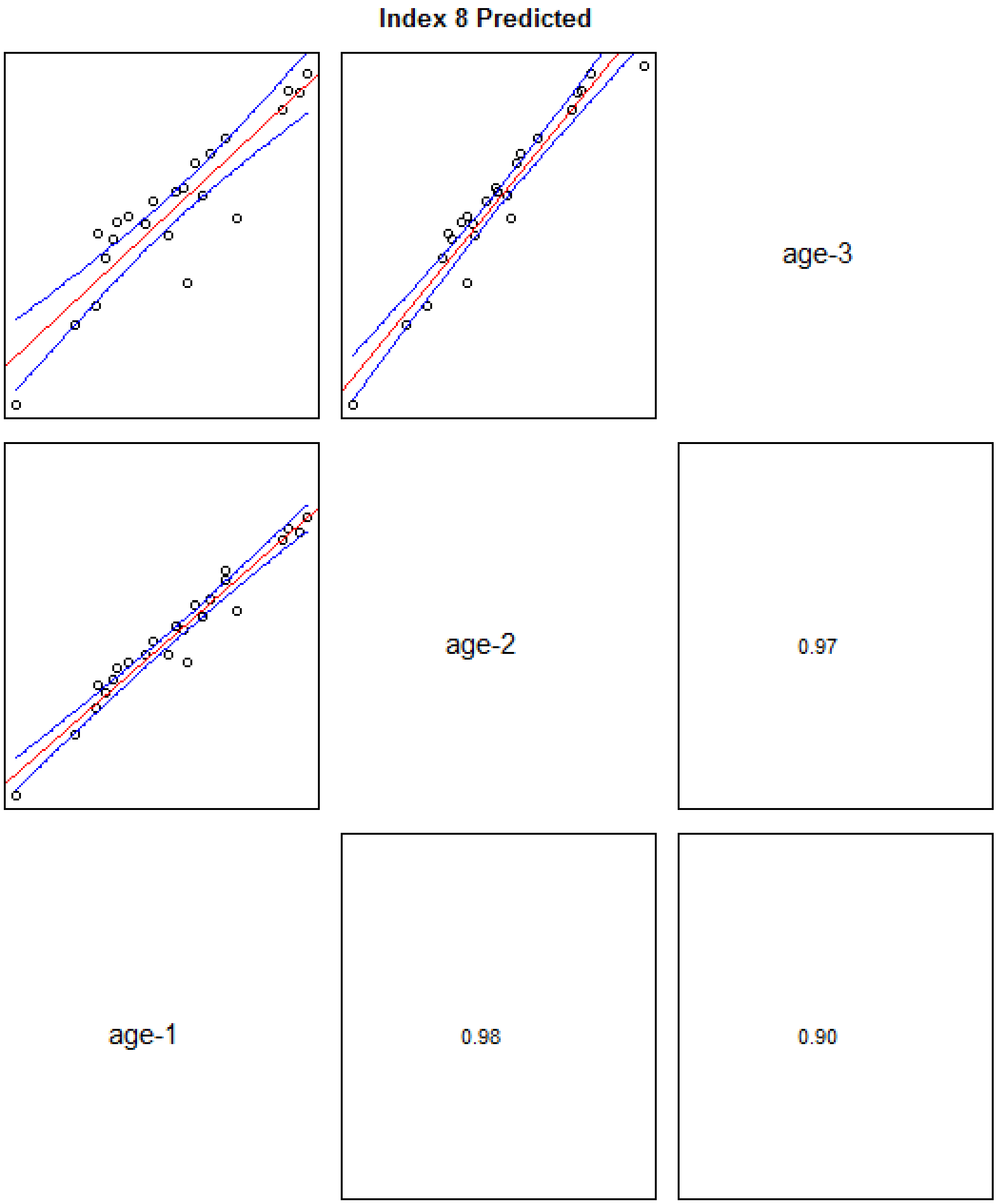


Figure B7.103. Predicted catch for the NJ ocean trawl survey. Note that age class labels are 1 greater than the modeled age class, so that “age-1” corresponds to age 0, “age-2” corresponds to age 1, etc.

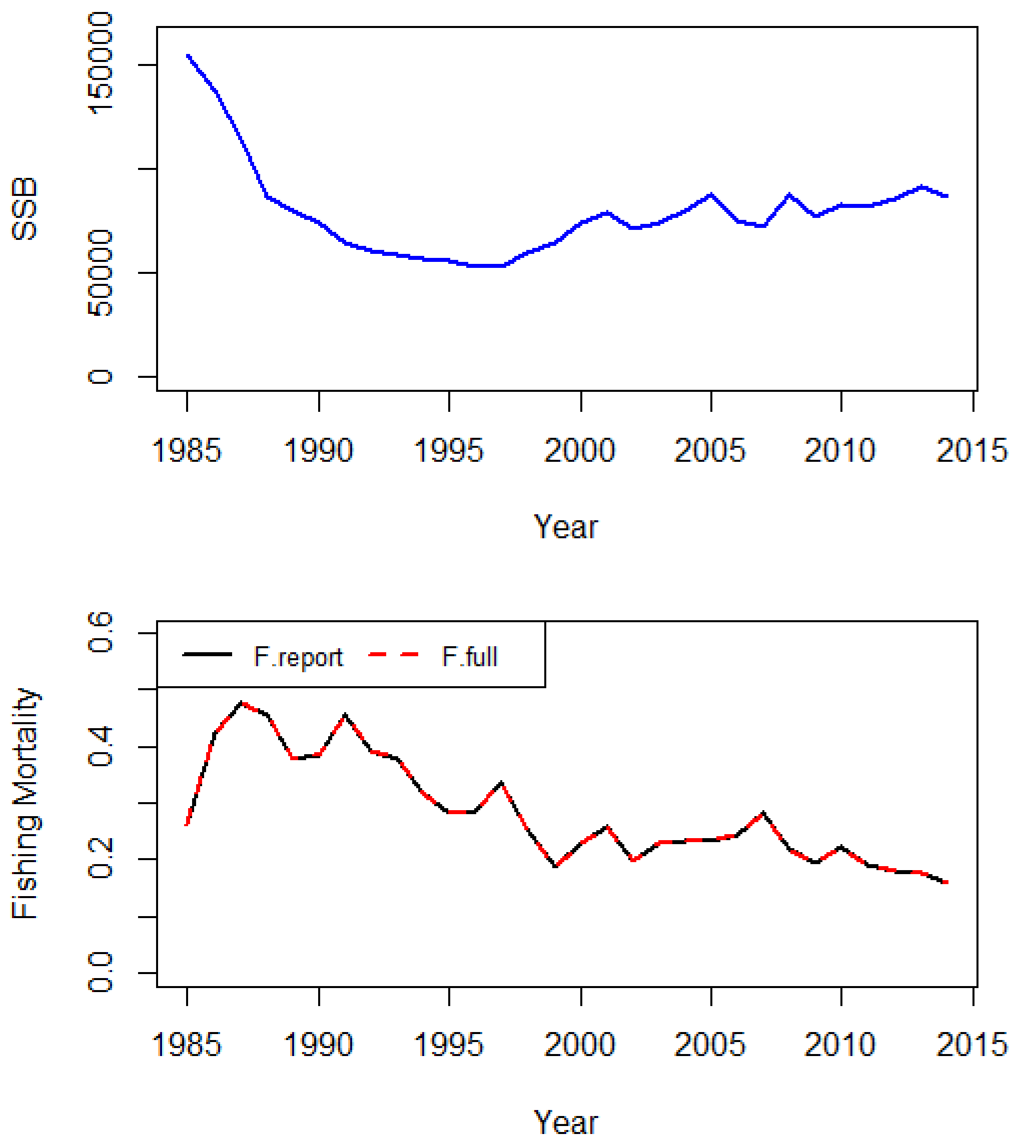


Figure B7.104. Estimated spawning stock biomass (top) and full fishing mortality (bottom) from 1985 to 2014 from the revised final model.

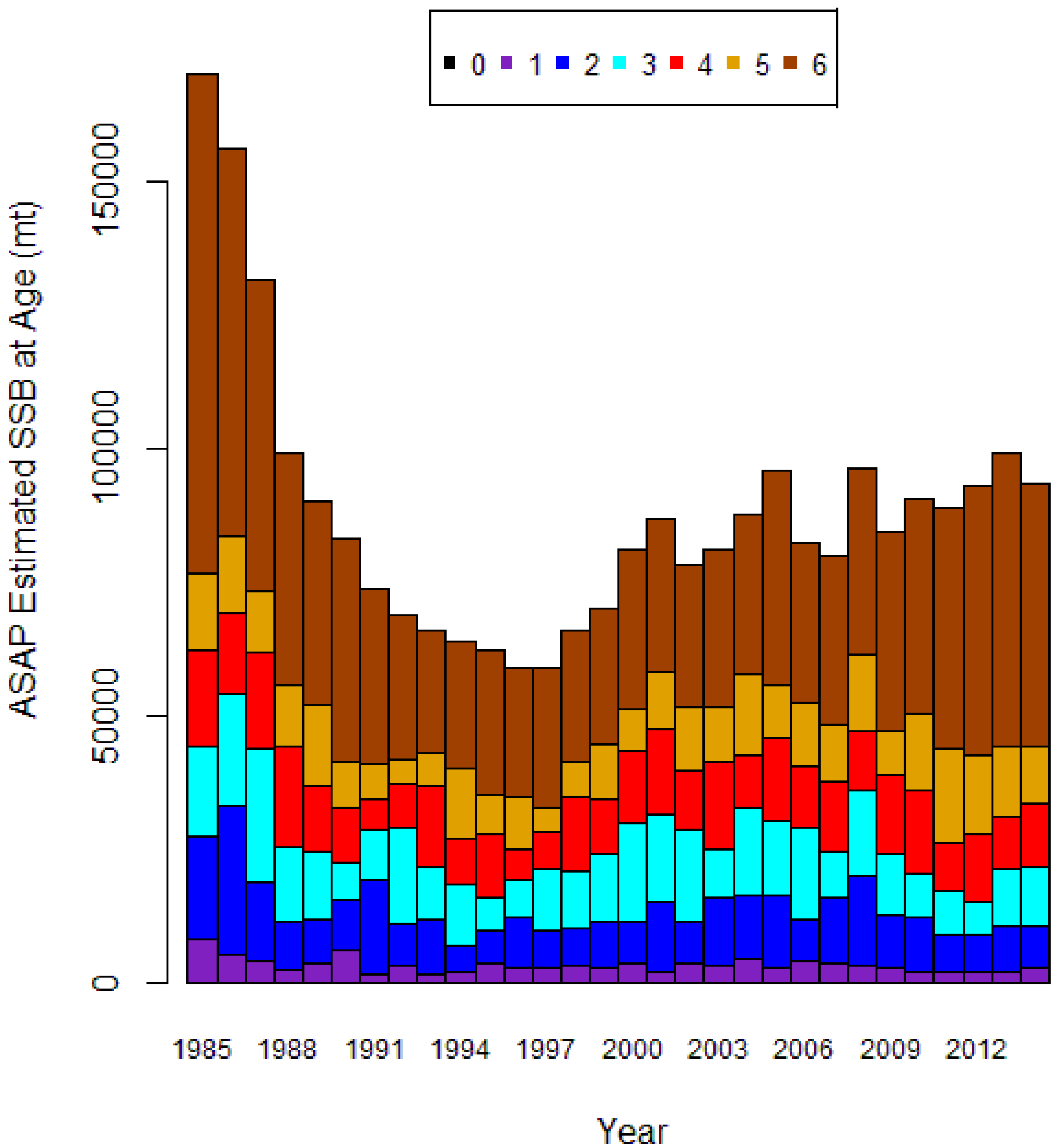


Figure B7.105. Age composition of the spawning stock biomass from 1985 to 2014.

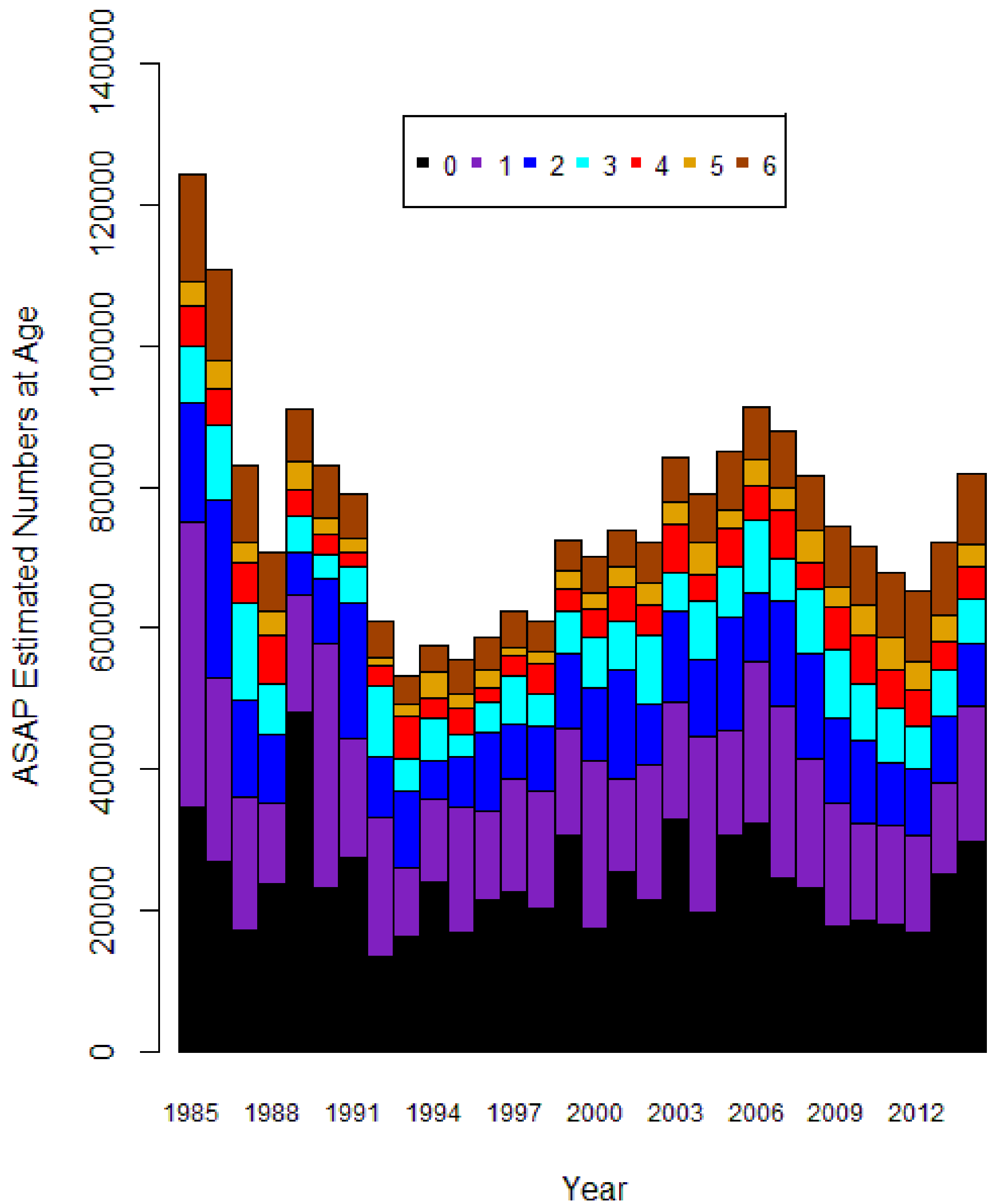


Figure B7.106. Estimated total numbers at age from 1985 to 2014.

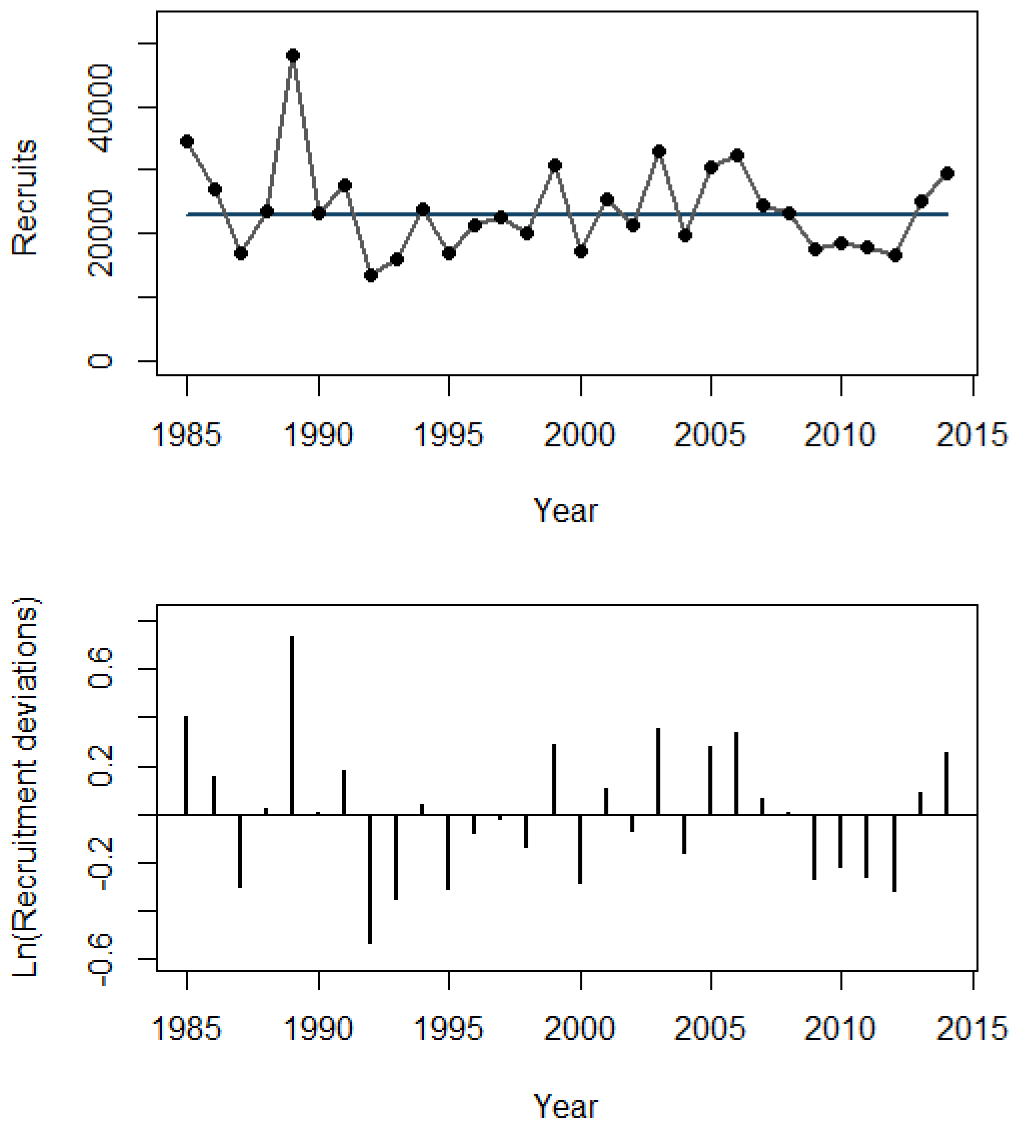


Figure B7.107. Recruitment estimates, mean recruitment, and recruitment deviations (log) from 1985 to 2014 from the final model.

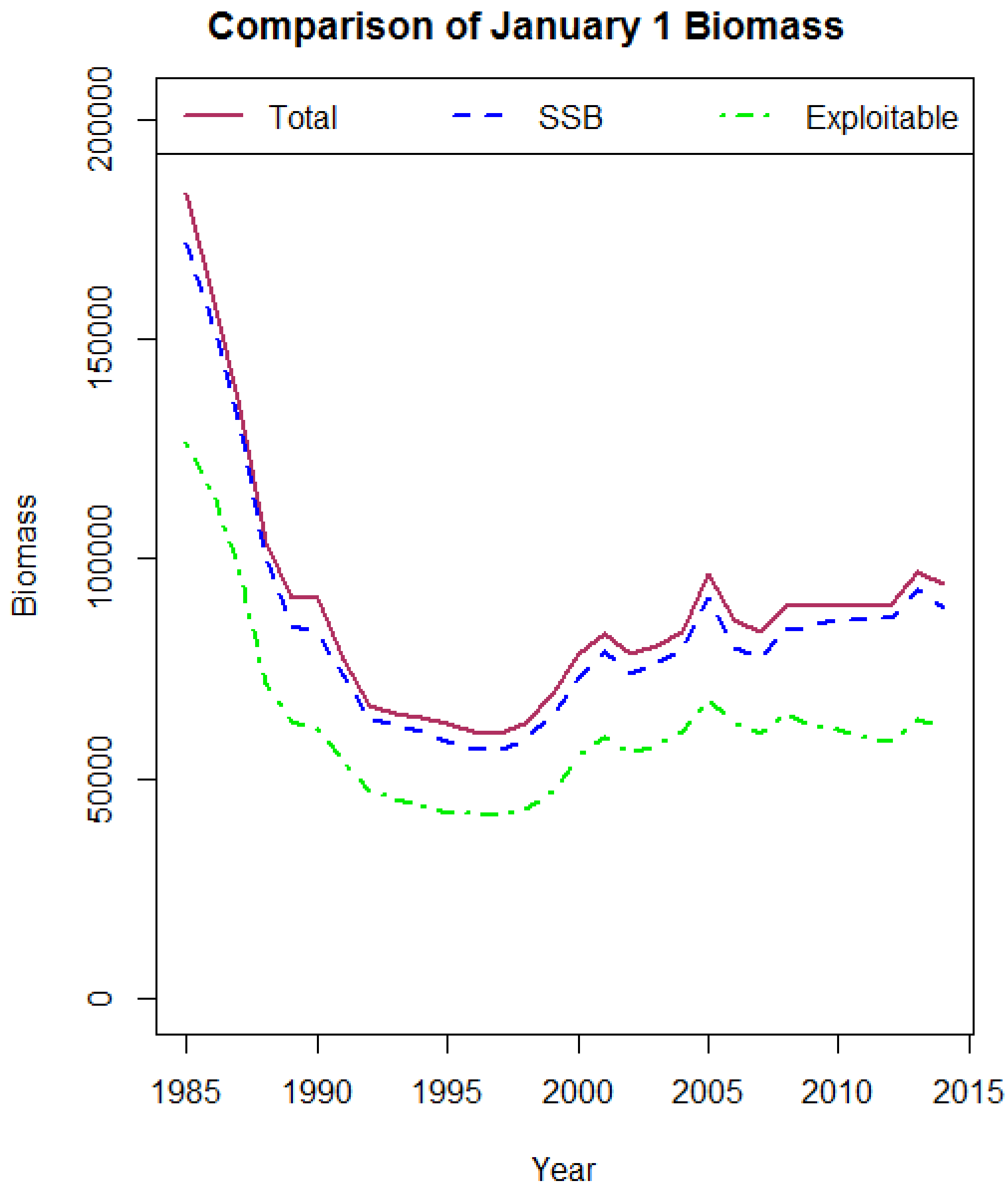


Figure B7.108. A comparison of total, spawning stock, and exploitable biomass from 1985 to 2014 from the final model.

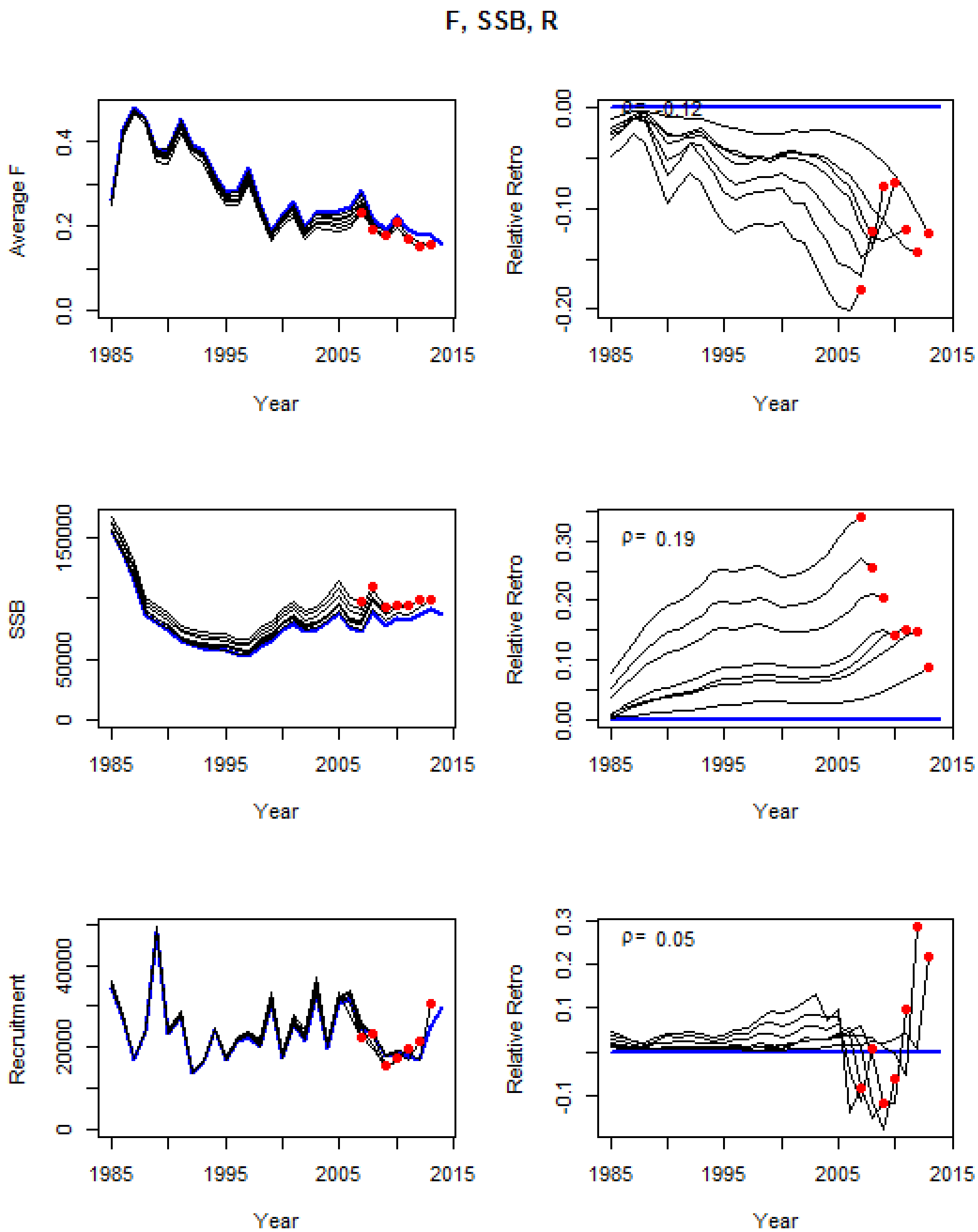


Figure B7.109. Retrospective plots for average fishing mortality, spawning stock biomass and recruitment from a 7 year peel carried out on the revised final model.

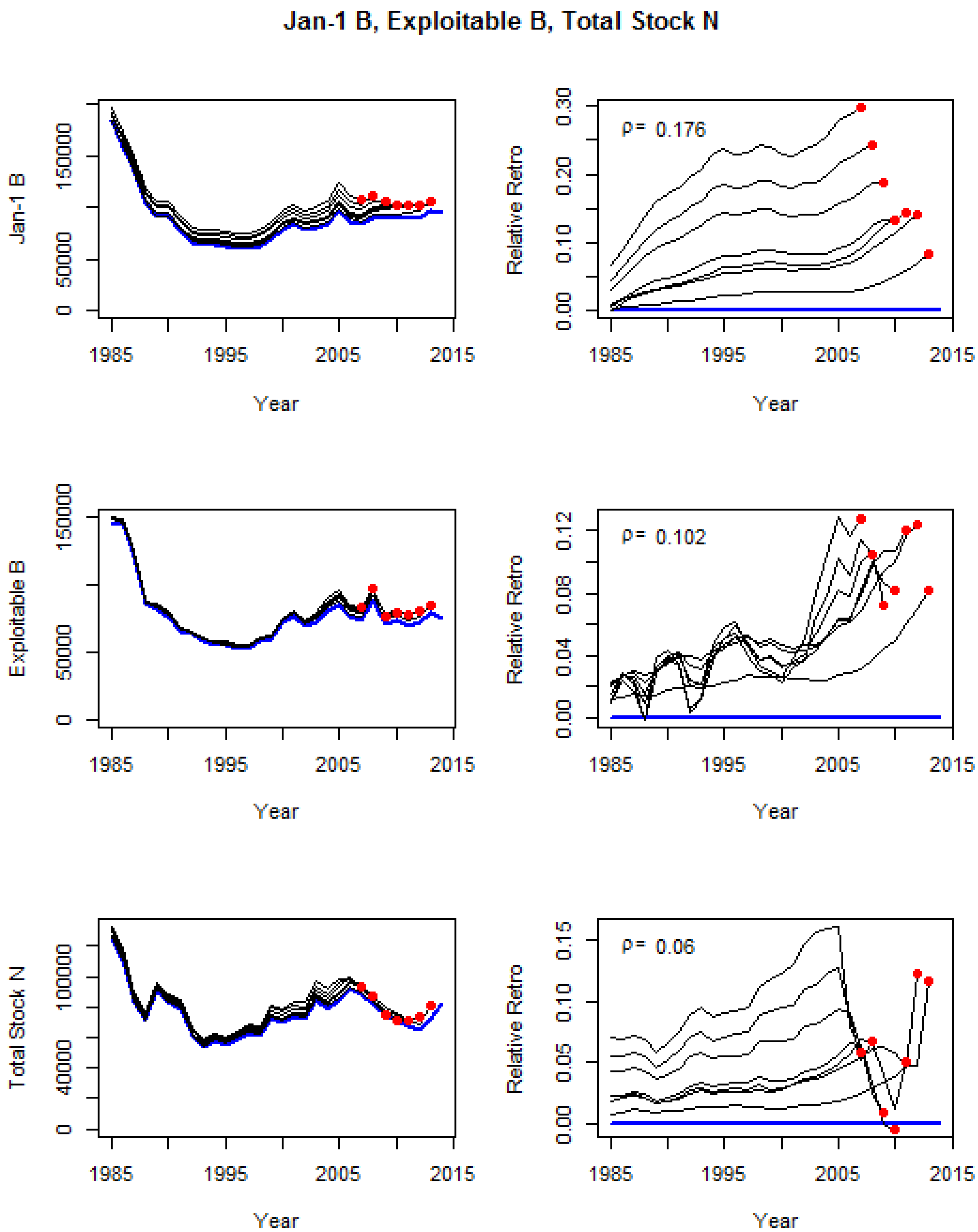


Figure B7.110. Retrospective plots for January-1 biomass, total biomass, and total stock numbers, from a 7 year peel carried out on the revised final model.

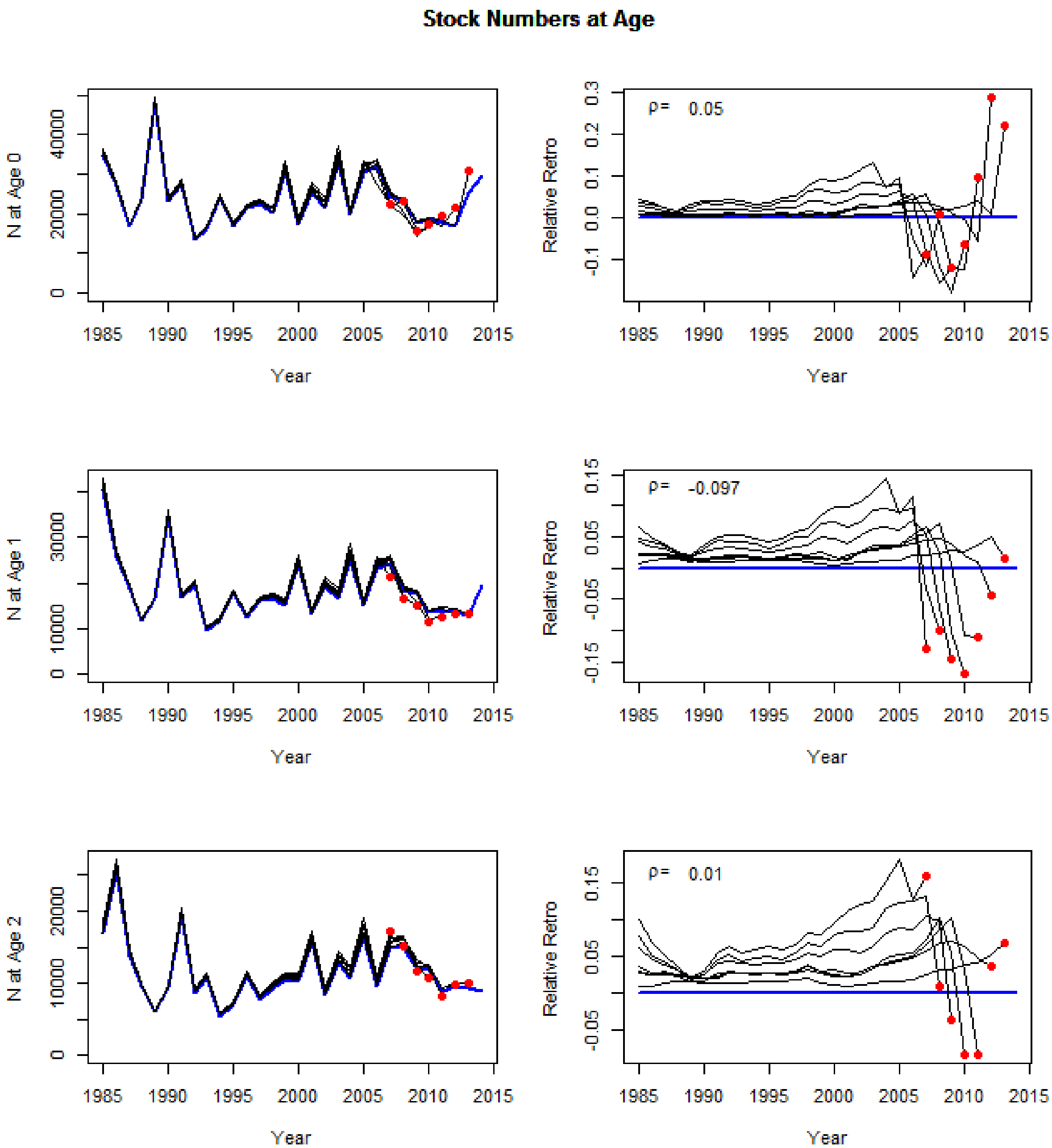


Figure B7.111. Retrospective plots for ages 0-2 from a 7 year peel carried out on the final model.

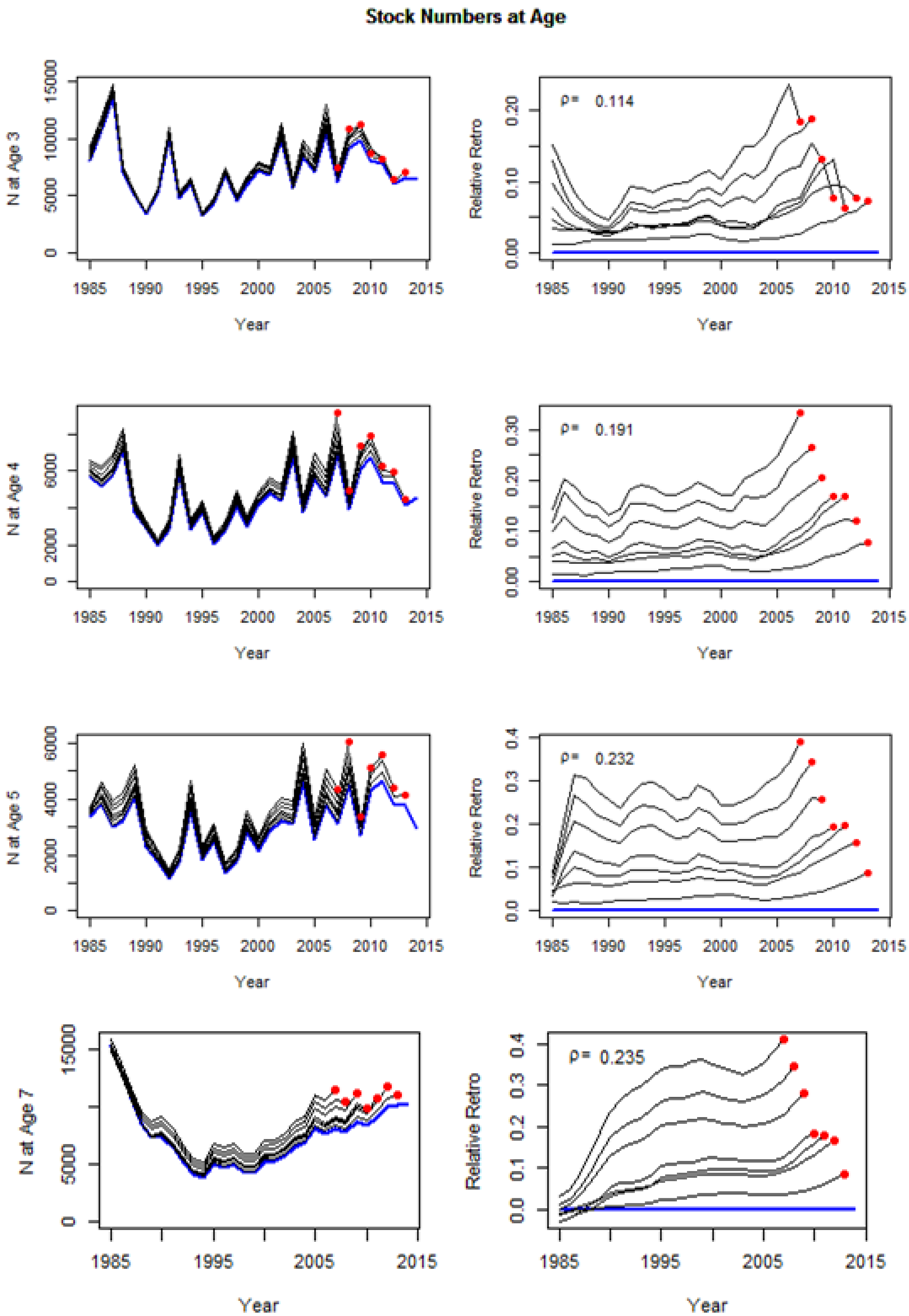


Figure B7.112. Retrospective plots for ages 3-6+ from a 7 year peel carried out on the final model.

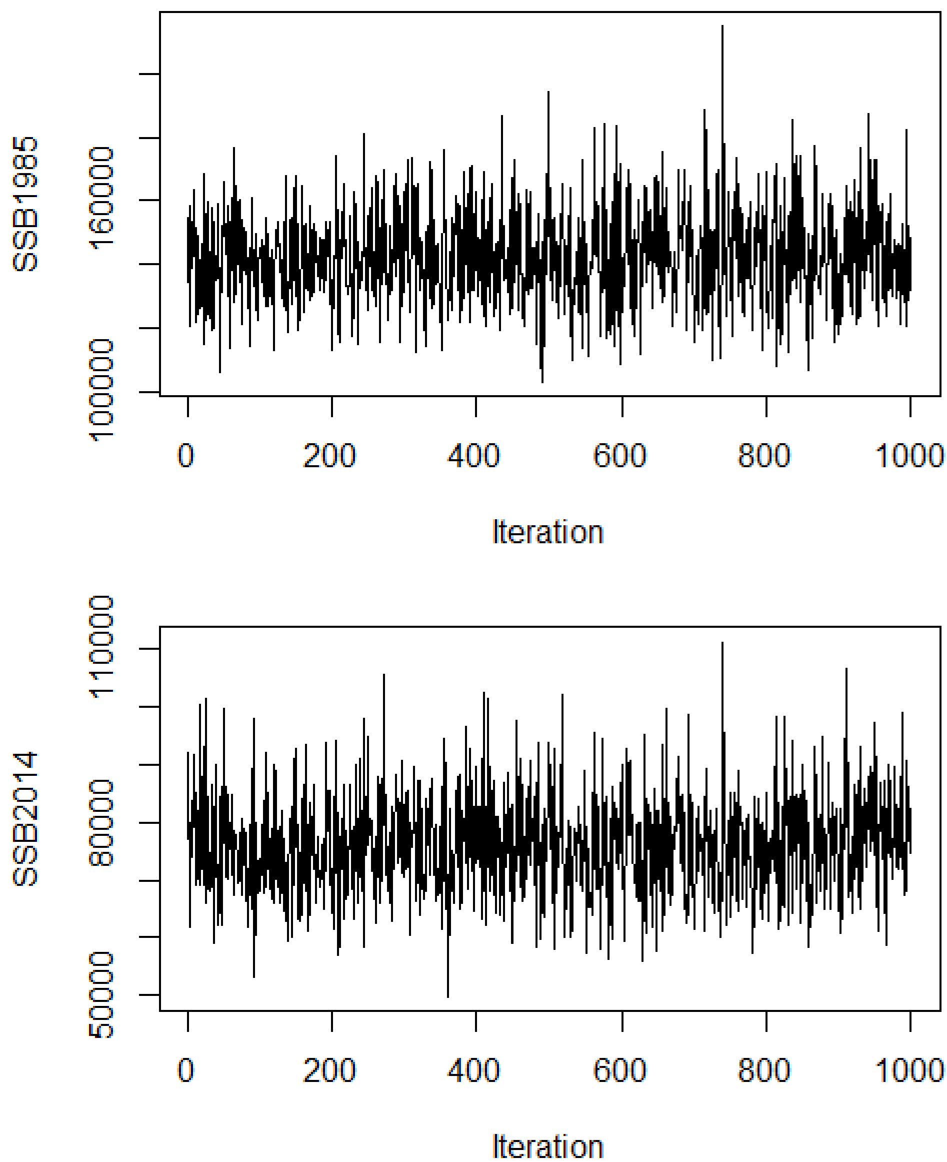


Figure B7.113. Trace plots for fishing mortality in 1985 and 2014 from 1000 MCMC and a thinning rate of 1000 (1,000,000 iterations).

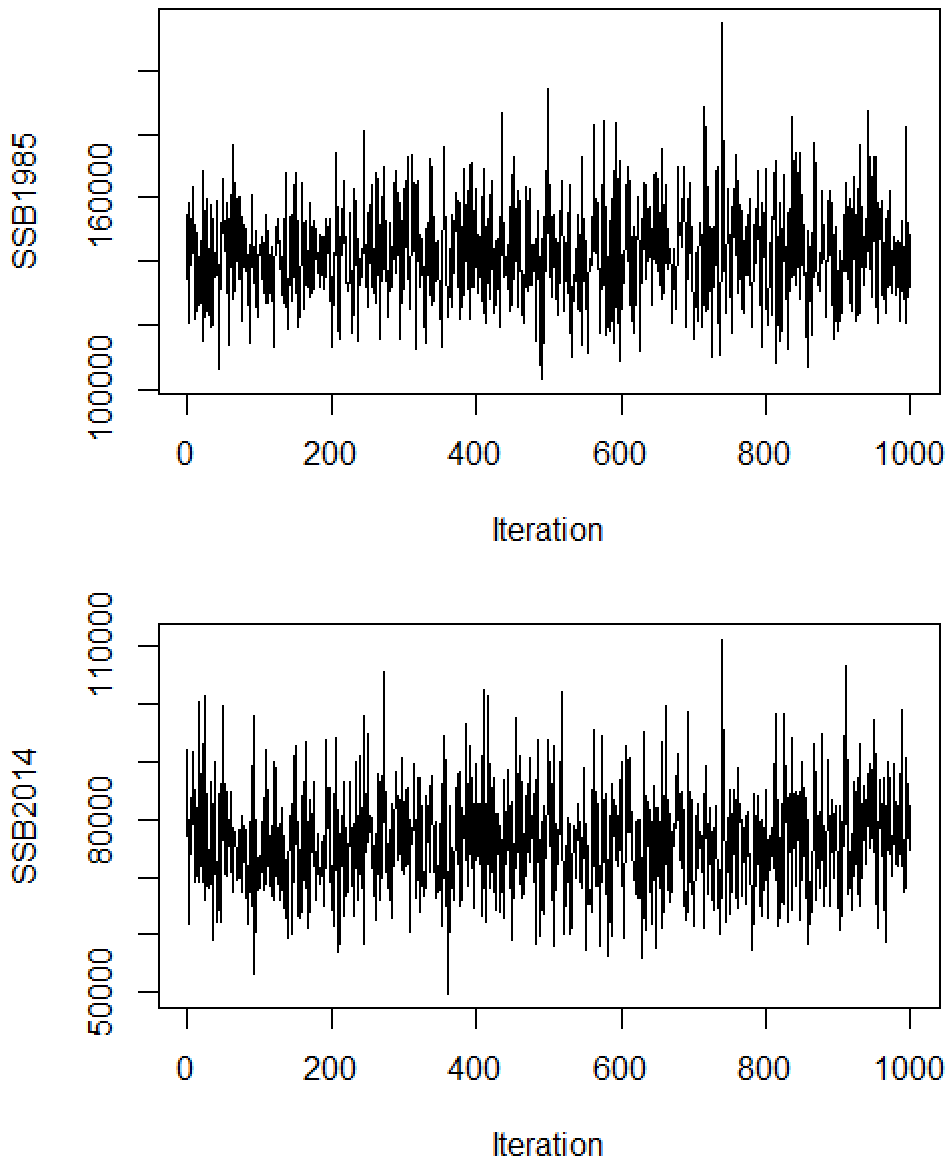


Figure B7.114. Trace plots for spawning stock biomass in 1985 and 2014 from 1000 MCMC and a thinning rate of 1000 (1,000,000 iterations).

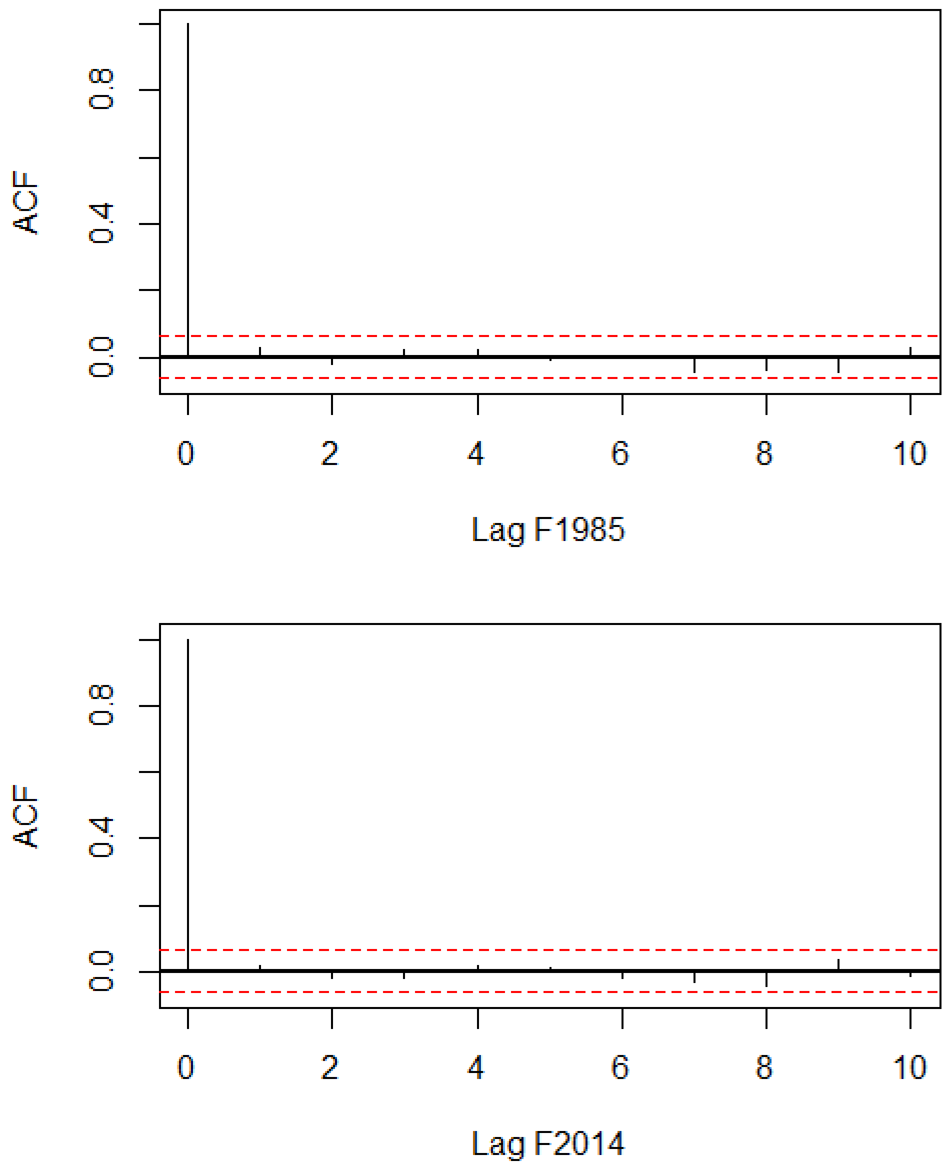
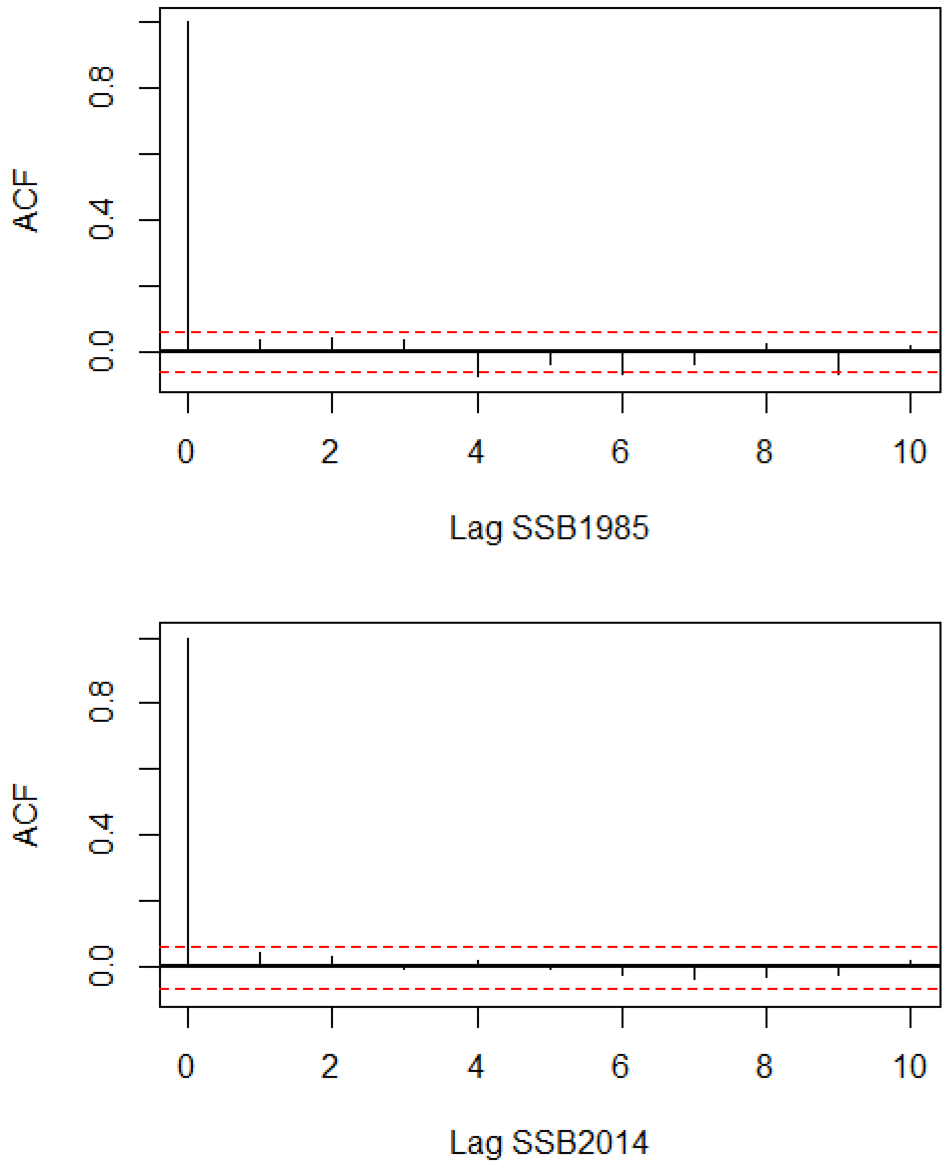


Figure B7.115. Autocorrelation for fishing mortality in the MCMC runs.

Figure B7.116. Autocorrelation for SSB in the MCMC runs.



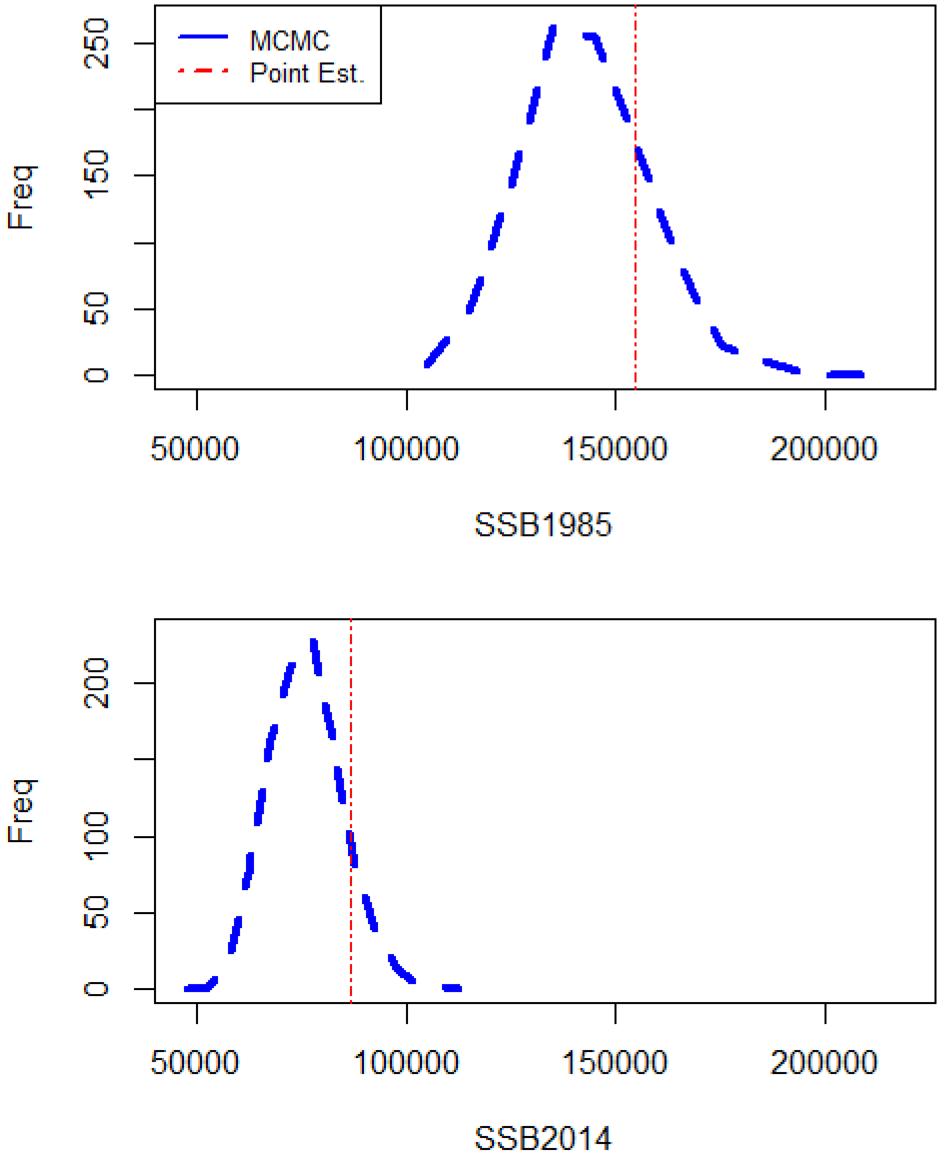


Figure B7.117. MCMC distribution plots for spawning stock biomass in 1985 and 2014 with point estimates from the revised final model.

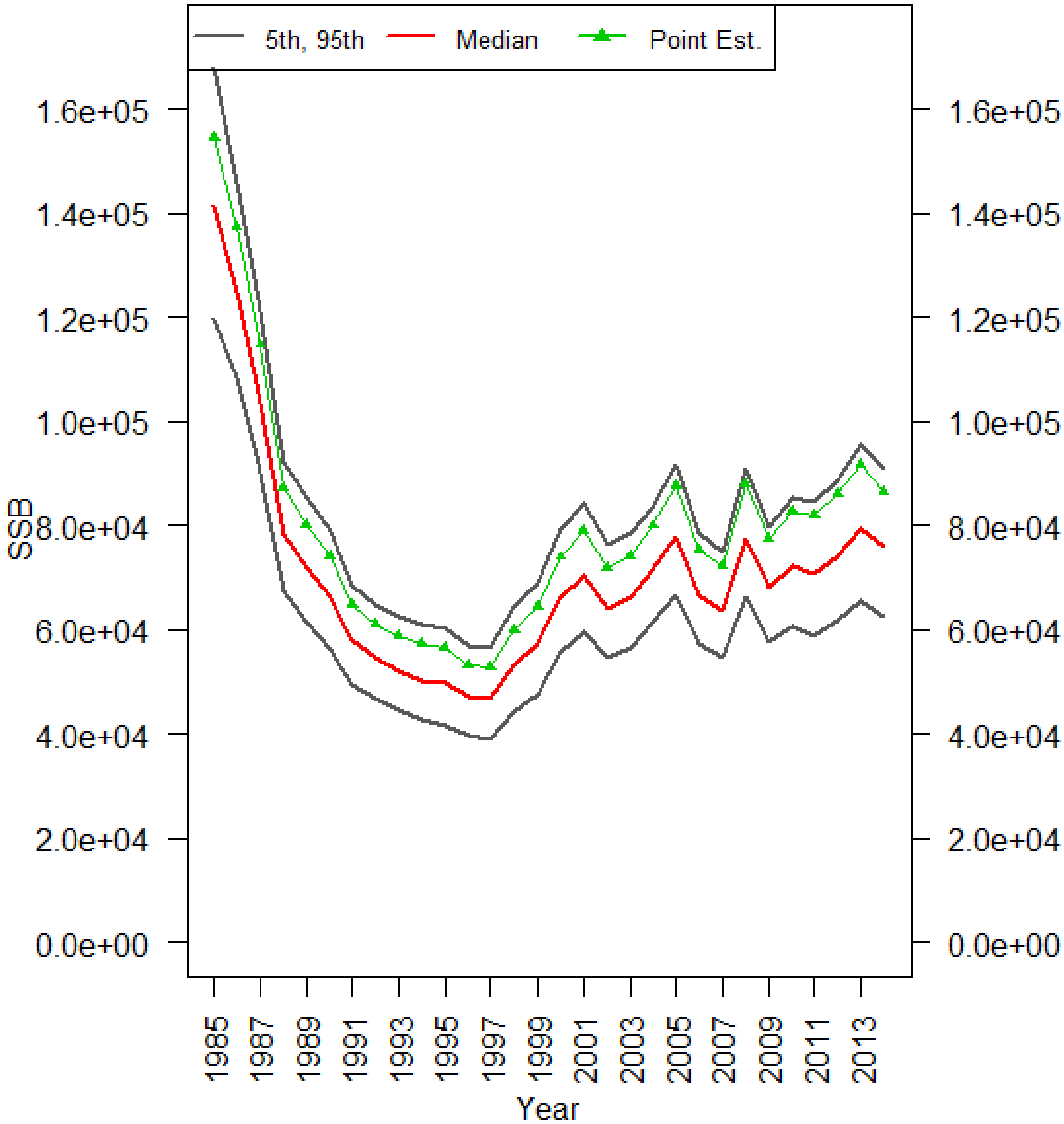


Figure B7.118. Median spawning stock biomass and 95 confidence intervals from the MCMC runs with point estimates from the revised final model.

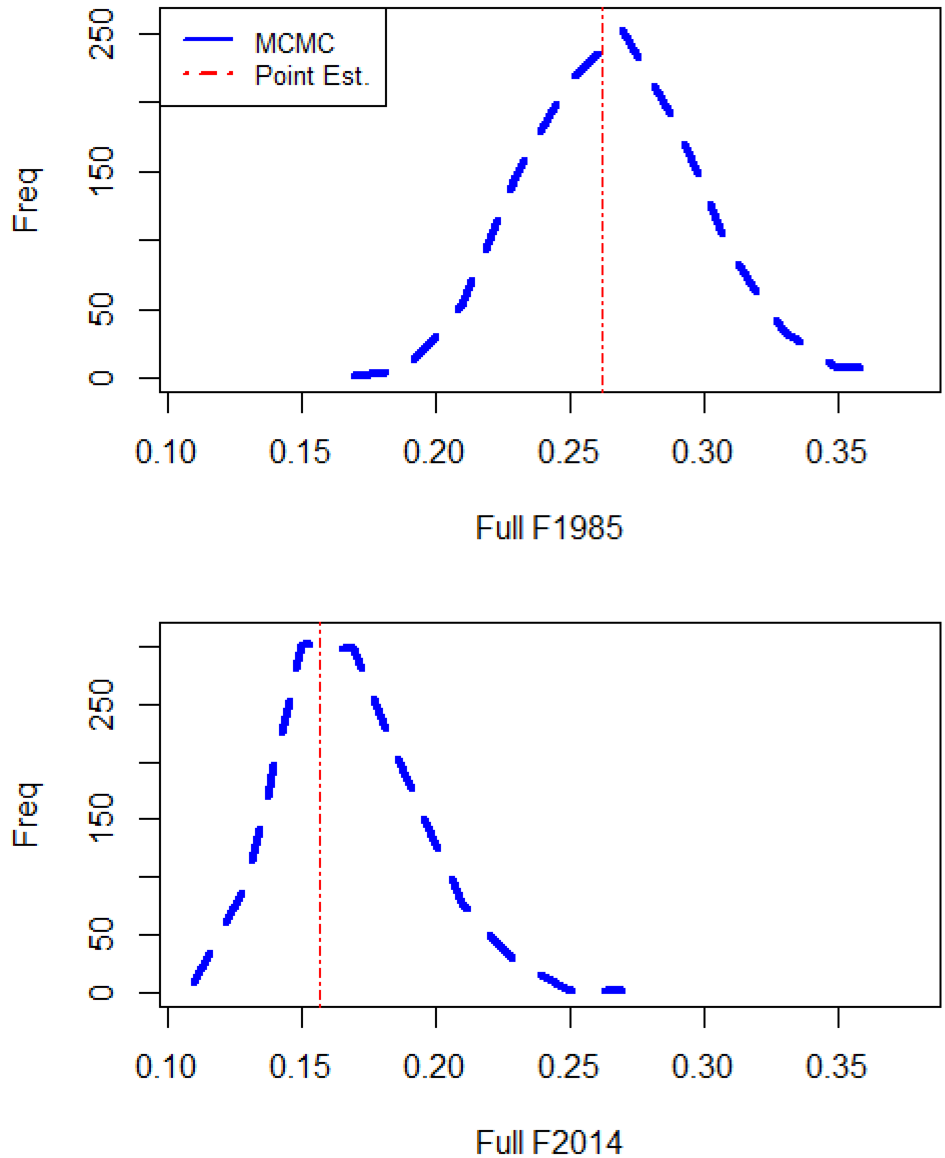


Figure B7.119. MCMC distribution plots for fishing mortality in 2985 and 2014 with point estimates from the revised final model.

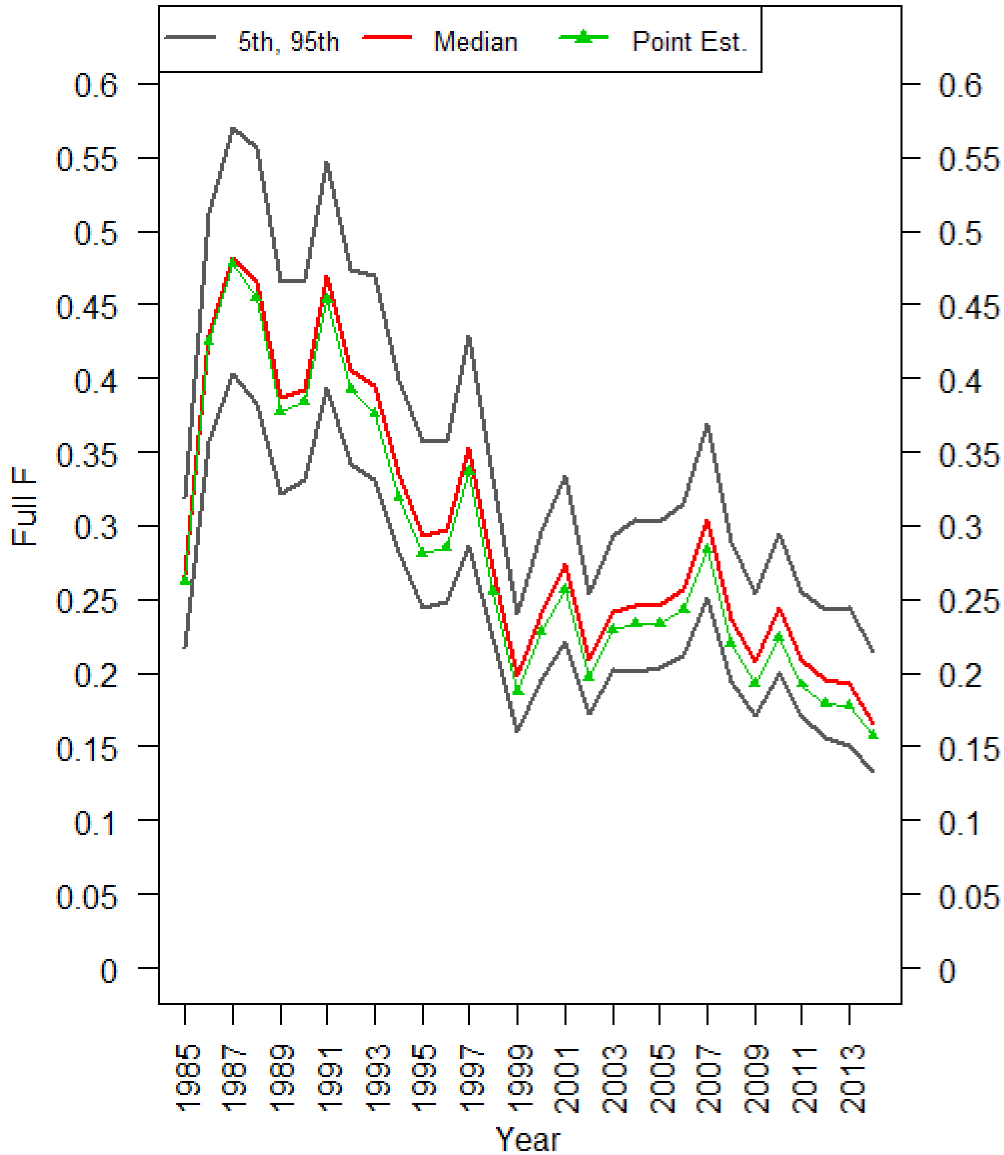


Figure B7.120. Median fishing mortality and 95% confidence intervals from the MCMC runs with point estimates from the revised final model.

Figure B7.121. Final model sensitivity run assume AB1 lengths for the recreational discards. Trends for the revised final model (B044) estimates are represented by the red line, with sensitivity run estimates (B044S5) represented by the black line.

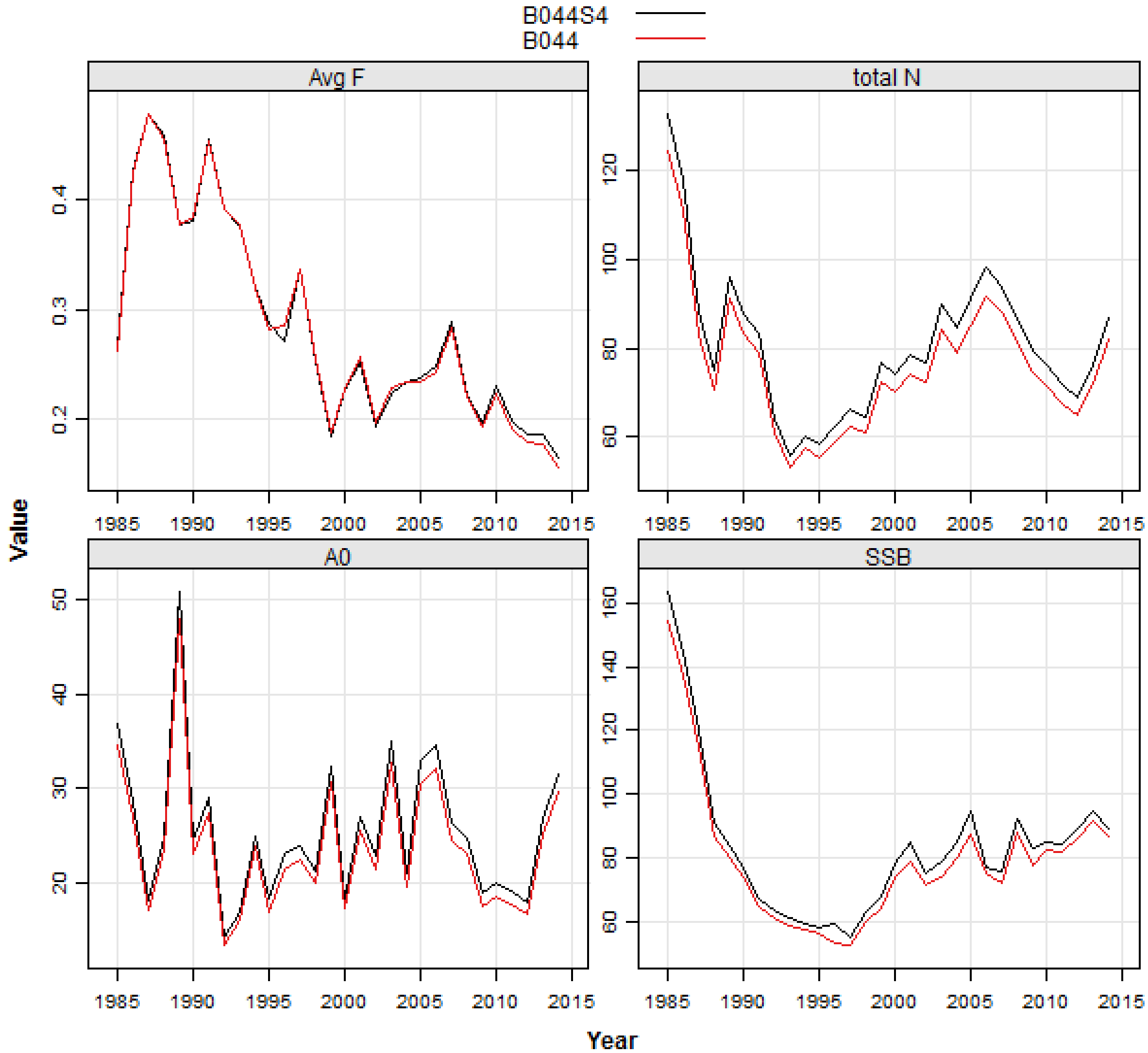


Figure B7.122. Final model sensitivity run assuming upper 95% CI for recreational catch.
Trends for the revised final model (B044) estimates are represented by the red line, with sensitivity run estimates (B044S4) represented by the black line.

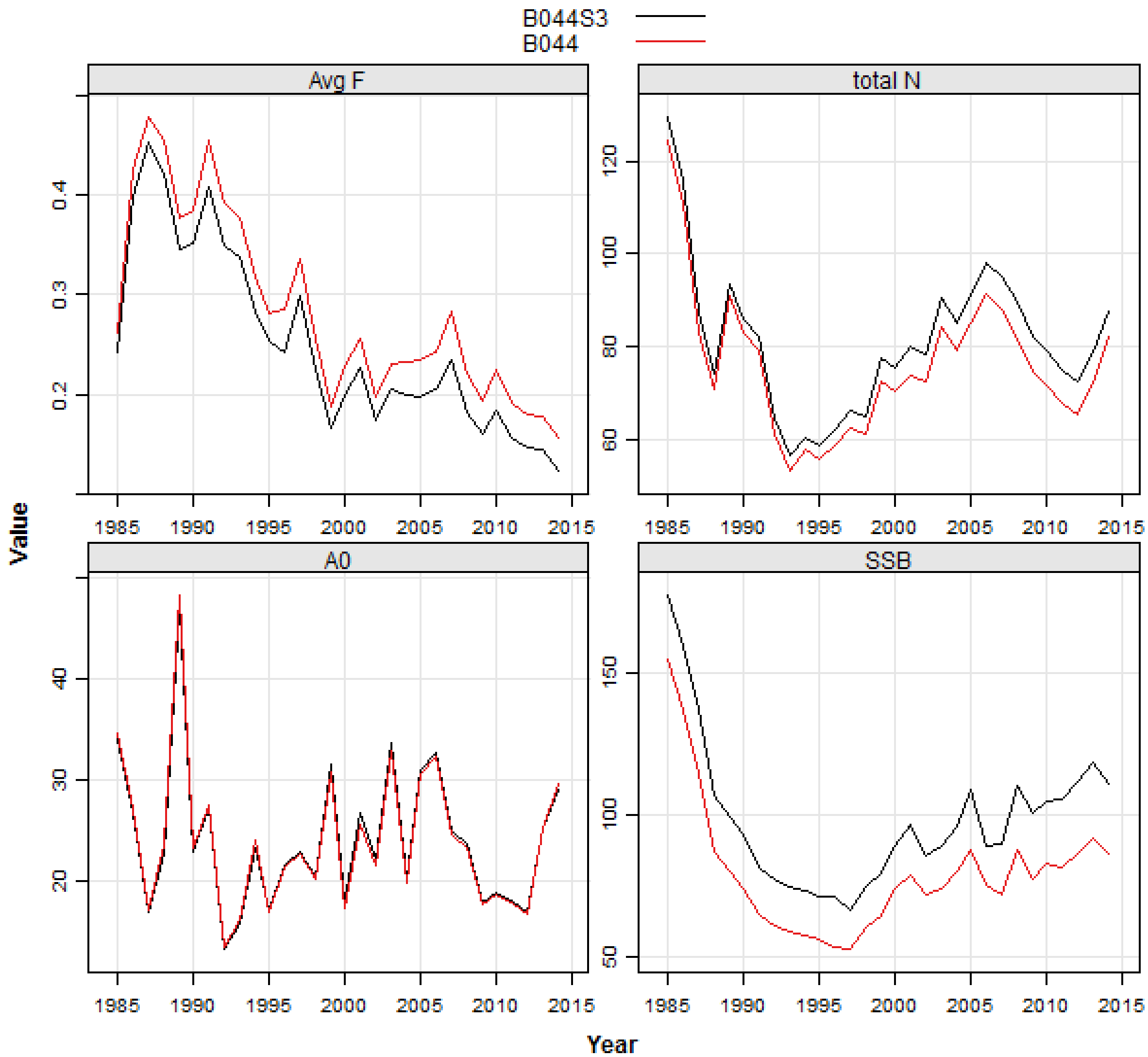


Figure B7.123. Final model sensitivity run assuming lower 95% CI for recreational catch.
Trends for the final model (B044) estimates are represented by the red line, with sensitivity run estimates (B044S3) represented by the black line.

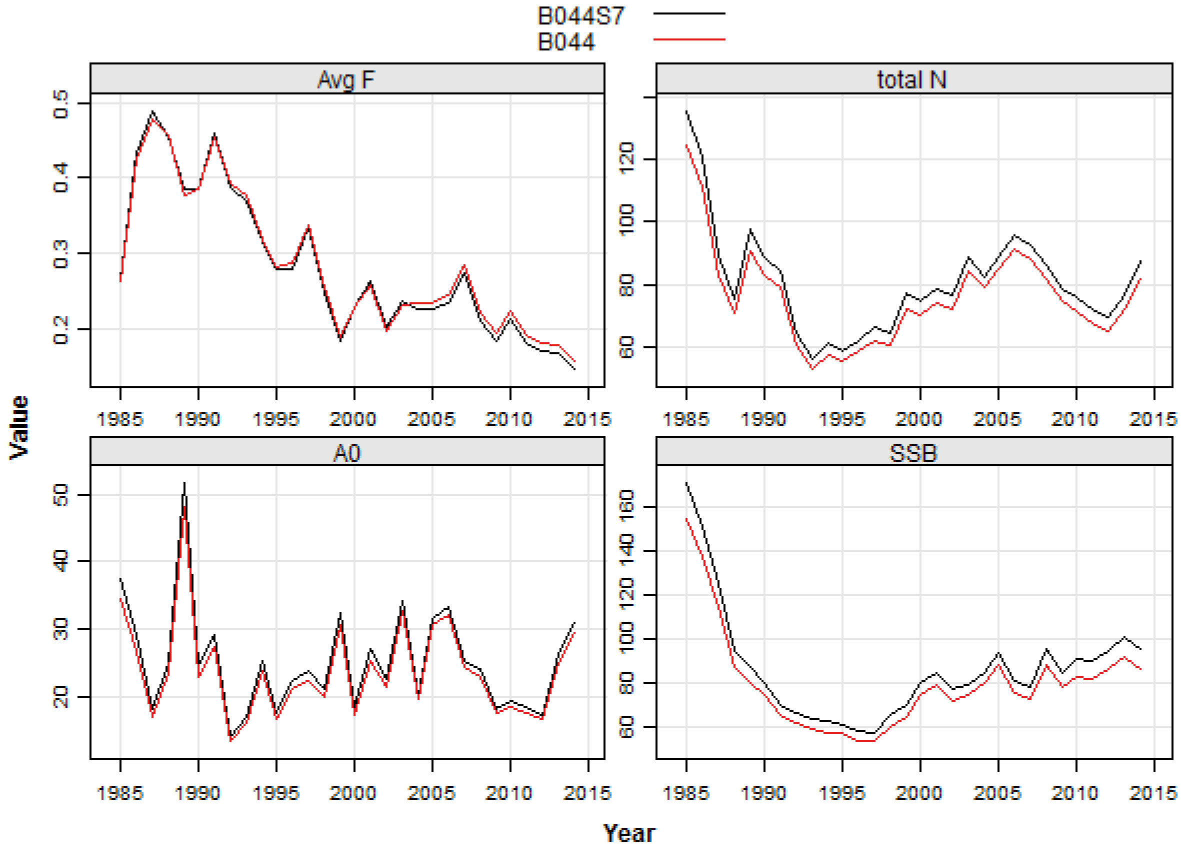


Figure B7.124. Final model sensitivity run assuming MRFSS number prior to 2004 for the recreational catch. Trends for the revised final model (B044) estimates are represented by the red line, with sensitivity run estimates (B044S7) represented by the black line.

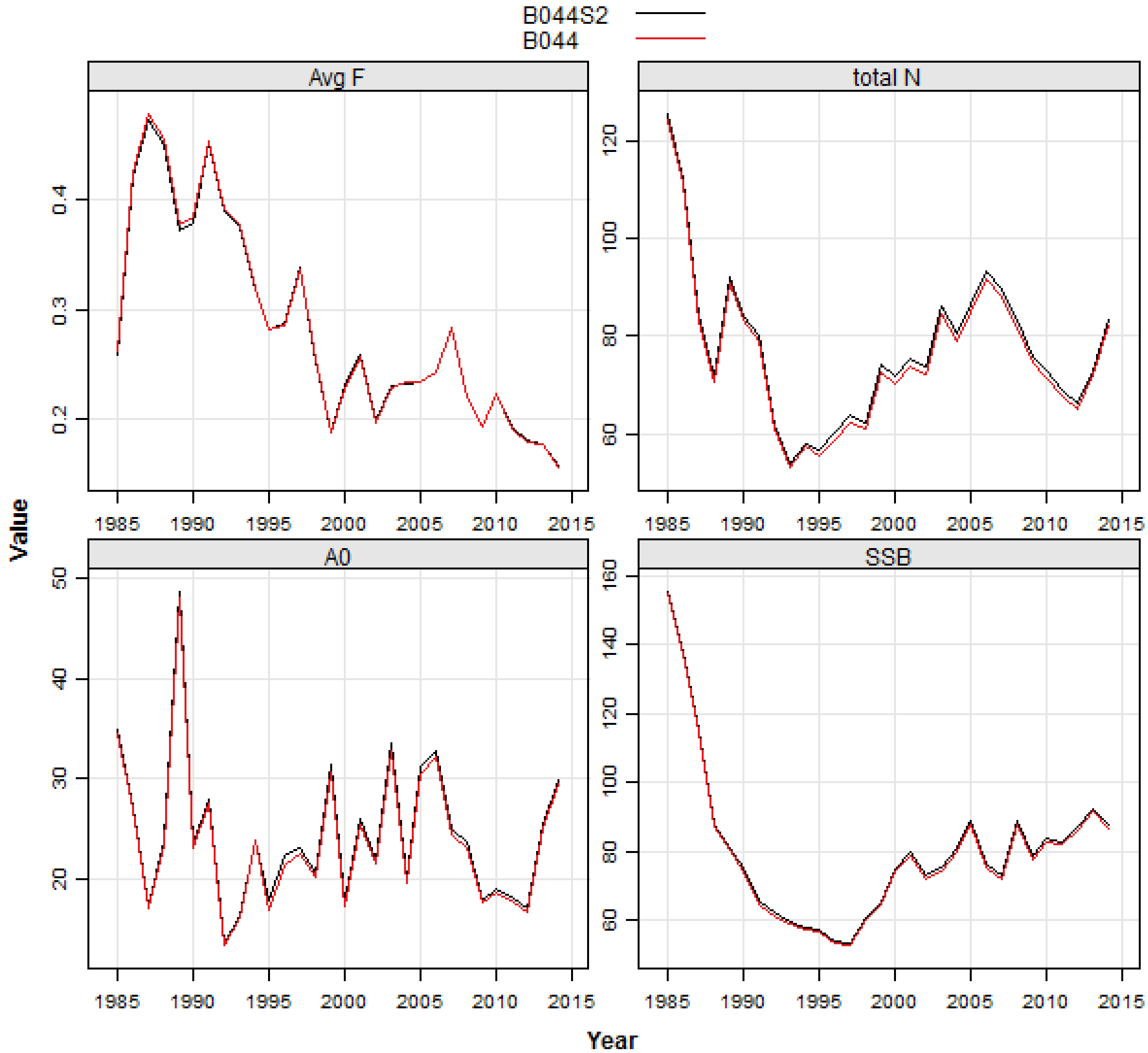


Figure B7.125. Final model sensitivity run assuming 17% mortality (instead of 15%) for the recreational discards. Trends for the final model (B044) estimates are represented by the red line, with sensitivity run estimates (B044S2) represented by the black line.

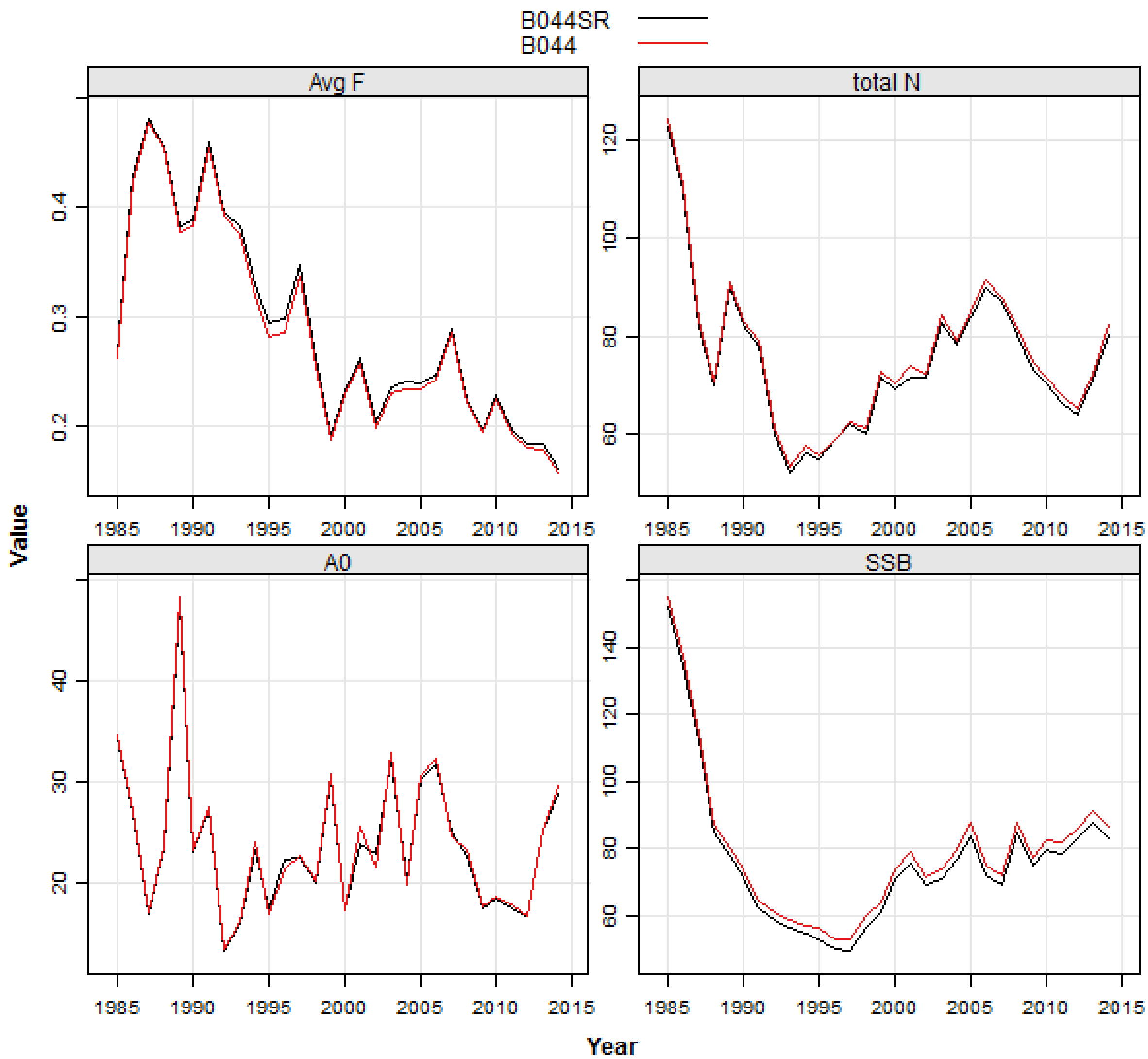


Figure B7.126. Final model sensitivity run assuming regional age-length keys from 2006 to 2014. Trends for the revised final model (B044) estimates are represented by the red line, with sensitivity run estimates (B044SR) represented by the black line.

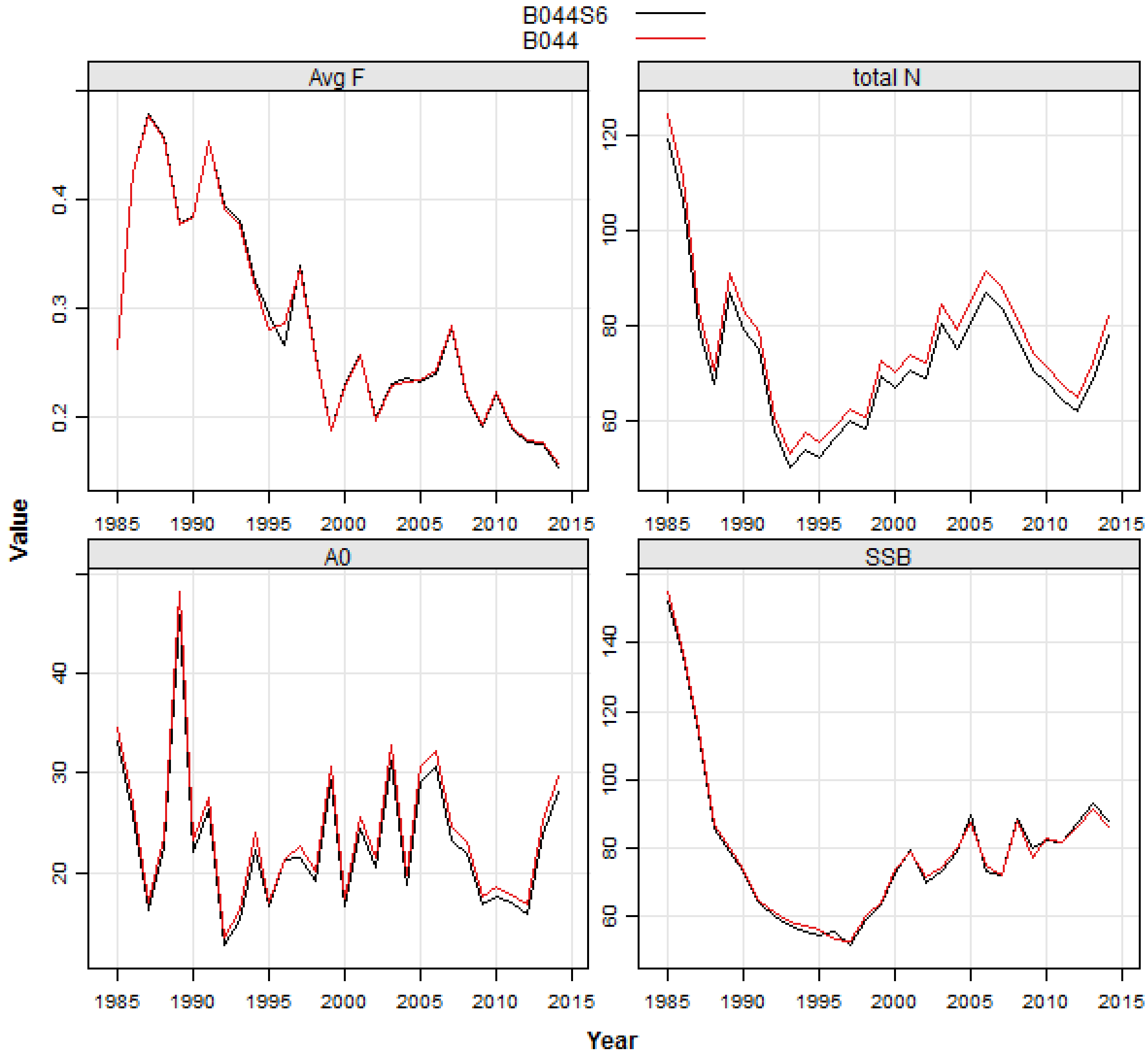


Figure B7.127. Final model sensitivity run assuming 3 time blocks for length-weight coefficients (1985-1994, 1995-2004, 2005-2014). Trends for the revised final model (B044) estimates are represented by the red line, with sensitivity run estimates (B044S6) represented by the black line.

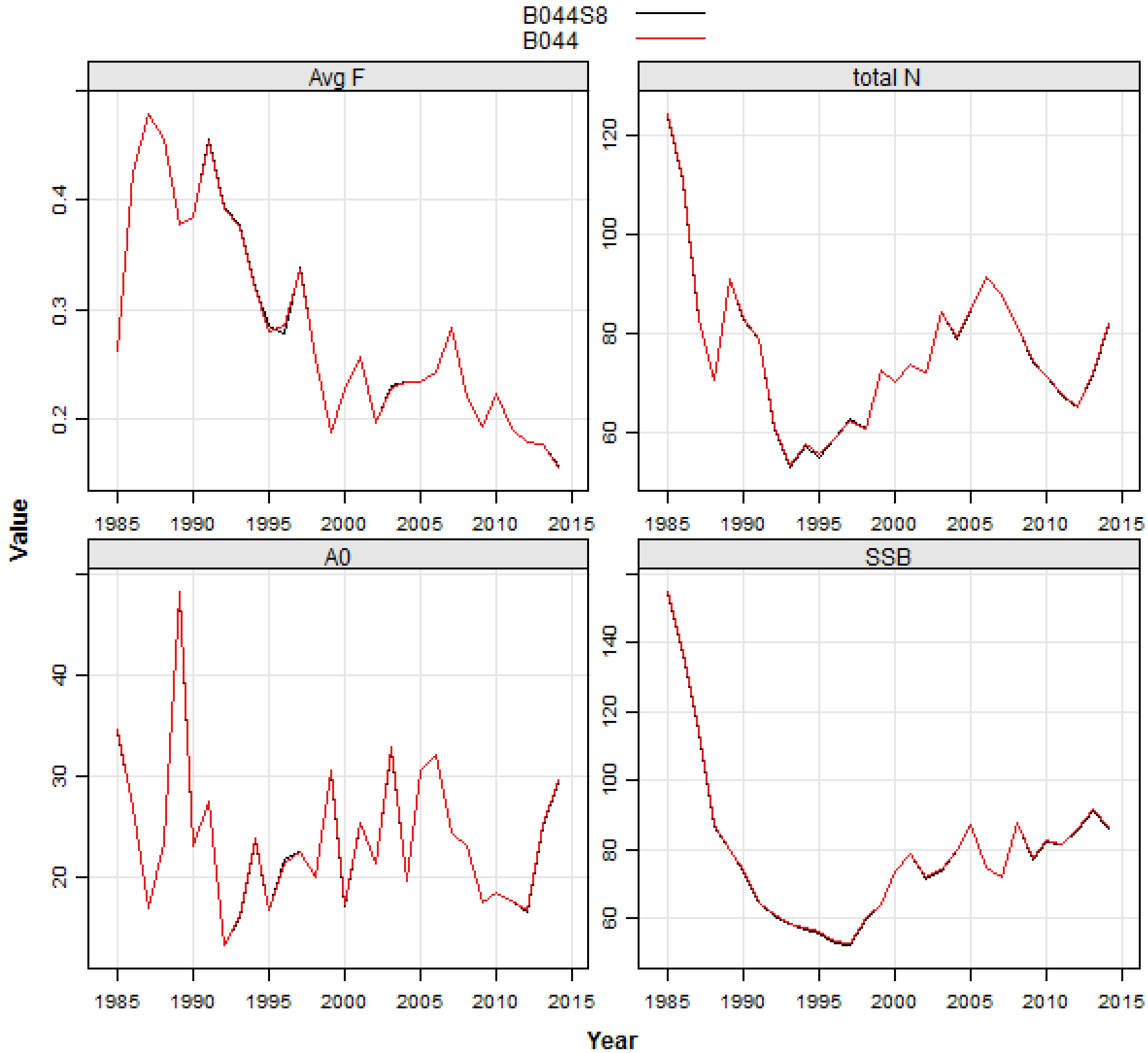


Figure B7.128. Final model sensitivity run assuming VA set 2 landings.
Trends for the revised final model (B044) estimates are represented by the red line, with sensitivity run estimates (B044S8) represented by the black line.

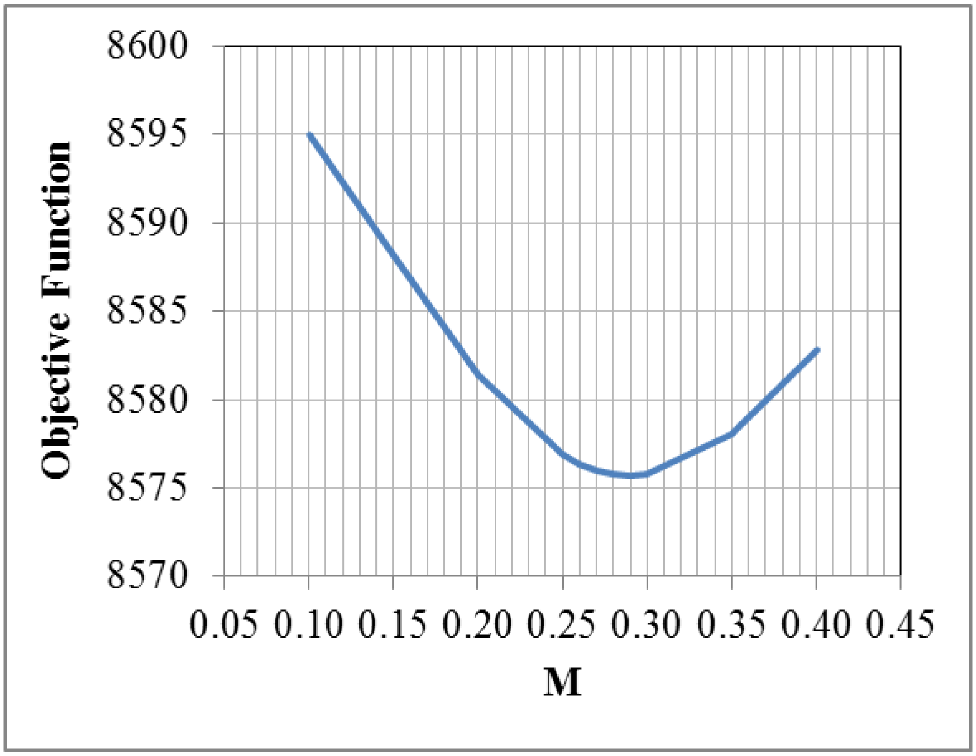


Figure B7.129. Final model objective function profile over different values of natural mortality.

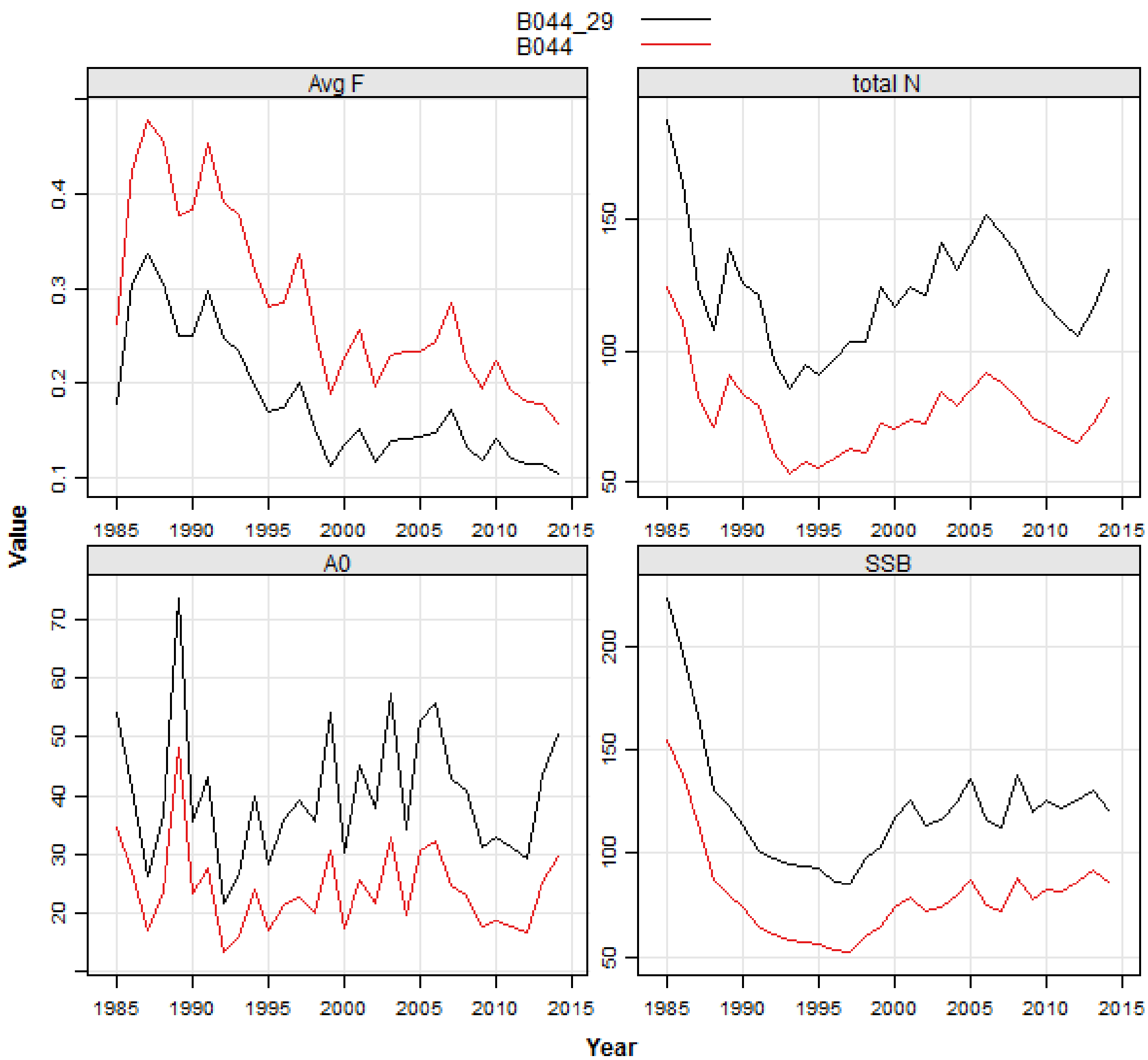


Figure B7.130. Final model sensitivity run assuming natural mortality equal to 0.29 (the value that minimizes the objective function). Trends for the final model (B044) estimates are represented by the blue line, with sensitivity run estimates (B044_29) represented by the black line.

Figure B7.131. Final model sensitivity run assuming age-based natural mortality estimates: Lorenzen scaled to Rule of Thumb (0.21) and Lorenzen scaled to (0.263: the value that minimizes the objective function. Trends for the revised final model (B044) estimates are represented by the blue line, with sensitivity run estimates from B043_LROT (Lorenzen scaled to rule of thumb: 0.21) represented by the red line and B043_L263 (Lorenzen scaled to 0.263) represented by the black line.

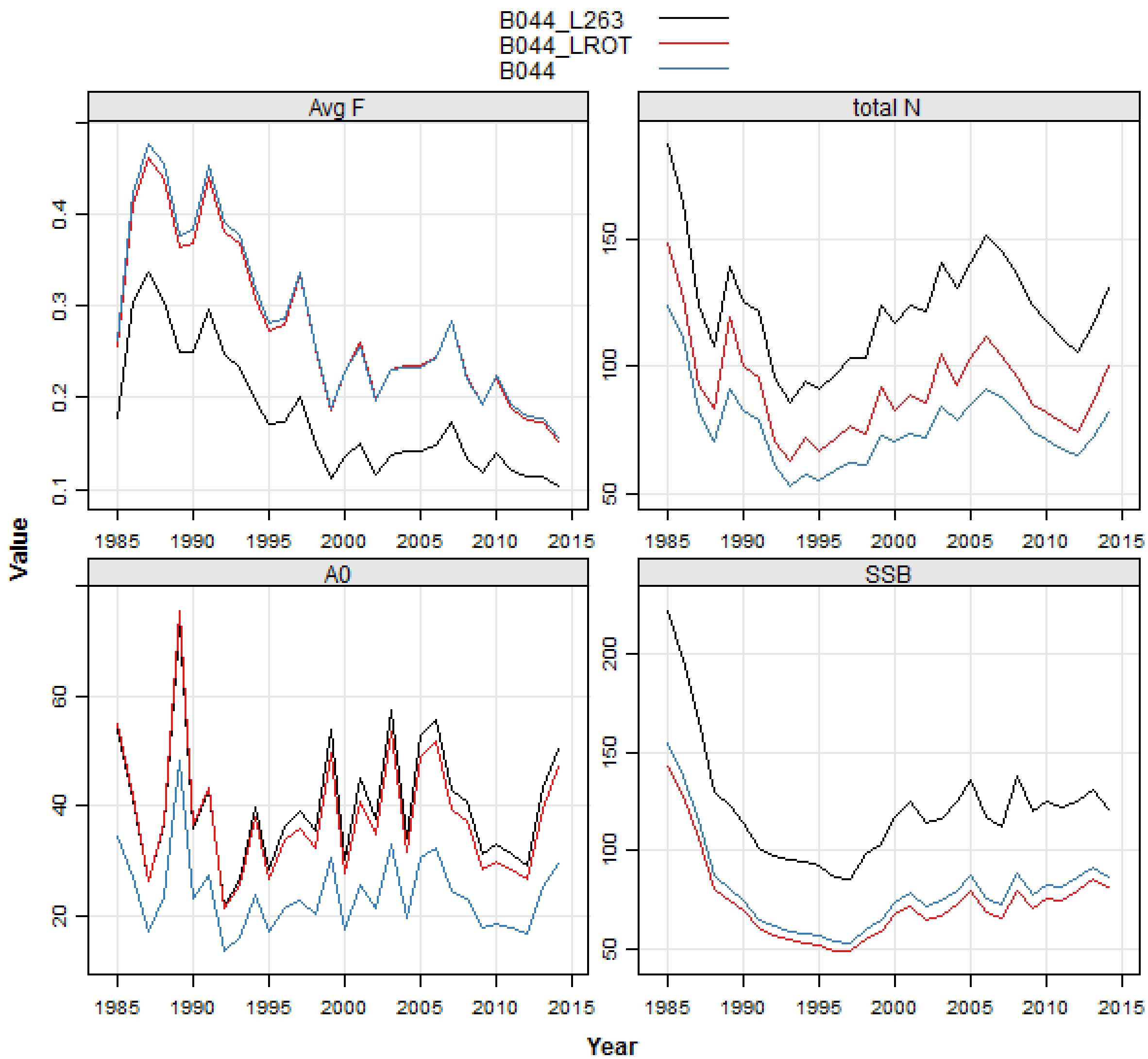
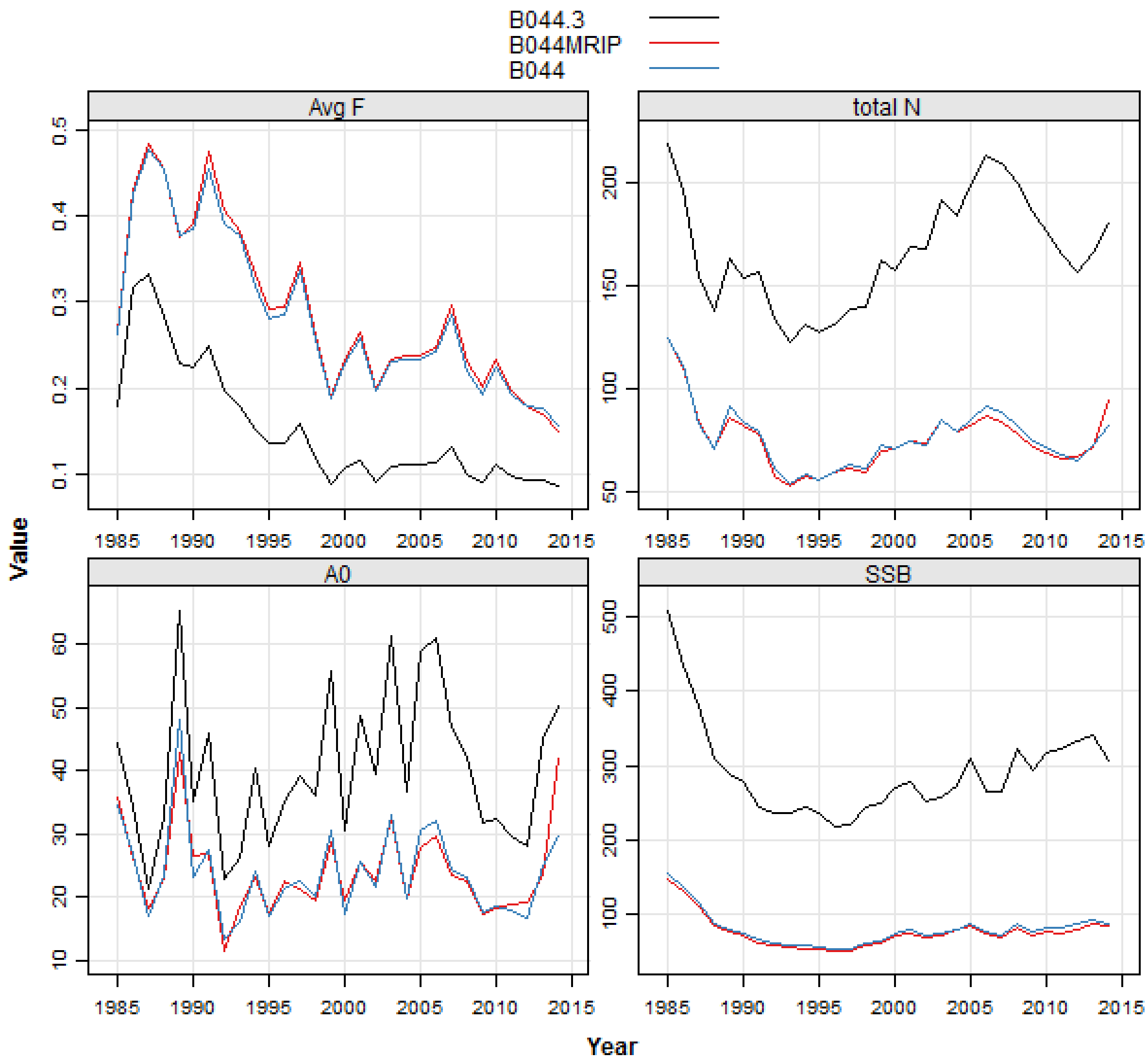


Figure B7.132. Final model sensitivity run exploring the effects of removing the MRIP index, and running the final model with only the fleets and MRIP index. Trends for the final model (B044) estimates are represented by the blue line, with sensitivity run estimates from B043MRIP (2 fleets+MRIP index) represented by the red line and B044.3 (no MRIP) represented by the black line.



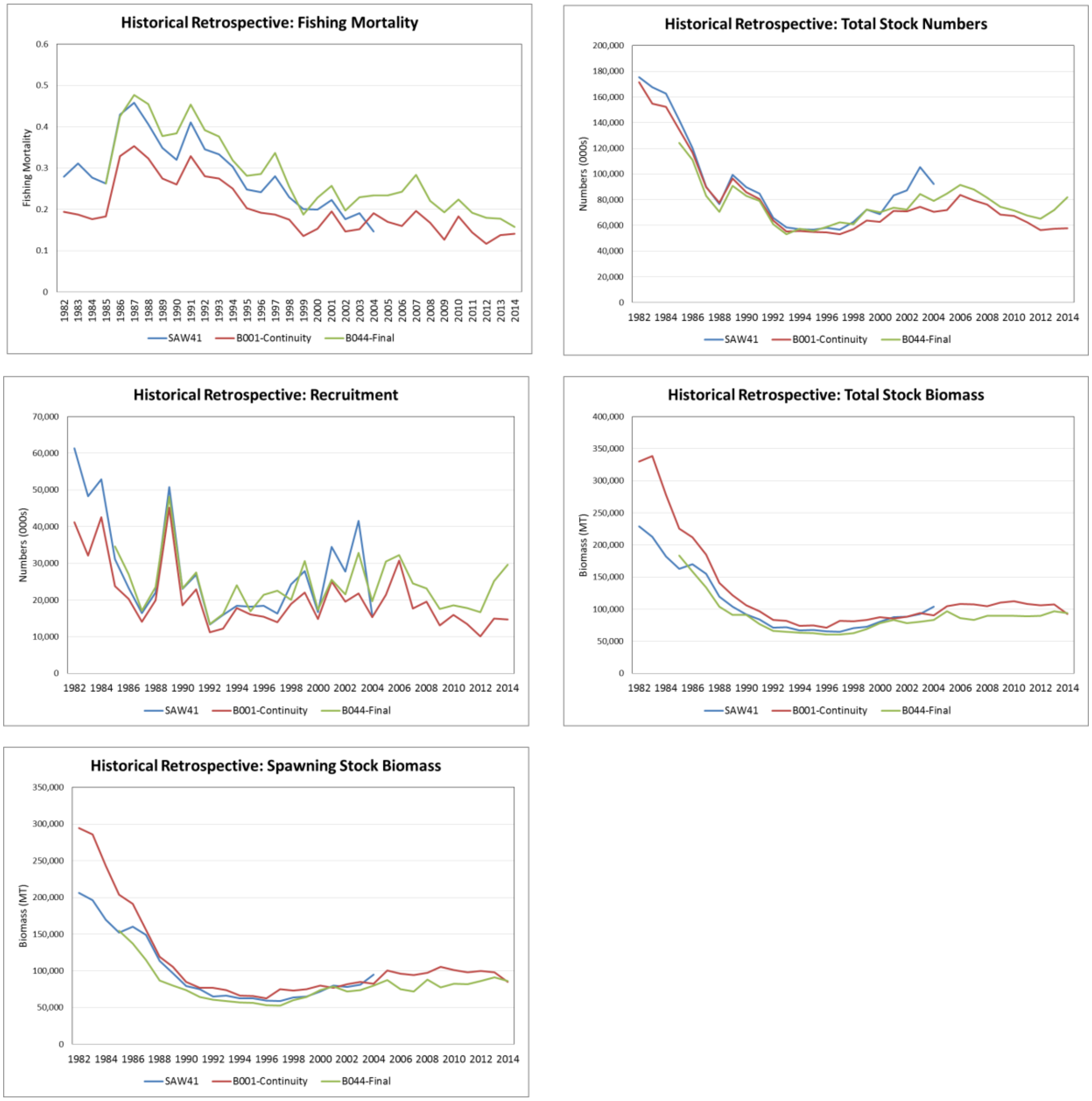


Figure B7.133. Historical retrospective plots comparing estimates of F, abundance, recruitment, total biomass and spawning stock biomass across the previous benchmark assessment model (SAW 41), the continuity run with updated data (B001) and the final preferred model from this assessment (BFinal).

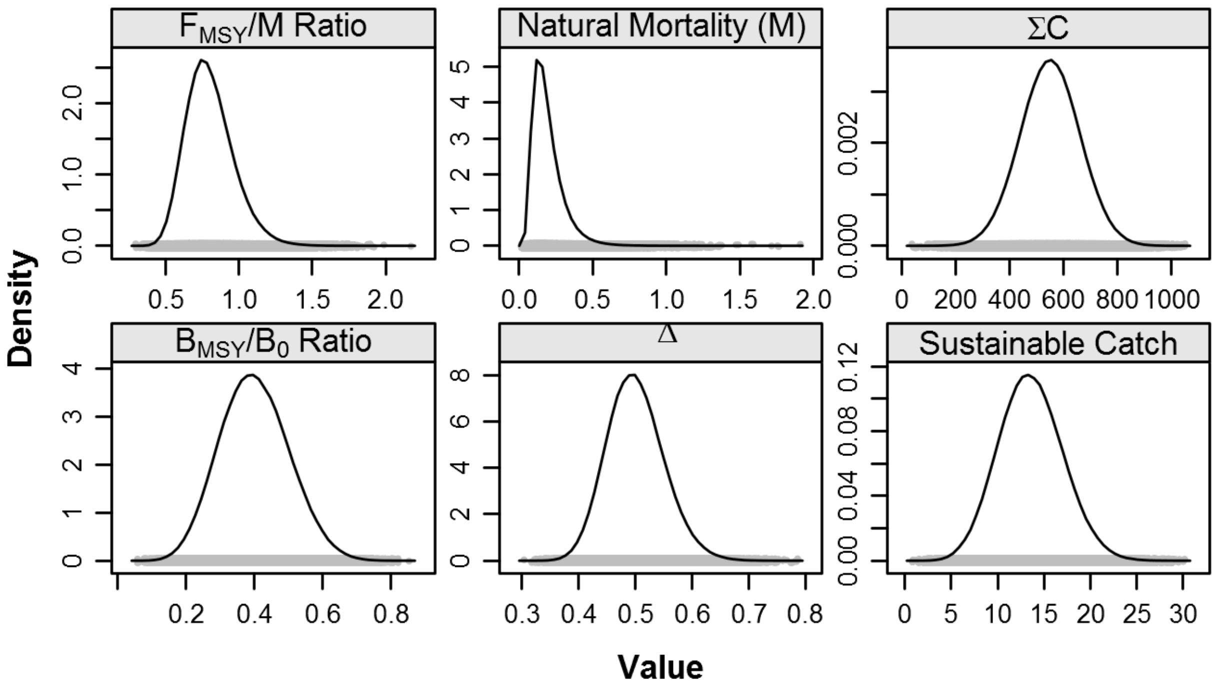


Figure B7.134: Density plot of individual parameter draws (top row panels; bottom row left & middle panels) and sustainable yield estimates (bottom right panel) based on 1,000,000 Monte Carlo simulations of the DCAC base model.

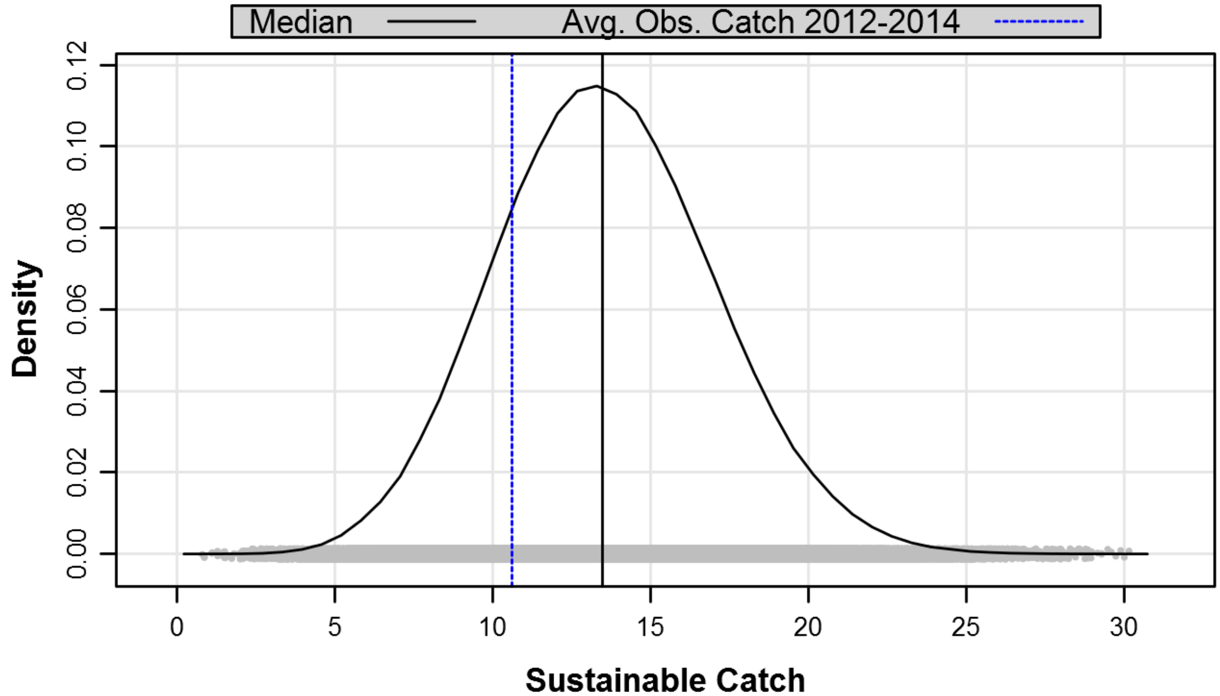


Figure B7.135: Density plot of sustainable yield based on 1,000,000 Monte Carlo simulations of the DCAC base model. Vertical lines represent the median sustainable yield estimate (black) and observed average catch (blue) during the three terminal years (2012-2014) of the assessment

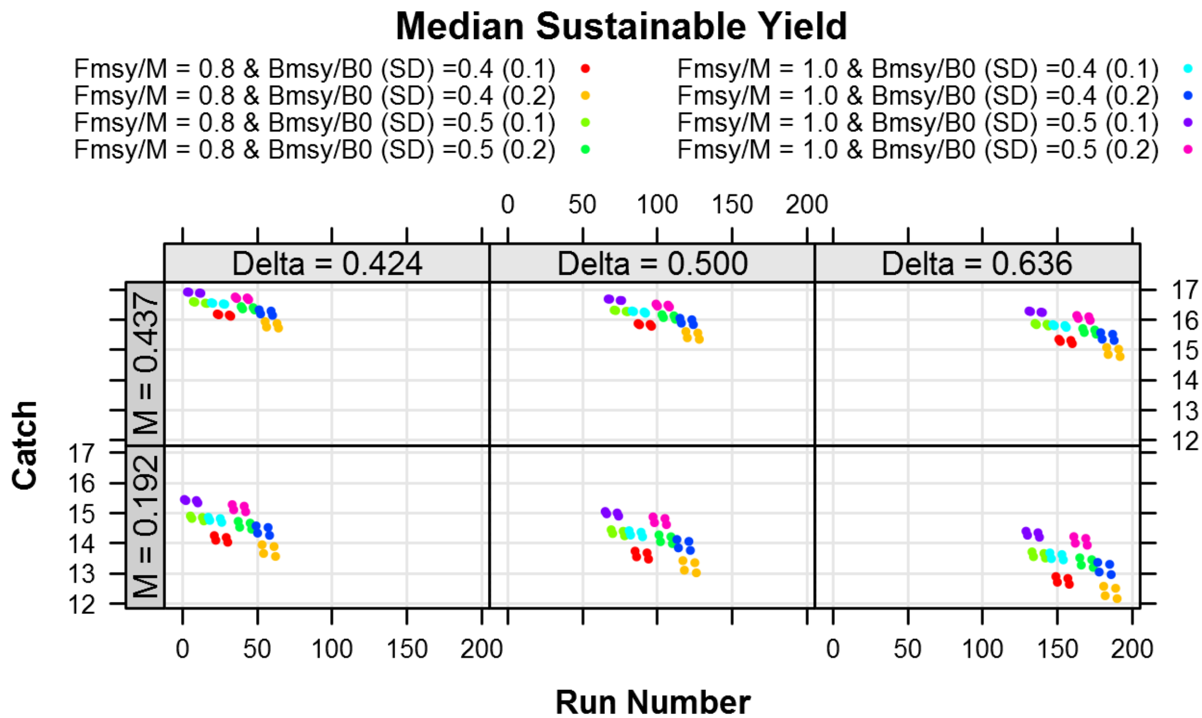


Figure B7.136: Y_{sust} **median estimates (in mt) derived from each of the 192 different model configurations (including the base DCAC model).**

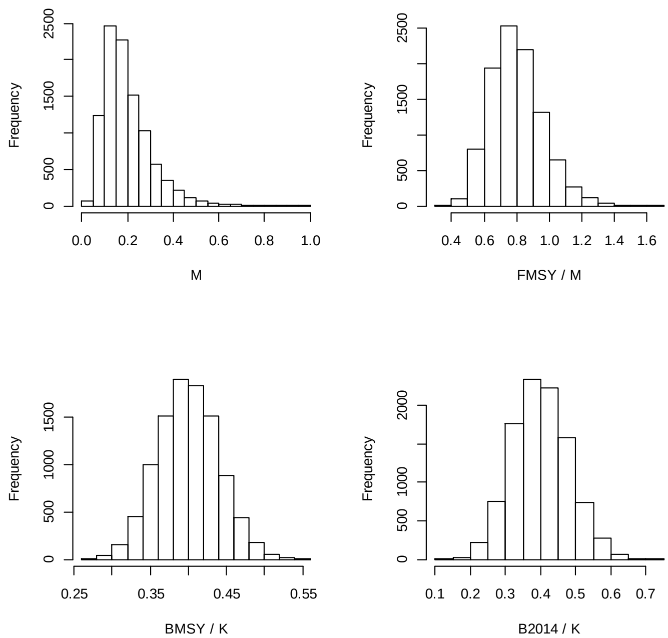


Figure B7.137. Distributions of drawn parameters for DBSRA model.

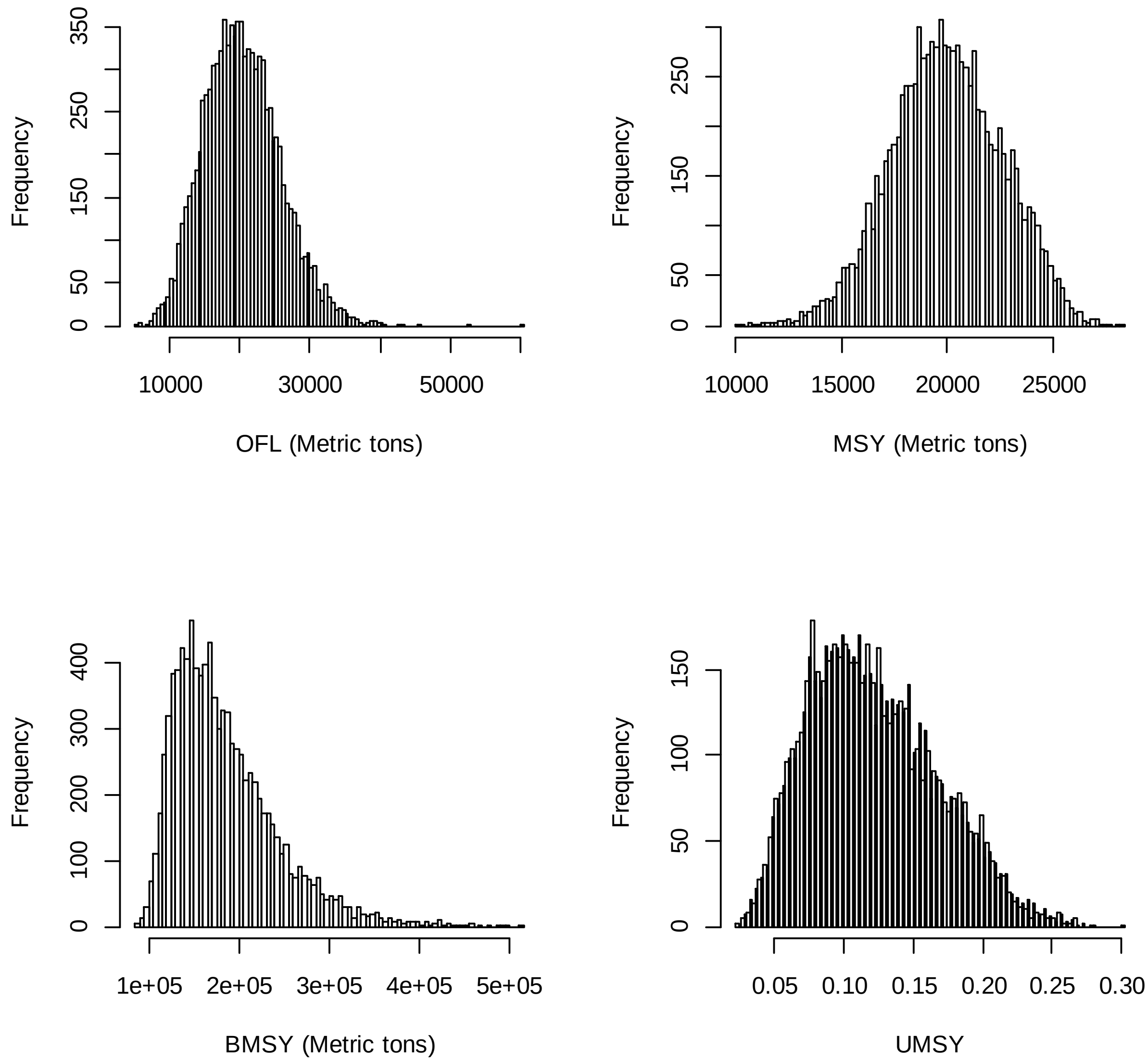


Figure B7.138. Distribution of management parameters from successful DBSRA model runs.

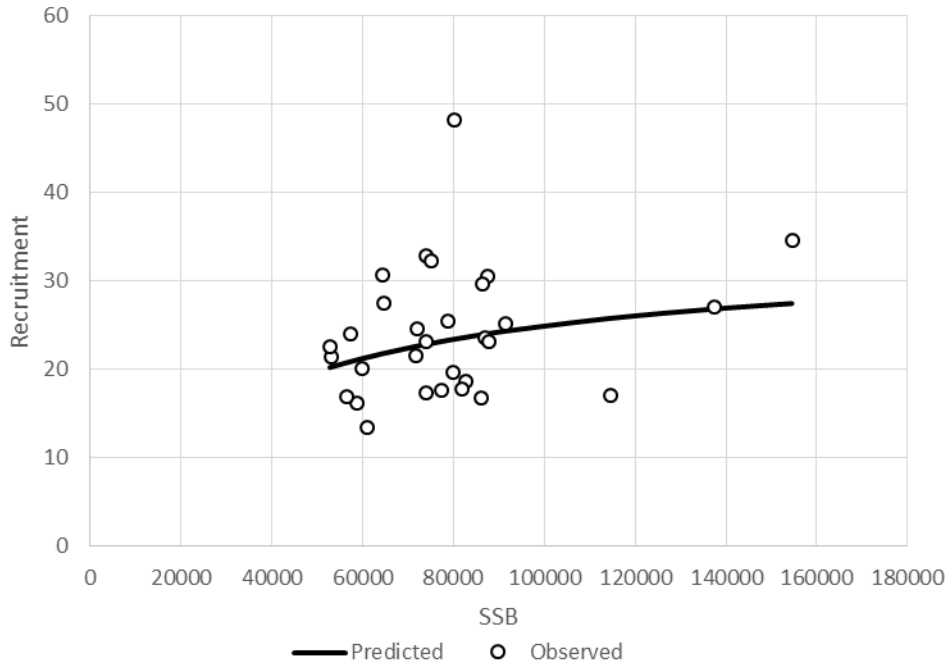


Figure B8.1. Observed stock-recruitment relationship plotted with a fitted curve.

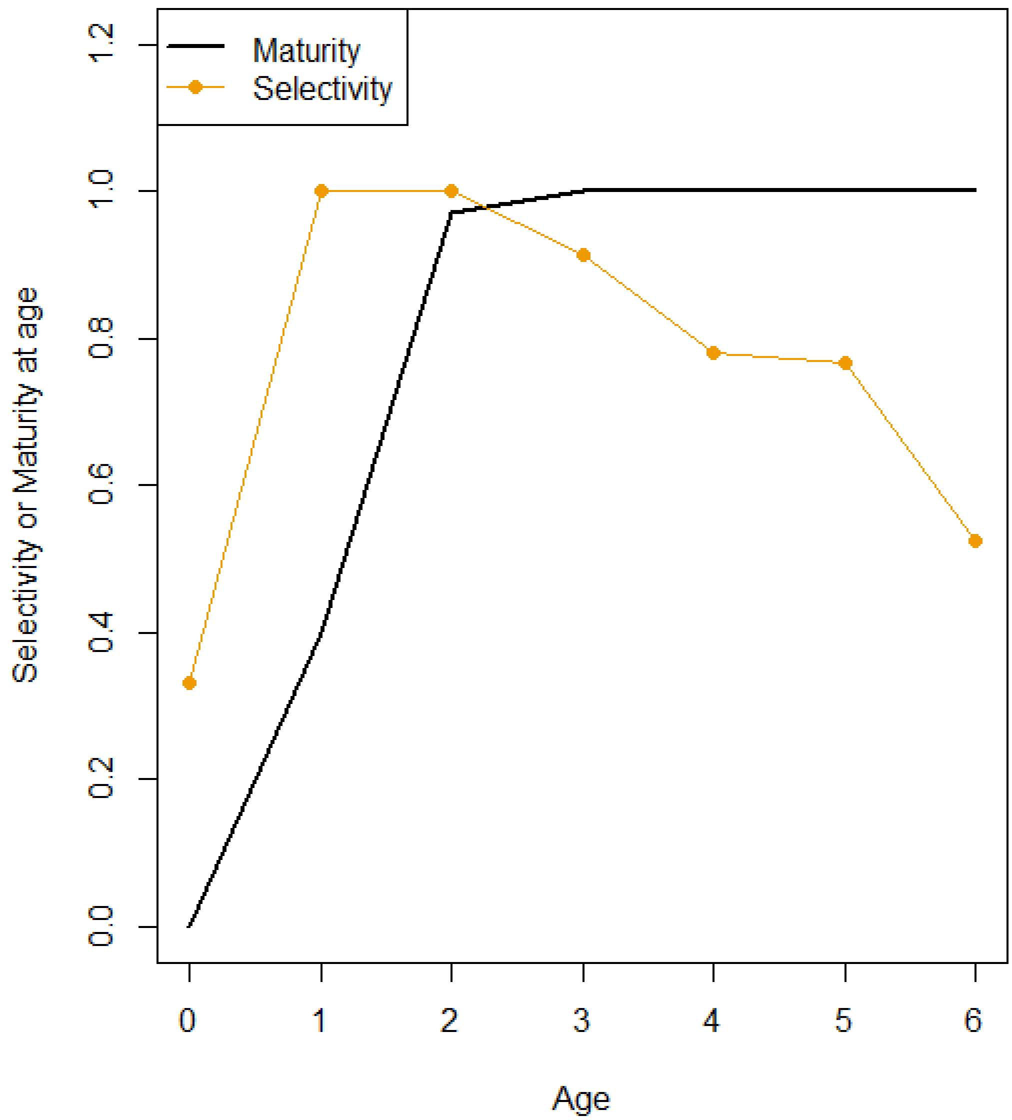


Figure B8.2. Maturity ogive and composite selectivity pattern used to estimate bluefish reference points.

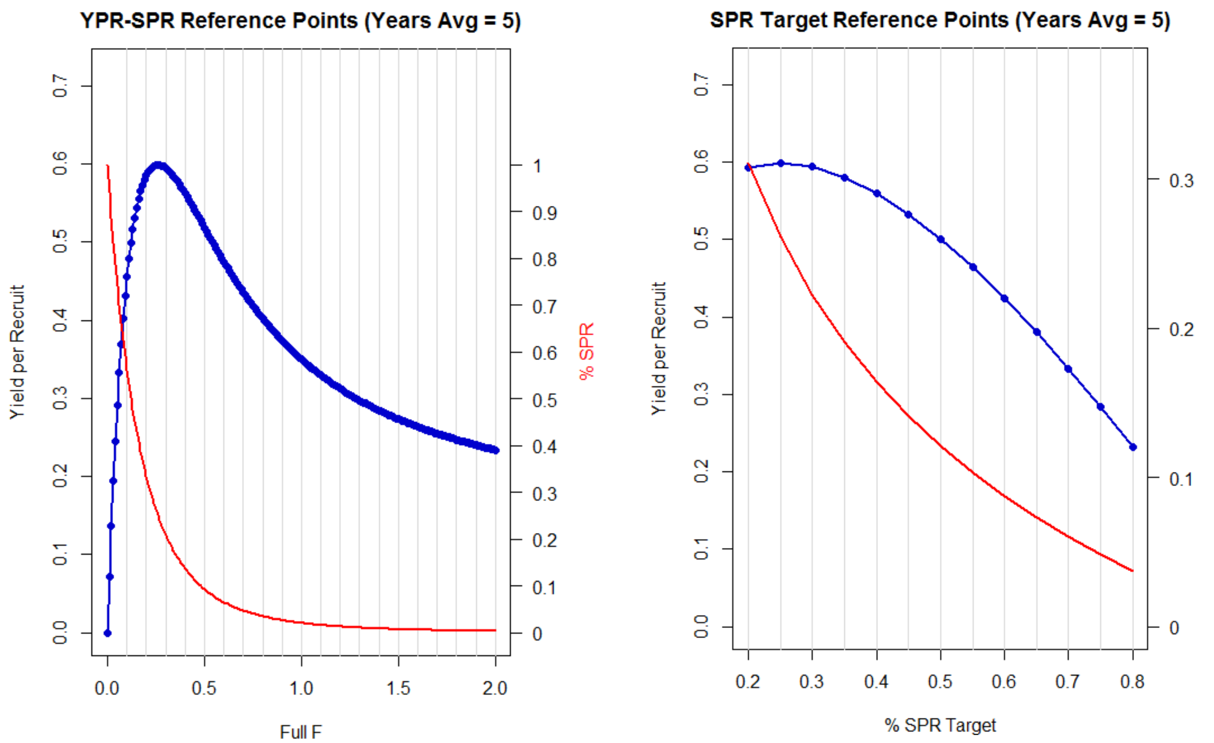


Figure B8.3. YPR and SPR curves for bluefish.

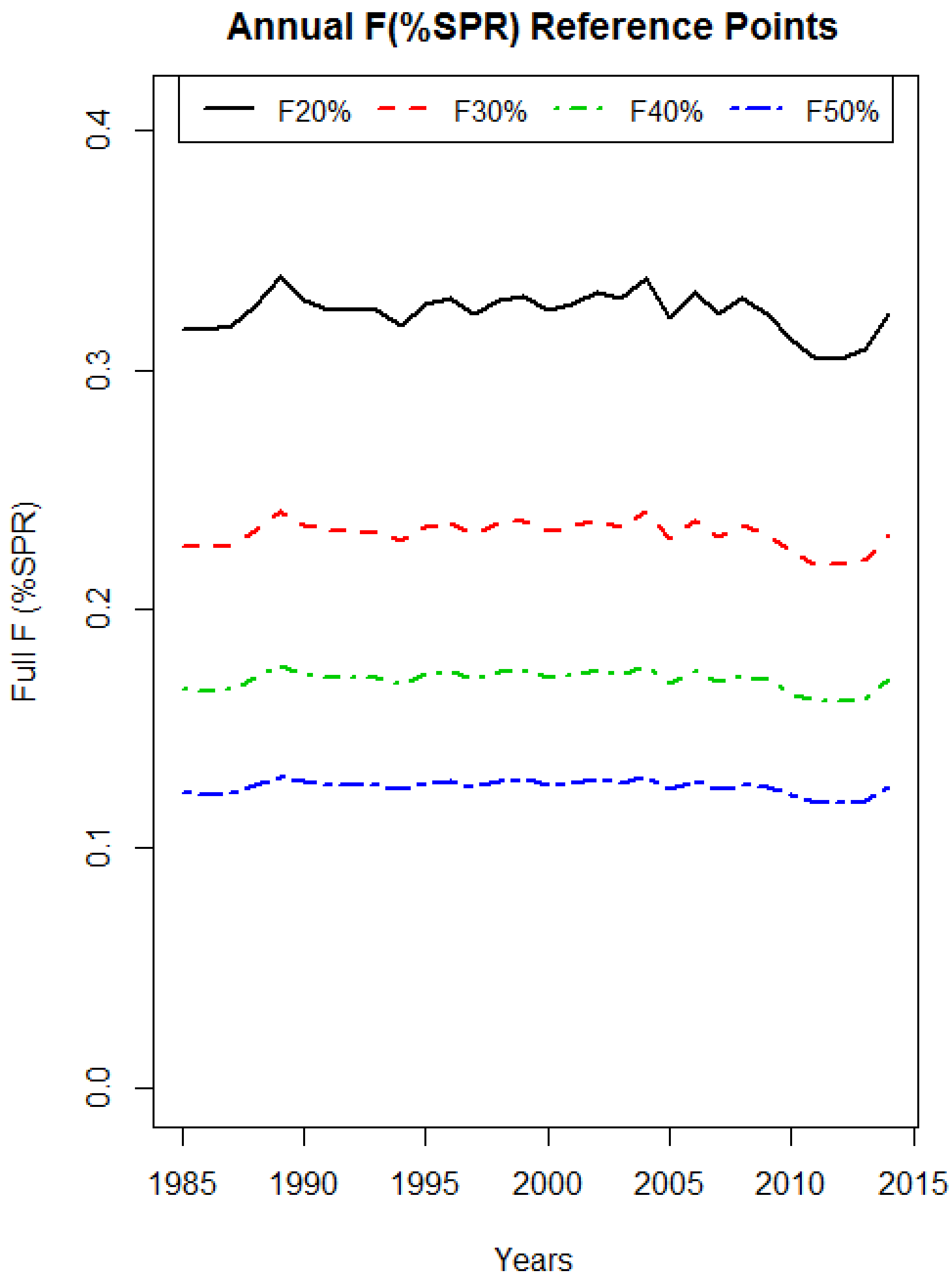


Figure B8.4. Annual estimates of F %SPR reference points.

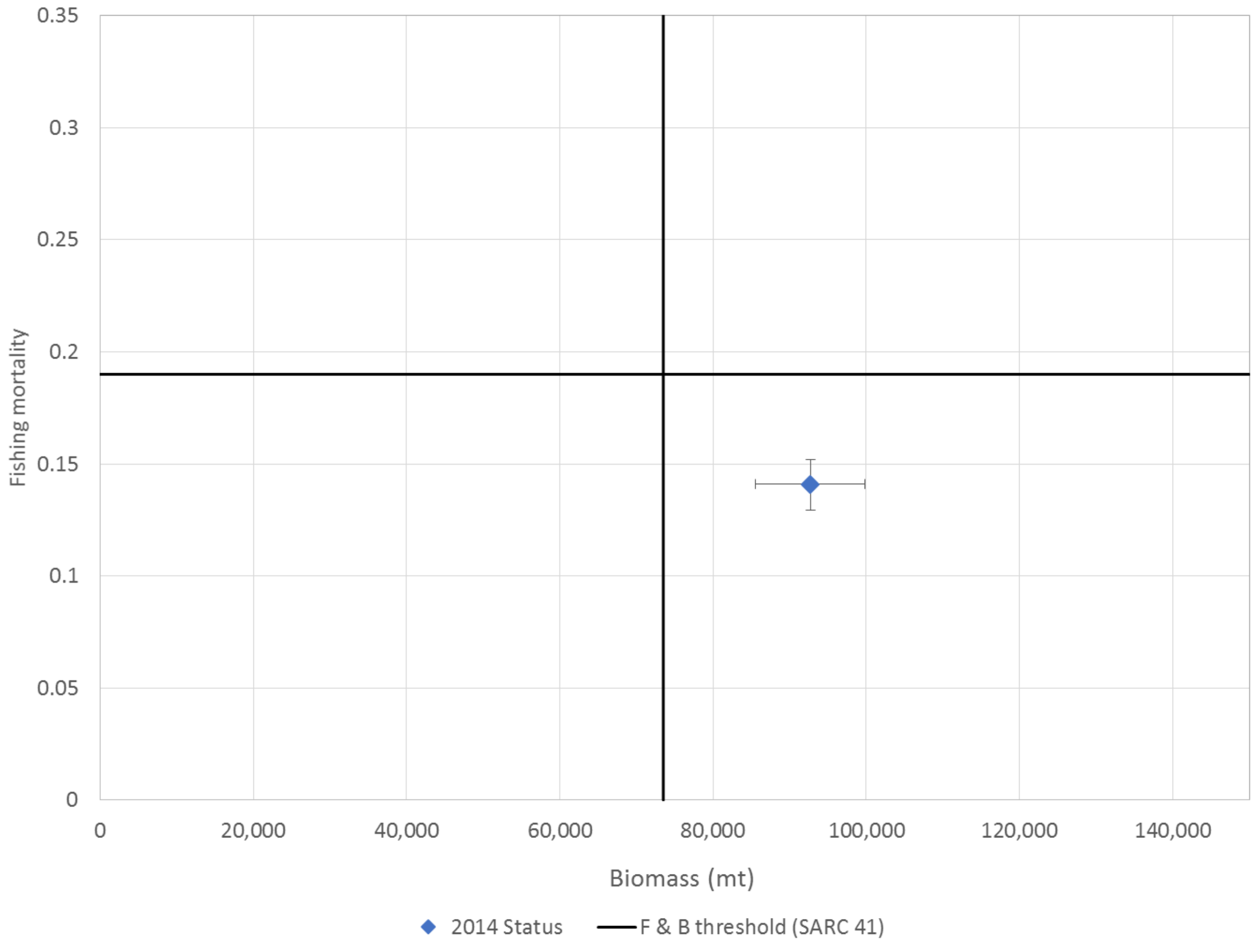


Figure B9.1. Stock status in 2014 (diamond) from the continuity run plotted with the F and biomass thresholds from the previous benchmark assessment (solid lines).
Error bars on the status estimated indicate 95% confidence intervals.

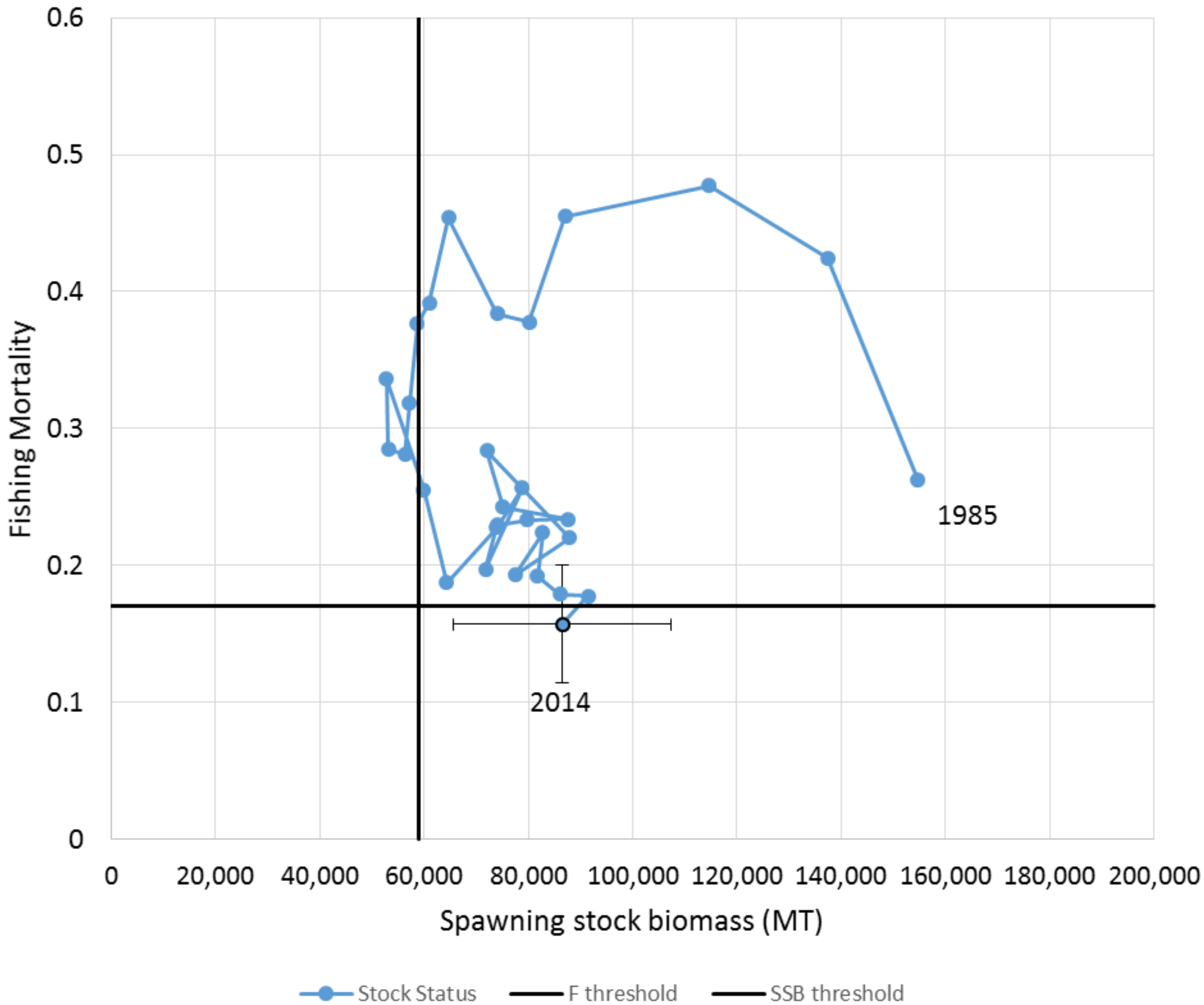
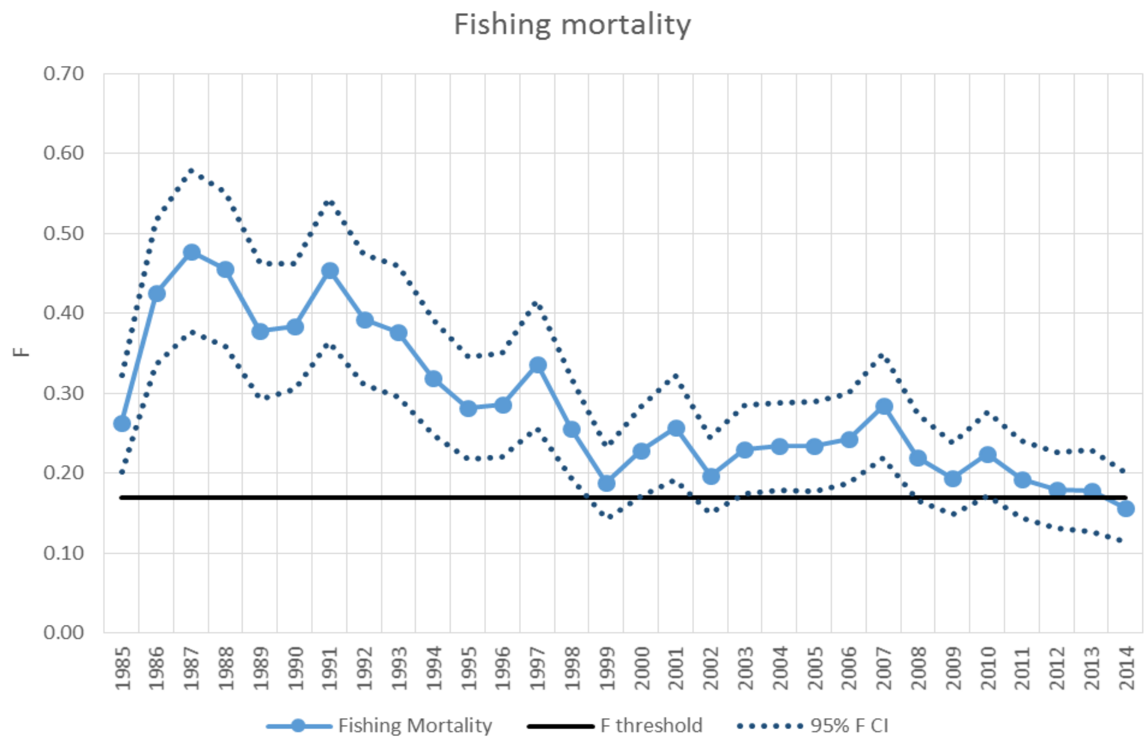


Figure B9.2. Annual stock status estimates from the final revised model run plotted with the F and biomass thresholds for this assessment (solid lines). Error bars on the status estimated indicate 95% confidence intervals.



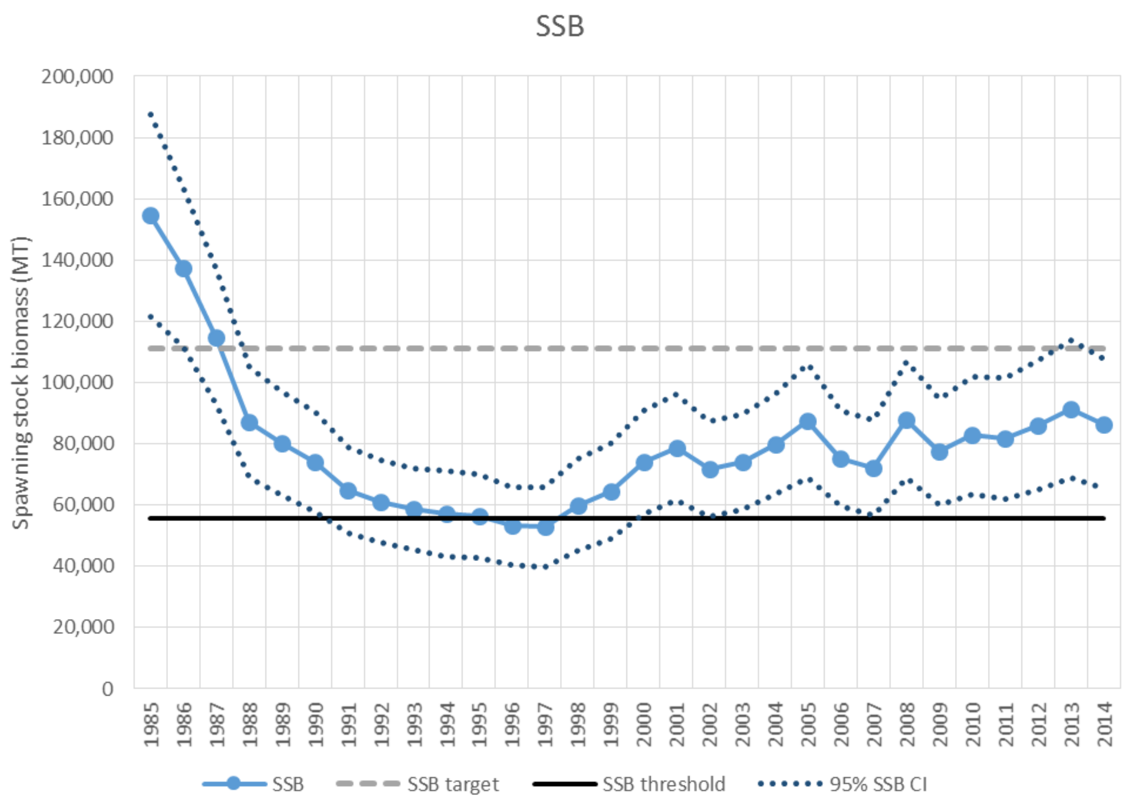


Figure B9.3. Fully selected F (top) and spawning stock biomass (bottom) from the final revised model run plotted with their respective overfishing and overfished thresholds and 95% confidence intervals.

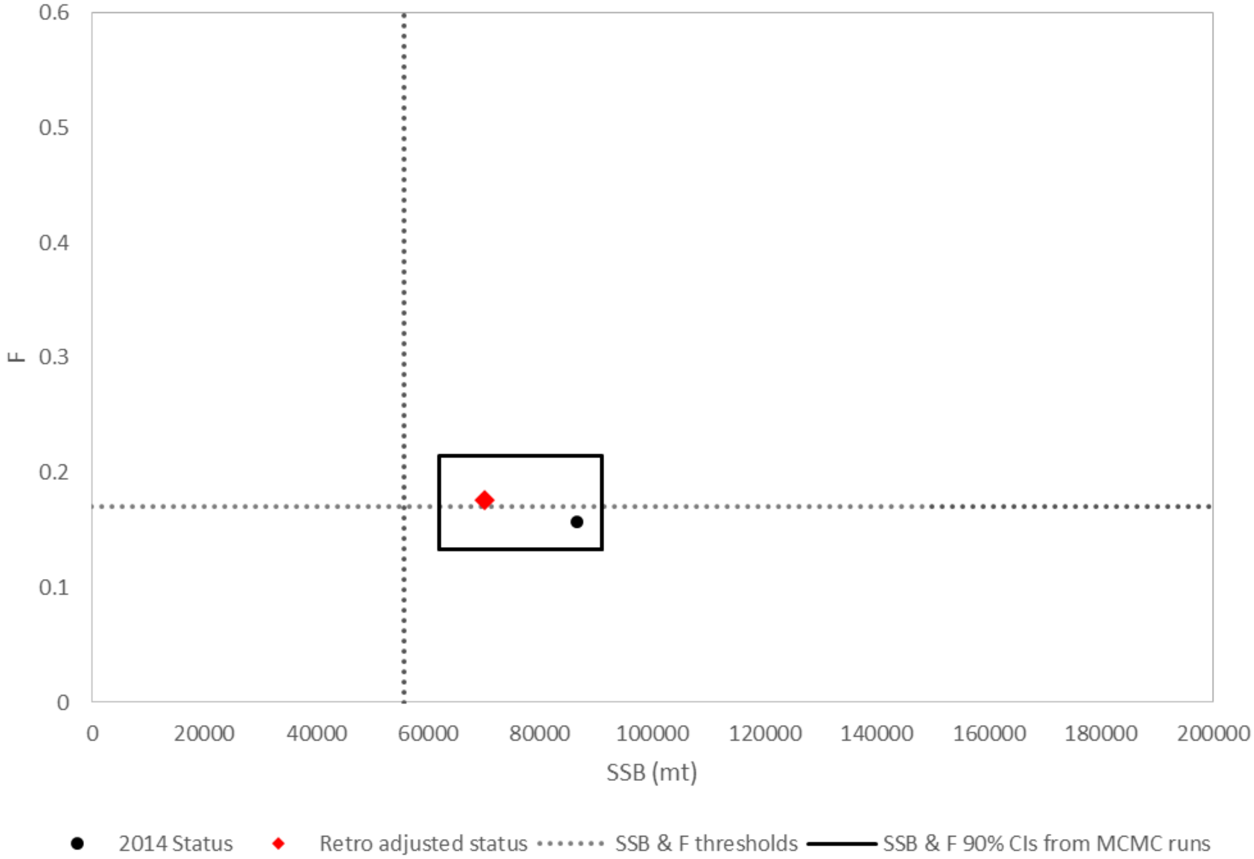
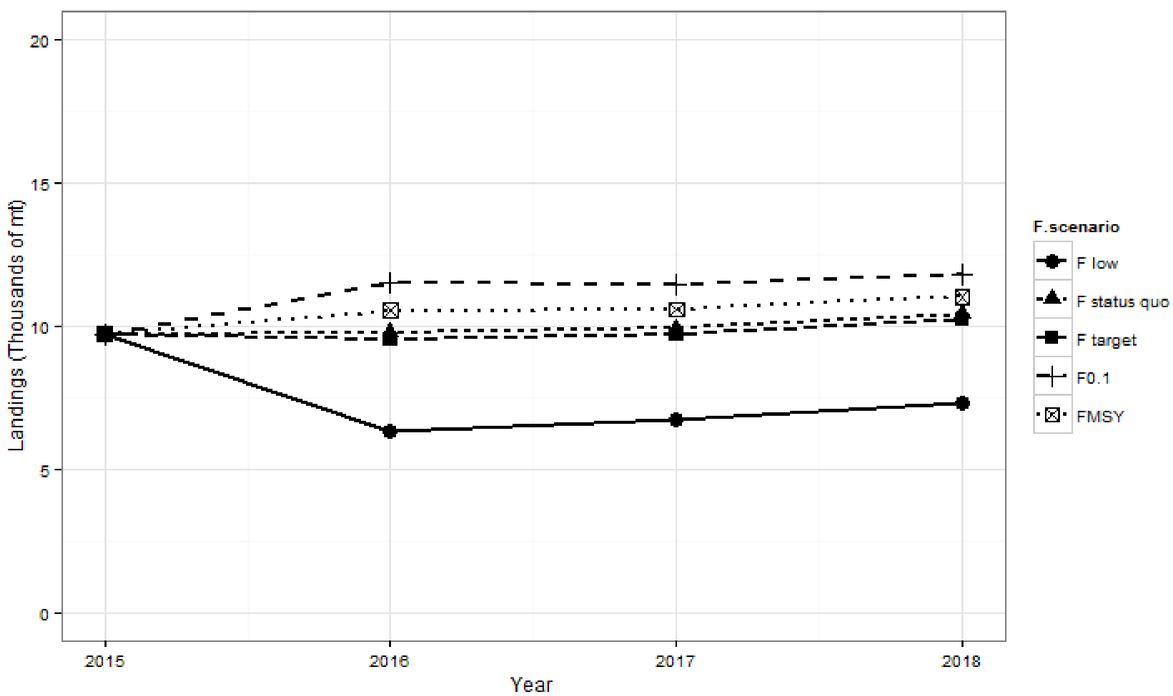
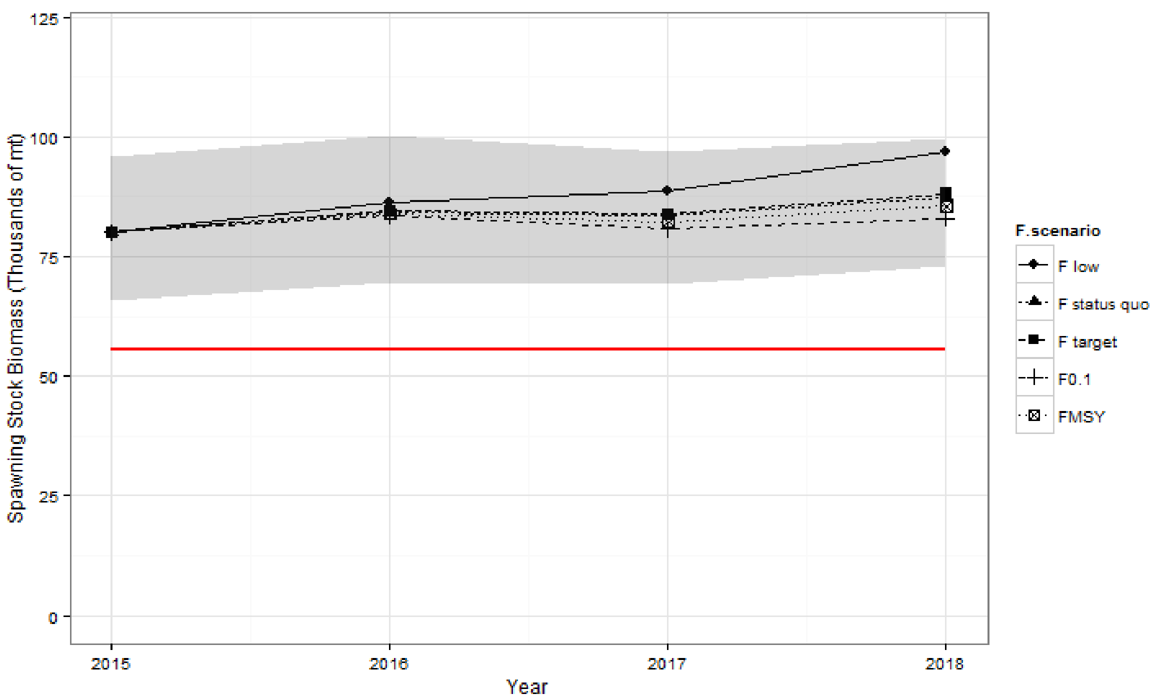


Figure B10.1. 2014 Stock status of bluefish with and without adjustment for retrospective bias, compared to the 90% confidence bounds of the MCMC model runs.

Figure B10.2. **Projected landings (top) and spawning stock biomass (bottom) under various F scenarios. Shaded bands indicated the 5th and 95th percentiles of the F_{MSY} bootstrap runs. The solid red line indicates the overfished biomass threshold.**





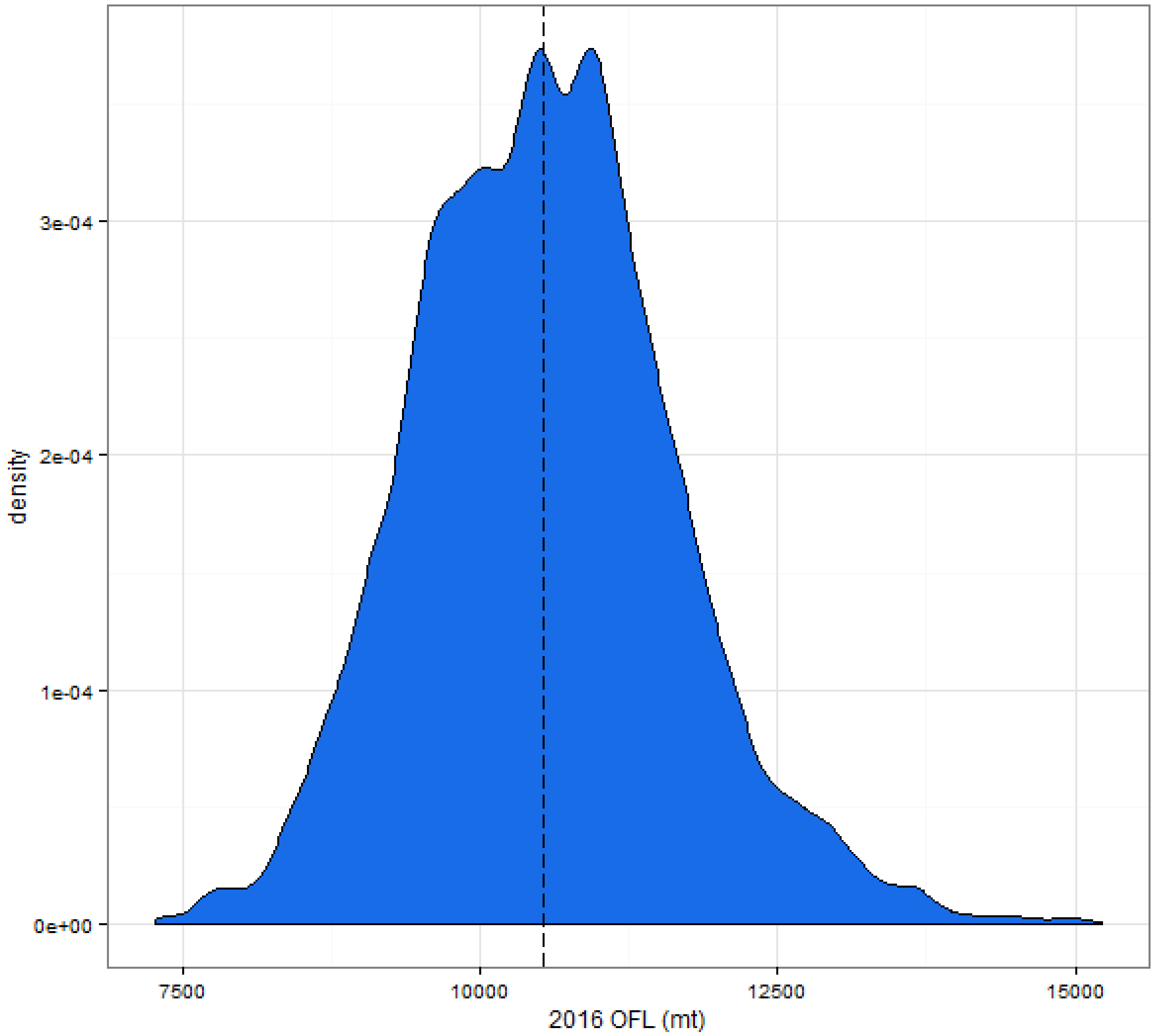


Figure B10.3. Distribution of 2016 OFL estimate from revised final model projections. The dashed vertical line indicates the median estimate.

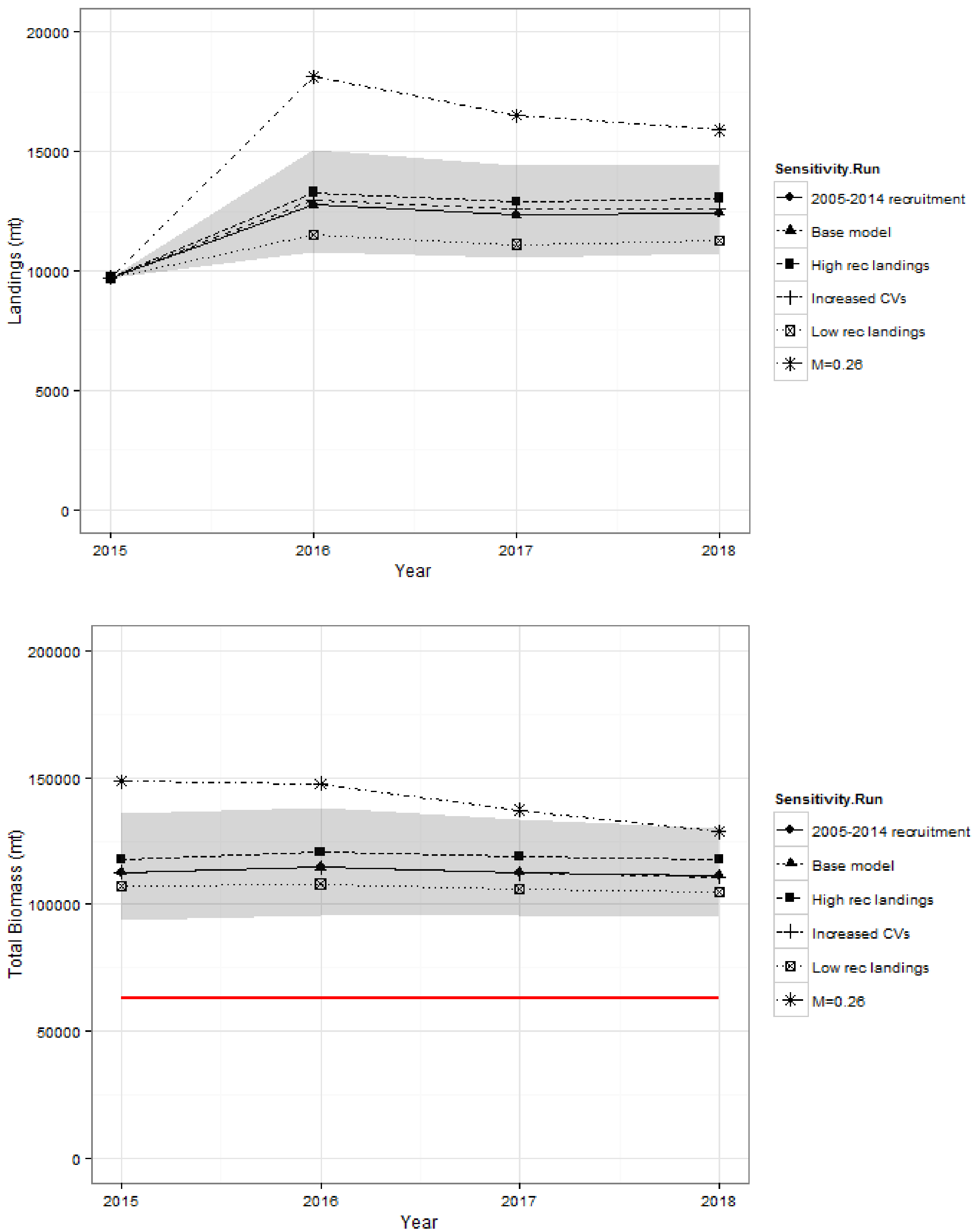


Figure B10.4. Sensitivity runs of projected landings (top) and biomass (bottom) under F_{MSY}. Shaded bands indicated the 5th and 95th percentiles of the preferred base model bootstrap runs. The solid red line indicates the overfished biomass threshold.

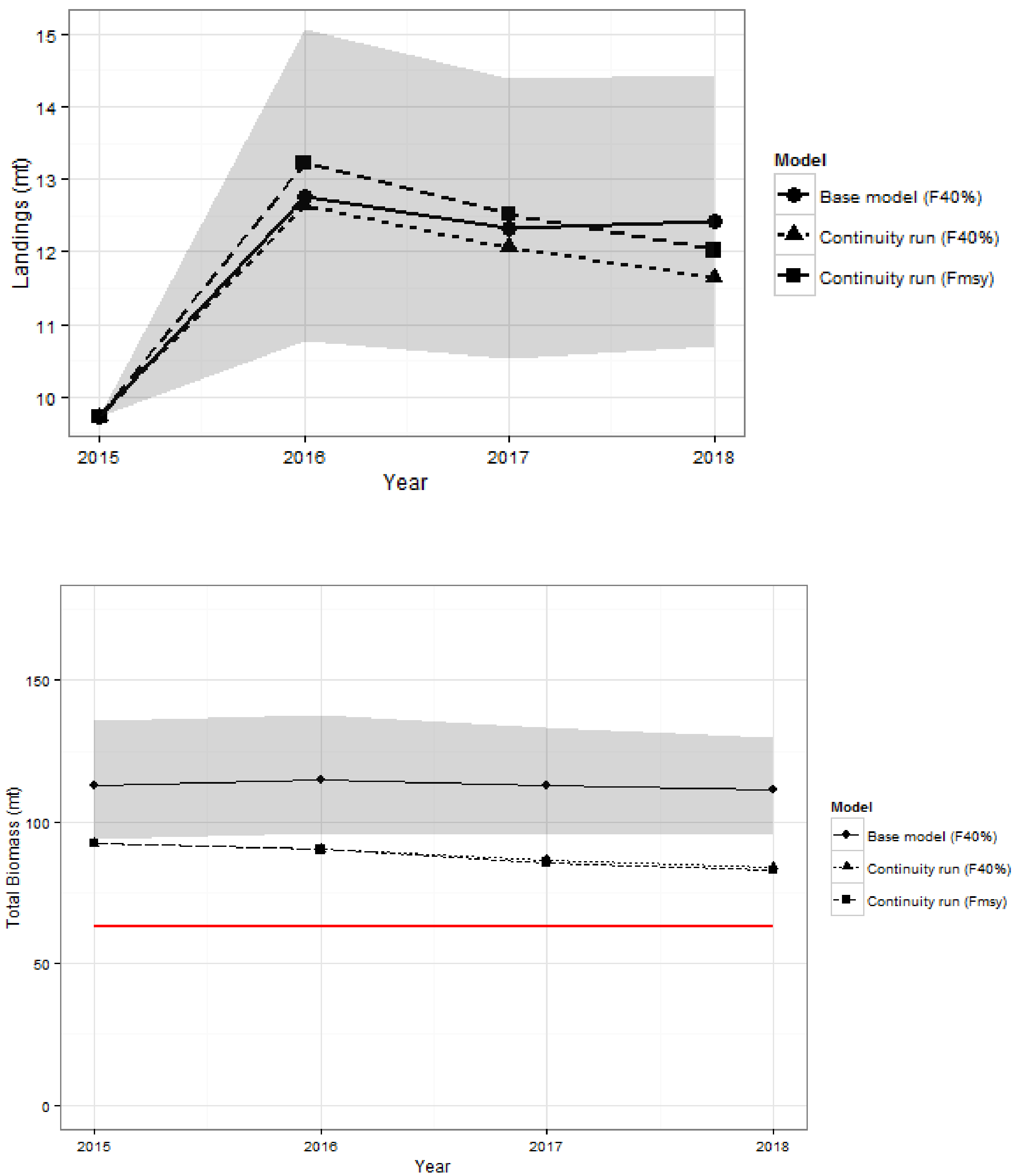


Figure B10.5. Projected landings (top) and biomass (bottom) for the continuity run model and the final revised model from this assessment. Shaded bands indicated the 5th and 95th percentiles of the preferred base model bootstrap runs. The solid red line indicates the overfished biomass threshold from the final revised model.

Appendix B1 – Data Workshop Attendance

The Atlantic States Marine Fisheries Commission (ASMFC) Bluefish Technical Committee met in Providence, RI on February 17-20, 2015 with the following participants:

Joey Ballenger – SC Dept. of Natural Resources
Mike Bednarski – MA Div. Marine Fisheries
Mike Celestino – NJ Dept Env. Protection
Katie Drew – ASMFC
Eric Durell- MD Dept Natural Resources
Beth Egbert – NC Div. Marine Fisheries (via phone)
Jim Gartland – VA Institute of Marine Science
Kurt Gottschall – CT Dept. Environmental Protection
Nicole Lengyel – RI DEM Div. Fish and Wildlife
John Maniscalco – NY DEC (via phone)
José Montañez – Mid-Atlantic Fisheries Management Council
Joseph Munyandero – FL Fish & Wildlife Conservation Commission
Kirby Rootes-Murdy – ASMFC
Kevin Sullivan – NH Dept. Fish and Wildlife
Rich Wong – DE Division Marine Fisheries
Tony Wood – Northeast Fisheries Science Center

Appendix B2 – Modeling Workshop & Working Group

The SAW60 Bluefish Working Group met in Woods Hole, MA on April 27-29, 2015 with the following participants:

Joey Ballenger – SC Dept. of Natural Resources
Mike Bednarski – MA Div. Marine Fisheries
Mike Celestino – NJ Dept Env. Protection
Katie Drew – ASMFC
Nicole Lengyel – RI DEM Div. Fish and Wildlife
José Montañez – Mid-Atlantic Fisheries Management Council
Kirby Rootes-Murdy – ASMFC
Tony Wood – Northeast Fisheries Science Center

Appendix B3 – Other Surveys considered

Rhode Island

RIDEM Marine Fisheries Trawl Survey

The Rhode Island Department of Environmental Management Division of Fish and Wildlife (DEM) initiated a seasonal trawl survey in 1979 to monitor recreationally important finfish stocks in Narragansett Bay, Rhode Island Sound, and Block Island Sound. The survey aims to monitor trends in abundance and distribution, to determine population size/age composition, and to evaluate the biology and ecology of estuarine and marine finfish and invertebrate species occurring in RI waters. Over the years this survey has become an important component of fisheries resource assessment and management at the state and regional levels.

The survey employs a stratified random and fixed design defined by 12 fixed stations in Narragansett Bay, 14 random stations in Narragansett Bay, 6 fixed stations in Rhode Island Sound, and 12 fixed stations in Block Island Sound (Figure 13.17). In 2005, the Division replaced the research vessel and survey gear that has been utilized by the survey since its inception. The R/V Thomas J. Wright was replaced with a 50' research vessel, the R/V John H. Chafee. During the spring and summer of 2005, a series of paired tow trials were conducted using modern acoustic equipment and new nets designed to match the trawl net used by the National Marine Fisheries Service. The results of this experiment were used to calibrate the old and new vessels in order to maintain the continuity of the survey time series. Unfortunately, the new net design was too large for the new research vessel and could not be successfully towed in many of the areas required by the trawl survey. Because of this a new net was designed in the same dimensions as the net previously used for the survey and is used for the trawl survey. By using a similar net design to the previous survey net, the continuity of the survey is able to be maintained, though analysis to confirm this is still pending. In 2012 new doors were installed on the R/V John H. Chafee. A rigorous calibration experiment was done to calibrate the new trawl configuration with the new doors to the old trawl configuration with the old doors. The analysis has been conducted, but is unpublished at this point. The findings of the analysis were that there were not significant differences in the catch of lobster between the old and new door datasets. The net is a ¾ size North American type two seam otter trawl (40 in headrope/ 55 in. footrope) rigged with a 5/16 chain sweep and a 2 in. codend liner (¼ in. stretched mesh).

At each station a standard 20 minute tow is conducted at 2.5 knots. Catch is sorted by species. Length (cm/mm) is recorded for all finfish, skates, squid, scallops, Whelk lobster, blue crabs and horseshoe crabs. Similarly, weights (gm/kg) and number are recorded as well. Data on wind direction and speed, sea condition, air temperature and cloud cover as well as surface and bottom water temperatures, are recorded at each station. Sampling at each random and fixed station during the fall component of the survey typically occurs in September and October of each year however sampling has in the past also occurred in November.

New York

NYDEC Small Mesh Trawl Survey

The New York Department of Environmental Conservation's (NYSDEC) Peconic Bay Small Mesh Trawl Survey started in 1987. The survey area is divided into 77 sampling blocks each of which measured 1' latitude by 1' longitude located in the Peconic estuary in eastern Long Island (Figure 13.19). Each year from May to October, 16 stations are randomly chosen each week and sampled by an otter trawl (16 foot shrimp trawl with small mesh liner) and towed for 10 minutes

at 2.5 knots during daylight hours only.
Fish collected in each tow are sorted, identified, counted and measured to the nearest mm (fork or total length). Large catches were subsampled, with length measurement taken on a minimum of 30 randomly selected individual fish of each species. Some samples were stratified by length group such that all large individuals were measured and only a subsample of small (YOY or yearlings) specimens were measured. Subsampled counts could then be expanded by length group for each tow.

Catches of bluefish, which peak in August and September, consist almost entirely of YOY (99%).

Delaware

Delaware DFW Juvenile Trawl Survey

Delaware's Department of Natural Resources and Environmental Control (DNREC) Division of Fish and Wildlife's juvenile trawl survey targets juvenile fish and shellfish. This program was initiated in 1980 to monitor distribution, relative abundance, and year-class strength. The survey conducts monthly sampling from April to October at fixed stations in the Delaware Bay and River. Tows conducted during September were used to estimate an index of abundance as the geometric mean number per tow.

Delaware DFW Adult Trawl Survey

The DNREC Division of Fish and Wildlife began an adult trawl survey in 1966. The survey was discontinued in 1971, started again in 1979, discontinued after 1984, and finally resumed again in 1990. The aim is intended to track temporal trends in abundance and distribution and to characterize the size composition of select species. Trawl tows are carried out monthly from March to December at fixed stations in the Delaware Bay. Large numbers of bluefish are not common, but bluefish do occur in the catches, peaking in the fall. Tows from August to October were used to calculate the geometric mean number per tow as an index of bluefish abundance.

Virginia

Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP)

The Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP) Trawl Survey has been sampling the mainstem of the Chesapeake Bay, from Poole's Island, MD to the Virginian Capes at the mouth of the bay since 2002. ChesMMAP conducts 5 cruises annually, during the months of March, May, July, September, and November. This survey is designed to sample the late juvenile and adult stages of the living marine resources in Chesapeake Bay, and as such the timing of sampling is meant to coincide with the seasonal residency of these life stages in the estuary.

The ChesMMAP survey area is stratified into five latitudinal regions, and each region is comprised of three depth strata. Depth strata bounds are consistent across regions, and correspond to shallow (3.0m to 9.1m), middle (9.1m to 15.2m), and deep (>15.2m) waters in the bay. Sampling sites are selected for each cruise using a stratified random design; site allocation for a given stratum is proportional to the surface area of that stratum. A total of 80 sites are sampled per cruise, and a four-seam, two-bridle, semi-balloon bottom trawl is towed for 20 minutes at each sampling site with a target speed-over-ground of 3.5kts.

Encounter rates of bluefish on the ChesMMAP Survey are relatively low. Bluefish have yet to be collected during a March cruise, which is reasonable given the usual timing of the seasonal migrations of this species. Overall, bluefish have been collected on 6.3% of tows conducted between May and November since the inception of the survey. The percentage of tows with bluefish ranged from 2.5% to 14.7% per year, and between 3.2% and 10.4% by month over the time series. Bluefish were encountered most frequently during September and November cruises. Bluefish collected by ChesMMAP ranged between 119 mm FL to 537 mm FL and from age-0 to age-3. Catches ranged from 0 to 85 bluefish per tow, and 83.1% of tows where bluefish were caught comprised of two or fewer specimens.

VIMS Juvenile Fish and Blue Crab Trawl Survey

The VIMS Juvenile Fish and Blue Crab Trawl Survey has been sampling the Virginia portion of the mainstem of Chesapeake Bay, along with the James, York, and Rappahannock River systems, since 1955. This survey samples the three rivers each month of the year, and the mainstem bay in all but January and March. This survey is designed to sample the juvenile stages of the living marine resources in Chesapeake Bay. Survey design and sampling protocols have been consistent since 1988.

This trawl survey area is stratified by depth and latitudinal regions in the bay, and by depth and longitudinal region in each of the rivers. Depth strata bounds are consistent across regions, and correspond to shallow (1.2m to 3.7m), shallow-middle (3.7m to 9.1m), middle-deep (9.1m to 12.8m) and deep (>12.8m) areas. Sampling sites are selected using a stratified random design in the bay and rivers, while additional fixed sites are sampled in the river systems to maintain continuity with historical collections. Between 66 and 111 sites are sampled per cruise, and a four-seam, two-bridle, semi-balloon bottom trawl is towed for 5 minutes at each station. The trawl has a headline length of 9.1m, and is made of 15.2cm stretch mesh webbing in the body of the net and 7.6cm stretch mesh in the codend. The codend is outfitted with a 6.35mm stretch mesh liner, which is designed to retain juvenile fishes and invertebrates found in the survey area.

Encounter rates of bluefish on this survey are relatively low. Bluefish have yet to be collected between December and April, which is consistent with the seasonal residency of this species in this estuary. When considering the remaining months, bluefish have been collected on 2.8% of tows since 1988. The percentage of tows with bluefish ranged from 0.8% to 6.5% per year, and between 1.2% and 5.1% by month over the time series. Bluefish were encountered most frequently during October and November cruises. Catches ranged from 0 to 58 bluefish per tow, and 88.1% of tows where bluefish were caught comprised of two or fewer bluefish.

North Carolina

NCDMF Juvenile Trawl Survey

NCDMF has conducted a juvenile fish trawl survey during May and June since 1979. The survey samples fixed stations from the Cape Fear River to the mouth of Albemarle and Currituck Sounds at depths <2 meters. One-minute tows are carried out using a trawl with a 3.2 m headrope and 3.2 mm (0.13 in) mesh cod end. Indices of abundance developed from this survey using data for shrimp, croaker, and spot have shown good correlation with landings for those species, but catches of bluefish were typically low.

North Carolina Pamlico Sound Trawl Survey

NCDMF Pamlico Sound Trawl Survey began in 1987 and was initially designed to provide a long-term fishery-independent database for the waters of the Pamlico Sound, eastern Albemarle Sound and the lower Neuse and Pamlico rivers. However, in 1990 the Albemarle Sound sampling in March and December was eliminated, and sampling now occurs only in the Pamlico Sound and associated rivers and bays in June and September. From 1987-1989, a mongoose or falcon trawl was used for comparison with SEAMAP data of inshore and offshore catches. From 1990 to the present, fifty-two randomly selected stations (grids) are sampled over a two-week period, usually the second and third week of the month in both June and September. The stations sampled are randomly selected from strata based upon depth and geographic location. There are seven designated strata: Neuse River, Pamlico River, Pungo River, shallow (6-12 ft) and deep (>12 ft) Pamlico Sound east of Bluff Shoal, and shallow and deep Pamlico Sound west of Bluff Shoal. A minimum of three stations are maintained in each strata and a minimum of 104 stations are trawled every year. Tow duration is 20 minutes at 2.5 knots using the R/V Carolina Coast pulling double rigged demersal mongoose trawls (9.1 m headrope, 1.0 m x 0.6 m doors, 2.2 cm bar mesh body, 1.9 cm bar mesh cod end and a 100 mesh tailbag extension. All species are sorted and a total number and weight is recorded for each species. For target species, 30-60 individuals are measured and total weights are measured. The two catches from each tow are combined to form a single sample in an effort to reduce variability.

Appendix B4 – Depletion Corrected Average Catch Model (DCAC)

Introduction

In the late 2000s a host of work was done to develop modeling techniques that would allow the setting of an annual catch limit (ACL) for data-poor fisheries (e.g. fisheries lacking effort data, life history data, etc. that would be needed for more data intensive stock assessment procedures). This stemmed from the requirement, set forth in the reauthorized Magnuson-Stevens Fisheries Conservation and Management Act of 2007, to set ACLs for all federally managed species by 2011. Each of these approaches aimed to determine yield estimates that are likely to be sustainable for various stocks while allowing for moderately high yield from the stock. One such approach, originally proposed by MacCall (2009), is called Depletion-Corrected Average Catch (DCAC).

In such a data poor situation, the question becomes how does one come up with a sustainable yield estimate for data poor fisheries. The DCAC approach stems from the idea that, in the absence of other data, the most direct evidence for a sustainable yield is a prolonged period during which the average yield has been taken without any indication of a change in underlying resource abundance (i.e. average catch over period when population appears stable; MacCall 2009). While simple in theory, this is difficult to implement in practice because rarely does exploitation occur without changing underlying annual abundance, especially when the resource is initially exploited and hence theoretically causing a decline in population abundance from environmental carrying capacity. This initial decline in population abundance due to exploitation is the foundation of all surplus production models. In this situation, a portion of the harvest derives from that one-time decline and does not represent potential future yield supported by surplus production. The DCAC approach is designed to account for that initial "windfall" harvest that is not sustainable, and hence should not be included in any average harvest estimates of sustainable yield (MacCall 2009). DCAC accounts for the initial "windfall" harvest by representing this harvest in terms of "years" of potential harvest, and ultimately increasing the denominator used to calculate average catch over a period for which catch records are available. To this end, the DCAC is based on the potential-yield formula of Alverson and Pereyra (1969) and Gulland (1970):

$$Y_{pot} = \frac{B_{MSY}}{B_0} * \frac{F_{MSY}}{M} * M * B_0. \tag{1}$$

Here, Y_{pot} is potential yield, B_{MSY} is the population biomass at maximum sustainable yield, B_0 is the population carrying capacity, F_{MSY} is the fishing mortality rate associated with maximum sustainable yield, and M is the natural morality rate. Based on this, the "windfall" harvest is the total harvest associated with reducing abundance from B_0 to the assumed B_{MSY} level (MacCall 2009). After that initial reduction in biomass, Y_{pot} can be considered a sustainable annual yield. To represent this in terms of "years" of potential harvest, the "windfall ratio",

$$\frac{W}{Y_{pot}} = \frac{\frac{B_{MSY}}{B_0} * B_0}{\frac{B_{MSY}}{B_0} * \frac{F_{MSY}}{M} * M * B_0} = \frac{1}{\frac{F_{MSY}}{M} * M}, \tag{2}$$

is calculated, where W is the "windfall" harvest (MacCall 2009). This ratio expresses the magnitude of the windfall harvest relative to a single year of potential yield.

In this form, the windfall harvest is not very flexible because it does not take into account current stock status of the population. Hence, MacCall (2009) proposed an even more flexible accounting of the windfall harvest based on the relative reduction in vulnerable stock abundance from the first year to the last year of the catch time-series, i.e. where $W = B_{\text{first year}} - B_{\text{last year}}$. In most situations where this approach is applied, there is not enough information to directly estimate the change in biomass from the first year to the last year of the catch series. Instead, we estimate a relative decline in abundance, Δ, where

$$\Delta = \frac{B_{\text{first year}} - B_{\text{last year}}}{B_0} \text{ (MacCall 2009).} \quad (3)$$

Generally, we do not have enough information to directly estimate Δ, instead developing a rough estimate of the reduction in vulnerable biomass. Substituting Δ for $\frac{B_{MSY}}{B_0}$ in the numerator of equation 2, the general windfall ratio becomes

$$\frac{W}{Y_{pot}} = \frac{\Delta * B_0}{\frac{B_{MSY}}{B_0} * \frac{F_{MSY}}{M} * M * B_0} = \frac{\Delta}{\frac{B_{MSY}}{B_0} * \frac{F_{MSY}}{M} * M}. \quad (4)$$

MacCall (2009) allows the windfall ratio expressed in equation 4 to form the basis for a depletion correction of average catch in the DCAC method. MacCall (2009) argues, assuming that each year, on average, produces one unit of annual sustainable yield, the resulting catch stream is the sum of two components, one derived from sustainable annual production, and the other from a one-time windfall harvest. For a catch (C) series of length n, the total cumulative catch ($\sum C$) constitutes n years of sustainable production, plus a windfall equivalent to W/Y_{pot} years of potential yield, where the sustainable harvest (Y_{sust}) is estimated as

$$Y_{sust} = \frac{\sum C}{n + \frac{W}{Y_{pot}}} \text{ (MacCall 2009).} \quad (5)$$

To provide uncertainty estimates about the Y_{sust}, MacCall (2009) proposes the use of Monte Carlo exploration of DCAC estimates.

Inputs

To perform DCAC analysis, several data inputs or assumed data values are needed, including total catch ($\sum C$) during a given time period of length n, an estimate of stock productivity as represented by the ratio of B_{MSY}/B_0, an estimate of the ratio of F_{MSY} to M (F_{MSY}/M), and an estimate of the relative decline of abundance over the time series (Δ). Associated with each of these measures is an assumed level of uncertainty to be incorporated into Monte Carlo simulations. Based on the work of MacCall (2009) and Dick and MacCall (2011) we have some general recommendations for assumed values of many of these parameters.

Using the same landings data available for the ASAP statistical catch-at-age model (App. B4 Table 1), the sum of landings from 1985-2014 is approximately 550,000 mt with an annual average of 18,325 mt.

For the base model DCAC run, our Δ estimate is based on preliminary SCAA model runs and results of the last update (47.1%; http://www.asmfc.org/uploads/file/552ea3fe2014BluefishStockAssessmentUpdate.pdf) that suggested approximately a 50% depletion in spawning stock biomass over the catch period. For natural mortality (M), we used the Pauly$_{\text{nls-T}}$ estimator ($M = 4.118k^{0.73} L_{\infty}^{-0.33}$; $k = 0.311$ and $L_{\infty} = 815.3$ from Robillard et al. 2009) as presented in Then et al. (2015). This is very similar to the M estimate assumed in the ASAP SCAA base model. Other DCAC parameters were set to be consistent with MacCall (2009) and Dick and MacCall (2011) (App. B4 Table 2). DCAC was implemented with software available from the NMFS toolbox (DCAC V2.1.1; http://nft.nefsc.noaa.gov/DCAC.html). To estimate uncertainty, we performed 1,000,000 Monte Carlo simulations of the base DCAC model with the assumed parameters.

App. B4 Table 1. Total annual bluefish catch (in mt) from 1985-2014. Total catch over this 30 year time period is 549,747.11 mt.

Year	Catch	Year	Catch	Year	Catch
1985	33191.81	1995	12899.28	2005	16665.69
1986	54091.97	1996	12367.80	2006	14719.17
1987	47176.64	1997	14179.93	2007	17345.17
1988	30254.80	1998	11831.31	2008	16426.11
1989	25035.84	1999	9260.16	2009	12223.08
1990	22446.76	2000	12775.56	2010	14161.38
1991	23342.82	2001	15203.13	2011	11504.13
1992	19089.97	2002	10788.29	2012	10784.64
1993	16896.05	2003	13374.64	2013	11253.74
1994	15035.67	2004	15604.59	2014	9816.98

App. B4 Table 2: DCAC based model run assumed parameter estimates and error distributions.

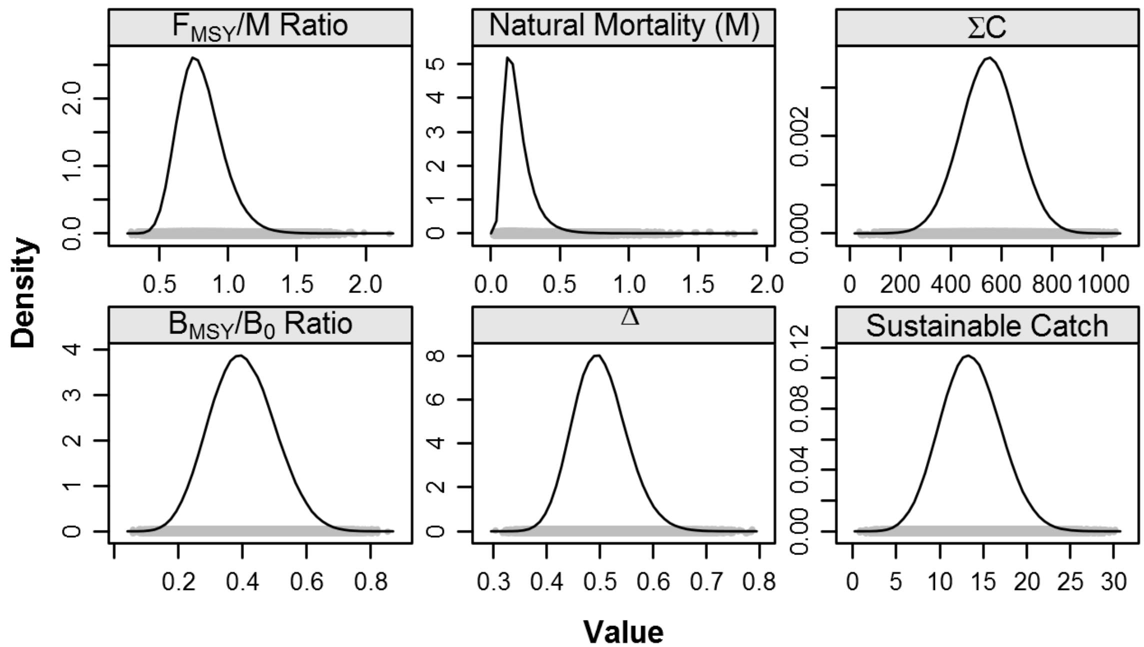
Parameter	Value	Source	SD	Source	Distribution
CV of $\sum C$	0.2	–	–	–	normal
M	0.192	Then et al. (2015) $\text{Pauly}_{\text{nls-T}}$ estimator	0.5	MacCall (2009)	lognormal
F_{MSY}/M	0.8	MacCall (2009); Dick & MacCall (2011)	0.2	MacCall (2009)	lognormal
B_{MSY}/B_0	0.4	MacCall (2009); Dick & MacCall (2011)	0.1	MacCall (2009); Dick & MacCall (2011)	bounded beta
Δ	0.5	Preliminary SCAA model runs	0.1	–	lognormal

Base Run Results

Based on the Monte Carlo simulations, the median estimate of Y_{sust} is approximately 13,480 mt, with a 95% confidence interval of approximately 7,130 mt to 20,520 mt (App. B4 Table 3, Figure X).

App. B4 Table 3. Y_{sust} estimates derived from 1,000,000 Monte Carlo simulations using the base DCAC model assumptions.

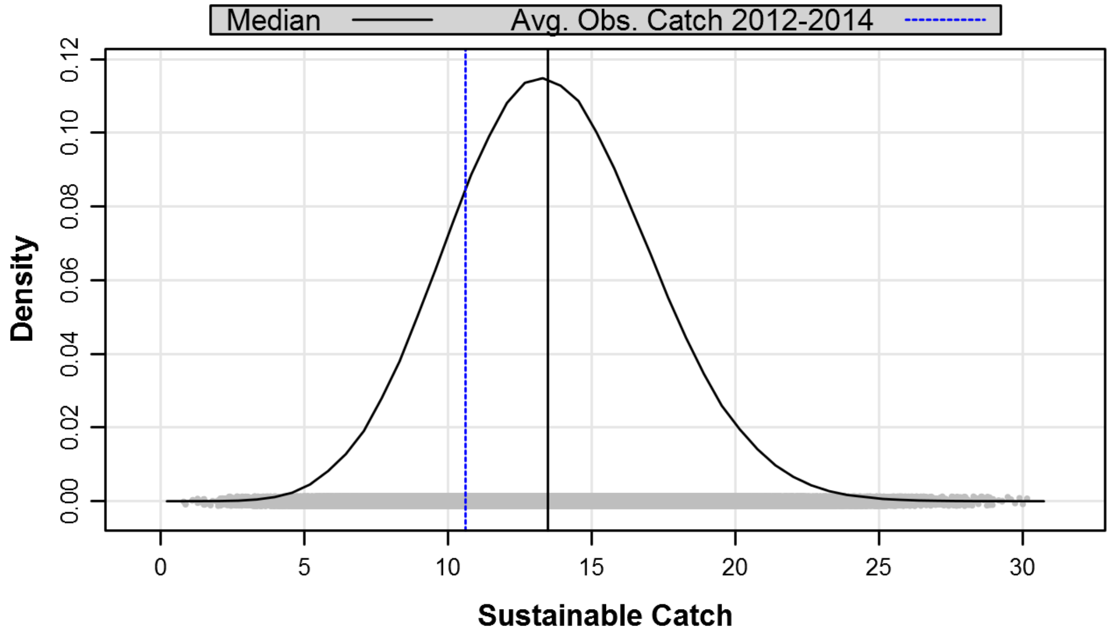
		95% Confidence Interval		90% Confidence Interval	
Average	**Median**	**Lower**	**Upper**	**Lower**	**Upper**
13,569.60	13,479.37	7,133.98	20,516.88	8,077.81	19,357.62



App. B4, Figure.1: Density plot of individual parameter draws (top row panels; bottom row left & middle panels) and sustainable yield estimates (bottom right panel) based on 1,000,000 Monte Carlo simulations of the DCAC base model.

Recent Catch vs DCAC Sustainable Catch

The average harvest of bluefish throughout the region during the period 2012-2014 was 10,618 mt, with no year exceeding 11,254 mt. This suggests that recent annual harvests were at sustainable levels as compared to the median Y_{sust} estimate from the base DCAC model run (App. B4, Figure 2).



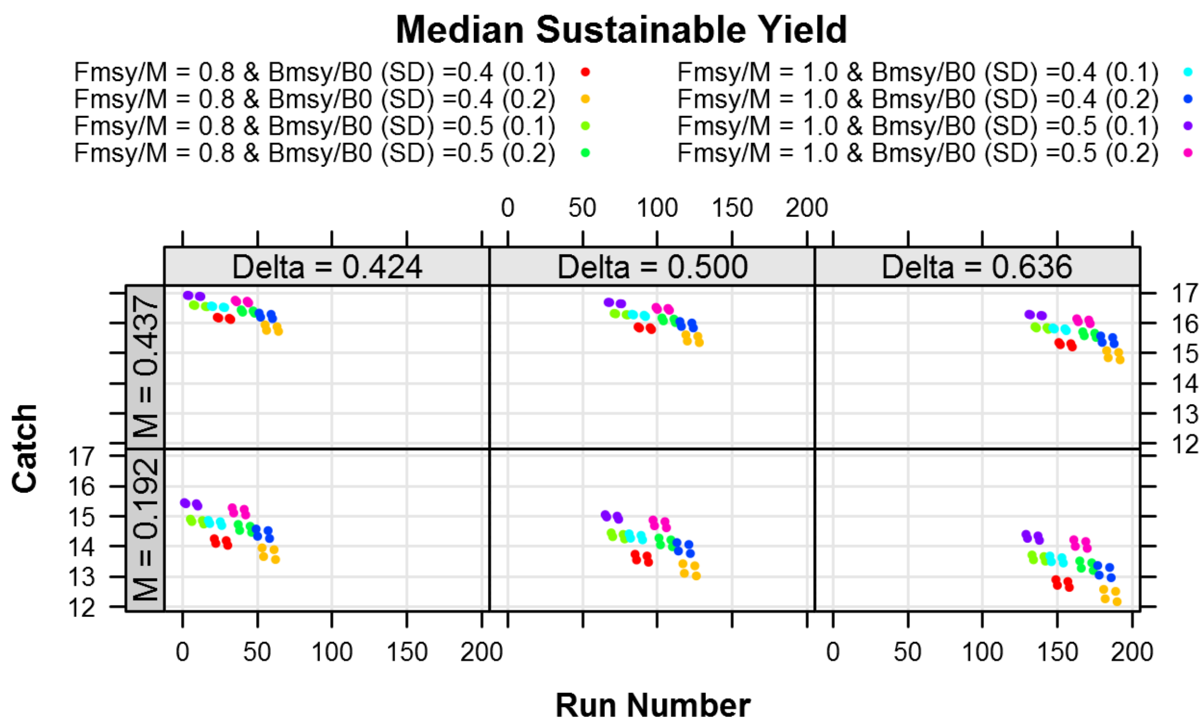
App. B4, Figure 2: Density plot of sustainable yield based on 1,000,000 Monte Carlo simulations of the DCAC base model. Vertical lines represent the median sustainable yield estimate (black) and observed average catch (blue) during the three terminal years (2012-2014) of the assessment.

Sensitivity Analyses

We performed a number of DCAC sensitivity analyses to look at the impact assumed model parameters had on sustainable yield estimates (App. B4, Table 4). All possible combinations of input parameters were investigated, resulting in a total of 192 individual model runs (including the base run presented above). Results of all runs suggested that recent average harvest of bluefish in the terminal 3 years of the assessment (10,618 mt) were sustainable as median sustainable yield levels from all DCAC runs exceeded this value (App. B4, Figure 3).

App. B4, Table 4. DCAC alternative assumed parameter estimates for sensitivity analyses.

		Alternative 1		Alternative 2	
Variable	**Value**	**Value**	**Source**	**Value**	**Source**
CV of $\sum C$	0.2	0.1	–	–	–
M	0.192	0.437	Then et al. (2015) Hoenig_{nls}	–	–
SD of M	0.5	–	–	–	–
F_{MSY}/M	0.8	1.0	MacCall (2009)	–	–
SD of F_{MSY}/M	0.2	0.1	Lower variance estimate	–	–
B_{MSY}/B_0	0.4	0.5	MacCall (2009)	–	–
SD of B_{MSY}/B_0	0.1	0.2	–	–	–
Δ	0.5	0.424	B_0: 1.5xSSB in 1982*	0.636	B_0: SSB in 1982*



App. B4, Figure 3: Y_{sust} median estimates (in mt) derived from each of the 192 different model configurations (including the base DCAC model).

Appendix B5 – Depletion-Based Stock Reduction Analysis (DBSRA)

Introduction

Depletion-based stock reduction analysis (DBSRA) is a technique developed by Dick and MacCall (2010, 2011) to generate sustainable yield reference points for data-poor groundfish stocks in the Pacific Northwest. It has been used to provide management advice or as complementary analysis on the Atlantic coast with species like black drum and tautog (e.g., ASMFC 2015). It is a variation on stochastic stock reduction analysis (Walters et al., 2006) that uses a production model rather than an age-structured model to describe the underlying population dynamics.

Natural mortality (M), the ratio of fishing mortality corresponding to MSY and natural mortality (F_{MSY}/M), biomass corresponding to MSY relative to carrying capacity (B_{MSY}/K), and biomass in the terminal year relative to carrying capacity (B_{2014}/K) are leading parameters used to derive MSY reference points and are based on data, meta-analysis, or expert opinion. F_{MSY} is derived from the product of F_{MSY}/M and M.

The only additional parameter necessary to derive reference points is K. The first year of the removal time series is assumed to be the first year of exploitation and, therefore, the stock is assumed to be at unfished conditions (i.e., K) in the beginning of the first year. An initial K parameter is specified and stock biomass is projected forward in each subsequent year with a production model and the time series of removals. K is then solved for iteratively conditional on the assumed B_{2014}/K and specified bounds around K. If the absolute difference between the estimated B_{2014}/K and assumed B_{2014}/K is not within a specified range (tolerance), or if any biomass estimates are non-positive, the model is considered implausible and is rejected. If the model is accepted, the parameters are used to derive MSY reference points.

Model Structure

The Pella-Tomlinson production function used in DB-SRA was reparameterized by Fletcher (1978).

$$P = g * MSY * \left(\frac{B_{t-a}}{K}\right) - g * MSY * \left(\frac{B_{t-a}}{K}\right)^{n}$$

The production function was hybridized with a Schaefer production function to address excessive production estimates at low biomasses of highly skewed Pella-Tomlinson production curves, as noted by Fletcher (1978). The hybridized production function estimates production with a Pella- Tomlinson-Fletcher production function at biomasses above a specified biomass (B_{join}) and a Schaefer production function at biomasses below B_{join}. The optimal B_{join} is dependent on the shape of the production curve (i.e., BMSY/K) and recommendations by Dick and McCall (2011) were used for specifying B_{join}. The recommendations result in a hybridized production function that estimates production for low biomass levels similar to a Beverton-Holt stock-recruitment relationship.

$$if\,\frac{B_{MSY}}{K} < 0.3, \frac{B_{join}}{K} = \frac{0.5B_{MSY}}{K};$$

$$if\ 0.3 < \frac{B_{MSY}}{K} > 0.5, \frac{B_{join}}{K} = 0.75\left(\frac{B_{MSY}}{K}\right) - 0.075$$

$$if\,\frac{B_{MSY}}{K} > 0.5, use\ PTF\ for\ all\ biomass\ estimates$$

Biomass was estimated using a delay-difference model in the original method developed by Dick and McCall (2011) that requires an additional age-at-maturity parameter. Bluefish recruit to exploitable biomass before age-at-maturity. Therefore, biomass was estimated in this analysis using a traditional production model with no lag between production and recruitment by setting the age-at-maturity equal to one.

Uncertainty of leading parameters is addressed by drawing the parameters from a prior distribution and running a specified number of model iterations. MSY reference points from each plausible iteration are output in probability distributions. The model was coded in the R software language, version 3.0.2 for Windows (R Development Core Team 2013).

Model Inputs

Input parameters (App. B5, Table 1; App. B5, Figure 1) are drawn from distributions based on expert opinion about bluefish and meta-analysis of similar stocks. Uncertainty about these parameters is incorporated into the final estimates of *K* and the management parameters of interest (MSY, OFL). DBSRA requires as complete a time-series of catch as possible, so harvest from 1950-2014 was used. Estimates of commercial landings were available from 1950 onwards through ACCSP. Recreational harvest estimates are available from MRFSS/MRIP from 1982 onwards. To hindcast recreational landings, the average ratio of recreational to commercial harvest from 1982-2014 was used to scale the commercial landings up from 1950-1982. Dick and MacCall (2011) assume that catch is known without error, which is not the case with a recreationally important species like bluefish. To incorporate some of that uncertainty into this analysis, the catch history was also drawn from a series of lognormal distributions that used each year of the observed time-series of catch as the median (App. B5, Figure 2). The standard deviation was assumed higher in the early years of the time series (s.d.=0.2 for 1950-1981, s.d.=0.1 for 1982-2014) to account for the higher degree of uncertainty in the hindcast recreational catch estimates. Natural mortality was assumed to be 0.2, consistent with the ASAP model runs. The ratio of F_{MSY} to M and B_{MSY} to K followed distributions recommended by MacCall (2009), as was done with the DCAC runs. The ratio of B_{2014} to K was based on the estimates of B_{2014} to B_{MSY} from the most recent update of the ASAP model where a stock-recruitment model was used to estimate MSY-based reference points.

Dick and MacCall (2011) assume the population starts out at K; however, it is easy to extend this model to allow the population to start out at some level relative to K and treat this ratio of B_1/K as another leading parameter. For this analysis, the population was assumed to be near K (B_1/K =

0.90), due to the low levels of exploitation occurring at the beginning of the time series.

A series of sensitivity runs were also conducted to look at the sensitivity of management parameters to the assumptions about leading parameters. These included:

- Higher natural mortality (M=0.30)
- Higher ratio of F_{MSY} to M (F_{MSY}/M = 0.95)
- Lower ratio of B in the terminal year to K (B_{2014}/K = 0.15)
- Fixing the ratio of B in the initial year to K at 1 (B_{1950}/K = 1)

Results

The base model had a relatively high acceptance rate for parameter combinations, with approximately 75% of all runs being accepted. This is most likely due to the fact that the bluefish population does not become heavily depleted over the time-series, and thus the model does not have to thread the needle of maintaining observed catch without driving the population extinct or ending at too high a biomass. There was not a noticeable pattern in the distributions of accepted vs. rejected parameters, with the exception of natural mortality, where the rejected runs used higher values of M (App. B5, Figure .3).

DBSRA estimated a median MSY for bluefish of 18,822 mt, with an OFL for 2015 of 18,835 mt (App. B5, Table.2; App. B5., Figure.5). This method cannot be used to assess stock status (i.e., overfished or experiencing overfishing), because status relative to *K* is one of the inputs to the model. However, the management parameters (MSY, OFL) derived from this model are robust to assumptions about stock status. Results of all runs suggested that recent average harvest of bluefish in the terminal 3 years of the assessment (10,618 mt) were sustainable, as they are below the estimated MSY from the DBSRA.

Discussion

The data poor models corroborate the scale of the ASAP model and agree with the determination that harvest in recent years has been sustainable.

All three models produced roughly similar estimates of sustainable harvest for bluefish, and indicate that recent harvest has been below the maximum sustainable yield. DBSRA estimated the highest MSY, but encompasses the estimates of the other two models in the 5^{th} and 95^{th} percentiles of the estimate.

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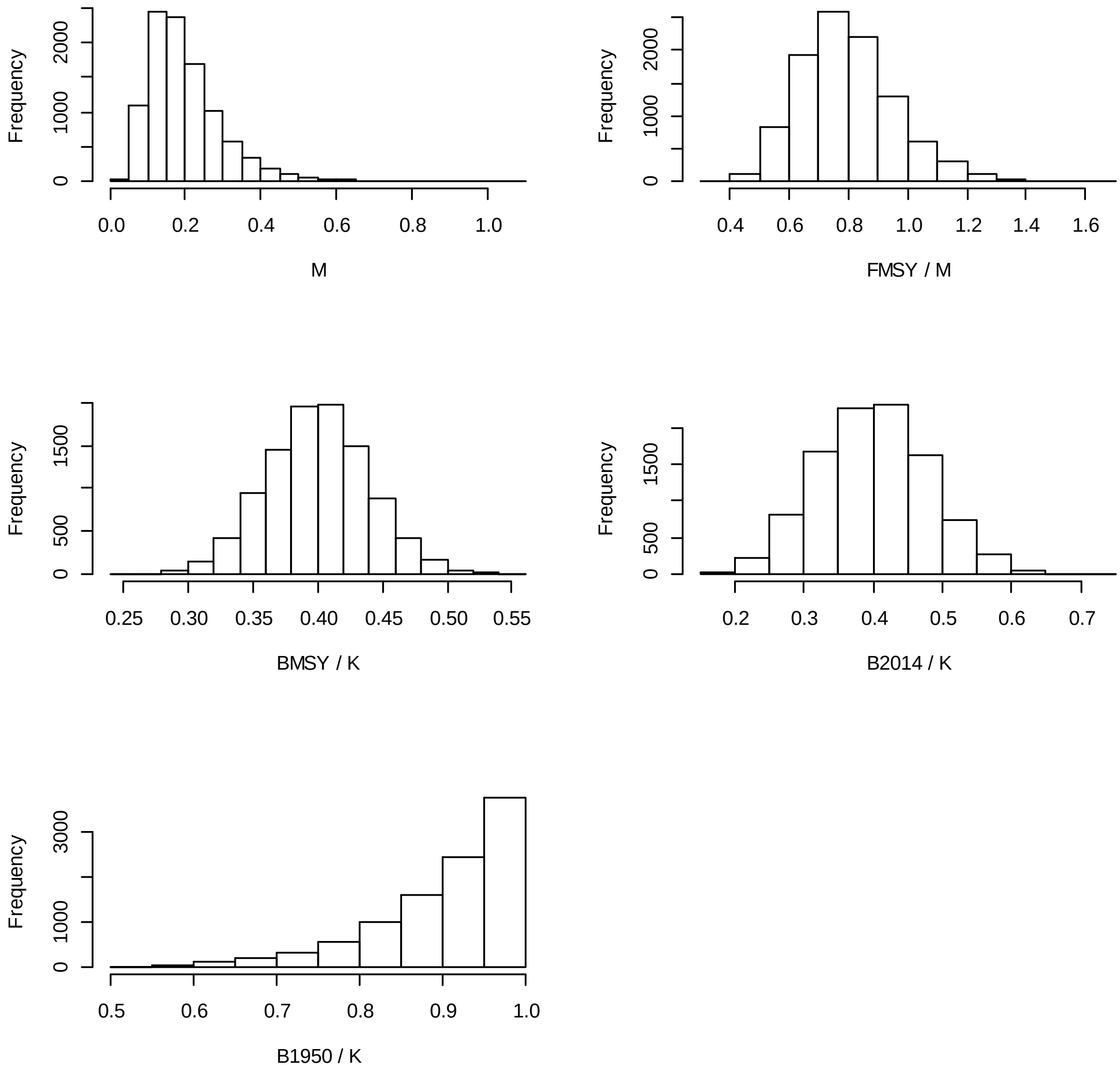
App. B5, Table.1. Input values for the base run of the DBSRA model for bluefish.

Parameter	Value	Source	SD	Source	Distribution
Annual harvest	–	ACCSP, MRIP	0.2,0.1	MRIP PSEs	lognormal
M	0.2	2015 Assessment	0.5	MacCall (2009)	lognormal
F_{MSY}/M	0.8	MacCall (2009); Dick & MacCall (2011)	0.2	MacCall (2009)	lognormal
B_{MSY}/K	0.4	MacCall (2009); Dick & MacCall (2011)	0.1	MacCall (2009); Dick & MacCall (2011)	bounded beta
B_{2014}/K	0.4	2014 Assessment Update	0.2	–	bounded beta
B_{1950}/K	0.90	Expert opinion	0.1	--	bounded beta

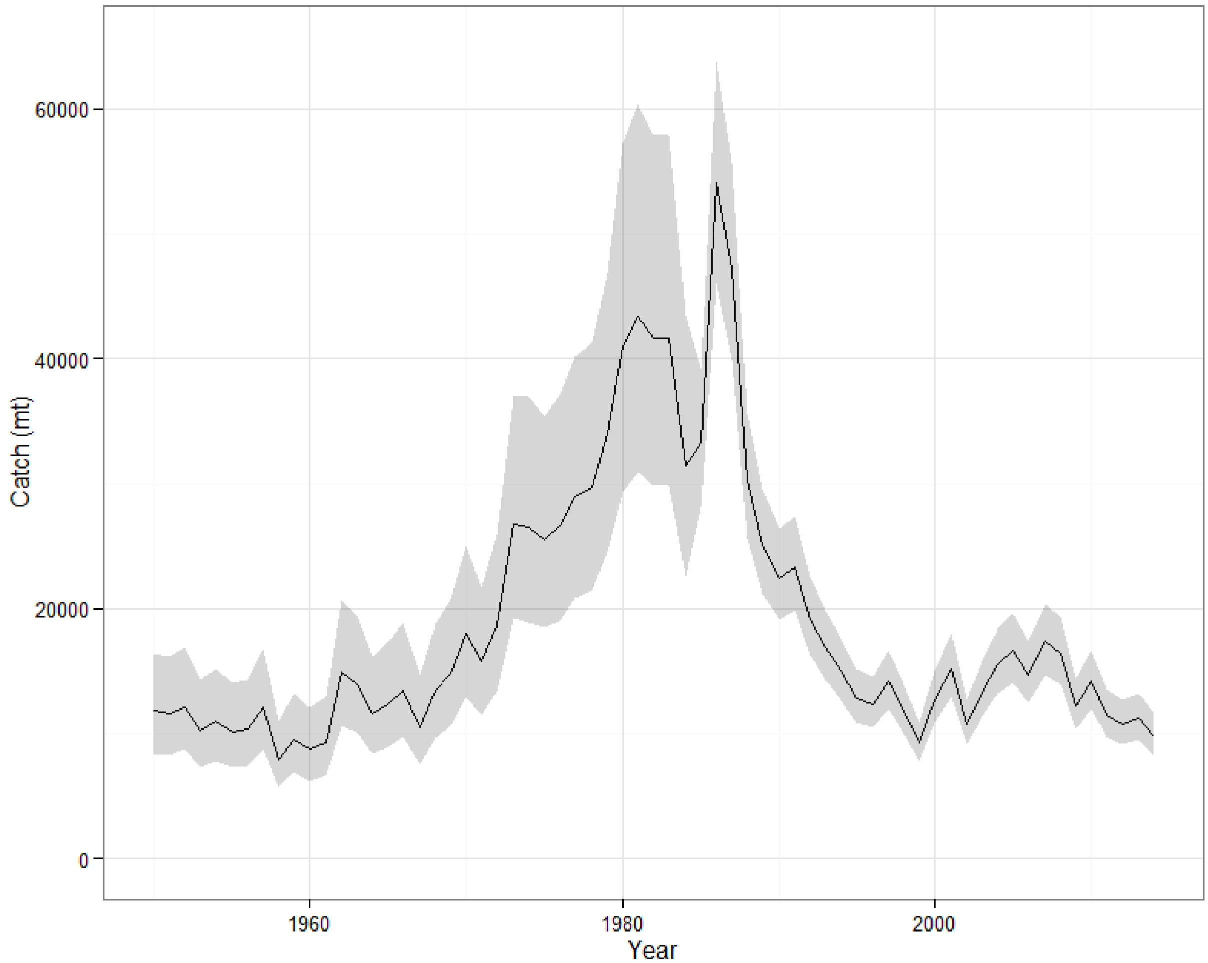
App. B5, Table 2: Median management benchmarks (and 5th and 95th quantiles) from DBSRA model.

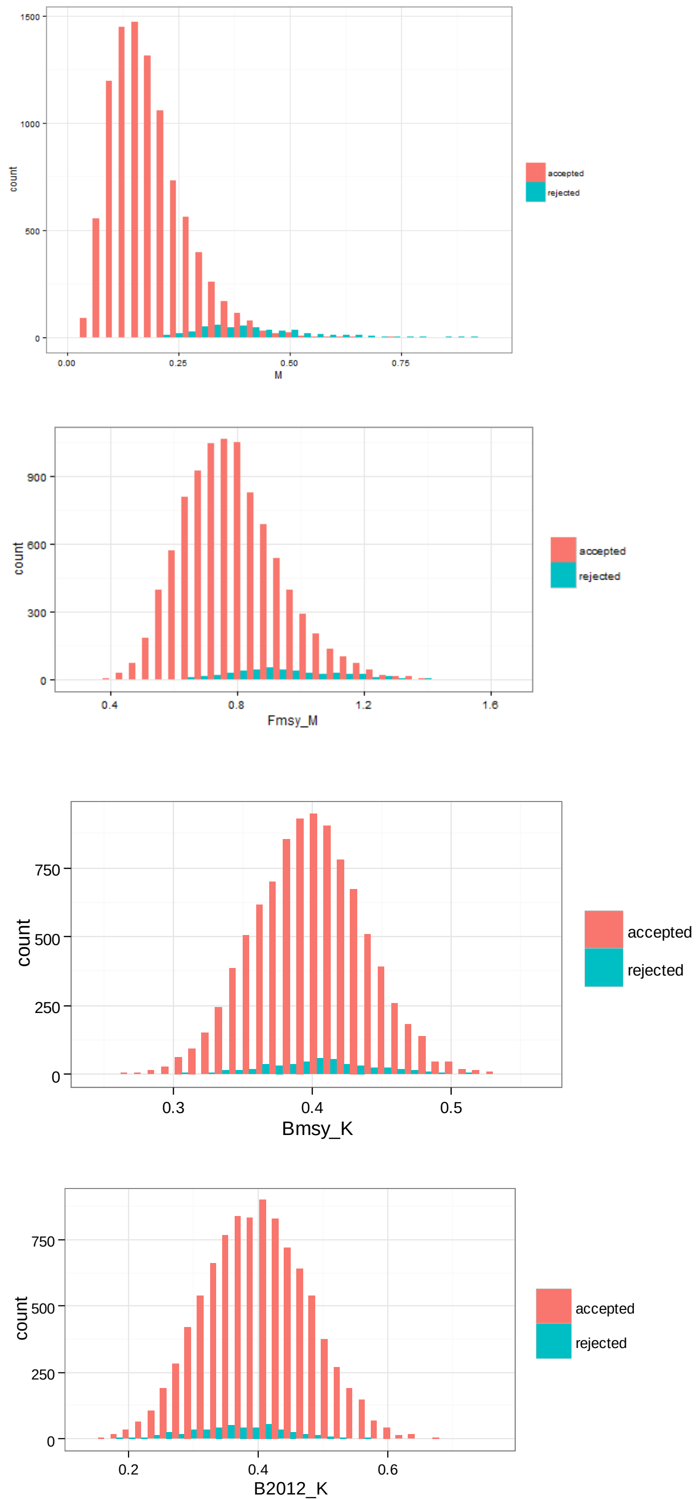
	U_{MSY}	K	MSY	B_{MSY}
Base run	0.12 (0.05 - 0.21)	432,049 mt (277,232 – 831,884 mt)	19,954 mt (14,905 – 24,943 mt)	172,010 mt (110,510 – 324,853 mt)
B_{1950}/K= 1.0	0.11 (0.05 - 0.19)	486,155 mt (335,848 – 818,767 mt)	22,054 mt (17,196 – 26,991 mt)	193,296 mt (134,003 – 323,877 mt)
M=0.3	0.15 (0.07 – 0.25)	362,326 mt (253,605 – 643,905 mt)	21,602 mt (16,559 – 25,919 mt)	144,444 mt (100,799 – 253,396 mt)
B_{2014}/K = 0.15	0.11 (0.05 – 0.20)	431,900 mt (293,528 – 695,749 mt)	19,097 mt (12,610 – 24,226 mt)	171,582 mt (118,868 – 279,060 mt)
F_{MSY}/M = 0.95	0.13 (0.06 – 0.23)	394,231 mt (264,141 – 730,846 mt)	20,735 mt (15,575 – 25,517 mt)	156,604 mt (105,296 – 287,679 mt)

App. B5, Figure.1. Distributions of leading parameters for the base model DBSRA runs for bluefish.

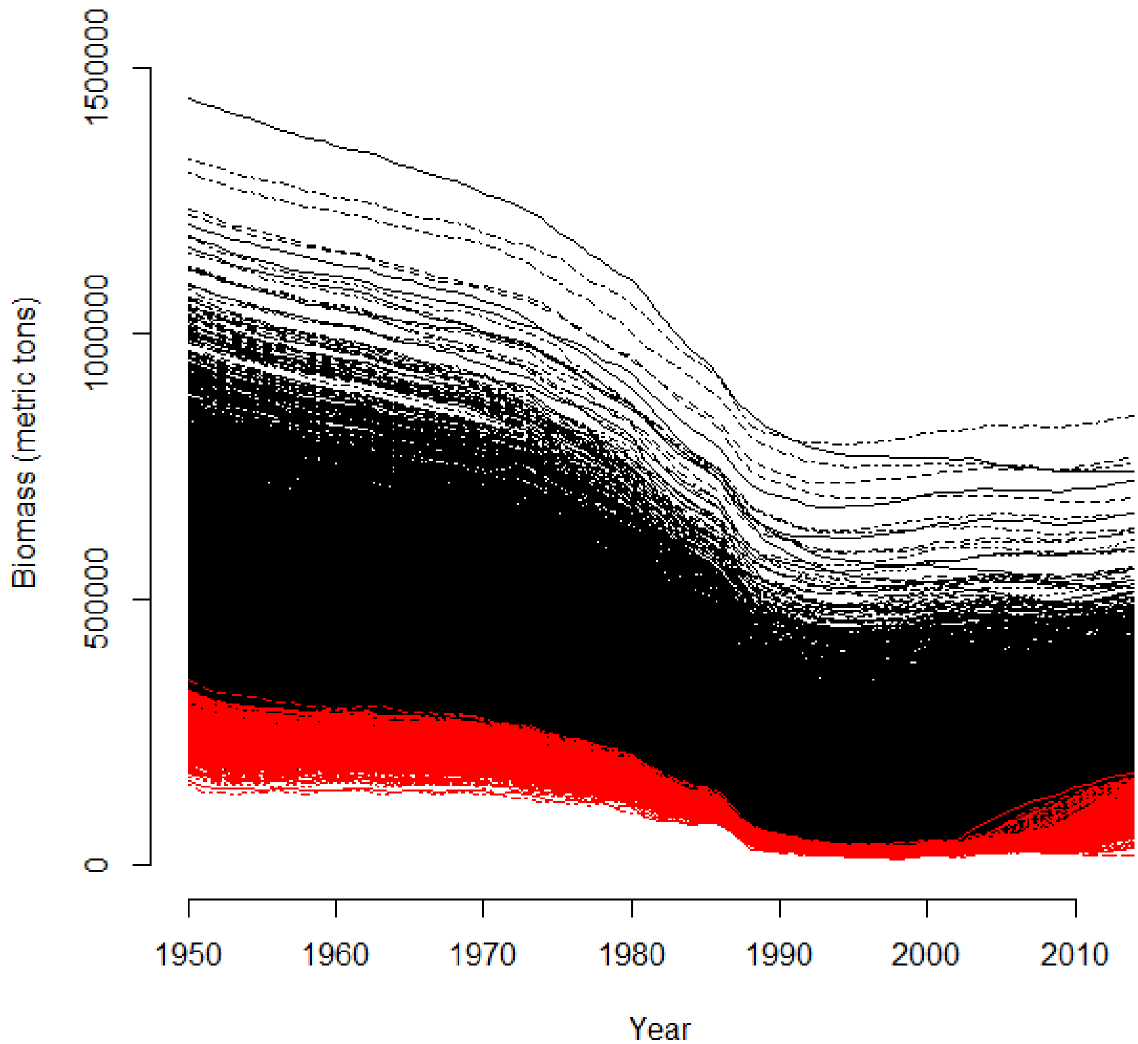


App. B5, Figure .2. Distribution of the drawn catch for the base model DBSRA runs for bluefish.

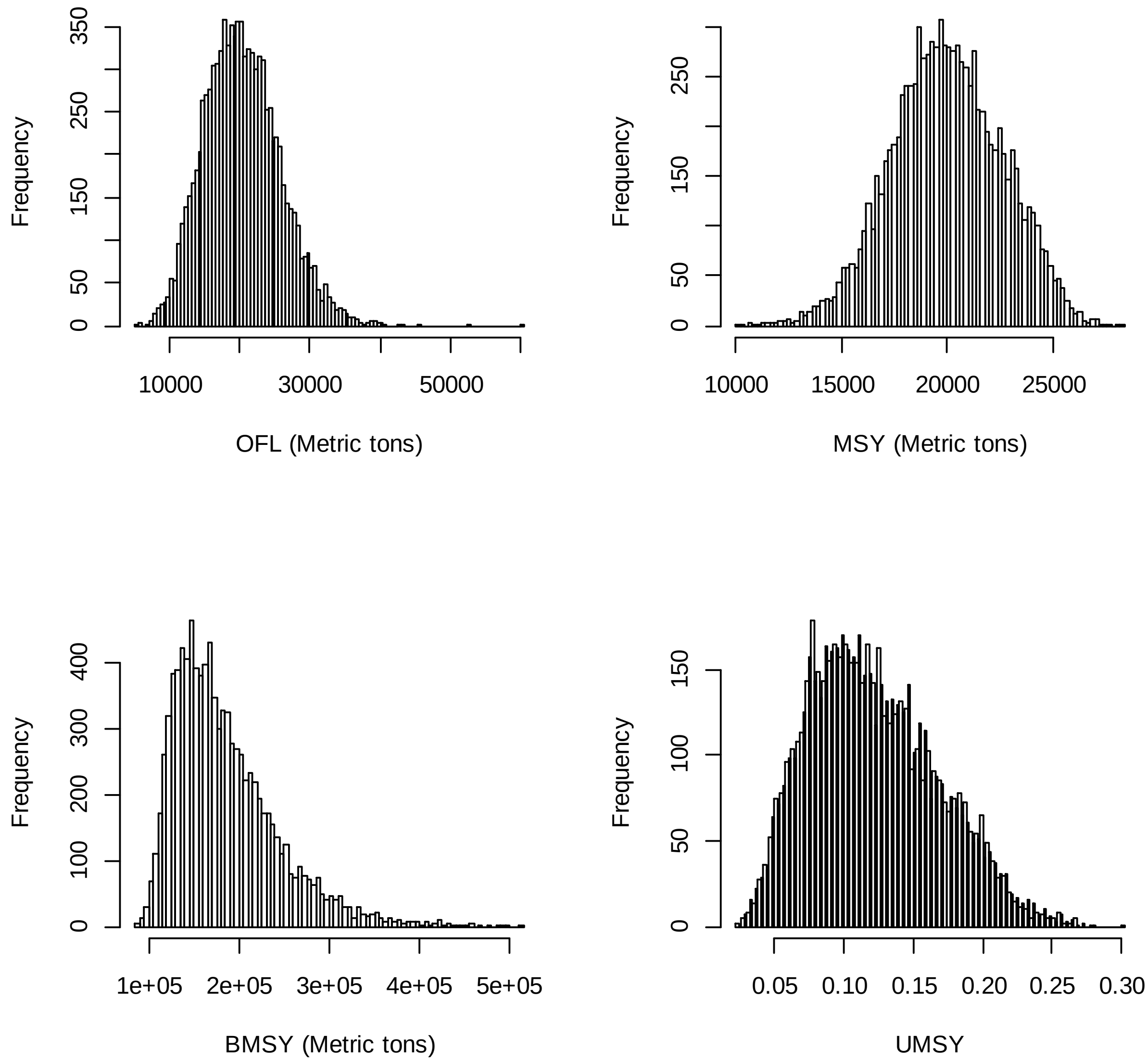




App. B5, Figure.3. Distributions of drawn parameters for runs that were accepted and rejected from the base model DBSRA configuration.



App. B5, Figure.4. Biomass trajectories of accepted DBSRA runs (black) and rejected DBSRA runs (red) for the base model configuration.



App. B5, Figure 5. Distribution of management parameters from successful runs of the base DBSRA model for bluefish.

Appendix B6 – Response to SARC 41 comments on 2005 bluefish benchmark assessment

Prepared by: SAW 60 Working Group

Introduction

The SARC 41 reviewed the 2005 bluefish benchmark stock assessment. The SARC 41 provided a constructive criticism, which provided guidance on how to improve future bluefish assessments. This document details how the specific recommendations of the SARC 41 were addressed by the SAW 60 working group for the 2015 bluefish benchmark stock assessment.

First recommendation - **Continue to develop statistically appropriate models for this stock, including evaluation of uncertainty and sensitivity. This modeling should also test sensitivity to data quality. The Bluefish Technical Committee (BTC) should avoid double use of the data as model input.**

The SARC 41 praised the 2005 bluefish assessment for using a catch-at-age model to assess stock status. Accordingly, the SAW 60 working group continued to utilize this approach while concurrently working to improve the statistical validity of the model. The model was adjusted to increase the CV present on several indices and for several results, allowing the data to better guide the model. The SAW 60 WG explored 13 sensitivity runs to examine the effects of factors such as different levels of constant mortality, age varying natural mortality, different selectivity blocks etc. These sensitivity runs served to guide the research recommendations put forth by the SAW 60 WG and the BTC.

Second recommendation - **Evaluate the fishery-independent surveys used to tune the model with special emphasis on determining if the state surveys can be combined to yield better temporal and spatial representation of stock abundance. The BTC should encourage the states to coordinate their survey efforts for bluefish to improve the quality of data that can be obtained. We suggest a workshop to address this and other data issues.**

The ASMFC convened a data workshop with the BTC in February 2015 to discuss which surveys were available to include in the benchmark assessment. The group reached a consensus on which surveys were appropriate or inappropriate for further consideration.

Because changes in design to existing state surveys were not a feasible option, the BTC standardized indices using a GLM based approach to better combine and compare indices among states.

Further, the SAW 60 WG created a composite young of year index for bluefish using the Conn et al. method. This index used a hierarchical approach to combine seine surveys among many states, resulting in a more realistic representation of young of year abundance - providing better information for which the model to estimate recruitment from.

Third recommendation - **Evaluate the use of otolith and scale ageing of bluefish. We suggest this be a separate workshop to evaluate the best ageing structure and its reliability for stock assessment input. After the evaluation, intensify collection of age data from commercial and recreational fisheries, and evaluate the validity of combining age classes**

across years in an ALK.

The ASMFC convened a bluefish aging workshop in 2011. At this workshop, aging experts concluded that otoliths are the preferred structure with which to age bluefish, set a standardized processing and reading method, recommended that a digital archive of reference structures be created, and recommended that a coastwide sampling program for obtaining bluefish otoliths be begun in 2012.

Based on the recommendations of the aging workshop, the ASMFC added addendum 1 to the bluefish FMP, requiring all states that account for >5% of total coastwide harvest to provide at least 100 otolith based bluefish ages. Most of this data was available for the 2015 benchmark assessment and was utilized by the SAW 60 WG.

To evaluate the validity of combining age classes across years in an ALK, the SAW 60 WG explored several methods. First, the SAW 60 WG performed sensitivity runs of the ASAP model based on pooled versus non pooled keys to see how model results were influenced by the pooling age data. Second, the SAW 60 WG constructed several sets of ALKs using multinomial logistic regression. Within the regression model set, models that included parameters for effects such as year or state were compared to models that did not include such factors using AICc.

Fourth Recommendation - **Improve sampling coast wide by gear and fishery sector to obtain information with special emphasis on mid-size fish. This may require alternative fisheries independent assessment methodologies (such as lidar, archival tagging, sonar).**

Progress has been made towards better capturing information on mid-sized bluefish. At the request of the SAW 60 WG and the BTC, Manderson and Hare constructed a parametric thermal niche model that quantified the influence of temperature on bluefish distribution, providing a measure of bluefish availability for index interpretation. Availability will be able to be incorporated as a covariate in the next version of ASAP, and future assessments are likely to be able to incorporate variables, such as temperature, that may influence survey catches.

Fifth Recommendation - **Increase fishery-independent sampling to better represent the population's offshore and southern habitat.**

In response to a 2011 bluefish aging workshop, the ASMFC added Addendum I to the bluefish fishery management plan. This Addendum required the states of MA, RI, CT, NY, NJ, NC and VA to collect a minimum of 100 bluefish otoliths. The information garnered from these collections was included in the 2015 benchmark assessment.

Sixth Recommendation - **Determine if discard mortality of 15% for the recreational fishery is accurate.**

The SAW 60 WG performed a meta-analysis on available data to better determine if a discard rate of 15% was appropriate for the 2015 bluefish benchmark assessment. Four methods were used to calculate point estimates of post-release mortality. These methods resulted in a range of estimates from 14-17%. The SAW 60 WG and the BTC approved a 15% (S.D. = 0.143) discard mortality rate for the 2015 bluefish benchmark assessment.

Appendix B7 – Model Results and Diagnostics From Original Final Model B043 as Presented to the SARC Panel

At the SARC review of bluefish the review panel discovered a model misspecification in the selectivity parameters for the MRIP index. A parameter in the function describing the curve for selectivity was fixed when it was intended to have been freely estimated by the model. This was causing patterning in the age composition residuals for this index. The final revised model corrects this misspecification. ***The values presented in this appendix reflect the output from the early model presented in the draft WP document and at the peer review, before final revision. For the final SAW/SARC60 assessment results, readers should see the main body of the bluefish report.***

B7 TERM OF REFERENCE #4: ESTIMATE RELATIVE FISHING MORTALITY, ANNUAL FISHING MORTALITY, RECRUITMENT, TOTAL ABUNDANCE, AND STOCK BIOMASS (BOTH TOTAL AND SPAWNING STOCK) FOR THE TIME SERIES, AND ESTIMATE THEIR UNCERTAINTY. EXPLORE INCLUSION OF MULTIPLE FLEETS IN THE MODEL. INCLUDE BOTH INTERNAL AND HISTORICAL RETROSPECTIVE ANALYSES TO ALLOW A COMPARISON WITH PREVIOUS ASSESSMENT RESULTS AND PREVIOUS PROJECTIONS. EXPLORE ALTERNATIVE MODELING APPROACHES IF FEASIBLE.

B7.3.3 A Final Model

Model BFINAL final adjustments to input CVs and effective sample sizes

Final model data summary: Catch proportions for the recreational fleet ranged from 66% to 84% of the total catch (App. B7 Figure B7.26). Catch-at-age for both fleets is predominantly age 0 to age 3, with the recreational fleet catching more age 0, and both fleets catching lesser numbers at older ages (App. B7 Figures B7.27 and B7.28). Overall survey index trends are generally flat, with noticeable peaks for some of the indices early in the time series, and around 2005 (App. B7 Figure B7.29). Input age composition for the indices are presented in App. B7 Figures B7.30 through B7.35. Final model inputs for weight-at-age of the fleets, natural mortality, and maturity-at-age are presented in App. B7 Figures B7.36 through B7.41.

The main contributions to the objective function were from the likelihood components of the index and catch age compositions (App. B7 Figure B7.42). Compared to the previous assessment model from SAW41, which was heavily weighted towards the single catch fleet, model BFINAL gives equal weight to all components. One of the final changes to model BFINAL was iterative adjustments made to the input CV of each index to account for additional process error. The model was re-run and adjustments were made for each index until the root mean square error of the index was close to a value of 1.0 (App. B7 Figure B7.43). In addition to fine tuning the input CVs of the surveys, a low effective sample size was assigned to the middle period time block 1997-2005. The working group decided while the age information in this time block was poor (because of pooled age keys and borrowing across years) a small effective sample size should be input to generate some information about age composition in these years.

B7.4 Final Model Diagnostics

BFINAL model diagnostic plots for the fit to the two catch fleets are presented in App. B7 Figures B7.44 through B7.51. Diagnostic plots for the 9 survey indices are presented in App. B7 Figures B7.52 through B7.81. For reference when viewing some of the plots:

Fleet 1 = commercial
Fleet 2 = recreational
Index 1 = NEFSC Inshore trawl
Index 2 = NEFSC Bigelow trawl
Index 3 = MRIP recreational CPUE
Index 4 = NEAMAP trawl
Index 5 = SEAMAP Age 0
Index 6 = PSIGN gillnet
Index 7 = CT LISTS trawl
Index 8 = NJ Ocean trawl
Index 9 = Composite YOY seine

The final model run had similar estimates to model B042 with slightly greater fishing mortality, total stock number, and recruitment estimates, and slightly decreased estimates of biomass (Table B7.1). Selectivity at-age estimates for the two catch fleets were both domed, with a bi-modal pattern still evident in the commercial fleet (App. B7 Figures B7.82 and B7.83). Fishing mortality for the recreational fleet has always been higher than the commercial fleet, in some year two to three times as much. Fishing mortality estimates in 2014 for the commercial and recreational fleets were 0.043 and 0.092, respectively (App. B7 Figure B7.84). Final model estimates for the index selectivities show a rapid decrease in selectivity after age 0. A few of the indices have higher selectivity towards larger/older fish, the most important being MRIP and PSIGNS, and to a lesser extent the Bigelow survey (App. B7 Figure B7.85). Observed and predicted catch-at-age for the two fleets and nine indices are presented in App. B7 Figures B7.86 through B7.103. Estimates of age composition at older ages are poorly predicted for some of the components.

B7.5 Final Model Results
Average F for from 1985 to 2014 from the final model was 0.249 and average SSB was 105,904 mt (Table B7.4). Spawning stock biomass dipped from a high of 191,476 mt in 1985 to a low of 72,173 mt in 1997 and has steadily increased to a value of 117,827 mt in 2014 (Table B7.4, App. B7 Figure B7.104). The majority of the spawning stock biomass (50-60%) is in the age 6+ group for the entire time-series (App. B7 Figure B7.105). Estimates of F have remained below average since 1997 and the 2014 estimate of 0.136 is well below the time series average (Table B7.4, App. B7 Figure B7.104). There has been a steady decline in fishing mortality since 2007.

Estimates from model BFINAL showed a decrease in total abundance since 2006, declining from 106.5 million to 78.1 million fish in 2012 (Table B7.5, App. B7 Figure B7.106). Total abundance increased in 2013, and 2014, to 84.9 and 94.2 million, respectively. Age 0 and age 1 fish collectively average around 50% of abundance for the time-series. Below average (25.9 million) recruitment began in 2008 with an estimate of 25.7 million fish (Table B7.4, App. B7 Figure B7.107). Low recruitment persisted through 2012 to the lowest estimate of the time-series at 18.4 million. Recruitment for 2013 and 2014 have increased above the average to 27.2 and 31.1 million fish, respectively. Throughout the time series the plus group contains the majority of the biomass (Table B7.6). Biomass estimates for 6-plus bluefish have remained above the time series average of 60,492 mt since 2010. Total mean biomass in 2014 equaled 127,061 mt, a slight decrease from the 2013 estimate of 132,930 mt (Table B7.6, App. B7 Figure B7.108).

Retrospective bias for the final model was examined for F, spawning stock biomass, recruitment, total biomass, exploitable biomass, total abundance, and abundance-at-ages 1 through 6. The analysis shows little evidence of bias in the estimates of F (Mohn's rho = -0.057), SSB (Mohn's rho = 0.076), and recruitment (Mohn's rho = -0.012) (App. B7 Figure B7. 109). Similarly, there is little retrospective bias in estimates of total biomass (Mohn's rho = 0.071), exploitable biomass (Mohn's rho = 0.046) and total abundance (Mohn's rho = -0.005) (App. B7 Figure B7.110). There does appear to be minor retrospective bias in some of the estimates of abundance-at-age, particularly numbers at age 1 (Mohn's rho = -0.139) and numbers at age 5 (Mohn's rho = 0.13) (App. B7 Figures B7.111 and B7.112).

The variation in the final model results for F and SSB was determined using a Monte Carlo Markov chain with 1000 iterations and a thinning factor of 1000 (1,000,000 iterations). Trace plots for both SSB and F show little to no patterning (App. B7 Figures B7.113 and B7.114).There is no significant autocorrelation in the F chain (App. B7 Figure B7.115). Autocorrelation plots show minor autocorrelation in the SSB (both 1985 and 2014) chain at a lag of 1, with no autocorrelation at a lag greater than 2 (App. B7 Figure B7.116). The MCMC results of SSB for 2014 ranged from 82,000 to 137,000 mt, with a median estimate of 105,000 mt, and 80% confidence interval ranging from 92,119 mt to 121,467 mt. The 2014 SSB point estimate from the final model (117,827 mt) is greater than the median estimate from the MCMC distribution (App. B7 Figure B7.117 and B7.118). Variation around F ranged from 0.103 to 0.193, with the 80% CI between 0.121 and 0.166. The point estimate from the final model (0.136) is slightly less than the median estimate (0.142) from the MCMC distribution (App. B7 Figure B7.119 and B7.120).

B7.6 Final model sensitivity runs

A number of sensitivity runs were carried out by changing data inputs to the final model.

Changes to the recreational data

The first group of sensitivities explored different changes made to the estimation of various components of the recreational catch. A total of 5 sensitivity runs were conducted for the recreational data: 1. Assume recreational landings (AB1) lengths apply to the recreational discards (B2), 2. Assume recreational catch at the upper 95% CI of estimates, 3. Assume recreational catch at the lower 95% CI of the estimates, 4. Use MRFSS numbers prior to 2004 (no conversion to MRIP equivalents), and 5. Assume 17% recreational discard mortality instead of 15%. Comparisons between final model and sensitivity run estimates of F, total stock numbers, recruitment, and SSB are presented in App. B7 Figures B7.121 through B7.125.

Changes to data structure and inputs

Additional final model sensitivity runs were conducted that changed other components of the input data: 1, A regional sensitivity run was explored that used northern and southern regional age-length keys to age the fleets and surveys from 2006 to 2014, 2. Length-weight coefficients were varied over time by three time blocks, 1985-1994, 1995-2004, 2005-2014, 3. Virginia landings date were calculated using a different methodology (VA set 2). Comparisons between final model and sensitivity run estimates of F, total stock numbers, recruitment, and SSB for these sensitivity runs are presented in App. B7 Figures B7.126 through B7.128.

Sensitivity runs were also carried out the final model assuming different input values for natural mortality. A profile of the objective function was calculated over a range of natural mortality estimates, and the objective function was minimized at a value of 0.263 (Table B7.7 and App. B7 Figures B7.129 and B7.130). Age-based inputs for natural mortality were also explored (Table 1.50 and App. B7 Figure B7.131). The estimates assuming age-based M derived from equations in Gislason et al. 2010 resulted in unrealistic model estimates (Table B7.8).

Changes to the survey indices

Sensitivity of the final model to individual survey indices was also tested by removing each index and re-running the model (Table B7.9). The model is fairly insensitive to the removal of all the indices except for the MRIP recreational CPUE index, which is driving the model along with the two catch fleets. The reason this index is so important is because it provides most of the information for model estimates at older ages. Removing the MRIP index and re-running the final model results in a significant decrease in fishing mortality estimates and an increase in abundance and biomass estimates (Table B7.9 and App. B7 Figure B7.132). An additional model run using just the two catch fleets and the single MRIP index was also conducted. Without the other indices the model loses some information to inform estimates of younger ages and recruitment is scaled up. However, the overall trend and scale of biomass and fishing mortality estimates are not that different from the final model (App. B7 Figure B7.132).

Investigating habitat suitability indices

Habitat suitability information was also investigated for the NEFSC surveys as well as the NEAMAP survey. Annual estimates of habitat suitability were input as a covariate on availability in the ASAP model (catchability = availability*efficiency, where efficiency was assumed = 1). The use of the habitat suitability indices did not improve the fit of the model to the respective indices. This is not surprising, since the annual estimates of available thermal habitat sampled by the NEFSC and NEAMAP surveys did not show significant trends which would cause a bias in trends of relative abundance (App. B7 Figure B6.21). In addition, these indices used a hindcasted estimate of sea bottom temperature to derive estimates of bluefish habitat suitability. The ocean model used to hindcast these temperatures was not available for 2013 and 2014 and as a result no index of habitat suitability was available for these years (See

WP B4 for full details). The working group decided to go forward without incorporating habitat suitability in the model. There was concern because recent information was not available, as well concern for the ocean model that was used to develop the indices. A habitat suitability index developed from an ocean model using real-time or forecasted sea-surface temperature would be more appropriate for bluefish. This is included as a research recommendation and could be developed for future bluefish assessments.

B8 TERM OF REFERENCE #5: STATE THE EXISTING STOCK STATUS DEFINITIONS FOR "OVERFISHED" AND "OVERFISHING". THEN UPDATE OR REDEFINE BIOLOGICAL REFERENCE POINTS (BRPS; POINT ESTIMATES OR PROXIES FOR B_{MSY}, $B_{THRESHOLD}$, F_{MSY}, AND MSY) AND PROVIDE ESTIMATES OF THEIR UNCERTAINTY. IF ANALYTIC MODEL-BASED ESTIMATES ARE UNAVAILABLE, CONSIDER RECOMMENDING ALTERNATIVE MEASURABLE PROXIES FOR BRPS. COMMENT ON THE SCIENTIFIC ADEQUACY OF EXISTING BRPS AND THE "NEW" (I.E., UPDATED, REDEFINED, OR ALTERNATIVE) BRPS.

The current biological reference points for bluefish were determined in SARC 41 and are F_{MSY} (0.19) and B_{MSY} (147,052 mt). The basis for the reference points was the Sissenwine-Shepherd method using the Beverton-Holt stock recruitment parameters and SSB per recruit results generated by the SARC 41 ASAP model results. B_{MSY} was calculated using mean weights at age and is therefore comparable to mean biomass in year *t*. Overfishing of a stock occurs if F exceeds F_{MSY} and a stock is considered overfished if total biomass is less than half of B_{MSY} ($B_{THRESHOLD}$). The existing definition of overfishing is $F > 0.19$ and $B < 73{,}526$ mt.

The TC and WG concluded that new reference points were required because of the uncertainty present in the stock recruitment relationship estimated by the current model. The time series of spawning stock biomass and recruitment does not contain any data about recruitment levels at low stock sizes (App. B7 Figure B8.1), and the BTC and the SAW 60 WG did not believe the fitted parameters adequately described the stock-recruitment relationship for bluefish.

Because MSY based reference points require a stock recruitment relationship, MSY proxies are required. As a proxy for F_{MSY}, the BTC and the SAW 60 WG recommend $F_{40\%\ SPR}$. The input maturity and composite selectivity curves are shown in App. B7 Figure B8.2. The resulting YPR and SPR curves are shown in App. B7 Figure B8.3.

To calculate the associated proxy for B_{MSY}, the population was projected forward for one hundred years under current conditions with fishing mortality set at the F_{MSY} proxy and recruitment drawn from the observed time series. The resulting equilibrium biomass is the recommended B_{MSY} proxy, with the overfishing threshold set at ½ B_{MSY}. Similarly, the equilibrium landings under $F_{40\%SPR}$ were set as the MSY proxy.

The revised reference points are F_{MSY} proxy = F40% = 0.181 and B_{MSY} proxy = 126,504 mt (½ B_{MSY} = 63,252 mt). The MSY proxy is 14,188 mt.

The usage of these proxies has been accepted in many other assessments and is considered adequate in cases where a stock recruitment relationship is not estimable. Recent SAW assessments where MSY proxies have been used include the Gulf of Maine haddock (2014), summer flounder (2013), and white hake (2013).

SPR-based reference points are not sensitive to uncertainty in the stock-recruitment relationship, but do not link future recruitment to spawning stock biomass. The projection approach used to establish the B_{MSY} proxy incorporates the observed variability in recruitment, but assumes that recruitment is independent of SSB. This assumption is not unreasonable over the observed high levels of bluefish abundance, and maintaining the stock close to the proposed target should minimize the risk of this assumption.

B9 TERM OF REFERENCE #6: EVALUATE STOCK STATUS WITH RESPECT TO THE EXISTING MODEL (FROM PREVIOUS PEER REVIEW ACCEPTED ASSESSMENT) AND WITH RESPECT TO A NEW MODEL DEVELOPED FOR THIS PEER REVIEW.

B9.1 Stock status from the continuity run

c. **When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the existing BRP estimates.**

The existing reference points are F_{MSY} = 0.19 and B_{MSY} = 147,052 mt (½ B_{MSY} = 73,526 mt). The 2014 F estimate (0.141) is well below F_{MSY} and the 2014 estimate of B is 92,755 mt, below B_{MSY} but well above ½ B_{MSY}. This indicates that overfishing is not occurring and that the stock is not overfished (App. B7 Figure B9.1).

B9.2 Stock status for the current assessment

d. **Then use the newly proposed model and evaluate stock status with respect to "new" BRPs and their estimates (from TOR-5).**

The new reference points are F_{MSY} proxy = F40% = 0.181 and B_{MSY} proxy = 126,504 mt (½ B_{MSY} = 63,252 mt). The 2014 F estimate (0.136) is below $F_{40\%}$ and the 2014 B estimate (127,061 mt) is greater than ½ B_{MSY}, indicating that overfishing is not occurring and that the stock is not overfished (App. B7 Figure B9.2 and B9.3).

In addition, since biomass is greater than the B target, the stock can be considered rebuilt.

	SARC 41		**Updated**	
Reference Point	Definition	Value	Definition	Value
$\mathbf{F_{THRESHOLD}}$	F_{MSY}	0.19	$F_{40\%SPR}$	0.181
$\mathbf{B_{TARGET}}$	B_{MSY}	147,052 mt	Equilibrium biomass under $F_{40\%SPR}$	126,504 mt
$\mathbf{B_{THRESHOLD}}$	½ B_{MSY}	73,526 mt	½ $B_{MSY\ Proxy}$	63,252 mt

B10. TERM OF REFERENCE #7: DEVELOP APPROACHES AND APPLY THEM TO CONDUCT STOCK PROJECTIONS AND TO COMPUTE THE STATISTICAL DISTRIBUTION (E.G., PROBABILITY DENSITY FUNCTION) OF THE OFL (OVERFISHING LEVEL; SEE APPENDIX TO THE SAW TORS).

B10.1 Provide annual projections (3 years). For given catches, each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment)

Short-term projections were conducted using AGEPRO v.4.2.2 (available from the NOAA Fisheries Toolbox, http://nft.nefsc.noaa.gov/AGEPRO.html).

Removals in 2015 were assumed to be equal to the 2015 quota (9,722 mt). For 2016-2018, a constant level of fishing mortality was applied. The population was projected forward under five different F levels:

- F_{low} = 0.1
- $F_{status\ quo}$ = 0.136
- $F_{0.1}$ = 0.203
- F_{TARGET} = 90%$F_{MSY\ Proxy}$ = 0.163
- $F_{MSY\ Proxy}$ = $F_{40\%SPR}$ = 0.181

Uncertainty was incorporated into the projections primarily via estimates of recruitment and initial abundance-at-age. Estimates of recruitment were drawn from the 1985-2014 time-series of observed recruitment from the preferred ASAP model. Initial abundance-at-age estimates were drawn from distributions of terminal abundance-at-age developed from the MCMC runs of the preferred ASAP model. A small amount of uncertainty was incorporated into biological parameters such as weight-at-age, maturity-at-age, and natural mortality; estimates of these parameters were drawn from lognormal distributions with mean values used in the terminal year of the assessment and a CV of 0.01.

The projections were conducted with a single fleet. Selectivity was calculated by summing the commercial and recreational F-at-age for each age from the preferred ASAP model over the last three years of the model and dividing by the maximum F-at-age to develop a composite selectivity curve. A CV of 0.01 was also applied to the selectivity-at-age estimates.

None of the fishing mortality scenarios resulted in total biomass going below the biomass threshold (½ $B_{MSY\ Proxy}$) in any year of the projection; total biomass remained above the biomass threshold with 100% probability in all years (Table B10.1, App. B7 Figure B10.1).

The median OFL for 2016, calculated as landings at $F_{MSY\ Proxy}$ was estimated as 12,752 mt (5th and 95th percentiles = 10,722 – 15,074 mt).
A sensitivity analysis approach was used to determine the effects of major sources of model uncertainty that could not be encompassed through the MCMC runs of the base model. This

included:

- Limiting the empirical recruitment distribution to the CDF of observed recruitment for 2006-2014 (the years of the best available age data)
- Higher M (M=0.26)
- Increased uncertainty in selectivity-at-age, weight-at-age, and maturity-at-age (CV of 0.1 instead of 0.01)

Using the more limited recruitment time series did not significantly change the estimates of landings or biomass from the projections (Table B10.2, App. B7 Figure B10.2). This is not surprising, since the median recruitment of the 2005-2014 period (26.4 million fish) is not significantly different from the median recruitment of the entire time series (24.5 million fish). Higher M values resulted in higher estimates of landings and biomass, but did not change the probability of going below the biomass threshold (0% in all years). Increasing the CV on the biological parameters did not significantly change the median of the distributions for biomass or landings in each year, but did increase the confidence intervals. The probability of being above the biomass threshold remained 100%.

B10.2 Comment on which projections seem most realistic. Consider the major uncertainties in the assessment as well as sensitivity of the projections to various assumptions.

The WG considers the base model configuration the most realistic projection scenario. While estimates of recruitment in the most recent 10 years of the time-series (derived in part from the best age information) are likely more reliable than the estimates from the beginning of the time-series, the median recruitment and projection time-series are virtually indistinguishable.

B10.3 Describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming overfished, and how this could affect the choice of ABC.

Bluefish are a fast-growing, fast-maturing species with a moderately long life span. Although they recruit to the fishery before they are fully mature, larger, older fish are considered unpalatable, reducing demand for those sizes in the commercial market and encouraging the release of those size classes in the recreational fishery. The resulting dome-shaped selectivity of the fleets offers protection to the spawning stock biomass. Although they are a popular gamefish, demand for this species is not extreme and the quota is rarely met or exceeded.

Bluefish are opportunistic predators that do not depend on a single prey species. Their range covers the whole of the Atlantic coast, and their spawning is protracted both temporally and geographically. As a result, they are not as vulnerable as many other species to major non-fishery drivers such as climate change that would result in the loss of critical forage or nursery habitat.

This assessment indicates bluefish are near their target biomass and well above their overfished threshold. Short-term projections indicate no risk of driving the biomass below the overfished threshold while fishing at or near the FMSY proxy. Overall, bluefish have a low degree of vulnerability to becoming overfished, and the ABC can be set on the basis of the FMSY proxy without risk of causing the stock to become overfished.

App. B7 Table B7.1. Bluefish model building starting with continuity run and ending at final model. The models shown highlight the important changes in the progression from one model to the next. 2014 estimates of F, F40%, total stock numbers, spawning stock biomass, total stock biomass and recruitment are presented for each model step.

MODEL	DESCRIPTION	Obj Func	#pars	2014 Estimates					
				F	F40%	TSN (000s)	SSB (mt)	TSB (mt)	Rec (000s)
B001	Continuity run. Update SAW2005 model through 2014.	3094.79	101	0.141	0.171	57,671	84,800	92,755	14,696
B002	Continuity run cropped to start in 1985: No age data for 1982-1984 found.	2637.25	95	0.145	0.200	70,867	84,551	91,808	21,528
B004	Base model run. SAW2005 model with new CAA, WAA, and Indices.	2282.17	114	0.146	0.172	57,534	81,241	90,381	15,731
B006	Changed indices from index-at-age to estimating age composition.	7692.99	108	0.119	0.175	76,803	105,632	103,359	23,573
B007	Changed from one catch fleet to two: Recreational and commercial.	8546.78	138	0.143	0.172	64,470	83,839	91,462	16,174
B008	New maturity ogive based on preliminary analyses of maturity data.	8546.78	138	0.143	0.175	64,470	85,738	91,462	16,174
B011	Change from fixed fleet selectivities-at-age estimated selectivities.	8480.29	148	0.145	0.202	78,047	117,234	125,019	18,723
B020	Change to two selectivity blocks per fleet: 1985-2005, 2006-2014	7748.80	155	0.105	0.146	109,651	182,995	193,733	23,828
B020A	No estimated age composition for fleets in middle time period 1997-2005: ESS = 0	7559.01	155	0.103	0.148	112,281	189,369	200,420	24,194
B021	Set Lambdas to 0 or 1 to act as a switch for CV and inclusion in Obj Func. Needed to adjust fleet ESS and CV to get model to converge.	2719.28	164	0.111	0.128	82,875	102,157	110,871	24,289
B021A	Turn Likelihood constant off in objective function.	8134.61	164	0.155	0.224	102,891	142,077	152,889	28,581

B022	Turn number in the first year deviation penalty off	7937.38	164	0.136	0.230	117,420	174,184	186,480	31,335
B023	New maturity ogive based on final analyses of maturity data.	7937.38	164	0.136	0.230	117,420	174,888	186,480	31,334
B024	Increase CV on recruitment from 0.5 to 1.0.	7950.68	164	0.137	0.230	117,082	174,284	185,906	31,286
B025	Switch from selectivity-at-age to double logistic in time block 2.	7951.81	159	0.134	0.223	115,067	169,754	181,167	30,933
B027	Switch from double logistic selectivity to selectivity-at-age for NEFSC surveys.	7942.52	164	0.135	0.221	113,697	167,409	178,658	30,509
B028	Switch back to one selectivity block per fleet before including corrected data.	8014.38	155	0.126	0.191	101,276	153,752	164,139	27,028
B029	Switch NEFSC surveys to split off Bigelow: Inshore bands 1985-2008, Bigelow (Outer Inshore band) 2009-2014.	7641.45	155	0.128	0.189	99,476	149,216	159,673	26,856
B030	Switch MRIP selectivity to match starting values at-age of Rec fleet.	7649.17	154	0.113	0.194	114,851	184,961	197,207	29,543
B033	New data that corrects North Carolina scale ages from 1985-1996.	7425.96	154	0.094	0.204	142,050	243,972	258,068	34,263
B035	Switched PSIGN from double logistic selectivity to selectivity-at-age.	7427.21	156	0.091	0.205	147,082	256,007	270,667	35,152
B042	Switch MRIP selectivity from at-age to single logistic. Increased CV around recreational fleet from 0.1 to 0.15.	7464.98	151	0.124	0.178	90,014	126,802	135,011	24,583
BFINAL	Final adjustments to index input CV and ESS. Low ESS in middle block: 1997-2005.	8593.52	151	0.136	0.181	94,202	117,827	127,061	31,054

App. B7 Table B7.2. Model specifications for Model B001, the continuity run.

	Age						
Time Frame: All Years	**0**	**1**	**2**	**3**	**4**	**5**	**6+**
Natural Mortality	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Maturity	0.00	0.25	0.75	1.00	1.00	1.00	1.00
Fleet Selectivity: Fixed	0.338	1	0.942	0.476	0.343	0.694	0.914

Fleet 1		
CV	0.01	All Years
ESS	30	All Years

Recruitment Deviations		
CV	0.5	All Years
Lambda	1	--

Lambda for Catch weight	10
Lambda for Fmult Year 1	0.5
CV Fmult Year 1	0.9
Lambda Fmult Deviations	0
CV Fmult Deviations	0.9

	Lambda	**CV**
N in First Year Deviations	1	0.9
Deviation from initial Steepness	0	0.6
Deviation from initial SR Scaler	0	0.6

Phases	
Fmult in year 1	2
Fmult deviations	3
Recruitment Devs	3
N in year 1	4
Catchability in year 1	1
Catchability Devs	-5
SR Scaler	2
Steepness	-4

Indices		
	1	2 to 28
Lambda	10	5
Lambda for Catchability	0.01	0.01
CV for Catchability	0.9	0.9
Lambda for Catchability Deviations	100	100
CV for Catchability Deviations	0.9	0.9
Index Selectivities	Input at-age: Fixed	

App. B7 Table B7.3. Model specifications for Model B043, the final model.

	Age						
Time Frame: All Years	**0**	**1**	**2**	**3**	**4**	**5**	**6+**
Natural Mortality	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Maturity	0.00	0.40	0.97	1.00	1.00	1.00	1.00
Fleet 1 Selectivity: Input	0.338	-1	0.942	0.476	0.343	0.694	0.914
Fleet 2 Selectivity: Input	0.338	-1	0.942	0.476	0.343	0.694	0.914

Fleets			
	1	2	Time Block
CV	0.1	0.15	All Years
ESS	30	50	1985-1996
ESS	20	25	1997-2005
ESS	50	100	2006-2014

Recruitment Deviations		
CV	1.0	All Years
Lambda	1	--

	Lambda	**CV**
N year 1	0	0.9
Steepness	0	0.6
SR Scaler	0	0.6

	Fleet 1	**Fleet 2**
Lambda for Catch weight	1	1
Lambda for Fmult Year 1	0	0
CV Fmult Year 1	0.9	0.9
Lambda Fmult Deviations	0	0
CV Fmult Deviations	0.9	0.9

Phases	
Fmult in year 1	2
Fmult deviations	3
Recruitment Devs	1
N in year 1	1
Catchability in year 1	1
Catchability Devs	-5
SR Scaler	1
Steepness	-5

Indices	
	ALL
Lambda	1
Lambda for Catchability	0
CV for Catchability	0.9
Lambda for Catchability Deviations	0
CV for Catchability Deviations	0.9

App. B7 Table B7.3 continued

Input Index Selectivities (-1 = fixed full selectivity)							
Index	**Age**						
	0	**1**	**2**	**3**	**4**	**5**	**6+**
NEFSC Inshore	-1	0.25	0.1	0.1	0.1	0.05	0.05
NEFSC Bigelow	-1	0.25	0.1	0.1	0.1	0.05	0.05
MRIP	Single Logistic: A50 = 1, Slope = 0.5						
NEAMAP	-1	0.25	0.1	0.1	0.1	0.05	0.05
SEAMAP	-1						
PSIGN	0.338	-1	0.942	0.476	0.343	0.694	0.914
CT LISTS	-1	0.25	0.1	0.1	0.1	0.05	0.05
NJ OCEAN	-1	0.5	0.1				
COMPOSITE YOY	-1						

App. B7 Table B7.4. Annual SSB (mt), recruitment (000s), total abundance (000s), and F from the ASAP model updated through 2013.

Year	SSB	Recruitment	F
1985	191,476	36,743	0.246
1986	172,059	28,771	0.400
1987	147,048	18,084	0.450
1988	114,649	24,369	0.421
1989	106,535	50,212	0.344
1990	99,809	24,293	0.345
1991	87,241	29,153	0.403
1992	82,983	14,284	0.342
1993	80,624	17,023	0.325
1994	80,088	25,342	0.274
1995	77,967	17,817	0.243
1996	72,796	22,581	0.248
1997	72,173	24,542	0.290
1998	81,296	21,778	0.219
1999	85,940	33,833	0.162
2000	96,940	19,205	0.196
2001	102,797	28,505	0.220
2002	93,860	23,700	0.169
2003	96,980	36,430	0.197
2004	104,483	21,891	0.200
2005	115,988	33,629	0.200
2006	99,731	35,477	0.205
2007	97,077	27,160	0.238
2008	118,635	25,661	0.182
2009	105,828	19,474	0.162
2010	114,135	20,560	0.187
2011	114,025	19,666	0.161
2012	119,665	18,354	0.151
2013	126,473	27,184	0.150
2014	117,827	31,054	0.136
Average	**105,904**	**25,892**	**0.249**

App. B7 Table B7.5 Abundance at age (000s) for bluefish from the final SAW60 model, BFINAL.

Year	Age							Total
	0	1	2	3	4	5	6+	
1985	36,743	44,412	19,267	9,316	6,757	3,989	19,373	**139,857**
1986	28,771	27,522	28,434	12,335	6,087	4,616	17,077	**124,842**
1987	18,084	20,214	15,100	15,600	6,933	3,681	14,641	**94,254**
1988	24,369	12,483	10,552	7,882	8,380	4,044	12,101	**79,810**
1989	50,212	17,252	6,707	5,669	4,419	5,068	10,831	**100,158**
1990	24,293	36,344	10,016	3,894	3,390	2,812	10,965	**91,714**
1991	29,153	17,776	21,082	5,810	2,355	2,181	9,658	**88,014**
1992	14,284	20,937	9,727	11,536	3,340	1,455	8,104	**69,382**
1993	17,023	10,466	12,178	5,657	6,998	2,154	6,743	**61,218**
1994	25,342	12,545	6,189	7,201	3,484	4,567	6,272	**65,600**
1995	17,817	18,997	7,811	3,854	4,641	2,358	7,721	**63,199**
1996	22,581	13,488	12,194	5,014	2,551	3,208	7,383	**66,420**
1997	24,542	17,121	8,619	7,792	3,317	1,763	7,719	**70,873**
1998	21,778	18,312	10,485	5,278	4,953	2,220	6,827	**69,854**
1999	33,833	16,668	12,048	6,899	3,582	3,494	6,709	**83,232**
2000	19,205	26,421	11,608	8,391	4,929	2,633	7,740	**80,927**
2001	28,505	14,759	17,776	7,810	5,786	3,520	7,754	**85,911**
2002	23,700	21,705	9,700	11,682	5,267	4,058	8,301	**84,414**
2003	36,430	18,382	15,007	6,706	8,254	3,835	9,326	**97,940**
2004	21,891	27,898	12,354	10,085	4,604	5,871	9,797	**92,501**
2005	33,629	16,744	18,707	8,284	6,907	3,268	11,595	**99,134**
2006	35,477	25,630	11,226	12,542	5,650	4,885	11,071	**106,481**
2007	27,160	27,066	17,087	7,484	8,539	3,992	11,815	**103,142**
2008	25,661	20,428	17,469	11,028	4,933	5,876	11,543	**96,938**
2009	19,474	19,671	13,937	11,919	7,640	3,532	13,003	**89,175**
2010	20,560	15,112	13,699	9,706	8,458	5,581	12,573	**85,688**
2011	19,666	15,802	10,259	9,300	6,725	6,061	13,569	**81,382**
2012	18,354	15,237	11,016	7,152	6,592	4,907	14,856	**78,113**
2013	27,184	14,256	10,731	7,758	5,110	4,840	15,060	**84,939**
2014	31,054	21,086	10,050	7,565	5,538	3,748	15,161	**94,202**

App. B7 Table B7.6 Jan-1 Biomass at age (mt) for bluefish as estimated from the final SAW60 model: BFINAL

Year	Age							Total
	0	1	2	3	4	5	6+	
1985	1,988	16,637	19,394	17,701	21,571	16,102	129,412	**222,805**
1986	995	7,323	24,664	21,352	16,946	18,224	105,194	**194,699**
1987	637	4,736	13,274	26,463	19,571	14,256	89,313	**168,249**
1988	1,964	2,876	8,760	13,711	21,749	15,076	69,457	**133,595**
1989	2,952	5,478	6,455	10,386	12,689	18,388	62,279	**118,627**
1990	2,716	8,901	8,672	7,511	11,642	11,133	68,090	**118,665**
1991	1,359	3,576	15,706	9,140	6,646	8,864	55,627	**100,919**
1992	390	4,491	5,154	17,654	8,604	5,518	47,325	**89,136**
1993	1,428	1,878	8,780	8,825	17,371	7,713	41,197	**87,192**
1994	1,100	3,366	4,342	11,093	9,769	15,898	41,647	**87,216**
1995	1,586	4,373	5,466	5,913	12,493	9,168	45,786	**84,783**
1996	1,513	4,380	8,921	6,775	6,476	12,443	41,051	**81,559**
1997	1,087	4,321	6,854	10,991	7,372	5,797	44,230	**80,653**
1998	1,490	4,135	6,886	8,612	13,373	7,414	42,329	**84,238**
1999	2,768	4,120	8,253	10,026	11,101	13,459	42,198	**91,924**
2000	1,921	6,330	7,381	13,634	14,489	9,924	48,063	**101,742**
2001	1,890	3,780	11,268	11,901	18,702	13,688	45,906	**107,135**
2002	1,541	5,535	6,484	15,941	14,325	15,505	42,087	**101,418**
2003	1,421	4,779	11,229	9,497	18,521	12,161	45,885	**103,494**
2004	1,086	5,797	10,078	15,650	10,581	18,209	46,537	**107,938**
2005	3,366	4,081	12,566	13,995	17,917	11,184	62,611	**125,721**
2006	2,274	7,397	7,956	16,360	14,018	15,936	47,828	**111,768**
2007	2,279	6,076	11,720	8,956	16,923	12,774	50,569	**109,297**
2008	2,566	5,481	12,808	14,972	10,848	16,332	56,216	**119,223**
2009	1,860	5,038	9,362	15,433	17,070	11,507	59,551	**119,821**
2010	1,425	3,560	8,771	10,048	15,306	17,286	65,126	**121,522**
2011	1,516	3,284	5,985	9,929	9,661	19,428	72,867	**122,671**
2012	1,009	3,342	6,058	7,292	11,305	13,513	81,111	**123,630**
2013	2,466	3,136	6,528	9,513	8,827	15,114	87,347	**132,930**
2014	2,453	5,229	6,532	10,345	12,595	11,981	77,925	**127,061**

App. B7 Table B7.7 Final model objective function profiled over different estimates of natural mortality.

M	Objective Function	F40%
0.10	8610.89	0.125
0.15	8601.51	0.157
0.20	8593.52	0.181
0.21	8592.36	0.185
0.22	8591.38	0.189
0.23	8590.61	0.192
0.24	8590.04	0.196
0.25	8589.68	0.199
0.26	8589.54	0.202
0.263	8589.53	0.203
0.27	8589.60	0.205
0.28	8589.86	0.208
0.29	8590.30	0.211
0.30	8590.92	0.214
0.35	8596.06	0.228

App. B7 Table B7.8 Final model sensitivity runs at different age-based estimates of natural mortality.

MODEL	DESCRIPTION	Obj Func	#pars	2014 Estimates					
				F	F40%	TSN (000s)	SSB (mt)	TSB (mt)	Rec (000s)
B043	Final bluefish model estimates	8593.52	151	0.136	0.181	94,202	117,827	127,061	31,054
B043_M_LROT	M at age: Lorenzen scaled to Rule of Thumb (0.21)	8643.51	151	0.119	0.166	124,516	142,528	154,100	51,450
B043_M_L263	M at age: Lorenzen scaled to minimum objective function M (0.263)	8652.55	151	0.081	0.189	206,655	213,470	234,845	93,210
B043_M_LGIS	M at age: Gislason et al 2010	8840.99	151	0	0.211	5.23E+09	2.96E+07	3.46E+07	3.67E+09

(NOTE: The values presented in this Appendix B7 reflect the output from the early model presented in the draft WP document and at the peer review, before final revision. For the final SAW/SARC60 assessment results, readers should see the main body of the bluefish report.)

App. B7 Table B7.9 Sensitivity of the final model to removal of individual indices.

MODEL	DESCRIPTION	Obj Func	#pars	2014 Estimates					
				F	F40%	TSN (000s)	SSB (mt)	TSB (mt)	Rec (000s)
B043	Final bluefish model estimates	8593.52	151	0.136	0.181	94,202	117,827	127,061	31,054
B043-1	Remove NEFSC inshore survey	8109.97	144	0.136	0.181	93,737	116,829	126,008	30,948
B043-2	Remove NEFSC Bigelow survey	7740.18	144	0.135	0.181	93,234	116,929	125,605	31,175
B043-3	Remove MRIP rec CPUE	6484.00	149	0.088	0.215	177,579	300,527	321,140	49,791
B043-4	Remove NEAMAP survey	7903.23	144	0.137	0.181	95,704	116,638	126,068	33,058
B043-5	Remove SEAMAP age 0 index	8099.78	150	0.136	0.181	94,787	116,800	126,071	31,826
B043-6	Remove PSIGN survey	7800.24	144	0.138	0.180	92,534	111,302	119,983	30,988
B043-7	Remove CT LISTS survey	7448.40	144	0.131	0.181	95,626	120,743	129,982	30,559
B043-8	Remove NJ Ocean Trawl survey	7882.93	148	0.139	0.181	92,035	115,006	124,216	30,517
B043-9	Remove composite YOY index	8119.36	150	0.136	0.181	94,748	117,175	126,426	31,964
B043MRIP	All removed except MRIP rec CPUE	6323.18	111	0.132	0.18	101,459	114,326	123,152	39,596

App. B7 Table B10.1 Short-term projections for bluefish under different F scenarios.

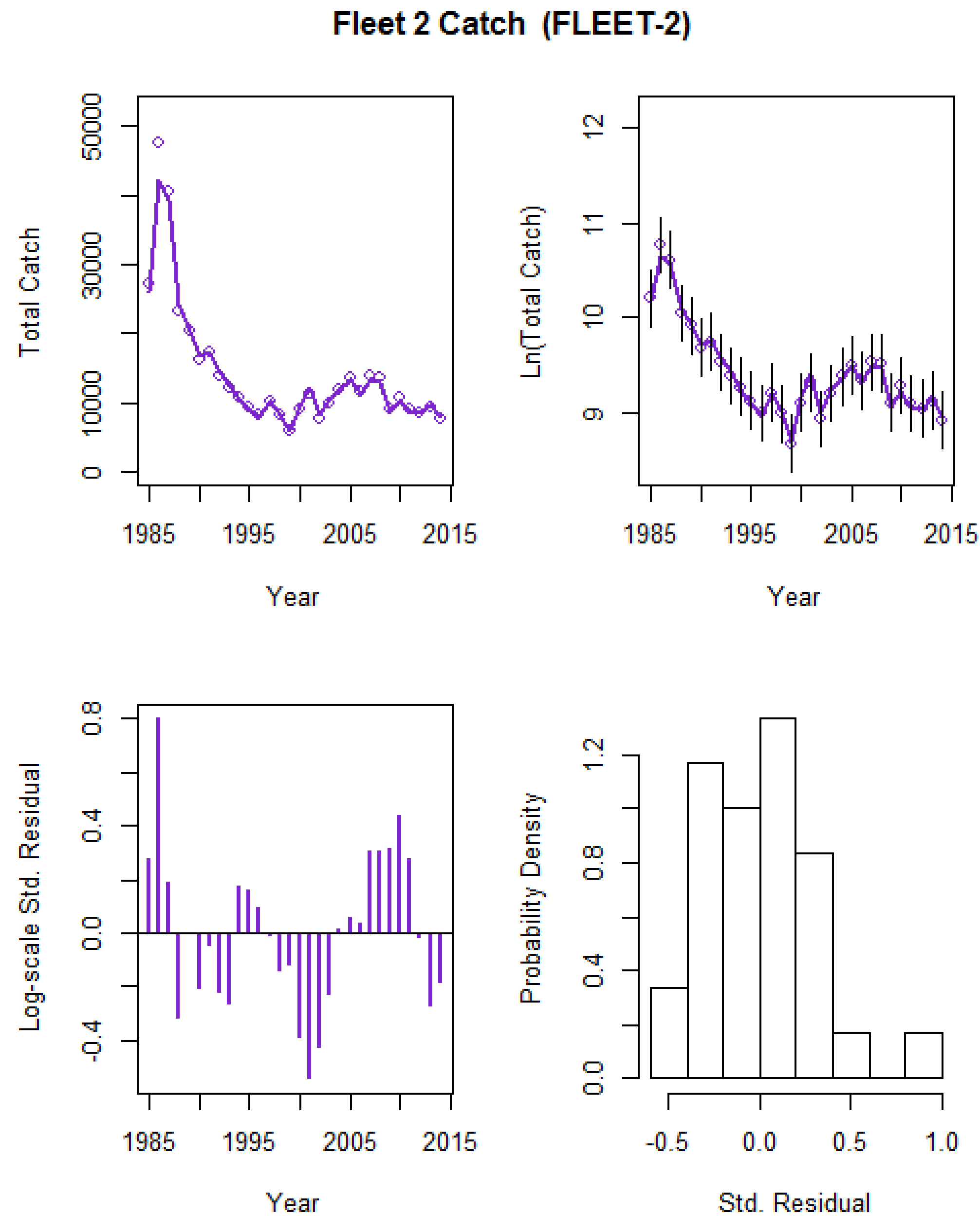
F Scenario	Landings (mt)			Total Biomass (mt)			P (2018) > Bthreshold
	2016	2017	2018	2016	2017	2018	
FMSY = 0.181	12,752	12,332	12,420	114,731	112,758	111,347	1.00
Ftarget = 0.163	11,552	11,306	11,512	114,731	114,010	113,818	1.00
F2014 = 0.136	9,725	9,691	10,031	114,731	115,922	117,645	1.00
Flow = 0.100	7,236	7,388	7,817	114,731	118,530	122,966	1.00
F0.1 = 0.203	14,200	13,531	13,452	114,731	111,240	108,405	1.00

(NOTE: The values presented in this Appendix B7 reflect the output from the early model presented in the draft WP document and at the peer review, before final revision. For the final SAW/SARC60 assessment results, readers should see the main body of the bluefish report.)

App. B7 Table B10.2. Sensitivity analysis for short-term projections for bluefish

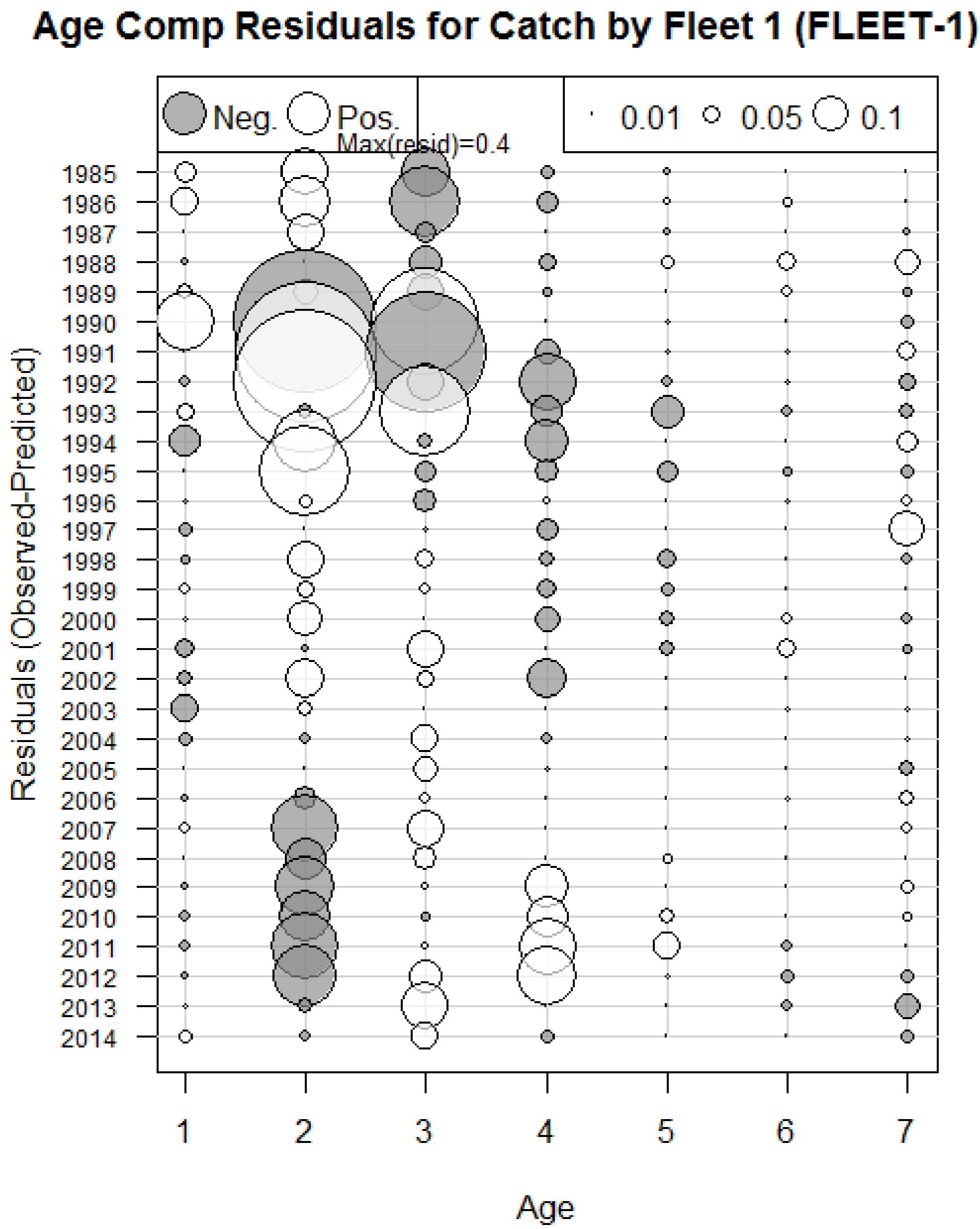
	Landings (mt)			Total Biomass (mt)		
F = Fmsy	2016	2017	2018	2016	2017	2018
Base model	12,752	12,332	12,420	114,731	112,758	111,347
Increased CVs	12,984	12,599	12,615	114,699	112,497	110,765
M=0.26	18,122	16,513	15,891	147,636	137,192	128,747
2006-2014 recruitment	12,743	12,279	12,313	114,670	112,483	110,758
High rec landings	13,285	12,902	13,038	120,611	118,971	117,867
Low rec landings	11,500	11,104	11,271	108,055	106,100	104,870
Continuity model	12,641	12,055	11,641	90,271	86,258	84,003
F = F 2014	2016	2017	2018	2016	2017	2018
Base model	9,725	9,691	10,031	114,731	115,922	117,645
Increased CVs	9,904	9,905	10,198	114,699	115,712	117,161
M=0.26	9,187	8,969	9,166	147,636	146,276	146,042
2006-2014 recruitment	9,717	9,651	9,944	114,670	115,645	117,029
High rec landings	10,668	10,624	10,980	120,611	121,710	123,335
Low rec landings	7,899	7,927	8,333	108,055	109,868	112,427
Continuity model	10,006	9,846	9,747	90,271	88,955	89,055

(NOTE: The values presented in this Appendix B7 reflect the output from the early model presented in the draft WP document and at the peer review, before final revision. For the final SAW/SARC60 assessment results, readers should see the main body of the bluefish report.)

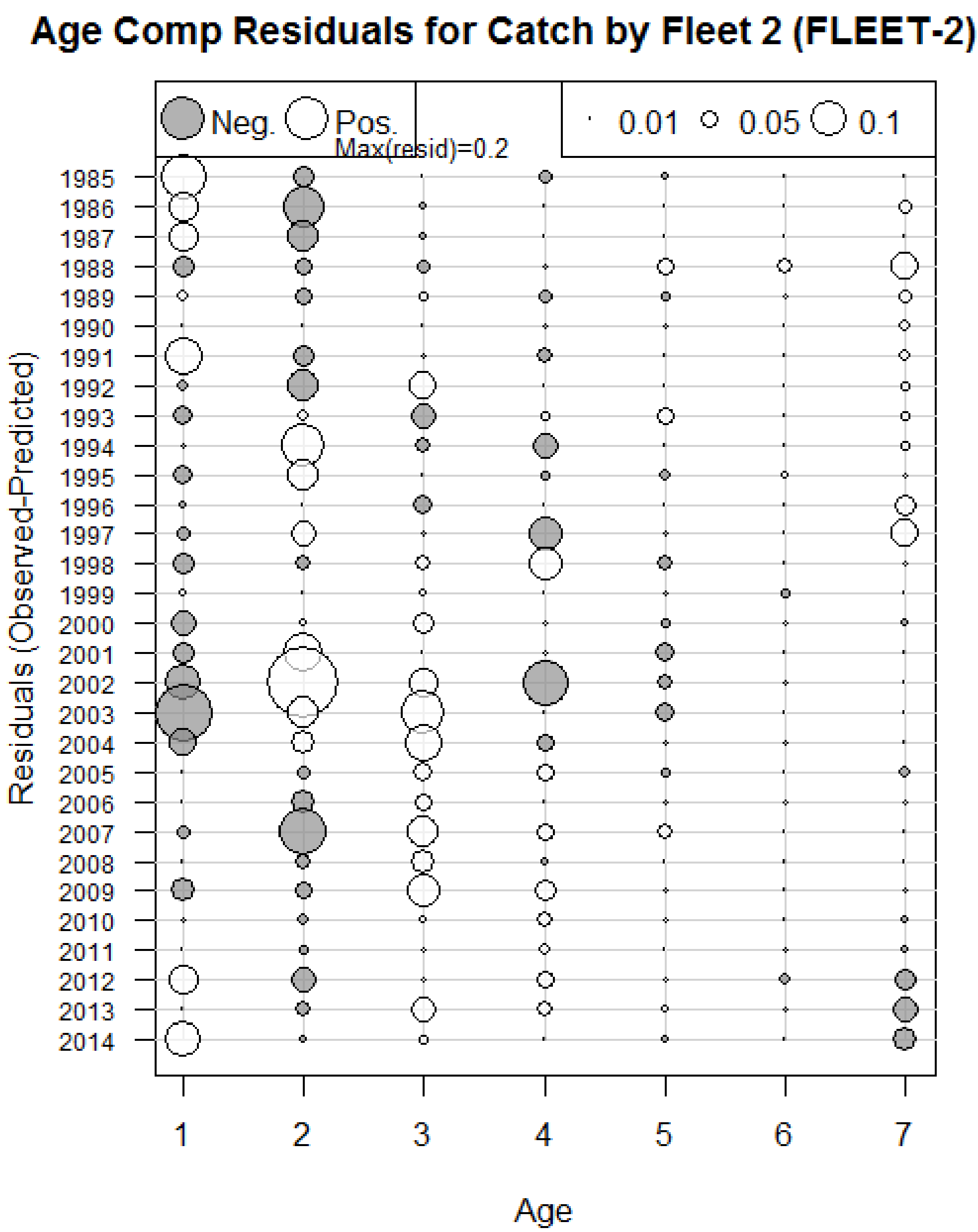


App. B7 App. B7 Figure B7.45. Final model fit to the recreational catch fleet with log-scale standardized residuals and residual probability density.

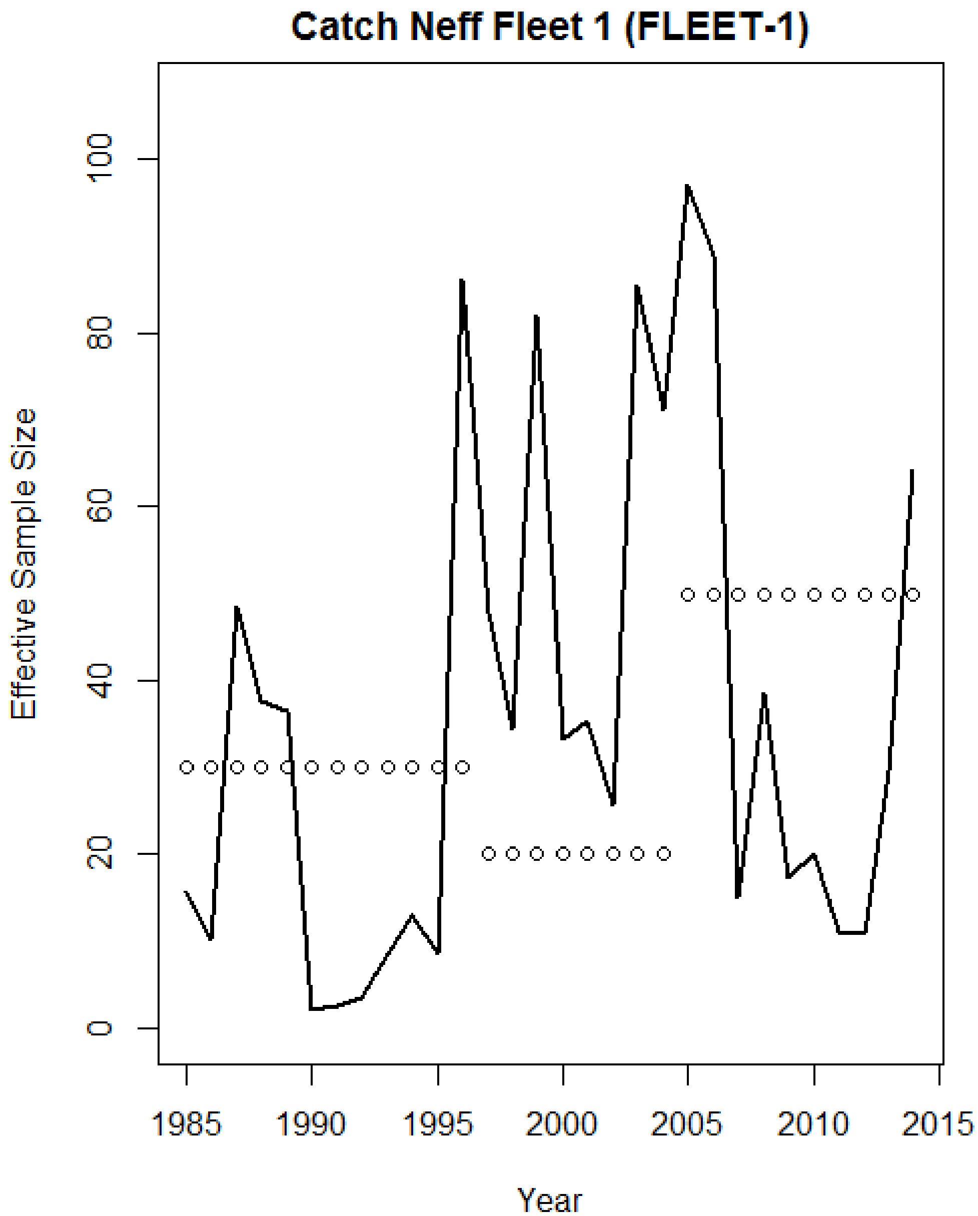
(NOTE: The values presented in this Appendix B7 reflect the output from the early model presented in the draft WP document and at the peer review, before final revision. For the final SAW/SARC60 assessment results, readers should see the main body of the bluefish report.)



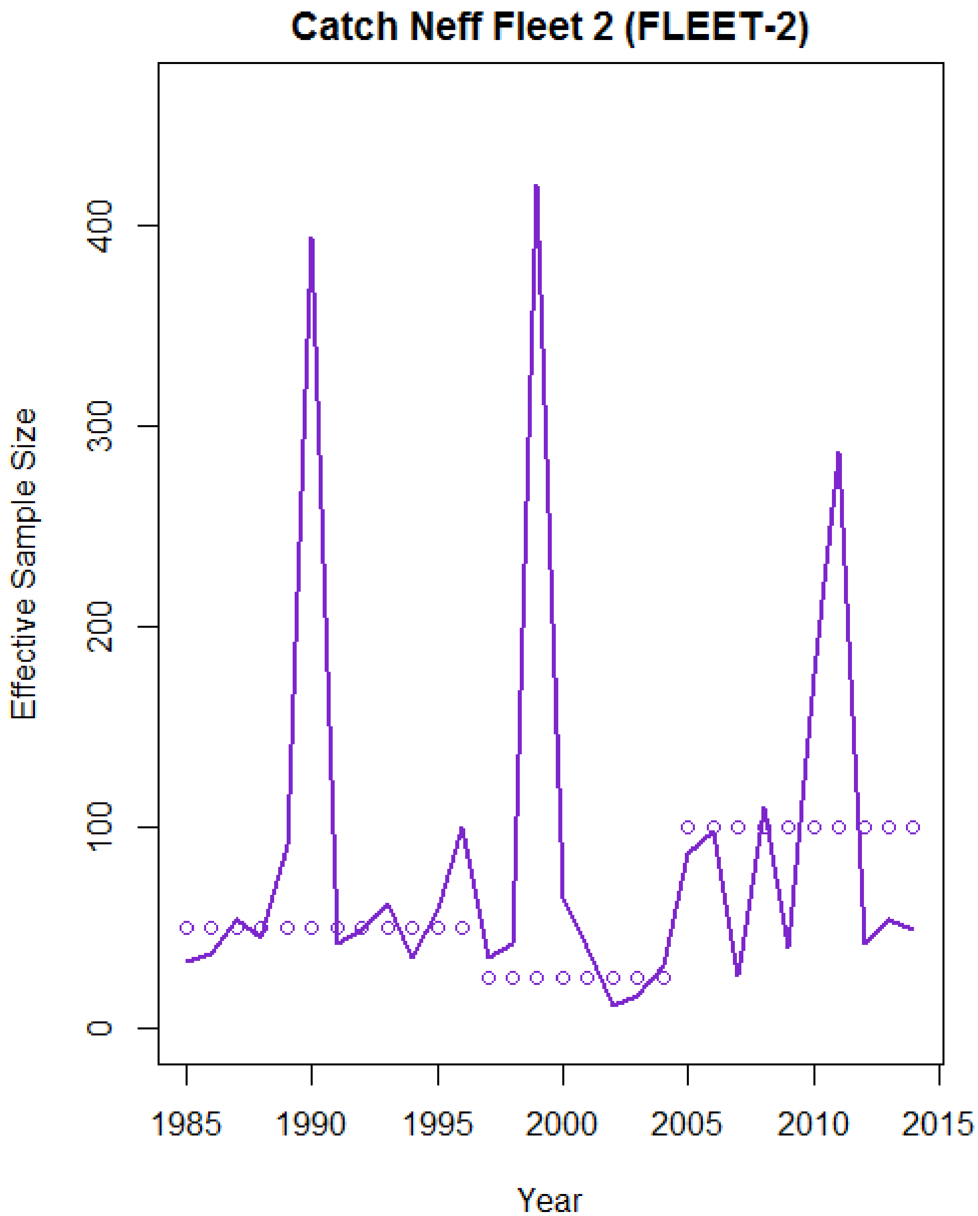
App. B7 Figure B7.46. Age-composition residuals for the commercial catch fleet.



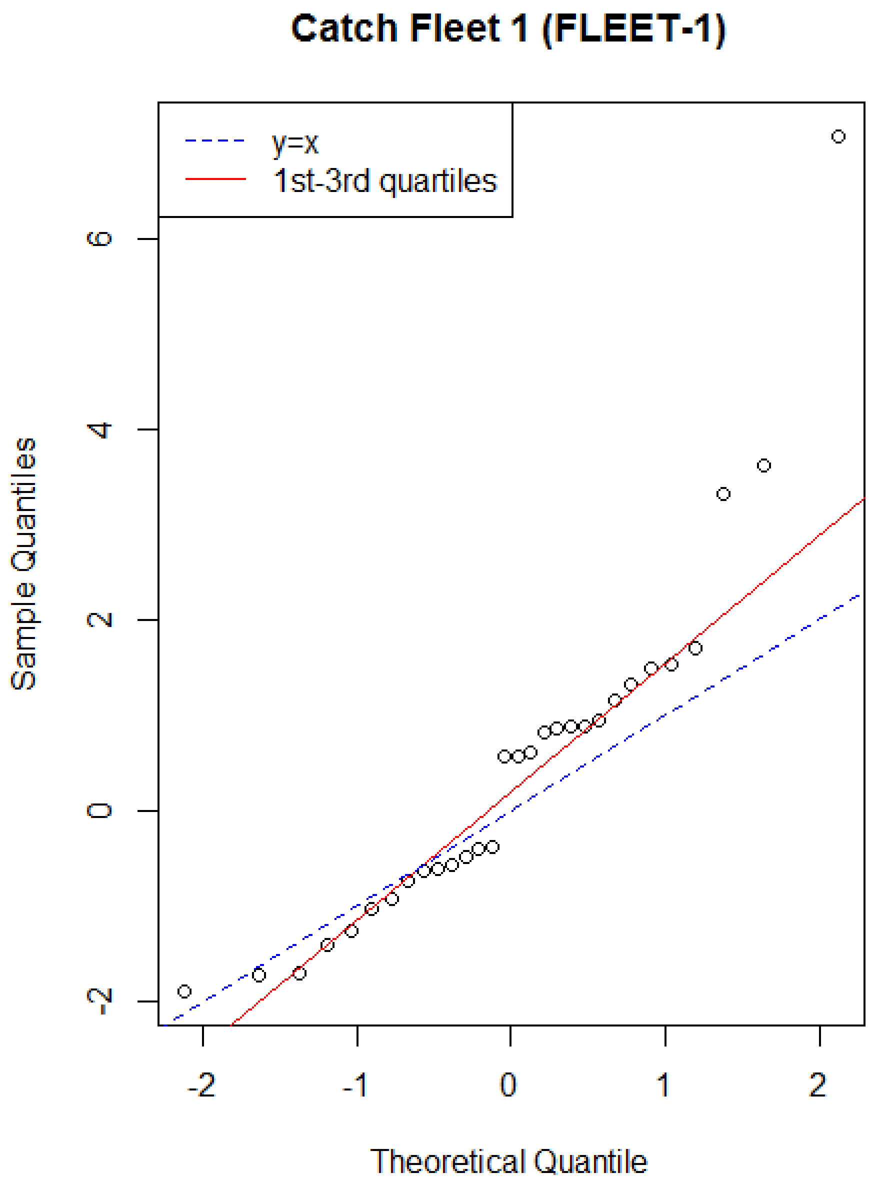
App. B7 Figure B7.47. Age composition residuals for the recreational catch fleet.



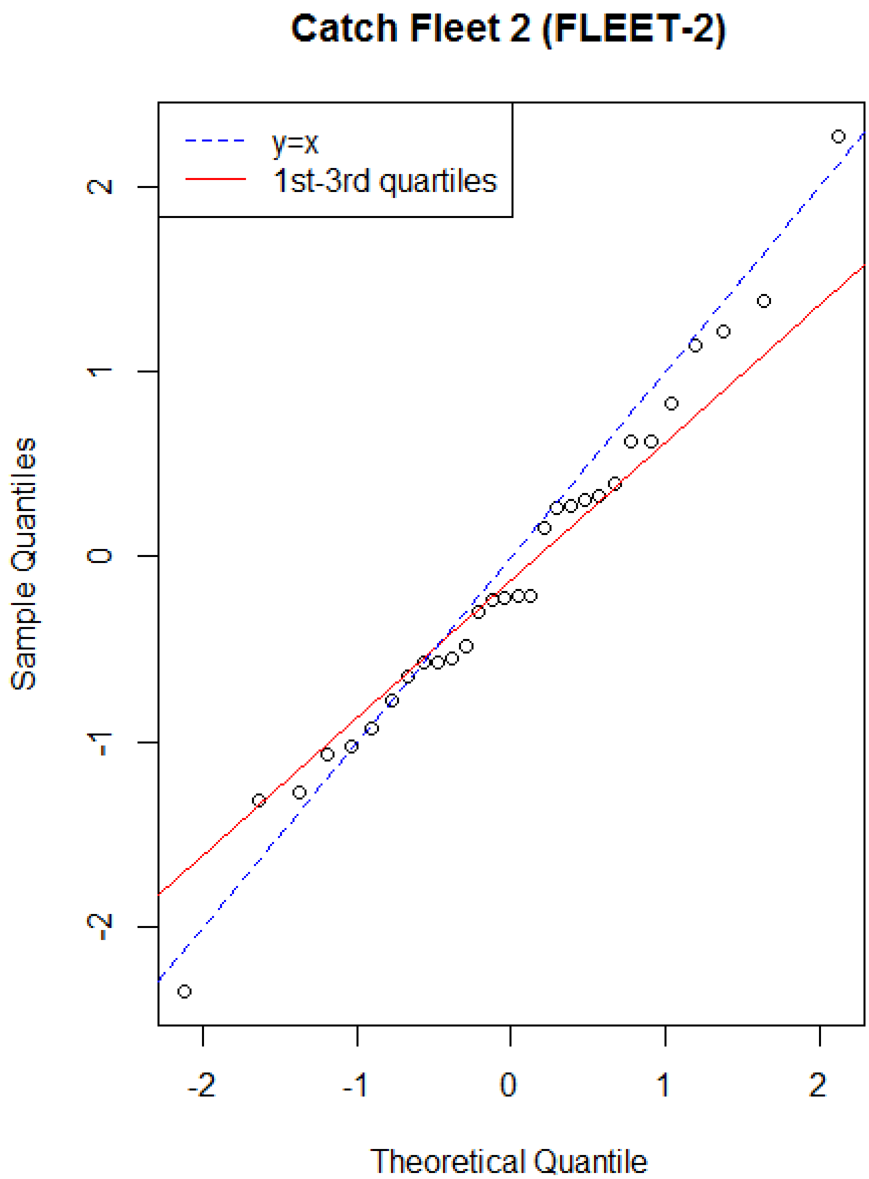
App. B7 Figure B7.48. Input and estimated effective sample size for the commercial catch fleet.



App. B7 Figure B7.49. Input and estimated effective sample size for the recreational catch fleet.

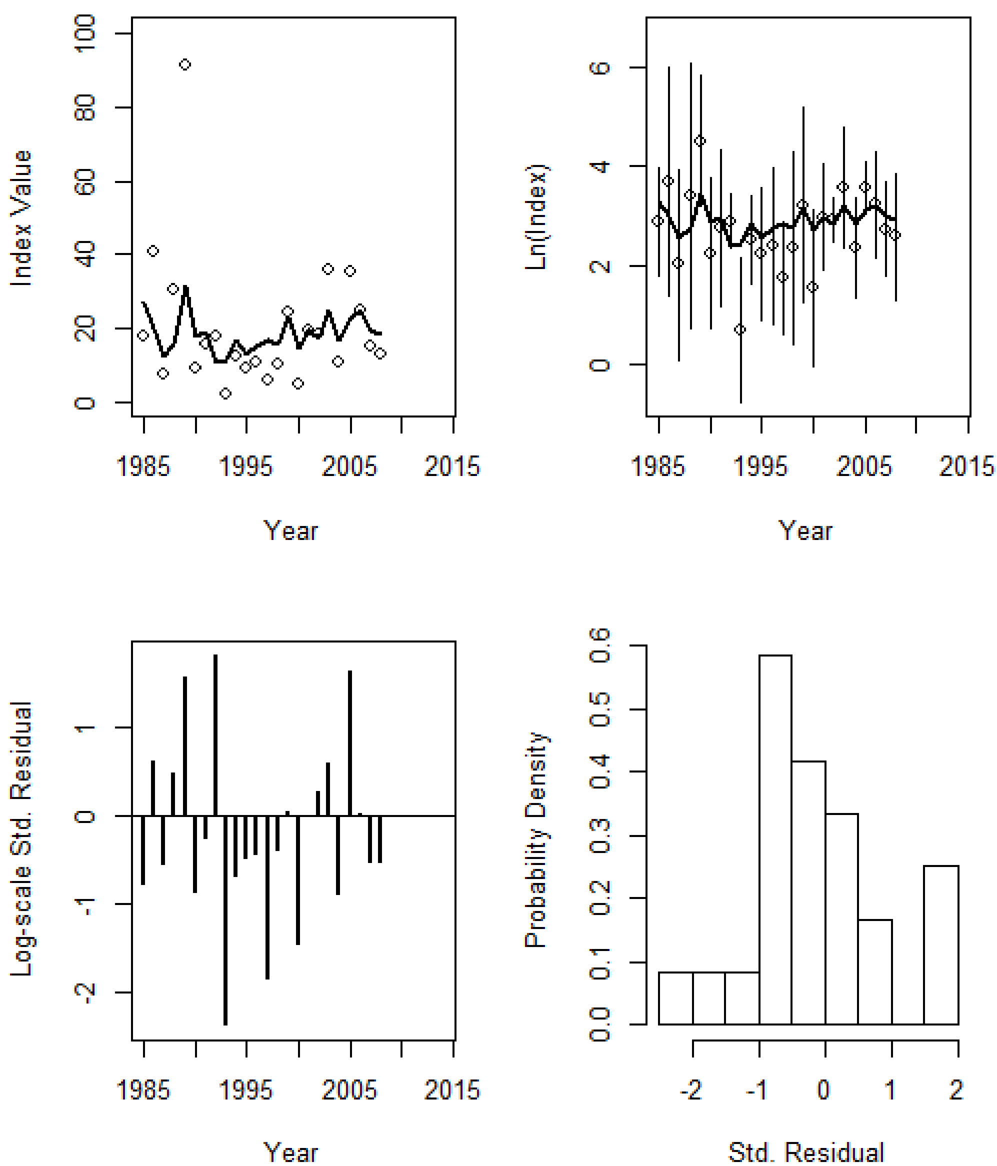


App. B7 Figure B7.50. QQ-plot for the observed versus predicted mean catch for the commercial catch fleet.

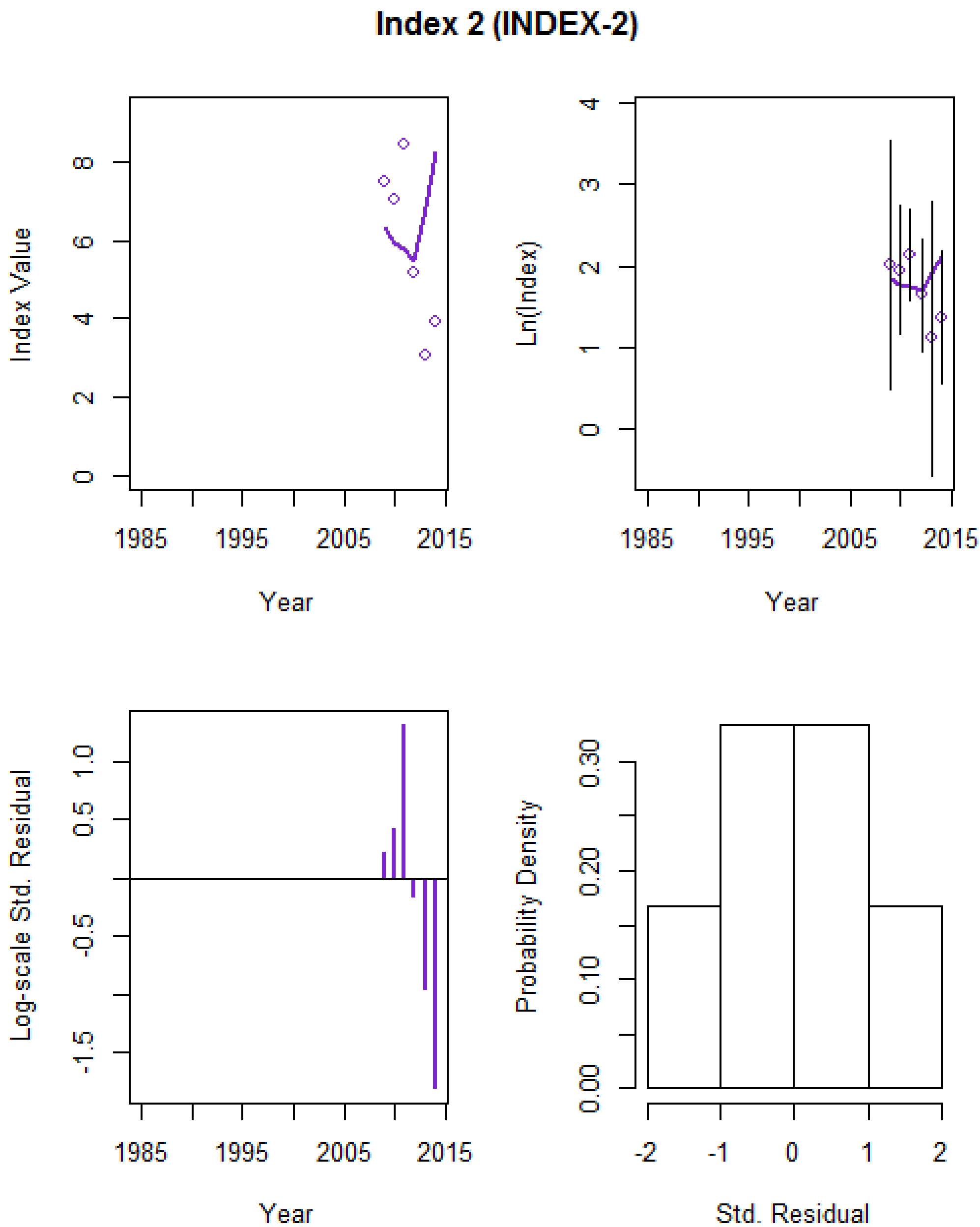


App. B7 Figure B7.51. QQ-plot for the observed versus predicted mean catch for the recreational catch fleet.

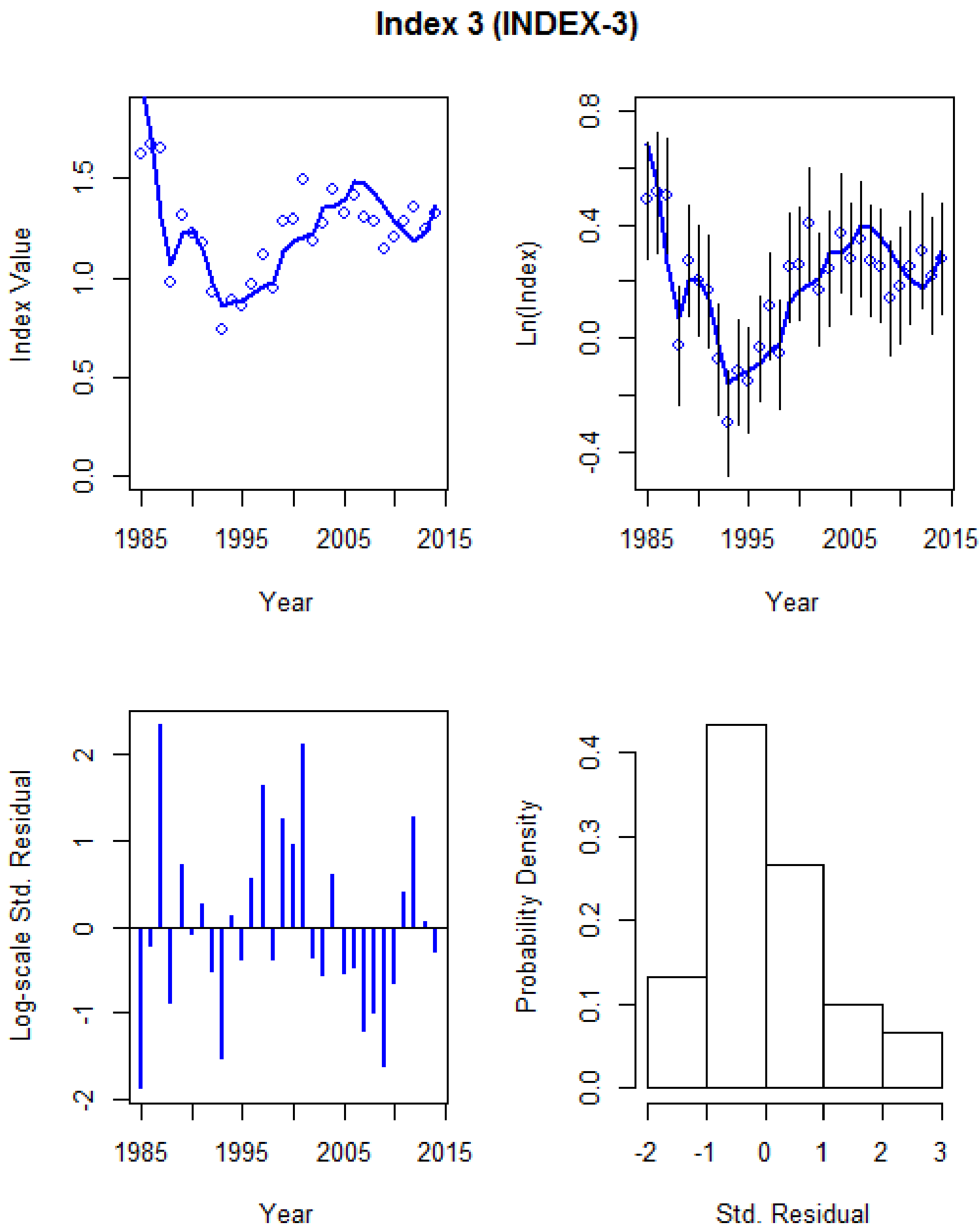
Index 1 (INDEX-1)



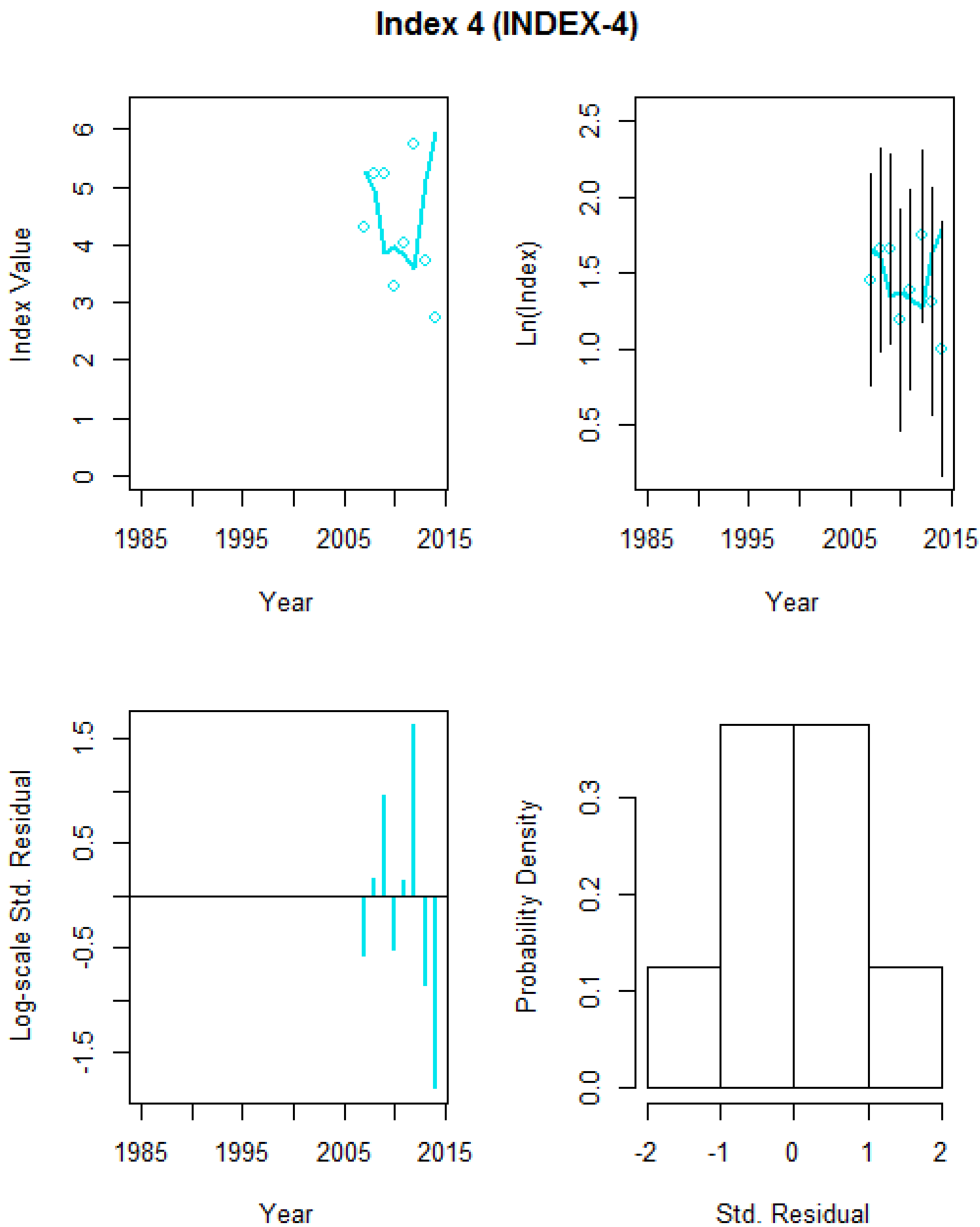
App. B7 Figure B7.52. Final model fit to the NEFSC Inshore survey with log-scale standardized residuals and residual probability density.



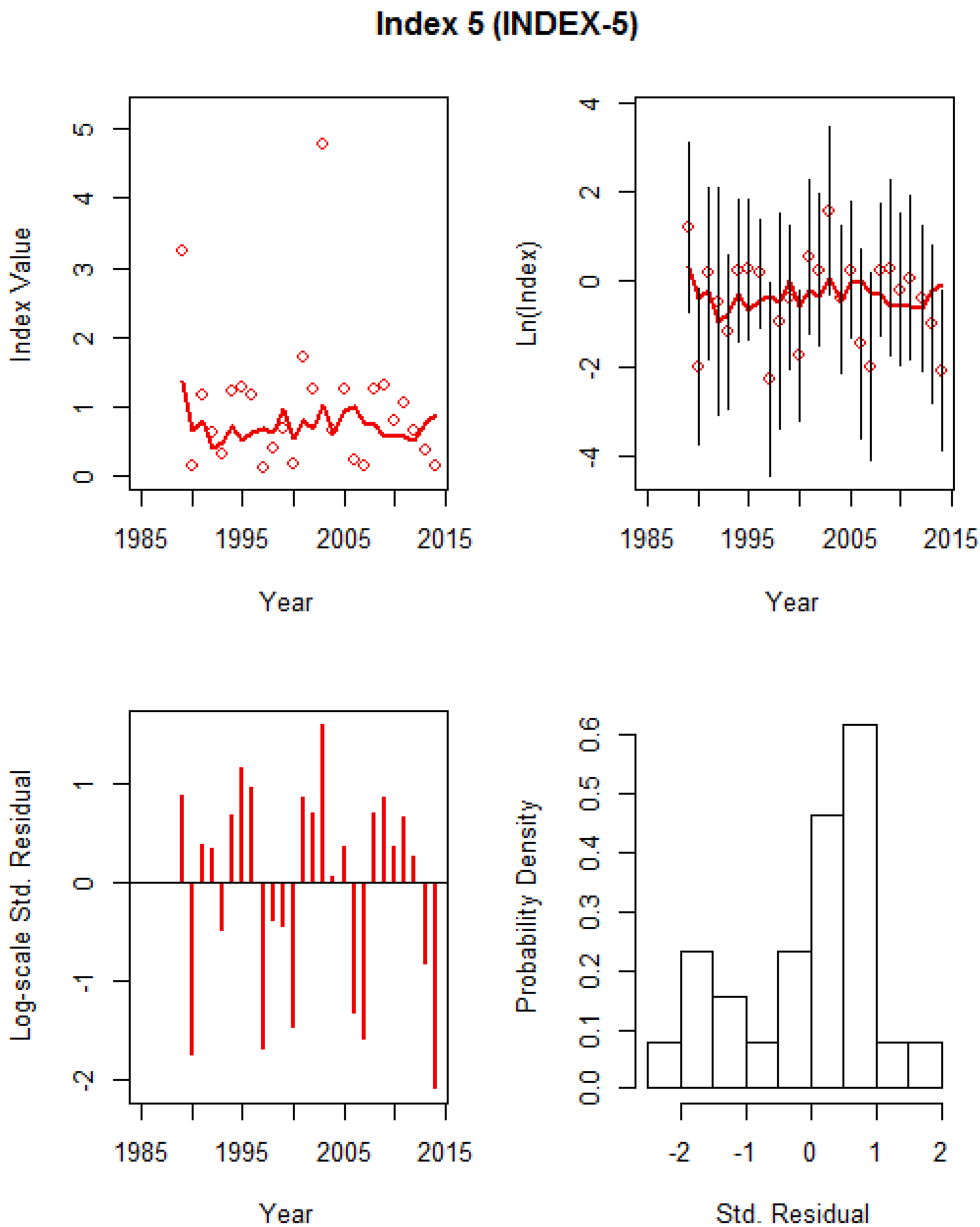
App. B7 Figure B7.53. Final model fit to the NEFSC Bigelow survey with log-scale standardized residuals and residual probability density.



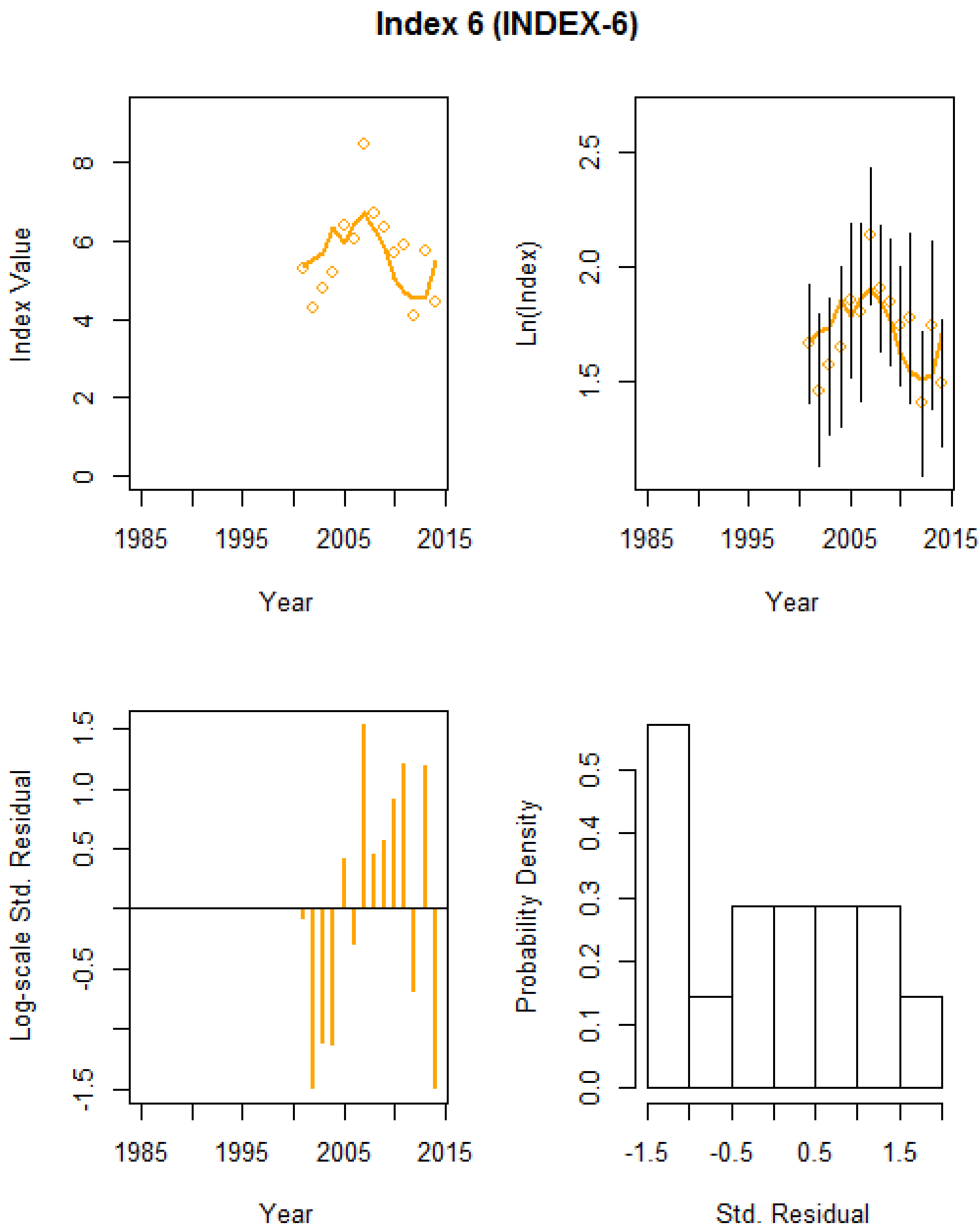
App. B7 Figure B7.54. Final model fit to the MRIP recreational CPUE index with log-scale standardized residuals and residual probability density.



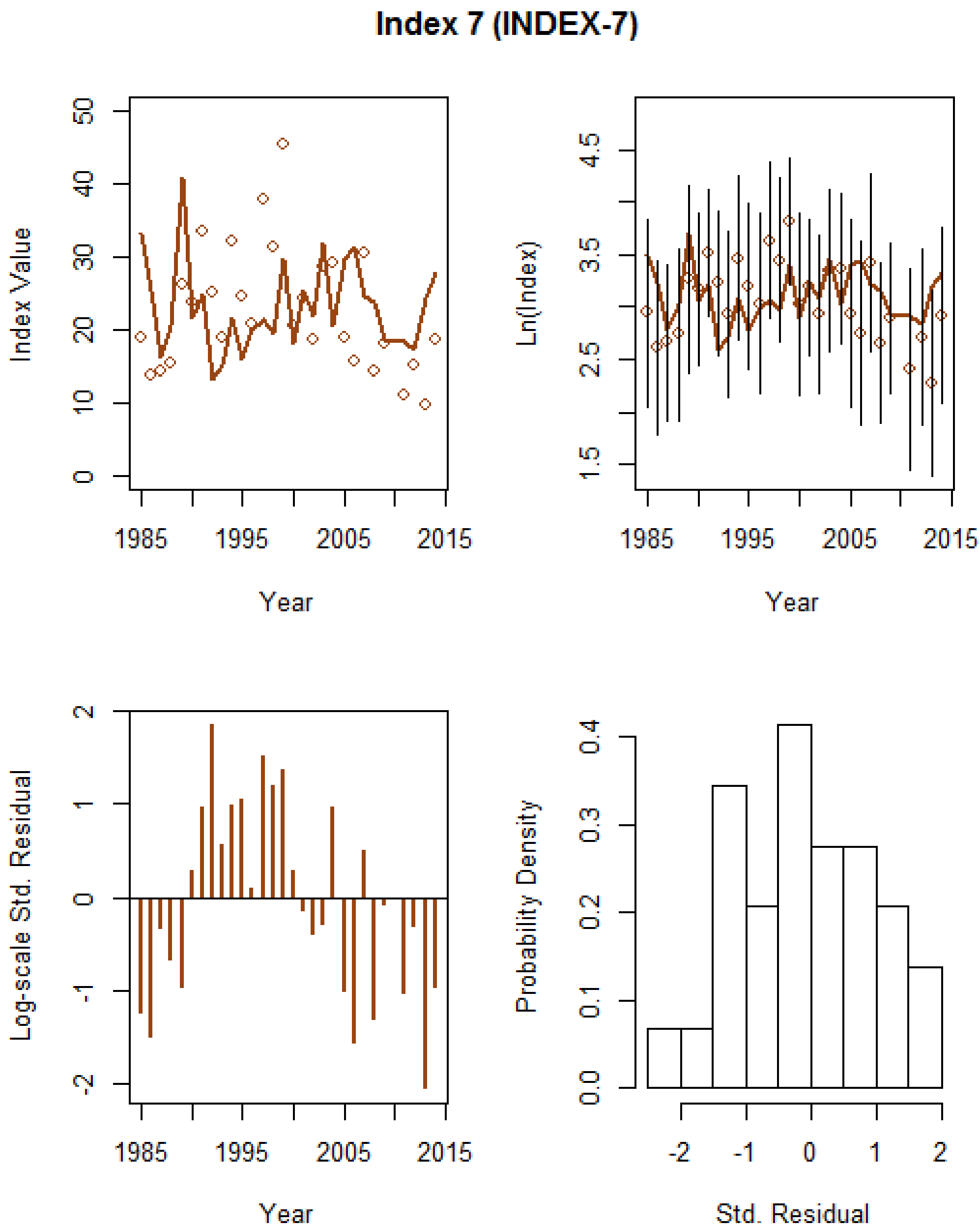
App. B7 Figure B7.55. Final model fit to the NEAMAP survey with log-scale standardized residuals and residual probability density.



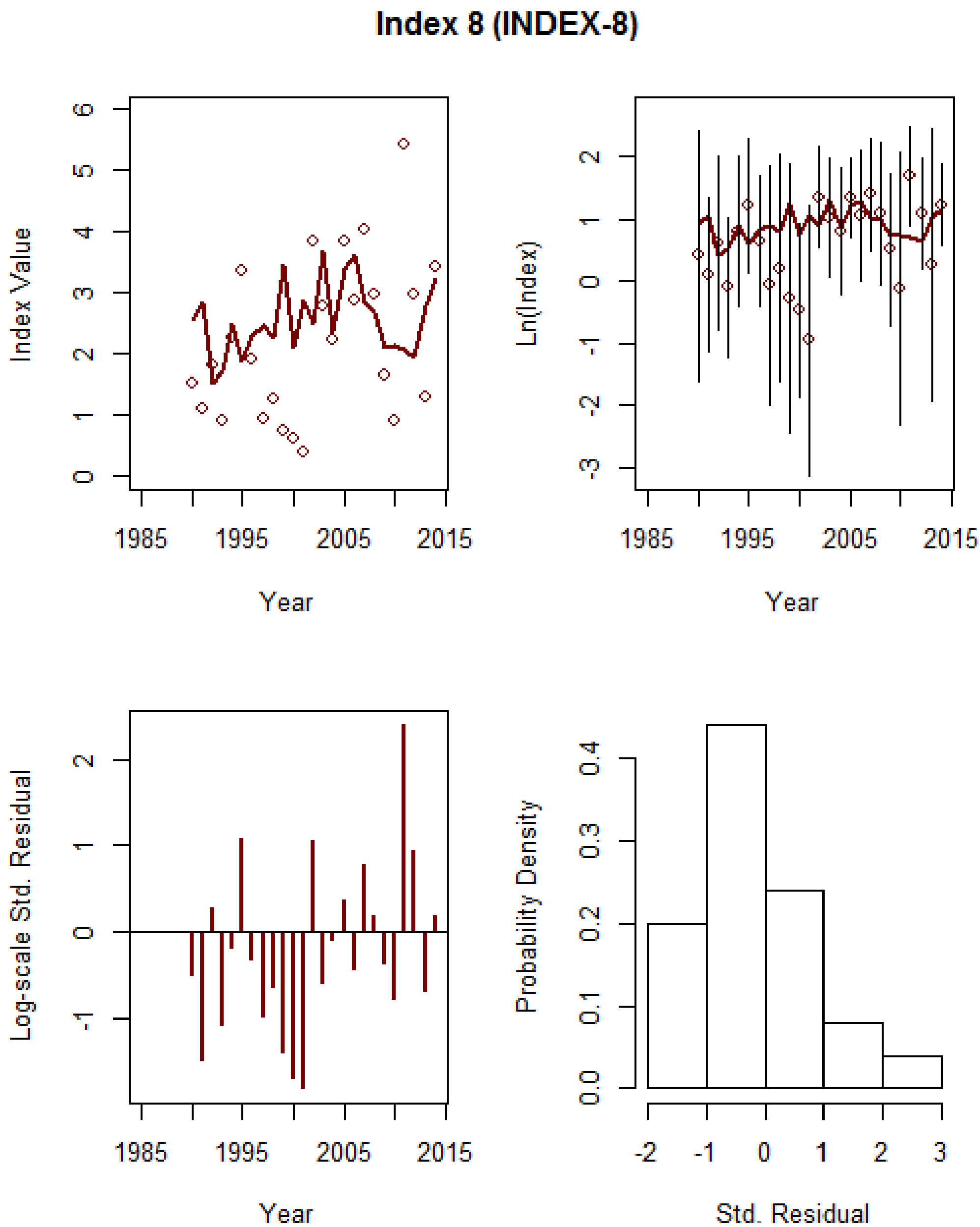
App. B7 Figure B7.56. Final model fit to the SEAMAP Age 0 index with log-scale standardized residuals and residual probability density.



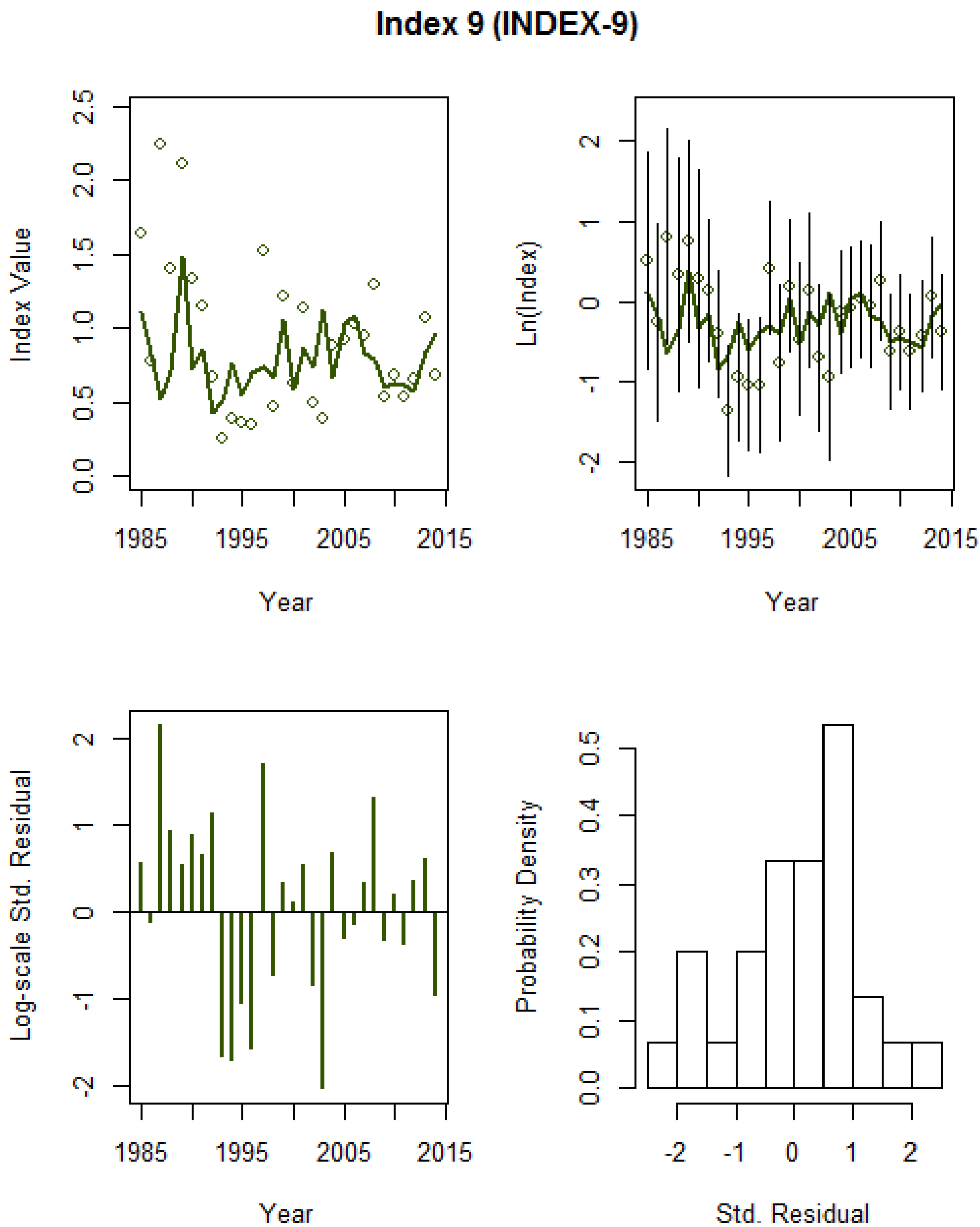
App. B7 Figure B7.57. Final model fit to the PSIGNS gillnet survey with log-scale standardized residuals and residual probability density.



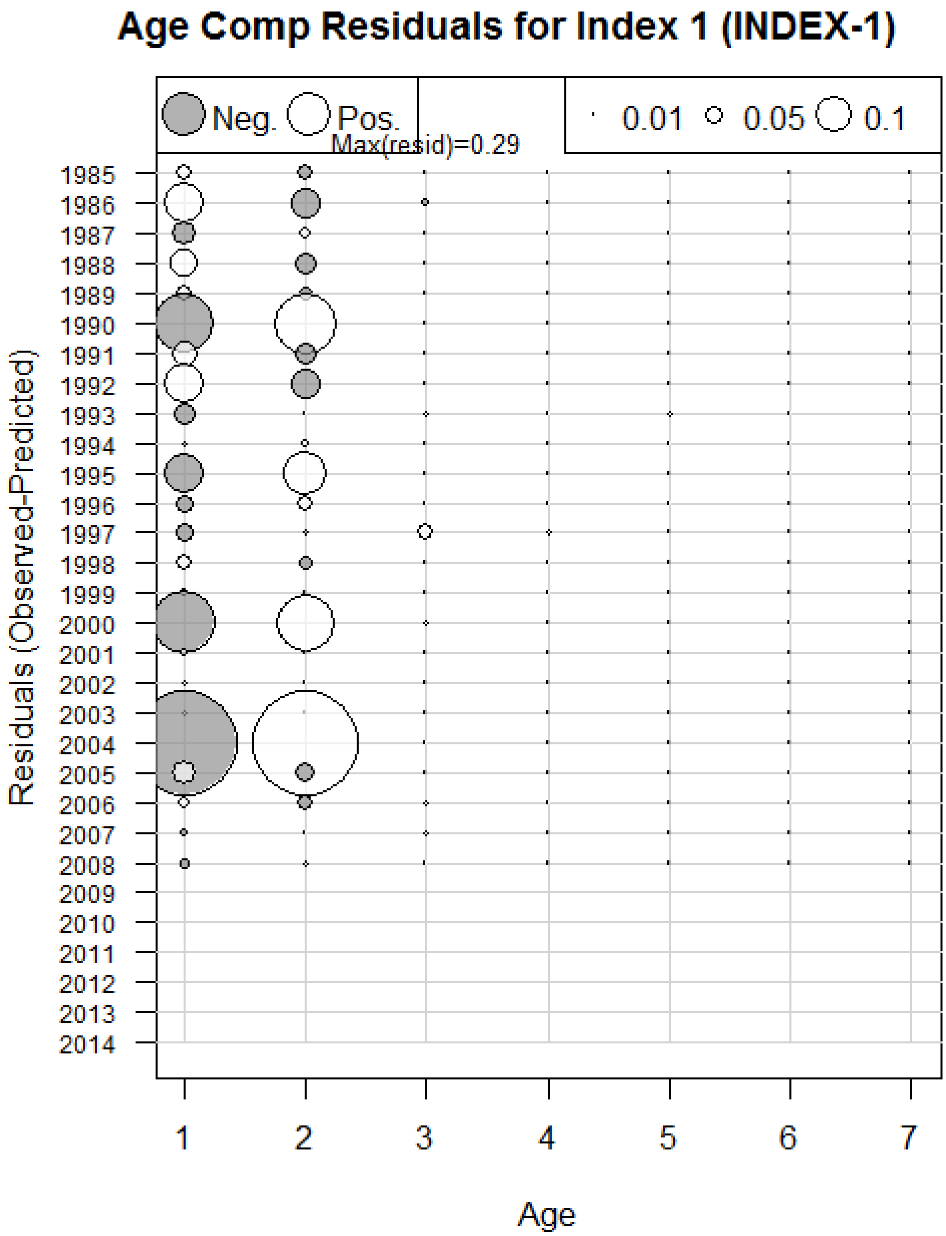
App. B7 Figure B7.58. Final model fit to the CT LISTS trawl survey with log-scale standardized residuals and residual probability density.



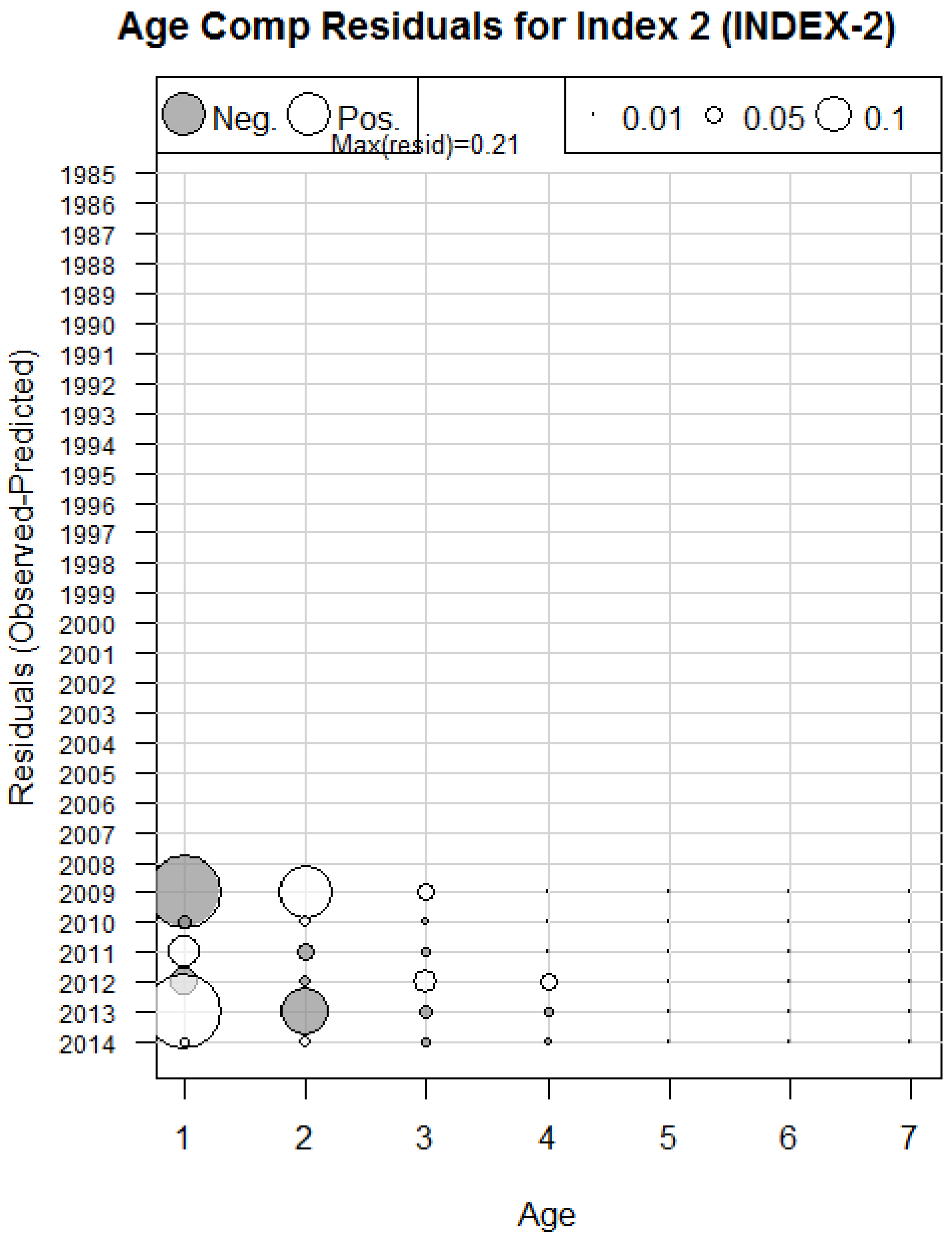
App. B7 Figure B7.59. Final model fit to the NJ ocean trawl survey with log-scale standardized residuals and residual probability density.



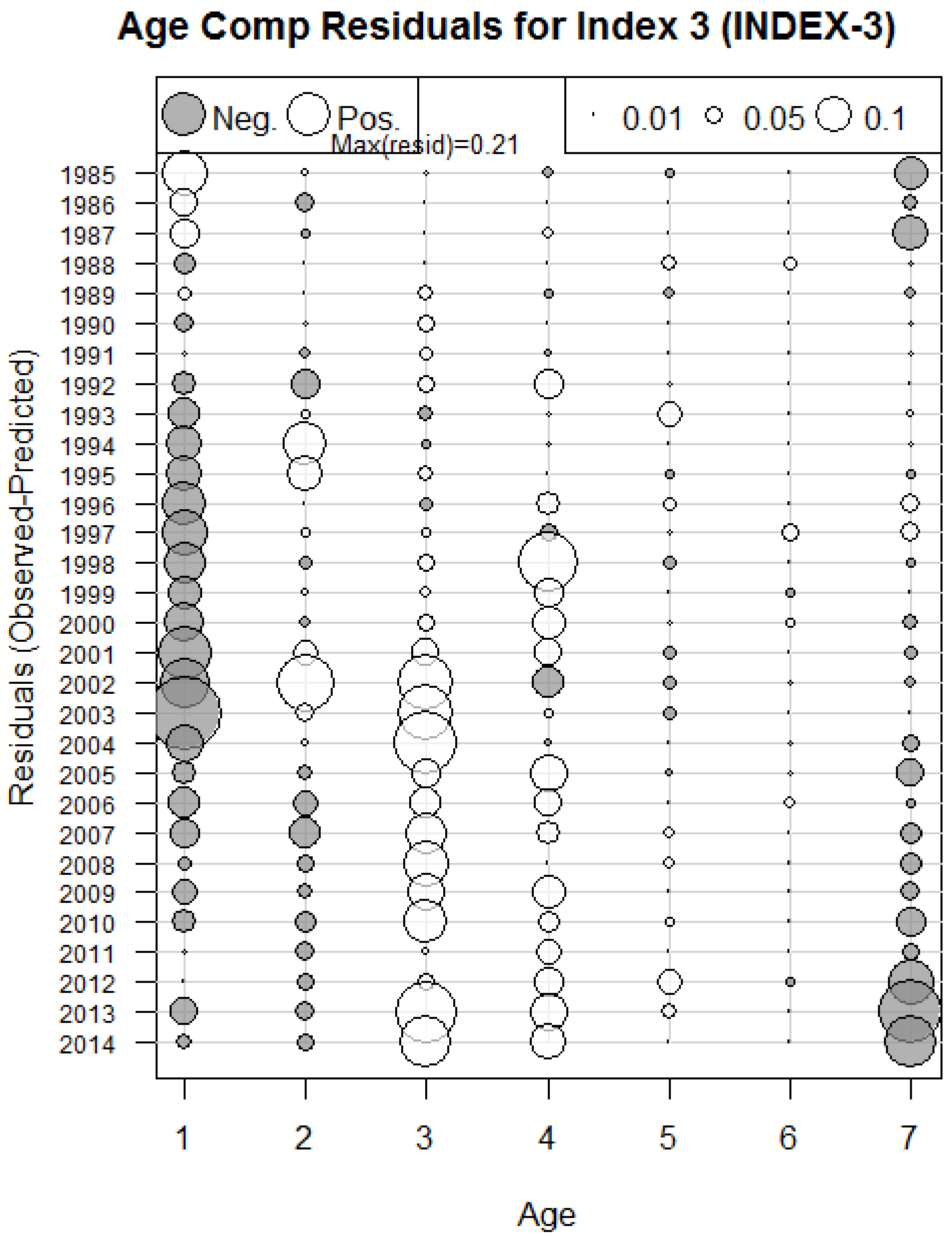
App. B7 Figure B7.60. Final model fit to the composite YOY seine survey with log-scale standardized residuals and residual probability density.



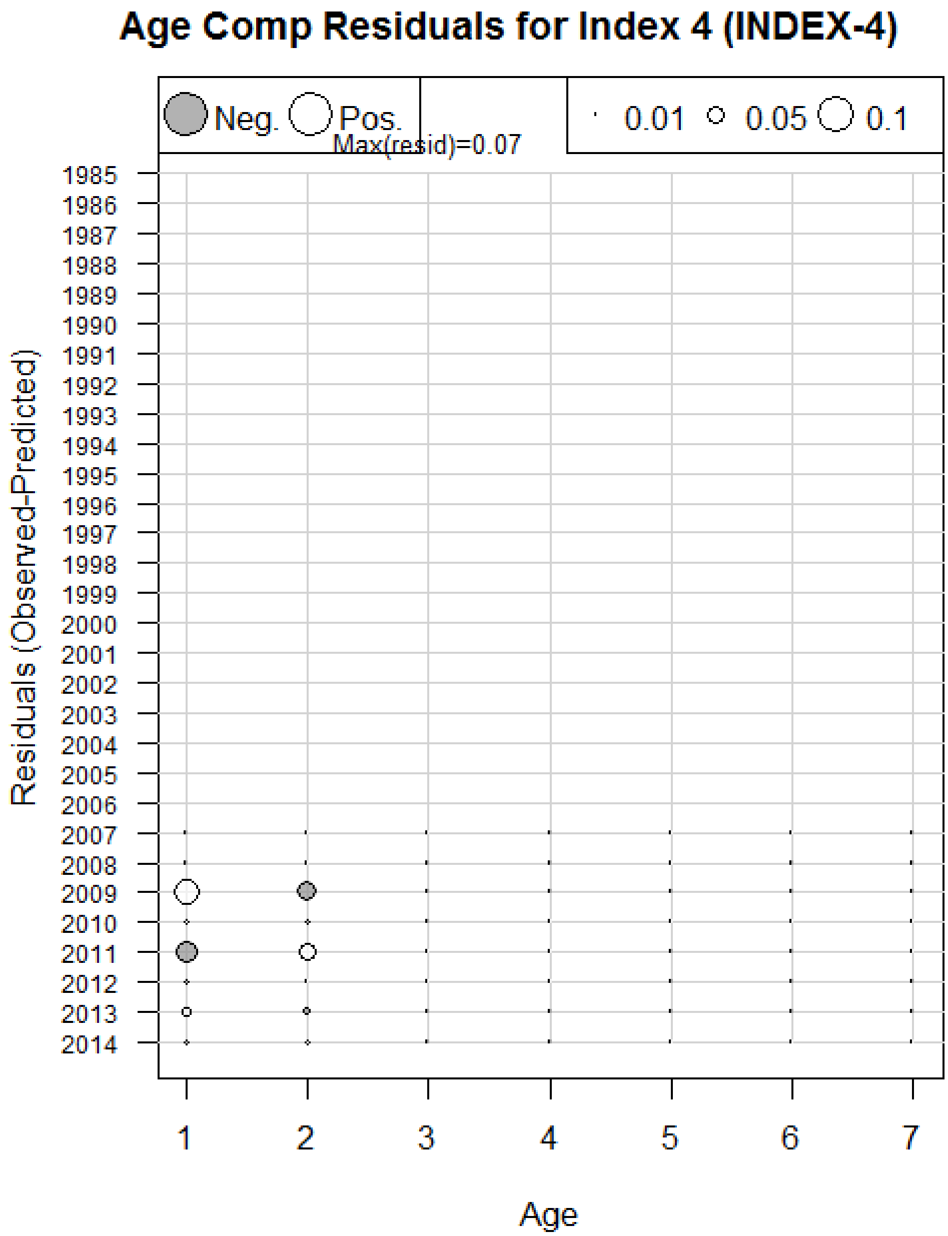
App. B7 Figure B7.61. Age composition residuals for the NEFSC Inshore survey.



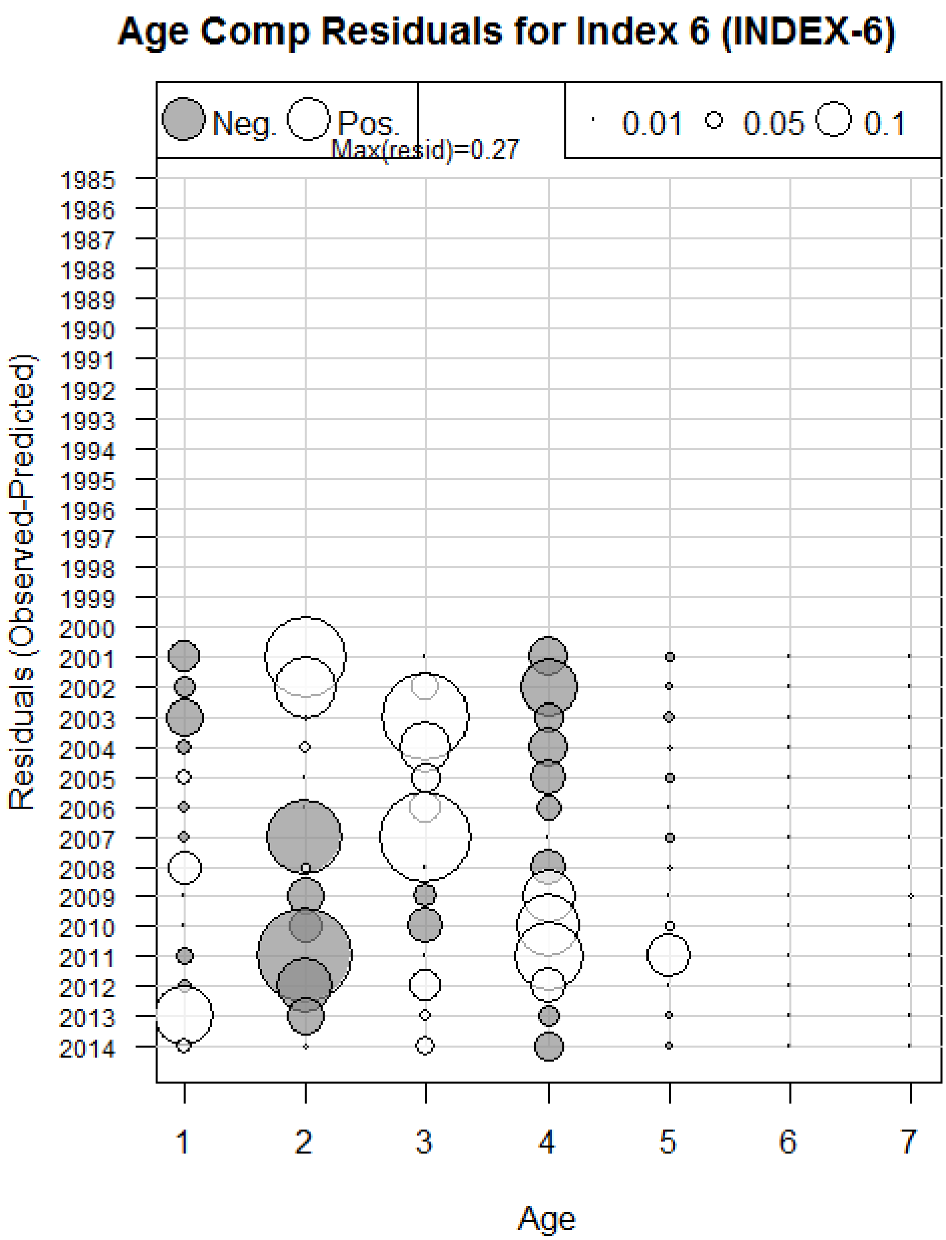
App. B7 Figure B7.62. Age composition residuals for the NEFSC Bigelow survey.



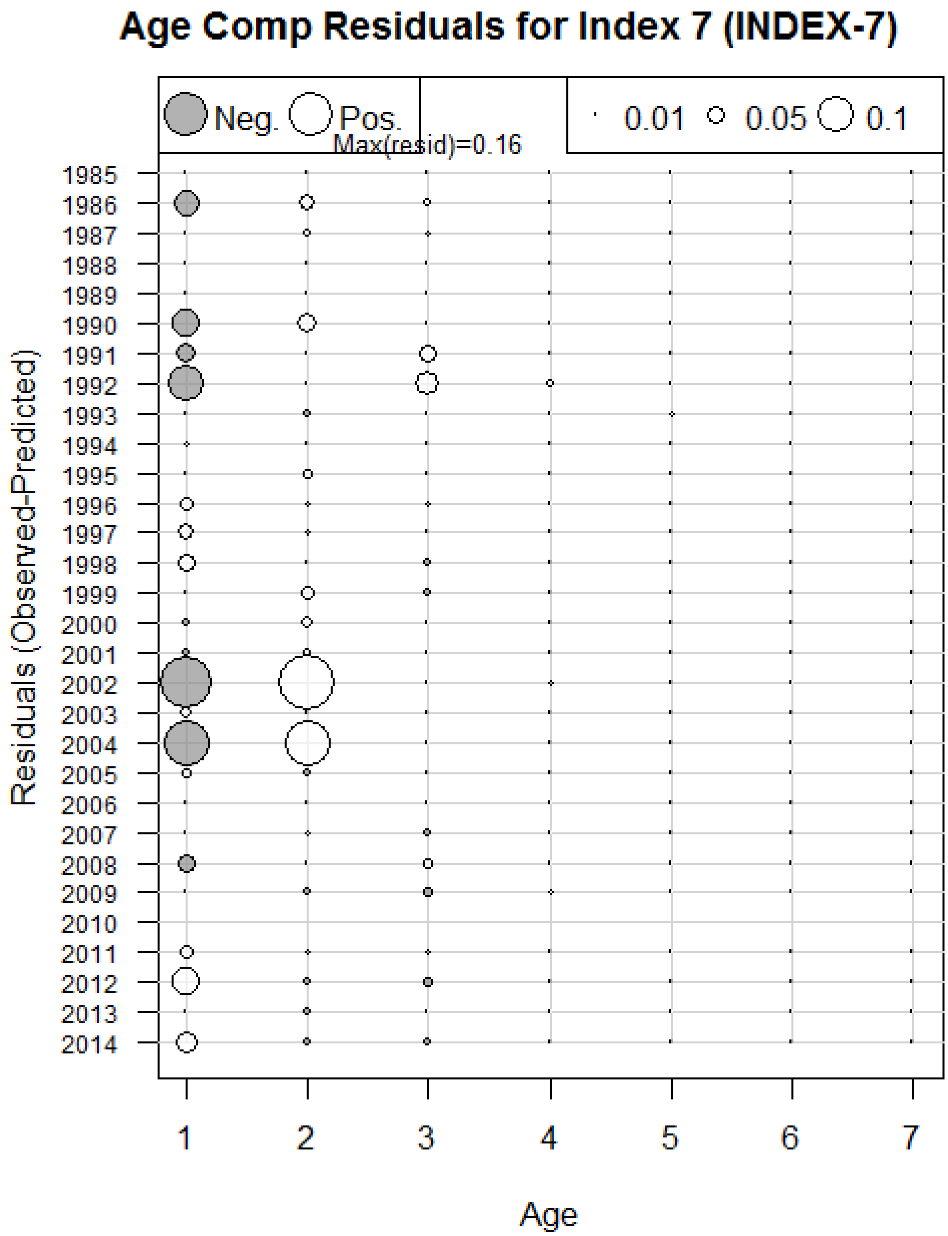
App. B7 Figure B7.63. Age composition residuals for the MRIP recreational CPUE index.



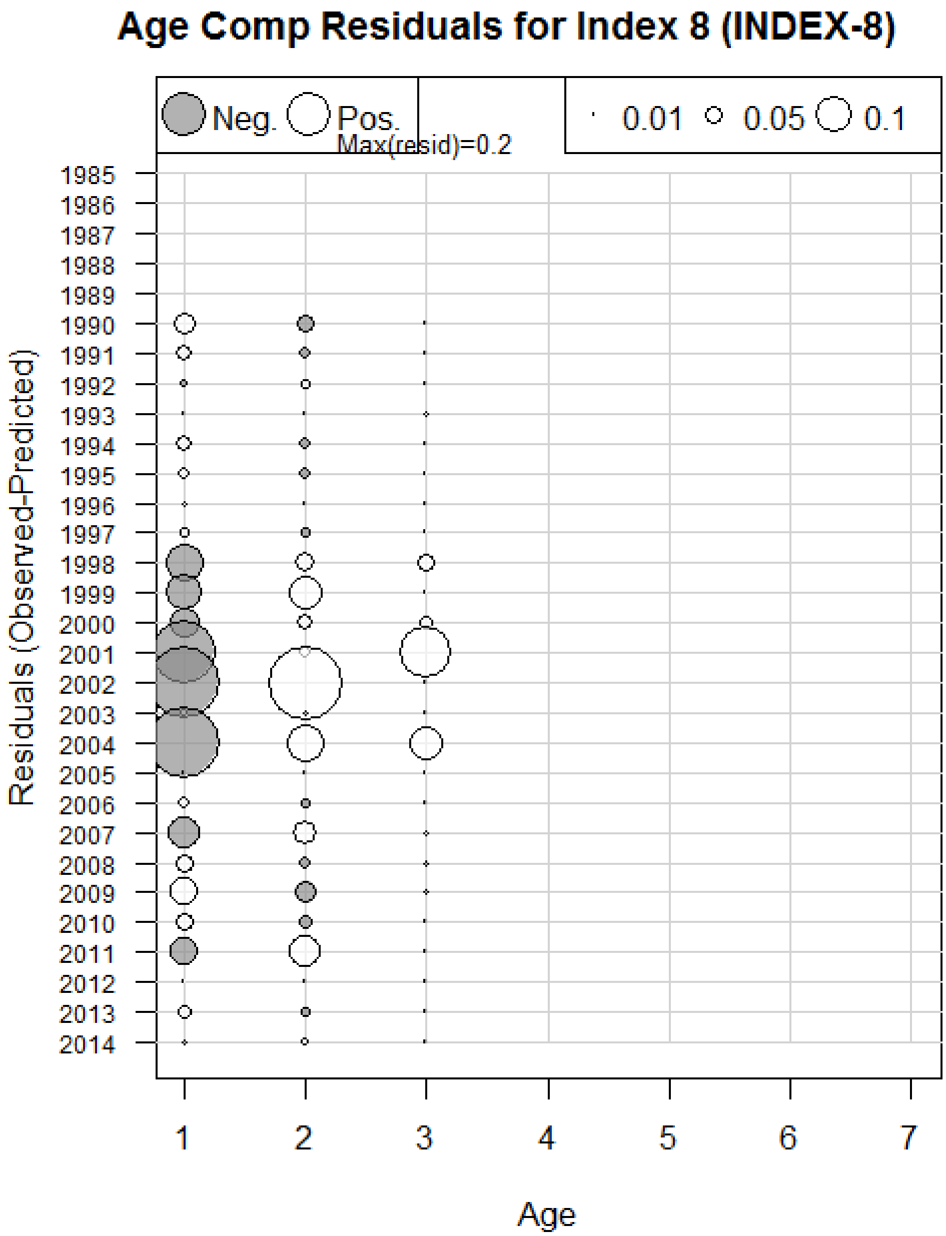
App. B7 Figure B7.64. Age composition residuals for the NEAMAP survey.



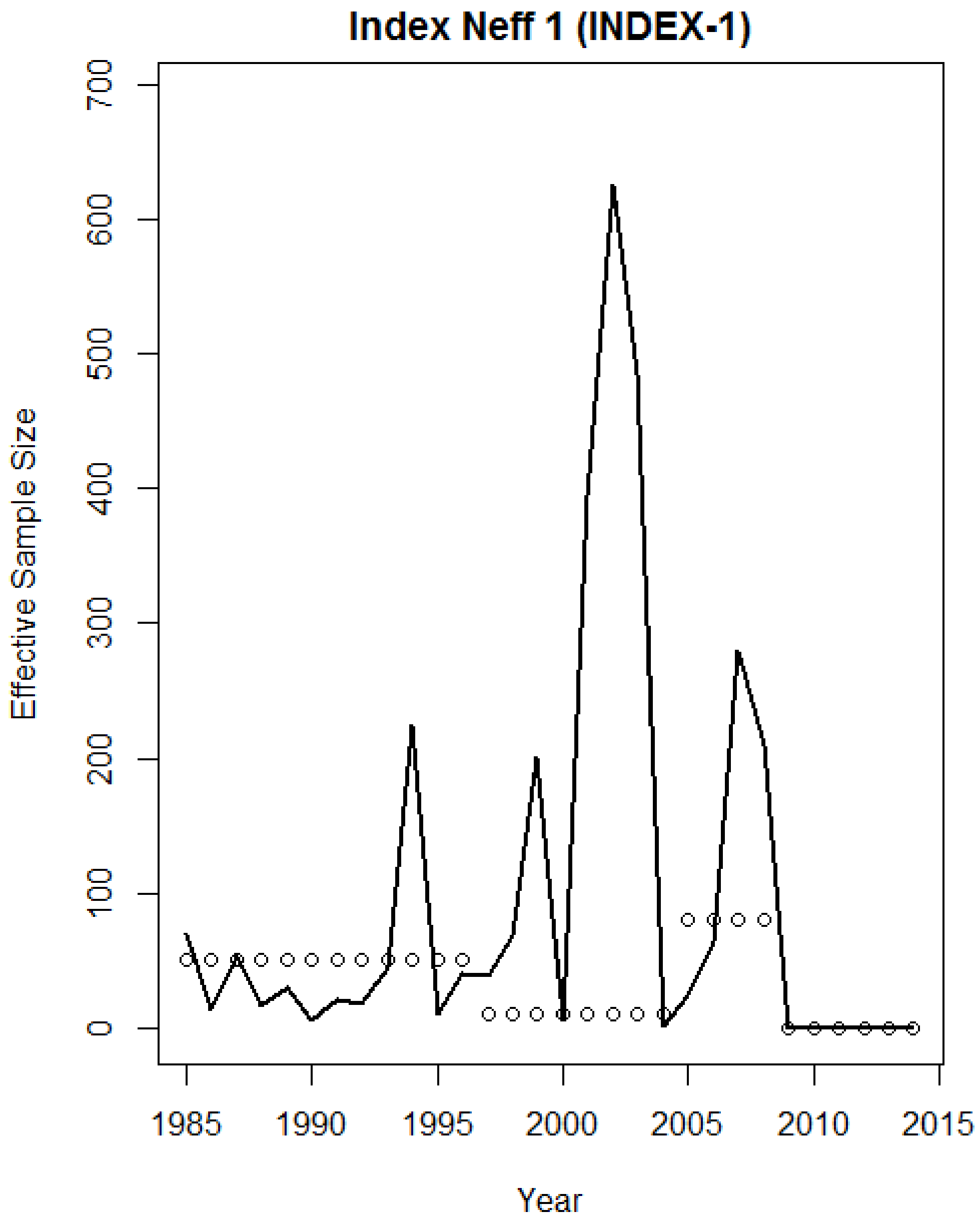
App. B7 Figure B7.65. Age composition residuals for the PSIGNS gillnet survey.



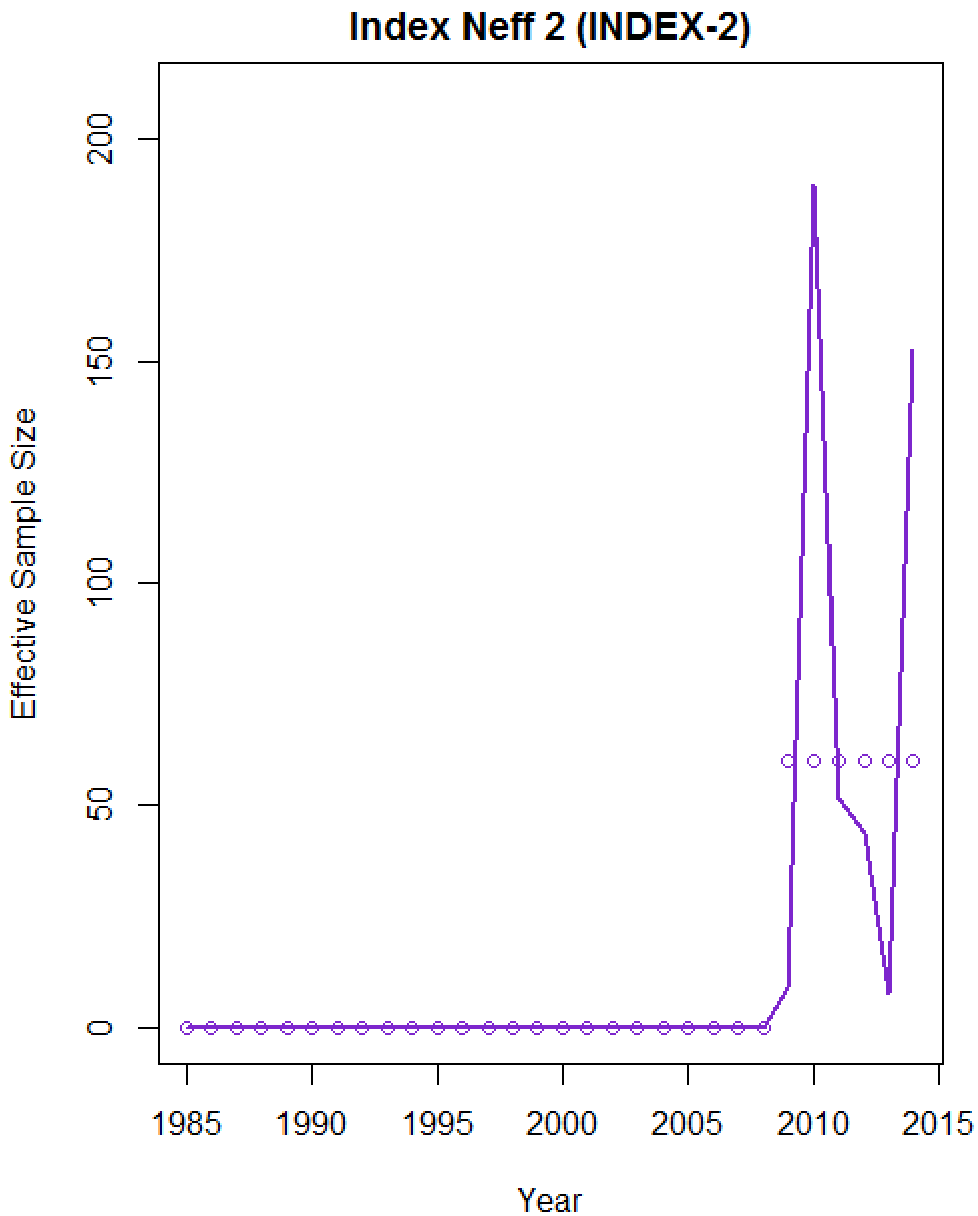
App. B7 Figure B7.66. Age composition residuals for the CT LISTS trawl survey.



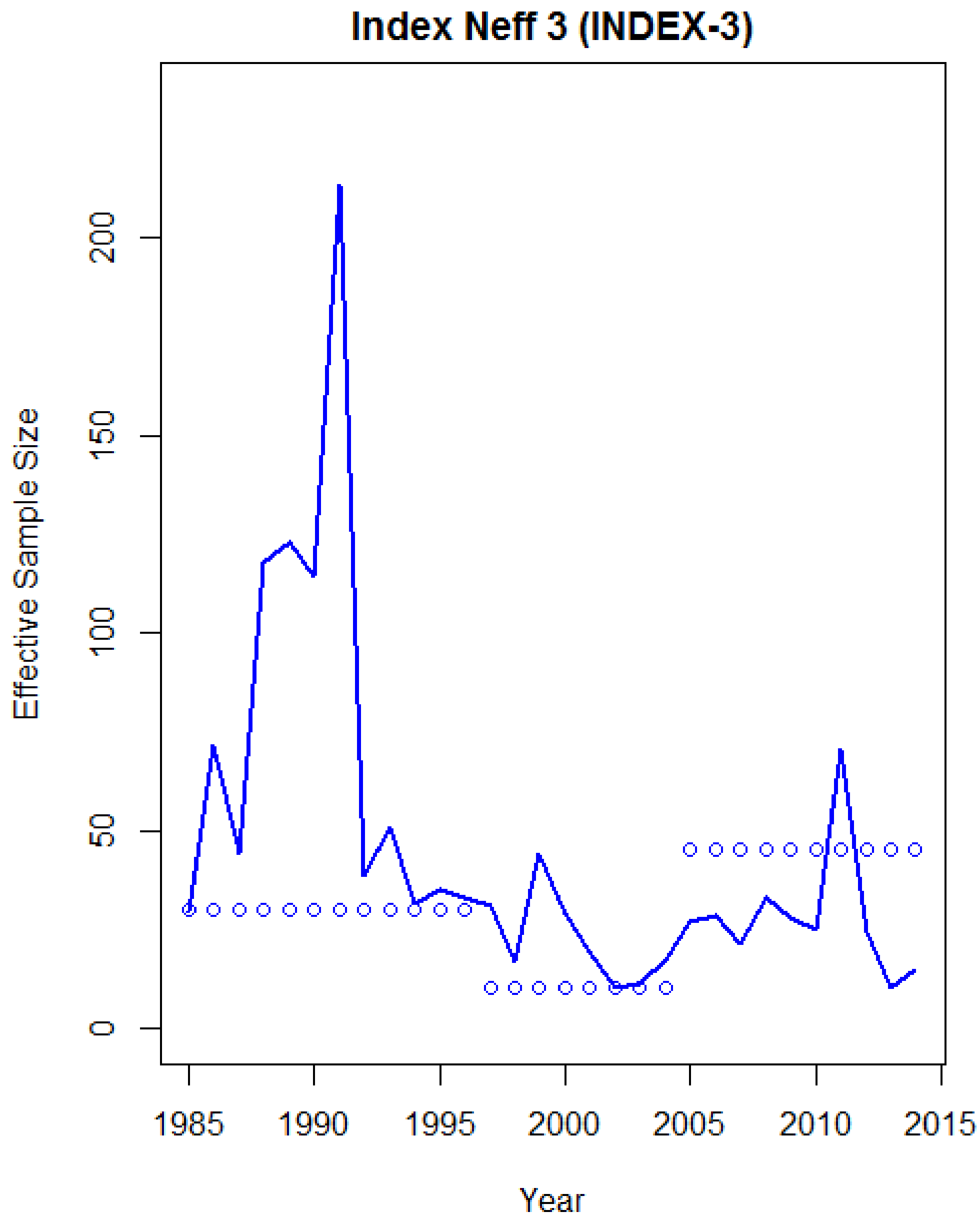
App. B7 Figure B7.67. Age composition residuals for the NJ ocean trawl survey.



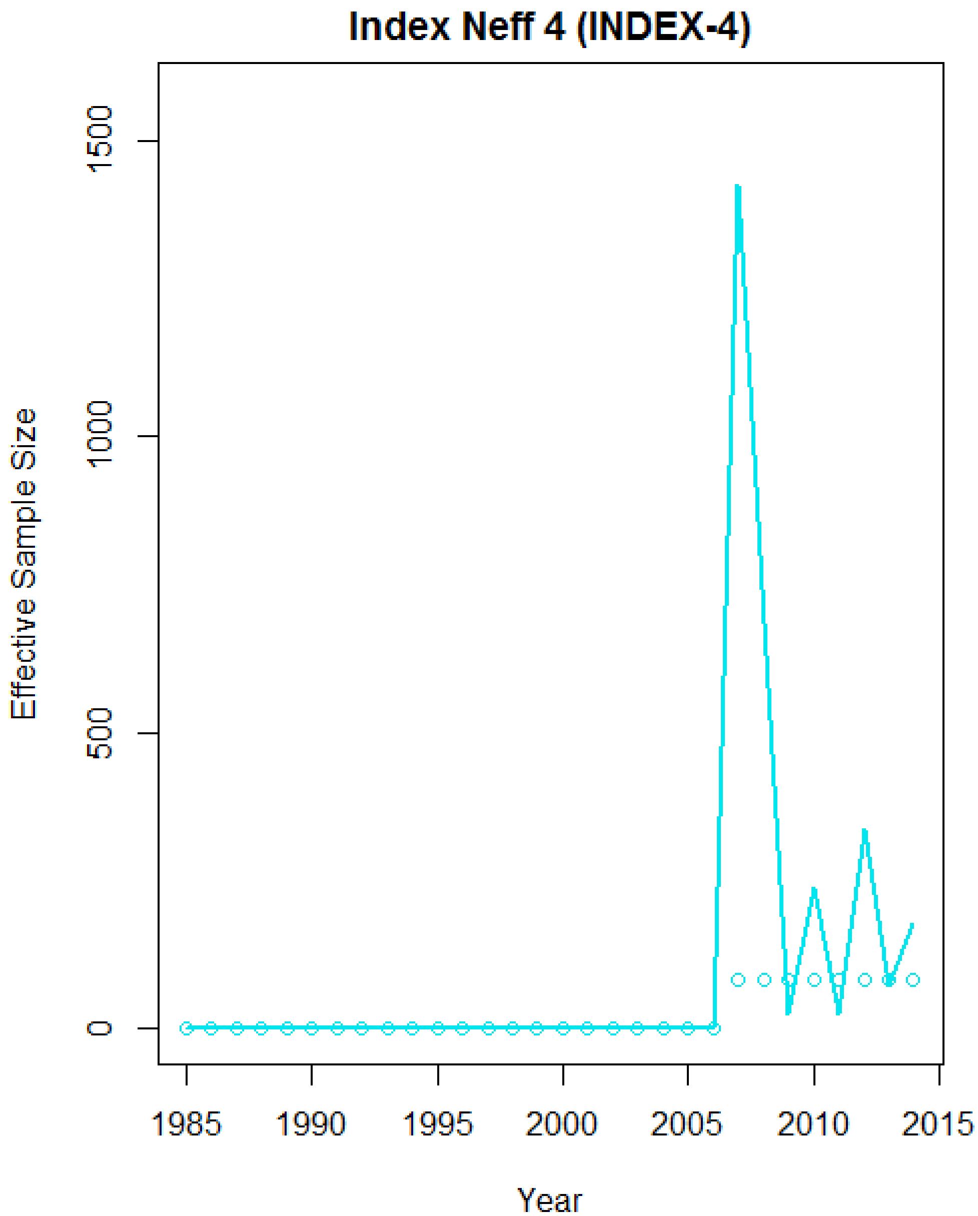
App. B7 Figure B7.68. Input and estimated effective sample size for the NEFSC Inshore survey.



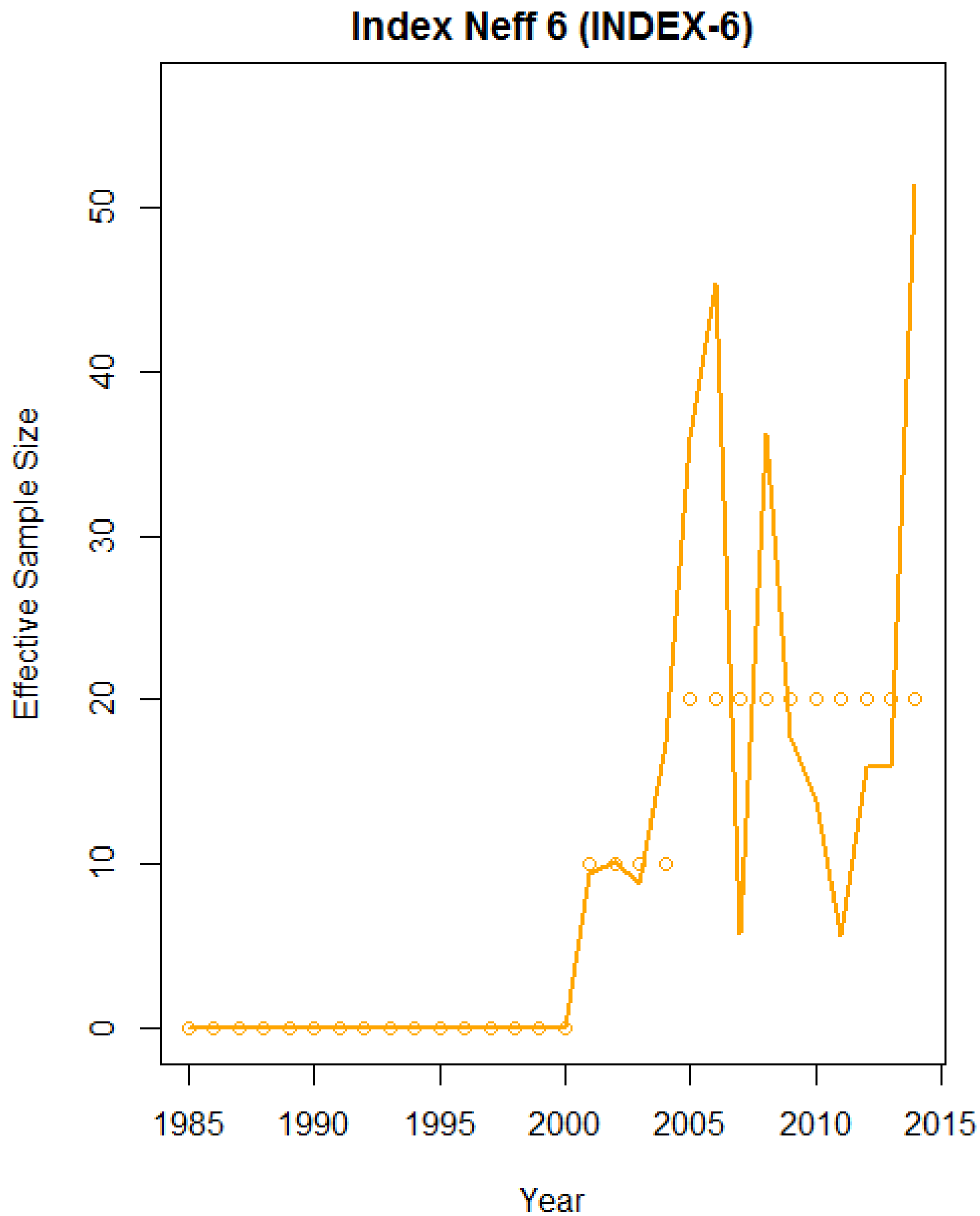
App. B7 Figure B7.69. Input and estimated effective sample size for the NEFSC Bigelow survey.



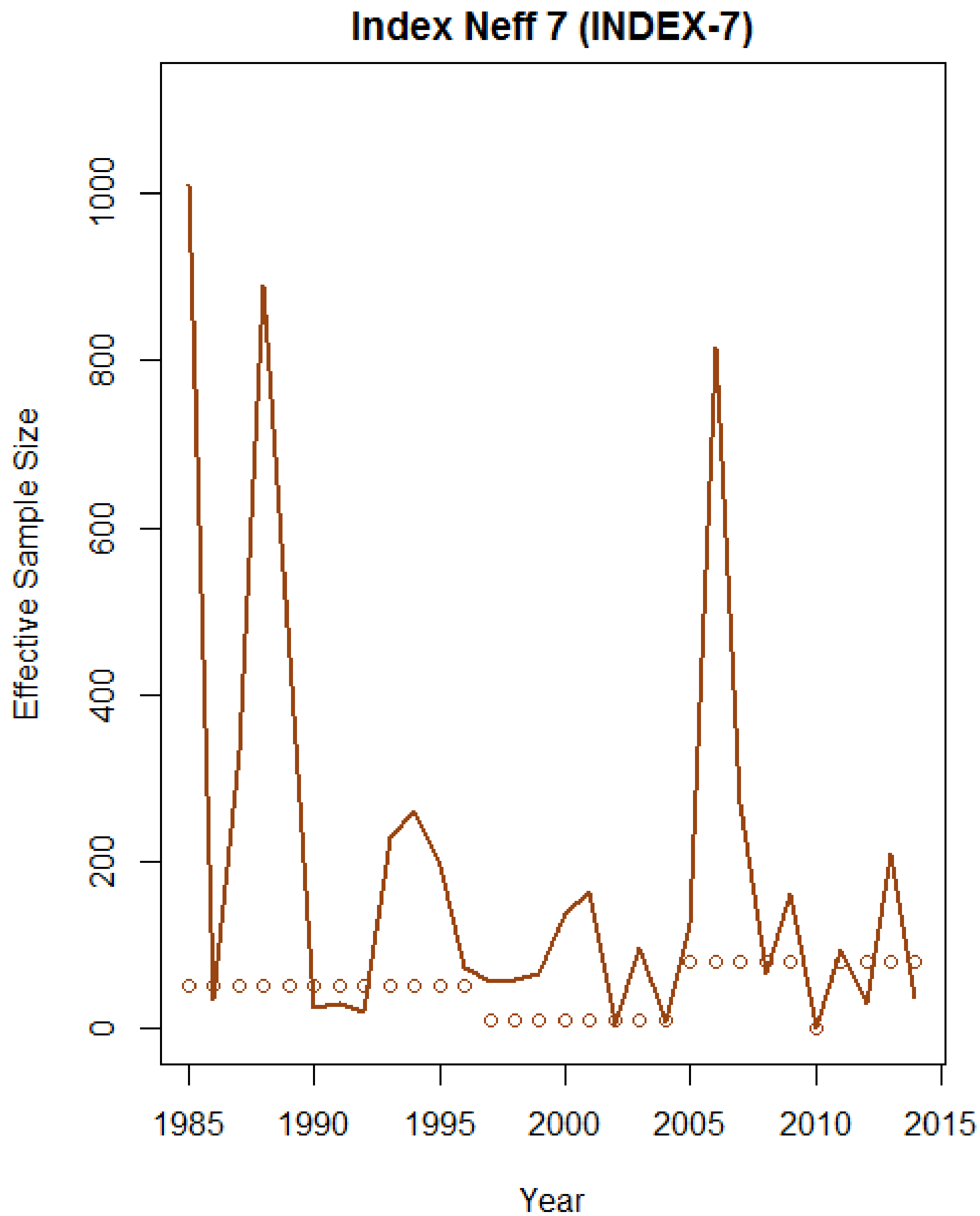
App. B7 Figure B7.70. Input and estimated effective sample size for the MRIP recreational CPUE index.



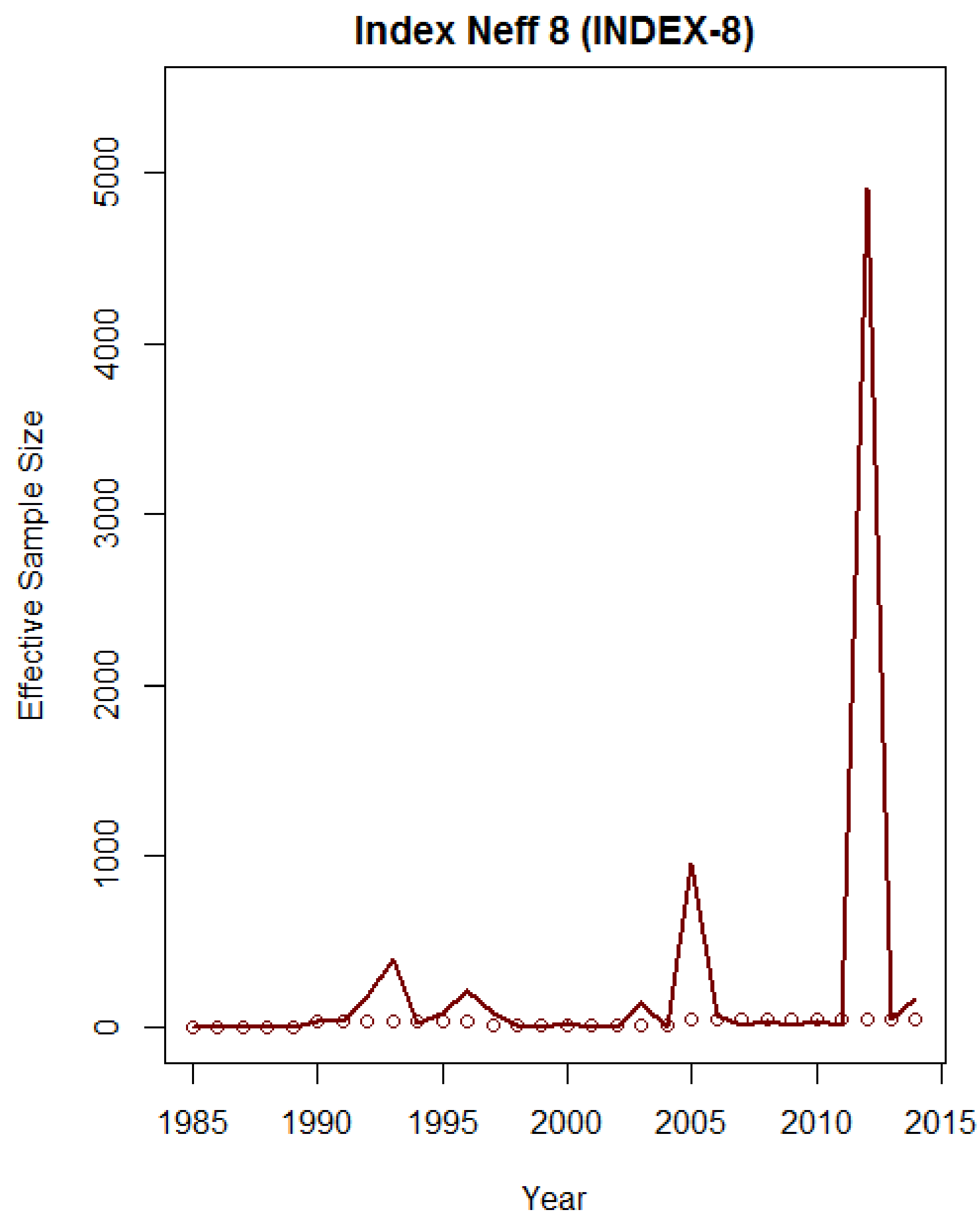
App. B7 Figure B7.71. Input and estimated effective sample size for the NEAMAP survey.



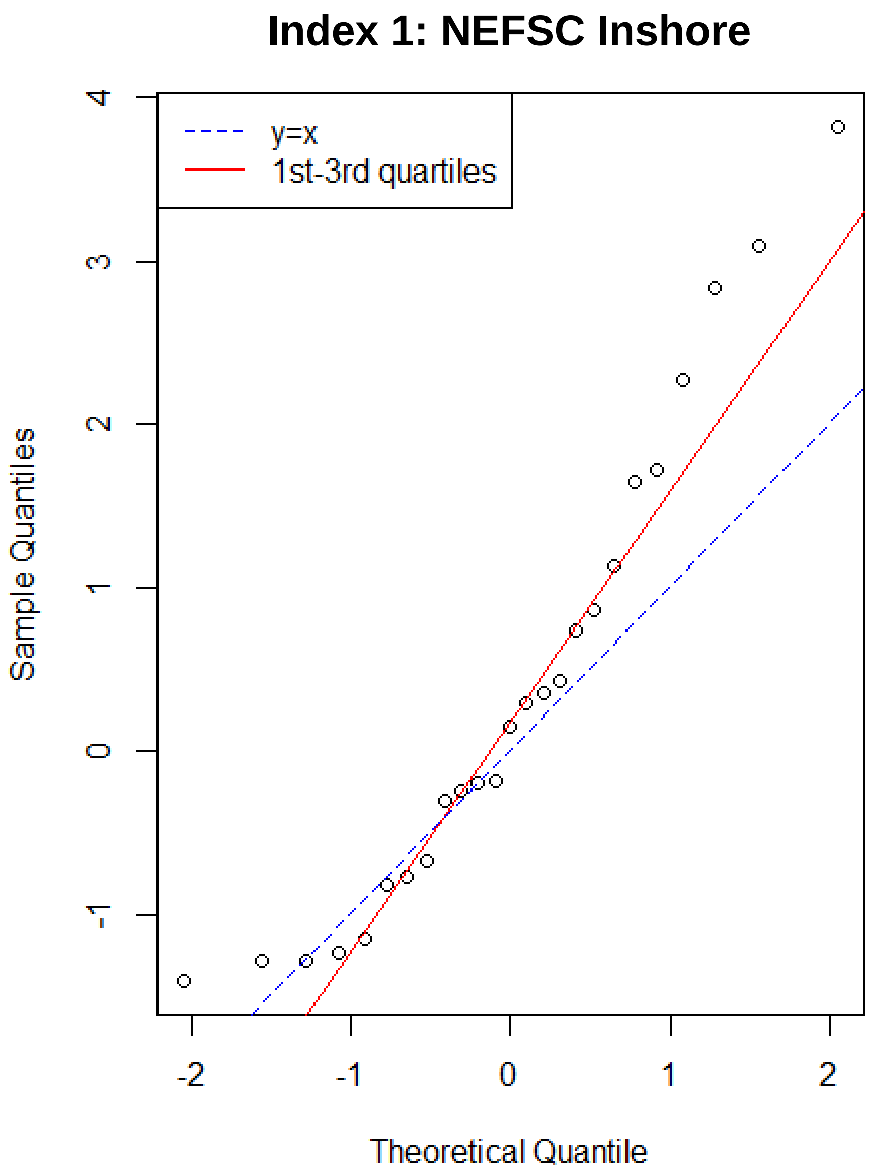
App. B7 Figure B7.72. Input and estimated effective sample size for the PSIGNS gillnet survey.



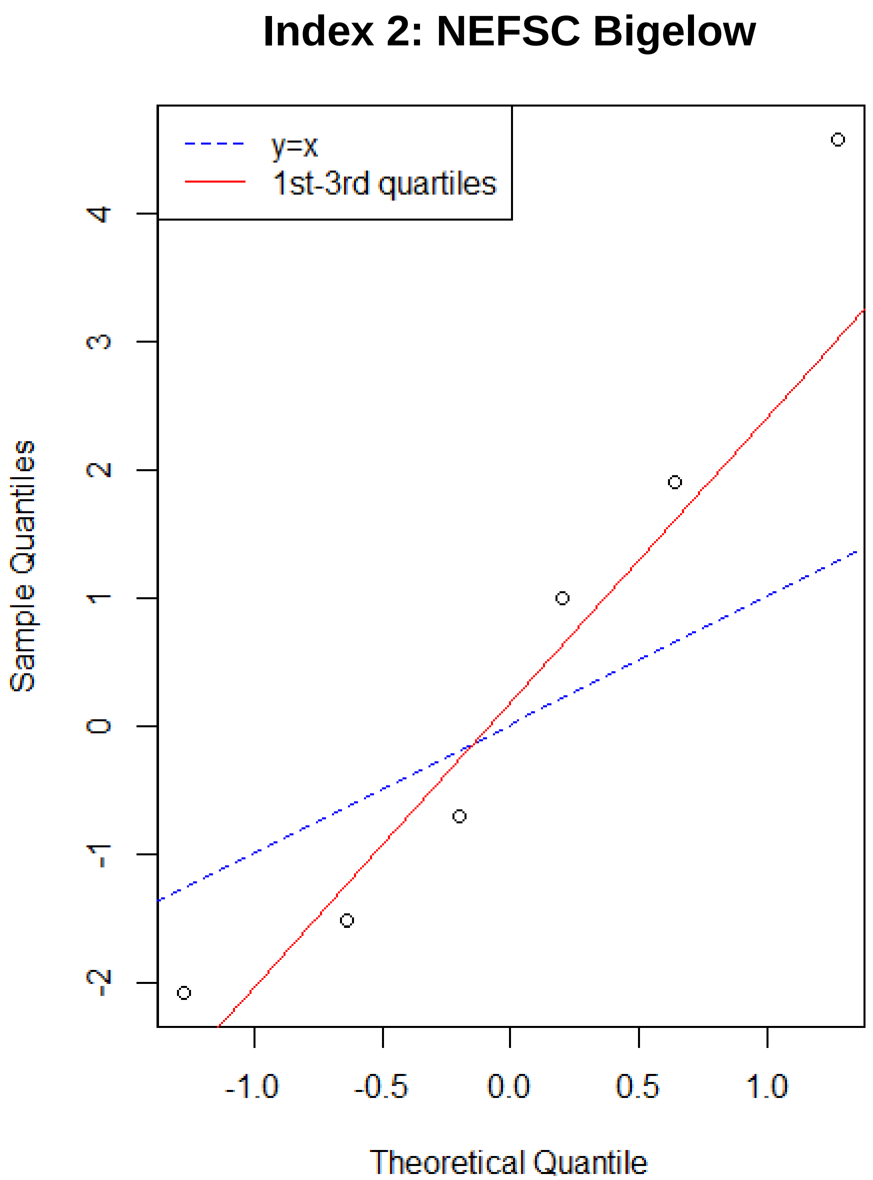
App. B7 Figure B7.73. Input and estimated effective sample size for the CT LISTS trawl survey.



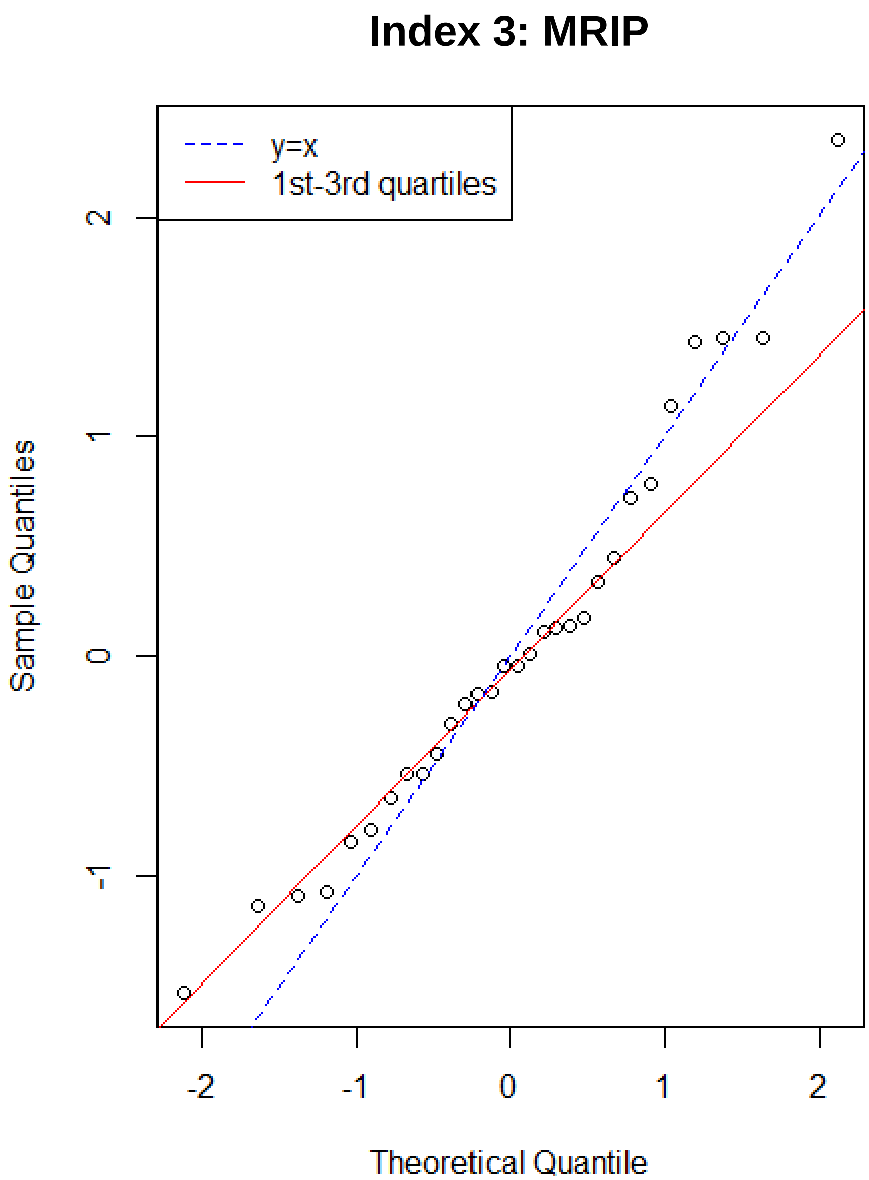
App. B7 Figure B7.74. Input and estimated effective sample size for the NJ ocean trawl survey.



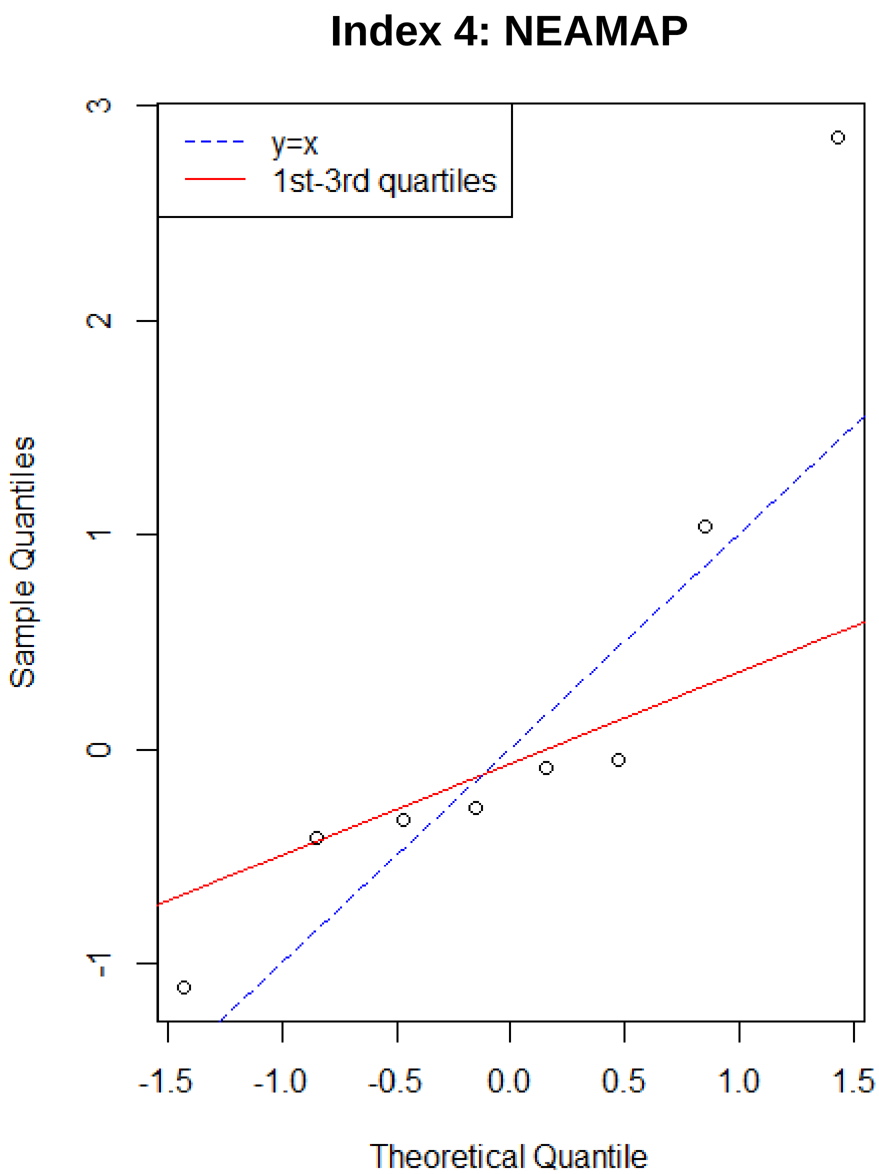
App. B7 Figure B7.75. QQ-plot for the observed versus predicted mean catch for the NEFSC Inshore survey.



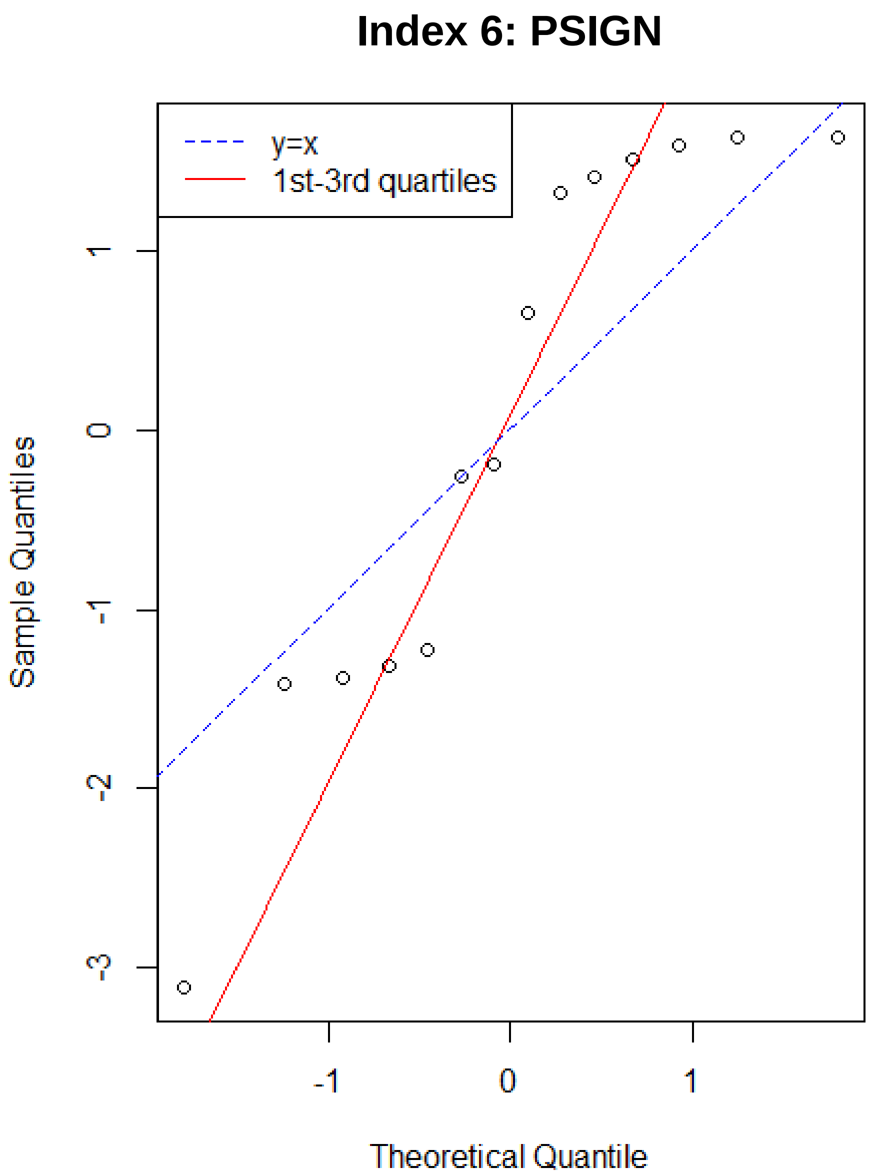
App. B7 Figure B7.76. QQ-plot for the observed versus predicted mean catch for the NEFSC Bigelow survey.



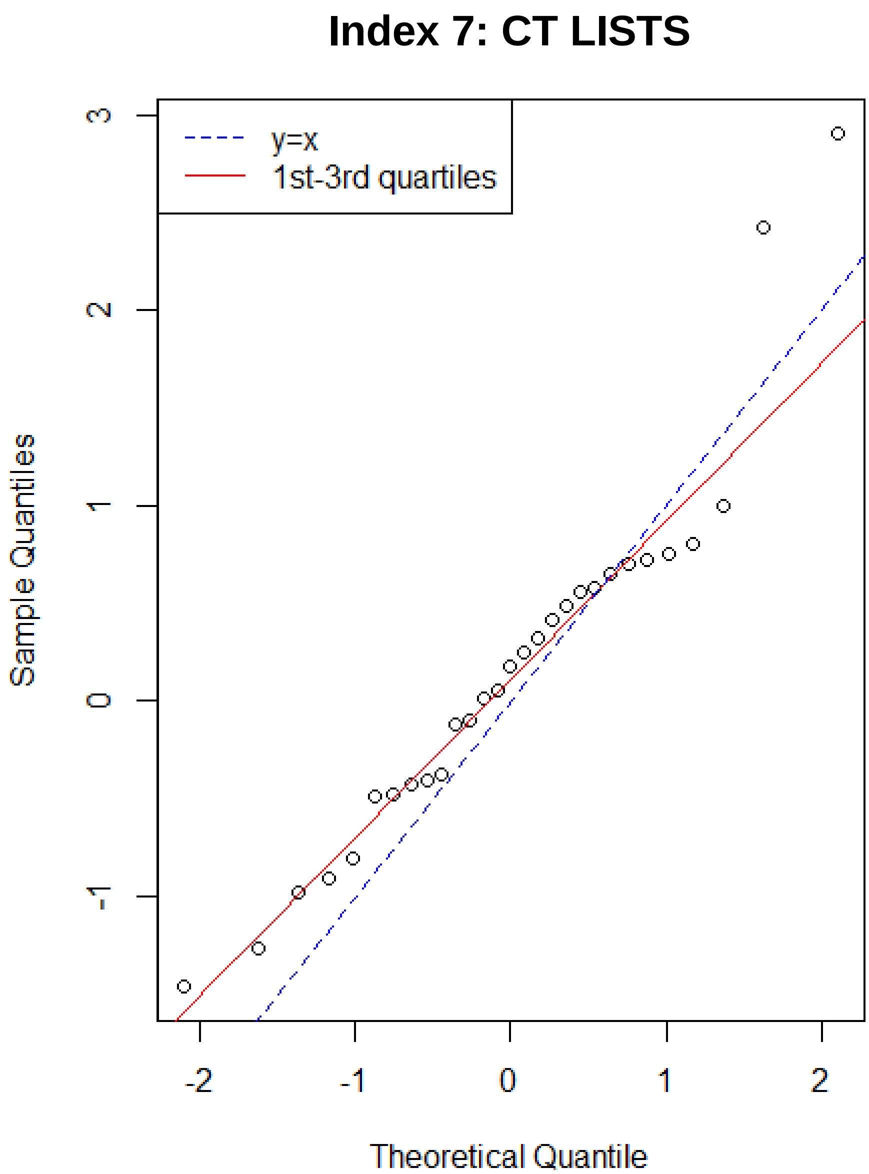
App. B7 Figure B7.77. QQ-plot for the observed versus predicted mean catch for the MRIP recreational CPUE index.



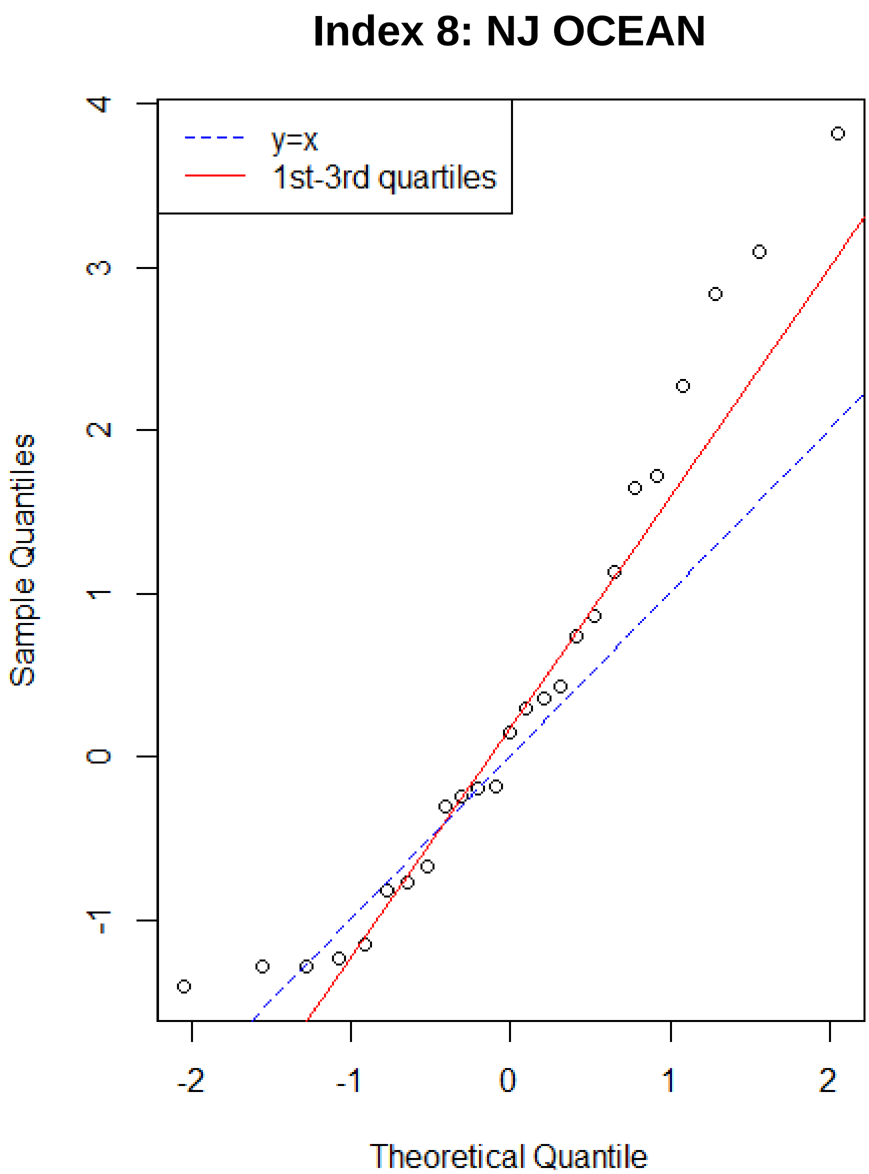
App. B7 Figure B7.78. QQ-plot for the observed versus predicted mean catch for the NEAMAP survey.



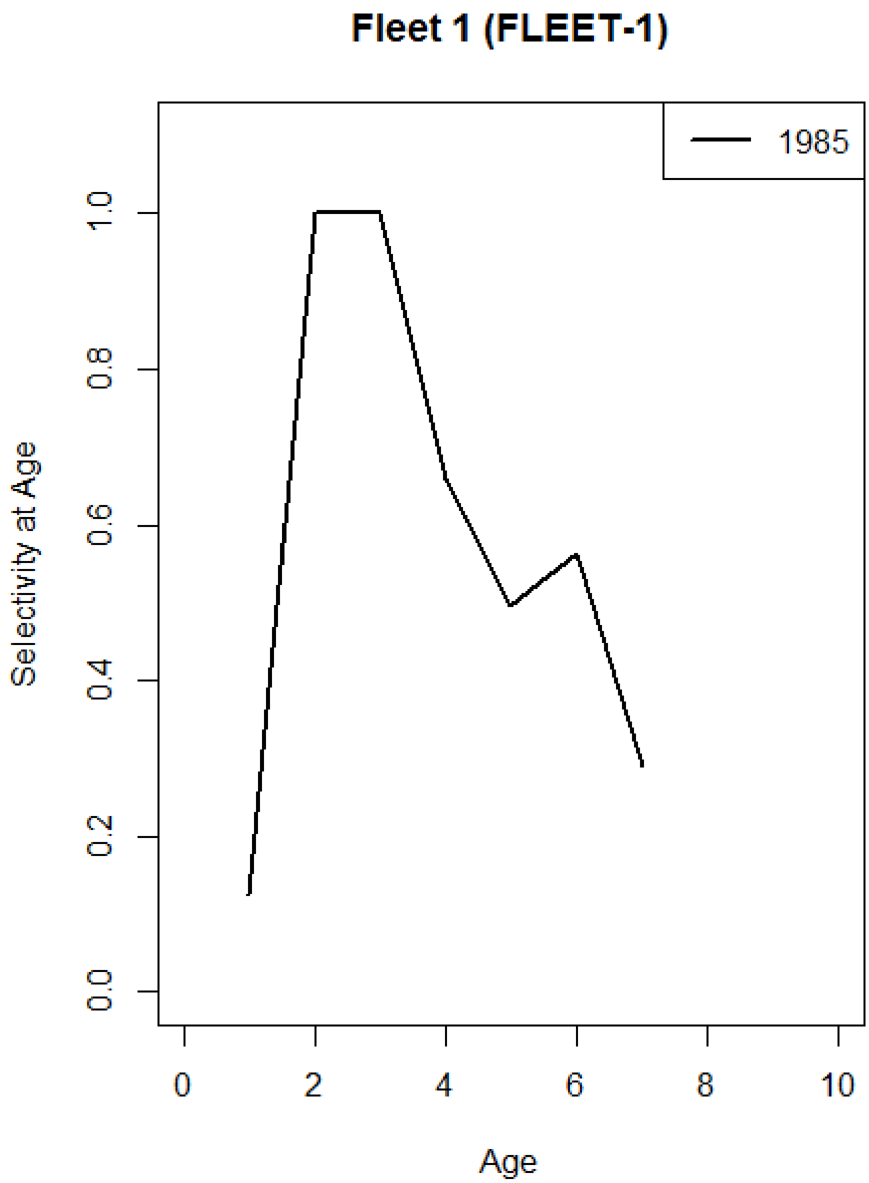
App. B7 Figure B7.79. QQ-plot for the observed versus predicted mean catch for the PSIGNS gillnet survey.



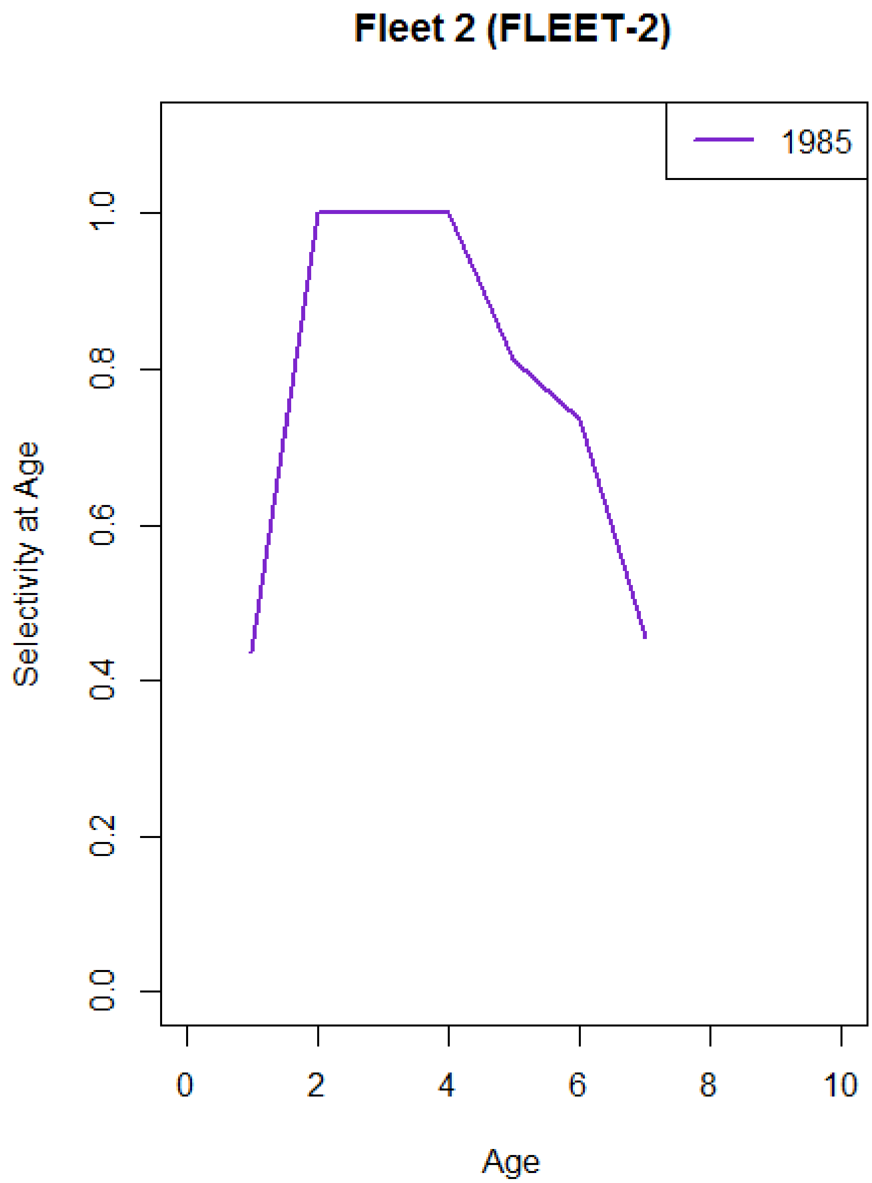
App. B7 Figure B7.80. QQ-plot for the observed versus predicted mean catch for the CT LISTS trawl survey.



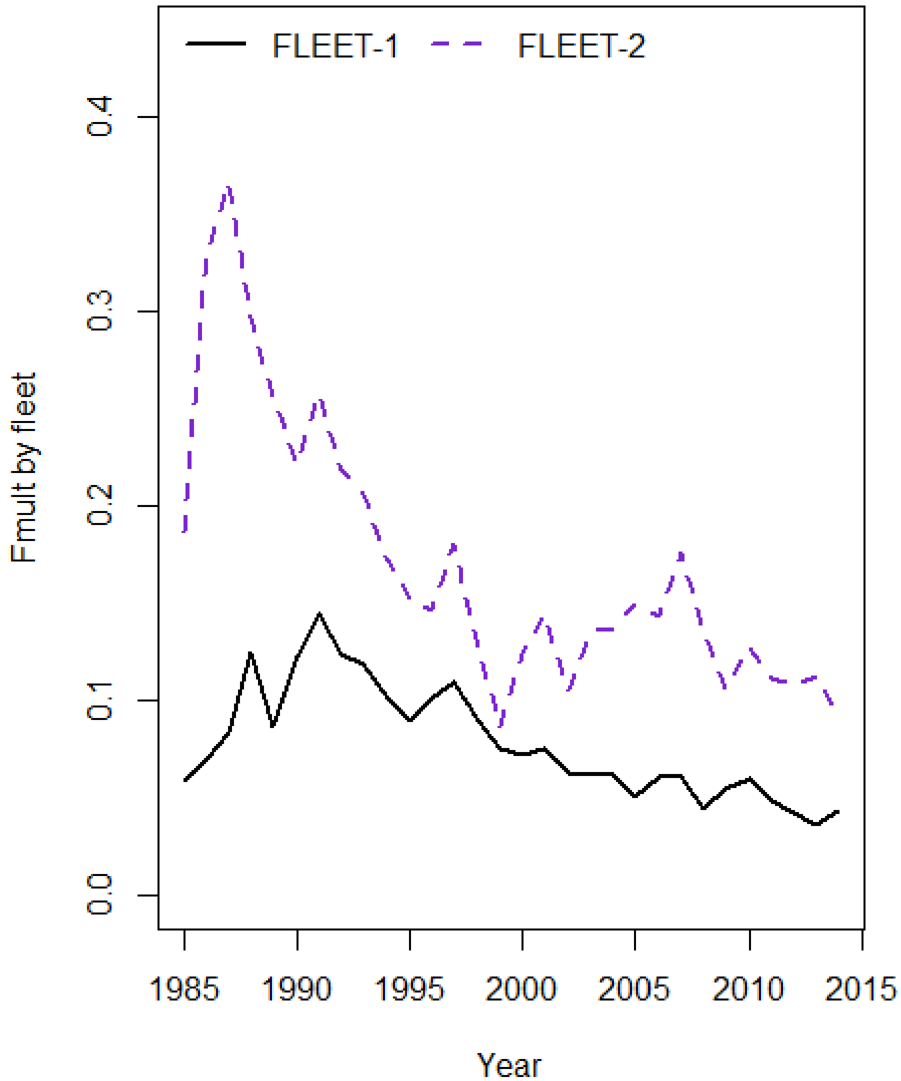
App. B7 Figure B7.81. QQ-plot for the observed versus predicted mean catch for the NJ ocean trawl survey.



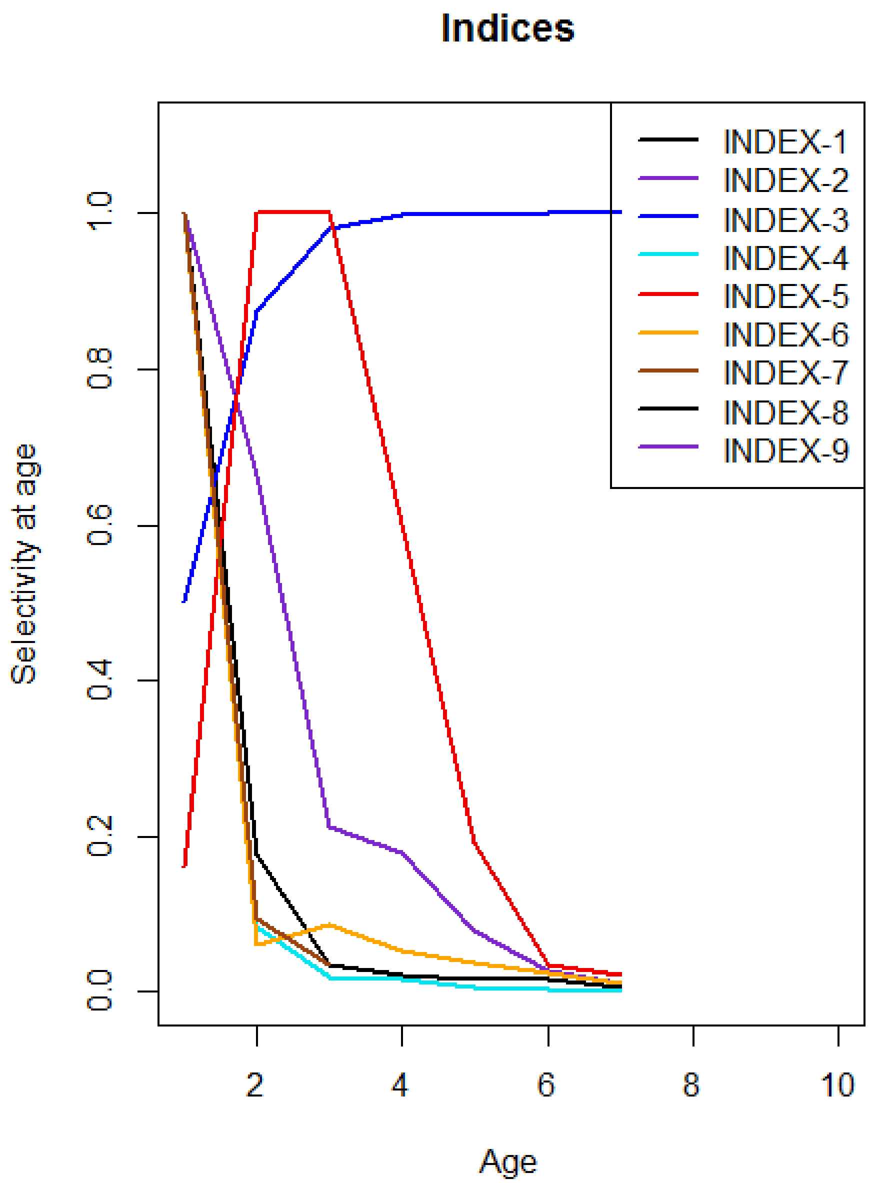
App. B7 Figure B7.82. Estimated selectivity for the commercial fleet from the final model



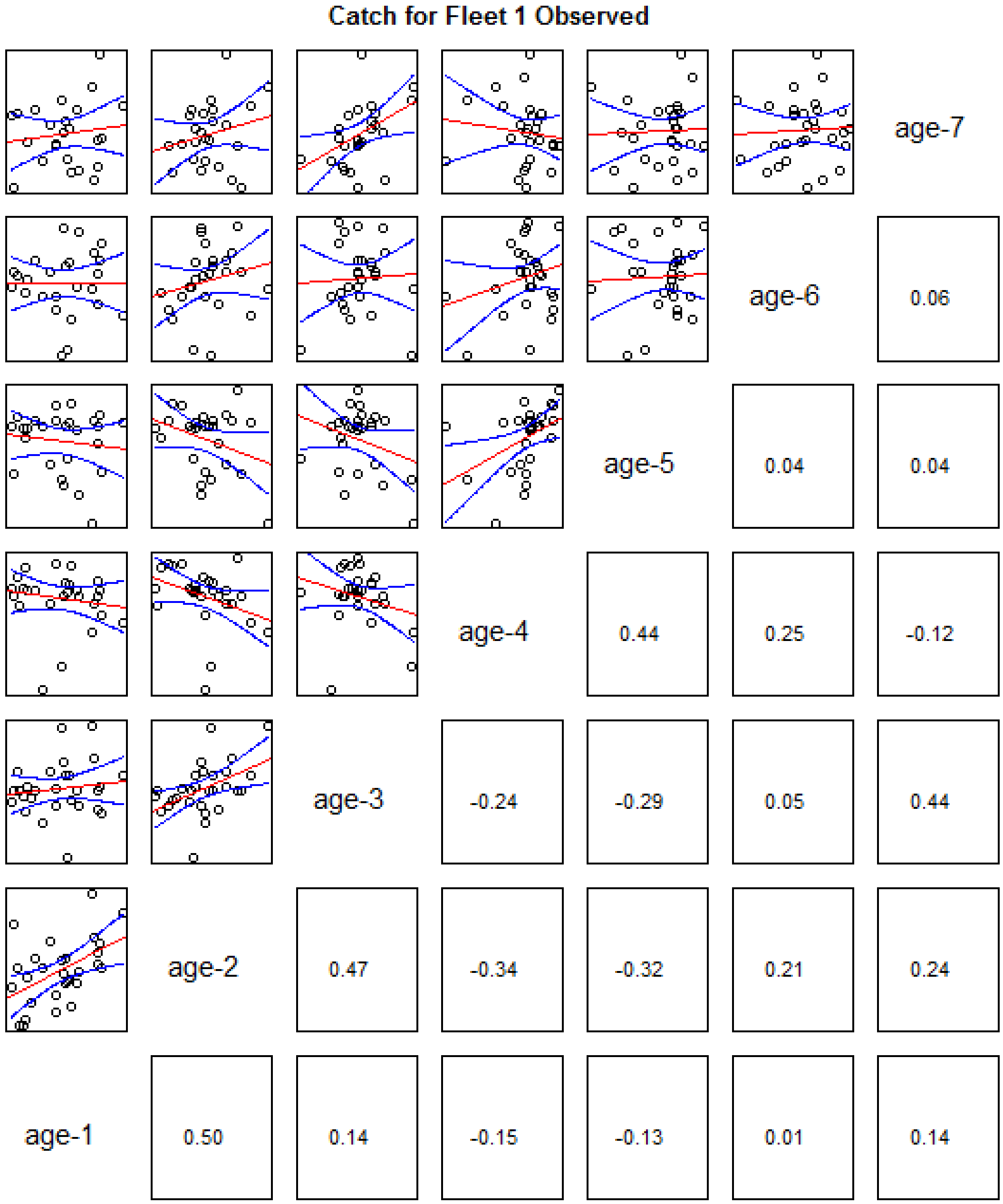
App. B7 Figure B7.83. Estimated selectivity for the recreational fleet from the final model.



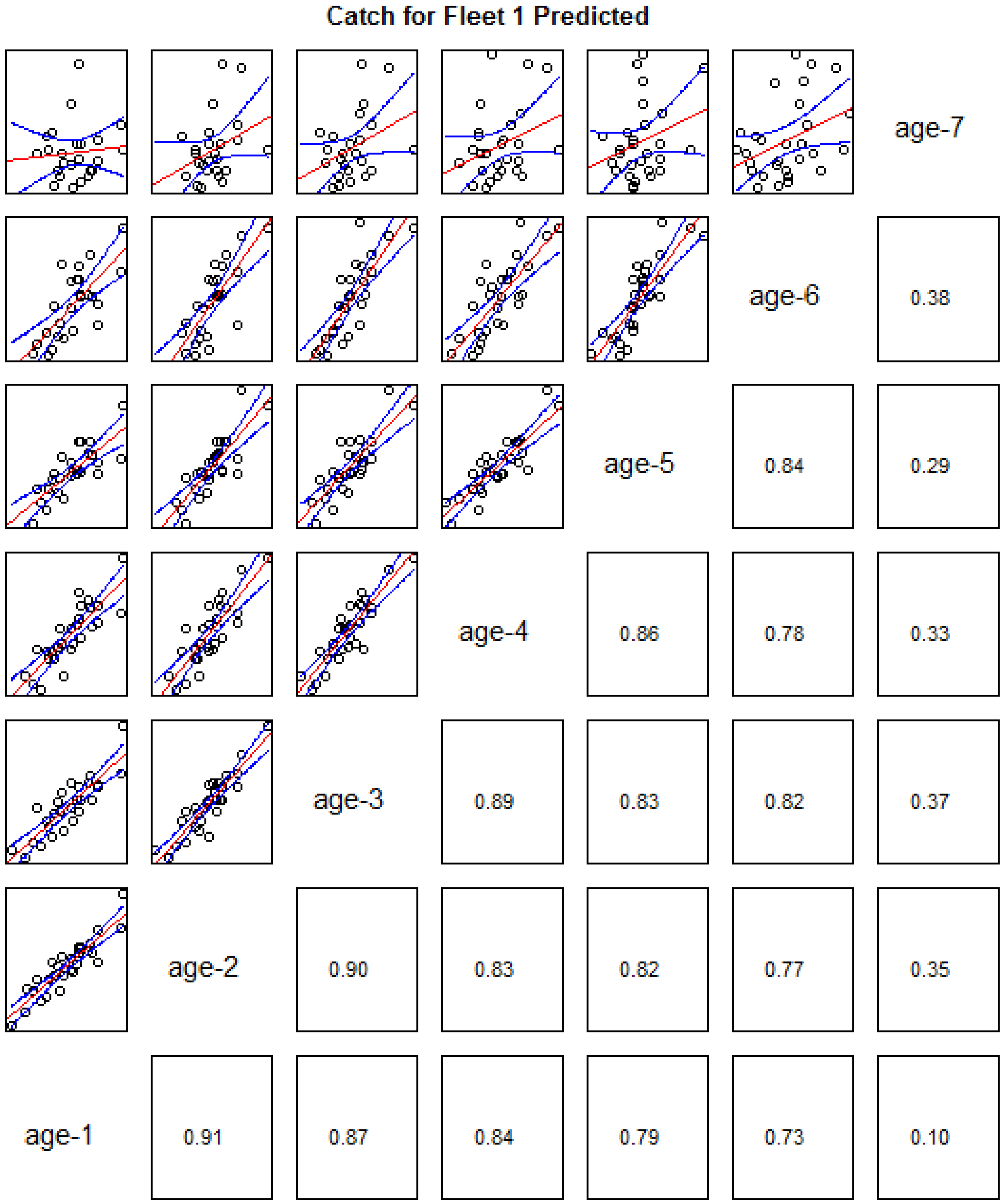
App. B7 Figure B7.84. Fmult estimates for the commercial (fleet 1) and recreational (fleet 2) fleets.



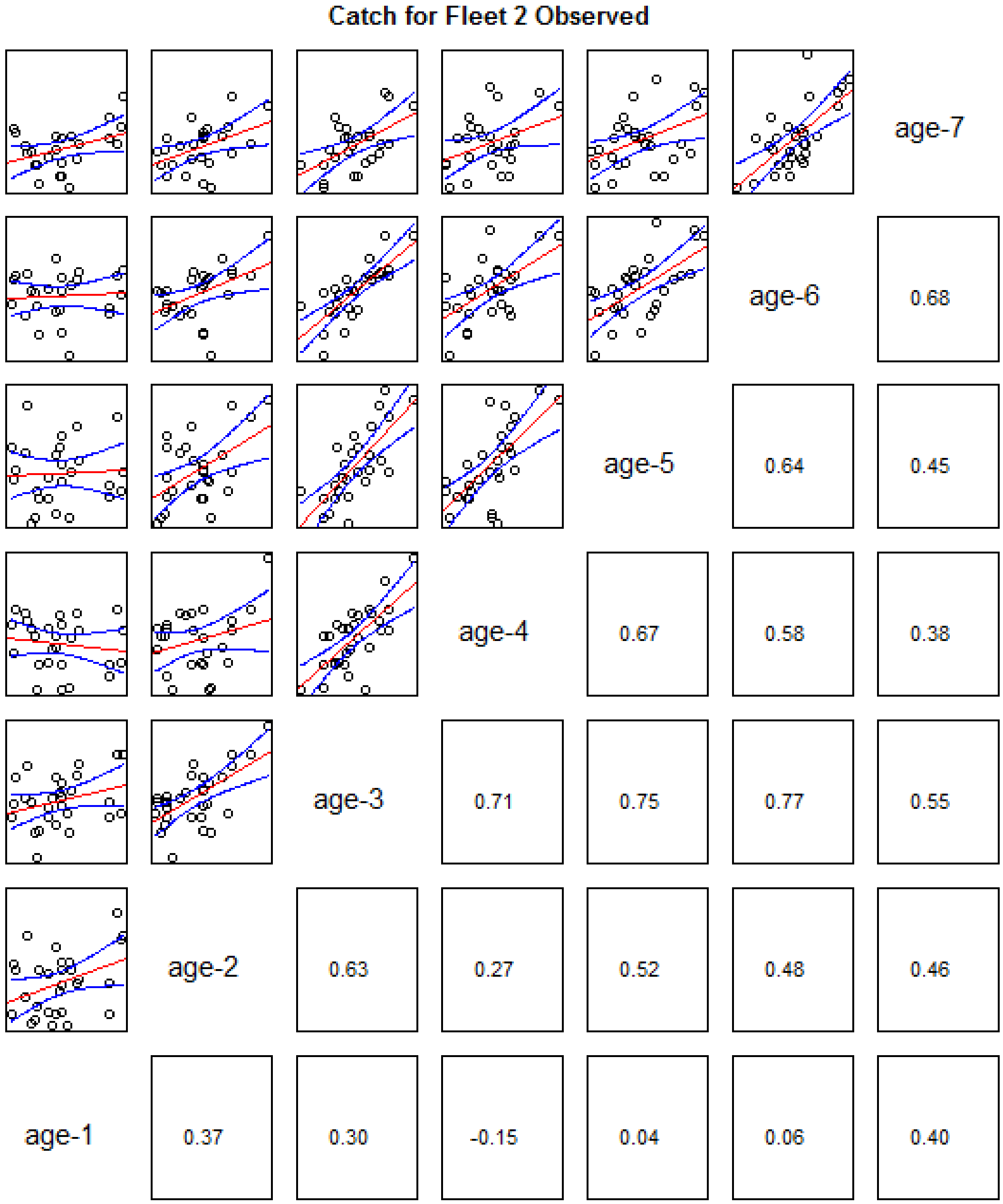
App. B7 Figure B7.85. Estimated selectivities for the indices from the final model. Note the two age 0 indices are not plotted so only 7 selectivities are shown. In this plot: Index 1 = NEFSC Inshore, Index 2 = NEFSC Bigelow, Index 3 = MRIP, Index 4 = NEAMAP, Index 5 = PSIGN, Index 6 = CT LISTS, and Index 7 = NJ ocean.



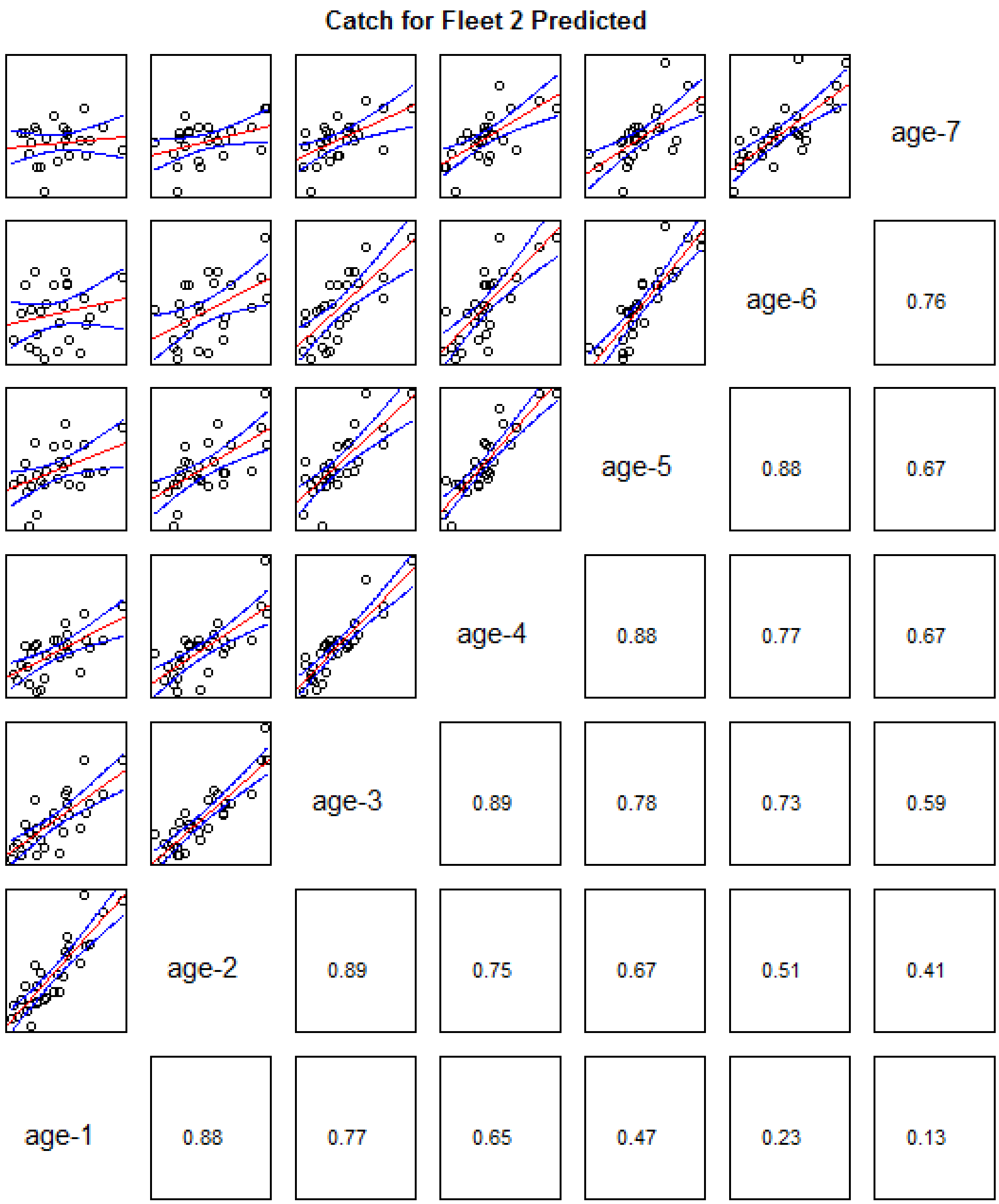
App. B7 Figure B7.86. Observed catch for the commercial fleet.



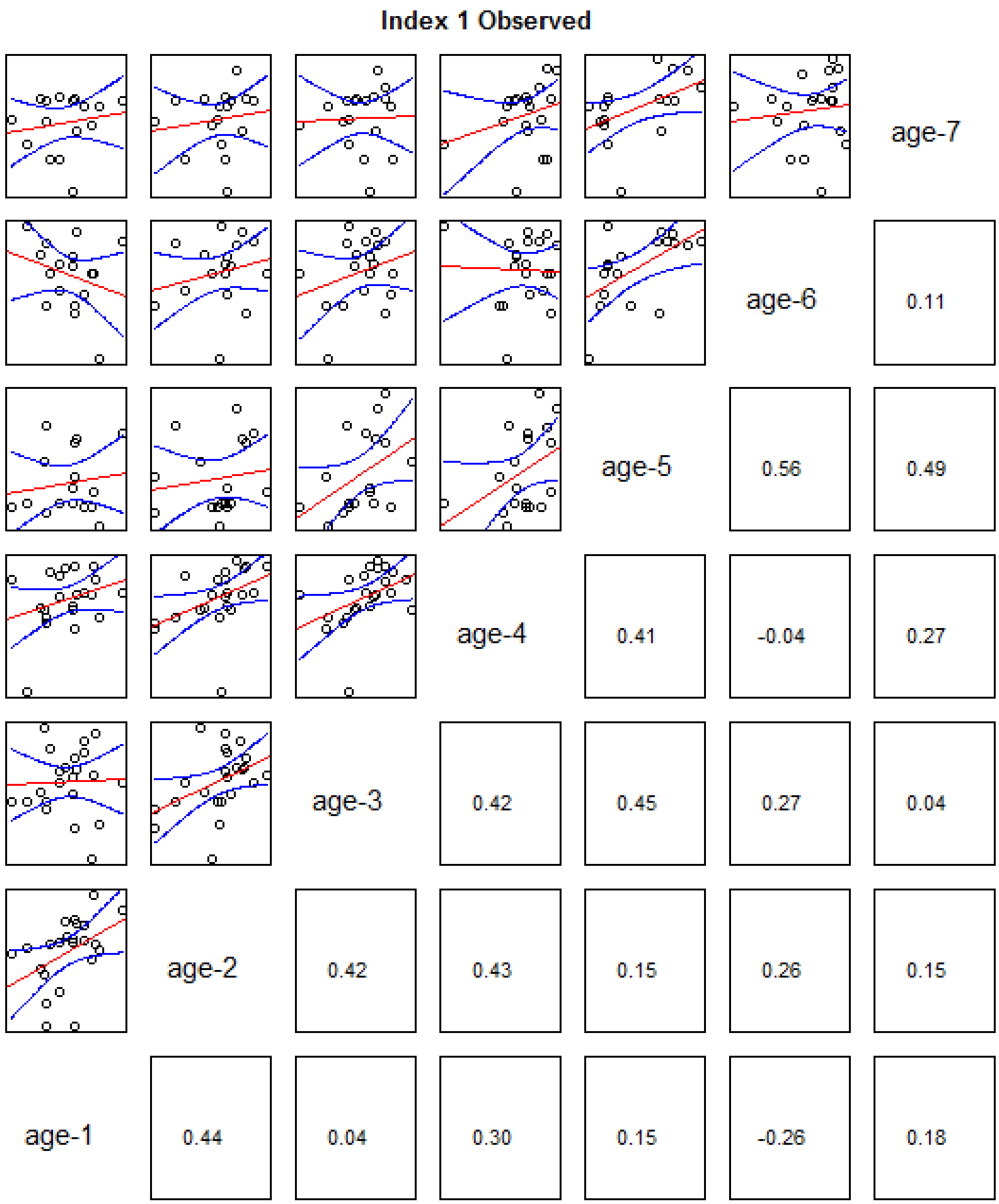
App. B7 Figure B7.87. Predicted catch for the commercial fleet.



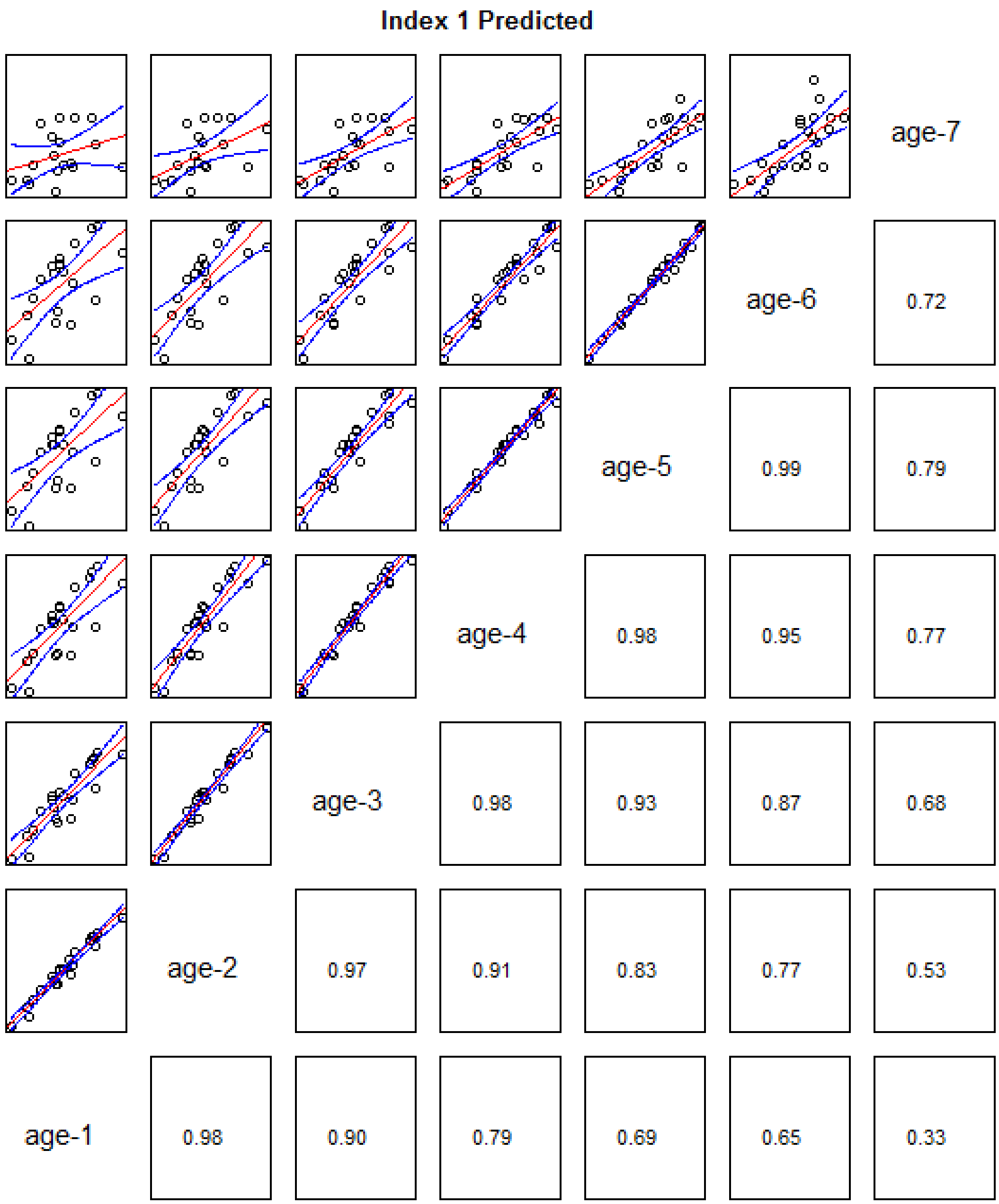
App. B7 Figure B7.88. Observed catch for the recreational fleet.



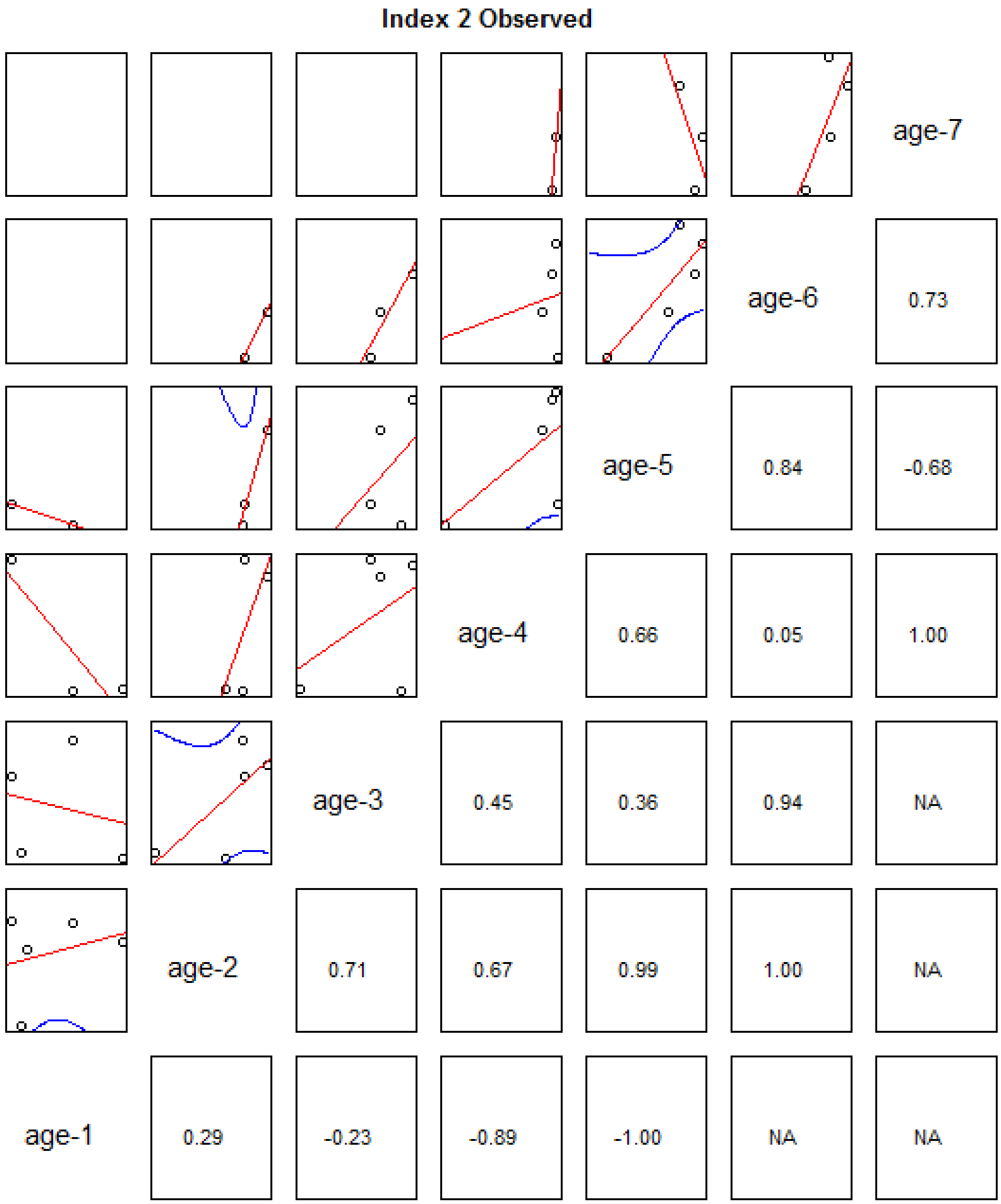
App. B7 Figure B7.89. Predicted catch for the recreational fleet.



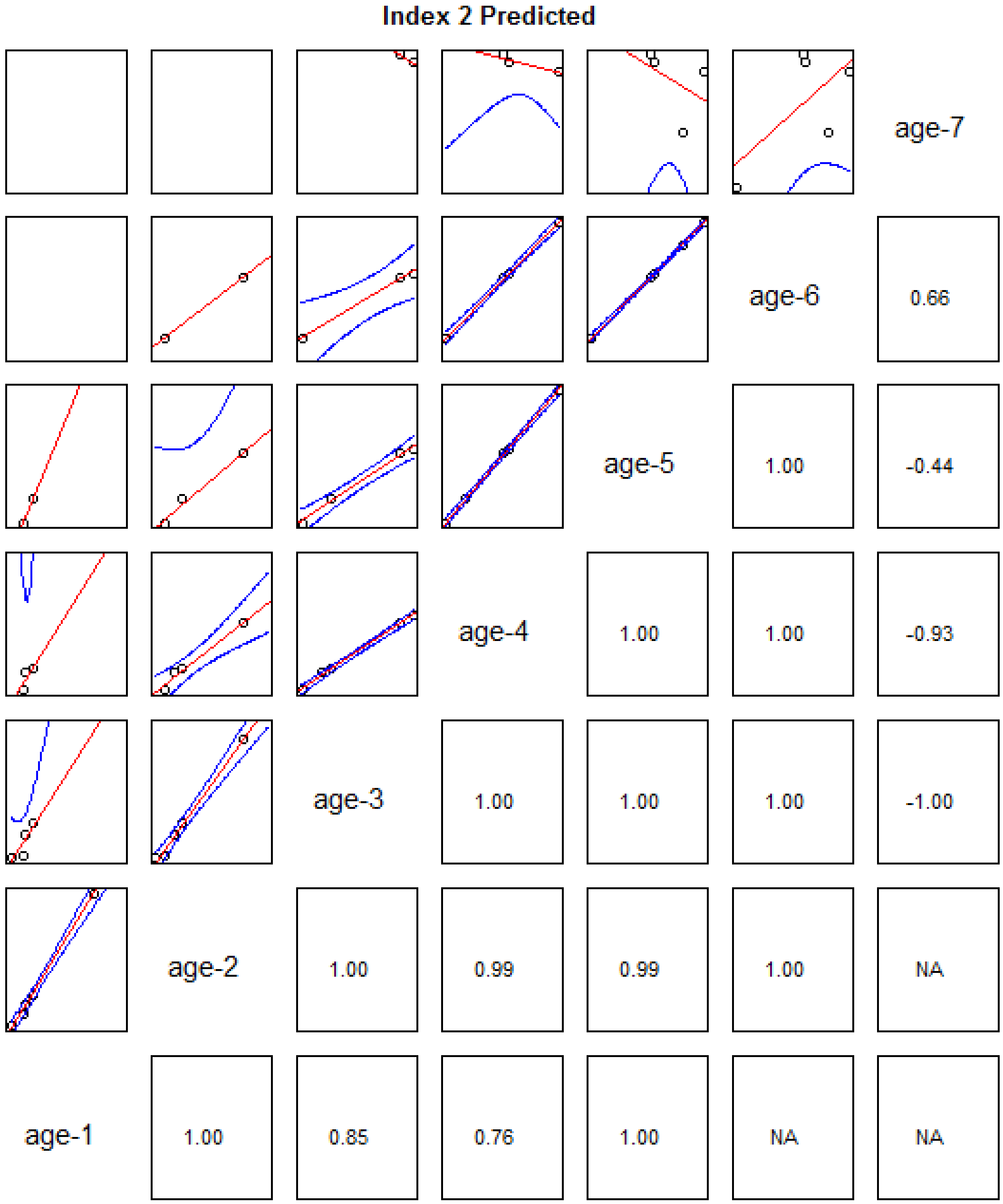
App. B7 Figure B7.90. Observed catch for the NEFSC Inshore survey.



App. B7 Figure B7.91. Predicted catch for the NEFSC Inshore survey.

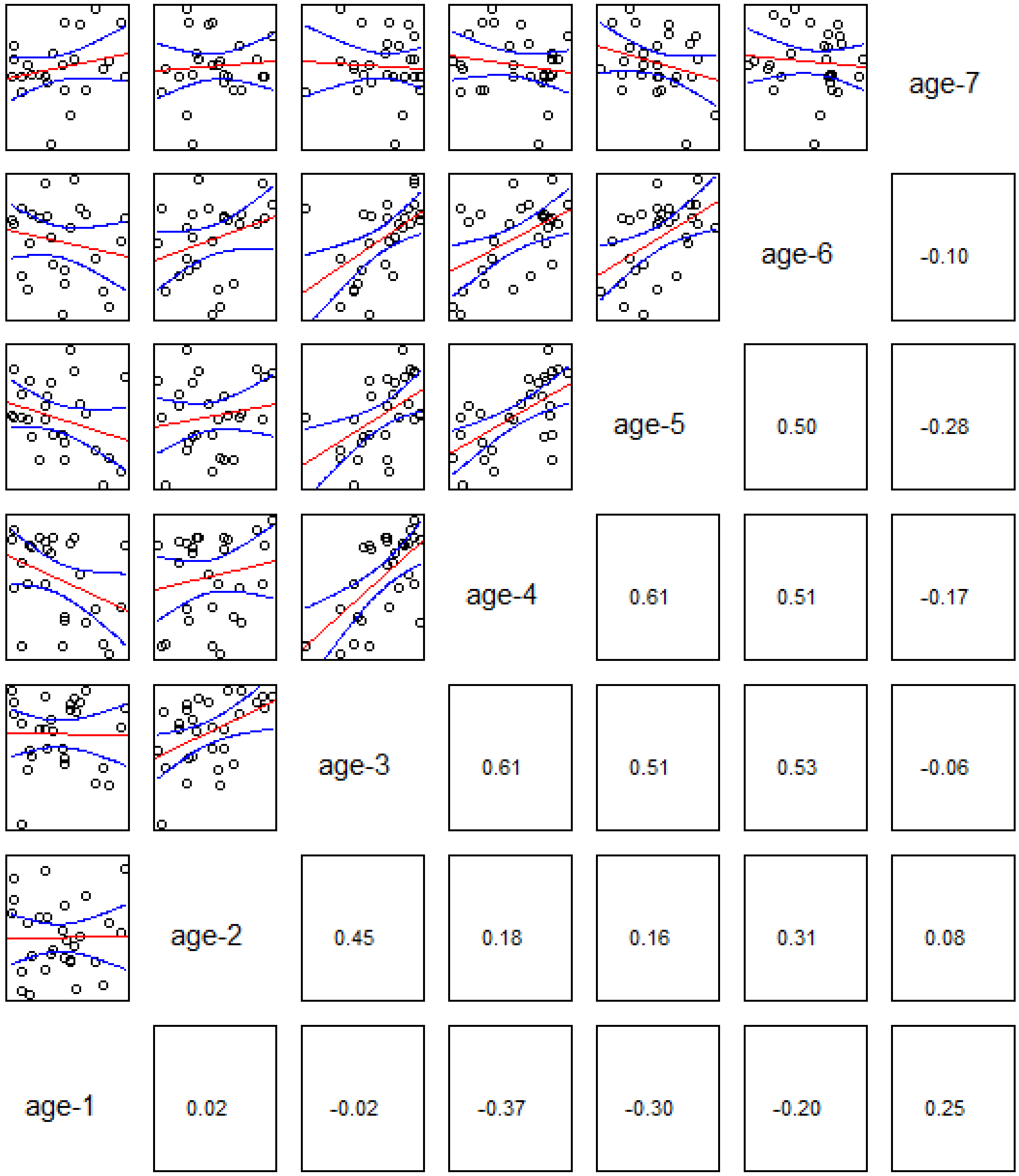


App. B7 Figure B7.92. Observed catch for the NEFSC Bigelow survey.

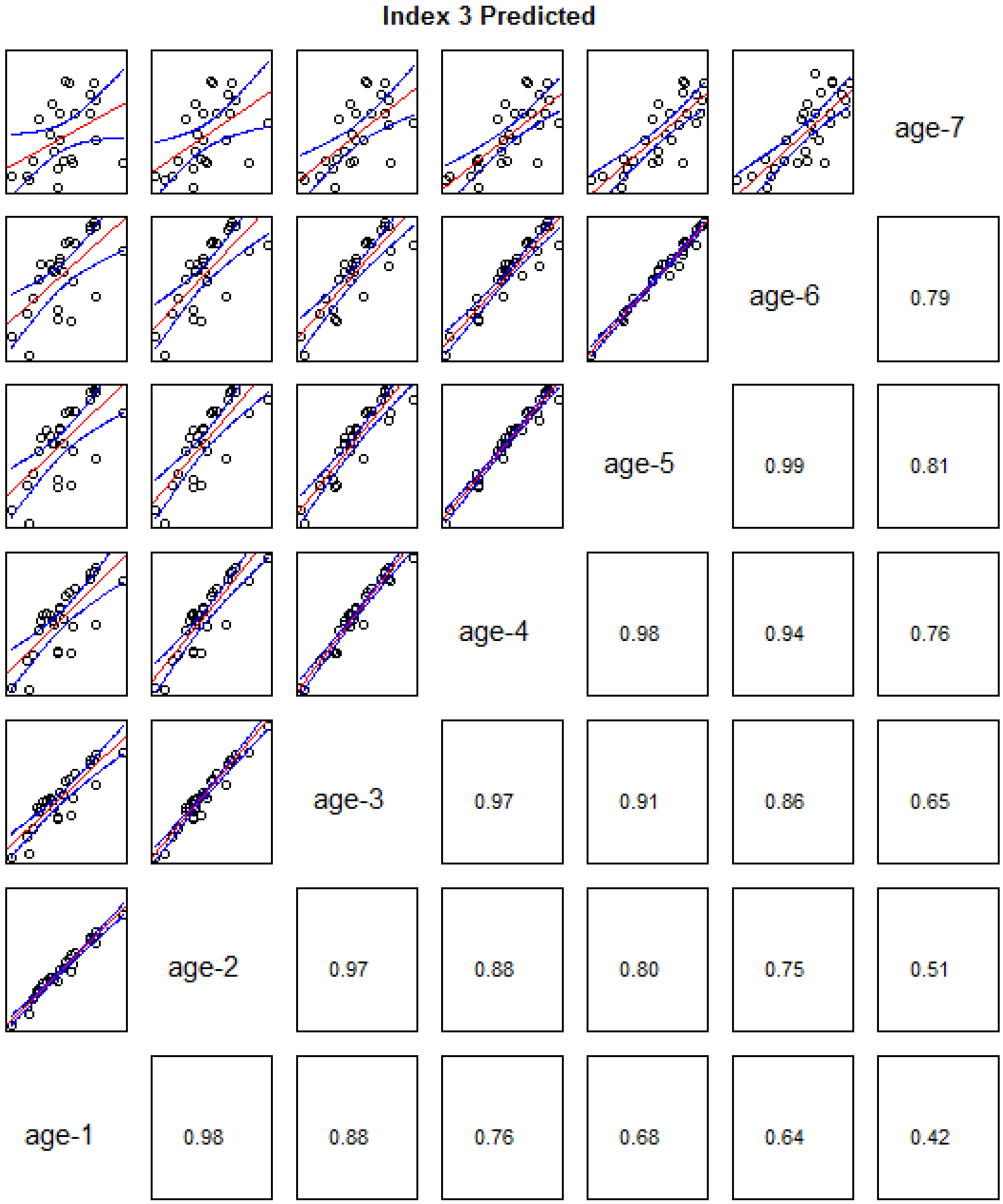


App. B7 Figure B7.93. Predicted catch for the NEFSC Bigelow survey.

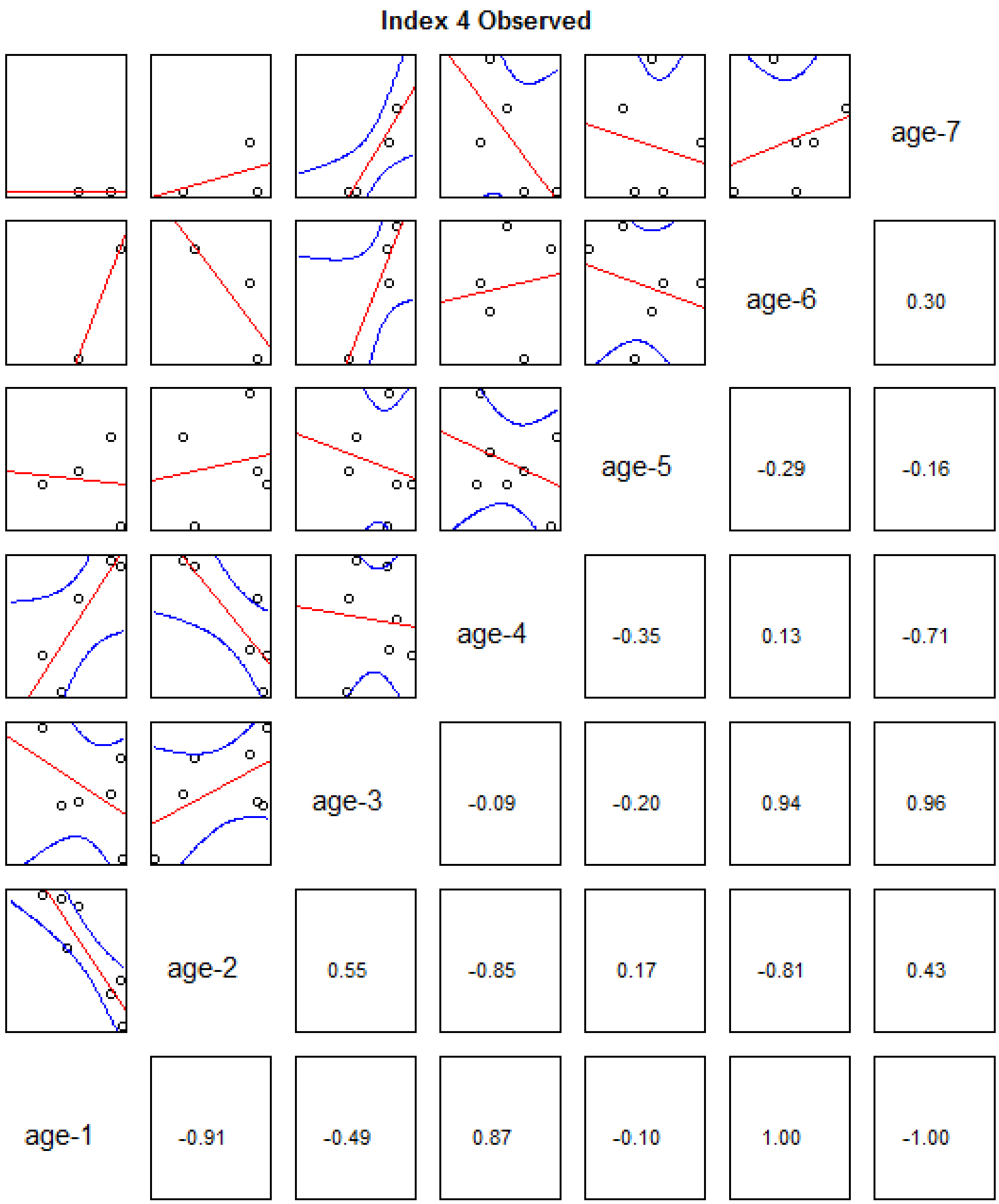
Index 3 Observed



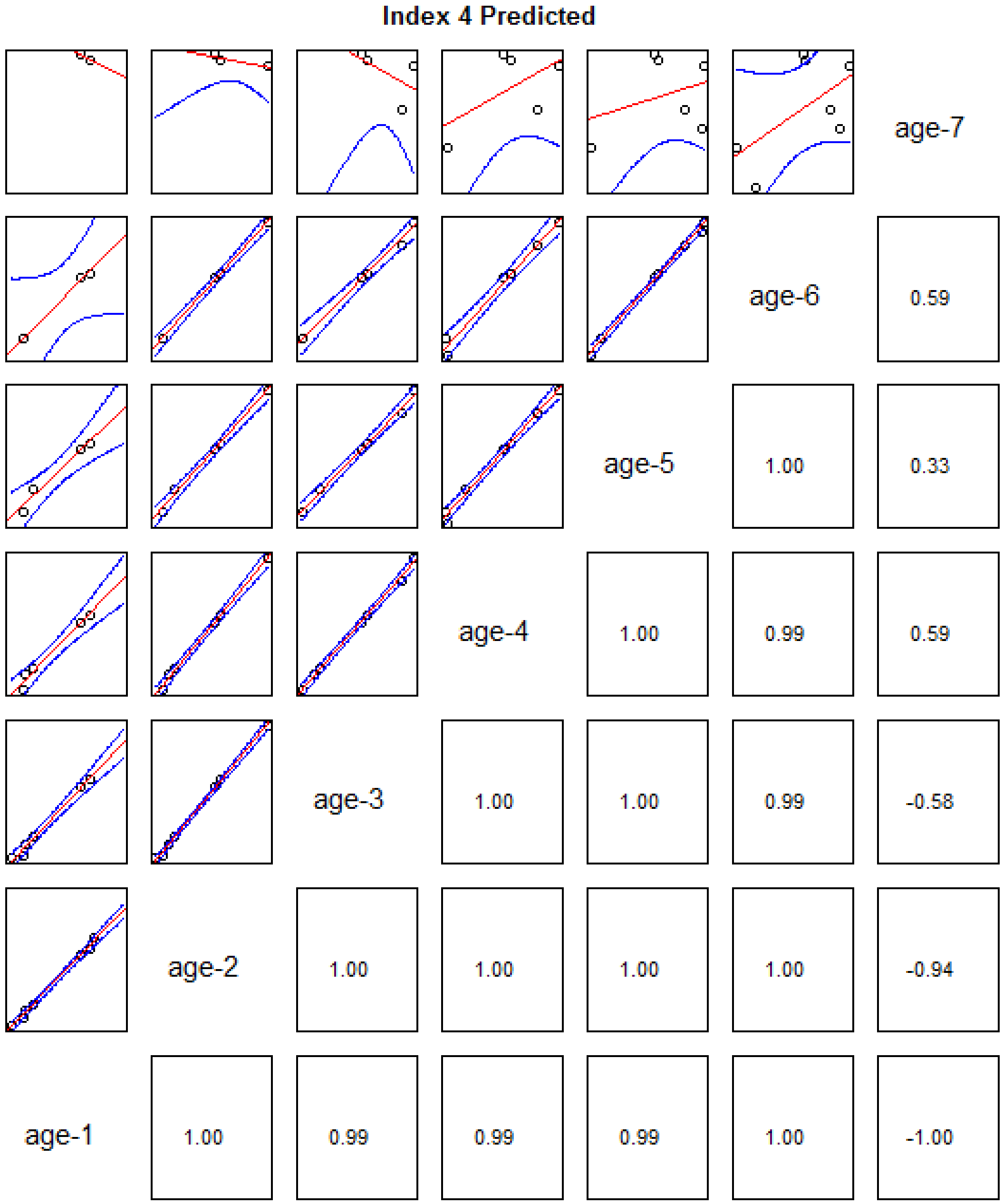
App. B7 Figure B7.94. Observed catch for the MRIP recreational CPUE index.



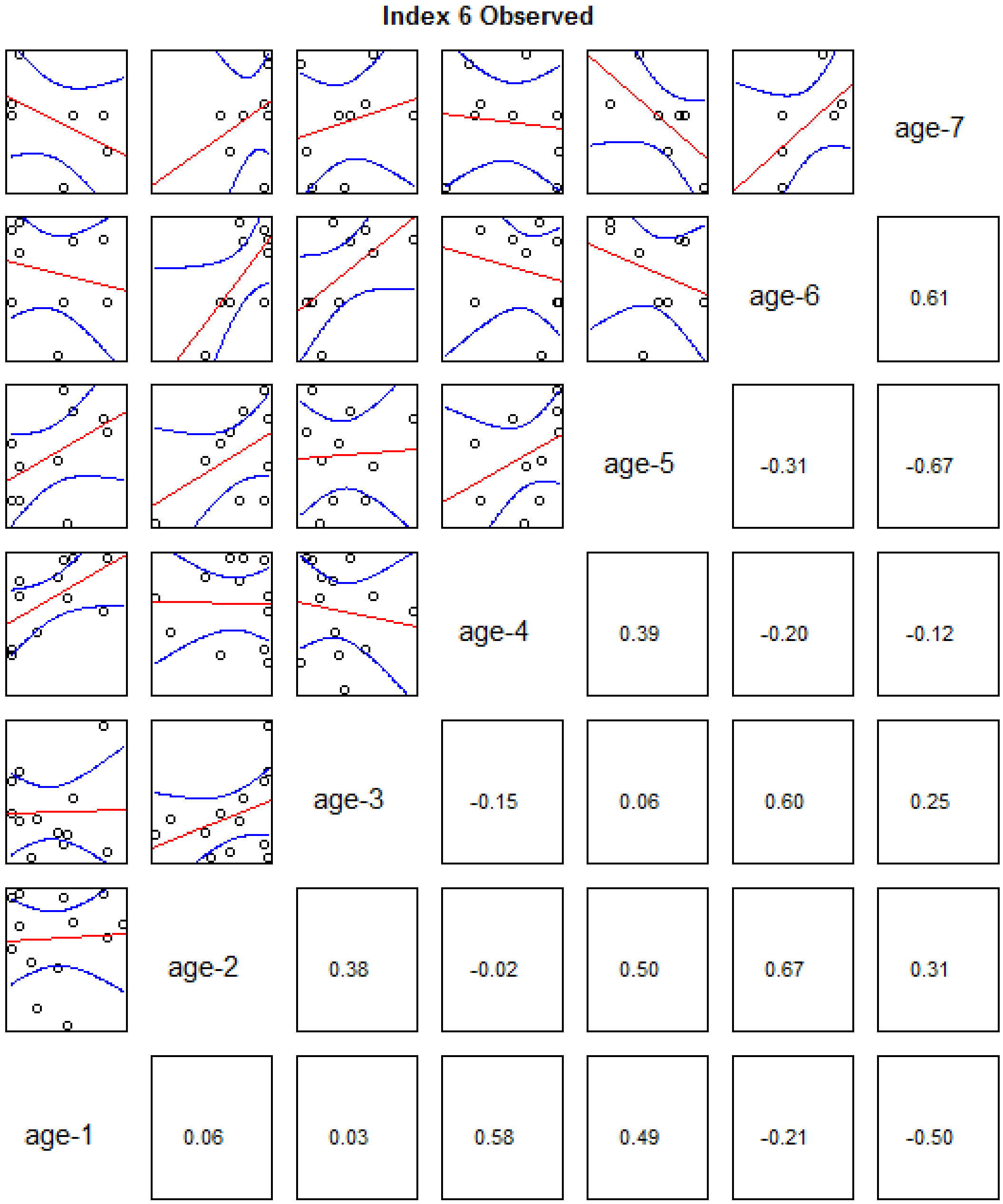
App. B7 Figure B7.95. Predicted catch for the MRIP recreational CPUE index.



App. B7 Figure B7.96. Observed catch for the NEAMAP survey.

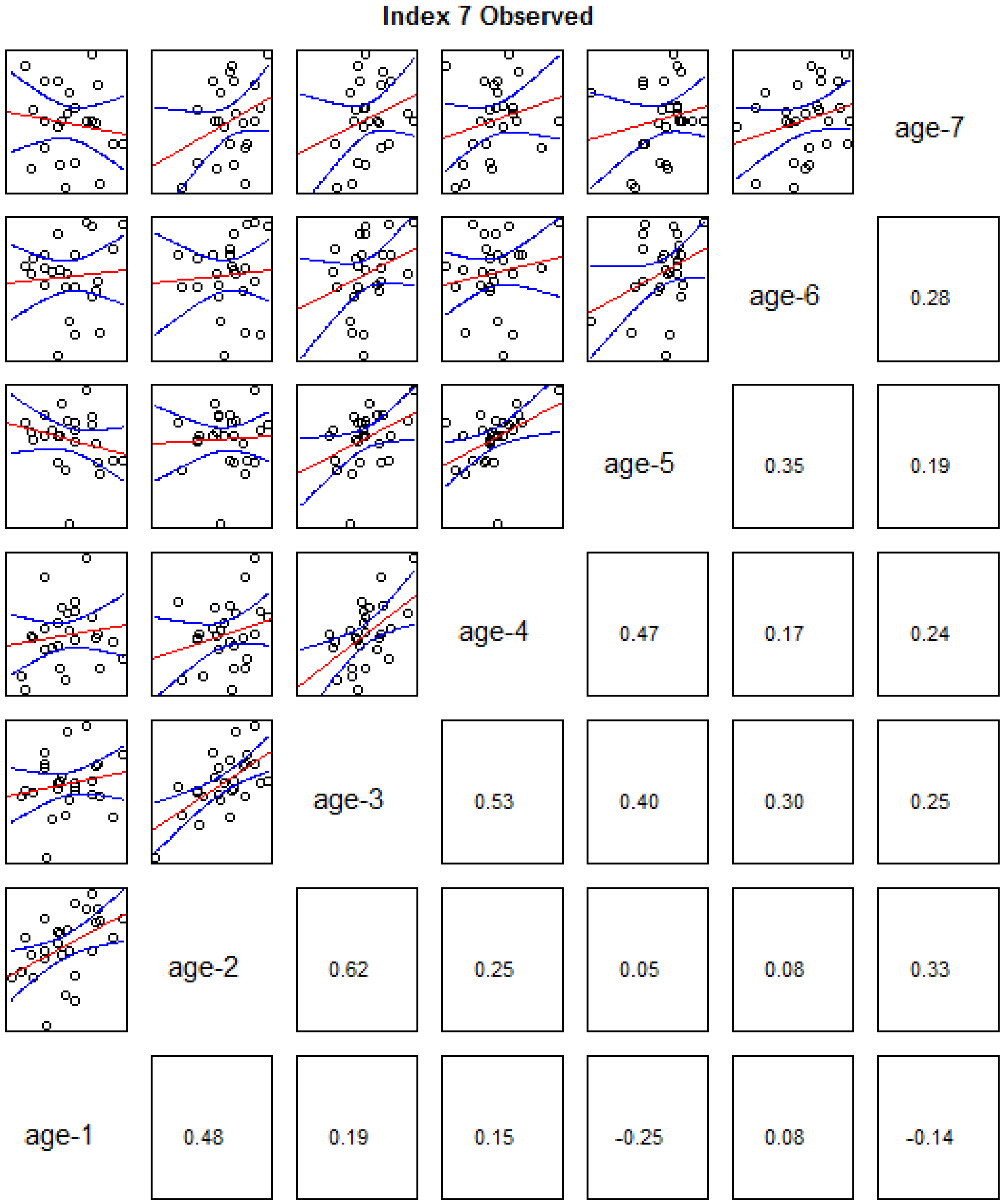


App. B7 Figure B7.97. Predicted catch for the NEAMAP survey.

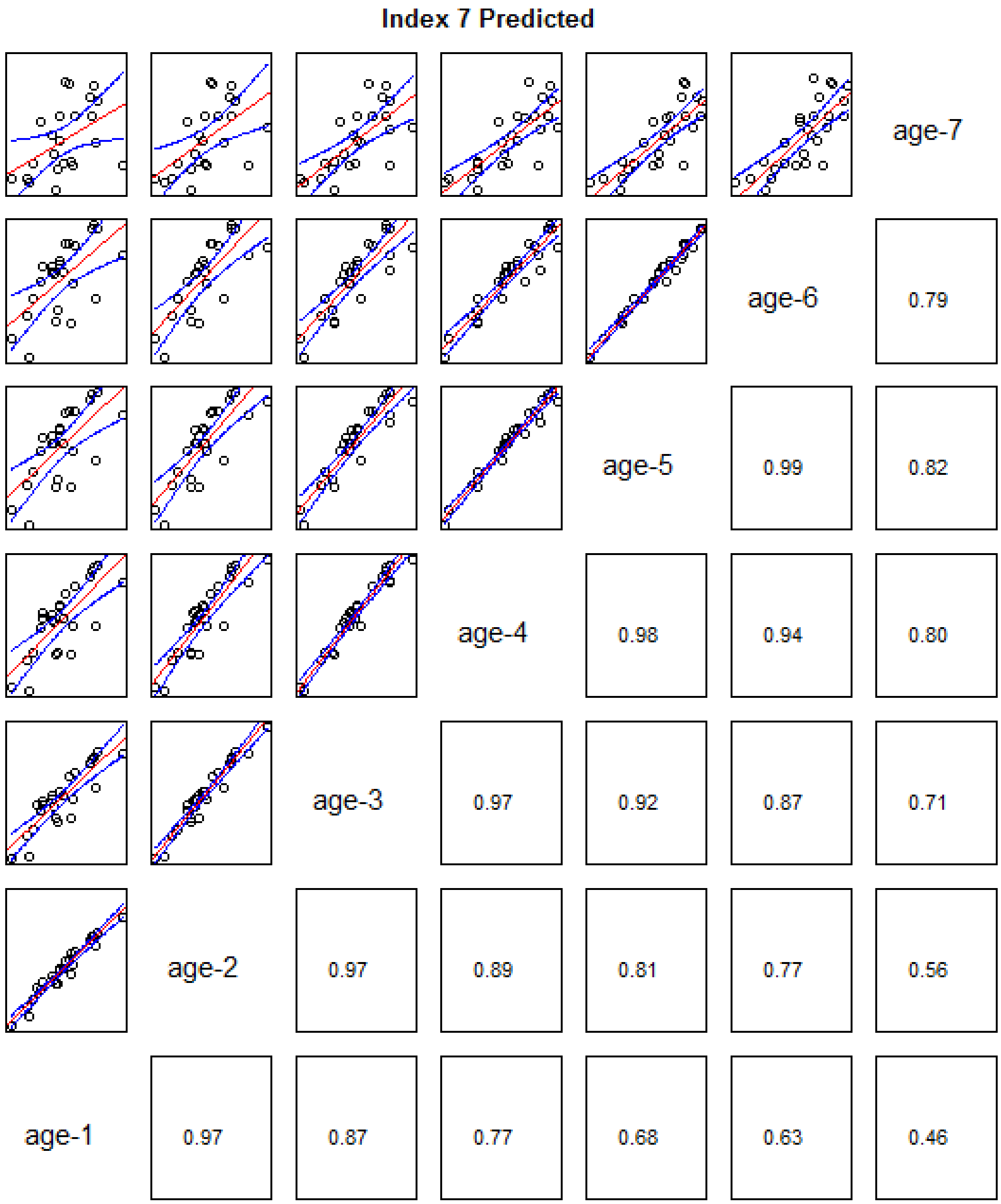


App. B7 Figure B7.98. Observed catch for the PSIGNS gillnet survey.

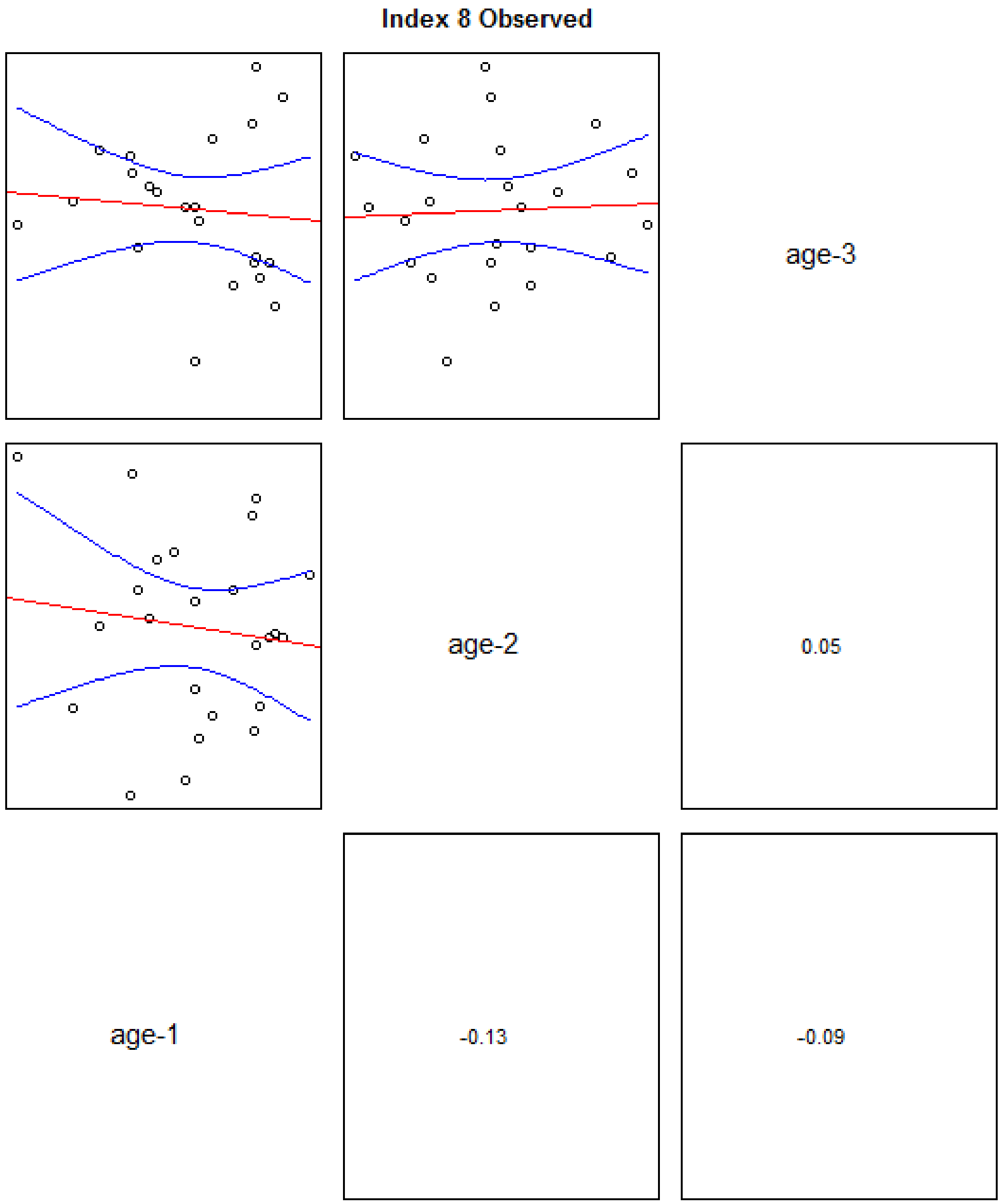
App. B7 Figure B7.99. Predicted catch for the PSIGNS gillnet survey.



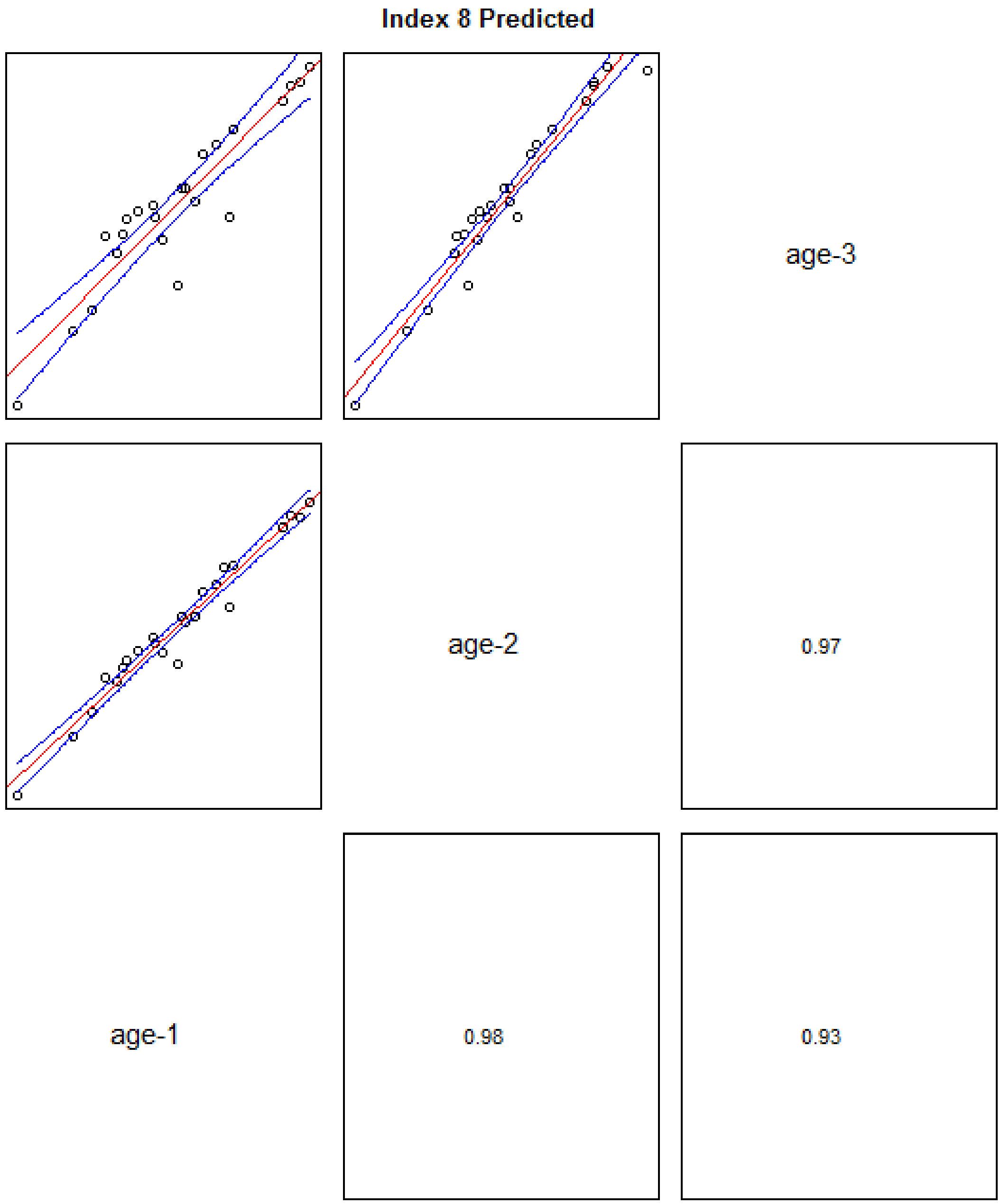
App. B7 Figure B7.100. Observed catch for the CT LISTS trawl survey.



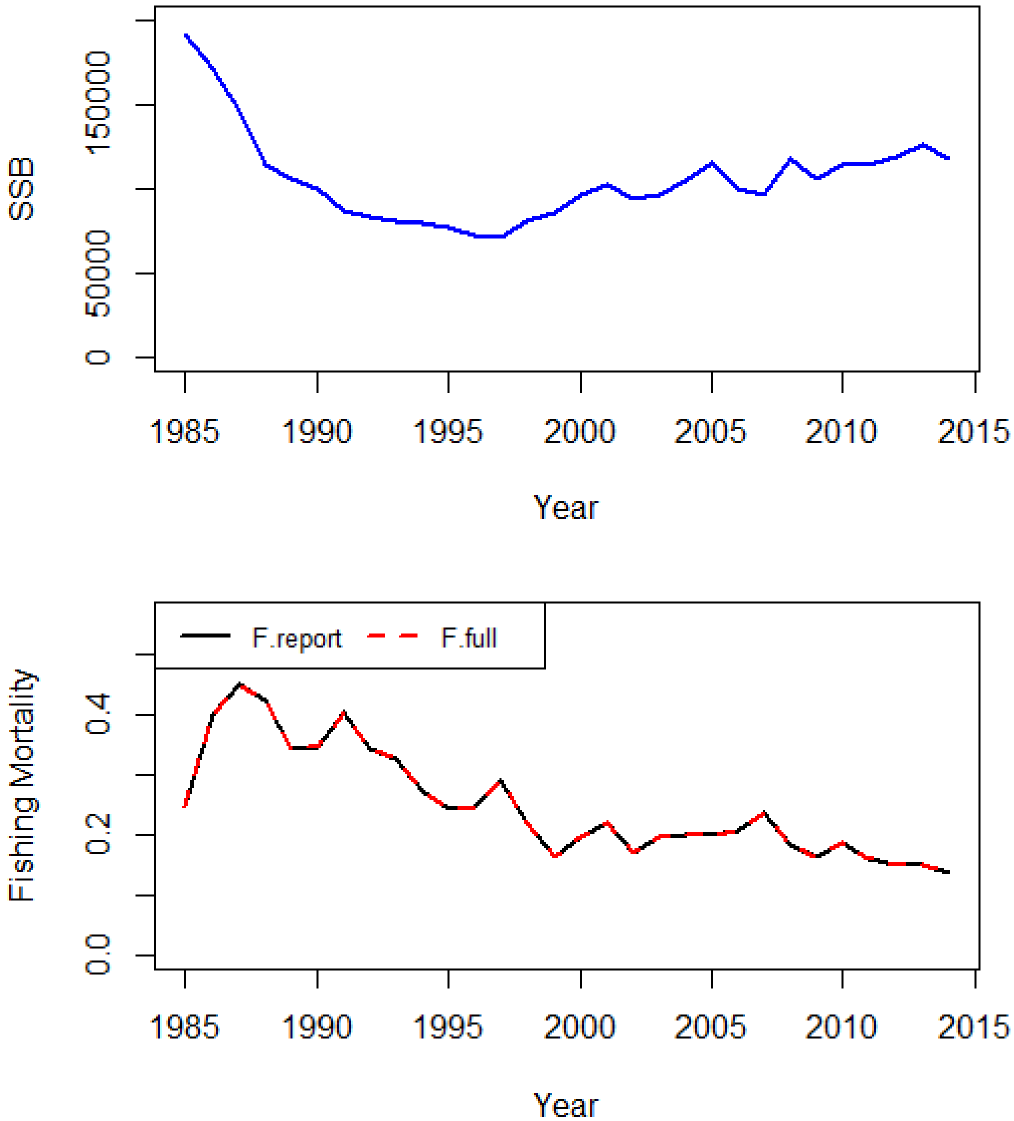
App. B7 Figure B7.101. Predicted catch for the CT LISTS trawl survey.



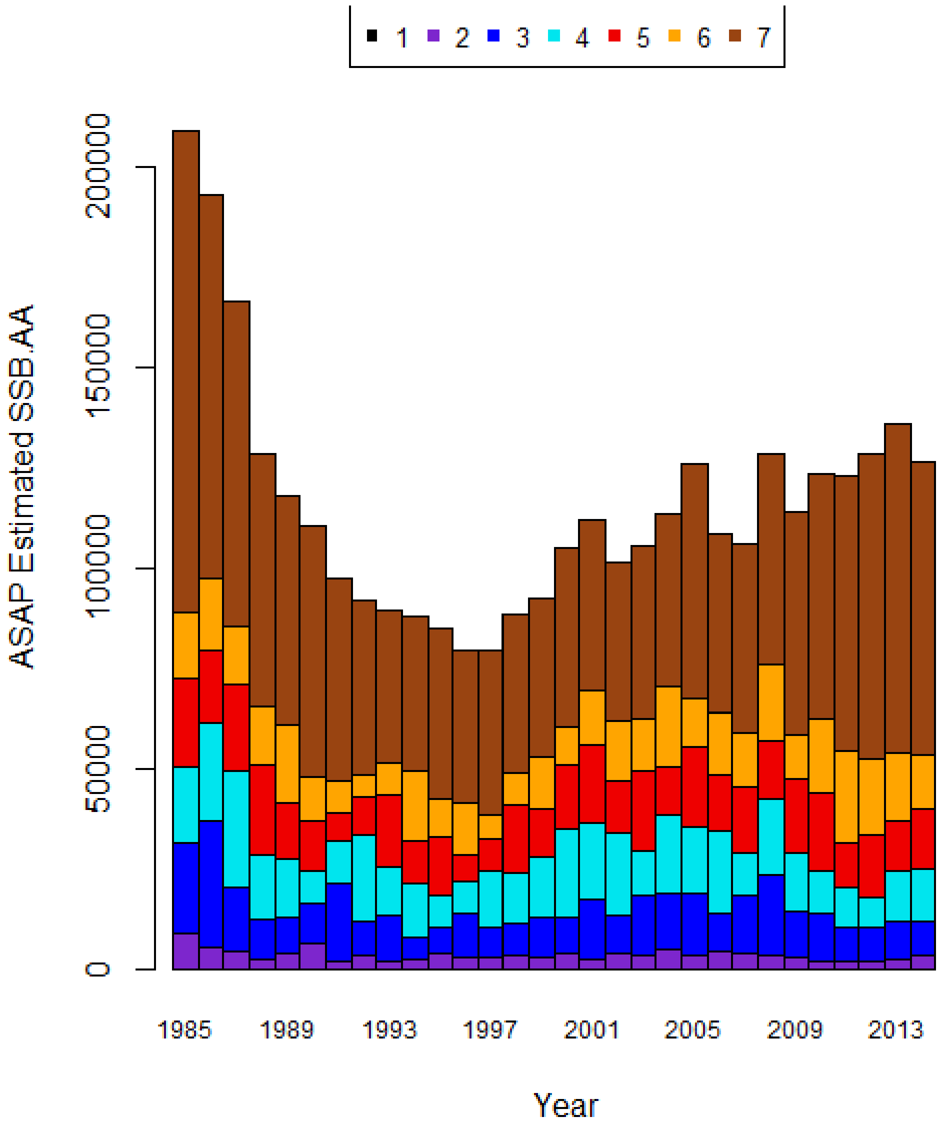
App. B7 Figure B7.102. Observed catch for the NJ ocean trawl survey.



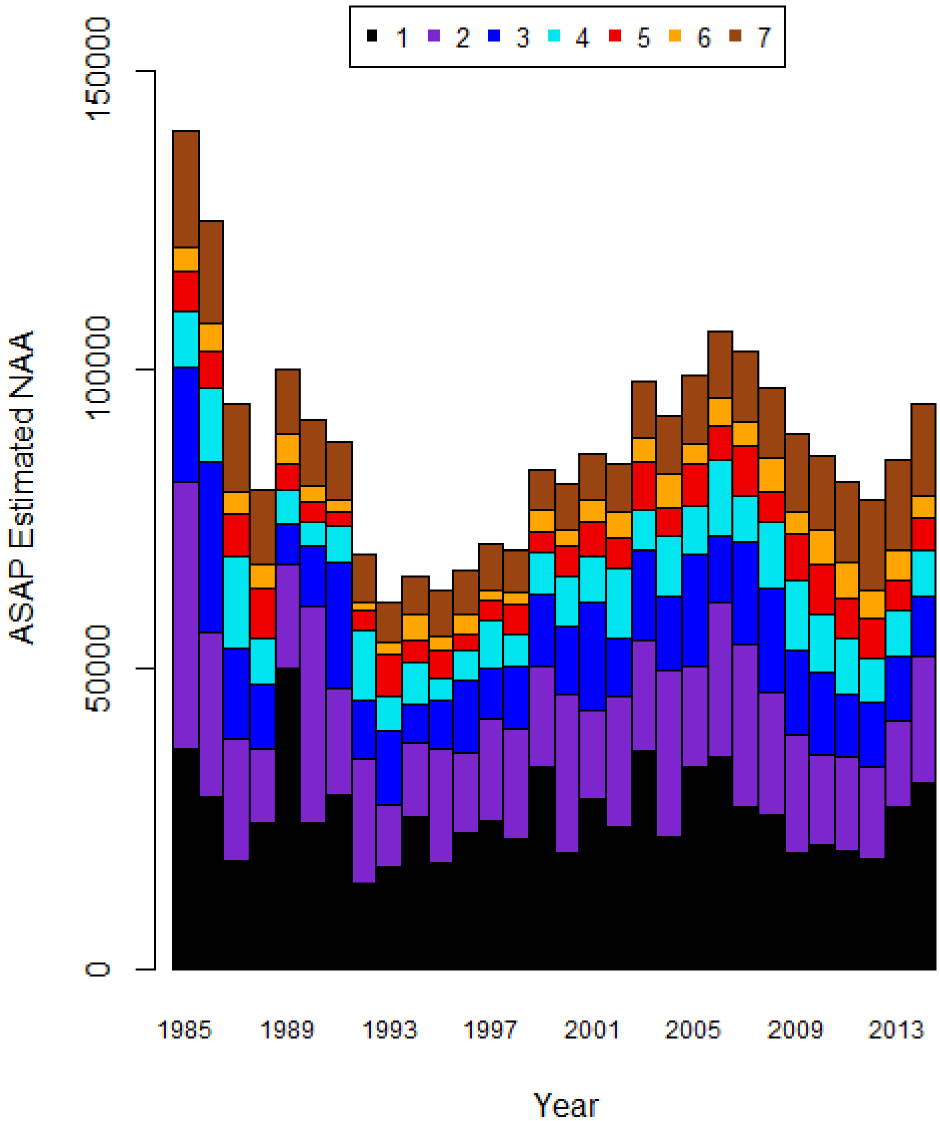
App. B7 Figure B7.103. Predicted catch for the NJ ocean trawl survey.



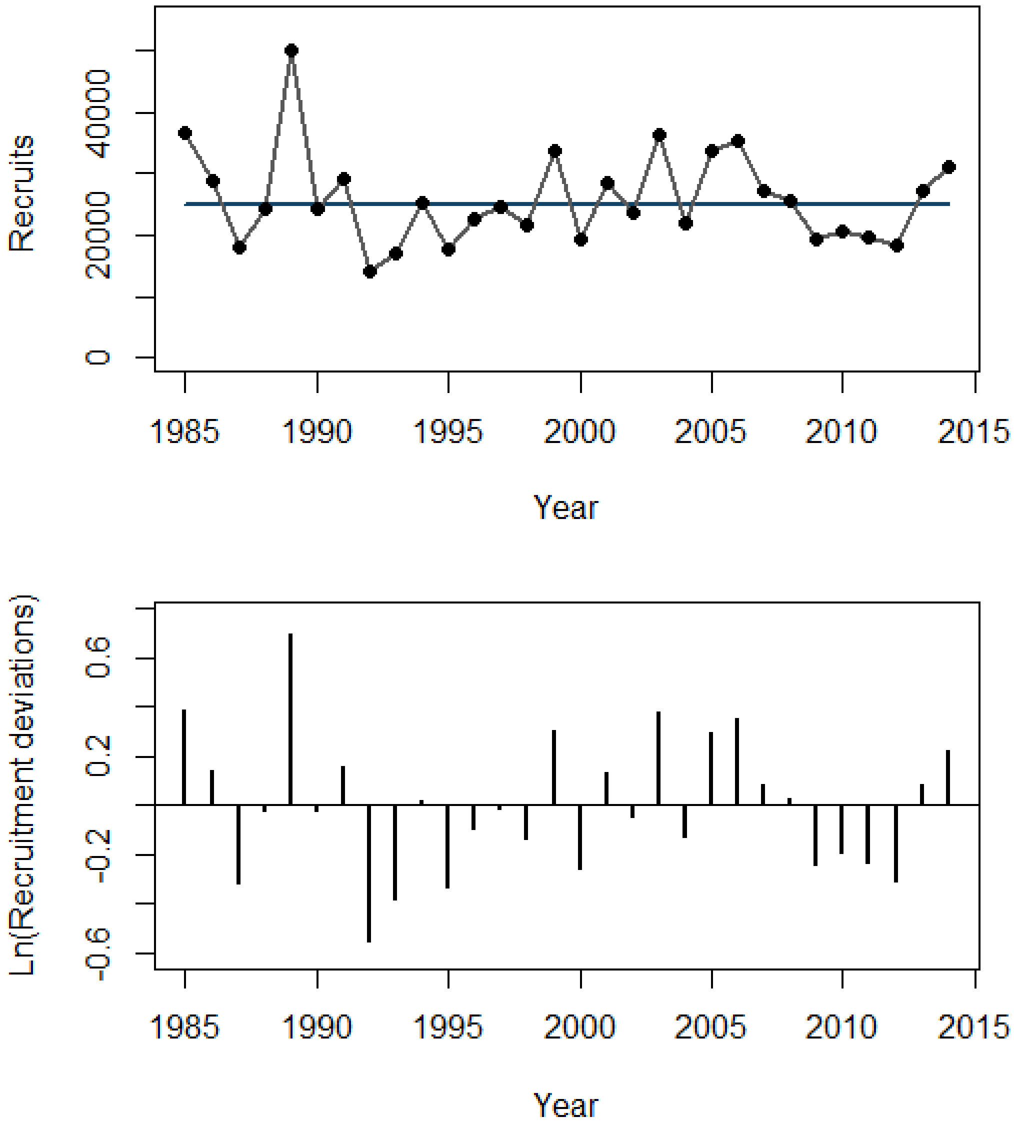
App. B7 Figure B7.104. Estimated spawning stock biomass and full fishing mortality from 1985 to 2014 from the final model.



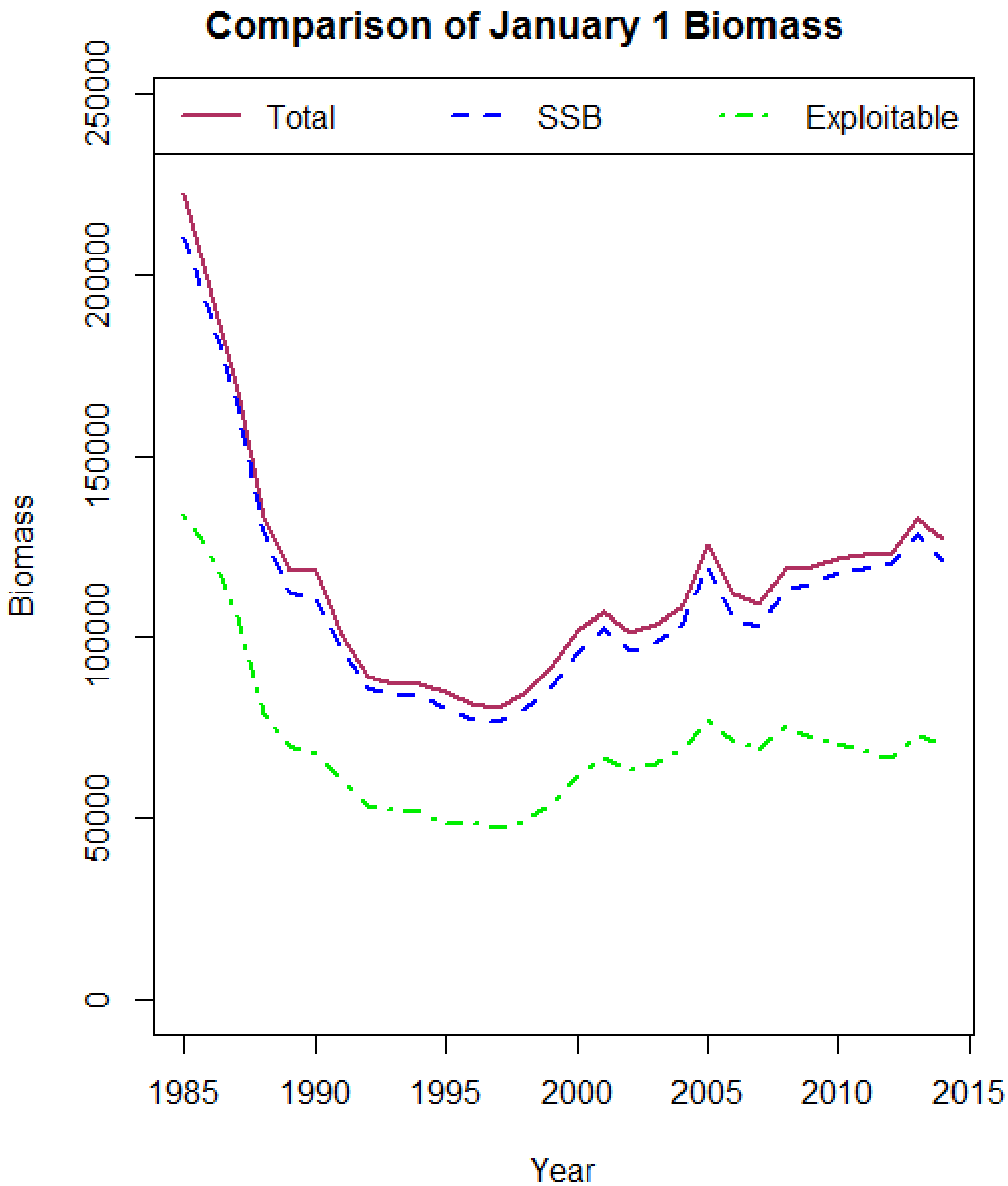
App. B7 Figure B7.105. Age composition of the spawning stock biomass from 1985 to 2014.



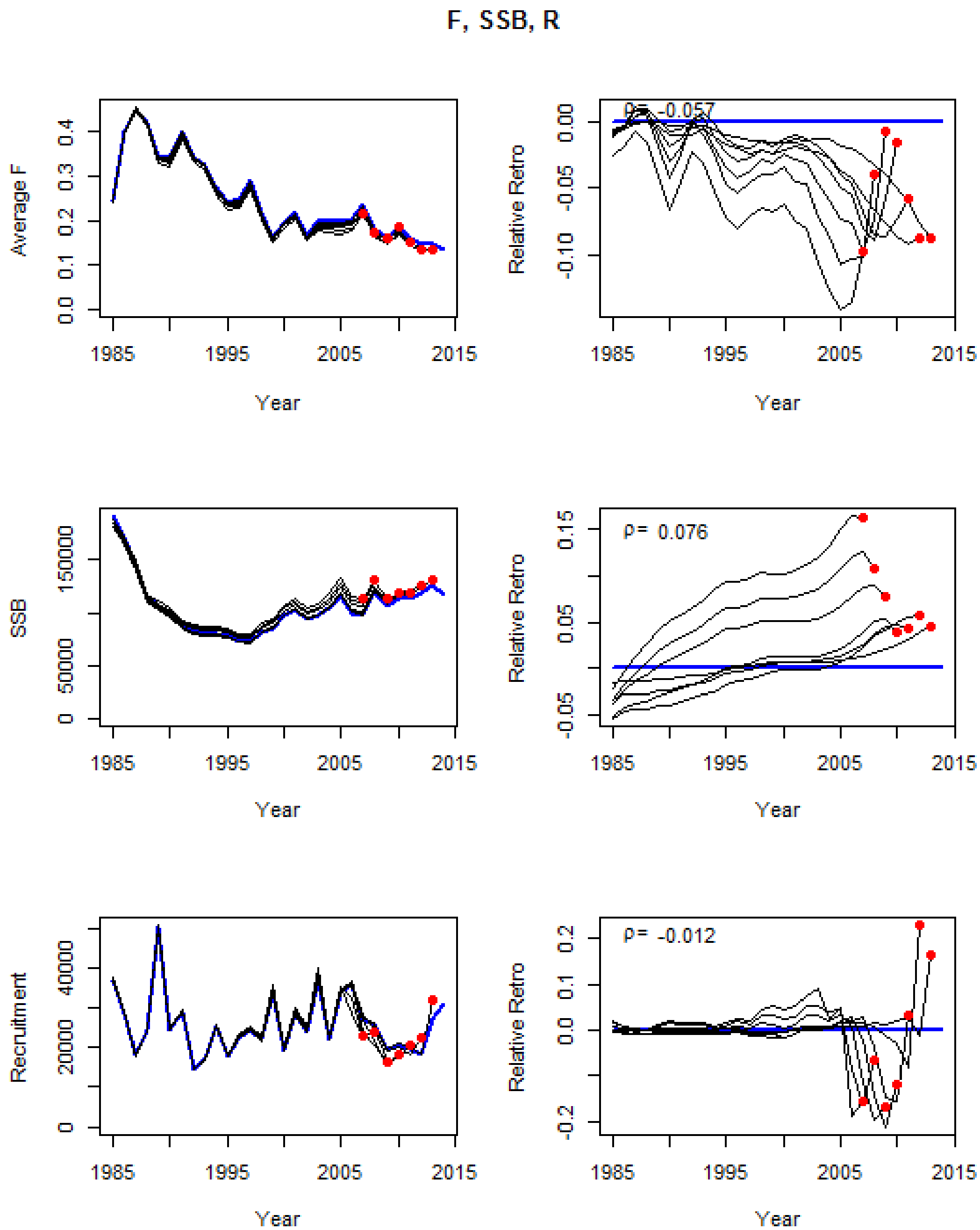
App. B7 Figure B7.106. Estimated numbers at age from the final model from 1985 to 2014.



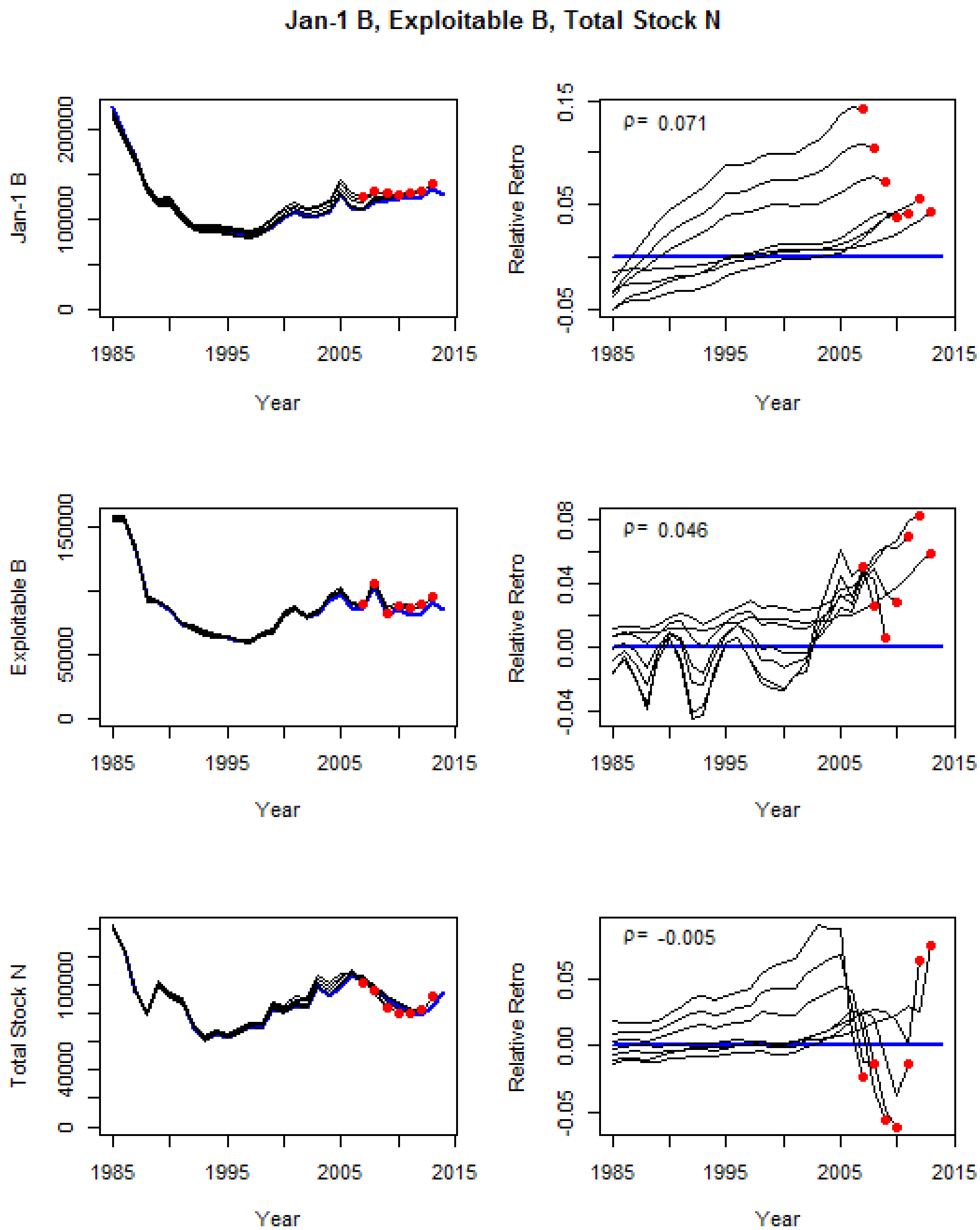
App. B7 Figure B7.107. Recruitment estimates, mean recruitment, and recruitment deviations (log) from 1985 to 2014 from the final model.



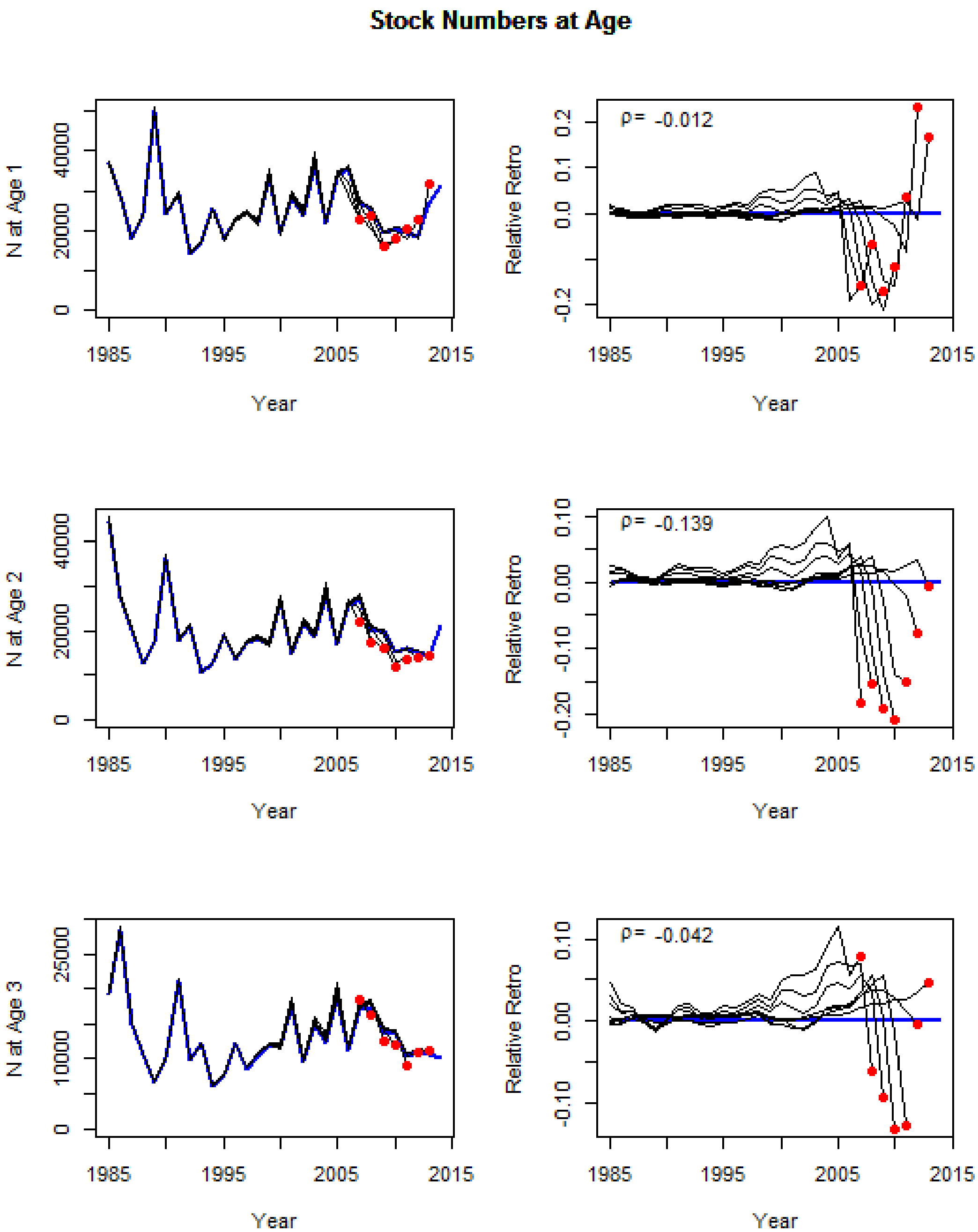
App. B7 Figure B7.108. A comparison of total, spawning stock, and exploitable biomass from 1985 to 2014 from the final model.



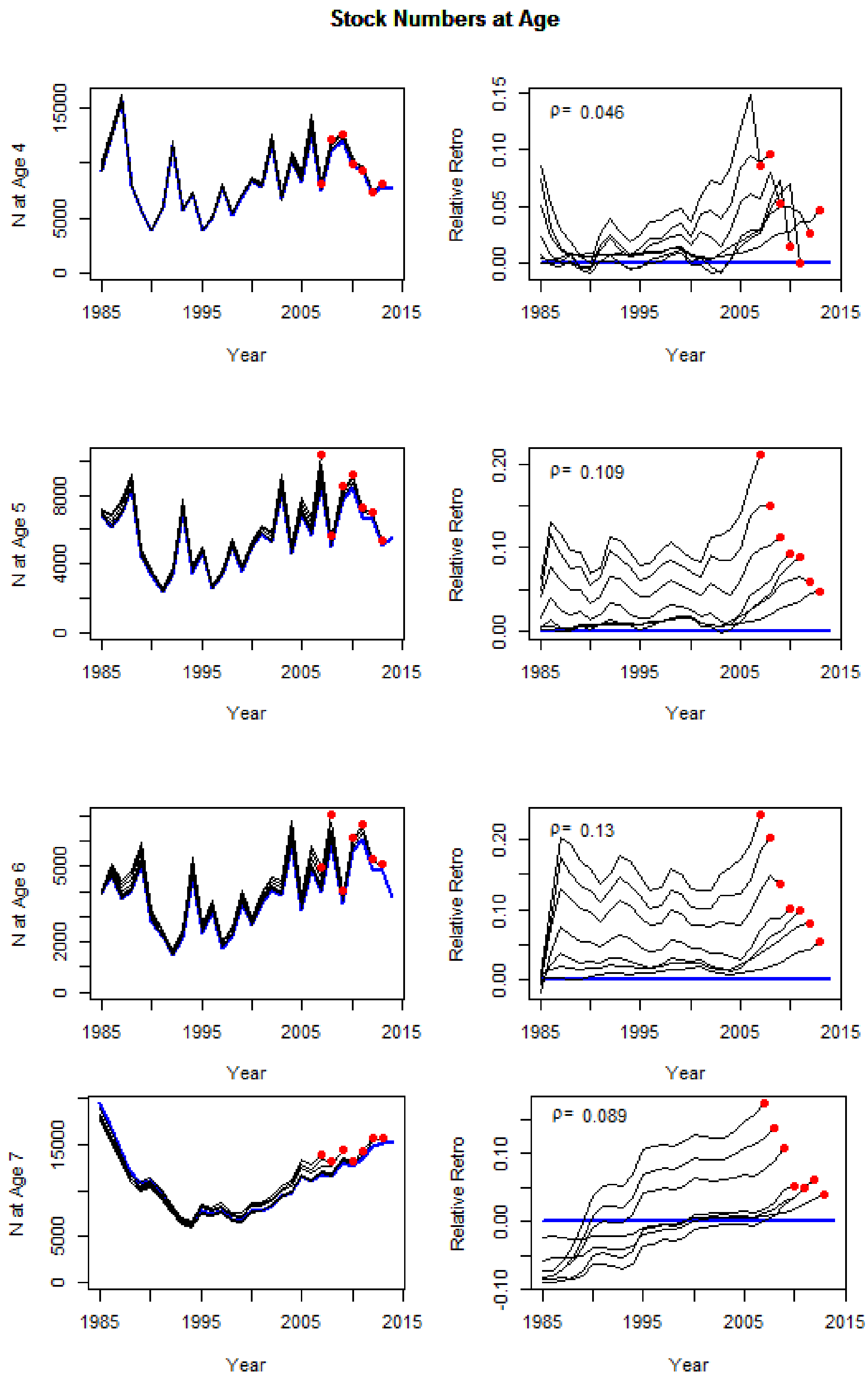
App. B7 Figure B7.109. Retrospective plots for average fishing mortality, spawning stock biomass and recruitment from a 7 year peel carried out on the final model.



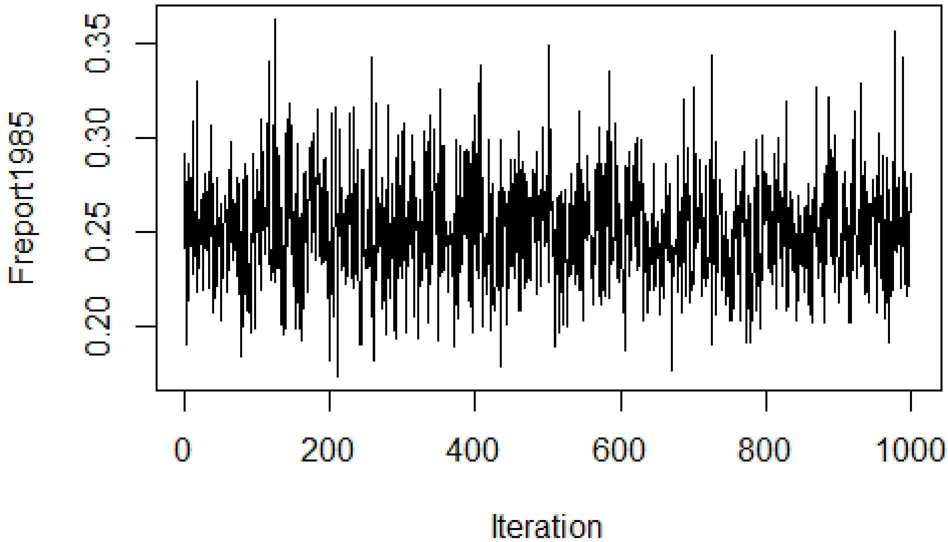
App. B7 Figure B7.110. Retrospective plots for January-1 biomass, total biomass, and total stock numbers, from a 7 year peel carried out on the final model.

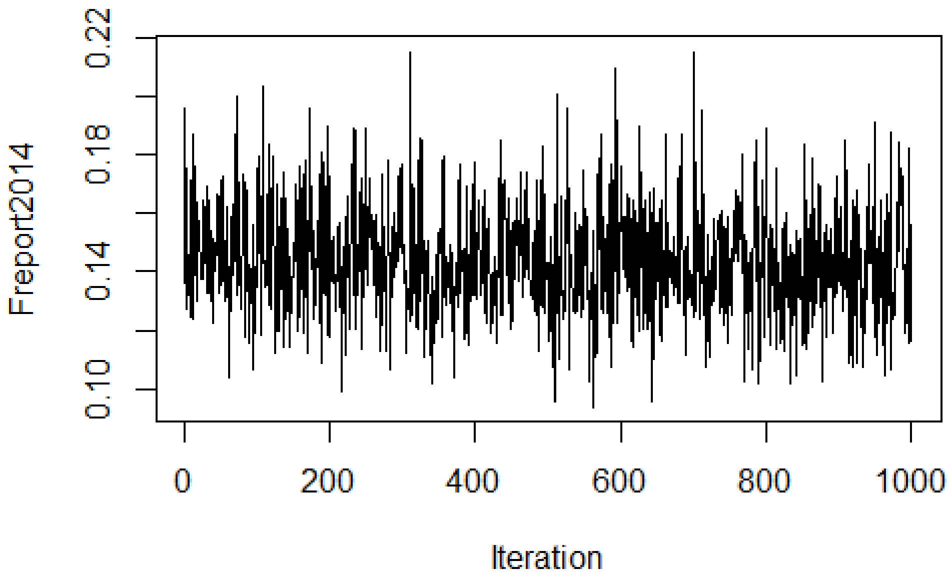


App. B7 Figure B7.111. Retrospective plots for ages 0-2 from a 7 year peel carried out on the final model.

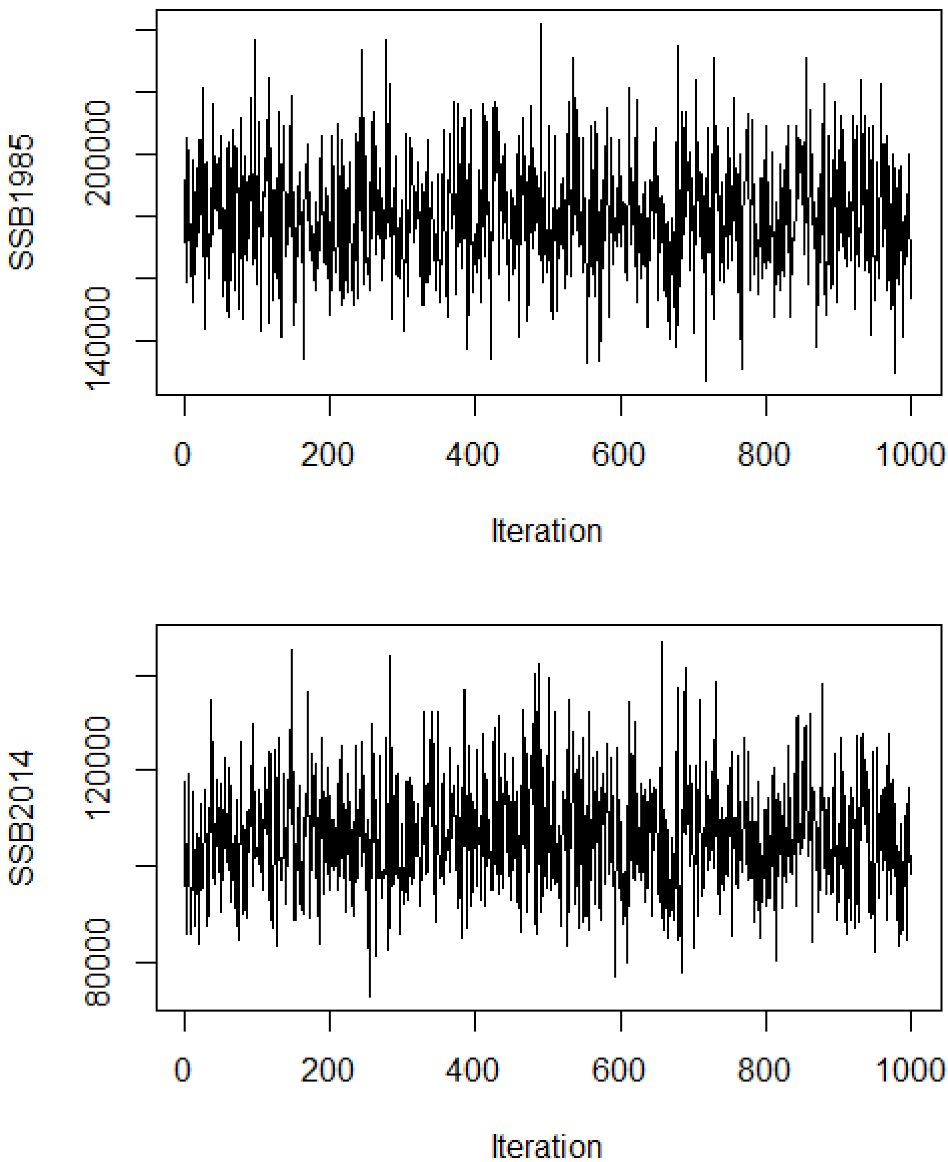


App. B7 Figure B7.112. Retrospective plots for ages 3-6+ from a 7 year peel carried out on the final model.

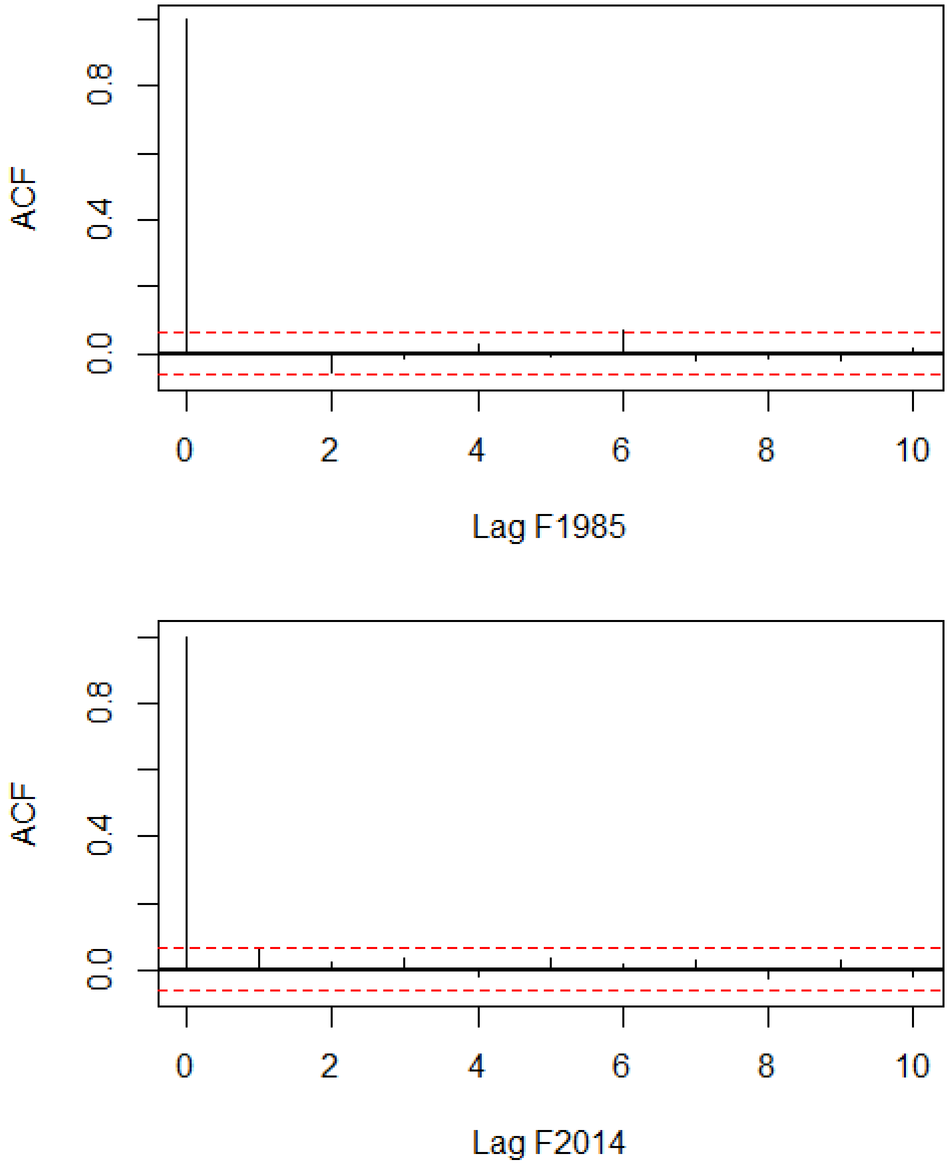




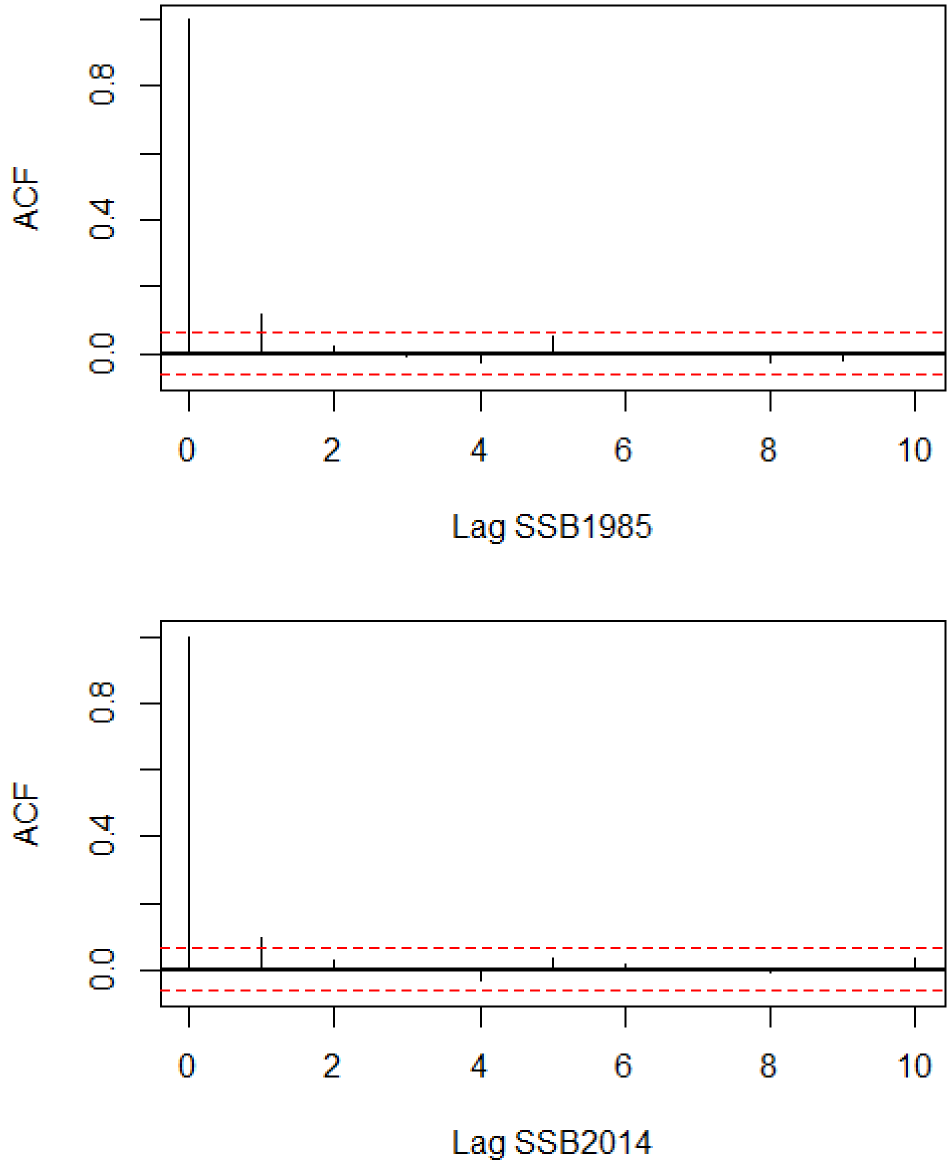
App. B7 Figure B7.113. Trace plots for fishing mortality in 1985 and 2014 from 1000 MCMC and a thinning rate of 1000 (1,000,000 iterations).



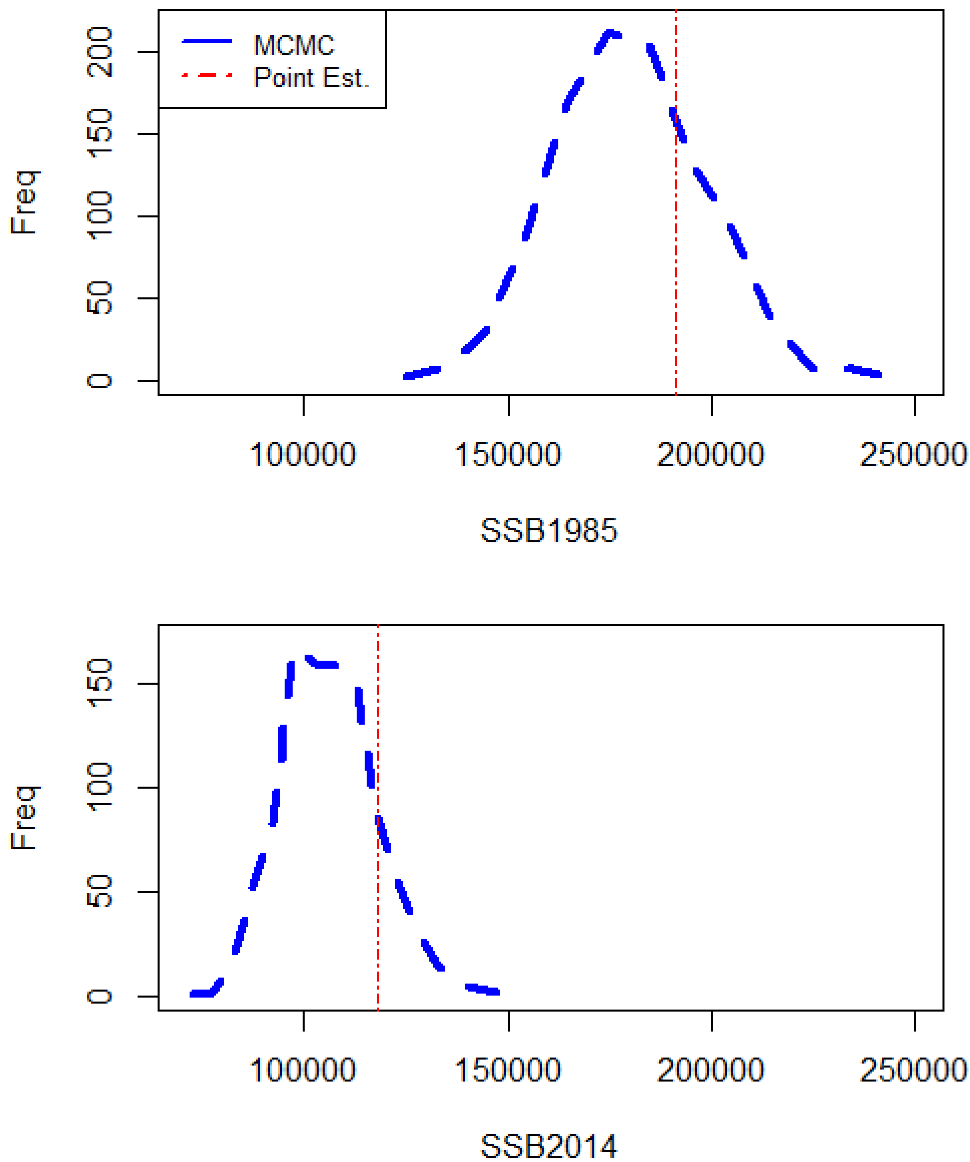
App. B7 Figure B7.114. Trace plots for spawning stock biomass in 1985 and 2014 from 1000 MCMC and a thinning rate of 1000 (1,000,000 iterations).



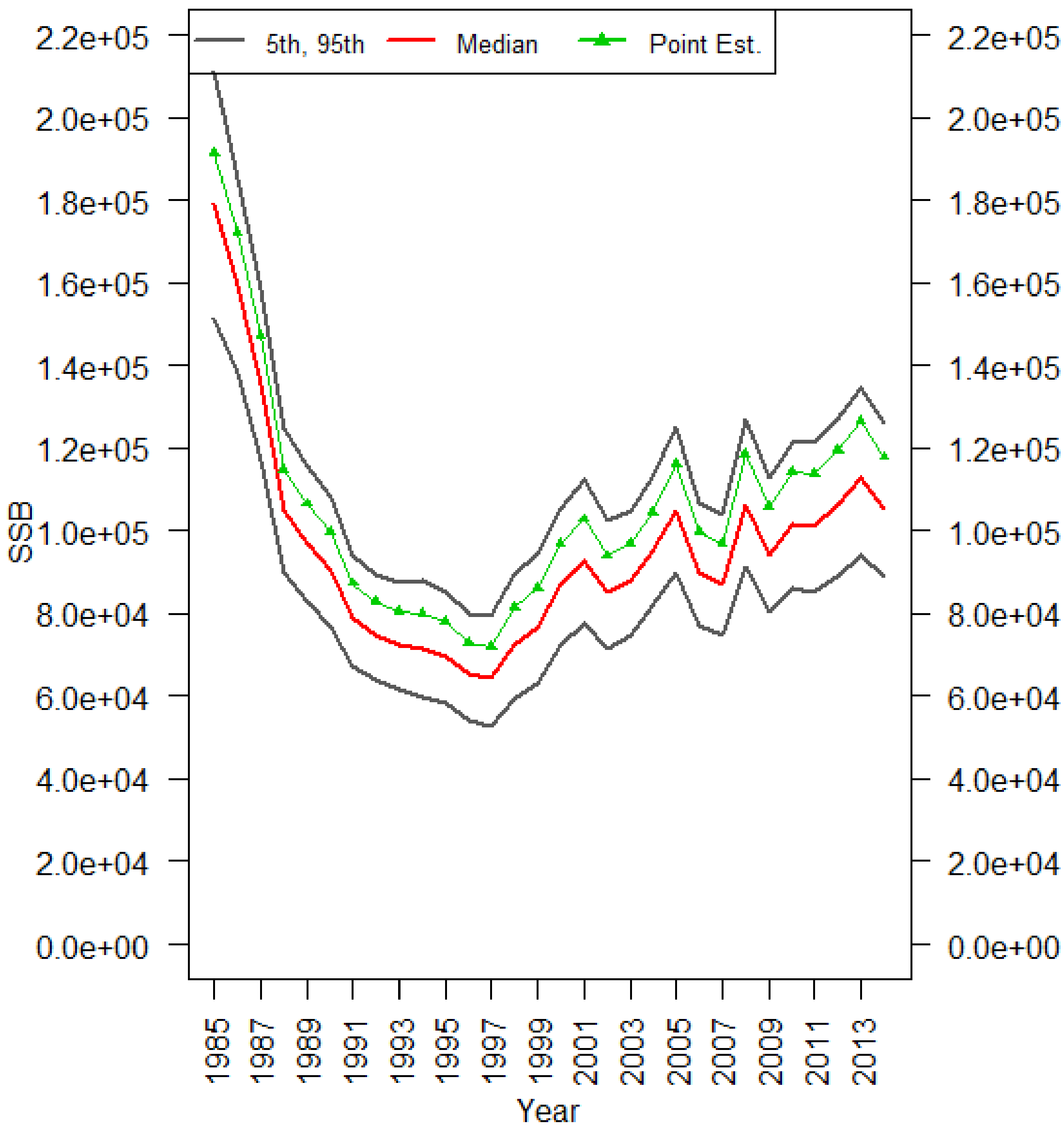
App. B7 Figure B7.115. Autocorrelation for fishing mortality in the MCMC runs.



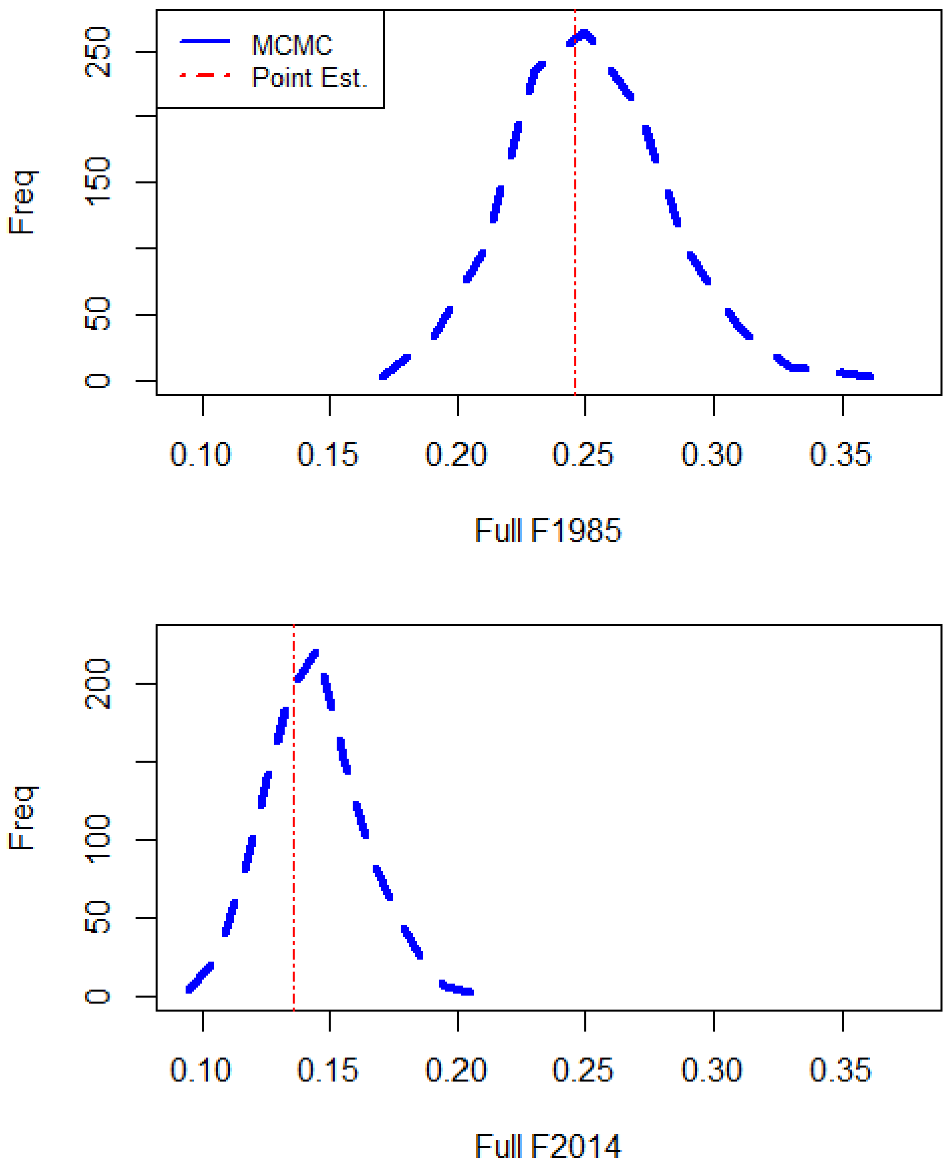
App. B7 Figure B7.116. Autocorrelation for SSB in the MCMC runs.



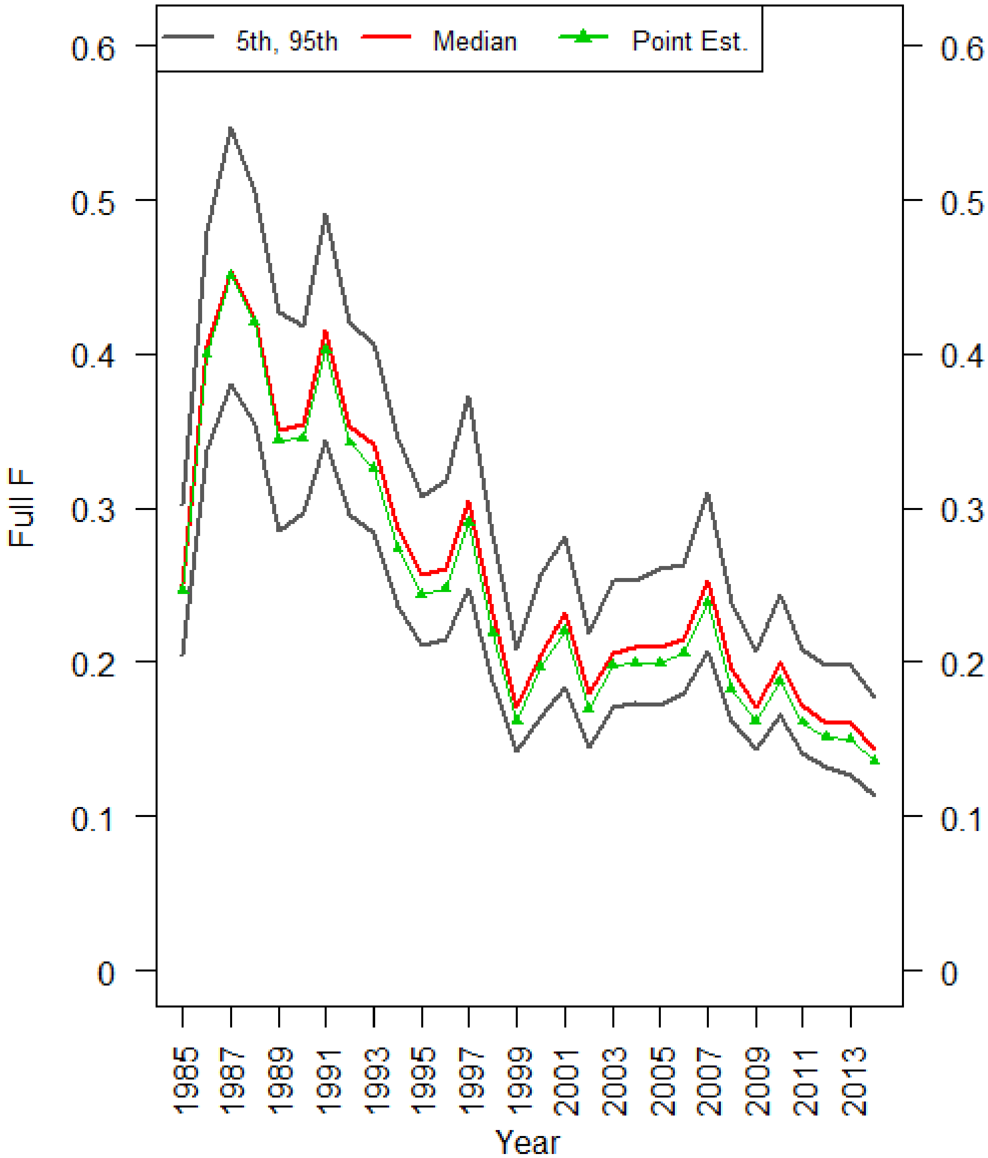
App. B7 Figure B7.117. MCMC distribution plots for spawning stock biomass in 1985 and 2014 with point estimates from the final model.



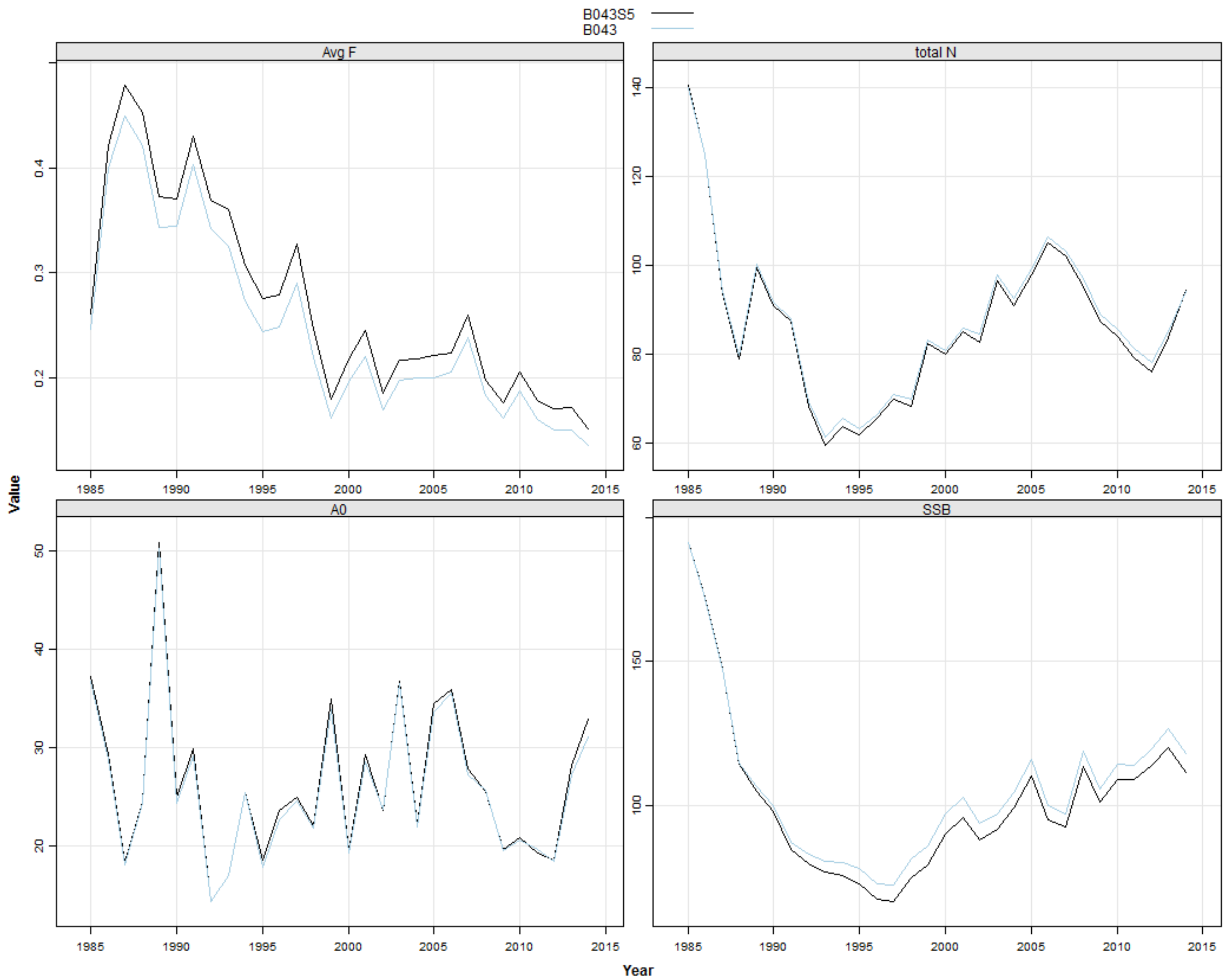
App. B7 Figure B7.118. Median spawning stock biomass and 95 confidence intervals from the MCMC runs with point estimates from the final model.



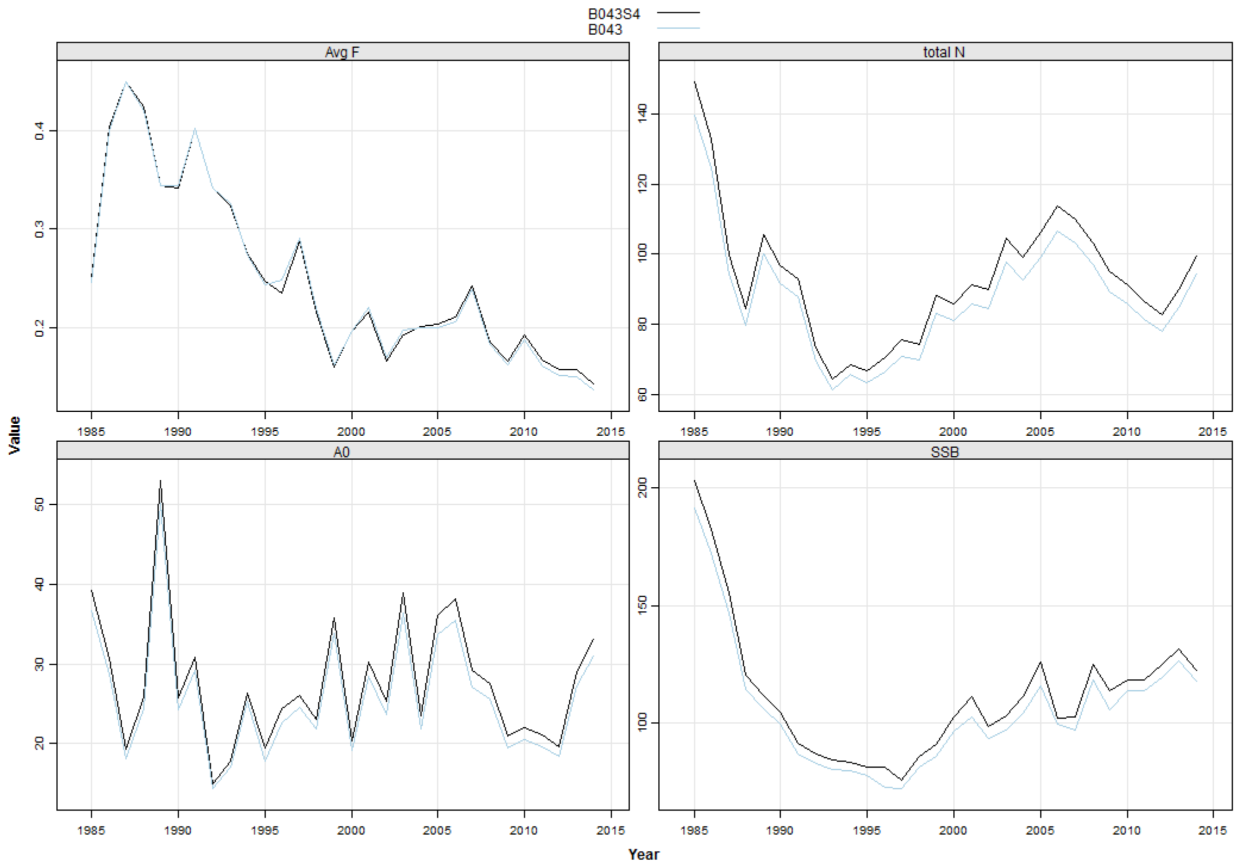
App. B7 Figure B7.119. MCMC distribution plots for fishing mortality in 1985 and 2014 with point estimates from the final model.



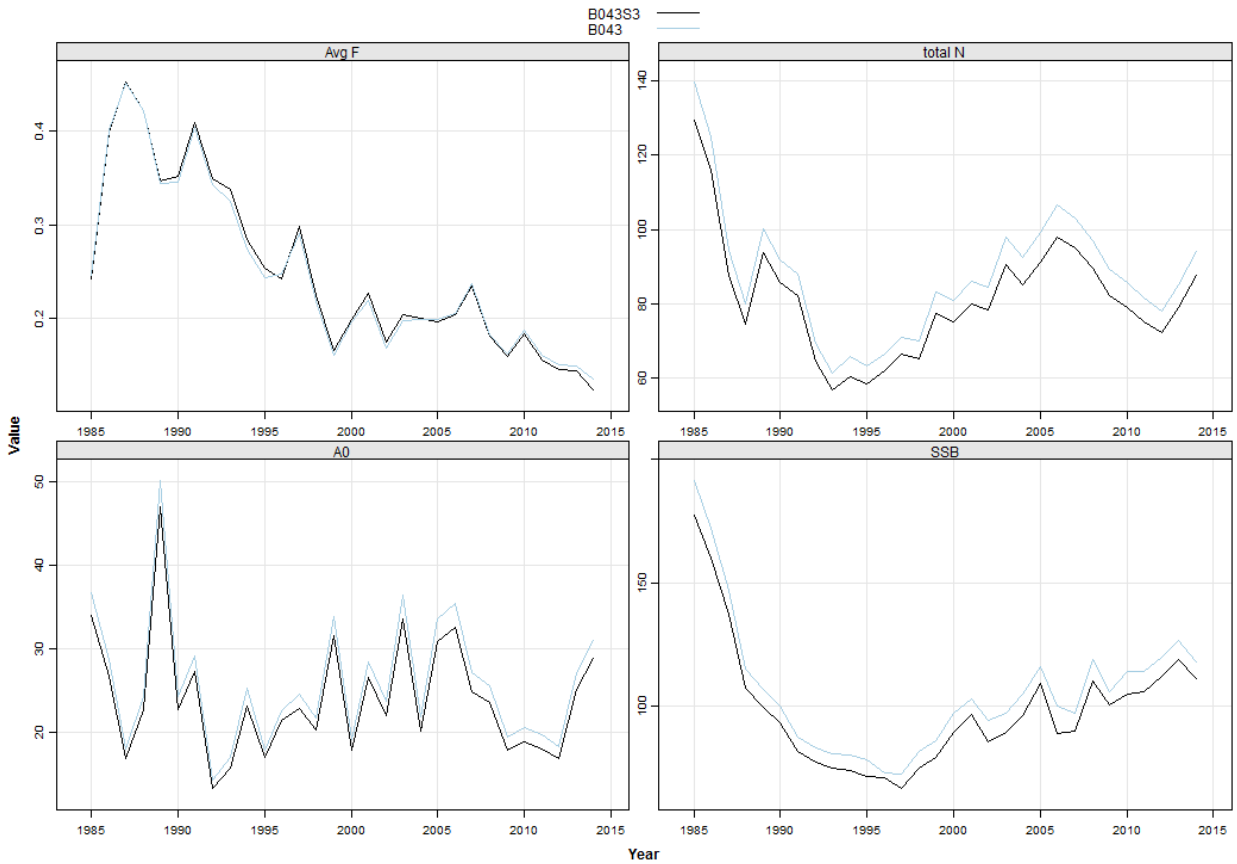
App. B7 Figure B7.120. Median fishing mortality and 95 confidence intervals from the MCMC runs with point estimates from the final model.



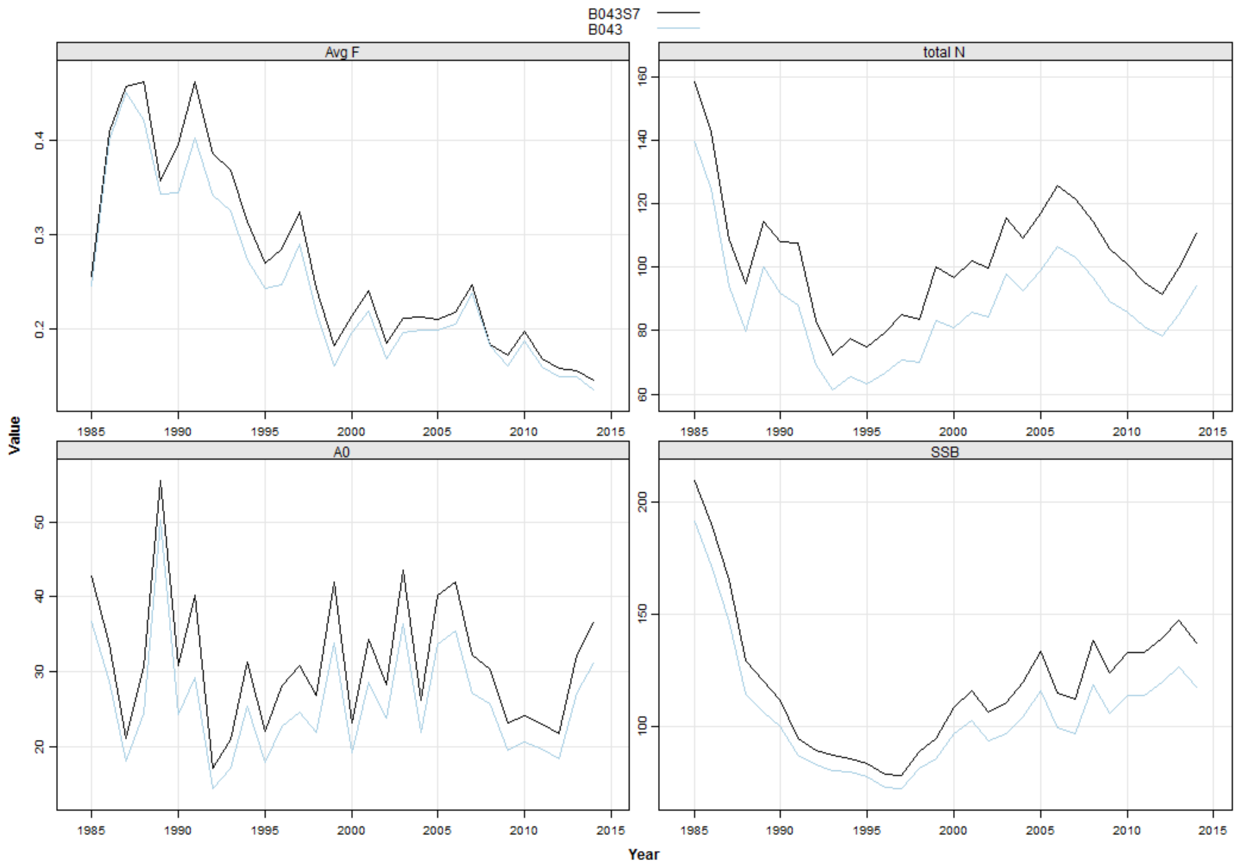
App. B7 Figure B7.121. Final model sensitivity run assume AB1 lengths for the recreational discards. Trends for the final model (B043) estimates are represented by the blue line, with sensitivity run estimates (B043S5) represented by the black line.



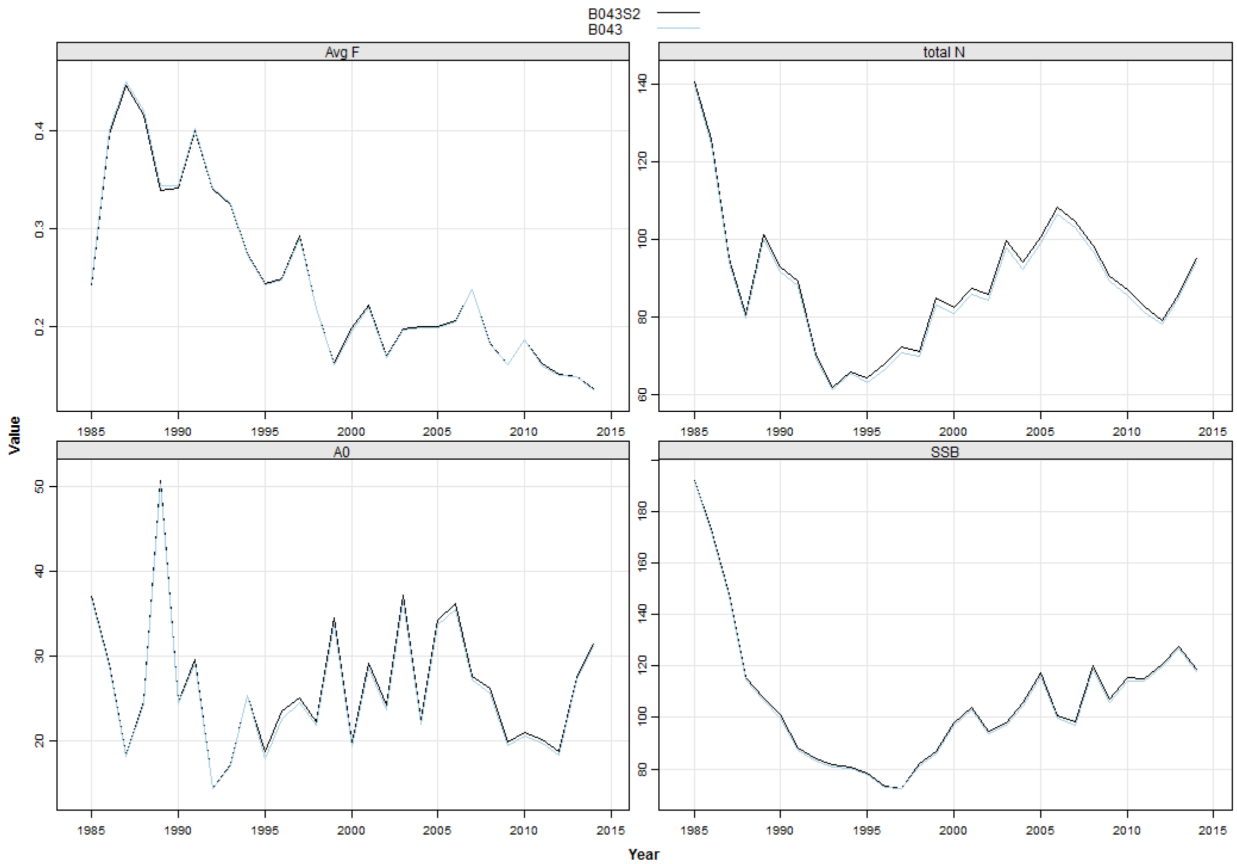
App. B7 Figure B7.122. Final model sensitivity run assuming upper 95% CI for recreational catch. Trends for the final model (B043) estimates are represented by the blue line, with sensitivity run estimates (B043S4) represented by the black line.



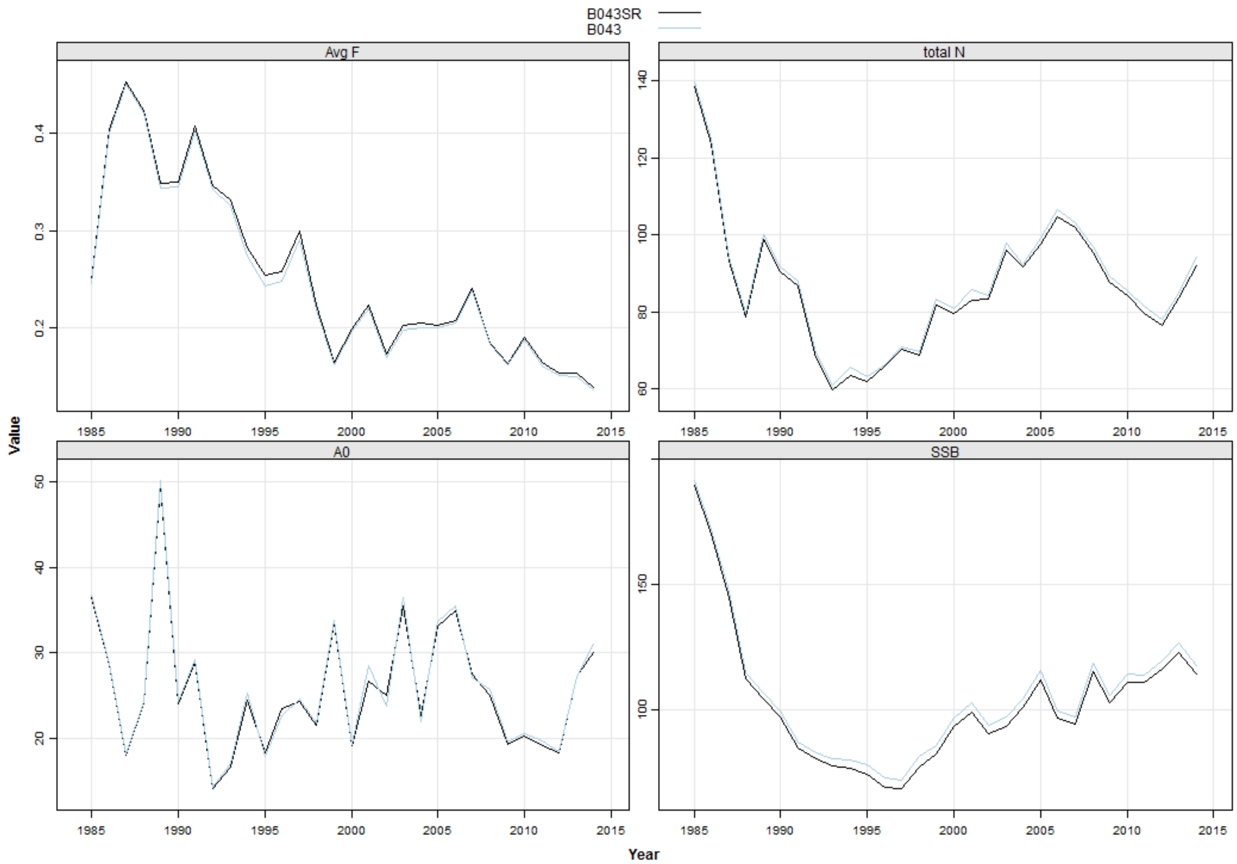
App. B7 Figure B7.123. Final model sensitivity run assuming lower 95% CI for recreational catch. Trends for the final model (B043) estimates are represented by the blue line, with sensitivity run estimates (B043S3) represented by the black line.



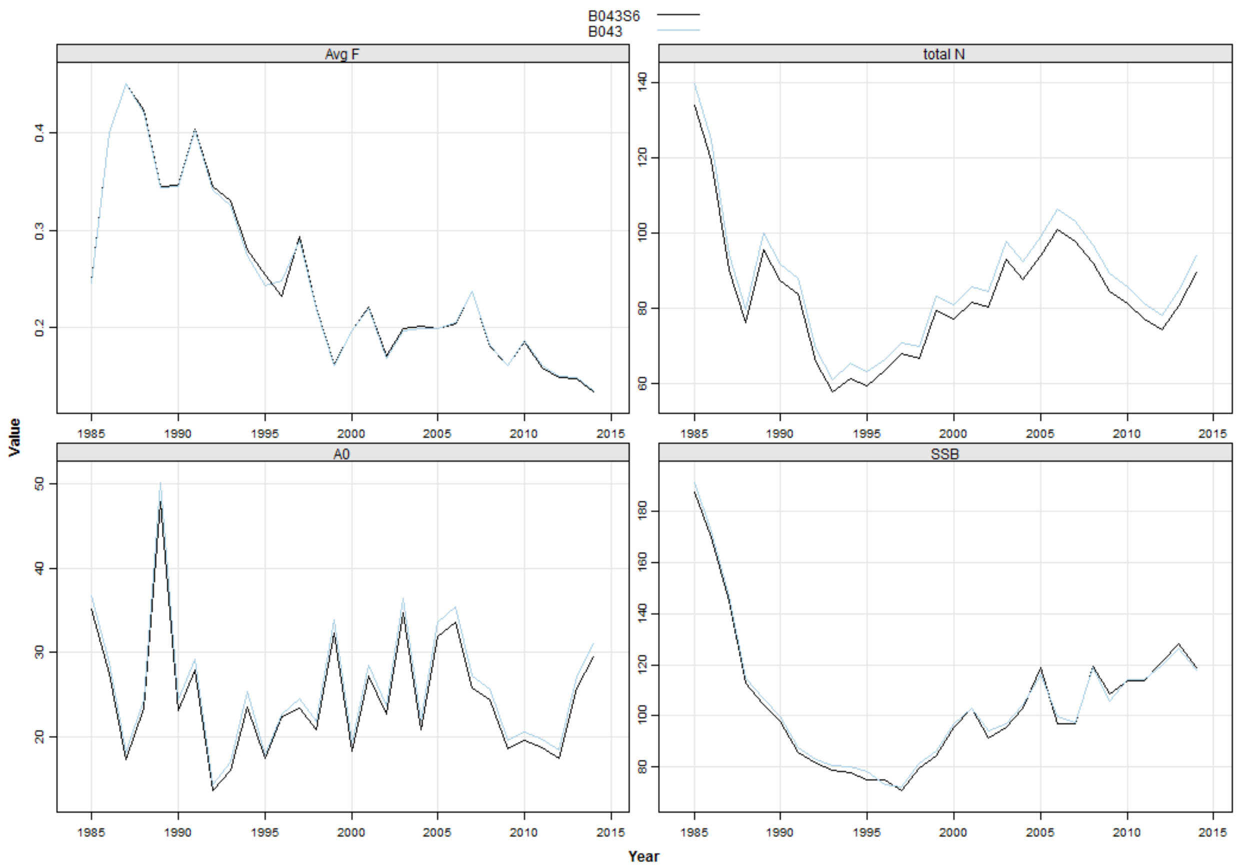
App. B7 Figure B7.124. Final model sensitivity run assuming MRFSS number prior to 2004 for the recreational catch. Trends for the final model (B043) estimates are represented by the blue line, with sensitivity run estimates (B043S7) represented by the black line.



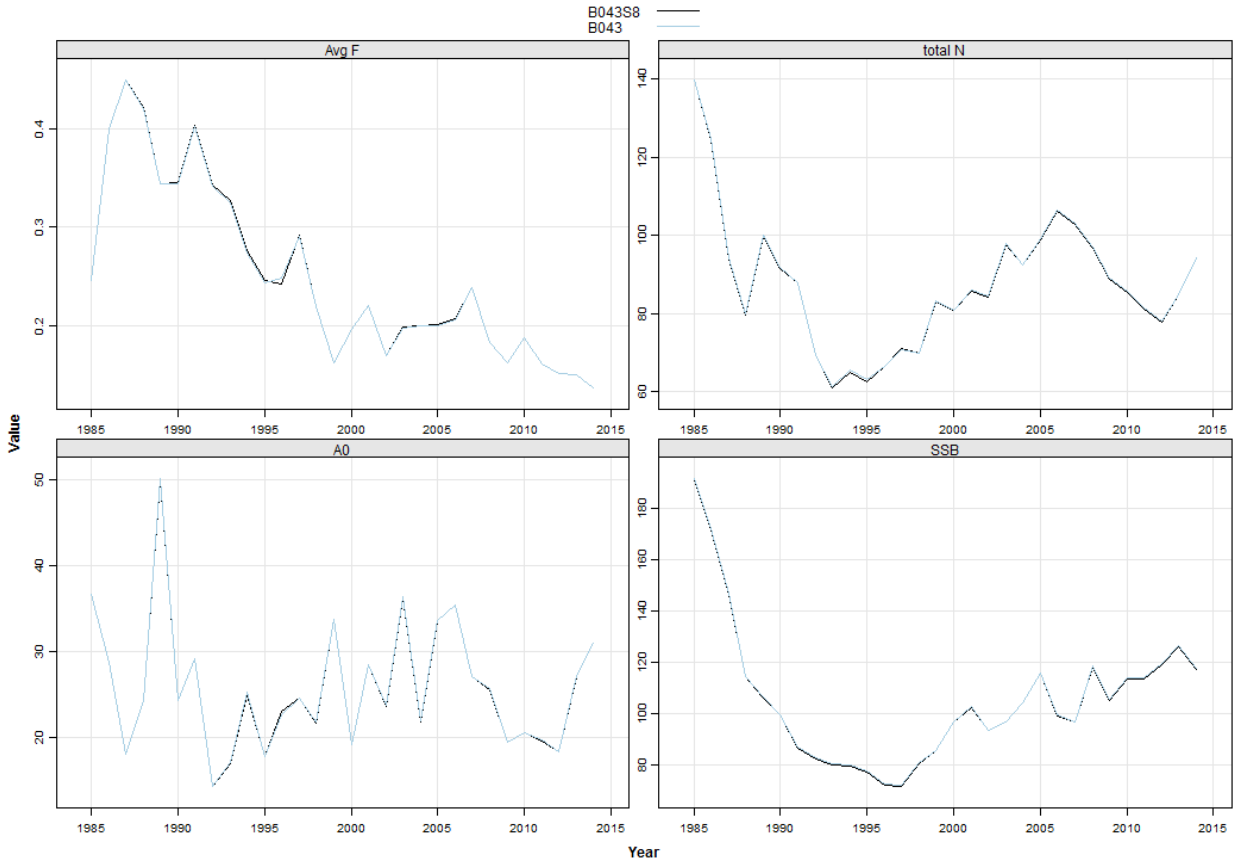
App. B7 Figure B7.125. Final model sensitivity run assuming 17% mortality (instead of 15%) for the recreational discards.   Trends for the final model (B043) estimates are represented by the blue line, with sensitivity run estimates (B043S7) represented by the black line.



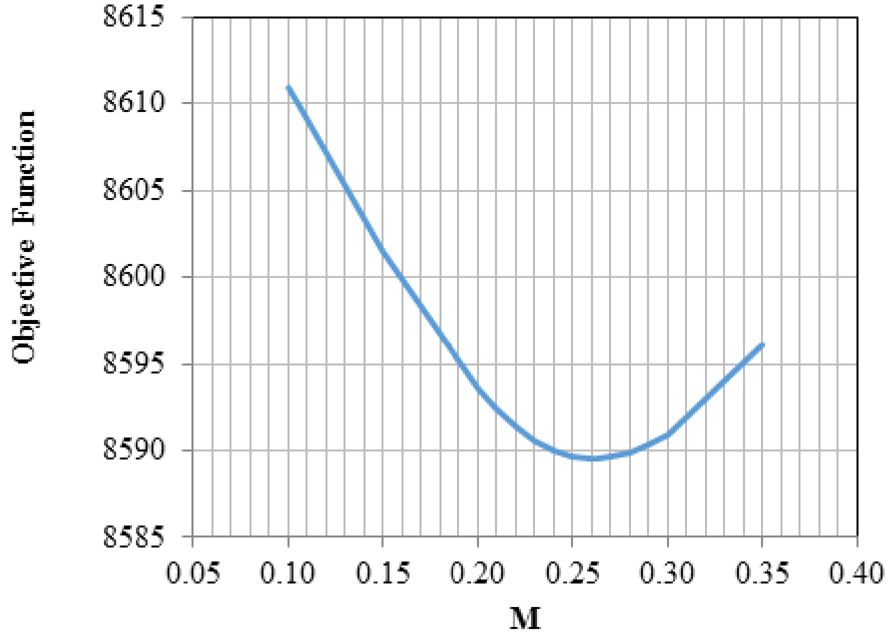
App. B7 Figure B7.126. Final model sensitivity run assuming regional age-length keys from 2006 to 2014. Trends for the final model (B043) estimates are represented by the blue line, with sensitivity run estimates (B043SR) represented by the black line.



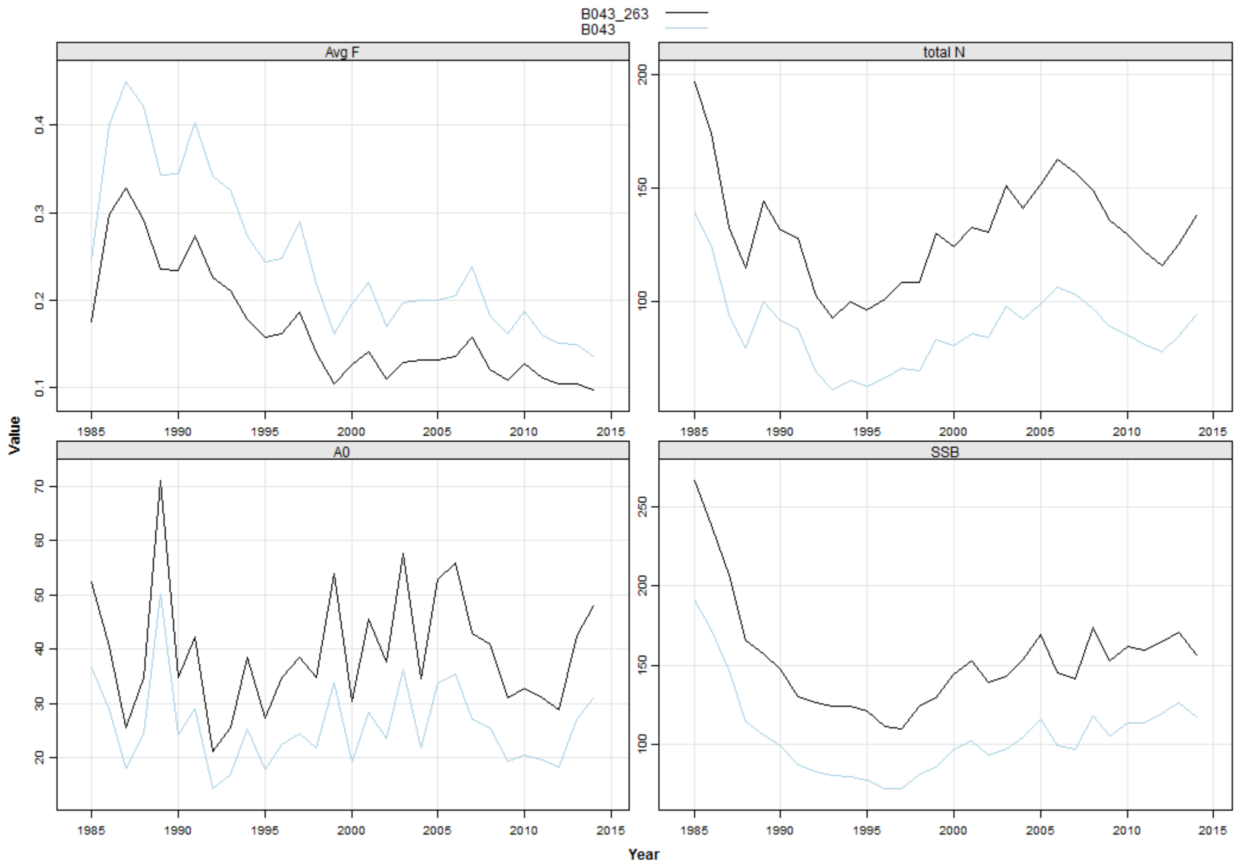
App. B7 Figure B7.127. Final model sensitivity run assuming 3 time blocks for length-weight coefficients (1985-1994, 1995-2004, 2005-2014). Trends for the final model (B043) estimates are represented by the blue line, with sensitivity run estimates (B043S6) represented by the black line.



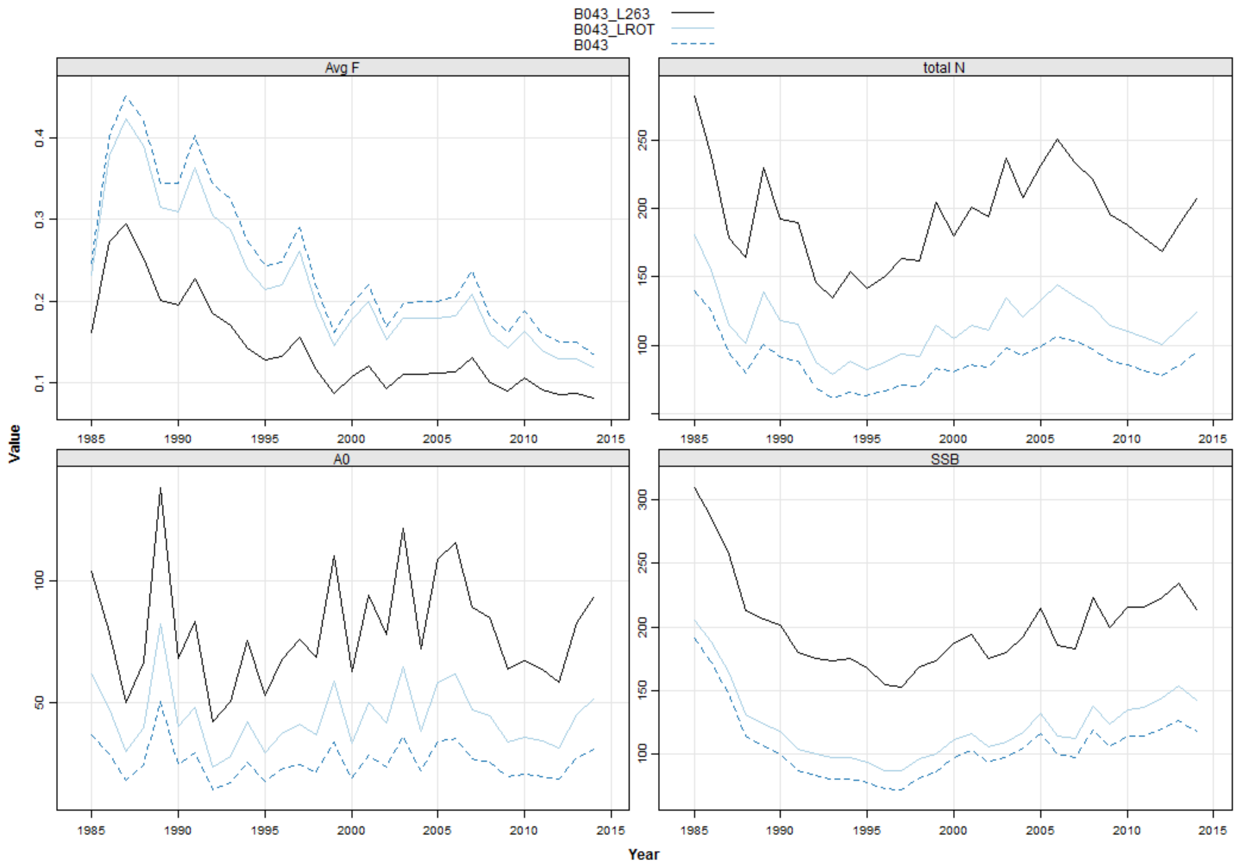
App. B7 Figure B7.128. Final model sensitivity run assuming VA set 2 landings. Trends for the final model (B043) estimates are represented by the blue line, with sensitivity run estimates (B043S8) represented by the black line.



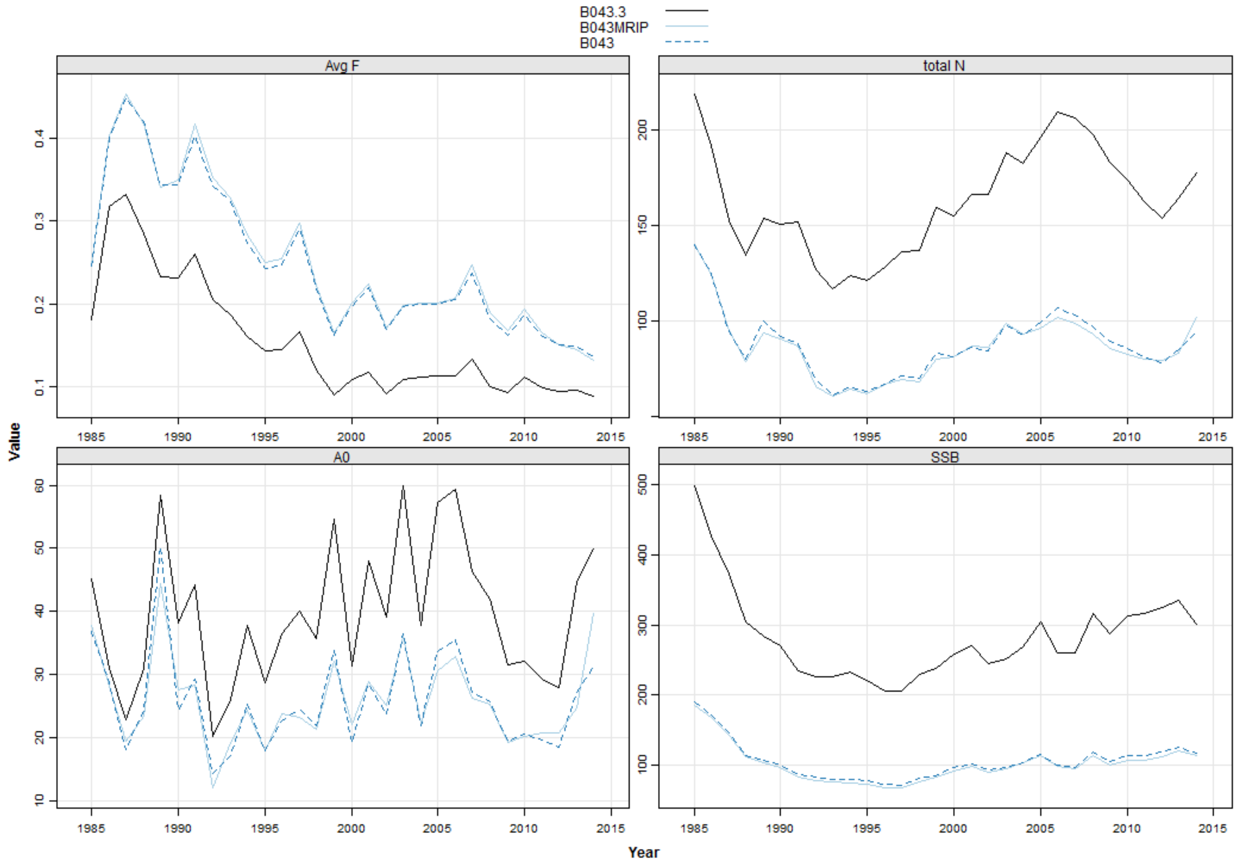
App. B7 Figure B7.129. Final model objective function profile over different values of natural mortality.



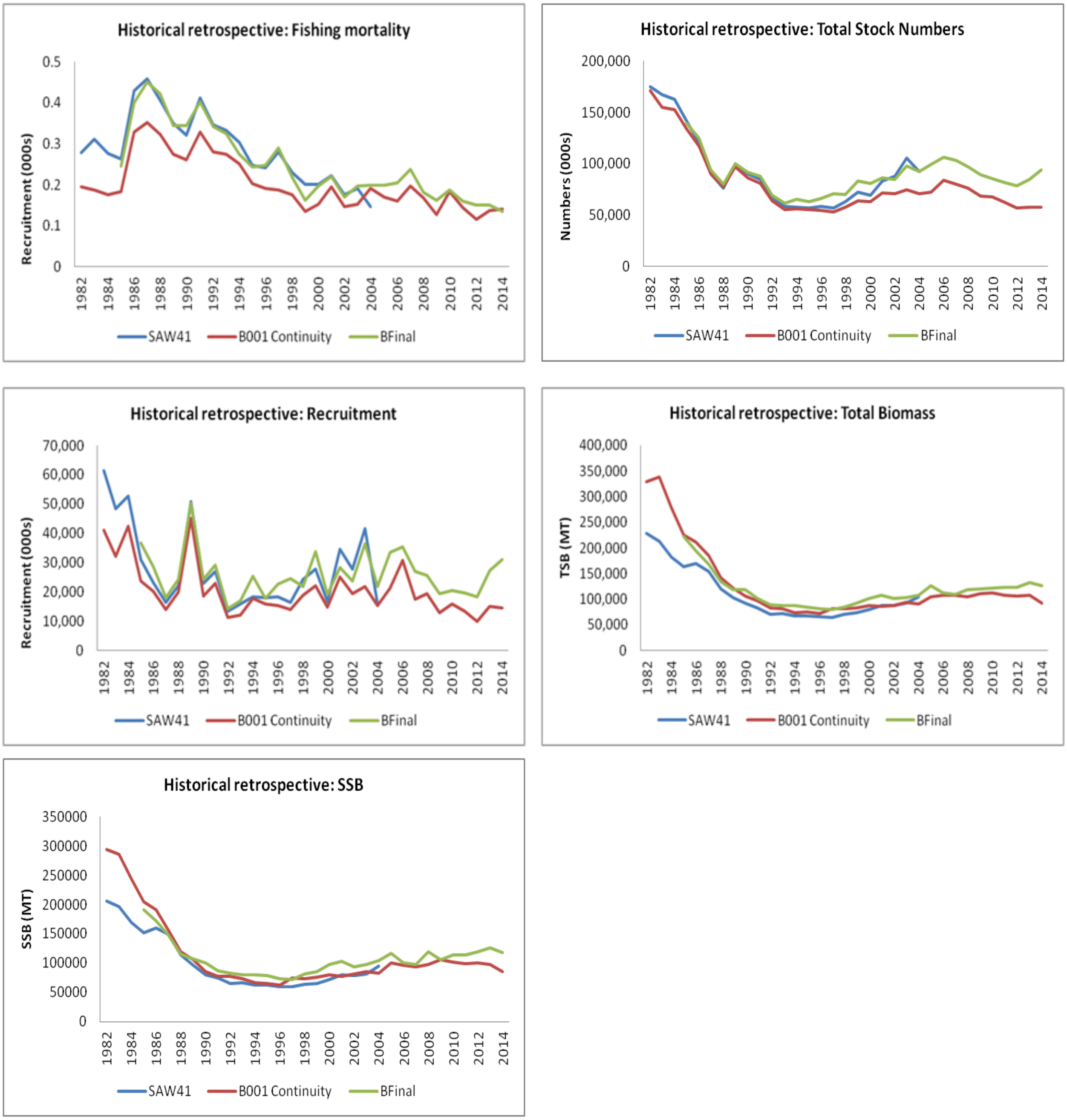
App. B7 Figure B7.130. Final model sensitivity run assuming natural mortality equal to 0.263 (the value that minimizes the objective function). Trends for the final model (B043) estimates are represented by the blue line, with sensitivity run estimates (B043_263) represented by the black line.



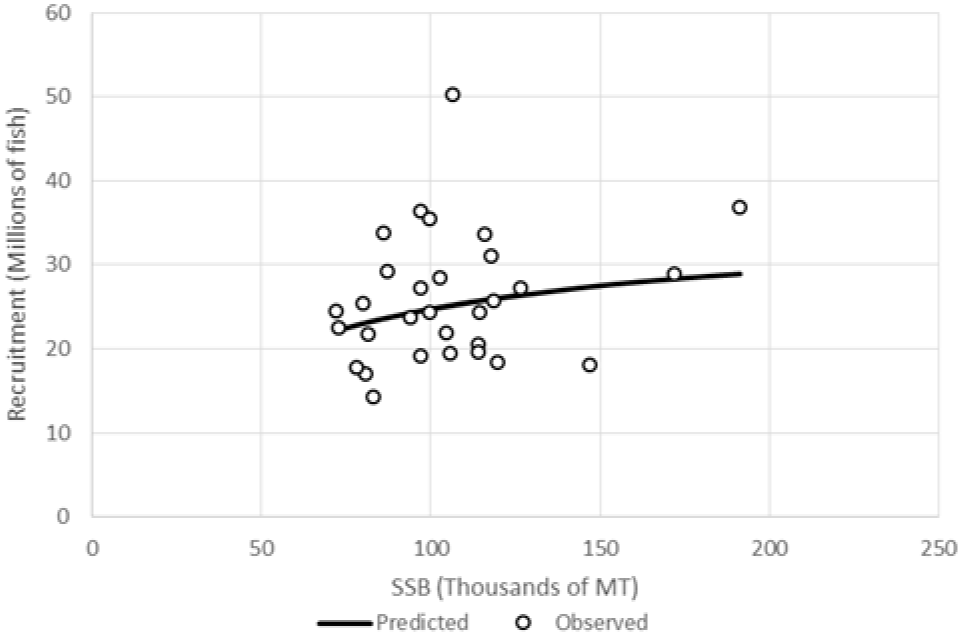
App. B7 Figure B7.131. Final model sensitivity run assuming age-based natural mortality estimates: Lorenzen scaled to Rule of Thumb (0.21) and Lorenzen scaled to (0.263: the value that minimizes the objective function. Trends for the final model (B043) estimates are represented by the dotted blue line, with sensitivity run estimates from B043_LROT (Lorenzen scaled to rule of thumb: 0.21) represented by the solid blue line and B043_L263 (Lorenzen scaled to 0.263) represented by the black line.



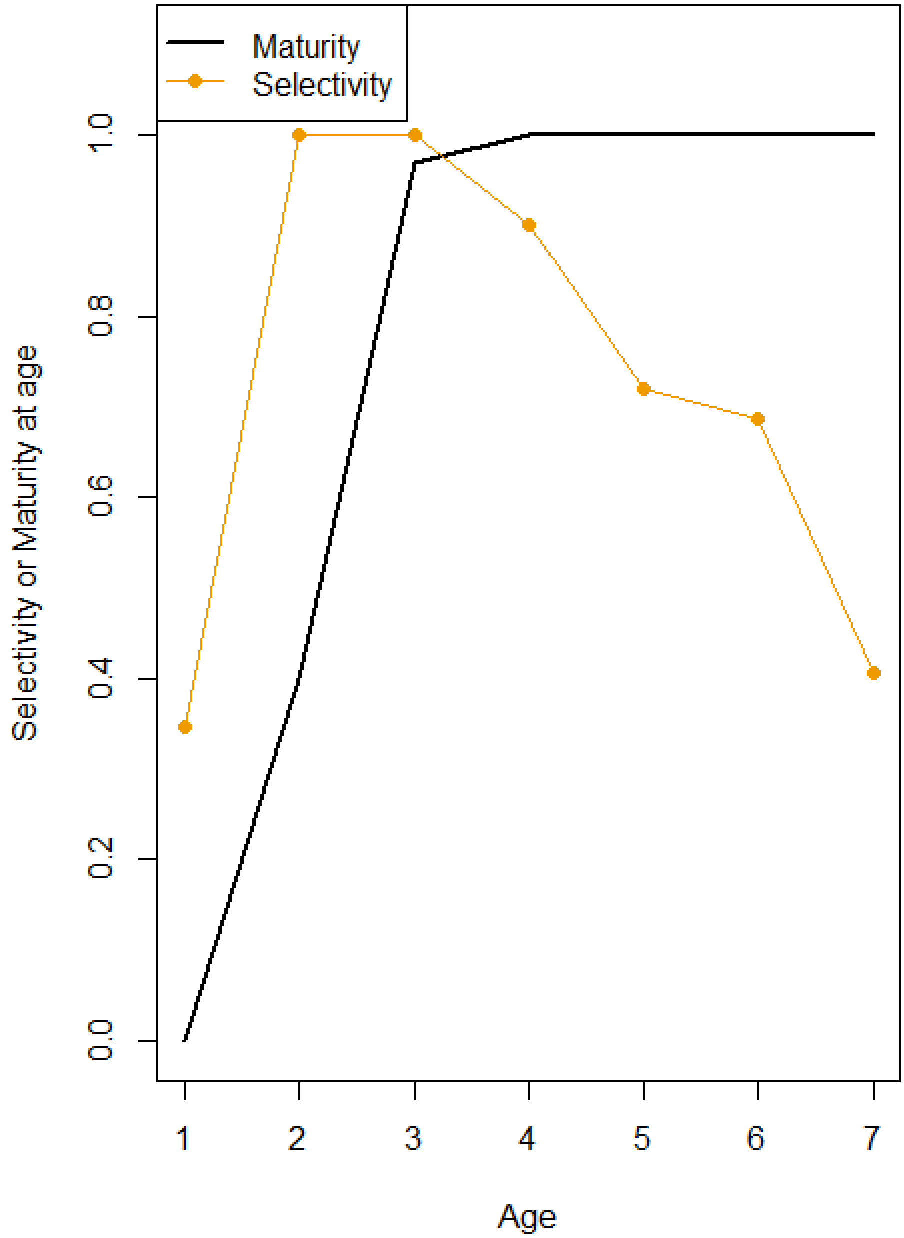
App. B7 Figure B7.132. Final model sensitivity run exploring the effects of removing the MRIP index, and running the final model with only the fleets and MRIP index. Trends for the final model (B043) estimates are represented by the dotted blue line, with sensitivity run estimates from B043MRIP (2 fleets+MRIP index) represented by the solid blue line and B043.3 (no MRIP) represented by the black line.



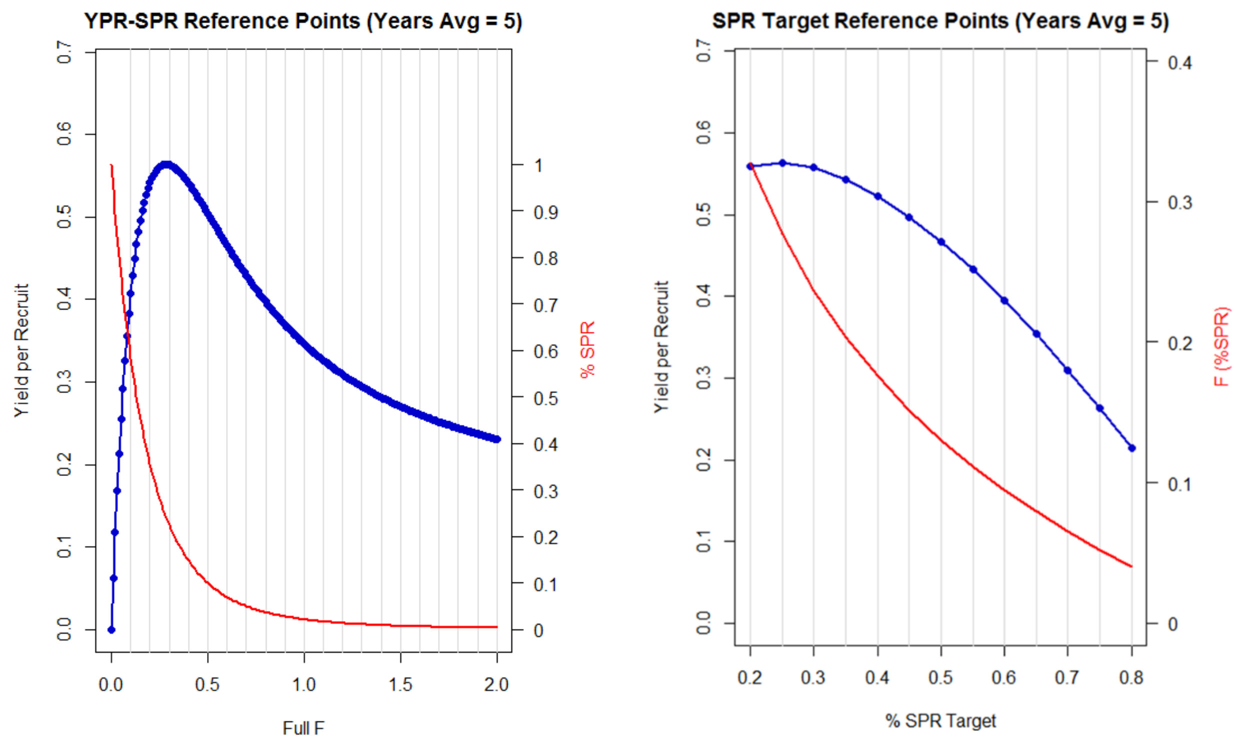
App. B7 Figure B7.133. Historical retrospective plots comparing estimates of F, abundance, recruitment, total biomass and spawning stock biomass across the previous benchmark assessment model (SAW 41), the continuity run with updated data (B001) and the final preferred model from this assessment (BFinal).



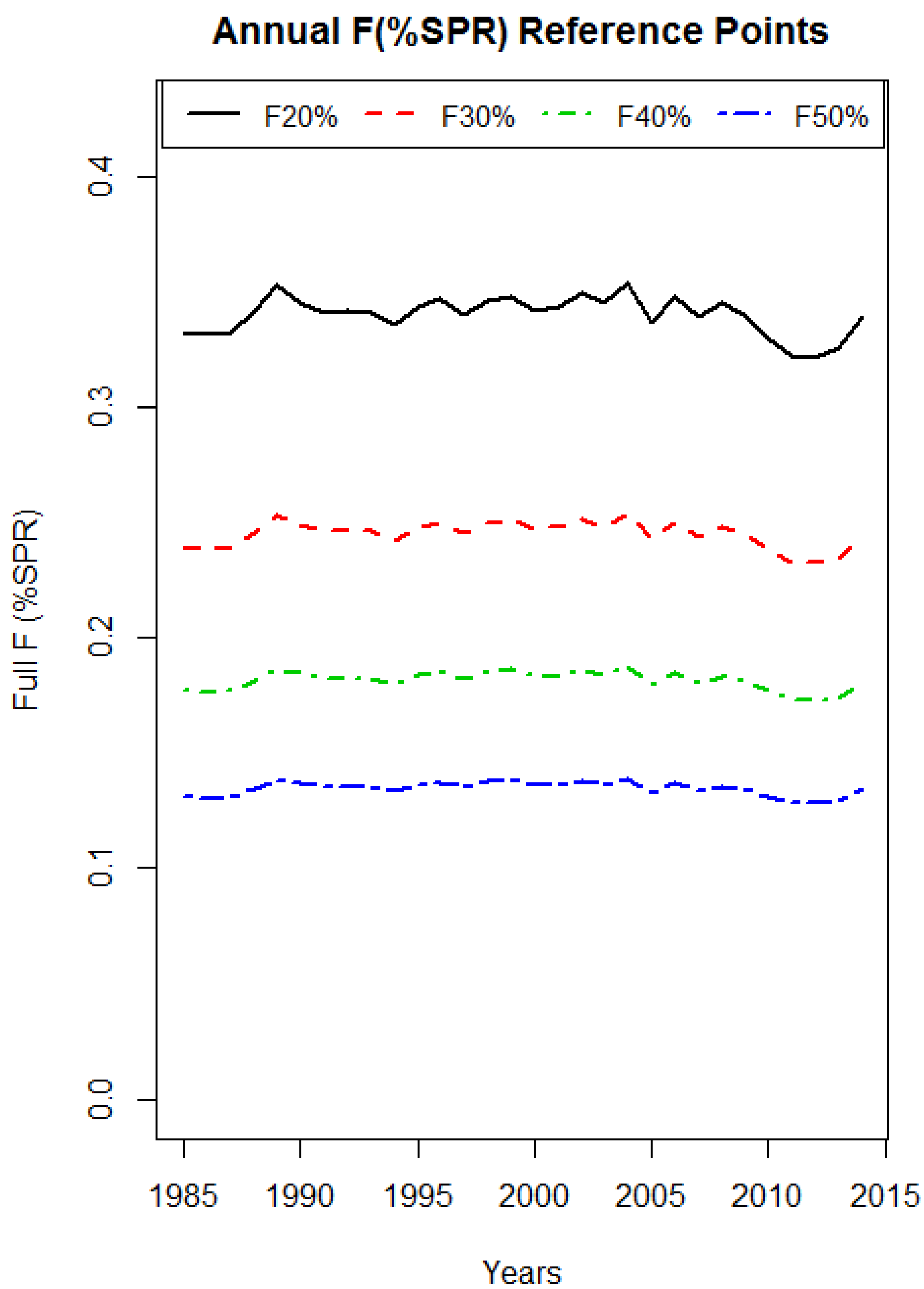
App. B7 Figure B8.1. Observed stock-recruitment relationship plotted with a fitted curve.



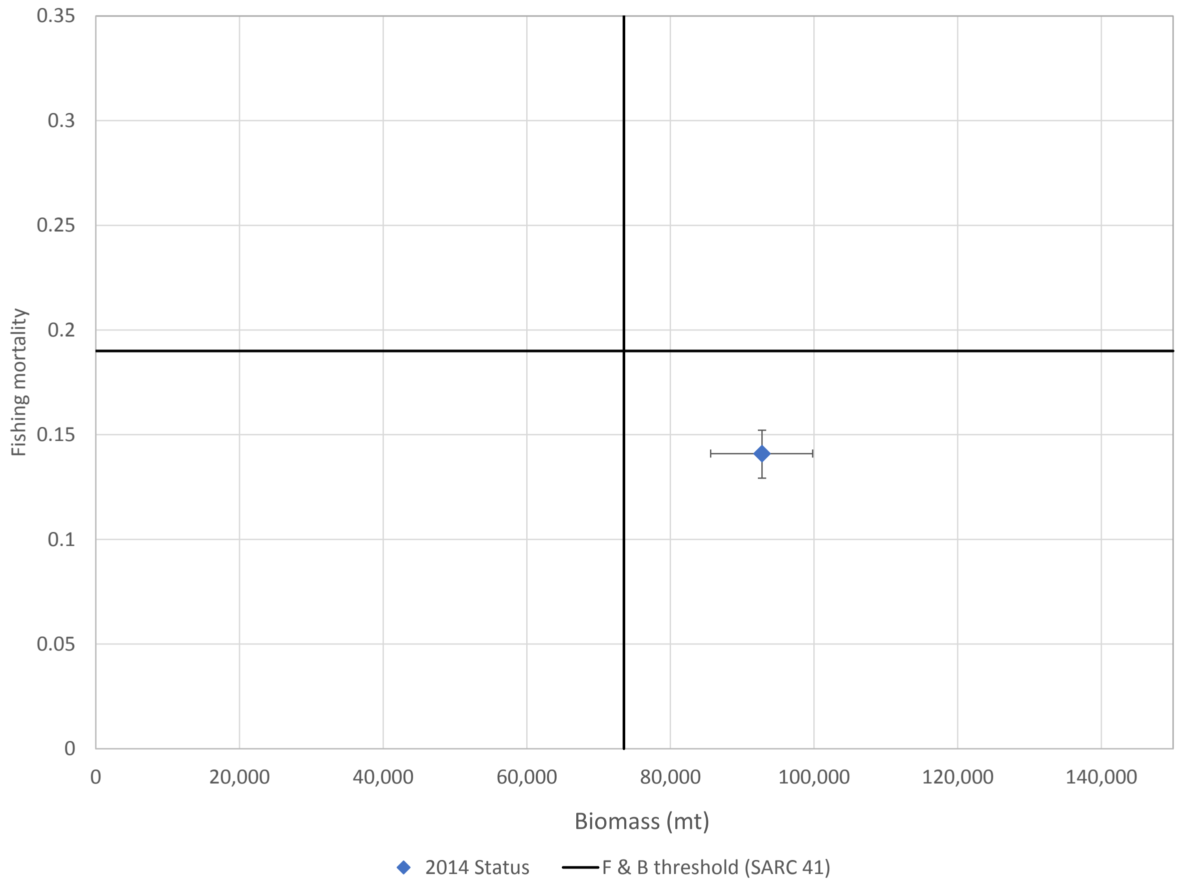
App. B7 Figure B8.2. Maturity ogive and composite selectivity pattern used to estimate bluefish reference points.



App. B7 Figure B8.3. YPR and SPR curves for bluefish.

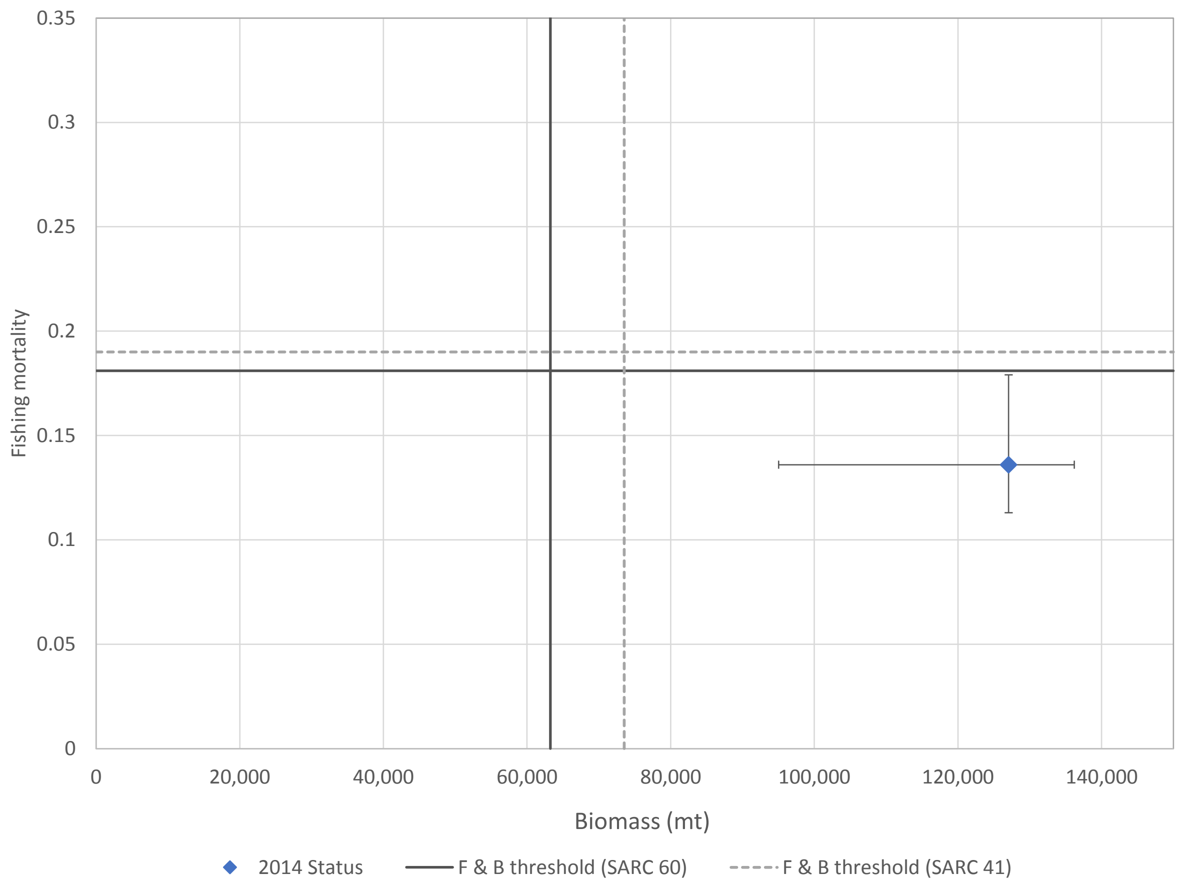


App. B7 Figure B8.4. Annual estimates of F %SPR reference points.



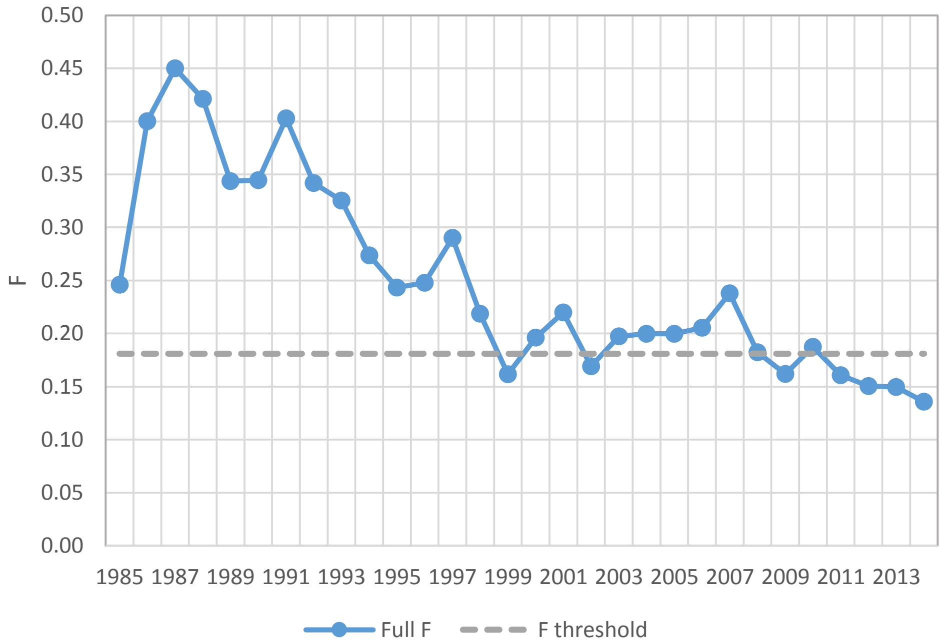
App. B7 Figure B9.1. Stock status in 2014 (diamond) from the continuity run plotted with the F and biomass thresholds from the previous benchmark assessment (solid lines).Error bars on the status estimated indicate 5th and 95th posterior probabilities.

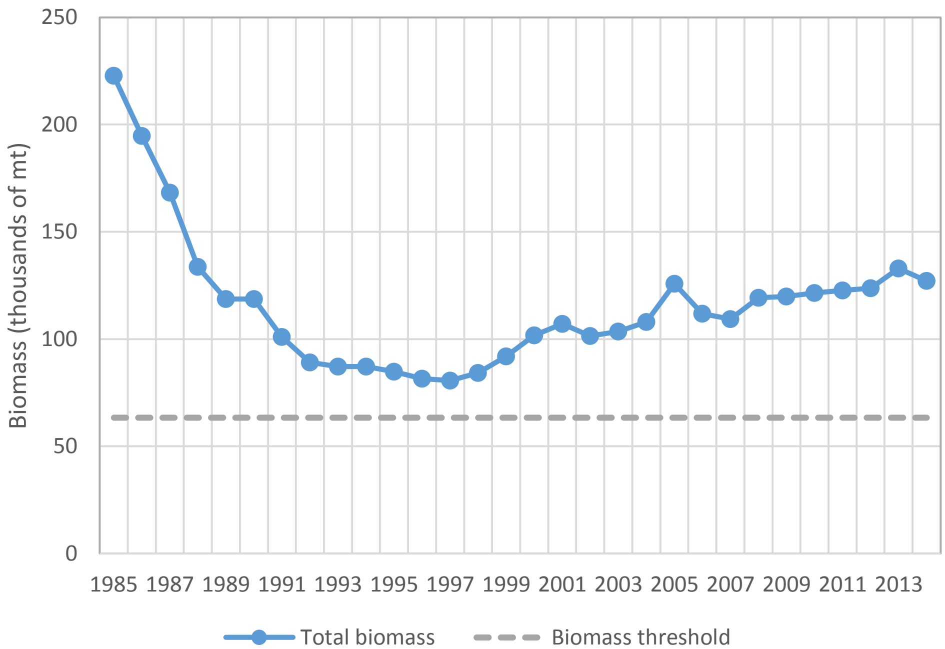
(NOTE: The values presented in this Appendix B7 reflect the output from the early model presented in the draft WP document and at the peer review, before final revision. For the final SAW/SARC60 assessment results, readers should see the main body of the bluefish report.)



App. B7 Figure B9.2. Stock status in 2014 (diamond) from the final model run plotted with the F and biomass thresholds for this assessment (solid line) and the previous benchmark assessment (dashed line). Error bars on the status estimated indicate 5th and 95th posterior probabilities.

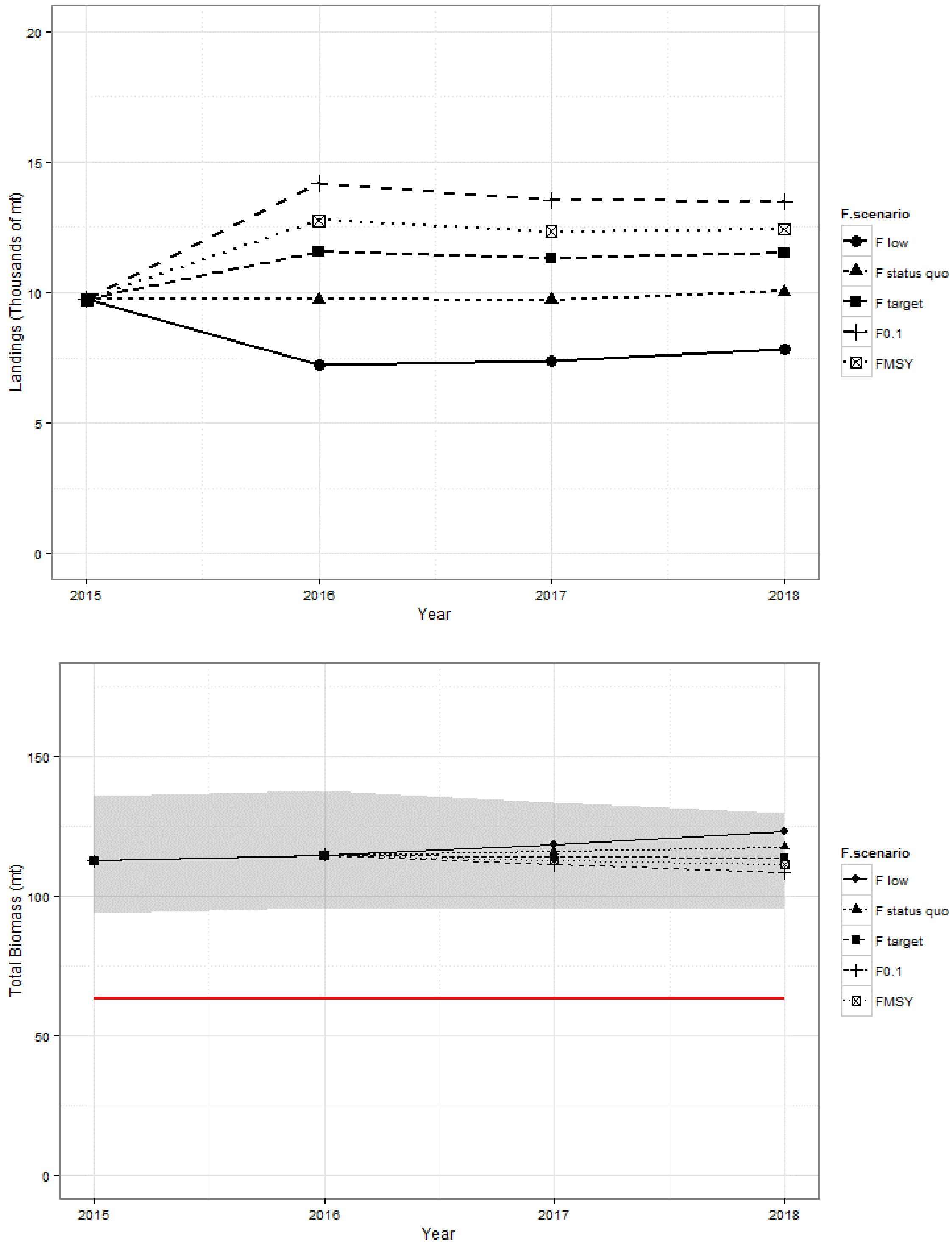
(NOTE: The values presented in this Appendix B7 reflect the output from the early model presented in the draft WP document and at the peer review, before final revision. For the final SAW/SARC60 assessment results, readers should see the main body of the bluefish report.)



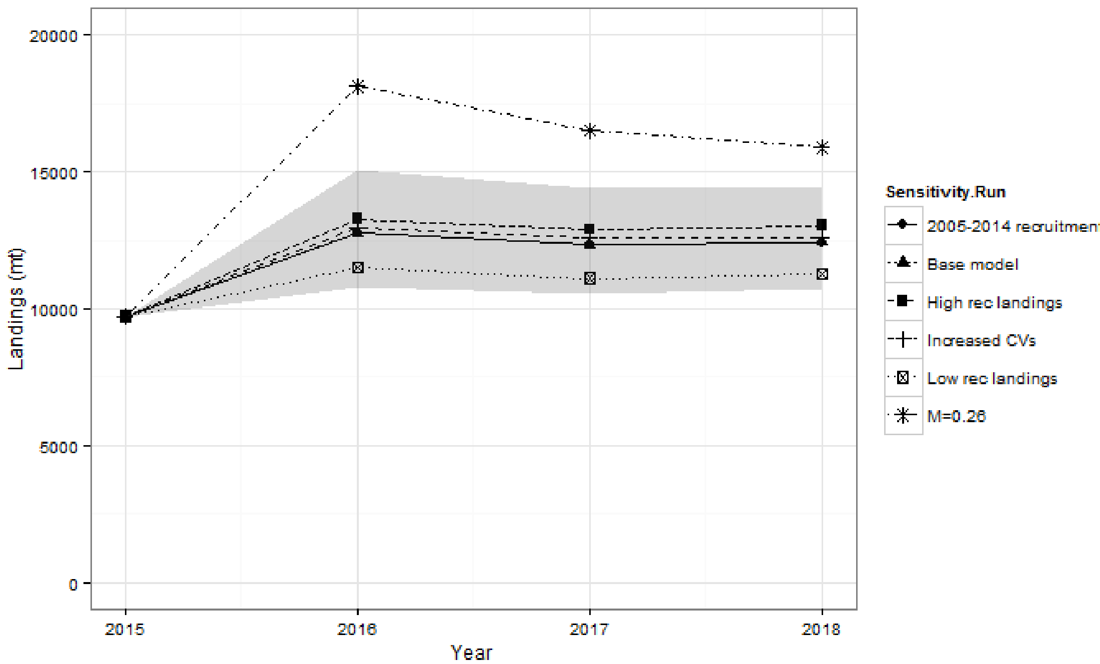


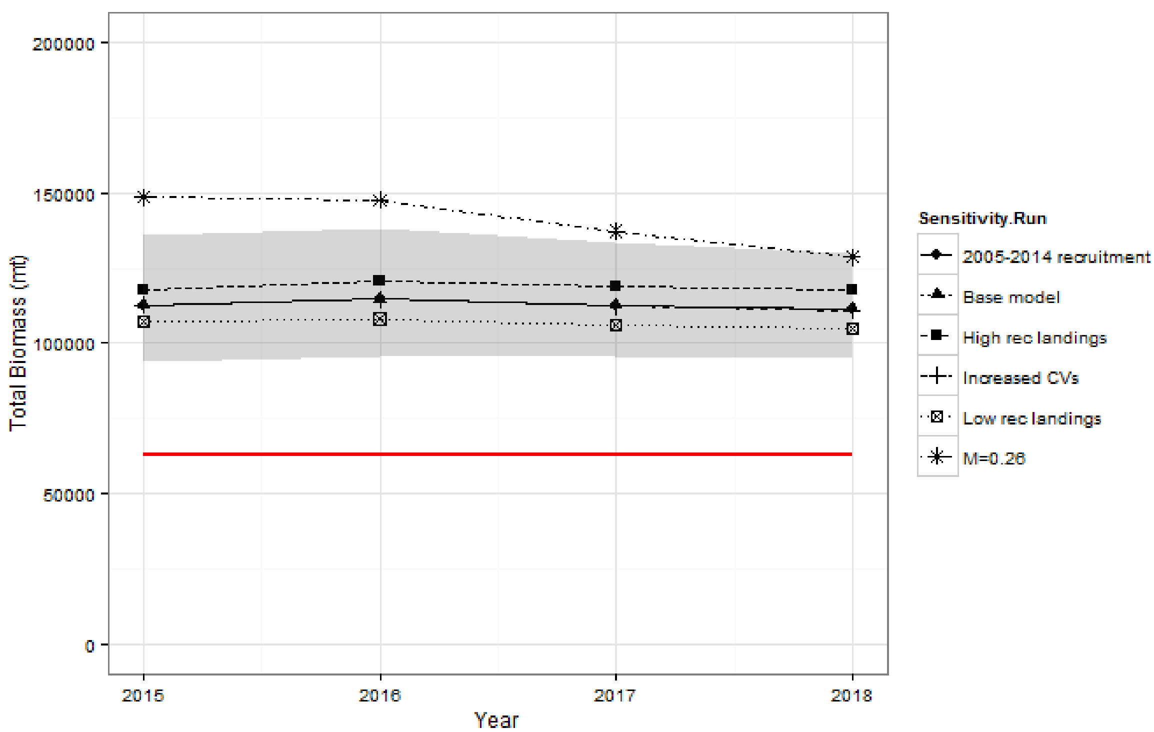
App. B7 Figure B9.3. Fully selected F (top) and total biomass (bottom) plotted with their respective overfishing and overfished thresholds.

(NOTE: The values presented in this Appendix B7 reflect the output from the early model presented in the draft WP document and at the peer review, before final revision. For the final SAW/SARC60 assessment results, readers should see the main body of the bluefish report.)

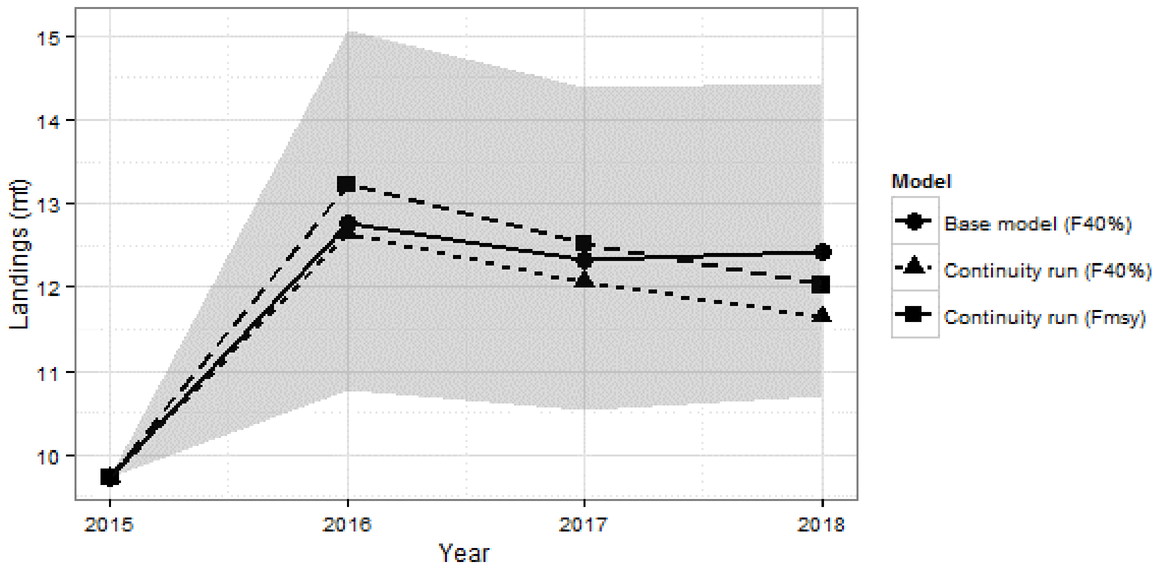


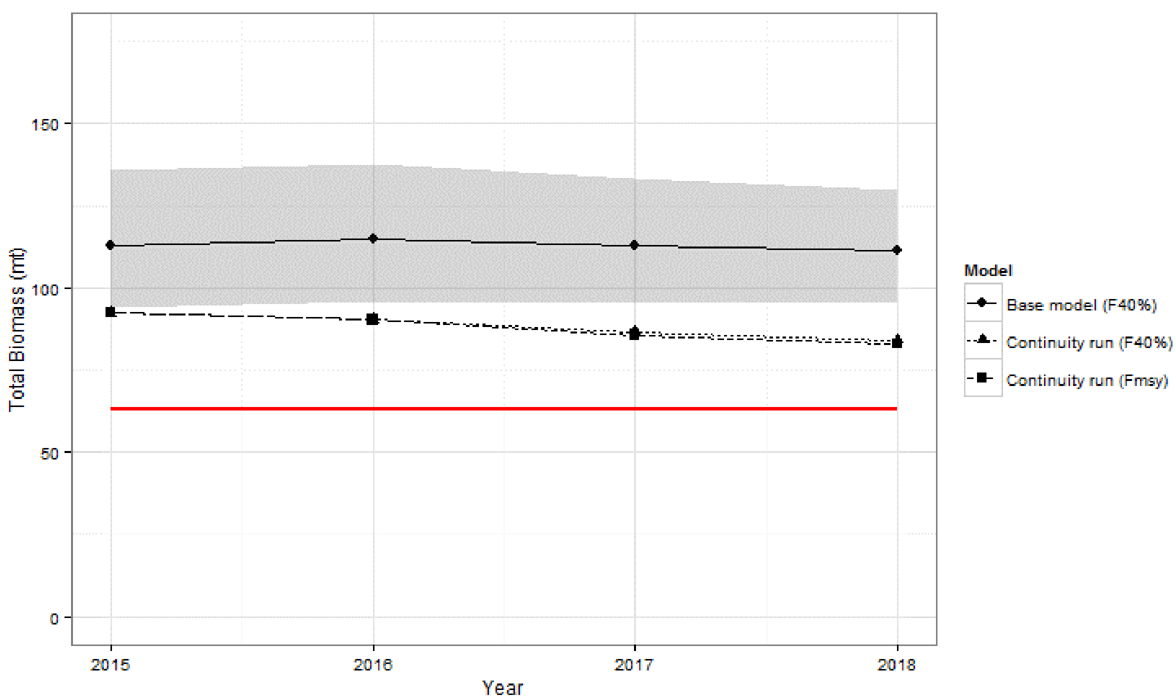
App. B7 Figure B10.1. Projected landings (top) and biomass (bottom) under various F scenarios. Shaded bands indicated the 5th and 95th percentiles of the F_{MSY} bootstrap runs. The solid red line indicates the overfished biomass threshold.





App. B7 Figure B10.2. Sensitivity runs of projected landings (top) and biomass (bottom) under F_{MSY}. Shaded bands indicated the 5th and 95th percentiles of the preferred base model bootstrap runs. The solid red line indicates the overfished biomass threshold.





App. B7 Figure B10.3. Projected landings (top) and biomass (bottom) for the continuity run model and the preferred model from this assessment. Shaded bands indicated the 5th and 95th percentiles of the preferred base model bootstrap runs. The solid red line indicates the overfished biomass threshold.

(NOTE: The values presented in this Appendix B7 reflect the output from the early model presented in the draft WP document and at the peer review, before final revision. For the final SAW/SARC60 assessment results, readers should see the main body of the bluefish report.)

Appendix B8 – Report of the July 2015 Meeting of the MAFMC SSC

[SAW Editor's Note:]

[The Mid-Atlantic Fishery Management Council's Scientific and Statistical Committee (MAFMC SSC) met in July 2015, shortly after the June 2015 SAW/SARC60 peer review. Based on the 2015 bluefish stock assessment, the SSC made a bluefish ABC recommendation to the MAFMC. During the SSC meeting, the SSC chose to revise the bluefish Biological Reference Points (BRPs) that were recommended by SAW/SARC60. The July 2015 MAFMC SSC report is included in Appendix B8 in its entirety.]

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Richard B. Robins, Jr., Chairman | Lee G. Anderson, Vice Chairman
Christopher M. Moore, Ph.D., Executive Director

MEMORANDUM

DATE: 27 July 2015

TO: Richard M. Robins, Jr., MAFMC Chairman

FROM: John Boreman, Ph.D., Chair, MAFMC Scientific and Statistical Committee

SUBJECT: Report of the July 2015 Meeting of the MAFMC SSC

The SSC met in Baltimore, MD, on 21-23 July 2015 for the main purpose of developing new ABC recommendations for Bluefish, Scup, Summer Flounder, and Black Sea Bass. The SSC also reviewed an early draft of the Terms for Reference for the upcoming benchmark assessment of Black Sea Bass, and were updated on a several ongoing activities of the MAFMC. The final meeting agenda is attached (Attachment 1).

A total of 10 SSC members were in attendance on July 21st, 13 in attendance on July 22nd, and 12 in attendance on July 23rd, all of which constituted quorums (Attachment 2). Also in attendance were staff from the NMFS Northeast Fisheries Science Center (in person and by phone), Council members and staff, ASMFC staff, and representatives from the fishing industry and general public. Discussion of ABC recommendations for each species began with a review of supporting information by the MAFMC staff lead and/or NEFSC assessment lead, then the SSC species leads (Attachment 3) and any members of the public attending the meeting were given an opportunity to comment, followed by SSC deliberations.

Most documents cited in this report can be accessed via the MAFMC SSC website (http://www.mafmc.org/ssc-meetings/2015/july-21-23).

Terms of reference (TORs) provided by the Council for the four species are in *italics*.

Bluefish

For Bluefish, the SSC will provide a written report that identifies the following for fishing years 2016-2018:

1) The level of uncertainty that the SSC deems most appropriate for the information content of the most recent stock assessment, based on criteria listed in the Omnibus Amendment.

The SARC 60 benchmark assessment was a significant improvement over previous assessments. Many uncertainties were addressed regarding input data and there was a characterization of uncertainty in the

OFL, which was adjusted upward by 50% from the model output by the assessment team to account for un-modeled uncertainty.

Despite these improvements, the SSC deems the assessment uncertainty level that requires an SSC-derived coefficient of variation (CV) for the OFL as the most appropriate for the new benchmark assessment, for the following reasons:

- The estimated OFL uncertainty provided by the assessment committee (15%) was low relative to meta-analysis results;
- There are uncertainties in the OFL that the assessment could not capture with respect to the highly influential MRIP index and selectivity;
- The OFL uncertainty provided by the assessment team is low relative to the between assessment model runs for SSB that examined assumptions for the natural mortality rate (M), selectivities, and including various indices.

2) If possible, the level of catch (in weight) and the probability of overfishing associated with the overfishing limit (OFL) based on the maximum fishing mortality rate threshold or, if appropriate, an OFL proxy.

The SSC noted that the F_{msy} proxy of $F_{40\%}$ might be inappropriate for Bluefish, a highly productive species (Thorson et al. 2012; Rothschild et al. 2012). A proxy of $F_{35\%}$ is indicated by various published meta-analyses for the order Perciformes.

Using $F_{35\%}$, the SSC recommends an OFL of:

2016	**11,686 mt**
2017	**11,995 mt**
2018	**12,688 mt**

3) The level of catch (in weight) and the probability of overfishing associated with the acceptable biological catch (ABC) for the stock, the number of fishing years for which the ABC specification applies and, if possible, interim metrics that can be examined to determine if multi-year specifications need reconsideration prior to their expiration.

A CV of 60% was applied to the OFL, instead of the previously used CV of 100%, to reflect the much-improved treatment of uncertainty in the current Bluefish assessment, and is consistent with the rationale used by the SSC to determine CV for the Summer Flounder assessment OFL. Three-year specifications are required. The OFL level for 2016 was determined by using $F_{35\%} = 0.19$. The equilibrium catch (a proxy for MSY) under this scenario is 14,443 mt. The SSB_{msy} is therefore 101,343 mt and SSB_{2014} = 86,534 mt, so the $SSB/SSB_{msy} = 0.85$, with an SSB threshold of 50,672 mt. The SSC applied the Council policy of P* = 0.307 in 2016. This results in an ABC of:

2016	**8,825 mt** (P* = 0.307)
2017	**9,363 mt** (P* = 0.328)
2018	**9,895 mt** (P* = 0.327)

An updated assessment is preferred for the SSC review of the Bluefish ABCs next year.
Otherwise, the SSC would like to review an updated trawl survey index and updated MRIP index.

4) The most significant sources of scientific uncertainty associated with determination of OFL and ABC.

In order of importance:

- Uncertainty in the stock recruitment relationship adds to uncertainty in appropriate reference points.
- The uncertainty in MRIP sampling overall, which is the most influential data in the assessment. Questions have been raised about the uncertainty in the historical MRFSS/MRIP estimates in general, and are particularly relevant here given the highly episodic nature of Bluefish catches in the recreational fisheries coast wide.
- Approximately 60% of the population biomass is in the aggregated 6+ age group for which there is relatively little information.
- The extent to which the MRIP index and MRIP catch are partially redundant in the assessment needs to be determined.
- Commercial discards are assumed to be insignificant, which may not be the case.

5) Ecosystem considerations accounted for in the stock assessment, and any additional ecosystem considerations that the SSC took into account in selecting the ABC, including the basis for those additional considerations.

The ABCs were not modified by the SSC based on ecosystem considerations.

The stock assessment included ecosystem considerations:

- An index of habitat suitability was calculated based on a thermal niche model. It was fit as a covariate to survey catchability, but did not improve model fits.
- Diet compositions from multiple surveys were included as auxiliary information

6) Prioritized research or monitoring recommendations that would reduce the scientific uncertainty in the ABC recommendation and/or improve the assessment level.

- Develop a fishery independent index that better captures older, larger fish, which would reduce reliance on MRIP sampling.
- Develop Bluefish-specific MSY reference points or proxies.
- Evaluate species associations with recreational angler trips targeting Bluefish to potentially modify the MRIP index used in the assessment.
- Low frequency environmental variability may have caused changes in the timing of the movement of juvenile Bluefish through the region that, in turn, may have affected availability. Changes in the selectivity of age-0 Bluefish in the survey relative to water column or surface temperature and date should be examined.
- Evaluate methods for integrating disparate indices produced at multiple spatial and temporal resolutions into a stock-wide assessment model, especially for a migratory species like Bluefish.
- Initiate fishery-dependent and fishery-independent sampling of offshore populations of Bluefish.

7) The materials considered in reaching its recommendations.

- Montañez, J. 2015. Staff memorandum to Chris Moore, dated 7 July 2015, entitled: “Atlantic Bluefish Management Measures for 2016-2018.” 30 pp.
- MAFMC Staff. 2015. Atlantic Bluefish Advisory Panel Information Document. Mid-Atlantic Fishery Management Council. 17 pp.

- MAFMC Staff. 2015. 2015 MAFMC Bluefish Fishery Performance Report. Mid-Atlantic Fishery Management Council. 6 pp.
- Northeast Fisheries Science Center. 2015. A Report of the 60th Northeast Regional Stock Assessment Workshop: Assessment summary report – pre-publication draft (dated 6-30-2015). 25 pp.
- Jones, C. M., N. Hall, S. Kupschus, and K. Stokes. 2015. Summary Report of the 60th Northeast Regional Stock Assessment Review Committee (SARC 60). Center for Independent Experts. 62 pp.
- Hall, N. G. 2015. Report on the SARC Review of SAW 60 Stock Assessments for Scup and Bluefish, June 2015. Center for Independent Experts. 57 pp.
- Kupschus, S. 2015. Review report for the benchmark stock assessment for Scup and Bluefish, SAW/SARC60. Center for Independent Experts. 45 pp.
- Stokes, K. 2015. Independent Peer Review Report on the 60th Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC): Benchmark stock assessments for Scup and Bluefish. Center for Independent Experts. 51 pp.
- Northeast Fisheries Science Center. 2015. A Report of the 60th Northeast Regional Stock Assessment Workshop: Assessment report. 864 pp.
- Thorson, J. T., J. M. Cope, T. A. Branch, and O. P. Jensen. 2012. Spawning biomass reference points for exploited marine fishes, incorporating taxonomic and body size information. Canadian Journal of Fisheries and Aquatic Sciences 69: 1–13 (2012).
- Rothschild, B. J., Y. Jiao, and S.-Y. Hyun. 2012. Simulation Study of Biological Reference Points for Summer Flounder. Transactions of the American Fisheries Society 141: 126-136.

8) A certification that the recommendations provided by the SSC represent the best scientific information available.

To the best of the SSC's knowledge, these recommendations are based on the best available scientific information.

General Comment

The SSC received the full description of the Bluefish stock assessment less than one day before our meeting to set Acceptable Biological Catches (ABCs) for this stock. This was a particular problem because the base model was changed during the peer review and the description, results, and diagnostics of the final configuration were not in the version of the assessment report for peer review that was previously provided to the SSC. Without the details in the full, updated assessment report, the SSC would have been unable to determine whether the assessment results constituted best available science and, thus, would not have been able to determine ABCs. Furthermore, the delay in providing the report to the SSC underserves the strong work that was done on the assessment by the stock assessment working group.

Scup

For Scup, the SSC will provide a written report that identifies the following for fishing years 2016-2018:

1) The level of uncertainty that the SSC deems most appropriate for the information content of the most recent stock assessment, based on criteria listed in the Omnibus Amendment.

The SSC determined the level of uncertainty of OFL in the assessment requires an SSC-specified CV.

The SSC accepted the MSY proxy used in the assessment as a reasonable foundation for OFL and ABC determination.

The SSC had typically used a CV = 100% for OFL as a default when the stock assessment lacked reliable guidance on the uncertainty. The Scup assessment is a clear improvement over this level. The SAW/SARC recommended a CV = 30%; however, in a meta-analysis of stock assessments, a CV = 30% is typical of the very best quality assessments that fully quantify all sources of uncertainty in the OFL (Ralston et al. 2011). Accordingly, the SSC recommends a CV = 60% based on: (1) the SSC's understanding that the assessment considers uncertainty primarily in biomass and does not include fully the uncertainty in the fishing mortality proxy or the association between the biomass and exploitation proxies; and (2) precedence with other assessments it has considered.

The SSC is committed to re-evaluating the CV for the uncertainty in the OFL for Scup in future specifications of ABC.

2) If possible, the level of catch (in weight) and the probability of overfishing associated with the overfishing limit (OFL) based on the maximum fishing mortality rate threshold or, if appropriate, an OFL proxy.

Based on projection estimates provided in the SAW/SARC document, the level of catch associated with the OFL for 2016-2018, assuming that 75% of the ABC in 2015 is caught, are:

2016	**16,238 mt**
2017	**14,556 mt**
2018	**13,464 mt**

3) The level of catch (in weight) and the probability of overfishing associated with the acceptable biological catch (ABC) for the stock, the number of fishing years for which the ABC specification applies and, if possible, interim metrics that can be examined to determine if multi-year specifications need reconsideration prior to their expiration.

The SSC accepted the CV of 60% in the OFL as the foundation for the ABC. Using the Council's published risk policy for a stock for which B/BMSY > 1, the recommended ABCs are as follows:

2016	**14,110 mt**
2017	**12,881 mt**
2018	**12,270 mt**

These values are equivalent to ~87% of the OFL.

Next year, in the absence of an assessment update, which the SSC prefers, the SSC will consider the following interim metrics to determine whether the ABCs recommended here are appropriate:

1. Survey CPUE (kg/tow) in the fall NEFSC survey;
2. Mean size and size-structure in the fall NEFSC survey; and
3. Exploitation ratio (catch / survey biomass).

4) The most significant sources of scientific uncertainty associated with determination of OFL and ABC.

- While older age Scup (age 3+) are represented in the catch used in the assessment model, most indices used in the model do not include ages 3+. As a result, the dynamics of the older ages of Scup are driven principally by catches and inferences regarding year class strength.
- Uncertainty exists with respect to the estimate of natural mortality (M) used in the assessment.
- Uncertainty exists as to whether the MSY proxies ($SSB_{40\%}$, $F_{40\%}$) selected and their precisions are appropriate for this stock.
- The SSC assumed that OFL has a lognormal distribution with a CV = 60%, based on a meta-analysis of survey and statistical catch at age (SCAA) model accuracies.
- Survey indices are particularly sensitive to Scup availability, which results in high inter-annual variability – efforts were made to address this question in the SAW/SARC that should be continued; and
- The projection on which the ABC was determined is based on an assumption that the quotas would be landed in 2016, 2017, and 2018.

5) Ecosystem considerations accounted for in the stock assessment, and any additional ecosystem considerations that the SSC took into account in selecting the ABC, including the basis for those additional considerations.

The ABCs were not modified based on ecosystem considerations. The stock assessment included ecosystems considerations, specifically efforts to estimate habitat suitability based on a thermal niche model that was fit to survey catchability, but this did not improve model fits.

6) Prioritized research or monitoring recommendations that would reduce the scientific uncertainty in the ABC recommendation and/or improve the assessment level.

In order of priority:

1. Improve estimates of discards and discard mortality for commercial and recreational fisheries.
2. Evaluate the degree of bias in the catch, particularly the commercial catch.
3. Explore the utility of incorporating ecological relationships, predation, and oceanic events that influence Scup population size on the continental shelf and its availability to resource surveys used in the stock assessment model.
4. An MSE could evaluate the effectiveness of Scup management procedures.
5. Conduct experiments to estimate catchability of Scup in NEFSC surveys.
6. Explore additional source of age-length data from historical surveys to inform the early part of the time series to provide additional context for model results.

7) The materials considered in reaching its recommendations.

- Northeast Fisheries Science Center. 2015. A Report of the 60th Northeast Regional Stock Assessment Workshop: Assessment summary report – pre-publication draft (dated 6-30-2015). 25 pp.
- Jones, C. M., N. Hall, S. Kupschus, and K. Stokes. 2015. Summary Report of the 60th Northeast Regional Stock Assessment Review Committee (SARC 60). Center for Independent Experts. 62 pp.
- Hall, N. G. 2015. Report on the SARC Review of SAW 60 Stock Assessments for Scup and Bluefish, June 2015. Center for Independent Experts. 57 pp.
- Kupschus, S. 2015. Review report for the benchmark stock assessment for Scup and Bluefish, SAW/SARC60. Center for Independent Experts. 45 pp.

- Stokes, K. 2015. Independent Peer Review Report on the 60th Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC): Benchmark stock assessments for Scup and Bluefish. Center for Independent Experts. 51 pp.
- Northeast Fisheries Science Center. 2015. A Report of the 60th Northeast Regional Stock Assessment Workshop: Assessment report. 864 pp.
- Beaty, J., and K. Dancy. 2015. Staff memo to Chris Moore, dated 9 July 2015, entitled "Scup Management Measures for 2016 - 2018." 12 pp.
- Cadrin, S., J.-J. Maguire, and R. Leaf. 2015. Scup Stock Assessment Team Report. Science Center for Marine Fisheries (SCeMFiS). 39 pp.
- MAFMC. 2015. Summer Flounder, Scup, and Black Sea Bass Fishery Performance Reports June 2015. 9 pp.
- MAFMC. 2015. Summer Flounder, Scup, and Black Sea Bass Advisory Panel: Additional Comments, June 2015. 4 pp.
- MAFMC SSC. 2015. Draft working paper on "Description and Foundation of the Mid-Atlantic Council's ABC Control Rule," dated March 11, 2015. 11 pp.
- MAFMC. 2015. Scup fishery information document, June 2015. 11 pp.
- Ralston, S., A. E. Punt, O. S. Hamel, J. D. DeVore, and R. J. Conser. 2011. A meta-analytic approach to quantifying scientific uncertainty in stock assessments. Fishery Bulletin 109: 217-231.

8) A certification that the recommendations provided by the SSC represent the best scientific information available.

To the best of the SSC's knowledge, these recommendations are based on the best available scientific information.

Summer Flounder

For Summer Flounder, the SSC will provide a written report that identifies the following for fishing years 2016-2018:

1) The level of uncertainty that the SSC deems most appropriate for the information content of the most recent stock assessment, based on criteria listed in the Omnibus Amendment;

The SSC was provided with an assessment update based on the model formulation approved at SAW/SARC 57. The reference points accepted at the SAW/SARC were $F_{35\%}$ as F_{MSY} proxy = 0.309 and SSB_{MSY} proxy = 62,394 mt.

Because the assessment model was unchanged from SAW/SARC 57, the SSC did not alter its categorization of the assessment as an assessment requiring an SSC-derived CV for the OFL. The SSC also concluded that no new information was presented that would cause the SSC to deviate from using an OFL CV of 60%.

2) If possible, the level of catch (in weight) and the probability of overfishing associated with the overfishing limit (OFL) based on the maximum fishing mortality rate threshold or, if appropriate, an OFL proxy.

The level of catch associated with the OFL in 2016 is **8,194 mt**.

3) The level of catch (in weight) and the probability of overfishing associated with the acceptable biological catch (ABC) for the stock based on an approach which phases-in any required reductions in the ABC specifications over a three-year period without exceeding the OFL or P = 50%. If possible, identify interim metrics that can be examined to determine if multi-year specifications need reconsideration prior to their expiration.*

Using a three-year phase in of the required reduction in ABC assuming a CV in the OFL of 60% and that the ABC is caught in each year for the period under consideration are:

Year	ABC	P*	OFL	SSB
2016	**7,375 mt**	0.425	**8,194 mt**	45,885
2017	**7,193 mt**	0.344	**8,991 mt**	50,052
2018	**7,111 mt**	0.260	**10,159 mt**	54,966

The SSC recognizes that the phased in approach does not meet the Council's risk policy for the probability of overfishing in the first two years of the phased period. The Council asked the SSC to deviate from the Council's risk policy because of socio-economic concerns over the magnitude of the reduction in the fishery catch in 2016 that would be potentially destabilizing. The SSC notes that the projected biomass for the stock in 2018 is approximately equal to that expected to be present if the Council's risk policy had been followed for all three years.

An assessment update must be conducted in 2016 to guide the Council and SSC in determining future ABCs.

4) The most significant sources of scientific uncertainty associated with determination of OFL and ABC.

- Retrospective patterns evident in the assessment update have substantial implications for the reliability of model projections and inferences regarding the status of the stock. The causes of the retrospective pattern are unknown.
- Projections are made assuming the ABC will be harvested fully, but not exceeded. However, there are trends in harvest indicating an increasingly likelihood of catches exceeding ABCs.
- In 2016 and 2017, the probability of overfishing is higher than the Council's risk policy.
- The potential exists for sex-specific differences in life history parameters.
- The existence of spatially distinct size distributions.
- NEFSC surveys and PMAFS fishery sampling confirm sexually-dimorphic and time-varying spatial differences in growth that are not fully accounted for in the stock assessment because not all fishery and survey catches were fully and independently sampled by sex.
- Landings from commercial fishery assume no under-reporting of Summer Flounder landings and thus should be considered minimal estimates.
- The current assumption for M remains an ongoing source of uncertainty. M is highly influential on assessment results and impacts nearly all aspects of the assessment and evaluation of status.
- The stock-recruitment relationship could not be defined internally in the model and thus an F_{MSY} proxy was used to calculate the OFL.

5) Ecosystem considerations accounted for in the stock assessment, and any additional ecosystem considerations that the SSC took into account in selecting the ABC, including the basis for those additional considerations.

There were no additional ecosystem recommendations considered by the SSC.

6) Prioritized research or monitoring recommendations that would reduce the scientific uncertainty in the ABC recommendation and/or improve the assessment level.

The SSC recommends an expedited benchmark assessment to seek to improve model performance and reduce the retrospective bias present in the current assessment update.

The SSC recognizes the research recommendations provided in the assessment report. In addition, the SSC recommends research be conducted to:

- Evaluate uncertainties in biomass to determine potential modifications to OFL CV employed;
- Evaluate fully the sex- and size distribution of landed and discarded fish, by sex, in the Summer Flounder fisheries;
- Evaluate past and possible future changes to size regulations on retention and selectivity in stock assessments and projections; and
- Incorporate sex-specific differences in size at age into the stock assessment.

7) The materials considered in reaching its recommendations.

- Dancy, K., and J. Beaty. 2015. Staff memo to Chris Moore, dated 9 July 2015, entitled "Summer Flounder Management Measure for 2016 - 2018." 11 pp.
- Dancy, K., and J. Coakley. 2015. Staff memo to Chris Moore, dated 17 July 2015, entitled "Summer Flounder ABC Recommendations for 2016 – 2018." 2 pp.
- NEFSC. 2015. Stock assessment update of Summer Flounder for 2015. 17 pp.
- MAFMC. 2015. Summer Flounder, Scup, and Black Sea Bass Fishery Performance Reports, June 2015. 9 pp.
- MAFMC. 2015. Summer Flounder, Scup, and Black Sea Bass Advisory Panel: Additional Comments, June 2015. 4 pp.
- MAFMC. 2015. Summer Flounder fishery information document, June 2015. 14 pp.
- Amory, M. 2015. Letter to SSC, dated 16 July 2015. 2 pp.
- Virginia Seafood Council. 2015. Letter to SSC, dated 16 July 2015. 2 pp.
- Donofrio, J. 2015. Recreational Fishing Alliance letter to John Boreman, dated 21 July 2015. 2 pp.
- Schill, J. 2015. NC Fisheries Association letter to John Boreman, dated 21 July 2015. 1 pp.
- Pallone, F., Jr., R. Mendez, and C. A. Booker. 2015. Congressional letter to Richard B. Robins, Jr., and John Boreman, dated 21 July 2015. 2 pp.

8) A certification that the recommendations provided by the SSC represent the best scientific information available.

To the best of the SSC's knowledge, these recommendations are based on the best available scientific information.

Black Sea Bass

For Black Sea Bass, the SSC will provide a written report that identifies the following for fishing years 2016-2017:

1) The level of uncertainty that the SSC deems most appropriate for the information content of the most recent stock assessment, based on criteria listed in the Omnibus Amendment;

The SSC determined that the OFL could not be specified given the current state of knowledge.

2) If possible, the level of catch (in weight) and the probability of overfishing associated with the overfishing limit (OFL) based on the maximum fishing mortality rate threshold or, if appropriate, an OFL proxy.

Because no OFL was specified for this species, the level of catch cannot be derived.

3) The level of catch (in weight) and the probability of overfishing associated with the acceptable biological catch (ABC) for the stock, the number of fishing years for which the ABC specification applies and, if possible, interim metrics that can be examined to determine if multi-year specifications need reconsideration prior to their expiration.

The SSC recommends the 2016-2017 ABC should be based on a constant catch policy of **2,494 mt (= 5.5 M lbs)**. This revised constant catch level remains less than the 6 M lbs that was taken during rebuilding, is approximately the 50th percentile of the observed cumulative catch distribution, and likely represents approximately 75% of F_{MSY}.

The SSC notes in its advice to the Council that this is a short term, empirical measure. The SSC commits to evaluate a new approach to setting ABC developed by McNamee et al. (2015 working paper) in September 2015. This new approach has been proposed until a revised assessment is completed (expected December 2016) that will be reviewed by the SAW/SARC by Spring 2017 in time for ABC determination for 2018.

4) The most significant sources of scientific uncertainty associated with determination of OFL and ABC.

- Atypical life history strategy (protogynous hermaphrodite) means that determination of appropriate reference points is difficult;
- Assessment assumes a completely mixed stock, while tagging analyses suggest otherwise;
- Evidence of changes in the spatial distribution of the species, specifically an expansion of the species into more northern areas (Bell et al. 2014);
- Uncertainty exists with respect to M — because of the unusual life history strategy the current assumption of a constant M in the model for both sexes may not adequately capture the dynamics in M; and
- Concern about the application of trawl calibration coefficients (ALBATROSS IV vs BIGELOW) and their influence on the selectivity pattern and results of the assessment. There was concern that the pattern of the calibration coefficients across lengths was difficult to justify biologically.

5) Ecosystem considerations accounted for in the stock assessment, and any additional ecosystem *considerations that the SSC took into account in selecting the ABC, including the basis for those additional considerations.*

No additional ecosystem considerations were included in the determination of ABC.

6) Prioritized research or monitoring recommendations that would reduce the scientific uncertainty in the ABC recommendation and/or improve the assessment level.

1. Develop a first principles foundation for establishing reference points and assessment methods to account for Black Sea Bass' life history.
2. Explore the utility of a spatially structured assessment model for Black Sea Bass to address the incomplete mixing in the stock.
3. Consider a directed study of the genetic structure in the population north of Cape Hatteras.
4. Develop a reliable fishery independent index for Black Sea Bass beyond the existing surveys. This may require development and implementation of a new survey.
5. Additional monitoring and compliance investments to control ABCs at recommended levels are necessary if predicted scientific outcomes for future stock biomasses are to be realized.
6. Evaluate the implications of range expansion to stock and fishery dynamics.

7) The materials considered in reaching its recommendations.

- Dancy, K. 2015. Staff memo to Chris Moore, dated 10 July 2015, entitled "Black Sea Bass Management Measures for 2016 – 2017." 10 pp.
- NEFSC. 2015. Black Sea Bass 2014 Catch and Survey Information for Northern Stock. 19 pp.
- MAFMC. 2015. Summer Flounder, Scup, and Black Sea Bass Fishery Performance Reports, June 2015. 9 pp.
- MAFMC. 2015. Summer Flounder, Scup, and Black Sea Bass Advisory Panel: Additional Comments, June 2015. 4 pp.
- MAFMC. 2015. Black Sea Bass fishery information document. 14 pp.
- McNamee, J., G. Fay, and S. Cadrin. 2015. Data limited techniques for Tier 4 stocks: an alternative approach to setting harvest control rules using closed loop simulations for management strategy evaluation. RI Division of Fish and Wildlife and University of Massachusetts Dartmouth. 57pp.
- Miller, T. 2013. SSC memo to Richard B. Robins, Jr., dated 30 January 2013, entitled "Report of January 23, 2013 Meeting of the MAFMC Scientific and Statistical Committee on Black Sea Bass ABC determination." 9 pp.
- J. McNamee, G. Fay, and S. Cadrin. 2015. Memo to SSC, dated 18 July 2015, entitled "Recommendation for an ABC for Black Sea Bass based on the Data Limited analysis." 4 pp.
- Dawson, J. 2015. Email to Kiley Dancy, dated 19 July 2015, entitled "Black Sea Bass Stock Assessment."
- Bell, R. J., D. E. Richardson, J. A. Hare, P. D. Lynch, and P. S. Frantantoni. 2014. Disentangling the effects of climate, abundance, and size on the distribution of marine fish: an example based on four stocks from the Northeast US shelf. ICES Journal of Marine Science 72(5): 1311-1322.

8) A certification that the recommendations provided by the SSC represent the best scientific information available.

To the best of the SSC's knowledge, these recommendations are based on the best available scientific information.

Summary of Species Information Requests

The following is a summary of the information requests made at the meeting by the SSC for next year's round of ABC deliberations. Questions about specifics can be directed to the SSC species leads (Attachment 3).

The SSC would prefer to have updated assessments in 2016 for Bluefish and Scup. If updated assessments are not possible for either or both of these species, then the SSC would like to have the following information in hand prior to its July 2016 meeting:

- Bluefish: updated trawl survey index and updated MRIP index
- Scup:
  - Survey CPUE (kg/tow) in the fall NEFSC survey;
  - Mean size and size-structure in the fall NEFSC survey; and
  - Exploitation ratio (catch / survey biomass).

For Summer Flounder, an assessment update **must** be conducted in 2016 to guide the Council and SSC in determining future ABCs. Also, the SSC recommends an expedited benchmark assessment to seek to improve model performance and reduce the retrospective bias present in the current assessment update.

For Black Sea Bass, the SSC commits to evaluate a new approach to setting ABC developed by McNamee et al. (2015 working paper) in September 2015. This new approach has been proposed until a revised assessment is completed (expected December 2016) that will be reviewed by the SAW/SARC by Spring 2017 in time for ABC determination for 2018.

Other Business

The SSC Chair briefed the SSC on the status of several ongoing SSC projects, including development of non-OFL approaches for setting ABCs for Blueline Tilefish, the rumble strip approach for setting multi-year ABCs, and the report of the National SSC Workshop held in February 2015. Rich Seagraves briefed the SSC on progress being made to develop a universal list of research priorities for the MAFMC, and Julia Beaty briefed the SSC on progress being made by MAFMC staff to define and develop management options for forage species in the mid-Atlantic region. Finally, Olaf Jensen led the SSC through a review of an early draft of proposed terms of reference for the upcoming benchmark stock assessment for Black Sea Bass; suggested changes made by the SSC were transmitted to the NEFSC.

cc: SSC Members, Lee Anderson, Chris Moore, Rich Seagraves, Kiley Dancy, José Montañez, Julia Beaty, Mark Terceiro, Tony Wood, Gary Shepherd, Jason McNamee, Kirby Rootes-Murdy

Attachment 1

Mid-Atlantic Fishery Management Council
Scientific and Statistical Committee Meeting
July 21-23, 2015
Final Agenda

Tuesday, July 21 2015

1300 Bluefish 2016-2018 ABC Specifications (Montañez/Wood/Jones)
1730 Adjourn

Wednesday, July 22 2015

0800 Scup 2016-2018 ABC Specifications (Dancy/Beaty/Terceiro/Gabriel)
1245 Lunch
1345 Summer Flounder 2016-2018 ABC Specifications (Dancy/Terceiro/Wilberg)
1730 Adjourn

Thursday, July 23 2015

0800 Black Sea Bass 2016-2018 ABC Specifications (Dancy/Shepherd/McNamee/Jensen)
1130 Other Business
- Research Priorities (Seagraves)
- Update on Unmanaged Forage Initiative (Beaty)
- Blueline Tilefish Issues (Boreman)
- Fifth National SSC Report (Boreman)
- Rumble Strip Update (Wilberg)
- Review of Preliminary TORs for Black Sea Bass Benchmark Assessment (Jensen)

1300 Adjourn

Attachment 2

MAFMC Scientific and Statistical Committee
21-23 July Meeting
Baltimore, MD

Name	Affiliation
SSC Members in Attendance:	
John Boreman (SSC Chairman)	North Carolina State University
Tom Miller (SSC Vice-Chair, 7/22 and 7/23 only)	University of Maryland - CBL
Mike Wilberg	University of Maryland - CBL
Doug Lipton	NMFS
David Secor	University of Maryland – CBL
David Tomberlin (7/21 only)	NMFS Office of Science and Technology
Mark Holliday	NMFS (Retired)
Cynthia Jones (7/21 and 7/22 only)	Old Dominion University
Sarah Gaichas	NMFS Northeast Fisheries Science Center
Sunny Jardine (7/22 and 7/23 only)	University of Delaware
Mike Frisk	Stony Brook University
Olaf Jensen	Rutgers University
Wendy Gabriel	NMFS Northeast Fisheries Science Center
Ed Houde (7/22 and 7/23 only)	University of Maryland – CBL
Others in attendance:	
Rich Seagraves	MAFMC staff
José Moñtanez (7/21 only)	MAFMC staff
Julia Beaty``	MAFMC staff
Kiley Dancy	MAFMC staff
Chris Moore (7/22 only)	MAFMC staff
Tony Wood (7/21 only)	NMFS Northeast Fisheries Science Center
Gary Shepherd (by phone, 7/22 and 7/23 only)	NMFS Northeast Fisheries Science Center
Mark Terceiro (7/22 and 7/23 only)	NMFS Northeast Fisheries Science Center
Rick Robins (7/21 and 7/22 only)	MAFMC Chair
Greg DiDomenico (7/22 only)	GSSA
Kirby Rootes-Murdy	ASMFC staff
John Maniscalco (7/22 and 7/23 only)	NYDEC
Moira Kelly (7/22 and 7/23 only)	NMFS GARFO
Mike Luisi (7/22 only)	MD DNR, MAFMC Council Member
Jason McNamee (7/22 and 7/23 only)	RI F&W
Alexei Sharov (7/22 and 7/23 only)	MD DNR
Tom Fote (7/22 and 7/23 only)	ASMFC Commissioner, NJ
Joe Grist (7/22 and 7/23 only)	VMRC
Bob Rush (7/22 only)	United Boatmen of NJ
John DePersonaire (7/22 only)	Recreational Fishing Alliance (NJ)
Spencer Talmage (7/22 only)	ASMFC staff

Attachment 3

Species and Topic Leads for MAFMC SSC Members

Species/Topic	Biology/Assessment Lead	Socio-economics Lead
Atlantic Mackerel	Dave Secor	Mark Holliday
Atlantic Surfclam	Wendy Gabriel	Bonnie McCay
Ocean Quahog	Ed Houde	Bonnie McCay
Spiny Dogfish	Yan Jiao	David Tomberlin
Bluefish	Cynthia Jones	Doug Lipton
Butterfish	Rob Latour	Mark Holliday
Black Sea Bass	Tom Miller/Olaf Jensen	Marty Smith
Golden Tilefish	Doug Vaughan	Marty Smith
Scup	Wendy Gabriel	Mark Holliday
Summer Flounder	Mike Wilberg	Doug Lipton
Long-finned Squid	Mike Frisk	Sunny Jardine
Short-finned Squid	Tom Miller	Sunny Jardine
Ecosystems	Ed Houde	Doug Lipton
Deep Sea Corals	John Boreman	Bonnie McCay
Blueline Tilefish	Sarah Gaichas	David Tomberlin

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